DASH FLOODING

ANALYSIS OF ALTERNATIVES

ALEXANDRIA, VA

Source: City of Alexandria

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Executive Summary

Background

The City of Alexandria (City) is developing a Feasibility Study and Campus Master Plan for a 55-acre area that contains City services departments to ascertain how their spatial needs can be more effectively met. This area, generally referred to as the Witter Wheeler Campus, is bounded by Wheeler Avenue on the west, Witter Field to the east, Duke Street and Colvin Street to the north, and Business Center Drive to the south. The DASH facility which is located within the campus area has experienced regular flooding from severe rain events which has caused structural and equipment damage and interrupted business operations. As the City develops the Master Plan, it intends to incorporate opportunities that would mitigate the flooding at DASH.

Built in 2009, the 151,000-square-foot multi-level facility, serves as a hub for the operation and maintenance of buses and trolleys. During heavy storms, the main storm sewer system surcharges and floods out of existing manholes located near the northern driveway. This causes flooding depths up to one foot within the facility interior. The Transportation and Environmental Services (T&ES) Stormwater Management Division upgraded the surcharging stormwater manhole junctions at the DASH facility into larger stormwater junction boxes that are structurally more stable and capable of handling the intense hydraulic pressures these structures are exposed to. This has prevented damages previously experienced to the northern driveway pavement during severe flooding episodes.

The City is in the process of permanently floodproofing the DASH facility by installing flood barriers that will automatically deploy during severe weather. Additional flood proof measures will be installed, such as flood doors and flood walls, to protect both the facility and outside equipment. In addition to physical protective measures, the City wants to reduce flooding from the storm sewer system. Since 2013, they have conducted several studies to investigate potential measures to reduce flooding around the facility. In 2019, the City requested Michael Baker International (Michael Baker) to review previous studies, develop a list of flood mitigation alternatives, and prepare cost estimates for selected alternatives.

Michael Baker reviewed available previous studies and relied on two of the more recent studies to model the storm sewer network and develop flood mitigation alternatives. These two studies are the 2015 City of Alexandria Storm Sewer Capacity Analysis (CASSCA) study and the 2017 DASH Facility Flood Mitigation Study by URS Corporation. Both studies had modeled the storm sewer network in the DASH area using the proprietary XPSWMM software. Both studies investigated flood mitigation solutions and provided concept-level mitigation alternatives. These consisted of increasing pipe conveyance at the DASH facility (CASSCA and URS study), providing increased storage at the upstream Quaker Hill Pond (URS study), providing watertight storm sewer system at the DASH facility (URS study) and placing a detention pond west of the DASH facility which is now the City’s vehicle impound lot (CASSCA study). The CASSCA study also investigated the use of Green Infrastructure solutions to mitigate flooding and found that even with the widespread use of such practices, significant flood reduction is not possible at the DASH.

Storm Sewer System Model Development and Key Findings

An updated XPSWMM model (version 2018sp2) was developed using information from the two previously developed models. The 2-D URS model was converted into a 1-D model (no surface routing) and merged with the CASSCA model which included additional adjacent sewershed areas. Updates were made to the model where new as-built information or survey information was available. This modified XPSWMM model (baseline model) was used to model the hydraulic conditions in the storm sewer system in and around the DASH facility (**Figure ES- 1**) during a 24-hour, 10-year return period design storm event.

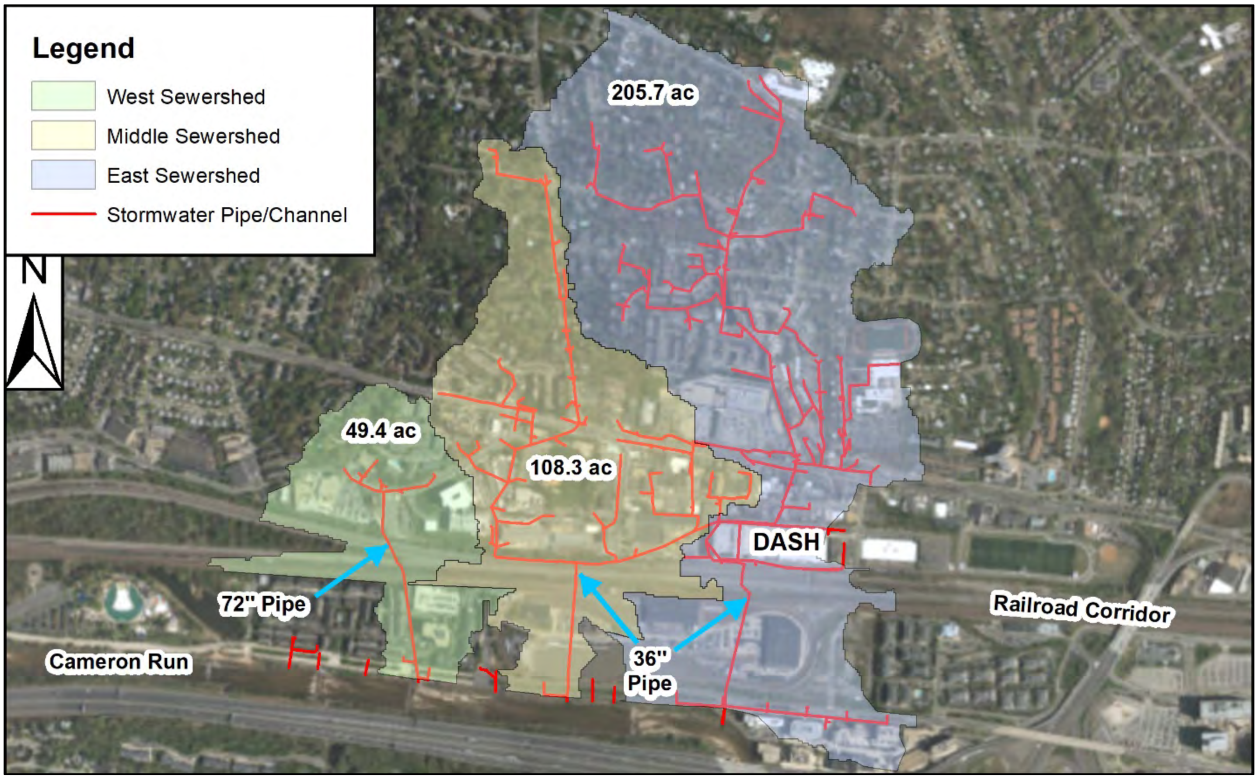

Figure ES- 1. Modeled Sewershed System

The modeled area consists of three main sewer watersheds based on the three culvert locations that convey stormwater through the railway corridor to Cameron Run (**Figure ES- 1**). The East sewershed, which is the largest at 206 acres and includes the DASH facility drains via a system of culverts located south of the DASH facility. The Middle sewershed (108 acres) drains via a culvert system located west of the South Quaker Lane and Business Center Drive and the West sewershed (49 acres) which is the smallest drains via a culvert system further west. Each culvert system consists of a series of culverts of varying sizes that convey flow southward across the tracks to Cameron Run. In each of the culvert systems, the upstream culvert or pipe contains the smallest size pipe which limits the amount of flow which limits the flow capacity entering the railroad ROW. The smallest pipe diameter for both the East and Middle sewershed's culvert systems is a 36-inch diameter pipe whereas for the West sewershed it is a 72-inch diameter opening. The design storm model shows that surcharge conditions does not occur at the West Sewershed system given its larger size and smaller drainage area but that they do occur at the other two systems.

Within the DASH facility, there are two different storm sewer systems (**Figure ES- 2**). One system collects local drainage and conveys it to the stormwater management pond located west of the DASH facility. This local system receives flow from an area of 14 acres and contributes minimally to surface flooding during the design storm event. The second system is the main storm sewer system that routes the upstream watershed's stormwater around the DASH facility along twin 42-inch diameter pipes. This system enters the DASH site from Colvin Street at the large stormwater junction box along the northern driveway and routes it west along the driveway to another smaller manhole box. From there, flow is routed south, west of the building to Business Center Drive.

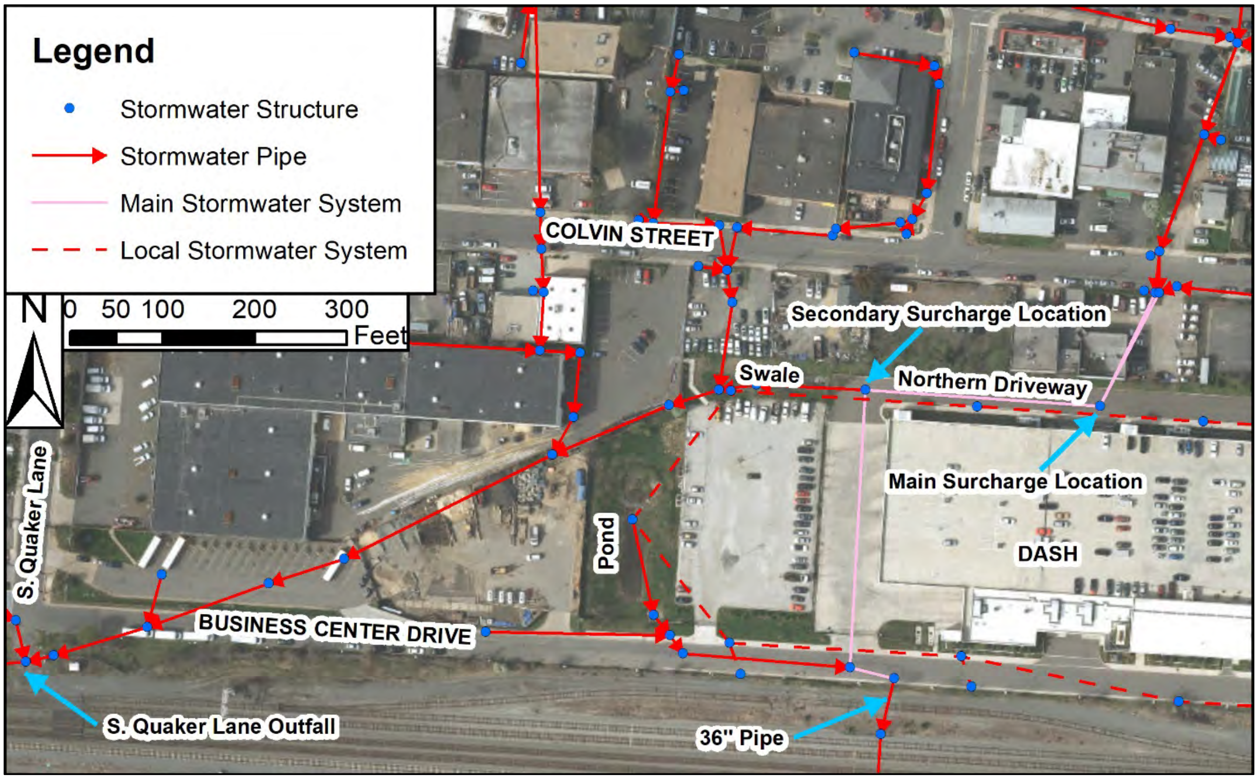

Figure ES- 2. Storm Sewer System at DASH Facility

The primary reason for flooding at the DASH facility is the severe hydraulic surcharge conditions existing in the main system at the DASH facility contributing to surface flooding via the two junction boxes along the northern driveway. The system conveys flow from an area of over 150 acres and during severe storm events surcharges quickly. The large stormwater volume, the decreasing slope of the system by the DASH facility, and the constriction of the system downstream of the DASH facility after Business Center Drive where the stormwater is routed into a single 36-inch diameter pipe all contribute to the hydraulic capacity issues of the system at DASH. The surface discharge from the first junction box is the most severe which during the design event is approximately 362,000 cubic-feet. The second box contributes much less and is approximately 11,000 cubic-feet. These are the most severely surcharged junctions in the modeled system.

<u>Mitigation Alternatives</u>

Flood mitigation alternatives that were extensively investigated and modeled include: stormwater storage opportunities within the DASH sewershed (East sewershed), increasing the pipe capacities of the main storm sewer system at and downstream of DASH, and re-routing flow away from the DASH facility along new storm sewer networks. For each selected alternative, detailed construction cost estimates were developed based on takeoff quantities and best available data.

Storage Opportunities

Several underground storage opportunities were evaluated along Colvin Street and at the Alexandria Commons shopping center. However, it was found that underground upstream storage opportunities do not provide significant flood reduction at the DASH facility due to the large amount of stormwater that must be temporarily detained. The Alexandria Commons shopping center parking lot, under maximum sizing of the storage vault can provide a reduction of 24 percent of flooding at the DASH facility. It is likely that the maximum sizing of the storage vault which covered most of front parking lot and was considered as a best-case scenario may not be feasible due to potential sub-surface site constraints.

Additionally, surface storage opportunities were also evaluated, and the most suitable location was at the City's current impound lot located west of the DASH facility. Conversion of this area into a detention pond that receives stormwater from the main storm sewer system from the northern driveway's west most junction box structure can reduce flooding at the DASH facility by almost 28 percent during the design event. Such an option was also recommended in the CASSCA study and would be less costly than underground storage but would make this area unavailable for any expansion plans for the DASH facility operations.

Upgrade the DASH facility's main storm sewer system

Several options were evaluated for upgrading the DASH facility's main storm sewer pipe system. Increasing the pipe capacity of this system throughout the DASH facility to a twin 60-inch diameter pipe (from the current 42-inch diameter) reduces the surcharging of stormwater onto the surface by almost 86 percent. However, this results in exacerbating flood conditions at Business Center Drive where the flow is constricted due to the 36-inch diameter pipe leading into the railroad ROW (**Figure ES- 1**). The excess flooding at Business Center Drive may have some minimal impacts to the DASH facility but will likely flow along Business Center Drive and on to the railroad ROW area. Increasing the pipe capacity of the 36-inch diameter pipe maybe possible as it traverses only one railroad track and larger pipes/culverts exist further downstream. However, this will need to be coordinated with the railroad companies and its feasibility is unknown at this time.

Re-routing Stormwater from DASH facility

Re-routing stormwater away from the DASH facility is most feasible along Colvin Street. Most of the stormwater received at the DASH facility is conveyed from Colvin Street along a twin pipe system. Re-routing one of the twin pipes along Colvin Street will redirect approximately half of the stormwater away from the DASH facility. Based on the opportunities, three re-routing alternatives were identified that would significantly reduce the surcharge conditions at the DASH facility. It should be noted that no detailed utility survey data was available and therefore potential utility conflicts may need to be addressed when such information is available. The three re-routing alternatives modeled are:

- ❖ Route-1 – Divert flow from the main system via a 60-inch diameter pipe along Colvin Street to a manhole junction west of the Colvin Street and Sweeley Street junction where it connects to an existing system (**Figure ES- 3**). The storm sewer system downstream from this connection is upgraded to meet the additional flows. The downstream system mostly falls within City-owned properties and daylights at the S. Quaker Lane where it flows to the open channel originating at this structure. On account of the re-routing, the open channel will receive additional flows.
- ❖ Route-2 – Similar to Route-1, this diverts flow from the main system via a 60-inch diameter pipe along Colvin Street but is extended west all the way to S. Quaker Lane. Flow is then diverted south along S. Quaker Lane to the S. Quaker Lane outfall (**Figure ES- 3**). There is a higher probability for underground utility conflicts under this alternative where approximately 1,700 feet of new pipes will need to be installed. This alternative will also introduce additional flow to the open channel initiating at the S. Quaker Lane outfall.
- ❖ Route-3 – Similar to Route-1 this alternative diverts flow along Colvin Street but without upgrades to the downstream system. It also contains the DASH main storm sewer system upgrades to twin 60-inch pipes.
- ❖ Route-4 – Divert flow from the main system along Colvin Street east to the storm sewer system at Roth Street. The receiving system is part of the Taylor Run watershed which was not modeled in this study. Therefore, hydraulic impacts of the additional flows received into this system will need to be analyzed and mitigated accordingly. Cost estimates for this alternative do not account for upgrades to the Taylor Run watershed.

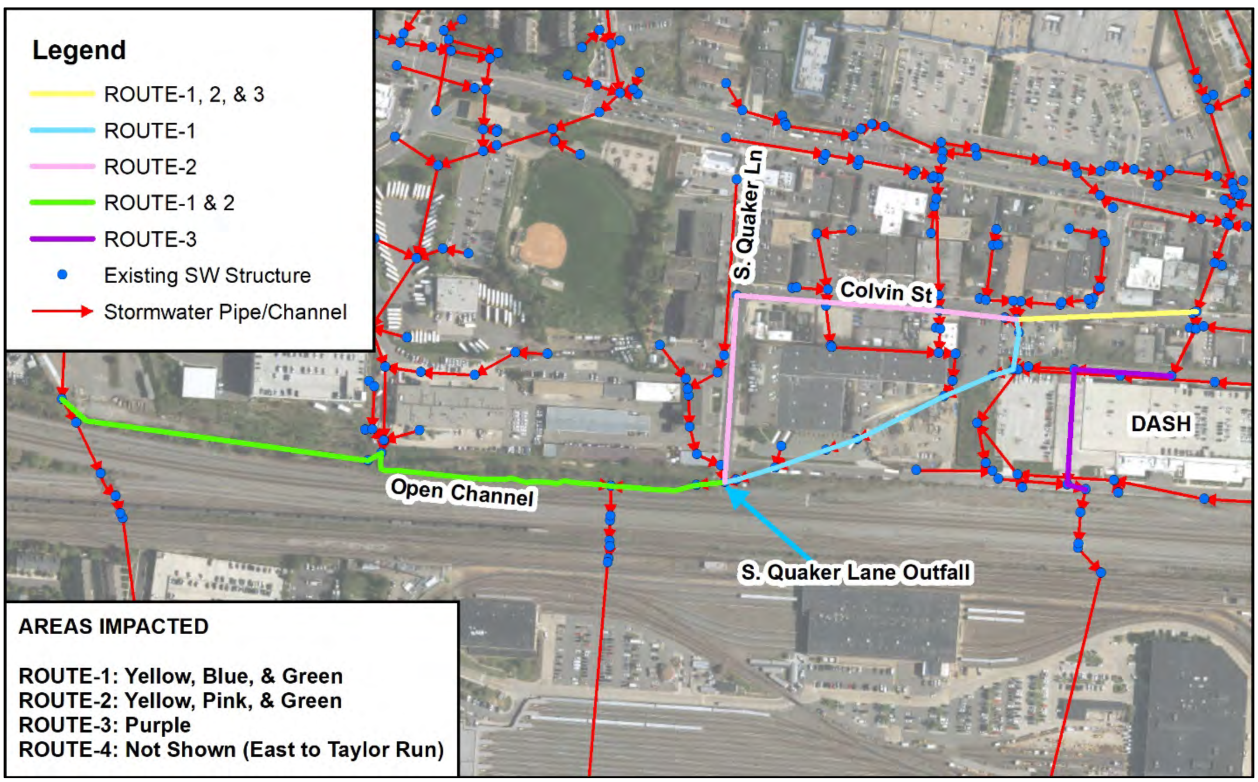

Figure ES- 3. Flow Diverting Pathways for Re-routing Alternatives

Based on model results, all re-routing alternatives provide flood reduction at the DASH facility in excess of 70 percent thus providing significant flood reduction. Both Route-1 and Route-2 alternatives introduce additional flow to the open channel at the S. Quaker Lane outfall which conveys flow to the Middle culvert system. A potential opportunity to address this issue is to alter the channel, such that more flow is conveyed to its western end and to the West culvert system which retains capacity during the design storm. This would mitigate part of the excess flow introduced at S. Quaker Lane outfall and to the Middle culvert system. The developed models and cost estimates include these improvements; however, Michael Baker determined the improvements based on aerial imagery and pipe and channel information from the XPSWMM model and topographic data. Additional detailed site information will be required, including consultation with the rail companies to fully identify potential constraints and improvement opportunities.

Summary Analysis of Mitigation Alternatives

Proposed Solutions	Flood Reduction	$/ft^3	Total Cost
Re-Routing on Colvin Street			
ROUTE-1	73%	8.1	$2,148,385
ROUTE-2	79%	12.5	$3,586,064
ROUTE-3	87%	7.2	$2,272,465
ROUTE-4	91%	4.7	$1,564,789*
Existing System Upgrade at DASH			
UPGRADE	86%	4.5	$1,381,022
Storage Opportunities			
STORAGE-1	24%	73.33	$6,431,635
STORAGE-2	3%	109.93	$1,373,355
STORAGE-3	28%	17.93	$1,793,698

*Estimate does not include modifications required to exiting downstream stormwater system in Taylor Run watershed.

Storage	
Alternative	**Description**
STORAGE-1	Alexandria Commons Shopping Center
STORAGE-2	Colvin Street Properties
STORAGE-3	Detention Pond (Interim Impound Lot)

Re-Routing	
Alternative	**Description**
ROUTE-1	New pipe heading west on Colvin Street with an upgraded system downstream of the new pipe.
ROUTE-2	New pipe heading west on Colvin Street without an upgraded system downstream of the new pipe.
ROUTE-3	New pipe heading west on Colvin Street with upgraded pipes to the Main Stormwater System.
ROUTE-4	New pipe heading east on Colvin Street.

Conclusions

Based on the results from the model and cost estimates, the upgrade to the DASH system and the re-routing alternatives are the most suitable flood mitigation alternatives. These alternatives will reduce the surface discharge of stormwater in excess of 70 percent. The re-routing of stormwater to the Taylor Run watershed will likely have increased costs once the impacts to that watershed are investigated. Therefore, this re-routing alternative requires significant further analysis to verify its viability. Detailed survey and utility information along with discussions with property managers will be required to further identify the suitability of the proposed mitigation alternatives.

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1. Background Information

The Alexandria Transit Company provides public bus and trolley services for the City of Alexandria (City) through its Driving Alexandria Safely Home (DASH) system. In 2009, a new DASH facility came into operation at 3000 Business Center Drive in Alexandria, VA, 22314. The location of the DASH facility within the City of Alexandria is shown in **Figure 1**. The approximately 151,000-square-foot multi-level facility, located on a nine-acre City-owned parcel, serves as a hub for the operation and maintenance of buses and trolleys. Immediately south of the DASH facility is a large railroad corridor that is used by both passenger and freight train lines. Further south of the tracks is the WMATA Alexandria Rail Yard. See **Figure 2** for a map of the DASH facility and its adjoining area.

Figure 1. Location of the DASH Facility.

Since its opening, over the past ten years there have been several instances where the DASH facility has been flooded from stormwater during severe rain events. In July 8th 2019, DASH facility was extensively flooded due to an intense storm event that occurred, which according to the National Weather Service (NWS) records at Reagan National Airport dropped 3.3 inches of rainfall in one hour. This rain event produced surcharge conditions in the main storm sewer system north of the DASH facility and stormwater gushed out of manholes and inlets along the facility's northern driveway, flooding the interior of the building. By most accounts, approximately one to two feet of water was present behind the facility and dissipated quickly once the storm intensity reduced. However, the waters damaged expensive equipment used for vehicle maintenance during that short period.

The DASH facility is flood prone primarily due to the lack of capacity in the main storm sewer system that conveys flow around it, resulting in surcharge flooding from manholes along the northern driveway of the building. This storm sewer system receives flow from an urbanized drainage area of approximately 150 acres with a steep upstream gradient that results in it significantly and quickly being overwhelmed during severe storm events. Previous studies investigated mitigation opportunities and provided recommendations. This study takes those recommendations, further evaluates them, and provides additional evaluations of flood mitigation opportunities along with concept-level cost information of the most suitable alternatives.

Figure 2. DASH Facility Adjoining Area

1.1. Previous Studies (CASSCA; URS)

The City has been investigating alternatives to mitigate the flooding at the DASH facility when it became apparent that the facility was incurring repeated flood damage. Two of the past studies, which are considered still relevant, were reviewed in detail to determine the feasibility of several solutions put forth to mitigate the flooding and to identify any additional opportunities. These two studies are identified in the reference section.

1.1.1. CASSCA: Problem and Solution Identification and Prioritization (June 2015)

The City of Alexandria Storm Sewer Capacity Analysis (CASSCA) was conducted by the City to analyze storm sewer capacity issues, identify problem areas, develop and prioritize solutions, and provide support for public outreach and education. The study looked at the City's entire storm sewer system and reported on deficiencies and opportunities. One of the key elements of the study was that it developed an XPSWMM model (version 2014sp1) of the City's entire storm sewer network.

The DASH facility fell within the Cameron Run Center watershed of the CASSCA model. This watershed, or sewershed, has a drainage area of approximately 383 acres. The model for the Cameron Run Center sewershed showed that the DASH facility would experience flooding during a 10-year, 24-hour design storm event due to stormwater flooding from the surcharged storm pipes. Several mitigation strategies were examined, including improving conveyance by increasing hydraulic capacity, reducing capacity limitations by adding distributed storage to the system, and reducing stormwater inflows by implementing green infrastructure (GI). While the study reported that by increasing the size of the main storm sewer pipes that wrap around the DASH building to dual 8.5-foot diameter would lessen or resolve the flooding at the facility, it did acknowledge that some of the peak flow and volume would be passed downstream, thus creating new flooding and capacity limitations. The study also looked at increasing the amount of GI to lessen the peak and volume of flow in the storm sewer system.

1.1.2. DASH Facility Flood Mitigation Study (June 2017)

In 2016, the City undertook another study to investigate additional alternatives to mitigate or reduce flooding of the DASH facility. As part of this study, the City's XPSWMM model was updated with more accurate storm sewer invert elevations, dimensions, and connectivity. Additionally, hydrologic catchments and catchment parameters were also updated in the model from as-built survey data provided by the City. The XPSWMM model was truncated to include the portion that contributes runoff to the DASH facility. The model was also converted into a 2D model that was capable of routing surface flow when the underground storm pipes surcharged to the surface via manholes or inlets. The 2D model was based on City-provided topographic information. Following those updates and changes, the XPSWMM model was calibrated with information gathered from a July 2015 storm event.

Using the more detailed and calibrated XPSWMM model (version2016), the study investigated various opportunities to mitigate flooding at the DASH facility. **Table 1** shows a summary of all the alternatives investigated during the study along with those that were recommended for further consideration.

Table 1. List of Mitigation Alternatives from the June 2017 Study

Solution Category	Potential Solution	Significant Flood Reduction	Further Consideration
No Action	Continue repaving northern driveway and provide temporary flood proofing (sandbags) prior to heavy rain events.	No	Yes (as the no action alternative)
Flood Proofing	Sandbagging	No	No
	Permanent Floodproofing	No	Yes (In conjunction with other measures)
Diversion	Divert East	No	No
	Divert West	No	No
	Divert East and West	No	No
Storm Sewer Improvements	Larger Upstream Pipes to Change Timing	No	No
	Increase Pipe Sizes On-Site	Yes	Yes
	Watertight Pipes and Manholes	Yes	Yes
Storage	Existing Quaker Hill Pond - Increase Storage	Yes	Yes (with CMAC)
	Existing Quaker Hill Pond - With Continuous Monitoring and Adaptive Control (CMAC)	Yes	Yes (with increase storage)
	Other Upstream Location	No	No
	On-Site Storage	No	No
Combinations	Storage Plus Diversion	No	No

As **Table 1** shows, the two main alternatives proposed by this study were to implement a watertight storm sewer system by the DASH facility and to increase storage capacity at the Quaker Hill pond. Given that the Quaker Hill pond is a private pond which may present challenges to implementing storage modifications, the study recommended the watertight storm sewer system alternative as the preferred option. These alternatives were proposed in addition to the permanent floodproofing of the DASH facility, which would be an added safeguard against flood damage.

The 2017 study also reported on prior studies that had investigated potential measures to alleviate flooding around the DASH facility.

- One study involved evaluating feasible improvements to the downstream storm sewer system that runs under the railroad tracks south of the DASH facility. The twin 42-inch storm sewer pipes from DASH connect to a 36-inch culvert at the south boundary of the DASH facility and act as a bottleneck in the main storm sewer system. Improving the existing 36-inch outfall was deemed infeasible due to the cost of trenching across the tracks and the constraint of keeping all the rail tracks operational during construction. In addition, jack and bore was determined to be infeasible since there was no available space to install a receiving pit for jack and bore operations as all rail tracks had to be kept operational.
- Additionally, preliminary modeling by the City suggested that increasing pipe capacity under the rail lines did not relieve flooding sufficiently to warrant the expense of construction across the rail lines. Another study looked at increasing the on-site storage

including increasing the size of the existing detention pond (west of the DASH facility) and replacing the existing 42-inch pipes with 54-inch/60-inch pipes; however, preliminary modeling by the City indicated that the flooding was not significantly reduced to warrant the expense of construction.

1.2. Field Data Gathering

As part of its data gathering efforts, Michael Baker performed two site visits and obtained field information at critical points of the storm sewer system in the vicinity of the DASH facility. Data gathered from the field visits were combined with information provided by the City (as-builts information, photographic information from actual flood events) to verify and modify, as necessary, any parameters in the XPSWMM model. Furthermore, this information was used in the identification and development of mitigation alternatives.

1.3. Review Existing Data/Model

The City provided two different XPSWMM models of the storm sewer system that were developed during previous studies.

Since both models had their advantages and disadvantages for application in the current study, the two models were merged to create a new XPSWMM model. That process is explained in the section below.

1.4. XPSWMM Baseline Model

As mentioned earlier, this study combined specific elements of the two models previously developed to create an updated XPSWMM model to simulate the existing hydraulic performance of the storm sewer system during a 10-year design storm event. The 2016 URS model had the most up-to-date information of the storm sewer system by the DASH facility; however, it did not contain information of the systems adjacent to the DASH facility that drained to other outfalls immediately north of the rail tracks. The CASSCA model contained the entire sewershed area within this watershed; however, some of the information is dated. Since a complete picture of the storm sewer system in the watershed was desired along with using the most up-to-date information, the two models were merged. Refer to **Figure 3** for a map of the entire sewershed area modeled, along with the portion where information was obtained from the URS model.

The merging of the two models essentially resulted in replacing the portion of the CASSCA model in the vicinity of the DASH facility with the updated URS model. All 2D elements were removed and the baseline model was run under a 1D regime using the latest XPSWMM version, which is the 2018sp2 version. Running under a 1D regime does not allow overland routing of stormwater when surcharged nodes (manholes and inlets) result in surface flooding. As a conservative approach, nodes that would allow for surface flooding were modeled with the "allow ponding" approach which returns ponded water back into a node as it regains hydraulic capacity. Results of the baseline model for the 10-year return event are included in **Appendix C** and are comparable to the previous models where the north side of the DASH building experiences the worst flooding. However, some minor differences exist due to the merging of models, the conversion to a 1D model, and the execution under a different model version.

It is important to note that the hydraulic model of the sewer system was performed to primarily analyze the pipe capacities by allowing the catchment runoff to directly enter the nodes (inlets) of the modeled storm sewer system. This approach does not model the flow restrictions that may occur at some of the surface inlets. The flow directly entering the collection system without any restrictions provides a conservative or "worst case" evaluation of pipe capacities. However, it may also not capture some localized ponding issues due to insufficient inlet capacities. Refer to the previous studies documented in Section 1.1 for a full review of other limitations and assumptions in the model which are essentially carried over into this baseline model.

Figure 3. Area of CASSCA Model Update with URS Model

In addition to modeling the 10-year rainfall event, rainfall data from the July 8, 2019 storm event that caused severe flooding at the DASH facility was also modeled. The results of this analysis are shown in **Appendix A**. The results show that the peak intensity of the July 8th event exceeded the peak intensity of the 10-year event and causes almost 40 percent more flooding.

1.5. Design Storm

The design storm used as an input for the XPSWMM model is the same one used on the studies reported on previously. According to those reports, the 24-hour synthetic rainfall distribution for the 10-year design storm event was developed based on rainfall data from the existing intensity-duration-frequency (IDF) curve for the 10-year return period for Alexandria (City of Alexandria, 1989). The peak rainfall intensity was selected from the IDF curve based on a 15-minute time interval. Outside of the peak intervals, a variable time interval approach was used to generate the design hyetograph. The design hyetograph was developed to yield maximum rainfall intensity at the approximate center of the 24-hour storm. The 24-hour rainfall total is 5.04 inches, and the rainfall intensity over the peak 15-minute time interval is 5.9 inches per hour (in/hr).

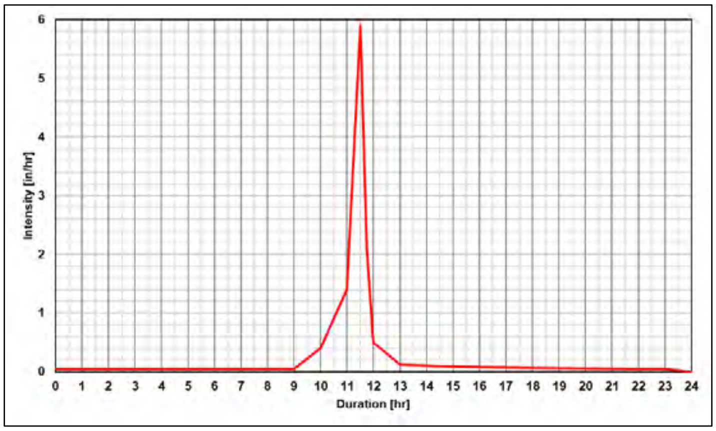

Figure 4. Existing 10-Year, 24-Hour Design Hyetograph

Table 2. Existing 10-year 24-hour Design Hyetograph Data

Time Interval [min]	Duration [min]	Rainfall [in]	Intensity [in/hr]
0	60	0.050	0.050
60	60	0.050	0.050
120	60	0.050	0.050
180	60	0.050	0.050
240	60	0.050	0.050
300	60	0.050	0.050
360	60	0.050	0.050
420	60	0.050	0.050
480	60	0.050	0.050
540	60	0.050	0.050
600	60	0.400	0.400
660	30	0.700	1.400
690	15	1.475	5.900
705	15	0.525	2.100
720	60	0.500	0.500
780	180	0.360	0.120
960	360	0.480	0.080
1320	60	0.050	0.050
1380	60	0.050	0.050

2. Identification of Critical Issues

2.1. Key Features of the Storm Sewer System

The evaluated storm sewer system covers approximately 383 acres of the Cameron Run Watershed. The area evaluated is between the Taylor Run Watershed to the east and the Strawberry Run watershed to the west, all of which ultimately drain into Cameron Run. All these watersheds contain storm sewer systems that collect stormwater north of the railroad corridor and convey it through a series of parallel culvert systems under the tracks and the downstream areas further south before flowing into Cameron Run. Within the evaluated storm sewer system of Cameron Run, there are no named stream sections unlike in the adjacent systems of Taylor Run and Strawberry Run. In this system, storm sewer pipes predominantly convey stormwater with a few open channels present by the railroad corridor.

2.1.1. The storm sewer system by the DASH facility

The DASH facility accommodates two storm sewer systems.

1) One system collects local stormwater runoff from approximately 14 acres consisting of the DASH building and surrounding parking areas and conveys it to a stormwater management pond west of the building for quality and quantity control. Outflow from the pond is conveyed to a manhole junction (Node 003546SMH) directly south of the western driveway to the DASH facility on Business Center Drive.
2) The other system is the main storm sewer system that conveys off-site flows from the upstream reaches of the watershed. This system conveys runoff from over 150 acres and consists of a twin pipe system that enters the DASH site from the north and wraps around the DASH building's west side before flowing into the same manhole junction described in #1 above.

These two systems are responsible for conveying stormwater at the DASH facility. From the manhole junction where the two systems meet, flow is conveyed along Business Center Drive to another junction (Node 003547SMH). From there, flow is conveyed into the Railroad corridor ROW along a single 36-inch diameter pipe where it traverses one track line before daylighting prior to entering a culvert pipe system that conveys water under the rest of the railroad tracks. Refer to **Figure 5** for a map of the storm sewer system by the DASH facility.

2.1.2. Modeled System

The storm sewer system in the modeled watershed flows through three separate culvert systems that convey stormwater across the railroad corridor to Cameron Run. While some sections of the railroad corridor are traversed by long culverts other sections have short culverts that daylight between the rail track embankments. Refer to **Figure 6** for a map of the modeled section of Cameron Run watershed and its storm sewer system that show the drainage areas to the three culvert systems. For the purposes of this study, these three culvert systems are called the East culvert system, the Middle culvert system and the West culvert system. They have the following key properties:

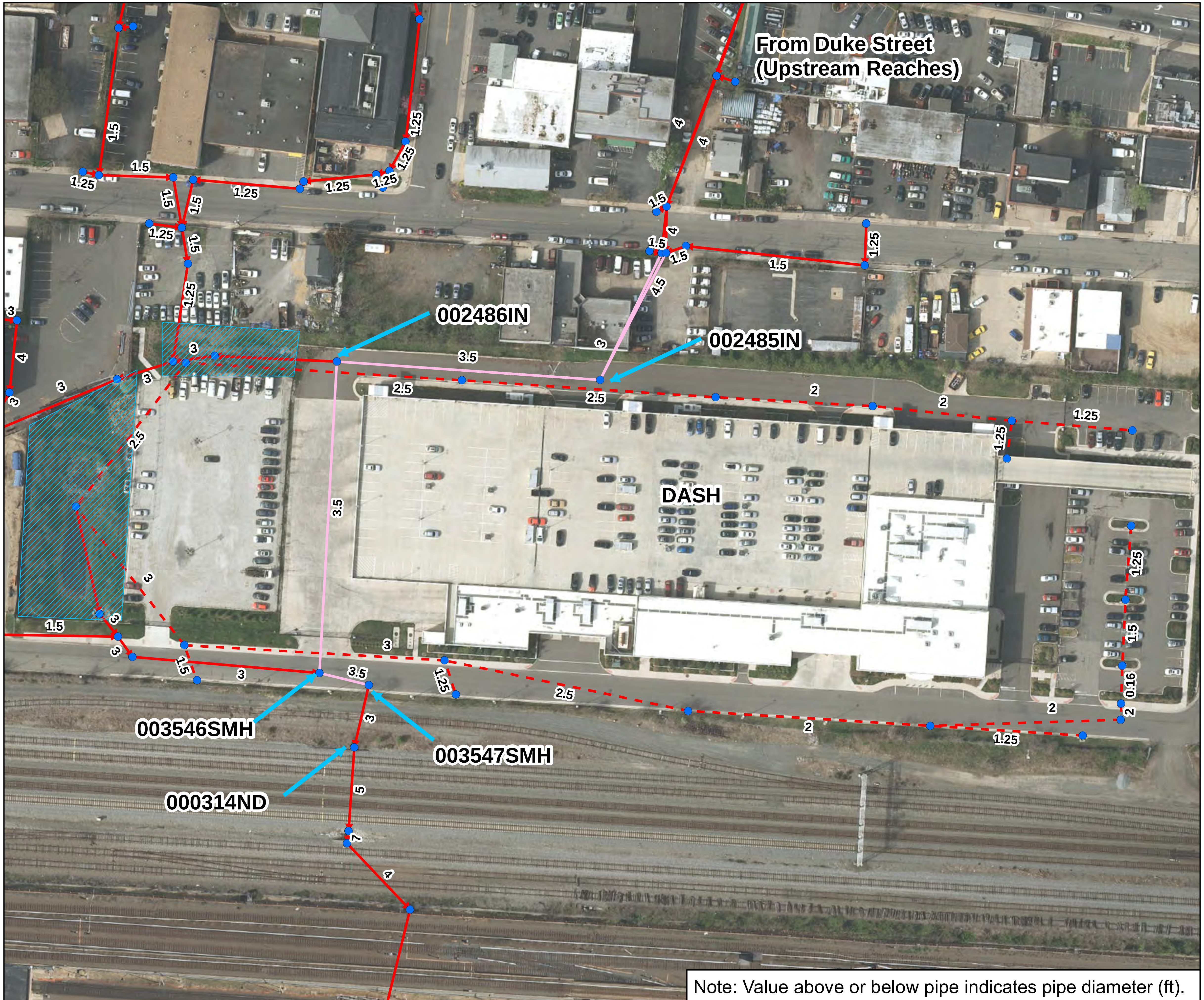

Figure 5. Stormwater Systems by DASH Facility

Alexandria, Virginia

N
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S

Legend

- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System
- Pond/Swale
- Stormwater Structure

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0 35 70 140 210 Feet

1 inch = 92 feet

DASH FLOODING ANALYSIS
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Figure 6. Watersheds of the storm sewer system

Alexandria, Virginia

N
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Legend

- Watershed West
- Watershed Middle
- Watershed East
- Stormwater Pipe/Channel

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0 205 410 820 1,230
Feet

1 inch = 600 feet

DASH FLOODING ANALYSIS
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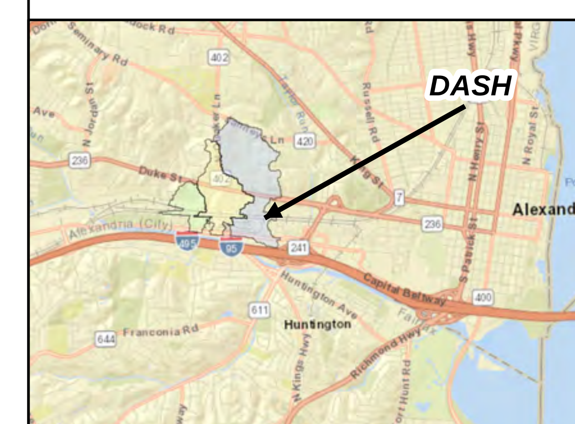

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1) The East culvert system has a drainage area of 206 acres. It consists of a 5-foot box culvert, a 4-foot box culvert, and a 4-foot diameter dual pipe before discharging into Cameron Run. Between the culverts the system daylights briefly at the boundaries of the track embankments. This drainage area includes the DASH facility.
2) The Middle culvert system has a drainage area of 108 acres. It consists of a series of 3-foot diameter culvert pipes and one downstream 5.5-foot diameter pipe before discharging into Cameron Run. Between the culverts the system daylights briefly at the boundaries of the track embankments.
3) The West culvert system has a drainage area of 50 acres. It consists of a 6-foot diameter pipe and a series of 8-foot diameter pipes before discharging into Cameron Run. Between the culverts the system daylights briefly at the boundaries of the track embankments.

All three culvert systems likely receive additional surface flow from connections within the railroad ROW and from areas further south. It is not known if all these connections are captured in the model because some connections may be from private lots and may not have been included in the original CASSCA model. However, the West culvert system that has the smallest contributing drainage area also has the larger culverts (6-foot diameter). The other two culvert systems have 3-foot diameter pipes that constrict flow into them, but they have larger contributing drainage areas. **Figure 7** shows the pipe sizes at the upstream and downstream end of each culvert system.

While there are three culvert systems that convey stormwater across the railroad corridor, as described above, the upstream storm sewer system in the watershed conveys stormwater to the railroad corridor at four locations. At two locations, storm sewer pipes convey flow directly into the culverts, while at two other locations, the pipes discharge into an open channel that conveys stormwater to a culvert. Refer to **Figure 7** for a map of these locations which are described in more detail below:

1) The eastern most discharge location is immediately south of the DASH facility at Business Center Drive (Node 003547SMH and referred to as DASH outfall) and has a drainage area of 163 acres. This location is a manhole junction that receives flow from the storm sewer system upstream of the DASH facility and flow from the stormwater management pond. A single 36-inch diameter pipe conveys flow from this junction under a single railroad track after which stormwater daylights before being conveyed under other tracks through the culverts that form the Eastern culvert system.
2) Another discharge location is west of the DASH facility south of the intersection of S. Quaker Lane and Business Center Drive (Node 00615IO and referred to as the S. Quaker Lane outfall). Flow from this outfall daylights into an open channel, where stormwater flows approximately 250 feet west parallel to the railroad tracks before entering the Middle culvert system. The storm sewer system has a drainage area of 35 acres to the S. Quaker Lane outfall.
3) The next discharge location is immediately east of the Alexandria City Police Department (Node 000613IO and referred to as the Police outfall). Flow from this outfall daylights into an open channel, where stormwater flows approximately 600 feet east parallel to the railroad tracks before flowing into the same Middle culvert system. The storm sewer system has a drainage area of 60 acres to the Police Station outfall.
4) The western most discharge location is by the EZ Storage facility at 3640 Wheeler Avenue (node 00031CP and referred to as the EZ Storage outfall). Flow from this

outfall daylights briefly before entering the West culvert system. The storm sewer system to this location has a drainage area of 38 acres.

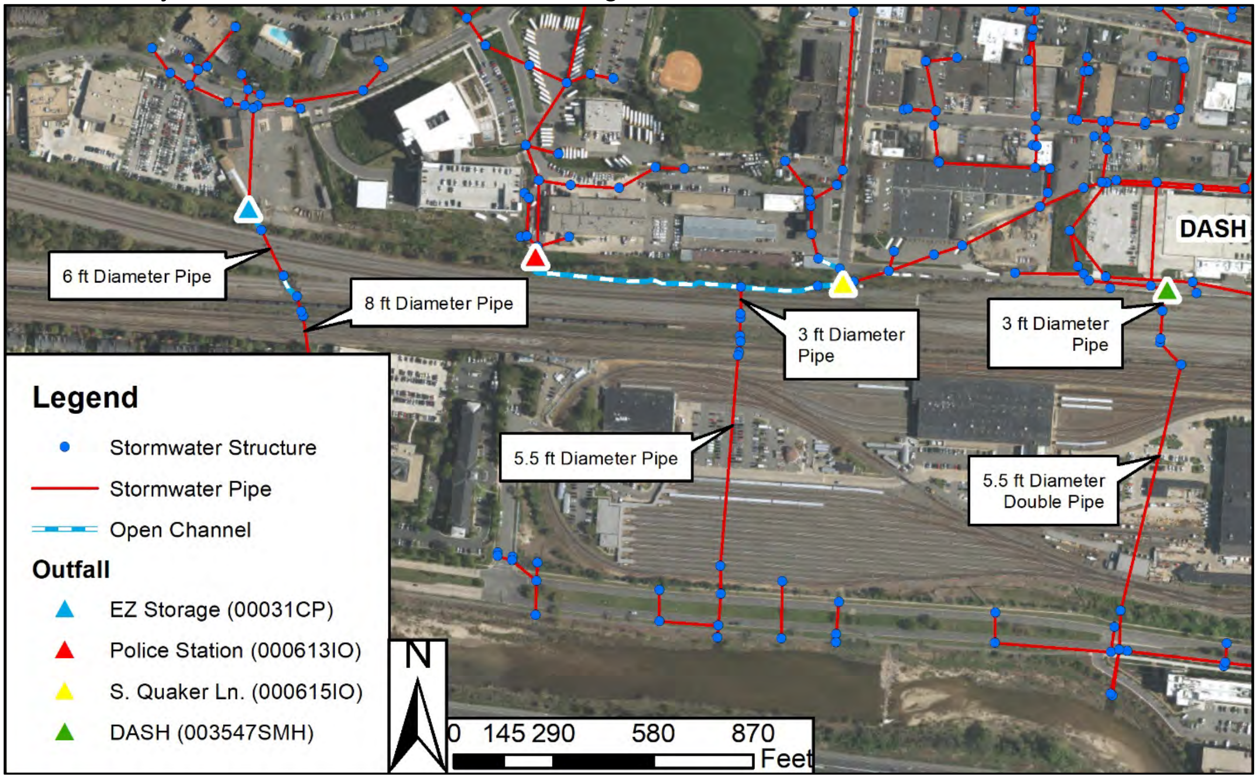

Figure 7. Outfalls of the Storm Sewer System

2.2. Key Deficiencies in the Storm Sewer System

Based on the information in the previous Section and a thorough review of the XPSWMM model results, four key deficiencies in the storm sewer system were identified that contribute to flooding at the DASH facility. Two of these directly impact the flooding whereas two others have indirect impacts. The identified deficiencies are described below.

2.2.1. Severe surcharge of main storm sewer system along northern driveway of DASH

The storm sewer system upstream of the DASH facility conveys runoff from over 150 acres. This system routes stormwater runoff from Colvin Street to the storm sewer junction at the northern driveway of the facility (Node 002485IN) along twin pipes with 3-foot and 5.5-foot diameters. The approximately 10-foot drop in elevation between Colvin Street and the northern boundary of the DASH facility results in the storm sewer pipes having an almost eight percent slope. This steep gradient introduces flow rapidly to the main storm sewer junction at the DASH facility where both twin pipes flow into. This flow encounters severe head loss at the junction where it must turn 90 degrees and is conveyed along a slight 0.5 percent gradient further downstream. This storm sewer junction has the most severe surcharge of flow occurring in the entire analyzed system, with over 360,000 cubic feet of stormwater surcharging to the surface during the modeled 10-year event.

The subsequent downstream junction at the northwest corner of the facility (Node 002486IN) also is severely surcharged and contributes to surface flooding at the DASH facility. During the 10-year event, the ponded amount is more than 10,500 cubic feet. The surface flow from these two structures is primarily responsible for flooding of the DASH facility. The significant flow in the pipes, the severe reduction in gradient of the system, and the numerous 90 degree turns all contribute to the system surcharging at the DASH facility.

2.2.2. Swale west of DASH facility causing backflow

The open channel (swale) located northwest of the DASH facility is connected to the main drainage system through the manhole junction northwest of the DASH facility (Node 002486IN) by a 36-inch RCP double pipe system. Backflow occurs though this connection where flow from the open channel contributes to the main storm sewer system at the DASH facility (see **Figure 9**). The swale receives approximately 97,000 cubic feet of stormwater from the main upstream storm sewer system to the west, with only 75,000 cubic feet being conveyed back to the downstream system during the modeled 10-year event. This results in approximately 23,000 cubic feet of stormwater being conveyed as backflow to the DASH facility and to the stormwater pond to the south. During peak events the water level in the swale surcharges higher than the invert elevation of the connection pipe from the DASH facility's northwest manhole junction which causes backflow to occur on to the DASH facility. The main storm sewer system to the west of the swale is also surcharged downstream of the swale, but it does not cause significant overland flooding. This storm sewer system discharges at the S. Quaker Lane outfall and then flows into the open channel along the tracks to the Middle culvert system.

Due to the contribution of stormwater from the swale to the DASH system, the elimination or alteration of this connection is desired. Initially, this connection was placed to alleviate the flooding at the DASH facility, but according to the modeling, it has had the opposite effect during severe storm events. According to City Impound Lot Site Plan, this swale may be eliminated altogether and enclosed to provide more area for equipment and vehicle storage. The benefits of controlling stormwater with the open channel is very limited and its removal is likely the best approach to rectify this issue.

Figure 8. Node 002485IN (DASH) Surcharged During July 8, 2019 Event

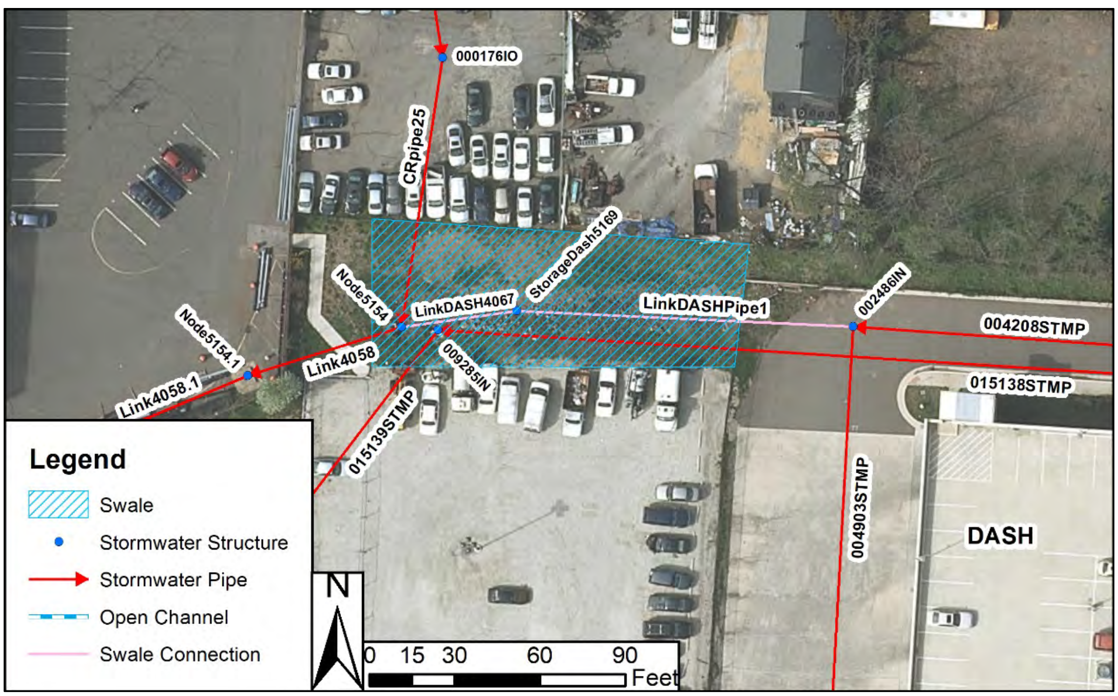

Figure 9. Swale West of DASH

2.3. Flow capacity constriction of main storm sewer system downstream of DASH facility

The DASH outfall (Node 003547SMH) on Business Center Drive acts as a severe bottleneck in the storm sewer system. Its inflow pipe is a dual 42-inch diameter pipe; however, outflow occurs via a single 36-inch diameter pipe on to the railroad corridor (Link 013332STMP). This causes surcharge conditions in the upstream system which is already flowing at full capacity during a 10-year event. While this contributes flood surcharge to the DASH facility, most of the surcharge from this pipe system results in flooding Business Center Drive. Therefore, its impact to the DASH facility is not as significant as the two deficiencies identified in the previous Sections.

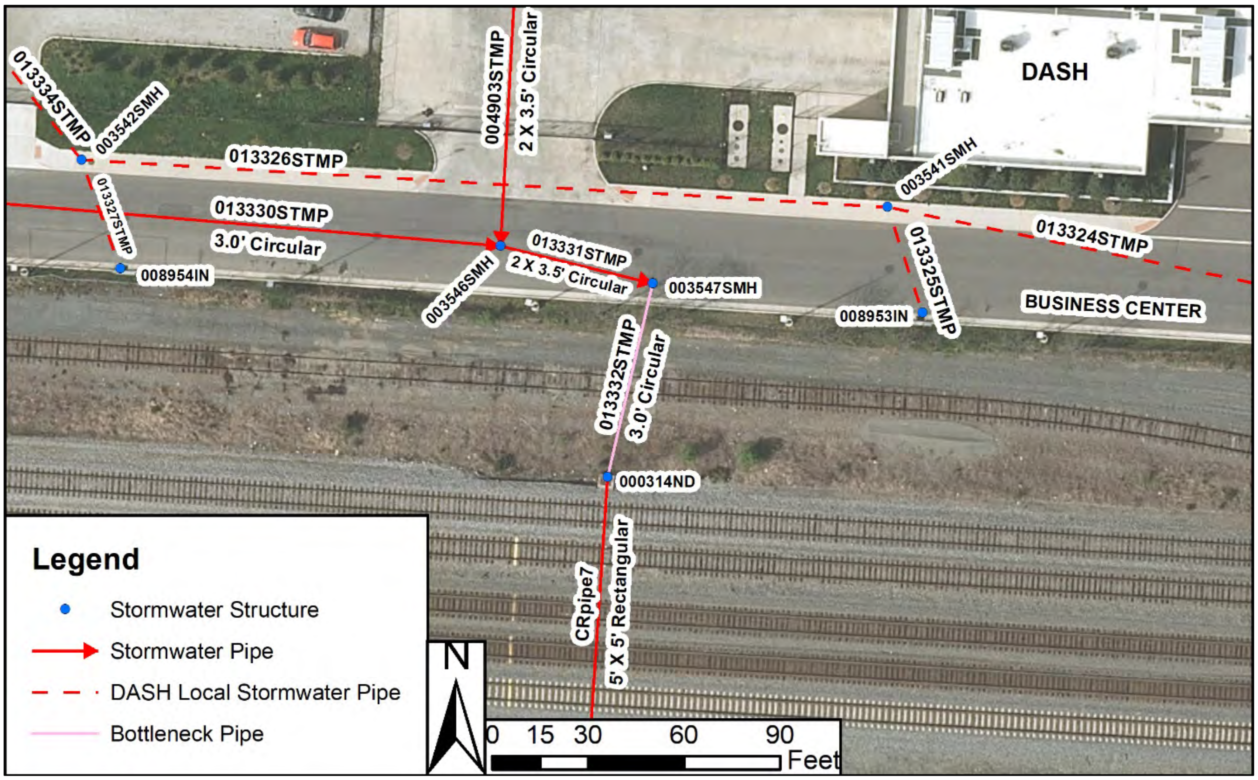

Figure 10. Stormwater System Bottleneck South of DASH

2.4. Sag Point at Node Between Links 004203STM and 004202STM

Previous data from the City, including the CASSCA XPSWMM model, show a sag point in the pipe system west of the DASH facility that conveys flow south of the Alexandria Bus Depot to the S. Quaker Lane outfall. The 2012 CCTV Survey did not include invert elevations, slopes, or comments to either confirm or deny the presence of the sag. Additionally, the URS model did not model this pipe network and did not provide any data to confirm the sag.

This pipe system is surcharged during a 10-year event which occurs whether it is modeled with a sag point or not. However, surcharged conditions are worse with the sag. Also, the outflow of this system at the S. Quaker Lane outfall to the open channel needs maintenance to remove siltation and vegetation. These deficiencies, while they do not contribute directly to flooding at the DASH facility or cause significant flooding at other properties, is a system that could be improved if possible. So, while it is not identified as a critical deficiency, it is listed as an opportunity to improve the drainage patterns in the watershed. **Figure 11** displays the location of the potential sag point.

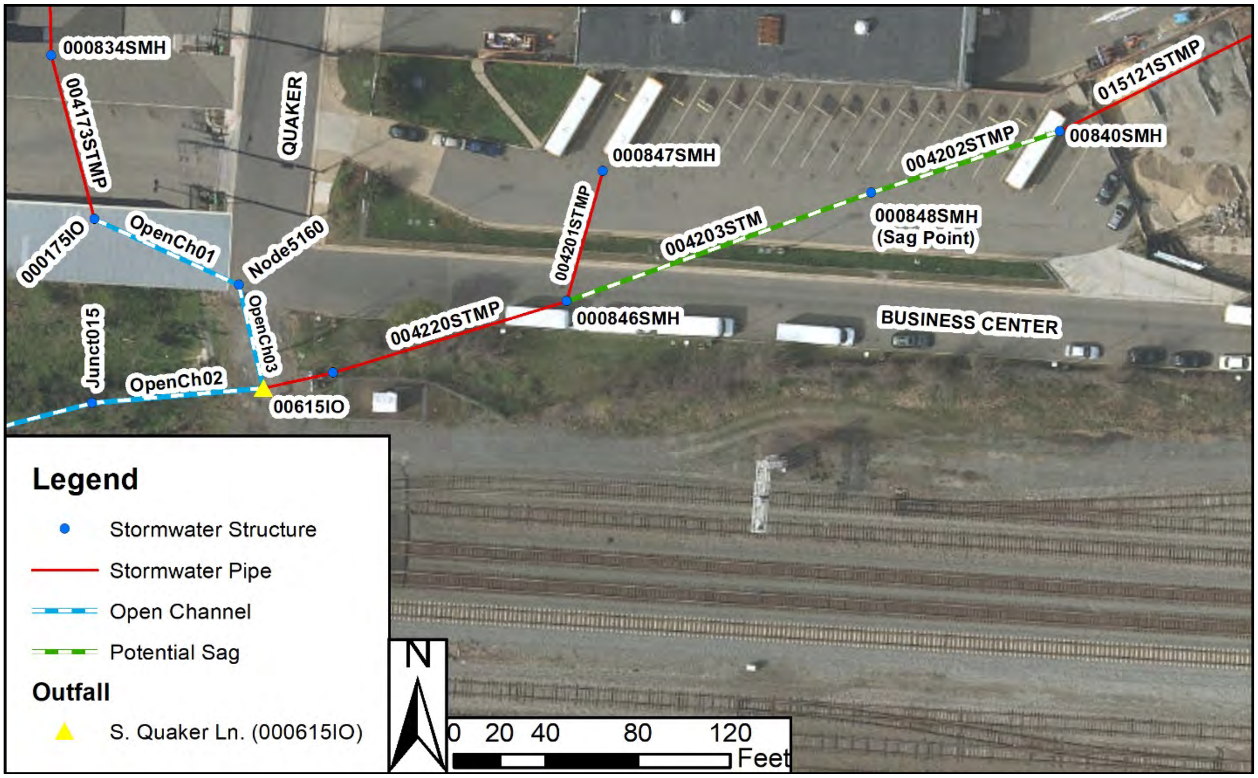

Figure 11. Sag Point at Node Between Link 004203STM and 004202STM

3. Development of Mitigation Alternatives with Model Results

3.1. Preferred Solutions from Previous Studies

Of the flood mitigation opportunities provided by the two previous reports that were reviewed, three opportunities are retained with some modifications to two of them. **Table 3** presents the major solutions proposed in those studies along with an explanation of which solutions are kept for consideration.

Table 3. Proposed Mitigation Alternatives from CASSCA and URS Studies

Study Alternative	Constraints/ Issues	Considered
CASSCA Study		
Increase Pipe size at DASH from twin 3.5-foot diameter to 8.5-foot diameter	Downstream peak flows increase by over 50 percent; significant increase in size	Yes (Different pipe size)
Provide storage at lot immediately west of DASH	Loss of surface space; does not completely resolve flooding	Yes (Underground storage)
Incorporate Green Infrastructure	Does not significantly address flood issue at DASH	No
URS Study		
Make main storm system by DASH watertight	Will have some environmental issues; will cause flooding at Colvin Street	Yes
Increase storage at Quaker Hill Pond with the use of CMAC* technology	Private pond and community buy-in needed; may have other issues limiting raising pond elevation	No

*CMAC - Continuous Monitoring and Adaptive Control

The URS study also reported on permanent floodproofing of the DASH facility as a solution to be considered in conjunction with other potential solutions. This solution is currently being implemented, along with the junction box improvement at 002485IN. Therefore, this report does not cover them as they are not stand-alone solutions.

3.2. Development of flood mitigation options

The critical deficiencies of the storm sewer system that were identified during the model review guided the identification of mitigation alternatives. As reported in Section 2.2, there were two key deficiencies in the storm sewer pipe network that directly contribute to flooding at DASH. These are the severe surcharge of flow in the main storm sewer system at the northern driveway and the backflow from the swale west of the DASH facility to the main storm sewer system. Suitable mitigation options were evaluated to address these deficiencies, especially the surcharging of flow onto the surface. **Table 4** presents the identified mitigation options that are suitable based on the model and site location.

Table 4. Identified Opportunities to Address Key Deficiencies

Mitigation Method	Available Opportunity	Suitability
Surcharge of Main Storm Sewer System at DASH		
Reduce flow volumes in pipes	Provide upstream detention storage	Opportunity pursued; suitable locations identified
	Re-route flow to another pipe system	Opportunity pursued; suitable routes identified
Increase pipe hydraulic capacity	Increase pipe sizes or add another storm pipe for conveyance	Opportunity pursued (Not optimal as will result in increased downstream flooding at Business Center Dr. where pipe sizes/ gradients are set)
Provide detention storage by DASH facility	Route peak flows to an adjacent detention structure and relieve peak surcharge conditions	Opportunity pursued; suitable location is immediately west of DASH at parking lot
Backflow from Swale West of DASH		
Eliminate Backflow	Remove connection to Channel	Opportunity pursued; connection removed
	Redesign Channel to eliminate instances of backflow	Not pursued, as the open channel has limited functionality in providing storage and hence better use of this area is preferred either for development or storage

Additionally, opportunities to address the other two deficiencies which do not directly impact the DASH facility flooding were explored during the development of mitigation alternatives.

For the storm sewer pipe constriction south of the DASH facility at Business Center Drive, the downstream pipe could be increased; however, it will result in increased flow into the railroad corridor. Therefore, the entire culvert system (East culvert system) downstream may need to be enhanced to ensure no adverse impacts occur within the railroad corridor. Given that there is limited information on the suitability of that approach, this study only presents the modeling effects of improving the immediate bottleneck at Business Center Drive. This is to primarily investigate how it impacts the flooding at the DASH facility.

3.3. UPGRADE

According to the baseline model, the main flooded nodes at the DASH facility are 002485IN and 002486IN, which are located on the northern driveway. These are linked by a 3.5-foot diameter double pipe (see **Figure 12**). One option to mitigate the severe surcharging of this system is to increase the capacity of the existing pipes and, consequently, alleviate the surcharge/overflow starting at node 002485IN.

The results of upgrading the capacity of these pipes to 5-foot diameter double barrel are shown in **Table 5**. This alternative mitigates a significant amount of flooding volume at the near-DASH system, resulting in lowering the surface flooding at node 002485IN by 86 percent. This storm sewer system has on average ten feet of depth or more (from invert to rim), and therefore provides enough clearance to install 5-foot diameter pipes. However, more surface flooding occurs south of the Dash facility due to the manholes at Business Center Drive receiving more stormwater runoff. Proposed modifications for this alternatives can be found in **Figure 13** and **Table 6**.

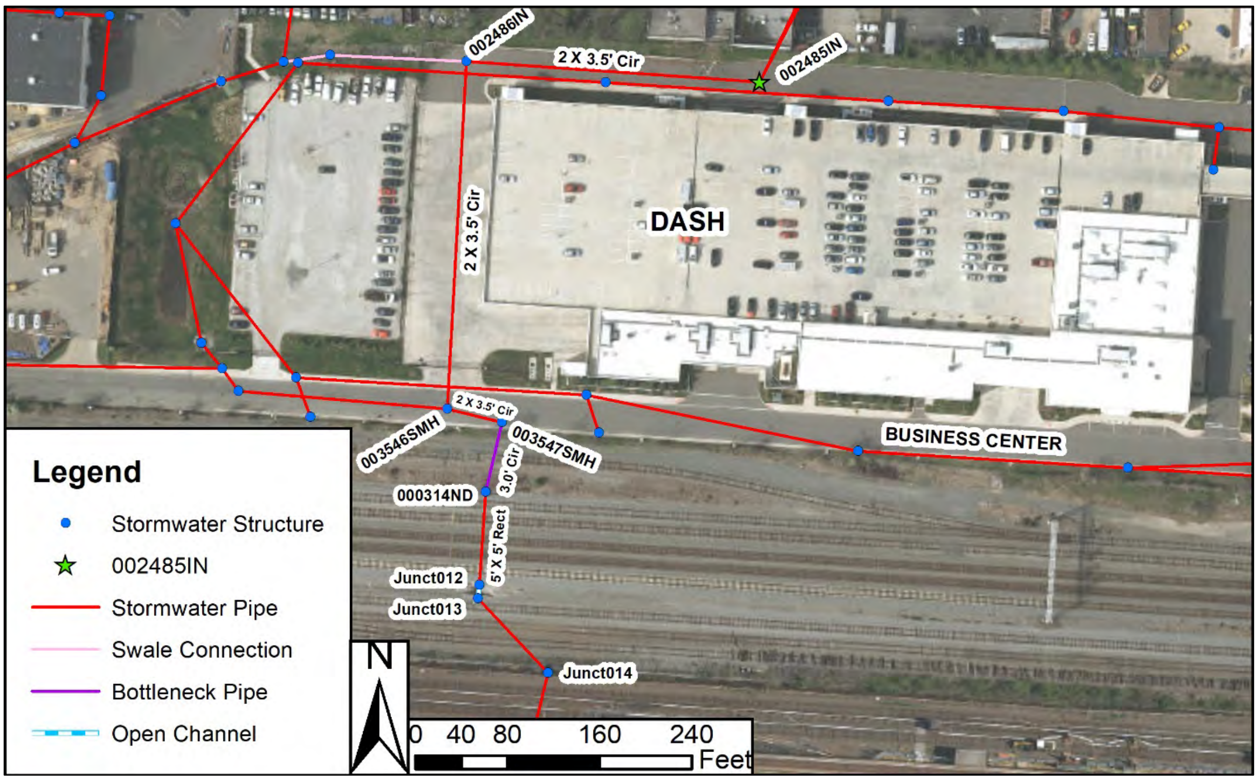

Figure 12. Existing Conditions of the Main Storm Sewer System at DASH

Table 5. UPGRADE Model Results

Node	Flood Volume [ft^3]		
	Baseline	Proposed Alternative	Flood Reduction
002485IN	361,555	52,312	86%
002486IN	10,467	9,310	11%
003546SMH	0	1,452	Increased Flooding
003547SMH	0	0	0%
000314ND	0	0	0%
Junct013	0	0	0%
Junct014	0	4,634	Increased Flooding

Table 6. Proposed Modifications for UPGRADE

Link	Status	From Node	To Node	Shape	Diameter/ Height [ft]	Barrels/Z	Length [ft]	US Elev. [ft]	DS Elev. [ft]	Comments
004208STMP	Replace	002485IN	002486IN	Circular	5	2	216	30.7	29.93	Improve capacity
004903STMP	Replace	002486IN	0035465SMH	Circular	5	2	304	29.63	28.89	Improve capacity
013331STMP	Replace	0035465SMH	003547SMH	Circular	5	2	51	28.44	28.4	Improve capacity

Figure 13: UPGRADE

Alexandria, Virginia

N
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Legend

- Utilities
- Replace SW Pipe/Channel
- Existing SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

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0 15 30 60 90 Feet

1 inch = 40 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
Baker Project No: 169362

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3.4. Underground Storage Opportunities

For underground storage opportunities, preliminary assessments were based on determining availability of storage areas, how much runoff can be diverted to these areas, and costs associated with implementation. Three locations were identified as more suitable for underground storage opportunities:

- STORAGE-1 – In the Alexandria Commons Shopping Center
- STORAGE-2 – Properties along Colvin Street
- STORAGE-3 – Adding a new Pond at the Interim Impound Lot

Approximate locations for the underground storage opportunities are shown in **Figure 14**. Initially, Michael Baker used underground chambers such as StormTech's MC-4500 Chamber for conceptual design. While they provide a cost-effective method, these chambers are designed primarily to be used under parking lots and open spaces as they cannot support heavy loads such as buildings.

The City's Department of Planning & Zoning specified that surface parking on any redeveloped parcel, besides that which is on-street, is typically prohibited per Taylor Run/Duke St. Small Area Plans and plan updates. This restriction, along with the inability of the StormTech type chamber systems to provide large storage volumes, made them less desirable than vaults. While Michael Baker also modeled all the above locations with chamber-type facilities, those results are not mentioned in this report and only the results of storage using underground vaults are reported.

In the XPSWMM models for underground storage, storage nodes for the vaults were modeled with the assumption that the selected sites would hold maximum capacity based on available surface area and the proximity of the proposed location to the storm sewer system. During the modeling, tie-in elevations were not considered, thus vault bottom elevations were lower than the outlet invert elevations. This generated ponded water at the bottom of the vault for an extended period. With these model characteristics, that would inevitably maximize flood reduction, the results showed that underground storage would not have as much of a significant impact as the other alternatives proposed in this report.

It is important to note that the results shown for each proposed location include these characteristics and depict a best-case scenario. Alternative XPSWMM models were processed to evaluate the results shown in this report to a more stringent scenario (smaller vault systems to match invert elevations and remove detained water) but produced negative results. When a more detailed study is conducted and more site restrictions considered, it would reduce the overall size and storage of the vault, and consequently reduce the amount of flood reduction to the DASH facility.

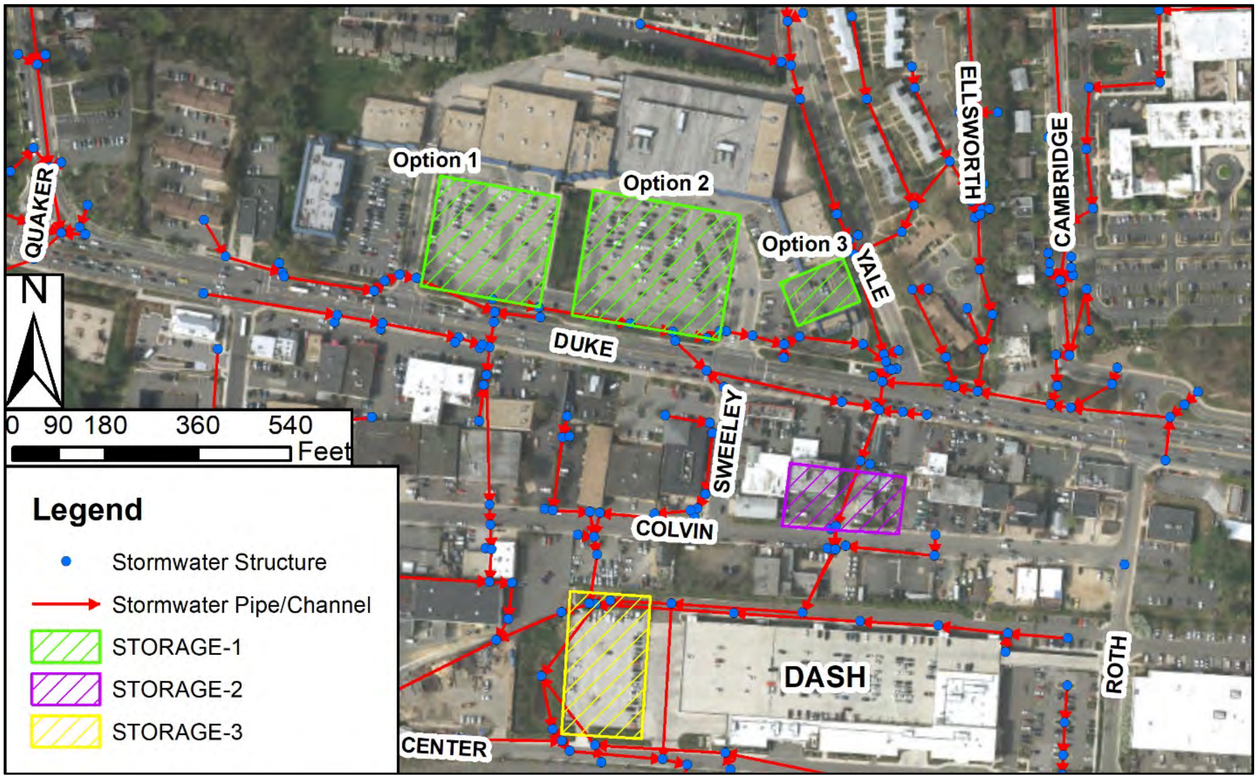

Figure 14. Underground Storage Opportunities

3.4.1. STORAGE-1

An underground stormwater vault structure was considered at the Alexandria Commons Shopping Center. For sizing and cost purposes, a typical detention vault size, similar to the StormCapture vault shown in **Figure 15**, was selected as the underground storage structure. However, any other manufacturer of concrete panel vaults, either precast or custom engineered for stormwater detention, could be used. Detention vaults provide cost-effective solutions for site-specific applications where stormwater needs to be detained and allowed to discharge at a controlled rate. They allow detention to be placed efficiently and easily under parking lots and roadways with very little cover. Higher load conditions can also be accommodated with the aid of support beams which allow buildings to be constructed above them.

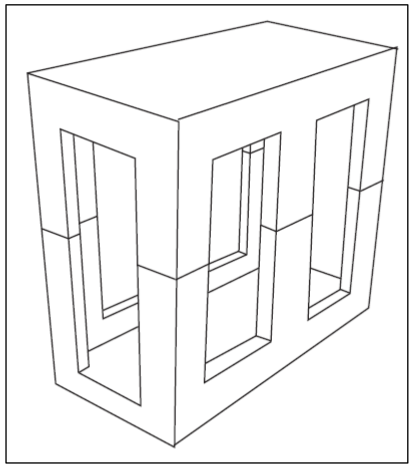

Figure 15. StormCapture Module SC2

Michael Baker investigated three viable locations for underground storage at the Alexandria Commons Shopping Center. See **Figure 16** for locations of the three options.

The pipes that connect to the vault under Option 1 (004197STMP), Option 2 (Node 000811SMH), and Option 3 (004190STMP) convey approximately 123,500 cubic feet, 1,634,795 cubic feet, and 1,650,200 cubic feet of stormwater, respectively, during a 10-year rainfall event. Option 2 was selected as the optimal opportunity. It provides an optimal location to tie-in to the existing storm sewer system is from Yale Drive northeast of the Alexandria Commons Shopping Center and maximizes the contributing drainage area to the vault. Proposed pipe locations and profiles used for cost estimation can be found in **Appendix E**.

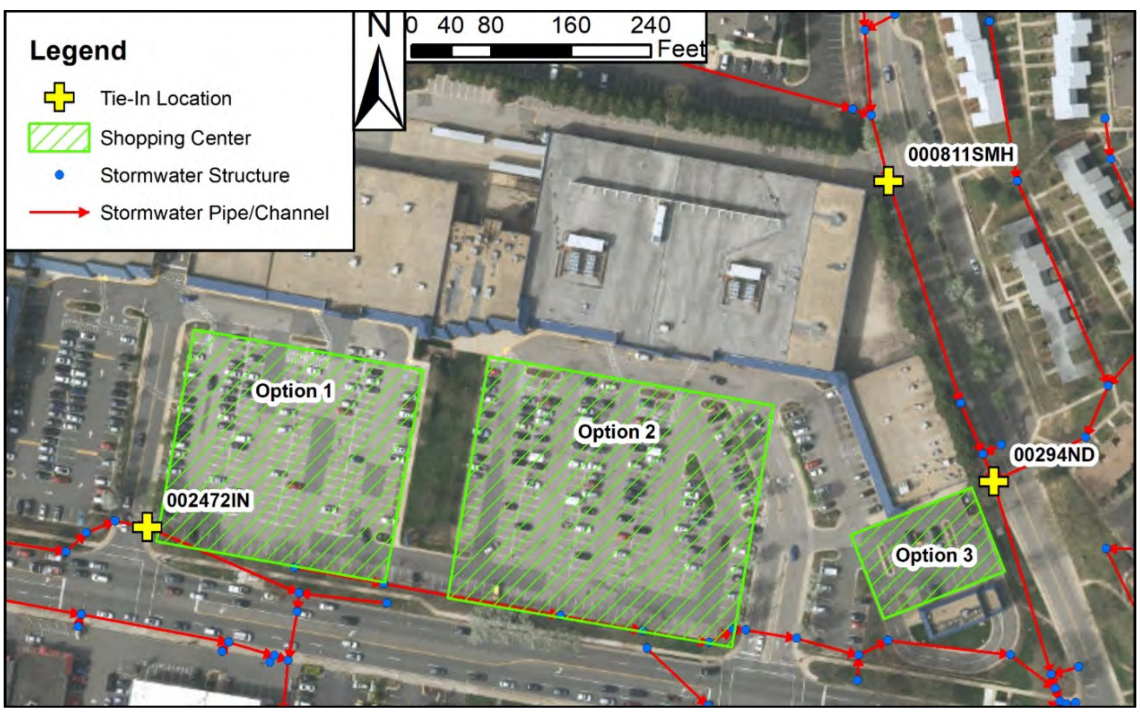

Figure 16. Storage Alternative Locations for STORAGE-1

The underground stormwater detention vault was designed using HydroCAD with a depth of 14 feet to maximize storage. A summary of the results is displayed in below.

Table 7. Vault Underground Storage Opportunity Summary (STORAGE-1)

Parameter	Option 1	Option 2	Option 3
Link	004197STMP	003639STMP	00294ND
Storage Node	002472IN	000811SMH	00294ND
Upstream Node	002472IN	000811SMH	00294ND
Downstream Node	002470IN	002403IN	000293ND
Number of Rows	21	24	9
Chambers per Row	11	14	6
Row Length (ft)	176	224	96
Base Width (ft)	168	192	72
Chamber Height (ft)	15.17	8.17	15.17
Perimeter Wall (ft^3)	2,062	2,488	1,002
Number of Chambers	231	336	54
Chamber Storage (ft^3)	370,310	269,572	86,046
Displacement (ft^3)	448,440	326,138	104,830
Overall System Size (ft^3)	448,448	326,144	104,832
Overall System Size (yd^3)	16,609	12,080	3,883
Ponded Flow Node 002485IN Before (ft^3) *	361,555	361,555	361,555
Ponded Flow Node 002485IN After (ft^3) *	360,346	273,919	357,277
Ponded Flow Reduction	**0.33%**	**24.24%**	**1.18%**

*Node 002485IN is the severely surcharged node north of the DASH facility.

Option 2 provides the largest vault detention system from the three options considered within the Alexandria Commons Shopping Center parking lot area and provides a 12.32 percent reduction of ponded flow at the DASH Facility (Node 002485IN).

3.4.2. STORAGE-2

Using the underground vault system discussed in the previous Section, several parcel combinations were considered for underground storage opportunities within properties along Colvin Street. All possible parcels considered are displayed in **Figure 17**. Preliminary calculations demonstrated that obtaining four parcel areas (33.C, 32, 31, and 30) with a total area of 24,975 square feet and implementing a detention vault type system, would only provide a 1.5 percent reduction in ponded flow at the most severely surcharged stormwater structure at the DASH Facility. **Table 8** shows the results of this option.

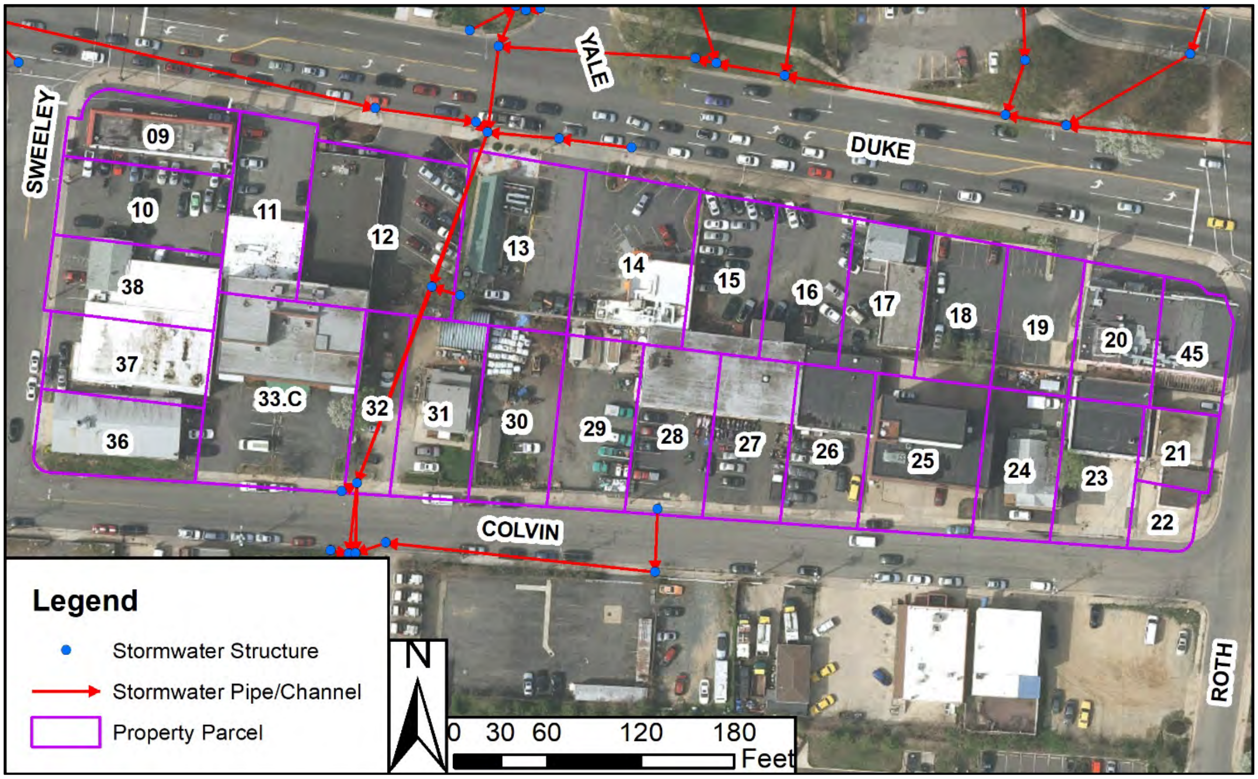

Figure 17. Parcel Locations for STORAGE-2

Table 8. Underground Storage Opportunities Summary (STORAGE-2)

Parameter	Value
Link	Link3263
Storage Node	000819SMH
Upstream Node	000313ND; 000844SMH
Downstream Node	000309ND; 002435IN
Number of Rows	21
Chambers per Row	5
Row Length (ft)	80
Base Width (ft)	168
Chamber Height (ft)	15.17
Perimeter Wall (ft^3)	1,510
Number of Chambers	105
Chamber Storage (ft^3)	119,821
Displacement (ft^3)	145,598
Overall System Size (ft^3)	145,600
Overall System Size (yd^3)	5,393
Ponded Flow Node 002485IN Before (ft^3) *	361,555
Ponded Flow Node 002485IN After (ft^3) *	349,063
Ponded Flow Reduction	**3.46%**

*Node 002485IN is the severely surcharged node north of the DASH facility.

If Yale Drive is extended south past Duke Street as part of future development plans to provide pedestrian access to Colvin Street, it may provide additional opportunities to incorporate underground storage and green infrastructure in coordination with the new development. The City's Planning Department is looking to increase the amount of green spaces, and if any are proposed in this area, potential underground storage opportunities could also be investigated. Adding more green spaces along with green stormwater practices, such as bio-retention facilities, will by themselves also slightly reduce some of the capacity issues in the storm sewer system.

3.4.3. STORAGE-3

A storage detention pond was also considered in place of the interim impound lot. Location and tie-in structures are shown in **Figure 18** and the results from the model are show in **Table 9**. It should be noted that the CASSCA study also recommended this location as suitable for storage opportunities. However, during the CASSCA study this area was unused open space. According to the information provided by the City, DASH is planning to construct an overhead structure in this location in the future. Taking this into consideration, if changes occur to the proposed plans for this area, an above-ground storage option was evaluated.

Under existing conditions, node StorageDash5169 discharges into the existing pond through an overflow structure. For the proposed plans, flow will be diverted into the new pond instead through the same means. The new pond was designed to have a similar overflow structure as the existing pond but instead of discharging to 003544SMH, the pond will discharge directly to 003546SMH.

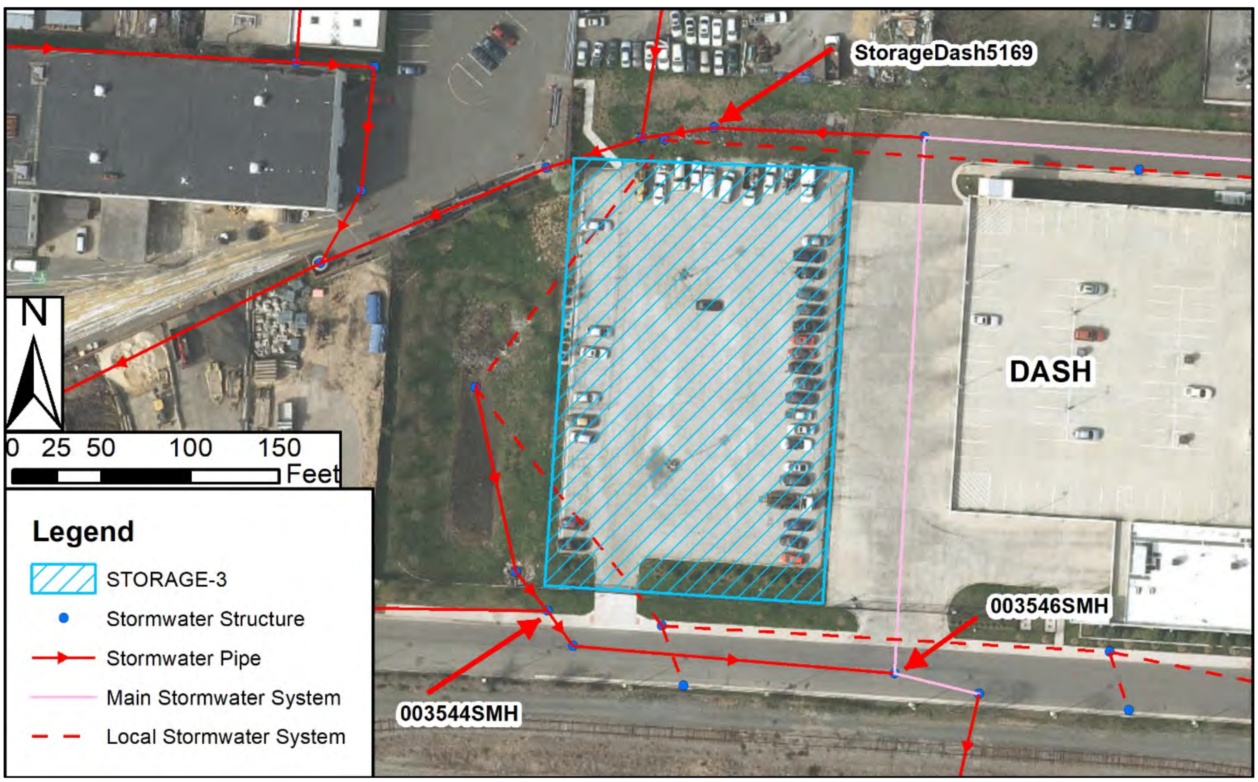

Figure 18. Proposed Detention Pond for STORAGE-3

Table 9. Detention Pond Summary (STORAGE-3)

Parameter	Value
Surface Area (ft^2)	36,972
Depth (ft)	7
Overall System Size (ft^3)	206,254
Ponded Flow Node 002485IN Before (ft^3)	361,555
Ponded Flow Node 002485IN After (ft^3)	261,598
Ponded Flow Reduction	**27.64%**

*Node 002485IN is the severely surcharged node north of the DASH facility.

3.4.1. Additional Storage Investigation

Michael Baker investigated storage opportunities along Colvin Street using underground detention vaults. This opportunity has several fatal flaws due to restrictions such as utility conflicts, tie-in invert elevations, and overall topography. Regardless, underground storage was modeled without these restrictions to see the effects of adding storage at this location. The length of the vault system was selected as 500 feet and the width as 40 feet for design and modeling purposes. Exact dimensions will be expected to vary based on utility and other field constraints. **Figure 19** shows the location of the proposed solution.

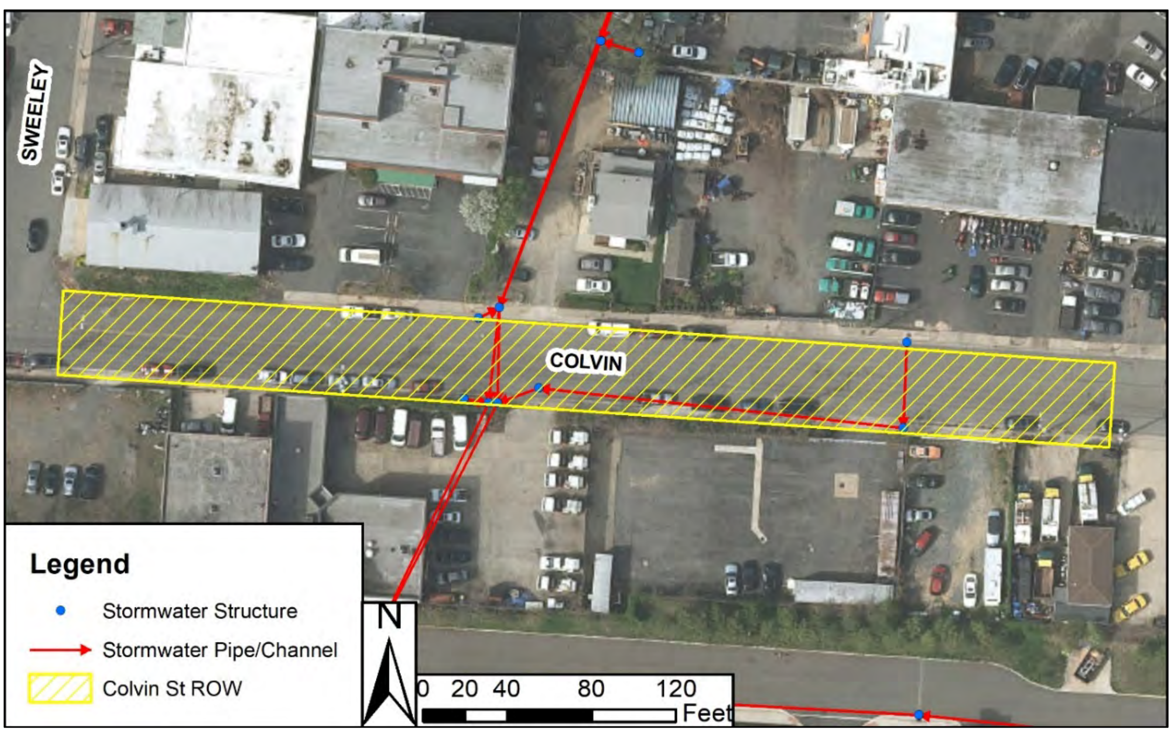

Figure 19. Proposed Underground Storage for Colvin Street ROW

3.5. Re-routing Stormwater Discharge

For re-routing opportunities, the main storm sewer system upstream and downstream of the DASH facility was analyzed in detail to determine suitable locations. The key objective of re-routing is to reduce the flow in the DASH facility's main storm sewer system by diverting part of the existing flow into new storm sewer pipes which will bypass the DASH site. The diverted flow is introduced back into the existing storm sewer system at suitable locations before conveying to the culverts at the railroad tracks. Re-routing opportunities were identified based on the following main criteria:

- Suitable points upstream of the DASH facility that would reroute a significant amount of stormwater away from the DASH site.
- Suitable points downstream of the DASH facility that would not increase localized or downstream flooding.
- Minimal impacts to private lots and main roads such as Duke Street.
- Improve any additional deficiencies identified in the main storm sewer system.

Based on a thorough review of the DASH facility's upstream sewershed and using the above criteria, two opportunities for diverting flow were evaluated. The first re-routing option was to divert flow at Duke Street, and the second re-routing option was to divert at Colvin Street. While Duke Street was an option for re-routing storm flow, it was deemed less practical as it would have a more significant impact to traffic, require longer re-routing paths, have more significant conflicts with existing underground utilities, and convey less volume of stormwater away from the DASH facility than the Colvin Street option. The primary advantages offered by re-routing the main storm sewer system at Colvin Street are:

- Colvin Street manhole junctions are the most downstream locations of the main storm sewer system before it enters the DASH facility and therefore reduce the largest amount of stormflow from the system.
- Colvin Street is less traveled than Duke Street. Utility upgrades from Colvin Street would cause less disruption to local traffic.
- The storm sewer manhole junction at Colvin Street is almost ten feet in elevation higher than the DASH facility and therefore allows many opportunities to connect the re-routed flow back into the existing system after by-passing the DASH facility.

Along Colvin Street ROW, the existing main sewer system (that conveys flow to the DASH facility) currently discharges to a manhole junction located along the northern sidewalk of Colvin Street approximately 200 feet east of the Colvin Street and Sweeley Street junction. Flow is then discharged along twin pipes under Colvin Street to two different manhole junctions along the southern side of Colvin Street which also receive additional surface flow from Colvin Street inlets. From each manhole junction, an outlet pipe conveys flow to the DASH facility's main manhole junction located along its norther driveway. Refer to **Figure 20** for a close-up illustration of the main storm sewer system in the vicinity of Colvin Street and the DASH facility. It should be noted that further west another main storm sewer system traverses Colvin Street (west of the Colvin Street and Sweeley Street junction). This system does not convey flow to the DASH facility.

Both the manhole junction on the northern side of Colvin Street (Node 000819SMH in **Figure 20**) and the two manhole junctions located on the southern side of Colvin Street (Node 002435IN and Node 000309ND in **Figure 20**) provide suitable locations to connect new storm sewer pipes to divert flow away from the DASH main system. Opportunities to route flow along either direction of Colvin Street (along the east or the west) were explored, and three re-routing alignments were determined to connect the re-routed flow back into existing systems.

- Along the west- to a manhole west of the Colvin Street and Sweeley Street junction that would convey re-routed flow along the storm sewer system west of the DASH facility which daylights at the S Quaker Lane outfall.
- Along the west- directly to the S Quaker Lane outfall after re-routing along Colvin Street and S. Quaker Lane.
- Along the east- no connection points exist within the DASH sewershed and the flow would need to be routed to the adjacent Taylor Run watershed as the DASH facility borders the eastern edge of its watershed. A suitable manhole was identified on Roth Street where a connection could be made that would convey the re-routed flow to the Taylor Run storm sewer system.

The re-routing along the west options investigated addressing the additional flow introduced to the existing downstream system. Modeling the Taylor Run watershed was outside the scope of this study and therefore, the impacts of introducing additional flow to the Taylor Run system was not investigated in the re-routing to the east option. Based on the opportunities available to re-route stormwater away from the DASH facility, four re-routing alternatives were identified that would significantly reduce the surcharge conditions at the DASH facility and are feasible from a constructability point of view. It should be noted that no detailed utility survey data was available in this area and therefore potential utility conflicts may need to be addressed when such information is available. For this study, the potential existence of underground utilities was identified using evidence gleaned from aerial imagery and field visits. See **Appendix B** for identified utility information in this vicinity. The four re-routing alternatives are described in detail below:

1) **ROUTE-1 – Re-routing along Colvin Street to the west to manhole junction west of the Colvin Street and Sweeley Street junction:** This alternative diverts flow from the manhole Node 000819SMH and connects it to the manhole node 00244IN (see **Figure 21**) along a 5-foot diameter pipe approximately 470 feet long. This would divert approximately half of the flow received at the upstream manhole thereby removing it from contributing to the DASH facility system. The connection to the rectangular 4' by 4' pipe that traverses Colvin Street is to be blocked so that it does not convey flow to the DASH site. At the downstream end of the connection, the storm sewer system size must be increased to handle the additional flows. The downstream system is currently surcharged during significant events and mostly falls within City-owned properties. The only exception is the upstream section immediately south of Colvin Street which runs under an open private auto lot. Upgrading the downstream section will improve the hydraulic conditions in the system which may have additional deficits such as a sag, which was not altogether ascertained with available data. The system daylights at the S. Quaker Lane outfall. Downstream of the outfall, the channel will receive additional flows that could adversely impact the rail tracks. A potential approach to mitigating these impacts are provided at the end of this section.
2) **ROUTE-2 – Re -routing along Colvin Street to the west to intersection with S. Quaker Lane and re-routing along S. Quaker Lane to the S. Quaker Lane outfall:** Similar to Option 1, this alternative diverts flow from the manhole Node 000819SMH but

re-routes it all the way to the S. Quaker Lane outfall along a new storm sewer system (see **Figure 22**). This option provides a larger possibility for underground utility conflicts; however, all work will be done within public ROW. Nevertheless, approximately 1,700 feet of new pipes will be installed. Similar to Option 1, this re-route would divert approximately half of the flow at the upstream manhole, and the 4' by 4' pipe that crosses Colvin Street would be abandoned or removed. Mitigation opportunities to address the introduction of additional flow at the S. Quaker Lane outfall are discussed at the end of this section.

3) **ROUTE-3:** This is similar to ROUTE-1 alternative but does not include the improvements to the storm sewer system downstream of node 00244IN. It includes upgrades to the DASH facility storm sewer system as reported in Section 3.3.
4) **ROUTE-4 – Re-routing along Colvin Street to the east to the Taylor Run storm sewer system at Roth Street**: This alternative diverts flow from the manhole Node 000309ND and routes it along Colvin Street (approximately 550 feet) to the junction with Roth Street and then routes it a further 110 feet south along Roth Street to a manhole junction from where flow is conveyed further west in the existing system. That system will likely need improvements to handle the excess flow which has not been investigated in this study. Under this alternative, the circular 4.5-foot diameter pipe conveying flow to the DASH site will be capped such that all flow received at the manhole node is re-routed away from the DASH site.

All four re-routing alternatives mentioned above will remove in excess of 70 percent of the stormwater which is conveyed to the DASH facility from the surcharged storm sewer system. See Section 5 for percent reduction levels. As expected, the modeling showed that the downstream point of each re-routed system receives more runoff than under existing conditions. Essentially, there are two downstream locations that could be impacted based on the re-routing to the west or to the east on Colvin Street; at S. Quaker Lane outfall or at the manhole junction south of Colvin Street and Roth Street that falls within the Taylor Run watershed. Since modeling the Taylor Run watershed

Figure 20: Main Storm Sewer System in the Vicinity of Colvin Street

Alexandria, Virginia

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Legend

- Stormwater Structure
- Suitable MH for Re-Routing
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System

Michael Baker INTERNATIONAL

0 15 30 60 90 Feet

1 inch = 50 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
Baker Project No: 169362

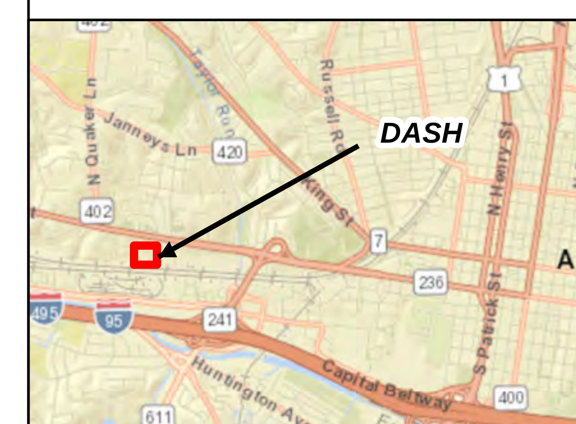

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Figure 21: ROUTE - 1 OVERVIEW

Alexandria, Virginia

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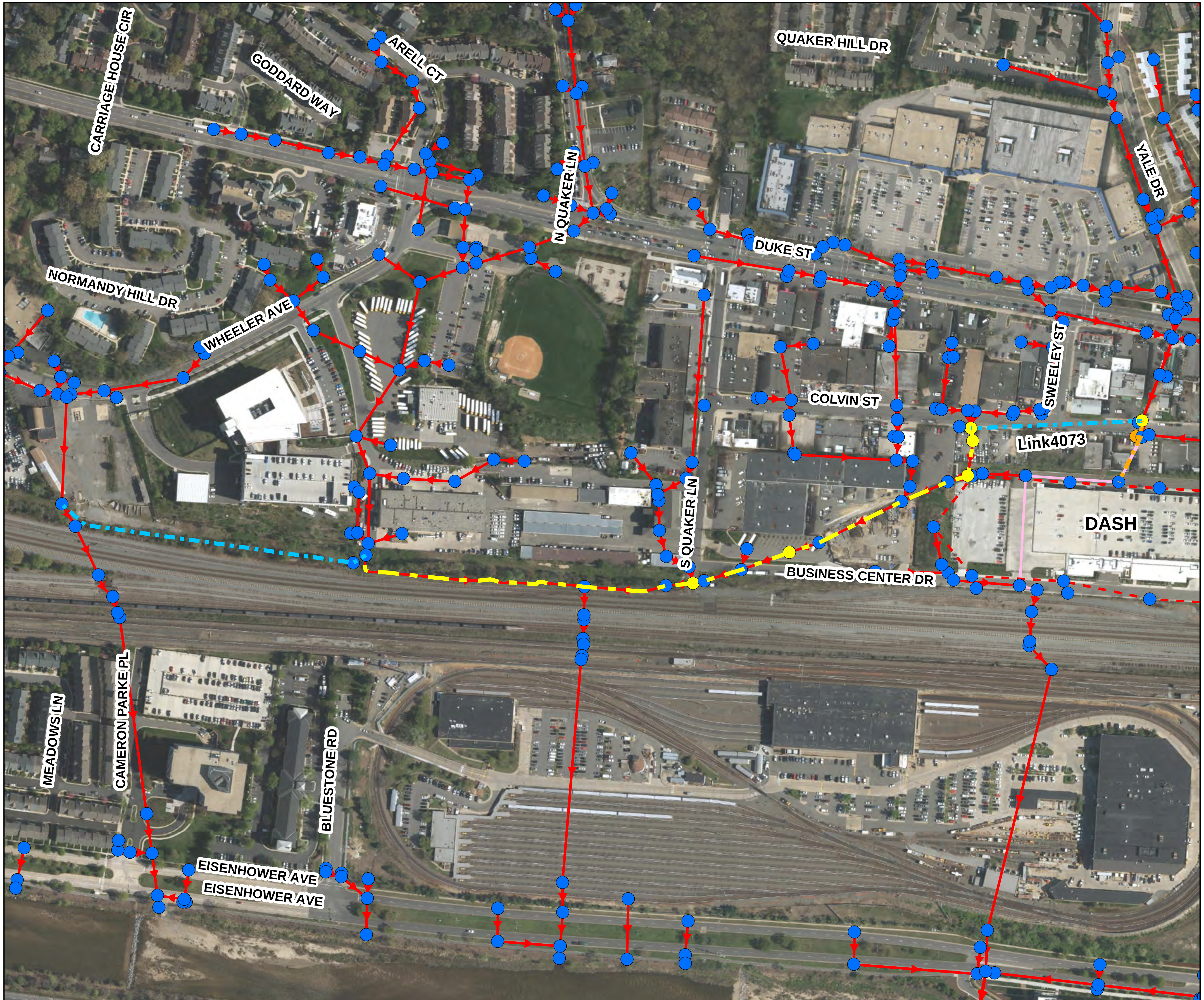


Legend

- New SW Pipe/Channel
- Remove SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- Remove SW Structure
- Replace SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System

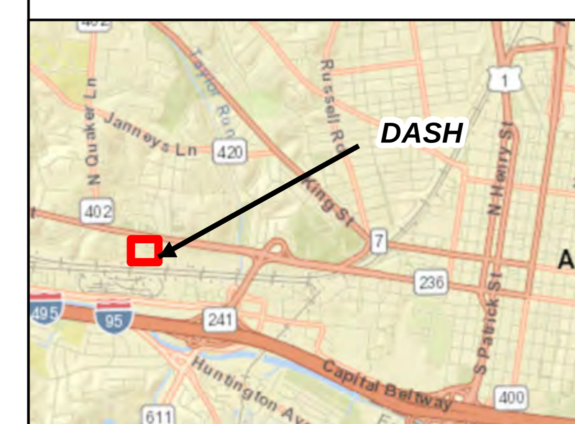
CITY OF ALEXANDRIA VIRGINIA

Michael Baker INTERNATIONAL

0 100 200 400 600 Feet

1 inch = 260 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
Baker Project No: 169362



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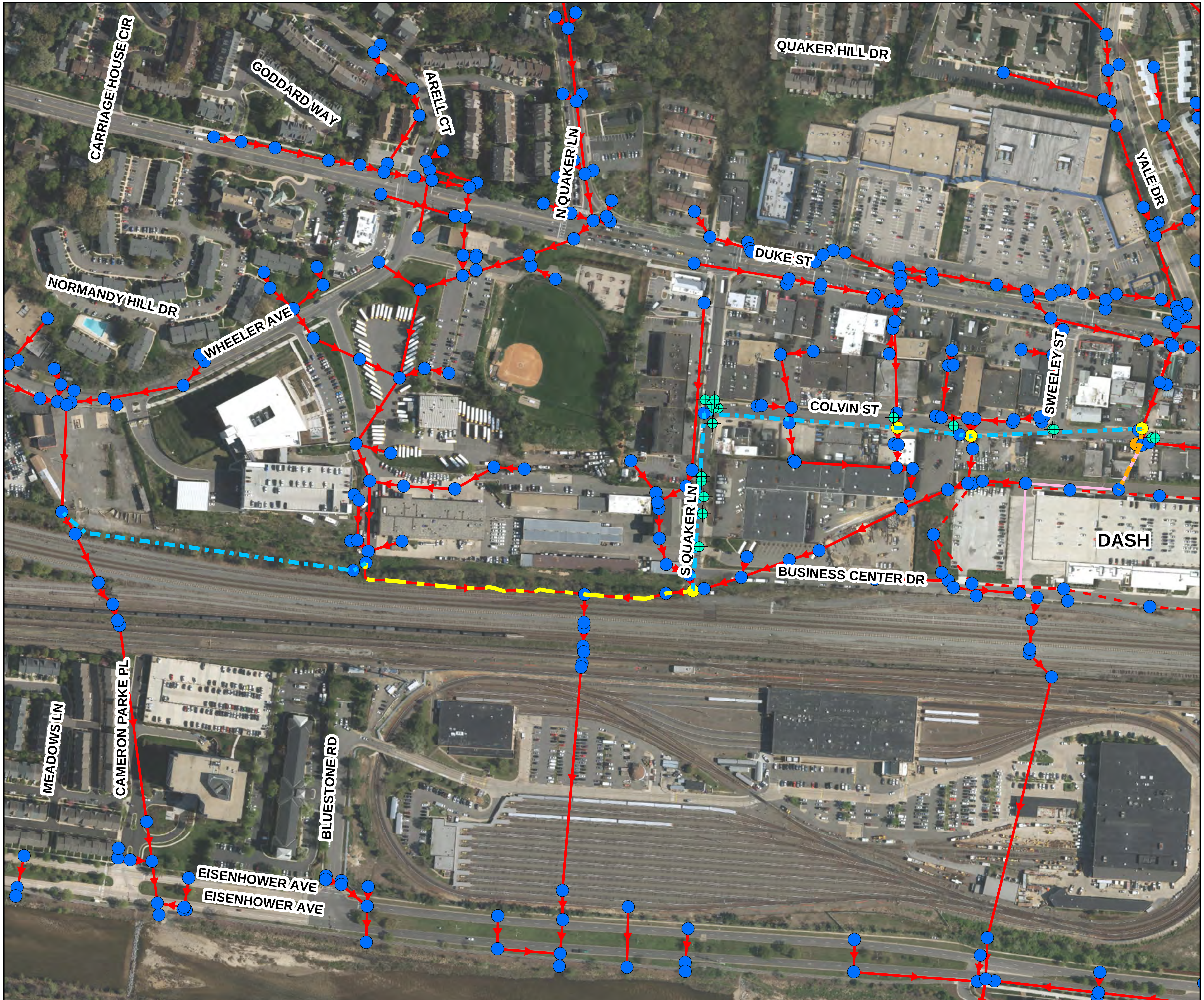

Figure 22: ROUTE - 2 OVERVIEW

Alexandria, Virginia

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Legend

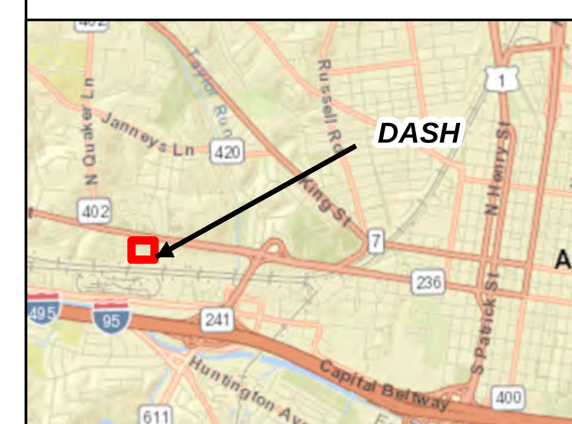
- Utilities
- New SW Pipe/Channel
- Remove SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- Remove SW Structure
- Replace SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System

Michael Baker INTERNATIONAL

0 100 200 400 600 Feet

1 inch = 260 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
Baker Project No: 169362



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was outside the scope of this study, Michael Baker did not investigate what upgrades are needed in the Taylor Run watershed storm sewer system to accommodate the additional flows for the re-route to the east on Colvin Street option. This has been noted in the result and cost discussions, as additional efforts would be required to investigate the feasibility of upgrading that system. In addition to investigating upgrades to the system in the Taylor Run watershed, potential capacity issues at the Taylor Run Culverts under the railroad tracks will also need to be investigated.

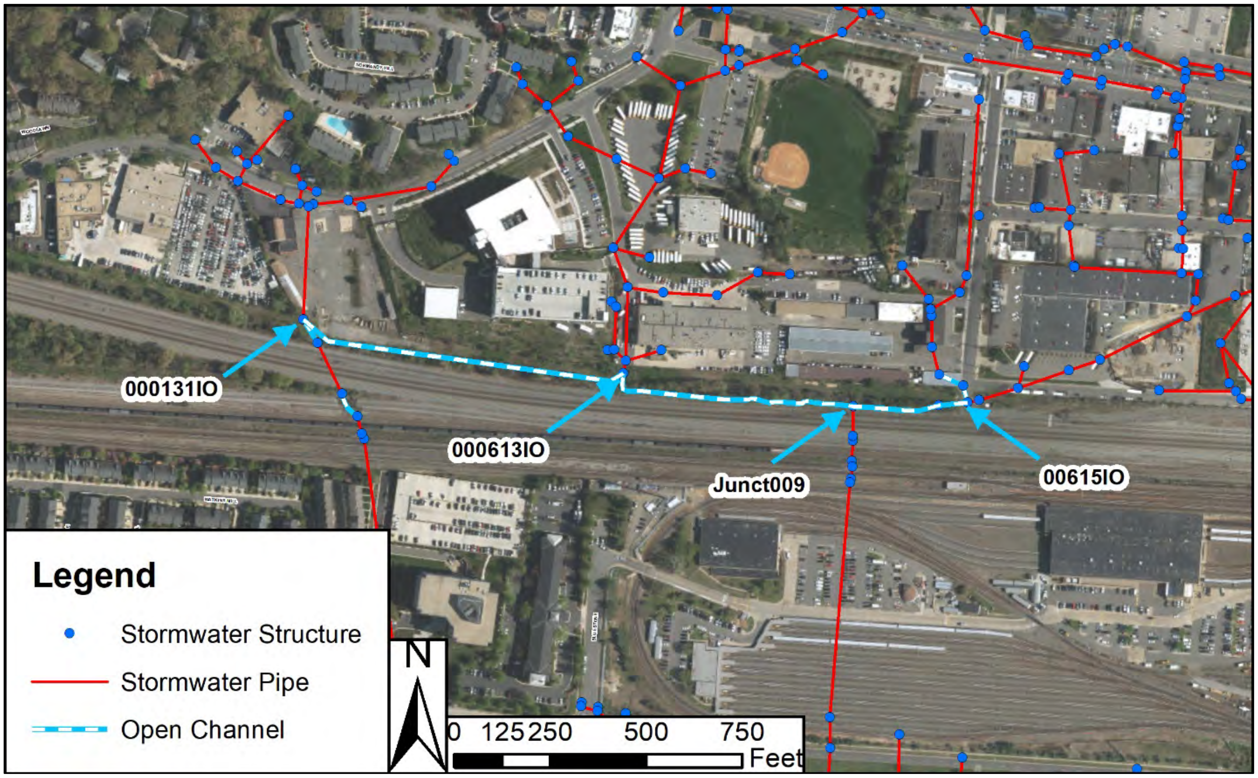


Figure 23. Overview of Open Channel

Improvements to the open channel downstream of the S. Quaker Lane Outfall

To accommodate the additional flow received at the S. Quaker Lane outfall by either ROUTE-1 or ROUTE-2 alternatives, modifications to the open channel west of the outfall, would be needed. **Figure 23** shows a close-up of this area. It should be noted that Michael Baker determined the proposed improvements based on aerial imagery and pipe and channel information from the XPSWMM model and topographic data. Additional detailed site information will be required, including consultation with the CSX and Norfolk Southern rail companies to fully identify potential constraints and the most suitable options available.

Below are some of the key elements for re-routing within the open channel:

- The open channel that conveys runoff from the S. Quaker Lane outfall also receives runoff from the Police Station outfall to the west. The open channel conveys its runoff to the Middle culvert system. Parts of this system run under flooding conditions during the 10-year event. Therefore, the introduction of additional runoff into this channel, from re-routing to the S. Quaker Lane outfall, will exacerbate the conditions in the channel and at the culvert system.

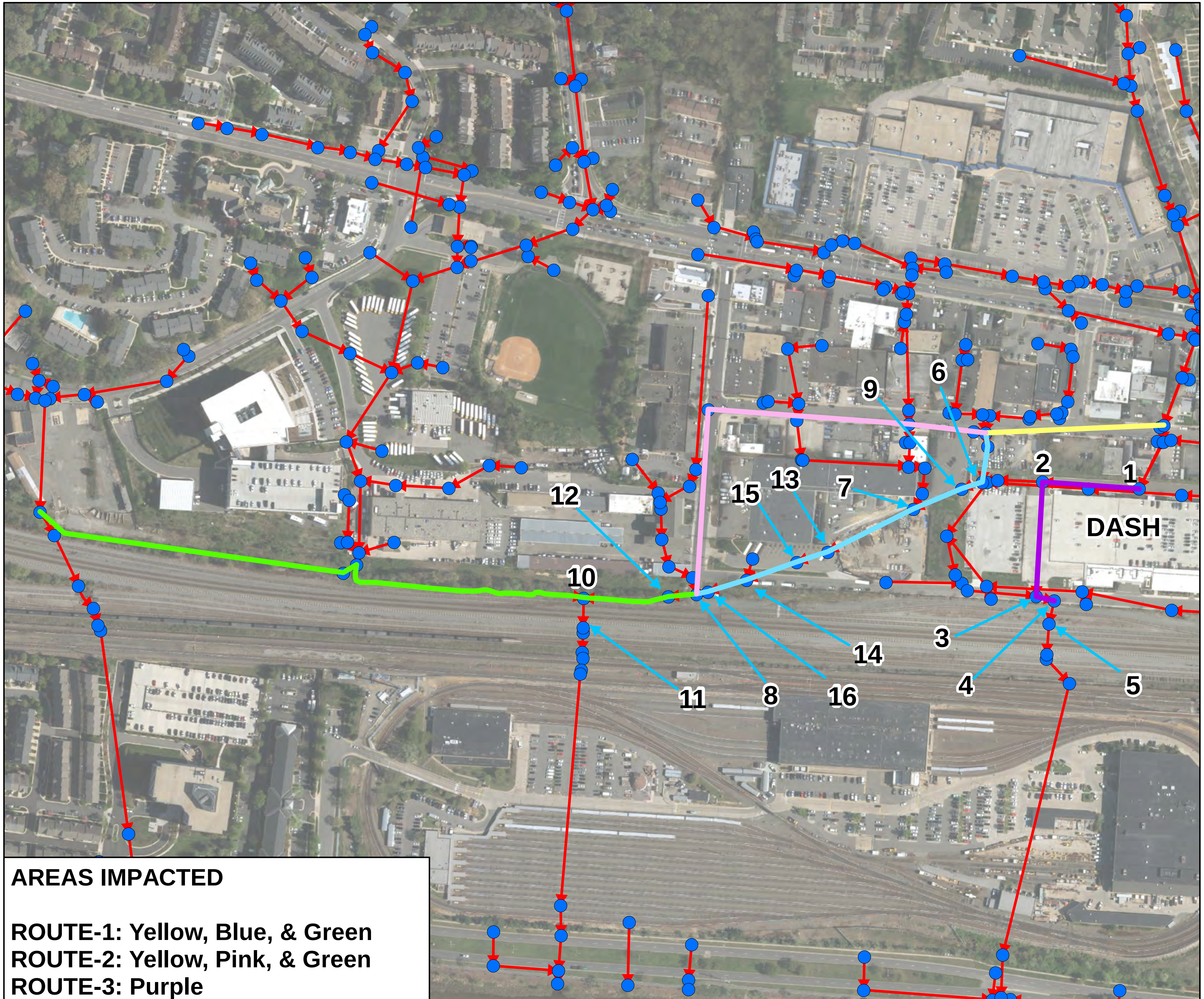
- ❖ To offset the additional flow from the S. Quaker Lane outfall, it is proposed to re-route the flow from the Police Station outfall to a channel west of the outfall that would convey flow to the West culvert system. The West culvert system has excess capacity during the 10-year event since its drainage area is small (approximately 50 acres) and its minimum pipe diameter is six feet.
- ❖ To enable the Police Station outfall to convey flow to the west channel rather than to the east channel, high-ground immediately west of the outfall will need to be re-graded to allow positive drainage. Some modifications to the channel may be required to ensure it can safely accommodate the additional flows.
- ❖ This modification will allow the peak volumes to be spread out more evenly amongst the three culvert systems in the watershed.
- ❖ During the modeling it was noted that the increased flow at the S. Quaker Lane outfall exceeds the flow from the Police Station outfall. Therefore, under this scenario, the Middle culvert system will still receive increased runoff volumes.
- ❖ While it is likely that this increased volume will not impact the conditions at that channel, which can hold a significant amount of water for a short duration, a potential modification would be to make the channel between the Middle culvert system and the Police Station outfall revert slightly towards the Police Station outfall with a berm further west. Therefore, if flow buildup occurs within the channel, it can flow over the berm and into the channel further west and to the West culvert system which retains hydraulic capacity during the 10-year event. This option will need to be carefully evaluated with more field data, but as a worst-case condition, the modeling and cost proposals also consider this option.

The above approach would ensure that the stormwater diverted from the DASH facility area can still be conveyed to Cameron Run without any significant impact to any downstream locations within the watershed. Additionally, it leverages existing infrastructure to convey stormwater away from critical structures and without the need to impact railroad operations. However, a significant amount of work within the railroad ROW will be required. It should be noted that a thorough investigation will need to be performed to identify the suitability of upgrading the open channel to better convey flow between the two culvert systems (Middle Culvert system and West Culvert system). The City data shows the open channel in its GIS data and channel invert elevations suggest that the flow can be diverted to better utilize the hydraulic capacities of the two culvert systems. Some flooding within the channel area will not cause any adverse impacts and there may be multiple opportunities to mitigate any adverse impacts from the additional flow.

Figure 24 shows the portion of the existing system that is potentially affected due to either of the re-routing options to the west on Colvin Street. The model results of the affected portion are compared to the baseline model for each of the proposed alternatives (for easier comparison, the nodes are numbered in **Figure 24** and referenced in the following Tables).

Figure 24: ROUTING WEST

Alexandria, Virginia



N
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Legend

- ROUTE-1, 2, & 3
- ROUTE-1
- ROUTE-2
- ROUTE-1 & 2
- ROUTE-3
- Existing SW Structure
- Stormwater Pipe/Channel

Michael Baker INTERNATIONAL

0 125 250 500 Feet

1 inch = 250 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
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3.5.1. ROUTE-1, 2, & 3

ROUTE-1

Table 10 shows the comparison of model results of this alternative to the baseline model for specific stormwater structures as identified in **Figure 24** near the DASH facility. According to the results, re-routing to the west on Colvin Street and connecting to the system west of the DASH facility could mitigate most of the flooding at DASH, by almost 90 percent at 002485IN, which is the most critical node. Proposed pipe and structure modifications for this alternatives are outlined in **Table 11** and **Table 12** and overview maps are provided in **Figure 25** through **Figure 28**.

Table 10. XPSWMM Results for ROUTE-1

Node		Flood Volume [ft^3]		
		Baseline	Proposed Alternative	Flood Reduction
1	002485IN	361,555	96,358	73%
2	002486IN	10,467	7,018	34%
3	003546SMH	0	0	0%
4	003547SMH	0	0	0%
5	000314ND	0	0	0%
6	Node5154	27,374	0	100%
7	Node5158	0	0	0%
8	00615IO	65,927	37,941	42%
9	Node5154.1	0	0	0%
10	Junct009	134,380	41,299	69%
11	Junct008	850	0	100%
12	Junct015	56,089	22,354	60%
13	00840SMH	0	0	0%
14	000846SMH	0	0	0%
15	000848SMH	0	0	0%
16	002382ND	17,131	8,629	49%

***Green: Near-DASH pipe system**

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Figure 25: ROUTE - 1

Alexandria, Virginia

N W E S

Legend

- Utilities
- New SW Pipe/Channel
- Remove SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- Remove SW Structure
- Replace SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

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0 20 40 80 120 Feet

1 inch = 60 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
Baker Project No: 169362

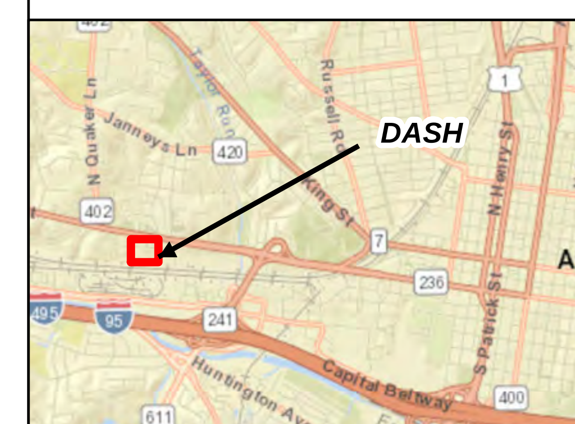

Table 11. Proposed Pipe Modifications for ROUTE-1

Link	Status	From Node	To Node	Shape	Diameter/ Height [ft]	Barrels/Z	Length [ft]	US Elev. [ft]	DS Elev. [ft]	Comments
001263STMP	Remove	000819SMH	002435IN	-	-	-	-	-	-	Helps to reroute
004205STMP	Remove	002435IN	002485IN	-	-	-	-	-	-	Helps to reroute
001264STMP	Remove	002436IN	002435IN	-	-	-	-	-	-	Helps to reroute
Link4073	New	000819SMH	002444IN	Circular	4.5	2	472	43	40	New pipe through Colvin St
001249STMP	Replace	002444IN	000176IO	Circular	4.5	2	34.8	40	41.8	Improve capacity
CRpipe25	Replace	000176IO	Node5154	Circular	4.5	2	97.3	39	35.83	Improve capacity
Link4058	Replace	Node5154	Node5154.1	Circular	5	2	60	35.83	35.8	Improve capacity
Link4058.1	Replace	Node5154.1	Node5158	Circular	5	2	132	35.82	35.77	Improve capacity
015121STMP	Replace	Node5158	000840SMH	Circular	5	2	267.69	35.77	35.19	Improve capacity
004202STMP	Replace	000840SMH	000848SMH	Circular	5	2	85.51	35.19	35.1	Improve capacity
004203STM	Replace	000848SMH	000846SMH	Circular	5	2	141.31	35.1	35.04	Improve capacity
004220STMP	Replace	000846SMH	002382ND	Circular	5	2	116.87	35.04	33.32	Improve capacity
015110STMP	Replace	002382ND	00615IO	Circular	5	2	35.63	33.32	33	Improve capacity
OpenCh02	Replace	00615IO	Junct015	Natural	6	0.5	118.517	33	33	Change to trapezoid channel (6/0.5/4)
OpenCh04	Replace	Junct015	Junct009	Natural	6	0.5	197.76	33	33	Change to trapezoid channel (6/0.5/4)
OpenCh05	Replace	Junct009	000613IO	Natural	6	0.5	638.157	33	32	Reverse Flow. Change to trapezoid channel (6/0.5/4)
OpenChW	New	000613IO	000031CP	Natural	6	0.5	847	32	30	Open Chanel (Width:6/Z:0.5/D:4)
Weir Channel	New	000613IO	Node5169	Weir	3	-	10			Hydraulic Structure

Table 12. Proposed Structure Modifications for ROUTE-1

Node	Status	Spill Crest [ft]	Invert Elevation [ft]	Ponding	Comments
002436IN	Remove	-	-	-	Helps to reroute
002435IN	Remove	-	-	-	Helps to reroute
000819SMH	Replace	51.725	43	Allowed	Lower Invert
002444IN	Replace	49.093	40	Allowed	Lower Invert
000176IO	Replace	48.303	39	Allowed	Lower Invert
Node5154	Replace	43	35.83	Allowed	Raise Spill Crest
000848SMH	Replace	42.1	35.1	Allowed	Raise Invert
000613IO	Replace	46.79	32	Allowed	Lower Invert
00615IO	Replace	38.12	33	Allowed	Lower Invert
Node5170	New	36	32	None	For Weir
Junct015	Replace	38.5	33	Allowed	Lower Invert
Junct009	Replace	38	33	Allowed	Lower Invert

Figure 26: ROUTE - 1

Alexandria, Virginia

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Legend

- Utilities
- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- Replace SW Structure
- Stormwater Pipe
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

CITY OF ALEXANDRIA VIRGINIA

Michael Baker INTERNATIONAL

0 20 40 80 120 Feet

1 inch = 60 feet

DASH FLOODING ANALYSIS
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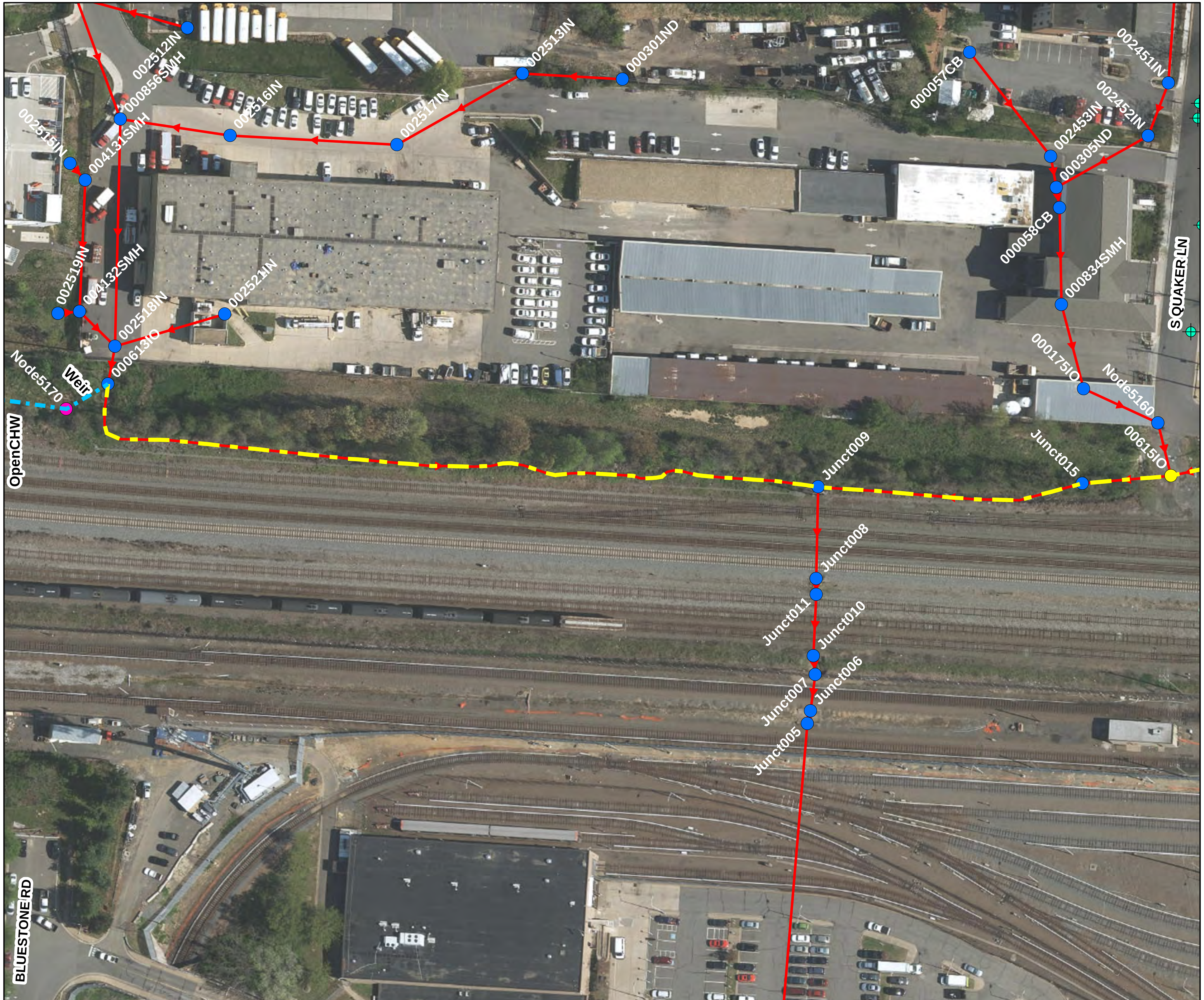
Figure 27: ROUTE - 1

Alexandria, Virginia



N
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Legend

- Utilities
- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- New SW Structure
- Replace SW Structure
- Stormwater Pipe

Michael Baker INTERNATIONAL

0 30 60 120 180 Feet

1 inch = 80 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
Baker Project No: 169362

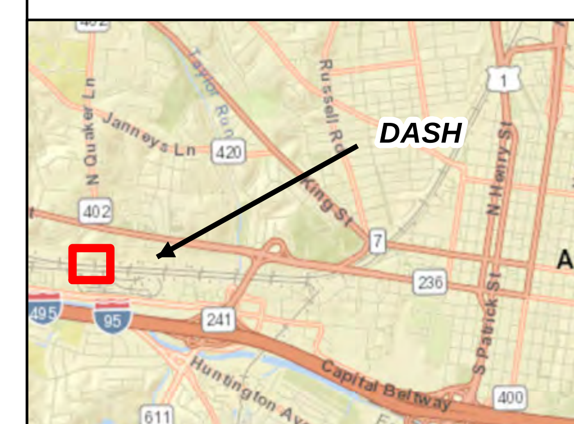

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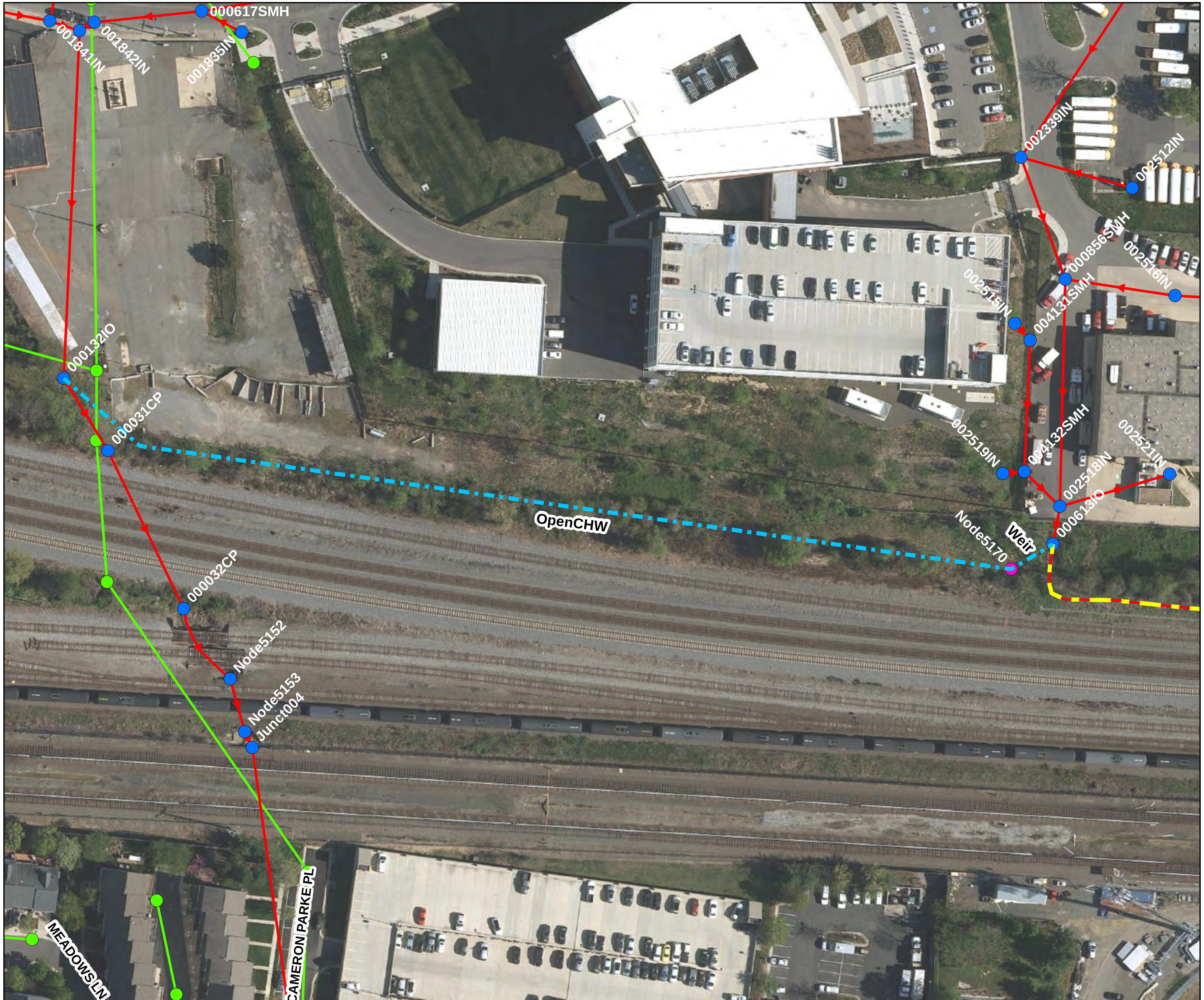
Figure 28: ROUTE - 1

Alexandria, Virginia



N
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Legend

- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- New SW Structure
- Stormwater Pipe
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

Michael Baker INTERNATIONAL

0 30 60 120 180 Feet

1 inch = 80 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
Baker Project No: 169362

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ROUTE-2

The model results of this alternative show a significant reduction of flooding at the stormwater structures at the DASH facility amounting to a 75 percent reduction at node 002485IN. Despite the significant reduction of flooding, some nodes still surcharge and results in contributing to surface flooding (**Table 13**). A combination of upstream storage and upgrading the existing stormwater system may be incorporated to mitigate most of the remaining flooding. Proposed pipe and structure modifications for this alternative are outlined in **Table 14** and **Table 15** and overview maps are provided in **Figure 29** through **Figure 32**.

Table 13. XPSWMM Results for ROUTE-2

Node		Flood Volume [ft^3]		
		Baseline	Proposed Alternative	Flood Reduction
1	002485IN	361,555	75,429	79%
2	002486IN	10,467	968	91%
3	003546SMH	0	0	0%
4	003547SMH	0	0	0%
5	000314ND	0	0	0%
6	Node5154	27,374	7,358	73%
7	Node5158	0	0	0%
8	00615IO	65,927	42,583	35%
9	Node5154.1	0	0	0%
10	Junct009	134,380	13,808	90%
11	Junct008	850	0	100%
12	Junct015	56,089	17,821	68%
13	00840SMH	0	0	0%
14	000846SMH	0	0	0%
15	000848SMH	0	0	0%
16	002382ND	17,131	10,285	40%

***Green: Near-DASH pipe system**

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Figure 29: ROUTE - 2

Alexandria, Virginia

N
W E
S

Legend

- Utilities
- New SW Pipe/Channel
- Remove SW Pipe/Channel
- Existing SW Structure
- Remove SW Structure
- Replace SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

Michael Baker INTERNATIONAL

0 20 40 80 120 Feet

1 inch = 60 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
Baker Project No: 169362

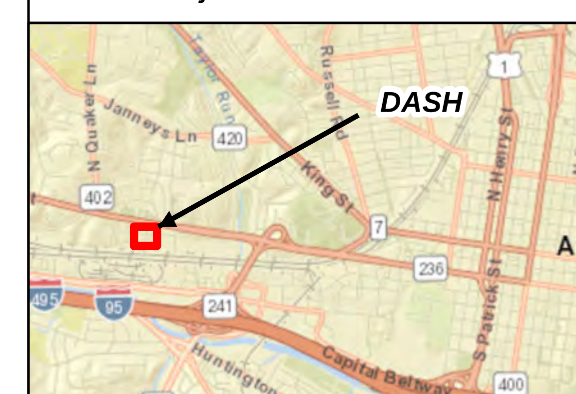

Table 14. Proposed Pipe Modifications for ROUTE-2

Link	Status	From Node	To Node	Shape	Diameter/ Height [ft]	Barrels/Z	Length [ft]	US Elev. [ft]	DS Elev. [ft]	Comments
004205STMP	Remove	002435IN	002485IN	-	-	-	-	-	-	Helps to reroute
001264STMP	Remove	002436IN	002435IN	-	-	-	-	-	-	Helps to reroute
Link4073	New	000819SMH	002444IN	Circular	4.5	2	472	43	40	Pipe through Colvin St.
Link4074	New	002444IN	00826SMH	Circular	4.5	2	204	40	39	Improve capacity
Link4078	New	00826SMH	Node5169	Circular	4.5	2	555	39	37	Improve capacity
Link4077	New	Node5169	00615IO	Circular	4.5	2	480	39	33	Improve capacity
OpenCh02	Replace	00615IO	Junct015	Natural	4		118.517	33	33	Change to trapezoid channel (6/0.5/4)
OpenCh04	Replace	Junct015	Junct009	Natural	4		197.76	33	33	Change to trapezoid channel (6/0.5/4)
OpenCh05	Replace	Junct009	000613IO	Natural	4		638.157	33	32	Reverse Flow. Change to trapezoid channel (6/0.5/4)
OpenChW	New	Node5170	000031CP	Natural	4		847	32	30	Open Chanel (Width:6/Z:0.5/D:4)
Weir Channel	New	000613IO	Node5170	Weir	3	-	10	-	-	Hydraulic Structure

Table 15. Proposed Structure Modifications for ROUTE-2

Node	Status	Spill Crest [ft]	Invert Elevation [ft]	Ponding	Comments
002436IN	Remove	-	-	-	Helps to reroute
002435IN	Remove	-	-	-	Helps to reroute
000819SMH	Replace	51.725	43	Allowed	Lower Invert
002444IN	Replace	49.093	40	Allowed	Lower Invert
00826SMH	Replace	53.69	39	Allowed	Lower Invert
Node5169	New	70	37	Allowed	Colvin St./S. Quaker. Ln.
000613IO	Replace	46.79	32	Allowed	Lower Invert
00615IO	Replace	38.12	33	Allowed	Lower Invert
Node5170	New	36	32	None	For Weir
Junct015	Replace	38.5	33	Allowed	Lower Invert
Junct009	Replace	38	33	Allowed	Lower Invert

Figure 30: ROUTE - 2

Alexandria, Virginia

N
W E
S

Legend

- Utilities
- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- New SW Structure
- Replace SW Structure
- Stormwater Pipe
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

Michael Baker INTERNATIONAL

0 25 50 100 150 Feet

1 inch = 70 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
Baker Project No: 169362

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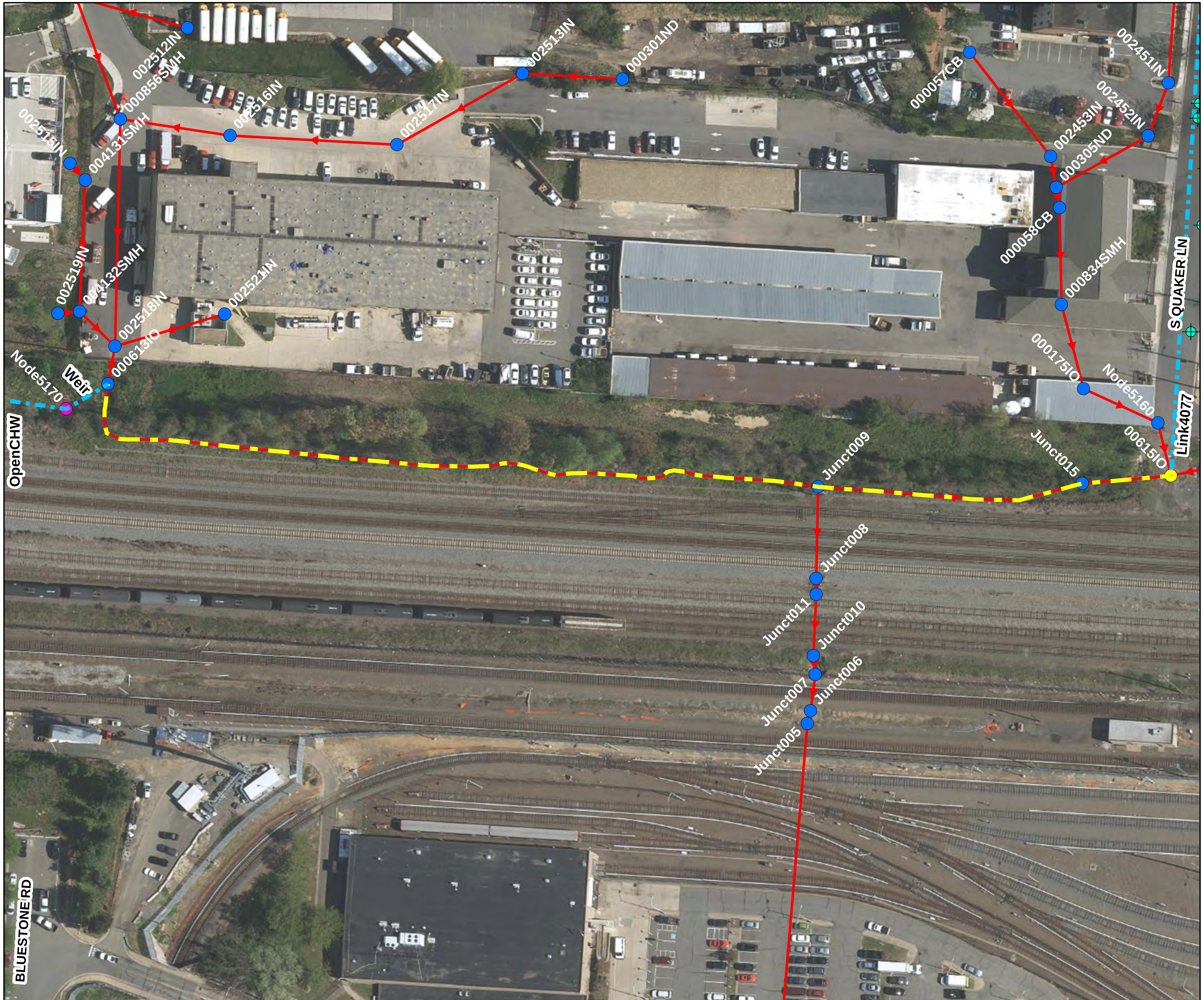
Figure 31: ROUTE - 2

Alexandria, Virginia

N
W E
S



Legend

- Utilities
- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- New SW Structure
- Replace SW Structure
- Stormwater Pipe

Michael Baker INTERNATIONAL

0 30 60 120 180 Feet

1 inch = 80 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
Baker Project No: 169362

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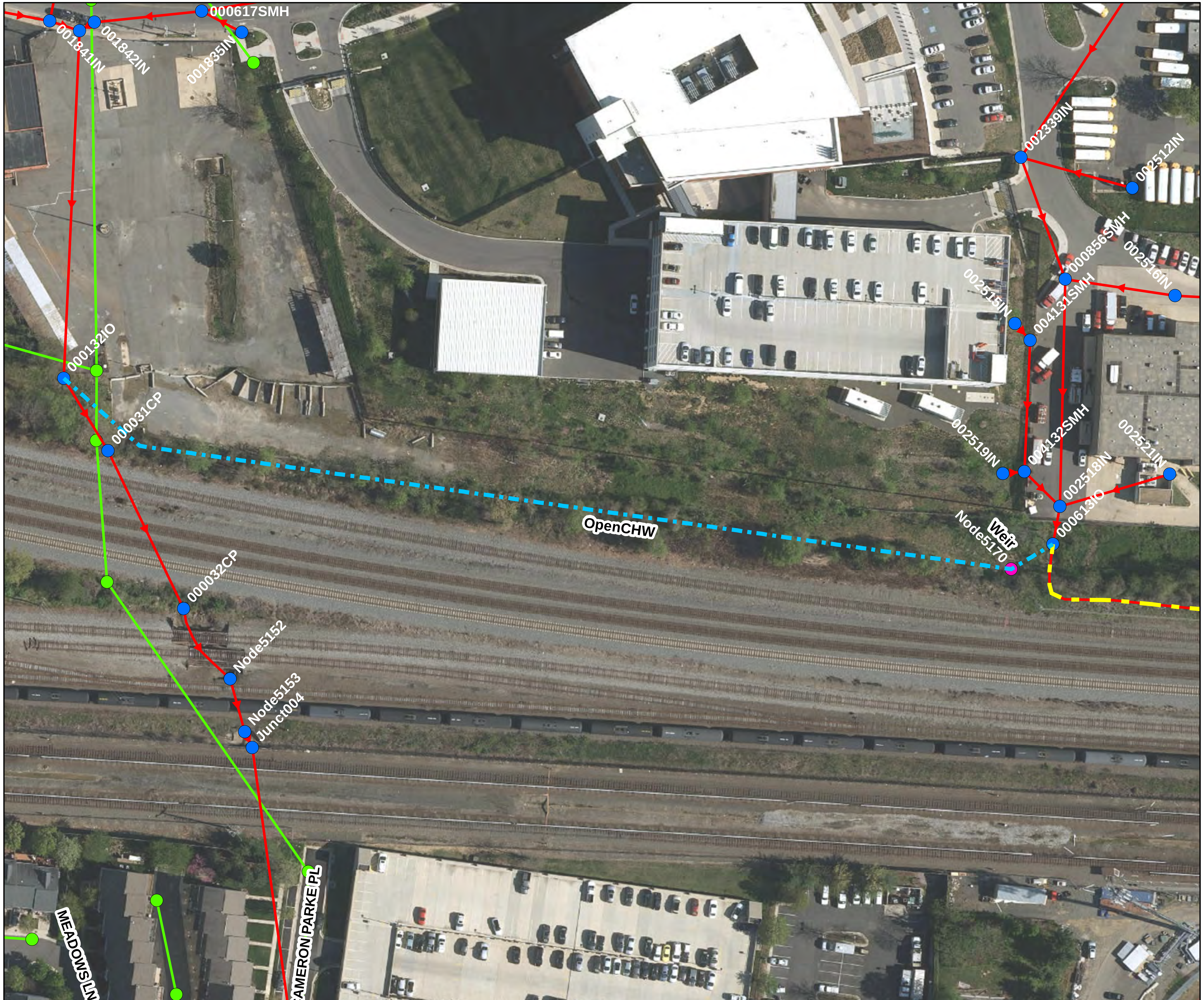

Figure 32: ROUTE - 2

Alexandria, Virginia

N
W E
S

Legend

- Utilities
- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- New SW Structure
- Stormwater Pipe
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

0 30 60 120 180 Feet

1 inch = 80 feet

DASH FLOODING ANALYSIS
OF ALTERNATIVES
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ROUTE-3

This alternative is similar to the first proposed re-routing alternative but does not involve upgrading the downstream storm sewer system west of the DASH facility. Instead, it involves upgrading the main storm sewer system at the DASH facility to 5-foot diameter twin pipes. Similar to the first proposed re-routing alternative, this option also significantly reduces the flooded volume at many of the critical nodes. At node 002485IN there is a reduction of 89 percent as compared to 75 percent when only re-routing was incorporated (**Table 16**). Proposed pipe and structure modifications for this alternative are outlined in **Table 17** and **Table 18** and overview maps are provided in **Figure 33**.

Table 16. XPSWMM Results for ROUTE-3

Node		Flood Volume [ft^3]		
		Baseline	Proposed Alternative	Flood Reduction
1	002485IN	361,555	45,664	87%
2	002486IN	10,467	9,346	13%
3	003546SMH	0	2,203	Increased Flooding
4	003547SMH	0	0	0%
5	000314ND	0	0	0%
6	Node5154	27,374	25,295	8%
7	Node5158	0	0	0%
8	00615IO	65,927	63,008	4%
9	Node5154.1	0	0	0%
10	Junct009	134,380	129,012	4%
11	Junct008	850	598	28%
12	Junct015	56,089	53,440	5%
13	00840SMH	0	0	0%
14	000846SMH	0	0	0%
15	000848SMH	0	0	0%
16	002382ND	17,131	16,516	3%

***Green: Near-DASH pipe system**

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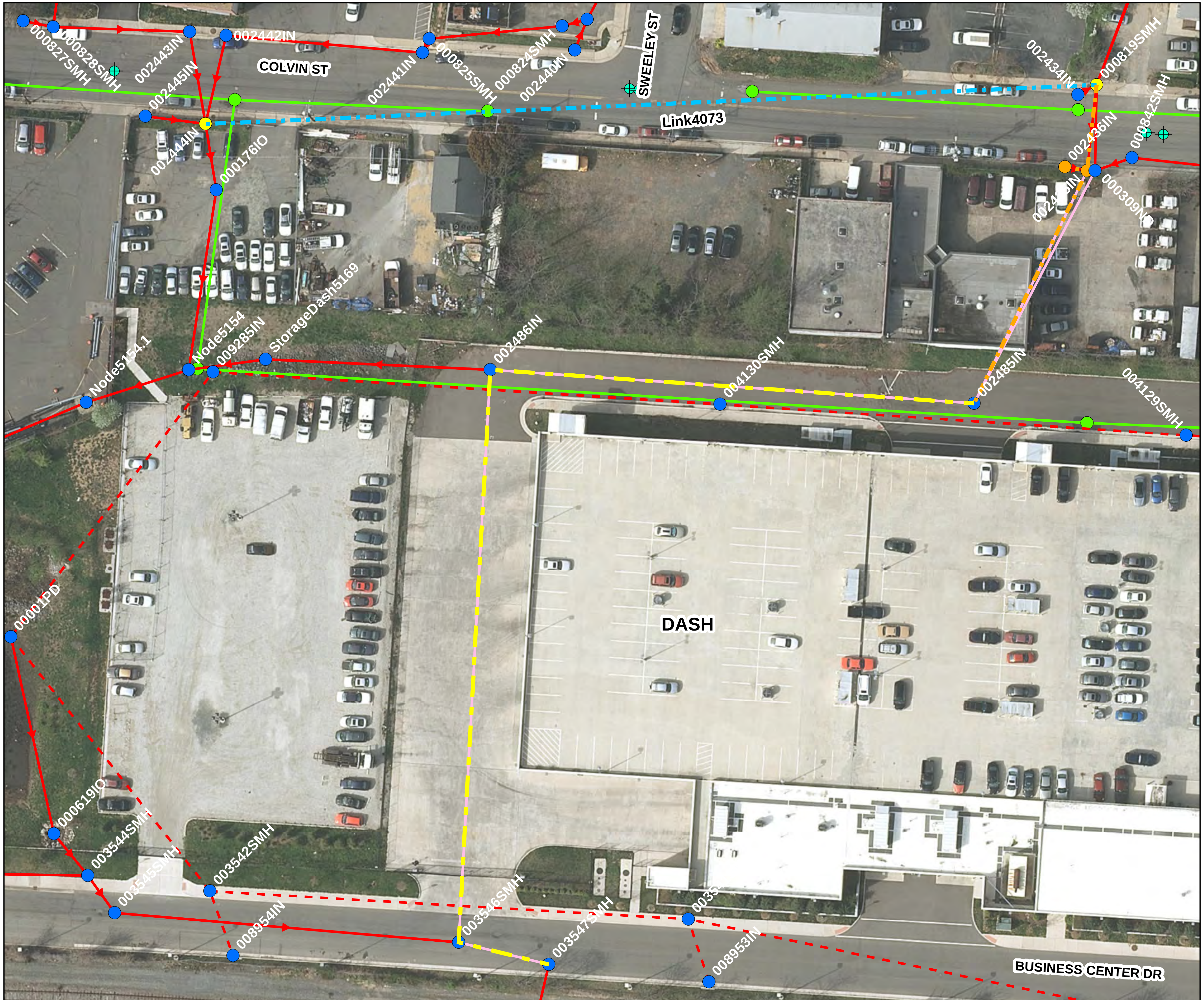

Figure 33: ROUTE - 3

Alexandria, Virginia

N W E S

Legend

- Utilities
- New SW Pipe/Channel
- Remove SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- Remove SW Structure
- Replace SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe

Michael Baker INTERNATIONAL

0 15 30 60 90 Feet

1 inch = 50 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
Baker Project No: 169362

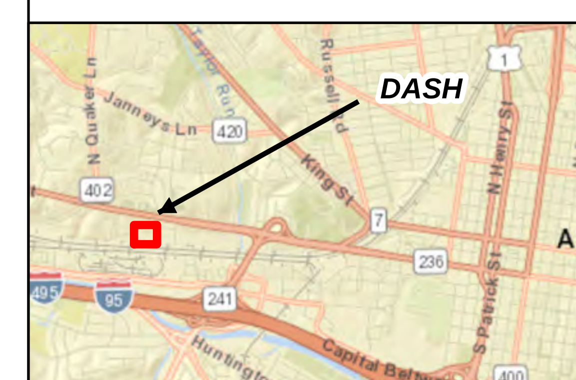

Table 17. Proposed Pipe Modifications for ROUTE-3

Link	Status	From Node	To Node	Shape	Diameter/ Height [ft]	Barrels/Z	Length [ft]	US Elev. [ft]	DS Elev. [ft]	Comments
001263STMP	Remove	000819SMH	002435IN	-	-	-	-	-	-	Helps to reroute
004205STMP	Remove	002435IN	002485IN	-	-	-	-	-	-	Helps to reroute
001264STMP	Remove	002436IN	002435IN	-	-	-	-	-	-	Helps to reroute
Link4073	New	000819SMH	002444IN	Circular	4.5	2	472	44.325	42	Through Colvin St.
004208STMP	Replace	002485IN	002486IN	Circular	5	2	216	30.7	29.93	Improve Capacity
004903STMP	Replace	002486IN	0035465SMH	Circular	5	2	304	29.63	28.89	Improve Capacity
013331STMP	Replace	0035465SMH	003547SMH	Circular	5	2	51	28.44	28.4	Improve Capacity

Table 18. Proposed Structure Modifications for ROUTE-3

Node	Status	Spill Crest [ft]	Invert Elevation [ft]	Ponding	Comments
002436IN	Remove	-	-	-	Helps to reroute
002435IN	Remove	-	-	-	Helps to reroute
002444IN	Replace	49.093	42	Allowed	Lower Invert

3.5.2. ROUTE-4

Only one alternative was modeled for re-routing east on Colvin Street and connecting to the storm sewer system in the Taylor Run watershed. The results show a significant amount of surcharge mitigated from some critical nodes, including a 90 percent reduction at node 002485IN (**Table 19**). However, lack of information downstream of Colvin St. within the Taylor Run stormwater system could invalidate this alternative if significant downstream capacity issues exist.

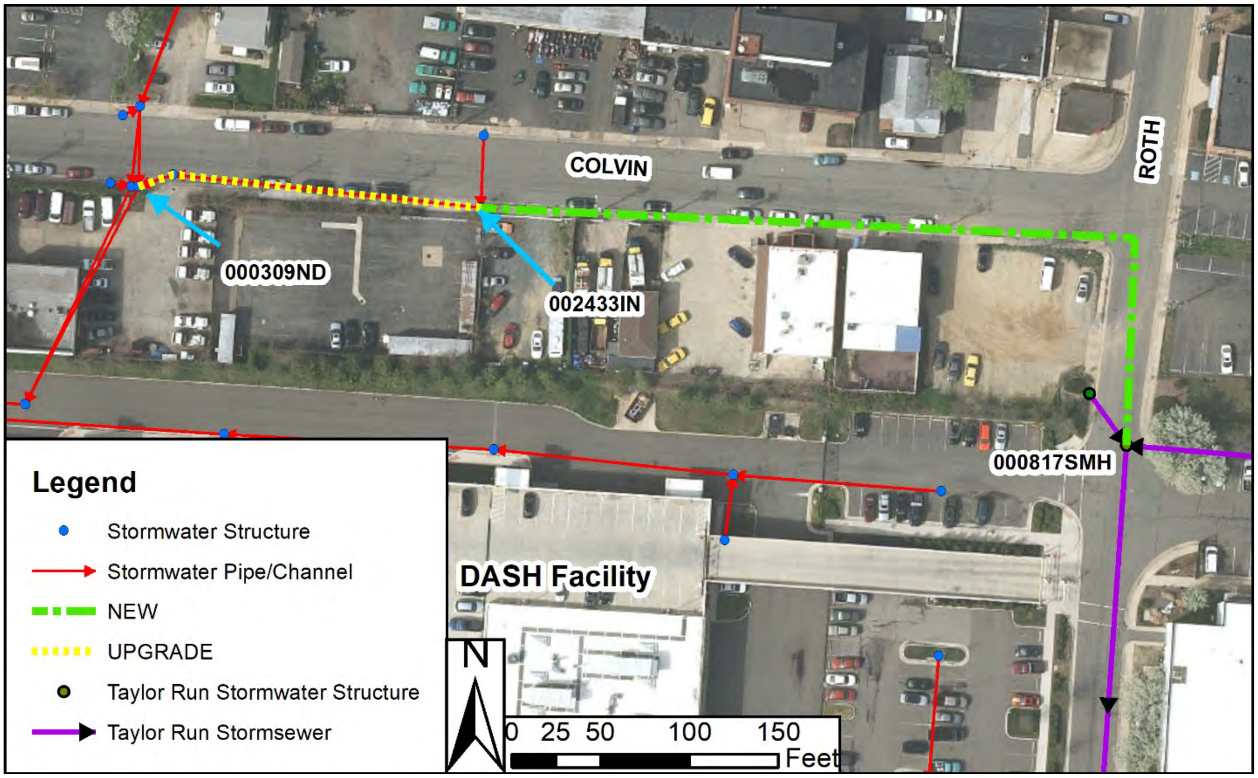

Figure 34. ROUTE-4 Overview

Table 19. XPSWMM Results for ROUTE-4

Node		Flood Volume [ft^3]		
		Baseline	Proposed Alternative	Flood Reduction
1	002485IN	361,555	30,791	91%
2	002486IN	10,467	796	93%
3	003546SMH	0	500	Increased Flooding
4	003547SMH	0	0	0%
5	000314ND	0	0	0%
6	Node5154	27,374	7,907	71%
7	Node5158	0	0	0%
8	00615IO	65,927	53,583	19%
9	Node5154.1	0	0	0%
10	Junct009	134,380	118,117	12%
11	Junct008	850	139	83%

Node		Flood Volume [ft³]		
		Baseline	Proposed Alternative	Flood Reduction
12	Junct015	56,089	48,069	14%
13	00840SMH	0	0	0%
14	000846SMH	0	0	0%
15	000848SMH	0	0	0%
16	002382ND	17,131	12,537	27%

***Green: Near-DASH pipe system**

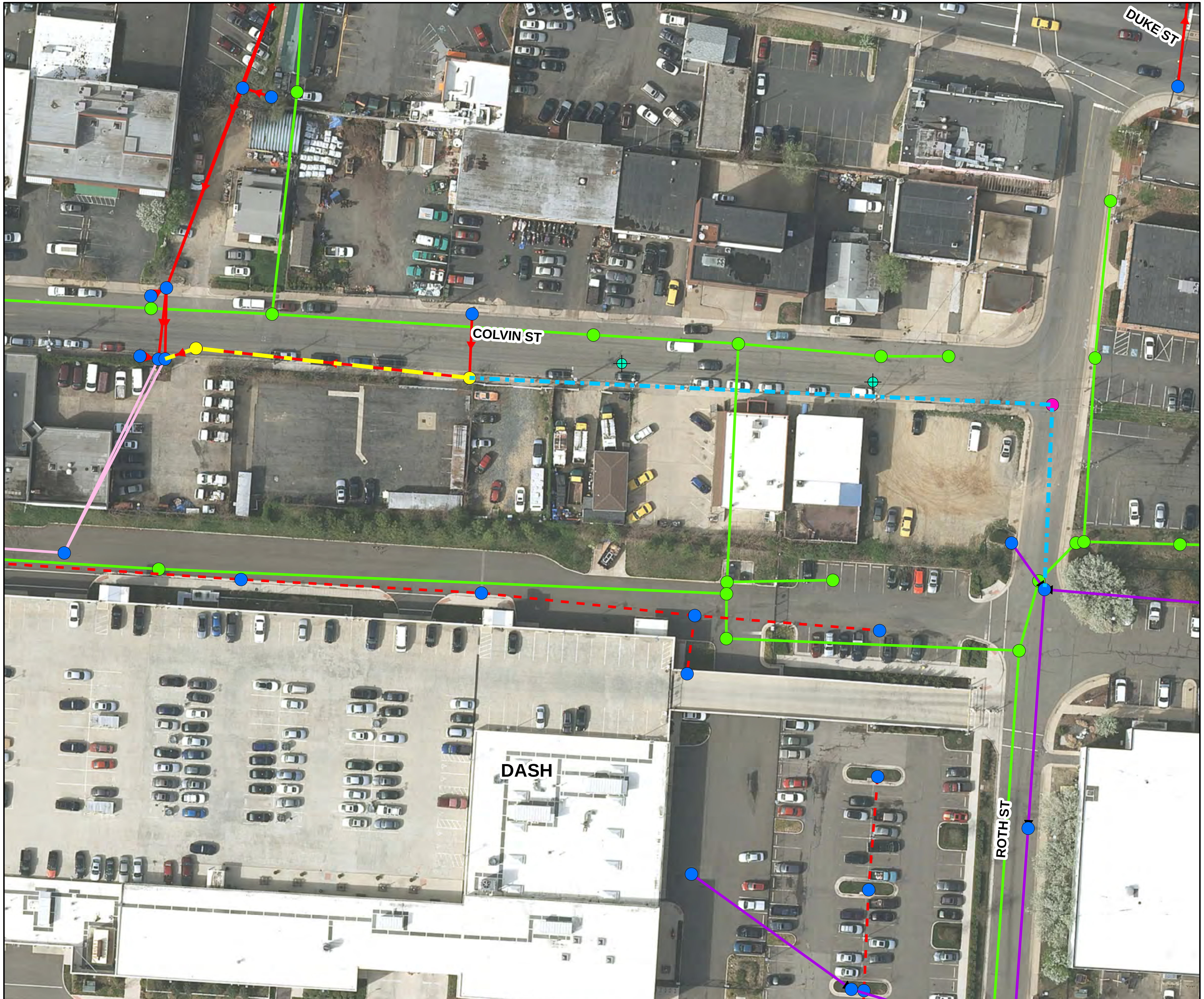

Figure 35: ROUTE - 4

Alexandria, Virginia

N
W E
S

Legend

- Utilities
- New SW Pipe/Channel
- Replace SW Pipe/Channel
- Existing SW Structure
- New SW Structure
- Replace SW Structure
- Stormwater Pipe
- Main Stormwater System
- Local Stormwater System
- Sanitary Sewer Structure
- Sanitary Sewer Pipe
- Taylor Run Stormwater Pipe

Michael Baker INTERNATIONAL

0 15 30 60 90 Feet

1 inch = 60 feet

DASH FLOODING ANALYSIS OF ALTERNATIVES
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Table 20. Proposed Pipe Modifications for ROUTE-4

Link	Status	From Node	To Node	Shape	Diameter/ Height [ft]	Barrels/Z	Length [ft]	US Elev. [ft]	DS Elev. [ft]	Comments
001263STMP	Remove	000819SMH	002435IN	-	-	-	-	-	-	Helps to reroute
004205STMP	Remove	002435IN	002485IN	-	-	-	-	-	-	Helps to reroute
001264STMP	Remove	002436IN	002435IN	-	-	-	-	-	-	Helps to reroute
001265STMP	Replace	000309ND	000842SMH	Circular	4.5	2	20.07	42.29	40	Reverse flow
004170STMP	Replace	000842SMH	002433IN	Circular	4.5	2	174	40	38	Reverse flow

Table 21. Proposed Structure Modifications for ROUTE-4

Node	Status	Spill Crest [ft]	Invert Elevation [ft]	Ponding	Comments
002436IN	Remove	-	-	-	Helps to reroute
002435IN	Remove	-	-	-	Helps to reroute
000842SMH	Replace	49.41	40	Allowed	Lower invert
002433IN	Replace	45.59	38	Allowed	Lower invert. Convert to outfall (simulating re-routing to Taylor Run)

3.6. Directional Drilling

Michael Baker investigated the feasibility of Horizontal Directional Drilling (HDD) into Cameron Run under the rail tracks. The railroads are used and operated by WMATA, VRE, CSX, and Amtrak. Carrier pipes located on CSX Transportation, Inc.'s (CSXT) ROW or under tracks which CSXT operates must be manufactured in accordance with the following specifications:

- CSXT – Design and Construction Standards Specifications – Pipeline Occupancies

These specifications apply to the design and construction of pipelines carrying flammable or non-flammable substances and casings containing wires, cables, and carrier pipes across and along CSXT property and facilities. These specifications provide construction requirements for different methods of installation listed below:

- Bore and Jack (Steel Pipe)
- Jacking (RCP and Steel Pipe)
- Tunneling (Tunnel Liner Plate)
- Horizontal Directional Drilling (HDD)
- Jack Conduit
- Open Cut – Not a readily accepted practice

The specifications state that HDD is considered a variance to CSXT Pipeline Occupancy Specifications. For additional information and instructions on HDD, the specifications reference the following document:

- Interim Guidelines for Horizontal Directional Drilling (HDD) Under the Property and Track(s) of CSX Transportation, Inc.

The document provides guidelines to govern the approval and execution of pipeline and wire line occupancies utilizing HDD. The CSXT guidance states the following:

- 4. Any pipe/conduit, regardless of commodity, with an outside diameter exceeding eight (8) inches shall be installed at a minimum depth of twenty-five (25) feet from base of rail. Any pipe that contains a liquid commodity (flammable or non-flammable) shall be installed at a minimum depth of 25' from base of rail. For natural gas, fiber optics, and electrical installations within a pipe/conduit with an outside diameter of eight (8) inches or less shall be installed at minimum depth of 15 feet from base of rail.

Improving the existing 36-inch outfall under the railroad tracks is infeasible using HDD if a minimum depth of 25-feet below the rail tracks is to be provided, as it would not be possible to have positive drainage to Cameron Run from the new system.

In January 2013, VRE undertook a study to determine the feasibility of proposed modifications to Alexandria Union Station intended to improve both ADA accessibility and passenger train operations. These modifications include a new pedestrian tunnel from the King Street-Old Town Metrorail Station to Alexandria Union Station and modifications to the east station platform. Due to railroad operational considerations, open cut construction was not considered for the new pedestrian tunnel. Three construction methods were considered within the feasibility study:

- **Tunnel Shield** - This method consists of a circular tunnel comprised of steel liner plates set inside a jacked and mined tunnel shield with cast-in-place lining. The liner plates are advanced using a hydraulic jack. Soil is then removed to form the tunnel.

- **Culvert Jacking** - This method consists of precast concrete square or rectangular tunnel segments jacked using a hydraulic jack. Soil is removed from the interior of the segments to form the tunnel (this method is not addressed in CSXT's – Design & Construction Standard Specifications - Pipeline Occupancies).
- **Sequential Excavation Method (SEM)** - In its classic form, the SEM attempts to mobilize the self-supporting capability of the ground to an optimum, thus achieving economy in ground support (this method is not addressed in CSXT's – Design & Construction Standard Specifications - Pipeline Occupancies).

The study was based on the use of the tunnel shield method for the following reasons:

- Culvert jacking and SEM are not addressed in CSXT's criteria, which could increase CSXT review time and construction monitoring requirements.
- A recent pedestrian tunnel project under CSXT tracks successfully used the tunnel shield method.

Based on CSXT – Design and Construction Standards Specifications – Pipeline Occupancies, casing/carrier pipes (conveying non-flammable substances) placed under CSXT track(s) shall be not less than 5.5 feet from base of rail to top of pipe at its shallowest point. Thus, if another method is proposed in place of HDD, improving the existing 36-inch outfall under the railroad tracks may be feasible.

The specifications require that a steel pipe shall not be used to convey sewage, stormwater, or other liquids that could cause corrosion. This limits the methods available to place or upgrade the existing storm sewer pipe. This restriction prevents us from using the Tunnel Shield method used by the VRE study. Thus, the only feasible method offered by the specifications is the Jacking of a Reinforced Concrete Pipe (RCP). This method consists of pushing sections of pipe into position with jacks placed against a backstop and excavation performed by hand from within the jacking shield at the head of the pipe. Jacking shall be in accordance with the current AREMA Guidelines, Chapter 1, Section 4.13, "Earth Boring and Jacking Culvert Pipe Through Fills." This operation shall be conducted without hand mining ahead of the pipe and without the use of any type of boring, auguring, or drilling equipment. Below are the required assumptions to design an RCP using the Jacked method:

- American Concrete Pipe Association design manual shall be used for design with:
  - Marston load theory used for earth load
  - Bedding (Load Factor) - LF = 3.0
  - Factor of safety = 1.25
  - Railroad impact as per Design Requirements-Design Loads Section of this specification.
  - Others – As approved by CSXT

Based on our analysis, it does not seem feasible to use HDD for constructing a new culvert under the railroad tracks. But CSXT may have special considerations for improving existing pipe systems. However, this will require a review from their engineers to identify potential options that may be feasible. Due to this, no cost estimates are provided for this option.

4. Conceptual Level Cost Analysis

The construction cost estimates are based on the best available information and engineering assumptions regarding the anticipated scope of each alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the detailed design and engineering process.

To create the estimates, Michael Baker International's Cost Management Division (CMD) compiled cost estimates for the flood mitigation alternatives based on drawings, interviews with manufacturers, dealers, distributors, and contractors, information provided by the City of Alexandria, and price lists available online for specific services and products. This estimate assumes a competitive bid situation and is an opinion of probable costs based on fair market value and is not a prediction of the anticipated low bid. This estimate assumes no control over the cost of labor and materials, the General Contractor's or any subcontractor's method of determining price, or competitive bidding and market conditions.

This opinion of probable cost of construction is made based on the experience, qualifications, and best judgment of the Cost Estimator. Proposals, bids, and actual construction costs may vary from these estimates. This estimate was prepared in accordance with generally accepted cost estimating practices and industry standards.

The following table provides a summary of the total cost request for each alternative proposed. The detailed cost breakdown can be found in **Appendix E**.

Table 22. Cost Summary Table

Name	Ponded Flow Reduction at Node 002485IN (ft^3)	Total Cost ($)	Cost Per ft^3 of Ponded Flow Reduction ($\$/ft^3$)
Watertight Storm System by DASH (URS Study)	108,461	$1,051,054	9.69
UPGRADE	309,646	$1,381,022	4.46
STORAGE-1	87,708	$6,431,635	73.33
STORAGE-2	12,493	$1,373,355	109.93
STORAGE-3	100,039	$1,793,698	17.93
ROUTE-1	265,233	$2,148,385	8.10
ROUTE-2	286,198	$3,586,064	12.53
ROUTE-3	316,059	$2,272,465	7.19
ROUTE-4	330,822	$1,564,789*	4.73

*Estimate does not include modifications required to existing downstream stormwater system.

5. Recommendations

Table 23 displays the flood reduction and cost summaries for the final selected mitigation alternatives.

Table 23. Summary Analysis of Mitigation Alternatives

Proposed Solutions	Flood Reduction	$/ft^3	Total Cost
Re-Routing on Colvin Street			
ROUTE-1	73%	8.1	$2,148,385
ROUTE-2	79%	12.5	$3,586,064
ROUTE-3	87%	7.2	$2,272,465
ROUTE-4	91%	4.7	$1,564,789*
Existing System Upgrade at DASH			
UPGRADE	86%	4.5	$1,381,022
Downstream Bottleneck Upgrade	6.4%	Unknown	
Remove Swale Link	0.6%	Minimal	
Storage Opportunities			
STORAGE-1	24%	73.33	$6,431,635
STORAGE-2	3%	109.93	$1,373,355
STORAGE-3	28%	17.93	$1,793,698

*Estimate does not include modifications required to exiting downstream stormwater system in Taylor Run watershed.

Based on the results, the re-routing alternatives all provide significant improvements at the DASH facility. It should be noted that the re-routing to Taylor Run does not include modifications required to the existing downstream stormwater system in the Taylor Run watershed. These will likely significantly increase the cost of this alternative.

Of the storm sewer system upgrades, the improvements to the DASH facility storm sewer system will have a significant improvement on flooding; however, this will introduce additional flooding to the south of the facility at Business Center Drive. None of the underground storage opportunities in the upstream watershed provide significant flood reduction at the DASH facility and they come at a high cost as well. The only feasible storage option is STORAGE-3, but that would remove the available space at the impound lot area. Additionally, it provides only a quarter of flood reduction at the DASH facility. Therefore, storage opportunities are not considered as suitable alternatives when compared to the DASH system upgrade and re-routing alternatives.

The URS study recommended watertight pipes at the DASH facility. However, this will cost approximately one million dollars and not provide full flood reduction. This alternative is not recommended either. Furthermore, creating a new conveyance system under the railroad tracks using HDD is not feasible. However, discussions with the railroad owners are recommended to identify if special considerations are available with regard to modifying existing conveyance pipes.

6. References

CH2M HILL and Michael Baker International. *Task 4: Problem and Solution Identification and Prioritization for Cameron Run, Alexandria, Virginia*. Draft Report. Alexandria: The City of Alexandria Transportation and Engineering Services, 29 June 2015. PDF.

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Virginia Railway Express. *Alexandria Station Pedestrian Tunnel Feasibility Study Report Draft Final*. Alexandria, 17 January 2013.

Appendices

Appendix A. July 8, 2019 Rainfall Event

Convective summer thunderstorms are known for their short duration and high intensity, and some of these events can surcharge very quickly to the stormwater system of a relatively small area causing local damage. On July 8, 2019, the City of Alexandria was hit by an approximate 1-hour rainfall event which collapsed the stormwater system near DASH and severely flooded the area (and inside the facility). The event (**Table A1**), registered a maximum intensity of 0.87 inches in 5-minutes, and a total rainfall of 3.92 inches at the end of the day.

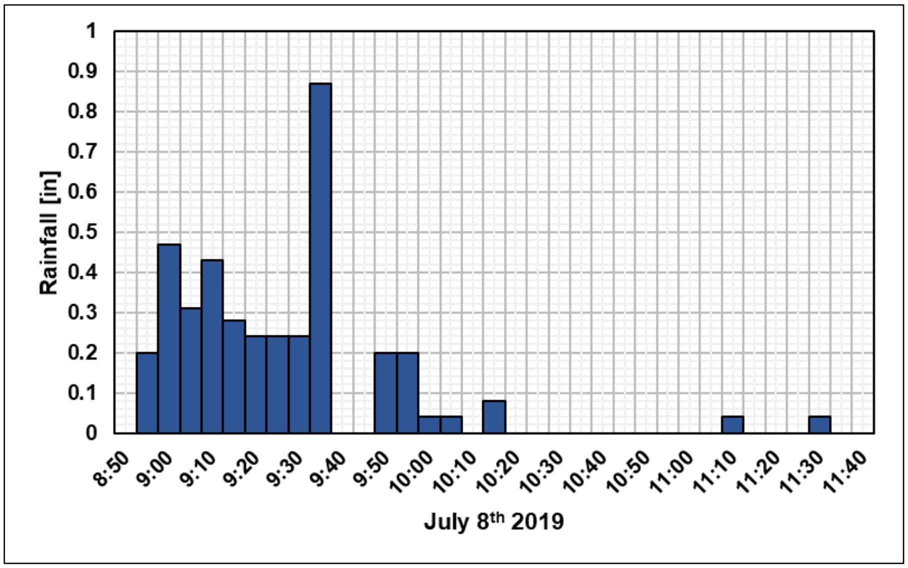

Figure A1. July 8, 2019 rainfall event

Table A1. July 8, 2019 rainfall event

Time	Acc. Time [min]	Duration [min]	Rainfall [in]	Time	Acc. Time [min]	Duration [min]	Rainfall [in]
7/8/2019 8:50	530	5	0	7/8/2019 10:15	615	5	0.08
7/8/2019 8:55	535	5	0.2	7/8/2019 10:20	620	5	0
7/8/2019 9:00	540	5	0.47	7/8/2019 10:25	625	5	0
7/8/2019 9:05	545	5	0.31	7/8/2019 10:30	630	5	0
7/8/2019 9:10	550	5	0.43	7/8/2019 10:35	635	5	0
7/8/2019 9:15	555	5	0.28	7/8/2019 10:40	640	5	0
7/8/2019 9:20	560	5	0.24	7/8/2019 10:45	645	5	0
7/8/2019 9:25	565	5	0.24	7/8/2019 10:50	650	5	0
7/8/2019 9:30	570	5	0.24	7/8/2019 10:55	655	5	0
7/8/2019 9:35	575	5	0.87	7/8/2019 11:00	660	5	0
7/8/2019 9:40	580	5	0	7/8/2019 11:05	665	5	0
7/8/2019 9:45	585	5	0	7/8/2019 11:10	670	5	0.04
7/8/2019 9:50	590	5	0.2	7/8/2019 11:15	675	5	0
7/8/2019 9:55	595	5	0.2	7/8/2019 11:20	680	5	0
7/8/2019 10:00	600	5	0.04	7/8/2019 11:25	685	5	0
7/8/2019 10:05	605	5	0.04	7/8/2019 11:30	690	5	0.04
7/8/2019 10:10	610	5	0	7/8/2019 11:35	695	5	0

According to the NOAA Atlas 14 dataset, this event was close to a 500-year recurrence interval event for the maximum rainfall in a 5-minute duration (0.87 inches), and a 200-year recurrence interval event for the maximum rainfall in a 60-minute duration (3.48 inches). See **Table A3**.

Table A2. Average Recurrence Interval for Boothe Park gage

Duration	Average recurrence interval (years) for Boothe Park gage (NOAA)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.359	0.431	0.512	0.572	0.648	0.705	0.761	0.816	0.887	0.942
10-min	0.574	0.689	0.820	0.915	1.03	1.12	1.21	1.29	1.40	1.48
15-min	0.717	0.866	1.04	1.16	1.31	1.42	1.53	1.63	1.77	1.86
30-min	0.983	1.20	1.47	1.68	1.94	2.14	2.34	2.54	2.81	3.02
60-min	1.23	1.50	1.89	2.18	2.58	2.90	3.23	3.56	4.03	4.40
2-hr	1.42	1.74	2.20	2.56	3.07	3.48	3.92	4.38	5.03	5.56
3-hr	1.52	1.85	2.35	2.74	3.30	3.77	4.26	4.78	5.54	6.16
6-hr	1.86	2.25	2.84	3.33	4.05	4.66	5.32	6.03	7.09	7.98

Please refer to NOAA Atlas 14 document for more information.

Table A3. Average Recurrence Interval for the July 8, 2019 rainfall event

Duration	Total Rainfall [in]	Average Recurrence Interval [years]
5-min	0.87	428
10-min	1.11	47
15-min	1.35	34
30-min	2.3	90
60-min	3.48	176
2-hr	3.84	91
3-hr	3.92	65
6-hr	3.92	22

An XPSWMM simulation showed a flooding volume of 518,000 ft^3 at Node 002485IN (north of DASH) for the Baseline scenario, which is 40 percent more than the 370,000 ft^3 10-year, 24-hour design event on the same node. Other scenarios were tested and are shown in **Table A4** on that same node, for comparison.

Table A4. Comparison of flood volumes at Node 02485IN with different events

Event	Model - Alternatives			
	Baseline	Re-route West CS	Re-route East to TR	Upgrade DASH
10-year 24-hour	361,555	34,640	37,725	52,787
July 8th 2019	518,122	51,292	50,453	71,653

Appendix B. Utilities near DASH facility (Roth St, Colvin St, and S. Quaker Ln.)

Figure B1. Utilities discovered by visual inspection in Roth St, Colvin St, and S. Quaker Ln.

Some of the utilities along Roth St., Colvin St., and South Quaker Ln. can be found by visible inspection. These can be categorized as Clean Water, Electricity, Sanitary, or Gas utilities. Further examination is needed to confirm their presence and identify their categorization and properties, such as invert elevation and junctions. Note that many of these utilities can drastically change the feasibility of the proposed alternatives, due to the increase in costs or viability to solve/dodge the acknowledged utility obstruction.

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Appendix C. Detailed Baseline Model Output

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	Node ID						Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft^3]	
Link ID	US	DS	Length [ft]	D/H [ft]	Max Flow [ft^3/s]	Max Velocity [ft/s]	US	DS	US	DS	US	DS	US	DS	US	DS
Weir2	00001PD	000619IO	33.0	0.5	2.36	11.44	390	131	6.17	Flooded	-0.90	Flooded	-	120	-	53,623
Weir2.1	00001PD	000619IO	-	-	38.97	-	390	131	6.84	Flooded	-0.90	Flooded	-	120	-	53,623
003339STMP	000031CP	000032CP	158.8	6	113.64	10.85	-	-	-3.52	-4.47	-5.52	-12.97	-	-	-	-
OpenCh17	000032CP	Node5152	121.9	6	113.99	4.29	-	-	-4.47	-3.89	-12.97	-6.89	-	-	-	-
Weir3.1	00003PD	000170IO	-	-	252.58	-	40	-	Surcharged	5.00	Surcharged	-4.64	-	-	-	-
001040STMP	000046CB	000476SMH	45.3	1.25	14.03	11.34	40	54	1.57	Flooded	-0.38	Flooded	-	36	-	1,795
002309STMP	000047CB	000192ND	45.9	1.25	0.00	0.00	-	-	-1.25	1.57	-5.50	-6.05	-	-	-	-
000686STMP	000048CB	000481SMH	12.9	1.25	1.61	2.46	-	-	-0.04	0.25	-5.79	-5.91	-	-	-	-
000694STMP	000049CB	000195ND	31.4	1.5	8.69	8.86	22	28	2.61	5.07	-1.89	-0.92	-	-	-	-
001029STMP	000050CB	000489SMH	19.3	1.25	20.57	16.36	35	32	Flooded	Flooded	Flooded	Flooded	17	12	1,294	2,211
003976STMP	000057CB	002453IN	111.0	1.25	0.00	0.00	-	103	-1.25	Flooded	-10.00	Flooded	-	65	-	8,236
003978STMP	000058CB	000834SMH	81.6	1.25	20.34	16.55	107	-	Flooded	-0.40	Flooded	-4.55	85	-	29,663	-
004198STMP	000059CB	002474IN	19.3	1.25	0.00	0.00	-	-	-1.25	-1.25	-2.00	-5.00	-	-	-	-
001244STMP	000060CB	002475IN	15.3	1.25	0.00	0.00	-	-	-1.25	-1.25	-3.00	-5.00	-	-	-	-
001245STMP	000061CB	002476IN	12.8	1.25	0.00	0.00	-	-	-1.25	-1.25	-3.75	-4.70	-	-	-	-
CRpipe1	000062CB	000063CB	90.7	1	0.00	0.00	-	-	-1.00	-1.00	-1.50	-1.50	-	-	-	-
CRpipe2	000063CB	000833SMH	148.2	1	0.00	0.00	-	4	-1.00	1.60	-1.50	-1.00	-	-	-	-
006318STMP	000064CB	000561ND	9.3	1	0.00	0.00	-	18	-1.00	3.42	-5.40	-10.18	-	-	-	-
006319STMP	000065CB	000064CB	70.1	1	0.00	0.00	-	-	-1.00	-1.00	-2.40	-5.40	-	-	-	-
005420STMP	000071CB	003728IN	69.4	3	1.59	-1.29	19	-	0.30	-1.83	-10.30	-10.83	-	-	-	-
001042STMP	000096IO	001147IN	23.1	0.833	5.72	10.45	176	221	Flooded	Flooded	Flooded	Flooded	121	36	3,011	1,155
001025STMP	000097IO	000480SMH	31.3	0.833	0.00	0.00	-	-	-0.83	0.15	-5.00	-4.37	-	-	-	-
CRpipe27	000102IO	002368IN	52.2	1.5	19.93	11.08	13	11	4.27	3.34	-5.23	-0.36	-	-	-	-
OpenCh13	000132IO	000031CP	68.9	3	71.22	0.54	-	-	-0.75	-0.52	-2.60	-5.52	-	-	-	-
Link3605	000170IO	000297ND	56.7	5	252.59	15.34	-	-	-1.14	-0.58	-4.64	-9.19	-	-	-	-
OpenCh14	000173IO	000346IO	4.6	2	29.70	13.29	-	-	-1.49	-0.97	-1.49	-2.77	-	-	-	-
OpenCh01	000175IO	Node5160	79.8	2	20.34	9.71	-	-	-0.74	-0.68	-5.74	-1.13	-	-	-	-
CRpipe25	000176IO	Node5154	97.3	1.25	18.19	14.48	20	104	5.11	Flooded	-0.14	Flooded	-	99	-	27,374
Link3082	000192ND	001162IN	100.9	3	91.42	17.85	-	21	-0.18	2.50	-6.05	-2.30	-	-	-	-
Link2960	000193ND	000194ND	25.8	1.75	18.03	12.57	-	-	-0.74	-0.54	-4.77	-5.56	-	-	-	-
Link4004	000194ND	000481SMH	14.6	1.75	18.03	10.49	-	-	-0.54	-0.25	-5.56	-5.91	-	-	-	-
Link3043	000195ND	000489SMH	30.0	3	99.91	14.03	28	32	3.57	Flooded	-0.92	Flooded	-	12	-	2,211
000776STMP	000200ND	000479SMH	58.6	1.75	0.00	0.00	-	33	-1.75	2.86	-3.00	-0.49	-	-	-	-
000682STMP	000201ND	000480SMH	99.6	1.75	0.00	0.00	-	-	-1.75	-0.77	-2.25	-4.37	-	-	-	-
Link3079	000202ND	000477SMH	99.1	3	80.89	21.61	-	-	-1.44	-1.37	-8.88	-8.17	-	-	-	-
001126STMP	000203ND	000478SMH	65.2	1.25	0.00	0.00	-	-	-1.25	-0.63	-2.50	-7.10	-	-	-	-
002123STMP	000205ND	001245IN	91.4	1.5	0.00	0.00	-	-	-1.50	-1.50	-2.00	-7.80	-	-	-	-
Link3065	000206ND	000485SMH	137.0	3.5	196.58	20.29	42	46	Flooded	Flooded	Flooded	Flooded	6	23	1	4,603
002318STMP	000207ND	000479SMH	163.1	1.25	0.00	0.00	-	33	-1.25	3.36	-1.75	-0.49	-	-	-	-
Link3111	000209ND	000497SMH	14.4	1.25	4.71	5.16	12	12	4.04	4.42	-1.10	-0.23	-	-	-	-
002373STMP	000210ND	001259IN	54.1	1.25	0.00	0.00	-	-	-1.25	-1.25	-1.75	-4.00	-	-	-	-
003332STMP	000233ND	001840IN	46.9	1.5	-1.57	2.84	-	26	-0.88	Flooded	-5.88	Flooded	-	13	-	721
003345STMP	000240ND	001846IN	165.3	1	0.00	0.00	-	26	-1.00	5.23	-20.70	-4.37	-	-	-	-
005816STMP	000256IO	001208SMH	53.0	1.5	-10.40	-5.87	1415	38	Flooded	0.76	Flooded	-4.82	58	-	8,662	-
Link3112	000291ND	000799SMH	11.8	1.5	7.73	15.57	-	-	-1.04	-0.78	-5.64	-4.09	-	-	-	-
Link2977	000293ND	000298ND	14.5	5	287.34	20.72	8	8	0.68	0.85	-4.09	-2.64	-	-	-	-
Link3047	000294ND	000293ND	201.1	5	284.44	21.00	-	8	-1.13	0.68	-4.21	-4.09	-	-	-	-
Link2975	000295ND	000294ND	26.6	5	277.22	20.96	-	-	-1.34	-1.13	-3.54	-4.21	-	-	-	-
Link3338	000296ND	002414IN	99.1	5	253.57	19.23	-	-	-1.80	-1.69	-9.27	-6.99	-	-	-	-
Link3339	000297ND	002412IN	278.2	5	253.53	20.75	-	-	-2.04	-1.83	-9.19	-11.69	-	-	-	-
Link2976	000298ND	000806SMH	15.6	5	308.62	20.93	8	9	0.85	0.99	-2.64	-1.51	-	-	-	-
Link3120	000299ND	002399IN	16.5	2.5	104.38	21.23	-	-	1.14	0.20	-3.43	-4.20	-	-	-	-
Link3119	000300ND	000299ND	40.7	2.5	104.49	21.12	22	-	3.46	1.14	-2.27	-3.43	-	-	-	-
003595STMP	000301ND	002513IN	84.4	1	1.75	3.49	10	21	Flooded	Flooded	Flooded	Flooded	9	9	27	273
Link3131	000303ND	000841SMH	17.6	1.25	11.30	9.18	7	-	0.62	0.41	-5.59	-4.54	-	-	-	-
004270STMP	000304ND	002338IN	46.4	1.5	0.00	0.00	-	-	-1.50	-1.50	-2.00	-3.00	-	-	-	-
Link3134	000305ND	000058CB	15.9	1.25	15.06	11.95	102	107	Flooded	Flooded	Flooded	Flooded	79	85	31	29,663

	Node ID						Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft^3]	
Link ID	US	DS	Length [ft]	D/H [ft]	Max Flow [ft^3/s]	Max Velocity [ft/s]	US	DS	US	DS	US	DS	US	DS	US	DS
003671STMP	000306ND	002379IN	42.3	1.25	0.00	0.00	-	-	-1.25	-0.66	-11.00	-3.41	-	-	-	-
003672STMP	000307ND	002387IN	15.1	1.25	0.00	0.00	-	-	-1.25	-1.25	-12.00	-5.20	-	-	-	-
003670STMP	000308ND	000794SMH	32.2	1.25	0.00	0.00	-	-	-1.25	-1.25	-1.75	-4.00	-	-	-	-
Link3238	000309ND	002485IN	151.8	4.5	329.45	20.18	15	123	0.80	Flooded	-3.20	Flooded	-	107	-	361,555
004225STMP	000311ND	002522IN	135.8	1	0.00	0.00	-	-	-1.00	2.00	-14.00	-12.40	-	-	-	-
Link3499	000312ND	000857SMH	192.1	2.5	67.69	20.11	-	-	-0.95	0.03	-9.45	-13.87	-	-	-	-
Link3263	000313ND	000819SMH	135.5	4	220.11	17.41	16	-	1.83	0.40	-3.09	-3.00	-	-	-	-
CRpipe7	000314ND	Junct012	125.1	5	240.51	10.65	-	-	-0.42	-2.76	-3.20	-7.06	-	-	-	-
Link3262	000315ND	004458IN	61.5	2	62.70	20.86	14	31	2.00	2.85	-4.18	-6.65	-	-	-	-
004271STMP	000316ND	000864SMH	52.7	1.5	0.00	0.00	-	-	-1.50	-1.50	-5.00	-5.10	-	-	-	-
003674STMP	000318ND	000794SMH	33.3	1	0.00	0.00	-	-	-1.00	-1.00	-7.50	-4.00	-	-	-	-
004272STMP	000319ND	000865SMH	92.1	1.25	0.00	0.00	-	-	-1.25	-1.25	-4.00	-9.22	-	-	-	-
004229STMP	000320ND	000861SMH	189.0	5.5	-0.83	-0.79	-	-	-0.98	-3.71	-1.48	-9.61	-	-	-	-
004218STMP	000321ND	002368IN	75.3	2	0.00	0.00	-	11	-2.00	2.84	-2.50	-0.36	-	-	-	-
004207STMP	000346IO	004458IN	279.1	2.5	29.73	13.45	-	31	-1.47	2.35	-2.77	-6.65	-	-	-	-
005724STMP	000467ND	003722IN	26.8	1.75	0.00	0.00	-	-	-1.75	-0.32	-5.25	-5.07	-	-	-	-
004396STMP	000468ND	003717IN	31.2	1.75	0.00	0.00	-	-	-1.75	-0.42	-7.25	-6.67	-	-	-	-
Link3285	000469ND	000471ND	101.7	8	166.98	15.17	-	-	-5.88	-5.43	-5.88	-6.93	-	-	-	-
Link3286	000470ND	000065CP	23.5	8	226.25	14.48	-	-	-5.21	-5.21	-7.21	-5.76	-	-	-	-
Link3869	000471ND	000470ND	133.1	8	188.41	13.37	-	-	-5.43	-5.21	-6.93	-7.21	-	-	-	-
000950STMP	000472SMH	001148IN	67.0	0.833	-0.10	0.30	163	220	1.06	Flooded	-0.91	Flooded	-	219	-	30,485
004541STMP	000473ND	000071CB	22.0	2	-4.99	3.47	-	19	-0.64	1.30	-11.64	-10.30	-	-	-	-
005726STMP	000474ND	000071CB	21.1	1.5	-3.16	4.55	-	19	-0.14	1.80	-11.64	-10.30	-	-	-	-
001039STMP	000476SMH	000480SMH	112.3	1.25	18.03	16.33	54	-	Flooded	-0.27	Flooded	-4.37	36	-	1,795	-
001118STMP	000477SMH	001155IN	134.5	3	80.96	20.16	-	-	-1.37	-1.06	-8.17	-6.86	-	-	-	-
001125STMP	000478SMH	000192ND	24.3	1.5	-1.35	2.79	-	-	-0.88	1.32	-7.10	-6.05	-	-	-	-
005810STMP	000479ND	000257IO	165.7	1	12.24	13.17	35	-	Flooded	0.00	Flooded	-0.11	34	-	457	-
001023STMP	000479SMH	000206ND	49.5	1.75	13.46	7.09	33	42	2.86	Flooded	-0.49	Flooded	-	6	-	1
005836STMP	000480ND	001215SMH	112.4	5.033	368.80	27.86	-	-	-3.42	-1.10	-6.39	-14.17	-	-	-	-
Link4005	000480SMH	000193ND	10.8	1.75	18.03	13.01	-	-	-0.77	-0.74	-4.37	-4.77	-	-	-	-
005802STMP	000481ND	003800IN	52.5	1.25	2.60	6.30	7	15	0.23	Flooded	-0.27	Flooded	-	1	-	4
000687STMP	000481SMH	000482SMH	97.0	1.75	18.03	9.23	-	-	-0.25	-0.96	-5.91	-8.31	-	-	-	-
000690STMP	000482SMH	000483SMH	195.1	1.75	18.03	16.92	-	-	-0.96	-0.86	-8.31	-4.86	-	-	-	-
005798STMP	000483ND	003787IN	80.7	5.5	142.83	26.12	-	-	-4.06	-2.96	-4.56	-6.46	-	-	-	-
000691STMP	000483SMH	000484SMH	97.9	1.75	18.03	14.87	-	-	-0.86	-0.76	-4.86	-4.96	-	-	-	-
001026STMP	000484SMH	000489SMH	254.2	1.75	18.23	13.84	-	32	-0.76	Flooded	-4.96	Flooded	-	12	-	2,211
002050STMP	000485SMH	000486SMH	10.9	3.5	196.55	20.36	46	46	Flooded	Flooded	Flooded	Flooded	23	18	4,603	2,847
002055STMP	000486SMH	001181IN	25.6	3.5	196.54	20.37	46	49	Flooded	2.70	Flooded	-0.31	18	-	2,847	-
001373STMP	000487SMH	001196IN	72.0	1.5	38.87	21.90	81	13	4.09	0.97	-0.91	-3.73	-	-	-	-
000772STMP	000488SMH	001205IN	123.2	0.833	0.00	0.00	-	65	-0.83	2.69	-2.55	-0.57	-	-	-	-
Link3066	000489SMH	000206ND	98.8	3.5	187.84	20.43	32	42	Flooded	Flooded	Flooded	Flooded	12	6	2,211	1
002130STMP	000491SMH	001254IN	103.7	1.5	9.63	14.76	-	-	-0.94	-0.58	-10.59	-13.58	-	-	-	-
002134STMP	000492SMH	000496SMH	347.8	1.5	9.64	9.02	-	8	-0.51	2.75	-8.16	-0.50	-	-	-	-
002135STMP	000493SMH	000492SMH	56.7	1.5	9.85	6.11	-	-	-0.17	-0.51	-9.27	-8.16	-	-	-	-
002368STMP	000494SMH	000493SMH	51.2	1.5	9.88	12.04	-	-	-0.85	-0.17	-7.20	-9.27	-	-	-	-
002370STMP	000495SMH	000494SMH	11.0	1.5	9.88	14.49	-	-	-0.89	-0.85	-6.49	-7.20	-	-	-	-
002381STMP	000496SMH	001268IN	18.3	1.5	9.48	10.32	8	10	2.75	3.50	-0.50	-0.20	-	-	-	-
002384STMP	000497SMH	001299IN	207.7	1.5	24.24	13.75	12	21	4.17	Flooded	-0.23	Flooded	-	18	-	1,662
003979STMP	000500SMH	000851SMH	178.7	2	36.63	11.53	36	48	Flooded	Flooded	Flooded	Flooded	25	39	1,877	3,804
001248STMP	000561ND	002446IN	228.8	2	53.68	17.16	18	-	2.42	-0.19	-10.18	-3.49	-	-	-	-
OpenCh05	000613IO	Junct009	638.2	3	223.31	2.54	-	128	-0.73	Flooded	-3.53	Flooded	-	112	-	134,380
002786STMP	000617SMH	001842IN	90.9	1.25	4.72	3.82	25	34	2.32	Flooded	-1.13	Flooded	-	23	-	3,806
003334STMP	000618SMH	001841IN	48.0	3	49.30	6.91	30	31	4.67	Flooded	-0.83	Flooded	-	15	-	1,451
013328STMP	000619IO	003544SMH	28.2	3	81.42	11.44	131	135	Flooded	4.88	Flooded	-0.98	120	-	53,623	-
003336STMP	000619SMH	000132IO	308.1	3	69.64	9.96	32	-	Flooded	-0.75	Flooded	-2.60	24	-	3,950	-
003335STMP	000621SMH	000618SMH	121.2	3	49.31	7.04	27	30	4.19	4.67	-4.81	-0.83	-	-	-	-
003928STMP	000788SMH	000789SMH	310.9	1.5	4.97	10.75	-	-	-1.07	-0.76	-3.67	-7.96	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft³/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft³]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
003927STMP	000789SMH	000790SMH	156.1	1.5	15.59	18.07	-	-	-0.76	-0.77	-7.96	-7.07	-	-	-	-
003926STMP	000790SMH	000791SMH	111.8	1.5	15.58	18.35	-	-	-0.77	-0.77	-7.07	-7.27	-	-	-	-
003932STMP	000791SMH	000792SMH	23.5	1.5	15.59	18.05	-	-	-0.77	-0.74	-7.27	-7.24	-	-	-	-
003933STMP	000792SMH	000809SMH	123.3	1.5	15.60	17.39	-	7	-0.74	2.60	-7.24	-2.90	-	-	-	-
003937STMP	000793SMH	002375IN	26.9	2	0.00	0.00	-	-	-2.00	-2.00	-14.50	-3.70	-	-	-	-
003946STMP	000794SMH	000795SMH	216.0	1.5	0.00	0.00	-	-	-1.50	-0.90	-4.00	-2.90	-	-	-	-
003944STMP	000795SMH	000797SMH	139.7	1.5	7.72	12.03	-	-	-0.90	-0.98	-2.90	-3.48	-	-	-	-
015100STMP	000796SMH	000795SMH	16.4	1.25	0.03	0.55	-	-	-0.84	-0.65	-2.89	-2.90	-	-	-	-
Link3398	000797SMH	000291ND	47.3	1.5	7.73	14.41	-	-	-0.98	-1.04	-3.48	-5.64	-	-	-	-
003621STMP	000799SMH	000801SMH	104.3	1.5	12.61	15.49	-	-	-0.78	-0.85	-4.09	-3.35	-	-	-	-
003956STMP	000800SMH	000799SMH	7.5	1	-0.43	1.98	-	-	-0.83	-0.28	-4.33	-4.09	-	-	-	-
003622STMP	000801SMH	000802SMH	90.6	1.75	12.62	15.70	-	-	-1.10	-1.13	-3.35	-9.68	-	-	-	-
003623STMP	000802SMH	002388IN	69.8	1.75	12.62	15.67	-	-	-1.13	-0.88	-9.68	-6.13	-	-	-	-
003641STMP	000803SMH	000808SMH	146.5	5	0.00	0.00	-	-	-5.00	-5.00	-8.10	-8.10	-	-	-	-
003628STMP	000804SMH	002391IN	224.9	1.25	0.00	0.00	-	-	-1.25	-0.70	-6.60	-8.25	-	-	-	-
003634STMP	000805SMH	000835SMH	37.3	2	57.36	18.15	17	26	6.69	Flooded	-2.31	Flooded	-	8	-	1,762
004605STMP	000806SMH	000836SMH	28.3	5.033	309.58	20.87	9	8	0.96	1.22	-1.51	-1.45	-	-	-	-
003637STMP	000807SMH	000806SMH	7.0	1.75	-0.57	1.23	72	9	3.97	4.25	-2.28	-1.51	-	-	-	-
004182STMP	000808SMH	000299ND	61.9	5	0.00	0.00	-	-	-5.00	-1.36	-8.10	-3.43	-	-	-	-
003939STMP	000809SMH	002376IN	25.8	2	15.72	15.19	7	16	2.10	8.80	-2.90	-4.30	-	-	-	-
003649STMP	000810SMH	002410IN	62.6	1.5	13.83	14.33	-	-	-0.70	-0.58	-9.13	-5.98	-	-	-	-
003639STMP	000811SMH	002403IN	234.8	5	275.81	21.39	-	-	-1.87	-1.62	-5.87	-4.42	-	-	-	-
003656STMP	000812SMH	002415IN	73.0	1.25	0.00	0.00	-	-	-1.25	-0.42	-7.76	-11.01	-	-	-	-
001263STMP	000819SMH	002435IN	45.3	4	122.03	17.69	-	53	0.40	2.24	-3.00	-2.26	-	-	-	-
Link3284	000819SMH	000309ND	45.5	4.5	325.17	23.94	-	15	-0.10	0.80	-3.00	-3.20	-	-	-	-
001266STMP	000821SMH	000822SMH	119.1	1.25	7.70	7.82	-	-	-0.29	-0.50	-5.64	-4.95	-	-	-	-
004149STMP	000822SMH	000823SMH	32.4	1.25	7.70	10.39	-	-	-0.50	-0.71	-4.95	-5.76	-	-	-	-
004151STMP	000823SMH	000824SMH	13.5	1.25	7.70	15.11	-	-	-0.71	-0.72	-5.76	-7.47	-	-	-	-
004152STMP	000824SMH	000825SMH	70.3	1.25	7.70	14.82	-	-	-0.72	-0.56	-7.47	-5.51	-	-	-	-
004153STMP	000825SMH	002441IN	8.0	1.25	7.70	11.50	-	-	-0.56	-0.48	-5.51	-5.44	-	-	-	-
Link3001	000826SMH	000315ND	48.9	2	53.67	22.37	3	14	0.21	2.00	-3.29	-4.18	-	-	-	-
002812STMP	000827SMH	000828SMH	16.1	1.25	0.55	-0.63	10	9	1.63	1.57	-0.42	-0.38	-	-	-	-
004165STMP	000828SMH	002443IN	72.0	1.5	1.62	0.94	9	9	1.32	1.44	-0.38	-0.46	-	-	-	-
004166STMP	000829SMH	000833SMH	81.0	1.25	0.00	0.00	-	4	-1.25	1.35	-4.70	-1.00	-	-	-	-
004168STMP	000833SMH	002450IN	42.1	1.5	-1.18	2.86	4	9	1.10	2.71	-1.00	-0.19	-	-	-	-
004173STMP	000834SMH	000175IO	84.8	2	20.34	15.03	-	-	-1.15	-0.74	-4.55	-5.74	-	-	-	-
Link3463	000835SMH	000300ND	145.5	2.5	85.37	17.05	26	22	Flooded	3.46	Flooded	-2.27	8	-	1,762	-
001250STMP	000836SMH	000844SMH	55.4	5.5	433.00	18.24	8	8	0.75	0.65	-1.45	-2.55	-	-	-	-
004274STMP	000837SMH	002471IN	31.2	1.25	9.81	7.95	21	21	2.91	Flooded	-5.84	Flooded	-	18	-	3,735
004178STMP	000838SMH	002473IN	177.4	2	0.00	0.00	-	19	-2.00	0.92	-5.90	-0.18	-	-	-	-
004180STMP	000839SMH	000840SMH	37.4	1.25	0.74	2.90	4	4	0.38	0.94	-6.07	-5.51	-	-	-	-
004181STMP	000840SMH	000866SMH	72.8	2	63.20	20.85	4	-	0.19	-0.52	-5.51	-11.62	-	-	-	-
001247STMP	000841SMH	000561ND	77.1	2	53.69	22.44	-	18	-0.34	2.42	-4.54	-10.18	-	-	-	-
001265STMP	000842SMH	000309ND	20.1	1.5	-9.13	-5.09	80	15	3.35	3.80	-1.95	-3.20	-	-	-	-
Link3186	000844SMH	000313ND	105.6	4	220.13	17.46	8	16	2.15	1.83	-2.55	-3.09	-	-	-	-
015124STMP	000844SMH	000819SMH	241.0	4	220.46	17.43	8	-	2.15	0.40	-2.55	-3.00	-	-	-	-
004220STMP	000846SMH	002382ND	116.9	3	68.56	5.15	116	304	2.76	Flooded	-0.74	Flooded	-	97	-	17,131
004201STMP	000847SMH	000846SMH	66.4	1.25	1.49	4.08	118	116	3.04	4.51	-3.06	-0.74	-	-	-	-
004203STM	000848SMH	000846SMH	141.3	3	68.67	4.80	2823	116	6.48	2.76	-1.02	-0.74	-	-	-	-
004212STMP	000850SMH	000852SMH	233.6	1.5	31.68	19.41	49	-	Flooded	-0.30	Flooded	-4.30	46	-	4,865	-
004213STMP	000851SMH	000850SMH	31.3	2	34.48	14.40	48	49	Flooded	Flooded	Flooded	Flooded	39	46	3,804	4,865
004235STMP	000852SMH	000853SMH	157.4	1.5	31.68	21.10	-	-	-0.30	-0.35	-4.30	-4.35	-	-	-	-
003980STMP	000853SMH	000854SMH	200.4	1.5	31.68	21.70	-	-	-0.35	-0.32	-4.35	-4.32	-	-	-	-
003669STMP	000854SMH	000855SMH	200.9	1.5	31.68	21.88	-	-	-0.32	-0.36	-4.32	-4.56	-	-	-	-
015106STMP	000855SMH	000840SMH	129.7	1.5	31.68	22.35	-	4	-0.36	0.69	-4.56	-5.51	-	-	-	-
004285STMP	000856SMH	002518IN	191.6	3.5	217.29	22.42	18	-	4.75	-0.05	-6.06	-10.55	-	-	-	-
002879STMP	000857SMH	002522IN	123.4	3.5	153.11	21.05	-	-	-0.97	-0.50	-13.87	-12.40	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft³/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft³]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
004249STMP	000858SMH	000857SMH	55.4	3.5	85.75	12.23	-	-	-1.09	-0.97	-15.09	-13.87	-	-	-	-
004246STMP	000859SMH	000858SMH	36.5	1.25	11.06	12.99	-	-	-0.47	1.16	-15.72	-15.09	-	-	-	-
004247STMP	000860SMH	000858SMH	104.6	3	74.83	22.02	-	-	-1.65	-0.59	-20.65	-15.09	-	-	-	-
004230STMP	000861SMH	000871SMH	133.5	5.5	31.98	5.09	-	-	-3.71	-4.66	-9.61	-12.47	-	-	-	-
004261STMP	000862SMH	002537IN	158.8	1.5	0.00	0.00	-	2	-1.50	0.04	-7.09	-3.66	-	-	-	-
004268STMP	000863SMH	002538IN	69.0	1.5	19.80	11.19	18	20	2.37	2.35	-0.53	-0.64	-	-	-	-
004256STMP	000864SMH	002501IN	104.4	1.5	0.00	0.00	-	-	-1.50	-0.77	-5.10	-5.67	-	-	-	-
004273STMP	000865SMH	002474IN	115.1	1.75	0.00	0.00	-	-	-1.75	-1.75	-9.22	-5.00	-	-	-	-
Link3185	000866SMH	000312ND	128.3	2.5	63.21	20.78	-	-	-1.02	-0.95	-11.62	-9.45	-	-	-	-
003965STMP	000868SMH	002350IN	97.4	2	57.64	21.13	-	-	-0.41	0.18	-8.80	-11.62	-	-	-	-
002570STMP	000869SMH	002350IN	74.5	2.5	15.14	5.98	-	-	-1.31	-0.32	-11.21	-11.62	-	-	-	-
003968STMP	000870SMH	00003PD	32.6	3	85.99	12.28	40	40	1.94	Surcharged	-3.46	Surcharged	-	-	-	-
004226STMP	000871SMH	002528IN	24.8	2	31.98	23.21	-	-	-1.16	-0.46	-12.47	-11.76	-	-	-	-
004282STMP	000907SMH	Node5158	46.4	3	95.96	13.49	95	105	3.07	2.91	-4.44	-4.96	-	-	-	-
000951STMP	001139IN	000472SMH	57.9	0.833	-0.07	0.19	34	163	0.06	1.06	-1.06	-0.91	-	-	-	-
001038STMP	001146IN	000476SMH	15.4	1	9.72	13.17	53	54	Flooded	Flooded	Flooded	Flooded	53	36	7,631	1,795
001041STMP	001147IN	000046CB	76.3	1	5.72	7.44	221	40	Flooded	1.82	Flooded	-0.38	36	-	1,155	-
CRpipe22	001148IN	000096IO	137.2	0.833	4.84	8.74	220	176	Flooded	Flooded	Flooded	Flooded	219	121	30,485	3,011
001043STMP	001149IN	001150IN	43.9	1	0.00	0.00	-	-	-1.00	-0.58	-8.50	-7.88	-	-	-	-
001115STMP	001150IN	000202ND	68.4	1.25	4.90	10.85	-	-	-0.83	0.31	-7.88	-8.88	-	-	-	-
001117STMP	001151IN	001152IN	50.7	1	0.00	0.00	-	-	-1.00	-1.00	-5.50	-5.00	-	-	-	-
001116STMP	001152IN	001150IN	25.6	1.25	0.00	0.00	-	-	-1.25	-0.83	-5.00	-7.88	-	-	-	-
001120STMP	001153IN	001154IN	14.2	1	0.00	0.00	-	-	-1.00	-1.00	-7.69	-8.00	-	-	-	-
001121STMP	001154IN	001155IN	23.3	1	0.00	0.00	-	-	-1.00	0.94	-8.00	-6.86	-	-	-	-
Link3132	001155IN	000192ND	66.0	3	91.62	19.18	-	-	-1.06	-0.18	-6.86	-6.05	-	-	-	-
001123STMP	001156IN	001157IN	17.2	1	0.00	0.00	-	-	-1.00	-1.00	-6.50	-7.30	-	-	-	-
001124STMP	001157IN	000478SMH	12.5	1.25	0.00	0.00	-	-	-1.25	-0.63	-7.30	-7.10	-	-	-	-
001127STMP	001158IN	001159IN	19.1	1	0.00	0.00	-	-	-1.00	-1.00	-4.50	-5.50	-	-	-	-
001128STMP	001159IN	000047CB	6.0	1	0.00	0.00	-	-	-1.00	-1.00	-5.50	-5.50	-	-	-	-
002310STMP	001160IN	001161IN	8.2	1	1.23	1.87	24	26	3.55	4.07	-3.25	-2.93	-	-	-	-
002311STMP	001161IN	001162IN	6.2	1.25	2.03	2.00	26	21	3.82	4.25	-2.93	-2.30	-	-	-	-
Link3061	001162IN	000195ND	40.1	3	91.39	15.73	21	28	2.50	3.57	-2.30	-0.92	-	-	-	-
001021STMP	001163IN	001164IN	8.1	1	2.99	3.76	33	35	Flooded	Flooded	Flooded	Flooded	7	19	137	1,719
001022STMP	001164IN	000479SMH	4.8	1	13.38	16.70	35	33	Flooded	3.61	Flooded	-0.49	19	-	1,719	-
000684STMP	001165IN	000193ND	22.2	1	0.00	0.00	-	-	-1.00	0.01	-4.00	-4.77	-	-	-	-
000683STMP	001166IN	001165IN	14.7	1	0.00	0.00	-	-	-1.00	-1.00	-3.00	-4.00	-	-	-	-
000685STMP	001167IN	000048CB	26.3	1	0.79	3.56	-	-	-0.30	0.21	-5.80	-5.79	-	-	-	-
000688STMP	001168IN	001169IN	4.9	1	-0.28	3.60	-	-	-0.73	-0.52	-5.53	-5.52	-	-	-	-
000689STMP	001169IN	000194ND	7.8	1	0.77	4.26	-	-	-0.52	0.21	-5.52	-5.56	-	-	-	-
000692STMP	001170IN	001171IN	8.6	1	0.84	3.76	21	22	2.31	2.55	-2.19	-1.95	-	-	-	-
000693STMP	001171IN	000049CB	10.2	1	1.38	3.63	22	22	2.55	3.11	-1.95	-1.89	-	-	-	-
001027STMP	001172IN	001173IN	6.3	1	4.17	5.19	33	35	Flooded	Flooded	Flooded	Flooded	11	19	361	1,240
001028STMP	001173IN	000050CB	6.5	1	10.56	13.04	35	35	Flooded	Flooded	Flooded	Flooded	19	17	1,240	1,294
002047STMP	001174IN	001175IN	4.9	1	-1.53	-3.52	47	47	3.05	3.23	-0.45	-0.42	-	-	-	-
002048STMP	001175IN	001176IN	12.5	1	1.96	3.56	47	56	3.23	4.41	-0.42	-0.24	-	-	-	-
002049STMP	001176IN	000485SMH	14.1	1.25	2.60	2.68	56	46	4.16	Flooded	-0.24	Flooded	-	23	-	4,603
002051STMP	001177IN	000485SMH	10.1	1.25	3.40	2.75	71	46	4.51	Flooded	-0.04	Flooded	-	23	-	4,603
002052STMP	001178IN	001177IN	11.7	1	2.76	3.50	52	71	3.80	4.76	-0.20	-0.04	-	-	-	-
002053STMP	001179IN	001178IN	7.2	1	1.87	3.91	47	52	3.12	3.80	-0.08	-0.20	-	-	-	-
002054STMP	001180IN	001179IN	10.1	1	0.88	3.71	41	47	2.19	3.12	-0.31	-0.08	-	-	-	-
002056STMP	001181IN	00003PD	32.0	3.5	235.26	24.38	49	40	2.70	Surcharged	-0.31	Surcharged	-	-	-	-
002057STMP	001182IN	001183IN	30.9	1.25	-0.23	0.85	15	28	0.24	0.87	-2.51	-2.48	-	-	-	-
002058STMP	001183IN	001184IN	30.8	1.25	0.78	2.81	28	44	0.87	3.08	-2.48	-2.17	-	-	-	-
002059STMP	001184IN	001185IN	42.0	2	20.69	8.09	44	58	2.33	3.61	-2.17	-0.19	-	-	-	-
001100STMP	001185IN	00003PD	13.8	2	23.93	7.89	58	40	3.61	Surcharged	-0.19	Surcharged	-	-	-	-
002060STMP	001186IN	001184IN	79.7	1.75	21.06	10.12	28	44	0.92	2.58	-3.99	-2.17	-	-	-	-
001101STMP	001187IN	001186IN	60.6	1.25	7.65	13.12	-	28	-0.70	1.42	-8.45	-3.99	-	-	-	-

	Node ID						Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft^3]	
Link ID	US	DS	Length [ft]	D/H [ft]	Max Flow [ft^3/s]	Max Velocity [ft/s]	US	DS	US	DS	US	DS	US	DS	US	DS
001102STMP	001188IN	001190IN	99.4	1.25	0.00	0.00	-	-	-1.25	-1.25	-5.75	-7.75	-	-	-	-
001103STMP	001189IN	001187IN	97.6	1.25	0.00	0.00	-	-	-1.25	-0.70	-10.00	-8.45	-	-	-	-
002312STMP	001190IN	001187IN	83.0	1.25	0.00	0.00	-	-	-1.25	-0.70	-7.75	-8.45	-	-	-	-
Link3110	001191IN	000202ND	31.9	3	75.88	21.21	-	-	-1.49	-1.44	-6.19	-8.88	-	-	-	-
002319STMP	001192IN	001251IN	203.8	2.5	91.90	19.34	29	45	4.56	Flooded	-1.04	Flooded	-	43	-	33,369
002315STMP	001193IN	001194IN	7.1	1	2.21	3.53	30	43	5.42	5.85	-1.08	-0.65	-	-	-	-
005720STMP	001193SMH	000470ND	72.5	1.5	0.26	1.04	-	-	-0.03	1.29	-6.53	-7.21	-	-	-	-
002316STMP	001194IN	001195IN	5.8	1	6.50	8.02	43	26	5.85	Flooded	-0.65	Flooded	-	12	-	885
002314STMP	001195IN	001192IN	37.8	2.5	91.92	18.51	26	29	Flooded	4.56	Flooded	-1.04	12	-	885	-
001372STMP	001196IN	001195IN	138.8	1.75	39.31	21.38	13	26	0.72	Flooded	-3.73	Flooded	-	12	-	885
001376STMP	001197IN	001198IN	7.7	1	11.10	13.94	80	80	Flooded	Flooded	Flooded	Flooded	74	75	4,507	4,779
000767STMP	001198IN	001199IN	13.6	1	13.00	16.25	80	81	Flooded	Flooded	Flooded	Flooded	75	70	4,779	7,448
001374STMP	001199IN	000487SMH	35.0	1.75	31.23	12.83	81	81	Flooded	3.84	Flooded	-0.91	70	-	7,448	-
000768STMP	001200IN	001199IN	300.7	1.25	14.59	11.75	82	81	Flooded	Flooded	Flooded	Flooded	81	70	7,222	7,448
000770STMP	001201IN	001202IN	13.5	1	4.91	9.60	82	82	3.12	Flooded	-0.38	Flooded	-	61	-	2,731
000771STMP	001202IN	001200IN	41.1	1.25	8.30	6.74	82	82	Flooded	Flooded	Flooded	Flooded	61	81	2,731	7,222
000773STMP	001203IN	001204IN	8.8	1	5.24	8.02	67	68	Flooded	Flooded	Flooded	Flooded	40	65	2,542	15,886
000774STMP	001204IN	001205IN	16.9	1	15.75	19.52	68	65	Flooded	2.53	Flooded	-0.57	65	-	15,886	-
000769STMP	001205IN	001200IN	60.0	1.25	15.73	15.65	65	82	2.28	Flooded	-0.57	Flooded	-	81	-	7,222
000775STMP	001206IN	001205IN	47.8	1.25	-0.04	0.12	-	65	-0.75	2.28	-4.51	-0.57	-	-	-	-
002320STMP	001207IN	001208IN	8.3	1	4.44	7.90	64	64	8.23	8.56	-1.77	-0.99	-	-	-	-
002321STMP	001208IN	001209IN	12.5	1	8.84	11.23	64	64	8.56	Flooded	-0.99	Flooded	-	37	-	1,708
005817STMP	001208SMH	000259IO	99.1	1.5	12.39	7.04	38	-	0.76	-0.17	-4.82	-1.56	-	-	-	-
001375STMP	001209IN	000487SMH	104.9	1.25	24.74	19.35	64	81	Flooded	4.34	Flooded	-0.91	37	-	1,708	-
005823STMP	001209SMH	001210SMH	297.8	1.25	-0.86	0.99	-	13	-0.49	3.20	-4.66	-1.15	-	-	-	-
002322STMP	001210IN	001209IN	78.5	1.25	22.70	17.61	63	64	Flooded	Flooded	Flooded	Flooded	60	37	3,249	1,708
005801STMP	001210SMH	001211SMH	152.5	2	9.03	3.40	13	16	2.45	3.14	-1.15	-1.06	-	-	-	-
002323STMP	001211IN	001212IN	10.7	1.25	21.60	17.01	60	59	Flooded	Flooded	Flooded	Flooded	58	54	6,176	2,480
005804STMP	001211SMH	001212SMH	148.2	2.25	38.85	9.70	16	10	2.89	1.39	-1.06	-2.76	-	-	-	-
CRpipe21	001212IN	001210IN	143.7	1.25	22.25	20.28	59	63	Flooded	Flooded	Flooded	Flooded	54	60	2,480	3,249
005833STMP	001212SMH	001213SMH	290.8	2.5	44.25	9.01	10	-	1.14	-0.15	-2.76	-7.45	-	-	-	-
002324STMP	001213IN	001215IN	67.3	1.25	20.61	17.31	50	50	Flooded	5.08	Flooded	-1.12	47	-	5,334	-
005805STMP	001213SMH	001214SMH	285.9	3	44.26	8.08	-	-	-0.65	-2.27	-7.45	-10.87	-	-	-	-
002326STMP	001214IN	001215IN	6.7	1	1.67	2.44	50	50	4.88	5.33	-1.62	-1.12	-	-	-	-
005838STMP	001214SMH	001215SMH	24.7	3	44.26	23.12	-	-	-2.27	0.93	-10.87	-14.17	-	-	-	-
CRpipe20	001215IN	001211IN	256.1	1.25	20.13	18.19	50	60	5.08	Flooded	-1.12	Flooded	-	58	-	6,176
005837STMP	001215SMH	000612IO	135.7	5.5	218.19	12.04	-	-	-1.57	-1.58	-14.17	-4.08	-	-	-	-
015104STMP	001215SMH	000611IO	132.9	5.5	219.07	12.09	-	-	-1.57	-1.58	-14.17	-4.08	-	-	-	-
002328STMP	001216IN	001218IN	46.8	1	0.00	0.00	-	48	-1.00	Flooded	-3.00	Flooded	-	41	-	2,132
002329STMP	001217IN	001218IN	6.5	1	5.03	6.38	48	48	Flooded	Flooded	Flooded	Flooded	38	41	1,788	2,132
002325STMP	001218IN	001213IN	30.1	1.25	8.47	7.79	48	50	Flooded	Flooded	Flooded	Flooded	41	47	2,132	5,334
002330STMP	001219IN	001220IN	30.0	1	3.88	5.07	50	51	2.00	Flooded	-1.00	Flooded	-	49	-	3,207
002332STMP	001220IN	001213IN	268.5	1.25	11.95	9.80	51	50	Flooded	Flooded	Flooded	Flooded	49	47	3,207	5,334
002333STMP	001221IN	001222IN	4.2	1	2.48	4.65	51	51	3.40	Flooded	-0.60	Flooded	-	18	-	429
002334STMP	001222IN	001223IN	6.7	1	4.78	6.02	51	53	Flooded	Flooded	Flooded	Flooded	18	45	429	4,418
002331STMP	001223IN	001220IN	40.3	1.25	10.04	8.02	53	51	Flooded	Flooded	Flooded	Flooded	45	49	4,418	3,207
002336STMP	001224IN	001225IN	5.7	1	-0.20	1.69	-	-	-0.15	0.18	-3.15	-2.32	-	-	-	-
002335STMP	001225IN	001223IN	177.9	1.25	17.23	14.98	-	53	-0.07	Flooded	-2.32	Flooded	-	45	-	4,418
002351STMP	001239IN	001248IN	315.5	1.25	0.00	0.00	-	-	-1.25	-0.22	-3.30	-4.77	-	-	-	-
002352STMP	001240IN	001242IN	40.4	1.25	0.00	0.00	-	-	-1.25	-1.25	-4.70	-7.10	-	-	-	-
002353STMP	001241IN	001240IN	52.7	1.25	0.00	0.00	-	-	-1.25	-1.25	-2.75	-4.70	-	-	-	-
002354STMP	001242IN	001246IN	269.6	1.5	0.00	0.00	-	24	-1.50	2.05	-7.10	-4.75	-	-	-	-
002120STMP	001243IN	001246IN	39.8	2	0.00	0.00	-	24	-2.00	1.55	-10.80	-4.75	-	-	-	-
002121STMP	001244IN	001243IN	63.3	2	0.00	0.00	-	-	-2.00	-2.00	-3.80	-10.80	-	-	-	-
002122STMP	001245IN	001244IN	155.1	1.5	0.00	0.00	-	-	-1.50	-1.50	-7.80	-3.80	-	-	-	-
002124STMP	001246IN	001248IN	41.4	3	43.83	6.40	24	-	0.55	-1.97	-4.75	-4.77	-	-	-	-
002125STMP	001247IN	001248IN	10.9	1.25	-0.04	0.65	-	-	-0.37	-0.22	-4.62	-4.77	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft³/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft³]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
002126STMP	001248IN	001249IN	249.4	3	43.84	20.48	-	-	-1.97	-1.97	-4.77	-4.37	-	-	-	-
002313STMP	001249IN	001191IN	218.6	3	43.79	19.19	-	-	-1.97	-1.49	-4.37	-6.19	-	-	-	-
002317STMP	001250IN	001195IN	122.8	2	52.10	19.81	11	26	Flooded	Flooded	Flooded	Flooded	11	12	1,139	885
002127STMP	001251IN	000489SMH	175.7	2.5	96.17	19.40	45	32	Flooded	Flooded	Flooded	Flooded	43	12	33,369	2,211
002128STMP	001252IN	001253IN	22.9	1.5	0.00	0.00	-	-	-1.50	-0.89	-8.00	-9.14	-	-	-	-
002129STMP	001253IN	000491SMH	16.7	1.5	9.64	14.58	-	-	-0.89	-0.94	-9.14	-10.59	-	-	-	-
002131STMP	001254IN	001256IN	185.1	1.5	20.09	17.12	-	16	-0.58	5.36	-13.58	-7.34	-	-	-	-
002132STMP	001255IN	001254IN	81.3	1.25	10.50	12.98	-	-	-0.48	-0.33	-6.03	-13.58	-	-	-	-
002133STMP	001256IN	000102IO	38.2	1.5	19.97	11.05	16	13	5.36	4.27	-7.34	-5.23	-	-	-	-
002369STMP	001257IN	001258IN	30.1	1.5	-0.04	0.38	-	-	-1.07	-0.68	-5.87	-5.88	-	-	-	-
002371STMP	001258IN	000495SMH	13.6	1.5	9.88	10.39	-	-	-0.68	-0.89	-5.88	-6.49	-	-	-	-
002372STMP	001259IN	001258IN	44.5	1.25	0.00	0.00	-	-	-1.25	-0.43	-4.00	-5.88	-	-	-	-
002383STMP	001268IN	000497SMH	15.8	1.5	19.65	15.00	10	12	3.50	4.17	-0.20	-0.23	-	-	-	-
002386STMP	001269IN	000209ND	62.2	1.25	4.90	10.47	-	12	-0.50	4.04	-2.45	-1.10	-	-	-	-
002382STMP	001270IN	000496SMH	27.1	1.25	0.64	2.53	4	8	0.84	3.00	-2.61	-0.50	-	-	-	-
Link3210	001298IN	000209ND	31.4	1.25	-0.71	2.51	9	12	3.05	4.04	-1.60	-1.10	-	-	-	-
002418STMP	001299IN	001300IN	237.3	1.5	19.80	11.41	21	34	Flooded	Flooded	Flooded	Flooded	18	30	1,662	2,565
002419STMP	001300IN	001301IN	208.8	1.5	16.14	10.08	34	36	Flooded	Flooded	Flooded	Flooded	30	34	2,565	4,653
002421STMP	001301IN	000500SMH	12.2	1.75	25.16	10.34	36	36	Flooded	Flooded	Flooded	Flooded	34	25	4,653	1,877
002420STMP	001302IN	001300IN	58.2	1.25	8.14	8.38	33	34	Flooded	Flooded	Flooded	Flooded	32	30	2,226	2,565
002787STMP	001835IN	000617SMH	38.2	1.25	2.79	5.25	25	25	1.31	2.32	-2.74	-1.13	-	-	-	-
003329STMP	001836IN	000617SMH	220.1	1.25	0.00	0.00	-	25	-1.25	2.32	-6.80	-1.13	-	-	-	-
002788STMP	001837IN	001836IN	88.2	1.25	0.00	0.00	-	-	-1.25	-1.25	-6.30	-6.80	-	-	-	-
003328STMP	001838IN	001837IN	22.2	1.25	0.00	0.00	-	-	-1.25	-1.25	-10.00	-6.30	-	-	-	-
003330STMP	001839IN	001840IN	39.8	1.25	17.45	14.03	29	26	Flooded	Flooded	Flooded	Flooded	27	13	4,825	721
003331STMP	001840IN	001841IN	48.5	2	17.65	11.65	26	31	Flooded	Flooded	Flooded	Flooded	13	15	721	1,451
003333STMP	001841IN	000619SMH	27.0	3	85.32	11.94	31	32	Flooded	Flooded	Flooded	Flooded	15	24	1,451	3,950
015101STMP	001842IN	000619SMH	14.3	1.5	19.43	10.76	34	32	Flooded	Flooded	Flooded	Flooded	23	24	3,806	3,950
003340STMP	001845IN	001846IN	28.1	0.833	2.08	6.64	25	26	3.22	5.40	-4.95	-4.37	-	-	-	-
003341STMP	001846IN	000621SMH	50.2	2.5	38.34	10.00	26	27	3.73	4.69	-4.37	-4.81	-	-	-	-
003347STMP	001848IN	000621SMH	67.3	1.5	11.12	11.26	0	27	0.04	5.69	-7.06	-4.81	-	-	-	-
003346STMP	001849IN	001846IN	42.2	2	31.42	15.32	21	26	2.15	4.23	-6.15	-4.37	-	-	-	-
003348STMP	001850IN	001848IN	90.2	1.25	0.00	0.00	-	0	-1.25	0.29	-5.50	-7.06	-	-	-	-
001448STMP	002319IN	002320IN	3.2	1	-0.07	1.28	-	-	-0.63	-0.42	-3.43	-3.42	-	-	-	-
001449STMP	002320IN	002323IN	4.3	1	-0.05	-0.44	-	-	-0.42	-0.39	-3.42	-3.39	-	-	-	-
003831STMP	002321IN	002322IN	5.0	1.25	-0.02	0.85	-	-	-1.16	-1.13	-3.91	-3.68	-	-	-	-
003830STMP	002322IN	002324IN	5.4	1.25	-0.10	1.28	-	-	-1.13	-0.97	-3.68	-3.52	-	-	-	-
003100STMP	002323IN	000788SMH	22.6	1.5	5.00	7.80	-	-	-0.89	-1.07	-3.39	-3.67	-	-	-	-
003101STMP	002324IN	000788SMH	9.9	1.25	-0.09	0.87	-	-	-0.97	-0.82	-3.52	-3.67	-	-	-	-
003833STMP	002325IN	002326IN	7.3	1	0.00	0.00	-	-	-1.00	-1.00	-9.00	-8.80	-	-	-	-
003837STMP	002326IN	002330IN	12.8	1	0.00	0.00	-	-	-1.00	-0.97	-8.80	-8.27	-	-	-	-
003832STMP	002327IN	002328IN	5.7	1.25	-0.08	1.28	-	-	-1.09	-0.88	-8.34	-7.52	-	-	-	-
003834STMP	002328IN	002329IN	11.6	1.25	-0.16	1.45	-	-	-0.88	-0.59	-7.52	-7.04	-	-	-	-
003835STMP	002329IN	000789SMH	27.5	1.25	10.63	15.94	-	-	-0.59	-0.51	-7.04	-7.96	-	-	-	-
003836STMP	002330IN	000789SMH	11.8	1.25	-0.02	0.18	-	-	-1.22	-0.51	-8.27	-7.96	-	-	-	-
003930STMP	002331IN	000791SMH	26.8	1.5	0.00	0.00	-	-	-1.50	-0.77	-6.70	-7.27	-	-	-	-
004286STMP	002332IN	002527IN	211.9	1.25	0.00	0.00	-	-	-1.25	-0.79	-7.02	-21.18	-	-	-	-
004264STMP	002333IN	002334IN	122.5	1.5	0.00	0.00	-	-	-1.50	-1.50	-3.98	-3.67	-	-	-	-
004265STMP	002334IN	002335IN	69.6	1.5	0.00	0.00	-	-	-1.50	-1.50	-3.67	-3.17	-	-	-	-
004266STMP	002335IN	002336IN	102.9	1.5	0.00	0.00	-	18	-1.50	Flooded	-3.17	Flooded	-	15	-	1,317
004269STMP	002336IN	000863SMH	98.6	1.5	19.78	11.07	18	18	Flooded	2.37	Flooded	-0.53	15	-	1,317	-
004243STMP	002338IN	002501IN	85.9	1.5	0.00	0.00	-	-	-1.50	-0.77	-3.00	-5.67	-	-	-	-
002813STMP	002339IN	000856SMH	109.4	3.5	204.35	21.04	14	18	5.28	4.75	-7.92	-6.06	-	-	-	-
004278STMP	002340IN	002475IN	263.1	1.25	0.00	0.00	-	-	-1.25	-1.25	-4.36	-5.00	-	-	-	-
004288STMP	002341IN	002342IN	60.5	1.5	0.00	0.00	-	-	-1.50	-1.50	-6.18	-7.00	-	-	-	-
004290STMP	002342IN	001186IN	120.9	1.5	0.00	0.00	-	28	-1.50	1.17	-7.00	-3.99	-	-	-	-
004289STMP	002343IN	002341IN	122.9	1.5	0.00	0.00	-	-	-1.50	-1.50	-4.61	-6.18	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft³/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft³]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
004291STMP	002344IN	002343IN	39.8	1.25	0.00	0.00	-	-	-1.25	-1.25	-3.65	-4.61	-	-	-	-
003663STMP	002345IN	002343IN	57.5	1.5	0.00	0.00	-	-	-1.50	-1.50	-5.04	-4.61	-	-	-	-
003664STMP	002346IN	002345IN	38.7	1.25	0.00	0.00	-	-	-1.25	-1.25	-3.92	-5.04	-	-	-	-
003667STMP	002347IN	002348IN	34.0	2	39.11	12.32	14	16	3.29	3.15	-1.51	-2.85	-	-	-	-
003666STMP	002348IN	002349IN	110.9	2	57.64	18.50	16	-	3.15	-0.46	-2.85	-7.46	-	-	-	-
003668STMP	002349IN	000868SMH	198.9	2	57.62	22.14	-	-	-0.46	-0.41	-7.46	-8.80	-	-	-	-
003966STMP	002350IN	002354IN	187.1	3	81.42	14.85	-	15	-0.82	0.39	-11.62	-4.11	-	-	-	-
002571STMP	002351IN	000869SMH	41.5	1.25	15.22	17.05	-	-	-0.42	-0.06	-10.90	-11.21	-	-	-	-
004215STMP	002353IN	000869SMH	85.3	1.75	0.00	0.00	-	-	-1.75	-0.56	-9.68	-11.21	-	-	-	-
003967STMP	002354IN	000870SMH	64.6	3	86.12	15.24	15	40	0.39	1.94	-4.11	-3.46	-	-	-	-
003969STMP	002355IN	002348IN	23.7	1.5	18.52	14.04	11	16	2.37	3.65	-3.83	-2.85	-	-	-	-
003970STMP	002356IN	002355IN	38.9	1.25	12.56	16.38	3	11	0.50	2.62	-4.70	-3.83	-	-	-	-
003971STMP	002357IN	002356IN	97.7	1.25	12.56	17.13	-	3	-0.53	0.50	-3.38	-4.70	-	-	-	-
003972STMP	002358IN	002357IN	105.7	1.25	12.56	11.38	6	-	0.06	-0.53	-2.91	-3.38	-	-	-	-
003973STMP	002359IN	002358IN	54.6	1.25	8.42	13.33	-	6	-0.67	0.06	-3.26	-2.91	-	-	-	-
003974STMP	002360IN	002358IN	39.8	1.25	-4.88	-3.89	2841	6	Flooded	0.06	Flooded	-2.91	29	-	2,255	-
003975STMP	002361IN	002358IN	110.0	1.25	8.86	7.84	-	6	-0.09	0.06	-3.04	-2.91	-	-	-	-
003675STMP	002362IN	000294ND	108.8	1.25	7.72	13.40	-	-	-0.71	2.62	-6.76	-4.21	-	-	-	-
004219STMP	002363IN	000869SMH	101.1	1.25	0.00	0.00	-	-	-1.25	-0.06	-3.00	-11.21	-	-	-	-
CRpipe3	002364IN	002451IN	459.5	1.5	0.00	0.00	-	-	-1.50	-0.79	-2.00	-3.79	-	-	-	-
002564STMP	002365IN	000840SMH	64.7	1.25	5.91	11.62	-	4	-0.78	0.94	-4.03	-5.51	-	-	-	-
004217STMP	002366IN	002365IN	79.6	1.25	0.03	0.26	-	-	-1.02	-0.78	-3.37	-4.03	-	-	-	-
002563STMP	002367IN	000840SMH	46.8	1.25	0.00	0.00	-	4	-1.25	0.94	-3.40	-5.51	-	-	-	-
003665STMP	002368IN	002347IN	59.3	2	19.93	7.19	11	14	2.84	3.29	-0.36	-1.51	-	-	-	-
003935STMP	002370IN	002371IN	20.3	1	0.00	0.00	-	-	-1.00	-1.00	-6.50	-6.40	-	-	-	-
003929STMP	002371IN	002331IN	15.5	1	0.00	0.00	-	-	-1.00	-1.00	-6.40	-6.70	-	-	-	-
003931STMP	002372IN	000791SMH	27.2	1.25	0.00	0.00	-	-	-1.25	-0.52	-7.70	-7.27	-	-	-	-
003936STMP	002373IN	002372IN	16.2	1	0.00	0.00	-	-	-1.00	-1.00	-8.00	-7.70	-	-	-	-
003934STMP	002374IN	002373IN	20.5	1	0.00	0.00	-	-	-1.00	-1.00	-8.50	-8.00	-	-	-	-
003938STMP	002375IN	000809SMH	132.7	2	0.00	0.00	-	7	-2.00	2.10	-3.70	-2.90	-	-	-	-
003940STMP	002376IN	000805SMH	60.8	2	57.36	17.77	16	17	8.80	6.69	-4.30	-2.31	-	-	-	-
003941STMP	002377IN	002405IN	167.0	1.5	0.00	0.00	-	-	-1.50	-1.60	-6.20	-7.30	-	-	-	-
003942STMP	002378IN	002377IN	35.0	1.25	0.00	0.00	-	-	-1.25	-1.50	-4.85	-6.20	-	-	-	-
003943STMP	002379IN	000795SMH	3.6	1.25	7.75	13.68	-	-	-0.66	-0.65	-3.41	-2.90	-	-	-	-
003945STMP	002380IN	000796SMH	13.8	1.25	0.02	0.32	-	-	-0.86	-0.84	-3.01	-2.89	-	-	-	-
003948STMP	002381IN	002383IN	158.5	1.25	12.85	12.45	-	-	-0.23	-0.52	-3.58	-9.67	-	-	-	-
003947STMP	002382IN	002381IN	41.0	1.25	12.87	11.45	-	-	-0.16	-0.23	-3.51	-3.58	-	-	-	-
015110STMP	002382ND	00615IO	35.6	3	67.09	4.72	304	142	Flooded	Flooded	Flooded	Flooded	97	114	17,131	65,927
003949STMP	002383IN	002391IN	110.1	1.25	7.72	10.74	-	-	-0.52	-0.70	-9.67	-8.25	-	-	-	-
003950STMP	002383IN	002384IN	65.5	4.216	5.13	3.33	-	-	-3.49	-3.71	-9.67	-6.90	-	-	-	-
003951STMP	002384IN	002386IN	23.0	3.333	5.04	6.28	-	-	-2.83	-2.40	-6.90	-6.07	-	-	-	-
003952STMP	002385IN	000797SMH	12.6	1.25	0.00	0.00	-	-	-1.25	-0.73	-6.00	-3.48	-	-	-	-
Link4054	002386IN	000799SMH	30.9	0.833	5.01	9.36	-	-	0.10	-0.12	-6.07	-4.09	-	-	-	-
003673STMP	002387IN	000291ND	7.4	1.25	0.00	0.00	-	-	-1.25	-0.79	-5.20	-5.64	-	-	-	-
003625STMP	002388IN	000300ND	82.1	2	20.20	14.10	-	22	-1.13	3.96	-6.13	-2.27	-	-	-	-
003624STMP	002389IN	002388IN	85.2	1.25	0.00	0.00	-	-	-1.25	-0.38	-4.40	-6.13	-	-	-	-
003626STMP	002390IN	000803SMH	31.2	1.5	0.00	0.00	-	-	-1.50	-1.50	-9.00	-8.10	-	-	-	-
003642STMP	002391IN	002362IN	56.7	1.25	7.73	14.95	-	-	-0.70	-0.71	-8.25	-6.76	-	-	-	-
003627STMP	002392IN	000804SMH	162.8	1.25	0.00	0.00	-	-	-1.25	-1.25	-1.75	-6.60	-	-	-	-
003629STMP	002393IN	002395IN	37.2	1.25	0.00	0.00	-	-	-1.25	-1.25	-6.30	-6.00	-	-	-	-
003630STMP	002394IN	002393IN	36.0	1.25	0.00	0.00	-	-	-1.25	-1.25	-6.70	-6.30	-	-	-	-
003631STMP	002395IN	002398IN	193.4	2	0.00	0.00	-	20	-2.00	7.46	-6.00	-1.44	-	-	-	-
003632STMP	002396IN	002397IN	33.7	1.25	0.00	0.00	-	-	-1.25	-0.66	-7.20	-6.91	-	-	-	-
003633STMP	002397IN	002398IN	91.8	1.25	-0.79	2.38	-	20	-0.66	8.21	-6.91	-1.44	-	-	-	-
004174STMP	002398IN	000835SMH	39.8	2.5	38.68	8.77	20	26	6.96	Flooded	-1.44	Flooded	-	8	-	1,762
003635STMP	002399IN	000836SMH	126.8	5.5	108.40	11.34	-	8	-2.80	0.75	-4.20	-1.45	-	-	-	-
003636STMP	002400IN	000807SMH	9.4	1	-0.25	1.51	91	72	4.24	4.72	-2.26	-2.28	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft^3/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft^3]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
004604STMP	002401IN	000806SMH	33.7	1	0.30	1.88	33	9	2.94	5.00	-2.06	-1.51	-	-	-	-
003638STMP	002402IN	000293ND	29.0	1.25	-0.34	1.25	18	8	2.33	4.43	-2.43	-4.09	-	-	-	-
Link2974	002403IN	000295ND	57.5	5	276.61	21.10	-	-	-1.62	-1.34	-4.42	-3.54	-	-	-	-
003643STMP	002404IN	000295ND	26.1	1.25	-0.39	1.38	61	-	1.44	2.41	-3.31	-3.54	-	-	-	-
CRpipe26	002405IN	000812SMH	43.0	1.25	0.00	0.00	-	-	-1.25	-1.51	-7.30	-7.76	-	-	-	-
003645STMP	002406IN	002408IN	38.0	1.25	0.00	0.00	-	-	-1.25	-1.95	-9.50	-8.70	-	-	-	-
003644STMP	002407IN	002406IN	36.0	1.25	0.00	0.00	-	-	-1.25	-1.73	-7.41	-9.50	-	-	-	-
003646STMP	002408IN	002409IN	34.0	1.5	0.00	0.00	-	-	-1.50	-1.62	-8.70	-9.92	-	-	-	-
003647STMP	002409IN	000810SMH	64.0	1.5	0.00	0.00	-	-	-1.50	-2.25	-9.92	-9.13	-	-	-	-
003648STMP	002410IN	002411IN	33.0	2	13.69	9.78	-	20	0.68	1.37	-5.98	-5.88	-	-	-	-
003650STMP	002411IN	002416IN	120.5	2	13.69	7.20	20	51	1.74	3.87	-5.88	-1.33	-	-	-	-
Link3118	002412IN	000296ND	86.4	5	253.54	19.36	-	-	-1.83	-1.80	-11.69	-9.27	-	-	-	-
003676STMP	002413IN	000296ND	30.6	1.25	-0.01	0.04	-	-	-1.23	-0.23	-9.62	-9.27	-	-	-	-
003654STMP	002414IN	000811SMH	67.8	5	275.65	20.14	-	-	-1.69	-1.87	-6.99	-5.87	-	-	-	-
003655STMP	002415IN	000810SMH	40.6	1.25	13.81	15.94	-	-	-0.42	-2.23	-11.01	-9.13	-	-	-	-
003657STMP	002416IN	002417IN	33.7	2	13.66	5.98	51	57	4.04	4.48	-1.33	-1.71	-	-	-	-
003658STMP	002417IN	002418IN	149.0	2	13.66	4.28	57	134	4.91	6.54	-1.71	-5.11	-	-	-	-
003659STMP	002418IN	00003PD	100.0	2	34.62	10.78	134	40	7.00	Surcharged	-5.11	Surcharged	-	-	-	-
003661STMP	002419IN	000297ND	10.1	1.25	2.76	2.23	159	-	2.39	2.59	-7.64	-9.19	-	-	-	-
003660STMP	002420IN	002419IN	40.0	1.25	-0.18	0.32	71	159	1.30	2.08	-7.91	-7.64	-	-	-	-
003662STMP	002421IN	002420IN	53.0	1.25	-0.11	0.41	-	71	-0.55	1.10	-8.24	-7.91	-	-	-	-
003653STMP	002422IN	002414IN	19.9	2	41.94	20.64	-	-	-0.83	1.31	-6.63	-6.99	-	-	-	-
003957STMP	002423IN	002422IN	284.1	1.75	0.00	0.00	-	-	-1.75	-0.58	-6.00	-6.63	-	-	-	-
003958STMP	002424IN	002427IN	40.0	2.25	-8.36	-3.70	71	76	4.30	4.41	-1.94	-1.79	-	-	-	-
003959STMP	002425IN	002424IN	105.0	1.5	-1.92	3.26	62	71	3.92	4.95	-0.38	-1.94	-	-	-	-
003960STMP	002426IN	002425IN	50.6	1.5	-0.20	0.36	47	62	2.66	3.92	-0.04	-0.38	-	-	-	-
003961STMP	002427IN	00003PD	59.7	2.25	-8.38	4.71	76	40	4.41	Surcharged	-1.79	Surcharged	-	-	-	-
004279STMP	002428IN	002395IN	84.7	1	0.00	0.00	-	-	-1.00	-1.00	-3.00	-6.00	-	-	-	-
001261STMP	002432IN	002433IN	40.6	1.25	3.14	6.88	49	81	0.80	Flooded	-0.75	Flooded	-	56	-	8,238
004170STMP	002433IN	000842SMH	174.0	1.5	-9.11	-5.09	81	80	Flooded	3.35	Flooded	-1.95	56	-	8,238	-
001262STMP	002434IN	000819SMH	11.0	1.5	-2.29	2.59	56	-	2.37	2.90	-3.13	-3.00	-	-	-	-
004205STMP	002435IN	002485IN	148.8	3	121.98	21.93	53	123	3.24	Flooded	-2.26	Flooded	-	107	-	361,555
001264STMP	002436IN	002435IN	11.8	1.5	-3.08	3.40	91	53	4.03	4.74	-3.47	-2.26	-	-	-	-
001267STMP	002437IN	000821SMH	20.2	1.25	7.70	6.14	6	-	0.13	-0.29	-5.34	-5.64	-	-	-	-
004148STMP	002438IN	002478IN	46.6	1	0.00	0.00	-	-	-1.00	-1.00	-4.90	-8.30	-	-	-	-
001268STMP	002439IN	002437IN	88.3	1.25	0.10	0.36	-	6	-0.79	0.13	-5.94	-5.34	-	-	-	-
004150STMP	002440IN	000823SMH	17.3	1.25	0.00	0.00	-	-	-1.25	-0.71	-4.30	-5.76	-	-	-	-
004155STMP	002441IN	002442IN	103.8	1.25	7.71	10.86	-	9	-0.48	1.59	-5.44	-0.56	-	-	-	-
004154STMP	002442IN	002444IN	47.7	1.5	7.71	8.74	9	14	1.34	Flooded	-0.56	Flooded	-	7	-	224
004156STMP	002443IN	002444IN	49.2	1.5	9.31	9.28	9	14	1.44	Flooded	-0.46	Flooded	-	7	-	224
001249STMP	002444IN	000176IO	34.8	1.5	18.34	15.34	14	20	Flooded	4.86	Flooded	-0.14	7	-	224	-
004157STMP	002445IN	002444IN	31.9	1.25	1.31	2.65	11	14	Flooded	Flooded	Flooded	Flooded	7	7	95	224
004158STMP	002446IN	000826SMH	39.5	2	53.64	11.76	-	3	-0.19	0.21	-3.49	-3.29	-	-	-	-
004163STMP	002448IN	000828SMH	143.4	1.5	0.00	0.00	-	9	-1.50	1.32	-4.70	-0.38	-	-	-	-
004167STMP	002449IN	000829SMH	12.2	1.25	0.00	0.00	-	-	-1.25	-1.25	-4.50	-4.70	-	-	-	-
004169STMP	002450IN	000173IO	104.7	1.75	29.69	13.24	9	-	2.46	-1.24	-0.19	-1.49	-	-	-	-
004171STMP	002451IN	002452IN	47.5	1.5	0.08	0.22	-	-	-0.79	-0.64	-3.79	-3.14	-	-	-	-
004172STMP	002452IN	000305ND	89.5	2.25	17.48	10.52	-	102	-1.39	Flooded	-3.14	Flooded	-	79	-	31
Link3417	002453IN	000305ND	27.9	1.25	8.10	6.53	103	102	Flooded	Flooded	Flooded	Flooded	65	79	8,236	31
004183STMP	002454IN	000298ND	54.8	3	26.98	8.88	-	8	-0.24	2.85	-7.74	-2.64	-	-	-	-
004184STMP	002455IN	002456IN	25.4	1.5	0.00	0.00	-	-	-1.50	-0.69	-3.60	-6.19	-	-	-	-
004185STMP	002456IN	002457IN	33.1	2.5	17.22	12.57	-	-	-1.69	-1.68	-6.19	-7.68	-	-	-	-
004186STMP	002457IN	002454IN	124.0	2.5	17.19	11.04	-	-	-1.68	0.26	-7.68	-7.74	-	-	-	-
004188STMP	002458IN	002456IN	64.4	2.5	17.20	10.57	-	-	-1.57	-1.69	-6.87	-6.19	-	-	-	-
004187STMP	002459IN	002458IN	51.6	2.5	17.18	10.62	-	-	-1.59	-1.57	-5.89	-6.87	-	-	-	-
004189STMP	002460IN	002459IN	12.9	2.25	17.17	14.51	-	-	-1.51	-1.34	-6.56	-5.89	-	-	-	-
004190STMP	002461IN	002460IN	27.5	2.25	-0.28	1.08	-	-	-2.06	-1.51	-7.11	-6.56	-	-	-	-

Link ID	Node ID US	Node ID DS	Length [ft]	D/H [ft]	Max Flow [ft³/s]	Max Velocity [ft/s]	Duration of Surcharge [hr] US	Duration of Surcharge [hr] DS	Surcharge/Depth Above Crown [ft] US	Surcharge/Depth Above Crown [ft] DS	Freeboard/Depth Below Rim [ft] US	Freeboard/Depth Below Rim [ft] DS	Duration of Flooding [hr] US	Duration of Flooding [hr] DS	Flooded Volume [ft³] US	Flooded Volume [ft³] DS
001252STMP	002462IN	002478IN	83.9	1.25	0.00	0.00	-	-	-1.25	-1.25	-8.60	-8.30	-	-	-	-
004191STMP	002463IN	002461IN	67.9	2.25	0.00	0.00	-	-	-2.25	-2.06	-7.00	-7.11	-	-	-	-
004192STMP	002464IN	002463IN	83.8	2.25	0.00	0.00	-	-	-2.25	-2.25	-6.80	-7.00	-	-	-	-
004195STMP	002465IN	002470IN	89.3	1.25	0.00	0.00	-	20	-1.25	1.07	-1.75	-2.18	-	-	-	-
004193STMP	002468IN	002464IN	180.3	2	0.00	0.00	-	-	-2.00	-2.00	-7.60	-6.80	-	-	-	-
Link4071	002469IN	002468IN	91.1	2	0.00	0.00	-	-	-2.00	-2.00	-8.30	-7.60	-	-	-	-
015127STMP	002470IN	004126SMH	19.0	2	42.42	13.03	20	-	0.32	-0.23	-2.18	-4.54	-	-	-	-
004196STMP	002471IN	002472IN	32.8	1.5	36.85	20.61	21	20	Flooded	2.19	Flooded	-3.51	18	-	3,735	-
004197STMP	002472IN	002470IN	166.1	2	36.85	11.62	20	20	1.69	0.32	-3.51	-2.18	-	-	-	-
004176STMP	002473IN	000837SMH	27.9	1.25	9.73	9.93	19	21	1.67	2.91	-0.18	-5.84	-	-	-	-
004177STMP	002474IN	000838SMH	8.8	1.75	0.00	0.00	-	-	-1.75	-1.75	-5.00	-5.90	-	-	-	-
001243STMP	002475IN	002476IN	88.6	1.25	0.00	0.00	-	-	-1.25	-1.25	-5.00	-4.70	-	-	-	-
002566STMP	002476IN	002477IN	150.7	1.5	0.00	0.00	-	-	-1.50	-0.45	-4.70	-5.15	-	-	-	-
Link3552	002477IN	000303ND	44.9	1.25	-0.39	0.93	-	7	-0.20	0.62	-5.15	-5.59	-	-	-	-
001251STMP	002478IN	002479IN	270.0	1.5	0.00	0.00	-	-	-1.50	-0.79	-8.30	-3.69	-	-	-	-
001253STMP	002479IN	002480IN	65.3	1.5	0.80	2.31	-	47	-0.79	3.80	-3.69	-3.00	-	-	-	-
003550STMP	002480IN	000844SMH	9.8	1.5	9.07	5.15	47	8	3.80	4.65	-3.00	-2.55	-	-	-	-
003551STMP	002481IN	000844SMH	46.3	1.25	1.07	2.80	7	8	0.58	4.90	-3.17	-2.55	-	-	-	-
004199STMP	002482IN	002481IN	46.9	1.25	0.62	2.39	-	7	-0.49	0.58	-3.69	-3.17	-	-	-	-
004208STMP	002485IN	002486IN	216.2	3.5	245.31	12.52	123	105	Flooded	Flooded	Flooded	Flooded	107	90	361,555	10,467
004903STMP	002486IN	003546SMH	304.1	3.5	229.71	11.77	105	136	Flooded	5.29	Flooded	-1.82	90	-	10,467	-
LinkDASHPipe1.1	002486IN	StorageDash5169	39.0	3	-55.28	-8.05	105	103	Flooded	Surcharged	Flooded	Surcharged	90	-	10,467	-
LinkDASHPipe2	002486IN	StorageDash5169	40.0	3	-54.27	-7.67	105	103	Flooded	Surcharged	Flooded	Surcharged	90	-	10,467	-
004209STMP	002487IN	002490IN	189.0	1.25	0.00	0.00	-	40	-1.25	0.54	-3.50	-1.11	-	-	-	-
004179STMP	002488IN	000839SMH	46.1	1.25	0.00	0.00	-	4	-1.25	0.38	-11.60	-6.07	-	-	-	-
004211STMP	002489IN	000850SMH	36.0	1.5	6.13	6.71	43	49	0.60	Flooded	-0.80	Flooded	-	46	-	4,865
004210STMP	002490IN	002489IN	7.6	1.25	4.84	7.65	40	43	0.54	0.85	-1.11	-0.80	-	-	-	-
004214STMP	002491IN	000851SMH	13.3	1.25	21.34	17.17	51	48	Flooded	Flooded	Flooded	Flooded	47	39	6,348	3,804
004233STMP	002492IN	000852SMH	30.7	1.25	0.00	0.00	-	-	-1.25	-0.05	-4.00	-4.30	-	-	-	-
004234STMP	002493IN	000852SMH	24.3	1.5	0.00	0.00	-	-	-1.50	-0.30	-3.55	-4.30	-	-	-	-
004236STMP	002494IN	000853SMH	48.3	1.25	0.00	0.00	-	-	-1.25	-0.10	-10.00	-4.35	-	-	-	-
004237STMP	002495IN	000853SMH	45.8	1	0.00	0.00	-	-	-1.00	0.15	-5.60	-4.35	-	-	-	-
004238STMP	002496IN	000854SMH	42.1	1	0.00	0.00	-	-	-1.00	0.18	-5.20	-4.32	-	-	-	-
004239STMP	002497IN	000854SMH	24.5	1.25	0.00	0.00	-	-	-1.25	-0.07	-5.30	-4.32	-	-	-	-
004240STMP	002498IN	000855SMH	25.0	1.25	0.00	0.00	-	-	-1.25	-0.11	-5.00	-4.56	-	-	-	-
004241STMP	002499IN	000855SMH	48.2	1	0.00	0.00	-	-	-1.00	0.14	-5.80	-4.56	-	-	-	-
004242STMP	002500IN	002499IN	64.3	1	0.00	0.00	-	-	-1.00	-1.00	-3.50	-5.80	-	-	-	-
004244STMP	002501IN	002502IN	97.3	1.5	11.66	13.53	-	-	-0.77	-0.69	-5.67	-13.69	-	-	-	-
003588STMP	002502IN	002506IN	138.8	1.5	11.54	12.57	-	4	-0.69	3.14	-13.69	-6.18	-	-	-	-
004275STMP	002506IN	002507IN	120.8	2.5	24.47	10.45	4	8	2.14	5.93	-6.18	-4.77	-	-	-	-
004284STMP	002507IN	002339IN	216.1	3.5	197.82	22.16	8	14	4.93	5.28	-4.77	-7.92	-	-	-	-
004276STMP	002508IN	002507IN	73.3	1.5	5.21	8.96	-	8	-0.16	6.93	-14.65	-4.77	-	-	-	-
003592STMP	002509IN	002508IN	67.6	1.25	0.00	0.00	-	-	-1.25	0.09	-11.75	-14.65	-	-	-	-
003594STMP	002512IN	002339IN	97.4	1	0.00	0.00	-	14	-1.00	7.78	-6.30	-7.92	-	-	-	-
003600STMP	002513IN	002517IN	121.7	1	12.16	14.71	21	27	Flooded	Flooded	Flooded	Flooded	9	23	273	3,195
015141STMP	002515IN	004131SMH	19.1	1.25	0.00	0.00	-	-	-1.25	-1.25	-4.50	-7.50	-	-	-	-
003598STMP	002516IN	000856SMH	93.5	1.25	15.83	14.75	20	18	3.94	7.00	-0.76	-6.06	-	-	-	-
003599STMP	002517IN	002516IN	140.6	1.25	12.69	10.26	27	20	Flooded	3.94	Flooded	-0.76	23	-	3,195	-
004224STMP	002518IN	000613IO	32.3	5	229.13	16.58	-	-	-1.55	-2.73	-10.55	-3.53	-	-	-	-
015140STMP	002519IN	004132SMH	18.2	1.25	8.34	23.73	-	-	-0.86	-0.67	-4.11	-10.17	-	-	-	-
015131STMP	002521IN	002518IN	96.5	1	4.06	11.07	-	-	-0.57	2.45	-5.57	-10.55	-	-	-	-
004277STMP	002522IN	002507IN	247.8	3.5	169.42	23.90	-	8	-0.50	4.93	-12.40	-4.77	-	-	-	-
004248STMP	002523IN	000859SMH	5.7	1	11.06	14.77	-	-	-0.07	-0.22	-14.07	-15.72	-	-	-	-
004245STMP	002524IN	000857SMH	38.7	1.25	0.00	0.00	-	-	-1.25	1.28	-13.82	-13.87	-	-	-	-
002568STMP	002525IN	000312ND	34.3	1	4.51	11.12	-	-	-0.53	0.55	-6.21	-9.45	-	-	-	-
004250STMP	002526IN	002525IN	76.2	0.833	0.00	0.00	-	-	-0.83	-0.36	-2.24	-6.21	-	-	-	-
004251STMP	002527IN	000860SMH	28.3	1.5	6.28	10.80	-	-	-1.04	-0.15	-21.18	-20.65	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft^3/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft^3]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
004228STMP	002528IN	000860SMH	82.4	2	68.71	26.80	-	-	-0.46	-0.65	-11.76	-20.65	-	-	-	-
004252STMP	002529IN	002528IN	103.9	1.75	37.12	19.18	-	-	-0.46	-0.21	-4.51	-11.76	-	-	-	-
004255STMP	002530IN	000861SMH	25.8	1.5	32.16	17.85	19	-	4.10	0.30	-5.40	-9.61	-	-	-	-
004254STMP	002531IN	002530IN	55.1	1.25	0.32	1.34	-	19	-0.83	4.35	-13.29	-5.40	-	-	-	-
004257STMP	002532IN	002533IN	27.4	1.25	0.00	0.00	-	-	-1.25	-1.25	-6.35	-8.23	-	-	-	-
004258STMP	002533IN	002534IN	52.0	1.5	0.00	0.00	-	-	-1.50	-1.50	-8.23	-9.69	-	-	-	-
004259STMP	002534IN	002535IN	100.1	1.5	0.00	0.00	-	-	-1.50	-1.50	-9.69	-7.38	-	-	-	-
004260STMP	002535IN	000862SMH	75.9	1.5	0.00	0.00	-	-	-1.50	-1.50	-7.38	-7.09	-	-	-	-
004253STMP	002536IN	002529IN	49.9	1.75	37.12	15.68	21	-	1.61	-0.46	-1.24	-4.51	-	-	-	-
004263STMP	002537IN	002538IN	25.0	1.5	2.08	3.85	2	20	0.04	2.35	-3.66	-0.64	-	-	-	-
004262STMP	002538IN	002536IN	84.1	1.5	19.87	11.16	20	21	2.35	1.86	-0.64	-1.24	-	-	-	-
013308STMP	003503SMH	Junct016	116.7	0.833	0.00	0.00	-	-	-0.83	-0.83	-8.60	-9.11	-	-	-	-
013312STMP	003504SMH	003503SMH	119.2	0.833	0.00	0.00	-	-	-0.83	-0.83	-13.60	-8.60	-	-	-	-
013311STMP	003505SMH	003506SMH	140.4	0.833	0.00	0.00	-	-	-0.83	-0.83	-6.00	-10.60	-	-	-	-
013310STMP	003506SMH	003504SMH	138.5	0.833	0.00	0.00	-	-	-0.83	-0.83	-10.60	-13.60	-	-	-	-
013320STMP	003540SMH	008951IN	184.4	2	12.89	4.06	44	111	Flooded	2.69	Flooded	-0.02	3	-	23	-
013326STMP	003541SMH	003542SMH	249.2	3	34.04	4.80	108	118	2.08	Flooded	-1.51	Flooded	-	100	-	8,487
013334STMP	003542SMH	00001PD	181.0	3	32.99	3.12	118	390	Flooded	4.10	Flooded	-0.90	100	-	8,487	-
013329STMP	003544SMH	003545SMH	23.0	3	81.32	11.41	135	135	4.89	4.93	-0.98	-0.46	-	-	-	-
013330STMP	003545SMH	003546SMH	185.7	3	81.54	11.45	135	136	5.15	6.10	-0.46	-1.82	-	-	-	-
013331STMP	003546SMH	003547SMH	51.2	3.5	240.51	24.75	136	133	5.74	2.91	-1.82	-4.37	-	-	-	-
013332STMP	003547SMH	000314ND	17.4	3	240.51	33.77	133	-	3.69	1.80	-4.37	-3.20	-	-	-	-
005419STMP	003717IN	003726IN	27.7	2	22.57	10.04	-	-	-0.67	-0.49	-6.67	-7.49	-	-	-	-
005417STMP	003718IN	001193SMH	80.9	1.5	0.00	0.00	-	-	-1.50	-0.03	-4.41	-6.53	-	-	-	-
005733STMP	003719IN	003720IN	8.4	1	-0.16	1.63	-	-	-0.65	-0.23	-7.65	-7.26	-	-	-	-
005416STMP	003720IN	001193SMH	7.9	1.5	-0.40	1.75	-	-	-0.73	-0.03	-7.26	-6.53	-	-	-	-
005722STMP	003721IN	000471ND	59.0	3	23.19	5.32	-	-	-1.30	-0.43	-5.10	-6.93	-	-	-	-
005723STMP	003722IN	003721IN	34.2	3	-0.11	0.12	-	-	-1.57	-1.30	-5.07	-5.10	-	-	-	-
005729STMP	003723IN	003724IN	89.3	1.5	0.24	0.56	-	27	-0.92	1.82	-4.25	-2.72	-	-	-	-
005725STMP	003724IN	000251IO	23.0	1.5	31.94	17.95	27	-	1.82	0.00	-2.72	-0.24	-	-	-	-
005731STMP	003725IN	003727IN	91.5	1.5	0.00	0.00	-	-	-1.50	-0.94	-4.29	-5.33	-	-	-	-
005418STMP	003726IN	003728IN	169.4	2	22.56	9.18	-	-	-0.49	-0.83	-7.49	-10.83	-	-	-	-
005730STMP	003727IN	000247IO	26.8	1.5	9.54	15.92	-	-	-0.94	-0.94	-5.33	-0.94	-	-	-	-
005732STMP	003728IN	000248IO	140.1	3.5	22.55	8.02	-	-	-2.33	-2.33	-10.83	-3.63	-	-	-	-
005812STMP	003782IN	003783IN	9.8	1	-0.19	1.29	18	24	3.15	4.08	-0.05	-0.11	-	-	-	-
005814STMP	003783IN	003785IN	44.8	1.25	-0.45	-0.36	24	27	3.83	4.27	-0.11	-0.02	-	-	-	-
005813STMP	003784IN	003785IN	10.0	1	-0.29	1.89	25	27	3.94	4.52	-0.06	-0.02	-	-	-	-
005815STMP	003785IN	001208SMH	92.3	1.5	22.78	12.69	27	38	4.02	0.76	-0.02	-4.82	-	-	-	-
005818STMP	003786IN	003809IN	90.0	1.5	-0.34	0.76	-	6	-1.30	1.06	-4.54	-3.04	-	-	-	-
005819STMP	003787IN	003808IN	93.3	5.5	142.84	14.10	-	-	-2.96	-2.17	-6.46	-6.47	-	-	-	-
005799STMP	003788IN	003807IN	93.5	1.25	-0.06	0.40	-	-	-0.76	-0.28	-3.50	-3.12	-	-	-	-
005835STMP	003789IN	003806IN	88.3	1.5	0.00	0.00	-	-	-1.50	-0.87	-3.71	-3.77	-	-	-	-
005800STMP	003790IN	003805IN	72.8	1.25	0.00	0.00	-	18	-1.25	1.55	-10.82	-15.20	-	-	-	-
005834STMP	003791IN	001213SMH	56.0	1.5	0.00	0.00	-	-	-1.50	0.85	-6.21	-7.45	-	-	-	-
005828STMP	003792IN	003794IN	7.7	1	0.29	2.46	-	-	-0.33	0.02	-4.33	-4.36	-	-	-	-
005827STMP	003793IN	003794IN	8.0	1	-0.24	2.13	-	-	-0.39	0.02	-4.39	-4.36	-	-	-	-
005832STMP	003794IN	001212SMH	57.3	1.75	2.00	3.43	-	10	-0.73	1.89	-4.36	-2.76	-	-	-	-
005824STMP	003795IN	001210SMH	58.1	1.25	9.37	10.37	9	13	1.14	3.20	-1.20	-1.15	-	-	-	-
005822STMP	003796IN	001209SMH	57.1	1.5	0.00	0.00	-	-	-1.50	-0.74	-4.63	-4.66	-	-	-	-
005821STMP	003797IN	001209SMH	7.4	1.25	-0.34	1.80	-	-	-0.98	-0.49	-4.54	-4.66	-	-	-	-
005825STMP	003798IN	001210SMH	9.8	1.25	0.68	2.19	12	13	2.39	3.20	-2.36	-1.15	-	-	-	-
005826STMP	003799IN	003800IN	27.2	1.25	5.39	4.31	15	15	Flooded	Flooded	Flooded	Flooded	8	1	575	4
005803STMP	003800IN	001211SMH	32.1	1.5	30.95	17.24	15	16	Flooded	3.64	Flooded	-1.06	1	-	4	-
005829STMP	003801IN	003803IN	8.5	1	0.33	1.89	13	14	1.55	2.14	-4.46	-4.48	-	-	-	-
005830STMP	003802IN	003803IN	5.6	1	-0.83	2.57	15	14	1.71	2.14	-4.49	-4.48	-	-	-	-
005831STMP	003803IN	001212SMH	7.0	1.5	1.04	2.18	14	10	1.64	2.14	-4.48	-2.76	-	-	-	-
005806STMP	003804IN	001213SMH	12.2	1.5	-0.70	2.22	12	-	0.28	0.85	-8.22	-7.45	-	-	-	-

Link ID	Node ID		Length [ft]	D/H [ft]	Max Flow [ft³/s]	Max Velocity [ft/s]	Duration of Surcharge [hr]		Surcharge/Depth Above Crown [ft]		Freeboard/Depth Below Rim [ft]		Duration of Flooding [hr]		Flooded Volume [ft³]	
	US	DS					US	DS	US	DS	US	DS	US	DS	US	DS
005807STMP	003805IN	001215SMH	24.3	1.5	23.91	13.45	18	-	1.30	2.43	-15.20	-14.17	-	-	-	-
005808STMP	003806IN	003805IN	339.3	1.5	8.17	10.10	-	18	-0.87	1.30	-3.77	-15.20	-	-	-	-
005809STMP	003807IN	000260IO	23.7	1.25	4.93	4.86	-	-	-0.28	-0.35	-3.12	-2.06	-	-	-	-
005820STMP	003808IN	000258IO	34.3	5.5	190.93	12.71	-	-	-2.17	-2.17	-6.47	-3.67	-	-	-	-
005811STMP	003809IN	003808IN	172.2	1.5	15.60	8.79	6	-	1.06	1.83	-3.04	-6.47	-	-	-	-
002565STMP	004126SMH	000841SMH	49.4	2	42.42	15.11	-	-	-0.23	-0.34	-4.54	-4.54	-	-	-	-
015135STMP	004127SMH	004128SMH	138.0	2	10.83	4.01	17	84	1.34	1.46	-1.23	-0.60	-	-	-	-
015136STMP	004128SMH	004129SMH	142.3	2	10.87	3.57	84	95	1.51	1.81	-0.60	-0.76	-	-	-	-
015137STMP	004129SMH	004130SMH	257.0	2.5	10.89	2.99	95	111	1.31	2.22	-0.76	-1.12	-	-	-	-
015138STMP	004130SMH	009285IN	265.9	2.5	24.70	5.00	111	118	2.22	2.12	-1.12	-2.03	-	-	-	-
015142STMP	004131SMH	004132SMH	110.8	1.25	0.00	0.00	-	-	-1.25	-0.67	-7.50	-10.17	-	-	-	-
015143STMP	004132SMH	002518IN	42.0	1.5	8.34	11.16	-	-	-0.92	1.95	-10.17	-10.55	-	-	-	-
004280STMP	004436IN	002477IN	11.3	1.5	-0.45	1.79	-	-	-1.20	-0.45	-5.25	-5.15	-	-	-	-
001246STMP	004437IN	000303ND	7.0	1.5	11.49	9.30	-	7	-0.10	0.37	-4.90	-5.59	-	-	-	-
004164STMP	004438IN	002448IN	41.9	1.5	0.00	0.00	-	-	-1.50	-1.50	-7.75	-4.70	-	-	-	-
004162STMP	004439IN	002448IN	14.3	1.5	0.00	0.00	-	-	-1.50	-1.50	-3.35	-4.70	-	-	-	-
004206STMP	004457IN	000313ND	20.1	1.25	-1.82	3.06	30	16	2.69	4.58	-3.71	-3.09	-	-	-	-
004221STMP	004458IN	004459IN	43.7	3	92.02	12.96	31	93	1.85	3.20	-6.65	-3.20	-	-	-	-
004222STMP	004459IN	000907SMH	70.1	4	95.95	7.61	93	95	2.20	2.07	-3.20	-4.44	-	-	-	-
006317STMP	004857IN	000315ND	8.8	1	9.56	11.96	20	14	2.91	3.00	-4.09	-4.18	-	-	-	-
OpenCh02	00615IO	Junct015	118.5	2	74.96	1.37	142	123	Flooded	Flooded	Flooded	Flooded	114	106	65,927	56,089
004202STMP	00840SMH	000848SMH	85.5	3	68.71	5.29	115	2823	3.05	6.48	-0.95	-1.02	-	-	-	-
013319STMP	008949IN	003540SMH	15.3	2	-0.93	-1.15	42	44	1.94	Flooded	-0.01	Flooded	-	3	0	23
013321STMP	008950IN	008951IN	148.0	1.25	2.84	2.29	106	111	Flooded	3.52	Flooded	-0.02	19	-	851	-
013323STMP	008951IN	008952IN	234.2	2	11.22	3.54	111	109	2.77	Flooded	-0.02	Flooded	-	11	-	283
013324STMP	008952IN	003541SMH	241.1	2.5	11.18	2.27	109	108	Flooded	2.58	Flooded	-1.51	11	-	283	-
013325STMP	008953IN	003541SMH	38.2	1.25	-7.60	-6.08	138	108	Flooded	3.83	Flooded	-1.51	40	-	5,053	-
013327STMP	008954IN	003542SMH	34.7	1.5	6.42	3.60	122	118	Flooded	Flooded	Flooded	Flooded	49	100	743	8,487
015139STMP	009285IN	00001PD	121.6	2.5	24.67	5.00	118	390	2.12	4.41	-2.03	-0.90	-	-	-	-
CRpipe14	Junct004	000469ND	542.4	8	166.97	11.08	-	-	-5.21	-5.88	-5.21	-5.88	-	-	-	-
CRpipe13	Junct005	000483ND	613.0	5.5	142.83	10.98	-	-	-2.38	-4.06	-2.38	-4.56	-	-	-	-
OpenCh08	Junct006	Junct005	10.8	3	142.89	4.37	-	-	-1.06	0.12	-3.06	-2.38	-	-	-	-
CRpipe11	Junct007	Junct006	31.2	3	142.83	27.11	-	-	-0.89	-1.06	-2.89	-3.06	-	-	-	-
OpenCh06	Junct008	Junct011	13.2	2.2	143.50	2.95	72	90	Flooded	Flooded	Flooded	Flooded	47	48	850	887
CRpipe10	Junct009	Junct008	77.5	3	144.14	20.16	128	72	Flooded	Flooded	Flooded	Flooded	112	47	134,380	850
OpenCh07	Junct010	Junct007	15.7	1	142.83	3.61	-	-	-0.54	1.11	-4.54	-2.89	-	-	-	-
CRpipe12	Junct011	Junct010	51.9	3	142.83	21.72	90	-	Flooded	-2.54	Flooded	-4.54	48	-	887	-
OpenCh09	Junct012	Junct013	10.1	7	250.32	19.02	-	-	-4.76	-2.07	-7.06	-3.48	-	-	-	-
CRpipe8	Junct013	Junct014	92.5	4	243.01	15.17	-	-	0.93	-7.13	-3.48	-8.22	-	-	-	-
CRpipe9	Junct014	000480ND	737.9	5.5	241.01	11.17	-	-	-2.82	-3.89	-8.22	-6.39	-	-	-	-
OpenCh04	Junct015	Junct009	197.8	3	86.48	0.39	123	128	Flooded	Flooded	Flooded	Flooded	106	112	56,089	134,380
013307STMP	Junct016	000790SMH	55.7	0.833	0.00	0.00	-	-	-0.83	-0.11	-9.11	-7.07	-	-	-	-
013309STMP	Junct017	003505SMH	227.5	0.833	0.00	0.00	-	-	-0.83	-0.83	-1.33	-6.00	-	-	-	-
Link4056	Node5152	Node5153	33.0	6	114.37	13.38	-	-	-3.89	-3.78	-6.89	-7.28	-	-	-	-
OpenCh18	Node5153	Junct004	33.0	6	114.72	4.92	-	-	-3.78	-3.21	-7.28	-5.21	-	-	-	-
Link4058	Node5154	Node5154.1	60.0	3	-39.04	-6.62	104	104	Flooded	2.77	Flooded	-1.43	99	-	27,374	-
Link4058.1	Node5154.1	Node5158	132.0	3	-38.97	-5.63	104	105	2.75	2.94	-1.43	-4.96	-	-	-	-
015121STMP	Node5158	00840SMH	267.7	3	68.74	4.84	105	115	2.94	3.05	-4.96	-0.95	-	-	-	-
OpenCh03	Node5160	00615IO	41.4	2	20.34	2.22	-	142	-0.68	Flooded	-1.13	Flooded	-	114	-	65,927
Link4069	Node5166	003544SMH	195.8	1.5	3.23	4.53	122	135	2.68	6.38	-1.11	-0.98	-	-	-	-
LinkDASH4061	NodeDash5162	NodeDash5163	72.2	1.25	-0.03	0.21	-	-	-0.56	-0.29	-2.20	-2.28	-	-	-	-
LinkDASH4062	NodeDash5163	NodeDash5164	62.8	1.5	-0.07	0.28	-	6	-0.27	0.01	-2.28	-2.21	-	-	-	-
LinkDASH4063	NodeDash5164	008949IN	35.0	0.16	-0.09	-3.94	6	42	1.44	3.96	-2.21	-0.01	-	-	-	0
LinkDASH4064	NodeDash5165	004127SMH	36.3	1.25	-0.40	0.78	25	17	1.43	1.53	-1.37	-1.23	-	-	-	-
LinkDASH4065	NodeDash5166	004127SMH	114.8	1.25	-0.32	0.78	79	17	1.73	2.03	-1.02	-1.23	-	-	-	-
LinkDASH4067	StorageDash5169	Node5154	3.0	3	-39.46	-6.68	103	104	Surcharged	Flooded	Surcharged	Flooded	-	99	-	27,374
Catch Basin to Pond	StorageDash5169	009285IN	-	-	29.19	7.24	103	118	Surcharged	4.62	Surcharged	-2.03	-	-	-	-

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Appendix D. Model Profiles

Baseline Model Profiles

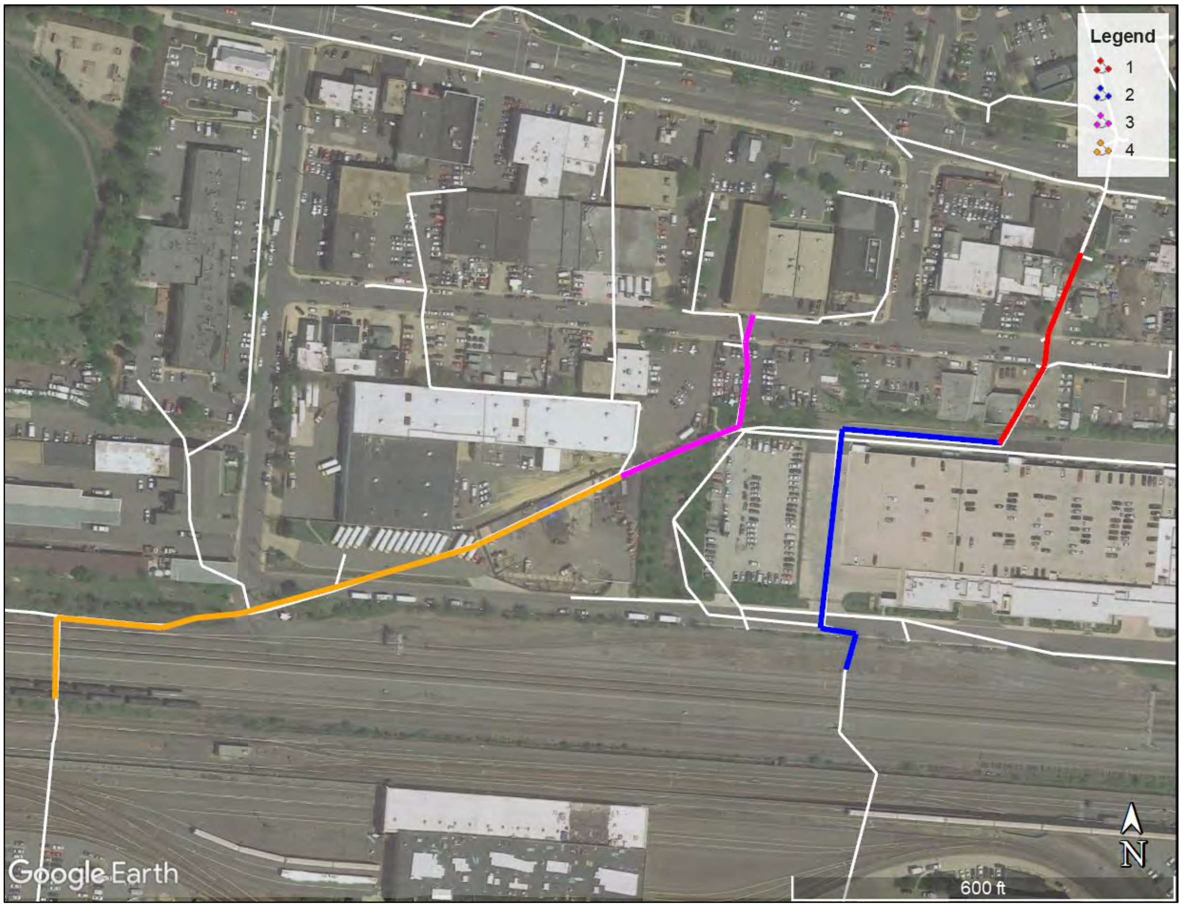

Figure D1. Baseline – Profile Location

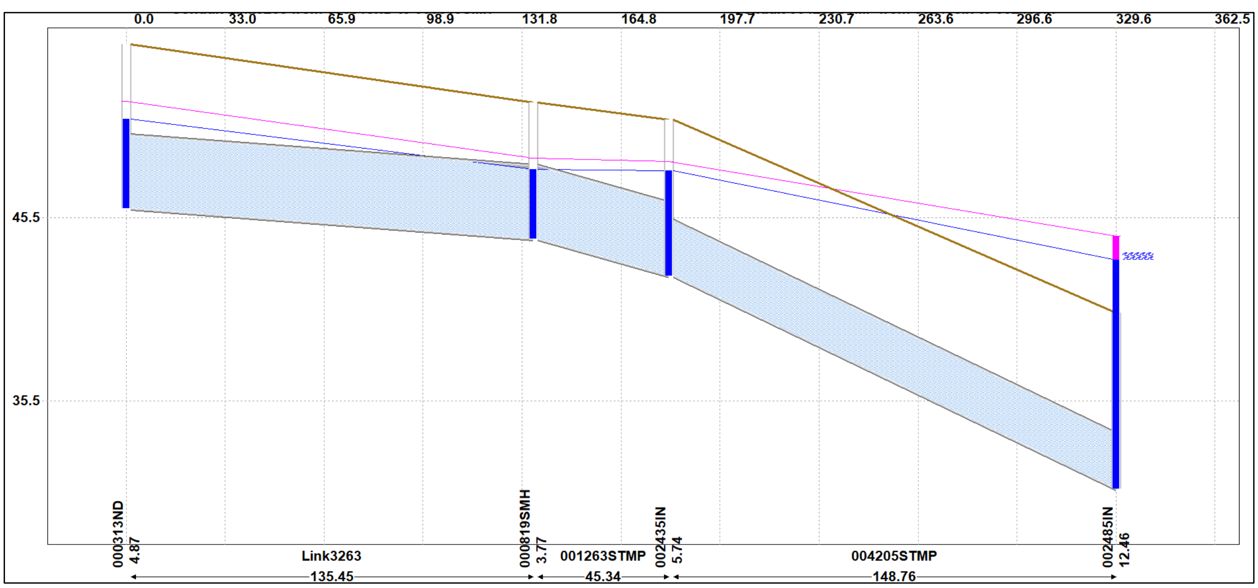

Figure D2. Baseline - Profile 1 from 000313ND to 002485IN

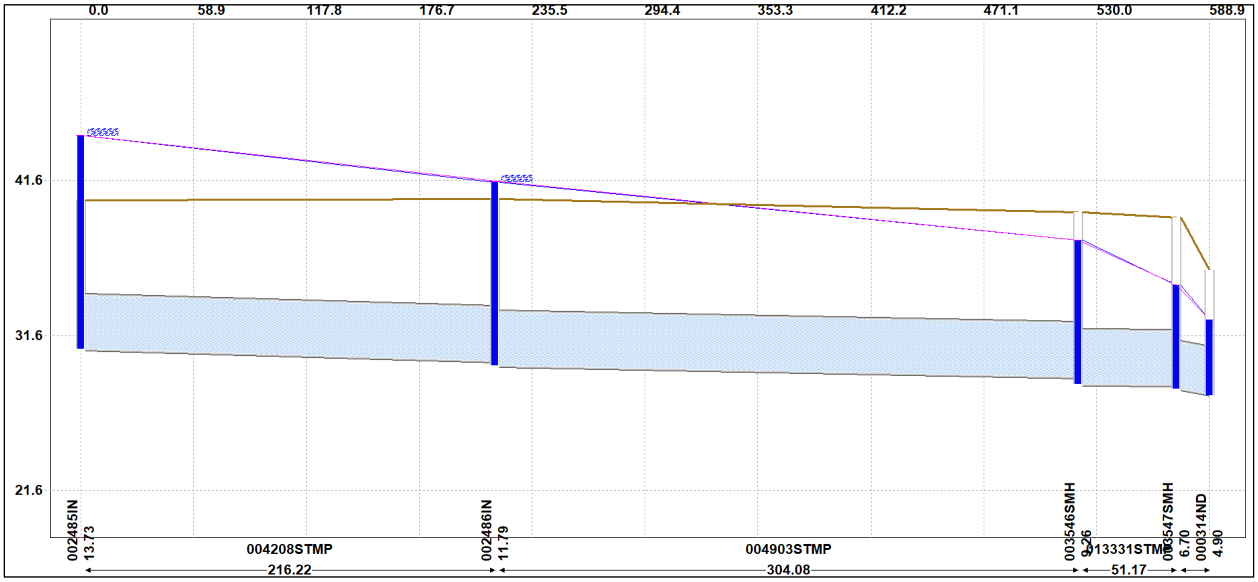

Figure D3. Baseline - Profile 2 from 002485IN to 000314ND

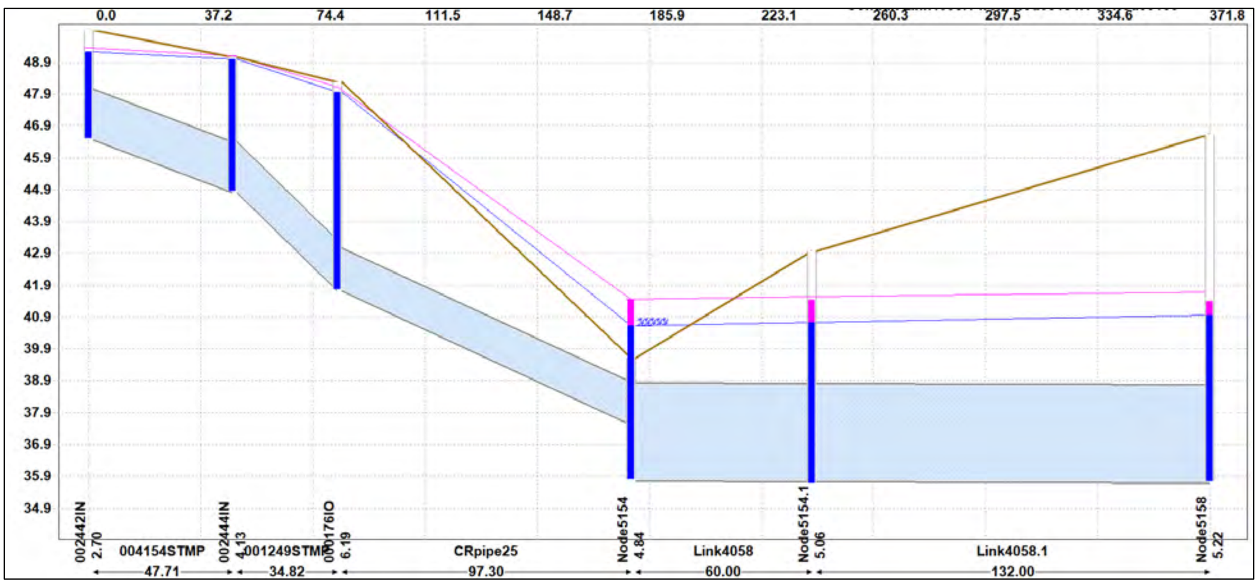

Figure D4. Baseline - Profile 3 from 002442IN to Node5158

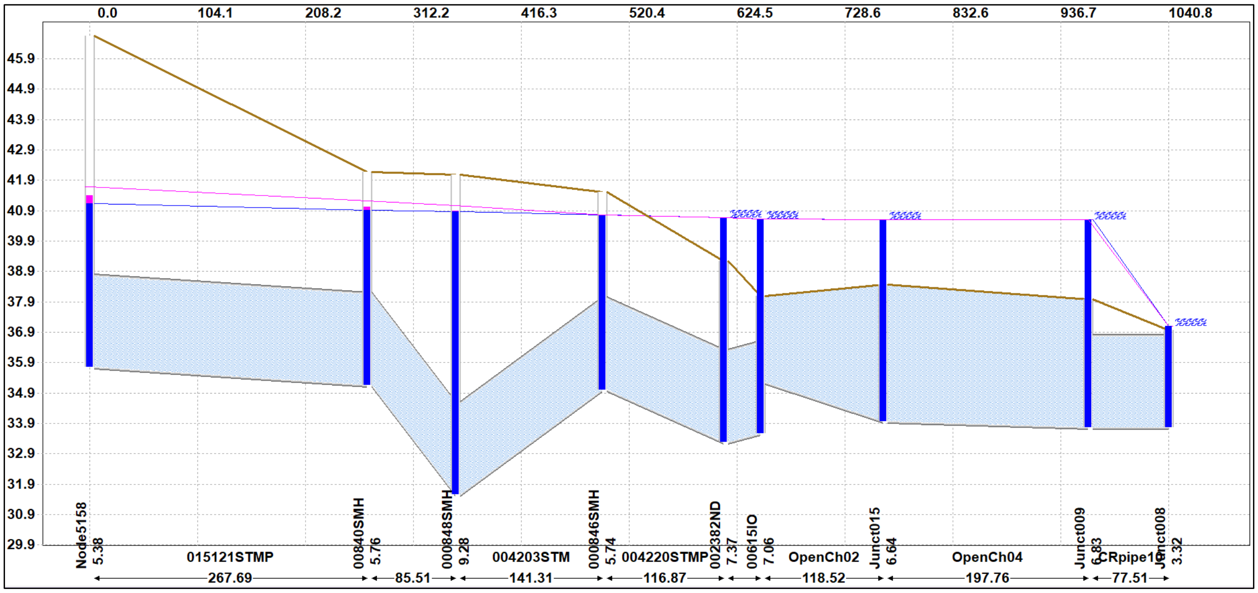

Figure D5. Baseline - Profile 4 from Node5158 to Junct008

<u>ROUTE-1 Model Profiles</u>

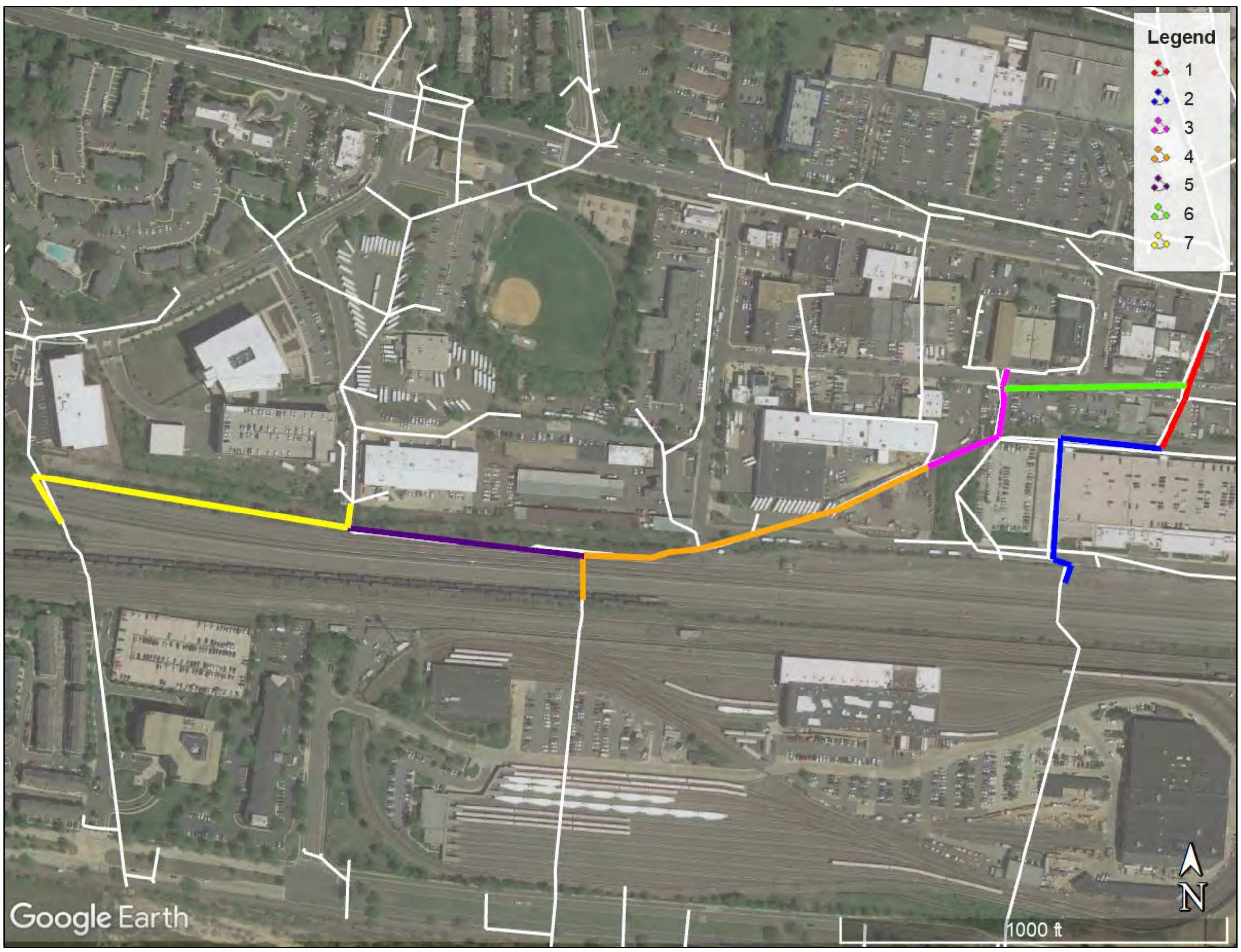

Figure D6. ROUTE-1 – Profile locations

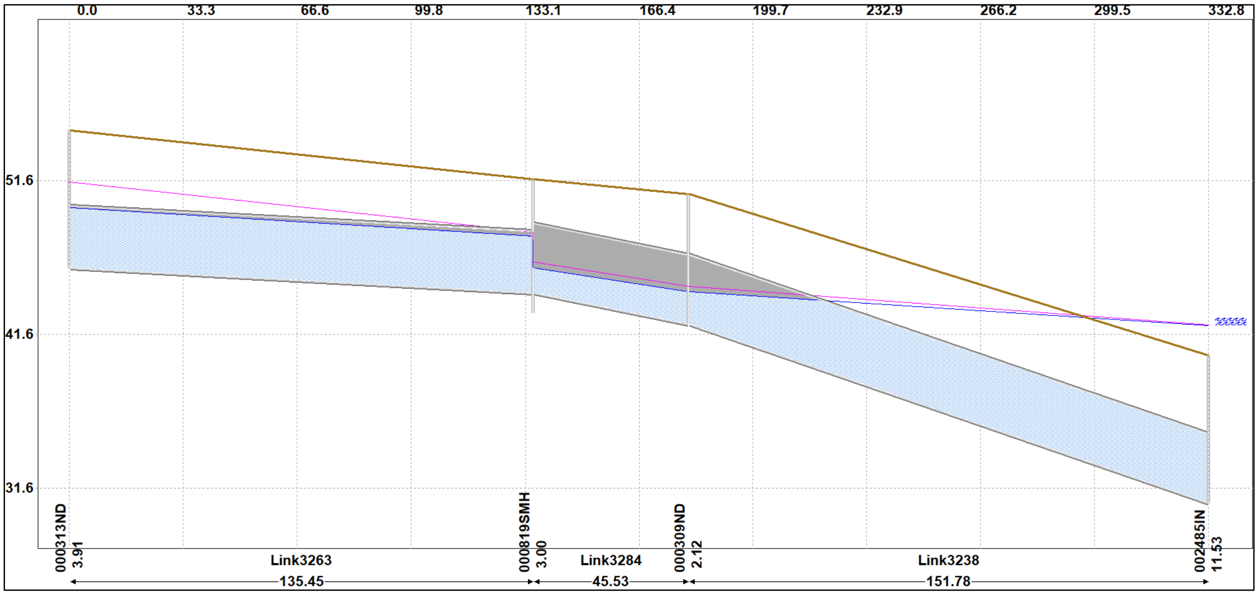

Figure D7. ROUTE-1 – Profile 1 from 000313ND to 002485IN

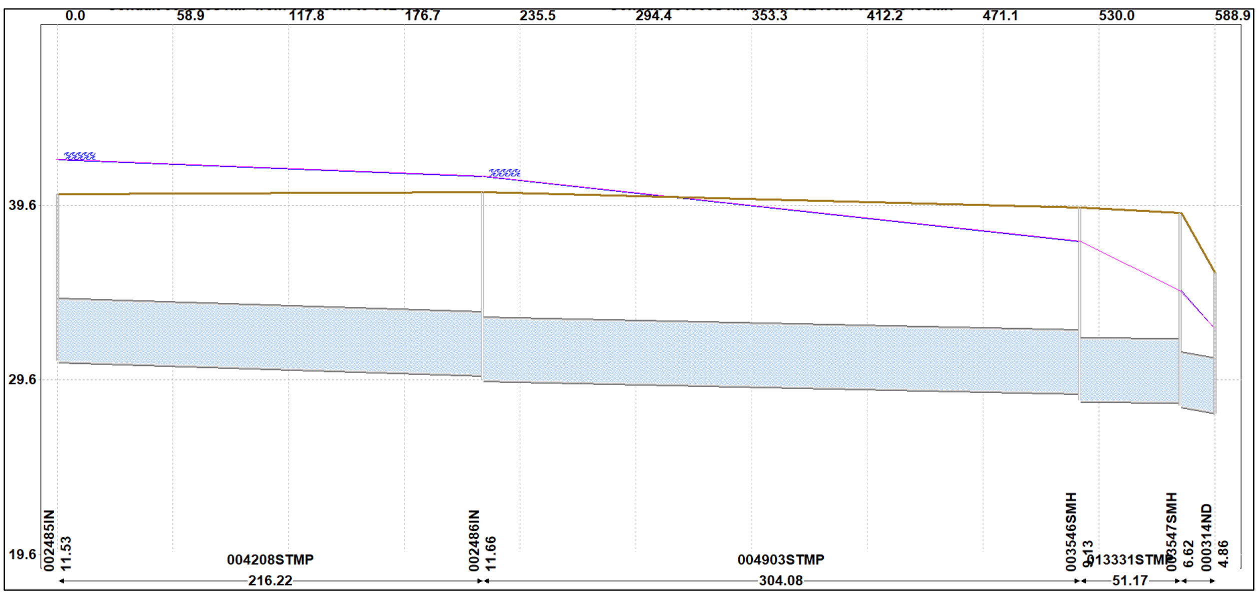

Figure D8. ROUTE-1 – Profile 2 from 002485IN to 000314ND

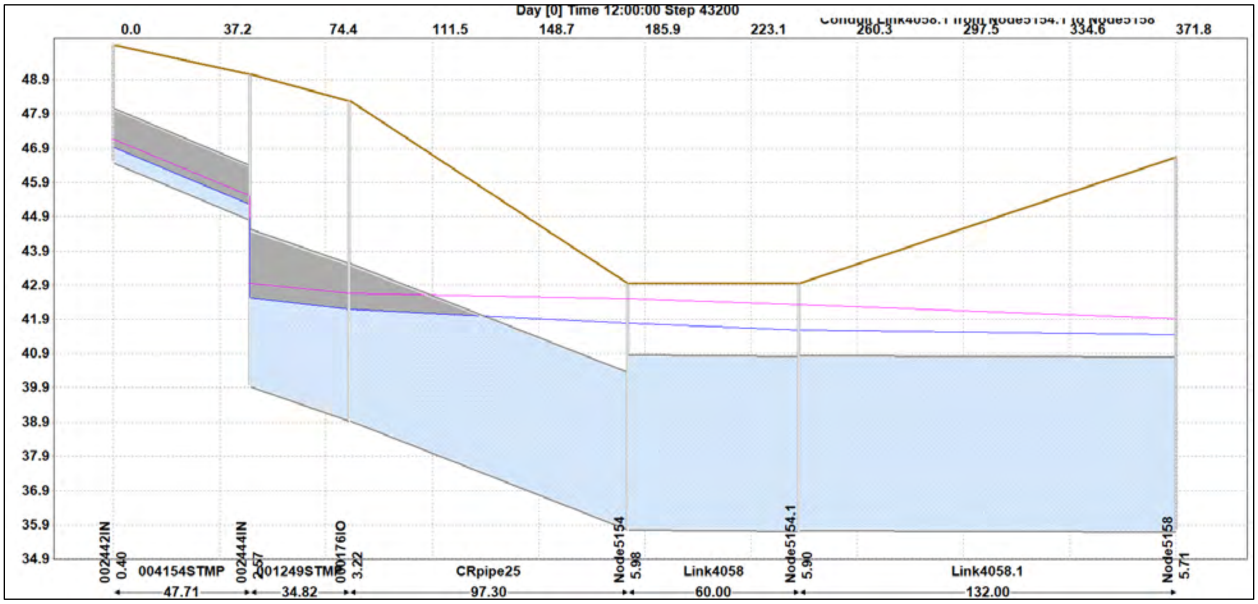

Figure D9. ROUTE-1 – Profile 3 from 002442IN to Node5158

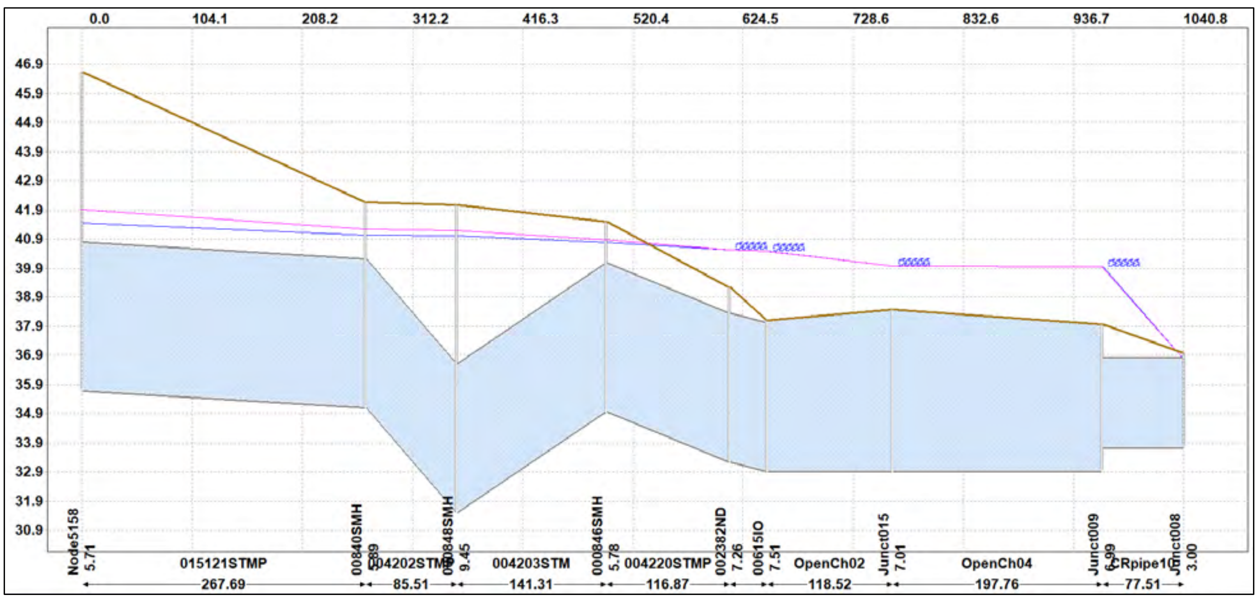

Figure D10. ROUTE-1 – Profile 4 from Node5158 to Junct008

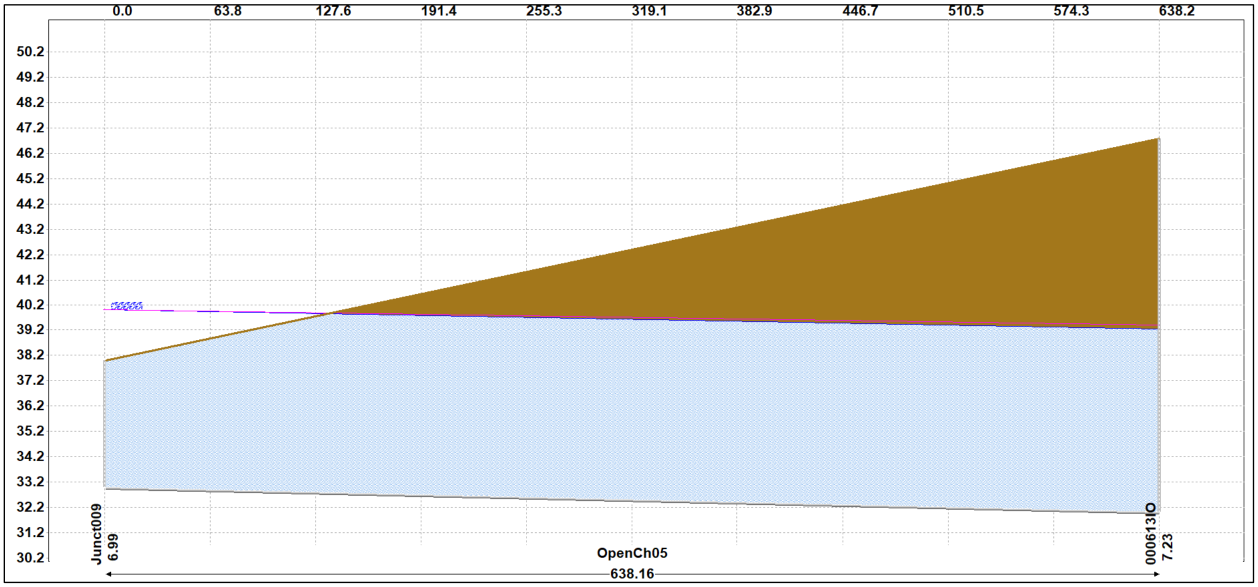

Figure D11. ROUTE-1 – Profile 5 from Junct009 to 000613IO

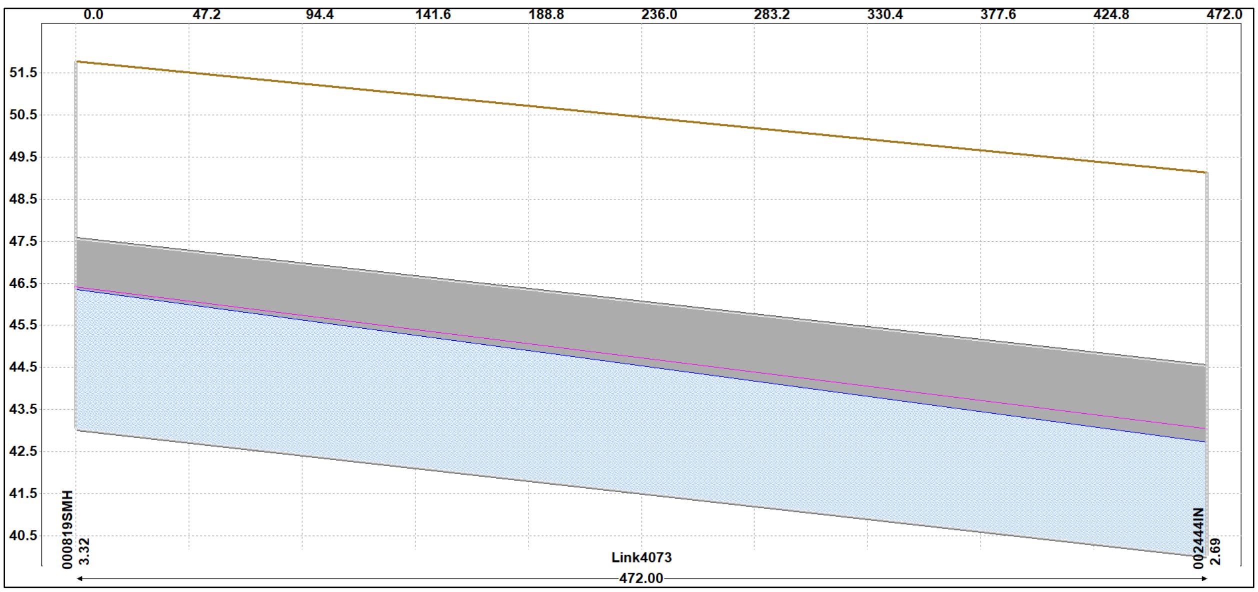

Figure D12. ROUTE-1 – Profile 5 from 000819SMH to 002444IN

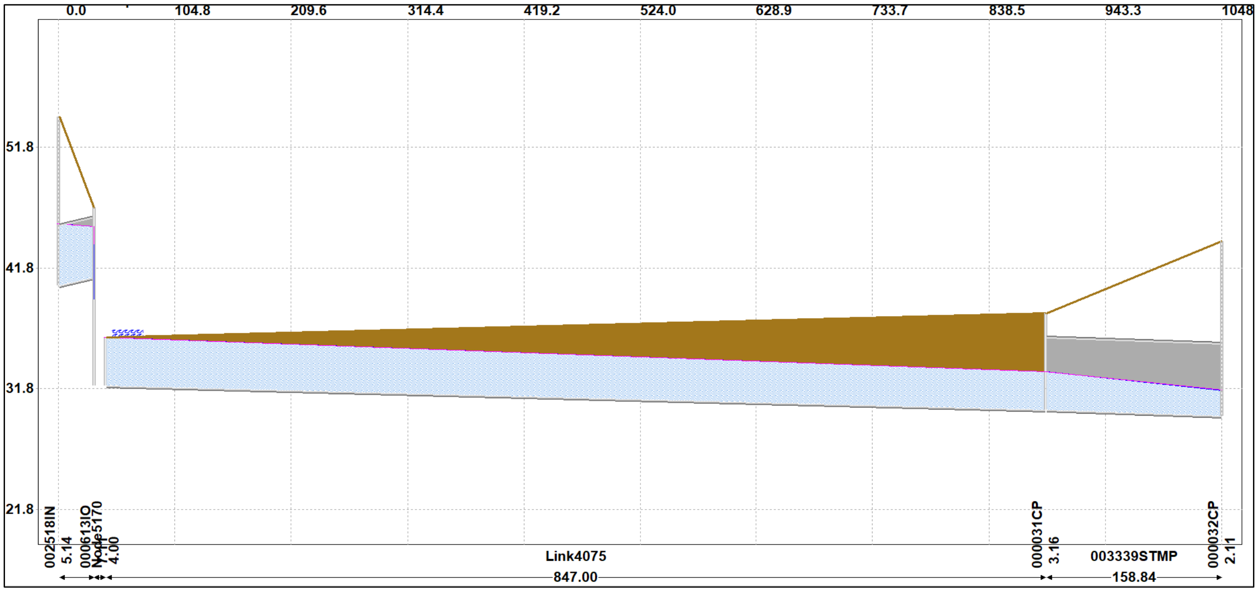

Figure D13. ROUTE-1 – Profile 7 from 002518IN to 000032CP

ROUTE-2 Model Profiles

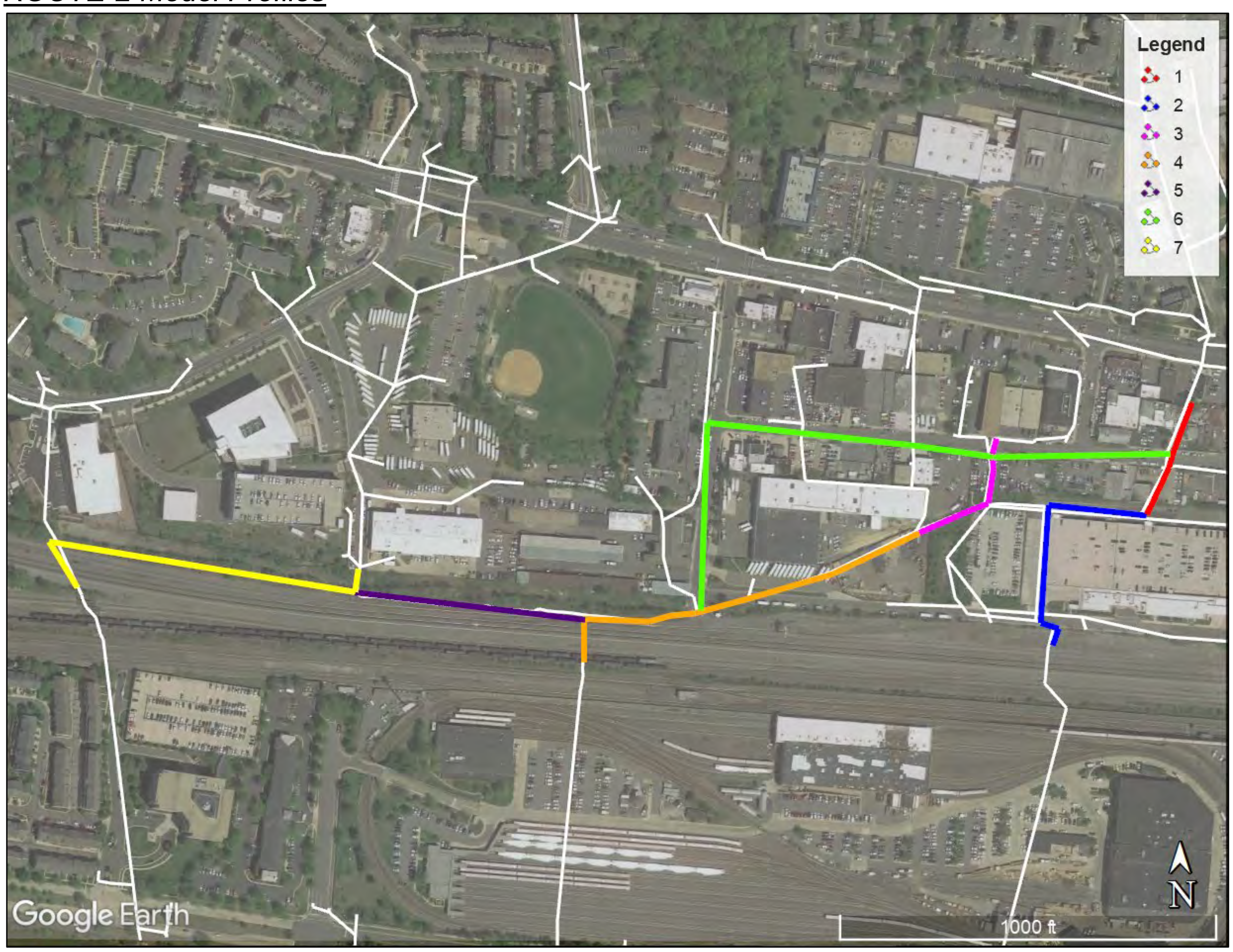

Figure D14. ROUTE-2 – Profile locations

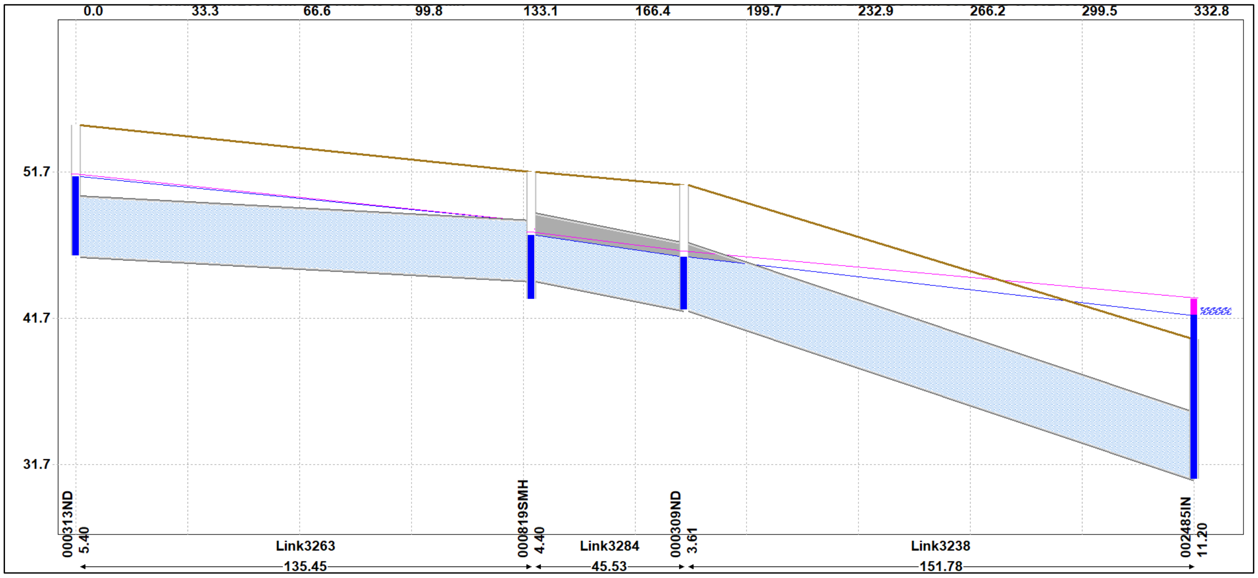

Figure D15. ROUTE-2 – Profile 1 from 000313ND to 002485IN

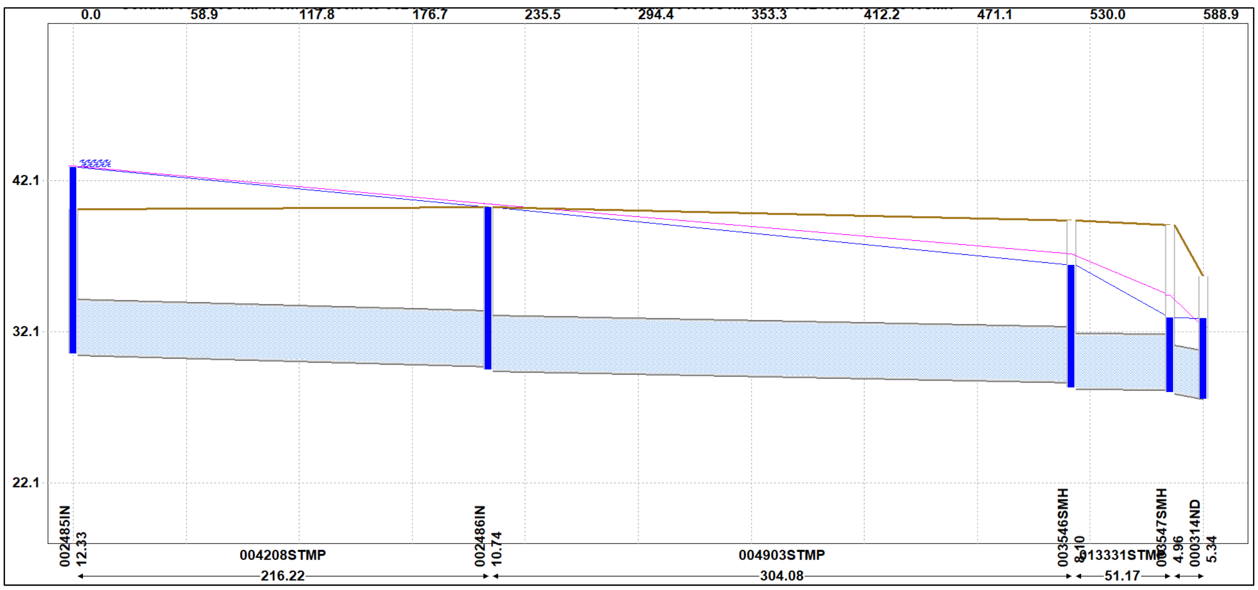

Figure D16. ROUTE-2 – Profile 2 from 002485IN to 000314ND

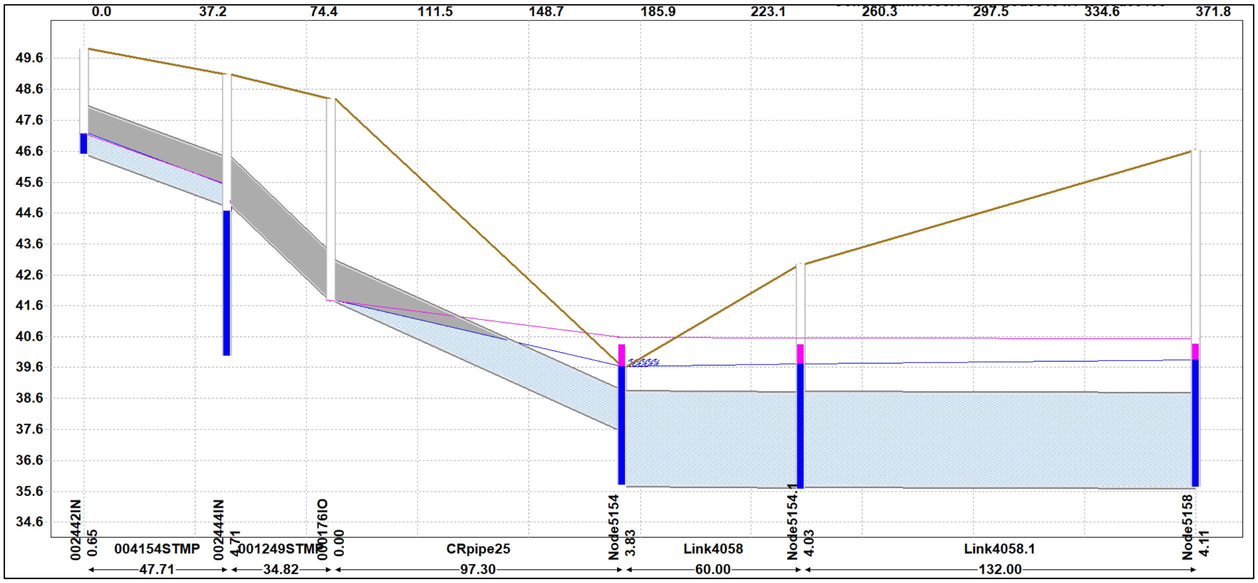

Figure D17. ROUTE-2 – Profile 3 from 002442IN to Node5158

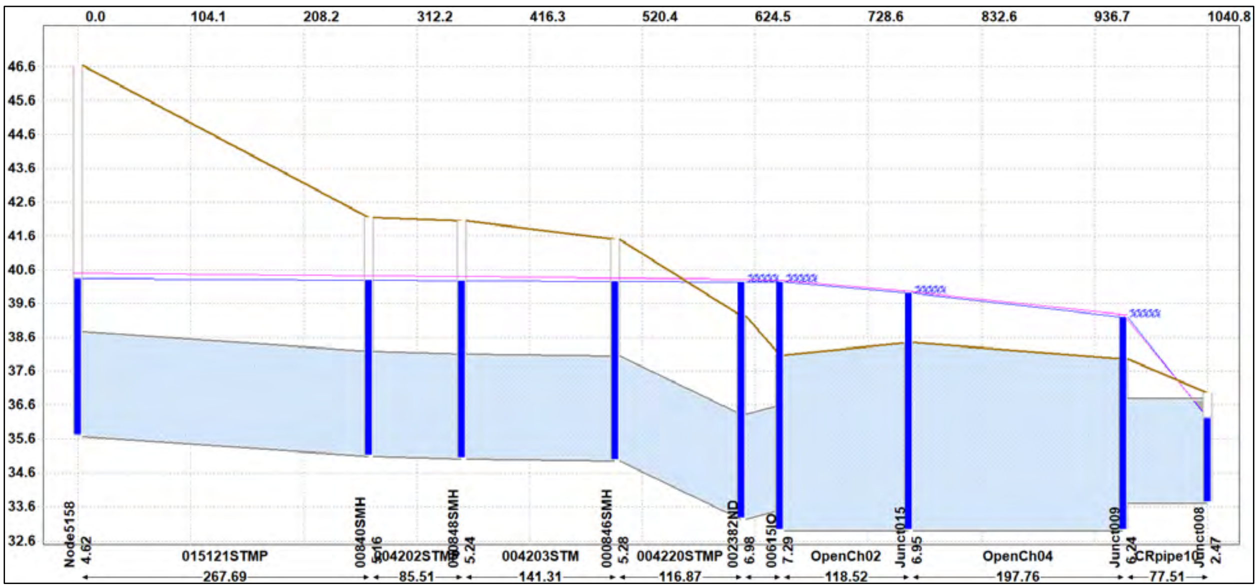

Figure D18. ROUTE-2 – Profile 4 from Node5158 to Junct008

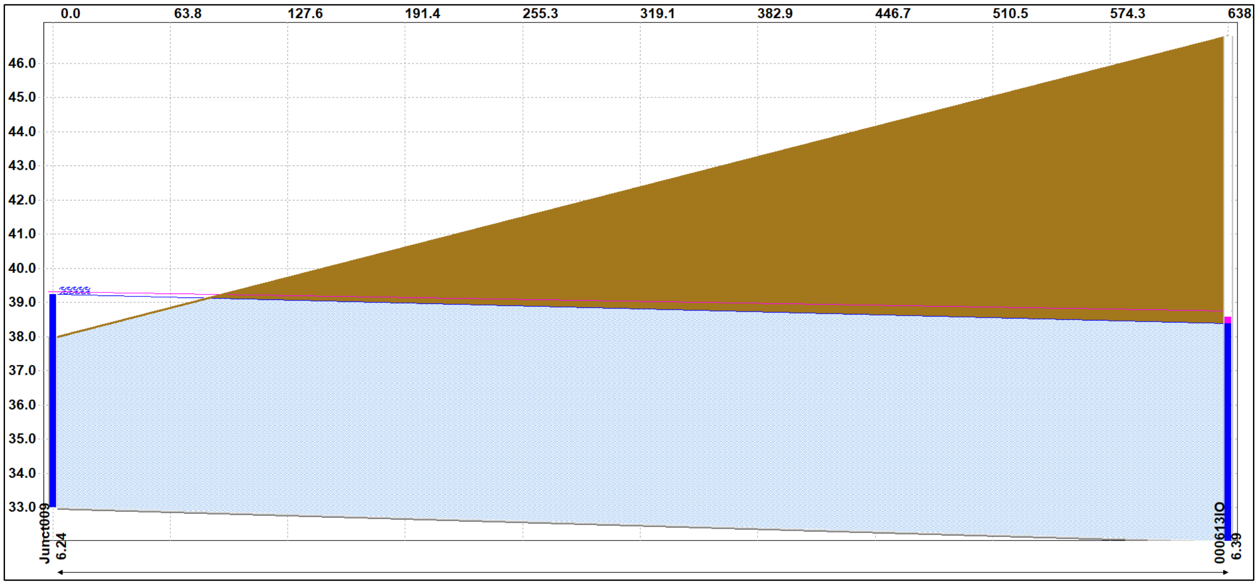

Figure D19. ROUTE-2 – Profile 5 from Junct009 to 000613IO

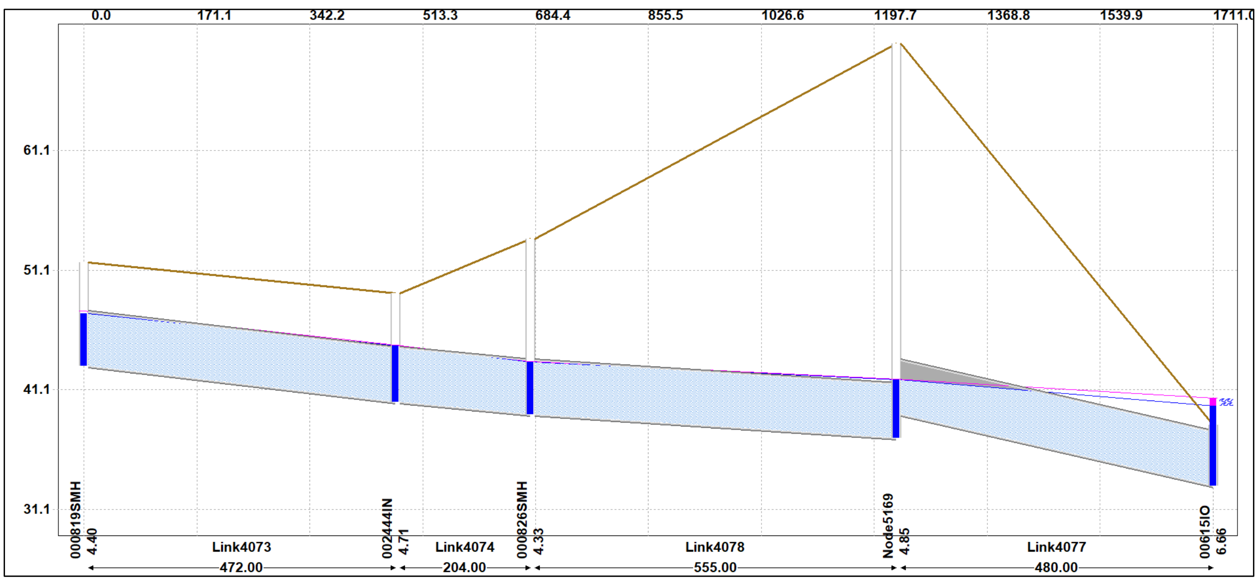

Figure D20. ROUTE-2 – Profile 6 from 000819SMH to 00615IO

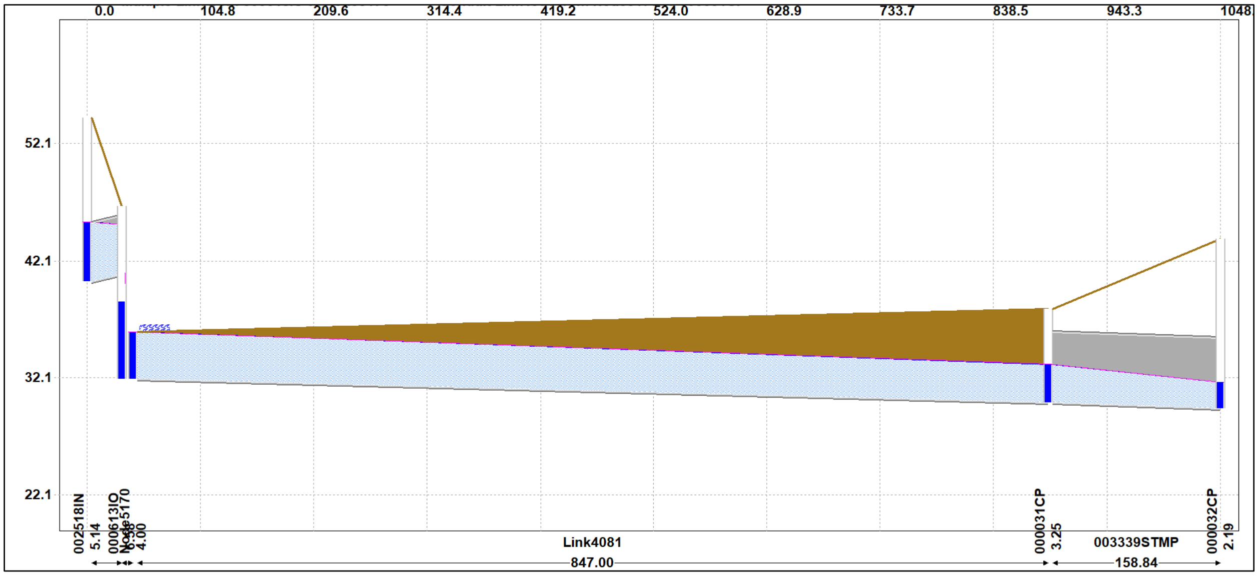

Figure D21. ROUTE-2 – Profile 7 from 002518IN to 000032CP

ROUTE-3 Model Profiles

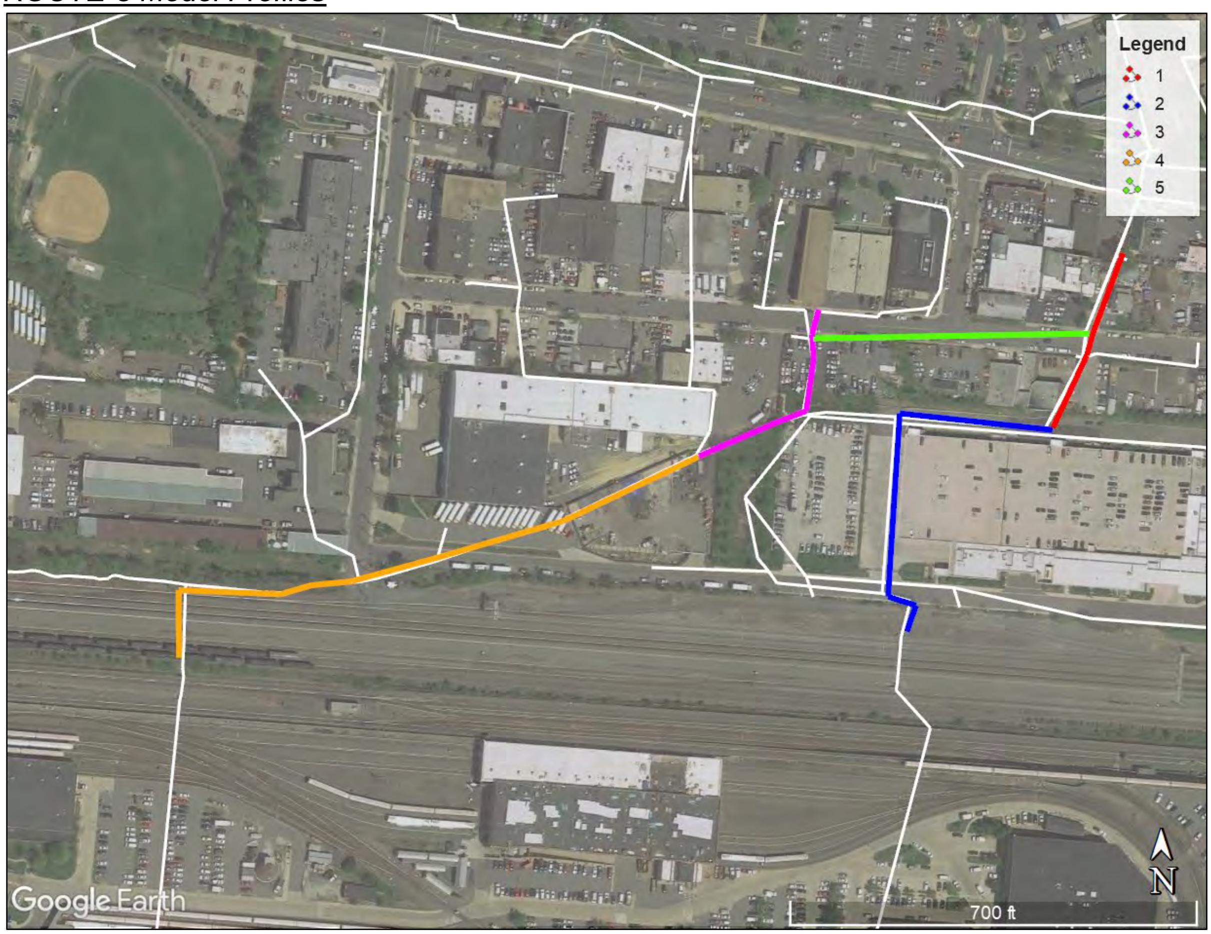

Figure D22. ROUTE-3 – Profile locations

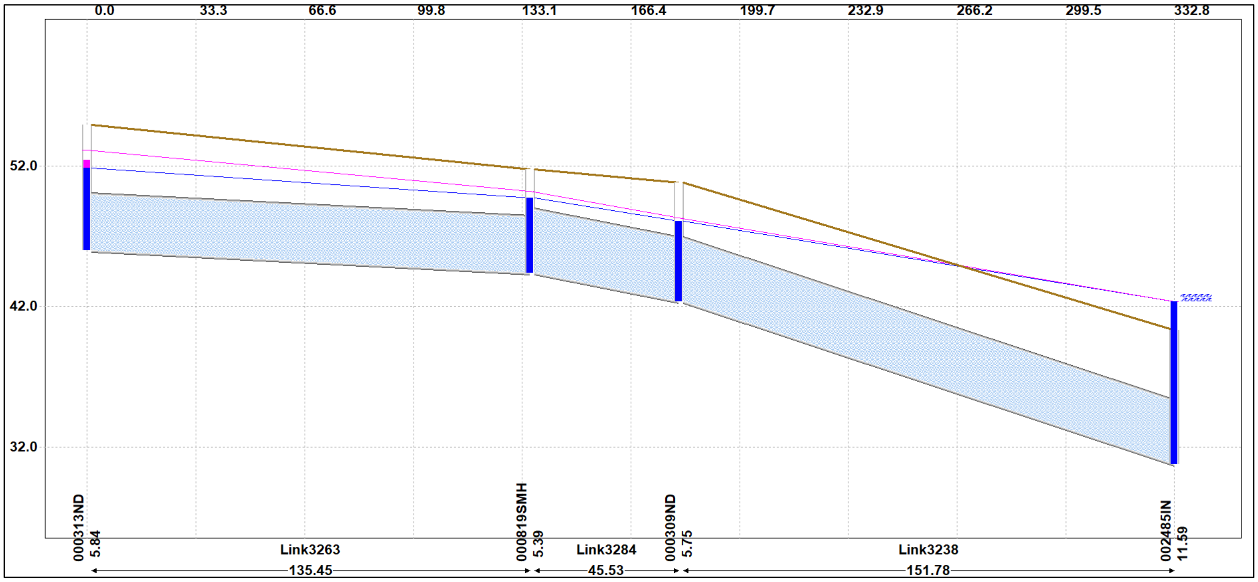

Figure D23. ROUTE-3 – Profile 1 from 000313ND to 002485IN

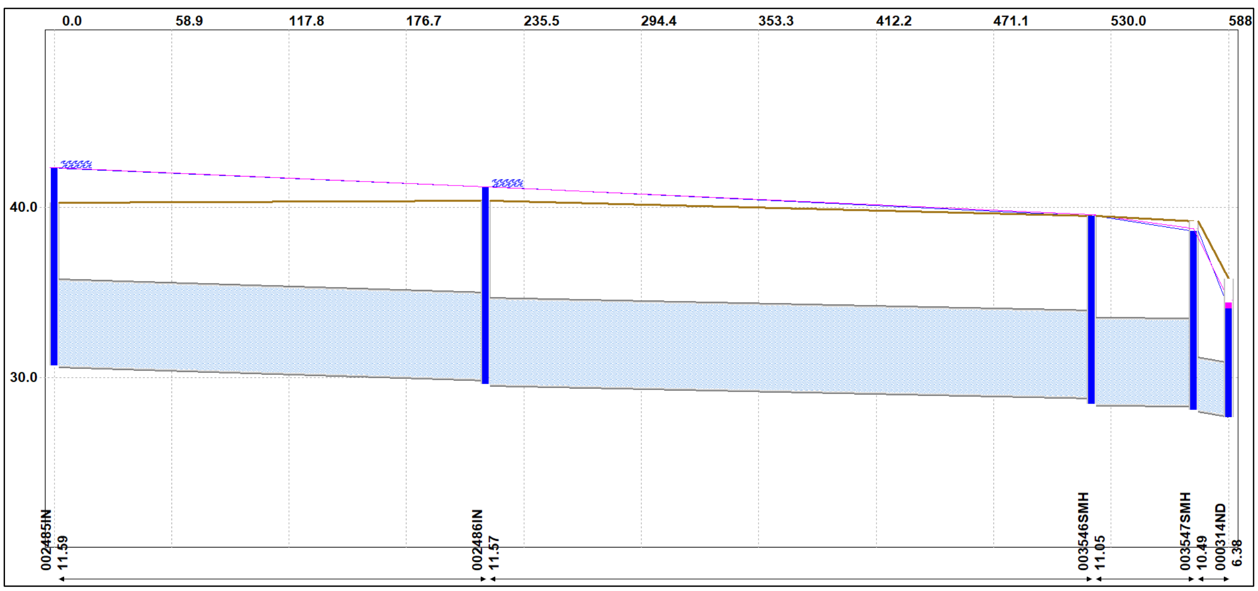

Figure D24. ROUTE-3 – Profile 2 from 002485IN to 000314ND

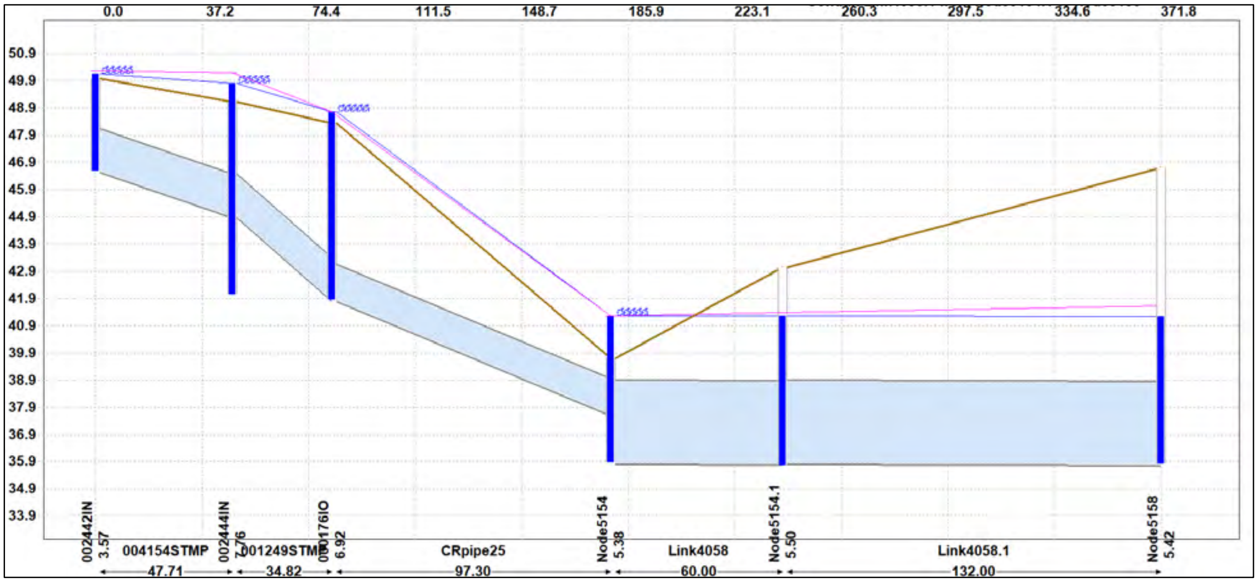

Figure D25. ROUTE-3 – Profile 3 from 002442IN to Node5158

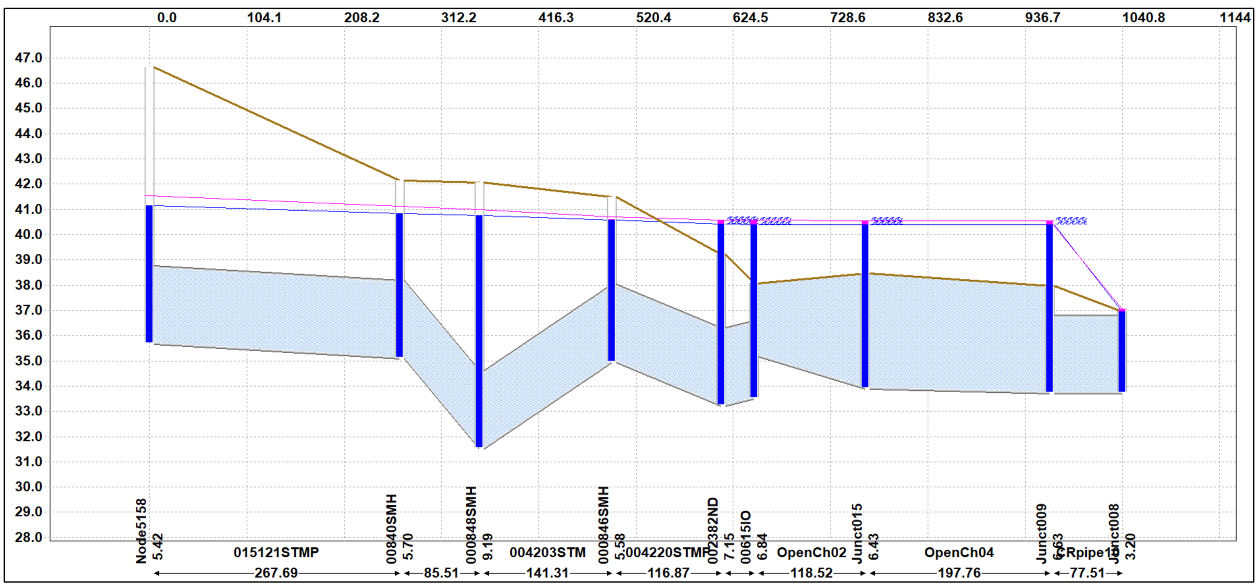

Figure D26. ROUTE-3 – Profile 4 from Node5158 to Junct008

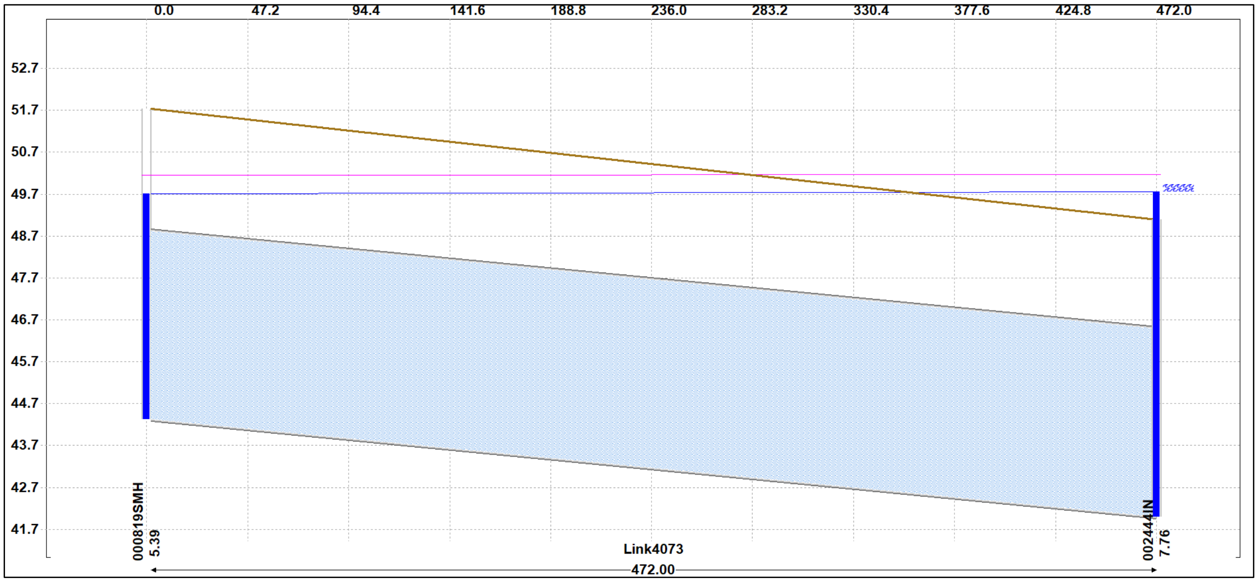

Figure D27. ROUTE-3 – Profile 5 from 000819SMH to 00244IN

Appendix E. Cost Estimates

DASH Stormwater Mitigation Alternatives

Cost Estimates

Prepared for:

Michael Baker International, Alexandria, VA Office

November 22, 2019

S.O. No. TBD

Michael Baker International's Cost Management Division (CMD) was tasked to support the MBI Alexandria Office by providing cost estimating services for the DASH Stormwater Mitigation Alternatives. The primary objective of this project is to determine the costs to modify the existing stormwater management system located in the vicinity of the DASH Headquarters in Alexandria, VA., reduce potential for flooding during ten-year storm events.

This estimate was developed based on DASH Flooding Analysis of Alternatives drawings of November 2019., and includes five design alternatives for this project.

Construction Cost Estimate (CCE) for the five alternatives:

Alternative ROUTE-1	$2,148,385
Alternative ROUTE-2	$3,586,064
Alternative ROUTE-3	$2,272,465
Alternative UPGRADE	$1,381,022
Alternative ROUTE-4	$1,564,789

The work breakdown structure for the estimate follows the CSI Masterformat and was developed using Timberline estimating software. Takeoff quantities for each of the Alternatives were provided by the Michael Baker Surface Water Division in Alexandria, VA.

The estimate is based on the following assumptions:

- Design Contingency – 15%
- General Requirements – 5%
- General Conditions – 10%
- Contractor Home Office Costs – 3%
- Bonds & Insurance – 2.5%
- Contractor Profit – 2.5%
- Does not include additional engineering, design, and assessments, prior to construction
- Does not consider weather and timing of construction activities
- Regular 5-day, 40-hour work week has been applied. Overtime has been excluded.
- Excludes escalation

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11/22/2019

Dash Stormwater Mitigation Alternative ROUTE-1 Cost Estimate

Alexandria, VA — SITE AREA (ACRES): 10.00 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$1,379,939	
	Subtotal		$1,379,939	$137,993.89
Design Contingency		15.00%	$206,991	$20,699.08
	Subtotal		$1,586,930	$158,692.97
General Requirements		5.00%	$79,346	$7,934.65
General Conditions		10.00%	$158,693	$15,869.30
Home Office Costs		3.00%	$47,608	$4,760.79
Bonds & Insurance		2.50%	$45,624	$4,562.42
	Subtotal		$1,918,201	$191,820.13
Profit		12.00%	$230,184	$23,018.42
	Subtotal		$2,148,385	$214,838.54
Escalation		0.00%	$0	$0.00
	Total Construction		$2,148,385	$214,838.54

Dash Stormwater Mitigation Alternative ROUTE-1 Cost Estimate **11/22/2019**

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	10.00		$10,188.20		$1,018.82
02	EXISTING CONDITIONS	10.00		$97,214		$9,721.37
31	EARTHWORK	10.00		$9,475		$947.50
32	EXTERIOR IMPROVEMENTS	10.00		$19,359		$1,935.85
33	UTILITIES	10.00		$1,243,703		$124,370.33
	TOTAL - DIRECT COSTS	10.00		$1,379,939		$137,993.89

11/22/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Alternative ROUTE-1 Cost Estimate **10.00 ACRES**

Alexandria, VA

ID			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
					MATERIAL	LABOR	EQPT	TOTAL	COST TO
02	EXISTING CONDITIONS		QUANTITY	UOM	UNIT COST	UNIT COST	UNIT COST	UNIT COST	PRIME
		REMOVE PIPE							
	001249STMP	Circular - Single, 18" Diameter (to be replaced)	35	LF	0.00	33.62	26.49	60.11	2,093
	CRPipe25	Circular - Single, 15" Diameter (to be replaced)	97	LF	0.00	30.56	25.47	56.04	5,452
	Link4058	Circular - Single, 36" Diameter (to be replaced)	60	LF	0.00	40.75	27.51	68.26	4,096
	Link4058.1	Circular - Single, 36" Diameter (to be replaced)	132	LF	0.00	40.75	27.51	68.26	9,010
	015121STMP	Circular - Double, 36" Diameter (to be replaced)	268	LF	0.00	45.85	33.62	79.47	21,273
	004202STMP	Circular - Double, 36" Diameter (to be replaced)	86	LF	0.00	45.85	33.62	79.47	6,795
	004203STMP	Circular - Double, 36" Diameter (to be replaced)	141	LF	0.00	45.85	33.62	79.47	11,230
	004220STMP	Circular - Double, 36" Diameter (to be replaced)	117	LF	0.00	45.85	33.62	79.47	9,287
	015110STMP	Circular - Double, 36" Diameter (to be replaced)	36	LF	0.00	45.85	33.62	79.47	2,831
	001263STMP	Rectangular, Single, 48" x 48"	45	LF	0.00	50.94	35.66	86.60	3,927
	004205STMP	Circular - Single, 36" Diameter	149	LF	0.00	40.75	27.51	68.26	10,154
		REMOVE STRUCTURE							
	000819SMH	Stormwater Manhole (to be replaced)	1	EA	0.00	254.71	101.88	356.59	357
	002444IN	Inlet (to be replaced)	1	EA	0.00	173.20	71.32	244.52	245
	000176IO	Junction (to be replaced)	1	EA	0.00	152.82	61.13	213.95	214
	Node5154	Inlet (to be replaced)	1	EA	0.00	173.20	71.32	244.52	245
	000848SMH	Stormwater Manhole (to be replaced)	1	EA	0.00	254.71	101.88	356.59	357
	00615IO	Junction (to be replaced)	1	EA	0.00	152.82	61.13	213.95	214
	002436IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
	002435IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
		REMOVE CHANNEL							
	OpenCh02	Natural, Circular, Channel 2 (to be replaced)	119	LF	0.00	2.24	1.33	3.58	424
	OpenCh04	Natural, Circular, Channel 4 (to be replaced)	198	LF	0.00	2.24	1.33	3.58	707
	OpenCh05	Natural, Circular, Channel 5 (to be replaced)	638	LF	0.00	2.24	1.33	3.58	2,282
		Load & Haul Debris	40	TONS	0.00	34.64	5.09	39.73	1,589
		Dump Fees	40	TONS	95.52	0.00	3.06	98.58	3,943
02	**EXISTING CONDITIONS SUBTOTAL**								**97,214**
31	EARTHWORK								
		Clear & grub - 20% of site	2.00	ACRES	0.00	2,547.05	2,190.46	4,737.51	9,475
31	**EARTHWORK**								**9,475**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	2.00	AC	6,368.11	2,292.35	1,018.82	9,679.27	19,359
					0.00	0.00	0.00	0.00	0
					0.00	0.00	0.00	0.00	0
32	**EXTERIOR IMPROVEMENTS**								**19,359**
33	UTILITIES	(Piping & U/G utilities includes excavation, backfill & compaction)							
	Link4073	Circular, Single, 54" Diameter	472	LF	875.87	249.63	56.92	1,182.42	558,103
	001249STMP	Circular - Double, 18" Diameter	35	LF	261.70	124.66	22.37	408.74	14,233
	CRPipe25	Circular - Double, 15" Diameter	97	LF	183.40	118.18	21.40	322.98	31,425
	Link4058	Circular - Single, 36" Diameter	60	LF	391.00	175.80	29.34	596.14	35,768
	Link4058.1	Circular - Double, 36" Diameter	132	LF	434.43	206.94	37.14	678.51	89,563
	015121STMP	Circular - Double, 36" Diameter	268	LF	434.43	206.94	37.14	678.51	181,631
	004202STMP	Circular - Double, 36" Diameter	86	LF	434.43	206.94	37.14	678.51	58,017
	004203STMP	Circular - Double, 36" Diameter	141	LF	434.43	206.94	37.14	678.51	95,881
	004220STMP	Circular - Double, 36" Diameter	117	LF	434.43	206.94	37.14	678.51	79,298
	015110STMP	Circular - Double, 36" Diameter	36	LF	434.43	206.94	37.14	678.51	24,175
	OpenCHW	Natural, Trapezoidal Channel	847	LF	1.59	4.64	2.75	8.98	7,605
	OpenCh02	Natural, Trapezoidal Channel	119	LF	1.59	4.64	2.75	8.98	1,064
	OpenCh04	Natural, Trapezoidal Channel	198	LF	1.59	4.64	2.75	8.98	1,776

11/22/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Alternative ROUTE-1 Cost Estimate **10.00 ACRES**

Alexandria, VA

ID		QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
OpenCh05	Natural, Trapezoidal Channel	638	LF	1.59	4.64	2.75	8.98	5,730
Node5170	Weir, 10' long	1	EA	3,375.10	835.43	519.60	4,730.13	4,730
000819SMH	Stormwater Manhole, precast concrete	1	EA	7,896.46	1,492.57	1,146.17	10,535.20	10,535
002444IN	Inlet, precast concrete	1	EA	5,986.02	1,222.58	774.30	7,982.91	7,983
000176IO	Junction, precast concrete	1	EA	6,368.11	1,375.41	1,090.14	8,833.65	8,834
Node5154	Inlet, precast concrete	1	EA	5,986.02	1,222.58	774.30	7,982.91	7,983
000848SMH	Stormwater Manhole, precast concrete	1	EA	7,896.46	1,492.57	1,146.17	10,535.20	10,535
00615IO	Junction, precast concrete	1	EA	6,368.11	1,375.41	1,090.14	8,833.65	8,834
				0.00	0.00	0.00	0.00	0
				0.00	0.00	0.00	0.00	0
33 UTILITIES								**1,243,703**
TOTAL - DIRECT COST, LOCAL MARKET								**1,379,939**
TOTAL DIRECT COST								**1,379,939**

11/22/2019

Dash Stormwater Mitigation Alternative ROUTE-2 Cost Estimate
Alexandria, VA

SITE AREA (ACRES): 7.50 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$2,303,381	
	Subtotal		$2,303,381	$307,117.43
Design Contingency		15.00%	$345,507	$46,067.61
	Subtotal		$2,648,888	$353,185.04
General Requirements		5.00%	$132,444	$17,659.25
General Conditions		10.00%	$264,889	$35,318.50
Home Office Costs		3.00%	$79,467	$10,595.55
Bonds & Insurance		2.50%	$76,156	$10,154.07
	Subtotal		$3,201,843	$426,912.42
Profit		12.00%	$384,221	$51,229.49
	Subtotal		$3,586,064	$478,141.91
Escalation		0.00%	$0	$0.00
	Total Construction		$3,586,064	$478,141.91

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SUMMARY & OPTIONS

Dash Stormwater Mitigation Alternative ROUTE-2 Cost Estimate **11/22/2019**

Alexandria, VA

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	7.50		$10,188		$1,358.43
02	EXISTING CONDITIONS	7.50		$20,123		$2,683.10
31	EARTHWORK	7.50		$7,106		$947.50
32	EXTERIOR IMPROVEMENTS	7.50		$14,519		$1,935.85
33	UTILITIES	7.50		$2,251,444		$300,192.54
	TOTAL - DIRECT COSTS	7.50		$2,303,381		$307,117.43

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11/22/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Alternative ROUTE-2 Cost Estimate **7.50 ACRES**
Alexandria, VA

ID			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
02	EXISTING CONDITIONS		QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
		REMOVE PIPE							
	001263STMP	Rectangular, Single, 48" x 48"	45	LF	0.00	50.94	35.66	86.60	3,927
	004205STMP	Circular - Single, 36" Diameter	149	LF	0.00	40.75	27.51	68.26	10,154
		REMOVE STRUCTURE							
	000819SMH	Stormwater Manhole (to be replaced)	1	EA	0.00	254.71	101.88	356.59	357
	002444IN	Inlet (to be replaced)	1	EA	0.00	173.20	71.32	244.52	245
	000826SMH	Stormwater Manhole (to be replaced)	1	EA	0.00	254.71	101.88	356.59	357
	00615IO	Junction (to be replaced)	1	EA	0.00	152.82	61.13	213.95	214
	002436IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
	002435IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
		REMOVE CHANNEL							
	OpenCh02	Natural, Circular, Channel 2 (to be replaced)	119	LF	0.00	2.24	1.33	3.58	424
	OpenCh04	Natural, Circular, Channel 4 (to be replaced)	198	LF	0.00	2.24	1.33	3.58	707
	OpenCh05	Natural, Circular, Channel 5 (to be replaced)	638	LF	0.00	2.24	1.33	3.58	2,282
		Load & Haul Debris	7	TONS	0.00	34.64	5.09	39.73	278
		Dump Fees	7	TONS	95.52	0.00	3.06	98.58	690
02	**EXISTING CONDITIONS SUBTOTAL**								**20,123**
31	EARTHWORK								
		Clear & grub - 20% of site	1.50	ACRES	0.00	2,547.05	2,190.46	4,737.51	7,106
31	**EARTHWORK**								**7,106**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	1.50	AC	6,368.11	2,292.35	1,018.82	9,679.27	14,519
					0.00	0.00	0.00	0.00	0
					0.00	0.00	0.00	0.00	0
32	**EXTERIOR IMPROVEMENTS**								**14,519**
33	UTILITIES	(Piping & U/G utilities includes excavation, backfill & compaction)							
	Link4073	Circular, Single, 54" Diameter	472	LF	875.87	249.63	56.92	1,182.42	558,103
	Link4074	Circular, Single, 54" Diameter	204	LF	875.87	249.63	56.92	1,182.42	241,214
	Link4078	Circular - Double, 54" Diameter	555	LF	972.84	293.69	71.15	1,337.68	742,414
	Link4077	Circular - Double, 54" Diameter	480	LF	972.84	293.69	71.15	1,337.68	642,088
	OpenCHW	Natural, Trapezoidal Channel	847	LF	1.59	4.64	2.75	8.98	7,605
	OpenCh02	Natural, Trapezoidal Channel	119	LF	1.59	4.64	2.75	8.98	1,064
	OpenCh04	Natural, Trapezoidal Channel	198	LF	1.59	4.64	2.75	8.98	1,776
	OpenCh05	Natural, Trapezoidal Channel	638	LF	1.59	4.64	2.75	8.98	5,730
	Node5170	Weir, 10' long	1	EA	3,375.10	835.43	519.60	4,730.13	4,730
	Node5169	Junction, precast concrete	1	EA	6,368.11	1,375.41	1,090.14	8,833.65	8,834
	000819SMH	Stormwater Manhole, precast concrete	1	EA	7,896.46	1,492.57	1,146.17	10,535.20	10,535
	002444IN	Inlet, precast concrete	1	EA	5,986.02	1,222.58	774.30	7,982.91	7,983
	000826SMH	Stormwater Manhole, precast concrete	1	EA	7,896.46	1,492.57	1,146.17	10,535.20	10,535
	00615IO	Junction, precast concrete	1	EA	6,368.11	1,375.41	1,090.14	8,833.65	8,834
					0.00	0.00	0.00	0.00	0
					0.00	0.00	0.00	0.00	0
33	**UTILITIES**								**2,251,444**
	TOTAL - DIRECT COST, LOCAL MARKET								**2,303,381**
	TOTAL DIRECT COST								**2,303,381**

11/22/2019

Dash Stormwater Mitigation Alternative ROUTE-3 Cost Estimate

Alexandria, VA

SITE AREA (ACRES): 8.00 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$1,459,637	
	Subtotal		$1,459,637	$182,454.63
Design Contingency		15.00%	$218,946	$27,368.19
	Subtotal		$1,678,583	$209,822.82
General Requirements		5.00%	$83,929	$10,491.14
General Conditions		10.00%	$167,858	$20,982.28
Home Office Costs		3.00%	$50,357	$6,294.68
Bonds & Insurance		2.50%	$48,259	$6,032.41
	Subtotal		$2,028,987	$253,623.34
Profit		12.00%	$243,478	$30,434.80
	Subtotal		$2,272,465	$284,058.14
Escalation		0.00%	$0	$0.00
	Total Construction		$2,272,465	$284,058.14

Michael Baker INTERNATIONAL

Dash Stormwater Mitigation Alternative ROUTE-3 Cost Estimate **11/22/2019**

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	8.00		$10,188		$1,273.53
02	EXISTING CONDITIONS	8.00		$65,165		$8,145.57
31	EARTHWORK	8.00		$7,580		$947.50
32	EXTERIOR IMPROVEMENTS	8.00		$15,487		$1,935.85
33	UTILITIES	8.00		$1,361,217		$170,152.18
	TOTAL - DIRECT COSTS	8.00		$1,459,637		$182,454.63

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11/22/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Alternative ROUTE-3 Cost Estimate **8.00 ACRES**

Alexandria, VA

	ID		QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
02	EXISTING CONDITIONS								
		REMOVE PIPE							
	004208STMP	Circular - Double, 42" Diameter (to be replaced)	216	LF	0.00	48.90	33.62	82.52	17,843
	004903STMP	Circular - Double, 42" Diameter (to be replaced)	304	LF	0.00	48.90	33.62	82.52	25,094
	013331STMP	Circular - Single, 42" Diameter (to be replaced)	51	LF	0.00	44.32	30.26	74.58	3,816
	001263STMP	Rectangular, Single, 48" x 48"	45	LF	0.00	50.94	35.66	86.60	3,927
	004205STMP	Circular - Single, 36" Diameter	149	LF	0.00	40.75	27.51	68.26	10,154
		REMOVE STRUCTURE							
	002444IN	Inlet (to be replaced)	1	EA	0.00	173.20	71.32	244.52	245
	002436IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
	002435IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
		Load & Haul Debris	26	TONS	0.00	34.64	5.09	39.73	1,033
		Dump Fees	26	TONS	95.52	0.00	3.06	98.58	2,563
02	**EXISTING CONDITIONS SUBTOTAL**								**65,165**
31	EARTHWORK								
		Clear & grub - 20% of site	1.60	ACRES	0.00	2,547.05	2,190.46	4,737.51	7,580
31	**EARTHWORK**								**7,580**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	1.60	AC	6,368.11	2,292.35	1,018.82	9,679.27	15,487
					0.00	0.00	0.00	0.00	0
					0.00	0.00	0.00	0.00	0
32	**EXTERIOR IMPROVEMENTS**								**15,487**
33	UTILITIES	(Piping & U/G utilities includes excavation, backfill & compaction)							
	Link4073	Circular, Single, 54" Diameter	472	LF	875.87	249.63	56.92	1,182.42	558,103
	004208STMP	Circular - Double, 60" Diameter	216	LF	1,026.54	293.69	71.15	1,391.38	300,844
	004903STMP	Circular - Double, 60" Diameter	304	LF	1,026.54	293.69	71.15	1,391.38	423,090
	013331STMP	Circular - Double, 60" Diameter	51	LF	1,026.54	293.69	71.15	1,391.38	71,197
	002444IN	Inlet, precast concrete	1	EA	5,986.02	1,222.58	774.30	7,982.91	7,983
					0.00	0.00	0.00	0.00	0
					0.00	0.00	0.00	0.00	0
33	**UTILITIES**								**1,361,217**
	TOTAL - DIRECT COST, LOCAL MARKET								**1,459,637**
	TOTAL DIRECT COST								**1,459,637**

Michael Baker INTERNATIONAL

11/22/2019

Dash Stormwater Mitigation Alternative UPGRADE Cost Estimate

Alexandria, VA SITE AREA (ACRES): 6.00 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$887,050	
	Subtotal		$887,050	$147,841.74
Design Contingency		15.00%	$133,058	$22,176.26
	Subtotal		$1,020,108	$170,018.01
General Requirements		5.00%	$51,005	$8,500.90
General Conditions		10.00%	$102,011	$17,001.80
Home Office Costs		3.00%	$30,603	$5,100.54
Bonds & Insurance		2.50%	$29,328	$4,888.02
	Subtotal		$1,233,056	$205,509.26
Profit		12.00%	$147,967	$24,661.11
	Subtotal		$1,381,022	$230,170.38
Escalation		0.00%	$0	$0.00
	Total Construction		$1,381,022	$230,170.38

Dash Stormwater Mitigation Alternative UPGRADE Cost Estimate 11/22/2019

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)	Direct Cost ($)	Cost/Acre ($)
01	GENERAL REQUIREMENTS	6.00	$10,188	$1,698.03
02	EXISTING CONDITIONS	6.00	$64,431	$10,738.50
31	EARTHWORK	6.00	$5,685	$947.50
32	EXTERIOR IMPROVEMENTS	6.00	$11,615	$1,935.85
33	UTILITIES	6.00	$795,131	$132,521.86
	TOTAL - DIRECT COSTS	6.00	$887,050	$147,841.74

Michael Baker INTERNATIONAL

11/22/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Alternative UPGRADE Cost Estimate **6.00 ACRES**

Alexandria, VA

	ID		QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
02	EXISTING CONDITIONS								
		REMOVE PIPE							
	004208STMP	Circular - Double, 42" Diameter (to be replaced)	216	LF	0.00	48.90	33.62	82.52	17,843
	004903STMP	Circular - Double, 42" Diameter (to be replaced)	304	LF	0.00	48.90	33.62	82.52	25,094
	013331STMP	Circular - Single, 42" Diameter (to be replaced)	51	LF	0.00	44.32	30.26	74.58	3,816
	001263STMP	Rectangular, Single, 48" x 48"	45	LF	0.00	50.94	35.66	86.60	3,927
	004205STMP	Circular - Single, 36" Diameter	149	LF	0.00	40.75	27.51	68.26	10,154
		Load & Haul Debris	26	TONS	0.00	34.64	5.09	39.73	1,033
		Dump Fees	26	TONS	95.52	0.00	3.06	98.58	2,563
02	**EXISTING CONDITIONS SUBTOTAL**								**64,431**
31	EARTHWORK								
		Clear & grub - 20% of site	1.20	ACRES	0.00	2,547.05	2,190.46	4,737.51	5,685
31	**EARTHWORK**								**5,685**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	1.20	AC	6,368.11	2,292.35	1,018.82	9,679.27	11,615
32	**EXTERIOR IMPROVEMENTS**								**11,615**
33	UTILITIES	(Piping & U/G utilities includes excavation, backfill & compaction)							
	004208STMP	Circular - Double, 60" Diameter	216	LF	1,026.54	293.69	71.15	1,391.38	300,844
	004903STMP	Circular - Double, 60" Diameter	304	LF	1,026.54	293.69	71.15	1,391.38	423,090
	013331STMP	Circular - Double, 60" Diameter	51	LF	1,026.54	293.69	71.15	1,391.38	71,197
33	**UTILITIES**								**795,131**
	TOTAL - DIRECT COST, LOCAL MARKET								**887,050**
	TOTAL DIRECT COST								**887,050**

Michael Baker INTERNATIONAL

11/22/2019

Dash Stormwater Mitigation Alternative ROUTE-4 Cost Estimate

Alexandria, VA

SITE AREA (ACRES): 6.00 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$1,005,087	
	Subtotal		$1,005,087	$167,514.44
Design Contingency		15.00%	$150,763	$25,127.17
	Subtotal		$1,155,850	$192,641.61
General Requirements		5.00%	$57,792	$9,632.08
General Conditions		10.00%	$115,585	$19,264.16
Home Office Costs		3.00%	$34,675	$5,779.25
Bonds & Insurance		2.50%	$33,231	$5,538.45
	Subtotal		$1,397,133	$232,855.55
Profit		12.00%	$167,656	$27,942.67
	Subtotal		$1,564,789	$260,798.21
Escalation		0.00%	$0	$0.00
	Total Construction		$1,564,789	$260,798.21

Dash Stormwater Mitigation Alternative ROUTE-4 Cost Estimate 11/22/2019

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	6.00		$10,188.20		$1,698.03
02	EXISTING CONDITIONS	6.00		$31,789		$5,298.11
31	EARTHWORK	6.00		$5,685		$947.50
32	EXTERIOR IMPROVEMENTS	6.00		$11,615		$1,935.85
33	UTILITIES	6.00		$945,810		$157,634.94
	TOTAL - DIRECT COSTS	6.00		$1,005,087		$167,514.44

Michael Baker INTERNATIONAL

11/22/2019

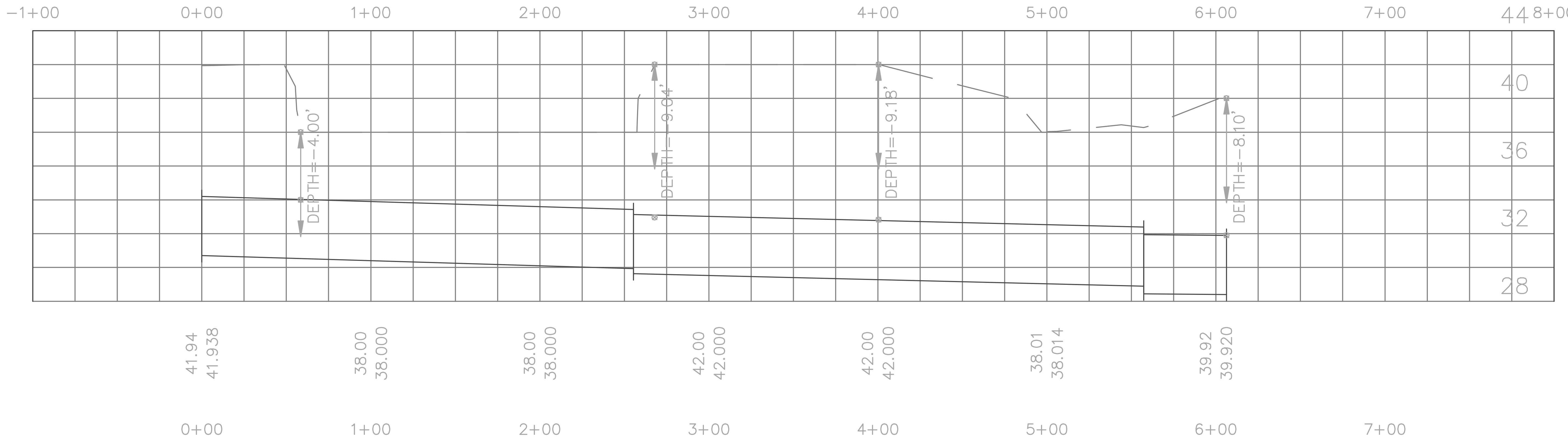
DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Alternative RR-W1 Cost Estimate **6.00 ACRES**

Alexandria, VA

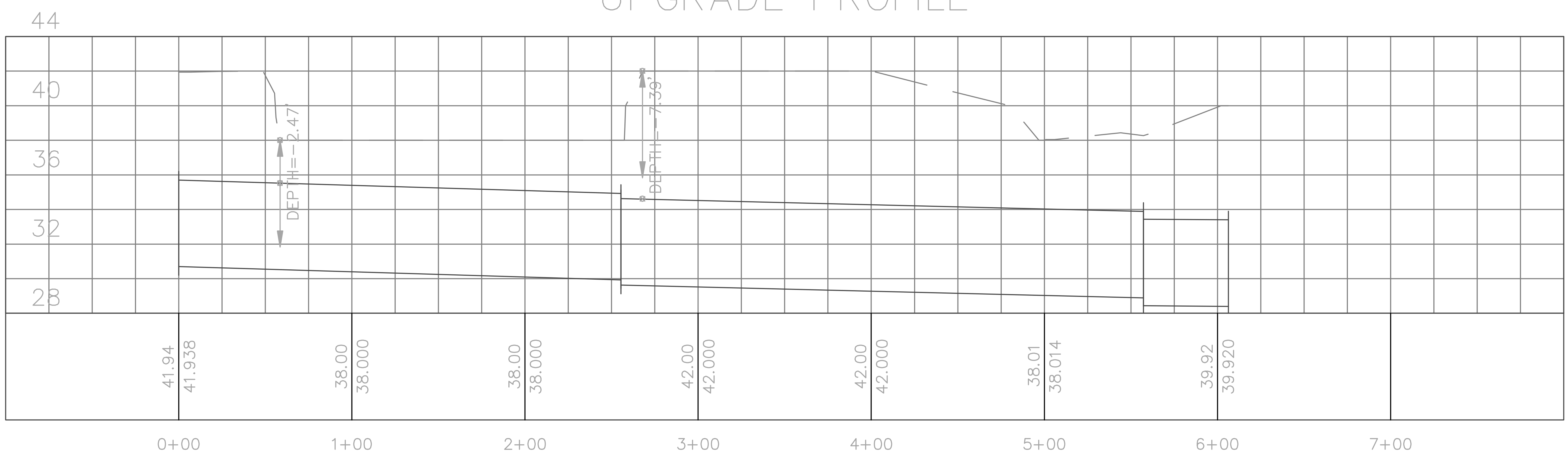
	ID			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS									
			CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
			MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
			DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**									**10,188**
						MATERIAL	LABOR	EQPT	TOTAL	COST TO
02	EXISTING CONDITIONS			QUANTITY	UOM	UNIT COST	UNIT COST	UNIT COST	UNIT COST	PRIME
			REMOVE PIPE							
		001265STMP	Circular - Single, 15" Diameter (to be replaced)	20	LF	0.00	30.56	25.47	56.04	1,121
		004170STMP	Circular - Single, 15" Diameter (to be replaced)	174	LF	0.00	30.56	25.47	56.04	9,750
		001263STMP	Rectangular, Single, 48" x 48"	45	LF	0.00	50.94	35.66	86.60	3,927
		004205STMP	Circular - Single, 36" Diameter	149	LF	0.00	40.75	27.51	68.26	10,154
			REMOVE STRUCTURE							
		000842SMH	Stormwater Manhole (to be replaced)	1	EA	0.00	254.71	101.88	356.59	357
		002433IN	Inlet (to be replaced)	1	EA	0.00	173.20	71.32	244.52	245
		Node5170	Junction (to be replaced)	1	EA	0.00	152.82	61.13	213.95	214
		002436IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
		002435IN	Inlet	1	EA	0.00	173.20	71.32	244.52	245
			Load & Haul Debris	40	TONS	0.00	34.64	5.09	39.73	1,589
			Dump Fees	40	TONS	95.52	0.00	3.06	98.58	3,943
02	**EXISTING CONDITIONS SUBTOTAL**									**31,789**
31	EARTHWORK									
			Clear & grub - 20% of site	1.20	ACRES	0.00	2,547.05	2,190.46	4,737.51	5,685
31	**EARTHWORK**									**5,685**
32	EXTERIOR IMPROVEMENTS									
			Site Landscaping Allowance (includes irrigation systems as req'd)	1.20	AC	6,368.11	2,292.35	1,018.82	9,679.27	11,615
32	**EXTERIOR IMPROVEMENTS**									**11,615**
33	UTILITIES		(Piping & U/G utilities includes excavation, backfill & compaction)							
		Link4074	Circular - Double, 54" Diameter	369	LF	972.84	293.69	71.15	1,337.68	493,605
		Link4075	Circular - Double, 54" Diameter	117	LF	972.84	293.69	71.15	1,337.68	156,509
		001265STMP	Circular - Double, 54" Diameter	20	LF	972.84	293.69	71.15	1,337.68	26,754
		004170STMP	Circular - Double, 54" Diameter	174	LF	972.84	293.69	71.15	1,337.68	232,757
		Node5172	Junction, precast concrete	1	EA	6,368.11	1,375.41	1,090.14	8,833.65	8,834
		000842SMH	Stormwater Manhole, precast concrete	1	EA	7,896.46	1,492.57	1,146.17	10,535.20	10,535
		002433IN	Inlet, precast concrete	1	EA	5,986.02	1,222.58	774.30	7,982.91	7,983
		Node5170	Junction, precast concrete	1	EA	6,368.11	1,375.41	1,090.14	8,833.65	8,834
33	**UTILITIES**								**945,810**	
TOTAL - DIRECT COST, LOCAL MARKET									**1,005,087**	
TOTAL DIRECT COST									**1,005,087**	

Existing Conditions

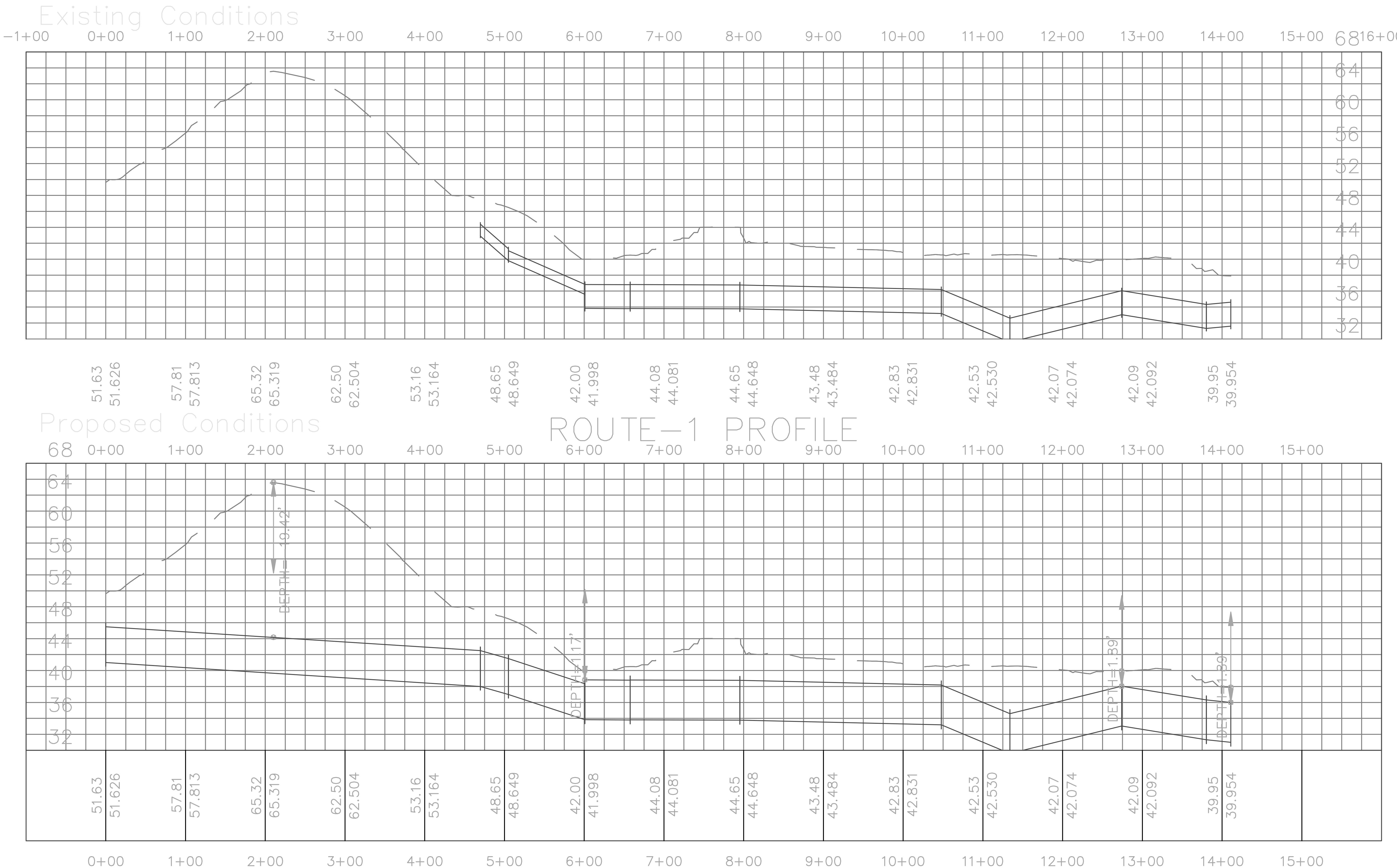


Proposed Conditions

UPGRADE PROFILE

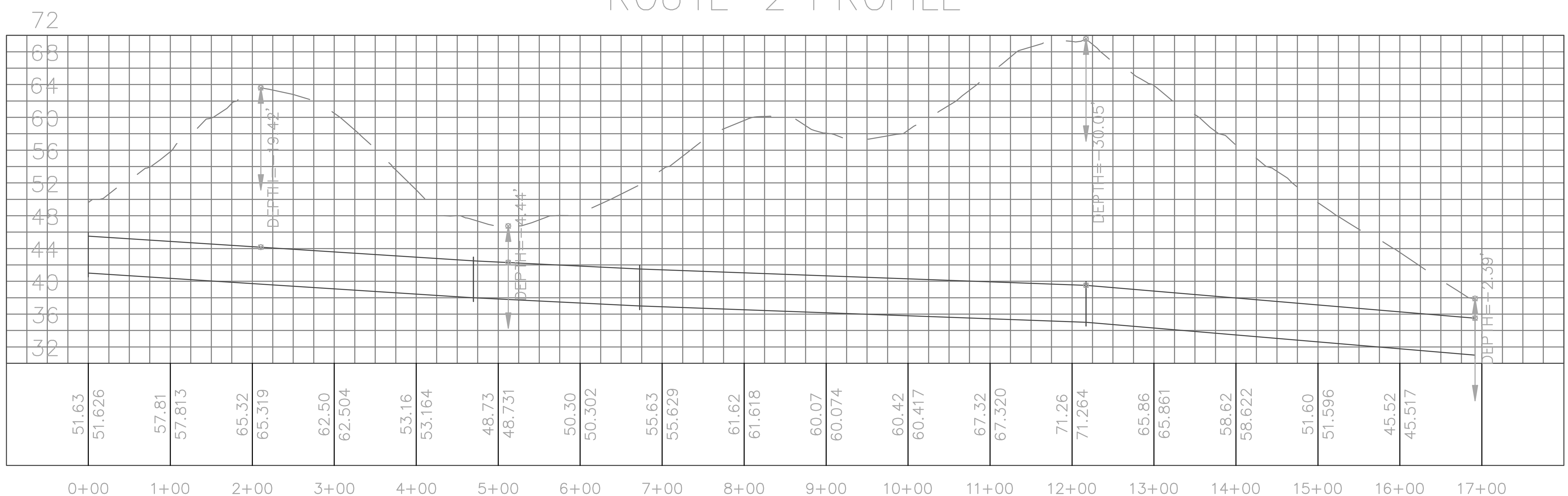


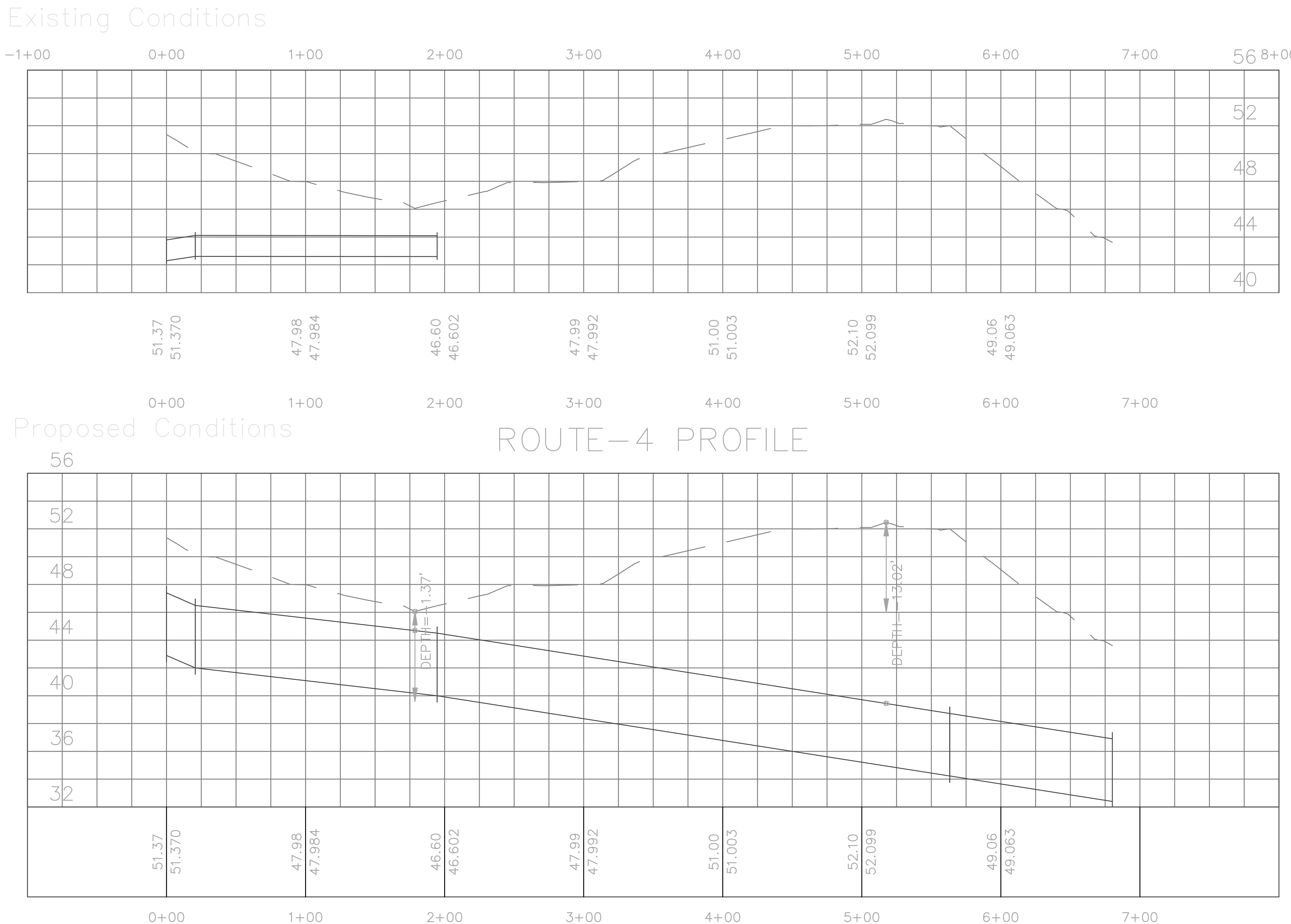
ROUTE–1 PROFILE



Proposed Conditions

ROUTE-2 PROFILE




Existing Conditions
-1+00
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
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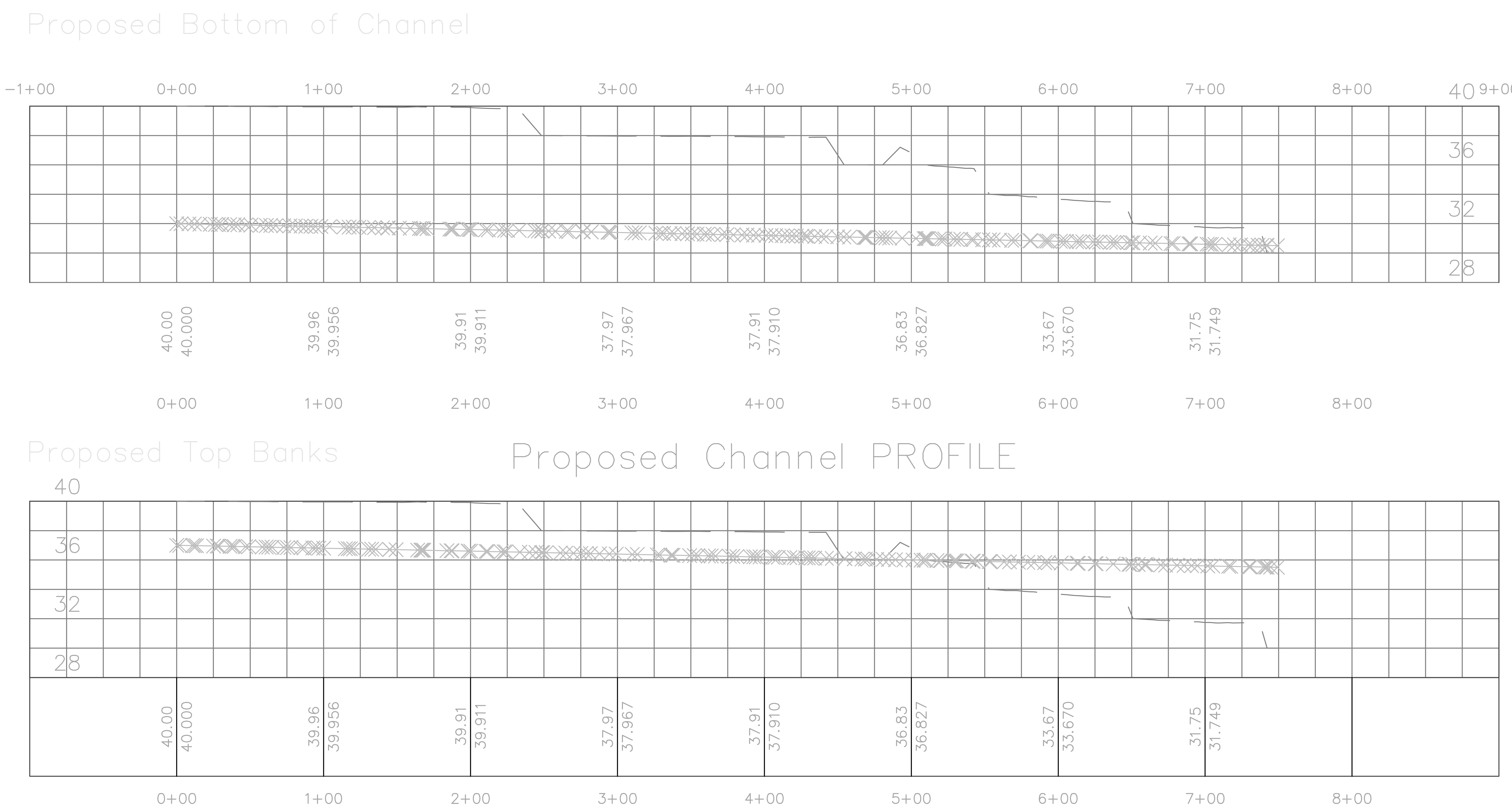
52
48
44
40
51.37
51.370
47.98
47.984
46.60
46.602
47.99
47.992
51.00
51.003
52.10
52.099
49.06
49.063
Proposed Conditions
ROUTE-4 PROFILE
32
36
DEPTH=-1.37'
DEPTH=-13.02'



Proposed Bottom of Channel
−1+00
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
40
36
32
28
40.00 40.000
39.96 39.956
39.91 39.911
37.97 37.967
37.91 37.910
36.83 36.827
33.67 33.670
31.75 31.749
Proposed Top Banks
Proposed Channel PROFILE

DASH Stormwater Storage Alternatives

Cost Estimates

Prepared for:

Michael Baker International, Alexandria, VA Office

December 2, 2019

S.O. No. TBD

Michael Baker International's Cost Management Division (CMD) was tasked to support the MBI Alexandria Office by providing cost estimating services for the DASH Stormwater Storage Alternatives. The primary objective of this project is to determine the costs to modify the existing stormwater management system located in the vicinity of the DASH Headquarters in Alexandria, VA., reduce potential for flooding during ten-year storm events.

This estimate was developed based on DASH Flooding Analysis of Alternatives drawings of November 2019., and includes three design alternatives for this project.

Construction Cost Estimate (CCE) for the three storage alternatives:

Storage-1	$5,765,493
Storage-2	$1,294,853
Storage-3	$1,793,698

The work breakdown structure for the estimate follows the CSI Masterformat and was developed using Timberline estimating software. Takeoff quantities for each of the Alternatives were provided by the Michael Baker Surface Water Division in Alexandria, VA.

The estimate is based on the following assumptions:

- Design Contingency – 15%
- General Requirements – 5%
- General Conditions – 10%
- Contractor Home Office Costs – 3%
- Bonds & Insurance – 2.5%
- Contractor Profit – 2.5%
- Does not include additional engineering, design, and assessments, prior to construction
- Does not consider weather and timing of construction activities
- Regular 5-day, 40-hour work week has been applied. Overtime has been excluded.
- Excludes escalation

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12/3/2019

Dash Stormwater Mitigation Storage-1 Cost Estimate
Alexandria, VA

SITE AREA (ACRES): 1.40 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$3,703,259	
	Subtotal		$3,703,259	$2,644,491.10
Design Contingency		15.00%	$555,489	$396,673.67
	Subtotal		$4,258,748	$3,041,164.77
General Requirements		5.00%	$212,937	$152,058.24
General Conditions		10.00%	$425,875	$304,116.48
Home Office Costs		3.00%	$127,762	$91,234.94
Bonds & Insurance		2.50%	$122,439	$87,433.49
	Subtotal		$5,147,761	$3,676,007.91
Profit		12.00%	$617,731	$441,120.95
	Subtotal		$5,765,493	$4,117,128.86
Escalation		0.00%	$0	$0.00
	Total Construction		$5,765,493	$4,117,128.86

Dash Stormwater Mitigation Storage-1 Cost Estimate 12/3/2019

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	1.40		$10,188.20		$7,275.38
02	EXISTING CONDITIONS	1.40		$574,791		$410,457.62
31	EARTHWORK	1.40		$1,885,081		$1,346,133.15
32	EXTERIOR IMPROVEMENTS SUBTOTAL	1.40		$536,076		$382,811.22
33	UTILITIES SUBTOTAL	1.40		$697,122		$497,813.73
	TOTAL - DIRECT COSTS	1.40		$3,703,259		$2,644,491.10

12/3/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Storage-1 Cost Estimate **1.40 ACRES**

Alexandria, VA

ID			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
02	EXISTING CONDITIONS		QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
		REMOVE ASPHALT PAVING							
		Remove Parking Asphaltic Pavement & Base, Concrete Curb & Gutter	61,000	SF	0.00	2.80	1.71	4.51	275,329
		Load & Haul Debris	2,165	TONS	0.00	34.64	5.09	39.73	86,029
		Dump Fees	2,165	TONS	95.52	0.00	3.06	98.58	213,434
02	**EXISTING CONDITIONS SUBTOTAL**								**574,791**
31	EARTHWORK								
		Clear & grub - 20% of site	0.28	AC	0.00	2,547.05	2,190.46	4,737.51	1,327
		Rough Grade - Parking Lot	61,000	SF	0.00	0.03	0.02	0.05	3,091
		Excavate vault area	22,615	CY	0.00	0.41	0.94	1.34	30,415
		Load & Haul Soil	24,877	TONS	0.00	28.53	4.58	33.11	823,709
		Dump Fees	24,877	TONS	38.21	0.00	3.06	41.27	1,026,540
31	**EARTHWORK SUBTOTAL**								**1,885,081**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	0.28	AC	6,368.11	2,292.35	1,018.82	9,679.27	2,711
		Parking Lot (2 1/2", 1 1/2", 6" BASE - includes C&G, sidewalks and islands)	61,000	SF	0.00	6.86	1.88	8.74	533,365
32	**EXTERIOR IMPROVEMENTS SUBTOTAL**								**536,076**
33	UTILITIES	(Piping & U/G utilities, includes horizontal boring & jacking pits)							
		RCP 30" Diameter tie-out	151	LF	789.65	224.14	71.32	1,085.10	163,851
		RCP 60" Diameter tie-in	321	LF	1,260.89	305.65	94.75	1,661.28	533,271
33	**UTILITIES SUBTOTAL**								**697,122**
	TOTAL - DIRECT COST, LOCAL MARKET								**3,703,259**
	TOTAL DIRECT COST								**3,703,259**

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12/3/2019

Dash Stormwater Mitigation Storage-2 Cost Estimate

Alexandria, VA

SITE AREA (ACRES): 0.51 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$831,703	
	Subtotal		$831,703	$1,646,771.15
Design Contingency		15.00%	$124,755	$247,015.67
	Subtotal		$956,458	$1,893,786.82
General Requirements		5.00%	$47,823	$94,689.34
General Conditions		10.00%	$95,646	$189,378.68
Home Office Costs		3.00%	$28,694	$56,813.60
Bonds & Insurance		2.50%	$27,498	$54,446.37
	Subtotal		$1,156,119	$2,289,114.82
Profit		12.00%	$138,734	$274,693.78
	Subtotal		$1,294,853	$2,563,808.60
Escalation		0.00%	$0	$0.00
	Total Construction		$1,294,853	$2,563,808.60

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Dash Stormwater Mitigation Storage-2 Cost Estimate **12/3/2019**

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	0.51		$10,188.20		$20,172.64
02	EXISTING CONDITIONS	0.51		$216,675		$429,016.45
31	EARTHWORK	0.51		$405,593		$803,075.12
32	EXTERIOR IMPROVEMENTS SUBTOTAL	0.51		$193,339		$382,811.22
33	UTILITIES SUBTOTAL	0.51		$5,907		$11,695.73
	TOTAL - DIRECT COSTS	0.51		$831,703		$1,646,771.15

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12/3/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Storage-2 Cost Estimate **0.51 ACRES**

Alexandria, VA

ID			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
02	EXISTING CONDITIONS								
		48" Diameter Pipe Removal	115	LF	0.00	48.90	32.60	81.51	9,373
		REMOVE ASPHALT PAVING							
		Remove Parking Asphaltic Pavement	22,000	SF	0.00	2.80	1.71	4.51	99,299
		Load & Haul Debris	781	TONS	0.00	34.64	5.09	39.73	31,027
		Dump Fees	781	TONS	95.52	0.00	3.06	98.58	76,976
02	**EXISTING CONDITIONS SUBTOTAL**								**216,675**
31	EARTHWORK								
		Clear & grub - 20% of site	0.10	AC	0.00	2,547.05	2,190.46	4,737.51	479
		Rough Grade - Parking Lot	22,000	SF	0.00	0.03	0.02	0.05	1,115
		Excavate vault area	4,858	CY	0.00	0.41	0.94	1.34	6,534
		Load & Haul Soil	5,344	TONS	0.00	28.53	4.58	33.11	176,947
		Dump Fees	5,344	TONS	38.21	0.00	3.06	41.27	220,519
31	**EARTHWORK SUBTOTAL**								**405,593**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	0.10	AC	6,368.11	2,292.35	1,018.82	9,679.27	978
		Parking Lot (2 1/2", 1 1/2", 6" BASE - includes C&G, sidewalks and islands)	22,000	SF	0.00	6.86	1.88	8.74	192,361
32	**EXTERIOR IMPROVEMENTS SUBTOTAL**								**193,339**
33	UTILITIES	(Piping & U/G utilities, includes horizontal boring & jacking pits)							
		RCP 48" Diameter Outlet Pipe	5	LF	853.33	244.52	83.54	1,181.39	5,907
33	**UTILITIES SUBTOTAL**								**5,907**
	TOTAL - DIRECT COST, LOCAL MARKET								**831,703**
	TOTAL DIRECT COST								**831,703**

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12/3/2019

Dash Stormwater Mitigation Storage-3 Cost Estimate
Alexandria, VA

SITE AREA (ACRES): 0.85 Acres

PROJECT CONSTRUCTION COST SUMMARY

			Construction Cost ($)	Cost /Acres ($)
Direct Cost to Prime Contractor			$1,152,118	
	Subtotal		$1,152,118	$1,356,385.20
Design Contingency		15.00%	$172,818	$203,457.78
	Subtotal		$1,324,935	$1,559,842.98
General Requirements		5.00%	$66,247	$77,992.15
General Conditions		10.00%	$132,494	$155,984.30
Home Office Costs		3.00%	$39,748	$46,795.29
Bonds & Insurance		2.50%	$38,092	$44,845.49
	Subtotal		$1,601,516	$1,885,460.20
Profit		12.00%	$192,182	$226,255.22
	Subtotal		$1,793,698	$2,111,715.43
Escalation		0.00%	$0	$0.00
	Total Construction		$1,793,698	$2,111,715.43

Dash Stormwater Mitigation Storage-3 Cost Estimate **12/3/2019**

Alexandria, VA

DIRECT COST SUMMARY & OPTIONS

	DESCRIPTION	Site Development Area (Acres)		Direct Cost ($)		Cost/Acre ($)
01	GENERAL REQUIREMENTS	0.85		$10,188.20		$11,994.54
02	EXISTING CONDITIONS	0.85		$348,644		$410,457.62
31	EARTHWORK	0.85		$790,819		$931,029.25
32	EXTERIOR IMPROVEMENTS SUBTOTAL	0.85		$2,466		$2,903.78
33	UTILITIES SUBTOTAL	0.85		$0		$0.00
	TOTAL - DIRECT COSTS	0.85		$1,152,118		$1,356,385.20

Michael Baker INTERNATIONAL

12/3/2019

DETAIL DIRECT COST WORKSHEET

Dash Stormwater Mitigation Storage-3 Cost Estimate **0.85 ACRES**
Alexandria, VA

ID			QUANTITY	UOM	MATERIAL UNIT COST	LABOR UNIT COST	EQPT UNIT COST	TOTAL UNIT COST	COST TO PRIME
01	GENERAL REQUIREMENTS								
		CARRIED ON SUMMARY PAGE			0.00	0.00	0.00	0.00	0
		MOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
		DEMOBILIZATION	1	LS	0.00	5,094.10	0.00	5,094.10	5,094
01	**GENERAL REQUIREMENTS SUBTOTAL**								**10,188**
					MATERIAL	LABOR	EQPT	TOTAL	COST TO
02	EXISTING CONDITIONS		QUANTITY	UOM	UNIT COST	UNIT COST	UNIT COST	UNIT COST	PRIME
		REMOVE ASPHALT PAVING							
		Remove Parking Asphaltic Pavement	37,000	SF	0.00	2.80	1.71	4.51	167,003
		Load & Haul Debris	1,313	TONS	0.00	34.64	5.09	39.73	52,182
		Dump Fees	1,313	TONS	95.52	0.00	3.06	98.58	129,460
02	**EXISTING CONDITIONS SUBTOTAL**								**348,644**
31	EARTHWORK								
		Clear & grub - 20% of site	0.17	AC	0.00	2,547.05	2,190.46	4,737.51	805
		Excavate pond area	7,639	CY	0.00	0.41	0.94	1.34	10,273
		Rough Grade - Pond	38,000	SF	0.00	0.03	0.02	0.05	1,925
		Finish grade pond bottom	38,000	SF	0.00	2.38	1.64	4.02	152,835
		Load & Haul Soil	8,403	TONS	0.00	28.53	4.58	33.11	278,234
		Dump Fees	8,403	TONS	38.21	0.00	3.06	41.27	346,747
31	**EARTHWORK SUBTOTAL**								**790,819**
32	EXTERIOR IMPROVEMENTS								
		Site Landscaping Allowance (includes irrigation systems as req'd)	0.25	AC	6,368.11	2,292.35	1,018.82	9,679.27	2,466
32	**EXTERIOR IMPROVEMENTS SUBTOTAL**								**2,466**
	TOTAL - DIRECT COST, LOCAL MARKET								**1,152,118**
	TOTAL DIRECT COST								**1,152,118**

Oldcastle Infrastructure
A CRH COMPANY

Regional Sales, Oldcastle Infrastructure - Stormwater
Chris Allen
Phone: 540-395-6397

September 24, 2019

Quotation Contract

All Bidders

Quotation No.: S046689

Project Name: 500-DASHB.3 SC (Budget)
Project Location: FOB Jobsite
Alexandria, VA 22301
Anticipated Delivery Date: TBD

Dear : **Bidder**

We are pleased to provide the following quote for a StormCapture® system for the referenced project. This proposal is based upon the design criteria noted below. Any changes to the layout or the design criteria will be potential cause for price adjustment. Please contact us with any questions.

StormCapture System Information:

- Storage Volume Provided 726,304 CF
- Approximate System Footprint 192 Feet X 288 Feet
- Heaviest Piece Weight 30,340 Lbs
- Delivery Date is Approximately TBD Weeks After Receipt of Approved Signed Submittals

Design Criteria:

- System is designed to AASHTO HS20-44 with impact. Construction equipment exceeding design loading shall not be allowed on structure.
- Precast Concrete in accordance with ACI-318.
- Assumed Water Table: Below Bottom of StormCapture System
- No lateral surcharge from adjacent structures is assumed.
- Required Aggregate Base Layer: Not Applicable
- Minimum Depth of Cover 0.5 Feet
- Maximum Depth of Cover 3.0 Feet
- Required Soil Bearing Capacity 3,000 PSF
- Assumed Soil Density 120 PCF
- Dry Lateral Earth Pressure 45 PCF
- Lateral Live Load Surcharge 80 PSF
- Lateral Seismic Pressure N/A PSF Seismic Pressure Applied as: Not Applicable

Information Provided to Oldcastle at Time of Quotation:

	Yes	No	Dated
Construction Plans		x	
Specifications		x	
Geotechnical Report		x	
Required Elevations (Rim, Invert)		x	

Qty	Unit	Description	Unit Price	Amount
		****BUDGET****		
1	Ea	**SC-7'x15'x14' ID precast storm capture system designed for 726,304 cf storage, HS-20 loading at .5' to 3' fills with ground water assumed below the structure. Manufactured in 245 base sections 245 top sections, 187 each Link and Grade Slabs. Maximum section weight approx 15.5 tons. Includes (8) frames/covers, gasket material, and risers to grade.**		3,535,240.00
58	Ea	StormCapture 7' Tall Perimeter Module-Top		
58	Ea	StormCapture 7' Tall Perimeter Module-Bottom		

187	Ea	StormCapture 7' Tall Interior Module-Top
187	Ea	StormCapture 7' Tall Interior Module-Bottom
187	Ea	StormCapture Link Slab 9'x17'x8"
187	Ea	Link Slab - Grade Slab 8'X16'X7"
606	Roll	Sealant - 1"x14.5' ConSeal CS-102
245	Ea	Joint Wrap - CS 212 (8" x 50') - Roll
16	Ea	8oz Geotextile - Roll
8	Ea	30" Heavy Duty Cast Iron Frame and Oldcastle Stormwater
112	Ea	Ladder Rung -PS1-PF Plastic Step
2	Ea	On Site Service Technician (DEL)
94	Ea	Wide Delivery (non-taxable)
397	Ea	Legal Delivery (non-taxable)

Sub Total:	$3,535,240.00
Tax:	$165,794.07
Total:	**$3,701,034.07**

A. INCLUSIONS:

1 Delivery to the project site on flatbed trailers. Shipping based on Max 8 Loads Per Day, additional loads per day possible upon request.
2 Joint tape and joint wrap.
3 Access risers and cast iron ring & covers.
4 On-site representation at start of system installation, if applicable.

B. EXCLUSIONS:

1 State or local sales or use taxes.
2 Unloading, setting, or installing any components quoted herein.
3 Cast-in-place concrete slab (if required).
4 Granular bedding material.
5 Epoxy coated or galvanized rebar.
6 Exterior or interior concrete coating.

C. CONDITIONS:

1 Proposal is based upon full truck load quantities and includes one hour per truck for unloading of product. Additional truck time over 1 hour to be charged at $100/Hour.
2 Purchase Order or Signed Proposal, along with written approval of submitted shop drawings, is required prior to manufacture of StormCapture system.
3 The Purchaser is responsible to provide safe and sufficient access for tractor trailer delivery.
4 Product not accepted for delivery within 30 days of agreed upon delivery date will be invoiced in full, and will be subject to product storage fee.
5 Unless otherwise specified and subject to Purchaser's credit approval, payment for materials furnished under this contract is due thirty (30) days after their receipt by Purchaser, without retention.
6 Signing below indicates acceptance of standard terms and conditions available at **https://oldcastleinfrastructure.com/customer-support/terms-conditions/material-sales**.

Please indicate your acceptance of this proposal by signing below and returning.

Sincerely,

Chris Allen Date
Regional Sales, Oldcastle Infrastructure - Stormwater
540-395-6397

Accepted by:

(Customer Signature) Date
Printed name:
Title:
Company:

We appreciate your business!

REVISIONS

REVISION	DATE	REV BY	DESCRIPTION OF REVISION
0	N/A	N/A	

STAGE-STORAGE

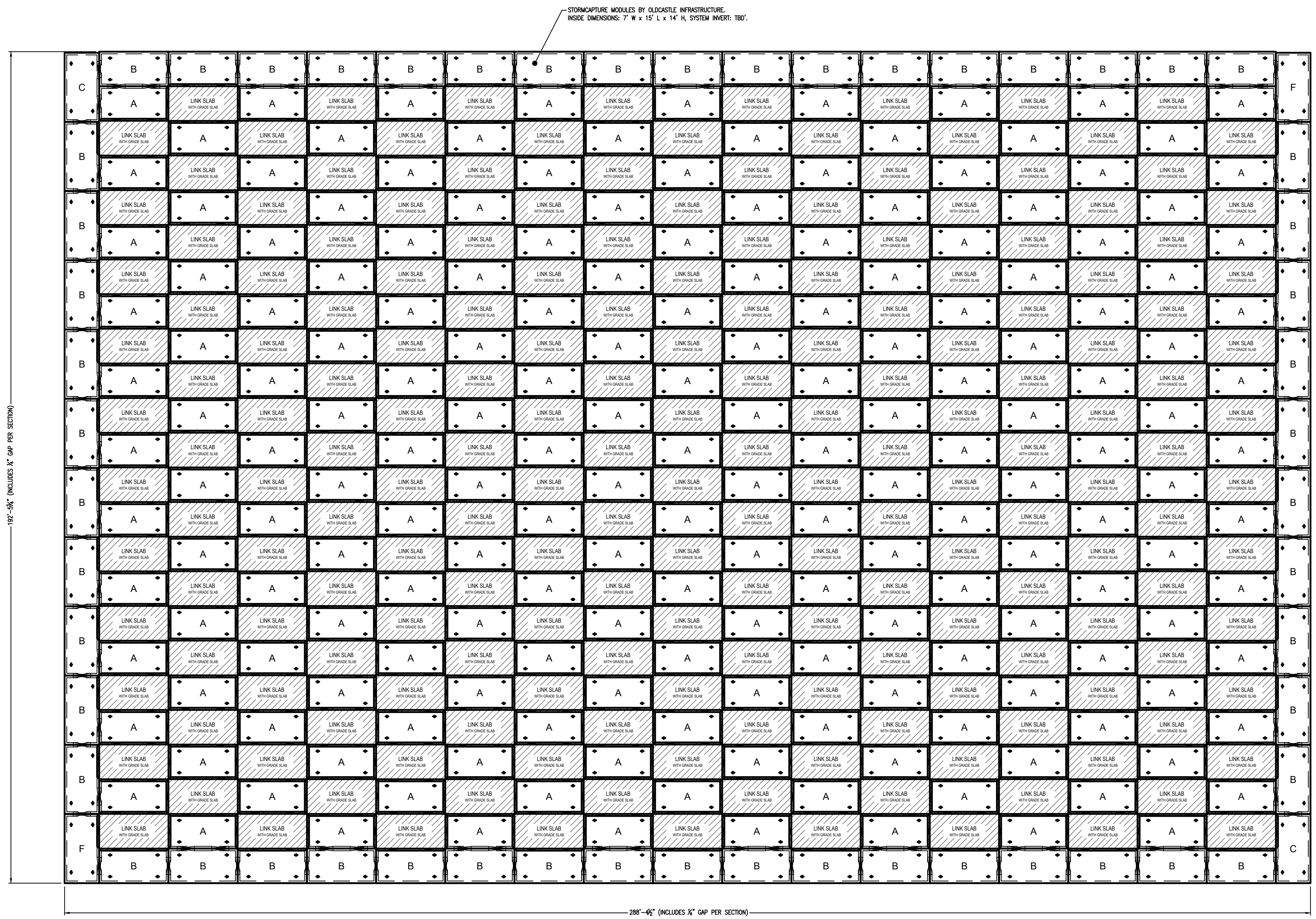
STAGE HEIGHT (FT)	VOLUME (CF)
0.00	0
0.50	25,317
1.00	50,633
1.50	76,814
2.00	102,994
2.50	129,175
3.00	155,355
3.50	181,536
4.00	207,716
4.50	233,897
5.00	260,077
5.50	286,258
6.00	312,438
6.50	338,133
7.00	363,827
7.50	390,008
8.00	416,188
8.50	442,369
9.00	468,549
9.50	494,730
10.00	520,910
10.50	547,091
11.00	573,271
11.50	599,452
12.00	625,632
12.50	651,813
13.00	676,643
13.50	701,474
14.00	726,304

DESIGN NOTES:

1. DESIGN LOADINGS:
   A. AASHTO HS-20-44 W/ IMPACT.
   B. DEPTH OF COVER = 6" - 3'-0" (120 PCF ASSUMED).
   C. ASSUMED WATER TABLE = BELOW BOTTOM OF PRECAST.
   D. DRY LATERAL EARTH PRESSURE (EFP) = 45 PCF.
   E. LATERAL LIVE LOAD SURCHARGE = 80 PSF (APPLIED TO 8' BELOW GRADE).
   F. NO LATERAL SURCHARGE FROM ADJACENT BUILDINGS, WALL PIERS, OR FOUNDATIONS.
2. CONCRETE 28 DAY COMPRESSIVE STRENGTH SHALL BE 6,000 PSI.
3. STEEL REINFORCEMENT: REBAR, ASTM A-615 OR A-706, GRADE 60.
4. MESH REINFORCEMENT: ASTM A-1064, S1.2, GRADE 80.
5. CEMENT: ASTM C-150 SPECIFICATION.
6. STORMCAPTURE MODULE TYPE = DETENTION.
7. REQUIRED BASE LAYER DEPTH = NOT APPLICABLE.
8. REQUIRED NATIVE ALLOWABLE SOIL BEARING PRESSURE = 3,000 PSF. NATIVE SOIL SHOULD BE LEVEL/SCREEDED AND COMPACTED ADEQUATELY TO ALLOW FOR REQUIRED BEARING CAPACITY.
9. REFERENCE STANDARDS:
   A. ASTM C 890
   B. ASTM C 891
   C. ASTM C 913
10. CONSTRUCTION EQUIPMENT EXCEEDING DESIGN LOADING SHALL NOT BE ALLOWED ON STRUCTURE. ANY DESIGN CONSTRAINT DIFFERENT FROM ABOVE REQUIRES CUSTOM STRUCTURAL DESIGN AND MAY REQUIRE THICKER SUBGRADE AND REVISED PRICING.

NOTES TO REVIEWING ENGINEER:

1. THIS SYSTEM IS DESIGNED TO THE PARAMETERS NOTED. PLEASE VERIFY THAT THESE PARAMETERS MEET PROJECT REQUIREMENTS (I.E. LIVE LOAD AND FILL RANGE). IF DESIGN PARAMETERS ARE INCORRECT NOTIFY OLDCASTLE IMMEDIATELY FOR REDESIGN AND RE-PRICING.
2. REVIEWING ENGINEER TO CONFIRM ALL PIPE PENETRATION LOCATIONS, SIZES, AND INVERTS.
3. REVIEWING ENGINEER TO CONFIRM ALL MANWAY ACCESS LOCATIONS AND RIM ELEVATIONS.
4. UNLESS OTHERWISE NOTED, ALL PIPE SUPPLIED AND INSTALLED BY OTHERS.
5. THIS SYSTEM IS DESIGNED FOR A GROUNDWATER TABLE BELOW SYSTEM INVERT. REVIEWING ENGINEER TO VERIFY THAT THE DESIGN GROUNDWATER TABLE IS BELOW INVERT OF PRECAST. IF DESIGN PARAMETERS ARE INCORRECT NOTIFY OLDCASTLE IMMEDIATELY FOR REDESIGN AND REVISED PRICING.
6. THIS SYSTEM IS DESIGNED WITHOUT A CONTAINMENT MEMBRANE LINER. IF A LINER IS NEEDED PLEASE CONTACT OLDCASTLE TO PROVIDE THIS OPTION IN THE FINAL DESIGN.



PLAN VIEW
SCALE: 1/30" = 1'-0"

- PRELIMINARY -
NOT FOR CONSTRUCTION

Detention/
Infiltration

Oldcastle Infrastructure™ A CRH COMPANY

Ph: 800.579.8819 | www.oldcastleinfrastructure.com/stormwater

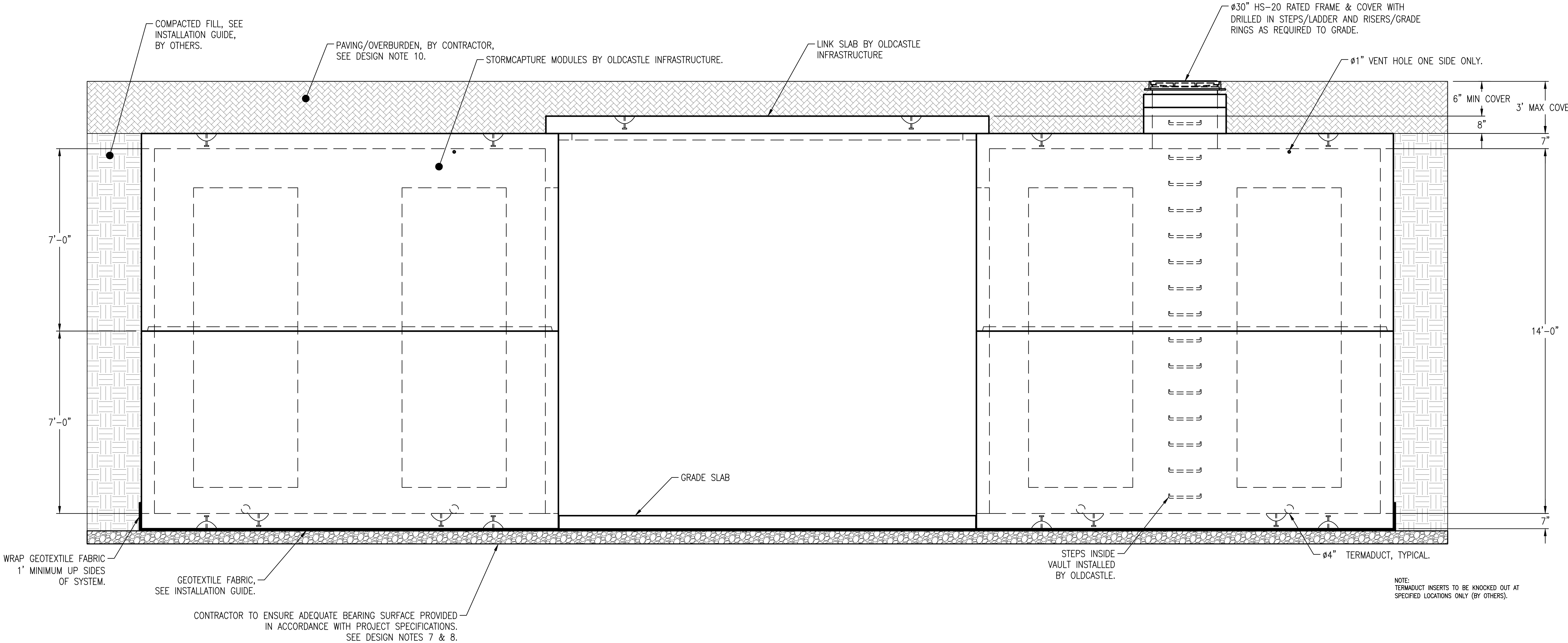
STORMCAPTURE ®
SC2 Detention System

Customer:
Michael Baker International

Job Name:
DASHB.3 - Alexandria, VA

DATE	SALES	DRAWN	ENGINEER	CHECKED	SALES ORDER
9/20/19	CRA	CJS	CJS	-	-

DRAWING NUMBER	REVISION	SHEET
SCDD-1450-0-SC2_DT	- REV DATE N/A	1 OF 2



TYPICAL ELEVATION

SCALE: 1/4" = 1'-0"

- PRELIMINARY -
NOT FOR CONSTRUCTION

Oldcastle Infrastructure™
A CRH COMPANY

Ph: 800.579.8819 | www.oldcastleinfrastructure.com/stormwater

STORMCAPTURE ®
SC2 Detention System

Customer:
Michael Baker International

Job Name:
DASHB.3 - Alexandria, VA

DATE	SALES	DRAWN	ENGINEER	CHECKED	SALES ORDER
9/20/19	CRA	CJS	CJS	-	-
DRAWING NUMBER				REVISION	SHEET
SCDD-1450-0-SC2_DT				- REV DATE N/A	2 OF 2

Detention/ Infiltration

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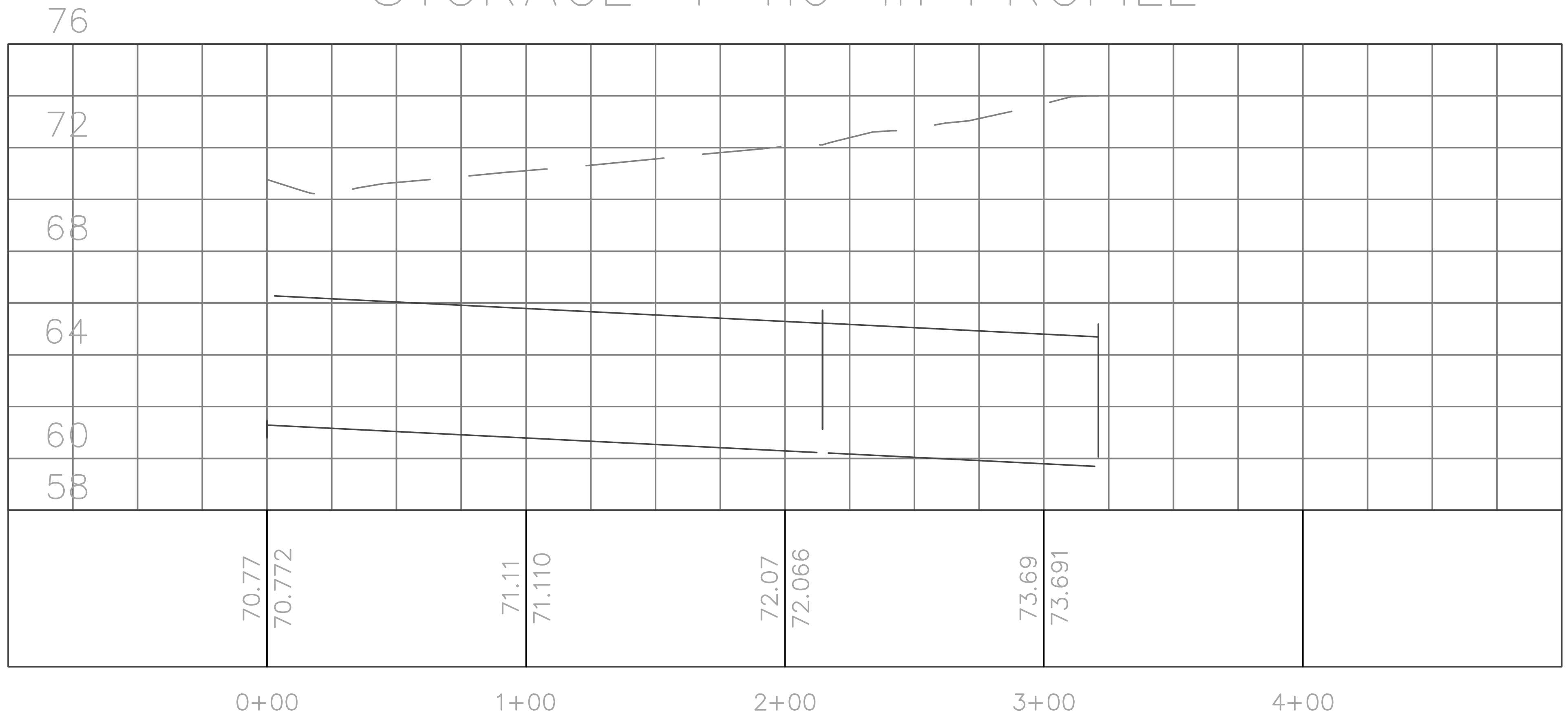
Proposed Tie-In
BP: 0+00.00
0+00
1+00
2+00
PI: 2+14.49
76.00
74.00
EP: 3+20.99
STORAGE-1
75.43
73.22
68.78
68.07
68.73
Proposed Tie-Out
1+00
EP: 1+50.52
1+51
65.26

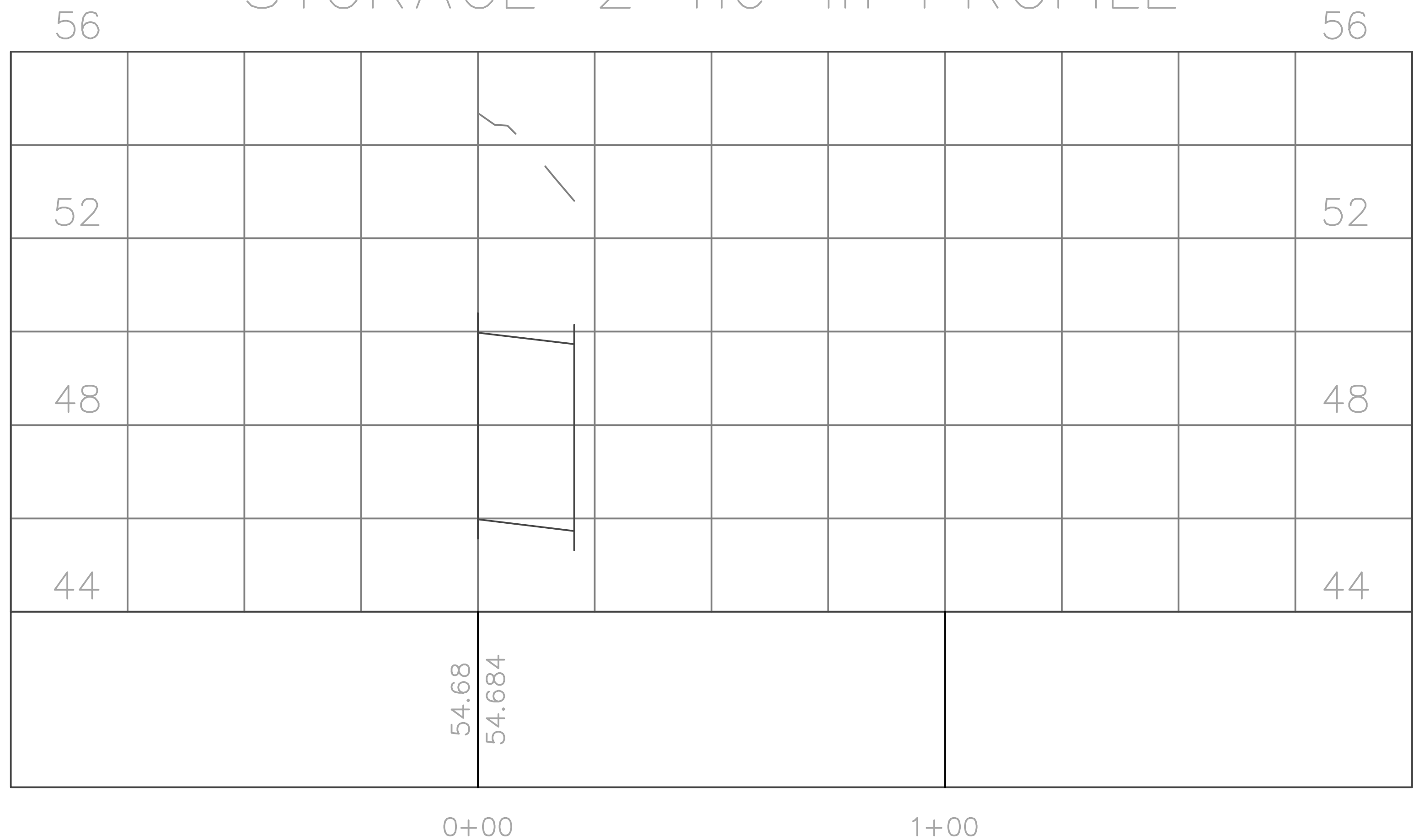
STORAGE-1 Tie-In PROFILE



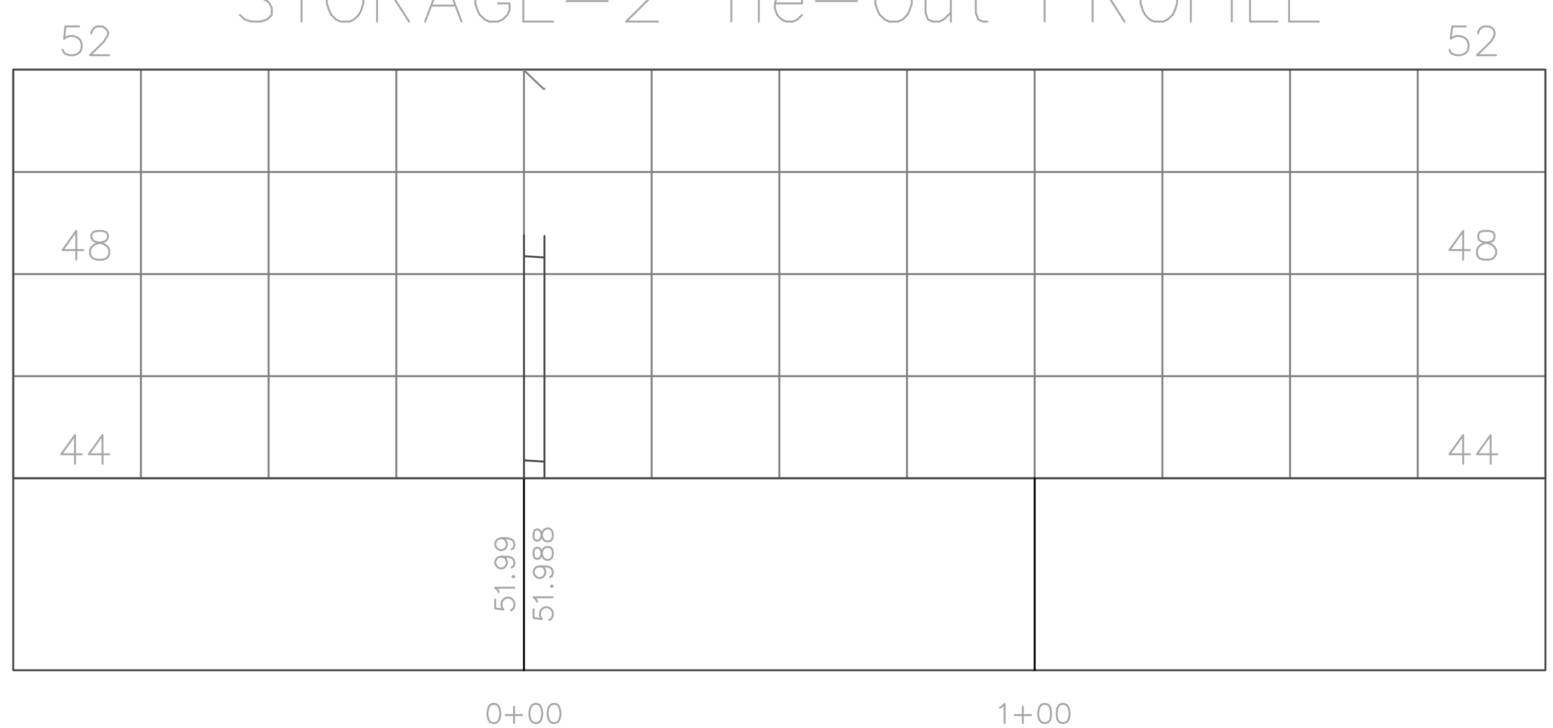
STORAGE-1 Tie-Out PROFILE


Proposed Tie-In
BP: 0+00.00
EP: 0+20.82
Proposed Tie-In
STORAGE-2
BP: 0+00.00
EP: 0+04.00
Proposed Tie-Out

STORAGE-2 Tie-In PROFILE



STORAGE-2 Tie-Out PROFILE




BP: 0+00.00
Proposed Tie-In
Upstream Inv Elev = 30.975'
Downstream Inv Elev = 30.7'
EP: 0+52.57
STORAGE-3
TOP BANK ELEV = 38.7'
BOTTOM BANK ELEV = 30.7'
BP: 0+00.00
Proposed Tie-Out
EP: 0+70.59

STORAGE-3 Tie-Out PROFILE