PRELIMINARY DESIGN MEMORANDUM
FOUR-MILE RUN PROJECT
PITTSBURGH, PA

PREPARED FOR:

PITTSBURGH WATER AND SEWER AUTHORITY
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Pittsburgh, PA 15222

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CEC Project 174-960

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Civil & Environmental Consultants, Inc.

TABLE OF CONTENTS

LIST OF DRAWING FIGURES

APPENDICES Page Location

EXECUTIVE SUMMARY

The Pittsburgh Water and Sewer Authority (PWSA) is evaluating design alternatives to meet four goals and benefits at the Four Mile Run (4MR) Stormwater Improvement Project (Project) in Pittsburgh Pennsylvania. The goals and benefits are: Reduce Combined Sewer Overflows; Reduce Flood Risks and Basement Backups; Reduce Sedimentation and Erosion and Leverage Resources for Regional Benefit. The alternatives that were developed and assembled; the evaluation criteria and comparison; along with background information, additional data collected and recommendations for design are provided in a Preliminary Design Memorandum (PDM), which represents a 30% submittal associated with the progress of the design.

The Four Mile Run Project area covers approximately 320 acres in an area locally known as Schenley Park, which is located in the Oakland, Squirrel Hill and Greenfield neighborhoods of Pittsburgh. The topography of the area creates a valley arrangement that generates positive drainage beginning at the northeastern end of the Project area and concluding near the center of the Project area. This central portion of the Project area is more rural in nature and includes Schenley Park and Junction Hollow, a recreational extension of Schenley Park. Surficial features in Schenley Park and Junction Hollow consist primarily of forested areas, streams, a lake, grass fields, athletic fields and park amenities such as trails and stone bridges across streams. From the center of the Project area to the end of the Project area at the Monongahela River, the topography is more level and undulating and does not promote positive drainage. This portion of the Project area is urban in nature and includes arterial and neighborhood streets and residential and commercial buildings in a residential and commercial area known as Four Mile Run neighborhood. At the extreme south end of the Project area, a former steel plant adjacent to the Monongahela River, known as the Hazelwood Green site has been decommissioned and is in the process of redevelopment.

The PWSA currently handles stormwater and combined sewer flow originating within and upstream of the site through the use of two large diameter pipe systems that date back to the early twentieth century. Surface streams within Schenley Park are captured in the combined sewer system (CSS) at various locations and join with the other captured historic streams that form the backbone of the CSS that drains the historic 4MR watershed. These large diameter pipes also handle stormwater and sewer flow from seven distinct sub-watershed areas upstream of the site, including the Oakland, Squirrel Hill and Greenfield areas. The pipes terminate at Diversion Chamber M-29, a combined sewer overflow (CSO) and weir structure, owned and operated by the Allegheny County Sanitation Authority (ALCOSAN). An ALCOSAN interceptor sewer/deep tunnel system connected to the Diversion Chamber extends beneath the Monongahela River and carries the flow to the ALCOSAN treatment facility approximately 6.5 miles downstream. Diversion Chamber M-29 directs dry weather flow to the ALCOSAN treatment plant, but wet weather flow overwhelms the system, resulting in CSOs to the Monongahela River (ca. 400 million gallons per year). The M29 sewershed is the third largest source of CSOs in PWSA's service area. Due to increases in impervious areas due to continuing commercial, industrial and residential site development, the increase in annual precipitation in Pittsburgh, which reached an all-time record amount in 2018, possibly due to climate change and the reduction of vegetated areas to absorb stormwater, increases in wet weather flow and CSO volume and frequency have been observed. The CSO backups occur not only at the M-29 Diversion Chamber, but extend to certain manholes throughout the watershed, and depending upon the volume of stormwater resulting from the storm, the elevation of the manhole and the water surface elevation of the Monongahela River, sometimes overflow at the ground surface of the manhole or back up the laterals. The overflow creates surface flooding in the area; this flooding or the lateral backups occasionally reach the basements of commercial and residential buildings in the Four Mile Run neighborhood.

PWSA prioritized the Project in its Citywide Green First Plan (2016, http://pgh2o.com/city-wide-green-plan) due to the potential to remove significant direct stream inflows in an economical manner making use of available public land, thereby reducing CSOs, localized flooding from sewer surcharges, and basement backups. The Project also has a significant history of prior planning and investment by local institutional partners and the philanthropic community. The Citywide conceptual urban plan for the M-29 watershed includes redirecting stormwater from surrounding neighborhoods through the Schenley Park stream system and Panther Hollow Lake and reestablishing a direct connection to the Monongahela River through Junction Hollow and the Hazelwood Green site.

The first two goals and benefits, reducing CSOs and localized flooding, lie within PWSA's direct responsibility. However, the 4MR project was prioritized in the Green First Plan partly due to its alignment with other redevelopment initiatives to achieve synergistic goals; thereby, the project will require complementary funding from other sources to achieve the greatest overall public good.

In April of 2018, PWSA selected a mostly-local consultant team consisting of nine engineering and consulting firms and led by Civil & Environmental Consultants, Inc., to conduct site assessments, to perform monitoring, to co-ordinate community and stakeholder engagements, to develop design alternatives to advance the Project goals and benefits, to perform and prepare a Project design and to prepare the PDM.

A kickoff meeting was conducted in May of 2018 that included members of the design team and certain stakeholders for the Project. Project investigation activities initiated thereafter and consisted of dozens of site reconnaissance visits to review site conditions and the identification of areas where additional data was needed. Based on the large area of the Project, twelve (12) distinct Project segments were established, which form the basis for the information presented in this

PDM. A scope of services was developed based on the investigative information referenced above and, over a 4 month period, physical investigations were performed. These investigations consisted of the installation of real-time data collection equipment such as rain gages and flow monitoring devices in existing piping systems and conducting subsurface geotechnical investigations, a cultural resources determination, wetland delineations, an invasive species study and Phase I Environmental Site Assessment.

In conjunction with the initiation of site investigation activities, meetings were scheduled with appropriate agencies, most notably with Pennsylvania Department of Environmental Protection (PADEP), to present the proposed goals and benefits of the Project and to determine the necessary permits needed for construction. A Joint Permit Application (JPA) for the Pennsylvania Chapter 105 Water Obstruction and Encroachment Permit and a USACE Section 404 Permit will be required. A Dam Safety Permit will also be required, and an Erosion and Sedimentation (E&S) control plan and a National Pollutant Discharge Elimination System (NPDES) notice of intent for construction activities not associated with the JPA will need to be prepared.

Topographic mapping that was prepared in 2016 and provided by PWSA was reviewed and additional topographic and planimetric elements identified during site reconnaissance activities and needed to support the design were documented. Additional topographic and planimetric field surveys were performed to locate these elements. A revised base map was prepared for utilization in the design and development of alternatives.

In conjunction with the site investigations, a design one call was made to identify the utilities within the Project area. Upon receipt of mapping and narrative information, meetings were established with the utility owners to review as-built or design drawings and to obtain additional information based upon the historical experience of the professionals representing the utility companies. The hard copy or electronic drawing information obtained was transferred onto existing topographic and planimetric mapping of the site. To verify the depth and location of critical utilities or to obtain utility depths not shown on drawings, a non-destructive potholing program was initiated. Deviations between the as-built locations and verified locations of below-grade utilities were noted and modified on the base mapping for the site.

In August of 2018, two alternative development workshops were conducted. Attendees at the workshop, including representative of the design team, PWSA and participating stakeholders reviewed site conditions and project goals, reviewed concept drawings and historical reports, presented and discussed technologies and concepts, and determined decision criteria and the weighting/importance of the decision criteria in the creation and evaluation of alternatives to be considered for design. The workshop identified 10 technologies applicable to the Project and established the five design criteria for alternative evaluation. In order of importance, they consist of Opinion of Construction Cost, Performance, Public Perception, Operation, Maintenance & Inspection and Risk. Four additional criteria were identified for alternative evaluation, based upon additional project team discussion; these additional criteria consist of Infrastructure Obstructions, Implementability, Schedule and Sanity Check. Three criteria were identified by the workshop team as non-important, partly because they overlapped substantially with other criteria. These criteria included Route and Length, Permitting, and Synergy with Other Projects. Numerical preliminary values were assigned to each criterion to take into account their relative importance (based upon workshop ranking by workshop participants, or weighting in alternative selection.

After elimination of three criteria that were deemed not important due to low values, numerical values were adjusted to obtain an aggregate weight of one (1.0). The weighted criteria is as follows:

- Performance 0.19
- Construction Cost 0.19
- Public Perception 0.11
- Operation, Maintenance and Inspection 0.10
- Risk 0.10
- Infrastructure Obstructions 0.09
- Implementability 0.08
- Schedule 0.07
- Sanity Check 0.07

In addition to the workshops, watershed expansion meetings were conducted. The watershed expansion team consisted of representatives from CEC and three of the subcontracted engineering firms. The team was tasked with evaluating the impact of future disconnected and redirected runoff from developed areas outside of the Project but within the watershed on the proposed drainage design within the Project area. Using existing topographic, land use and drainage system information, the team developed a strategy to quantify, qualify and separate peak wet-weather flows from upstream areas so that the proposed drainage within the Project can consider the management of these flows. To the extent possible, hydraulic design in the Project area will consider these future flows and determine if they should be immediately accommodated, or documented for a separate future design upgrade to the Project. A Watershed Expansion Report was prepared in April of 2019 to present the conclusions and recommendations for this analysis. The Watershed Expansion Report is presented in the Appendix J to this PDM.

Between November of 2018 and June of 2019, the project team held three public community engagement events to obtain feedback on proposed designs. Additionally, the project team contacted and coordinated with representatives from Hazelwood Green, ALCOSAN, Pittsburgh Department of Mobility and Infrastructure, Pittsburgh Department of Public Works, Pittsburgh Parks Conservancy, public utility companies, and CSX Railroad.

Alternatives were developed for each Project segment to create the stormwater conveyance backbone to remove a significant volume of stormwater from the CSS and direct it to the Monongahela River, both in this current phase and in future expansions. From upstream to downstream, the Project segments are described below.

Alternative No. 1 – Phipps Run Stream Restoration: and
Alternative No. 2 – Panther Hollow Run Stream Restoration:
Phipps Run and Panther Hollow Run are two of the last remaining natural, open channel streams in the City. However, they are heavily impacted by urban stream syndrome whereby flashy hydrology leads to excess erosion and biological degradation. These streams are listed by Pennsylvania Department of Environmental Protection (PADEP) as impaired for sediment. This excess sediment settles in Panther Hollow Lake, reducing its capacity to manage stormwater. The Project proposes to stabilize these streams to reduce sediment loading in the lake. Stabilizing Panther Hollow Run would also improve its ability to handle additional stormwater inputs associated with upper watersheds from the Squirrel Hill area in the future.

To complement stream restoration activities, peak flows entering Panther Hollow Run and Phipps Run will be attenuated using green stormwater infrastructure installations. These project components consist of a variety of detention and stormwater retrofits designed to slow down stormwater generated from roadways and other impervious areas within Schenley Park, to attenuate peak flows and reduce erosion and sedimentation. In so doing, these components enhance overall project performance, reduce long-term maintenance and economize pipe system and channel sizes downstream.

These alternatives only reduce CSO and remove stormwater from the existing PWSA piping system when combined with other alternatives. If they are not implemented, the sediment could be removed periodically from Panther Hollow Lake or from an enlarged forebay.

Alternative No. 3 - Panther Hollow Lake (PHL) Restoration: The Project proposes dredging Panther Hollow Lake to its original bottom to increase capacity and manage stormwater, excavation to return the lake to its historic shape and size, creating a coarse sediment forebay and fine sediment pre-treatment wetland, demolishing the concrete edging on the lake and replacing trails for recreational use.

One optional alternative (**Alternative No. 3A**) consists of the upgrading of the lake by the addition of the following: a clay liner to reduce infiltration; material substrate to promote a healthy lake, creating a naturalized wetland edge and an automated opti-weir to draw down the lake and provide more storage in advance of a storm event. This alternative or enhancement, which is not directly tied to stormwater function can be incorporated into construction only if funding from third party or outside sources becomes available.

Alternative No. 4 – Principal Spillway Pipe, Emergency Spillway and Embankment Raise: In order to meet the requirements of PADEP Division of Dam Safety, the crest of the existing embankment will be raised by approximately 3 feet at its high point and a principal spillway pipe and open channel emergency spillway will be provided to allow more effective handling of stormwater. The principal spillway pipe will be installed beneath the railroad tracks. These hydraulic facilities could also provide the opportunity to handle additional stormwater inputs associated with upper watersheds from the Oakland and Squirrel Hill areas in the future The principal spillway pipe will need to be jack and bored beneath two railroad track lines operated by CSX that divide Panther Hollow in Schenley Park and Junction Hollow.

Two optional alternatives for consideration consist of the following: Alternative No. 4A) Providing a large diameter culvert with an elevated pedestrian walkway inside the culvert. The culvert will be beneath the tracks to safely connect patron traffic between Schenley Park and Junction Hollow; and/or Alternative No. 4B) Providing an open channel, stone lined cascading spillway that will discharge water flow from the lake through the culvert and beneath the pedestrian walkway. These alternatives or enhancements, which are not directly tied to stormwater function can be incorporated into construction only if funding from third party or other sources becomes available.

Alternative No. 5 - Junction Hollow Engineered Channel: The spillway pipe from PHL and extending beneath existing railroad tracks will be sized to allow only a select volume of stormwater to be conveyed. An open channel is planned for Junction Hollow that conveys the stormwater from PHL, from the Junction Hollow watershed and possibly future inputs of stormwater from Oakland. The channel would be designed with uniform bottom slope and a basic trapezoidal shape, with a low flow channel at the channel invert. Stone will be placed over an engineered fabric to reduce infiltration and minimize erosion. A temporary trail will need to be established on the east side of Junction Hollow to maintain non-vehicular traffic during construction.

One optional alternative (**Alternative 5A**) consists of the upgrading of the engineered channel to provide a stream setting with the addition of instream structures, vegetation conducive to stream construction, trees, riparian material and woody material. The channel cross section and bottom slope will be modified to create a stream condition.

Alternative No. 6 – East Side Drainage in Junction Hollow: The barren drainage channel for the valley slope on the east side of Junction Hollow will be upgraded to redirect and convey additional flow from streams that currently inflow to the CSS where they meet the railroad tracks and will be directed out of the existing PWSA CSS and into a proposed piping system through the Four Mile Run neighborhood, discussed below.

Alternative No. 7 – Soccer Field Headwall: The open channel stormwater flow through Junction Hollow will need to be directed below ground, due to limited space for open channel flow and the need to navigate through the urban setting of the Four Mile Run neighborhood. A concrete headwall will be designed and constructed to transition the open channel flow into a subsurface pipe system that will transfer flow to the Monongahela River.

Alternative No. 8 – Piping System to Four Mile Run Park: A piping system consisting of two 36-inch diameter HDPE pipes will be designed and constructed below ground and extend beneath Boundary Street at the south entrance to Junction Hollow and through a portion of the Four Mile Run neighborhood to Saline Street. The piping system will slope to promote gravity drainage of stormwater and extend beneath the basketball courts under the I-376 bridge structure and beneath the Frazier Street bridge structure. The depth of the piping system will vary between 0 feet and 25 feet below ground. Due to the shallow and/or flat topography in the area, some locations may require fill to be placed above the ground surface to cover the pipe.

One optional alternative (**Alternative No. 8A**) consists of the replacement of a segment of the pipe system where the installation depth is shallow with an open channel stream. The ideal location for the stream would be in an existing, triangular shaped grassed area known locally as Four Mile Run Park. The stream would be designed with instream structures, vegetation conducive to stream construction, trees, riparian material and woody material and undulate in bottom slope. This alternative or enhancement, which is not directly tied to stormwater function can be incorporated into construction only if funding from third party or other sources becomes available.

Alternative No. 9 – Deep Gravity Pipe Drainage System: The gravity drainage pipe system discussed in Alternative No. 8 will continue beneath Saline Street over a distance of approximately 1,500 feet until it reaches the Hazelwood Green site, south of Second Avenue. A third gravity draining 36-inch HDPE pipe will be designed and constructed adjacent to the other two proposed pipes to address future stormwater flow from the Naylor Run area, which is to be evaluated under Phase II of this Project. A gradual increase in elevation on Saline Street downstream of Four Mile Run Park will result in a 500 foot segment of the proposed pipe system having a depth in excess of 25 feet below ground surface. The piping system will need to navigate and maintain sufficient clearance around many existing underground utilities located below the asphalt surface of Saline Street, Greenfield Avenue and Second Avenue. It will also need to navigate between the foundations for piers and abutments of two railroad bridges owned by CSX Railroad. The two bridges cover a linear distance of approximately 200 feet along and above Greenfield Avenue. A traffic plan will need to be prepared and implemented during the construction of this segment of the Project to maintain vehicular access to the Four Mile Run neighborhood, because Saline Street is the only roadway into the area.

Two optional alternatives for consideration consist of the following: **Alternative No. 9A** consists of the design of a pump station with appurtenant mechanical and electrical features, an underground concrete collection chamber and a small, above ground aesthetic-type building at south end of the triangular-shaped Four Mile Run Park. Two pumps and one backup pump along with an emergency backup generator will be designed and housed in the building to 'lift' the water from the Junction Hollow and the future Naylor Run area to a higher elevation to implement Alternative No. 9B. In **Alternative 9B, a** shallow depth piping system can be installed parallel to and below the asphalt surface of Saline Street and Greenfield Avenue and perpendicular and below Second Avenue to reach the Hazelwood Green site. The estimated 6 to 7 feet depth of excavation could reduce construction time, reduce interference with underground utilities and reduce interference with the foundations of the CSX railroad bridges. The shallower depth of excavation, when compared to Alternative No. 9 will also shorten traffic impacts associated with construction.

Alternative No. 10 – Hazelwood Green Deep Gravity Pipe System and Monongahela River Outfall: The deep gravity drainage pipe system discussed in Alternative No. 9 will continue beneath the Hazelwood Green site and discharge at the Monongahela River. The depth to the piping system will be in excess of 20 feet and will need to avoid the building foundations that remain from the former LTV steel site that was decommissioned in 1985. Prior to the deep gravity piping system accessing the Monongahela River outfall, it will need to be jack and bored to extend beneath Signature Boulevard/Blair Street, a recently constructed city street and beneath a private set of railroad tracks. The piping system will also need to maintain sufficient clearance around several underground utilities. No traffic impacts are anticipated.

Three optional alternatives for consideration consist of the following:

Alternative No. 10A consists of a shallow depth piping system to be installed below the Hazelwood Green site. This piping system is connected to the pump station and shallow piping system, a continuation of the two optional alternatives presented in Alternative No. 9, if contemplated. The estimated 7 to 10 feet depth of excavation could reduce construction time, reduce interference with underground utilities and reduce interference with decommissioned foundations. **Alternative No. 10B** consists of an open channel stream designed and constructed over a 300 feet length between Second Avenue and Signature Boulevard/Blair Street to replace the deep gravity drainage pipe system. The stream would be designed using the same features as discussed in previous stream alternatives.

Alternative No. 10C consists of an open channel stream designed and constructed over a 300 feet length between Second Avenue and Signature Boulevard to replace the shallow gravity drainage piping system. The stream would be designed using the same features as discussed in previous stream alternatives.

Each of the optional alternatives presented above will include the advancement of the piping system beneath Signature Boulevard and privately owned railroad tracks using jack and bore techniques.

Alternative No. 11 – Tunnel from Soccer Field headwall to Hazelwood Green Site; and: Alternative No. 12 – Culvert from Tunnel to Monongahela River

To avoid the potential conflicts associated with utilities, bridges, traffic and the impacts to the Four Mile Run neighborhood, Alternative No. 11 contemplates a deep tunnel beginning at a location near the soccer field in Junction Hollow and extending through the western valleyside slope to outlet at the Hazelwood Green site. The tunnel would be a gravity draining tunnel extending beneath the residential area known as South Oakland. A concrete drop shaft structure with a depth in excess of 50 feet would be designed and constructed near the soccer field, to access the invert of the 8-feet diameter tunnel and to provide an inlet for stormwater drainage from upstream watershed areas. The tunnel would be excavated using a shielded Tunnel Boring Machine (TBM), beginning at the Hazelwood Green site and working back to Junction Hollow.

On the Hazelwood Green site, the tunnel would be extended to the Monongahela River using a concrete culvert matching the diameter of the eight feet tunnel. This culvert, known as Alternative No. 12, is designed for a shallow depth. Due to the minimum earth cover, an open excavation will be utilized for culvert installation. The culvert will need to be jack and bored beneath a private set of railroad tracks to discharge into the Monongahela River, but will not interfere with local roads.

Although not included in the alternative development, ancillary areas currently contributing stormwater to the CSS will be studied in the future to identify methods for reducing stormwater into the CSS. These areas consist of the following:

Watershed Expansion Areas: These areas comprise a majority of acreage in the 4MR watershed, where most of the runoff generated in the shed originates. These areas are located in the neighborhoods of Oakland, Squirrel Hill, and Greenfield. The runoff generated in these neighborhood areas may be connected to the Project in future project phases. Methods for connection of the expansion areas and for stormwater management are described in the Watershed Expansion Report. The current Project design considers the conveyance infrastructure that could be used to connect these areas in future phases.

Naylor Run: This area consists of runoff from Overlook Drive, the Bridle Trail, and Greenfield Road, which runs off into an existing stream that flows into the CSS near Naylor Street. Insufficient pipe capacity results in localized flooding during storms. The project is evaluating methods to slow down and detain runoff and to create a dedicated storm sewer that directs this water to the Monongahela River, while also connecting to runoff generated from the Highway I-376 and the Greenfield Bridge (both of which also consist of additional direct stream inflows). Connection of this Naylor Run area is cost effective if the open channel-pipe system through The Run neighborhood is constructed first.

The Nine evaluation criteria identified in the workshops were used to evaluate the twelve alternatives and nine optional alternatives. A rating of 1 through 5 were assigned to each of the criteria for each of the alternatives and these were weighted and summed to provide a score for each segment and alternative. In this evaluation scheme, a low total score indicates a better alternative than a high score.

A description of each rating is as follows:

1. Very Easy, Very Inexpensive, Very Fast
   Very Safe, Very Low Risk, Very Effective, Very Positively Perceived
2. Easy, Inexpensive, Fast,
   Safe, Low Risk, Effective, Positively Perceived
3. Nominal/Average/Typical
4. Difficult, Expensive, Slow, Negatively Perceived
   Unsafe, High Risk, Ineffective
5. Very Difficult, Very Expensive, Very Slow
   Very Unsafe, Very High Risk, Very Ineffective, Very Negatively Perceived

The following table summarizes the results of the comparison of alternatives.

TABLE 8-1 ALTERNATIVE WEIGHTED CRITERIA MATRIX

Project Name: 4 Mile Run
Project No. 174-960
Date: 7/1/2019 rev 9-3-19

Criteria	Weight	Alt.-1		Alt.-2		Alt.-3		Alt.-3A		Alt.-4		Alt.-4A		Alt.-4B		Alt.-5		Alt.-5A		Alt.-6		Alt.-7	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Performance	0.19	2	0.38	2	0.38	3	0.57	3	0.57	2	0.38	2	0.38	2	0.38	3	0.57	2	0.38	3	0.57	2	0.38
Construction Cost	0.19	3	0.57	3	0.57	3	0.57	4	0.76	2	0.38	5	0.95	5	0.95	2	0.38	2	0.38	2	0.38	2	0.38
Public Perception	0.11	2	0.22	2	0.22	1	0.11	2	0.22	4	0.44	2	0.22	2	0.22	4	0.44	1	0.11	3	0.33	3	0.33
Operation, Maintenance and Inspection	0.10	2	0.20	2	0.20	3	0.30	3	0.30	2	0.20	2	0.20	2	0.20	2	0.20	2	0.20	2	0.20	2	0.20
Risk	0.10	1	0.10	1	0.10	1	0.10	1	0.10	2	0.20	5	0.50	5	0.50	2	0.20	2	0.20	2	0.20	1	0.10
Infrastructure Obstructions	0.09	1	0.09	1	0.09	1	0.09	1	0.09	2	0.18	4	0.36	4	0.36	1	0.09	1	0.09	2	0.18	1	0.09
Implementability	0.08	3	0.24	3	0.24	2	0.16	2	0.16	2	0.16	4	0.32	4	0.32	1	0.08	1	0.08	3	0.24	1	0.08
Schedule	0.07	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	4	0.28	1	0.07	2	0.14	2	0.14	1	0.07
Sanity Check	0.07	1	0.07	1	0.07	1	0.07	3	0.21	2	0.14	3	0.21	3	0.21	2	0.14	1	0.07	2	0.14	1	0.07
Sum of Score			2.08		2.08	x	2.18		2.62	x	2.29		3.35		3.42		2.17	x	1.65	x	2.38	x	1.70

Criteria	Weight	Alt.-8		Alt.-8A		Alt.-9		Alt.-9A		Alt.-9B		Alt.-10		Alt.-10A		Alt.-10B		Alt.-10C**		Alt.-11		Alt.-12	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Performance	0.19	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	1	0.19	1	0.19
Construction Cost	0.19	3	0.57	3	0.57	4	0.76	3	0.57	3	0.57	3	0.57	3	0.57	2	0.38	3	0.57	5	0.95	4	0.76
Public Perception	0.11	2	0.22	2	0.22	3	0.33	2	0.22	2	0.22	4	0.44	3	0.33	2	0.22	2	0.22	2	0.22	3	0.33
Operation, Maintenance and Inspection	0.10	1	0.10	1	0.10	1	0.10	4	0.40	2	0.20	2	0.20	2	0.20	3	0.30	2	0.20	3	0.30	2	0.20
Risk	0.10	2	0.20	4	0.40	4	0.40	2	0.20	2	0.20	3	0.30	2	0.20	2	0.20	2	0.20	3	0.30	3	0.30
Infrastructure Obstructions	0.09	4	0.36	4	0.36	5	0.45	2	0.18	3	0.27	3	0.27	3	0.27	2	0.18	3	0.27	4	0.36	2	0.18
Implementability	0.08	2	0.16	3	0.24	4	0.32	3	0.24	3	0.24	3	0.24	4	0.32	3	0.24	4	0.32	4	0.32	3	0.24
Schedule	0.07	2	0.14	2	0.14	3	0.21	2	0.14	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	2	0.14
Sanity Check	0.07	1	0.07	2	0.14	2	0.14	3	0.21	2	0.14	2	0.14	2	0.14	3	0.21	2	0.14	2	0.14	2	0.14
Sum of Score		x	2.20		2.55		3.09	x	2.54	x	2.43		2.75		2.62		2.32	x	2.51		2.99		2.48

Note: Alternative 10C is the jacking and boring of a pipe beneath Signature Blvd and beneath the MetalTech railroad and the outlet structure at the Monongahela River
Note: Alternative 10C is not considered a stand alone alternative. It is combined (added) seperately to each of the Alternatives No. 10, No. 10A and No. 10B
Note: Alternative with lighter highlighting and 'x' adjacent to sum score are the selected alternatives and discussed in Recommendation

Based upon the scores associated with each alternative, developed by multiplying the weighting by the rating, the recommendation for design will consist of the combination of the following alternatives:

Alternative No. 1 – Phipps Run Stream Restoration
Alternative No. 2 – Panther Run Stream Restoration
Alternative No. 3 - Panther Hollow Lake (PHL) Restoration
Alternative No. 4 – Principal Spillway Pipe and Emergency Spillway
Alternative No. 5A - Junction Hollow Stream Channel
Alternative No. 6 – East Side Drainage in Junction Hollow
Alternative No. 7 – Soccer Field Headwall
Alternative No. 8 – Piping System to Four Mile Run Park
Alternative No. 9A– Saline Street Pump Station
Alternative No. 9B/10C – Saline Street and Hazelwood Green Shallow Pressure and Gravity Pipe to Monongahela River

This group of alternatives is selected based upon the following rationale:

- Alternative No.1 and No. 2 rehabilitate existing streams that have been vertically eroded by increased stormwater volumes and velocities resulting from increased site development and commercialism in the watershed areas contributing to the stream. The erosion has contributed to sedimentation in the stream and in Panther Hollow Lake. The modified cross-section of the streams will provide long-term stability and integrity, improve the environmental health of the streams, increase discharge capacity and contribute to required water quality improvements to these streams, based on their current designation as impaired for sediment. These alternatives only 'reduce CSO and removes stormwater from the existing PWSA piping system' when combined with other alternatives; therefore, it does not achieve these goals as stand-alone alternatives. Additional review and discussion are necessary to determine if the alternative will be recommended for design.
- Alternative No. 3 provides a forebay for coarse sediment accumulation conveyed by Phipps Run and Panther Hollow Run, a bypass cascade to prevent the forebay from flooding and a treatment wetland to capture and filter nutrients, contaminants, pathogens and fine sediment conveyed by the subject streams. Alternative No. 3 also uses excavation or dredging to remove decades of sediment accumulation in the lake and to reestablish the original lake bottom and removes the concrete curbing to connect the lake to a newly graded, natural sloping earthen shoreline.
- Alternative No. 4 provides the hydraulic components necessary to bring Panther Hollow Lake into compliance with regulations established by PADEP Department of Dam Safety

and alos provides a more effective management of stormwater. A principal spillway pipe will maintain the lake at its current elevation, provides the necessary flow to downstream hydraulic features and is the most upstream mechanism responsible for removing stormflow from the CSS and reducing CSO, flood risks and basement backups. Raising the embankment also provides the storage volume needed for controlling a 100 year-24 hour storm event, while also creating an amphitheater setting on the western perimeter of the lake.

- Alternative No. 5A provides a natural stream through Junction Hollow as an upgrade to an engineered channel for only a moderate increase in cost, collects and routes stormwater flow from the west facing slope of Junction Hollow and contributes to reducing flood risks and basement backups in the Four Mile Run neighborhood and reducing CSOs and sedimentation for the Project.
- Alternative No. 6 removes stream flows from the CSS, provides additional stormwater discharge with an increased channel capacity and controls streamflow on the east facing slope of Junction Hollow. It also contributes to reducing CSOs, flood risks and basement backups in the Four Mile Run neighborhood.
- Alternative No. 7 provides a location to transition between open channel flow in Junction Hollow and the subsurface piping system needed to convey stormwater flow through the Four Mile Run neighborhood.
- Alternative No. 8 provides the hydraulic subsurface route needed to navigate through the Four Mile Run neighborhood comprised of gradual undulating topography, limited or no public property for construction and city streets. The piping system proposed will need to be designed and constructed to avoid underground utilities operated by a half-dozen public and private agencies. The alternative will remove flow from the current CSS and discharge stormwater at the Monongahela River, thereby reducing CSOs, flood risks and basement backups.
- Alternative No. 9A provides a turbine pump system and a pump station building that will be designed to accept the flow from the upstream areas of the Project. The pump station and associated hydraulic facilities of these alternatives could also provide the opportunity to handle additional future stormwater inputs associated with upper watersheds from the Greenfield area, also known as Naylor Run and also from drainage mechanisms connected to Interstate 376 (I-376), owned by the Pennsylvania Department of Transportation (PennDOT). The alternative allows for the selection of the specific downstream alternatives, which provide a capital cost savings for the Project. Pump design can account for changes in flow rates.
- Alternative No. 9B/10C allows for the installation of the piping system beneath Saline Street, Greenfield Avenue and Second Avenue to be installed at a depth of approximately six feet below ground surface, much less than other gravity pipe flow alternatives. The

shallow depth of the nipping system, which will be part pressure flow and part gravity flow will expedite construction and reduce the time needed for traffic restrictions. It will also avoid underground utilities operated by a half-dozen public and private agencies, the foundations for abutments at two railroad bridges and potential underground foundations from a decommissioned steel facility. It also provides a pipe outlet above the normal pool of the Monongahela River, which will reduce tailwater issues associated with gravity drainage. The alternative will remove flow from the current CSS and discharge stormwater at the Monongahela River, thereby reducing CSOs, flood risks and basement backups.

The estimated opinion of costs for these ten alternatives was developed using guidelines established by the American Association of Cost Estimating (AACE). A Class V estimate was prepared, based upon the level of definition, or the percent of completion of the Project associated with this PDM and the current amount of Project data collected. A contingency, or expected accuracy range, was established at +50% or -25%.

The opinion of costs of the ten alternatives recommended, including contingency is between $8.2M and $16.2M.

1.0 INTRODUCTION

This Preliminary Design Memorandum (PDM) was prepared by Civil & Environmental Consultants, Inc. (CEC) in collaboration with nine engineering and consulting firms to present the results of CEC's evaluation of alternatives to address selected goals associated with the Four Mile Run Project (Project) in Pittsburgh, Pennsylvania (Site). The goals of the Project have been established by the Pittsburgh Water and Sewer Authority (PWSA) and include the following: Reduce Combined Sewer Overflows (CSOs); Reduce Flood Risks and Basement Backups; Reduce Sedimentation and Erosion; and leverage Resources for Regional Benefit. This PDM was prepared in accordance with the PWSA Request for Proposal for the Four Mile Run Green Stormwater Infrastructure (GSI) Project (No. PWSA89) dated January 10, 2018, herein after known as the RFP. It was also prepared as discussed in our Proposal for Professional Services dated February 18, 2018 and supplemented with our letter dated April 9, 2018 that provides the scope, schedule and budget for separating the Project into Phase I and Phase II components.

The February 18, 2018 proposal was developed to present the approach to performing and completing six (6) Tasks presented in the RFP. However, upon agreement to separate the Project into phases, Phase I of the Project will complete in full the four scope items presented in the RFP and identified as Task 1 - 'Preliminary Design and Assessment' and complete a portion of the three scope items presented in the RFP and identified as Task 3 - 'Stakeholder Coordination and Outreach'. Tasks 2, 4, 5 and 6 and remaining portions of Task 3 will be completed as part of Phase II. The Phase I scope items are as follows:

<u>Task 1</u>

(1) Development and Validation of Alternatives – Conduct a project kickoff meeting, review the Preliminary Design Report for possible beneficial modifications, and conduct an Alternatives Workshop to discuss more efficient concepts and solutions.

(2) Flow Monitoring – Identify flow monitoring locations, install, calibrate and operate the monitors and prepare/QC reports on the results.

(3) Utility/Site Investigations - Perform utility site investigations consisting of closed circuit TV (CCTV), design utility one calls to applicable agencies, high quality potholing and topographic and planimetric surveys to fill data gaps identified during review of historical reports. Perform a geotechnical investigation to supplement existing geotechnical data, collect and submit soil samples to laboratories for testing and obtain soil parameters to be used in design.

(4) Preliminary Design Memorandum – prepare a written memorandum summarizing the information collected and discussed above and identify, evaluate and compare alternatives for a final design. Provide design criteria, calculations, drawings depicting the alternatives,

an opinion of cost for each alternative and present a recommendation for a final design. Provide a list of permits and regulatory approvals needed for construction and a schedule identifying the construction phases and durations.

<u>Task 3</u>

(1) Regulatory Agency Coordination – Identify the permits needed for the Project and meet with the agencies responsible for review.

(2) Utility Coordination – Contact and meet with utility companies to identify and locate above and below grade utility lines within the Project area and obtain design or as-built drawings of the utilities for use in Project design. Contact and meet with CSX Transportation, who operate two mainlines within the Project area and identify the submittal and review process for design work affecting their facilities.

(3) Community Engagement – develop a Public Outreach Plan for the community and attend meetings to discuss and present its content. Prepare the necessary documents for presentation and attend community meetings that present the evolving Project design. Coordinate with PWSA shareholders and attend group meetings administered by PWSA

This PDM is being submitted to summarize all of the work completed as part of the Phase I component of the Project and is essentially equivalent to a 30% Submittal level deliverable. Following a review of the PDM by PWSA and affiliated community stakeholders, and after addressing comments from the same, a Final PDM will be submitted to PWSA, thereby completing Task 1 of the Project and portions of Task 3.

1.1 PURPOSE

The purpose of CEC's activities associated with Phase I of the Project consist of: reviewing historical reports on the project and community stakeholder input and survey findings; reviewing existing flow data, identifying improvements to the existing ecological system; and performing additional field investigations and utility survey to fill 'data gaps' in existing information and identify potential conflicts/concerns in design.

Additionally, the purpose includes evaluating and screening technology options, developing and comparing a variety of alternatives for addressing the goals associated with the Site and preparing opinions of cost.

The alternatives developed by CEC are based on a review of previously prepared documents, information and reports, information collected during investigation and site reconnaissance activities performed between July 2017 and March 2019, analyses of the information collected and input from a core design team and a group of community shareholders identified by PWSA. This PDM presents a description and summary of the alternatives developed by CEC to address the above goals and our evaluation of those alternatives. The information and recommendations contained in this PDM will be used to support continued design of the Project during Phase II.

1.2 REPORT ORGANIZATION

This PDM includes sections on background information, historical information, site reconnaissance activities and investigations, data obtained, workshop collaboration, identification and screening of technologies for system improvements, development and evaluation of alternatives for system improvements, opinion of probable costs, public engagement and recommendations. Appendices to this PDM include figures, engineering analysis and reports, field reports, photographs, data collected, and estimated quantities and opinion of costs.

2.0 PROJECT DESCRIPTION

2.1 SITE DESCRIPTION AND HISTORY

The Site is located in Pittsburgh, Pennsylvania and covers an area of approximately 150 acres; however the drainage area extends well beyond the Site limits and covers approximately 2,300 acres. It is is bounded to the north by Phipps Conservatory, Schenley Drive and Circuit Road; to the east by Overlook Drive; to the south by a neighboorhood know as Four Mile Run, a brownfield site known as Hazelwood Green and the Monongahela River; and to the west by Swineburn Street, Boundary Street and the neighboorhood know as South Oakland. A United States Geologic Survey (USGS) map of the Site is presented on Figure 2-1.

Figure 2-1 USGS Topographic Image of the Site

A Google Site Plan is presented in Figure 2-2

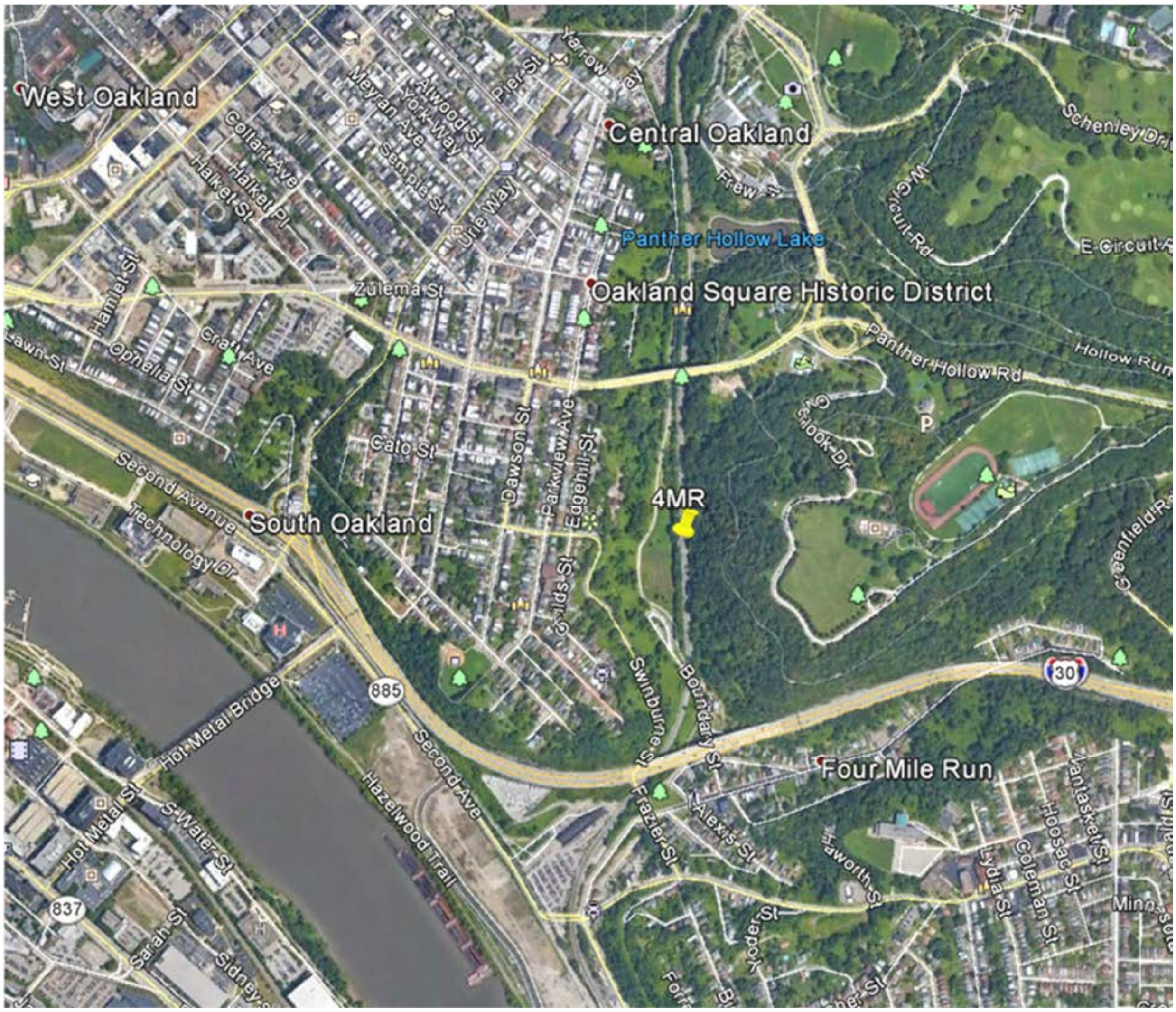


Figure 2-2 Google Aerial Image of the Site

The principle features on the Site include Phipps Run and Panther Hollow Run, Panther Hollow Lake, Junction Hollow, the Four Mile Run neighborhood, Saline Street/Greenfield Avenue and the Hazelwood Green site. Phipps Run is an existing stream approximately 3,400 feet long located at the north end of the Project. The stream generally flows in a north to south direction and is contained within a wooded area of Schenley Park. Panther Hollow Run is located just south of Phipps Run and is approximately 4,100 feet long. It generally flows in a east to west direction and is also located within a wooded area of Schenley Park. Phipps Run joins Panther Hollow Run approximately 100 feet upstream of Panther Hollow Lake. The lake covers an area of approximately 2.43 acres and has a current capacity of approximately 6 acre-feet. Junction Hollow is located at the southern and western end of Schenley Park and is approximately 2,500 feet long within the park. The area is primarily grassed covered in the hollow bottom and wooded on the slopes and is seperated from Panther Hollow Lake by two sets of railroad tracks operated by CSX Railroad. The tracks extend along the entire eastern border of Junction Hollow and use a bridge to cross over Boundary Street, which serves as the southern entrance to Junction Hollow. The Four Mile Run neighboorhood is located just south and east of Junction Hollow. Vehicular access to the Four Mile Run neighborhood is via a segment of Saline Street, a two lane road approximately 750 feet long and generally extending in a north and south direction, and a segment of Greenfield Avenue, a three lane road approximately 250 feet long and extending in an east and west direction. The CSX railroad tracks extend along the western border of Saline Street and use a bridge to cross Greenfield Avenue. The Hazelwood Green site covers an overall area of 175 acres, but is approximately one to two acres within the Site and is located west of Greenfield Avenue, Saline Street and Second Avenue. It parallels the Monongahela River and is accessable via Second Avenue, which also provides pedestrian and vehicular access to Greenfield Avenue and Saline Street.

2.2 PROJECT BACKGROUND INFORMATION

PWSA's downstream regional wastewater treatment provider is ALCOSAN, whose wastewater treatment plant (WWTP) currently processes an average of 250 million gallons per day (mgd) of wastewater. The PWSA sewer system is primarily a combined collection system that serves the City of Pittsburgh. The PWSA sewage collection system also serves as a conveyance system for portions of flows from 24 neighboring municipalities. Wastewater flows generated in neighboring communities are conveyed through parts of the PWSA collection system to the ALCOSAN interceptor system. The PWSA sewer collection system consists of approximately 1,080 miles of sewer ranging in size from six inches to 156 inches, and 29,000 manholes. Approximately 77 percent of the PWSA service area is served by combined sewers; however, the percentage of separate sanitary and storm sewers is gradually increasing as required sewer separation occurs during redevelopment. There are 74 active diversion structures, also known as diversion chambers, within the PWSA sewer system.

In 2015, the Mayor of the City of Pittsburgh tasked the PWSA with evaluating the benefits of incorporating Green Infrastructure (GI) approaches within the city limits. The evaluation would be incorporated into a Green First program that utilizes applicable social, economic and environmental components of GI and gray infrastructure to address regulatory requirements, collect and treat sewage and stormwater, treat stormwater, reduce combined sewer overflows (CSOs) and improve water quality in conveyance systems.

In 2017, PWSA completed the *The Green First Plan: A City-Wide Green Infrastructure Assessment*, which identified improvements to the existing sewer systems utilizing GI alternatives that addressed many of the above issues. One of the focal sheds in *The Green First Plan* was M29, which largely coincides with the historic Four Mile Run (4MR) watershed. M29/4MR has a contributing drainage area of approximately 2,400 acres and includes flow from the Squirrel Hill, Greenfield, Oakland, and Hazelwood neighborhoods that converge within Schenley Park. It is the third largest CSO contributor in the city, contributing approximately 400 million gallons of CSO annually to the Monongahela River. It is also documented as a chronic basement backup and neighborhood flooding issue in the 4MR neighborhood, hereinafter known as "The Run".

The M-29 sewershed is the 3rd largest CSO contributor in the city and has approximately 400 million gallons of water flow through the sewershed. The contributing drainage area includes flow from the Squirrel Hill, Greenfield, Oakland, and Hazelwood neighborhoods and initial proposed solutions have a significant footprint within Schenley Park. The City-Wide conceptual urban plan for the M-29 Sewershed includes redirecting stormwater from surrounding neighborhoods through the Schenley Park stream system and Panther Hollow Lake and reestablishing a direct connection back with the Monongahela River via the Hazelwood Green, the property formally known as the Almono site.

2.3 PROPOSED WORK

The scope of work for the Project has been seperated and broken down into multiple tasks at a Phase I and Phase II level. The Phase I tasks, as presented in the CEC Proposal entitled "Part 1 – Technical Proposal – Four Mile Run Green Stormwater Infrastructure (GSI) Project February 14, 2018" and as clarified in a letter to PWSA dated April 9, 2018 entitled "Phased Budget and Deliverables for PWSA Project PWSA89" are as follows:

<u>Task 1: Preliminary Design Assessment and Expansion:</u>

Preliminary Design Assessment and Expansion
- Project Kickoff Meeting
- Evaluation of Preliminary Design Report

Flow Monitoring
- Flow Monitor Site Identification and Report

Utility/Site Investigation
- Topographical and Utility Survey
- Geotechnical Investigation

- Preliminary Geotechnical Investigation Report
- Wetland and Stream Delineation and Assessment and Report
- Invasive Species Inventory and Control Plan
- Phase I and Phase II Environmental Site Assessments

Preliminary Design Memorandum

- Preliminary Design Memorandum

Task 3: Stakeholder Coordination and Outreach:

- Regulatory Agency Coordination
- Utility Coordination
- Community Engagement

Project Management during the completion of these tasks will be performed by CEC and be supported by the nine collaborating engineering and consulting firms.

2.4 PDM OBJECTIVES

Objectives of the Preliminary Design (Phase I) of the Project are as follows:

1. Review the Preliminary Design Report prepared in November of 2017 to identify the need for additional information and to identify design alternatives previously evaluated.
2. Review the topographic and planimetric survey previously performed to identify missing or mis-located information and to determine planimetric survey needs.
3. Perform a Pennsylvania Design One Call and obtain ticket providing list of known utilities with the Site area.
4. Schedule and attend meetings with utility companies to familiarize them with Project scope and location and obtain design or as-built sketches and drawings.
5. Review utility drawings to familiarize and verify information and to identify conflicts with existing topographic and planimetric surveys.
6. Perform a site reconnaissance to verify features indicated on the existing topographic survey and the utility surveys and to identify physical planimetric features not shown on these surveys.
7. Perform a topographic survey and a planimetric survey of the Site to supplement and collect missing information and locate all pertinent existing at grade structures, above grade structures or below grade structures with features that extend to ground surface.

8. Perform a series of Site reconnaissance visits with PWSA professionals and shareholders to familiarize design professionals with site conditions and to collect information from the same.
9. Attend meetings with professionals from the Pennsylvania Department of Environmental Protection (PADEP) to obtain information necessary for the submission of permits needed for construction.
10. Communicate with local property owners to obtain permission and install 10 rain gauges/weather stations.
11. Install 17 additional flow meters at existing PWSA sewer locations to supplement existing flow meters.
12. Conduct a series of geotechnical investigations at the Site, consisting of test borings, test pits and piezometer installations.
13. Prepare a preliminary Geotechnical Report summarizing the results of the investigation, testing and conclusions and recommendations, if necessary.
14. Monitor and collect data from raingauges, flowmeters and weather stations for use in site hydrologic and hydraulic analysis that will model existing and future conditions.
15. Communicate with representatives of CSX to familiarize them with Project scope and location, obtain design or as-built sketches and drawings for existing features affected by the Project design and establish written contract for engineering consultation support.
16. Schedule, coordinate and attend an Alternatives Workshop with engineering professionals, PWSA representatives and shareholders to review previously prepared reports and surveys and to utilize peer experience in a group setting to identify conflicts and concerns and to generate technologies and ideas to address the goals of the Project.
17. Prepare a hydrologic model using SWMM software that provides flows, depths and velocities within existing and proposed conveyance structures and that incorporates the geometric features of the proposed assortment of conveyance, storage and infiltration structures.
18. Prepare a preliminary design to modify the Phipps Run and Panther Run Stream Channels.
19. Prepare a preliminary design to physically and ecologically modify Panther Hollow Lake, decommission an existing hydraulically inadequately sized outfall, dredge sediment from the lake, remove concrete lake edging and design a hydraulically adequate open or closed channel spillway structure.
20. Prepare and submit a permit application for Panther Hollow Lake for submission to PADEP Division of Dam Safety that details the following:
    - Uses the results of the drilling and laboratory testing to perform geotechnical analyses that develops conclusions and recommendations for dam geometry.
    - Provides hydraulic and hydrologic analyses to verify the adequacy of the dam and associated spillway to protect human health and the environment.

- Provides structural and hydraulic design of a concrete drop inlet spillway to address applicable stormwater events in the reservoir.
- Evaluates steady state seepage through the embankment to calculate embankment stability.

21. Prepare a preliminary design for park improvements, including vegetation, wetlands and walkways.
22. Prepare a preliminary design for a drainage pipe from the Panther Hollow Lake spillway structure to the Junction Hollow stream that extends beneath existing CSX railroad tracks and evaluate a combination drainage and pedestrian culvert connecting park features that are separated by and can only be accessed by crossing over existing CSX railroad tracks.
23. Prepare a preliminary design of a new stream and associated appurtenances through Junction Hollow.
24. Prepare a preliminary design for the regrading of an existing channel collecting flow from the existing valleyside slope east of the CSX railroad tracks and direct the flow to a collection point for incorporation into proposed project conveyance/drainage features.
25. Prepare a structural and hydraulic design of collection basin for the transfer of streamflow from Junction Hollow into subsurface culverts.
26. Prepare preliminary geotechnical, structural and hydraulic design of a pipe system extending from the southern end of Junction Hollow to the Hazelwood Green site with a proposed route below existing City of Pittsburgh streets that needs to navigate approximately 15-20 existing utilities and that will extend through abutment and pier structures of bridges that carry CSX railroad traffic.
27. Prepare a preliminary design of a short segment of new stream and associated appurtenances through the Four Mile Run neighborhood area.
28. Prepare a preliminary design of a short segment of new stream and associated appurtenances through the Hazelwood Green site.
29. Prepare a preliminary design for a drainage pipe from the Hazelwood Green site to the Monongahela River that extends beneath existing privately owned railroad tracks.
30. Prepare a preliminary design for a drainage pipe from the Hazelwood Green site to the Monongahela River that extends beneath existing privately owned roadway.
31. Prepare preliminary drawing figures illustrating the above design features.
32. Prepare an outline of technical specifications to be used during construction of the Project.
33. Prepare an engineer's opinion of cost for construction of the facility.
34. Prepare this Preliminary Design Memorandum (PDM) summarizing the process, criteria and information associated with the design, including hydrologic and hydraulic data, geotechnical data, structural data and an order of magnitude cost estimate, and submit the PDM to PWSA and its shareholders for review.
35. Respond to comments from PWSA on the initial PDM and prepare the Final PDM for PWSA.

3.0 SUMMARY OF PERTINENT DATA

3.1 SITE HISTORY

Schenley Park is a large municipal park located in Pittsburgh, Pennsylvania, between the neighborhoods of Oakland, Greenfield, and Squirrel Hill. It is listed on the National Register of Historic Places as a historic district. In 2011, the park was named one of "America's Coolest City Parks" by Travel+Leisure.

In 1889, Edward Bigelow, the Director of the Department of Public Works in Pittsburgh entered into an agreement with Mary Schenley to donate 300 acres of the Mt. Airy Tract with an option to purchase 120 more acres, under the conditions that the park be named after her and never be sold. The city agreed and immediately purchased the additional 120 acres of land. Bigelow began to develop the newly renamed Schenley Park for recreational uses. Another 36 acres were acquired at a later date, bringing the park's total size to 456 acres, making it the second largest municipal park in Pittsburgh.

The park borders the campuses of Carnegie Mellon University and the University of Pittsburgh.

3.2 PREVIOUS REPORTS OR STUDIES

Between 2001 and 2018, several reports have been prepared presenting various information on the Site. These reports include the following:

3.2.1 Pittsburgh's Regional Parks Master Plan

In 2001, a consortium of six engineering and consulting firms prepared Pittsburgh's Regional Parks Master Plan: A New Ethic of Stewardship. The Plan identified opportunities to enhance the quality of Panther Hollow Lake, including enhancing its ability to better manage storm flows, as well as reducing sources of erosion in Panther Hollow streams.

3.2.2 Stream Restoration and Daylighting: Opportunities in the Pittsburgh Region

In 2002, the Three Rivers Second Nature project from Carnegie Melon University published a study that evaluated stream restoration and daylighting opportunities in the Pittsburgh Region. One of the identified opportunities included daylighting Four Mile Run from Panther Hollow Lake through Junction Hollow. The concept presented for Four Mile Run included pointing out the challenges and opportunities for economic development of daylighting the stream through the Four Mile Run neighborhood and connecting it to the Monongahela River. The report also identified sources of degradation of the existing streams that contribute to problems of excess runoff and sedimentation, including impervious runoff, and erosion from existing Park trails and roads, and "significant stormwater management problems" in the immediate watershed within the Park, such as poorly functioning culverts, pipes, and drainage systems. The report addressed coordination of a stream daylighting project with plans for mobility connections through Schenley Park.

3.2.3 Pittsburgh Regional Parks Natural Areas Study

In June of 2010, a consortium of four engineering and consulting firms prepared the Pittsburgh Regional Parks Natural Areas Study: Natural Areas Program Phase 1 Report: Assessment Results and Management Plan Framework. The report was prepared for the City of Pittsburgh Department of City Planning and the Department of Public Works and provided an ecological assessment/analysis of natural resources in four city parks and to identify needs and opportunities. Schenley Park, which is located within the Project Site limits, is one of the parks that was evaluated.

3.2.4 Restoring the Health of Panther Hollow: A Plan for Watershed Restoration

In 2011, Pittsburgh Parks Conservancy released a plan outlining goals for improving Panther Hollow, with significant emphasis on stormwater management. It outlined a number of overall goals as well as several pilot projects, many of which have been implemented. These potential projects included interventions aimed at delaying stormwater runoff, reducing erosion, and enhancing stormwater management of streams, wetlands, and Panther Hollow Lake.

3.2.5 Regional Parks Master Plan 2012 Update

Pittsburgh Parks Conservancy produced this update to its 2001 plan, where further concepts for Panther Hollow and Junction Hollow were presented. The plan recommended improving visitor access to Panther Hollow, including providing a pedestrian crossing between Junction Hollow and Panther Hollow Lake. Watershed improvements, stormwater management, and connection to the Monongahela River through the Almono site (Hazelwood Green).

3.2.6 Hazelwood Green

In July of 2018, the City of Pittsburgh Planning Commission approved the Preliminary Land Development Plan for Hazelwood Green. The plan designates Block 7, near the intersection of Second Avenue and Greenfield Avenue, for green infrastructure, including plans to "bring a day-lit stream through this space". The Plan states "Collaborative steps are being taken by Allegheny County Sanitary Authority (ALCOSAN), PWSA, and the City, with added investment support from local foundations, to create a green infrastructure solution that provides public open space benefits and reduces the impacts of the CSO from this watershed."

3.2.7 Four Mile Run Daylight Project

In June of 2009, Natural Systems International prepared a CSO Disconnection and Stream Daylighting: Conceptual Design & Feasibility Report for the Pittsburgh Parks Conservancy. The report provided preliminary hydraulic and hydrologic analysis of the Site and presented 16 options for designing daylight routes for the Site. Feasibility constraints and an opinion of cost were also prepared and provided.

3.2.8 Draft Basis of Design Technical Memorandum (Four Mile Run Schenley Park Green Infrastructure Concept 20% Preliminary Design

In November of 2017, Burns and McDonnell, in conjunction with Phronesis prepared a Draft Basis of Design Technical Memorandum. The memorandum was prepared for the Pittsburgh Parks Conservancy and reflects a 20% submittal effort associated with the green infrastructure design over an area approximately equal to the Site area. The principal components of the memorandum include the evaluation of the watershed, the site investigations performed, the hydrologic and hydraulic analyses, conceptual design, permitting and opinion of probable cost.

3.3 SITE MAPPING AND SURVEY

In 2016, Phronesis, LLC (Phronesis) contracted with AWK Consulting Engineers, LLC (AWK) to perform a topographic survey of the Site in conjunction with the Four Mile Run Schenley Park Green Infrastructure Concept 20% Preliminary Design. AWK commenced the original field work in January 2017 and completed the field work in March 2017. The survey was completed in the North American Vertical Datum (NAVD) 1988 and Pennsylvania State Plane (feet) coordinates NAD 83 modified to the ground. Benchmarks and control points were set within the proposed project limits.

As part of the Project, CEC reviewed the original topographic survey prepared by AWK and contracted with AWK to provide additional supplemental survey field work in support of the design work and to fill data gaps. AWK provided CEC with the survey AutoCAD file, which was used to prepare the existing conditions base map that the design team utilized to develop the design alternatives.

3.4 REAL ESTATE AND EASEMENT

Permanent and/or temporary easements and property acquisitions may be required to complete the project. A majority of the project work will be completed on property owned and maintained by the City of Pittsburgh; however, there are sections that will impact parcels owned by entities other than the City. Regardless of the selected project alignment, a temporary and permanent easement will need to be obtained from Almono LP through the Hazelwood Green development. If the tunnel alignment is selected, additional subsurface easements from the property owner's above the alignment will be required. Please refer to Section 8.3.6 of this PDM for additional easement requirements associated with the tunneling option. Additional easement and/or property acquisition needs may need to be identified during the final design.

3.5 PROJECTS BY OTHERS IN SITE FOOTPRINT

There are four principal projects in various stages of preliminary design that are within the boundary of the Project. The City of Pittsburgh's Department of Mobility and Infrastructure (DOMI) is conceptually evaluating the viability of a mobility corridor that will connect the Hazelwood Green Site adjacent to the Monongahela River with the Oakland area, specifically the University of Pittsburgh and Carnegie-Mellon University areas. Preliminary paths for the corridor consist of a route through the Four Mile Run neighborhood, over Boundary Street at the south entrance to Junction Hollow, through Junction Hollow and connecting to the north segment of Boundary Street, which is north of Panther Hollow Lake. The Design of the Project in the Junction Hollow area will incorporate a corridor for this route.

The Almono Partners LP, a consortium of Partners Hazelwood Green Site is soliciting developers to gage interest in transitioning the Hazelwood Green site, a former brownfield area, adjacent to the banks of the Monongahela River into a sustainable mixed-use waterfront development and green open space area consisting of commercial, residential and light industrial real estate. The design of the Project may result in stormwater conveyance crossing the site to gain access to the river.

The Allegheny County Sanitation Authority (ALCOSAN) is in the preliminary design stages for an upgrade to their existing wastewater treatment plant. The upgrade is expected to consist of a concrete tunnel to carry CSO and sanitary sewer flow (SSO) along a route that includes the Junction Hollow portion of the Site. The design of the Project will not be affected by this work.

MetalTech Industries operates a railroad spur that connects to the CSX trackage approximately 0.75 miles east of the Site and extends to their facility approximately 1.0 miles west of the site. Maintenance of the track spur consisting of the addition of ballast is expected to occur in 2019.

Design of the Project may include the construction of a water conveyance feature beneath their tracks.

4.0 REFERENCES

1. Draft Basis of Technical Design Memorandum, Four Mile Run-Schenley Park Green Infrastructure Concept-20% Preliminary Design. Burns McDonnell, 2017
2. Four Mile Run: Schenley Park – Pittsburgh, Pennslyvania - CSO Disconnection and Stream Daylighting, Conceptual Design Memo. NSI and EDC, June 09, 2009
3. Pittsburgh Regional Parks Natural Areas Study, Natural Areas Program Phase 1 Report: Assessment Results and Management Plan Framework. City of Pittsburgh, June 2010
4. Pittsburgh's Regional Parks Master Plan - A New Ethic of Stewardship. Laquatra Bonci Associates / Michael A. Stern / Biohabitats,Inc. / Tai +Lee Architects
5. PWSA Four Mile Run Drainage Study. Chester Engineers
6. Regional Parks Master Plan - 2012 Update, Envisioning the Historic Regional Parks as Cornerstones of a Vibrant Parks and Open Space System for a Sustainable 21st Century City. City of Pittsburgh and the Pittsburgh Parks Conservancy, Nov. 2014
7. National Resources Conservation Service (NRCS) Soil Survey of Allegheny County, Pennsylvania
8. Geotechnical Investigation Services, Green Infrastructure Concepts Plan for Schenley Park, Pittsburgh, Pennsylvania. AWK Consulting Engineers, Inc., March 2017

5.0 SITE RECONNAISSANCE

5.1 GENERAL

This section of the PDM discusses site reconnaissance performed for the Site. The observations discussed below are shown to the extent possible on the preliminary design drawings.

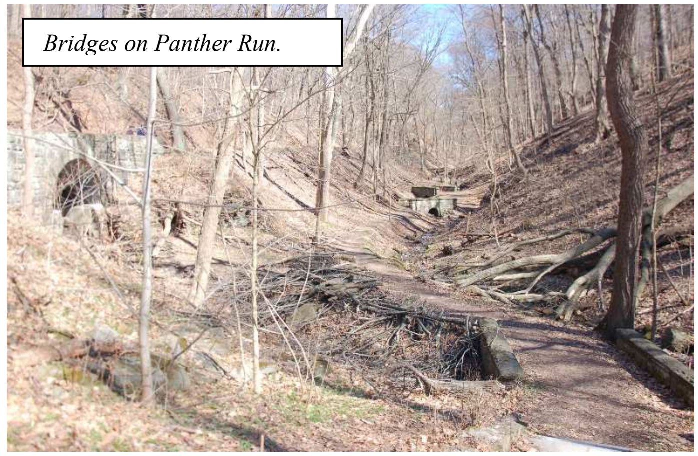
5.2 VISUAL SITE RECONNAISSANCE

Over twenty (20) visits to the Site were conducted between May of 2018 and April of 2019. The purpose of these visits was to develop a familiarization with the Site, to create a visual relationship between the site conditions and the design features proposed and to supplement existing information and the information contained in reports identified in Section 3 of this PDM with the information collected during the site visits. The most recent site reconnaissance was performed by CEC on April 1, 2019. Reconnaissance activities generally consisted of the general observation of appurtenances in the area, observations of vegetation and trails, observation of the existing location of the dam and reservoir, observations of streams, identification of existing hydraulic facilities, including manholes, catch basins and piping, observations of wet areas or areas of unusual drainage, observations of areas adjacent to the existing Panther Hollow Lake, including wetlands, landslides, weirs and overflow structures, and the development of field notes with photographs of critical elements. Subsequent site visits were performed in conjunction with specific tasks or scope items associated with the design. Based upon the overall length of the Project, the Site was divided into selected segments. Division of the segments was determined using geographic, topographic and physical features, in conjunction with urban or rural settings. The findings in each segment associated with these visits are discussed in detail below.

5.2.1 Panther Run

The Panther Run segment of the project is approximately 4,130 feet of headwater stream that begins near the intersection of Bartlet St. and Serpentine Dr. and terminates at Panther Hollow Lake. Panther Run is situated in a narrow wooded valley with pedestrian trails along one or both sides throughout the project reach. Panther Run is entirely located within Schenley park and is crossed by a total of 9 bridges or culverts.

Panther Run.


Bridges on Panther Run.

Panther Run begins near three large (24" culverts) and starts to flow regularly at small spring located in a relatively wide low gradient section of valley. Valley walls come down to the stream bank on both sides of the valley and the slope steepens through the middle portion of Panther Run. The valley widens and stream gradient decreases in the lowest reach of Panther Run where the stream is bordered by a pedestrian trail on the right (south) and wetland on the left (north). Four notable tributaries flow into Panther Run all from the north valley wall. Numerous small tributaries draining hillslopes or roads and trails enter Panther Run along its entire course.

Sediment sources include stream bed and banks, tributary inputs, and colluvial inputs from the valley walls. The native parent bedrock tends to supply gravel sized plate like particles that make up the majority of substrate compositions. Plate like sediments would be expected to have low entrainment thresholds as compared to heavier more rounded particles with similar intermediate axis dimensions (Buffington and Montgomery, 1997[1]). However, some the more competent bedrock supplies large boulder sized particles that are immobile or only partially mobile in the current channel geometry under the current hydrologic regime. Anthropogenic sediment sources supply particles ranging from angular pea gravel (and likely smaller) to boulder sized limestone and include slag, bricks, asphalt, and other materials common throughout the urban landscape.

The majority of Panther Run is a gravel bed stream dominated by plain bed morphology intermixed with varying degrees of bedrock control. Panther Run generally lacks cascade, step pool, and pool riffle morphologies with well-defined vertical variability. The combination of fine grained substrate and lack of vertical variability suggests streams generally have large sediment supplies relative to transport capacity (Parker et al., 1982; Dietrich et al., 1989; Church et al., 1998). However, reaches with exposed bedrock indicate transport capacity locally exceeds sediment supply (Montgomery and Buffington, 1997). The combination of reaches with high and low transport capacity relative to the sediment supply indicates the system as a whole is in disequilibrium and contributing high rates of sediment into the watershed.

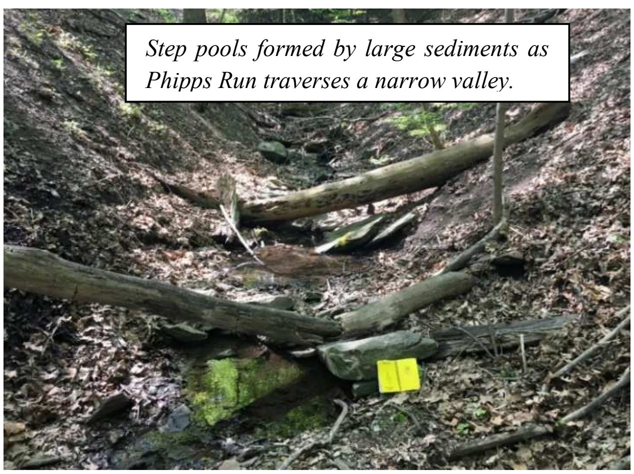
[1] Buffington, J. M., & Montgomery, D. R. (1997). A systematic analysis of eight decades of incipient motion studies, with special reference to gravel-bedded rivers. Water Resources Research, 33(8), 1993-2029.

5.2.2 <u>Phipps Run</u>

Phipps Run near Panther Hollow Lake.

The Phipps Run segment of the project is approximately 3,430 ft of headwater stream that originates at the edge of the wood line on Bob O'Connor Golf Course along Schenley Drive and terminates at the confluence with Panther Run near Panther Hollow Lake. Phipps run traverses through narrow valleys but unlike Panther Run only borders a pedestrian trail in the lower 550' portion of stream. The entire length of the Phipps Run is located in forested valley of Schenley Park with the exception of the portion running under Circuit Drive

Phipps Run originates at a couple small (<12" diameter) culverts and flows through a colluvial bedrock controlled channel with two small waterfalls.



Step pools formed by large sediments as Phipps Run traverses a narrow valley.

Small water fall at Phipps Run origin. Large sediment partially covered by smaller more mobile particles (lower left)

Phipps transitions to a more alluvial step pool system and traverses through a narrow steep valley.

The valley widens and narrows just upstream of the Westinghouse Memorial and Phipps Run becomes a wide depositional meandering stream with braiding tendencies before flowing underground at the memorial

Origin of Phipps near Schenley Drive at the tree line of the golf course.

Presumably Phipps Run traverses under Circuit Rd and becomes a free flowing stream at a steep cliff face near clay drains with substrate comprised predominantly by cobble sized angular limestone.

From here Phipps flows precipitously downstream over a predominantly bedrock bed and around boulder sized colluvial clasts.

Upper most portion of the wide depositional reach of Phipps Run upstream of the Westinghouse Memorial.

Phipps Hollow becomes wider and shallow sloping downstream of the bedrock reach and upstream of the tufa Phipps Run deposits much of the courser bed material.

From the tufa bridge downstream the banks of Phipps Run are comprised of large rectilinear boulders and substrate composition is predominantly gravel.

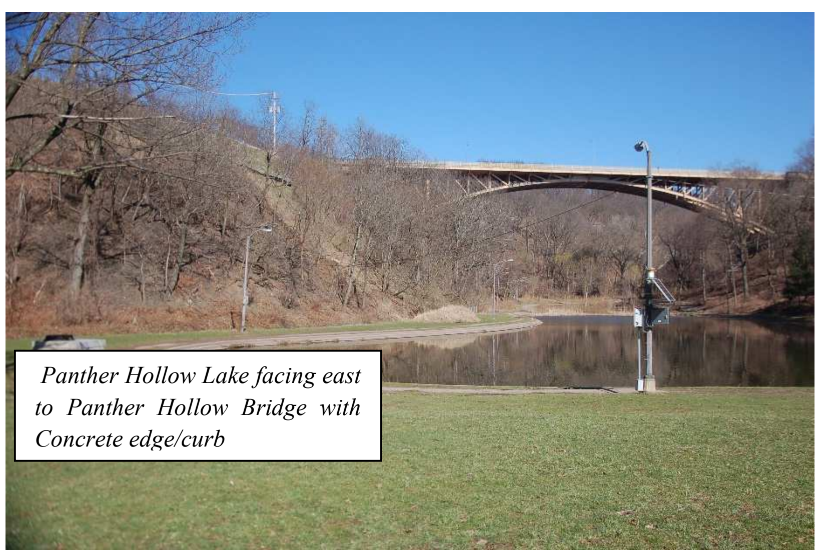
Boulder sized colluvial clasts sit on a bed rock dominated bed

Sediment sources substrate characteristics on Phipps Run are similar to those of Panther Run with a few notable discrepancies. The distinction between stream bank and valley wall is ambiguous through large portions of Phipps Run. The close proximity of Phipps Run to the valley walls allows sediments derived from hillslope failure to directly enter the stream channel. The direct connectivity between upland hillslope process and Phipps Run has created cobble and boulder dominated reaches rather than the almost ubiquitously gravel substrate that characterized Panther Run. The rapid change in substrate characteristics along Phipps indicates the stream has yet to balance sediment transport characteristics with sediment supplied.

Looking upstream to the depositional reach located below the portion Phipps with bedrock bed

5.2.3 <u>Panther Hollow Lake and Appurtenances</u>

Panther Hollow Lake, a man-made reservoir in Schenley Park, covers approximately 2.43 acres Two tributaries, Phipps Run and Panther Hollow Run, converge immediately upstream of the Lake, and provide the majority of the base and storm flow from the Oakland neighborhood of Pittsburgh near Carnegie Mellon University and from the Squirrel Hill neighborhood, near Bartlett Street, respectively. The Lake itself has a concrete step edge with pedestrian paths around the perimeter. This area of the park is highly utilized not only as a passage but also as social commons during both dry and wet weather. However, observations made during a 100-yr storm (September 10, 2018) showed that the park amenities around the Lake become unusable due to flooding, mud and debris accumulation, and ice. Properly managed, the Lake provides valuable water storage services during rain events. The storage service the Lake provides during large storms will be discussed further under Site Characterization.



Panther Hollow Lake facing east to Panther Hollow Bridge with Concrete edge/curb

Flow to the lake is controlled by means of a simple in-channel diversion structure, located at the confluence. During base flow and small storm conditions, flow from the tributaries is conveyed directly to the Lake through a small rectangular orifice

(approx. 1’-9” wide x 12 to18” high) in a low concrete dam, approximately 2’-0” high. During larger storms, an 8’-0” bypass weir is engaged, which conveys larger flows to a concrete, trapezoidal bypass channel, having a bottom width of 3’-0” and a depth of approximately 3’-0”. The channel effectively bypasses the Lake, and discharges into the combined sewer system by way of a large, grated ALCOSAN overflow structure, located in the northeast corner of the lake. This bypass channel also picks up several hillside seeps and stormwater discharges from the roadway above, and collected considerable overland flow from the long, steep hillside immediately north of the Lake.

5.2.4 Junction Hollow

Junction Hollow is an area immediately west of Panther Hollow lake in Schenley Park. It broadly consists of a foot trail and parallel railroad tracks that run between the Panther Hollow neighborhood to the north and Four Mile Run neighborhood to the south. It is approximately 2,500 feet long.


Junction Hollow looking North

Panther Hollow Lake drains into a stormwater inlet at the northwest corner of the lake. The stormwater pipe extends approximately 125 feet beneath the grass embankment for the lake and the railroad tracks parallel to the embankment where it joins larger combined sewer lines that flow south towards the Monongahela River. The railroad tracks are built atop stone ballast and cover a width of approximately 40 feet. As the railroad tracks continue south, they abut a thin lot of trees and the 10-20-foot wide Junction Hollow Trail on the western side. There is a chain-link fence between the trees and much of the foot trail to prevent pedestrians from travelling on the railroad tracks. Power lines attached to wooden poles run along the east side of the tracks. Several perennial, intermittent, and ephemeral streams originate on the eastern hillside and terminate in a ditch that parallels the railroad tracks, which outlets to the combined sewer system near the railroad trestle that crosses Boundary Street at the southern end of Junction Hollow.

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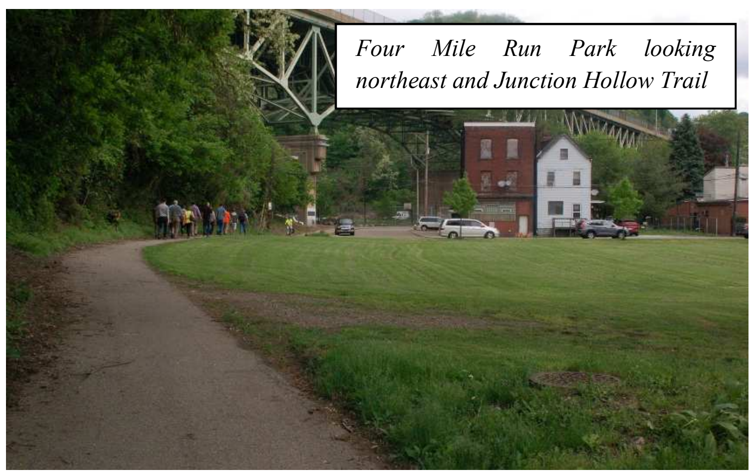
The western hillside of Junction Hollow is dominated by invasive plants, notably Japanese knotweed and porcelainberry vines. Metal manhole covers occur near the trail roughly every 300 feet. These manholes service underground utilities including two large combined sewers and a high-voltage electrical duct bank.

The area between Junction Hollow trail and the railroad tracks opens into a 2-acre lawn with a soccer field and catch basins for excess stormwater drainage. South of the soccer field is a parking area at the end of Boundary Street that accommodates 41 vehicles. Boundary Street and Junction Hollow Trail curve toward the railroad tracks and join beneath the CSX railroad bridge. The railroad tracks turn southwest for a short stretch until they curve back to run parallel to the Monongahela River. Boundary Street leads into the Run neighborhood next to Four Mile Run Playground. Junction Hollow trail departs Boundary Street for 770 feet beneath the I-376 before finally meeting Saline Street in the Run neighborhood.

CSX Bridge at Boundary Street/Parking lot looking south

5.2.5 <u>Four Mile Run Neighborhood</u>

The Four Mile Run segment of the Project is approximately 1000 feet long and generally extends from the railroad bridge at the south end of Junction Hollow to the Frazier Street Bridge that extends over Saline Street. Located within the neighborhood is a triangular grass area known as Four Mile Run Park. The park covers approximately one-half of an acre and is bounded by Alexis Street, Saline Street and a natural tree covered slope which supports the CSX railroad tracks. There is little to no topographic change in the park area. The Junction Hollow Trail extends through the park along the embankment slope.



Four Mile Run Park looking northeast and Junction Hollow Trail

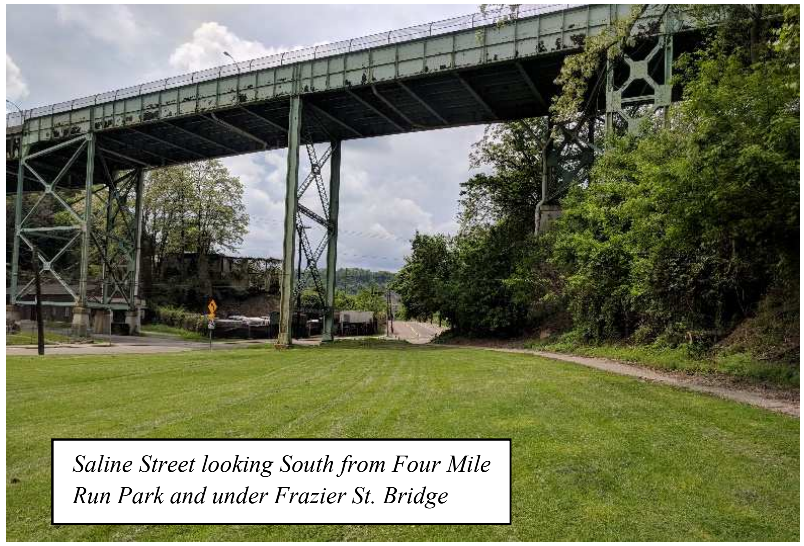
5.2.6 Saline Street

The Saline Street segment of the Project is approximately 1000 feet long and extends from the south end of Four Mile Run Park to Second Avenue. The segment includes a 250 feet length of Greenfield Avenue, which extends beneath two railroad bridges. The northernmost railroad bridge is operated by CSX Transportation (CSX) and is used to convey two tracks over Greenfield Avenue. The southernmost railroad bridge was a former railroad track spur for the existing railroad and is currently utilized as a parking area, possibly for employees of UPMC.

Saline Street looking South

Saline Street is a two lane roadway with a speed limit of 25 MPH. The vehicle lanes are approximately 12 feet wide and are bounded by sidewalks on both sides. A bicycle path is located between the southbound traffic lane and the western sidewalk. The elevation of Saline Street at Four Mile Run Park is approximately 738 ft. MSL and rises to an elevation of 754 ft. MSL approximately halfway along its 1000 feet length. The street then descends to an elevation of 745 feet at the intersection of Saline Street, Greenfield Avenue and Irvine Street, at the two railroad bridges discussed above.

The west side of Saline Street is bounded primarily by wooded areas that slope upward from the road surface. The trees separate the CSX railroad tracks located at approximate elevation 767 ft. MSL from the street. The east side of Saline Street is bounded by old stone retaining walls of varying heights that support a private commercial driveway located at elevation 762 ft. MSL. Saline Street is an asphalt-surfaced road with a minimum amount of 'alligator' cracking in the asphalt surface and sporadic asphalt patching.


Saline Street looking South from Four Mile Run Park and under Frazier St. Bridge

Several utilities are located within this segment. Water, sewer and electric lines are located beneath the road surface at various depths and parallel the street. These utility lines appear to be primary lines, based upon a review of the existing utility drawings and their orientation parallel to the road. Overhead electric lines supported by utility poles are located between the bicycle path and the sidewalk on the west side of the street. Gas lines are located at the north end of Saline Street. Other secondary utility lines for water, electric, sewer and gas extend in directions perpendicular to the street. Several manholes are visible along the centerline of the road. The location of these utilities is shown on Figures 8-17 and 8-17A.

5.2.7 Second Avenue

The Second Avenue segment of the Project is approximately 500 feet long and is generally located between Greenfield Avenue and Swinburne Street. The street is an asphalt-surfaced road with a minimum amount of 'alligator' cracking in the asphalt surface.

Second Avenue is a three lane roadway with a speed limit of 35 MPH. The southbound direction contains two left turn lanes to allow entrance between the abutments of the bridge over Greenfield Avenue. The vehicle lanes are approximately 11 feet wide and are bounded by sidewalks on both sides. The elevation of Saline Street at Greenfield Avenue is approximately 739 ft. MSL and decreases to an elevation of 731 ft. MSL at Swinburn Street.

Greenfield Avenue looking South toward Second Avenue under CSX Railroad Bridge

The west side of Second Avenue is bounded by a stone retaining wall four to eight feet in height that maintains the ground surface elevation of the Hazelwood Green approximately 10 to 15 feet above the road surface elevation. A lightly wooded slope is located above the stone retaining wall. The east side of Second Avenue is bounded by a concrete retaining wall that supports the former railroad track spur for the existing CSX railroad. The wall is approximately 15 to 20 feet tall.

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Several utilities are located within this segment. Water, sewer and electric lines are located beneath the road surface at various depths and parallel the street. These utility lines appear to be primary lines, based upon a review of the existing utility drawings and their general orientation parallel to the road. Overhead electric lines and street lights supported by utility poles are located on the west side of Second Avenue between the stone retaining wall and the sidewalk. Other secondary utility lines for water, electric, sewer and gas extend in directions perpendicular to the street. Several manholes are visible within the southbound lanes. The location of these utilities is shown on Figure 8-18.

Second Avenue looking North

5.2.8 Hazelwood Green (Almono Site)

Hazelwood Green (formerly known as the Almono Site) is located at the downstream-most point of the proposed Project's alignment. It is a brownfield site and former location of the LTV Steel plant. The surface has been raised by several feet of fill, making it several feet higher than adjacent Second Avenue. A private railroad line is located along the southwestern edge of the property, which runs parallel to the Monongahela River alignment. CEC understands the railroad line is owned by Almono Partners and is used by MetalTech.


Blair Street and Hazelwood Green site

Adjacent to the railroad line, is the recently constructed Blair Street (formerly Signature Boulevard). This newly constructed street is currently private but will eventually become a public street. The Blair Street corridor consists of an approximately 10-foot wide asphalt bike path, an approximately 7-foot concrete sidewalk, an approximately 38-foot wide asphalt roadway accommodating two-way traffic flow, and an approximately 10-foot wide concrete sidewalk. The corridor also contains numerous utility lines, including sanitary sewer, natural gas, domestic water, storm sewer piping and structures, and electrical conduit to support street lighting located along the length of the roadway. Street trees are also located along the length of the roadway, spaced approximately every 120-feet. Between the private railroad line and Signature Boulevard, a post-construction stormwater retention basin has been constructed in conjunction with the new roadway construction. Stormwater runoff from Signature Boulevard is collected via catch basins and conveyed to the retention basin via storm sewer piping.

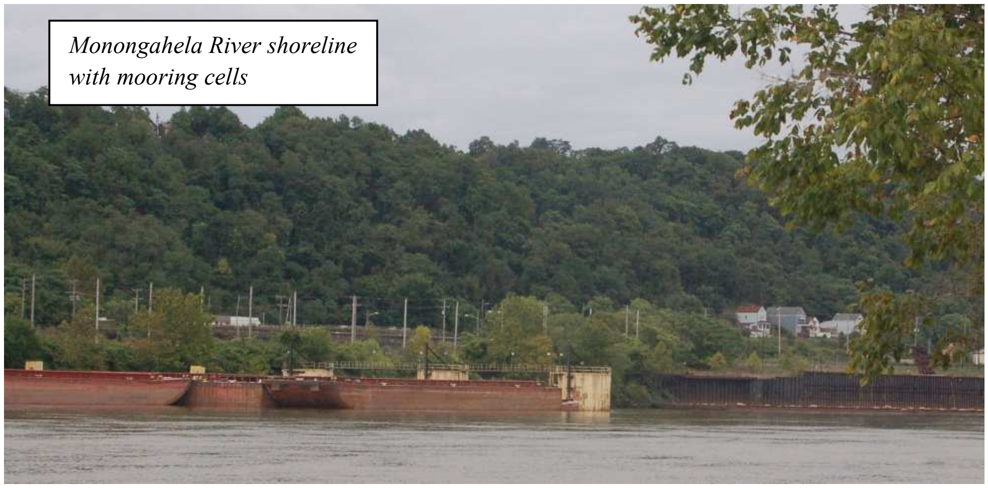
Between Blair Street and Second Avenue, the surface has been graded to create a large, relatively flat pad that can support potential future development. The elevation of the development pad is approximately 737 and the surface is a mixture of gravel and soil. CEC understands Almono Partners has issued Development Request for Proposals (RFPs) for possible development of this area, but there are not currently any plans in place.

Blair St./Hazelwood Green site (foregr) with CSX Railroad Bridge over Greenfield Avenue (backgr)

The Allegheny County Sanitary Authority (ALCOSAN) M-29 Diversion Structure and Overflow Pipe and Outfall are located on the site. In addition, the ALCOSAN interceptor tunnel, which collects and conveys flows from the M-29 diversion structure is located in the subsurface beneath the property.

5.2.9 Monongahela River Shoreline

The shoreline along the Monongahela River within the Project area consists of natural and manmade sloping embankments and manmade concrete and stone retaining walls. The sloping embankments are primarily located at the east end of the project area and cover a length of approximately 1,000 feet. The elevation at the top of the embankment varies from 730 feet to 734 feet and the embankment height varies from approximately 19 feet to 23 feet (measured vertically), based on a Monongahela River water elevation of 711 feet. They slope from the river's edge at a rate that varies between one and one-half horizontal to one vertical (1.5H:1V) and 1.0H:1V. The natural embankment slopes are covered with brush and trees while the manmade slopes are covered with concrete rubble, rocks and general fill and possess very little to no vegetation.



Monongahela River shoreline with mooring cells

Adjacent to the shoreline where sloping embankments are located at the east end of the project, three sheet pile mooring cells with diameters of 20 feet are located in the Monongahela River and are arranged perpendicular to the shoreline. The mooring cells are used to temporarily stage empty and fully loaded barges until a time when the barges can be 'locked through' the locks at Lock and Dam No. 2, located upstream on the Monongahela River, or the Emsworth Lock and Dam, located downstream on the Ohio River. Seven smaller mooring dolphins located parallel to the shoreline maintain the barges in a position parallel to the shoreline. The mooring dolphins extend for a distance 1000 feet downstream from the mooring cells.

The manmade concrete retaining walls are vertically oriented and primarily located at the west end of the project area. The walls are remnants of the shoreline facilities constructed by LTV Steel in the early 1900's. The walls vary in the distance they project out into the river, however, the location of the wall at the water's edge approximately corresponds with the location of the toe of the sloping embankment. The overall length of three different walls is approximately 600 feet.

Retaining Walls on Monongahela River

5.2.10 <u>Contributing Sub-Watersheds</u>

The Design Team, led by CEC, is tasked with developing the 30% plans for the transformation and daylighting of Four Mile Run and Panther Hollow Lake within Schenley Park. The intent of the design is to separate stormwater runoff from the CSS and convey it so that it discharges directly to the Monongahela River. Separate conveyance of stormwater runoff to the river will reduce CSOs and mitigate flooding issues within the Four Mile Run neighborhood and elsewhere. The current scope-of-work involves design interventions within Schenley Park and downstream to Hazelwood Green and the Monongahela River, including daylighting of the stream within Junction Hollow, restoration of streams within the park, and improvements to Panther Hollow Lake. The expectation, however, is that runoff from developed areas outside of the Park and within the watershed will in the future be diverted toward surface and subsurface drainage networks created or enhanced by the project, without discharging to combined sewers, or discharging only during exceptional storm events to the CSS. Ethos collaborative, evolveEA and eDesign Dynamics (the Watershed Expansion Team or WET) are leading the effort to strategize and quantify the future extent of separated flows from upstream areas so that the constructed stream networks within the Park can be located and sized for adequate management of peak wet-weather flows. Hydrologic features within the Park must be designed to accommodate all future (phased) separations from upstream in order to avoid the need for later modifications.

The Watershed Expansion Team formally met on 29 June, 26 July, 15 August, 01 November, and 05 December. Meeting summaries from these team meetings are attached separately.

The Preliminary Upper Shed Analysis Memo describes in detail 19 sub-catchment areas. In broad terms, each neighborhood is fairly homogenous in land use and disconnection strategy. Topography throughout the sewershed could allow for a gravity-based hybrid of green and gray infrastructure to convey stormwater to the Four Mile Run valley.

South and Central Oakland are largely residential with attached and unattached residential units. This area is near to the project area and could be easily disconnected. North Oakland is largely institutional and is home to a sizeable portion of the shed’s impervious area. Because much of the property is under consolidated ownership, those institutions could be partners in connecting separated sewer areas to the Four Mile Run valley.

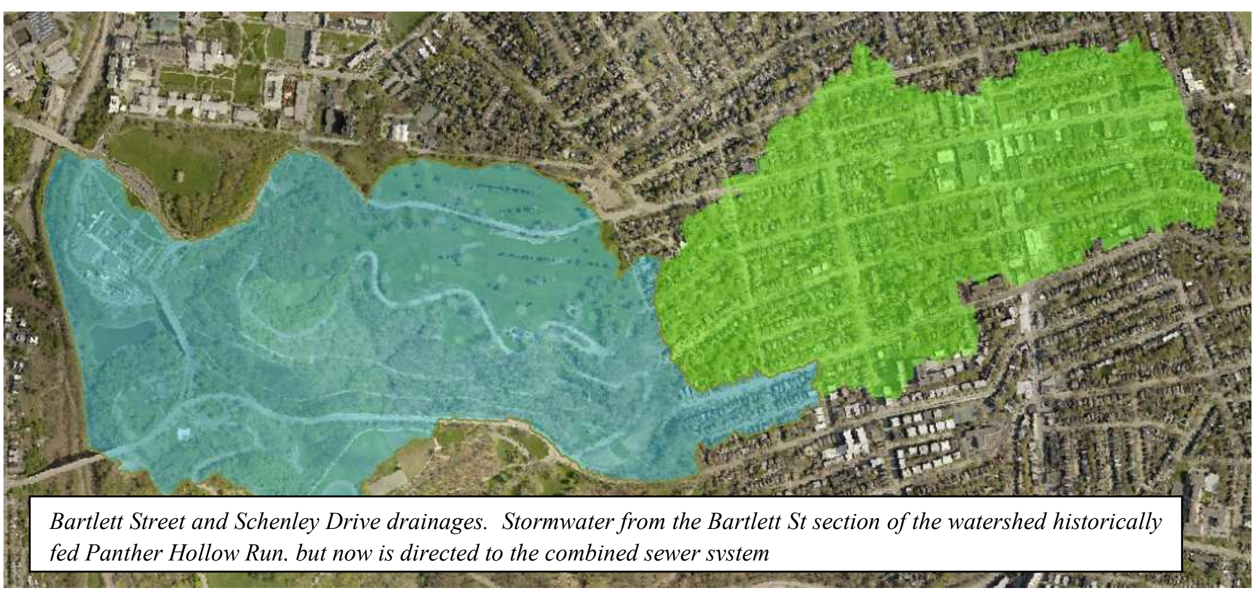
North Squirrel Hill is largely detached single family homes. There are a few opportunities within this neighborhood for site-based detention and release installations, including Wightman Park which is due for reconstruction. Connecting Squirrel Hill North to the Four Mile Run valley would require strategic installation of major infrastructure under Carnegie Mellon’s campus. The business case for such infrastructure is yet to be determined.

South Squirrel Hill has similar development patterns to Squirrel Hill North albeit with more multi-family housing and strong retail corridors on Forbes and Murray. Parts of Squirrel Hill South could connect to the top of Panther Hollow Run via conveyance along Bartlett Street. Other parts of Squirrel Hill South could connect to the Saline Street branch of Four Mile Run if a connection can be made along the Parkway East (I-376).

The upper portion of the Panther Hollow Run drainage area is no longer connected to the Lake. This upper section of the sub-watershed represents portions of eastern Squirrel Hill, and the stormwater runoff from these streets and rooftops is directed from the surface into the combined sewer system, leaving the water level in Panther Hollow Run frequently low. These regions were explored in-depth as part of a feasibility study on Watershed Expansion. The Watershed Expansion strategy aims to re-connect developed portions of the upper watershed to the stream, thus increasing baseflow and wet weather flow in Panther Hollow Run while decreasing stormwater contributions to the combined sewer system, and consequently decreasing the frequency and volume of combined sewer overflows to the Monongahela River.

Greenfield is similarly developed to Squirrel Hill South and could also connect to the Saline Street branch of Four Mile Run if a connection can be made along the Parkway East (I-376). Large parts of Greenfield could connect to Magee Field, a large opportunity for detention and slow release infrastructure. Hazelwood is located adjacent to the Monongahela River and where a connection independent of the Project can be made.

Panther Hollow Lake also receives direct drainage from portions of the Phipps Conservatory and Botanical Gardens and Schenley Park regions including the Park Oval and Anderson Playground Complex. Runoff from these regions follows the steeply sloping hillsides to the Lake, exacerbating landslide-prone topography. Panther Hollow Run and Phipps Run also provide water to the Lake. These historic streams currently drain areas that are largely located within Schenley Park. Phipps Run and Panther Hollow Run both run through steep-sided valleys, with a



Bartlett Street and Schenley Drive drainages. Stormwater from the Bartlett St section of the watershed historically fed Panther Hollow Run. but now is directed to the combined sewer svstem combination of wooded and grassy land cover (the Bob O'Connor Golf Course). An overall land cover map of the M29 sewershed area is shown in Figure 5-1.

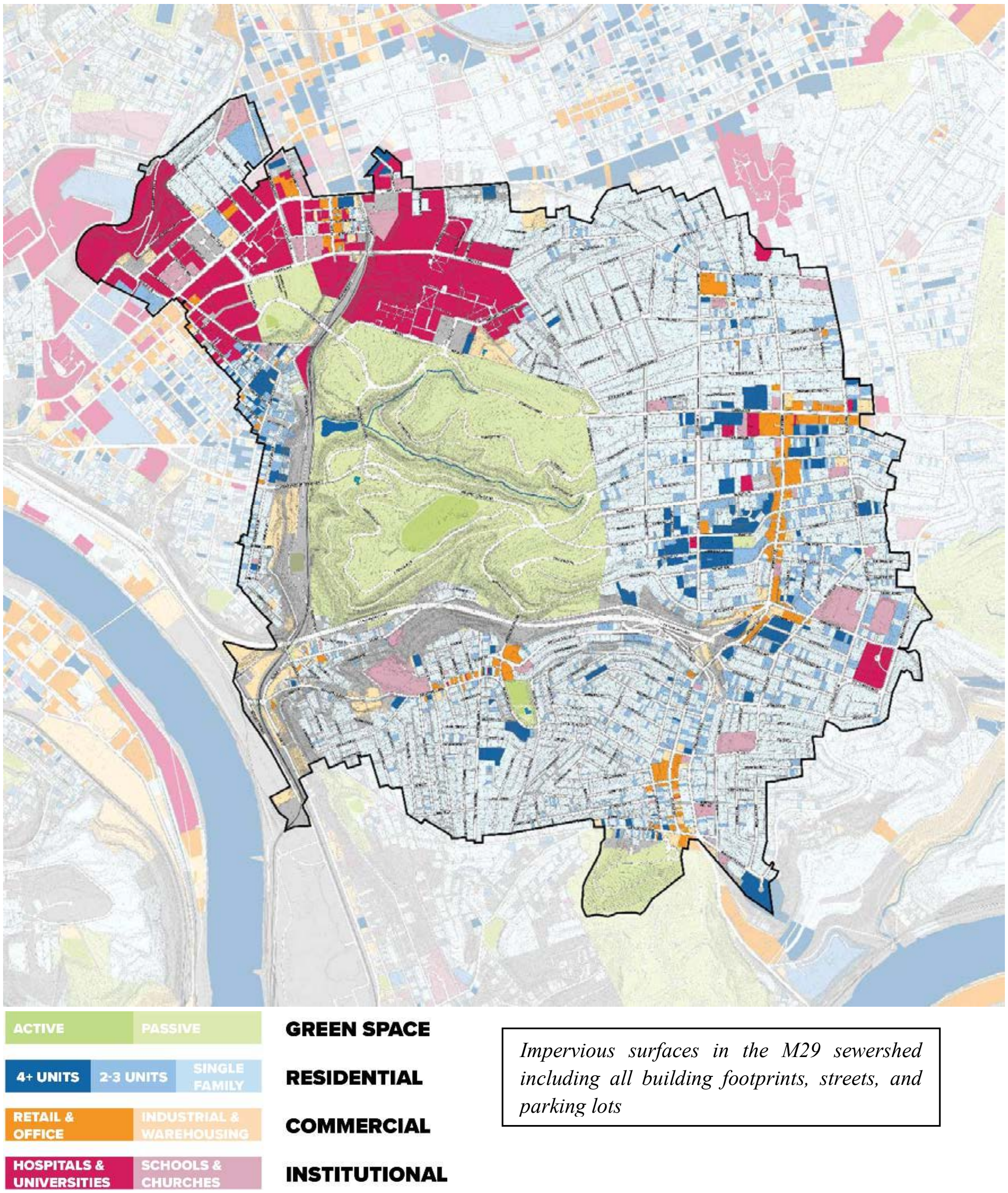


Figure 5-1 M29 Sewershed Land Cover

6.0 SITE INVESTIGATION AND CHARACTERIZATION

6.1 STREAM GEOMORPHIC INVESTIGATION (CEC)

Civil & Environmental Consultants, Inc. (CEC) completed a geomorphic stream survey during the summer of 2018. The survey incorporated observational methods, traditional stream bottom surveys (e.g., pebble counts), and high-resolution survey grade GPS and aerial LiDAR with small unmanned aerial systems (sUAS). The data produced from the survey provides the level of detail required to make accurate decisions regarding stream restoration opportunities and approaches. Detailed longitudinal stream profiles extending the length of the project site and 18 cross sections of riffles and pools were collected for analysis of channel evolutionary patterns. Particle distributions for channel classification and sediment transport analysis were produced based on 15 pebble count surveys (Wolman, 1954[2]). This data provides the basis for understanding areas of stability and instability in the existing conditions, as well as indicators of site hydrology important for developing the proposed condition concepts. The aerial LiDAR and ortho-photography supplement the ground surveys with high-resolution terrain data and detailed photography to observe site constraints. A report

Streams in the project area are classified and described using the Rosgen Stream Classification system (Rosgen, 1994[3]) and supplemented with reach morphology classification of Montgomery and Buffington (1997)[4]. It is important to note that while classifications are beneficial tools a continuum of morphologies exist and that individual streams may not perfectly fit into discrete classification systems. Rosgen classification utilizes quantitative descriptive variables that must be measured to determine stream type. Montgomery and Buffington classification is based on distinctive channel-bed morphology allowing for rapid visual classification. These classification systems are summarized and provide the foundation for geomorphic interpretation of channels in the project site.

To assess annual stream bank erosion on Phipps Run and Panther Hollow Run CEC utilized Bank Erosion Hazard Index (BEHI) combined with Near Bank Stress (NBS) in the procedure known as "Bank Assessment for Non-point Source Consequences of Sediment" (BANCS) which when properly applied can be an excellent predictor of stream bank erosion rate (Rosgen, 2001; Doll et

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[2] Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions American Geophysical Union. Volume 35. Number 6. Pp. 951-956.

[3] Rosgen, D.L. 1994. A classification of natural rivers. *Catena, 22*, 169−199.

[4] Montgomery, D. R., and Buffington, J. M. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109(5), 596-611

al., 2003). Stream bank erosion rates of the existing conditions is calculated using BANCS. Sediment load is determined by multiplying erosion rate by, bank height, length of stream, and bulk density. The estimate of bank erosion on Panther Hollow is 25.07 tons per year, and an estimate of 13.72 tons per year for Phipps Run. Sediment reduction via restoration is estimated using the conservative estimate of 50% reduction in erosion rates.

Details of the stream geomorphic survey and sediment supply estimation are provided in an Appendix C to this PDM.

6.2 GEOTECHNICAL INVESTIGATIONS

In order to collect information for the preliminary design of the Project, several geotechnical investigations were performed between May and October of 2018. CEC and Sci-Tek procured the services of Terra Testing (TTI) and AWK Drilling (AWKD) to perform the test drilling, install piezometers and excavate test pits at the Site. CEC and AWK provided an inspector on a full-time basis to observe the investigation programs.

6.2.1 Geotechnical Investigation No. 1

Between November 7, 2018 and November 18, 2018, CEC conducted a geotechnical investigation and supervised the drilling of eleven (11) test borings. Terra Testing completed the drilling. The test borings drilled at the site were advanced to evaluate the stability and excavation characteristics of the existing soils. The test borings were generally advanced through the overlying fill and into the soil zone consisting of alluvial soils using hollow stem auger drilling methods. Piezometers, used to record groundwater levels, were installed at three test boring locations. Rock coring was performed at several test boring locations. The test borings varied in depth from 10 to 30 feet and totaled approximately 282 feet of soil sampling and 40 feet of rock sampling.

6.2.2 Geotechnical Investigation No. 2

On June 11 and 12, 2018, CEC performed a supplemental geotechnical investigation consisting of the drilling of three (3) test borings. The test borings drilled at the site to collect soil conditions in the vicinity of Panther Hollow Lake. The test borings were generally advanced through the subject fill and into the underlying alluvial soils. Hollow stem auger drilling methods were utilized. Piezometers, used to record groundwater levels, were installed at three test boring locations. The test borings ranged in depth from approximately 10 to 20 feet bgs and totaled approximately 44 feet of soil sampling.

6.2.3 Geotechnical Investigation No. 3

CEC conducted a test pit investigation consisting of the excavating and sampling of eleven (11) test pits. Bag samples were collected from the test borings at selected depth intervals and subjected to geotechnical laboratory testing to obtain soil parameters required for detailed geotechnical design.

6.2.4 Geotechnical Report

CEC completed a preliminary Geotechnical Report for the Site in March of 2018 that includes information for Geotechnical Investigation No. 1 through No. 3. The report provided a summary of all three investigations, the data obtained and general conclusions on findings. During Phase II of the Project, additional geotechnical investigations will be performed to supplement the information collected during Phase I. The Geotechnical Report is presented in the Appendix B to this PDM.

6.3 LITERATURE REVIEW AND HISTORICAL DOCUMENTS

Prior to commencing the Project's geotechnical investigation program, the CEC team reviewed available historical geologic and subsurface information in the vicinity of the project area. This information included the National Resources Conservation Service (NRCS) Soil Survey of Allegheny County, Pennsylvania, the Geotechnical Investigation Services, Green Infrastructure Concepts Plan for Schenley Park, Pittsburgh, Pennsylvania, dated March 2017 prepared by AWK Consulting Engineers, Inc. (AWK), and various geotechnical investigations performed by the Pennsylvania Department of Transportation (PennDOT) as part of the Parkway East construction.

The CEC project team also collected and reviewed a variety of archive photos and design plans of the project Site from various public sources and the City of Pittsburgh Department of Public Works. An example archive photograph, showing the installation of the 50" water line along Greenfield Avenue, is shown below. These archive photographs and design plans were reviewed by the CEC design team to understand existing infrastructure constructed within the project Site's limits and how that existing infrastructure may impact the construction of the Project's site improvements.

Historical Construction of the PWSA culverts beneath the CSX Bridge at Greenfield Ave.

6.4 FLOW MONITORING AND RAIN GAUGES

An extensive flow and rainfall monitoring program was conducted, primarily to provide data to support the hydrologic modeling effort. The basis of this phase of work is a sixth-month monitoring program from July through December 2018. A total of 17 flow meters and ten rain gauges were installed and maintained for the six-month monitoring program. The locations of the flow meters and rain gauges are illustrated in Figure 6-1, below. Most of the flow monitors were left in place of six months, which was deemed sufficient for initial model calibration and validation. Thus, in early January 2019, 13 of the 17 sewer flow meters were removed from service. However, due to significant apparent groundwater influence in the larger sewer pipes, four flow monitors were left in place and are planned to stay in service through May 2019, the time period when groundwater is generally most influential to sewer flows. The data collected from these meters will be used for further calibration validation of the hydrologic and hydraulic model. The four extended-term meters are located at key monitoring sites that cover larger tributary areas of the sewershed and are identified as: MH054F012 – 91", MH054F011, MH054E003 and MH029H073. To complement the extended flow monitoring, all ten (10) existing rain gauges are will be maintained in service through May 2019.

Specific information collected relative to the flow and rainfall monitoring program consist of the following:

- Review of locations
- Site evaluation worksheets and Manhole Inspection Forms
- Flow Monitoring Equipment and Installation
- Flow Data Collection and Equipment Maintenance

- Rain Gauge Network
- Rain Gauge Flow Meter Assignments
- Compilation Of Flow And Rainfall Data

This information can be found in an Appendix A to this PDM.

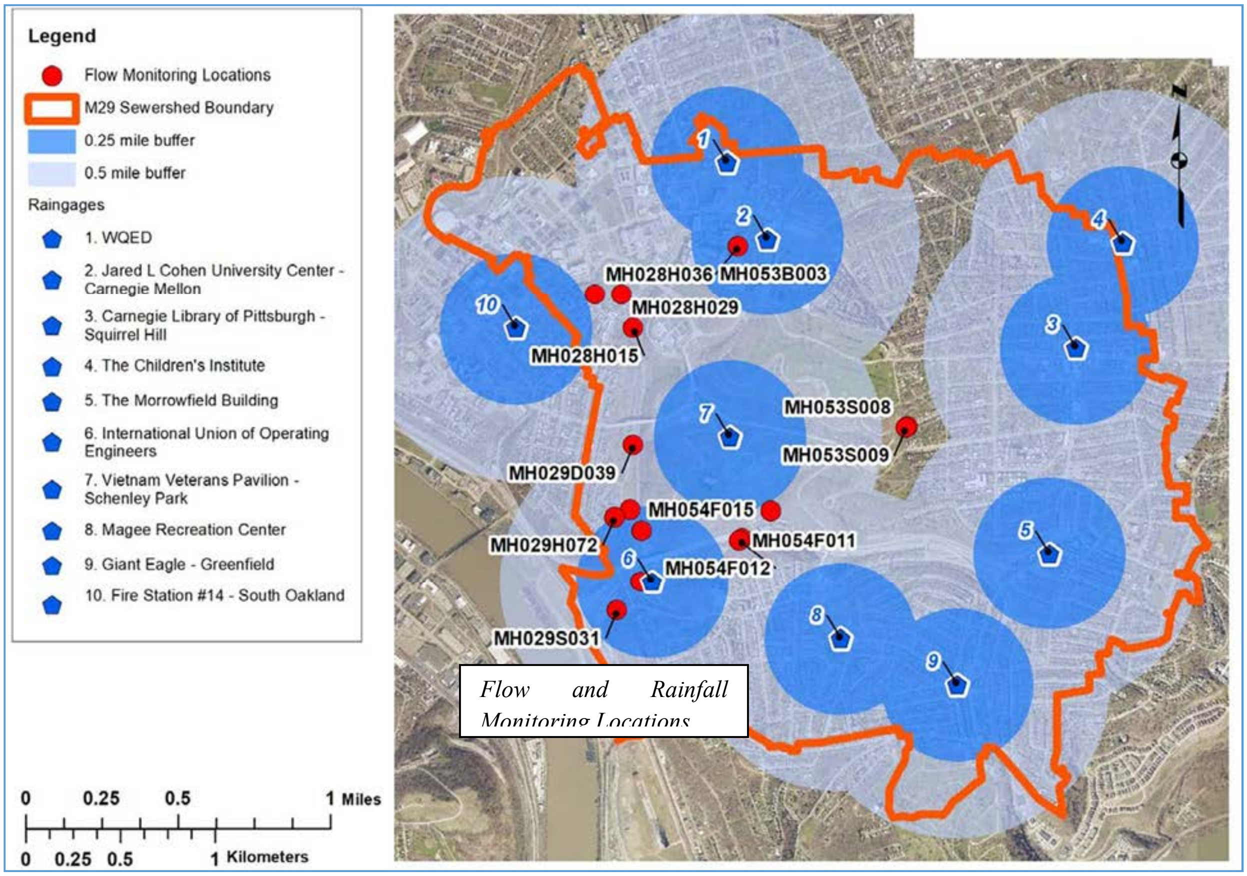


Figure 6-1 Flow Meter and Rain Guage Locations

6.5 HYDROLOGIC AND HYDRAULIC MODELING

6.5.1 Hydrologic Modelling (SWMM)

The 4MR watershed is located within the M-29 sewershed boundary of the Allegheny County Sanitary Authority's (ALCOSAN's) Main Rivers collection system model (Main Rivers model). The Main Rivers model includes the downtown central business district and an area bounded by the Allegheny and Monongahela Rivers. The Main Rivers model was originally developed by Chester Engineers (now Hatch) as part of ALCOSAN's 2008-2011 collection system model development efforts to support the development of a wet weather plan focused on mitigating both combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) from the collection system. ALCOSAN built this model using the EPA SWMM modeling software and provided this System model to the PWSA to serve as starting point for the model updated as part of the 4MR Project.

The ALCOSAN M-29 model was primarily developed to evaluate large scale gray infrastructure projects to mitigate CSO discharges. As such, the ALCOSAN model had a greater focus on flows entering the M-29 diversion structure and less focus on the upstream portions of the collection system. The M-29 System model was modified by the CEC Team to make it more suitable for evaluating the 4MR Project. These modifications included greatly expanding the detail of the M-29 System and recalibrating based on additional rainfall and flow monitoring data. The updated 4MR Project model generally includes the addition of open channels and pipes to the model network, the collection of new flow monitoring and rainfall data, and updating the model's structure and calibration. The intent of updating the 4MR Project model was to use currently available information, adding the necessary detail and additional infrastructure so that it can be used to evaluate potential alternatives that redirect stormwater from the combined sewer system to new stormwater conveyance infrastructure. Various alternatives currently under development by were also evaluated using the model. The model's development and analysis of alternatives is further detailed in the Four Mile Run (4MR) Modeling Report, prepared by Mott MacDonald.

6.5.2 Hydraulic Modelling (SSA and GeoHECRAS)

A combination of Autodesk Storm & Sanitary Analysis (SSA) and GeoHECRAS were used to perform a hydraulic analysis of the Four Mile Run Project. Autodesk SSA is a comprehensive hydrologic and hydraulic analysis application. It helps you plan and design urban drainage systems, storm sewers, and sanitary sewers. GeoHECRAS is an AutoCAD, MicroStation, and ESRI ArcGIS compatible interactive two-dimensional/three-dimensional graphical user interface data wrapper to the U.S. Army Corps of Engineers (USACE) HEC-RAS software. GeoHECRAS was developed by CivilGEO, Inc. and performs one-dimensional and two-dimensional hydraulic analyses using the USACE HEC-RAS version 5.0.6 engine. Each software application provides a unique value to the project. Autodesk SSA was used to analyze the capacity of the proposed storm culvert and pipe alignments and GeoHECRAS was used to perform detailed two-dimensional channel and floodplain modeling.

Inundation maps were developed in GeoHECRAS based on the discharges provided in Mott MacDonald's Modeling Report for the 25-Year Storm Event (24-Hour duration). Flow hydrographs were developed to fit the SCS dimensionless unit hydrograph based on the peak discharges provided in the Mott MacDonald modeling report for various input locations. These hydraulic models are preliminary and will be refined to model additional scenarios and account for timing and attenuation not so far accounted for. The Modeling Report is presented in the Appendix A to this PDM.

6.6 PHASE I ENVIRONMENTAL SITE ASSESSMENT

6.6.1 Phase I Environmental Site Assessment

CEC subcontracted the services of AWK Consulting Engineering Inc. (AWK) to prepare a Phase I Environmental Assessment (Phase I ESA) for the 4MR Project. Specifically, this Phase I ESA evaluated the area of Junction Hollow, starting approximately 200 feet northwest of Panther Hollow Lake, continued to the Hollow's conjunction with the Monongahela River Valley, and across Hazelwood Green site to the Monongahela River. AWK completed the Phase I ESA in June 2018. Our summary of AWK's Recognized Environmental Conditions (RECs) are as follows:

- The Hazelwood Green site (formerly the LTV Steel Works Facility and later, the Almono property), located at the southern portion of the Project area, is covered by an environmental covenant limiting the handling of soil and groundwater. Activity and use limitations include but are not limited to:
    - no groundwater shall be used for drinking or agricultural purposes
    - no activities will be allowed that have the potential to encounter soils above the Act 2 standards within one foot of the soil cap without following the approved Soil Management Plan (SMP)
- The source of the fill used within the Junction Hollow Valley is believed to be from former steel production activities located on the current Hazelwood Green site. This fill potentially contains slag or other types of historic fill and a Waste Management Plan (WMP, commonly also referred to as a SMP) was recommended to address handling, testing, and potential disposal of slag.
- A metal fragment was found in a soil boring from a previous site investigation. The boring was located at the northern end of the Project area, between the western portion of Panther

Hollow Lake and the railroad tracks perpendicular to Junction Hollow Valley. The material near this location may be impacted.

- A 120-foot long structure was identified on a 1969 fire insurance map approximately 200 feet south of the Charles Anderson Bridge, between a former section of Boundary Street and Edgehill Street, located in the northwest portion of the Project area. This structure was labeled as a contractor's garage in 1969 but was not depicted on the 1958 or 1979 fire insurance maps. The soil near this location may have hydrocarbon contamination associated with historic automotive operations and an SMP was recommended for any below ground activities in this area.
- The building located on Wormser Way that is currently occupied by the Pittsburgh Department of Public Works may also have a potential for hydrocarbon contamination associated with vehicle maintenance activities. A SMP was also recommended for any below ground activities in this area. This facility is not located within the current 4MR Project extent.
- The railroad right-of-way extending perpendicular to Junction Hollow Valley along the Project area, has the potential for contamination related to spills from railroad cars and railroad maintenance activities.

6.6.2 Preliminary Observations Associated with the 4MR Phase II Geotechnical Drilling and Additional Due Diligence

CEC completed drilling associated with the 4MR Phase II Geotechnical Assessment in July 2019. Drilling occurred within the extent of the Phase I ESA area, along the 30% design route. After drilling was completed, geotechnical soil samples were screened with a photoionization detector (PID) to assess the presence of organic vapors associated with potential soil contamination. The PID screening was completed to further investigate the potential for soil impacts identified in the Phase I REC's. The following section provides further discussion of the Phase I RECs with regard to the additional information gained from the geotechnical drilling:

- PID readings from soil samples collected in the Hazelwood Green did not indicate the presence of any detectable organic vapors. All future work in this area should follow the existing environmental covenant and associated SMP.
- Borings along Junction Hollow Valley contained fill that consisted of silty clay mixed with slag, bricks, miscellaneous debris, and black sand. No strong hydrocarbon odors or free product were observed. PID readings in this area were negligible and did not indicate the presence of any detectable organic vapors.

- No metal fragments were observed in the additional soil borings between Panther Hollow Lake and the railroad tracks. PID readings in this area were negligible and did not indicate the presence of any detectable organic vapors.
- It is unsafe to install a soil boring at the former contractor's garage approximately 200 feet south of Charles Anderson Bridge between the former section of Boundary Street and Edgehill Street due to large underground utilities. However, soil samples from borings advanced close to this area did not have any hydrocarbon odors or soil staining. PID readings in this area did not indicate the presence of any organic vapors associated with hydrocarbon contamination.
- No construction related to the 4MR Project is currently planned in the area around the Pittsburgh Department of Public Works building and therefore no soil investigation activities have occurred in this area.
- Borings along the railroad right-of-way did not observe any strong hydrocarbon odors or soil staining. PID readings in this area did not indicate the presence of any organic vapors associated with hydrocarbon contamination.

After review of the conclusions in the AWK Phase I ESA and additional historical aerial images, CEC made the following additional observations:

- Proctors Garage at 100 Boundary Street is reported to be a historic machine shop and is currently an automotive repair shop. No hydrocarbon odors or soil staining was observed during drilling. PID readings in this area did not indicate the presence of any organic vapors associated with hydrocarbon contamination.
- A building was observed northwest of the end of the present day Boundary Street loop and southwest of the existing soccer field on aerial photos before 2006. Our understanding is that this building was used for ground maintenance. No hydrocarbon odors or soil staining was observed during drilling. PID readings in this area were negligible and did not indicate the presence of any detectable organic vapors.

Based on the findings of the Phase I, the preliminary geotechnical results and the additional due diligence, CEC installed additional direct push borings along the current 4MR Project design route to further investigate potential soil impacts. Soil samples were submitted for laboratory analysis on August 23, 2019 for the following parameters: target analyte list (TAL) metals, target compound list (TCL) volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and polychlorinated biphenyls (PCBs). The analytical results from this sampling will be available in September 2019. CEC will review the results of these analyses and recommend whether a SMP is required for soil work in this area.

6.7 CULTURAL RESOURCES ASSESSMENT

In order to fulfill Section 106 of the National Historic Preservation Act of 1966, and the implementing regulations (36 CFR Part 800) of the Advisory Council on Historic Preservation; along with Article 1, Section 27 of the Pennsylvania Constitution, and the Pennsylvania History Code, 37 PA. Cons. Stat. Section 500 et seq. (1988), the project coordinated initial project information with the Pennsylvania State Historic Preservation Office (PA SHPO) of the Pennsylvania Historical and Museum Commission (PHMC)

A Project Review Form (PRF) was sent to the PHMC that requested initial consultation with the SHPO for the Project on October 22, 2018. This initial consultation consisted of a project description of the features found through data research at the PHMC files in and around the project area, along with mapping and photographs.

The PA SHPO responded on November 13, 2018. The returned response is included in an Appendix E to this PDM. Based on the location of the project within a National Register Listed Place (Schenley Park) and that contributing elements of the Park are within the project area, additional information was requested by PA SHPO. Additionally, PA SHPO stated that since the Project has the potential to affect historic resources, the Project should be notifying consulting parties to work with the project design to minimize and potentially mitigate impacts to cultural resources.

Over the next phase of the Project, the project team will be coordinating with PHMC and the consulting parties on the project design and collecting additional data necessary to receive cultural resource clearance for the Permit Application.

6.8 WETLAND DELINEATION

CEC conducted wetland and stream delineations on the Project between May and July of 2018. The purpose of this study was to identify, delineate, and classify wetlands, streams, and other waters located within the limits of the 327-acre study area.

CEC ecologists reviewed the study area for potential wetlands in accordance with the routine, onsite determination methodology described in the U.S. Army Corps of Engineers (USACE) *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987); referred to hereafter as Corps Manual, supplemented by the following technical guidance documents:

- *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont Region (Version 2.0)* (January 2012); referred to hereafter as Regional Supplement;
- *National Wetland Plant List* (Lichvar, et al. 2016); and
- *Field Indicators of Hydric Soils in the United States* (USDA-NRCS 2017).

CEC ecologists walked the study area and collected sampling points at wetlands and representative upland locations. Data collected at each sampling point was recorded on a Wetland Determination Data Form.

Concurrent with wetland delineations, CEC ecologists assessed the site for streams and other waters such as ponds, seeps, springs, and vernal pools. These aquatic resources can be identified by the presence of an ordinary high water mark in accordance with USACE Regulatory Guidance Letter No. 05-05: Ordinary High Water Mark Identification (USACE 2005).

For streams, physical and biological data were used to infer the stream's hydrologic flow regime, using a weight-of-evidence approach. CEC used field indicators such as flow, substrate composition, presence of defined bed and bank, origin of hydrologic sources, presence/absence of vegetation within the stream channel, and presence/absence benthic macroinvertebrates, fish, and other aquatic biota to classify onsite stream segments into one of three stream types – ephemeral, intermittent, or perennial.

Fifteen (15) wetlands were identified within the project study area. Eleven (10) were classified as palustrine emergent (PEM), three (3) were classified at palustrine scrub-shrub (PSS), one (1) was classified as PEM/PSS, and one (1) wetland had both PEM and palustrine unconsolidated bottom (PUB) components. In total, 0.947 acre of wetland was delineated within the study area. This was comprised of 0.793 acre of PEM, 0.119 acre of PSS, and 0.036 acre of PUB.

Thirty six (36) streams were identified within the project study area. Twenty (20) of the streams were classified as ephemeral, nine (9) were classified as intermittent, and four (4) were classified as perennial; three (3) streams had ephemeral and intermittent segments. In total, 2.96 miles of stream channel was delineated within the study area. This was comprised of 0.68 mile of ephemeral, 0.66 mile of intermittent, and 1.62 mile of perennial stream channel.

Twenty two (22) drainage features, twenty one (21) seeps, and one pond, Panther Hollow Lake, were identified within the study area. Erosional drainage features convey runoff during storm events, but lacked sufficient hydrology, and characteristics such as defined bed and bank, to be classified as streams. Seeps are location were groundwater is discharged but cannot be characterized as wetlands as they lack hydric soils and/or hydric plants.

Wetlands, streams and other waters that meet the guidelines contained in the Corps Manual, Regional Supplement, and Regulatory Guidance Letter No. 05-05 are subject to regulation by USACE as “Waters of the U.S. (WOTUS)”, as defined by 33 CFR 328.3(a) (U.S. Congress 1986). USACE has authority to permit the discharge of dredged or fill material into waters of the U.S. under Section 404 of the federal Clean Water Act (U.S. Congress 1977). Additionally, Section 401 of the Clean Water Act requires state agencies to evaluate whether discharges to these waters comply with state water quality standards (U.S. Congress 1977). A Section 401 Water Quality Certification is required for activities that require federal permits or authorizations. The Wetland and Stream Delineation Report, dated October 2018, is included in the project technical file.

6.9 PRELIMINARY JURISDICTIONAL DETERMINATION

A Jurisdictional Determination field view was requested by the PWSA for agency review of the delineation of Waters of the United States (WOTUS). PWSA invited the US Army Corps of Engineers (USACE) and the Pennsylvania Department of Environmental Protection (PADEP) to a field view of the project area.

The field view was held over two separate days, the first on August 29, 2018 with a number of officials from the PWSA, the Pittsburgh Parks Conservancy (PPC), USACE and PADEP in attendance; with the second field view held on October 10, 2018 to review the remainder of the project area. The project area was walked and the Project discussed by all parties.

The PADEP requested additional information concerning features in the project area which were distributed after the August field view. Field view meeting minutes and sign-in sheets are included in the project technical file. Once the second field view was completed, the USACE gave concurrence to the delineated WOTUS boundaries. This concurrence email is included in an Appendix D to this PDM.

6.10 PADEP PRE-APPLICATION MEETING

In order to verify permitting requirements, a PADEP Pre-Application meeting was held on June 14, 2018 to discuss the Project and the permitting required. This meeting, held at the PADEP Southwest Regional office, introduced the Project to the USACE and the PADEP. Meeting minutes and sign-in sheets were prepared. At the conclusion of the meeting, and based on the proposed impacts associated to WOTUS, a Joint Permit Application (JPA) for the Pennsylvania Chapter 105 Water Obstruction and Encroachment Permit and a USACE Section 404 Permit will need to be submitted to PADEP and USACE for approval.

A second Pre-Application meeting was held with the USACE and PADEP on November 8, 2018 to update the agencies on the latest project design, the public involvement process, and the updated proposed project impacts. PADEP Dam Safety was also conferenced in to discuss the dam structures within the project area, mainly at Panther Hollow Lake. A Dam Safety Permit will be required for the project along with the JPA and other Erosion and Sedimentation (E&S) permit applications. Meeting minutes and sign-in sheets for this November meeting were prepared.

6.11 INVASIVE SPECIES AND CONTROL PLAN

CEC conducted a plant community assessment and developed an invasive plant species assessment and control plan for the Junction Hollow area of the Project. The Pittsburgh Parks Conservancy (PPC) provided supplemental funding to support expansion of the assessment area to other portions of Schenley Park. CEC teamed with the Pennsylvania Natural Heritage Program (PNHP) of Western Pennsylvania Conservancy to describe and map plant community types, and identify invasive plant threats. Field activities were conducted August through October 2018. A report entitled, "Final Report - Plant Community and Invasive Plant Species Assessment" was prepared and completed by CEC in January of 2019.

Major plant community types within the Park are identified, mapped and described in the report. The major land use/plant community cover types identified in the Park, include:

- Developed Land/Maintained Landscapes,
- Dry Oak – Mixed Hardwood Forest,
- Urban Forest,
- Two aquatic communities, Panther Hollow Pond and Cattail Marsh

The project team identified native and alien plants, collected plant community data, and completed a qualitative assessment of invasive plant species cover and distribution in areas of the park that were predominantly covered by forested or otherwise unmanaged plant communities. Invasive plants were defined as those alien plants included on the Pennsylvania Department of Conservation and Natural Resources' lists of invasive plants and/or the Pennsylvania Noxious Weed List.

Invasive plants are present throughout the park in every plant community, particularly the western slopes of Junction Hollow and the unmowed areas in Junction Hollow. The identified invasive plants, if not managed, could have an adverse impact on proposed landscapes in Schenley Park. The use of herbicides is an effective invasive plant management method to control the spread of invasive species and promote development of stable, diverse plant communities that require little maintenance.

Manual or mechanical control methods for invasive species control can be applied to small infestations, in sensitive environmental areas of the park, or incorporated into later phases of an integrated invasive plant control plan. Based on previous projects, invasive plant control usually requires herbicide applications in the first few years of management to achieve long-term success. Recommended control measures for individual species and specific management units are presented in the report.

Tree planting planned for the site should occur immediately following construction and be completed when invasive plants are largely under control (two to five years after starting management), Spot herbicide and/or mechanical treatments can be implemented periodically to control new invasive species growth.

Monitoring will be necessary to determine the success of control measures and make mid-course adjustments. A written monitoring plan should be developed during the early stages of the project which clearly identifies invasive plant management objectives and target species, provides a sampling design for field sampling methods and data analysis, identifies methods for evaluating the monitoring results, and provides a protocol for adapting the management approaches to site conditions..

6.12 UTILITY INVESTIGATION AND COORDINATION

Prior to the performance of any preliminary layout design, CEC initiated a utility investigation covering the project Site. The investigation consisted of a design one call, meetings with utility companies/contractors, collection of information and drawing development.

On June 4, 2018, CEC submitted a PA underground utility line protection request using the One Call website (delivery@PA1call.net) for the project area. On June 7, 2018, CEC received a response list identifying twelve utility companies with project area. The companies that identified utilities in the project area included the following:

- Peoples Natural Gas Company, LLC
- Pittsburgh Water and Sewer Authority
- Allegheny County Sanitary Authority
- Duquesne Light Company

Companies that responded with no utilities within the project area included the following:

- Comcast Cable Communication

- Lightower Fiber Networks LLC
- Verizon Business (formerly MCI)
- University of Pittsburgh
- Verizon Pennsylvania

Three companies did not respond to the request.

Following the one call request, CEC arranged meetings with the four utility companies or their appointed representatives. The meetings were conducted at the project site or at the offices of the utility company. During the meetings, CEC presented the project objectives and plan views of the project area and walked the site, if applicable. The utility companies and CEC reviewed schematic layouts of the utility locations and verified the project area on the layouts. Using the layouts, the companies were able to retrieve Adobe based as-built drawings of their utility locations and provide the drawings in electronic format to CEC. To maintain continuity with the project, CEC obtained a name of a representative who would be the point of contact for all questions or requests for information.

In July of 2018, CEC met with representatives of Hazelwood Green, who provided as-built drawings of their parcels within the project area.

In conjunction with the collection of electronic data, CEC provided the Adobe PDF based data to AWK Engineers for use in their development of topographic and planimetric mapping. A comparison of this electronic data received directly from the utility companies and topographic mapping and utility locations prepared by AWK Engineers under a previous contract with PWSA identified inconsistencies in some utility locations. Potholing will be performed to verify utility locations.

The current mapping of existing utilities is provided in the existing conditions mapping and is shown on Figures G100xxx through G108XXX.

6.12.1 Potholing

As conceptual project alignments were developed, locations were identified where the proposed improvements crossed existing utility lines. As noted previously, many of the existing utility line locations shown on the survey are approximate and based on archive design plans or as-built plans provided by the utility company. In order for the design team to understand if/how these existing utility lines will be impacted by the proposed development, a more detailed investigation (potholing) was performed to determine exact location, depth, size, material, etc. of specified utility lines at specified locations along the project alignment. The information obtained during this investigation was used to update the survey base file shown in the design documents. An exhibit identifying the locations of potholing is included in an Appendix L to this PDM.

6.12.2 Closed Circuit Television (CCTV)

In addition to the potholing investigation, the design team also performed a closed circuit television (CCTV) investigation on select utility lines within the project boundary. The CCTV investigation was performed to serve two (2) primary purposes. The first was to verify storm pipe locations and sizes shown on the survey base file. Many of the storm pipe and structure locations shown were approximate based on archive design plans or as-built plans and the design team wanted to verify this information, especially in the vicinity of the proposed development. The other purpose of the CCTV investigation was to observe the condition of the existing pipes within the project boundary to determine if replacement or rehabilitation measures should be included in the project recommendations. The design team also reviewed archive CCTV investigation footage provided by PWSA. The CCTV Report is presented in the Appendix L to this PDM.

CEC reviewed the CCTV data provided by Insight Pipe Contracting, LLC, specifically the video and the data sheets and prepared an exhibit identifying the location of areas of concern, which included infill runners, infill gushers, infill weepers, infill drippers, holes in pipe walls, mineral and sediment deposit buildups, tap locations, . The exhibit and data sheets are included in an Appendix L to this PDM.

6.12.3 Right-of-Way and Easements

In conjunction with the location of utilities, right-of-way and easements associated with select utilities, highways, railroads and properties were identified and documented. Critical locations of right-of-ways or easements are needed for the CSX railroad tracks, which separate Panther Hollow Lake from Junction Hollow, Second Avenue, which is a PennDOT roadway, Boundary Street, Four Mile Run Road and Saline Street, which are city roads, Signature Boulevard/Blair Street which is located on the Hazelwood Green site and railroad tracks leased to MetalTech and operated by Hazelwood Green. Design and subsequent construction of the Project will need to consider these restrictions/limitations.

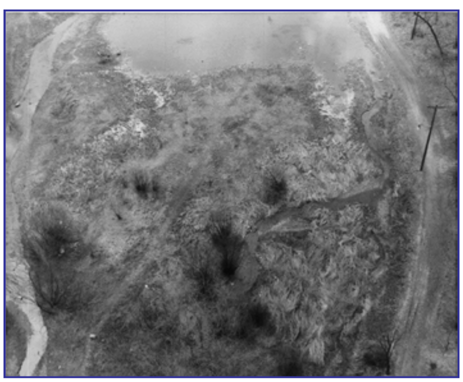
6.13 LAKE INVESTIGATION

Ethos Collaborative led a detailed investigation and review of historical documents regarding Panther Hollow Lake. A detailed Site Investigation and Characterization for Panther Hollow Lake is included as an Appendix G to this PDM. This information is summarized below.

Panther Hollow Lake has been in existences since at least 1908, when it was enlarged from an existing smaller open body of water for the purpose of enhancing recreation in the relatively new Schenley Park. Since then, its last major renovation was in 1957, with dredging, construction of a concrete edge in the modernist style, and a bypass channel that diverted high flows around instead of through the lake.

Since its creation, Panther Hollow Lake has experienced problems with sedimentation that result in poor water quality, reduce its value as a recreational resource, and decrease its effectiveness for potential stormwater attenuation. Sedimentation is a process common to all lakes and streams but can particularly problematic in steeply-sloped urban areas, where upstream development contributes to higher intensity stream flows and stream channel incision over time. In man-made lakes, the sedimentation/deposition process can proceed faster than in natural lakes, resulting in the need for periodic dredging if the lake is to maintain design depths and perform design functions.

Panther Hollow Run and Phipps Run continue to deposit sediment sourced from upstream areas, a process which led to considerable filling in of the eastern portion of Panther Hollow Lake and creation of an emergent wetland. To reduce ongoing maintenance needs for Panther Hollow Lake, the Lake was drained and dredged in the late 1950's, and the edge reinforced with concrete edge walls.

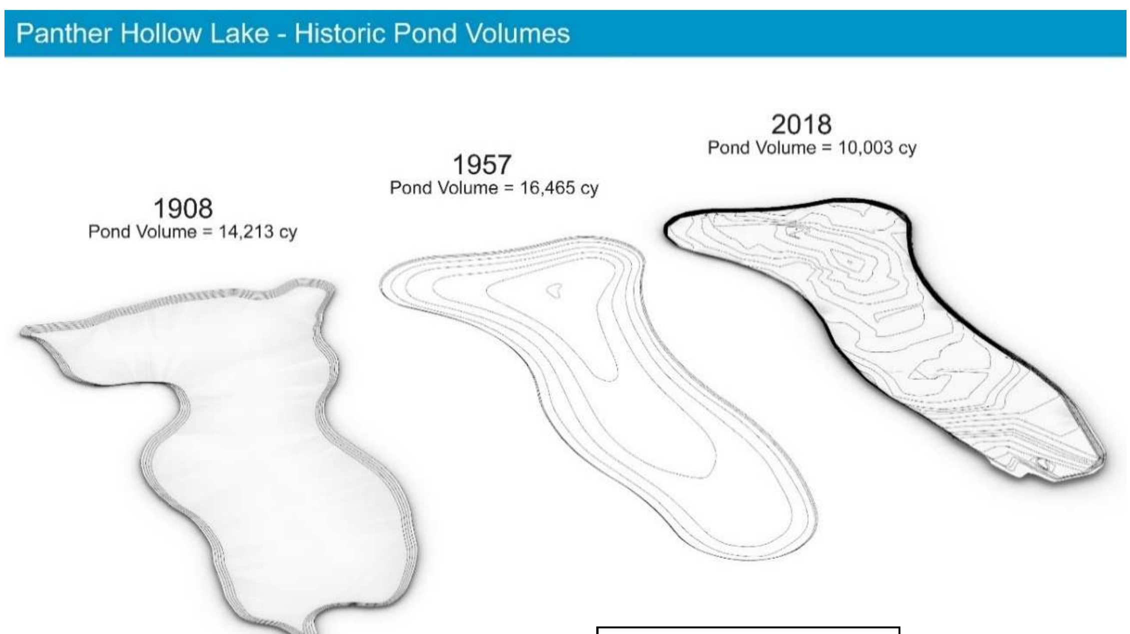


Sediment accumulation forms a wetland in 1958 (left, as pictured from Panther Hollow Bridge) and in 2018 (right, as pictured from the east) within Panther Hollow Lake.

Another source of sediment to the Lake is the steep slopes surrounding the site. Historical and modern-day landslides have been observed on the steep slopes to the north and south of the Lake. Note the similarities between the historic landslide from 1957 and one that occurred in mid-2018, immediately below the solar panel array at Phipps Conservatory.

The slopes above the lake have a history of landslides as shown in 1957 (left) and in 2018 (right).

Ethos Collaborative estimated that sedimentation has reduced the volume of the Lake by 39% since it was last dredged in the late 1950's. Figure 6-2 shows the historic change in lake volume from 1908 to 2018.



Change in Lake Volume.

Figure 6-2 Historic Panther Hollow Lake Volumes

Nutrients and bacteria attached to the sediment load can increase the risk of eutrophication and pose some level of public health and safety risk. Decreasing water depth also increases the temperature of the water, which can also increase eutrophication and negatively impact aquatic habitat. With this accumulation history in mind, Lake restoration plans explored by this Design Team include elements intended to decrease sediment management requirements, reduce periodic dredging, and prolong the functionality of the designed Lake ecosystem.

6.13.1 Existing Real Time Control System (RTC)

In 2018, PWSA installed a 16-inch Opti RTC valve at the Lake, which ties for the largest installation for Opti to date. Located at the northwest corner of the lake, the system installed provides real-time control for the existing 15" outlet pipe, connecting to real-time weather and lake depth data and reacting in anticipation of storm events to reduce wet-weather discharges. Although only recently operations, the valve has the potential to increase the detention capacity of the lake, while simultaneously increasing the overall water quality of the receiving waterbody during wet weather flows.

The control structure housing the valve and actuator is located between the Lake and the existing ALCOSAN manhole, intercepting the 15" clay pipe that collects the Lake overflow. Real-time sensors supporting the system include a rain gauge and a lake level sensor. The "smart" technology behind RTCs is scalable and adaptable, and the technology is presently being explored for use in the proposed Four Mile Run restoration design for optimizing lake capacity.

6.13.2 Wet Weather Behavior

Presently, the Panther Hollow Lake and surrounding environs have not been designed to manage stormwater during large storm events, except to drain them directly to the ALCOSAN combined sewer system. Observations made during large events indicate that the Lake overtops its banks and floods the surrounding paths on a regular basis. High water events flood the trails, create iced paths in the winter, deposit debris on the trail and along the shoreline, and erode unpaved trails. Water that drains from the Lake enters the combined sewer system. Water that overtops the berm to the west, near the railroad tracks, flows along a drainage swale then enters the combined sewer system downstream. Pedestrian paths around the Lake are largely impassible during heavy rains, affecting circulation patterns and visitor experience.

LEFT: Flooding overtops the berm and enters a drainage swale on the west side of Panther Hollow Lake. RIGHT: Flooded trail surrounding the Lake. This picture was taken during a 100-year storm event on September 10, 2018, looking west

6.14 SUMMARY OF PERMITS AND AGENCY APPROVALS

The permits that are needed from various agencies and public entities to construct the Project are summarized below.

- Joint Permit Application (JPA), Chapter 105 and Section 404 – reviewed by the PADEP and USACE for impacts to streams and wetlands; information and approvals listed immediately below will be included in the JPA:
  - Erosion and Sedimentation Control Permit – reviewed by PADEP and or the County Conservation District for impacts associated with earth moving and sedimentation;
  - Hydrologic and Hydraulic Assessment – reviewed by the PADEP for impacts associated with stream flow and negating potential flooding;
  - Cultural Resources – impacts to the National Register Listed Schenley Park and contributing elements will need to be approved by State Historical Preservation Officer (SHPO) and other local consulting parties;
  - PA Natural Heritage Program (PNHP) – for clearance of state and federal threatened and endangered species impacts;
- Chapter 105 Dam Permit – reviewed by PADEP Dam Safety for impacts and construction associated with the embankment rise and principal spillway and emergency spillway of the replacement of the dam on Panther Hollow Lake, dredging of Panther Hollow Lake, lake edge modification and improvements, and forebay lake design;
- Submerged Land License Agreement (SLLA) - reviewed by PADEP, if needed, for potential access or impacts to the Monongahela River;
- Pipe Outflow Permit to Monongahela River – review by USACE;
- FEMA floodplain mapping review, update, and approval – if needed, review by FEMA;

- Highway Occupancy Permits (HOP) - reviewed by PennDOT Engineering District 11-0 for access and crossing of state-owned roadways;
- City of Pittsburgh Department of Public Works Maintenance and Protection of Traffic (MPT) Permit – for closure of single lanes of traffic during construction;
- CSX Railroad Permits – reviewed by CSX for access and construction on and under railroad-owned property, approvals for Panther Hollow lake dam spillway pipeline beneath RR tracks and for piping beneath railroad bridges at Soccer Field and Greenfield Avenue entrances;
- City of Pittsburgh Department of Public Works (DPW) and Department of Mobility and Infrastructure (DOMI) - review and approvals for tree removal and replacement, city roads and access, and pedestrian/bicyclist trails;
- City of Pittsburgh Permits, Licenses and Inspections (PLI) - for Land Operations Permit of construction, roadway crossings, inspections of new facilities, outdoor signage, and licensing of facilities and occupancy;
- Hazelwood Green / ALMONO – crossing of property and MetalTech RR access and crossing;
- Appropriate zoning permits, as needed;
- Building, Plumbing, and Electrical permits, as needed;
- Fire Department review and approvals of buildings and occupancy permits, as needed.

6.15 CULVERT AND CATCH BASIN RECONNAISSANCE

In June of 2018, a site reconnaissance was performed to identify the culverts, erosional features, streams, and tributaries located within and around the 456-acre park, and identify any functional or maintenance issues associated with the park's infrastructure regarding stormwater runoff and erosion. The area consisted of the Project boundaries plus any nearby or adjacent land known to be or suspected of being connected via the stormwater network. A Culvert and Stormwater Network Report that summarizes the finding is presented in the Appendix F to this PDM

7.0 ALTERNATIVES WORKSHOP

7.1 WORKSHOP MEETINGS

On August 1, 2018, and again on August 22, 2018, CEC administered two alternatives workshop meetings at the PWSA offices on Liberty Avenue, Pittsburgh, PA. The meetings were attended by representatives of several of the consulting firms and by professionals from PWSA. The purpose of the of the workshop was to utilize the experience of the participants in a group discussion format to conduct a brainstorming session to identify technologies and alternatives and to identify and establish weighting criteria to address the goals of the Project, i.e., CSO overflows, reduction of localized flooding, reduction of basement flooding, promote park improvements, and align with routes of least resistance at the site.

7.1.1 Alternative/Speculation/Brainstorming

During the August 1, 2018, session that lasted approximately 4 hours, the following areas/segments of the Project were discussed (from upstream to downstream):

- Panther Run and Phipps Run Streams
- Panther Hollow Lake
- Junction Hollow and the Soccer Field/Parking Lot Area
- Tunnel Route
- Four Mile Run Park and Saline Street
- Second Avenue and Greenfield Avenue Railroad Bridge
- Hazelwood Green (Almono Site)

A summary of the pertinent information regarding existing conditions, important design elements, and thoughts and suggestions on approaches to design discussed during the workshop is presented in Appendix H of this PDM.

7.1.2 Workshop Weighting Criteria

Prior to the alternatives workshop, members of the project team identified elements that will be common amongst the anticipated formation of alternatives that could be used during a side-by-side comparison of the alternatives. Eight elements, referred to as evaluation criteria were preliminarily identified. These criteria consisted of the following:

- A - Route and length (Shortest path to longest path, property permissions)

- B - Infrastructure Obstructions (Electric, gas, PWSA, Railroad, PennDOT, property)
- C - Implementability (Difficult to Easy)
- D - Opinion of Construction Costs (Material, Labor, O&P)
- E - Schedule (Procurement, RFIs/Submittals, construction, commissioning
- F - Permitting (State, Federal, City, Contractor, PennDOT, CSX, Utility)
- G - Operation & Maintenance, Inspection (storm event cleanout, periodic inspections, vegetation management)
- H - Performance (CSO reduction, flood reduction, park enhancements, sediment reduction, climate resilience, etc.)

During the workshop, four additional criteria were proposed and incorporated into the evaluation process. Therese criteria consisted of the following:

- I - Public perception (value and input)
- J- Risk (proactively decreasing flooding potential)
- K- Synergy with other projects (e.g., park initiatives, development, mobility)
- L- Sanity Check (do the alternatives make sense)

Following the acceptance of these criteria, the alternatives workshop team was asked to rate the importance of the evaluation criteria. A weighting value was to be assigned to as few as or as many as the criteria as deemed important, with a value as low as 0.0 and as high as 1.0; however, the sum of the weighting factors evaluated must equal one (1.0). Approximately one dozen project team members provided ratings, without knowledge of other project team selections. These weightings were averaged among respondents. The top five criteria and their weight is as follows:

- Performance 0.17
- Construction Cost 0.17
- Public Perception 0.10
- Operation, Maintenance and Inspection 0.09
- Risk 0.09

The greatest weighting assigned to any criteria was 0.35 while the lowest weighting assigned to any criteria was 0.0. Upon review of the weighting, three criteria that received weighting of less than 0.058 were identified by the workshop team as non-important, partly because they overlapped substantially with other criteria. These criteria included Route and Length, Permitting, and Synergy with Other Projects and will not be utilized in evaluation. The total weight of these three criteria was 0.11. This resulted in nine criteria accepted for comparative analysis. The four additional criteria and their weighting were identified and consist of:

- Infrastructure Obstructions 0.08
- Implementability 0.07
- Schedule 0.06
- Sanity Check 0.06

The total weighting of these nine criteria is 0.89. Adjusting the values to obtain an aggregate weight of one (1.0) results in the following weighted criteria.

- Performance 0.19
- Construction Cost 0.19
- Public Perception 0.11
- Operation, Maintenance and Inspection 0.10
- Risk 0.10
- Infrastructure Obstructions 0.09
- Implementability 0.08
- Schedule 0.07
- Sanity Check 0.07

7.2 DESIGN DEVELOPMENT WORKSHOPS

Following the first public meeting on 17 September, evolveEA and CEC convened three multi-disciplinary workshops to comprehensively discuss all elements of the project. These workshops were designed to facilitate discussion between team members working on adjacent portions of the project, define design problems and desired parameters, and ensure that the project as a whole was being developed in an integrated manner. The outcome of these workshops was a thorough understanding of all the project interdependencies and a clear path toward developing the design in anticipation of the 14 November public meeting.

The three workshops dealt with three different project areas:

- Workshop A: From the Run neighborhood to the Monongahela River (08 October 1pm-4pm @ CEC)
- Workshop B: Junction Hollow (04 October 9am-1pm @ CEC)
- Workshop C: Panther Hollow Lakes and Streams (08 October 11am-1pm @ CEC)

Meeting summaries from these three workshops is presented in Appendix H of this PDM.

7.3 WORKSHOP SUMMARY

The Preliminary Design Workshop Summary is attached as Appendix H to this PDM.

8.0 ALTERNATIVES ASSEMBLY

8.1 INTRODUCTION

In this section, technologies that may mitigate and/or manage the stormwater and sewer water flows and discharges at the Site will be identified and screened to determine if they should be selected and used in the assembly of alternatives. Each technology will be qualitatively evaluated/screened using two screening criteria utilized by the United States Environmental Protection Agency (USEPA) in the screening of alternatives during the preparation of Feasibility Study level documents. These two screening criteria consist of Performance/Effectiveness and Implementability. Following the screening discussion, a conclusion and explanation for retaining and including the technology in the assembly of alternatives or elimination from consideration will be provided. Those conclusions will be presented in narrative form to allow for a side-by-side comparison of the technologies and their associated screening.

A description of the two criteria are provided below.

8.2 TECHNOLOGY SCREENING CRITERIA

8.2.1 Performance or Effectiveness

This criterion addresses the degree to which each can satisfy operational reliability, or the ability of the alternative to meet specified process efficiencies or performance goals. Several performance goals may be identified for each alternative, based upon the various elements of construction associated with the alternative. Several important performance factors include the ability of the project to reduce flooding in critical areas, the ability of the project to reduce sediment deposition, the ability of the project to reduce operation and maintenance and the ability of the project to remove the stormwater component from the existing piping, result in only sanitary discharge and conveyance.

8.2.2 Implementability

The alternatives must be evaluated to estimate the degree to which each can satisfy implementability criteria. Implementability refers to the technical and administrative feasibility of implementing an alternative, and the availability of various materials and services required during its implementation. The following factors must be considered during the implementability analysis:

- Technical Feasibility: The relative ease of implementing or completing an action based on site-specific constraints, including ability to construct the alternative as a whole (constructability); the ability to incorporate future actions that may be required; and ability to monitor the effectiveness of the remedy.

- Administrative Feasibility: The ability and time required to obtain any necessary approvals and permits from other agencies.

- Availability of Services and Materials: The availability of the materials or services required to implement an alternative, including: available location of storage, and disposal services; availability of necessary equipment and specialists and provisions to ensure any necessary additional resources; timing of the availability of prospective alternatives under consideration; and availability of services and materials, plus the potential for obtaining bids which are competitive (which may be particularly important for innovative technologies). It may also include availability of capacity and treatment services, should environmental issues arise.

8.3 DESCRIPTION AND SCREENING OF TECHNOLOGIES

Potential technologies applicable to the design of the Project were identified and screened to select those technologies that should be used to assemble alternatives. Ten technologies were identified and consist of the following:

- Stream Restoration
- Lake Restoration
- Open Channel Conveyance
- Pump Station
- Piping/Culverts
- Tunneling
- Detention/Retention
- Green Infrastructure
- Embankment Modifications for Dam Permitting
- Drop Shaft from Junction Hollow Channel/Stream to PWSA Piping

A description of the technology and the screening of the technology to determine if it should be eliminated or carried forward in alternative development is presented in Appendix M.

8.4 ASSEMBLY AND EXPLANATION OF ALTERNATIVES

Using the technologies retained from the screening presented in Section 8.3 of this PDM, alternatives were assembled to address the objectives presented in Section 8.1 and to present a range of approaches for the various segments discussed in Section 5.2 of this PDM. The alternatives incorporate multiple and differing technologies to cover the variety of differing conditions and needs throughout the entire length of the Site.

Initially, the alternatives were assembled using applicable segments discussed above along the entire Project length and an appropriate technology for the segment. This resulted in a developed alternative consisting of several components. Many of the segments and associated technologies are repeated for various alternatives, resulting in a repetition and previous referencing of components for each alternative discussion.

In order to reduce the repetition, the Alternatives have been developed based primarily on the segment and secondarily on the technologies applicable to the segment. The alternative numbers will be utilized in the development of the engineers' opinion of cost.

The assembled alternatives are presented below. They include an explanation/description of the alternative components, the technologies used for each alternative, and periodic map figures identifying the location of the alternative.

8.4.1 Alternative No. 1 Phipps Run Stream Channels

In order to reduce continuing erosion of streambanks and sediment loading and to stabilize channel cross sections, the Phipps Run stream channel will be modified and restored to support an ecologically functioning riparian area and stable profile. Based on hydraulic modeling, the modifications will also provide a 5-10% reduction in peak storm discharge during the 100-yr 24-hr storm. The proposed profile has vertical expansions and contractions to maintain water depth during low flows and dissipate flow energy during large events.

The bankfull discharge, which generally coincides with the 1.5-yr peak discharge (calculated using the SWMM Green-Ampt runoff estimates), provides the basis of design for stable stream channels. The following subsections provide greater detail, but in summary, channels that are designed for a smaller event tend to erode whereas those that are designed for a larger event tend to aggrade with sediment, which can lead to instability when those sediments wash out. Stable channels designed for the bankfull discharge are accompanied by floodplains that contain and convey higher discharges at lower velocity and shear stress. Thus, stream channels are designed for flows between base flow and bankfull discharge (1.5-yr discharge) and floodplains are designed to accommodate flows between 1.5 and 100-yr (or greater). Generally, the width of floodplains is determined by adjacent landforms or other constraints, such the need to protect infrastructure.

The proposed width-to-depth ratio of the bankfull channel has been increased in confined existing reaches to flatten channel side slopes to reduce erosive potential and increase stability. The proposed wider and shallower channel relocates high shear stress areas into the center of the flow, resulting in lower shear stress at the stream bed and bank to decrease erosion and reduce sediment supplied to downstream reaches. Where existing channel conditions are overly wide and lack transport capacity the proposed channel is narrow prevent in channel aggradation and lateral migration.

8.4.1.1 Floodplains

The proposed designs incorporate a floodplain bench to increase entrenchment ratio and allow flood flows to disperse during large precipitation events. The proposed stream design will contain a bankfull channel to convey flow at the 1.5 year recurrence interval and a floodplain within the meander belt width to attenuate flows and shear stress. The proposed floodplain width is greater in the proposed condition to spread out flood flows, attenuate peak flows, and convey additional flow. Dispersing flood flows decreases shear stress during overbank events and increases discharge capacity while maintaining channel stability and decreasing sediment loads. Floodplain widths are designed to convey additional water as upstream sewer sheds become disconnected or to attenuate increased peak discharge. The floodplain provides a low-gradient surface between the stream and valley walls where hillslope derived sediments can deposit to decompose in place and rather than entering the stream. Floodplain surfaces provide areas of low shear stress which deposit fine sediments during overbank flows and improve downstream water quality. Wetland depressions further reduce shear stress to collect fine overbank sediments and offer the opportunity to provide ecological services that are currently limited in the project reach. The channel riparian area should be planted with native successional vegetation that will further increase channel stability.

8.4.1.2 Proposed Channel Layout

The proposed channel planform balances the need to transport sediment and reduce shear stress to maintain stability. Because an overly sinuous channel will aggrade and eventually straighten, and an overly straightened channel will degrade and eventually erode banks to increase sinuosity (Schumm, 1985[5]), a meandering layout will be utilized. This will also dissipate flow energy and increase instream hydraulic retention time.

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[5] Schumm, S. A. (1985). Patterns of Alluvial Rivers. Annual Review of Earth and Planetary Sciences, 13, 5.

Lower-slope reaches have increased sinuosity to produce form drag and dissipate flow energy through pools. Increased sinuosity of the lower reaches increases hydraulic residence time compared to the existing conditions which in turn helps attenuate peak flows.

Steep-slope reaches are designed relatively straight to contain areas of high shear stress within the bankfull channel extents and reduce stress on valley walls. Flow energy is dissipated using vertical variability in steep streams rather than by creating a sinuous plan form as is done for low-gradient reaches. The proposed meander belt width is within the designed floodplain bench to disperse shear stress during overbank events over a larger area as compared to the existing conditions.

The planform of the bankfull channel extents is buffered from the valley walls by the floodplain. The floodplain buffer between channel and valley walls reduces stress on valley walls and buttresses the toe of the slope to increase slope stability. The proposed floodplain also provides a bench to catch colluvial sediments derived from valley walls further reducing sediment inputs to the stream. Thus the floodplain component of the design is critical for increasing flow capacity and decreasing sediment supply.

8.4.1.3 Proposed Channel Profile

The channel profile consists of reach scale vertical variability superimposed on valley-scale slope. Valley-scale slope and hydrology sets up the hydraulic conditions that determines the smaller reach-scale vertical variability. The proposed channel profiles utilize pools, appropriately spaced for the hydraulic conditions, to create vertical variability, to dissipate flow energy vertically during high flow and provide instream aquatic habitat during low flow. Pool-to-pool spacing and thus vertical variability in the longitudinal direction when scaled to channel width becomes dependent on channel slope (Chin and Wohl, 2005[6]). Reach-scale variability consists of steps and pools at steep slope and pool and riffles a low slopes.

The proposed channel profile at the valley scale is elevated in areas that are currently entrenched with small or non-existent floodplains. The elevated profile works in conjunction with planform geometry to increase floodplain width and reduce stress near valley walls. The channel profile was adjusted to balance the need for increased floodplain and flow capacity within the natural geologic constraints (and naturally other constraints including earthwork, etc.). Once the slope was set to create adequate floodplain width, channel morphology and reach-scale vertical variability was graded in to mimic alluvial morphology naturally created under similar geomorphic settings.

[6] Chin, A. and Wohl, E., 2005. Toward a theory for step pools in stream channels. Progress in physical geography, 29(3), pp.275-296.

Hydraulic modelling was performed to optimize pool-to-pool variability within the range of values expected for this hydrogeomorphic setting.

Steeper-sloped channels, which have stepped bed morphologies, have closer pool-to-pool spacing to further dissipate flow energy. Shallow slopes have longer frequent pool-to-pool spacing and dissipate flow energy through a combination of skin friction form drag comprised of a vertical and lateral component.

The step pool sequence is the primary morphologic and ecologic unit of steep reaches and is characterized by the tumbling flow regime. The proposed design extensively utilizes the stepped bed morphology to concentrate hydraulic forces to the center of the channel and promote stability. Hydraulic jets set up in the tumbling flow regime are responsible for creating and determining pool location and frequency along a steep stream reach. The exclusion zone, located downstream of a stable step in the area of jet flow produced of supercritical flow over the step, create local flow conditions that nearly always prohibit deposition of new steps within that zone (Curran and Wilcock, 2005[7]; Curran, 2007[8]). For design purposes we limit step spacing to ensure subsequent steps are beyond the exclusion zone. The length of the exclusion zone created by the supercritical flow is approximately 6h, where h is the flow depth in the super critical flow region (Comiti and Lenzi, 2006[9]). Typical Wbkf/Dbkf (bankfull width to bankfull depth ratio) in steep streams is about 12, if the flood-prone depth over the step is assumed to be twice Dbkf then we can conclude that steps should be spaced out by at least Wbkf to avoid being in the exclusion zone during high flow events. Indeed, research shows that pool-to-pool spacing and thus step spacing is rarely tighter than 1Wbkf. This design utilizes a minimum step spacing of 1.5Wbkf where the extra 0.5Wbkf beyond the exclusion zone during flood events is provided as a factor of safety and to promote tread formation and support macroinvertebrate communities.

Mild and shallow-sloped channels have less frequent pool spacing to balance transport capacity required to maintain pool depth with energy dissipation. The foundational work of Leopold and others illustrated the importance of pool-to-pool spacing in stable shallow-sloped pool-riffle channel morphologies. Increasing pool-to-pool spacing on low-gradient reaches causes a corresponding decrease in riffle slope, which promotes in-channel sediment deposition and may lead to lateral migration (and thus instability and erosion). Too frequent pool-to-pool spacing increases riffle slope, which is better capable of transporting upstream sediments but can

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[7] Curran, J. C., & Wilcock, P. R. (2005). Characteristic dimensions of the step-pool bed configuration: An experimental study. Water Resources Research, 41(2).

[8] Curran, J. C. (2007). Step–pool formation models and associated step spacing. Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group, 32(11), 1611-1627.

[9] Comiti, F., & Lenzi, M. A. (2006). Dimensions of standing waves at steps in mountain rivers. Water resources research, 42(3).

encourage channel incision by eroding riffle substrate (also leading to instability and erosion). Initial pool-to-pool spacing is selected based on reference conditions and refined by interpreting shear stress calculations produced using 2D hydraulic models.

8.4.1.4 Proposed Channel Morphology

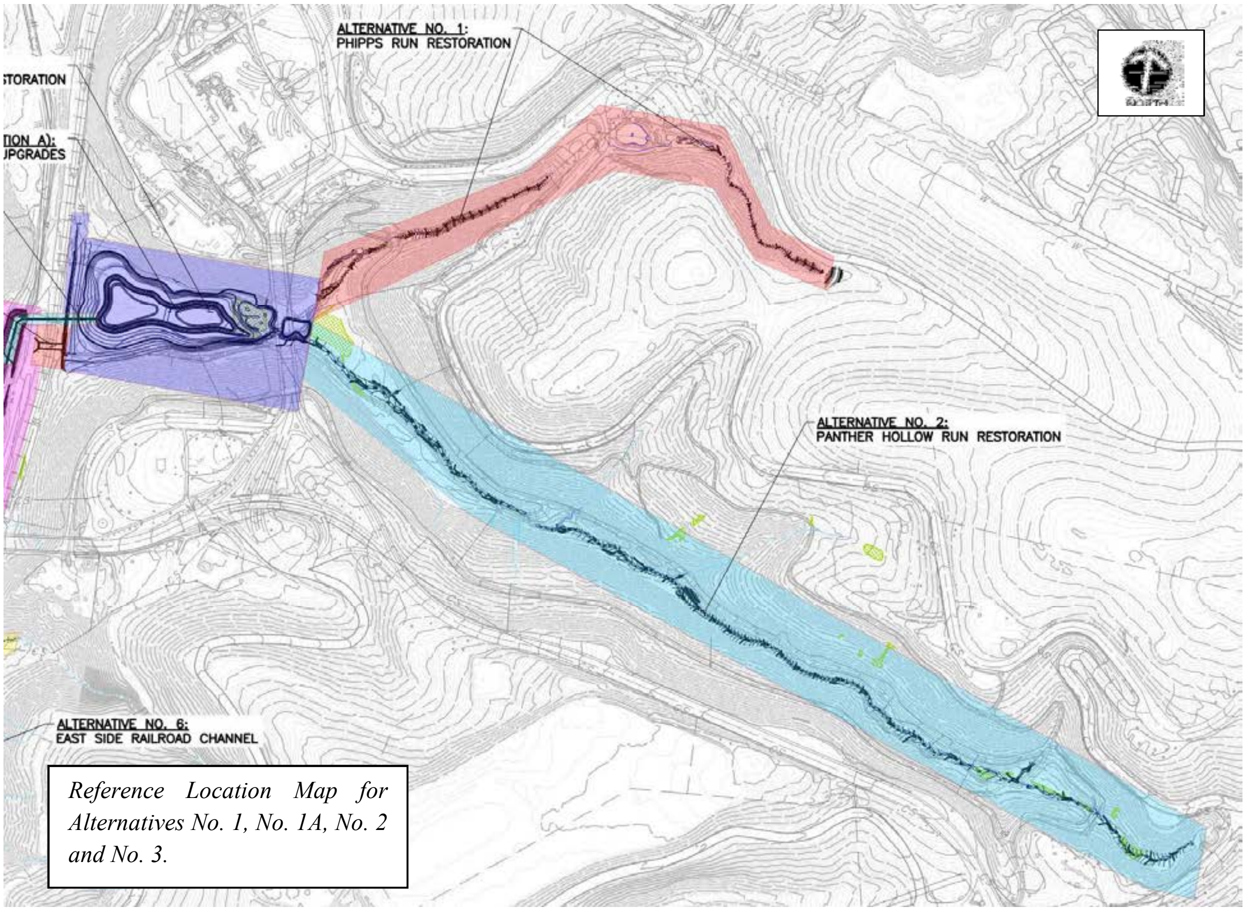
The manifestation of the proposed channel geometry, planform, and profile, which largely reflects the quantitative classification proposed by Rosgen, into proposed morphology, described by Montgomery and Buffington, follows as such. Appropriate width-to-depth ratio is set to transport sediment inputs during low-magnitude storm events and entrenchment ratio is enlarged to provide sufficient stream power to maintain vertical variability in the longitudinal profile. It also reduces shear stress during extreme events that can destabilize morphology established by lower magnitude more commonly experienced flow events that cause fine sediments to deposit in the floodplain. The plan form and profile to be established during construction will replicate naturally formed channels under the expected hydrologic and sediment regimes.

Design of the steep streams in the most confined reaches will be relatively straight Rosgen A type with stepped bed morphology dominated by cascade units interspersed with step pool sequences as slopes become milder. While the cascade and step pool morphologies technically differ on the basis of channel-spanning pools, both concentrate shear stress away from the channel boundary to promote stability. Milder sloped reaches will be designed with more access to floodplains and have slightly increased sinuosity representative of Rosgen B streams with stepped bed morphology dominated by step pool sequences with cascade and pool riffle units interspersed at steeper and shallower sloped transitional reaches respectively. Shallowly sloping streams will have extensive flood prone areas to attenuate flows, a low-flow inner berm channel, and increased sinuosity representative of Rosgen C type streams with pool riffle sequences interspersed with tread containing step pool sequences at mild slopes. As stream slope decreases and floodplain extent increases more opportunities exist to develop off-channel features to better meet the hydrologic, geomorphic, and ecologic objectives within the scope of this project.

Shallow ephemeral wetlands are prescribed for floodplains and riparian areas particularly on lower-gradient reaches with more extensive floodplains. This wetland-stream connectivity affords the project several important aquatic, geomorphological, and ecological functions, including flood-flow attenuation, water quality maintenance, and habitat diversification. Floodplain depression wetlands and vernal pools help to attenuate flood peaks by increasing the volume of off-channel storage, where water can be detained and slowly released during the receding limb of the hydrograph (Adamaus and Stockwell, 1983[10]). They produce areas of low shear stress during overbank flows, which promotes deposition of fine sediments and reduces downstream sediment loading. Water stored in wetlands infiltrates through the ground to the stream during low flow periods, which increases instream flow (Demissie and Khan 1993[11]) and helps to modulate temperature during warm summer months. In addition to sediment removal, depressional wetlands with restricted outlets function to detain flood water and surface run-off, increasing contact time with vegetation, detrital mats, soil, and associated microorganisms allowing physiochemical and biogeochemical transformation and removal of pollutants (Adamus and Stockwell 1983). Depressional wetlands also provide important habitats for diverse invertebrate and vertebrate fauna, macroinvertebrate production, amphibian breeding sites, and watering and foraging areas for birds and mammals (Majumdar et al 1989[12]).

Plane-bed reaches are avoided in the proposed condition because they lack meso-habitat units that support healthy aquatic ecosystems and laterally disperse shear stress across the bed such that near bank stress can lead to instabilities.

[10] Adamus, P.R. and L.T. Stockwell. 1983. A Method for Wetland Functional Assessment. Vol. I. Critical Review and Evaluation Concepts. Report No. FHWA-IP-82-23. Federal Highway Administration, Washington, D.C. 176 pp.
[11] Demissie, M., & Khan, A. (1993). Influence of wetlands on streamflow in Illinois. SWS Contract report; 561.
[12] Majjumdar, S.K, R.P. Brooks, F.J. Brenner, and R.W. Tiner (Eds.). 1989. Wetlands Ecology and Conservation: Emphasis in Pennsylvania. The Pennsylvania Academy of Science, Easton, PA, 395 pp.



Reference Location Map for Alternatives No. 1, No. 1A, No. 2 and No. 3.

8.4.2 <u>Alternative No. 1A Green Infrastructure Upstream of Phipps Run and Panther Hollow Run Stream Channels</u>

Upstream of Phipps Run and Panther Hollow Run streams, green infrastructure features will be designed to improve the functionality of the stormwater management system including the conveyance through Phipps Run and Panther Hollow streams, attenuation at the lake, and connection of ancillary upstream watersheds. These green infrastructure features include the following:

8.4.2.1 Phipps Run - Schenley Drive Detention

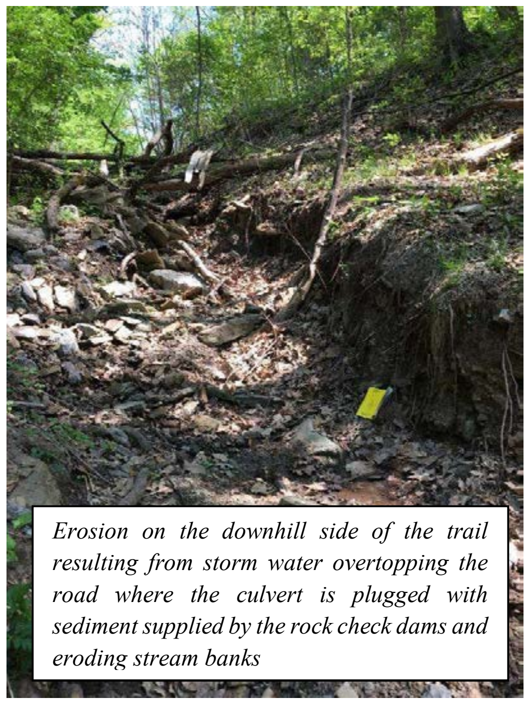
Located to the south of Schenley Drive just above the head of Phipps Run lies a fairly large bowl-like landform. At this base of this area, dampness as well as signs of soil erosion lead directly to the head of the stream. Runoff from the manicured slopes of the golf course currently drain to this area. This runoff as well as additional road runoff from Schenley Drive could be detained in this location with a detention facility designed to attenuate and slow down storm water runoff, reduce erosion potential on Phipps Run and provide additional wetland area. With the volume of storage limited in this location, a series of connected detention or wetland areas along Schenley Drive may be required to control the 1.5" design storm

8.4.2.2 Phipps Run - Golf Course Edge Vegetation Strip

A 10 to 20 foot wide transitional vegetation strip at select locations on the golf course will slow runoff with the potential to infiltrate some additional water prior to reaching the erosion prone steep slope that lead to Phipps Run. This strip is constructed by simply tilling up this buffer to reduce soil compaction and reestablish a new turf consisting of a variety of native grasses and wildflowers. Further discussions with golf course personnel and City staff will be required.

8.4.2.3 Phipps Run - Abandoned Channel Wetland Complex

A wetland complex in the abandoned portion of Phipps Run will attenuate peak discharge during storm events and improve groundwater recharge. The wetland complex consists of numerous small wetlands created by placing clay plugs in the abandoned portion of Phipps Run. The plug and pond restoration technique will be modified so that the wetlands drain within 48 hours following a storm event to prevent mosquito larvae from reaching maturity.



Erosion on the downhill side of the trail resulting from storm water overtopping the road where the culvert is plugged with sediment supplied by the rock check dams and eroding stream banks

8.4.2.4 Panther Hollow Steam – Rock Check Dam Improvement Wetlands and Stream

Off West Circuit Road, three existing rock check dams are filled with sediment, thereby eliminating the ability to attenuate storm flows. The sediment is carried downstream and has filled a culvert, forcing water to overtop and erode the trail during rain events. The reclamation of the check dams and added detention would stabilize eroding banks, reduce peak flows and prevent further down cutting to reduce sediment supplied downstream. The plugged culvert would be replaced with a larger culvert capable of passing storm water and any sediment that transported to the culvert entrance limiting future maintenance.

8.4.2.5 8.4.2.5 Sycamore Flats Proposed Wetland and Stream

A large culvert leading to Panther Hollow stream at Circuit Drive and Panther Hollow Trail conveys stormwater runoff from impervious surfaces and has a significant impact to peak flows in the stream. Using adjacent topography, a wetland and stream through Sycamore Flats to spread this runoff out to adjacent vegetated areas would redirect storm water from outflow described above to the east of Tributary 4 in Panther Hollow. The relocated stream would require the current culvert be relocated about 50 ft to the northwest along Panther Hollow Trail. The stream would convey water from the new culvert through a newly created wetland area and would drain into the existing wetland at the confluence of Phipps and Panther Runs. The proposed stream would create a stable flow path for storm water and the newly created wetland would help attenuate peak discharge.

Location of culvert entrance that is plugged with sediment supplied by rock check dams and erosion on stream banks

8.4.2.6 Roadside Ditch and Wetland on the South Side of Panther Hollow.

Stormwater off of the Panther Hollow trail as well as the adjacent steep slopes drains to a small ditch to the south of the trail. A number of existing culverts appear to have been installed to allow this water to drain back into the stream, but at many locations, these culverts are partially or fully blocked limiting their function and increasing the risk of water traveling over the trail carrying sediment into the stream. A series of connected wetlands will convey and attenuate storm water derived from the southern valley wall along the lower end of Panther Hollow trail. The roadside ditch would convey water from a number of small tributaries draining Panther Hollow Rd. and associated hillslope to the wetland complex along the trail and over to the newly restored Panther Hollow Run. The wetland would also intercept overbank flows during storm events to attenuate peak discharge and provide additional wetland habitat in the project area.

8.4.2.7 Panther Hollow Wetlands

In order to maximize the effectiveness of the Panther Hollow Stream restoration, nine small wetlands are proposed within the Panther Hollow stream corridor. Wetlands in Panther Hollow are designed to offset impacts from construction to existing wetlands and to attenuate peak flow during storm events. Panther Hollow wetlands are located in relatively gentle sloping reaches of Panther Hollow with wider floodplain extents. Some wetlands are designed as off channel that fill only during overbank flow events while some are designed to intercept storm water from the trails and roads and slowly release this water to Panther Hollow.

8.4.2.8 Panther Hollow – Vegetated Berms

A small tributary and minor swales draining surface water leading from a spot on the golf course to Panther Hollow. Above the mowed fairway lies a naturalizing area that is out of bounds to the course. It consists of mixed grasses, shrubs, and small trees. Green infrastructure feature in this location would consist of low mounds installed on the contour. The mounds would allow surface runoff and potentially road runoff to be reduced and delayed in reaching the upper end of this tributary

8.4.2.9 Panther Hollow – Eagle Rock Area

"Eagle Rock" is located near where the Bridle trail meets the Steve Faloon Memorial Trail (SFMT). Water quickly rushes down the steep portion of the SFMT which is causing increased sediment erosion and gullies forming on the sides of the trail. Modifications to the surface grades and improved stormwater conveyance can reduce erosion and direct water the existing catch basin. This basin could be raised and incorporated into a minor detention area.

The green infrastructure features discussed above are provided in Figures 8-1 through 8-4B.

8.4.3 Alternative No. 2 Panther Hollow Run Stream Channels

In order to reduce continuing erosion of streambanks and sediment loading and to stabilize channel cross sections, the Panther Hollow Run stream channel will be modified and restored to support an ecologically functioning riparian area and stable profile. Based on hydraulic modeling, the modifications will also provide a 5-10% reduction in peak storm discharge during the 100-yr 24-

hr storm. The proposed profile has vertical expansions and contractions to maintain water depth during low flows and dissipate flow energy during large events.

The proposed bankfull geometry balances the need to maintain low shear stress to resist channel erosion (reducing sediment supply) while still transporting sediments downstream (to reduce problematic aggradation). The proposed channel geometry includes floodplains to reduce instream stress, store fine sediment during large events, and provide stormwater attenuation. These floodplains buttress slip-prone valley walls to reduce landslide potential and offer a low-gradient surface to store sediments derived from valley walls.

The basis for design for Alternative No. 2 is the same as presented in Section 8.4.1 of this PDM for Alternative No. 1 (Phipps Run).

8.4.4 Alternative No. 3 Panther Hollow Lake and Dam and Forebay Ponds

Downstream of Phipps Run and Panther Hollow Run streams, Panther Hollow Lake and its adjacent hydraulic facilities will be restored to improve ecological function, manage lake sediment impairment and preserve existing wetlands adjacent to the lake. Beginning upstream, the design will consist of the following components.

8.4.4.1 Wet Sediment Forebay

The Wet Sediment Forebay serves as a sediment sump for material transported by Phipps Run and Panther Hollow Run. The Forebay sits east of the lake receiving discharges from both streams. During dry weather and "normal" rainfall, the Forebay slows the velocity of the contributing flows allowing particles to drop out of the water column before over-flowing to the Treatment Wetland, thus limiting the build-up of sediment within the Lake itself. During periods of higher contributing flows, larger debris will drop out but fines will remain suspended and will progress to the Lake by way of the Bypass Cascade. Spatial constraints prevent enlarging the Forebay to provide better settling.

During normal operation, the Forebay will remain wet with levels controlled by the downstream Flow Control Structure. Periodic maintenance will include excavation of the accumulated material for replacement elsewhere. The design includes a dewatering gate valve and perforated bottom drain to allow for full drawdown in advance of maintenance, and a geo-grid reinforced ramp allowing for equipment to enter the area.

8.4.4.2 Flow Control Structure

The Flow Control Structure regulates and directs discharges from the Forebay. The concrete Structure passes low and moderate flows through a discharge pipe sized to constrain the flow to 10 cfs to the Treatment Wetland to prevent scour. As wet weather flows increase to beyond the capacity of the discharge pipe, levels in the Forebay rise and water flows over a weir, under the pedestrian bridge, and to the Bypass Cascade. The Structure will also provide passage of a dewatering pipe with a filtered inlet beneath the Forebay. The Forebay dewatering pipe leads to the Lake for discharge, and is opened by a locked gate valve, thus permitting draining and easier maintenance access to the Forebay.

8.4.4.3 Bypass Cascade

During periods of higher flows from Panther Hollow Run and Phipps Run, the water level in the Wet Sediment Forebay will rise to overtop the weir of the Flow Control Structure, will pass under the historic pedestrian bridge, and then release to a stone-armored channel that leads to the Lake. The channel will be configured as a cascade or series of steps that resemble the stone cascade that once existed at the site. Stones will be sized to prevent scour, and access will be permitted during dry weather.

8.4.4.4 Treatment Wetland

The Treatment Wetland is a mounded area that possesses a circuitous channel planted with native wetland species suited to the hydrologic regime. The channel receives discharges from the Forebay by means of a pipe that restricts flow to a maximum of 10 cfs, a level that will not promote scour, and conveys the flow for release to the Lake. By passing water through the planted circuitous channel, nutrients, contaminants, pathogens and sediment are filtered or captured and processed by the natural systems. The Treatment Wetland was designed with the intent of resembling the existing wetland area that has formed at the east end of the Lake, and to provide additional water quality benefits at a later date if it appears that the Lake water requires further treatment. This would be provided by a recirculation system that continuously lifts Lake water to the top of the channel, thus imposing added contact with the wetland plants and soil. The wetland habitat will also provide refuge for invertebrates, amphibians, and spawning fish, and will be accessible from the shoreline.

8.4.4.5 Panther Hollow Lake

The approximate 2-acre Lake redesign is driven by several priorities relevant not only to stormwater management but also to park amenities. The overall shape of the existing Lake is largely preserved in the design, and space is designated for later development of a lakeside pavilion or other facility on the south shore at the same location as the historical boat house. In addition, the Lake must provide adequate storage volume in order to regulate the rate of discharge downstream during and after rain events.

Proposed changes to the existing Lake include dredging of accumulated sediments and additional material in order to deepen the center to a maximum of ten feet. This helps regulate temperature during summer months, helps to support over-wintering of fish and limits the frequency with which subsequent maintenance dredging must occur, since some loading of fines to the Lake interior is inevitable. The existing concrete curbing around the lake shoreline will be removed and graded and the new shoreline will be planted with a range of native transitional and upland plants, or turf in areas designated for recreation.

8.4.5 Alternative 3A Panther Hollow Lake Additional Amenities (Option A)

The lake design features described above may be supplemented with additional amenities that can increase stormwater storage, enhance ecological function and provide recreational benefits. Design will include the following:

- The Lake bottom will be relined with three inches of clay to prevent infiltration losses, and then covered with 18 inches of loamy sand, which is conducive to growth of native plants and supports benthic invertebrates. No slopes shall exceed 3:1, and the edges will be planted as an aquatic bench with a diversity of native emergent plants. At several points, stone jetties will extend over the aquatic bench and into the shallows, inviting visitors to connect with the water and habitat supported there. In response to wet weather, the Lake level will rise and fall, alternately covering and exposing the aquatic bench.

- A normally-closed drain line will allow for complete (or substantial) drawdown of the lake when needed, and a geo-grid reinforced ramp will help accommodate maintenance access.

- If it is necessary to sustain adequate water quality, lake water can be lifted/pumped to the top of the Treatment Wetland and recirculated, and bubblers can be added to increase dissolved oxygen. A floating treatment wetland island will also provide better water quality.

- The 16-inch opti RTC system can be modified to release lake water in advance of rain events in order to provide additional storage. During dry weather, a restricted pipe will convey a small baseflow from the Lake to the downstream channel below in order to maintain flow within the new stream channel. At no time shall peak contributing flows cause the Lake elevation to reach the railroad.

- An elevated boardwalk trail will extend over the northwest portion of the lake and over an aquatic bench and wetland habitat area, which will be excavated to expand the lake footprint. This trail will tie into the proposed lake perimeter trail.

These amenities are shown on Figures 8-10B and 8-10C.

8.4.6 Alternative 4 Panther Hollow Lake Principal Spillway Riser/Pipe, Emergency Spillway Channel and Embankment Raise

In order to facilitate a hydraulic connection between Panther Hollow Lake and the proposed channel/stream extending southward through Junction Hollow, and to meet PADEP requirements associated with permitting a dam, it will be necessary to design a principal spillway and emergency spillway from the lake. A review of Title 25 of the Pennsylvania Code, Chapter 105, Subchapter B Dams and Reservoirs was performed to identify the criteria associated with the design of the dam at Panther Hollow Lake. Several sectionsections in the chapter provide information on the design of specific components of the dam. The applicable sections are outlined below:

- Section 105.13 – regulated activities – information and fees. This section discusses the forms, the fees and the administrative and supplemental information required as part of the application forms. Administrative/supplemental information includes stormwater analysis, floodplain analysis, risk assessments, photographs, project description and/or Impacts analysis.
- Section 105.81 – Permit application for construction and modification of dams and reservoirs. This section discusses the more technical information that is to be prepared and submitted with the application. For this Project, this information includes a geotechnical investigation report, a hydrologic and hydraulic report, an emergency action plan, an operation and maintenance plan, construction plan drawings, specifications and a design report.
- Sections 105.92 through 105.97. These sections discuss the design criteria associated with specific components of the dam and reservoir, including foundations, design stresses, spillways, freeboard, outlet works and stability of the structure.
- Section 105.98 – Design Flood Criteria. This section recommends the design flood to be used for the dam, based upon the classification of the dam.

The principal spillway will consist of a pipe and riser inlet structure extending from the lake and beneath a pair of existing railroad tracks owned by CSX. The riser inlet structure will be smooth wall HDPE pipe with a diameter of approximately 36-inches. The spillway pipe will be smooth wall steel and HDPE pipe with a diameter of 24-inches. Steel pipe is needed for jacking beneath the railroad tracks, per CSX design guidelines. The diameter at the outlet of the pipe may vary between 18-inches and 21-inches, based on a hydraulic and hydrologic analysis of the lake. The diameter will utilize the available storage capacity of the lake to store stormwater runoff while discharging a volume of stormwater that minimizes the size and capacity of the stream or channel in Junction Hollow and hydraulic features downstream. The pipe will be generally oriented in an east and west direction and extend beyond the approximate limits of the easements provided to the railroad by PWSA, estimated at 80 feet. An additional length of pipe will be added to the downstream end of the spillway pipe, to provide a location for pedestrian access to both sides of the stream or channel. No pedestrian access beneath the railroad tracks is to be provided at this time. The emergency spillway will be designed as an open channel hydraulic facility with a concrete control section set an elevation that will activate during a storm event greater than 100 year- 24 hour rainfall. The emergency spillway will discharge into the east drainage ditch adjacent to the CSX railroad tracks

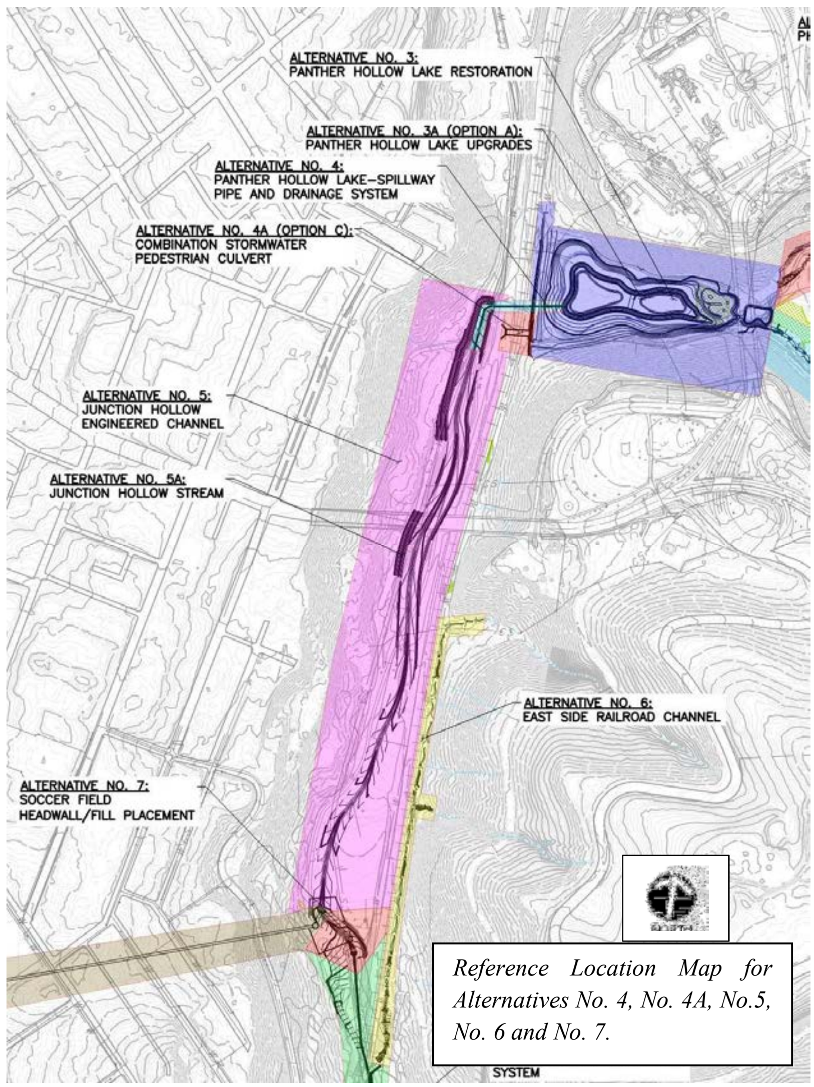
The inlet structure will consist of a vertically oriented section of pipe secure by a concrete thrust block. The steel pipe will be jacked beneath the railroad tracks from a jacking pit located on the west side of the tracks. The depth of the pit is the same as the approximate invert of the pipe, estimated at 12 feet below the elevation of the tracks, or elevation 794 MSL. This depth will be slightly higher than the sloping pipe that will outlet at the elevation of the stream or channel at the upstream end of Junction Hollow, which is estimated at elevation 792 MSL, approximately 8 feet below ground surface (bgs). From the railroad tracks, the pipe will slope upwards to the east at 5%, terminating at the approximate bottom of the dredged lake and at the location of the thrust block. On the exit (west) side, the end of the pipe will be designed with a taper at a slope of approximately 2.5H:1V to match the grading of the slope that begins the stream or channel.

Structural design of the pipe, coordination with the engineering department of CSX and submission of design packages at 30%, 60% and 90% be required. No cast-in-place retaining walls will be necessary.

In addition to the spillway pipe design, a design will be performed to raise the embankment of Panther Hollow Lake by approximately 3 feet. The raise will occur along the west side of the existing crest of the embankment, which is conservatively estimated at 50 to 60 feet in width. The raise will create a 12-foot wide new crest and side slopes of three horizontal to one vertical (3H:1V) on the west side and 12H:1V on the east, lake facing side, resulting in an overall width of approximately 55 feet. The additional height will create in excess of 300,000 cubic feet (2.25M gallons) of storage for storm events. The elevation of the riser pipe will be maintained at the current lake elevation of 806 feet. In conjunction with the riser pipe design, Panther Hollow Lake will be capable of safely discharging a 100 year-24 hour storm event without activating the emergency spillway. Calculations associated with the hydrologic and hydraulic design of the principal and emergency spillway pipe and the storage volume associated with the embankment raise are presented in Appendix I to this PDM.

8.4.7 Alternative 4A Spillway Upgrade (Option B)

In conjunction with the upstream retaining wall, a stone and concrete spillway consisting of a broad crested weir and chute will be designed to connect Panther Hollow Lake with the Combination Stormwater/Pedestrian Culvert under the Railroad. The spillway will transition stormwater from the lake elevation beneath the railroad tracks, a vertical distance of approximately 25 feet. Step-like stone riffles on a concrete foundation will be incorporated into the spillway to create a cascading waterfall effect on the surface. The spillway will transition from a width of approximately 200 feet at the edge of the lake/top of the weir to a width of approximately 15 feet at the culvert under the railroad. Notches will be incorporated into the weir to allow water flow from the lake to cover a majority of the cascading waterfall/spillway surface. A concrete retaining/chute wall will provide retainage and separation between the soil embankment and the spillway. Design of the spillway and associated concrete appurtenances will be performed in accordance with PADEP regulations and as applicable, Engineering Manuals published by the United States Army Corps of Engineers (USACE).



Reference Location Map for Alternatives No. 4, No. 4A, No.5, No. 6 and No. 7.

8.4.8 Alternative 4B Combination Stormwater/Pedestrian Culvert under Railroad (Option C)

In addition to providing a hydraulic connection between the modifications associated with the spillway at Panther Hollow Lake and the proposed stream extending southward through Junction Hollow, a pedestrian connection between the two locations may be considered. To accommodate this consideration, a large diameter culvert beneath a pair of existing railroad tracks owned by CSX Transportation (CSX) will be designed. The culvert will be precast concrete material and be elliptical in shape to provide a greater width for pedestrian and bicycle traffic, while minimizing the burial depth of the culvert. The interior dimensions of the culvert is approximately 11 feet in height and 18 feet in width, measured along the centerlines of the culvert. Culvert segment lengths vary between 6 and 10 feet. It will be oriented in an east and west direction and extend beyond the approximate limits of the easements provided to the railroad by PWSA, estimated at no less than 80 feet. The culvert will function as a hydraulic channel and as a pedestrian walkway beneath the railroad tracks, to connect the two separate park areas. The walkway will be metal fabricated and supported/elevated approximately 1.5 feet above the invert of the culvert, to allow for water flow beneath. It will be approximately 10 feet wide and be located near the vertical centerline of the culvert. Railing will protect pedestrians on the walkway and lighting will be provided. A plan view and a cross section are presented in the Figure 8-11A.

Prior to the design, it will be necessary to coordinate with the engineering department of CSX to obtain approval for construction of the culvert beneath the tracks. Discussions with CSX design department in Jacksonville, FL, have indicated that construction of the culvert will need to be performed using a process called jacking, where segments of the precast concrete culverts are pushed through the soils beneath the railroad tracks in series and the soils removed from the interior of the culvert by excavation after a segment is pushed. A custom-manufactured static cutting device will be attached to the leading edge of the precast concrete culvert to reduce the friction during the jacking process. Dynamic actions associated with jacking are not recommended to minimize disturbance to the tracks. Open cut installation is not permitted by CSX.

The culvert will be jacked beneath the railroad tracks from a jacking pit located on the west side of the tracks. The depth of the pit is estimated at 22 feet below the elevation of the tracks, at elevation 786 MSL. This depth corresponds to the elevation of the stream channel at the upstream end of Junction Hollow, which is approximately 15 feet below ground surface (bgs). At this depth, there will be a minimum of 10 feet of soil cover over the culvert. Gaskets will be installed between each culvert segment, to provide protection against water seepage.

Structural design of the culvert will be performed using guidance provided in the CSX Design Manual (2012). After live loads associated with the train and soil loads over the culvert are determined, the structural design will be provided to a concrete culvert manufacturer, who will provide a culvert unit meeting the structural and geometric requirements.

After the pipe has been jacked beneath the tracks beyond the easement limits, the soil surrounding the culvert will be pressure grouted to fill any voids that may have been created adjacent to the culvert during the jacking process. The grouting will also provide an additional layer of continuous protection around the precast culvert. Upon completion of grouting, a cast-in-place concrete retaining wall will be designed on the entrance (east) side of the culvert to retain the soils adjacent to the pipe. The retaining wall will also function as a water control barrier for the spillway chute that will discharge normal flow and flood flow from the lake and direct it through the culvert. The wall selected will either be a gravity retaining wall or cantilever wall. A cantilever retaining wall consists of a relatively thin vertical stem and a base slab oriented in the shape of an ‘L’. The heel is the part of the base slab that is either located under/beneath the backfill or on the ground surface opposite of the backfill location. The backfill over the heel prevents the wall from sliding or overturning. A cantilever wall requires a relatively large amount of steel reinforcing, especially at the stem and base interface to prevent the perpendicular connection from failing due to the shear and moment forces from the backfill.

The gravity retaining wall is a triangular shaped wall that is wide at the bottom and thin at the top of the wall. This wall utilizes the larger volume of concrete to resist the sliding or overturning forces associated with the backfill that it retains. They do not typically require steel reinforcement. Cantilever and gravity wall details will be included in the 60% and 90% design phases.

The structural and hydraulic design of the retaining wall will be performed in accordance with EM 1110-2-2104 for reinforced concrete supplemented by ACI 350-06. Earth pressures were determined by taking the maximum forces assuming a general wedge analysis per EM 1110-2-2502 and Coulomb’s wedge assumptions using the active and passive pressures provided in the geotechnical report.

On the exit (west) side, the culvert will be designed with a taper at a slope of approximately 2.5H:1V to match the grading of the slope to begin the stream channel. The culvert manufacturer will provide the final tapered section.

Design packages will be submitted to CSX at the same 30%, 60% and 90% intervals as the design for PWSA. CSX will provide comments on the design.

8.4.9 Alternative 5 Junction Hollow Engineered Channel

To route the flow of water or stormwater from the Panther Hollow Lake hydraulic facilities (the spillway pipe or the combination stormwater/pedestrian culvert), through Junction Hollow, an engineered channel will be designed. The channel depth and width will be able to accommodate the maximum flow from the lake, depending on the hydraulic facility selected while also providing a smaller interior channel for base flow. The bottom of the channel will be designed to meet the velocity and shear stresses associated with the flow or design storm and the side slopes will be designed with vegetative lining and with slopes that will allow access to the channel. The bottom slope will vary between 1% and 2%, to reduce channel depth as measured from the existing ground surface, to reduce the volume of material to be excavated and to meet the invert elevation of the discharging and receiving hydraulic structures at the upstream and downstream end of the channel, respectively. The main channel, where a majority of the excavation will take place will be approximately 15 to 20 feet wide and adjacent flood plain slopes on both sides of the main channel will be approximately 15 to 20 feet wide and tie into existing ground. The location of the engineered channel is shown on Figures 8-12 through 8-12B.

8.4.10 Alternative 5A Junction Hollow Stream (Option D)

The design of a stream to flow through Junction Hollow follows the same general approach as discussed in Section 8.4.1.

The proposed bankfull geometry balances the need to maintain low shear stress to resist channel erosion (reducing sediment supply) while still transporting sediments downstream (to reduce problematic aggradation). The proposed channel geometry includes floodplains to reduce instream stress, store fine sediment during large events, and provide stormwater attenuation.

The bankfull discharge, which generally coincides with the 1.5-yr peak discharge (calculated using the SWMM Green-Ampt runoff estimates), provides the basis of design for stable stream channels. Section 8.4.1 provides a detailed discussion of the basis for channel and floodplain design, but in summary, channels that are designed for a smaller event tend to erode whereas those that are designed for a larger event tend to aggrade with sediment, which can lead to instability when those sediments wash out. Stable channels designed for the bankfull discharge are accompanied by floodplains that contain and convey higher discharges at lower velocity and shear stress. Thus, stream channels are designed for flows between base flow and bankfull discharge (1.5-yr discharge) and floodplains are designed to accommodate flows between 1.5 and 100-yr (or greater). Generally, the width of floodplains is determined by adjacent landforms or other constraints, such the need to protect infrastructure.

Due to the relative flatness of this stream and the fact that it is a new stream and not modification of an existing stream as discussed in Section 8.4.1 of this PDM, select design components were added, altered or removed. These components include the following features:

The floodplain elevation of Junction Hollow is set to provide positive gradient for water to flow from the principal spillway pipe structure beneath the railroad tracks, as presented in Alternative 4 and as discussed in Section 8.4.1 of this PDM to the south end of the soccer field. The upstream elevation is set by pipe outlet elevation under the railroad tracks from Panther Hollow Lake. The downstream bankfull elevation is set just below existing ground surface elevation and is sloped to generally follow existing grade, to reduce earthwork quantities. Once the floodplain elevation was set the bankfull channel geometry, planform, and profile was set in accordance with valley slope.

As currently designed, the bankfull channel is designed for 24 cfs and the floodplain is designed to contain and convey flows greater than 30 cfs. The spillway pipe size constrains discharge to no more than 32 cfs with an 18-inch outflow pipe. As design progresses, if discharge assumptions change, bankfull stream design may need to be adjusted but these changes would not require changes to floodplain design because it is large enough to contain a wide variety of flooding depths.

The upstream reach of Junction Hollow is a low gradient (slope = 0.26%) meandering C type stream with pool riffle morphology. The low-gradient characteristics of the upstream portion of Junction Hollow stream is designed to spread flood waters out and attenuate flood flows.

The lower section of Junction Hollow is mildly sloping and designed to have step pool morphology with well-developed treads. The cross sectional area of the stream in the lower portion of Junction Hollow is reduced to account for the steeper slope this reach. With steeper stream reaches the degree of meandering was reduced to prevent excessive shear stress on the channel banks. The pool to pool spacing was reduced to increase the number of pools available to dissipate flow energy during large events.

8.4.11 Alternative 6 East Side Railroad Channel

On the east side of the CSX railroad tracks, several streams flow down the hill slope and either enter the combined system through dedicated sewers located perpendicular to Junction Hollow or flow into an existing drainage channel that at a combined sewer inlet located just south of the railroad tracks at the soccer field entrance.

The proposed design will disconnect the streams from the combined sewer system and create an enhanced open channel at approximately the same location as the existing channel; however, because the largest of the connected streams currently flows into its own sewer pipe just south of the Boulevard of the Allies, capacity of the receiving channel needs to be increased. At the downstream end of the channel, an inlet headwall or an inlet catch basin or similar structure will divert the flow into a pipe which will extend to the Monongahela River. Applicable channel morphology and planform as discussed for the Junction Hollow stream will be utilized for the channel design, but at a smaller scale. The channel is approx. 5 to 6 feet wide with a depth that varies between 0.6 and 1.8 feet. The channel sideslopes vary from 2H:1V to 6H:1V and the bottom slope varies between 1% and 18%, corresponding to the existing channel slope. Bankfull discharge varies between 10 and 20 cubic feet per second (determined using SWMM runoff estimates). Flows exceeding the capacity of banks will be contained and conveyed in a small floodplain defined by existing grade (railroad embankment on the west, hillslope on the east.

8.4.12 Alternative 7 Soccer Field Headwall/Berm

As discussed in Section 8.4.9, the current existing width and topography of Junction Hollow and the rural setting allows for a stream or engineered channel with a cross section to handle base stream flow and adjacent floodplains to handle flows associated with a 100-year or greater storm event. At the southern end of Junction Hollow, the topography and property characteristics change. The Four Mile Run neighborhood is an urban setting, consisting of residential homes, businesses, streets and recreational areas. Space readily available for open channel stream flow becomes limited in this area. It will be necessary to design a structure to convey streamflow originating from upstream of this area and to facilitate the incorporation of subsurface drainage structures downstream to transfer flow to the Monongahela River.

A precast or cast-in-place reinforced concrete headwall with wingwalls will be designed and constructed to transition stream or channel flow into subsurface drainage facilities. Additional fill will be graded adjacent to the wingwalls to cover the subsurface drainage facilities and to create an area for channeling flow. Based upon the flow discharging from the hydraulic structure at Panther Hollow Lake, the subject area is anticipated to maintain a pool of water for a short period of time. The fill and headwall will be oriented in an east and west direction and will be located at the southern end of Junction Hollow and will be approximately 7 feet high. During most of the year, base flow will be entering the pool area and discharging through the subsurface drainage facility. During a peak storm event, the depth of water will increase to approximately four (4) feet or approximately one foot above the pipe.

The headwall will be outfitted with 36-inch diameter HDPE pipe. The invert of the pipe will be established at approximate elevation 758 feet, which is the same elevation as the downstream end of proposed stream or engineered channel extending through Junction Hollow. The size of this pipe and the small headwater buildup at the entrance is sufficient to accommodate the flow outletting from the principal spillway pipe controlling the lake elevation and the stormwater runoff associated with the western slope of the Junction Hollow watershed area. A plan view of the headwall structure is presented in Figure 8-15.

If an overflow condition were to occur at the headwall, existing downstream catch basins connected to the existing PWSA sewer system would accept the stormwater. Drainage from the headwall to these catch basins will be designed in future submissions.

8.4.13 <u>Alternative 8 Four Mile Run Park Piping System</u>

The piping system that is initiated at the headwall in Junction Hollow will be designed to extend approximately 750 feet through the Four Mile Run neighborhood before connecting to the Saline Street piping system, as discussed below. The depth of the piping system at some locations is shallow, as a result of the relatively flat topography through this area and a low spot in the proposed pipe route at Boundary Street beneath the Interstate 376 Parkway East Bridge. The elevation in this area varies from 740 feet MSL at the railroad bridge to the low spot elevation of 734 to an elevation of 737 at the south end of Four Mile Run Park. To reduce the depth of the pipe at points downstream, certain lengths of pipe will be set at or near existing ground surface and fill will be used to above grade to cover the pipe. The plan location of the pipe is shown on the Figure 8-16.

8.4.14 <u>Alternative 8A Four Mile Run Park Stream Segments (Option E)</u>

At the downstream end of Junction Hollow the engineered channel or stream enters a pipe within the headwall that extends approximately 750 feet beneath a railroad trestle at the entrance to Junction Hollow and Boundary Street. Over the next 750 feet, from north of the basketball court under Interstate 376-Parkway East to Saline Street, a stream channel will be designed. The stream will extend through Four Mile Run Park, beginning at the intersection of Alexis Street and Four Mile Run Road and extending southwest to Saline Street. Design of this segment of the stream will be performed using the same design approach applied to the Junction Hollow stream in Alternative No. 1, as discussed in Section 8.4.1. The slope of the stream in this segment is approximately 1% to 2%, which is steeper than the pipe beneath Saline Street, discussed below. The flatter slope will provide a transition between the two pipe slopes; however, in conjunction with the design of the stream geomorphology will result in a slower water velocity, which will increase the cross sectional area occupied by the stream. A plan view of this stream segment is presented in Figures 8-16A and 8-16B.

8.4.15 Alternative 9 Saline Street Deep Gravity Piping System

The existing open and green space through Four Mile Run Park, in conjunction with the relatively flat topography provides a location to design and construct a stream in close proximity to the Four Mile Run neighborhood. However, once beneath the Frazier Street Bridge, space for an open channel is not available and topographic high points that do not promote positive drainage eliminate the potential for open channel design. At this location, a piping system will be designed to continue to convey base flow and stormwater flow from Junction Hollow and from the east side railroad channel to the Hazelwood Green Site and eventually to the Monongahela River. In the absence of any easements owned by PWSA, the piping system will be designed to extend beneath a 750 feet length of Saline Street, a 230 feet length of Greenfield Avenue and a 50 feet width of Second Avenue.

Three HDPE pipes with diameters of 36-inches will be designed along this route. The first pipe will convey flow from Junction Hollow and the second pipe will convey flow from the east side railroad channel. The third pipe is for conveying flow from the Naylor Run area, the volume of which has yet to be determined. The diameter indicated for the pipes also will aid in reducing potential impacts and conflicts with the various existing underground utilities that are located beneath the street, both laterally and longitudinally. HDPE pipe segment lengths vary between 20 and 40 feet. The pipe will be sloped to gravity drain at a grade of 0.3% from the pipe or stream at Four Mile run Park and be oriented along the centerline of the road. The depth of the pipe invert beneath Saline Street varies from 5 feet to 25 feet. The grade of Saline Street increases in elevation from 739 feet to 754 feet moving in a northeast to southwest direction before decreasing to elevation 749 at the intersection with Greenfield Avenue. The greater depth is a result of the 0.3% downward slope of the pipe from Four Mile Run park and the 3.5% upward slope of Saline Street over a 500 feet distance. The depth of the pipe invert beneath Greenfield Avenue and Second Avenue is approximately 20 feet.

In conjunction with the design, it will be necessary to coordinate with the engineering department from the City of Pittsburgh to prepare and obtain a permit and approval for construction of the piping system beneath the road surface and to obtain a Maintenance and Protection of Traffic (MPT) Plan. Currently, the alignment of the piping system is proposed beneath the centerline of the northbound traffic lane; therefore, limited segments of Saline Street will need to be temporarily closed. An MPT Plan will be prepared that will discuss methods to reduce traffic delays or time spent waiting in traffic, to maintain traffic flow throughout the work area and the surrounding areas and to provide a safe environment for the work force and motoring public. The MPT Plan will also discuss the project in general and the pipe installation methods.

One method applicable to installation of the pipe for this Project is referred to as the haulback technique.

In the haulback technique, excavation of soil proceeds from a designated start location to a specified distance southwest along Saline Street. This material is temporarily stockpiled adjacent to the excavation. Upon reaching an acceptable working distance from the excavation start point, the piping is installed according to the manufacturer's installation guide or the project specifications. Excavation then continues to the southwest along Saline Street and the soil excavated is immediately used as fill over the previously placed pipe. The process is repeated and the installation of the pipe and the subsequent fill 'chase' the excavation. This process minimizes the size of the deep portion of the open excavation. Depending on depth, the sideslopes of the excavation can be 'laid back' at a slope that meets the requirements of the Occupational Safety and health Administration (OSHA).

The bottom width and sideslopes of trench excavation for the piping system does not allow for a single lane of traffic to be maintained to access the residential and commercial areas of Four Mile Run and Naylor Run, therefore, a temporary sheeting, shoring and bracing system will need to be designed. The design and construction of shoring systems can be complex due to the soil structure, depth of cut and ground water, weather conditions, superimposed loads, seismic loads, vibrations, and/or adjacent construction. At locations where the depth of the pipe approaches 25 feet, the design of sheeting, shoring and bracing in conjunction with the avoidance of utilities can become difficult.

Structural design of the pipe will be performed using guidance provided in geotechnical engineering manuals. After live loads associated with the vehicular and soil loads over the pipe are determined, the pipe will be designed against crushing, buckling and deflection.

Prior to design of the piping system along the 250 feet length of Greenfield Avenue, it will be necessary to coordinate with the engineering department of CSX to obtain approval for construction of the piping system beneath or below the foundations of the stone and concrete abutments and the steel piers of a steel bridge supporting their tracks. The estimated depth of the pipe beneath the road surface under the bridge is approximately 20 to 25 feet. At this depth, care must be taken to minimize the disturbance of the concrete foundations supporting the piers and abutments of the bridge. It is anticipated that the foundations are either reinforced concrete spread foundation or concrete or wood pile foundations. Sheeting, shoring and bracing of the excavation in these areas will be quite difficult. Equipment used for installation will need to be capable of operating beneath the bridge deck, which is approximately 14.5 feet above the road surface. At the depth of sheeting required and the limited bridge clearance, piling may need to be partially driven and a second sheet welded to the initial sheet.

Design of the pipe beneath Second Avenue will be performed in a manner similar to Saline Street. The depth of the pipe is approximately 724.5 ft. MSL, which is 15 feet beneath the road surface. In addition to the design of the pipe beneath the road, a design will be prepared to extend beneath the stone retaining wall and the sidewalk, before entering the Hazelwood Green site.

The pipe invert will outlet in the Hazelwood Green site at approximate elevation 723-724 ft. MSL. HDPE pipe segment will be fusion welded, to provide protection against water seepage and to prevent water exfiltration should a pressure flow situation develop. A plan view of the pipe along Saline Street and Greenfield Avenue and across Second Avenue is presented in Figure 8-17.

8.4.16 Alternative 9A Saline Street Pump Station (Option F)

The gravity piping system presented in Alternative 9, Section 8.4.15 requires excavation to depths in excess of 20 feet at one location along Saline Street, one location on Greenfield Avenue under the CSX railroad bridge and one location on Second Avenue. An alternative to reduce the depth of excavation in these areas consists of the design of a pump station at a low elevation location between the soccer field headwall and the Monongahela River. The incorporation of a pump station can reduce the excavation depth for the piping system along a majority of the entire route to the Monongahela River to a depth less than 8 feet, depending on the diameter of the pipe and depth of cover needed.

The pump station will be located in the triangular grass covered area of Four Mile Run Park and adjacent to Saline Street, in the vicinity of the piers for the Frazier Street Bridge, at approximate elevation 739 feet. Pipe located upstream of this location will carry water by gravity flow. The pump station will be designed to pump water in a pipe to a high point in Saline Street, at approximate elevation of 754 feet. From this location, water then is transferred by gravity flow to the Hazelwood Green site. This gravity flow distance is approximately 600 feet and the elevation change is approximately 20 vertical feet.

The pump station will be located below ground to the extent possible; however, a small shed-like building may be required to house the pump motor and the electric controls and to provide ventilation for operation. The building may also be needed to contain a generator for emergency backup electric power. A steel or reinforced concrete stormwater collection chamber will be needed below ground to collect stormwater for eventual pumping downstream. The pump will operate in a wet well condition, i.e., the pump will be located below the elevation of the water that will enter the chamber via the gravity flow piping. The gravity flow pipe will extend from the concrete headwall located at the soccer field and will be a circular pipe fabricated from steel, HDPE or concrete.

The discharge pipe from the pump located within the chamber may need to be steel or ductile iron pipe, which is more durable and will reduce potential for corrosion. Once outside the chamber, HDPE pipe will be used for transferring water to Hazelwood Green. The connection between steel or ductile iron pipe and HDPE pipe can be completed using flanging, the size of which will be determined based upon the design pressure imparted to the pipe by the pump and motor. All of the discharge piping will be designed to be below ground. The wall thickness of the pipe will also be designed based on the pressure associated with the pump and motor.

It is anticipated that three pipes with diameters of 36-inches will be entering the stormwater collection chamber from upstream locations, including one future pipe to convey stormwater from the Naylor Run area. The estimated diameter of gravity flow portions of the HDPE pipes extending from the pump station is 36-inches. Two pumps will be dedicated to the three possible pipes.

The pumps will be designed to accommodate the maximum full pipe flow from each of the three incoming pipes, but will also be designed to accommodate normal and low flow conditions from upstream locations. These variable conditions will impact the head that the pump will be operating against, and the average/typical head. The pumps will be designed for the typical head, but must need to fall within the minimum and maximum head range.

Based upon the importance of these pumps operating continuously both during normal flow and peak flow storm events, a third backup pump will be evaluated for design. Piping from the backup pump will be tied into the piping for the two primary pumps and into the three HDPE pipes outside of the chamber. The backup pump will be activated periodically to ensure proper operation in the event of an emergency resulting from failure of one of the other pumps.

A backup generator will also be evaluated for design. The generator will be activated in the event that electric power to the pumps is interrupted, such as during a storm event. The generator will be housed in the same building as the pump motors and motor control panels. The building will be designed to blend in aesthetically with the surrounding area; to the extent possible, trees can also be used to obscure the building from sight.

A typical wet well pump station design is shown on Figure 8-17B.

8.4.17 Alternative 9B Saline Street and Hazelwood Green Shallow Pressure Pipe System (Option G)

As discussed briefly in Alternative 9A, and in conjunction with Alternative 9A, a shallow pipe system will be designed to transfer stormwater from the pump station to the Hazelwood Green site and eventually to the Monongahela River. This pipe system will replace the deep gravity pipe system presented in Alternative 9. The pipe will be HDPE with a diameter of 36-inches and be designed for a pressure condition over the 500 feet distance immediately downstream of the pump station; there will be three such pipes running parallel as discussed above. Over this distance, the pipe will increase in elevation approximately 15 feet, corresponding to the elevation difference in Saline Street. The remaining 600 feet length to the Hazelwood Green site is designed for gravity flow but could be a pressure condition if flowing full. With the incorporation of the pump system, the pipe system can be installed with minimum cover, that which is needed to reduce crushing and buckling and to meet vehicular traffic loading. The depth from the street level to the top of the 36-inch diameter pipe could be as little as 3 feet, which results in a excavation depth of 6 to 7 feet. This excavation depth is much less than the 25 feet depth required at select locations on Saline Street, Greenfield Avenue and Second Avenue associated with the deep gravity pipe system.

8.4.18 Alternative 10 Hazelwood Green Deep Gravity Piping System

A piping system similar to the piping system discussed in Section 8.4.15 will be constructed through the Hazelwood Green site. Three HDPE pipes with diameters of 36-inches will be connected to the three pipes outletting beneath Second Avenue in a previous alternative and extend over a distance of approximately 300 linear feet beneath the Hazelwood Green site to connect to hydraulic facilities near the Monongahela River, as discussed below. The depth of the pipes beneath the ground surface is approximately 18 feet. This depth is partly due to the large amount of fill that has been placed on the Hazelwood Green site. Currently, the surface elevation of the Hazelwood Green site is 742 feet MSL, this is approximately 5 feet above the elevation of Second Avenue. The remaining depth is required to clear underground utilities under Second Avenue and to maintain gravity flow of stormwater in the pipes. The piping system will flow in an east to west direction at a slope of approximately 1.2%. A plan view and section of the piping system is shown in Figure 8-18.

8.4.19 Alternative 10A Hazelwood Green Deep Open Channel (Option H)

Once the pipe system associated with Alternative 9 or 9B is south and west of Second Avenue, it will daylight into an open conveyance stream on a parcel at the Hazelwood Green site. The open conveyance stream is proposed to meet one of the requests in the Hazelwood Green development plan, to create a daylit stream and green infrastructure within a park environment on-site. The stream will be located approximately 17 feet below the existing ground surface, based on the outlet of the 0.3% slope of the piping system beneath Saline Street and Second Avenue. This depth is partly due to the large amount of fill that has been placed on the Hazelwood Green site. Currently, the surface elevation of the Hazelwood Green site is 742 feet MSL, this is approximately 5 feet above the elevation of Second Avenue. The remaining depth is required to clear underground utilities under Second Avenue. The excavation for the stream will be oriented in a northeast to southwest flow direction and the side slopes of the channel will be approximately 2H:1V. Excavation will need to account for the possible concrete foundations that are anticipated to be buried in the Hazelwood Green site. An 80-foot-wide floodplain would allow a sunken park-like feature to be developed. Incorporating the flood plain width and the excavated side slopes will require approximately 150 feet of surface width at elevation 742 feet. A riprap or concrete apron at the pipe outlet will be designed to function as an erosion control mechanism. Design of the stream segment will be performed as discussed in Section 8.4.1 of this PDM. Structural design of the headwall will be performed using guidance provided in applicable USACE Engineering Manuals.

8.4.20 Alternative 10B Hazelwood Green Shallow Open Channel (Option I)

As discussed in Alternative 9B, the pump station located in Four Mile Run park and the shallow pressure pipe system at a higher elevation beneath Saline Street, Greenfield Avenue, and Second Avenue allows for design of an open channel that will be constructed at a depth less than the open stream channel proposed in Alternative 10A. Using the existing ground surface elevation in Hazelwood Green site of 742 feet, the depth to the stream banks will be approximately 10 feet. There would be a 60-ftoot-wide floodplain at stream elevation. Incorporating the flood plain width and the excavated side slopes will require approximately 100 feet of surface width at elevation 742 feet. The geometry and cross section of the stream channel are the same as described in Alternative 10A.

8.4.21 Alternative 10C Pipe beneath Railroad and Monongahela River Outfall

In order to create the hydraulic connection between the proposed piping system or stream at the Hazelwood Green site and the proposed outlet at the Monongahela River, it will be necessary to design a piping system beneath one pair of existing railroad tracks utilized by MetalTech, Inc., and beneath Blair Street, on the Hazelwood Green site. The piping system will be designed using steel material with a diameter of 36-inches. The steel pipe will be connected to the HDPE pipe beneath the Hazelwood Green site. If a stream is selected as an alternative through the Hazelwood Green site, a reinforced concrete headwall will be designed around the pipe entrance with a riprap or concrete apron to function as an erosion control mechanism and to transition the stormwater flow into the piping system.

The steel pipe will be jacked beneath Blair Street and beneath the tracks in a manner similar to the jacking process discussed in Section 8.4.8 of this PDM. It is anticipated that the jacking process will be initiated prior to the HDPE pipe installation or the stream construction and begin on the Hazelwood Green site. At this location, a jacking pit can be easily excavated and sufficient space is available for support equipment and for pipe sections to be easily accessed.

The piping system will outlet on the shoreline at approximate elevation 717 feet MSL. This is approximately 6 feet above normal pool of the Monongahela River and 15 feet below the elevation of the railroad tracks. The shoreline at this location is relatively steep with a slope of steeper than 1H:1V and covered with trees and brush. Access from the landside to complete pipe installation may be difficult; therefore, a working barge may be needed to collect cleared and grubbed material and excess soil resulting from the pipe jacking. Concrete erosion protection in the form of riprap or precast articulated concrete revetment will be installed from the invert of the pipe to the water's edge. Based upon the shoreline slope, an erosion protection that is anchored from the top and laid on a prepared slope may be more appropriate than protection that needs a foundation to be installed upon. Turbidity curtains will also need to be installed in the river at the pipe location to reduce sediment migration.

8.4.22 Alternative 11 Tunnel Along New West Route To Monongahela River

The lower flows designed to be conveyed through the alignment as discussed above allow for the design of open stream segments in the Four Mile Run Park area. However, these lower flows and the limited space available along Saline Street and Greenfield Avenue may eliminate the possibility of additional piping for conveyance. At the location of the Soccer Field Detention Headwall/Berm, a tunnel will be designed to convey stormflows in excess of the base flows directly to the Monongahela River.

The tunnel will be oriented in a southwest direction, beneath the neighborhood known as South Oakland. It will slope at a grade of 0.35% and outlet at the Monongahela River approximately

1,400 feet downstream from the outlet of previously discussed alternatives. This location is at the extreme west end of the Hazelwood Green site. Based upon an 1,800 feet length of tunnel, the outlet of the tunnel will be established at elevation 715 feet and the inlet at elevation 723 feet. At least 10 feet of cover will be provided over the tunnel at the Hazelwood Green site. At other locations the depth of cover could be as great as 200 feet. The finished diameter of the pipe-in-tunnel final lining is recommended to be 120 inches (10 feet), but the excavated tunnel diameter is recommended not to exceed 168 inches (14 feet).

The tunnel will be excavated using a shielded Tunnel Boring Machine (TBM). Tunneling with a TBM involves excavating the ground with a rotary cutterhead and installing support as the excavation progresses. As the TBM and the TBM shield move forward, the initial lining is erected, typically with a system of expanded steel ribs and hardwood timber lagging or steel liner plates. This provides ground support as the machine excavates forward and is followed by the final lining.

The final lining will consist of a pipe-in-tunnel. The pipe-in-tunnel final lining will be fiberglass reinforced pipe (FRP) or centrifugally cast fiberglass reinforced polymer mortar pipe (CCFRPM). A reinforced concrete pipe (RCP) can also be utilized. The pipes will be transported in the tunnel utilizing the pipe carriers. Once in place each pipe section will be secured on blocks to the required line and grade as well as blocked in the crown to prevent flotation of the pipe during backfill grouting. Typically, the backfill grout is injected through threaded ports in each pipe section.

Two shafts will be utilized during construction of the tunnel – a launching shaft and receiving shaft. The launching shaft is located near the river while the receiving shaft will be excavated in overburden soil materials, mainly fills, and in bedrock.

The shaft excavations need to be sized to accommodate the tunneling equipment, tunnel utilities, efficient access for workers and materials, and future permanent access structures. The size of the launching shaft excavation, for TBM tunneling, should be at least 25 feet wide by 35 feet long. Receiving shafts (used only to retrieve the TBM) can be smaller - minimum 25 feet in diameter. Space must be provided for a large mobile crane, as well as spoil/muck storage. During shaft excavation, the excavated material (muck) will be raised to the surface through the shaft via crane and muck container. For tunnel excavation, the crane will lift rail muck cars up and out of the shaft for tipping.

8.4.23 Alternative 12 Open Cut Tunnel Along New West Route to Monongahela River

In order to facilitate a connection between the tunnel and the Monongahela River, a precast concrete culvert matching the cross sectional characteristics of the tunnel will be designed. The design will include a culvert beneath a pair of existing railroad tracks owned by MetalTech, a private commercial company. Similar to the design of hydraulic structures beneath CSX tracks, design and construction of the culvert will need to be performed using a process called jacking, where segments of the precast concrete culverts are pushed through the soils beneath the railroad tracks in series and the soils removed from the interior of the culvert by excavation after a segment is pushed.

The culvert will be jacked beneath the railroad tracks from a jacking pit located on the north side of the tracks. The depth of the pit is estimated at 15 to 20 feet below the elevation of the tracks, which are at elevation 731 MSL. At this depth, there will be a minimum of 5 to 10 feet of soil cover over the culvert. Gaskets will be installed between each culvert segment, to provide protection against water seepage.

Structural design of the culvert will be performed using guidance provided in professional engineering documents or the CSX Design Manual (2012). After live loads associated with the train and soil loads over the culvert are determined, the structural design will be provided to a concrete culvert manufacturer, who will provide a culvert unit meeting the structural and geometric requirements. After live loads associated with the vehicular and soil loads over the culvert are determined, the pipe will be designed against crushing, buckling and deflection.

The outfall at the Monongahela River can be designed using two approaches. The existing stable, retaining walls that remain from the former LTV site can be utilized for the headwall of the piping system. Openings in the walls will be created by coring the concrete to accept the pipes. It will be necessary to investigate the geometry of the walls to identify any issues prior to advancing a design. The second approach would consist of locating openings between the existing walls where steep sloping earthen embankment are located. A new cast-in-place concrete headwall can be designed for the pipes.

8.5 EVALUATION CRITERIA

The alternatives presented in Section 8.4 are assessed in this section with respect to evaluation criteria developed during the Design Workshop. The criteria selected and their weighting consist of the following:

- Performance 0.19
- Construction Cost 0.19
- Public Perception 0.11
- Operation, Maintenance and Inspection 0.10
- Risk 0.10

- Infrastructure Obstructions 0.09
- Implementability 0.08
- Schedule 0.07
- Sanity Check 0.07

Performance and Implementability were primary criteria identified for screening technologies. These criteria were discussed in Section 8.2.

Important subcriteria of performance were considered and an overall rating was based on the average of these subcriteria. The performance subcriteria related to the project goals as well as how performance to meet those goals could be increased with future Watershed Expansion projects. Our understanding of performance of each alternative will be enhanced when results of recent modeling efforts to address CSOs, flooding, and basement backups are available.

The remaining seven criteria were developed during the workshop and identified as critical in assessing the assembly/development of alternatives. They are discussed in the sections below.

8.5.1 Opinion of Construction Cost

The costs were evaluated in terms of estimates of total present worth cost (capital costs plus long-term costs) with an accuracy of -50 to +100%. Costs with less accuracy are associated with uncertainties related to variable material characteristics and quantities and methods of installation. Each alternative cost was developed to a consistent accuracy such that a comparative cost analysis of the alternatives could be performed.

8.5.2 Public Perception

This criterion addresses how the Project 'appears to the public' and the degree to which each alternative is acceptable to the public. For this Project, input on the planning and implementation from the community is necessary.

8.5.3 Operations, Maintenance and Inspection

Operation, Maintenance and Inspection of the alternatives is evaluated to determine the post-construction activities necessary to ensure the continued effectiveness of the alternative. They typically refer to long-term material replacement costs, potential power costs (such as the operational costs of pumps), equipment replacement costs, and long-term monitoring costs. Periodic inspection is necessary to verify that the project maintains the characteristics/look like and functions as it was constructed.

8.5.4 Risk

The alternatives must be evaluated to estimate the risk associated with each alternative. The primary risks include the ability to construct the project as designed, the unknowns associated with subsurface conditions, the probability that selected design parameters will be exceeded, the design to accept the future contribution of stormwater from ancillary watersheds, the accuracy of the location of existing utilities, the influence of stormwater from ancillary highways, the physical and potential makeup of existing soils, and the impact of concurrent construction by others

8.5.5 Infrastructure Obstructions

This criterion addresses the degree to which the alternative minimizes the interference with or eliminates the pathway of existing infrastructure located above or beneath the ground surface. These obstructions include but are not limited to: underground gas, water, electric, communication or sanitary pipelines, cables and conduits, soils with elevated concentrations of constituents that may be considered harmful to human health and environment, concrete footings associated with above ground structures and above ground features that cannot be disturbed, such as railroad tracks and public and private roadways.

8.5.6 Schedule

The alternatives must be evaluated to estimate if the time needed to implement the components of the Project varies between alternatives. Construction time for elements common to alternatives will not vary, but the additional time needed to complete construction elements unique to an alternative will affect schedule.

8.5.7 Sanity Check

This criterion addresses the degree to which an alternative 'makes sense' and meets the goals and objectives of the Project. The sanity check will also identify if all technologies and alternatives were evaluated properly and if specific components of the Project are really necessary.

8.6 DETAILED EVALUATION OF EACH ALTERNATIVE

In this section, each of the nine (9) evaluation criteria presented above will be applied to 'each' of the twelve segmented alternatives. The advantages/strengths, disadvantages/weaknesses and uncertainties will be explained as they relate to the criteria. A side by side comparison between the alternatives using the nine criteria will be presented in Section 8.7

During the discussion of each criterion, a value for each of the criteria listed will be prepared using a modified version of the Likert scale. A rating of 1 through 5 will be assigned to each of the criteria for each of the alternatives.

A description of each rating is as follows:

1. Very Easy, Very Inexpensive, Very Fast
   Very Safe, Very Low Risk, Very Effective, Very Positively Perceived
2. Easy, Inexpensive, Fast,
   Safe, Low Risk, Effective, Positively Perceived
3. Nominal/Average/Typical
4. Difficult, Expensive, Slow, Negatively Perceived
   Unsafe, High Risk, Ineffective
5. Very Difficult, Very Expensive, Very Slow
   Very Unsafe, Very High Risk, Very Ineffective, Very Negatively Perceived

8.6.1 Alternative No. 1 Phipps Run Stream Channels

- Performance Overall Rating **2**

The reconstruction of the Phipps Run stream, the shorter of the two streams in the area, and the upstream green infrastructure installations will reduce erosion and subsequent sediment deposition by approximately 50% and will also reduce peak discharge during the 100-yr 24-hr storm by an estimated 5-10%. It will also provide an effective route for movement of stormwater, provide an ecological and healthy waterway and provide further stormwater attenuation.

- Opinion of Construction Cost Overall Rating **3**

The capital cost associated with this alternative is about $734, 315, including contingency and is considered inexpensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately 0ne-half of the costs are associated with instream structures, which are critical in the construction of streams. Materials associated with maintenance are inexpensive.

- Public Perception Overall Rating **2**

The public perception of this alternative is very positively perceived, as it re-establishes a recreational stream through a popular and often visited city park.

- Operations, Maintenance and Inspection Overall Rating **2**

Operations, Maintenance and Inspection (OM&I) elements associated with this alternative are easy and effective. Inspection of the stream can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform the inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP. Materials associated with maintenance are easy to install.

- Risk Overall Rating **1**

There is a very low risk associated with construction, as the watershed boundary is well established, and the stream channel is capable of handling stormwater flows from a 25 year-24 hour event. Additional channel flow is available should small percentages of upper watershed areas be incorporated into the project.

- Infrastructure Obstructions Overall Rating **1**

There are no subsurface obstructions associated with Alternative No. 1.

- Implementability Overall Rating **3**

Implementability associated with Alternative No. 1 is Easy. Access to the area is available using an existing road behind Phipps Conservatory; however, access along the stream route is more difficult, as no road is present. Materials utilized in construction are readily available from on-site and off-site sources. Conventional construction equipment, such as small dump trucks, excavators, hi-lift cranes and dozers can be utilized for construction. Routes for access can be established adjacent to the lake and along the existing streams.

- Schedule Overall Rating **3**

The schedule for construction of this alternative would be considered average to slow to complete. This is due primarily to accessibility issues for construction equipment and delivery of materials, as there is no roads in the area. Consideration for pedestrian safety in the park will also slow construction efficiency.

- Sanity Check Overall Rating **1**

This alternative meets several goals of the project, in that it reduces sediment deposition, attenuates peak discharge and when combined with other downstream alternatives, reduces CSO and removes stormwater from the existing PWSA piping system. The stormwater removal may reduce basement flooding to residential areas at downstream locations of the Project. This alternative only 'reduces CSO and removes stormwater from the existing PWSA piping system' when combined with other alternatives; therefore, it does not achieve these goals as a stand-alone alternative. Additional review and discussion are necessary to determine if the alternative will be recommended for design in Section 10.0 of this PDM.

8.6.2 Alternative No. 2 Panther Hollow Run Stream Channels

- Performance Overall Rating **2**

The reconstruction of the Panther Hollow Run stream, the longer of the two streams in the area, will reduce erosion and subsequent sediment deposition by approximately 50% and will also reduce peak discharge during the 100-yr 24-hr storm by an estimated 5-10%. It will also provide an effective route for movement of stormwater, provide an ecological and healthy waterway and provide further stormwater attenuation.

- Opinion of Construction Cost Overall Rating **3**

The capital cost associated with this alternative is about $1,853,956, including contingency and is considered average to expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately three-quarters of the costs are associated with instream structures, reconstruction of the historic bridges and channel fill material, all of which are critical in the construction of streams. Materials associated with maintenance are inexpensive.

- Public Perception Overall Rating **2**

The public perception of this alternative is very positively perceived, as it re-establishes a recreational stream through a popular and often visited city park.

- Operations, Maintenance and Inspection Overall Rating **2**

OM&I elements associated with this alternative are easy and effective. Inspection of the stream can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform the inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP. Materials associated with maintenance are easy to install.

- Risk Overall Rating **1**

There is a very low risk associated with construction, as the watershed boundary is well established, and the stream channel is capable of handling stormwater flows from a 25 year-24 hour event. Additional channel flow is available should small percentages of upper watershed areas be incorporated into the project.

- Infrastructure Obstructions — Overall Rating 1

There are no subsurface obstructions associated with Alternative No. 2. Five historic stone pedestrian bridges over the stream will need to be removed, salvaged and rebuilt to provide the additional hydraulic geometry needed for the reconstructed stream.

- Implementability — Overall Rating 3

Implementability associated with Alternative No. 2 is Easy. Access to the area is available using an existing road behind Phipps Conservatory; however access along the stream route is more difficult, as no road is present. Materials utilized in construction are readily available from on-site and off-site sources. Reconstruction of the historic pedestrian bridges will utilize skilled labor and the stone salvaged from demolition; additional stone may need to be purchased and cast-in-place concrete and steel substructure will be needed. Conventional construction equipment, such as small dump trucks, excavators, hi-lift cranes and dozers can be utilized for construction. Routes for access can be established adjacent to the lake and along the existing streams.

- Schedule — Overall Rating 3

The schedule for construction of this alternative would be considered slow to complete. This is due primarily to accessibility issues for construction equipment, delivery of materials, as there is no roads in the area and the length of the stream. Consideration for pedestrian safety in the park will also slow construction efficiency.

- Sanity Check — Overall Rating 1

This alternative meets several goals of the project, in that it reduces sediment deposition, attenuates peak discharge and when combined with other downstream alternatives, reduces CSO and removes stormwater from the existing PWSA piping system. The stormwater removal may reduce basement flooding to residential areas at downstream locations of the Project. This alternative only 'reduces CSO and removes stormwater from the existing PWSA piping system' when combined with other alternatives; therefore, it does not achieve these goals as a stand-alone alternative. Additional review and discussion are necessary to determine if the alternative will be recommended for design in Section 10.0 of this PDM.

8.6.3 Alternative No. 3 Panther Hollow Lake and Dam and Forebay Ponds

- Performance — Overall Rating 3

The construction of the principal components in this Alternative will be effective as follows. The wet forebay pond will act as a collection mechanism for sediment that does emanate from Phipps Run and Panther Hollow Run, thereby reducing sediment deposition into Panther Hollow Lake.

The treatment wetland provides additional wetland area to the project and improves water quality prior to the water entering the lake. The lake will provide greater storage capacity as a result of the excavation of years of sediment accumulation, which aids in protection of downstream residents against flooding during storm events and also creates a healthier condition for plants and fish habitat and . The removal of the concrete berm provides a connection between the lake and the pedestrians in the park.

- Opinion of Construction Cost — Overall Rating **3**

The capital cost associated with this alternative is about $962,700, including contingency and is considered average to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-third of the costs are associated with sediment excavation and lake shaping excavation, both of which are critical in the rehabilitation of the lake. Materials associated with maintenance are inexpensive.

- Public Perception — Overall Rating 1

The public perception of this alternative is very positively perceived, as it re-establishes a lake that has been modified from its original shape and condition in a popular and often visited city park.

- Operations, Maintenance and Inspection — Overall Rating **3**

OM&I elements associated with this alternative are easy and effective. Inspection of the lake can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform the inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP. Materials associated with maintenance are easy to install.

- Risk — Overall Rating **1**

There is a very low risk associated with construction, as there are no above or below grade utilities in the area, the watershed boundary is well established, and the lake is capable of handling stormwater flows from a 100year-24 hour event. Additional lake volume capacity is available should small percentages of upper watershed areas be incorporated into the project.

- Infrastructure Obstructions — Overall Rating **1**

There are no major above or below grade obstructions associated with Alternative No. 3. Trails circling the lake will need to be reconstructed upon completion of excavation activities.

- Implementability Overall Rating **2**

Implementability associated with Alternative No. 3 is Easy. Access to the area is available using an existing road behind Phipps Conservatory. Materials utilized in construction are readily available from on-site and off-site sources. Conventional construction equipment, such as small dump trucks, excavators, and dozers can be utilized for construction. Smaller sized equipment may need to be utilized, due to the limited width of the access routes and the presence of pedestrians in the park. Once at the lake, suitable space is available. Dewatering of the lake to excavate sediment will be required and can be performed using centrifugal pumps. This work should be done in conjunction with Alternative No. 4, since dewatering is required for those activities.

- Schedule Overall Rating **3**

The schedule for construction of this alternative would be considered average to complete. This is due primarily to accessibility issues for construction equipment. Consideration for pedestrian safety in the park will also slow construction efficiency.

- Sanity Check Overall Rating **1**

This alternative meets several goals of the project, in that it further controls sediment deposition from upper watershed hydraulic facilities and when combined with other downstream alternatives, reduces CSO and removes stormwater from the existing PWSA piping system. The stormwater removal may reduce basement flooding to residential areas at downstream locations of the Project.

8.6.4 Alternative No. 3A Panther Hollow Lake Upgrades

- Performance Overall Rating **3**

The construction of the upgrades will not provide any additional effectiveness in protecting downstream residents against flooding. It is primarily effective at providing better aquatic habitat and water quality. The addition of the fill will reduce the storage capacity of the lake.

- Opinion of Construction Cost Overall Rating **4**

The capital cost associated with this alternative is about $1,166,115, including contingency and is considered average to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately three-quarters of the costs are associated with the boardwalk trail, the clay liner and the loam fill. Materials associated with maintenance are inexpensive.

- Public Perception Overall Rating 2

The public perception of this alternative is positively perceived, based upon water quality, sedimentation and deteriorating edge concerns. Poor water quality and loss of depth impact the , aesthetics of the lake. The upgrades may restore safe public use and provide a healthy and attractive habitat for birds, fish, amphibians and invertebrates.

- Operations, Maintenance and Inspection Overall Rating 3

OM&I elements associated with this alternative are average to difficult. Inspection of the loam and the clay liner can only be performed during lake dewatering or during a dive inspection. The opti-weir can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. Materials associated with maintenance are difficult to install, again requiring lake dewatering.

- Risk Overall Rating 1

There is a low risk associated with construction, as there are no above or below grade utilities in the area. Placement of the soils in the lake will result in a reduced storm volume, unless additional excavation is performed to maintain volume.

- Infrastructure Obstructions Overall Rating 1

There are no major above or below grade obstructions associated with this alternative.

- Implementability Overall Rating 2

Implementability associated with Alternative No. 3A is easy. Access to the area is available using an existing road behind Phipps Conservatory. Materials utilized in construction are readily available from on-site and off-site sources. Conventional construction equipment, such as small dump trucks, excavators, and dozers can be utilized for construction. Smaller sized equipment may need to be utilized, due to the limited width of the access routes and the presence of pedestrians in the park. Once at the lake, suitable space is available. Dewatering of the lake to place fill will be required and can be performed using centrifugal pumps.

- Schedule Overall Rating 3

The schedule for construction of this alternative would be considered average to complete. This is due primarily to accessibility issues for construction equipment. Consideration for pedestrian safety in the park will also slow construction efficiency.

- Sanity Check Overall Rating 3

This alternative does not meet the goals of the project, in that it does not controls sediment deposition, does not reduce CSO and does not reduce basement flooding to residential areas at downstream locations of the Project.

8.6.5 Alternative 4 Panther Hollow Lake Spillway Riser/Pipe under Railroad and Embankment Raise

- Performance Overall Rating 2

The construction of the principal spillway, in conjunction with the placement of fill to raise the embankment crest elevation will be very effective in protecting downstream residents against flooding associated with a 100 year-24 hour rain event. It provides the proper amount of flow for maintaining hydraulic features in Junction Hollow but also minimizes the amount of flow that results in a an optimized, cost effective sizing of hydraulic features through the Four Mile Run area.

- Opinion of Construction Cost Overall Rating 2

The capital cost associated with this alternative is about $245, 295, including contingency and is considered very inexpensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-third of the costs are associated with the jacking and boring of the pipe beneath CSX railroad tracks and the material and installation costs associated with sediment excavation and lake shaping excavation, both of which are critical in the rehabilitation of the lake. Materials associated with maintenance are inexpensive.

- Public Perception Overall Rating 4

The public perception of this alternative is positively perceived, as the spillway and embankment raise provides protection for downstream residents against flooding associated with storm events and the embankment raise provides an amphitheater type setting for the lake from the west.

- Operations, Maintenance and Inspection Overall Rating 2

OM&I elements associated with this alternative are easy and effective. Inspection of the spillway can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform the inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP. Materials associated with maintenance are easy to install. OM&I of the embankment raise will primarily consist of observation of the embankment slopes to observe instability and for burrowing animals that reduce the integrity of the fill.

- Risk Overall Rating **2**

This construction carries some high risk. PWSA maintains a 50" diameter steel waterline within the lake embankment, beneath the area where embankment raise is proposed. It does not currently interfere with the design as described above, but is aged and may need replaced. Replacement may be contingent upon PADEP's review of the project to obtain a permit for the dam and upon future design needs. The pipe location will interfere with a pedestrian culvert proposed to be designed and constructed by others. A 15" ductile iron pipe (DIP) is also located within the embankment, directly beneath the embankment raise. Replacement for reasons presented above may be necessary.

The design to extend a pipe beneath two tracks operated by CSX will require coordination with CSX personnel located in Trevose, PA and Jacksonville, FL. CSX has indicated that the jack and bore process is preferred over an open cut process and that the pipe beneath the tracks should be steel. CSX is requesting submissions for their review at the 30%, 60% and 90% design phases, similar to the submittal process to be utilized on this Project. CSX will review the submissions and provide comments. CSX has been authorized by PWSA to invoice labor costs associated with the submissions.

There is a very low risk associated with design and construction of the remaining portions of the spillway pipe and the embankment raise.

- Infrastructure Obstructions Overall Rating **2**

The infrastructure obstructions in Alternative No. 4 include the 50" diameter steel waterline and the 15" diameter DIP. Their impact on the project is discussed above.

- Implementability Overall Rating **2**

Implementability associated with Alternative No. 3 varies from easy to difficult. Access to the area is available using an existing road behind Phipps Conservatory or through Junction Hollow. Construction. . Conventional construction equipment, such as small dump trucks, excavators, and dozers can be utilized for earthmoving activities. Smaller sized equipment may need to be utilized, due to the limited width of the access routes and the presence of pedestrians in the park. Once at the lake, suitable space is available. Materials utilized in construction are readily available from on-site and off-site sources. Dewatering of the lake to install the spillway pipe will be required and can be performed using centrifugal pumps. This work should be done in conjunction with Alternative No. 3, since dewatering is required for those activities.

The jack and bore method and equipment utilized to advance the pipe beneath active tracks, although more routine than 20 years ago, will require a high level of detail and precision, with oversight of CSX personnel. Connection of the steel and HDPE pipe is routine and requires hand equipment and semi-skilled labor

- Schedule Overall Rating **3**

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to efficiencies associated with earthwork and the installation of pipe. The jack and bore process will slightly slow construction efficiency.

- Sanity Check Overall Rating **2**

This alternative meets the goals of the project, in that it further controls sediment deposition from upper watershed hydraulic facilities, reduces CSO and is the feature that removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. It also augments the park setting with the placement of fill to create a theater setting of the lake.

8.6.6 Alternative 4A Combination Stormwater/Pedestrian Culvert under Railroad (Option C)

- Performance Overall Rating **2**

The construction of the combination culvert will be effective at safely connecting the Panther Hollow Lake and the Junction Hollow recreation areas, eliminating the need for pedestrians to randomly cross CSX railroad tracks. It will be ineffective in protecting downstream residents against flooding associated with a 100 year-24 hour rain event because the size and open channel design does not restrict the volume of flow entering Junction Hollow. Therefore, it does not optimize and cost effectively size the hydraulic features through the Four Mile Run area..

- Opinion of Construction Cost Overall Rating **5**

The capital cost associated with this alternative is about $2, 155,837, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than one-half of the costs are associated with the purchase, jacking and boring of a large elliptical culvert beneath CSX railroad tracks.

- Public Perception Overall Rating **2**

The public perception of this alternative is positively perceived, as it provides safe below grade access between the two recreational areas separated by the CSX tracks.

- Operations, Maintenance and Inspection — Overall Rating **2**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the combination culvert can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform the inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP Dam Safety or by CSX.

- Risk — Overall Rating **5**

This construction is very high risk. PWSA maintains a 50" diameter steel waterline within the lake embankment, beneath the area where embankment raise is proposed. The line is aged and may need replaced and will need to be relocated so as not to interfere with the location of the combination culvert. Relocation of an active line of this size is requires a shutdown of the line and connection of new pipe to an aged pipe. Replacement may be contingent upon PADEP's review of the project to obtain a permit for the dam. A 15" ductile iron pipe (DIP) is also located within the embankment and will also need to be relocated.

The design to extend the large combination culvert beneath two tracks operated by CSX will require coordination with CSX personnel located in Trevose, PA and Jacksonville, FL. CSX has indicated that the jack and bore process is preferred over an open cut process and that a culvert of this size located beneath the tracks should be concrete or steel. CSX is requesting submissions for their review at the 30%, 60% and 90% design phases, similar to the submittal process to be utilized on this Project. CSX will review the submissions and provide comments. CSX has been authorized by PWSA to invoice labor costs associated with the submissions. During construction, CSX personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions — Overall Rating **4**

The infrastructure obstructions in Alternative No. 4A include the 50" diameter steel waterline and the 15" diameter DIP. Their impact on the project is discussed above.

- Implementability — Overall Rating **4**

Implementability associated with Alternative No. 4A is very difficult. Access to the area is easy, using an existing road behind Phipps Conservatory or through Junction Hollow. Conventional construction equipment, such as small dump trucks, excavators, and dozers can be utilized for earthmoving activities.

The jack and bore method and equipment utilized to advance the culvert beneath active tracks, although more routine than 20 years ago, will require a high level of detail and precision, with oversight of CSX personnel. More specialized equipment to align/withstand push forces and the excavation/support of jacking and receiving pits will be necessary. The large elliptical precast concrete culvert will require special fabrication and design by concrete manufacturers to handle the loads associated with locomotives. Installation of this culvert will need to minimize disturbance to the railroad tracks and operation.

Installation of the pedestrian walkway in the combination culvert is easy to complete and will utilize metal framing and walking surfaces. Hand equipment with skilled labor can perform this work.

Construction of the reinforced cast-in place concrete headwalls is easy to implement and utilizes conventional construction equipment such as excavators, dump trucks, concrete mixers and pump trucks. Skilled laborers can construct the formwork and install the reinforcement for the walls. Placement of concrete in the forms is easy to perform.

- Schedule Overall Rating **3**

The schedule for construction of this alternative would be considered average to slow to complete. This is due primarily to the critical jack and bore installation of the combination culvert and the cast-in-place concrete headwalls.

- Sanity Check Overall Rating **3**

This alternative does not meet the goals of the project, in that it does not control sediment deposition, or reduce CSO. The route removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. It also augments the park setting with the safe connection between two park areas.

8.6.7 Alternative 4B Step Spillway Upgrade (Option B)

- Performance Overall Rating **2**

The construction of the step spillway upgrade will be effective at transferring water from the lake to the combination stormwater/pedestrian culvert discussed in Alternative 4A. It will be ineffective in protecting downstream residents against flooding associated with a 100 year-24 hour rain event because of the size and open channel nature of the combination culvert. Therefore, it does not optimize and cost effectively size the hydraulic features through the Four Mile Run area.

- Opinion of Construction Cost Overall Rating **5**

The capital cost associated with this alternative is about $2, 749,050, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than one-half of the costs are associated with the construction of the concrete and stone spillway, utility relocations and earthwork.

- Public Perception Overall Rating **2**

The public perception of this alternative is positively perceived, as it provides an aesthetic waterfall like movement of water between the lake and the combination culvert.

- Operations, Maintenance and Inspection Overall Rating **2**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the spillway can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform the inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP Dam Safety.

- Risk Overall Rating **5**

This construction is high risk. PWSA maintains a 50" diameter steel waterline within the area of the spillway. The line is aged and may need replaced and will need to be relocated so as not to interfere with the location of the combination culvert. Relocation of an active line of this size is requires a shutdown of the line and connection of new pipe to an aged pipe. Replacement may be contingent upon PADEP's review of the project to obtain a permit for the dam. A 15" ductile iron pipe (DIP) is also located within the embankment and will also need to be relocated.

- Infrastructure Obstructions Overall Rating **4**

The infrastructure obstructions in Alternative No. 4B include the 50" diameter steel waterline and the 15" diameter DIP. Their impact on the project is discussed above.

- Implementability Overall Rating **4**

Implementability associated with Alternative No. 4B is difficult. Access to the area is easy, using an existing road behind Phipps Conservatory or through Junction Hollow. Conventional construction equipment, such as small dump trucks, excavators, and dozers can be utilized for earthmoving activities.

Construction of the reinforced cast-in place concrete step spillway, the baffles/blocks at the lake edge and the retaining wall is easy to implement and utilizes conventional conrete equipment such as concrete mixers and pump trucks. Skilled laborers can construct the formwork and install the reinforcement for the walls. Placement of concrete in the forms is easy to perform. Skilled labor will be required for installation of the stone steps in the spillway. The step spillway and walkway will need to tie in to the combination culvert.

- Schedule Overall Rating **4**

The schedule for construction of this alternative would be considered slow to complete. This is due primarily to the stepped cast-in-place concrete foundations and stone for the spillway and the concrete for the baffles and retaining wall at the lake edge.

- Sanity Check Overall Rating **3**

This alternative does not meet the goals of the project, in that it does not control sediment deposition, or reduce CSO. The route removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. It also augments the park setting with the an aesthetic waterway, when combined with other downstream alternatives.

8.6.8 Alternative 5 Junction Hollow Engineered Channel

- Performance Overall Rating **3**

The construction of the channel, will reduce erosion and subsequent sediment, provide an effective route for movement of stormwater and provide an ecological and healthy waterway.

- Opinion of Construction Cost Overall Rating **2**

The capital cost associated with this alternative is about $1,471,200, including contingency and is considered average to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the costs are associated with excavation and fill placement. Materials associated with construction are inexpensive.

- Public Perception Overall Rating **4**

The public perception of this alternative is very positively perceived, as it creates an open channel flow of water from Panther Lake through a popular and often visited city park.

- Operations, Maintenance and Inspections Overall Rating **2**

OM&I) elements associated with this alternative are easy and effective. Inspection of the channel can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **2**

There is a very low risk associated with construction, as the watershed boundary is well established, and the stream channel is capable of handling stormwater flows from a minimum 25 year-24 hour event. Additional channel flow is available should small percentages of upper watershed areas be incorporated into the project.

- Infrastructure Obstructions Overall Rating **1**

These obstructions are parallel to the Project work and consist of electric, sewer and water lines located within the Boundary Street right-of way and should not impact construction.

- Implementability Overall Rating **1**

Implementability associated with this alternative is Easy. Access to the area is available using the south end of Junction Hollow entrance at Boundary Street.. Materials utilized in construction are readily available from on-site and off-site sources. Conventional construction equipment, such as dump trucks, excavators, dozers and compaction equipment can be utilized for construction.

- Schedule Overall Rating **1**

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to the ease of excavation in an area with minimum interference and open work space. Consideration for pedestrian safety in the park may slightly slow construction efficiency.

- Sanity Check Overall Rating **2**

This alternative meets the goals of the project, in that it further controls sediment deposition from upper watershed hydraulic facilities, reduces CSO and is the feature that removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. It also augments the park setting with the construction of an open channel waterway in the park. It will be necessary to provide an alternate trail location through Junction Hollow during construction.

8.6.9 Alternative 5A Junction Hollow Upgrade from Channel to Stream

- Performance Overall Rating **2**

The construction of the stream will reduce erosion and subsequent sediment deposition, provide an effective route for movement of stormwater and provide an ecological and healthy waterway. It will provide these conditions in a manner more efficient than Alternative No. 5.

- Opinion of Construction Cost Overall Rating **2**

The capital cost associated with this alternative is about $500,000, including contingency and is considered inexpensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the costs are associated with instream structures. Materials associated with construction are inexpensive.

- Public Perception Overall Rating **1**

The public perception of this alternative is very positively perceived, as it creates a natural stream from Panther Lake through a popular and often visited city park.

- Operations, Maintenance and Inspections Overall Rating **2**

OM&I) elements associated with this alternative are easy and effective. Inspection of the channel can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **2**

There is a very low risk associated with construction, as the watershed boundary is well established, and the stream is capable of handling stormwater flows from a minimum 25 year-24 hour event. Additional channel flow is available should small percentages of upper watershed areas be incorporated into the project.

- Infrastructure Obstructions Overall Rating **1**

These obstructions are parallel to the Project work and consist of electric, sewer and water lines located within the Boundary Street right-of way and should not impact construction.

- Implementability Overall Rating **1**

Implementability associated with this alternative is Easy. Access to the area is available using the south end of Junction Hollow entrance at Boundary Street.. Materials utilized in construction are readily available from on-site and off-site sources. Conventional construction equipment, such as dump trucks, excavators, dozers and compaction equipment can be utilized for construction.

- Schedule Overall Rating 2

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to the ease of excavation in an area with minimum interference and open work space. Consideration for pedestrian safety in the park may slightly slow construction efficiency.

- Sanity Check Overall Rating 1

This alternative meets the goals of the project, in that it further controls sediment deposition from upper watershed hydraulic facilities, reduces CSO and is the feature that removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. It also augments the park setting with the upgrading of a engineered channel to a new stream in the park. It will be necessary to provide an alternate trail location through Junction Hollow during construction.

8.6.10 Alternative 6 East Side Railroad Channel

- Performance Overall Rating 3

The construction of this small, short stream will reduce erosion and subsequent sediment deposition, provide an effective route for movement of stormwater and provide an ecological and healthy waterway.

- Opinion of Construction Cost Overall Rating 2

The capital cost associated with this alternative is about $125,000, including contingency and is considered very inexpensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the costs are associated with a synthetic stream liner and instream structures, which are critical in the construction of streams. Materials associated with maintenance are generally inexpensive.

- Public Perception Overall Rating 3

The public perception of this alternative is average, as it is a waterway construction not within the 'limits' of the park and separated from park occupants by CSX railroad tracks.

- Operations, Maintenance and Inspection Overall Rating 2

OMI elements associated with this alternative are easy and effective. Inspection of the stream can be performed on as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. Materials associated with maintenance are easy to install.

- Risk Overall Rating **2**

There is a very low risk associated with construction, as the watershed boundary is well established, and the stream channel is capable of handling stormwater flows from a 25 year-24 hour event. Additional channel flow is available should small percentages of upper watershed areas be incorporated into the project.

- Infrastructure Obstructions Overall Rating **2**

There are no subsurface obstructions associated with this alternative..

- Implementability Overall Rating **3**

Implementability associated with this alternative is Easy to difficult. Access to the area is difficult and is only available from the terminal or south end of the stream; no road is present. Materials utilized in construction are readily available from on-site and off-site sources, but will need to be carried by small excavator from a stockpile over a distance of up to one-quarter mile. . Conventional construction equipment, such as dump trucks and small excavators can be utilized for construction.

- Schedule Overall Rating **2**

The schedule for construction of this alternative would be considered very fast to complete. This is due primarily to the small size and scope of the project component.

- Sanity Check Overall Rating **2**

This alternative meets several goals of the project, in that it reduces sediment deposition and when combined with other downstream alternatives, reduces CSO and removes stormwater from the existing PWSA piping system. The stormwater removal may reduce basement flooding to residential areas at downstream locations of the Project.

8.6.11 Alternative 7 Soccer Field Headwall/Berm

- Performance Overall Rating **2**

The construction of the concrete headwall and the placement of fill around the headwall will be very effective in creating the transition from open channel to closed conveyance/pipe flow and provide adequate volume for stormwater to pond if necessary to promote flow through the pipe. .

- Opinion of Construction Cost Overall Rating **2**

The capital cost associated with this alternative is about $50,000, including contingency and is considered very inexpensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the cost is associated with the cast in place concrete

- Public Perception Overall Rating **3**

The public perception of this alternative is average perceived, as the structure is very small compared to the overall Project.

- Operations, Maintenance and Inspection Overall Rating **2**

OM&I elements associated with this alternative are easy and effective. Inspection of the headwall can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. OM&I of the embankment raise will primarily consist of observation of the embankment slopes to observe instability and for burrowing animals that reduce the integrity of the fill.

- Risk Overall Rating **1**

This design and construction carries some very low risk. There are no utilities in the area and the structure is very small compared to the overall Project.

- Infrastructure Obstructions Overall Rating **1**

The infrastructure obstructions in Alternative No. 4 include the 50" diameter steel waterline and the 15" diameter DIP. Their impact on the project is discussed above.

- Implementability Overall Rating **1**

Implementability associated with Alternative No. 7 is very easy. Access to the area is available using. Conventional construction equipment, such as dump trucks, excavators, and concrete equipment can be utilized for concrete and earthmoving activities. Materials utilized in construction are readily available from on-site and off-site sources.

Construction of the reinforced cast-in place concrete headwall is easy to implement and utilizes conventional concrete equipment such as concrete mixers and pump trucks. Skilled laborers can construct the formwork and install the reinforcement for the walls. Placement of concrete in the forms is easy to perform.

- Schedule Overall Rating **1**

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to the very small size of the structure compared to the overall Project.

- Sanity Check Overall Rating **1**

This alternative partially aids in meeting the goals of the project, in that it reduces CSO and removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project.

8.6.12 Alternative 8 Four Mile Run Park Piping System

- Performance Overall Rating **2**

The construction of the below grade piping system, which includes two pipes for collecting stormwater from points upslope of and including Junction Hollow and the east side drainage channel, will contain and move stormwater through the Four Mile Run neighborhood, reducing the basement flooding of local homeowners and the street flooding that occurs on several local roadways during select storm events and reduce CSO. The smoothness of the HDPE pipe is effective in transferring stormwater flow from the hydraulic features in Junction Hollow and detention areas to the Monongahela River

- Opinion of Construction Cost Overall Rating **3**

The capital cost associated with this alternative is about $2, 378702, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than two-thirds of the costs are associated with the purchase and installation of the HDPE pipe and the replacement of asphalt over pipe installation.

- Public Perception Overall Rating **2**

The public perception of this alternative is average. There will be traffic obstructions associated with construction on Boundary Street at the southern entrance to Junction Hollow which will incur temporary inconvenience; however, upon completion of construction, none of the Project components will be visible.

- Operations, Maintenance and Inspection Overall Rating **1**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the HDPE pipe can be performed on as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **2**

This construction is high risk. There are numerous obstructions between Junction Hollow and Four Mile Run Park. These consist of gas, electric, stormwater, sanitary sewer and waterlines that vary in depth and location along the Project route. There are approximately 10 utility obstruction in this segment; there are approximately 50 for the entire project. The utilities may bound the piping above, below or adjacent to the proposed elevation and location of the piping. In order to facilitate a route through the subject areas, the clearances between the pipe and some utilities could be less than 15-inches. Some utilities will require relocation either horizontally or vertically.

There is also one location where the pipe will need to navigate between CSX bridge foundations and piers. The depth of the pipe should not be below the foundations. Public roadways and associated features, such as sidewalks, bicycle paths and park areas will also be affected.

The design to extend the piping systems beneath bridges supporting tracks operated by CSX will require coordination with CSX personnel located in Trevose, PA and Jacksonville, FL. CSX is requesting submissions for their review at the 30%, 60% and 90% design phases, similar to the submittal process to be utilized on this Project. CSX will review the submissions and provide comments. CSX has been authorized by PWSA to invoice labor costs associated with the submissions. During construction, CSX personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions Overall Rating **4**

The infrastructure obstructions in Alternative No. 8 are discussed above. The severity of these obstructions are lessened slightly by the reduced depth of the two 36-inch diameter HDPE pipes beneath Boundary Street. The HDPE pipes provide flexibility to navigate horizontally around existing underground utilities, compared to a rigid, concrete box culvert.

- Implementability Overall Rating **2**

Implementability associated with Alternative No. 8 varies from easy to difficult. Access to the area easily available along the entire route of pipe installation. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Installation of pipe between the foundations of the bridges carrying CSX tracks will require oversight of CSX personnel. Connection of HDPE pipe using the butt fusion welding method is routine but requires special equipment (heat plates and pipe clamps) operated by semi-skilled labor

The reduced, shallower depth of the two 36-inch diameter HDPE pipes beneath Saline Street, Greenfield Avenue and Second Avenue will be easier to construct; however, the rate of excavation to uncover the utilities will be slow, due to the potential for inaccuracies associated with the as-built drawings and so as not to damage the utility.

- Schedule Overall Rating **2**

The schedule for construction of this alternative would be considered slow to fast to complete. Shallow pipe installation will expedite the process; however, the overall length of the pipe installation and the infrastructure obstructions will slow construction.

- Sanity Check Overall Rating **1**

This alternative provides a cost savings associated with earthmoving and infrastructure obstructions. The shallow depth of excavation eliminates the need for sheet pile bracing and shoring and provides an ease of pipe installation beneath the bridge carrying CSX tracks over Boundary Street. The conveyance of stormwater in a pipe creates a closed system and reduces the potential for overbank flow of alternate open channel structures to enter into the residential neighborhoods.

8.6.13 Alternative 8A Four Mile Run Park Stream Segments (Option E)

- Performance Overall Rating **2**

The construction of the alternating pipe and stream system will contain and move stormwater through the Four Mile Run neighborhood and reduce CSO. Portions will also and provide an ecological and healthy waterway.

- Opinion of Construction Cost Overall Rating **3**

The capital cost associated with this alternative is about $2,052,751, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the costs are associated asphalt demolition and disposal, pipe purchase and installation and asphalt reconstruction. Materials associated with maintenance are inexpensive.

- Public Perception Overall Rating **2**

The public perception of this alternative is positively perceived, as it creates a short segment recreational stream through a small park where no stream previously existed.

- Operations, Maintenance and Inspection Overall Rating 1

OM&I elements associated with this alternative are easy and effective. Inspection of the piping and stream can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event. It may be necessary to perform stream inspections on a semi-annual basis for the first several years, based upon requirements established by PADEP.

- Risk Overall Rating 4

This construction is high risk. There are numerous obstructions between Junction Hollow and Four Mile Run Park. These consist of gas, electric, stormwater and sanitary sewer and water lines that vary in depth and location along the Project route. There are approximately 10 utility obstructions in this segment; there are approximately 50 for the entire project. The utilities may bound the piping above, below or adjacent to the proposed elevation and location of the piping. In order to facilitate a route through the subject areas, the clearances between the pipe and some utilities could be less than 15-inches. Some of these utilities may require relocation either horizontally or vertically.

There is also one location where the pipe will need to navigate between CSX bridge foundations and piers. The depth of the pipe should not be below the foundations. Public roadways and associated features, such as sidewalks, bicycle paths and park areas will also be affected.

The design to extend the piping systems beneath bridges supporting tracks operated by CSX will require coordination with CSX personnel located in Trevose, PA and Jacksonville, FL. CSX is requesting submissions for their review at the 30%, 60% and 90% design phases, similar to the submittal process to be utilized on this Project. CSX will review the submissions and provide comments. CSX has been authorized by PWSA to invoice labor costs associated with the submissions. During construction, CSX personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

At Four Mile Run Park, the open channel stream segment provides an open, non-confined conveyance in a neighborhood already prone to flooding. The stream channel elevation (730 feet) at the park is only 8 feet above the annual storm elevation for the Monongahela River (722 feet). Should a high elevation event occur on the Monongahela River, stream flow from Junction Hollow unable to discharge to the river can back up in the lowest elevation open channel in the Project, possibly creating unnecessary flooding. The 100 year flood elevation on the Monongahela River is at elevation 733, which is above this stream invert.

- Infrastructure Obstructions Overall Rating 4

The infrastructure obstructions in this alternative are discussed above and include gas, electric, stormwater, sanitary sewer and water.

- Implementability Overall Rating 3

Implementability associated with this alternative No. 8 varies from easy to difficult. Access to the area easily available along the entire route of pipe installation. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Installation of pipe between the foundations of the bridges carrying CSX tracks will require oversight of CSX personnel. Connection of HDPE pipe using the butt fusion welding method is routine but requires special equipment (heat plates and pipe clamps) operated by semi-skilled labor

- Schedule Overall Rating 2

The schedule for construction of this alternative would be considered slow to fast to complete. Shallow pipe installation will expedite the process; however, the overall length of the pipe installation and the infrastructure obstructions will slow construction.

Although not directly impacting construction time, the schedule is also influenced by the time needed by PADEP to approve a Joint Permit Application from PADEP, primarily for construction of the streams.

- Sanity Check Overall Rating 2

The roughness and reduced velocity in the open channel would require a pipe system at Saline Street larger than the upstream pipe system, to recollect the slower flow with greater cross sectional area and transfer it downstream.

Design and additional construction costs will be incurred for erosion protection at the entrance or outlet at four locations with the inclusion of the stream segment.

8.6.14 <u>Alternative 9 Saline Street Deep Gravity Pipe System</u>

- Performance Overall Rating 2

The construction of the piping system, which includes two pipes for collecting stormwater from points upslope of and including Junction Hollow and a separate pipe that will collect stormwater flow from Naylor Run, will contain and move stormwater through the Four Mile Run and Naylor

Run neighborhoods, reducing the basement flooding of local homeowners and the street flooding that occurs on several local roadways during select storm events. The smoothness of the HDPE pipe is effective in transferring stormwater flow from the hydraulic features in Junction Hollow and detention areas to the Monongahela River

- Opinion of Construction Cost Overall Rating **4**

The capital cost associated with this alternative is about $2, 205,093, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than one-half of the costs are associated with the purchase and installation of the HDPE pipe and the replacement of asphalt over pipe installation.

- Public Perception Overall Rating **3**

The public perception of this alternative is average. There will be traffic obstructions associated with construction along Saline Street which will incur temporary inconvenience; however, upon completion of construction, none of the Project components will be visible.

- Operations, Maintenance and Inspection Overall Rating **1**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the HDPE pipe can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **4**

This construction is very high risk. There are numerous obstructions between Junction Hollow and the Hazelwood Green site. These consist of gas, electric, stormwater and sanitary sewer, water and communication lines that vary in depth and location along the Project route. There are approximately 20 utility obstruction in this segment; there are approximately 50 for the entire project. The utilities may bound the piping above, below or adjacent to the proposed elevation and location of the piping. In order to facilitate a route through the subject areas, the clearances between the pipe and some utilities could be less than 15-inches. Some of these utilities may require relocation either horizontally or vertically.

A temporary sheeting, shoring and bracing system will need to be designed for the estimated 25 feet depth of pipe installation. The design and construction of this shoring systems is complicated by the depth and utility obstructions.

There are also two locations where footings for bridge foundations, bridge abutments and piers will affect the project route. Public roadways and associated features, such as sidewalks, bicycle paths and retaining walls will also be affected.

Obstructions in the Hazelwood Green site include private roadways and sidewalks, underground utilities including gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site, and the potential for soils with elevated concentrations of constituents left in place during the decommissioning of the former LTV site.

The design to extend the piping systems beneath bridges supporting tracks operated by CSX will require coordination with CSX personnel located in Trevose, PA and Jacksonville, FL. CSX is requesting submissions for their review at the 30%, 60% and 90% design phases, similar to the submittal process to be utilized on this Project. CSX will review the submissions and provide comments. CSX has been authorized by PWSA to invoice labor costs associated with the submissions. During construction, CSX personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions Overall Rating **5**

The infrastructure obstructions in Alternative No. 9B are discussed above. The severity of these obstructions are lessened slightly by the reduced depth of the two 36-inch diameter HDPE pipes beneath Saline Street, Greenfield Avenue and Second Avenue. The HDPE pipes provide flexibility to navigate horizontally around existing underground utilities, compared to a rigid, concrete box culvert They are also lessened by the use of a single use, smaller diameter stormwater pipe and riser structure from Panther Hollow Lake, in lieu of a multi-use, larger diameter culvert for pedestrian and stormwater passage from Panther Hollow Lake and beneath CSX railroad tracks. The smaller cross sectional area occupied by the two HDPE pipes, compared to the larger rectangular box culvert will also provide additional obstruction avoidance.

- Implementability Overall Rating **4**

Implementability associated with Alternative No. 9B varies from easy to difficult. Access to the area easily available along the entire route of pipe installation. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Installation of pipe between the foundations of the bridges carrying CSX tracks will require oversight of CSX personnel. Connection of HDPE pipe using the butt fusion welding method is routine abut requires special equipment (heat plates and pipe clamps) operated by semi-skilled labor

The reduced, shallower depth of the two 36-inch diameter HDPE pipes beneath Saline Street, Greenfield Avenue and Second Avenue will be easier to construct however, the rate of excavation to uncover the utilities will be slow, due to the potential for inaccuracies associated with the as-built drawings and so as not to damage the utility.

- Schedule Overall Rating 3

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to the shallow pipe installation and the reduced number of infrastructure obstructions.

- Sanity Check Overall Rating 2

This alternative, while providing an underground hydraulic connection between Four Mile Run Park and the Monongahela River, requires excavations to depths in excess of 20 feet. The geotechnical design associated with this depth, the cost for sheeting shoring and bracing of the excavation and the many existing utilities in the area create numerous concerns. The above concerns are exacerbated where the piping system needs to extend beneath the bridge piers and abutments that carry CSX tracks over Greenfield Avenue. At this location, overhead clearances are restricted to approximately 14 feet. Other options may provide a capital cost savings.

8.6.15 Alternative 9A Saline Street Pump Station (Option F)

- Performance Overall Rating 2

The addition of the pump station adds additional operation and maintenance to the project, but it does not reduce the potential for the alternative to be reliable in meeting the project goals.

- Opinion of Construction Cost Overall Rating 3

The capital cost associated with this alternative is about $2, 029,500, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than two-thirds of the costs are associated with the purchase and installation of the pumps and motors, the backup generator and the mechanical and electrical hookup. Operation and maintenance costs associated with the operation of the pumps are approximately $150,000.

- Public Perception Overall Rating **2**

The public perception of this alternative is average to positively perceived to poorly perceived. The pump station provides a system that allows can control stormwater from a selected storm, with the opportunity to handle additional flows from ancillary areas not in the Project. The need for an above ground building to contain the pump motors, electric panels, backup electric facilities and some piping may be objectionable to local residents. The building can be surrounded by landscape to aid in its concealment.

- Operations and Maintenance, Inspection Overall Rating **4**

The pump operation should be visually observed on a periodic basis, ranging from daily to weekly. Daily operation can be observed using wireless connection. Maintenance of the pump and motor should be performed in accordance with the installation and operations manual and at a minimu should be performed annually by PWSA or their appointed representative. Inspections during visual observations should include unusual noise, vibration and bearing, temperature, pump and piping leaks. Motor inspections should verify that the unit is clean and ventilation is adequate.

- Risk Overall Rating **2**

There is a risk associated with the operation of the pump station. The reliance on a mechanical system operated by electric and requiring periodic observation and maintenance to convey water increases the risk when compared to other alternatives that utilize a pipe system designed for gravity flow.

- Infrastructure Obstructions Overall Rating **2**

There are no infrastructure obstruction at the small area associated with the pump station.

- Implementability Overall Rating **3**

Implementability of the pump station varies from easy to difficult. Access to the area is easy, as it is adjacent to Saline Street. Conventional construction equipment, such as small dump trucks, excavators, and cranes can be utilized for earthmoving and pumps station construction activities.

Construction of the reinforced cast-in place concrete basin for stormwater collection, the baffles/blocks at the lake edge and the retaining wall is easy to implement and utilizes conventional construction equipment such as excavators, dump trucks, concrete mixers and pump trucks. Skilled laborers can construct the formwork and install the reinforcement for the walls. Placement of concrete in the forms is easy to perform. Skilled labor will be required for installation of the stone steps in the spillway. The step spillway and walkway will need to tie in to the combination pedestrian culvert.

Installation of the pumps and motors and the generator will require skilled labor. Mechanical hookups between the pumps and piping will need to be performed and electrical hookups between the pump and existing electrical power from utility poles and between the emergency generator will be required. Construction of the building to enclose appropriate facilities will be east and require semi-skilled labor.

- Schedule Overall Rating 3

The schedule for construction of this alternative would be considered average to complete. This is due primarily to the concrete below grade stormwater collection basin and the pump and motors.

- Sanity Check Overall Rating 3

The pump station provides an opportunity for cost savings, in that associated with the construction of hydraulic facilities downstream; it eliminates the additional excavation, shoring and bracing needed to install the pipe system at deep locations beneath portions of Saline Street, below the CSX railroad bridge and the between the bridge foundations at Greenfield Avenue and beneath Second Avenue. The pipe route also reduces the conflicts and number of relocations for several underground utility lines in the area. This alternative meets the goals of the project, in that it further controls sediment deposition from upper watershed hydraulic facilities, reduces CSO and is the feature that removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project.

8.6.16 Alternative 9B Saline Street and Hazelwood Green Shallow Pressure Pipe System (Option G)

- Performance Overall Rating 2

The construction of the piping system, which includes two pipes for collecting stormwater from points upslope of and including Junction Hollow and a separate pipe that will collect stormwater flow from Naylor Run, will contain and move stormwater through the Four Mile Run and Naylor Run neighborhoods, reducing the basement flooding of local homeowners and the street flooding that occurs on several local roadways during select storm events. The smoothness of the HDPE pipe is effective in transferring stormwater flow from the hydraulic features in Junction Hollow and detention areas to the Monongahela River

- Opinion of Construction Cost Overall Rating 3

The capital cost associated with this alternative is about $3,097,893, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than one-half of the costs are associated with the purchase and installation of the HDPE pipe and the replacement of asphalt over pipe installation.

- Public Perception Overall Rating **2**

The public perception of this alternative is average. There will be traffic obstructions associated with construction along Saline Street which will incur temporary inconvenience; however, upon completion of construction, none of the Project components will be visible.

- Operations, Maintenance and Inspection Overall Rating **2**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the HDPE pipe can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **2**

This construction is very high risk. There are numerous obstructions between Four Mile Run Park and the Hazelwood Green site. These consist of gas, electric, stormwater and sanitary sewer, water and communication lines that vary in depth and location along the Project route. There are approximately 20 utility obstruction in this segment; there are approximately 50 for the entire project. Some of these utilities may require relocation.

There are also two locations where footings for bridge foundations, bridge abutments and piers will affect the project route. Public roadways and associated features, such as sidewalks, bicycle paths and retaining walls will also be affected.

Obstructions in the Hazelwood Green site include private roadways and sidewalks, underground utilities including gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site, and the potential for soils with elevated concentrations of constituents left in place during the decommissioning of the former LTV site

The design to extend the piping systems beneath bridges supporting tracks operated by CSX will require coordination with CSX personnel located in Trevose, PA and Jacksonville, FL. CSX is requesting submissions for their review at the 30%, 60% and 90% design phases, similar to the submittal process to be utilized on this Project. CSX will review the submissions and provide comments. CSX has been authorized by PWSA to invoice labor costs associated with the submissions. During construction, CSX personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions Overall Rating 3

The infrastructure obstructions in Alternative No. 9B are discussed above. The severity of these obstructions are lessened slightly by the reduced depth of the two 36-inch diameter HDPE pipes beneath Saline Street, Greenfield Avenue and Second Avenue. The HDPE pipes provide flexibility to navigate horizontally around existing underground utilities, compared to a rigid, concrete box culvert. They are also lessened by the use of a single use, smaller diameter stormwater pipe and riser structure from Panther Hollow Lake, in lieu of a multi-use, larger diameter culvert for pedestrian and stormwater passage from Panther Hollow Lake and beneath CSX railroad tracks. The smaller cross sectional area occupied by the two HDPE pipes, compared to the larger rectangular box culvert will also provide additional obstruction avoidance.

- Implementability Overall Rating 3

Implementability associated with Alternative No. 9B varies from easy to difficult. Access to the area easily available along the entire route of pipe installation. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Installation of pipe between the foundations of the bridges carrying CSX tracks will require oversight of CSX personnel. Connection of HDPE pipe using the butt fusion welding method is routine abut requires special equipment (heat plates and pipe clamps) operated by semi-skilled labor

The reduced, shallower depth of the two 36-inch diameter HDPE pipes beneath Saline Street, Greenfield Avenue and Second Avenue will be easier to construct. .

- Schedule Overall Rating 3

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to the shallow pipe installation and the reduced number of infrastructure obstructions.

- Sanity Check Overall Rating 2

In conjunction with Alternative 9A, this alternative provides a cost savings associated with earthmoving and infrastructure obstructions. The shallower depth of excavation eliminates the need for sheet pile bracing and shoring and provides an ease of pipe installation beneath the bridge carrying CSX tracks over Greenfield Avenue. It will also reduce the need to excavate below existing utilities, as in previous alternatives utilizing gravity flow pipe systems and result in less time for maintenance and protection of traffic coordination.

8.6.17 Alternative 10 and 10C Hazelwood Green Deep Gravity Pipe System, Pipe beneath Railroad and Monongahela River Outfall

- Performance Overall Rating 2

The construction of the piping system, which includes three pipes for collecting stormwater from points upslope of Saline Street and the jack and bore of the pipes beneath Signature Boulevard and the MetalTech railroad will contain and move stormwater through the Hazelwood Green site. The smoothness of the HDPE pipe is effective in transferring stormwater flow to the Monongahela River.

- Opinion of Construction Cost Overall Rating 3

The capital cost associated with this alternative is about $1,502, 529, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Slightly less than one-half of the costs are associated with the jack and bore and installation of the three pipes beneath Signature Boulevard and the Metal Tech railroad.

- Public Perception Overall Rating 4

The public perception of this alternative is average. There will be no traffic obstructions associated with construction along Signature Boulevard and upon completion of construction, none of the Project components will be visible.

- Operations, Maintenance and Inspection Overall Rating 2

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the HDPE pipe can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating 3

This construction is average to high risk. Obstructions in the Hazelwood Green site include private roadways and sidewalks, underground utilities including gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site, and the potential for soils with elevated concentrations of constituents left in place during the decommissioning of the former LTV site.

A temporary sheeting, shoring and bracing system will need to be designed for the estimated 20 feet depth of pipe installation. The design and construction of this shoring systems is complicated by the depth and utility obstructions.

- Infrastructure Obstructions Overall Rating 3

The infrastructure obstructions in Alternative No. 10 and 10D are discussed above. The HDPE pipes provide some flexibility to navigate horizontally around existing underground utilities, compared to a rigid, concrete or steel structures. The smaller cross sectional area occupied by the two HDPE pipes, compared to larger concrete or steel structures will also provide additional obstruction avoidance. The location of the pipe outfalls at the Monongahela River may require modification of existing retaining walls that are remaining from the former LTV plant.

- Implementability Overall Rating 3

Implementability associated with this alternative from easy to difficult. Access to the area is easily available along the entire route of pipe installation, but will require permission from Hazelwood Green representatives. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Installation of pipe to depths of up to 20 vertical feet will require open sloped excavations or shoring, sheeting and bracing. Possible foundations remaining from the decommissioned LTV facility may be present. Connection of HDPE pipe using the butt fusion welding method is routine abut requires special equipment (heat plates and pipe clamps) operated by semi-skilled labor

The jack and bore method and equipment utilized to advance the pipe beneath active tracks, although more routine than 20 years ago, will require a high level of detail and precision, with oversight of MetalTech personnel. More specialized equipment to align/withstand push forces and the excavation/support of jacking and receiving pits will be necessary. The steel pipe will require fabrication and design to handle the loads associated with locomotives. Installation of this pipes will need to minimize disturbance to the railroad tracks and operation.

- Schedule Overall Rating 3

The schedule for construction of this alternative would be considered slow to complete. This is due primarily to the number of infrastructure obstructions and the jack and bore process for three pipes beneath Signature Boulevard and the MetalTech railroad. Construction of the outfall at the Monongahela River may slow the construction process.

- Sanity Check Overall Rating 2

This alternative, while providing an underground hydraulic connection between Second Avenue and the Monongahela River, requires excavations to depths in excess of 20 feet. The geotechnical design associated with this depth, the cost for sheeting shoring and bracing of the excavation and the many existing utilities in the area create numerous concerns.

8.6.18 Alternative 10A and 10C Hazelwood Green Deep Open Stream Channel, Pipe beneath Railroad and Monongahela River Outfall

- Performance Overall Rating **2**

The construction of the open channel, which includes the jack and bore of three pipes beneath Signature Boulevard and the MetalTech railroad will contain and move stormwater through the Hazelwood Green site. This will also reduce the basement and street flooding of upstream local homeowners during select storm events

- Opinion of Construction Cost Overall Rating **3**

The capital cost associated with this alternative is about $1,702,122, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the costs are associated with the jack and bore and installation of the three pipes beneath Signature Boulevard and the Metal Tech railroad.

- Public Perception Overall Rating **3**

The public perception of this alternative is positive. There will be no traffic obstructions associated with construction along Signature Boulevard. The open channel in the Hazelwood Green site will provide visible moving water in a park setting in an area with future residential, recreational and/or commercial development opportunities.

- Operations, Maintenance and Inspection Overall Rating **2**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the HDPE pipe system and the stream channel can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **2**

This construction is very high risk. Obstructions in the Hazelwood Green site include private roadways and sidewalks, underground utilities including gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site, and the potential for soils with elevated concentrations of constituents left in place during the decommissioning of the former LTV site

The design to extend the piping systems beneath MetalTech railroad tracks will require coordination with MetalTech personnel. It is anticipated that MetalTech personnel will request a submissions for their review and provide comments. During construction, metal Tech personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions — Overall Rating 3

The infrastructure obstructions in this alternative are discussed above. The severity of these obstructions are greater with the open excavation needed for the stream channel side slopes, which will be between 2H:1V and 3H:1V.

- Implementability — Overall Rating 4

Implementability associated with this alternative are difficult. Access to the area easily available along the entire route, but will require permission from Hazelwood Green representatives. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Construction of the reinforced cast-in place retaining endwalls at either end of the stream channel is easy to implement and utilizes conventional concrete equipment such as concrete mixers and pump trucks. Skilled laborers can construct the formwork and install the reinforcement for the walls. Placement of concrete in the forms is easy to perform.

The jack and bore method and equipment utilized to advance the pipe beneath active tracks, although more routine than 20 years ago, will require a high level of detail and precision, with oversight of MetalTech personnel. More specialized equipment to align/withstand push forces and the excavation/support of jacking and receiving pits will be necessary. The steel pipe will require fabrication and design to handle the loads associated with locomotives. Installation of this pipes will need to minimize disturbance to the railroad tracks and operation.

Construction of the outfall of the pipes at the Monongahela River may require removal or modification of an existing retain wall remaining from the LTV operations.

- Schedule — Overall Rating 3

The schedule for construction of this alternative would be considered slow to complete. This is due to the number of infrastructure obstructions in Hazelwood Green and the jack and bore process for three pipes beneath Signature Boulevard and the MetalTech railroad. Construction of the outfall at the Monongahela River may slow the construction process.

- Sanity Check — Overall Rating 2

This alternative provides an opportunity for ‘a day-lit stream’ and a park setting within the Hazelwood Green site, but would create greater acreage that could not be used for development. The depth from the current ground surface at Hazelwood Green to the stream channel is approximately 20 feet, which could create a 'gully' effect. Side slopes can be shallowed to provide for a more open feel and pedestrian access, but would require more surface area to accomplish.

8.6.19 Alternative 10B and 10C Hazelwood Shallow Open Channel, Pipe beneath Railroad and Monongahela River Outfall

- Performance Overall Rating **2**

The construction of the open channel, which includes the jack and bore of three pipes beneath Signature Boulevard and the MetalTech railroad will contain and move stormwater through the Hazelwood Green site. This will also reduce the basement and street flooding of upstream local homeowners during select storm events

- Opinion of Construction Cost Overall Rating **2**

The capital cost associated with this alternative is about $1,587,372, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. Approximately one-half of the costs are associated with the jack and bore and installation of the three pipes beneath Signature Boulevard and the Metal Tech railroad.

- Public Perception Overall Rating **2**

The public perception of this alternative is positive. There will be no traffic obstructions associated with construction along Signature Boulevard. The shallower, open channel in the Hazelwood Green site will provide visible moving water in a park setting in an area with future residential, recreational and/or commercial development opportunities.

- Operations, Maintenance and Inspection Overall Rating **3**

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the HDPE pipe system and the stream channel can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating **2**

This construction is low to very high risk. Obstructions in the Hazelwood Green site include private roadways and sidewalks, underground utilities including gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site, and the potential for soils with elevated concentrations of constituents left in place during the decommissioning of the former LTV site; however, these risks are lessened with the shallower open stream channel.

The design to extend the piping systems beneath MetalTech railroad tracks will require coordination with MetalTech personnel. It is anticipated that MetalTech personnel will request a submission for their review and provide comments. During construction, MetalTech personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions Overall Rating **2**

The infrastructure obstructions in this alternative are discussed above. The severity of these obstructions are lessened with the shallower, open excavation needed for the stream channel side slopes, which will be between 2H:1V and 3H:1V.

- Implementability Overall Rating **3**

Implementability associated with this alternative are difficult. Access to the area easily available along the entire route, but will require permission from Hazelwood Green representatives. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and pipe installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

Construction of the reinforced cast-in place retaining endwalls at either end of the shallower stream channel is easy to implement and utilizes conventional concrete equipment such as concrete mixers and pump trucks. Skilled laborers can construct the formwork and install the reinforcement for the walls. Placement of concrete in the forms is easy to perform.

The jack and bore method and equipment utilized to advance the pipe beneath active tracks, although more routine than 20 years ago, will require a high level of detail and precision, with oversight of MetalTech personnel. More specialized equipment to align/withstand push forces and the excavation/support of jacking and receiving pits will be necessary. The steel pipe will require fabrication and design to handle the loads associated with locomotives. Installation of this pipes will need to minimize disturbance to the railroad tracks and operation.

Construction of the outfall of the pipes at the Monongahela River may require removal or modification of an existing retain wall remaining from the decommissioned LTV operations.

- Schedule Overall Rating **3**

The schedule for construction of this alternative would be considered slow to complete. This is due to the number of infrastructure obstructions in Hazelwood Green and the jack and bore process for three pipes beneath Signature Boulevard and the MetalTech railroad. Construction of the outfall at the Monongahela River may slow the construction process..

- Sanity Check Overall Rating **2**

This alternative provides an opportunity for a park setting within the Hazelwood Green site, but would create greater acreage that could not be used for development. The depth from the current ground surface at Hazelwood Green to the stream channel is approximately 12 feet, which could create a 'gully' effect. Side slopes can be shallowed to provide for pedestrian access, but would require more surface area to accomplish. The shallower stormwater conveyance could result in less backup from high water impacts on the Monongahela River, which would promote greater flow from hydraulic facilities upstream

8.6.20 Alternative 11 Tunnel along New West Route to Monongahela River

- Performance Overall Rating **1**

The tunnel will be very effective at removing stormwater from existing piping, conveying stormwater in large quantities associated with intensity-duration storm events from Junction Hollow to the Monongahela River and directing stormwater away from the areas prone to flooding. It can also transfer stormwater from upper watershed areas, which will be beneficial if asset management of stormwater from watershed areas upstream of the Project are to be included in future design and construction planning.

- Opinion of Construction Cost Overall Rating **5**

The capital cost associated with this alternative is about $16,199,400, including contingency and is considered very expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than one-half of the costs are associated with the materials and installation of the tunnel. Tunnel construction costs includes the test boring machine, the drop shaft for stormwater to the tunnel, multiple tunnel linings using material that will need to be staged above ground, removal of the soil and/or rock cuttings from below ground to above ground, ventilation and electric power for equipment and electric power for constant lighting.

- Public Perception Overall Rating **2**

The public perception of this alternative varies from positively perceived to negatively perceived. The details associated with construction of a tunnel beneath portions of the South Oakland neighborhood may need to be discussed with concerned citizens prior to construction. The amount of work area in Junction Hollow and in Hazelwood Green is the greatest, when compared to other alternatives and may be negatively viewed by the park patrons. From a positive standpoint, the tunnel eliminates all of the construction south and downstream of Junction Hoillow.

- Operations and Maintenance, Inspection Overall Rating 3

Additional inspections of the tunnel and drop shaft will need to be performed on an as-needed basis, but at a minimum, annually or after a large storm event, the intensity of which will need to be determined. Occasional cleanout of sediment and debris will need to be performed within the tunnel and the drop shaft.

- Risk Overall Rating 3

The tunnel construction is low risk. No utilities are expected to be encountered during construction beneath the South Oakland neighborhood. The geotechnical conditions along the route need to be further identified, specifically the location of soft rock or soils, but upon completion of this task, tunnel construction provides long-term reliability.

- Infrastructure Obstructions Overall Rating 4

No utilities are expected to be encountered during tunnel construction beneath the South Oakland neighborhood, between Junction Hollow and Second Avenue. If a jacking pit is proposed in the Hazelwood Green site, subsurface utilities beneath Second Avenue include water, gas and electric. The tunnel jack and bore is anticipated to be beneath these utilities.

The obstructions in the Hazelwood Green site along the tunnel route are underground and include gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site. Jacking of a tunnel beneath the MetalTech railroad tracks will still be necessary, but no privately owned roads or sidewalks are in the area

- Implementability Overall Rating 4

Implementability associated with the tunnel will be difficult to very difficult. A tunnel boring machine is not common equipment and very skilled labor is necessary to operate the equipment. The depth of the tunnel at the upstream end will be 40 to 60 feet, and a shaft will need to be constructed to initially provide access for labor and equipment and eventually to provide a conveyance route for stormwater. Construction of the tunnel includes multiple linings using material that will need to be staged above ground. Removal of the soil and/or rock cuttings from below ground to above ground will need to be performed and the underground work will require ventilation for labor and equipment, electric power for equipment and electric power for constant lighting. Construction of a tunnel typically begins at the downstream end, therefore a launch pit will need to be established in the Hazelwood Green site.

- Schedule Overall Rating **3**

The schedule for construction of this alternative would be considered slow to complete. Preparation of the jacking and receiving pits and overexcavation in Junction Hollow to construct the drop shaft will be above ground construction activities. Tunnel construction will not be visible, except for the soil remove during jacking. Tunnel construction may be performed independent of other construction components in the Project. The work could be completed before Junction Hollow Project components are started.

- Sanity Check Overall Rating **2**

This alternative partially aids in meeting the goals of the project, in that it reduces CSO and removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. The numerous infrastructure obstructions between Junction Hollow and the Monongahela River, including the obstructions associated with the bridge abutment and pier foundations at Greenfield Avenue and the jacking of pipe beneath roads and railroad tracks at the Hazelwood Green site are eliminated using the tunnel route. Impacts to traffic are also eliminated using the tunnel route. It also provides the opportunity for large quantities of additional stormwater from upper watersheds beyond the Project area to be conveyed to the Monongahela River. To move theses large quantities of water will require upgrades to select proposed upstream hydraulic features, such as Junction Hollow and Panther Hollow Lake.

8.6.21 Alternative 12 Open Cut Tunnel along New West Route to Monongahela River

- Performance Overall Rating **1**

The construction of this open cut culvert tunnel will contain and move stormwater from the west route tunnel to the Monongahela River.

- Opinion of Construction Cost Overall Rating **4**

The capital cost associated with this alternative is about $1,156,950, including contingency and is considered expensive to complete, when compared against other alternatives and considering the relative cost of construction of projects currently being performed in Western Pennsylvania, Ohio and West Virginia. More than three-quarters of the costs are associated with the purchase and installation of the concrete culvert and the jack and bore of the culvert beneath the MetalTech railroad.

- Public Perception Overall Rating 3

The public perception of this alternative is average. There will be no traffic obstructions associated with construction along Second Avenue which will incur temporary inconvenience; however, upon completion of construction, none of the Project components will be visible.

- Operations, Maintenance and Inspection Overall Rating 2

OM&I elements associated with this alternative are easy and effective. Hydraulic and structural inspection of the concrete culvert can be performed on as as-needed basis, but at a minimum, annual inspection should be performed by experienced professionals and an inspection should be performed after a specified intensity rainfall event.

- Risk Overall Rating 3

This construction is high risk. Obstructions in the Hazelwood Green site are underground utilities and include gas, electric, stormwater and sanitary sewer, water and communication lines, abandoned underground slab and footings remaining from the decommissioning of the former LTV site, and the potential for soils with elevated concentrations of constituents left in place during the decommissioning of the former LTV site. The depth of soil cover over the tunnel in this area is approximately 10 to 15 feet and could be impacted by these utilities and undocumented obstacles at the west end of the Hazelwood Green property adjacent to the Monongahela River and remaining from the decommissioned LTV site.

The design to extend the piping systems beneath MetalTech railroad tracks will require coordination with MetalTech personnel. It is anticipated that MetalTech personnel will request a submissions for their review and provide comments. During construction, metal Tech personnel will be on-site monitoring the condition of the rail line, to verify that operations are not impacted.

- Infrastructure Obstructions Overall Rating 2

The infrastructure obstructions in this alternative are discussed above. The severity of these obstructions are lessened slightly by the reduced depth of the culvert.

- Implementability Overall Rating 3

Implementability associated with this alternative are difficult. Access to the area easily available along the entire route, but will require permission from Hazelwood Green representatives. Conventional construction equipment, such as dump trucks, excavators, dozers and cranes can be utilized for earthmoving and precast concrete culvert installation activities. Materials utilized in construction are readily available from on-site and off-site sources.

The jack and bore method and equipment utilized to advance the pipe beneath active tracks, although more routine than 20 years ago, will require a high level of detail and precision, with oversight of MetalTech personnel. More specialized equipment to align/withstand push forces and the excavation/support of jacking and receiving pits will be necessary. The steel pipe will require fabrication and design to handle the loads associated with locomotives. Installation of this pipes will need to minimize disturbance to the railroad tracks and operation.

Construction of the outfall of the pipes at the Monongahela River may require removal or modification of an existing retain wall remaining from the decommissioned LTV operations.

- Schedule — Overall Rating **2**

The schedule for construction of this alternative would be considered fast to complete. This is due primarily to the shallow pipe installation and the reduced number of infrastructure obstructions.

- Sanity Check — Overall Rating **2**

This alternative partially aids in meeting the goals of the project, in that it reduces CSO and removes stormwater from the existing PWSA piping system, which may reduce basement flooding to residential areas at downstream locations of the Project. There are a limited number of obstructions in Hazelwood Green, including the LTV site obstructions, which when combined with the shallow excavations, will make implementations easier. In conjunction with the west route tunnel, the alternative provides the opportunity for large quantities of additional stormwater from upper watersheds beyond the Project area to be conveyed to the Monongahela River. To move theses large quantities of water will require upgrades to select proposed upstream hydraulic features, such as Junction Hollow and Panther Hollow Lake.

8.7 ANCILLARY ALTERNATIVES FOR FINAL DESIGN CONSIDERATION

In addition to the grouping of alternatives identified in Section 8.4 and evaluated in Section 8.6 of this PDM, several other locations and options that were discussed as either possibly contributing to the stormwater and basement flooding issues in the Project or reducing the stormwater and basement flooding issues were identified and will be evaluated for potential incorporation into the Project. These locations and options were discussed during design team project meetings and during meetings between the design team and PWSA that occurred between February and May of 2019. These locations and options consist of the following:

8.7.1 Naylor Run Neighborhood

In conjunction with the design of the Project, it was necessary to discuss the integration of plans to address the impacts of flooding of residential homes along the extreme eastern end of Saline

Street, in an area known as Naylor Run neighborhood. The Naylor Run neighborhood was originally to be addressed as a separate project. Flooding in this area appears to be a result of drainage issues at four locations. The first location is along a 1,000 feet length of Pennsylvania Interstate 376, also known as the Parkway East. At this location a bridge carries the Parkway East over a segment of Saline Street adjacent to Naylor Street. Drainage from highwall diversion channels created by highway construction cuts along the north side of the Parkway East that collect surface water runoff from the south facing slope of Schenley Park is problematic and results in stormwater discharging in an easterly direction to the west abutment of the bridge that carries the Parkway East highway over the Naylor Run neighborhood. The bridge structure and superstructure varies between 20 and 40 feet above the ground surface. During rainfall events, stormwater discharges from the channel in an easterly direction and across an unvegetated slope beneath the bridge onto Saline Street. There are also two scuppers connected to the west abutment that discharge directly to the ground surface, eventually reaching Saline Street. There is no catch basin on the street in the vicinity of the discharge to collect stormwater.

The second location is in a forested valley approximately 1,500 feet long that begins at the intersection of Greenfield Road and Panther Hollow Road in Schenley Park and ends in an empty lot adjacent to Naylor Street. This valley, so-called Naylor Valley collects stormwater from the steep slopes in the valley, which is in Schenley Park. Stormwater from Overlook Drive, Greenfield Road and the Bridle Trail, which is a trail in Schenley Park that parallels Overlook Drive all discharge to this valley. The elevation difference between the top and the bottom of the valley is over 200 vertical feet. The watershed area in in excess of 25 acres.

The third location is surface water runoff from the moderately steep slopes behind the homes on the north side of Saline Street. In the absence of any drainage channels, the runoff sheet flows down the slope and enters Saline Street at various locations.

The fourth location is the gabion riprapped drainage channel that was constructed as part of the Greenfield Avenue Bridge rehabilitation. The channel terminates at the east (dead) end of Saline Street. The current storm sewer in the area is not capable of handling flows from larger storm events.

Potential solutions for the flooding in these four locations consists of the design and construction of an inline storage piping system beneath the street level of Saline Street. Large HDPE piping installed beneath Saline Street to provide detention would be connected to piping that collects stormwater from the subject areas mentioned above. Drainage from other selected residential areas can also be directed to this inline storage, depending on capacity. In addition to the inline subsurface detention storage, individual at-grade detention facilities can be constructed in Naylor Valley, to slow stormwater entering the inline detention structures. As the inline piping enters the

Four Mile Run area, a third HDPE pipe system will be installed parallel to the two HDPE pipes beneath Saline Street and collecting stormwater from Junction Hollow, as described in above alternatives to connect to the inline storage and convey stormwater directly to the Monongahela River. The size of the HDPE piping will be based upon the largest storm event that can be conveyed through the piping in a cost effective manner while providing minimal interference with downstream infrastructure, especially utilities.

8.7.2 Watershed Expansion

The SWMM model that was discussed in Section 6.5 of this PDM incorporated a percentage of stormwater runoff from seven (7) ancillary watershed areas located upslope of the Project Site. As part of future design work, this specified percentage of stormwater runoff will be incorporated into the Project. As part of this incorporation, attenuation and detention systems will be designed to temporarily store stormwater, then release it after a peak runoff period for the Project Site has passed. These detention systems will not be designed as part of the Project, but the estimate of stormwater volume will be included in hydraulic analysis.

8.7.3 Proctor Garage

A local commercial property area, located south of the southern access to Junction Hollow, with a Boundary Street address and adjacent to the Naylor Run neighborhood is being evaluated by PWSA for acquisition. If acquired, the property will provide area for additional detention and provide a transition location for future design of piping to connect the Naylor Run neighborhood to hydraulic features in the Four Mile Run neighborhood and along Saline Street, as described in above alternatives.

8.7.4 Scuppers from I-376

At two locations over the Four Mile Run neighborhood, there are six (6) scuppers from a bridge that carries traffic associated with Pennsylvania Interstate 376 that discharge stormwater from the paved highways directly to disturbed areas beneath the bridge. Riprapped channels are constructed to carry the flow from several of the scuppers to catch basins on Boundary Street, Four Mile Run Road and Saline Street; however, the steep slope and length of the channels result in overflow directly into streets in the Four Mile Run neighborhood. This overflow could be contributing to basement flooding. One potential option is to direct the scuppers into the HDPE piping system described in above alternatives. The connection would occur along Boundary Street or Four Mile Run Road, contingent upon utility obstruction clearance.

8.7.5 Early Action Construction

PWSA is reviewing conceptual design and drawings for early action projects focused on improving existing stormwater runoff within the Naylor Street Valley. The projects should contribute to the overall project goals of reducing combined sewage overflows and flooding risk, complement the overall project when complete, and be able to be constructed without lengthy state and federal permitting processes. These projects could be constructed in 2019 based on basic design drawings and construction oversight by experienced professionals, using City of Pittsburgh or PWSA contracted construction crews. The design utilizes and modifies street curbs and inlets that are in poor condition, allows existing vegetative areas to grow without mowing and increases vegetative cover in open areas or under sparse tree canopies. Conceptual solutions consist of the following:

- Overlook Drive Bump-outs
- Overlook Drive Bioretention
- Overlook Drive Vegetated Filter Strip
- Overlook Drive Reinforced Turf
- Vegetated Swale North Side of Overlook Drive
- Vegetated Filter Area
- Greenfield Road-Panther Hollow Road-Overlook Drive Detention
- Bridle Trail Reinforced Detention Channel

8.7.6 Modeling with Recent Monongahela River Elevations

In June of 2019, ALCOSAN provided PWSA with detailed river elevations of the Monongahela River over a several year period. This information will supplement the current SWMM modeling results that estimates river elevations at 711 feet (normal Pool elevation) and 722 (the annual high water elevation).

8.7.7 DOMI Corridor

DOMI has initiated discussions with PWSA to consider options for incorporating a corridor within the Project limits to carry specialized vehicles from the Four Mile Run neighborhood through Junction Hollow to the terminal end of Boundary Street, located north of the Project and into the Central Oakland neighborhood. DOMI has selected a location on the east side of Junction Hollow, parallel to the CSX railroad tracks, where a temporary trail will be constructed to facilitate pedestrian and bicycle traffic around construction in Junction Hollow. The sub-base elevation of the corridor would be based upon the volume of fill generated during Project construction that will be placed in a controlled manner in the Junction Hollow segment. Two workshops were conducted in July of 2019 between representatives of DOMI and CEC to coordinate the corridor location with the location of the stream in Junction Hollow and with connecting locations at the north and south ends of their project.

8.7.8 PWSA Sewer Line

The 50-inch diameter steel sewer pipe that runs in a north and south direction extends through the embankment of Panther Hollow Lake and along the route of the east drainage channel that is to be graded and/or modified. The pipe is approximately 100 years old, is less than 3 feet below existing ground surface in specific areas and is in close proximity to proposed grading in the east drainage channel. An investigation to locate the sewer line using ground penetrating radar (GPR) is forthcoming. Following the investigation, a letter report will be prepared that discusses alternatives and prepares an opinion of cost for PWSA to consider in the future capital budgets. Alternatives could include one of no action, lining the existing pipe, replacing the pipe, or replacing and relocating the pipe at a less intrusive location. If pipe construction is not feasible in the next several years, the subsequent construction of the east drainage channel will need to be disturbed and reconstructed. However, the construction cost of this component is small and would be integrated into the pipe rehabilitation/reconstruction cost.

8.7.9 Drop Shaft from Junction Hollow Channel/Stream to PWSA Piping and M29 Chamber Modification

In an attempt to reduce the conflicts associated with construction of a pipeline system beneath Saline Street, Greenfield Avenue and Second Avenue and through the Hazelwood Green site, an option to dedicate one of the two existing PWSA sewers in Junction Hollow to stormwater was developed. The option consists of the following:

- A 78” diameter sewer pipe carrying CSO through Junction Hollow that is located approximately 25 feet below the ground surface will be severed at the approximate location of the soccer field parking lot.
- The upslope (northern) portion of the pipe carrying CSO will be rerouted approximately 20 feet and connected to the 98” sewer pipe that parallels the 78” pipe on its east side that also carries CSO.
- The downslope (southern) portion of the sewer pipe will become a stormwater pipe. This re-tasked stormwater pipe will be connected to the headwall that accepts stormwater flow from the new Junction Hollow stream. Connection will be performed between the at grade

headwall and the existing re-tasked below grade PWSA stormwater pipe using a cast-in-place concrete dropshaft to a depth of approximately 40 feet.

- A second concrete dropshaft with a depth of approximately 30 feet will be constructed on Saline Street to transfer water from at grade Naylor Run stormwater design to the existing below grade re-tasked PWSA stormwater pipe.
- The 78” pipe enlarges to a 108” pipe and enters the M-29 chamber, where the 98” pipe enlarges to a 168” pipe and also enters the M-29 chamber. A 168” pipe exits the M-29 chamber and extends to the Monongahela River.
- The existing 40 feet long by 18 feet wide by 20 feet high M-29 chamber located approximately 10 feet beneath Second Avenue will be enlarged to twice its current width. A concrete wall will be installed to separate the M-29 chamber into a stormwater chamber on the west (existing) side and a CSO chamber on the east (enlarged) side. The enlarged width side will be outfitted with a new 168” CSO concrete pipe that will extend from M-29 to the Monongahela River. The existing 168” CSO pipe entering the M-29 chamber will be cut/trimmed to connect to the new, enlarged portion of the M-29 chamber.

The presence of this facility eliminates the need to provide additional new hydraulic facilities (i.e., piping) to route stormwater through the Four Mile Run neighborhood and the Hazelwood Green area to reach the Monongahela River. Excavation will be required to a depth to expose the existing piping system and to construct the drop shaft, which will be designed with horizontal baffles to slow the drop of water and reduce the forces at the bottom of the shaft.

8.8 COMPARATIVE ANALYSIS OF ALTERNATIVES

The table below provides a side-by-side comparison of the alternatives discussed in Section 8.4 and the evaluation criteria and weighting discussed in Section 8.5 of this PDM. The scores associated with each alternative were developed by multiplying the weighting of the nine criteria by the rating that varied from 1 to 5, noting that a low numerical rating indicates a beneficial outcome.

TABLE 8-1 ALTERNATIVE WEIGHTED CRITERIA MATRIX

Project Name: 4 Mile Run
Project No. 174-960
Date: 7/1/2019 rev 9-3-19

Criteria	Weight	Alt.-1		Alt.-2		Alt.-3		Alt.-3A		Alt.-4		Alt.-4A		Alt.-4B		Alt.-5		Alt.-5A		Alt.-6		Alt.-7	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Performance	0.19	2	0.38	2	0.38	3	0.57	3	0.57	2	0.38	2	0.38	2	0.38	3	0.57	2	0.38	3	0.57	2	0.38
Construction Cost	0.19	3	0.57	3	0.57	3	0.57	4	0.76	2	0.38	5	0.95	5	0.95	2	0.38	2	0.38	2	0.38	2	0.38
Public Perception	0.11	2	0.22	2	0.22	1	0.11	2	0.22	4	0.44	2	0.22	2	0.22	4	0.44	1	0.11	3	0.33	3	0.33
Operation, Maintenance and Inspection	0.10	2	0.20	2	0.20	3	0.30	3	0.30	2	0.20	2	0.20	2	0.20	2	0.20	2	0.20	2	0.20	2	0.20
Risk	0.10	1	0.10	1	0.10	1	0.10	1	0.10	2	0.20	5	0.50	5	0.50	2	0.20	2	0.20	2	0.20	1	0.10
Infrastructure Obstructions	0.09	1	0.09	1	0.09	1	0.09	1	0.09	2	0.18	4	0.36	4	0.36	1	0.09	1	0.09	2	0.18	1	0.09
Implementability	0.08	3	0.24	3	0.24	2	0.16	2	0.16	2	0.16	4	0.32	4	0.32	1	0.08	1	0.08	3	0.24	1	0.08
Schedule	0.07	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	4	0.28	1	0.07	2	0.14	2	0.14	1	0.07
Sanity Check	0.07	1	0.07	1	0.07	1	0.07	3	0.21	2	0.14	3	0.21	3	0.21	2	0.14	1	0.07	2	0.14	1	0.07
Sum of Score			2.08		2.08	x	2.18		2.62	x	2.29		3.35		3.42		2.17	x	1.65	x	2.38	x	1.70

Criteria	Weight	Alt.-8		Alt.-8A		Alt.-9		Alt.-9A		Alt.-9B		Alt.-10		Alt.-10A		Alt.-10B		Alt.-10C**		Alt.-11		Alt.-12	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Performance	0.19	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	2	0.38	1	0.19	1	0.19
Construction Cost	0.19	3	0.57	3	0.57	4	0.76	3	0.57	3	0.57	3	0.57	3	0.57	2	0.38	3	0.57	5	0.95	4	0.76
Public Perception	0.11	2	0.22	2	0.22	3	0.33	2	0.22	2	0.22	4	0.44	3	0.33	2	0.22	2	0.22	2	0.22	3	0.33
Operation, Maintenance and Inspection	0.10	1	0.10	1	0.10	1	0.10	4	0.40	2	0.20	2	0.20	2	0.20	3	0.30	2	0.20	3	0.30	2	0.20
Risk	0.10	2	0.20	4	0.40	4	0.40	2	0.20	2	0.20	3	0.30	2	0.20	2	0.20	2	0.20	3	0.30	3	0.30
Infrastructure Obstructions	0.09	4	0.36	4	0.36	5	0.45	2	0.18	3	0.27	3	0.27	3	0.27	2	0.18	3	0.27	4	0.36	2	0.18
Implementability	0.08	2	0.16	3	0.24	4	0.32	3	0.24	3	0.24	3	0.24	4	0.32	3	0.24	4	0.32	4	0.32	3	0.24
Schedule	0.07	2	0.14	2	0.14	3	0.21	2	0.14	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	3	0.21	2	0.14
Sanity Check	0.07	1	0.07	2	0.14	2	0.14	3	0.21	2	0.14	2	0.14	2	0.14	3	0.21	2	0.14	2	0.14	2	0.14
Sum of Score		x	2.20		2.55		3.09	x	2.54	x	2.43		2.75		2.62		2.32	x	2.51		2.99		2.48

Note: Alternative 10C is the jacking and boring of a pipe beneath Signature Blvd and beneath the MetalTech railroad and the outlet structure at the Monongahela River
Note: Alternative 10C is not considered a stand alone alternative. It is combined (added) seperately to each of the Alternatives No. 10, No. 10A and No. 10B
Note: Alternative with lighter highlighting and 'x' adjacent to sum score are the selected alternatives and discussed in Recommendation

The alternatives are ranked as follows:

*Alternative No. 5A- Junction Hollow Upgrade from Channel to Stream	1.65
*Alternative No. 7- Soccer Field Headwall/Berm	1.70
Alternative No. 2- Panther Hollow Run Stream Channel	2.08
Alternative No. 1- Phipps Run Stream Channels	2.08
*Alternative No. 3- Panther Hollow Lake and Dam and Forebay Ponds	2.18
Alternative No. 5- Junction Hollow Engineered Channel	2.17
*Alternative No. 8- Four Mile Run Park Piping System	2.20
*Alternative No. 4 Panther Hollow Lake Spillway Riser/Pipe under Railroad and Embankment Raise	2.29
Alternative No. 10B (combine with 10C)- Hazelwood Shallow Open Channel, Pipe beneath Railroad and Monongahela River Outfall	2.32
*Alternative No. 6- East Side Railroad Channel	2.38
*Alternative No. 9- Saline Street Deep Gravity Pipe System	2.43
*Alternative No. 9B- Saline Street and Hazelwood Green Shallow Pressure Pipe System	2.43
Alternative No. 12- Open Cut Tunnel West Route to Monongahela River	2.48
Alternative No. 10C (See 10, 10A and 10B)	2.51
*Alternative No. 9A- Saline Street Pump Station	2.54
Alternative No. 8A- Four Mile Run Park Stream Segments	2.55
Alternative No. 10A-(combine with 10C) Hazelwood Green Deep Open Stream Channel, Pipe beneath Railroad and Monongahela River Outfall	2.62
Alternative No. 3A- Panther Hollow Amenities	2.62
Alternative No. 10-(combine with 10C) Hazelwood Green Deep Gravity Pipe System, Pipe beneath Railroad and Monongahela River Outfall	2.75
Alternative No. 11- Tunnel along New West Route To Monongahela River	2.99
Alternative No. 4A- Combination Stormwater/Pedestrian Culvert under Railroad	3.35
Alternative No. 4B- Step Spillway Upgrade	3.42

The following clarifications should be noted:

- Alternative No. 10C is not evaluated on its own merit. It is added to Alternative No. 10 (Alternative No. 10 and 10C), Alternative No. 10A (Alternative No. 10A and 10C) and Alternative No. 10B (Alternative No. 10B and 10C) as described in Section 8.6.17 through 8.6.19.
- Alternative No. 5A is not evaluated on its own merit. It is added to Alternative No. 5.

9.0 COMMUNITY ENGAGEMENT

Community engagement was led by evolveEA with support from the Community Engagement Working Group which consists of PWSA, the Pittsburgh Parks Conservancy, CEC, and eDesign Dynamics. The working group discussed the overall communications strategy of the project, including how to discuss this project in relation to the publicly opposed mobility project from the City Department of Mobility and Infrastructure (DOMI). The working group also planned public meetings, discussed website content, and discussed key stakeholder outreach. In support of the engagement strategy, the Pittsburgh Parks Conservancy and PWSA worked together to develop a shared contact list for all members of the public who have expressed an interest in this project.

A project website was created at www.4mr.org by evolveEA. It contains project information, public meeting information, and all materials from the public meetings. It also includes a contact form by which members of the public can submit questions and answers.

The Community Engagement Working Group formally met on 30 May, 29 June, 13 July, 01 October, 01 November, 05 November, and 05 December. Meeting summaries from these working group meetings are attached separately.

Two public meetings were held for this project. The first public meeting was held on 17 September 2018 at Phipps Conservatory and included a walking tour before the meeting. The second public meeting was held on 14 November 2018 at Saint John Chrysostom Byzantine Catholic Church and included seven project tables where the public could ask questions of team members and provide feedback about the designs. Public meeting summaries are attached separately.

10.0 RECOMMENDATIONS

10.1 SUMMARY

Based upon the scores associated with each alternative, developed by multiplying the weighting by the rating, the recommendation for design will consist of the combination of the following alternatives:

Alternative No. 1 – Phipps Run Stream Restoration (To be further evaluated by PWSA)
Alternative No. 2 – Panther Run Stream Restoration (To be further evaluated by PWSA)
Alternative No. 3 - Panther Hollow Lake (PHL) Restoration
Alternative No. 4 – Embankment Raise, Principal Spillway Pipe and Emergency Spillway Channel
Alternative No. 5A - Junction Hollow Stream Channel
Alternative No. 6 – East Side Drainage in Junction Hollow
Alternative No. 7 – Soccer Field Headwall
Alternative No. 8 – Gravity Piping System to Four Mile Run Park
Alternative No. 9A – Saline Street Pump Station
Alternative No. 9B/10C – Saline Street and Hazelwood Green Shallow Pressure and Gravity Pipe to Monongahela River

This group of alternatives is selected based upon the following rationale:

- Alternative No.1 and No. 2 rehabilitate existing streams that have been vertically eroded by increased stormwater volumes and velocities resulting from increased site development and commercialism in the watershed areas contributing to the stream. The erosion has contributed to sedimentation in the stream and in Panther Hollow Lake. The modified cross-section of the streams will provide long-term stability and integrity, improve the environmental health of the streams and increase discharge capacity. The associated green stormwater infrastructure improvements in the areas contributing stormwater to the streams helps reduce the effects of that development by reducing peak discharge, contributing to long-term sustainability of the streams and downstream infrastructure. It should be noted that this alternative only 'reduces CSO and removes stormwater from the existing PWSA piping system' when combined with other alternatives; therefore, it does not achieve these goals as a stand-alone alternative. Selection of these alternatives is preliminary at this time and may not be advanced through final design.
- Alternative No. 3 provides a forebay for sediment accumulation conveyed by Phipps Run and Panther Hollow Run, a bypass cascade to prevent the forebay from flooding and a treatment wetland to capture and filter nutrients, contaminants, pathogens and sediment conveyed by the subject streams. Alternative No. 3 also uses excavation or dredging to

remove decades of sediment accumulation in the lake and to reestablish the original lake bottom and removes the concrete curbing to connect the lake to a newly graded, natural sloping earthen shoreline.

- Alternative No. 4 provides the hydraulic and geotechnical components necessary to bring Panther Hollow Lake into compliance with regulations established by PADEP Department of Dam Safety. A principal spillway pipe will maintain the lake at its current elevation, provides the necessary flow to downstream hydraulic features and is the most upstream mechanism responsible for removing stormflow from the CSS and reducing CSO, flood risks and basement backups. The embankment raise provides the storage volume needed for controlling a 100 year-24 hour storm event, while also creating an amphitheater setting on the western perimeter of the lake.
- Alternative No. 5A provides a natural stream through Junction Hollow as an upgrade to an engineered channel for only a moderate increase in cost, collects and routes stormwater flow from the west facing slope of Junction Hollow and contributes to reducing CSOs, flood risks and basement backups in the Four Mile Run neighborhood.
- Alternative No. 6 removes stream flows from the CSS, provides additional stormwater discharge with an increased channel capacity and controls streamflow on the east facing slope of Junction Hollow. It also contributes to reducing CSOs, flood risks and basement backups in the Four Mile Run neighborhood.
- Alternative No. 7 provides a location to transition between open channel flow in Junction Hollow and the subsurface piping system needed conveying stormwater flow through the Four Mile Run neighborhood.
- Alternative No. 8 provides the hydraulic subsurface route needed to navigate through the Four Mile Run neighborhood comprised of gradual undulating topography, limited or no public property for construction and city streets. The piping system proposed will need to be designed and constructed to avoid underground utilities operated by a half-dozen public and private agencies.
- Alternative No. 9A provides a turbine pump system and a pump station building that will be designed to accept the flow from the upstream areas of the Project. The pump station and associated hydraulic facilities of these alternatives could also provide the opportunity to handle additional future stormwater inputs associated with upper watersheds from the Greenfield area, also known as Naylor Run and also from drainage mechanisms connected to Interstate 376 (I-376), owned by the Pennsylvania Department of Transportation (PennDOT). The alternative allows for the selection of the specific downstream alternatives, which provide a capital cost savings for the Project. Pump design can account for changes in flow rates.

- Alternative No. 9B/10C allows for the installation of the piping system beneath Saline Street, Greenfield Avenue and Second Avenue to be installed at a depth of approximately six feet below ground surface, much less than other gravity pipe flow alternatives. The shallow depth of the nipping system, which will be part pressure flow and part gravity flow will expedite construction and reduce the time needed for traffic restrictions. It will also avoid underground utilities operated by a half-dozen public and private agencies, the foundations for abutments at two railroad bridges and potential underground foundations from a decommissioned steel facility. It also provides a pipe outlet above the normal pool of the Monongahela River, which will reduce tailwater issues associated with gravity drainage. The alternative will remove flow from the current CSS and discharge stormwater at the Monongahela River, thereby reducing CSOs, flood risks and basement backups.

The estimated opinion of costs for these ten alternatives was developed using guidelines established by the American Association of Cost Estimating (AACE). A Class V estimate was prepared, based upon the level of definition, or the 30 percent level of completion of the Project associated with this PDM and the current amount of Project data collected. A contingency, or expected accuracy range, was established at +50% or -25%. The Opinion of Cost Summary is presented in the Appendix K to this PDM.

The opinion of costs of the ten alternatives with the application of the contingency is between $8.2M and $16.2M. the breakdown using the +50% contingency is as follows:

Alternative No. 1 – Phipps Run Stream Restoration	$884,315
Alternative No. 2 – Panther Run Stream Restoration	$1,853,956
Alternative No. 3 - Panther Hollow Lake (PHL) Restoration	$1,075,200
Alternative No. 4 – Embkmt. Raise, Principal Spillway Pipe & Emer. Spillway	$300,390
Alternative No. 5A - Junction Hollow Stream Channel	$1,635,712
+$748,780	
Alternative No. 6 – East Side Drainage in Junction Hollow	$237,367
Alternative No. 7 – Soccer Field Headwall	$37,600
Alternative No. 8 – Piping System to Four Mile Run Park	$2,378,702
Alternative No. 9A – Saline Street Pump Station	$2,029,500
Alternative No. 9B/10C – Saline Street and Hazelwood Green Shallow Pressure and Gravity Pipe to River	$3,097,893
Total Opinion of Cost	$14,279,414

Alternative 9A does carry an operation and maintenance cost of approximately $150,000/year to $175,000/year for the operation of the pump station.

Although not identified as an alternative, the ancillary alternative to design a Drop Shaft from Junction Hollow Channel/Stream to the existing PWSA Piping and the modification of the ALCOSAN M29 Chamber as discussed in Section 8.7.9 of this PDM will be further studied. The study will include conducting a hydraulic analyses to determine if the rerouting and combining of flow from two existing sewer pipes into one pipe is feasible under selected storm conditions.

10.2 OUTLINE OF TECHNICAL SPECIFICATIONS

Based upon the recommendations presented above, the design as discussed in the PDM will be refined and progressed to a 60% design submission consisting of construction drawings, technical specifications, permit applications, calculation briefs, quantities and an engineering opinion of cost.

Technical Specifications will be prepared to guide the contractor through construction of the Project. The specifications will be prepared in the MasterSpec format, which is the format utilized by PWSA. MasterSpec format is published by the National Institute of Building Sciences (www.wbdg.org) and is the preferred specification format of agencies such as the United States Army Corps of Engineers, United States Naval Facilities and the National Aeronautics and Space Administration. The specifications will include a table of contents and separate sections on the various components of work, which will include, at a minimum; the areas listed below. Each section of these specification sections will include Parts discussing the work performed, materials, execution and measurement and payment. The administrative/contractual/general requirements portion of the specifications for use in the preparation of the bid documents will also be included. A preliminary table of contents for the technical specifications of the Project is listed below.

DIVISION 00 PROCUREMENT AND CONTRACT REQUIREMENTS

00 00 00	SPECIFICATION COVER	
00 01 15	LIST OF DRAWINGS	

DIVISION 01 GENERAL REQUIREMENTS

01 11 00	SUMMARY OF WORK	(01100)
01 14 00	WORK RESTRICTIONS	
01 22 00	MEASUREMENT AND PAYMENT	
01 22 00.10	GENERAL REQUIREMENTS	
01 20 00.00.20	PRICE AND PAYMENT PROCEDURES	(01200)
01 30 00 08/15	ADMINISTRATIVE REQUIREMENTS	(01300)

01 32 23	SURVEY AND LAYOUT DATA	
01 33 00	SUBMITTAL PROCEDURES	(01330)
01 33 29	SUSTAINABILITY REPORTING	
01 35 13	SPECIAL PROJECT PROCEDURES	
01 35 26	GOVERNMENTAL SAFETY REQUIREMENTS	(01250)
01 35 29.13	HEALTH, SAFETY, AND EMERGENCY RESPONSE PROCEDURES FOR CONTAMINATED SITES	
01 42 00	SOURCES FOR REFERENCE PUBLICATIONS	
01 45 00.00 10	QUALITY CONTROL	(01400)
01 45 00.00 20	QUALITY CONTROL	
01 45 00.00 40	QUALITY CONTROL	
01 45 00.10 20	QUALITY CONTROL FOR MINOR CONSTRUCTION	
01 45 35	SPECIAL INSPECTIONS	
01 57 19	TEMPORARY ENVIRONMENTAL CONTROLS	
01 51 36	TEMPORARY WATER	(01520)
01 50 00	TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS	(01500)
01 60 00	PRODUCT REQUIREMENTS	(01600)
01 70 00	EXECUTION AND CLOSEOUT REQUIREMENTS	(01700)
01 78 00	CLOSEOUT SUBMITTALS	
01 78 23	OPERATION AND MAINTENANCE DATA	

DIVISION 02 EXISTING CONDITIONS

02 41 00	DEMOLITION AND DECONSTRUCTION	
02 56 15	GEOSYNTHETIC CLAY LINER	
02 61 13	EXCAVATION AND HANDLING OF CONTAMINATED MATERIAL	
02 71 00	GROUNDWATER TREATMENT	

DIVISION 03 CONCRETE

03 30 00	CAST-IN-PLACE CONCRETE	(03300)
03 30 53	MISCELLANEOUS CAST-IN-PLACE CONCRETE	
03 15 00	CONCRETE ACCESSORIES	
03 20 00	CONCRETE REINFORCING	
03 35 00	CONCRETE FINISHING	
03 39 00	CONCRETE CURING	
03 48 13	PRECAST CONCRETE BOLLARDS	
03 48 26	PRECAST CONCRETE PARKING BUMPERS	

03 62 00	NON-SHRINK GROUTING	(03600)
03 64 00	INJECTION GROUTING	

03 11 13	STRUCTURAL CAST-IN-PLACE CONCRETE FORMING
03 15 16	CONCRETE CONSTRUCTION JOINTS
03 22 16	EPOXY-COATED WELDED WIRE FABRIC REINFORCING
03 31 00	STRUCTURAL CONCRETE
03 81 00	CONCRETE CUTTING

DIVISION 05 METALS

DIVISION 06 WOOD, PLASTICS AND COMPOSITES

06 15 16	WOOD ROOF DECKING
06 18 00	GLUE-LAMINATED CONSTRUCTION
07 50 00	MEMBRANE ROOFING

DIVISION 07 THERMAL AND MOISTURE PROTECTION

07 62 00	SHEET METAL FLASHING AND TRIM
07 71 00	ROOF SPECIALTIES

DIVISION 08 OPENINGS

08 11 00METAL13	STEEL DOORS AND FRAMES
08 33 23	OVERHEAD COILING DOORS
08 50 00	WINDOWS
08 71 53	SECURITY DOOR HARDWARE

DIVISION 09 FINISHES

09 91 00	PAINTING

DIVISION 10 SPECIALITIES

10 14 53	TRAFFIC SIGNAGE

DIVISION 04 MASONRY

04 20 00	UNIT MASONRY

04 43 16	STONE FABRICATIONS	
22 11 00	FACILITY WATER DISTRIBUTION	

DIVISION 26 ELECTRICAL

26 05 00	COMMON WORK RESULTS FOR ELECTRICAL	
26 32 00	PACKAGED GENERATOR ASSEMBLIES	
26 51 00	INTERIOR LIGHTING	
26 52 00	SAFTEY LIGHTING	
26 56 00	EXTERIOR LIGHTING	

DIVISION 27 COMMUNUICATIONS

27 00 00	COMMUNICATIONS	

DIVISION 28 ELECTRONIC SAFETY AND SECURITY

28 15 00	ACCESS CONTROL HARDWARE DEVICES	
04 20 00	UNIT MASONRY	
04 43 16	STONE FABRICATIONS	

DIVISION 31 EARTHWORK

31 00 00	EARTHWORK	
31 05 16	AGGREGATES FOR EARTHWORK	(02060)
31 05 19	GEOTEXTILE	
31 05 20	GEOSYNTHETIC DRAINAGE LAYER	
31 05 21	GEOGRID SOIL REINFORCEMENT	
31 05 22	GEOTEXTILES USED AS FILTERS	
31 10 00	CLEARING FOR CIVIL WORKS	
31 11 00	CLEARING AND GRUBBING	(02230)
31 23 00.00 20	EXCAVATION AND FILL	
31 23 19	DEWATERING	(02241)
31 23 33	TRENCHING AND BACKFILLING	(02324)
31 25 00	EROSION AND SEDIMENTATION CONTROLS	(02374)
31 32 39	08/08 BIOENGINEERING PRACTICES FOR STREAM BANK AND&	

	SHORELINE STABILIZATION	
31 36 00	WIRE MESH GABIONS AND MATTRESSES]	
31 41 16	METAL SHEET PILING	
31 52 00	SHEET PILING COFFERDAMS	
31 53 00	CRIBBING AND WALERS	
31 60 00	FOUNDATION PREPARATION	(02316)
32 01 29.62	CONCRETE PAVEMENT RAISING	
33 01 30.16	TV INSPECTION OF SEWER PIPELINES	
33 01 30.72	RELINING SEWERS	(02971)

DIVISION 32 EXTERIOR IMPROVEMENTS

32 11 23	AGGREGATE BASE COURSES `	(02721)
32 12 13	BITUMINOUS TACK AND PRIME COATS	
32 12 16	HOT MIX ASPHALT FOR ROADS	(02740)
32 12 19	BITUMINOUS BINDER AND WEARING COURSES COLD MIX	
32 13 13.06	PORTLAND CEMENT CONCRETE PAVEMENT FOR ROADS AND/ SITE FACILITIES	(02750)
32 17 23	PAVEMENT MARKINGS	(02763)
32 31 13	CHAIN LINK FENCING AND GATES	
32 32 00	RETAINING WALLS	
32 92 19	SEEDING	

DIVISION 33 UTILITIES

33 01 30.16	TV INSPECTION OF SEWER PIPELINES	(02591)
33 01 30.72	RELINING SEWERS	(02971)
33 02 30.86	MANHOLE RIM ADJUSTMENT	(02281)
33 05 23	TRENCHLESS UTILITY INSTALLATION	
33 05 61	CONCRETE MANHOLES	(02082)
33 11 00	WATER UTILITY DISTRIBUTION PIPING	(02513)
33 14 19	VALVES AND HYDRANTS FOR WATER UTILITY SERVICE	(02085, 02086)
33 40 00	STORM DRAINAGE UTILITIES	(02630)
33 42 23	HEADWLLS AND ENDWALLS FOR STORMWATER PIPING	
33 42 41	GRATINGS AND FRAMES FOR STORMWATER DRAINAGE INLETS	
33 30 00	SANITARY SEWERAGE	

33 31 23.00 10	SANITARY SEWER FORCE MAIN PIPING
33 46 16	SUBDRAINAGE PIPING
33 61 13.19	VALVES, PIPING, AND EQUIPMENT IN VALVE MANHOLES
33 46 13	FOUNDATION DRAINAGE SYSTEM

DIVISION 35 WATERWAY AND MARINE CONSTRUCTION

35 31 19.40	STONE REVETMENTSREVETMENT PROTECTION
35 21 19.20	ARTICULATED CONCRTE BLOCK REVETMENT

The numbers indicated in parenthesis at the end of the specific specification sections is the corresponding 2010 specification section utilized by PWSA in their current library of construction specifications. It should be noted that the MasterSpec format transitioned from a five digit to a six digit numbering system for their specifications sometime between 2005 and 2009. The table includes several specification options for a specific type of construction, for example, erosion protection in waterways could consist of riprap (stone revetment protection) or precast articulated concrete revetment.

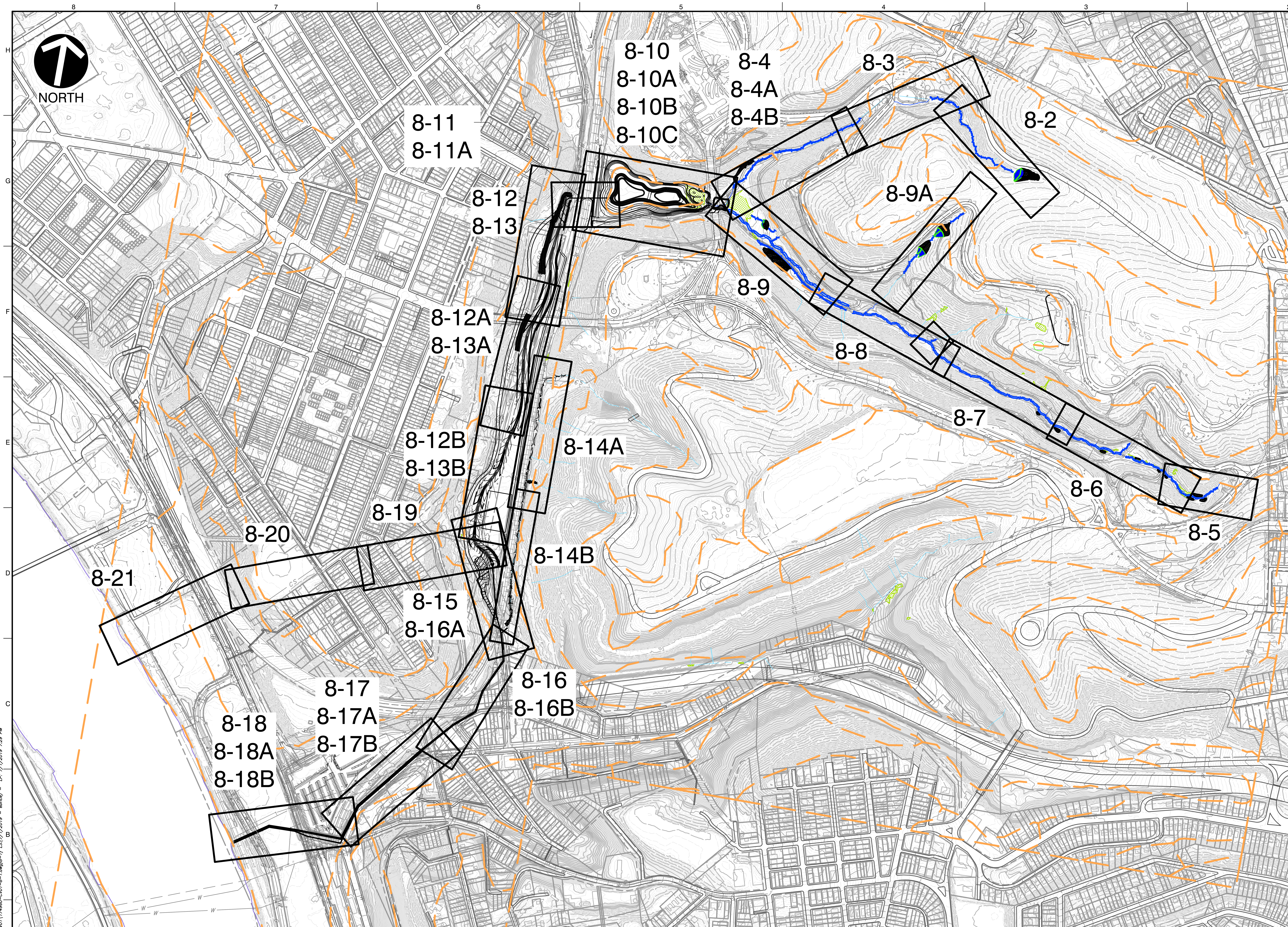
10.3 CONSTRUCTION SCHEDULE

Based upon the recommendation presented above, a design will be prepared to meet the 60%

Based upon the alternative recommendations presented above, a preliminary construction schedule has been prepared to identify primary construction tasks and estimated durations. The schedule is day based, since a start date can be influenced by the time needed by select agencies to approve permits. It is anticipated that construction will begin sometime between June of 2020 and September of 2020. The various components of construction and the overall length of the Project site allows for multiple construction activities to be performed simultaneously. The actual equipment and labor effort provided by the prime contractor and the number of subcontractors incorporated into the performance of work will establish the overall schedule. Portion of construction can be considered specialized, therefore subcontractors will be necessary. The schedule below anticipates that work at three locations can be initiated at the same time. Those three locations are the streams upslope of Panther Hollow Lake, the Pump Station at Saline Street and the piping system along Saline Street. An annual allocation of capital funds for the project will be developed during future design submissions. The schedule is presented below.

Item/Task	Start day	Finish day
Notice to Proceed	1	2
Mobilization of Equipment	2	14
Construction Survey and Layout	10	450
Phipps Run Stream Restoration	14	74
Panther Run Stream Restoration	60	140
Panther Hollow Lake (PHL) Restoration	120	220
Embankment Raise/Principal Spillway Pipe/Emergency Spillway	200	320
Junction Hollow Stream Channel	240	360
East Side Drainage in Junction Hollow	340	400
Soccer Field Headwall	380	420
Gravity Piping System to Four Mile Run Park	400	450
Saline Street Pump Station	30	180
Saline Street and Hazelwood Green Shallow Pressure and Gravity Pipe to Monongahela River	30	240

FIGURES



LEGEND

- EXISTING PROPERTY LINE
- EXISTING BUILDING
- EXISTING AUXILIARY BUILDING
- EXISTING INDEX CONTOUR (820)
- EXISTING INTERMEDIATE CONTOUR
- EXISTING CURB
- EXISTING EDGE ROAD
- EXISTING EDGE OF SIDEWALK
- EXISTING EDGE OF CONCRETE TRAIL
- EXISTING EDGE OF UNPAVED TRAIL
- EXISTING EDGE OF PAVED DRIVEWAY
- EXISTING ROAD CENTERLINE
- EXISTING BRIDGE
- EXISTING RAILROAD
- EXISTING WALL
- EXISTING BODY OF WATER
- EXISTING CEC DELINEATED STREAM
- EXISTING GIS STREAM
- EXISTING GUIDERAIL
- EXISTING FENCE
- EXISTING TREE/SHRUB LINE
- EXISTING TREE
- EXISTING POST/SIGN
- EXISTING GIS WETLAND
- EXISTING COMBINED SEWER LINE (CS)
- EXISTING STORM SEWER LINE (ST)
- EXISTING COMBINED SEWER MANHOLE
- EXISTING STORM SEWER MANHOLE
- EXISTING INLET
- EXISTING HEADWALL/ENDWALL
- EXISTING WATER LINE (W)
- EXISTING FIRE HYDRANT
- EXISTING GAS LINE (G)
- EXISTING GAS VALVE (GV)
- EXISTING OVERHEAD ELECTRIC WIRES (OH-E)
- EXISTING UNDERGROUND ELECTRIC DUCT (UG-E)
- EXISTING LIGHT POLE
- EXISTING UTILITY POLE
- EXISTING TRAFFIC POLE
- EXISTING JUNCTION BOX
- PROPOSED PAVED LIMITS
- PROPOSED STREAM
- PROPOSED ROADSIDE DITCH
- PROPOSED WETLAND
- PROPOSED DETENTION BASIN
- PROPOSED INDEX CONTOUR (780)
- PROPOSED INTERMEDIATE CONTOUR
- SOIL UNIT BOUNDARY
- SOIL UNIT LABEL (GpC)
- PROPOSED STORM SEWER LINE
- PROPOSED RIPRAP OUTFALL APRON
- PROPOSED HEADWALL/ENDWALL

REFERENCE

1. PANTHER HOLLOW LAKE BATHYMETRICAL SURVEY PERFORMED BY AWK CONSULTING ENGINEERS, INC., DATED OCTOBER 2017.
2. POTHOLING UTILITY INVESTIGATION PERFORMED BY TERRA TESTING INC., DATED OCTOBER AND NOVEMBER 2018.
3. EXISTING TOPOGRAPHY AND CONTOURS DERIVED FROM PHOTOGRAMETRY SURVEY PERFORMED BY LAND MAPPING, INC., DATED NOVEMBER 2016, AWK CONSULTING ENGINEERS, INC. FIELD SURVEY, DATED JUNE 2018, CIVIL & ENVIRONMENTAL CONSULTANTS, INC. FIELD SURVEY, DATED JULY–AUGUST 2018, AND ALLEGHENY COUNTY, PA LIDAR, DATED 2017.
4. STREAM AND WETLAND DELINEATION PERFORMED BY CIVIL & ENVIRONMENTAL CONSULTANTS, INC., DATED MAY–JULY 2018.

NOTES

1. EXISTING CONDITIONS AS DEPICTED ON THESE PLANS ARE GENERAL AND ILLUSTRATIVE IN NATURE. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO EXAMINE THE SITE AND BE FAMILIAR WITH EXISTING CONDITIONS PRIOR TO BIDDING ON THIS PROJECT. IF CONDITIONS ENCOUNTERED DURING EXAMINATION ARE SIGNIFICANTLY DIFFERENT THAN THOSE SHOWN, THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY.

DRAFT

SCALE IN FEET: 0 — 300 — 600

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NOT FOR CONSTRUCTION

REVISION RECORD		
NO	DATE	DESCRIPTION

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PITTSBURGH WATER & SEWER AUTHORITY
FOUR MILE RUN
STORMWATER IMPROVEMENT PROJECT
PITTSBURGH, ALLEGHENY COUNTY, PA

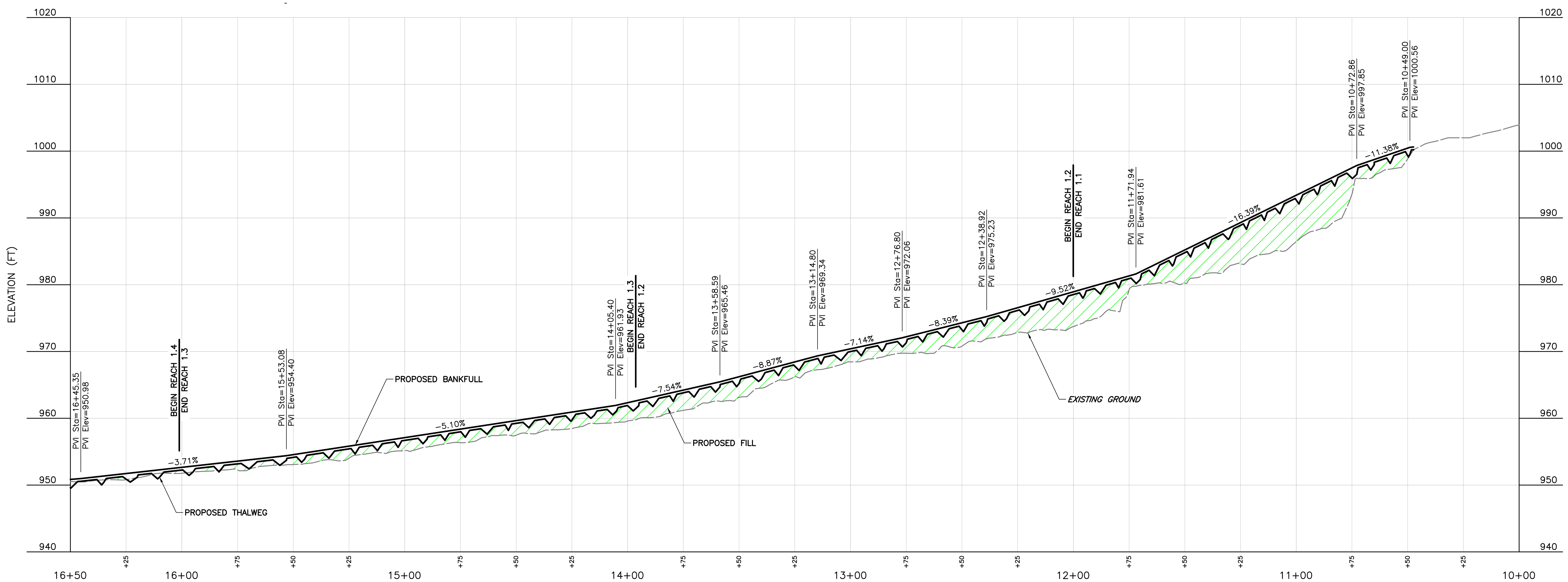
DRAWN BY:	EJB/AJB/JAL/GRH	CHECKED BY:	CJR	APPROVED BY:	PJS
DATE:	JULY 2019	DWG SCALE:	AS-SHOWN	PROJECT NO:	174-960

KEY PLAN

FIGURE NO.: **8-1**

ALTERNATIVE NO. 1 -PHIPPS RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET 0 30 60



ALTERNATIVE NO. 1 -PHIPPS RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET 0 30 60

VERTICAL SCALE IN FEET 0 10 20

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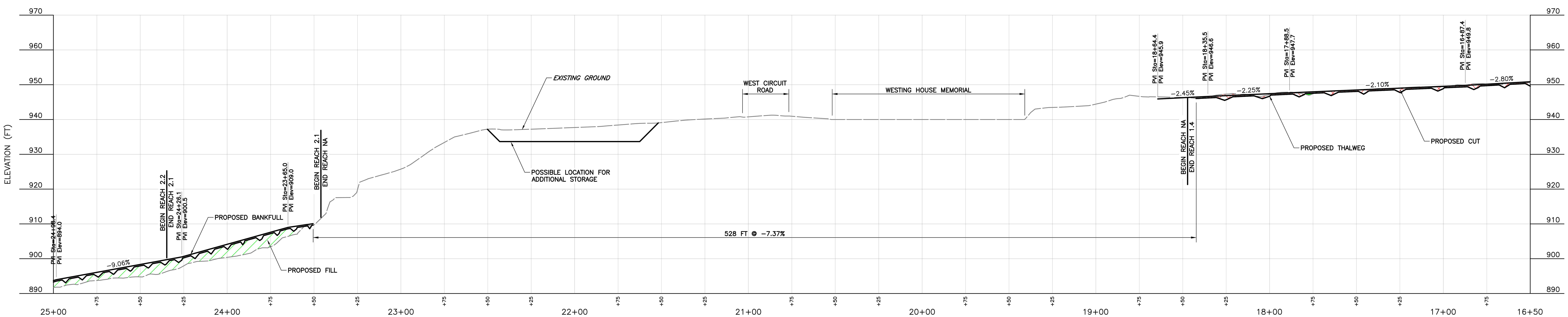
ALTERNATIVE NO. 1
PHIPPS RUN -GRADING PLAN AND PROFILE
10+00 TO 16+50

FIGURE NO.: 8-2

ALTERNATIVE NO. 1 -PHIPPS RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 1 -PHIPPS RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET: 0 30 60

VERTICAL SCALE IN FEET: 0 15 30

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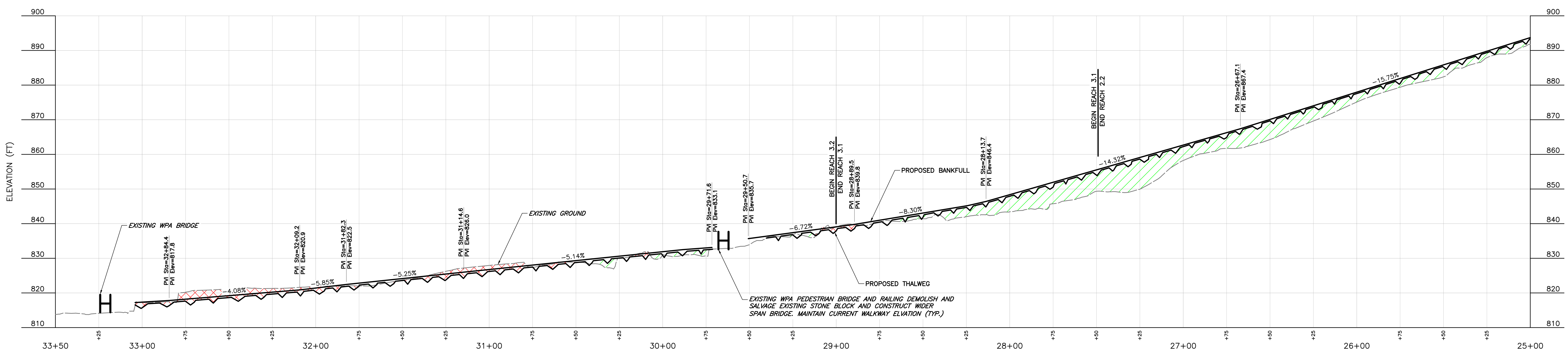
ALTERNATIVE NO. 1
PHIPPS RUN -GRADING PLAN AND PROFILE 16+50 TO 15+00

FIGURE NO.: **8-3**

ALTERNATIVE NO. 1 -PHIPPS RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 1 -PHIPPS RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 15 30

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ALTERNATIVE NO. 1
PHIPPS RUN -GRADING PLAN AND PROFILE 25+00 TO 33+50

FIGURE NO.: 8-4

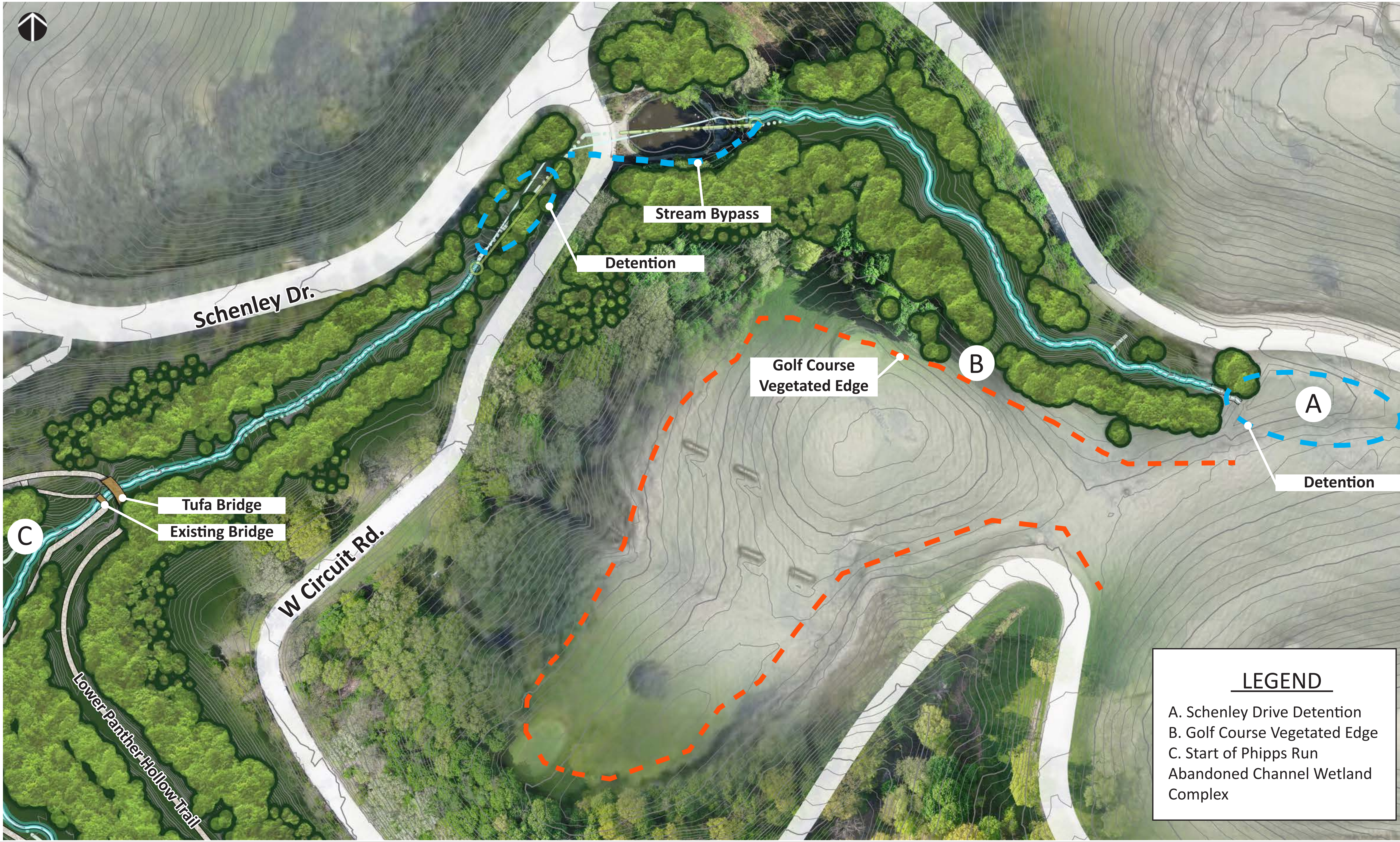

FIGURE 8.4A ALTERNATIVE NO. 1A - PHIPPS RUN: GREEN INFRASTRUCTURE • 1" = 120'

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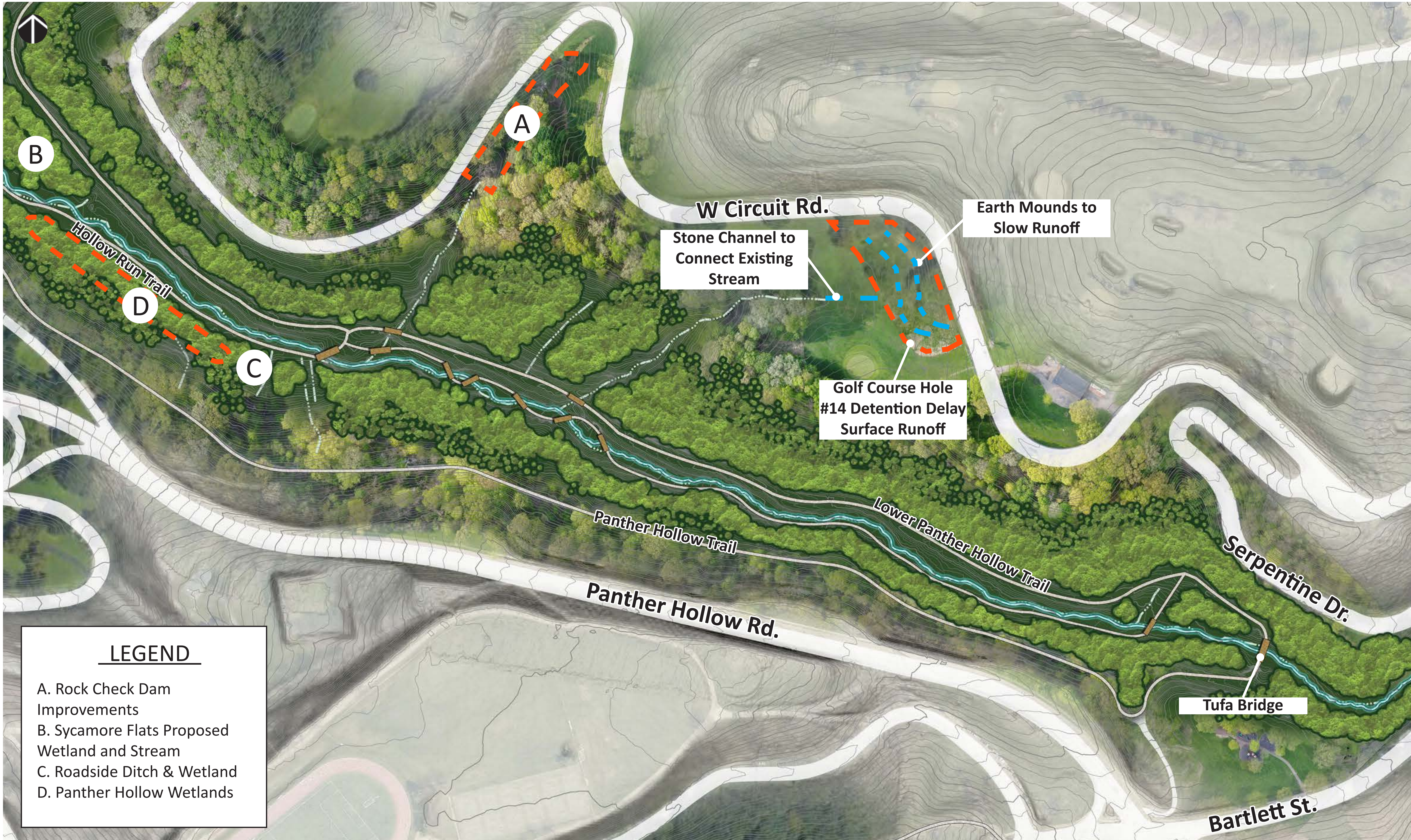

FIGURE 8.4B ALTERNATIVE NO. 1B - PANTHER HOLLOW RUN: GREEN INFRASTRUCTURE

• 1" = 200' • PWSA • ALLEGHENY COUNTY, PA • MARCH 1, 2019 • CEC: 174-960

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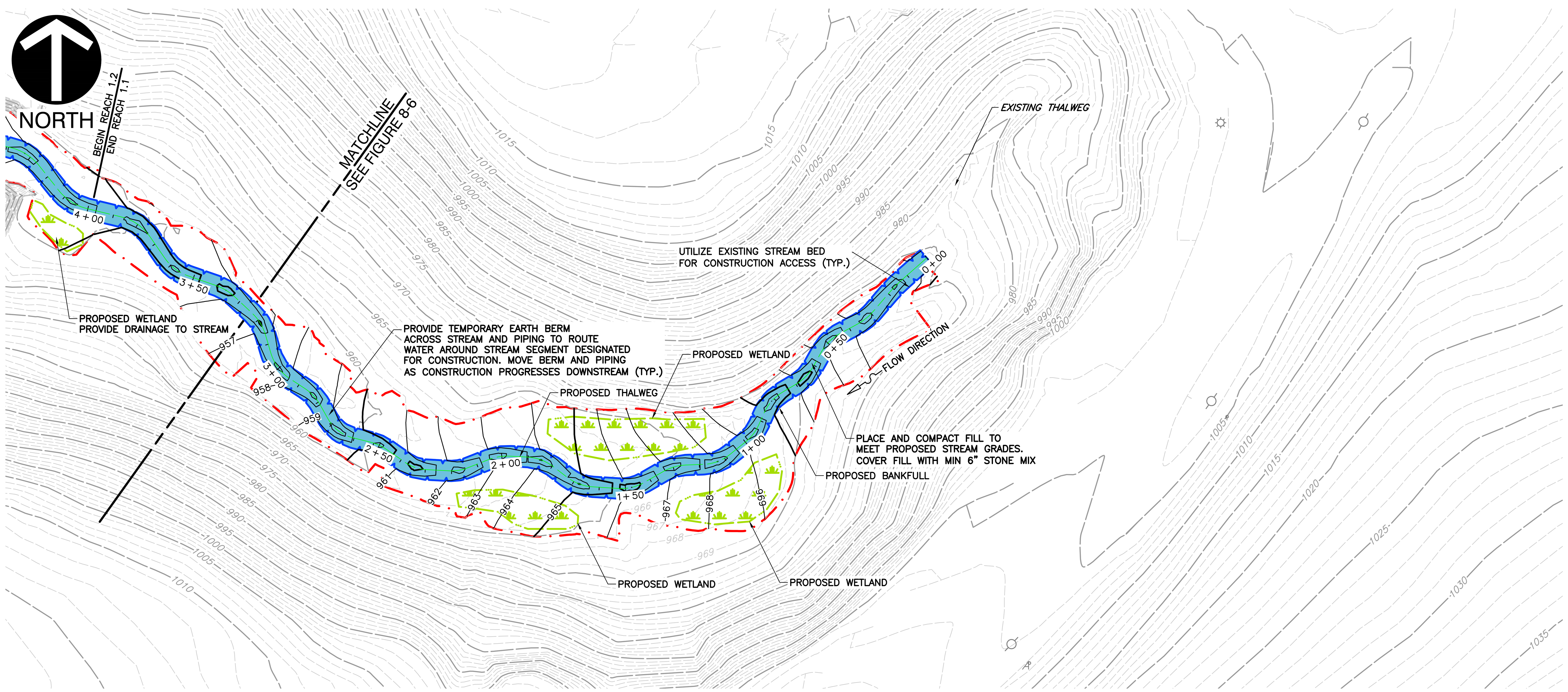
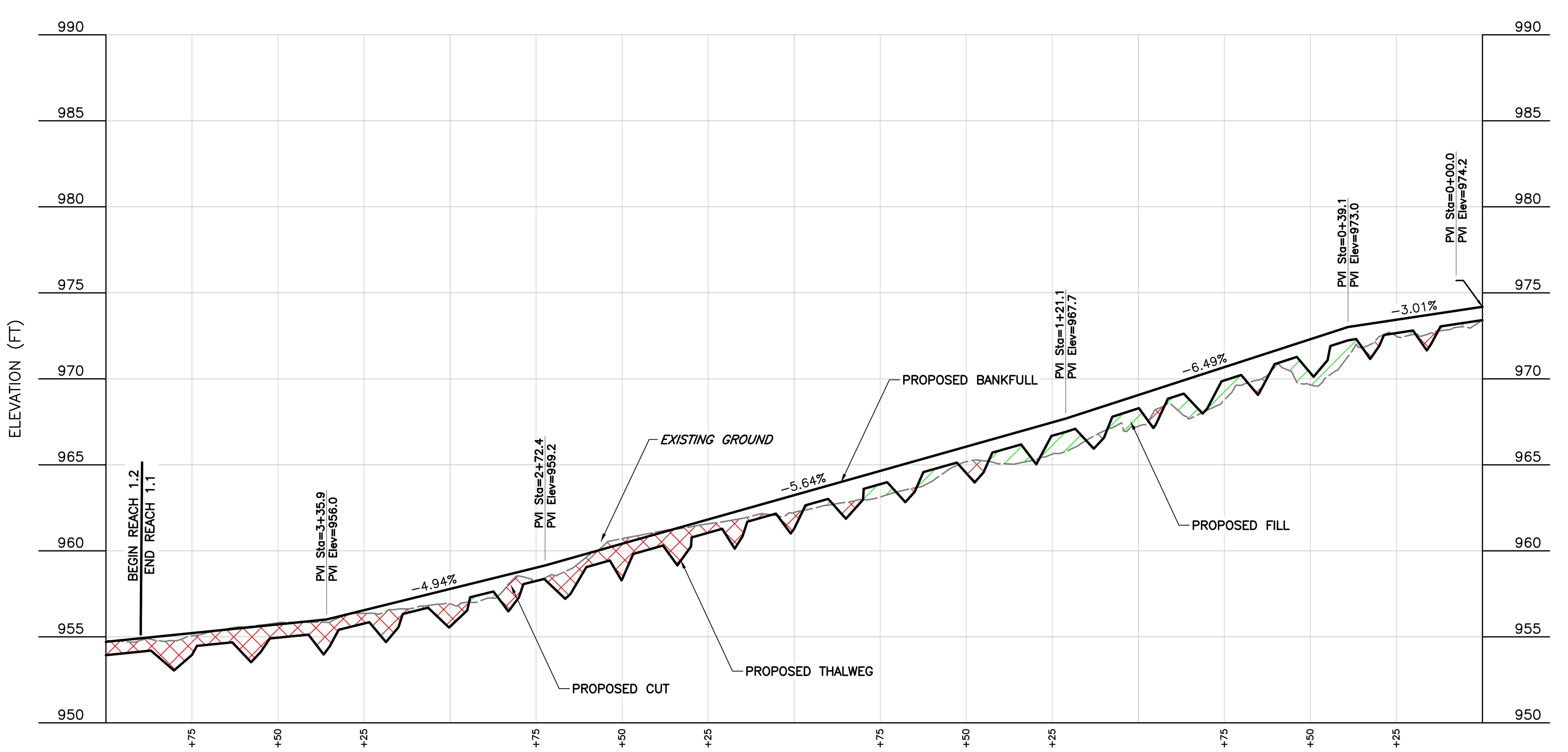


ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 6 12

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DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	

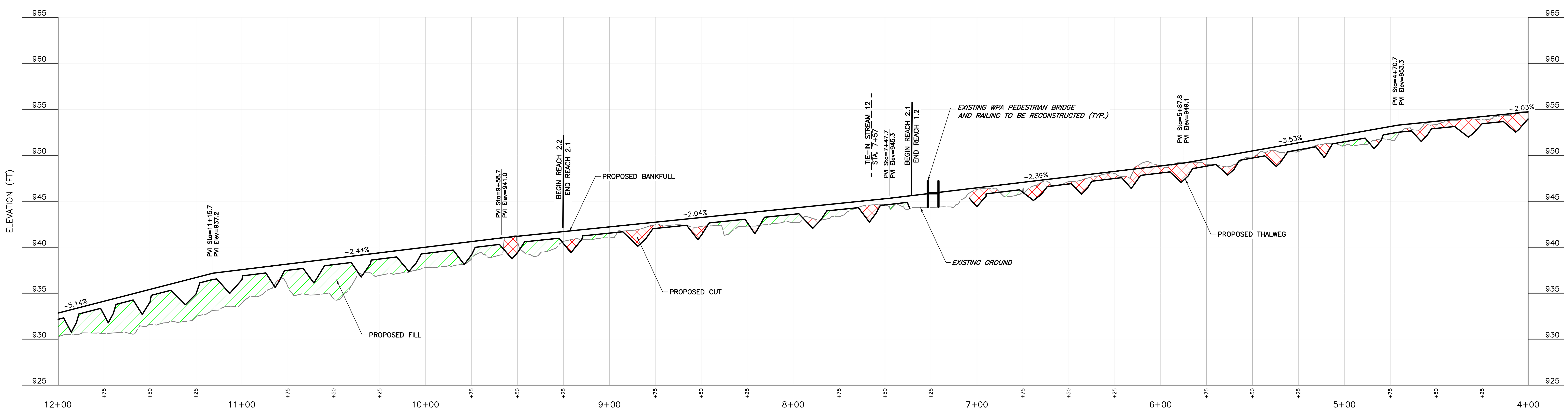
ALTERNATIVE NO. 2
PANTHER HOLLOW RUN -GRADING PLAN AND PROFILE 0+00 TO 4+00

FIGURE NO.: 8-5

ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET

0 30 60



ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET: 0 30 60

VERTICAL SCALE IN FEET: 0 6 12

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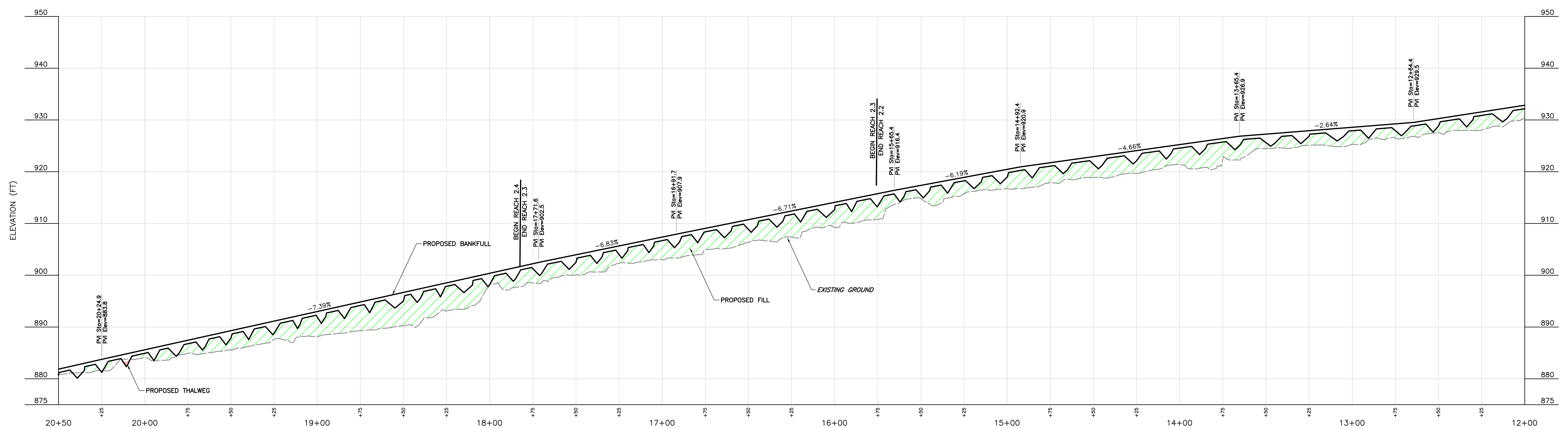
ALTERNAIVE NO. 2
PANTHER HOLLOW RUN -GRADING PLAN AND PROFILE 4+00 TO 12+00

FIGURE NO.: **8-6**

ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 10 20

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ALTERNATIVE NO. 2
PANTHER HOLLOW RUN -GRADING PLAN AND PROFILE 12+00 TO 20+50

FIGURE NO.: **8-7**

ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET 0 30 60

ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET 0 30 60

VERTICAL SCALE IN FEET 0 10 20

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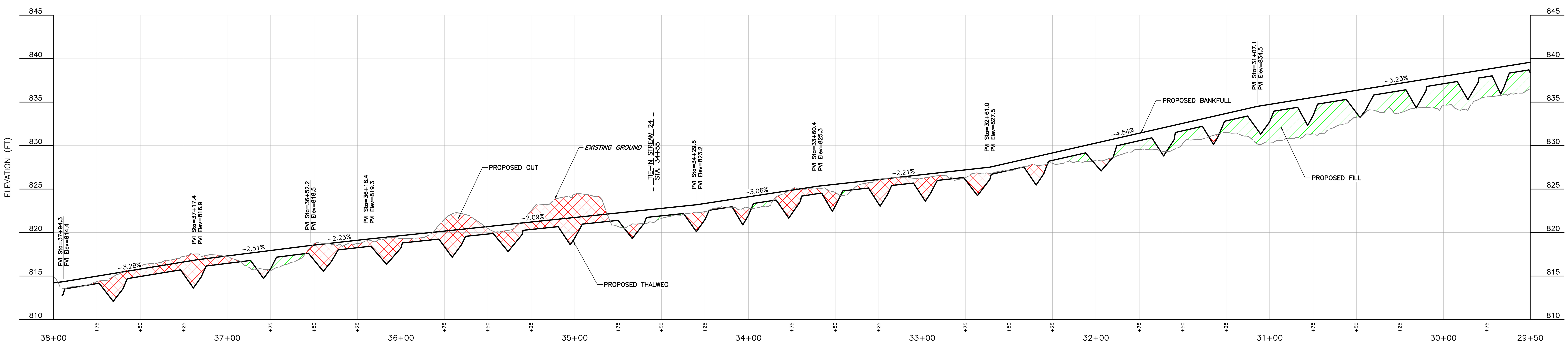
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	

ALTERNATIVE NO. 2
PANTHER HOLLOW RUN -GRADING PLAN AND PROFILE 20+50 TO 29+50

FIGURE NO.: 8-8

ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 2 -PANTHER HOLLOW RUN STREAM CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 6 12

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PRELIMINARY NOT FOR CONSTRUCTION

REVISION RECORD		
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**PITTSBURGH WATER & SEWER AUTHORITY
FOUR MILE RUN
STORMWATER IMPROVEMENT PROJECT
PITTSBURGH, ALLEGHENY COUNTY, PA**

DRAWN BY:	RLS	CHECKED BY:	CJR	APPROVED BY:	PJS
DATE:	JULY 2019	DWG SCALE:	AS-SHOWN	PROJECT NO:	174-960

ALTERNATIVE NO. 2
PANTHER HOLLOW RUN -GRADING
PLAN AND PROFILE 29+50 TO 38+00

FIGURE NO.: 8-9

ATERNATIVE NO. 2 STREAM 17 PLAN VIEW

SCALE IN FEET

0 30 60

DRAFT

PRELIMINARY
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REVISION RECORD		
NO	DATE	DESCRIPTION

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PITTSBURGH, ALLEGHENY COUNTY, PA

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ALTERNATIVE NO. 2
STREAM 17 DETENTION BASIN

FIGURE NO.: 8-9A

ALTERNATIVE NO. 3 - PANTHER HOLLOW LAKE RESTORATION AND FOREBAY PONDS PLAN VIEW

SCALE IN FEET
0 30 60

DRAFT

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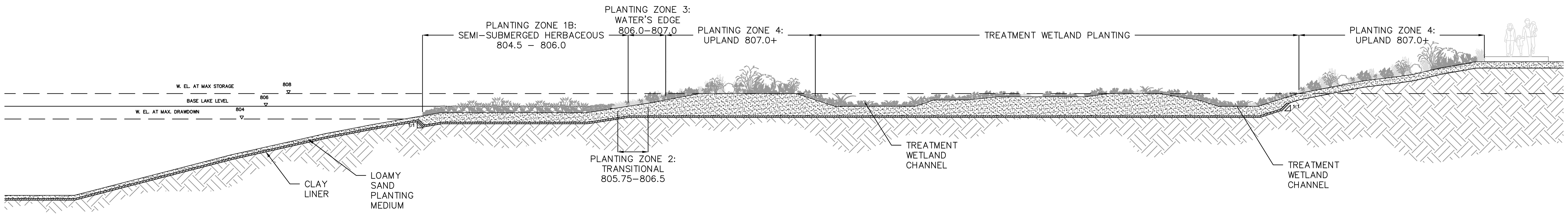
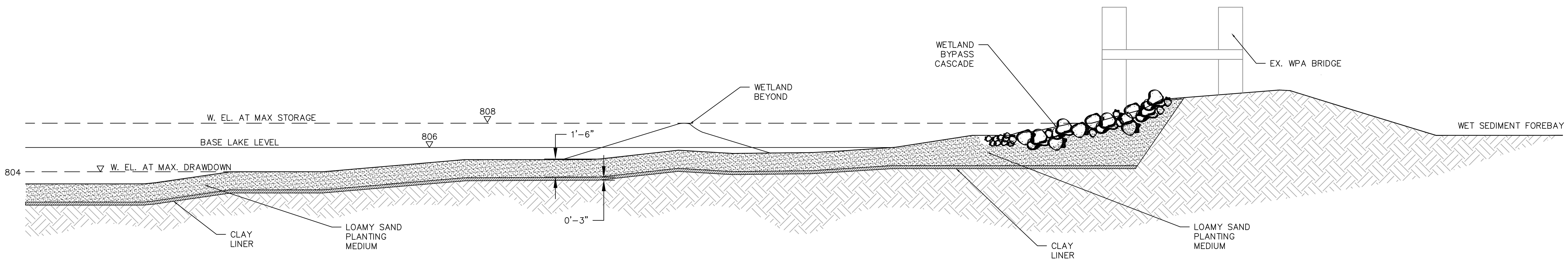
ALTERNATIVE NO. 3
PANTHER HOLLOW LAKE RESTORATION
AND FOREBAY PONDS PLAN VIEW

FIGURE NO.: **8-10**



CROSS SECTION THROUGH WETLAND

SCALE: 1" = 10'-0"



CROSS SECTION THROUGH WETLAND BYPASS CHANNEL

SCALE: 1" = 5'-0"

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PITTSBURGH, ALLEGHENY COUNTY, PA

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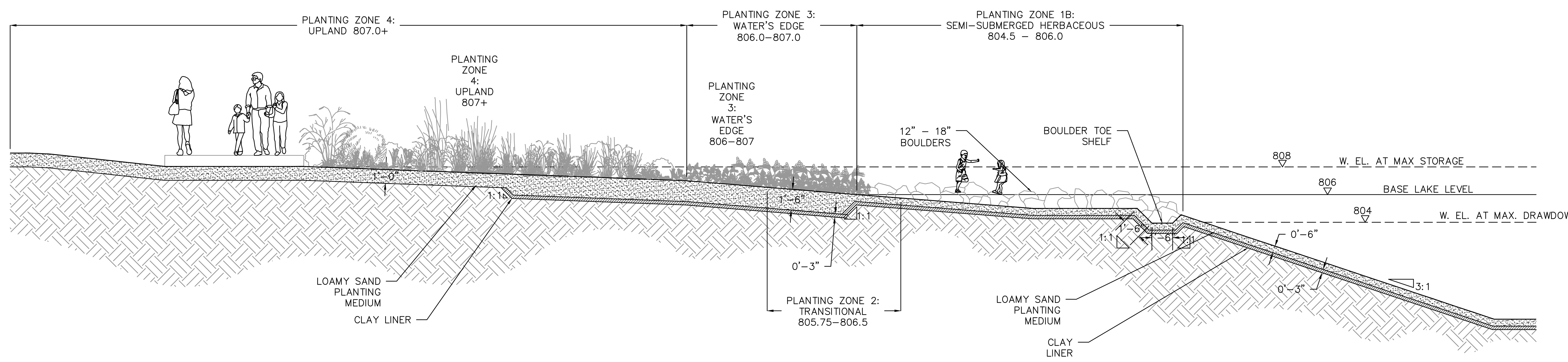
DATE: JAN. 2018	DWG SCALE: AS NOTED	PROJECT NO: 000-000.AW00

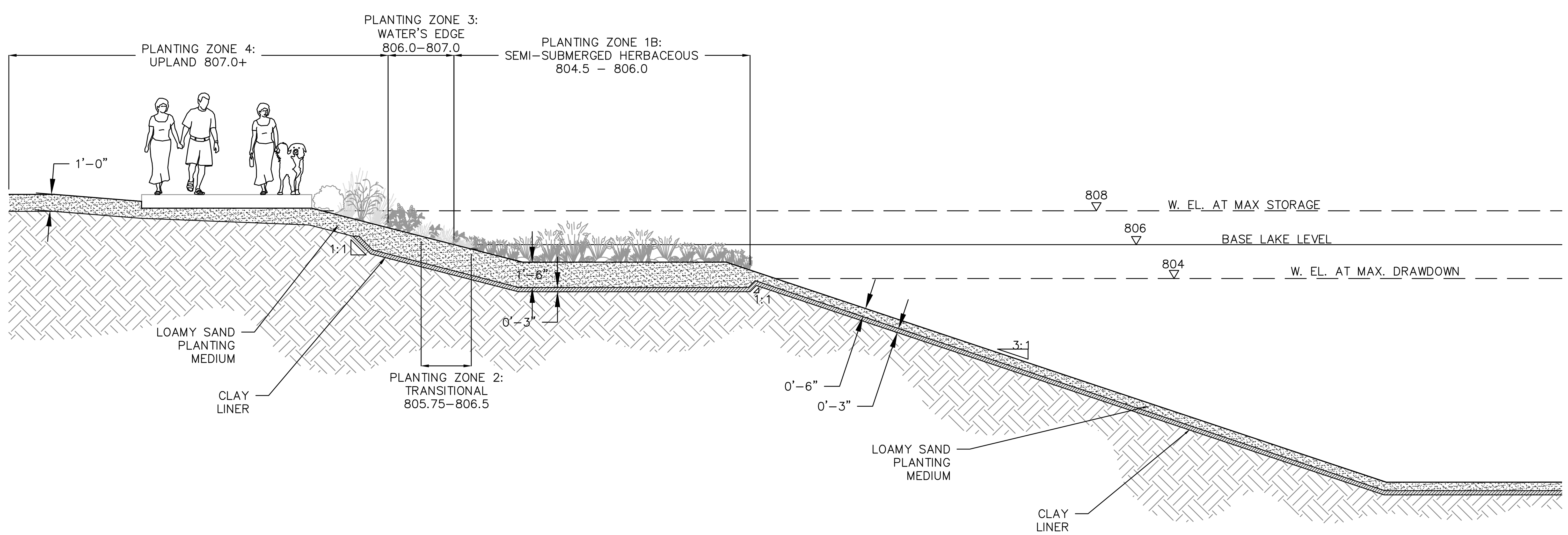
ALTERNATIVE NO. 3
PANTHER HOLLOW LAKE - DETAILS, TREATMENT WETLAND, AND WETLAND BYPASS

FIGURE NO.: 8-10A



SECTION A THROUGH WIDE AQUATIC BENCH

SCALE: 1" = 5'–0"



SECTION B THROUGH NARROW AQUATIC BENCH

SCALE: 1" = 5'–0"

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P:\CEC_Civil and Environmental Consultants\CEC1801 – Four Mile Run\02 – CEC1801 – Shared\03 – Drawings\C-6 THRU C-9 CROSS SECTION DETAILS.dwg|C-5 LAKE EDGE| LS:(3/18/2019 – emmajean) – LP: 3/18/2019 12:17 PM

SECTION THROUGH BOARDWALK AQUATIC EDGE

SCALE: 1" = 5'–0"

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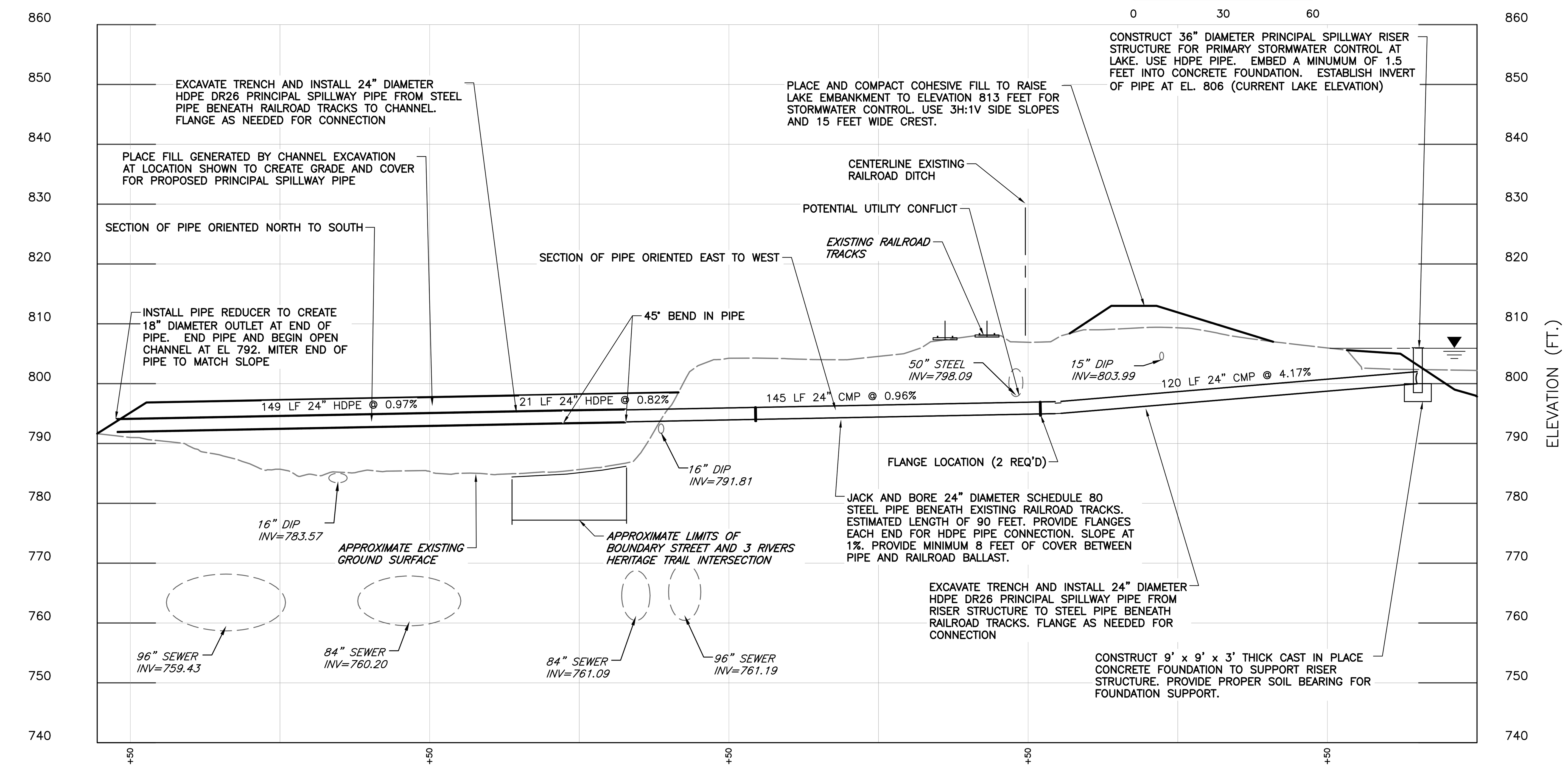
ALTERNATIVE NO. 4 - PANTHER HOLLOW LAKE PRINCIPLE AND EMERGENCY SPILLWAY PLAN VIEW

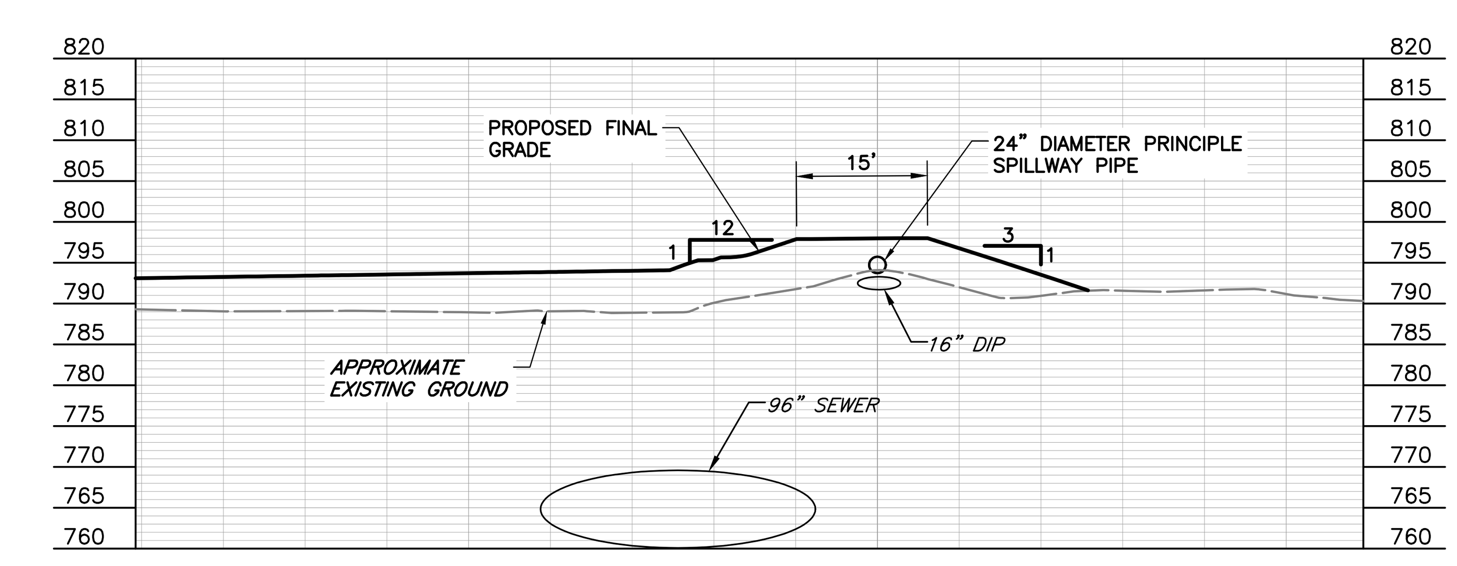
SCALE IN FEET 0 30 60



HORIZONTAL SCALE IN FEET 0 30 60 | VERTICAL SCALE IN FEET 0 15 30

ALTERNATIVE NO. 4 - PANTHER HOLLOW LAKE SPILLWAY PROFILE VIEW

SCALE H:1"=30'; V:1"=15'



STA 2+72.59

ALTERNATIVE NO. 4 - PANTHER HOLLOW LAKE SPILLWAY PIPE SECTION VIEW

SCALE H:1"=20'; V:1"=20'

SCALE IN FEET 0 20 40

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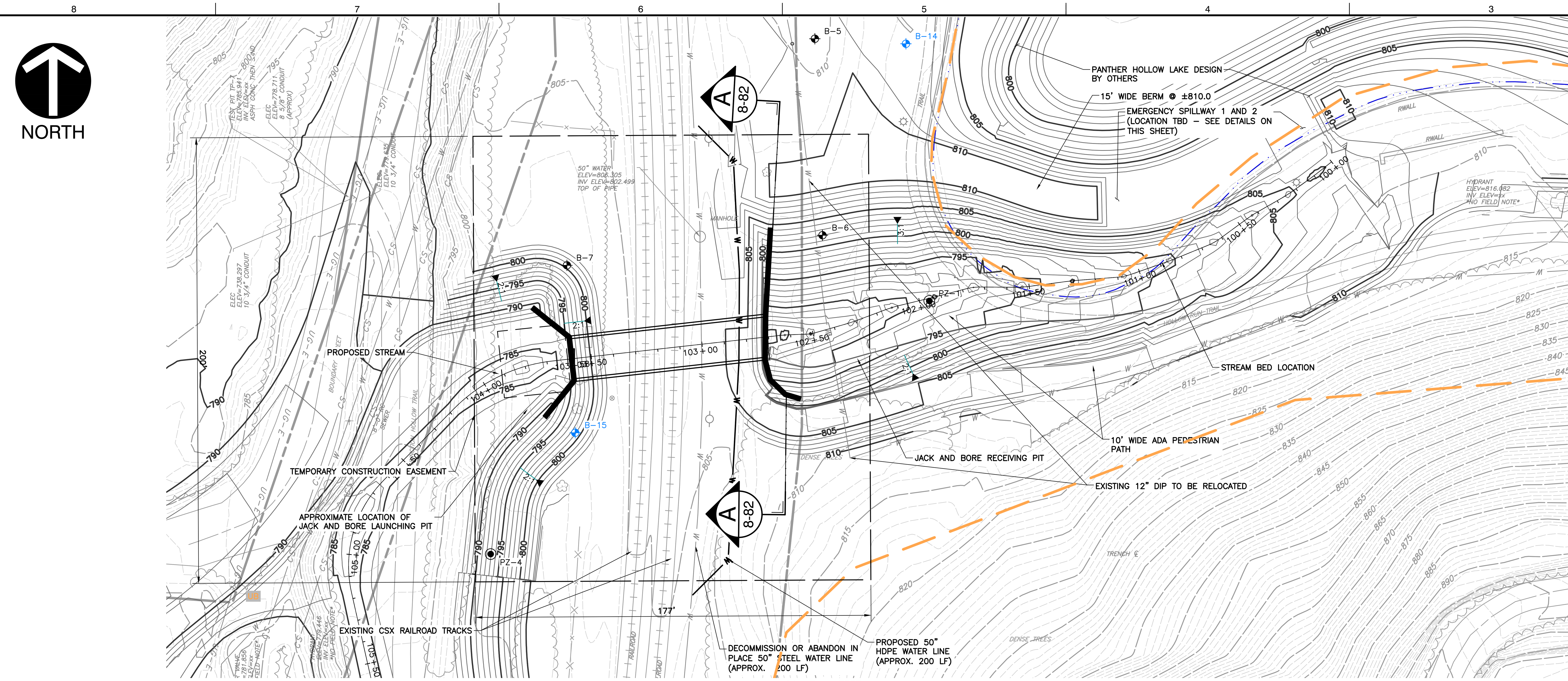
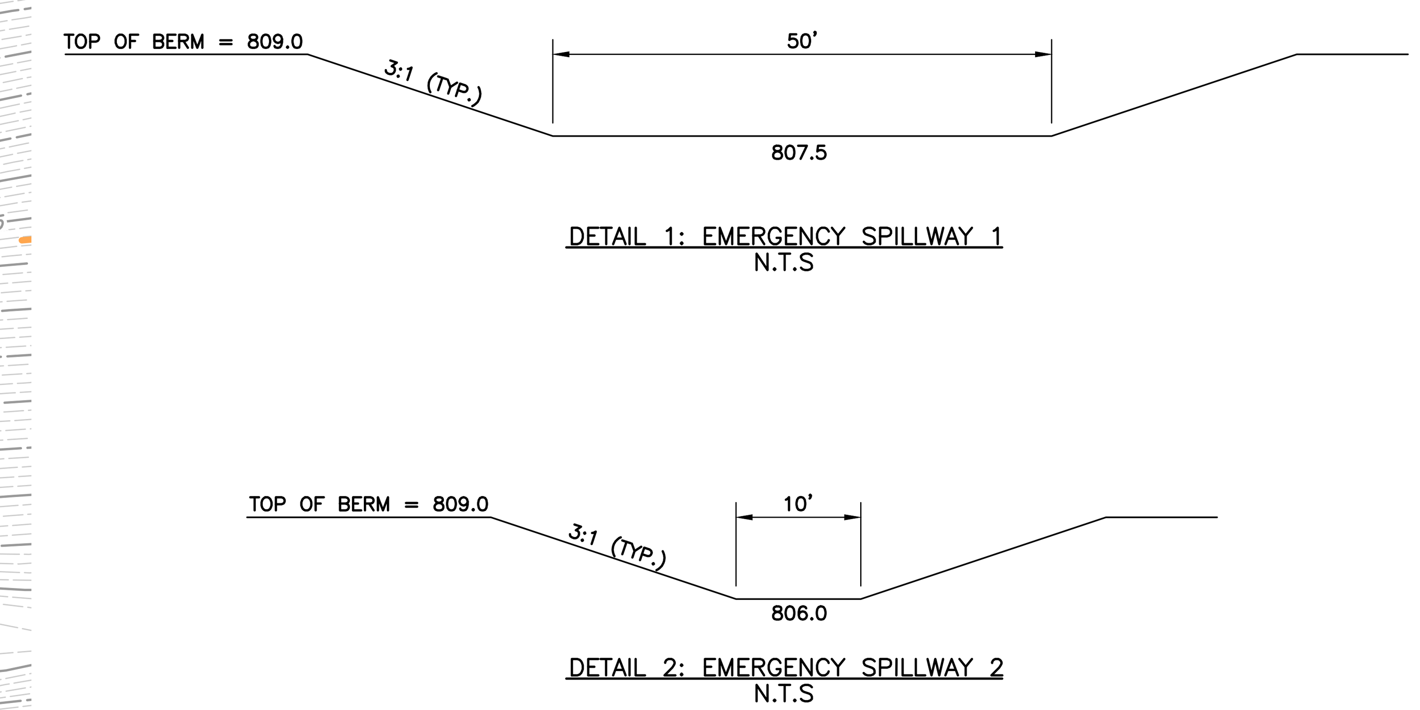
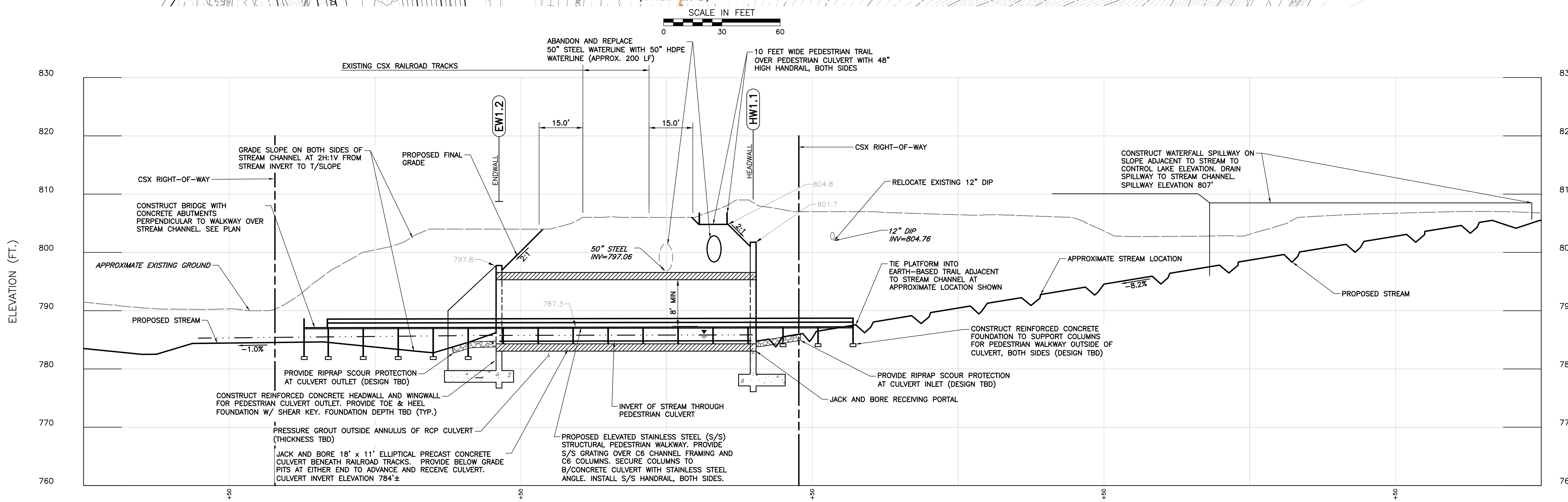
ALTERNATIVE NO. 4
PANTHER HOLLOW LAKE SPILLWAY
PLAN, PROFILE, AND SECTION

FIGURE NO.: 8-11







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NOTES

1. ADDITIONAL DETAIL FOR PROFILE AND PLAN TO BE PROVIDED AT 60% SUBMITTAL.

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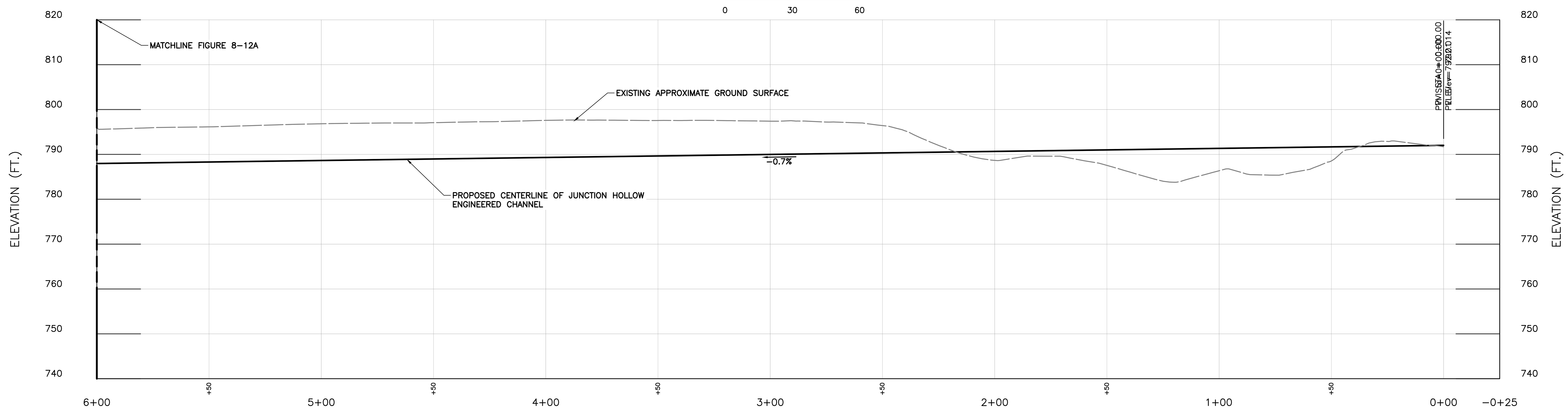
ALTERNATIVE NO. 4A - OPTION C
COMBINATION STORMWATER/PEDESTRIAN CULVERT UNDER RAILROAD
PLAN, PROFILE, AND DETAILS

FIGURE NO.: 8-11A

ALTERNATIVE NO. 5 - JUNCTION HOLLOW ENGINEERED CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 5 - JUNCTION HOLLOW ENGINEERED CHANNEL PROFILE VIEW

HORIZONTAL
SCALE IN FEET
0 30 60

VERTICAL
SCALE IN FEET
0 15 30

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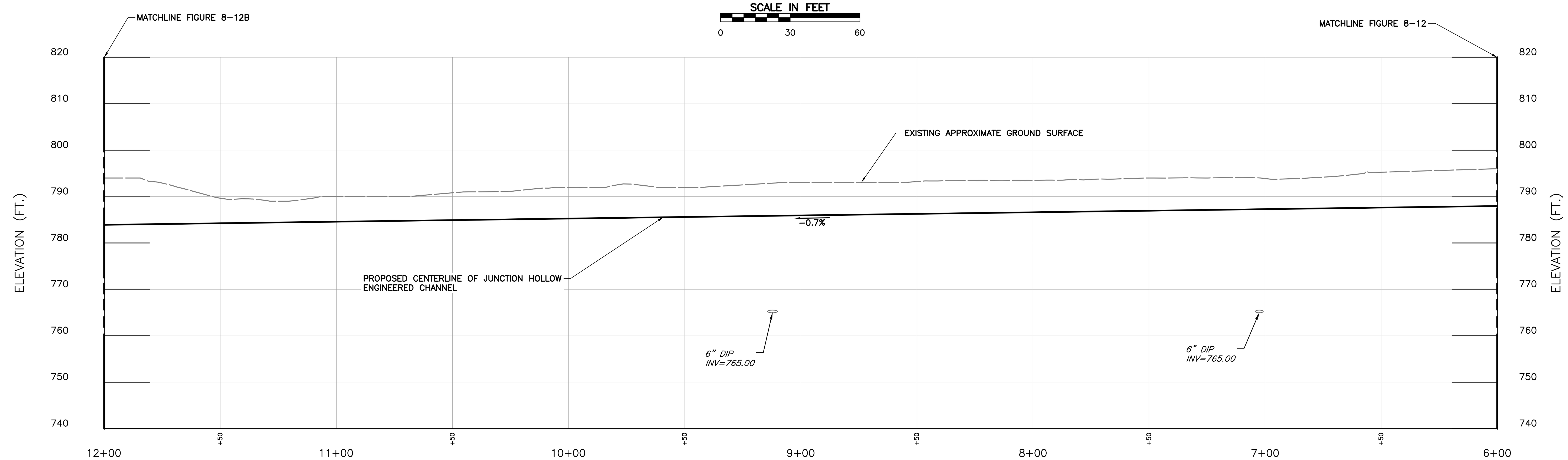
ALTERNATIVE NO. 5
JUNCTION HOLLOW ENGINEERED CHANNEL
PLAN AND PROFILE

FIGURE NO.: 8-12

ALTERNATIVE NO. 5 - JUNCTION HOLLOW ENGINEERED CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 5 - JUNCTION HOLLOW ENGINEERED CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 15 30

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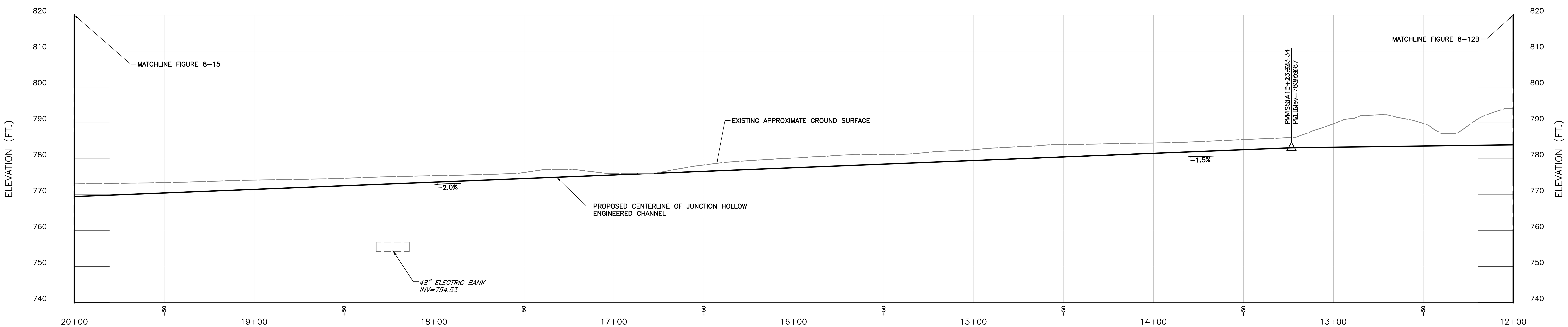
ALTERNATIVE NO. 5
JUNCTION HOLLOW ENGINEERED CHANNEL
PLAN AND PROFILE

FIGURE NO.: **8-12A**

ALTERNATIVE NO. 5 - JUNCTION HOLLOW ENGINEERED CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 5 - JUNCTION HOLLOW ENGINEERED CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 15 30

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ALTERNATIVE NO. 5
JUNCTION HOLLOW ENGINEERED CHANNEL
PLAN AND PROFILE

FIGURE NO.: 8-12B

ALTERNATIVE NO. 5A - JUNCTION HOLLOW STREAM UPGRADES (OPTION D)

SCALE IN FEET
0 30 60

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ALTERNATIVE NO. 5A JUNCTION HOLLOW STREAM

FIGURE NO.: 8-13

ALTERNATIVE NO. 5A - JUNCTION HOLLOW STREAM UPGRADES (OPTION D)

SCALE IN FEET

0 30 60

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ALTERNATIVE NO. 5A JUNCTION HOLLOW STREAM

FIGURE NO.: 8-13A

ALTERNATIVE NO. 5A - JUNCTION HOLLOW STREAM UPGRADES (OPTION D)

SCALE IN FEET

0 30 60

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ALTERNATIVE NO. 5A JUNCTION HOLLOW STREAM

FIGURE NO.: 8-13B

ALTERNATIVE NO. 6 - EAST SIDE RAILROAD CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60

ALTERNATIVE NO. 6 - EAST SIDE RAILROAD CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 6 12

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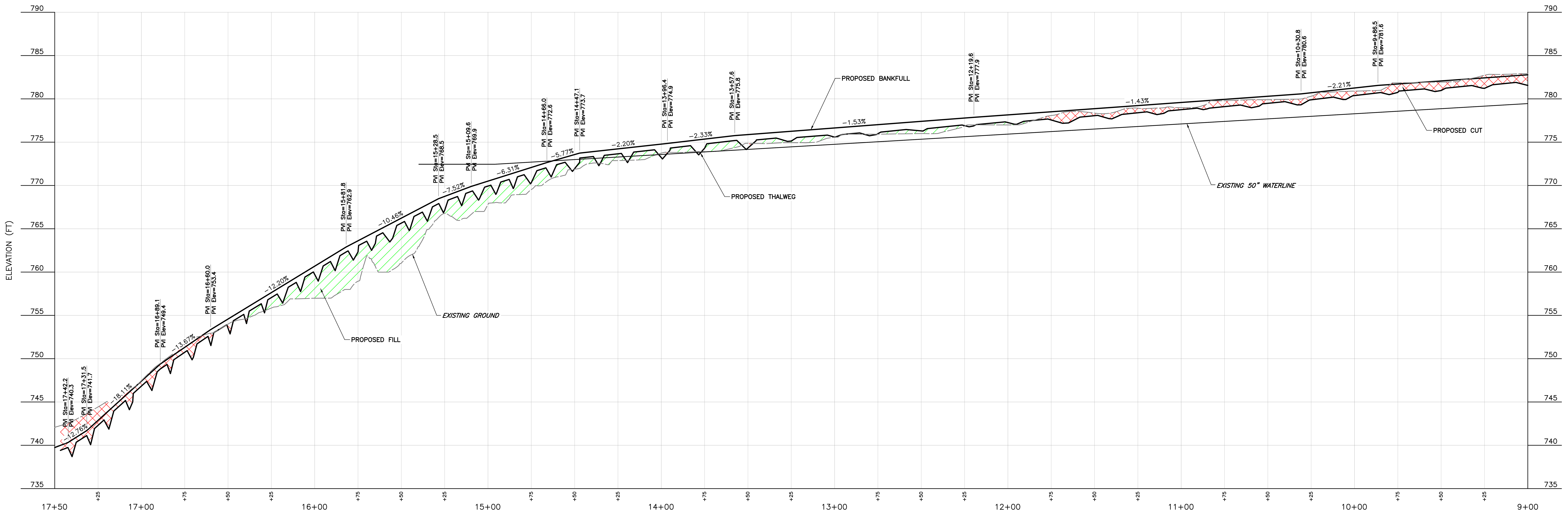
ALTERNATIVE NO. 6
EAST SIDE RAILROAD CHANNEL GRADING
PLAN AND PROFILE 0+00 TO 9+00

FIGURE NO.: 8-14A

ALTERNATIVE NO. 6 - EAST SIDE RAILROAD CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 6 - EAST SIDE RAILROAD CHANNEL PROFILE VIEW

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 10 20

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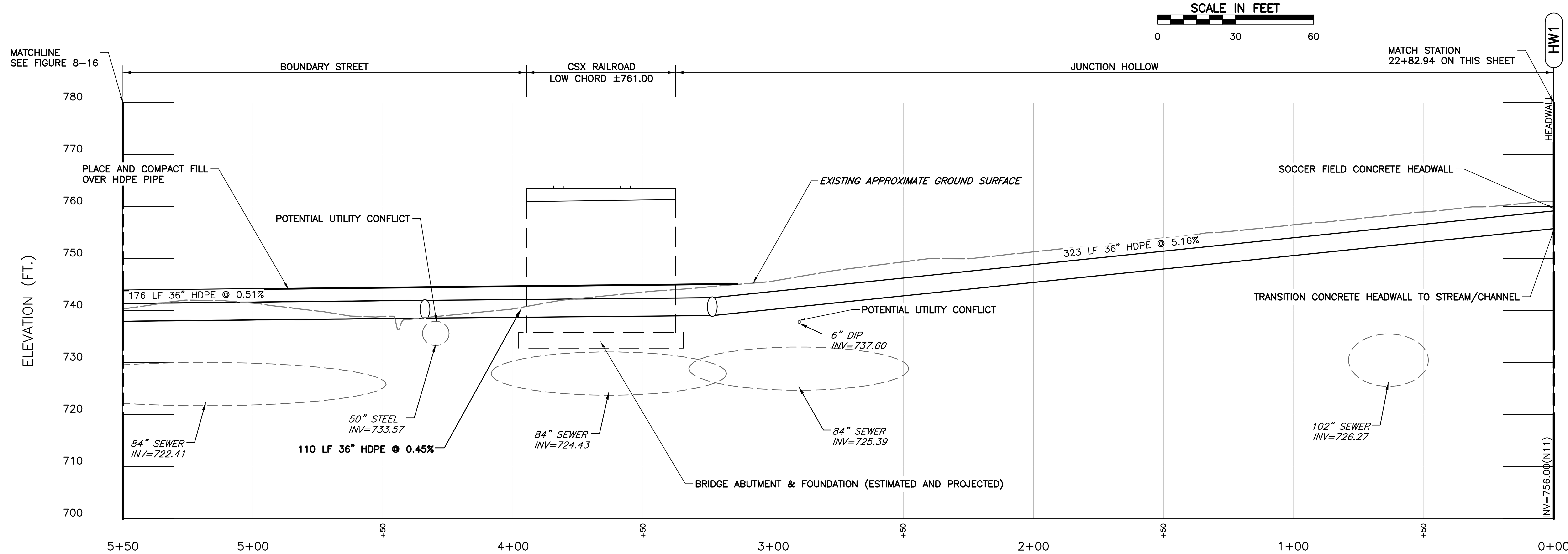
ALTERNATIVE NO. 6
EAST SIDE RAILROAD CHANNEL GRADING
PLAN AND PROFILE 9+00 TO 17+50

FIGURE NO.: 8-14B

ALTERNATIVE NO. 7 - SOCCER FIELD HEADWALL/BERM PLAN VIEW

SCALE IN FEET 0 30 60

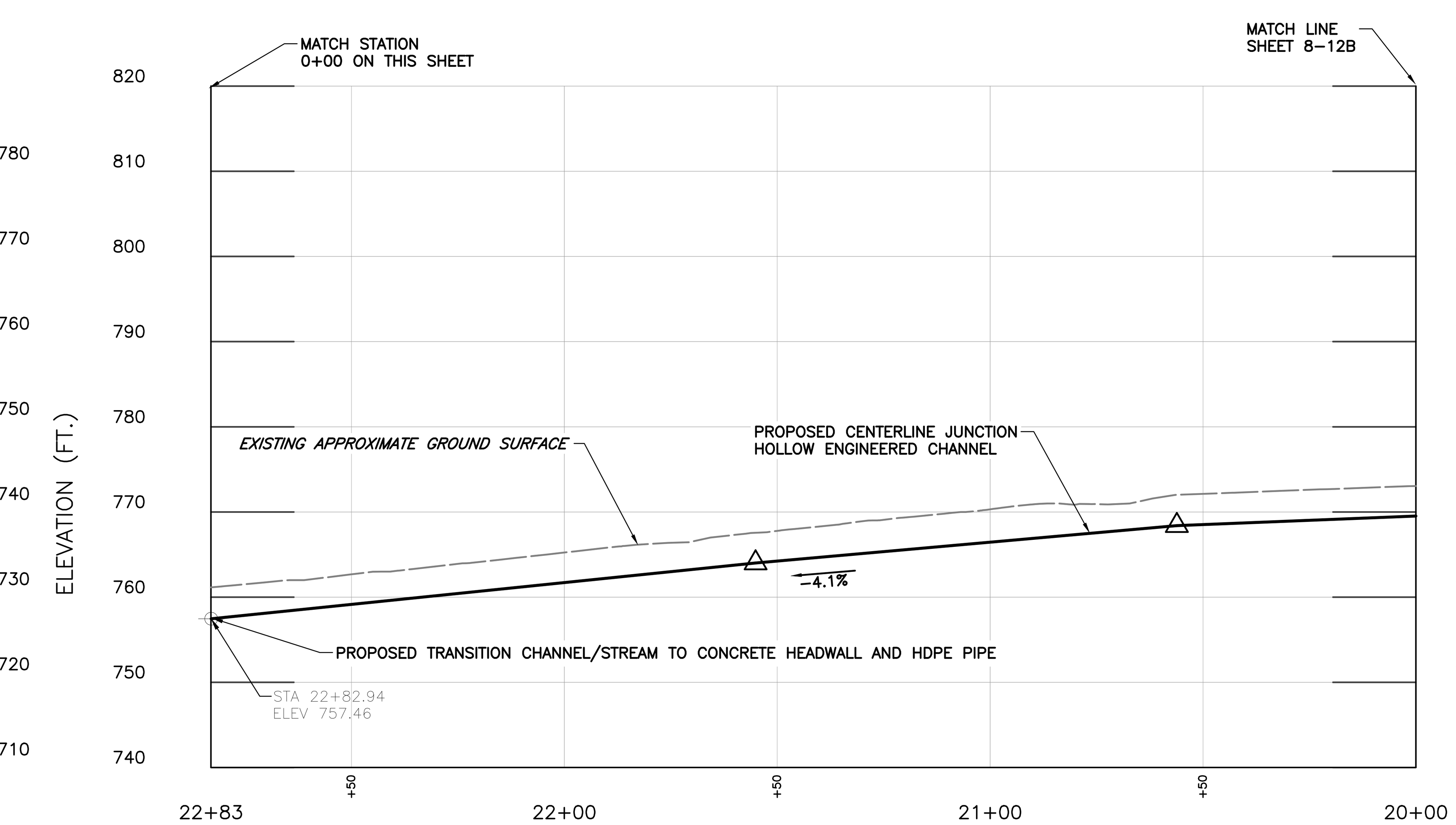


ALTERNATIVE NO. 7 - SOCCER FIELD HEADWALL/BERM PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET 0 30 60

VERTICAL SCALE IN FEET 0 15 30



ALTERNATIVE NO. 7 - SOCCER FIELD HEADWALL/BERM PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET 0 30 60

VERTICAL SCALE IN FEET 0 15 30

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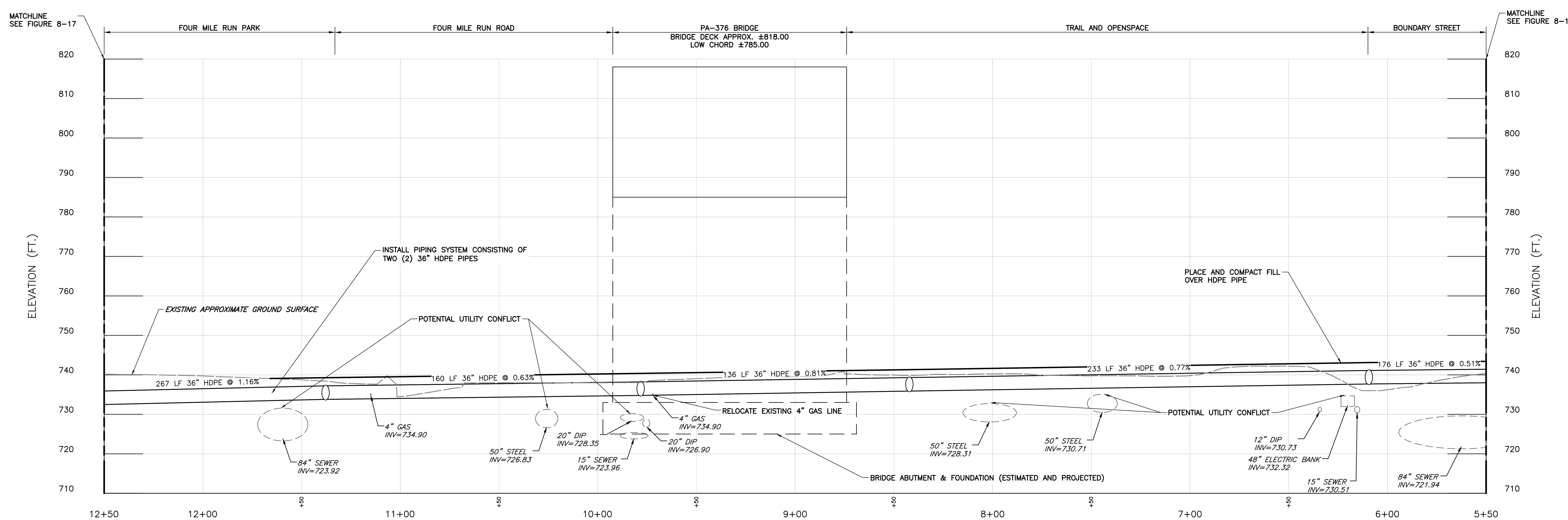
ALTERNATIVE NO. 7
SOCCERFIELD HEADWALL/BERM
PLAN AND PROFILE

FIGURE NO.: 8-15

ALTERNATIVE NO. 8 - FOUR MILE RUN PARK PIPING SYSTEM PLAN VIEW

SCALE IN FEET
0 30 60



ALTERNATIVE NO. 8 - FOUR MILE RUN PARK PIPING SYSTEM PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET: 0 30 60
VERTICAL SCALE IN FEET: 0 15 30

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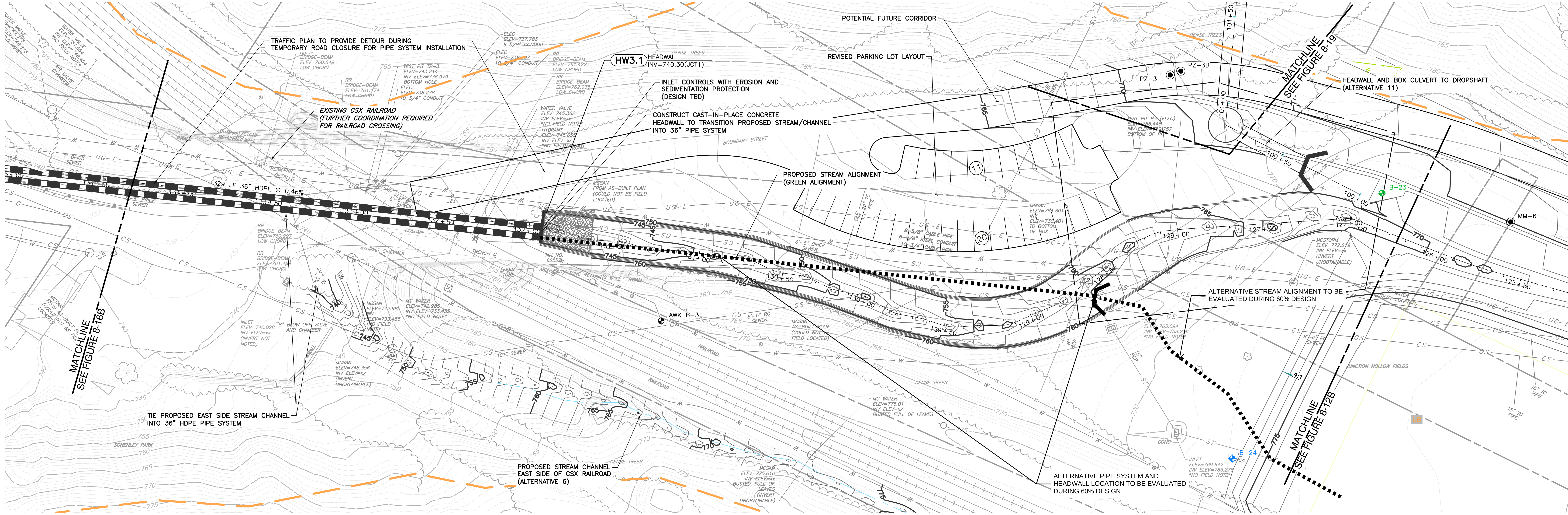
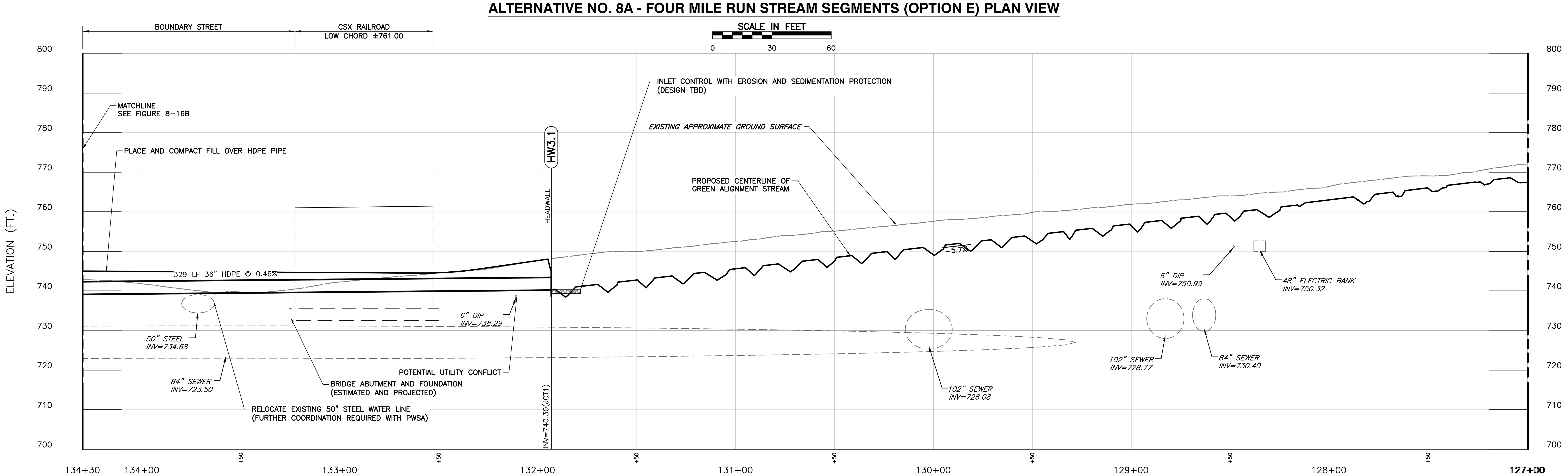
ALTERNATIVE NO. 8
FOUR MILE RUN PARK PIPING SYSTEM
PLAN AND PROFILE

FIGURE NO.: **8-16**



ALTERNATIVE NO. 8A - FOUR MILE RUN STREAM SEGMENTS (OPTION E) PLAN VIEW



ALTERNATIVE NO. 8A - FOUR MILE RUN STREAM SEGMENTS (OPTION E) PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET 0 30 60 — VERTICAL SCALE IN FEET 0 15 30

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ALTERNATIVE NO. 8A
FOUR MILE RUN STREAM SEGMENTS
PLAN AND PROFILE
OPTION E

FIGURE NO.: **8-16A**

ALTERNATIVE NO. 8A - FOUR MILE RUN STREAM SEGMENTS (OPTION E) PLAN VIEW

SCALE IN FEET
0 30 60

ALTERNATIVE NO. 8A - FOUR MILE RUN STREAM SEGMENTS (OPTION E) PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET: 0 30 60

VERTICAL SCALE IN FEET: 0 15 30

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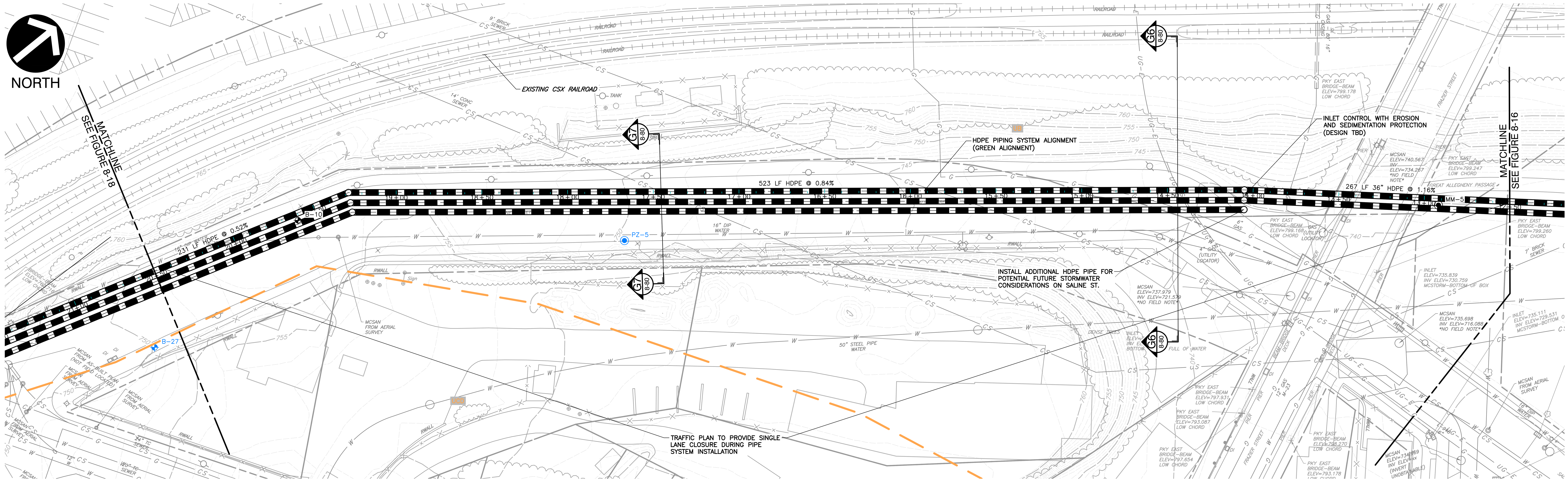
PITTSBURGH, ALLEGHENY COUNTY, PA

DRAWN BY: EJB/AJB/JAL/GRH	CHECKED BY: CJR	APPROVED BY: PJS	
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	

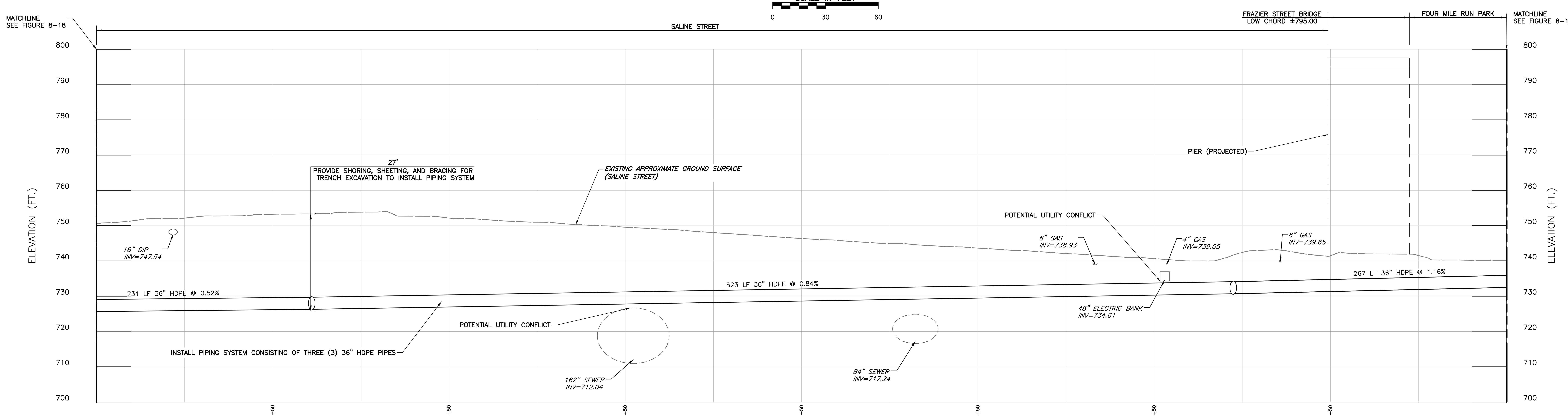
ALTERNATIVE NO. 8A
FOUR MILE STREAM SEGMENTS
OPTION E

FIGURE NO.: 8-16B



ALTERNATIVE NO. 9 - SALINE STREET DEEP GRAVITY PIPING SYSTEM PLAN VIEW

SCALE IN FEET: 0 30 60



ALTERNATIVE NO. 9 - SALINE STREET DEEP GRAVITY PIPING SYSTEM PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET: 0 30 60

VERTICAL SCALE IN FEET: 0 15 30

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PITTSBURGH WATER & SEWER AUTHORITY
FOUR MILE RUN
STORMWATER IMPROVEMENT PROJECT
PITTSBURGH, ALLEGHENY COUNTY, PA

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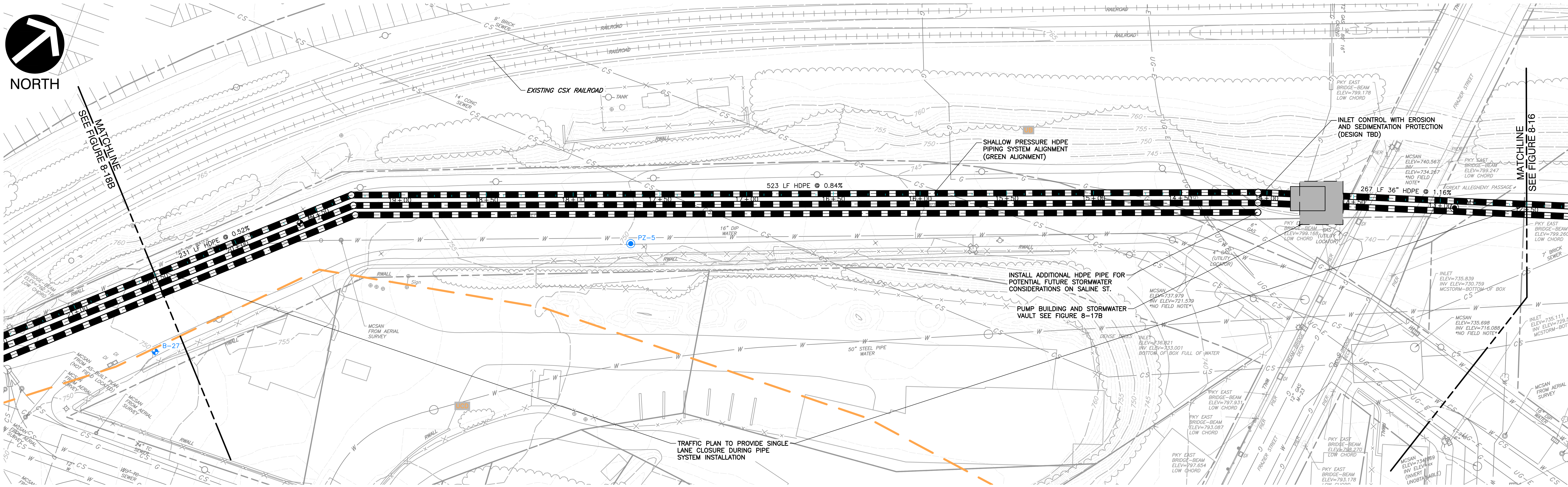
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960

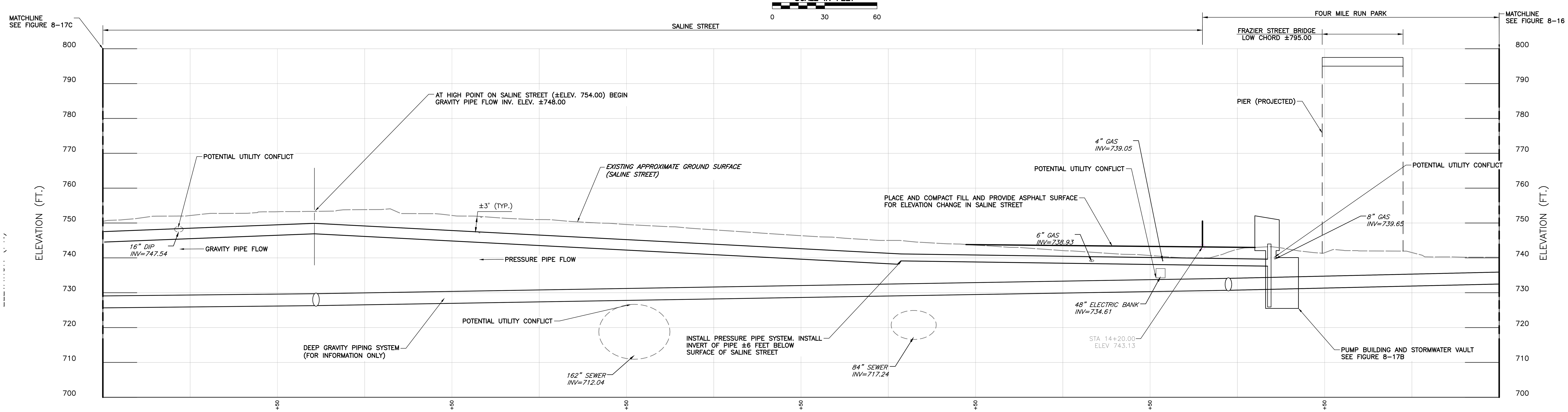
ALTERNATIVE NO. 9
SALINE STREET DEEP GRAVITY PIPING SYSTEM
PLAN AND PROFILE

FIGURE NO.: 8-17



ALTERNATIVE NO. 9A - SALINE STREET PUMP STATION AND SHALLOW PRESSURE PIPING SYSTEM PLAN VIEW

SCALE IN FEET 0 30 60



ALTERNATIVE NO. 9A - SALINE STREET PUMP STATION AND SHALLOW PRESSURE PIPING SYSTEM PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET 0 30 60

VERTICAL SCALE IN FEET 0 15 30

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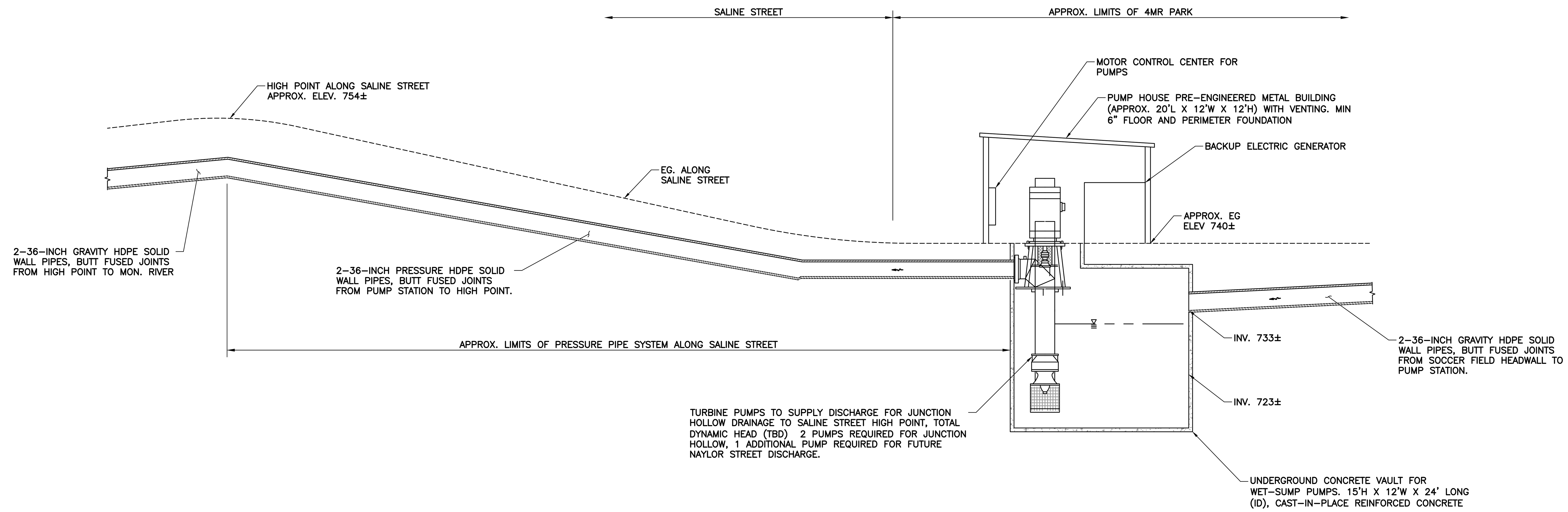
DRAWN BY: EJB/AJB/JAL/GRH	CHECKED BY: CJR	APPROVED BY: PJS	
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	

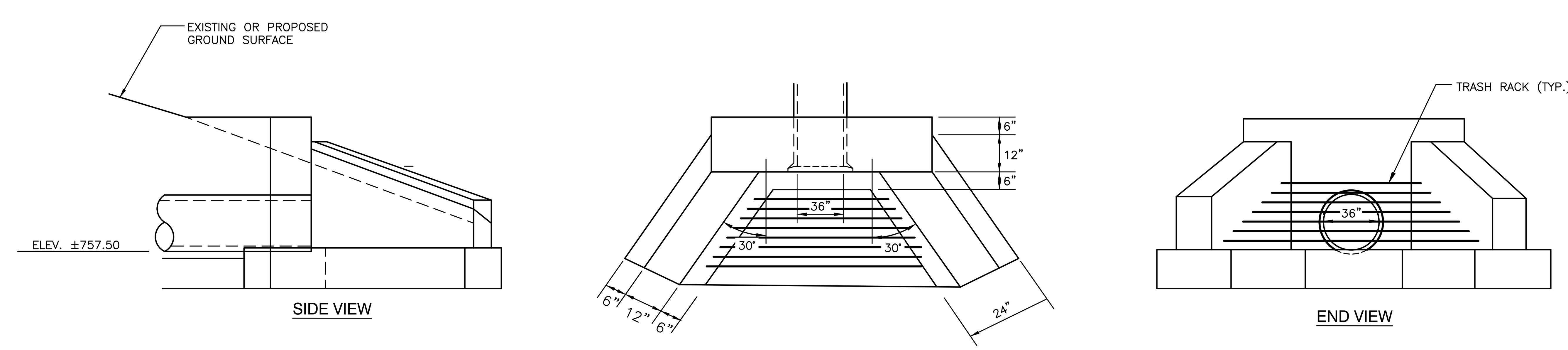
ALTERNATIVE NO. 9A
SALINE STREET PUMP STATION AND SHALLOW PRESSURE PIPING SYSTEM PLAN AND PROFILE
OPTION F AND G

FIGURE NO.: 8-17A



ALTERNATIVE NO. 9A - PUMP STATION ELEVATION VIEW

SCALE IN FEET
0 10 20



NOTE:
ALL DIMENSIONS, CONCRETE AND REINFORCING PER PENNDOT PUBLICATION 408, LATEST REVISION.

CAST-IN-PLACE REINFORCED CONCRETE HEADWALL

N.T.S

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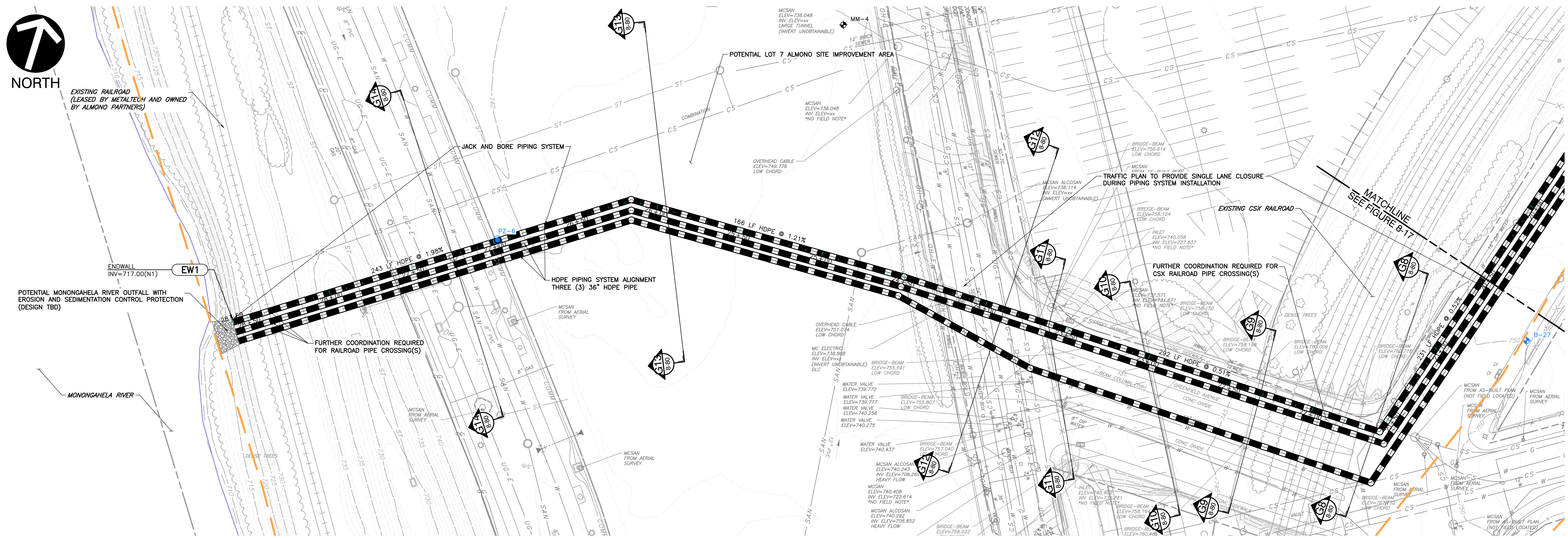
PITTSBURGH, ALLEGHENY COUNTY, PA

DRAWN BY: EJB/AJB/JAL/GRH	CHECKED BY: CJR	APPROVED BY: PJS	
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	
ALTERNATIVE NO. 9A SALINE PUMP STATION ELEVATION AND CONCRETE HEADWALL DETAIL OPTION F		FIGURE NO.: 8-17B	

P:\2017\174-960\-CADD\Dwg\CIVD1\Design Alternative 9A\174960-CV01-DESIGN ALTERNATIVE 9A.dwg{8-17B} LS:(7/2/2019 - ebrice) - LP: 7/2/2019 9:06 AM



ALTERNATIVE NO. 10 - HAZELWOOD GREEN DEEP GRAVITY PIPING SYSTEM PLAN VIEW

SCALE IN FEET 0 30 60

ALTERNATIVE NO. 10 - HAZELWOOD GREEN DEEP GRAVITY PIPING SYSTEM PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET 0 30 60 — VERTICAL SCALE IN FEET 0 15 30

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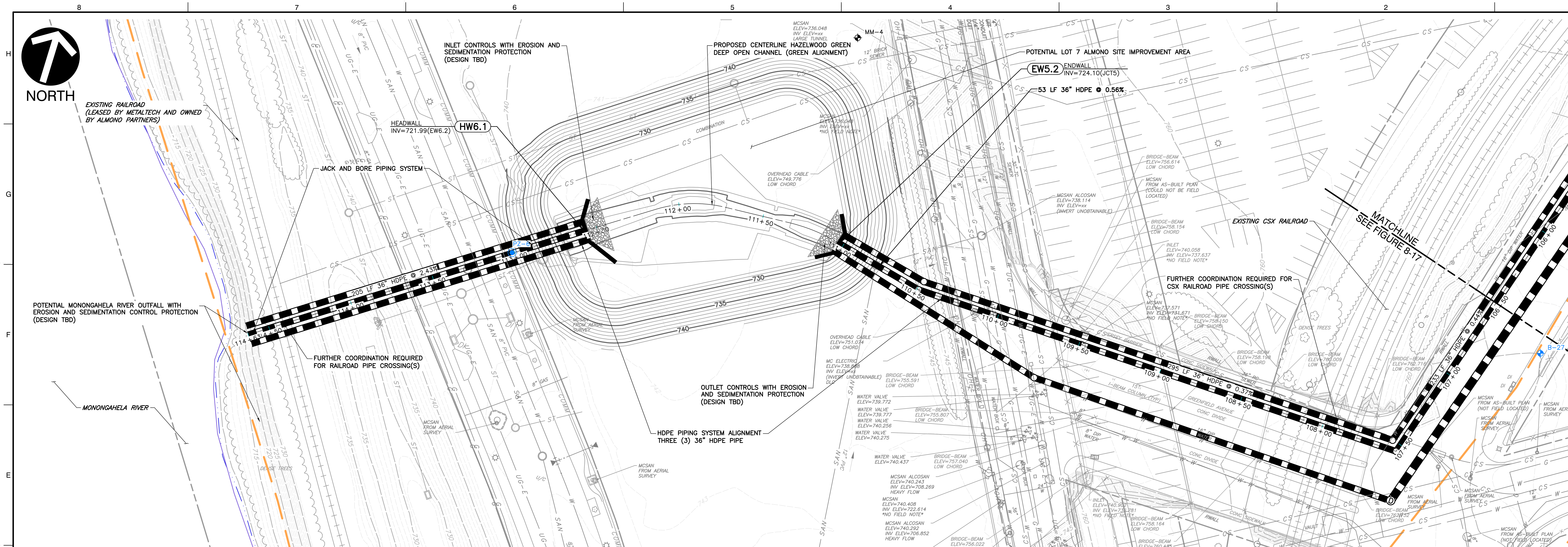
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	

ALTERNATIVE NO. 10
HAZELWOOD GREEN DEEP GRAVITY PIPING SYSTEM PLAN AND PROFILE

FIGURE NO.: 8-18



ALTERNATIVE NO. 10A - HAZELWOOD GREEN DEEP OPEN CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60

ALTERNATIVE NO. 10A - HAZELWOOD GREEN DEEP OPEN CHANNEL PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET
0 30 60

VERTICAL SCALE IN FEET
0 15 30

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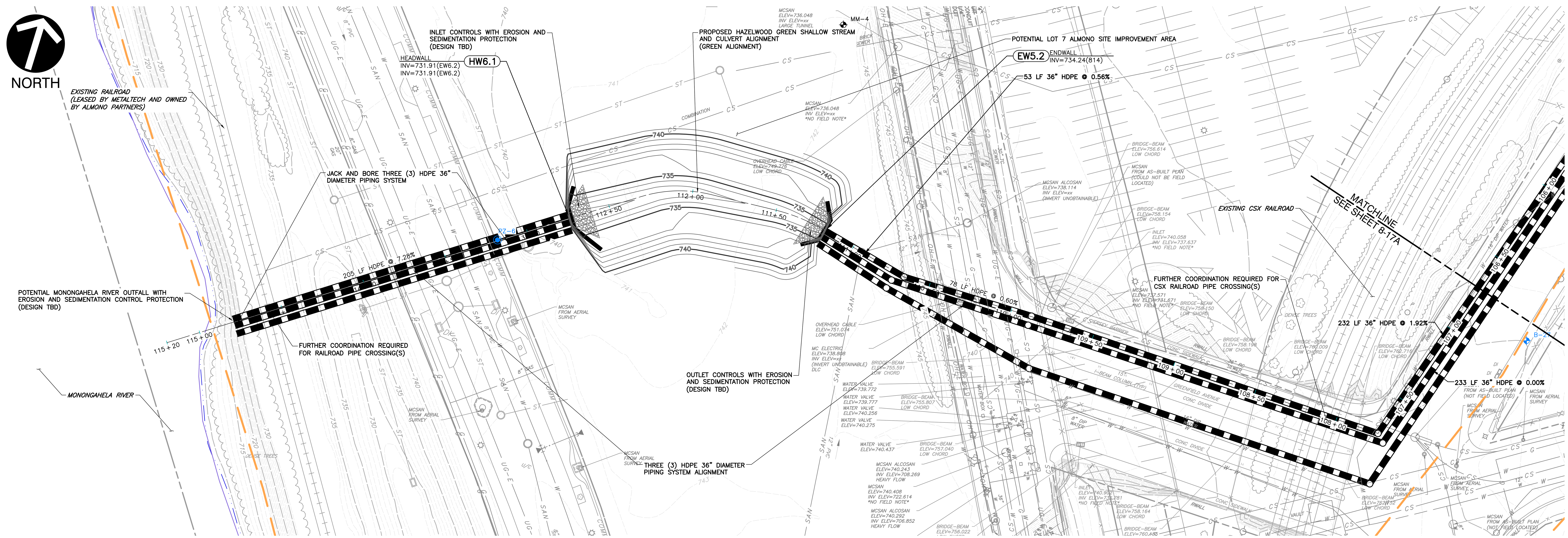
ALTERNATIVE NO. 10A
HAZELWOOD GREEN DEEP OPEN CHANNEL
PLAN AND PROFILE
OPTION H

FIGURE NO.: 8-18A



ALTERNATIVE NO. 10C - HAZELWOOD GREEN SHALLOW CHANNEL PLAN VIEW

SCALE IN FEET
0 30 60

ALTERNATIVE NO. 10C - HAZELWOOD GREEN SHALLOW CHANNEL PROFILE VIEW

SCALE H:1"=30'; V:1"=15'

HORIZONTAL SCALE IN FEET 0 30 60

VERTICAL SCALE IN FEET 0 15 30

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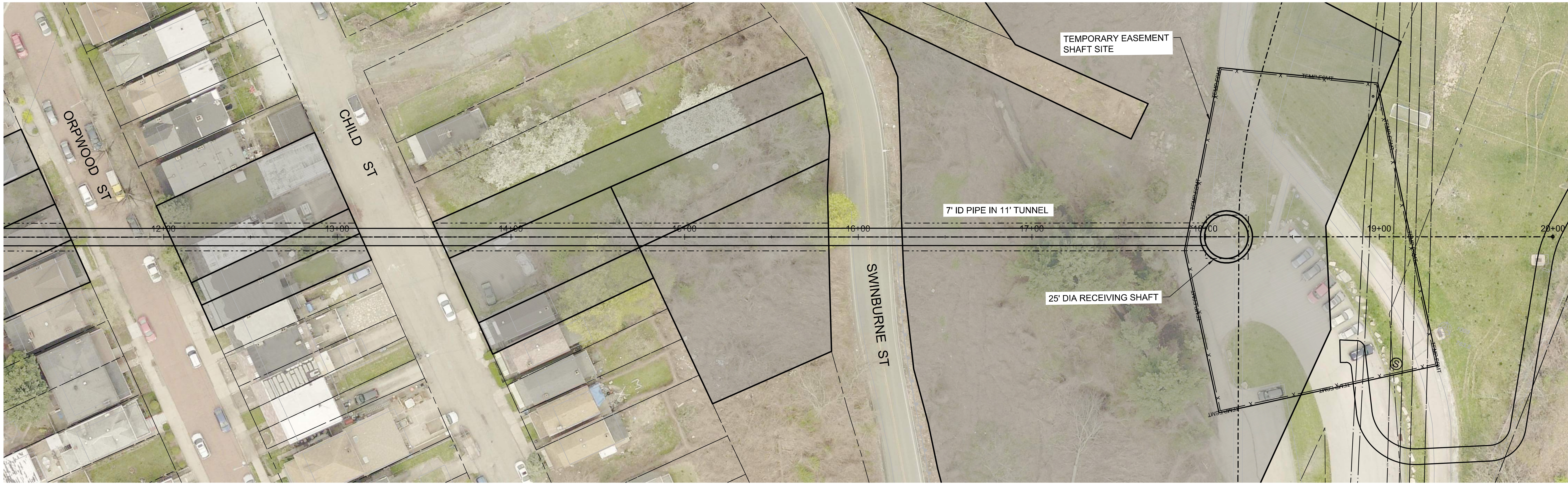
DATE: JULY 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 174-960	

ALTERNATIVE NO. 10B
HAZELWOOD GREEN SHALLOW OPEN CHANNEL
PLAN AND PROFILE
OPTION I

FIGURE NO.: **8-18B**

P:\2017\174-960\-CADD\Dwg\CIVIL\Design Alternative 10C\174960-CIV01-DESIGN ALTERNATIVE 10C.dwg{8-18B} LS:(7/2/2019 - ebride) - LP: 7/2/2019 9:17 AM



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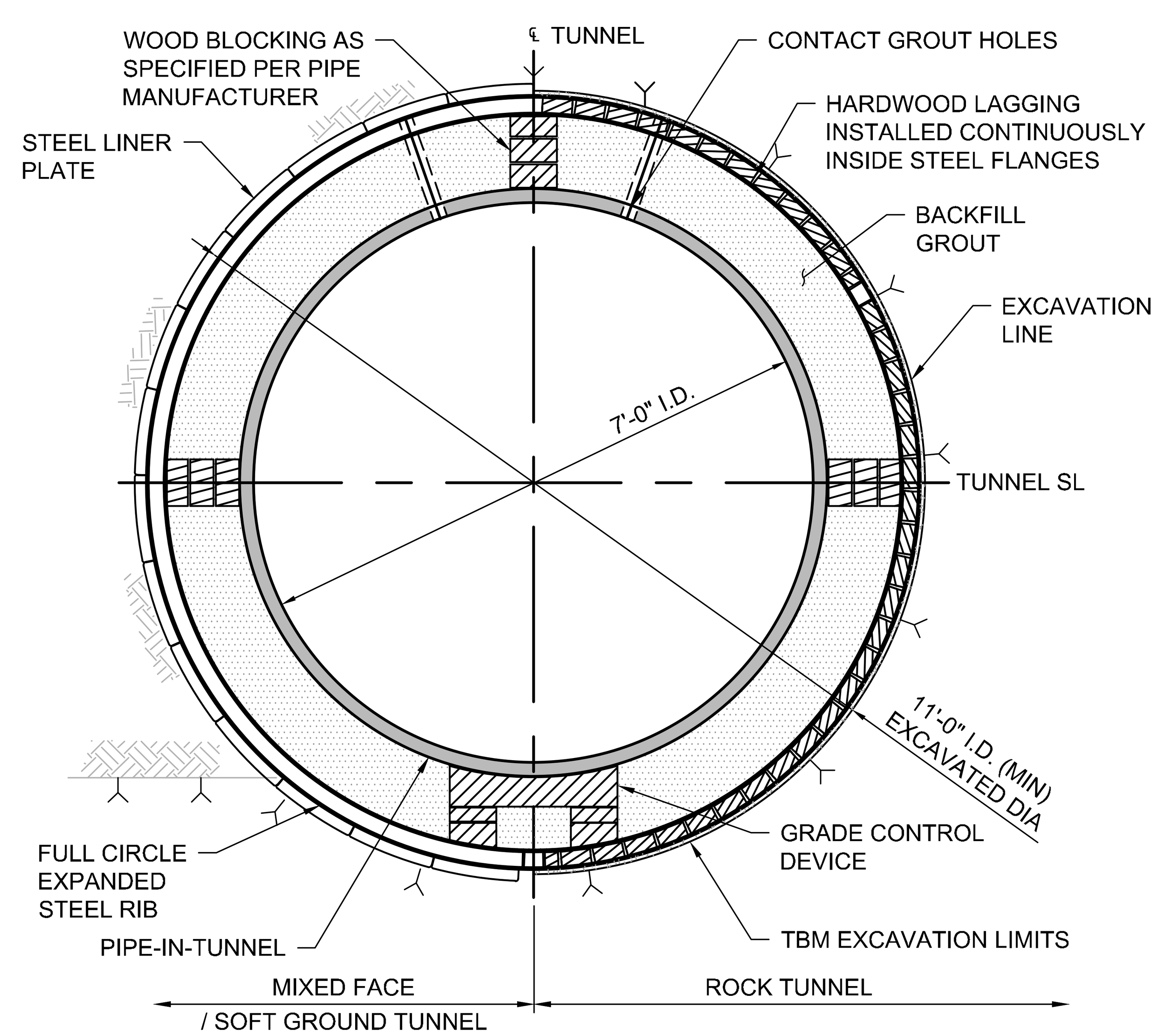
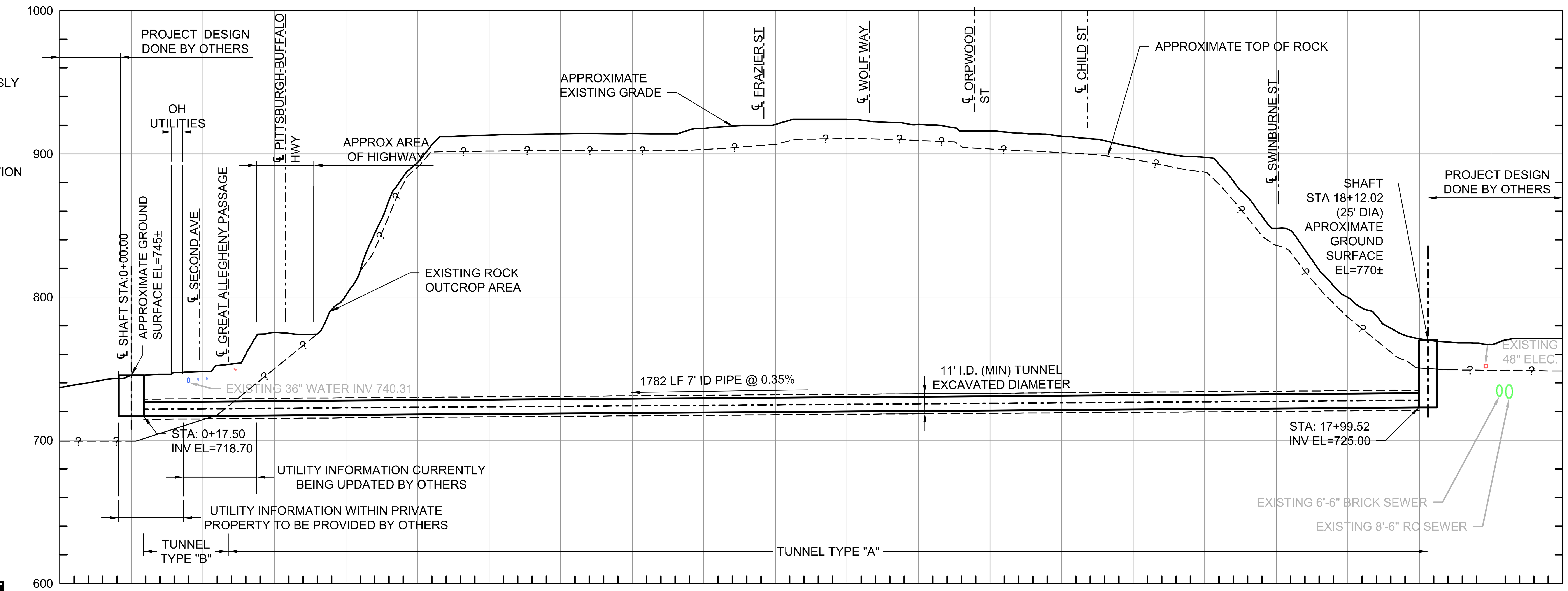


TWO PASS TBM TUNNEL
TYPICAL CROSS SECTION

SCALE: NOT TO SCALE



SCALE IN FEET 0 50 100
VERTICAL SCALE: 1" = 50'-0"

SCALE IN FEET 0 100 200
HORIZONTAL SCALE: 1" = 100'-0"

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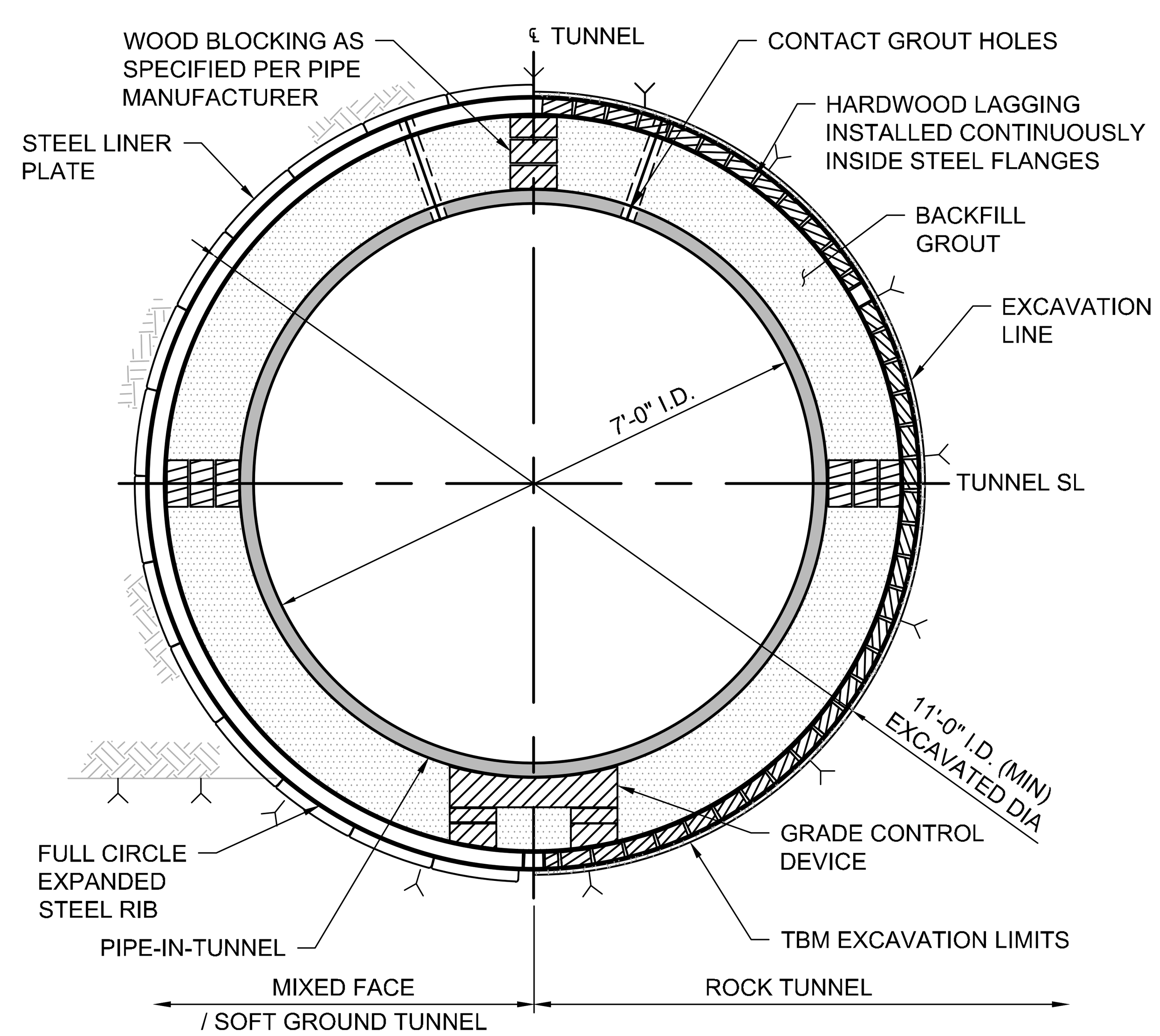
DRAWN BY: RGR	CHECKED BY: SS	APPROVED BY: RB
DATE: MARCH 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 000-000.AW00

ALTERNATIVE NO. 11
TUNNEL ALONG NEW WEST ROUTE TO SECOND AVENUE PLAN AND PROFILE

FIGURE NO.: 8-19



TWO PASS TBM TUNNEL TYPICAL CROSS SECTION

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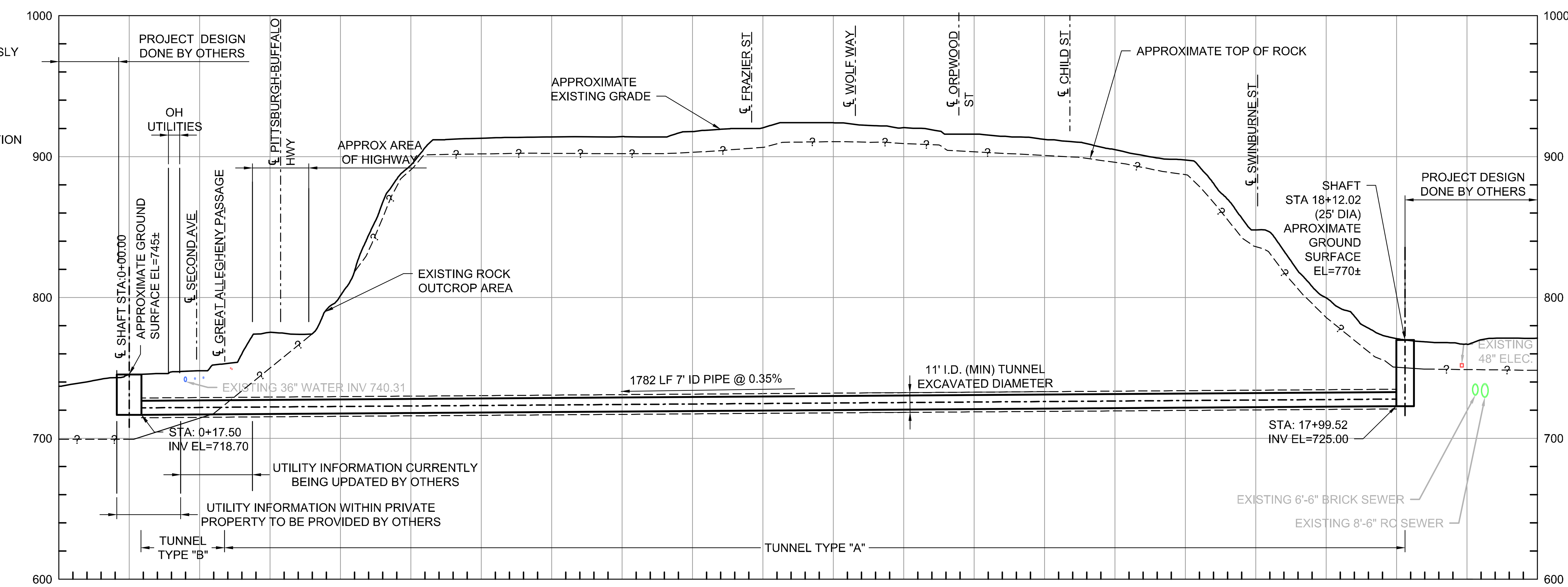

SCALE IN FEET 0 50 100
VERTICAL SCALE: 1" = 50'-0"

SCALE IN FEET 0 100 200
HORIZONTAL SCALE: 1" = 100'-0"

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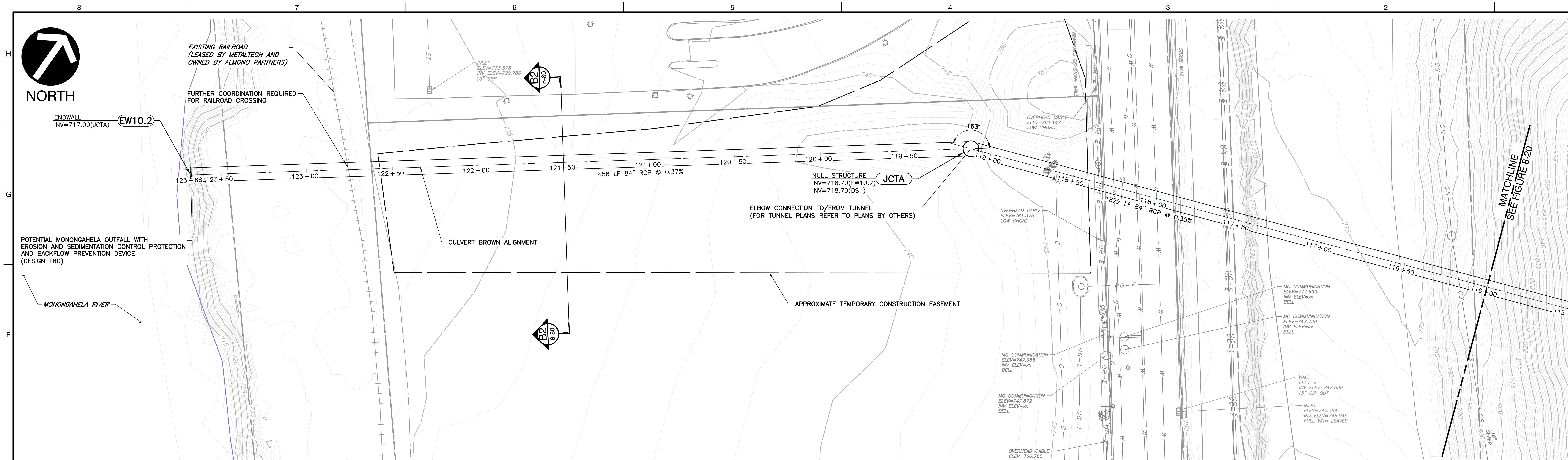
DRAWN BY: RGR	CHECKED BY: SS	APPROVED BY: RB
DATE: MARCH 2019	DWG SCALE: AS-SHOWN	PROJECT NO: 000-000.AW00

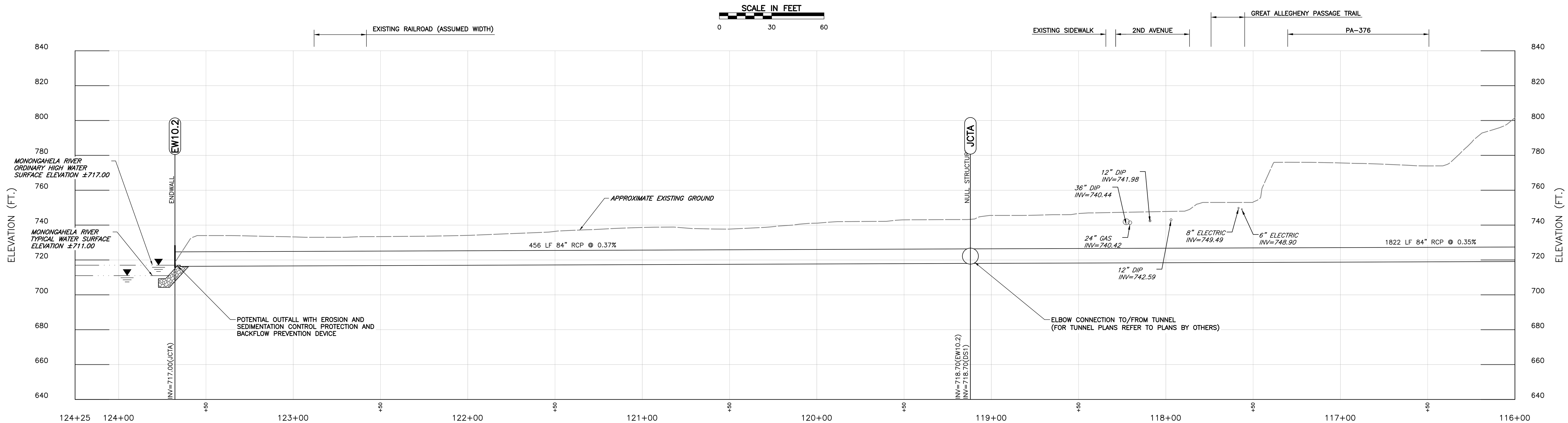
ALTERNATIVE NO. 11
TUNNEL ALONG NEW WEST ROUTE TO SECOND AVENUE PLAN AND PROFILE

FIGURE NO.: 8-20



ALTERNATIVE NO. 12 - OPEN CUT CULVERT ALONG NEW WEST ROUTE TO MONONGAHELA RIVER PLAN

SCALE IN FEET 0 30 60



ALTERNATIVE NO. 12 - OPEN CUT CULVERT ALONG NEW WEST ROUTE TO MONONGAHELA RIVER PROFILE

SCALE H:1"=30'; V:1"=30'

HORIZONTAL AND VERTICAL SCALE IN FEET 0 30 60

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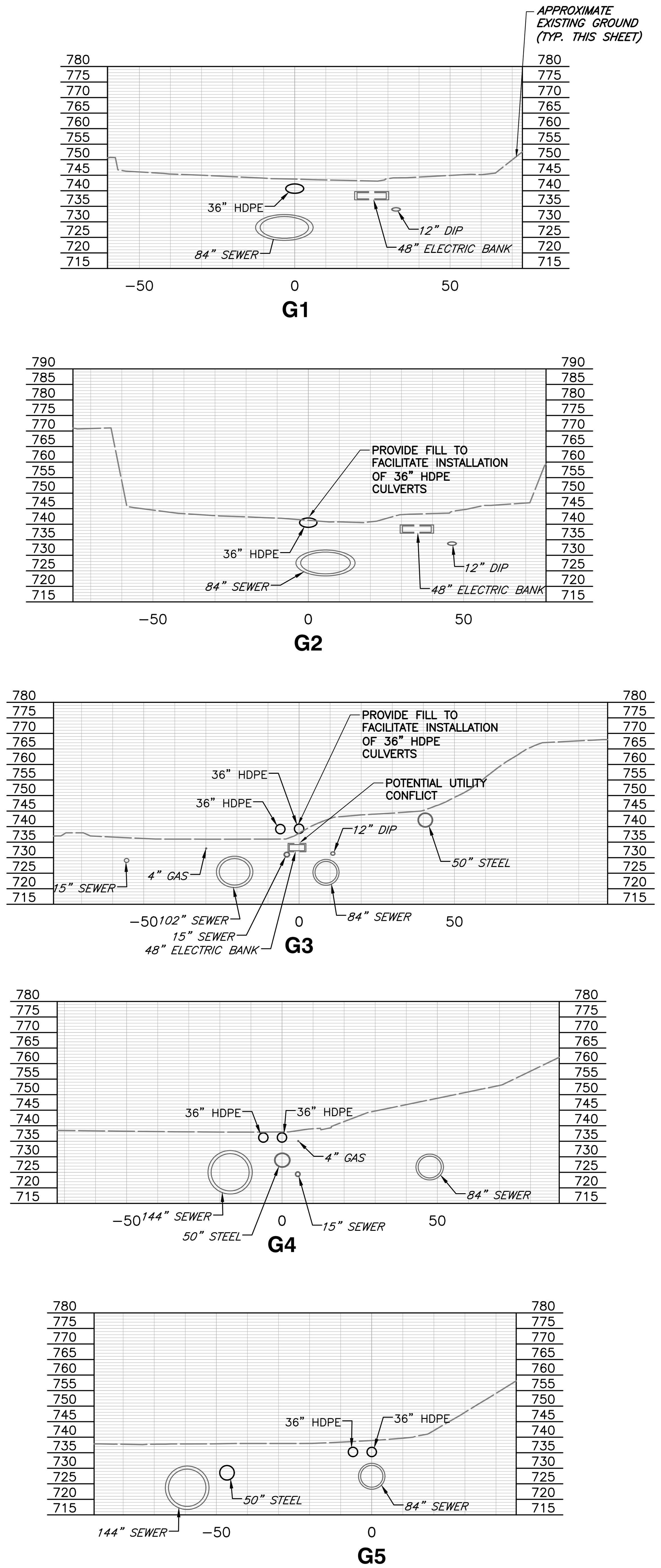
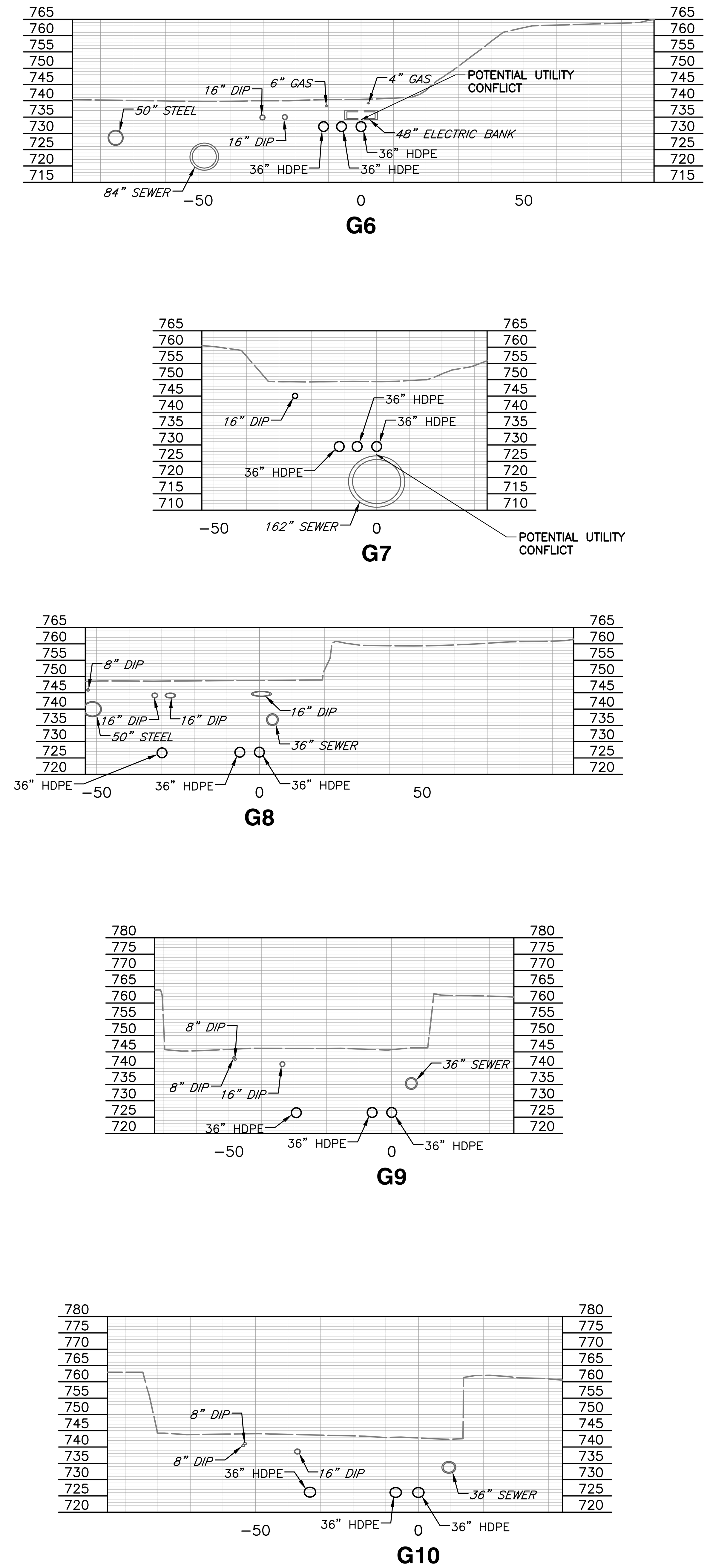
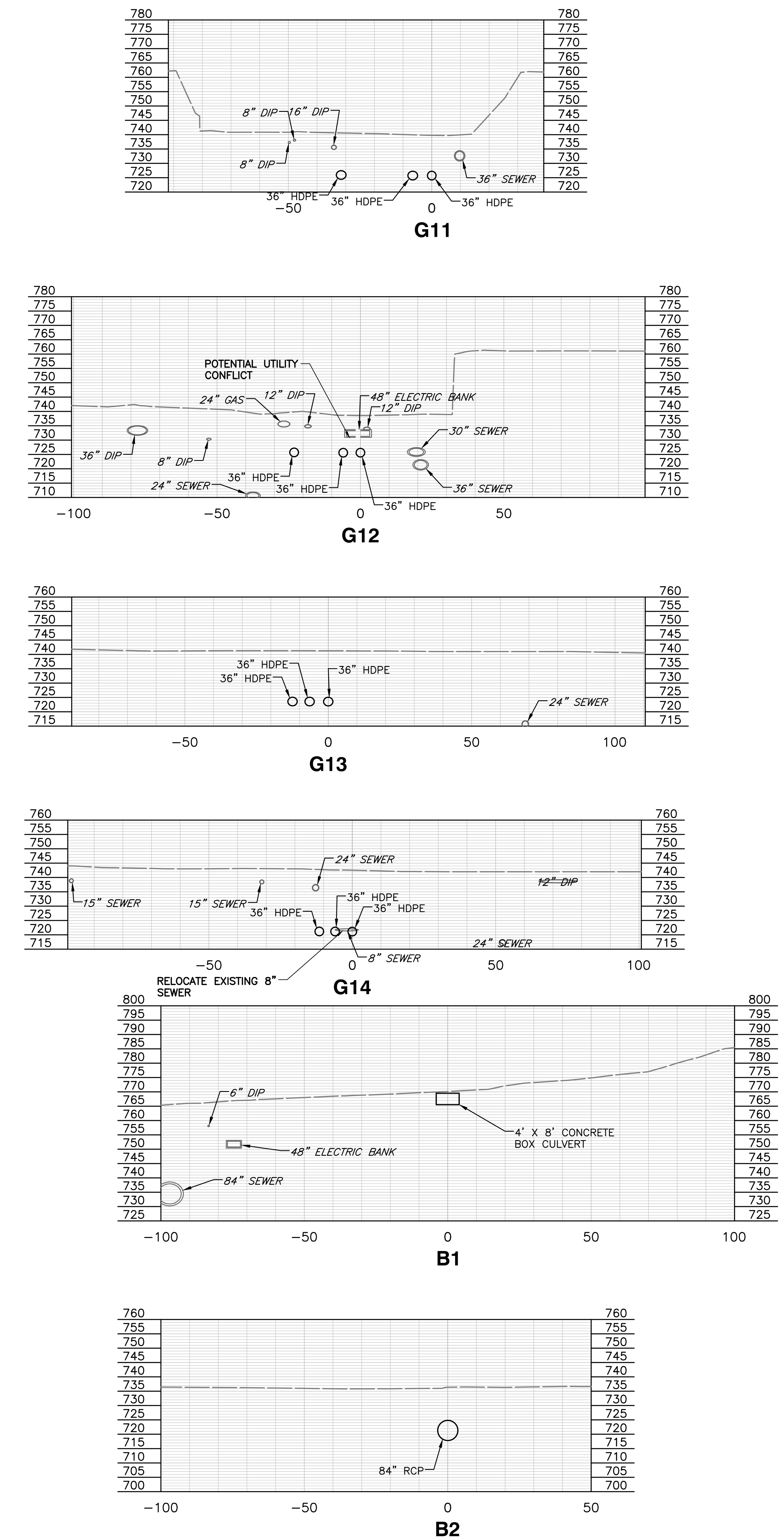
ALTERNATIVE NO. 12
OPEN CUT CULVERT ALONG NEW WEST ROUTE
TO MONONGAHELA RIVER PLAN AND PROFILE

FIGURE NO.: 8-21







ALTERNATIVE NO. 8 AND ALTERNATIVE NO. 9 CROSS SECTIONS

SCALE H:1"=30'; V:1"=30'

HORIZONTAL AND VERTICAL SCALE IN FEET

0 30 60

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ALTERNATIVE NO. 8 AND ALTERNATIVE NO. 9 CROSS SECTIONS

FIGURE NO.: **8-22**

APPENDICES

APPENDIX A

MODELING RESULTS/REPORT

MOTT MACDONALD

Four Mile Run (4MR) Modeling Report

June 10, 2019

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mottmac.com

Four Mile Run (4MR) Modeling Report

June 10, 2019

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
1	02/01/19	Brian Moore	Chavara	Chavara	Incorporation of CEC and other edits
2	06/10/19	Brian Moore	Parks/Healey Langley	Chavara	Incorporation of final CEC, PWSA DCA and Value Engineer's Comments

Document reference: 399786 | 01 | A

Information class: Standard

Contents

Appendices

Tables

Figures

Acronyms and abbreviations

3RWW	3 Rivers Wet Weather
4MR	Four Mile Run
ALCOSAN	Allegheny County Sanitary Authority
BG	Billion Gallons
BSF	Base Sanitary Flow
CCTV	Closed Circuit Television Video
CEC	Civil and Environmental Consultants
CIWEM	Chartered Institution of Water and Environmental Management
CSO	Combined Sewer Overflows
DCA	Design Criteria Area
DWF	Dry Weather Flow
EPA	Environmental Protection Agency
GIS	Geographic Information System
GI	Green Infrastructure
GWI	Ground Water Infiltration
HGL	Hydraulic Grade Line
MG	Million Gallons
MGD	Million Gallons per Day
PDR	Preliminary Design Report
PWSA	Pittsburgh Water and Sewer Authority
SSOAP	Sanitary Sewer Overflow Analysis and Planning
SSO	Sanitary Sewer Overflows
SRTC	Sensitivity-Based Radio Tuning Calibration
TY	Typical Year
SWMM	Stormwater Management Model
WWF	Wet Weather Flow

1 Introduction

The Civil and Environmental Consultants (CEC) team was selected by the Pittsburgh Water and Sewer Authority (PWSA) to develop and evaluate alternatives and prepare a preliminary design for conveyance and storage elements to redirect and convey stormwater from the Four Mile Run (4MR) project area, located in the M-29 sewershed, to discharge to the Monongahela River. A goal of the 4MR Project is to direct stormwater away from the combined sewer system to mitigate flooding and basement backups throughout the 4MR Project area. Mott MacDonald is the CEC team member tasked with performing related hydraulic and hydrologic analyses of the alternatives.

The 4MR watershed is located within the M-29 sewershed which is part of the Allegheny County Sanitary Authority's (ALCOSAN's) Main Rivers collection system model (Main Rivers model). The Main Rivers model includes the downtown central business district of the City of Pittsburgh primarily bounded by the Allegheny and Monongahela Rivers. The Main Rivers model was developed by Chester Engineers (now Hatch) as part of ALCOSAN's 2008-2011 collection system model development efforts to support the development of ALCOSAN's Wet Weather Plan focused on mitigating both combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) from the collection system. The overall ALCOSAN collection system model is composed of seven (7) sewershed models developed by various consultants using the Environmental Protection Agency (EPA) Stormwater Management Model (SWMM) modeling software. This collection system model (ALCOSAN model) was provided to PWSA by ALCOSAN and it served as the starting point for building an updated model to use for the 4MR Project (4MR Project model).

The ALCOSAN M-29 model (ALCOSAN model) was primarily developed to evaluate large scale gray infrastructure projects focused on mitigating CSO discharges. As such, the ALCOSAN model had a greater focus on flows entering the M-29 diversion structure and less focus on the upstream portions of the collection system. Since the 4MR Project has a different focus, the ALCOSAN model was updated for the 4MR Project to make it more suitable for evaluating the 4MR Project alternatives. These alternatives include offloading stormwater from the Schenley Park area from entering the combined sewer along with additional stormwater from the upstream portions of the sewershed to a new stormwater conveyance to the Monongahela River. One of the primary updates to the ALCOSAN model was adding existing open channel conveyances (such as Phipps Run and Panther Hollow Run) and storage (Panther Hollow Lake) that were not included in the ALCOSAN model. Also, to evaluate offloading stormwater from the upstream combined sewer areas, greater detail including more pipes, manholes and smaller drainage areas (subcatchments) were incorporated into the 4MR Project model. To support the calibration/validation of the 4MR Project model, new rainfall and flow metering data were collected. The 4MR Project model has been successfully built, calibrated, validated and used to evaluate initial alternatives included in the Preliminary Design Memorandum (PDM) submitted to PWSA by CEC in March 2019. As the design of the 4MR Project elements are further refined they will be integrated into the 4MR Project model.

2 Model comparison

The 4MR Project model incorporated many updates and changes from the original ALCOSAN model. Table 1 is a comparison of the current ALCOSAN M-29 sewershed model and the 4MR Project model.

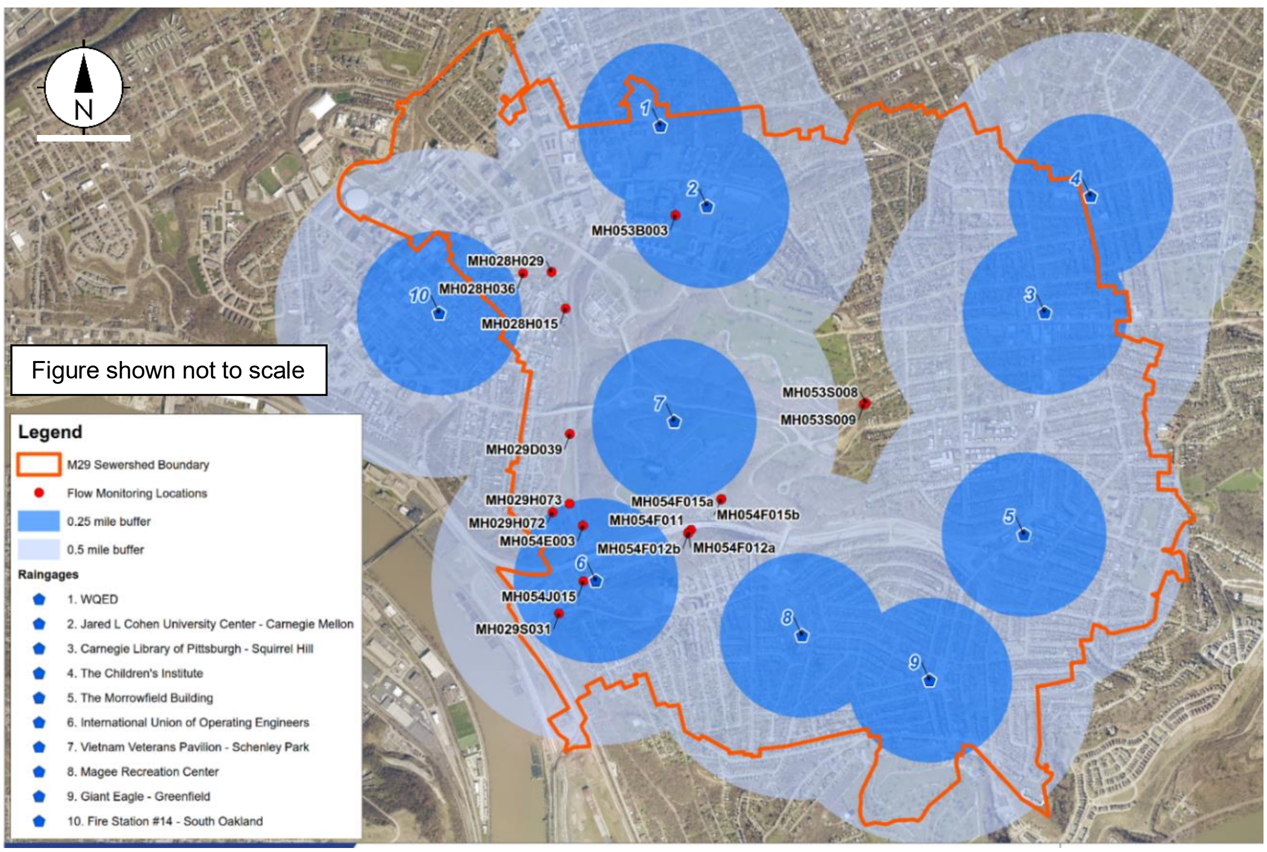
Table 1: M-29 sewershed model comparison (ALCOSAN model vs 4MR Project model comparison)

Category	ALCOSAN model	4MR Project model
Rainfall data	3 Rivers Wet Weather (3RWW) radar rainfall	2018 data from ten (10) new rain gages located in the M-29 sewershed
Flow meter data	Five flow meters installed during 2008-2009	2018 data from seventeen (17) flow meters located in the M-29 sewershed
Model network	Only pipes critical for conveying flows to the M-29 CSO diversion structure were included.	All pipes from the ALCOSAN M-29 model are included along with additional upstream pipes to improve overall model detail. New open channels and a storage element representing Panther Hollow Lake are new additions to the model.
Subcatchments	Large subcatchments averaging 60 acres were included in the original model to reflect the low level of pipe detail included.	The ALCOSAN subcatchments were subdivided into smaller areas averaging about 5 acres per subcatchment.
Dry weather flow (DWF)	DWF provided to the model via an external inflow file containing time series data calculated directly from ALCOSAN's 2008 flow meter data.	DWF components of base sanitary flow (BSF) and groundwater infiltration (GWI) were calculated from the 2018 flow meter data and allocated directly within the model.
Wet weather flow (WWF)	SWMM runoff with Green-Ampt infiltration method	SWMM runoff with Green-Ampt infiltration method

3 Flow monitoring and rainfall data

For this project, seventeen (17) flow meters and ten rain gages were installed from July 1, 2018, through January 1, 2019, throughout the M-29 sewershed area, with data collected at a 5-minute time interval. Four of the flow meters along with the ten rain gages remained in use through June 1st of 2019 to capture spring storm events and better understand seasonal variations. The flow meters primarily used the area-velocity method to calculate pipe flow based on the measured depths and velocities under free-flow and surcharged conditions. The flow meters included both pressure and ultrasonic depth sensors for redundancy along with a velocity sensor that used Doppler technology. At select locations during the flow monitoring, flow meters using Flo-Dar technology were installed when the initially installed flow meters were not recording reliable data. The rain gages were tipping bucket style rain gages. The flow meters and rain gages used wireless technology to transmit collected data. Figure 1 shows the locations of the flow meters and rain gages throughout the project area.

Figure 1: Flow meters and rain gages installed in M-29 Sewershed in 2018



The rainfall and flow meter data were critical for the calibration and validation of the 4MR Project model. Since rainfall determines the magnitude and timing of wet weather response in the collection system, spatially accurate rainfall is essential for high-quality model calibration. The rain gages were distributed throughout the M-29 area as shown in Figure 1 to capture the spatial variability in the rainfall which in Pittsburgh is known to be substantial. Table 2 includes all storm events greater than 0.1 inches of total rainfall using an inter-event time of six hours from August 20th (when all of the rain gages were online) through December 31st (when most flow meters were removed) at rain gage RG07. On the basis of flow meter and rain gage activity, the calibration/validation period selected was August 20 through December 31, 2018.

The flow meters represent points where field measured data is compared against the model simulation results to evaluate model performance. As a result, the number of flow meters installed and where they are placed are important decisions that directly affect the model's predictive reliability. Some of the seventeen (17) flow metering locations were selected to collect data in areas where stormwater was planned on being rerouted away from the combined sewer system. Other flow meters were placed in large diameter interceptors to check overall sewershed response. The Flow Monitoring section of the PDM has additional information on the locations, duration and data collected during the flow monitoring effort.

Flow metering data were reviewed to evaluate their accuracy and reliability before they were used for model calibration and validation. The two primary reasons that flow meter data were excluded from use in the model are meter downtime when no data is collected and if the data exhibited an erratic, inconsistent or repeating pattern that does not match expected patterns. Each of the flow meters experienced these issues to some degree and if storm events were excluded from calibration/validation usage, they are noted in the Appendix.

Table 2: Storm events during the calibration/validation period (RG07)

Storm #	Start Date/Time	Rainfall (in)	Duration (hrs)	Peak Intensity (in/hr)
1	08/29/2018 20:15	0.23	5.42	0.21
2	09/06/2018 11:55	0.45	5.75	0.43
3	09/08/2018 01:00	7.17	65.75	0.64
4	09/17/2018 09:00	1.01	19.00	0.50
5	09/21/2018 20:20	0.73	2.67	0.65
6	09/24/2018 15:45	1.17	25.08	0.17
7	09/26/2018 13:35	0.11	1.83	0.08
8	10/02/2018 15:55	0.27	7.00	0.21
9	10/04/2018 11:10	0.73	7.00	0.50
10	10/06/2018 10:25	0.82	5.17	0.74
11	10/13/2018 00:10	0.22	6.50	0.06
12	10/15/2018 14:50	0.15	7.33	0.08
13	10/26/2018 15:45	0.99	30.17	0.16
14	10/31/2018 15:50	0.32	17.25	0.08
15	11/02/2018 22:40	0.14	9.42	0.07
16	11/09/2018 05:50	0.75	10.50	0.18
17	11/12/2018 16:20	0.27	13.00	0.08
18	11/15/2018 08:35	0.26	8.92	0.09
19	11/17/2018 09:50	0.35	2.00	0.25
20	11/18/2018 22:20	0.67	24.00	0.11
21	11/24/2018 06:20	0.40	3.92	0.18
22	11/26/2018 04:00	0.18	6.50	0.06
23	12/01/2018 12:05	0.32	5.50	0.14
24	12/14/2018 18:50	1.64	39.92	0.22
25	12/21/2018 13:40	0.53	17.08	0.21

26	12/27/2018 22:25	0.27	2.25	0.15
27	12/31/2018 10:00	0.66	11.92	0.22

4 Model building and development

ALCOSAN's M-29 model was modified to include greater collection system detail and some changes in modeling approach to meet the needs of the 4MR Project as documented below.

4.1 Model network

The development of the 4MR Project model consisted of adding greater detail to the representation of existing conditions and then adding new detail to the model that will simulate the proposed alternatives of the 4MR Project. The existing conditions were updated to add new pipes and manholes and to subdivide the existing subcatchments in the model to generate wet weather flow entering these new pipes and manholes. The most significant update to the existing conditions included the addition of new detail within the Schenley Park area to include open channels, Panther Hollow Lake and detailed watersheds contributing runoff to the open channels. This new existing condition detail within Schenley Park allowed for a detailed calibration of flows generated within the Park. Table 3 summarizes the attributes of the existing conditions in both the original ALCOSAN model and the 4MR Project model.

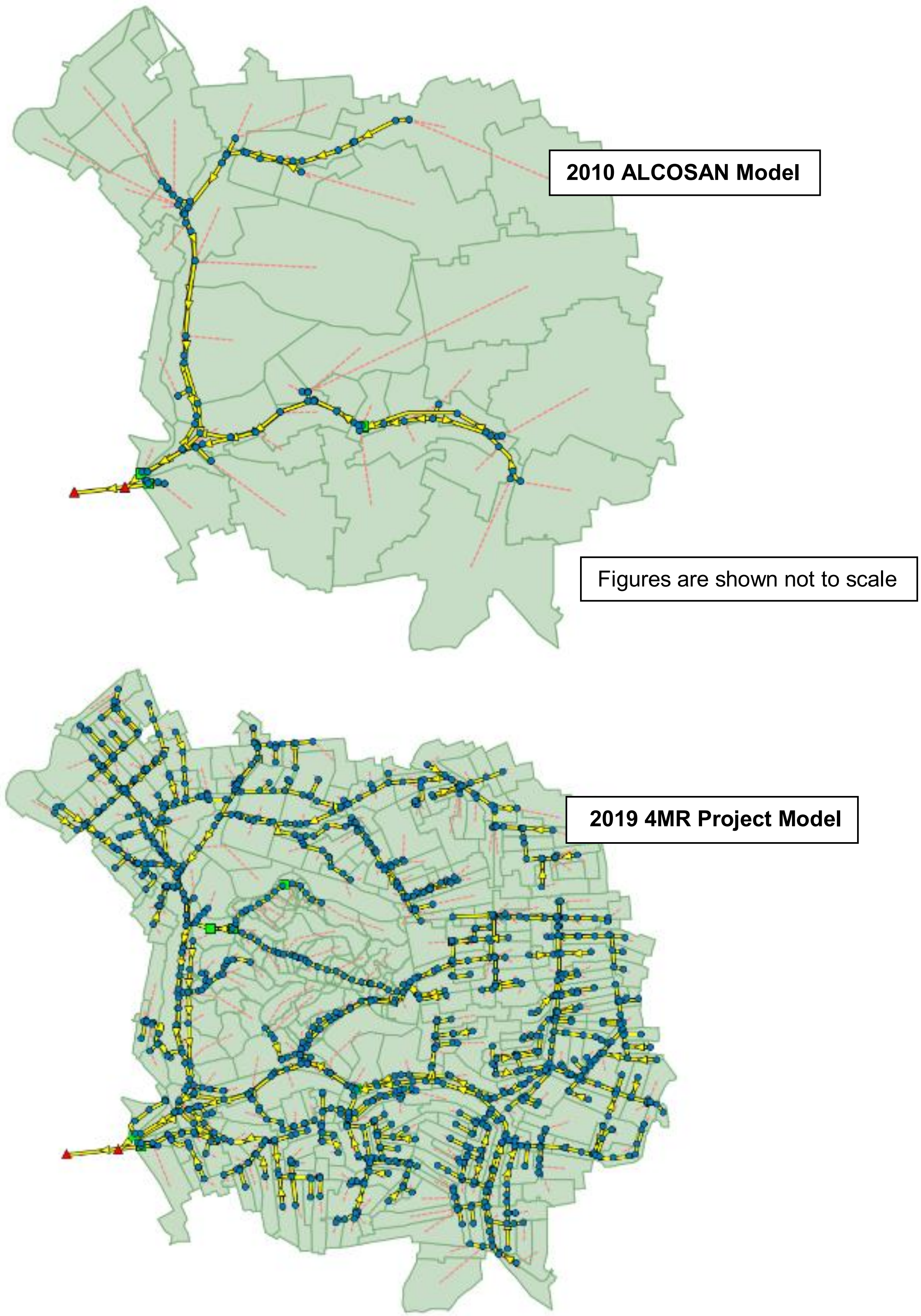
Table 3: M-29 existing conditions detailed model comparison

Category	ALCOSAN model	4MR Project model
Model pipes	88	1,319
Total pipes (3RWW Atlas)	2,550	2,550
Fraction of total pipes in model	3.5%	51.7%
Model manholes	84	997
Model subcatchments	40	458
Average subcatchment area (ac)	59.5	5.1
Average subcatchment slope	15.8%	10.4%
Total contributing area (ac)	2,378	2,418
Total impervious area (ac)	1,141	1,141
Model impervious area (ac)	363	585
Model impervious area fraction	31.8%	51.3%

Figure 2 is a visual representation of the increased detail in the 4MR Project model.

After the existing conditions were updated in the model, it was further modified to investigate proposed 4MR alternatives. The 4MR alternatives that were investigated and the updates that were made to the model to evaluate them are further detailed in Section 6 of this document.

Figure 2: M-29 sewershed models level of detail comparison



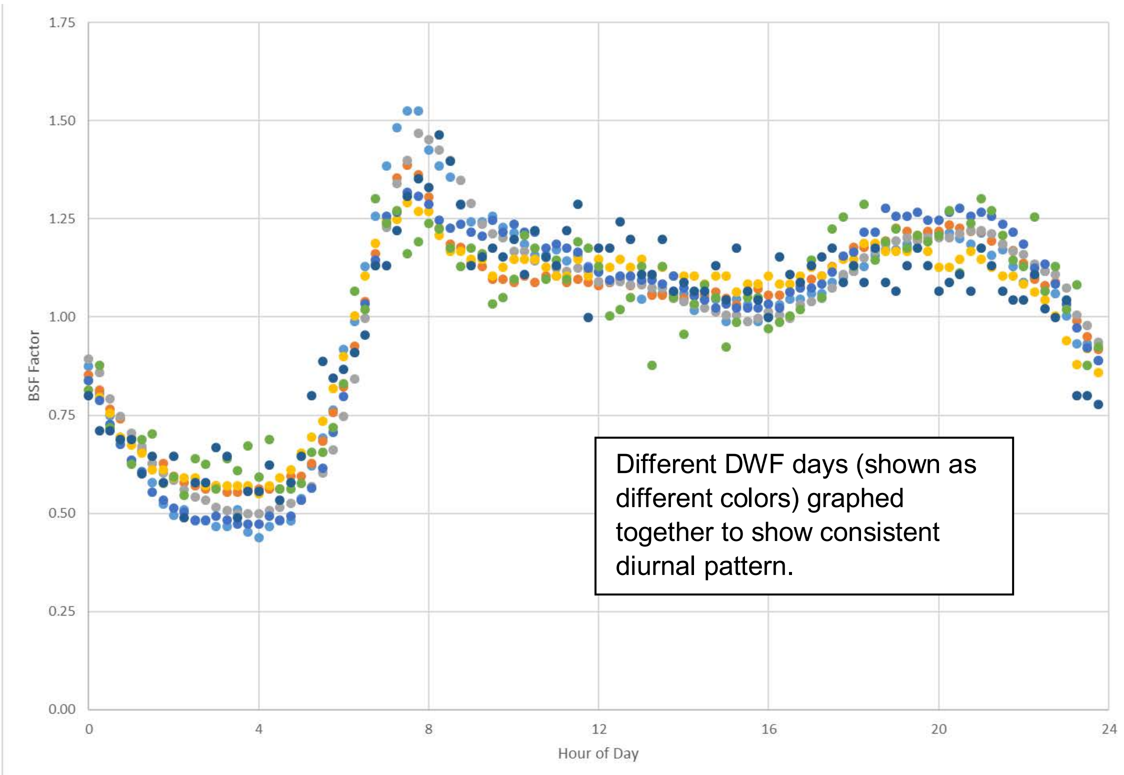
4.2 Dry weather flow determination

The EPA's Sanitary Sewer Overflow Analysis Planning (SSOAP) analysis tool was used to help calculate the DWF components for each flow meter. SSOAP is a commonly used tool that analyzes input rainfall data to identify days that meet specific criteria, such as no rainfall within the prior two (2) days. After the DWF days are identified, it extracts flow meter data for those days to define a typical DWF weekday and weekend day. In addition to the analytic tools available within SSOAP, the identification of DWF days over the 6-month rainfall and flow monitoring period was further refined based on visual inspection to ensure selected DWF days exhibited no or minimal wet weather influence. Potential DWF days were investigated and discarded if they had missing flow meter data or showed obvious signs of wet weather influence, such as unusual flow spikes potentially indicating rainfall influence. The DWF days that were retained were averaged together on a time step basis to form a typical DWF weekday and a typical DWF weekend day. Average DWF days were separated into its BSF and GWI components by applying the Stephens-Schutzbach equation (Determining Base Infiltration in Sewers, ADS, 2008, available for download at http://www.adsenv.com/resources/white-papers). This equation sets the dividing point between the BSF and GWI at about 75 percent of the minimum daily DWF. Although other industry accepted methods are used to divide DWF into its components, the Stephens-Schutzbach equation has proven reliable compared to other methods.

BSF includes diurnally varying sanitary sewage flow when the sanitary sewage is predominantly generated from residential, and institutional sources. These flows are largely population driven and the 4MR Project model allocated BSF based on population fraction. The populations of individual subcatchments were calculated by intersecting 2010 US Census block data with the subcatchment polygon boundaries. For each subcatchment, the population of an individual subcatchment versus the total population tributary to a flow meter represents the fraction of the flow meter's calculated BSF allocated to each specific subcatchment. After reviewing the DWF distribution in the 4MR Project model, additional adjustments were made to achieve the best overall fit to the available DWF periods identified for model calibration.

After the BSF was allocated to the subcatchments, a dimensionless diurnal pattern was applied to reflect how the BSF varies throughout the day. Figure 3 shows an example of the diurnal patterns calculated from the flow meter data. Diurnal patterns calculated from flow meters in larger subcatchment areas were substituted in cases where flow meters exhibited erratic diurnal patterns due to very small measured flows, limited usable DWF, or missing data. Separate diurnal patterns were calculated for weekdays and weekends since these two sets of days typically exhibit different temporal patterns. This analysis resulted in two diurnal flow patterns that were then imported into SWMM and applied to the appropriate subcatchments. The model automatically selects the appropriate diurnal pattern depending on the calendar day.

Figure 3: Example DWF diurnal patterns



Similar to the allocation of the BSF on a population fraction basis, the GWI was allocated based on a pipe “inch-mile” fraction basis. The pipe inch-mile value is calculated by multiplying the length of a pipe (in miles) by its diameter (in inches) as a representation of the surface area available for infiltration to enter the pipe. This industry standard approach assumes that subcatchments with more physical pipe surface area are expected to have greater GWI. The total number of physical pipes within a subcatchment were used for this calculation even though not all these pipes exist in the model. The total pipe inch-mile value calculated for the entire tributary area upstream of each flow meter was then fractionalized to individual subcatchments. These fractions were then multiplied by the computed GWI and entered into the model.

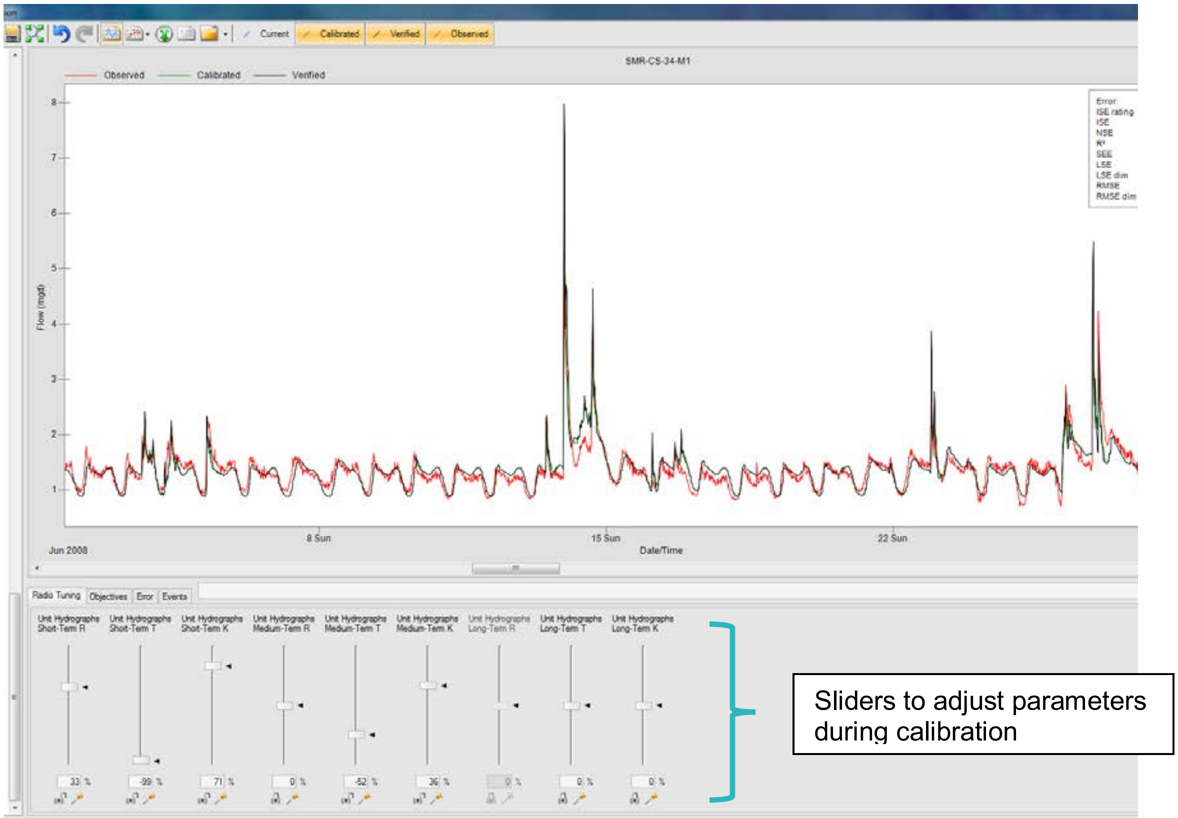
5 Model calibration and validation

After completion of the 4MR Project model building phase, model performance was evaluated during the model calibration and validation phase. Model calibration generally consists of changing the characteristics of the sewer network and subcatchments to achieve acceptable agreement between simulated and observed flows, depths and velocities. Model validation involves checking the model's performance against an independent set of storm events not used for model calibration. This represents an independent check of the model's "true" performance. In a highly reliable model, the model's calibration and validation performances should be somewhat similar. If the model performs noticeably different during validation than calibration, it may indicate that the model could be "overfit" to the calibration storms and that more storms need to be considered for calibration.

Model calibration starts with DWF calibration which is then followed by WWF calibration. WWF calibration evaluates the model's performance during and soon after storm events when flows in the conveyance system are elevated compared to their typical DWF levels. DWF calibration ensures that the collection system model realistically mimics the performance of the physical conveyance system under typical DWF conditions, and this provides a reliable foundation for performing WWF calibration. WWF calibration is more complex than DWF calibration since there are many variables that can affect the system's response to rainfall, such as antecedent conditions and changing groundwater influence. Since the M-29 sewershed is primarily composed of combined sewers, the WWF calibration process involved adjusting the SWMM RUNOFF variables (defined in Section 5.2) to provide the best match between simulated and measured results. Details about the 4MR Project project model's DWF and WWF calibrations are discussed below.

To aid the calibration process, the built-in semi-automated calibration tools within PC-SWMM were applied to this project. The Sensitivity Radio Tuning Calibration (SRTC) tool was applied to the DWF and WWF calibration processes to improve the overall calibration results compared to manual calibration approaches. A screenshot of this tool in use is shown in Figure 4 including how it allows for quickly determining the relative impact of different variables by using a slider function to estimate the changing variables' influence on the simulation results. This allows the user to quickly determine which variables to adjust to achieve the best match to the flow meter data. This approach is much more efficient than trial and error manual methods which are often time intensive and only allow time for investigating a limited number of model adjustments.

Figure 4: PC-SWMM SRTC screenshot



5.1 Dry weather calibration

DWF was distributed to the model subcatchments as discussed in Section 4.2. BSF typically does not change throughout the year, except potential changes due to transient populations, and the model applies the same BSF regardless of the time of year of the model simulation. The DWF periods used for calibration were taken from September, October and December of 2018 and would therefore include times when college students would be in semester. No reduction in BSF was applied to the 4MR Project model for the summer months. However, GWI can exhibit seasonal fluctuations due to changing groundwater table elevations or seasonal changes in the degree of soil saturation around the collection system pipes. The GWI for the 4MR Project model were defined as constant inflows because the collected flow monitoring data did not indicate large or consistent patterns in the GWI to warrant monthly varying adjustments. Normally the highest GWI periods occur in the late winter and spring seasons when there is more rain and elevated groundwater table elevations compared to other times during the year. Four of the seventeen (17) installed flow meters were extended through June 1, 2019 to determine if significant GWI variation is detected. If these data support applying monthly varying GWI factors to targeted areas within the model it will need to be documented and incorporated into a future model update. Comparisons between predicted and observed DWF were quantified in tabular form and visually through observed versus predicted plots at each flow monitoring location and are included in the Appendix.

The 2018 calendar year included the greatest total annual rainfall recorded in the City of Pittsburgh. As a result, there were fewer DWF days than is typically expected over a 6-month flow monitoring period. However, three 4-day DWF periods were identified with one each in the months of September, October and December. These three periods provide an adequate check of the 4MR Project model's DWF performance.

Quantitative calibration and validation criteria applied to the 4MR Project model were taken from the Chartered Institution of Water and Environmental Management (CIWEM) Code of Practice for the Hydraulic Modeling of Urban Drainage Systems (2017). The CIWEM is a United Kingdom-based organization that has long defined collection system modeling standards that are frequently applied throughout the world. Quantitative comparisons between the measured flow meter data and the model's dry weather results were performed to evaluate the 4MR Project model's DWF performance. The DWF calibration criteria are as follows:

- Modeled peak wastewater flows should be within -10% to +20% of the observed peak wastewater flows;
- Modeled 24-hour wastewater volumes should be within -10% to +20% of the observed wastewater volumes; and
- Modeled peak wastewater flow occurrences should be within 1 hour of the observed times of occurrence.

The model's DWF response was adjusted using the SRTC tool to get the best overall predicted DWF for the entire flow monitoring period.

5.2 Wet weather calibration

Following completion of the dry weather calibration, wet weather calibration was initiated. The wet weather response from the combined sewer system within the M-29 sewershed utilized the SWMM Runoff and Green-Ampt infiltration methodology. SWMM generates wet weather runoff in response to rainfall by using the following variables:

- Subcatchment Area;
- Depression Storage;
- Subcatchment Width;
- Subcatchment Slope;
- Overland Flow Routing Coefficient; and
- Green-Ampt Infiltration Variables (Pervious Areas).

A discussion of these variables is presented below.

5.2.1 Subcatchment area

Each individual subcatchment polygon contains three (3) variables that describe the area contributing runoff entering the open channel or piped conveyance network. These variables include:

- Total area;
- Percentage of total area that is impervious surface; and
- Percentage of impervious surface that has zero depression storage.

These variables were initially estimated from Geographic Information System (GIS) data obtained from PWSA and then refined during the calibration process. The total area represents the physical area of the specific subcatchment that is contributing flow to the collection system. The percentage impervious area is the percentage of the subcatchment area where runoff cannot infiltrate. This area includes paved roadways, sidewalks, and driveways and other miscellaneous impervious surfaces. The percent of impervious area that has zero depression storage represents area where nearly all the rainfall is immediately transformed into runoff to the collection system (typically roof areas). Since not all the physical impervious area is directly connected to the collection system, the impervious area that has zero depression storage is less than the total physical impervious area on the surface. This is because some impervious surfaces do not contribute to the collection system such as driveways draining to a backyard, or sidewalks draining to grass areas. This percentage of impervious areas that have zero depression storage variable was a key tuning variable during model calibration as it impacts both the volume of runoff produced and the peak flow from that runoff.

5.2.2 Depression storage

Depression storage represents the volume of rainfall that does not enter the conveyance system due to initial surface wetting, ponding, and evaporation at the beginning of a storm event. Infiltration involves water entering the soil increasing its level of saturation while depression storage represents water that due to physical constraints (such as pot holes in a roadway) or natural processes (such as tree leaves intercepting some rainfall before it reaches the ground). Plots of WWF versus rainfall were used to help define the point where rainfall did not produce any measured WWF response at each flow meter. This variable was adjusted during calibration to better match the WWF response during smaller storm events.

5.2.3 Subcatchment width

The subcatchment width is the primary variable used to adjust the hydrograph shape and to best match peak flow. From a physical standpoint, this variable affects the time of concentration of surface runoff. Larger width values (and hence smaller subcatchment length values) result in shorter times of concentration and larger peak flows. The subcatchment width was adjusted using the SRTC tool to increase or decrease the model's peak flow response without changing the WWF volume generated.

5.2.4 Subcatchment slope

The subcatchment slope represents the average overall gradient of the land surface, affecting the time of concentration of surface runoff. This variable is a secondary calibration parameter and was only slightly adjusted during WWF calibration.

5.2.5 Overland flow routing coefficient

The overland flow routing coefficient is equivalent to the Manning's Roughness Coefficient (n) which represents the resistance to flow as water travels overland. It is a secondary calibration parameter that can be used to alter the shape of the hydrograph and slightly adjust the peak flow. The variable was generally left unchanged from the initial values based on assigning the roughness based on surface cover. In the large pervious areas within Schenley Park this variable had greater influence on the model calibration because the flow contributions in this area are dominated by the pervious runoff response rather than impervious runoff response which dominates in the rest of the sewershed.

5.2.6 Green-Ampt infiltration variables (pervious areas)

Pervious surfaces can generate runoff leading to the collection system, but only after their infiltration capacity has been fully utilized. At the beginning of a storm event, rainfall on pervious surfaces will simply infiltrate into the soil and not generate any runoff to the collection system. However, once the soil becomes fully saturated and can accept no more water, any additional rainfall becomes runoff to the collection system. The Green-Ampt infiltration method was retained from the original ALCOSAN model for modeling pervious surface infiltration in the 4MR Project model. For continuous model simulations over multiple seasons, the runoff generated from pervious surfaces is typically very small compared to the runoff generated from impervious surfaces. As such the infiltration variables are secondary calibration variables and were largely left unchanged from their initial values.

5.2.7 Wet weather calibration goals and criteria

After completion of the DWF calibration, WWF calibration of the model was performed. Detailed below are the goals and criteria that were used to evaluate the state of the model's WWF calibration:

- A regression line with an R2 value close to 1.00 indicating a goodness-of-fit between the modeled and observed wastewater volumes and peak flows for wet weather events;
- An intercept of the regression line close to zero (0) indicating that the modeled wastewater volumes and peak flow rates for wet weather events were not biased with respect to the observed volumes and peak flows; and
- Matching as closely as possible the ratio of the wastewater time to peak for the modeled and observed wet weather events indicating that the shapes of the modeled and observed hydrographs are similar.

In addition to the WWF calibration goals, individual calibration criteria are defined for the comparison of simulated WWF and flow meter data collected during storm events. As mentioned previously, all numerical calibration criteria are based on accepted CIWEM standards. These criteria consist of the following:

- Modeled peak flows should be within +25 percent and -15 percent of the observed peak flows;
- Modeled wastewater volumes for wet weather events should be within +20 percent and -10 percent of the observed volumes;
- Modeled depths of flow in surcharged sewers should be within +18 inches and -4 inches (in sewers 21 inches in diameter and larger) and within +6 inches and -4 inches (in sewers smaller than 21 inches in diameter) of the observed depths of flow;
- Modeled depths of flow at unsurcharged critical points in the system should be within 4 inches of the observed depths of flow; and
- Shape and timing of the hydrographs should be similar.

5.2.8 Wet weather calibration results

The results of the WWF calibration are detailed in the Appendix. Overall WWF calibration generally showed a good agreement between the measured and simulated results based on calibration statistics and hydrograph plots of the flow meter vs. model results. However, in some cases the model's WWF simulation results do not match the corresponding flow meter's data within the WWF calibration range. The primary cause for the divergence between the measured and simulated WWF results is inconsistent WWF response between different storm events for the same flow meter. This issue often involves the underlying flow meter data, such as data dropouts during storm events. Table 3 provides a summary of the WWF calibration and validation performance by flow meter. The model performance is summarized by the number of storm events that meet 0, 1, 2, or all 3 of the CIWEM calibration/validation criteria listed in Section 5.2.7.

Table 4: Wet weather model calibration and validation summary

Flow Meter	Diameter	3 of 3 criteria	2 of 3 criteria	1 of 3 criteria	0 of 3 criteria
MH028H015	81"	5	4	2	0
MH028H029	54"	10	2	3	0
MH028H036	21"	1	4	5	0
MH029D039	48"	1	10	2	1
MH029H072	18"	4	8	2	0
MH029H073	78"	2	8	4	0
MH029S031	21"	5	8	1	0
MH053B003	48"	3	2	2	0
MH053S008	36"	8	3	3	1
MH053S009	48"	1	4	6	0
MH054E003	96"	4	7	2	1
MH054F011	68"	3	5	3	0
MH054F012	24"	Not Reported Due to Inconsistent Data			
MH054F012	81"	Not Reported Due to Inconsistent Response to Rainfall, See Appendix			
MH054F015	18"	Not Reported Due to Extremely Low Measured Flows			
MH054F015	30"	Not Reported Due to Evidence of Flow Bypass			
MH054J015	36"	4	9	1	0
	Totals	**51**	**74**	**36**	**3**

The calibration and validation results indicate that about one third of all storm events met all three numerical criteria and over 75% met at least two of the three numerical criteria. This represents acceptable model performance and that the model should have reliability for use throughout the 4MR Project. The reader is directed to the Appendix for additional details on the model calibration and validation results.

5.2.9 Calibration notes and limitations

Every collection system model is a mathematical representation of the very complex physical reality of a collection system. As such, all models have limitations to their reliable use and it is important to understand these limitations in interpreting their results. Below are some points to consider:

- Flow meter data from MH054F015 in the Naylor Run area are likely not capturing all the flow coming down the steep ravine because there is evidence that a significant portion of the flow is bypassing entry into the collection system. Flows measured at this flow meter in this location were abnormally low and should be further investigated.
- Extreme or out of range adjustments were not implemented in the model solely for the purpose of manipulating the matches between the flow meters and model simulation results. An example of this is the interceptor flow meter MH054F011 where the model produces an acceptable match to the measured peak flows but cannot match the long-

term infiltration "tail-effect" without physically unrealistic manipulations in the model. As a result, the model was adjusted within a reasonable range and the results provided at that point.

- Some adjustments were implemented in the model that significantly alter the distribution of interceptor flows compared to the ALCOSAN model. One example is a cross connection between the two parallel northern interceptors near Yarrow and Boundary Streets. After review of Closed Circuit Television Video (CCTV) data and as-built information obtained from PWSA, the cross connection now flows in the opposite direction. This change improved the balance of flows between the interceptors in the 4MR Project model, but it represents a significant change from ALCOSAN model. A second example is along the parallel interceptors to the east near the Greenfield Bridge. The ALCOSAN model had a substantial flow restriction along the north interceptor that forces more flow to the south interceptor. After review of CCTV provided by PWSA and as-built data no evidence could be found that this restriction exists, and it was subsequently removed from the 4MR Project model.
- Flow monitoring data is one of the most critical aspects of any modeling project as the model's performance is directly evaluated against it. Many factors including adverse hydraulics, debris, the presence of very low flows and other variables can make collecting high quality data difficult. The flow metering data used for model development and calibration exhibited the following issues to various degrees: meter drop outs (apparent periods of time when the meter was not recording data), abrupt changes in flow after meters were reset or cleaned, periods when the flow meter data indicated repeating flow, depth and/or velocity values for multiple time steps in a row and erratic data or drifting sensors. These issues are expected during a flow monitoring project. Although numerous storm events were recorded during the flow monitoring period, in some cases storm events were removed from calibration/validation comparisons because the flow meter data was not deemed reliable enough for a comparison, thereby reducing the number of storm events left to use for calibration and validation. The flow meter reset issue particularly affected some DWF comparisons as the DWF rate often changed abruptly after the flow meter was reset. In those cases where this was observed, during the DWF calibration, those DWF periods were not used for calibration.

5.3 Model validation

Following model calibration, model validation was conducted to check the model's performance against an independent set of storm events. This represents an independent check of the model's "true" performance representing its expected performance when simulating any arbitrary storm event. Model validation applies the same numerical criteria as model calibration that were discussed in Section 5.2.7. The 4MR Project model exhibited nearly the same validation performance as calibration performance indicating that the model should have acceptable overall performance when simulating new storm events.

6 4MR modeled alternatives analysis

After completion of the calibration and validation process, the model is capable of evaluating potential alternatives. However, before alternatives were investigated, the 4MR Project model was simulated for the typical year (TY) under three (3) different baseline conditions. The baselines represent different configuration assumptions for key elements that are not part of the 4MR Project, but that may exert significant influence the CSO discharge results. For the 4MR Project, three (3) different baselines were simulated as detailed in Table 5.

Table 5: Model baseline descriptions

Criteria	Existing Conditions	Baseline 1	Baseline 2
M-29 Flap Gate Installed	No	Yes	Yes
ALCOSAN WWTP Capacity	250 MGD	600 MGD	600 MGD
M-29 Diversion Weir Lowered 2.0 Feet	No	Yes	No

MGD – million gallons per day

The installation of the flap gate prevents water from the Monongahela River from entering and backing up into the M-29 diversion structure. SWMM provides the ability to simplistically represent a flap gate by toggling a flap gate property on or off for any pipe. Switching the flap gate on prevents reverse (river) flow entering the pipe but does not represent any of the head losses that a real-world flap gate produces. At the time of the completion of this report, for Baseline Conditions 1 and 2, the M-29 flap gate is incorporated into the model using the flap gate property "on". In the future when the head loss characteristics of the actual flap gate to be installed are available, a more detailed representation of the flap gate is recommended for inclusion into the 4MR Project model.

With the flap-gate analyses incorporated simplistically as "on," the inclusion of a flap gate has a modest effect on CSO discharges to the Monongahela River. The increase in the capacity of the ALCOSAN's Woods Run wastewater treatment plant has a dramatic impact on the M-29 CSO discharges by reducing CSO discharges by over 100 million gallons (MG) during the typical year. Weir modification in the M-29 diversion structure had the inverse effect, because lowering the weir crest elevation increases CSO discharge through the M-29 outfall pipe.

The 4MR Project model was simulated for each of the three (3) conditions to better understand how the baselines provide different starting points for the M-29 TY CSO volume. Table 6 lists the CSO discharges under these different baseline conditions.

Table 6: 4MR TY baseline CSO discharges (MG)

Baseline	TY CSO Discharge (MG)
Existing Conditions	382
Baseline 1	365
Baseline 2	266

6.1 Discussion of 4MR project alternatives

The 4MR Project goals consist of redirecting stormwater runoff away from the existing combined sewer collection system and into new dedicated stormwater conveyance features, resulting in new stormwater discharges into the Monongahela River. The “core” 4MR Project alternatives involve offloading flow tributary to the combined sewer system from Schenley Park through Panther Hollow Lake and capturing stormwater from the Naylor Run/Saline Street area and conveying both downstream through open channel and piped conveyances to a new stormwater discharge point at the Monongahela River.

The 4MR Project includes additional project scope termed “Watershed Expansion”. The Watershed Expansion portion of the project being completed by others investigates additional projects to offload stormwater from the combined sewer system further upstream in the M-29 sewershed. In concept, this offloaded stormwater would then be conveyed to the “core” project infrastructure for conveyance to the Monongahela River. Thirteen (13) potential Watershed Expansion subprojects are currently envisioned as part of the overall Watershed Expansion concept. A draft technical memorandum detailing these projects is titled “Four Mile Run Stormwater Improvement Project Watershed Expansion Memorandum”, dated April 11, 2019. The memorandum is currently available on PWSA’s e-Builder system.

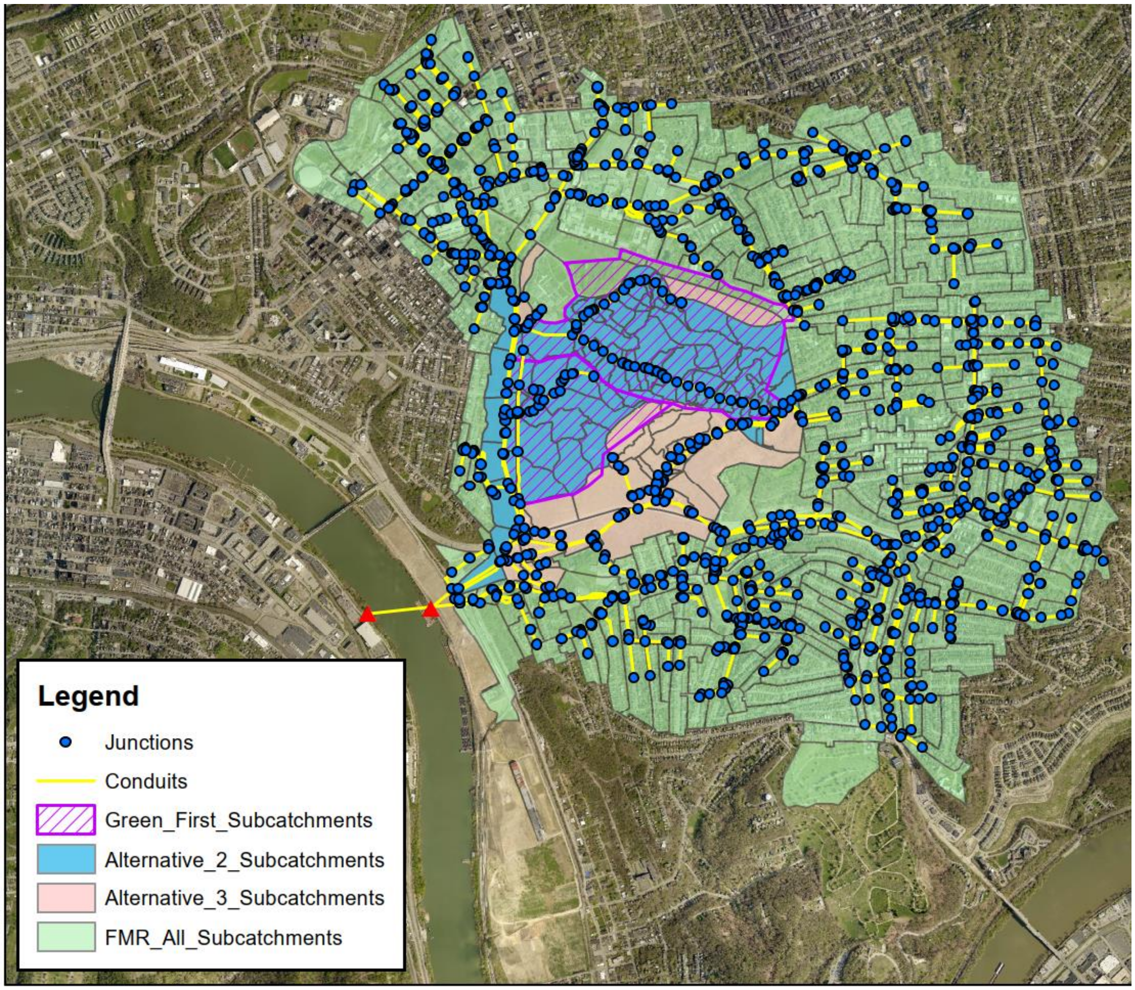
6.2 “Core” 4MR project alternatives

The “core” 4MR Project extends from open channels upstream within Schenley Park downstream to the Monongahela River. Three (3) primary alternatives have been modeled and are listed below:

- **Alternative 1:** Conveyance of upstream open channel flows from Phipps Run and Panther Hollow Run through Panther Hollow Lake to a new open channel through Junction Hollow eventually conveying the flows from the soccer field into a new tunnel discharge to the Monongahela River. The new tunnel under consideration is the Brown Alignment that would convey flow from the soccer field directly to the Monongahela River at the northern end of the Hazelwood Green Property; and
- **Alternative 2:** Identical to Alternative 1 but with a combination of open channel and culvert sections starting at the soccer field discharging to the Monongahela River adjacent to the Hazelwood Green development site; and
- **Alternative 3:** Identical to Alternative 2 but with redirected stormwater from the Naylor Run area also being routed to the Hazelwood Green stormwater discharge.

After discussions with PWSA following the completion of the draft 4MR Modeling Report, dated February 1, 2019, the decision was made to consider Alternative 3 as the “base alternative” to formally include the redirection of stormwater from Naylor Run. For this reason, Alternative 2 is considered obsolete and only Alternatives 1 and 3 are fully detailed as follows. However, for comparative purposes, Figure 5 graphically overlays the tributary areas for Alternative 2 and Alternative 3.

Figure 5: Comparison of Alternative 2 vs. Alternative 3 Tributary Areas



To better understand the components of the "core" 4MR Project alternatives they have been broken into upstream and downstream sections as detailed below:

- **Upstream Section** includes Panther Hollow Lake, Phipps Run and Panther Hollow Run open channels and the discharge from the lake through a culvert under the railroad tracks to a new open channel along Junction Hollow; and
- **Downstream Section** includes the area starting at the soccer field at the downstream end of Junction Hollow. In Model Alternative 1 the flow is conveyed from the soccer field through a new tunnel to discharge directly to the Monongahela River. For Model Alternatives 2 and 3, flow from the soccer field is conveyed downstream through new open channels and closed conduit through a local neighborhood to a new stormwater discharge at the shoreline of the Monongahela River at the Hazelwood Green property.

Design criteria were established to set a minimum level of acceptable performance for proposed alternatives. These design criteria, as provided by CEC, include the following considerations:

- A minimum of 1 foot of freeboard at Panther Hollow Lake for the 100-year design storm (PA Code Chapter 105, Dam Safety Requirements); and

- New open channel sections downstream of the soccer field storage must convey the 100-year design storm within their channel banks (PA Code Chapter 105, Water Encroachment Requirements).

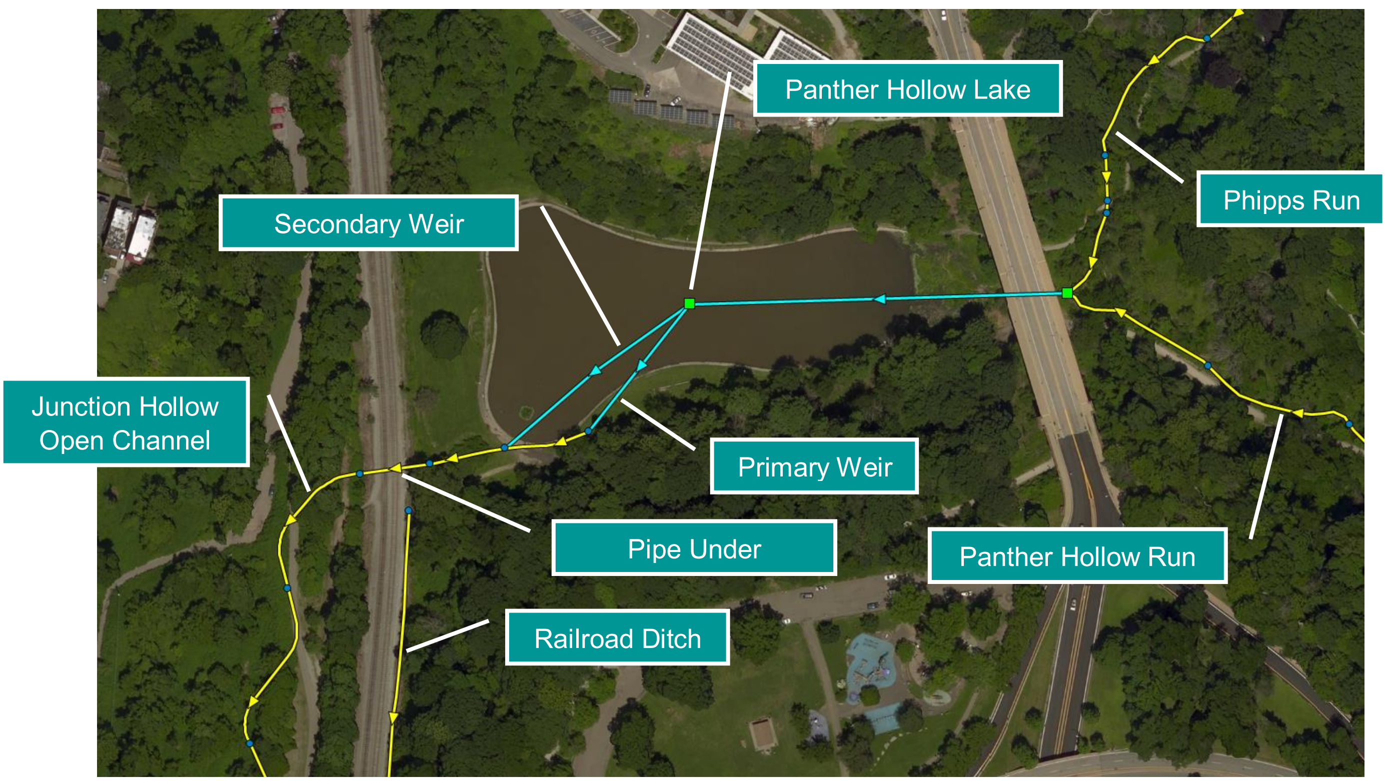
The infrastructure in the 4MR project was initially sized to meet the design criteria above, but the modeled pipe sizes will be further refined as the design progresses. Initially, round (circular) pipes were assumed for this analysis, but as the design progresses, the pipes could be configured in other shapes with an equivalent cross-sectional area.

Below is a detailed discussion of the upstream and downstream sections and the currently proposed 4MR improvements in each section.

6.2.1 4MR Project Alternative, Core Upstream section

Figure 6 illustrates the modeled components of the upstream section of "core" 4MR Project alternatives. The specific properties of the various components (pipe inverts, weir crests, etc.) were current as of the writing of the draft 4MR Modeling Report, dated February 1, 2019. Alternatives are actively being refined by the CEC Team under the direction of PWSA.

Figure 6: 4MR Project Alternative, Core Upstream Section



Both Alternative 1 and Alternative 3 have the same upstream components that are more fully detailed below.

- Updates to the Phipps Run and Panther Hollow Run open channels to enable them to convey higher peak flows by changing the slopes and alignments of the existing open channels and reducing sediment deposition to Panther Hollow Lake. Where existing walking trails cross over the open channels, the existing stone arch culverts will be replaced with larger structures to remove these hydraulic bottlenecks;

- Panther Hollow Lake will be dredged and deepened to create greater storage volume. A new forebay just upstream of the lake will help capture sediments before discharging into the lake. New primary and emergency open channel discharge spillways will be designed and the existing pipe connection from Panther Hollow Lake to the downstream combined sewer system will be removed;
- The installation of a new elliptical culvert under the existing railroad tracks will convey discharge from Panther Hollow Lake to Junction Hollow. The culvert will also provide pedestrian access between the two features. The Basis of Design report should be referenced for the details of this and other alternative components evaluated by the project team;
- A newly proposed Junction Hollow open channel ending at a new earthen berm downstream of the soccer field with the intent that Junction Hollow will inundate a wide floodplain during large storm events. The open channel will also convey runoff from the adjacent existing west hillside; and
- An updated railroad ditch which will convey runoff from the adjacent east hillside to a new downstream connection point instead of connecting to the combined sewer system.

A third connection between Panther Hollow Lake and the downstream Junction Hollow open channel is envisioned for Alternatives 1 and 3. A riser pipe with an Opti valve in it will provide a proactive ability to regulate the level of the Lake and discharges from it. The Opti valve is a real time control element intended to regulate flow from the Lake via some predefined operational logic. The riser pipe and the Opti functionality will be included in a later design phase update of the 4MR Project model and is not currently shown in Figure 6.

6.2.2 4MR Project Alternative, Core Downstream section

The downstream section begins at the soccer field. Alternative 1 simply conveys the flow from this point out to the Monongahela River. Alternative 3 conveys flow through a combination of open channels and closed conduits to a new stormwater outfall located adjacent to the Hazelwood Green development property. Figures 7 and 8 include further details on the modeling parameters included for these alternatives.

Figure 7: Alternative 3 – downstream of soccer field storage (northern section)

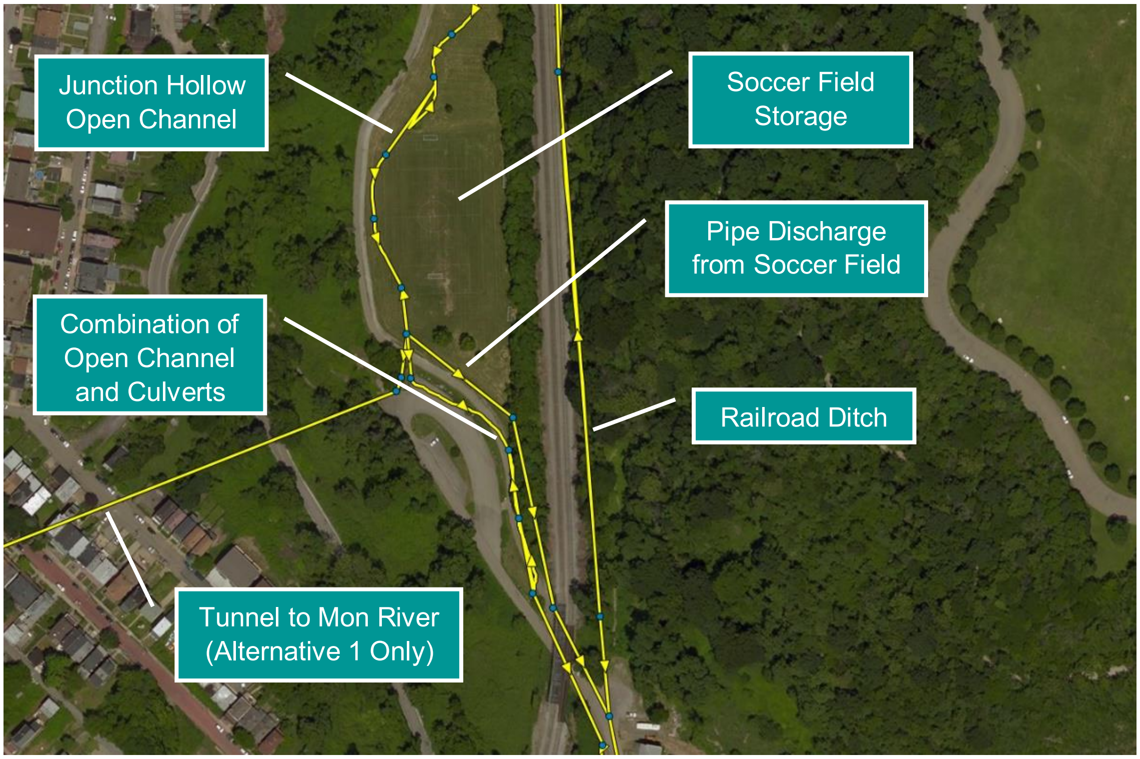
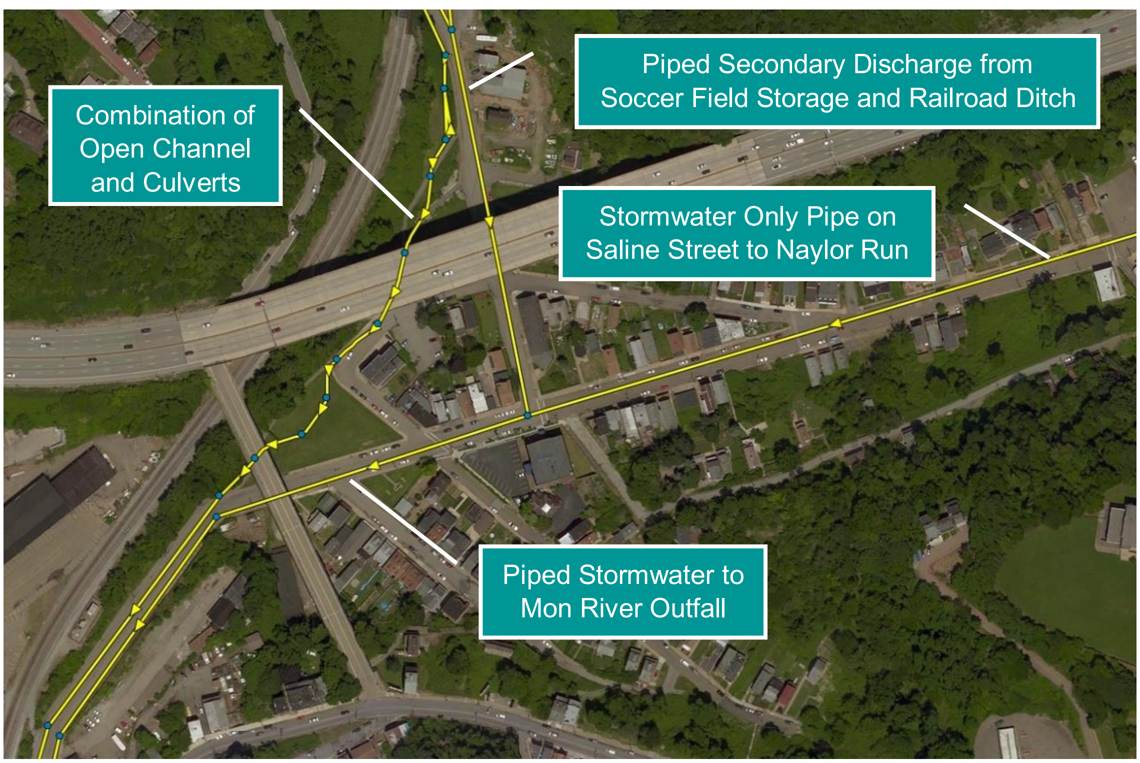


Figure 8: Alternative 3 – downstream of soccer field storage (southern section)



Alternative 3 includes:

- The installation of a new primary conveyance from the soccer field storage through a combination of culverts and open channel sections passing through a local neighborhood to the Hazelwood Green development site before discharging at the Monongahela River;
- Piped conveyance from the soccer field storage to an auxiliary culvert that will provide a secondary route of discharge from the soccer field storage under high flow conditions;
- A new connection from the updated railroad ditch to an auxiliary culvert passing through a local neighborhood leading to a separate stormwater discharge point at the Monongahela River;
- The installation of a pipe connection to the auxiliary culvert conveying storm flows from the Naylor Run area and future potential upstream redirection projects.

6.3 Watershed expansion projects

The Watershed Expansion projects represent upstream stormwater offloading opportunities that will connect to the downstream “core” 4MR Project alternatives already discussed in Section 6.2. These projects were identified and investigated by other members of the CEC team. Due to the conceptual state of these projects, these projects were modeled as virtual storage tanks sized to collect the runoff generated by 1.5 inches of rainfall from the tributary impervious area. For any storm events producing flows greater than the capacity of the virtual storage tanks, the model routes the excess flow to the combined collection system. The virtual storage tanks are continuously emptied (even while filling) if flow is present in the tank. The model parameters established using an underflow rate calculated to draw the tank down from completely full to empty over a 72-hour period with no additional upstream flows entering the tank. The standard used for all simulations including the watershed expansion projects is for the stormwater leaving the tank underflows to be routed to the downstream “core” 4MR project infrastructure and completely removed from the combined collection system. However, Design Criteria Area (DCA) 5, detailed in Section 7.5, also includes simulations where the tank underflows are also connected to the combined collection system and no stormwater is routed downstream to the “core” 4MR project. Figure 9 includes a “cut-out” from the overall 4MR Project model to highlight the “core” 4MR project elements. The points where the upstream watershed expansion flows connect to the downstream “core” infrastructure are highlighted.

Figure 9: Watershed Expansion Connections to "core" 4MR Project Infrastructure

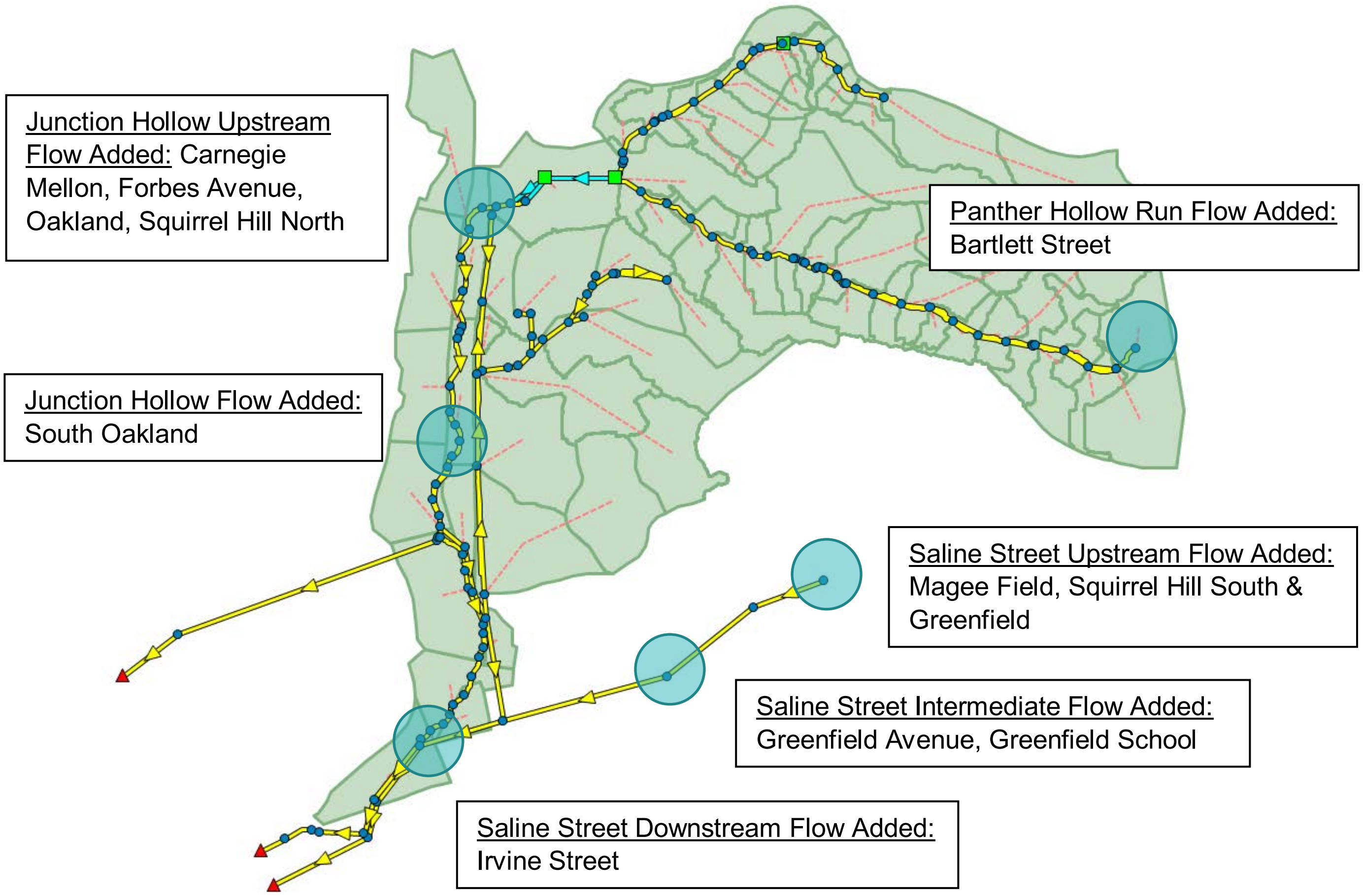


Table 7 relates the specific watershed expansion projects to their point of connection shown in Figure 9.

Table 7: Watershed expansion project details

Watershed Exp. Project	Connection Point	Impervious Area (ac)	Modeled (Virtual) Tank Size (gal)	Modeled (Virtual) Tank Size (cu ft)	Underflow Rate (cfs)
Bartlett Street	Panther Hollow Run	25.2	1,024,867	137,014	0.53
Carnegie Mellon	Junction Hollow Upstream	27.7	1,127,993	150,801	0.58
Forbes Avenue	Junction Hollow Upstream	2.9	116,993	15,641	0.06
Greenfield Avenue	Saline Street Intermediate	9.5	387,845	51,851	0.20
Greenfield School	Saline Street Intermediate	3.2	129,404	17,300	0.07
Irvine Street	Saline Street Downstream	10.0	405,783	54,249	0.21
Magee Field	Saline Street Upstream	5.7	232,791	31,122	0.12
Oakland	Junction Hollow Upstream	46.9	1,909,677	255,304	0.98
South Oakland	Junction Hollow	10.1	412,832	55,191	0.21
Squirrel Hill North	Junction Hollow Upstream	23.8	970,369	129,728	0.50
Squirrel Hill South & Greenfield	Saline Street Upstream	17.2	698,857	93,430	0.36
Totals		182.1	7,417,412	991,633	3.83

Note: Tank sizes are based on routing runoff generated from 1.5 inches of rainfall from the tributary impervious areas to each modeled (virtual) tank.

7 Design criteria areas

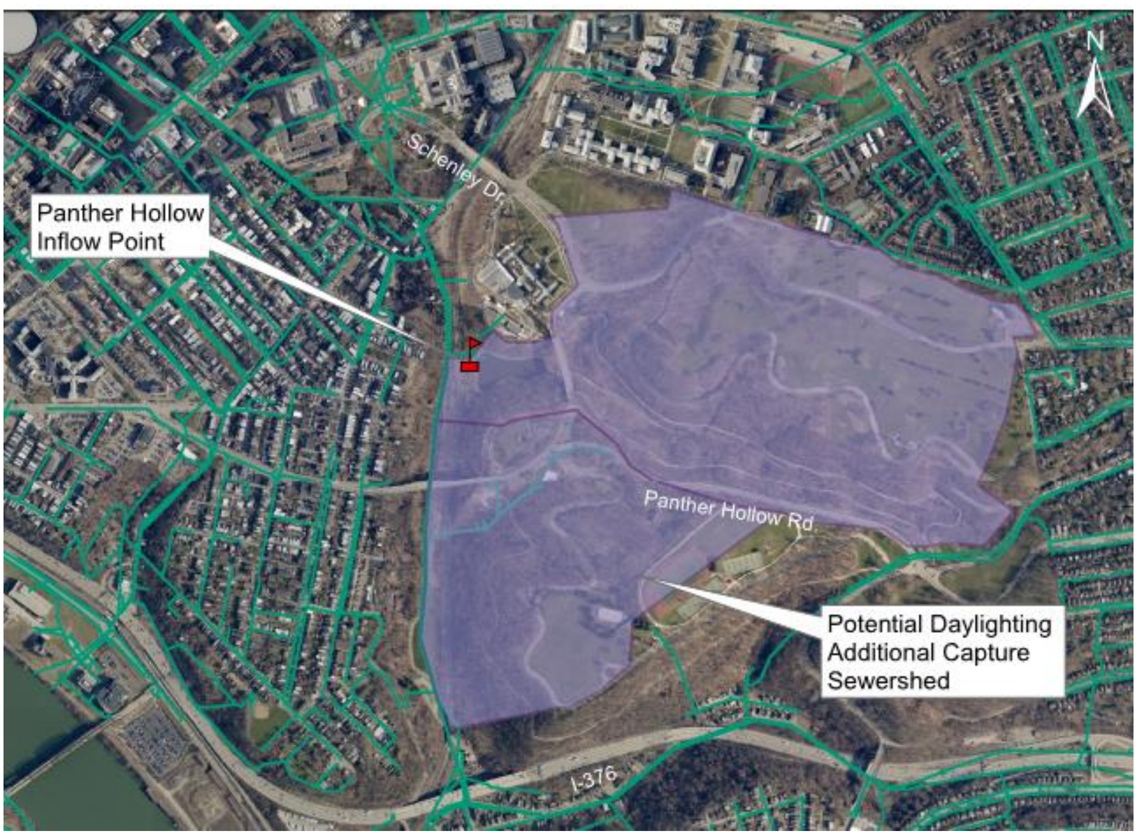
To further understand the potential benefits of 4MR Project Alternatives, PWSA requested additional modeling analyses to better understand the CSO mitigation, basement backup mitigation and flooding mitigation benefits potentially provided by the 4MR Project. These requests, referred to as design criteria areas (DCAs) were separately documented to PWSA in other deliverables and presentations. Thirty-seven (37) different model scenarios were simulated and various tables, figures and other presentations of the results were prepared.

7.1 Design criteria area 1

DCA 1 was focused on a comparison between the 4MR Project model with Alternative 3 and the original stream removal work detailed in the Green First Plan that originally included the disconnection of Panther Hollow Lake from the combined sewer system.

Section 5.3.5 of the Green First Plan states that the M-29 CSO reduction benefits derived from offloading the baseflow from Panther Hollow Lake and the wet weather contributions to the combined collection system of 270 upstream acres is 31.9 MG. The baseflow value for the Green First analysis assumed the baseflow was 68 MG based on 2015 ALCOSAN flow monitoring data collected at the Panther Hollow Lake discharge pipe, while the original ALCOSAN M-29 model only had 14 MG of baseflow. The 4MR Project model includes a base flow of approximately 30 MG from Panther Hollow Lake based on 2018 flow monitoring data.

Figure 10: Green First Plan Proposed Panther Hollow Lake disconnection and adjacent offloaded areas



The closest corresponding equivalent to the area offloaded in Figure 10 (copied here from the Green First Plan and as, originally identified as Figure 5-11), is the current 4MR Alternative 2. However, after discussions with PWSA, Alternative 3 was selected to use for comparison since it included additional area in the Naylor Run/Saline Street area.

Figure 11 overlays the 270-acre drainage area from Figure 10 on the larger Alternative 3 drainage area. The subcatchments added to Alternative 3 (which represent added area to Alternative 2) are also highlighted.

Figure 11: 4MR project alternatives 2 and 3 compared to Green First Plan

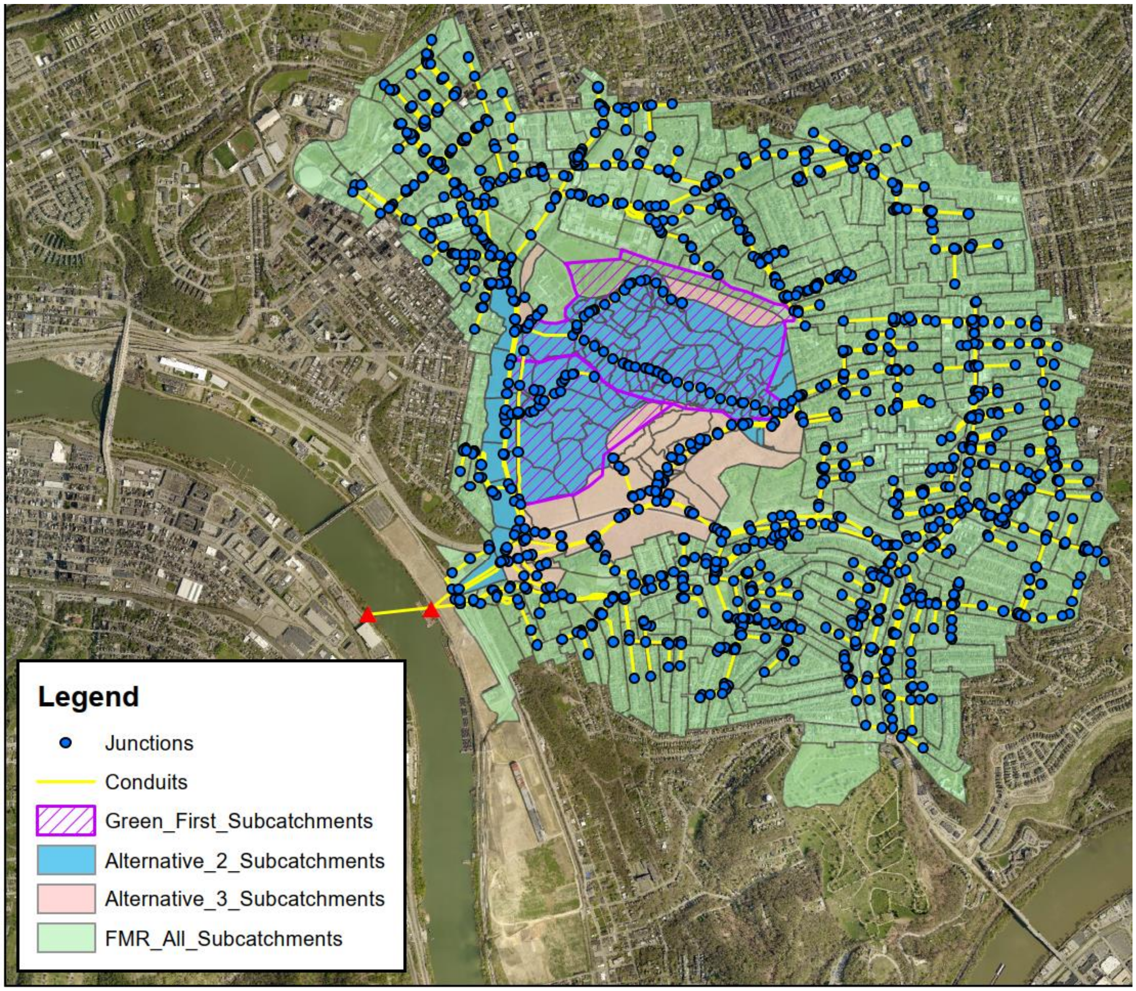


Table 8 includes a comparison of the total, impervious and pervious areas for both the Green First Plan and the 4MR Alternative 3 that are shown Figures 10 and 11. The 4MR Alternative 3 offloads 208.4 acres of additional tributary area (of which 37.2 acres is impervious), compared to the Green First Plan.

Table 8: Offloaded stormwater areas (Green First vs. 4MR Alternative 3)

Area Type	Green First Plan (ac)*	4MR Alternative 3
Impervious	21.6	58.8
Pervious	248.6	419.9
Total	270.3	478.7

*Green First Plan values were directly calculated from the ALCOSAN's M-29 collection system model used in development of the Green First Plan.

Table 9 lists the reductions for the 4MR Alternative 3 for the typical year. DCA Simulation_03 indicates the greatest CSO reduction, 158 MG, compared to existing conditions.

Table 9: 4MR TY project alternatives CSO volumes (MG)

DCA Simulation #	Scenario	CSO Volume	CSO Reduction vs. Existing Conditions
Simulation_00	Existing Conditions	382	N/A
Simulation_01	Existing Conditions + Flap Gate	380	-2
Simulation_02	Existing Conditions + Flap Gate + Alternative 3	341	-41
Simulation_03	Existing Conditions + Flap Gate + Alternative 3 + Watershed Expansion	224	-158

Table 2-2 in the Green First Plan detailed combined sewage inflow to the diversion structure, underflow and overflow typical year volumes for each of the 30 sewersheds included in that plan. Table 10 includes M-29 excerpts from Table 2-2 and newer values based on the 4MR Project model.

Table 10: M-29 diversion structure inflow, underflow and overflow volumes (MG)

Model	Inflow to Diversion Structure	Underflow to WWTP	CSO Volume	% Wet Weather Capture
Green First Plan*	1,426	1,024	402	72%
4MR Project model	2,377	1,995	382	84%

*Values taken from Table 2-2 in the Green First Plan

Table 10 shows that the combined sewage inflow entering the M-29 diversion structure from the upstream collection system has increased by nearly 1.0 billion gallons (BG) in the 4MR Project model. This increase is due to increases in both the dry weather and wet weather flow volumes, with the DWF volume increase accounting for more than 70% of the increase. The DWF calibration of the large diameter interceptors upstream of the M-29 diversion structure in the 4MR Project model indicates about 10.5 MGD average DWF. The Green First Plan model had average DWF entering the M-29 diversion structure of approximately 6.0 MGD.

The results shown in Table 10 also have the counterintuitive result of substantial increases in the total flow volume entering the M-29 diversion structure while also resulting in modest decreases in CSO discharge volume through the M-29 outfall pipe. Since DWF is entering the M-29 diversion structure every day and CSO discharges are only occurring intermittently, most of the increase flow volume is occurring when the M-29 outfall pipe is not active. Another contributing factor is that the Green First Plan model generally has higher wet weather peak flow response leading to higher CSO discharges. This is a logical result because the Green First Plan model only has the larger diameter interceptor sewers in it and none of the smaller diameter upstream sewers. Since the Green First Plan model flows are being directly added to large diameter pipes, greater peak flows can be conveyed downstream. The 4MR Project model has much greater detail in the upstream areas of the collection system which results in greater attenuation of the wet weather peak flows before those flows reach the M-29 diversion structure.

There is an inconsistent relationship between the changes in the M-29 sewershed and the impacts on CSO discharges throughout the larger collection system. In fact, the larger collection system shows both CSO increases and decreases at other combined sewer outfalls after Alternative 3 is implemented in the M-29 sewershed. Counterintuitively, some of the outfalls with CSO increases are those near M-29 and those that have some of the larger decreases are quite distant (such as A-73). Since the cause and effect relationship between the Four Mile Run project and changes in CSO discharges at other outfalls is not clearly understood, only CSO discharge changes at the M-29 outfall are reported in this document.

Comparing M-29 CSO reduction between the Green First Plan (32 MG) and the Four Mile Run Alternative 3 (41 MG) shows relatively good consistency between the two results when factoring in the differing stormwater areas offloaded from the combined sewer system and the different existing conditions for the M-29 typical year combined sewage inflow, underflow, and overflow volumes.

7.2 Design criteria area 2

DCA 2 focuses on better understanding the combined sewage flooding in and around Saline Street in the Lower Run neighborhood (this area is often referred to as the area near Big Jim's restaurant). This area is known to have experienced repeated flooding. Various potential flood mitigation alternatives have been investigated by ALCOSAN, (refer to M-29 Conceptual Flooding Report, dated November 2016 prepared by Chester Engineers). Simulation_04 through Simulation_09 were intended to help identify the root causes of flooding (tunnel hydraulic limitation, outfall hydraulic limitation from high river stage, and excessive upstream flow contributions) in response to PWSA DCA 2.A. Results from Simulation_04 through Simulation_06 are included in Table 11. These simulations apply a constant downstream river stage of 711 which represents the normal pool elevation of the Monongahela River at the M-29 outfall pipe.

Table 11: 25-yr, 24-hr design storm, river stage 711 feet – M-29 flooding volume (MG)

DCA Simulation #	Scenario	River Stage	Flood Volume (MG)
Simulation_04	Existing Conditions	711	9.1
Simulation_05	Existing Conditions + Flap Gate	711	9.1
Simulation_06	Existing Conditions + Flap Gate + Free Discharge to ALCOSAN Tunnel	711	9.0

The results in Table 11 illustrate the total flood volume experienced throughout the entire M-29 sewershed, not simply in the Big Jim's/Saline Street area. Flood volume as used throughout this document represents when the Hydraulic Grade Line (HGL) of a sewer exceeds the manhole rim elevation and a portion of the collection system flow is released at that manhole or location to the ground surface. Once the flow escapes to the ground surface, it will flow overland until it can re-enter the collection system or pools in a low point and collects. The SWMM model does not account for the overland conveyance of flood waters. The flooding nodes under existing conditions (Simulation_04) are widely distributed across the sewershed with many located in upstream areas. The results in Table 11 indicate that under the 711-elevation river stage neither adding the flap gate nor allowing free discharge to the ALCOSAN tunnel meaningfully reduces the 9.1 MG of flood volume across the M-29 sewershed. Most of the manholes that do experience flooding have relatively small flooding volumes (<0.1 MG). With these small flooding volumes, it is possible that the street flooding that the model indicates would not necessarily appear as “flooding” with something visually obvious like flow geysering out of a manhole. Instead this localized manhole flooding could easily appear as extra water running down the street since in most cases the flooding occurs while it is still raining. The widespread nature of the flooding explains why under the 711-elevation river stage, reverse flow from the river and tunnel are not meaningful root causes of flooding in the Big Jim’s area or throughout the M-29 sewershed. Without considering issues related to blockage or the need for aggressive pipe maintenance, the primary flooding cause under low river stage is limited conveyance capacity in the upstream collection system. Surface flooding in the Lower Run neighborhood generally conveys overland until it collects in the low-lying area near Big Jim’s (located at 201 Saline Street) adjacent to the intersection of Saline Street and Alexis Street. Manhole flooding near Big Jim’s accounts for approximately 0.6 MG of the total 9.1 MG of flooding volume across the M-29 sewershed.

Under high river stage conditions, the influence of reverse flow from the river on flooding in the Big Jim’s area changes dramatically. The lowest manhole rim elevation (meaning the first to experience flooding under high stage conditions) in the Lower Run neighborhood is approximately 737 feet, and this manhole is located near the intersection of Four Mile Run Road and Boundary Street, just behind Big Jim’s. The current 100-year FEMA regulated water surface elevation of the Monongahela River at the M-29 outfall is approximately 733 feet. Under this high river stage and with no flap gate installed on the M-29 outfall pipe, even small storm events could cause flooding at this manhole. The 4MR Project model has not incorporated the attributes (including head losses) of the proposed M-29 flap gate that is currently under design. When details of the proposed flap gate are incorporated into the 4MR Project model, the potential impacts on flooding in the Lower Run neighborhood can be more fully evaluated. Numerous factors, such as the head loss characteristics of the flap gate, the relative hydraulic grade levels of the Monongahela River, and the upstream collection system will impact how flooding may change in the neighborhood.

Table 12 shows the flooding results for the same 25-year, 24-hour storm event as Table 11 except the river stage boundary has been increased in elevation to 733 feet. As a result, the flooding volumes shown in Table 12 are more than double the flooding volumes from Table 11.

Table 12: 25-yr, 24-hr design storm, river stage 733 feet – M-29 flooding volume (MG)

DCA Simulation #	Scenario	River Stage	Flood Volume (MG)
Simulation_07	Existing Conditions	733	21.2
Simulation_08	Existing Conditions + Flap Gate	733	21.2
Simulation_09	Existing Conditions + Flap Gate + Free Discharge to ALCOSAN Tunnel	733	20.6

As discussed above, the selection of a final high river stage level will have an important impact on the primary flooding causes within the Lower Run neighborhood. Under low river stage conditions, both the river stage and the HGL of ALCOSAN’s deep tunnel at the M-29 drop shaft have small impacts on flooding throughout the M-29 sewershed. However, under high river stage conditions (elevation 733 feet), the river stage has the potential to significantly impact flooding in the Lower Run neighborhood.

7.3 Design criteria area 3

DCA 3 focused on design storm sizing and applicable regulations governing the 4MR Project design. As such, no additional model results were generated in response to this request.

7.4 Design criteria area 4

DCA 4 focused on understanding where the 4MR Project model indicates basement backups or there is a potential for elevated flooding risks. The following approach was prepared to outline parameters considered in response to PWSA's questions posed as DCA4:

- Using simulations already completed under DCAs 1-3, export the ground surface elevations and the peak depths (maximum hydraulic grade line) simulated for each node in the model.
- Nodes with a maximum HGL greater than the ground surface elevation (at a given location) will be considered locations with an elevated potential for flooding.
- Nodes where the maximum HGL is within five feet of the ground surface elevation will be considered locations with an elevated basement backup risk.
- Nodes where the maximum HGL is not within five feet of the ground surface elevation will be considered locations with a lower basement backup risk.

Although this methodology can help initially classify manholes and locations within the M-29 shed by their corresponding elevated potential for flooding or basement backup risk, it is important to recognize the following limitations and caveats while interpreting the results of the initial and high-level analyses:

- Many of the smaller diameter, upstream pipes that have been added to the 4MR Project model do not have invert information available either in the PWSA's GIS or on the 3RWW Online Sewer Atlas. The inverts of these pipes were inferred based on the assumption that the pipe invert is set 10 feet below grade. If this assumption deviates significantly from real world conditions, it will impact the assignment of basement backup risk.
- An elevated potential basement backup risk assumes basement backup risk exists where the model's HGL is within five feet of the ground surface. However, the true basement backup risk is also affected by the presence or absence of a house's basement, elevations of service laterals, and the local topography that could indicate if a specific house is elevated above, below, or at grade with the adjacent roadway (and associated sewer conveyance pipe).
- Although the 4MR Project model adds substantial detail to the previous M-29 sewershed collection system model, it does not include all the pipes in the physical collection system, and it does not include service lateral specifics. The lack of the smallest pipes in the collection system will have some impact on basement backup risk assignment.

Under the previously submitted response to DCAs 1-3, the following combinations of baselines, river stages and design storms were simulated.

- Three (3) different baseline conditions
  - Existing Conditions with M-29 Flap Gate
  - Existing Conditions with M-29 Flap Gate + Model Alternative 3
  - Existing Conditions with M-29 Flap Gate + Model Alternative 3 + Watershed Expansion
- Four (4) different design storms:

- 2-year, 24-hour
- 5-year, 24-hour
- 10-year, 24-hour
- 25-year, 24-hour

The modeled results from the DCA 4 analysis using these baselines and design storms are shown in Tables 13 – 15. The results demonstrate the benefits of Alternative 3 and the greater benefits of the Watershed Expansion in reduce basement backup and potential flooding risks.

Table 13: Manhole risk totals – existing conditions + flap gate

Risk Category	2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr
Elevated Potential Flooding Risk	27	44	60	77
Elevated Basement Backup Risk	255	336	411	506
Lower Basement Backup Risk	934	836	745	633

Table 14: Manhole risk totals – existing conditions + flap gate + Alternative 3

Risk Category	2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr
Elevated Potential Flooding Risk	23	43	58	72
Elevated Basement Backup Risk	247	330	400	482
Lower Basement Backup Risk	946	843	758	662

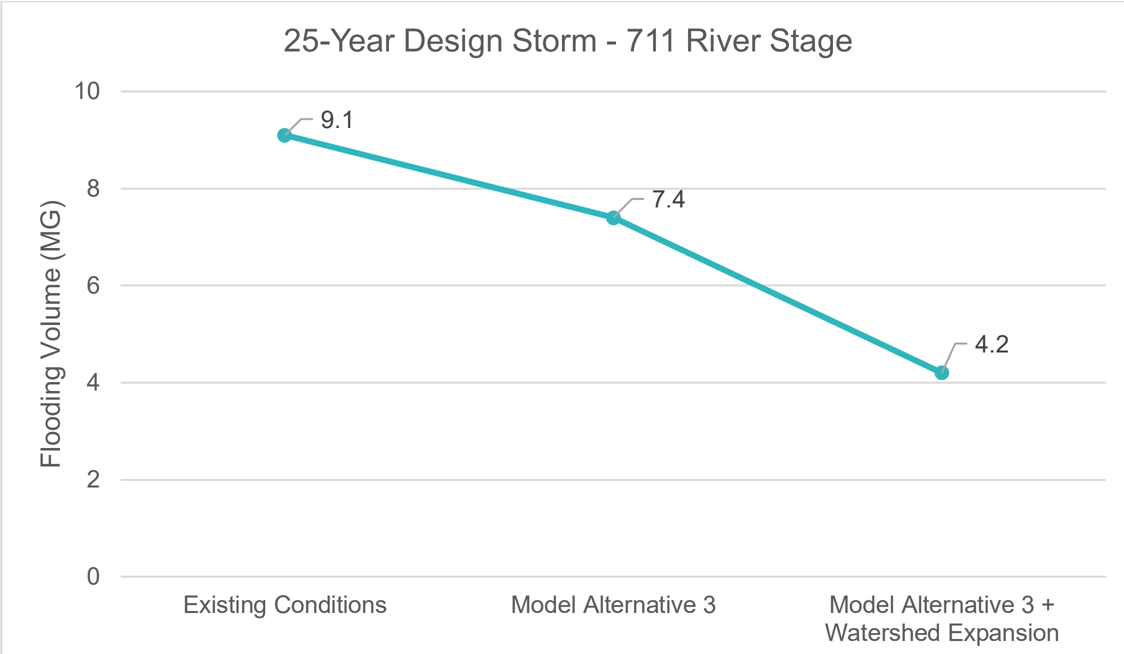
Table 15: Manhole risk totals – existing conditions + flap gate + Alternative 3 + Watershed Expansion

Risk Category	2-yr, 24-hr	5-yr, 24-hr	10-yr, 24-hr	25-yr, 24-hr
Elevated Potential Flooding Risk	15	26	40	49
Elevated Basement Backup Risk	189	231	292	400
Lower Basement Backup Risk	1,012	959	884	767

Various maps were produced to illustrate graphically locations of elevated potential for flooding or basement backup risk. These maps are attached to this Report in the Appendices. Areas that indicate an elevated potential for flooding were further investigated to determine the primary cause of the elevated flooding risk. For each of the highly flood prone areas investigated, hydraulic bottlenecks in the immediate downstream collection system were identified. These bottlenecks do not have the hydraulic capacity to convey all upstream flows causing flow to backup, surcharge and eventually reach the manhole rim elevation.

The model results also indicated the expected reduction in flooding volumes because of the improvements included within Model Alternative 3 and the Watershed Expansion projects. Figure 12 provides an example of how flooding volume across the M-29 sewershed changes with the inclusion of the 4MR Project.

Figure 12: Flooding mitigation from Alternative 3 and Watershed Expansion



7.5 Design criteria area 5

DCA 5 is focused on understanding the impacts of different baseline assumptions on the M-29 TY CSO discharge volumes. The following three baseline conditions were evaluated:

- Existing Conditions + M-29 Flap gate
- Same as previous, with 600 MGD WWTP, 1,835 impervious acres managed by Green Infrastructure (GI), three direct stream inflows removed (as per the Green First Plan).
- Same as previous, with nineteen (19) underflows opened at key diversion structures and sediment removed from the existing ALCOSAN tunnel (as per the Green First Plan).

For each of these DCA 5 baseline conditions, the Watershed Expansion projects were evaluated for both a detain and return scenario, as well as an option to fully separate flow from the collection system. Both the detain and return as well as the separate options utilize a modeled underdrain and an overflow. For the detain and return configuration, both the underdrain and overflow pipes are connected to the combined sewer system. In the separate configuration, the underdrain is connected to new stormwater infrastructure to ultimately convey the flow to a dedicated stormwater outfall on the Monongahela River. The overflow pipe in the separate configuration still connects to the combined sewer system and will convey flow when the storage is fully utilized. Under both options the watershed expansion storage elements were sized to capture the runoff generated from the first 1.5 inches of rainfall from the tributary impervious area. Table 13 includes the results of these simulations.

Table 16: 4MR TY CSO volumes for various baseline and Watershed Expansion options (MG)

Baseline	Detain and Return	Separate
Existing Conditions + Flap Gate	251	224
Same as Previous with 600MGD WWTP, 1,835 impervious acres managed by GI, three direct street inflows removed	157	137
Same as previous with nineteen (19) underflows opened and sediment removed from the existing ALCOSAN tunnel	151	133

8 Conclusions

The 4MR Project is focused on the multiple benefits that can be realized from strategically redirecting or removing stormwater from a combined sewer system. To evaluate the potential benefits that the 4MR Project can provide it was necessary to update the existing ALCOSAN model. These updates included:

- Collecting additional flow monitoring and rainfall data during 2018/2019 to support model calibration/validation;
- Adding new collection system detail to the model including substantially more pipes, manholes and new features such as open channel conveyances and Panther Hollow Lake; and,
- Subdividing the existing subcatchments into smaller drainage areas to more realistically replicate the overland flow timing before it enters the piped conveyance system.

The ultimate result of this modeling effort was a 4MR Project model that is well suited to evaluating the specific elements envisioned as part of the overall 4MR Project. The 4MR Project is composed of two (2) interlinked components that were evaluated using this 4MR Project model:

1. A “core” 4MR Project consists of downstream improvements to offload stormwater from the combined sewer system and establish a new stormwater conveyance and ultimate stormwater outfall to the Monongahela River. This “core” project includes improvements to the Phipps Run and Panther Hollow Run open channels within Schenley Park, modifications to Panther Hollow Lake, construction of a new open channel along Junction Hollow and a combination of open channels and closed conduits leading to a new stormwater outfall along the Hazelwood Green property. Stormwater from the Naylor Run area is redirected to a new stormwater pipe running down Saline Street and ultimately to discharge to the Monongahela River; and
2. The Watershed Expansion projects consist of a series of upstream stormwater projects located across the upstream portions of the M-29 sewershed. These projects are located where opportunities are available to offload significant volumes of stormwater from the combined sewer system. The stormwater from these Watershed Expansion projects will be conveyed downstream to the “core” 4MR Project and then discharged to the Monongahela River.

Although the specific details of the design of these two project components will evolve throughout the design process, the likely benefits were quantified in responding to PWSA’s DCA inquiries. These benefits and the modeled volumes noted herein will fluctuate as specific pipe conditions and details of the current collection system are further investigated/incorporated, and the proposed 4MR project designs are refined; however, initial 4MR Project model results indicate potential opportunities to reduce CSO discharges to the Monongahela River and influence the reduction of flooding and basement backup risks as defined herein and that presently exist within the sewershed, as follows:

- **Reduction in CSO discharges to the Monongahela River.** The “core” project and the Watershed Expansion together are estimated to reduce CSO discharges at the M-29 outfall by about 158 MG (see Table 9).

- **Reduction in flooding and basement backup risk.** The response to DCA 4 in Section 7.4 provides initial estimates that the combination of the "core" project plus Watershed Expansion may substantially reduce the number of manholes that indicate an elevated potential for flooding or elevated basement backup risk throughout the M-29 sewershed. These results, however, are based on limited site-specific data, and more information is needed to refine these estimates as the 4MR Project alternatives are advanced beyond the scope of the current project.

Appendices

A. General Notes

Numerous parallel pipes with cross connections and merge points are often common at the flow monitoring installation locations. In addition to the individual flow meter results, for pairs of flow meters installed in similar locations along parallel sewer lines, the calibration/validation results are also reported in aggregate. This dual reporting provides an additional check of the entire upstream flow being delivered downstream. Model results are sensitive to the configurations of the cross-connecting pipes and small changes can have a significant effect on model results and calibration. It is recommended that select locations be further field investigated to confirm the diameter, inverts and precise configuration of these important locations as discussed in the Four Mile Run Calibration and Validation Report.

All numerical criteria included in this appendix are taken from the CIWEM Code of Practice for collection system models. This is an industry wide standard that is most commonly used for collection system modeling.

Although specific storm events were selected for reporting calibration and validation statistics, the calibration process focused on best matching of the overall hydrograph timing and shape. Other calibration metrics that focus on the overall match between the flow meter vs. model simulation hydrograph were used to guide the calibration process even though those statistics are not reported. These referenced metrics include the Nash-Sutcliffe Efficiency, the Integral Square Error and the Root Mean Square Error.

B. Modeled Subcatchment Parameter Ranges

Table A.1 below includes the parameter ranges for common subcatchment properties that relate to surface runoff and infiltration.

Table B.1: Typical Subcatchment Parameter Ranges

Parameter	Range (Low – High)
Impervious Manning’s “n”	0.01 – 0.02
Pervious Manning’s “n”	0.03 – 0.3
Impervious Depression Storage (in)	0.012 – 0.072
Pervious Depression Storage (in)	0.085 – 1
Green-Ampt Suction Head (in)	7.5 – 11.5
Green-Ampt Conductivity (in/hr)	0.029 – 0.25
Green Ampt Initial Deficit	0.092 – 0.14

C. Calibration/Validation Storm Event Selection

Storm events were selected for calibration and validation based on a number of criteria including:

- General uptime of the installed flow meters – Potential storm events were removed from consideration if a significant portion of the flow meters experienced downtime during the storm;
- Characteristics of the storm event – The goal of calibration and validation is to utilize a wide spectrum of different types of storm event volumes, durations and intensities. If there are multiple storm events with the same characteristics only a single storm event may be chosen; and
- Temporal distribution of storm events – Storm events were chosen to include storms that occur in isolation having dry weather periods both before and after and storm events that occurred back-to-back.

Seventeen (17) flow meters and ten (10) rain gages were installed for a six-month period, starting on July 1, 2018. Generally, the quality of the flow metering data improved over time with a fewer number of flow meters experiencing downtime in the later months of the flow monitoring period. Table C.1 lists the aggregate flow meter downtime by month across all of the flow meters.

Table C.2: Aggregate Flow Meter Performance by Month

Month	Downtime Percentage (All Flow Meters)	Flow Meters with Extended Downtime
July	18.0%	9 flow meters
August	14.3%	6 flow meters
September	16.6%	4 flow meters
October	9.0%	4 flow meters
November	5.7%	3 flow meters
December	0.1%	0 flow meters

Table C.1 illustrates that flow meter data availability improved markedly throughout the project. The wide spread nature of the flow meter downtime from July into middle/late August resulted in no calibration and validation storms being selected during this time frame. Fortunately, the subsequent flow monitoring period had above average rainfall and sufficient calibration/validation storms available beginning in late August. Table A.2 provides a breakdown by day of the number of flow meter downtime timesteps that occurred for each day. The following points help explain Table C.2:

- Days with a calibration storm event occurring in them are shown in light blue shading with the dark blue text;
- Days with a validation storm event occurring in them are shown with a dark blue highlight with white text;
- Flow meter data were collected at a 5-minute increment, for a total of 288 timesteps each day;
- A zero value indicates that the flow meter collected data for all timesteps in that day;

- A value greater than zero and less than 24 is highlighted in yellow and indicates the flow meter had up to 2 hours of downtime during that day. To convert to time, multiple the number of timesteps by five (5) minutes; and
- Any value greater than 24 is shown in red and indicates substantial flow meter downtime during that day. A value of 288 indicates that the flow meter recorded no data for the entire day.
- Since December had inconsequential downtime, it is not included in Table A.2.

Table C.2 Dropped Flow Meter Time Steps by Day - July 2018																
Date	MH028H015 81"	MH028H029 54"	MH028H036 21"	MH029D039 48"	MH029H072 18"	MH029H073 78"	MH029S031 21"	MH053B003 48"	MH053S008 36"	MH053S009 48"	MH054E003 96"	MH054F011 68"	MH054F012 24"	MH054F012 81"	MH054F015 18"	MH054F015 30"	MH054J015 36"
07/01/18	0	0	0	0	0	0	0	0	0	2	0	1	0	0	276	32	0
07/02/18	0	0	1	14	0	129	0	0	0	52	62	0	0	0	276	24	0
07/03/18	0	0	0	0	0	288	0	0	0	288	227	0	0	0	288	32	0
07/04/18	0	0	1	0	0	288	0	0	0	288	288	0	189	0	245	8	0
07/05/18	0	0	0	0	0	288	0	0	0	288	288	0	288	0	225	0	0
07/06/18	15	0	1	1	0	288	0	0	0	288	288	0	123	0	245	14	27
07/07/18	0	0	0	0	0	288	0	288	0	288	288	0	0	0	288	4	0
07/08/18	0	0	0	0	0	288	0	288	0	288	288	0	0	0	288	2	0
07/09/18	0	0	0	0	0	288	0	288	0	137	288	0	0	0	288	2	0
07/10/18	1	0	0	0	0	288	0	288	0	0	288	0	0	0	288	8	0
07/11/18	0	0	0	2	0	133	0	288	0	0	125	0	0	0	288	3	0
07/12/18	0	0	0	0	24	0	0	288	0	0	0	0	0	0	288	14	0
07/13/18	1	0	14	0	0	0	0	288	0	0	242	0	0	0	288	9	0
07/14/18	1	0	0	1	0	0	0	288	0	0	288	0	0	0	288	6	0
07/15/18	0	0	0	0	0	0	1	288	0	3	288	0	0	0	288	3	0
07/16/18	0	0	1	0	0	0	0	288	0	0	288	0	0	0	288	3	0
07/17/18	0	0	0	0	0	0	0	288	0	1	119	0	0	0	288	6	0
07/18/18	0	0	0	0	0	0	0	142	0	0	0	0	0	0	288	10	0
07/19/18	1	0	0	0	0	0	2	0	0	0	0	0	0	0	288	1	0
07/20/18	0	0	0	0	0	0	0	1	0	0	0	92	0	13	288	0	0
07/21/18	0	0	0	0	0	0	0	147	0	0	0	288	0	0	288	1	98
07/22/18	0	0	0	0	0	0	0	288	0	16	23	288	0	0	288	2	288
07/23/18	0	0	0	0	0	7	0	288	0	0	0	288	0	162	288	1	288
07/24/18	0	12	0	0	0	0	0	288	1	0	16	146	0	125	288	3	148
07/25/18	1	73	0	0	0	0	0	147	0	3	15	3	0	5	288	0	0
07/26/18	0	0	0	0	0	0	0	3	0	0	0	2	8	288	288	8	0
07/27/18	0	2	2	0	0	1	0	27	0	7	27	105	0	288	279	9	0
07/28/18	1	0	0	0	0	0	0	9	0	0	84	3	1	288	288	8	0
07/29/18	0	0	0	0	0	0	0	17	0	0	5	1	40	288	288	3	0
07/30/18	0	0	0	0	1	0	0	28	0	0	0	0	288	288	288	4	1
07/31/18	0	0	5	0	0	101	0	47	15	4	70	0	132	212	262	5	0

Table C.2 Dropped Flow Meter Time Steps by Day - August 2018																	
Date	MH028H015 81"	MH028H029 54"	MH028H036 21"	MH029D039 48"	MH029H072 18"	MH029H073 78"	MH029S031 21"	MH053B003 48"	MH053S008 36"	MH053S009 48"	MH054E003 96"	MH054F011 68"	MH054F012 24"	MH054F012 81"	MH054F015 18"	MH054F015 30"	MH054J015 36"
08/01/18	0	0	0	0	0	288	0	11	0	0	1	0	288	0	288	20	0
08/02/18	0	0	0	0	0	288	0	1	38	0	0	0	288	272	288	9	0
08/03/18	0	0	0	0	0	288	0	2	288	0	0	0	288	288	288	12	0
08/04/18	0	0	0	0	0	288	0	0	288	0	0	0	288	288	288	0	0
08/05/18	0	1	0	0	0	288	1	0	288	0	0	2	288	288	288	0	0
08/06/18	0	0	0	0	0	288	0	1	288	0	0	7	288	288	288	1	0
08/07/18	0	0	5	0	0	159	0	0	122	0	0	1	156	150	288	4	0
08/08/18	4	0	0	0	0	288	0	1	0	0	0	1	0	0	288	3	0
08/09/18	0	0	0	1	2	288	0	4	0	0	0	6	0	0	288	0	0
08/10/18	4	1	6	0	0	288	0	12	0	0	0	0	0	238	264	2	0
08/11/18	0	0	0	1	0	288	0	0	0	0	0	60	0	288	288	34	0
08/12/18	0	0	0	0	0	288	0	9	0	0	0	2	0	288	288	36	0
08/13/18	0	0	0	0	0	288	0	5	0	0	0	0	0	288	288	17	0
08/14/18	0	0	2	0	0	288	0	4	1	0	0	3	0	153	288	25	0
08/15/18	2	0	0	1	0	136	0	6	0	0	0	2	0	0	288	58	0
08/16/18	0	0	1	0	0	0	0	6	0	0	0	0	0	0	288	22	0
08/17/18	0	0	0	0	0	15	0	13	0	0	0	1	0	0	288	9	0
08/18/18	0	0	0	0	0	0	0	2	0	0	0	2	0	0	288	52	0
08/19/18	0	0	0	0	0	0	0	92	0	0	0	0	0	0	288	50	0
08/20/18	0	1	0	0	0	0	0	3	0	0	0	2	0	0	288	0	0
08/21/18	0	0	0	0	0	9	0	16	0	0	0	0	0	0	288	24	0
08/22/18	0	0	0	0	0	2	0	1	0	0	0	2	0	0	288	34	0
08/23/18	0	0	0	1	0	3	1	2	0	0	0	0	0	3	288	111	0
08/24/18	5	3	6	0	5	0	4	0	0	0	0	98	0	0	288	288	0
08/25/18	0	1	0	1	0	1	1	2	0	0	0	141	0	0	288	288	0
08/26/18	1	0	0	0	0	1	0	0	0	0	0	91	0	0	288	288	0
08/27/18	0	1	0	2	0	0	0	0	0	0	0	46	4	0	288	169	0
08/28/18	0	0	0	0	0	0	1	0	0	0	0	40	0	0	288	5	0
08/29/18	0	0	0	3	0	5	0	30	0	0	0	66	0	24	283	12	0
08/30/18	0	0	0	0	0	0	0	32	0	0	0	132	0	0	288	1	0
08/31/18	0	0	0	0	0	0	0	16	0	0	0	13	0	0	288	5	1

Table C.2 Dropped Flow Meter Time Steps by Day - September 2018																	
Date	MH028H015 81"	MH028H029 54"	MH028H036 21"	MH029D039 48"	MH029H072 18"	MH029H073 78"	MH029S031 21"	MH053B003 48"	MH053S008 36"	MH053S009 48"	MH054E003 96"	MH054F011 68"	MH054F012 24"	MH054F012 81"	MH054F015 18"	MH054F015 30"	MH054J015 36"
09/01/18	1	0	0	1	0	0	1	17	2	0	0	0	19	0	288	275	0
09/02/18	0	0	0	0	0	0	0	66	5	0	0	0	19	0	288	281	0
09/03/18	0	3	0	0	0	0	0	135	9	0	0	0	13	0	288	284	0
09/04/18	1	0	0	2	0	0	0	107	3	0	0	0	53	0	288	286	0
09/05/18	1	0	0	0	0	0	0	257	5	0	0	0	79	0	288	286	0
09/06/18	1	0	5	2	0	0	0	132	11	0	0	0	45	9	276	244	0
09/07/18	0	0	0	0	0	0	0	45	9	0	0	0	3	2	288	254	0
09/08/18	0	0	1	4	0	0	0	68	0	0	0	0	2	0	231	161	0
09/09/18	0	0	0	0	0	0	0	145	0	0	0	0	0	163	0	66	0
09/10/18	0	0	0	0	0	0	0	281	0	0	0	0	0	288	0	64	0
09/11/18	0	0	0	0	0	0	0	200	0	0	0	0	0	288	203	91	0
09/12/18	0	0	0	5	0	0	0	54	0	0	0	0	0	143	288	201	1
09/13/18	0	0	0	0	1	0	0	187	0	0	0	0	0	0	288	113	0
09/14/18	0	0	0	0	0	0	0	288	0	0	2	0	0	0	288	98	0
09/15/18	0	0	0	0	0	0	0	288	0	0	0	0	0	0	288	88	0
09/16/18	0	0	0	0	0	0	0	288	0	0	0	0	0	0	288	75	0
09/17/18	0	0	0	0	0	0	0	209	0	0	1	0	0	0	252	66	0
09/18/18	0	0	0	0	1	0	0	221	0	0	0	0	0	0	254	81	0
09/19/18	0	0	0	0	0	0	0	77	0	0	12	0	0	0	288	63	0
09/20/18	0	0	0	0	0	0	0	5	0	0	0	0	1	0	288	36	0
09/21/18	0	0	0	0	0	0	0	30	0	1	0	0	0	1	252	67	0
09/22/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	87	0
09/23/18	3	0	0	0	0	0	0	1	0	0	0	2	0	0	288	46	0
09/24/18	1	0	5	0	0	0	0	13	0	0	0	0	0	0	288	52	0
09/25/18	0	0	0	0	0	0	1	4	0	0	0	0	0	0	88	49	0
09/26/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	271	66	0
09/27/18	0	0	0	0	0	0	0	0	0	0	5	0	0	0	288	140	0
09/28/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	97	0
09/29/18	0	0	0	0	0	0	0	0	0	0	0	0	1	0	288	52	0
09/30/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	48	0

Table C.2 Dropped Flow Meter Time Steps by Day - October 2018																	
Date	**MH028H015 81"**	**MH028H029 54"**	**MH028H036 21"**	**MH029D039 48"**	**MH029H072 18"**	**MH029H073 78"**	**MH029S031 21"**	**MH053B003 48"**	**MH053S008 36"**	**MH053S009 48"**	**MH054E003 96"**	**MH054F011 68"**	**MH054F012 24"**	**MH054F012 81"**	**MH054F015 18"**	**MH054F015 30"**	**MH054J015 36"**
10/01/18	1	0	12	0	0	0	0	0	0	0	12	0	0	0	288	0	0
10/02/18	0	0	2	2	1	0	0	32	0	0	0	0	1	0	261	1	0
10/03/18	1	0	0	0	1	1	0	22	1	0	0	0	0	0	288	0	0
10/04/18	0	1	7	1	0	0	0	37	0	0	0	0	0	0	185	0	0
10/05/18	1	0	0	0	0	9	0	0	0	0	0	0	0	0	280	1	0
10/06/18	0	0	5	0	0	1	0	61	0	0	1	0	0	0	187	0	0
10/07/18	1	0	0	0	0	1	0	80	0	0	16	0	0	0	231	3	0
10/08/18	0	0	0	0	0	0	0	288	0	0	0	0	0	0	288	2	0
10/09/18	0	0	0	0	0	0	0	288	0	0	1	0	0	0	288	0	0
10/10/18	4	0	1	0	5	17	5	288	0	0	0	0	0	0	288	0	0
10/11/18	0	0	5	0	0	0	0	288	0	0	0	0	0	0	288	0	0
10/12/18	0	0	0	0	0	0	0	288	0	0	0	0	0	0	288	0	0
10/13/18	0	0	0	0	0	0	0	288	0	0	0	0	0	0	288	1	1
10/14/18	0	0	0	0	1	0	0	288	0	0	0	0	0	0	288	0	1
10/15/18	0	0	0	0	0	0	0	288	0	0	0	0	0	155	279	25	0
10/16/18	0	0	0	0	0	0	0	147	0	0	0	0	0	135	288	173	0
10/17/18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	288	90	0
10/18/18	0	1	0	0	0	0	0	2	0	0	0	0	0	0	288	128	0
10/19/18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	288	131	0
10/20/18	0	0	0	4	0	0	0	5	0	0	0	0	0	0	288	6	0
10/21/18	0	0	0	46	0	0	0	7	0	0	0	0	0	0	288	26	0
10/22/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	104	0
10/23/18	3	0	0	0	0	0	0	0	0	0	0	3	0	14	288	154	0
10/24/18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	288	205	0
10/25/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	203	0
10/26/18	0	0	0	0	285	0	0	4	0	0	0	12	0	0	274	181	0
10/27/18	0	0	0	0	288	0	0	0	0	0	0	0	0	0	0	1	0
10/28/18	0	0	1	0	288	0	0	1	0	0	0	0	0	0	55	0	0
10/29/18	0	0	2	0	135	0	0	0	0	0	1	0	0	0	173	3	0
10/30/18	1	0	1	0	0	0	1	0	0	0	0	0	0	0	288	26	0
10/31/18	0	0	1	1	0	0	0	3	0	0	0	0	1	0	288	79	0

Table C.2 Dropped Flow Meter Time Steps by Day - November 2018																	
Date	**MH028H015 81"**	**MH028H029 54"**	**MH028H036 21"**	**MH029D039 48"**	**MH029H072 18"**	**MH029H073 78"**	**MH029S031 21"**	**MH053B003 48"**	**MH053S008 36"**	**MH053S009 48"**	**MH054E003 96"**	**MH054F011 68"**	**MH054F012 24"**	**MH054F012 81"**	**MH054F015 18"**	**MH054F015 30"**	**MH054J015 36"**
11/01/18	0	0	2	0	0	12	0	0	276	0	1	0	0	24	266	2	0
11/02/18	0	0	0	62	0	0	0	0	65	0	0	0	6	1	263	6	0
11/03/18	0	0	5	288	0	1	0	0	0	0	0	0	0	0	288	3	0
11/04/18	0	1	12	288	0	0	0	12	12	12	12	12	0	0	288	12	0
11/05/18	0	0	0	43	0	0	0	0	0	0	0	0	0	0	288	0	0
11/06/18	0	0	0	0	0	0	0	0	0	0	14	0	0	1	209	4	0
11/07/18	0	0	2	0	0	0	0	0	0	0	0	0	0	1	288	0	0
11/08/18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	288	0	0
11/09/18	0	0	0	1	0	0	0	0	0	0	2	0	0	0	87	1	0
11/10/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	5	188
11/11/18	0	0	0	0	0	0	0	0	0	0	0	0	0	3	288	6	272
11/12/18	0	0	1	0	0	0	0	0	0	0	0	0	0	0	288	4	288
11/13/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	0	169
11/14/18	0	0	0	0	0	0	0	0	0	0	0	1	1	0	288	0	0
11/15/18	0	0	0	145	0	0	0	0	0	0	0	0	0	0	134	0	0
11/16/18	0	0	0	287	0	0	0	0	0	0	0	0	0	0	1	1	0
11/17/18	0	0	0	17	0	0	0	0	0	0	0	0	0	0	14	0	2
11/18/18	0	0	0	10	0	0	0	0	0	0	0	0	0	0	186	0	33
11/19/18	0	0	0	59	0	0	0	0	0	0	0	0	0	0	7	0	1
11/20/18	0	0	0	2	0	0	0	0	0	0	0	0	0	0	5	0	0
11/21/18	0	0	2	0	0	0	0	0	0	0	2	0	0	0	123	0	0
11/22/18	1	0	0	0	1	0	0	0	0	0	0	0	0	0	288	3	0
11/23/18	0	0	1	0	0	0	1	0	0	0	0	0	0	0	288	6	0
11/24/18	0	0	0	5	0	0	0	0	0	0	0	0	0	0	94	1	0
11/25/18	0	0	0	0	0	1	1	0	0	0	0	0	0	5	4	0	0
11/26/18	4	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
11/27/18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	111	0	0
11/28/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	2	0
11/29/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	12	0
11/30/18	0	0	0	0	0	0	0	0	0	0	53	0	0	0	288	5	0

In addition to flow meter downtime which caused some potential calibration/validation storms to not be used, an issue with repeating data was also identified. This issue involves multiple sequential time steps having the exact same value (not produced by rounding) in the flow meter data. The issue could involve the either the depth, velocity or flow and potentially all of them repeating concurrently. If the flow and or depth were repeating at a time when the peak a storm occurred that storm event would be removed since the true peak flow or depth was not included in the flow meter data. This issue varied widely by flow meter and is summarized in Table C.3 below.

Table C.3: Flow Meter Data Repeat Occurrence

Flow Meter	Pipe Diameter (in)	Depth Repeats	Velocity Repeats	Flow Repeats	Total Repeats
MH028H015	81	43.8%	35.5%	22.7%	34.0%
MH028H029	54	1.0%	0.4%	0.5%	0.6%
MH028H036	21	0.6%	0.5%	0.4%	0.5%
MH053B003	48	12.7%	14.2%	19.7%	15.5%
MH029D039	48	10.1%	3.2%	11.3%	8.2%
MH053S008	36	6.3%	4.1%	4.5%	5.0%
MH053S009	48	5.0%	4.1%	4.2%	4.4%
MH054F015	18	82.1%	87.6%	84.4%	84.7%
MH054F015	30	4.8%	2.8%	18.5%	8.7%
MH029H072	18	6.0%	28.2%	7.5%	13.9%
MH029H073	78	36.9%	35.8%	23.7%	32.1%
MH029S031	21	4.4%	32.1%	5.6%	14.0%
MH054E003	96	33.1%	31.1%	18.2%	27.5%
MH054F011	68	3.9%	4.1%	3.6%	3.9%
MH054F012	24	11.5%	8.3%	30.4%	16.7%
MH054F012	81	29.4%	26.8%	20.0%	25.4%
MH054J015	36	5.7%	4.0%	4.2%	4.6%
Overall Average		**13.5%**	**14.7%**	**12.2%**	**13.4%**
Overall Median		**6.1%**	**6.2%**	**9.4%**	**11.3%**
Four Largest Pipes (Average)		**35.8%**	**32.3%**	**21.2%**	**29.8%**

The data did not indicate any particular trend other than that larger diameter pipes had greater occurrence of data repetition. Ultimately, storm events were removed from consideration for the following three reasons:

- Flow meter downtime meant there was no comparison possible between the flow meter data and the model simulation results.
- Data repetition occurred that prevented the flow meter from capturing the actual peak flow or peak depth so that a comparison of those results to the model simulation results was not possible.
- The flow meter results did not trend with the measured rainfall (i.e. small storm with high volume or peak flow or vice versa). In these cases, the model could not replicate the flow meter data. This could be due to the rainfall being non-representative or that the flow meter over or under reported compared to other storm events.

D. Flow Meter Specific Notes

Figure A.1 below shows a map of the M-29 sewershed indicating the locations of the installed flow meters and rain gages.

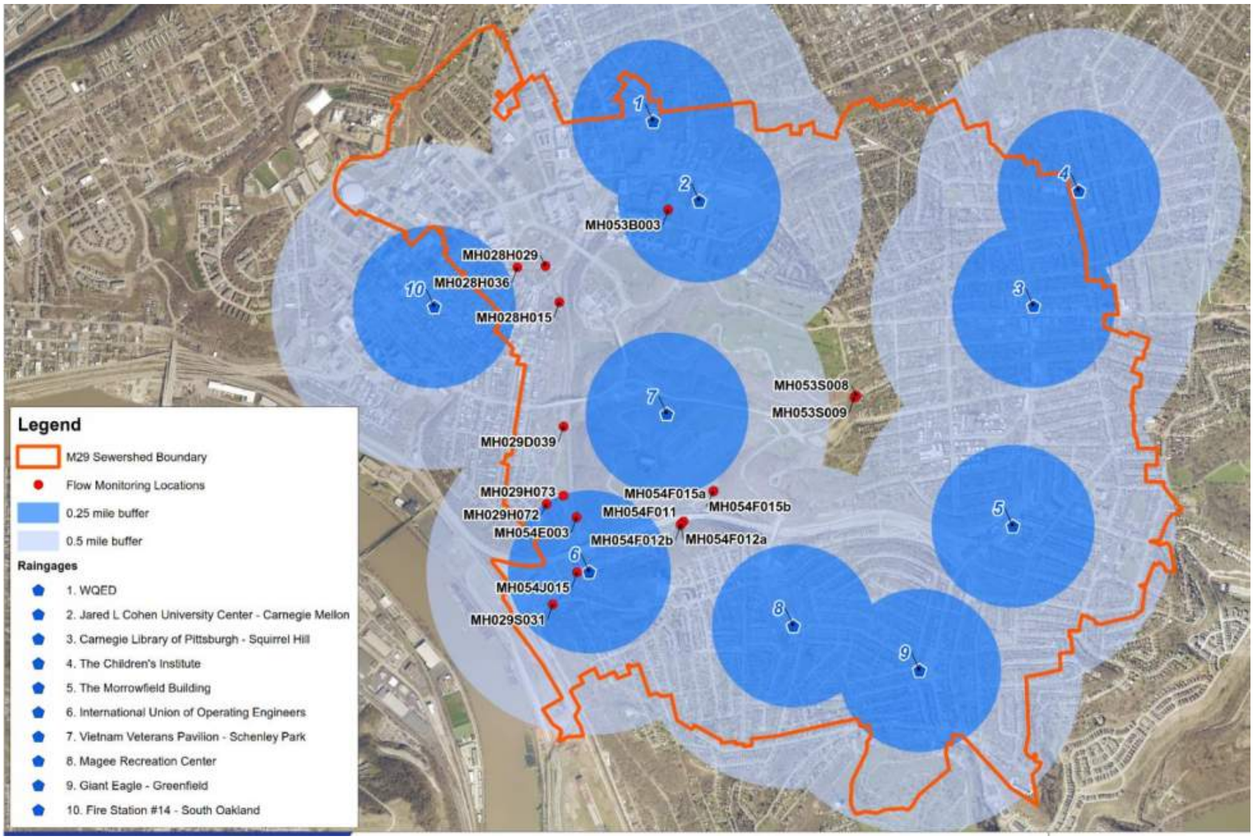


Figure A.1: Map of Flow Meter and Rain Gage Locations

Below are notes about specific flow meters that are important to understanding their overall calibration in the 4MR Project model.

- **MH053B003** – This meter experiences total aggregate downtime of almost 25% as shown in Table A.2. This downtime extended across most of the calibration and rainfall events so calibration and validation statistics were not calculated for this flow meter.
- **MH053S008 and MH053S009** – These flow meters are on parallel interceptors with an overlapping upstream drainage area due to cross connection. This cross connection caused calibration of the individual flow meters to be ineffective (both dry weather flow and wet weather flow) so effort was focused on calibrating to the aggregate flow of both meters. A good match for the aggregate flow indicates that the flow contribution of the upstream drainage area is being sufficiently represented, but additional field investigation to more precisely define the cross connection may be warranted. The flows from these two (2) meters are themselves immediately cross connected just downstream of the flow meter locations as shown in Figure A.2.

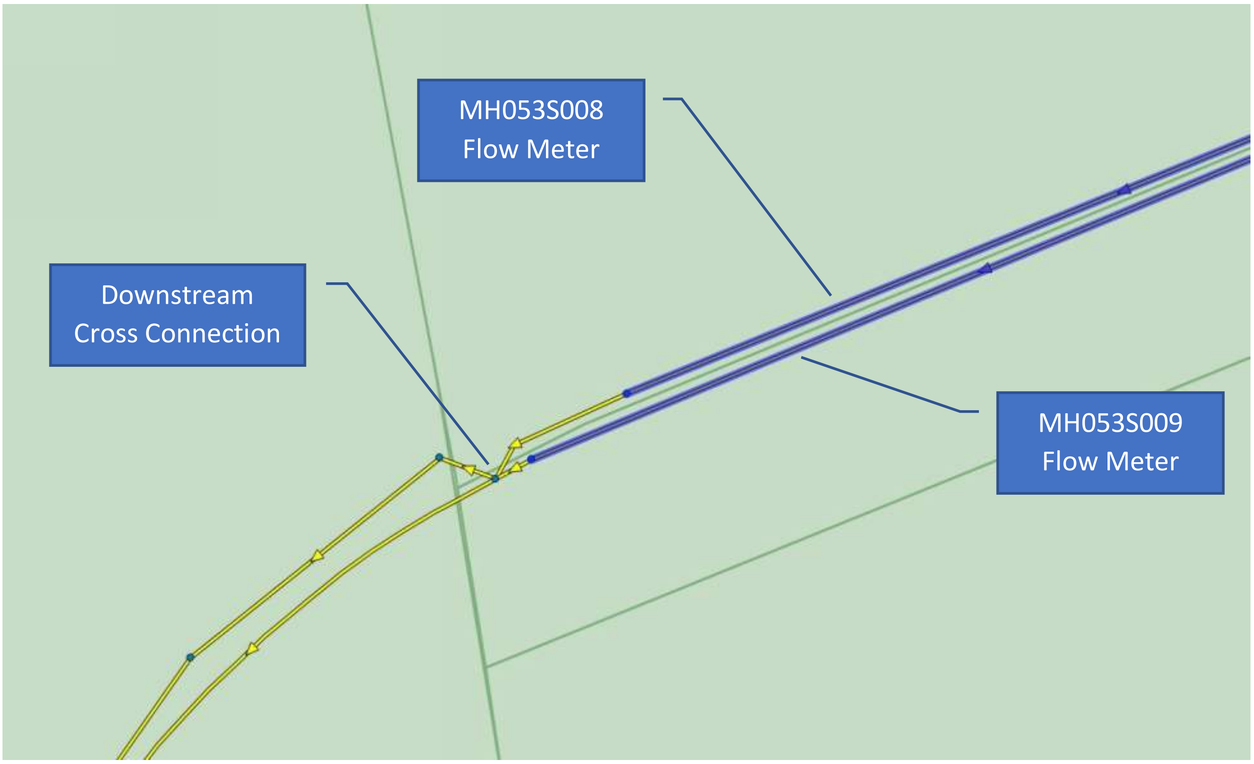


Figure A.2: Configuration of Pipes Near Flow Meters MH053S008 and MH053S009

- **MH054F015 (30" Pipe)** – The meter at this location proved unreliable because of field conditions indicating that overland flow from Naylor Run was bypassing the entry catch basin resulting in the flow meter substantially under-reporting the suspected actual flows. This is a challenging flow monitoring location and additional field investigation is needed to best determine how to accurately measure flows in this area. Results for this flow meter are not reported in the appendix.
- **MH054F015 (18" Pipe)** – The meter at this location recorded no flow for the vast majority of the flow monitoring period as shown in Table A.2. Results for this flow meter are not reported in the appendix.
- **MH028H036** – This meter is located in the Oakland area and is just downstream of where three (3) parallel pipes meet at a common structure and then two pipes exit the structure and continue downstream as shown in Figure A.3. This meter was challenging to calibrate because the junction structure and the inverts of the various entry and exit pipes have a substantial influence on the flows seen in MH028H036. Since there both merging flows and flow splits immediately upstream of MH028H036, it was difficult to determine if changes to the upstream flow generation characteristics of the sewershed were needed, modifications at the junction structure or both to provide the most realistic model performance. The meter also had exhibited periods of increasing flows during dry weather periods and wet weather periods where only a very mitigated response from the flow meter was recorded. Ultimately, the calibration was focused on matching the same flows range as the flow meter exhibited.

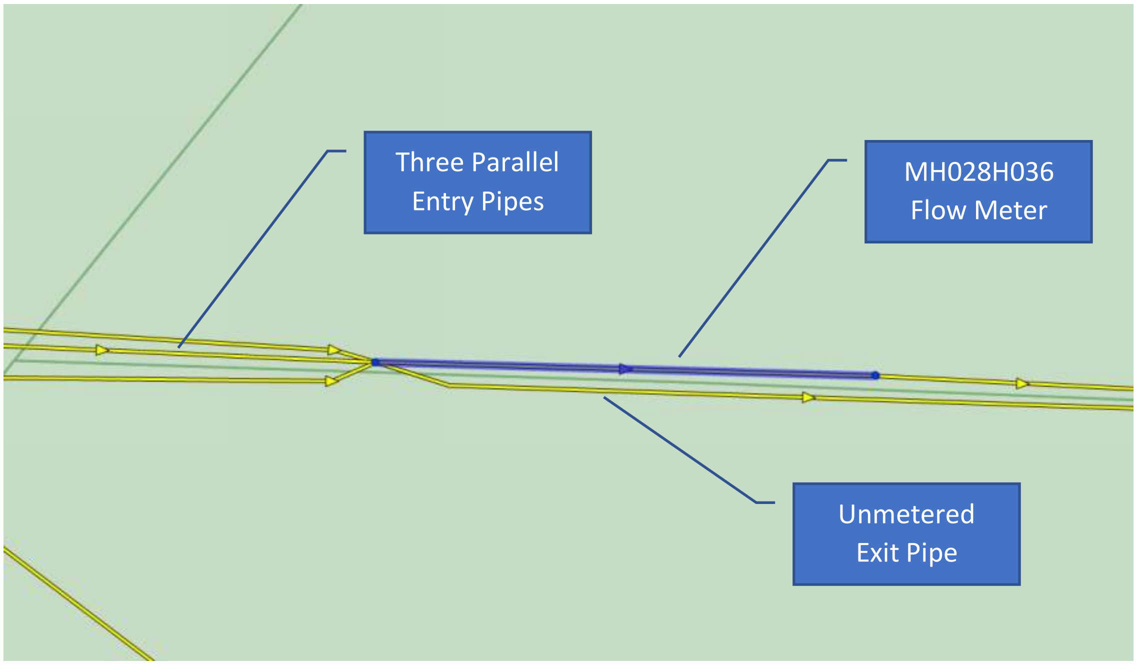


Figure A.3: Configuration of Pipes Near Flow Meter MH028H036

E. Calibration/Validation Results

Following are the various charts, graph and tables detailing the calibration and validation performance of the flow meters.

DWF Calibration Statistics MH028H015 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	2.39	1.63	**46.3%**
Volume - MG	7.67	4.96	**54.8%**
Depth (Avg) - in	3.30	2.71	**0.6**

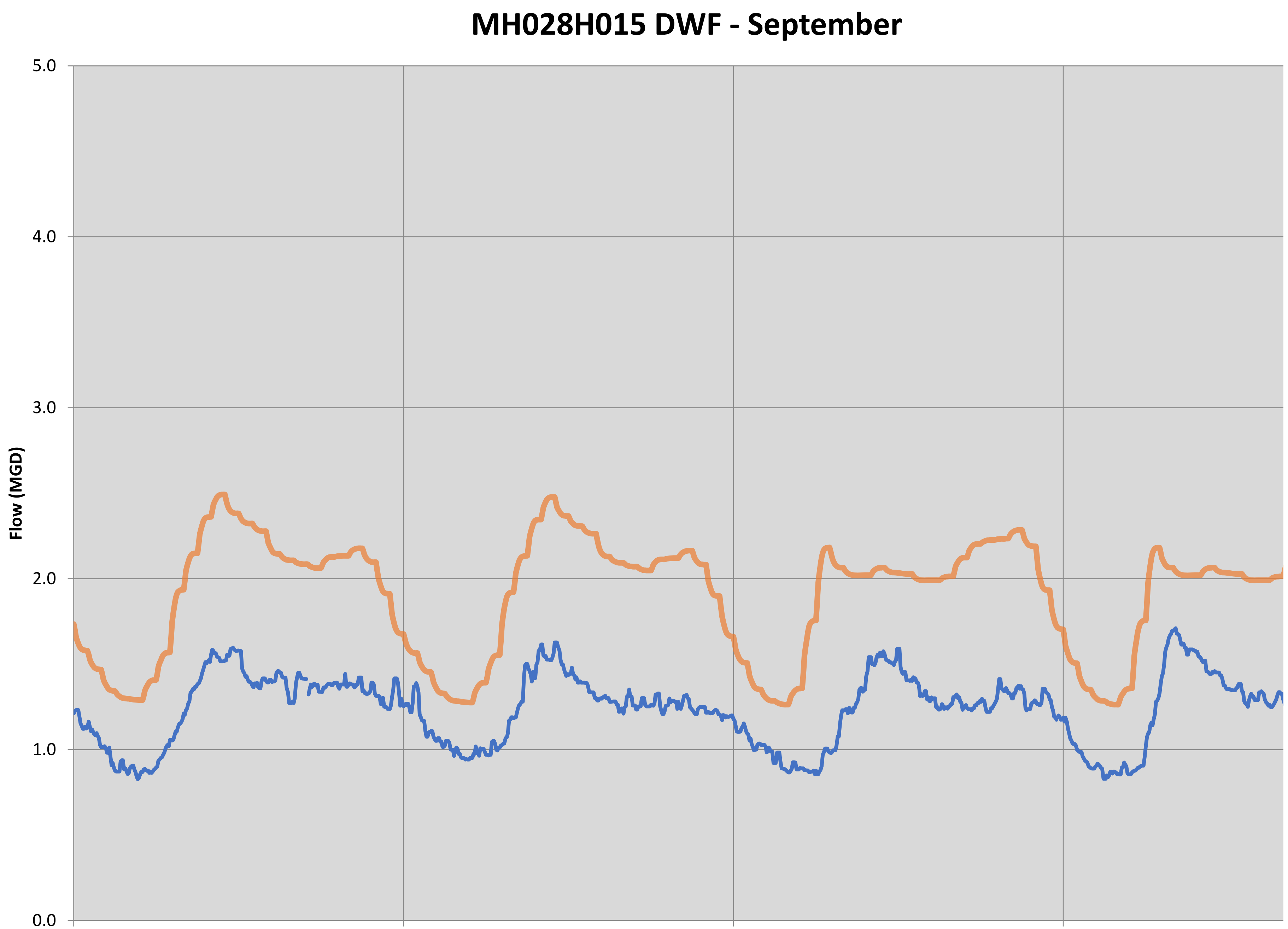
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	2.49	1.60
9/2/18	2.48	1.63
9/3/18	2.29	1.59
9/4/18	2.28	1.71

DWF Calibration Statistics MH028H015 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	2.36	1.86	**26.7%**
Volume - MG	7.96	5.79	**37.5%**
Depth (Avg) - in	3.35	2.74	**0.6**

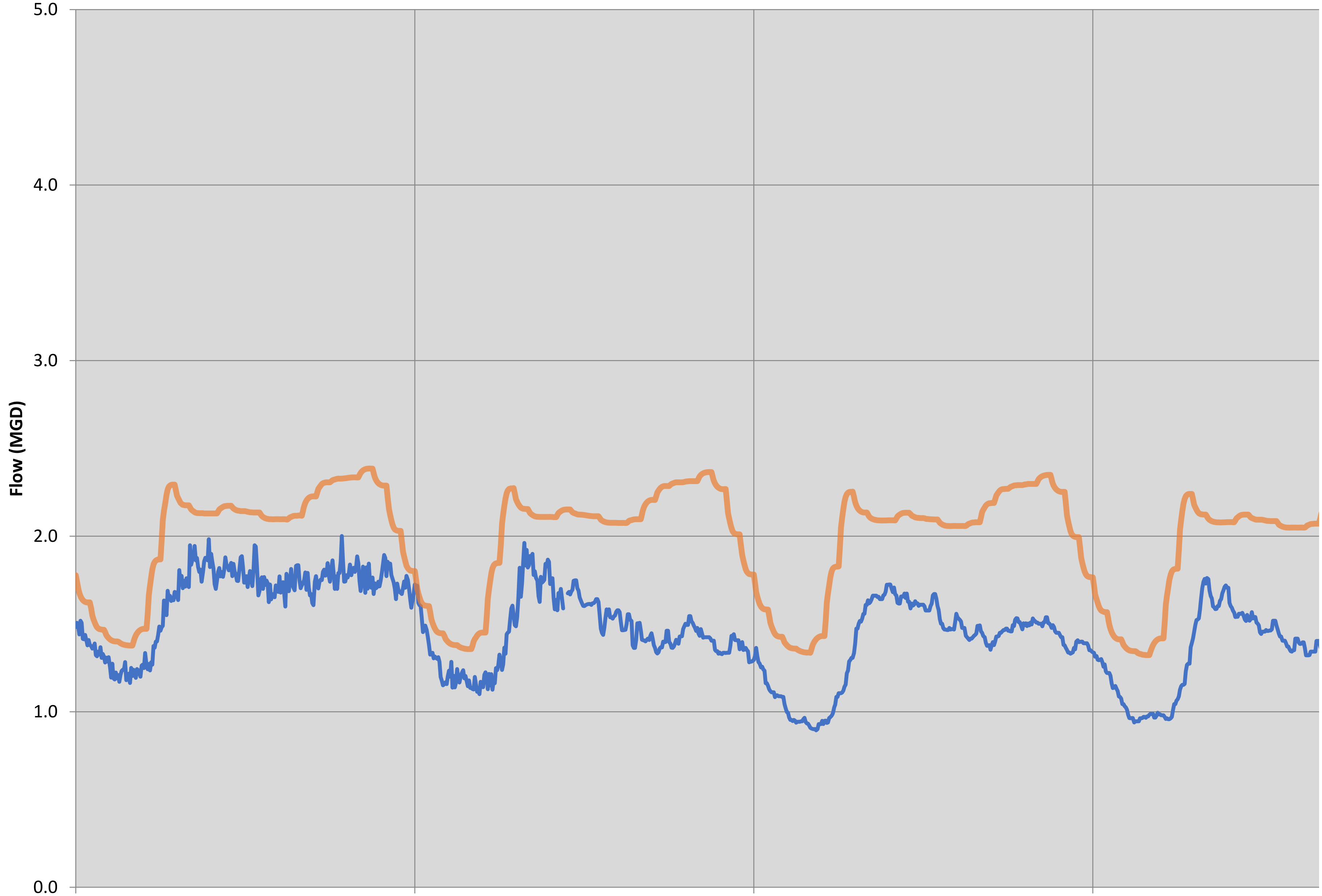
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	2.39	2.00
10/23/18	2.36	1.96
10/24/18	2.35	1.73
10/25/18	2.34	1.76

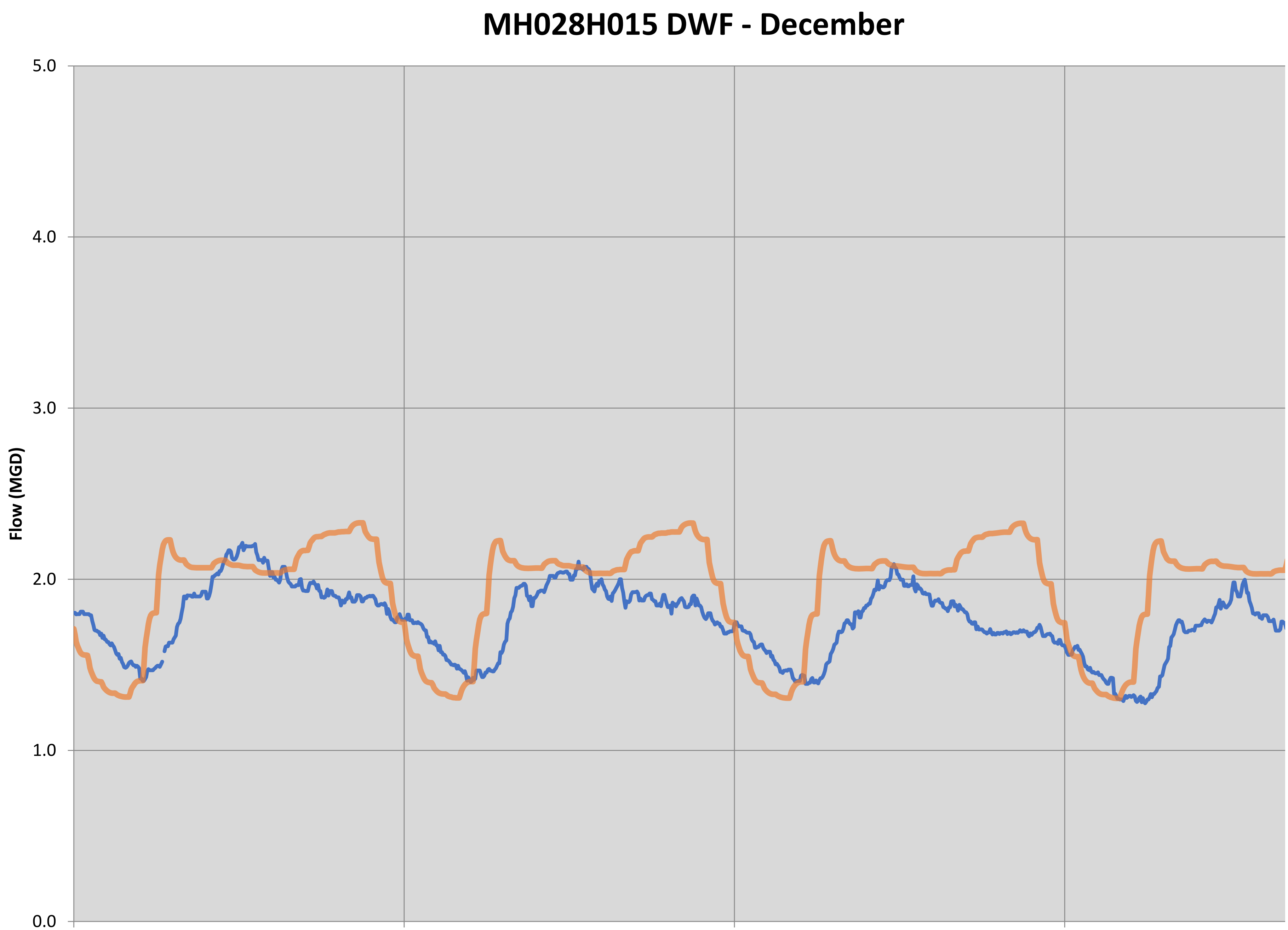
DWF Calibration Statistics MH028H015 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	2.33	2.10	**10.8%**
Volume - MG	7.81	6.99	**11.7%**
Depth (Avg) - in	3.33	3.17	**0.2**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	2.33	2.21
10/23/18	2.33	2.10
10/24/18	2.33	2.09
10/25/18	2.33	2.00


MH028H015 DWF - September
Flow (MGD)
5.0
4.0
3.0
2.0
1.0
0.0

MH028H015 DWF - October



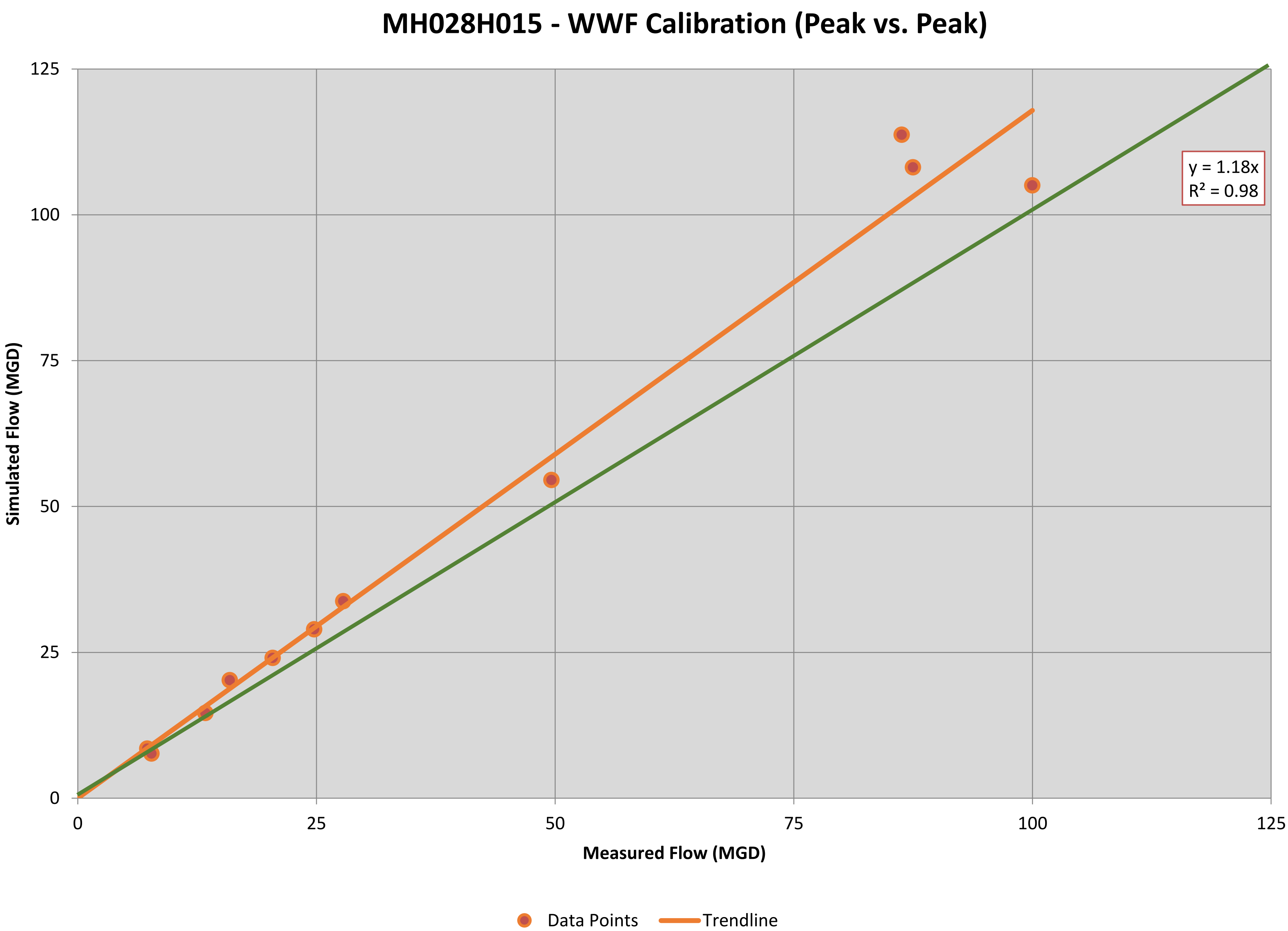

MH028H015 DWF - December
Flow (MGD)
5.0
4.0
3.0
2.0
1.0
0.0

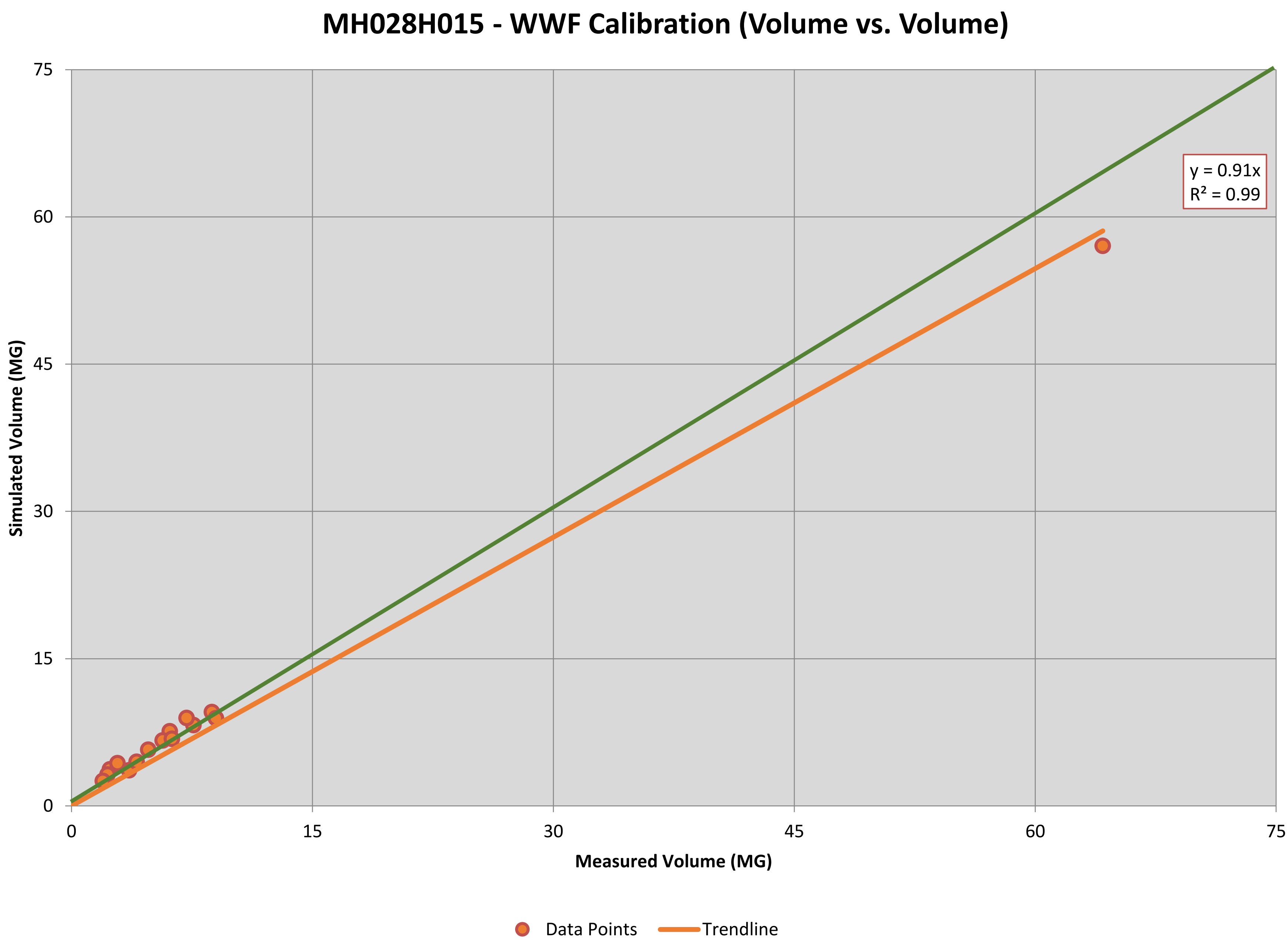
		MH028H015 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	27.81	33.77	21.4%	2.40	3.71	54.6%	9.9	12.3	2.4
09/06/18	Validation	87.49	108.12	23.6%	2.87	4.34	51.6%	18.1	27.2	9.2
09/07/18	Calibration	100.00	105.06	5.1%	64.21	57.05	-11.2%	19.0	26.6	7.6
09/17/18	Calibration	49.62	54.55	9.9%	7.60	8.22	8.1%	12.4	16.7	4.3
09/21/18	Validation	86.32	113.73	31.8%	6.12	7.59	24.0%	16.5	28.2	11.7
09/24/18	Validation	20.43	24.04	17.7%	8.74	9.56	9.4%	8.6	10.1	1.4
10/02/18	Validation				2.24	3.18	41.8%			
10/04/18	Calibration				5.69	6.65	17.0%			
10/06/18	Calibration				6.25	6.82	9.1%			
10/15/18	Calibration	7.28	8.50	16.7%	1.96	2.55	29.8%	5.6	5.9	0.3
10/26/18	Calibration	15.93	20.22	27.0%	7.18	8.94	24.6%	7.5	9.2	1.6
10/28/18	Calibration	7.73	7.63	-1.3%	3.59	3.62	0.8%	5.2	5.7	0.4
11/09/18	Calibration				4.78	5.73	19.9%			
11/15/18	Calibration									
11/18/18	Validation	13.37	14.58	9.0%	9.00	8.91	-1.0%	7.3	7.7	0.4
11/24/18	Validation	24.77	28.95	16.9%	4.06	4.49	10.7%	9.3	11.2	1.9
Totals		440.7	519.2	17.8%	136.7	141.4	3.4%	120	161	41.3

Notes:

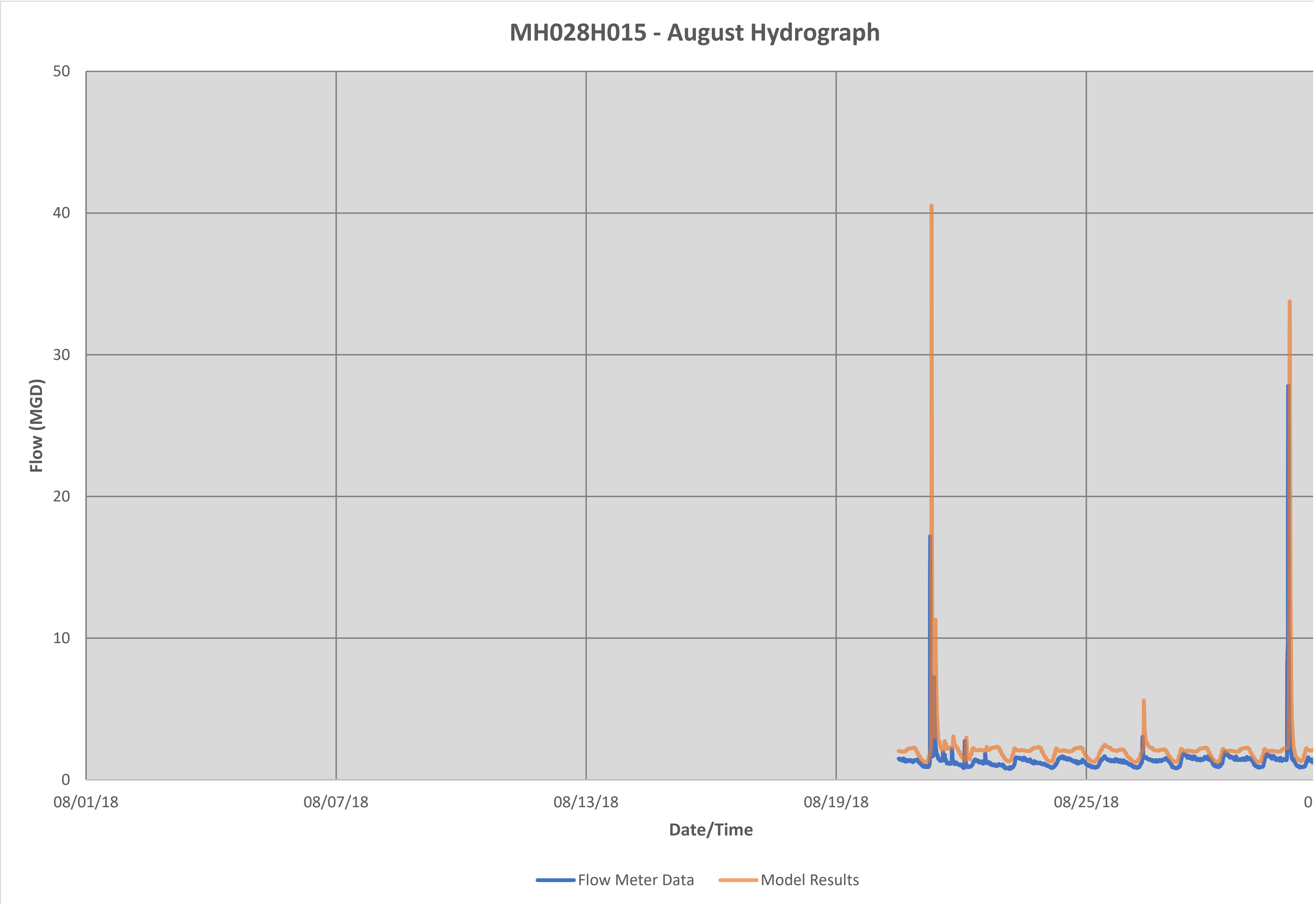
Storm events on 10/04/18 and 10/06/18 had peak depth/flow comparisons removed because of data repeat during the peak of the event

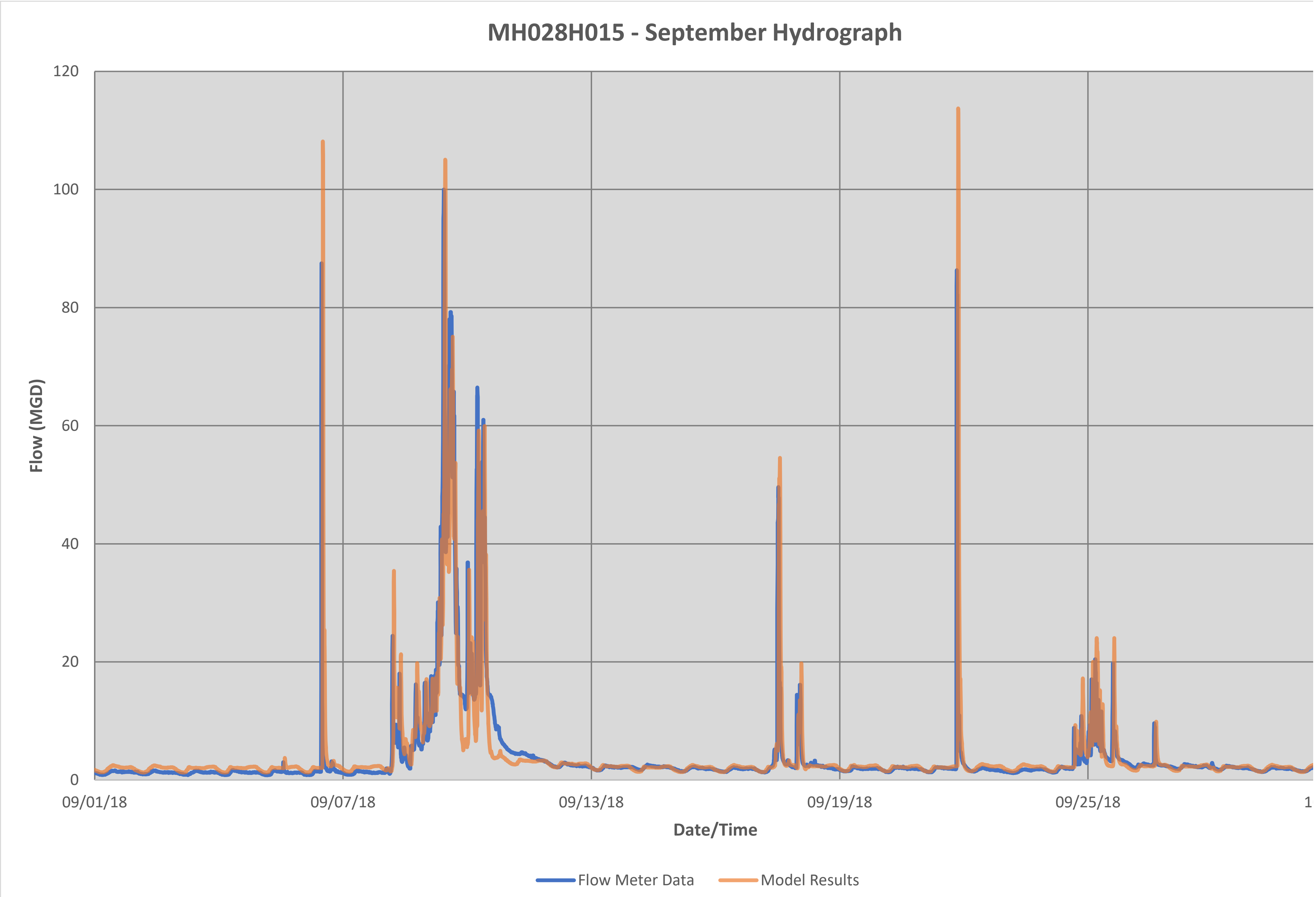
Storm event on 11/15/18 removed due to non representative rainfall


MH028H015 - WWF Calibration (Peak vs. Peak)
Simulated Flow (MGD)
Measured Flow (MGD)
0
25
50
75
100
125
y = 1.18x
R² = 0.98
Data Points
Trendline

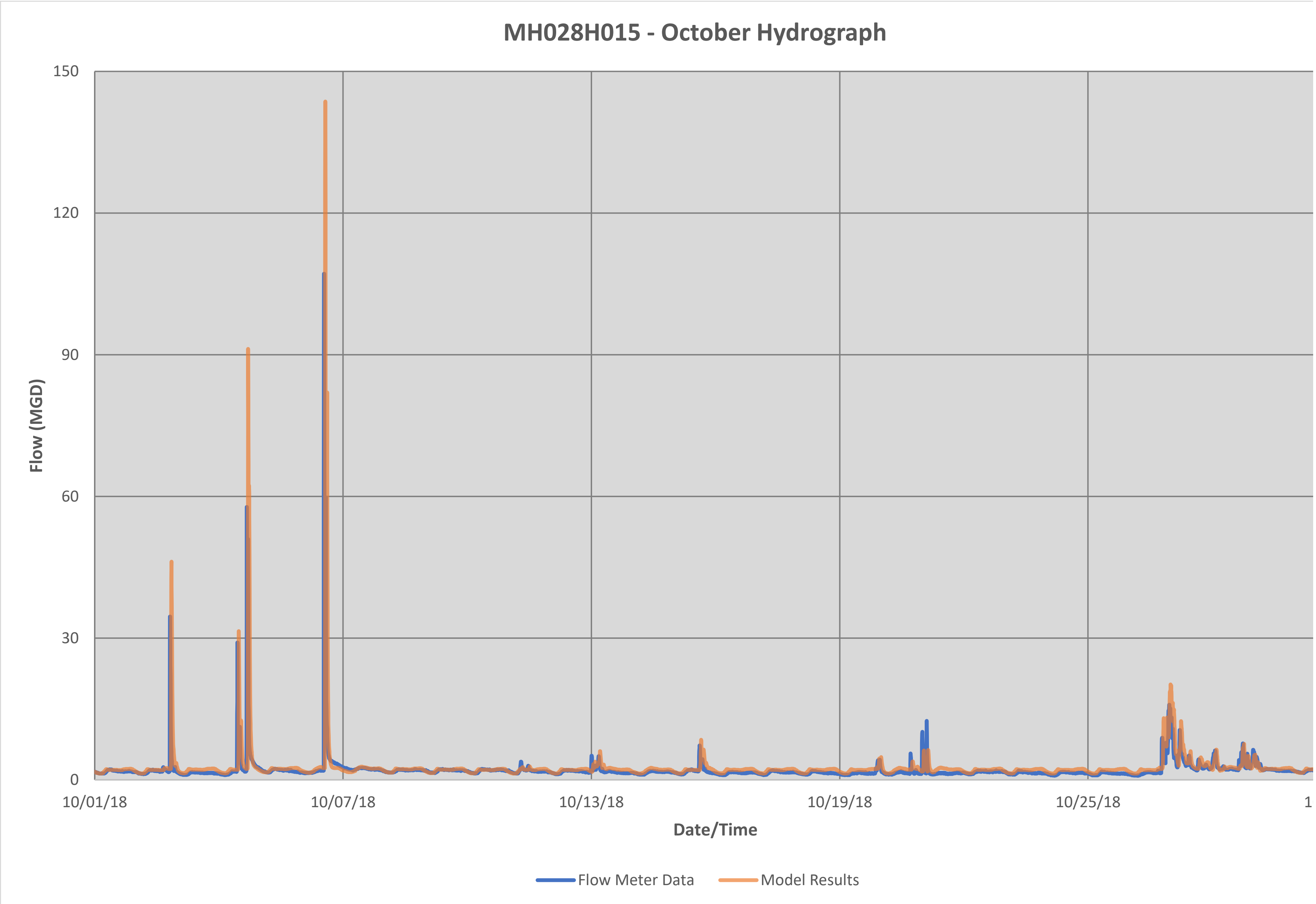


MH028H015 - WWF Calibration (Volume vs. Volume)
y = 0.91x
R² = 0.99
Simulated Volume (MG)
Measured Volume (MG)
0
15
30
45
60
75
Data Points
Trendline

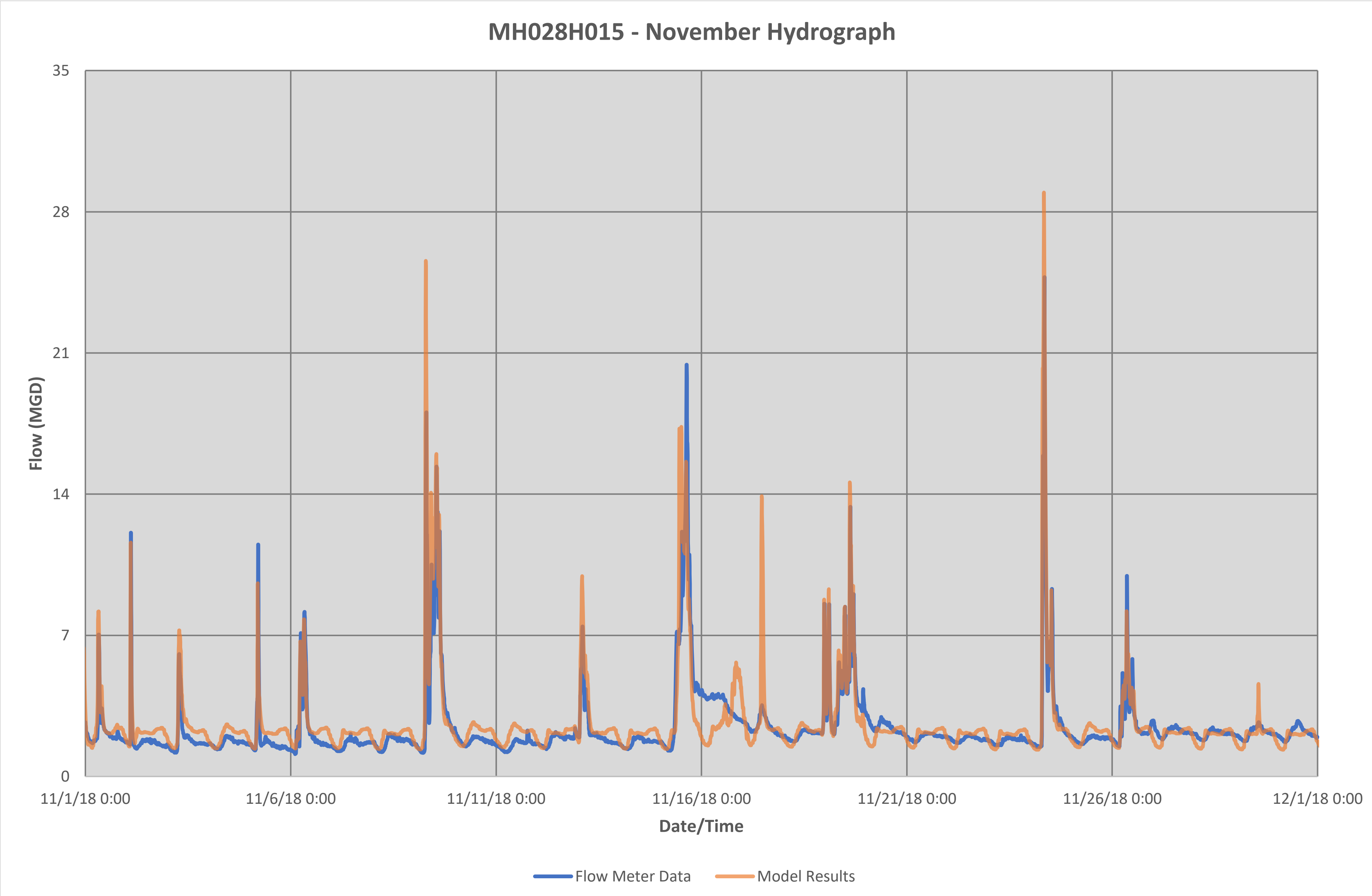

MH028H015 - August Hydrograph
Flow (MGD)
50
40
30
20
10
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results



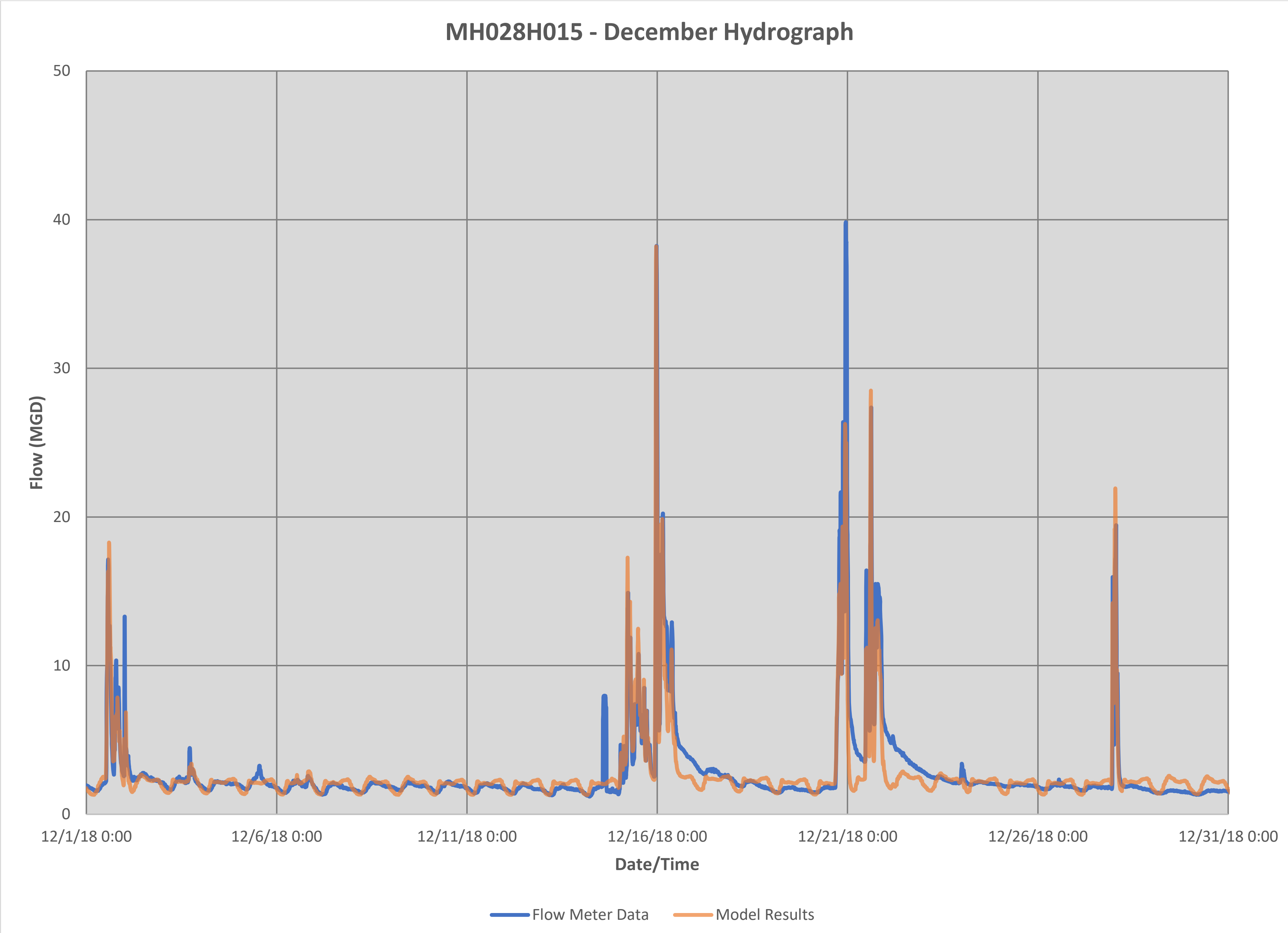
MH028H015 - September Hydrograph
120
100
80
60
40
20
0
Flow (MGD)
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH028H015 - October Hydrograph
150
120
90
60
30
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH028H015 - November Hydrograph
35
28
21
14
7
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1/18 0:00
Date/Time
Flow Meter Data
Model Results


MH028H015 - December Hydrograph
Flow (MGD)
50
40
30
20
10
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH028H029 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.89	2.23	**-15.5%**
Volume - MG	5.55	6.38	**-13.0%**
Depth (Avg) - in	2.88	3.88	**-1.0**

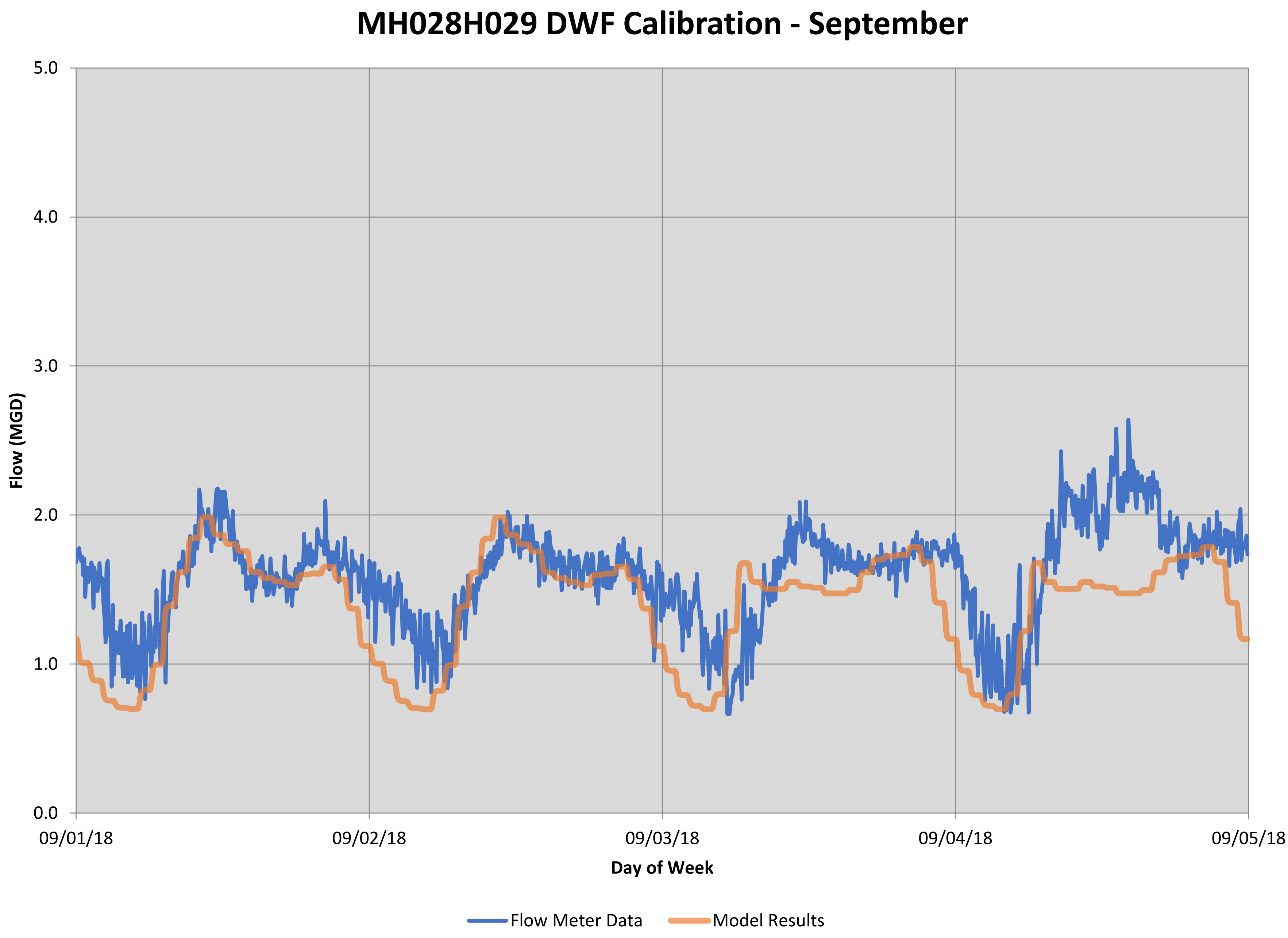
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	1.99	2.18
9/2/18	1.98	2.02
9/3/18	1.79	2.09
9/4/18	1.79	2.64

DWF Calibration Statistics MH028H029 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.79	2.07	**-13.4%**
Volume - MG	5.57	5.84	**-4.6%**
Depth (Avg) - in	2.89	3.51	**-0.6**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	1.79	2.06
10/23/18	1.79	2.08
10/24/18	1.79	2.11
10/25/18	1.79	2.02

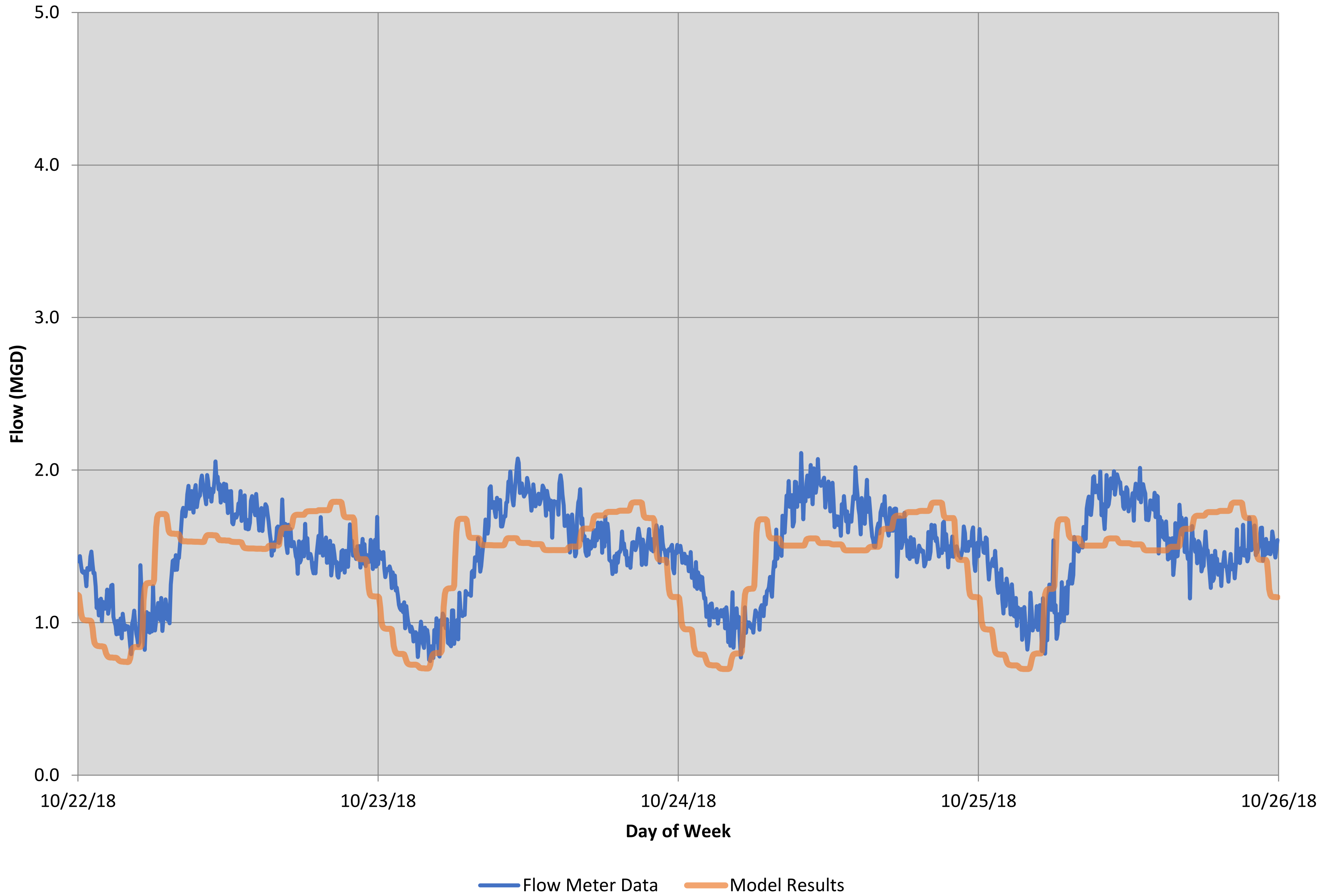
DWF Calibration Statistics MH028H029 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.79	2.31	**-22.7%**
Volume - MG	5.54	6.29	**-11.8%**
Depth (Avg) - in	2.89	3.65	**-0.8**

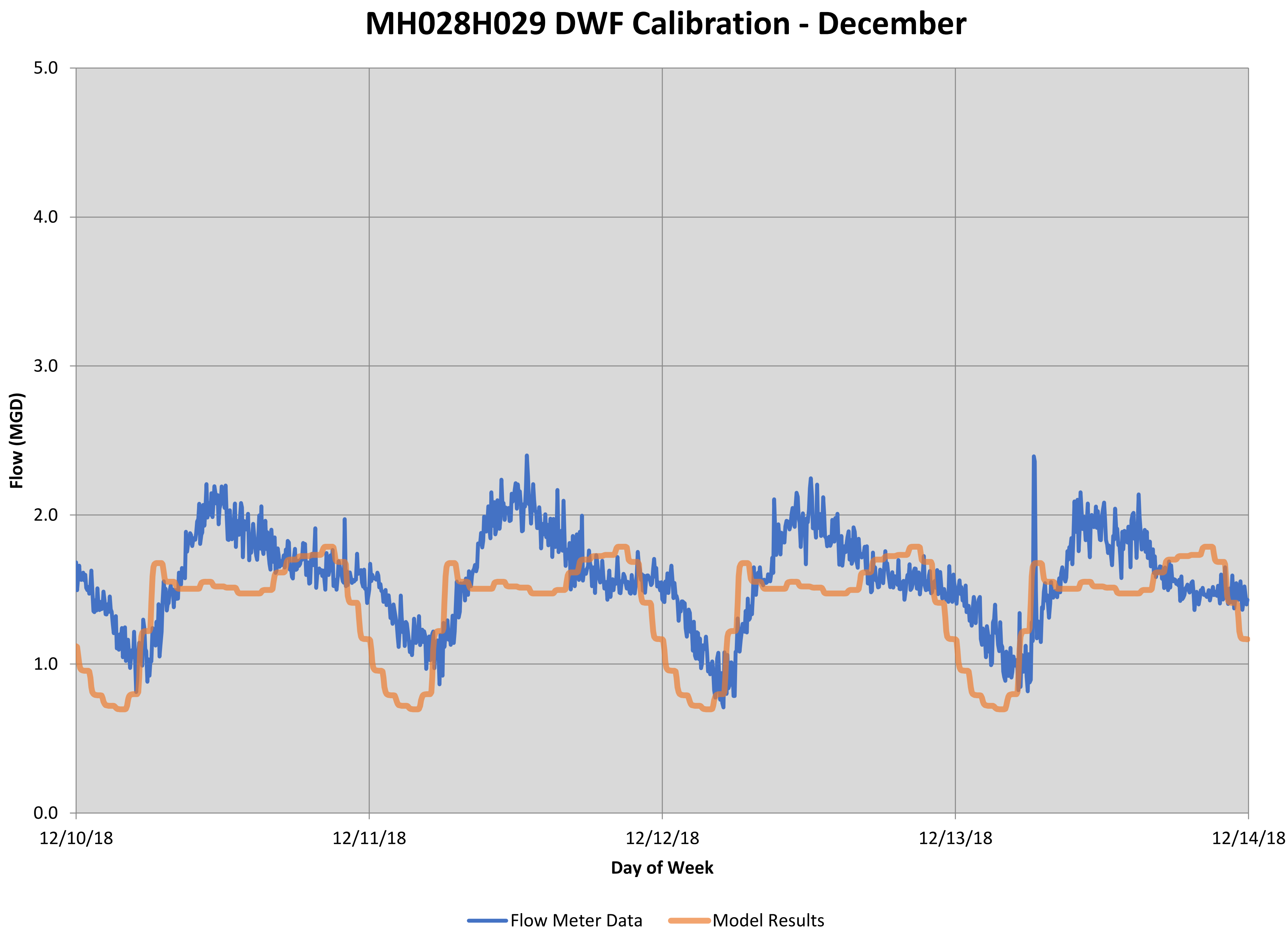
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	1.79	2.21
12/11/18	1.79	2.40
12/12/18	1.79	2.25
12/13/18	1.79	2.39



MH028H029 DWF Calibration - September
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

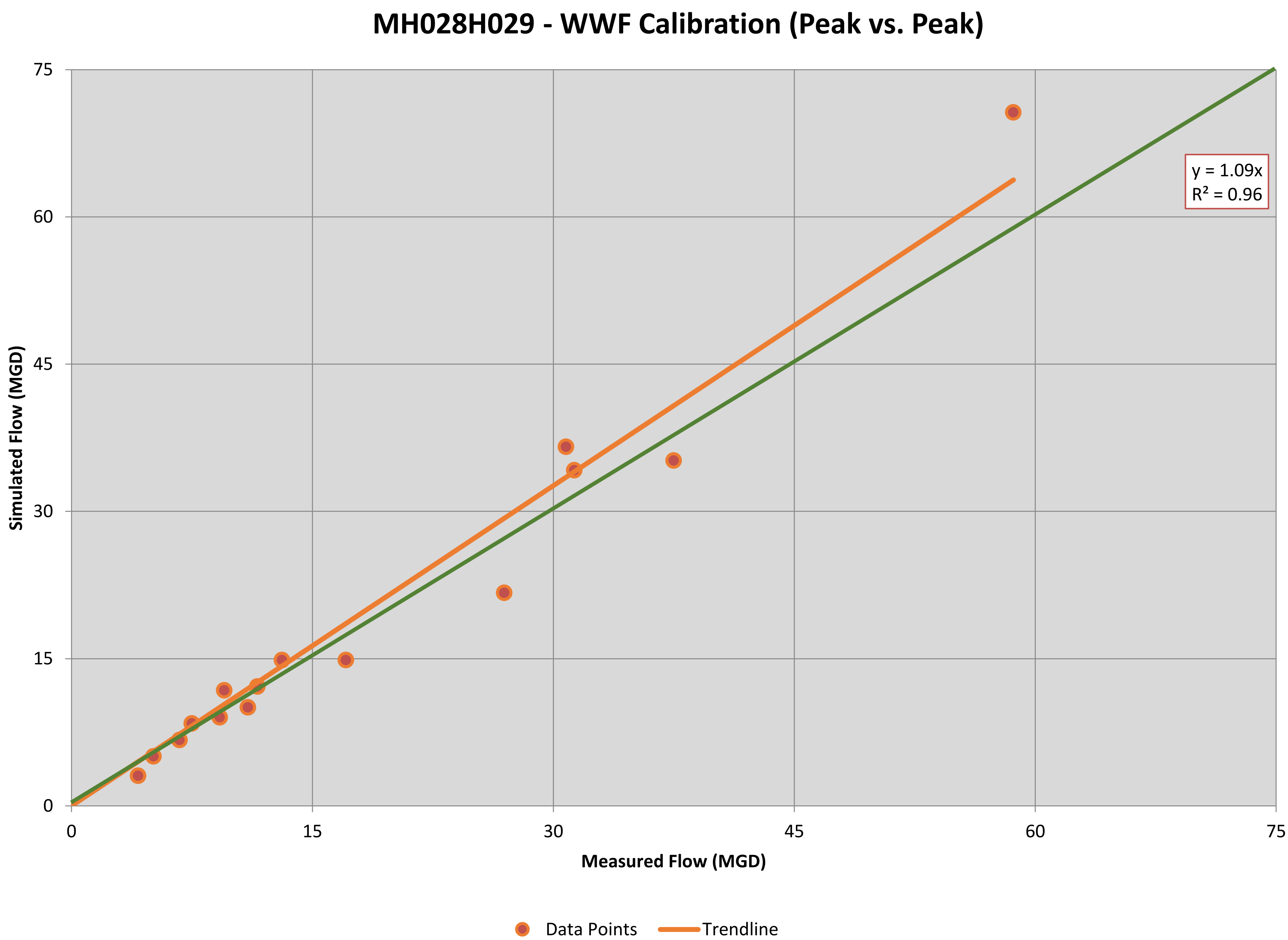
MH028H029 DWF Calibration - October

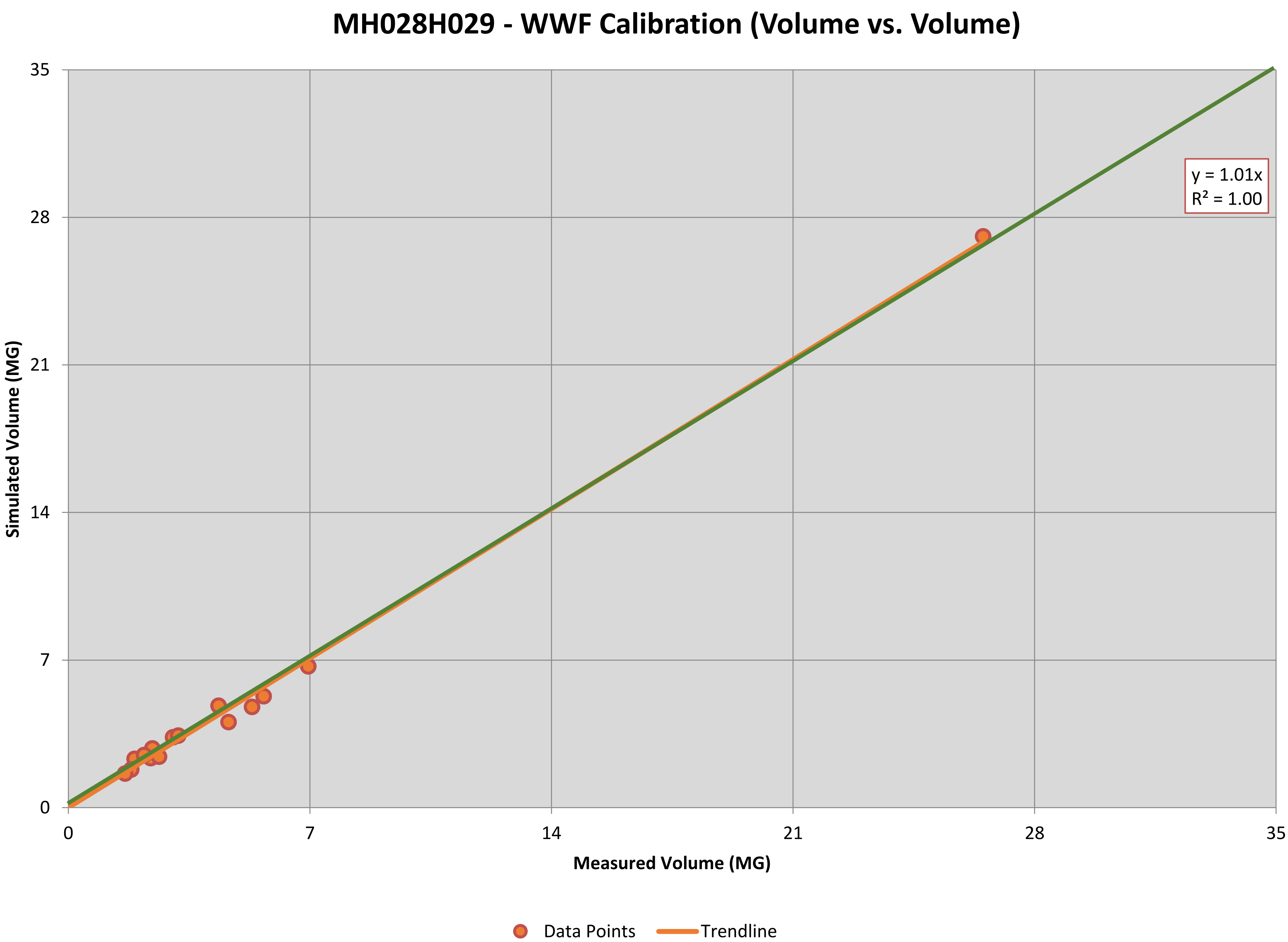




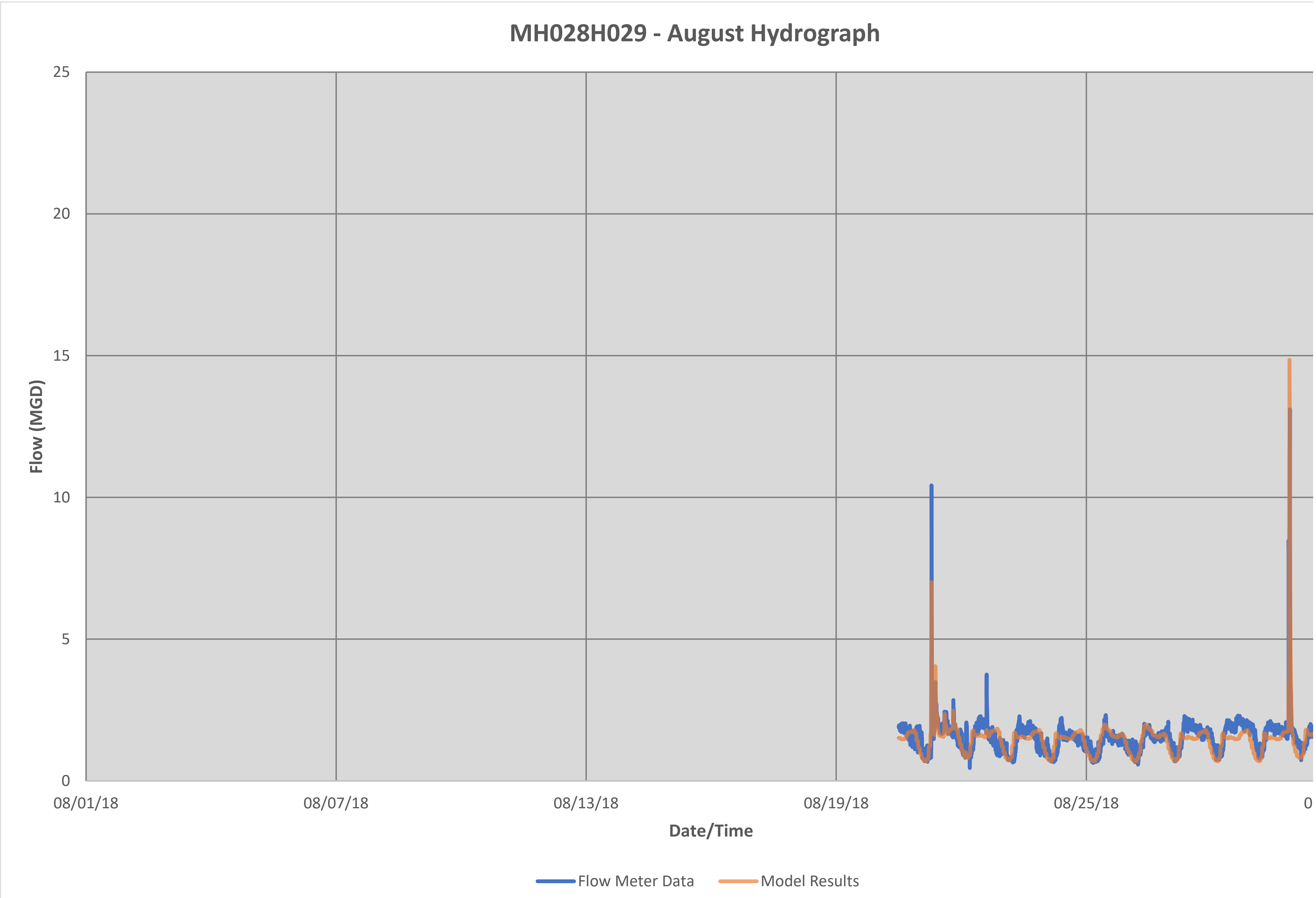
MH028H029 DWF Calibration - December
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

MH028H029 - Wet Weather Calibration/Validation Stats											
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)			
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	13.11	14.85	13.3%	2.39	2.34	-2.3%	11.5	9.3	-2.2
09/06/18	Validation	31.31	34.20	9.2%	1.92	2.31	20.3%	20.9	14.9	-5.9
09/07/18	Calibration	37.50	35.18	-6.2%	26.51	27.09	2.2%	17.0	15.2	-1.8
09/17/18	Calibration	17.09	14.86	-13.1%	4.65	4.06	-12.7%	13.9	9.3	-4.5
09/21/18	Validation									
09/24/18	Validation	10.99	10.03	-8.8%	5.33	4.78	-10.3%	10.7	7.6	-3.0
10/02/18	Validation	26.95	21.69	-19.5%	1.83	1.81	-1.0%	19.1	11.4	-7.7
10/04/18	Calibration	30.79	36.58	18.8%	3.04	3.33	9.7%	19.6	15.6	-4.0
10/06/18	Calibration	58.65	70.64	20.5%	3.19	3.41	6.9%	27.6	24.4	-3.2
10/15/18	Calibration	4.15	3.07	-25.9%	1.65	1.61	-2.2%	6.5	4.3	-2.3
10/26/18	Calibration	7.49	8.38	11.9%	4.36	4.83	10.9%	7.5	7.0	-0.5
10/28/18	Calibration	5.11	5.04	-1.4%	2.63	2.41	-8.5%	6.4	5.4	-1.0
11/09/18	Calibration	9.51	11.77	23.8%	2.44	2.80	14.9%	10.0	8.3	-1.8
11/15/18	Calibration	9.23	9.02	-2.2%	6.95	6.70	-3.7%	10.0	7.2	-2.7
11/18/18	Validation	6.73	6.71	-0.2%	5.66	5.28	-6.7%	7.9	6.2	-1.6
11/24/18	Validation	11.58	12.16	5.0%	2.20	2.49	13.4%	11.4	8.4	-3.0
Totals		280.2	294.2	5.0%	74.7	75.3	0.7%	200	155	-45.1

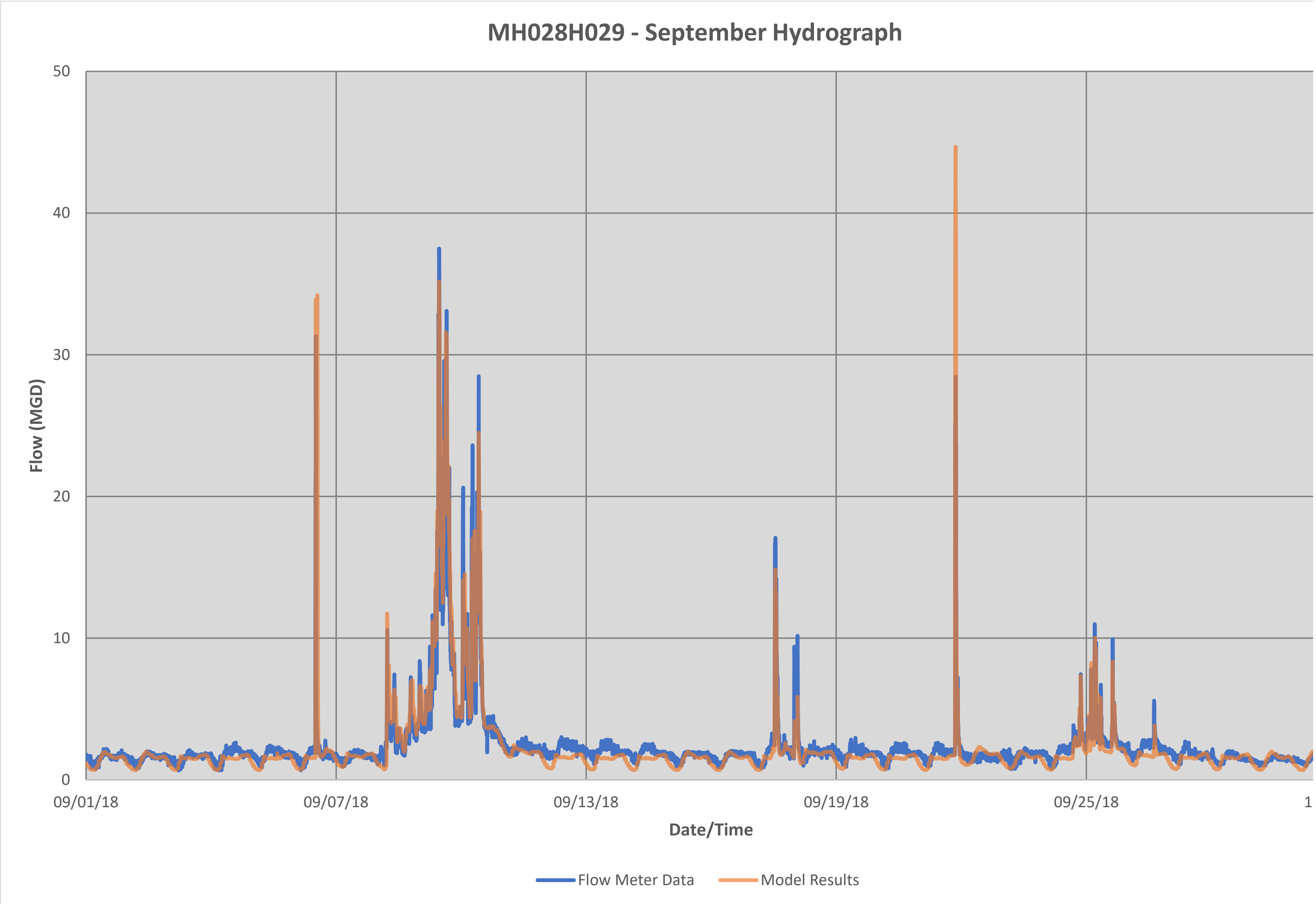

MH028H029 - WWF Calibration (Peak vs. Peak)
Simulated Flow (MGD)
Measured Flow (MGD)
0
15
30
45
60
75
y = 1.09x
R² = 0.96
Data Points
Trendline

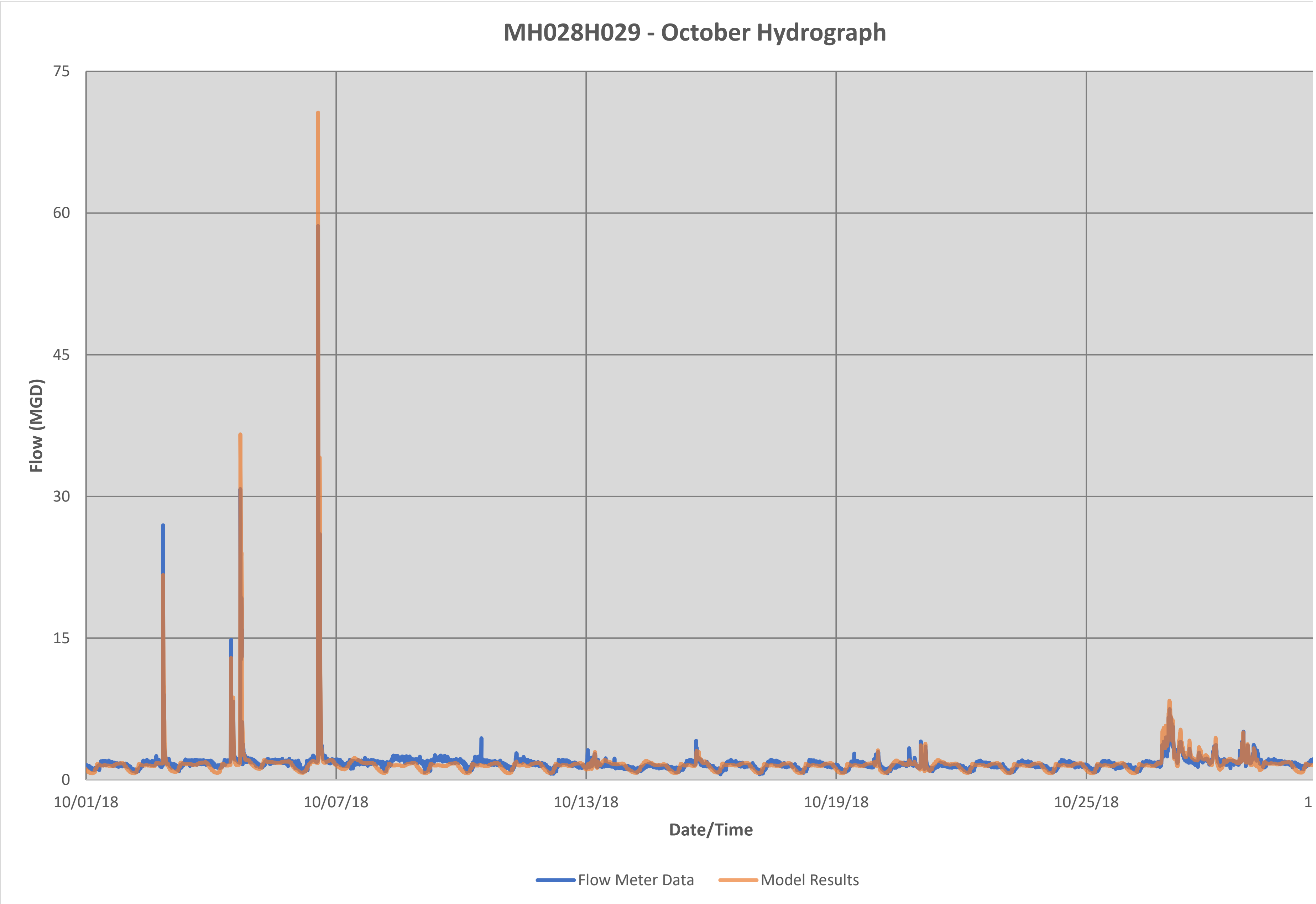


MH028H029 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
0
7
14
21
28
35
y = 1.01x
R² = 1.00
Data Points
Trendline

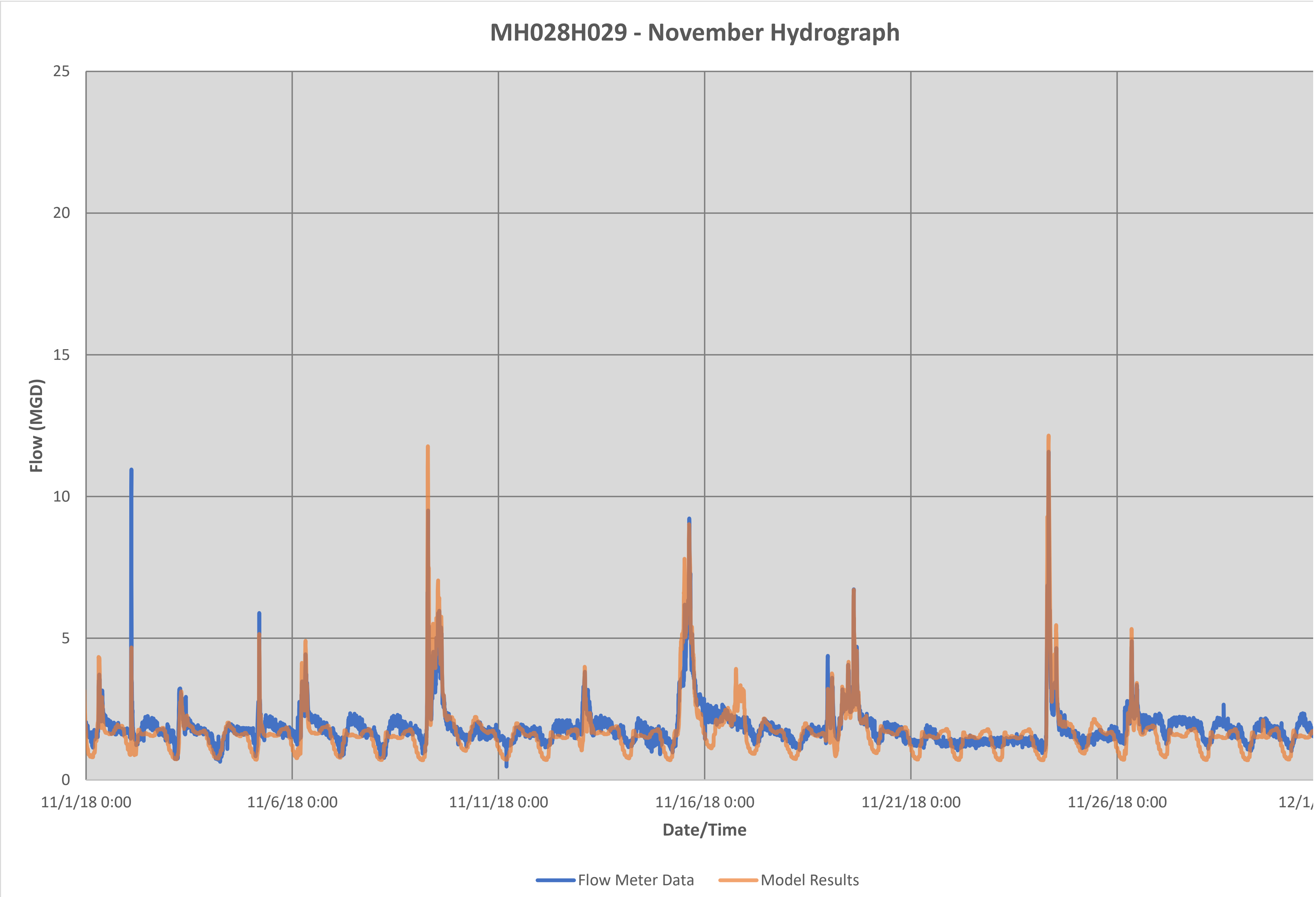


MH028H029 - August Hydrograph
25
20
15
10
5
0
Flow (MGD)
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results

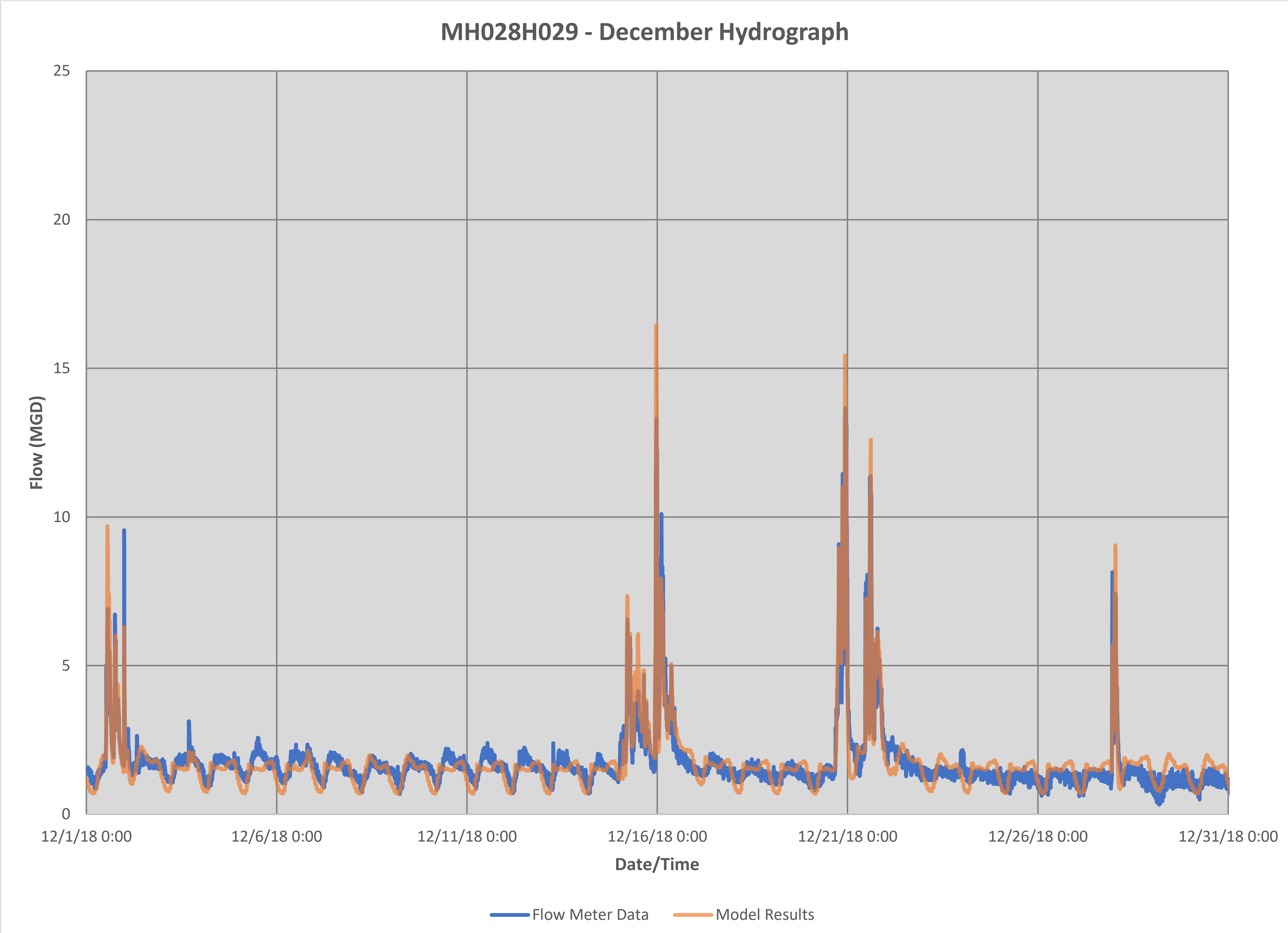

MH028H029 - September Hydrograph
Flow (MGD)
50
40
30
20
10
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH028H029 - October Hydrograph
75
60
45
30
15
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH028H029 - November Hydrograph
25
20
15
10
5
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1/
Date/Time
Flow Meter Data
Model Results



MH028H029 - December Hydrograph
Flow (MGD)
25
20
15
10
5
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH028H036 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.07	1.78	**-39.9%**
Volume - MG	3.40	4.62	**-26.4%**
Depth (Avg) - in	2.50	3.40	**-0.9**

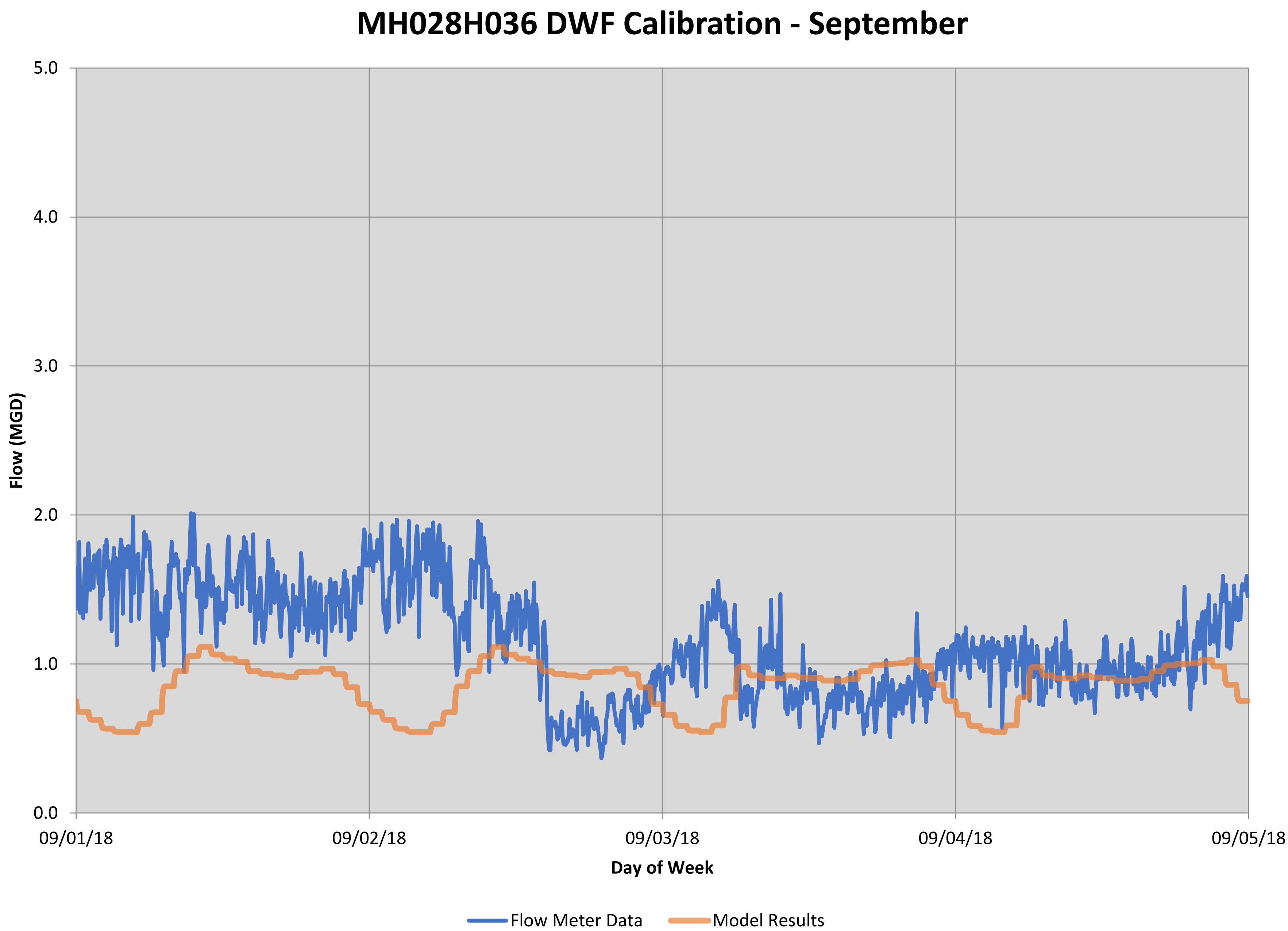
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	1.12	2.01
9/2/18	1.12	1.97
9/3/18	1.03	1.56
9/4/18	1.03	1.59

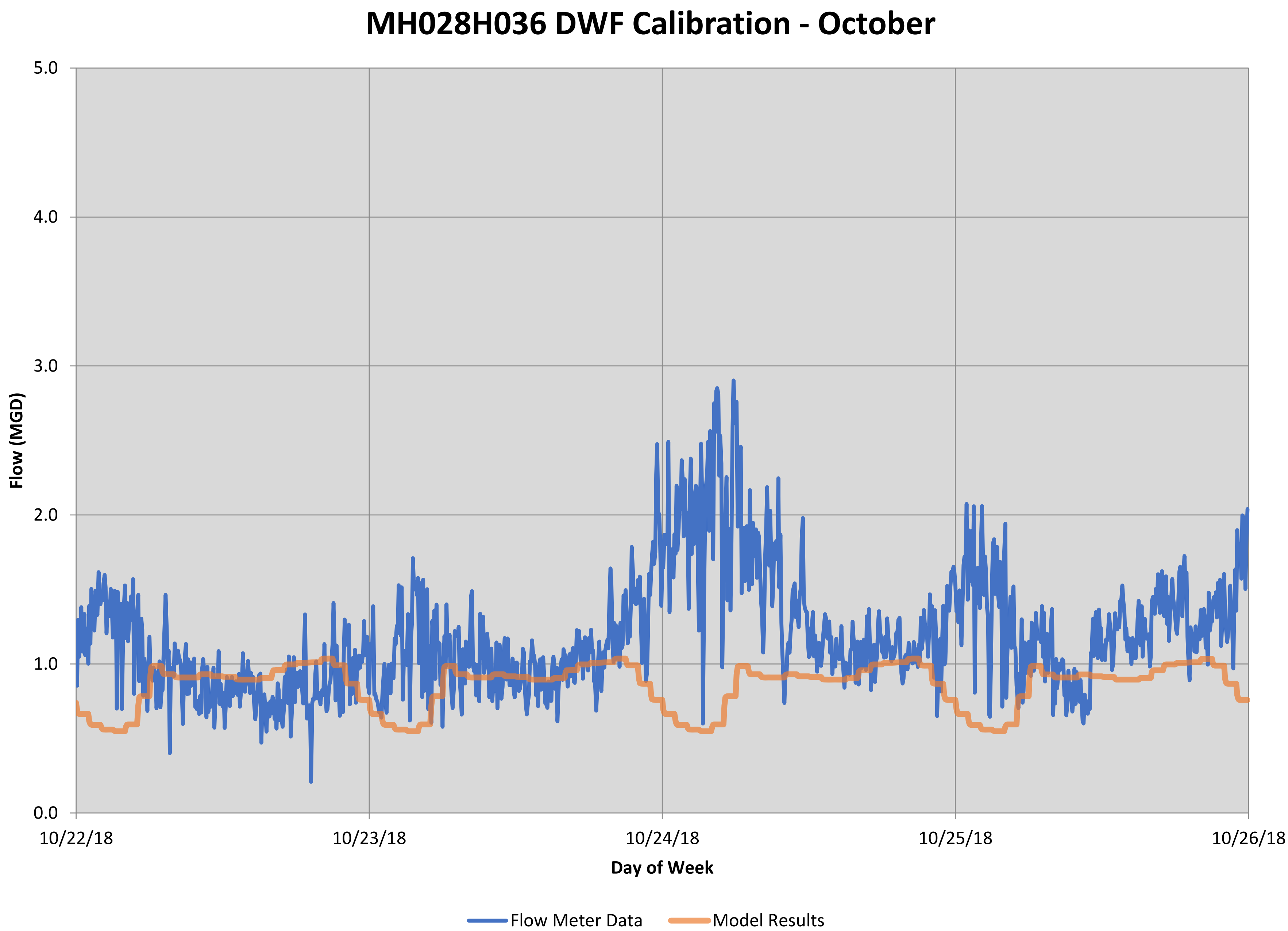
DWF Calibration Statistics MH028H036 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.04	2.27	**-54.3%**
Volume - MG	3.43	4.78	**-28.3%**
Depth (Avg) - in	2.51	3.56	**-1.0**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	1.04	1.62
10/23/18	1.04	2.48
10/24/18	1.04	2.90
10/25/18	1.04	2.07

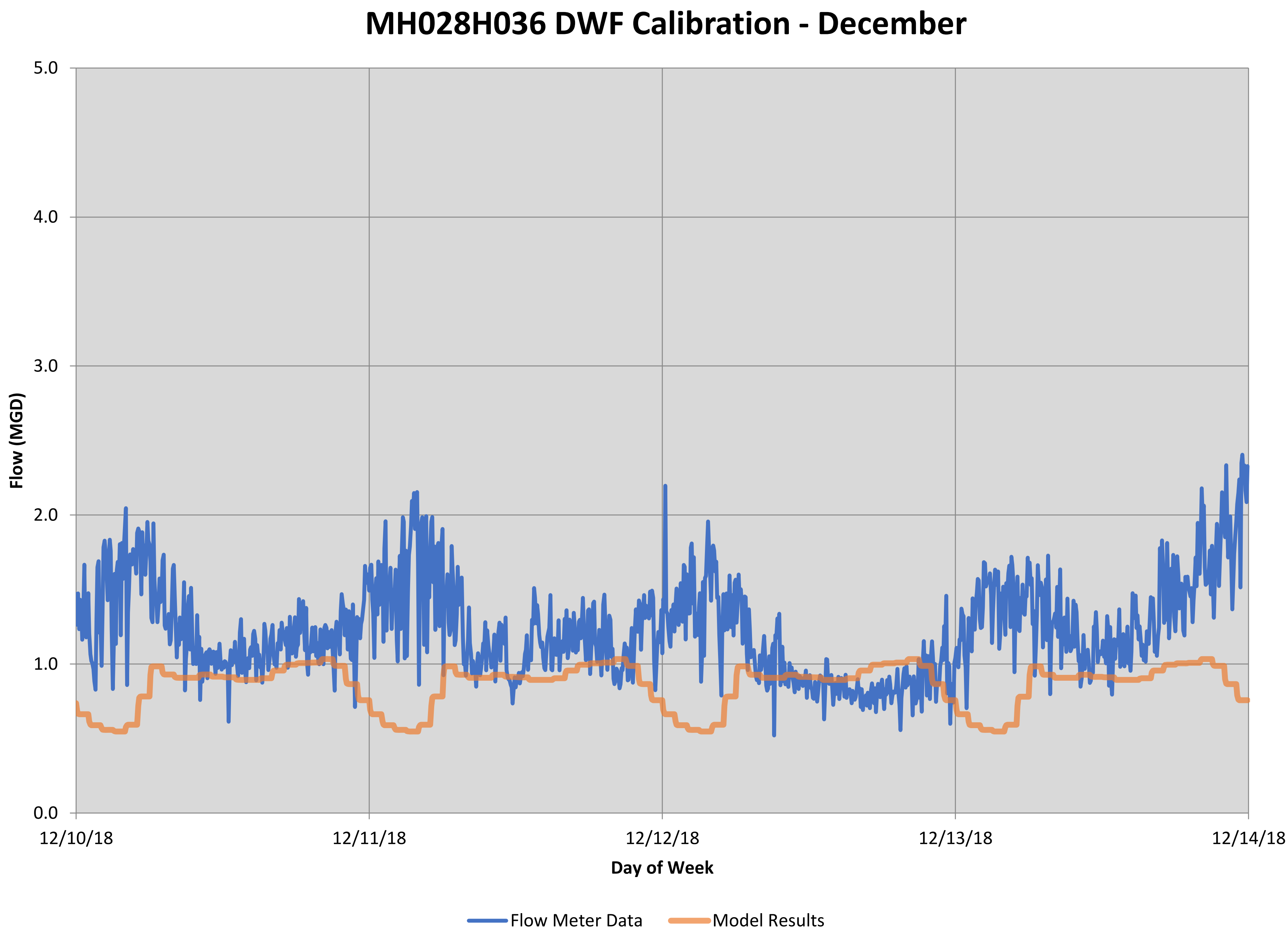
DWF Calibration Statistics MH028H036 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.03	2.20	**-53.0%**
Volume - MG	3.42	4.96	**-31.0%**
Depth (Avg) - in	2.51	3.48	**-1.0**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	1.03	2.05
12/11/18	1.03	2.15
12/12/18	1.03	2.20
12/13/18	1.03	2.40


MH028H036 DWF Calibration - September
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

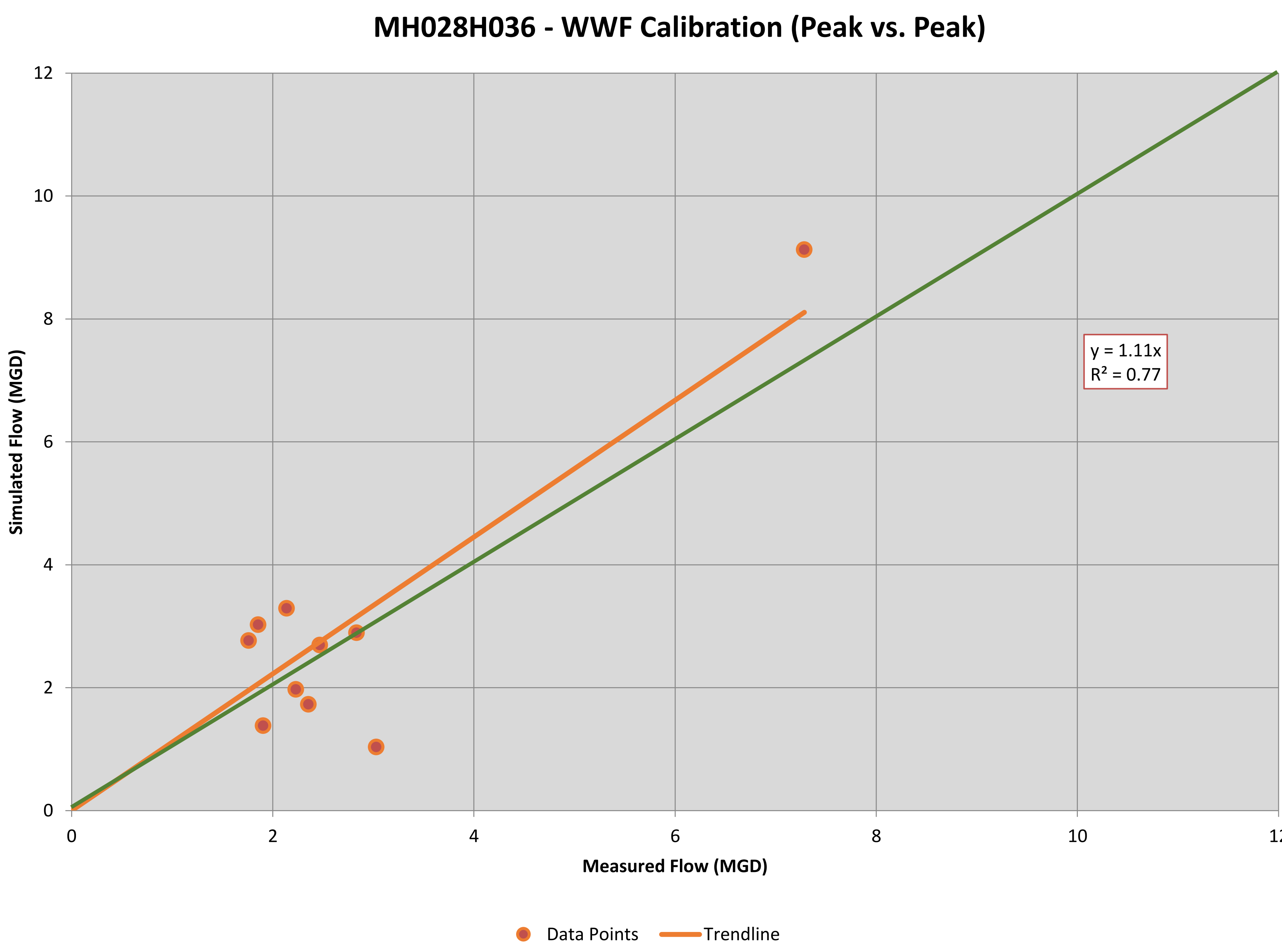


MH028H036 DWF Calibration - October
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

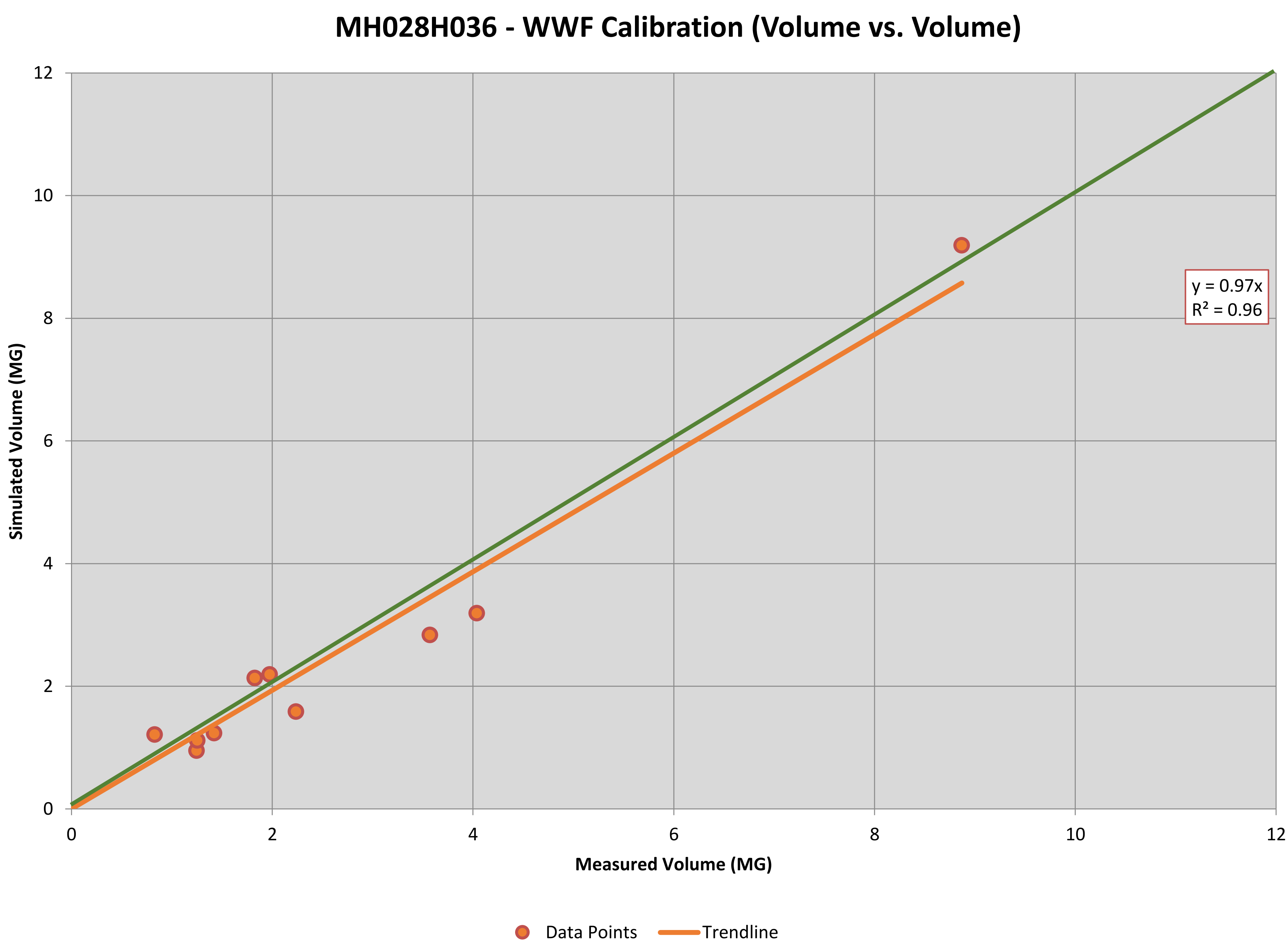


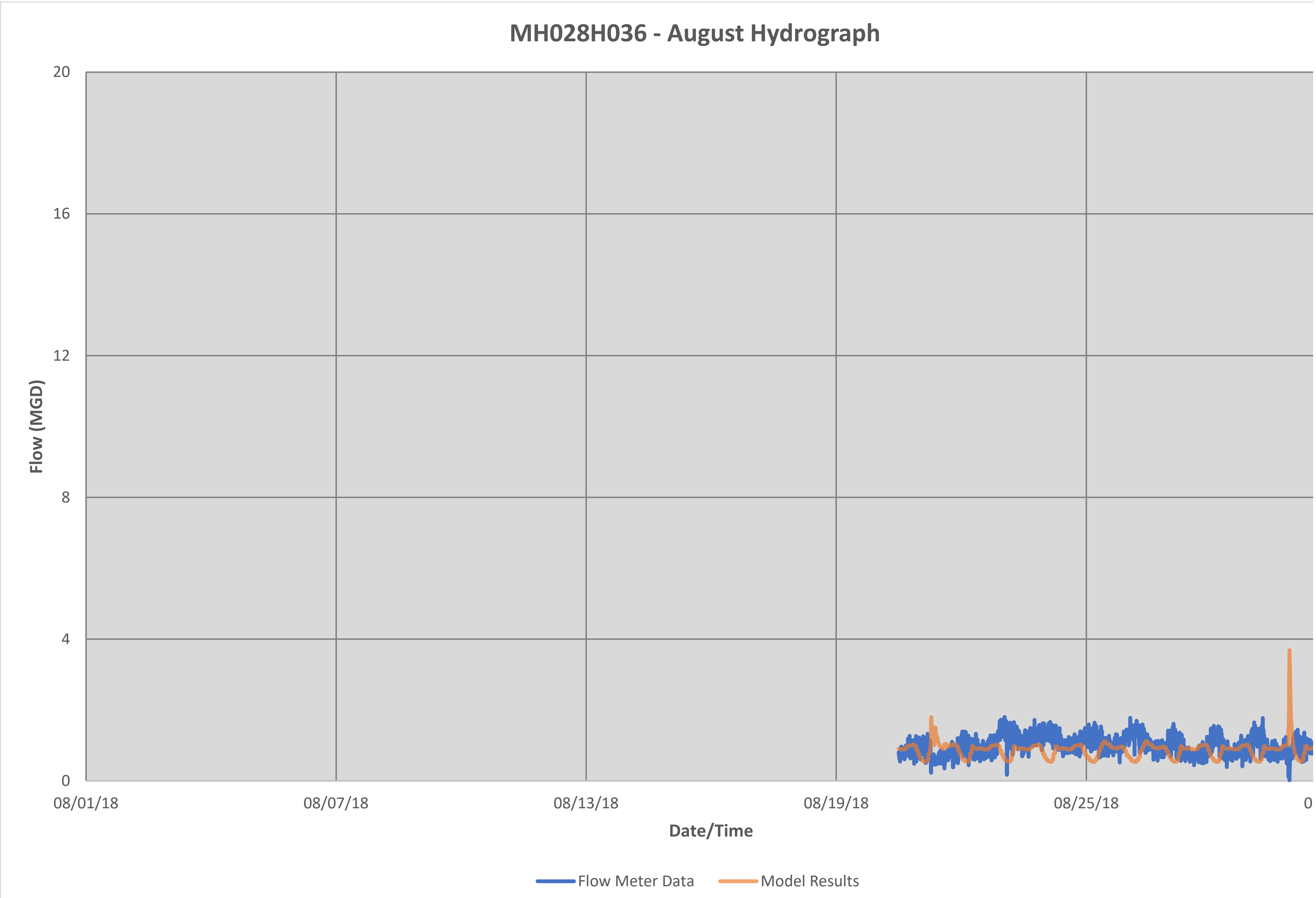
MH028H036 DWF Calibration - December
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

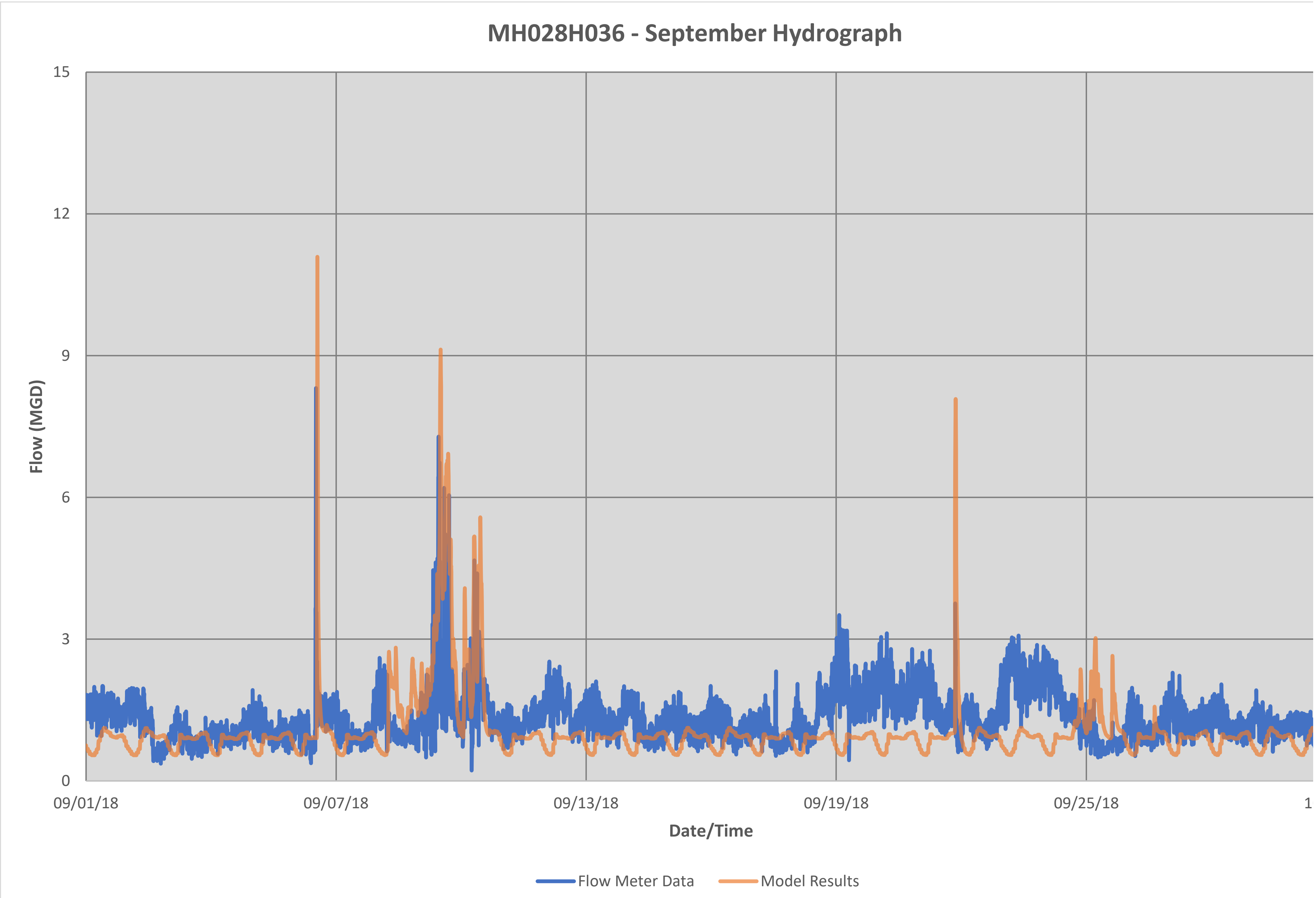
		MH028H036 - Wet Weather Calibration/Validation Stats								
Storm Date	**Type**	**Peak Flow (MGD)**			**Storm Volume (MG)**			**Peak Depth (Inches)**		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration									
09/06/18	Validation									
09/07/18	Calibration	7.29	9.13	25.3%	8.87	9.19	3.6%	9.5	10.0	0.5
09/17/18	Calibration	3.03	1.04	-65.8%	2.24	1.58	-29.2%	6.0	2.8	-3.2
09/21/18	Validation									
09/24/18	Validation	1.85	3.02	63.1%	1.97	2.19	10.9%	4.9	5.0	0.1
10/02/18	Validation									
10/04/18	Calibration									
10/06/18	Calibration									
10/15/18	Calibration	1.91	1.38	-27.5%	1.25	0.95	-23.8%	4.7	3.3	-1.4
10/26/18	Calibration	2.47	2.69	9.2%	1.83	2.14	16.9%	4.9	4.7	-0.2
10/28/18	Calibration	2.35	1.73	-26.6%	1.42	1.23	-13.1%	4.6	3.7	-1.0
11/09/18	Calibration	1.76	2.77	57.3%	0.83	1.21	46.2%	4.3	4.8	0.5
11/15/18	Calibration	2.83	2.89	2.2%	4.04	3.19	-21.0%	5.4	4.9	-0.5
11/18/18	Validation	2.23	1.97	-11.6%	3.57	2.84	-20.6%	4.4	4.0	-0.5
11/24/18	Validation	2.14	3.29	54.0%	1.25	1.12	-10.9%	4.4	5.3	0.9
Totals		**27.9**	**29.9**	**7.4%**	**27.3**	**25.6**	**-6.0%**	**53**	**48**	**-4.8**

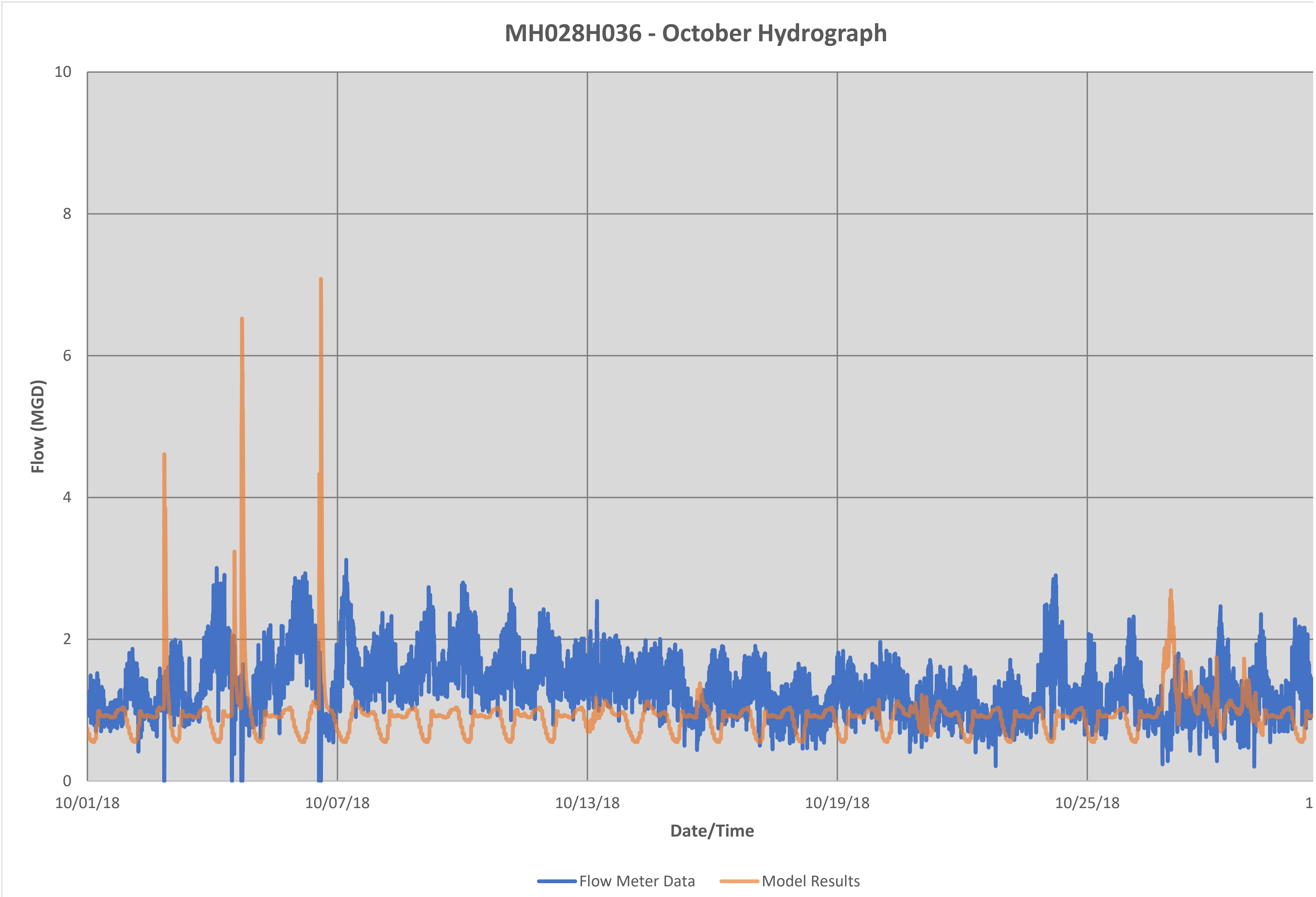


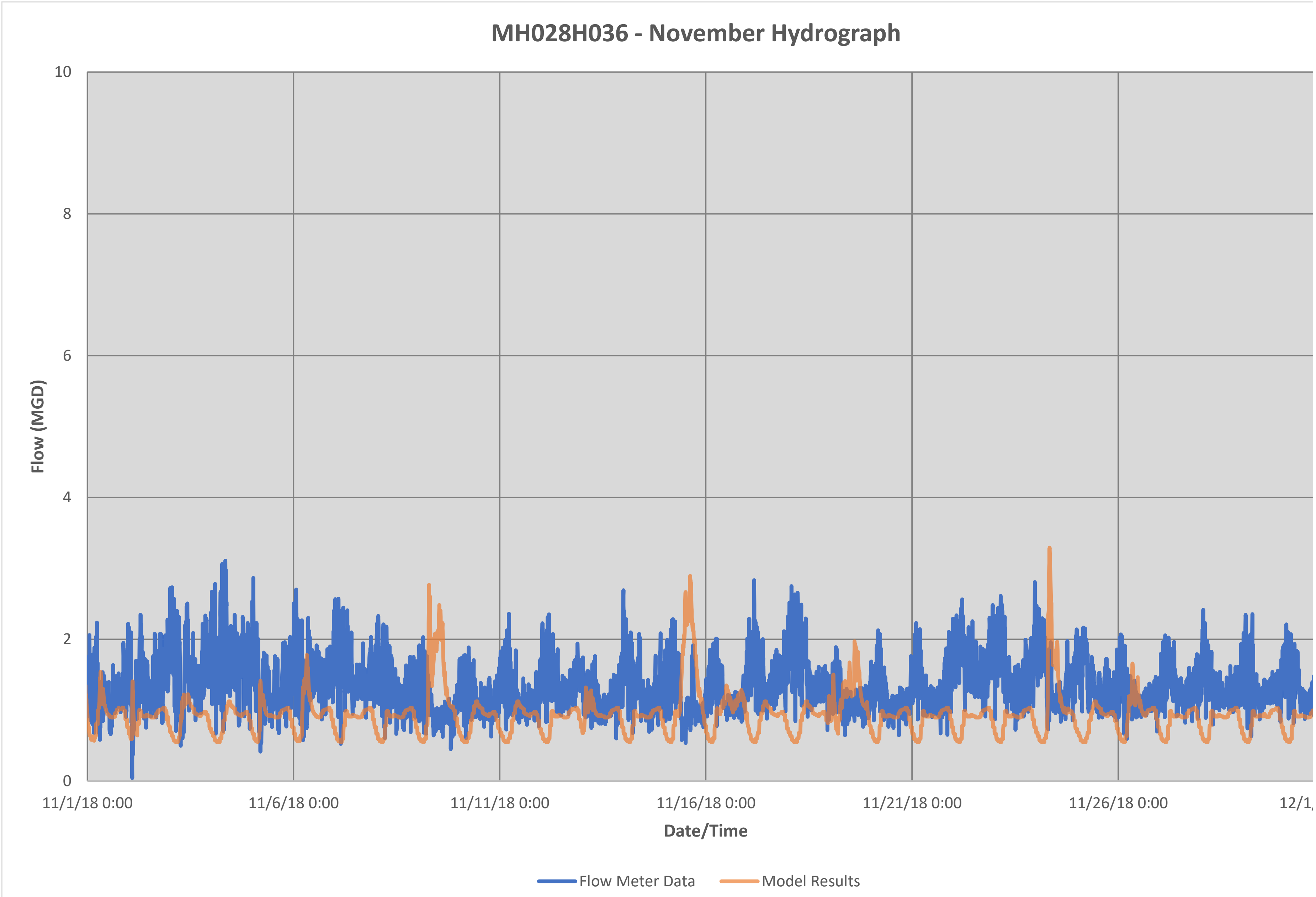
MH028H036 - WWF Calibration (Peak vs. Peak)
y = 1.11x
R² = 0.77
Simulated Flow (MGD)
Measured Flow (MGD)
0
2
4
6
8
10
12
Data Points
Trendline


MH028H036 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
y = 0.97x
R² = 0.96
0
2
4
6
8
10
12
Data Points
Trendline

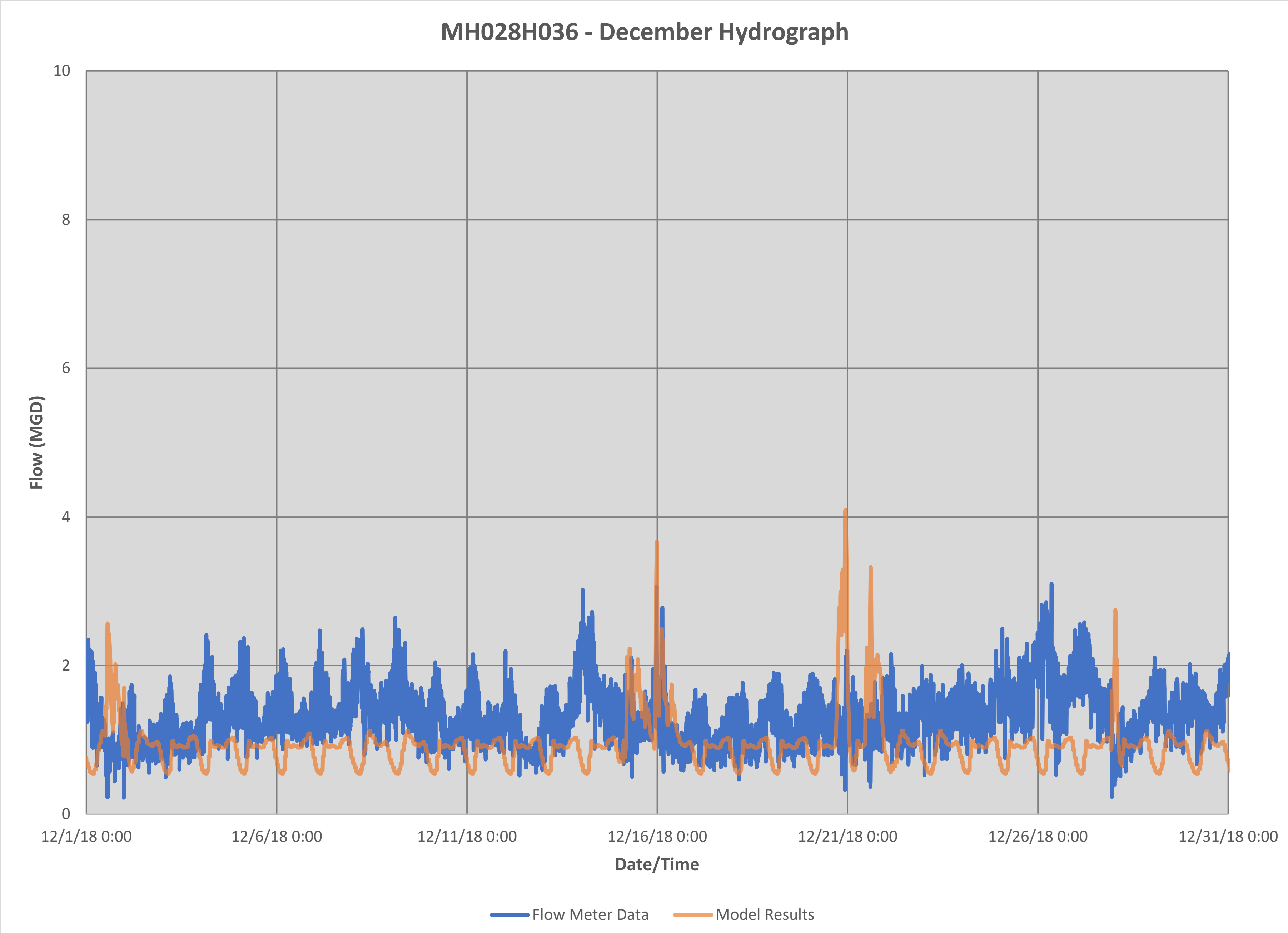

MH028H036 - August Hydrograph
Flow (MGD)
20
16
12
8
4
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results


MH028H036 - September Hydrograph
Flow (MGD)
15
12
9
6
3
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH028H036 - October Hydrograph
Flow (MGD)
10
8
6
4
2
0
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH028H036 - November Hydrograph
10
8
6
4
2
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
Date/Time
Flow Meter Data
Model Results



MH028H036 - December Hydrograph
Flow (MGD)
10
8
6
4
2
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH029D039 - September			
Category	Simulated	Measured	Difference
Peak Flow (Avg) - MGD	0.07	0.64	**-89.0%**
Volume - MG	0.28	0.52	**-46.5%**
Depth (Avg) - in	1.33	2.11	**-0.8**

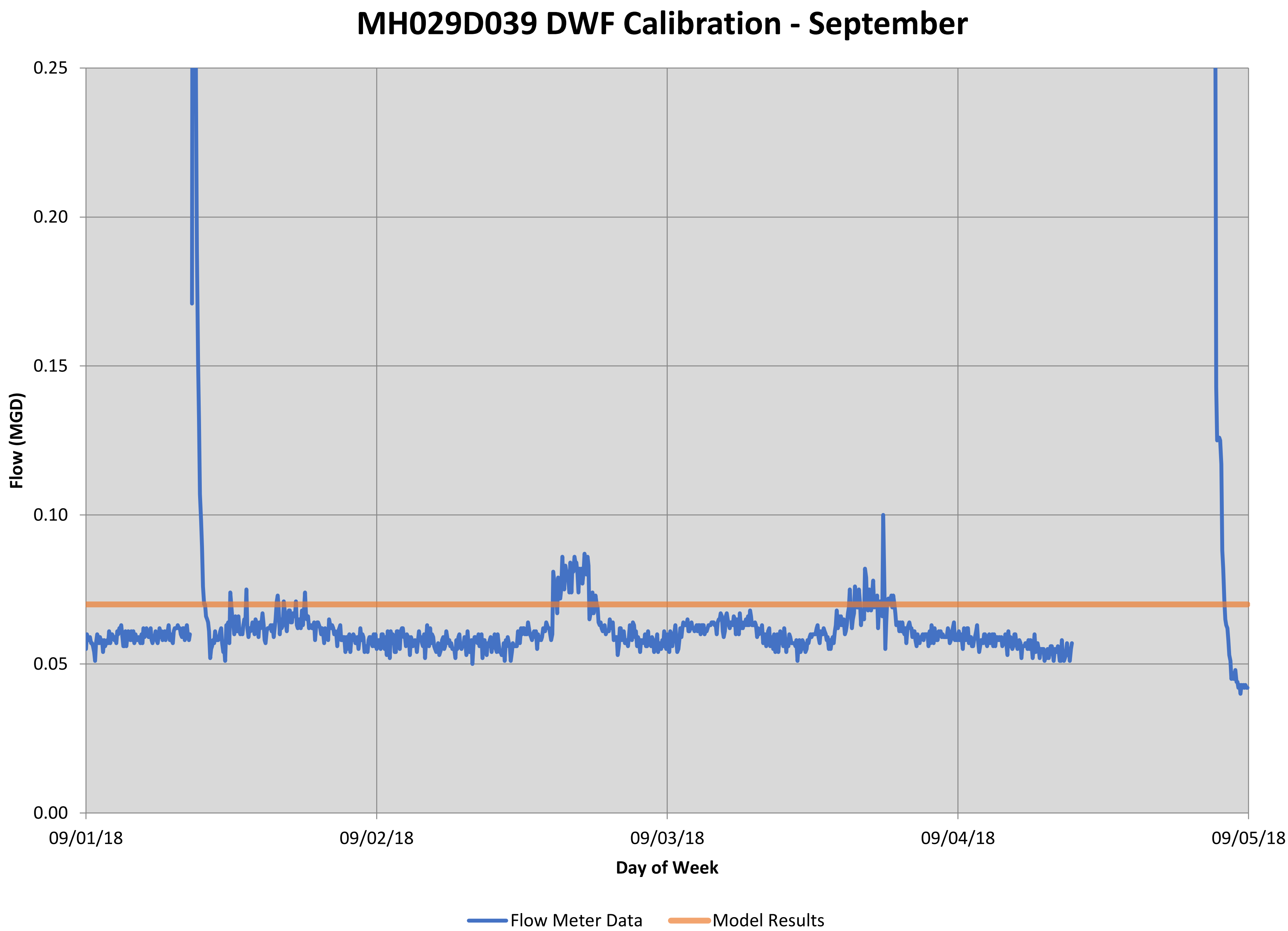
DWF Daily Peak Flows (MGD)		
DWF Day	Simulated	Measured
9/1/18	0.07	0.43
9/2/18	0.07	0.09
9/3/18	0.07	0.10
9/4/18	0.07	1.93

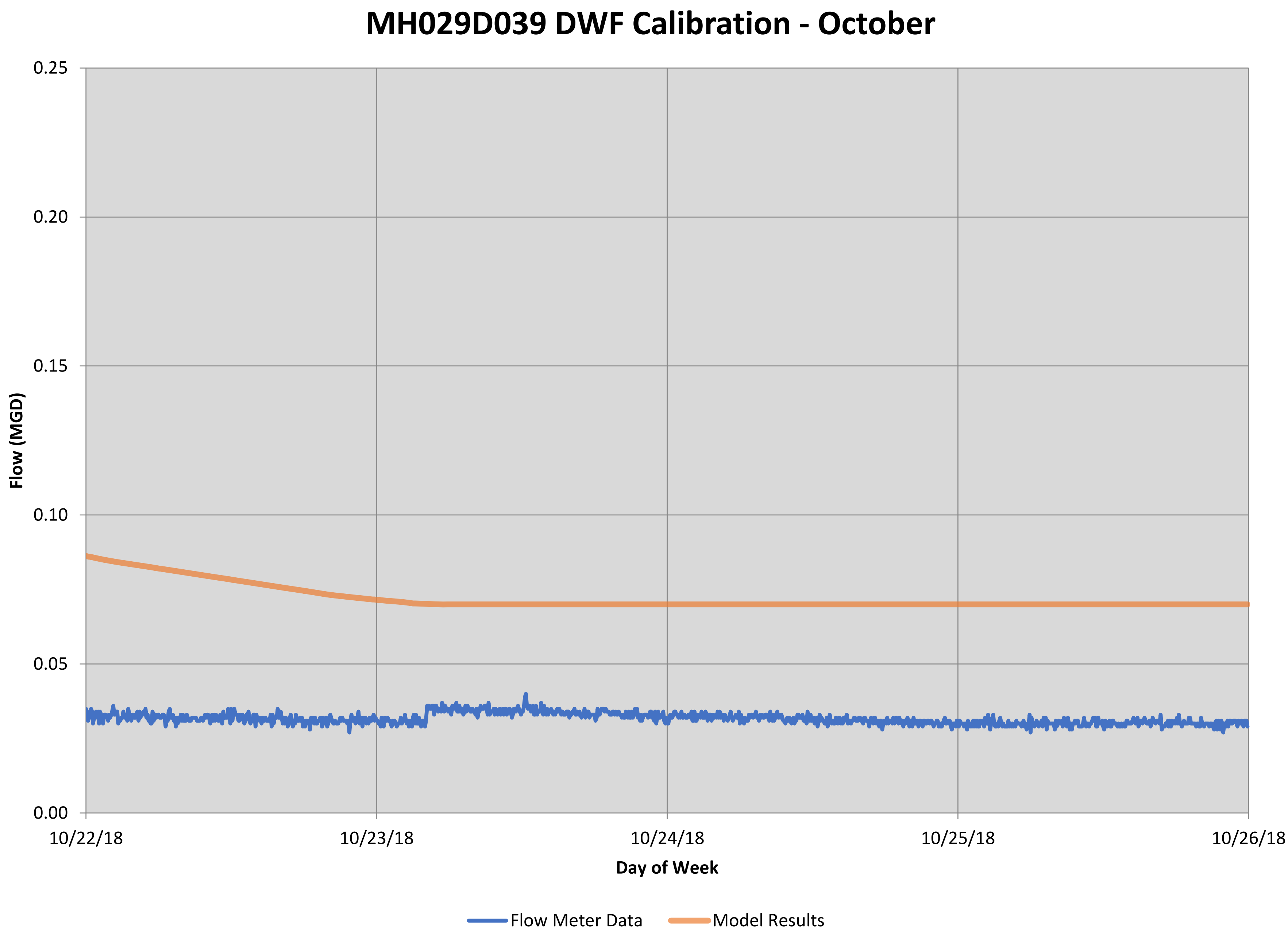
DWF Calibration Statistics MH029D039 - October			
Category	Simulated	Measured	Difference
Peak Flow (Avg) - MGD	0.07	0.04	**108.3%**
Volume - MG	0.29	0.13	**127.9%**
Depth (Avg) - in	1.36	1.55	**-0.2**

DWF Daily Peak Flows (MGD)		
DWF Day	Simulated	Measured
10/22/18	0.09	0.04
10/23/18	0.07	0.04
10/24/18	0.07	0.03
10/25/18	0.07	0.03

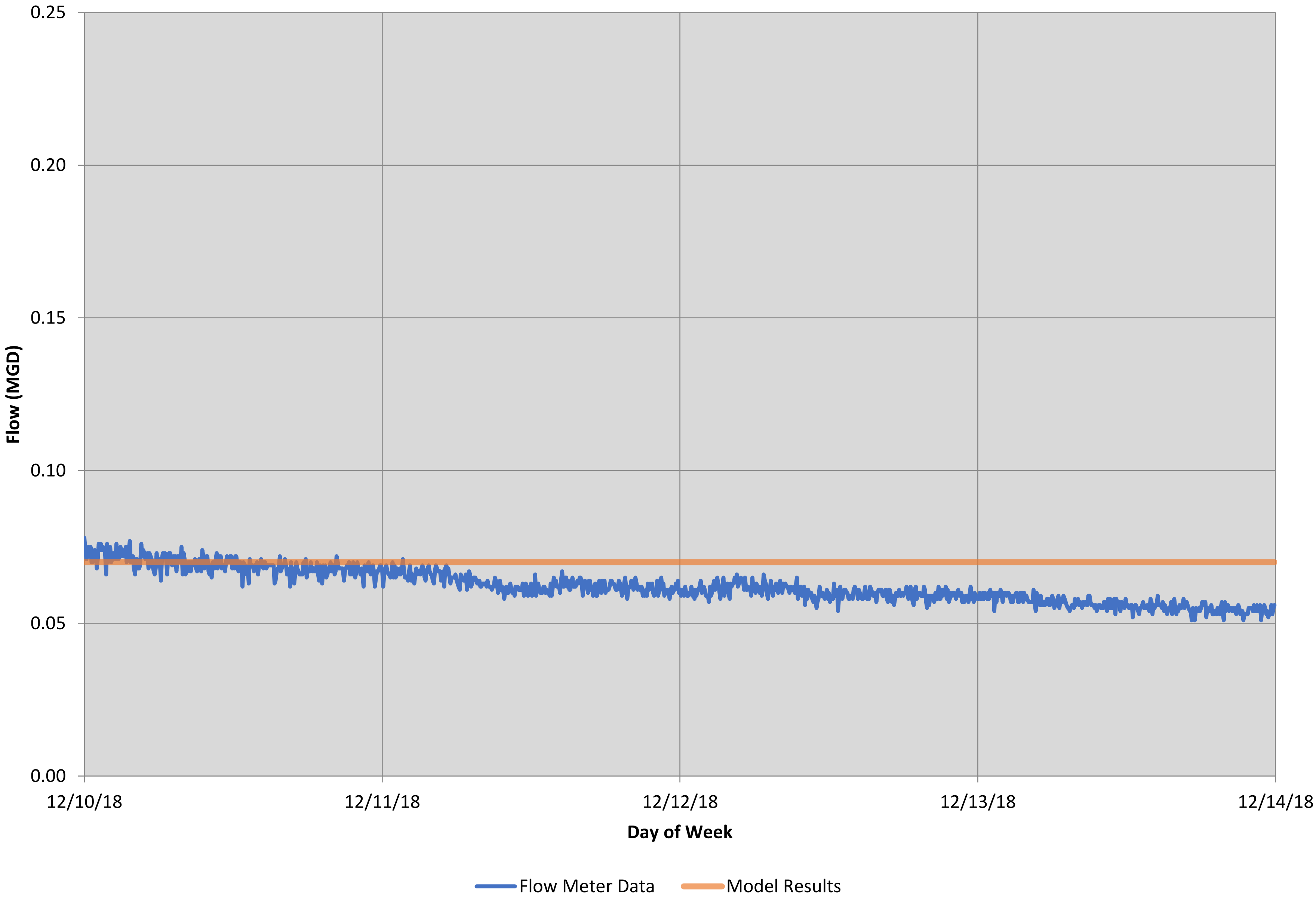
DWF Calibration Statistics MH029D039 - December			
Category	Simulated	Measured	Difference
Peak Flow (Avg) - MGD	0.07	0.07	**1.4%**
Volume - MG	0.28	0.25	**12.6%**
Depth (Avg) - in	1.34	2.09	**-0.8**

DWF Daily Peak Flows (MGD)		
DWF Day	Simulated	Measured
12/10/18	0.07	0.08
12/11/18	0.07	0.07
12/12/18	0.07	0.07
12/13/18	0.07	0.06


MH029D039 DWF Calibration - September
Flow (MGD)
0.25
0.20
0.15
0.10
0.05
0.00
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

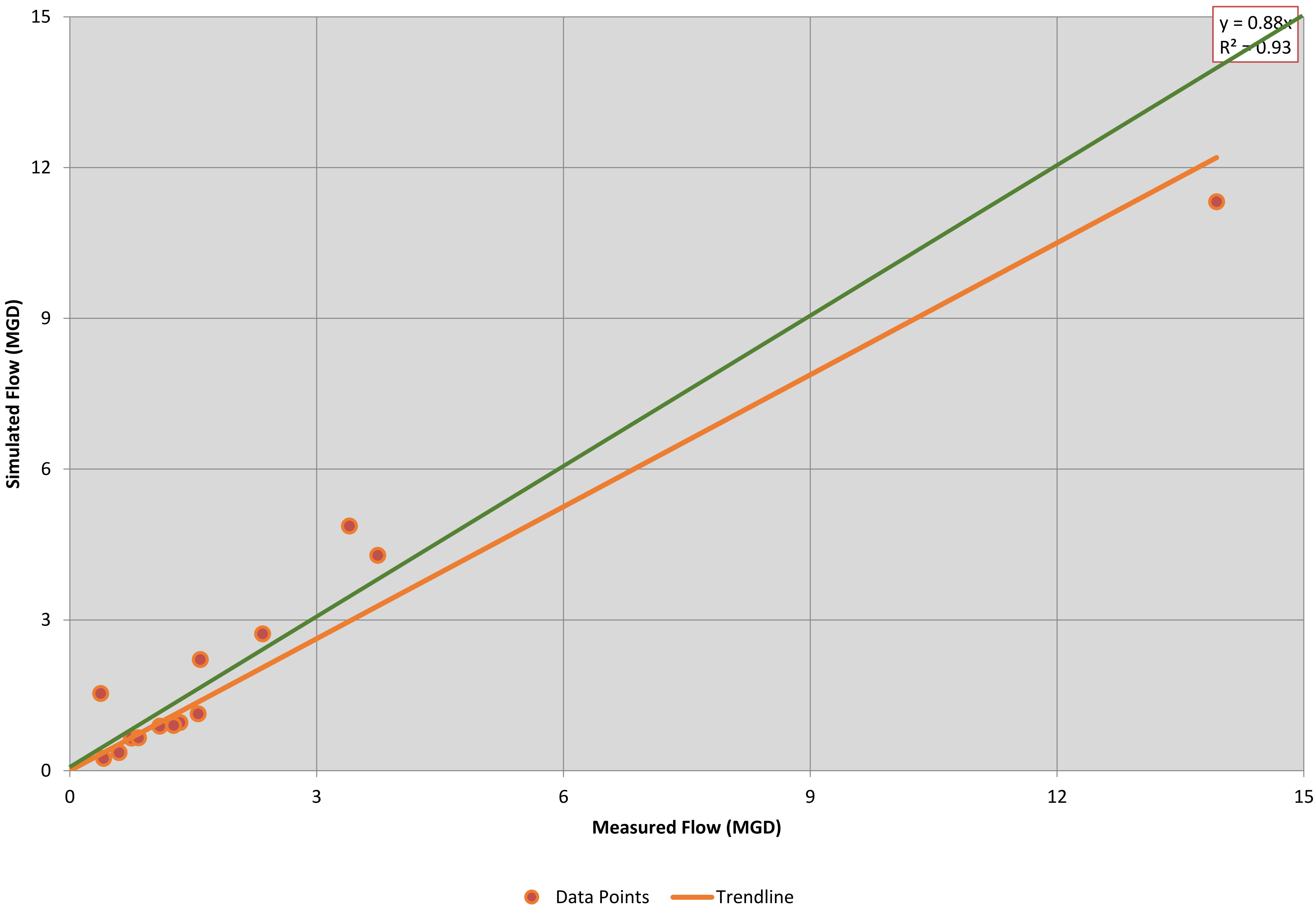

MH029D039 DWF Calibration - October
0.25
0.20
0.15
0.10
0.05
0.00
Flow (MGD)
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

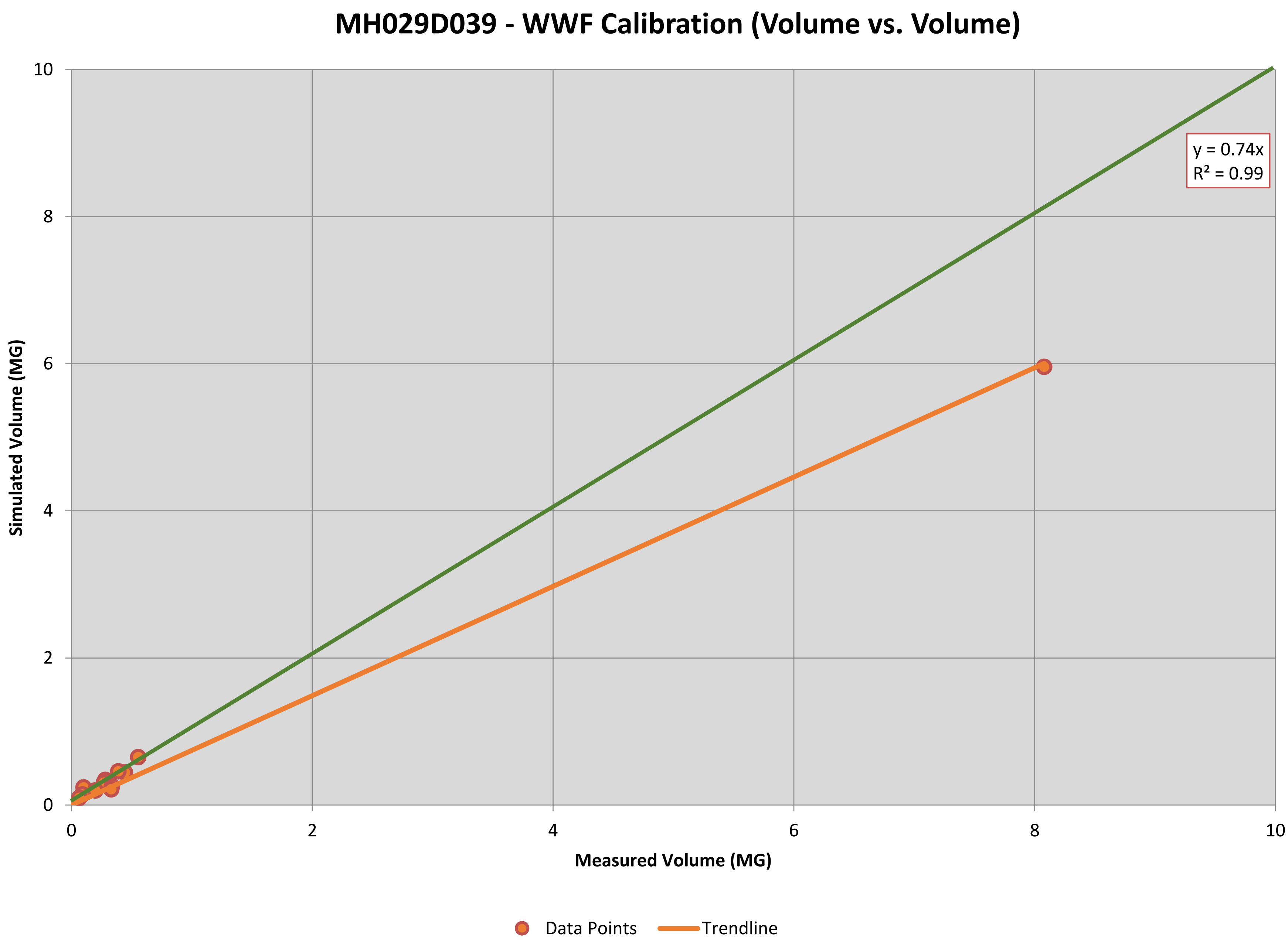
MH029D039 DWF Calibration - December



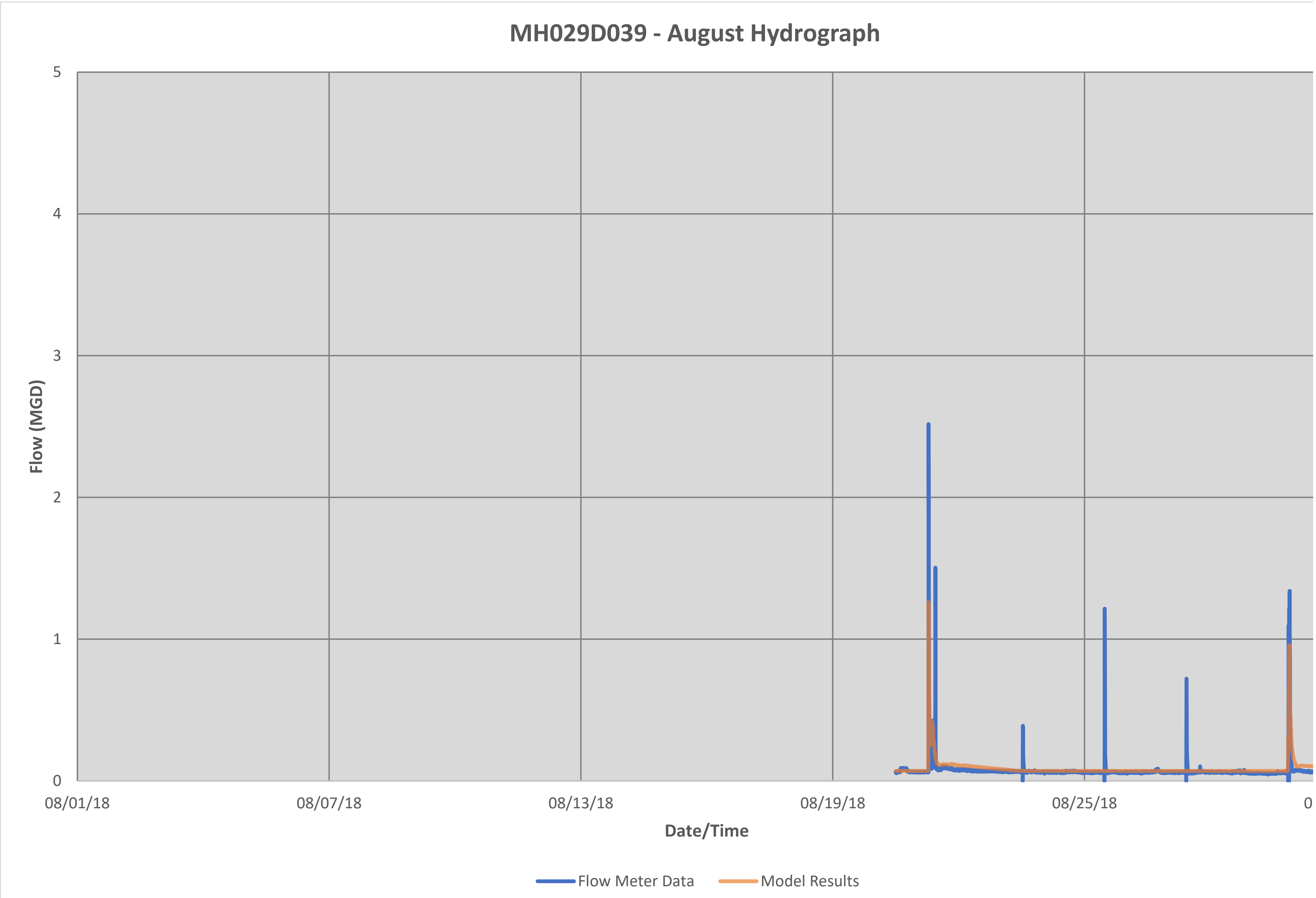
		MH029D039 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	1.34	0.96	-28.5%	0.12	0.17	41.3%	7.8	7.0	-0.8
09/06/18	Validation	3.40	4.87	43.2%	0.10	0.24	133.0%	12.3	17.0	4.8
09/07/18	Calibration	13.94	11.32	-18.8%	8.08	5.96	-26.3%	17.5	19.4	1.9
09/17/18	Calibration	1.59	2.21	39.4%	0.44	0.44	0.9%	6.3	10.3	4.0
09/21/18	Validation									
09/24/18	Validation	1.26	0.90	-29.0%	0.45	0.44	-0.7%	5.1	5.9	0.7
10/02/18	Validation	1.56	1.13	-27.6%	0.09	0.14	55.5%	7.9	8.2	0.2
10/04/18	Calibration	2.34	2.72	16.0%	0.28	0.34	20.7%	9.0	13.6	4.6
10/06/18	Calibration	3.75	4.28	14.4%	0.27	0.30	11.7%	10.0	17.4	7.4
10/15/18	Calibration	0.41	0.24	-41.5%	0.07	0.10	47.3%	3.4	2.8	-0.6
10/26/18	Calibration	0.75	0.65	-13.6%	0.39	0.46	17.1%	4.2	5.2	1.1
10/28/18	Calibration	0.60	0.36	-40.8%	0.20	0.20	-0.7%	3.9	3.1	-0.8
11/09/18	Calibration	0.84	0.65	-22.0%	0.34	0.26	-24.4%	4.7	5.9	1.2
11/15/18	Calibration	0.38	1.54	309.4%	0.56	0.65	16.8%	5.6	5.0	-0.7
11/18/18	Validation									
11/24/18	Validation	1.09	0.88	-19.4%	0.33	0.21	-35.5%	5.8	6.5	0.7
Totals		33.2	32.7	-1.6%	11.7	9.9	-15.4%	104	127	23.7

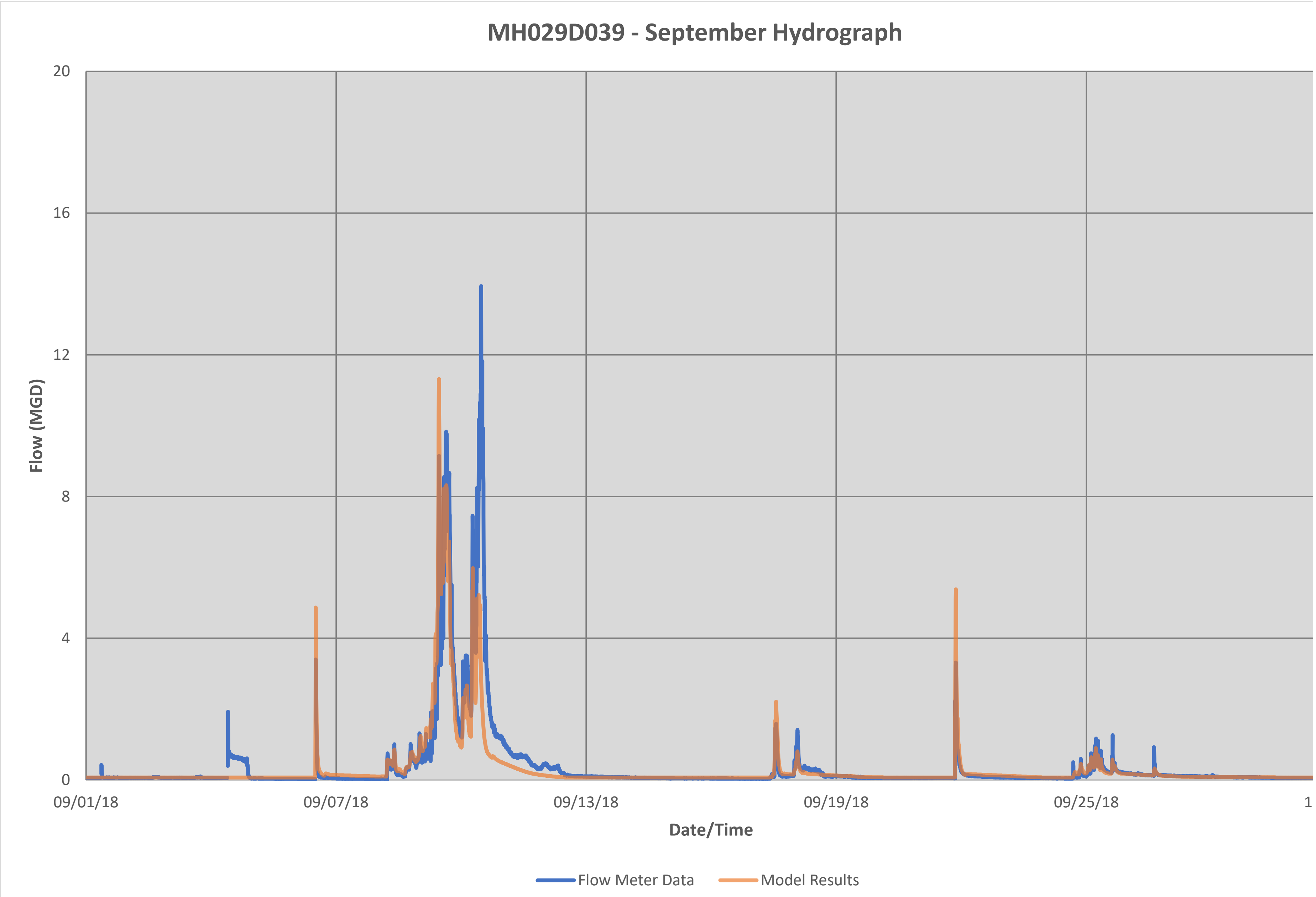
MH029D039 - WWF Calibration (Peak vs. Peak)



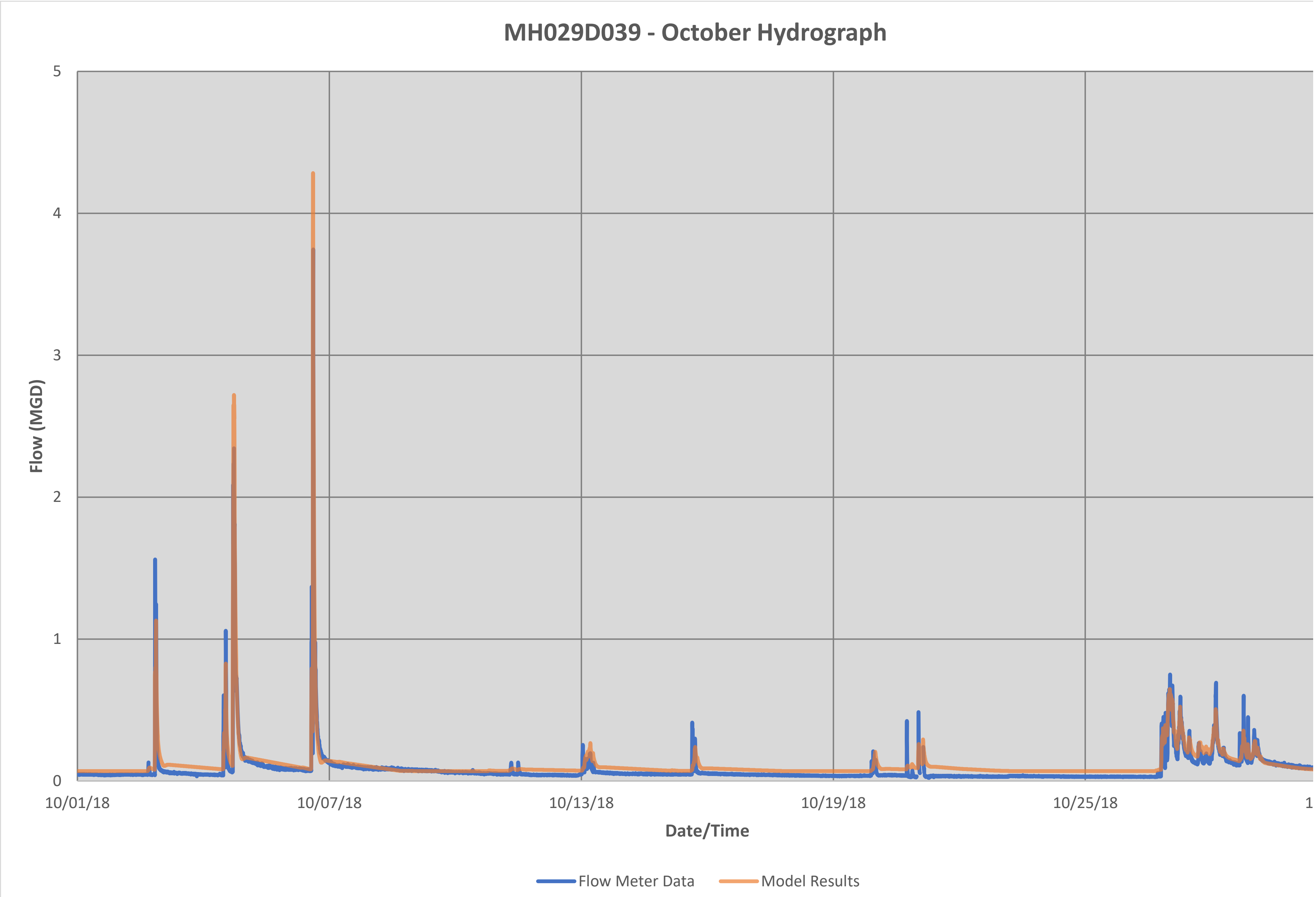


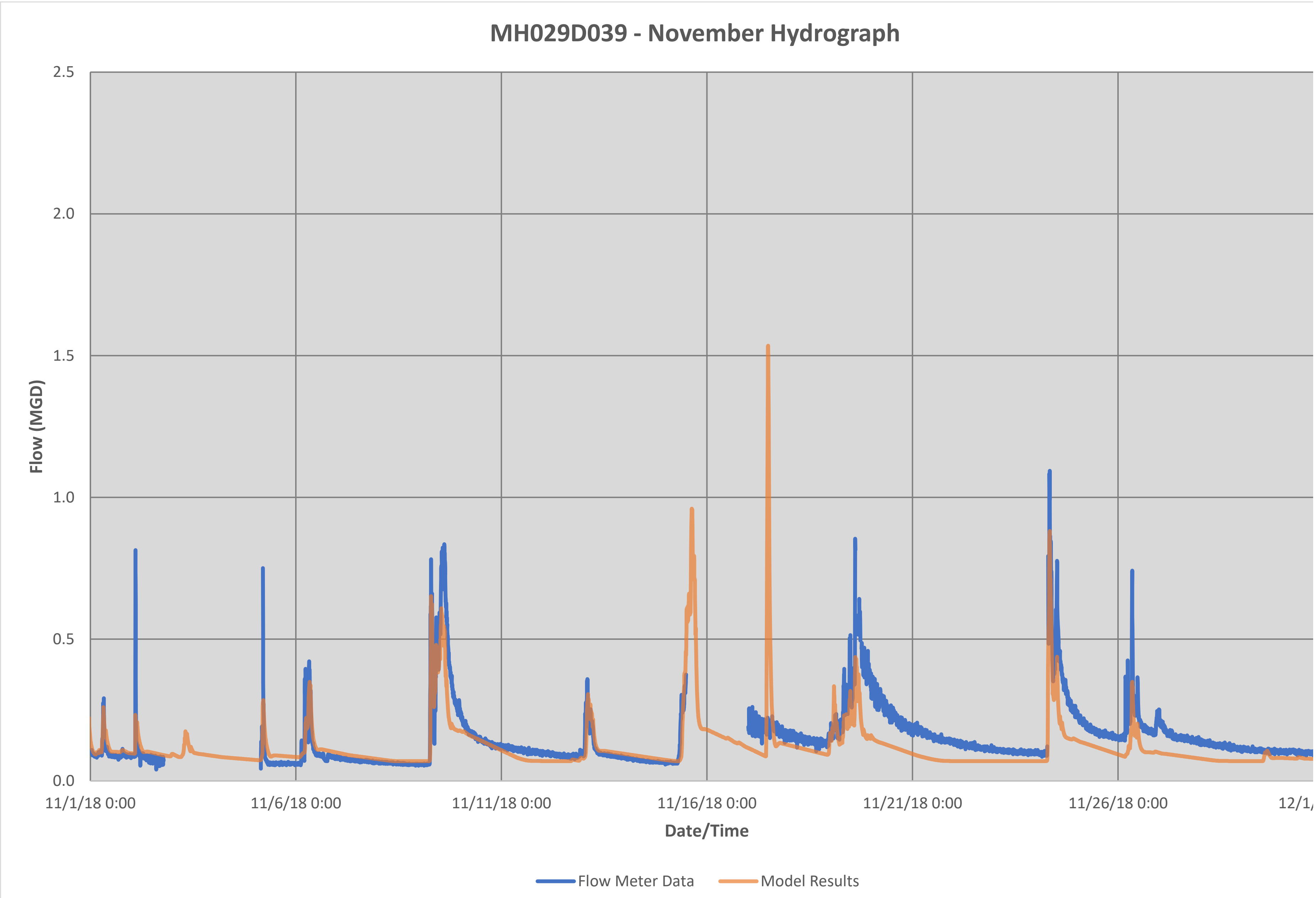
MH029D039 - WWF Calibration (Volume vs. Volume)
y = 0.74x
R² = 0.99
Simulated Volume (MG)
Measured Volume (MG)
0
2
4
6
8
10
Data Points
Trendline


MH029D039 - August Hydrograph
Flow (MGD)
5
4
3
2
1
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results

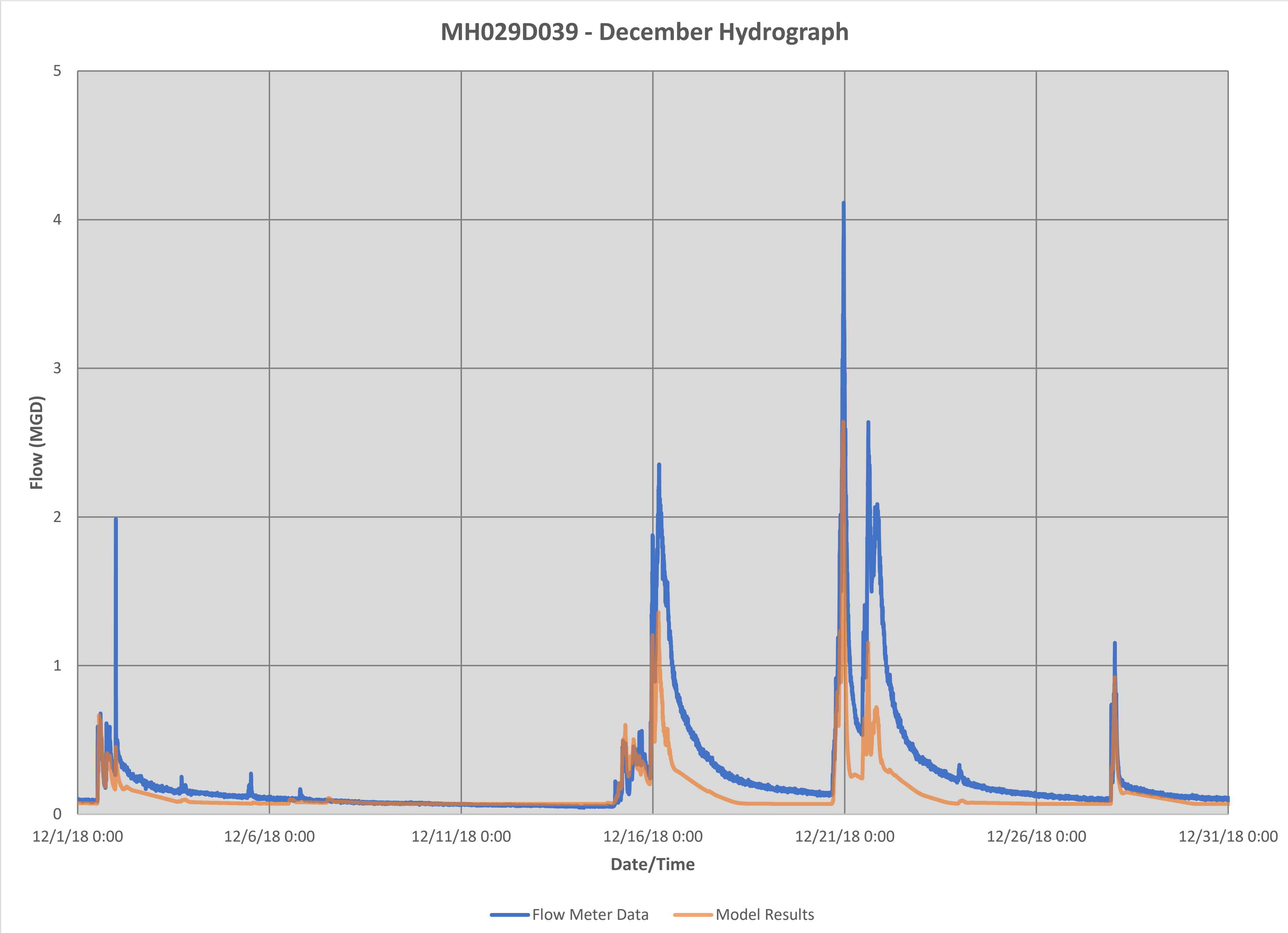


MH029D039 - September Hydrograph
Flow (MGD)
20
16
12
8
4
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH029D039 - October Hydrograph
Flow (MGD)
5
4
3
2
1
0
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH029D039 - November Hydrograph
Flow (MGD)
2.5
2.0
1.5
1.0
0.5
0.0
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1/
Date/Time
Flow Meter Data
Model Results


MH029D039 - December Hydrograph
Flow (MGD)
0
1
2
3
4
5
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH029H072 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.15	0.15	**-3.2%**
Volume - MG	0.44	0.31	**43.9%**
Depth (Avg) - in	1.02	1.00	**0.0**

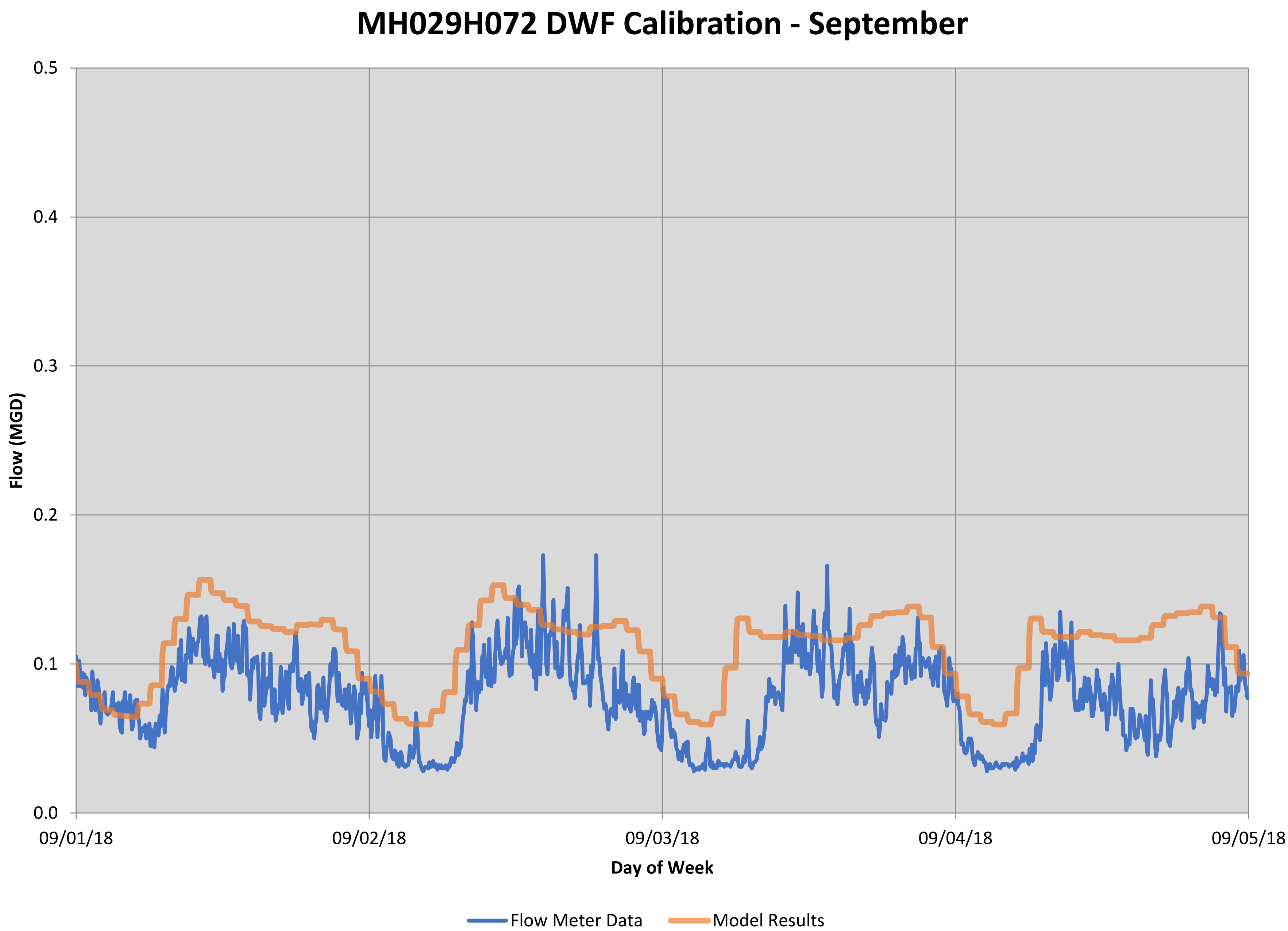
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	0.16	0.13
9/2/18	0.15	0.17
9/3/18	0.14	0.17
9/4/18	0.14	0.14

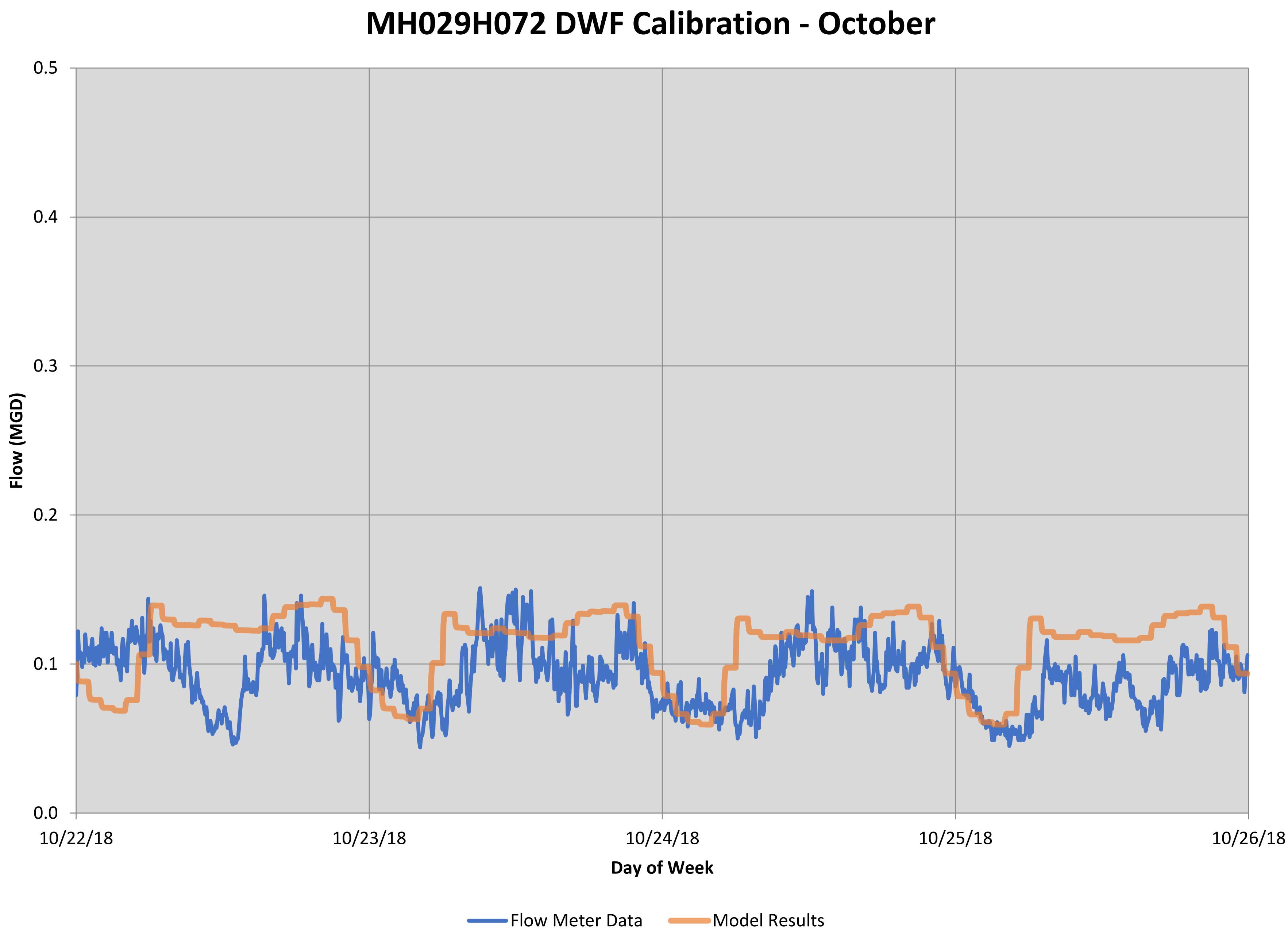
DWF Calibration Statistics MH029H072 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.14	0.14	**-1.5%**
Volume - MG	0.45	0.37	**22.0%**
Depth (Avg) - in	1.03	1.03	**0.0**

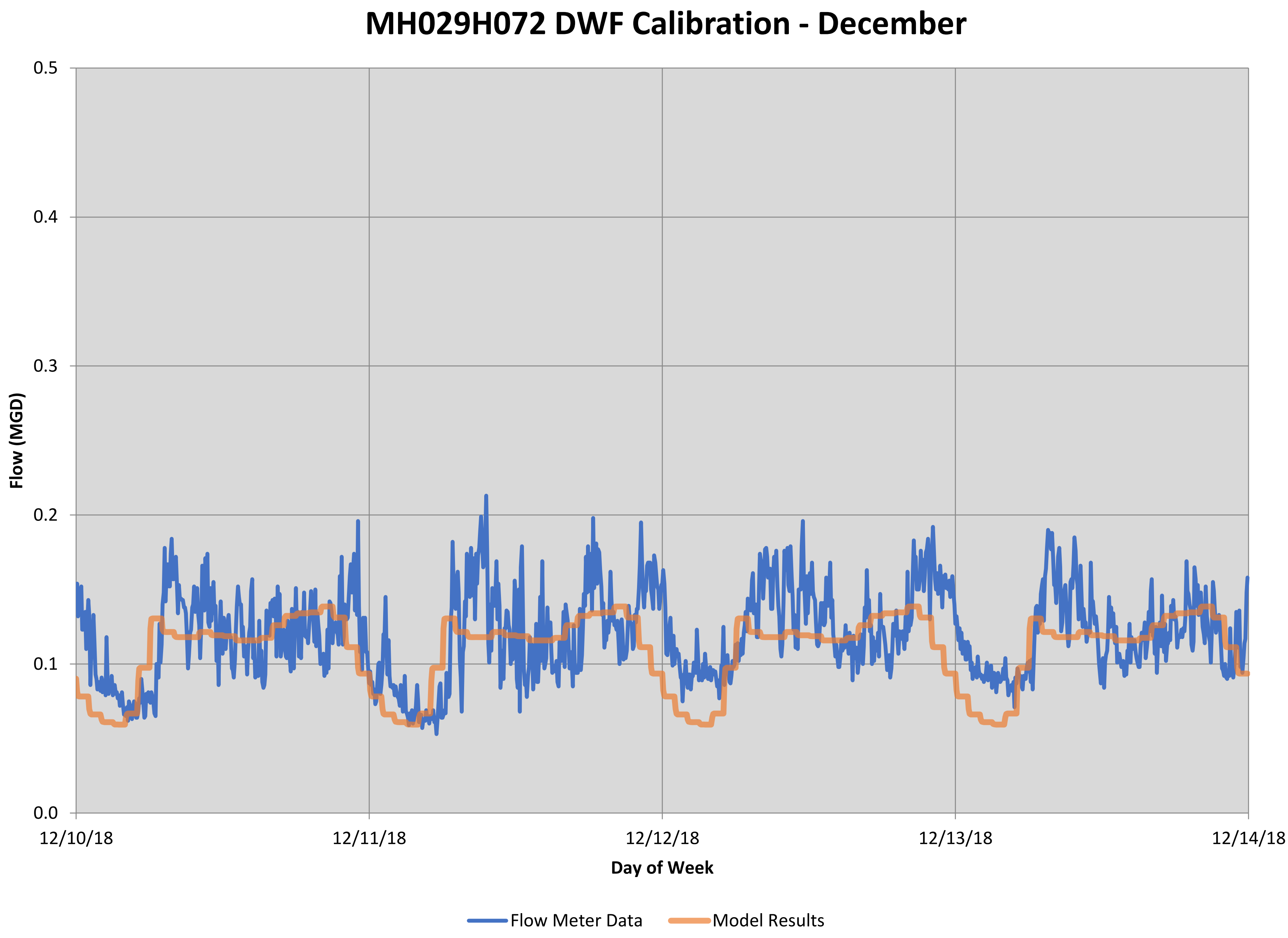
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	0.14	0.15
10/23/18	0.14	0.15
10/24/18	0.14	0.15
10/25/18	0.14	0.12

DWF Calibration Statistics MH029H072 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.14	0.20	**-30.2%**
Volume - MG	0.44	0.48	**-8.7%**
Depth (Avg) - in	1.02	1.12	**-0.1**

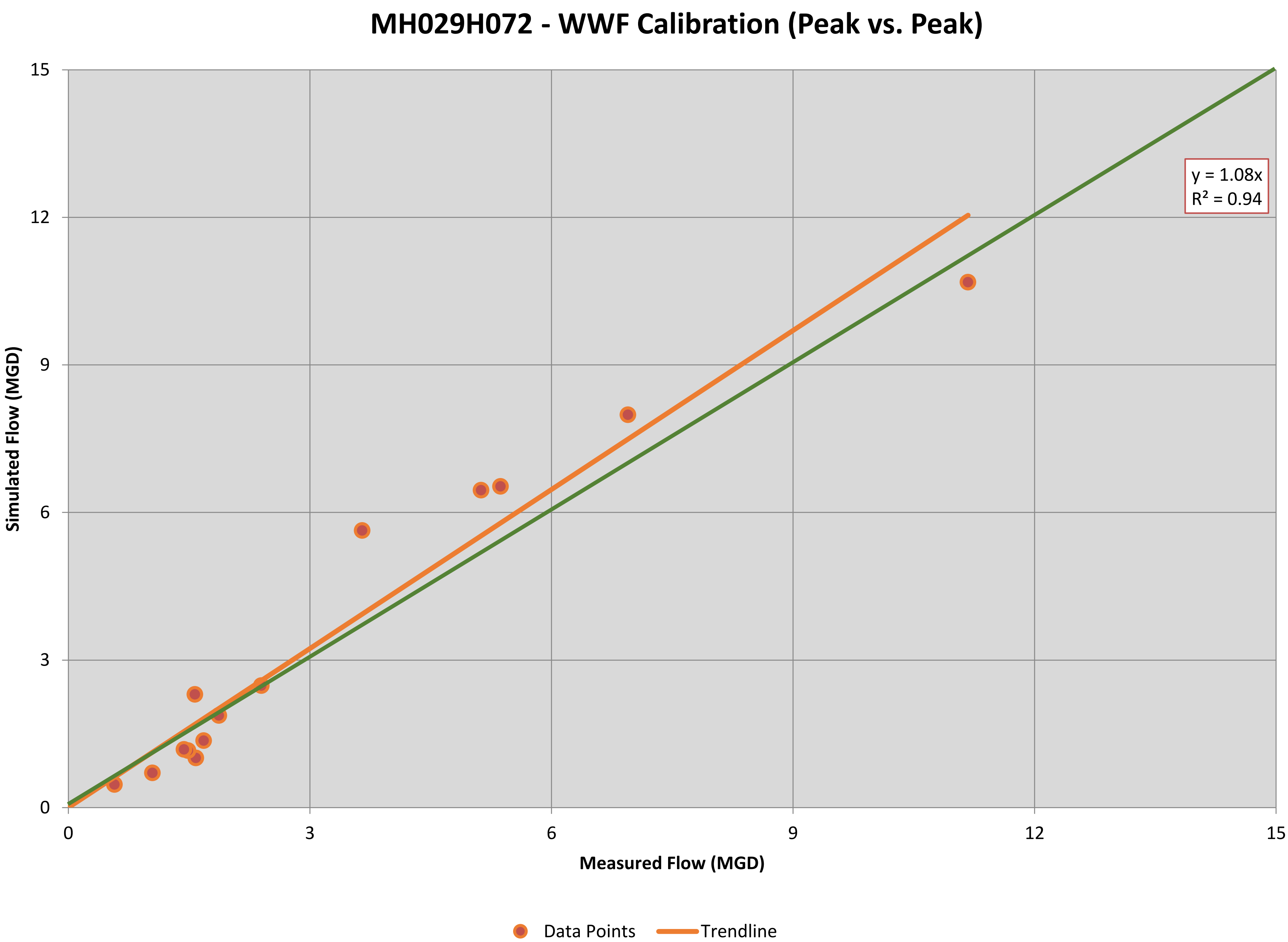
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	0.14	0.20
12/11/18	0.14	0.21
12/12/18	0.14	0.20
12/13/18	0.14	0.19


MH029H072 DWF Calibration - September
0.5
0.4
0.3
0.2
0.1
0.0
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

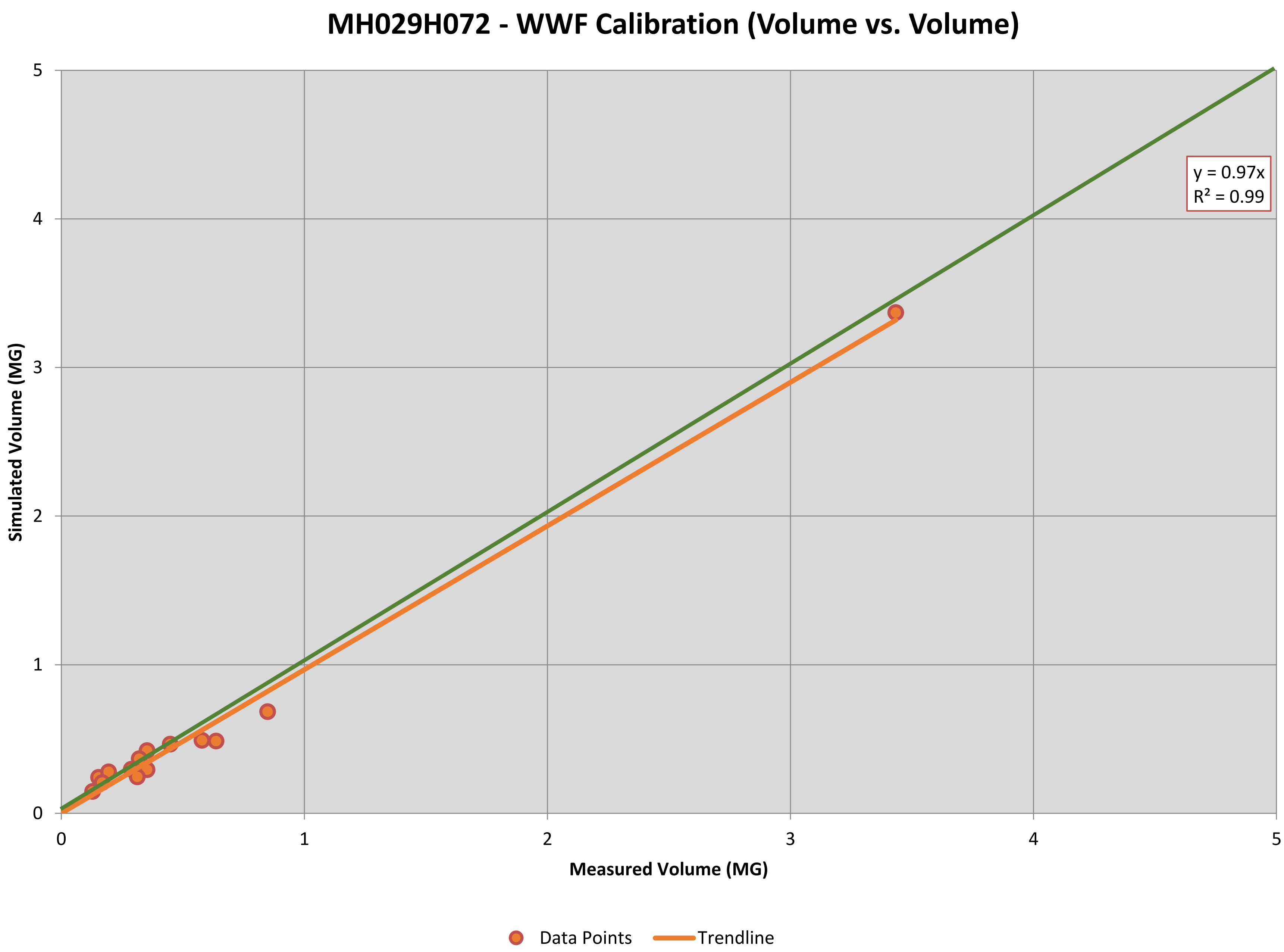

MH029H072 DWF Calibration - October
Flow (MGD)
0.5
0.4
0.3
0.2
0.1
0.0
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

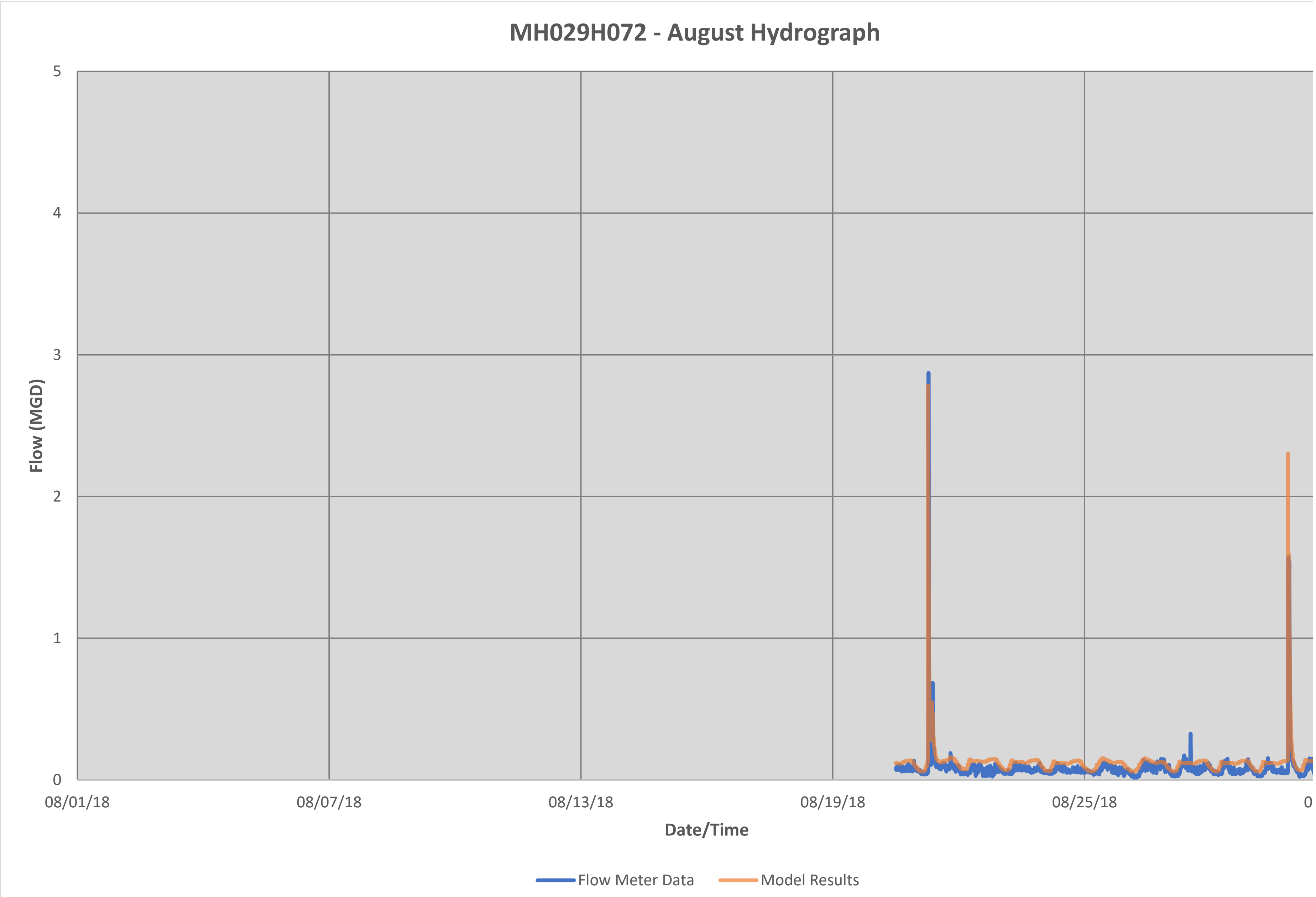

MH029H072 DWF Calibration - December
Flow (MGD)
0.5
0.4
0.3
0.2
0.1
0.0
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

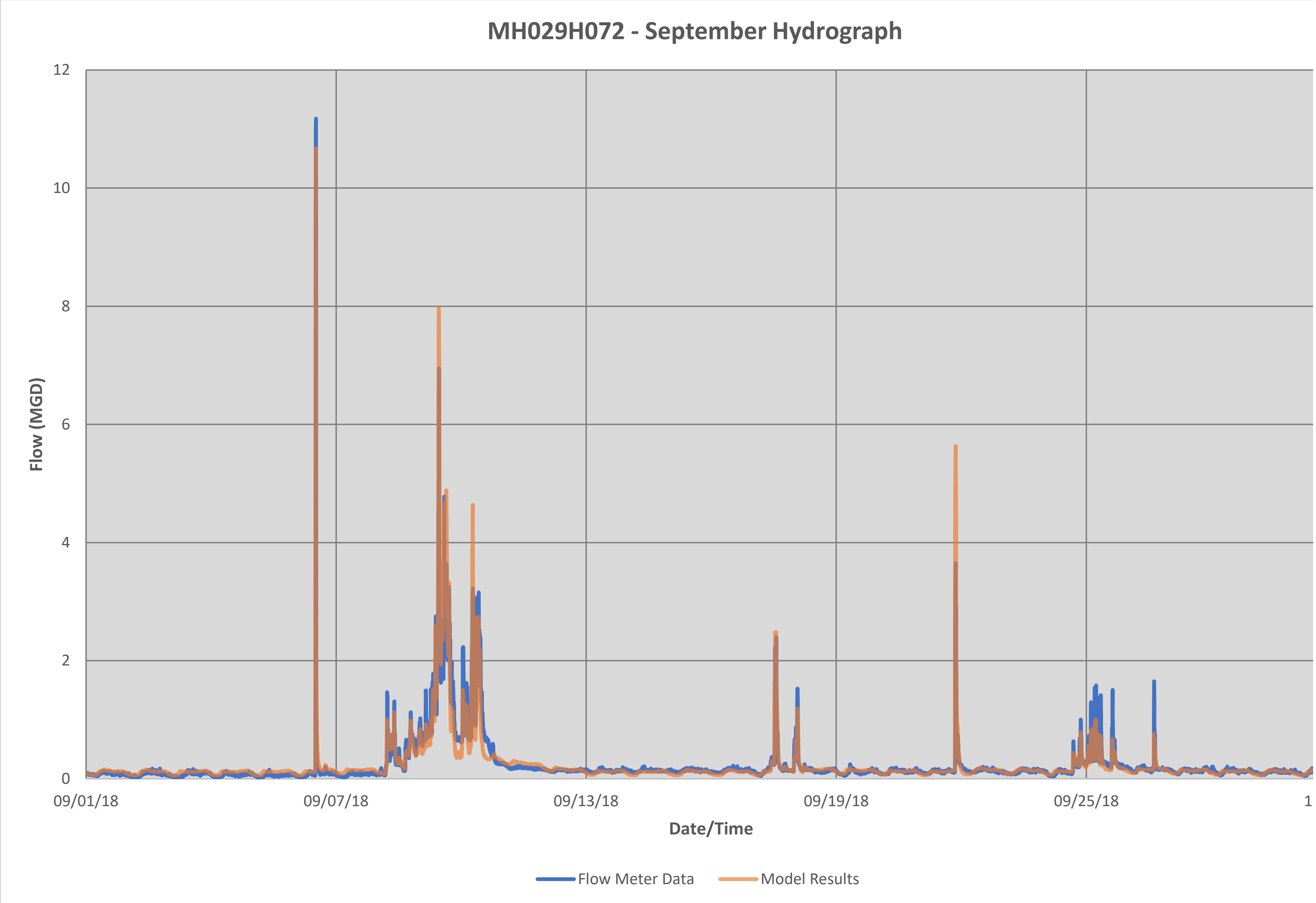
		MH029H072 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	1.57	2.30	46.3%	0.15	0.24	57.1%	4.6	5.1	0.5
09/06/18	Validation	11.18	10.68	-4.4%	0.20	0.28	42.4%	14.9	14.1	-0.8
09/07/18	Calibration	6.95	7.99	14.9%	3.43	3.37	-1.9%	8.7	11.3	2.6
09/17/18	Calibration	2.40	2.48	3.4%	0.45	0.46	3.4%	4.8	5.3	0.4
09/21/18	Validation	3.65	5.63	54.3%	0.35	0.42	19.4%	6.1	8.8	2.7
09/24/18	Validation	1.58	1.01	-36.4%	0.58	0.49	-15.4%	3.9	3.1	-0.8
10/02/18	Validation	1.87	1.87	0.0%	0.17	0.21	22.0%	5.2	4.4	-0.7
10/04/18	Calibration	5.13	6.45	25.9%	0.32	0.37	14.1%	7.4	9.7	2.3
10/06/18	Calibration	5.37	6.53	21.7%	0.29	0.30	2.9%	14.6	9.7	-4.9
10/15/18	Calibration	0.57	0.47	-18.1%	0.13	0.15	12.7%	2.5	2.0	-0.4
10/26/18	Calibration									
10/28/18	Calibration									
11/09/18	Calibration	1.49	1.16	-22.2%	0.35	0.29	-17.1%	3.6	3.4	-0.3
11/15/18	Calibration	1.44	1.18	-17.8%	0.85	0.68	-19.7%	3.5	3.4	-0.1
11/18/18	Validation	1.04	0.71	-32.4%	0.64	0.49	-23.7%	2.9	2.5	-0.4
11/24/18	Validation	1.68	1.36	-19.1%	0.31	0.24	-21.8%	3.9	3.7	-0.2
Totals		45.9	49.8	8.5%	8.2	8.0	-2.9%	87	86	-0.1

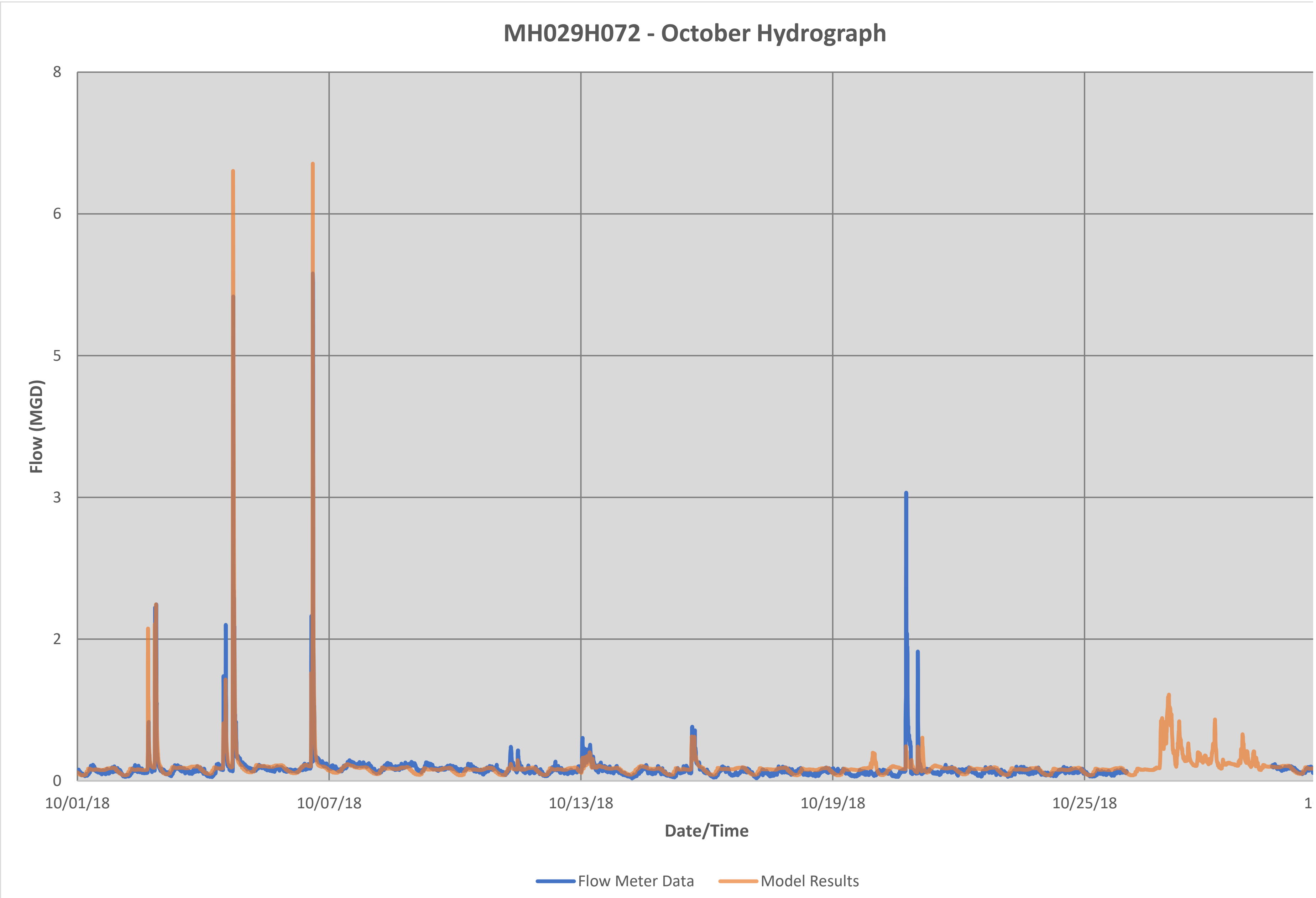


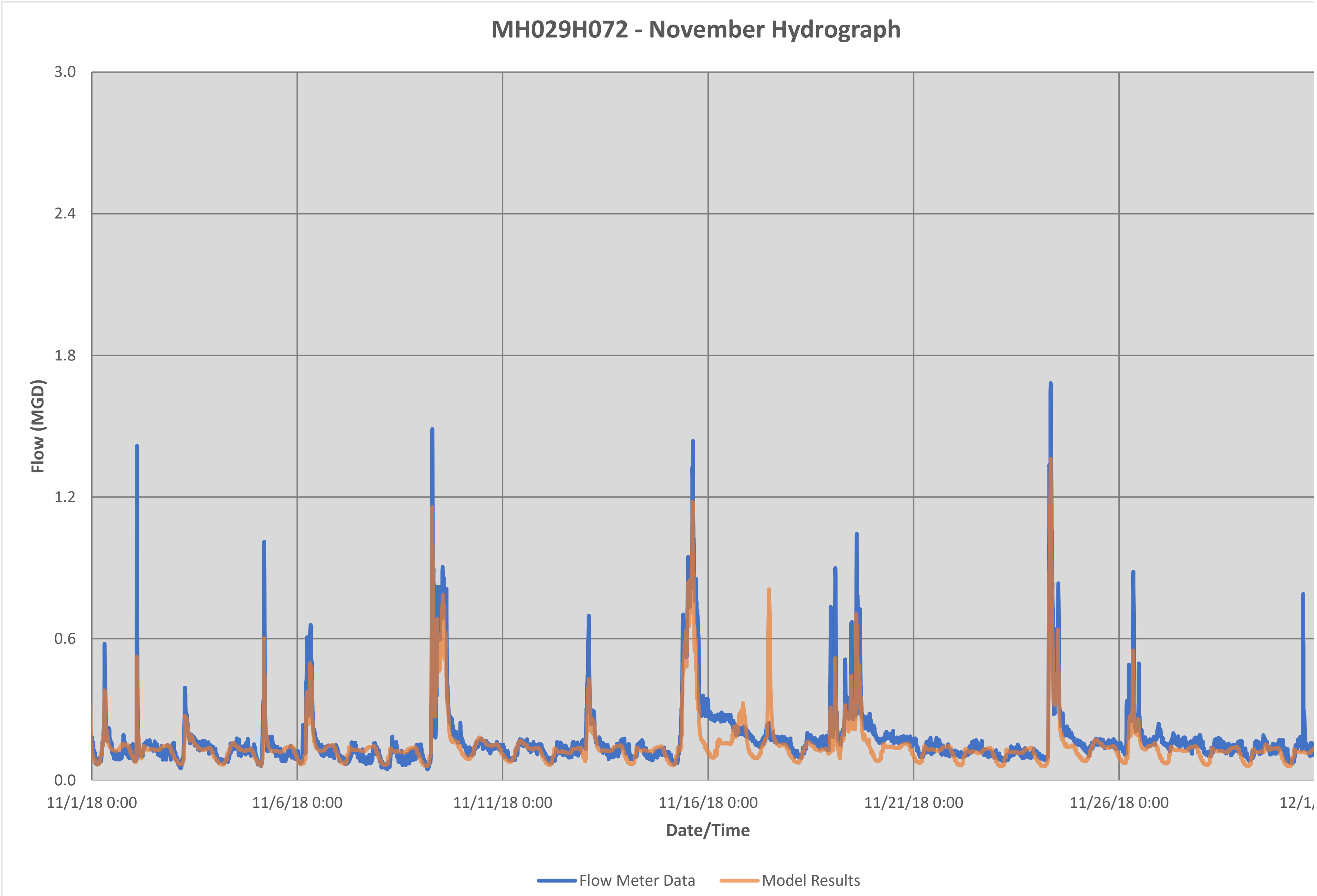
MH029H072 - WWF Calibration (Peak vs. Peak)
Simulated Flow (MGD)
Measured Flow (MGD)
0
3
6
9
12
15
y = 1.08x
R² = 0.94
Data Points
Trendline


MH029H072 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
0
1
2
3
4
5
0
1
2
3
4
5
y = 0.97x
R² = 0.99
Data Points
Trendline

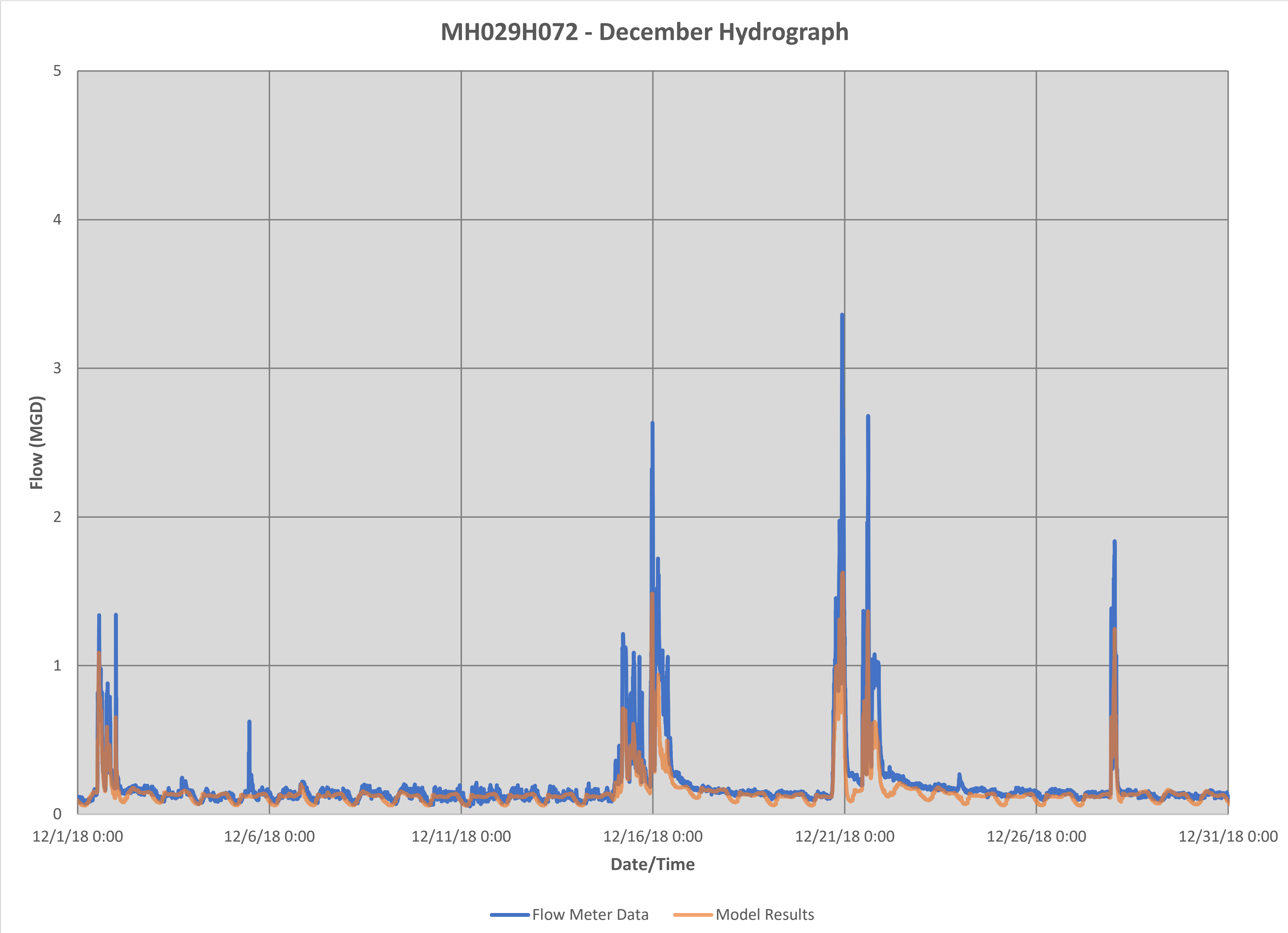

MH029H072 - August Hydrograph
5
4
3
2
1
0
Flow (MGD)
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results


MH029H072 - September Hydrograph
Flow (MGD)
12
10
8
6
4
2
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH029H072 - October Hydrograph
8
6
5
3
2
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH029H072 - November Hydrograph
Flow (MGD)
3.0
2.4
1.8
1.2
0.6
0.0
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1/
Date/Time
Flow Meter Data
Model Results


MH029H072 - December Hydrograph
Flow (MGD)
0
1
2
3
4
5
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH029H073 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	3.25	3.21	**1.2%**
Volume - MG	10.33	7.84	**31.7%**
Depth (Avg) - in	4.61	4.98	**-0.4**

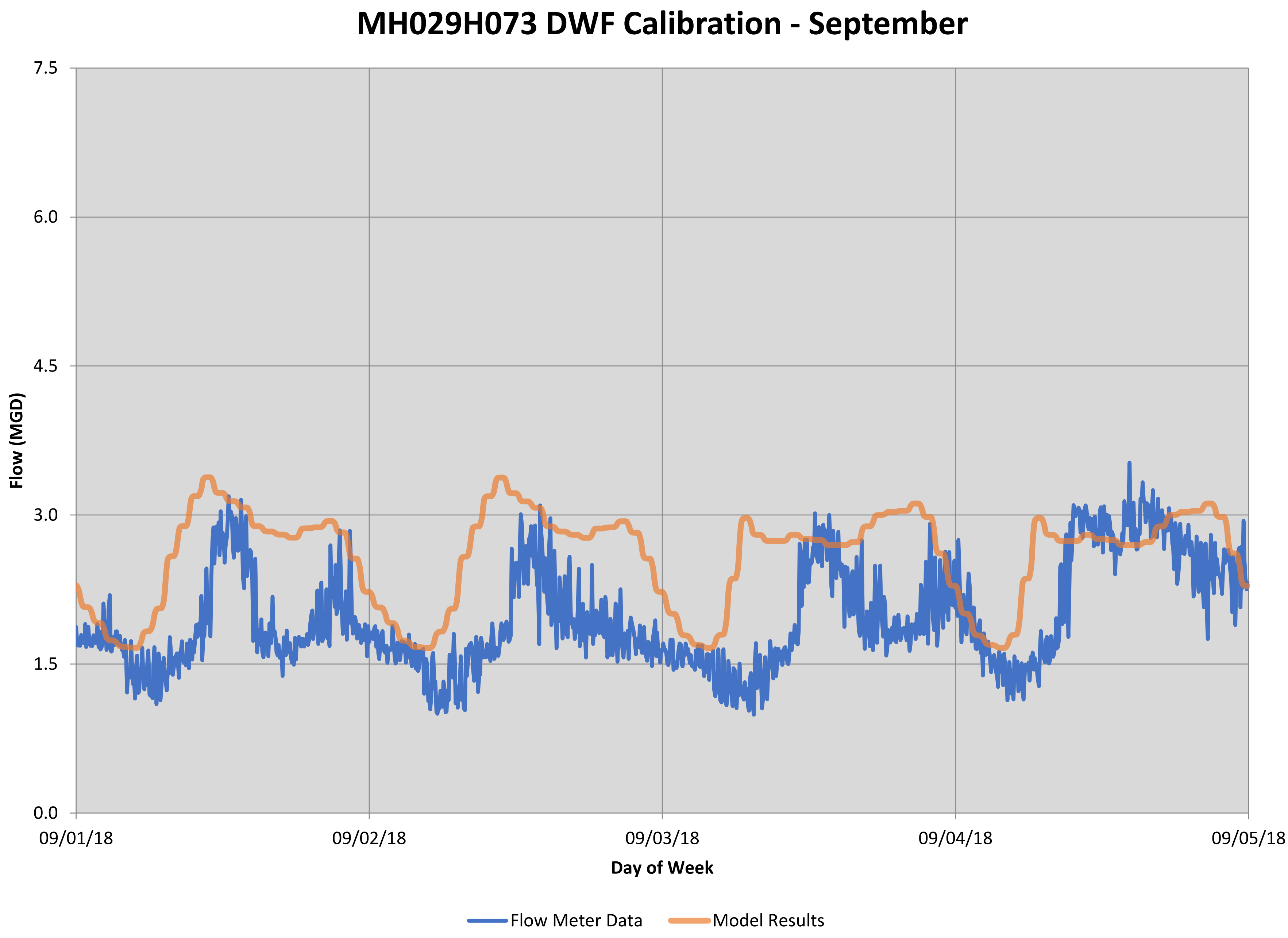
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	3.38	3.19
9/2/18	3.38	3.10
9/3/18	3.12	3.02
9/4/18	3.12	3.53

DWF Calibration Statistics MH029H073 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	3.12	3.85	**-18.9%**
Volume - MG	10.38	11.27	**-8.0%**
Depth (Avg) - in	4.63	5.60	**-1.0**

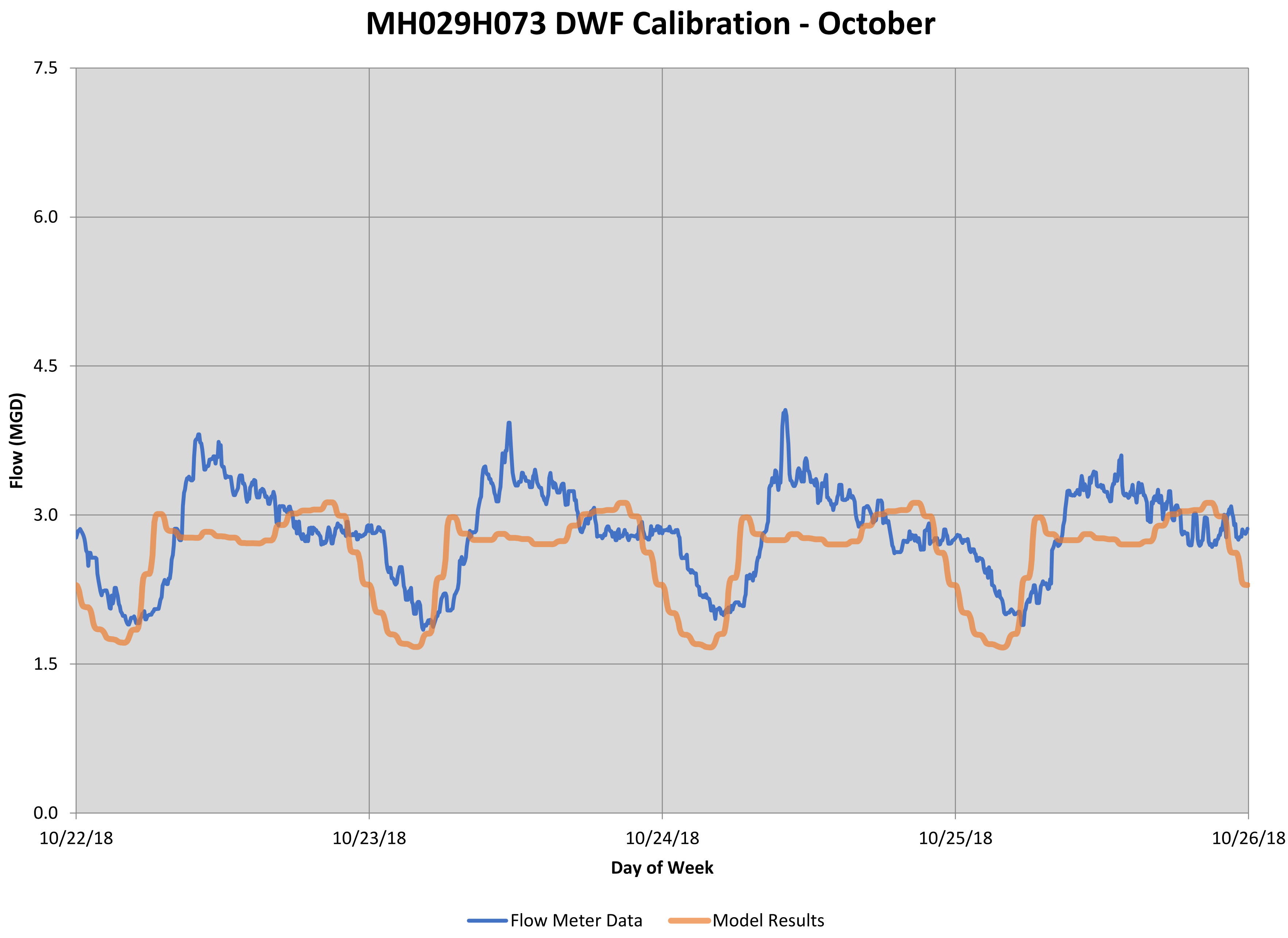
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	3.13	3.81
10/23/18	3.12	3.93
10/24/18	3.12	4.06
10/25/18	3.12	3.60

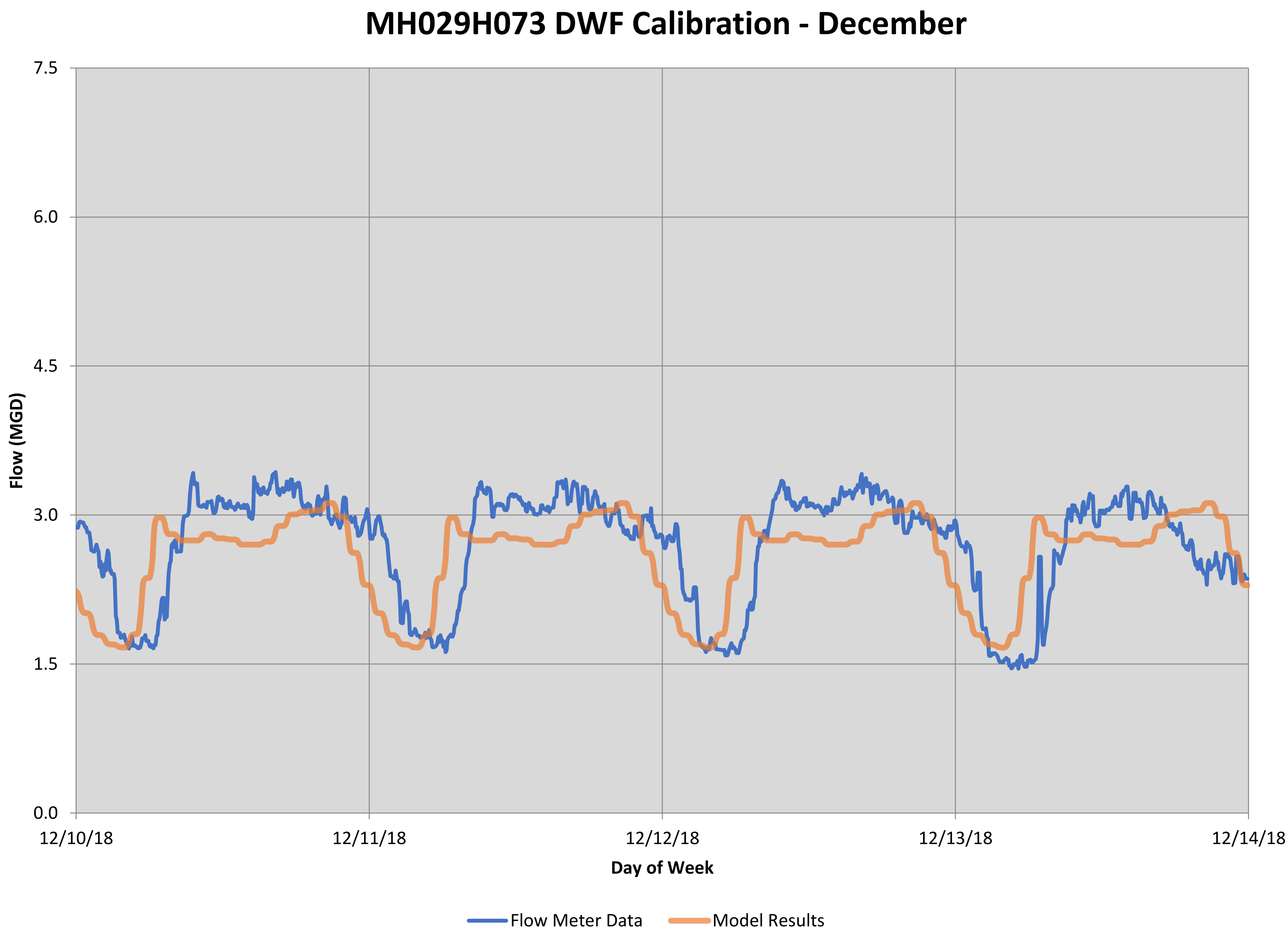
DWF Calibration Statistics MH029H073 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	3.12	3.37	**-7.5%**
Volume - MG	10.34	10.81	**-4.3%**
Depth (Avg) - in	4.62	5.68	**-1.1**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	3.12	3.43
10/23/18	3.12	3.36
10/24/18	3.12	3.41
10/25/18	3.12	3.29

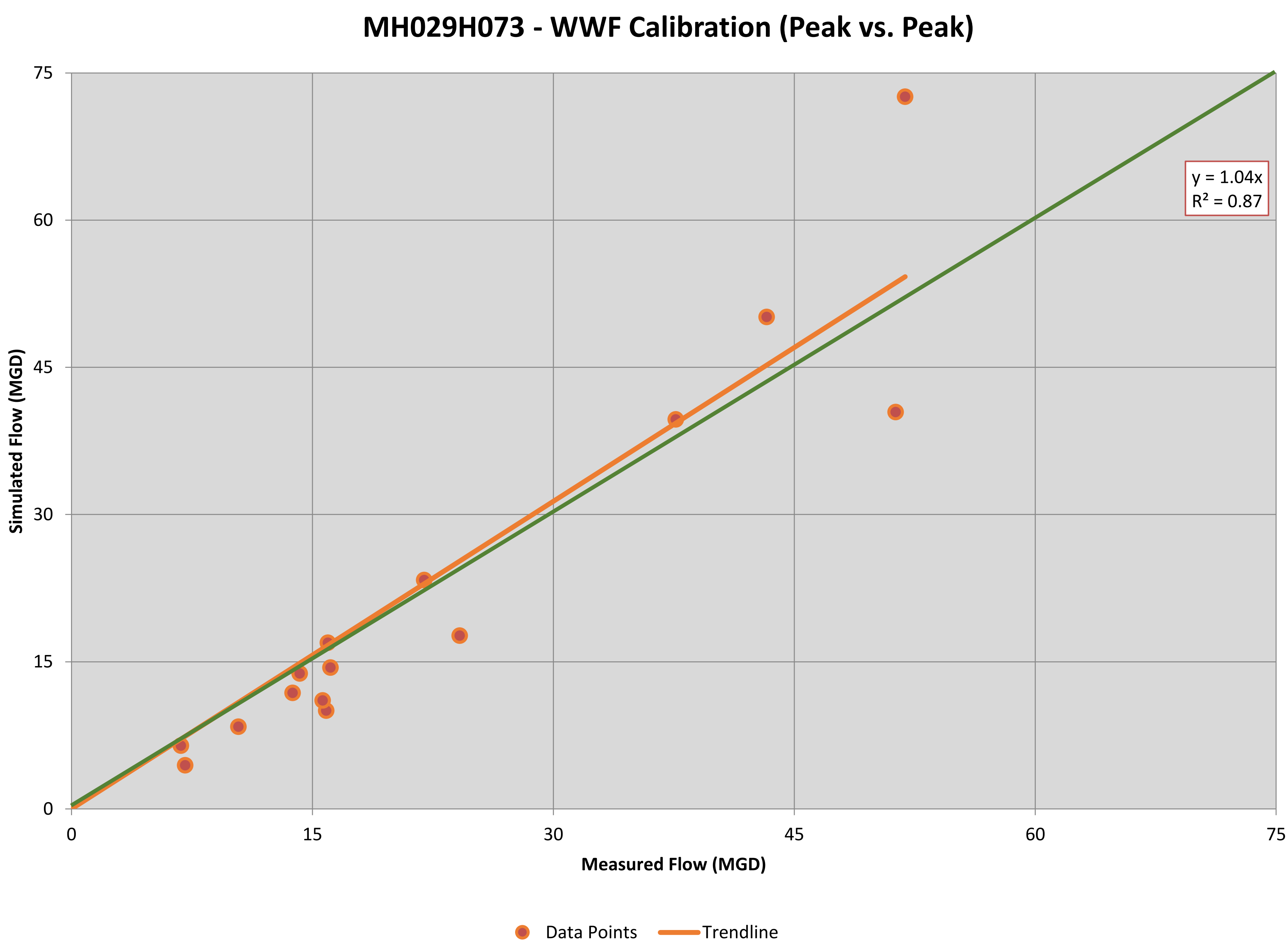


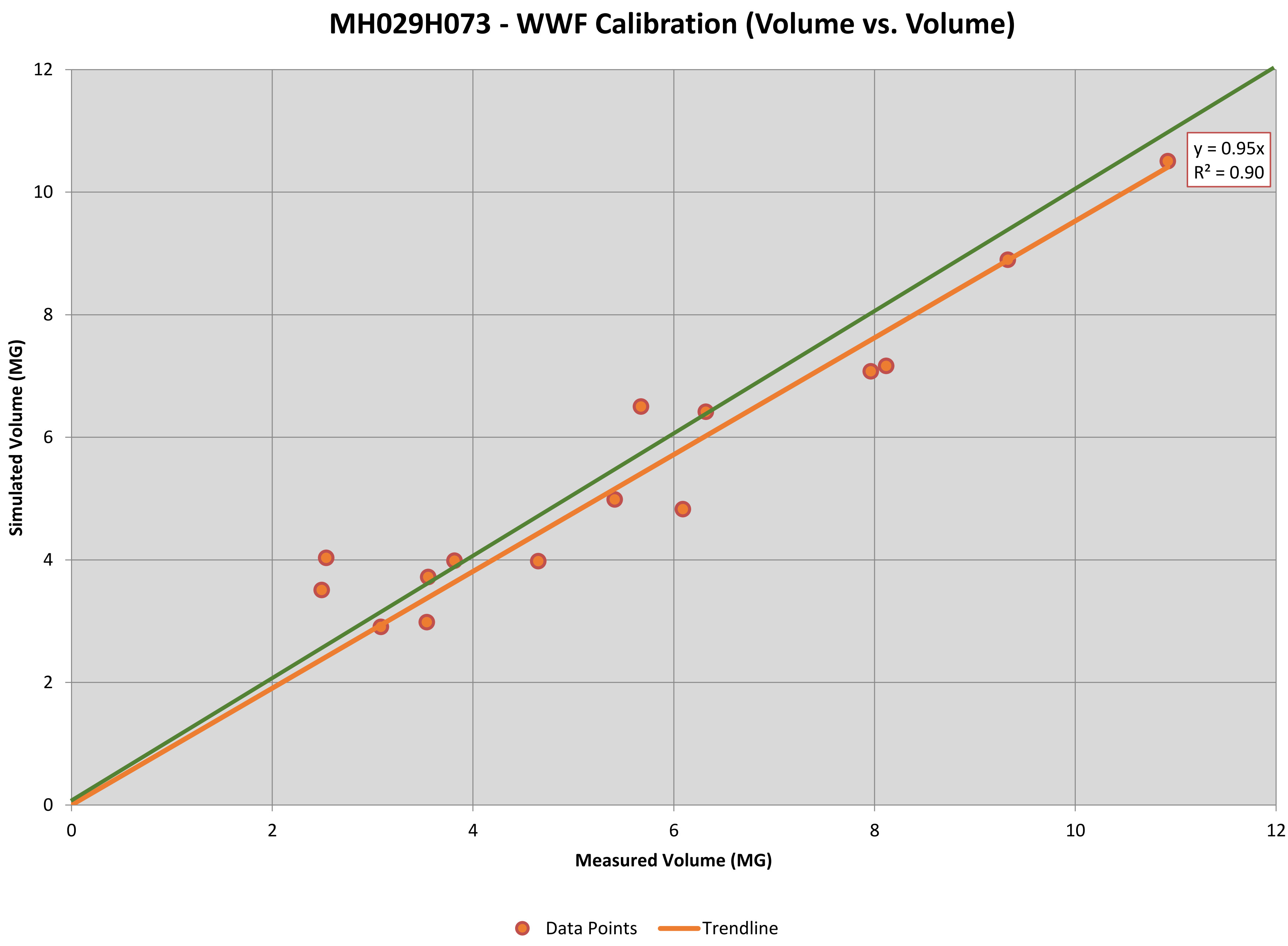
MH029H073 DWF Calibration - September
7.5
6.0
4.5
3.0
1.5
0.0
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results


MH029H073 DWF Calibration - October
Flow (MGD)
7.5
6.0
4.5
3.0
1.5
0.0
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

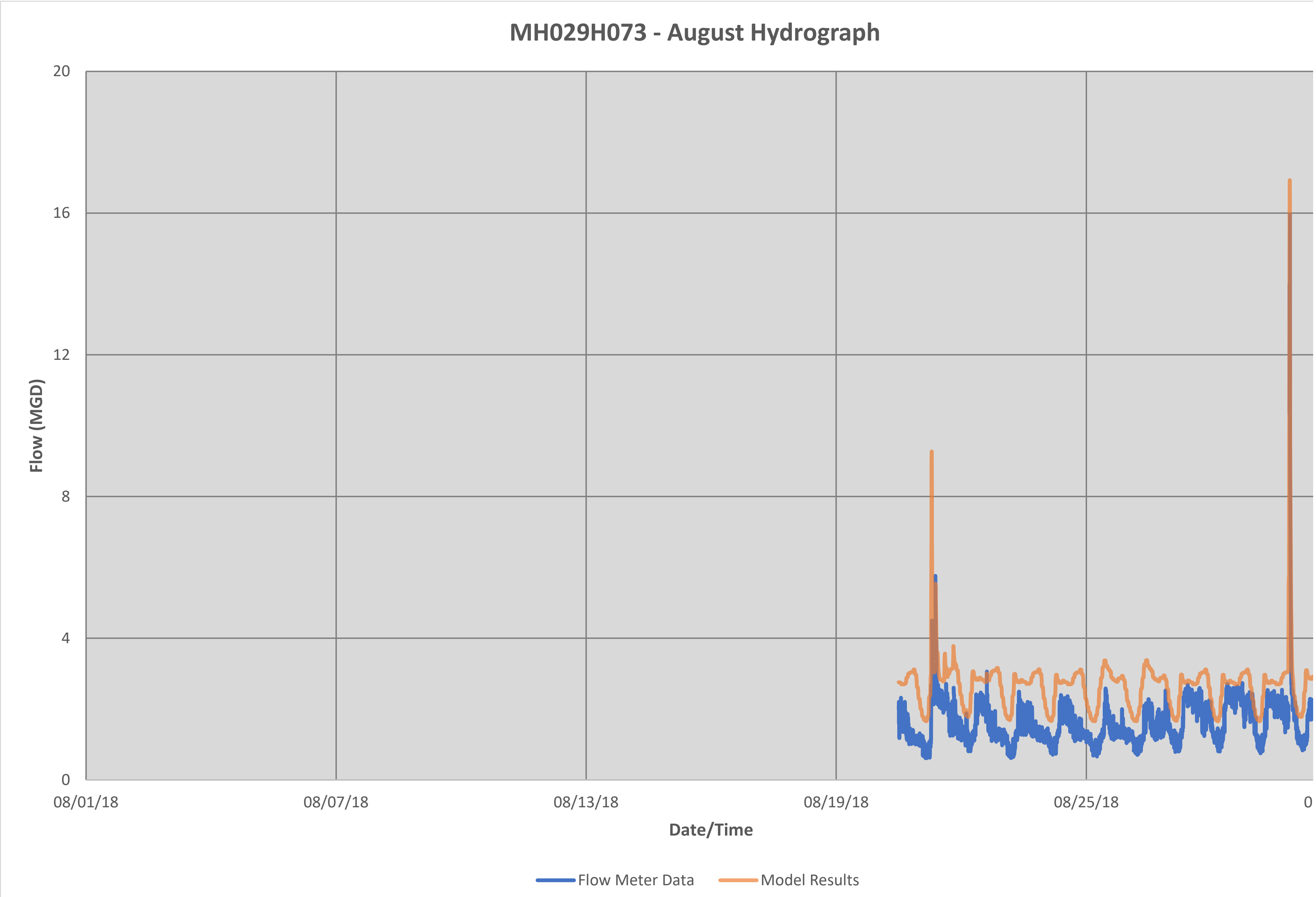

MH029H073 DWF Calibration - December
7.5
6.0
4.5
3.0
1.5
0.0
Flow (MGD)
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

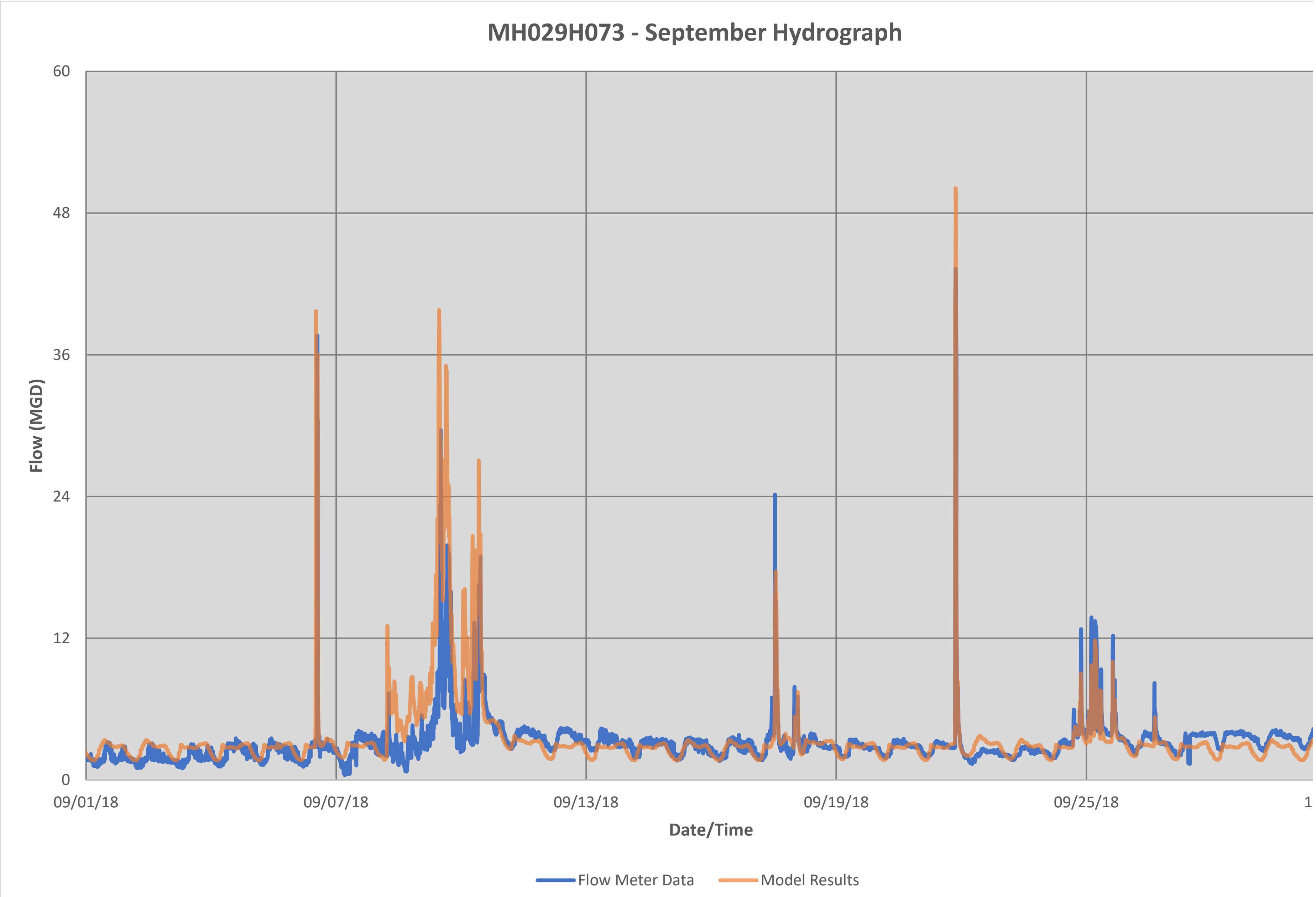
		MH029H073 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	15.97	16.93	6.0%	2.54	4.03	58.8%	15.8	12.5	-3.3
09/06/18	Validation	37.63	39.70	5.5%	2.49	3.51	40.6%	15.8	20.1	4.3
09/07/18	Calibration									
09/17/18	Calibration	24.18	17.65	-27.0%	6.32	6.42	1.6%	15.8	12.8	-2.9
09/21/18	Validation	43.29	50.12	15.8%	5.67	6.50	14.6%	20.1	23.1	2.9
09/24/18	Validation	13.78	11.83	-14.2%	8.12	7.16	-11.7%	11.3	10.3	-1.0
10/02/18	Validation	21.96	23.33	6.2%	3.54	2.98	-15.8%	14.6	14.9	0.3
10/04/18	Calibration	51.32	40.43	-21.2%	6.09	4.83	-20.7%	20.8	20.3	-0.5
10/06/18	Calibration	51.91	72.59	39.8%	5.41	4.98	-7.9%	19.7	28.6	8.8
10/15/18	Calibration	7.09	4.45	-37.3%	3.08	2.90	-5.8%	8.1	6.1	-2.0
10/26/18	Calibration	15.86	10.01	-36.9%	7.96	7.08	-11.1%	11.2	9.4	-1.8
10/28/18	Calibration	6.81	6.44	-5.5%	4.65	3.98	-14.5%	8.1	7.5	-0.7
11/09/18	Calibration	14.22	13.80	-3.0%	3.82	3.99	4.5%	11.5	11.2	-0.2
11/15/18	Calibration	15.65	11.06	-29.3%	10.92	10.50	-3.8%	11.9	10.0	-1.9
11/18/18	Validation	10.39	8.37	-19.4%	9.33	8.90	-4.6%	9.7	8.6	-1.1
11/24/18	Validation	16.14	14.39	-10.8%	3.55	3.72	4.6%	12.0	11.5	-0.5
Totals		346.2	341.1	-1.5%	83.5	81.5	-2.4%	207	207	0.4


MH029H073 - WWF Calibration (Peak vs. Peak)
Simulated Flow (MGD)
Measured Flow (MGD)
0
15
30
45
60
75
y = 1.04x
R² = 0.87
Data Points
Trendline

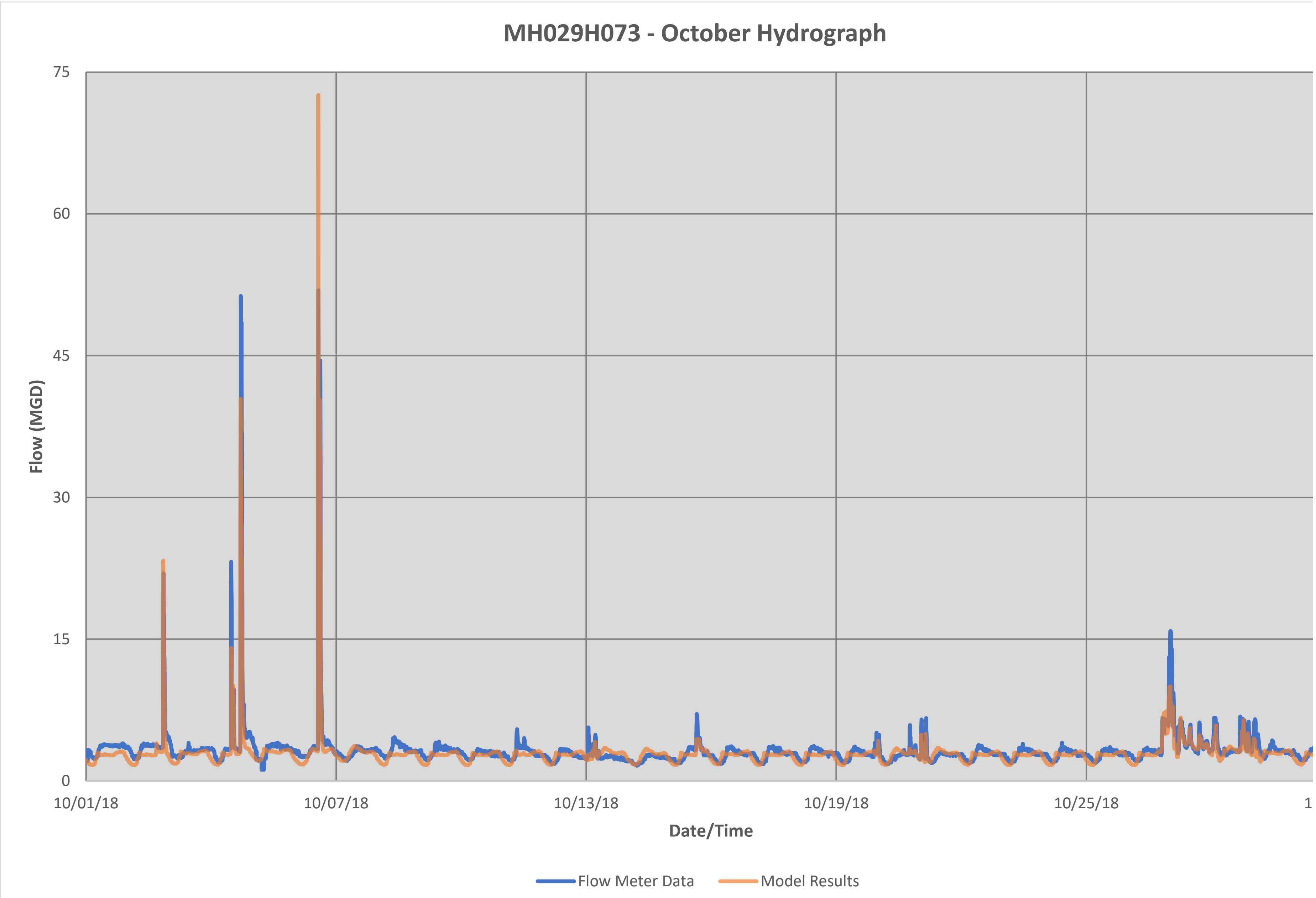


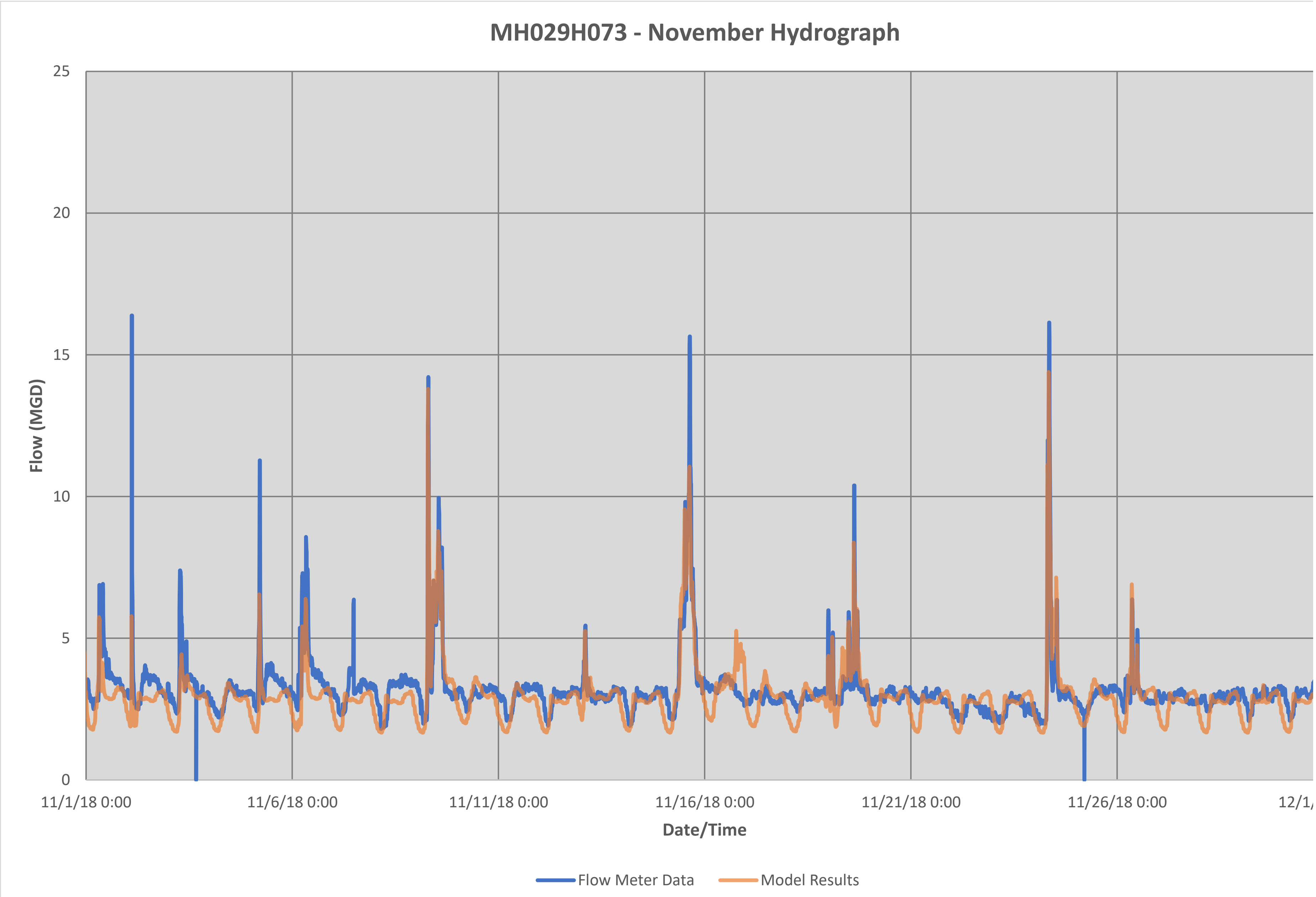
MH029H073 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
0
2
4
6
8
10
12
y = 0.95x
R² = 0.90
Data Points
Trendline


MH029H073 - August Hydrograph
20
16
12
8
4
0
Flow (MGD)
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results

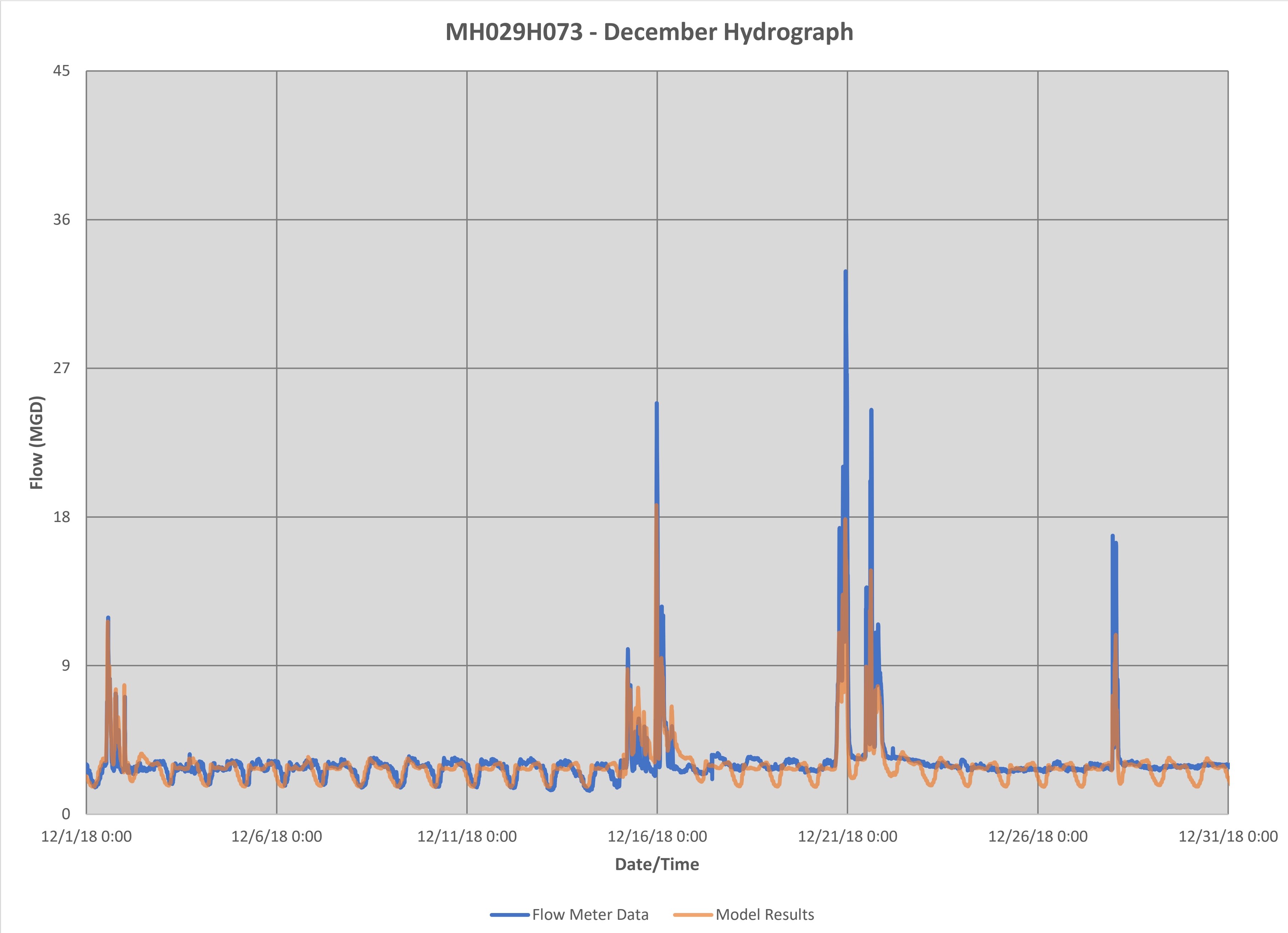


MH029H073 - September Hydrograph
60
48
36
24
12
0
Flow (MGD)
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH029H073 - October Hydrograph
Flow (MGD)
75
60
45
30
15
0
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH029H073 - November Hydrograph
25
20
15
10
5
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1/
Date/Time
Flow Meter Data
Model Results


MH029H073 - December Hydrograph
Flow (MGD)
45
36
27
18
9
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH029S031 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.10	0.12	**-17.5%**
Volume - MG	0.34	0.36	**-7.3%**
Depth (Avg) - in	0.89	0.93	**0.0**

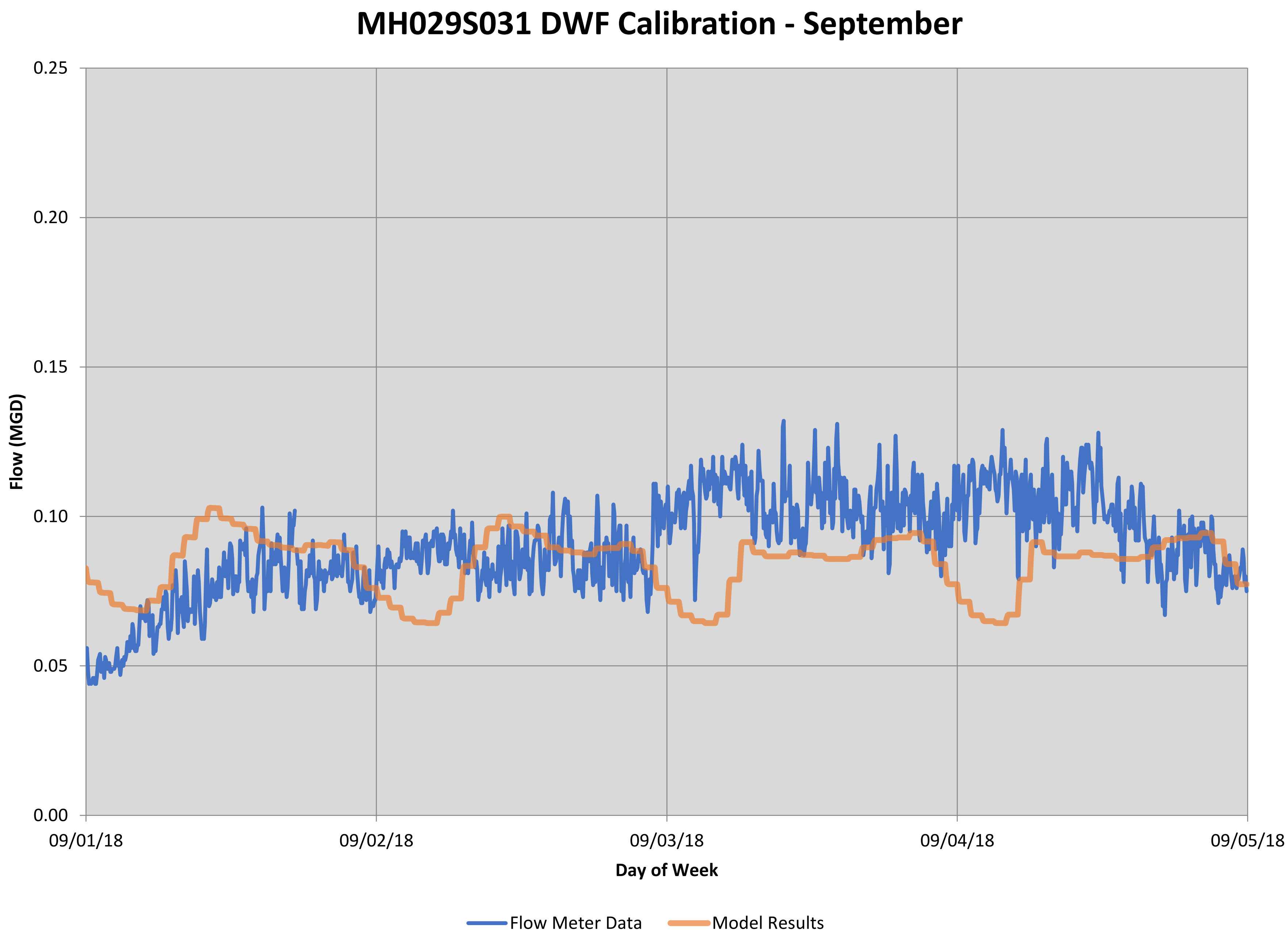
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	0.10	0.10
9/2/18	0.10	0.11
9/3/18	0.09	0.13
9/4/18	0.09	0.13

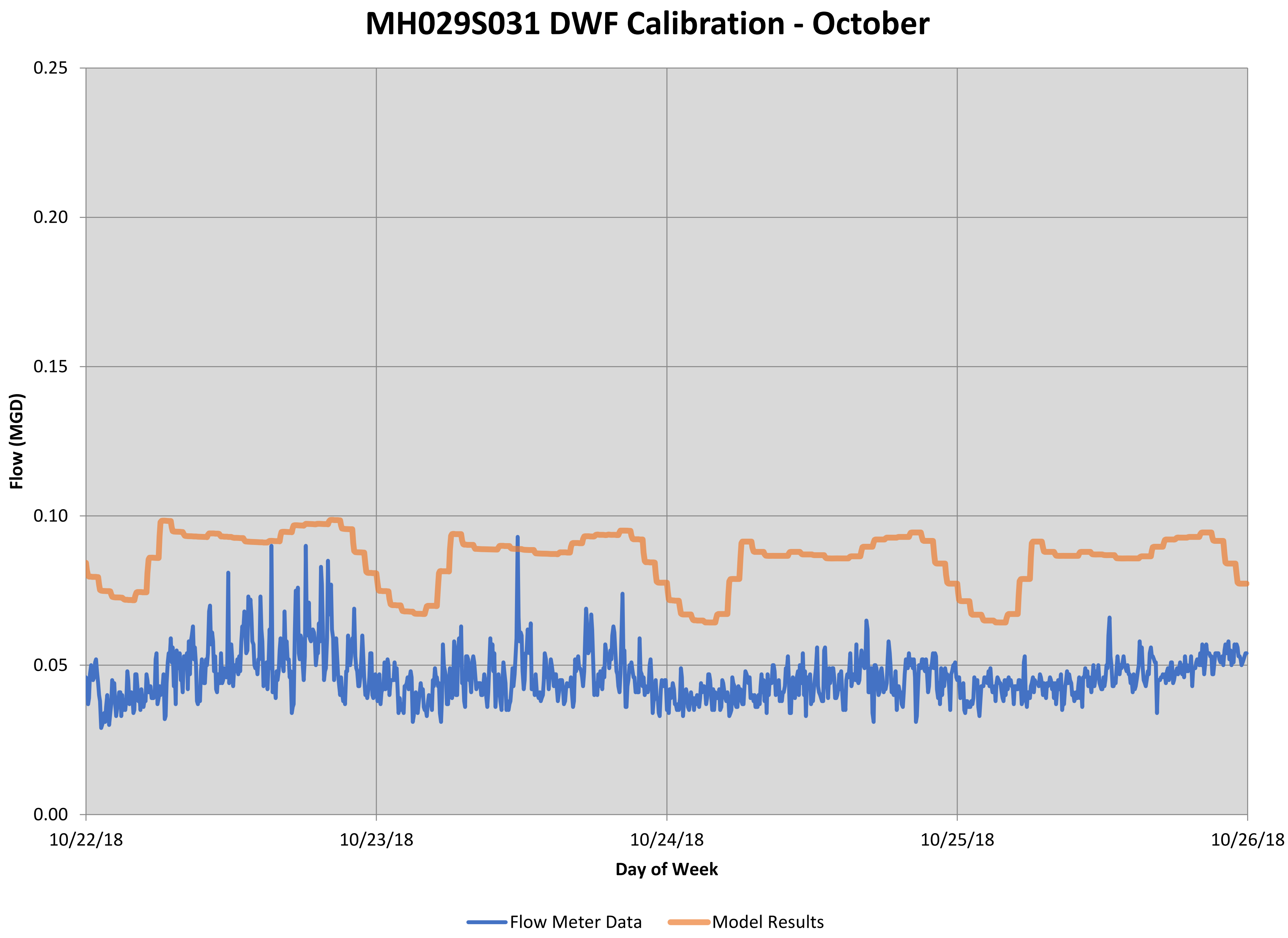
DWF Calibration Statistics MH029S031 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.10	0.08	**21.9%**
Volume - MG	0.34	0.18	**84.9%**
Depth (Avg) - in	0.90	0.82	**0.1**

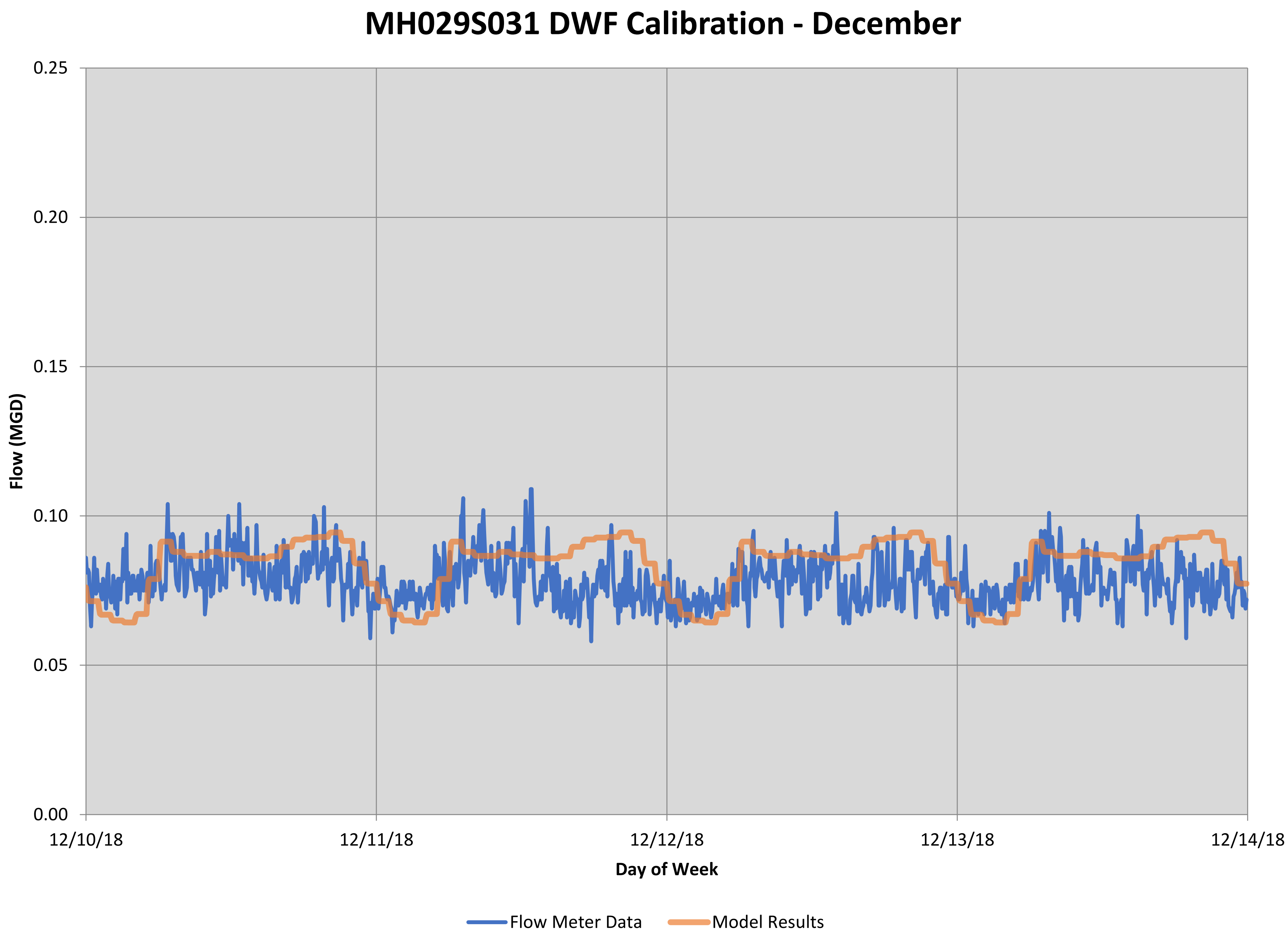
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	0.10	0.09
10/23/18	0.10	0.09
10/24/18	0.09	0.07
10/25/18	0.09	0.07

DWF Calibration Statistics MH029S031 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.09	0.10	**-8.9%**
Volume - MG	0.33	0.31	**6.6%**
Depth (Avg) - in	0.89	0.93	**0.0**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	0.09	0.10
12/11/18	0.09	0.11
12/12/18	0.09	0.10
12/13/18	0.09	0.10

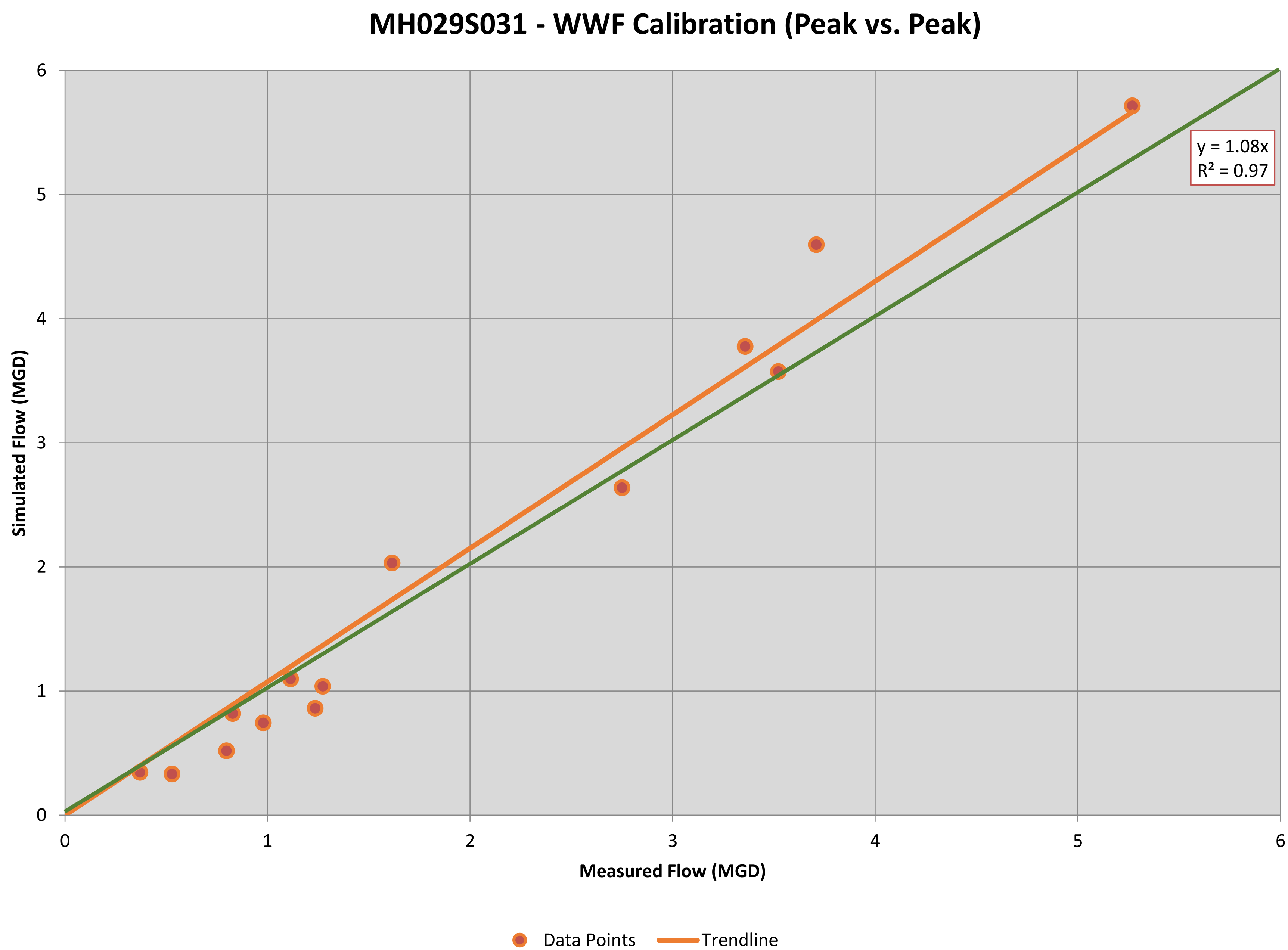

MH029S031 DWF Calibration - September
0.25
0.20
0.15
0.10
0.05
0.00
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

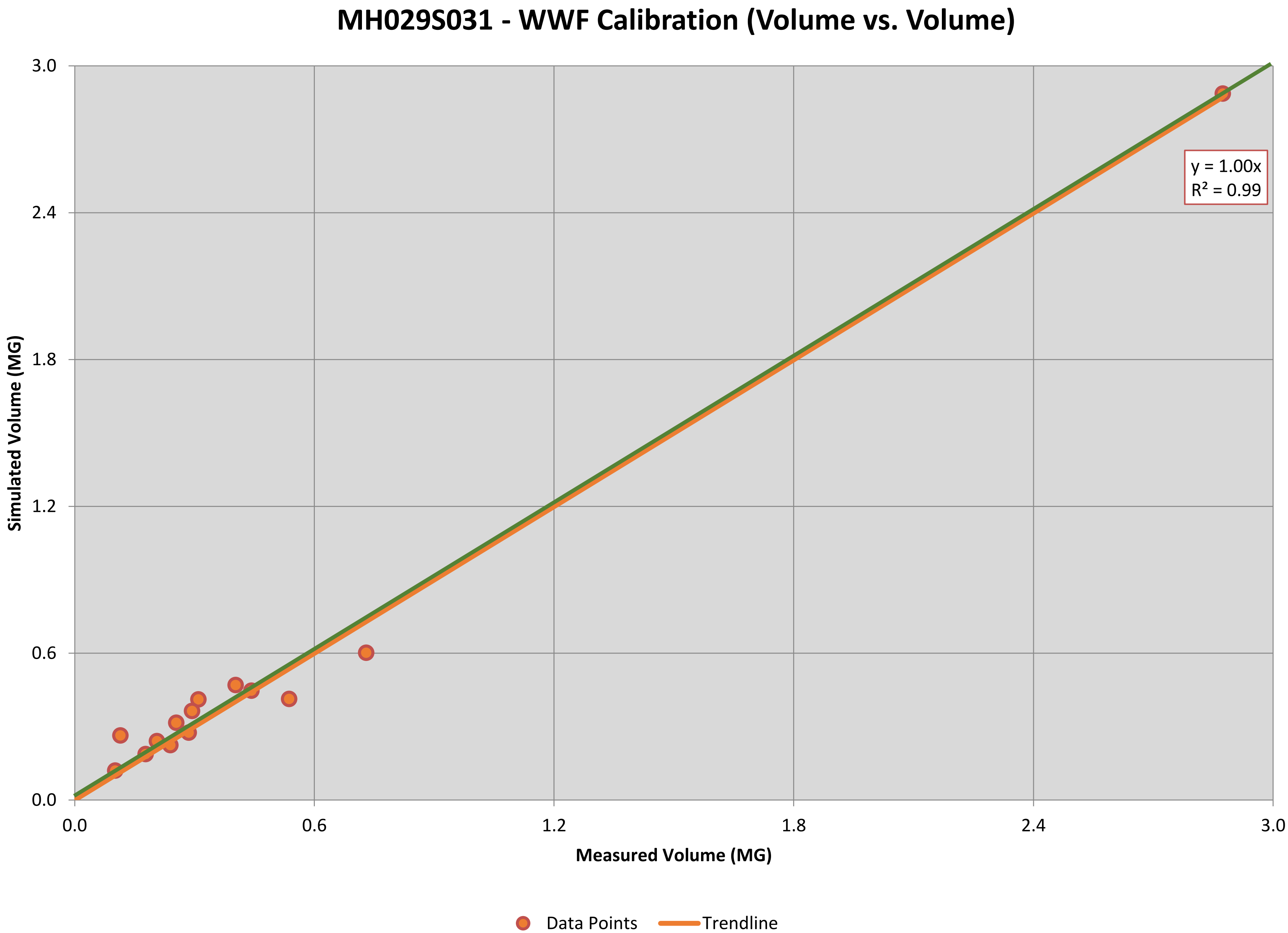

MH029S031 DWF Calibration - October
Flow (MGD)
0.25
0.20
0.15
0.10
0.05
0.00
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

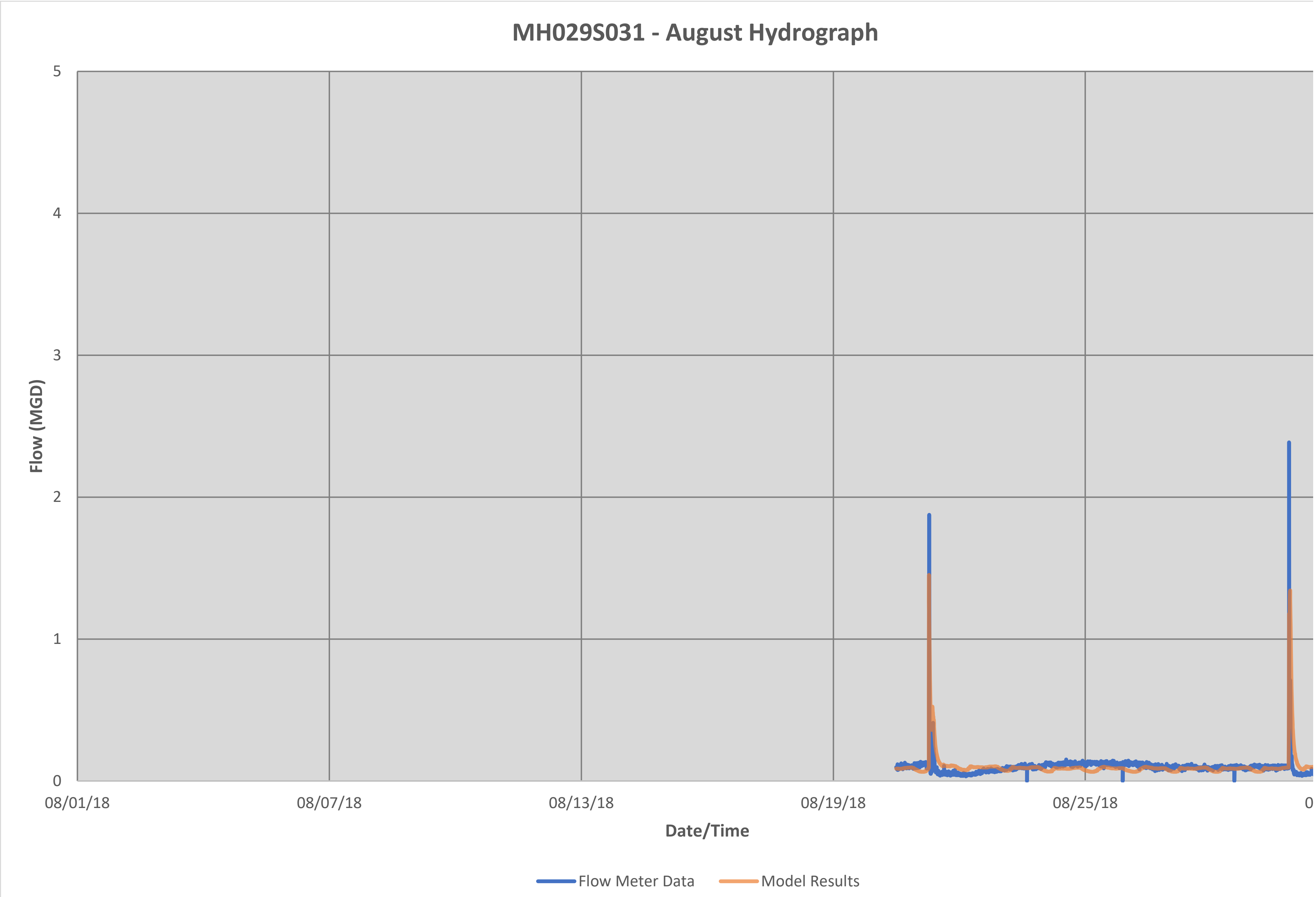


MH029S031 DWF Calibration - December
Flow (MGD)
0.25
0.20
0.15
0.10
0.05
0.00
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

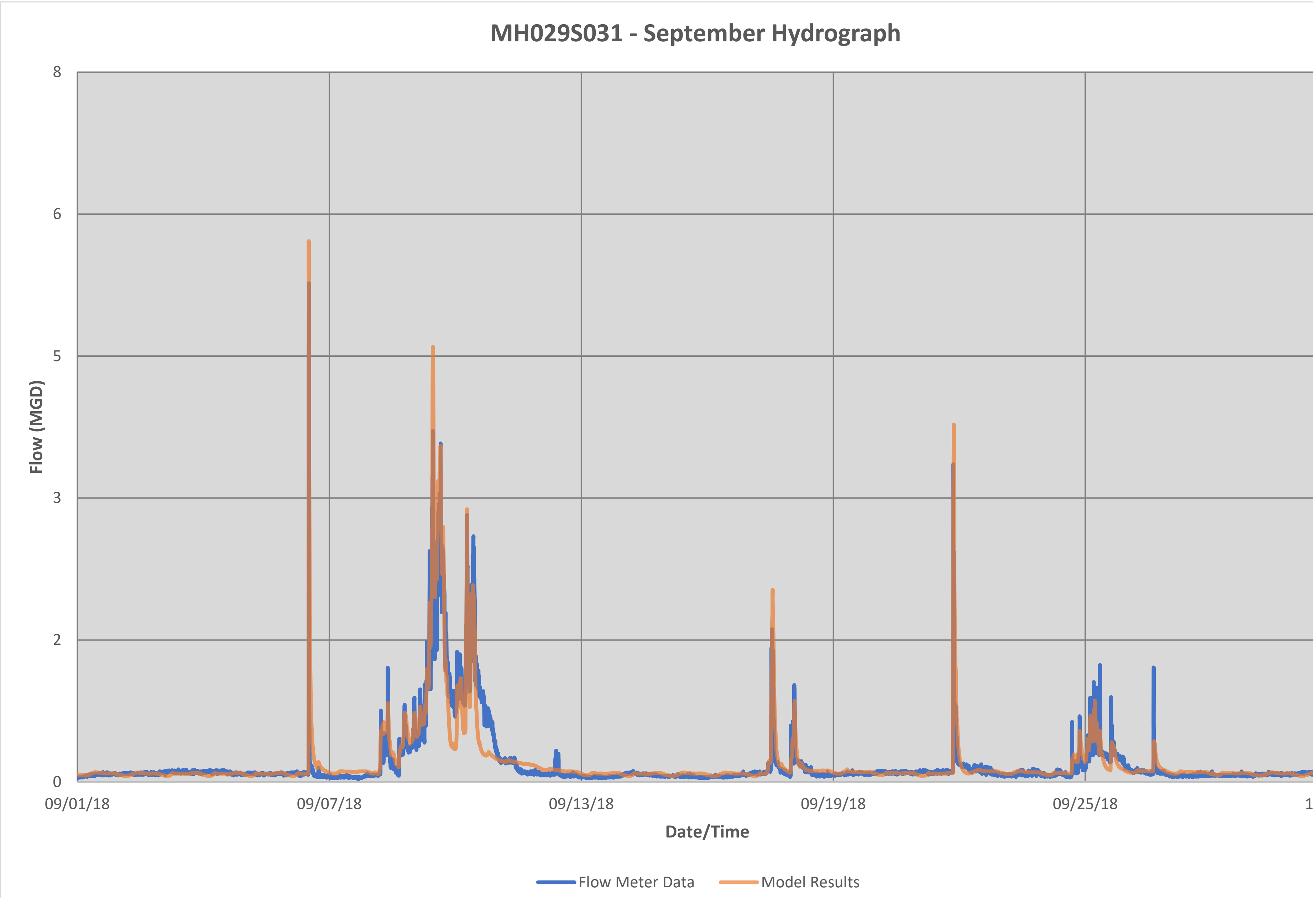
		MH029S031 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration									
09/06/18	Validation	5.27	5.71	8.4%	0.11	0.26	129.8%	7.8	7.2	-0.6
09/07/18	Calibration	3.71	4.60	23.9%	2.87	2.89	0.4%	5.7	6.4	0.7
09/17/18	Calibration	1.62	2.03	25.8%	0.31	0.41	32.4%	3.4	4.2	0.8
09/21/18	Validation	3.36	3.78	12.4%	0.29	0.36	23.9%	6.6	5.7	-0.9
09/24/18	Validation	1.24	0.86	-30.5%	0.44	0.45	0.8%	2.8	2.7	-0.1
10/02/18	Validation									
10/04/18	Calibration	3.52	3.57	1.5%	0.25	0.32	24.2%	5.7	5.6	-0.1
10/06/18	Calibration	2.75	2.64	-4.1%	0.21	0.24	16.6%	7.1	4.7	-2.4
10/15/18	Calibration	0.37	0.34	-7.1%	0.10	0.12	18.4%	1.6	1.7	0.1
10/26/18	Calibration	0.83	0.82	-1.2%	0.40	0.47	16.6%	2.4	2.6	0.3
10/28/18	Calibration	0.53	0.33	-37.5%	0.18	0.19	5.6%	1.9	1.7	-0.2
11/09/18	Calibration	0.98	0.74	-24.1%	0.29	0.27	-3.8%	2.6	2.5	0.0
11/15/18	Calibration	1.11	1.10	-1.5%	0.73	0.60	-17.6%	2.6	3.1	0.4
11/18/18	Validation	0.80	0.52	-35.2%	0.54	0.41	-23.2%	2.3	2.1	-0.2
11/24/18	Validation	1.27	1.04	-18.5%	0.24	0.22	-6.4%	2.9	3.0	0.1
Totals		27.4	28.1	2.6%	7.0	7.2	3.6%	55	53	-2.1


MH029S031 - WWF Calibration (Peak vs. Peak)
y = 1.08x
R² = 0.97
Simulated Flow (MGD)
Measured Flow (MGD)
0
1
2
3
4
5
6
Data Points
Trendline

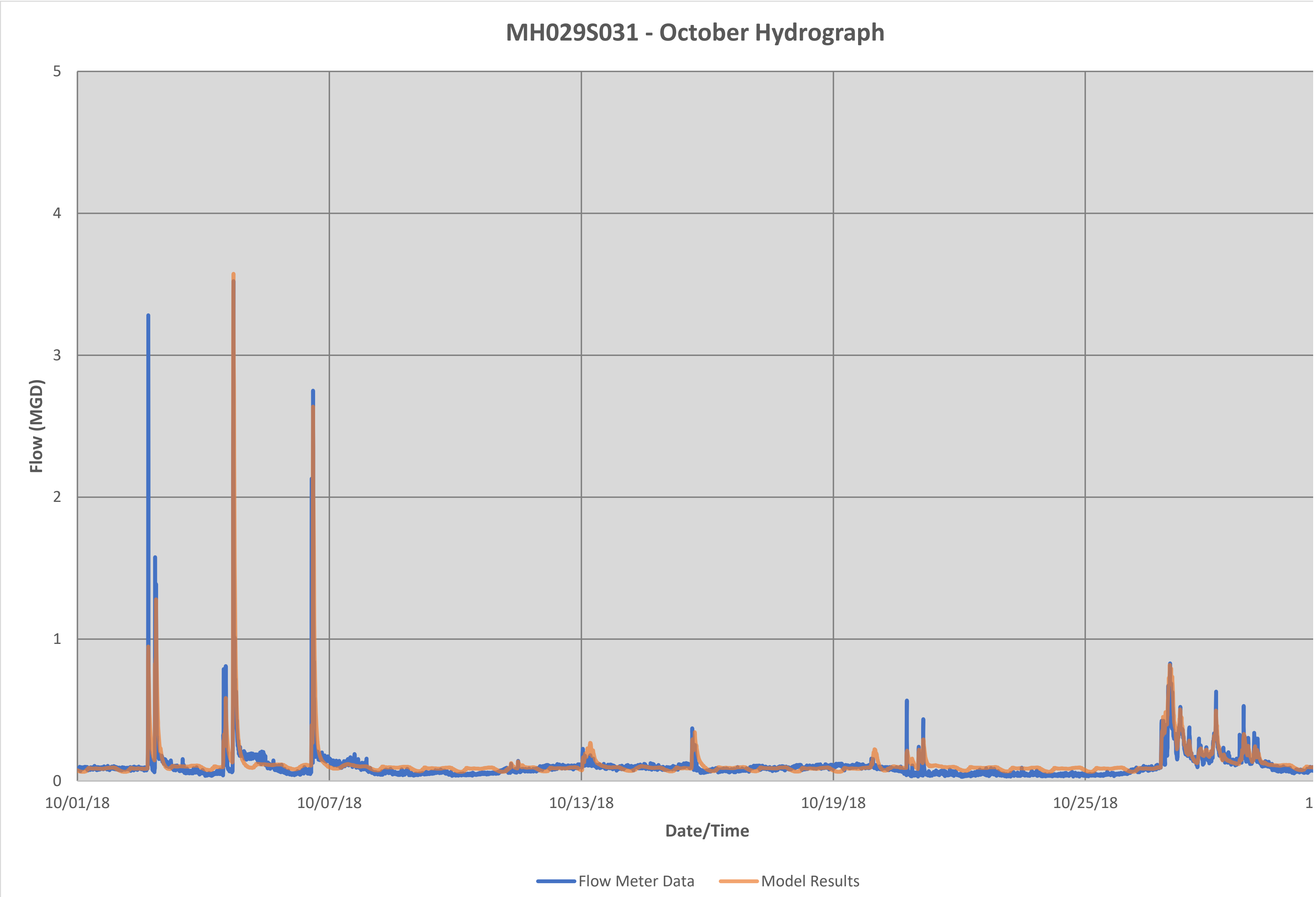

MH029S031 - WWF Calibration (Volume vs. Volume)
3.0
2.4
1.8
1.2
0.6
0.0
Simulated Volume (MG)
0.0
0.6
1.2
1.8
2.4
3.0
Measured Volume (MG)
y = 1.00x
R² = 0.99
Data Points
Trendline

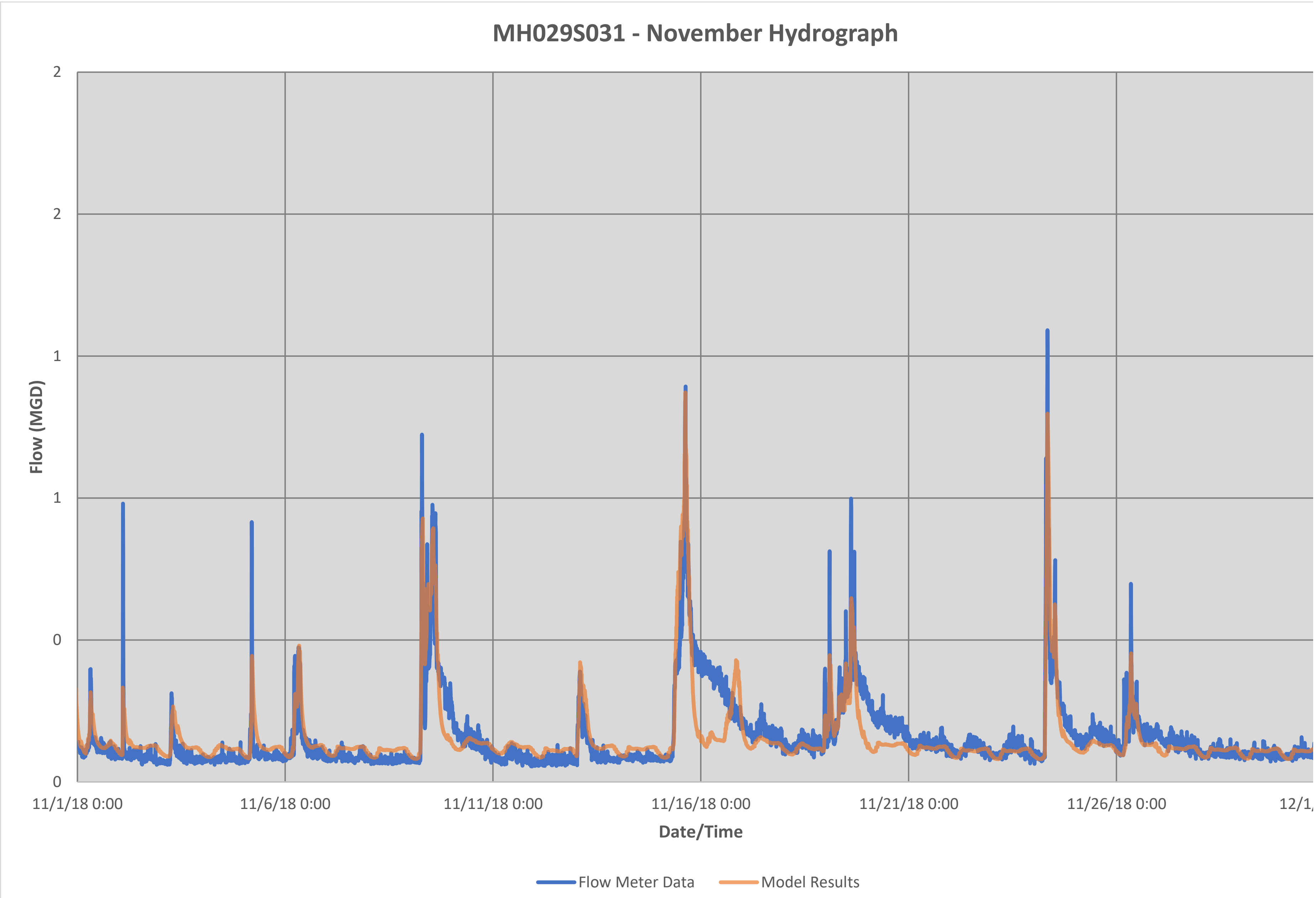


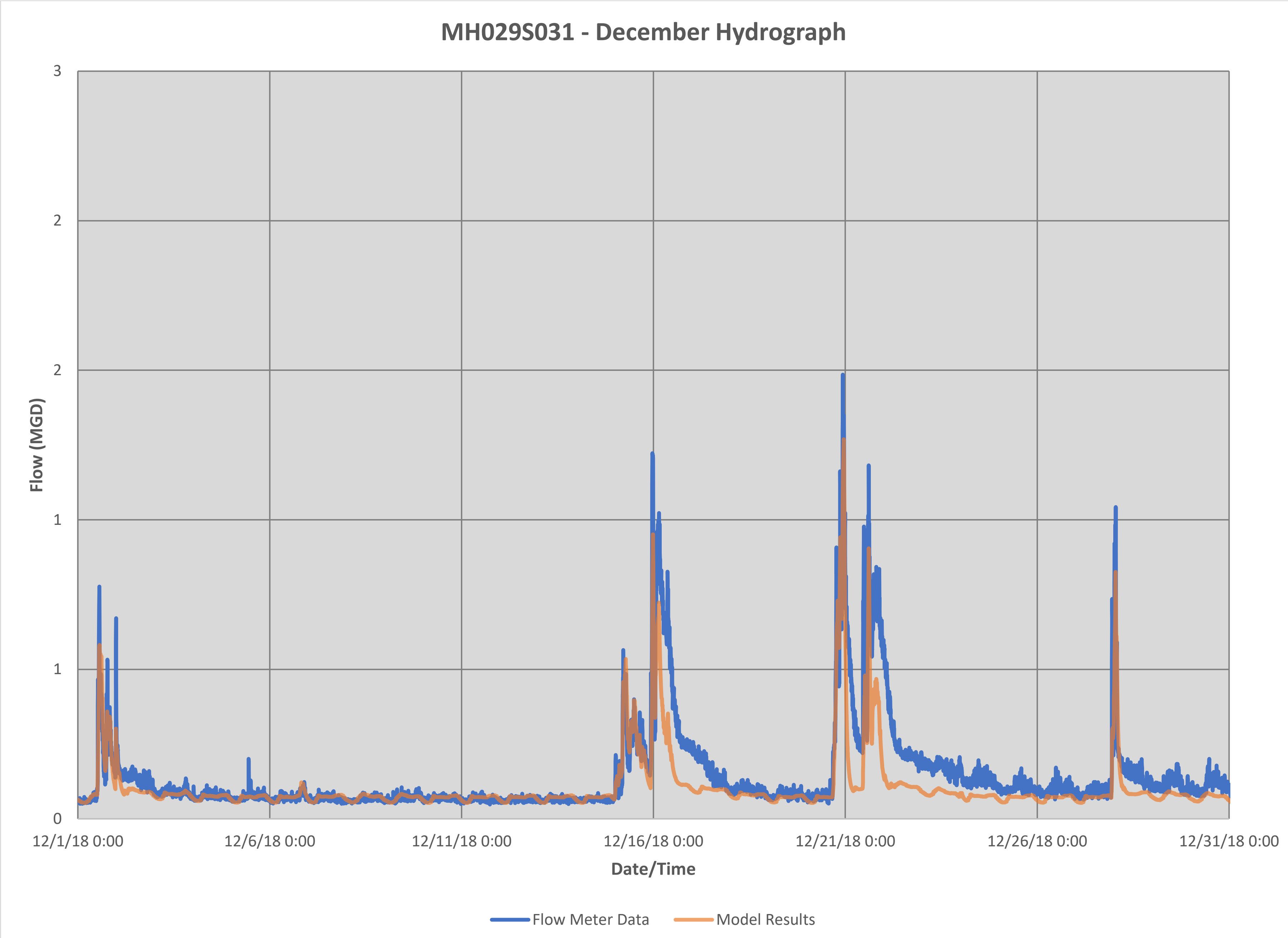
MH029S031 - August Hydrograph
Flow (MGD)
5
4
3
2
1
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results



MH029S031 - September Hydrograph
Flow (MGD)
8
6
5
3
2
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH029S031 - October Hydrograph
Flow (MGD)
5
4
3
2
1
0
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH029S031 - November Hydrograph
Flow (MGD)
2
2
1
1
0
0
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results


MH029S031 - December Hydrograph
Flow (MGD)
3
2
2
1
1
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH053B003 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.33	0.27	**19.1%**
Volume - MG	1.05	0.45	**132.0%**
Depth (Avg) - in	1.38	1.58	**-0.2**

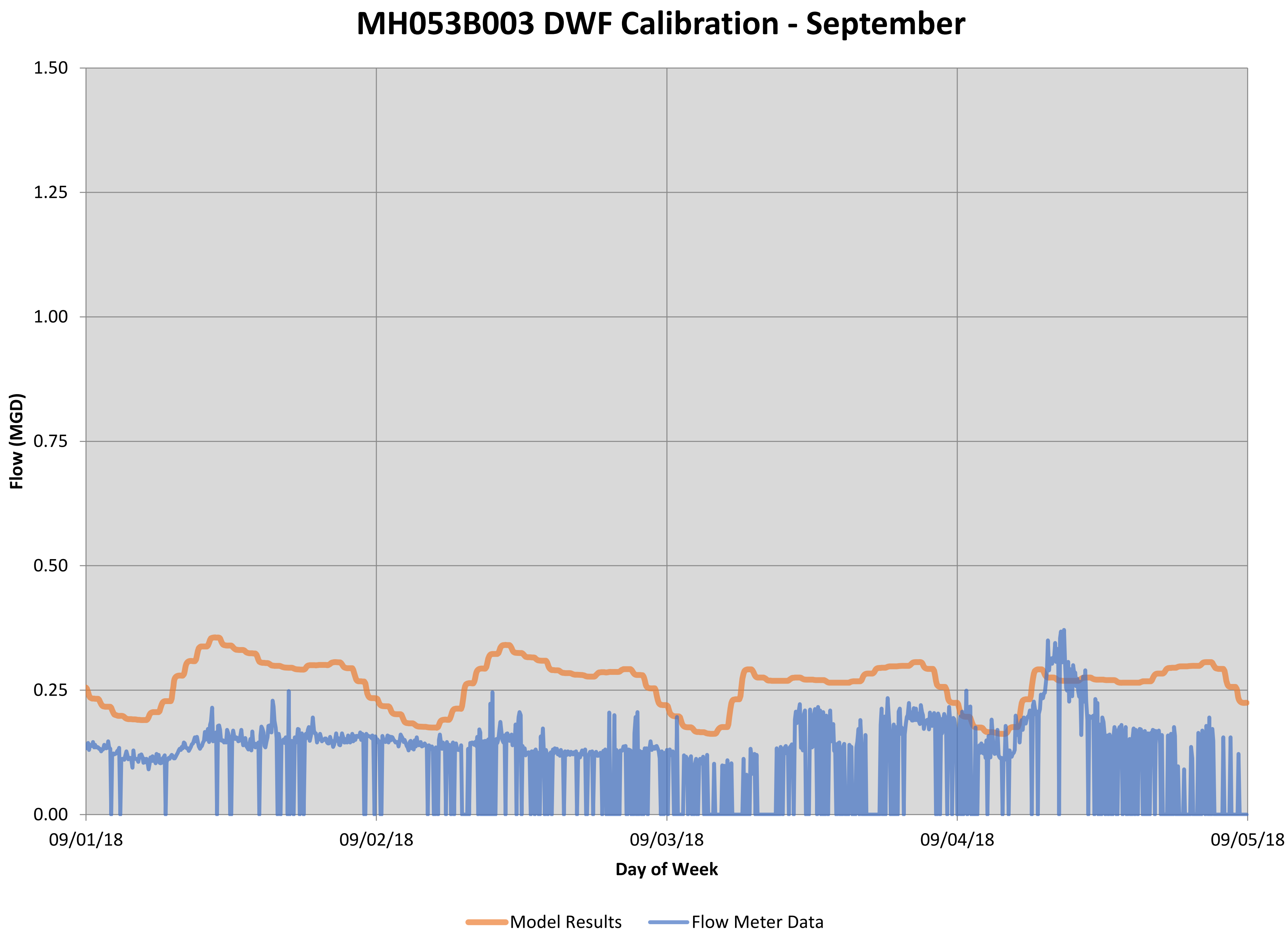
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	0.36	0.25
9/2/18	0.34	0.25
9/3/18	0.31	0.23
9/4/18	0.31	0.37

DWF Calibration Statistics MH053B003 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.32	0.38	**-15.6%**
Volume - MG	1.09	1.04	**5.0%**
Depth (Avg) - in	1.42	1.50	**-0.1**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	0.34	0.37
10/23/18	0.33	0.38
10/24/18	0.31	0.35
10/25/18	0.31	0.43

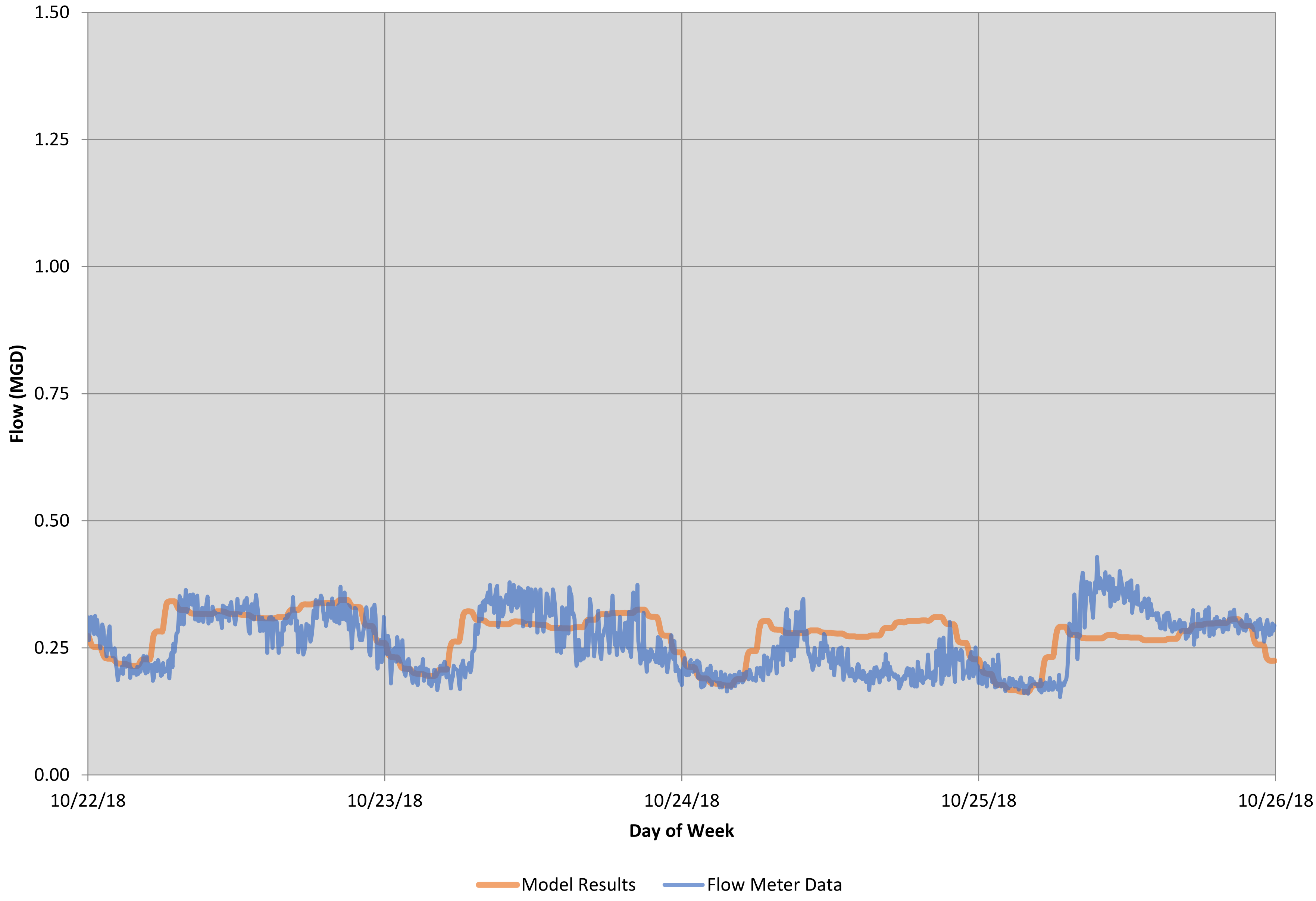
DWF Calibration Statistics MH053B003 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.31	0.34	**-9.5%**
Volume - MG	1.02	1.11	**-8.9%**
Depth (Avg) - in	1.37	1.40	**0.0**

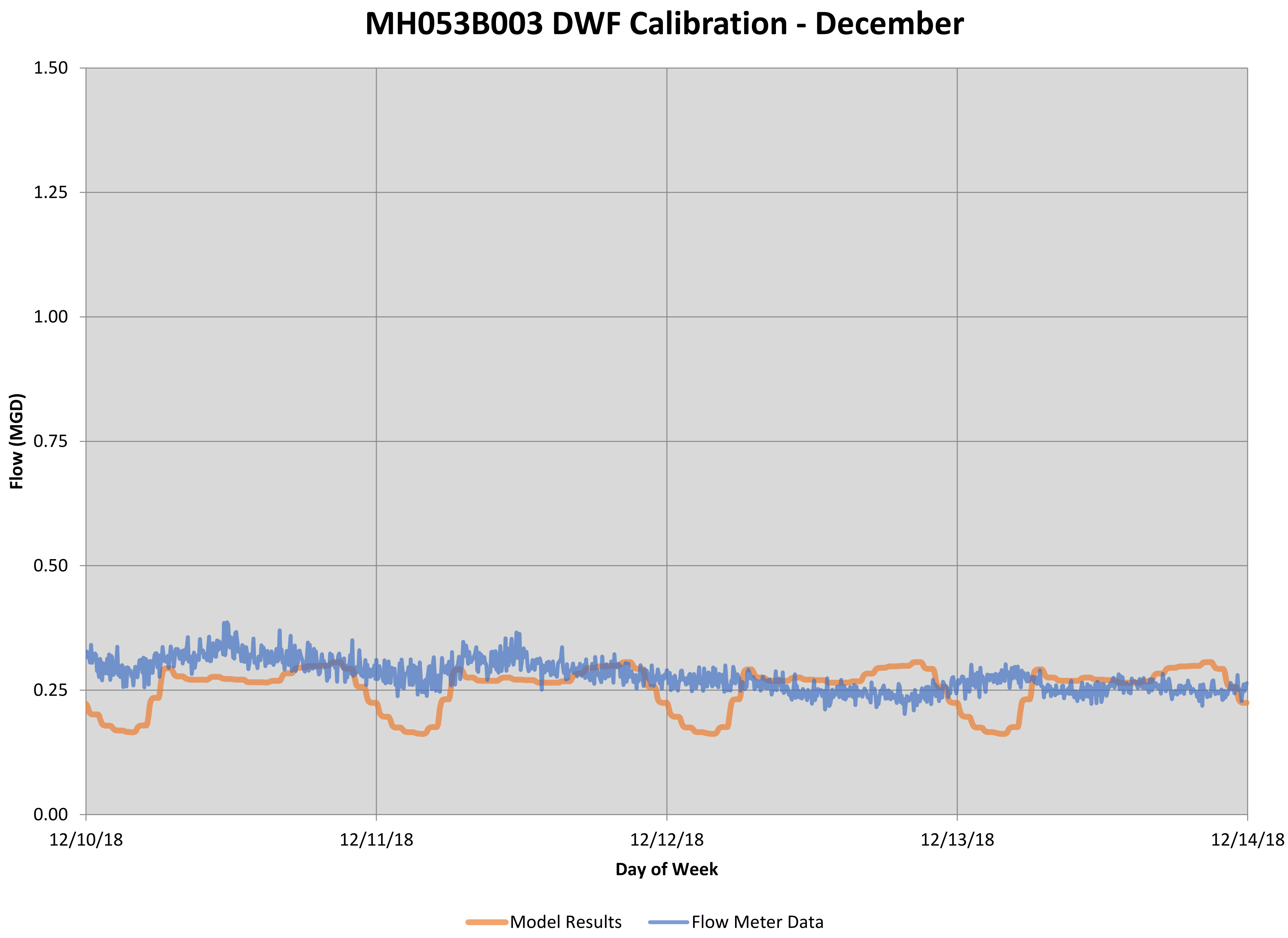
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	0.31	0.39
12/11/18	0.31	0.37
12/12/18	0.31	0.30
12/13/18	0.31	0.30



MH053B003 DWF Calibration - September
Flow (MGD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Model Results
Flow Meter Data

MH053B003 DWF Calibration - October

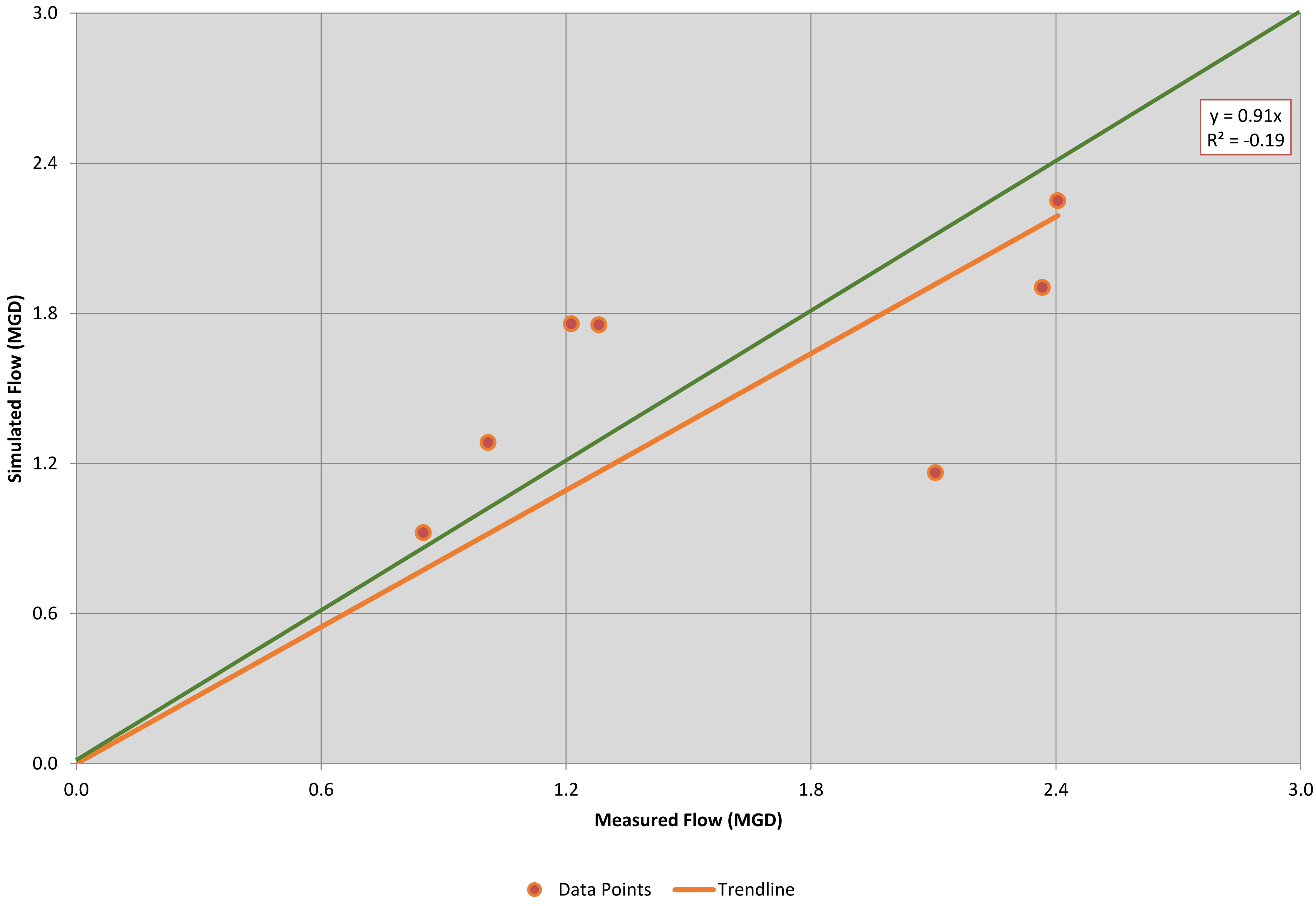


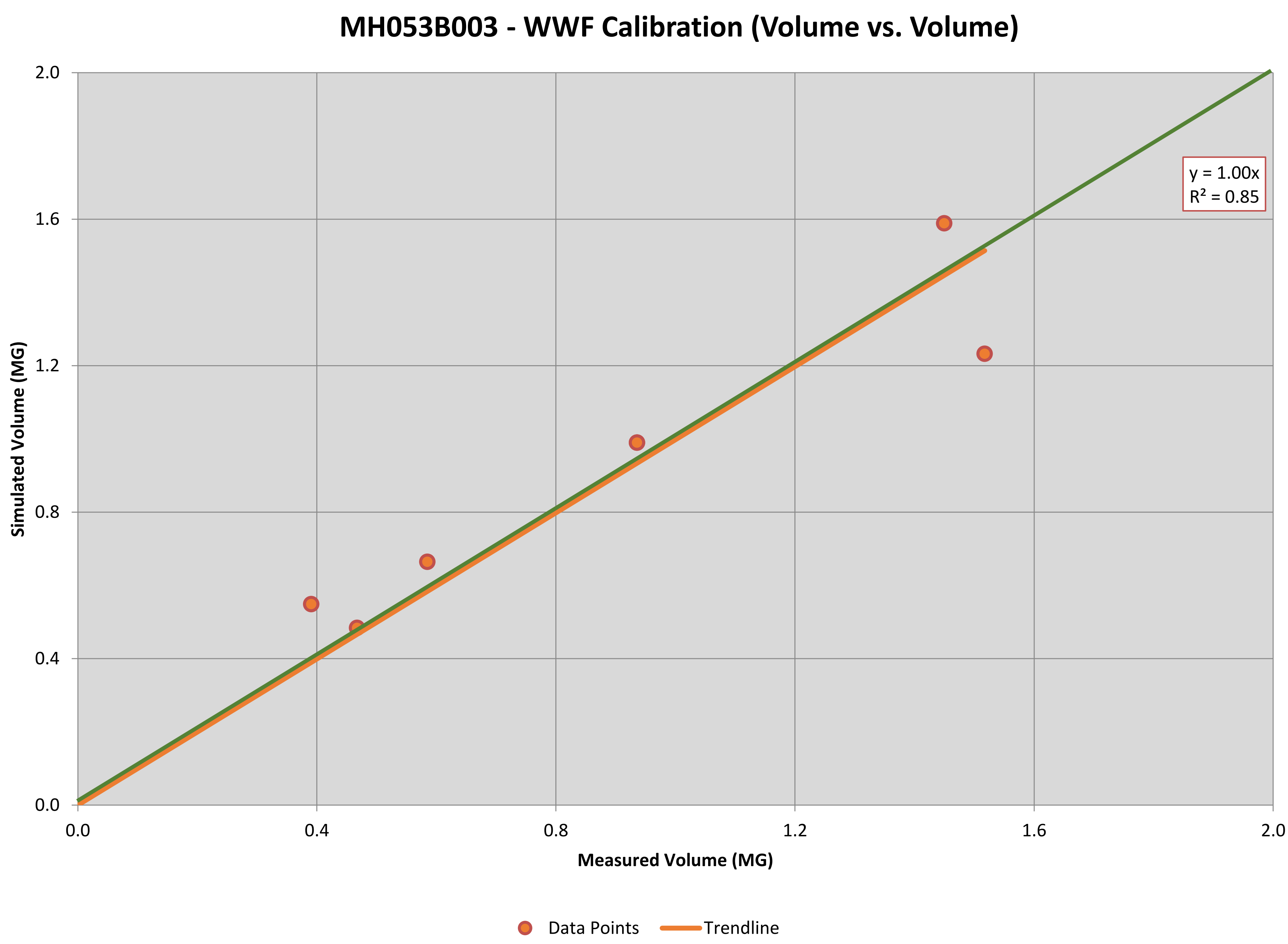


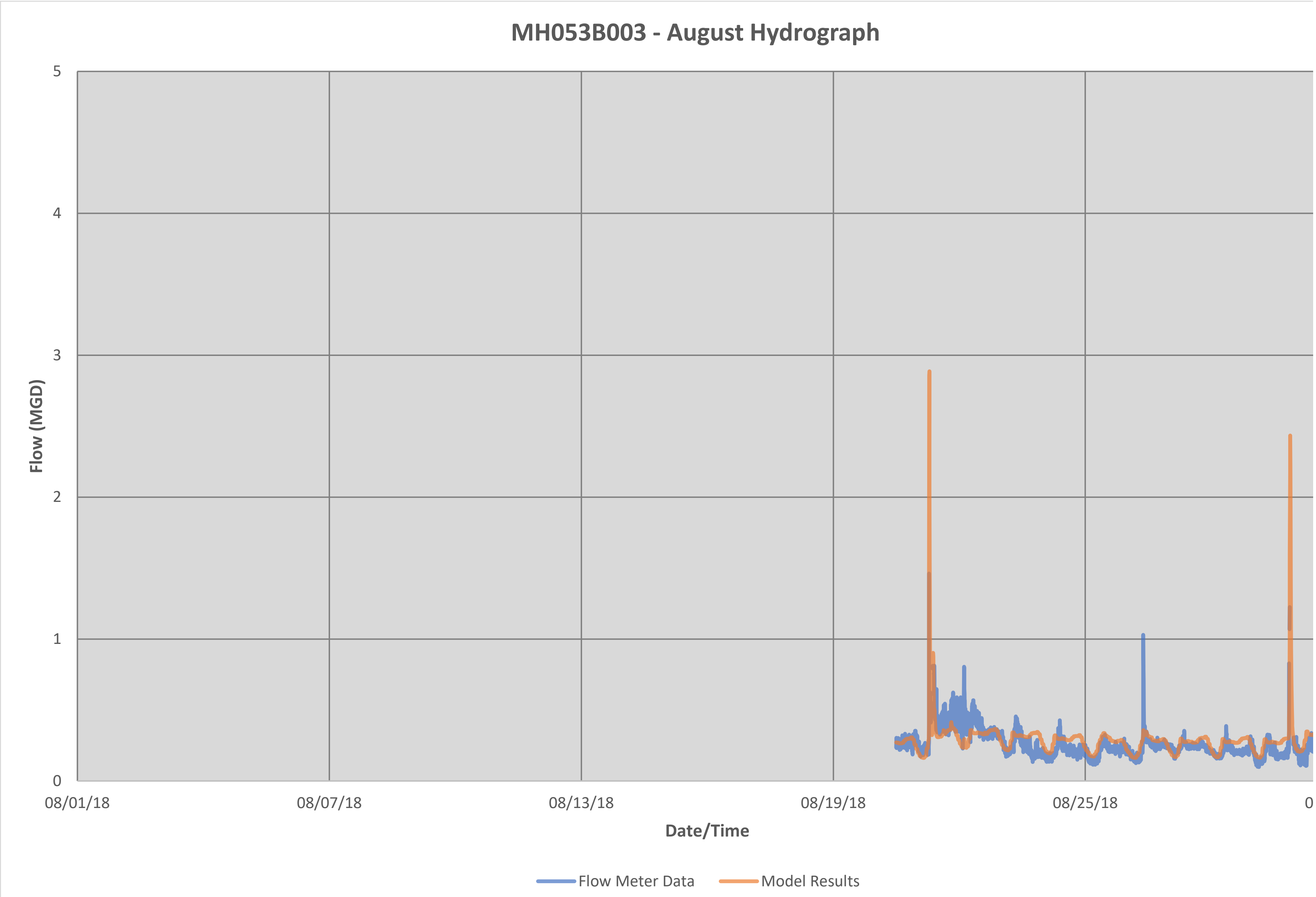
MH053B003 DWF Calibration - December
Flow (MGD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Model Results
Flow Meter Data

		MH053B003 - Wet Weather Calibration/Validation Stats								
Storm Date	**Type**	**Peak Flow (MGD)**			**Storm Volume (MG)**			**Peak Depth (Inches)**		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration									
09/06/18	Validation									
09/07/18	Calibration									
09/17/18	Calibration									
09/21/18	Validation									
09/24/18	Validation	2.41	2.25	-6.4%	0.94	0.99	5.4%	4.9	3.8	-1.1
10/02/18	Validation									
10/04/18	Calibration									
10/06/18	Calibration									
10/15/18	Calibration									
10/26/18	Calibration	1.01	1.28	21.4%	0.94	0.99	5.8%	2.7	2.9	0.2
10/28/18	Calibration	0.85	0.92	7.9%	0.58	0.66	13.5%	2.2	2.5	0.3
11/09/18	Calibration	1.28	1.75	27.0%	0.39	0.55	40.4%	2.8	3.4	0.6
11/15/18	Calibration	1.21	1.76	31.0%	1.45	1.59	9.6%	2.5	3.4	0.9
11/18/18	Validation	2.11	1.16	-81.0%	1.52	1.23	-18.8%	3.5	2.8	-0.7
11/24/18	Validation	2.37	1.90	-24.3%	0.47	0.48	3.6%	4.7	3.5	-1.2
Totals		**11.2**	**11.0**	**-1.7%**	**6.3**	**6.5**	**3.4%**	**23**	**22**	**-1.0**

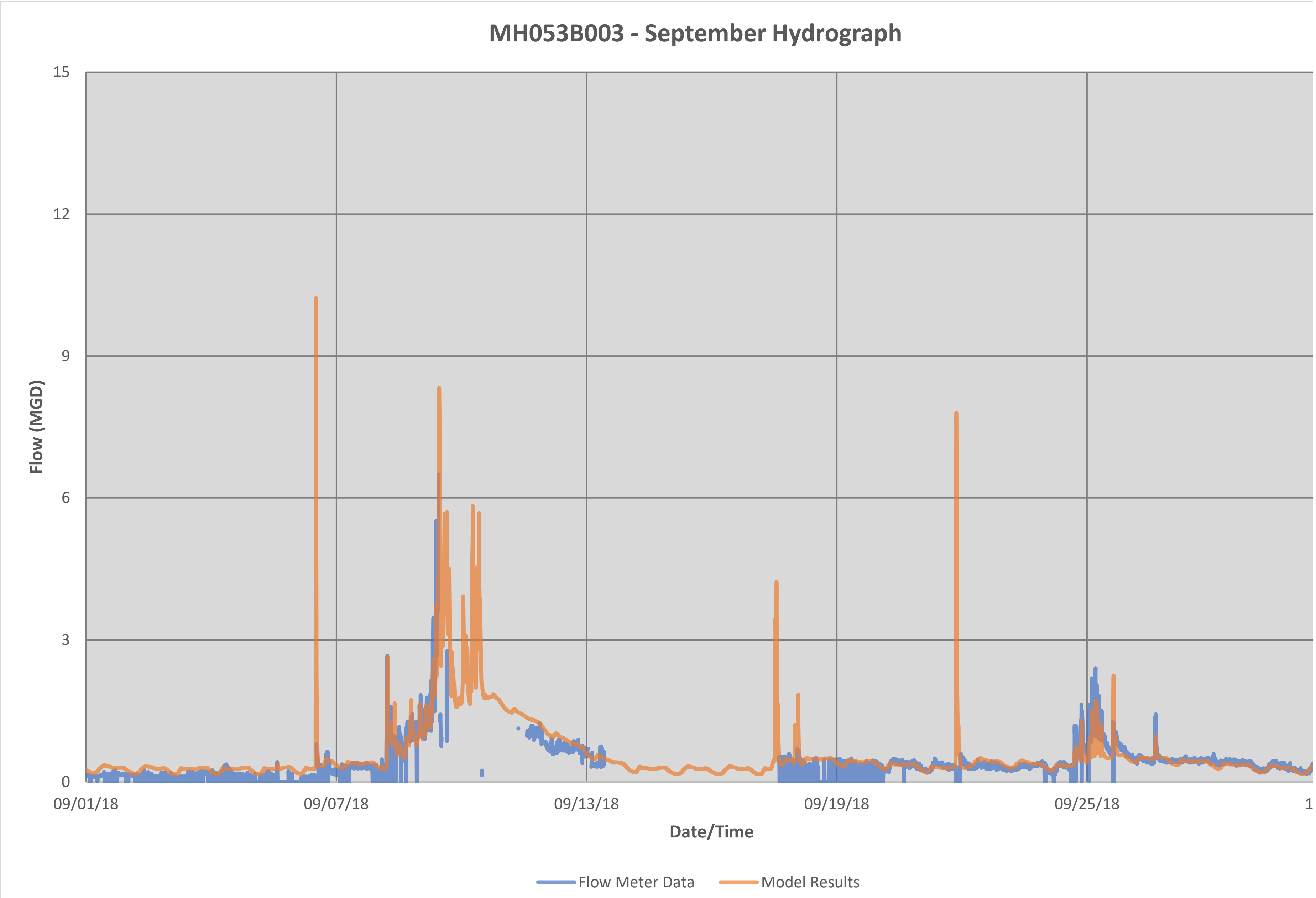
MH053B003 - WWF Calibration (Peak vs. Peak)

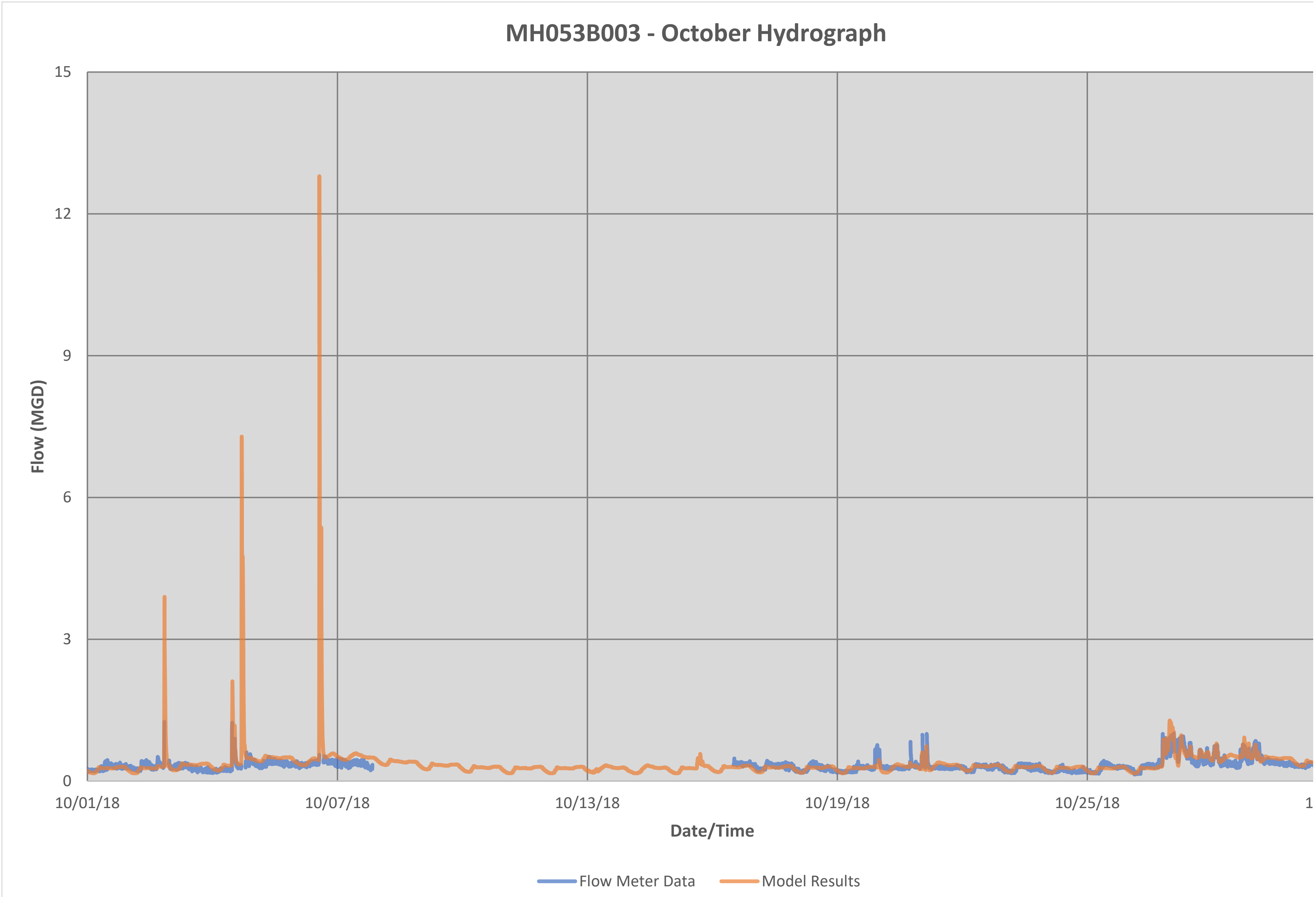



MH053B003 - WWF Calibration (Volume vs. Volume)
y = 1.00x
R² = 0.85
Simulated Volume (MG)
Measured Volume (MG)
0.0
0.4
0.8
1.2
1.6
2.0
Data Points
Trendline

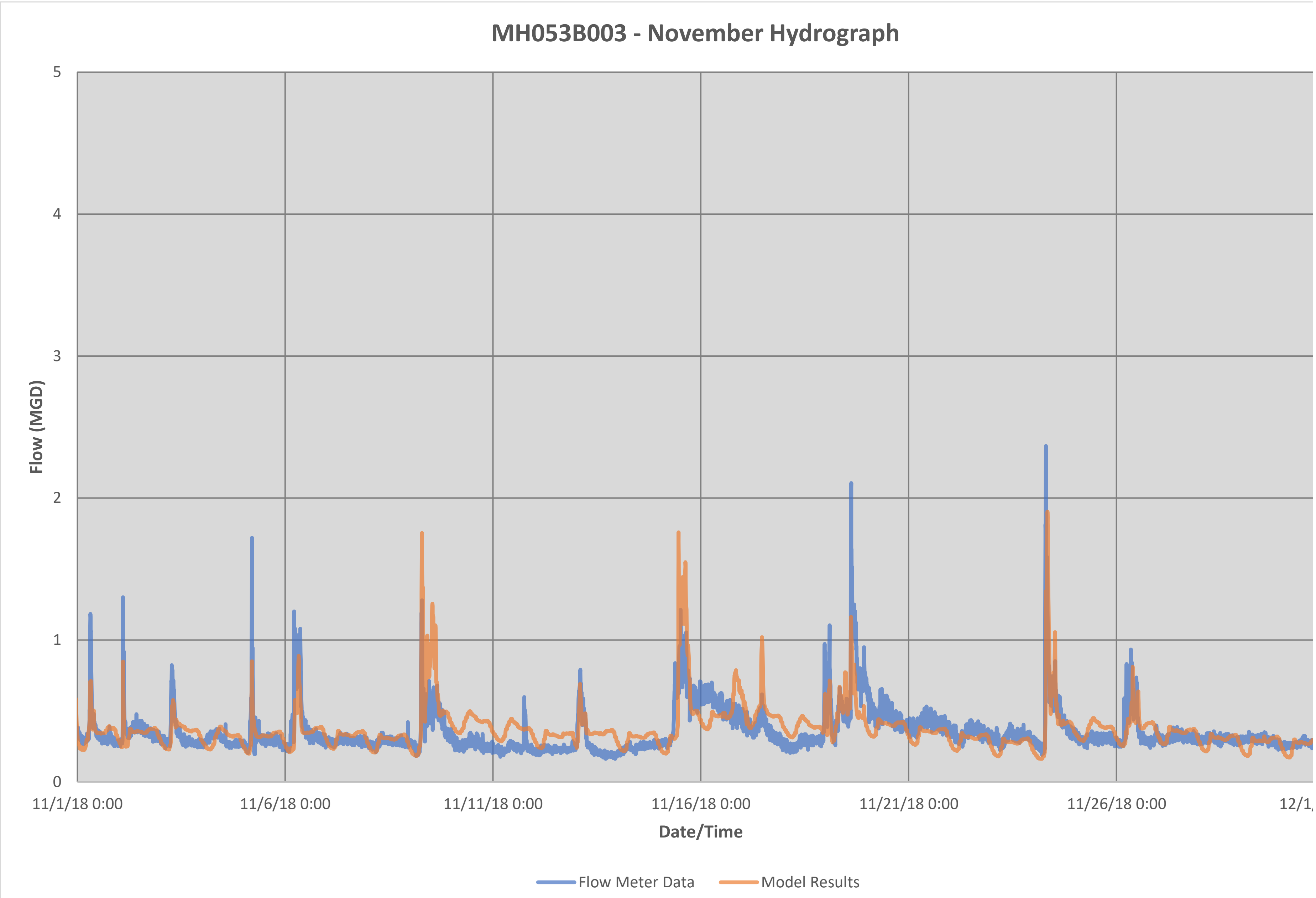


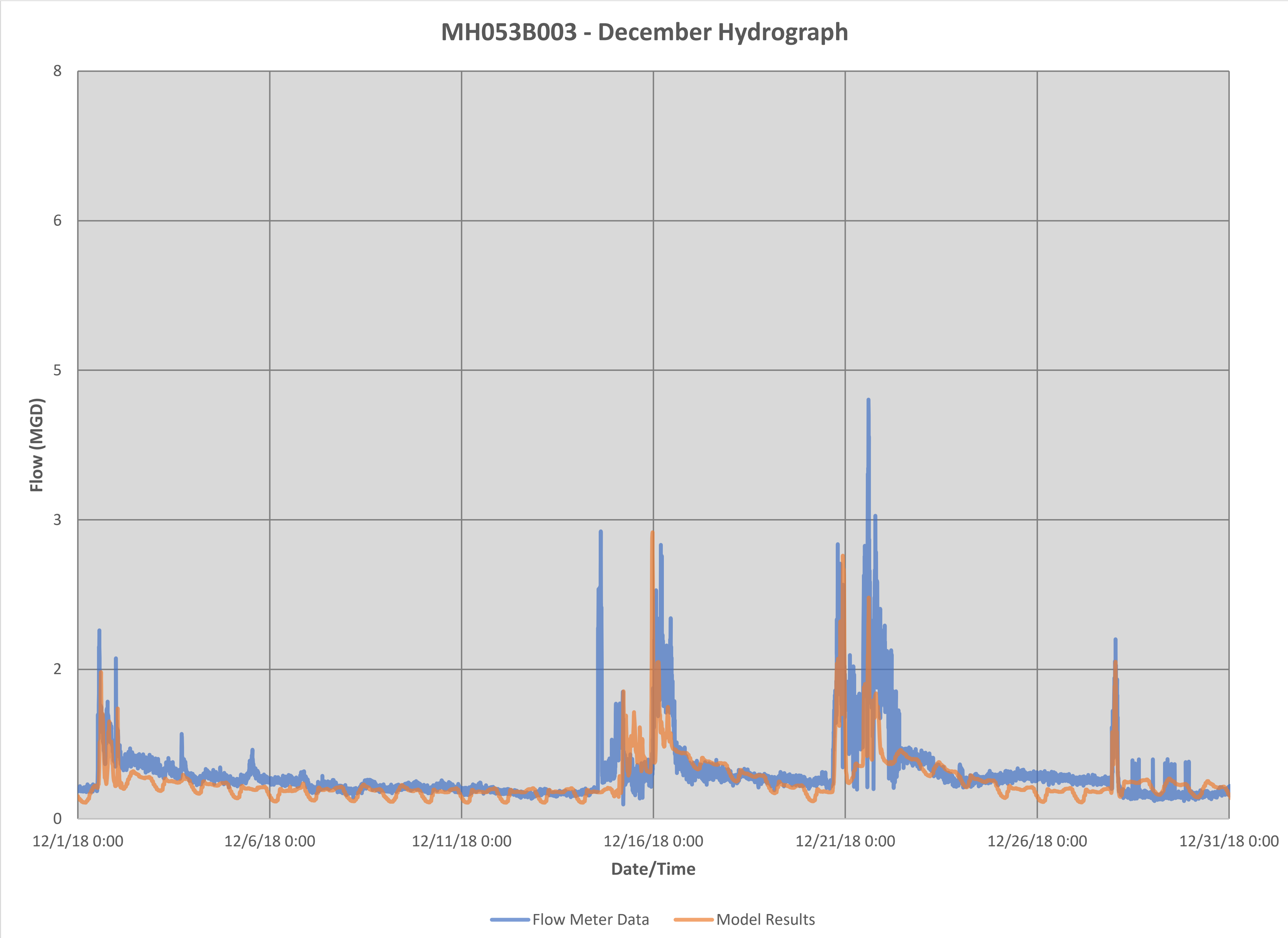
MH053B003 - August Hydrograph
Flow (MGD)
5
4
3
2
1
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results


MH053B003 - September Hydrograph
Flow (MGD)
15
12
9
6
3
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH053B003 - October Hydrograph
15
12
9
6
3
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH053B003 - November Hydrograph
Flow (MGD)
5
4
3
2
1
0
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results



MH053B003 - December Hydrograph
Flow (MGD)
8
6
5
3
2
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH053S008 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.17	0.38	**-55.4%**
Volume - MG	0.55	0.95	**-41.7%**
Depth (Avg) - in	1.22	1.64	**-0.4**

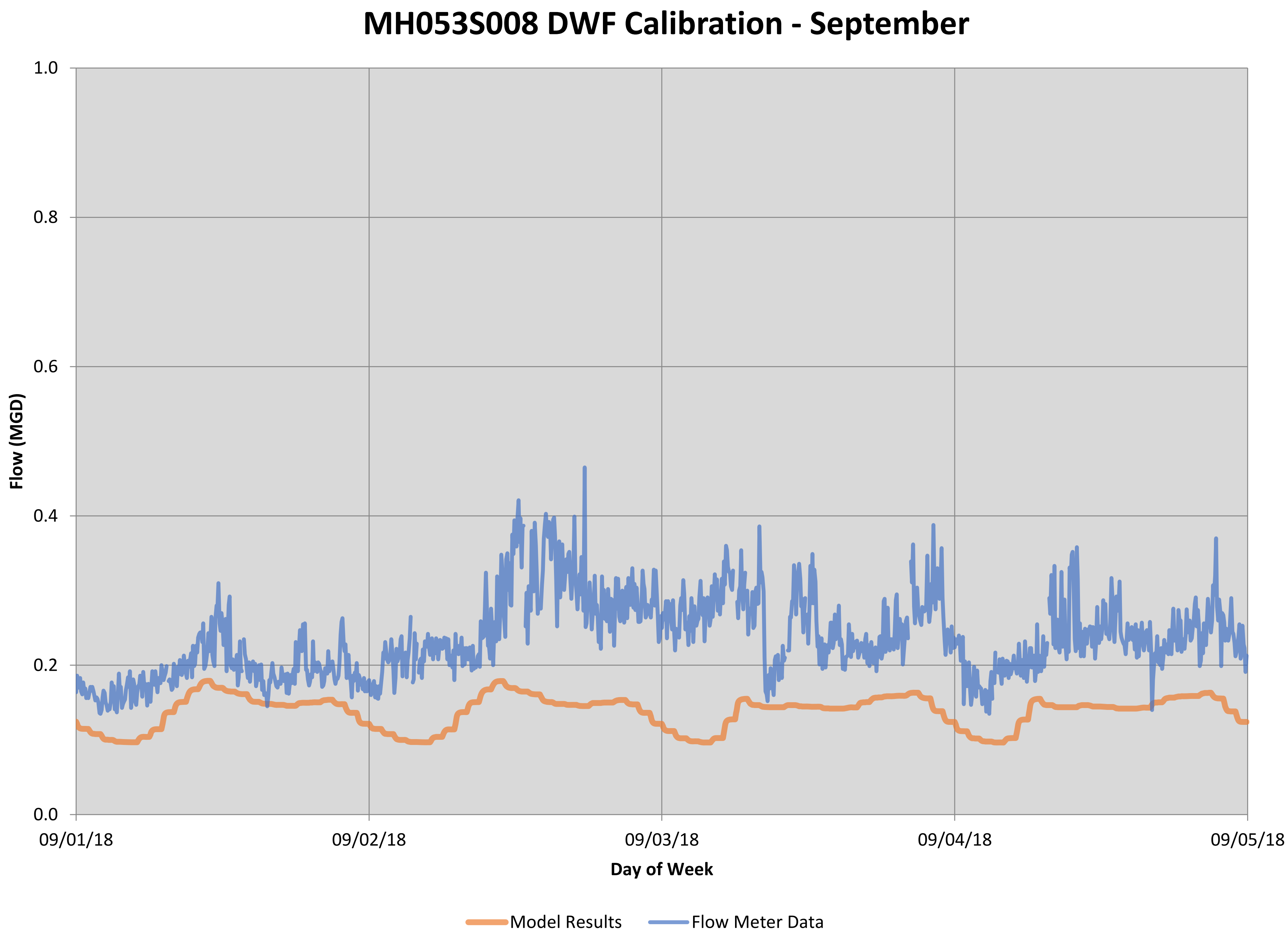
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	0.18	0.31
9/2/18	0.18	0.47
9/3/18	0.16	0.39
9/4/18	0.16	0.37

DWF Calibration Statistics MH053S008 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.16	0.39	**-58.0%**
Volume - MG	0.56	1.01	**-44.7%**
Depth (Avg) - in	1.23	1.59	**-0.4**

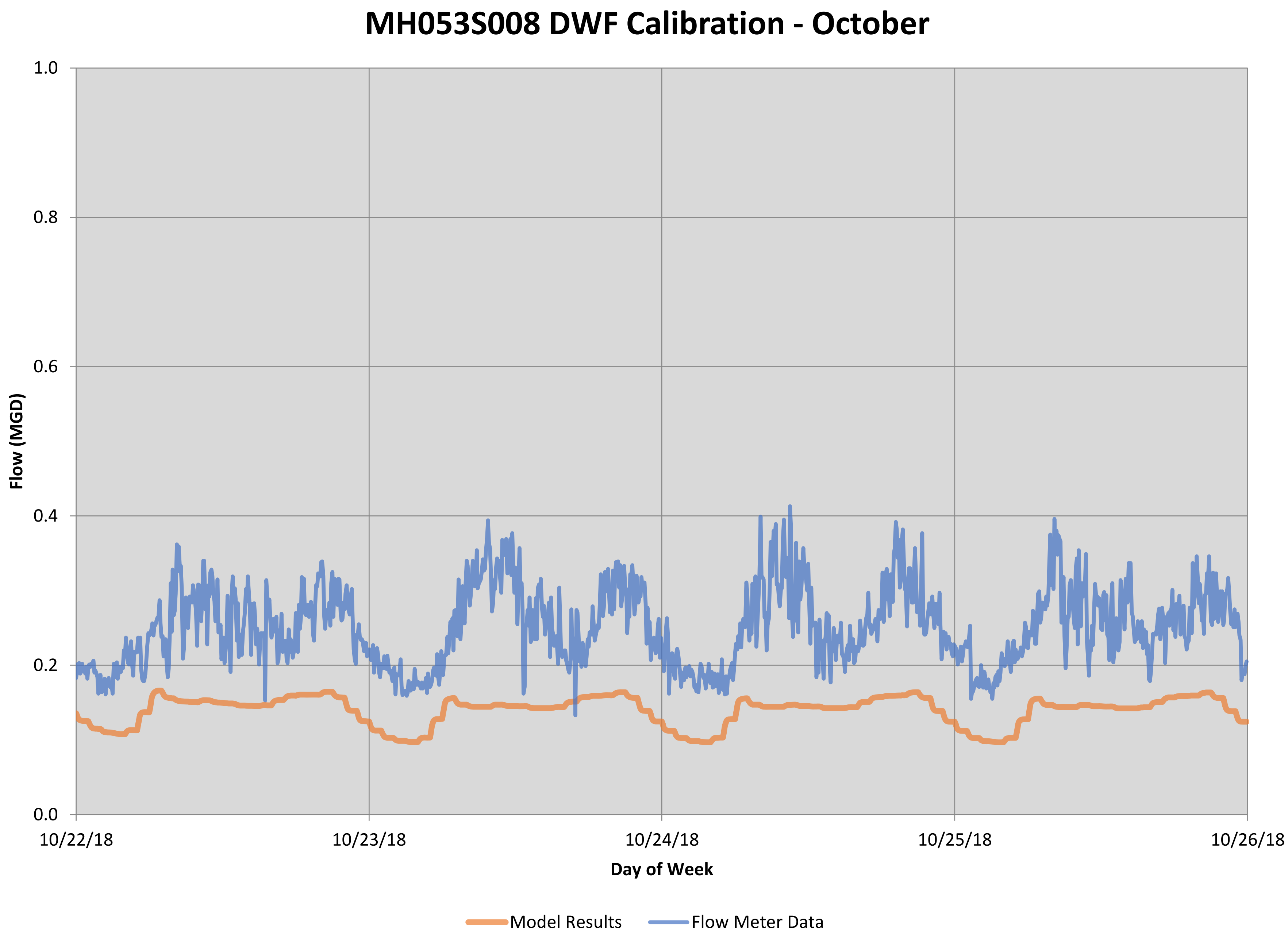
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	0.17	0.36
10/23/18	0.16	0.39
10/24/18	0.16	0.41
10/25/18	0.16	0.40

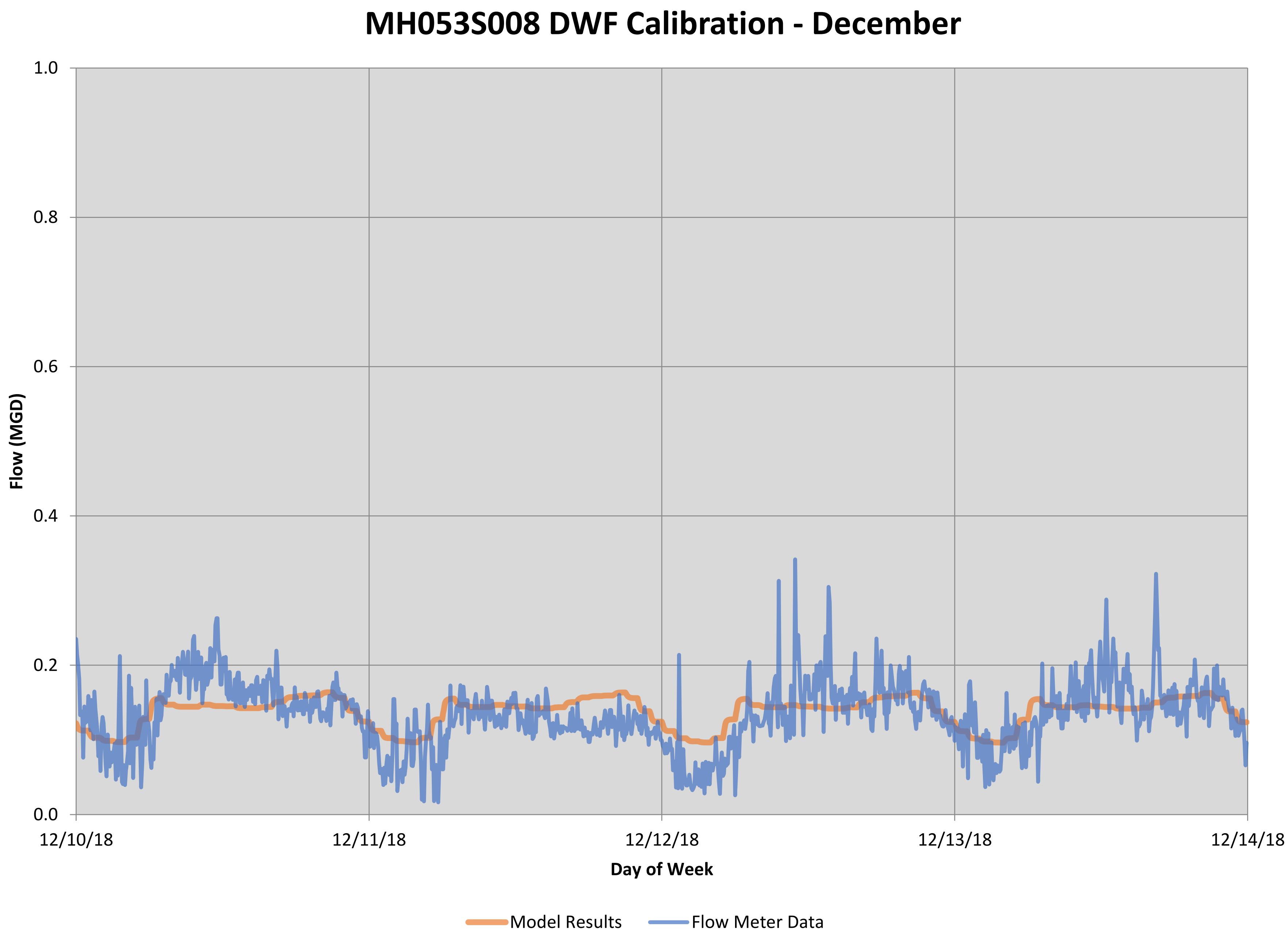
DWF Calibration Statistics MH053S008 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.16	0.28	**-40.6%**
Volume - MG	0.55	0.54	**2.5%**
Depth (Avg) - in	1.22	1.24	**0.0**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	0.16	0.26
12/11/18	0.16	0.17
12/12/18	0.16	0.34
12/13/18	0.16	0.32

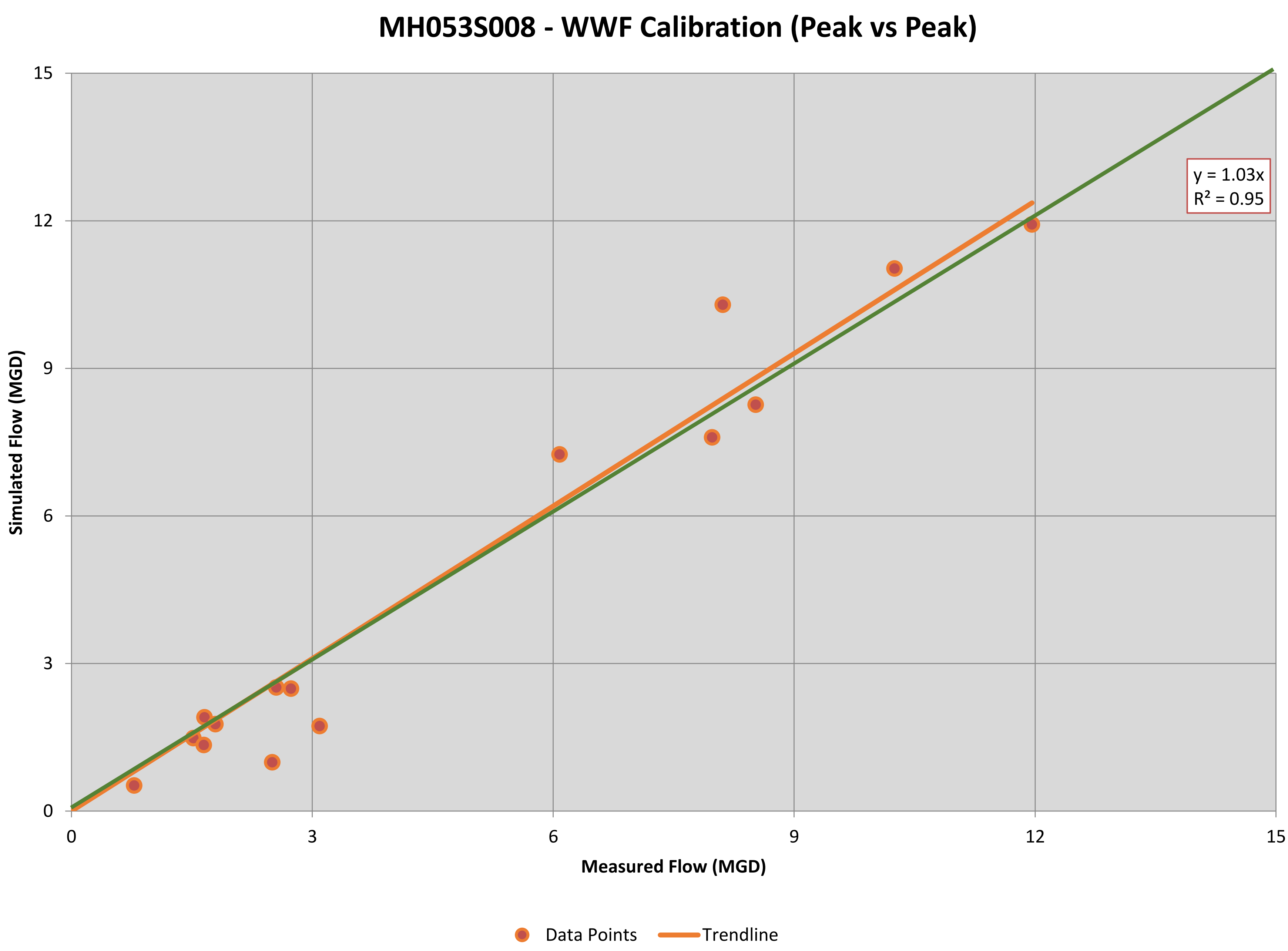


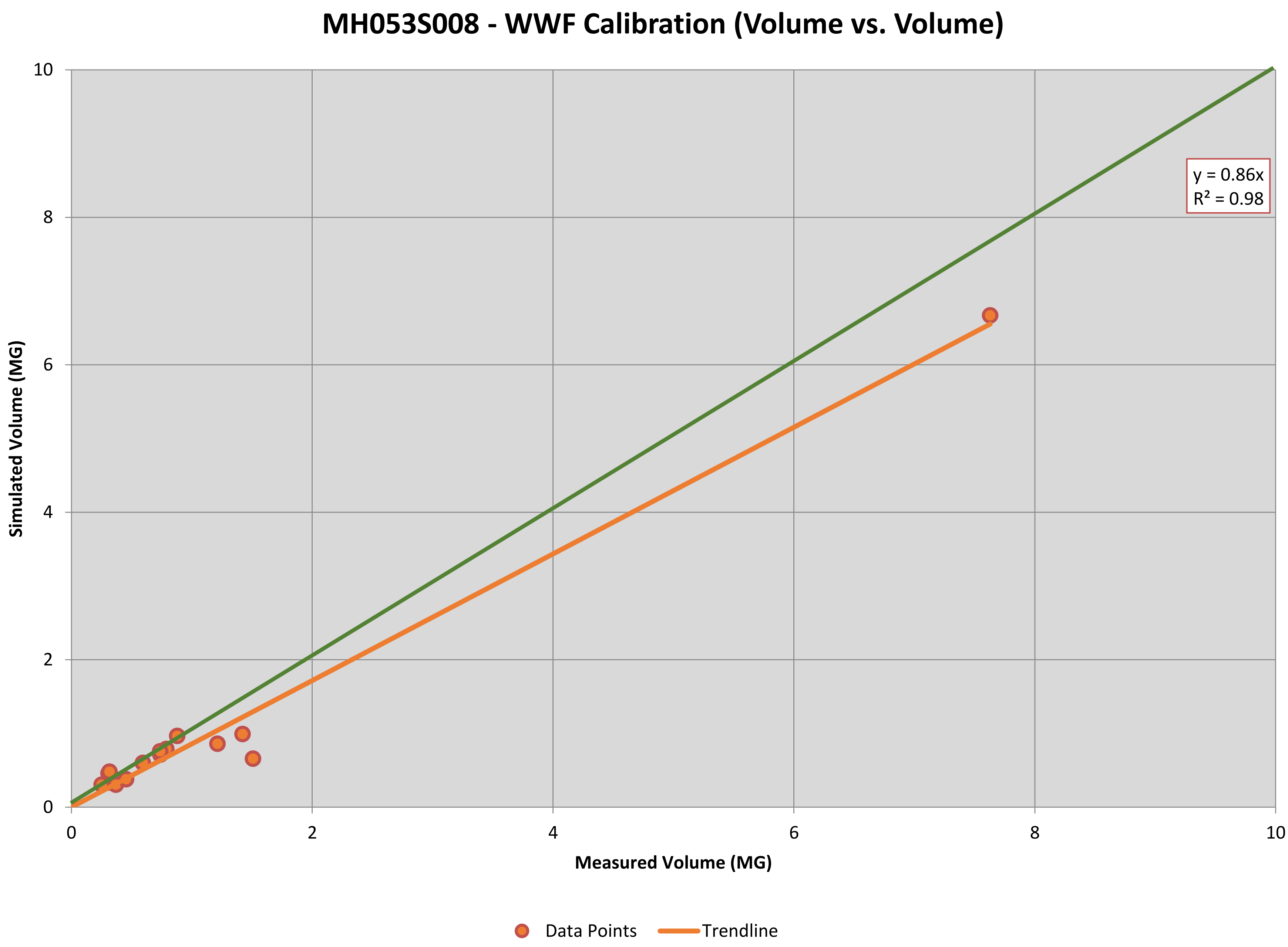
MH053S008 DWF Calibration - September
Flow (MGD)
1.0
0.8
0.6
0.4
0.2
0.0
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Model Results
Flow Meter Data

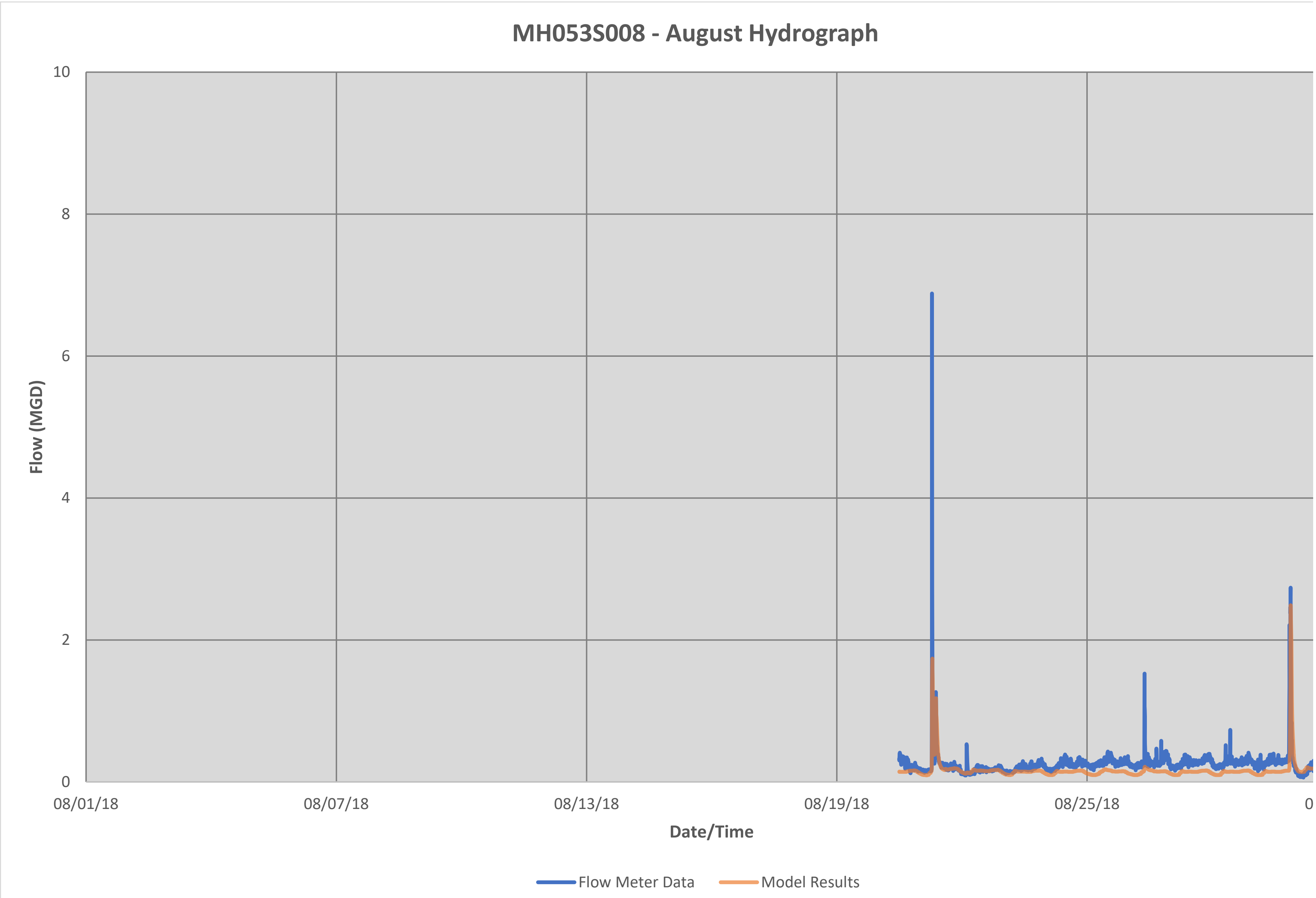

MH053S008 DWF Calibration - October
Flow (MGD)
1.0
0.8
0.6
0.4
0.2
0.0
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Model Results
Flow Meter Data

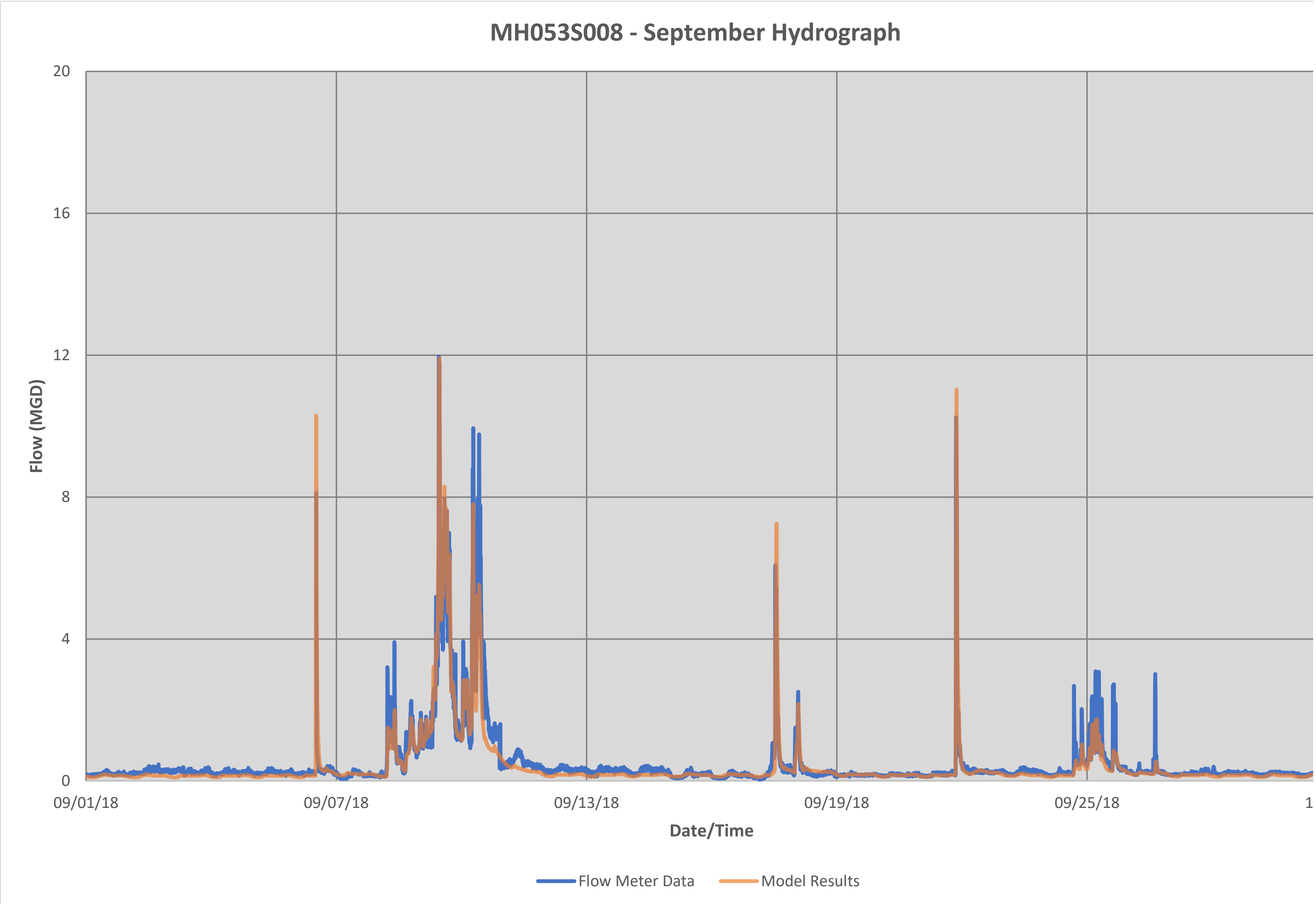

MH053S008 DWF Calibration - December
Flow (MGD)
1.0
0.8
0.6
0.4
0.2
0.0
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Model Results
Flow Meter Data

		Wet Weather Flow Statistics								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	2.74	2.49	**-9.0%**	0.31	0.33	**6.9%**	4.3	5.9	**1.6**
09/06/18	Validation	8.11	10.29	**26.9%**	0.31	0.46	**48.2%**	8.6	13.0	**4.4**
09/07/18	Calibration	11.96	11.92	**-0.3%**	7.63	6.67	**-12.6%**	10.0	14.4	**4.3**
09/17/18	Calibration	6.08	7.25	**19.2%**	0.88	0.96	**9.7%**	7.3	10.7	**3.4**
09/21/18	Validation	10.25	11.03	**7.6%**	0.79	0.79	**0.1%**	10.1	13.6	**3.5**
09/24/18	Validation	3.09	1.73	**-44.1%**	1.21	0.86	**-29.2%**	4.6	4.8	**0.2**
10/02/18	Validation	1.66	1.91	**14.8%**	0.25	0.30	**20.8%**	2.8	5.1	**2.3**
10/04/18	Calibration	7.98	7.60	**-4.8%**	0.74	0.71	**-3.8%**	7.5	10.9	**3.4**
10/06/18	Calibration	8.52	8.26	**-3.1%**	0.59	0.60	**0.9%**	8.6	11.4	**2.8**
10/15/18	Calibration									
10/26/18	Calibration	1.52	1.48	**-2.6%**	0.74	0.76	**2.4%**	3.2	4.4	**1.2**
10/28/18	Calibration	0.78	0.52	**-34.0%**	0.37	0.30	**-18.0%**	2.2	2.5	**0.3**
11/09/18	Calibration	1.65	1.34	**-18.6%**	0.32	0.48	**51.1%**	3.0	4.2	**1.2**
11/15/18	Calibration	2.55	2.51	**-1.7%**	1.42	0.99	**-30.3%**	4.0	5.9	**2.0**
11/18/18	Validation	2.50	0.99	**-60.4%**	1.51	0.66	**-56.4%**	4.0	3.6	**-0.4**
11/24/18	Validation	1.79	1.77	**-1.5%**	0.45	0.38	**-16.9%**	3.4	4.9	**1.5**
Totals		**71.2**	**71.1**	**-0.2%**	**17.5**	**15.3**	**-13.0%**	**84**	**115**	**31.8**

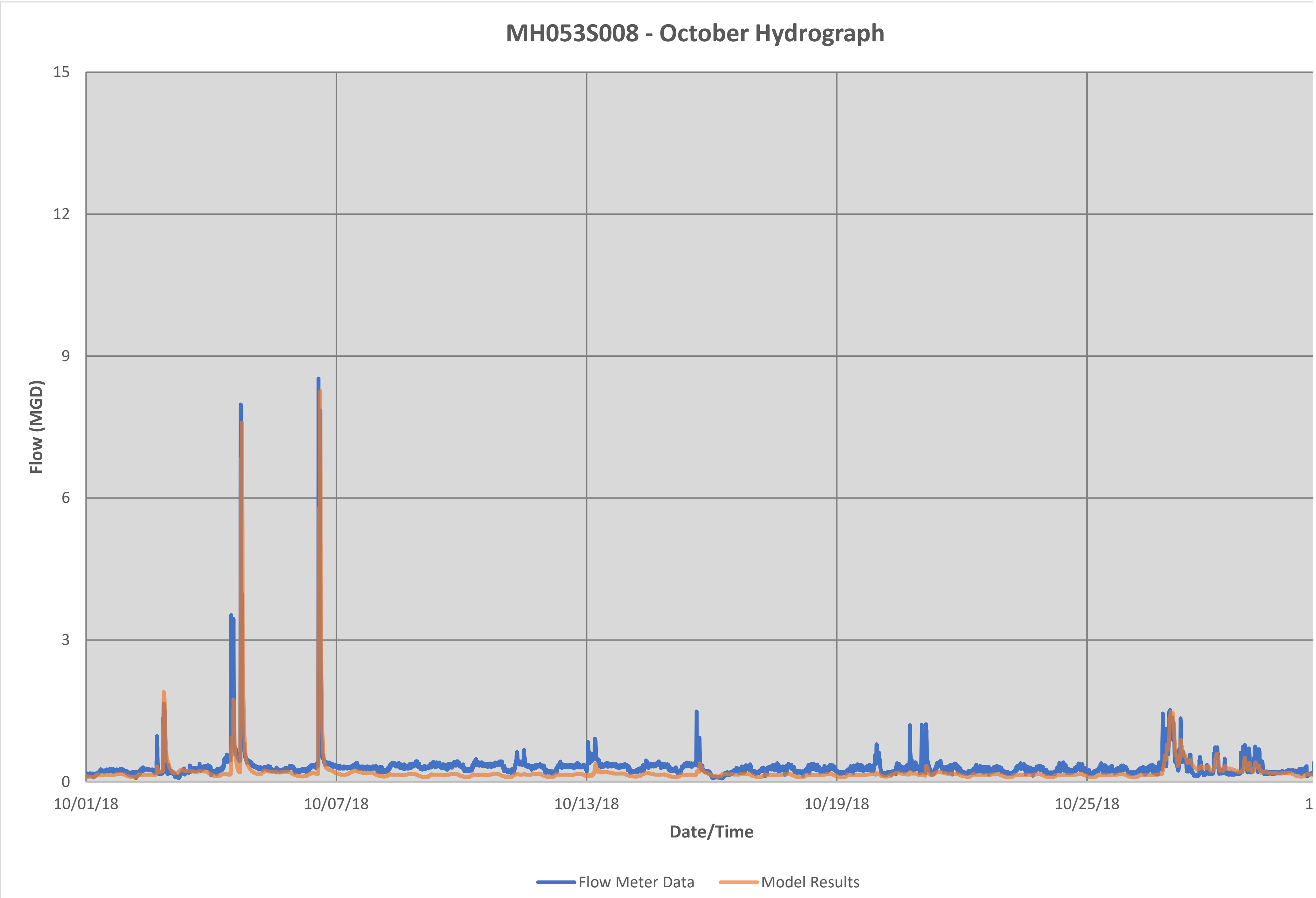

MH053S008 - WWF Calibration (Peak vs Peak)
Simulated Flow (MGD)
Measured Flow (MGD)
y = 1.03x
R² = 0.95
0
3
6
9
12
15
Data Points
Trendline


MH053S008 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
0
2
4
6
8
10
y = 0.86x
R² = 0.98
Data Points
Trendline

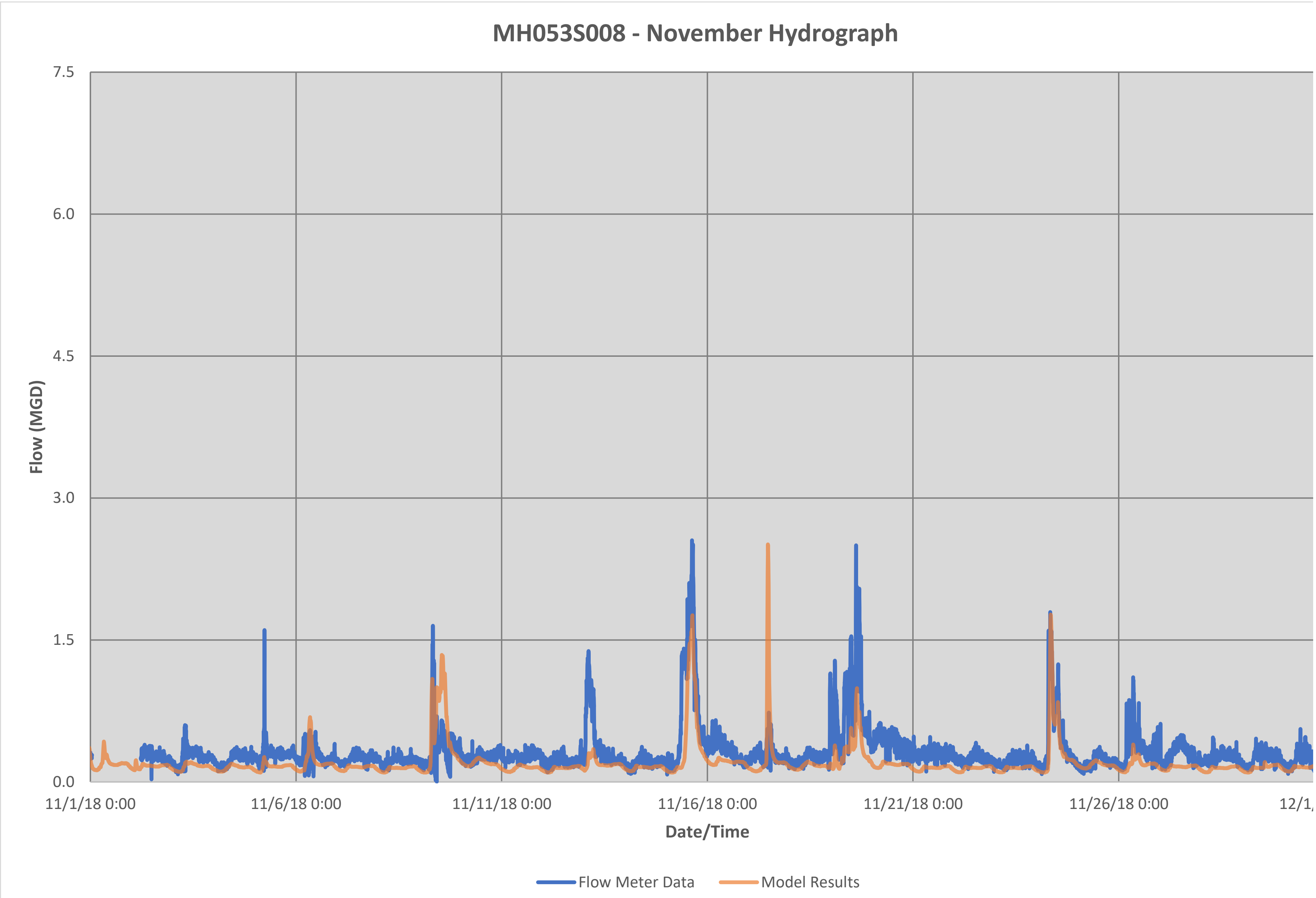

MH053S008 - August Hydrograph
Flow (MGD)
10
8
6
4
2
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results

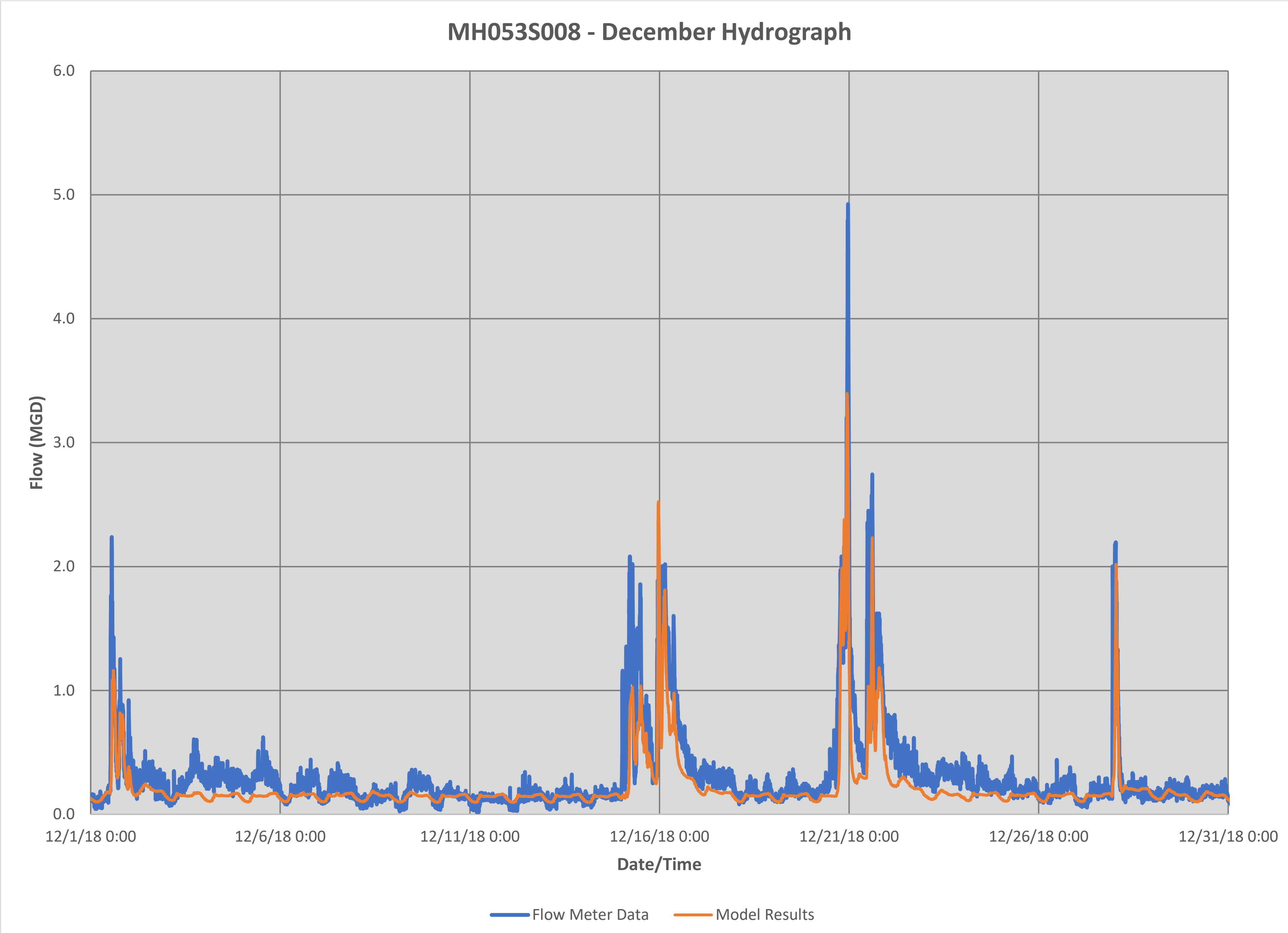


MH053S008 - September Hydrograph
Flow (MGD)
20
16
12
8
4
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH053S008 - October Hydrograph
Flow (MGD)
15
12
9
6
3
0
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH053S008 - November Hydrograph
7.5
6.0
4.5
3.0
1.5
0.0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results


MH053S008 - December Hydrograph
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH053S009 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.70	0.76	**-7.9%**
Volume - MG	2.14	1.97	**8.5%**
Depth (Avg) - in	2.36	1.99	**0.4**

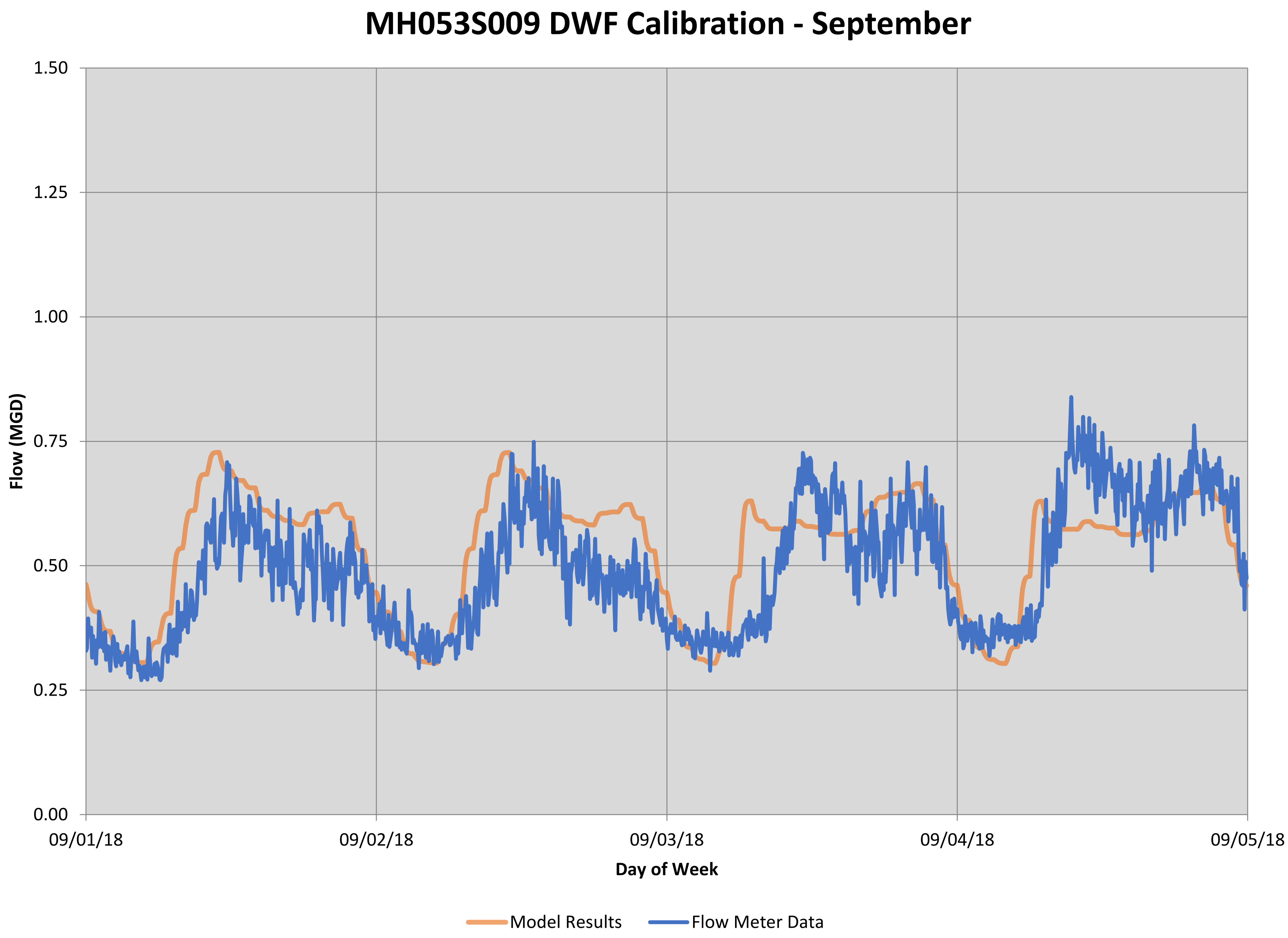
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	0.73	0.71
9/2/18	0.73	0.75
9/3/18	0.67	0.73
9/4/18	0.66	0.84

DWF Calibration Statistics MH053S009 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.67	0.76	**-12.7%**
Volume - MG	2.16	2.27	**-4.9%**
Depth (Avg) - in	2.38	2.19	**0.2**

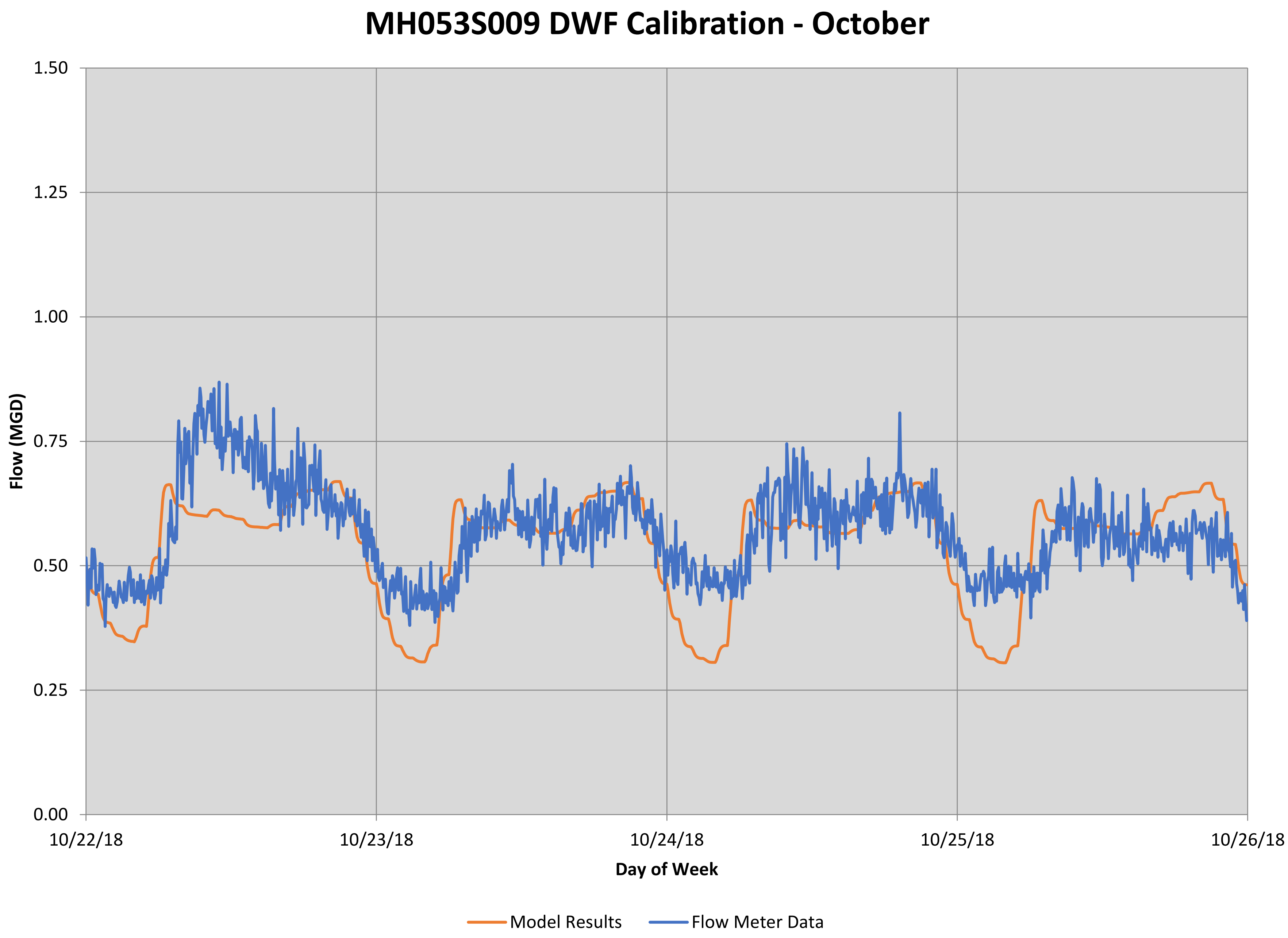
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	0.67	0.87
10/23/18	0.67	0.70
10/24/18	0.67	0.81
10/25/18	0.67	0.68

DWF Calibration Statistics MH053S009 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	0.67	0.49	**37.1%**
Volume - MG	2.14	1.23	**73.5%**
Depth (Avg) - in	2.36	1.34	**1.0**

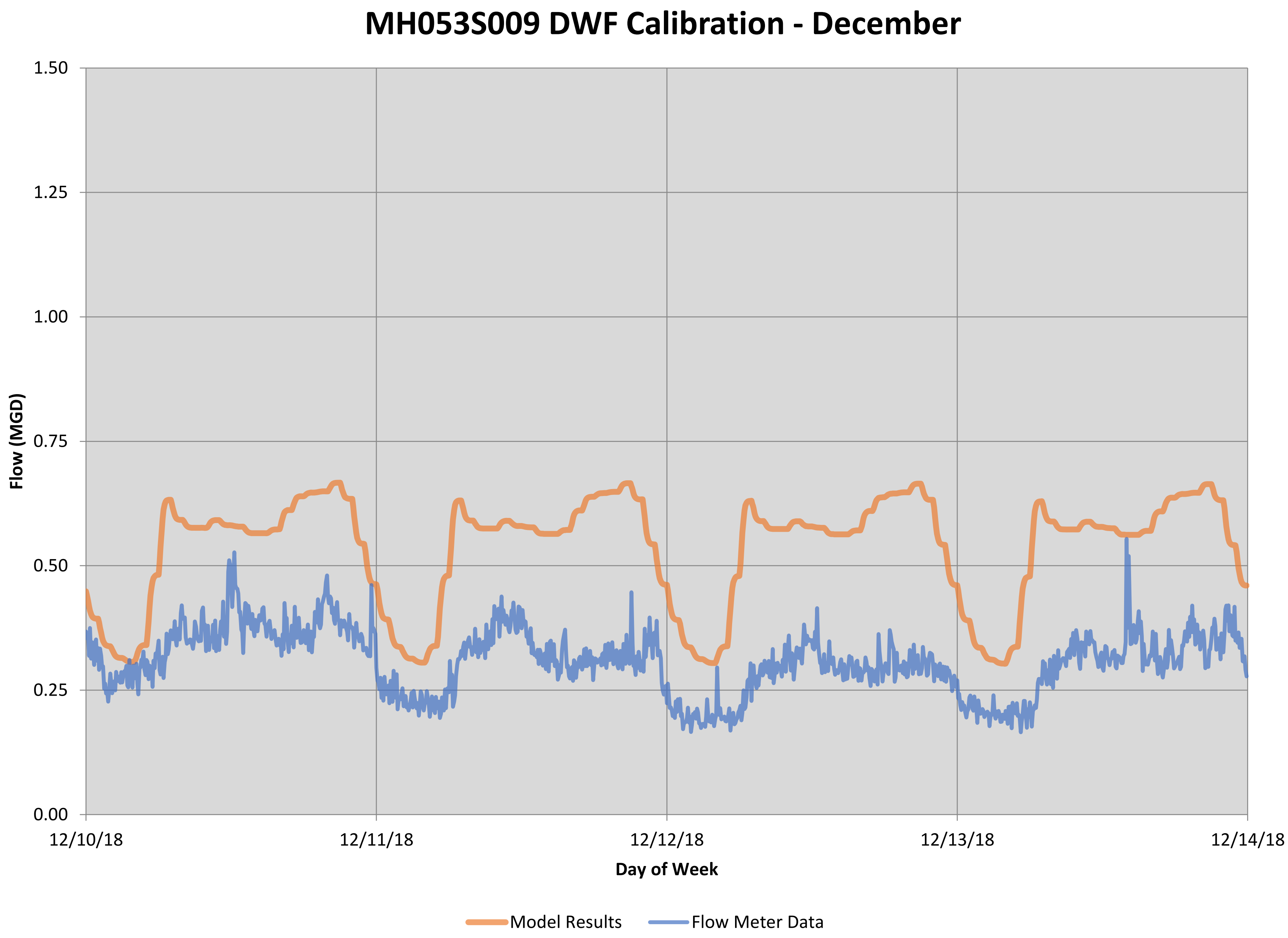
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	0.67	0.53
12/11/18	0.67	0.45
12/12/18	0.66	0.41
12/13/18	0.66	0.55



MH053S009 DWF Calibration - September
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Model Results
Flow Meter Data

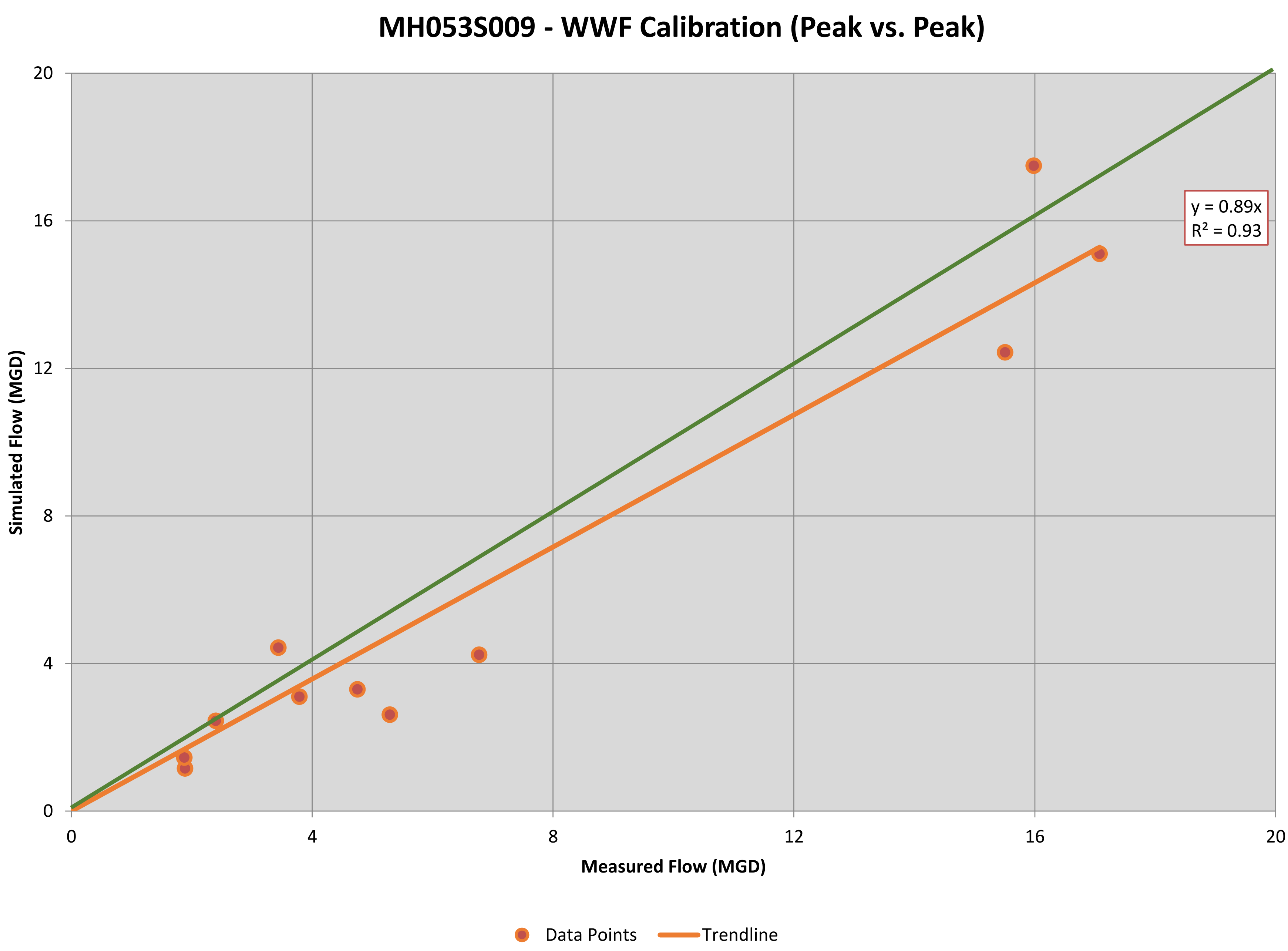


MH053S009 DWF Calibration - October
Flow (MGD)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Model Results
Flow Meter Data

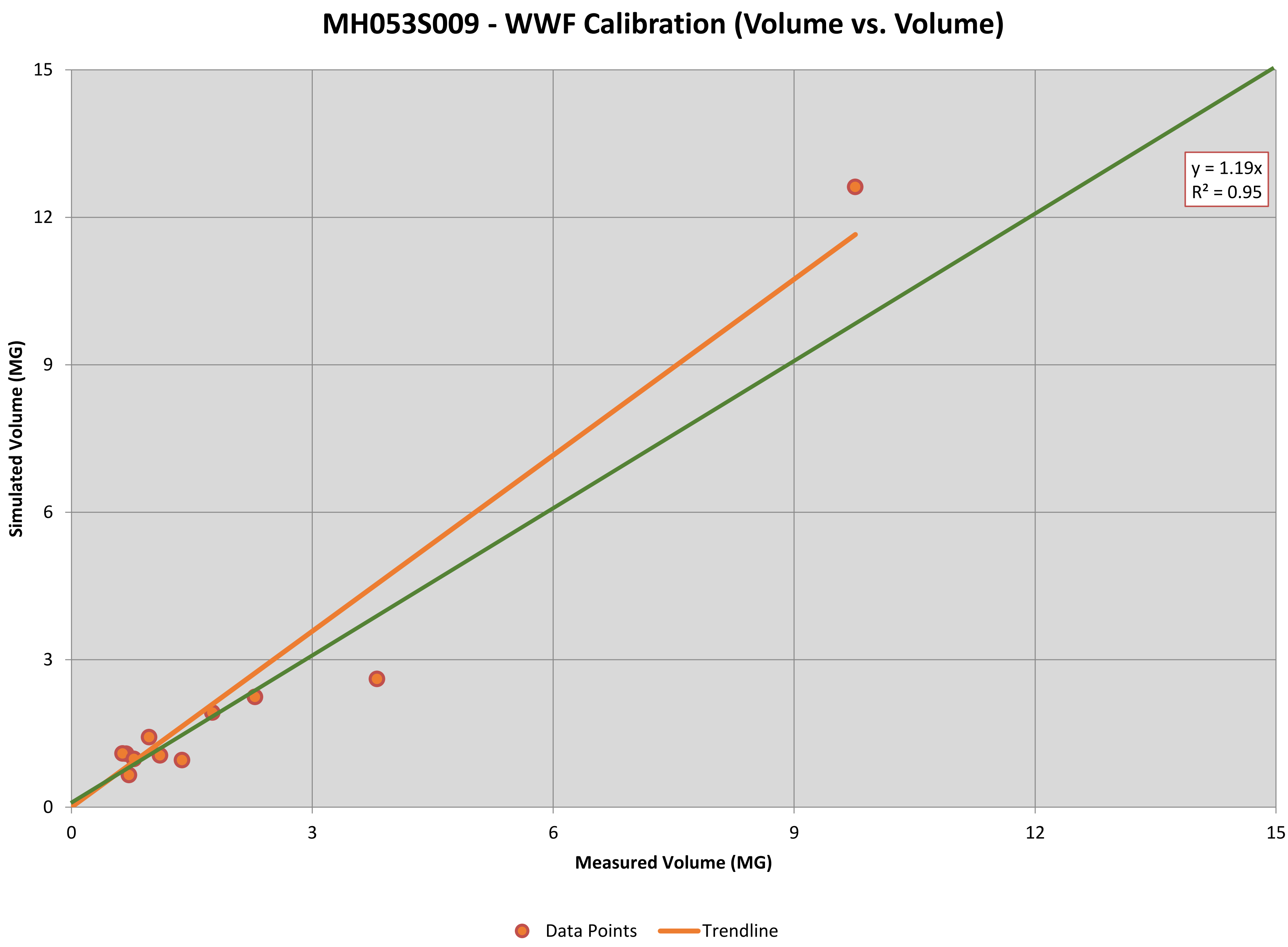


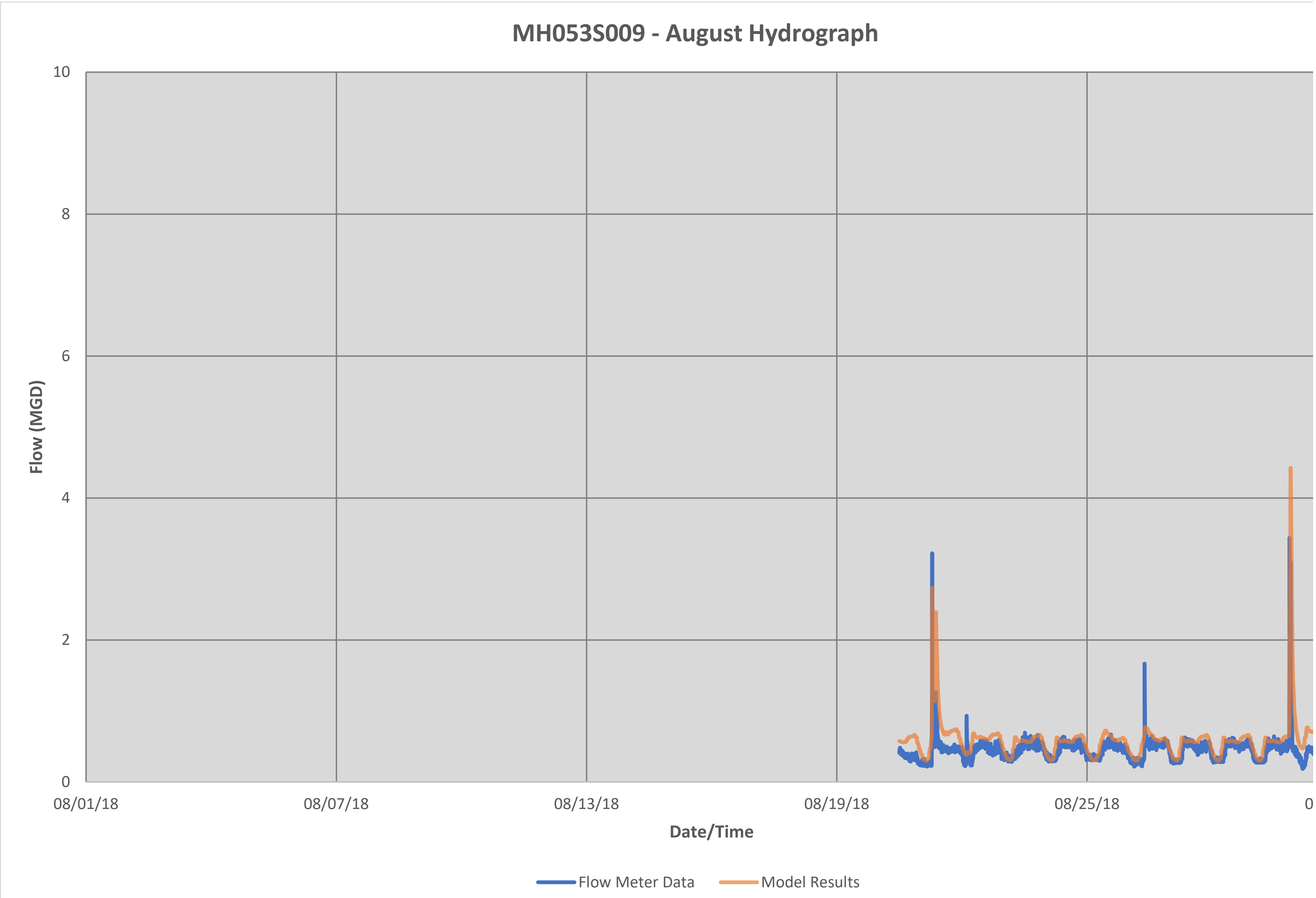
MH053S009 DWF Calibration - December
Flow (MGD)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Model Results
Flow Meter Data

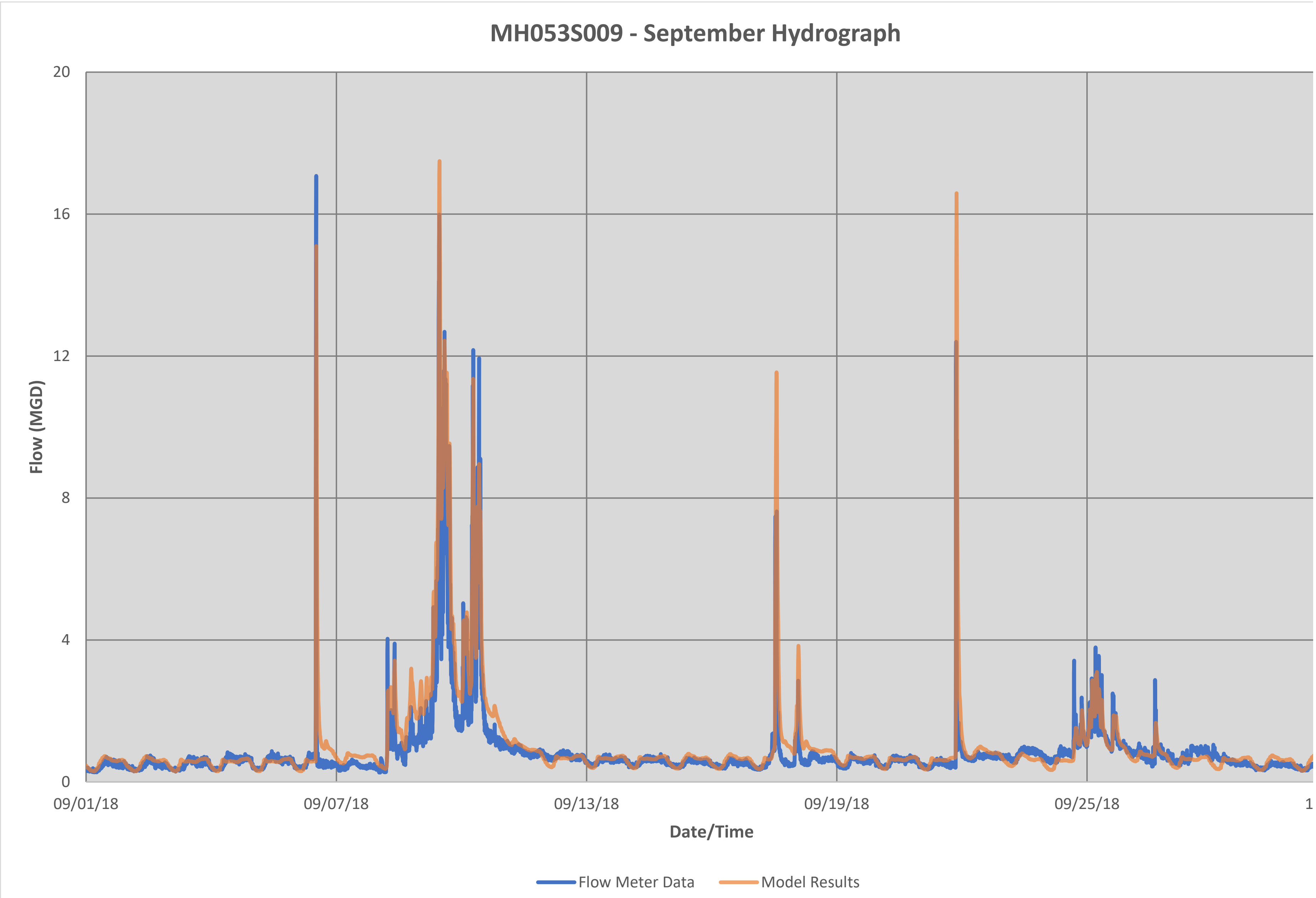
Storm Date	Type	Wet Weather Flow Statistics								
		Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	3.44	4.42	28.7%	0.68	1.09	59.6%	4.3	7.7	3.4
09/06/18	Validation	17.08	15.10	-11.6%	0.64	1.09	71.8%	11.8	15.0	3.2
09/07/18	Calibration	15.98	17.49	9.4%	9.76	12.62	29.2%	10.8	16.2	5.4
09/17/18	Calibration									
09/21/18	Validation									
09/24/18	Validation	3.79	3.10	-18.2%	2.29	2.24	-1.9%	4.6	6.3	1.7
10/02/18	Validation	6.77	4.24	-37.5%	0.78	0.98	25.7%	7.1	7.5	0.3
10/04/18	Calibration									
10/06/18	Calibration	15.51	12.43	-19.8%	0.97	1.42	47.0%	10.5	13.3	2.9
10/15/18	Calibration	1.89	1.15	-38.9%	0.72	0.65	-8.6%	3.2	3.7	0.5
10/26/18	Calibration	2.40	2.44	1.7%	1.75	1.92	9.7%	3.5	5.5	2.0
10/28/18	Calibration	1.88	1.45	-23.0%	1.10	1.05	-4.6%	3.1	4.1	1.0
11/09/18	Calibration									
11/15/18	Calibration	4.75	3.30	-30.6%	3.81	2.61	-31.4%	5.1	6.5	1.4
11/18/18	Validation									
11/24/18	Validation	5.29	2.61	-50.6%	1.38	0.96	-30.7%	6.0	5.7	-0.2
Totals		78.8	67.7	-14.0%	23.9	26.6	11.6%	70	92	21.6

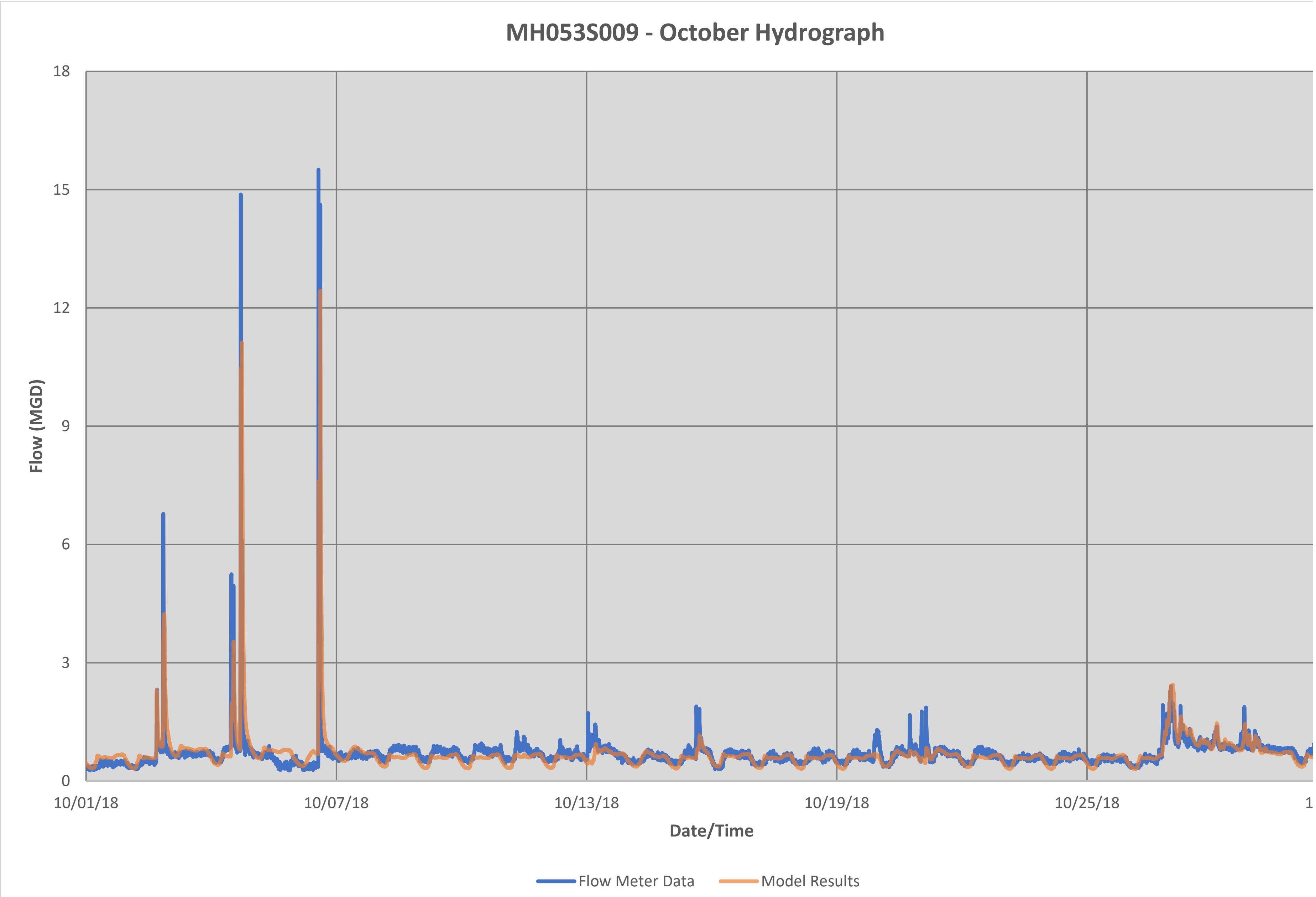


MH053S009 - WWF Calibration (Peak vs. Peak)
Simulated Flow (MGD)
Measured Flow (MGD)
0
4
8
12
16
20
y = 0.89x
R² = 0.93
Data Points
Trendline

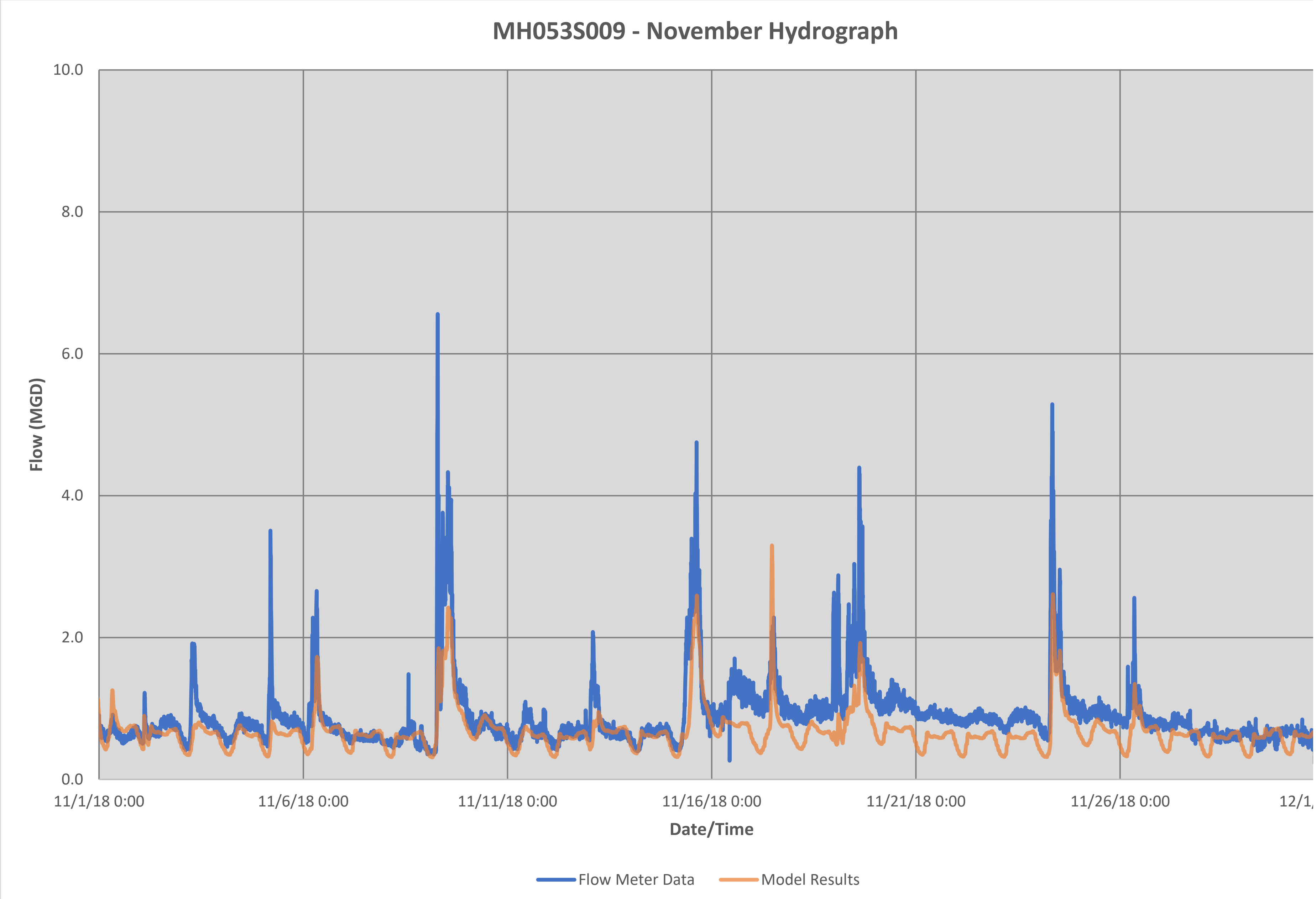

MH053S009 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
0
3
6
9
12
15
y = 1.19x
R² = 0.95
Data Points
Trendline


MH053S009 - August Hydrograph
Flow (MGD)
10
8
6
4
2
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results

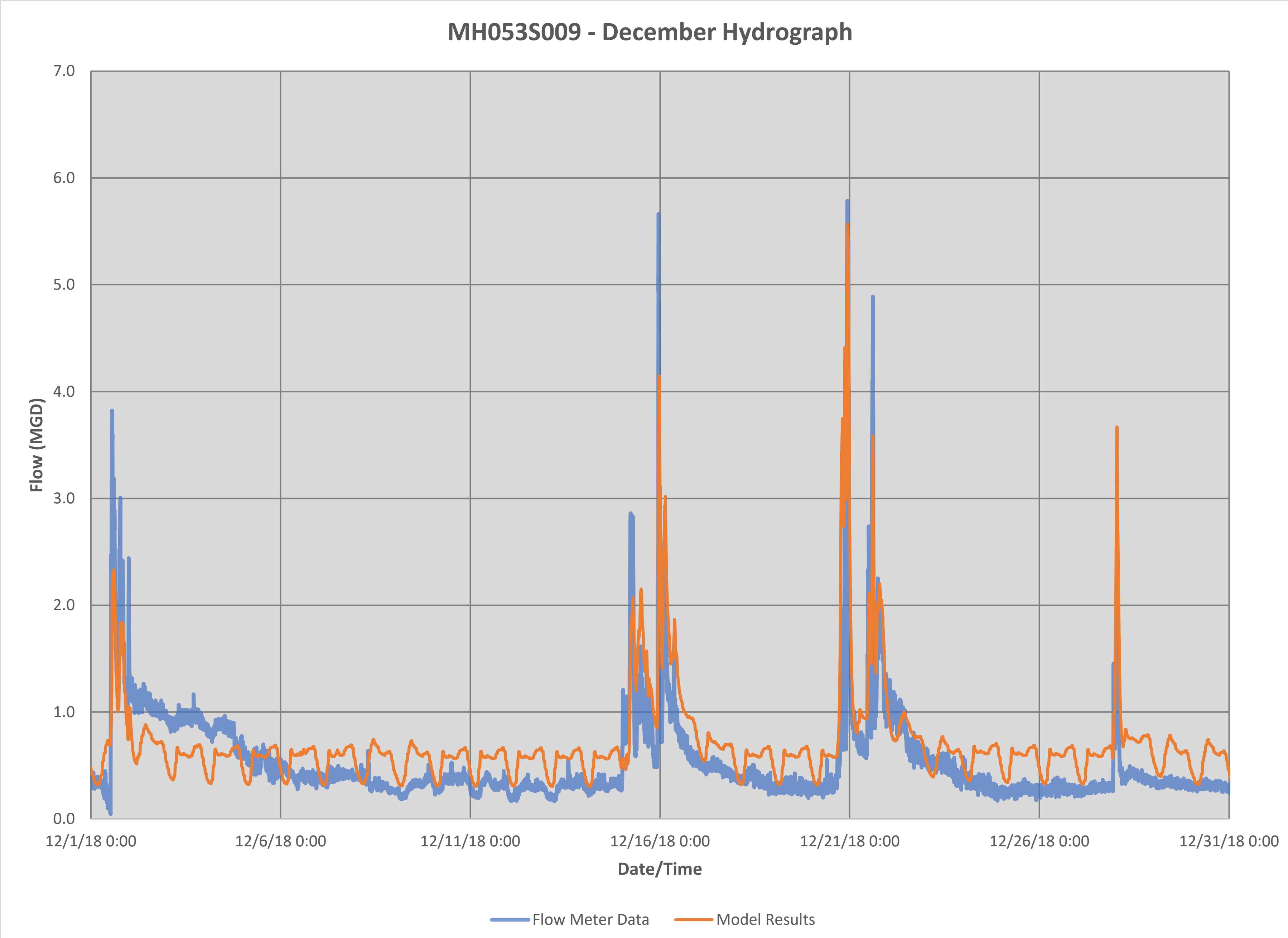

MH053S009 - September Hydrograph
20
16
12
8
4
0
Flow (MGD)
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH053S009 - October Hydrograph
18
15
12
9
6
3
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results



MH053S009 - November Hydrograph
10.0
8.0
6.0
4.0
2.0
0.0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results


MH053S009 - December Hydrograph
Flow (MGD)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH054E003 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	3.14	4.90	**-35.9%**
Volume - MG	10.70	12.39	**-13.6%**
Depth (Avg) - in	4.01	4.64	**-0.6**

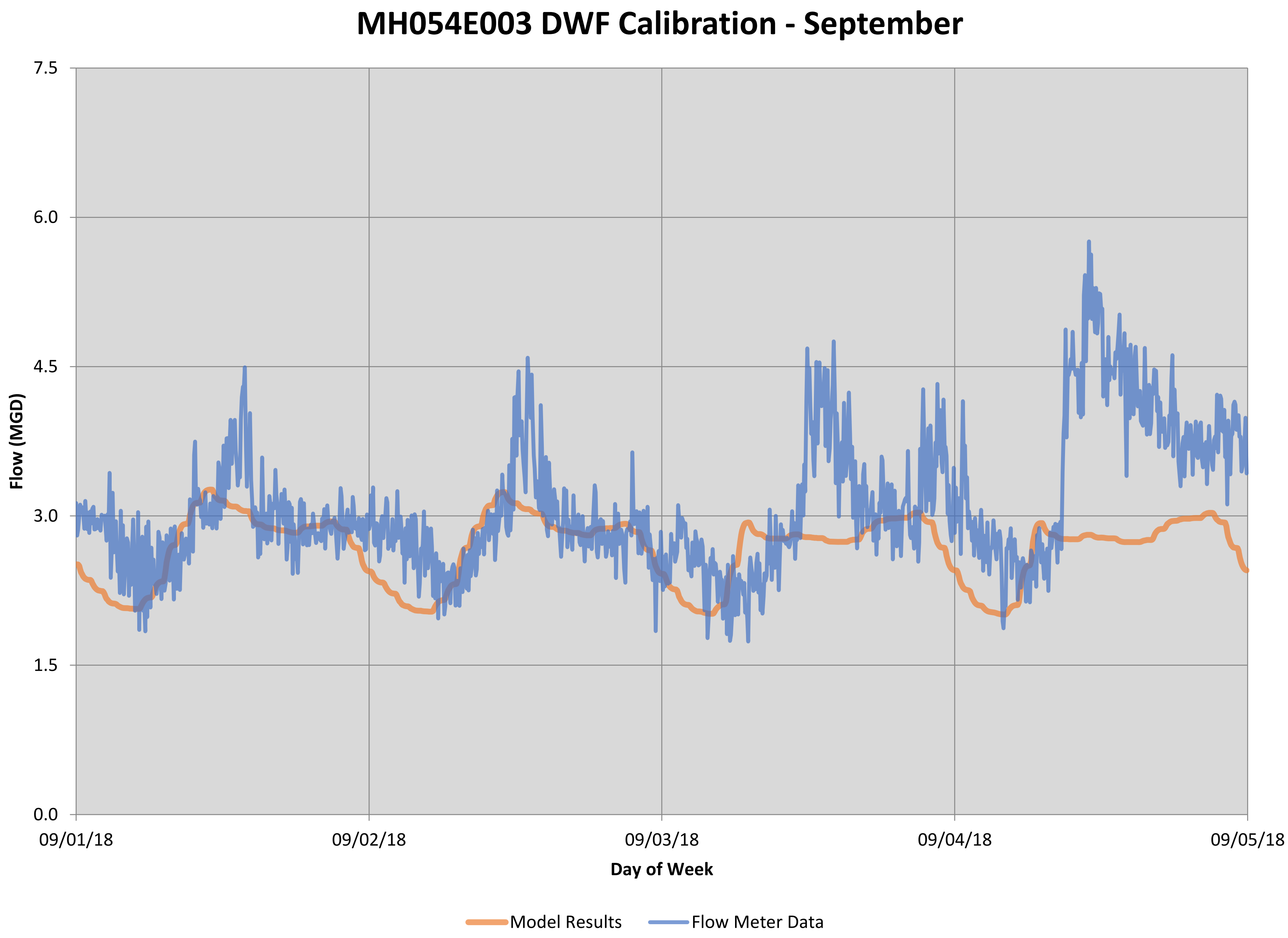
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	3.26	4.49
9/2/18	3.24	4.59
9/3/18	3.03	4.75
9/4/18	3.03	5.76

DWF Calibration Statistics MH054E003 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	3.13	2.92	**7.3%**
Volume - MG	11.07	9.51	**16.4%**
Depth (Avg) - in	4.06	4.35	**-0.3**

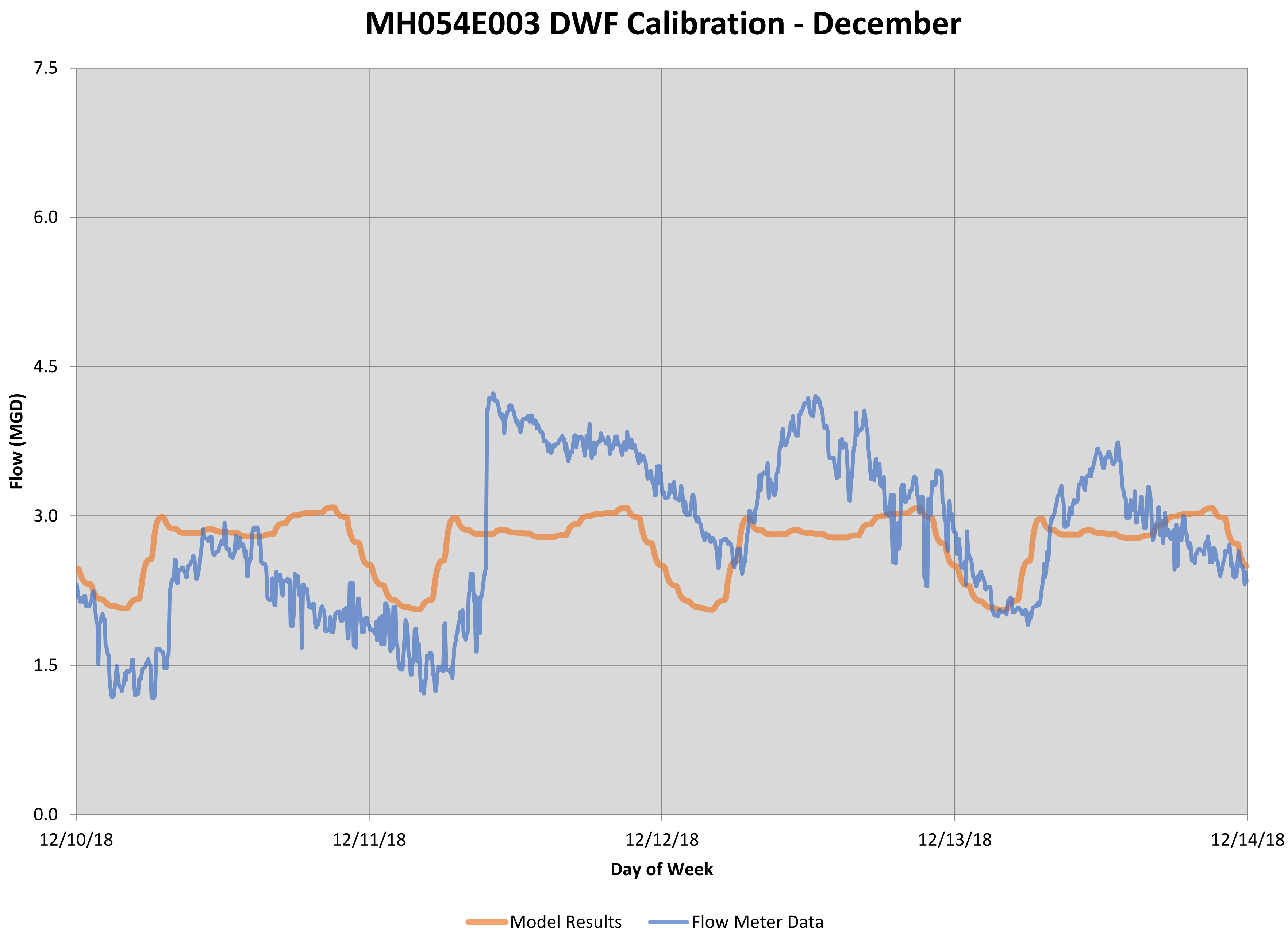
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	3.18	2.95
10/23/18	3.14	3.24
10/24/18	3.11	3.26
10/25/18	3.10	2.23

DWF Calibration Statistics MH054E003 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	3.08	3.78	**-18.5%**
Volume - MG	10.83	11.11	**-2.6%**
Depth (Avg) - in	4.03	4.68	**-0.6**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	3.09	2.93
12/11/18	3.08	4.23
12/12/18	3.08	4.21
12/13/18	3.08	3.74

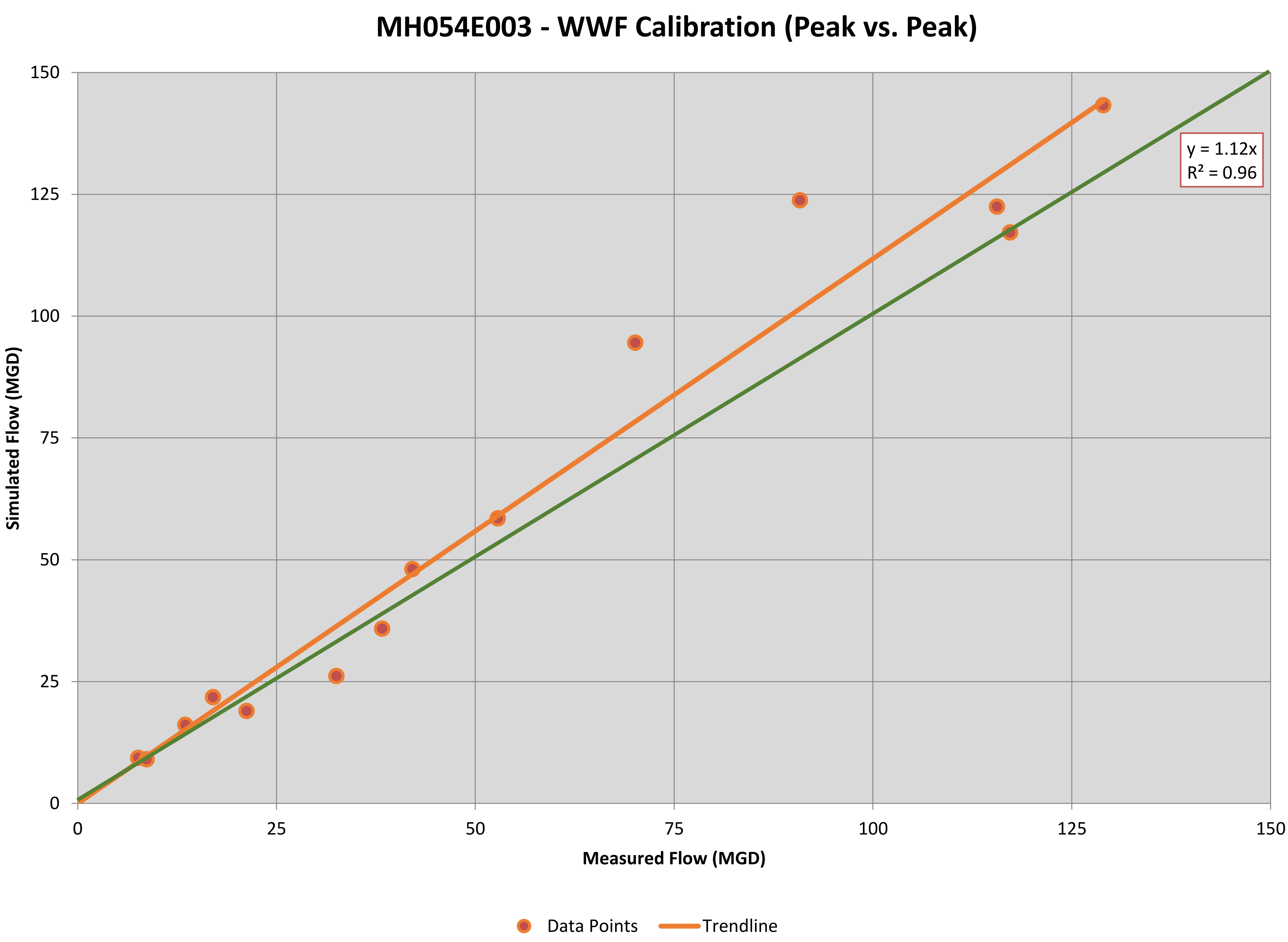

MH054E003 DWF Calibration - September
Flow (MGD)
7.5
6.0
4.5
3.0
1.5
0.0
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Model Results
Flow Meter Data

MH054E003 DWF Calibration - October

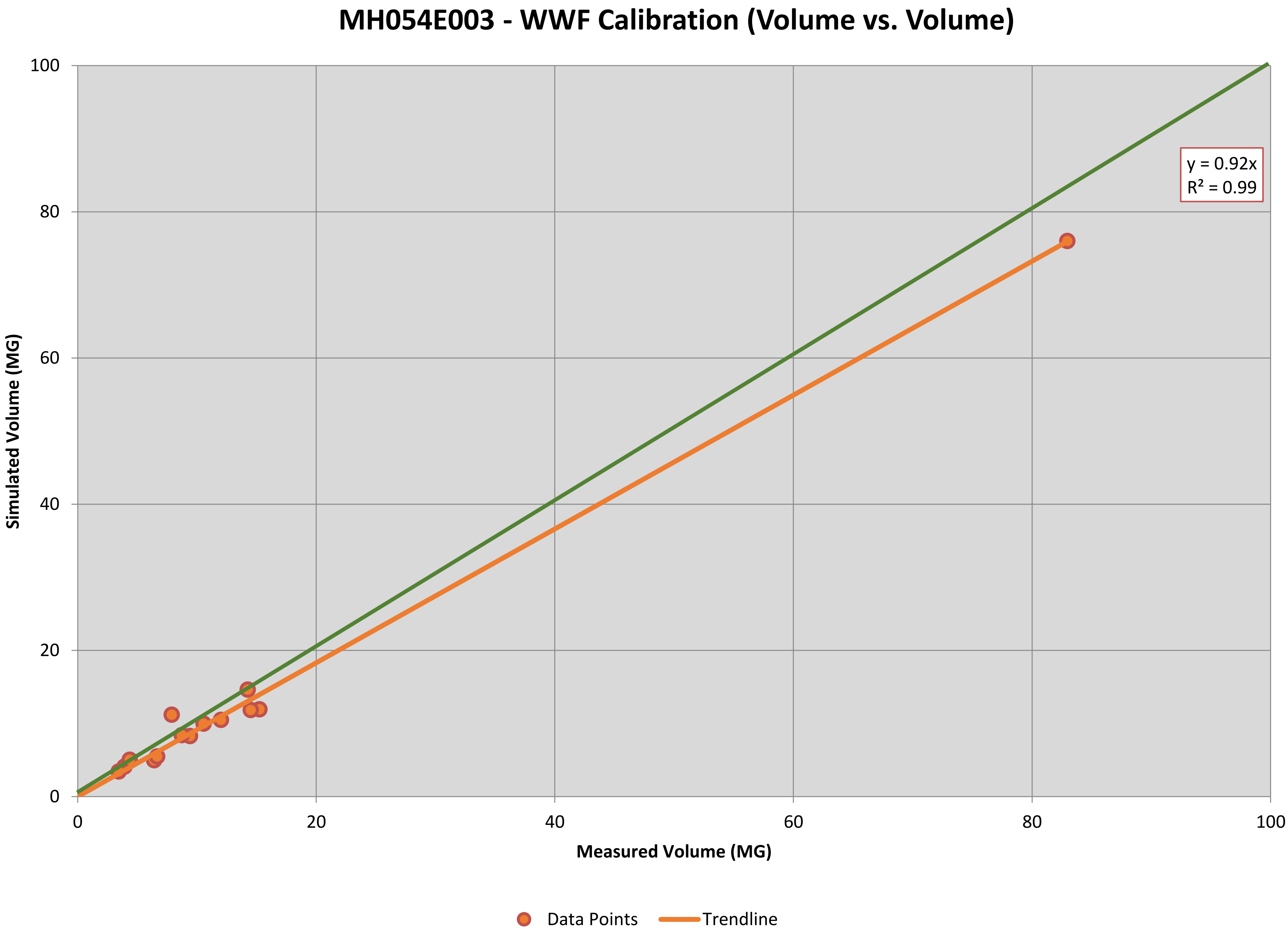


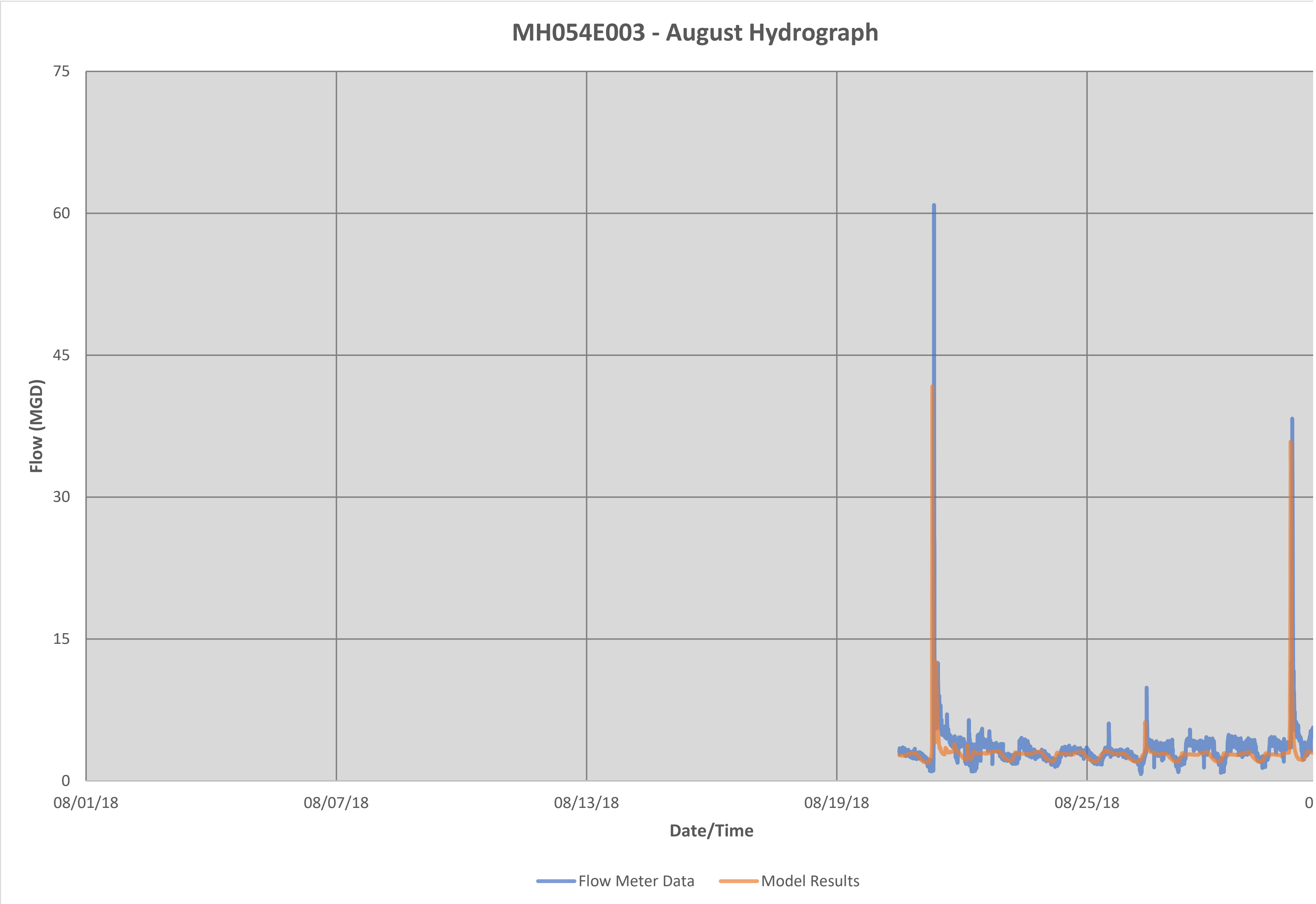
MH054E003 DWF Calibration - December
7.5
6.0
4.5
3.0
1.5
0.0
Flow (MGD)
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Model Results
Flow Meter Data

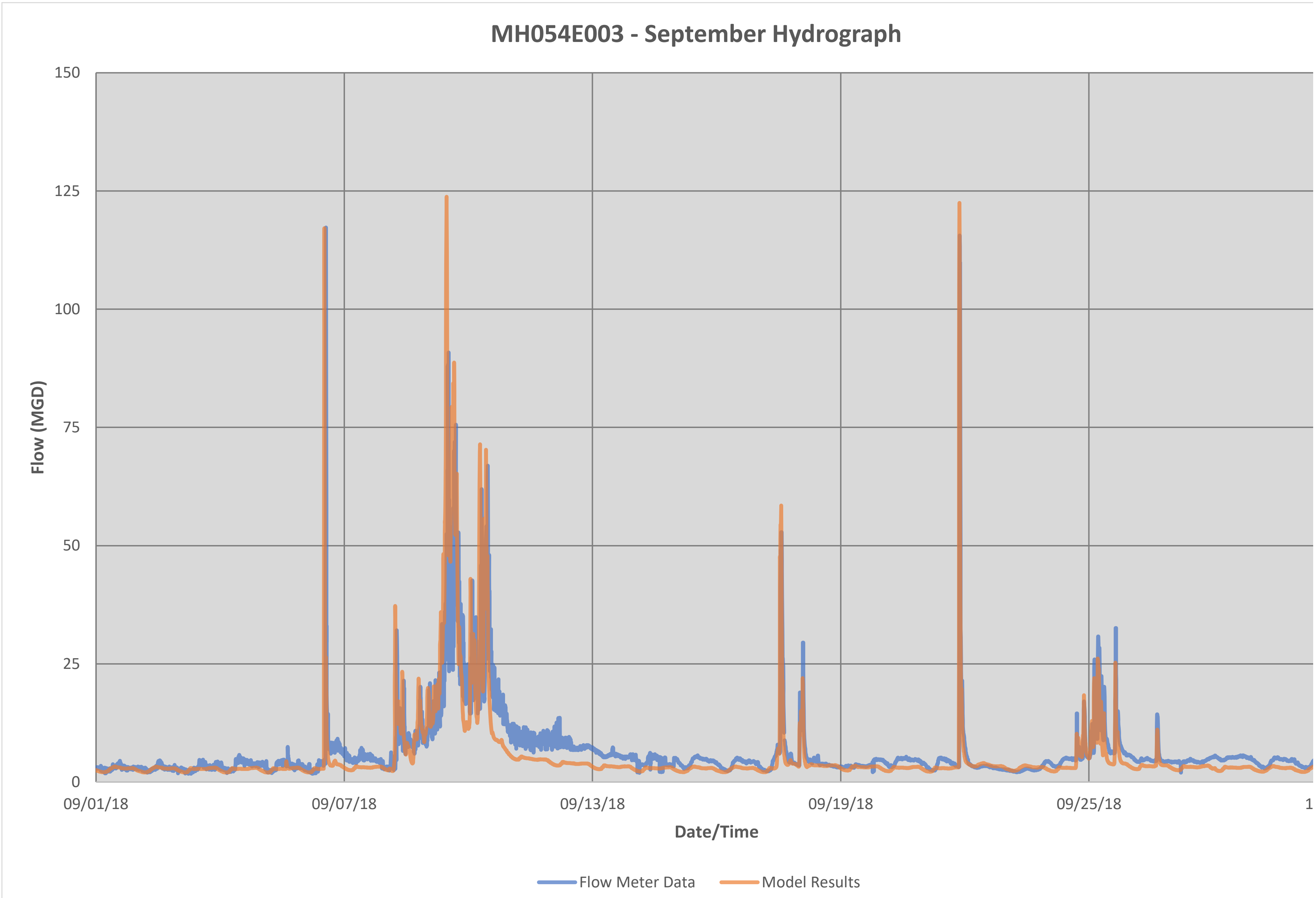
		MH054E003 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	38.30	35.86	-6.4%	6.41	4.96	-22.6%	12.0	12.7	0.7
09/06/18	Validation	117.26	117.16	-0.1%	6.67	5.47	-17.9%	24.4	26.6	2.2
09/07/18	Calibration	90.84	123.79	36.3%	82.97	75.99	-8.4%	23.8	27.6	3.8
09/17/18	Calibration	52.84	58.48	10.7%	12.02	10.48	-12.8%	13.9	16.9	3.1
09/21/18	Validation	115.60	122.49	6.0%	10.56	9.99	-5.4%	20.7	27.4	6.7
09/24/18	Validation	32.55	26.13	-19.7%	15.23	11.94	-21.6%	11.9	10.7	-1.2
10/02/18	Validation	42.11	48.10	14.2%	3.94	4.08	3.7%	13.2	15.0	1.9
10/04/18	Calibration	70.11	94.55	34.9%	9.42	8.28	-12.1%	16.3	23.0	6.7
10/06/18	Calibration	128.96	143.24	11.1%	8.73	8.41	-3.7%	22.3	30.5	8.2
10/15/18	Calibration	7.61	9.32	22.5%	3.45	3.42	-0.9%	7.1	6.6	-0.5
10/26/18	Calibration	17.01	21.79	28.1%	7.89	11.20	42.1%	8.4	9.7	1.4
10/28/18	Calibration	8.67	9.03	4.1%	4.37	5.02	14.9%	6.2	6.5	0.3
11/09/18	Calibration									
11/15/18	Calibration	21.25	18.93	-10.9%	14.26	14.62	2.6%	9.8	9.1	-0.7
11/18/18	Validation	13.54	16.11	19.0%	14.52	11.84	-18.5%	8.6	8.4	-0.2
11/24/18	Validation									
Totals		756.6	845.0	11.7%	200.4	185.7	-7.3%	198	231	32.3

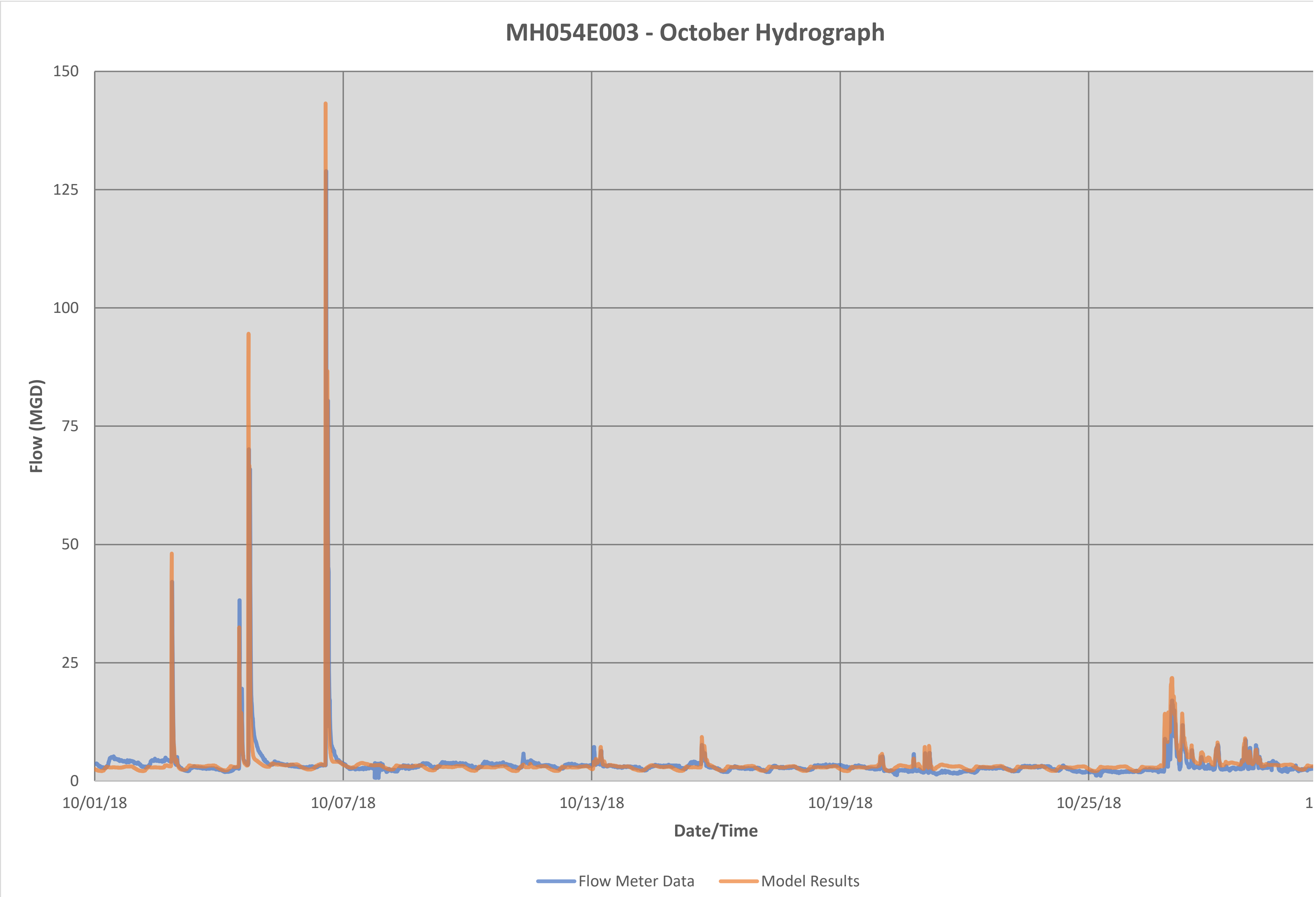


MH054E003 - WWF Calibration (Peak vs. Peak)
y = 1.12x
R² = 0.96
Simulated Flow (MGD)
Measured Flow (MGD)
0
25
50
75
100
125
150
Data Points
Trendline

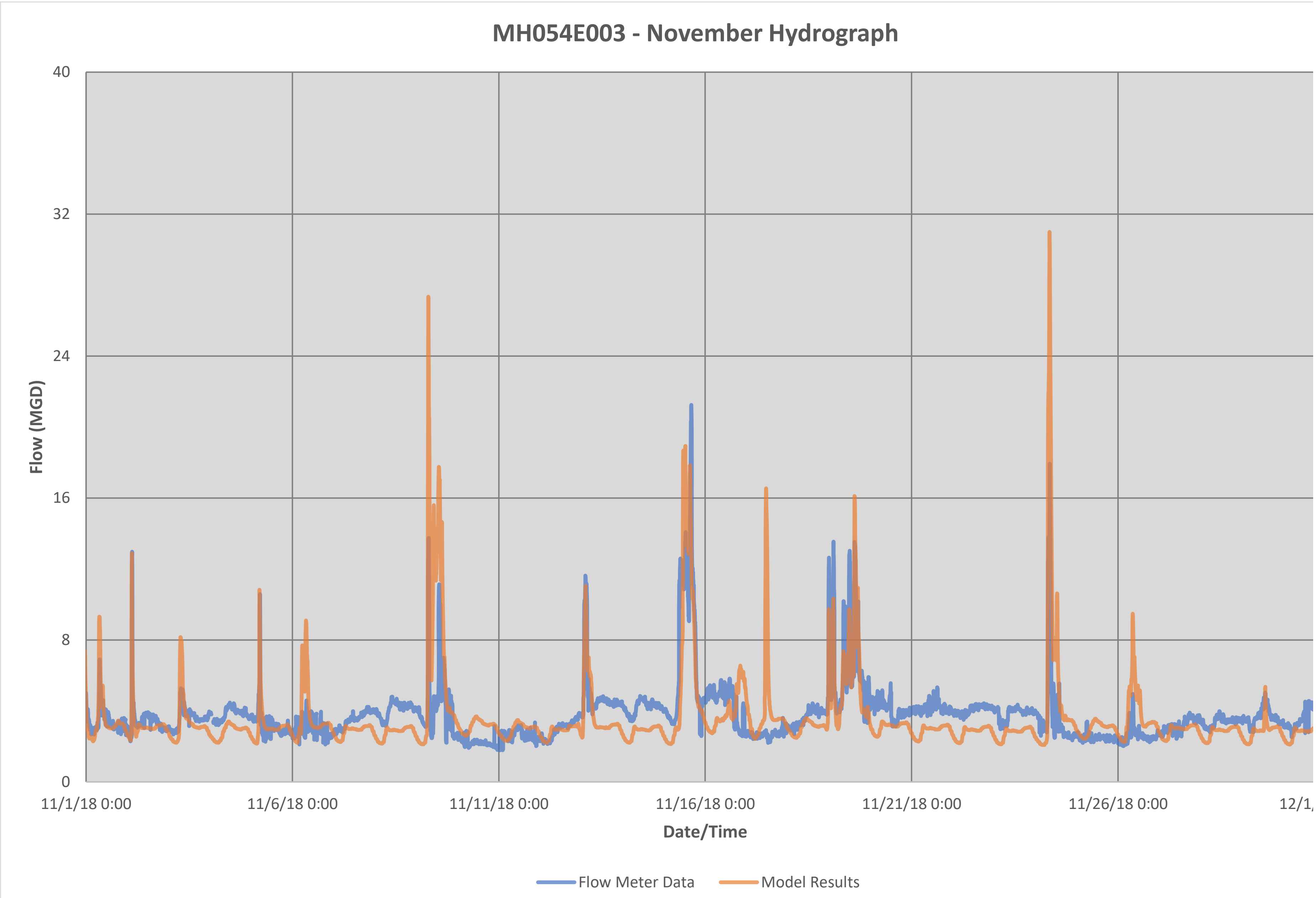

MH054E003 - WWF Calibration (Volume vs. Volume)
Simulated Volume (MG)
Measured Volume (MG)
0
20
40
60
80
100
y = 0.92x
R² = 0.99
Data Points
Trendline

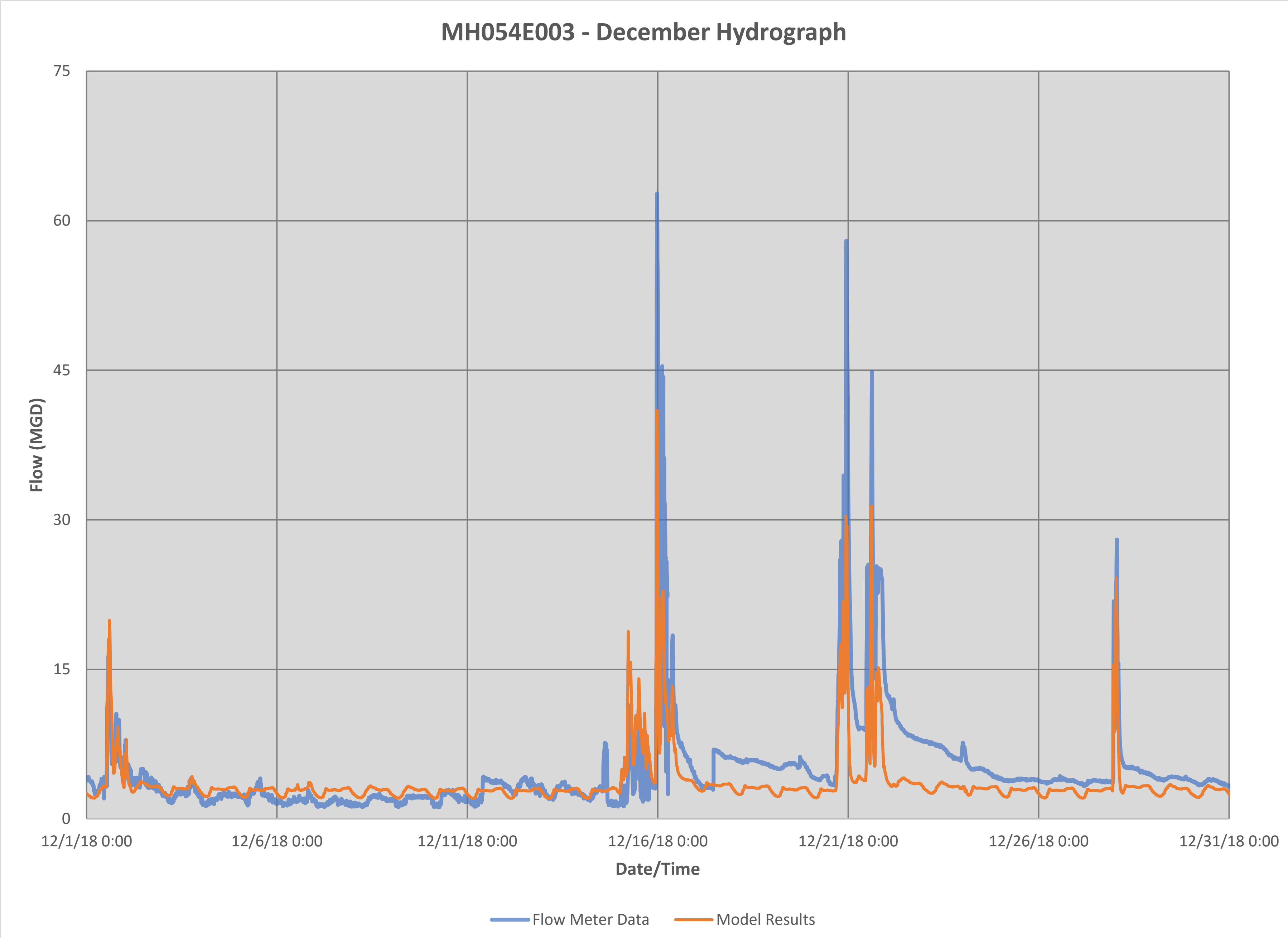

MH054E003 - August Hydrograph
Flow (MGD)
75
60
45
30
15
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results


MH054E003 - September Hydrograph
Flow (MGD)
150
125
100
75
50
25
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH054E003 - October Hydrograph
150
125
100
75
50
25
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH054E003 - November Hydrograph
40
32
24
16
8
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results


MH054E003 - December Hydrograph
Flow (MGD)
75
60
45
30
15
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH054F011 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.12	1.49	**-24.8%**
Volume - MG	3.59	4.67	**-23.1%**
Depth (Avg) - in	2.47	2.76	**-0.3**

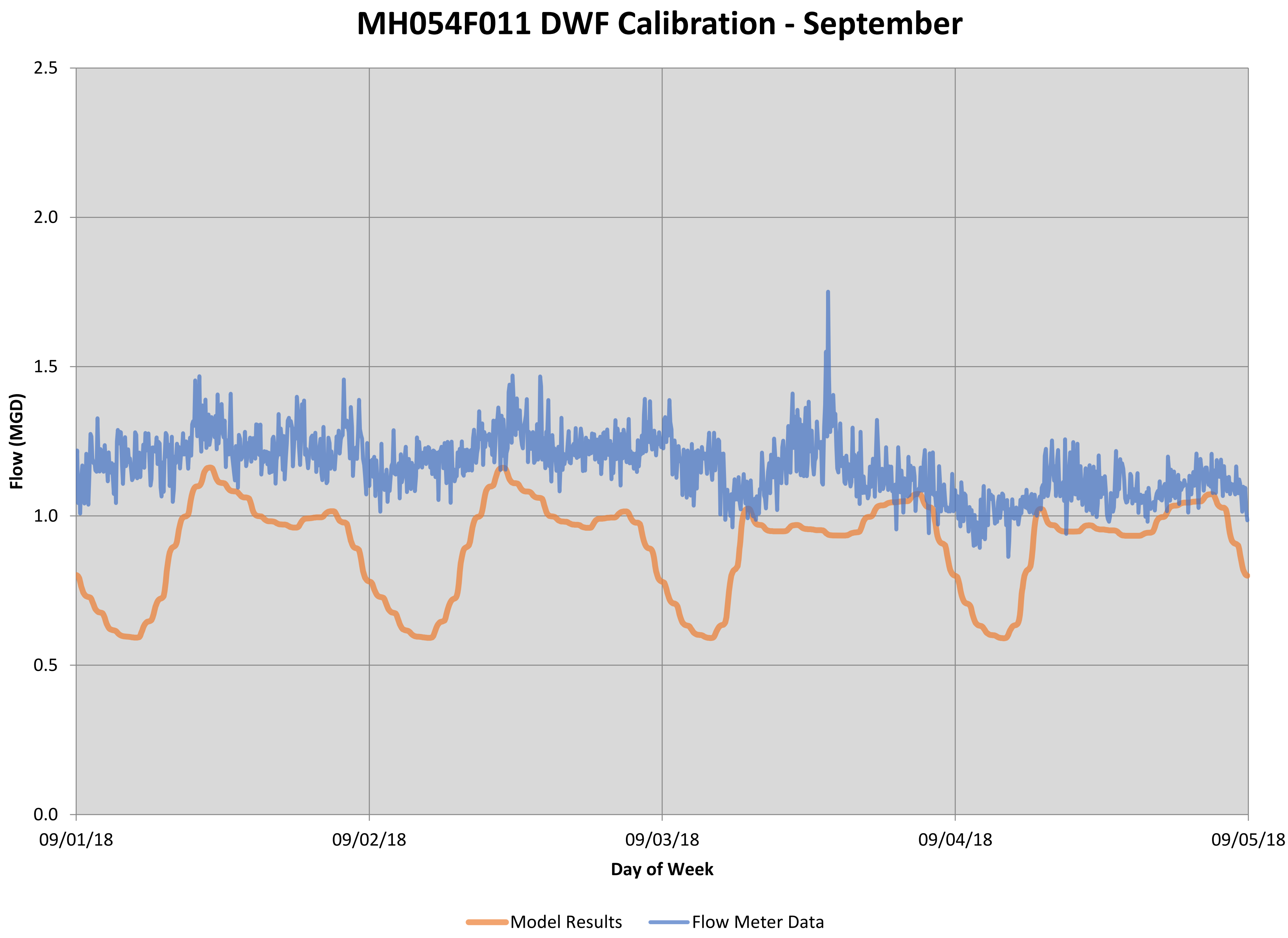
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	1.16	1.47
9/2/18	1.16	1.47
9/3/18	1.07	1.75
9/4/18	1.07	1.26

DWF Calibration Statistics MH054F011 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.08	1.23	**-12.7%**
Volume - MG	3.63	3.99	**-9.1%**
Depth (Avg) - in	2.49	2.49	**0.0**

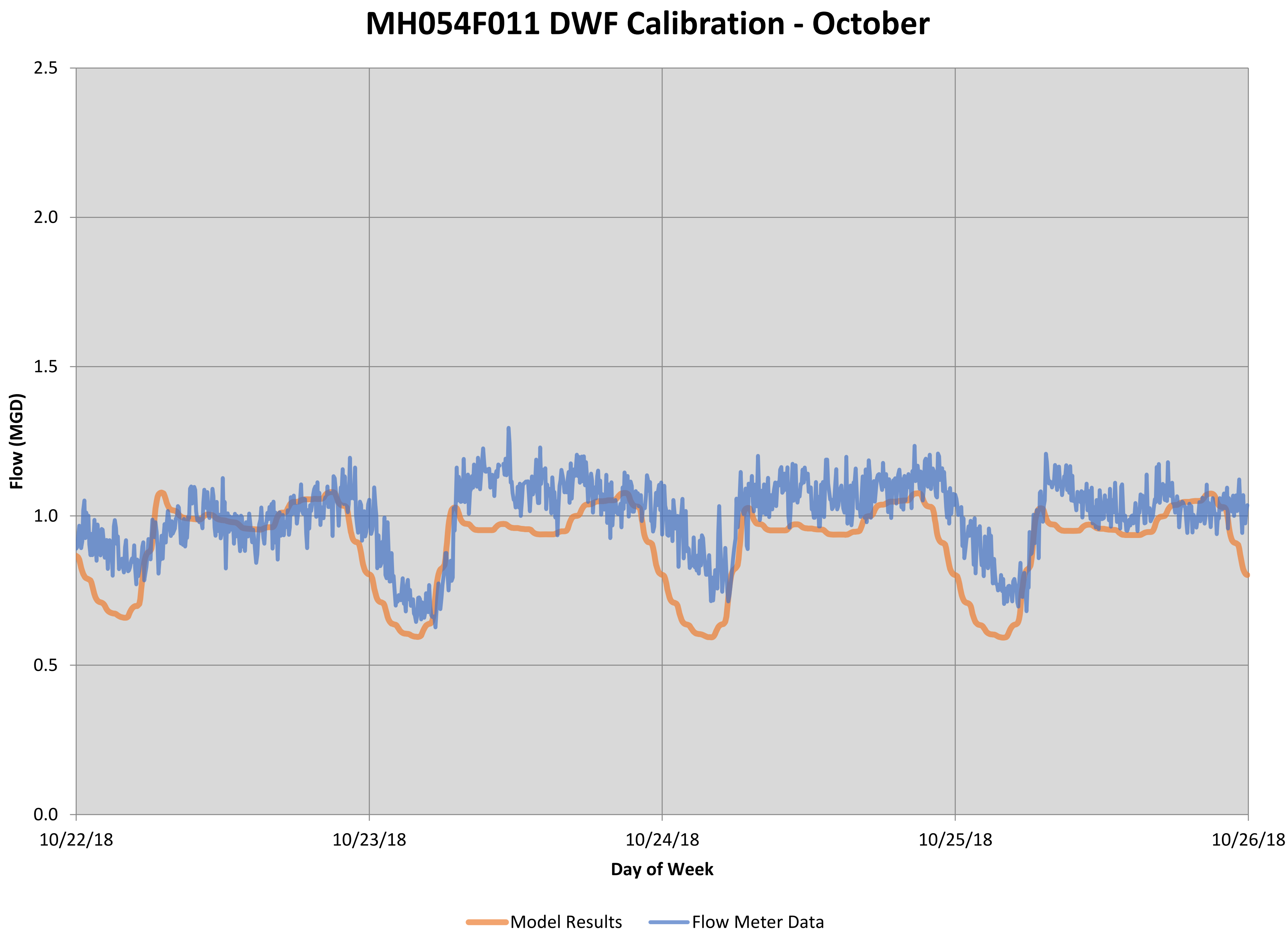
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	1.08	1.20
10/23/18	1.08	1.30
10/24/18	1.08	1.24
10/25/18	1.07	1.21

DWF Calibration Statistics MH054F011 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.07	2.44	**-55.9%**
Volume - MG	3.59	7.68	**-53.3%**
Depth (Avg) - in	2.47	3.78	**-1.3**

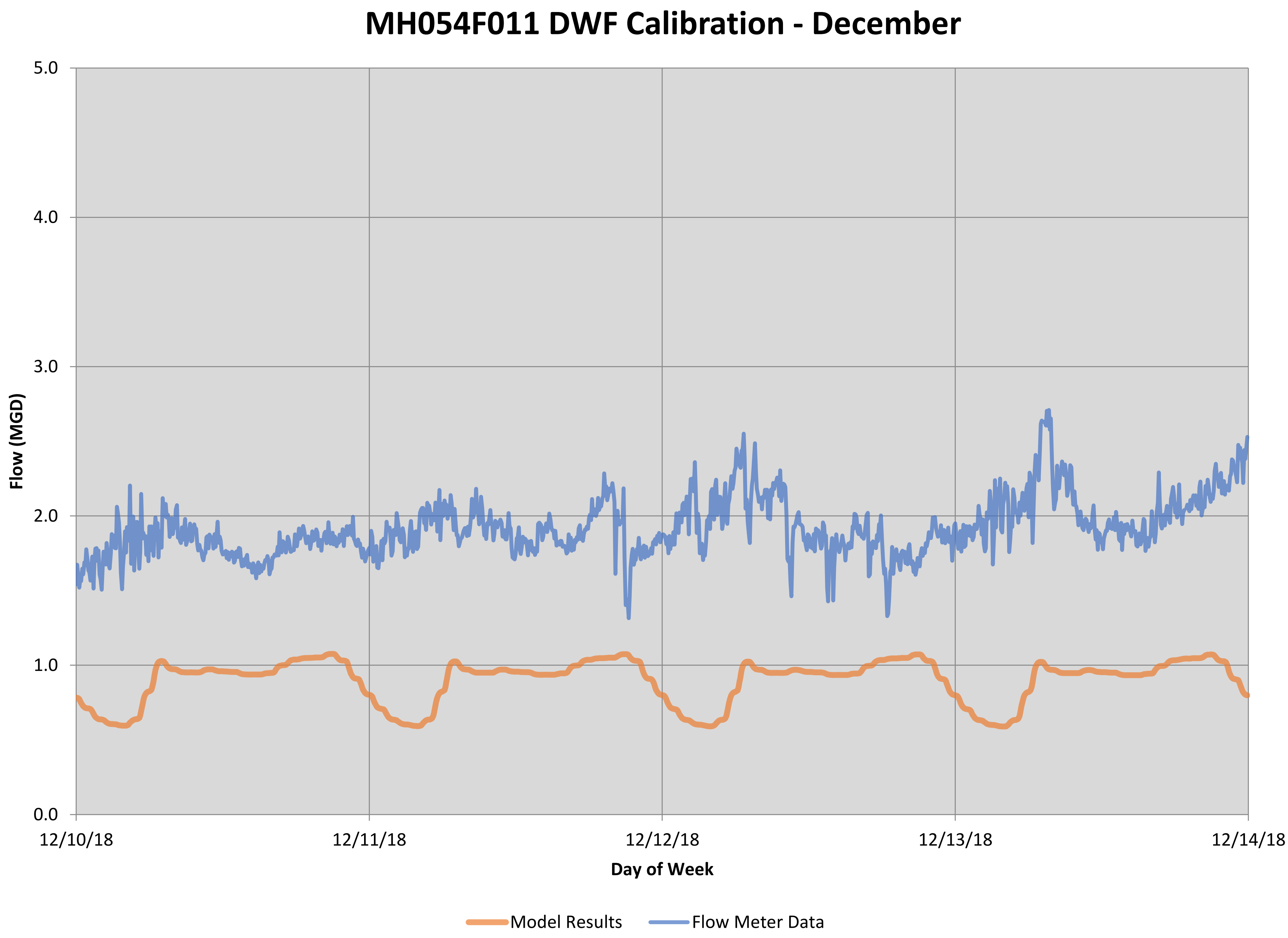
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	1.08	2.20
12/11/18	1.07	2.29
12/12/18	1.07	2.55
12/13/18	1.07	2.71



MH054F011 DWF Calibration - September
Flow (MGD)
2.5
2.0
1.5
1.0
0.5
0.0
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Model Results
Flow Meter Data

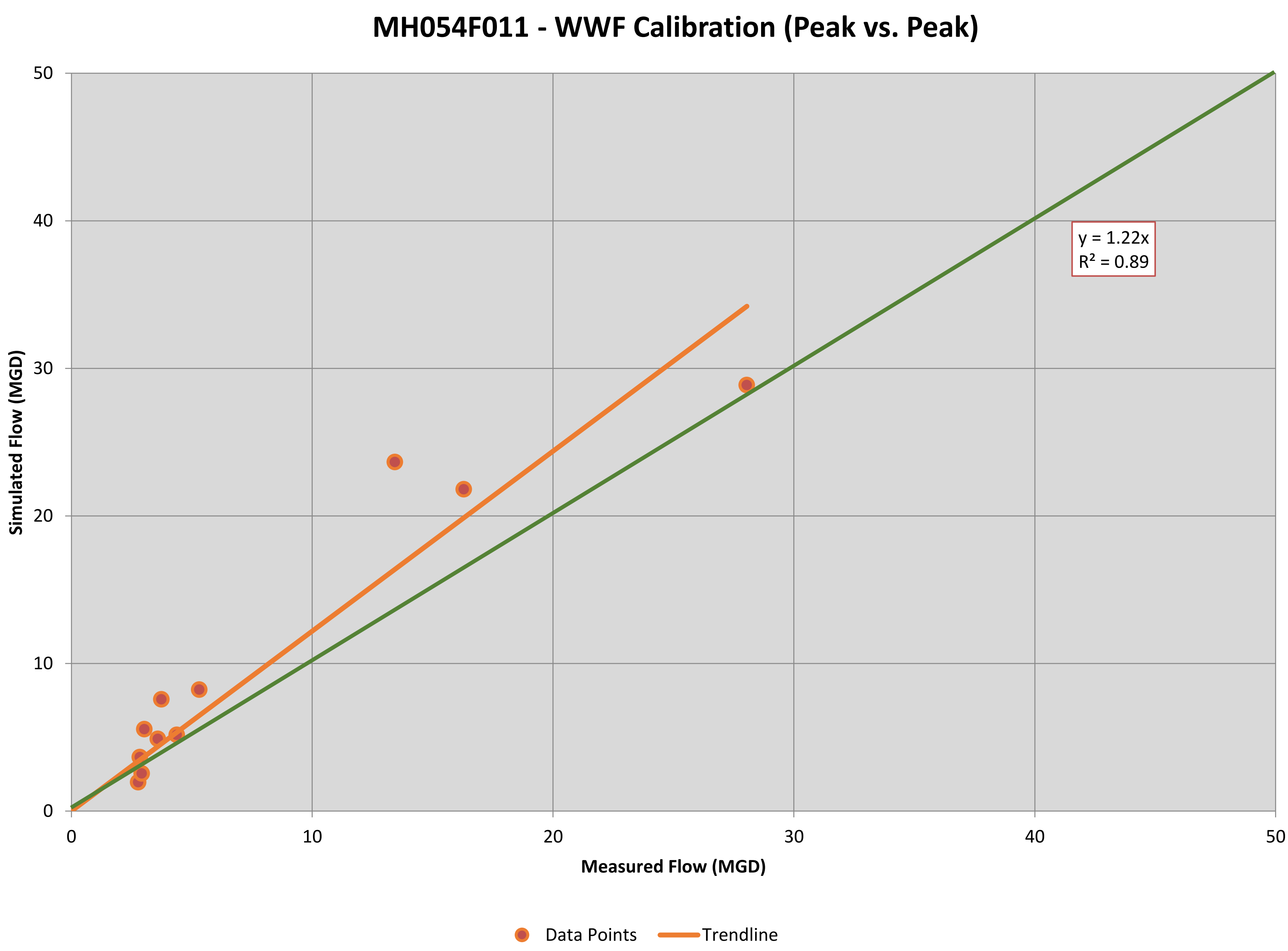


MH054F011 DWF Calibration - October
Flow (MGD)
2.5
2.0
1.5
1.0
0.5
0.0
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Model Results
Flow Meter Data

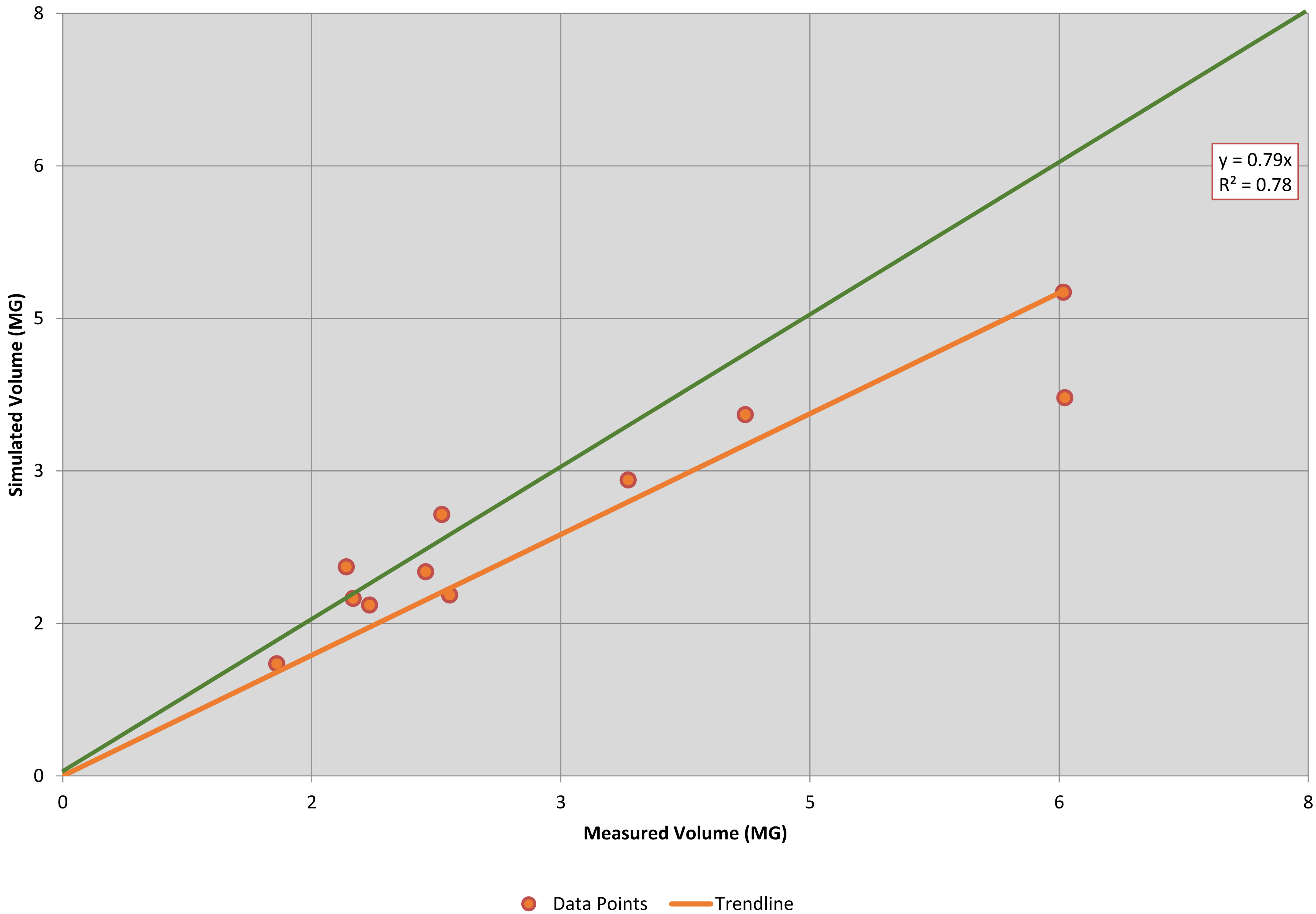


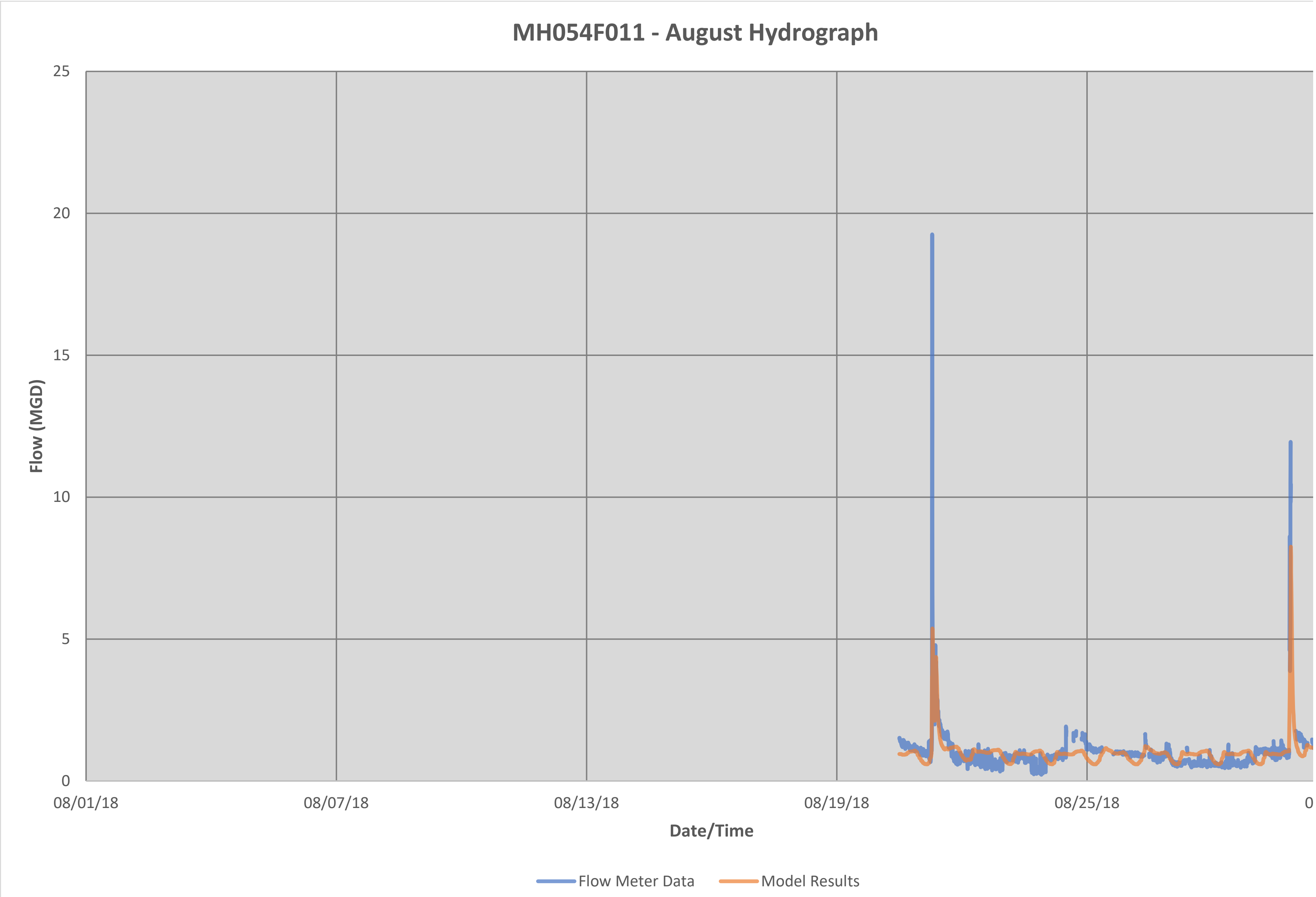
MH054F011 DWF Calibration - December
5.0
4.0
3.0
2.0
1.0
0.0
Flow (MGD)
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Model Results
Flow Meter Data

		MH054F011 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration									
09/06/18	Validation	28.05	28.86	2.9%	2.19	2.01	-8.3%	16.9	13.2	-3.7
09/07/18	Calibration									
09/17/18	Calibration									
09/21/18	Validation									
09/24/18	Validation									
10/02/18	Validation	5.31	8.23	55.0%	1.85	1.68	-9.1%	5.0	7.1	2.1
10/04/18	Calibration	16.29	21.80	33.8%	3.41	2.91	-14.6%	10.9	11.5	0.6
10/06/18	Calibration	13.44	23.65	76.1%	2.28	2.57	12.6%	9.0	12.0	3.0
10/15/18	Calibration	2.77	1.95	-29.7%	1.29	1.10	-14.6%	3.6	3.6	-0.1
10/26/18	Calibration	4.38	5.16	17.9%	4.11	3.55	-13.6%	4.9	5.7	0.8
10/28/18	Calibration	2.92	2.55	-12.6%	2.33	1.78	-23.7%	3.7	4.1	0.4
11/09/18	Calibration	3.59	4.88	35.9%	1.71	2.06	20.4%	3.9	5.5	1.7
11/15/18	Calibration	3.73	7.57	102.7%	6.03	4.76	-21.1%	4.0	6.8	2.8
11/18/18	Validation	2.84	3.65	28.5%	6.04	3.72	-38.4%	3.6	4.8	1.2
11/24/18	Validation	3.02	5.55	83.6%	1.75	1.75	-0.2%	4.3	5.9	1.6
Totals		86.3	113.9	31.9%	33.0	27.9	-15.5%	70	80	10.6

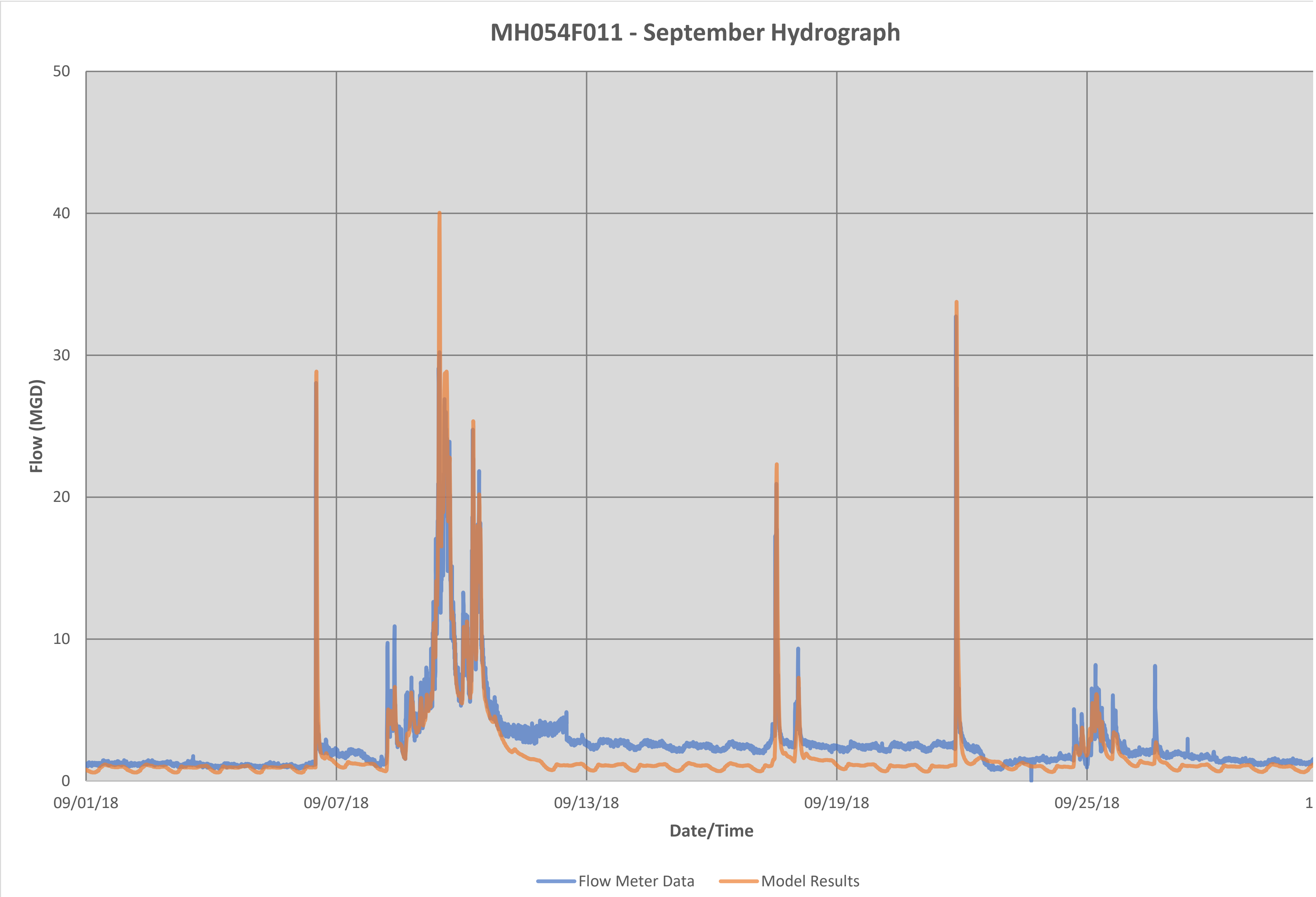

MH054F011 - WWF Calibration (Peak vs. Peak)
y = 1.22x
R² = 0.89
Simulated Flow (MGD)
Measured Flow (MGD)
0
10
20
30
40
50
Data Points
Trendline

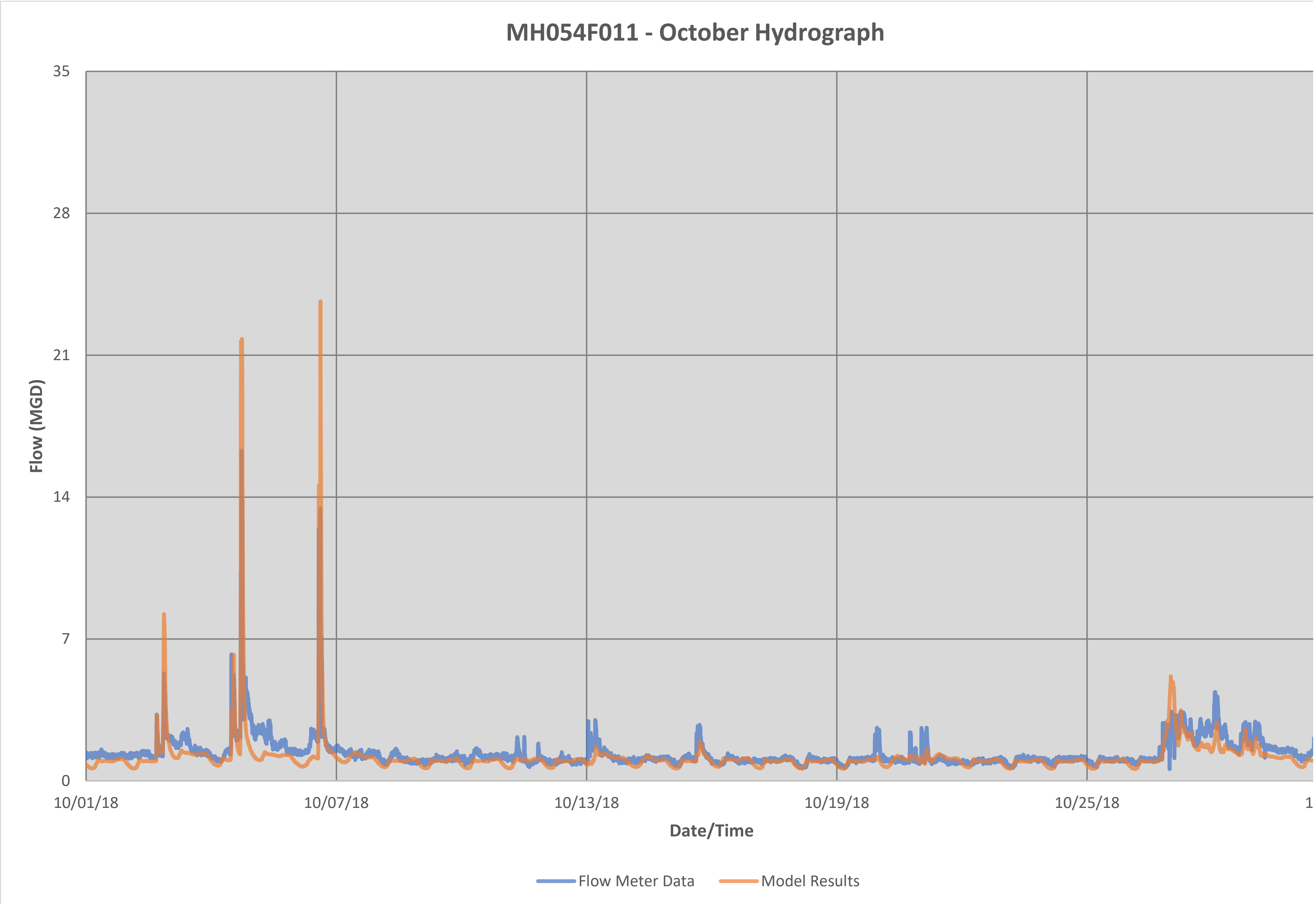
MH054F011 - WWF Calibration (Volume vs. Volume)

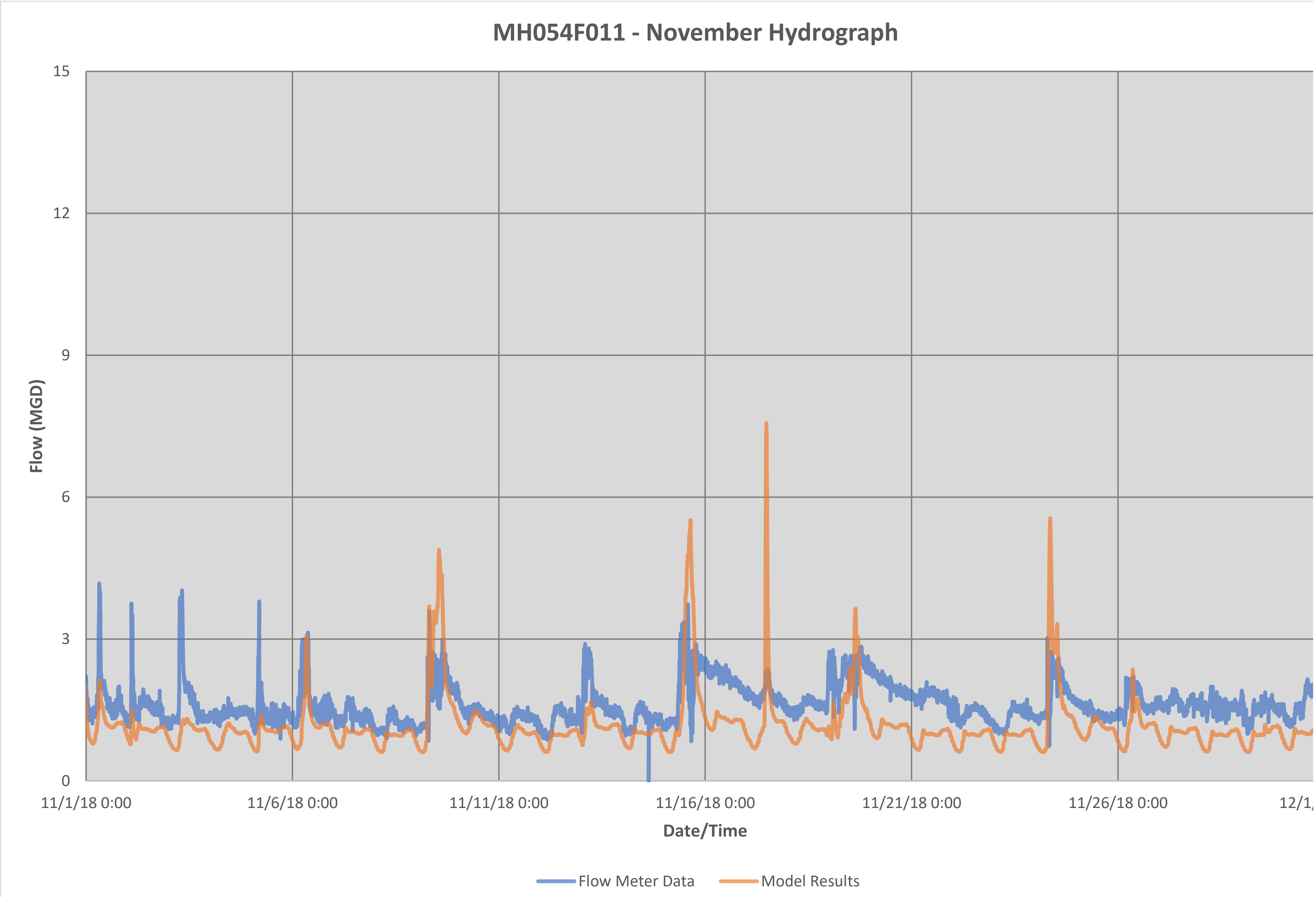


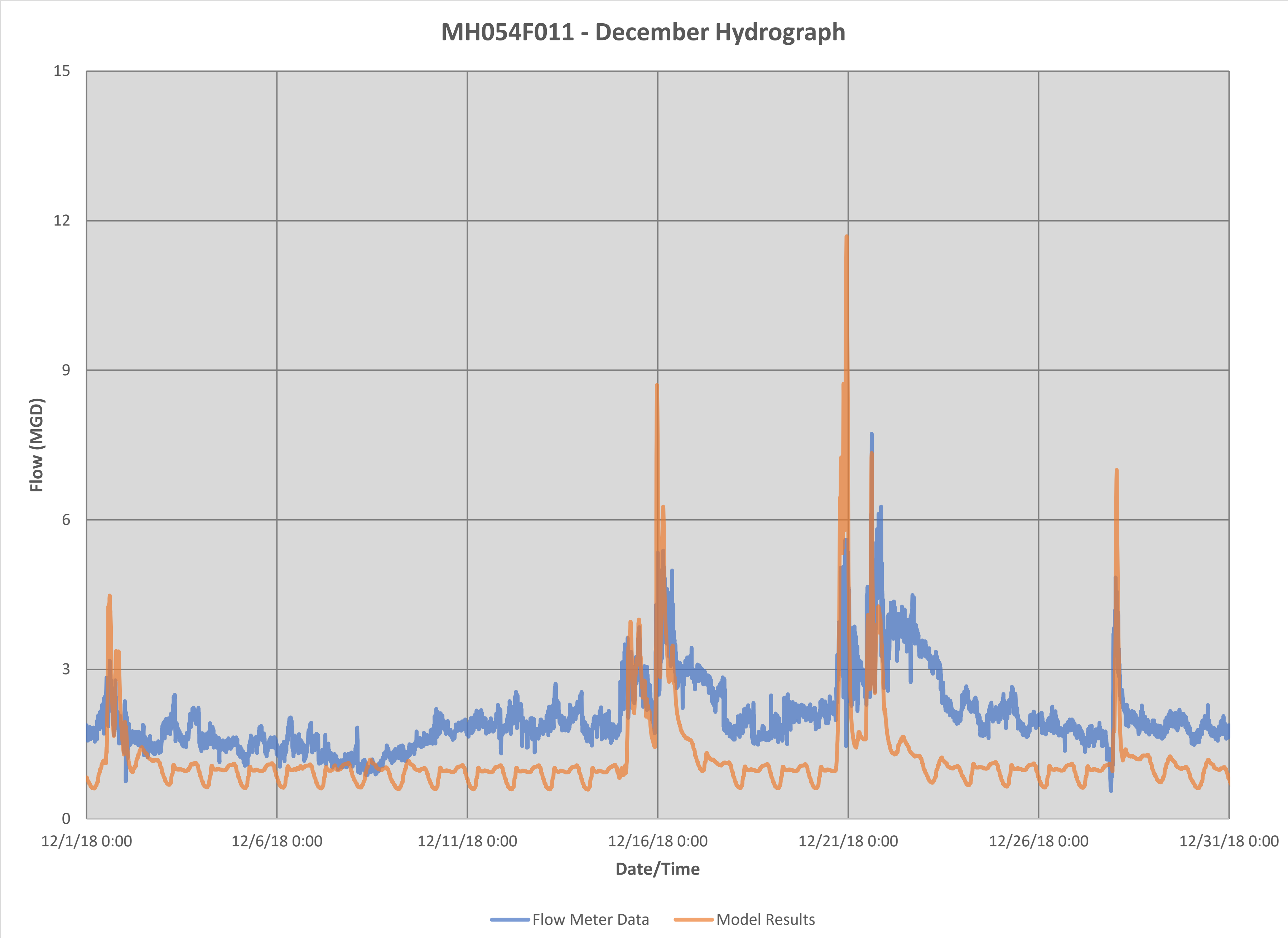


MH054F011 - August Hydrograph
Flow (MGD)
25
20
15
10
5
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results


MH054F011 - September Hydrograph
Flow (MGD)
50
40
30
20
10
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH054F011 - October Hydrograph
35
28
21
14
7
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH054F011 - November Hydrograph
Flow (MGD)
15
12
9
6
3
0
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results


MH054F011 - December Hydrograph
15
12
9
6
3
0
Flow (MGD)
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH054F012 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	4.32	4.83	**-10.7%**
Volume - MG	13.76	15.57	**-11.6%**
Depth (Avg) - in	3.24	2.70	**0.5**

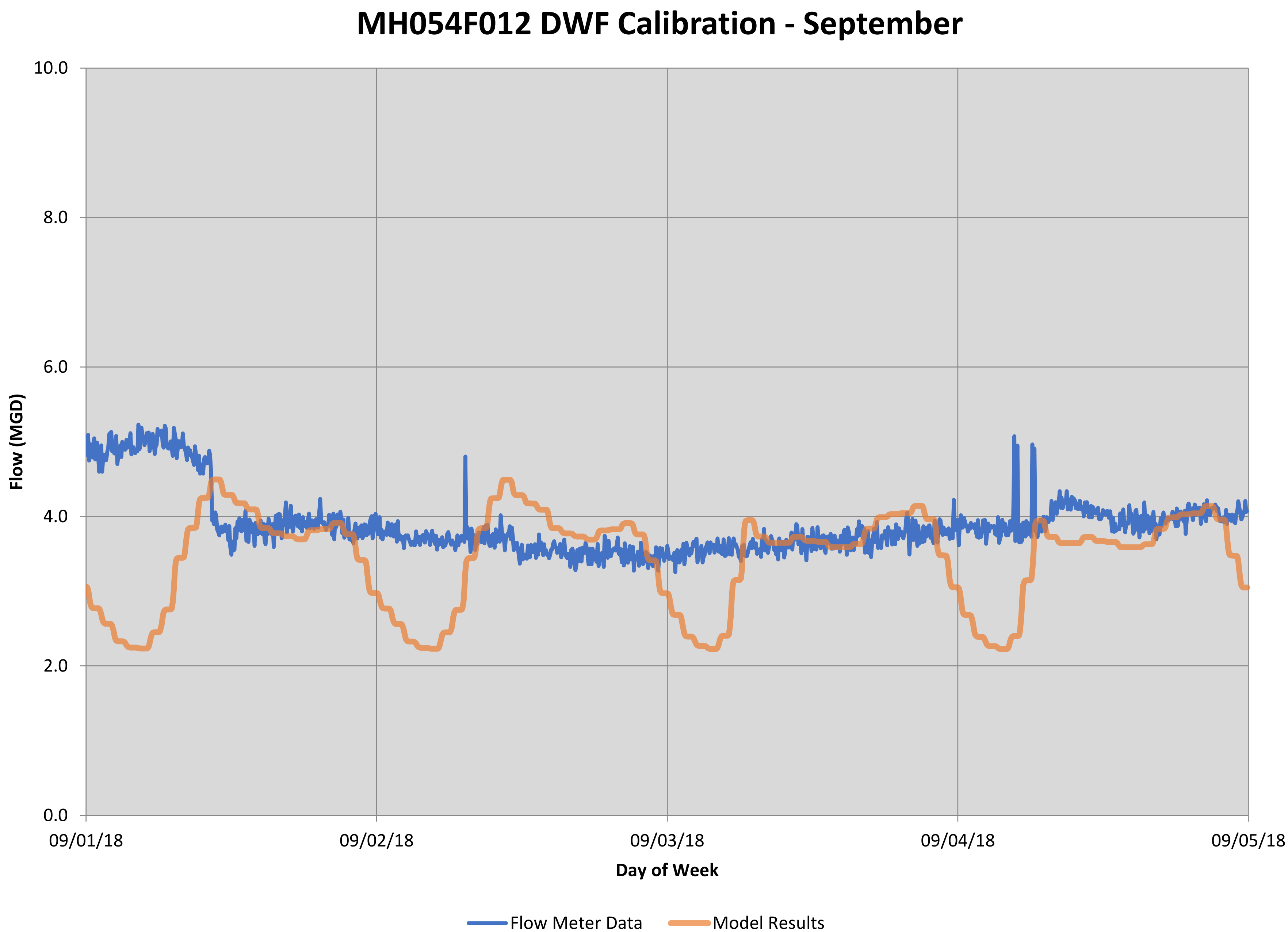
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	4.49	5.23
9/2/18	4.49	4.80
9/3/18	4.14	4.22
9/4/18	4.14	5.08

DWF Calibration Statistics MH054F012 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	4.16	4.20	**-1.0%**
Volume - MG	13.92	13.93	**-0.1%**
Depth (Avg) - in	3.26	2.99	**0.3**

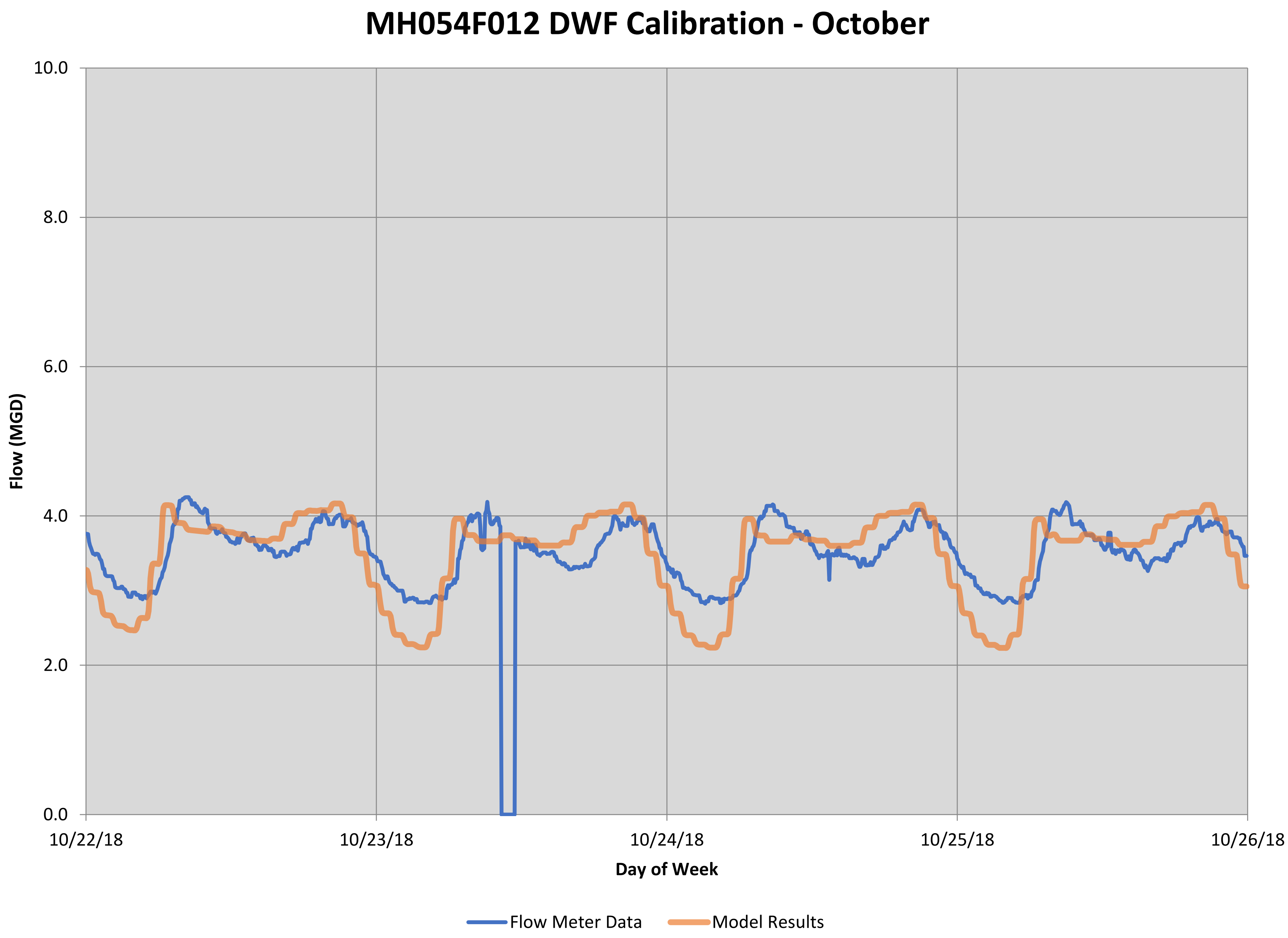
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	4.17	4.25
10/23/18	4.16	4.19
10/24/18	4.15	4.15
10/25/18	4.15	4.19

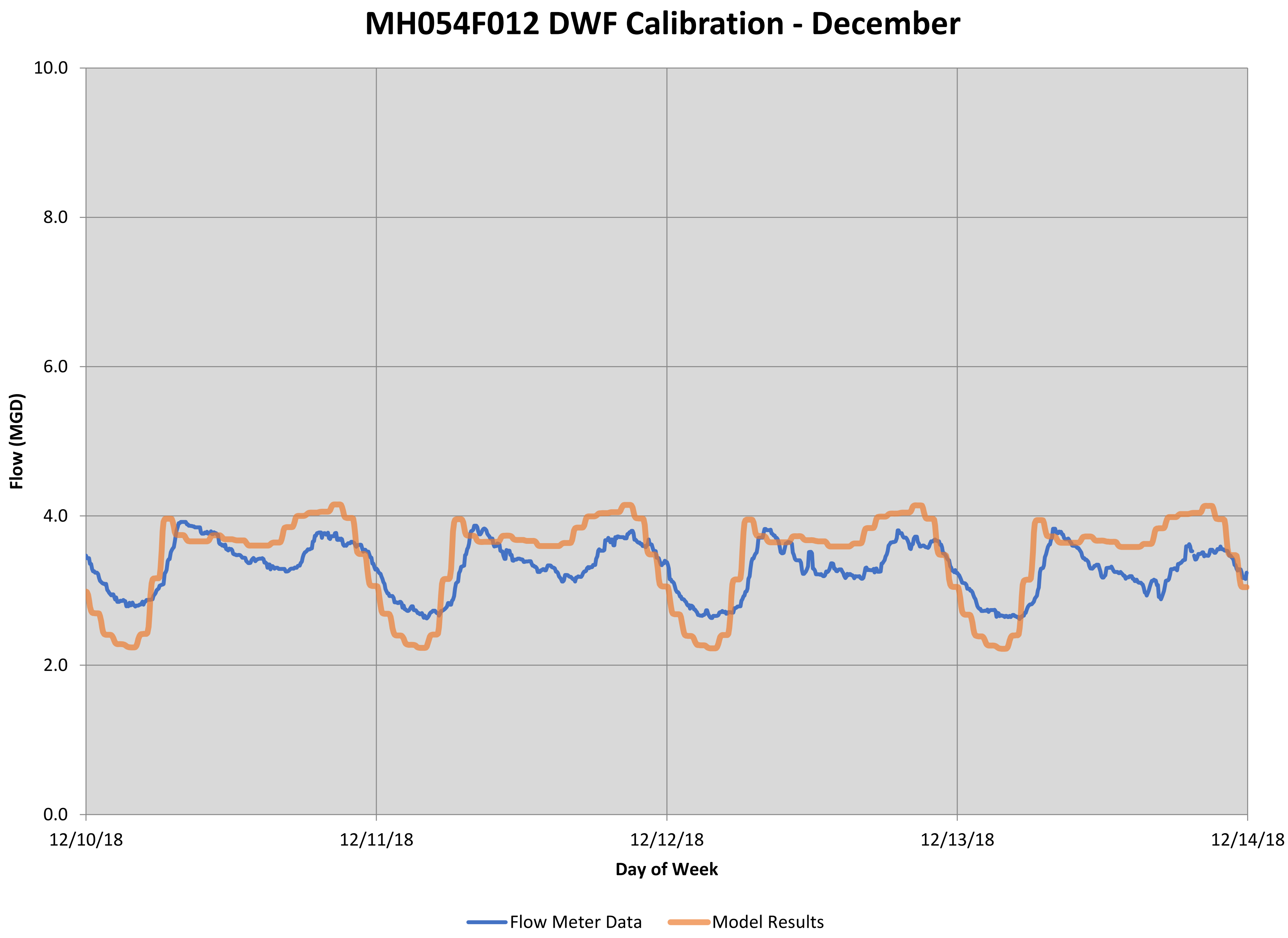
DWF Calibration Statistics MH054F012 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	4.14	3.86	**7.4%**
Volume - MG	13.77	13.20	**4.3%**
Depth (Avg) - in	3.24	2.93	**0.3**

DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	4.15	3.92
12/11/18	4.15	3.87
12/12/18	4.14	3.83
12/13/18	4.14	3.83



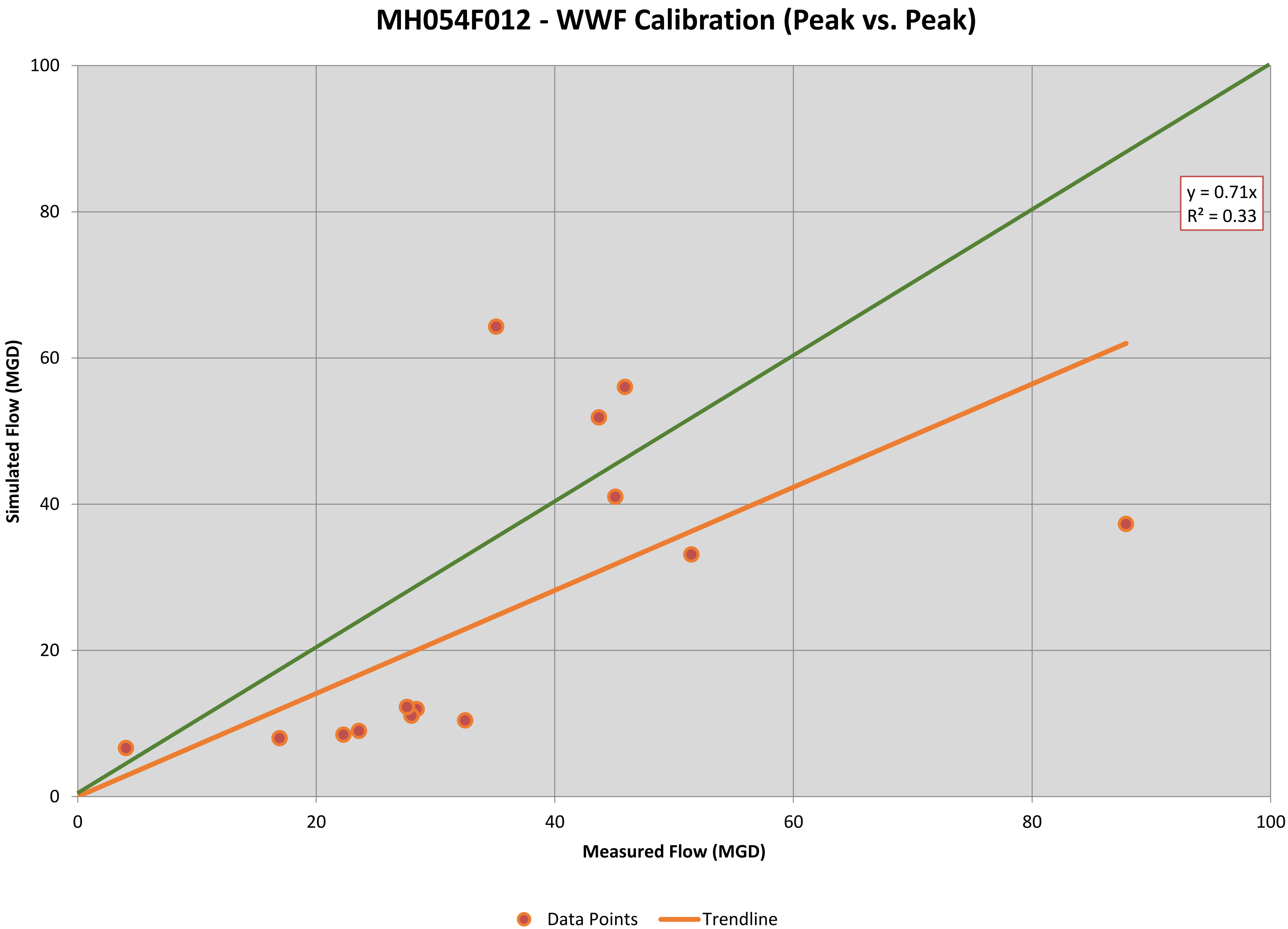
MH054F012 DWF Calibration - September
10.0
8.0
6.0
4.0
2.0
0.0
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

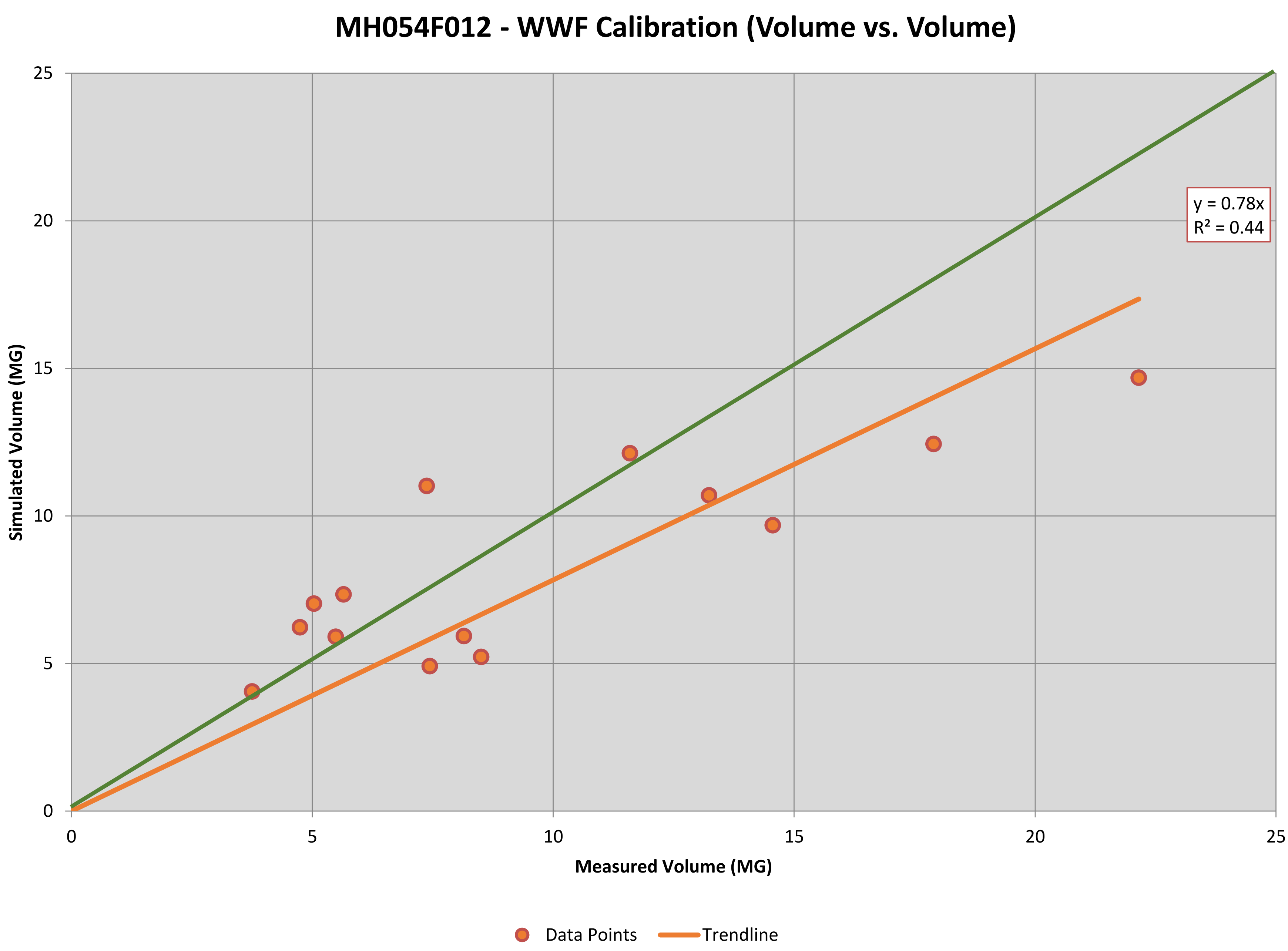

MH054F012 DWF Calibration - October
Flow (MGD)
10.0
8.0
6.0
4.0
2.0
0.0
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

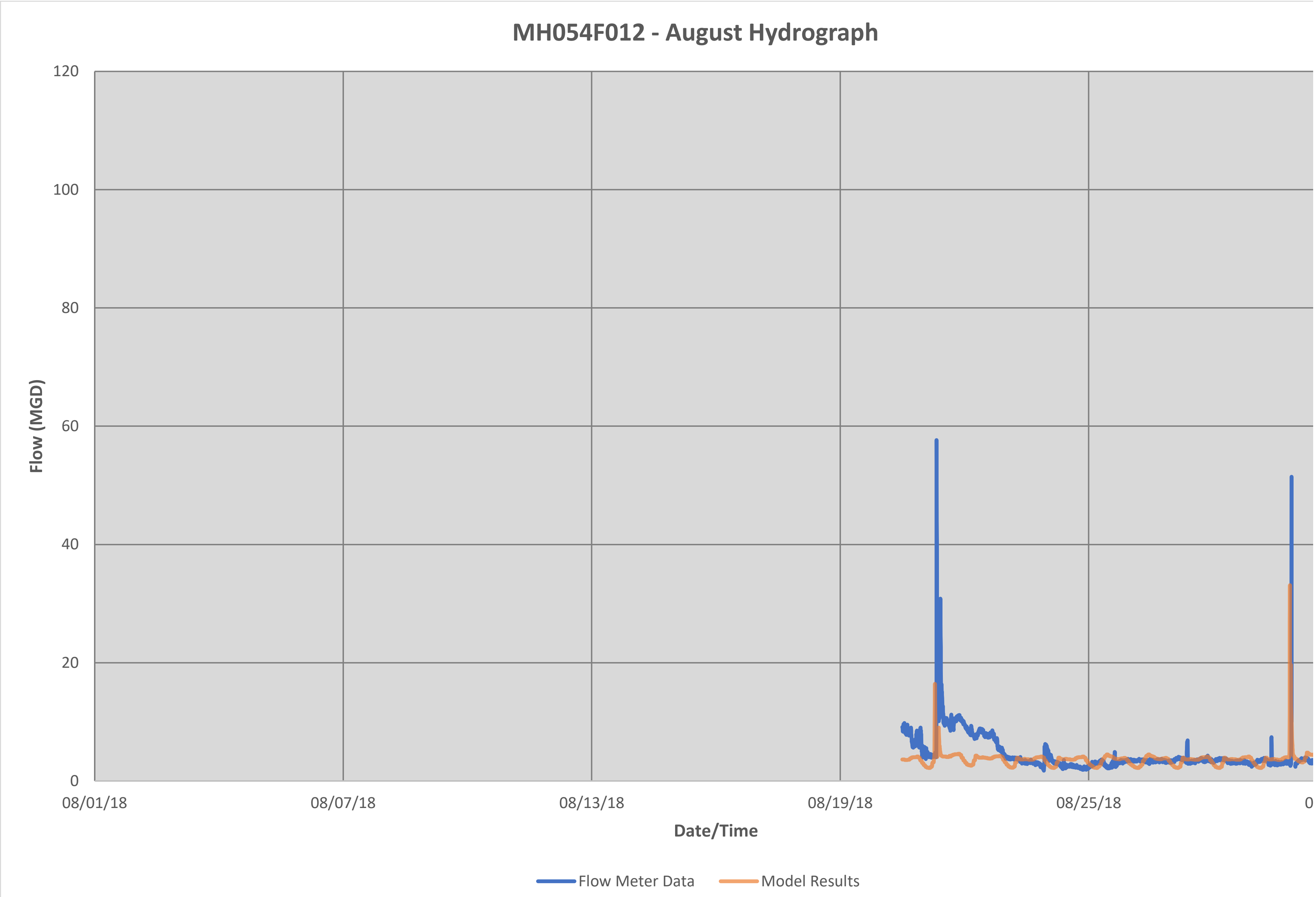


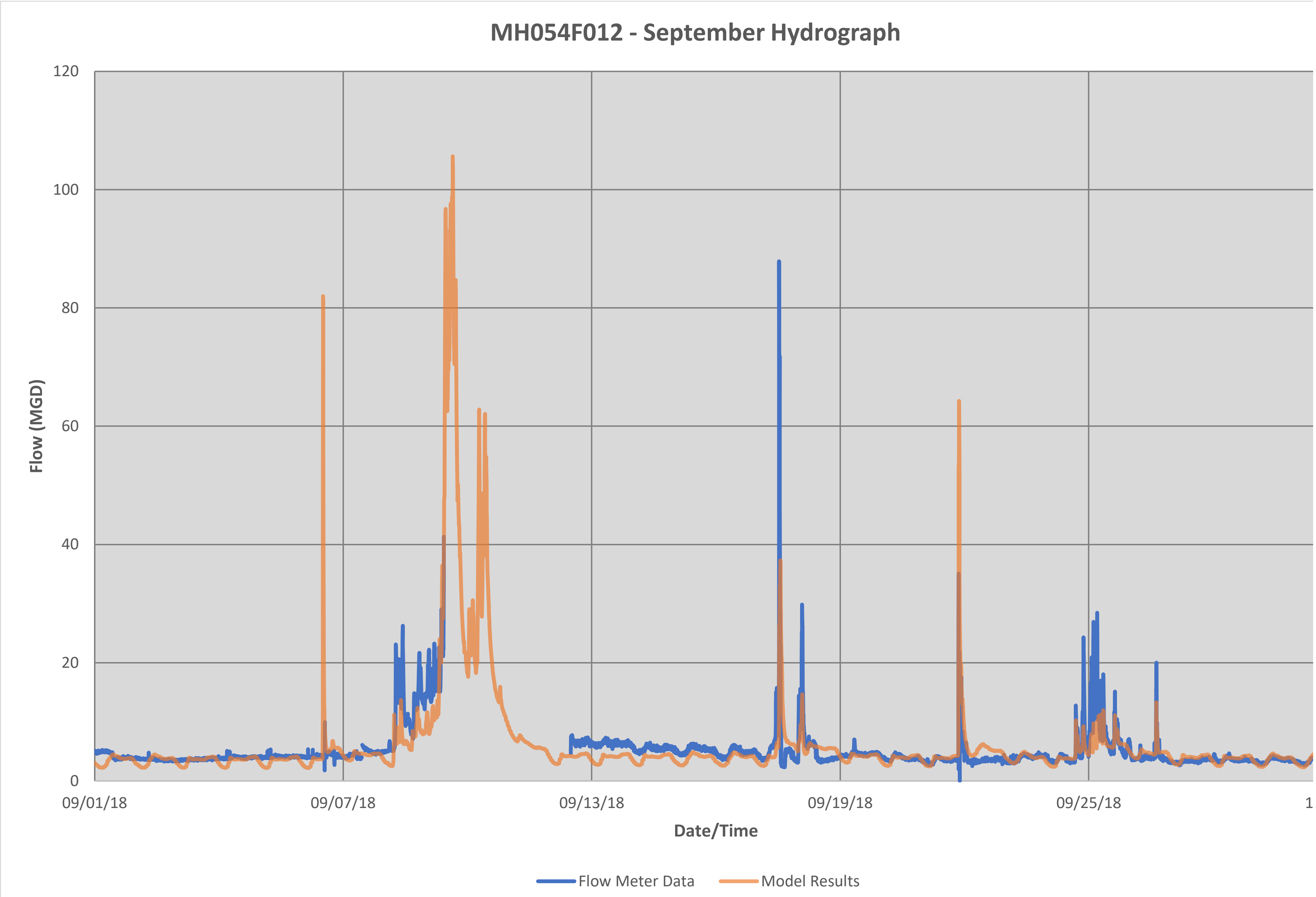
MH054F012 DWF Calibration - December
10.0
8.0
6.0
4.0
2.0
0.0
Flow (MGD)
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

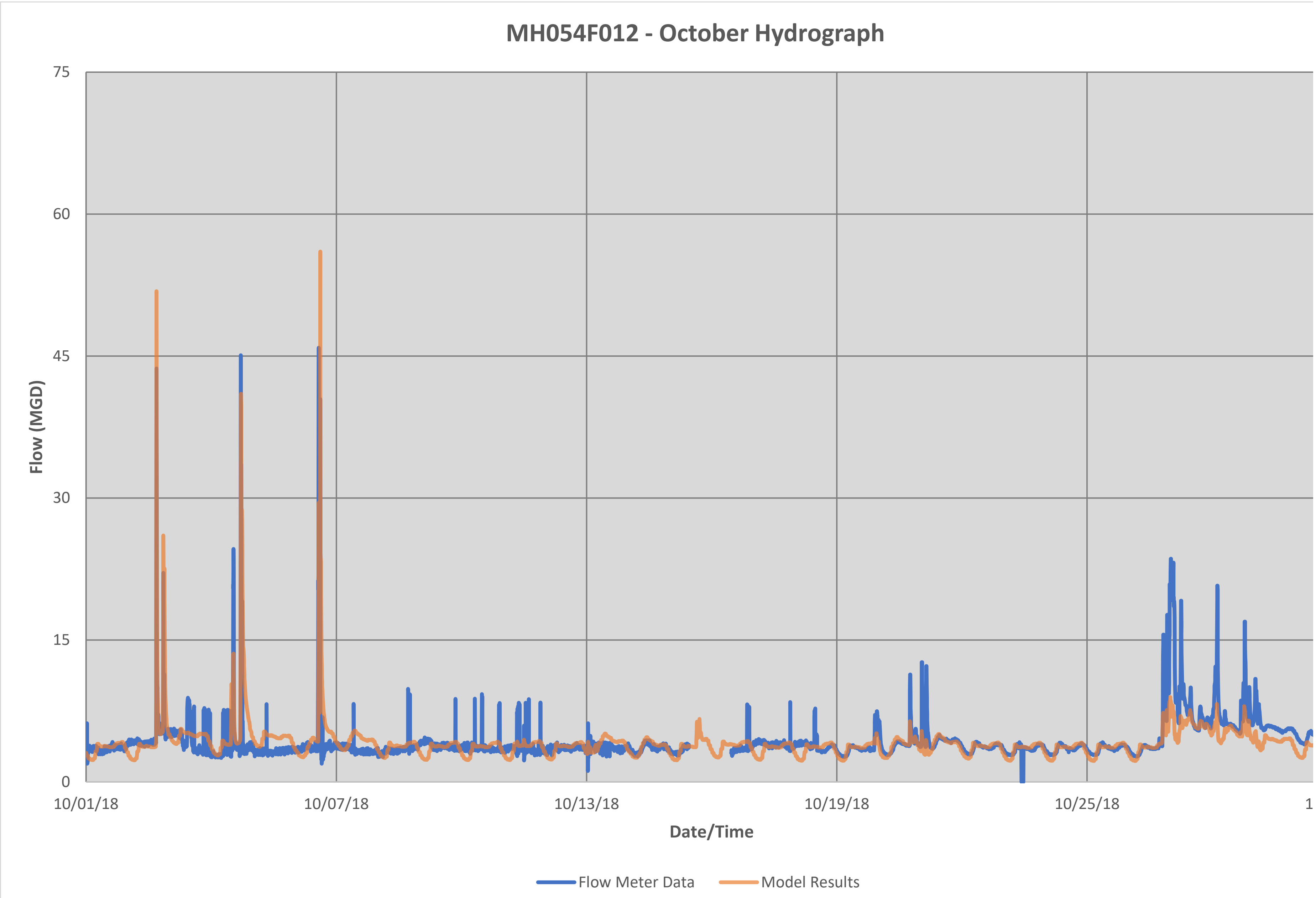
		MH054F012 - Wet Weather Calibration/Validation Stats								
Storm Date	Type	Peak Flow (MGD)			Storm Volume (MG)			Peak Depth (Inches)		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration	51.44	33.11	-35.6%	4.74	6.23	31.3%	12.9	10.8	-2.1
09/06/18	Validation									
09/07/18	Calibration									
09/17/18	Calibration	87.89	37.30	-57.6%	11.59	12.12	4.5%	15.3	11.6	-3.6
09/21/18	Validation	35.09	64.29	83.2%	7.38	11.01	49.3%	8.2	16.4	8.2
09/24/18	Validation	28.42	11.95	-58.0%	13.23	10.69	-19.2%	6.9	5.9	-1.0
10/02/18	Validation	43.70	51.86	18.7%	5.48	5.91	7.7%	10.8	14.4	3.5
10/04/18	Calibration	45.07	41.01	-9.0%	5.65	7.34	30.0%	11.1	12.3	1.2
10/06/18	Calibration	45.87	56.05	22.2%	5.03	7.03	39.6%	10.3	15.1	4.8
10/15/18	Calibration	4.05	6.65	64.2%	3.75	4.05	8.0%	2.9	4.3	1.4
10/26/18	Calibration	23.59	8.97	-62.0%	14.56	9.68	-33.5%	7.1	5.1	-2.0
10/28/18	Calibration	16.94	7.99	-52.8%	8.14	5.92	-27.3%	6.0	4.7	-1.3
11/09/18	Calibration	27.98	11.08	-60.4%	8.50	5.22	-38.6%	7.6	5.7	-1.9
11/15/18	Calibration	27.60	12.24	-55.7%	22.15	14.68	-33.7%	7.5	6.0	-1.5
11/18/18	Validation	22.29	8.45	-62.1%	17.90	12.44	-30.5%	6.9	4.9	-2.0
11/24/18	Validation	32.49	10.42	-67.9%	7.44	4.91	-34.0%	8.5	5.5	-3.0
Totals		492.4	361.3	-26.6%	135.6	117.2	-13.5%	122	123	0.7


MH054F012 - WWF Calibration (Peak vs. Peak)
100
80
60
40
20
0
Simulated Flow (MGD)
0
20
40
60
80
100
Measured Flow (MGD)
y = 0.71x
R² = 0.33
Data Points
Trendline

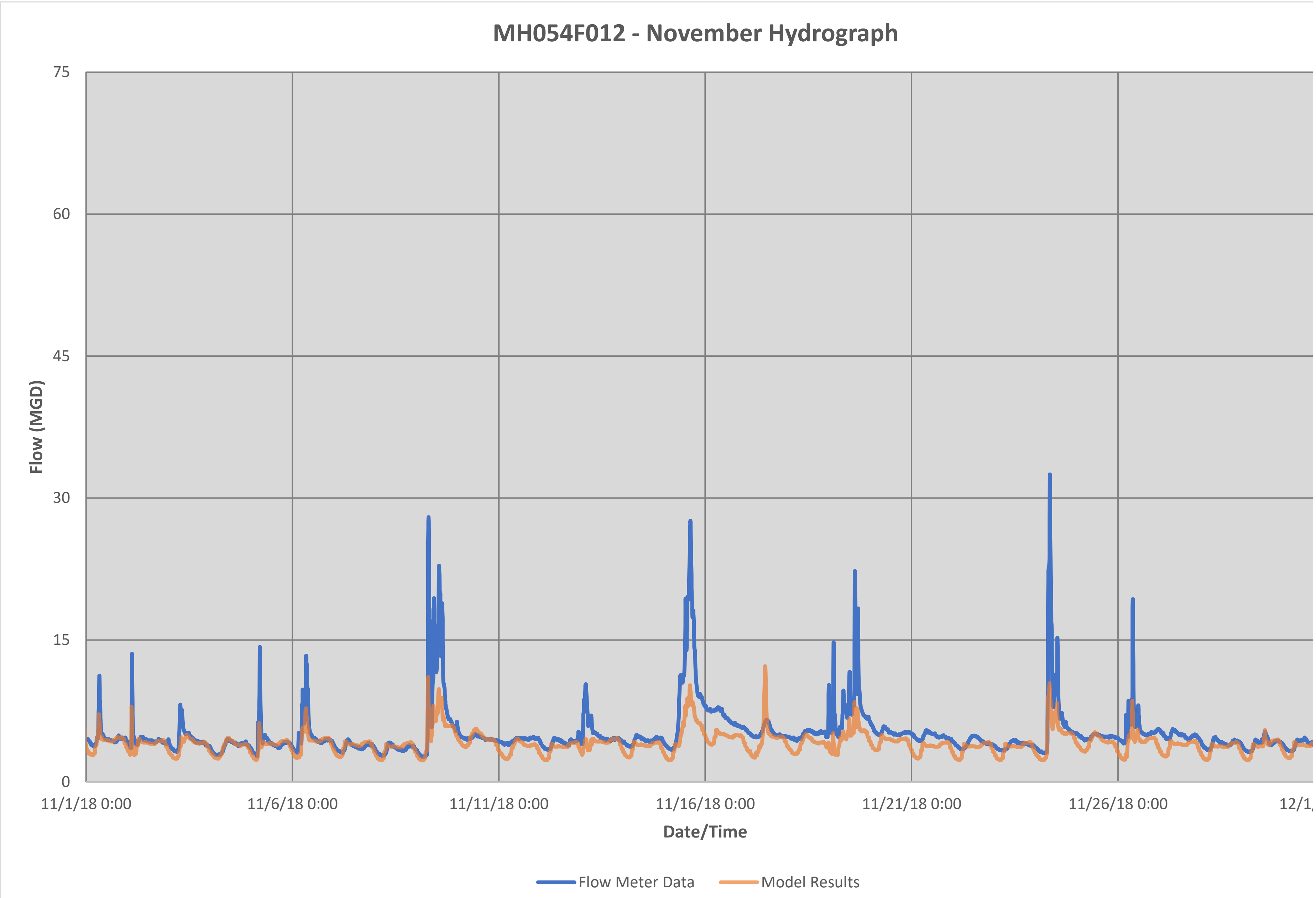

MH054F012 - WWF Calibration (Volume vs. Volume)
y = 0.78x
R² = 0.44
Simulated Volume (MG)
Measured Volume (MG)
0
5
10
15
20
25
Data Points
Trendline

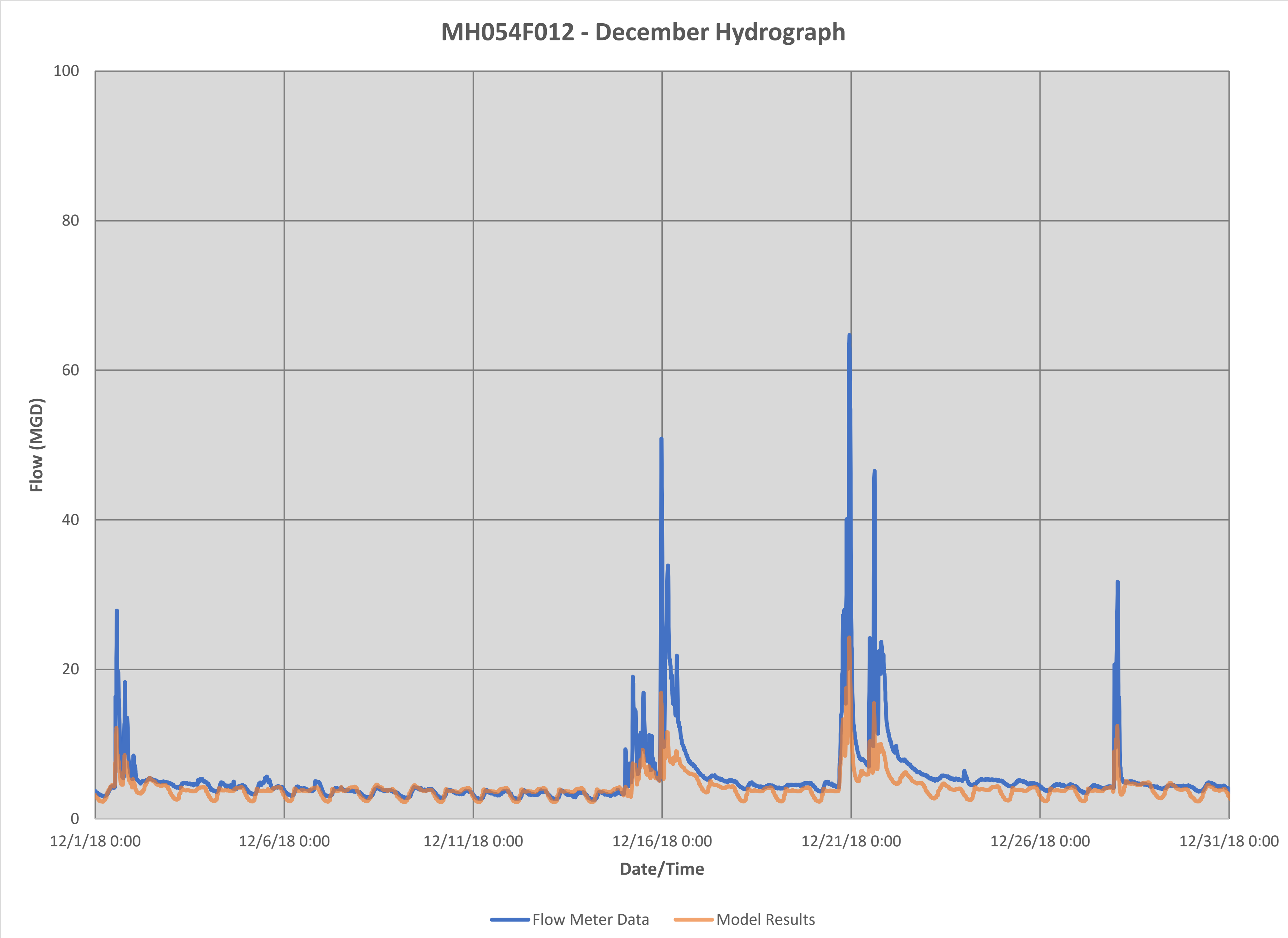

MH054F012 - August Hydrograph
120
100
80
60
40
20
0
Flow (MGD)
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results


MH054F012 - September Hydrograph
120
100
80
60
40
20
0
Flow (MGD)
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results

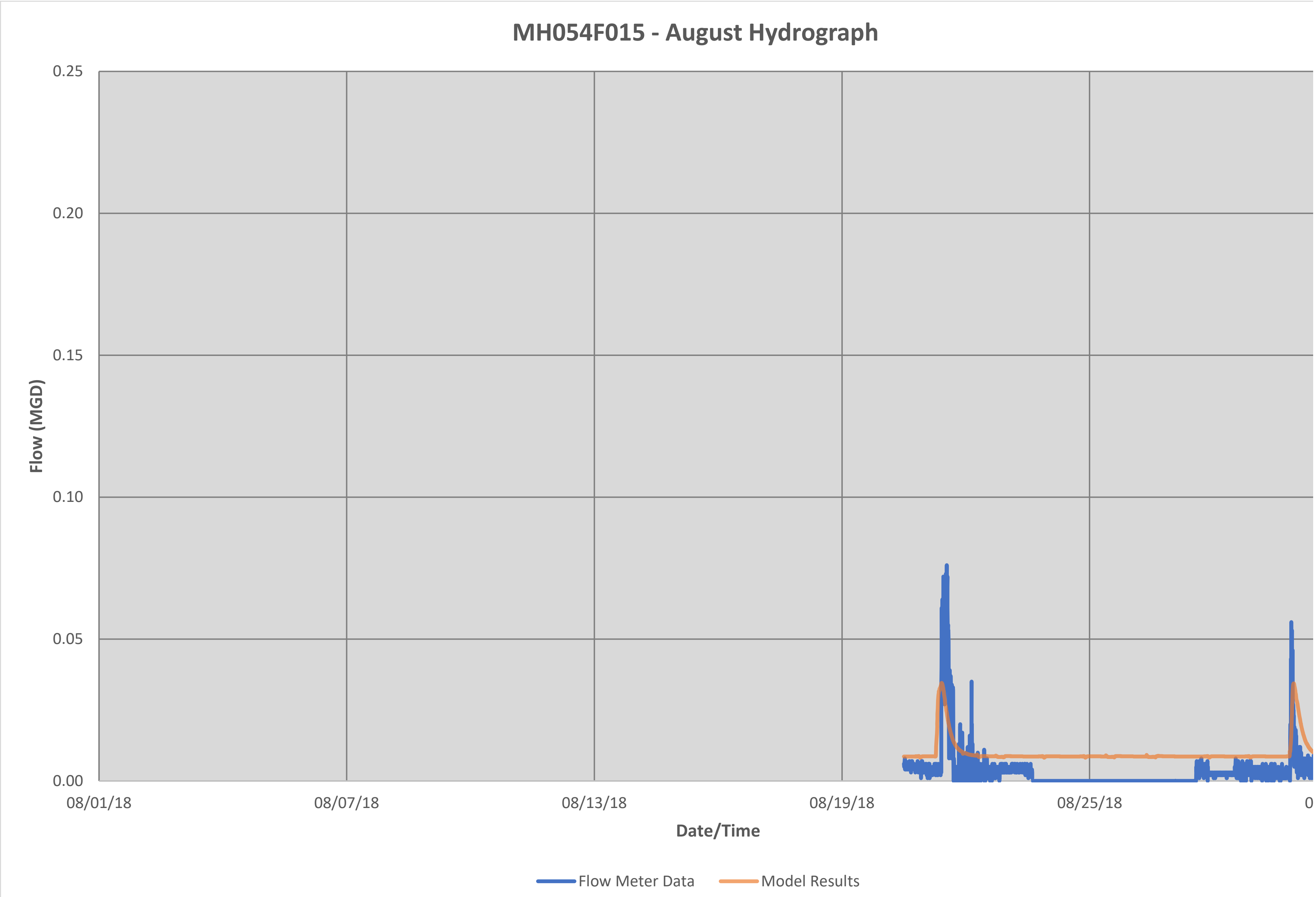


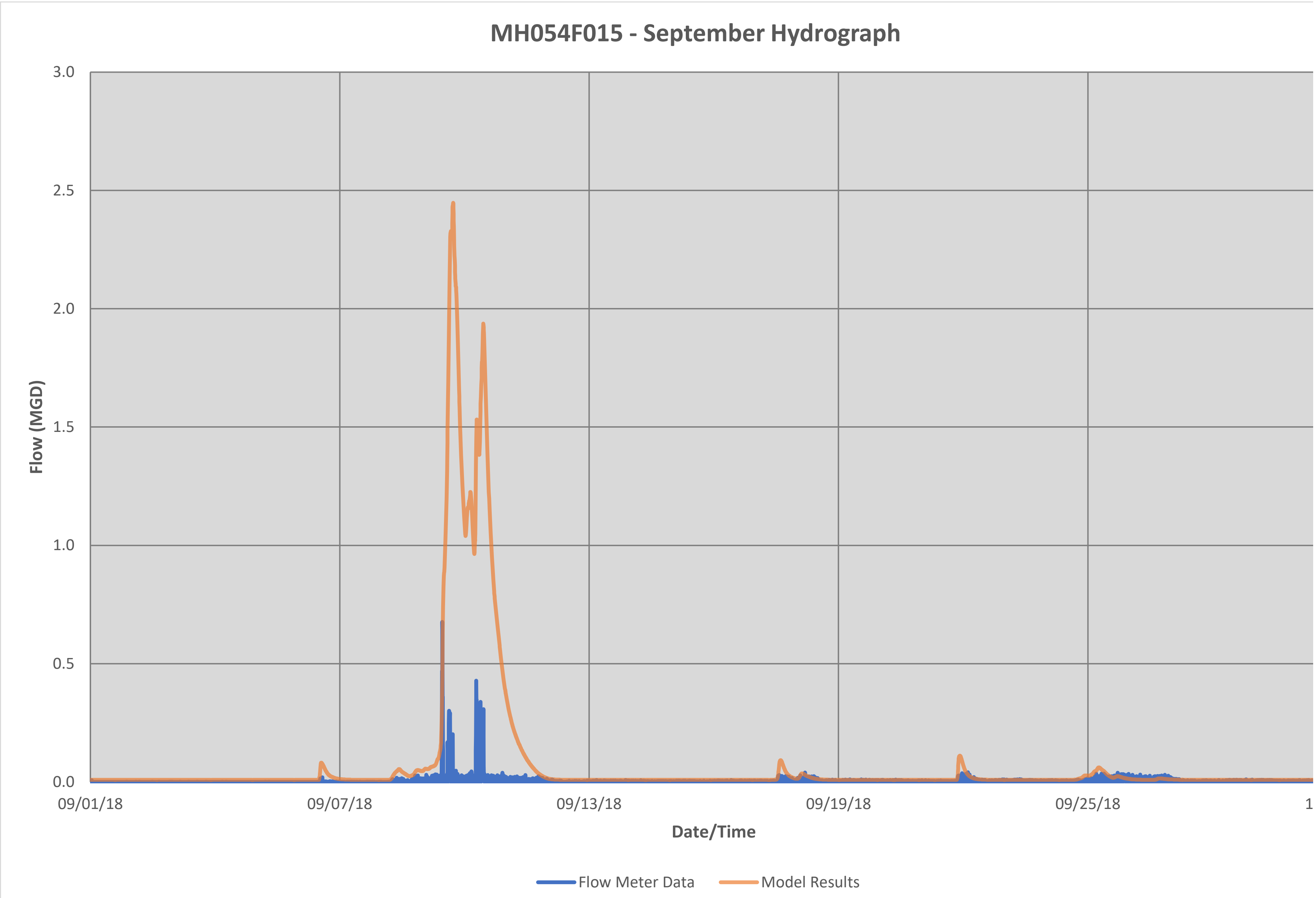
MH054F012 - October Hydrograph
Flow (MGD)
75
60
45
30
15
0
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH054F012 - November Hydrograph
75
60
45
30
15
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
12/1,
Date/Time
Flow Meter Data
Model Results

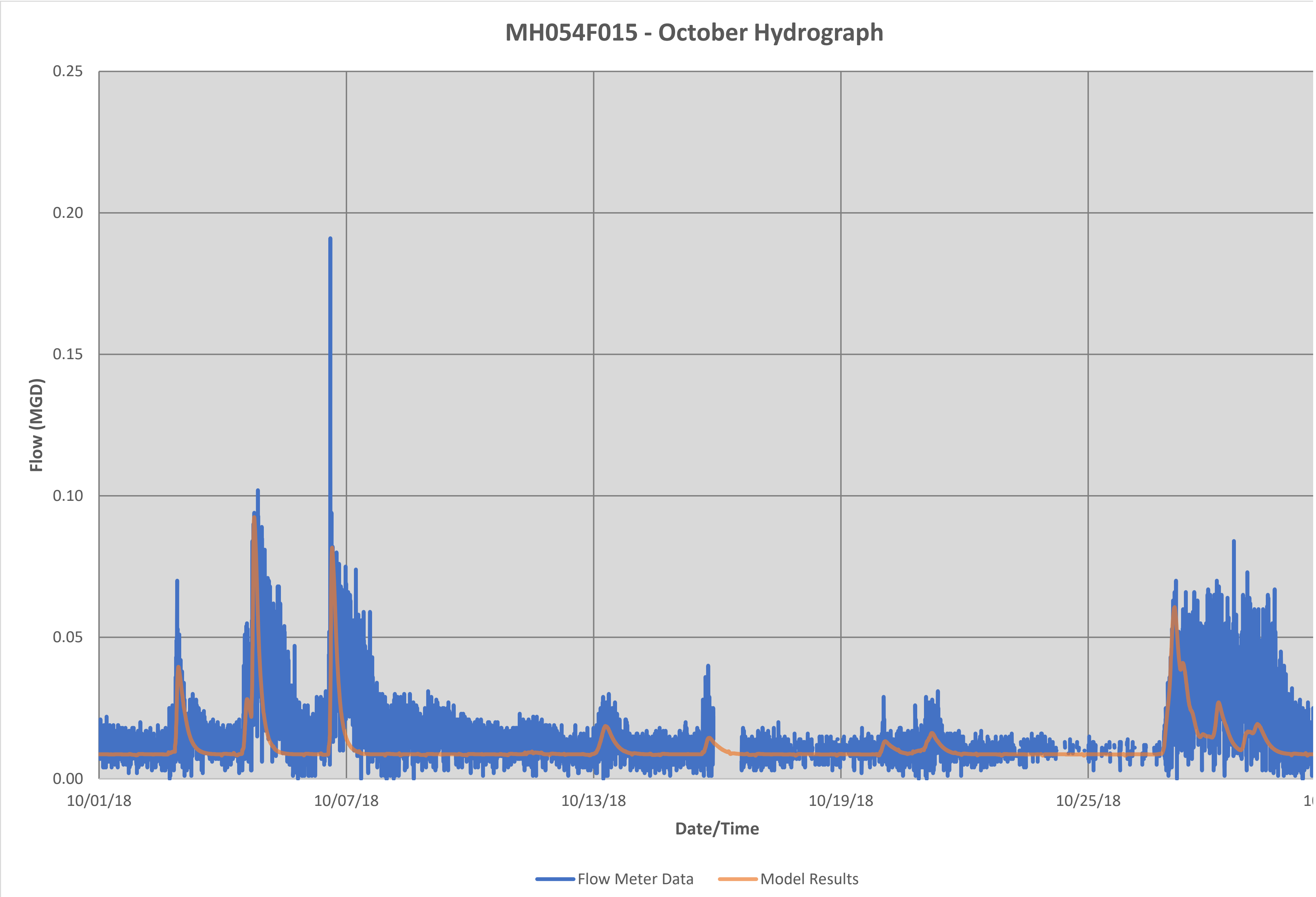


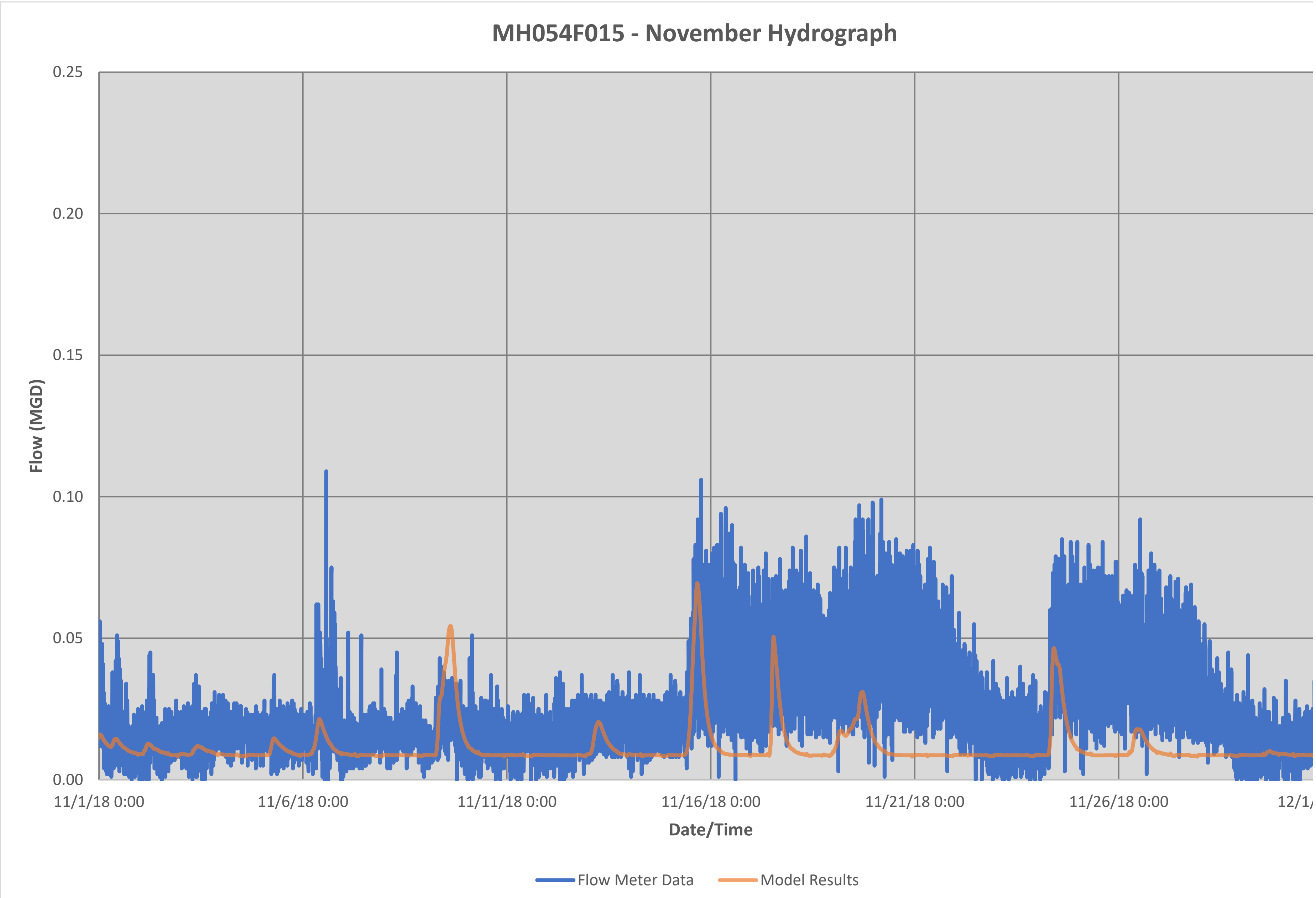
MH054F012 - December Hydrograph
Flow (MGD)
100
80
60
40
20
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

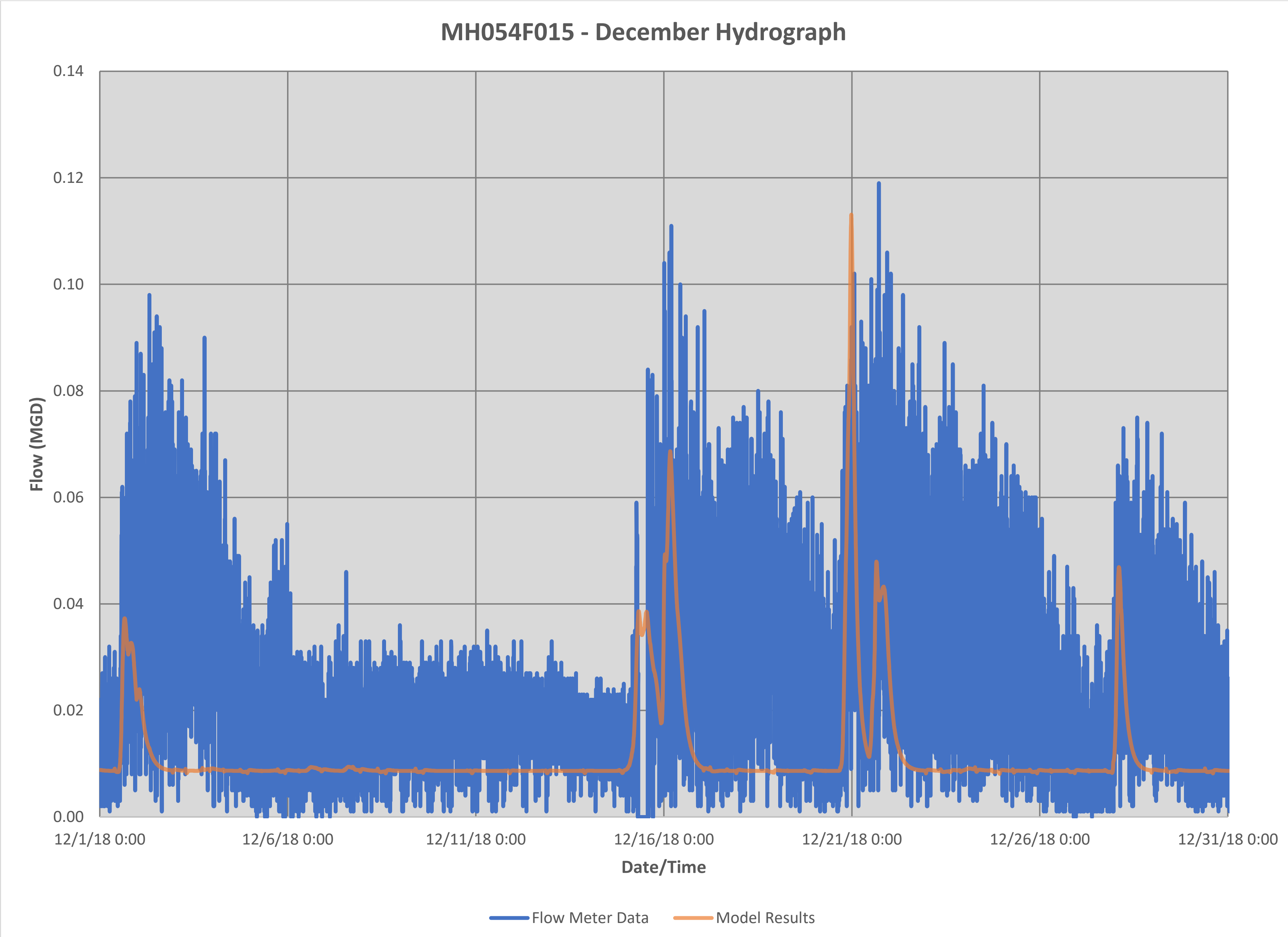

MH054F015 - August Hydrograph
Flow (MGD)
0.25
0.20
0.15
0.10
0.05
0.00
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results



MH054F015 - September Hydrograph
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Flow (MGD)
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results


MH054F015 - October Hydrograph
0.25
0.20
0.15
0.10
0.05
0.00
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
Date/Time
Flow Meter Data
Model Results


MH054F015 - November Hydrograph
Flow (MGD)
0.25
0.20
0.15
0.10
0.05
0.00
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
Date/Time
Flow Meter Data
Model Results


MH054F015 - December Hydrograph
Flow (MGD)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

DWF Calibration Statistics MH054J015 - September			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.03	0.99	**4.5%**
Volume - MG	3.81	3.20	**18.9%**
Depth (Avg) - in	2.17	2.22	**-0.1**

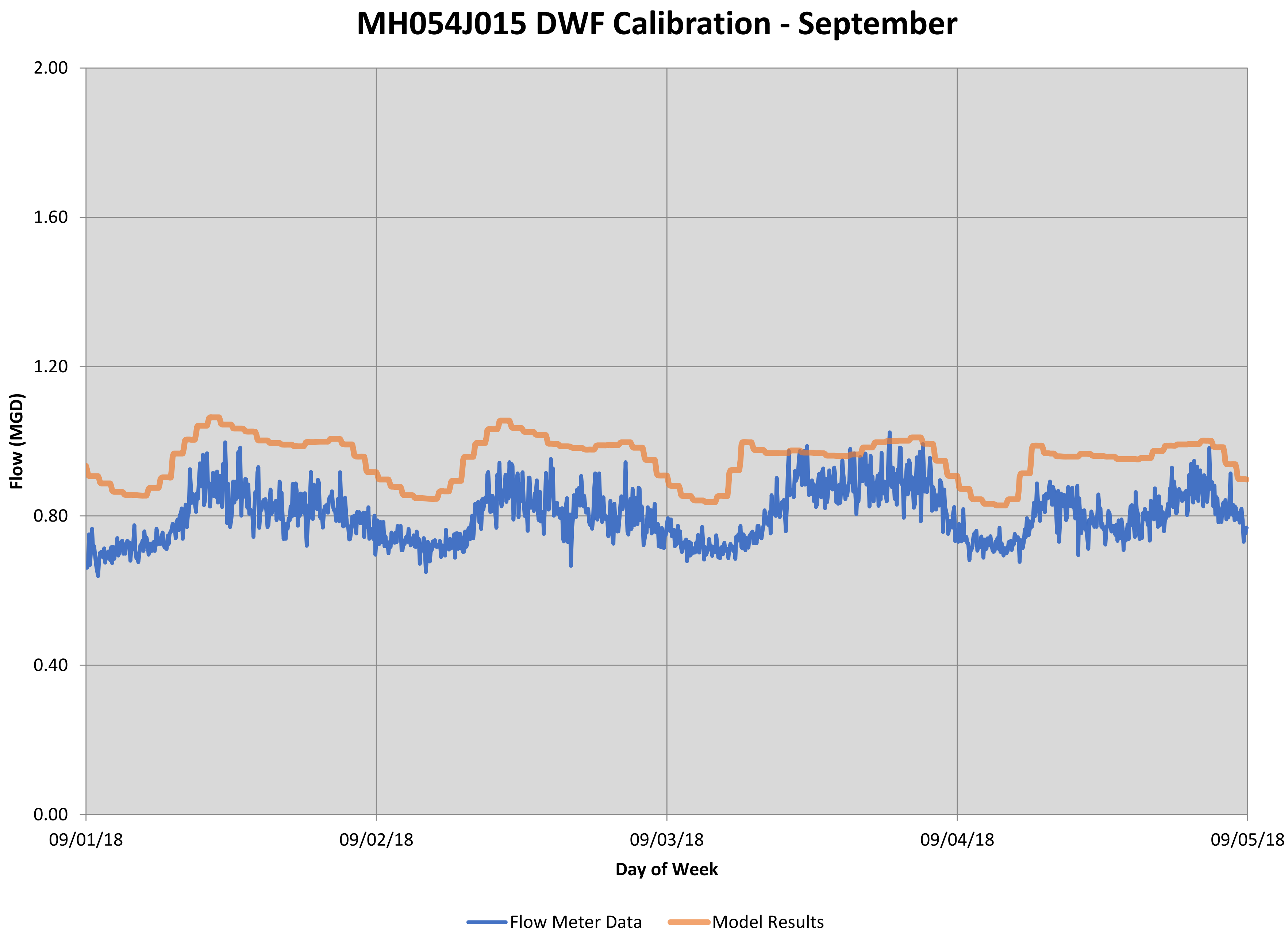
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
9/1/18	1.06	1.00
9/2/18	1.06	0.95
9/3/18	1.01	1.02
9/4/18	1.00	0.98

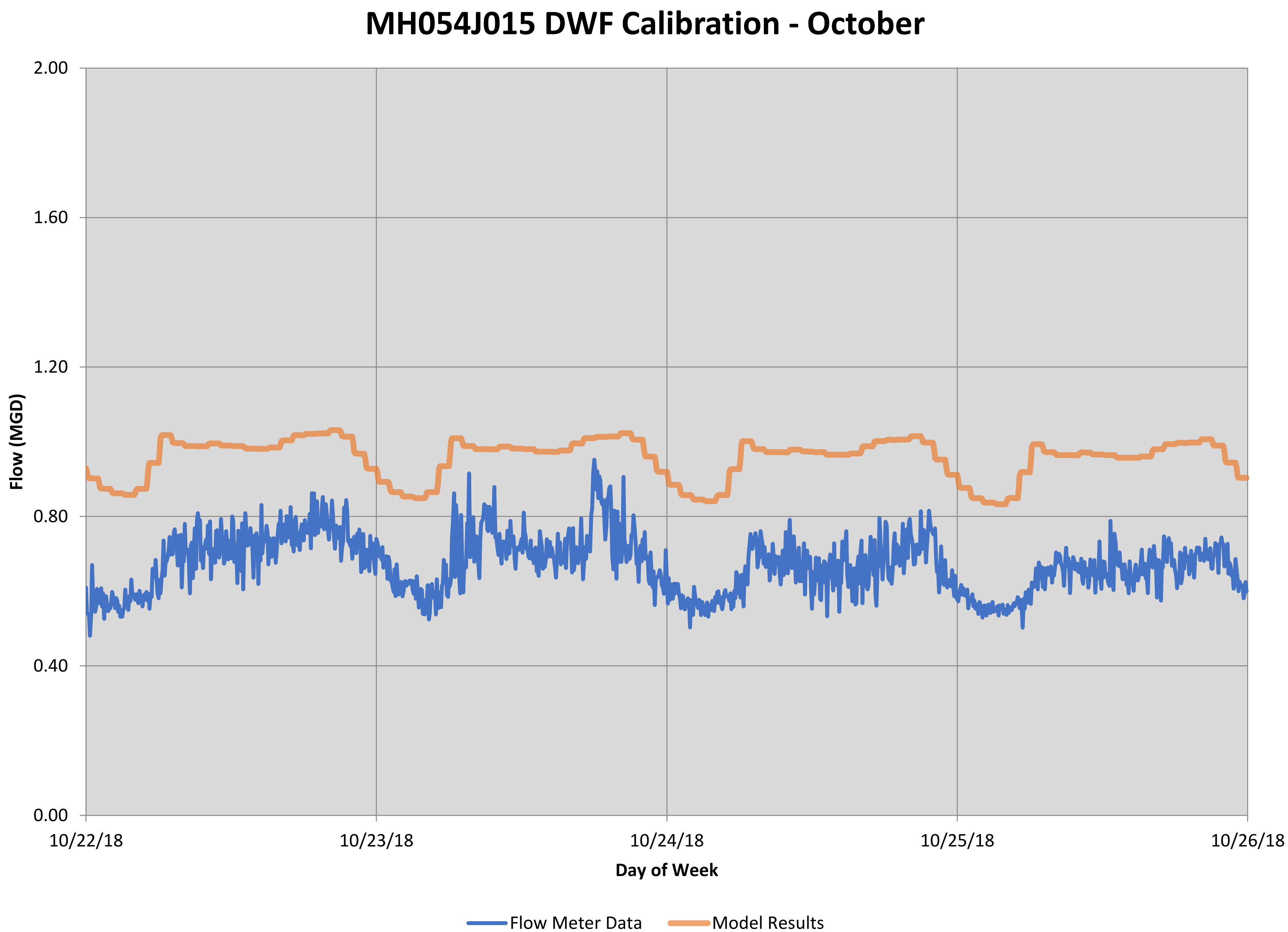
DWF Calibration Statistics MH054J015 - October			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.02	0.85	**19.3%**
Volume - MG	3.82	2.68	**42.4%**
Depth (Avg) - in	2.17	2.13	**0.0**

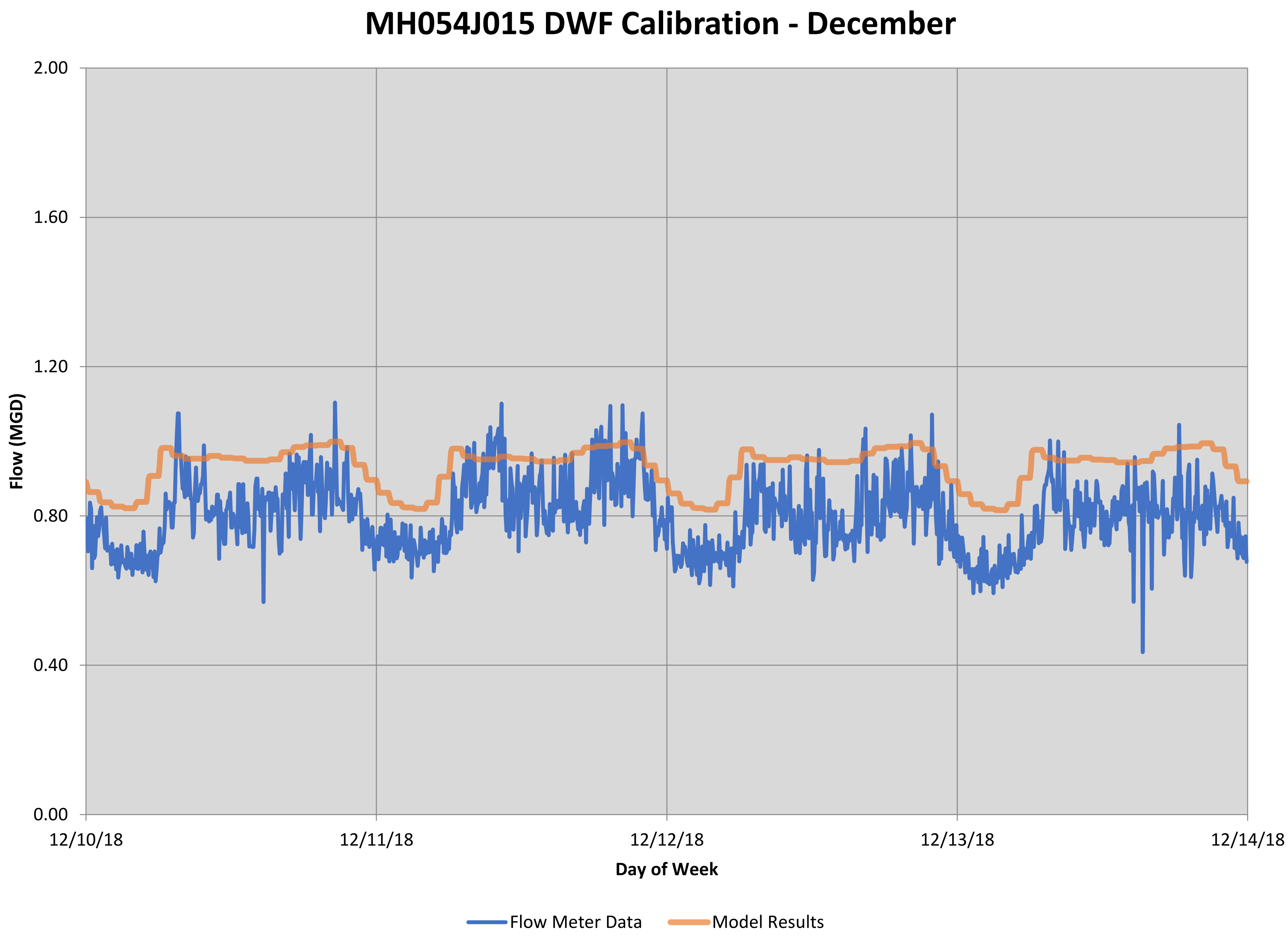
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
10/22/18	1.03	0.86
10/23/18	1.02	0.95
10/24/18	1.01	0.82
10/25/18	1.01	0.79

DWF Calibration Statistics MH054J015 - December			
Category	**Simulated**	**Measured**	**Difference**
Peak Flow (Avg) - MGD	1.00	1.08	**-7.7%**
Volume - MG	3.72	3.19	**16.6%**
Depth (Avg) - in	2.14	2.32	**-0.2**

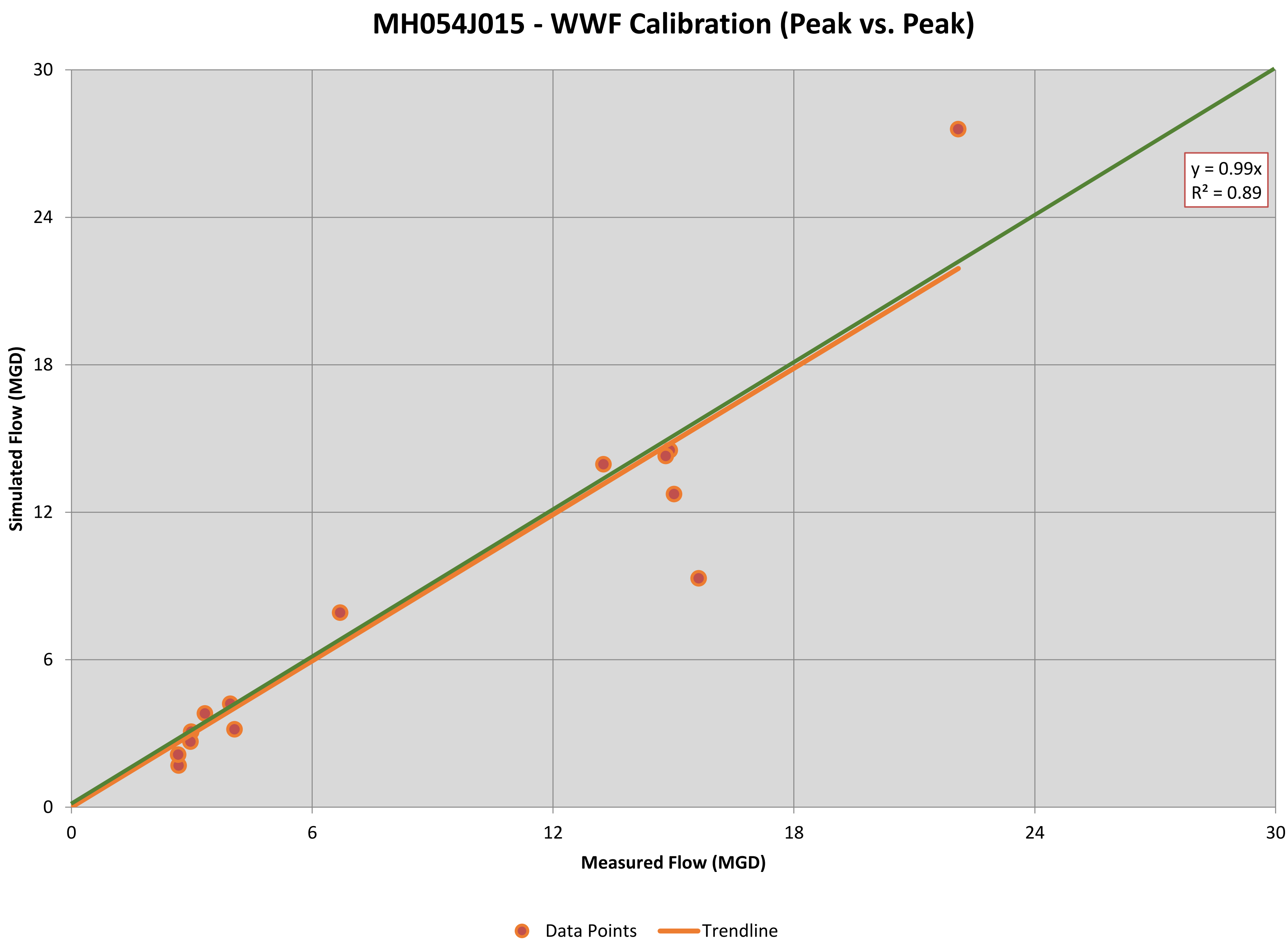
DWF Daily Peak Flows (MGD)		
DWF Day	**Simulated**	**Measured**
12/10/18	1.00	1.10
12/11/18	1.00	1.10
12/12/18	1.00	1.07
12/13/18	1.00	1.04


MH054J015 DWF Calibration - September
2.00
1.60
1.20
0.80
0.40
0.00
Flow (MGD)
09/01/18
09/02/18
09/03/18
09/04/18
09/05/18
Day of Week
Flow Meter Data
Model Results

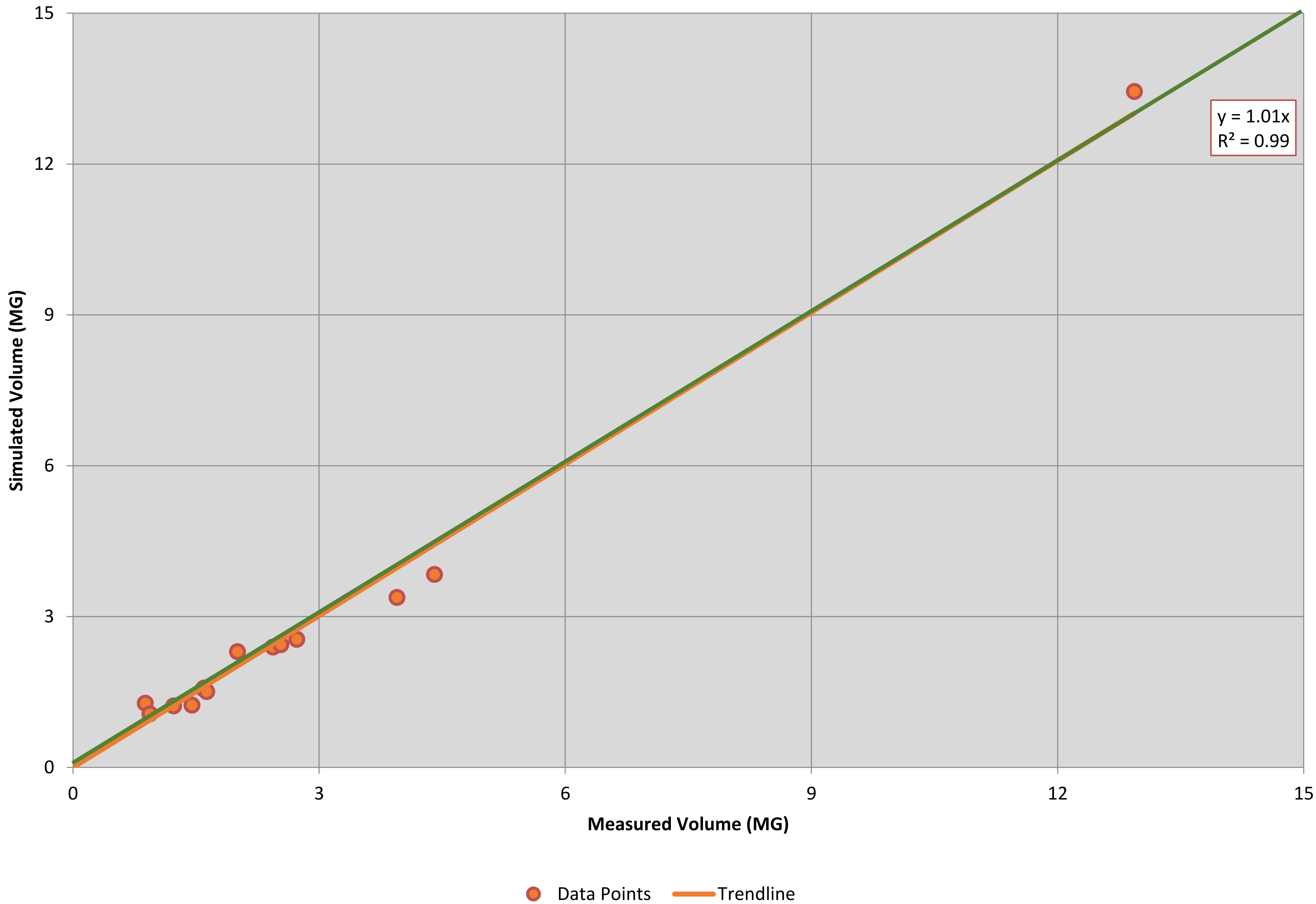

MH054J015 DWF Calibration - October
2.00
1.60
1.20
0.80
0.40
0.00
Flow (MGD)
10/22/18
10/23/18
10/24/18
10/25/18
10/26/18
Day of Week
Flow Meter Data
Model Results

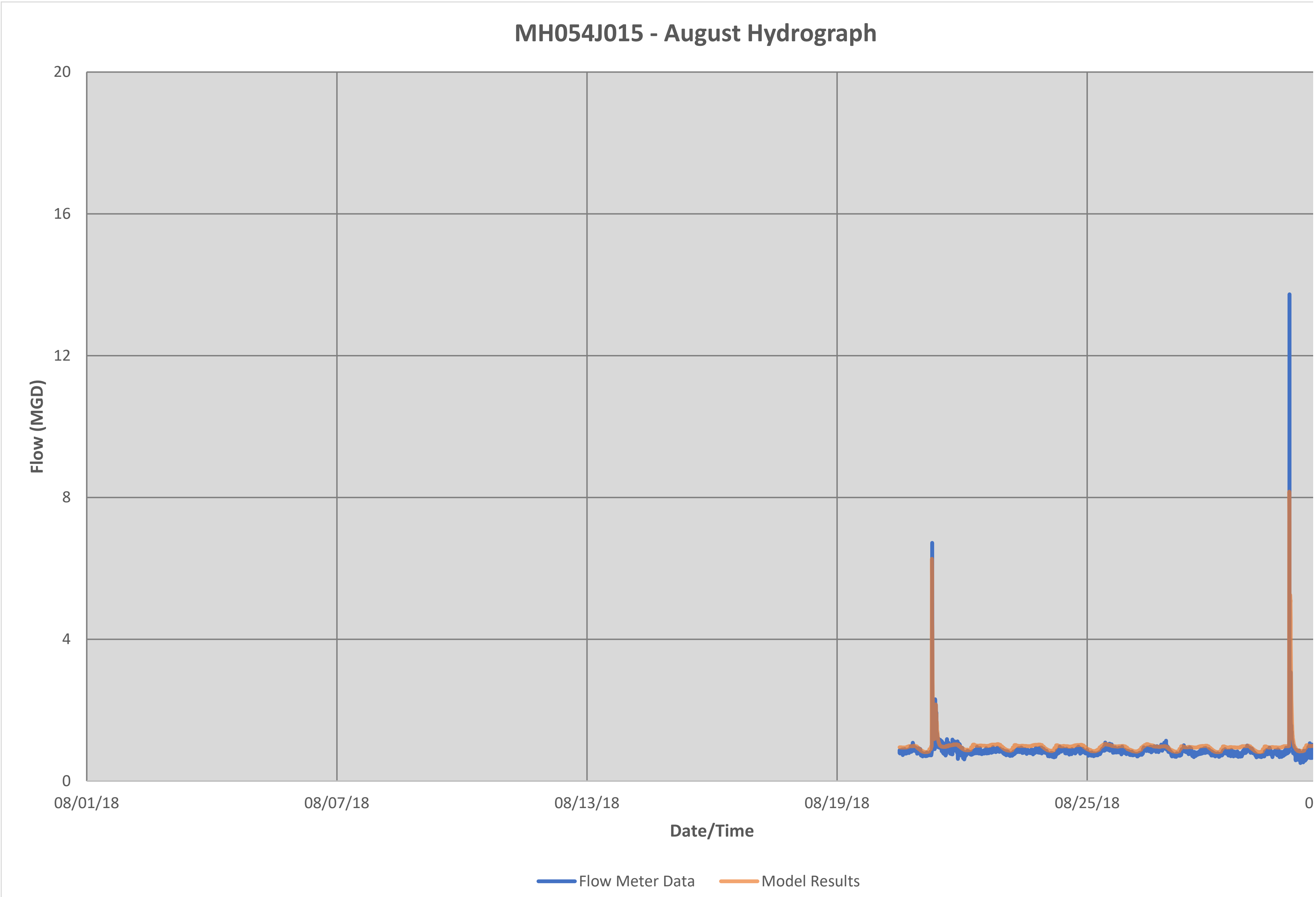

MH054J015 DWF Calibration - December
Flow (MGD)
2.00
1.60
1.20
0.80
0.40
0.00
12/10/18
12/11/18
12/12/18
12/13/18
12/14/18
Day of Week
Flow Meter Data
Model Results

		MH054J015 - Wet Weather Calibration/Validation Stats								
Storm Date	**Type**	**Peak Flow (MGD)**			**Storm Volume (MG)**			**Peak Depth (Inches)**		
		Measured	Simulated	% Diff.	Measured	Simulated	% Diff.	Measured	Simulated	Diff.
08/29/18	Calibration									
09/06/18	Validation	22.10	27.58	**24.8%**	0.88	1.28	**44.6%**	14.7	12.8	**-1.9**
09/07/18	Calibration	14.91	14.51	**-2.7%**	12.94	13.44	**3.9%**	30.6	15.1	**-15.6**
09/17/18	Calibration	6.70	7.92	**18.2%**	2.44	2.39	**-1.9%**	6.6	6.0	**-0.6**
09/21/18	Validation	14.81	14.29	**-3.5%**	2.01	2.30	**14.5%**	11.5	8.2	**-3.3**
09/24/18	Validation	4.07	3.16	**-22.3%**	2.73	2.55	**-6.7%**	4.8	3.8	**-0.9**
10/02/18	Validation	15.63	9.31	**-40.5%**	1.23	1.22	**-0.4%**	13.3	6.5	**-6.8**
10/04/18	Calibration	13.26	13.95	**5.3%**	1.59	1.56	**-1.7%**	9.9	8.2	**-1.8**
10/06/18	Calibration	15.02	12.74	**-15.2%**	1.60	1.58	**-1.5%**	10.0	7.7	**-2.3**
10/15/18	Calibration	2.67	1.70	**-36.5%**	0.94	1.06	**13.3%**	3.9	2.9	**-1.1**
10/26/18	Calibration	2.99	3.07	**2.9%**	2.53	2.44	**-3.7%**	4.2	3.8	**-0.4**
10/28/18	Calibration	2.66	2.13	**-19.9%**	1.63	1.51	**-7.6%**	3.9	3.2	**-0.7**
11/09/18	Calibration									
11/15/18	Calibration	3.33	3.81	**14.6%**	4.41	3.84	**-13.0%**	4.4	4.2	**-0.2**
11/18/18	Validation	2.97	2.66	**-10.2%**	3.95	3.38	**-14.4%**	4.2	3.5	**-0.6**
11/24/18	Validation	3.96	4.21	**6.3%**	1.45	1.23	**-15.0%**	4.7	4.4	**-0.3**
Totals		**125.0**	**121.0**	**6.3%**	**40.3**	**39.8**	**-1.4%**	**127**	**90**	**-36.5**

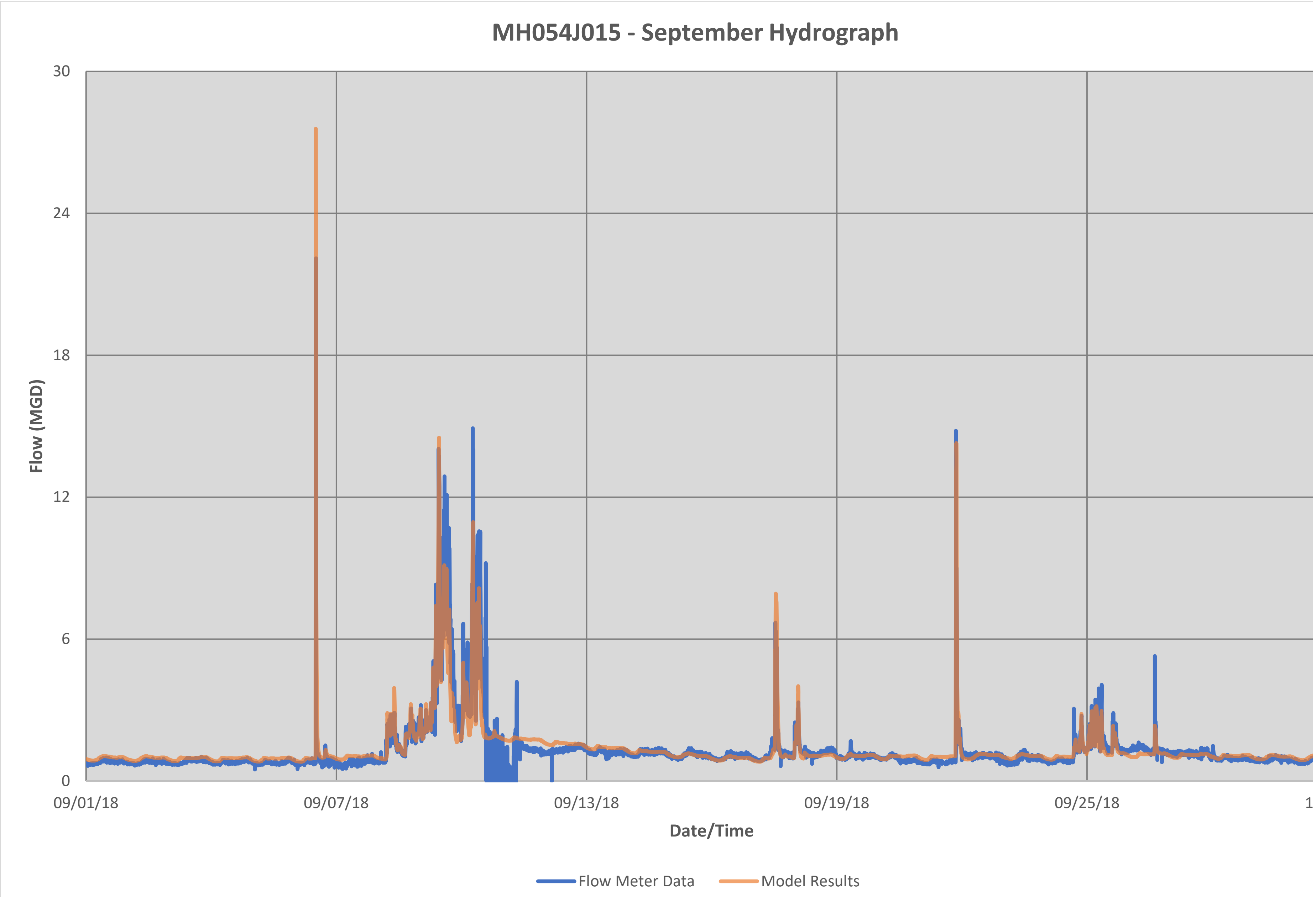

MH054J015 - WWF Calibration (Peak vs. Peak)
y = 0.99x
R^2 = 0.89
Simulated Flow (MGD)
Measured Flow (MGD)
0
6
12
18
24
30
Data Points
Trendline

MH054J015 - WWF Calibration (Volume vs. Volume)

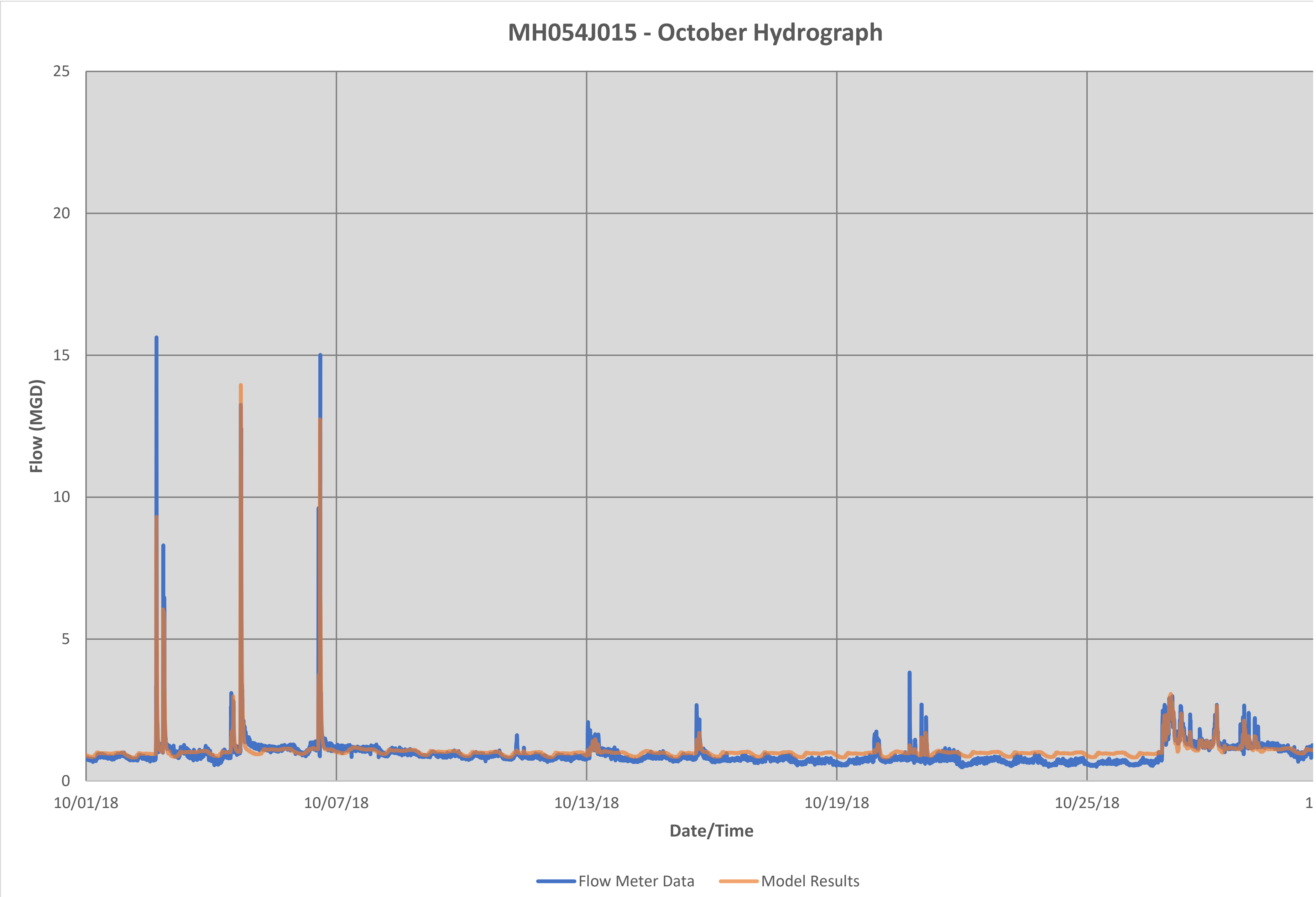




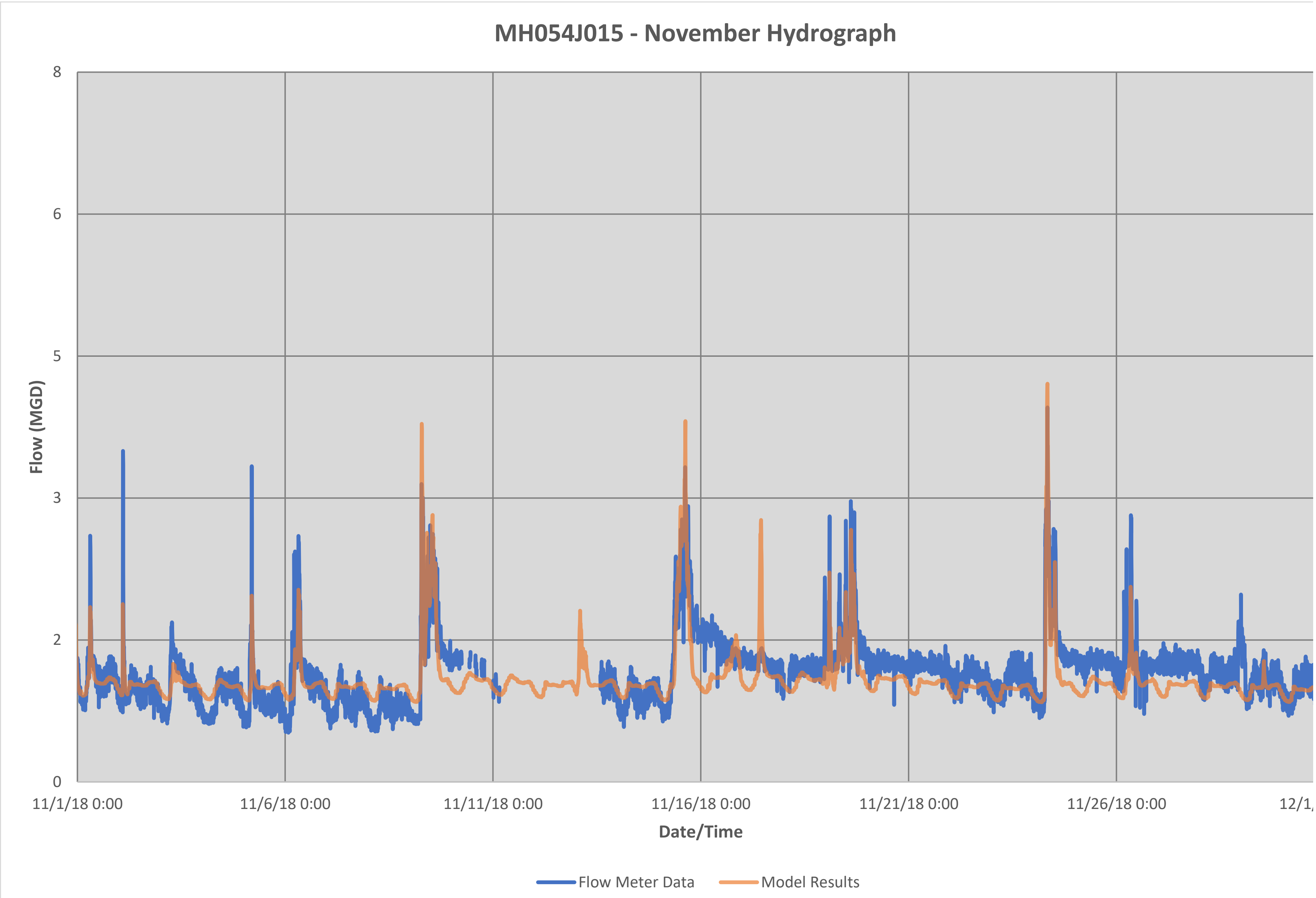
MH054J015 - August Hydrograph
Flow (MGD)
20
16
12
8
4
0
08/01/18
08/07/18
08/13/18
08/19/18
08/25/18
0
Date/Time
Flow Meter Data
Model Results

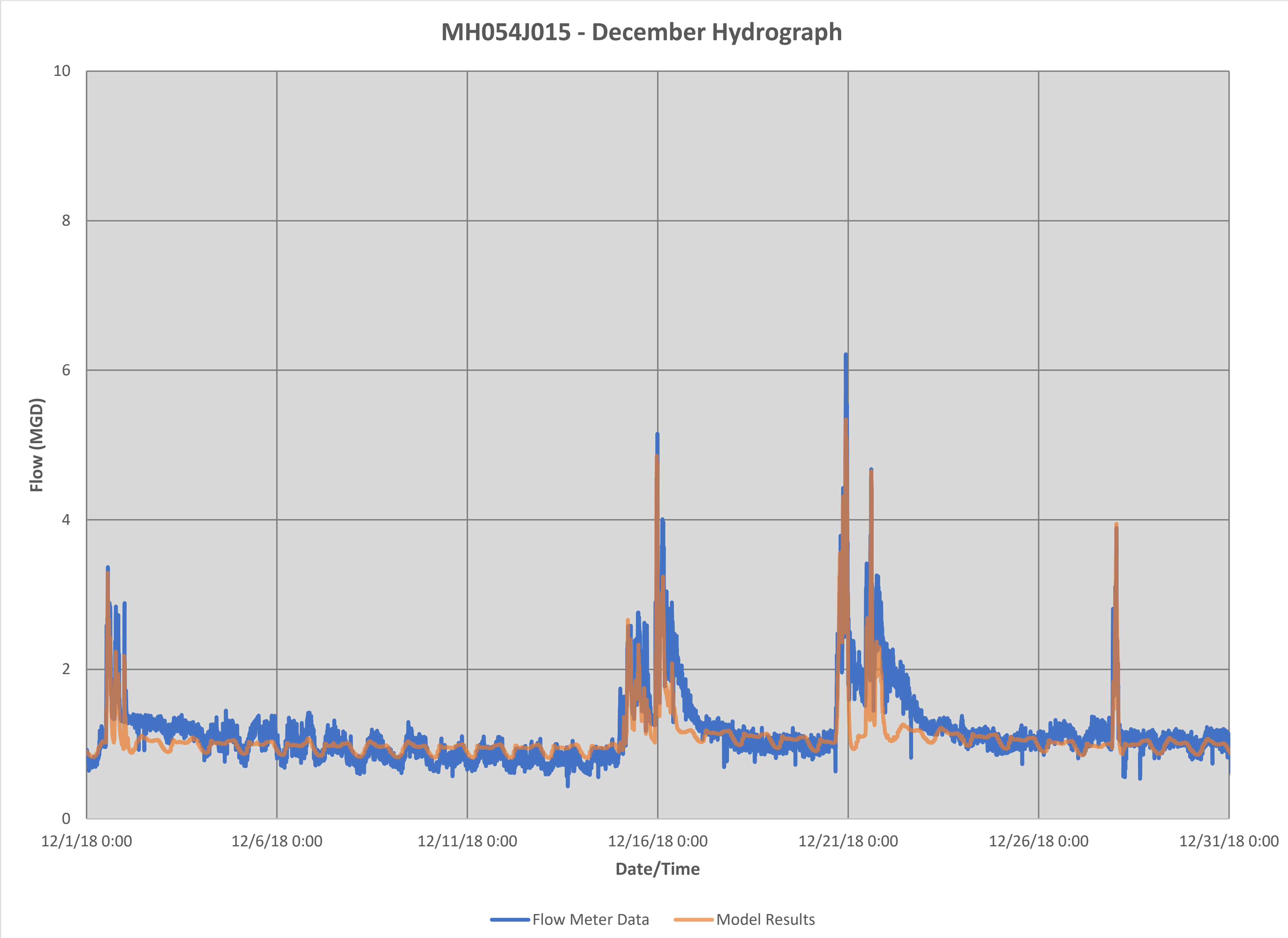


MH054J015 - September Hydrograph
Flow (MGD)
30
24
18
12
6
0
09/01/18
09/07/18
09/13/18
09/19/18
09/25/18
1
Date/Time
Flow Meter Data
Model Results



MH054J015 - October Hydrograph
25
20
15
10
5
0
Flow (MGD)
10/01/18
10/07/18
10/13/18
10/19/18
10/25/18
1
Date/Time
Flow Meter Data
Model Results


MH054J015 - November Hydrograph
8
6
5
3
2
0
Flow (MGD)
11/1/18 0:00
11/6/18 0:00
11/11/18 0:00
11/16/18 0:00
11/21/18 0:00
11/26/18 0:00
Date/Time
Flow Meter Data
Model Results



MH054J015 - December Hydrograph
Flow (MGD)
10
8
6
4
2
0
12/1/18 0:00
12/6/18 0:00
12/11/18 0:00
12/16/18 0:00
12/21/18 0:00
12/26/18 0:00
12/31/18 0:00
Date/Time
Flow Meter Data
Model Results

F. Mott MacDonald DCA 1-3 Response Letter (04.12.19)

MOTT MACDONALD

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PWSA Design Criteria Areas 1 Through 3 Response

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April 12, 2019

Mr. Nuttle

Following is the Mott MacDonald's responses to PWSA's Design Criteria Areas (DCA) 1 through 3 requested items for the Four Mile Run Project. Mott MacDonald's responses are shown in green and items highlighted in red indicate items where CEC needs to complete the response before this document is forwarded to PWSA.

Kathy Chavara, PE
Principal Project Manager

MOTT MACDONALD

Design Criteria Area 1

CSO Reduction of Stream Removal and Cost-Effectiveness Metric

A. Provide a comparison of the CSO reduction and associated disconnected impervious area of the current planned stream removal project as compared to the disconnected impervious areas and CSO reduction determined for the stream removal in the Green First Plan. Reference Section 5 and Table 9-6 of the PWSA Green First Plan. The CSO reduction should be run in the Model under the same conditions used in the Green First Plan, i.e., 250 MGD WWTP capacity, system wide model.

Section 5.3.5 of the Green First Plan details the CSO reduction benefits at the M-29 outfall from offloading contributions from Panther Hollow Lake and a total 270 tributary acres from the combined sewer system. Flow from Panther Hollow Lake is conveyed through a 15" diameter pipe to the downstream combined sewer system. ALCOSAN has a long-term flow meter installed in this pipe. References to simulation results from the Green First Plan in this document are based upon a systemwide combination of the various ALCOSAN basin models developed by ALCOSAN during the development of their Wet Weather Plan. The M-29 model was comprehensively updated during the Four Mile Run (4MR) project (referred to as the "updated 4MR model" throughout this document). Model Alternative 3 detailed in the draft 4MR Modeling Report represents the "core" 4MR project elements and is roughly similar to the stormwater offloading detailed in Section 5.3.5 of the Green First Plan report. Table 1 compares the baseflow, CSO reduction and offloaded areas from Section 5.3.5 of the Green First Plan and the 4MR Model Alternative 3 under existing conditions.

Table 1 – Green First Plan (Section 5.3.5) vs. 4MR Model Alternative 3

Criterion	Green First Plan	4MR Model Alternative 3
Panther Hollow Baseflow	68MG**	30MG
CSO Reduction*	32MG***	41MG
Impervious Area Offloaded	22ac	59ac
Pervious Area Offloaded	259ac	420ac
Total Area Offloaded	271ac	479ac

*CSO reduction values are compared to the existing conditions results from both models. The Green First Plan model had a typical year CSO volume of 402 MG at M-29, while the updated 4MR model has a typical year CSO volume of 382 MG.

**The original ALCOSAN M-29 model included 14 MG of baseflow from Panther Hollow Lake. That value was increased to 68 MG in the Green First Plan based on 2015 ALCOSAN flow metering data.

***Increasing the Panther Hollow Lake baseflow from 14 MG to 68 MG also increased the existing conditions typical year M-29 CSO volume from 402 MG to 424 MG. The 32 MG CSO reduction referenced in Table 1 is calculated from the revised 424 MG value and not the original 402 MG value.

Figure 1 shown below is copied from the Green First Plan, originally identified as Figure 5-11. This figure details the two subcatchments and the total of 271 tributary acres offloaded from the combined sewer system.

Figure 1 – Green First Plan Panther Hollow Run and adjacent area offloaded

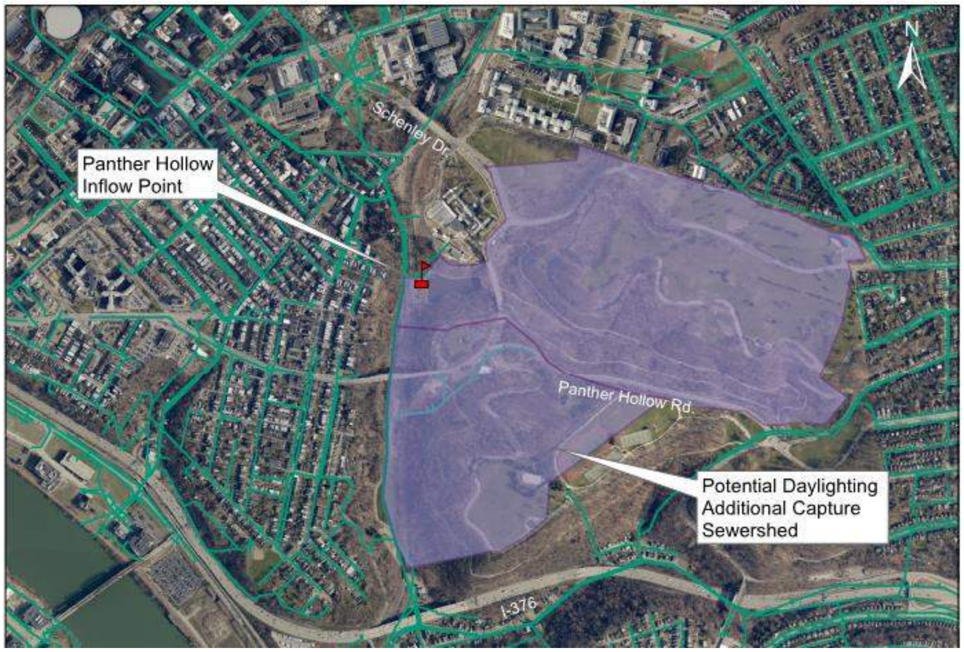
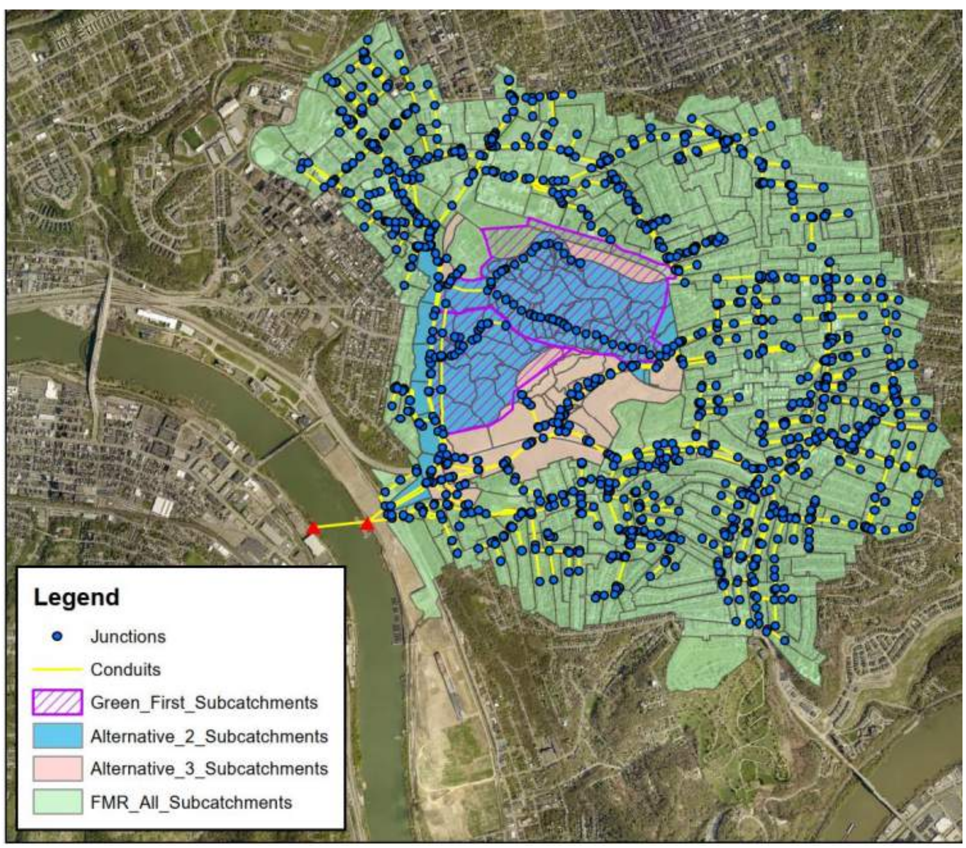


Figure 2 shows the two Green First subcatchments from Figure 1 overlaid with Model Alternatives 2 and 3 taken from the draft 4MR Modeling Report. Model Alternative 2 is the closest in tributary area offloaded to the area from Figure 1. However, after discussions with PWSA Alternative 3 was selected to use as the "core" 4MR project alternative because it included all of the tributary area from Model Alternative 2 but also the drainage area in the Naylor Run/Saline Street vicinity which was a priority for PWSA.

Figure 2 – Four Mile Run Alternative 3 offloaded stormwater area



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B. Explain any differences in the CSO reduction values. Include a comparison between the model used in the Green First Plan and the updated model from this project for:

a. wet weather Inflow volumes,

b. stream flows and volumes entering the sewer system,

c. underflow volumes and,

d. overflow volumes.

As shown in Table 1, the CSO reductions computed in the Green First Plan (Section 5.3.5) the Model Alternative 3 are different. The root cause of these differences is that the two collection system models have different levels of detail and different flow metering data available for their calibration. Table 2 below includes typical year M-29 CSO discharges for the updated 4MR model under various conditions.

Table 2 – Green First Plan (Section 5.3.5) vs. 4MR Model Alternative 3

Scenario	CSO Volume	CSO Decrease vs. Existing Conditions
Existing Conditions	382	N/A
Existing Conditions + Flap Gate	380	-2
Existing Conditions +Flap Gate + Model Alternative 3	341	-41
Existing Conditions + Flap Gate + Model Alternative 3 + Watershed Expansion	224	-158

Table 2-2 in the Green First Plan detailed inflow, underflow and overflow typical year volumes for each of the 30 sewersheds included in that plan. Table 3 includes excerpts from Table 2-2 and newer values based on the updated 4MR model.

Table 3 – Existing Conditions Inflow, Underflow and Overflow Volumes (MG)

Model	Inflow to Diversion Structure	Underflow to WWTP	Overflow (CSO)	% WW Capture
Green First Plan*	1,426	1,024	402	72%
Updated 4MR Model	2,377	1,995	382	84%

*Values taken from Table 2-2 in Green First Plan

It is important to consider the following when interpreting Table 3:

- The inflow entering the M-29 diversion structure from the upstream collection system has increased by nearly 1.0 billion gallons (BG) in the updated 4MR model. This increase is due to increases in both the dry weather and wet weather flow volumes, but the DWF volume increase accounts for more than 70% of the increase. The DWF calibration of the large diameter interceptors upstream of the M-29 diversion structure in the updated 4MR model indicates about 10.5 MGD average DWF. The Green First Plan model had average DWF entering the M-29 diversion structure of approximately 6.0 MGD.

- The results have the counterintuitive result of significant increases in the total flow volume entering the M-29 diversion structure while also resulting in modest decreases in CSO discharge volume through the M-29 outfall pipe. The most significant explanation for this situation is that the increased flow volume entering the M-29 diversion structure is mostly being added when overflow is not occurring. Another contributing factor is that the Green First Plan model generally has higher wet weather peak flow response leading to higher CSO discharges. This is a logical result because the Green First Plan model only has the larger diameter interceptor sewers in it and none of the smaller diameter upstream sewers. Since flows are being directly added to large diameter pipes greater peaks flows can be conveyed downstream. The updated 4MR model has much greater detail in the upstream areas of the collection system which results in greater attenuation of the wet weather peak flows before those flows reach the M-29 diversion structure.

C. Confirm the updated model has been calibrated and validated to CIWEM (formerly WAPUG) standards. Provide supporting modeled versus measured summary tables and graphs for each flow meter for peak flow, volume, and depth.

The calibration and validation results for the updated 4MR model are documented in the draft 4MR Modeling Report which PWSA has already reviewed and provided comments. The 4MR Modeling Report also has an appendix that includes all of the various summary tables and graphs requested for this item. The updated 4MR model's results and performance were also discussed with PWSA during a meeting on April 4, 2019. As documented in the 4MR Modeling Report Appendix and discussed during the April 4th meeting, the majority of the flow meters used for calibration/validation reveal good hydrograph trending and compliance with the CIWEM criteria for many of the storm events. However, as also discussed during the April 4th meeting, the focus of the model calibration was the overall hydrograph response rather than trying to optimize the model solely to statistical criteria. The 4MR Modeling Report Appendix also includes discussion on specific flow meters that had less than expected performance and potential reasons for those result. Some of these reasons include locations where it was identified that flow may have been bypassing the flow meter (such as flow meter MH054F012) or flow meters where data quality issues were experienced. However, the updated 4MR model generally exhibits good performance, particularly for flow meters in the largest interceptors that best capture the sewersheds overall response. Also, some current or future items could still positively impact the updated 4MR model's calibration performance, including additional flow metering being collected and performing field investigating where cross connections exist between parallel interceptors. Some of the storm events still included in the 4MR Modeling Report Appendix will be removed for data quality concerns which should also improve the calibration statistics.

D. Provide the cost per CSO gallon reduced of the current planned stream removal as compared to the Green First Plan.

   a. If the cost per gallon of CSO reduction is greater than $0.75 per gallon, provide recommendations on how to reduce the current project's cost or adjust the project's scope to reduce the cost to this target.

      This point to be addressed by CEC.

   b. Clearly call-out or provide a list of amenities - defined as items not directly necessary for CSO reduction - and the associated costs.

      This point to be addressed by CEC.

Design Criteria Area 2

Mitigating Flooding at Big Jim's/Saline Street Area

A. What is the root cause of the flooding and basement backups in this area? Infrastructure too small, backup from existing tunnel? Backup from river, etc.?

The root cause(s) of the flooding and basement backups in the Big Jim's/Saline Street area is dependent on the size of the storm event and the stages of the of the Monongahela River and the existing ALCOSAN tunnel. Model simulations were performed under both a 711 elevation (normal pool) assumption for the Monongahela River stage and a 733 elevation (FEMA 100-yr base flood elevation) assumption for the Monongahela River stage. The model results indicate that for small storm events, such as the 2-year, 24-hr design storm, little to no flooding occurs within the Big Jim's/Saline Street area. For smaller design storms and the lower Monongahela River stage, excess flows conveyed through the large diameter interceptors can be effectively conveyed to the Monongahela River through the M-29 outfall pipe. However, under the Monongahela River is the higher 733 elevation river stage, discharges to the river are restricted and HGLs are increased. The presence or absence of a flap gate on the M-29 outfall pipe does not significantly change the flooding conditions when the Monongahela River is at high stage. If no flap gate is present, the river will back-up through the M-29 diversion and into the upstream tributary collection system. When a flap gate is installed, reverse flow from the river is eliminated, but the high river stage hydraulically limits discharges to the river from the collection system. If flow cannot effectively discharge the river or to the existing ALCOSAN deep tunnel (which occurs during large design storms and high river stages), flow backs up into the collection system and causes significant flooding in the Big Jim's/Saline Street area.

B. Provide a summary of the effects that lowering the weir (as currently planned) at the CSO diversion will have on reducing flooding and increases to CSO volume. Does lowering the weir as currently planned eliminate flooding or basement backups in the area up to a certain size storm event?

Chester Engineers performed a detailed investigation of potential grey improvements in the vicinity of the M-29 diversion structure with the goal of reducing flooding in the immediate area. One of the alternatives that they investigated was lowering the M-29 diversion weir by 2.0 feet to reduce the HGLs in the upstream sewers. Chester's results indicated that dropping the weir by 2.0 feet had modest flooding reduction benefits (reducing flooding in the area for an approximately 50-yr, 1-hr storm event from 4.2MG to 3.5MG) The draft 4MR Modeling Report included results for implementing the weir drop as one of the baselines simulated. Those results indicated that the typical year, existing conditions the M-29 CSO discharge volume increased by approximately 100MG. This represented an approximately 25% increase in typical year CSO discharges compared to an existing condition M-29 CSO discharge volume of 382MG.

C. What infrastructure sizing is necessary to mitigate flooding and basement backups in this area in the 2-year, 5-year, 10-year and 25-year storms? What are the associated costs?

For the smaller design storms, such as the 2-yr and 5-yr events, little to no flooding is predicted in the Big Jim's/Saline Street area. However, under large design storm conditions, particularly when combined with a high Monongahela River stage, significant flooding in the Big Jim's/Saline Street area is experienced. The Chester Report referenced under item B above investigated a variety of significant grey improvements in the vicinity of the M-29 diversion structure to mitigate flooding in the area. There results indicated that for the approximate 50-yr, 1-hr storm event that they investigated even the installation of infrastructure as significant as a new 10-feet diameter from Four Mile Run Road to the Monongahela River did not completely eliminate flooding in the area. Many of the potential improvement concepts explored in the Chester Report were expected to be quite expensive, difficult to practically construct or both.

D. How would this proposed infrastructure connect to the proposed stream removal conveyance?

Any proposed infrastructure within the Big Jim's/Saline Street area to mitigate flooding and/or basement backups could connect to either the open channel/culvert conveyance from Junction Hollow to the new stormwater outfall to be located at parcel 7 on the Hazelwood Green site or to the auxiliary stormwater pipe expected to route down Saline Street from Naylor Run to a second stormwater outfall.

E. If this area were separated from the CSS, how much additional modeled CSO reduction would be achieved?

Much of the overland stormwater flow in the Big Jim's/Saline Street area will already being conveyed to the new 4MR project infrastructure under Model Alternative 3 (see Figure 2). So, the CSO reduction benefits from capturing this stormwater is already included in the CSO reduction results reported for Model Alternative 3 as shown in Table 2.

<u>Design Criteria Area 3</u>

Design Storm Basis for sizing the stream channels, pond/detention and conveyance channel/tunnel to the River for the stream separation

A. Provide and explain the DEP permit requirements for sizing the stream channels, pond/detention and conveyance

This point to be addressed by CEC.

B. Can the stream channels and conveyance to the River be sized for a 2-year storm or the largest storm in the typical year? If no, what is necessitating the infrastructure to be sized to a larger storm event?

This point to be addressed by CEC, but the FEMA issue certainly plays into this response.

C. Both in the Park area and along Junction Hollow to the River.

a. Provide the change in flooding extents, necessary under the design storms to fulfill the DEP Permit requirements, i.e., improvements "do no harm", from current conditions to proposed project conditions. Recognizing that current conditions is the existing combined sewers flooding.

CEC has met with the DEP to discuss floodplain and related issues. CEC to address the "do no harm" aspect of the DEP Permit requirements.

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It is noted that the maximum HGLs in the two parallel interceptors under Junction Hollow do not exceed the ground surface under all simulated conditions resulting in no surface flooding in this area. However, it is the design intent for Junction Hollow under Model Alternative 3 to inundate a wide “floodplain” area for larger design storms to mitigate downstream peak flows.

Recall that, the maximum HGL at manhole MH054J006 located behind Big Jim’s exceeds the ground surface under design storms larger than the 10-yr, 24-hr design storm conditions. The addition of Model Alternative 3 and the Watershed Expansion only reduce HGLs across the sewershed and in the Park and along Junction Hollow to the Monongahela River.

b. Is the proposed conveyance sized for a 100-year storm? If yes, please explain the justification.

CEC to address this item based on current design of the Junction Hollow and downstream conveyance elements.

c. What would the change in flooding extents be between current conditions, and with the stream removed, if the stream channels and conveyance to the River were sized for a 2-year storm or largest storm in the typical year? What about under a 5-yr or 10-yr storm event?

This point to be addressed by CEC, but the following text is included.

If the open channels and culverts were sized to only keep smaller design storms within the banks, such as the 2-yr, 24-hr storm, then flooding would result during larger storms occurred. Since this represent a new source of potential flood waters, it is assumed that this would change the flooding extents of the area under existing conditions.

d. If item c above was used, how would the project costs be reduced?

This point to be addressed by CEC

D. Is the current proposed stream channel in Junction Hollow being sized to provide sufficient excavated material to build the new proposed autonomous vehicle road?

a. If Yes, please explain why and how much cost other partners will be contributing to the project to offset PWSA’s cost.

This point to be addressed by CEC

b. If No, please explain where the excavated material will be hauled to or how it will be used?

This point to be addressed by CEC

c. If a larger excavation is provided than currently proposed will this allow managing a larger storm event?

This point to be addressed by CEC

G. Mott MacDonald HGL Plots Combined Tech Memo (04.24.19)

MOTT MACDONALD

Technical note

Project:	PWSA Four Mile Run Project		
Our reference:	507399786	**Your reference:**	
Prepared by:	Brian Moore	**Date:**	04/24/19
Checked by:	Kathy Chavara		
Subject:	HGL Plots of Interceptors in the Big Jim's Area		

Maximum Hydraulic Grade Line (HGL) plots

Attached to this document are Maximum Hydraulic Grade Line (HGL) plots for 4 storm event scenarios. These results relate to the large diameter interceptors in the lower run neighborhood (Big Jim's area). These plots provide understanding of how the HGLs in the various interceptors are affected by different design storm conditions, different Monongahela River stages, and the potential implementation of different improvements from the Four Mile Run project.

The maximum HGL represents the maximum water depth in each manhole based on the hydraulic model simulations under various conditions and design storms. These simulations were completed in response to questions in PWSA's January 29, 2019 Design Criteria Areas 1 through 3. The following model conditions were simulated:

- Three (3) different baseline conditions
  1. Existing Conditions plus Flap Gate
  2. Existing Conditions plus Flap Gate and Model Alternative 3
  3. Existing Conditions plus Flap Gate, Model Alternative 3 and Watershed Expansion
- Two (2) different Monongahela River stage conditions:
  1. 711 elevation
  2. 733 elevation
- Four (4) different design storms:
  1. 2-year, 24-hour
  2. 5-year, 24-hour
  3. 10-year, 24-hour
  4. 25-year, 24-hour

The simulation results are provided on two different figure types that are attached to this technical memorandum. The first set of figures (Figures 1 – 8) summarize the relative reductions in the HGL for the Model Alternative 3 + the Watershed Expansion for the two different river stages and the four different design storms. The second set of figures (Figures 9-14) present the difference in HGL results for each of the three baseline conditions, per design storm. The general trend of the HGL results indicate that the addition of Model Alternative 3 plus the addition of Watershed Expansion reduce flooding volumes and the basement backup risk in the lower run neighborhood across the design storms that were evaluated.

When interpreting the attached HGL plots, the following are important points to keep in mind:

- Potential basement backup risk assumes that basement backup risk exists where the model's HGL is within a set depth below the ground surface. Given the information currently available and after discussions regarding this approach with the PWSA, an HGL elevation within 5 feet of the ground surface is used to identify a location of potential basement backup. Mott MacDonald has discussed with the PWSA that the results inferred or interpreted from the attached HGL plots must be investigated further. Basement backup risk is based on the presence/absence of a house's basement (and the elevation of such), and also based on the survey information that could indicate if a specific house is elevated above/below/or at grade with the adjacent roadway (i.e., manhole rim elevation).
- Flooding in the context on this document is when the HGL level of the collection system exceeds the ground rim elevation of a manhole. This indicates that water is escaping from the collection system to the ground surface.
- The updated 4MR collection system model includes the addition of substantial detail to the previous M-29 sewersheds collection system model. However, the updated 4MR collection system model does not include all of the pipes within the physical collection system and therefore, cannot capture all potential locations that may be at risk of basement backup. These HGL model results do not capture the influence of localized topographic low points and restrictions that may also impact the risk of basement backup.
- The SWMM model used to calculate the HGL plots does not have the capability of routing flood waters overland. If flooding is experienced in the lower run neighborhood, the overland transport and reentry of flow could impact the simulation results shown within the attached HGL plots.
- The hydraulic characteristics of the flap gate to be installed on the M-29 outfall pipe have not been incorporated into the updated 4MR collection system model. The headloss characteristics of the selected flap gate are expected to have some impact on the upstream HGLs.

Table 1 below presents information that can be gleaned from the various HGL plots for a particular manhole. This table summarizes an overview of model results at manhole MH054J006. This manhole is located immediately behind Big Jim's. This manhole location experiences surface flooding in the lower run neighborhood. The results without color shading on Table 1 indicate conditions when the peak HGL is below five feet of the ground elevation indicating low basement backup risk. The results with orange shading indicate events where the peak HGL is within/above 5 feet of the ground elevation indicating the potentially elevated basement backup risk. The results with red shading are storm events where the peak HGL is greater than the ground elevation indicating that flow from the collection system is escaping to the surface.

Table 1: HGL Levels at Manhole MH054J006 (Behind Big Jim's)						
River Stage	711			733		
Ground Elevation	737.5			737.5		
Existing Conditions + Flap Gate	X	X	X	X	X	X
Model Alternative 3		X	X		X	X
Watershed Expansion			X			X
2-yr, 24-hr storm	726.44	725.65	724.32	737.5+	737.22	735.41
5-yr, 24-hr storm	728.21	726.83	725.53	737.5+	737.5+	736.86
10-yr, 24-hr storm	730.67	728.05	727.40	737.5+	737.5+	737.5+
25-yr, 24-hr storm	733.01	730.17*	731.17*	737.5+	737.5+	737.5+

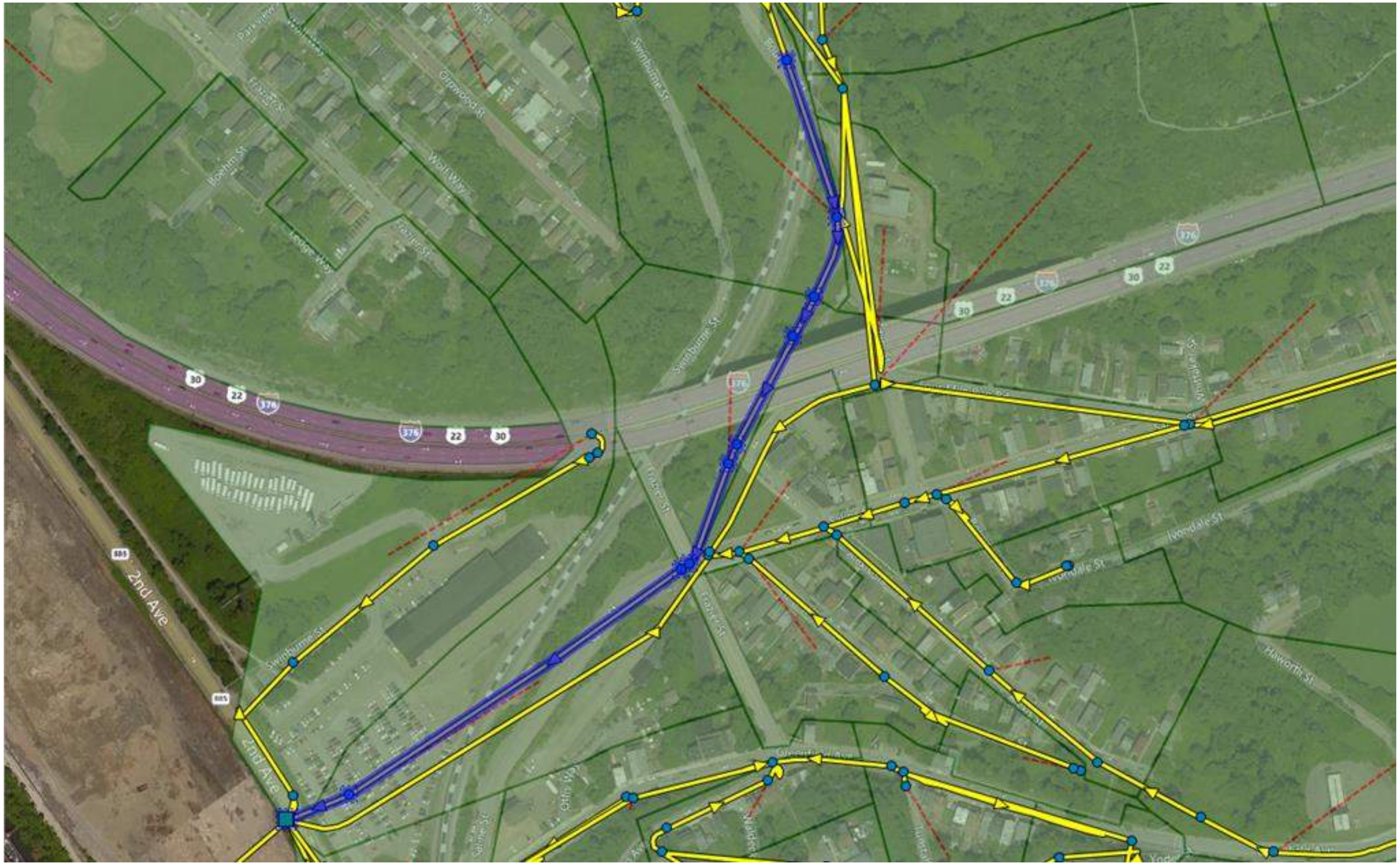
*The peak HGL for Model Alternative 3 is less than the Model Alternative 3 + Watershed Expansion because of the timing of upstream flooding.

Figure 1A - Simulations_10, 18, and 26 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm



Simulations_10, 18, and 26 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm

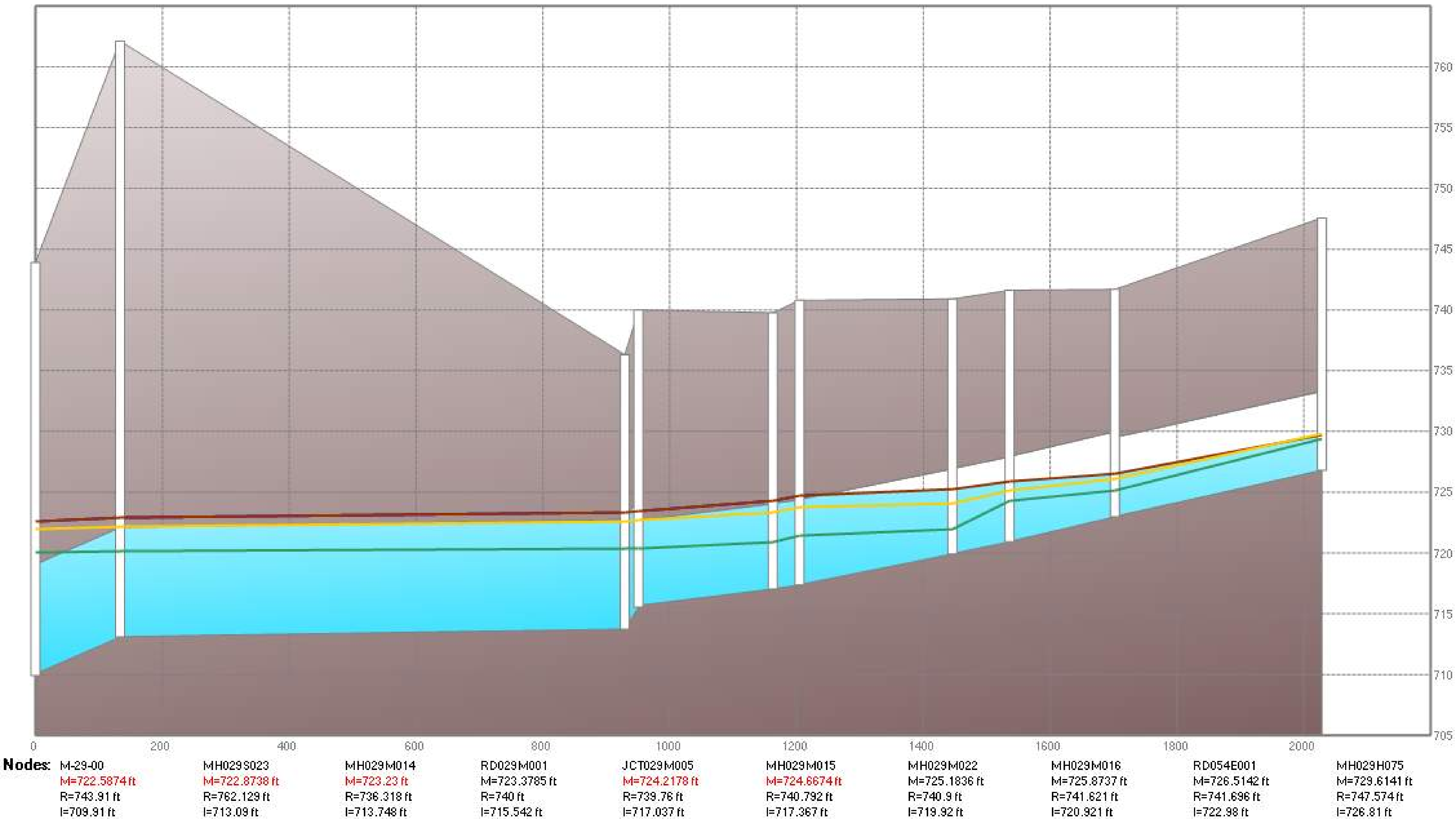
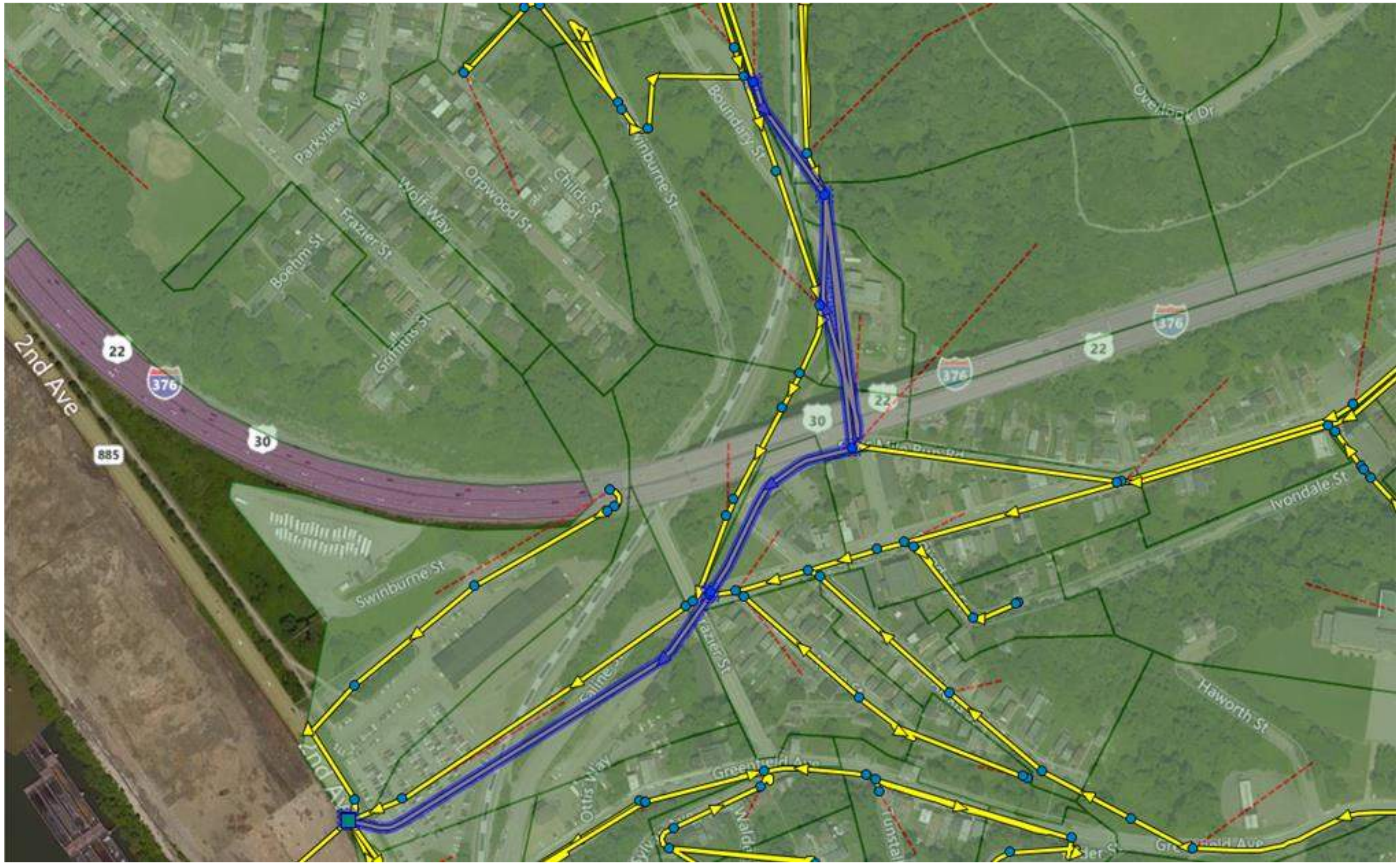


Figure 1B - Simulations_10, 18, and 26 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm



Simulations_10, 18, and 26 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm

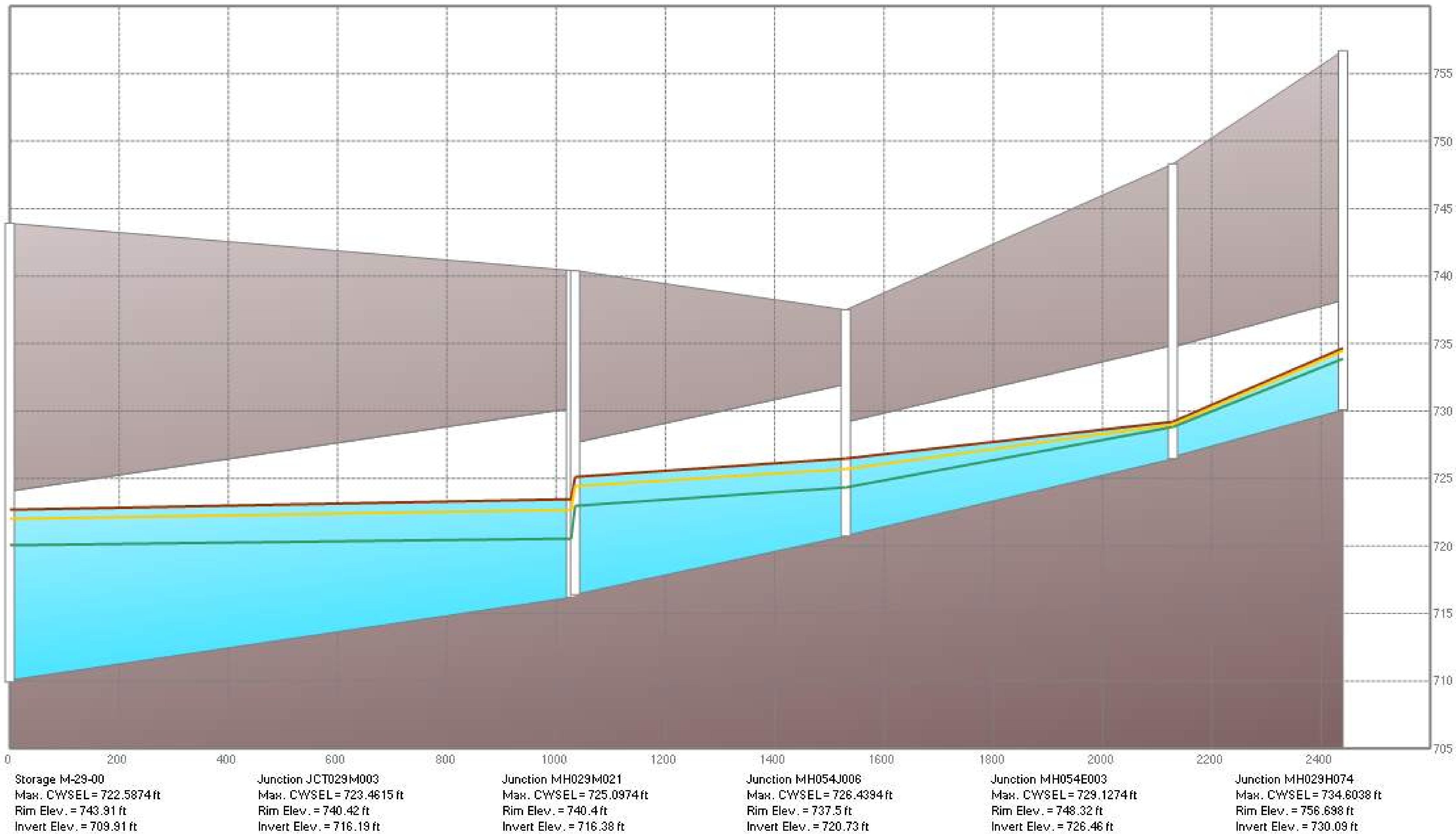
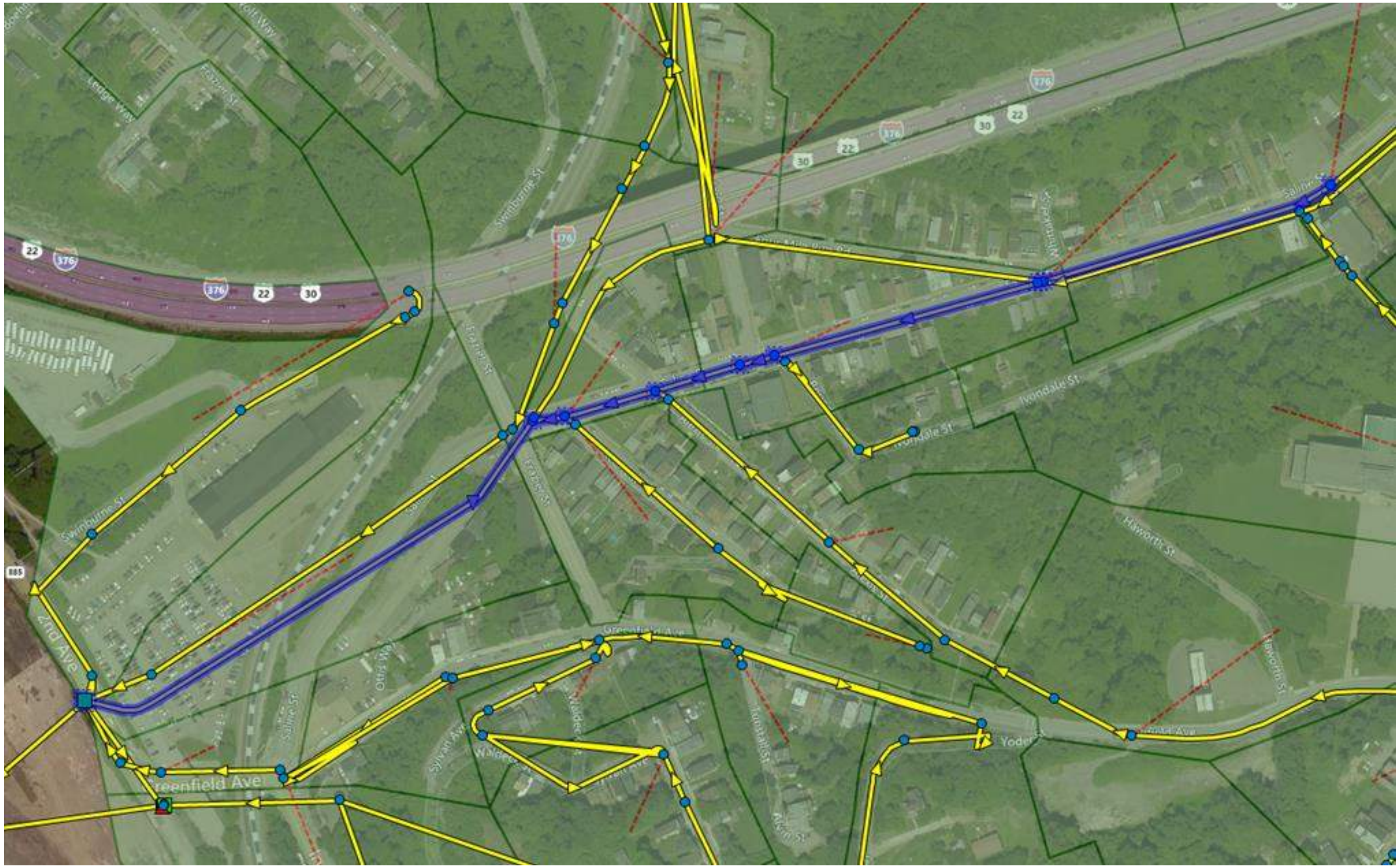


Figure 1C - Simulations_10, 18, and 26 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm



Simulations_10, 18, and 26 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm

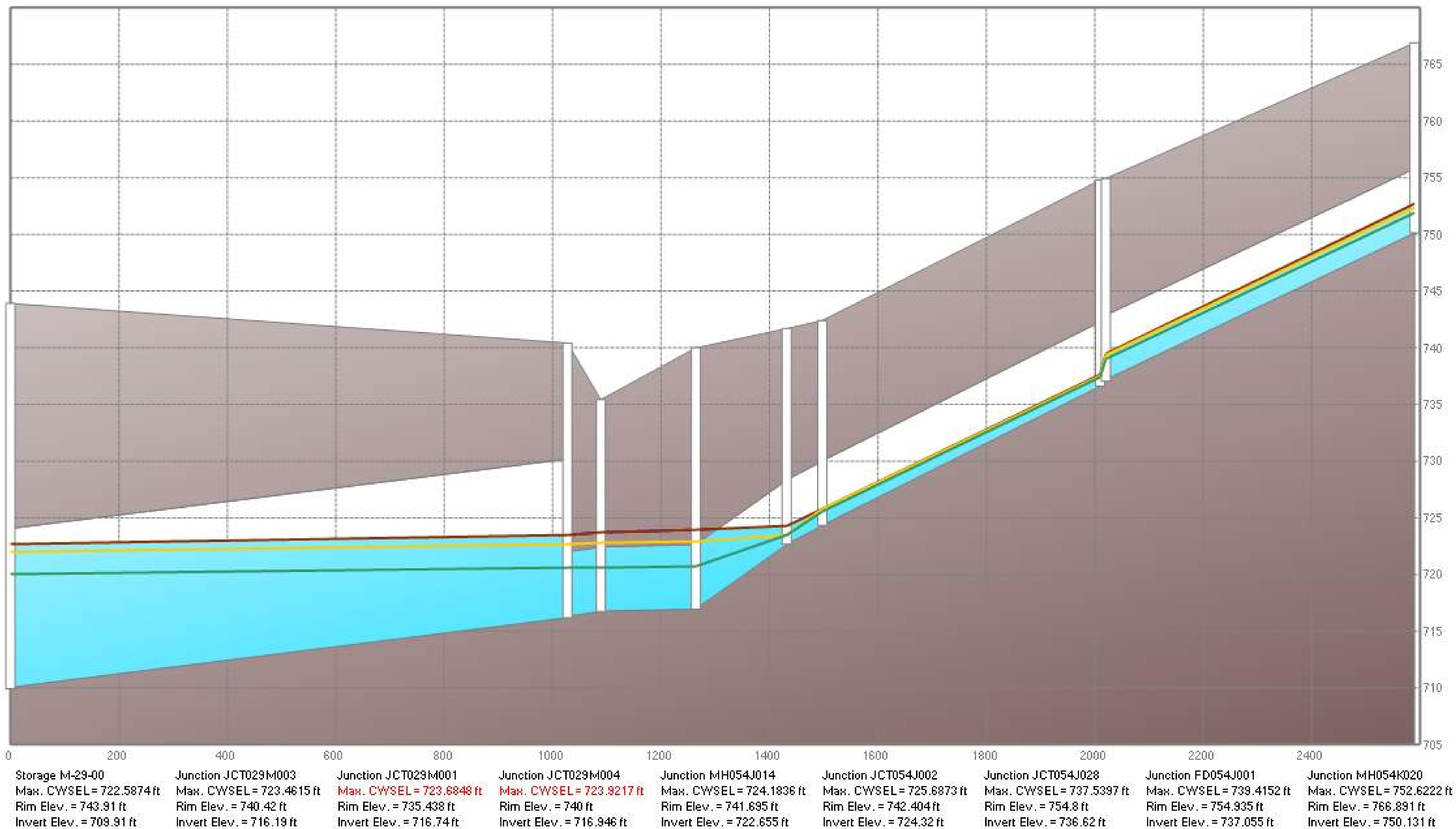
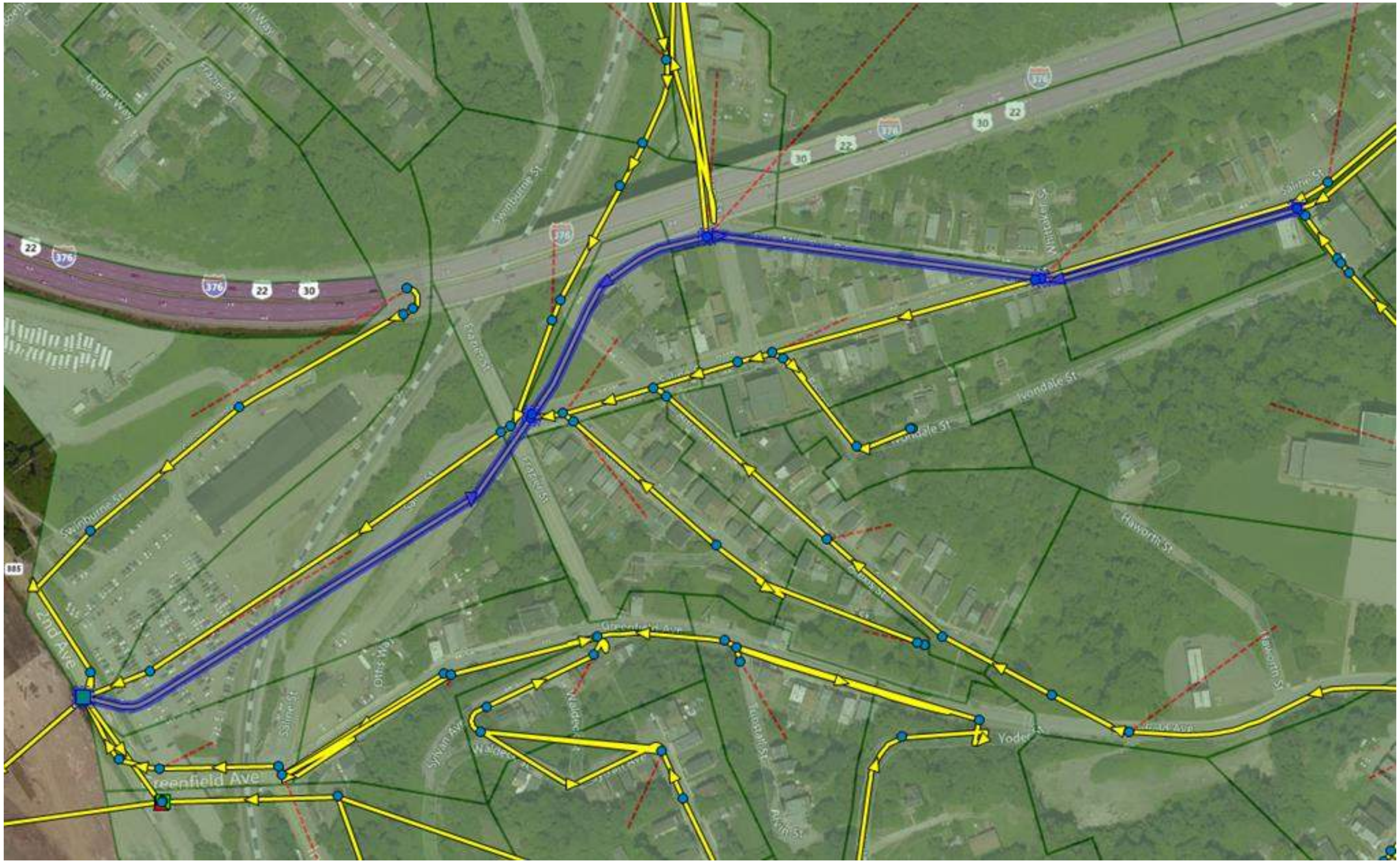


Figure 1D - Simulations_10, 18, and 26 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm



Simulations_10, 18, and 26 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 02-Year, 24-Hour Design Storm

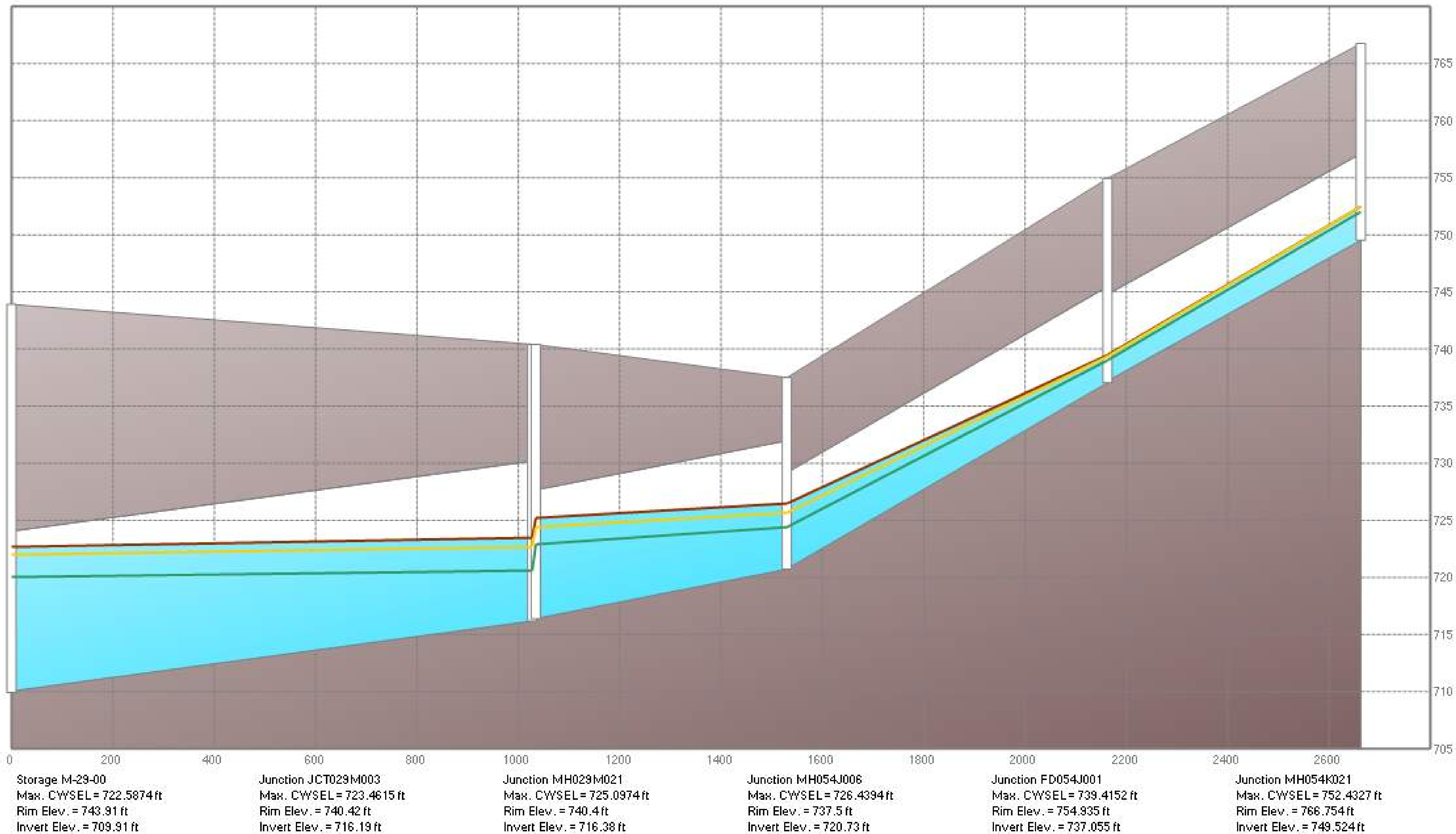
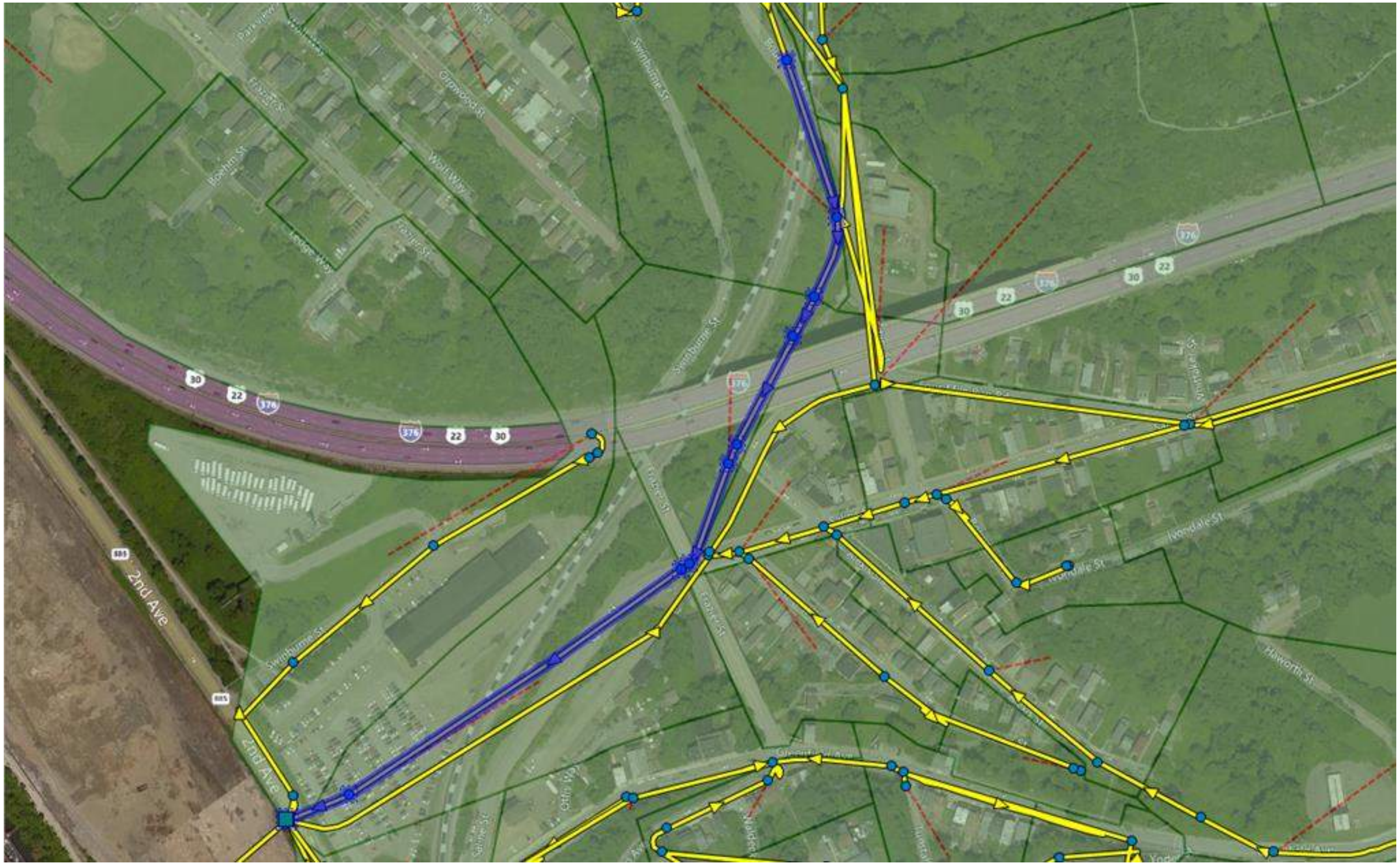


Figure 2A - Simulations_11, 19, and 27 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm



Simulations_11, 19, and 27 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm

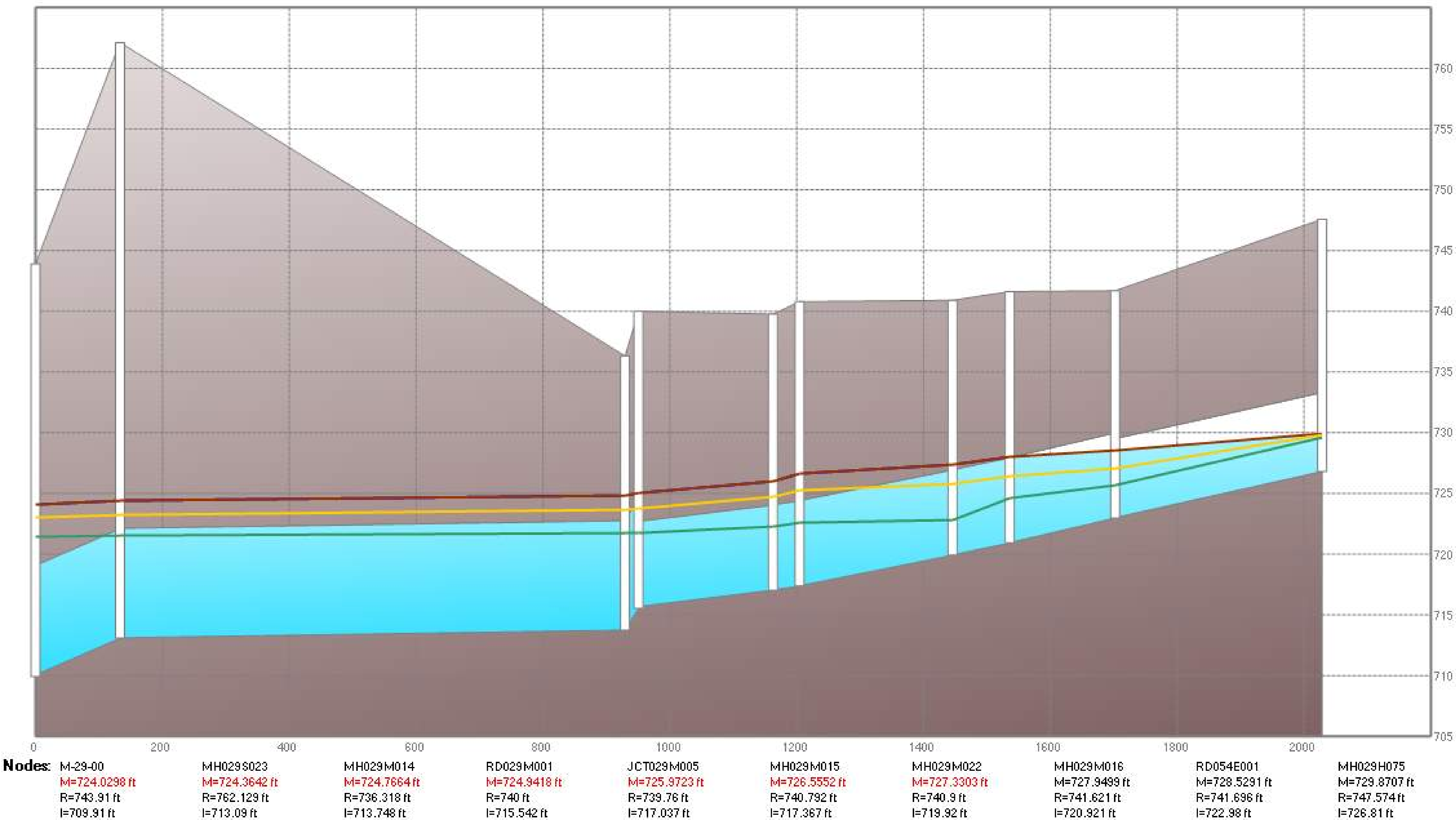
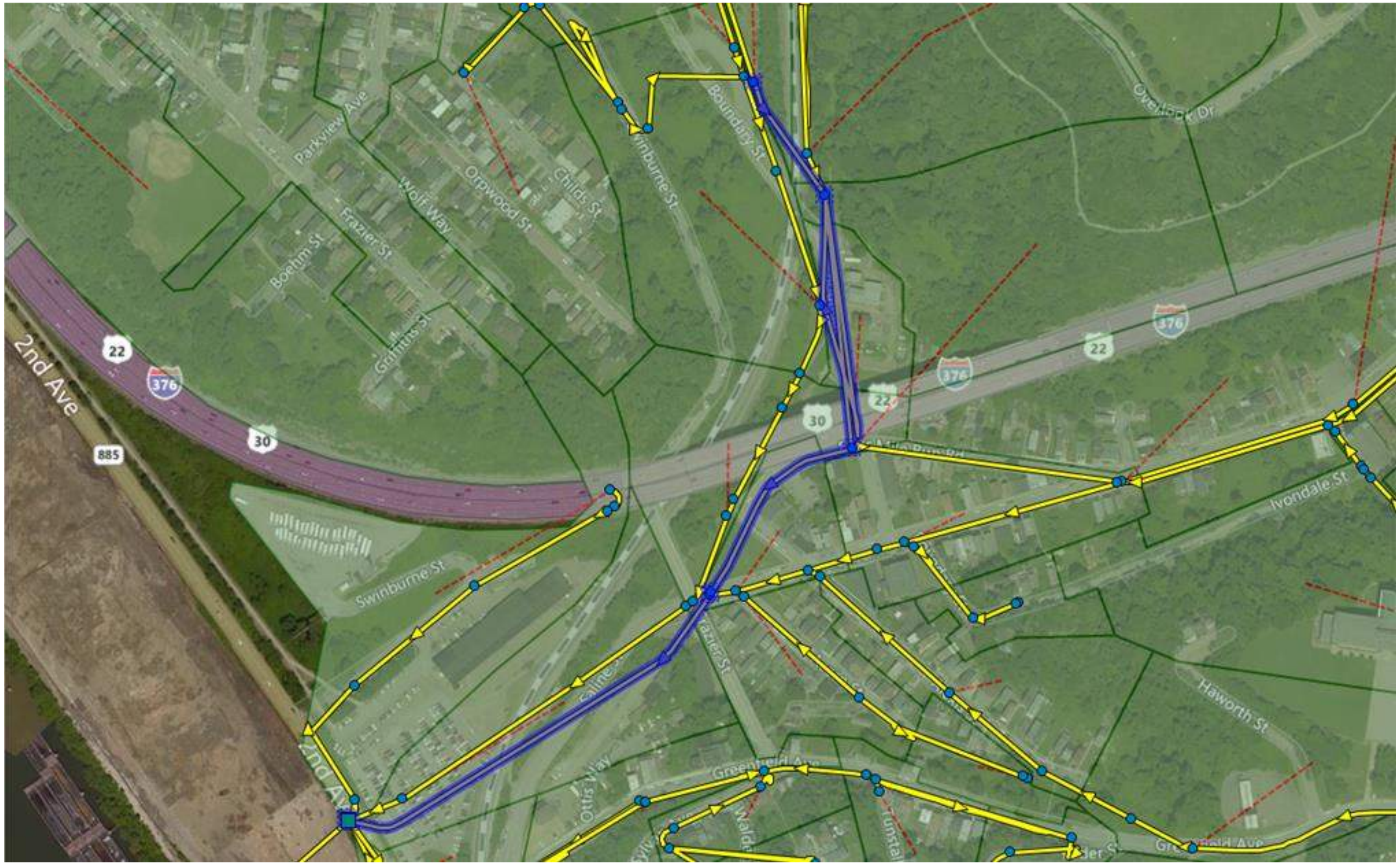


Figure 2B - Simulations_11, 19, and 27 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm



Simulations_11, 19, and 27 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm

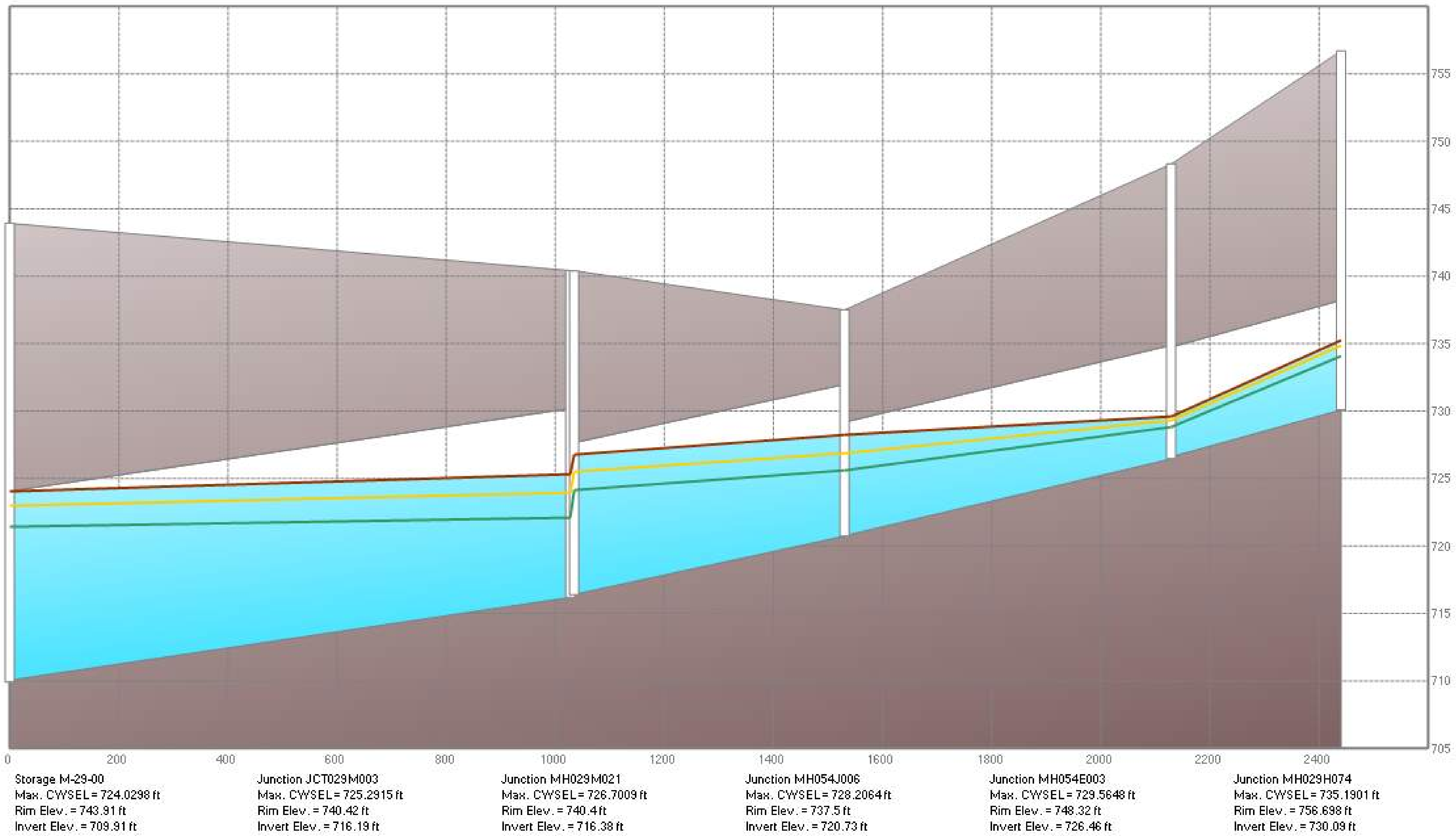
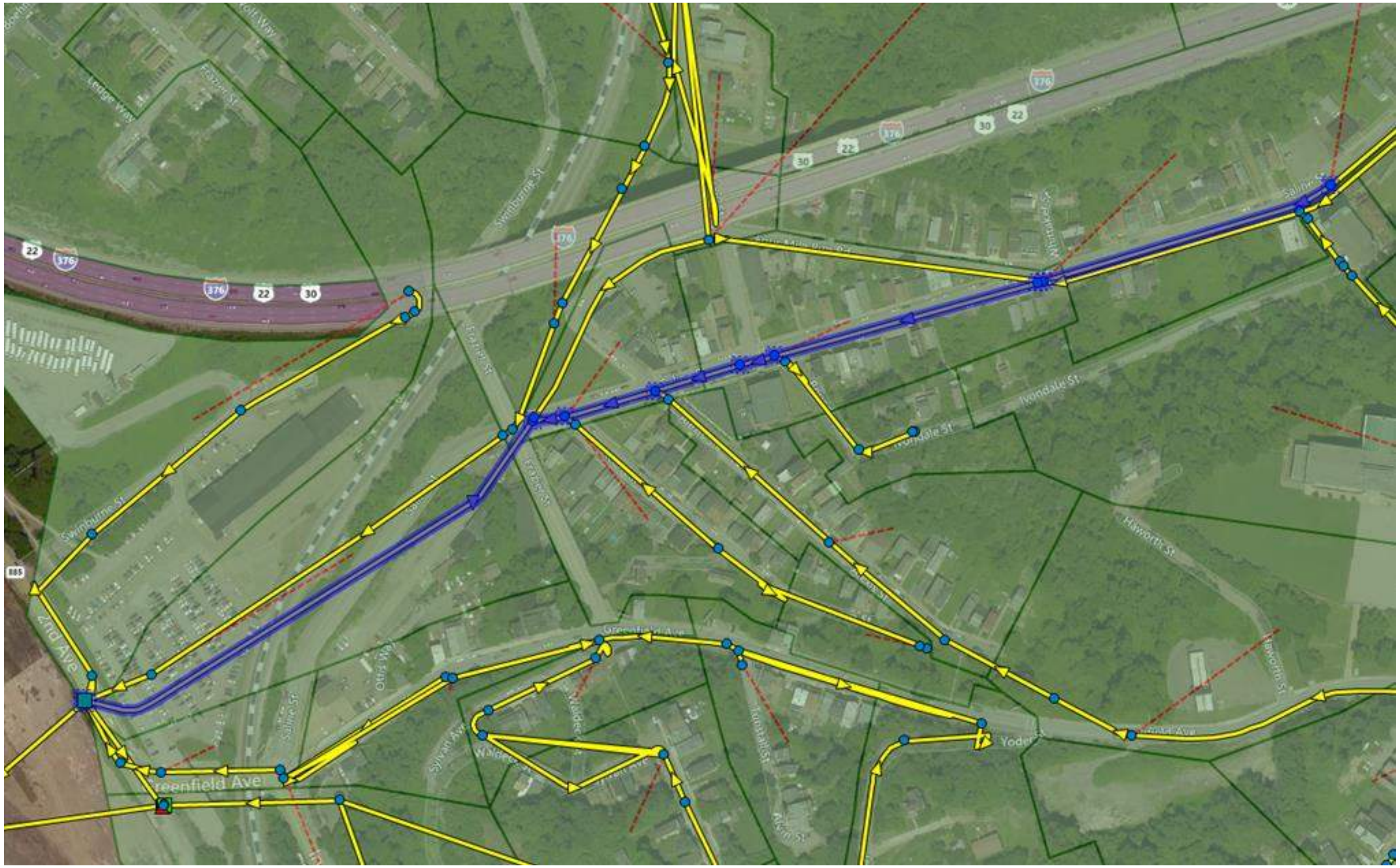


Figure 2C - Simulations_11, 19, and 27 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm



Simulations_11, 19, and 27 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm

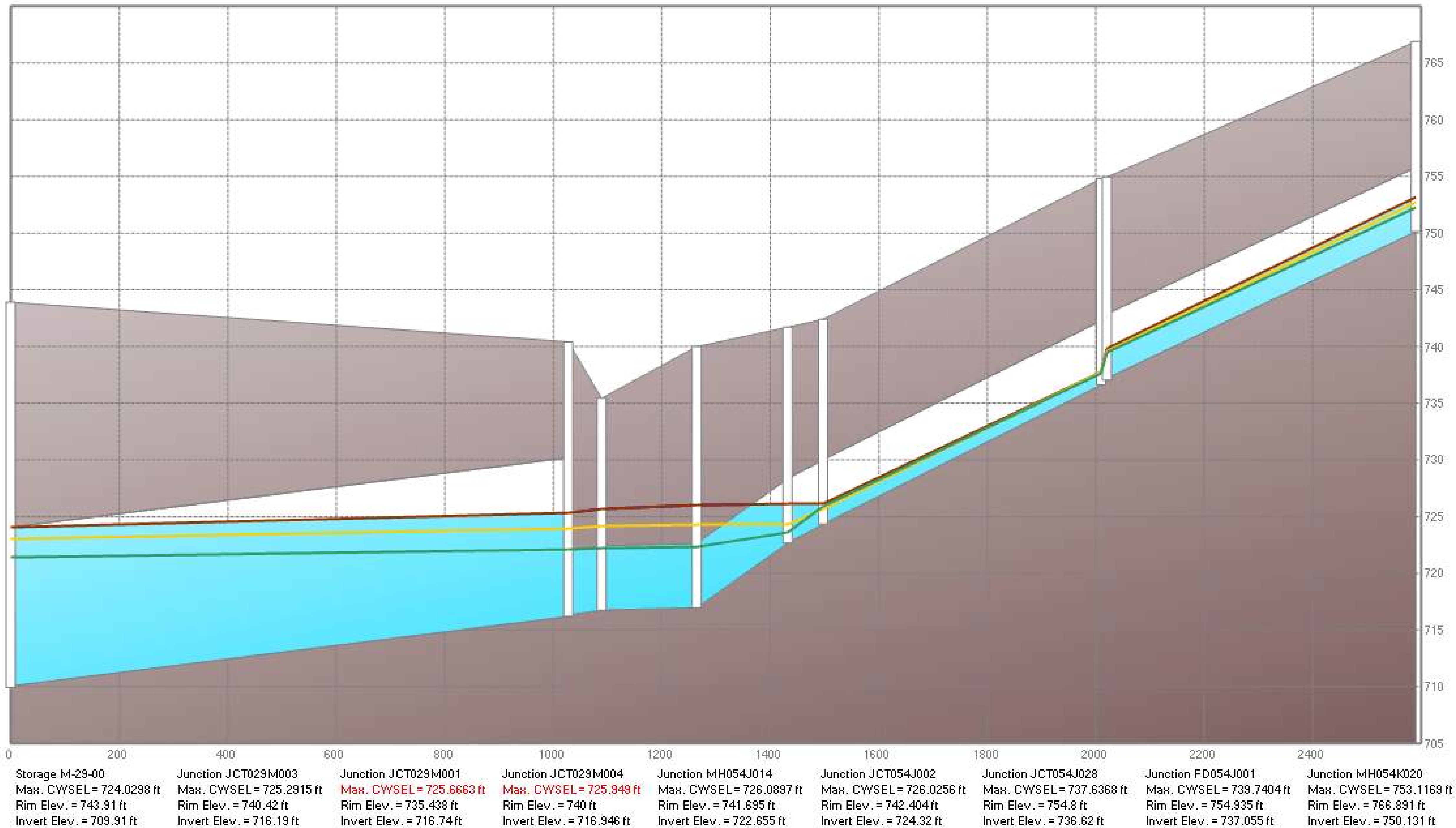
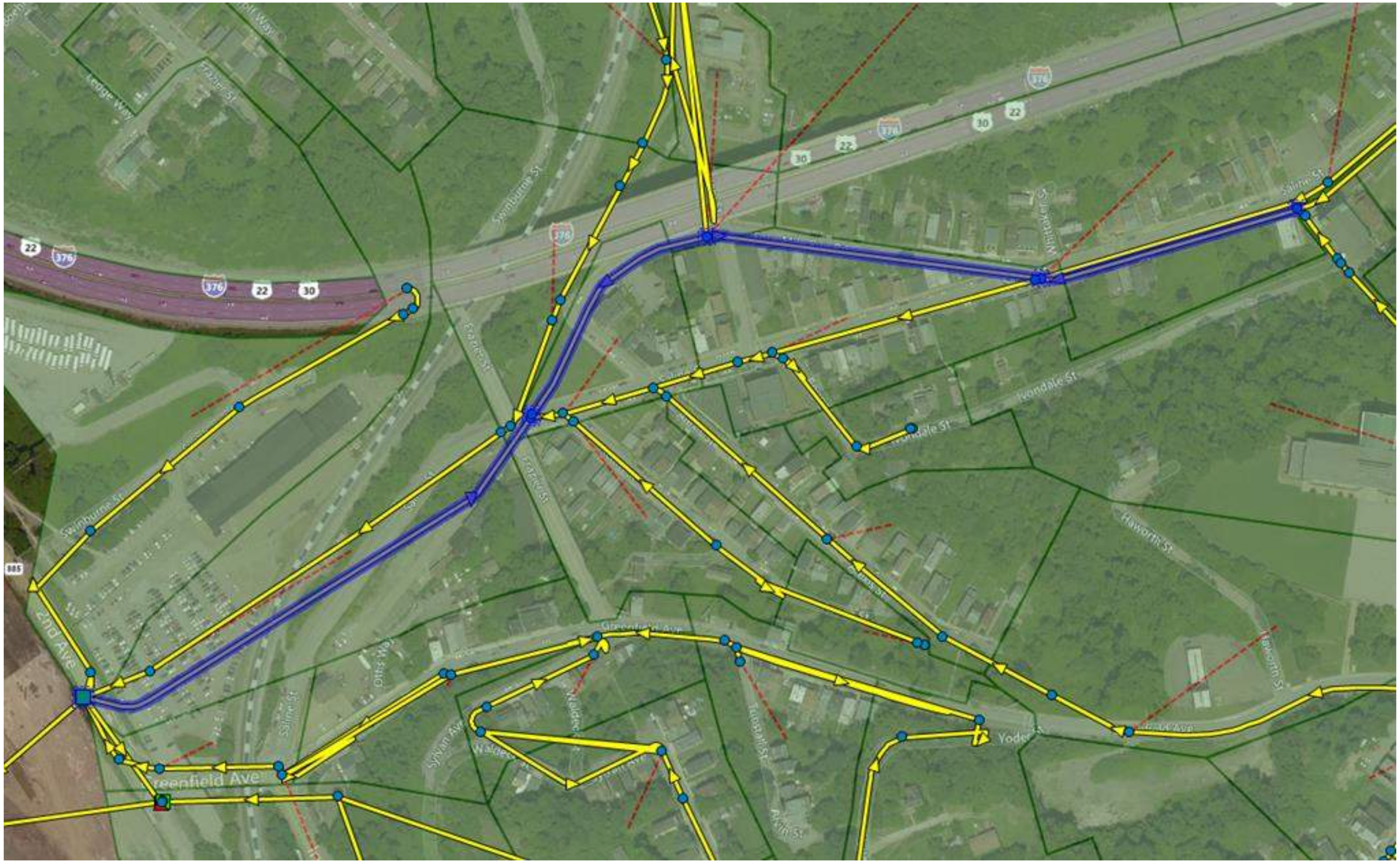


Figure 2D - Simulations_11, 19, and 27 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm



Simulations_11, 19, and 27 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 05-Year, 24-Hour Design Storm

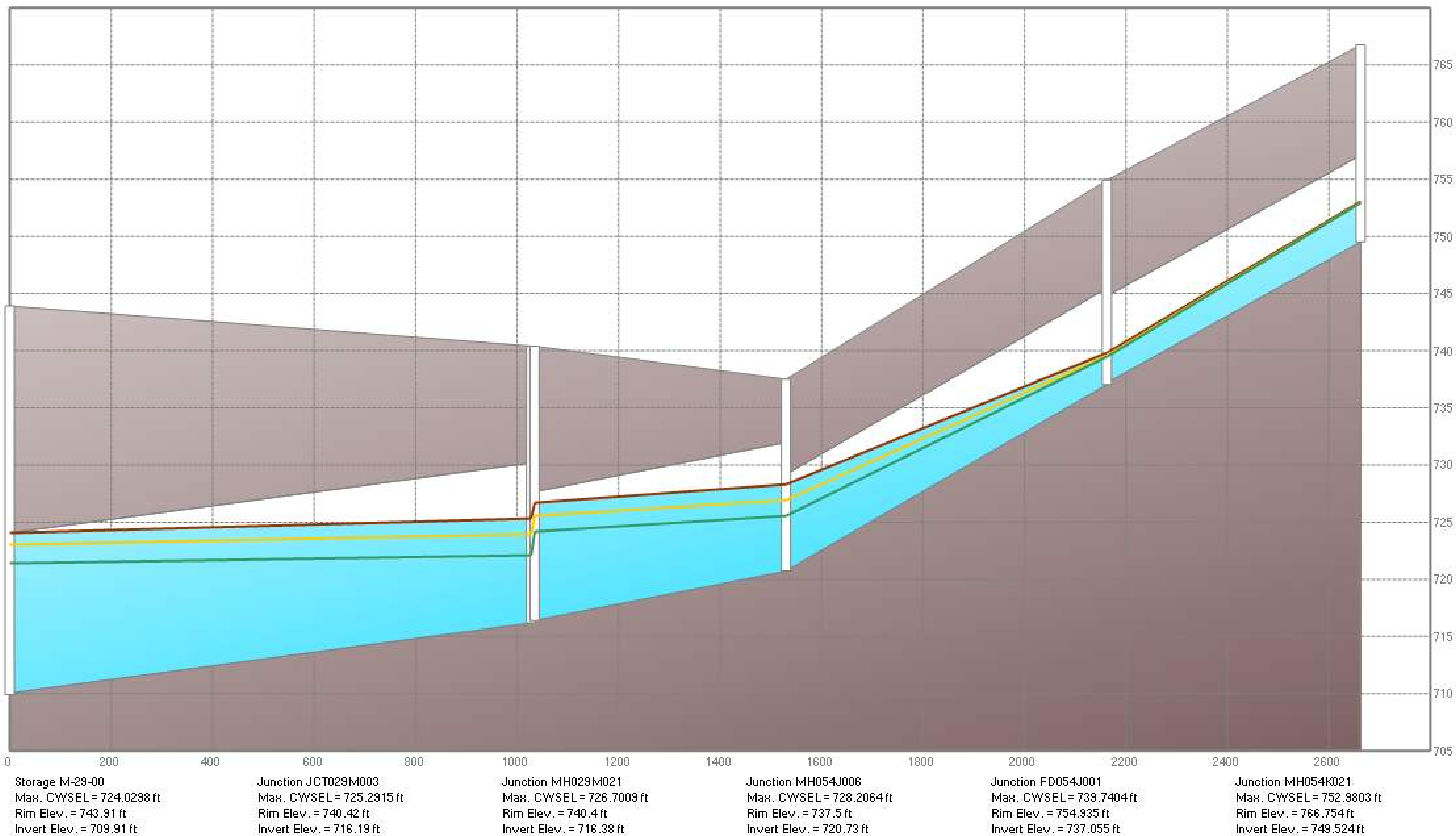
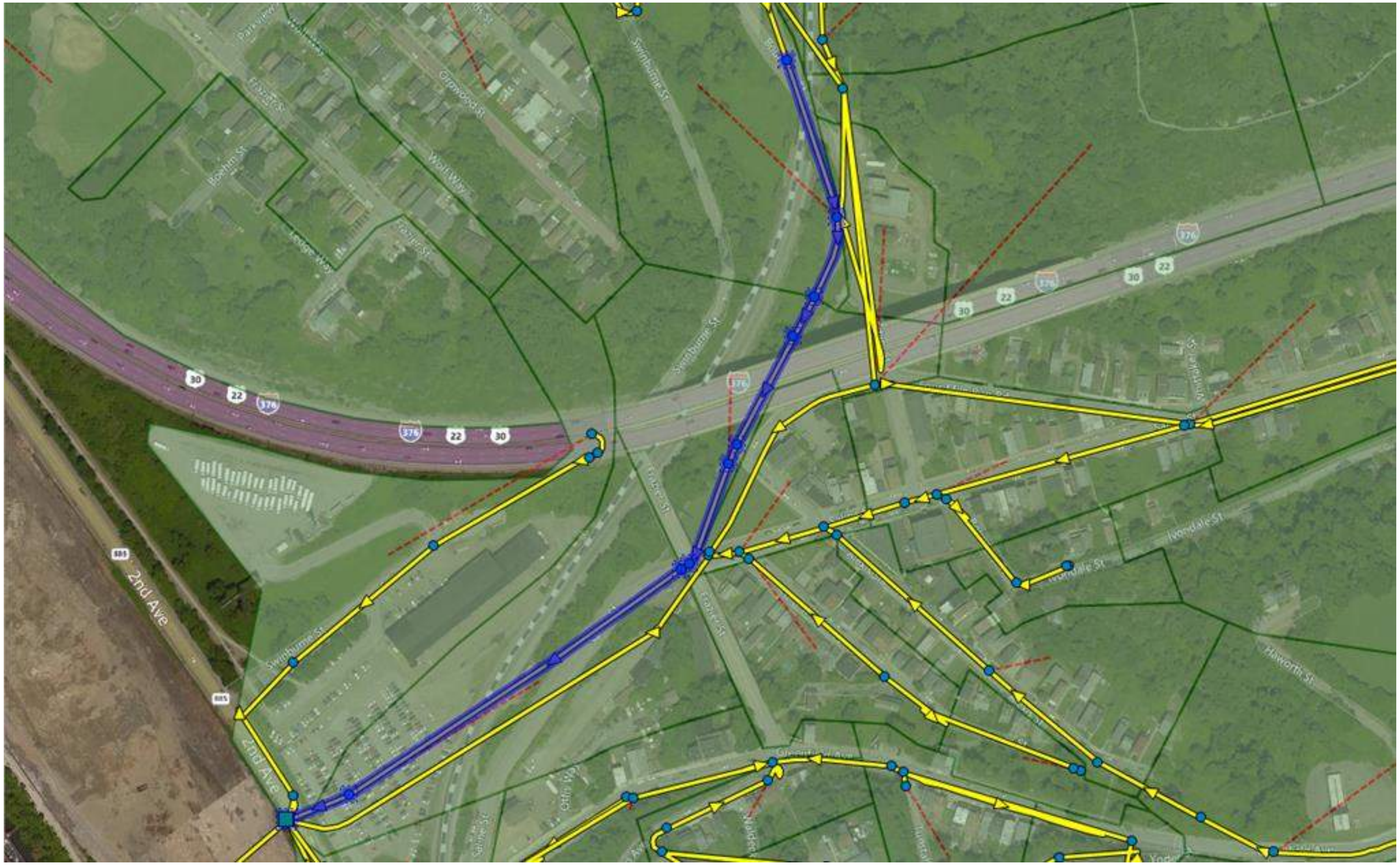


Figure 3A - Simulations_12, 20, and 28 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm



Simulations_12, 20, and 28 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm

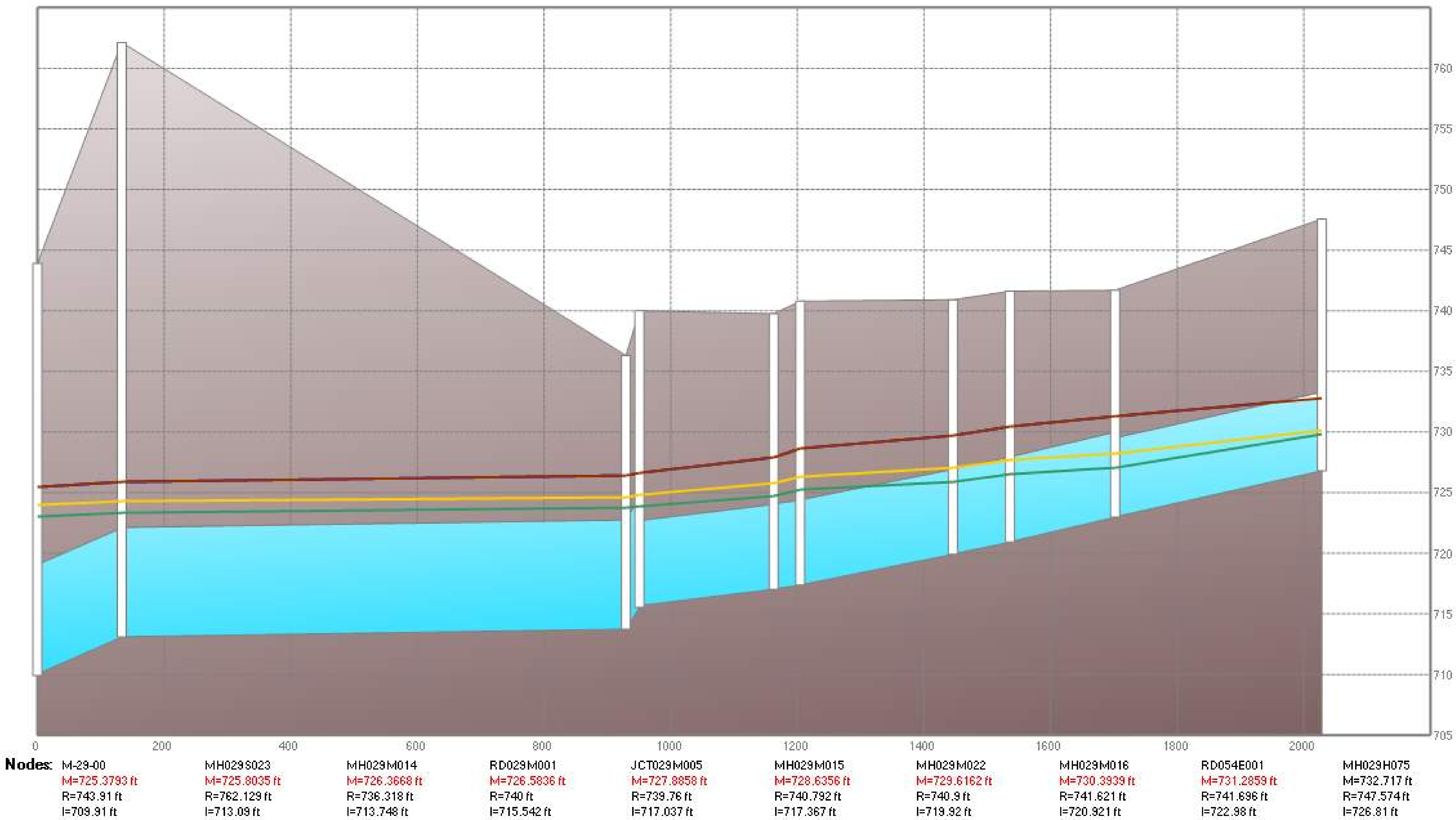
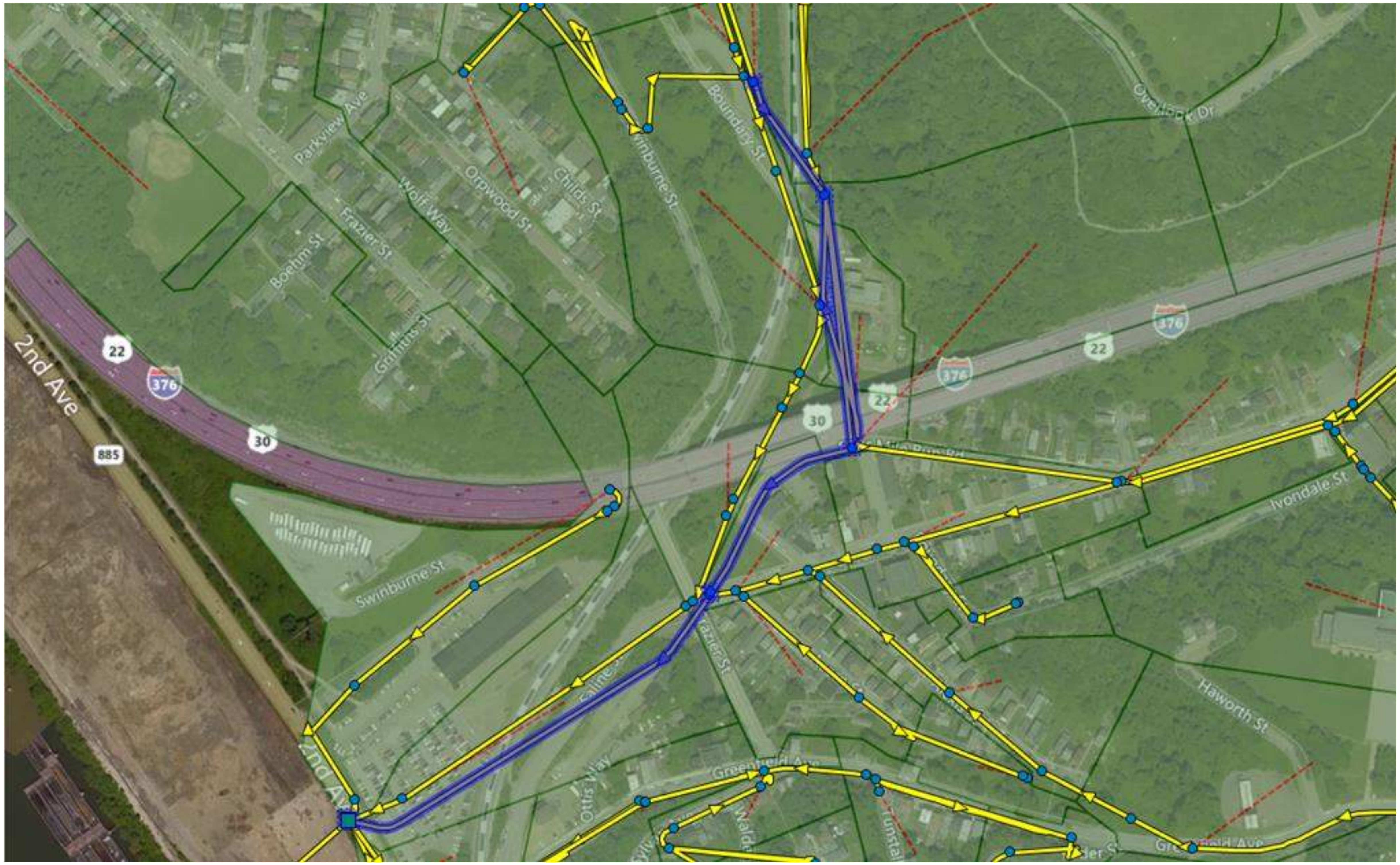


Figure 3B - Simulations_12, 20, and 28 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm



Simulations_12, 20, and 28 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm

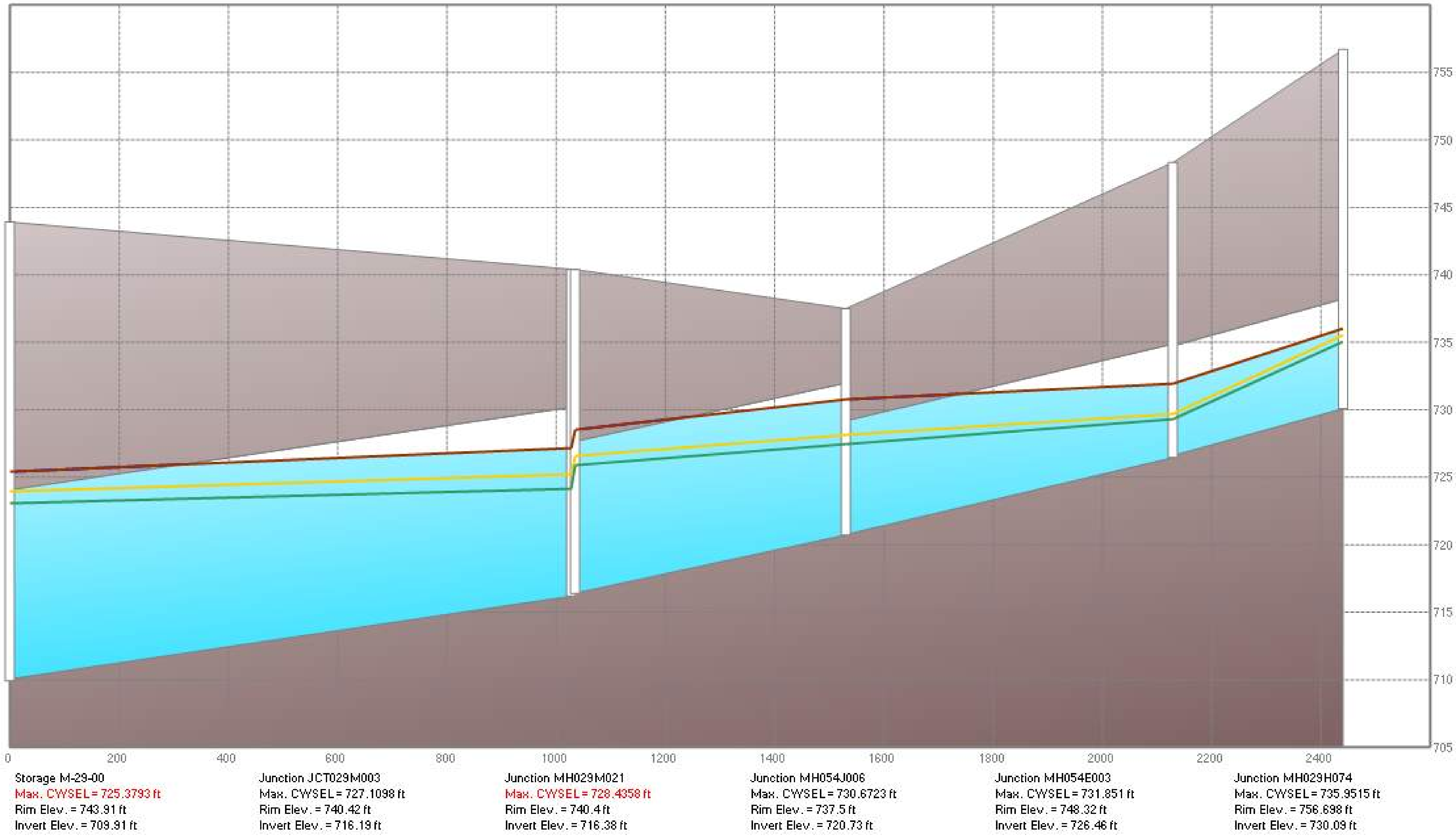
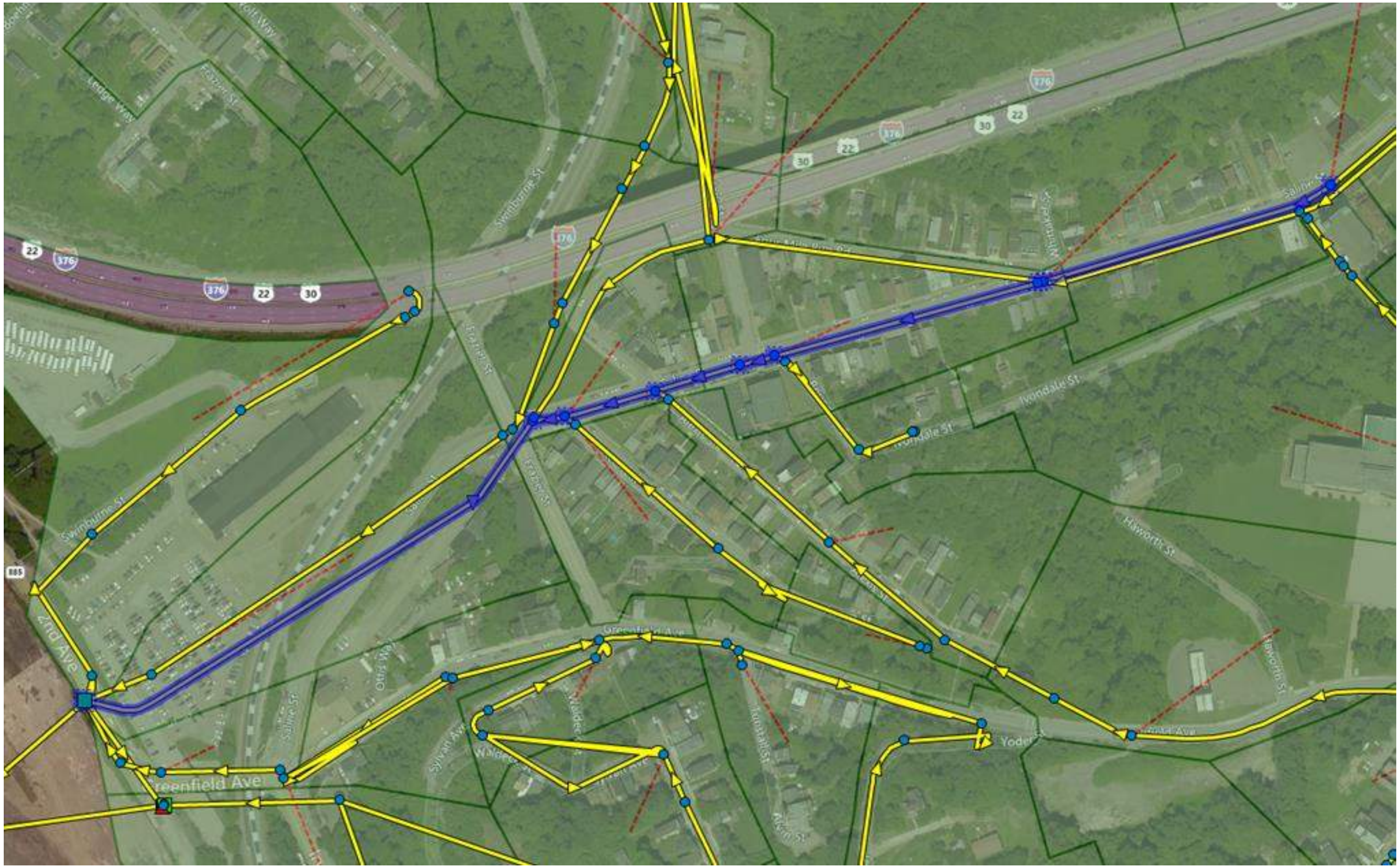


Figure 3C - Simulations_12, 20, and 28 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm



Simulations_12, 20, and 28 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm

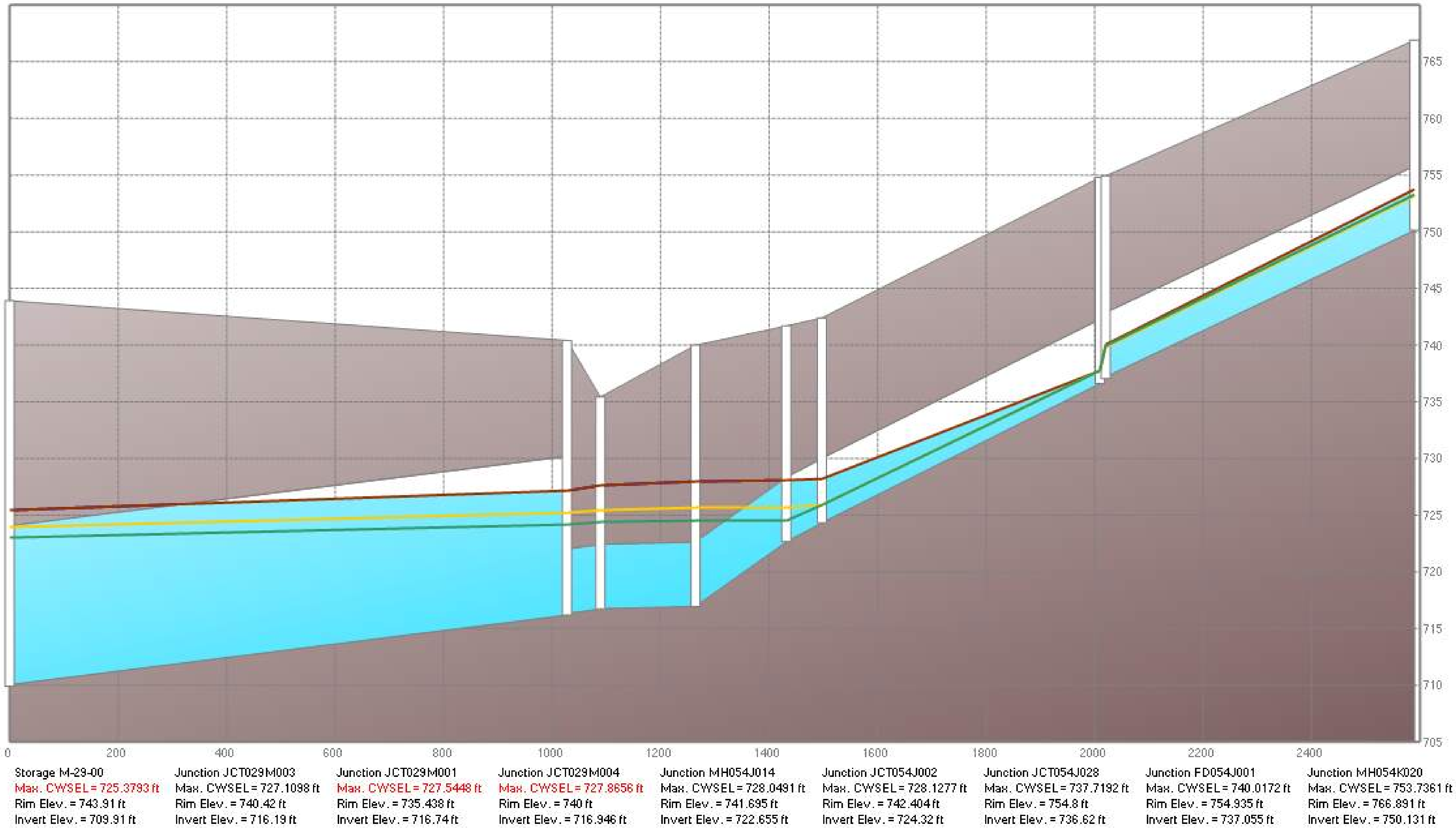
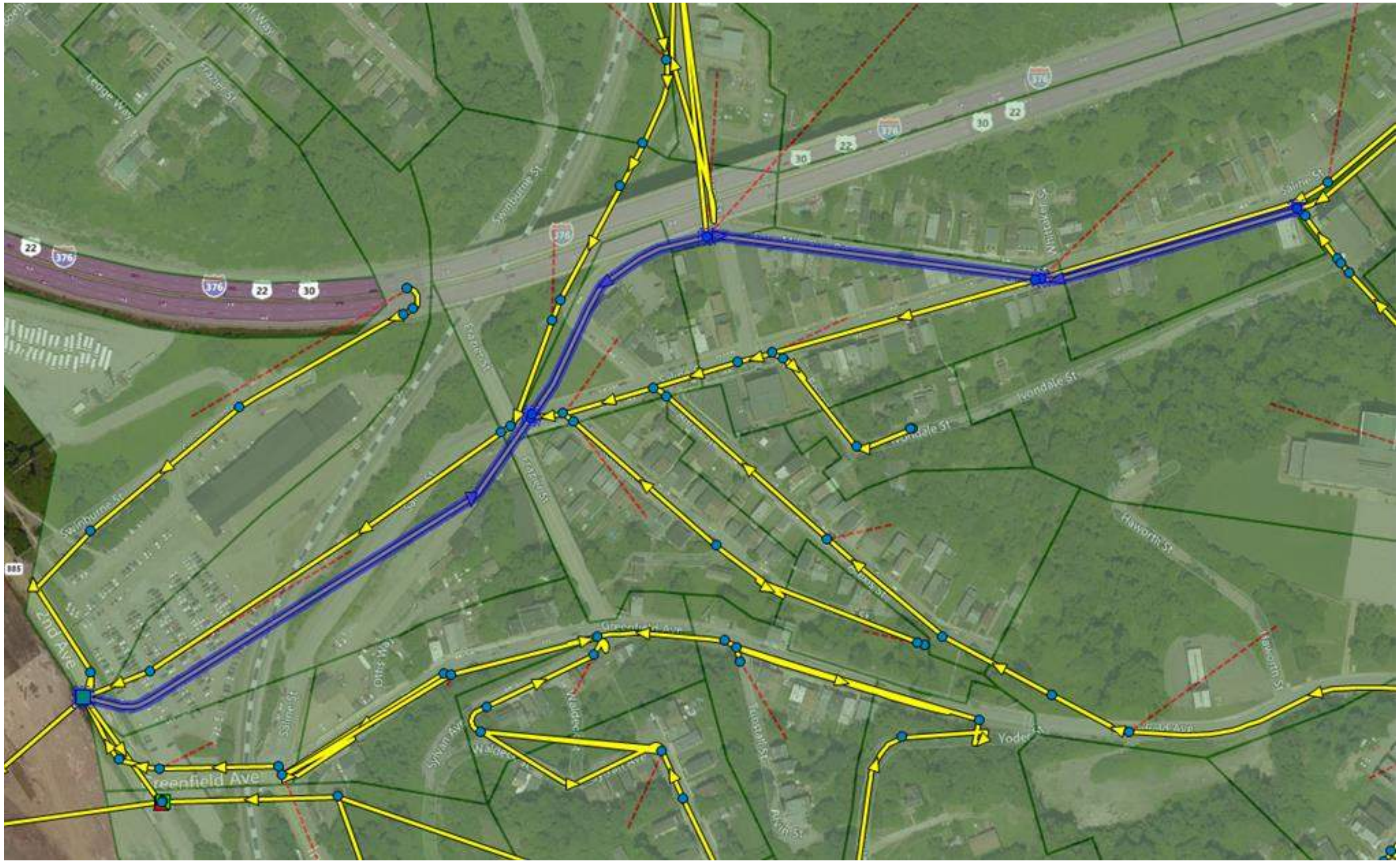


Figure 3D - Simulations_12, 20, and 28 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm



Simulations_12, 20, and 28 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 10-Year, 24-Hour Design Storm

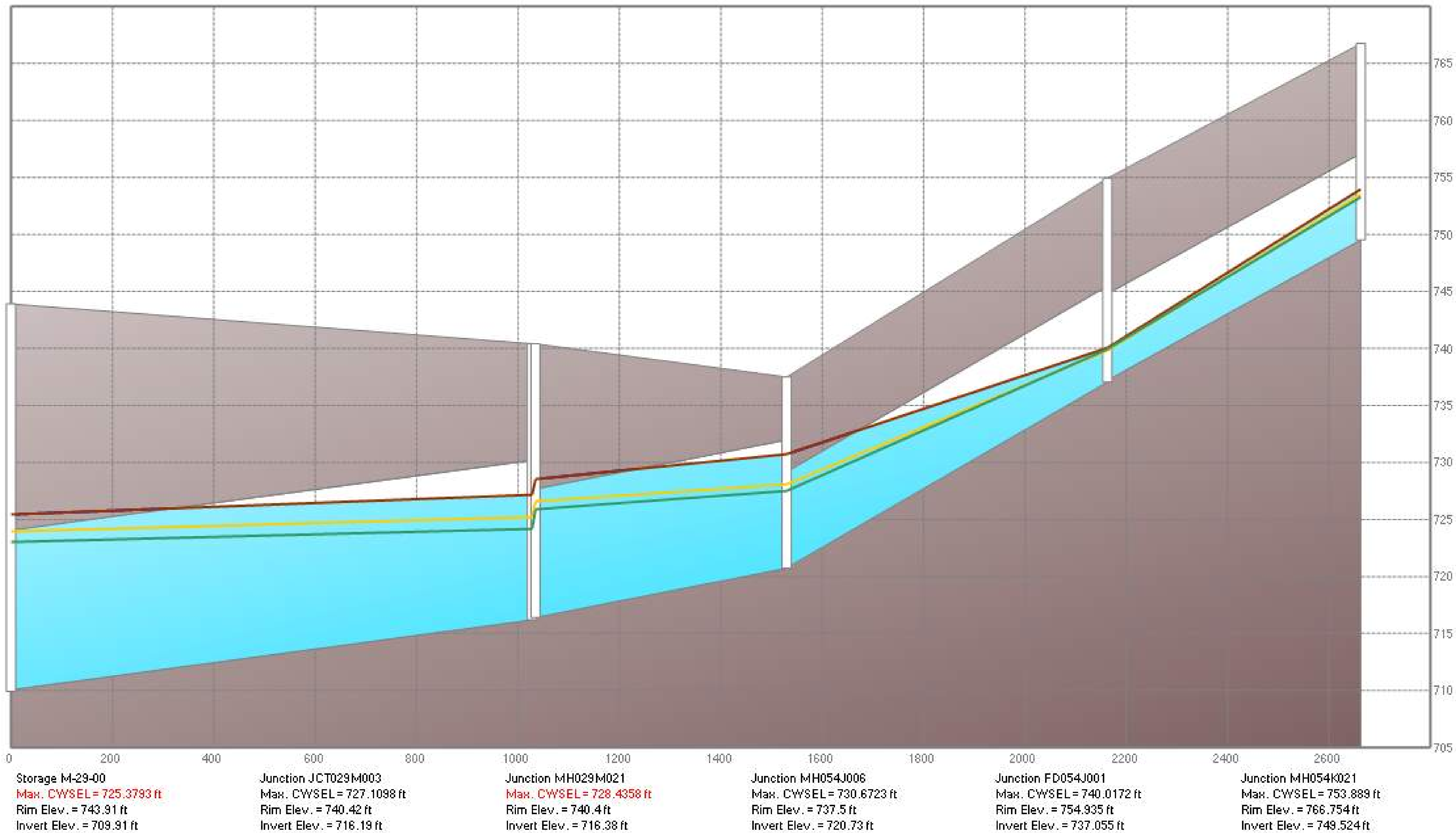
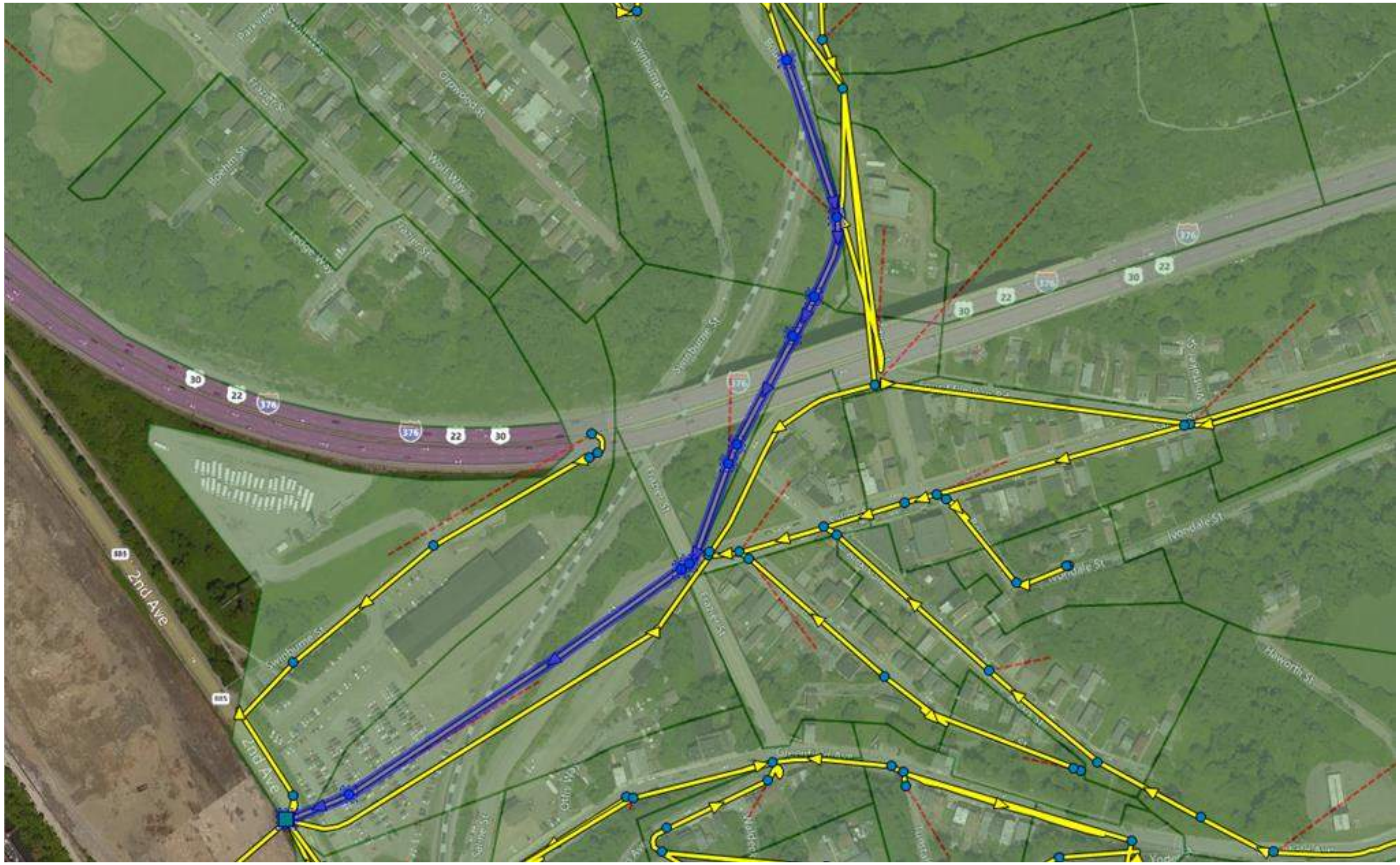


Figure 4A - Simulations_13, 21, and 29 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm



Simulations_13, 21, and 29 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm

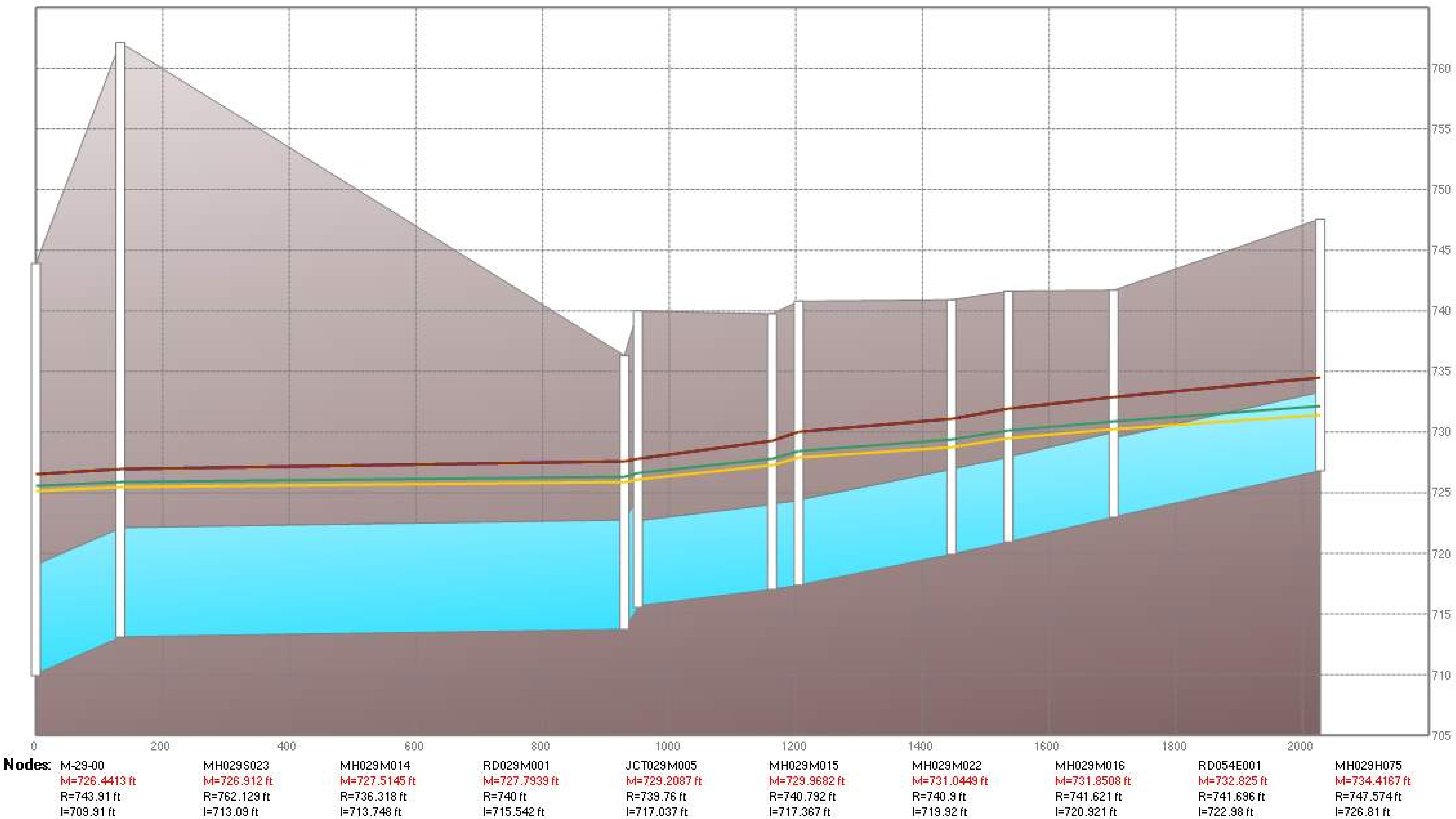
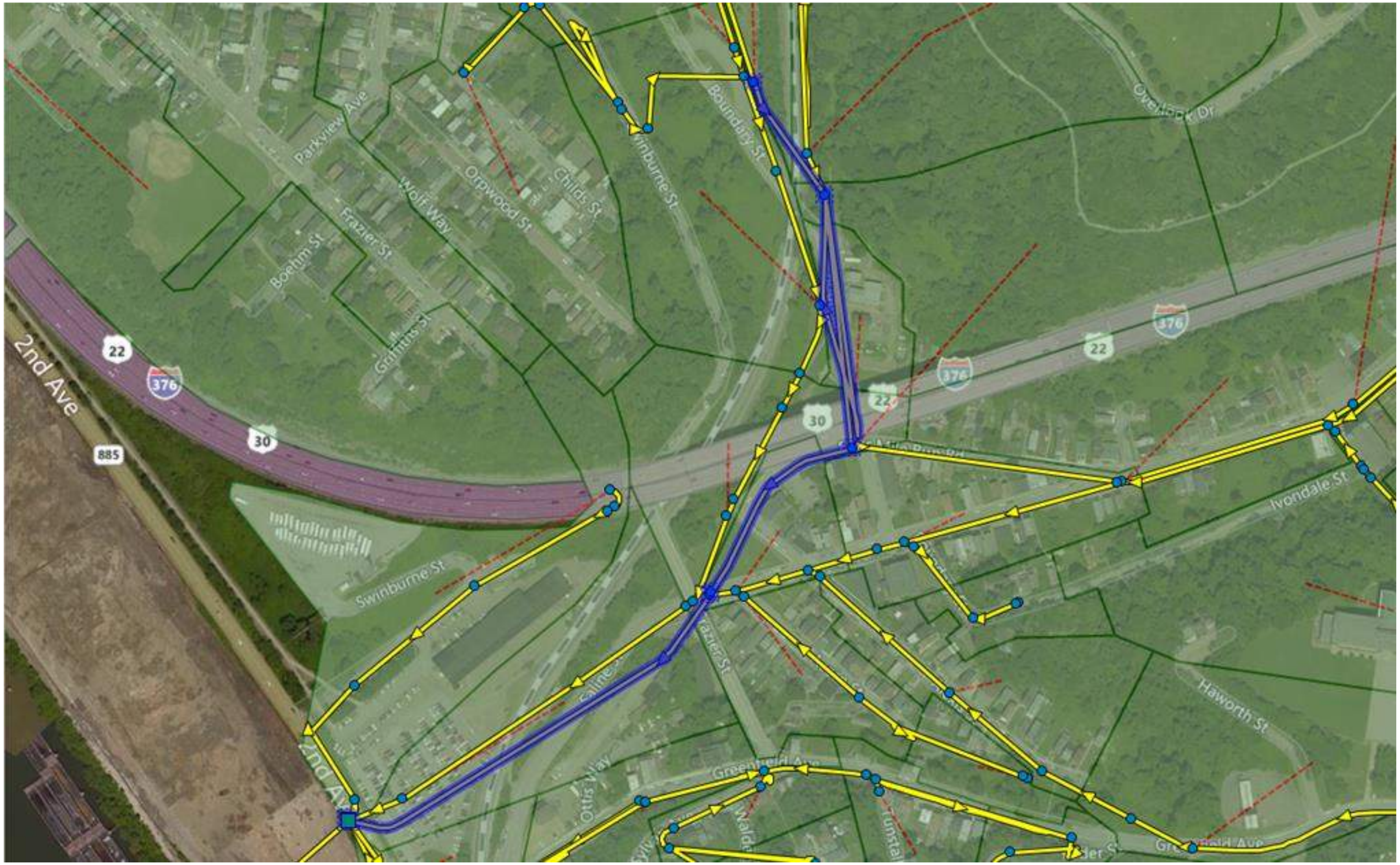


Figure 4B - Simulations_13, 21, and 29 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm



Simulations_13, 21, and 29 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm

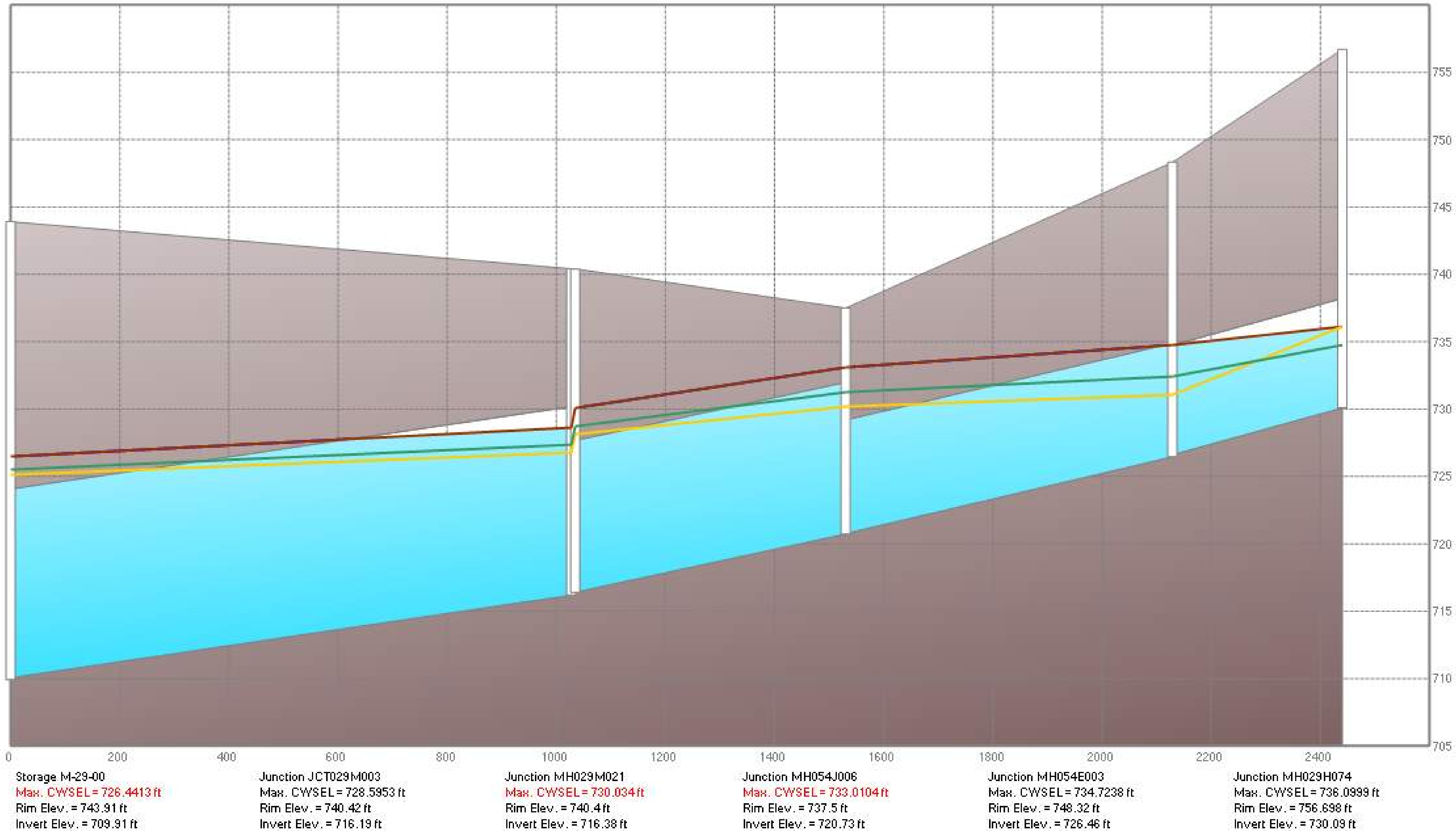
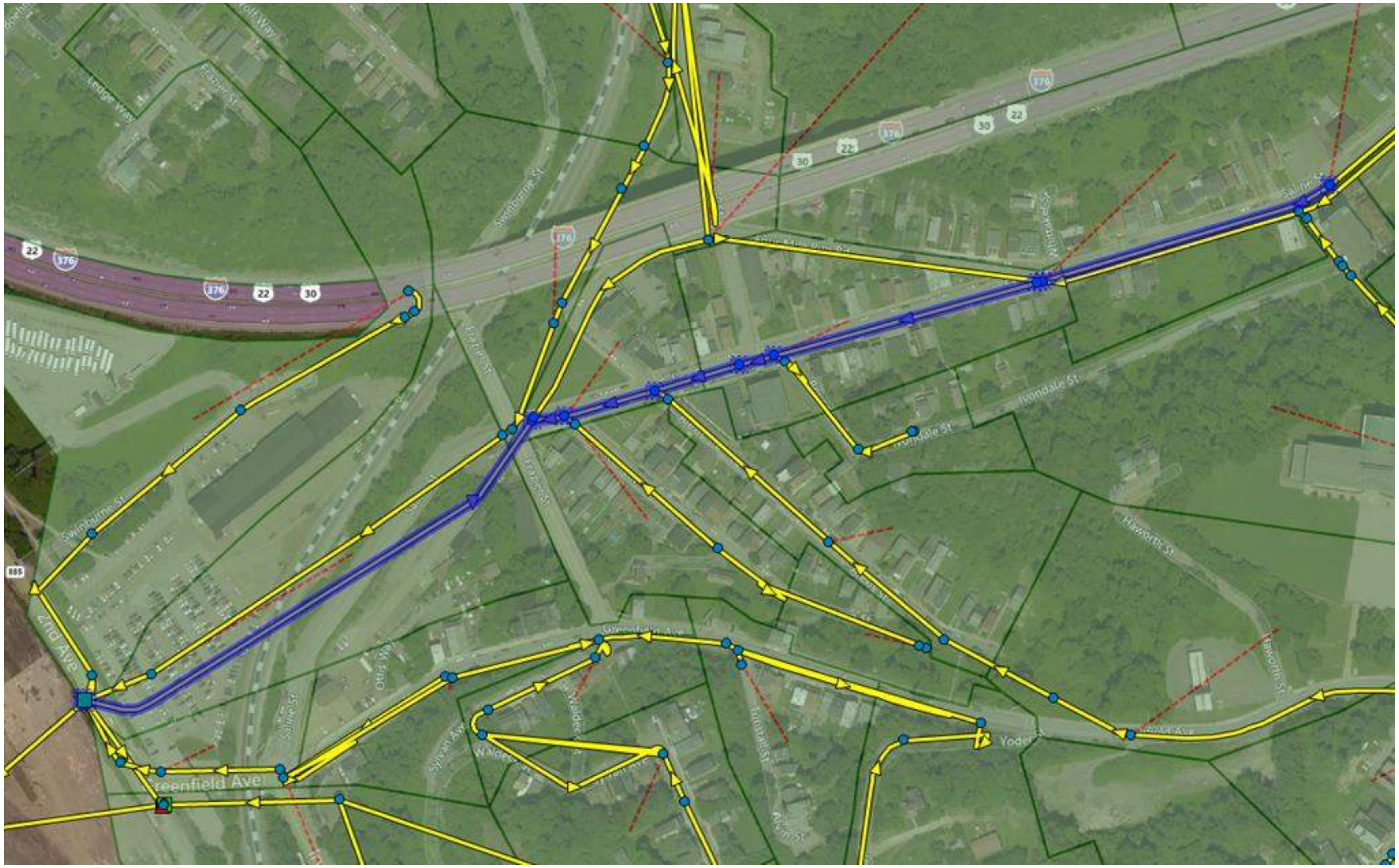


Figure 4C - Simulations_13, 21, and 29 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm



Simulations_13, 21, and 29 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm

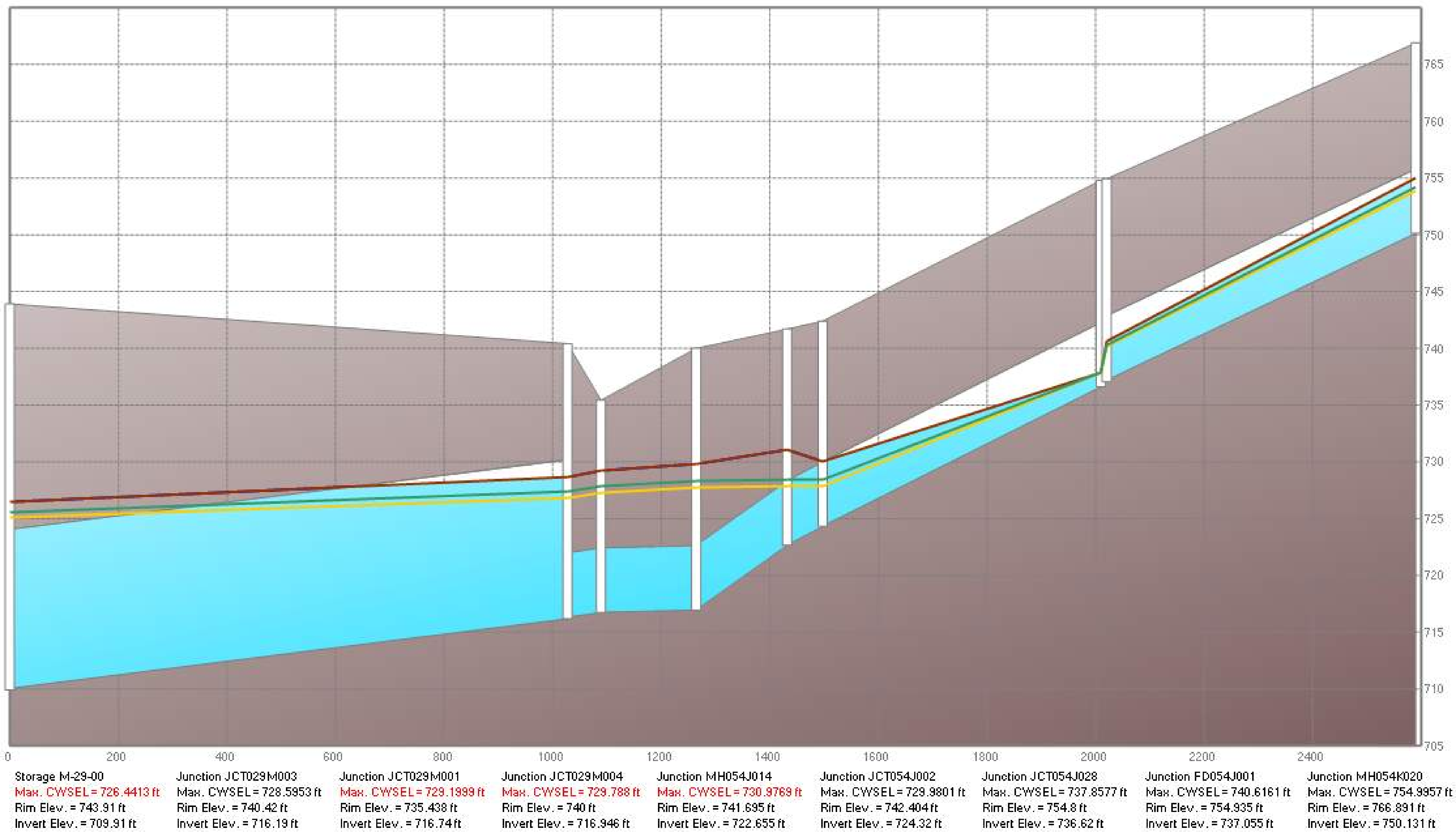
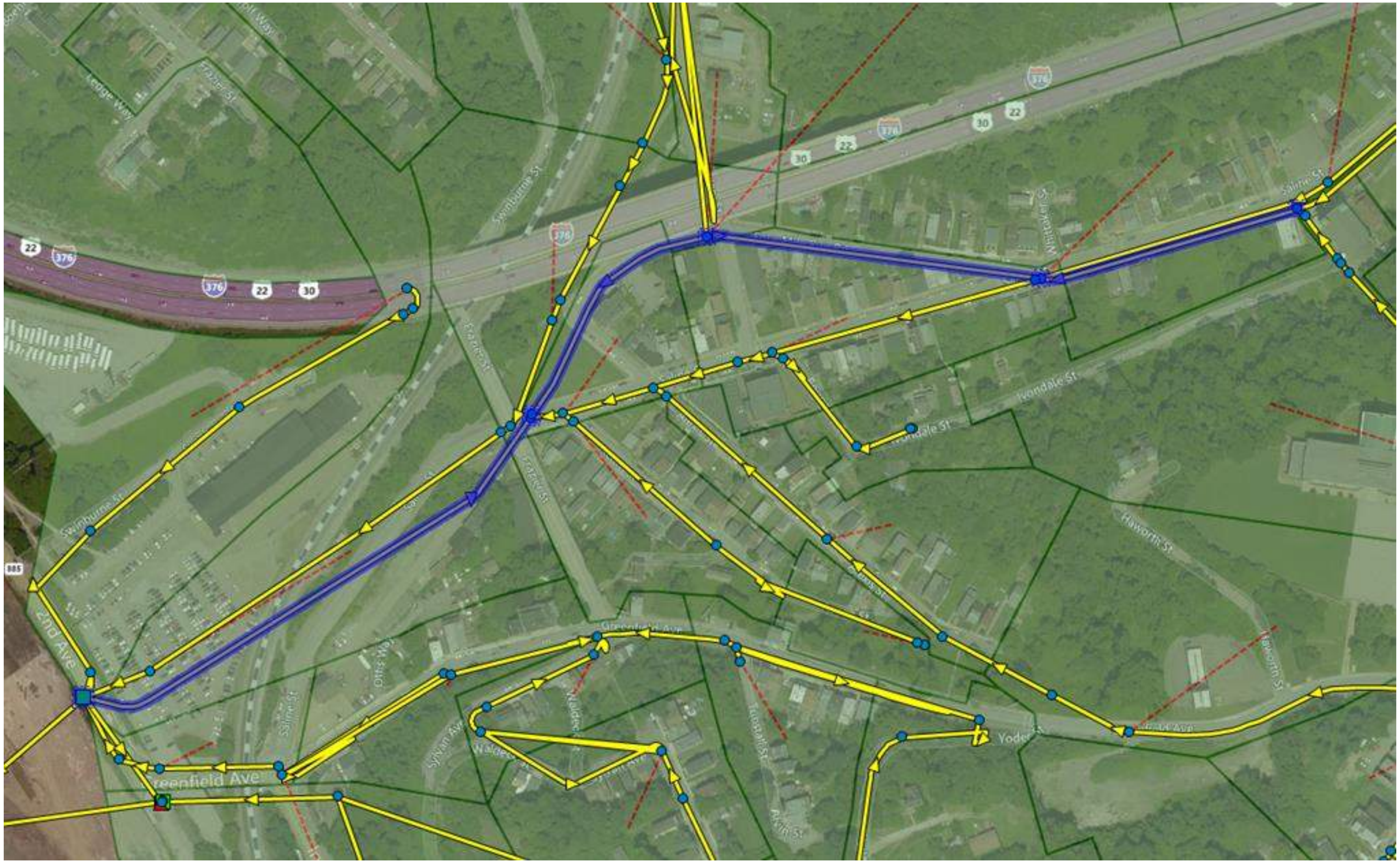


Figure 4D - Simulations_13, 21, and 29 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm



Simulations_13, 21, and 29 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storm: 25-Year, 24-Hour Design Storm

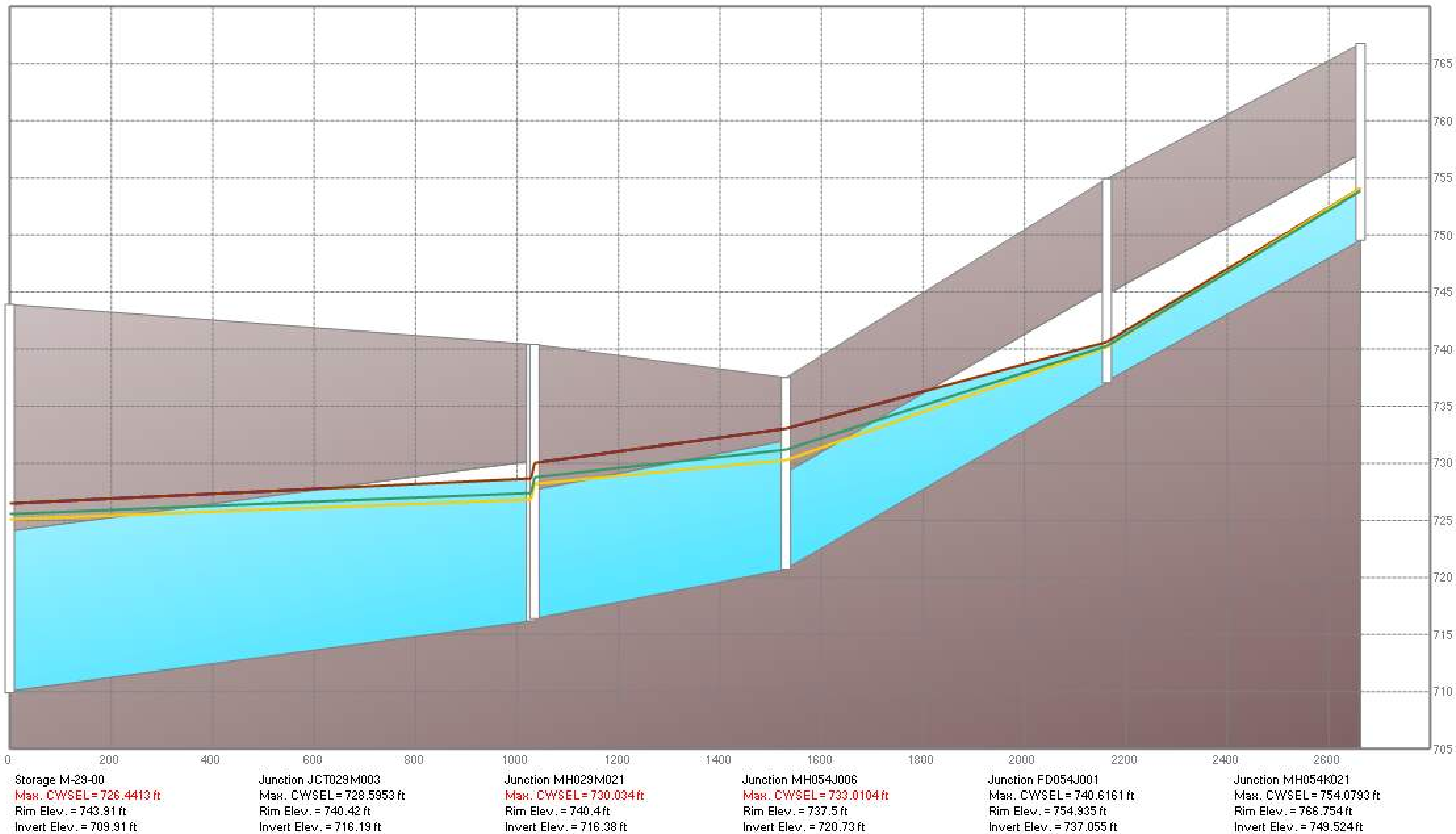
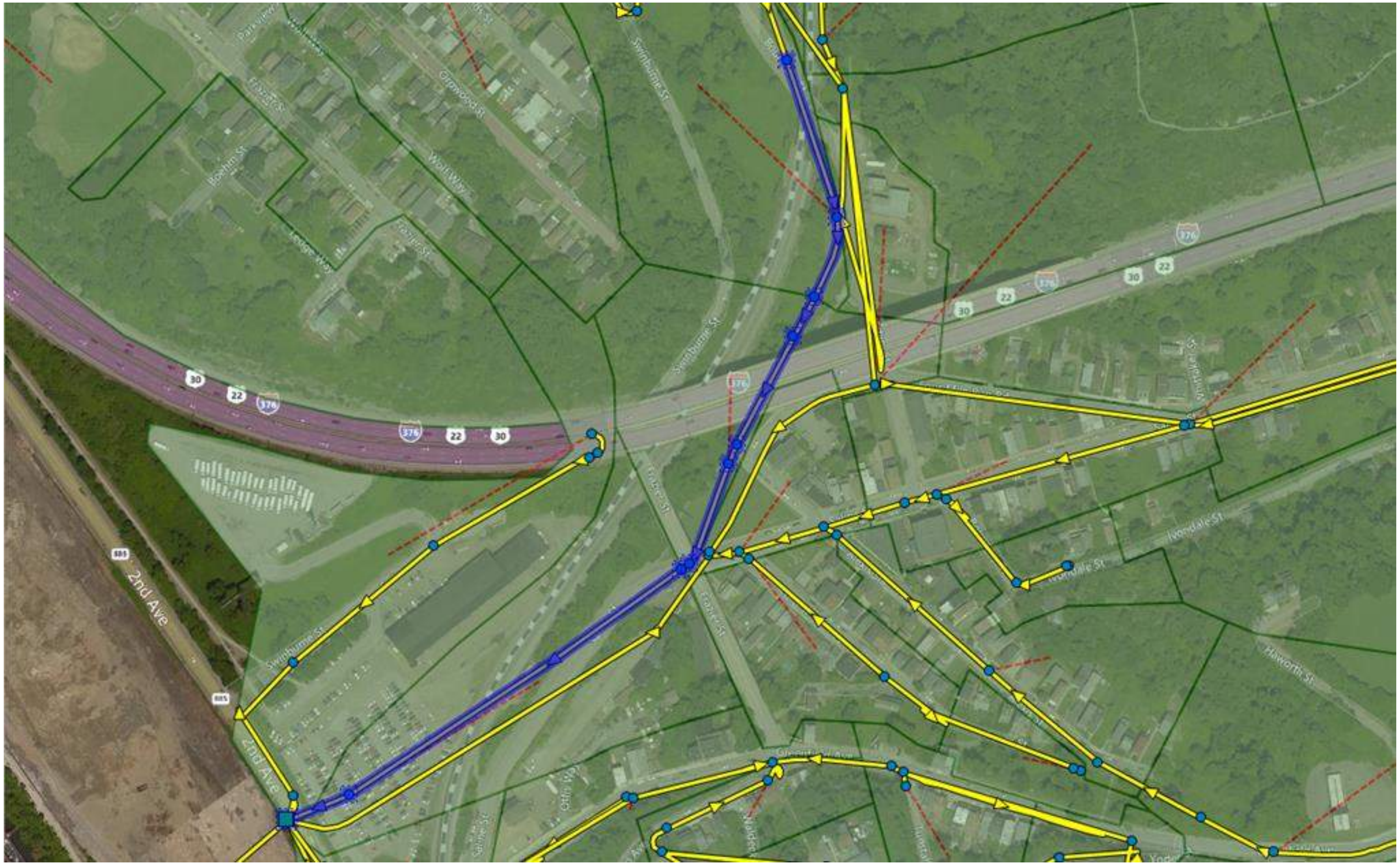


Figure 5A - Simulations_14, 22, and 30 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm



Simulations_14, 22, and 30 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm

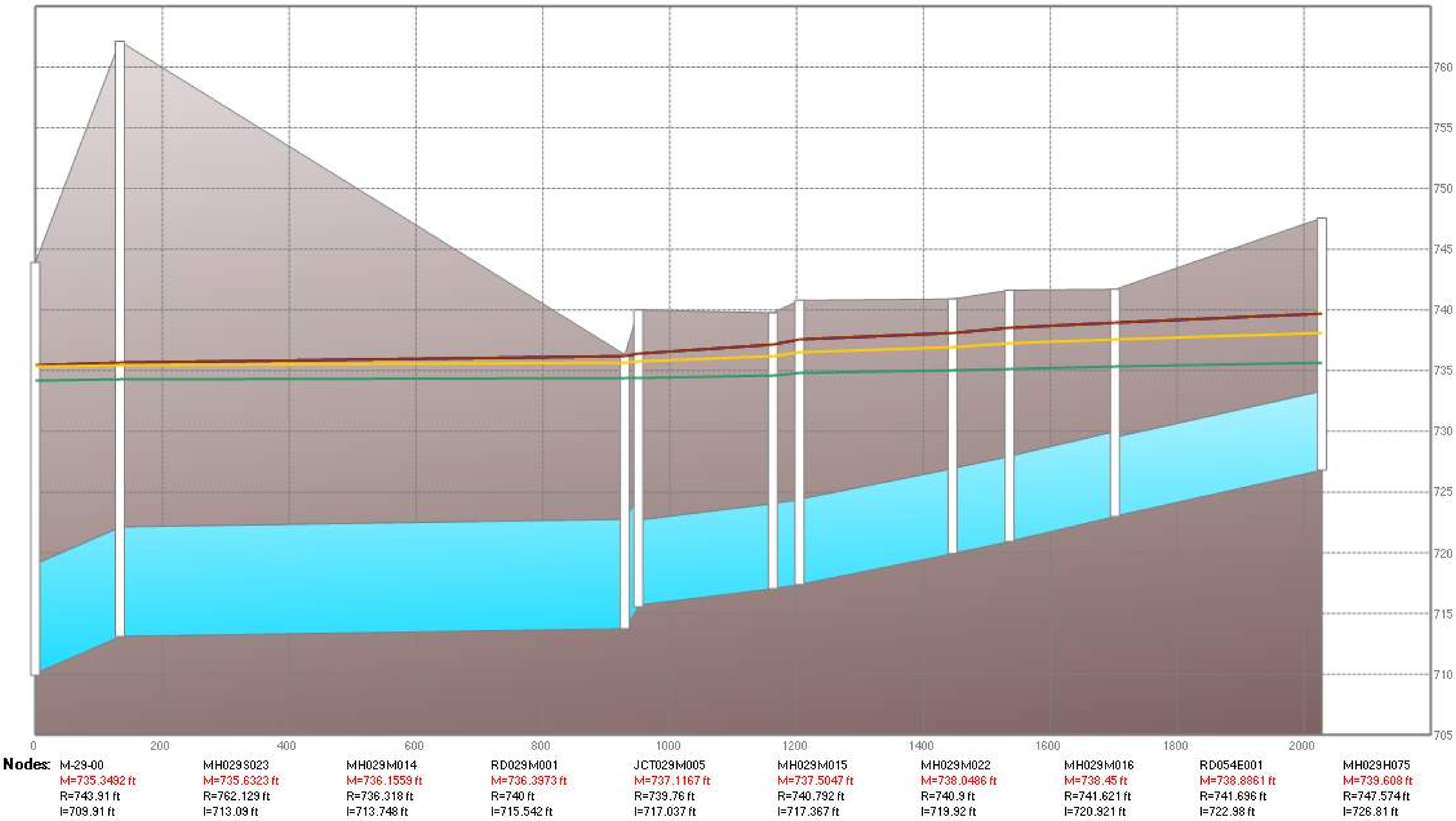
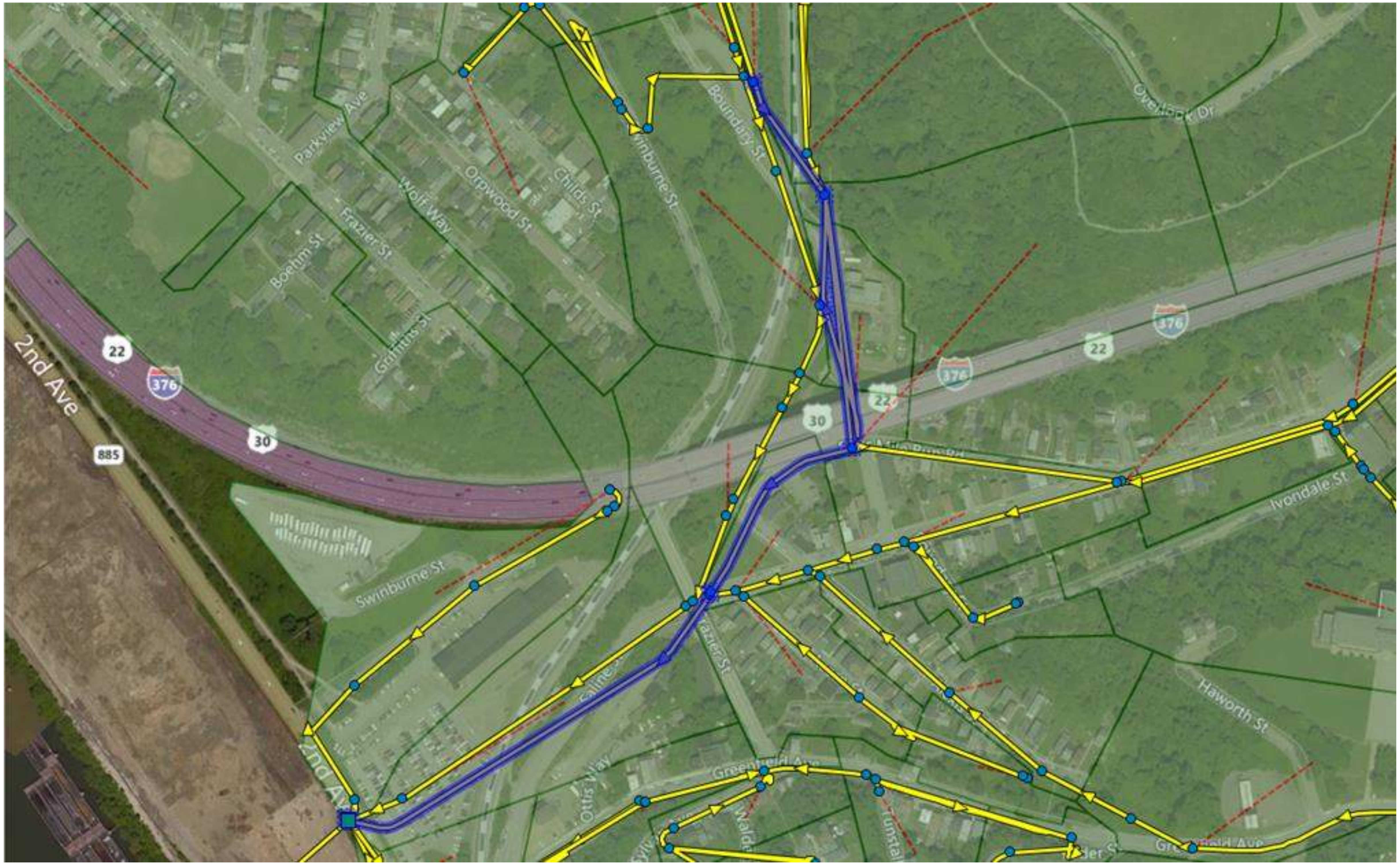


Figure 5B - Simulations_14, 22, and 30 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm



Simulations_14, 22, and 30 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm

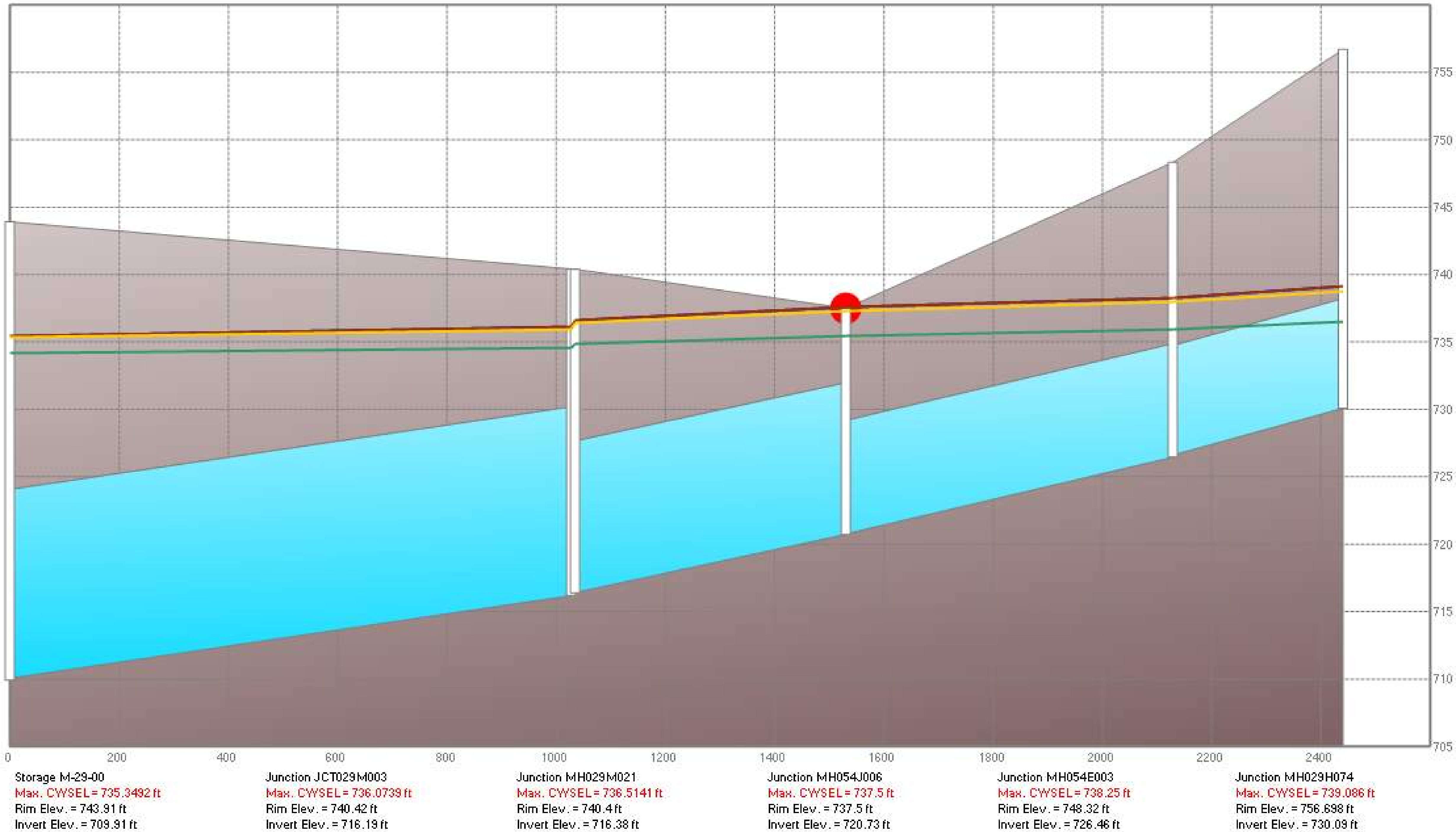
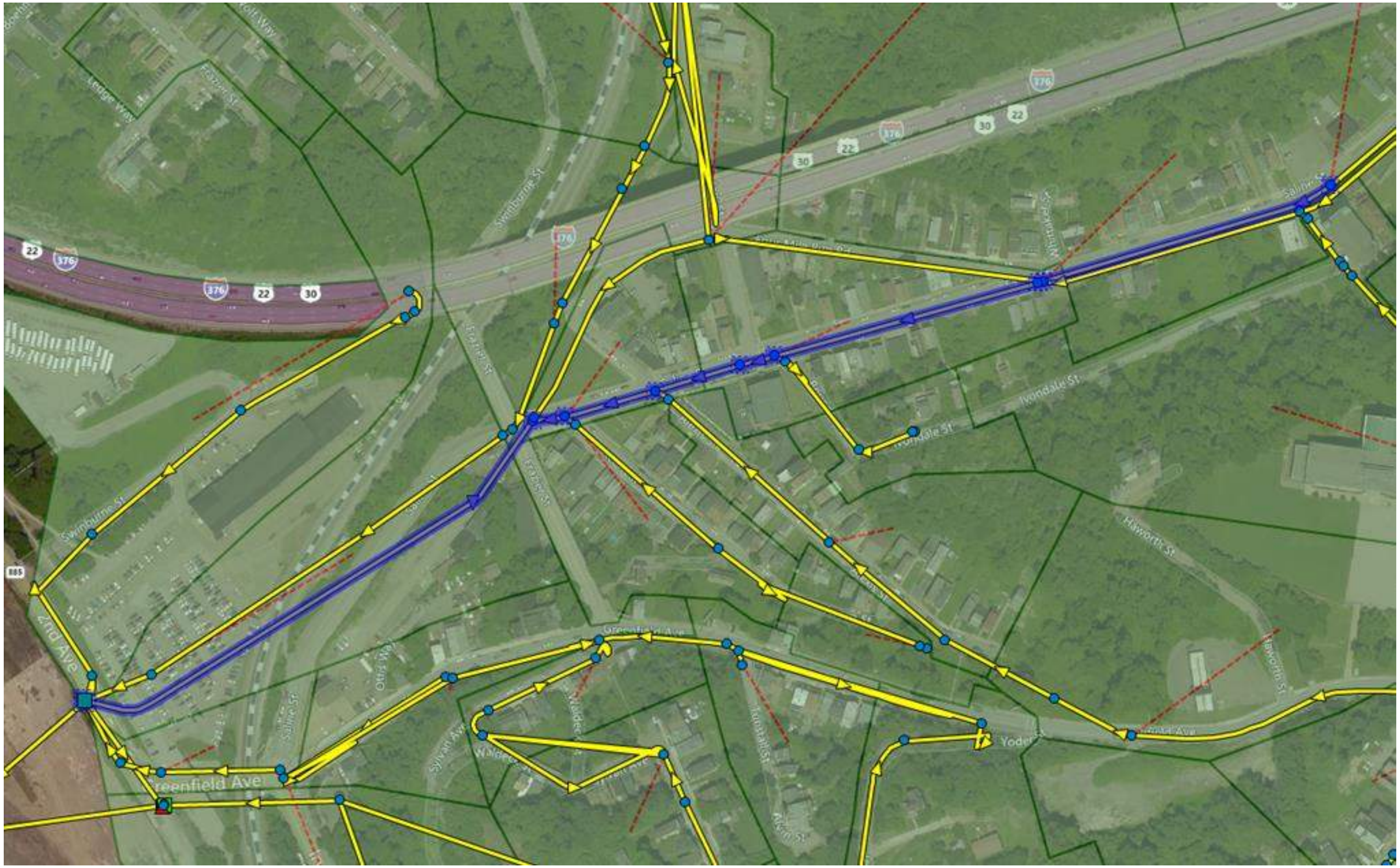


Figure 5C - Simulations_14, 22, and 30 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm



Simulations_14, 22, and 30 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm

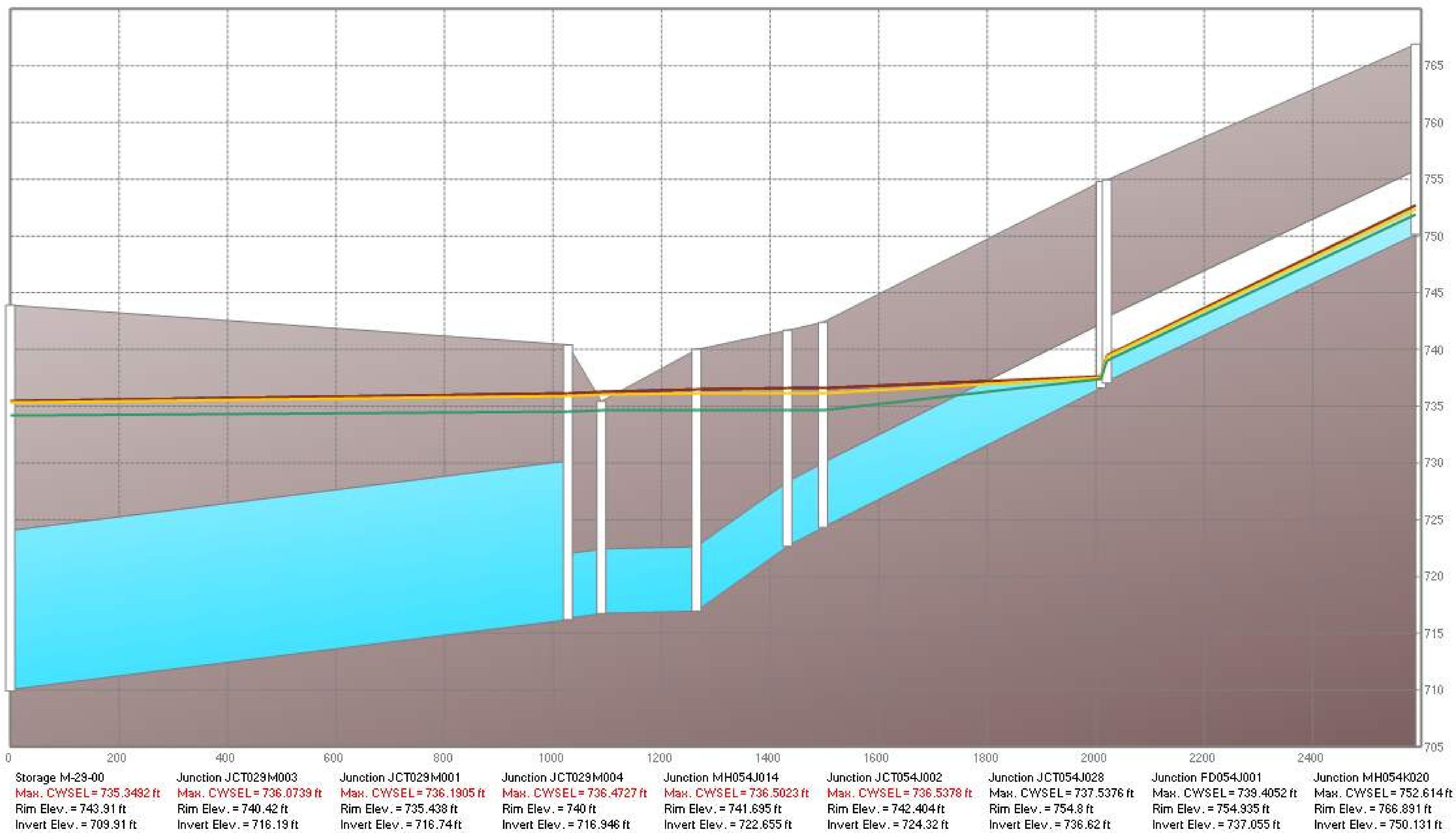
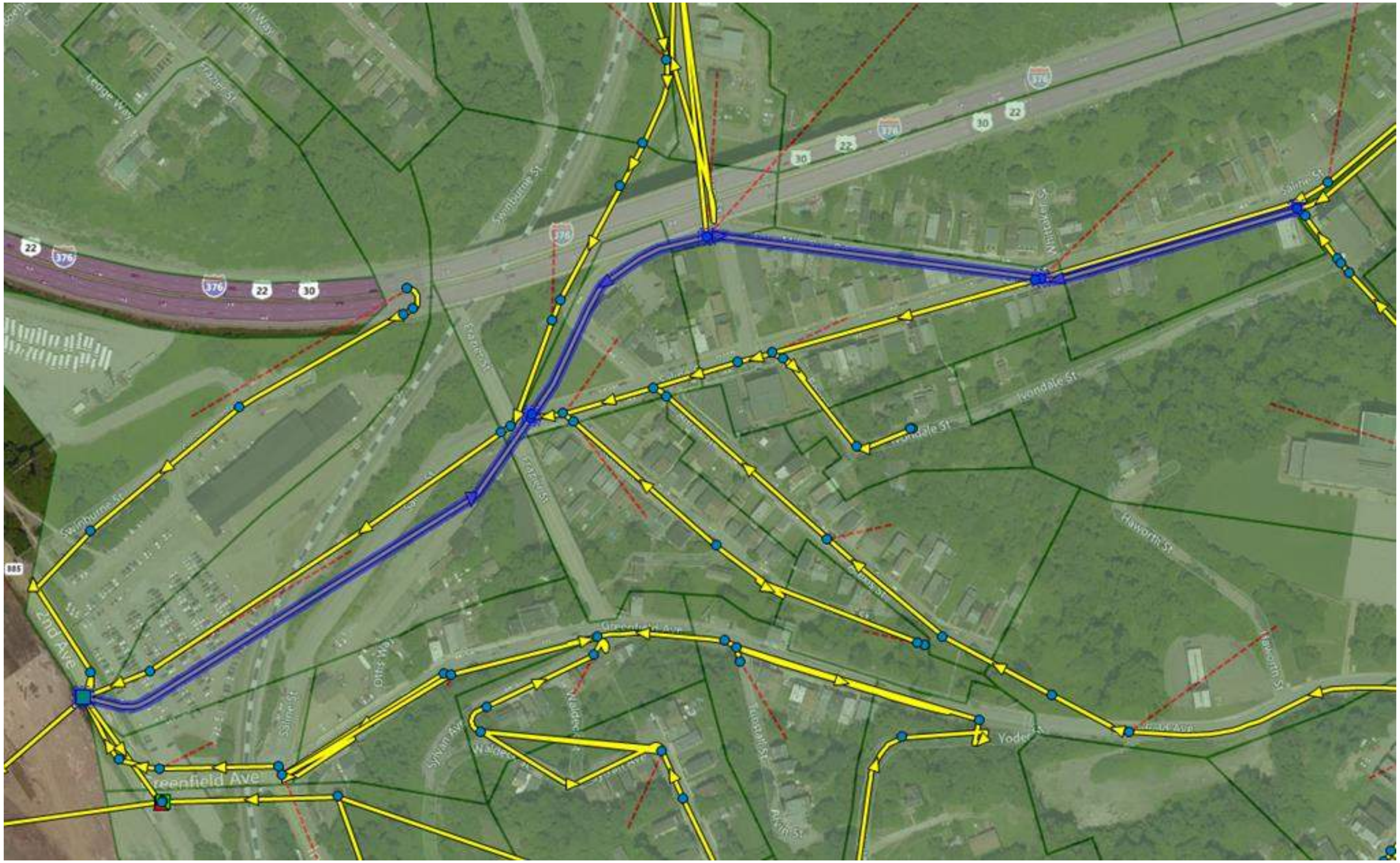


Figure 5D - Simulations_14, 22, and 30 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm



Simulations_14, 22, and 30 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 02-Year, 24-Hour Design Storm

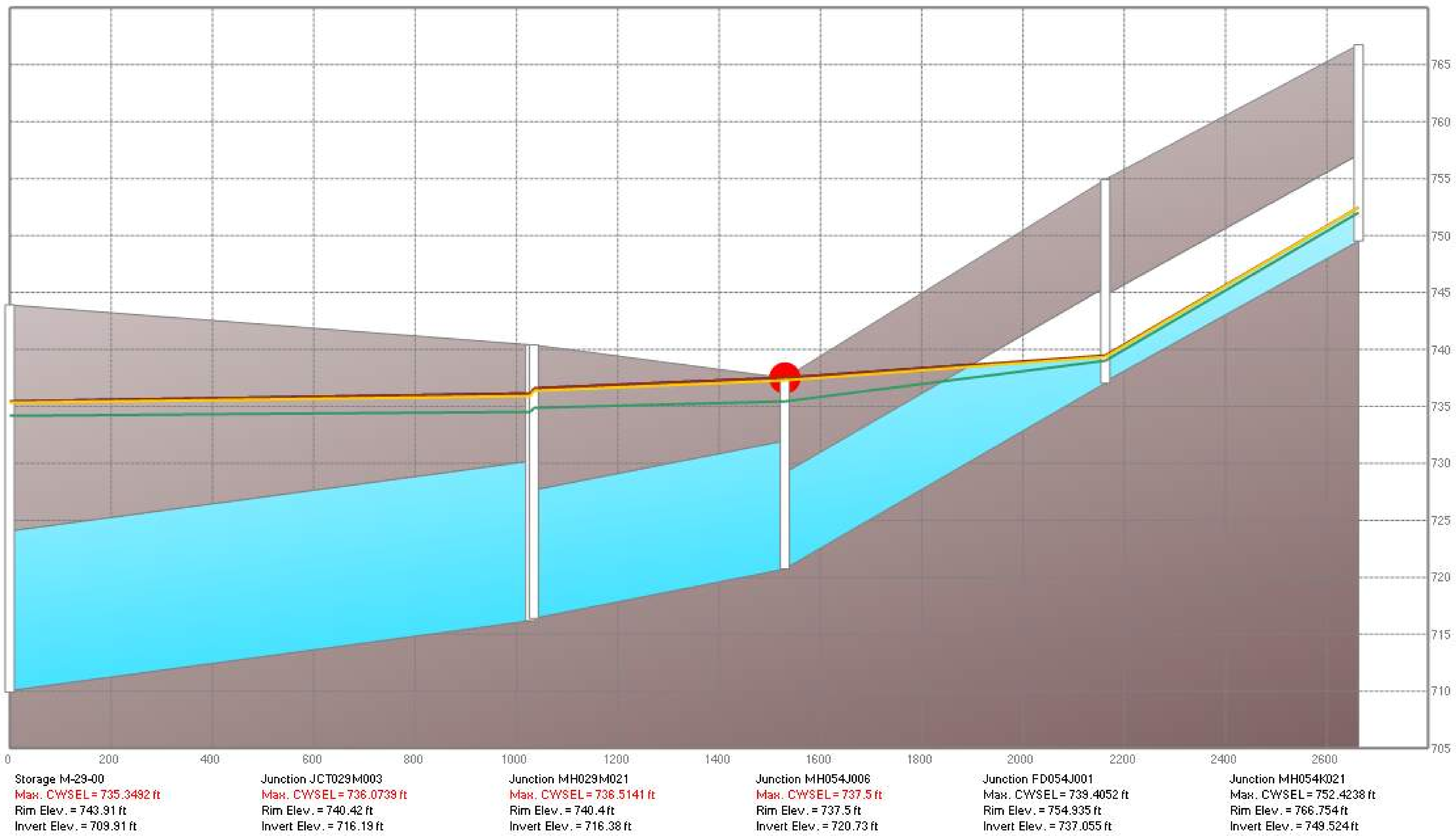
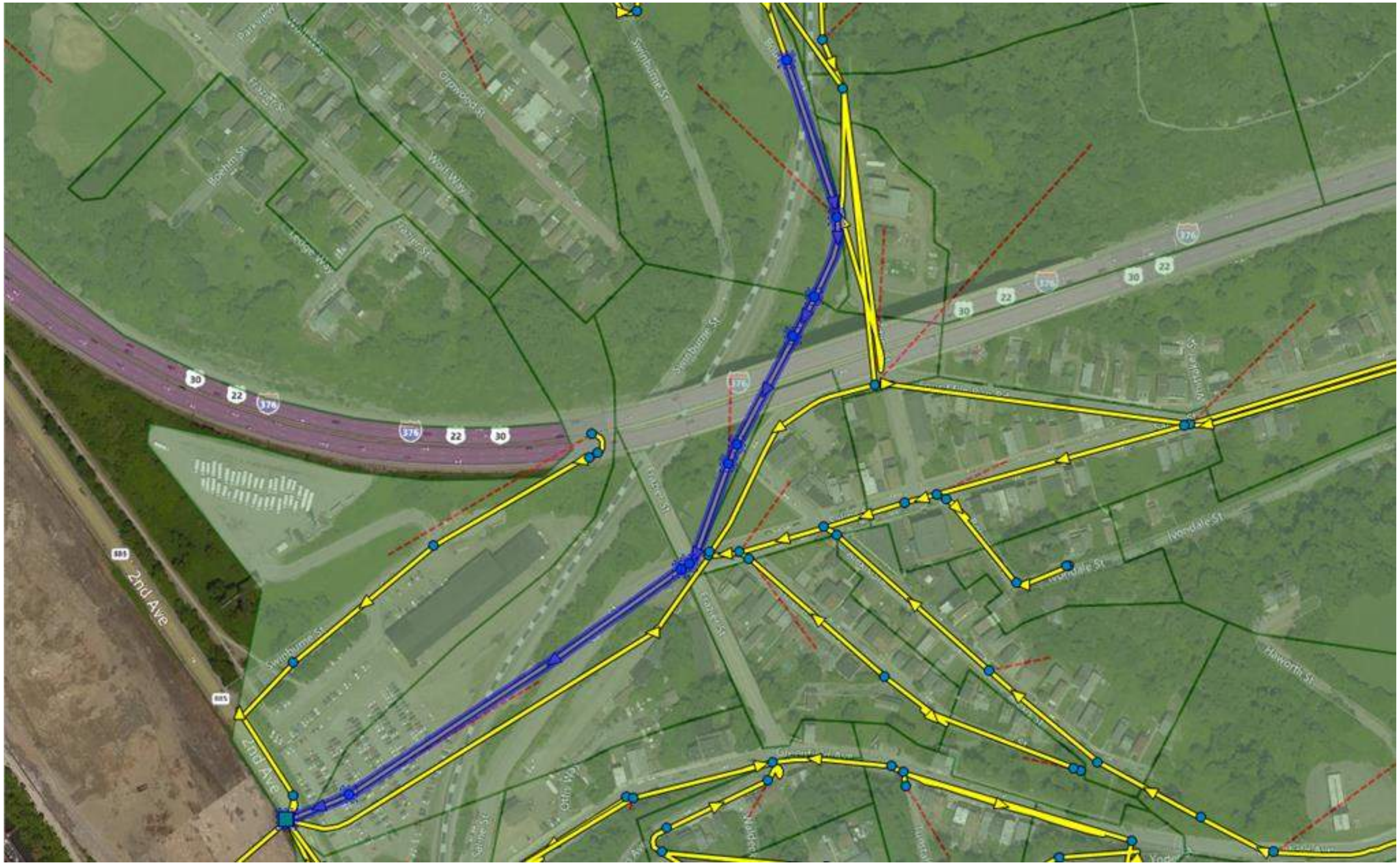


Figure 6A - Simulations_15, 23, and 31 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm



Simulations_15, 23, and 31 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm

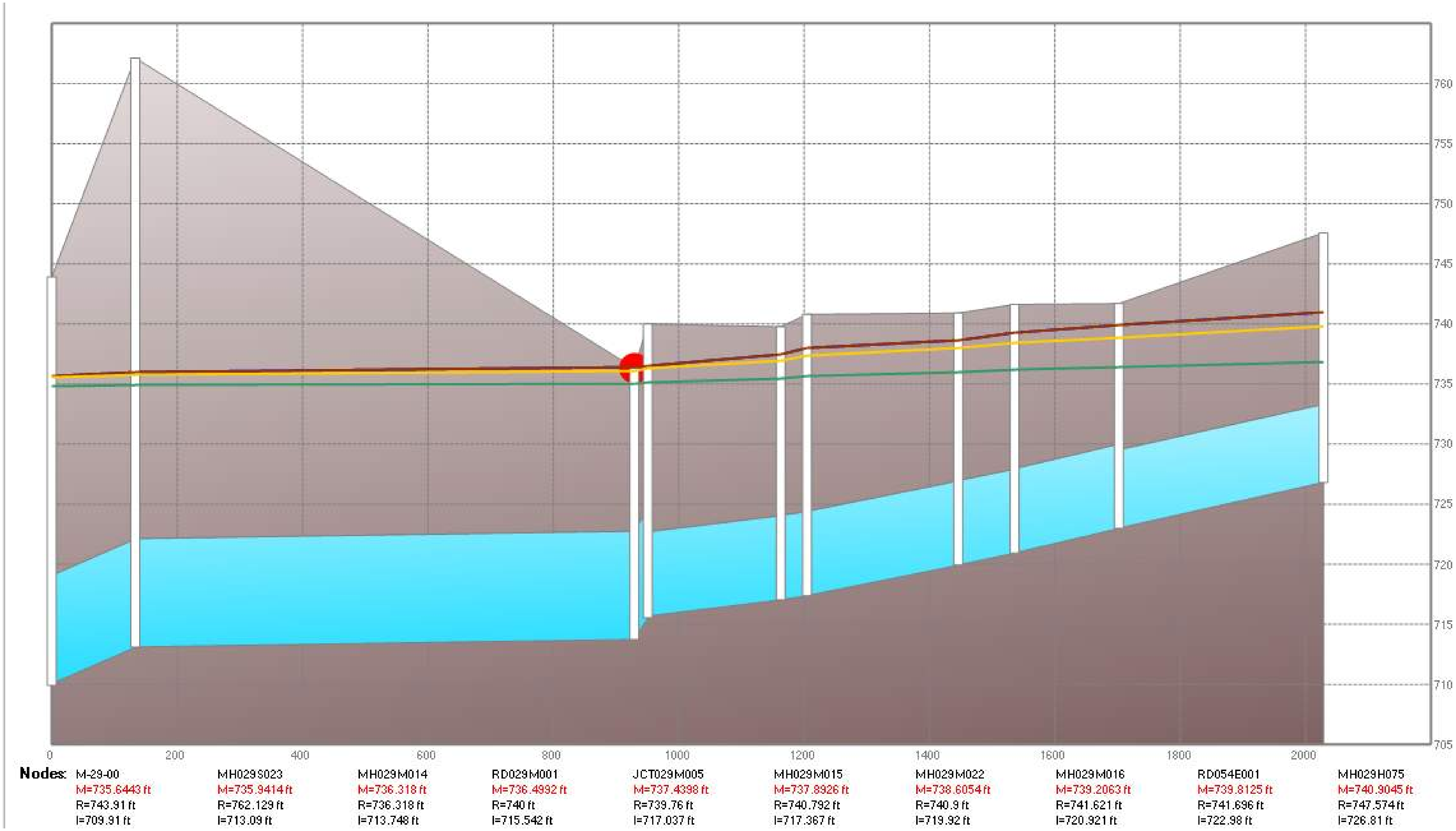
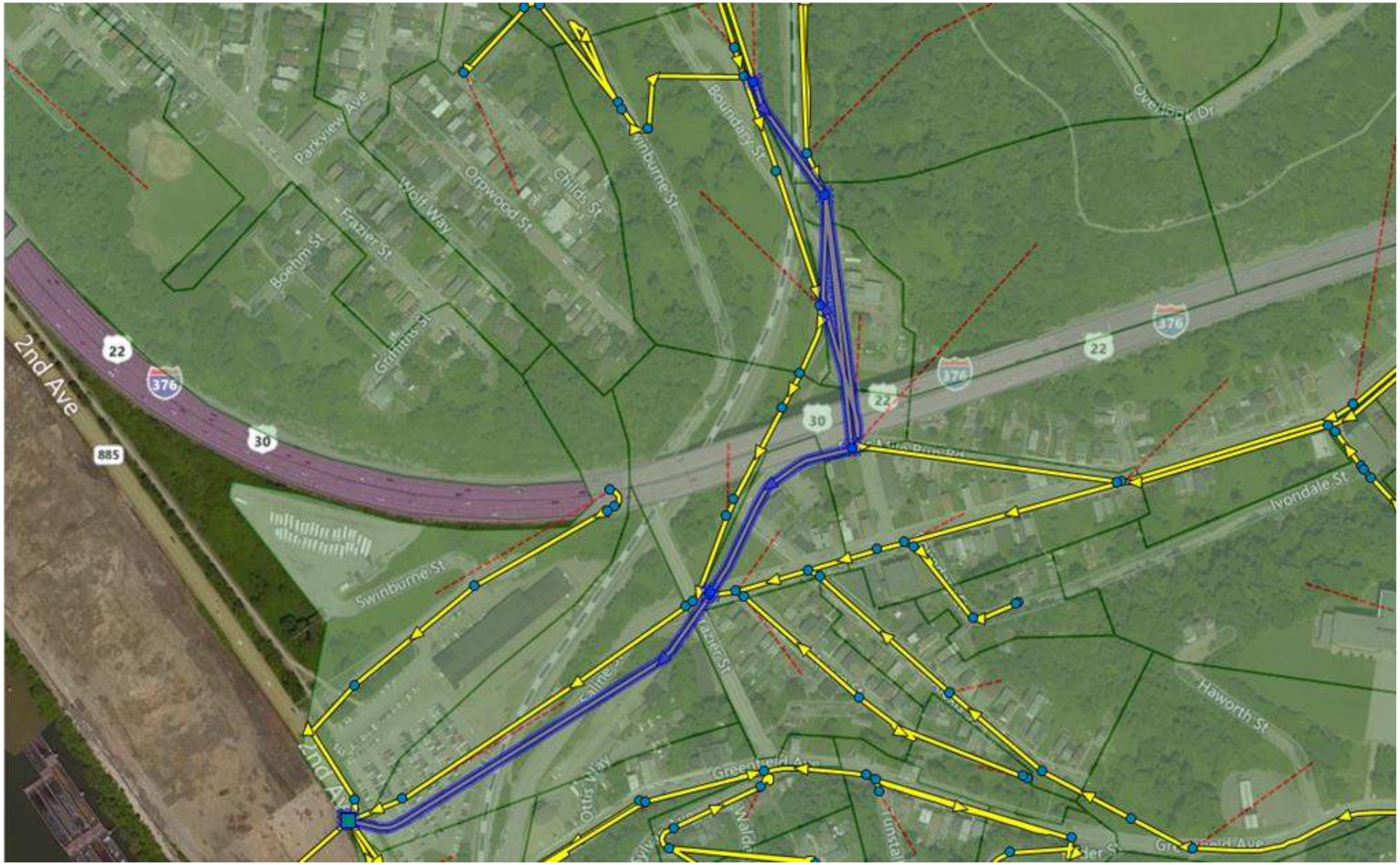


Figure 6B - Simulations_15, 23, and 31 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm



Simulations_15, 23, and 31 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm

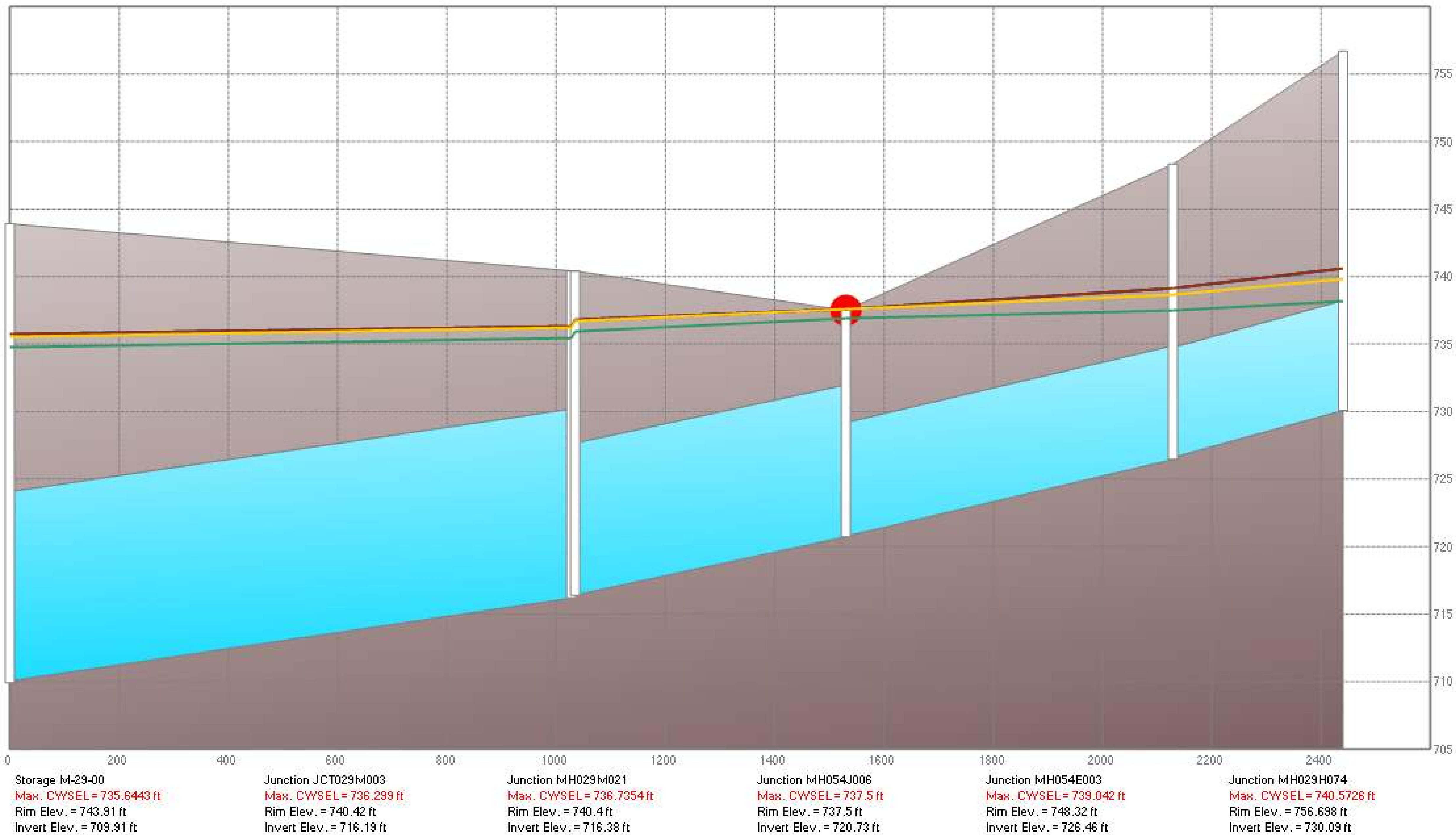
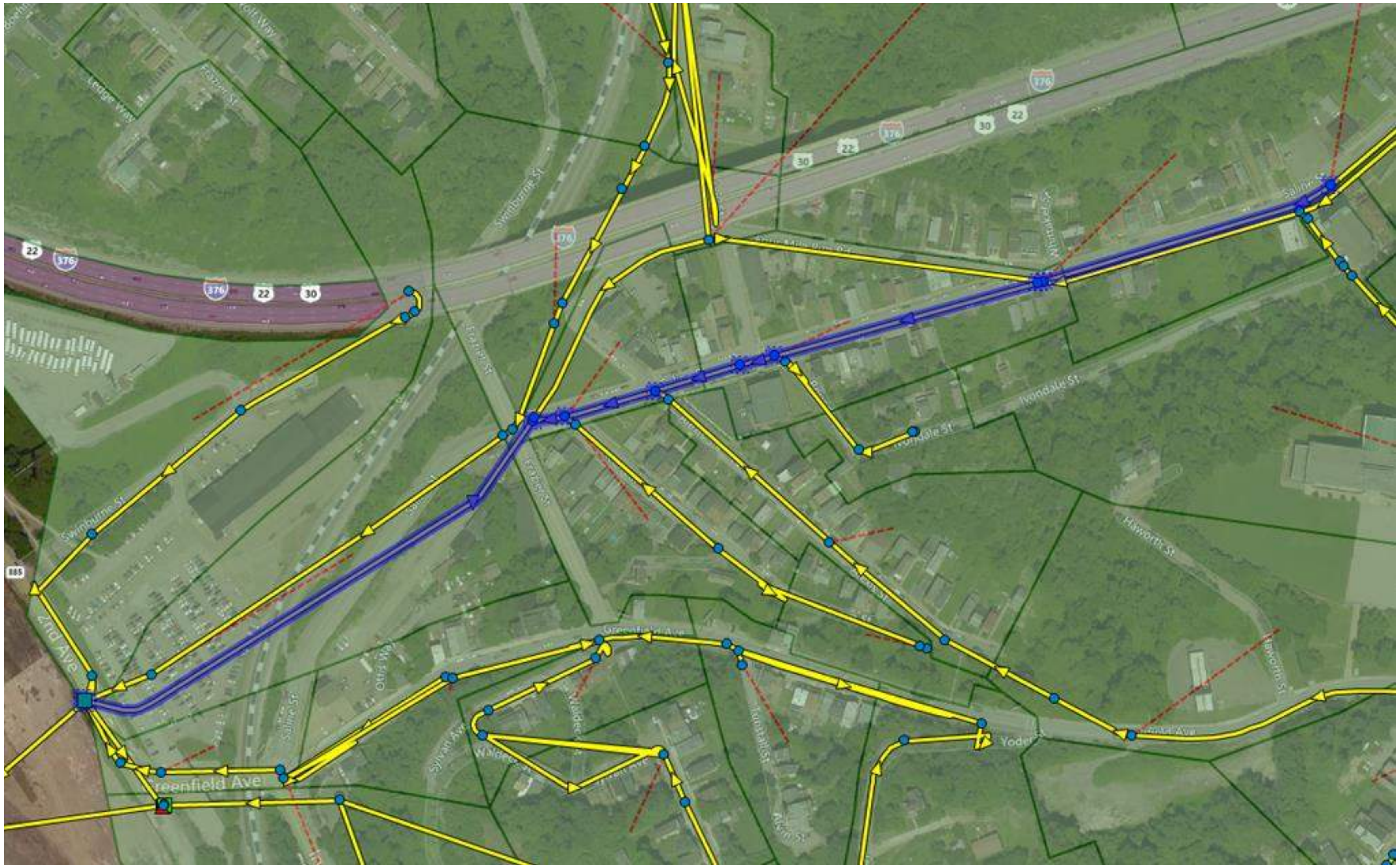


Figure 6C - Simulations_15, 23, and 31 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm



Simulations_15, 23, and 31 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm

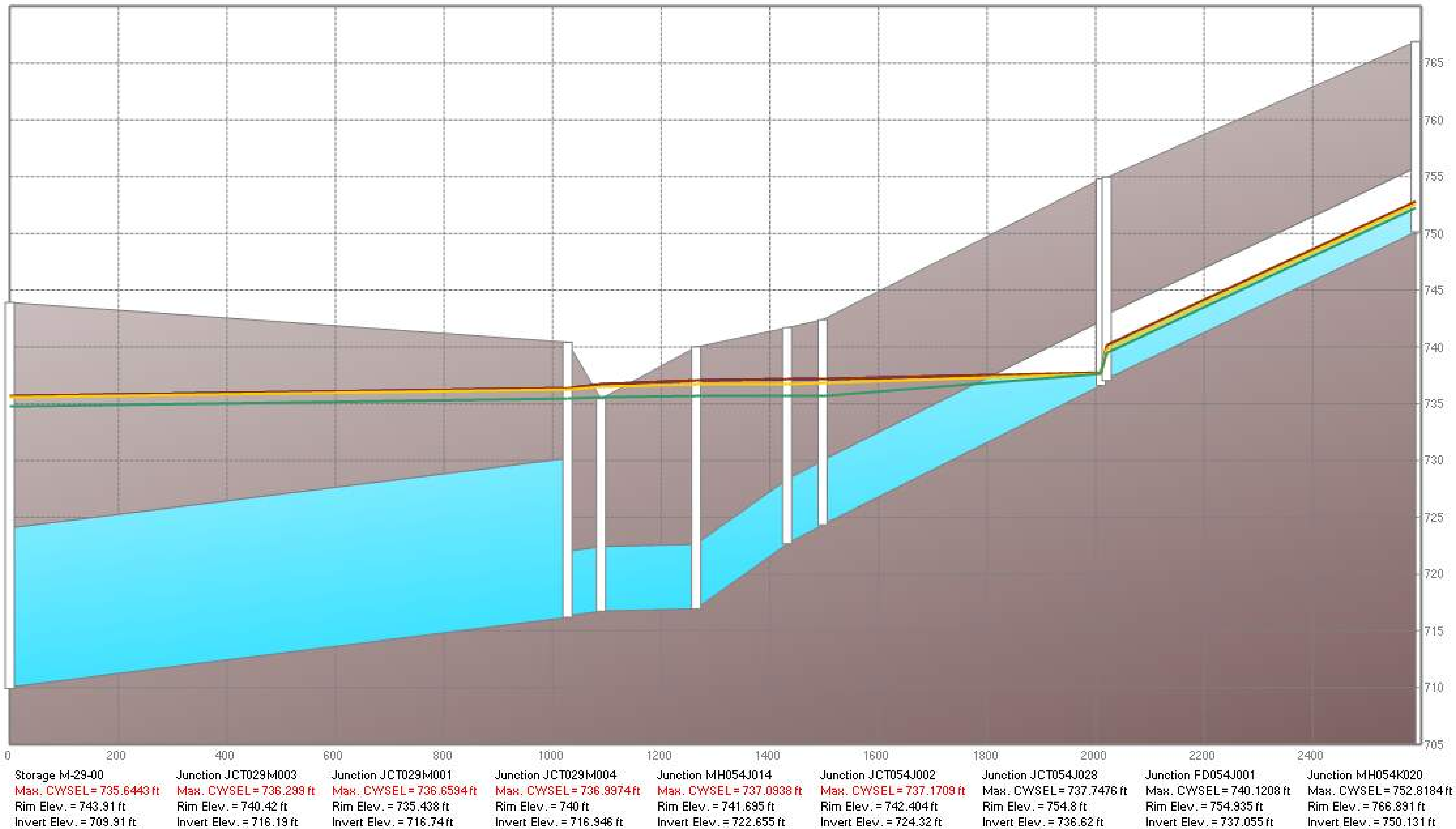
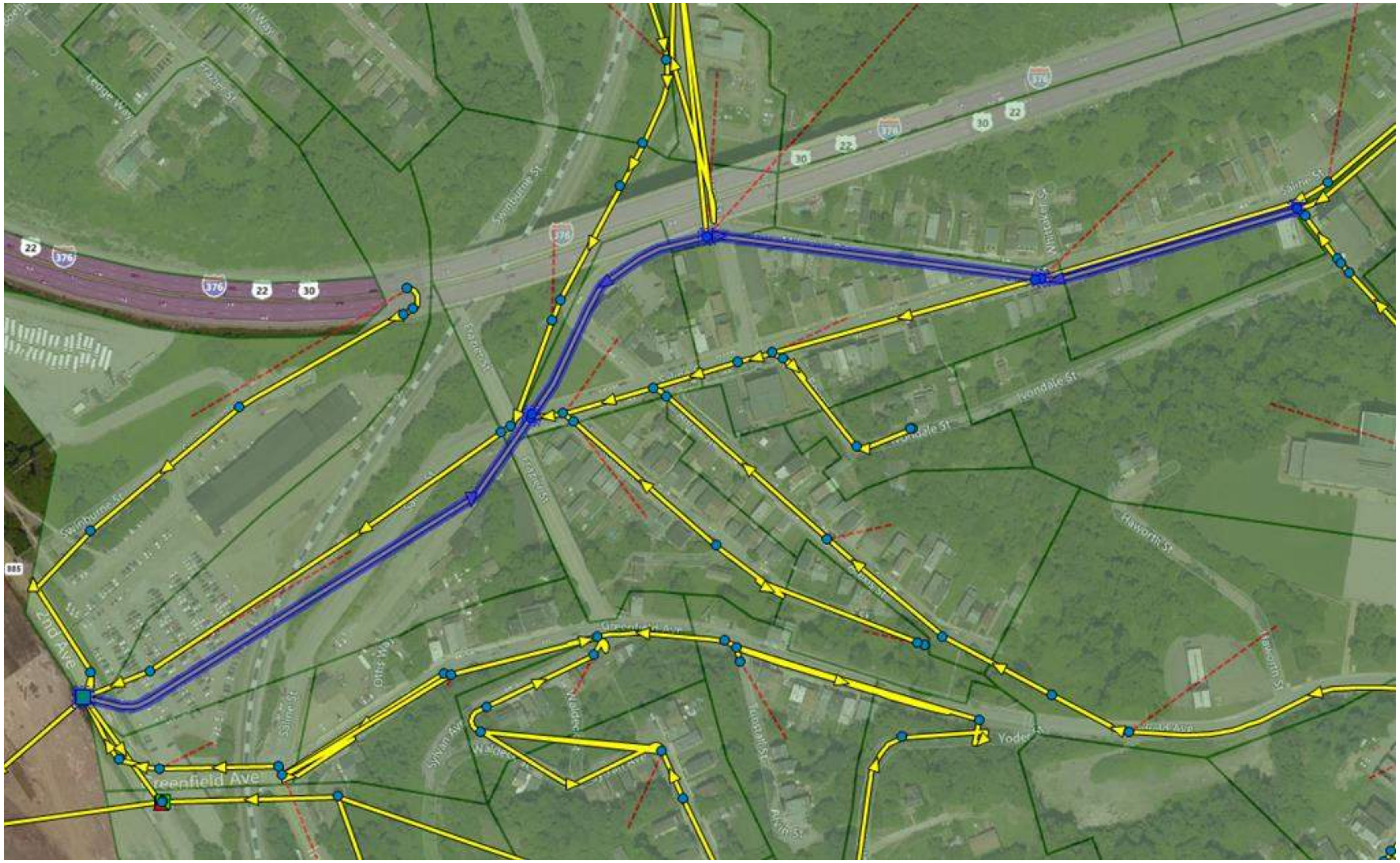


Figure 6D - Simulations_15, 23, and 31 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm



Simulations_15, 23, and 31 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 05-Year, 24-Hour Design Storm

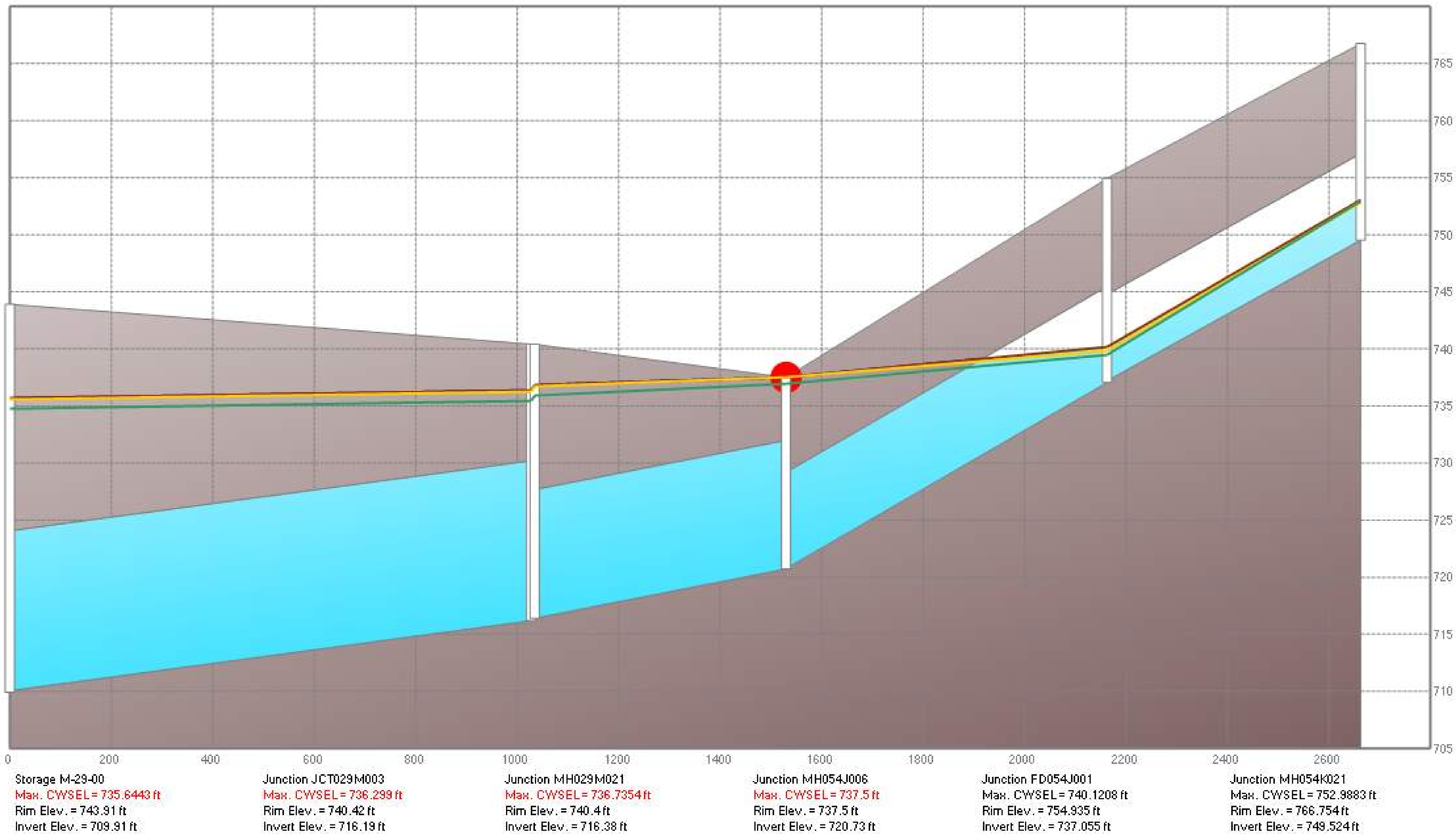
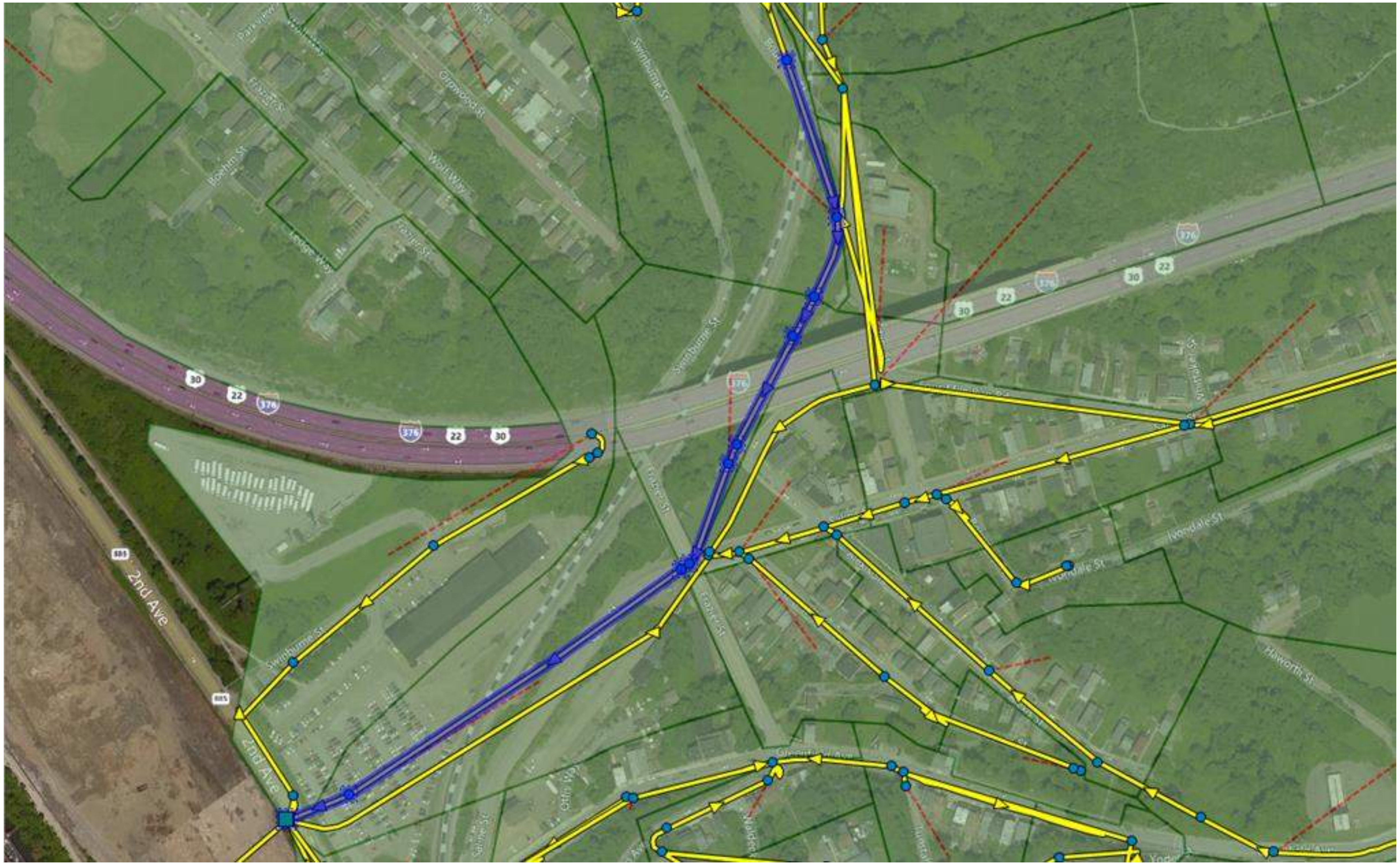


Figure 7A - Simulations_16, 24, and 32 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm



Simulations_16, 24, and 32 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm

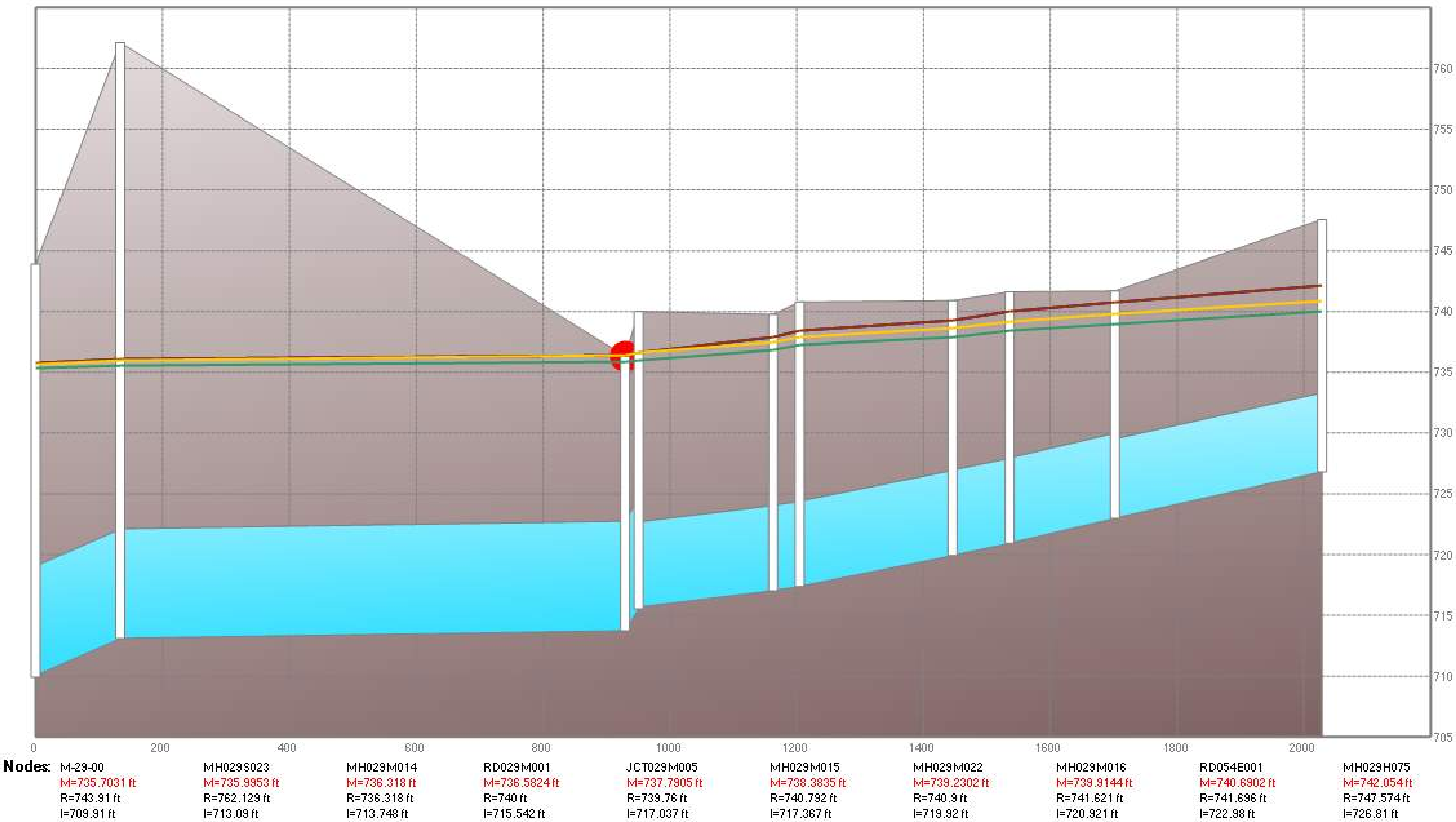
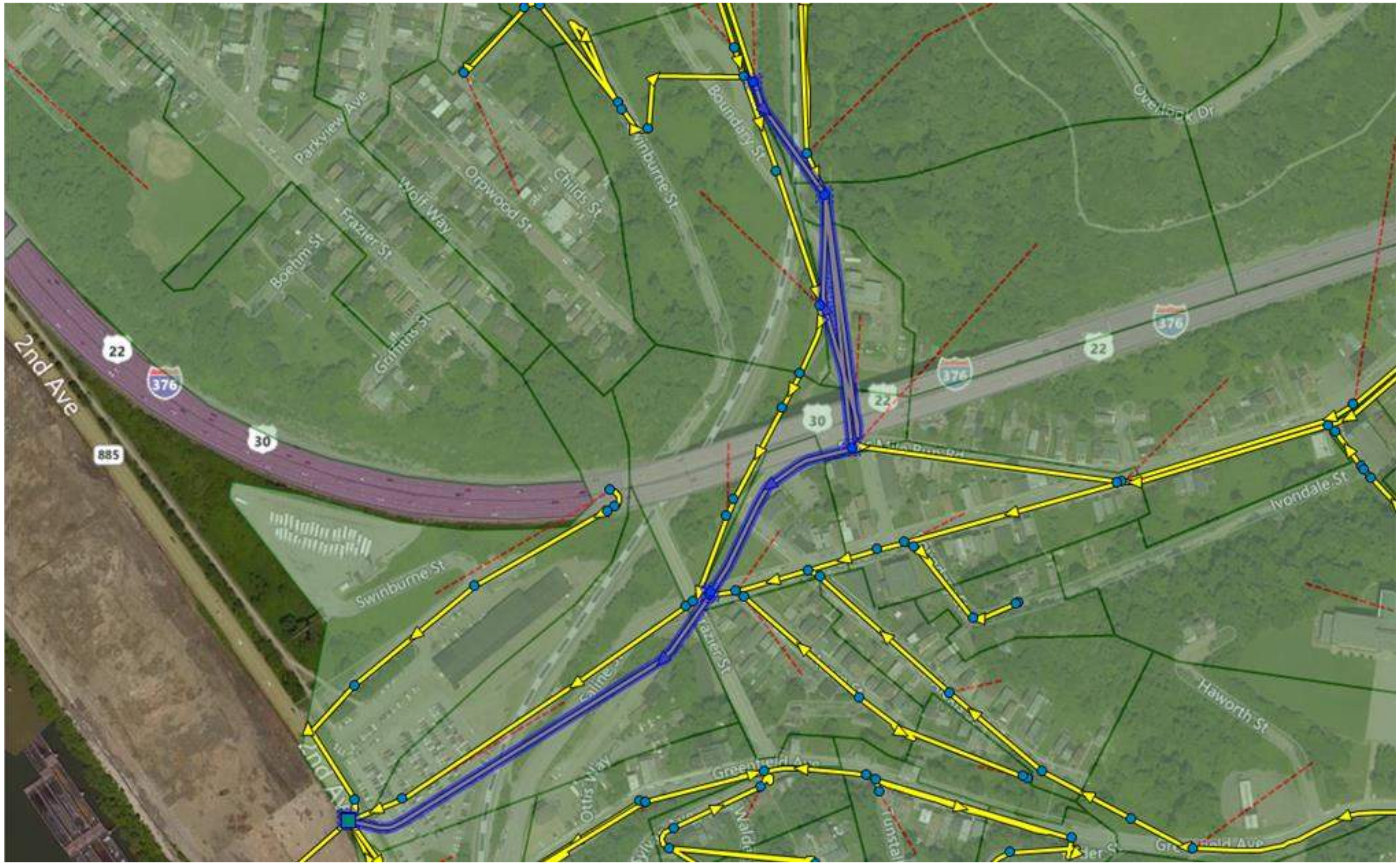


Figure 7B - Simulations_16, 24, and 32 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm



Simulations_16, 24, and 32 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm

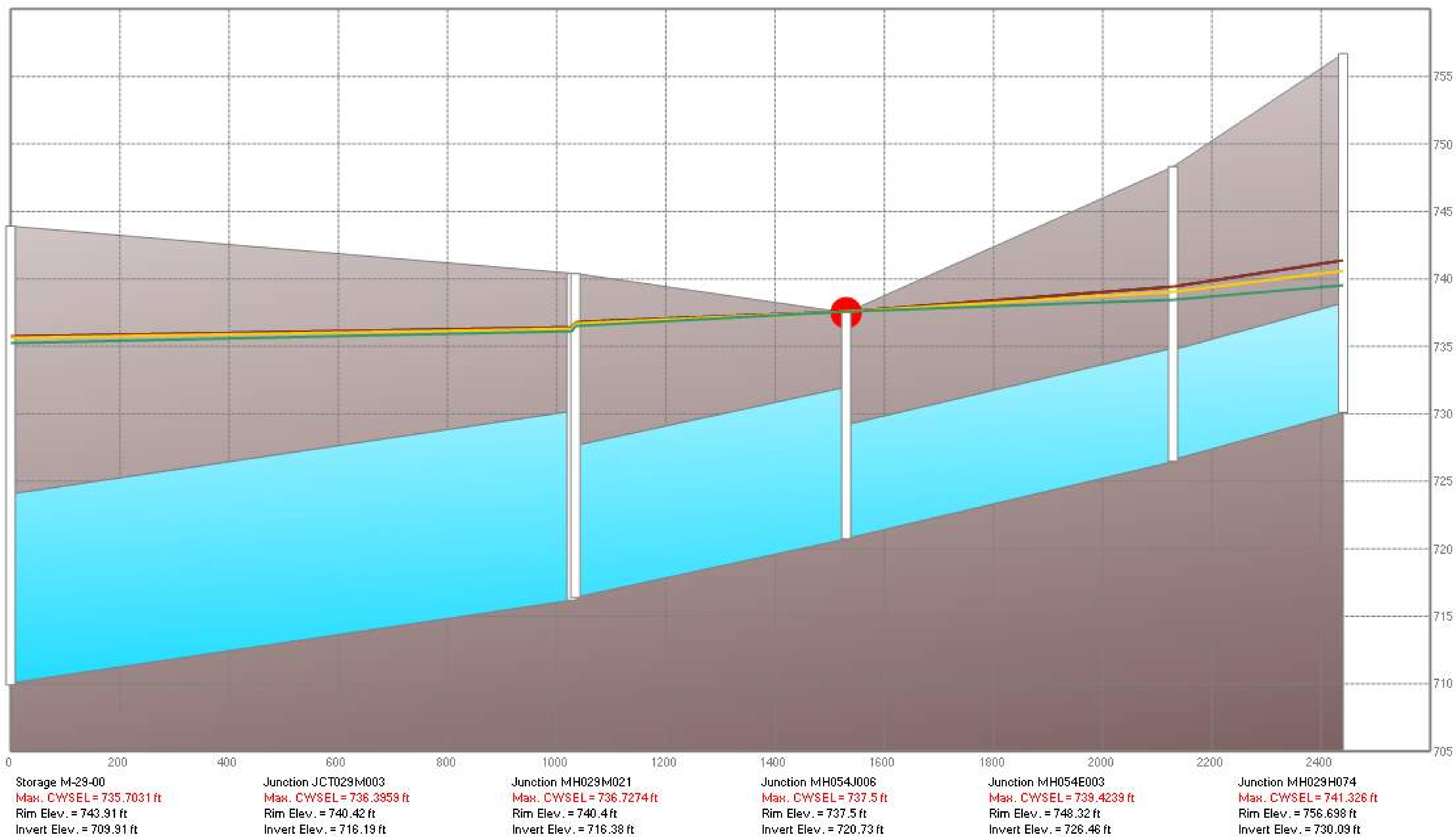
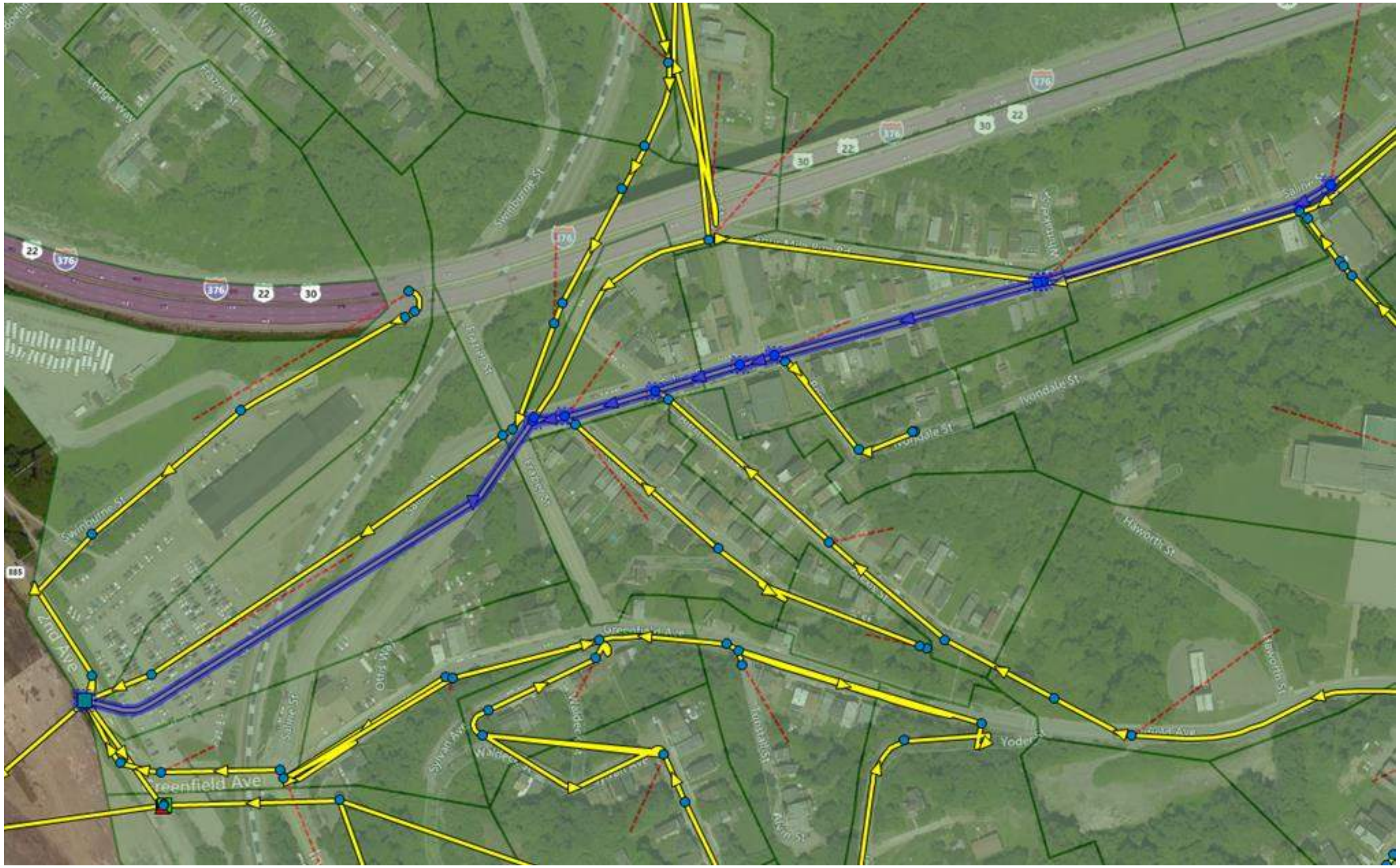


Figure 7C - Simulations_16, 24, and 32 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm



Simulations_16, 24, and 32 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm

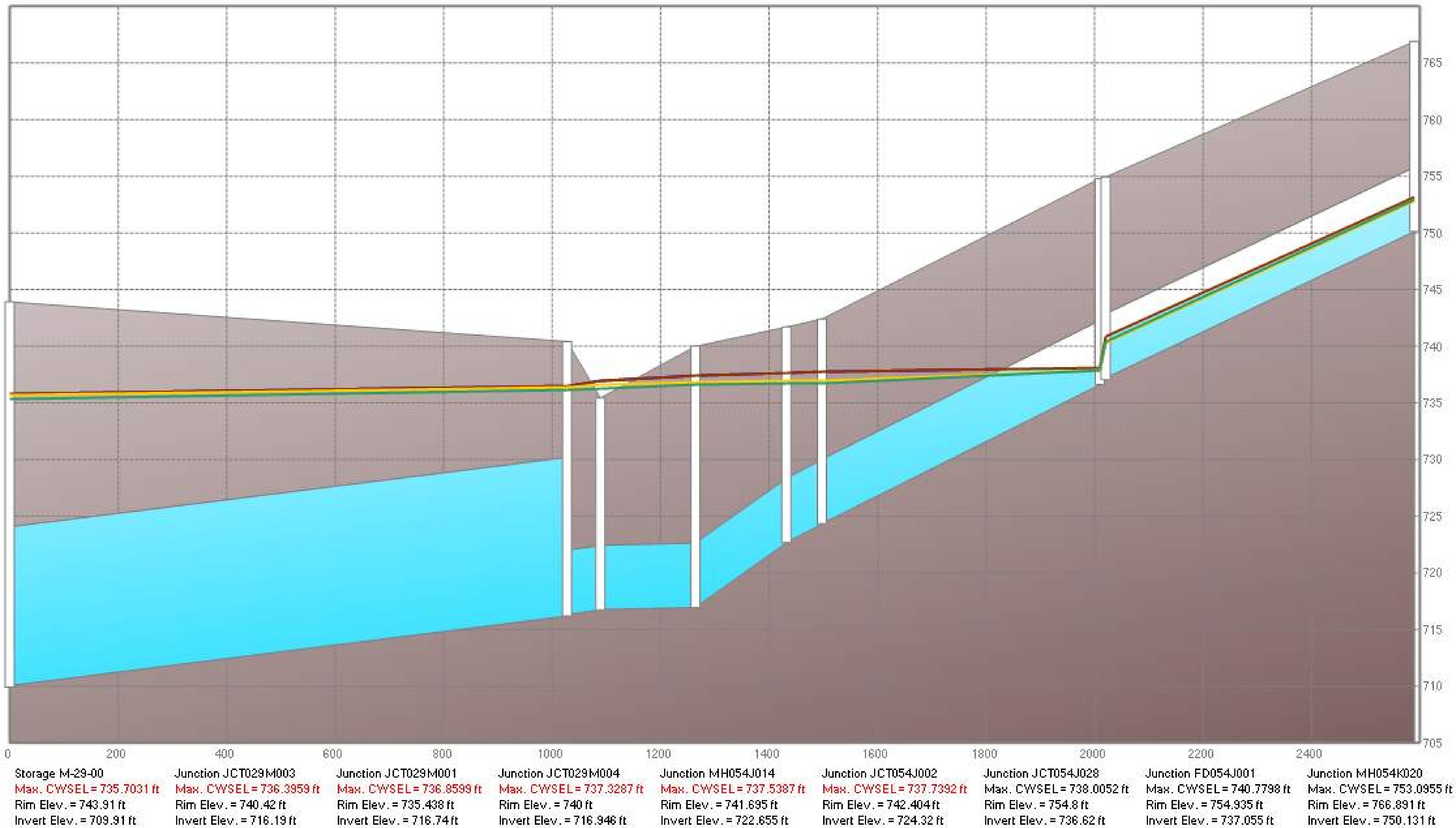
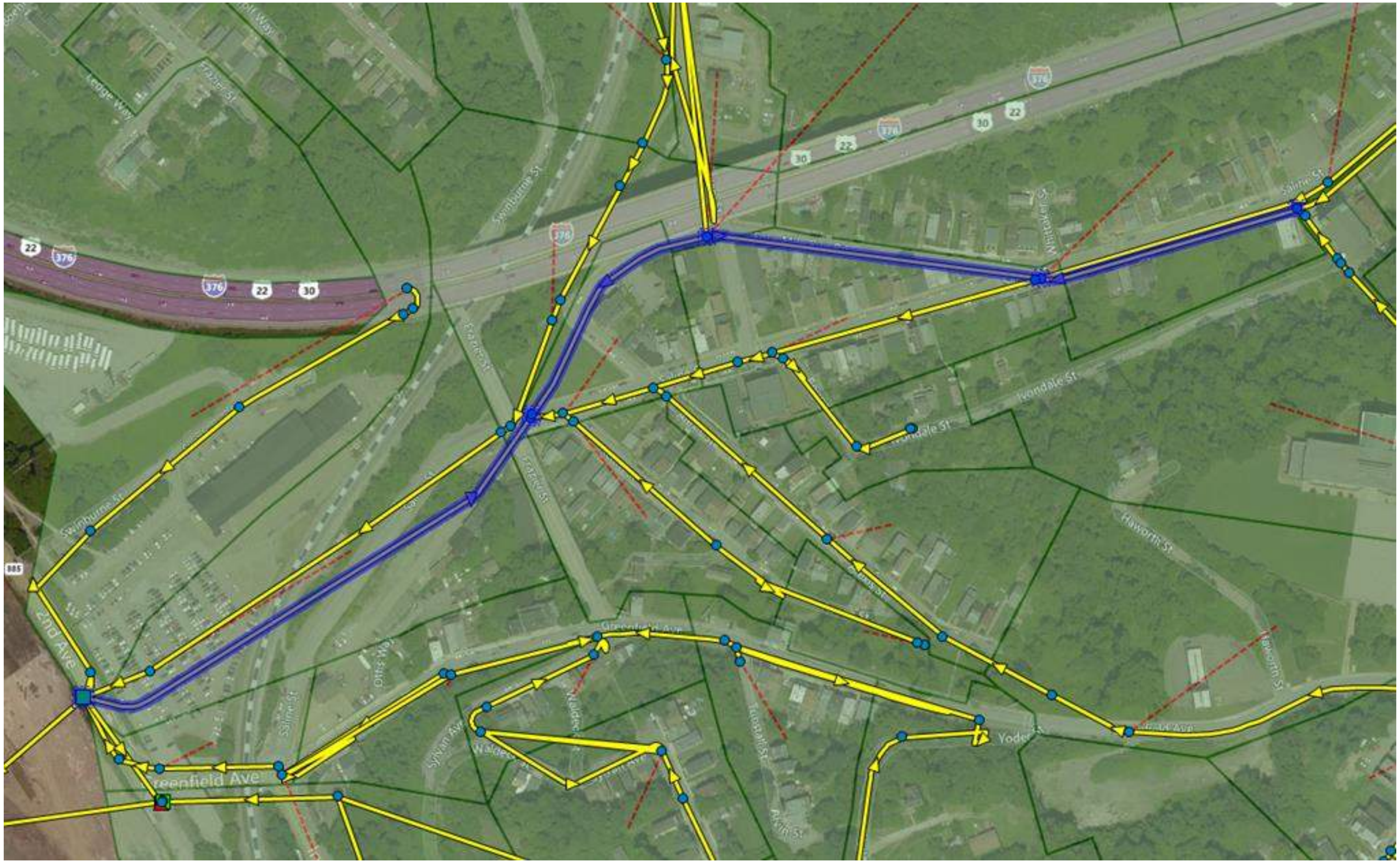


Figure 7D - Simulations_16, 24, and 32 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm



Simulations_16, 24, and 32 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 10-Year, 24-Hour Design Storm

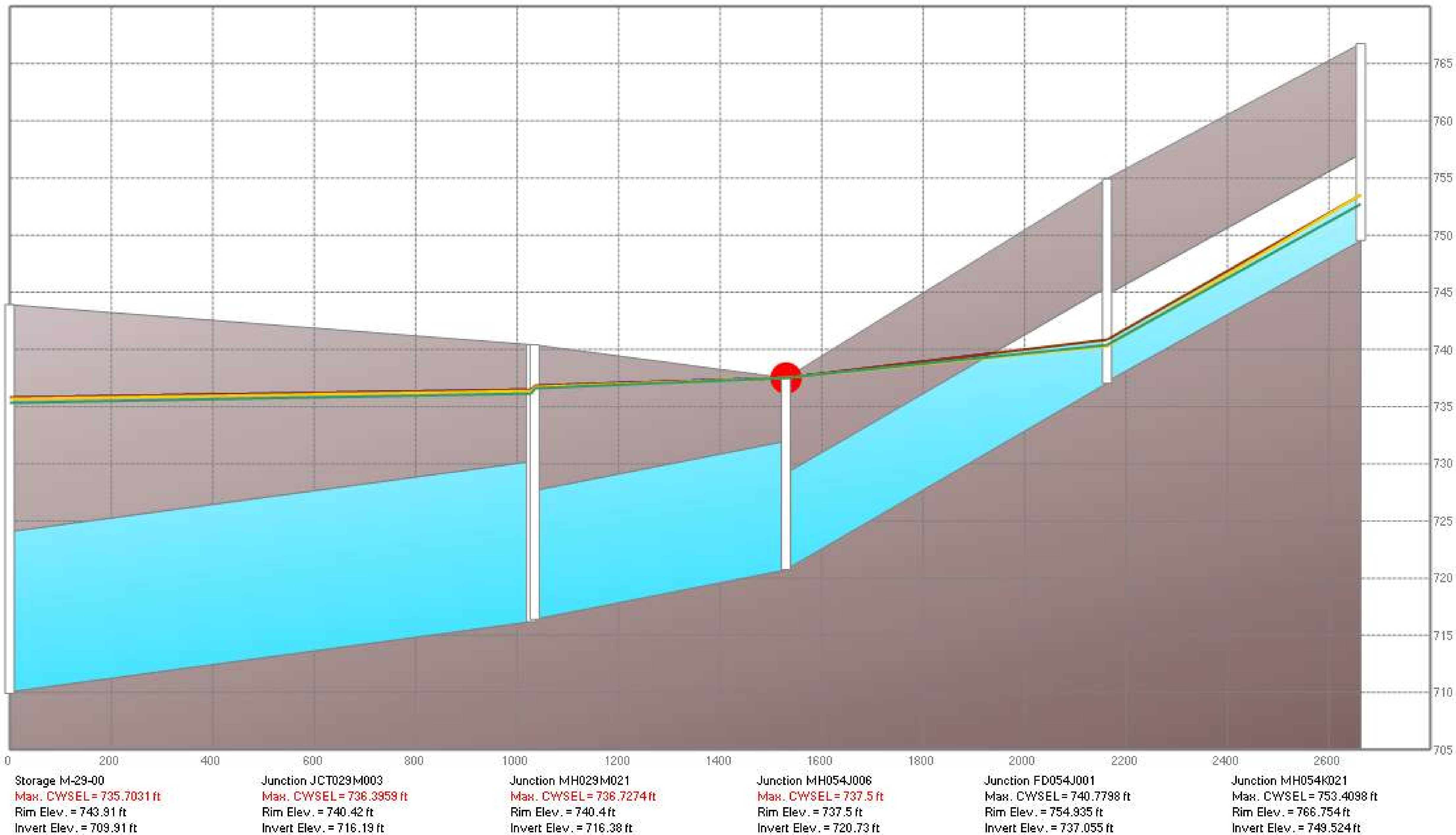
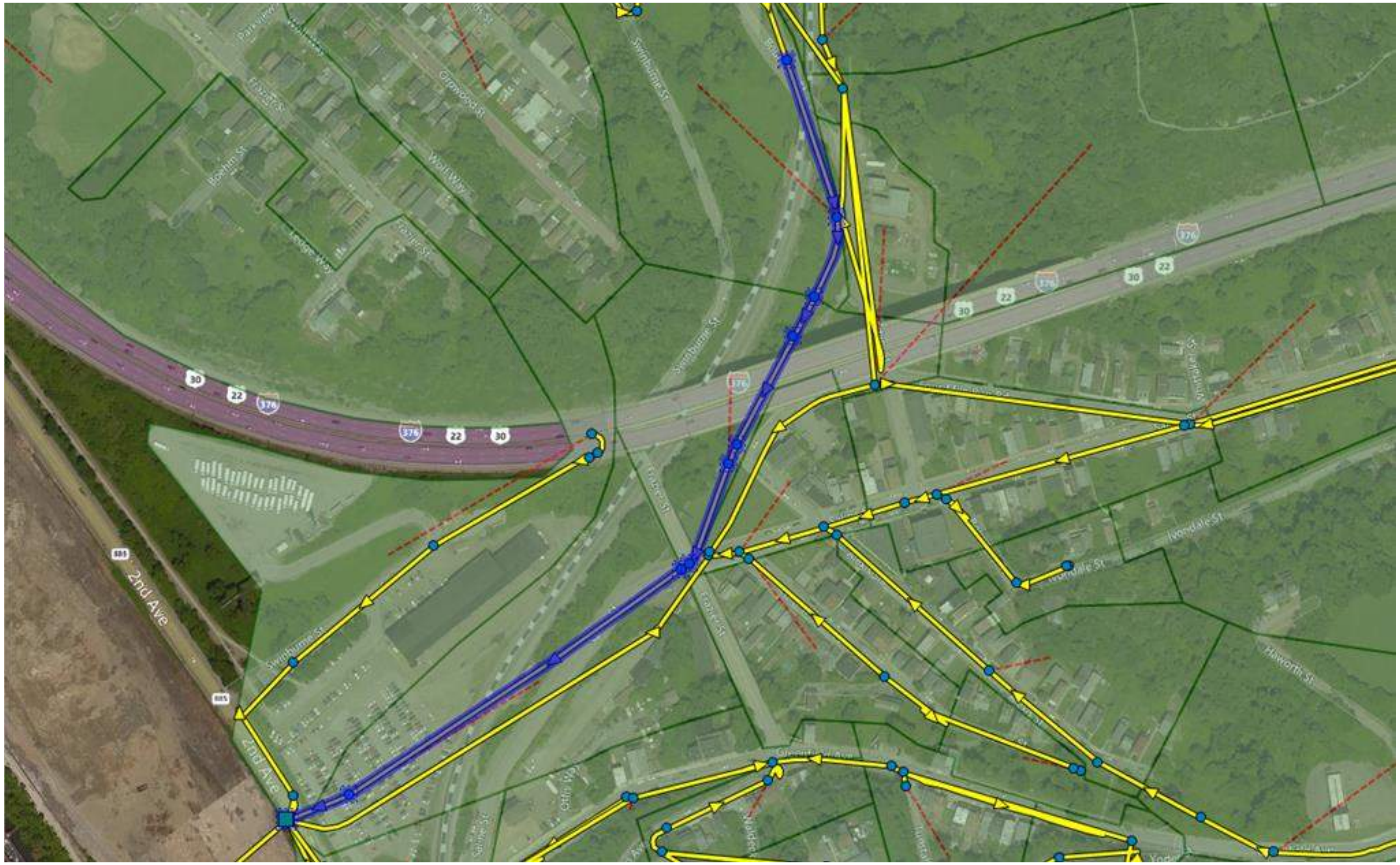


Figure 8A - Simulations_17, 25, and 33 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm



Simulations_17, 25, and 33 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm

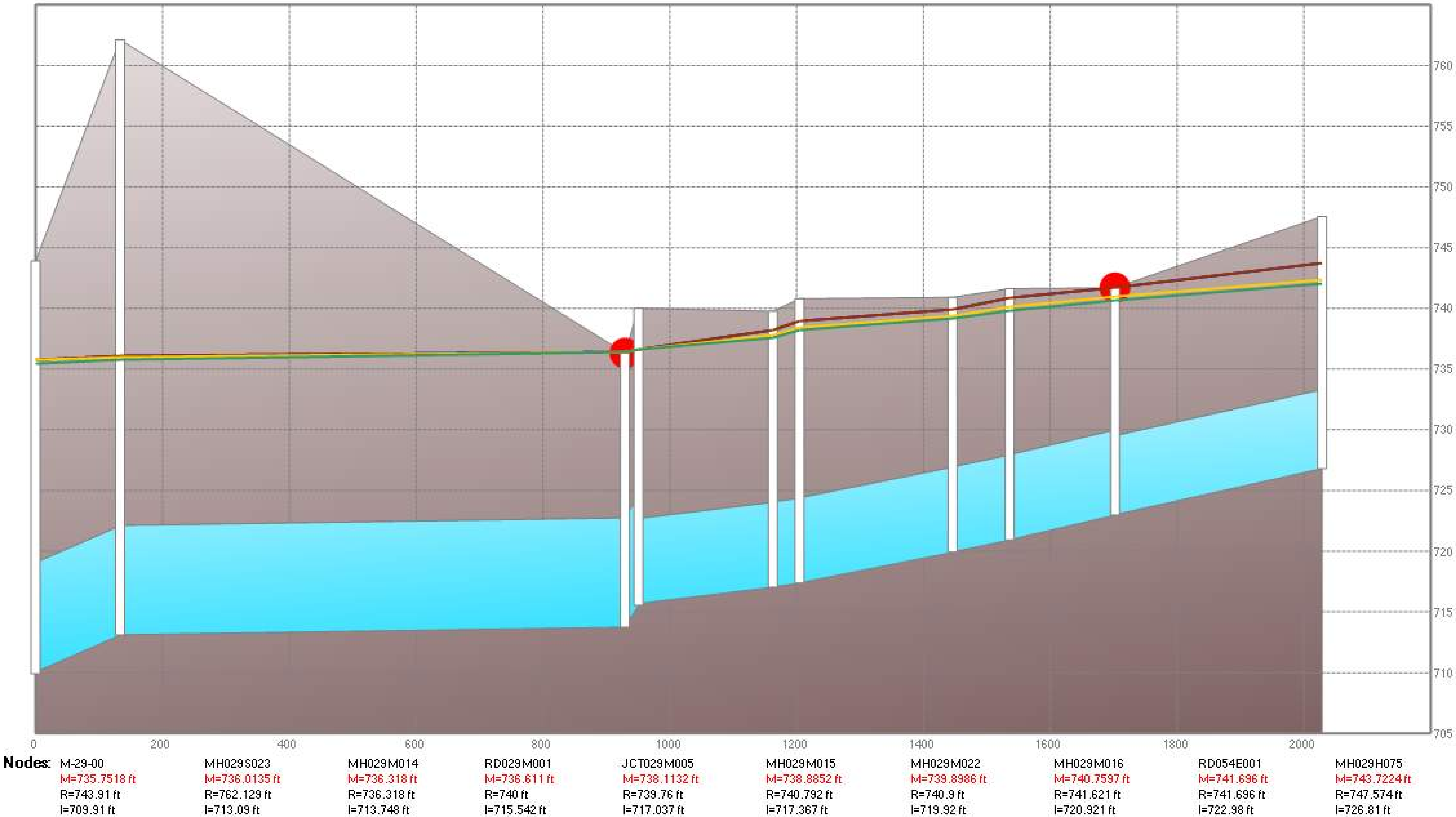
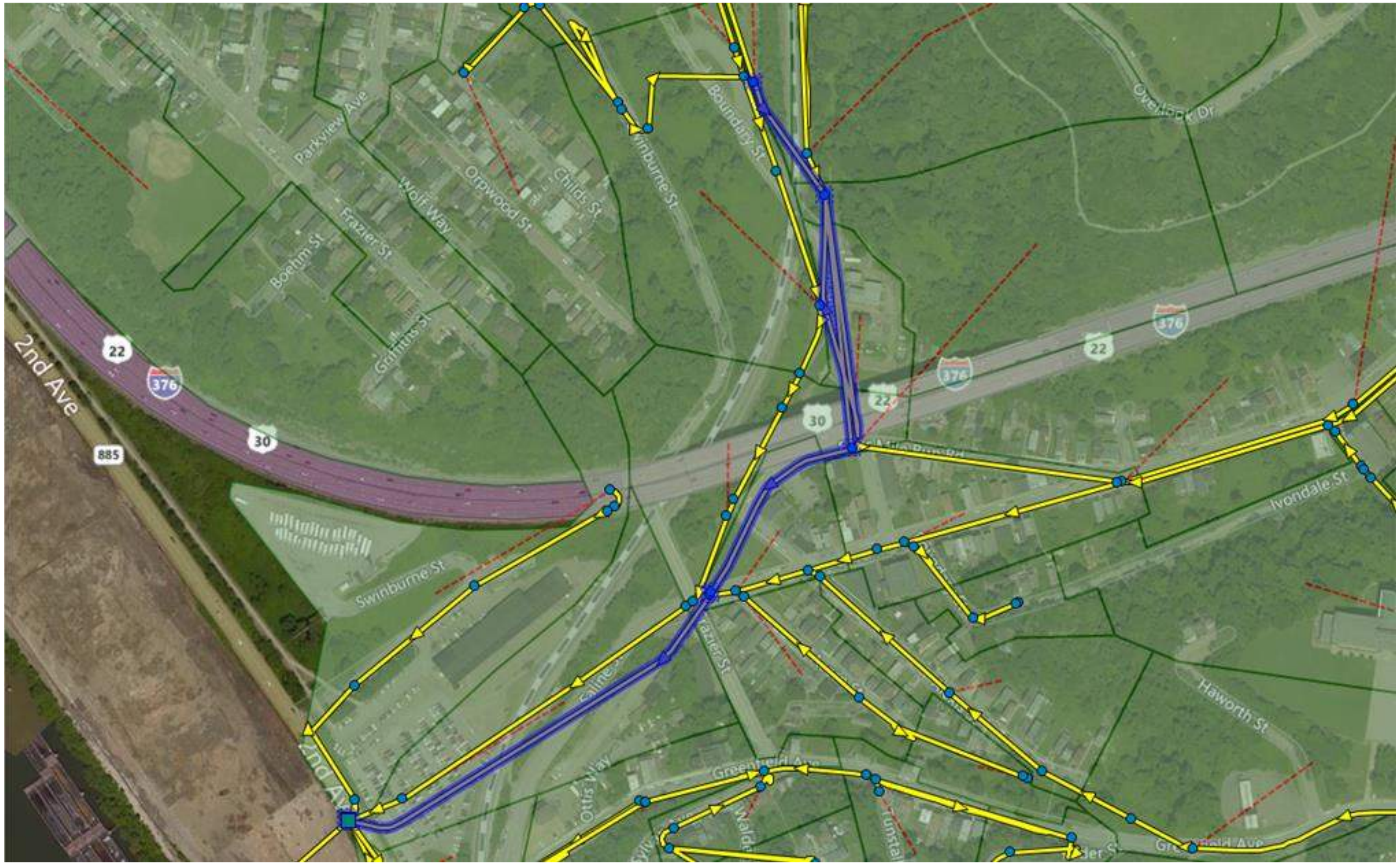


Figure 8B - Simulations_17, 25, and 33 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm



Simulations_17, 25, and 33 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm

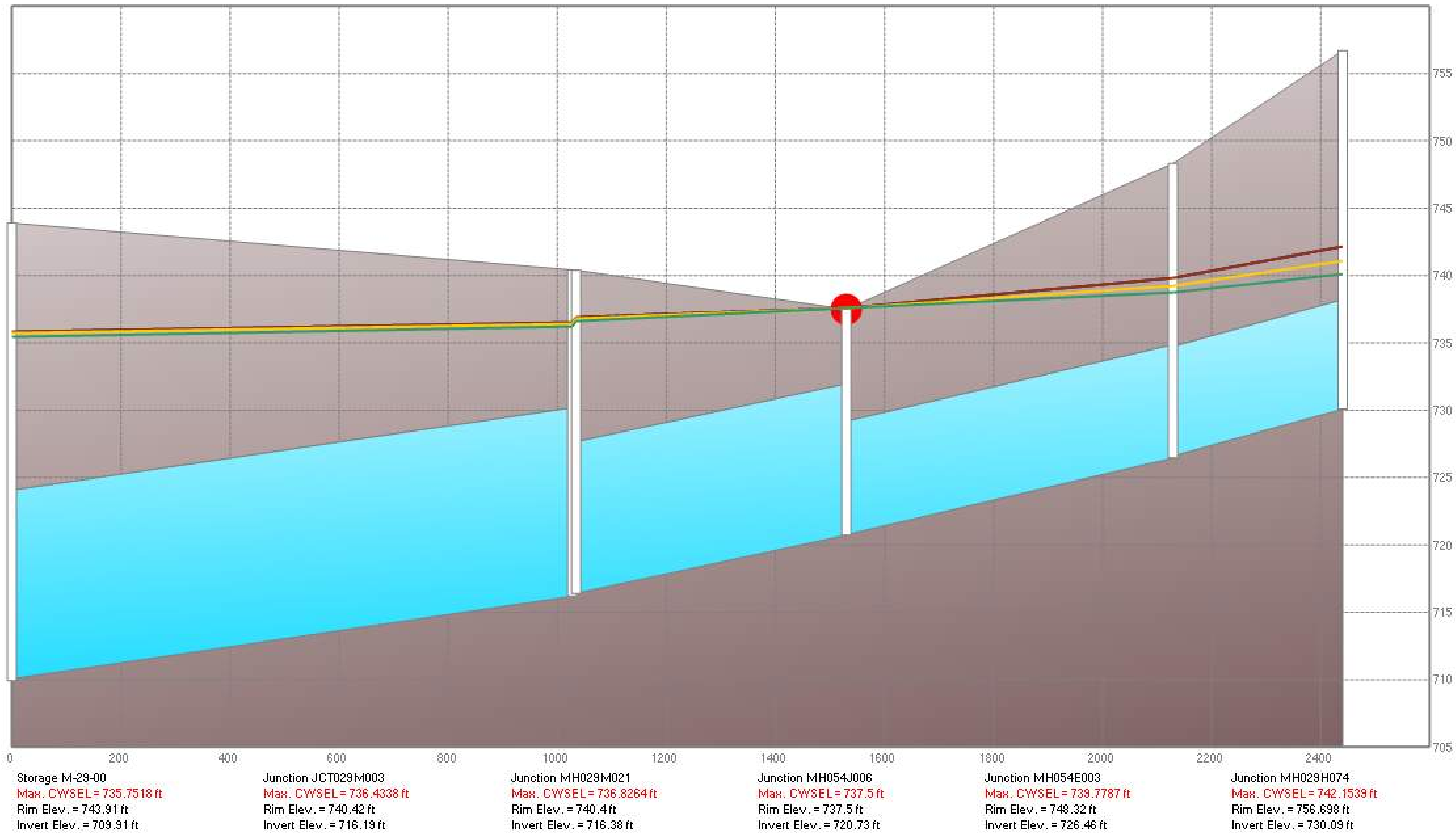
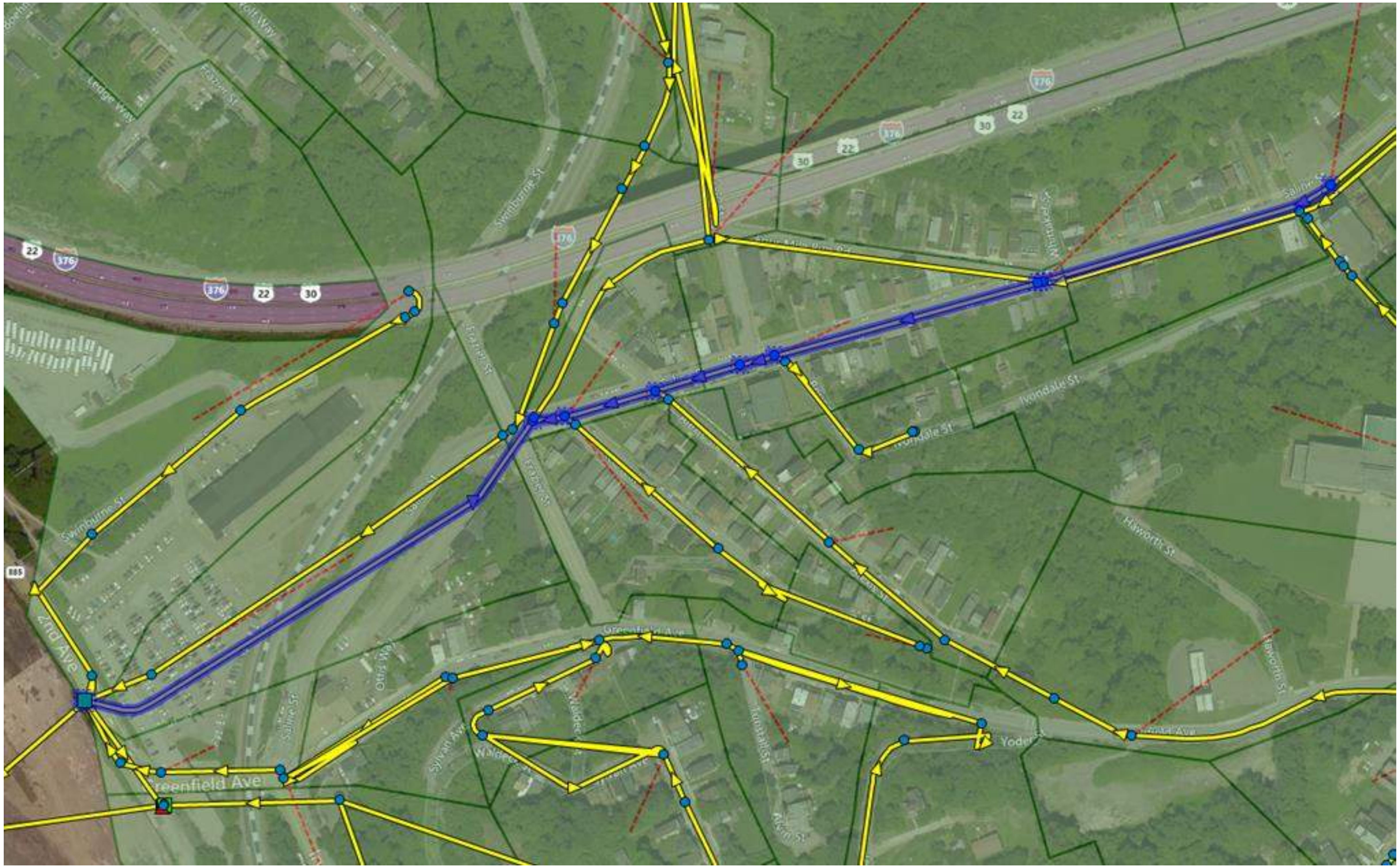


Figure 8C - Simulations_17, 25, and 33 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm



Simulations_17, 25, and 33 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm

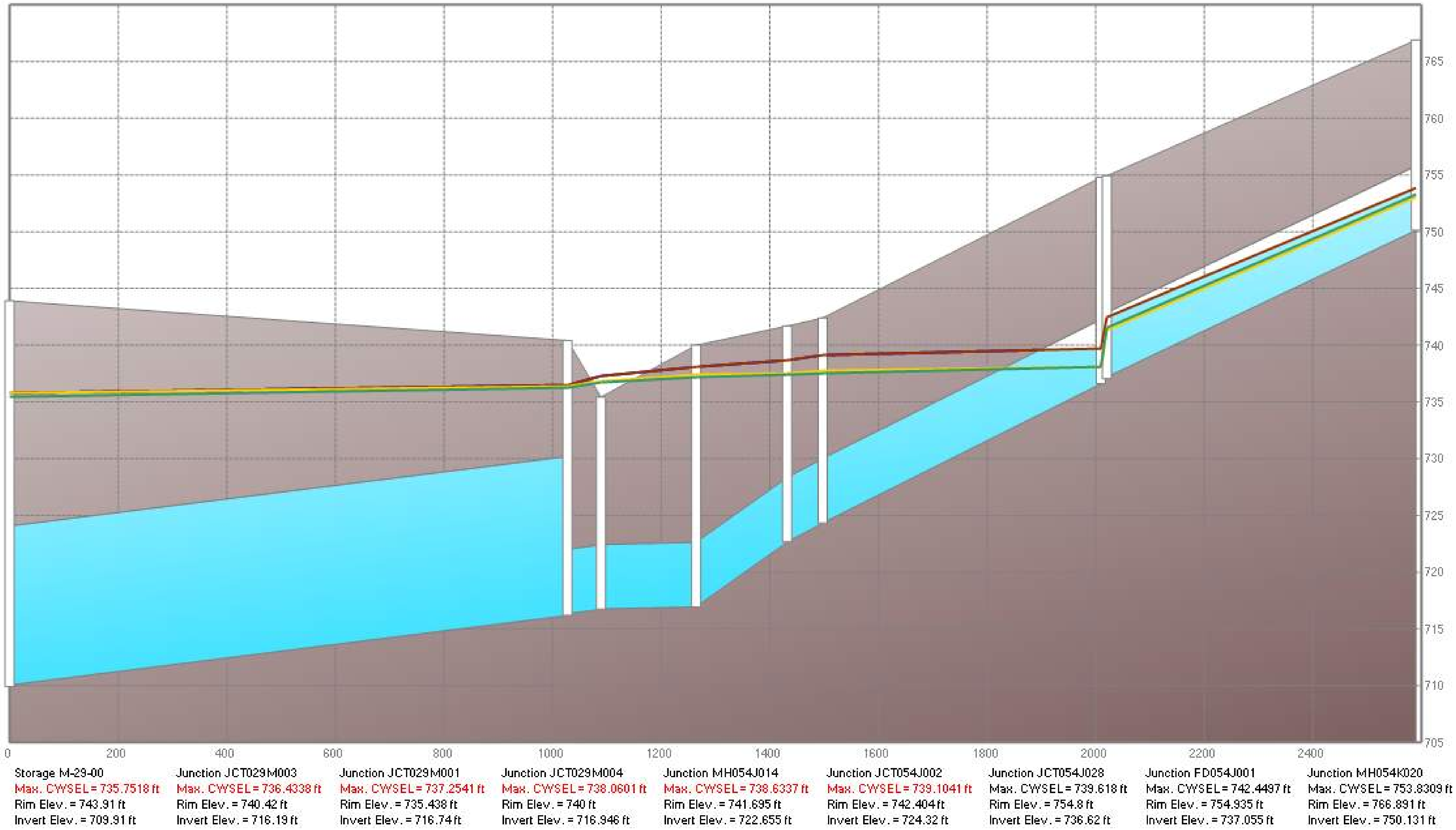
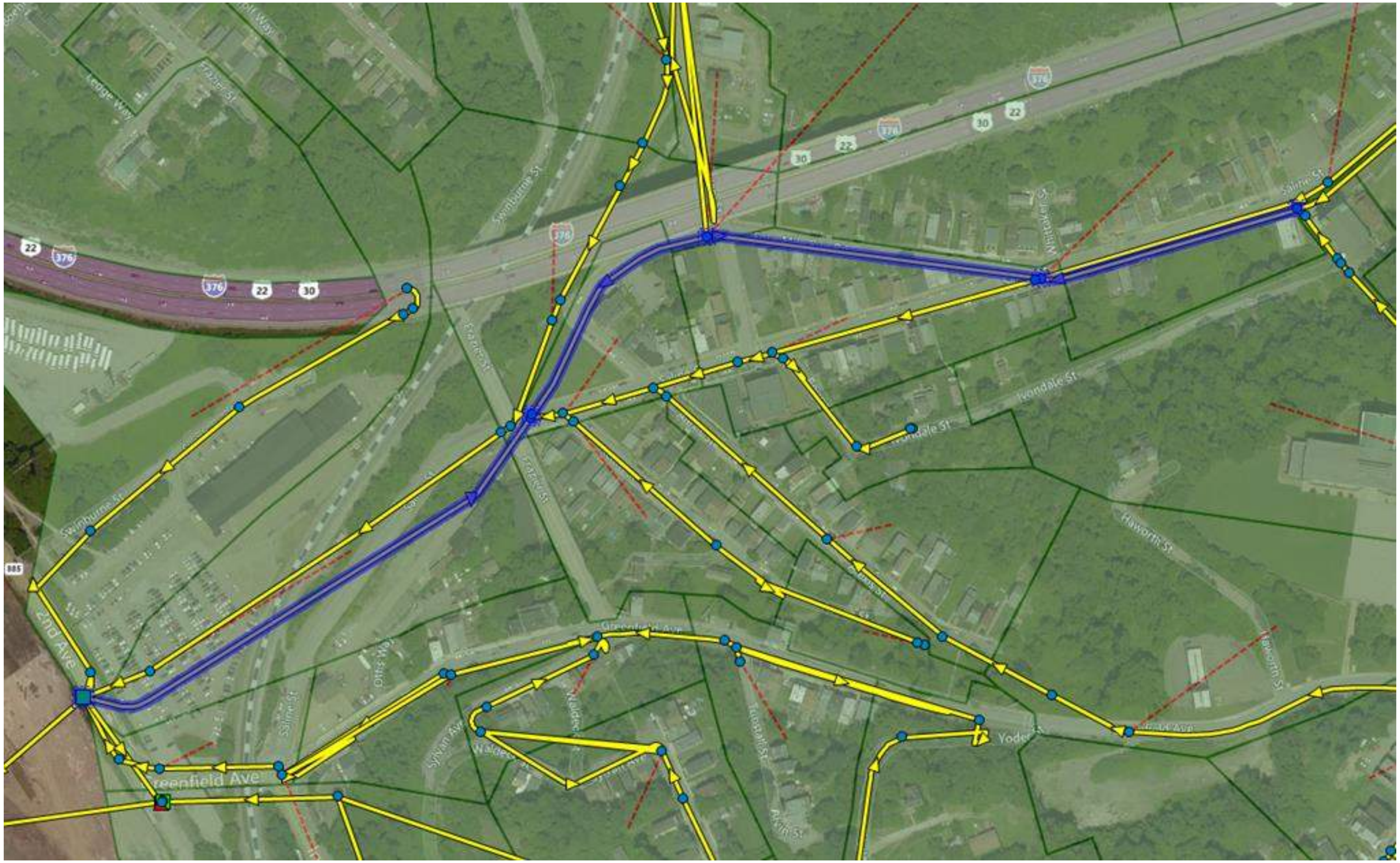


Figure 8D - Simulations_17, 25, and 33 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm



Simulations_17, 25, and 33 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storm: 25-Year, 24-Hour Design Storm

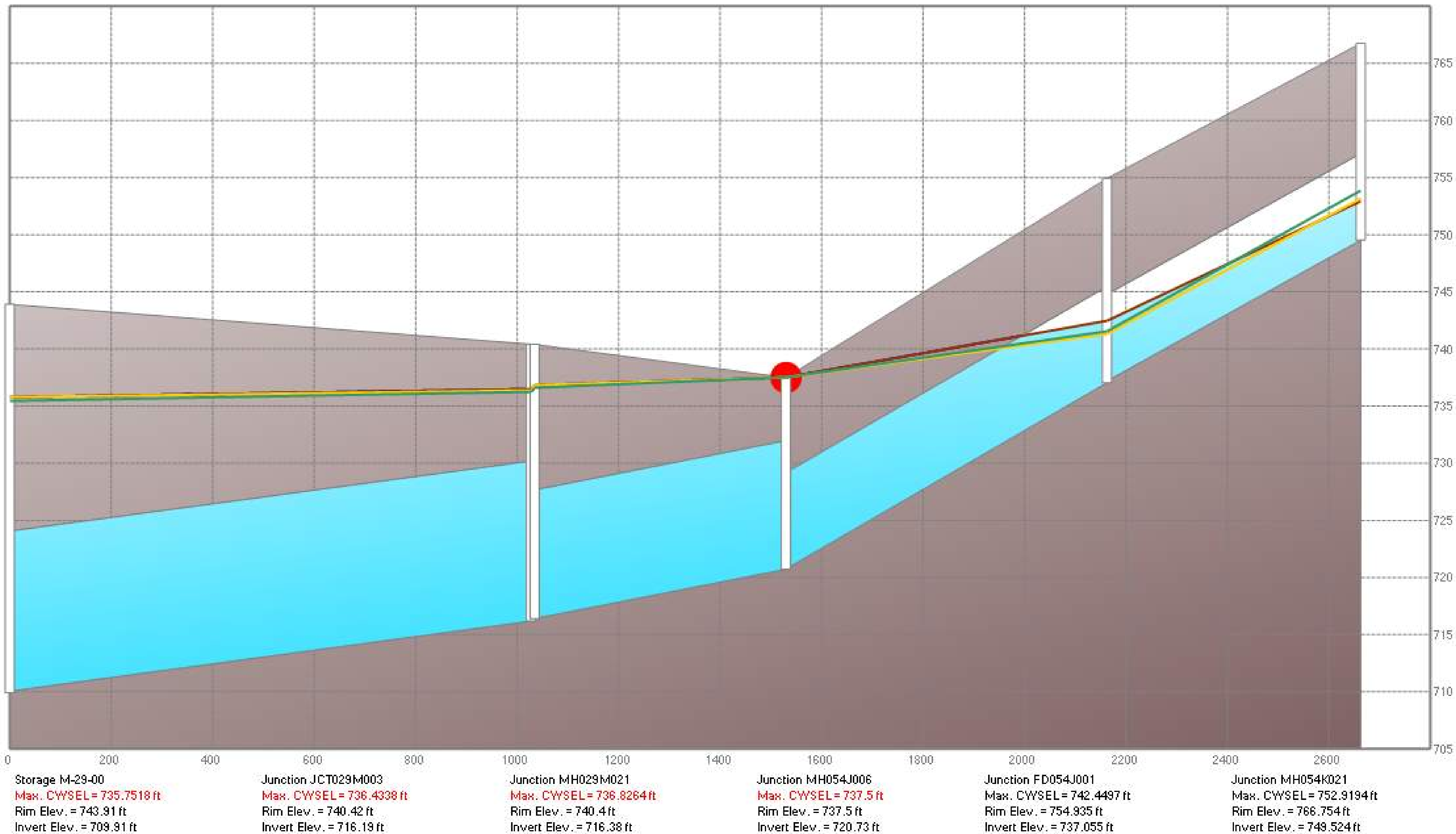
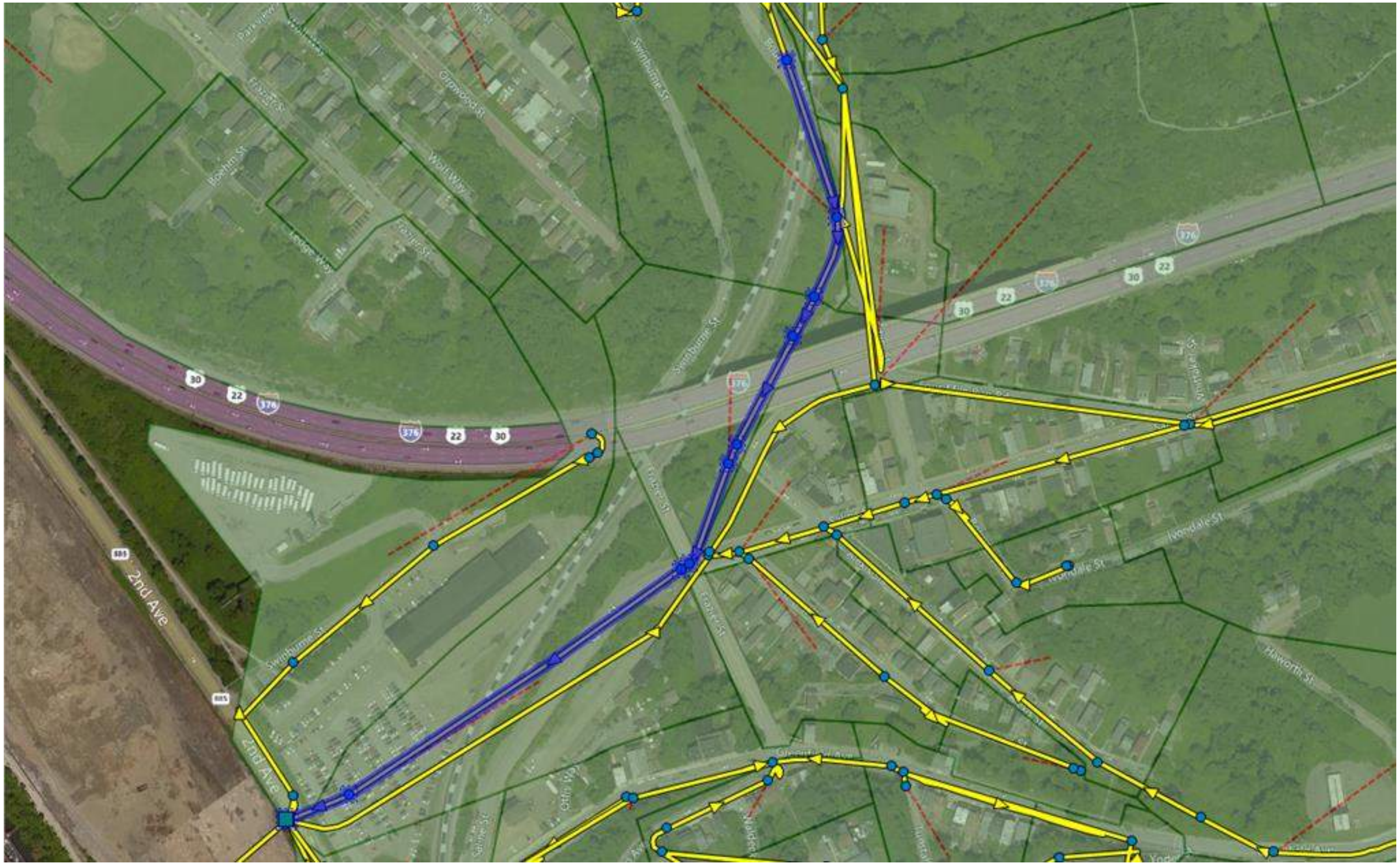


Figure 9A - Simulations_10, 11, 12, and 13 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_10, 11, 12, and 13 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

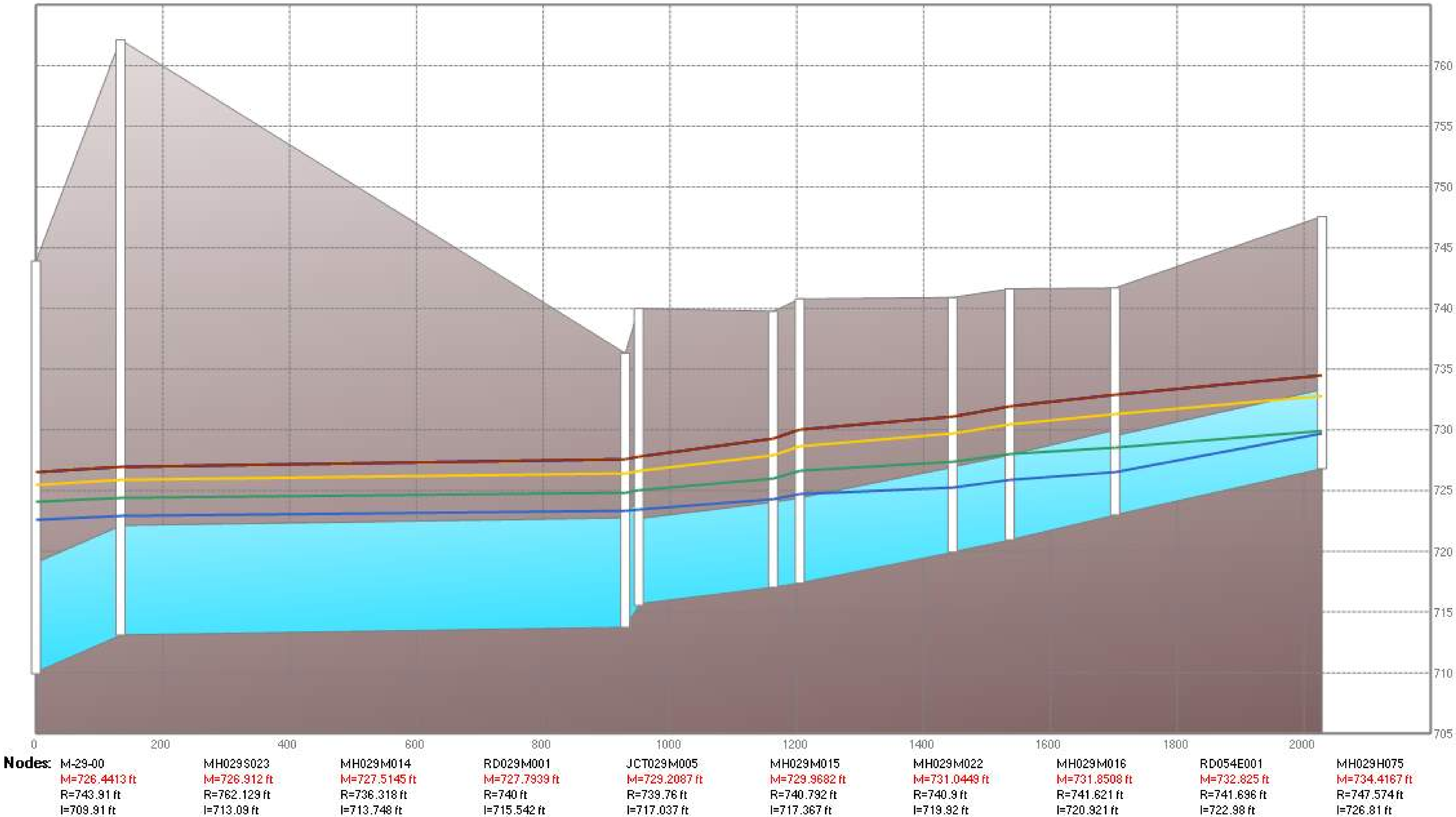
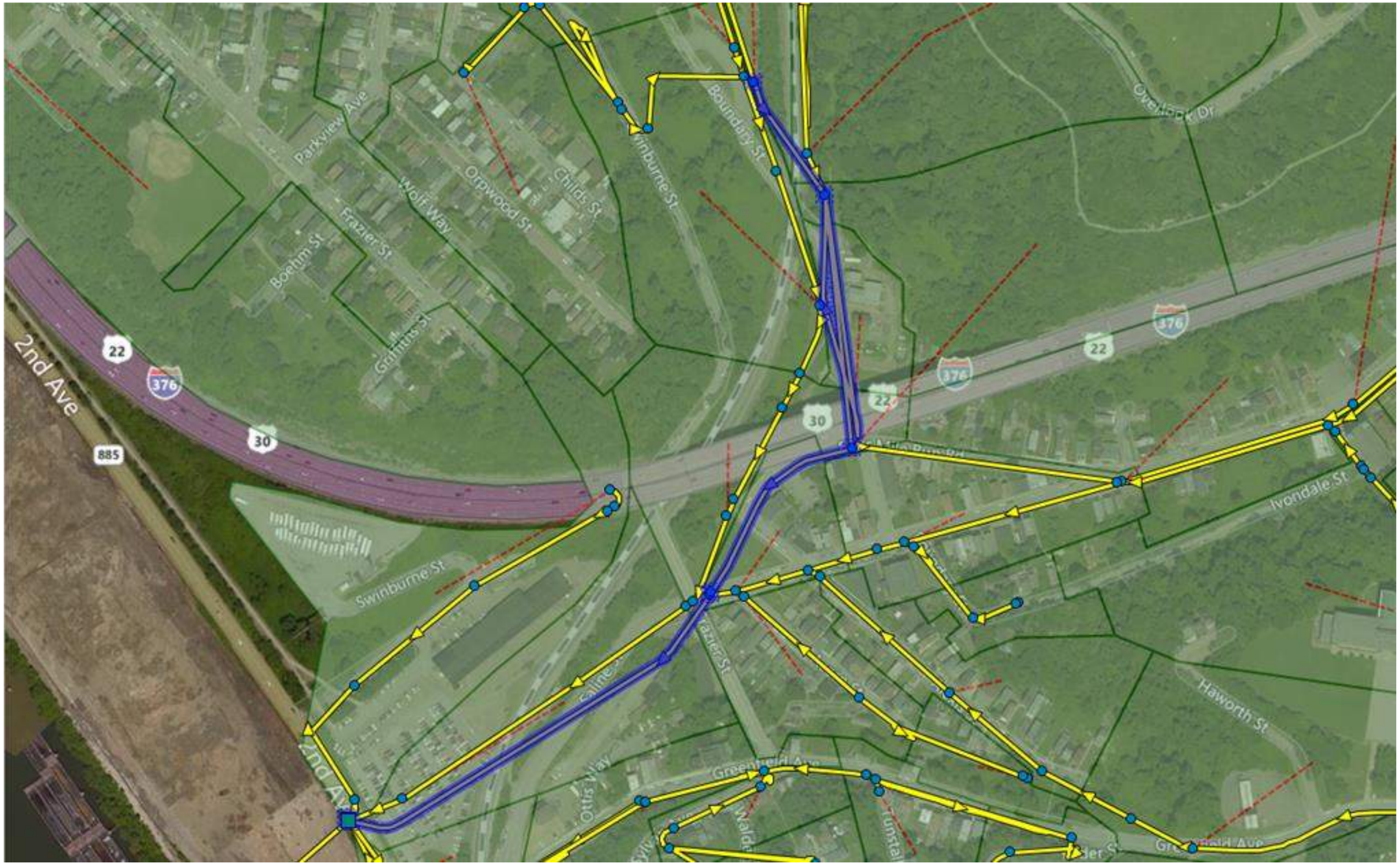


Figure 9B - Simulations_10, 11, 12, and 13 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_10, 11, 12, and 13 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

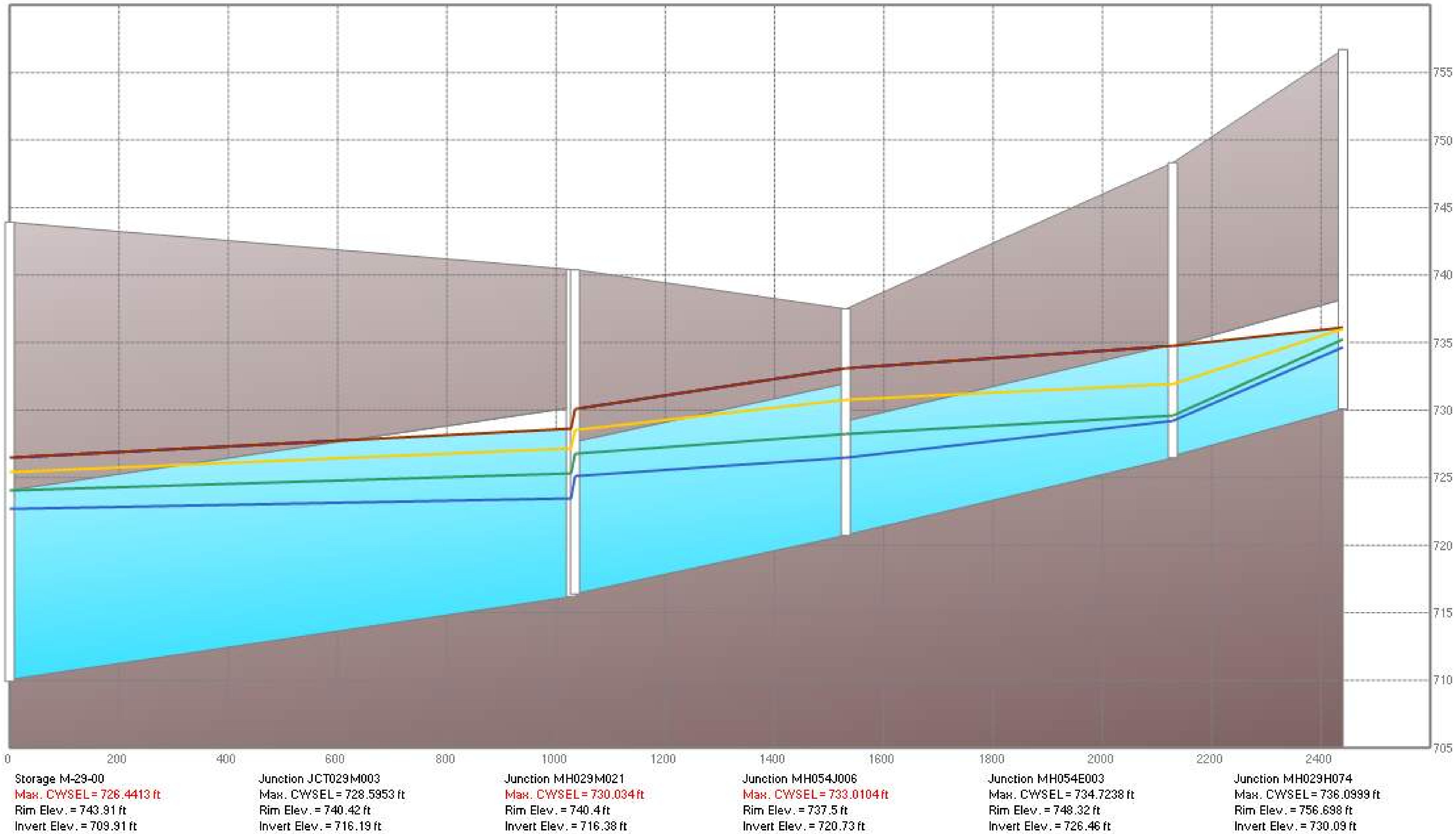
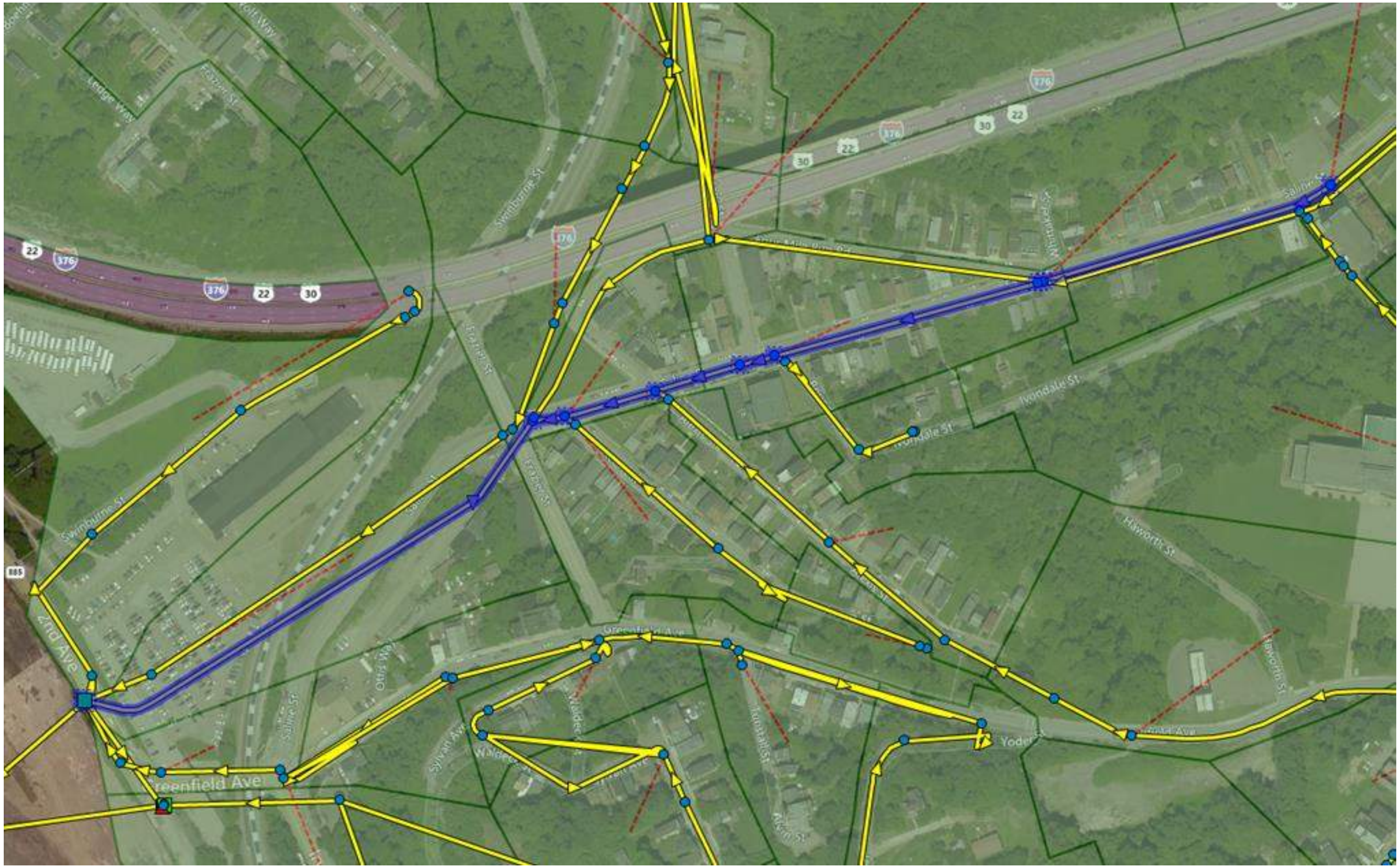


Figure 9C - Simulations_10, 11, 12, and 13 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_10, 11, 12, and 13 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

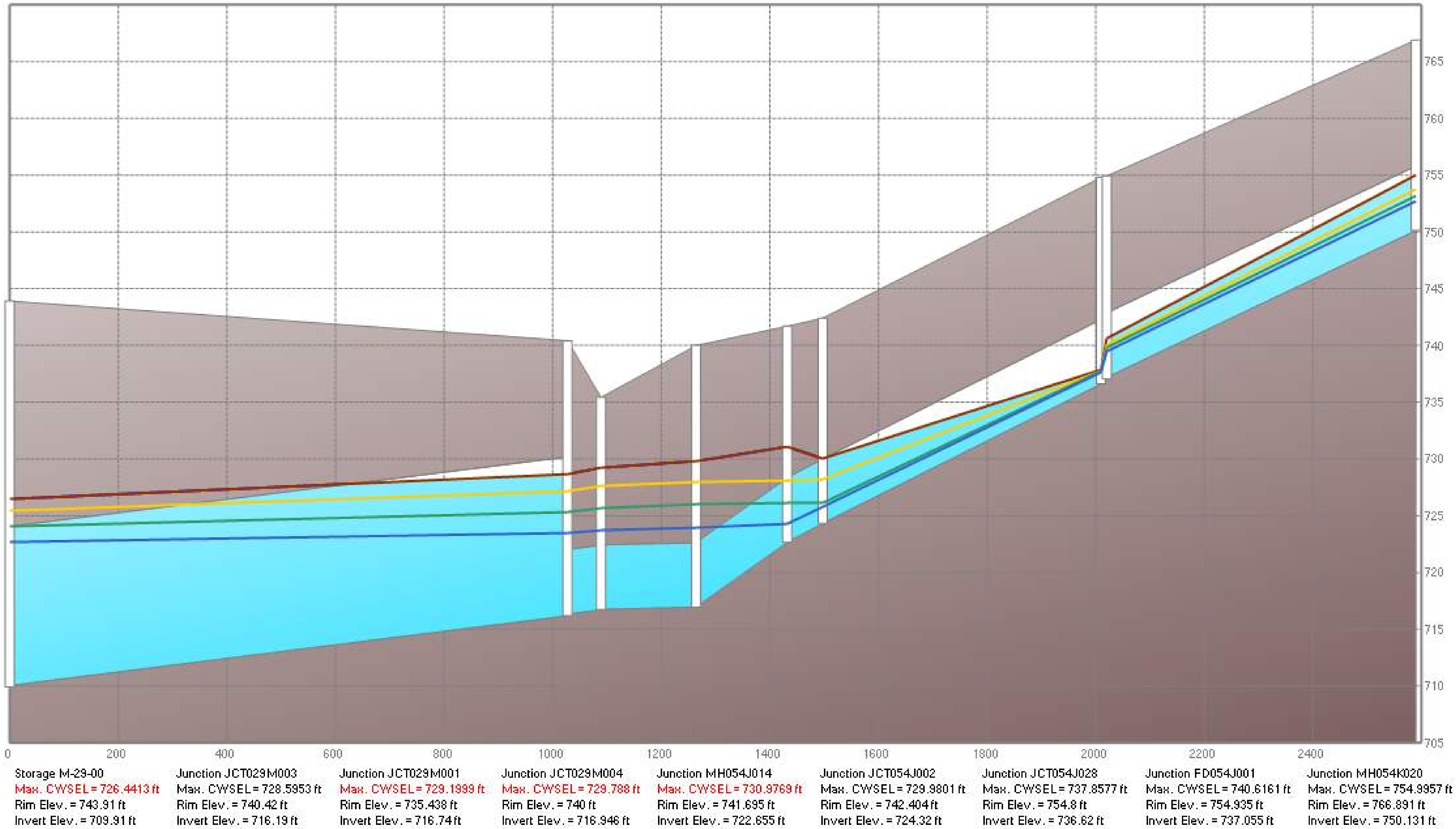
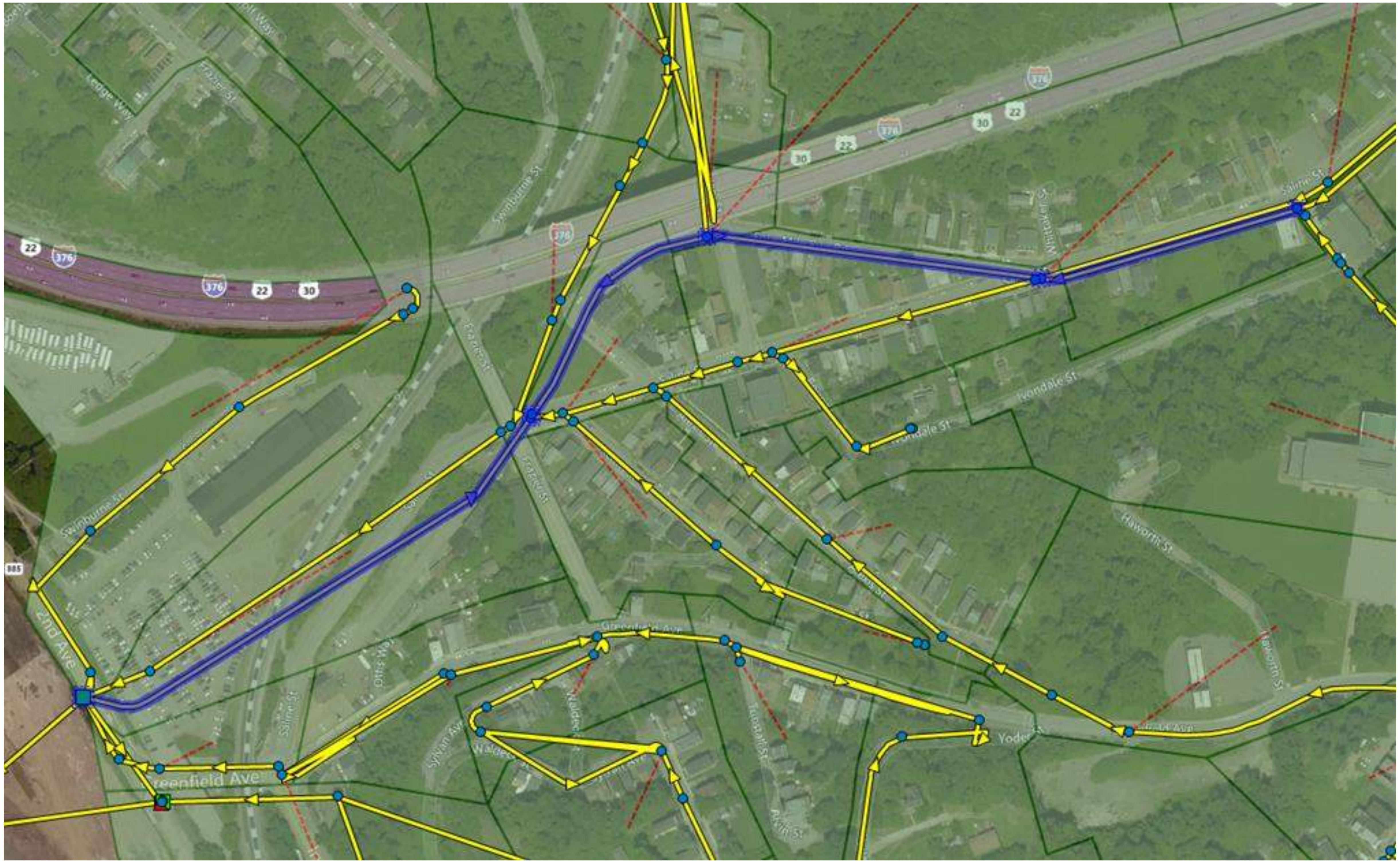


Figure 9D - Simulations_10, 11, 12, and 13 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_10, 11, 12, and 13 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

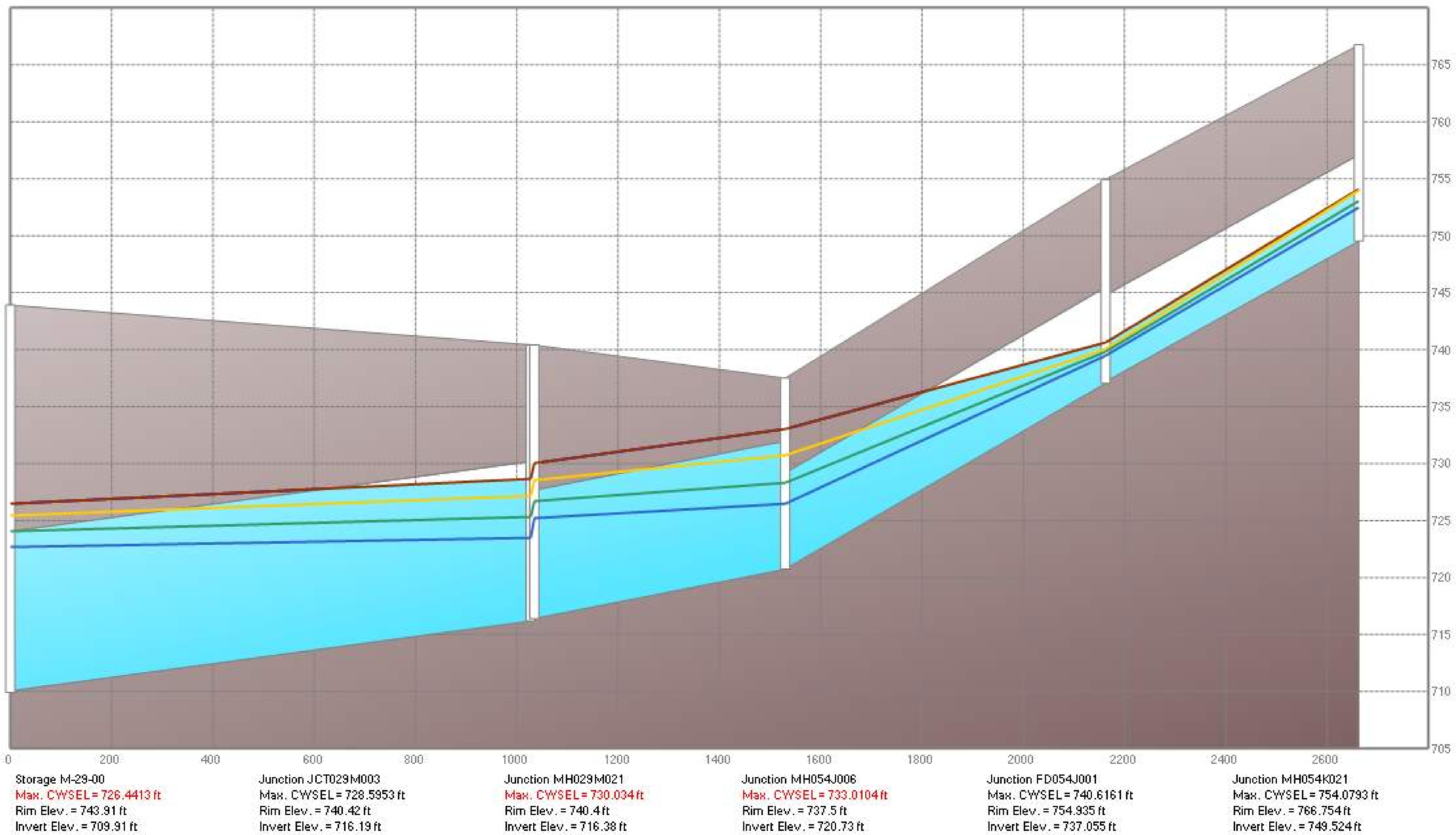
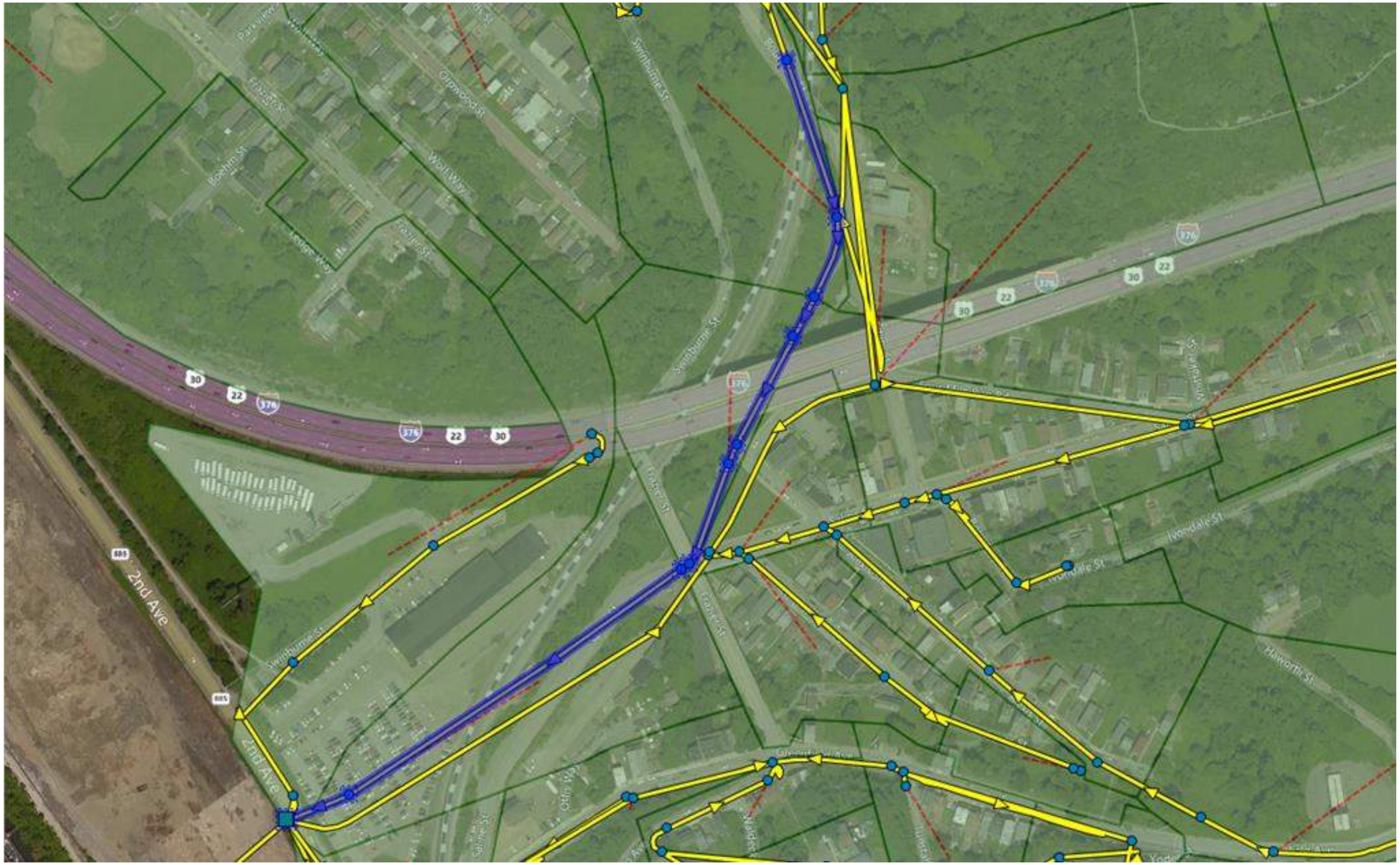


Figure 10A - Simulations_14, 15, 16, and 17 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_14, 15, 16, and 17 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

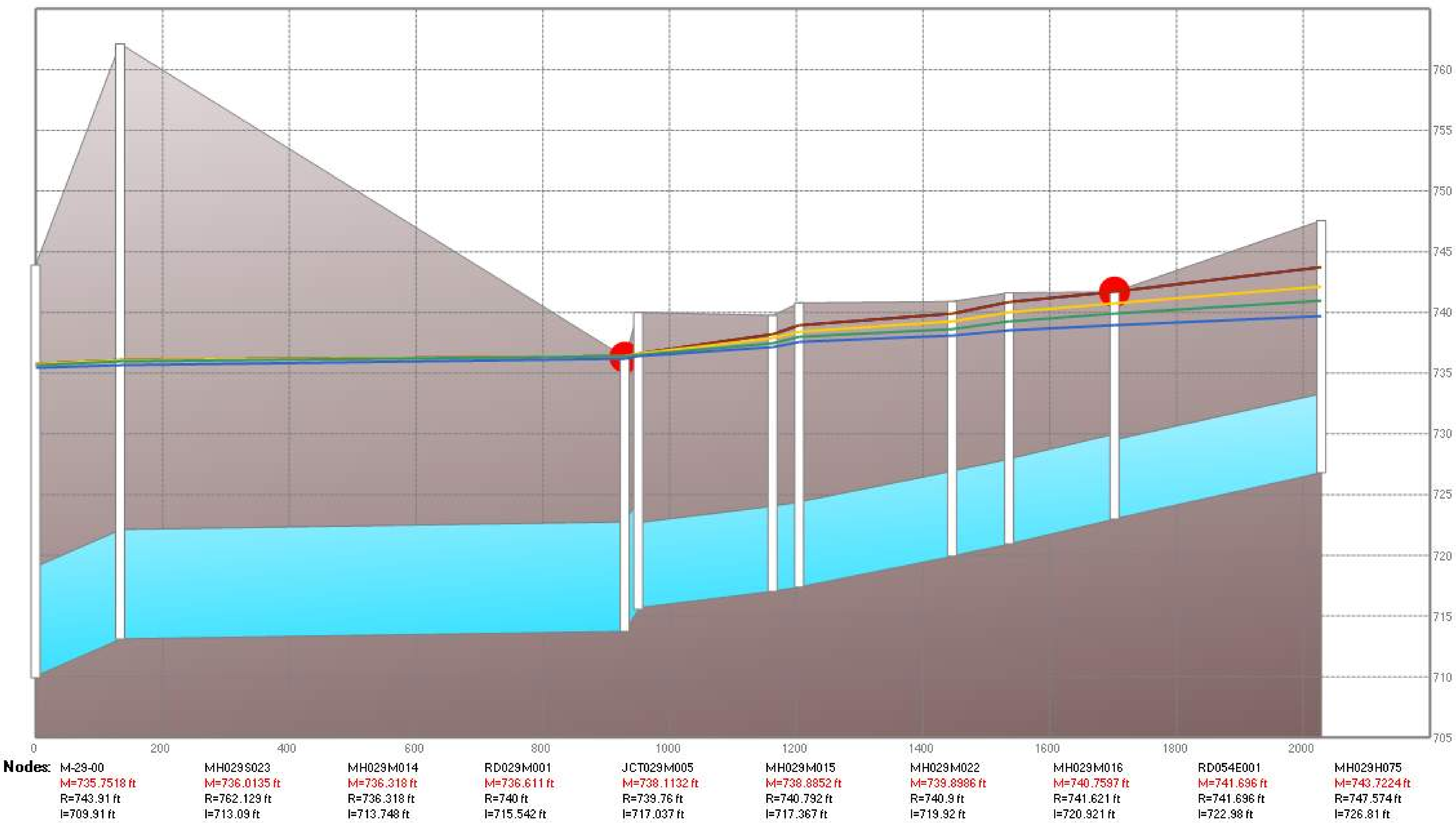
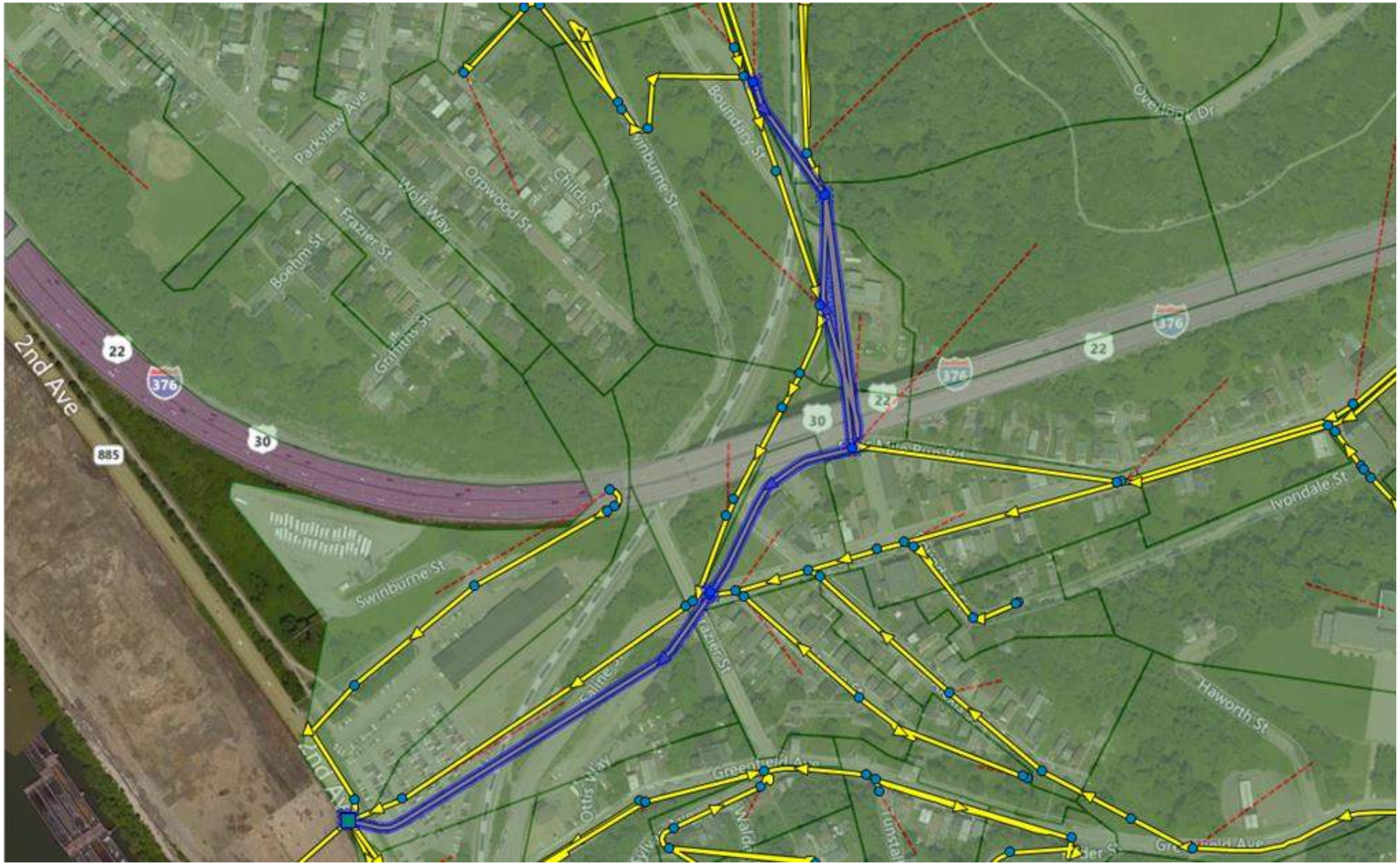


Figure 10B - Simulations_14, 15, 16, and 17 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_14, 15, 16, and 17 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

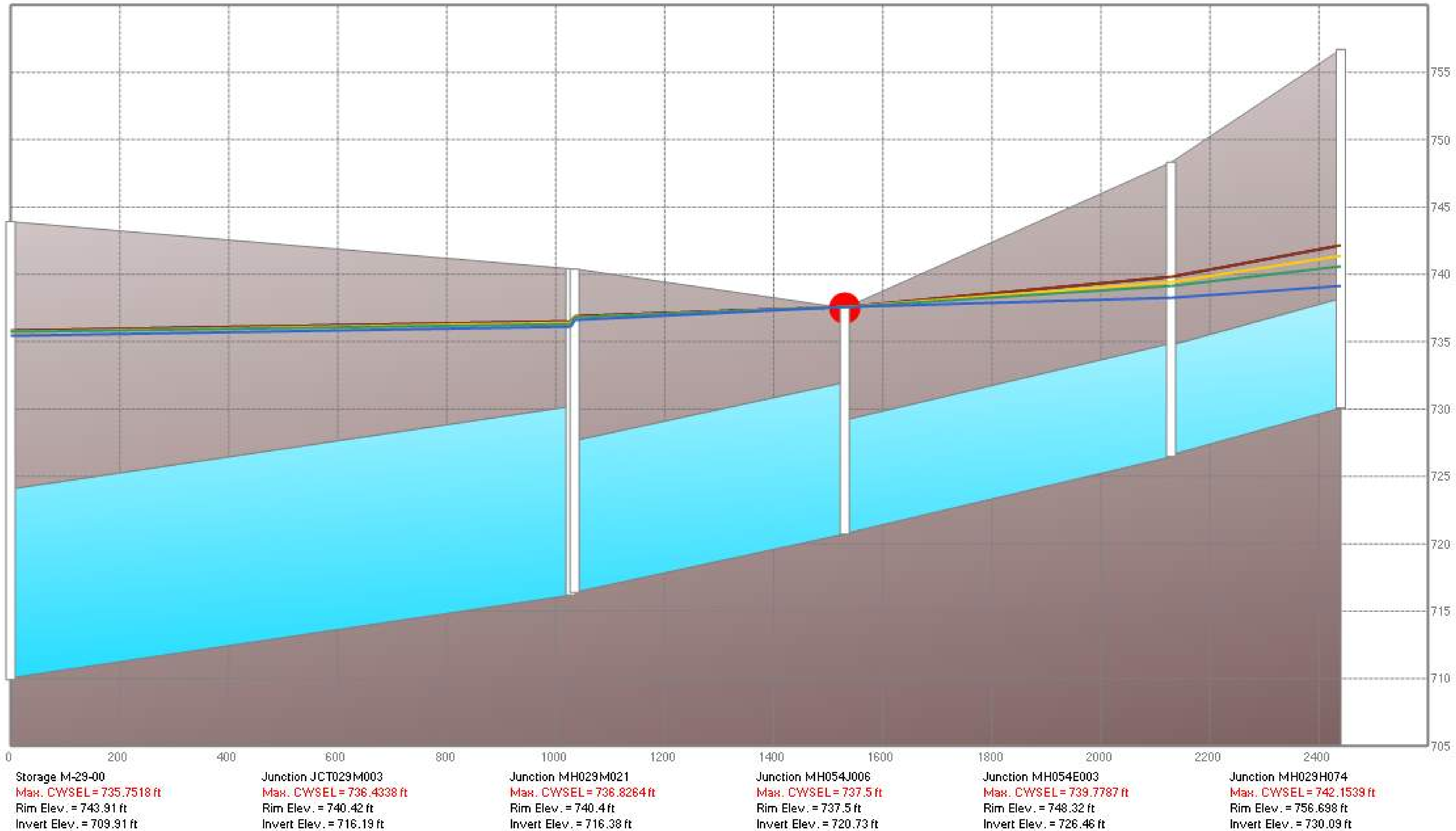
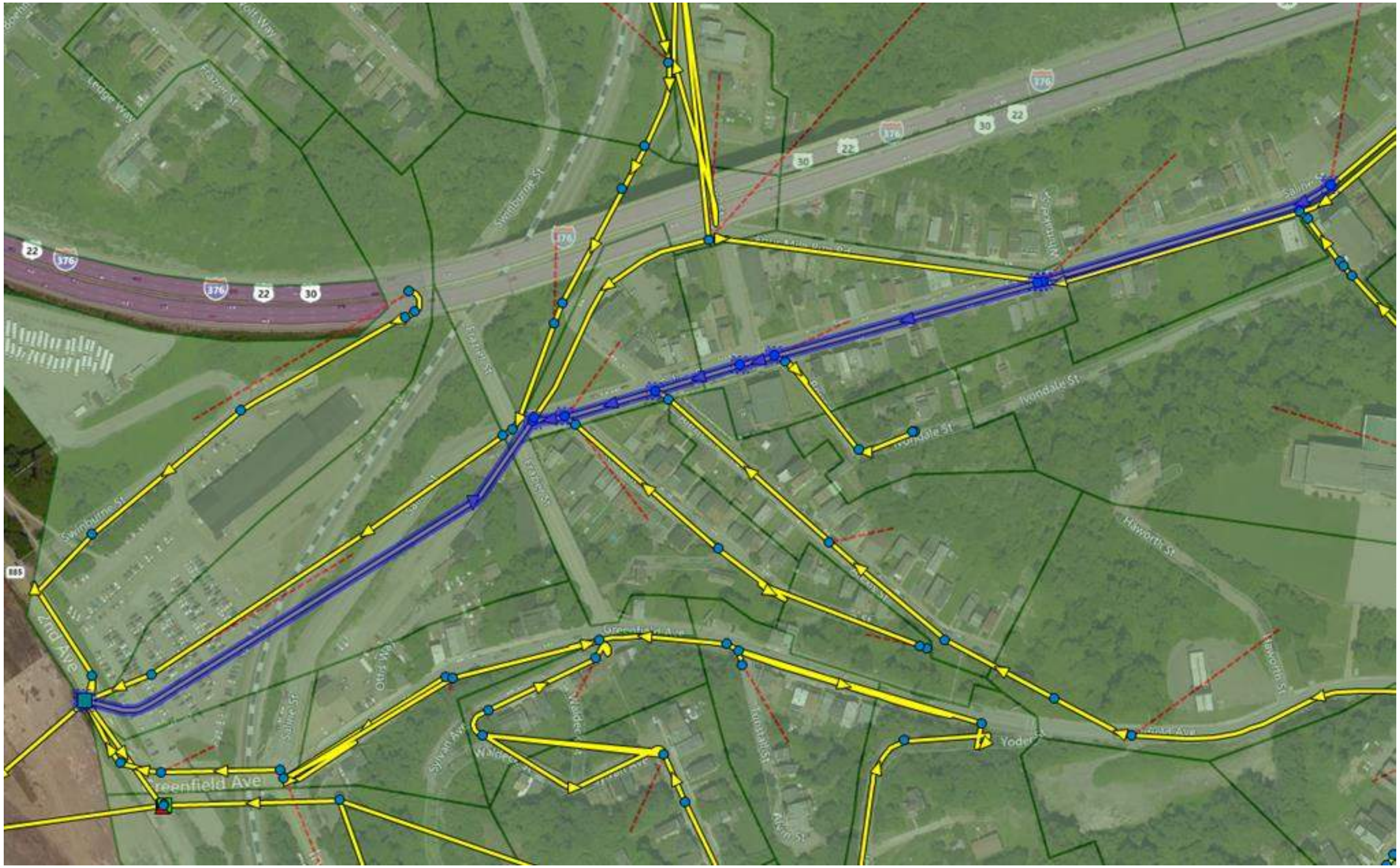


Figure 10C - Simulations_14, 15, 16, and 17 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_14, 15, 16, and 17 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

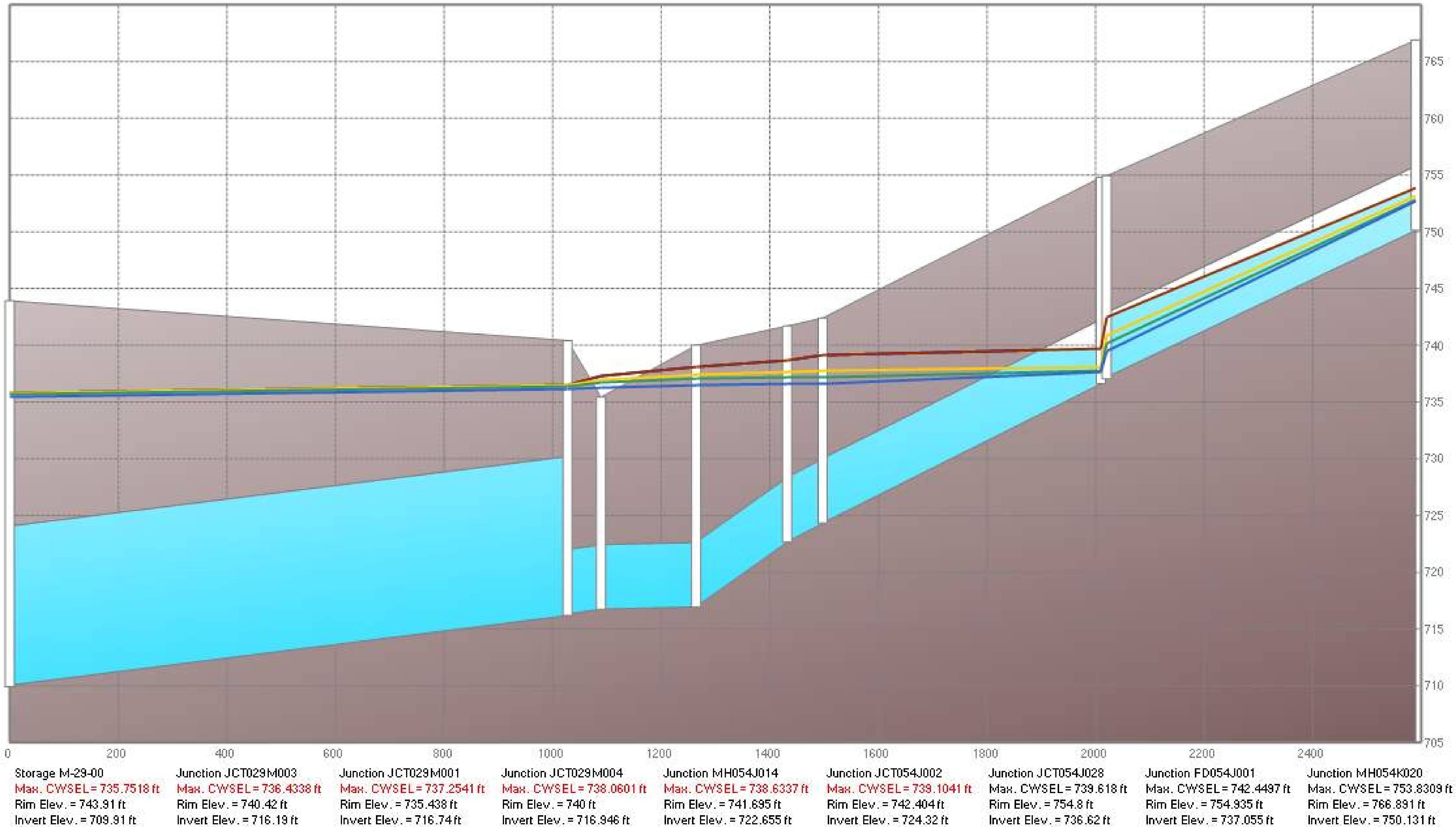
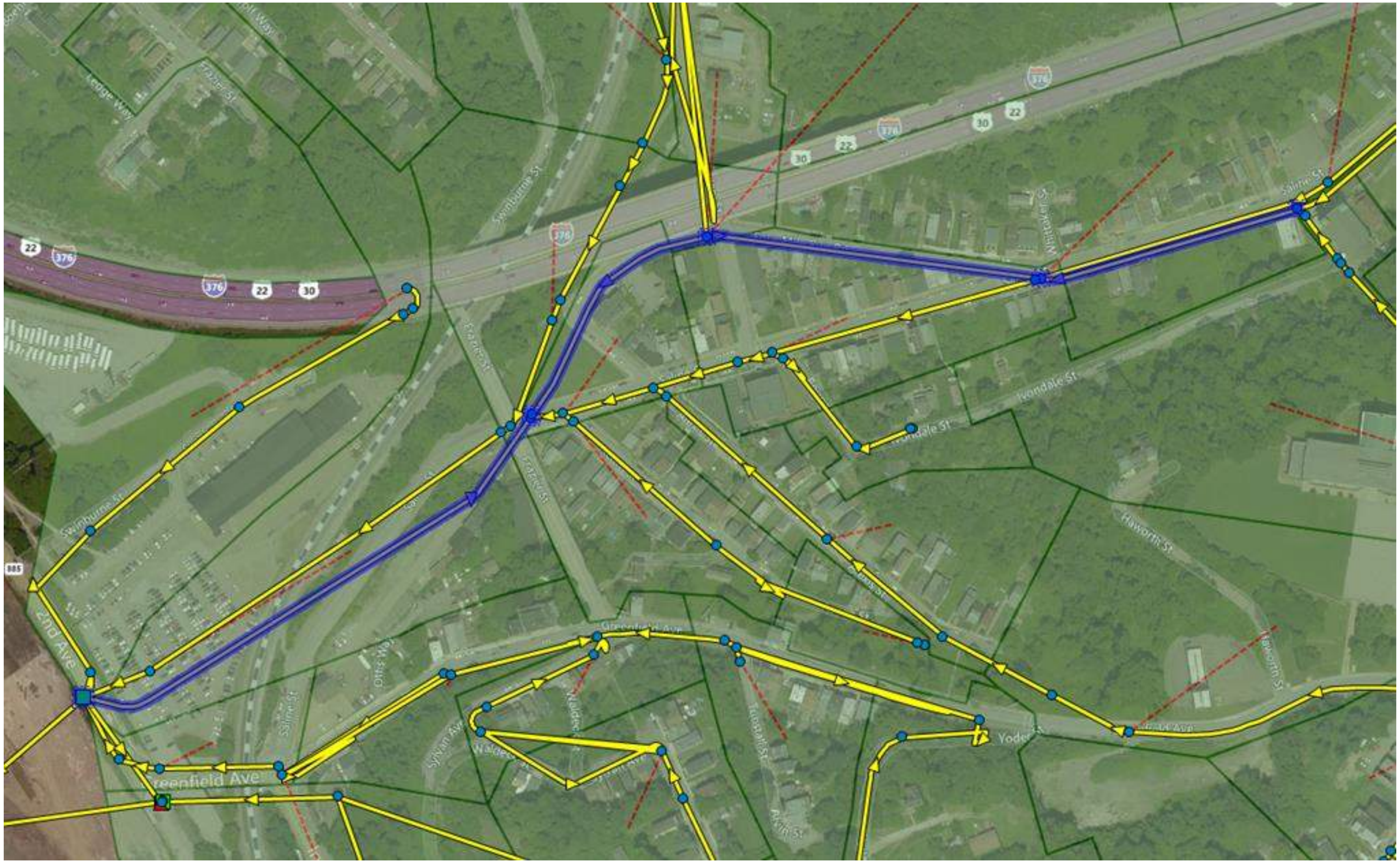


Figure 10D - Simulations_14, 15, 16, and 17 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_14, 15, 16, and 17 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

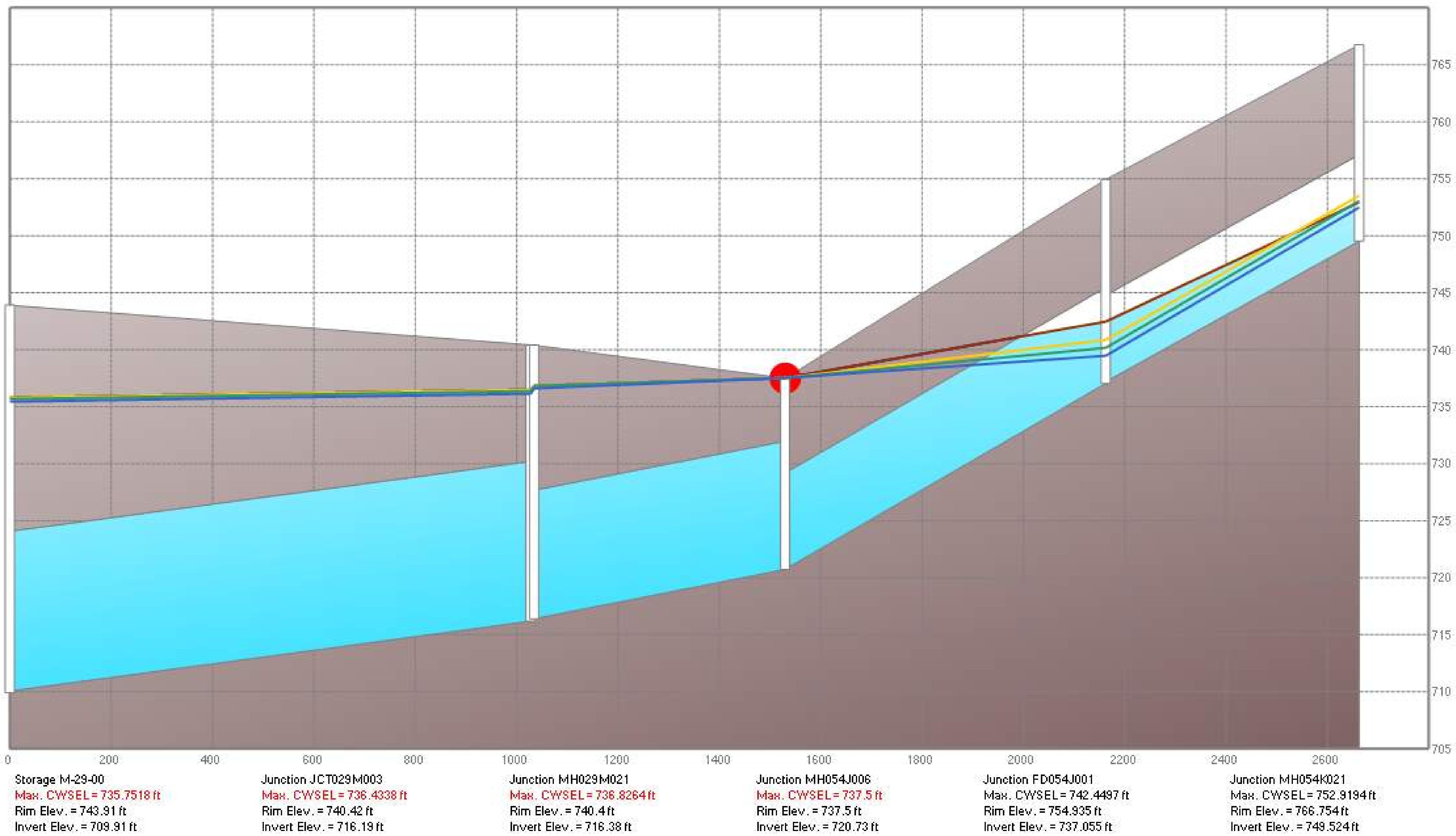
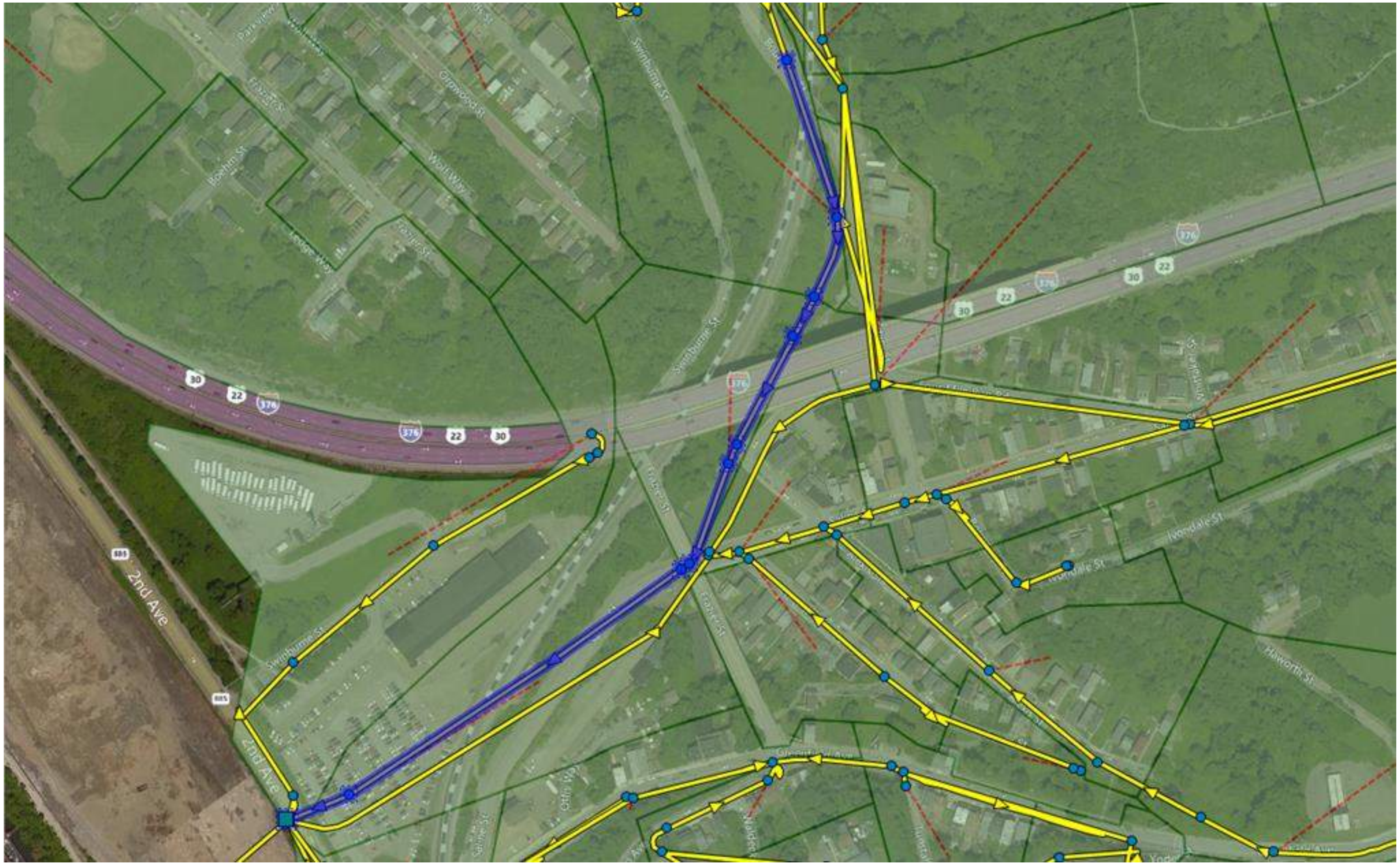


Figure 11A - Simulations_18, 19, 20, and 21 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_18, 19, 20, and 21 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

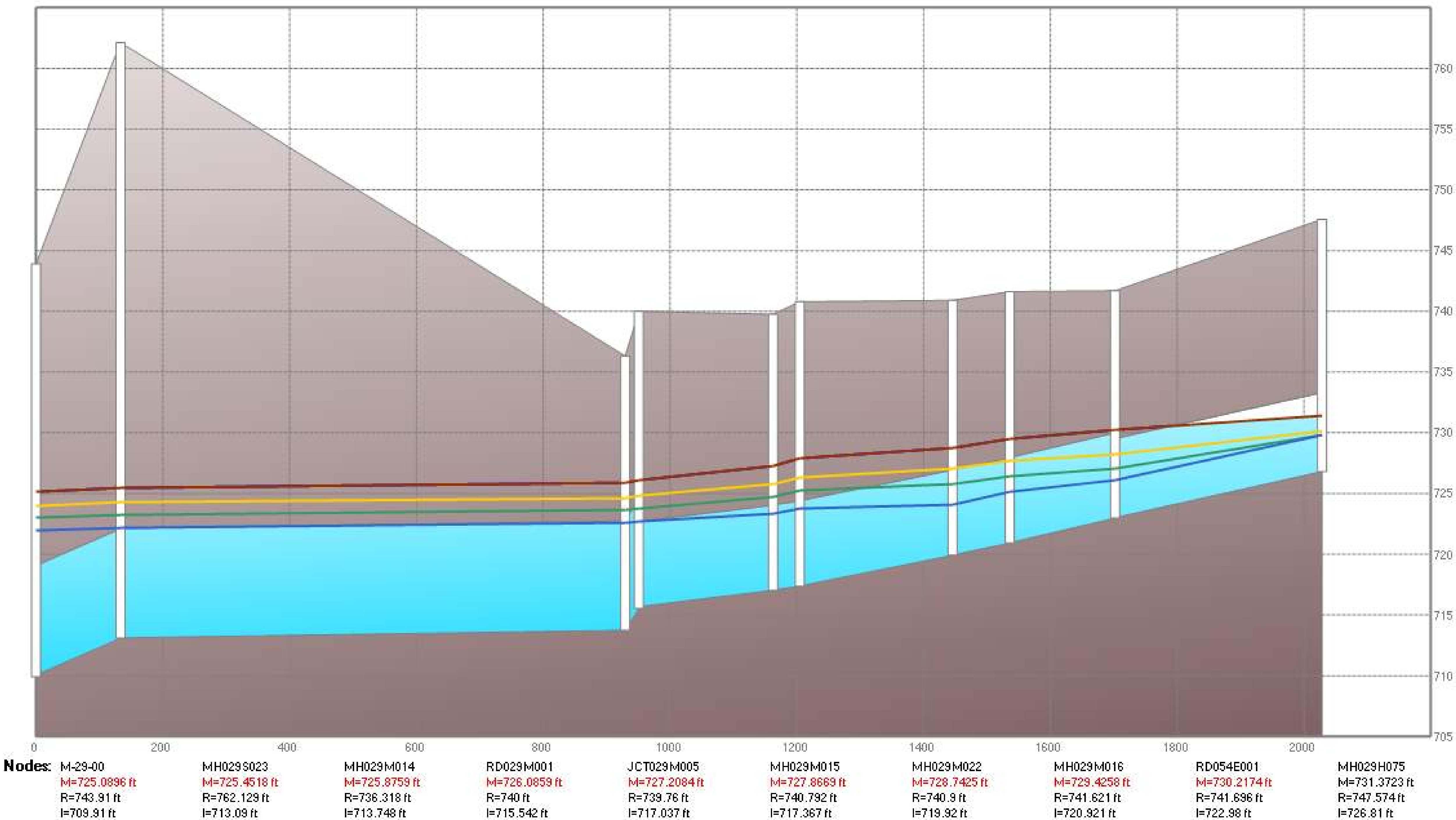
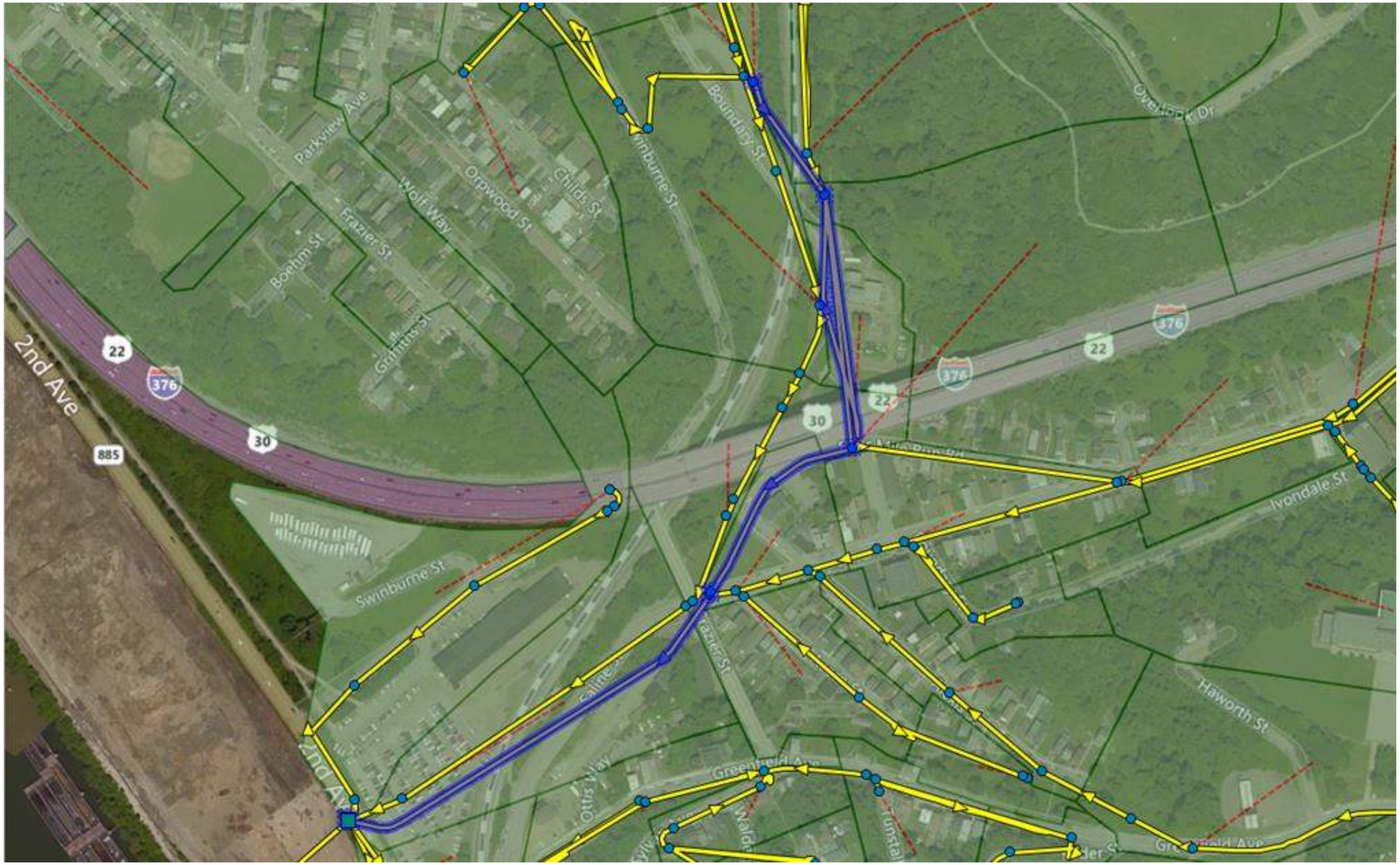


Figure 11B - Simulations_18, 19, 20, and 21 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_18, 19, 20, and 21 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

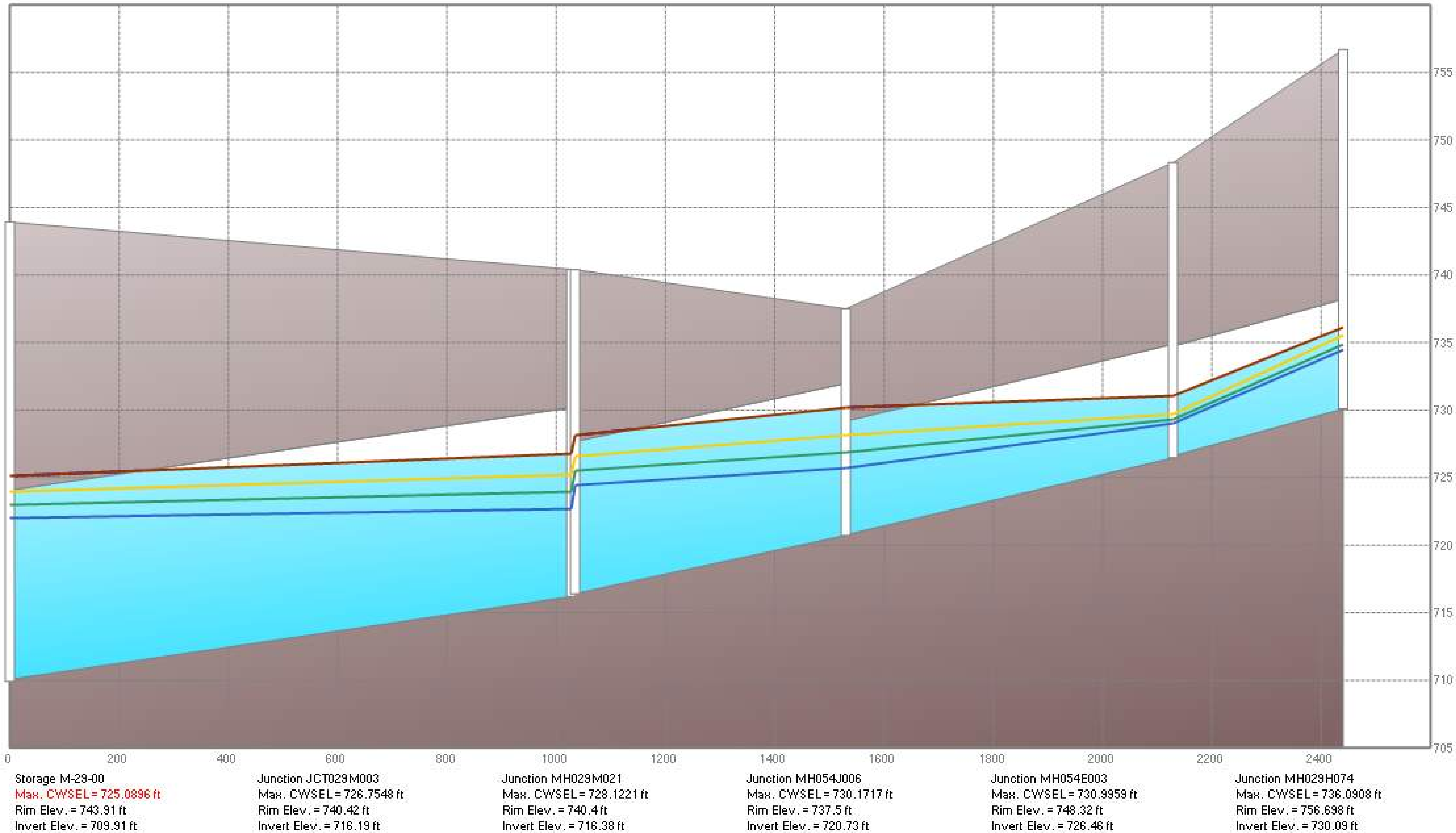
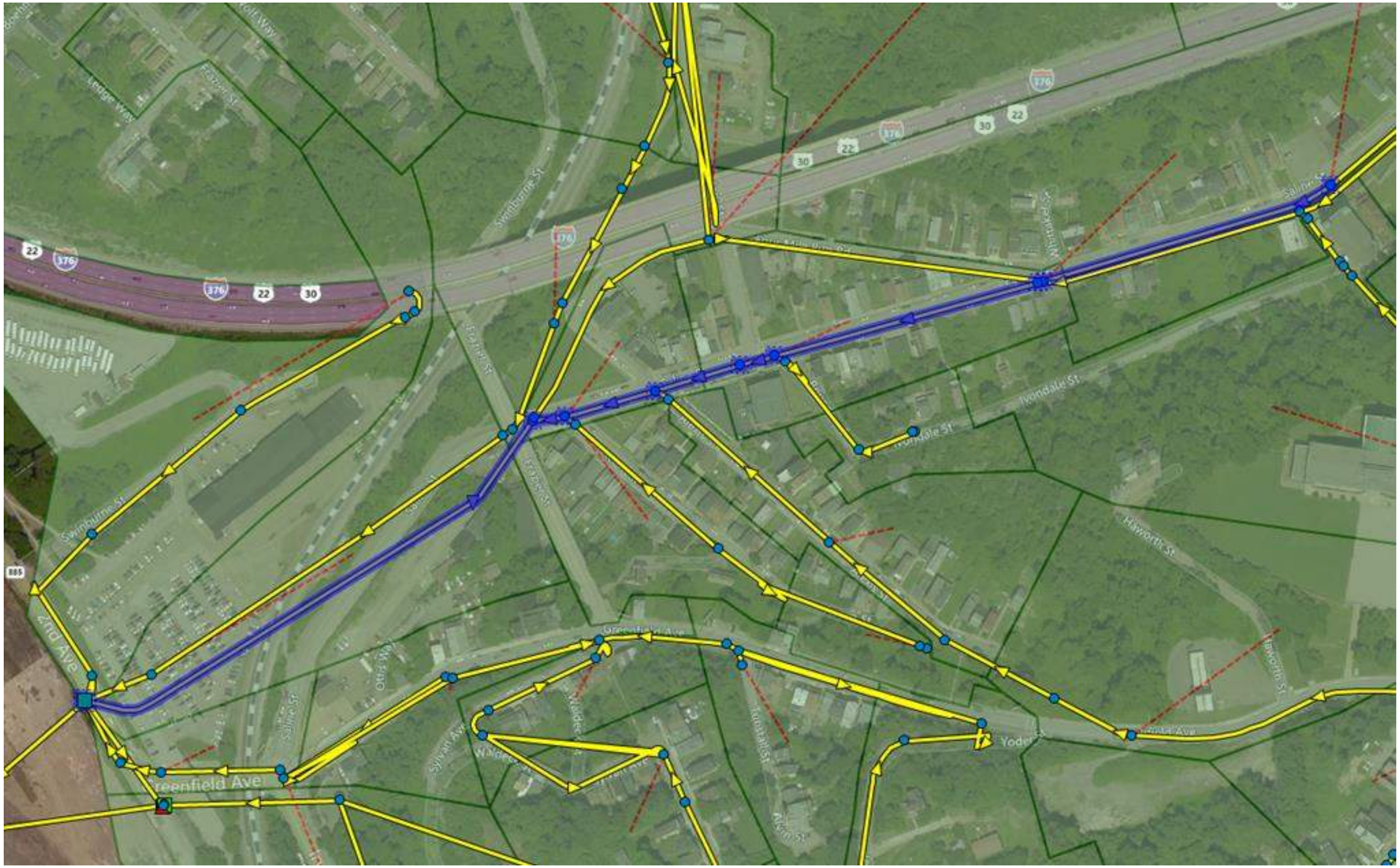


Figure 11C - Simulations_18, 19, 20, and 21 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_18, 19, 20, and 21 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

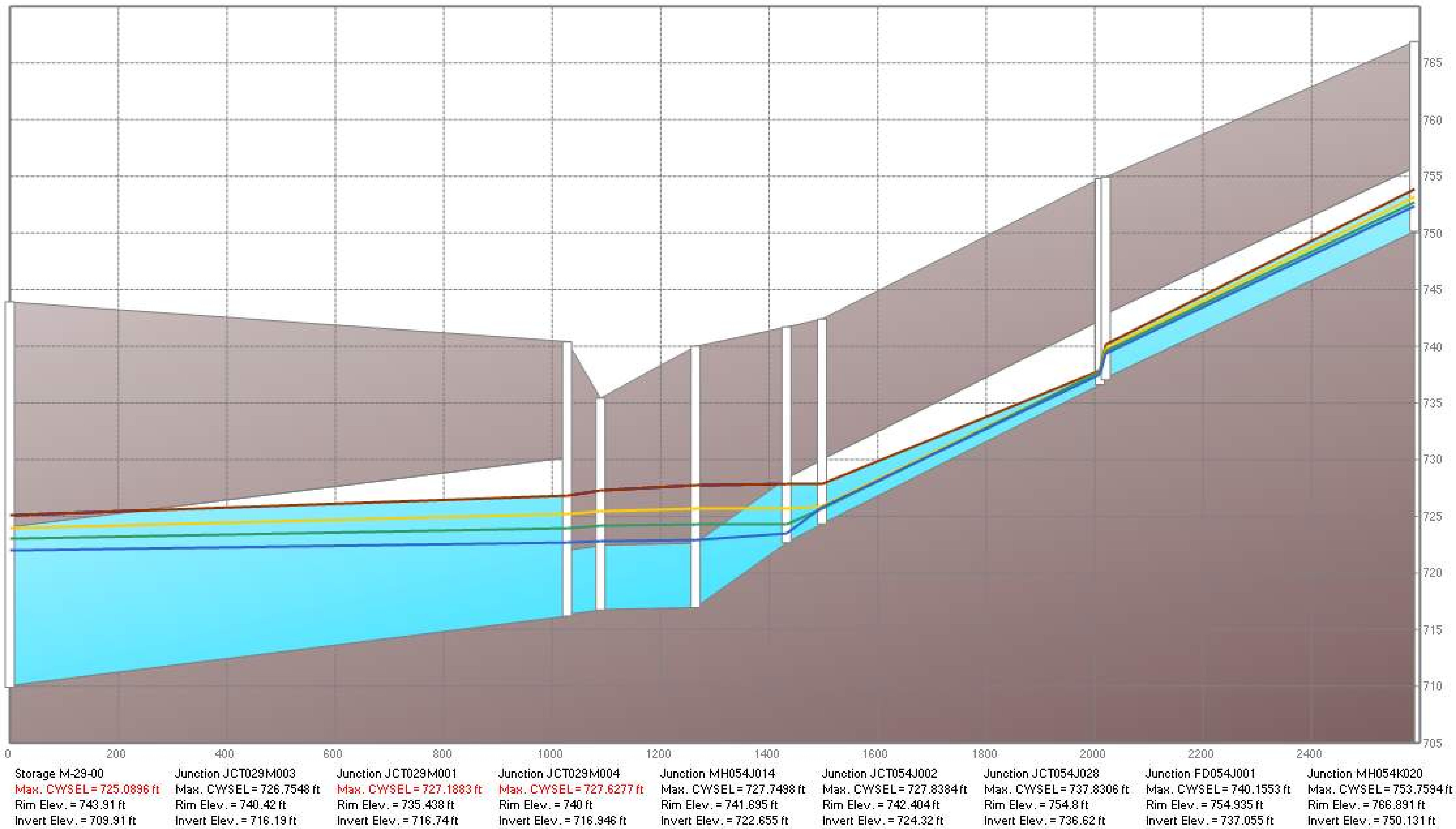
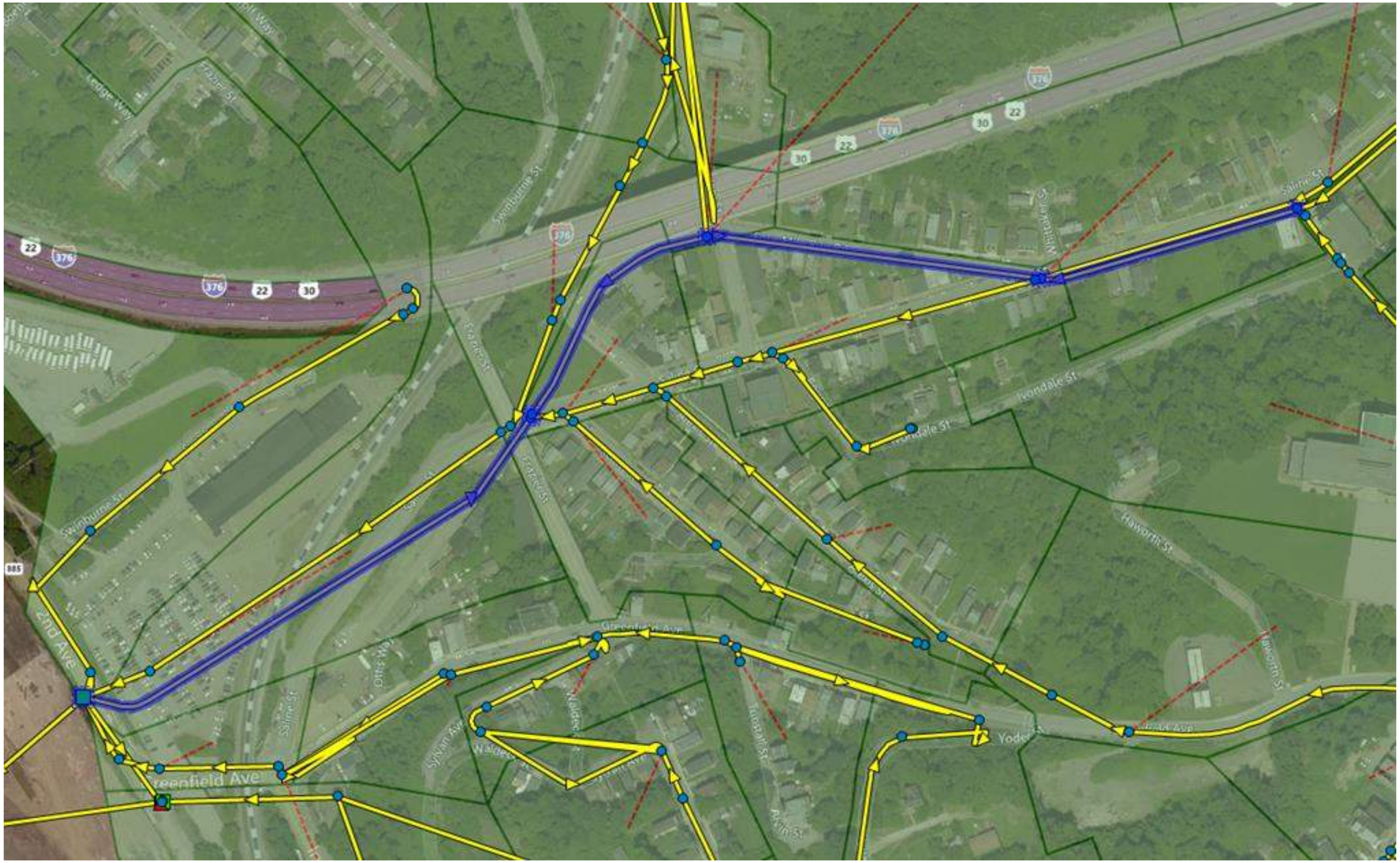


Figure 11D - Simulations_18, 19, 20, and 21 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_18, 19, 20, and 21 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

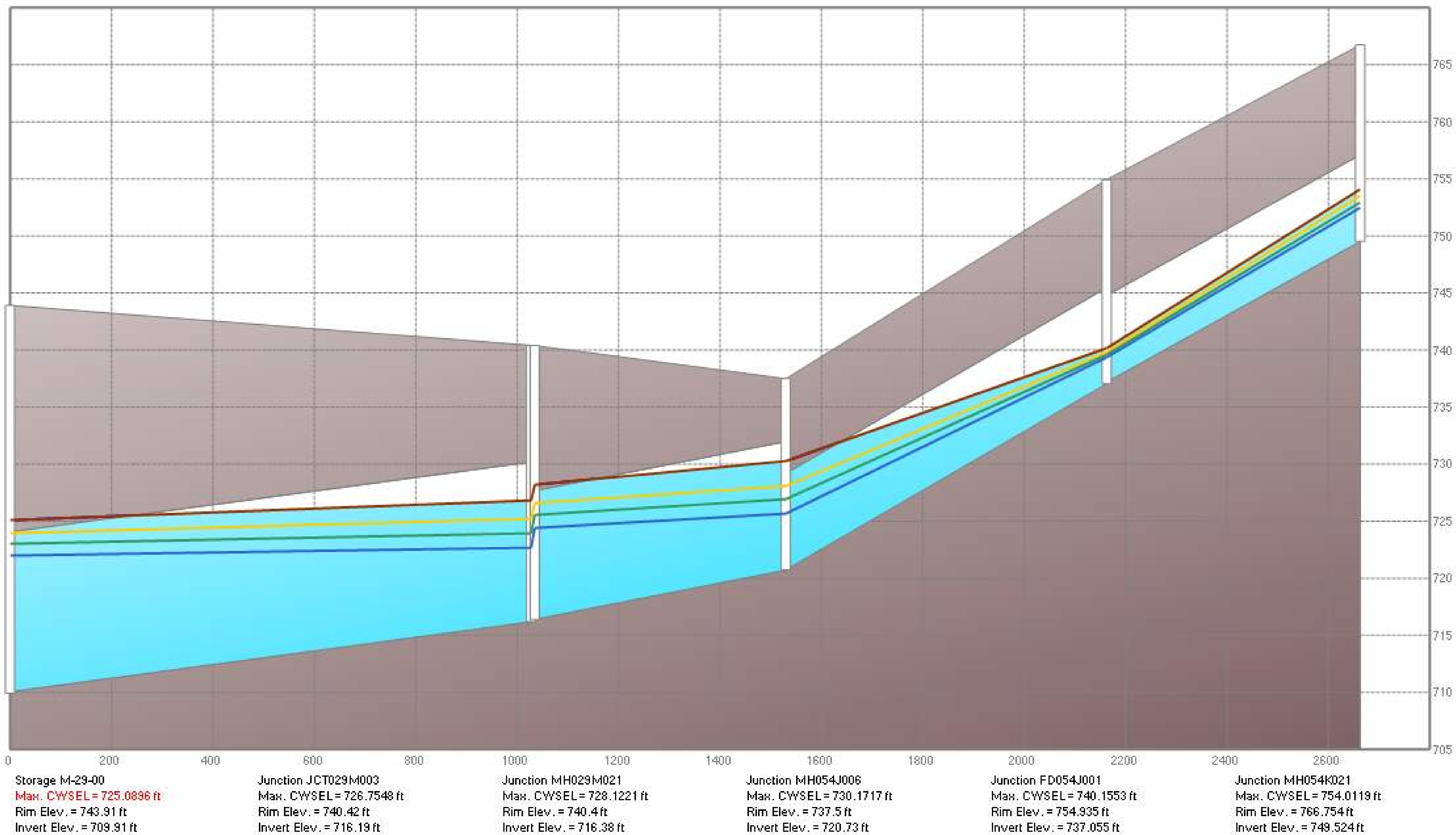
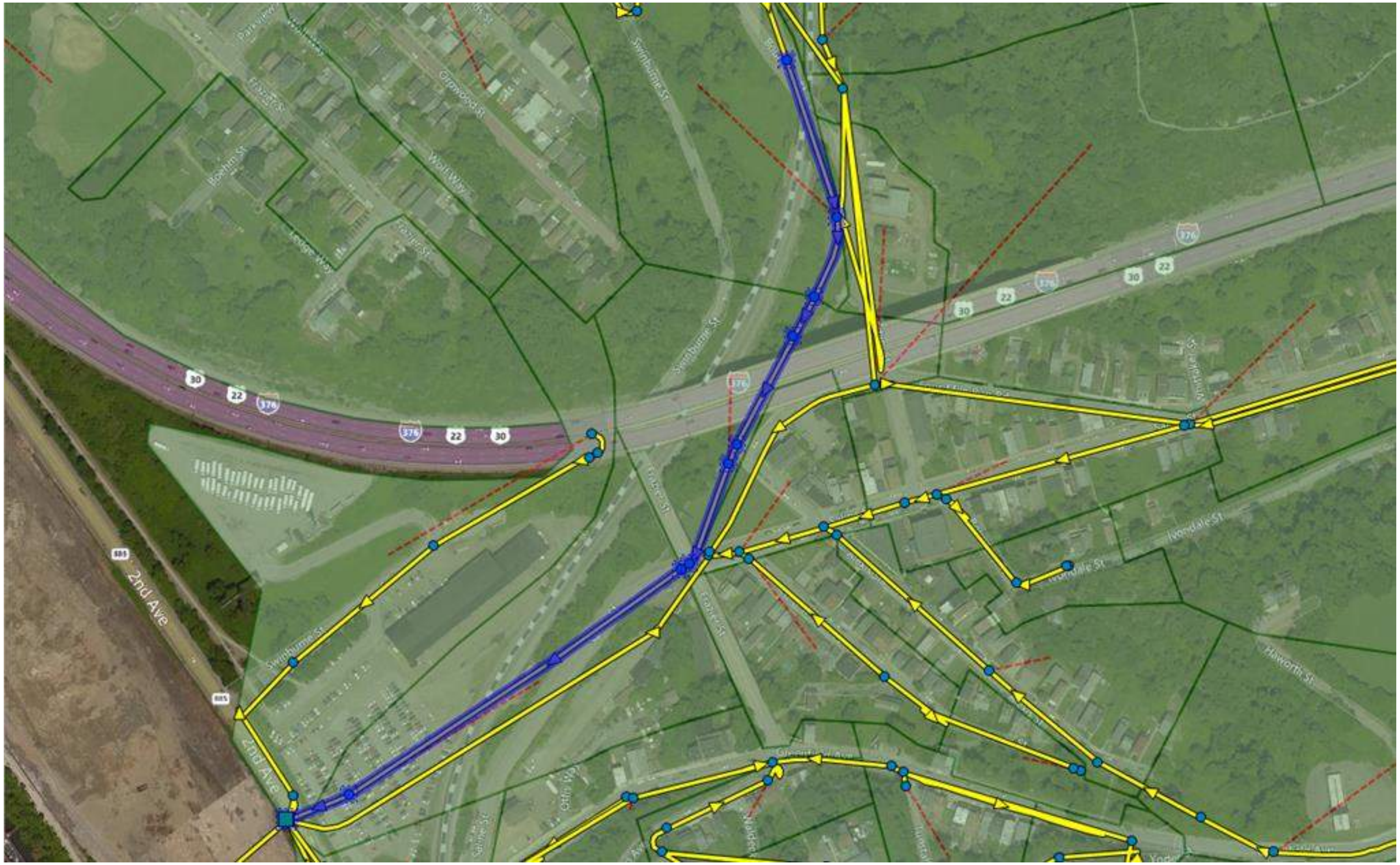


Figure 12A - Simulations_22, 23, 24, and 25 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_22, 23, 24, and 25 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

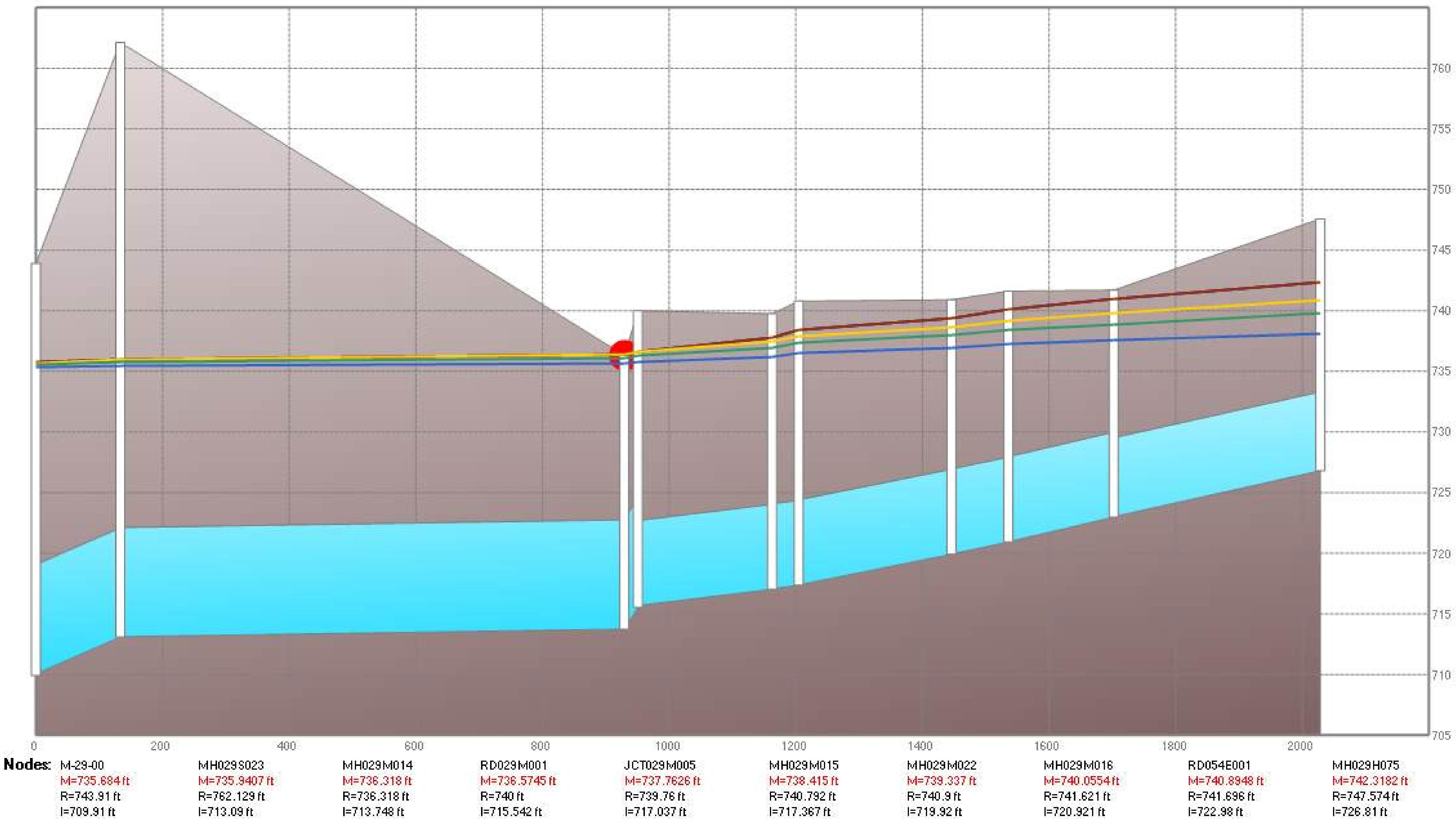
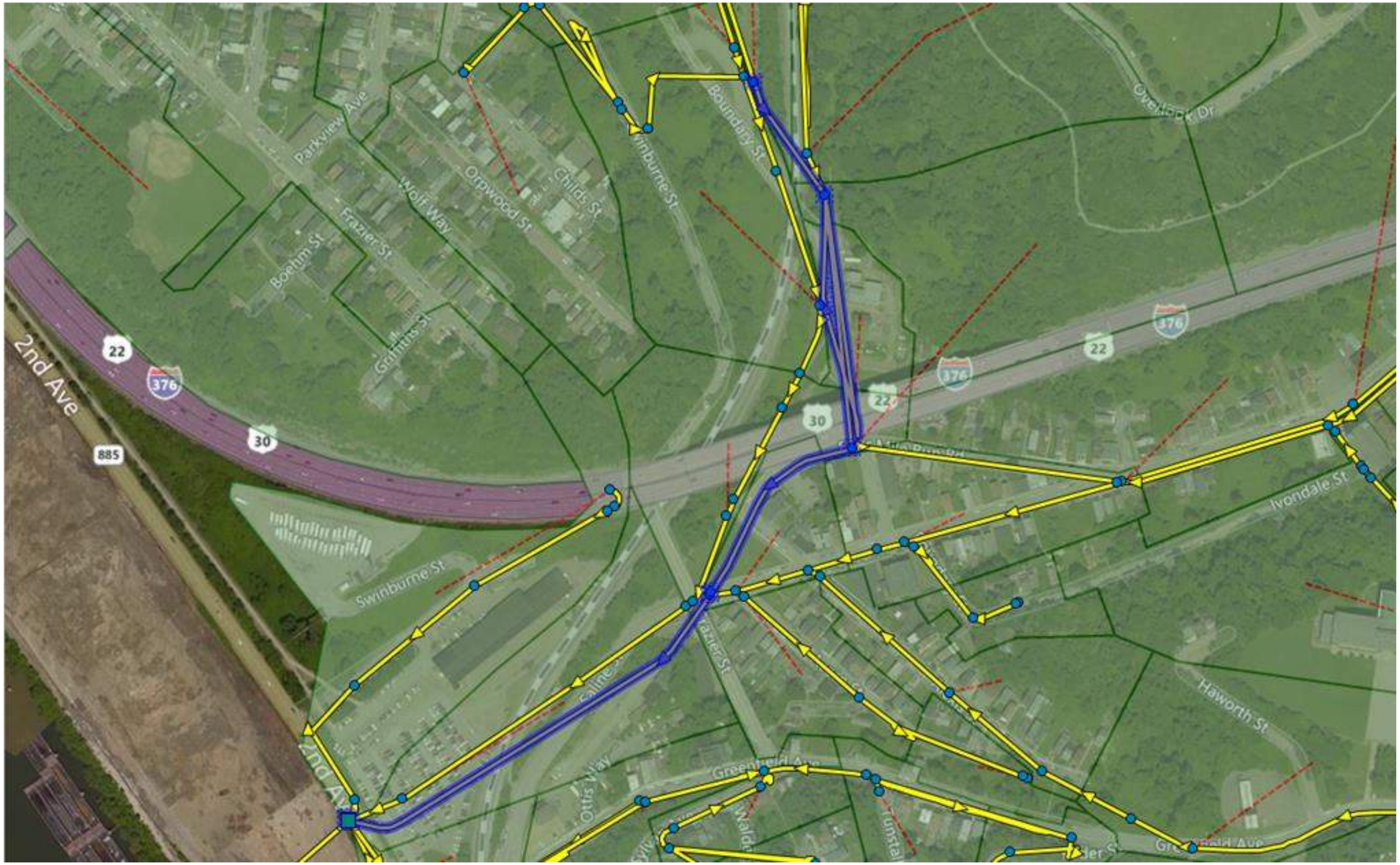


Figure 12B - Simulations_22, 23, 24, and 25 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_22, 23, 24, and 25 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

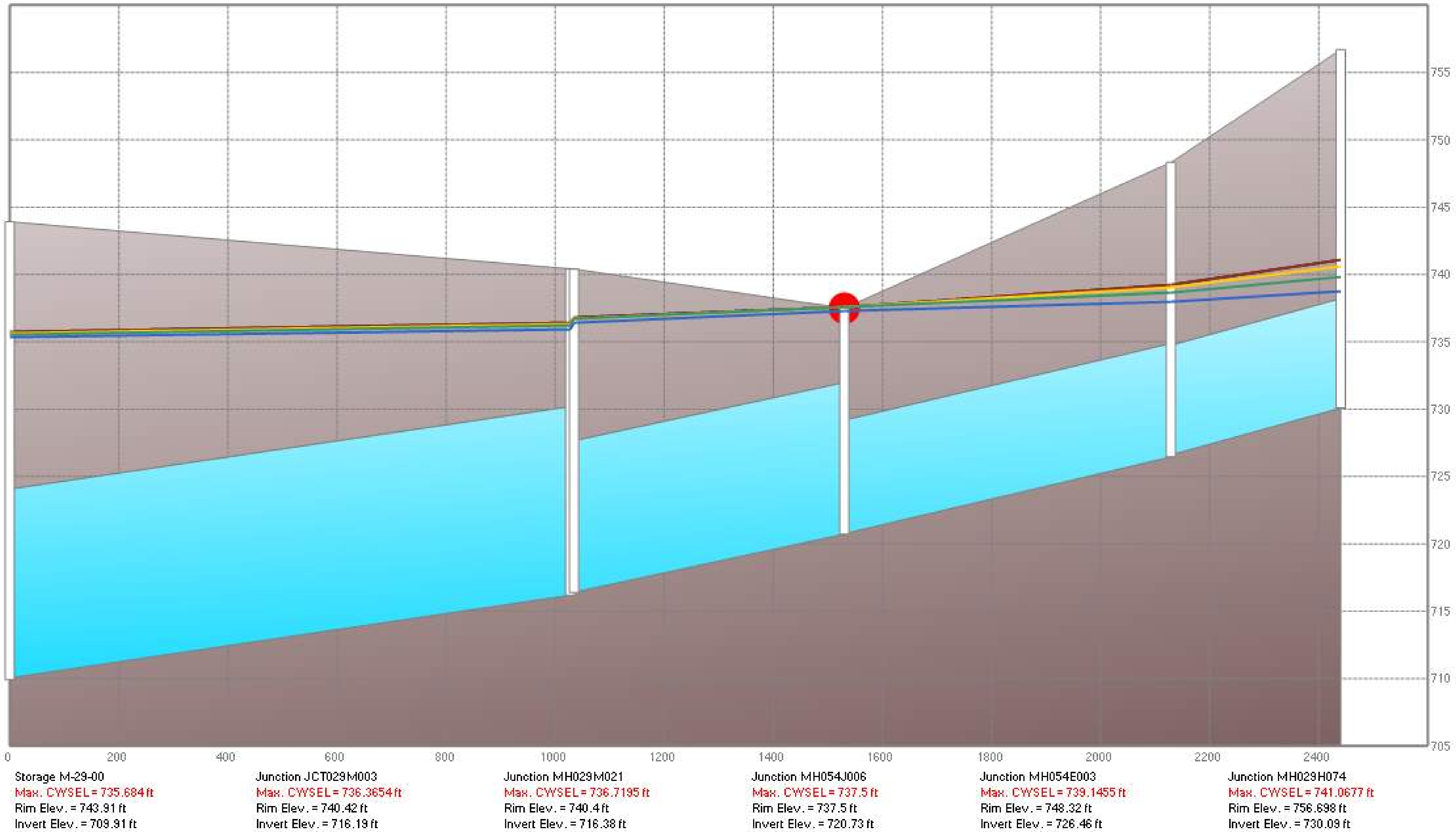
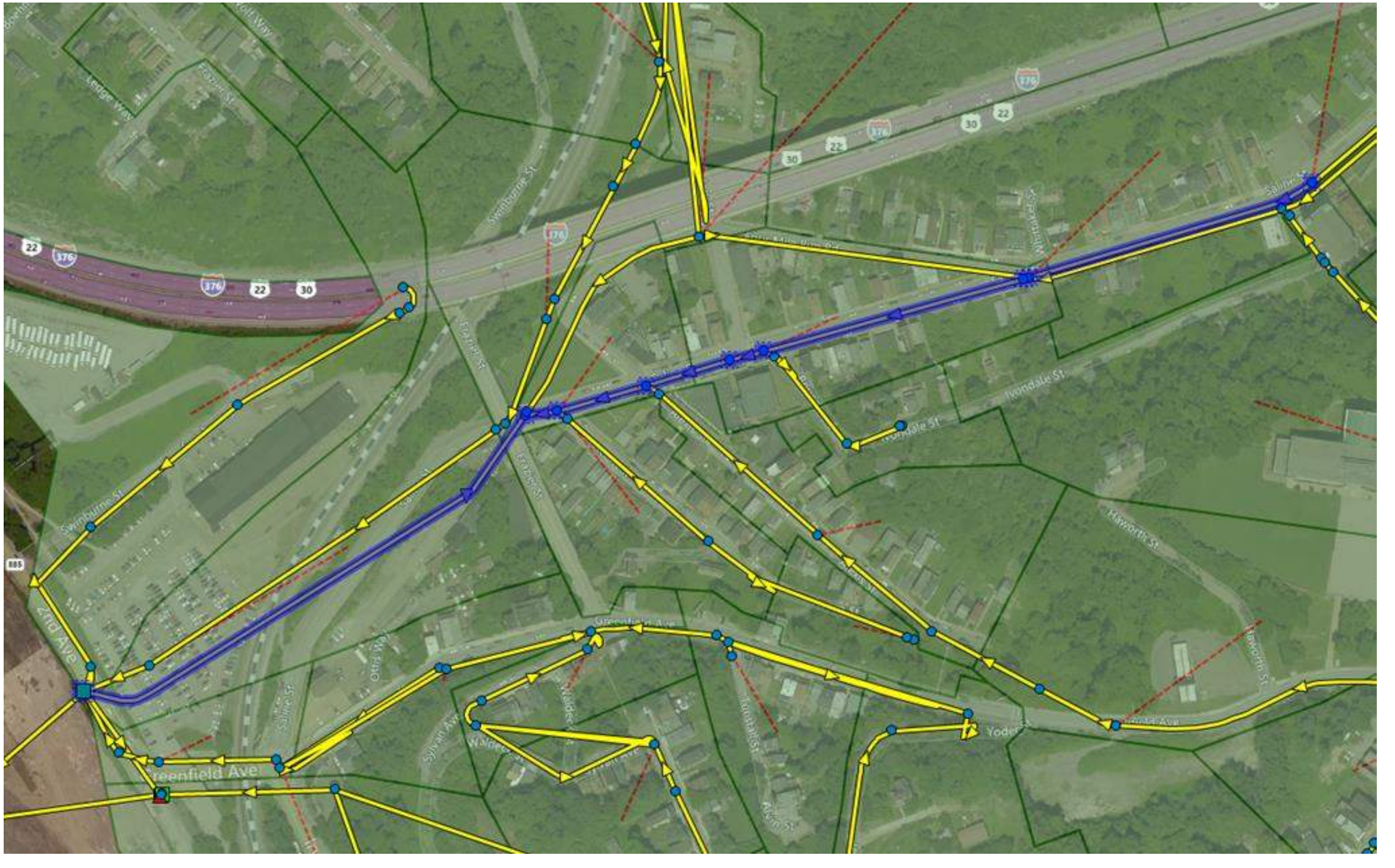


Figure 12C - Simulations_22, 23, 24, and 25 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_22, 23, 24, and 25 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

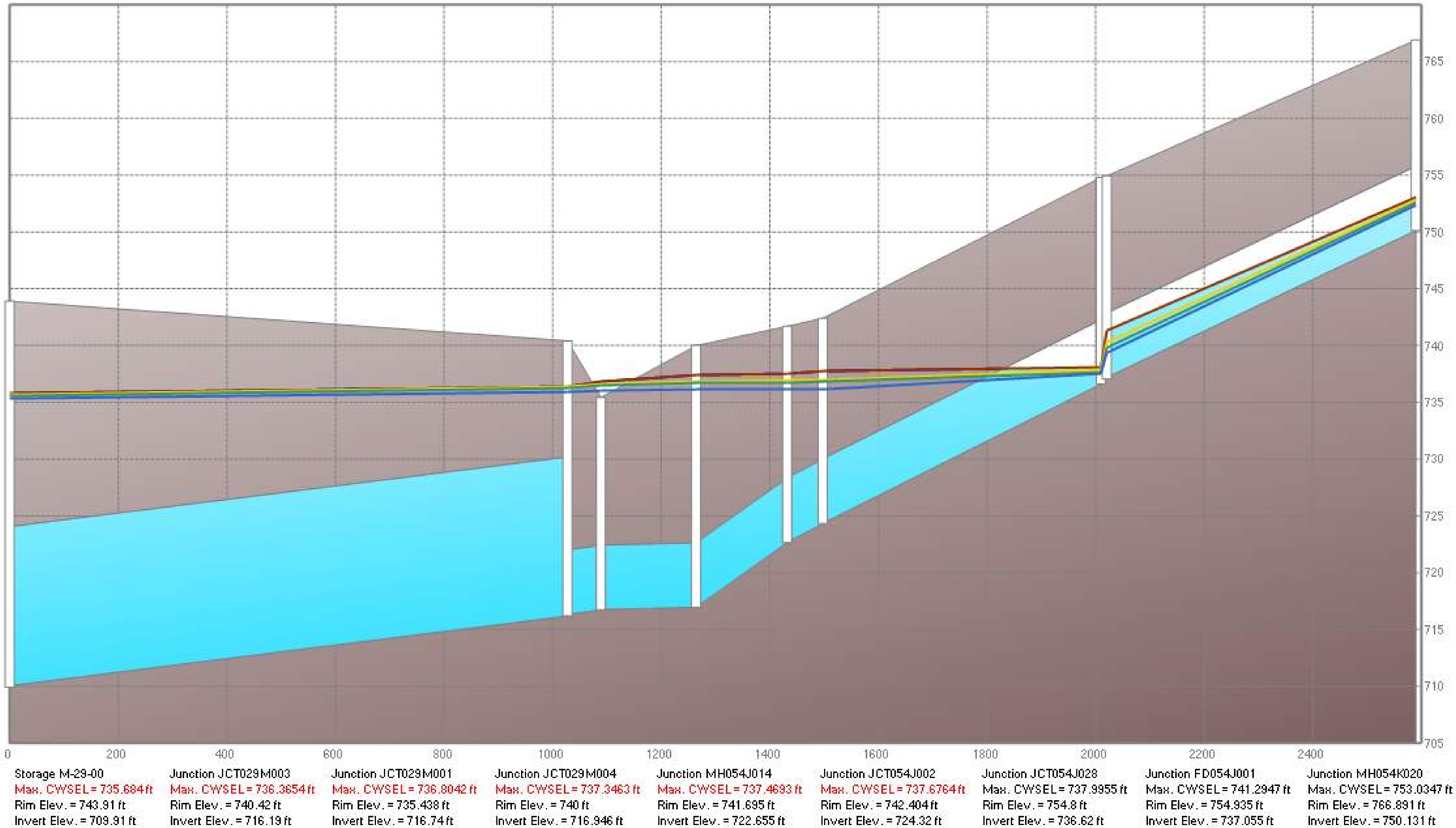
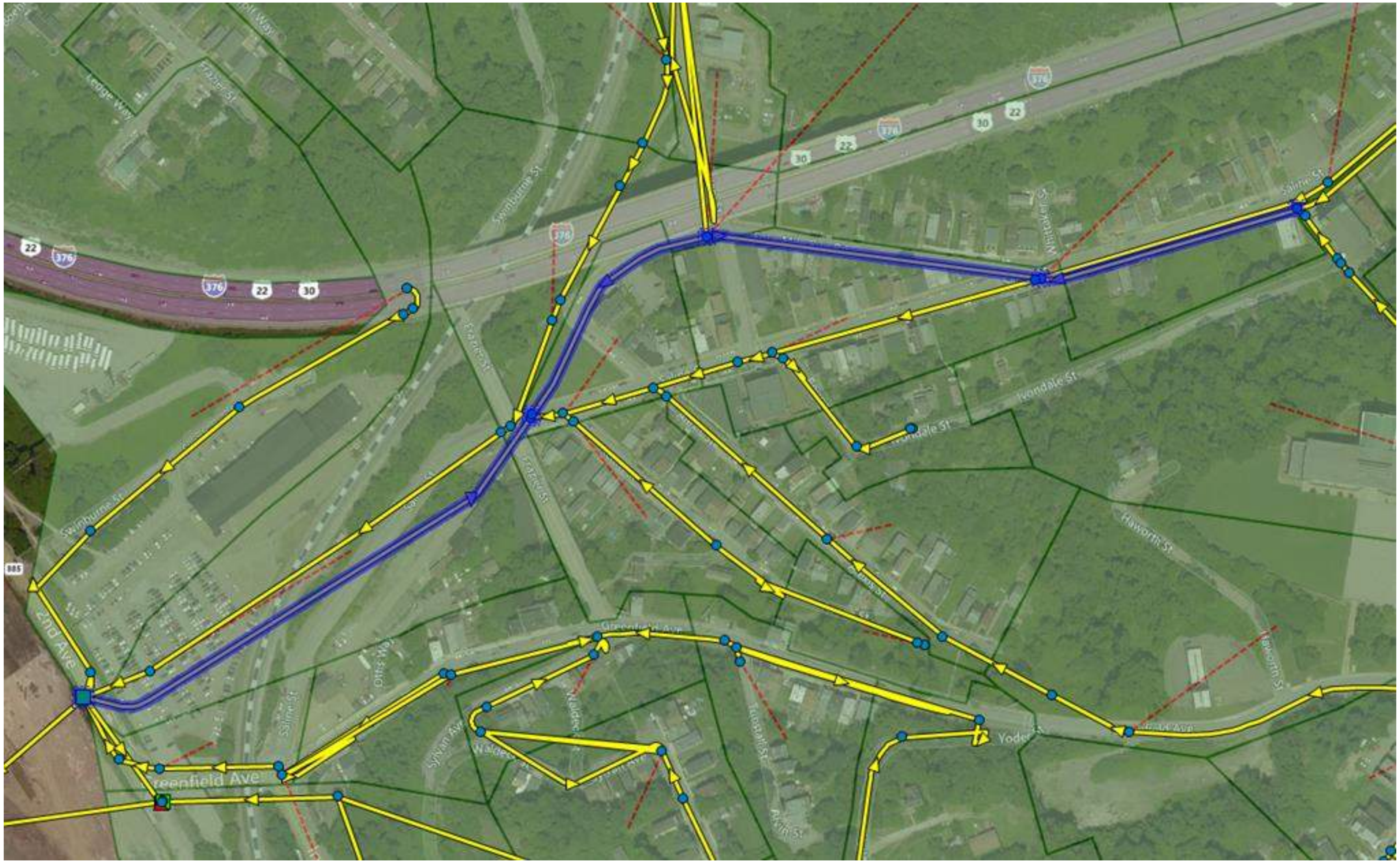


Figure 12D - Simulations_22, 23, 24, and 25 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_22, 23, 24, and 25 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

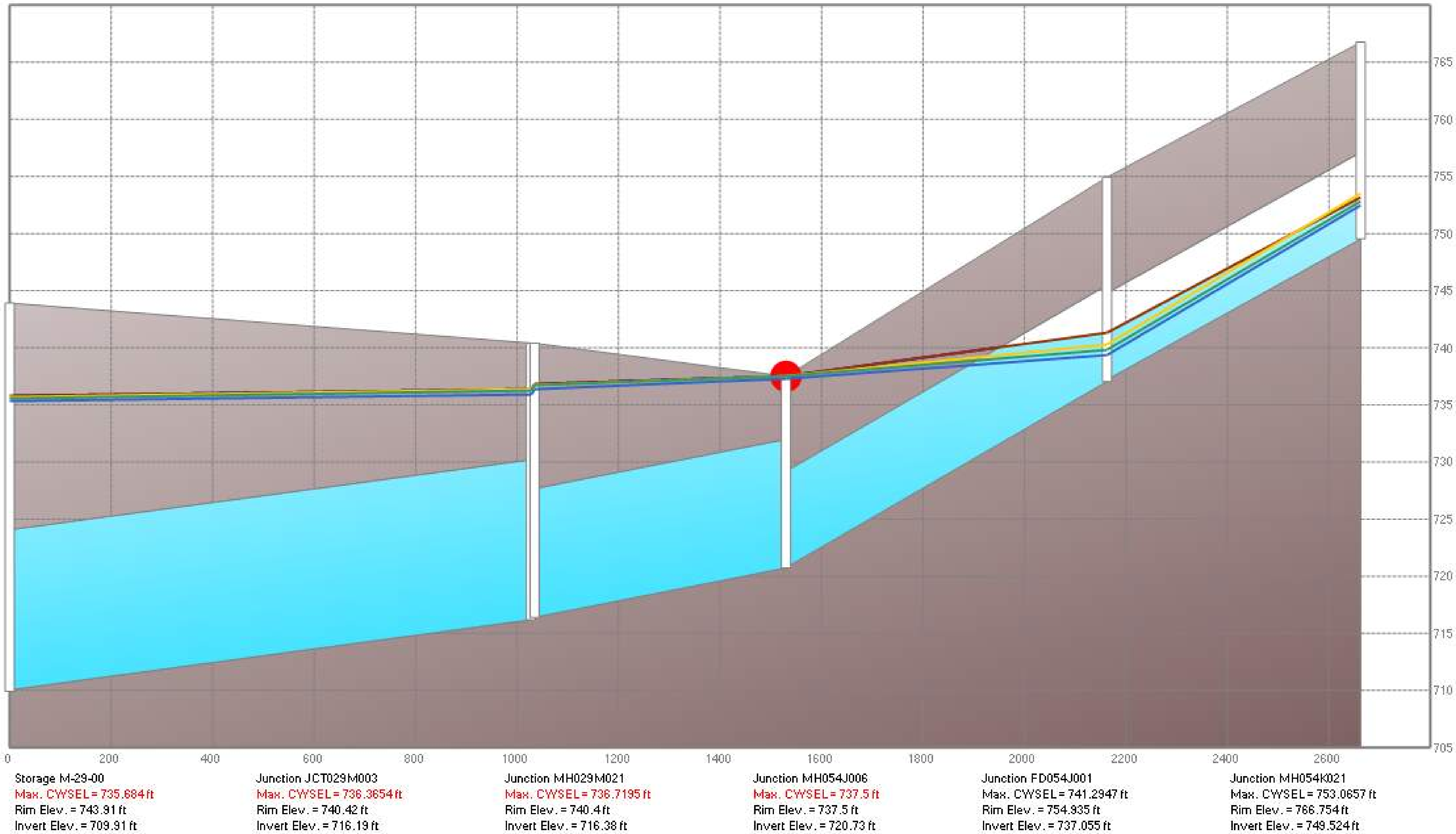
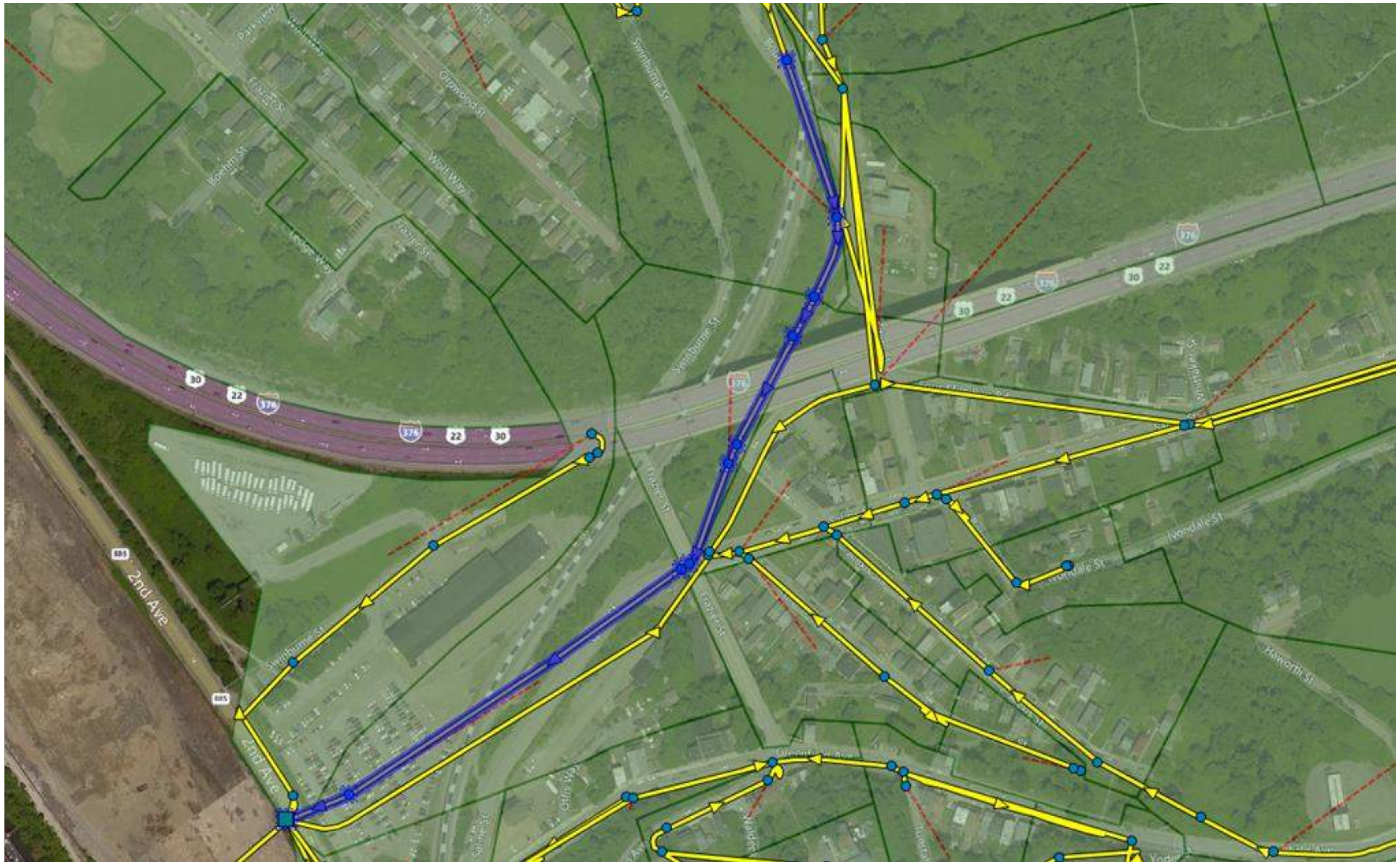


Figure 13A - Simulations_26, 27, 28, and 29 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_26, 27, 28, and 29 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

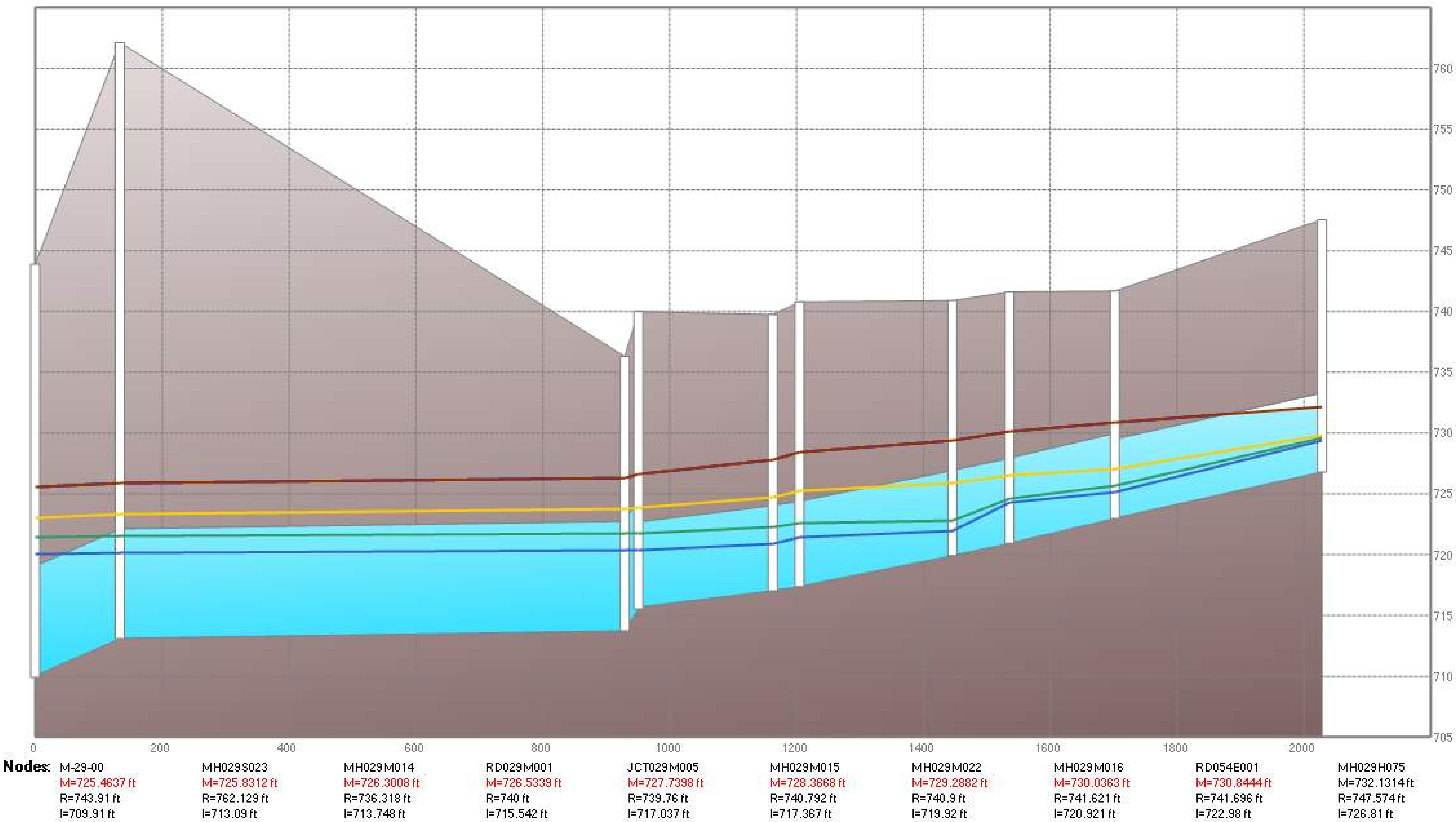
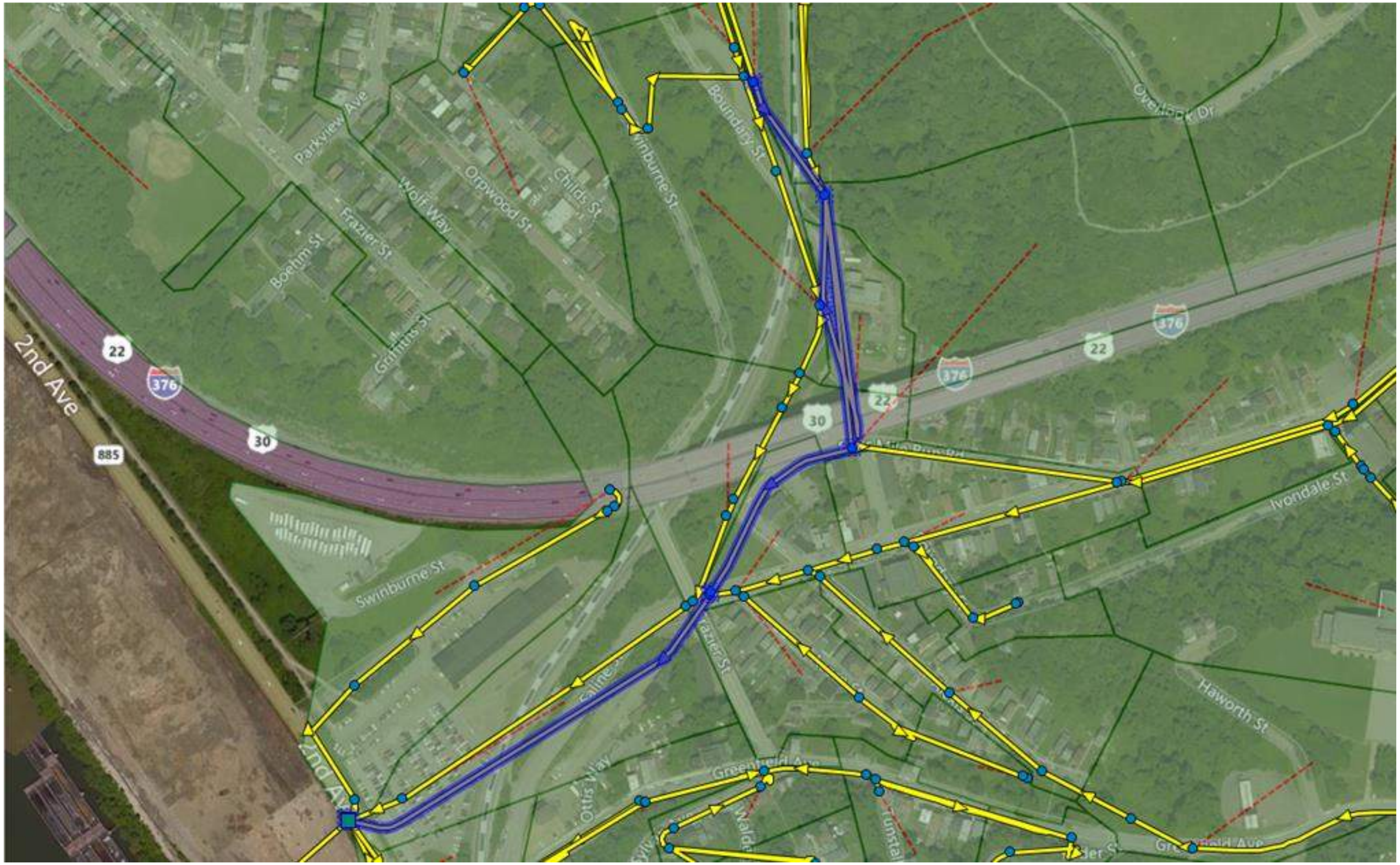


Figure 13B - Simulations_26, 27, 28, and 29 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_26, 27, 28, and 29 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

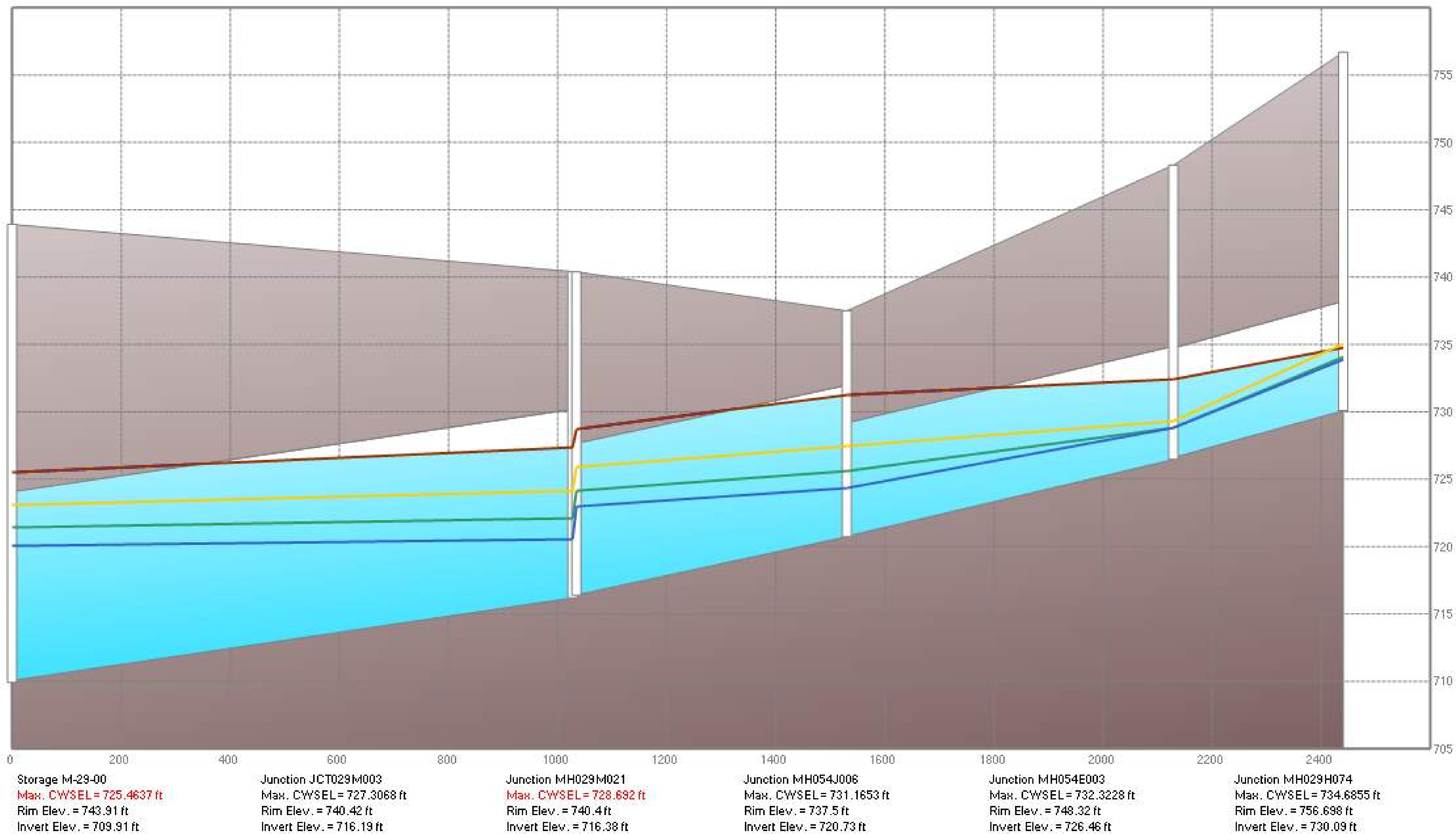
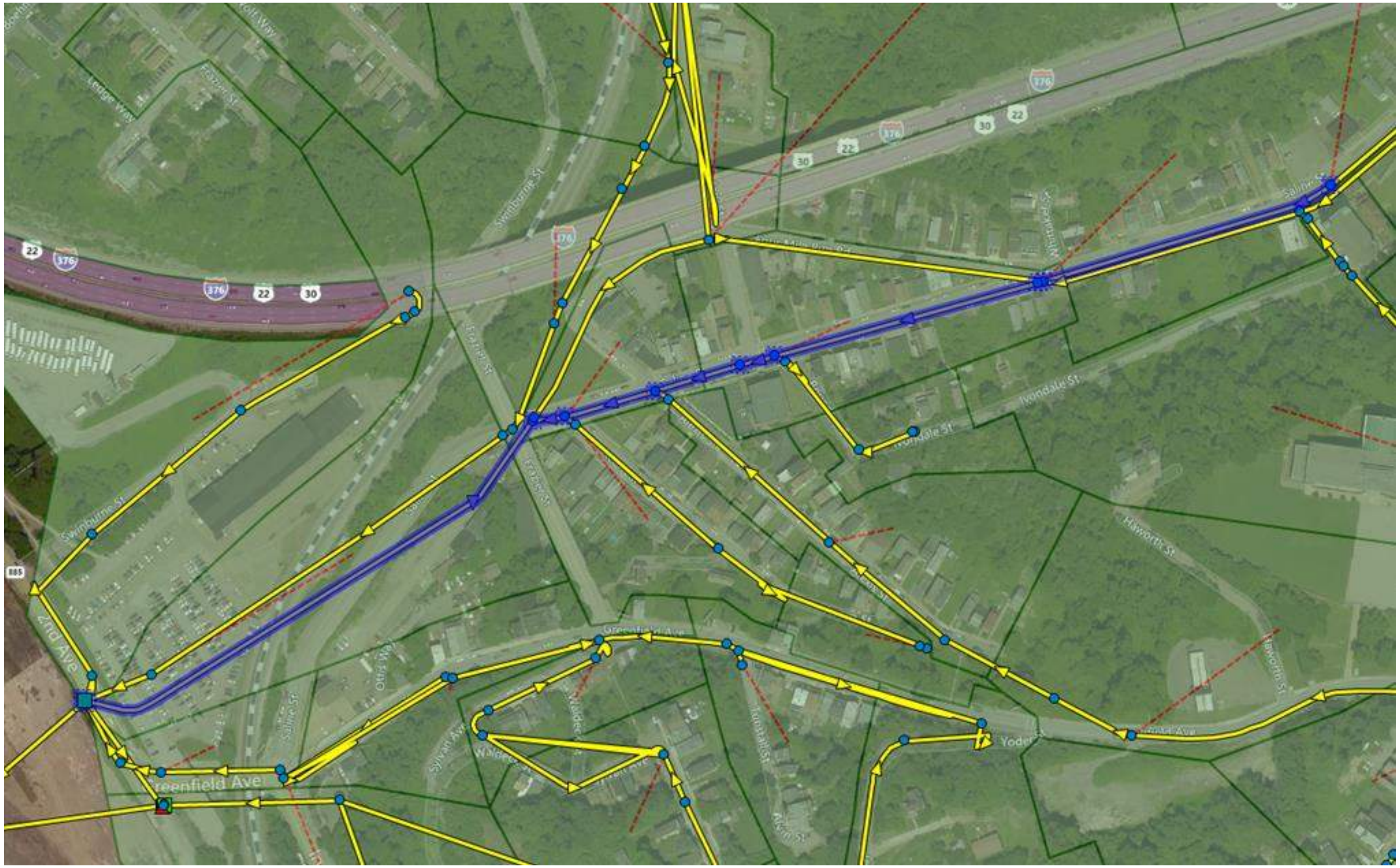


Figure 13C - Simulations_26, 27, 28, and 29 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_26, 27, 28, and 29 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

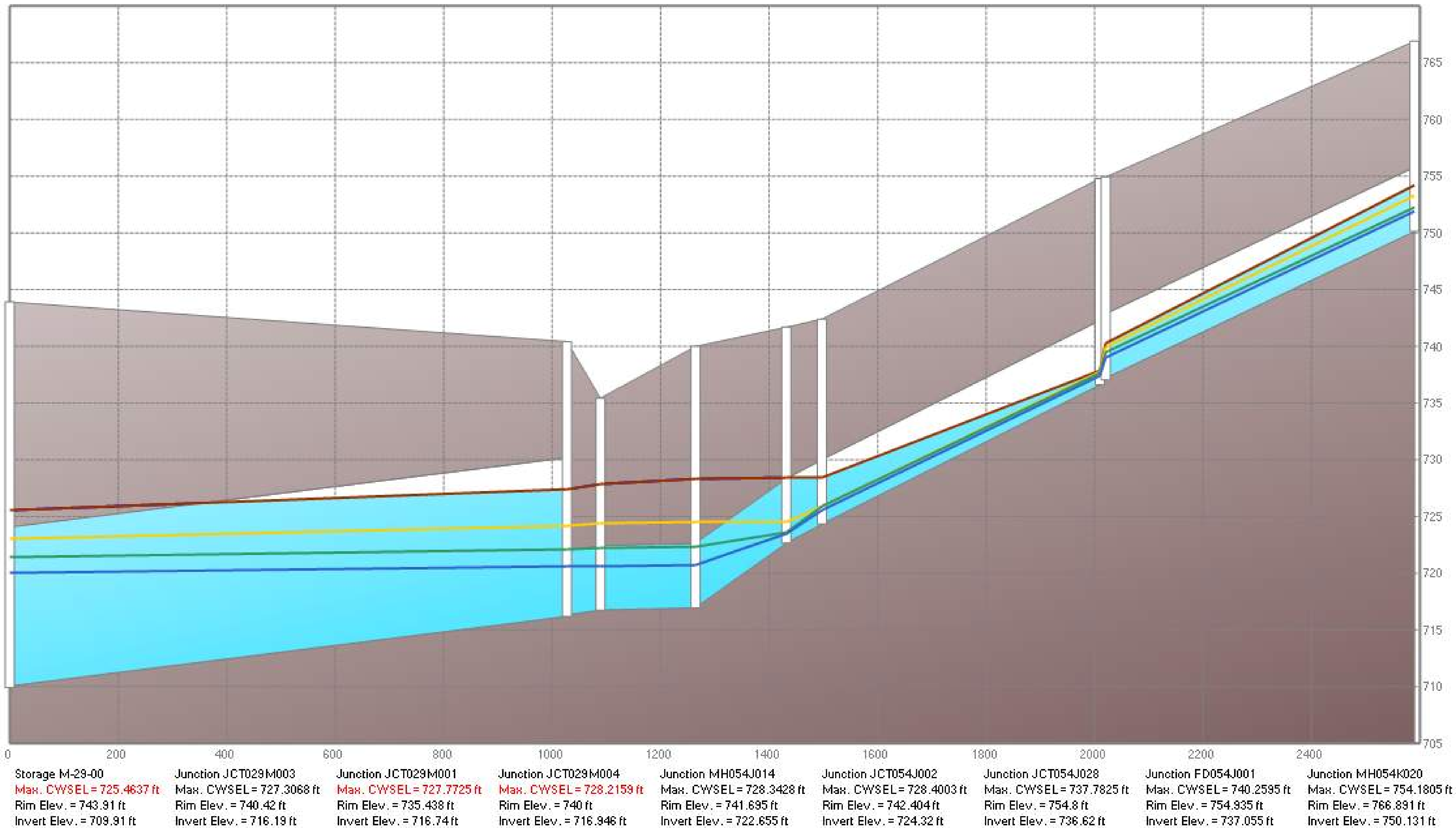
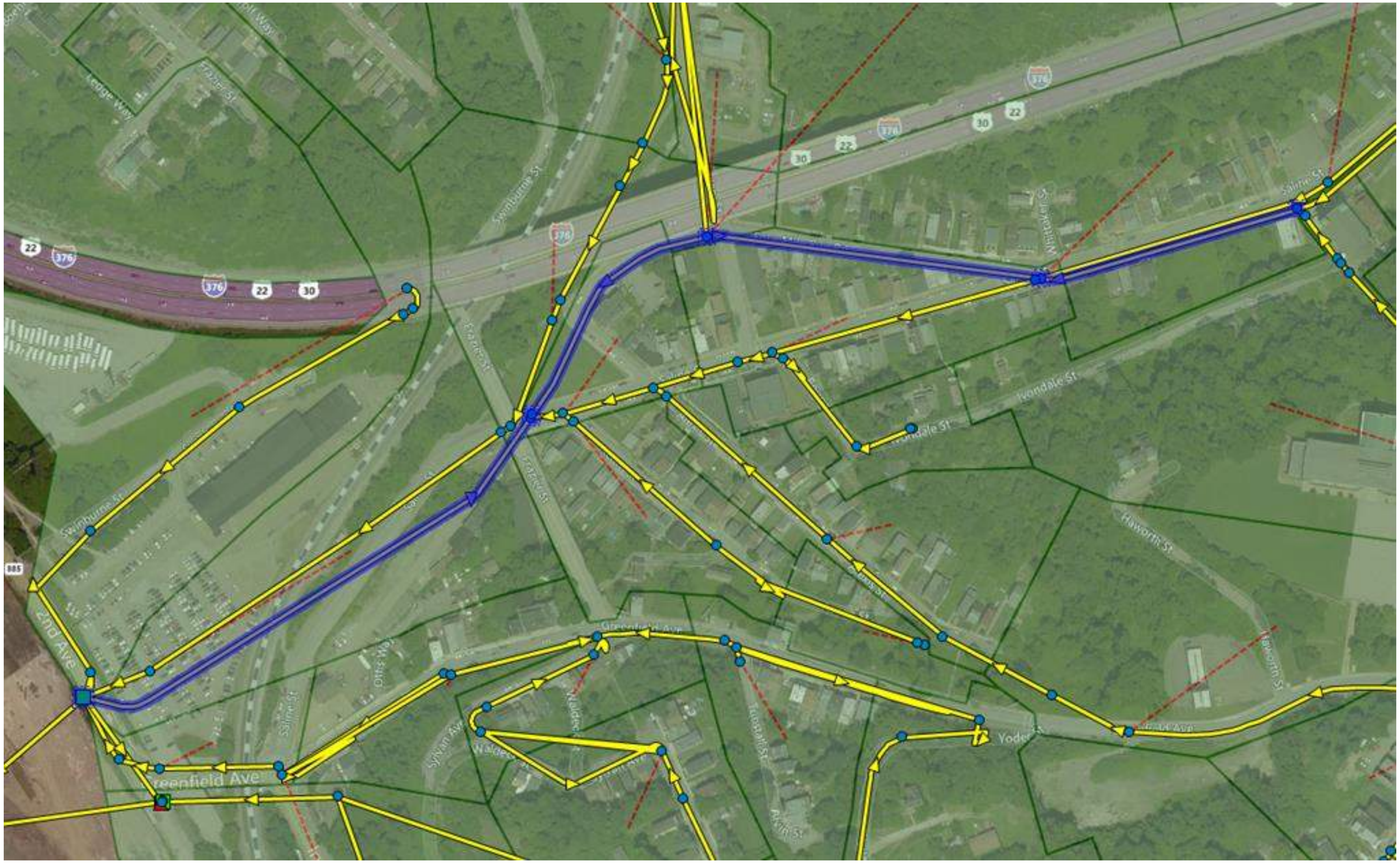


Figure 13D - Simulations_26, 27, 28, and 29 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_26, 27, 28, and 29 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 711

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

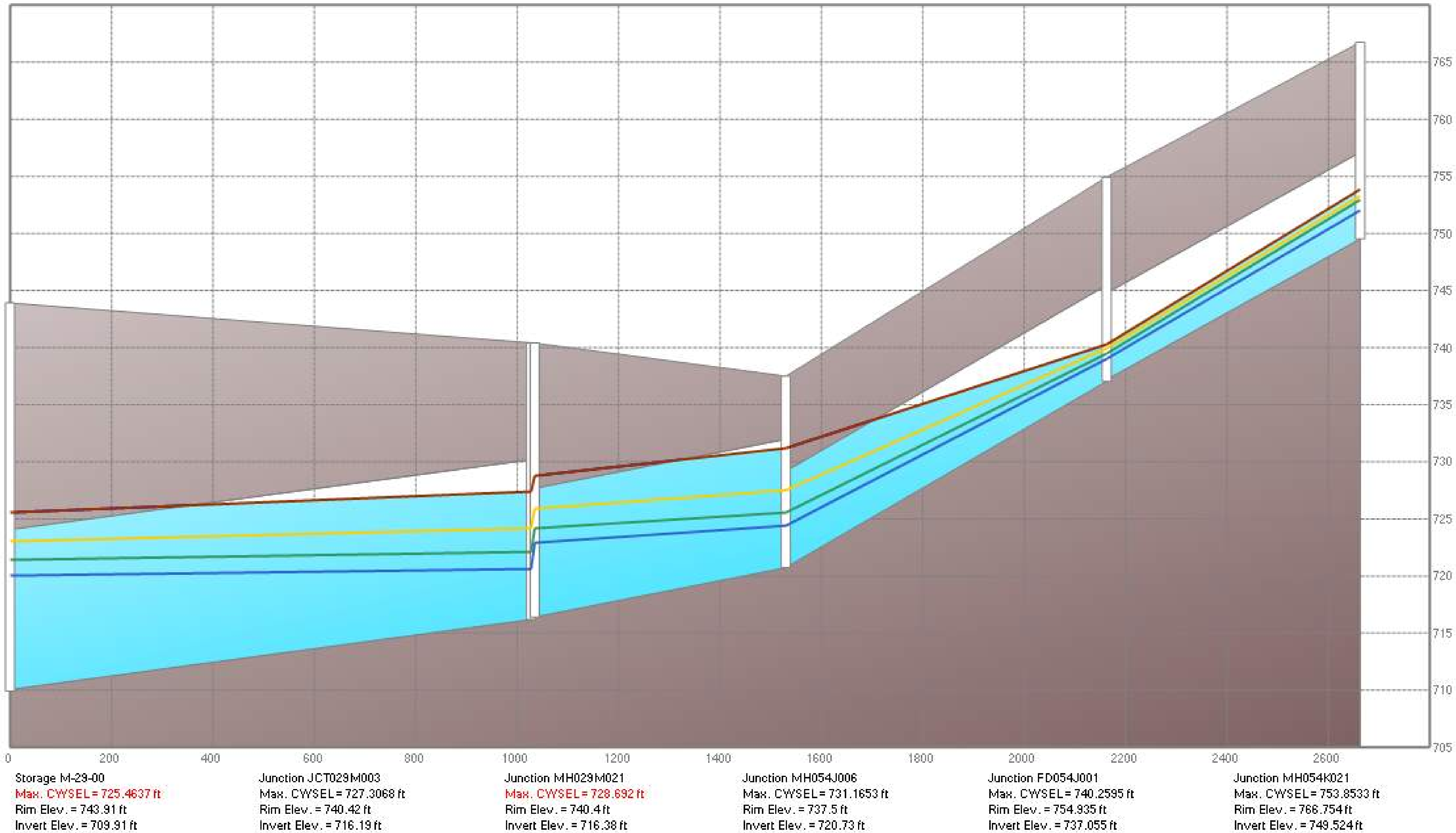
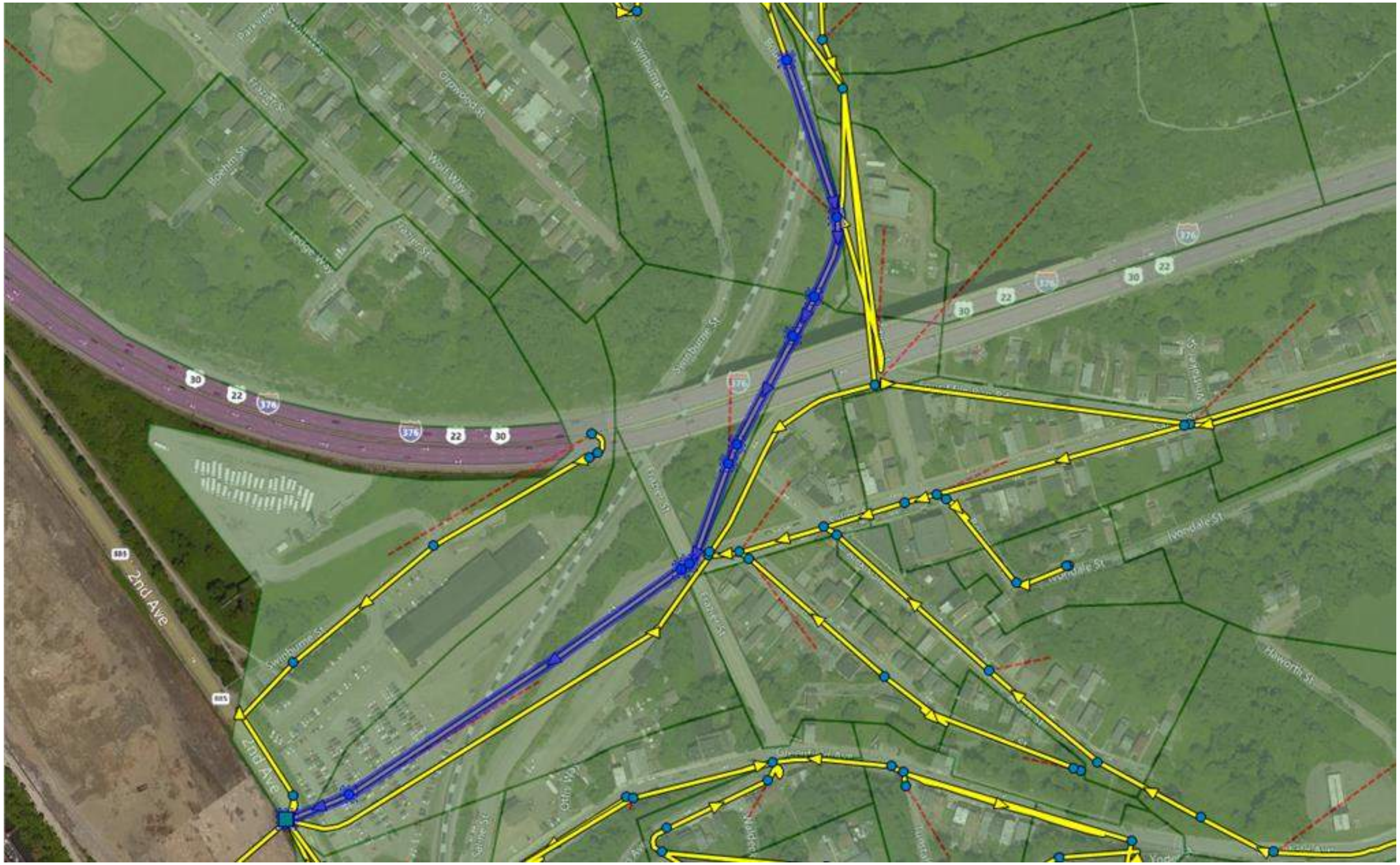


Figure 14A - Simulations_30, 31, 32, and 33 HGL Plots – Left Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_30, 31, 32, and 33 HGL Plots – Left Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

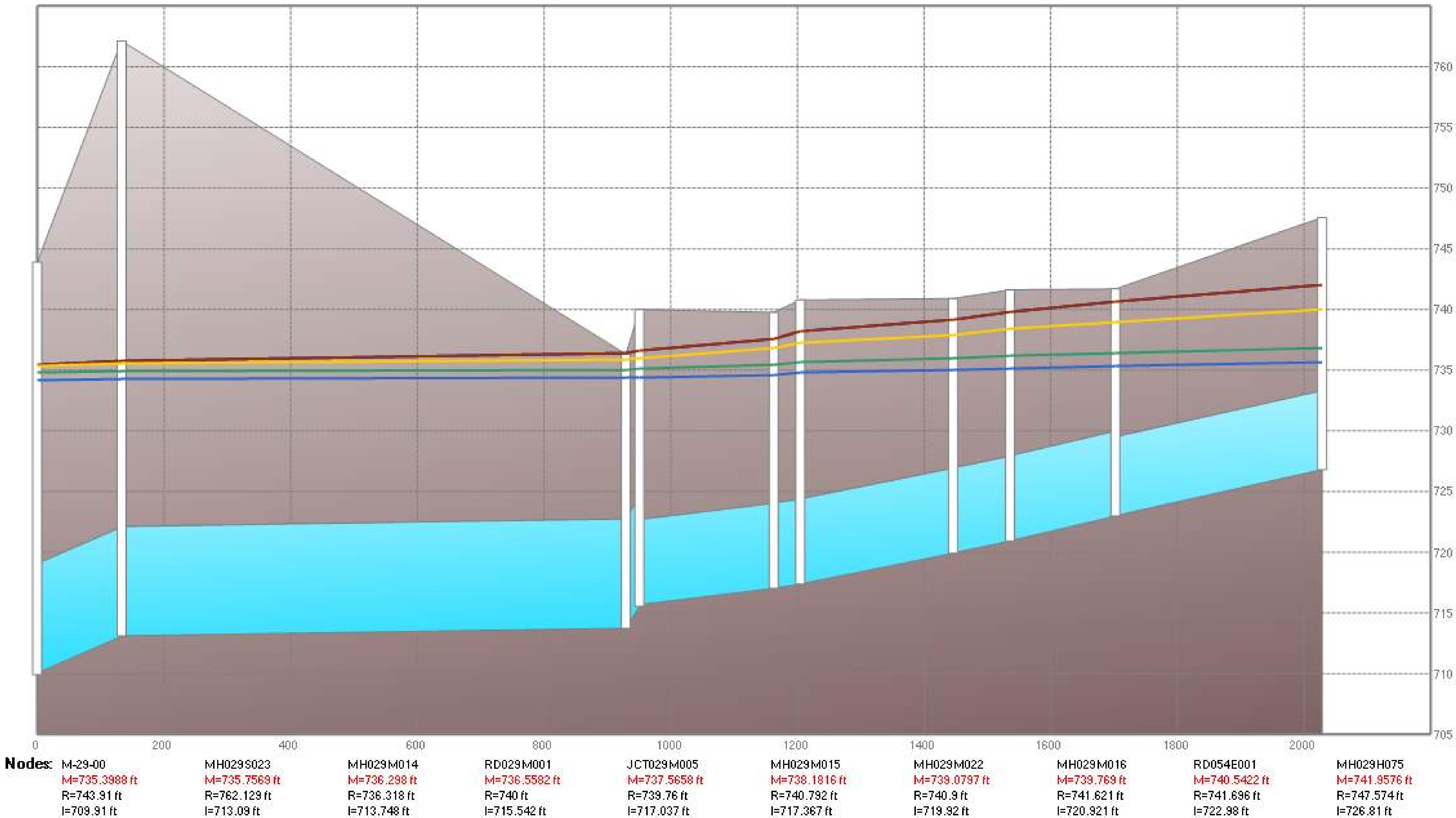
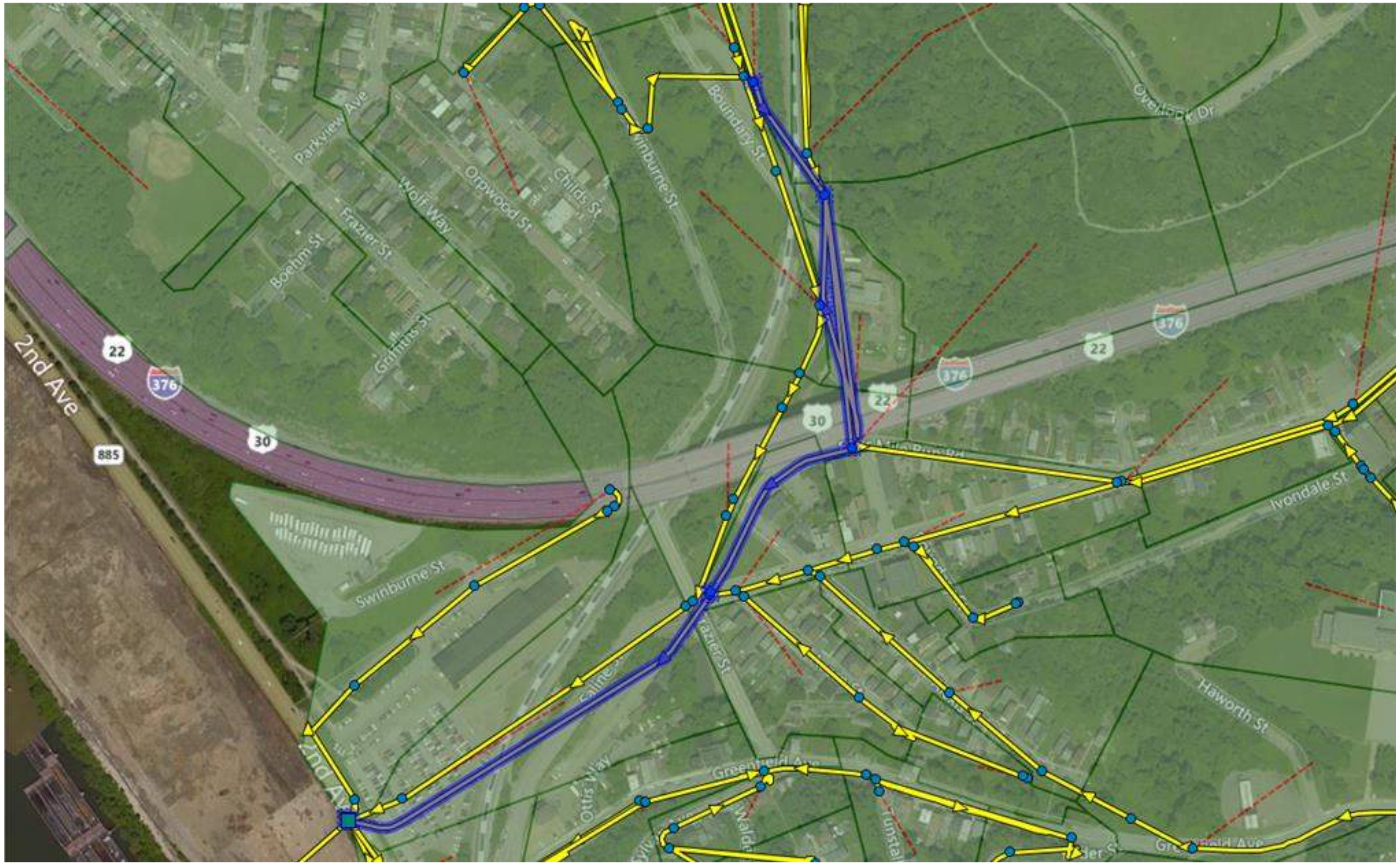


Figure 14B - Simulations_30, 31, 32, and 33 HGL Plots – Right Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_30, 31, 32, and 33 HGL Plots – Right Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

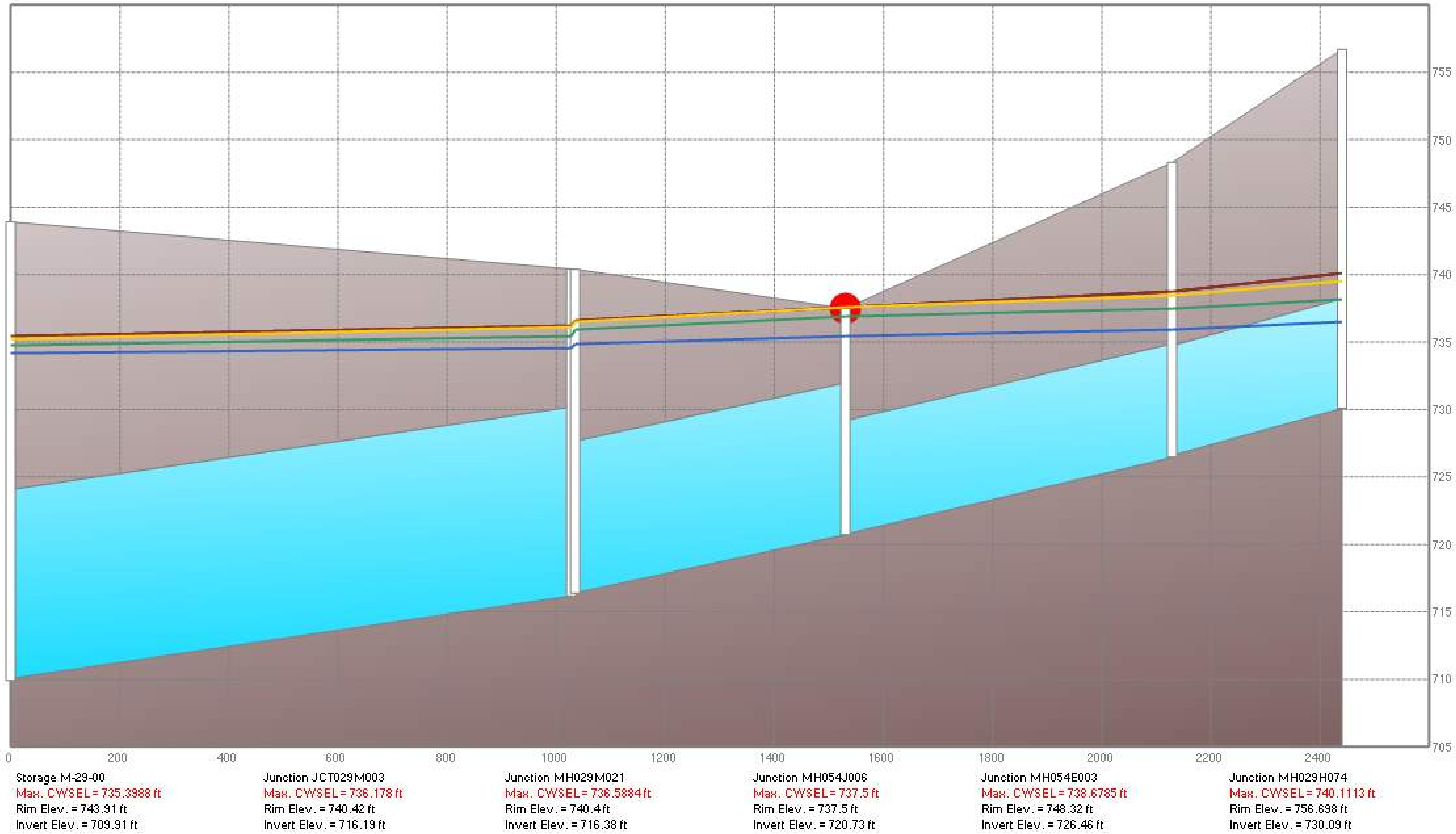
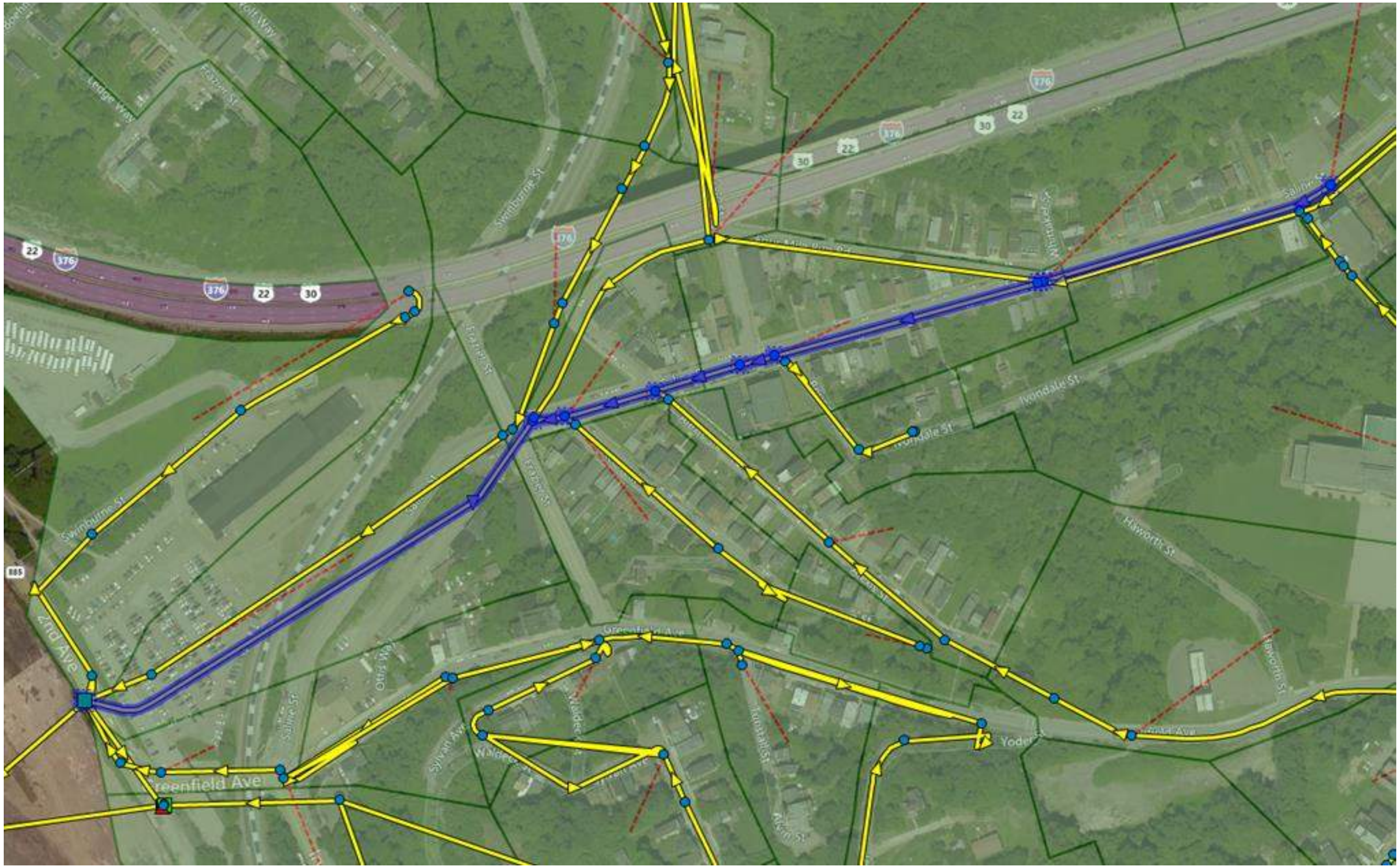


Figure 14C - Simulations_30, 31, 32, and 33 HGL Plots – North Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms



Simulations_30, 31, 32, and 33 HGL Plots – North Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

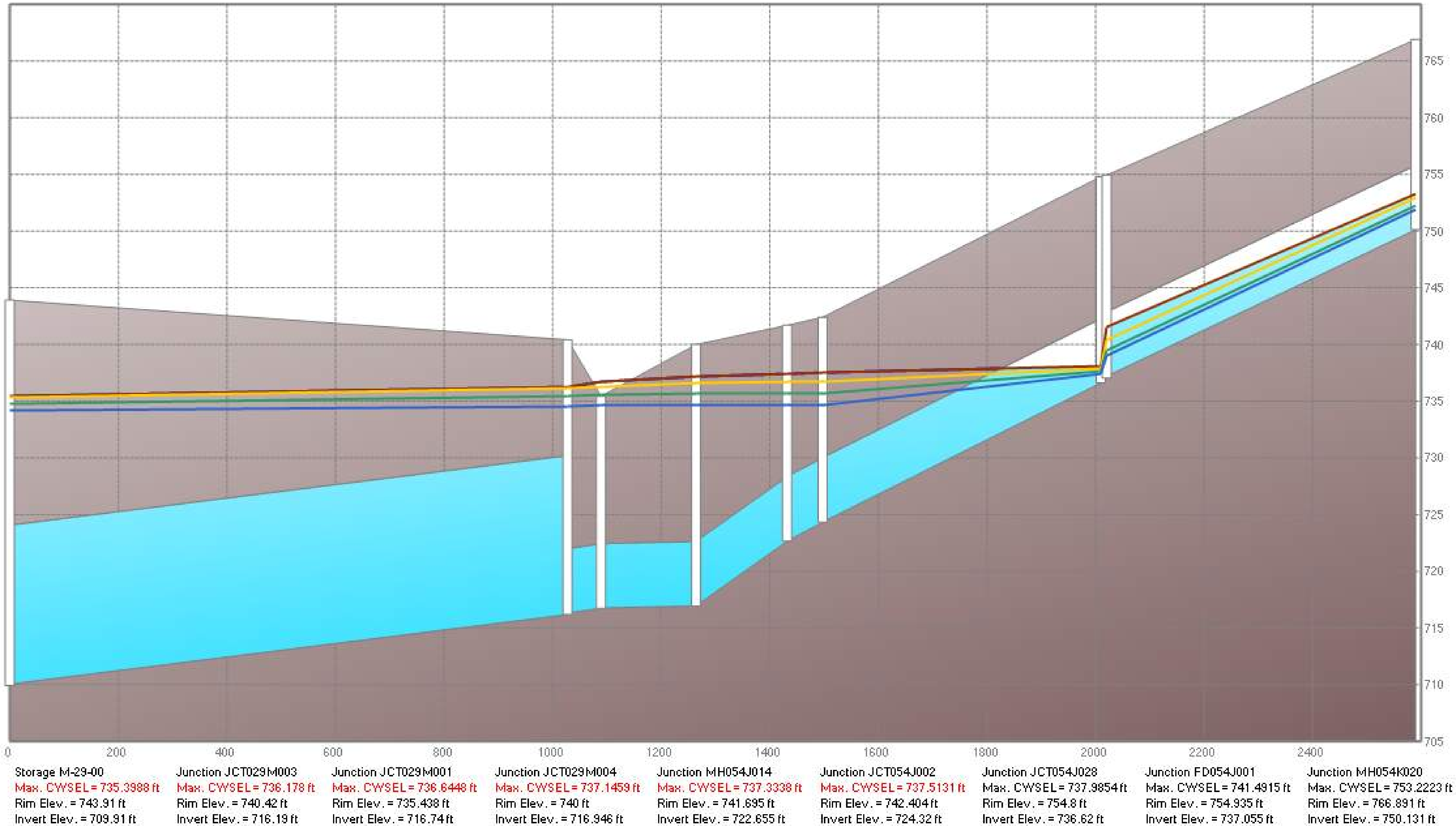
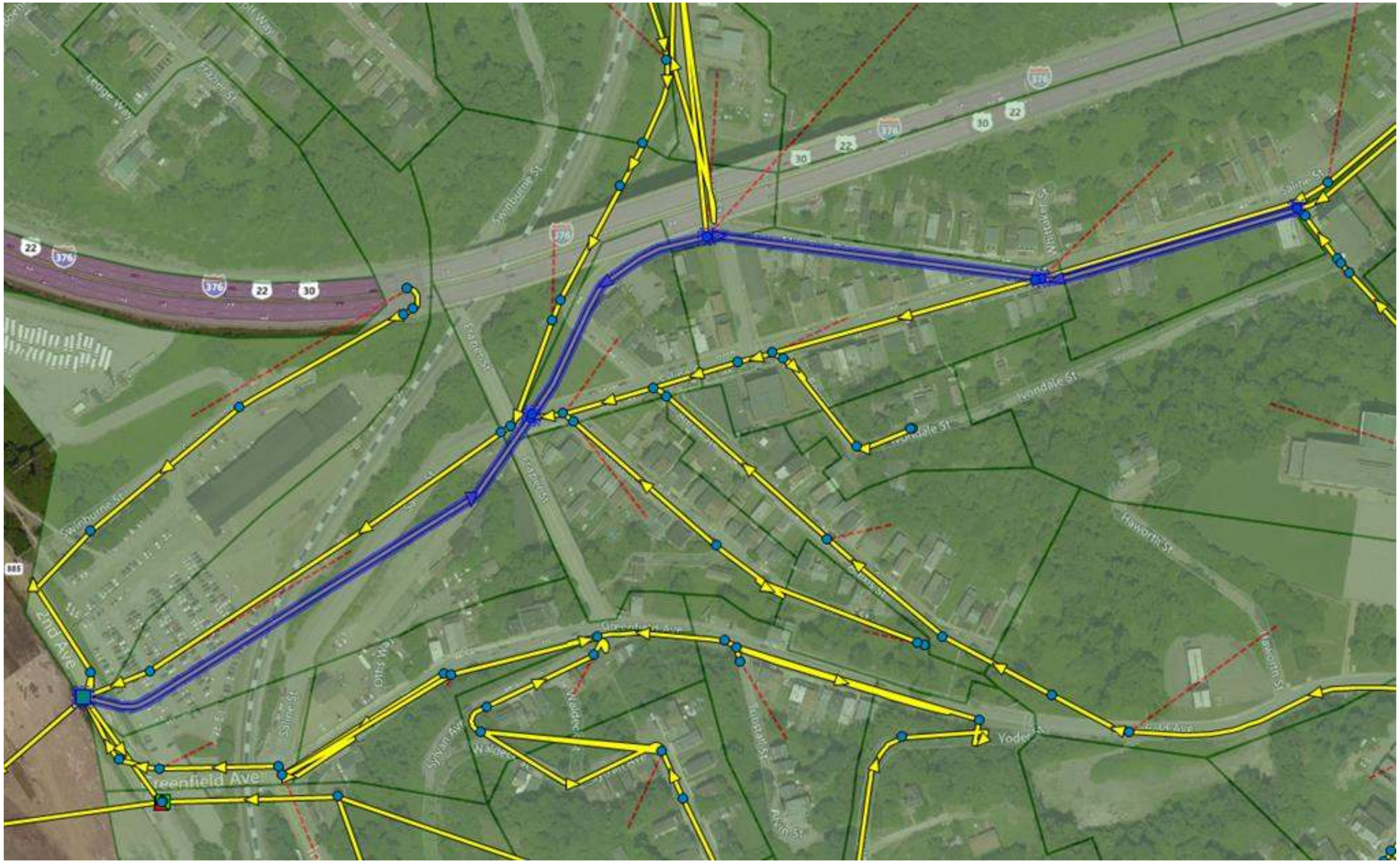


Figure 14D - Simulations_30, 31, 32, and 33 HGL Plots – South Interceptor Plan View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

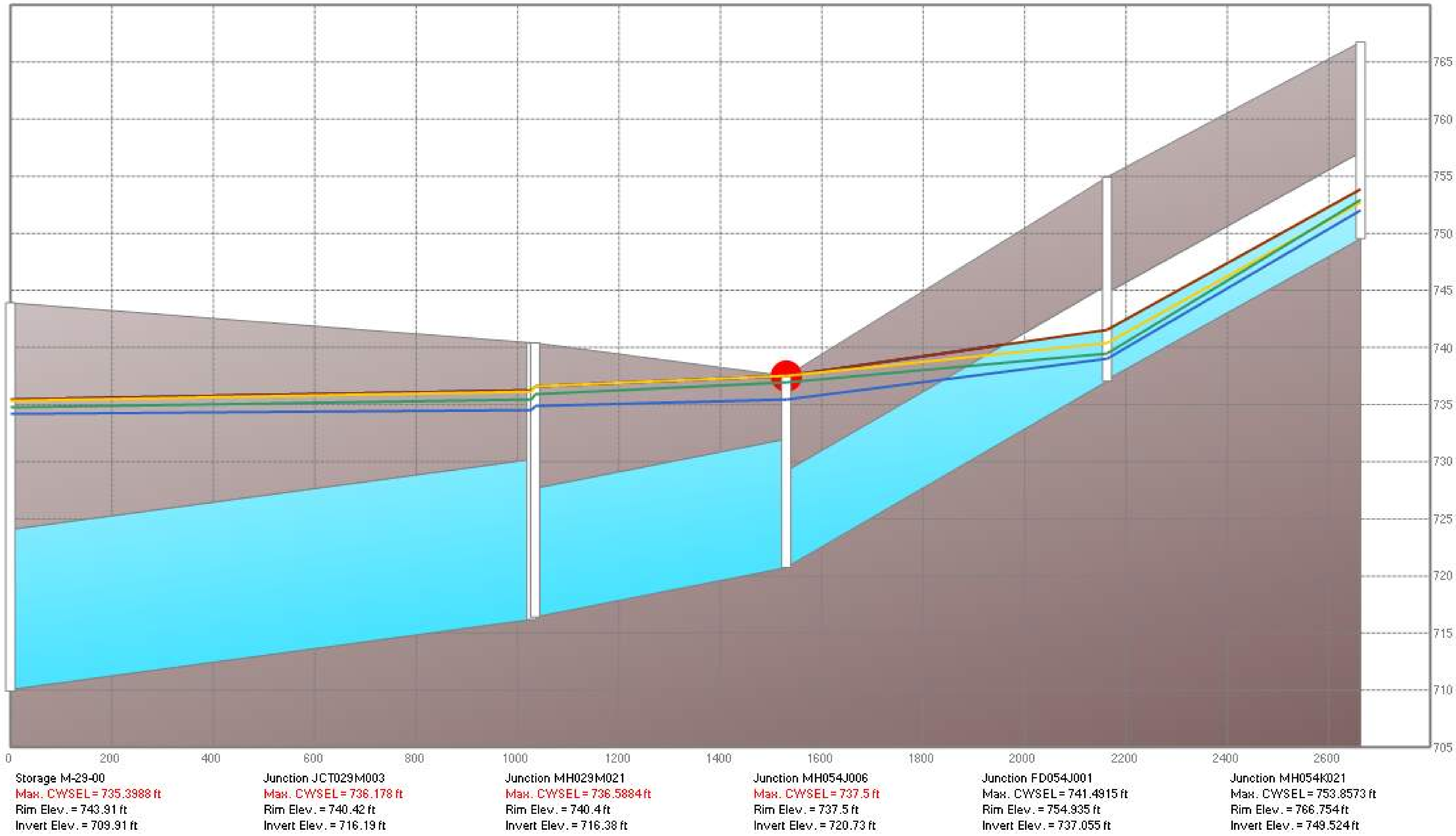


Simulations_30, 31, 32, and 33 HGL Plots – South Interceptor Profile View

Model Assumptions: Existing Conditions and Flap Gate, + Alternative 3, + Watershed Expansion

River Stage: 733

Storms: 02, 05, 10, and 25-Year, 24-Hour Design Storms

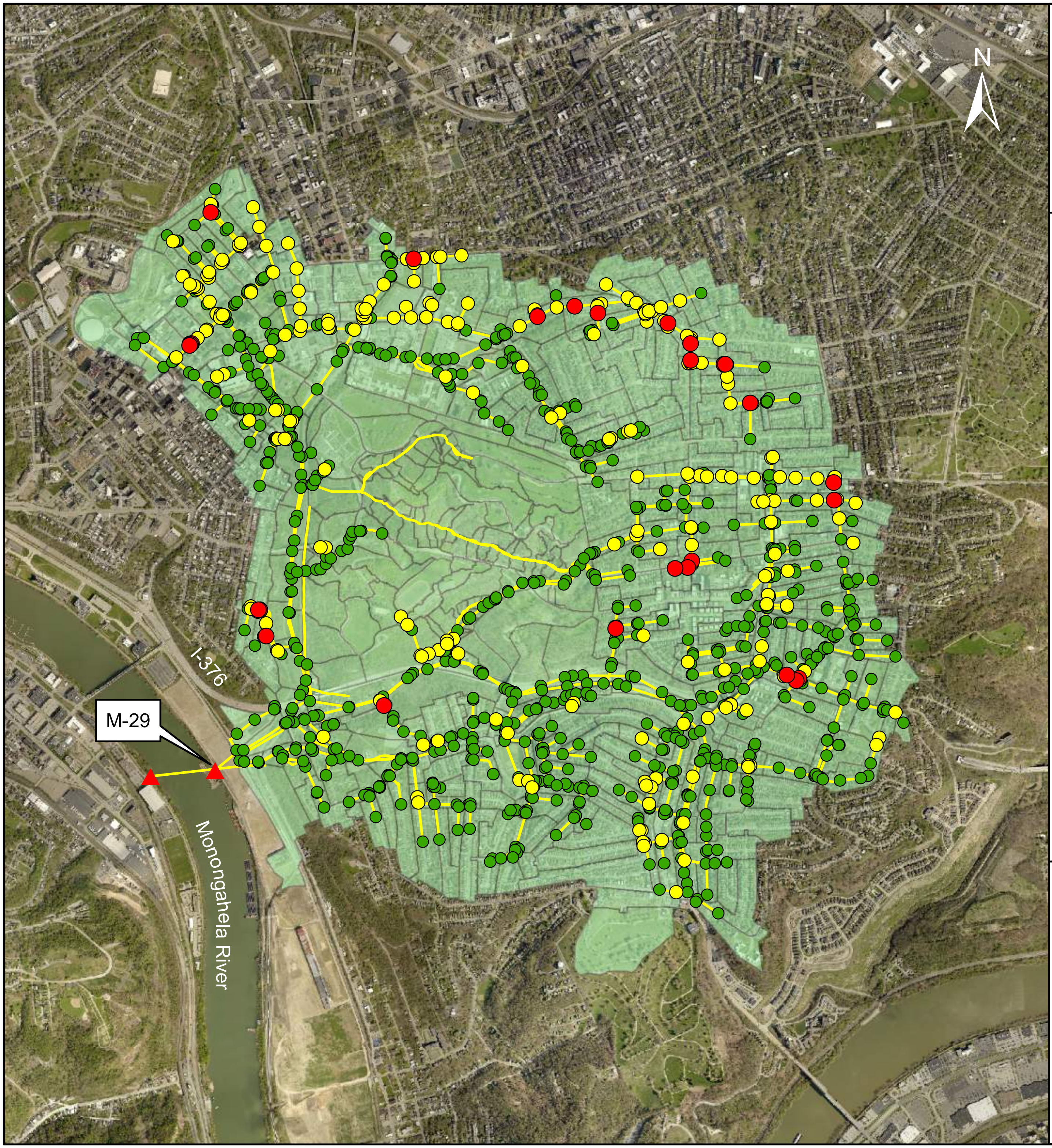


H. Mott MacDonald DCA 4 Response Mapping Figures (06.10.19)

Existing Conditions + Flap Gate

(2-year, 24-hour Design Storm)

06/10/2019



Notes:

- Smaller diameter, upstream pipes have been added to the updated 4MR collection system model. Limited invert information was available from PWSA's GIS or from the 3 Rivers Wet Weather (3RWW) Online Sewer Atlas. Some pipes inverts were inferred based on the assumption that pipe inverts are set 10 feet below grade. As the project design advances, inverts should be surveyed and actual inverts incorporated into the model to best understand potential basement backup risks within this shed.

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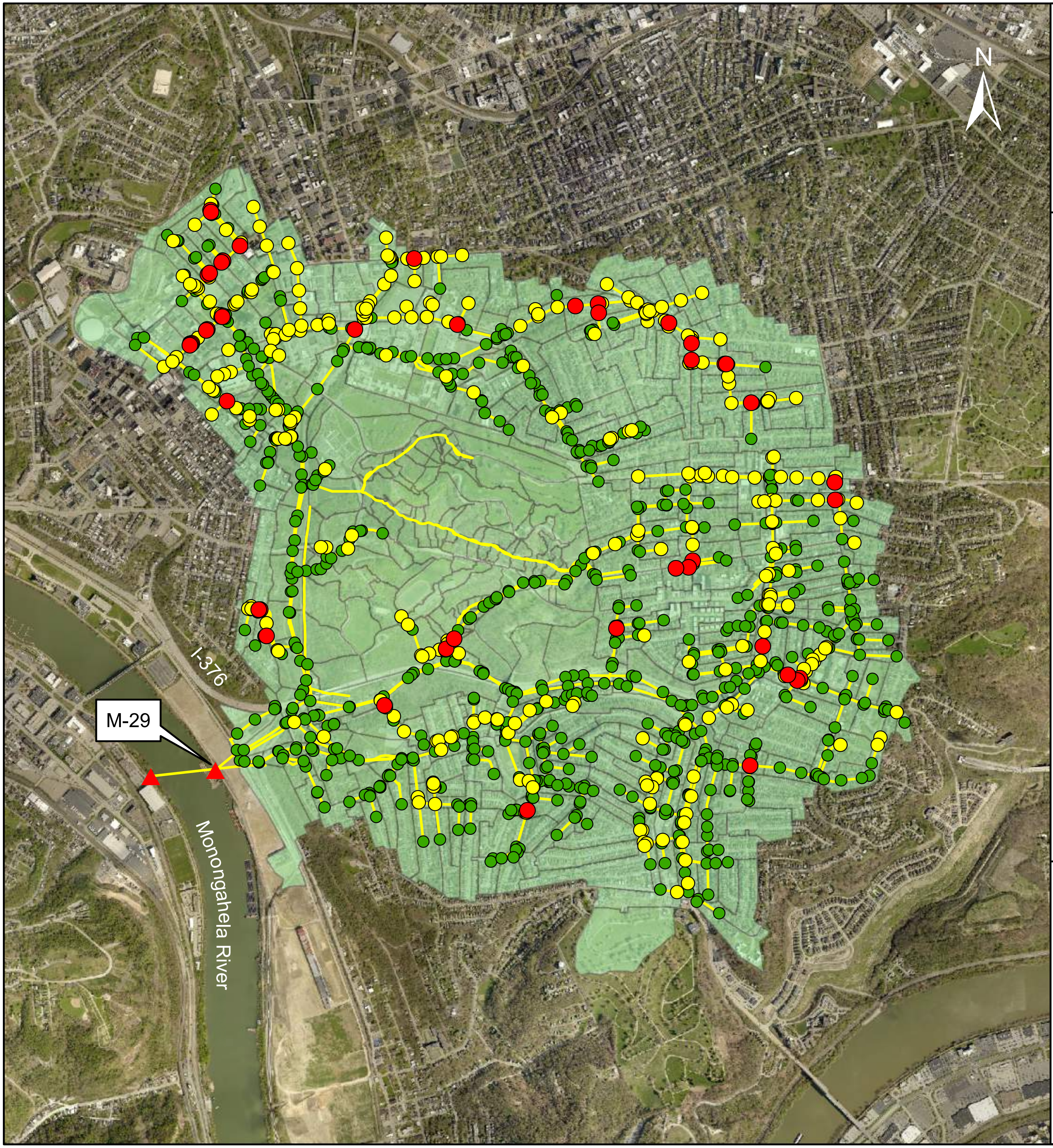
- The updated 4MR collection system model incorporated substantial detail to the previous M-29 sewershed collection system model. It does not include all of the pipes in the physical collection system. The lack of the smallest pipes in the collection system could have some impact on the basement backup risk presented on this graphic.

- Manholes depicted with potential flooding have a simulated peak HGL greater than 0.1' above the manhole rim elevation. This threshold helps to remove potential false positive locations where the HGL is very close to the ground surface.

DCA 4 - Potential Manhole Risks

- Elevated Potential Flooding Risk
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale



Existing Conditions + Flap Gate

(5-year, 24-hour Design Storm)

06/10/2019

Notes:

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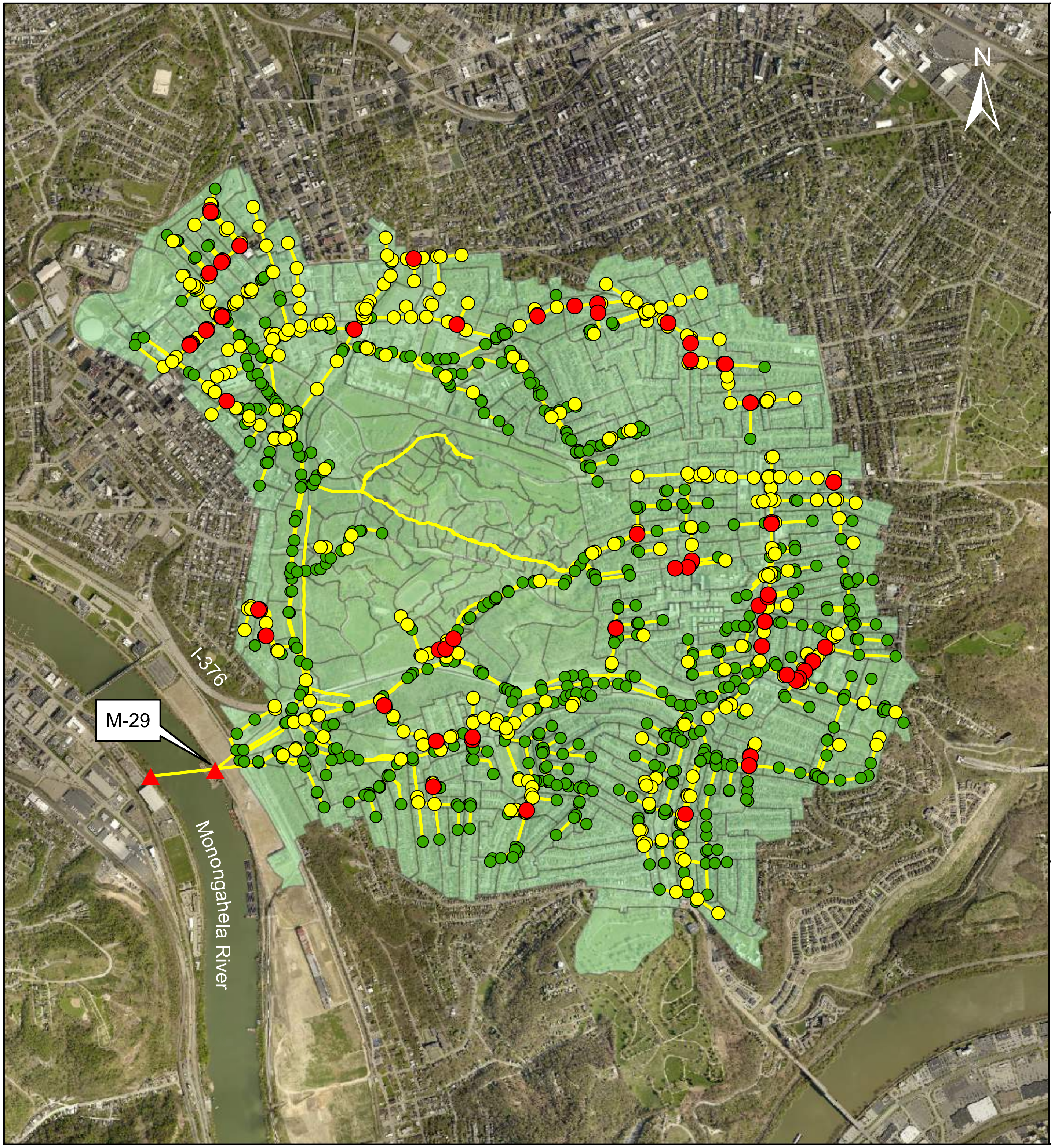
DCA 4 - Potential Manhole Risks

- Elevated Potential Flooding Risk
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale



Existing Conditions + Flap Gate

(10-year, 24-hour Design Storm)

06/10/2019

Notes:

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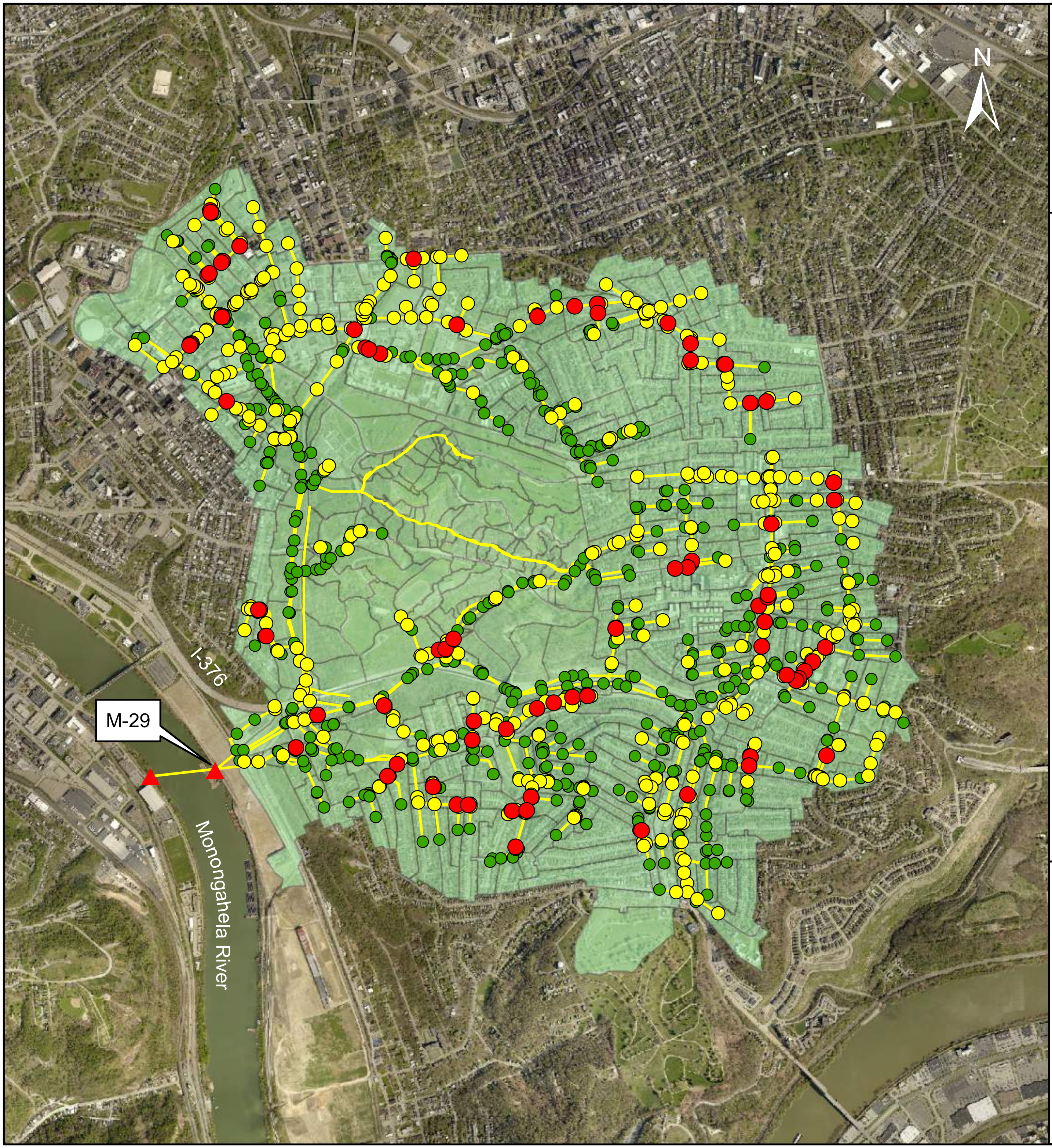
DCA 4 - Potential Manhole Risks

- Elevated Potential Flooding Risk
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale



Existing Conditions + Flap Gate

(25-year, 24-hour Design Storm)

06/10/2019

Notes:

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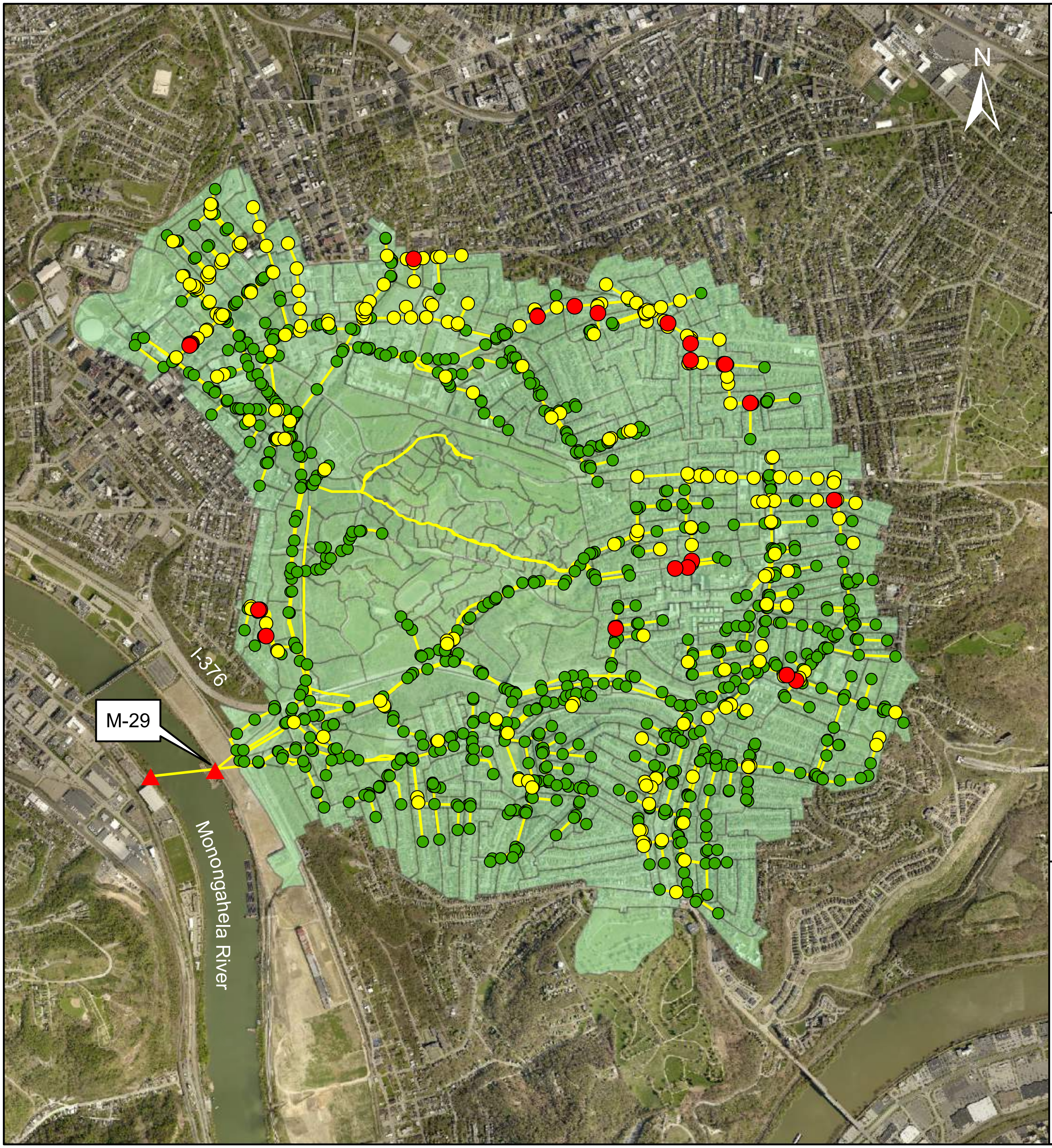
DCA 4 - Potential Manhole Risks

- Elevated Potential Flooding Risk
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale



Existing Conditions + Flap Gate + Model Alternative 3

(2-year, 24-hour Design Storm)

06/10/2019

Notes:

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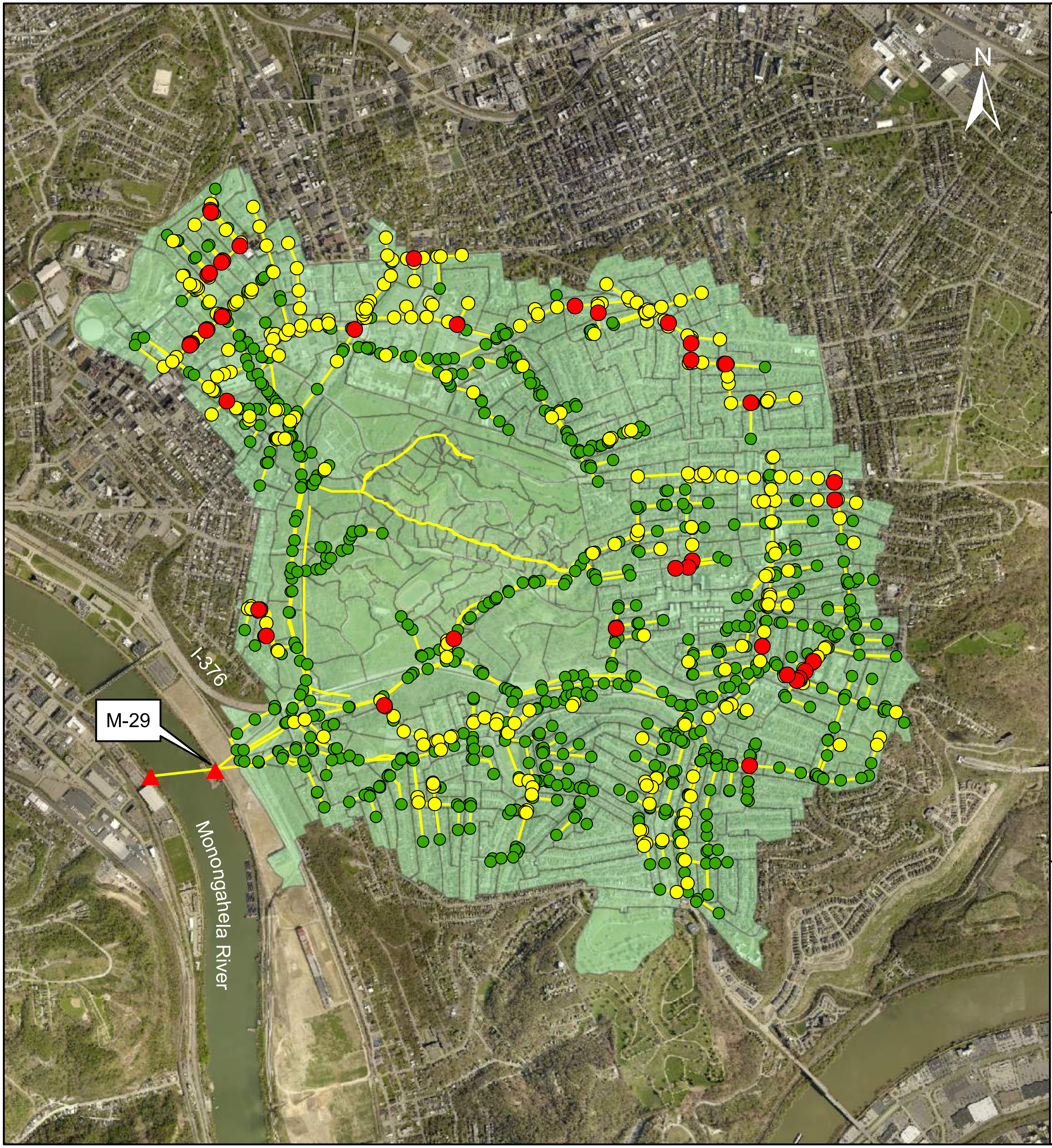
DCA 4 - Potential Manhole Risks

- Elevated Potential Flooding Risk
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale



Existing Conditions + Flap Gate + Model Alternative 3

(5-year, 24-hour Design Storm)

06/10/2019

Notes:

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DCA 4 - Potential Manhole Risks

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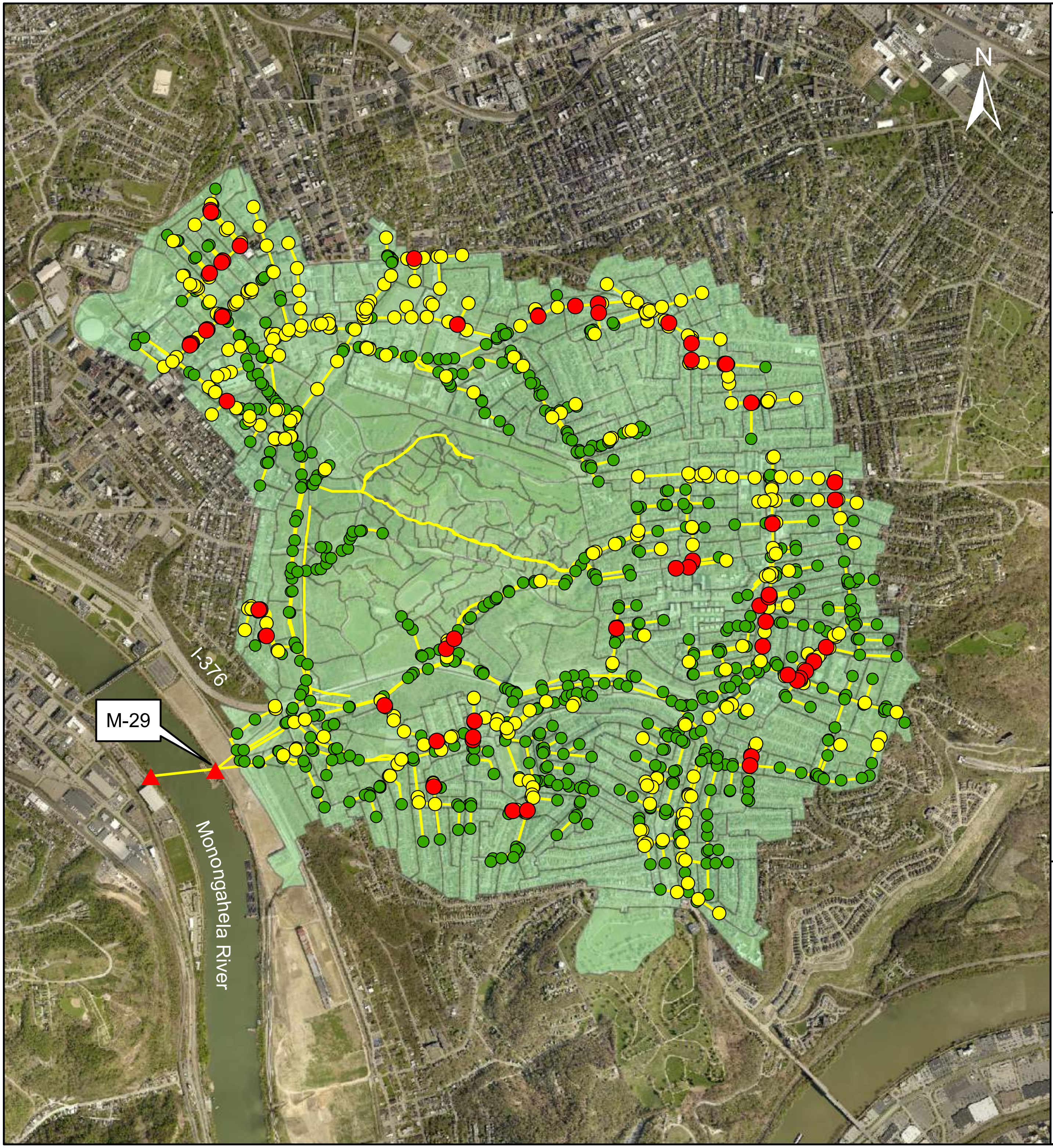
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale

Existing Conditions + Flap Gate + Model Alternative 3

(10-year, 24-hour Design Storm)

06/10/2019



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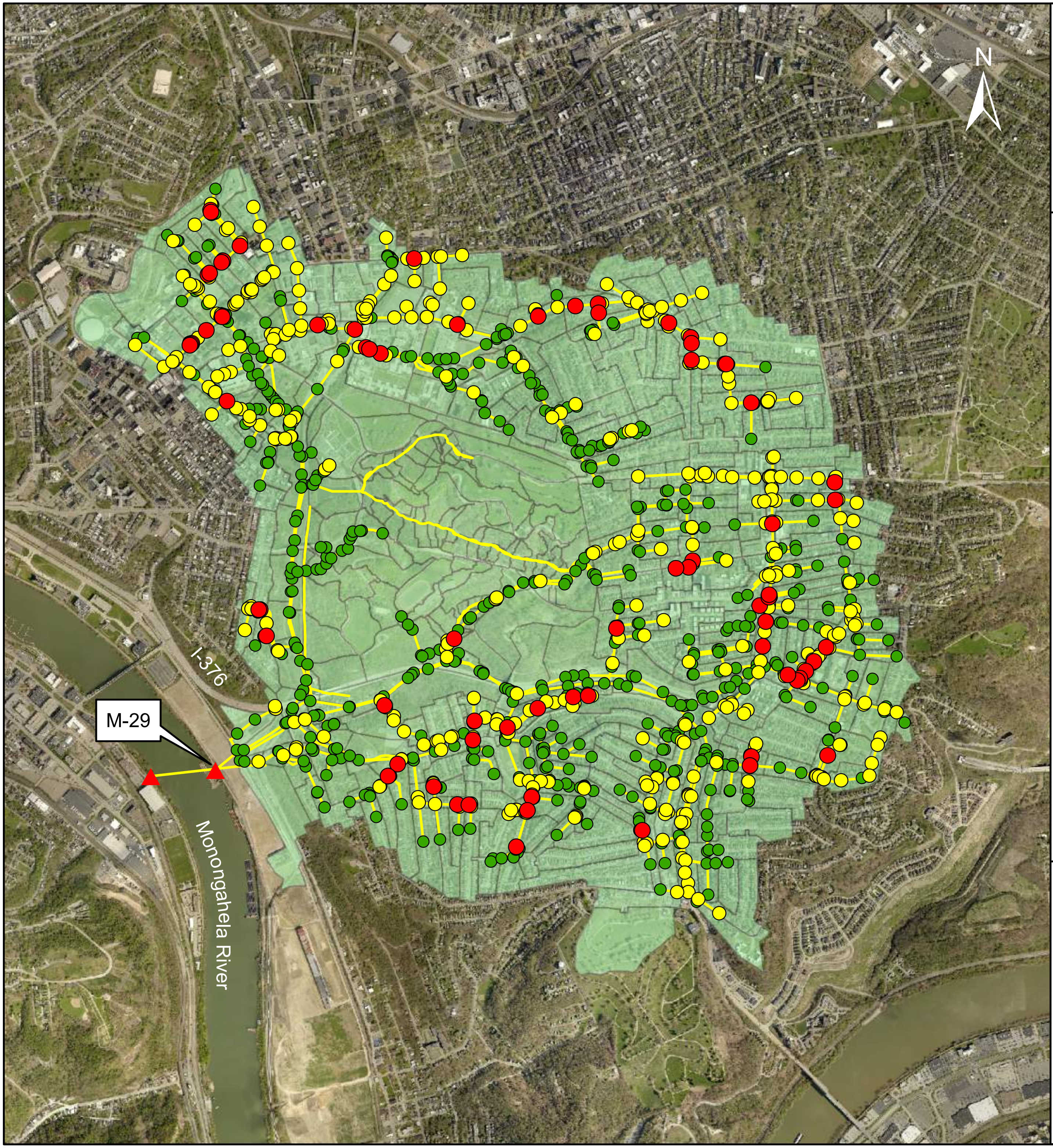
Drawing Not to Scale



Existing Conditions + Flap Gate + Model Alternative 3

(25-year, 24-hour Design Storm)

06/10/2019

Notes:

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DCA 4 - Potential Manhole Risks

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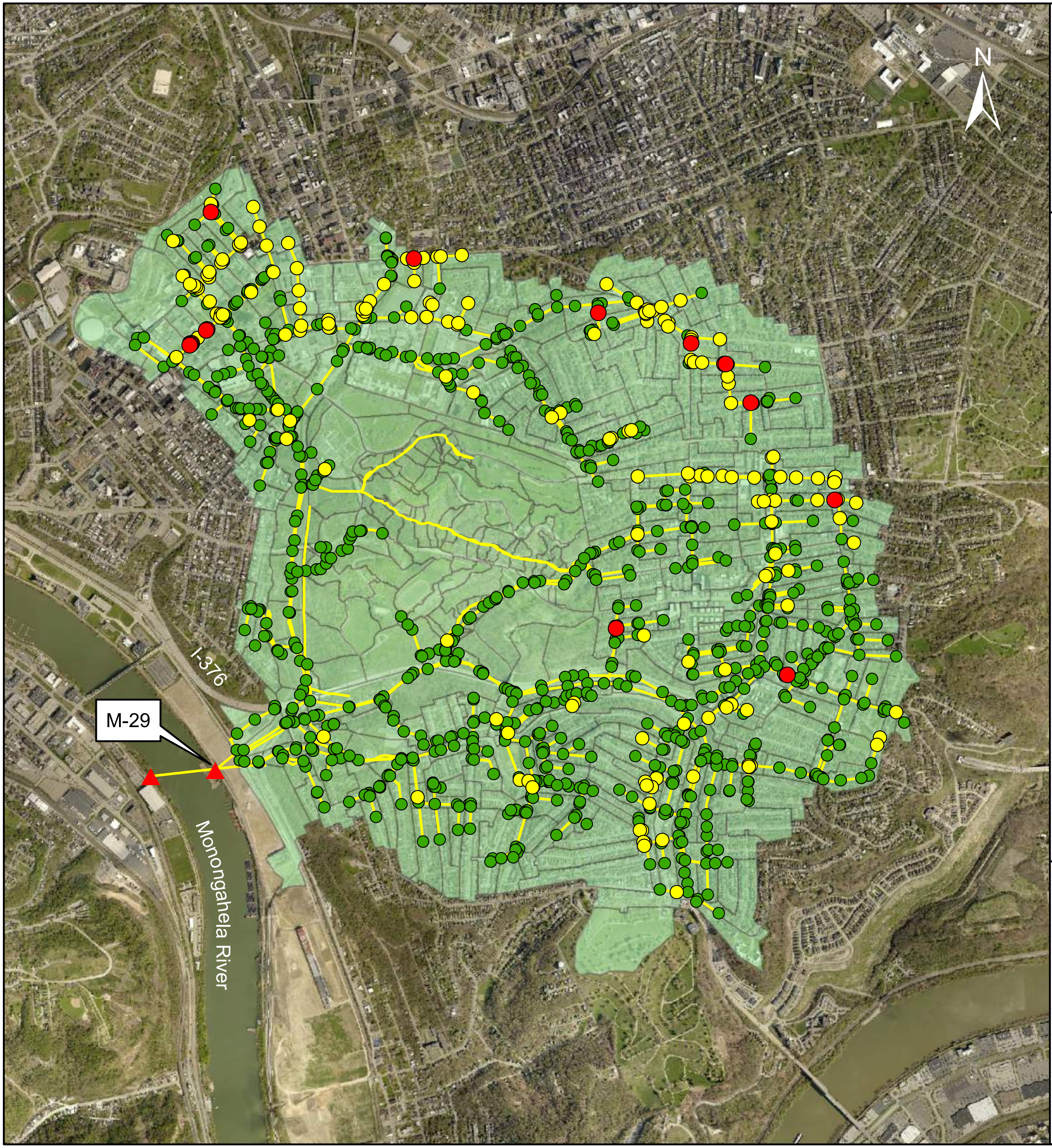
- Elevated Basement Backup Risk
- Lower Basement Backup Risk
- Conduits
- Subcatchments

Drawing Not to Scale

Existing Conditions + Flap Gate + Model Alternative 3 + Watershed Expansion

(2-year, 24-hour Design Storm)

06/10/2019



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DCA 4 - Potential Manhole Risks

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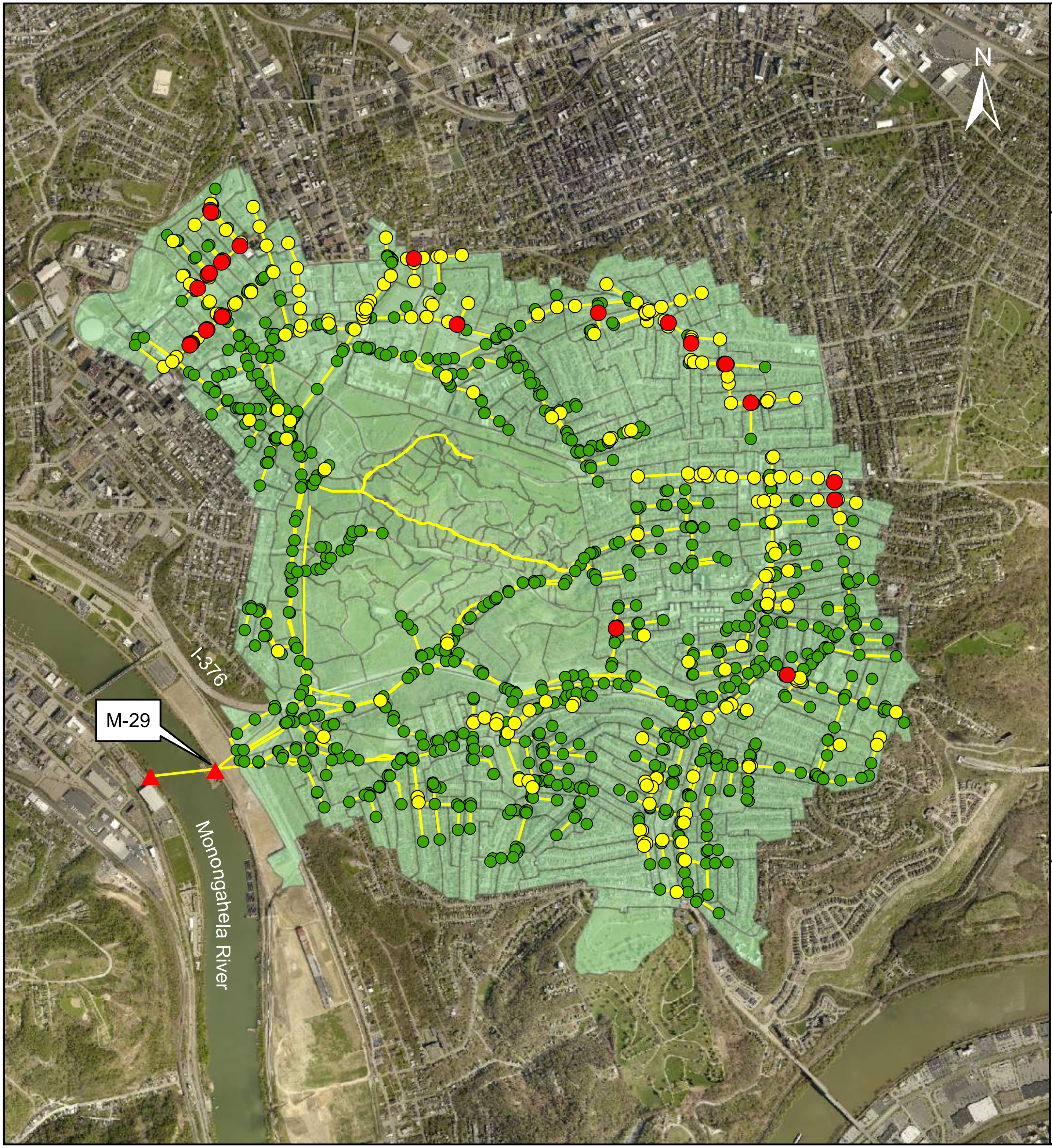
Drawing Not to Scale



Existing Conditions + Flap Gate + Model Alternative 3 + Watershed Expansion

(5-year, 24-hour Design Storm)

06/10/2019

Notes:

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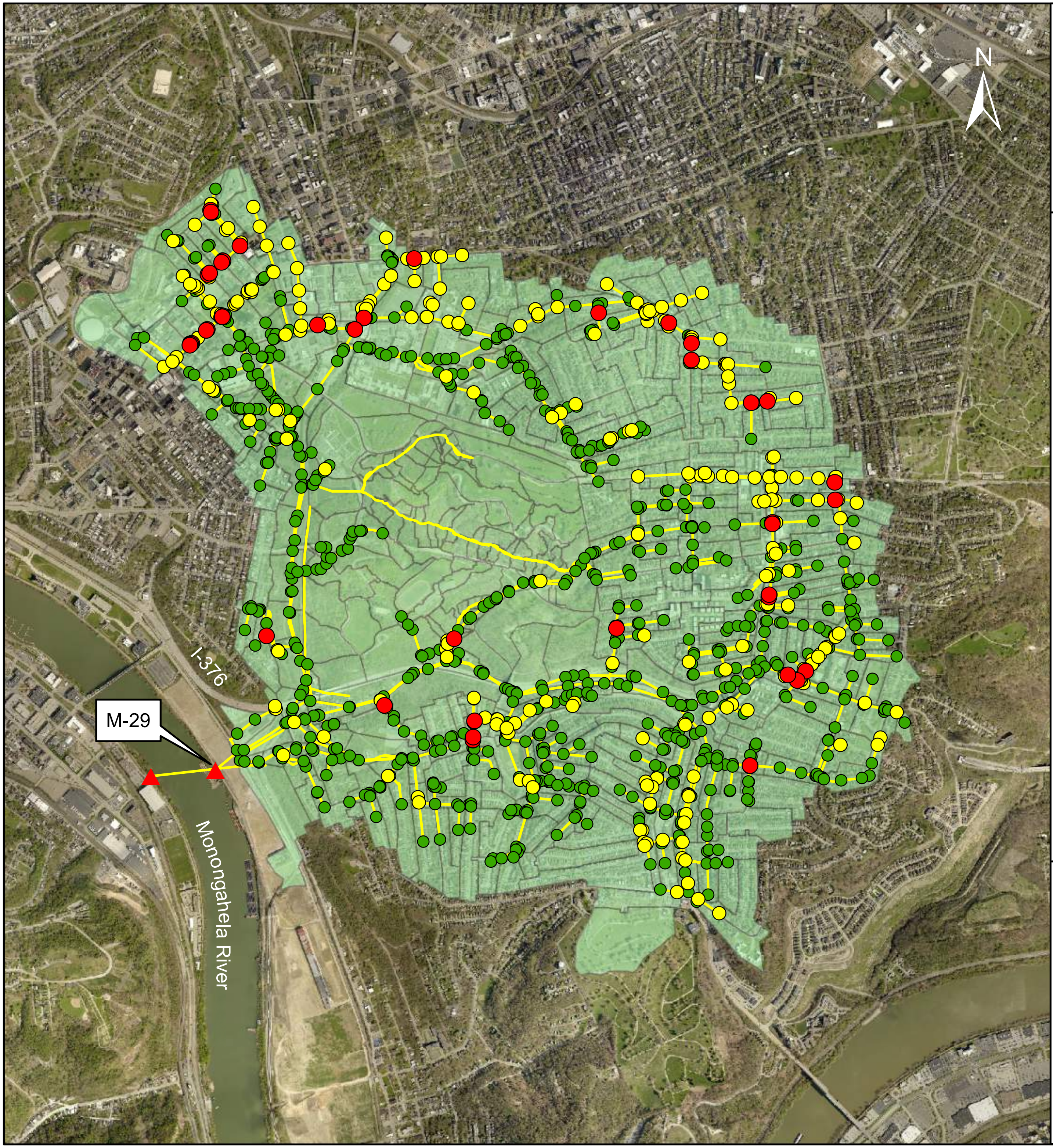
- Subcatchments

Drawing Not to Scale



Existing Conditions + Flap Gate + Model Alternative 3 + Watershed Expansion

(10-year, 24-hour Design Storm)

06/10/2019

Notes:

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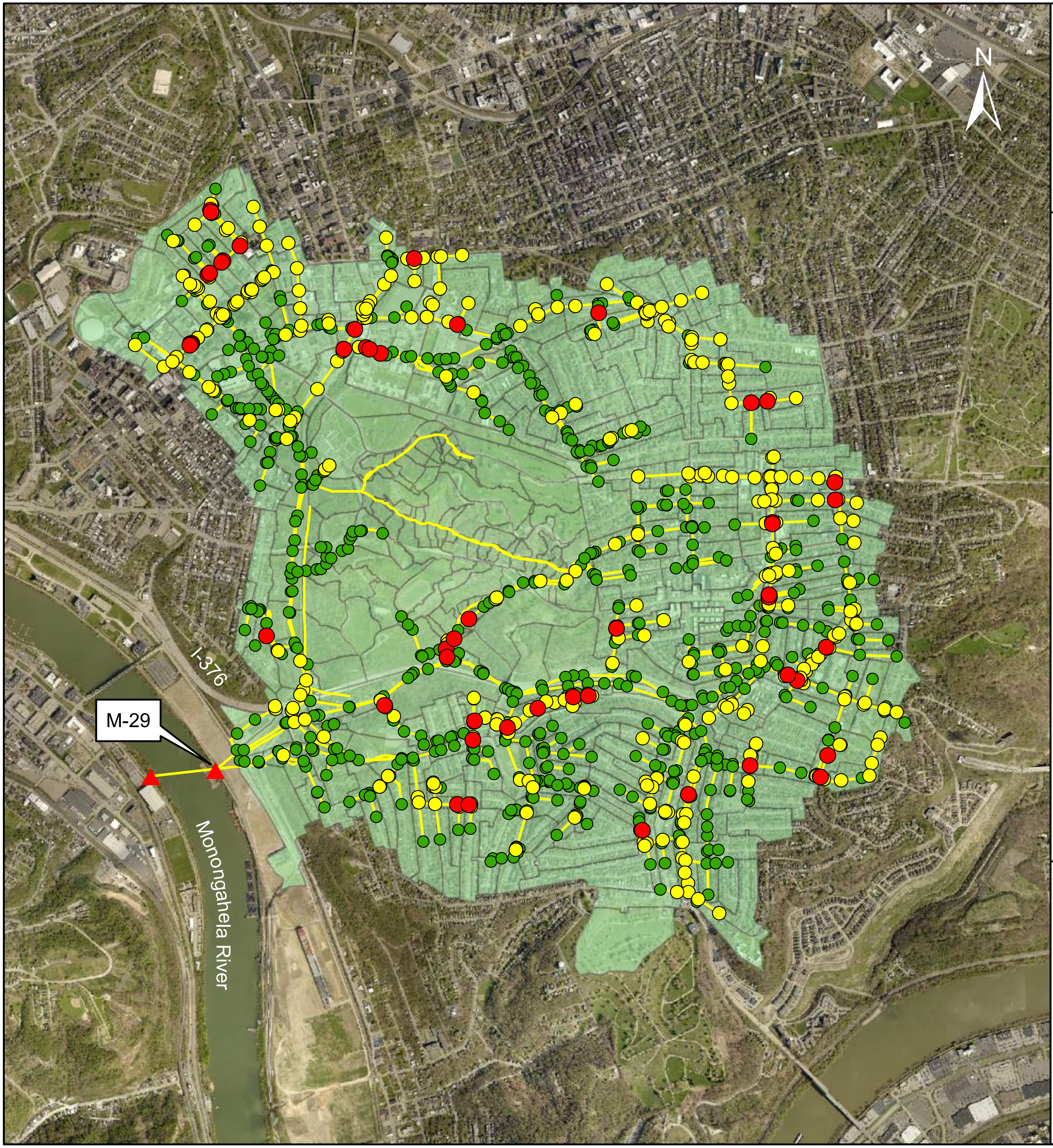

Existing Conditions + Flap Gate + Model Alternative 3 + Watershed Expansion

(25-year, 24-hour Design Storm)

06/10/2019

Notes:

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Drawing Not to Scale