COASTAL RESILIENCE SIMULATION MEMO

WOODS HOLE GROUP

- COASTAL FLOOD MODELING FOR VISION PLAN DESIGN

MEMORANDUM

DATE December 2, 2019

TO Amy Whitesides
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FROM Woods Hole Group
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CC Julie Eaton, P.E., Weston and Sampson

Moakley Park Master Plan – Task 1.1Q - Coastal Assessment of Initial Design

A. Introduction

Woods Hole Group was tasked with assessing the coastal flood resiliency of the initial Moakley Park design as presented in the Moakley Park Vision plan, created by Stoss Landscape Urbanism. The proposed design concept primarily consisted of elevational elements (berms, hills, raised roads, etc.) that were integrated into the overall park vision and layout. The development of this proposed design vision utilized results from the Boston Harbor Flood Risk Model (BH-FRM) to assist in the conceptual design of the Moakley Park Master Plan. Specifically, the results of the flood risk model were utilized to help guide flood protection methods, locations, and elevations. The primary flood protection elements consist of a northern berm that crests at an elevation of approximately 16 feet NAVD88, two central hills with a frontal berm cresting at approximately 16-18 feet NAVD88, and a linear southern berm that elevates the harbor walk to the south of Moakley Park to an elevation of 16 feet NAVD88.[1]

B. Alternative Model Cases

Based on the probabilistic results and phasing of flood entry locations determined from the Boston Harbor Flood Risk Model, three model specific alternatives were created by modifying the existing Moakley Park landscape in BH-FRM. These three alternatives were developed to determine the relative contribution of ocean-based flood water to the Moakley Park area, as well as identify phasing approaches that could be implemented to reduce risk and allow for various construction timing/approaches. All three alternatives were developed from the vision plan design elements to assess the coastal flood resiliency of the Park with the design elements in place (post-construction). The three alternative model cases considered were:

- Alternative 1 includes the complete flood protection layout for the Moakley Park area as presented in the Moakley Park Vision plan. This alternative includes the northern berm extension that fronts the MWRA Columbus Park Headworks building, the two central hills within Moakley Park, and the linear southern berm that extends from the southern end of Moakley Park and becomes the new elevated Harbor walk

[1] NAVD88 datum can be converted to the City-wide datum Boston City Base (BCB) by using a conversion factor of NAVD88 + 6.46 feet = BCB.

fronting Bayside and portions of UMass-Boston. Figure 1 presents the areas within the BH-FRM model grid that were modified to represent the proposed Moakley Park vision. These areas (shown in yellow) were modified in terms of elevations and layouts to represent the design concept. The proposed digital elevation model (DEM) for the Moakley Park vision was provided by Stoss to Woods Hole Group and changes were made in the model domain by Woods Hole Group.

- Alternative 2 removed the southern berm from the proposed layout and only includes the northern berm extension and the hills within the park. This alternative focused on the design changes that primarily resided within Moakley Park (eliminating the longer linear berm to the south). Additionally, this alternative was simulated to evaluate the potential volumetric flood contributions that were entering the area from the Bayside flood pathway relative to direct entry from the Moakley Park shoreline. Figure 2 presents the areas that were modified (shown in yellow) in the model domain for Alternative 2.

- Alternative 3 includes only the northern berm extension and the northern hill located within the park. This alternative was identified as a potential first construction phase based on the higher probability flood pathways shown in the BH-FRM. For example, Figure 3 presents the 2030 probabilistic results for the Moakley Park area and shows a higher probability of flooding (orange colors) entering the northern portion of the Moakley Park shoreline and flooding the northern section of the Park. As such, it may be warranted, especially if funding is limited, to construct the northern hill portion as a first element of the Moakley Park design. This phased construction approach may provide potential cost savings and a more flexible design approach. Figure 4 presents the areas that were modified (shown in yellow) in the model domain for Alternative 3.

Figure 1: Alternative 1 representing the full Moakley Park design concept.

Figure 2: Alternative 2 removing the southern linear berm.

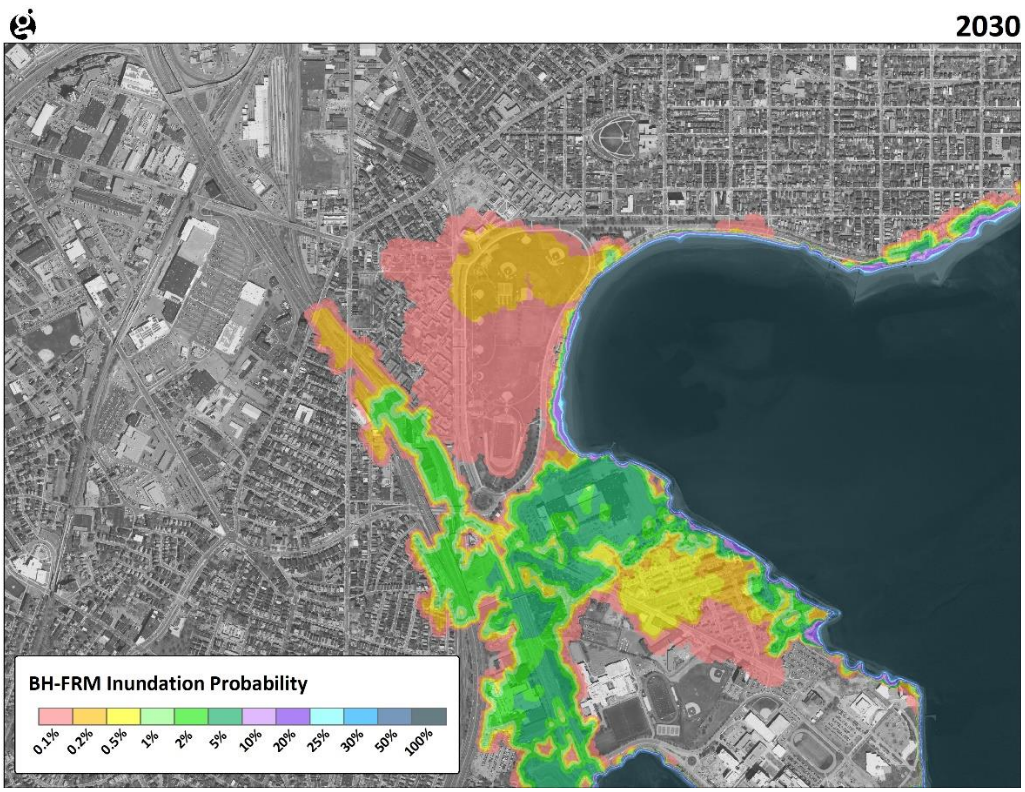

Figure 3: BH-FRM results indicating higher probability of flooding and entry point of flooding on northern portion of Moakley Park.

Figure 4: Alternative 3 including just the northern berm extension and the northern hill within Moakley Park.

C. Results

The performance of each of the alternatives in providing flood protection for Moakley Park (as well as inland areas) was determined by simulating BH-FRM with the proposed alternative configurations in place (constructed). Two specific return period storm events (1% or 100-year return period and 10% or 10-year return period) with climate conditions representing 2030- and 2070-time horizons, consistent with MassDOT and Climate Ready Boston scenarios, were simulated. The storm events and flooding results were compared for existing conditions (no alternative) and post-construction conditions (alternatives 1, 2, and 3). Flooding extents were evaluated for a 1% annual chance storm (100-year return period) and a 10% annual chance storm (10-year return period) for 2030 (approximately 9 inches of sea-level rise) and 2070 (approximately 40 inches of sea-level rise) climate conditions. While the entire suite of probabilistic storms (100s to 1000s of storm events) that make up the BH-FRM results were not simulated, these select storm events adequately capture the efficacy of the design alternatives in providing coastal flood resiliency to Moakley Park.

Additionally, for each storm scenario, the waves, wave run-up, and wave overtopping occurring during the storm events were dynamically simulated in the BH-FRM model. Specifically, this includes these processes that would occur on the proposed berm designs. For example, the volume of water that may propelled over the crest of each berm for each incoming wave. This analysis is dynamically computed throughout the length of the storm at each berm location.

Figure 5 presents the comparison results for a 1% annual exceedance storm in 2030. The dark blue area shows the flooding extent for existing conditions (upper left panel) and is also shown for comparison purposes in the alternative panels. The flooding extent for the same storm with the alternative designs (1,2, and 3) in place is shown as light blue areas in each of the alternative panels. The full Moakley Park vision, alternative 1, provides full protection for the entire Park and surrounding areas (e.g., Bayside, UMass-Boston, etc.) under 2030 1% storm conditions. Flood risk is reduced in the Bayside area and interior areas where flooding from the Bayside entry point caused further inland flooding. Alternative 2 also keeps Moakley Park free of coastal storm-based flooding; however, flood waters do enter through the Bayside area, flooding Morrissey Blvd and surrounding areas. Alternative 3 shows similar results to Alternative 2 as the flooding south of Moakley Park remains. The comparison between Alternative 2 and 3 also indicates that the northern berm extension and northern hill (Alternative 3) could be constructed without inclusion of the southern hill and provide the same protection level for near to mid-term conditions, and likely offer the same level of protection as Alternative 2 for more frequent storms in the mid to long-term. As such, the construction of the Moakley Park design could be phased with early emphasis given to the northern portions of the design concept.

Additionally, the 10% annual chance storm event for sea-level rise conditions in 2030 was simulated; however, flood extents for this event did not change between alternatives and no flooding occurred for existing conditions.

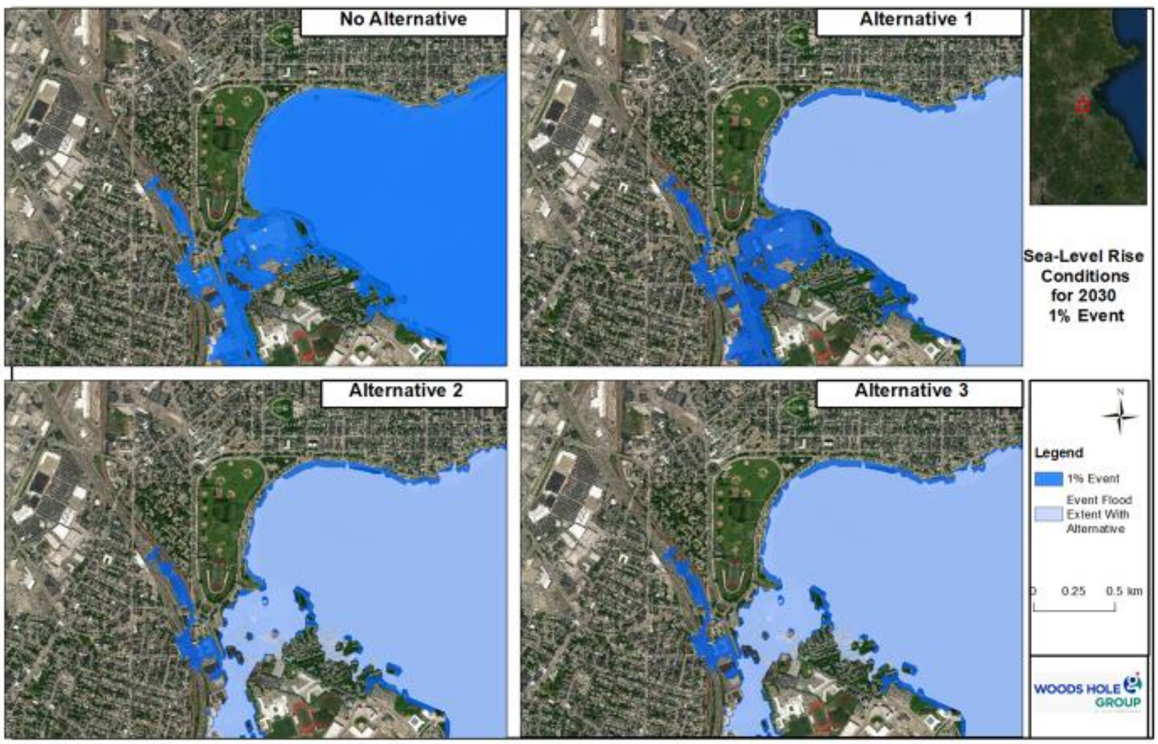

Figure 5: Flooding extents for the three design alternatives for the 1% annual chance storm for 2030 climate conditions.

Figure 6 presents the comparison results for a 10% annual exceedance storm in 2070. Again, the dark blue area shows the flooding extent for existing conditions (upper left panel) and is also shown for comparison purposes in the alternative panels. The flooding extent for the same storm with the alternative designs (1,2, and 3) in place is shown as light blue areas in each of the remaining panels. As was the case for the 2030 1% results, the full Moakley Park vision provides full protection for the entire Park; however, it does not adequately function for the surrounding areas (e.g., Bayside, UMass-Boston, Morrissey Blvd. etc.) to the south of the Park. While the proposed linear berm along the shoreline south of Moakley Park adequately inhibits coastal storm waters from entering from the Bayside shoreline, coastal flooding propagates to the area from the south at Morrissey Blvd and specifically the area near the entrance to UMass-Boston (at Pattens Cove and Bianculli Blvd). Therefore, this renders the southern berm ineffective by 2070 if actions are not taken to the south of the UMass-Boston peninsula as well. Under the 2070 10% storm scenario, Alternative 2 functions essentially the same as Alternative 1, keeping Moakley Park dry, while flooding to the south persists. Results for Alternative 3 indicate that coastal flood waters will enter Moakley Park if the southern hill(s) are not constructed. As such, by 2070, the interior hill designs are required to keep Moakley Park from flooding during a coastal storm event.

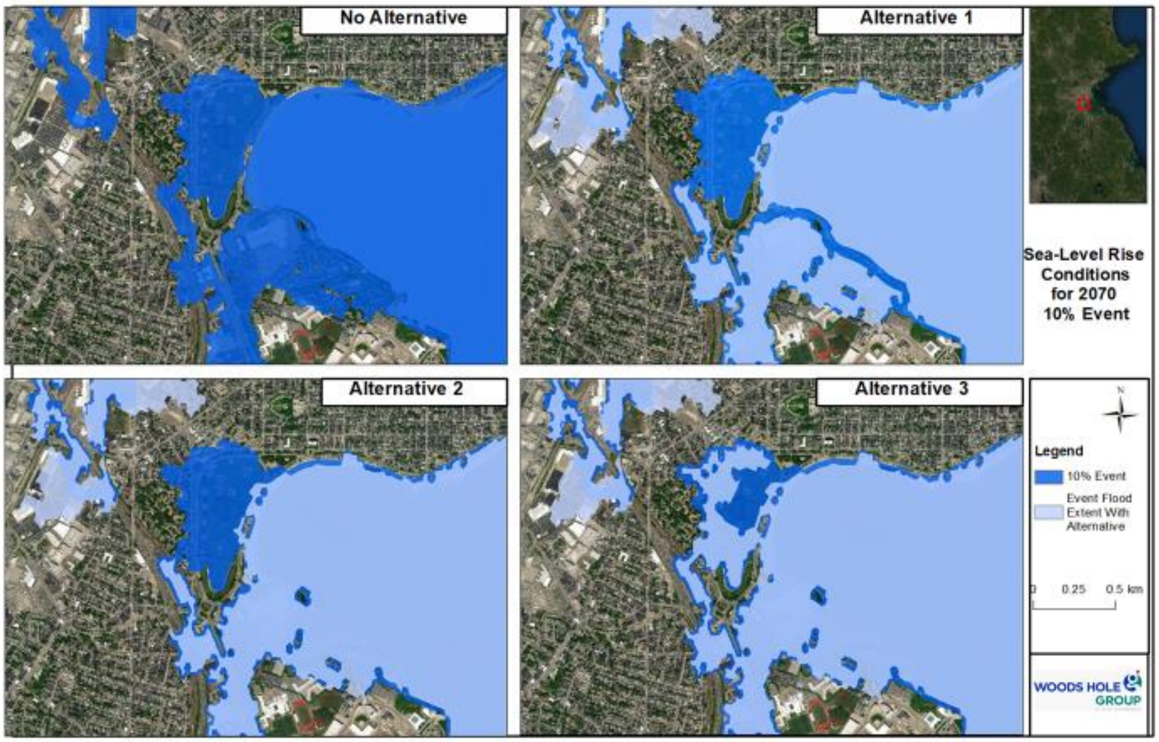

Figure 6: Flooding extents for the three design alternatives for the 10% annual chance storm for 2070 climate conditions.

Figure 7 presents the comparison results for a 1% annual exceedance storm in 2070. Again, the dark blue area shows the flooding extent for existing conditions (upper left panel) and is also shown for comparison purposes in the alternative panels. The flooding extent for the same storm with the alternative designs (1,2, and 3) in place is shown as light blue areas in each of the remaining panels. As was the case for the 2070 10% event, the full Moakley Park vision provides full protection for the entire Park; however, it does not adequately function for the surrounding areas (e.g., Bayside, UMass-Boston, Morrissey Blvd. etc.) to the south of the Park. Coastal flood extents and volumes are increased as more flood water enters from the north (from the Fort Point Channel flood pathway), but this added volume does not enter Moakley Park, rather just increases Morrissey Blvd flooding. Similar to the 10% 2070 results, the proposed linear berm along the shoreline south of Moakley Park adequately inhibits coastal storm waters from entering from the Bayside shorelines; however, coastal flooding propagates to the area from Morrissey Blvd and specifically the area near the entrance to UMass-Boston (at Pattens Cove and Bianculli Blvd). Therefore, this renders the southern berm ineffective by 2070 if actions are not taken to the south of the UMass-Boston peninsula as well. Under the 2070 1% storm scenario, Alternative 2 functions essentially the same as Alternative 1, keeping Moakley Park dry, while flooding to the south persists. Results for Alternative 3 indicate that coastal flood waters will enter Moakley Park if the southern hill(s) are not constructed. As such, by 2070, the interior hill designs are required to keep Moakley Park from flooding during a coastal storm event.

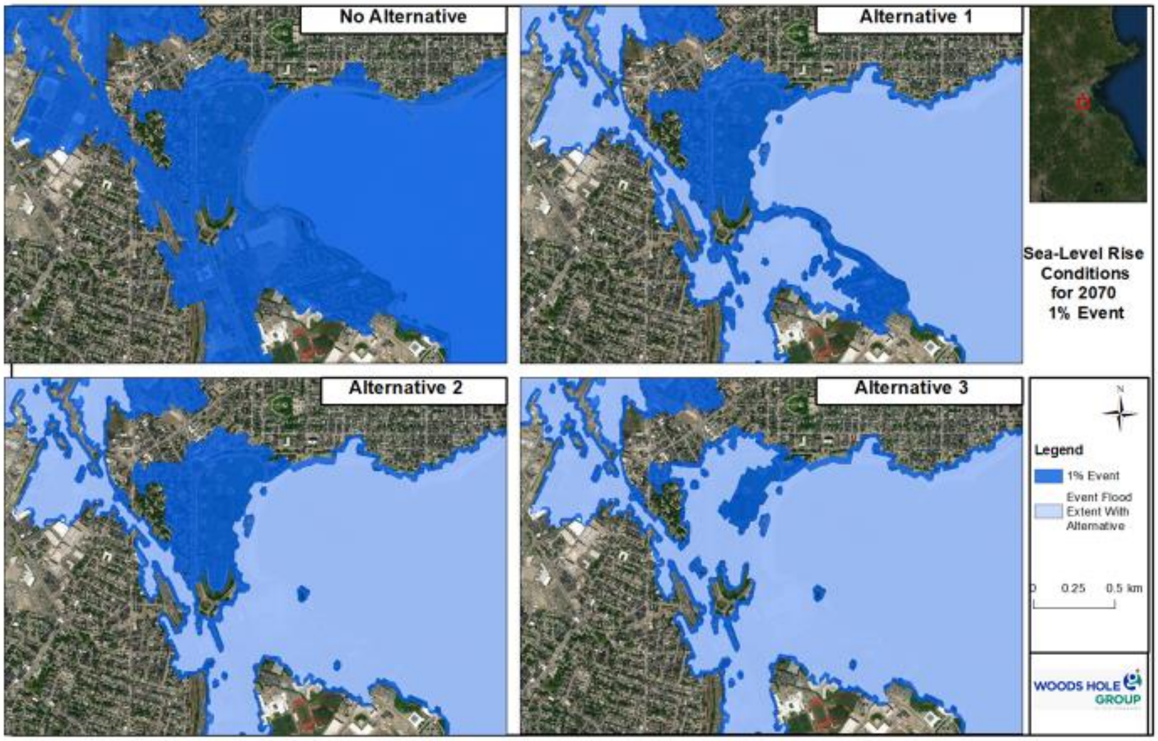

Figure 7: Flooding extents for the three design alternatives for the 1% annual chance storm for 2070 climate conditions.

Technical Review Committee (TRC) Form

PROJECT: Moakley Park Master Plan

TASK NUMBER: 1.1: Baseline Technical Assessment

SUB-TASK NUMBER: 1.1Q: Coastal Assessment of Initial Design

CLIENT: Boston Parks & Recreation Department

DATE: December 2, 2019

This form is intended to: 1) be completed by the TRC reviewer(s) at each stage of deliverable review; 2) assure that the deliverable satisfies the project team's quality standards; 3) reduce the project team's exposure to liability by detecting and correcting gross negligence and errors and; 4) reduce the possibility of future extra work due to errors and omissions on our part. The sub-task leader is responsible for hosting a kick-off meeting at the start of each task and the designated TRC reviewer must attend the kick-off meeting. This form is required for all project deliverables, but not necessarily all sub-tasks. This form should be attached to draft and final project deliverables.

Deliverable Description: 1.1Q: Coastal Assessment of Initial Design

Deliverable Type (Interim or Final): Final; work completed to date includes critical predecessors:

- 1.1J: Boston Harbor Flood Risk Model Grid Modifications
- 1.1M: Simulation Runs and Model Results

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TRC Hours Spent Reviewing Project: 4.5

Date for Meeting with Team to Discuss Resolution of Comments, if Required: Not required

Major Comments on Project Review:

1. Minor text edits were included as PDF comments in the Technical Memorandum.
2. Was potential for wave overtopping assessed for the storm events simulated at the northern and southern berms? It's not clear in the document if this was taken into account. If not, this should be considered or provide reasoning for why it was not assessed at this stage. If so, please clarify and provide additional details/assumptions (i.e. side slopes assumed for the berms).

   Response: Wave overtopping was explicitly assessed and this discussion was added to the deliverable technical memorandum.

W&S Review Comments:
1. Please add conversion between NAVD88 and BCB to the report.

FINAL DELIVERABLE REVIEW SIGN-OFF SHEET

This sign-off is intended to ensure that all members of the project team are satisfied that they have adequately reviewed the attached deliverable, and that the deliverable can be used by others for project advancement.

By signing this sheet, the reviewers indicate that they have completed an independent final review of the deliverable and feel that, pending execution of all changes recommended by the reviewer, the deliverable represents industry best practices and can be considered final. The sub-task lead shall initiate the form. The Principal-in Charge shall be the last to sign-off. Copies of the original and the draft deliverables shall be saved in the SharePoint folder directory.

	NAME	**SIGNATURE**	**DATE**
Project Director			
Project Manager			
Sub-task Lead			
TRC Reviewer			
TRC Reviewer			
Principal-in-Charge			

PERMIT MATRIX

NITSCH ENGINEERING AND WESTON & SAMPSON

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Overall Permitting Feasibility Study

June 2020

MOAKLEY PARK
BOSTON, MASSACHUSETTS

PREPARED FOR:
CITY OF BOSTON PARKS AND RECREATION

PREPARED BY:
WESTON & SAMPSON ENGINEERS, INC
NITSCH ENGINEERING

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EXECUTIVE SUMMARY

Using the Moakley Park Vision Plan Final Report (January 2019) for conceptual design, a permitting feasibility study was conducted for the City of Boston Parks and Recreation Department to determine which local, state and federal permits would likely be required for Moakley Park overall improvements. Nitsch Engineering conducted the local permit requirement investigation while Weston & Sampson conducted the state and federal permit investigation.

A preliminary desktop survey of environmental resource areas within the proposed limit of work for Moakley Park project was conducted in ArcView using MassGIS data layers. Once environmental resources at the park were identified, the overall project was then split up into five components, including park improvements, berm construction, promenade construction, beach improvements, and ocean barrier system.

Likely required local, state and federal permits were then identified for each of the components. Accompanying permit costs and review periods were then identified for each component to determine different costs and review periods for each component. Table ES-1, below, provides overall permitting costs and review durations for each of the five components of the Moakley Park project.

Table ES-1. Overall Permit Costs and Review Duration

Component	Cost	Review Duration (months)
Park improvement	$205,000 - $432,500	18
Berm construction	$205,000 - $432,500	18
Promenade system construction	$160,000 – $365,000	9
Beach improvement	$255,000 - $432,500	43
Ocean barrier system	$390,000 - $537,000	43

The components considered less costly and with shorter local, state and federal permit approval timelines included park improvements, berm construction and promenade system construction. Permitting costs for these can range between $160,000 and $432,500 and require up to 18 months to gain permit approval. The more environmentally complex beach improvement and ocean barrier system permitting costs can range from $255,000 to $537,000 with state and federal review times up to 43 months. These permitting costs are provided for each component as stand-alone project. Permitting cost savings may be realized should multiple components be undertaken simultaneously or in conjunction with each other.

If the City wants to start the Moakley Park improvements process, but does not have the finances to undertake all five park component efforts, the City may want to consider permitting just the park improvements, berm construction and promenade system construction components first. These components could be permitted together which would reduce permitting costs and permit approval timelines. Once these projects have been completed, the City may then be ready to undertake the more expensive and longer duration beach improvement and ocean barrier system components of the project.

INTRODUCTION

As part of the initial planning efforts for the Moakley Park project, the City of Boston Parks and Recreation Department should understand associated local, state and federal permits. Using the Moakley Park Vision Plan Final Report (January 2019) for conceptual design, this permitting feasibility study provides permits, associated costs and approval schedules. As project design is fine-tuned, so will be the list of required permits, costs and timelines.

Moakley Park is located in South Boston and overlooks Boston Harbor and is bordered to the east and south by Day Boulevard and to the north and west by Columbia Road. The Vision Plan for the park has contains the following goals:

- Provide climate resiliency thereby protecting the community from future flood impacts
- Rehabilitate the recreational facilities at the park
- Provide improved access to the park

The park currently contains numerous sporting areas including softball and baseball fields, running track, sports court complex, soccer and multi-use fields and a beachfront plaza. The layout of these facilities can be more efficiently arranged which would allow for additional opportunities at the park, including a sledding hill, waterpark, field houses, waterfront café, playground area and BBQ area.

The park is considered a water pathway for flooding events in neighboring communities. The park currently has insufficient stormwater infrastructure and the fields frequently flood. Flooding will only increase in the future based on climate change projections. The Moakley Park vision plan notes that the park will be vulnerable to coastal flooding by 2030 and, in fact, has already experienced coastal flooding episodes. With an increase of 3-feet in sea level, Moakley Park and neighboring Fort Point Channel will become a flood pathway for the south end of Boston and Roxbury during the 100-year storm events.

The Vision Plan proposed many park renovations to improve stormwater management, maximize park enjoyment and improve park accessibility. These renovations include, but are not limited to:

- Re-organization and construction of fields
- Construction of 2,600-foot earthen levee/vegetated berm barrier
- Installation of large underground chambers to retain stormwater
- Create stormwater wetland systems
- Creation of sledding and viewing hill
- Creation of waterfront promenade
- Creation of event plaza
- Creation of adventure play forest
- Creation of restaurant and shelters
- Creation of offshore barrier
- Beach improvement

Before park renovations can begin, various permits will need to be submitted to, and approved by, various local, state and federal permitting agencies. For the purpose of this report, permit requirements, timelines and costs will be grouped into five different stand-alone components; permits required for work at the park, for the berm construction, for promenade construction, for beach improvements and for ocean barrier installation. Figure 1 shows the location of these five components.

Figure 1. Component areas.

The park improvements component would include re-organization and construction of fields, creation of sledding and viewing hill, creation of event plaza, creation of adventure play forest, and creation of restaurant and shelters. Moving in an easterly/seaward direction, the berm would include the construction of a 6-8-foot high, 2,600-foot length earthen levee/vegetated berm barrier. The promenade system would involve the creation of waterfront promenade on what is currently the William J. Day Boulevard. Further east would be the beach improvement project which would include beach nourishment. Finally, furthest east and in the ocean would be the ocean barrier.

It should be noted that Boston Parks and Recreation Department (BPRD) owns the land for the park improvement area and berm area components, but does not own the area associated with the promenade, beach nourishment and ocean barrier components. Land ownership also plays a role in permitting. If BPRD wants to permit all five components of the project, the permitting process will be much easier on land it owns compared to permitting a project on land that it does not own.

Permitting cost savings may be realized should multiple components be undertaken simultaneously or in conjunction with each other.

Environmental permitting requirements are provided in Section 2, while summary and conclusions are provided in Section 3.

A description of the typical permits that might be required for these components can be seen in Appendix A, while Appendix B provides a permit approval schedule for the project and Appendix C provides a permitting cost summary table.

Overall permitting considerations are compiled in matrix form in Appendix D. This Permitting Matrix includes permit type and jurisdiction (federal, local, or state), timeline, cost, and ownership for each component.

ENVIRONMENTAL PERMITTING REQUIREMENTS

To determine which permits will be required for the Moakley Park project, protected resource areas must first be identified. Once identified, area impacts must then be estimated to then determine which permits would be required as many of these permits are triggered by impact areas. Resource areas are identified, below, followed by estimates of impact based on the conceptual design provided in the Vision Plan.

1.1 Environmental Impact Areas

A preliminary desktop survey of environmental resource areas at the proposed limit of work for Moakley Park project was conducted in ArcView using MassGIS data layers. The environmental resources map contained the following information resources:

- Aerial photography
- Perennial rivers and intermittent streams (USGS 1:25,000 Topographic Quadrangle)
- Ponds, lakes, oceans, reservoirs (USGS 1:25,000 Topographic Quadrangle)
- MassDEP mapped wetlands (Stereo color infrared photography at 1:12,000 scale)
- 100-year flood zone (FEMA, 2017)
- Natural Heritage and Endangers Species Program (NHESP) Estimated and Priority habitats (NHESP, 2017)
- NHESP certified vernal pools (NHESP, 2017)
- Areas of Environmental Concern (ACECs) (EEA, 2009)
- Chapter 91 jurisdictional areas (MassDEP c. 91 Tidelands Jurisdiction, 2014)

Figure 2, below, provides an ArcGIS map showing environmental resources and limit of work. The westerly-most environmental resource area is Land Subject to Coastal Storm Flowage (LSCSF), also known in general terms as the coastal flood zone. Jurisdictional filled tidelands (defined as filled tidelands seaward of the first public right of way, including right of way), includes William J. Day Boulevard (the first right of way) and land seaward of the boulevard. Further east is coastal beach, which is also the location of mapped NHESP habitat area. Furthest east is the ocean and land under ocean.

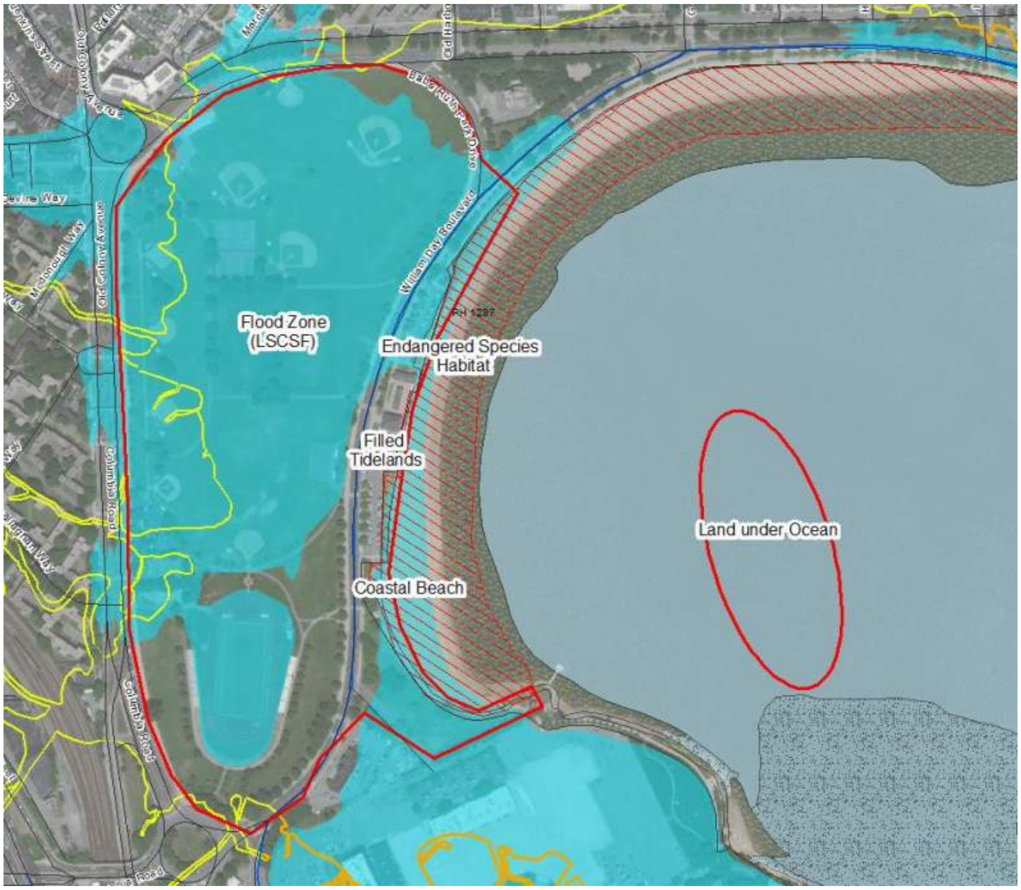

Figure 2. MassGIS environmental resources mapping with limits of work.

Environmental resources that will be impacted as part of the park improvements work include the following (all calculations are estimates based on current conceptual designs):

- Land Subject to Coastal Storm Flowage (60 acres)

The berm construction work will impact the following:

- Land Subject to Coastal Storm Flowage (0.6 acres)

Additional environmental impacts associated with the proposed barrier system include:

- Land under Ocean (> 10 acres). While there is only a conceptual design, a conservative estimate of barrier area size of 10 acres was used to trigger the most permits. When design plans are developed, a better estimate of required permits, costs and review times will be had.

Other areas will be impacted, however without design plans, these areas cannot be calculated. The resource areas will, however, be included as part of this report. These resources include:

- Coastal beach
- Natural Heritage and Endangered Species Program (NHESP) habitat for any work on the beach
- Jurisdictional filled tidelands for any work east of William Day Boulevard
- Navigable waters of the United States

1.2 Local Permitting Strategy

It should be noted that the local permitting strategy information came from the November 2019 Nitsch Engineering local permitting report for the Moakley Park project. The Nitsch report was submitted to Weston & Sampson to be incorporated into this larger, overall permitting strategy report.

1.2.1 Potential Local Permits

See Appendix A for a more in-depth discussion of each permit and how they are applicable to the project. An overview of local permits for each component is provided, below.

Park Improvements, Berm Construction, and Promenade System

The **park improvements** component includes work to the west of William J. Day Boulevard on Boston Parks and Recreation Department (BPRD) land. Currently, an estimated 60 acres of land under coastal storm flowage will be impacted due to this work.

Figure 3, below, shows conceptual ideas of that may be incorporated as part of the park improvement component.

Figure 3. Park Improvements

Parts of the park improvement component include, but are not limited to, re-organization and construction of fields, creation of sledding and viewing hill, creation of event plaza, creation of adventure play forest, and creation of restaurant and shelters.

Similar to the park improvement project mentioned above, work to construct a **berm** would be located west of William J. Day Boulevard and located on Boston Parks and Recreation department (BPRD) land. The berm would act to stop flood waters from entering the park, thus eliminating an estimated 60 acres of LSCSF landward of the berm.

Figure 4, below, shows the general location of the berm.

Figure 4: Wave attenuation (barrier) and berm.

From a conceptual design, the berm would be constructed 6- to 8-foot high with a length of 2,600-feet. The berm at this point in time is considered to be an earthen levee/vegetated berm.

The creation of a waterfront promenade would occur on what is currently the William J. Day Boulevard. Impacted resource areas for this work will include LSCSF and filled tidelands.

Figure 5, below, give a visual representation of what the promenade may look like.

Figure 5. Promenade.

These three components would each require the following local permits:

A Boston Water and Sewer Commission Site Plan Approval will be required for modifications or connections to the Boston Water and Sewer Commission sewer, water, or drainage systems; and for change in surface cover on the site.

A Boston Conservation Commission Notice of Intent (NOI) will be required for proposed removal, fill, dredge and/or alteration of a resource. The Massachusetts Wetlands Protection Act (MGL c.131 § 40) (WPA) and implementing regulations (310 CMR 10.00) is a State statute administered locally by the Boston Conservation Commission. The WPA requires the preparation of a NOI for work within a wetland resource area, work within 100 feet of certain resource areas and/or within the 100-year flood plain. The general performance standards for work or activities occurring within each wetland resource are identified in the WPA.

A Boston Public Improvement Commission Specific Repairs approval may be required if there are proposed modifications within City of Boston Public Right-of-Ways, including surface improvements.

A Boston Transportation Department Construction Management Plan approval, Transportation Access Plan Agreement and/or design approval may be required if there is roadway and/or intersection modifications to City of Boston Right-of-Ways.

A Boston Public Works Department Site Plan and/or roadway modifications review will be required if there is site work completed in the City of Boston. BPDA approval under small or large project review (depending on size of the building) would be required. If the BPDA deems it necessary, they may even want to call this a Planned Development Area which would undergo a separate review process.

Boston Parks Department Street Tree Removal and/or Approval will be required for site work within 100-feet of a City, State, or Federal park or parkway and/or the removal of street trees.

Boston Planning and Development Agency Development Review will be required if there is development of sites which require modifications to the zoning code.

An MWRA 8(m) permit will be required for work within an MWRA easement or other property interests held by the Authority.

Beach Improvement

Sand augmentation to the existing DCR owned beach would occur as part of this effort. Coastal beach and endangered species habitat would be impacted as a result of this work. Assuming more than 10 acres of coastal beach is impacted, local permits associated with the beach improvement would likely include the following:

A Boston Conservation Commission Notice of Intent (NOI) will be required for proposed removal, fill, dredge and/or alteration of a resource. The Massachusetts Wetlands Protection Act (MGL c.131 § 40) (WPA) and implementing regulations (310 CMR 10.00) is a State statute administered locally by the Boston Conservation Commission. The WPA requires the preparation of a NOI for work within coastal wetland resource area, including coastal beach.

Boston Parks Department approval will be required for site work within 100-feet of a City, State, or Federal park or parkway and/or the removal of street trees.

Boston Planning and Development Agency Development Review will be required if there is development of sites which require modifications to the zoning code.

An MWRA 8(m) permit will be required for work within an MWRA easement or other property interests held by the Authority.

Ocean Barrier System

To attenuate ocean wave action, the creation of an offshore ocean barrier is proposed as part of the Vision Plan. Figure 6, below, shows a conceptual image of how the barrier may look in the ocean.

Figure 6. Ocean Barrier System.

While the design of this barrier structure is not yet known, it is assumed that it will be larger than 10 acres.

The ocean barrier system work would require the following local permits:

A Boston Conservation Commission Notice of Intent (NOI) will be required for proposed removal, fill, dredge and/or alteration of a resource. The Massachusetts Wetlands Protection Act (MGL c.131 § 40) (WPA) and implementing regulations (310 CMR 10.00) is a State statute administered locally by the Boston Conservation Commission. The WPA requires the preparation of a NOI for work within a wetland resource area, including land under ocean.

Boston Parks Department approval will be required for site work within 100-feet of a City, State, or Federal park or parkway.

1.2.2 Local Permit Costs

Local permitting costs are provided, below, for each component as stand-alone projects. Permitting cost savings may be realized should multiple components be undertaken simultaneously or in conjunction with each other. Permits noted "if required" are subject to the reviewing authority's discretion, given the separation of the work into stand-alone projects. Costs provided below for local permitting include the following:

- Preparation of application form(s) and address all relevant elements
- Preparation of Project Narrative providing history and justification of project
- Identification of resources and methods for mitigation and restoration as well as minimization of impacts
- Incorporation of plans illustrating project limits and resource areas
- Provide public advertising as required
- Attend and assist in presentation of project at public site meetings
- Continued communication with reviewing agencies throughout the permit review period
- Incorporation of agency and client comments from site meeting

Permitting costs do not include the following:

- Engineering design
- Plan set development
- No project segmentation within component
- Studies or monitoring efforts as may be required by the MEPA, NEPA, MESA, or any other review agency as part of their permit review.

Permit costs can vary depending on resource area impacts, project complexity, and reviewer comments.

Table 1. Local City of Boston Permit Costs for Park Improvements

Permit	Minimum Cost	Maximum Cost
Boston Water and Sewer Commission	$15,000	$30,000
Boston Conservation Commission	$20,000	$40,000
Boston Public Improvement Commission	$15,000	$30,000
Boston Transportation Department	$15,000	$50,000
Boston Public Works Department	$20,000	$40,000
Boston Parks Department (if required)	$10,000	$50,000
Boston Planning and Development Agency (if required)	$15,000	$50,000
MWRA 8(m)	$5,000	$10,000
TOTAL	**$115,000**	**$300,000**

Potential local City of Boston permit costs associated with the berm construction work include:

Table 2. Local City of Boston Permit Costs for Berm Construction Work

Permit	Minimum Cost	Maximum Cost
Boston Water and Sewer Commission	$15,000	$30,000
Boston Conservation Commission	$20,000	$40,000
Boston Public Improvement Commission	$15,000	$30,000
Boston Transportation Department	$15,000	$50,000
Boston Public Works Department	$20,000	$40,000
Boston Parks Department (if required)	$10,000	$50,000
Boston Planning and Development Agency (if required)	$15,000	$50,000
MWRA 8(m)	$5,000	$10,000
TOTAL	**$115,000**	**$300,000**

Potential local City of Boston permit costs associated with the promenade system include:

Table 3. Local City of Boston Permit Costs for Promenade System Work

Permit	Minimum Cost	Maximum Cost
Boston Water and Sewer Commission	$15,000	$30,000
Boston Conservation Commission	$20,000	$40,000
Boston Public Improvement Commission	$15,000	$30,000
Boston Transportation Department	$15,000	$50,000
Boston Public Works Department	$20,000	$40,000
Boston Parks Department (if required)	$10,000	$50,000
Boston Planning and Development Agency (if required)	$15,000	$50,000
MWRA 8(m)	$5,000	$10,000
TOTAL	**$115,000**	**$300,000**

Potential local City of Boston permit costs associated with the beach improvement work include:

Table 4. Local City of Boston Permit Costs for Beach Improvement Work

Permit	Minimum Cost	Maximum Cost
Boston Conservation Commission	$20,000	$40,000
Boston Parks Department (if required)	$10,000	$50,000
Boston Planning and Development Agency (if required)	$15,000	$50,000
TOTAL	**$45,000**	**$140,000**

Potential local City of Boston permit costs associated with the ocean barrier system include:

Table 5. Local City of Boston Permit Costs for Ocean Barrier System Work

Permit	Minimum Cost	Maximum Cost
Boston Conservation Commission	$20,000	$40,000
Boston Parks Department (if required)	$10,000	$50,000
TOTAL	**$30,000**	**$90,000**

1.2.3 Local Permit Approval Schedule

To efficiently gain local permit approvals, it is recommended that the project proponent meet with the reviewing agencies before finalizing design or submitting permits. It is helpful to understand what the reviewer's questions or concerns will be and incorporate their comments when applicable into the permit submission. Once reviewers' comments are incorporated into the design plans, it is recommended that the Boston Planning and Development agency plan be submitted first for the park improvements project. Of the local permits, this permit has the longest approval time, up to 175 days. It is helpful to get initial comments first and incorporate these comments into the remaining permit submissions to minimize the amount of back and forth with all reviewers involved.

For the **park improvements, berm and promenade** components, upon Boston Planning and Development Agency submission and receipt of any initial comments, the remaining local permits can be submitted simultaneously to the reviewing agencies. These submissions include:

- Boston Water and Sewer application
- Boston Conservation Commission Notice of Intent
- Boston Public Improvement Commission submission
- Boston Transportation Department application
- Boston Public Works Department application
- Boston Parks Department – tree hearing application and/or approval
- MWRA 8(m)

In all, total permitting time to gain local approvals is upwards of 9 months for the park improvements, berm and promenade components.

For the **beach nourishment** component, once the Boston Planning and Development Agency submission and receipt of any initial comments, the remaining local permits would include:

- Boston Conservation Commission Notice of Intent
- Boston Parks Department approval
- MWRA 8(m)

In all, total permitting time to gain local approvals is upwards of 6 months for the beach nourishment component.

Finally, upwards of 2 months would be required for local permit approval for the **ocean barrier system** component since the local permits would include:

- Boston Conservation Commission Notice of Intent
- Boston Parks Department approval

See Appendix B for a visual representation of local, state and federal permitting timelines.

1.3 State Permitting Strategy

1.3.1 Potential State Permits

Please see Appendix A for a more in-depth discussion of each permit and how they are applicable to the project. An overview of state permits for each component is provided, below.

Park Improvements:
Park improvements includes work to the west of William J. Day Boulevard on Boston Parks and Recreation Department (BPRD) land. Currently, an estimated 60 acres of land under coastal storm flowage will be impacted due to this work. This level of impact, combined with the project receiving state funding (Municipal Vulnerability Preparedness (MVP) funding), would result in a need to submit an Environmental Notification Form (ENF) followed by an Environmental Impact Report (EIR) to the Massachusetts Environmental Protection Act (MEPA) office. The more complex EIR is triggered because of more than 50 acres of land being disturbed as well as impacting more than 10 acres of other wetlands being impacted (LSCSF). Construction and access in this area will require a MassDOT State Highway Construction and Access permit.

Berm Construction:
Similar to the park improvement project mentioned above, work to construct a berm would be located west of William J. Day Boulevard and located on Boston Parks and Recreation department (BPRD) land. The berm would act to stop flood waters from entering the park, thus eliminating an estimated 60 acres of LSCSF landward of the berm. As is the case with the park improvements project, this will trigger an ENF and EIR under the State MEPA process because of more than 10 acres of other wetlands may be impacted (LSCSF). Construction and access in this area will require a MassDOT State Highway Construction and Access permit.

Promenade System:
The creation of a waterfront promenade would occur on what is currently the William J. Day Boulevard. Impacted resource areas for this work will include LSCSF and filled tidelands.

Because work would be in the first right of way landward of ocean (William J. Day Boulevard), a non-water dependent Chapter 91 license will be required.

William J. Day Boulevard is considered a Massachusetts Department of Conservation and Recreation (DCR) property. As such, this work will require a DCR Construction and Associated Access to DCR Park Lands and Roadways.

While this work will not directly impact Columbia Road, there will likely be indirect impacts. By closing this section of William J. Day Boulevard, traffic demands will likely be increased at Columbia Road, which is considered a state highway. As such, the Massachusetts Department of Transportation (MassDOT) should be notified of the work to see if they would have any concerns over possible impacts to Columbia Road.

Beach Improvement:
Sand augmentation to the existing DCR owned beach would occur. Coastal beach and endangered species habitat would be impacted as a result of this work. Assuming more than 10 acres of coastal beach is impacted, state permits associated with the beach improvement would likely include the following:

- MassDEP Chapter 91 permit
- MEPA EIR or expanded ENF (with copies being sent to Division of Marine Fisheries, Massachusetts Historical Commission and Massachusetts Board of Underwater Archaeological Resources and other reviewers for comments).
- MassDEP 401 Water Quality Certification
- Massachusetts Endangered Species Act (MESA) Project Review
- DCR Construction and Associated Access to DCR Park Lands and Roadways

Construction and access in this area will require a MassDOT State Highway Construction and Access permit.

Ocean Barrier System:
To attenuate ocean wave action, the creation of an offshore barrier is proposed as part of the Vision Plan. While the design of this barrier structure is not yet known, it is assumed that it will be larger than 10 acres. Anticipated required state permits include:

- MassDEP Chapter 91 license (for structure)
- MEPA EIR or expanded ENF (with copies being sent to Division of Marine Fisheries, Massachusetts Historical Commission and Massachusetts Board of Underwater Archaeological Resources and other reviewers for comments).
- MassDEP 401 Water Quality Certification
- DCR Construction and Associated Access to DCR Park Lands and Roadways

Construction and access in this area will require a MassDOT State Highway Construction and Access permit depending on staging area and access locations.

1.3.2 State Permit Costs

State permitting costs are provided, below, for each component as stand-alone projects. Permitting cost savings may be realized should multiple components be undertaken simultaneously or in conjunction with each other. Costs provided below include the following:

- Preparation of application form(s) and address all relevant elements
- Preparation of Project Narrative providing history and justification of project
- Identification of resources and methods for mitigation and restoration as well as minimization of impacts
- Incorporation of plans illustrating project limits and resource areas
- Provide public advertising as required
- Attend and assist in presentation of project at public site meetings
- Continued communication with reviewing agencies throughout the permit review period
- Incorporation of agency and client comments from site meeting

Permitting costs do not include the following:

- Engineering design
- Plan set development
- No project segmentation within component
- Studies or monitoring efforts as may be required by the MEPA, NEPA, MESA, or any other review agency as part of their permit review.

Permit costs can vary depending on resource area impacts, project complexity, and reviewer comments. The typical range of costs per likely required permit for the **park improvements** project is provided in Table 6, below.

Table 6. State Permit Costs for Park Improvements

Permit	Minimum Cost	Maximum Cost
MEPA ENF/EIR	$50,000	$75,000
MassDOT State Highway Access	$5,000	$10,000
TOTAL	$55,000	$85,000

It is assumed that one MassDOT access permit will be required for the entire project and would be carried through multiple years if needed.

Berm construction work would trigger the following State permits:

Table 7. State Permit Costs for Berm Construction Work

Permit	Minimum Cost	Maximum Cost
MEPA ENF/EIR	$50,000	$75,000
MassDOT State Highway Access	$5,000	$10,000
TOTAL	$55,000	$85,000

It is assumed that one MassDOT access permit will be required for the entire project and would be carried through multiple years if needed.

All state permit costs associated with the **promenade** system include:

Table 8. State Permit Costs for Promenade System Work

Permit	Minimum Cost	Maximum Cost
MassDEP Ch 91 license	$10,000	$15,000
DCR Construction and Access permit	$10,000	$15,000
MassDOT State Highway Access	$5,000	$10,000
TOTAL	$25,000	$40,000

Impact area for the promenade work would occur only within existing, altered Boulevard. Not impacts outside the Boulevard would occur. It is assumed that one MassDOT access permit will be required for the entire project and would be carried through multiple years if needed.

All state permit costs associated with the **beach improvement** work include:

Table 9. State Permit Costs for Beach Improvement Work

Permit	Minimum Cost	Maximum Cost
MEPA ENF/EIR	$50,000	$75,000
MassDEP Ch 91 permit	$20,000	$25,000
MassDEP 401 WQC	$20,000	$25,000
MESA Project Review	$20,000	$30,000
DCR Construction and Access permit	$10,000	$15,000
MassDOT State Highway Access	$5,000	$10,000
TOTAL	$125,000	$180,000

It is assumed that part of the impact area will be within the ocean, or seaward of the mean low water line. One DCR construction and access permit and one MassDOT access permit will be required for the entire project and would include multiple locations and years if needed.

All state permit costs associated with the **ocean barrier** system include:

Table 10. State Permit Costs for Ocean Barrier System Work

Permit	Minimum Cost	Maximum Cost
MEPA ENF/EIR	$150,000	$175,000
MassDEP Ch 91 license	$30,000	$40,000
MassDEP 401 WQC	$30,000	$40,000
MESA Project Review	$20,000	$30,000
DCR Construction and Access permit	$10,000	$15,000
TOTAL	$240,000	$300,000

These costs assume that the ocean barrier will be at least 10 acres in size. One DCR construction and access permit will be required for the entire project and would include multiple locations and years if needed.

1.3.3 State Permit Approval Schedule

To efficiently gain permit approvals, it is recommended that the project proponent meet with the reviewing agencies before finalizing design or submitting permits. It is helpful to understand what the reviewer's questions or concerns will be and incorporate their comments when applicable into the permit submission. Once design plans are finalized, it is recommended that the MEPA ENF/EIR process be completed before submitting other permits since this review solicits input from many different state reviewing agencies whose comments will be compiled and used for final design plans for the park improvements project. It is helpful to get the MEPA comments first and incorporate these comments into the remaining permit submissions to minimize the amount of back and forth with reviewers. Once submitted, the review time for the ENF/EIR submission is approximately 18 months for a project of this magnitude.

For the park improvements, berm and promenade component, upon MEPA approval, the remaining state permits can be submitted simultaneously. In all, total permitting time to gain state approvals is upwards of 18 months for the park improvements, berm and promenade component.

For the beach nourishment and ocean barrier projects, a lengthier review period will be required depending on impacts and permits. Upon MEPA approval, the local Notice of Intent and MESA permits should be submitted to incorporate local comments and endangered species concerns. Review time for these permits can be up to 8 months. Upon NOI approval (receipt of the Order of Conditions), the remaining permits (401 WQC, Ch. 91, and DCR, and MassDOT) can be submitted simultaneously. The joint 401 WQC / Chapter 91 submission can take up to 8 months for review, depending on if MassDEP determines there are administrative or technical deficiencies with the submission and requests additional information. It should be noted that a Ch 91 license will be needed for the ocean barrier work (because of a structure being involved), and a Ch 91 permit will be required for the beach nourishment work (because no structure involved). The time required to obtain state permit approvals for the beach improvement and ocean barrier projects can be upwards of 43 months.

Please see Appendix B for a visual representation of local, state and federal permitting timelines.

1.4 Federal Permitting Strategy

1.4.1 Potential Federal Permits

Please see Appendix A for a more in-depth discussion of each permit and how they are applicable to the project. An overview of federal permits for each component is provided, below.

Park Improvements:

Currently, an estimated 60 acres of land under coastal storm flowage (LSCSF) will be impacted due to this work. This level of impact, combined with the project receiving federal funding, a National Environmental Protection Act (NEPA) environmental assessment (EA) will be required, and, based on the EA determination, a NEPA Environmental Impact Statement (EIS) will likely be required. The EA is triggered because of more than 50 acres of land being disturbed as well as impacting more than 10 acres of other wetlands being impacted (LSCSF).

Because more than one acre of land will be disturbed, a US Environmental Protection Agency (EPA) National Pollution Discharge Elimination System (NPDES) Construction General Permit will be required. As part of this submission, a stormwater pollution prevention plan (SWPPP) will need to be developed.

Berm Construction:

The berm would act to stop flood waters from entering the park, thus eliminating an estimated 60 acres of LSCSF landward of the berm. As is the case with the park improvements project, a NEPA environmental assessment (EA) will be required, and, based on the EA determination, a NEPA Environmental Impact Statement (EIS) will likely be required.

Assuming the berm will physically disturb more than one acre of land by removing topsoil, an EPA NPDES Construction General Permit will be required.

Upon project completion, a Federal Emergency Management Agency (FEMA) Letter of Map Revision (LOMR) will need to be submitted after project completion for to update FEMA flood insurance rate maps (FIRM). The construction of the berm effort does not need to gain FEMA approval before work begins. However, upon project completion, documentation will need to be submitted to FEMA so that they can update their flood insurance maps. For example, at this point in time, the park is mapped within the FEMA flood zone. However, after a berm is constructed, flood waters would no longer enter the park, so the FEMA flood maps will need to be updated to show that the park is no longer in the FEMA flood zone.

Promenade System:

This work includes creation of waterfront promenade on what is currently the William J. Day Boulevard. Impacted resource areas for this work will include LSCSF and filled tidelands.

Assuming more than 1 area will be disturbed as a result of the creation of the promenade system, an EPA NPDES Construction General Permit will be required.

Beach Improvement:
This work will include adding sand to the DCR owned beach. Coastal beach and endangered species habitat would be impacted as a result of this work. Assuming more than 10 acres of coastal beach is impacted, state permits associated with the beach improvement would likely include the following:

- NEPA EA and possible EIS
- ACOE Individual Permit
- Coastal Zone Management Federal Consistency Review

Ocean Barrier System:
This work will include the creation of an offshore ocean barrier to attenuate wave action. While the design of this barrier structure is not yet known, it is assumed that it will be larger than 10 acres. Anticipated required federal permits include:

- NEPA EA and likely EIS
- ACOE Individual Permit
- Coastal Zone Management Federal Consistency Review
- US Coast Guard Private Aids to Navigation Application

1.4.2 Federal Permit Costs

Federal permitting costs are provided, below, for each component as stand-alone projects. Permitting cost savings may be realized should multiple components be undertaken simultaneously or in conjunction with each other. Similar to the State permitting costs, costs provided below for federal permitting include the following:

- Preparation of application form(s) and address all relevant elements
- Preparation of Project Narrative providing history and justification of project
- Identification of resources and methods for mitigation and restoration as well as minimization of impacts
- Incorporation of plans illustrating project limits and resource areas
- Provide public advertising as required
- Attend and assist in presentation of project at public site meetings
- Continued communication with reviewing agencies throughout the permit review period
- Incorporation of agency and client comments from site meeting

Permitting costs do not include the following:

- Engineering design
- Plan set development
- No project segmentation within component
- Studies or monitoring efforts as may be required by the MEPA, NEPA, MESA, or any other review agency as part of their permit review.

Permit costs can vary depending on resource area impacts, project complexity, and reviewer comments. The typical range of costs per likely required federal permit for the park improvements project is provided in Table 11, below.

Table 11. Federal Permit Costs for Park Improvements

Permit	Minimum Cost	Maximum Cost
NEPA EA/EIS	$50,000	$75,000
NPDES CGP	$20,000	$25,000
TOTAL	$70,000	$100,000

Costs for the National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP) includes cost to develop a Stormwater Pollution Prevention Plan (SWPPP).

All federal permit costs associated with the **berm** construction work are provided in Table 12 and include:

Table 12. Federal Permit Costs for Berm Construction Work

Permit	Minimum Cost	Maximum Cost
NEPA EA/EIS	$50,000	$75,000
NPDES CGP	$20,000	$25,000
TOTAL	$70,000	$100,000

Costs for the National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP) includes cost to develop a Stormwater Pollution Prevention Plan (SWPPP).

Promenade system work would require the following federal permits:

Table 13. Federal Permit Costs for Promenade System Work

Permit	Minimum Cost	Maximum Cost
NPDES CGP	$20,000	$25,000
TOTAL	$20,000	$25,000

It is assumed that the impact areas would not trigger a NEPA EA or EIS.

All federal permit costs associated with the **beach improvement** work include:

Table 14. Federal Permit Costs for Beach Improvement Work

Permit	Minimum Cost	Maximum Cost
NEPA EA/EIS	$150,000	$175,000
ACOE Individual Permit	$40,000	$50,000
CZM Federal Consistency Review	$25,000	$30,000
TOTAL	$215,000	$255,000

It is assumed that part of the impact area will be within the ocean, or seaward of the mean low water line.

All federal permit costs associated with the ocean **barrier system** include:

Table 15. Federal Permit Costs for Ocean Barrier System Work

Permit	Minimum Cost	Maximum Cost
NEPA EA/EIS	$150,000	$175,000
ACOE Individual Permit	$40,000	$50,000
CZM Federal Consistency Review	$25,000	$30,000
USCG Private Aids to Navigation	$10,000	$15,000
TOTAL	$225,000	$270,000

These costs assume that the ocean barrier will be at least 10 acres in size.

1.4.3 Federal Permit Approval Schedule

To efficiently gain permit approvals, it is recommended that the project proponent meet with the reviewing agencies before finalizing design or submitting permits. It is helpful to understand what the reviewer's questions or concerns will be and incorporate their comments when applicable into the permit submission. After incorporating reviewer comments into design plans, it is recommended that the NEPA EA/EIS submissions be submitted first for the park improvements project. The process requires consideration of environmental impacts that include, among others, impacts on social, cultural, and economic resources, as well as natural resources. Opportunities for public review and comment are also provided. It is helpful to get these comments first and incorporate these comments into the remaining permit submissions to minimize the amount of back and forth with reviewers. Once submitted, the NEPA review time can be up to 18 months for such a complex project. After incorporating the NEPA comments into the remaining permits, the USGS and NPDES CGP can be submitted which have a 3-month and 0 month review time, respectively.

For the park improvements, berm and promenade component, upon NEPA approval, the remaining federal permits can be submitted simultaneously. In all, total permitting time to gain federal approvals is upwards of 18 months for the park improvements, berm and promenade component.

For the beach nourishment and ocean barrier projects, a lengthier review period will be required depending on impacts and permits. Before the CZM federal consistency review can be submitted, the state 401 WQC and Ch 91 approvals need to be in hand (approximately 34 months after MEPA/NEPA submission). CZM approval is normally obtained within three months of submittal.

The ACOE Individual permit should be submitted after CZM approval (37 months after MEPA/NEPA submission), with a review time of six months.

The NPDES CGP does not have a time review period since it only needs to be submitted electronically to EPA as formal notification. No approval is provided by the Environmental Protection Agency (EPA).

The federal review times for both the beach improvement and ocean barrier project would require a total of up to 43 months to gain approval of all federal permits because of the additional need to obtain CZM and ACOE approval.

Please see Appendix B for a visual representation of local, state and federal permitting timelines for all five project components.

SUMMARY

To determine local, state and federal permitting requirements for the Moakley Park project, potentially impacted environmental resources for the entire site were estimated using MassGIS data layers to map these resources. The overall project was then split up into five components, including:

- Park improvements
- Berm construction
- Promenade construction
- Beach improvements
- Ocean barrier system

Likely required local, state and federal permits were then identified for each of the components. Associated permit costs and review periods were then identified for each component to determine different costs and review periods for each component. A description of the typical permits that might be required for these components can be seen in Appendix A, while Appendix B provides a permit approval schedule for the project and Appendix C provides a permitting cost summary table. Table 16, below, provided overall permitting costs and review durations for each of the five components of the Moakley Park project.

Table 16. Overall Permit Costs and Review Duration

Component	Cost	Review Duration (months)
Park improvement	\$205,000 - \$432,500	18
Berm construction	\$205,000 - \$432,500	18
Promenade system construction	\$160,000 – \$365,000	9
Beach improvement	\$255,000 - \$432,500	43
Ocean barrier system	\$390,000 - \$537,000	43

A permitting matrix has been developed (see Appendix D) to rank the following permitting categories for each component:

- Required permits
- Permit approval schedule
- Costs
- Land ownership (is land owned by BPRD or not)

A value between 1 and 5 was assigned for each category for each component, with the value of “1” representing the least favorable and a value of “5” being considered the most favorable. The matrix indicates that the park improvements and berm components rank the most favorable components to permit while the beach improvement and ocean barrier system rank the least favorable for BPRD to permit.

CONCLUSION

The following protected environmental resources are present at the overall potential project limits of the overall Moakley Park project:

- Land Subject to Coastal Storm Flowage
- Land Under Ocean
- Coastal Bank
- NHESP Habitat
- Filled Tidelands
- Navigable Waters of the United States

The components considered less costly and with shorter local, state and federal permit approval timelines included **park improvements, berm construction and promenade system construction**. Permitting costs for these can range between $160,000 and $432,500 and require up to 18 months to gain permit approval. Additionally, the park improvements and berm component areas are owned by BPRD, thus making these components easier for BPRD to permit than the other three components. The more environmentally complex **beach improvement and ocean barrier system** permitting costs can range from $255,000 to $537,000 with state and federal review times up to 43 months.

These permitting costs are provided for each component as stand-alone project. Permitting cost savings may be realized should multiple components be undertaken simultaneously or in conjunction with each other.

The reviewing timelines provided are considered the longest duration for review times that may occur per local, state and federal regulations. It is possible that the components could obtain permit approvals sooner than the provided time frames.

If the City wanted to start the Moakley Park improvements process, but does not have the finances to undertake all five park component efforts at this point in time, the City may want to consider permitting just the park improvements, berm construction and promenade system construction components first. These components could be permitted all together which would reduce permitting costs and permit approval timelines rather than permitting and constructing each component one at a time. While these three components of the park project are being permitted and constructed, time can also be spent obtaining funding and additional information for the more complex beach improvement and ocean barrier system components. Once the park improvements, berm construction and promenade system construction efforts are completed, the City may then be ready to undertake the more expensive and longer duration beach improvement and ocean barrier system components of the project.

APPENDIX A

Permit Descriptions

LOCAL PERMITS

Boston Water and Sewer Commission: Site Plan Approval is required for any proposed changes to surface cover on a site, or modifications or connections to Boston Water and Sewer Commission water, sewer, or drainage infrastructure or work within an easement.

Boston Conservation Commission: A Notice of Intent (NOI) is required for proposed removal, fill, dredge and/or alteration of a resource. The Massachusetts Wetlands Protection Act (MGL c.131 § 40) (WPA) and implementing regulations (310 CMR 10.00) is a State statute administered locally by the Boston Conservation Commission. The WPA requires the preparation of a NOI for work within a wetland resource area, work within 100 feet of certain resource areas and/or within the 100-year flood plain. The general performance standards for work or activities occurring within each wetland resource are identified in the WPA.

Boston Public Improvement Commission: Specific Repairs approval required for any proposed modifications within City of Boston Public Right-of-Ways, including surface improvements.

Boston Transportation Department: Construction Management Plan, Transportation Access Plan Agreement, and/or Design Review approval, and design approval is required for roadway and/or intersection modifications to City of Boston Right-of-Ways.

Boston Public Works Department: Site Plan and/or roadway modifications review required for site work completed in the City of Boston.

Boston Parks Department: Street Tree Removal and/or Parks Review approval is required for site work within 100-feet of a City, State, or Federal park or parkway and/or the removal of Boston street trees.

Boston Planning and Development Agency: Development Review is required for development of sites which require modifications to the zoning code.

The MWRA 8(m) permit allows the MWRA to approve work to other entities to build, construct, excavate, or cross within an easement or other property interest held by the Authority under Section 8(m) of chapter 372 of the Acts of 1984.

STATE PERMITS

Massachusetts Environmental Policy Act (MEPA, 301 CMR 11.0)

The purpose of MEPA and 301 CMR 11.00 is to provide meaningful opportunities for public review of the potential environmental impacts of a project for which a Permit is required from an agency of the Commonwealth, and to assist agencies of the Commonwealth in using all feasible means to avoid damage to the environment or, to the extent damage to the environment cannot be avoided, to minimize and mitigate damage to the environment to the maximum extent practicable. MEPAs review is intended to inform the participating agencies of the project, to maximize consistency between agency actions, and to facilitate coordination of all environmental and development review and permitting processes of the Commonwealth. The MEPA process provides an opportunity for the project proponent to identify required agency actions and to describe and analyze how the project will comply with applicable regulatory standards and requirements. Through review of the MEPA documents, each participating agency can comment on aspects of the Project or issues regarding its agency action that require additional description or analysis.

MEPA review is required when one or more review thresholds are met or exceeded and the subject matter of at least one review threshold is within MEPA jurisdiction. Both of the Moakley Park project components (i.e., beach nourishment, offshore wave attenuation) are likely to trigger MEPA Wetlands, Waterways and Tidelands thresholds (301 CMR 11.03(3)). Although the project is still in the early planning phase, it is likely that the beach nourishment and offshore wave attenuation project components will trigger 301 CMR 11.03(a)1.b. which requires an Environmental Notification Form (ENF) and Mandatory Environmental Impact Report (EIR). This threshold applies to projects that require a Permit from an agency of the Commonwealth and also propose to alter ten or more acres of a wetland.

Upon filing an ENF for the project, the Secretary of Energy and Environmental Affairs will issue a Certificate outlining the scope and content of the EIR. Following review of the Draft and Final EIRs, the Secretary's Certificate that indicates the documents are adequate or that there has been other due compliance with MEPA and 301 CMR means that the proponent has adequately described and analyzed the project and its alternatives, and assessed its potential environmental impacts and mitigation measures. Upon completion of the MEPA process, each participating agency retains authority to fulfill its statutory and regulatory obligations in permitting or reviewing the project.

Massachusetts Endangered Species Act (MESA) (321 CMR 10.00)

Because the beach nourishment portion of the Moakley Park project is located within Priority Habitat mapped by the Massachusetts Natural Heritage and Endangered Species Program (NHESP), the project will be required to be reviewed under the Massachusetts Endangered Species Act (MESA) (321 CMR 10.00). The MESA review assists proponents with projects or activities that will take place in mapped Priority Habitat in order to avoid a take of a state-listed species. This review occurs at the same time as the NOI review by the Boston Conservation Commission.

Massachusetts 401 Water Quality Certification (314 CMR 9.00)

Projects in Massachusetts involving the discharge of dredged or fill material, dredging, or dredged material disposal activities in waters of the United States, which require federal licenses or permits are subject to 314 CMR 9.00. 314 CMR 9.07 also applies to any dredging project and the management of dredged material within the marine boundaries and at upland locations within the Commonwealth.

The purpose of the 401 Water Quality Certification is to ensure that proposed discharges of dredged or fill material, dredging and dredged material disposal in the waters of the United States within the Commonwealth comply with the Surface Water Quality Standards and other appropriate requirements of the state law.

Per 314 CMR 9.04(9), both the beach nourishment and offshore wave attenuation elements of the Moakley Park project will trigger the requirement for a 401 Water Quality Certification because they are subject to an individual Section 404 permit from the United State Army Corps of Engineers. If the projects involve dredged material reuse or disposal of 100 cubic yards or more, they would also trigger the need for a 401 Water Quality Certification per 314 CMR 9.04(12). Projects must meet the criteria listed in 314 CMR 9.06 and 9.07 to receive a Certification authorizing the work.

Massachusetts Waterways Regulation (310 CMR 9.00) (Ch. 91 Review)

310 CMR 9.00 was enacted for the following purposes: (1) to protect and promote the public's interest in tidelands, Great Ponds, and non-tidal rivers and streams in accordance with the public trust doctrine, (2) to preserve and protect the rights in tidelands of the inhabitants of the Commonwealth by ensuring that the tidelands are utilized only for water-dependent uses or otherwise serve a proper public purpose, (3) protect the public health, safety, and general welfare as it may be affected by any project in tidelands, Great Ponds, and non-tidal rivers and streams, (4) support public and private efforts to revitalize unproductive property along urban waterfronts in a manner that promotes public use and enjoyment of the water, and (5) foster the right of the people to clean air and water, freedom from excessive and unnecessary noise, and the natural, scenic, and historic, and esthetic qualities of their environment.

Per 310 CMR 9.05(2)(a) the beach nourishment portion of the Moakley Park project would be required to file an application for a Chapter 91 permit. The wave attenuation portion of the project would be required to file for a Chapter 91 license per 310 CMR 9.05(1)(a), as this work would involve the construction and/or placement of not previously authorized fill.

Massachusetts Historic Commission (MHC)

Because state actions (i.e. state permits and state funding) are involved with this project, an MHC permit will be required. An MHC submittal will address any historic locations in close proximity to the limit of work. This process will allow MHC to comment on the project and identify any historic properties currently unknown to exist the proponent..

FEDERAL PERMITS

National Environmental Policy Act (NEPA)

A project review under the NEPA process is triggered when a federal agency develops a proposal to take one or more federal actions. The actions include new and continuing activities, including projects and programs entirely or partly financed, assisted, conducted, regulated, or approved by a federal agency. The federal actions tend to fall within one of the following categories:

- Adoption of official policy, such as rules, regulations, and interpretations adopted pursuant to the Administrative Procedure Act, 5 U.S.C. 551 et seq.; treaties and international conventions or agreements; formal documents establishing an agency's policies which will result in or substantially alter agency programs.
- Adoption of formal plans, such as official documents prepared or approved by federal agencies which guide or prescribe alternative uses of federal resources, upon which future agency actions will be based.
- Adoption of programs, such as a group of concerted actions to implement a specific policy or plan; systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive.
- Approval of specific projects, such as construction or management activities located in a defined geographic area. Projects include actions approved by permit or other regulatory decision as well as federal and federally assisted activities.

Under the NEPA review process, potential impacts of the proposed project are evaluated and alternative actions to achieve the goals of the project are investigated. The process requires consideration of environmental impacts that include, among others, impacts on social, cultural, and economic resources, as well as natural resources. Opportunities for public review and comment are also provided.

For the Moakley Park project, NEPA review would be triggered if federal funding is used for project planning, engineering, permitting, or construction, or if any part of the project is located within the boundaries of the Boston Harbor Islands National Park. NEPA review can follow three basic pathways, or levels of analysis and documentation, depending on the complexity of the project; Categorical Exclusion (CE), Environmental Assessment (EA), or Environmental Impact Statement (EIS). It is possible the beach nourishment portion of the Moakley Park project would trigger the need for an EA, and likely that the offshore wave attenuation portion of the project would trigger the more detailed EIS filing. Following review of an EA or EIS, a Finding of No Significant Impact (FONSI) or Record of Decision (ROD) is issued when it is determined that the proponent has adequately described and analyzed the project and its alternatives, and assessed its potential environmental impacts and mitigation measures.

Massachusetts Coastal Zone Management Federal Consistency (15 CFR 930 Subparts A-I)

The federal consistency requirement of the CZMA (16 U.S.C. § 1456) holds that federal actions that have reasonably foreseeable effects on any land or water use or natural resources of a state coastal zone must be consistent with the enforceable policies of the federally approved coastal management program for that state. Within this authority of the CZMA, Massachusetts Coastal Zone Management (CZM) may review federal actions affecting their coastal uses and/or resources, regardless of whether the action occurs within or outside the state coastal zone boundary, to ensure that such activities are consistent with the state's enforceable program policies. The Massachusetts CZM reviews the coastal effects of proposed actions, including environmental effects (i.e., impacts on biological or physical resources found within the state coastal zone), as well as effects on human uses, such as fishing and boating, public access and recreation, scenic and aesthetic enjoyment, and resource creation or restoration.

The Moakley Park project will be subject to a federal consistency review by CZM because the project will be performed by a non-federal entity and will require an Individual Permit from the United States Army Corps of Engineers. An application demonstrating consistency of the project with CZM's coastal policies will be required in order to receive approval by CZM.

US Army Corps of Engineers General Permits for the Commonwealth of Massachusetts

The U.S. Army Corps of Engineers (Corps) regulates construction and other work in navigable waterways under Section 10 of the Rivers and Harbors Act of 1899, and has authority over the discharge of dredged or fill material into "waters of the United States" (a term which includes wetlands and all other aquatic areas) under Section 404 of the Clean Water Act. Under these laws, those who seek to carry out such work must first receive a permit from the Corps. The program considers the full public interest by balancing the favorable impacts against the detrimental impacts. This is known as the "public interest review." The program reflects the national concerns for both the protection and utilization of important resources.

In Massachusetts regional general permits can be issued for certain activities with no more than minimal adverse effects on the aquatic environment. Given the scope and extent of the Moakley park project, it is likely that the activities would not be eligible for authorization under a General Permit, and would therefore require an Individual Permit. The Individual Permit process includes a public notice with a public comment period.

US Coast Guard Private Aids to Navigation Application (33 CFR Part 66)

Private Aids to Navigation (PATON) refers to all marine aids to navigation operated in the federally recognized navigable waters of the United States other than those operated by the federal government or those operated in state waters for private aids to navigation. This includes lighted structures and day beacons, lighted and unlighted buoys, RACONs and fog signals.

To ensure the safety of the boating public the Coast Guard is required to review all work performed within the navigable waters of the United States and determine whether or not such work (i.e. installation of a fixed structure or floating object) will require to be marked with PATON. The required application is the US Coast Guard Private Aids to Navigation Application (CG-2554) Questionnaire. The ocean barrier will require this Coast Guard approval.

APPENDIX B

Permit Approval Schedule

Project Specific Environmental Agency Review Timeline: Boston - Moakley Park Project
Overall Permitting Timeline

Months

Project	Permit	Review Duration (months)
Park Improvements	MEPA	18
	NEPA	18
	MassDOT State Highway	2
	NPDES CGP	0
	Boston Water and Sewer Commission	5
	Boston Conservation Commission	2
	Boston Public Improvement Commission	3
	Boston Transportation Department	7
	Boston Public Works Department	3
	Boston Parks Department	2
	Boston Planning and Development Agency	6
	MWRA	2
Berm	MEPA	18
	NEPA	18
	MassDOT State Highway	2
	NPDES CGP	0
	Boston Water and Sewer Commission	5
	Boston Conservation Commission	2
	Boston Public Improvement Commission	3
	Boston Transportation Department	7
	Boston Public Works Department	3
	Boston Parks Department	2
	Boston Planning and Development Agency	6
	MWRA	2
Promenade	MassDEP Ch 91	8
	MassDOT State Highway	2
	DCR Construction and Access	2
	NPDES CGP	0
	Boston Water and Sewer Commission	5
	Boston Conservation Commission	2
	Boston Public Improvement Commission	3
	Boston Transportation Department	7
	Boston Public Works Department	3
	Boston Parks Department	2
	Boston Planning and Development Agency	6
	MWRA	2
Beach Improvement	MEPA	18
	NEPA	18
	NOI (local)	8
	Combined Ch 91/401 WQC	8
	MESA	8
	CZM	3
	MassDOT State Highway	2
	DCR Construction and Access	2
	ACOE Individual	6
	Boston Conservation Commission	2
	Boston Parks Department	2
	Boston Planning and Development Agency	6
	MWRA	2
Ocean Barrier	MEPA	18
	NEPA	18
	NOI (local)	8
	Combined Ch 91/401 WQC	8
	MESA	8
	CZM	3
	ACOE Individual	6
	MassDOT State Highway	2
	DCR Construction and Access	2
	USCG	3
	Boston Parks Department	2
	Boston Planning and Development Agency	6

APPENDIX C

Overall Permitting Costs Summary Table

Boston - Moakley Park
Permit Costs Summary

	Project Component Cost									
	Park		Berm		Promenade		Beach		Ocean Barrier	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Local Permits										
Boston Water and Sewer Commission	$15,000	$30,000	$15,000	$30,000	$15,000	$30,000				
Boston Conservation Commission	$20,000	$40,000	$20,000	$40,000	$20,000	$40,000	$20,000	$40,000	$20,000	$40,000
Boston Public Improvement Commission	$15,000	$30,000	$15,000	$30,000	$15,000	$30,000				
Boston Transportation Department	$15,000	$50,000	$15,000	$50,000	$15,000	$50,000				
Boston Public Works Department	$20,000	$40,000	$20,000	$40,000	$20,000	$40,000				
Boston Parks Department (if required)	$10,000	$50,000	$10,000	$50,000	$10,000	$50,000	$10,000	$50,000	$10,000	$50,000
Boston Planning and Development Agency	$15,000	$50,000	$15,000	$50,000	$15,000	$50,000	$15,000	$50,000		
MWRA	$5,000	$10,000	$5,000	$10,000	$5,000	$10,000	$5,000	$10,000		
Sub-Total	$115,000	$300,000	$115,000	$300,000	$115,000	$300,000	$50,000	$150,000	$30,000	$90,000
State Permits										
MEPA ENF/EIR	$50,000	$75,000	$50,000	$75,000			$50,000	$75,000	$150,000	$175,000
MassDEP Ch 91 permit					$10,000	$15,000	$20,000	$25,000	$30,000	$40,000
MassDEP 401 WQC							$20,000	$25,000	$30,000	$40,000
MESA Project Review							$20,000	$30,000	$20,000	$30,000
DCR Construction and Access permit					$10,000	$15,000	$10,000	$15,000	$10,000	$15,000
MassDOT State Highway Access	5000	10000	5000	10000	5000	10000	5000	10000		
Sub-Total	$55,000	$85,000	$55,000	$85,000	$25,000	$40,000	$125,000	$180,000	$240,000	$300,000
Federal Permits										
NEPA EA/EIS[1]	$15,000	$22,500	$15,000	$22,500	$0	$0	$15,000	$22,500	$45,000	$52,500
NPDES CGP	$20,000	$25,000	$20,000	$25,000	$20,000	$25,000				
ACOE Individual Permit							$40,000	$50,000	$40,000	$50,000
CZM Federal Consistency Review							$25,000	$30,000	$25,000	$30,000
USCG Private Aids to Navigation									$10,000	$15,000
Sub-Total	$35,000	$47,500	$35,000	$47,500	$20,000	$25,000	$80,000	$102,500	$120,000	$147,500
Overall Permitting Costs (TOTAL)	$205,000	$432,500	$205,000	$432,500	$160,000	$365,000	$255,000	$432,500	$390,000	$537,500

Note: Costs do not include engineering design, plan set development, or additional studies or monitoring efforts
1. Assumed MEPA and NEPA filing will be similar and filed simultaneously. NEPA costs will be 30% of MEPA costs

APPENDIX D

Permitting Matrix Table

Moakley Park
Boston, Massachusetts
Permitting Matrix
December, 2019

COMPONENT	Permit	Jurisdiction	Timeline (months, total)	Cost (total)	BPRD Ownership?
Park Improvement	NEPA NPDES CGP	Federal	**18**	**$205,000 - $432,500**	**YES**
	MassDOT State Highway MEPA	State			
	Boston Water and Sewer Commission Boston Conservation Commission Boston Public Improvement Commission Boston Transportation Department Boston Public Works Department Boston Parks Department Boston Planning and Development Agency MWRA	Local			
Berm	NEPA NPDES CGP	Federal	**18**	**$205,000 - $432,500**	**YES**
	MEPA MassDOT State Highway	State			
	Boston Water and Sewer Commission Boston Conservation Commission Boston Public Improvement Commission Boston Transportation Department Boston Public Works Department Boston Parks Department Boston Planning and Development Agency MWRA	Local			
Promenade	NPDES CGP	Federal	**9**	**$160,000 – $365,000**	**NO**
	MassDEP Ch 91 MassDOT State Highway DCR Construction and Access	State			
	Boston Water and Sewer Commission Boston Conservation Commission Boston Public Improvement Commission Boston Transportation Department Boston Public Works Department Boston Parks Department Boston Planning and Development Agency MWRA	Local			
Beach Improvement	NEPA ACOE Individual	Federal	**43**	**$255,000 - $432,500**	**NO**
	Combined Ch 91/401 WQC MEPA MESA CZM MassDOT State Highway DCR Construction and Access	State			
	NOI Boston Conservation Commission Boston Parks Department Boston Planning and Development Agency MWRA	Local			
Ocean Barrier	NEPA USCG ACOE Individual	Federal	**43**	**$390,000 - $537,000**	**NO**
	MEPA Combined Ch 91/401 WQC MESA CZM MassDOT State Highway DCR Construction and Access	State			
	Boston Parks Department Boston Planning and Development Agency NOI	Local			

Technical Review Committee (TRC) Form

PROJECT: Moakley Park Master Plan

TASK NUMBER: 1.2: Permitting Feasibility Study

SUB-TASK NUMBER: 1.2G: Overall Permitting Report

CLIENT: Boston Parks & Recreation Department

DATE: 06/26/20

This form is intended to: 1) be completed by the TRC reviewer(s) at each stage of deliverable review; 2) assure that the deliverable satisfies the project team's quality standards; 3) reduce the project team's exposure to liability by detecting and correcting gross negligence and errors and; 4) reduce the possibility of future extra work due to errors and omissions on our part. The sub-task leader is responsible for hosting a kick-off meeting at the start of each task and the designated TRC reviewer must attend the kick-off meeting. This form is required for all project deliverables, but not necessarily all sub-tasks. This form should be attached to draft and final project deliverables.

Deliverable Description: 1.2G: Local, state and federal permitting report including the permits needed, possible challenges and anticipated timelines

Deliverable Type (Interim or Final): Final (100%):

TRC Review Team:

Anthony Zerilli, Associate
Weston & Sampson Engineers, Inc.
978-977-0110
zerillia@wseinc.com

Design Team: (generally the sub-task lead & others key contributors)

Mel Higgins, Senior Environmental Scientist
Weston & Sampson Engineers, Inc.
978-977-0110
higginsm@wseinc.com

TRC Hours Spent Reviewing Project: 1

Date for Meeting with Team to Discuss Resolution of Comments, if Required:

Major Comments on Project Review:

After final document had been submitted, it was noticed that a permitting matric was not included in the final report.

FINAL DELIVERABLE REVIEW SIGN-OFF SHEET

This sign-off is intended to ensure that all members of the project team are satisfied that they have adequately reviewed the attached deliverable, and that the deliverable can be used by others for project advancement.

By signing this sheet, the reviewers indicate that they have completed an independent final review of the deliverable and feel that, pending execution of all changes recommended by the reviewer, the deliverable represents industry best practices and can be considered final. The sub-task lead shall initiate the form. The Principal-in Charge shall be the last to sign-off. Copies of the original and the draft deliverables shall be saved in the SharePoint folder directory.

	NAME	SIGNATURE	DATE
Project Director			
Project Manager	Julie Eaton		6/30/20
Sub-task Lead	Mel Higgins		6/30/20
TRC Reviewer	Anthony Zerilli		6/30/20
TRC Reviewer	Lee Koska		6/30/20
Principal-in-Charge	Cheri Ruane		6/30/20

UPDATED COASTAL DEFENSE STRATEGY

WOODS HOLE GROUP, STOSS + WESTON & SAMPSON

- BEACH NOURISHMENT MEMORANDUM + TRC FORM
- LANDSCAPE CROSS-SECTION: BEACH NOURISHMENT + FLOOD BARRIER
- CONSTRUCTION TOOLKIT

MEMORANDUM

DATE May 13, 2020 **JOB NO.** 2019-0056

TO Amy Whitesides
Studio Director
STOSS Landscape Urbanism
54 Old Colony Avenue | Third Floor | Boston, MA 02127

FROM Woods Hole Group, Inc.

Boston, MA – Moakley Park
Beach Nourishment Design, Modeling Assessment, and Development of Design Parameters

This technical work was completed to support Stoss and Weston and Sampson (W&S) in the continued development of a Vision Plan for Moakley Park aimed at fostering resilient open space. As a potential component of the overall resilient design, Woods Hole Group has evaluated conceptual restoration of the beach and dune system along Carson Beach, which lies just seaward of Moakley Park with William J Day Blvd bisecting the two. The coastal beach and dune system at Carson Beach represent the first line of the defense for Moakley Park, but also represents a significant entry point of flooding under future conditions. This future flood risk is not just limited to Moakley Park itself, but penetrates surrounding neighborhoods and beyond. This area represents one of the major flood pathways for the City of Boston, and therefore building resilience at Moakley Park and the surrounding region is important. Restoring and improving the dune and beach system at Carson Beach, while not able to limit storm surge based flooding as a standalone measure, represents a potential natural solution to ensure long-term resilience, improves the natural habitat and recreational potential of the site, and provides an energy buffer for waves and currents that helps support the resilient park features and elements.

In order to assist in the development of potential conceptual designs for the beach and dune improvement portion of the project, Woods Hole Group has evaluated the resilience of beach and dune restoration templates at Carson Beach by evaluating (1) potential reduction in wave energy during storm events in present day and future conditions (2070), (2) the potential movement of sediment in a cross-shore direction during these storm events, (3) the performance life of a proposed beach and dune restoration projects at Carson Beach, and (4) the impact a potential restoration project may have on design parameters (e.g., recommended design flood elevations).

Beach and Dune Restoration

Beach nourishment is typically the most non-intrusive technique for coastal protection and involves placing sand, from an offshore or upland source, in a designed template on an eroding beach. Beach nourishment is intended to widen the beach, as well as provide added storm protection, increased recreational area, and in some cases, added habitat area. Although nourished sand is eventually displaced alongshore or transported offshore, the nourished sand that is eroded takes the place of the upland area that would normally have been lost or eroded during a storm event. Therefore, beach nourishment serves a significant role in storm protection.

In addition, beach nourishment is the only alternative that introduces additional sand into the system. For coastlines with a dwindling sediment supply, this is critical for long-term usage of the beach and successful protection.

Environmental concerns with beach and dune restoration projects include the potential for temporary decreased water quality when sediments are deposited and disturbing natural habitat when placing the material. These concerns can be addressed by adhering to time windows that avoid periods of shellfish, finfish, and shorebird activity. Grain size compatibility between the borrowed and native beach sediments should be maximized in order to avoid disturbance of offshore resources such as shellfish and submerged aquatic vegetation, as well as to increase the lifespan of the nourished beach. For example, large differences in grain size between the native and borrow material may lead to changes in beach slope through natural adjustment of the new grain size introduced to the beach. This change in beach slope, as well as the change in grain size directly, may negatively influence the offshore resources when the sediment is distributed.

A successful beach nourishment project consists of more than simply placing sediment on a beach. Beach nourishment projects are engineered. A beach nourishment template, which consists of numerous design parameters, is based on the characteristics of the site and the needs of a project. Every beach nourishment design is unique, since different beaches in different areas have different physical, geologic, environmental, and economic characteristics, as well as different levels of required protection. The design must consider climatology, the shape of the beach, type of native sand, volume and rates of sediment transport, erosion patterns and causes, waves and water levels, historical data and previous storms, probability of certain beach behaviors at the site, existing structures and infrastructure, and past engineering activities in the area.

The structure of a nourishment template is designed to yield a protective barrier that also provides material to the beach. A restored beach berm is designed to absorb wave energy. Dunes may need to be constructed or existing dunes improved to reduce damage, including potential upland flooding, from storms. Figure 1 depicts a beach berm and dune on a typical beach profile. Nourishment length, berm height and width, dune height, and offshore slope are critical elements of a beach nourishment design. Periodic renourishment intervals are also usually a part of the nourishment design. If renourishment is required in less than 5 years, then the nourishment is probably not cost-effective. If renourishment is required around 10 years or more, then a nourishment project is likely cost-effective. The renourishment interval will vary based on the initial design, wave climate, sand used, number and types of storms, and project age. In addition, beach nourishment is not an exact science; variables and uncertainties exist. Actual periodic renourishment intervals may differ from planned intervals based on conditions at the nourished beach and the frequency and intensity of storms from year to year.

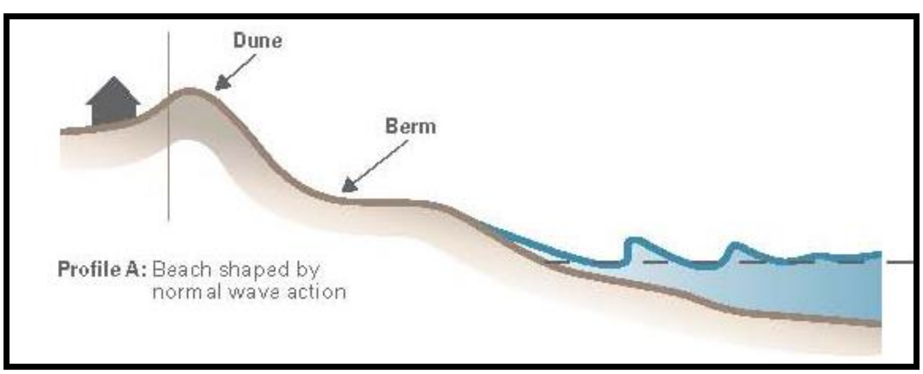

Figure 1: Typical beach profile and features (USACE, Coastal Engineering Manual, 2003).

Evaluated Alternatives

There were a wide range of alternatives that were screened prior to advancing to the more rigorous scientific evaluation. These alternatives were developed based on experience in beach and dune restoration, as well as existing topography at the site, and the project goals. The initial set of alternatives included a range of beach and dune templates (heights, widths, elevations, etc.). Ultimately, two distinct beach and dune restoration templates were selected to be evaluated that represented a smaller nourishment volume and a larger nourishment volume, but fits within the framework of the existing beach infrastructure. These two alternatives were also compared to existing conditions.

- **Alternative A –** This proposed dune and beach restoration template consisted of a smaller volume of nourishment (43,000 cubic yards) that would expand the existing dune to an elevation of 16.5 feet Boston City Base (BCB) or 10 feet NAVD88 with a crest width of 20 feet and a nourishment component that had a beach berm of 50 feet wide at an elevation of 12.5 feet BCB (6 feet NAVD88). The details of all parameters are presented in Table 1.
- **Alternative B –** This proposed dune and beach restoration template consisted of a larger volume of nourishment (128,000 cubic yards) that would expand the existing dune to an elevation of 17.8 feet BCB (11.3 feet NAVD88) with a crest width of 30 feet and a nourishment component that had a beach berm of 100 feet wide at an elevation of 12.5 feet BCB (6 feet NAVD88). The details of all parameters are presented in Table 1.

Table 1: Comparison of beach and dune restoration parameters for Alternative A and B.

Beach Restoration Parameter	**Alternative A (Smaller)**	**Alternative B (Larger)**
Nourishment Length (feet)	2900	2900
Beach Berm Width (feet)	50	100
Beach Berm Elevation (feet BCB)	12.5	12.5
Slopes	1/10	1/10
Dune Crest Elevation (feet BCB)	16.5	17.8
Dune Crest Width (feet)	20	30
Volume (cubic yards)	43,000	128,000
Grain Size	Matches Native	Matches Native

In all cases, the nourishment material was assumed to be beach compatible with the native sediment (same grain size distribution and a median grain size sand). Figure 2 shows an aerial view of Carson Beach that compares the approximate location of the Mean High Water (MHW) shoreline for existing conditions, as well as the potential location under the two alternatives. Figure 3 presents a comparison of the present-day beach to the Alternative B (larger nourishment).

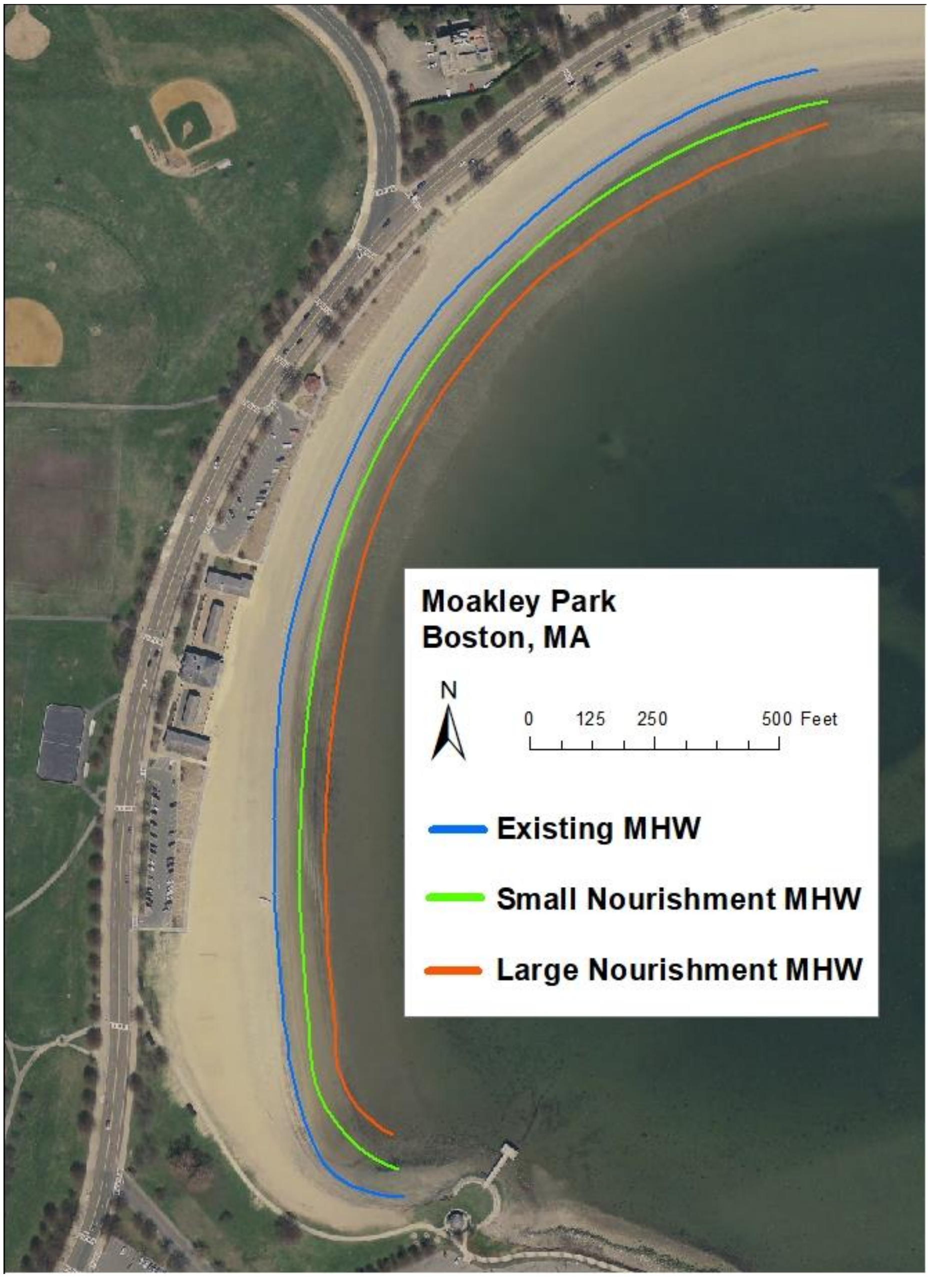

Figure 2: Location of Mean High Water (MHW) shoreline for existing conditions and alternatives (Background image source: MassGIS, 2019: USGS Color Ortho Imagery (2013/2014), https://docs.digital.mass.gov/dataset/massgis-data-usgs-color-ortho-imagery-20132014).

Moakley Park - Boston, MA

Figure 3: Aerial image showing the existing shoreline at Moakley Beach and the potential shoreline with the large nourishment (Alternative B) in place (Background image source: MassGIS, 2019: USGS Color Ortho Imagery (2013/2014), https://docs.digital.mass.gov/dataset/massgis-data-usgs-color-ortho-imagery-20132014).

Cross-shore Performance

In order to evaluate the conceptual design alternatives, estimate service life, and to determine the protective level of the proposed designs during high-energy storm events, a cross-shore sediment transport model (XBeach) was utilized. XBeach is a numerical model developed to simulate wave, hydrodynamic and morphodynamic processes. It has been developed with support of various agencies including the US Army Corps of Engineers, Rijkswaterstaat and the EU, together with a consortium of UNESCO-IHE, Deltares (formerly WL|Delft Hydraulics), Delft University of Technology, and the University of Miami.

The model includes the hydrodynamic processes of short-wave transformation (refraction, shoaling and breaking), long wave (infragravity wave) transformation (generation, propagation, and dissipation), wave-induced setup and unsteady currents, and overwash and inundation. The morphodynamic processes include bed load and suspended sediment transport, dune face avalanching, bed update and breaching. The model has been validated with a series of analytical, laboratory and field test cases using a standard set of parameter settings. Further details of the XBeach model and its theory can be found in the XBeach Technical Reference (Deltares, 2015).

To assess the proposed beach and dune templates in terms of wave impacts and erosional processes, XBeach was used to simulate the wave and sediment processes along a representative cross-shore transect. Figure 4 shows a plan view map of the transect utilized, which represents the one of the narrow sections along Carson Beach.

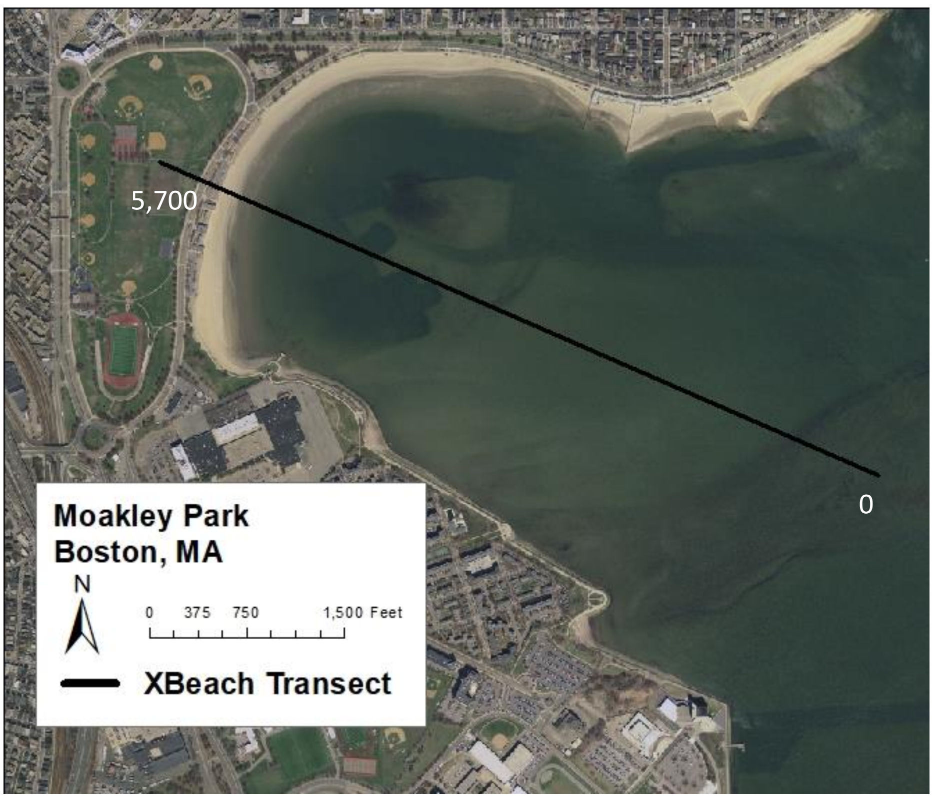

Figure 4: Transect location used for XBeach modeling (background image source: MassGIS, 2019: USGS Color Ortho Imagery (2013/2014), [https://docs.digital.mass.gov/dataset/massgis-data-usgs-col or-ortho-imagery-20132014](https://docs.digital.mass.gov/dataset/massgis-data-usgs-color-ortho-imagery-20132014)). The distance along the transect is indicated by the white numbers, such that zero (0) represents the start of the transect offshore of Moakley Park. The total distance of the transect is 5,700 feet, which ends in Moakley Park. Day Boulevard is located at approximately 5,650 along the transect.

Figure 5 shows a cross-sectional view of each alternative evaluated. Elevation along the transect is shown on the y-axis, while distance along the transect is shown on the x-axis. Figure 6 shows a conceptual visualization of these two dune and beach restoration alternatives, as provided by STOSS.

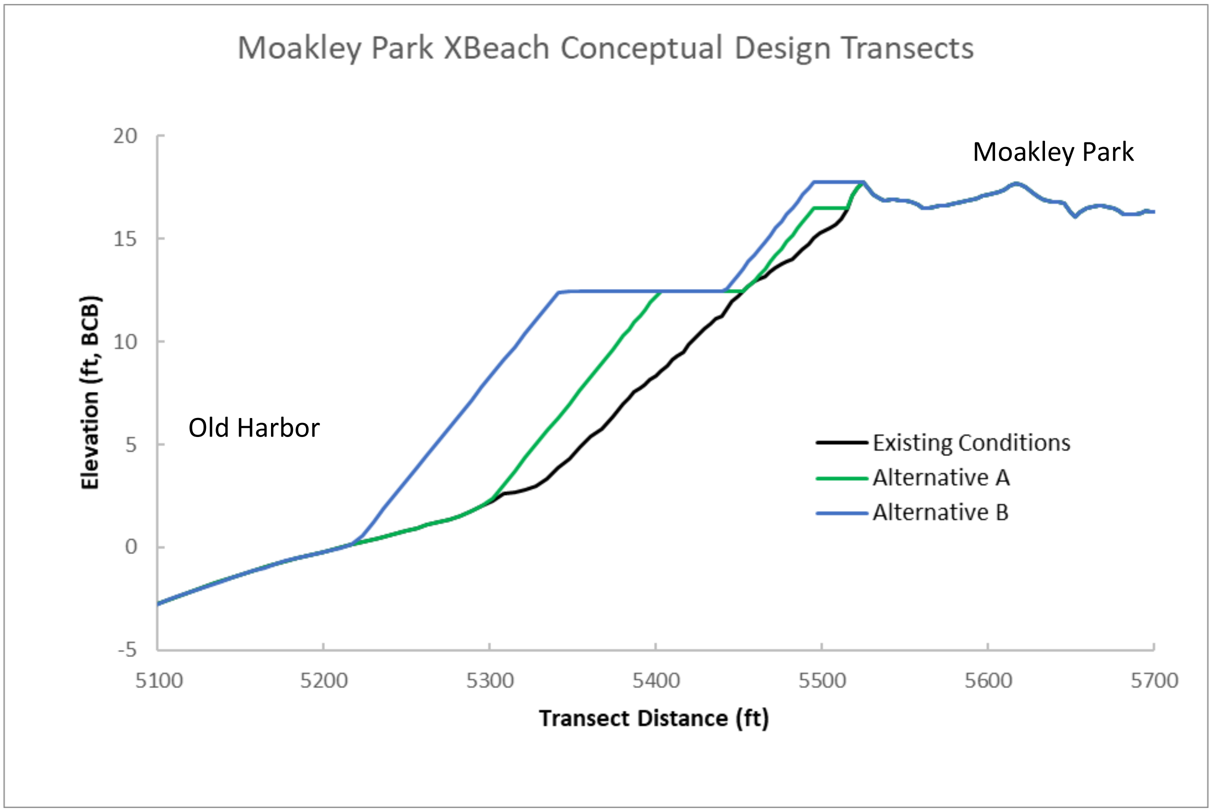

Figure 5: Cross-section alternatives used for XBeach modeling. The small nourishment (Alternative A) is shown in green, while the larger nourishment (Alternative B) is shown in blue.

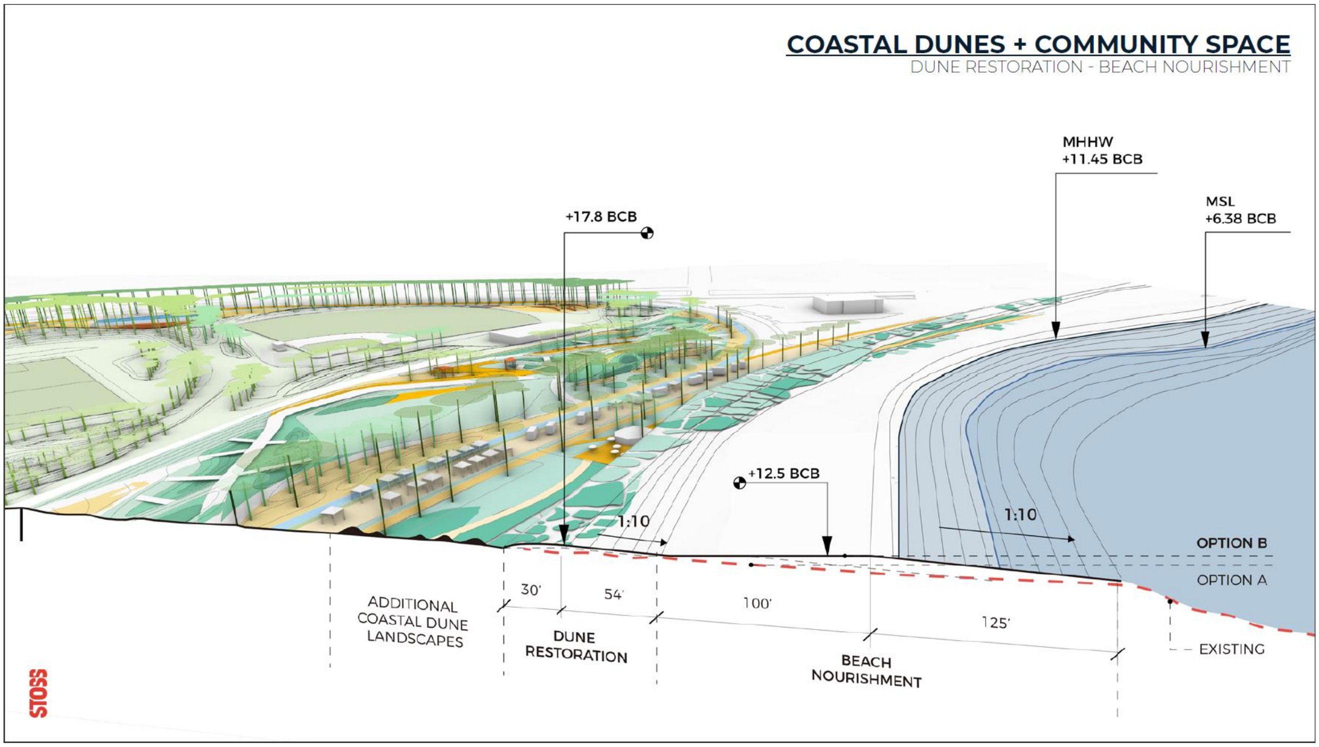

Figure 6: Conceptual visualization of proposed dune and beach restoration alternatives.

Each alternative, as well as existing conditions, was simulated using three (3) different storm cases:

1. A 100-year return period storm surge level combined with associated wave conditions with existing sea level.
2. A 100-year return period storm surge level combined with associated wave conditions with a sea level corresponding to 2030.
3. A 100-year return period storm surge level combined with associated wave conditions with a sea level corresponding to 2070.

To establish wave and water level boundary conditions for each of these simulation cases, site specific wave and water level model results were utilized. All boundary conditions utilized for this study were extracted from the Massachusetts Coast Flood Risk Model (MC-FRM) developed by Woods Hole Group for the Massachusetts Department of Transportation.

A storm corresponding to a 1% annual chance (100-yr return period) storm event at Moakley Park was selected from the overall MC-FRM storm set. A time series of wave and water level data from this storm was extracted at the start of the transect (Figure 4) for use as a boundary condition. Each case was run over a 48-hour period corresponding to the length of the storm extracted.

Model simulations were performed for existing conditions and each alternative using the three storm cases over time. The results from these simulations are displayed in Figures 7, 8, and 9. The vertical axes in these figures show the elevation (in feet, BCB), while the horizontal axes show the distance along the transect (in feet). The black line shows the existing conditions profile (without nourishment), while the orange, green, and blue lines show the final eroded profile after the storm case simulations for current, Alternative A, and Alternative B, respectively. The three figures demonstrate the performance of the beach and dune system for each alternative under each storm case and can be compared to the performance without a restoration element/project. For this exercise, no unerodable structures were simulated (road, buildings, walls, etc.). As such real results may be expected to differ from those simulated here where walls and hard structures are present.

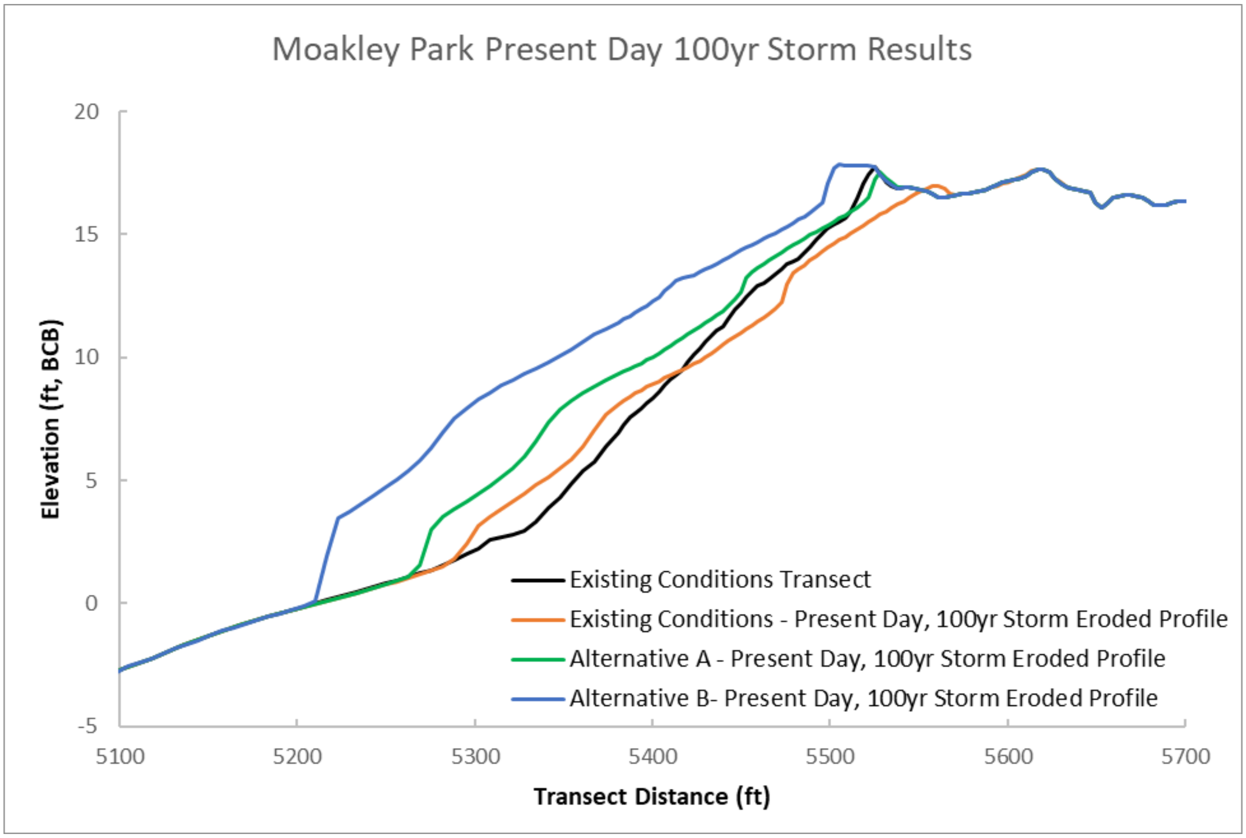

Figure 7: Erosion results for present day 1% storm case.

Figure 7 presents the results of the three different alternatives in a 100-yr event occurring in present day. The results indicate that under existing conditions (orange line), it would be expected that a majority of the beach and dune system would be eroded and not be able to provide robust protection against wave advancement inland, and certainly would be compromised during subsequent storm events. The small nourishment (Alt. A, green line), experiences erosion, but does not suffer a complete failure, and the beach and dune system remain viable after the storm event. This also indicates under a restored scenario; wave overtopping would be insignificant. With the large nourishment (Alt. B, blue line), there is relatively minor erosion due to the large beach berm that breaks wave energy offshore before it reaches the shoreline. The dune itself remains relatively intact and would provide a protective barrier against storm surge-based flooding.

The results of 2030 and 2070 (Figure 8 and 9 respectively) are similar to present day, except that a sediment is mobilized both offshore (to create a protective offshore bar against incoming storm waves) as well as transported landward into the parking lot areas. As expected, in 2030 and 2070, the existing conditions profile does not adequately function and allows wave energy to propagate landward. The small nourishment (Alt. A) does provide improved performance, reducing erosion, wave transmission, and less sediment being mobilized landward. The large nourishment (Alt. B) further improves overall performance. The nourished cases also lead to a wider beach after all storm cases than the existing conditions profile. This suggests that the nourished beach would recover better in a post-storm scenario since sediment is available offshore to move back onto the beach during normal wave conditions.

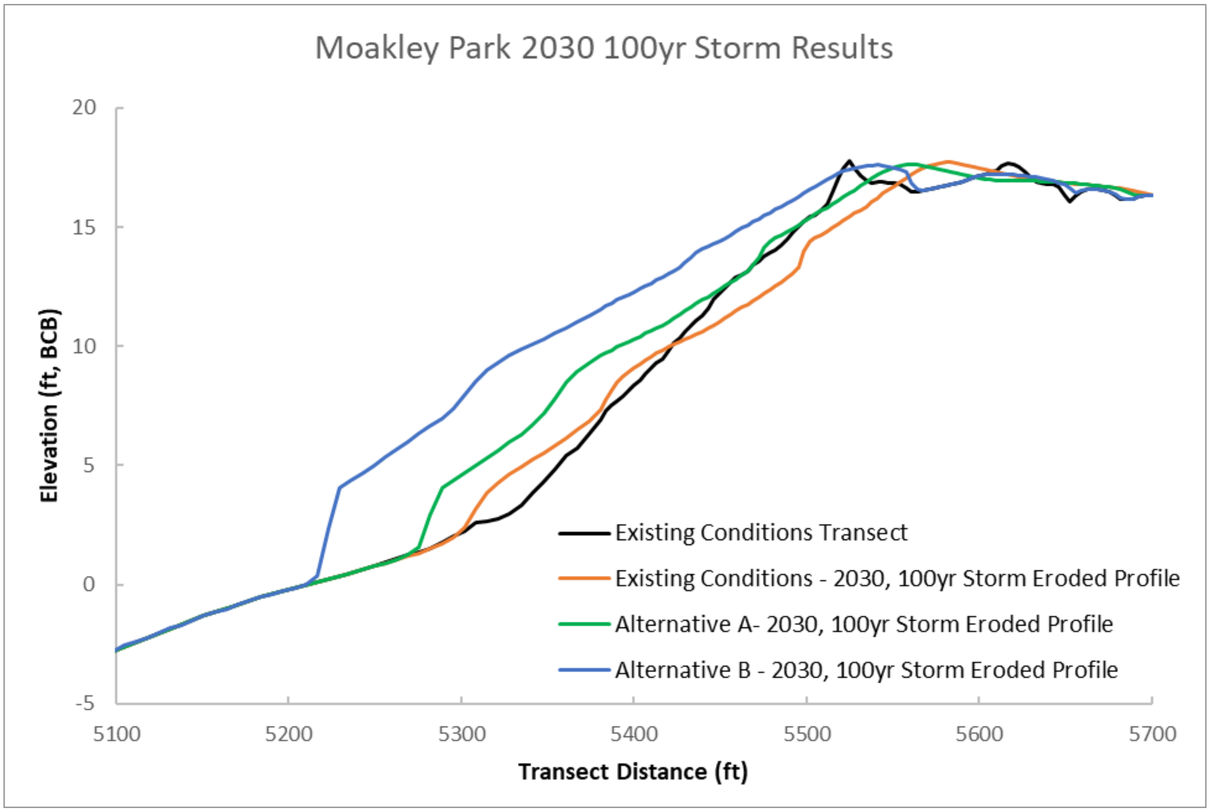

Figure 8: Erosion results for 2030 1% storm case.

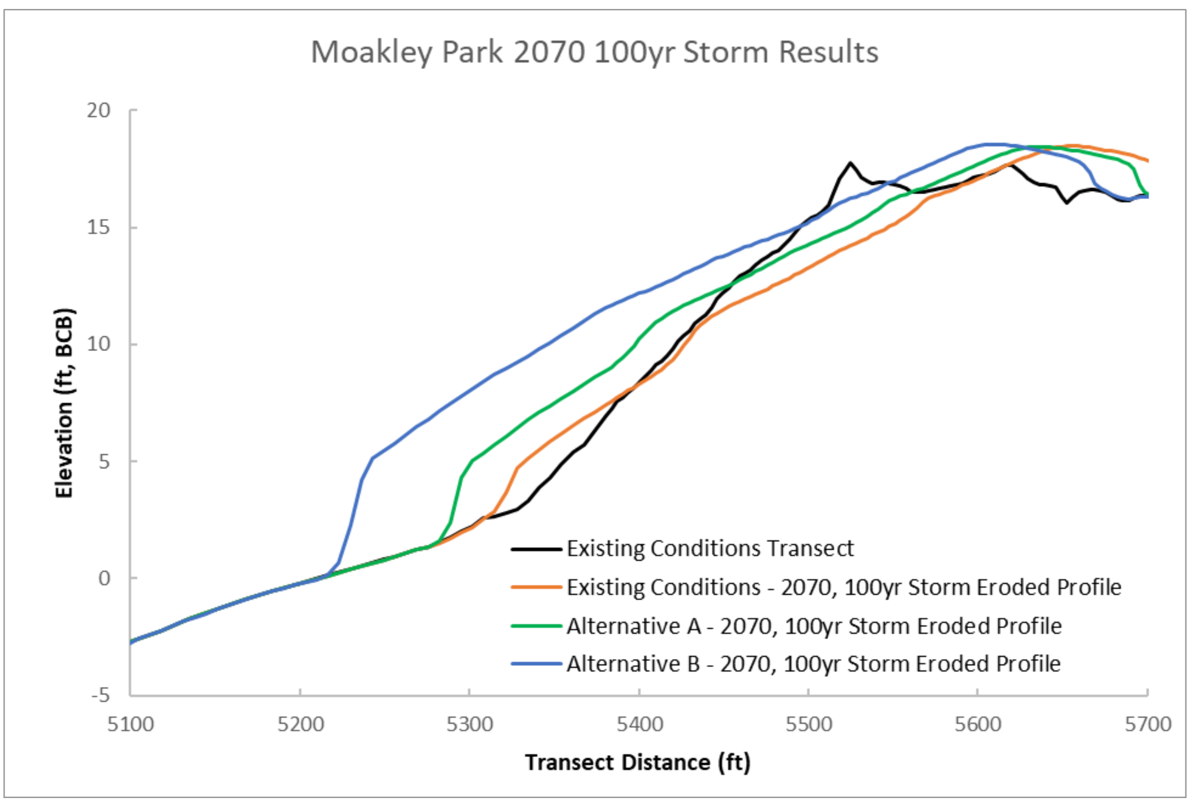

Figure 9: Erosion results for 2070 1% storm case.

Beach Performance Service Life

Since the nourishment material diffuses (spreads) over time, it is possible to evaluate the longevity of the nourishment by looking at the amount of material left in the project area. The lifetime of the beach nourishment is based upon the volume of the initial beach fill left within the boundary of the initial fill template. The percentage remaining will decrease with time, but that material is not necessarily lost from the system, it has just spread to regions outside of the original nourishment template. For example, sediment will likely be transported to other portions of the Carson Beach shoreline. Therefore, although the sediment no longer falls within the initial nourishment template, it has not disappeared from the system.

Evaluation of nourishment combines the conservation of sediment equation with the linearized transport equation. This formulation, called the Pelnard-Considére (1956) equation, is used in obtaining theoretical results to establish design and performance standards for nourishments. This formulation is the standard methodology applied to evaluate the performance of beach nourishment projects. More details on this can also be found in Dean (2002).

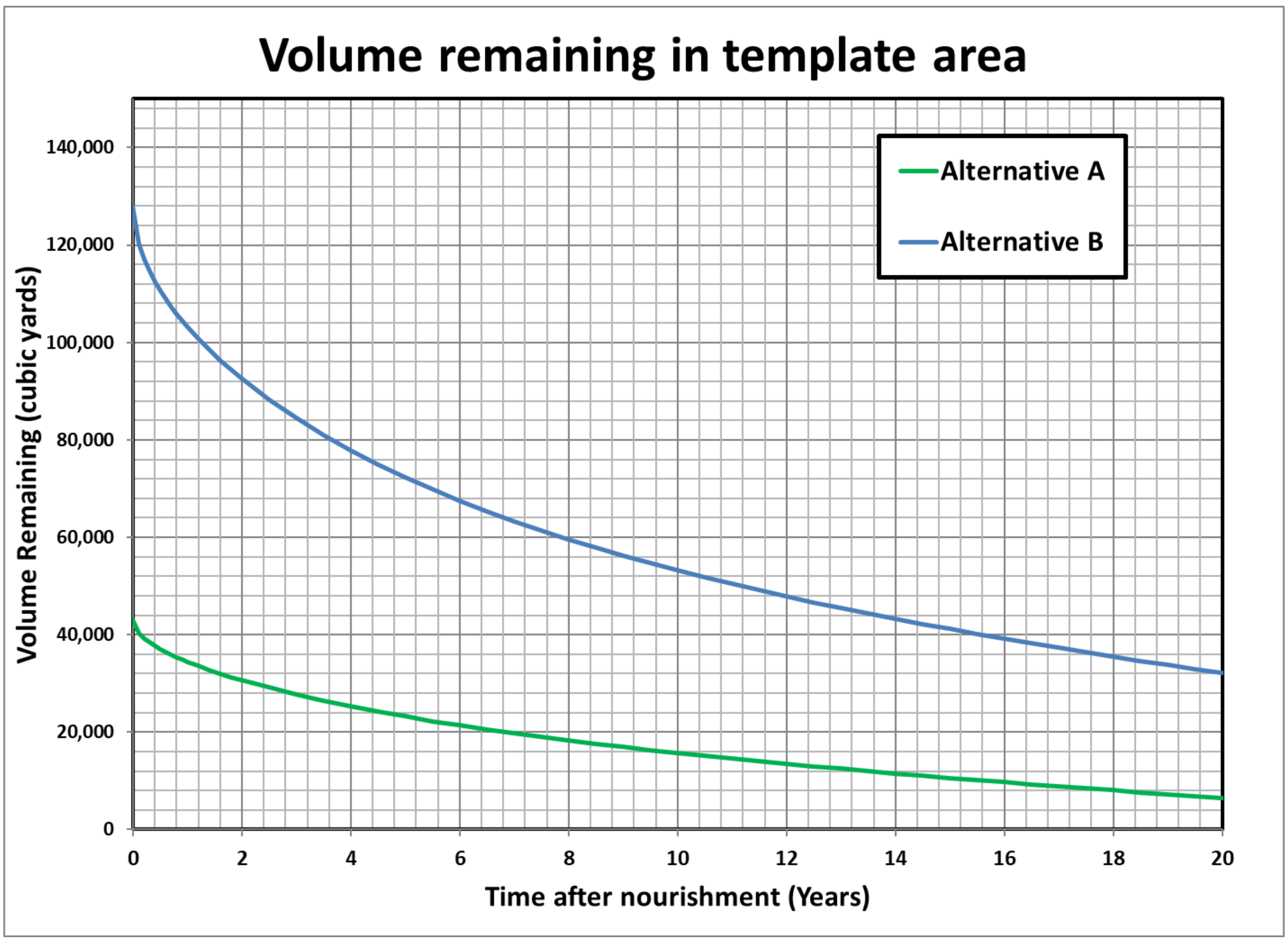

Figure 10: Beach restoration performance (volume remaining as a function of time) for Alternatives A and B at Carson Beach.

Figure 10 presents the performance of Alternatives A and B at Carson Beach. The performance is expressed in terms of amount of material remaining in the initial template region, as a function of time, for Alternative A (green line) and Alternative B (blue line). The volume of initial material remaining is presented along the vertical axis, while the time (in years) is presented along the bottom axis. For example, after 8 years, approximately 60,000 cubic yards of the initial Alternative B fill volume is remaining in the initial template area, whereas just under 20,000 cubic yards of the initial Alternative A fill volume remains in the initial template area. In each case, the initial fill volume that is not still residing in the initial template area has not necessarily been lost from the system. Curves similar to those presented in Figure 10 were also used to determine the relative performance impacts of various beach berm widths and heights.

Similarly, the berm width (i.e., beach area) can also be evaluated as a function of time. As the nourishment spreads over time, the available width of beach is reduced. Figure 11 presents the beach width remaining in years after the nourishment for each of the Alternatives at Carson Beach. The vertical axis presents the width of the beach berm in the center of the proposed nourishment region, while the horizontal axis represents years after placement. For example, after 10 years, the beach width under Alternative B would be 45 feet wider than the existing beach berm. In other words, a zero (0) beach berm width corresponds to the current location of the beach berm, and 50 feet on the vertical axis corresponds to a beach berm that is 50 feet wider than it is today.

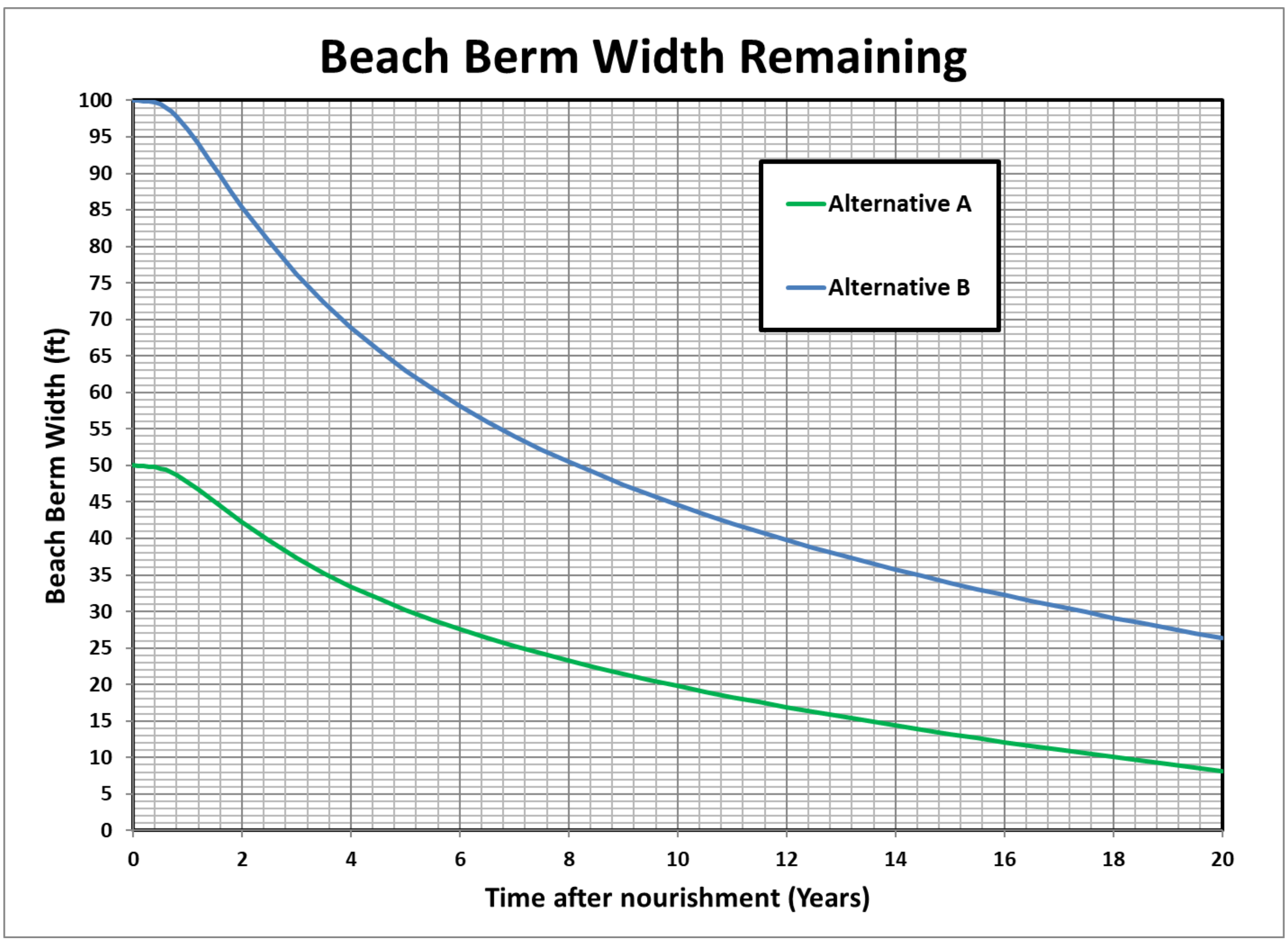

Figure 11: Beach restoration performance (beach berm width as a function of time) for Alternatives A and B at Carson Beach.

This beach performance assessment can also be used to provide a potential maintenance schedule for the beach and dune system. For example, once the beach material has spread to a certain extent, potential replenishment can be considered to restore the template to the full restoration amount. Typically, this occurs when the 30% of the original nourishment sediment is left in the nourishment template. For example, replenishment of Alternative B should be considered after approximately 18-20 years, while replenishment of Alternative A should be considered after approximately 14-15 years.

Wave Energy Reduction and Development of Design Parameters

In addition to the cross-shore movement and performance modeling, these analyses also were used to determine the flood protection benefits associated with a restored beach and dune system. For example, the wave propagation that occurs with and without the restored beach in place can be evaluated under 2030 and 2070 wave conditions. Therefore, updated design parameters for the inland flood protection features at Moakley Park were developed for conditions with the beach nourishment in place. Originally, design parameters (specifically design flood elevations [DFEs]) were developed using results of the Boston Harbor Flood Risk Model (BH-FRM). Subsequently, during the process of the development of the Moakley Park Master Plan, the Massachusetts Coastal Flood Risk Model (MC-FRM) was completed. As such, these updated data, along with the results of including a beach and dune restoration at Carson Beach, are utilized to provide updated design flood elevations). Table 2 presents the target design flood elevations for the various cases using a 1% 2070 storm condition as the design benchmark, consistent with the other Climate Ready Boston projects. The design flood elevation recommendations do not depend on which beach and dune restoration alternative is implemented. Both Alternative A (smaller nourishment) and Alternative B (larger nourishment) reduce the wave energy significantly enough to relax the target flood elevation. However, more frequent maintenance would be required with Alternative A, and it would be necessary to ensure that the restored beach and dune system is maintained for the corresponding target design flood elevations to remain the standard. ***The recommended design flood elevation to utilize for the Moakley Park coastal flood protection elements is 21.5 feet Boston City Base.*** As such, the beach nourishment effectively reduces the required DFE for the more landward coastal protection features. Additionally, with the beach and dune restoration element of the project in place, there would be no need for determination of wave forces, erosion, or scour processes at the Moakley Park coastal flood protection features since the wave energy would be insignificant. The beach and dune restoration would not have any significant impact on the overall coastal surge elevation (or still water level), but does play a role in reducing the wave energy at Moakley Park.

Table 2: Design Flood Elevations for Moakley Park Coastal Flood Protection Elements.

Model utilized	Beach restoration	Target Design Flood Elevation (feet-BCB)
BH-FRM	Not included	22.6
MC-FRM	Not included	23.8
BH-FRM	Included	20.5
MC-FRM	Included	**21.5**

Permitting Implications

A potential beach nourishment project at Carson Beach will require several permits, many of which can be incorporated into the overall Moakley Park permitting project or could be done independently at a later date. This section describes the potential permitting requirements for a beach and dune restoration project at Carson Beach.

Massachusetts Environmental Policy Act (MEPA, 301 CMR 11.0) - The purpose of MEPA and 301 CMR 11.00 is to provide meaningful opportunities for public review of the potential environmental impacts of a project for which a Permit is required from an agency of the Commonwealth, and to assist agencies of the Commonwealth in using all feasible means to avoid damage to the environment or, to the extent damage to the environment cannot be avoided, to minimize and mitigate damage to the environment to the maximum extent practicable. MEPAs review is intended to inform the participating agencies of the project, to maximize consistency between agency actions, and to facilitate coordination of all environmental and development review and permitting processes of the Commonwealth. The MEPA process provides an opportunity for the project proponent to identify required agency actions and to describe and analyze how the project will comply with applicable regulatory standards and requirements. Through review of the MEPA documents, each participating agency can comment on aspects of the Project or issues regarding its agency action that require additional description or analysis.

MEPA review is required when one or more review thresholds are met or exceeded and the subject matter of at least one review threshold is within MEPA jurisdiction. The Carson Beach restoration project is likely to trigger MEPA Wetlands, Waterways and Tidelands thresholds (301 CMR 11.03(3)). Although the project is still in the early planning phase, it is likely that the beach nourishment will trigger 301 CMR 11.03(a)1.b. which requires an Environmental Notification Form (ENF) and Mandatory Environmental Impact Report (EIR). This threshold applies to projects that require a Permit from an agency of the Commonwealth and propose to alter ten or more acres of a wetland.

Upon filing an ENF for the project, the Secretary of Energy and Environmental Affairs will issue a Certificate outlining the scope and content of the EIR. Following review of the Draft and Final EIRs, the Secretary's Certificate that indicates the documents are adequate or that there has been other due compliance with MEPA and 301 CMR means that the proponent has adequately described and analyzed the project and its alternatives, and assessed its potential environmental impacts and mitigation measures. Upon completion of the MEPA process, each participating agency retains authority to fulfill its statutory and regulatory obligations in permitting or reviewing the project.

National Environmental Policy Act (NEPA) - A project review under the NEPA process is triggered when a federal agency develops a proposal to take one or more federal actions. The actions include new and continuing activities, including projects and programs entirely or partly financed, assisted, conducted, regulated, or approved by a federal agency. The federal actions tend to fall within one of the following categories:

- Adoption of official policy, such as rules, regulations, and interpretations adopted pursuant to the Administrative Procedure Act, 5 U.S.C. 551 et seq.; treaties and international conventions or agreements; formal documents establishing an agency's policies which will result in or substantially alter agency programs.
- Adoption of formal plans, such as official documents prepared or approved by federal agencies which guide or prescribe alternative uses of federal resources, upon which future agency actions will be based.
- Adoption of programs, such as a group of concerted actions to implement a specific policy or plan; systematic and connected agency decisions allocating agency resources to implement a specific statutory program or executive directive.
- Approval of specific projects, such as construction or management activities located in a defined geographic area. Projects include actions approved by permit or other regulatory decision as well as federal and federally assisted activities.

Under the NEPA review process, potential impacts of the proposed project are evaluated and alternative actions to achieve the goals of the project are investigated. The process requires consideration of environmental impacts that include, among others, impacts on social, cultural, and economic resources, as well as natural resources. Opportunities for public review and comment are also provided.

For a potential beach nourishment project at Moakley Park, NEPA review would be triggered if federal funding is used for project planning, engineering, permitting, or construction, or if any part of the project is located within the boundaries of the Boston Harbor Islands National Park. NEPA review can follow three basic pathways, or levels of analysis and documentation, depending on the complexity of the project: Categorical Exclusion (CE), Environmental Assessment (EA), or Environmental Impact Statement (EIS). It is possible the beach nourishment portion of the Moakley Park project would trigger the need for an EA, and likely that the offshore wave attenuation portion of the project would trigger the more detailed EIS filing. Following review of an EA or EIS, a Finding of No Significant Impact (FONSI) or Record of Decision (ROD) is issued when it is determined that the proponent has adequately described and analyzed the project and its alternatives, and assessed its potential environmental impacts and mitigation measures. This process could be complete in concert with the MEPA review.

Massachusetts Wetlands Protection Act (310 CMR 10.00) - Any activity proposed or undertaken within a resource area protected by the Massachusetts Wetlands Protection Act (310 CMR 10.00), that will remove, fill, dredge or alter the resource, is subject to regulation under M.G.L. c. 131 §40 and requires the filing of a Notice of Intent (NOI) with the local Conservation Commission. The proponent must demonstrate that the proposed work within regulated resource area(s) will contribute to the protection of the interests identified in M.G.L. c. 131 §40 by complying with the general performance standards established by 310 CMR 10.00 for that area.

Wetland resources likely to be involved with the Moakley Park project include land under the ocean (310 CMR 10.25), coastal beach (310 CMR 10.27), coastal dune (310 CMR 10.28), land containing shellfish (310 CMR 10.34), and estimated habitats of rare wildlife (310 CMR 10.37). Consequently, it must be demonstrated to the Boston Conservation Commission and the Massachusetts Department of Environmental Protection (DEP) that the project meets the performance standards for work in each of these resource areas. Once the NOI has been filed and public hearings held, the Conservation Commission must issue an Order of Conditions (OOC) approving or denying the project. For approval OOCs, the Commission will often include special conditions specific to the proposed project that must be followed during the construction phase of the project.

Because the beach nourishment portion of the Moakley Park project is located within Priority Habitat mapped by the Massachusetts Natural Heritage and Endangered Species Program (NHESP), the project will be required to be reviewed under the Massachusetts Endangered Species Act (MESA) (321 CMR 10.00). The MESA review assists proponents with projects or activities that will take place in mapped Priority Habitat to avoid a Take of a State-listed Species. This review occurs at the same time as the NOI review by the Boston Conservation Commission.

Massachusetts 401 Water Quality Certification (314 CMR 9.00) - Projects in Massachusetts involving the discharge of dredged or fill material, dredging, or dredged material disposal activities in waters of the United States, which require federal licenses or permits, are subject to 314 CMR 9.00. 314 CMR 9.07 also applies to any dredging project and the management of dredged material within the marine boundaries and at upland locations within the Commonwealth. The purpose of the 401 Water Quality Certification is to ensure that proposed discharges of dredged or fill material, dredging and dredged material disposal in the waters of the United States within the Commonwealth comply with the Surface Water Quality Standards and other appropriate requirements of state law.

Per 314 CMR 9.04(9), the beach nourishment elements at Carson Beach will trigger the requirement for a 401 Water Quality Certification because they are subject to an individual Section 404 permit from the United State Army Corps of Engineers. If the projects involve dredged material reuse or disposal of 100 cubic yards or more, they would also trigger the need for a 401 Water Quality Certification per 314 CMR 9.04(12). Projects must meet the criteria listed in 314 CMR 9.06 and 9.07 to receive a Certification authorizing the work.

Massachusetts Waterways Regulation (310 CMR 9.00) - 310 CMR 9.00 was enacted for the following purposes: (1) to protect and promote the public's interest in tidelands, Great Ponds, and non-tidal rivers and streams in accordance with the public trust doctrine, (2) to preserve and protect the rights in tidelands of the inhabitants of the Commonwealth by ensuring that the tidelands are utilized only for water-dependent uses or otherwise serve a proper public purpose, (3) protect the public health, safety, and general welfare as it may be affected by any project in tidelands, Great Ponds, and non-tidal rivers and streams, (4) support public and private efforts to revitalize unproductive property along urban waterfronts in a manner that promotes public use and enjoyment of the water, and (5) foster the right of the people to clean air and water, freedom from excessive and unnecessary noise, and the natural, scenic, and historic, and esthetic qualities of their environment.

Per 310 CMR 9.05(2)(a) the beach nourishment project would be required to file an application for a Chapter 91 permit. The wave attenuation portion of the project would be required to file for a Chapter 91 license per 310 CMR 9.05(1)(a), as this work would involve the construction and/or placement of not previously authorized fill.

Massachusetts Coastal Zone Management Federal Consistency (15 CFR 930 Subparts A-I) - The federal consistency requirement of the CZMA (16 U.S.C. § 1456) holds that federal actions that have reasonably foreseeable effects on any land or water use or natural resources of a state coastal zone must be consistent with the enforceable policies of the federally approved coastal management program for that state. Within this authority of the CZMA, Massachusetts Coastal Zone Management (CZM) may review federal actions affecting their coastal uses and/or resources, regardless of whether the action occurs within or outside the state coastal zone boundary, to ensure that such activities are consistent with the state's enforceable program policies. The Massachusetts CZM reviews the coastal effects of proposed actions, including environmental effects (i.e., impacts on biological or physical resources found within the state coastal zone), as well as effects on human uses, such as fishing and boating, public access and recreation, scenic and aesthetic enjoyment, and resource creation or restoration.

The nourishment at Carson Beach will be subject to a federal consistency review by CZM because the project will be performed by a non-federal entity and will require an Individual Permit from the United States Army Corps of Engineers. An application demonstrating consistency of the project with CZM's coastal policies will be required to receive approval by CZM.

US Army Corps of Engineers General Permits for the Commonwealth of Massachusetts - The U.S. Army Corps of Engineers (Corps) regulates construction and other work in navigable waterways under Section 10 of the Rivers and Harbors Act of 1899, and has authority over the discharge of dredged or fill material into "waters of the United States" (a term which includes wetlands and all other aquatic areas) under Section 404 of the Clean Water Act. Under these laws, those who seek to carry out such work must first receive a permit from the Corps. The program considers the full public interest by balancing the favorable impacts against the detrimental impacts. This is known as the "public interest review." The program reflects the national concerns for both the protection and utilization of important resources.

In Massachusetts regional general permits can be issued for certain activities with no more than minimal adverse effects on the aquatic environment. Given the scope and extent of the Moakley Park project, it is likely that the activities would not be eligible for authorization under a General Permit and would therefore require an Individual Permit. The Individual Permit process includes a public notice with a public comment period.

Cost Estimates

This section provides an approximate cost estimate for a potential beach and dune nourishment project at Carson Beach. Costs for beach restoration projects can vary widely based on the source of the nourishment material. If using an upland source, current costs range from $30-45 per cubic yard (cy), depending on the quarry. For the Alternative A nourishment (43,000 cubic yards), an upland source would require approximately 1,650 loads using 26yd dump trailers with around 2,500cy delivered per day. This amount of trucking would require some post-construction road repairs (assume $2M), and costs for spreading the material into the engineered template ($48,000/day). Ideally, the beach restoration sediment could be supplied by an offshore borrow site or beneficial re-use dredged materials project that would lower the cost to approximately $25/cy with mobilization fees in the $2M range. The Alternative B nourishment project (128,000 cy) would be on the upper end of a feasible project to source from an upland quarry (due to the amount of material and construction length). Table 3 presents cost estimates for each alternative using a potential upland source and a potential dredged source.

Table 3: Cost Estimates for Potential Beach and Dune Restoration Project at Carson Beach.

Alternative	Volume (cy)	Upland Source (Cost in Millions of Dollars)	Dredge Source (Cost in Millions of Dollars)
A	43,000	$4.47	$3.08
B	128,000	$9.36	$5.20

Summary

The proposed beach and dune restoration at Carson Beach supports the overall flood resiliency and master planning effort at Moakley Park by reducing the flood risk, and subsequently the design flood elevation requirements, as well as expanding recreational and habitat areas. The enhanced system dissipates wave energy more efficiently before flood waters reach the proposed flood protection measures at Moakley Park. Therefore, the overall design flood elevation, as well as potential erosion countermeasures can be reduced. While the beach and dune restoration element do not halt the progression of flood waters during a coastal storm, nor do they significantly change the storm surge level, they do reduce the wave heights and energy at Moakley Park.

Since the design service life for the Moakley Park Master Plan is based on a 2070 1% annual chance storm condition, the beach and dune nourishment do not have to be constructed in the initial phases to provide the DFE reduction. While the beach and dune restoration project at Carson Beach certainly will provide flood protection benefits immediately under the current climate conditions, it is not essential that this component of the Master Plan be constructed now, or even in the relatively near-term time frame. Moakley Park flood protection elements are being designed for a 2070 1% annual exceedance coastal flood event; as such these flood protection features will be more than adequate for the storm of today and the near future (e.g., 2030). The beach and dune restoration element of the project can be considered a future phase of the project, but would then be required by approximately 2050 if Moakley Park flood protection elements are designed to the reduced DFE values presented in Table 2.

References

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Pelnard-Considère, R. 1956. Essai de Théorie de l'Evolution des Formes de Rivage en Plages de Sable et de Galets, 4th Journees de l'Hydraulique Les Energies de la Mer, Question III, Rapport No. 1.

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COASTAL DEFENSE STRATEGY

BEACH NOURISHMENT + FLOOD BARRIER
CROSS-SECTION

This drawing illustrates the relationship between beach nourishment, the flood management barrier, and their co-benefits including enhanced coastal habitat, expanded beach, and social gathering spaces. As described in Woods Hole Group's Beach Nourishment Design, Modeling Assessment, and Development of Design Parameters dated May 13, 2020, the implementation of beach nourishment would allow the project's DFE to be lowered to 21.5 BCB.

See 1.3A: Updated Coastal Defense Strategy for the complete memo.

STOSS

SEPTEMBER 28TH, 2020

August 26, 2020

Stoss Landscape Urbanism
c/o Ms. Cheri Ruane, RLA
Weston & Sampson
85 Devonshire Street, 3rd Floor
Boston, Massachusetts 02109

RE: Task 1.3 Construction Decision Toolkit
Proposed Moakley Park Improvements
Boston, Massachusetts

INTRODUCTION

In accordance with our agreement, Weston & Sampson Engineers, Inc. (Weston & Sampson) has developed preliminary foundation design alternatives for the proposed flood protection barrier to support Stoss in the continued development of the Vision Plan for Moakley Park. The foundation support alternatives have been prepared as part of the Construction Decision Toolkit for the project.

Based on the subsurface soil conditions observed in the geotechnical explorations completed to date and the proposed site grading plans and sections provided by Stoss, geotechnical engineering analyses have been performed to evaluate the impacts of proposed construction. At six (6) critical cross-sections along the proposed alignment of the flood protection barrier preliminary design evaluations of settlement, slope stability (i.e., global stability) and seepage have been completed. The results of the geotechnical analyses have been used as the design basis for the Construction Decision Toolkit.

The toolkit identifies feasible alternatives for the foundation support of the flood protection barrier, associated fill required to meet proposed grades, and proposed site features (e.g., hardscape, adventure play areas, etc.). In addition, the design alternatives have considered the presence of existing utilities and are intended to mitigate adverse impacts to those utilities based on the currently available information.

The Construction Decision Toolkit and preliminary foundation support alternatives demonstrate how the proposed design can be constructed using a combination of techniques, including the use of lightweight fill, lightweight fill in combination with an interior core wall, and column supported embankments. The preliminary design sections and engineering analyses will be summarized in more detail in the Task 3.2 design memorandum to be submitted under a separate cover.

Enclosures: Construction Decision Toolkit

MOAKLEY PARK

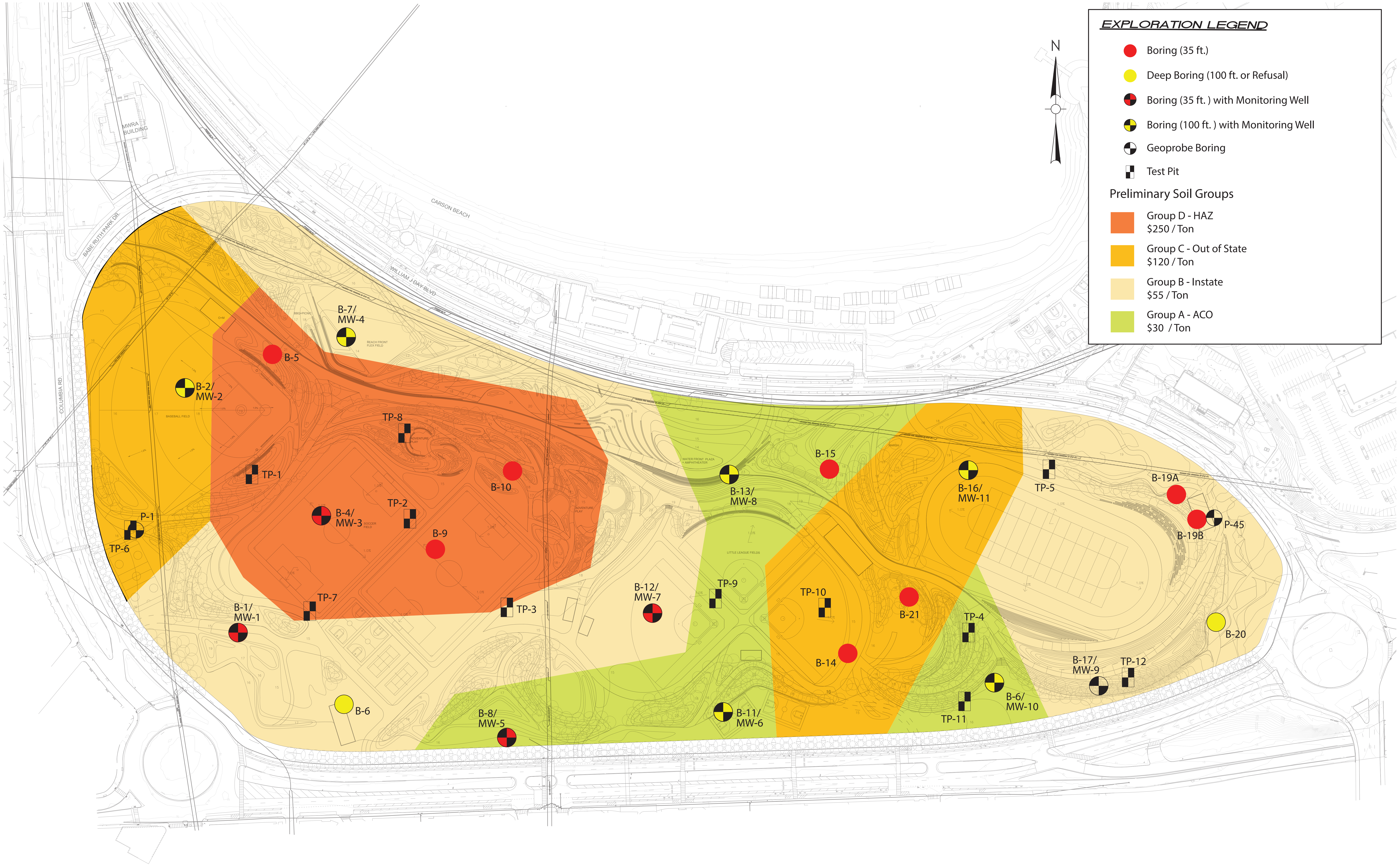
Construction Design Toolkit
07/14/2020

Mayor Martin J. Walsh

GEOTECHNICAL DESIGN CONSIDERATIONS

- GEOTECHNICAL FEASIBILITY PHASE EXPLORATIONS
- GENERALIZED SUBSURFACE SOIL CONDITIONS
- GEOTECHNICAL DESIGN CONSIDERATIONS
- EVALUATION OF FLOOD BARRIER SUPPORT ALTERNATIVES
- PRELIMINARY SUPPORT ALTERNATIVES ALONG FLOOD BARRIER
- NEXT STEPS AS DESIGN PROGRESSES
- QUESTIONS

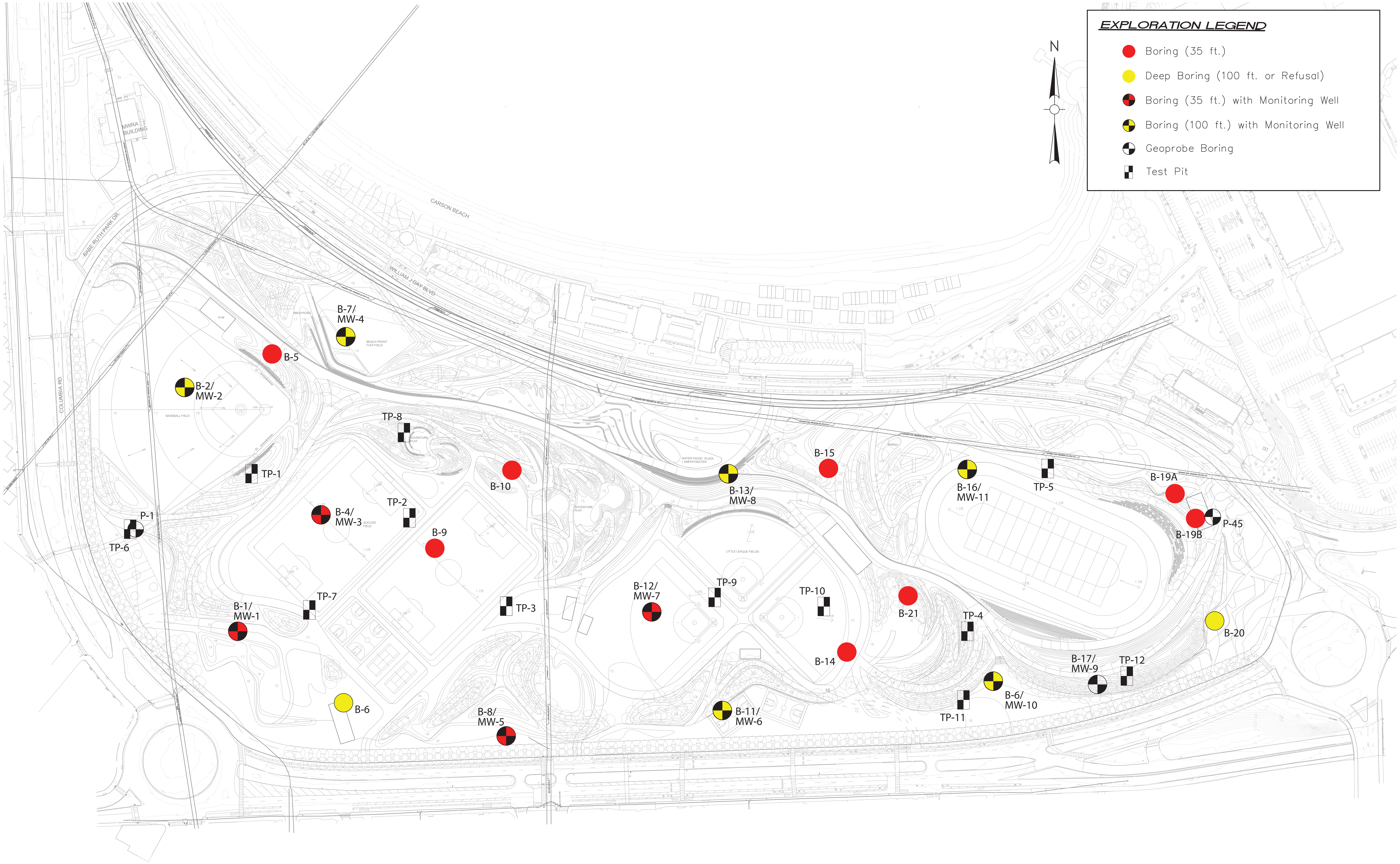
ENVIRONMENTAL SITE PLAN



STOSS

AUGUST 2020

GEOTECHNICAL SITE PLAN



STOSS AUGUST 2020

GENERALIZED SUBSURFACE CONDITIONS

Typical Boston Subsurface Stratigraphy

Urban Fill

- Up to 22 ft. thick
- Variable consistency, fine-grained silt and clay or sand with varying amounts of debris

Organics

- Intermittent layers up to about 4 ft. thick
- Very soft organics with varying amounts of clay/sand

Native Sand, Silt

- Generally up to about 10 ft. thick
- Loose to medium dense sand or very soft to soft silt with some clay

Boston Blue Clay

- Desiccated Clay Crust up to about 10 to 15 ft. thick
- Very Soft, Thick Deposits to 200 ft

Glacial Till

- Sand and Gravels at depths of 164 ft. and 218 ft.

Bedrock

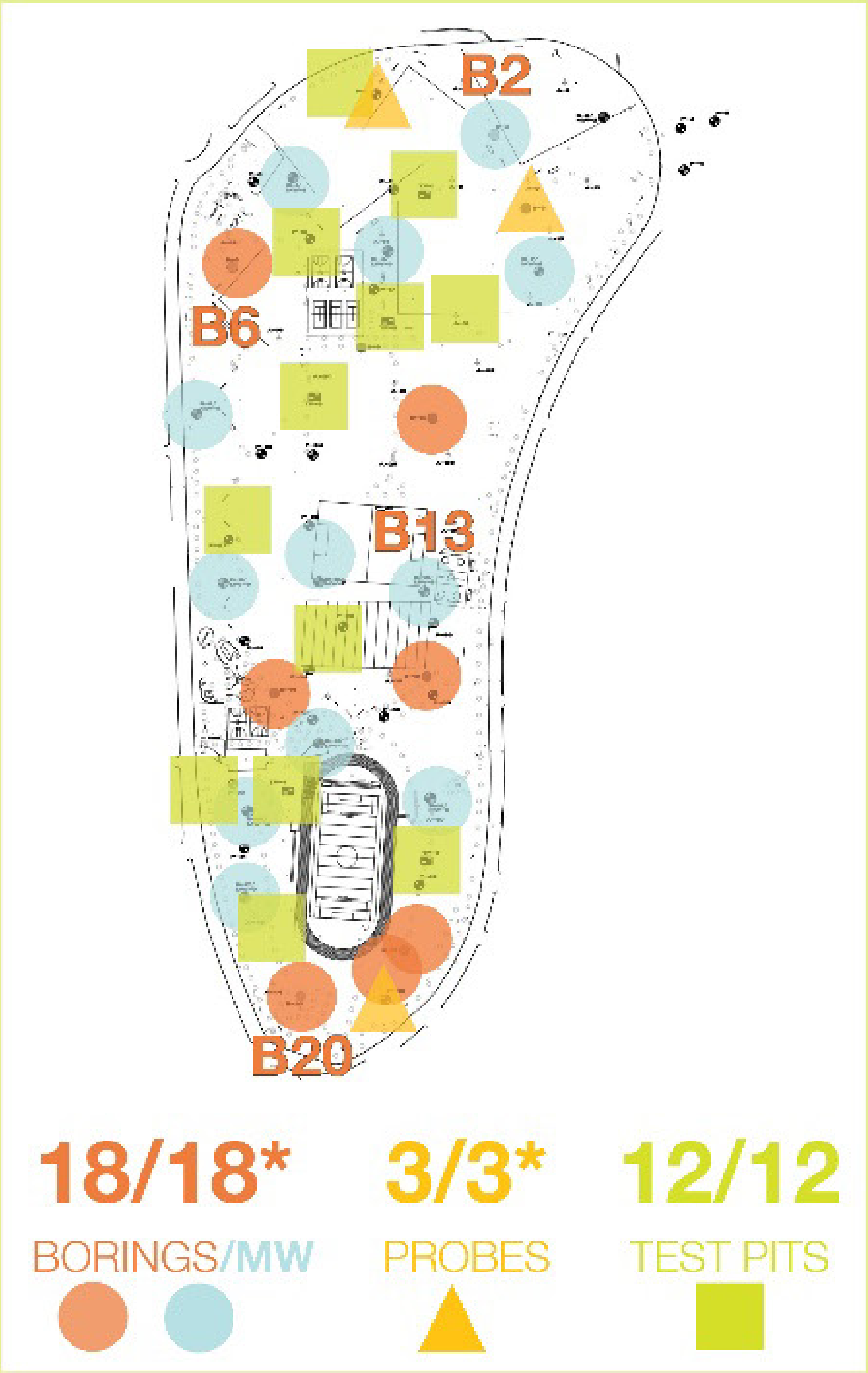
- Diabase intrusion in B-2, cored rock at 62 ft.
- Quickly drops in depth to the south

Groundwater

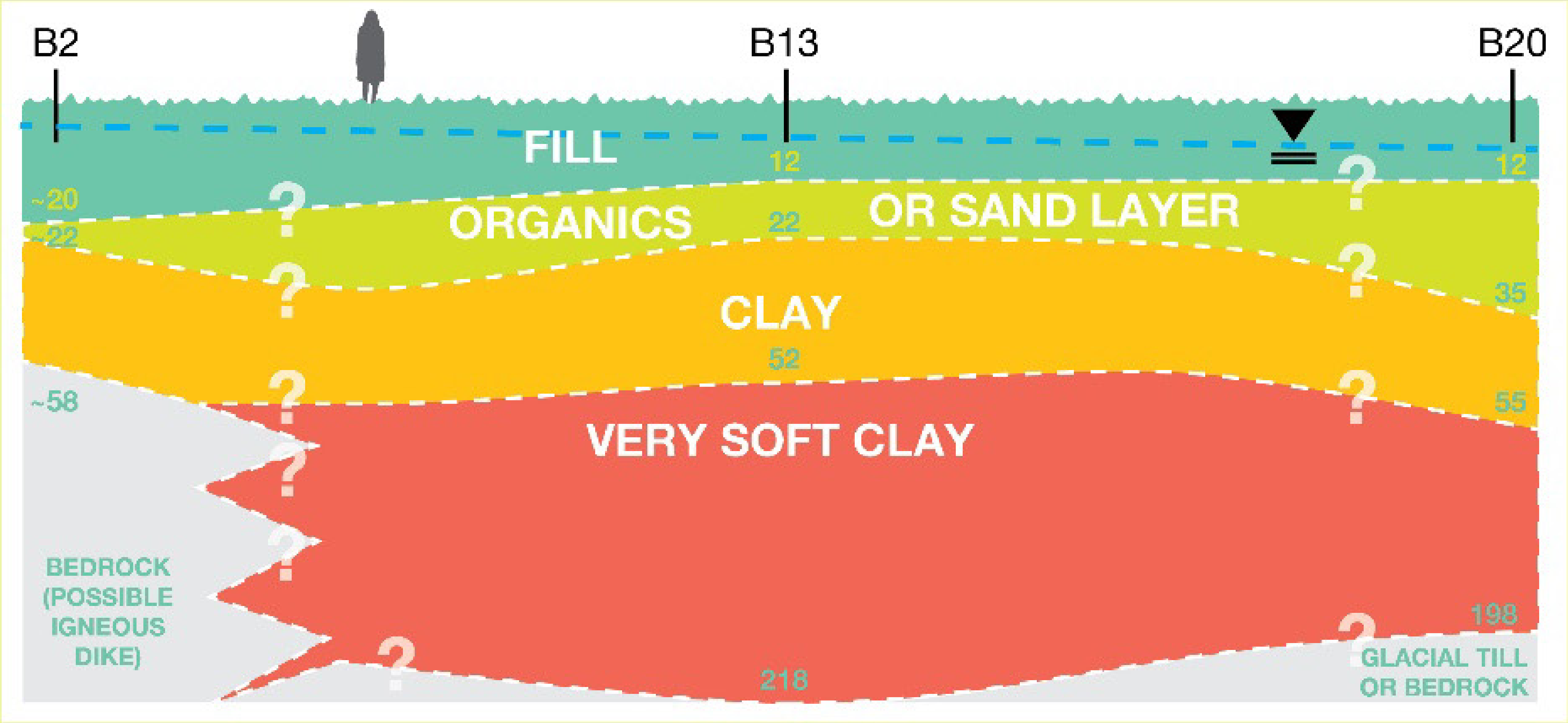
- Shallow, 4 to 8 ft. below existing grade

GENERALIZED SUBSURFACE CONDITIONS

SUBSURFACE EXPLORATION PROGRESS
As of October 23, 2019



GENERALIZED OBSERVATIONS - NOT FOR DESIGN



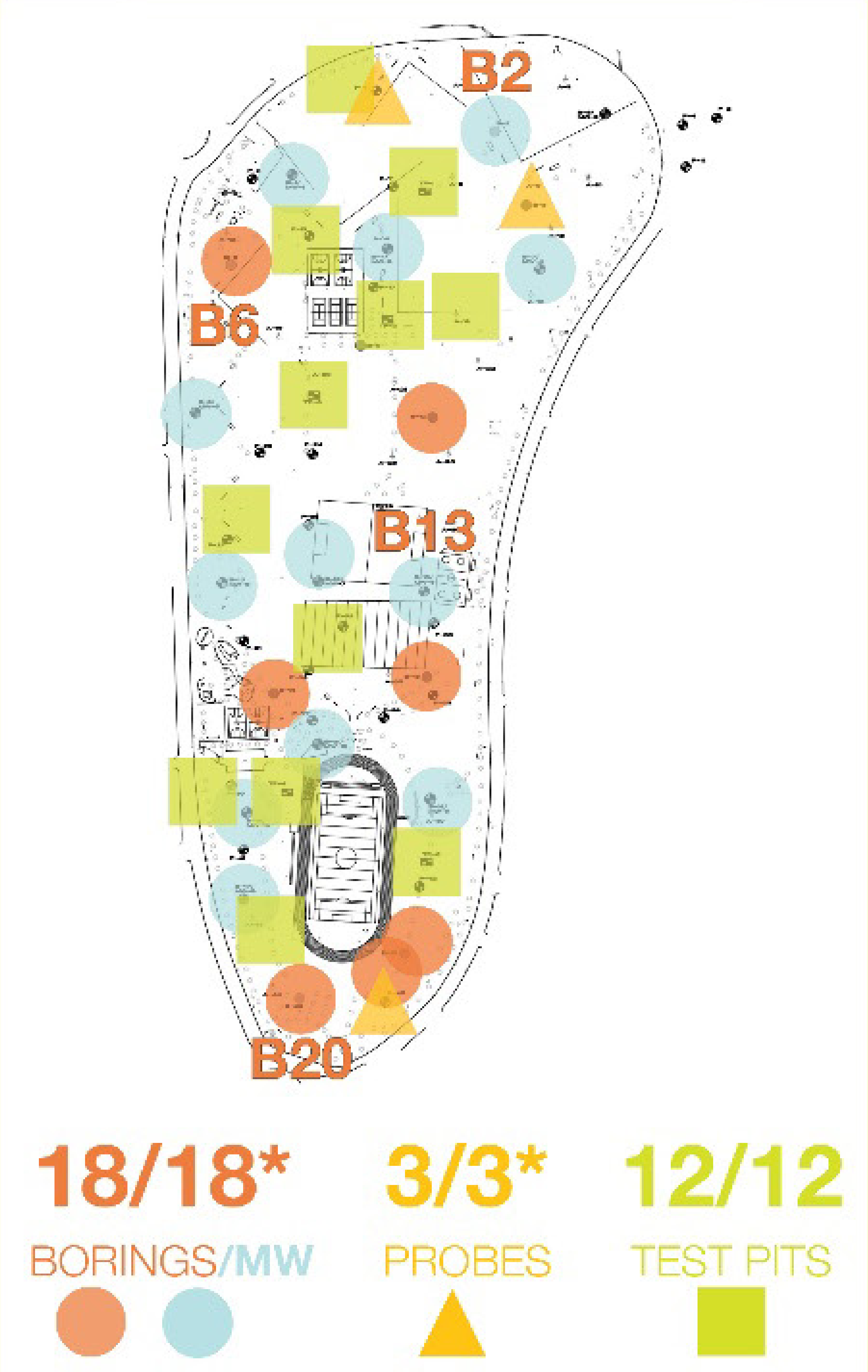
DRAFT DIAGRAM NOT TO BE USED FOR DESIGN.

SUBSURFACE LAYERS SHOWN ARE BASED ON CONDITIONS OBSERVED IN BORINGS B2, B13, AND B20. CONDITIONS MAY VARY BETWEEN BOREHOLE LOCATIONS. ALL THICKNESSES AND STRATA ARE APPROXIMATE. DIAGRAMS ARE NOT TO SCALE.

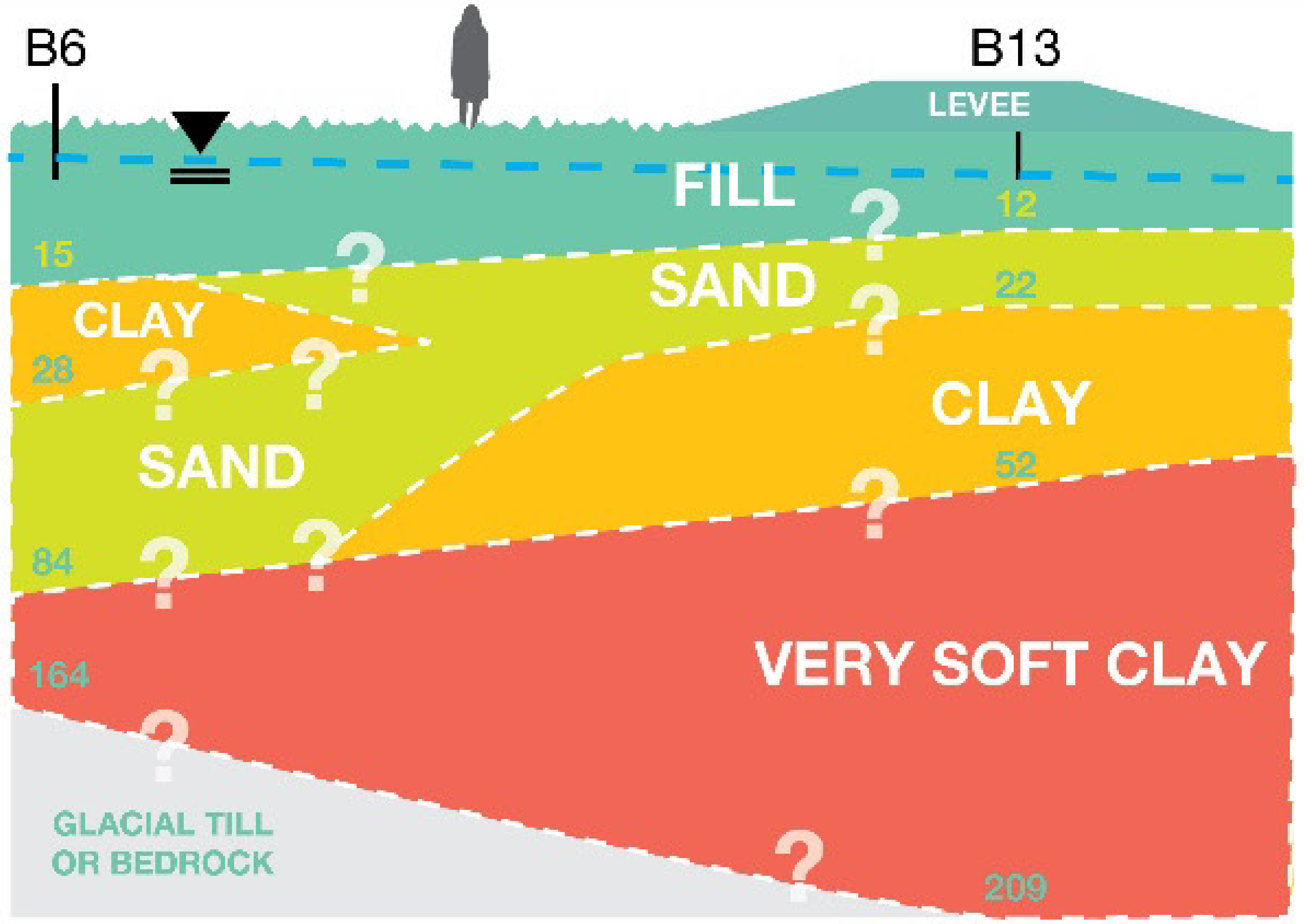
GENERALIZED SUBSURFACE CONDITIONS

SUBSURFACE EXPLORATION PROGRESS

As of October 23, 2019



GENERALIZED OBSERVATIONS - NOT FOR DESIGN



THICKNESS OF FILL

~12-22 FT

DEPTH TO GROUNDWATER

~4-8 FT

BELOW GROUND SURFACE

DRAFT DIAGRAM NOT TO BE USED FOR DESIGN.

SUBSURFACE LAYERS SHOWN ARE BASED ON CONDITIONS OBSERVED IN BORINGS B2, B13, AND B20. CONDITIONS MAY VARY BETWEEN BOREHOLE LOCATIONS. ALL THICKNESSES AND STRATA ARE APPROXIMATE. DIAGRAMS ARE NOT TO SCALE.

GENERALIZED SUBSURFACE CONDITIONS

Typical Boston Subsurface Stratigraphy

Variability of Existing Fill

- Non-uniform Immediate Settlement

Thick Deposits of Compressible Soils

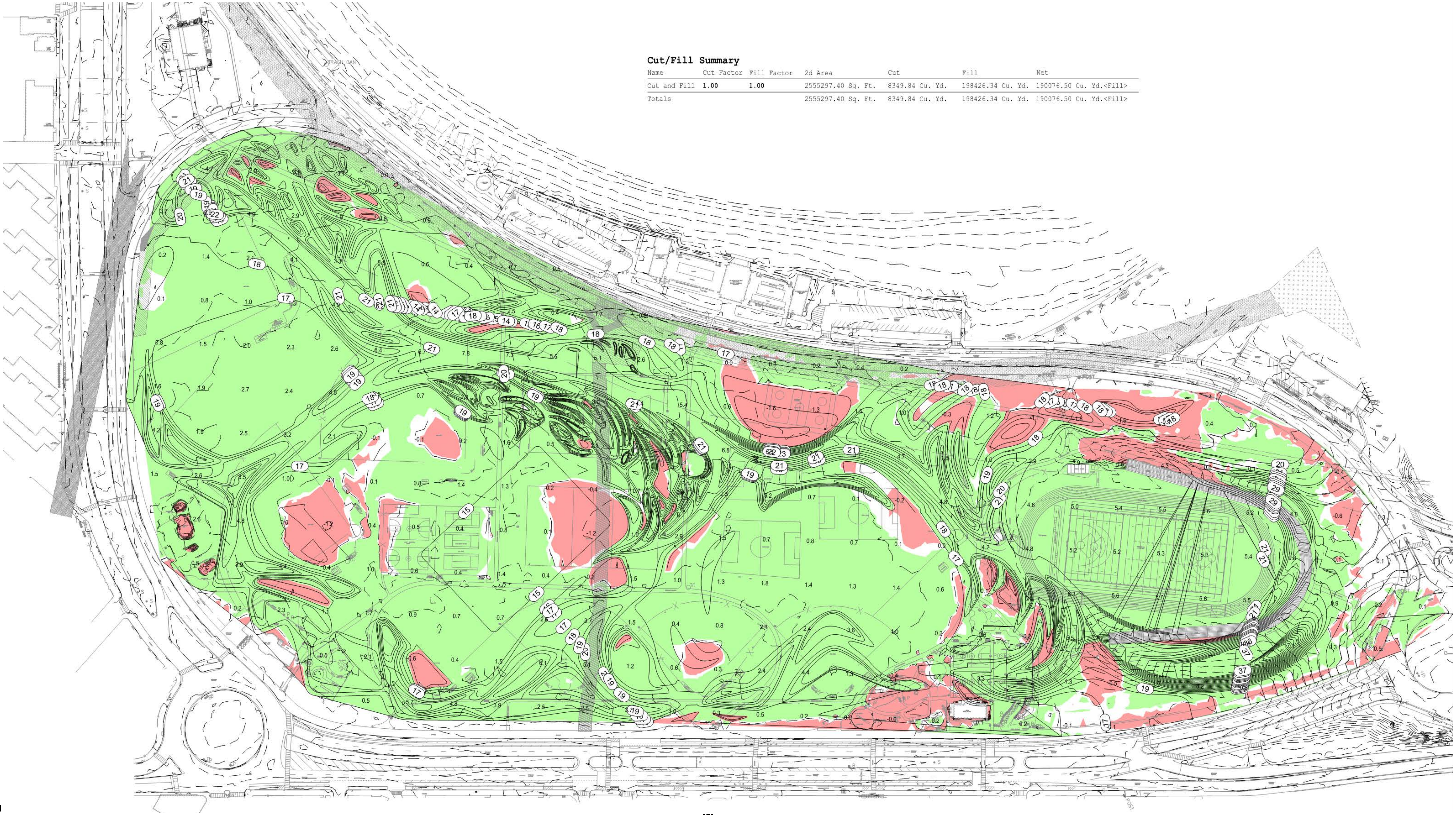
- Consolidation Settlement of the Organics/Clay
- Approx. 2 to 4 ft. of Settlement Possible
- Impacts to Buried Utilities
- Loss of Freeboard along Flood Barrier
- Impacts to Adjacent Roads and Utilities
- Slope Instability along the Flood Barrier

Poor Bearing for Proposed Structures

- Deep Foundations Required for Heavily Loaded Bldgs. (e.g, Piles, Drilled Shafts, Ground Improvement, etc.)

PRELIMINARY PROPOSED GRADING

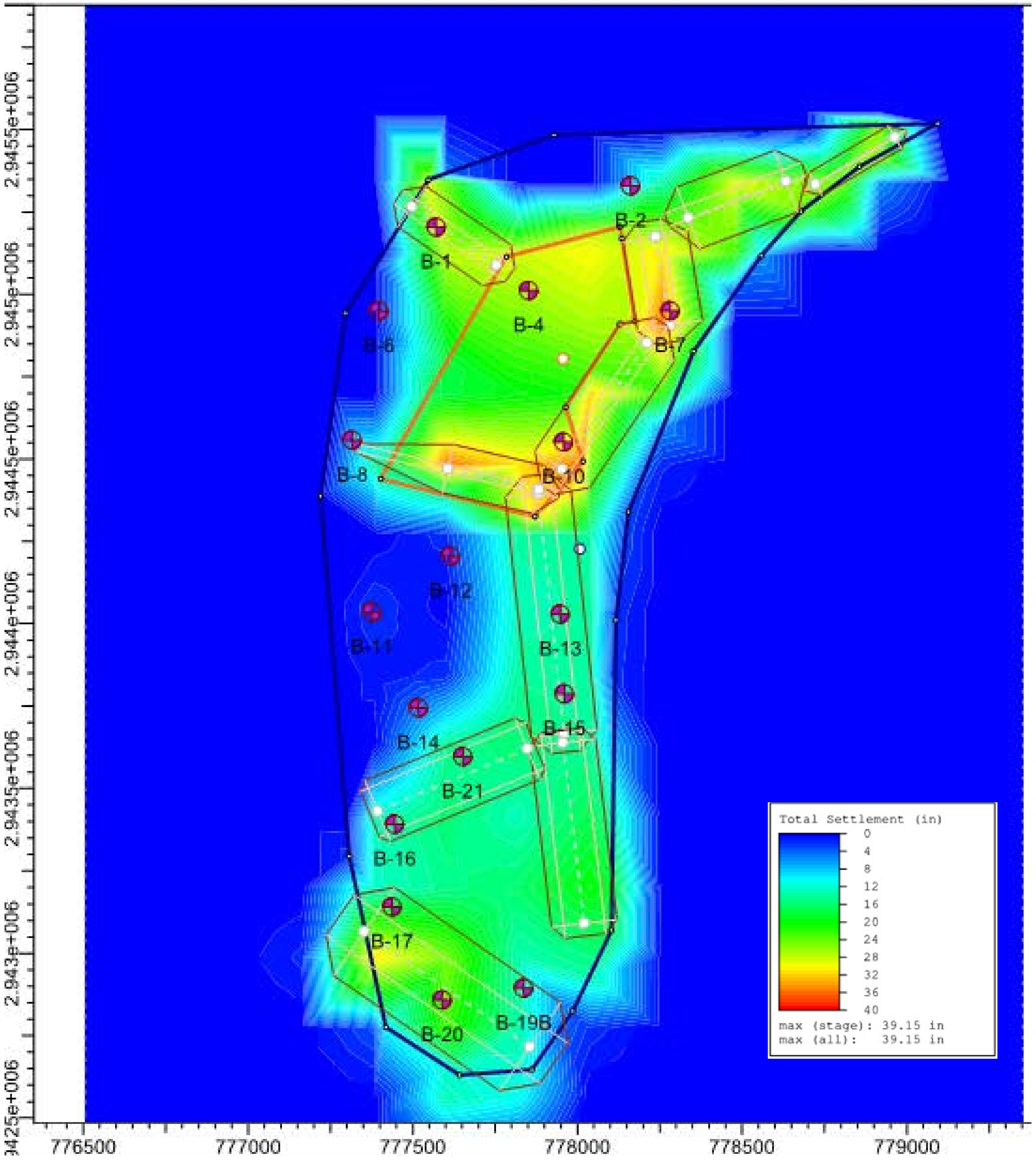
CUT (RED) AND FILL (GREEN) GRADING PLAN

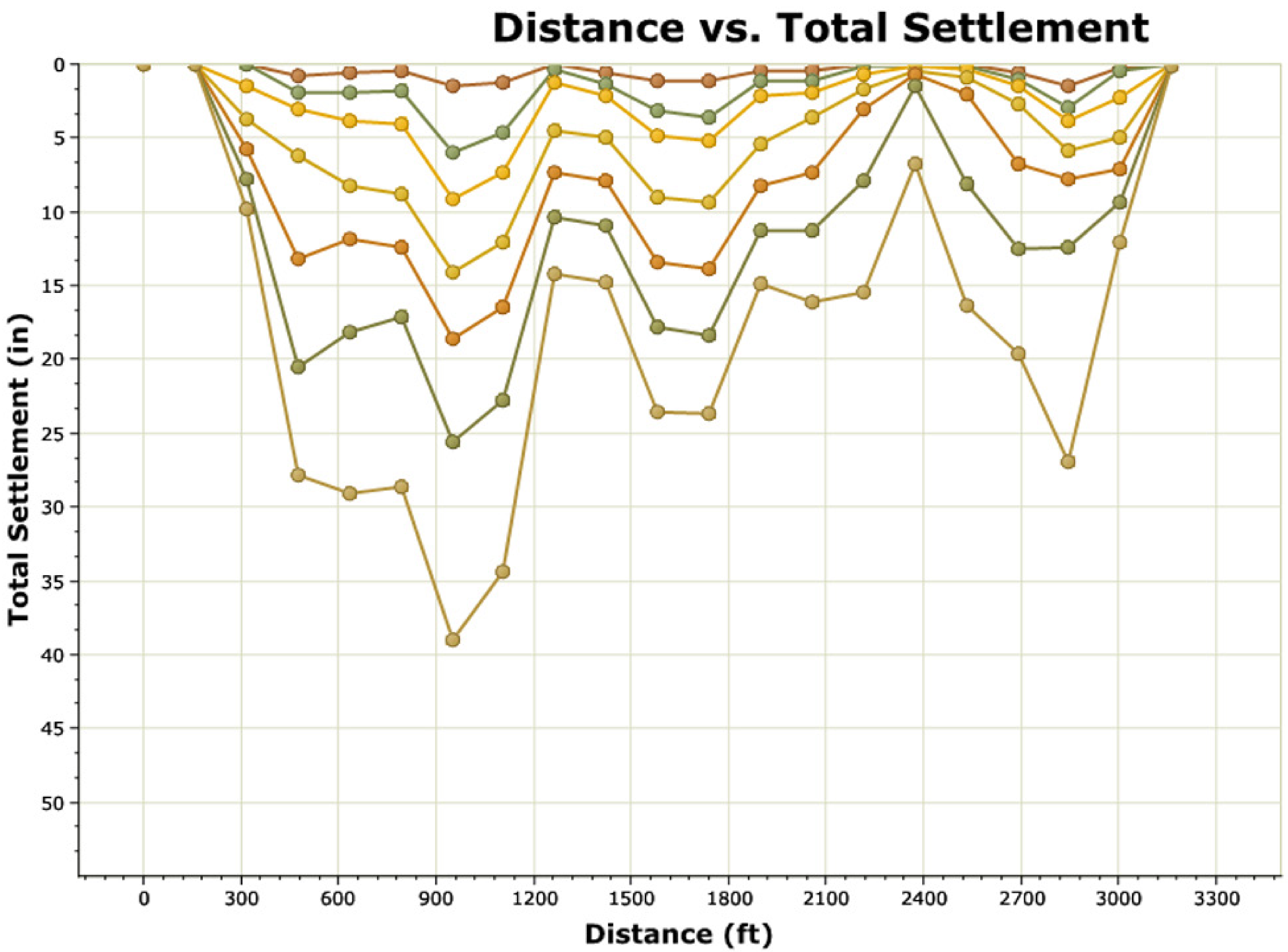


Cut/Fill Summary

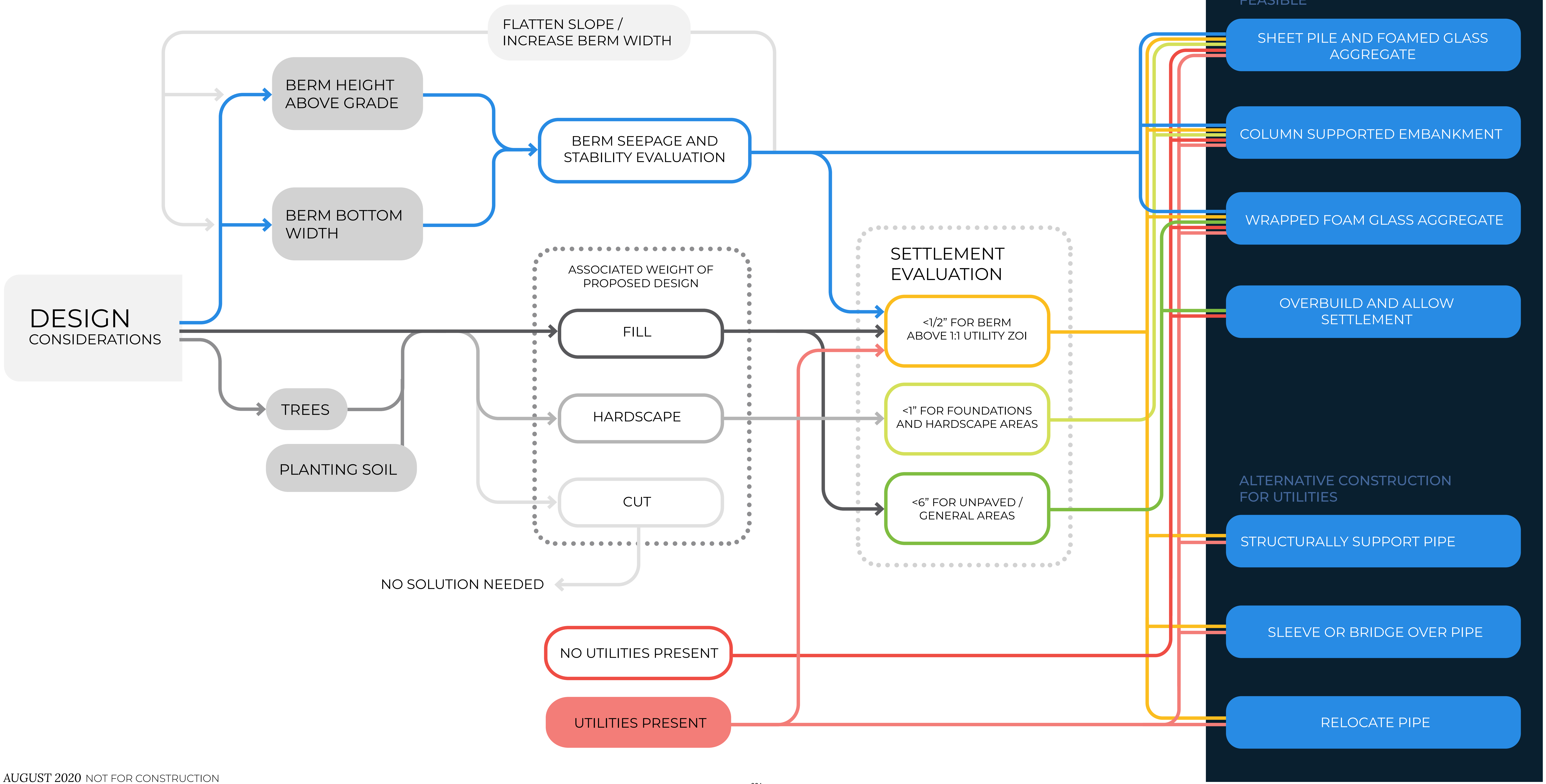
Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
Cut and Fill	**1.00**	**1.00**	2555297.40 Sq. Ft.	8349.84 Cu. Yd.	198426.34 Cu. Yd.	190076.50 Cu. Yd.<Fill>
Totals			2555297.40 Sq. Ft.	8349.84 Cu. Yd.	198426.34 Cu. Yd.	190076.50 Cu. Yd.<Fill>

PRELIMINARY SETTLEMENT ESTIMATES - NORMAL WEIGHT FILL



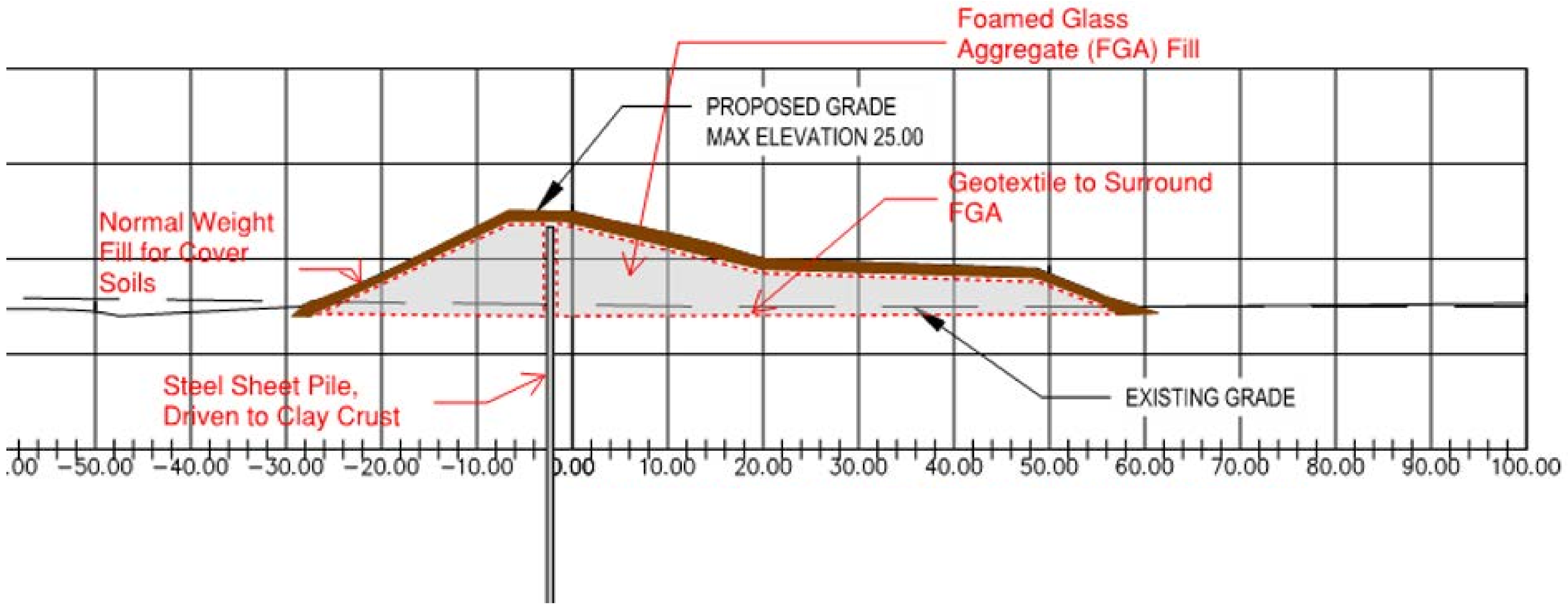


CONSTRUCTION DECISION FLOW DIAGRAM



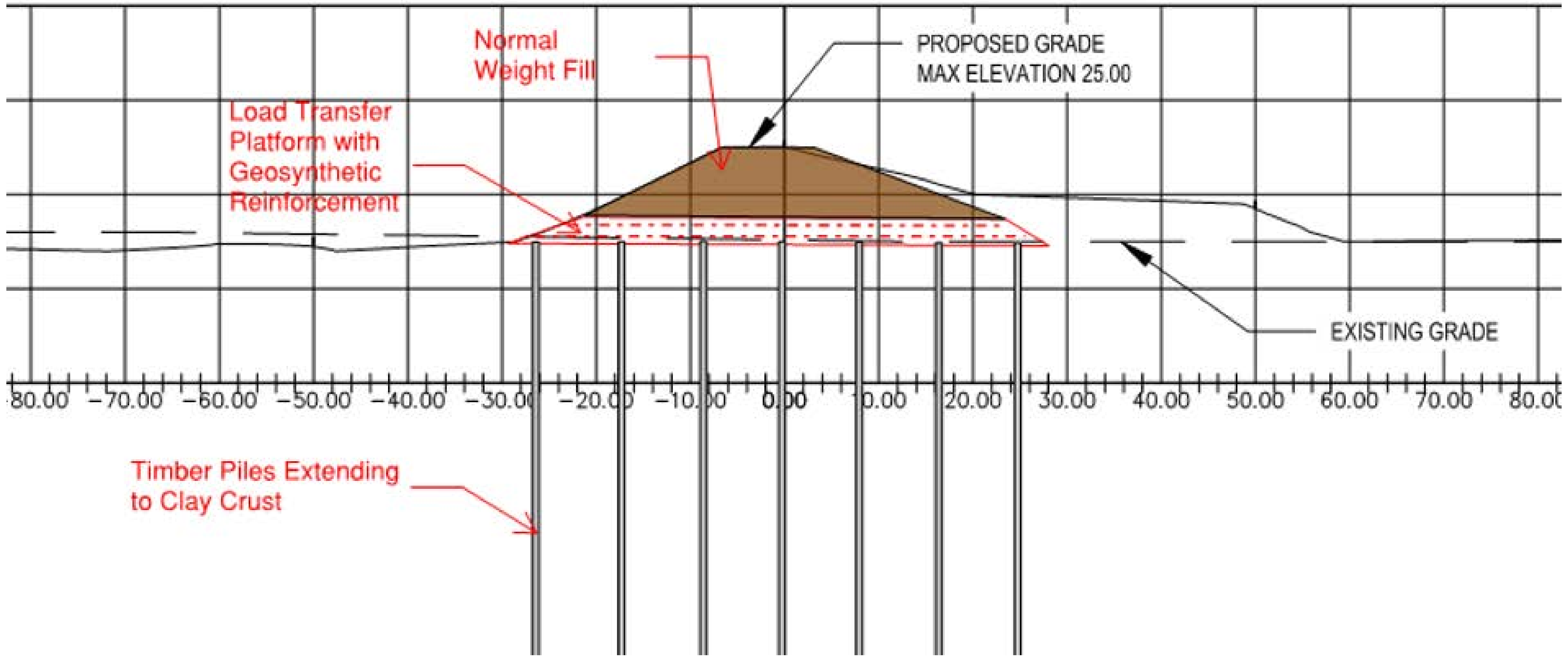
SHEET PILE AND FOAMED GLASS AGGREGATE

- Pile Cutoff Wall
  - Seepage Cutoff during Flood Events
- Lightweight Fill to Mitigate Settlement due to Grade Increases



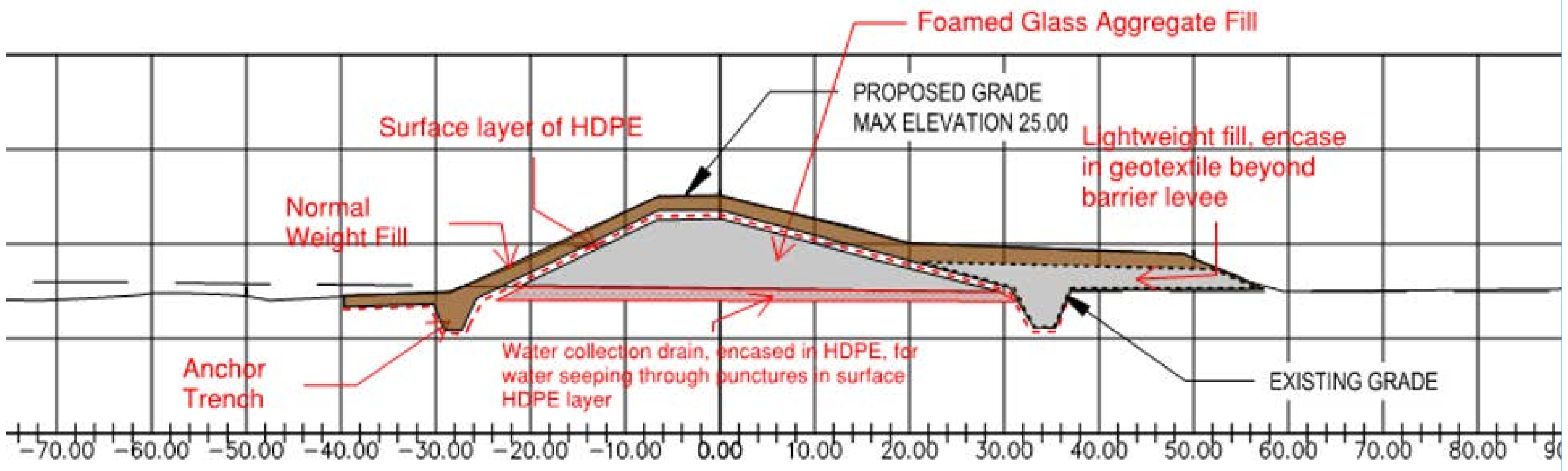
COLUMN SUPPORTED EMBANKMENT

- Pile or Ground Improvement Supported Embankment
- Reinforced Load Transfer Platform to Span Between Elements
- Normal Weight Fill or a Combination of Lightweight Fill Embankment



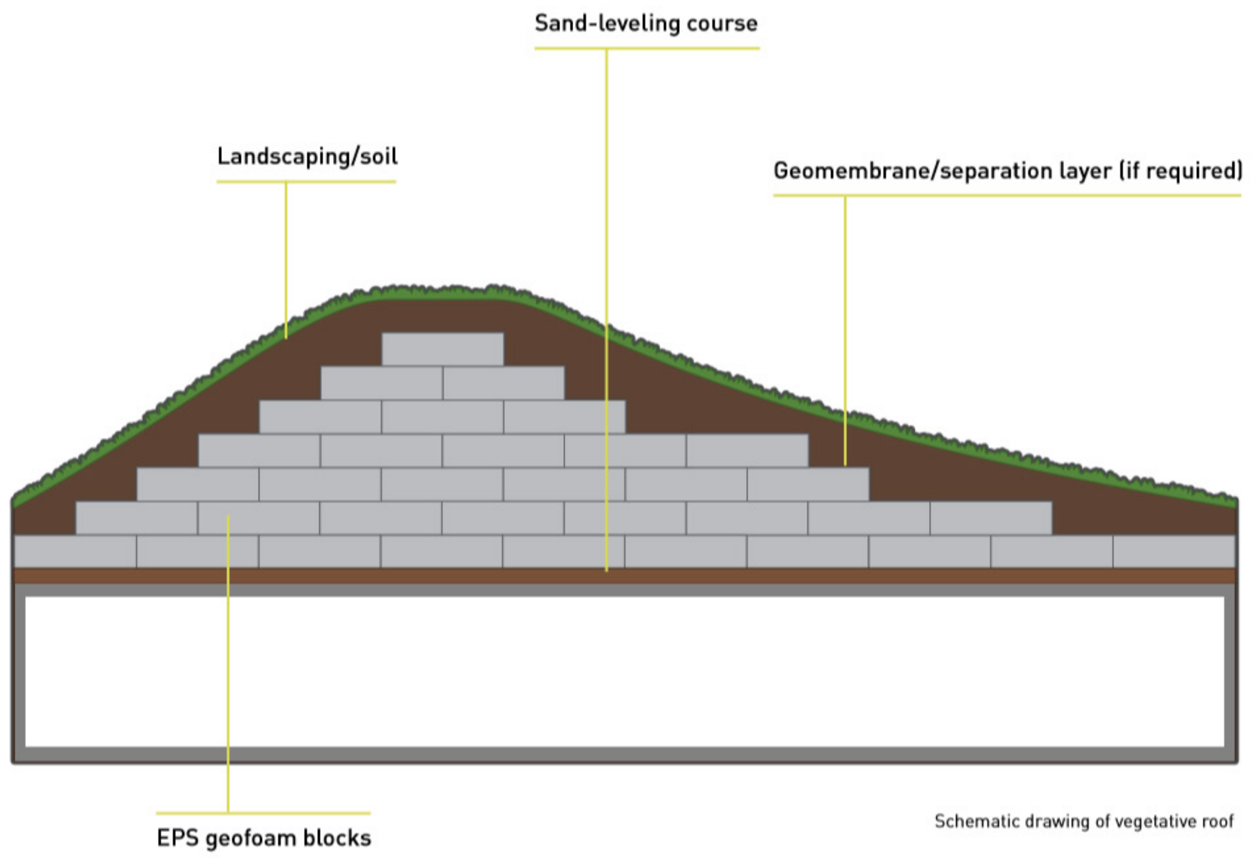
WRAPPED FOAM GLASS AGGREGATE

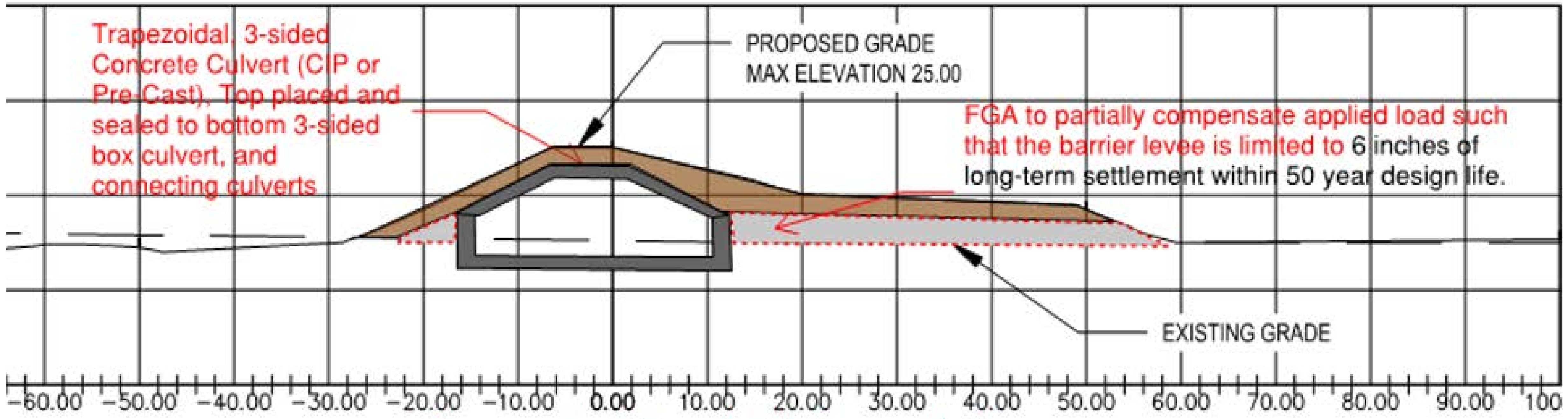
- Foamed Glass Aggregate (~20 PCF)
- Wrapped in HDPE Liner to Prevent Seepage and Uplift
- Interior Drain to Collect Potential Water Intrusion
- Normal Weight Soil Fill Cap for Plantings and Uplift Resistance



ALTERNATIVES
OTHER OPTIONS CONSIDERED

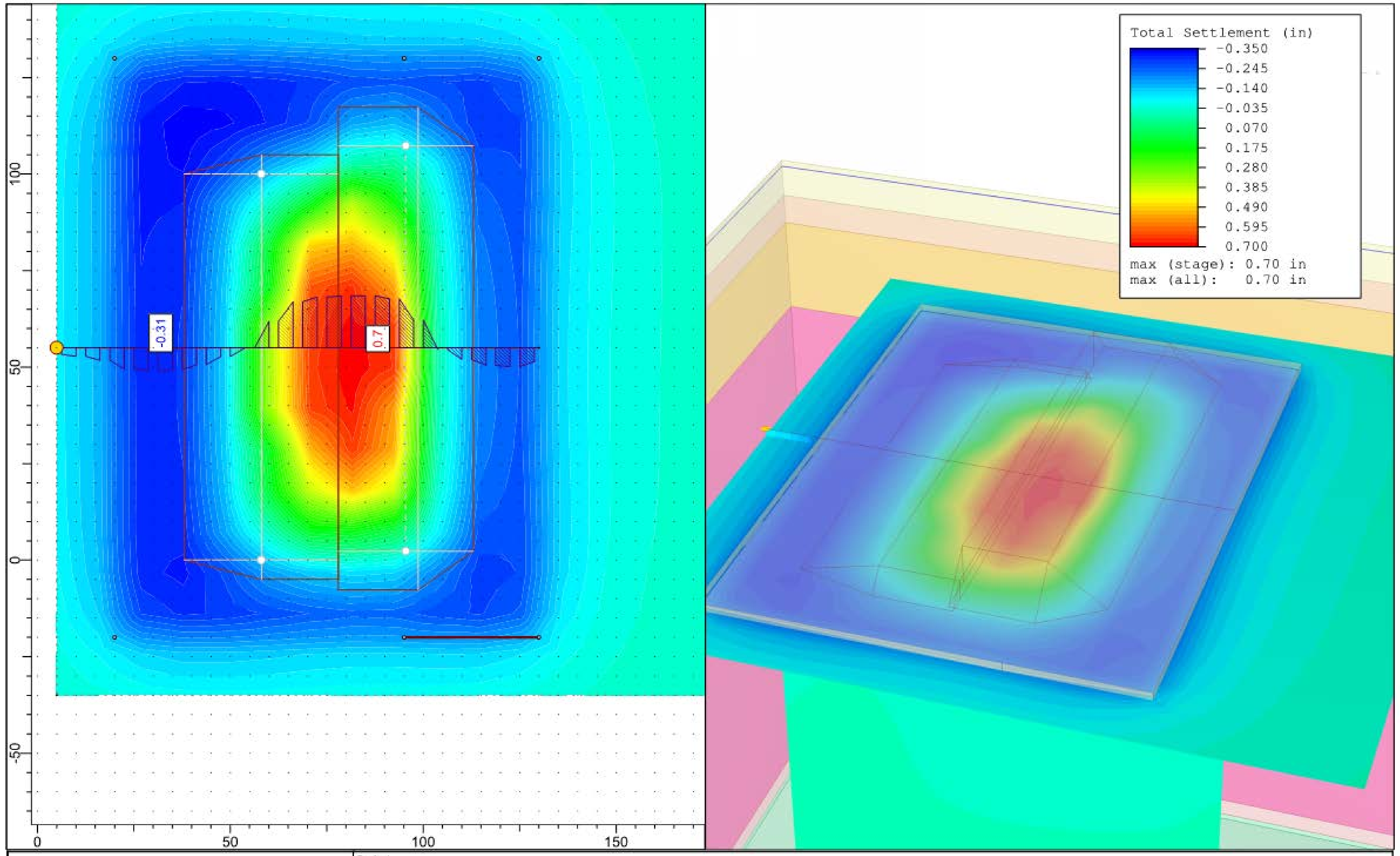
- EPS Block (Geofoam) Lightweight Fill
- Extremely Lightweight (~2 PCF)
- Susceptible to Uplift due to Buoyancy
- Pre-cast Concrete Culvert Along Interior of Barrier Alignment





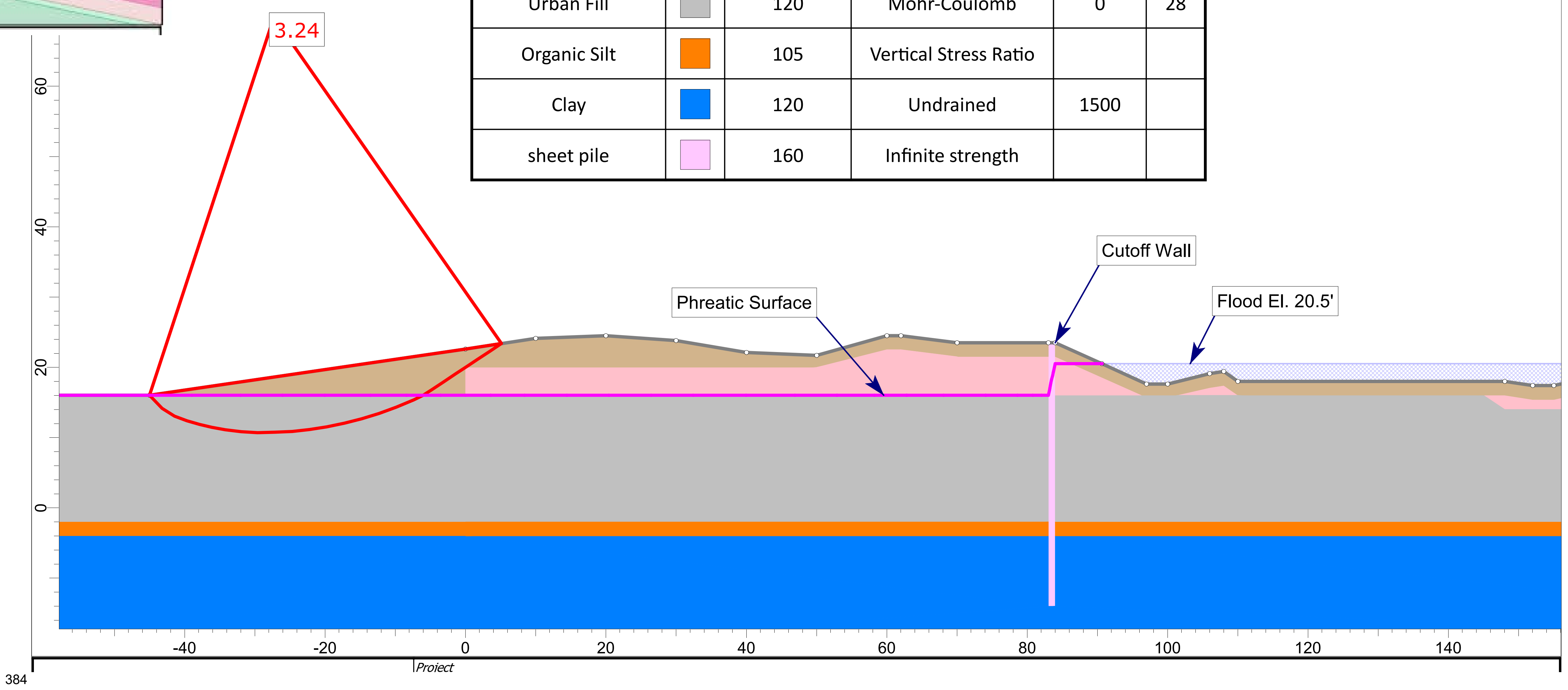
- Overexcavate existing soils to limit new applied pressure.
- Culverts will serve as emergency stormwater cistern during flash flooding. Drained/pumped out after storm. (Although need to consider temporary water weight on settlement).

GEOTECHINCAL ENGINEERING ANALYSES



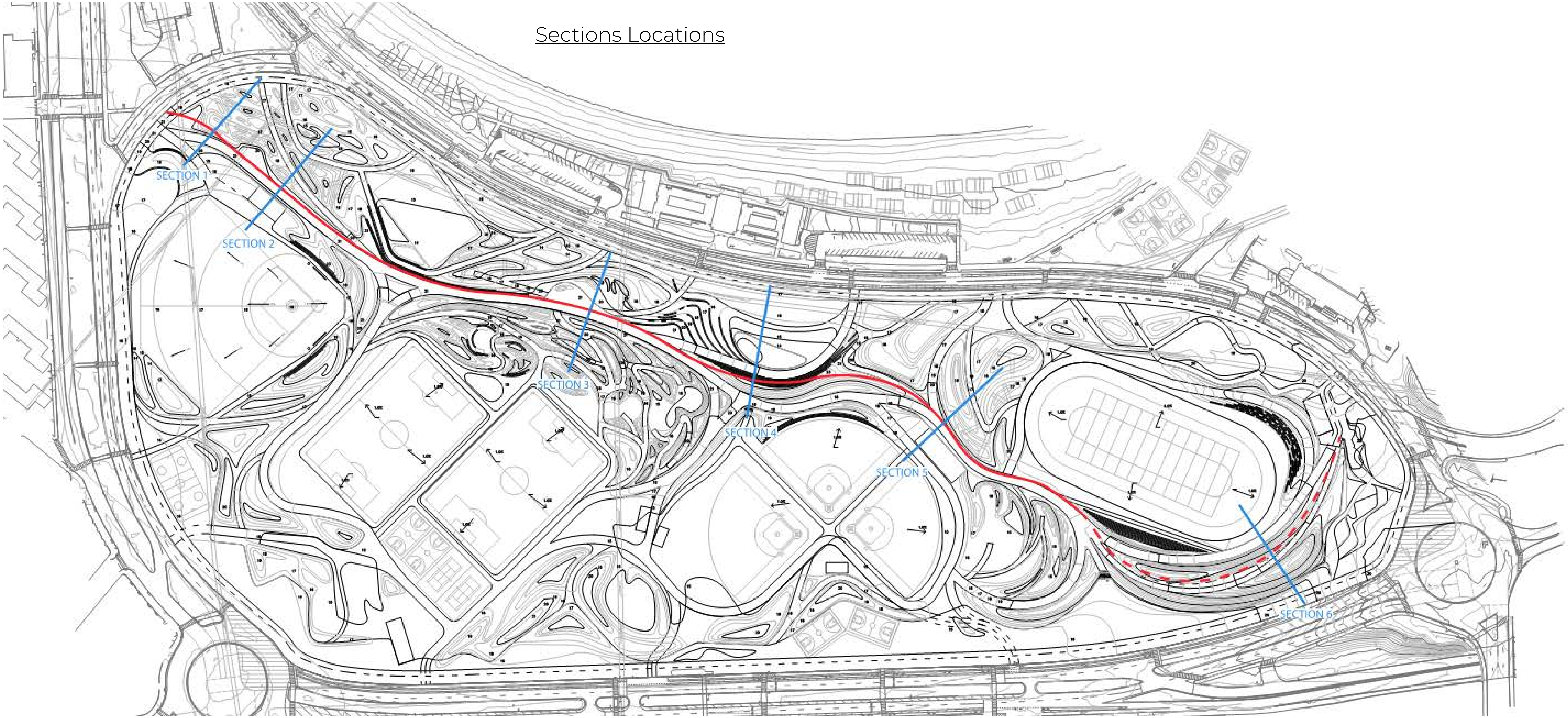
Estimated Settlement Due to New Loads

Slope Stability and Seepage Models



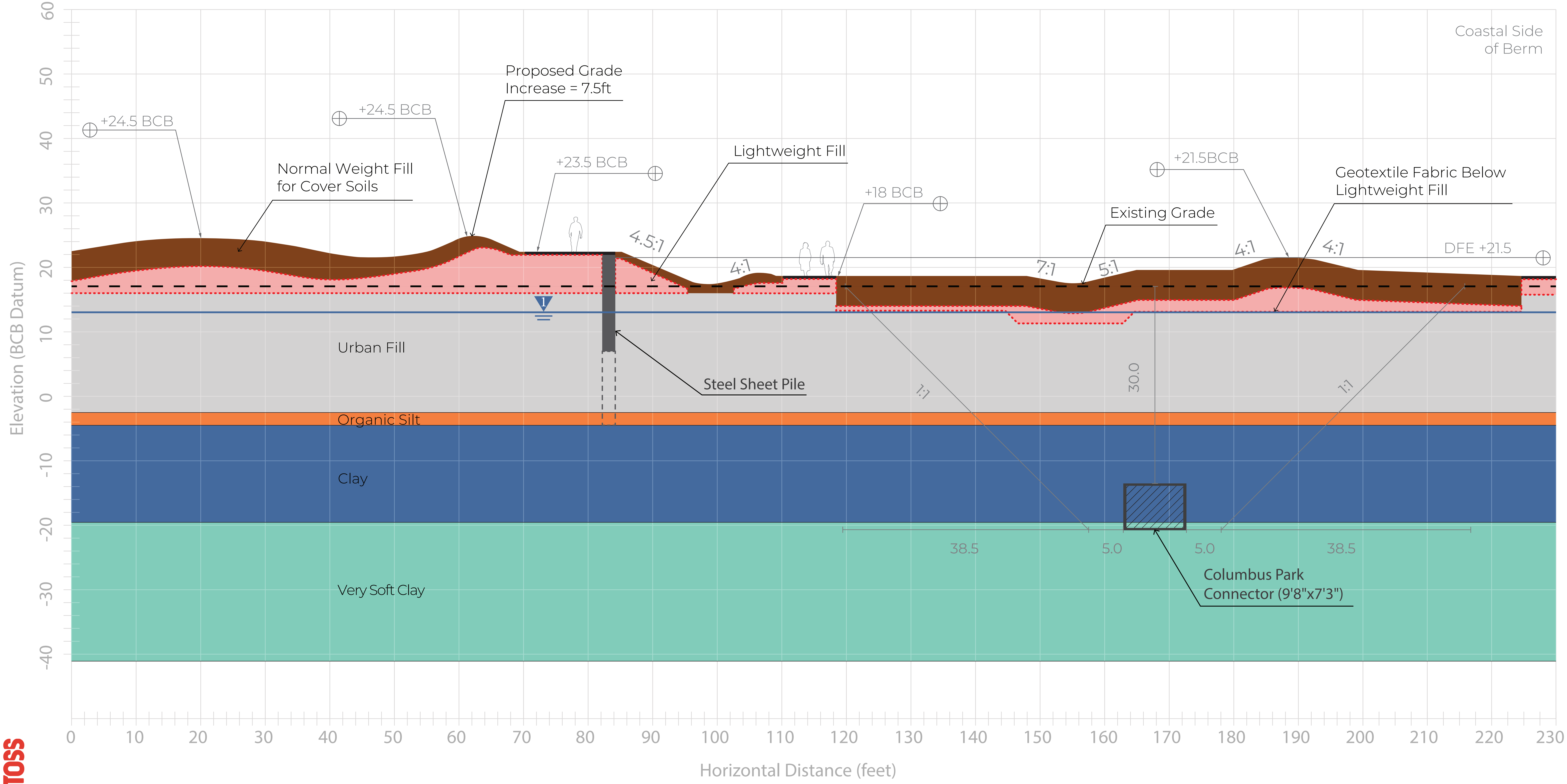
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
FGA Fill		20	Mohr-Coulomb	0	38
Normal Weight Fill		120	Mohr-Coulomb	0	34
Urban Fill		120	Mohr-Coulomb	0	28
Organic Silt		105	Vertical Stress Ratio		
Clay		120	Undrained	1500	
sheet pile		160	Infinite strength		

PRELIMINARY FLOOD BARRIER DESIGN



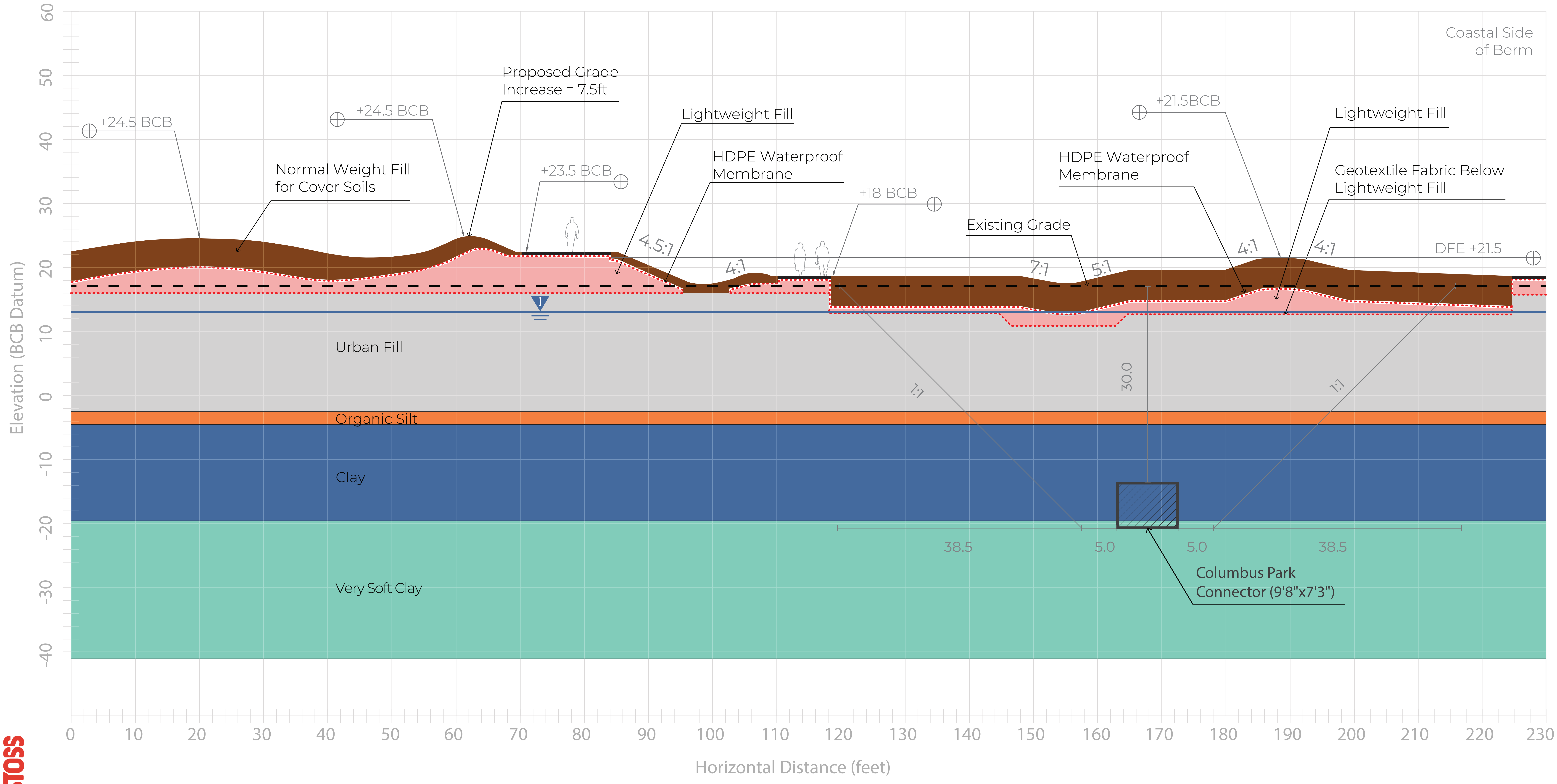
SECTION 1

Option A: Lightweight Fill and Interior Core Wall



SECTION 1

Option B: Lightweight Fill

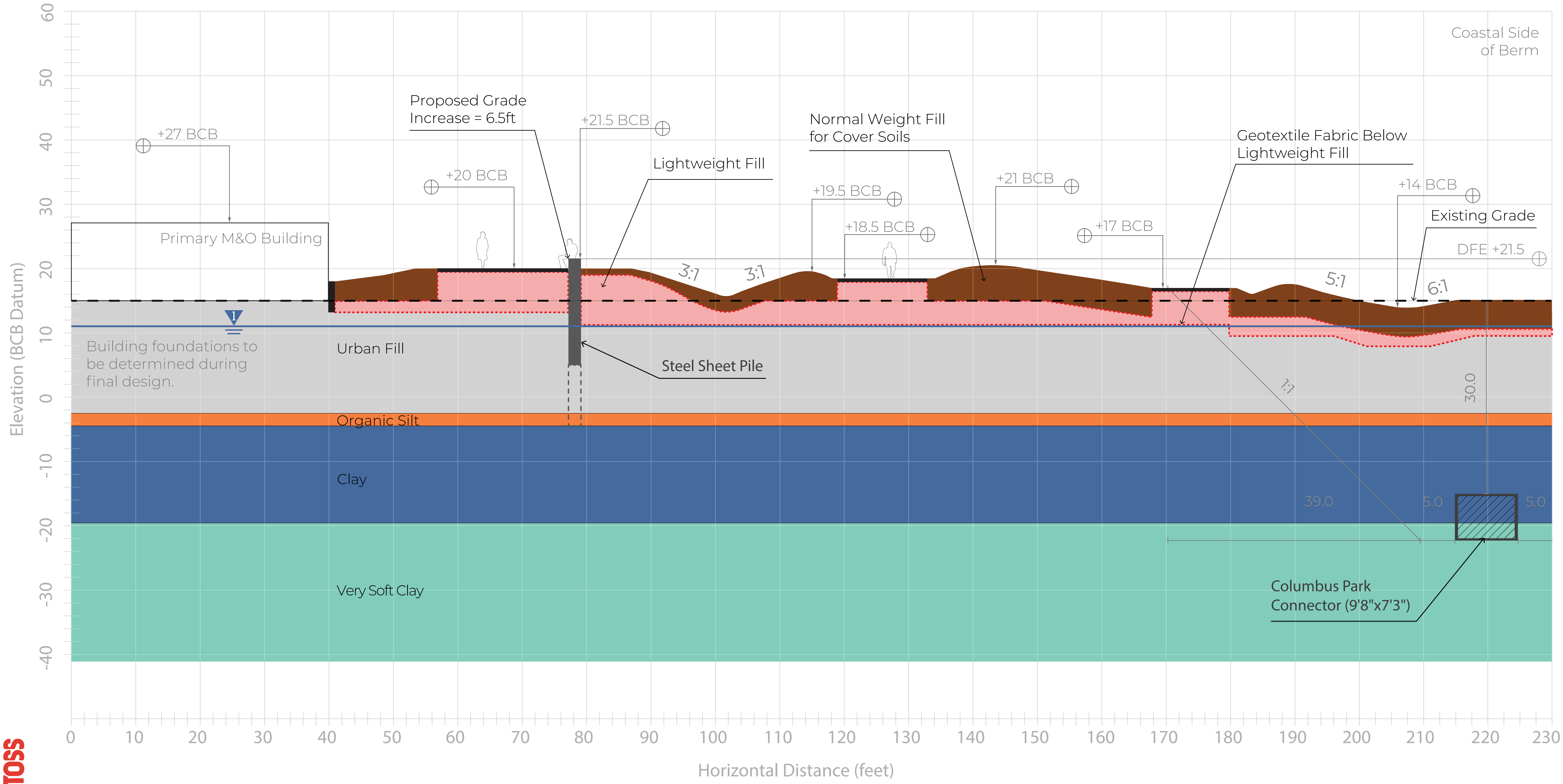


STOSS

AUGUST 2020

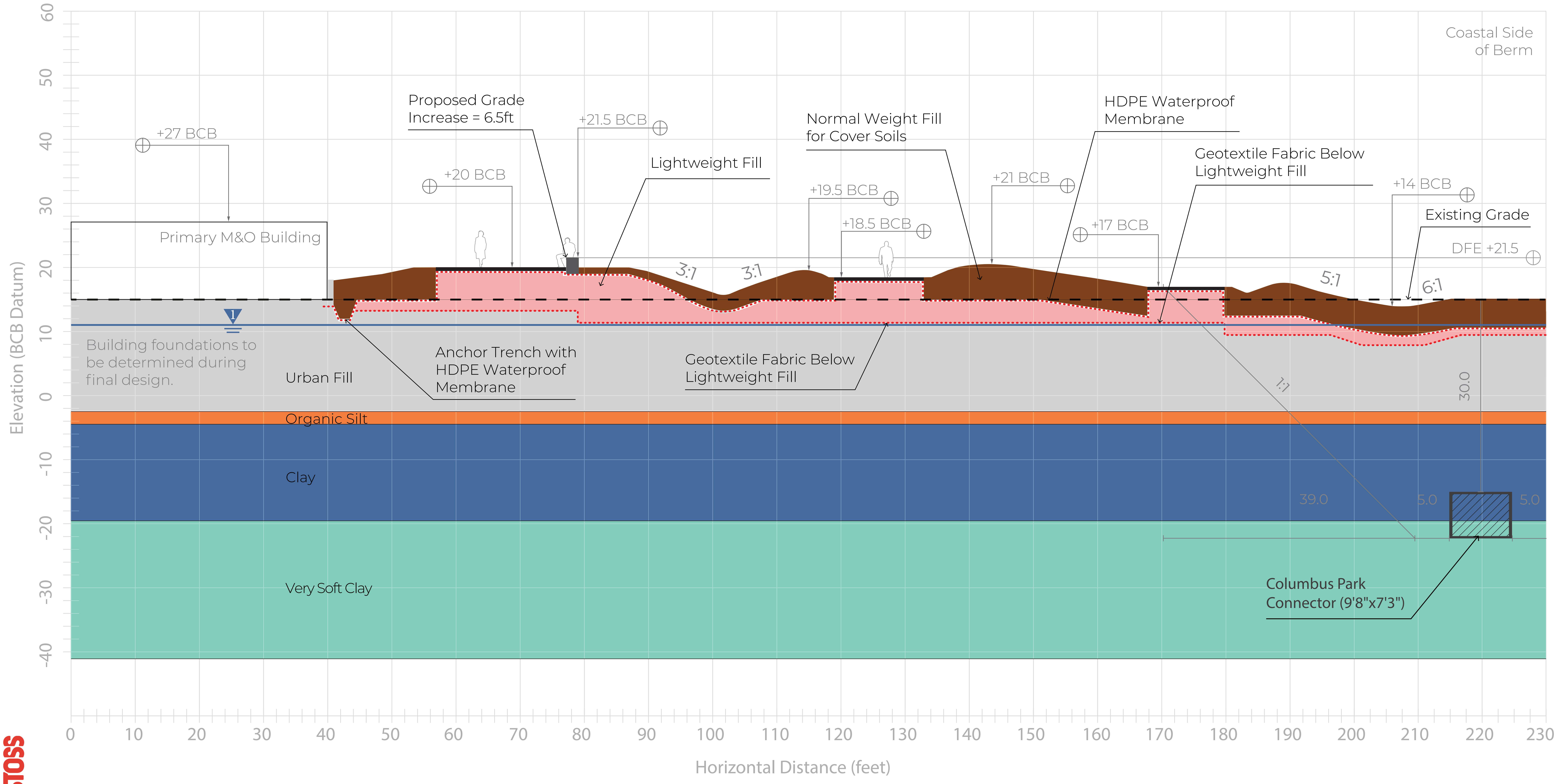
SECTION 2

Option A: Lightweight Fill and Interior Core Wall



SECTION 2

Option B: Lightweight Fill

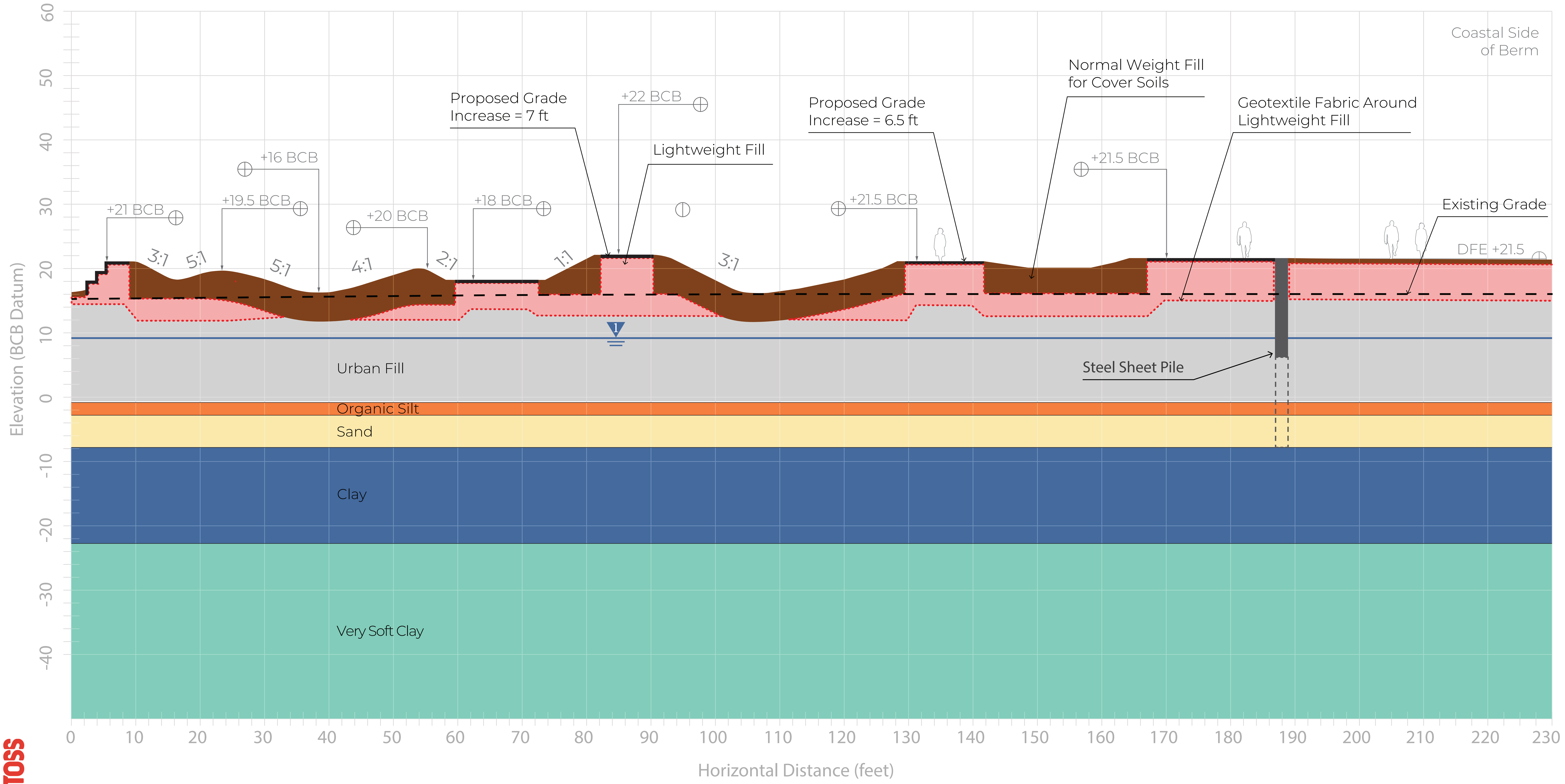


STOSS

AUGUST 2020

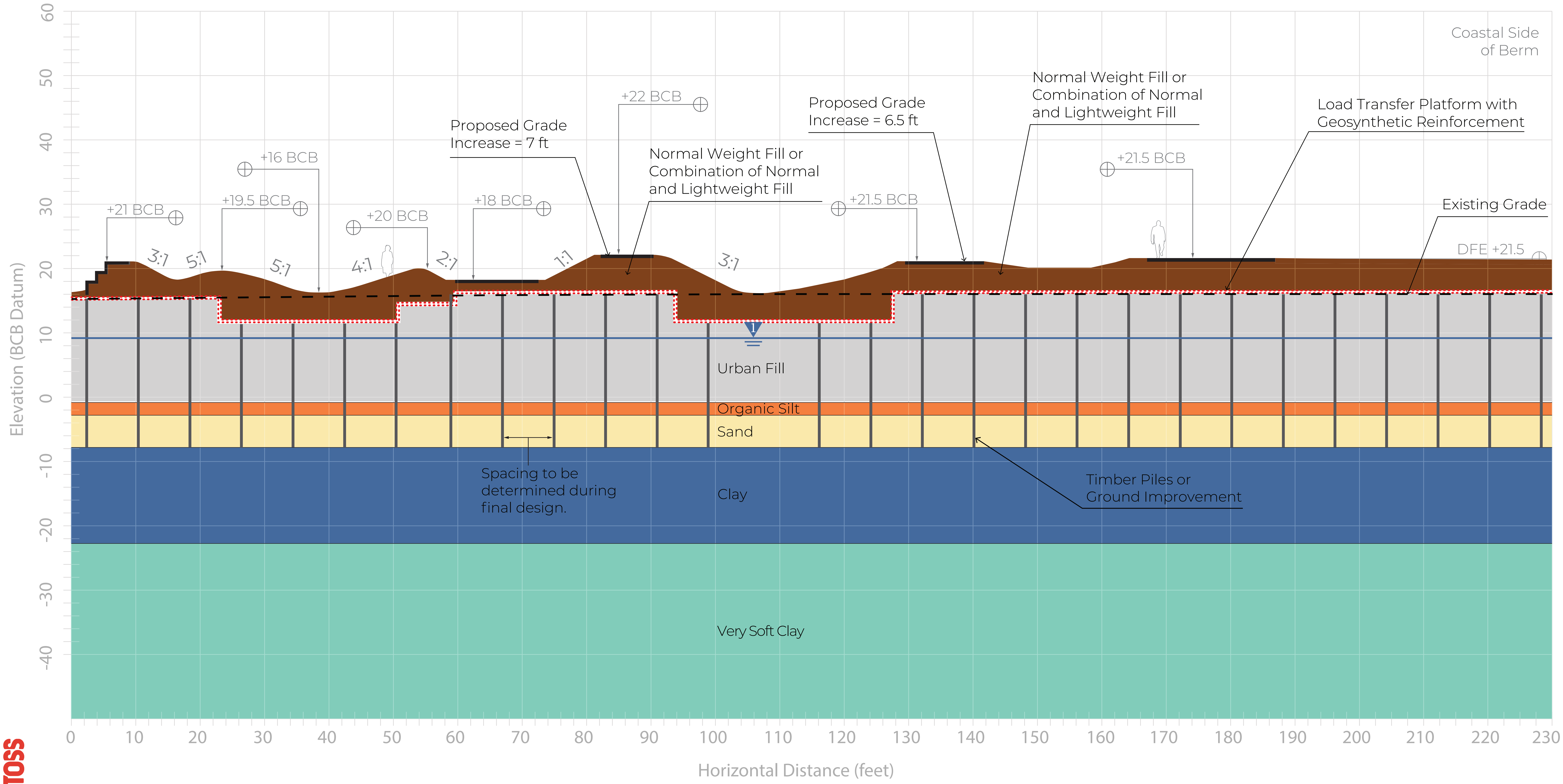
SECTION 3

Option A: Lightweight Fill and Interior Core Wall



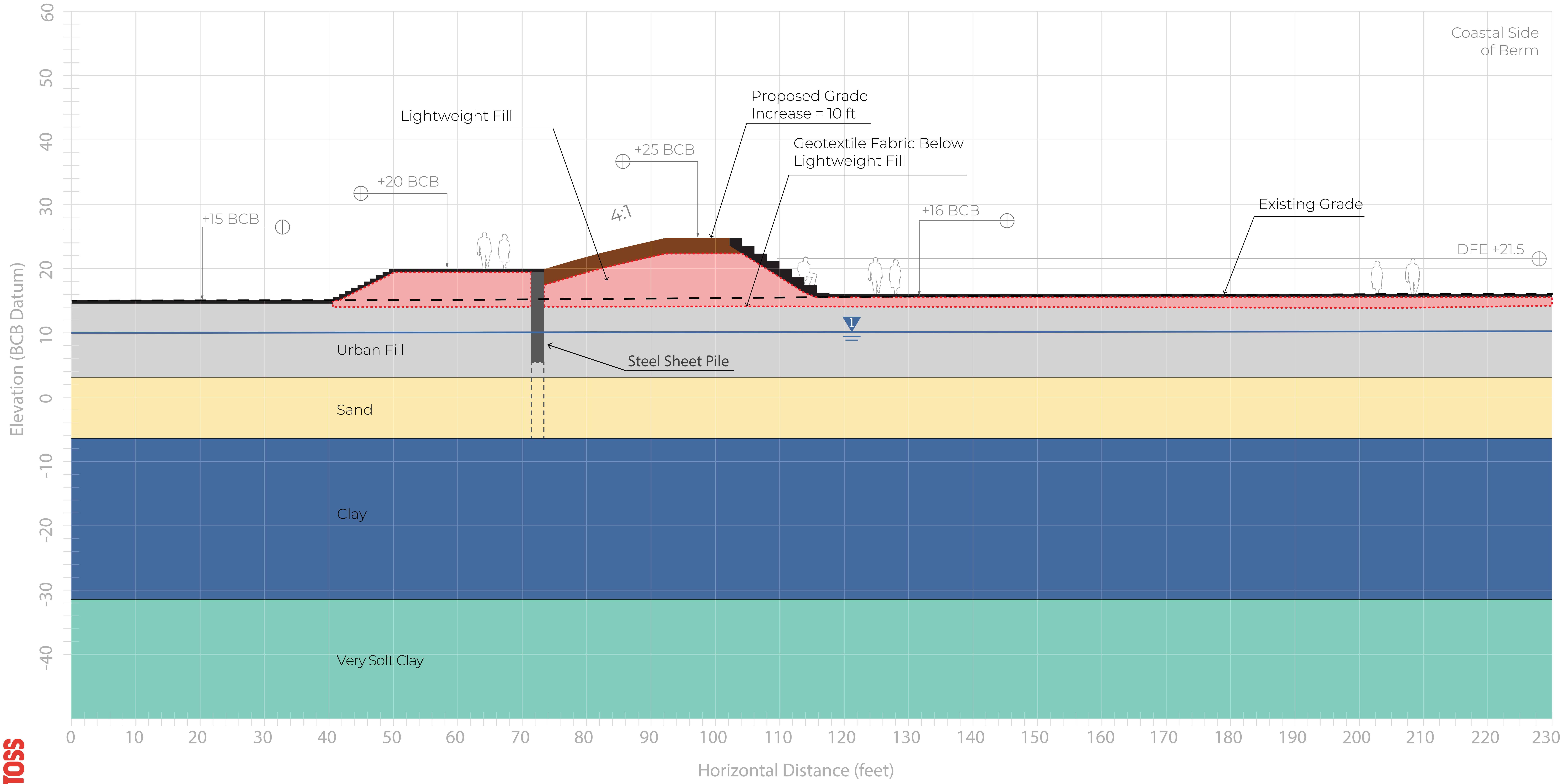
SECTION 3

Option B: Column Supported Embankment



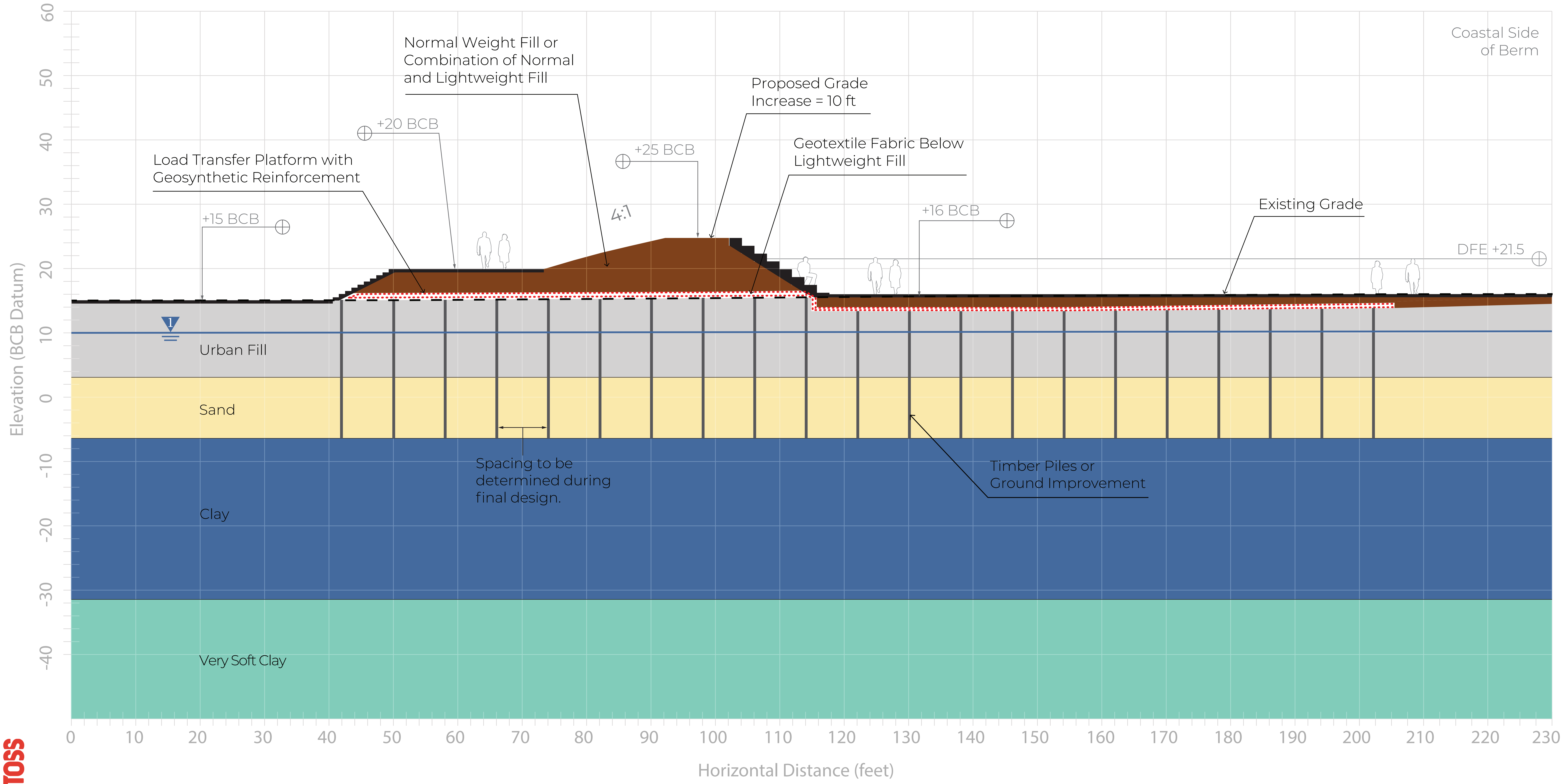
SECTION 4

Option A: Lightweight Fill and Interior Core Wall



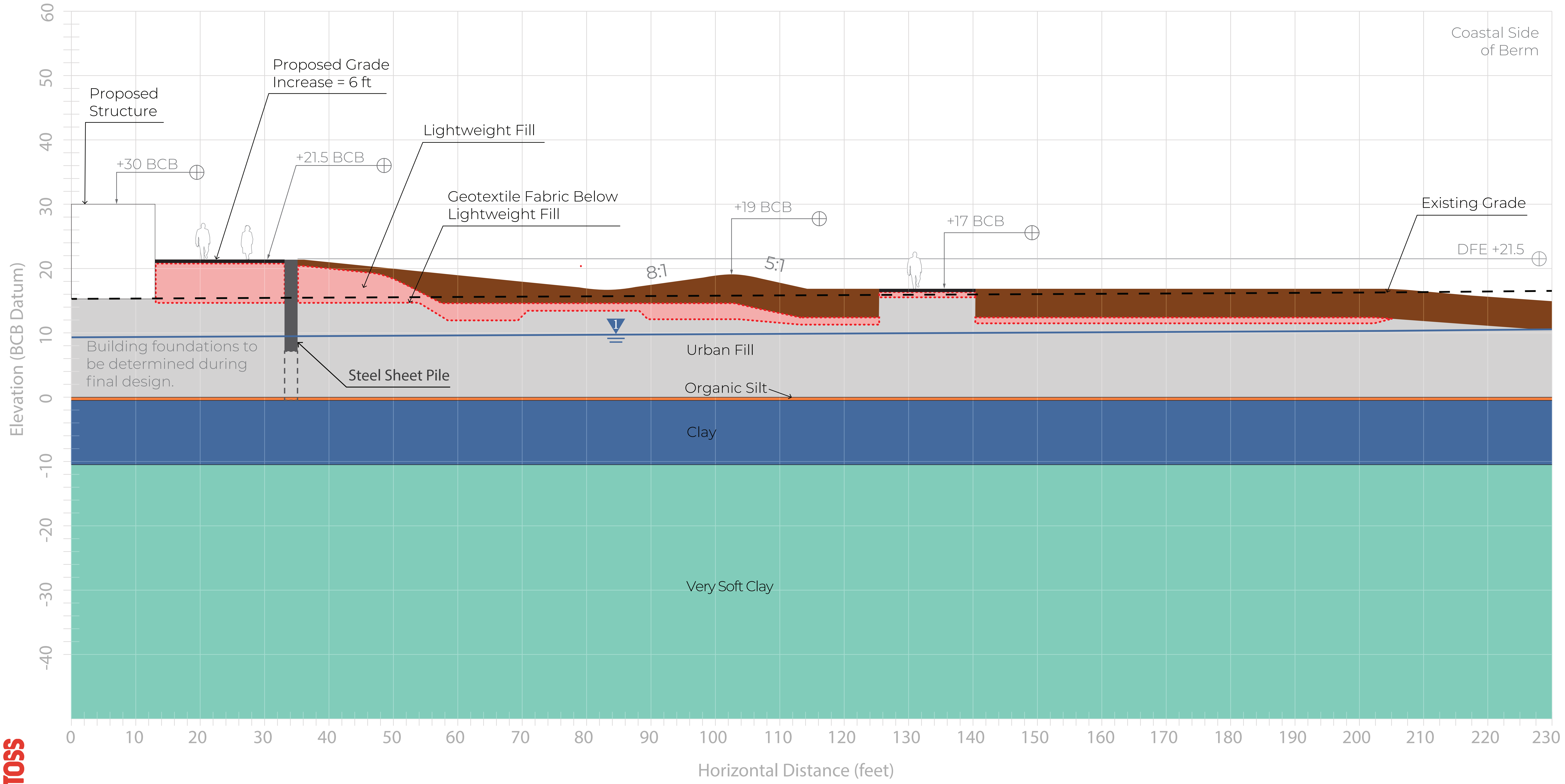
SECTION 4

Option B: Column Supported Embankment



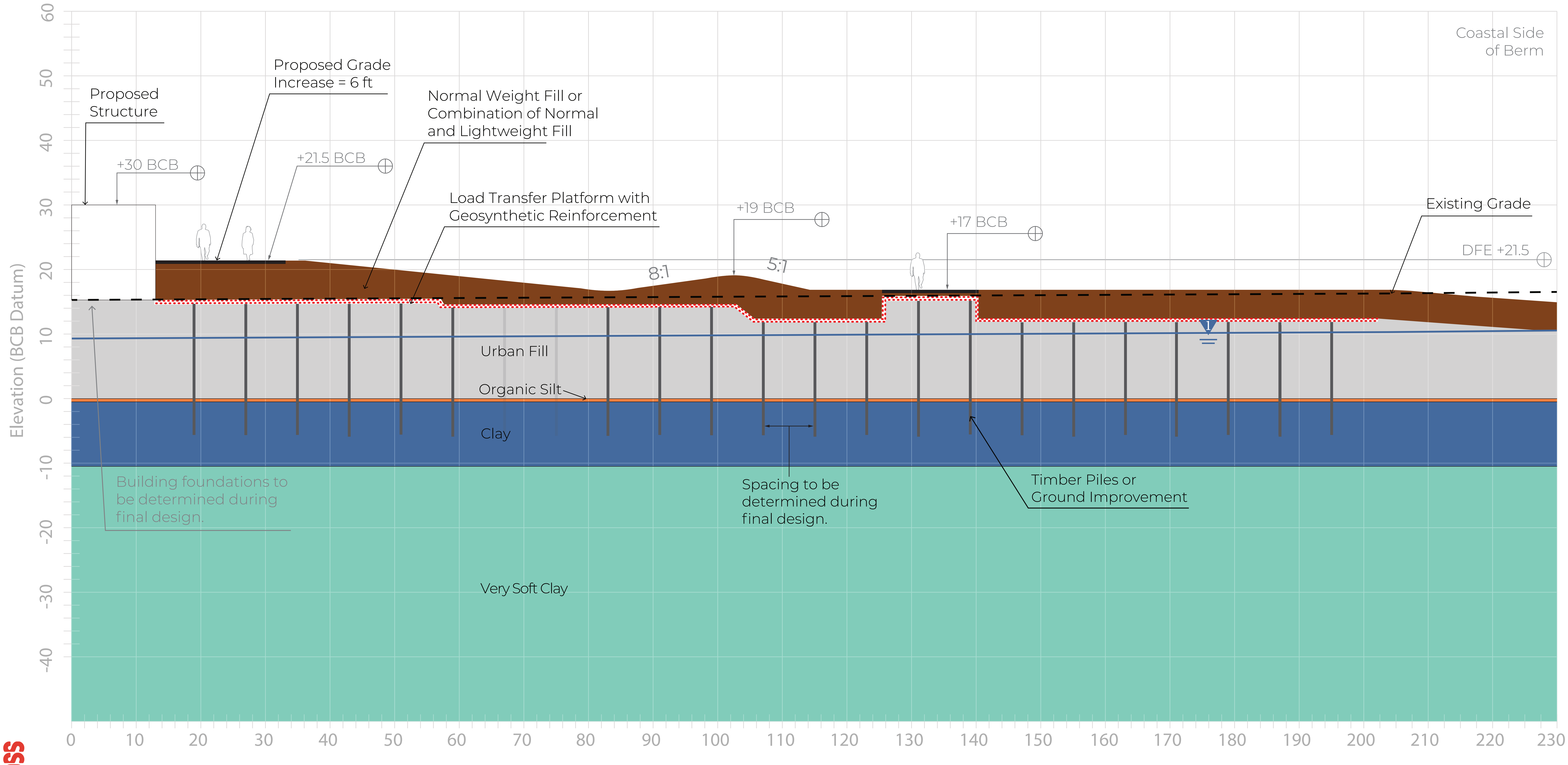
SECTION 5

Option A: Lightweight Fill and Interior Core Wall



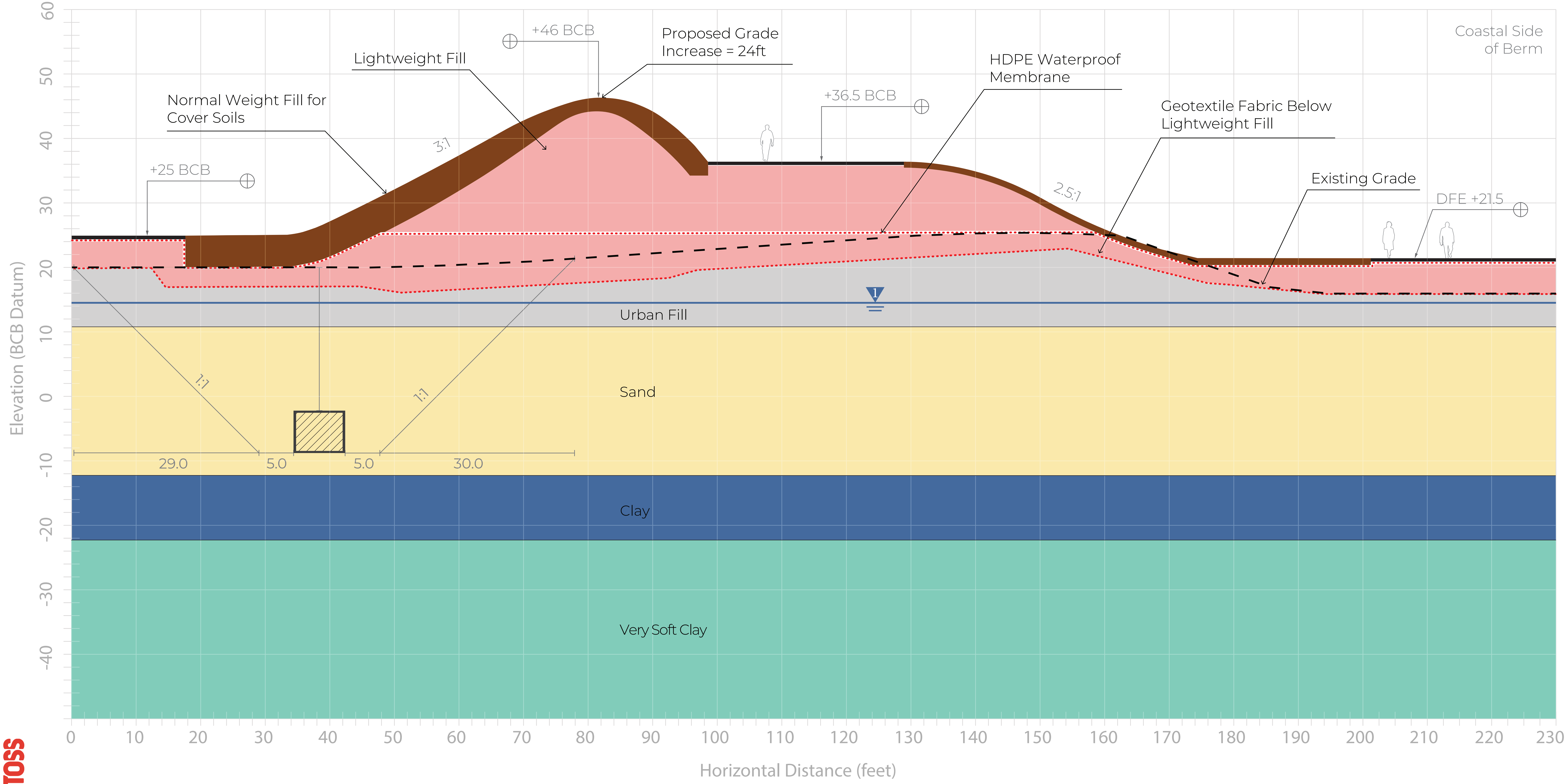
SECTION 5

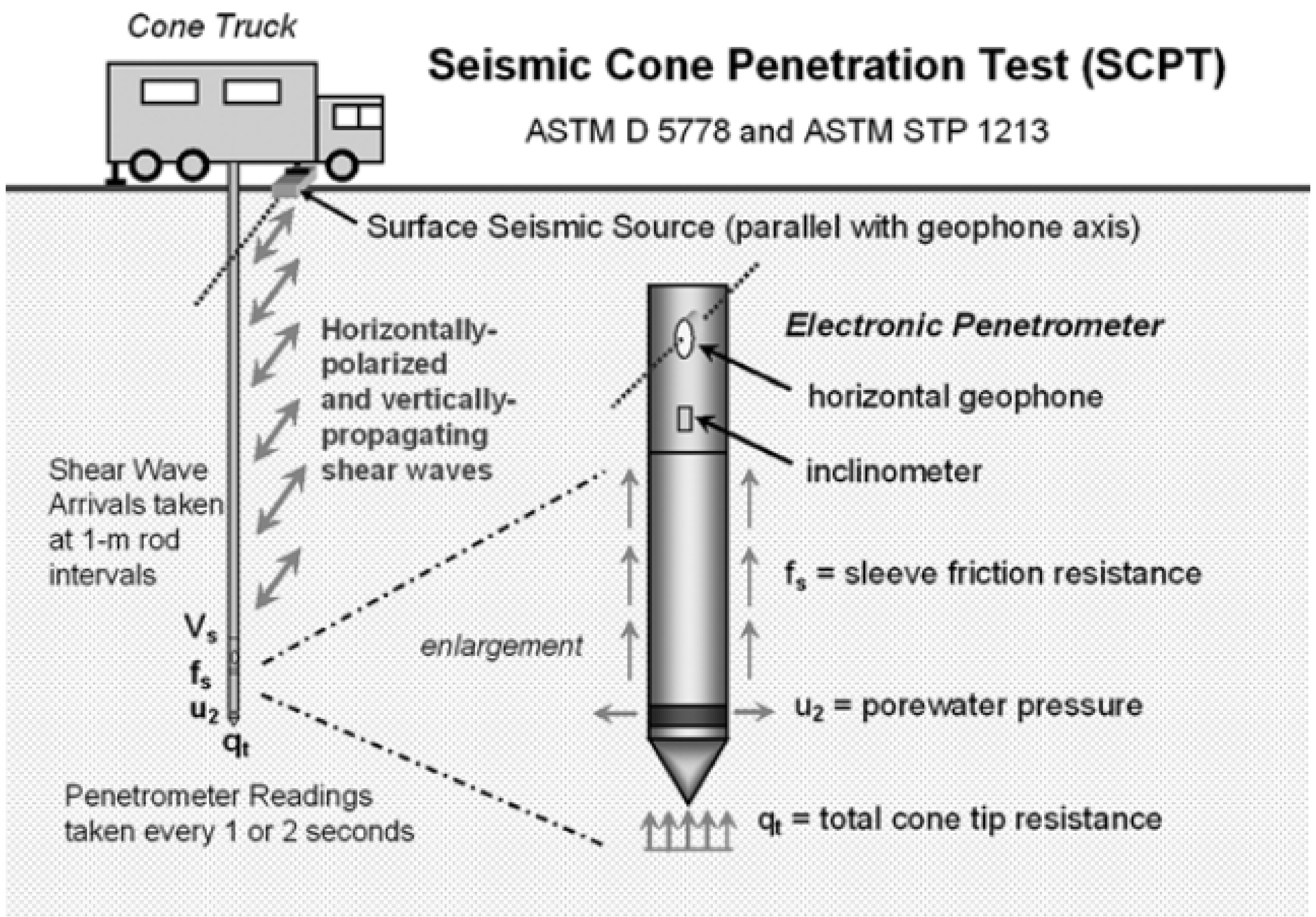
Option B: Column Supported Embankment



SECTION 6

Option A: Lightweight Fill





NEXT STEPS IN THE GEOTECHNICAL DESIGN

DESIGN PHASE GEOTECHNICAL EXPLORATIONS

SPT and CPT Explorations

- Evaluate Thickness and Strength of Clay Crust
- More Deep Explorations to Evaluate Strength Profile

Additional Laboratory Testing

- Soil Strength and Compressibility Testing

More Groundwater Monitoring Wells

ENGINEERING ANALYSES

Update Settlement, Slope Stability and Seepage Models

Incorporate CPT and Lab Soil Parameters

UPDATED STORMWATER MANAGEMENT PLAN

NITSCH ENGINEERING

- STORMWATER MANAGEMENT PLAN FOR REVISED LANDSCAPE DESIGN
- TRC FORM

Building better communities with you

Moakley Park Concept Verification: Task 1.3 Stormwater Design

Submitted to
Stoss
June 16, 2020
Nitsch #12462.1

Nitsch Engineering

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Table 8	Summary of Green Infrastructure Techniques and Sizing

Acronyms

BCB	Boston City Base Datum
BPRD	Boston Parks and Recreation Department
BWSC	Boston Water and Sewer Commission
CSO	Combined Sewer Overflow
H&H	Hydraulic and Hydrologic
HydroCAD	Computer Aided Design Tool for Modeling Stormwater Runoff
MWRA	Massachusetts Water Resources Authority
NOAA	National Oceanic and Atmospheric Administration
PCSWMM	Storm Water Management Model
TSS	Total Suspended Solids

SECTION 1
Introduction

Moakley Park is located in the Dorchester area of Boston, Massachusetts. The site is owned by Boston Parks and Recreation and is approximately 57 acres. It is bounded by Columbia Road to the north, William J Day Boulevard to the east, Columbia Road and Old Colony Avenue to the west, and Columbia Circle to the south (Figure 1). Immediately to the east of the William J Day Boulevard is Carson Beach, which borders on North Dorchester Bay.

Figure 1: Site Locus

In 2017, the City of Boston Parks and Recreation Department (BPRD) initiated a transformative project at Moakley Park that redevelops the Park into a vibrant and resilient open space that can reduce the impacts of climate change and sea level rise on the surrounding community. The first phase of the project, the Vision Plan, was completed in early 2018 by the Stoss team. The Vision Plan developed a concept for Moakley Park (the Park) that proposed four key elements:

- Building an earthen berm into the landscape to reduce the impact of sea level rise and storm surge,
- Relocating playing fields,
- Reconnecting the neighborhood with the waterfront, and
- Providing sustainable stormwater management through green infrastructure and underground storage.

Following the completion of the Vision Plan, the project entered a Concept Verification Phase (Task 1.1) to further review the existing conditions and Vision Plan conceptual design elements. To support this effort, Nitsch Engineering (Nitsch) performed a preliminary hydraulic and hydrologic (H&H) analysis using PCSWMM to understand how stormwater runoff from upstream of the Park and stormwater runoff from within the Park affect each other and create flooded conditions in the Park. This analysis helped to better understand the location, conveyance capacity, and overflow contributions of the combined sewer system located within and surrounding the Park, assess various current and future rainfall and tidal conditions, and identify the potential for surcharging within the Park. In Task 1.1, the results of the analysis showed that a “no action” scenario would leave the functionality of the existing system to be heavily dependent on the BWSC/MWRA infrastructure and downstream tailwater conditions.

Task 1.1 was completed in December 2019 and the project has since entered a Preliminary Stormwater Design phase (Task 1.3), the purpose of which is to provide conceptual sizing recommendations and identify the benefits of stormwater strategies, such as green infrastructure and underground storage in the Park to mitigate stormwater flooding under present and future conditions. This technical memorandum is intended to summarize the methodology, data sources, and results of the Preliminary Stormwater Design in Task 1.3 that will lead into the Schematic Design phases.

SECTION 2

Transition from Task 1.1 to Task 1.3

2.1 Existing BWSC and MWRA Infrastructure Clarifications

Nitsch Engineering (Nitsch), the Boston Parks and Recreation Department (BPRD), Stoss Landscape Urbanism (Stoss), and Weston and Sampson met with the Boston Water and Sewer Commission (BWSC) on January 15, 2020 to discuss the findings of Task 1.1. During the meeting, BWSC provided the Project Team with the following new information regarding the stormwater infrastructure in the vicinity of the Park. This information was further discussed and confirmed with the Massachusetts Water Resources Authority (MWRA) on March 16, 2020.

- The BWSC outfalls into North Dorchester Bay include the Vale St Overflow/BOS085, the Kemp St Overflow/BOS086, and the Morrissey Blvd Storm Drain/BOS087 as depicted in Figure 2. BOS085 and BOS086 convey combined sewage while the watershed that discharges to BOS087 has been separated and consists solely of stormwater runoff.

- In addition to the BWSC infrastructure that directs stormwater and combined sewage to the MWRA Columbus Park Headhouse, there is a 17-foot-diameter MWRA tunnel located along the eastern boundary of the park. The MWRA tunnel was constructed to provide a secondary control to prevent combined sewer overflows into North Dorchester Bay. The MWRA tunnel is a Combined Sewer Overflow (CSO) system.

- The MWRA tunnel captures and stores overflow from Vale St Overflow/BOS085, the Kemp St Overflow/BOS086, and the Morrissey Blvd Storm Drain/BOS087 before pumping after each storm event to the local BWSC system for handling at Columbus Park and treatment at Deer Island. The MWRA tunnel currently controls flow during storm events as indicated in the Table 1 below, provided by the MWRA:

Table 1. South Boston CSO and Stormwater Control Strategy (source: MWRA)

Storm Size	Control Objective
Up to 1-Year Storm **~2.8" of rain in 24 hours**	Capture all CSO and stormwater in tunnel from outfalls BOS085 and BOS086. Capture all stormwater from outfall BOS087.
1- to 5-Year Storm **2.8-4" of rain in 24 hours**	Capture all CSO and stormwater in tunnel from outfalls BOS085 and BOS086. After taking in first flush from BOS087, close gate to divert BOS087 stormwater to BWSC's Morrissey Boulevard Storm Drain.
5- to 25- Year Storm **>4" of rain in 24 hours**	Close BOS085, BOS086, and BOS087 stormwater gates. Dedicate tunnel to capturing CSO up to tunnel storage capacity (25-year, 24-hour storm).

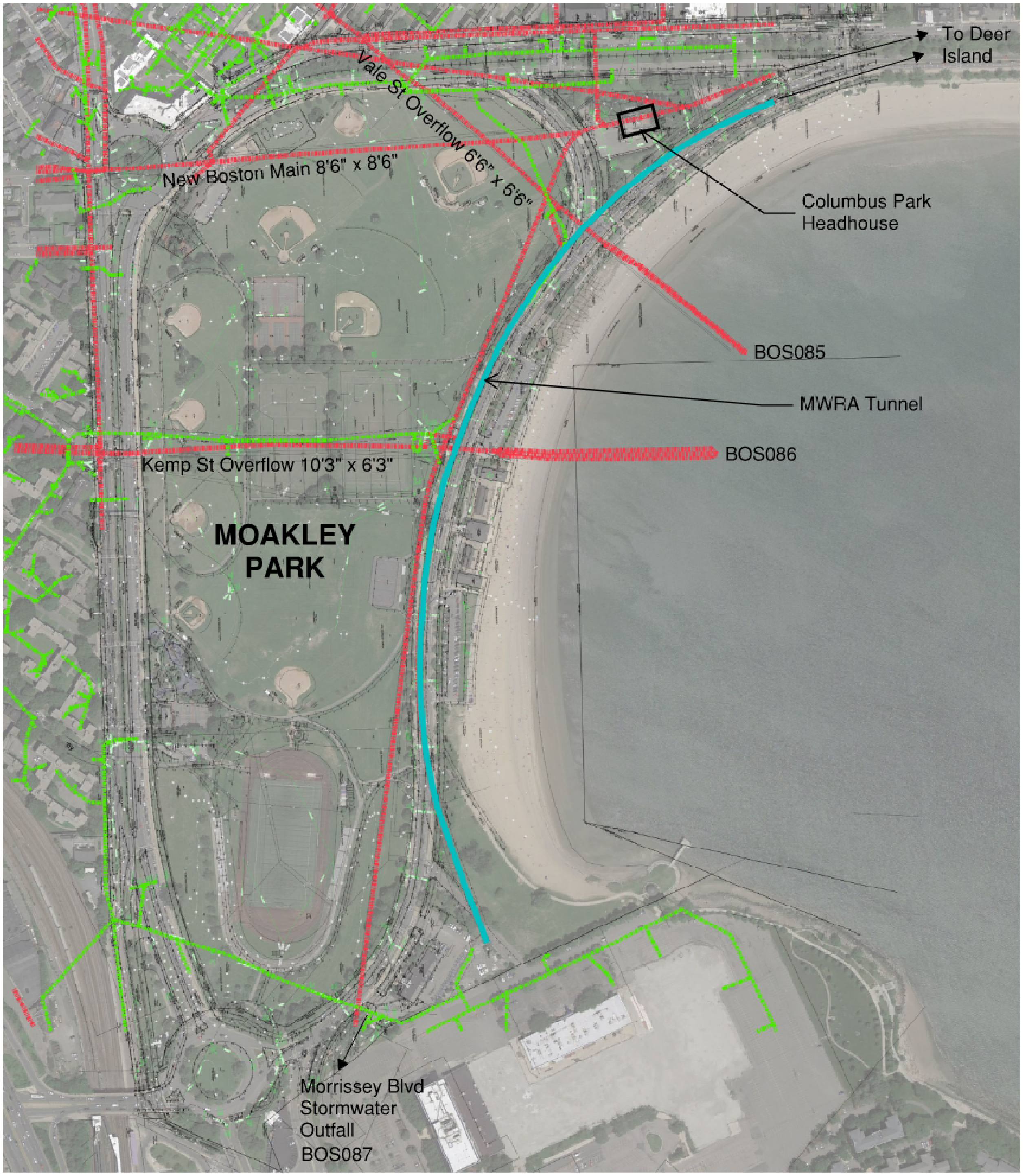


Figure 2. Existing BWSC and MWRA Infrastructure

- During the meetings, MWRA and BWSC indicated that the Vale St Overflow/BOS085 or the Kemp St Overflow/BOS086stormwater gates have never had to be closed during past storm conditions and the tunnel has accepted runoff from all rainfall events to-date. Refer to Appendix E for the record design and operation information from the MWRA.

- As noted in Table 1, storms greater than the 25-year storm outlined in the MWRA table have the potential to exceed tunnel capacity resulting in combined sewage and stormwater discharge to North Dorchester Bay or to the Morrissey Overflow.
    - Therefore, we understand that a goal of the MWRA and the BWSC is to separate stormwater from the combined sewer overflows so that the tunnel can accept more sewage flow during large storm events.
    - In our discussion with BWSC, they have requested that the Moakley Team reduce stormwater discharges to the MWRA tunnel by redirecting stormwater flow to the Morrissey Blvd Storm Drain/BOS087.
- BWSC indicated that the secondary control provided by the MWRA tunnel is not currently included in the city-wide PCSWMM stormwater model that was provided to the Moakley Park Project Team during Task 1.1. They indicated that this may be included in subsequent iterations of the model in the future.
- BWSC and MWRA indicated that there were tide gates as part of the MWRA tunnel system but have not confirmed the exact location of the tide gates at this point. Additional information will be provided to the Project Team regarding the tide gates when it becomes available.

2.2 Modeling Transition

The stormwater analysis in Task 1.1 built upon the BWSC PCSWMM model and modeled various storm scenarios using BWSC's infrastructure data and assumptions. Because the BWSC PCSWMM model does not currently include the MWRA tunnel or tide gates, the Task 1.1 model results indicated that the Vale St Overflow/BOS085 and the Kemp St Overflow/BOS086 discharge into North Dorchester Bay. From subsequent conversations with BWSC and MWRA, it has been clarified that these flows would first be intercepted by the MWRA tunnel before overflowing to the Bay, and that tidal flows are not likely to surcharge into the Park because there are tide gates installed as part of the MWRA tunnel.

Since BWSC's PCSWMM model does not yet include some of the key infrastructure elements (i.e. the MWRA tunnel and associated operating procedures), the model results do not accurately reflect the future flood risks at Moakley Park. Therefore, the BWSC PCSWMM model was not used under Task 1.3. As presented within this memorandum, Nitsch developed a spreadsheet and hydrologic model of the Park to provide conceptual sizing recommendations for the green infrastructure and underground stormwater storage systems.

SECTION 3

Overview of Scope and Goals for Task 1.3

The Task 1.3 stormwater analysis scope includes two boundary scenarios: Moakley Park itself – the primary focus area – and the immediately adjacent roadways – the secondary focus area. The secondary focus area includes only the adjacent roadways that immediately border and slope toward the Park, creating the potential for stormwater runoff that sheet flows off the road to be intercepted by stormwater features along the Park perimeter. The stormwater infrastructure required to treat and detain the stormwater runoff from the secondary focus area will be quantified separately from the primary area.

The Task 1.3 stormwater analysis excludes additional surface areas and roadways around the perimeter of the Park that would require additional infrastructure such as catch basins and piping to be routed into the Park. Offsite areas that are conveyed through the Park in the Boston Water and Sewer Commission (BWSC) and Massachusetts Water Resources Authority (MWRA) infrastructure are also excluded from the analysis.

The purpose of the Task 1.3 Stormwater Design phase is to provide conceptual sizing recommendations for stormwater strategies, such as green infrastructure and underground storage in the Park to provide stormwater treatment and mitigate flooding under present and future conditions. The analysis performed to determine the recommended sizing is based on the Project's ability to meet the following goals:

1. **Flood Resilience in Current and 2070 Conditions**

   The Moakley Park project seeks to increase short- and long-term flood resilience through the reduction of stormwater flooding within the Park and the immediately surrounding roadways. Flood resilience is being considered for current and future precipitation events and tidal conditions, specifically the current and 2070 100-year design storms. In the next phase of the design, Nitsch will evaluate how the proposed infrastructure will function in smaller and more frequent storm events such as the current and future (2070) 10-year storms.

2. **Regulatory Compliance with Current Local and State Stormwater Requirements**

   The Moakley Park project is subject to local and state stormwater requirements as promulgated by the City of Boston, BWSC, and the Massachusetts Department of Environmental Protection (MassDEP):

   - BWSC requires that all projects infiltrate a volume of runoff equivalent to one inch of rainfall times the total footprint of proposed impervious area onsite. The Boston Planning and Development Agency (BPDA), on June 14, 2018, increased this requirement from a 1-inch rainfall depth to the 1.25-inch depth to allow for a reduced pollutant loading on stormwater leaving the Park and to reduce excessive diversion of stormwater into the city's infrastructure.

   - The Wetlands Protection Act and its Regulations, including the MassDEP Stormwater Standards, which is under jurisdiction of the City of Boston Conservation Commission, requires peak runoff rate mitigation such that the proposed peak does not exceed the existing peak, water quality treatment for the 1.0 inch rainfall depth, and promotion of groundwater recharge (unless site conditions do not allow due to restrictive soils or high groundwater).

As part of the MassDEP Stormwater Standards, the project will be required to match the existing peak runoff rates of stormwater from the Park. Although portions of the Park ultimately discharge to a coastal water and therefore this standard may not be applicable, the Park will target meeting this requirement since the immediate design points are existing infrastructure owned by BWSC and MWRA.

To meet these goals, the Park is using a combination of underground storage and green infrastructure to slow, filter, and detain the contributing stormwater runoff prior to releasing from the Park to the downstream systems. The **underground systems** are the primary strategy to achieve flood resilience and peak runoff rate mitigation (refer to Section 5). The **green infrastructure systems** are the primary strategy to provide water quality treatment, while also providing peak rate mitigation in smaller storm events. The green infrastructure overflow will be routed to the underground systems.

SECTION 4

Preliminary Stormwater Storage Sizing

In concert with the proposed green infrastructure, underground systems are proposed to provide significant storage of current and future rainfall events to mitigate peak runoff rates and reduce the vulnerability to flooding within the Park during high tide conditions[1]. HydroCAD was used to analyze the storage required to hold/detain the current 100-year storm volumes as outlined under the Design Goals for Stormwater Strategies.

Three (3) underground systems are proposed for the Park and will be located beneath athletic fields in order to avoid conflicts with existing and proposed trees and other surface features:

- UG-1 is the system furthest to the north and will have the shallowest section of 2.33 feet.
- UG-2 is the central underground system and will have a section of 3.5 feet.
- UG-3 is located furthest to the south and will have a section of 5.5 feet.

Refer to Figure 4 for underground system locations. Nitsch has assumed chamber sizes for the underground systems based on where they are located in the Park. Shallower systems are proposed in the northern portion of the Park where earthwork is anticipated to be more costly based on the Subsurface Explorations (refer to Section 4.2). By keeping the system furthest north shallow, this will allow the drainage collection system to flow by gravity to the southern Morrissey Boulevard Stormwater Outfall connection point.

4.1 Tidal Influence

The results of Task 1.1 highlighted that the tidal conditions are a driving factor in how stormwater moves through the Park's drainage system. High tides in the current and future conditions restrict flows by gravity and indicate the need to delay discharge until the tide has gone down (the preferred approach) or to install a pump capable of discharging the stormwater during high tide. This information has helped inform the modelling performed under Task 1.3, specifically that the tailwater boundary condition must be accounted for, regardless of whether there are tide gates or not at all the discharge locations.

The Morrissey Boulevard Overflow discharges to the Savin Hill Cover to the south of the Park site. Nitsch Engineering assumes that the outfall will have the same tidal conditions as the outfalls directly adjacent to the Park in North Dorchester Bay. Table 2 shows the maximum tidal elevation of the Dorchester Bay in the current normal tide, "Grayson" Nor'easter Tide, projected 2070 Normal Tide, and projected 2070 Nor'easter tide on Boston City Base (BCB).

[1] For this analysis, the stormwater storage is assumed to be underground; however, future design scenario could include floodable surface areas such as sport courts or fields.

Table 2: Summary of Peak Tidal Elevations in North Dorchester Bay

Scenario	Max. Tidal Elevation (ft, BCB)
March 3, 2018 Nor'easter Tidal Condition	15+
Current Normal High Tide	9+
"Grayson" Nor'easter High Tide	16+
2070 Normal High Tide	16+
2070 Nor'easter High Tide	20+

The elevations of the underground storage systems must carefully consider tidal elevations so that check valves or tidal controls can be proposed as needed. Table 3 shows the maximum invert elevation of the underground systems based on the current design assumptions for system height, proposed grading, and the system cover requirements.

Table 3: Maximum Elevation of the Invert of the Proposed Underground Systems

System Name	Maximum Invert of System (BCB)
UG-1	11 ± ft
UG-2	9 ± ft
UG-3	8 ± ft

Comparing the maximum inverts of the UG systems in Table 3 to the tidal elevations in Table 2 confirms that there is risk for the high tide to be above the maximum invert of the systems in normal and storm scenarios.

Gate valves should be installed within the Park upstream of the connection points to the drainage systems to prevent tidal and/or other flows from the systems from backing up into the Park drainage system during high tide events. With these gate valves in place, the underground systems must be designed to provide full storage of the design storm runoff volume until low tide conditions allow the stored stormwater to discharge (further discussed in Section 4.1). This will protect the Park from surcharged conditions causing surface flooding.

4.2 Soils and Groundwater Considerations

Weston and Sampson performed 18 borings and 12 test pits within the Park to observe the subsurface soil and groundwater conditions. They also installed 11 monitoring wells. The soil profile was generally found to be variable urban fill over naturally occurring organics and clay. A sand layer was observed between the fill and organics layers towards the northwest portion of the Park. The depth of fill was generally found to be greater in the northern portion of the Park than the southern portion. The fill layer was observed to be between 12 and 22 feet deep. A portion of the Park was found to contain contaminated soils which make the soil unsuitable for infiltration. This portion of the Park is shown with cyan outline in Figure 4.

A memorandum prepared by Weston and Sampson, dated March 20, 2020 includes observations of the monitoring wells and elevations of the Estimated Seasonal High Groundwater Table elevation based on the Frimpter Method[2]. A summary of the monitoring well results and the proposed surface elevation are shown in Table 4.

Table 4: Proposed Surface Elevation vs. Seasonal High Groundwater Elevations (summarized from Weston and Sampson Report)

Monitoring Well	Proposed Surface Elevation (BCB)	Peak Observed Groundwater Elevation (BCB)	Estimated Seasonal High Groundwater Elevation (BCB)	Depth from Proposed Surface to Estimated Seasonal High Groundwater (ft)
MW 1	13.75	11.15	12.88	< 1
MW 2	17.51	11.22	12.92	4.6
MW 3	15.00	11.02	12.72	2.3
MW 4	18.89	14.82	15.46	3.4
MW 5	15.95	7.13	6.58	9.4
MW 6	15.49	11.84	13.12	2.4
MW 7	15.58	12.20	13.04	2.5
MW 8	21.62	13.19	14.06	7.6
MW 9	21.09	11.31	13.00	8.1
MW 10	17.61	13.07	14.79	2.8
MW 11	20.23	16.06	16.72	3.5

The depth from proposed surface to estimated seasonal high groundwater is an important indicator of the potential for infiltration of stormwater. MassDEP requires a minimum 2-foot separation between estimated seasonal high groundwater and the bottom of an infiltration system. Based on the depths shown in Table 4, a typical underground system with a height ranging from 3-6 feet could not be sited with adequate separation to groundwater. Therefore, all of the underground systems are currently assumed to provide detention only.

There is some potential for targeted green infrastructure practices to include infiltration; however, that will depend on the designed section and the location onsite. This could include a porous pavement section for pedestrian areas or a bioretention meadow that can be designed with a shallower footprint. The subsurface conditions and related stormwater constraints and opportunities will continue to be reviewed and refined by the Project Team in subsequent design phases.

[2] The United States Geological Survey (USGS) developed the Frimpter method to estimate probable high groundwater levels at unmonitored sites of interest in the early 1980s.

4.3 HydroCAD Model

The purpose of the Task 1.3 HydroCAD model is to provide a conceptual sizing of the underground systems proposed to meet the Park's stormwater design goals outlined in Section 3. The model also provides a preliminary evaluation of the potential for managing additional runoff from the secondary focus area that includes the roadways around the Park perimeter.

Design Points

The existing stormwater from the Park is collected into a closed drainage system and conveyed to the three (3) BWSC outfalls into North Dorchester Bay: Vale St Overflow/BOS085, the Kemp St Overflow/BOS086, and the Morrissey Blvd Storm Drain/BOS087. Currently, the northern and central portion of the Park are collected in area drains/catch basins and routed to the BWSC/MWRA system through either the Vale St Overflow/BOS085 or the Kemp St Overflow/BOS086 (Design Point 1). The southernmost portion of the Park discharges to Morrissey Blvd Storm Drain/BOS087 (Design Point 2).

In the proposed condition, a berm will traverse the Park in the north/south direction and will split the Park into two areas. Based on feedback from BWSC, Nitsch Engineering is proposing to decrease the area of the Park that discharges to the BWSC/MWRA system by rerouting the inland areas of the Park to Morrissey Blvd Storm Drain/BOS087. The coastal area to the east of the berm will be routed to the BWSC/MWRA system (DP-1). Any connections from the Park to the MWRA infrastructure will be made through existing BWSC infrastructure. No new connections to the MWRA infrastructure are proposed. All stormwater directed to the existing BWSC infrastructure will be treated and there will be a significant reduction in quantity of flow to this design point. The inland area on the west side of the berm will be routed south to the Morrissey Blvd Storm Drain/BOS087 (DP-2). Figure 3 shows the existing drainage areas to DP1 and DP2.

With the construction of the berm, the inland areas (west of the berm) will be protected from coastal storm flowage and therefore the inland stormwater system can be isolated to treat, detain, and slowly discharge to the Morrissey Blvd Storm Drain/BOS087 during low tide conditions. The coastal areas (east of the berm) will not be protected from coastal storm flowage and may therefore be inundated in high tide/storm surge events. Connecting the coastal green infrastructure to the inland portion of the Park would increase the risk of interior flooding during storm events. Therefore, green infrastructure on the coastal side of the berm will provide water quality treatment and mitigation in smaller storms prior to discharging to the existing BWSC/MWRA system connections.

Watershed Delineation and Landcover Assumptions

Throughout Task 1.3, the Project Team collaborated on layout and grading to develop proposed drainage areas based on the different programmatic zones. Stoss provided current assumptions for the anticipated land cover type in each zone, which were translated into pervious and impervious areas for each drainage area and for use in the Task 1.3 calculations and modeling. Nitsch considered these areas to be the "minor subcatchments" for the primary focus area, which were used to size and design the green infrastructure (Section 5). Refer to Figure 4 for the watershed delineations.

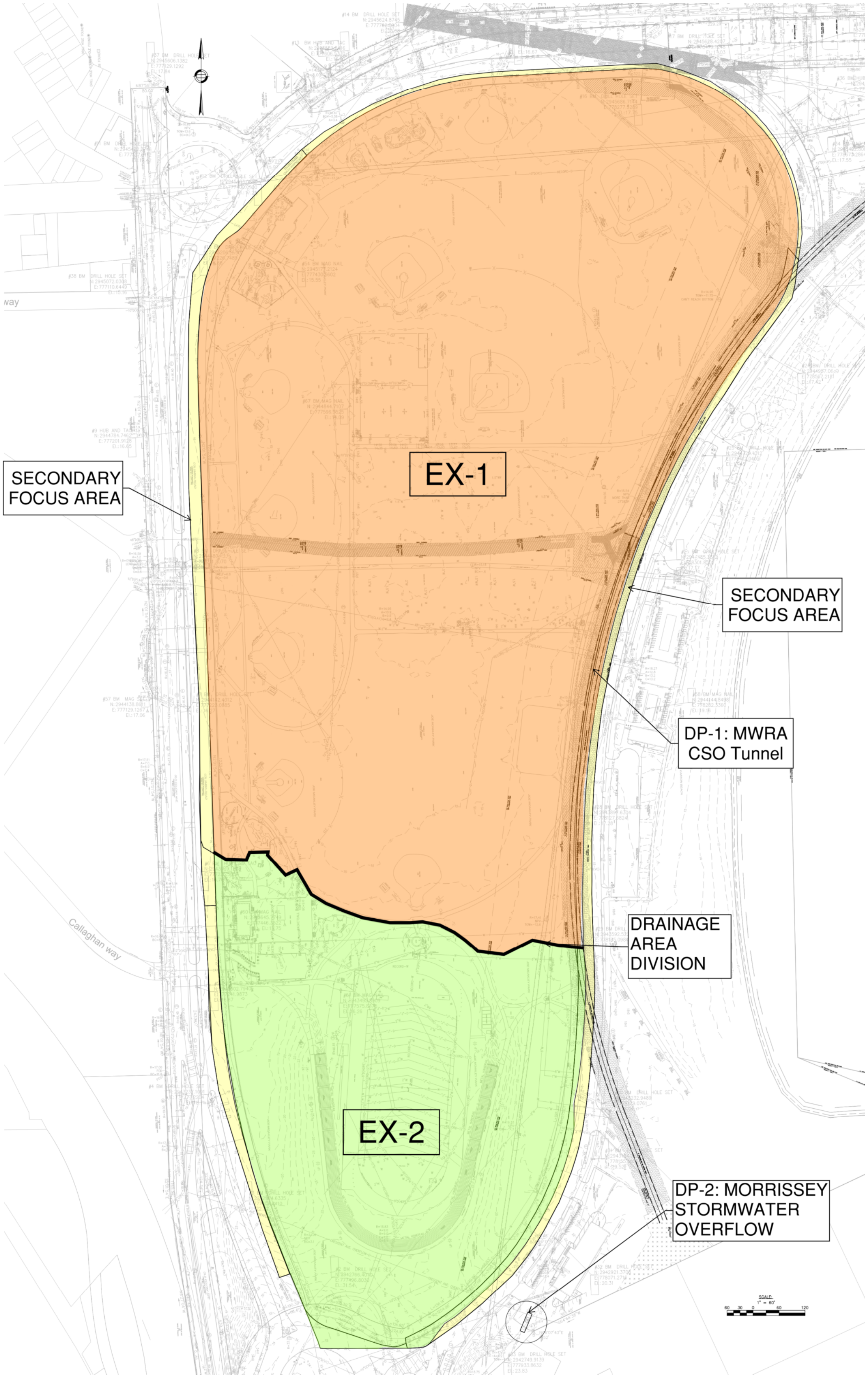


Figure 3: Existing Moakley Park Drainage Area Division

Primary Focus Area Subcatchments

- Baseball Field (DA-1)
- Soccer Fields (DA-2)
- Little League Fields (DA-3)
- Stadium (DA-4)
- Urban Edge South (DA-5)
- Urban Edge North and Center (DA-6)
- Waterfront Plaza (DA-7A and DA-7B)
- Adventure Play (DA-8A through DA-8E)
- Hammock Grove (DA-9A and DA-9B)
- Southern Edge (DA1-0)

In addition to the areas Stoss provided, Nitsch delineated the drainage areas for the secondary focus area which includes the adjacent roadways that pitch towards the Park.

Secondary Focus Area Subcatchments

- Roadway South (DA-11)
- Roadway North and Center (DA-12)
- Roadway East (DA-13)

The minor subcatchments flow into larger major subcatchments that reflect the associated underground systems. As noted previously, the underground systems are located interior of the proposed berm and overflow to the Morrissey Boulevard Overflow. Refer to Table 5 and Figure 4 for a summary of the minor subcatchments, major subcatchments, design points, and location of underground systems.

Table 5: Summary of Major Subcatchments and their Tributary Areas

Major Subcatchment/ Underground System	Location of System	Tributary Minor Subcatchments	Overall Design Point
UG-1	Underneath the Baseball Field	DA-1	Morrissey Blvd Overflow
UG-2	Underneath the Soccer Fields	DA-2	Morrissey Blvd Overflow
UG-3	Underneath the Little League Fields	DA-3, DA-5, DA-6, DA-8, DA-9, DA-11, DA-12	Morrissey Blvd Overflow
MWRA	Existing MWRA Tunnel	DA-4, DA-7A, and DA-7B, DA-10	MWRA Tunnel

Precipitation Events

The goal of Task 1.3 is to provide conceptual sizing of the underground systems and green infrastructure to meet the flood resilience and regulatory goals of the project. Based on the design goals outlined in Section 4, the following storm events were selected by the Project Team to be analyzed in the Task 1.3 Stormwater Design:

Water Quality Storm	1.25 inches (BWSC and BPDA)
Current 100-yr, 24-hr Storm	8.09 inches in 24 hours (Atlas 14)
2070 100-yr, 24-hr Storm	11.70 inches in 24 hours (City of Cambridge)

Note: By evaluating the water quality storms and the current and 2070 100 year, 24-hour storms to conceptually size the underground systems, the systems will be adequately sized for mid-sized storm events as well. For example, the 2070, 10-year, 24-hour storm depth is 6.4 inches whereas the current 100-year, 24-hr storm depth is 8.09 inches. Because the current 100-year storm depth was greater than the 2070, 10-year storm depth, the underground system sizing would be adequate to control flooding in the 2070, 10-year storm. In the next phase of the design, Nitsch will evaluate how the proposed infrastructure will function in smaller and more frequent storm events such as the current and future (2070) 10-year storms.

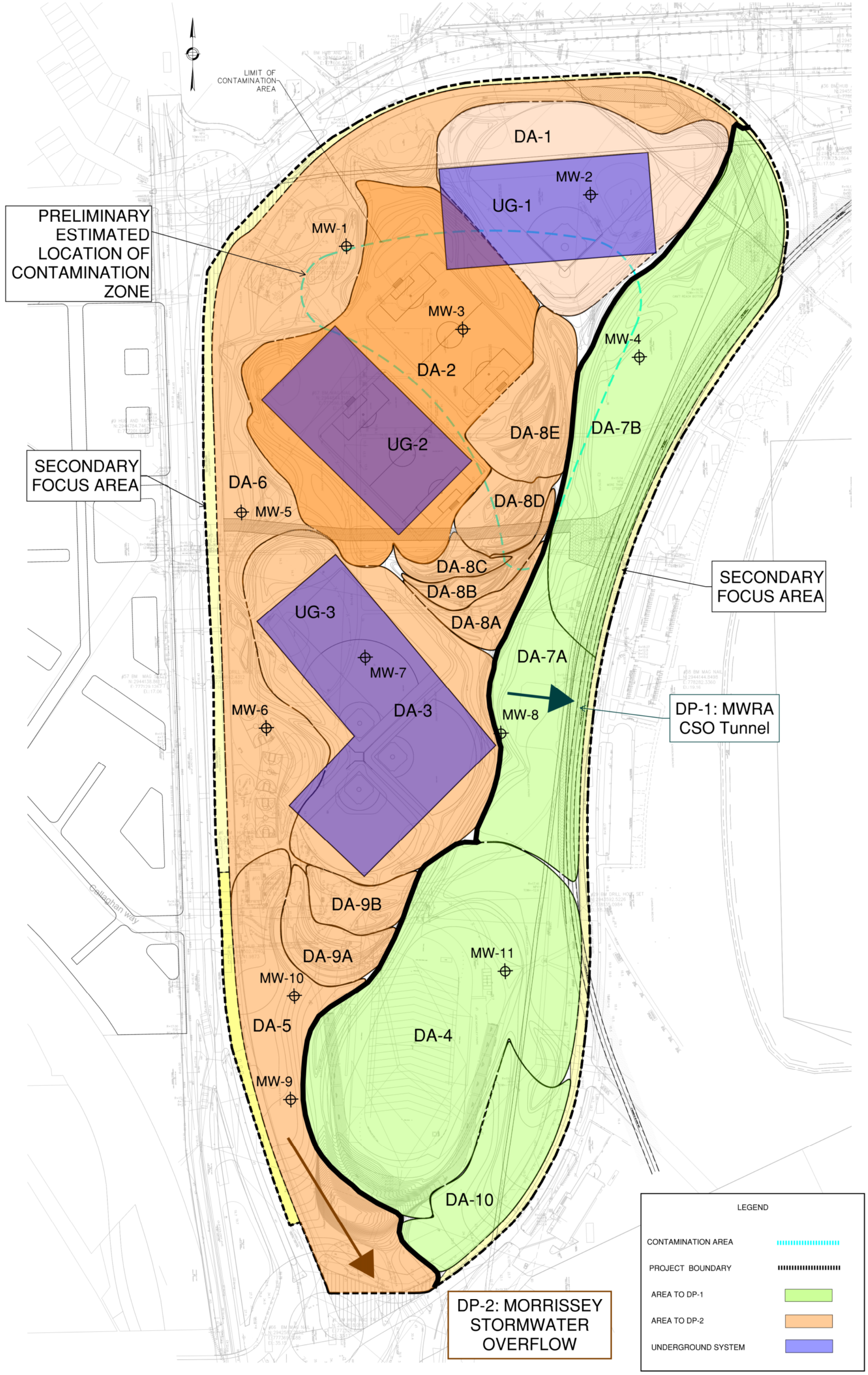


Figure 4: Proposed Moakley Park Drainage Area Division

Model Assumptions

The HydroCAD model is based on the following assumptions:

- The Time of Concentration is assumed to be six (6) minutes in both the existing and proposed conditions. Because the green infrastructure has not been fully sited and the layout and grading is in flux, Nitsch could not determine the time of concentration in the proposed condition. In order to be consistent from existing to proposed conditions, Nitsch assumed the same value of six minutes for both. This approach is conservative because it assumes that all stormwater runoff reaches the storage areas at the same time instead of being staggered.

- The Hydrologic Soil Group for the entire site is assumed to be "D" soil, indicating the soil is poorly drained. The geotechnical reports describe variable fill soil conditions and high groundwater. Nitsch chose to represent these conditions with HSG "D" soils for this analysis because it is a conservative approach that will produce more runoff and therefore larger required detention volumes.

- Based on the subsurface explorations, the underground systems are assumed to be lined and there will be no infiltration from the systems to the subgrade.

- In order to model the green infrastructure in HydroCAD, Nitsch assumed that the first 1.25-inches will be diverted to the green infrastructure and then overflow to the underground system via an underdrain. In the HydroCAD model, the rainfall greater than 1.25-inches bypasses the green infrastructure and is directed to the underground systems. As the design progresses and the green infrastructure is laid out throughout the Park, the model will be refined to show all of the stormwater being directed to the green infrastructure with appropriate overflow controls embedded into the individual green infrastructure elements to direct it to the underground systems.

- The underground systems are assumed to be plastic arch chambers because these systems provide better footprint to volume ratio than pipe storage and are generally less expensive and easier to construct than concrete chambers, which require a crane. Concrete chambers provide a higher void ratio than plastic chambers and could be considered in subsequent phases of the project if it becomes necessary to reduce the footprint of the systems.

4.4 Preliminary Underground System Sizing Recommendations

To address the goals of the Park to provide flood resilience and regulatory compliance, the HydroCAD model was used in two ways to provide sizing guidance for the underground systems:

(1) **Flood Resilience - Hydrologic analysis of the Park's contributing drainage area to determine the runoff volume from the primary and secondary focus areas.**
This analysis provides conceptual sizing of the underground system based on the total runoff volume from the contributing drainage area for the design storm events. It conservatively assumes that the storm duration will coincide with high downstream tailwater conditions (i.e. high tide, storm surge, or system surcharge). This will result in a condition where the underground systems will be required to hold the runoff volume until downstream conditions recede and flow can leave the Park. Using this methodology, the conceptual underground systems will be sized with enough volume to meet the flood resilience goal of the project. The sizing and system footprints shown on Figure 4 are preliminary and are intended to provide an estimate of the anticipated required volume. The geometry and footprint of each system will continue to be refined to avoid earthwork in areas of elevated contamination in subsequent design phases.

(2) **Regulatory Compliance - Hydrologic analysis of the proposed underground systems during low tide to estimate the maximum peak rates being discharged to the design points.**
This analysis provides a comparison of the peak rates of runoff being discharged from the Park when there is no tailwater impacts. This scenario is when the *maximum* peak runoff rates would be expected from the Park and therefore demonstrates that the underground systems are adequately sized to meet the regulatory rate reduction requirements.

Flood Resilience – Volume Recommendations

In the current 100-year, 24-hour storm, approximately 930,000 cubic feet of storage is required to detain the runoff volume generated by the proposed Park. This results in a total footprint of 433,100 square feet or 9.94 acres. The layout of these underground systems is shown in Figure 4 and Appendix 1.

Nitsch evaluated the implications of sizing the underground systems to hold additional stormwater runoff either from the secondary focus area (adjacent roadways) or from the Park in the future 2070, 100-year rainfall event. Table 6 includes a summary of the volume and square footage required in base conditions for the primary focus area and the current 100-year storm as well as the increase in storage volume that would be required in each subsurface system.

Table 6: Comparison of Underground Systems in Storm Scenarios

System	Current 100-Year Volume (cf)	Current 100-Year Footprint (sf)	Additional Storage for 2070, 100-Year Volume (cf, %)	Additional Volume for Roadways in Current 100-Year (cf)	Additional Footprint for Roadways in 2070, 100 Year (cf)
UG-1	123,000	126,000	72,700 (59%)	N/A	N/A
UG-2	217,000	118,100	119,000 (55%)	N/A	N/A
UG-3	590,000	189,000	329,000 (56%)	54,900 (9%)	80,100 (14%)
Total	930,000	433,100	520,700 (56%)	54,900 (9%)	80,100 (14%)

In the current 100-year storm condition, the Park would require an additional 9% of underground storage to capture the runoff from the adjacent roadway. In the future 2070 100-year storm condition, the Park would require 56% more storage in order to capture the runoff from within the Park and an additional 14% to capture stormwater runoff from the adjacent roadway (secondary focus area).

Regulatory Requirements – Peak Rate Reduction

Nitsch evaluated the change in peak runoff rate for the Park in the current and projected 2070, 100-year storms. Nitsch Engineering evaluated the peak runoff rates to both Design Points 1 and 2 and found a significant reduction in peak runoff rate to both. Refer to Table 7 for the existing and proposed 100-year peak runoff rates.

Table 7: Existing and Proposed Peak Runoff Rates in the Current and 2070, 100-year Storms

Design Point	Condition	Peak Runoff Rate (cfs) Current 100-Year Storm	Peak Runoff Rate (cfs) 2070 100-year Storm
DP-1 (BWSC/MWRA CSO System)	Existing	300 ±	460 ±
	Proposed	150 ±	220 ±
DP-2 (Morrissey Blvd Stormwater Outfall)	Existing	110 ±	160 ±
	Proposed	30 ±	60 ±

The peak runoff rate to DP-1 (BWSC/MWRA CSO System) will decrease by 55% in the existing 100-year storm and the peak runoff rate to DP-2 (Morrissey Blvd Stormwater Outfall) will decrease by 77% in the current 100-year storm. This analysis was performed for the current 100-year design storm, though rates for the 2- and 10-year storms can be expected to have similar reductions due to the amount of storage being provided in the underground systems.

SECTION 5

Preliminary Green Infrastructure Sizing

Green infrastructure will be integrated throughout the Moakley Park landscape to slow, filter, and detain runoff and meet the BWSC requirement to infiltrate or detain the 1.25-inch storm. Although infiltration will not be feasible in all areas of the Park, it will be promoted to the maximum extent practicable and green infrastructure will be used at a minimum, to provide treatment for the 1.25-inch water quality volume from impervious areas on the Park. A combination of green infrastructure strategies are proposed to meet this goal, including bioretention meadows, stormwater marshes, stormwater corridors, tree filters, and porous pavement. In future design phases, the green infrastructure locations will be evaluated to determine if infiltration is feasible based on the geotechnical investigations.

5.1 Proposed Green Infrastructure Systems

Bioretention Meadows

Bioretention meadows are a form of bioretention systems that filter stormwater using hearty native meadow plant species that can tolerate conditions of drought and flooding (Figure 5). Additionally, these systems incorporate soils and microbes to treat stormwater before water infiltrates into the ground and/or is discharged. Bioretention meadows aim to mimic the natural ecological functions found in wild meadows which is why these systems are vegetated with ornamental grasses intertwined with wildflowers, which when successful will imitate the ecological succession that occurs in wild meadow habitats.

Figure 5: Precedent for Stormwater Meadow - Butterfly Acres CARA Restoration, Lititz, PA (Land Studies)

Bioretention meadows can be used to infiltrate and provide pollutant removal including total suspended solids (TSS), phosphorus, nitrogen, and other metals. Bioretention meadows can be used in either inland or coastal conditions provided they are planted appropriately for anticipated fresh and saltwater conditions.

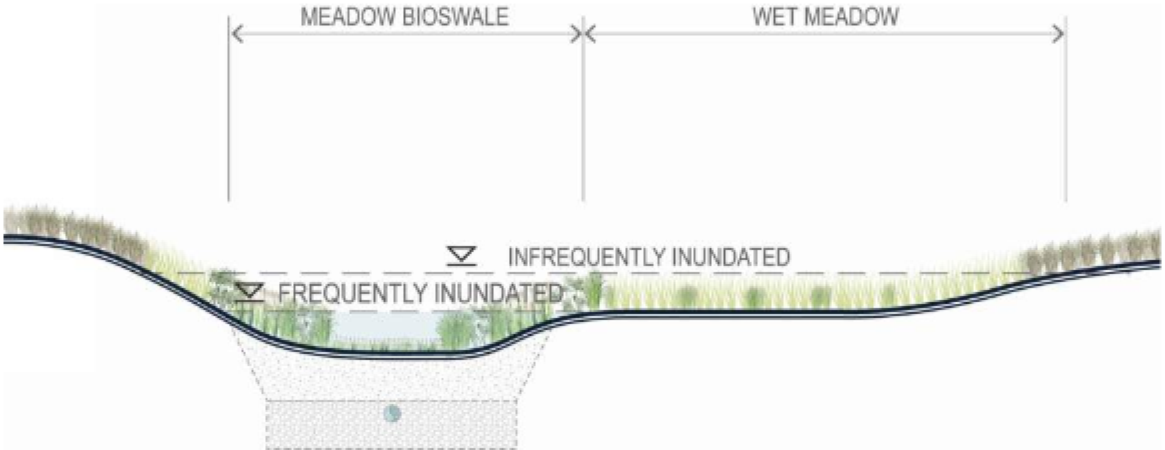


Figure 6: Typical Section for Stormwater Meadow / Meadow Bioswale

Stormwater Marshes

Stormwater marshes are a constructed wetland system that retain and filter stormwater (Figures 7 and 8). Treatment is provided to the stormwater runoff through the uptake of water through plantings and extended detention and settling. Salt tolerant plantings can be used to allow for seawater inundation. Stormwater marshes aim to mimic the natural ecological functions found in seaside habitats.

Figure 7: Precedent for Stormwater Marshes - North Carolina Museum of Art


Figure 8: Qunli Stormwater Wetland Park by Turenscape in Harbin

Stormwater Corridor (Grassed Trench or Swale)

Stormwater corridors are integrated systems that collect, filter, and convey stormwater runoff from a linear feature such as a walkway or parking edge (Figures 9 and 10). Impermeable surfaces are designed to slope towards grassed trenches or swales that are integrated into the section of the walkway to reduce the need for catch basins and area drains and associated piping. Stormwater corridors can be planted and designed to remove TSS, phosphorus, nitrogen, and other metals. Stormwater corridors can be used in both coastal and inland areas.

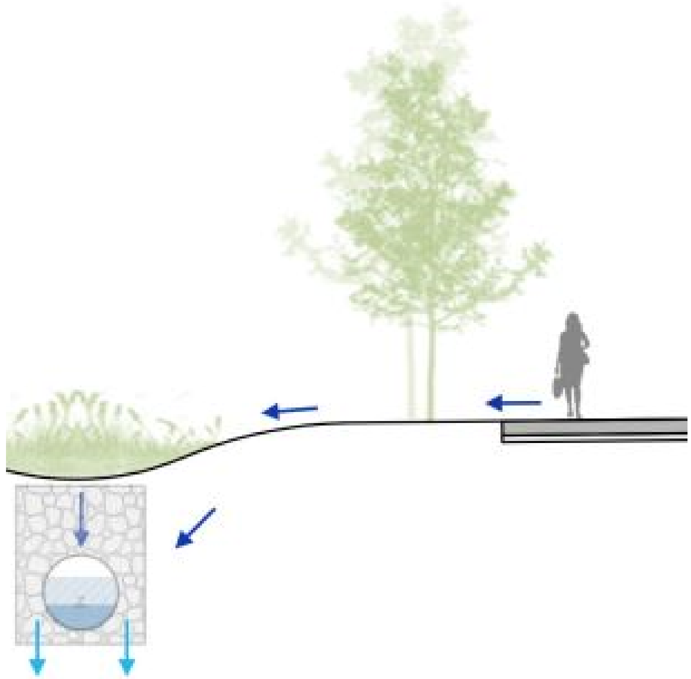


Figure 9. Typical Section for a swale along linear path with integrated trench

Figure 10. Precedent for Stormwater Corridor along parking and walkway – Cornell University

Tree Filters

Tree filters provide a decentralized approach for stormwater treatment along urban streetscapes. Stormwater percolates through the soil media and is either infiltrated into the ground or collected by an underdrain system. Excess water that is directed to a tree filter will be collected by the underdrain system and directed to the onsite closed drainage system. Tree filters can be used on either side of the proposed berm.

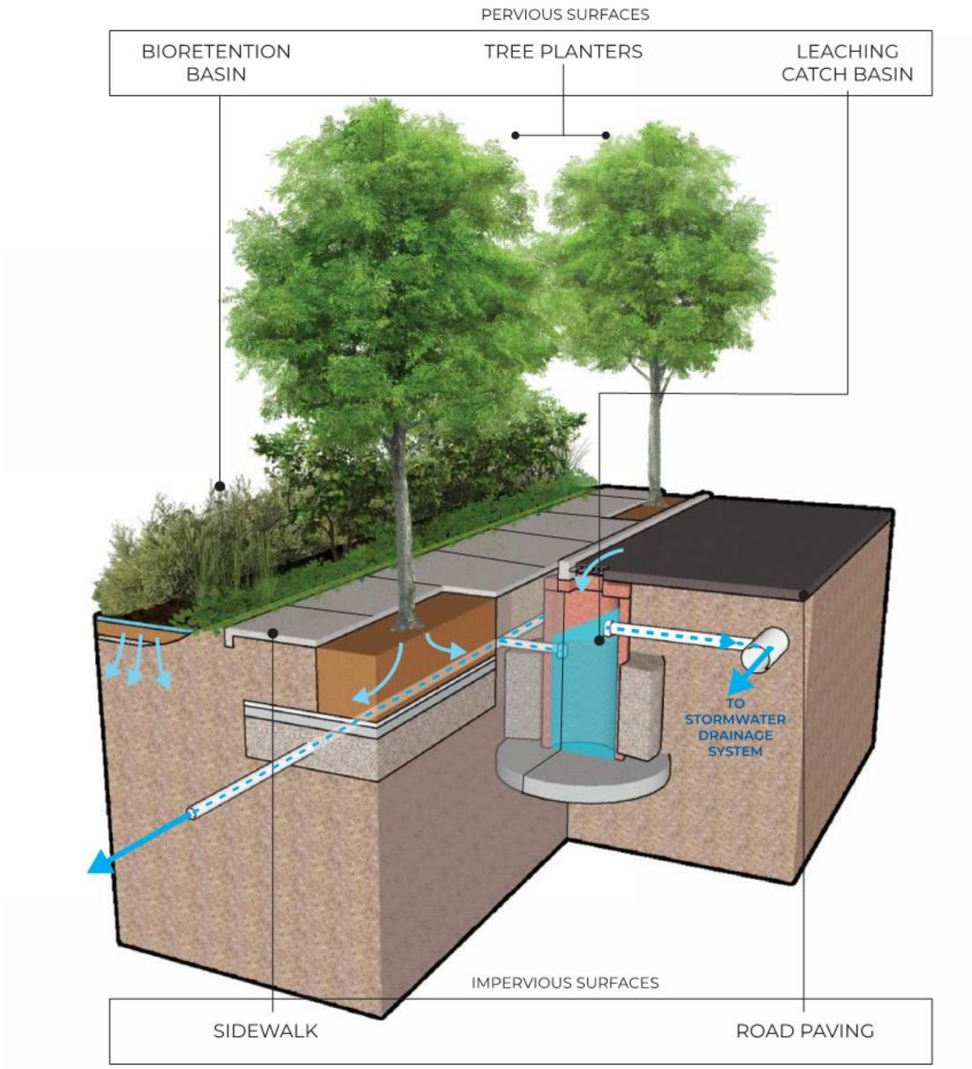


Figure 11. Typical Detail for Tree Filter (City of Cambridge)

Permeable Pavement

Permeable pavement provides a hardscape alternative that allows for water infiltration and pollutant removal. Implementing an area of permeable paving on a sidewalk or other paved area increases the permeability of an otherwise impermeable space (Figure 12). Permeable pavement can have an underdrain to allow the system to work with high groundwater conditions. Permeable pavement is not recommended on the east side of the proposed berm, due to the maintenance challenges associated with potential saltwater inundation and sand migration during coastal events.

Figure 12. Precedent for Plaza Permeable Pavers – Chicago Navy Pier

Rain Barrels and Rain Chains

Rain barrels can be used onsite as small-scale interventions to collect and reuse stormwater runoff (Figure 13). Rain barrels can be used as instructional tools for children to teach about the hydrologic cycle and the importance of water conservation. Collected stormwater can be used to water gardens and other small landscapes areas.

Rain chains can be used in coordination with stormwater collection systems such as a rain barrel or infiltration trench. Rain chains are a decorative feature that serve a similar function to a downspout- they direct stormwater runoff from the roof to a collection system in a controlled manner.

Figure 13: Rain Chain and Rain Barrel Precedent Images

Green Roofs

Green roofs consist of a planted area with a light planting media on structures (Figure 14). The plantings and planting media result in less stormwater runoff than a traditional roof. They can be used to treat stormwater runoff and provide peak rate mitigation in small rainfall events. Stormwater runoff is stored in the soil medium until plant roots take up the water and it is transpired back into the atmosphere. Excess stormwater that falls on a green roof is collected and discharged to the onsite closed drainage system.

As the building plans for the Park are still under development, green roofs were not included in the preliminary green infrastructure sizing plan. However, they should be considered in future design phases.

Figure 14. Precedent - Green Roof Precedent, New York City park

Rainwater Harvesting using Underground Systems

Rainwater harvesting systems can be used to capture, collect, and reuse site runoff for non-potable uses. Typically, rainwater harvesting systems are used to collect stormwater runoff from roofs, but they can also be used to collect site runoff when sufficient treatment is provided for the intended use. Potential uses for the captured stormwater include water play, drip or sprinkler irrigation of landscape areas or athletic fields, or reuse within buildings (i.e. toilet flushing). Rainwater harvesting systems contribute to the overall stormwater goals of the Park project by reducing potable water demands and reducing the quantity of stormwater being discharged from the Park.

The potential for a rainwater harvesting system in the Park should be studied more in future design phases, including the potential uses for the collected stormwater, the appropriate sizing of the collection system, and treatment needs for the system. Given the potential for public contact with many uses within the Park, it is likely that many uses will require the harvested water to be treated to potable standards.

5.2 Preliminary Green Infrastructure Sizing Recommendations

To provide conceptual design guidance on the green infrastructure in Task 1.3, the Project Team coordinated the sizing and types of green infrastructure that are appropriate in each of the zones. Green infrastructure has been integrated throughout the Park, as shown in Figures 15 and 16, with the aesthetics of the strategies mirroring the intended programming in each location. Each potential green infrastructure system was categorized as being either a “surface” or “subsurface” and evaluated based on the contributing drainage area to determine the conceptual sizing needed to treat the 1.25-inch water quality volume per the BWSC requirement.

For the purposes of the conceptual sizing in Task 1.3, Nitsch has assumed that “surface” green infrastructure includes bioretention meadows and stormwater marshes. Conceptually, these areas will have a surface ponding depth of approximately 12 inches that will be used to hold the 1.25-inch storm from tributary impervious areas. The depth of these systems can be increased to accommodate runoff from larger storm events if needed. The bioretention meadows and stormwater marshes will be designed with outlet controls to accommodate storm events greater than 1.25-inches which will be directed to the onsite closed drainage system and underground detention systems.

“Subsurface” green infrastructure systems include permeable pavement, tree filters, and stormwater corridors whose storage volumes are provided below grade within soil or stone layers. For the purposes of conceptual sizing, Nitsch assumed that these will have a standard depth of three (3) feet and are assumed to have an underdrain to discharge filtered water to the underground detention systems.

Using these sizing parameters, Nitsch estimated the required footprint of each green infrastructure system, as outlined in Table 8 and Figures 15 and 16.

Table 8: Summary of Green Infrastructure Types and Sizing

DA	Location	Green Infrastructure Strategy	Total Area (sf)	Percent of Drainage Area used for GI	Preliminary Recommended Surface Area (sf)
DA1	Baseball Field	Stormwater Meadow	249,220	1%	2,260
DA2	Soccer Fields	Stormwater Meadow	404,841	2%	7,629
		Stormwater Corridor		1%	2894
		Porous Strip (Basketball Perimeter)		1%	3356
DA3	Little League Fields	Stormwater Meadow	351,836	3%	9180
		Stormwater Corridor		2%	5787
DA4	Stadium + Marsh	Constructed Wetland	389,731	3%	13353
DA5	Urban Edge-South	Tree Plazas / Porous Pavement	178,043	4%	6534
DA6	Urban Edge-North/Center	Tree Plazas / Porous Pavement	354,554	3%	12010
DA7A	Waterfront Plaza	Stormwater Meadow/Dunes	154,470	16%	24334
DA7B	Waterfront North	Constructed Wetland	292,806	2%	6140
DA8A	Adventure Play	Stormwater Meadow	26,649	1%	358
DA8B	Adventure Play	Stormwater Meadow	21,545	3%	555
DA8C	Adventure Play	Stormwater Meadow	15,823	2%	395
DA8D	Adventure Play	Stormwater Meadow	34,949	3%	988
DA8E	Adventure Play	Stormwater Meadow	66,286	2%	1272
DA9A	Grove	Stormwater Meadow	37,664	1%	196
DA9B	Grove	Stormwater Meadow	30,173	2%	571
DA10	Southern Edge	Constructed Wetland	89,040	2%	2036

SUPPLEMENTAL STRATEGIES TO TREAT SECONDARY FOCUS AREA					
DA11	Roadway- South	Tree Plazas	21,993	-	2500
DA12	Roadway-North/Center	Tree Plazas	61,916	-	7200
DA13	Roadway- East	Constructed Wetland	49,440	-	5100

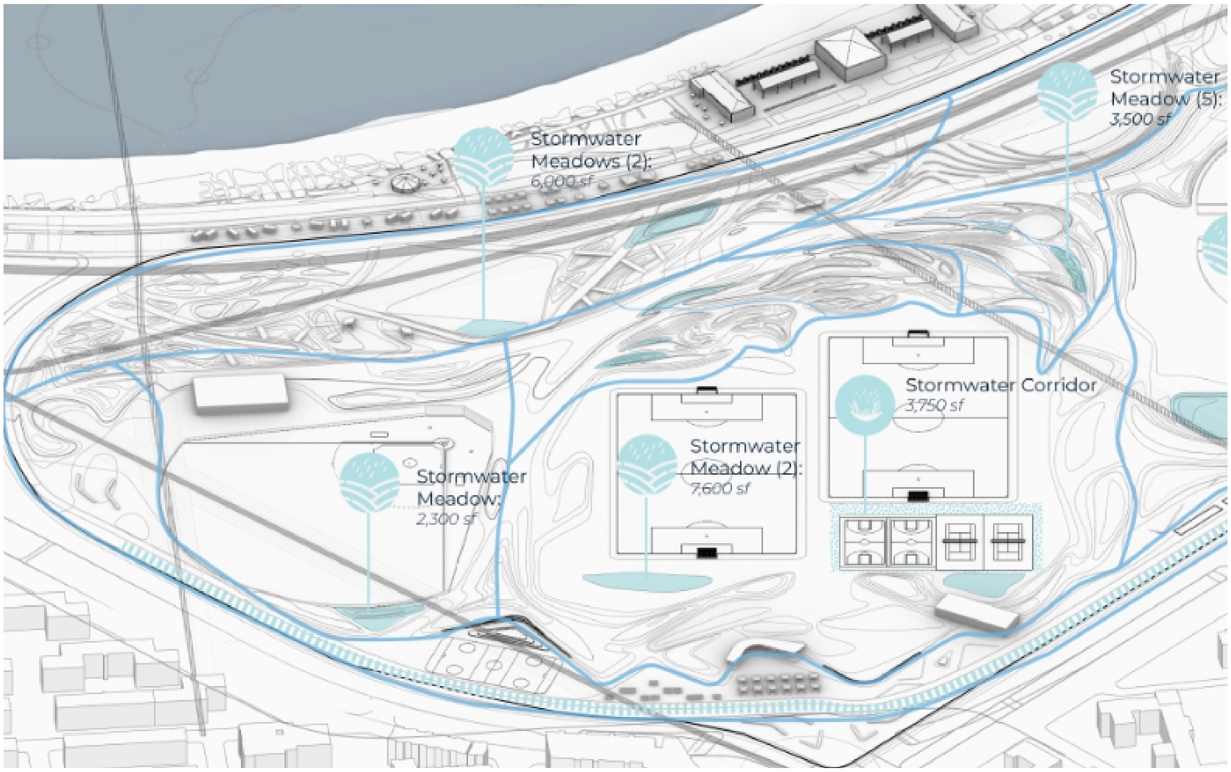


Figure 15. Conceptual green infrastructure locations – North (facing southeast), prepared by Stoss

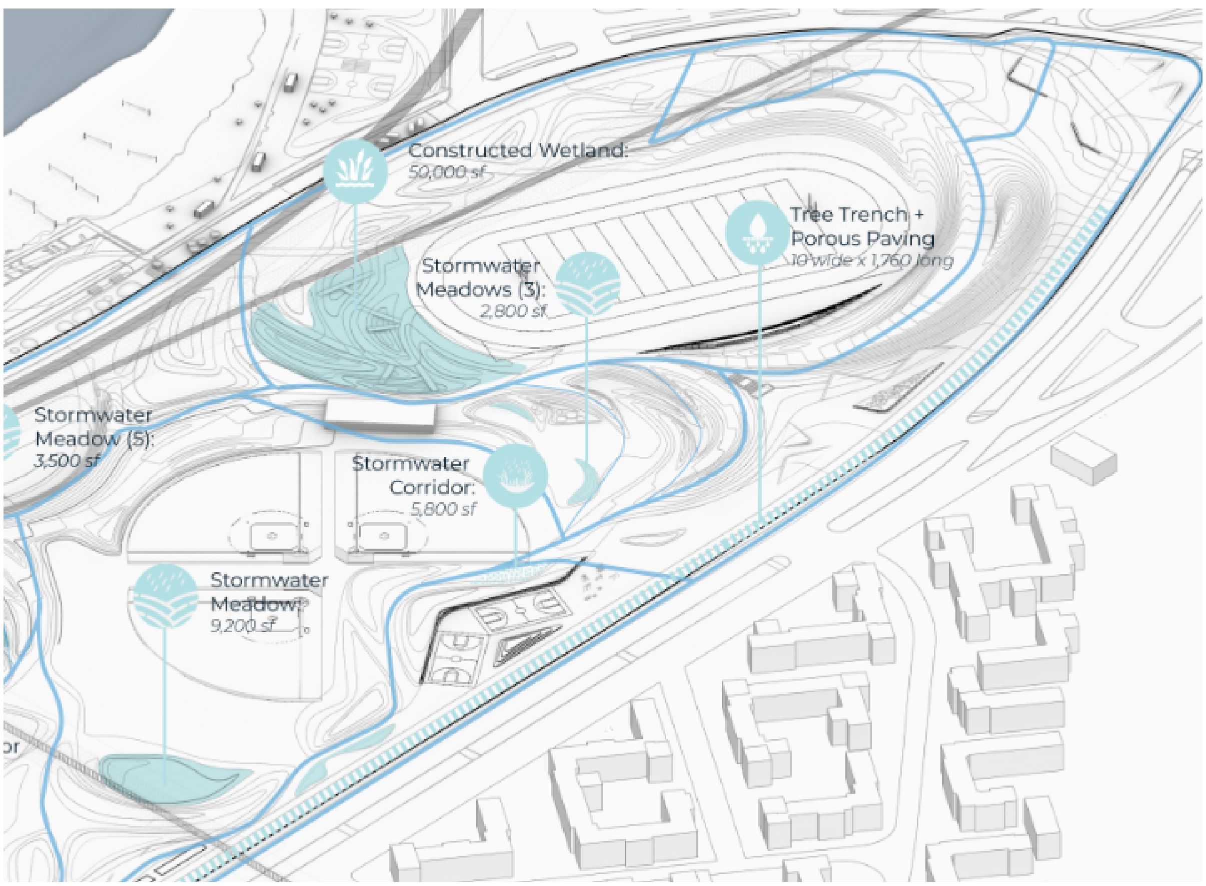


Figure 16. Conceptual green infrastructure locations – South (facing southeast), prepared by Stoss

SECTION 6

Moving Forward – Additional Considerations and Recommendations

As the Moakley Park project moves into Schematic Design, there continue to be many design opportunities and considerations that may impact the overall stormwater strategies for the Park:

- **Evaluate Effects of Phasing on Stormwater Design**
  The Project Team should consider the locations and interconnections of the stormwater system, including green infrastructure and underground systems, while defining project phasing and permitting limits. Nitsch understands this will continue to be an ongoing conversation leading into Schematic Design and subsequent phases.

- **Identify opportunities for infiltration (if possible)**
  As previously discussed, infiltration opportunities onsite will be limited due to soil contamination and high groundwater conditions. To account for this restriction, the underground systems and likely most of the green infrastructure will need to be lined and contain underdrains for full dewatering after storm events. In future design phases and as green infrastructure is sited more specifically, the Project Team will evaluate which green infrastructure systems could allow for infiltration (if any).

- **Continue coordination with BWSC**
  - In future design phases, close coordination with BWSC is needed to review and determine the appropriate connection locations for the proposed infrastructure to connect to the existing BWSC infrastructure. Nitsch is currently proposing to connect to the existing onsite BWSC infrastructure prior to its connection to the Massachusetts Water Resources Authority (MWRA) tunnel. Nitsch will also need to determine the appropriate location to connect to the Morrissey Boulevard Stormwater Outfall infrastructure and will look to BWSC to help determine the preferred connection location.

  - Nitsch also recommends reviewing the stormwater approach to redirect drainage from the east and west side of the berm with BWSC. Although the current stormwater approach is consistent with our previous conversations, BWSC has yet to see the revised approach to connect the infrastructure to the east of the berm to the existing MWRA tunnel and the infrastructure to the west of the berm to the Morrissey Boulevard Outfall.

  - BWSC also needs to provide the Design Team with any additional requirements to allow the Park to connect to the Morrissey Boulevard Outfall. These may include additional design parameters that the Park project will need to consider such as the timing of the discharge from the Park or required downstream improvements to accommodate new discharge.

  - Nitsch will also coordinate with BWSC to confirm the regulatory requirements for the Park where infiltration is not feasible. Nitsch currently proposes providing, at a minimum, treatment for the runoff from the impervious areas for the 1.25-inch storm using green infrastructure.

- **Confirm if pumps are required for stormwater discharge**
  Nitsch will continue to refine the closed drainage design to evaluate the elevations of the underground systems to confirm that a gravity connection to the Morrissey Stormwater

Overflow is feasible. This will need to be done in conjunction with the coordination with BWSC to confirm the elevation of the downstream connection point.

- **Review Perimeter Roadways and Neighborhood Opportunities**
  Nitsch recommends that the Design Team explore the opportunity to bring additional stormwater runoff from the surrounding roadways into the Park for treatment and detention. It is understood that there is a possibility the adjacent roadways will be reconstructed in the near-term, which may is an opportunity to improve stormwater mitigation and water quality treatment for the roadway. This could be done by integrating green infrastructure into the streetscape design or by potentially routing more runoff to the Park. For example, the future roadway projects could include stormwater meadows in the median, tree filters in the median or along the shoulder of the roadway, or porous strips in the shoulder, parking lanes, or bike paths.

- **Evaluate Additional Stormwater Storage Opportunities**
  The Project Team should continue to evaluate flexible and efficient opportunities for additional stormwater storage. There may be opportunities to direct flooding to athletic fields or courts or to use the underground parking garage for flood storage in large storm events. These options would be used only during storm events with a low probability of occurring such as the 100-year storm because they may require stormwater to be pumped out afterwards. Structures such as the underground parking garage could potentially be used to store stormwater runoff from the neighborhood in addition to the Park. Control measures such as this would require operational guidelines and further study.

APPENDICES

Appendix A: Moakley Park Drainage Area Division

Appendix B: Green Infrastructure Sizing Calculations

Appendix C: Monitoring Well Diagram

Appendix D HydroCAD Output

Appendix E: Record MWRA/BWSC Documentation

APPENDIX A: MOAKLEY PARK DRAINAGE AREA DIVISION

Appendix A: Existing Moakley Park Drainage Area Division

Appendix A: Proposed Moakley Park Drainage Area Division

APPENDIX B: GREEN INFRASTRUCTURE SIZING CALCULATIONS

Drainage Areas								Preliminary Green Infrastructure Analysis							
DA	Location	Total Area (SF)	% Pervious per Stoss Estimate	% Impervious per Stoss Estimate	Pervious Area (SF)	Artificial Turf (taken out of pervious)	Impervious Area (SF)	BWSC Treatment Volume Based on 1.25" Depth (cf)*	Green Infrastructure Strategy	Type of Storage**	Assumed Storage Depth (ft)	Target Area to Achieve BWSC Treatment Volume (sf) ***	Area indicated on plan (SF)	Design Notes	Underground System Location
DA1	Baseball field	249,220	91%	9%	227,526	0	21,694	2,260	Stormwater Meadow	Surface	1	2,260	8,200	Need to confirm impervious area can be graded to drain OR conveyed into the designated rain garden area	UG-1
DA2	Soccer Fields	404,841	69%	31%	277,607	0	73,234	7,629	Stormwater Meadow	Surface	1	7,629	7,700	Need additional area or other GI strategies to provide required volume.	UG-2
							25,000	2,604	Stormwater Corridor	Subsurface	3	2894	---	Storage below or alongside walkways to supplement other strategies	
							29,000	3,021	Porous Strip (Basketball Perimeter)	Subsurface	3	3356	---	Court perimeter is approximately 720 LF - Target area equates to a 5 foot porous strip around the court perimeter. Could also be a grassed stone trench.	
DA3	Little League Fields	351,836	61%	39%	213,708	0	88,128	9,180	Stormwater Meadow	Surface	1	9180	9300	Area shown on plan meets target area for treatment	UG-3
							50,000	5,208	Stormwater Corridor	Subsurface	3	5787	---	Storage below or alongside walkways to supplement other strategies	
DA4	Stadium + Marsh	389,731	67%	33%	201,539	60,000	128,192	13,353	Constructed Wetland	Surface	1	13353	20,000	Area shown on plan meets target area for treatment	GI overflow direct to BWSC/MWRA System
DA5	Urban Edge- South	178,043	68%	32%	121,587	0	56,456	5,881	Tree Plazas / Porous Pavement	Subsurface	3	6534	---	Target area translates to a corridor of approximately 10 ft wide by 560 feet long	UG-3
DA6	Urban Edge- North/Center	354,554	71%	29%	250,786	0	103,768	10,809	Tree Plazas / Porous Pavement	Subsurface	3	12010	---	Target area translates to a corridor of approximately 10 ft wide by 1200 feet long. Northernmost portion could also be directed into the stormwater meadow in DA 1.	UG-3
DA7A	Waterfront Plaza	154,470	55%	45%	84,388	0	70,082	7,300	Stormwater Meadow/Dunes	Surface	1	24334	---	Target area would require approx. 30% of the permeable area to be designated for stormwater.	GI overflow direct to BWSC/MWRA System
DA7B	Waterfront North	292,806	80%	20%	233,860	0	58,946	6,140	Constructed Wetland	Surface	1	6140	8600	Area shown on plan meets target area for treatment	
DA8A	Adventure Play	26,649	87%	13%	23,208	0	3,441	358	Stormwater Meadow	Surface	1	358	3000	Area shown on plan meets target area for treatment	UG-3
DA8B	Adventure Play	21,545	75%	25%	16,216	0	5,329	555	Stormwater Meadow	Surface	1	555	4400	Area shown on plan meets target area for treatment	UG-3
DA8C	Adventure Play	15,823	76%	24%	12,030	0	3,793	395	Stormwater Meadow	Surface	1	395	375	Small increase or reallocation of area is needed.	UG-3
DA8D	Adventure Play	34,949	73%	27%	25,461	0	9,488	988	Stormwater Meadow	Surface	1	988	500	Small increase or reallocation of area is needed.	UG-3
DA8E	Adventure Play	66,286	82%	18%	54,076	0	12,210	1,272	Stormwater Meadow	Surface	1	1272	3500	Area shown on plan meets target area for treatment	UG-3
DA9A	Grove	37,664	95%	5%	35,778	0	1,886	196	Stormwater Meadow	Surface	1	196	1500	Area shown on plan meets target area for treatment	UG-3
DA9B	Grove	30,173	82%	18%	24,688	0	5,485	571	Stormwater Meadow	Surface	1	571	2200	Area shown on plan meets target area for treatment	UG-3
DA10	Southern Edge	89,040	78%	22%	69,498	0	19,542	2,036	Constructed Wetland	Surface	1	2036	4900	Area shown on plan meets target area for treatment	GI overflow direct to BWSC/MWRA System
DA11	Roadway- South	21,993	0%	100%	0	0	21,993	2,291	Tree Plazas	Subsurface	3	2545	---	Potential addition to DA 5 - Increased target area translates to an additional 5 feet along the 560 foot corridor.	UG-3
DA12	Roadway- North/Center	61,916	0%	100%	0	0	61,916	6,450	Tree Plazas	Subsurface	3	7166	---	Potential addition to DA 6 - Increased target area translates to an additional 6 feet along the 1200 foot corridor.	UG-3
DA13	Roadway- East	49,440	0%	100%	0	0	49,440	5,150	Constructed Wetland	Surface	1	5150	---	Potential addition to DA 7B - Increased target area would require an additional 5,150 sf of constructed wetland area.	GI overflow direct to BWSC/MWRA System

Notes

* BWSC Treatment Volume (cf) = [1.25 inches / 12 inches per foot] x Impervious Area (sf)

** Void ratio for surface storage is assumed to be 100%. Void ratio for subsurface storage is assumed to be 30% (max. acceptable for stone by BWSC)

*** Target Area to Achieve BWSC Treatment Volume (sf) = BWSC Treatment Volume (cf) / Depth (ft) * Void Ratio

APPENDIX C: MONITORING WELL DIAGRAM

\\wse03.local\WSE\Projects\MA\Boston MA\Moakley Park\Geotechnical\Site Plan\For Report\Moakley Park Exploration Plan SAMPLING PLAN.dwg

PLAN REFERENCES

1. PARKS AND RECREATION DEPARTMENT
   BOSTON, MASSACHUSETTS, COLUMBUS PARK
   LAYOUT & DRAINAGE
   BY CAMP DRESSER & McKEE, INC
   SCALE: 1"=30', DATE: JUNE, 1993

2. PARKS AND RECREATION DEPARTMENT
   BOSTON, MASSACHUSETTS, COLUMBUS PARK
   GRADING AND UTILITIES PLAN
   BY STORCH ASSOCIATES
   SCALE: 1"=20'-0"', DATE: 10-7-74

3. CITY OF BOSTON PARKS & RECREATION DEPARTMENT
   COLUMBUS PARK, SOUTH BOSTON
   SITE PLAN EXISTING WORK
   SCALE: AS NOTED, DATE: MAY 15, 1973

4. SOUTH BOSTON BEACHES REHABILITATION
   METROPOLITAN DISTRICT COMMISSION
   CONTRACT NO. P95-1784-CIA
   BY CAROL R. JOHNSON ASSOCIATES, INC.
   WATER MAIN IMPROVEMENTS
   SCALE: 1"=40', DATE: 05-01-98
   SHEETS W-01 AND W-02

5. BOSTON WATER AND SEWER COMMISSION
   BWSC MAP 18L 17L, AND 19K 19L 18K
   SCALE" 1"=100', PRINTED: SEPTEMBER 13, 2007

6. KEMP ST. EXTENSION OF OVERFLOW
   FROM EXISTING SEWER EASTERLY, SOUTH BOSTON
   PLAN AND PROFILE
   SCALE" 1"=20' HORIZONTAL, 1"=50' VERTICAL
   STAMPED: CITY OF BOSTON STREET DEPARTMENT
   SEWER DIVISION
   DATE: MAY 21, 1910

7. MASSACHUSETTS WATER RESOURCES AUTHORITY
   BOS086 - GRADING PLAN
   NORTH DORCHESTER BAY CSO STORAGE TUNNEL
   SCALE" 1"=40'-0"
   SHEET NO. 87 OF 238
   DRAWING NO. C-129

8. MASSACHUSETTS WATER RESOURCES AUTHORITY
   BOS087 - SITE UTILITY PLAN
   NORTH DORCHESTER BAY CSO STORAGE TUNNEL
   SCALE" 1"=20'
   SHEET NO. 99 OF 238
   DRAWING NO. C-152

9. CITY OF BOSTON PARK DEPARTMENT
   WATER AND SEWER LINES AT COLUMBUS
   PARK, SOUTH BOSTON
   SCALE" 1"=100'
   SHEET NO. 99 OF 238
   DRAWING NO. C-152

10. PARKS AND RECREATION DEPARTMENT
    BOSTON, MASSACHUSETTS, COLUMBUS PARK
    UPGRADING EXISTING WATER CONDITIONS
    SCALE: 1"=20'-0"', DATE: FEBRUARY, 1989

11. KEYSPAN ENERGY DELIVERY
    PLANS 255, 256, 261, 264 AND 908

12. NSTAR ELECTRIC
    VARIOUS PLANS

13. MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
    PLAN 0194 AND 0195

14. BOSTON TRANSPORTATION DEPARTMENT
    NSTAR ELECTRIC COMPANY PROPOSED 345kV CONDUIT
    BY VANASSE HANGEN BRUSTLIN, INC.

15. COMCAST

16. PLAN SHOWING CITY OF BOSTON ROADS AND LANDS
    TRANSFERRED TO METROPOLITAN DISTRICT COMMISSION
    UNDER PROVISIONS OF CHAPTER 570 ACT OF 1955,
    CITY OF BOSTON, COLUMBIA RD., OLD COLONY AVE.
    SOUTH BOSTON
    PREPARED BY: JAMES W. HALEY, CHIEF ENGINEER,
    SURVEY DIVISION, PUBLIC WORKS DEPARTMENT
    DATED: MARCH 14, 1956, SCALE: 1"=100'
    CITY OF BOSTON LAYOUT NO. L-8709

17. WILLIAM J. DAY BOULEVARD, SOUTH BOSTON &
    DORCHESTER DISTRICTS, PLAN OF LAND TO BE TAKEN
    FROM THE CITY OF BOSTON BOARD OF PARK
    COMMISSIONERS UNDER THE PROVISIONS OF
    CHAPTER 509, ACTS OF 1949
    PREPARED BY: BENJAMIN W. FINK, DIRECTOR OF PARK
    ENGINEERING, COMMONWEALTH OF MASSACHUSETTS
    METROPOLITAN DISTRICT COMMISSION, PARKS DIVISION
    DATED: JANUARY 10, 1962, SCALE: 1"=100'
    MDC PLAN NOS. 38224 V.T. & 38225 V.T.

18. COLUMBIA ROAD, FRANKLIN PARK TO MARINE PARK
    PREPARED BY: WILLIAM JACKSON, CITY ENGINEER
    DATED: JUNE 10, 1877, SCALE: 1"=40'
    CITY OF BOSTON LAYOUT NO. L-2876

19. MASSACHUSETTS WATER RESOURCES AUTHORITY
    NORTH DORCHESTER BAY CSO STORAGE TUNNEL
    MWRA CONTRACT NO. 6244
    PREPARED BY: PARSONS BRINKERHOFF QUADE &
    DOUGLAS, INC., METCALF & EDDY AND BRYANT
    ASSOCIATES, INC.
    DATED: AUGUST 8, 2005, SCALE: 1"=40'
    PLAN BOOK 2006, PAGE 916

PLAN NOTES

1. THIS PLAN IS BASED ON THE CITED RECORD DESCRIPTIONS, ADDITIONAL REFERENCES AND SOURCES AS NOTED, AND AN ON-THE-GROUND SURVEY MADE SEPTEMBER, OCTOBER AND NOVEMBER, 2007 AND PARTIALLY UPDATED IN JUNE 2008 TO OBTAIN TOPOGRAPHICAL DATA WITHIN MWRA CONSTRUCTION AREAS AND IN APRIL 2009 TO SHOW THE LOCATION OF PROPERTY LINES.

2. COORDINATES, IN U.S. SURVEY FEET, ARE IN THE MASSACHUSETTS COORDINATE SYSTEM, MAINLAND ZONE, REFERENCED TO THE NORTH AMERICAN DATUM OF 1983 (NAD 83/CORS), AS DETERMINED BY SMC'S NETWORK OF G.P.S. OBSERVATIONS, BASED ON THE FOLLOWING NATIONAL GEODETIC SURVEY (NGS) CONTINUOUSLY OPERATING REFERENCE STATIONS (CORS): WMTS (WOBURN, MA) (NGS DATABASE ID AJ4072), FMTS (FRAMINGHAM, MA) (NGS DATABASE ID D10964) AND XMTS (FOXBORO, MA) (NGS DATABASE ID D10966).

3. PROPERTY LINE WAS COMPILED FROM AVAILABLE RECORD PLANS AND BASED ON THE LIMITED MONUMENTATION FOUND.

4. RECORD EASEMENTS, INCLUDING ANY CREATED BY MWRA CONTRACT NO. 6244, ARE NOT SHOWN ON THIS SURVEY. AS-BUILT RECORD DATA FOR MWRA PROJECT UNAVAILABLE AT TIME OF SURVEY.

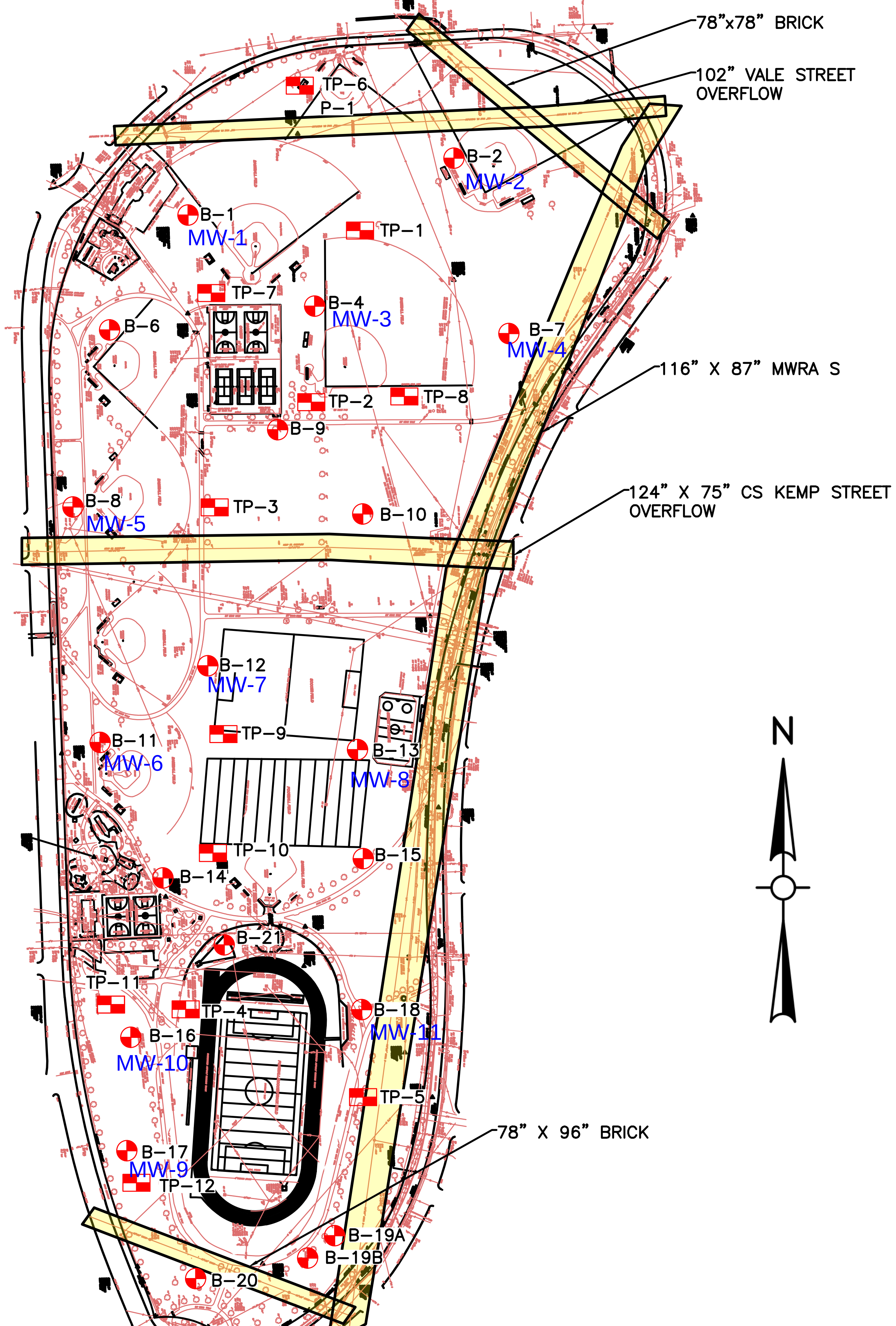
5. ELEVATIONS, IN U.S. SURVEY FEET, ARE REFERENCED TO THE BOSTON CITY BASE AS DEFINED BY MASSACHUSETTS HIGHWAY DEPARTMENT BENCHMARK #213D.

6. SUBSURFACE UTILITY LINES AND FEATURES, AS SHOWN HEREON, WERE COMPILED FROM FIELD EVIDENCE AND/OR AVAILABLE RECORD INFORMATION (SEE REFERENCES), AND THEIR LOCATIONS ARE ONLY APPROXIMATE. ACTUAL LOCATIONS MUST BE DETERMINED IN THE FIELD.

SMC ASSUMES NO RESPONSIBILITY FOR DAMAGES INCURRED AS A RESULT OF UTILITIES OMITTED OR INACCURATELY SHOWN.

BEFORE DESIGNING FUTURE CONNECTIONS, THE APPROPRIATE UTILITIES MUST BE CONSULTED.

BEFORE CONSTRUCTION, ALL UTILITIES, PUBLIC AND PRIVATE, MUST BE NOTIFIED (SEE MASSACHUSETTS GENERAL LAWS, CHAPTER 82 SECTION 40).
CALL "DIG SAFE" 1-888-DIG-SAFE.
(888-344-7233).



NOTES:

1. THIS FIGURE IS BASED ON A COMPILATION OF EXISTING RECORD PLANS AND UTILITY INFORMATION. REFER TO THE "PLAN REFERENCES" AND "PLAN NOTES" FOR ADDITIONAL INFORMATION.

2. BORINGS WERE COMPLETED BY NEW ENGLAND BORING CONTRACTORS, INC. BETWEEN AUGUST 13 AND SEPTEMBER 11, 2019, AS OBSERVED BY WESTON & SAMPSON.

3. PROPOSED BORINGS B-3, B-5 AND B-9 WERE NOT COMPLETED.

4. TEST PITS WERE EXCAVATED BY NEW ENGLAND BORING CONTRACTORS, INC. ON SEPTEMBER 12 AND 13, 2019, AS OBSERVED BY WESTON & SAMPSON.

5. BORING AND TEST PIT LOCATIONS SHOWN ARE BASED ON GPS SURVEY COMPLETED BY WESTON & SAMPSON.

6. EXISTING UTILITY LOCATIONS ARE APPROXIMATE.

LEGEND:

B-1	WSE BORING DESIGNATION AND APPROXIMATE LOCATION
TP-1	WSE TEST PIT DESIGNATION AND APPROXIMATE LOCATION

300 150 0 300 600

SCALE: 1"=300'

FIGURE 2

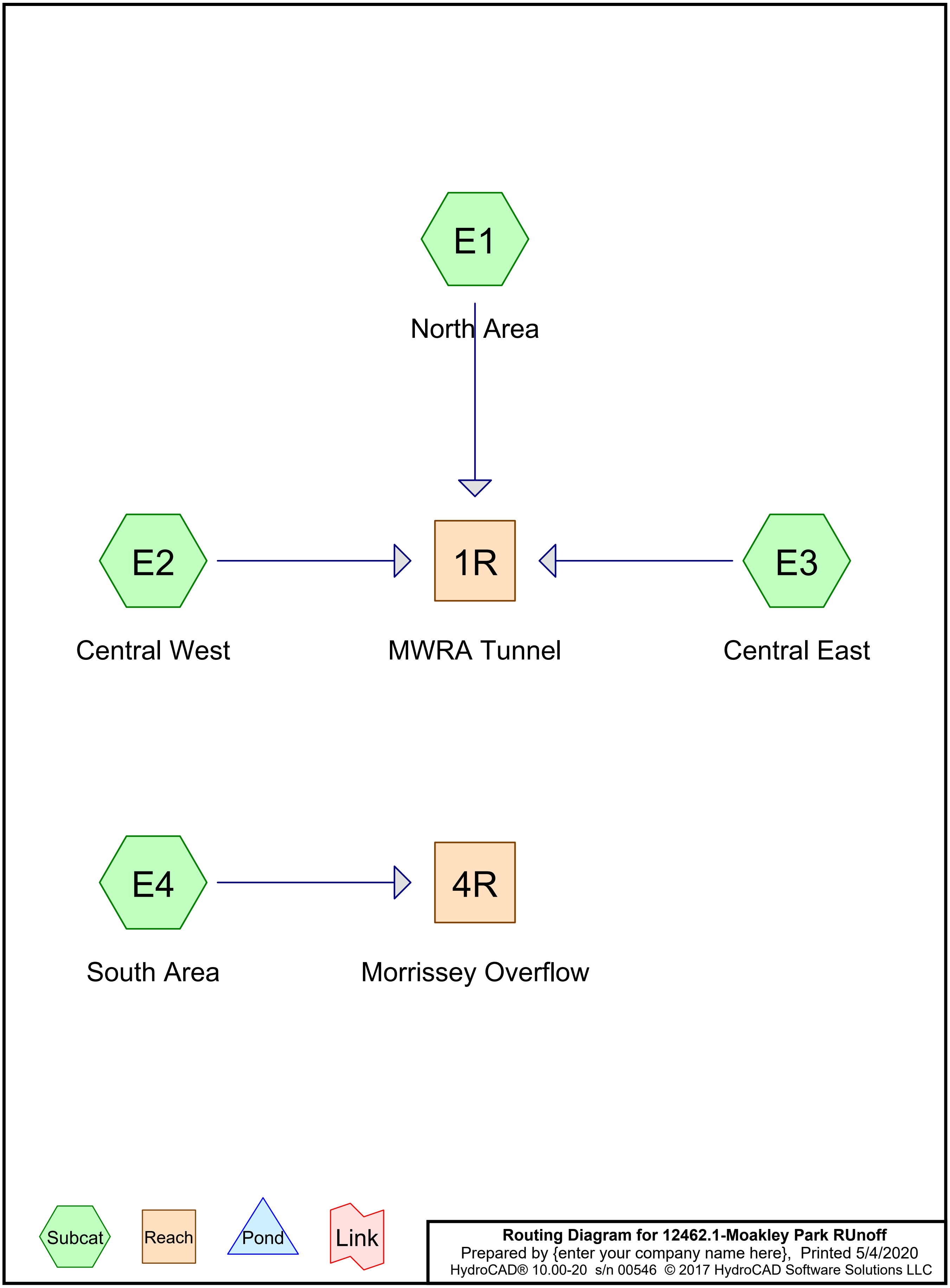
MOAKLEY PARK
BOSTON, MA

SITE PLAN

DESIGNED BY:	MDM	CHECKED BY:	STS	DATE:	DECEMBER 2019

Weston & Sampson

APPENDIX D HYDROCAD OUTPUT



Routing Diagram for 12462.1-Moakley Park RUnoff
Prepared by {enter your company name here}, Printed 5/4/2020

Area Listing (selected nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
2,012,752	80	>75% Grass cover, Good, HSG D (E1, E2, E3, E4)
684,877	98	Impervious, HSG D (E1, E2, E3, E4)
2,697,629	**85**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
0	HSG A	
0	HSG B	
0	HSG C	
2,697,629	HSG D	E1, E2, E3, E4
0	Other	
2,697,629		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	Su Nu
0	0	0	2,012,752	0	2,012,752	>75% Grass cover, Good	
0	0	0	684,877	0	684,877	Impervious	
0	**0**	**0**	**2,697,629**	**0**	**2,697,629**	**TOTAL AREA**	

Time span=0.00-72.00 hrs, dt=0.05 hrs, 1441 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

SubcatchmentE1: North Area Runoff Area=787,906 sf 18.75% Impervious Runoff Depth=6.06"
Tc=6.0 min CN=83 Runoff=119.18 cfs 398,115 cf

SubcatchmentE2: Central West Runoff Area=677,078 sf 7.93% Impervious Runoff Depth=5.83"
Tc=6.0 min CN=81 Runoff=99.40 cfs 328,792 cf

SubcatchmentE3: Central East Runoff Area=556,791 sf 23.71% Impervious Runoff Depth=6.18"
Tc=6.0 min CN=84 Runoff=85.39 cfs 286,825 cf

SubcatchmentE4: South Area Runoff Area=675,854 sf 52.01% Impervious Runoff Depth=6.78"
Tc=6.0 min CN=89 Runoff=109.92 cfs 381,582 cf

Reach 1R: MWRA Tunnel Inflow=303.97 cfs 1,013,732 cf
Outflow=303.97 cfs 1,013,732 cf

Reach 4R: Morrissey Overflow Inflow=109.92 cfs 381,582 cf
Outflow=109.92 cfs 381,582 cf

Total Runoff Area = 2,697,629 sf Runoff Volume = 1,395,314 cf Average Runoff Depth = 6.21"
74.61% Pervious = 2,012,752 sf 25.39% Impervious = 684,877 sf

Summary for Subcatchment E1: North Area

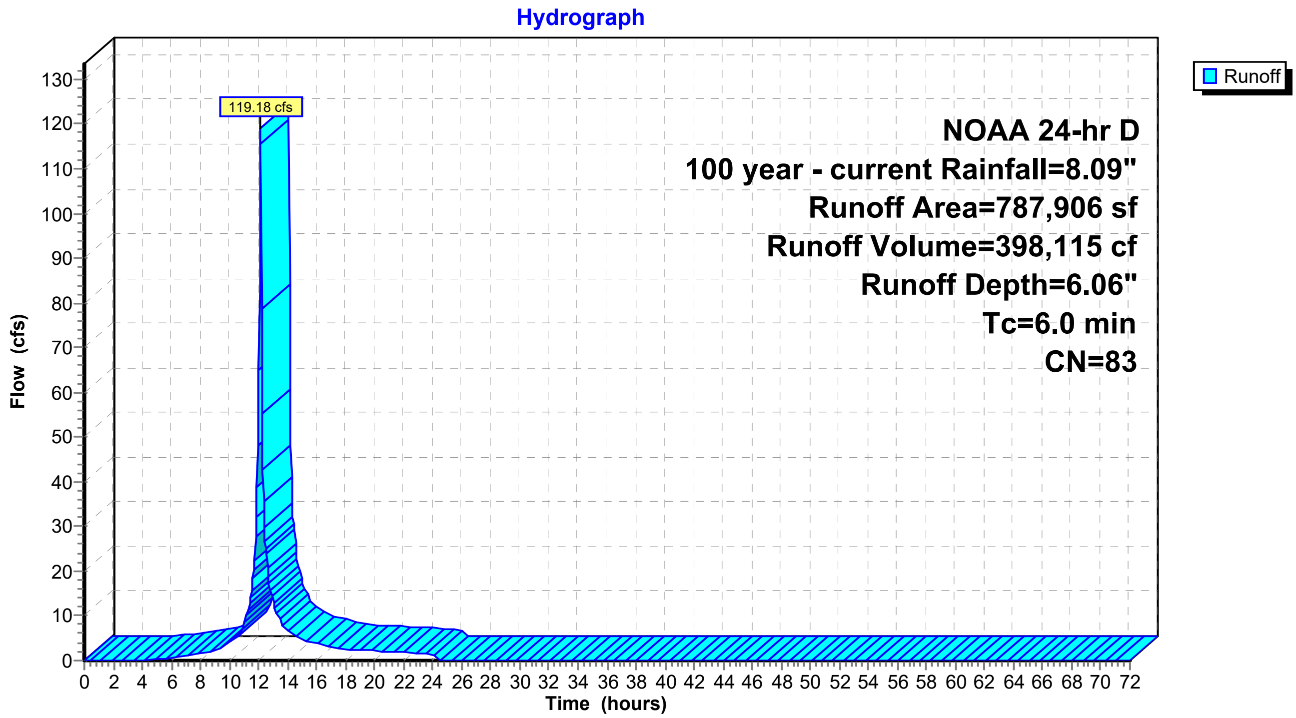
Runoff = 119.18 cfs @ 12.13 hrs, Volume= 398,115 cf, Depth= 6.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	147,703	98	Impervious, HSG D
	640,203	80	>75% Grass cover, Good, HSG D
	787,906	83	Weighted Average
	640,203		81.25% Pervious Area
	147,703		18.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E1: North Area



Summary for Subcatchment E2: Central West

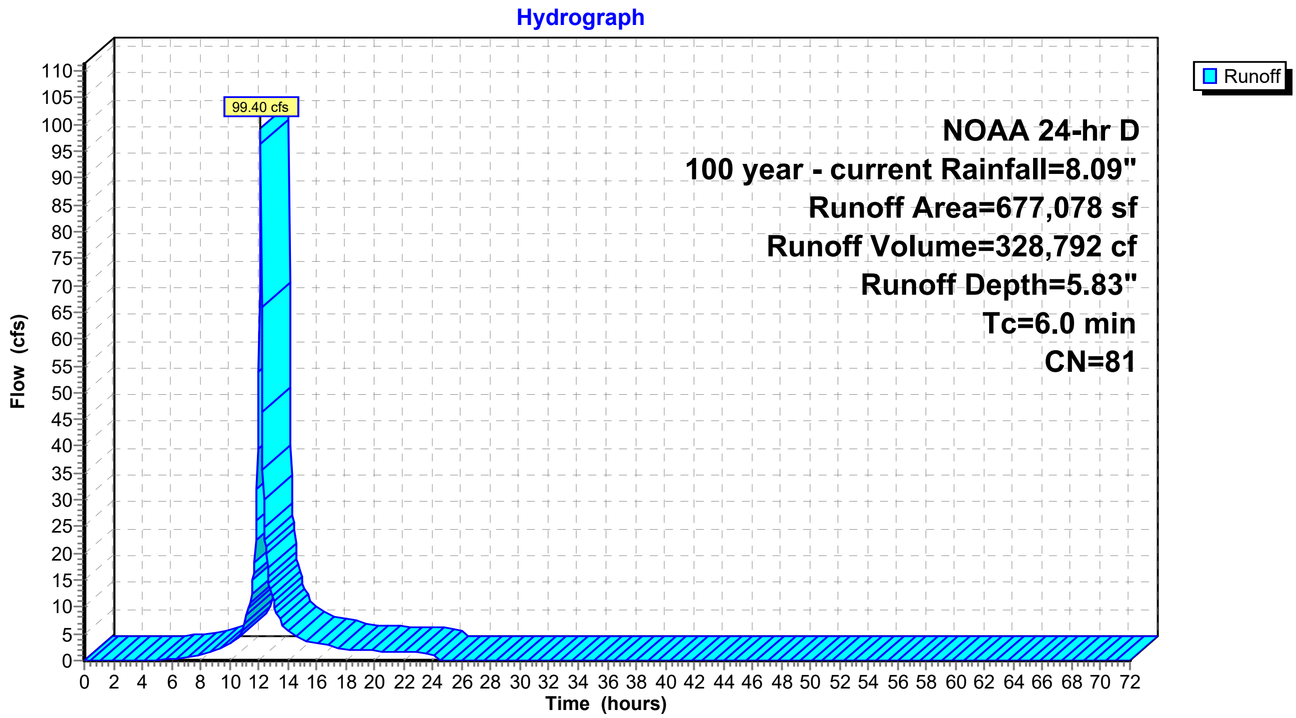
Runoff = 99.40 cfs @ 12.13 hrs, Volume= 328,792 cf, Depth= 5.83"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	53,661	98	Impervious, HSG D
	623,417	80	>75% Grass cover, Good, HSG D
	677,078	81	Weighted Average
	623,417		92.07% Pervious Area
	53,661		7.93% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E2: Central West



Summary for Subcatchment E3: Central East

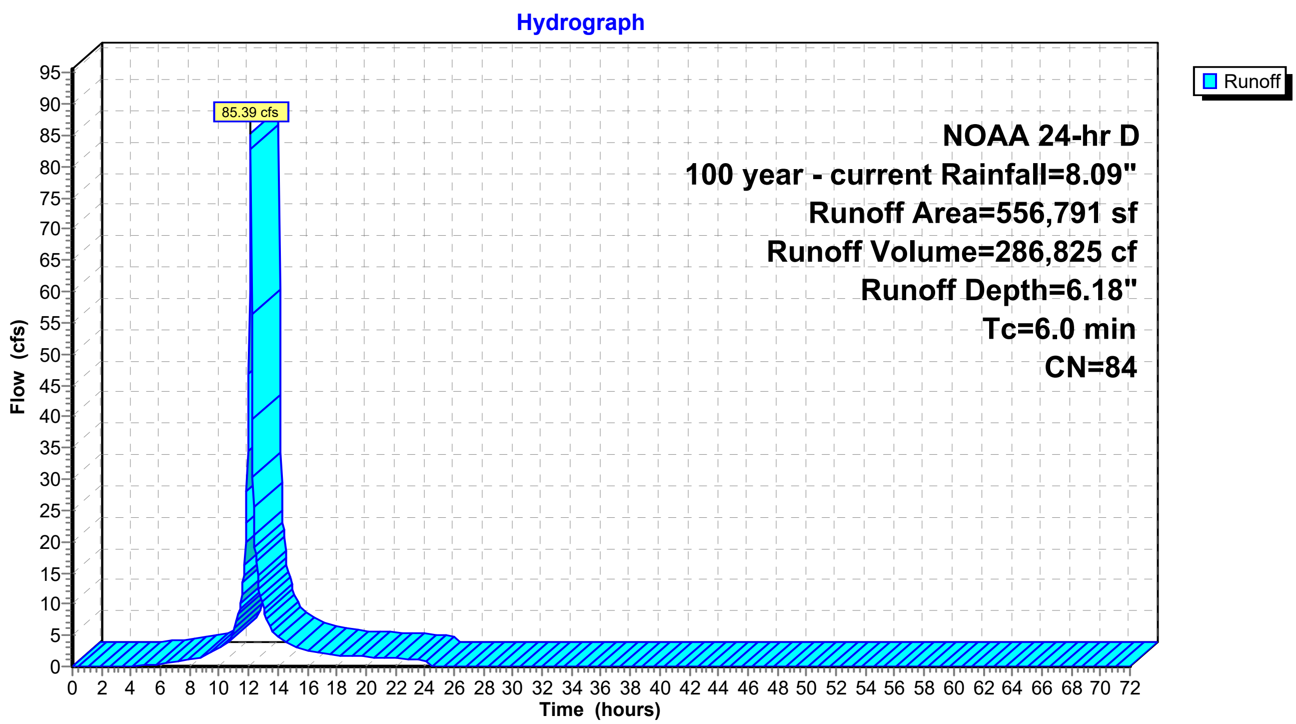
Runoff = 85.39 cfs @ 12.13 hrs, Volume= 286,825 cf, Depth= 6.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	132,012	98	Impervious, HSG D
	424,779	80	>75% Grass cover, Good, HSG D
	556,791	84	Weighted Average
	424,779		76.29% Pervious Area
	132,012		23.71% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E3: Central East



Summary for Subcatchment E4: South Area

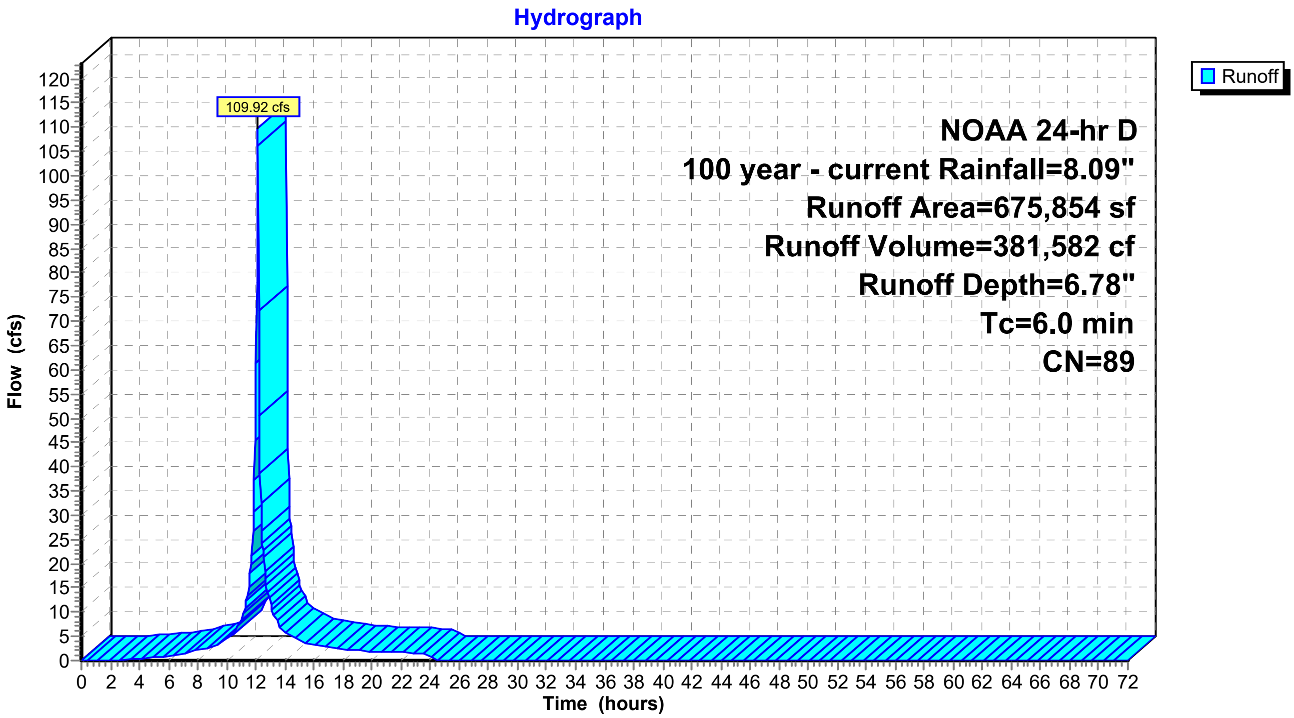
Runoff = 109.92 cfs @ 12.13 hrs, Volume= 381,582 cf, Depth= 6.78"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	351,501	98	Impervious, HSG D
	324,353	80	>75% Grass cover, Good, HSG D
	675,854	89	Weighted Average
	324,353		47.99% Pervious Area
	351,501		52.01% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E4: South Area



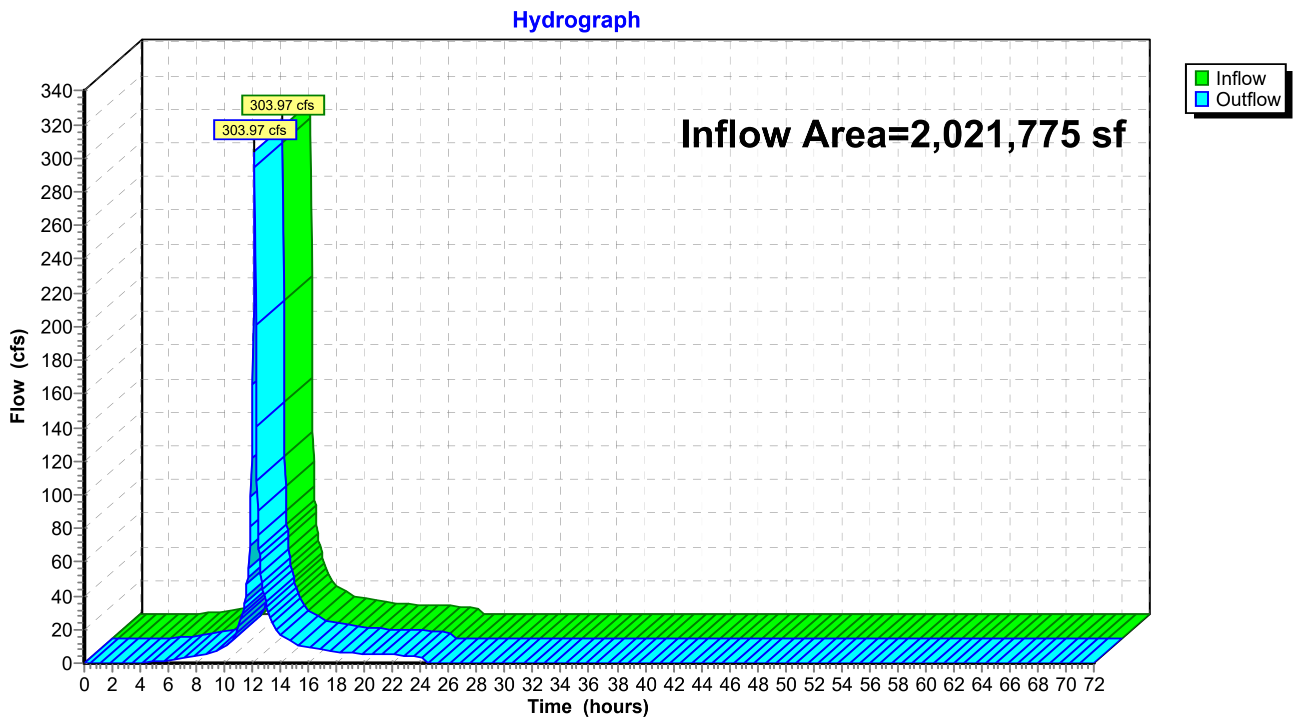
Summary for Reach 1R: MWRA Tunnel

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 2,021,775 sf, 16.49% Impervious, Inflow Depth = 6.02" for 100 year - current event
Inflow = 303.97 cfs @ 12.13 hrs, Volume= 1,013,732 cf
Outflow = 303.97 cfs @ 12.13 hrs, Volume= 1,013,732 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Reach 1R: MWRA Tunnel

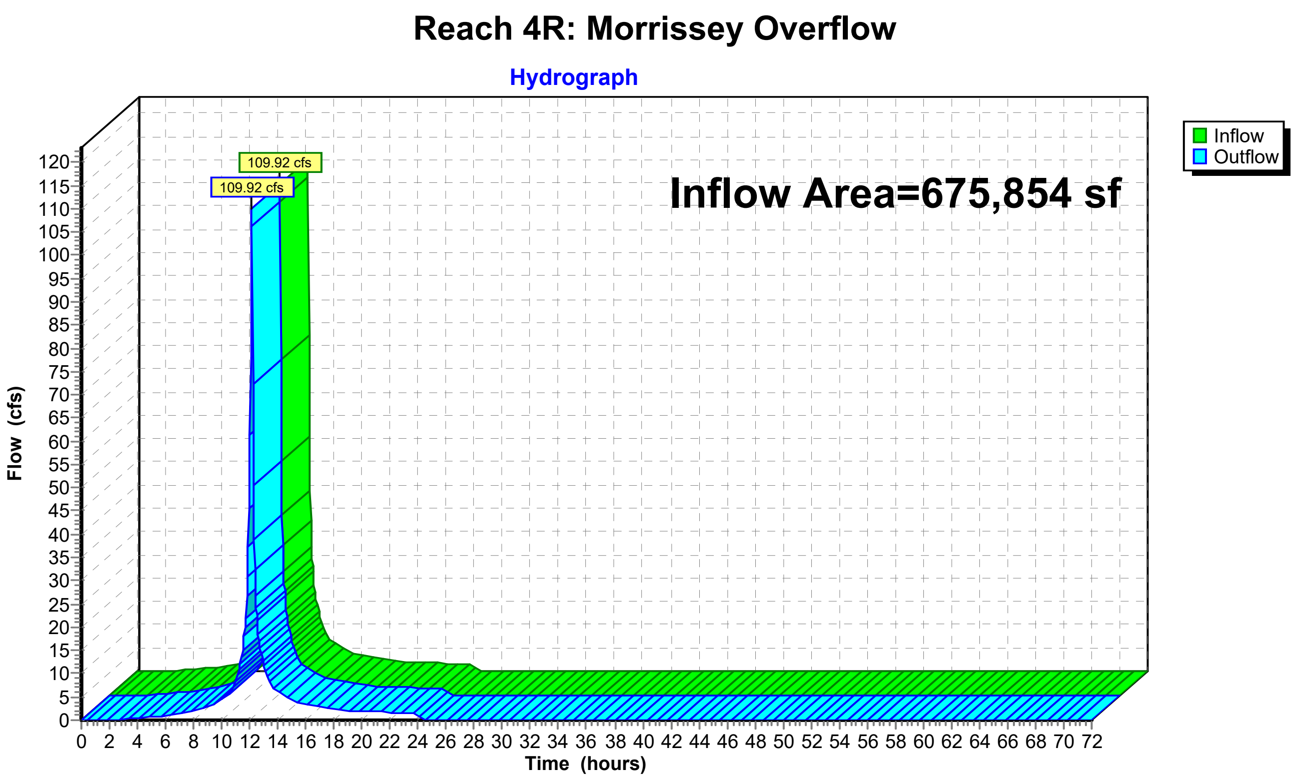


Summary for Reach 4R: Morrissey Overflow

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	675,854 sf,	52.01% Impervious,	Inflow Depth = 6.78"	for 100 year - current event
Inflow =	109.92 cfs @	12.13 hrs, Volume=	381,582 cf	
Outflow =	109.92 cfs @	12.13 hrs, Volume=	381,582 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs



Time span=0.00-72.00 hrs, dt=0.05 hrs, 1441 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

SubcatchmentE1: North Area Runoff Area=787,906 sf 18.75% Impervious Runoff Depth=9.56"
Tc=6.0 min CN=83 Runoff=182.62 cfs 627,480 cf

SubcatchmentE2: Central West Runoff Area=677,078 sf 7.93% Impervious Runoff Depth=9.29"
Tc=6.0 min CN=81 Runoff=154.16 cfs 524,197 cf

SubcatchmentE3: Central East Runoff Area=556,791 sf 23.71% Impervious Runoff Depth=9.69"
Tc=6.0 min CN=84 Runoff=130.12 cfs 449,546 cf

SubcatchmentE4: South Area Runoff Area=675,854 sf 52.01% Impervious Runoff Depth=10.34"
Tc=6.0 min CN=89 Runoff=163.36 cfs 582,206 cf

Reach 1R: MWRA Tunnel Inflow=466.90 cfs 1,601,223 cf
Outflow=466.90 cfs 1,601,223 cf

Reach 4R: Morrissey Overflow Inflow=163.36 cfs 582,206 cf
Outflow=163.36 cfs 582,206 cf

Total Runoff Area = 2,697,629 sf Runoff Volume = 2,183,429 cf Average Runoff Depth = 9.71"
74.61% Pervious = 2,012,752 sf 25.39% Impervious = 684,877 sf

Summary for Subcatchment E1: North Area

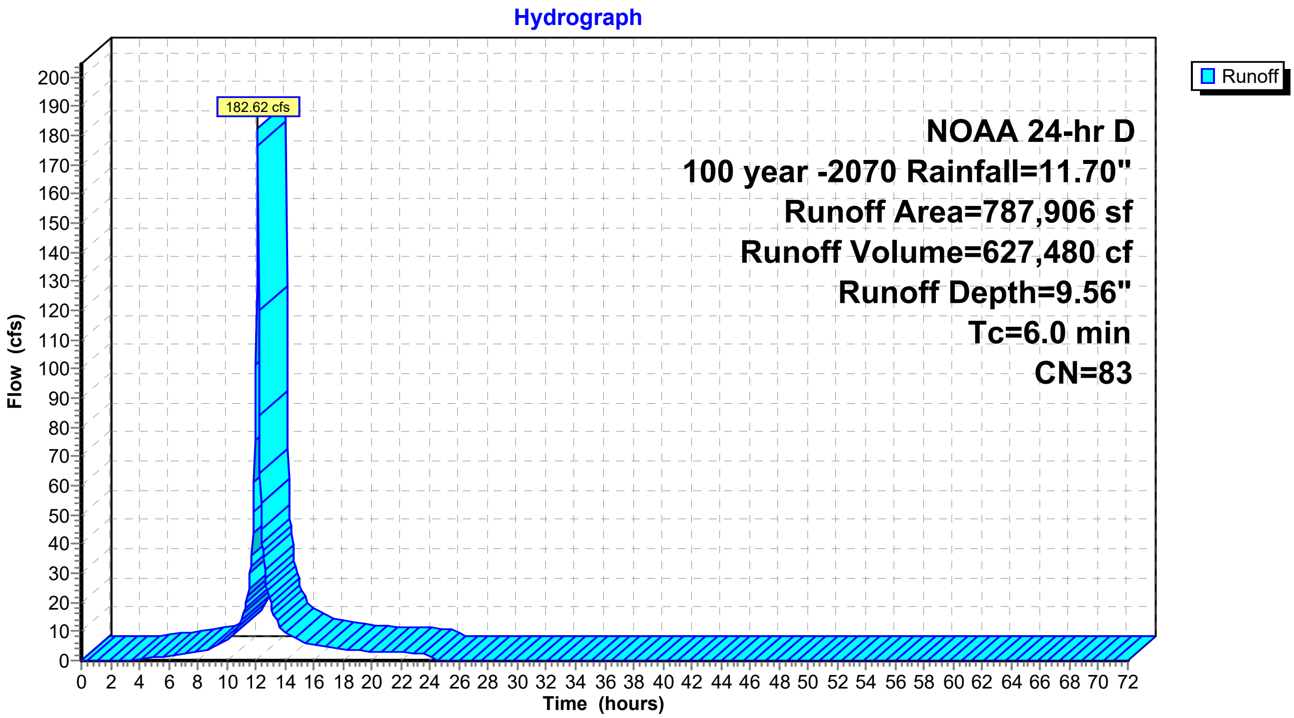
Runoff = 182.62 cfs @ 12.13 hrs, Volume= 627,480 cf, Depth= 9.56"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

	Area (sf)	CN	Description
*	147,703	98	Impervious, HSG D
	640,203	80	>75% Grass cover, Good, HSG D
	787,906	83	Weighted Average
	640,203		81.25% Pervious Area
	147,703		18.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E1: North Area



Summary for Subcatchment E2: Central West

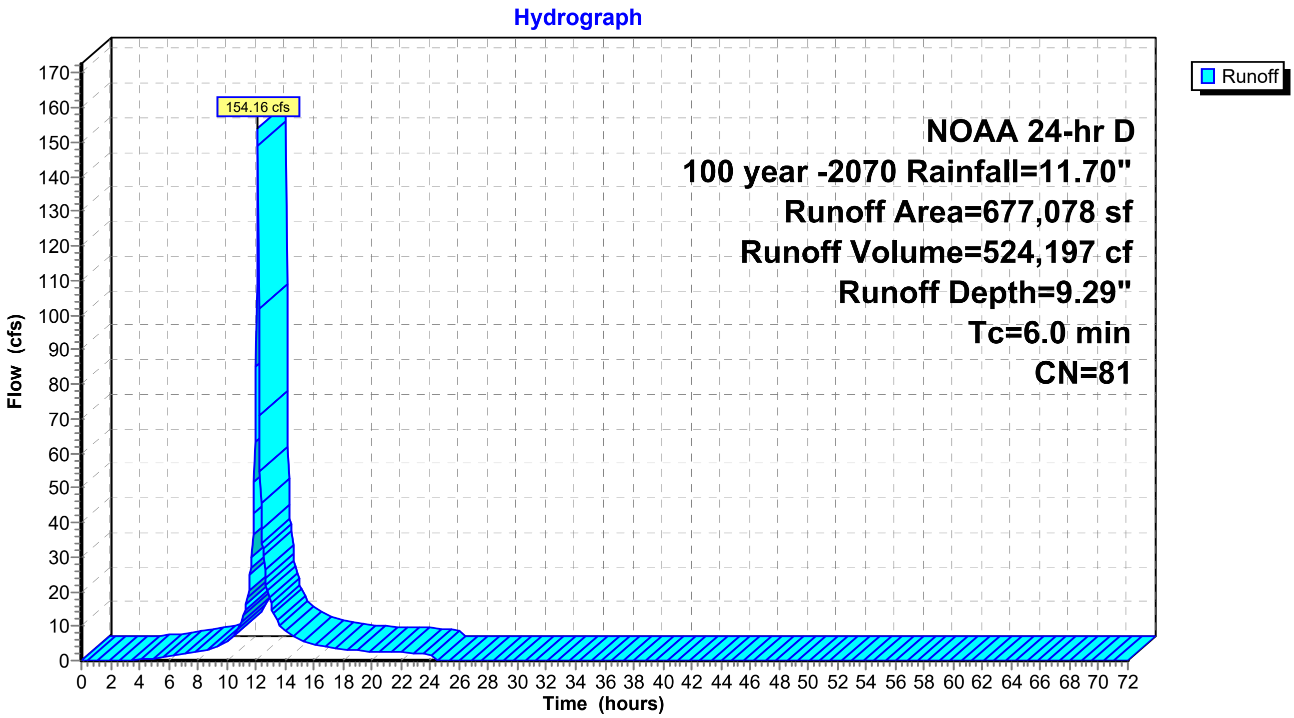
Runoff = 154.16 cfs @ 12.13 hrs, Volume= 524,197 cf, Depth= 9.29"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

	Area (sf)	CN	Description
*	53,661	98	Impervious, HSG D
	623,417	80	>75% Grass cover, Good, HSG D
	677,078	81	Weighted Average
	623,417		92.07% Pervious Area
	53,661		7.93% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E2: Central West



Summary for Subcatchment E3: Central East

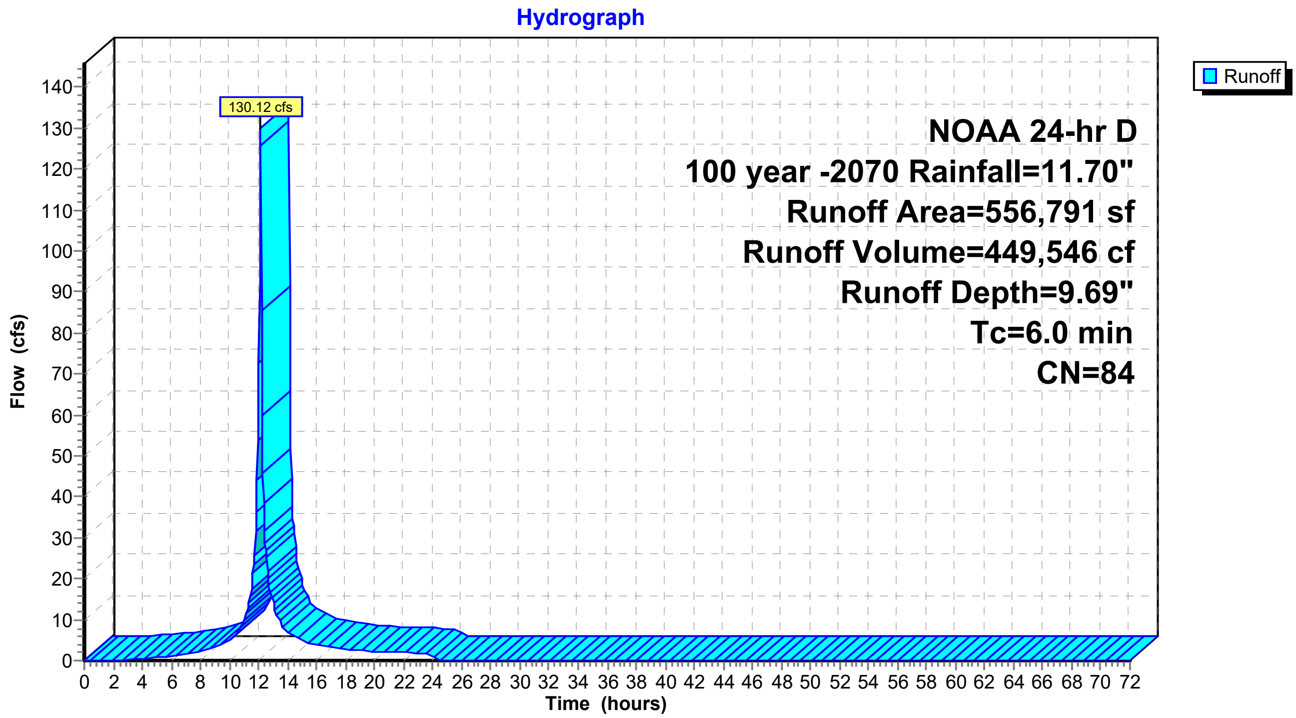
Runoff = 130.12 cfs @ 12.13 hrs, Volume= 449,546 cf, Depth= 9.69"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

	Area (sf)	CN	Description
*	132,012	98	Impervious, HSG D
	424,779	80	>75% Grass cover, Good, HSG D
	556,791	84	Weighted Average
	424,779		76.29% Pervious Area
	132,012		23.71% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E3: Central East



Summary for Subcatchment E4: South Area

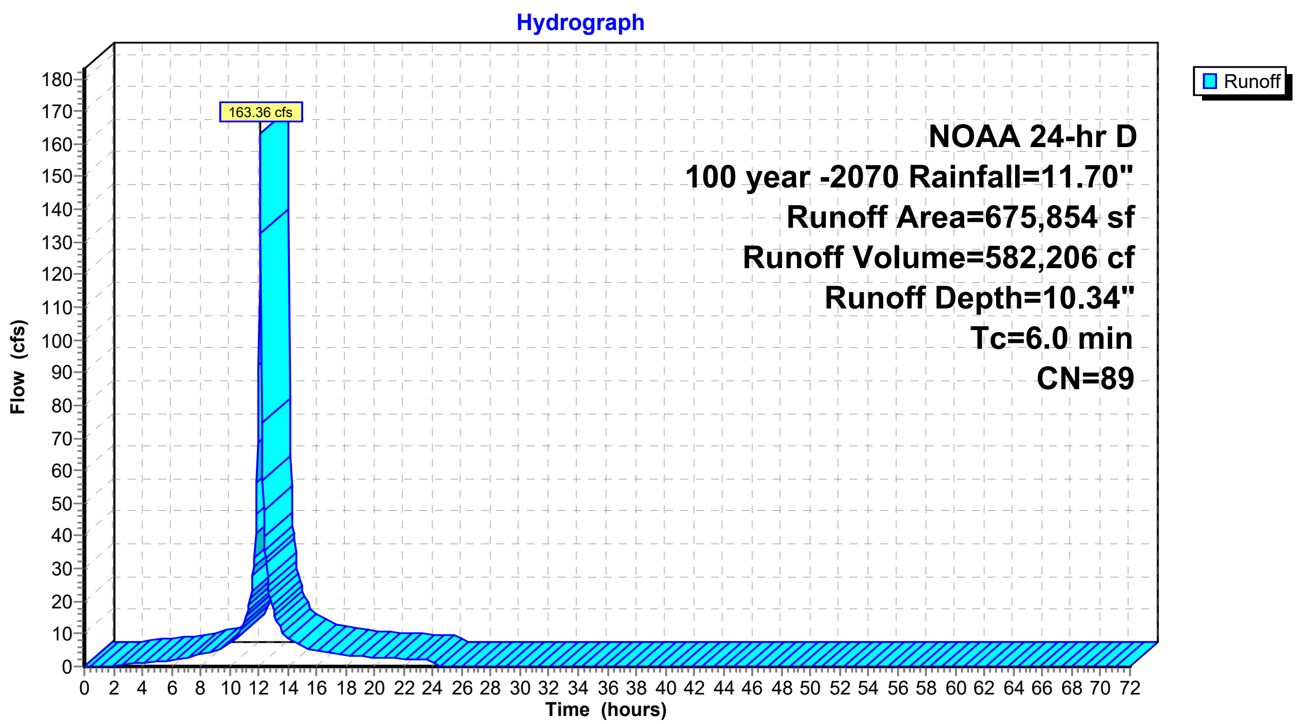
Runoff = 163.36 cfs @ 12.13 hrs, Volume= 582,206 cf, Depth=10.34"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

	Area (sf)	CN	Description
*	351,501	98	Impervious, HSG D
	324,353	80	>75% Grass cover, Good, HSG D
	675,854	89	Weighted Average
	324,353		47.99% Pervious Area
	351,501		52.01% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment E4: South Area



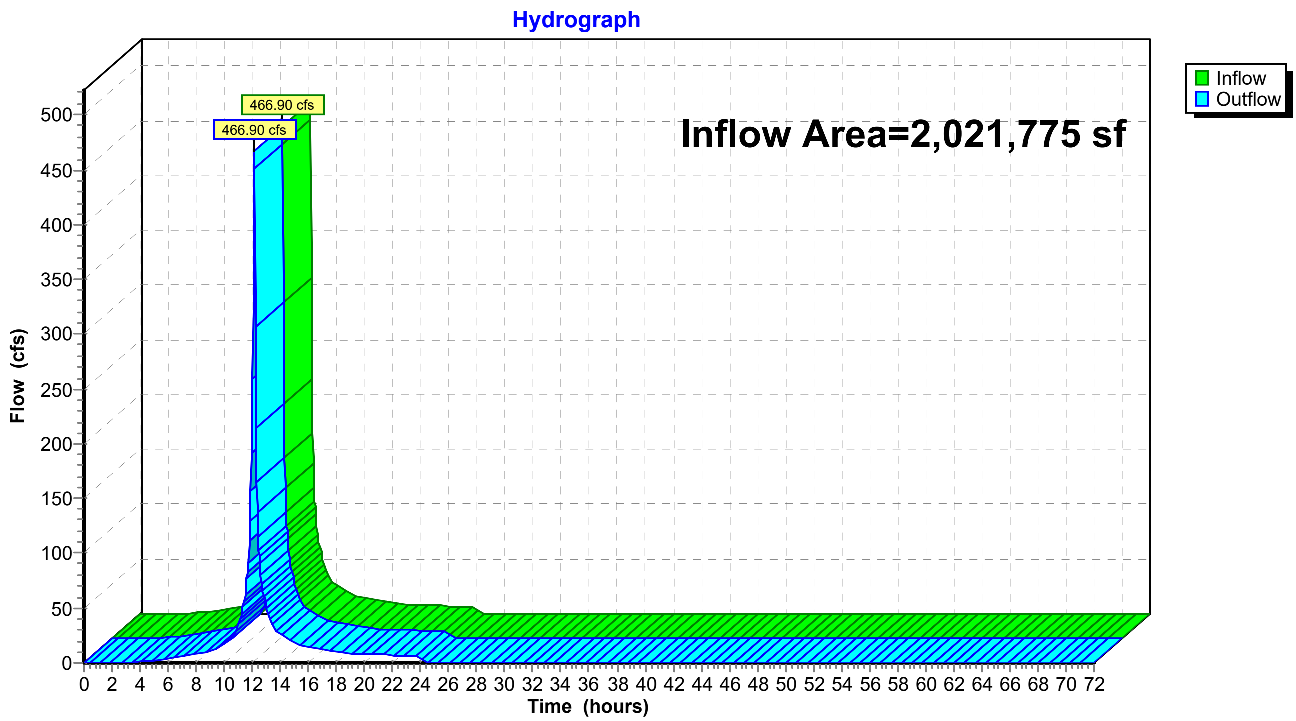
Summary for Reach 1R: MWRA Tunnel

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 2,021,775 sf, 16.49% Impervious, Inflow Depth = 9.50" for 100 year -2070 event
Inflow = 466.90 cfs @ 12.13 hrs, Volume= 1,601,223 cf
Outflow = 466.90 cfs @ 12.13 hrs, Volume= 1,601,223 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Reach 1R: MWRA Tunnel

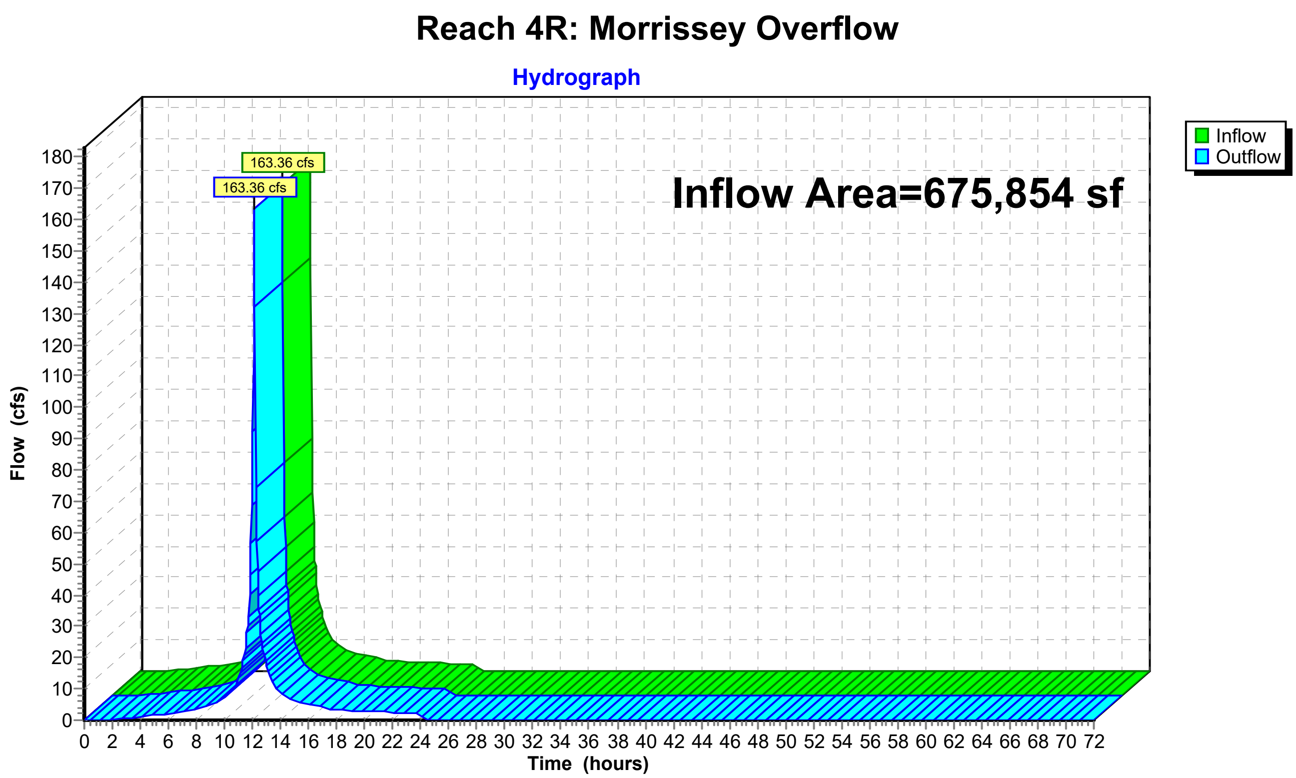


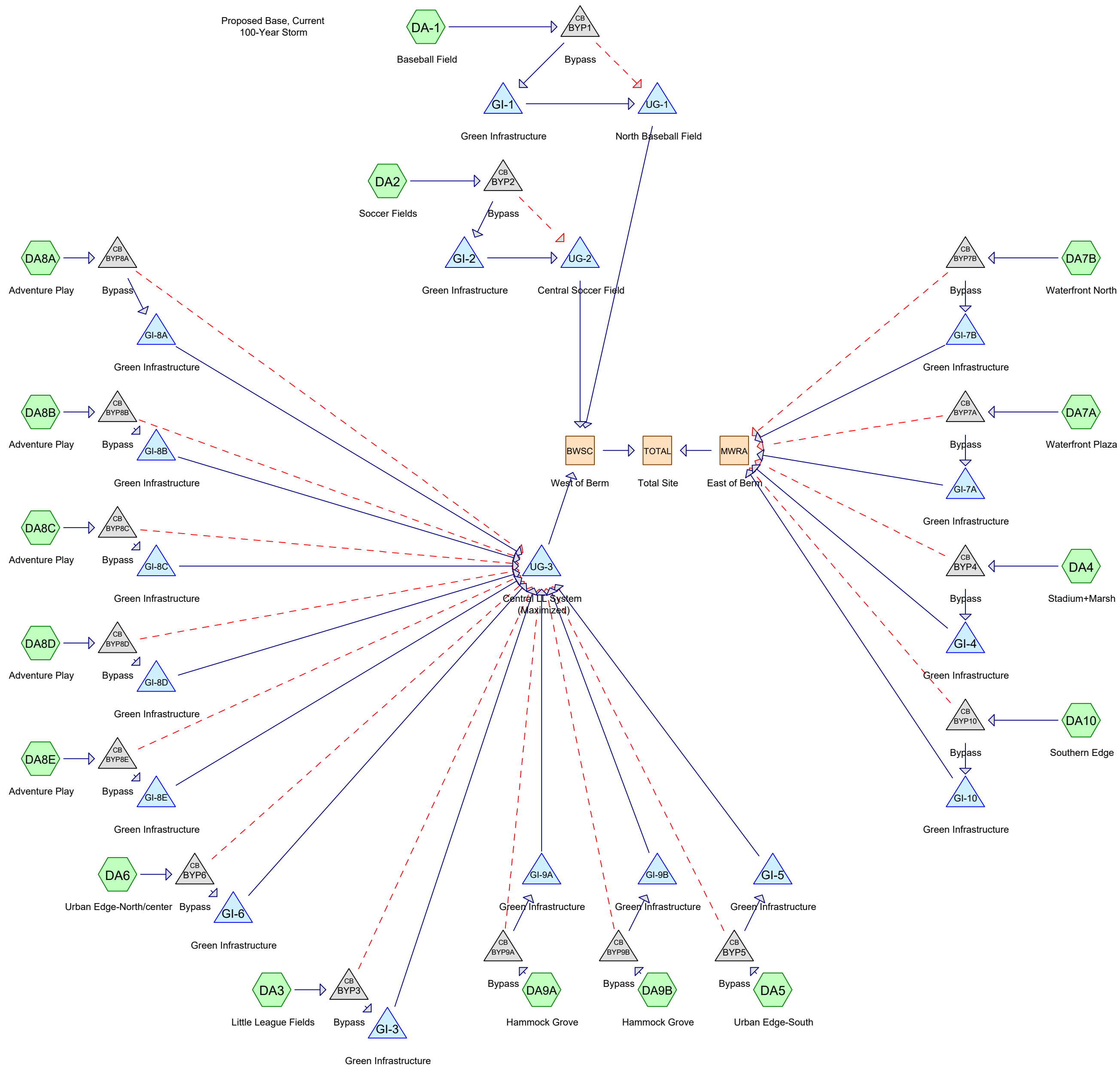
Summary for Reach 4R: Morrissey Overflow

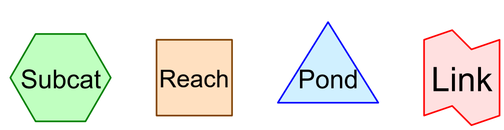
[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 675,854 sf, 52.01% Impervious, Inflow Depth = 10.34" for 100 year -2070 event
Inflow = 163.36 cfs @ 12.13 hrs, Volume= 582,206 cf
Outflow = 163.36 cfs @ 12.13 hrs, Volume= 582,206 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs







Routing Diagram for 12462.1-Moakley Park RUnoff
Prepared by {enter your company name here}, Printed 5/4/2020
HydroCAD® 10.00-20 s/n 00546 © 2017 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
1,871,956	80	>75% Grass cover, Good, HSG D (DA-1, DA10, DA2, DA3, DA4, DA5, DA6, DA7A, DA7B, DA8A, DA8B, DA8C, DA8D, DA8E, DA9A, DA9B)
765,674	98	Impervious, HSG D (DA-1, DA10, DA2, DA3, DA4, DA5, DA6, DA7A, DA7B, DA8A, DA8B, DA8C, DA8D, DA8E, DA9A, DA9B)
60,000	98	Turf Field (DA4)
2,697,630	**86**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
0	HSG A	
0	HSG B	
0	HSG C	
2,637,630	HSG D	DA-1, DA10, DA2, DA3, DA4, DA5, DA6, DA7A, DA7B, DA8A, DA8B, DA8C, DA8D, DA8E, DA9A, DA9B
60,000	Other	DA4
2,697,630		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	Su Nu
0	0	0	1,871,956	0	1,871,956	>75% Grass cover, Good	
0	0	0	765,674	0	765,674	Impervious	
0	0	0	0	60,000	60,000	Turf Field	
0	**0**	**0**	**2,637,630**	**60,000**	**2,697,630**	**TOTAL AREA**	

Time span=0.00-72.00 hrs, dt=0.05 hrs, 1441 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment DA-1: Baseball Field Runoff Area=249,220 sf 8.70% Impervious Runoff Depth=5.95"
Tc=6.0 min CN=82 Runoff=37.15 cfs 123,473 cf

Subcatchment DA10: Southern Edge Runoff Area=89,040 sf 21.95% Impervious Runoff Depth=6.18"
Tc=6.0 min CN=84 Runoff=13.66 cfs 45,868 cf

Subcatchment DA2: Soccer Fields Runoff Area=404,841 sf 31.43% Impervious Runoff Depth=6.42"
Tc=6.0 min CN=86 Runoff=63.70 cfs 216,545 cf

Subcatchment DA3: Little League Fields Runoff Area=351,836 sf 39.26% Impervious Runoff Depth=6.54"
Tc=6.0 min CN=87 Runoff=56.01 cfs 191,673 cf

Subcatchment DA4: Stadium+Marsh Runoff Area=389,731 sf 48.29% Impervious Runoff Depth=6.78"
Tc=6.0 min CN=89 Runoff=63.38 cfs 220,039 cf

Subcatchment DA5: Urban Edge-South Runoff Area=178,043 sf 31.71% Impervious Runoff Depth=6.42"
Tc=6.0 min CN=86 Runoff=28.01 cfs 95,233 cf

Subcatchment DA6: Urban Runoff Area=354,554 sf 29.27% Impervious Runoff Depth=6.30"
Tc=6.0 min CN=85 Runoff=55.10 cfs 186,144 cf

Subcatchment DA7A: Waterfront Plaza Runoff Area=154,470 sf 45.37% Impervious Runoff Depth=6.66"
Tc=6.0 min CN=88 Runoff=24.87 cfs 85,682 cf

Subcatchment DA7B: Waterfront North Runoff Area=292,806 sf 20.13% Impervious Runoff Depth=6.18"
Tc=6.0 min CN=84 Runoff=44.91 cfs 150,836 cf

Subcatchment DA8A: Adventure Play Runoff Area=26,649 sf 12.91% Impervious Runoff Depth=5.95"
Tc=6.0 min CN=82 Runoff=3.97 cfs 13,203 cf

Subcatchment DA8B: Adventure Play Runoff Area=21,545 sf 24.73% Impervious Runoff Depth=6.18"
Tc=6.0 min CN=84 Runoff=3.30 cfs 11,099 cf

Subcatchment DA8C: Adventure Play Runoff Area=15,823 sf 23.97% Impervious Runoff Depth=6.18"
Tc=6.0 min CN=84 Runoff=2.43 cfs 8,151 cf

Subcatchment DA8D: Adventure Play Runoff Area=34,949 sf 27.15% Impervious Runoff Depth=6.30"
Tc=6.0 min CN=85 Runoff=5.43 cfs 18,349 cf

Subcatchment DA8E: Adventure Play Runoff Area=66,286 sf 18.42% Impervious Runoff Depth=6.06"
Tc=6.0 min CN=83 Runoff=10.03 cfs 33,493 cf

Subcatchment DA9A: Hammock Grove Runoff Area=37,664 sf 5.01% Impervious Runoff Depth=5.83"
Tc=6.0 min CN=81 Runoff=5.53 cfs 18,290 cf

Subcatchment DA9B: Hammock Grove Runoff Area=30,173 sf 18.18% Impervious Runoff Depth=6.06"
Tc=6.0 min CN=83 Runoff=4.56 cfs 15,246 cf

Reach BWSC: West of Berm Inflow=25.38 cfs 929,503 cf
Outflow=25.38 cfs 929,503 cf

Reach MWRA: East of Berm Inflow=144.55 cfs 502,424 cf
Outflow=144.55 cfs 502,424 cf

Reach TOTAL: Total Site Inflow=156.18 cfs 1,431,927 cf
Outflow=156.18 cfs 1,431,927 cf

Pond BYP1: Bypass Peak Elev=17.60' Inflow=37.15 cfs 123,473 cf
Primary=6.11 cfs 81,393 cf Secondary=31.05 cfs 42,079 cf Outflow=37.15 cfs 123,473 cf

Pond BYP10: Bypass Peak Elev=16.87' Inflow=13.66 cfs 45,868 cf
Primary=1.29 cfs 26,246 cf Secondary=12.36 cfs 19,622 cf Outflow=13.66 cfs 45,868 cf

Pond BYP2: Bypass Peak Elev=18.70' Inflow=63.70 cfs 216,545 cf
Primary=7.28 cfs 133,014 cf Secondary=56.43 cfs 83,531 cf Outflow=63.70 cfs 216,545 cf

Pond BYP3: Bypass Peak Elev=17.95' Inflow=56.01 cfs 191,673 cf
Primary=10.16 cfs 133,898 cf Secondary=45.86 cfs 57,776 cf Outflow=56.01 cfs 191,673 cf

Pond BYP4: Bypass Peak Elev=18.83' Inflow=63.38 cfs 220,039 cf
Primary=7.41 cfs 138,476 cf Secondary=55.98 cfs 81,563 cf Outflow=63.38 cfs 220,039 cf

Pond BYP5: Bypass Peak Elev=24.80' Inflow=28.01 cfs 95,233 cf
Primary=2.97 cfs 44,307 cf Secondary=25.04 cfs 50,926 cf Outflow=28.01 cfs 95,233 cf

Pond BYP6: Bypass Peak Elev=18.13' Inflow=55.10 cfs 186,144 cf
Primary=6.70 cfs 114,467 cf Secondary=48.40 cfs 71,677 cf Outflow=55.10 cfs 186,144 cf

Pond BYP7A: Bypass Peak Elev=17.23' Inflow=24.87 cfs 85,682 cf
Primary=5.65 cfs 63,912 cf Secondary=19.21 cfs 21,770 cf Outflow=24.87 cfs 85,682 cf

Pond BYP7B: Bypass Peak Elev=17.81' Inflow=44.91 cfs 150,836 cf
Primary=6.35 cfs 96,191 cf Secondary=38.56 cfs 54,645 cf Outflow=44.91 cfs 150,836 cf

Pond BYP8A: Bypass Peak Elev=15.92' Inflow=3.97 cfs 13,203 cf
Primary=0.91 cfs 9,709 cf Secondary=3.06 cfs 3,494 cf Outflow=3.97 cfs 13,203 cf

Pond BYP8B: Bypass Peak Elev=15.83' Inflow=3.30 cfs 11,099 cf
Primary=0.86 cfs 8,509 cf Secondary=2.44 cfs 2,589 cf Outflow=3.30 cfs 11,099 cf

Pond BYP8C: Bypass Peak Elev=15.68' Inflow=2.43 cfs 8,151 cf
Primary=0.78 cfs 6,633 cf Secondary=1.64 cfs 1,518 cf Outflow=2.43 cfs 8,151 cf

Pond BYP8D: Bypass Peak Elev=16.17' Inflow=5.43 cfs 18,349 cf
Primary=1.02 cfs 12,892 cf Secondary=4.41 cfs 5,456 cf Outflow=5.43 cfs 18,349 cf

Pond BYP8E: Bypass Peak Elev=16.54' Inflow=10.03 cfs 33,493 cf
Primary=1.18 cfs 19,992 cf Secondary=8.85 cfs 13,501 cf Outflow=10.03 cfs 33,493 cf

Pond BYP9A: Bypass Peak Elev=16.14' Inflow=5.53 cfs 18,290 cf
Primary=1.01 cfs 12,404 cf Secondary=4.52 cfs 5,886 cf Outflow=5.53 cfs 18,290 cf

Pond BYP9B: Bypass Peak Elev=16.05' Inflow=4.56 cfs 15,246 cf
Primary=0.97 cfs 11,140 cf Secondary=3.59 cfs 4,106 cf Outflow=4.56 cfs 15,246 cf

Pond GI-1: Green Infrastructure Peak Elev=15.84' Storage=1,893 cf Inflow=6.11 cfs 81,393 cf
Outflow=6.00 cfs 81,393 cf

Pond GI-10: Green Infrastructure Peak Elev=15.57' Storage=1,170 cf Inflow=1.29 cfs 26,246 cf
Outflow=1.25 cfs 26,246 cf

Pond GI-2: Green Infrastructure Peak Elev=15.86' Storage=11,389 cf Inflow=7.28 cfs 133,014 cf
Outflow=6.51 cfs 133,013 cf

Pond GI-3: Green Infrastructure Peak Elev=15.95' Storage=13,729 cf Inflow=10.16 cfs 133,898 cf
Outflow=8.93 cfs 133,896 cf

Pond GI-4: Green Infrastructure Peak Elev=15.87' Storage=11,562 cf Inflow=7.41 cfs 138,476 cf
Outflow=6.67 cfs 138,475 cf

Pond GI-5: Green Infrastructure Peak Elev=15.66' Storage=3,857 cf Inflow=2.97 cfs 44,307 cf
Outflow=2.37 cfs 44,307 cf

Pond GI-6: Green Infrastructure Peak Elev=15.84' Storage=9,078 cf Inflow=6.70 cfs 114,467 cf
Outflow=6.05 cfs 114,467 cf

Pond GI-7A: Green Infrastructure Peak Elev=15.80' Storage=5,852 cf Inflow=5.65 cfs 63,912 cf
Outflow=5.18 cfs 63,912 cf

Pond GI-7B: Green Infrastructure Peak Elev=15.84' Storage=5,133 cf Inflow=6.35 cfs 96,191 cf
Outflow=5.96 cfs 96,191 cf

Pond GI-8A: Green Infrastructure Peak Elev=15.54' Storage=193 cf Inflow=0.91 cfs 9,709 cf
Outflow=0.90 cfs 9,709 cf

Pond GI-8B: Green Infrastructure Peak Elev=15.55' Storage=304 cf Inflow=0.86 cfs 8,509 cf
Outflow=0.77 cfs 8,509 cf

Pond GI-8C: Green Infrastructure Peak Elev=15.51' Storage=202 cf Inflow=0.78 cfs 6,633 cf
Outflow=0.71 cfs 6,633 cf

Pond GI-8D: Green Infrastructure Peak Elev=15.58' Storage=570 cf Inflow=1.02 cfs 12,892 cf
Outflow=0.94 cfs 12,892 cf

Pond GI-8E: Green Infrastructure Peak Elev=15.64' Storage=811 cf Inflow=1.18 cfs 19,992 cf
Outflow=1.08 cfs 19,992 cf

Pond GI-9A: Green Infrastructure Peak Elev=15.55' Storage=108 cf Inflow=1.01 cfs 12,404 cf
Outflow=1.00 cfs 12,405 cf

Pond GI-9B: Green Infrastructure Peak Elev=15.55' Storage=312 cf Inflow=0.97 cfs 11,140 cf
Outflow=0.96 cfs 11,140 cf

Pond UG-1: North Baseball Field Peak Elev=11.70' Storage=65,522 cf Inflow=36.98 cfs 123,473 cf
Outflow=3.16 cfs 122,784 cf

Pond UG-2: Central Soccer Field Peak Elev=10.24' Storage=116,809 cf Inflow=62.67 cfs 216,544 cf
Outflow=4.22 cfs 215,884 cf

Pond UG-3: Central LL System Peak Elev=10.34' Storage=291,586 cf Inflow=170.39 cfs 590,879 cf
Outflow=18.05 cfs 590,836 cf

Total Runoff Area = 2,697,630 sf Runoff Volume = 1,433,323 cf Average Runoff Depth = 6.38"
69.39% Pervious = 1,871,956 sf 30.61% Impervious = 825,674 sf

Summary for Subcatchment DA-1: Baseball Field

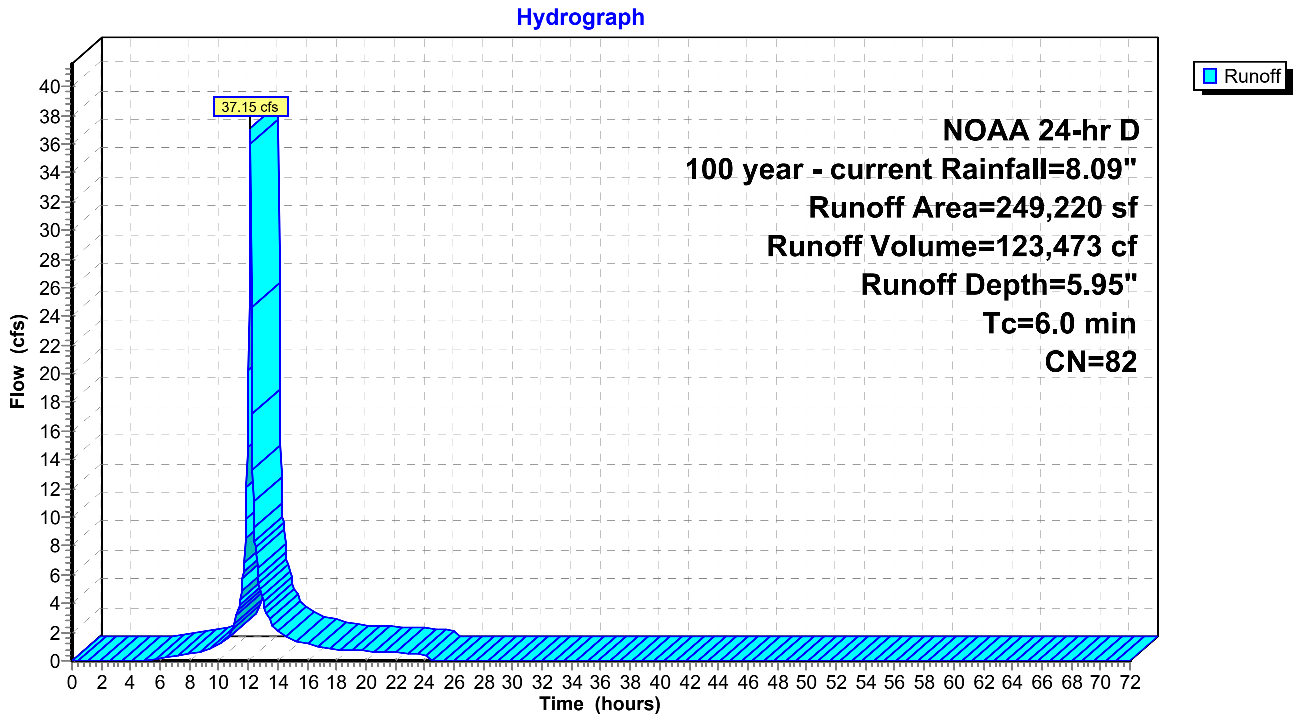
Runoff = 37.15 cfs @ 12.13 hrs, Volume= 123,473 cf, Depth= 5.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	227,526	80	>75% Grass cover, Good, HSG D
*	21,694	98	Impervious, HSG D
	249,220	82	Weighted Average
	227,526		91.30% Pervious Area
	21,694		8.70% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA-1: Baseball Field



Summary for Subcatchment DA10: Southern Edge

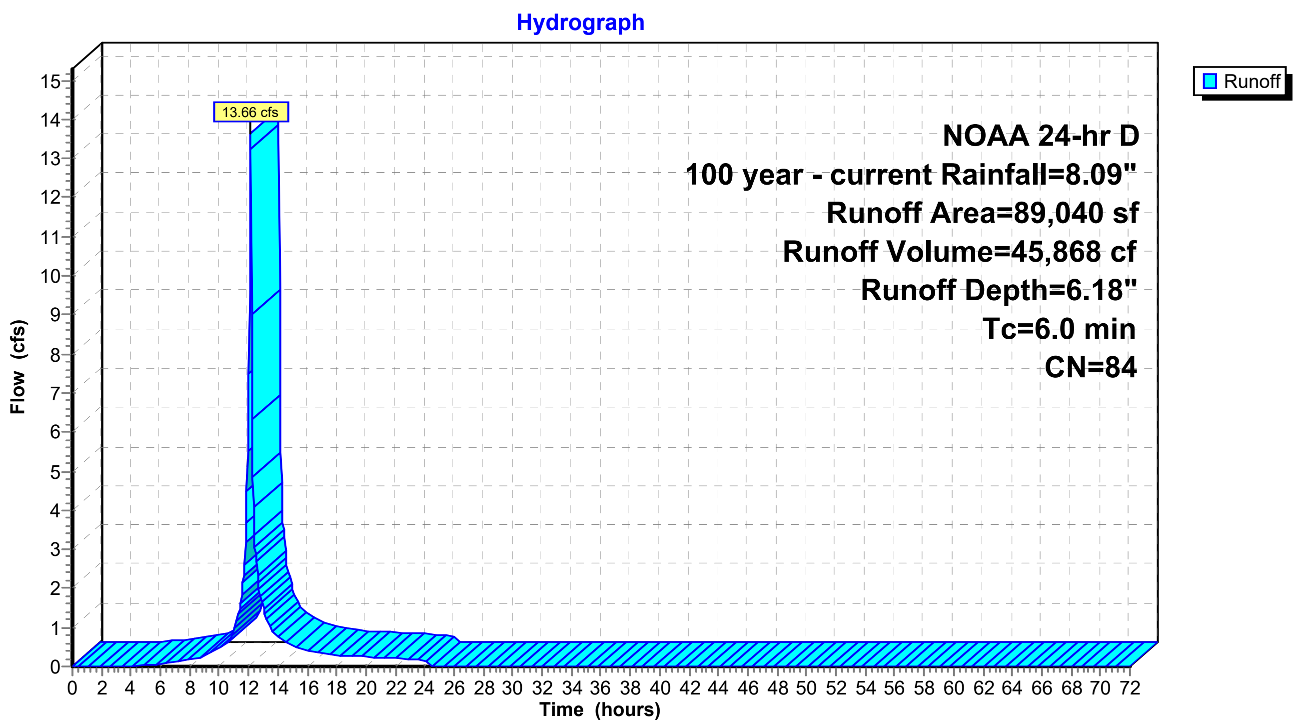
Runoff = 13.66 cfs @ 12.13 hrs, Volume= 45,868 cf, Depth= 6.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	69,498	80	>75% Grass cover, Good, HSG D
*	19,542	98	Impervious, HSG D
	89,040	84	Weighted Average
	69,498		78.05% Pervious Area
	19,542		21.95% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA10: Southern Edge



Summary for Subcatchment DA2: Soccer Fields

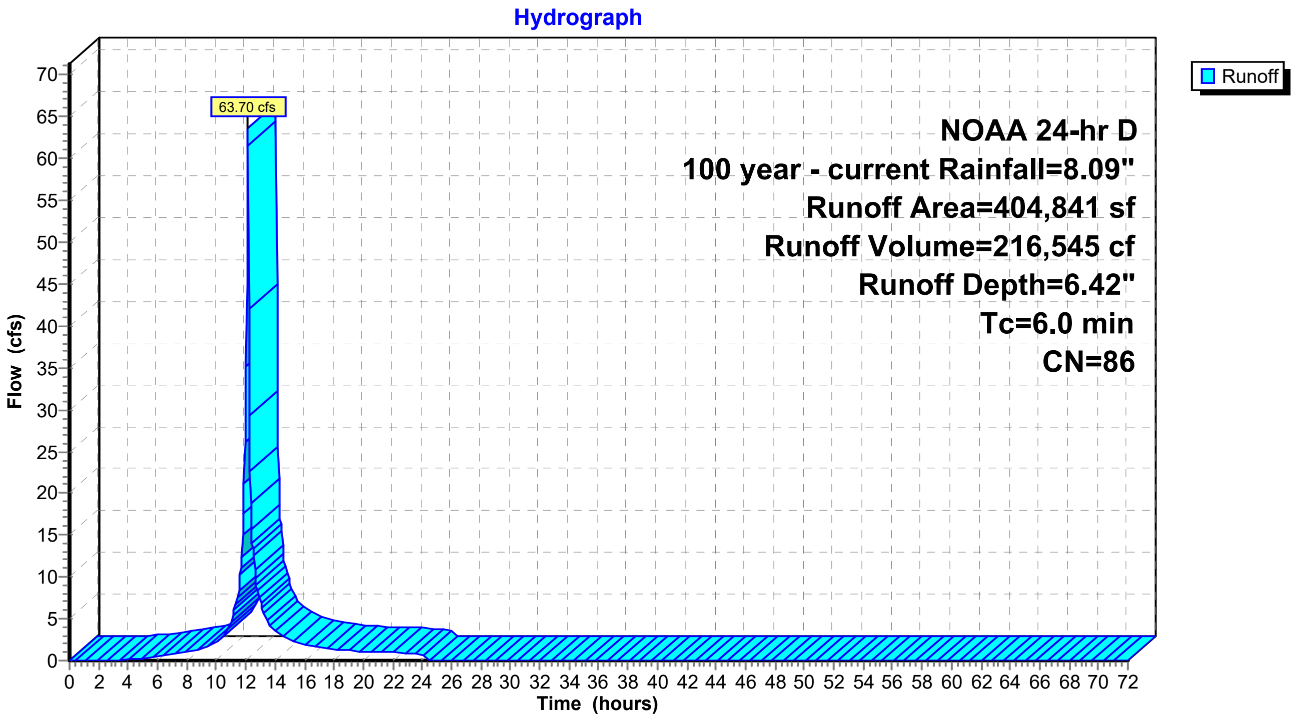
Runoff = 63.70 cfs @ 12.13 hrs, Volume= 216,545 cf, Depth= 6.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	277,607	80	>75% Grass cover, Good, HSG D
*	127,234	98	Impervious, HSG D
	404,841	86	Weighted Average
	277,607		68.57% Pervious Area
	127,234		31.43% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA2: Soccer Fields



Summary for Subcatchment DA3: Little League Fields

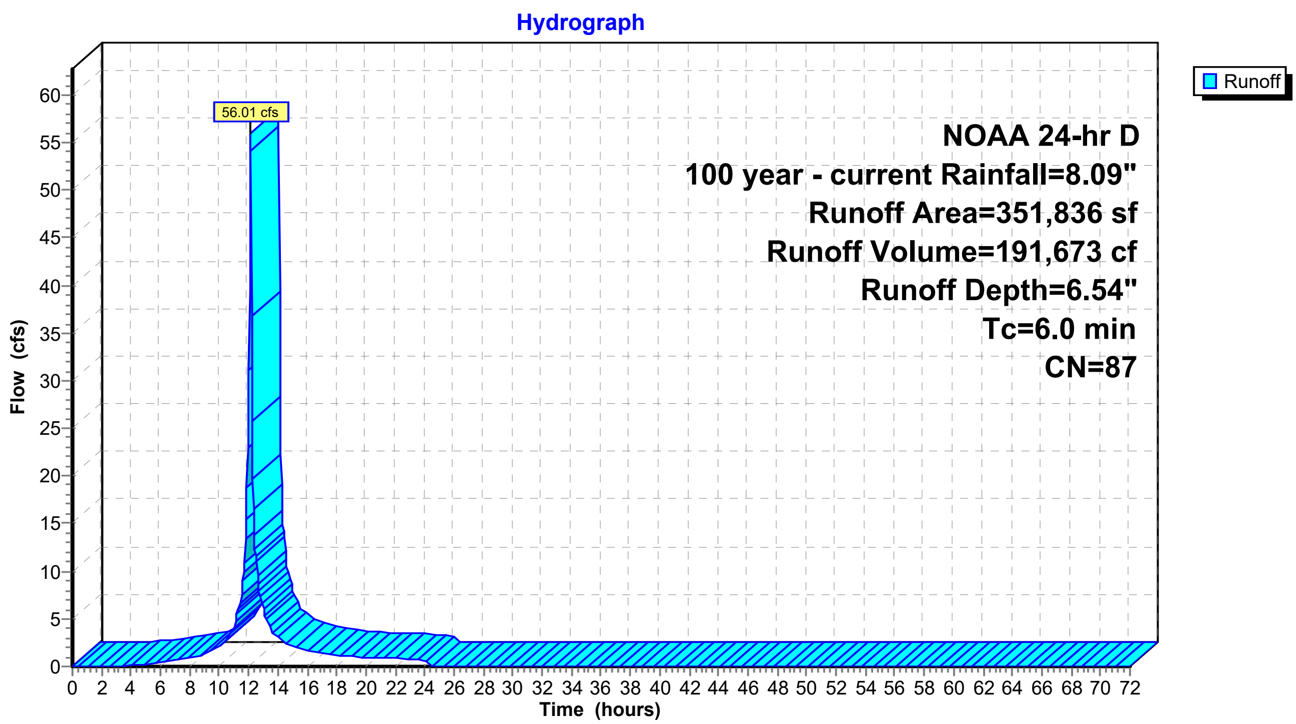
Runoff = 56.01 cfs @ 12.13 hrs, Volume= 191,673 cf, Depth= 6.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	213,708	80	>75% Grass cover, Good, HSG D
*	138,128	98	Impervious, HSG D
	351,836	87	Weighted Average
	213,708		60.74% Pervious Area
	138,128		39.26% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA3: Little League Fields



Summary for Subcatchment DA4: Stadium+Marsh

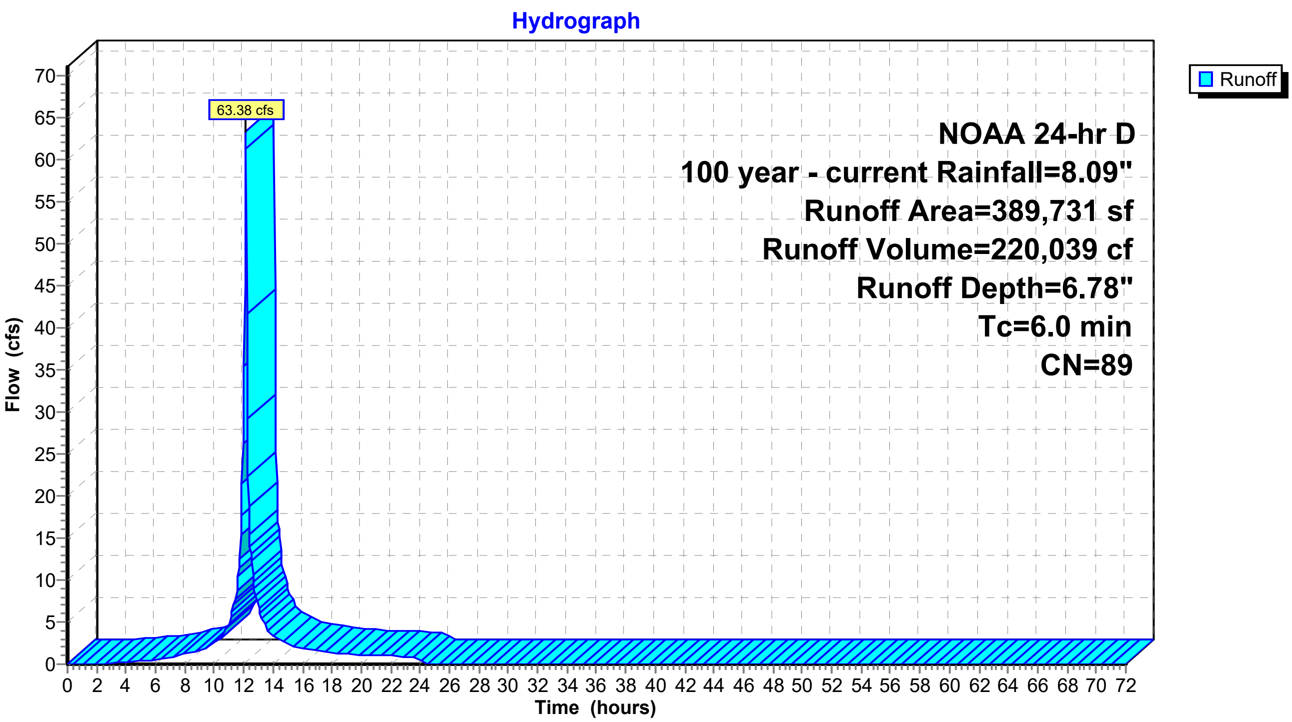
Runoff = 63.38 cfs @ 12.13 hrs, Volume= 220,039 cf, Depth= 6.78"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	201,539	80	>75% Grass cover, Good, HSG D
*	128,192	98	Impervious, HSG D
*	60,000	98	Turf Field
	389,731	89	Weighted Average
	201,539		51.71% Pervious Area
	188,192		48.29% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA4: Stadium+Marsh



Summary for Subcatchment DA5: Urban Edge-South

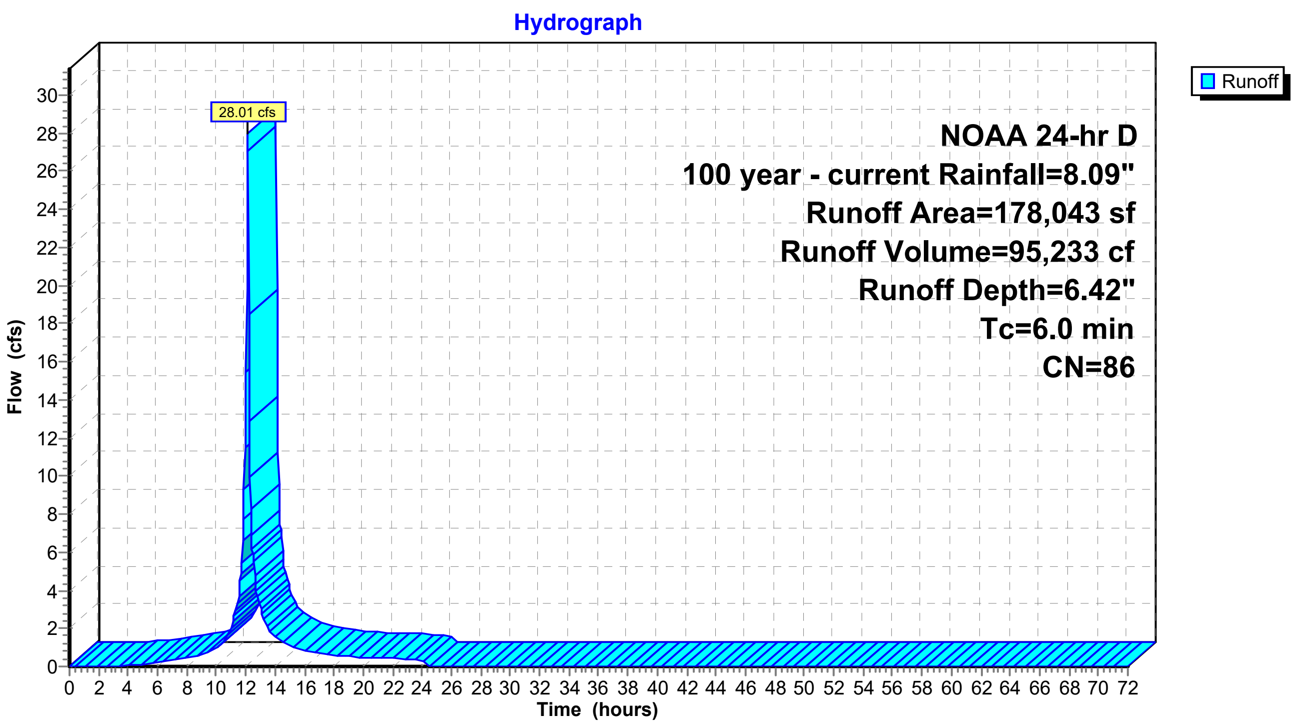
Runoff = 28.01 cfs @ 12.13 hrs, Volume= 95,233 cf, Depth= 6.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	121,587	80	>75% Grass cover, Good, HSG D
*	56,456	98	Impervious, HSG D
	178,043	86	Weighted Average
	121,587		68.29% Pervious Area
	56,456		31.71% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA5: Urban Edge-South



Summary for Subcatchment DA6: Urban Edge-North/center

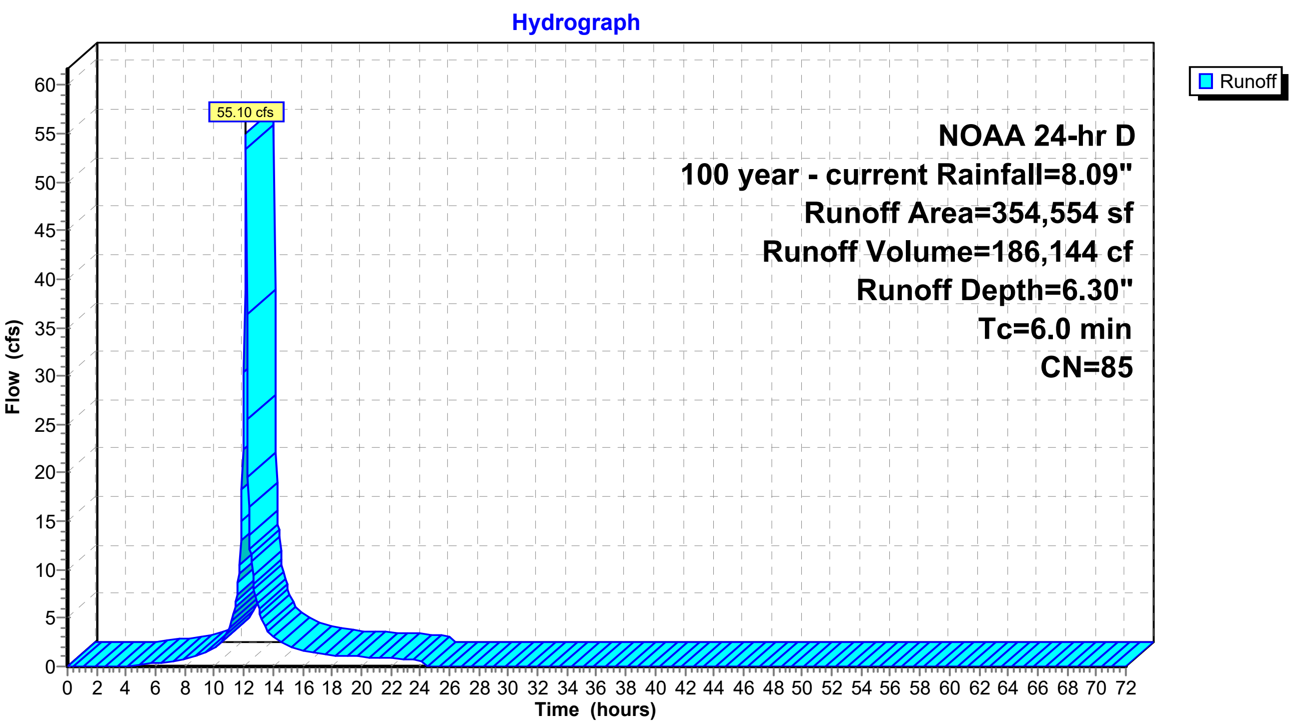
Runoff = 55.10 cfs @ 12.13 hrs, Volume= 186,144 cf, Depth= 6.30"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	250,786	80	>75% Grass cover, Good, HSG D
*	103,768	98	Impervious, HSG D
	354,554	85	Weighted Average
	250,786		70.73% Pervious Area
	103,768		29.27% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA6: Urban Edge-North/center



Summary for Subcatchment DA7A: Waterfront Plaza

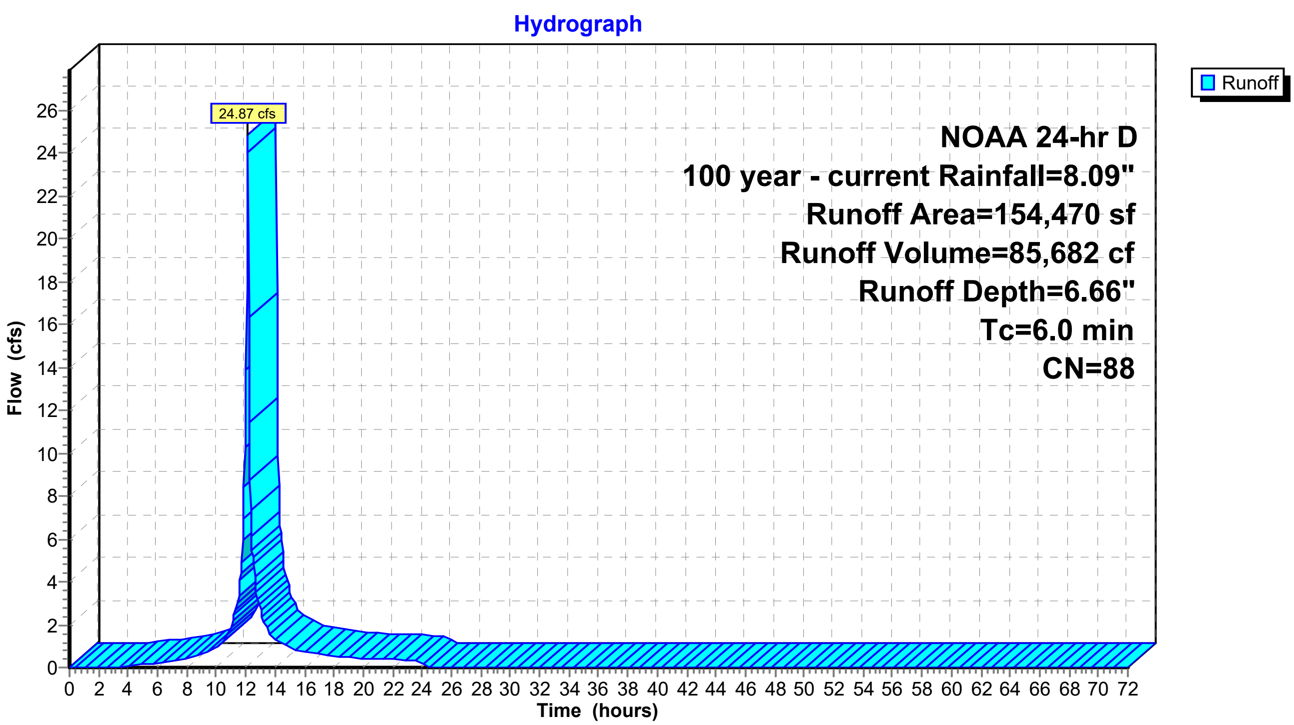
Runoff = 24.87 cfs @ 12.13 hrs, Volume= 85,682 cf, Depth= 6.66"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	84,388	80	>75% Grass cover, Good, HSG D
*	70,082	98	Impervious, HSG D
	154,470	88	Weighted Average
	84,388		54.63% Pervious Area
	70,082		45.37% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA7A: Waterfront Plaza



Summary for Subcatchment DA7B: Waterfront North

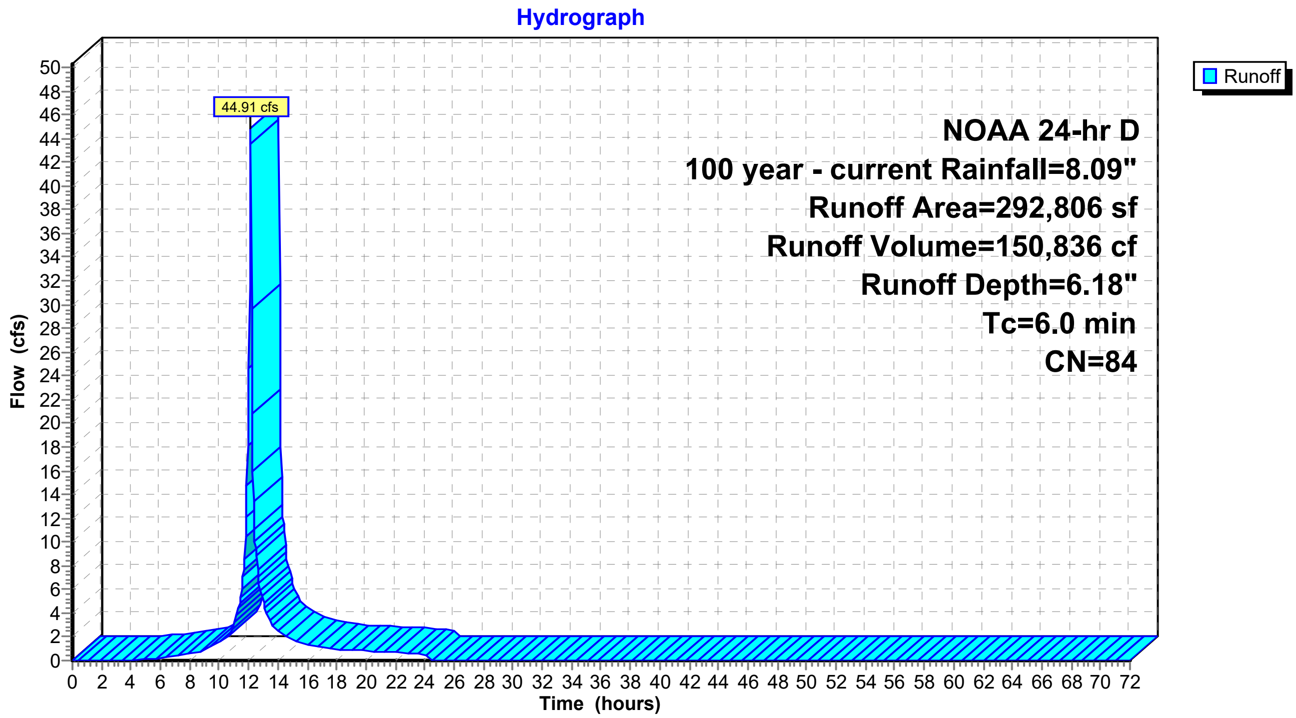
Runoff = 44.91 cfs @ 12.13 hrs, Volume= 150,836 cf, Depth= 6.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	233,860	80	>75% Grass cover, Good, HSG D
*	58,946	98	Impervious, HSG D
	292,806	84	Weighted Average
	233,860		79.87% Pervious Area
	58,946		20.13% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA7B: Waterfront North



Summary for Subcatchment DA8A: Adventure Play

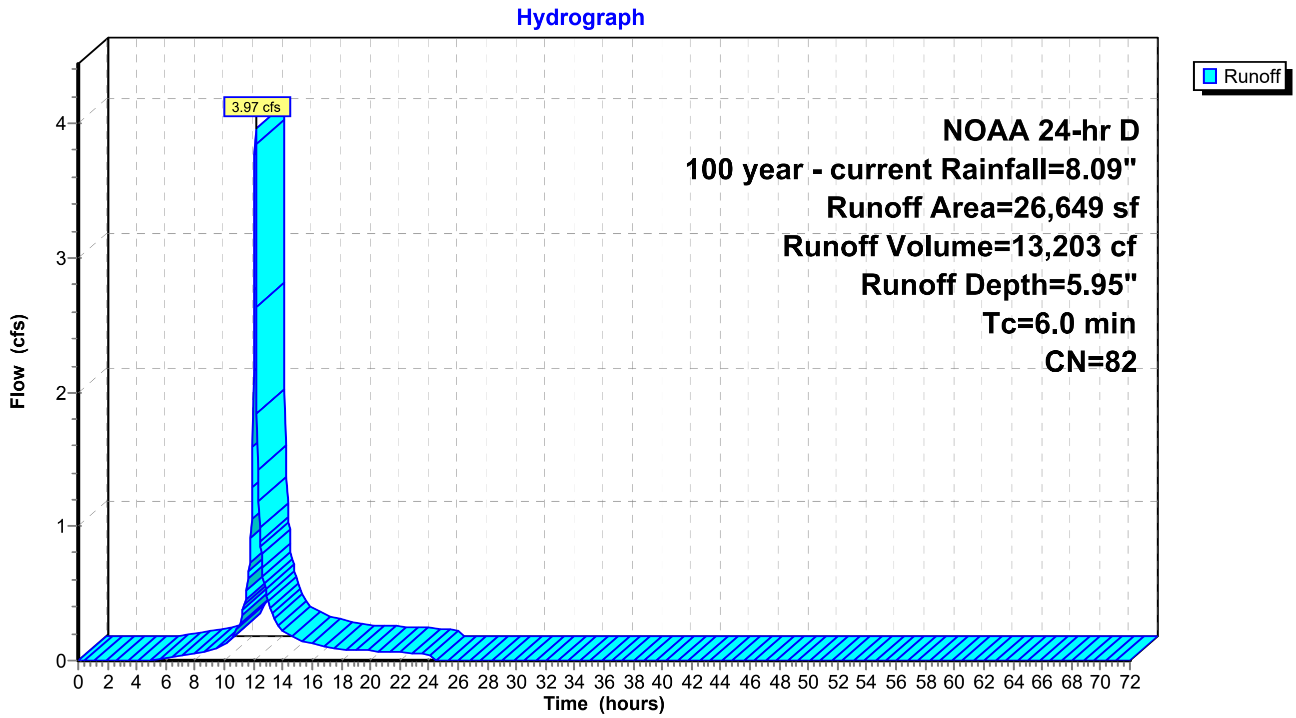
Runoff = 3.97 cfs @ 12.13 hrs, Volume= 13,203 cf, Depth= 5.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	23,208	80	>75% Grass cover, Good, HSG D
*	3,441	98	Impervious, HSG D
	26,649	82	Weighted Average
	23,208		87.09% Pervious Area
	3,441		12.91% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8A: Adventure Play



Summary for Subcatchment DA8B: Adventure Play

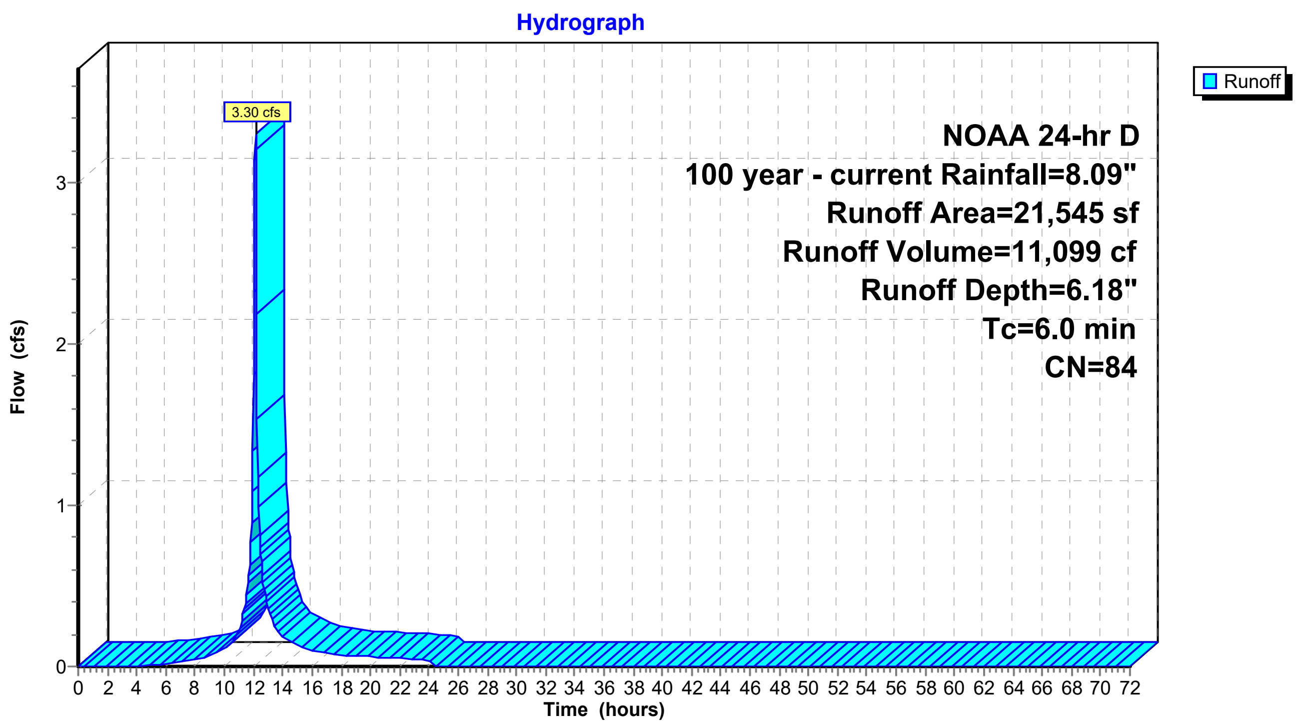
Runoff = 3.30 cfs @ 12.13 hrs, Volume= 11,099 cf, Depth= 6.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	16,216	80	>75% Grass cover, Good, HSG D
*	5,329	98	Impervious, HSG D
	21,545	84	Weighted Average
	16,216		75.27% Pervious Area
	5,329		24.73% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8B: Adventure Play



Summary for Subcatchment DA8C: Adventure Play

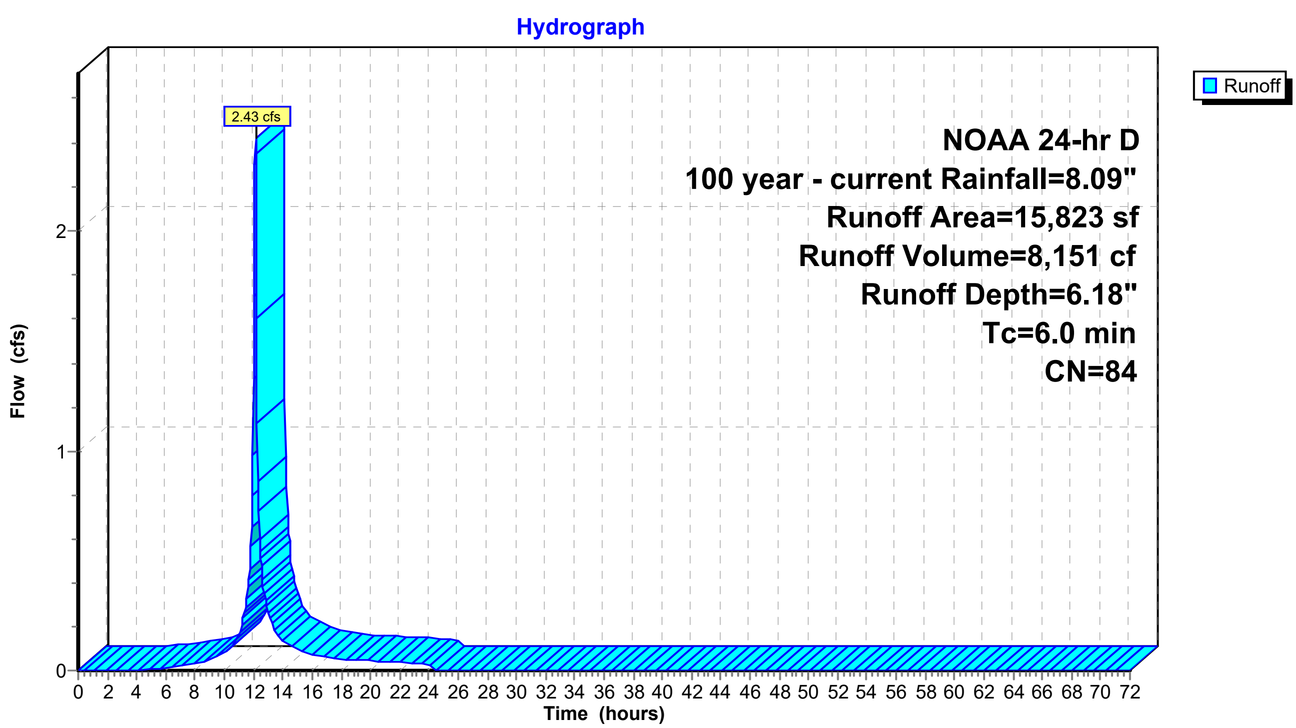
Runoff = 2.43 cfs @ 12.13 hrs, Volume= 8,151 cf, Depth= 6.18"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	12,030	80	>75% Grass cover, Good, HSG D
*	3,793	98	Impervious, HSG D
	15,823	84	Weighted Average
	12,030		76.03% Pervious Area
	3,793		23.97% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8C: Adventure Play



Summary for Subcatchment DA8D: Adventure Play

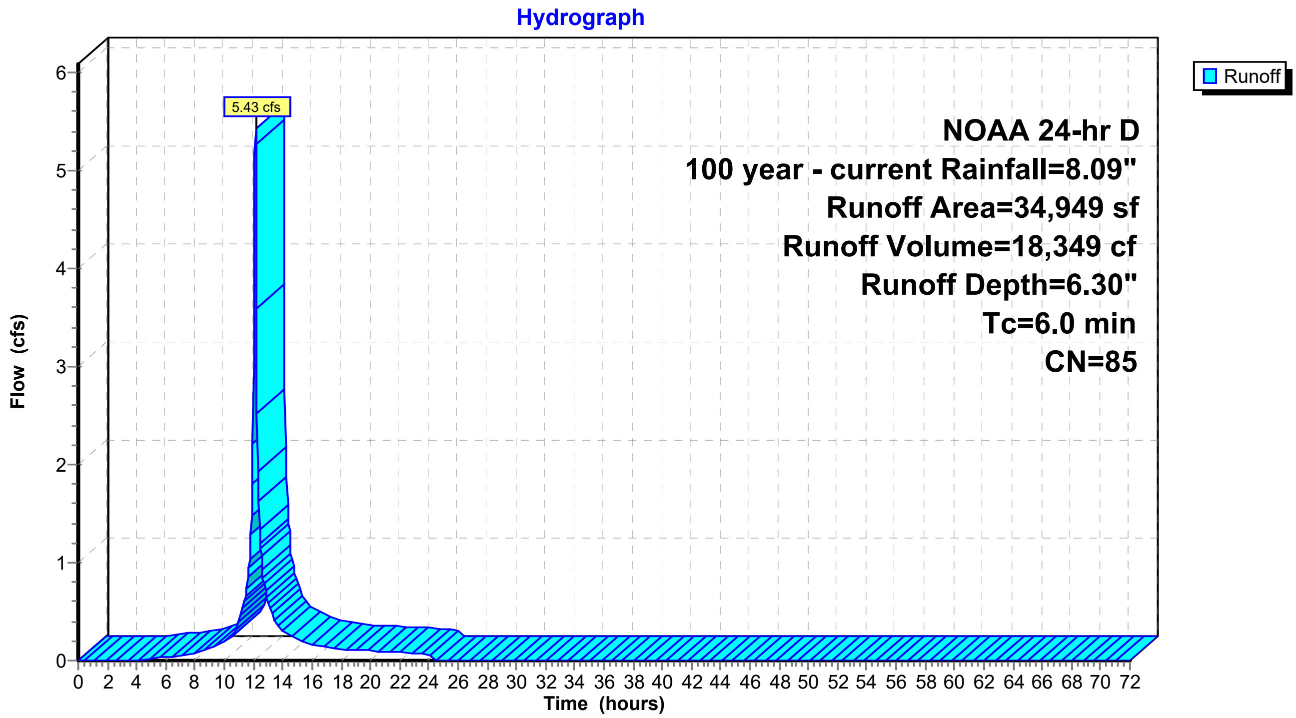
Runoff = 5.43 cfs @ 12.13 hrs, Volume= 18,349 cf, Depth= 6.30"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	25,461	80	>75% Grass cover, Good, HSG D
*	9,488	98	Impervious, HSG D
	34,949	85	Weighted Average
	25,461		72.85% Pervious Area
	9,488		27.15% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8D: Adventure Play



Summary for Subcatchment DA8E: Adventure Play

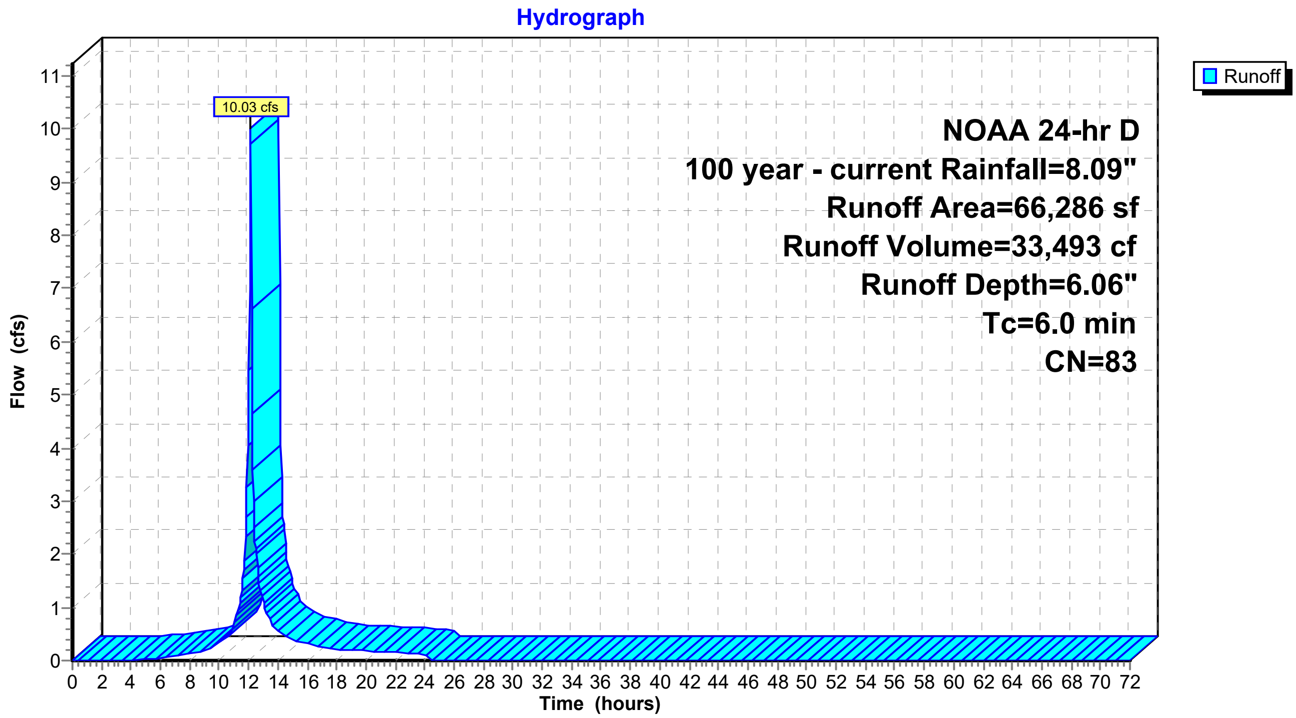
Runoff = 10.03 cfs @ 12.13 hrs, Volume= 33,493 cf, Depth= 6.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	54,076	80	>75% Grass cover, Good, HSG D
*	12,210	98	Impervious, HSG D
	66,286	83	Weighted Average
	54,076		81.58% Pervious Area
	12,210		18.42% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8E: Adventure Play



Summary for Subcatchment DA9A: Hammock Grove

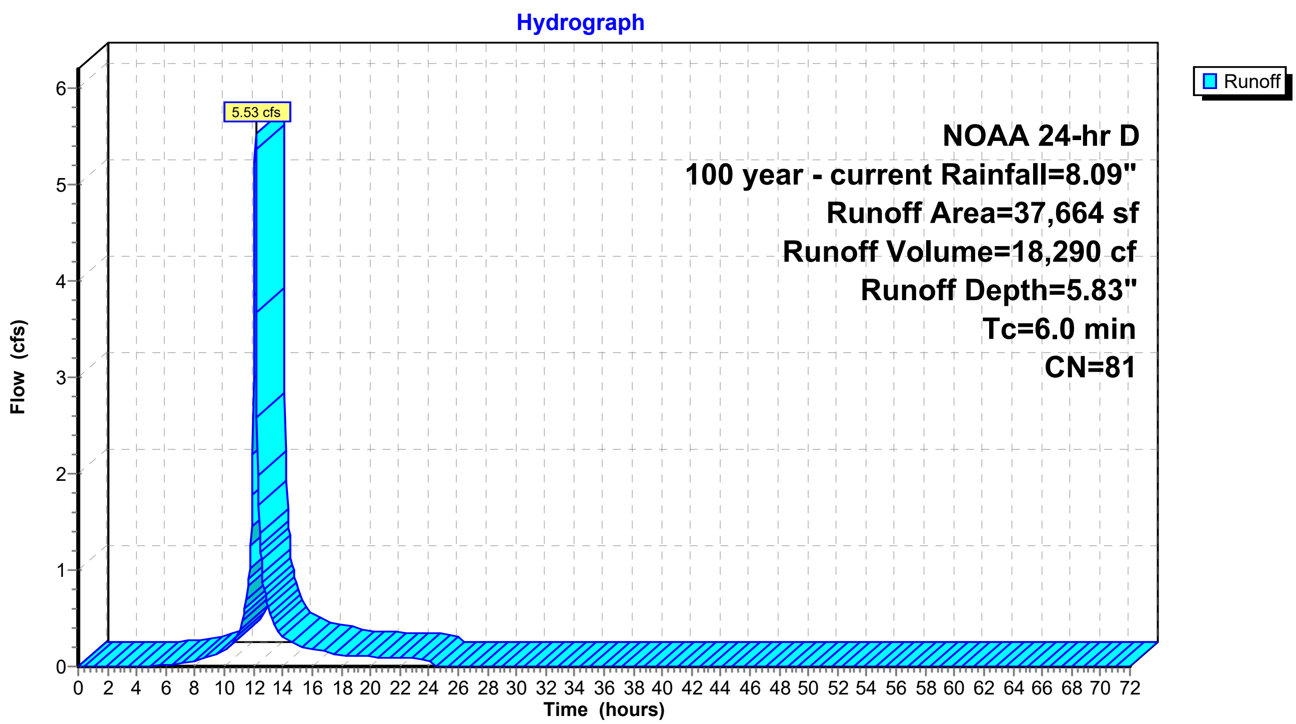
Runoff = 5.53 cfs @ 12.13 hrs, Volume= 18,290 cf, Depth= 5.83"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	35,778	80	>75% Grass cover, Good, HSG D
*	1,886	98	Impervious, HSG D
	37,664	81	Weighted Average
	35,778		94.99% Pervious Area
	1,886		5.01% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA9A: Hammock Grove



Summary for Subcatchment DA9B: Hammock Grove

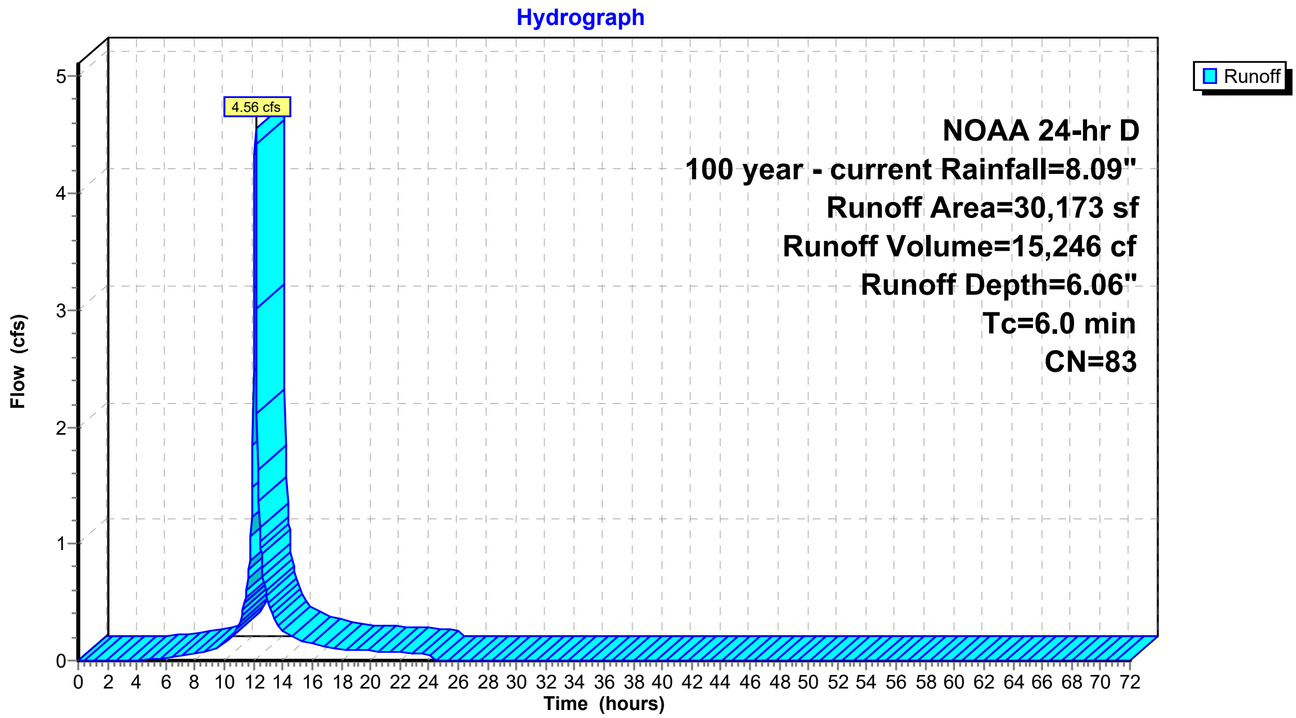
Runoff = 4.56 cfs @ 12.13 hrs, Volume= 15,246 cf, Depth= 6.06"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
	24,688	80	>75% Grass cover, Good, HSG D
*	5,485	98	Impervious, HSG D
	30,173	83	Weighted Average
	24,688		81.82% Pervious Area
	5,485		18.18% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA9B: Hammock Grove



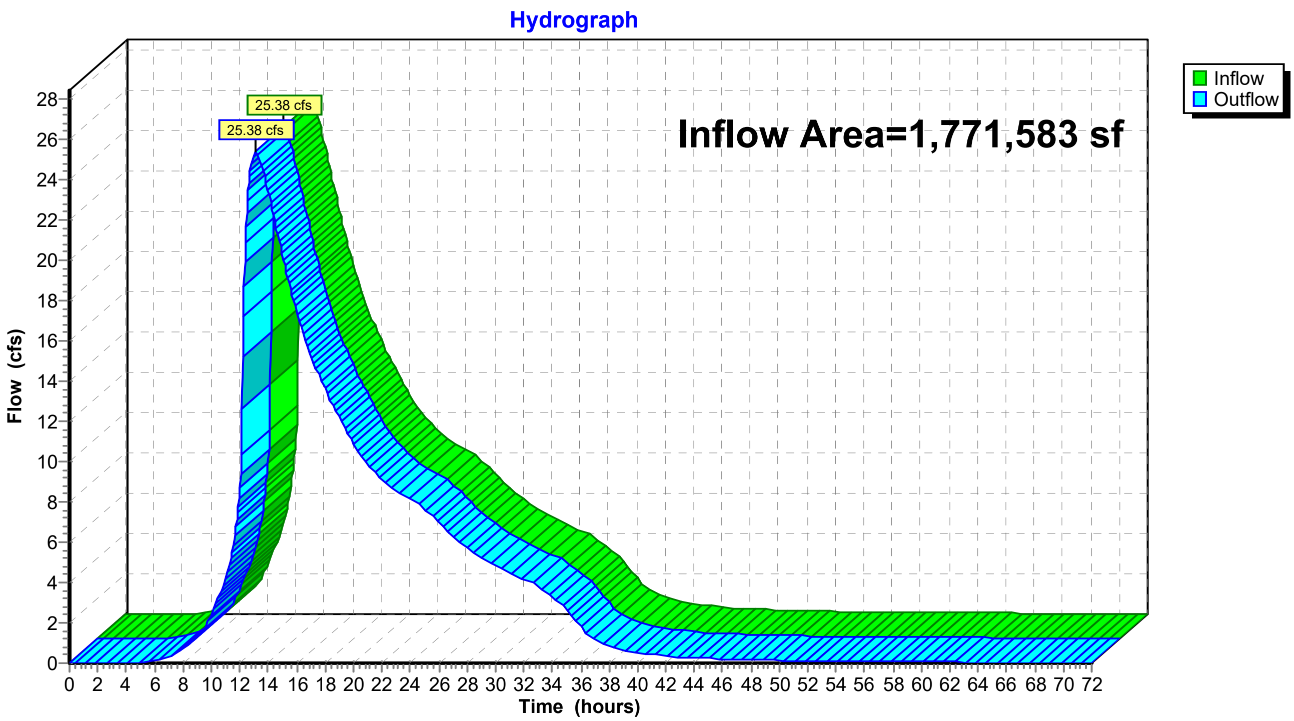
Summary for Reach BWSC: West of Berm

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	1,771,583 sf,	27.60% Impervious,	Inflow Depth > 6.30"	for 100 year - current event
Inflow =	25.38 cfs @	13.13 hrs, Volume=	929,503 cf	
Outflow =	25.38 cfs @	13.13 hrs, Volume=	929,503 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Reach BWSC: West of Berm



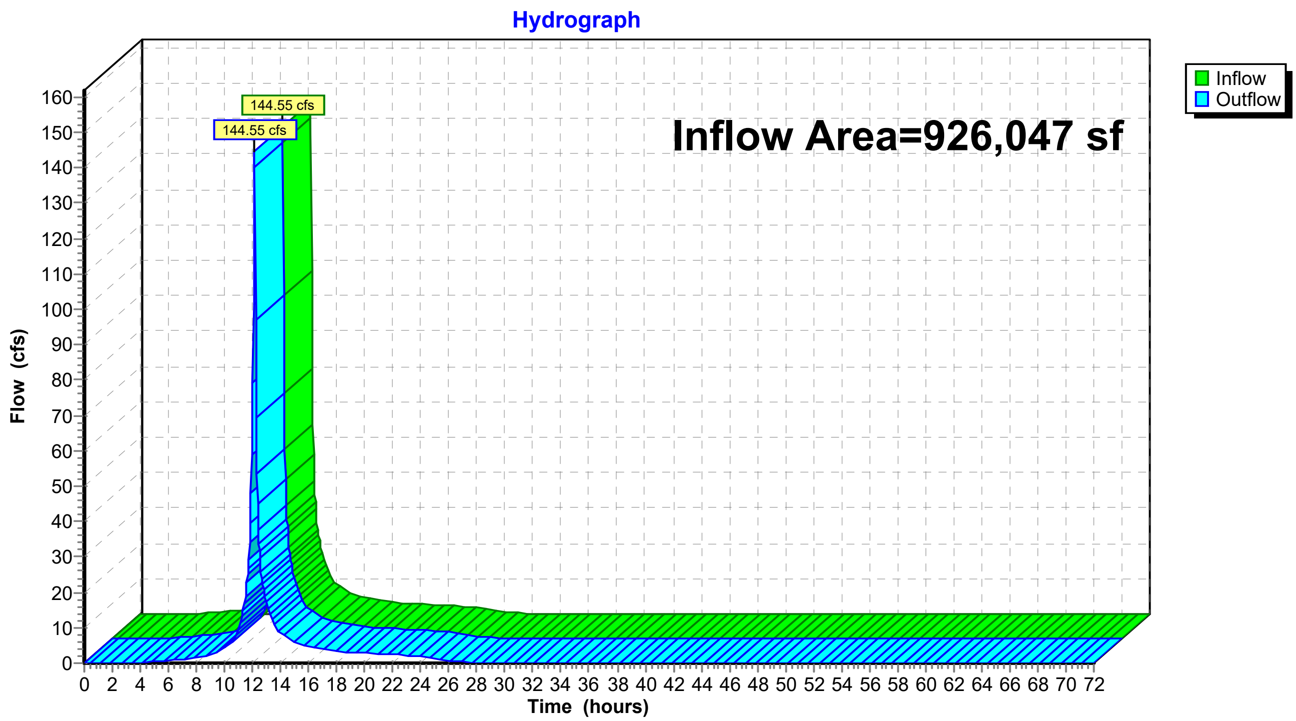
Summary for Reach MWRA: East of Berm

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 926,047 sf, 36.37% Impervious, Inflow Depth = 6.51" for 100 year - current event
Inflow = 144.55 cfs @ 12.13 hrs, Volume= 502,424 cf
Outflow = 144.55 cfs @ 12.13 hrs, Volume= 502,424 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Reach MWRA: East of Berm

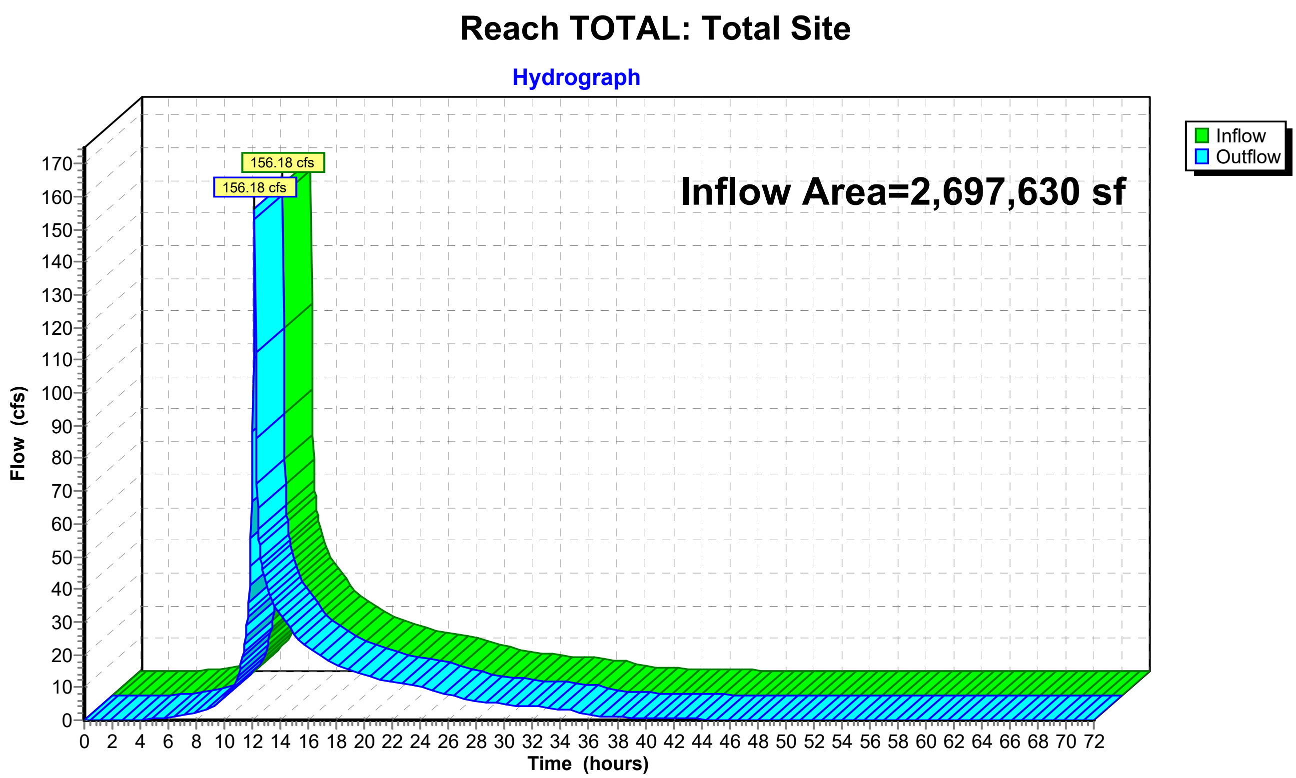


Summary for Reach TOTAL: Total Site

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	2,697,630 sf,	30.61% Impervious,	Inflow Depth > 6.37"	for 100 year - current event
Inflow =	156.18 cfs @	12.13 hrs, Volume=	1,431,927 cf	
Outflow =	156.18 cfs @	12.13 hrs, Volume=	1,431,927 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs



Summary for Pond BYP1: Bypass

[57] Hint: Peaked at 17.60' (Flood elevation advised)

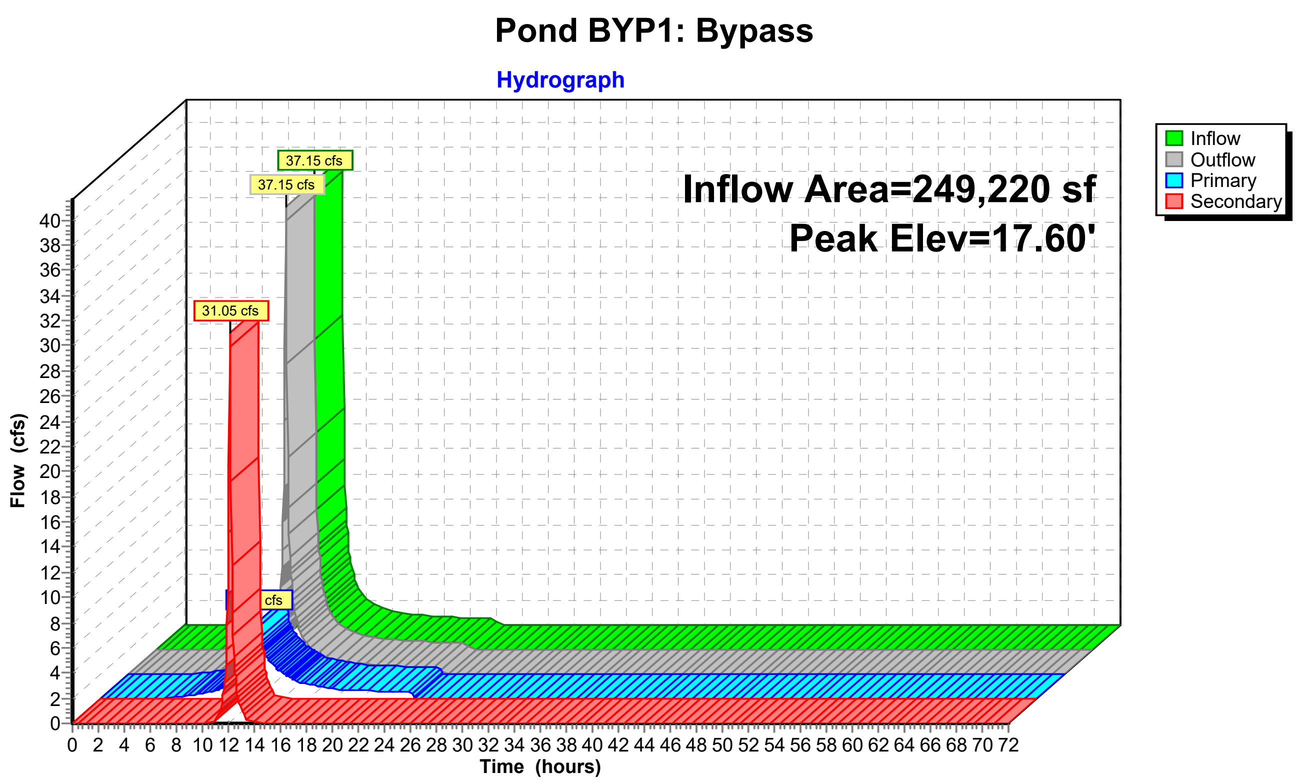
Inflow Area = 249,220 sf, 8.70% Impervious, Inflow Depth = 5.95" for 100 year - current event
Inflow = 37.15 cfs @ 12.13 hrs, Volume= 123,473 cf
Outflow = 37.15 cfs @ 12.13 hrs, Volume= 123,473 cf, Atten= 0%, Lag= 0.0 min
Primary = 6.11 cfs @ 12.13 hrs, Volume= 81,393 cf
Secondary = 31.05 cfs @ 12.13 hrs, Volume= 42,079 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 17.60' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.25'	**36.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=6.02 cfs @ 12.13 hrs HW=17.53' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 6.02 cfs @ 7.66 fps)

Secondary OutFlow Max=29.64 cfs @ 12.13 hrs HW=17.53' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 29.64 cfs @ 5.14 fps)



Summary for Pond BYP10: Bypass

[57] Hint: Peaked at 16.87' (Flood elevation advised)

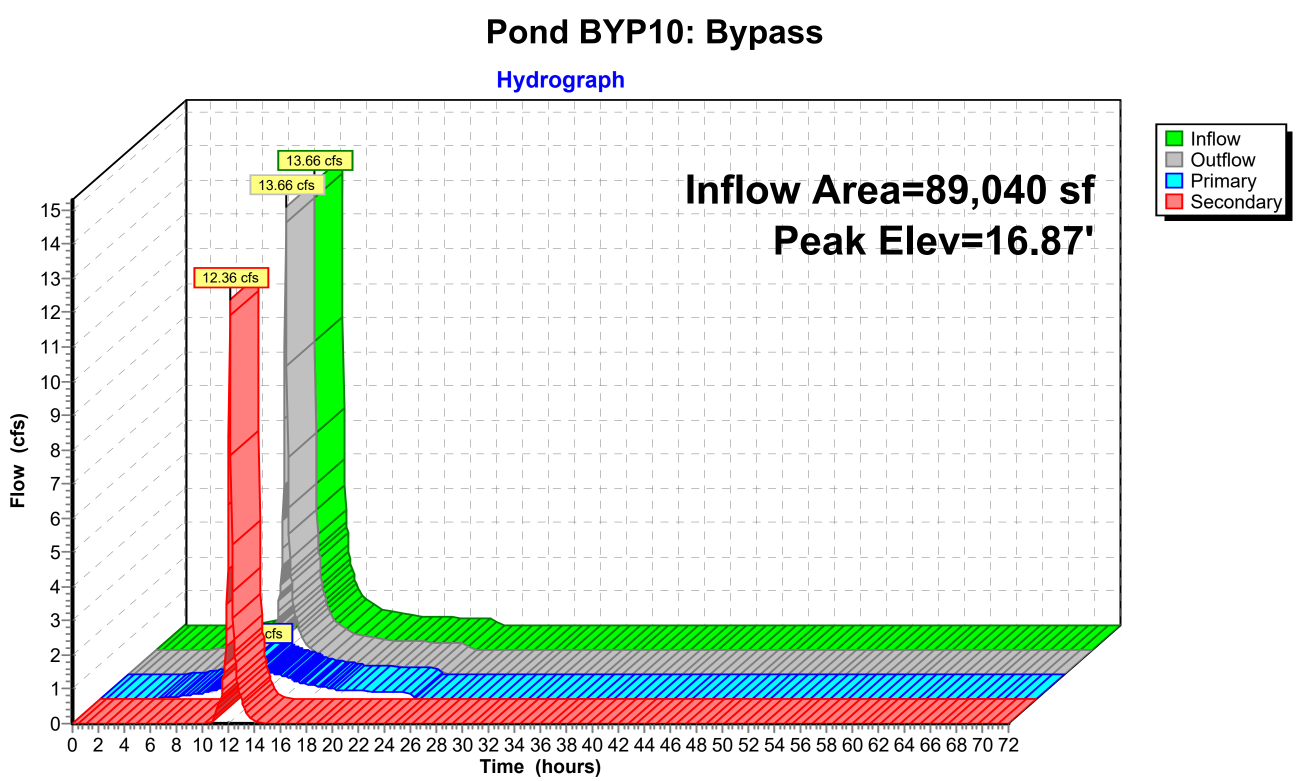
Inflow Area =	89,040 sf,	21.95% Impervious,	Inflow Depth = 6.18"	for 100 year - current event
Inflow =	13.66 cfs @	12.13 hrs, Volume=	45,868 cf	
Outflow =	13.66 cfs @	12.13 hrs, Volume=	45,868 cf,	Atten= 0%, Lag= 0.0 min
Primary =	1.29 cfs @	12.13 hrs, Volume=	26,246 cf	
Secondary =	12.36 cfs @	12.13 hrs, Volume=	19,622 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.87' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.40'	**30.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=1.28 cfs @ 12.13 hrs HW=16.83' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 1.28 cfs @ 6.51 fps)

Secondary OutFlow Max=11.83 cfs @ 12.13 hrs HW=16.83' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 11.83 cfs @ 4.07 fps)



Summary for Pond BYP2: Bypass

[57] Hint: Peaked at 18.70' (Flood elevation advised)

Inflow Area =	404,841 sf,	31.43% Impervious,	Inflow Depth = 6.42"	for 100 year - current event
Inflow =	63.70 cfs @	12.13 hrs, Volume=	216,545 cf	
Outflow =	63.70 cfs @	12.13 hrs, Volume=	216,545 cf,	Atten= 0%, Lag= 0.0 min
Primary =	7.28 cfs @	12.13 hrs, Volume=	133,014 cf	
Secondary =	56.43 cfs @	12.13 hrs, Volume=	83,531 cf	

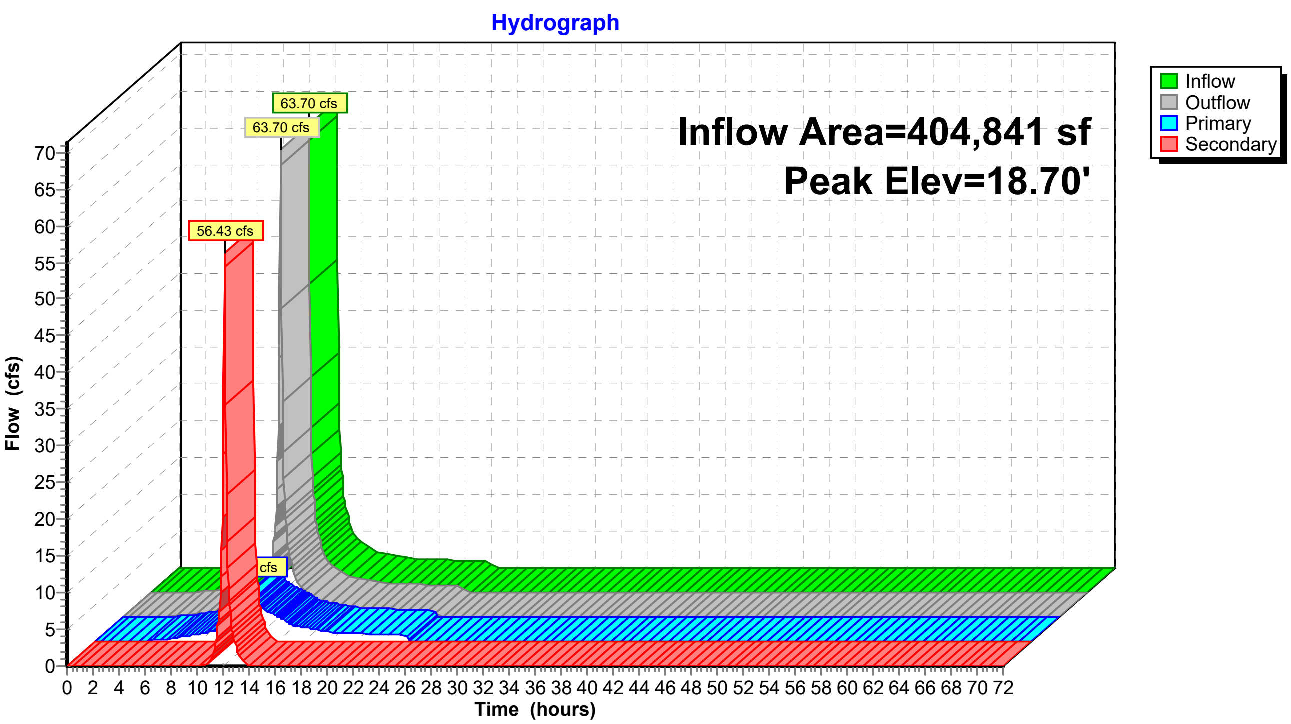
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 18.70' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.80'	**48.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=7.19 cfs @ 12.13 hrs HW=18.61' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 7.19 cfs @ 9.15 fps)

Secondary OutFlow Max=53.95 cfs @ 12.13 hrs HW=18.61' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 53.95 cfs @ 5.71 fps)

Pond BYP2: Bypass



Summary for Pond BYP3: Bypass

[57] Hint: Peaked at 17.95' (Flood elevation advised)

Inflow Area =	351,836 sf,	39.26% Impervious,	Inflow Depth = 6.54"	for 100 year - current event
Inflow =	56.01 cfs @	12.13 hrs,	Volume=	191,673 cf
Outflow =	56.01 cfs @	12.13 hrs,	Volume=	191,673 cf, Atten= 0%, Lag= 0.0 min
Primary =	10.16 cfs @	12.13 hrs,	Volume=	133,898 cf
Secondary =	45.86 cfs @	12.13 hrs,	Volume=	57,776 cf

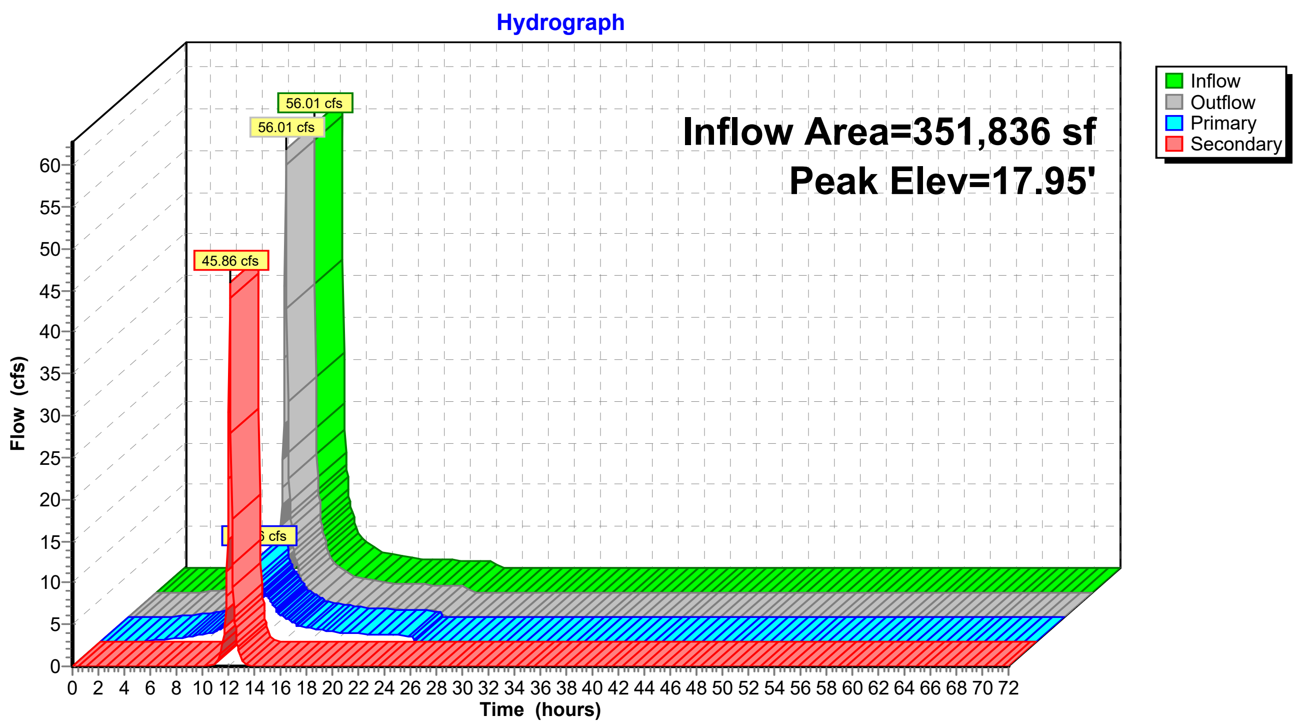
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 17.95' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**15.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.40'	**48.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=10.02 cfs @ 12.13 hrs HW=17.88' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 10.02 cfs @ 8.16 fps)

Secondary OutFlow Max=43.75 cfs @ 12.13 hrs HW=17.88' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 43.75 cfs @ 5.36 fps)

Pond BYP3: Bypass



Summary for Pond BYP4: Bypass

[57] Hint: Peaked at 18.83' (Flood elevation advised)

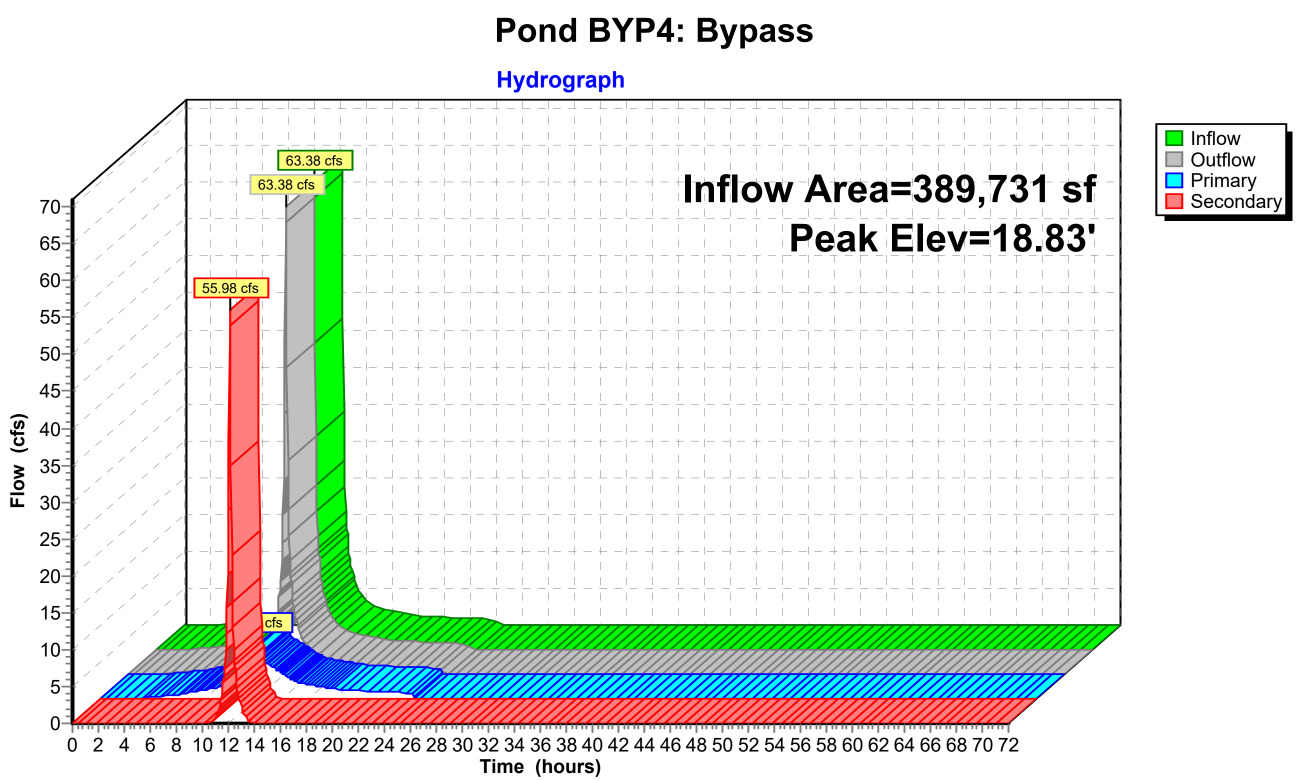
Inflow Area =	389,731 sf, 48.29% Impervious,	Inflow Depth = 6.78"	for 100 year - current event	
Inflow =	63.38 cfs @	12.13 hrs, Volume=	220,039 cf	
Outflow =	63.38 cfs @	12.13 hrs, Volume=	220,039 cf,	Atten= 0%, Lag= 0.0 min
Primary =	7.41 cfs @	12.13 hrs, Volume=	138,476 cf	
Secondary =	55.98 cfs @	12.13 hrs, Volume=	81,563 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 18.83' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.95'	**48.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=7.32 cfs @ 12.13 hrs HW=18.75' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 7.32 cfs @ 9.32 fps)

Secondary OutFlow Max=53.52 cfs @ 12.13 hrs HW=18.75' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 53.52 cfs @ 5.70 fps)



Summary for Pond BYP5: Bypass

[57] Hint: Peaked at 24.80' (Flood elevation advised)

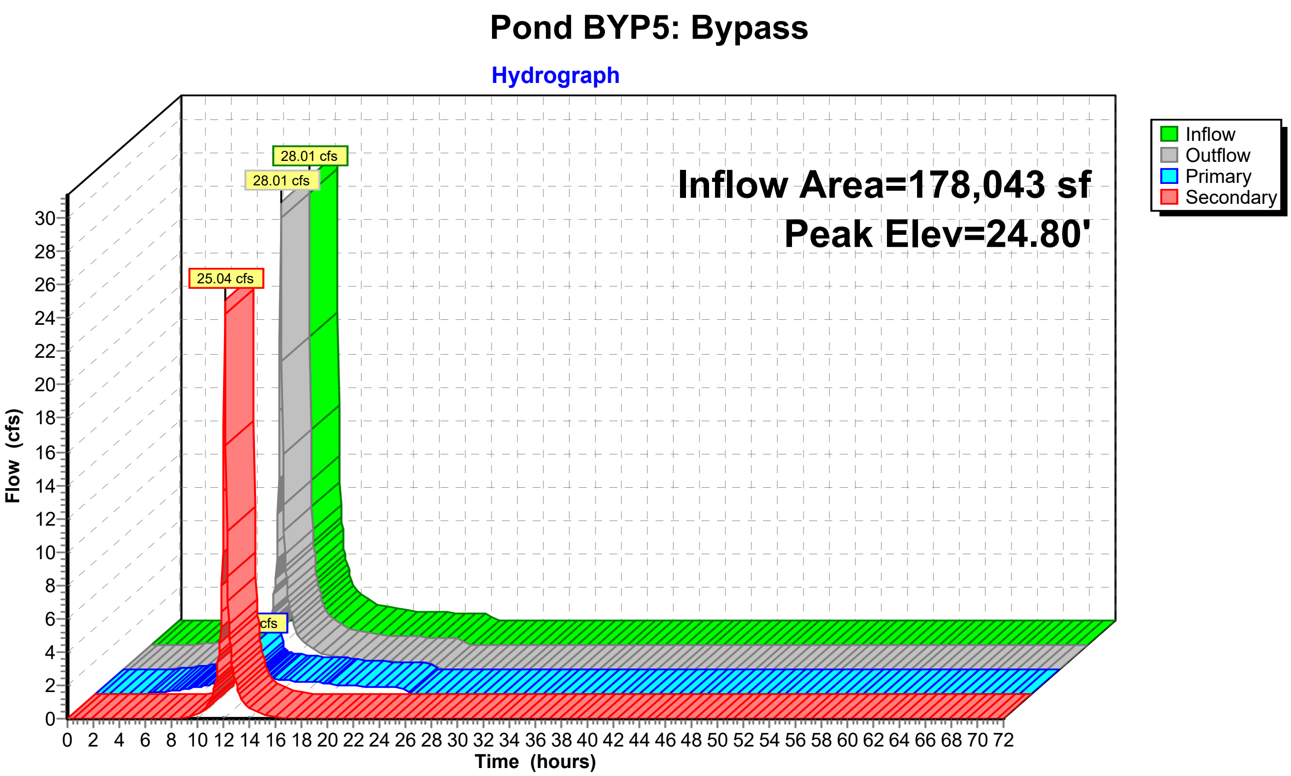
Inflow Area =	178,043 sf,	31.71% Impervious,	Inflow Depth = 6.42"	for 100 year - current event
Inflow =	28.01 cfs @	12.13 hrs, Volume=	95,233 cf	
Outflow =	28.01 cfs @	12.13 hrs, Volume=	95,233 cf,	Atten= 0%, Lag= 0.0 min
Primary =	2.97 cfs @	12.13 hrs, Volume=	44,307 cf	
Secondary =	25.04 cfs @	12.13 hrs, Volume=	50,926 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 24.80' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.50'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=2.87 cfs @ 12.13 hrs HW=24.22' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 2.87 cfs @ 14.62 fps)

Secondary OutFlow Max=24.02 cfs @ 12.13 hrs HW=24.22' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 24.02 cfs @ 13.59 fps)



Summary for Pond BYP6: Bypass

[57] Hint: Peaked at 18.13' (Flood elevation advised)

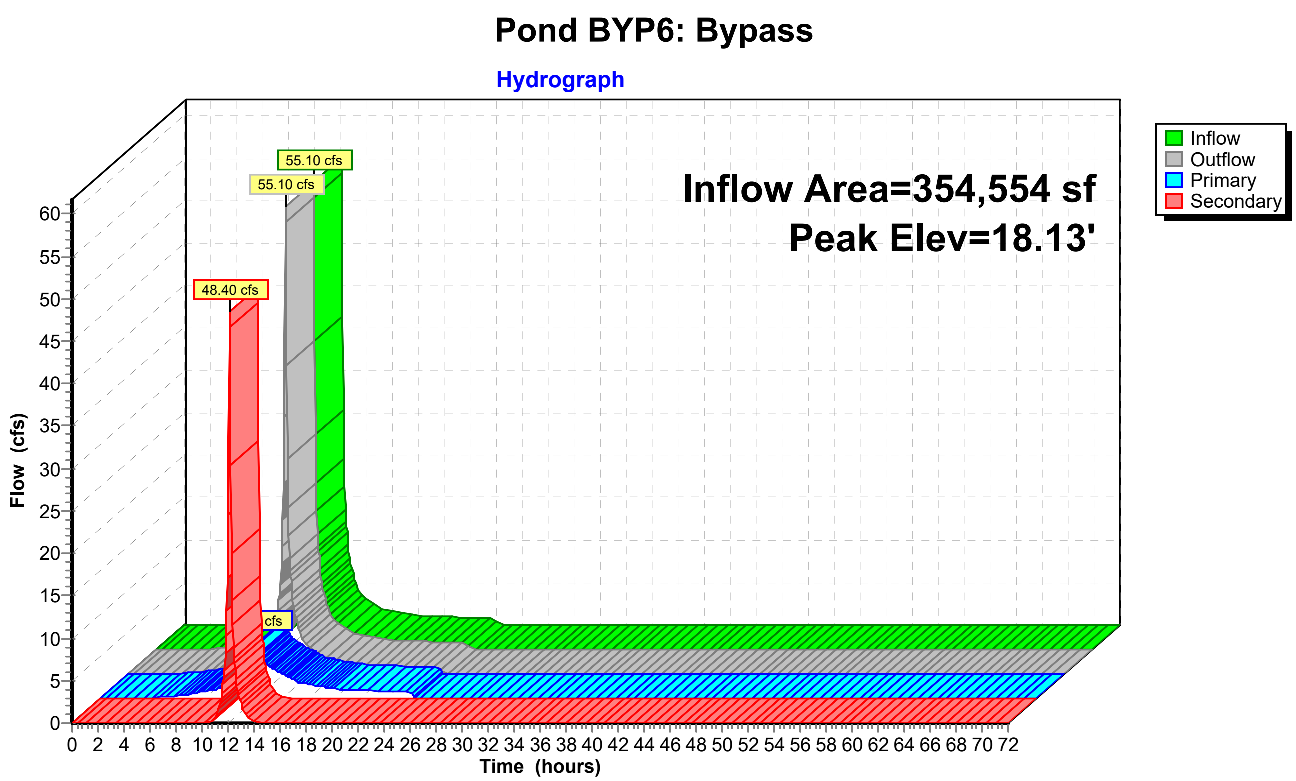
Inflow Area =	354,554 sf,	29.27% Impervious,	Inflow Depth = 6.30"	for 100 year - current event	
Inflow =	55.10 cfs @	12.13 hrs,	Volume=	186,144 cf	
Outflow =	55.10 cfs @	12.13 hrs,	Volume=	186,144 cf,	Atten= 0%, Lag= 0.0 min
Primary =	6.70 cfs @	12.13 hrs,	Volume=	114,467 cf	
Secondary =	48.40 cfs @	12.13 hrs,	Volume=	71,677 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 18.13' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.50'	**48.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=6.62 cfs @ 12.13 hrs HW=18.06' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 6.62 cfs @ 8.42 fps)

Secondary OutFlow Max=46.27 cfs @ 12.13 hrs HW=18.06' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 46.27 cfs @ 5.45 fps)



Summary for Pond BYP7A: Bypass

[57] Hint: Peaked at 17.23' (Flood elevation advised)

Inflow Area =	154,470 sf,	45.37% Impervious,	Inflow Depth = 6.66"	for 100 year - current event	
Inflow =	24.87 cfs @	12.13 hrs,	Volume=	85,682 cf	
Outflow =	24.87 cfs @	12.13 hrs,	Volume=	85,682 cf,	Atten= 0%, Lag= 0.0 min
Primary =	5.65 cfs @	12.13 hrs,	Volume=	63,912 cf	
Secondary =	19.21 cfs @	12.13 hrs,	Volume=	21,770 cf	

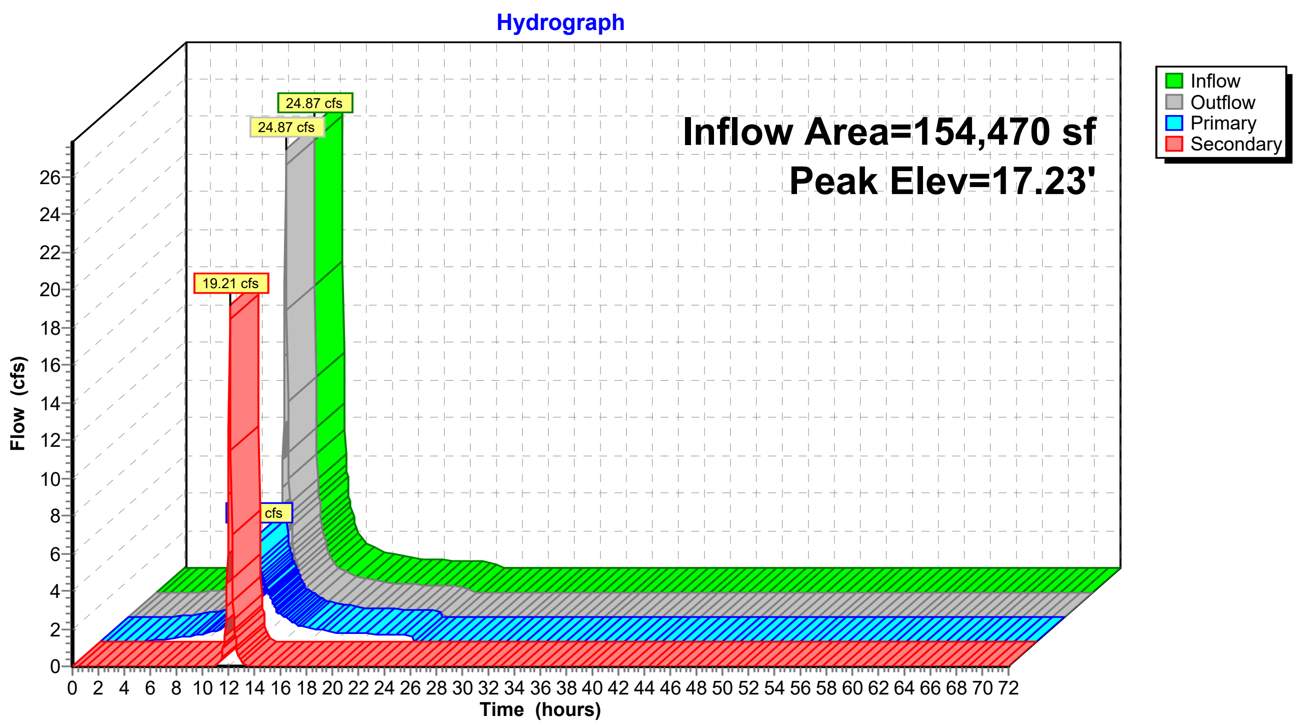
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 17.23' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.30'	**30.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=5.57 cfs @ 12.13 hrs HW=17.17' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 5.57 cfs @ 7.09 fps)

Secondary OutFlow Max=18.30 cfs @ 12.13 hrs HW=17.17' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 18.30 cfs @ 4.65 fps)

Pond BYP7A: Bypass



Summary for Pond BYP7B: Bypass

[57] Hint: Peaked at 17.81' (Flood elevation advised)

Inflow Area =	292,806 sf,	20.13% Impervious,	Inflow Depth = 6.18"	for 100 year - current event	
Inflow =	44.91 cfs @	12.13 hrs,	Volume=	150,836 cf	
Outflow =	44.91 cfs @	12.13 hrs,	Volume=	150,836 cf,	Atten= 0%, Lag= 0.0 min
Primary =	6.35 cfs @	12.13 hrs,	Volume=	96,191 cf	
Secondary =	38.56 cfs @	12.13 hrs,	Volume=	54,645 cf	

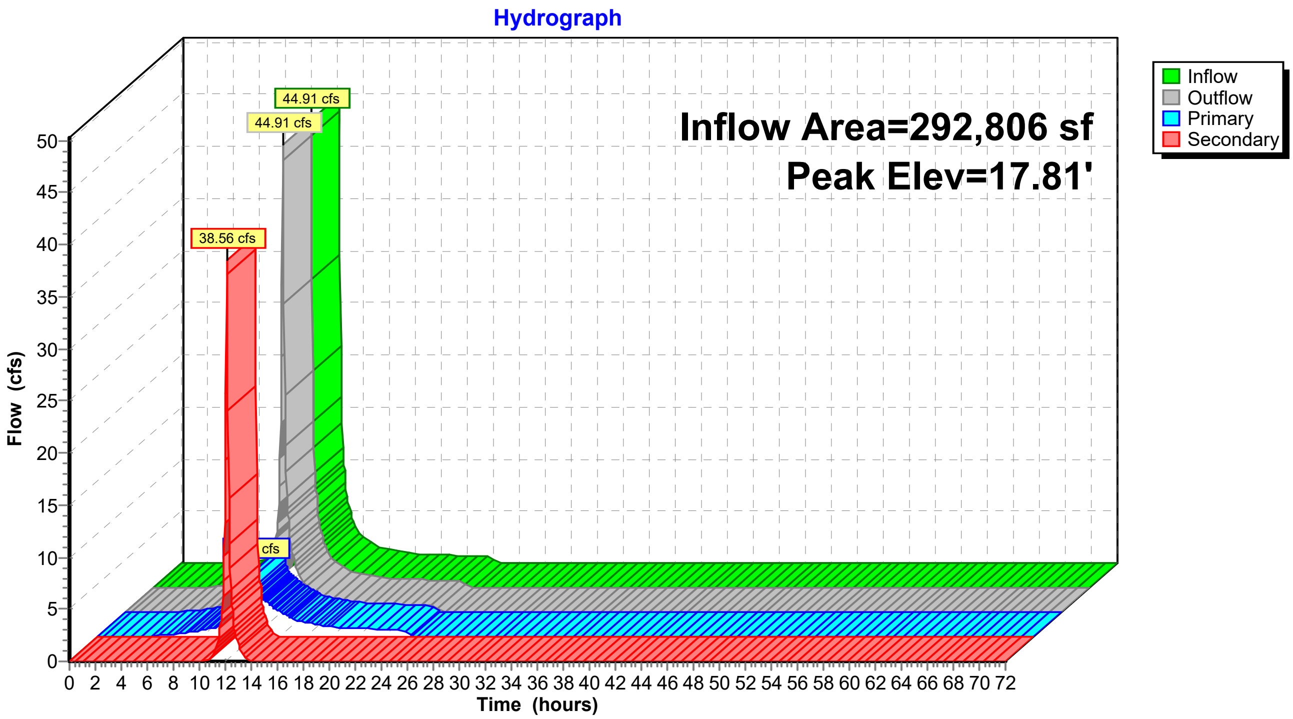
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 17.81' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.35'	**42.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=6.26 cfs @ 12.13 hrs HW=17.74' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 6.26 cfs @ 7.97 fps)

Secondary OutFlow Max=36.84 cfs @ 12.13 hrs HW=17.74' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 36.84 cfs @ 5.26 fps)

Pond BYP7B: Bypass



Summary for Pond BYP8A: Bypass

[57] Hint: Peaked at 15.92' (Flood elevation advised)

Inflow Area =	26,649 sf,	12.91% Impervious,	Inflow Depth = 5.95"	for 100 year - current event	
Inflow =	3.97 cfs @	12.13 hrs,	Volume=	13,203 cf	
Outflow =	3.97 cfs @	12.13 hrs,	Volume=	13,203 cf,	Atten= 0%, Lag= 0.0 min
Primary =	0.91 cfs @	12.13 hrs,	Volume=	9,709 cf	
Secondary =	3.06 cfs @	12.13 hrs,	Volume=	3,494 cf	

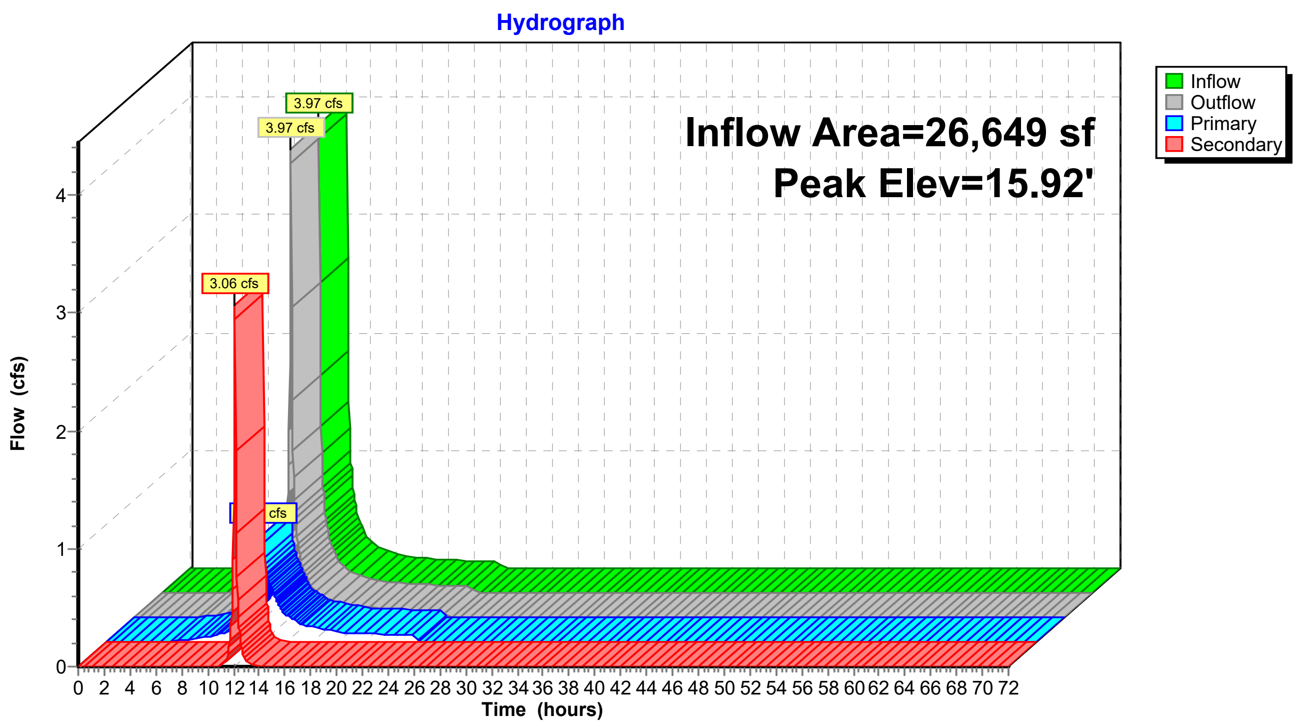
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.92' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.10'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.90 cfs @ 12.13 hrs HW=15.90' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 0.90 cfs @ 4.57 fps)

Secondary OutFlow Max=2.92 cfs @ 12.13 hrs HW=15.90' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 2.92 cfs @ 3.04 fps)

Pond BYP8A: Bypass



Summary for Pond BYP8B: Bypass

[57] Hint: Peaked at 15.83' (Flood elevation advised)

Inflow Area =	21,545 sf,	24.73% Impervious,	Inflow Depth = 6.18"	for 100 year - current event
Inflow =	3.30 cfs @	12.13 hrs, Volume=	11,099 cf	
Outflow =	3.30 cfs @	12.13 hrs, Volume=	11,099 cf,	Atten= 0%, Lag= 0.0 min
Primary =	0.86 cfs @	12.13 hrs, Volume=	8,509 cf	
Secondary =	2.44 cfs @	12.13 hrs, Volume=	2,589 cf	

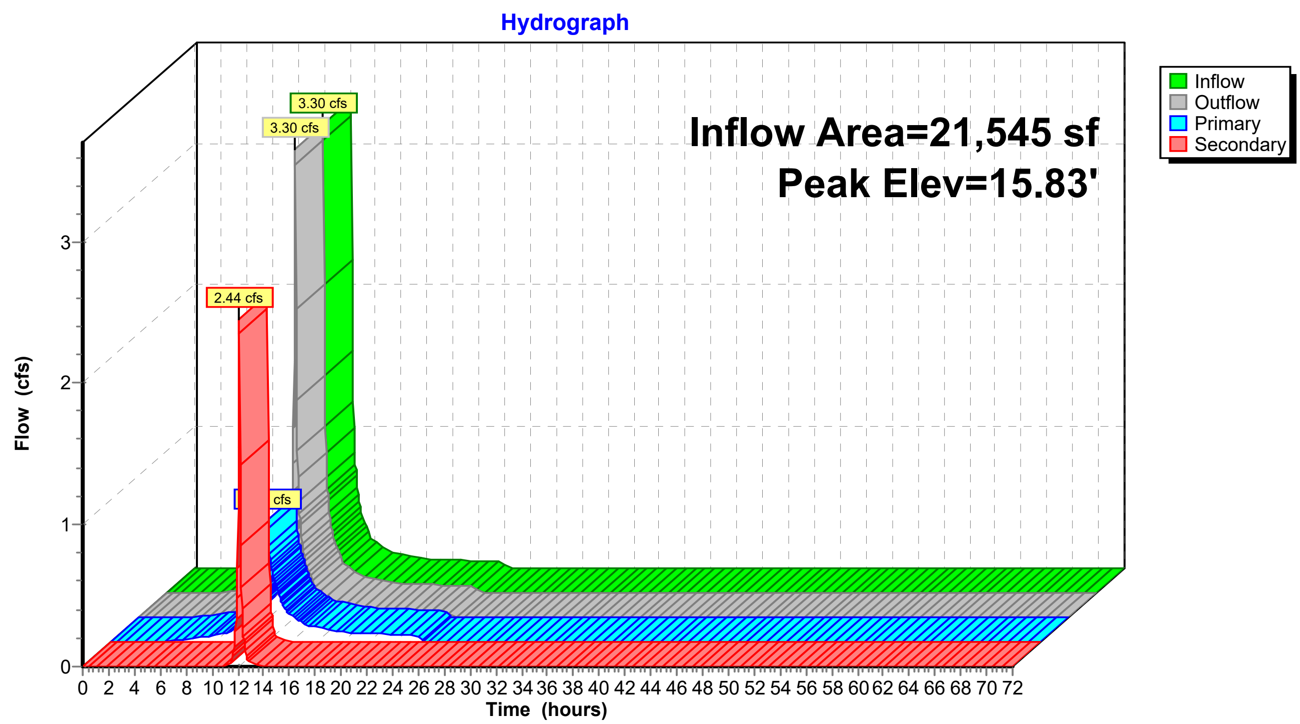
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.83' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.10'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.85 cfs @ 12.13 hrs HW=15.80' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 0.85 cfs @ 4.32 fps)

Secondary OutFlow Max=2.32 cfs @ 12.13 hrs HW=15.80' (Free Discharge)
↑—**2=Orifice/Grate** (Orifice Controls 2.32 cfs @ 2.86 fps)

Pond BYP8B: Bypass



Summary for Pond BYP8C: Bypass

[57] Hint: Peaked at 15.68' (Flood elevation advised)

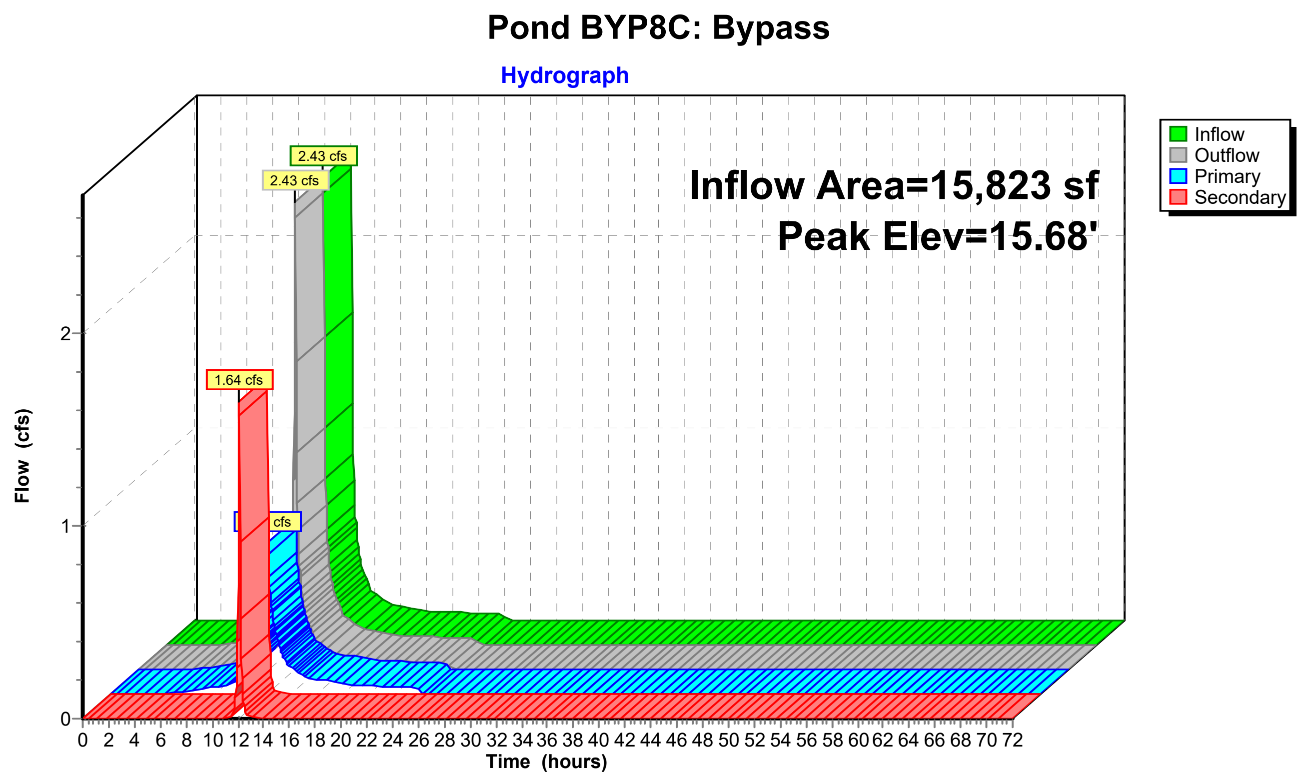
Inflow Area =	15,823 sf,	23.97% Impervious,	Inflow Depth = 6.18"	for 100 year - current event	
Inflow =	2.43 cfs @	12.13 hrs,	Volume=	8,151 cf	
Outflow =	2.43 cfs @	12.13 hrs,	Volume=	8,151 cf,	Atten= 0%, Lag= 0.0 min
Primary =	0.78 cfs @	12.13 hrs,	Volume=	6,633 cf	
Secondary =	1.64 cfs @	12.13 hrs,	Volume=	1,518 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.68' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.10'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.77 cfs @ 12.13 hrs HW=15.66' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 0.77 cfs @ 3.93 fps)

Secondary OutFlow Max=1.56 cfs @ 12.13 hrs HW=15.66' (Free Discharge)
↑—**2=Orifice/Grate** (Orifice Controls 1.56 cfs @ 2.56 fps)



Summary for Pond BYP8D: Bypass

[57] Hint: Peaked at 16.17' (Flood elevation advised)

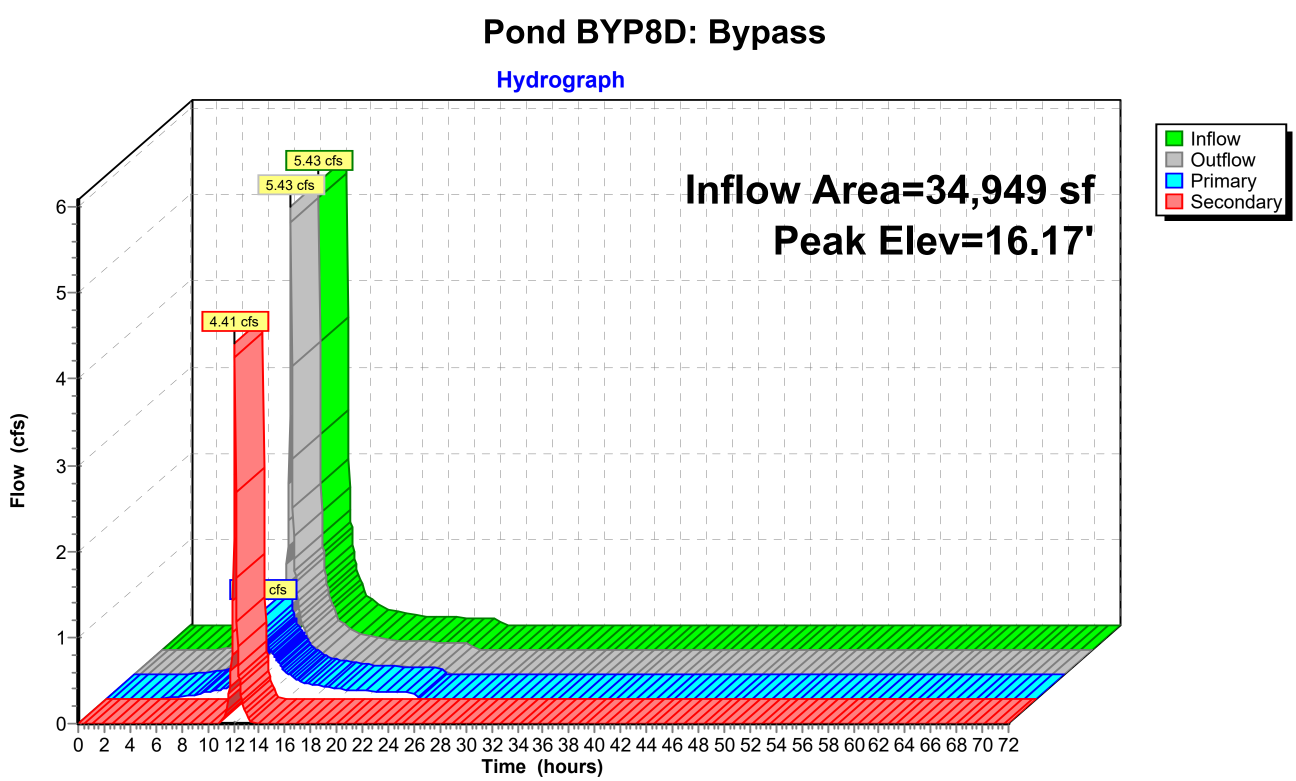
Inflow Area =	34,949 sf, 27.15% Impervious,	Inflow Depth = 6.30"	for 100 year - current event
Inflow =	5.43 cfs @ 12.13 hrs, Volume=	18,349 cf	
Outflow =	5.43 cfs @ 12.13 hrs, Volume=	18,349 cf, Atten= 0%, Lag= 0.0 min	
Primary =	1.02 cfs @ 12.13 hrs, Volume=	12,892 cf	
Secondary =	4.41 cfs @ 12.13 hrs, Volume=	5,456 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.17' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.15'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=1.01 cfs @ 12.13 hrs HW=16.14' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 1.01 cfs @ 5.14 fps)

Secondary OutFlow Max=4.20 cfs @ 12.13 hrs HW=16.14' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 4.20 cfs @ 3.39 fps)



Summary for Pond BYP8E: Bypass

[57] Hint: Peaked at 16.54' (Flood elevation advised)

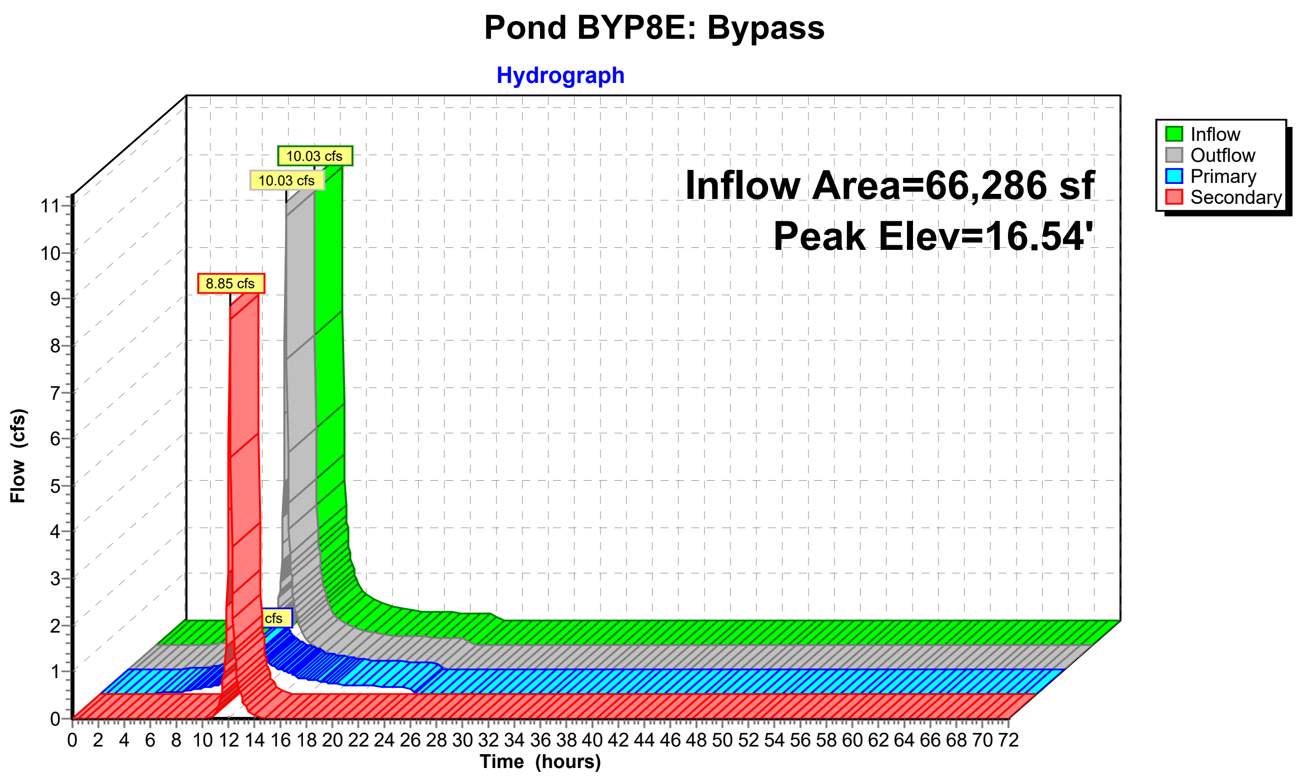
Inflow Area =	66,286 sf,	18.42% Impervious,	Inflow Depth = 6.06"	for 100 year - current event	
Inflow =	10.03 cfs @	12.13 hrs,	Volume=	33,493 cf	
Outflow =	10.03 cfs @	12.13 hrs,	Volume=	33,493 cf,	Atten= 0%, Lag= 0.0 min
Primary =	1.18 cfs @	12.13 hrs,	Volume=	19,992 cf	
Secondary =	8.85 cfs @	12.13 hrs,	Volume=	13,501 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.54' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.20'	**24.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=1.16 cfs @ 12.13 hrs HW=16.51' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 1.16 cfs @ 5.91 fps)

Secondary OutFlow Max=8.46 cfs @ 12.13 hrs HW=16.51' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 8.46 cfs @ 3.89 fps)



Summary for Pond BYP9A: Bypass

[57] Hint: Peaked at 16.14' (Flood elevation advised)

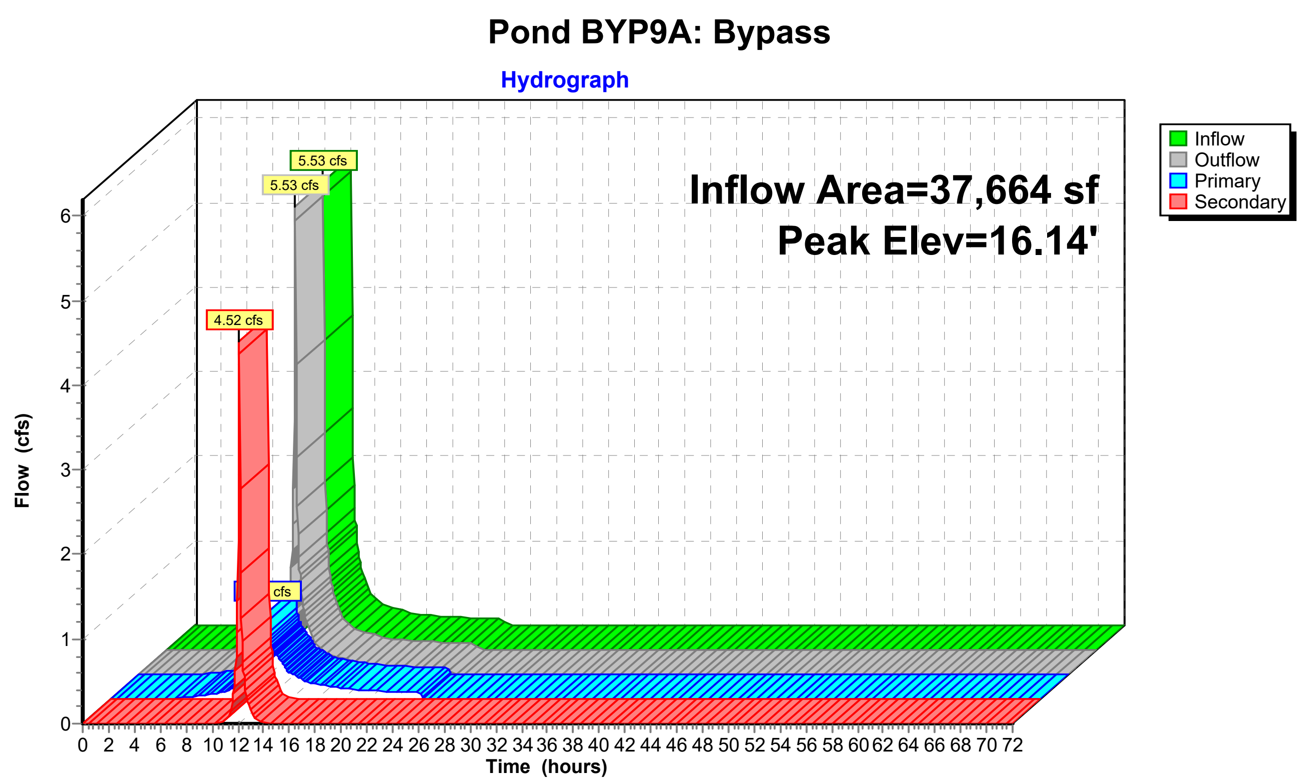
Inflow Area = 37,664 sf, 5.01% Impervious, Inflow Depth = 5.83" for 100 year - current event
Inflow = 5.53 cfs @ 12.13 hrs, Volume= 18,290 cf
Outflow = 5.53 cfs @ 12.13 hrs, Volume= 18,290 cf, Atten= 0%, Lag= 0.0 min
Primary = 1.01 cfs @ 12.13 hrs, Volume= 12,404 cf
Secondary = 4.52 cfs @ 12.13 hrs, Volume= 5,886 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.14' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.10'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.99 cfs @ 12.13 hrs HW=16.11' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 0.99 cfs @ 5.07 fps)

Secondary OutFlow Max=4.31 cfs @ 12.13 hrs HW=16.11' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 4.31 cfs @ 3.42 fps)



Summary for Pond BYP9B: Bypass

[57] Hint: Peaked at 16.05' (Flood elevation advised)

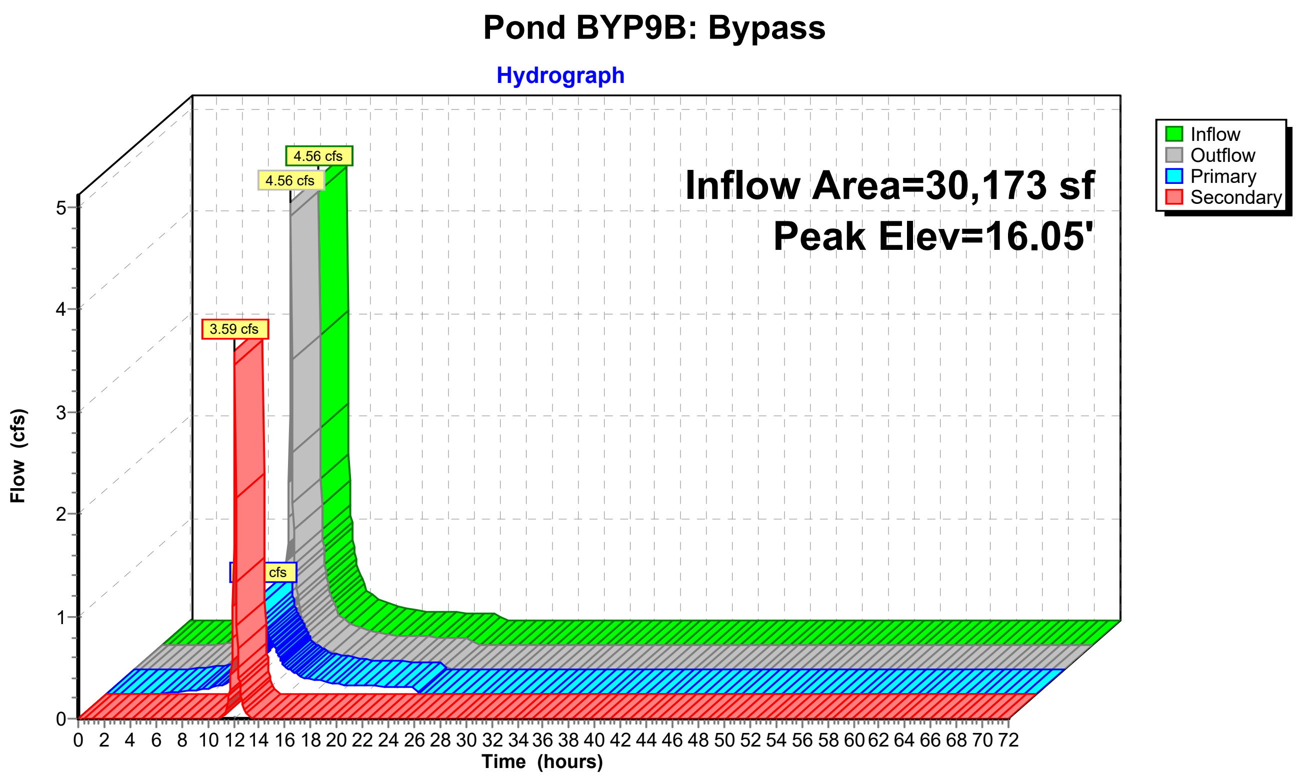
Inflow Area = 30,173 sf, 18.18% Impervious, Inflow Depth = 6.06" for 100 year - current event
Inflow = 4.56 cfs @ 12.13 hrs, Volume= 15,246 cf
Outflow = 4.56 cfs @ 12.13 hrs, Volume= 15,246 cf, Atten= 0%, Lag= 0.0 min
Primary = 0.97 cfs @ 12.13 hrs, Volume= 11,140 cf
Secondary = 3.59 cfs @ 12.13 hrs, Volume= 4,106 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.05' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.15'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.96 cfs @ 12.13 hrs HW=16.03' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 0.96 cfs @ 4.88 fps)

Secondary OutFlow Max=3.42 cfs @ 12.13 hrs HW=16.03' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 3.42 cfs @ 3.19 fps)



Summary for Pond GI-1: Green Infrastructure

[81] Warning: Exceeded Pond BYP1 by 0.35' @ 18.10 hrs

Inflow Area = 249,220 sf, 8.70% Impervious, Inflow Depth = 3.92" for 100 year - current event
Inflow = 6.11 cfs @ 12.13 hrs, Volume= 81,393 cf
Outflow = 6.00 cfs @ 12.15 hrs, Volume= 81,393 cf, Atten= 2%, Lag= 1.4 min
Primary = 6.00 cfs @ 12.15 hrs, Volume= 81,393 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.84' @ 12.15 hrs Surf.Area= 2,260 sf Storage= 1,893 cf

Plug-Flow detention time= 14.9 min calculated for 81,337 cf (100% of inflow)
Center-of-Mass det. time= 15.0 min (857.3 - 842.3)

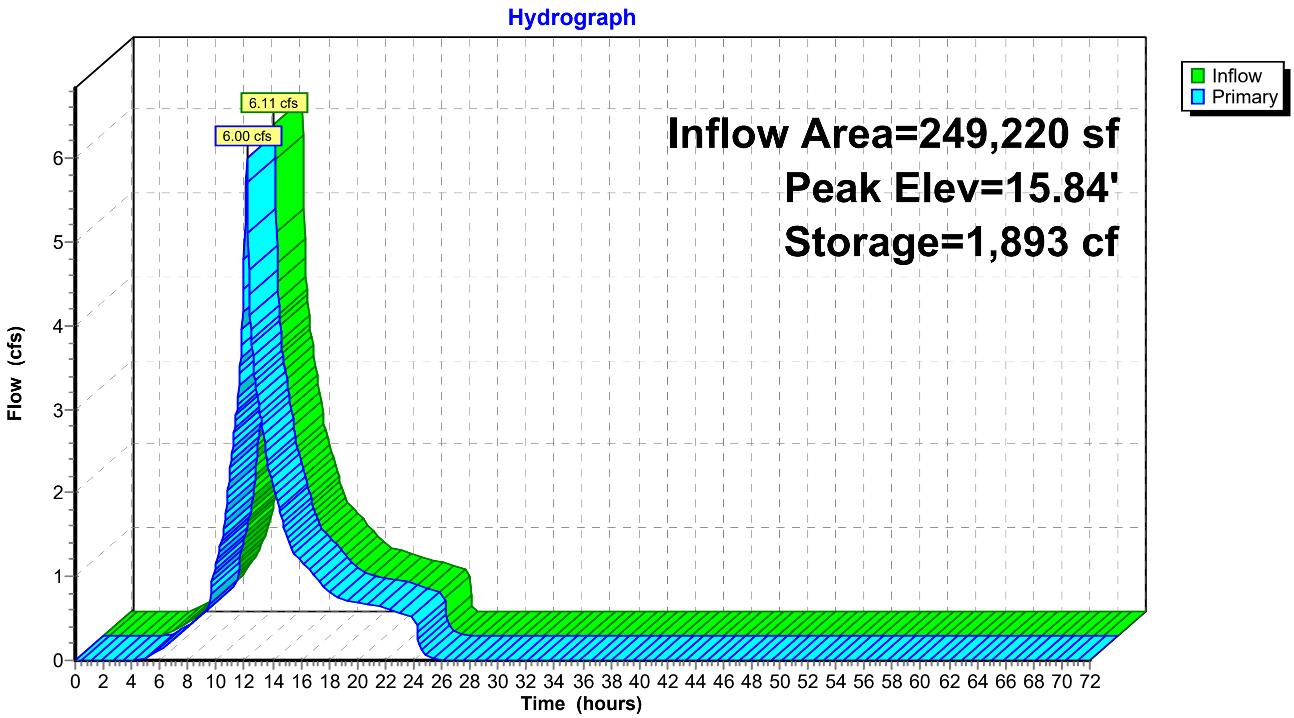
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	2,260 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	2,260	0	0
16.00	2,260	2,260	2,260

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=5.99 cfs @ 12.15 hrs HW=15.84' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.87 cfs @ 4.41 fps)
└─**2=Orifice/Grate** (Weir Controls 5.13 cfs @ 1.90 fps)

Pond GI-1: Green Infrastructure



Summary for Pond GI-10: Green Infrastructure

[81] Warning: Exceeded Pond BYP10 by 0.14' @ 15.10 hrs

Inflow Area = 89,040 sf, 21.95% Impervious, Inflow Depth = 3.54" for 100 year - current event
Inflow = 1.29 cfs @ 12.13 hrs, Volume= 26,246 cf
Outflow = 1.25 cfs @ 12.16 hrs, Volume= 26,246 cf, Atten= 3%, Lag= 2.2 min
Primary = 1.25 cfs @ 12.16 hrs, Volume= 26,246 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.57' @ 12.16 hrs Surf.Area= 2,036 sf Storage= 1,170 cf

Plug-Flow detention time= 20.3 min calculated for 26,228 cf (100% of inflow)
Center-of-Mass det. time= 20.4 min (869.4 - 849.0)

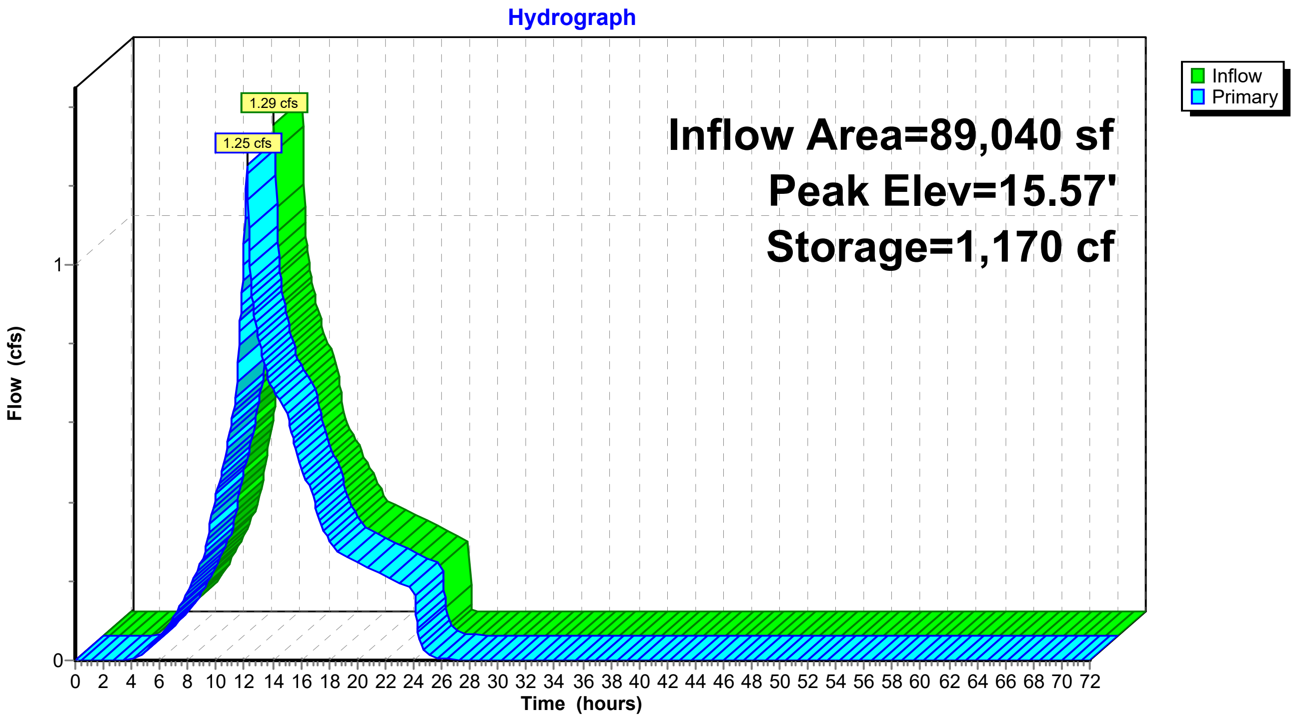
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	2,036 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	2,036	0	0
16.00	2,036	2,036	2,036

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=1.24 cfs @ 12.16 hrs HW=15.57' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.72 cfs @ 3.65 fps)
└─**2=Orifice/Grate** (Weir Controls 0.53 cfs @ 0.89 fps)

Pond GI-10: Green Infrastructure



Summary for Pond GI-2: Green Infrastructure

[81] Warning: Exceeded Pond BYP2 by 0.50' @ 24.20 hrs

Inflow Area = 404,841 sf, 31.43% Impervious, Inflow Depth = 3.94" for 100 year - current event
Inflow = 7.28 cfs @ 12.13 hrs, Volume= 133,014 cf
Outflow = 6.51 cfs @ 12.21 hrs, Volume= 133,013 cf, Atten= 11%, Lag= 4.9 min
Primary = 6.51 cfs @ 12.21 hrs, Volume= 133,013 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.86' @ 12.21 hrs Surf.Area= 13,254 sf Storage= 11,389 cf

Plug-Flow detention time= 70.7 min calculated for 133,013 cf (100% of inflow)
Center-of-Mass det. time= 70.3 min (902.8 - 832.5)

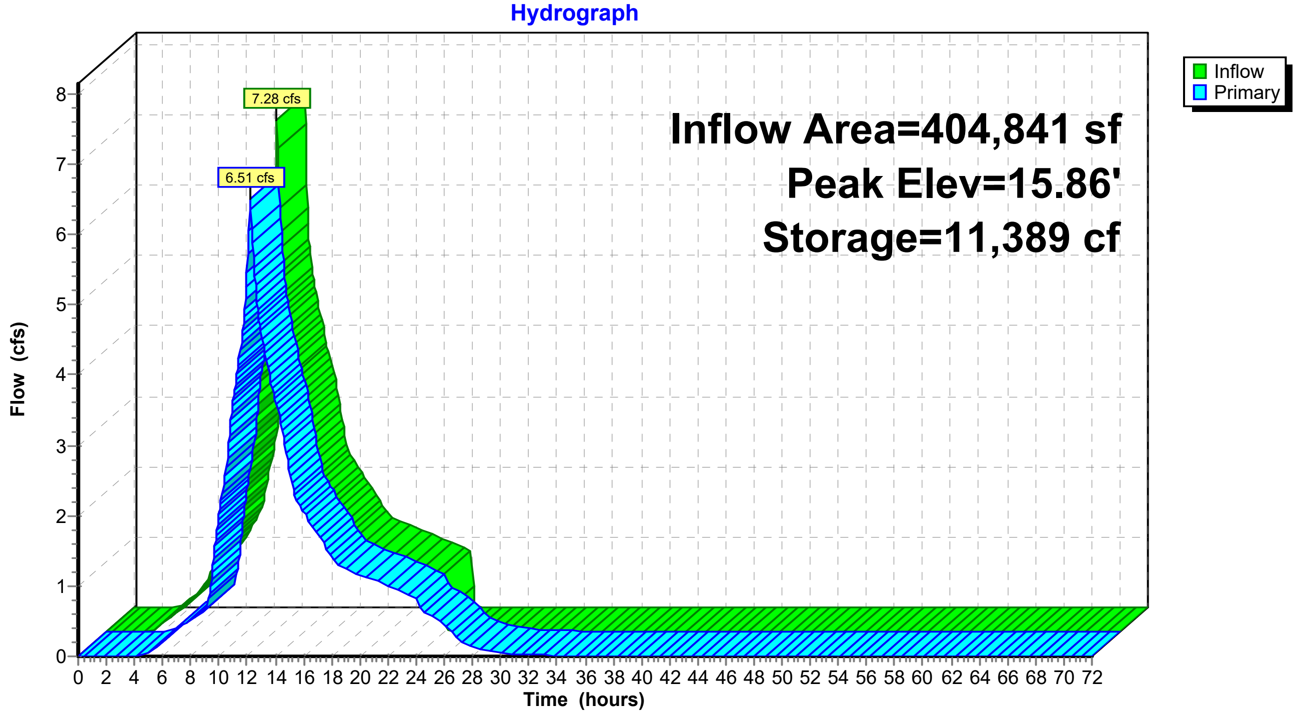
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	13,254 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	13,254	0	0
16.00	13,254	13,254	13,254

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=6.49 cfs @ 12.21 hrs HW=15.86' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.88 cfs @ 4.46 fps)
└─**2=Orifice/Grate** (Weir Controls 5.62 cfs @ 1.96 fps)

Pond GI-2: Green Infrastructure



Summary for Pond GI-3: Green Infrastructure

[81] Warning: Exceeded Pond BYP3 by 0.49' @ 24.20 hrs

Inflow Area = 351,836 sf, 39.26% Impervious, Inflow Depth = 4.57" for 100 year - current event
Inflow = 10.16 cfs @ 12.13 hrs, Volume= 133,898 cf
Outflow = 8.93 cfs @ 12.21 hrs, Volume= 133,896 cf, Atten= 12%, Lag= 4.9 min
Primary = 8.93 cfs @ 12.21 hrs, Volume= 133,896 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.95' @ 12.21 hrs Surf.Area= 14,388 sf Storage= 13,729 cf

Plug-Flow detention time= 74.2 min calculated for 133,803 cf (100% of inflow)
Center-of-Mass det. time= 75.2 min (891.3 - 816.1)

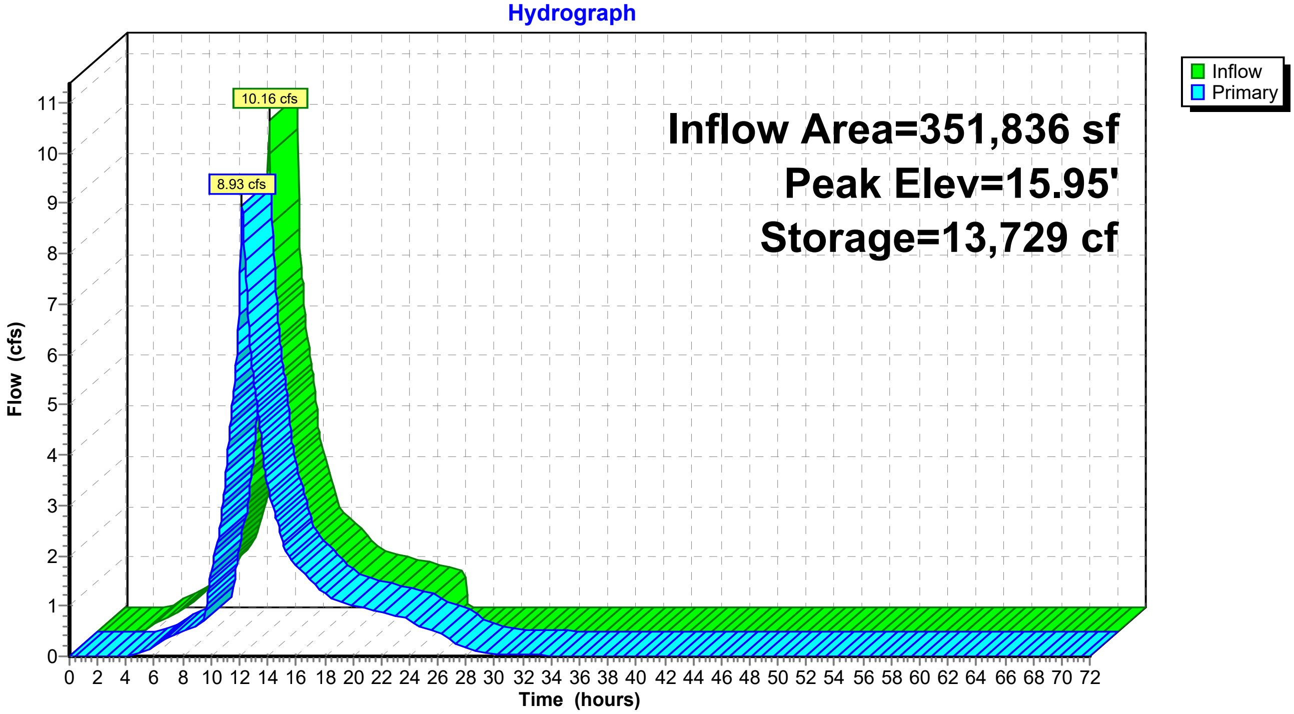
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	14,388 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	14,388	0	0
16.00	14,388	14,388	14,388

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=8.91 cfs @ 12.21 hrs HW=15.95' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.92 cfs @ 4.70 fps)
└─**2=Orifice/Grate** (Weir Controls 7.98 cfs @ 2.20 fps)

Pond GI-3: Green Infrastructure



Summary for Pond GI-4: Green Infrastructure

[81] Warning: Exceeded Pond BYP4 by 0.50' @ 24.20 hrs

Inflow Area = 389,731 sf, 48.29% Impervious, Inflow Depth = 4.26" for 100 year - current event
Inflow = 7.41 cfs @ 12.13 hrs, Volume= 138,476 cf
Outflow = 6.67 cfs @ 12.21 hrs, Volume= 138,475 cf, Atten= 10%, Lag= 4.9 min
Primary = 6.67 cfs @ 12.21 hrs, Volume= 138,475 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.87' @ 12.21 hrs Surf.Area= 13,353 sf Storage= 11,562 cf

Plug-Flow detention time= 70.7 min calculated for 138,475 cf (100% of inflow)
Center-of-Mass det. time= 70.3 min (885.7 - 815.3)

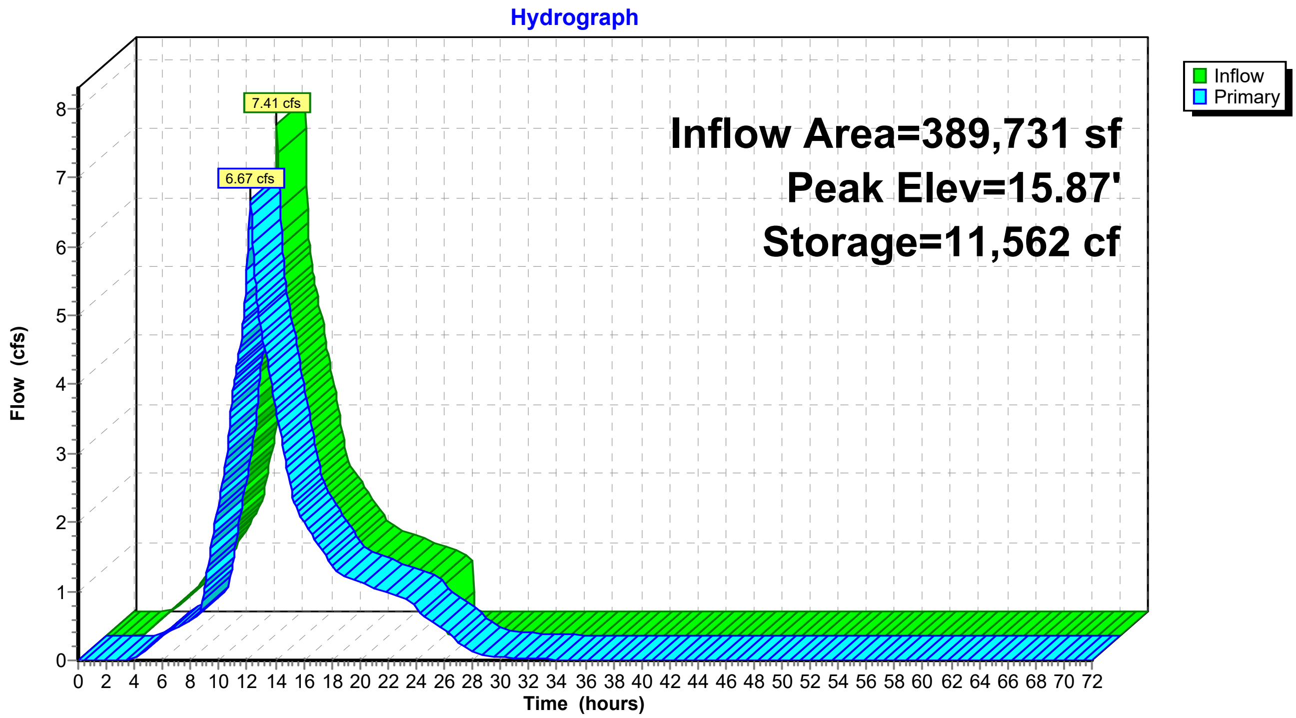
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	13,353 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	13,353	0	0
16.00	13,353	13,353	13,353

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=6.66 cfs @ 12.21 hrs HW=15.87' (Free Discharge)
1=Orifice/Grate (Orifice Controls 0.88 cfs @ 4.48 fps)
2=Orifice/Grate (Weir Controls 5.78 cfs @ 1.98 fps)

Pond GI-4: Green Infrastructure



Summary for Pond GI-5: Green Infrastructure

[81] Warning: Exceeded Pond BYP5 by 0.16' @ 24.20 hrs

Inflow Area = 178,043 sf, 31.71% Impervious, Inflow Depth = 2.99" for 100 year - current event
Inflow = 2.97 cfs @ 12.13 hrs, Volume= 44,307 cf
Outflow = 2.37 cfs @ 12.19 hrs, Volume= 44,307 cf, Atten= 20%, Lag= 3.7 min
Primary = 2.37 cfs @ 12.19 hrs, Volume= 44,307 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.66' @ 12.19 hrs Surf.Area= 5,881 sf Storage= 3,857 cf

Plug-Flow detention time= 58.0 min calculated for 44,277 cf (100% of inflow)
Center-of-Mass det. time= 58.4 min (915.8 - 857.4)

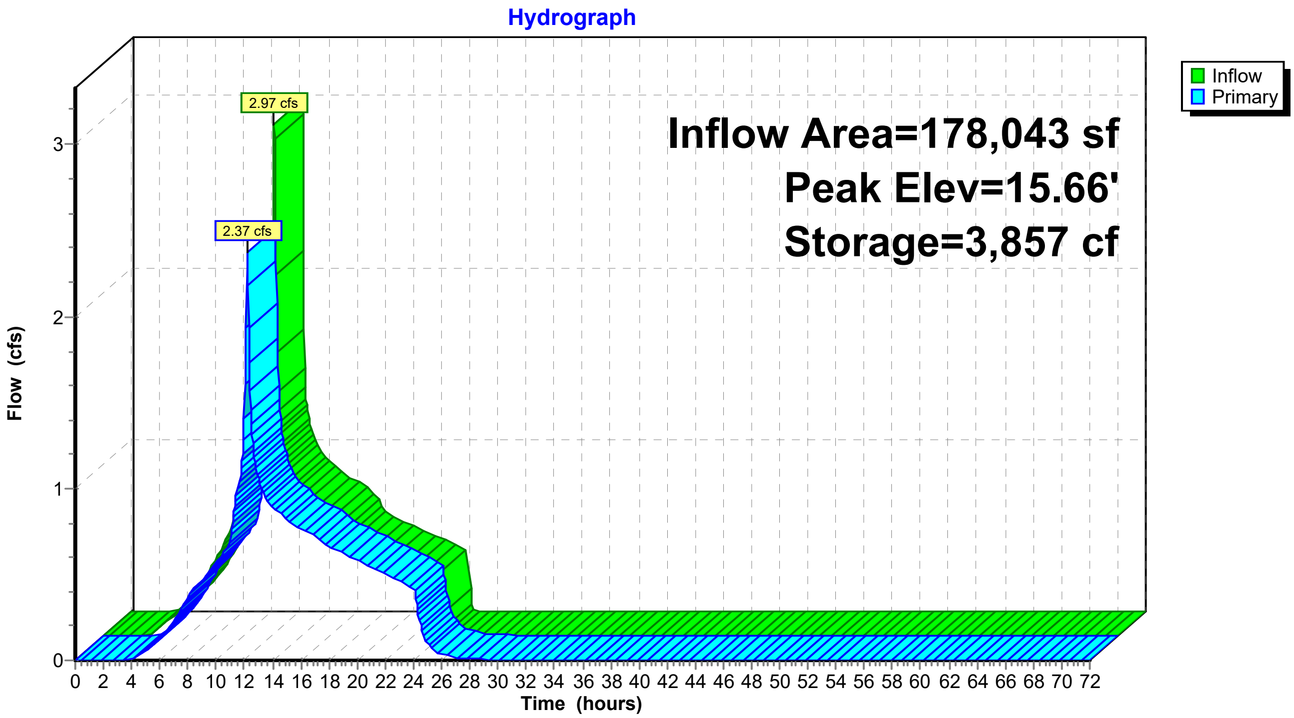
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	5,881 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	5,881	0	0
16.00	5,881	5,881	5,881

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=2.35 cfs @ 12.19 hrs HW=15.65' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.76 cfs @ 3.90 fps)
└─**2=Orifice/Grate** (Weir Controls 1.59 cfs @ 1.28 fps)

Pond GI-5: Green Infrastructure



Summary for Pond GI-6: Green Infrastructure

[81] Warning: Exceeded Pond BYP6 by 0.48' @ 24.20 hrs

Inflow Area = 354,554 sf, 29.27% Impervious, Inflow Depth = 3.87" for 100 year - current event
Inflow = 6.70 cfs @ 12.13 hrs, Volume= 114,467 cf
Outflow = 6.05 cfs @ 12.20 hrs, Volume= 114,467 cf, Atten= 10%, Lag= 4.5 min
Primary = 6.05 cfs @ 12.20 hrs, Volume= 114,467 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.84' @ 12.20 hrs Surf.Area= 10,809 sf Storage= 9,078 cf

Plug-Flow detention time= 62.9 min calculated for 114,467 cf (100% of inflow)
Center-of-Mass det. time= 62.4 min (899.4 - 836.9)

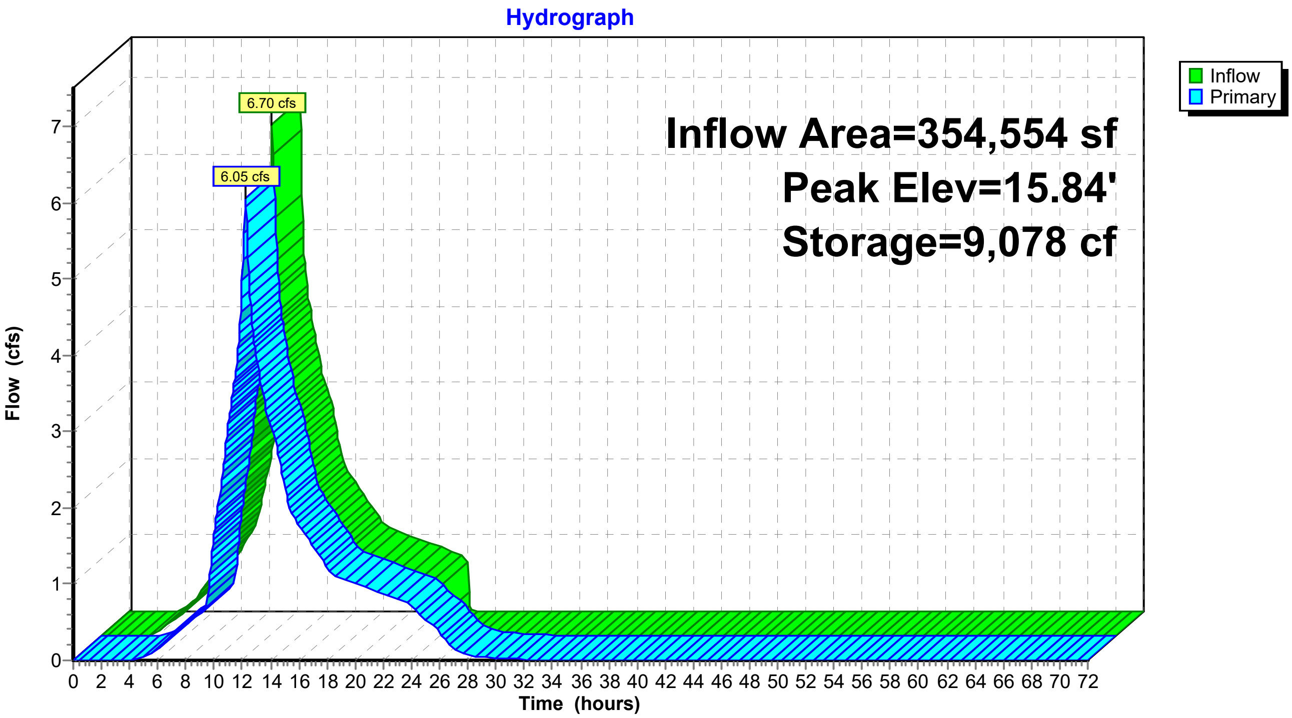
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	10,809 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	10,809	0	0
16.00	10,809	10,809	10,809

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=6.05 cfs @ 12.20 hrs HW=15.84' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.87 cfs @ 4.41 fps)
└─**2=Orifice/Grate** (Weir Controls 5.18 cfs @ 1.91 fps)

Pond GI-6: Green Infrastructure



Summary for Pond GI-7A: Green Infrastructure

[81] Warning: Exceeded Pond BYP7A by 0.35' @ 15.15 hrs

Inflow Area = 154,470 sf, 45.37% Impervious, Inflow Depth = 4.97" for 100 year - current event
Inflow = 5.65 cfs @ 12.13 hrs, Volume= 63,912 cf
Outflow = 5.18 cfs @ 12.19 hrs, Volume= 63,912 cf, Atten= 8%, Lag= 3.6 min
Primary = 5.18 cfs @ 12.19 hrs, Volume= 63,912 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.80' @ 12.19 hrs Surf.Area= 7,300 sf Storage= 5,852 cf

Plug-Flow detention time= 51.2 min calculated for 63,868 cf (100% of inflow)
Center-of-Mass det. time= 51.7 min (858.0 - 806.3)

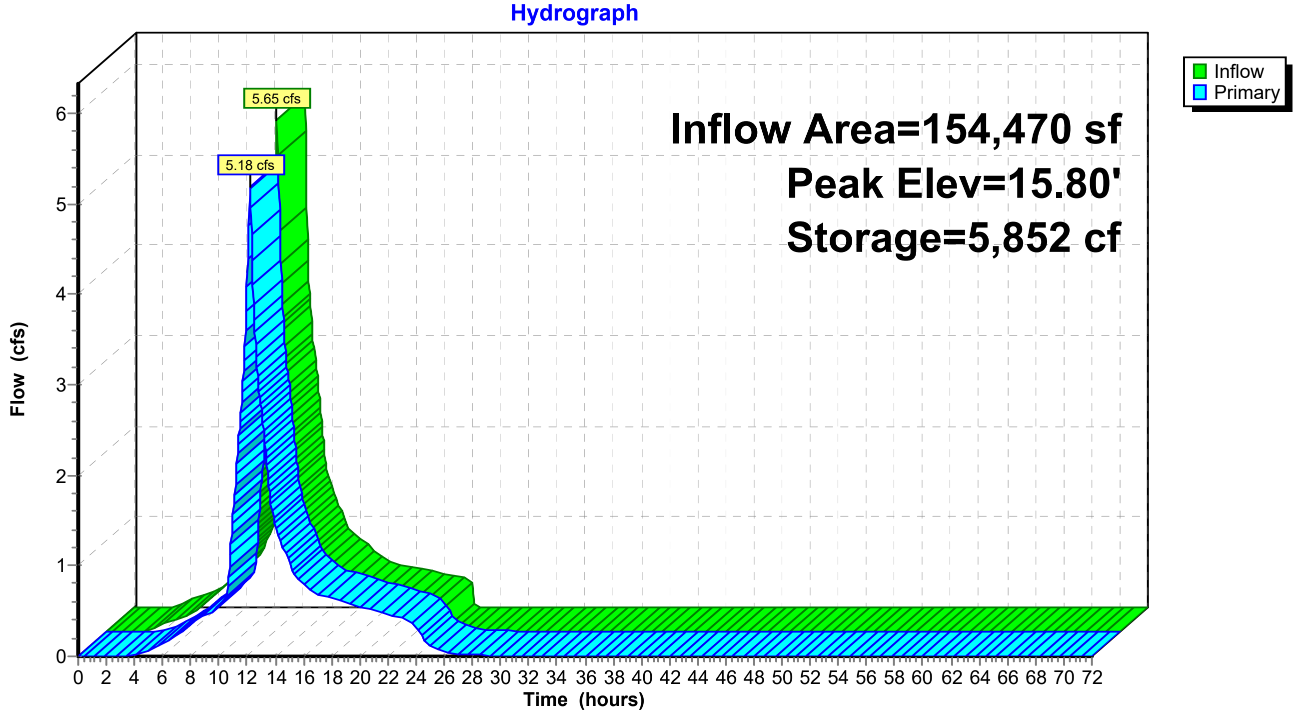
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	7,300 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	7,300	0	0
16.00	7,300	7,300	7,300

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=5.15 cfs @ 12.19 hrs HW=15.80' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.85 cfs @ 4.31 fps)
└─**2=Orifice/Grate** (Weir Controls 4.31 cfs @ 1.79 fps)

Pond GI-7A: Green Infrastructure



Summary for Pond GI-7B: Green Infrastructure

[81] Warning: Exceeded Pond BYP7B by 0.42' @ 24.20 hrs

Inflow Area = 292,806 sf, 20.13% Impervious, Inflow Depth = 3.94" for 100 year - current event
Inflow = 6.35 cfs @ 12.13 hrs, Volume= 96,191 cf
Outflow = 5.96 cfs @ 12.18 hrs, Volume= 96,191 cf, Atten= 6%, Lag= 3.0 min
Primary = 5.96 cfs @ 12.18 hrs, Volume= 96,191 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.84' @ 12.18 hrs Surf.Area= 6,140 sf Storage= 5,133 cf

Plug-Flow detention time= 38.2 min calculated for 96,124 cf (100% of inflow)
Center-of-Mass det. time= 38.5 min (876.2 - 837.7)

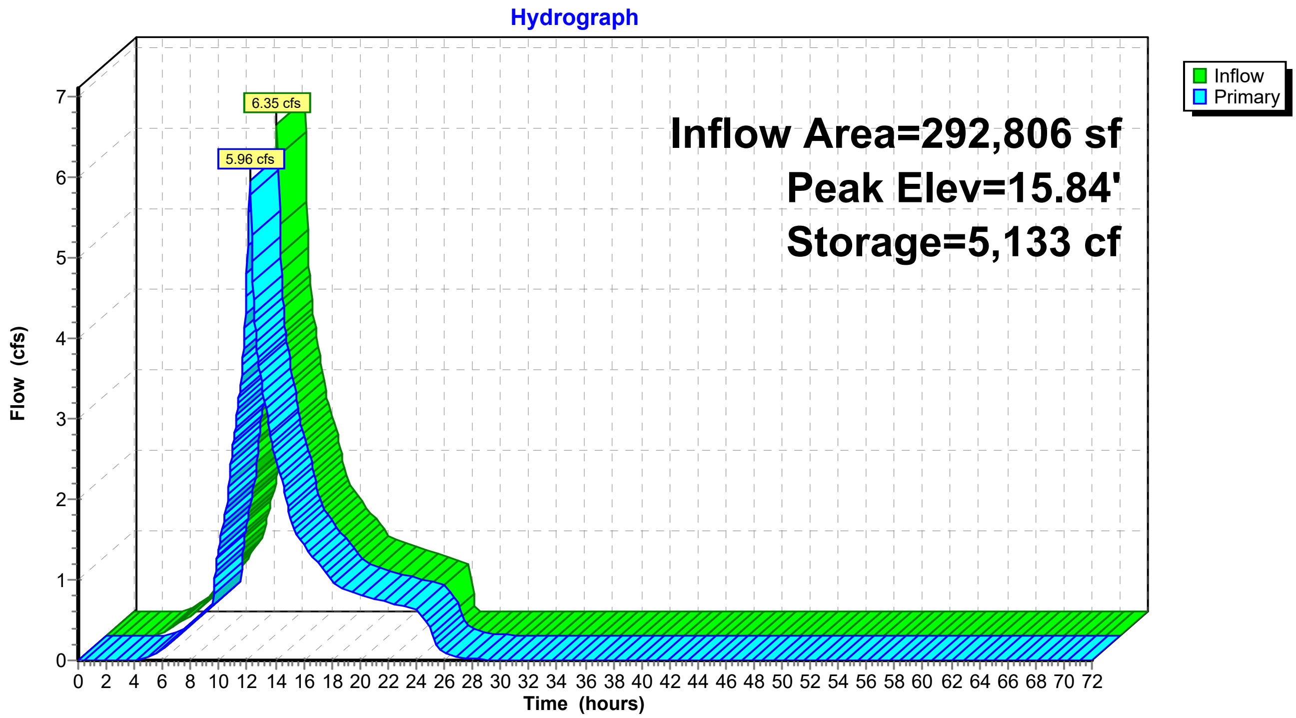
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	12,280 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	6,140	0	0
16.00	6,140	6,140	6,140
17.00	6,140	6,140	12,280

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=5.92 cfs @ 12.18 hrs HW=15.83' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.86 cfs @ 4.40 fps)
└─**2=Orifice/Grate** (Weir Controls 5.06 cfs @ 1.89 fps)

Pond GI-7B: Green Infrastructure



Summary for Pond GI-8A: Green Infrastructure

[81] Warning: Exceeded Pond BYP8A by 0.08' @ 12.40 hrs

Inflow Area = 26,649 sf, 12.91% Impervious, Inflow Depth = 4.37" for 100 year - current event
Inflow = 0.91 cfs @ 12.13 hrs, Volume= 9,709 cf
Outflow = 0.90 cfs @ 12.13 hrs, Volume= 9,709 cf, Atten= 1%, Lag= 0.1 min
Primary = 0.90 cfs @ 12.13 hrs, Volume= 9,709 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.54' @ 12.13 hrs Surf.Area= 358 sf Storage= 193 cf

Plug-Flow detention time= 3.9 min calculated for 9,702 cf (100% of inflow)
Center-of-Mass det. time= 3.9 min (835.0 - 831.1)

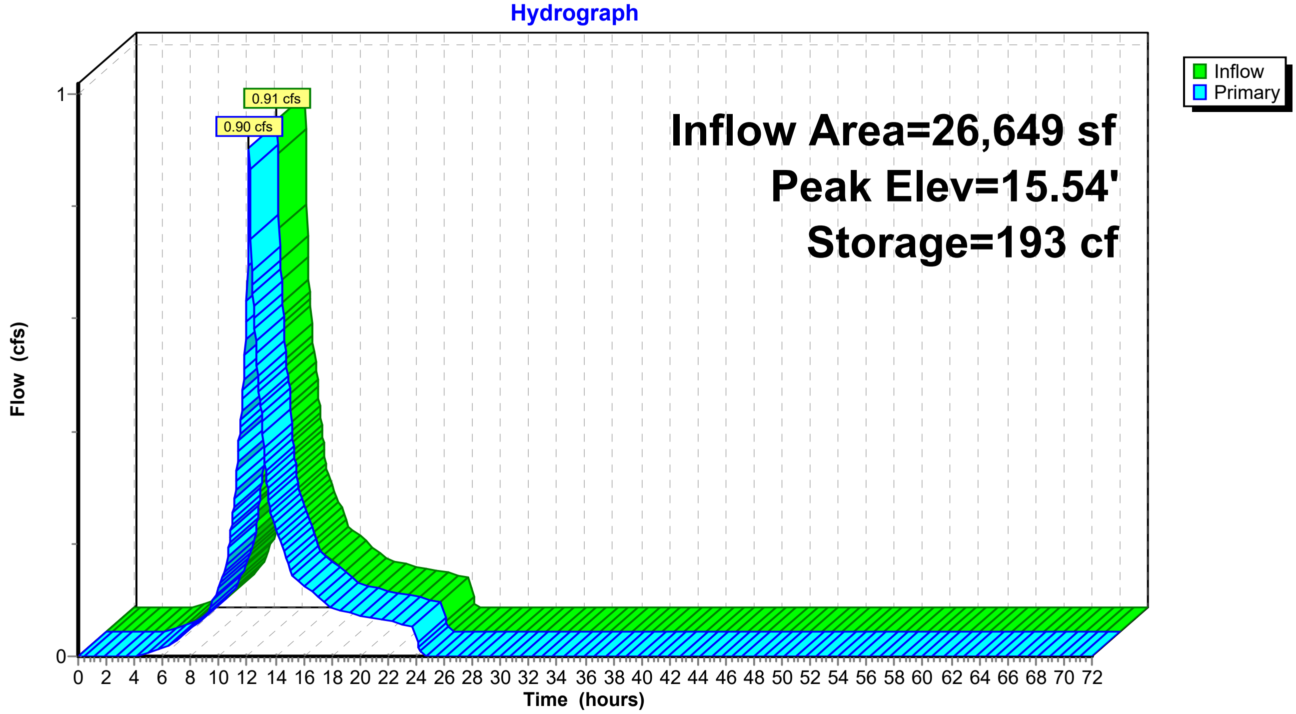
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	358 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	358	0	0
16.00	358	358	358

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.89 cfs @ 12.13 hrs HW=15.54' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.69 cfs @ 3.53 fps)
└─**2=Orifice/Grate** (Weir Controls 0.20 cfs @ 0.64 fps)

Pond GI-8A: Green Infrastructure



Summary for Pond GI-8B: Green Infrastructure

[81] Warning: Exceeded Pond BYP8B by 0.13' @ 12.40 hrs

Inflow Area =	21,545 sf,	24.73% Impervious,	Inflow Depth = 4.74"	for 100 year - current event
Inflow =	0.86 cfs @	12.13 hrs, Volume=	8,509 cf	
Outflow =	0.77 cfs @	12.21 hrs, Volume=	8,509 cf,	Atten= 11%, Lag= 4.8 min
Primary =	0.77 cfs @	12.21 hrs, Volume=	8,509 cf	

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.55' @ 12.21 hrs Surf.Area= 555 sf Storage= 304 cf

Plug-Flow detention time= 6.3 min calculated for 8,503 cf (100% of inflow)
Center-of-Mass det. time= 6.3 min (826.2 - 819.9)

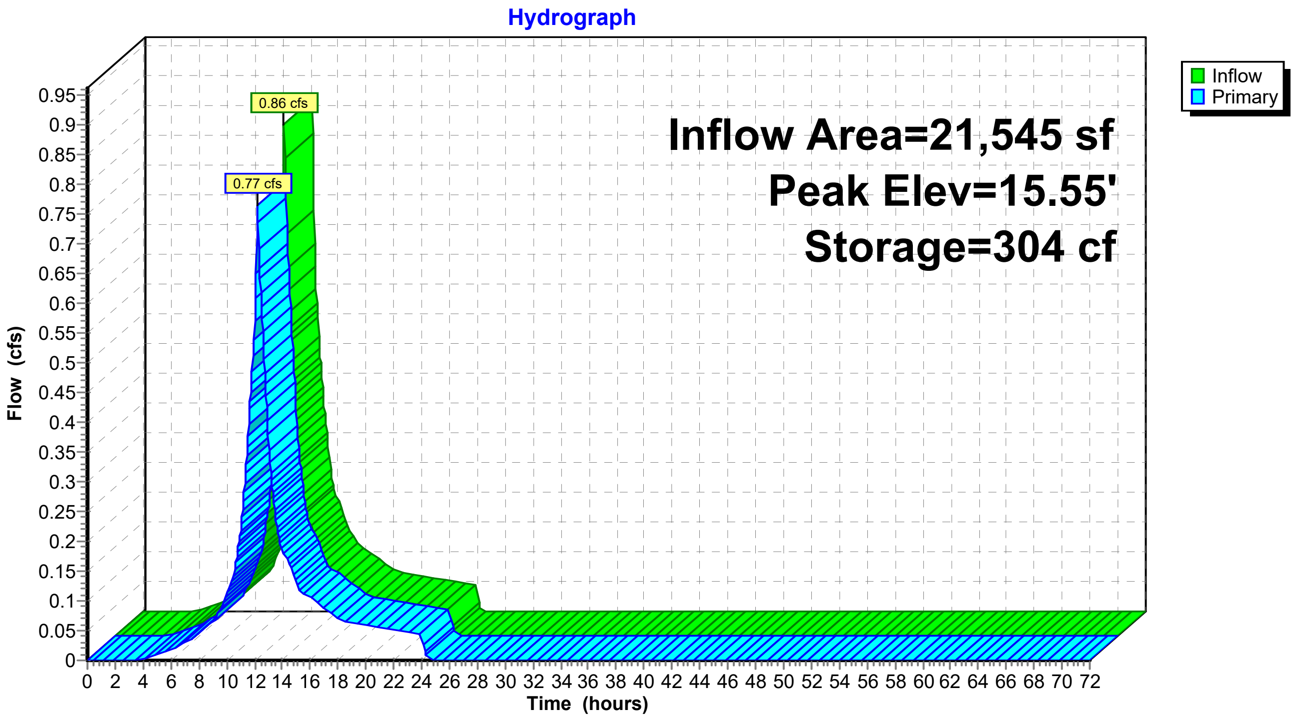
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	555 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	555	0	0
16.00	555	555	555

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" W x 24.0" H Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.76 cfs @ 12.21 hrs HW=15.54' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.70 cfs @ 3.55 fps)
└─**2=Orifice/Grate** (Orifice Controls 0.06 cfs @ 0.68 fps)

Pond GI-8B: Green Infrastructure



Summary for Pond GI-8C: Green Infrastructure

[81] Warning: Exceeded Pond BYP8C by 0.12' @ 12.35 hrs

Inflow Area = 15,823 sf, 23.97% Impervious, Inflow Depth = 5.03" for 100 year - current event
Inflow = 0.78 cfs @ 12.13 hrs, Volume= 6,633 cf
Outflow = 0.71 cfs @ 12.20 hrs, Volume= 6,633 cf, Atten= 9%, Lag= 4.4 min
Primary = 0.71 cfs @ 12.20 hrs, Volume= 6,633 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.51' @ 12.20 hrs Surf.Area= 395 sf Storage= 202 cf

Plug-Flow detention time= 4.7 min calculated for 6,629 cf (100% of inflow)
Center-of-Mass det. time= 4.7 min (819.4 - 814.7)

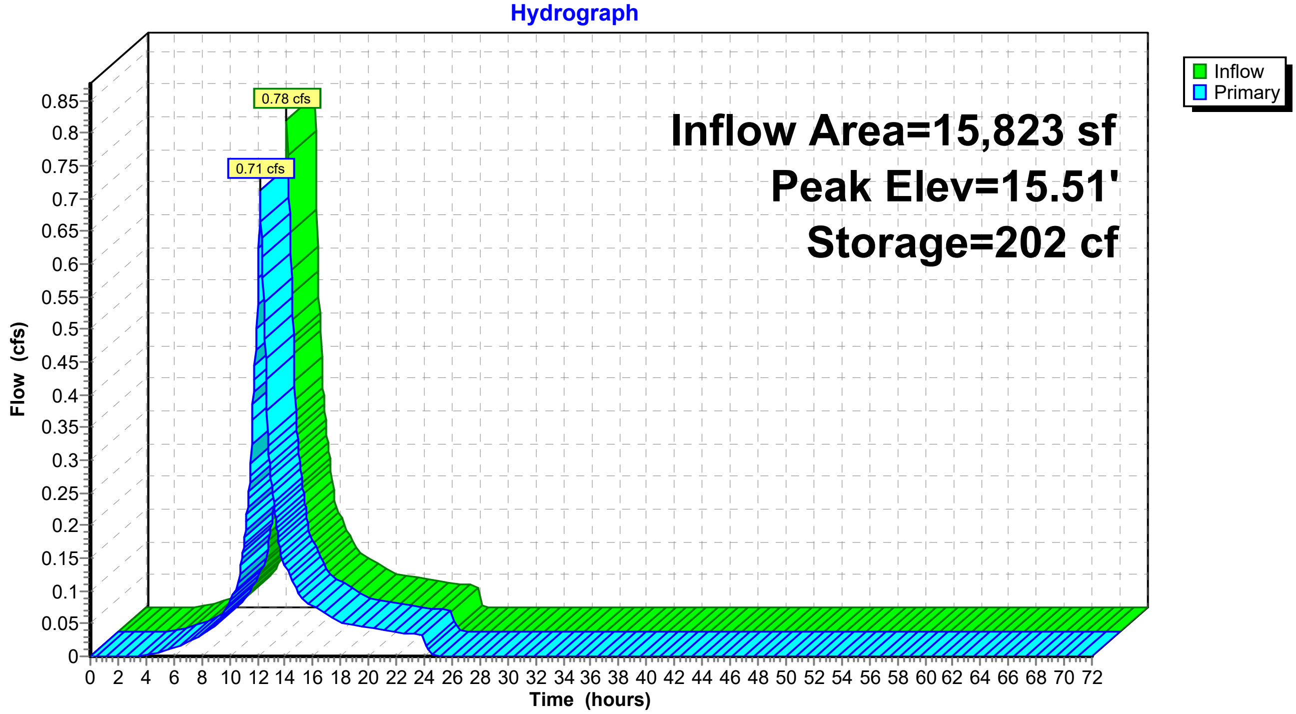
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	395 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	395	0	0
16.00	395	395	395

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.71 cfs @ 12.20 hrs HW=15.51' (Free Discharge)
1=Orifice/Grate (Orifice Controls 0.68 cfs @ 3.45 fps)
2=Orifice/Grate (Weir Controls 0.03 cfs @ 0.36 fps)

Pond GI-8C: Green Infrastructure



Summary for Pond GI-8D: Green Infrastructure

[81] Warning: Exceeded Pond BYP8D by 0.11' @ 12.70 hrs

Inflow Area = 34,949 sf, 27.15% Impervious, Inflow Depth = 4.43" for 100 year - current event
Inflow = 1.02 cfs @ 12.13 hrs, Volume= 12,892 cf
Outflow = 0.94 cfs @ 12.19 hrs, Volume= 12,892 cf, Atten= 8%, Lag= 4.0 min
Primary = 0.94 cfs @ 12.19 hrs, Volume= 12,892 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.58' @ 12.19 hrs Surf.Area= 988 sf Storage= 570 cf

Plug-Flow detention time= 10.5 min calculated for 12,883 cf (100% of inflow)
Center-of-Mass det. time= 10.6 min (834.6 - 824.1)

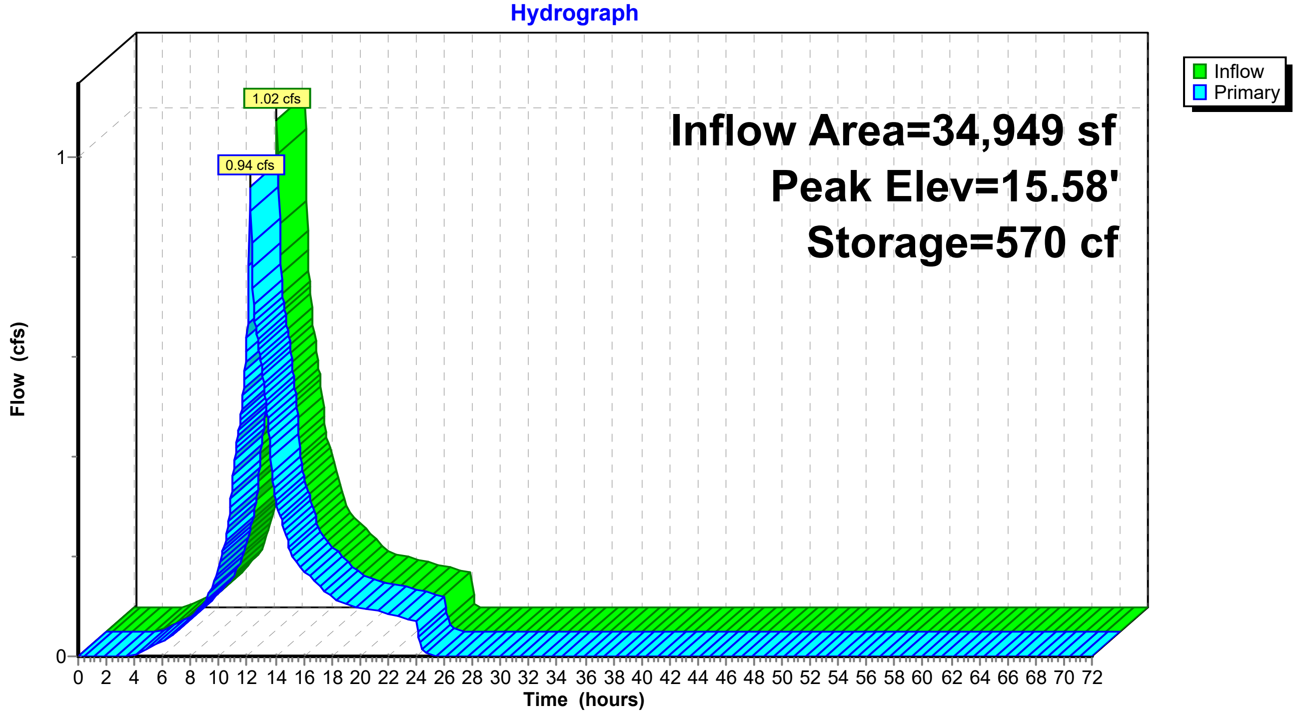
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	988 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	988	0	0
16.00	988	988	988

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.93 cfs @ 12.19 hrs HW=15.58' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.72 cfs @ 3.66 fps)
└─**2=Orifice/Grate** (Weir Controls 0.22 cfs @ 0.90 fps)

Pond GI-8D: Green Infrastructure



Summary for Pond GI-8E: Green Infrastructure

[81] Warning: Exceeded Pond BYP8E by 0.09' @ 13.60 hrs

Inflow Area = 66,286 sf, 18.42% Impervious, Inflow Depth = 3.62" for 100 year - current event
Inflow = 1.18 cfs @ 12.13 hrs, Volume= 19,992 cf
Outflow = 1.08 cfs @ 12.19 hrs, Volume= 19,992 cf, Atten= 8%, Lag= 3.8 min
Primary = 1.08 cfs @ 12.19 hrs, Volume= 19,992 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.64' @ 12.19 hrs Surf.Area= 1,272 sf Storage= 811 cf

Plug-Flow detention time= 12.9 min calculated for 19,978 cf (100% of inflow)
Center-of-Mass det. time= 12.9 min (861.8 - 848.8)

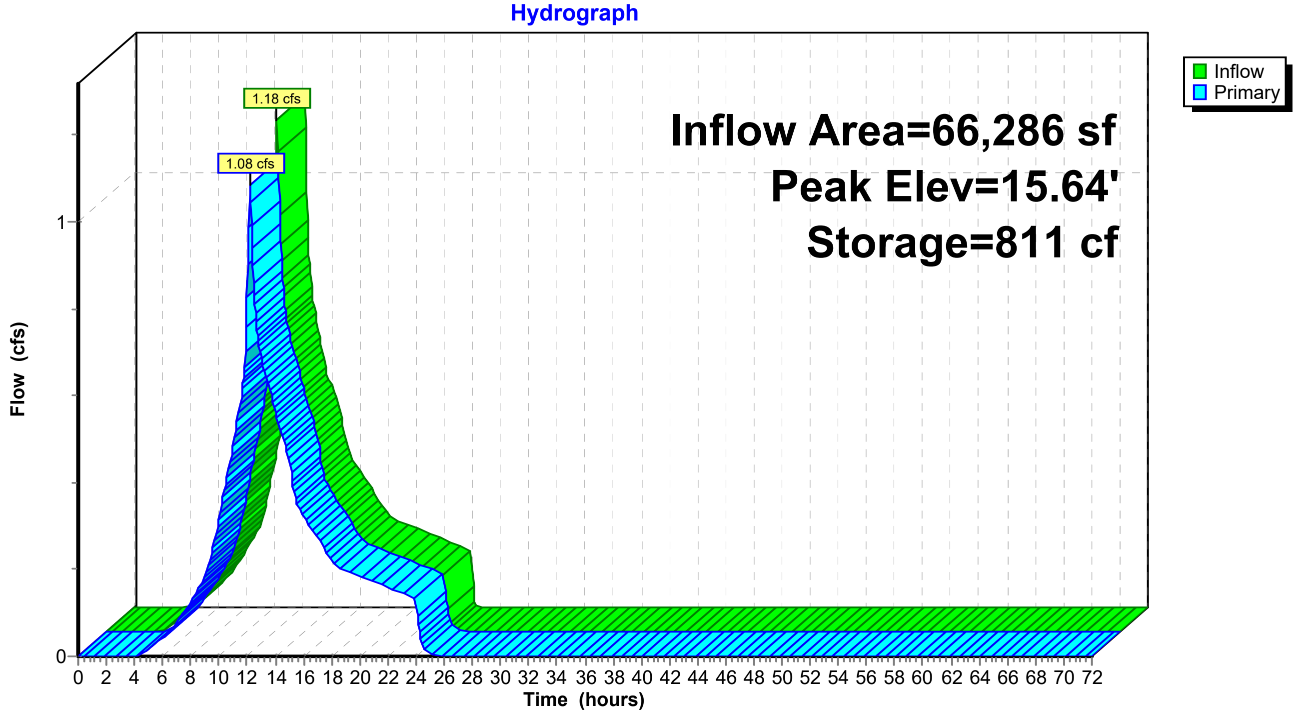
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	1,272 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	1,272	0	0
16.00	1,272	1,272	1,272

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" W x 24.0" H Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=1.08 cfs @ 12.19 hrs HW=15.64' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.75 cfs @ 3.84 fps)
└─**2=Orifice/Grate** (Orifice Controls 0.32 cfs @ 1.19 fps)

Pond GI-8E: Green Infrastructure



Summary for Pond GI-9A: Green Infrastructure

[81] Warning: Exceeded Pond BYP9A by 0.04' @ 12.60 hrs

Inflow Area = 37,664 sf, 5.01% Impervious, Inflow Depth = 3.95" for 100 year - current event
Inflow = 1.01 cfs @ 12.13 hrs, Volume= 12,404 cf
Outflow = 1.00 cfs @ 12.13 hrs, Volume= 12,405 cf, Atten= 1%, Lag= 0.2 min
Primary = 1.00 cfs @ 12.13 hrs, Volume= 12,405 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 15.55' @ 12.13 hrs Surf.Area= 196 sf Storage= 108 cf

Plug-Flow detention time= 2.0 min calculated for 12,396 cf (100% of inflow)
Center-of-Mass det. time= 2.0 min (845.0 - 843.0)

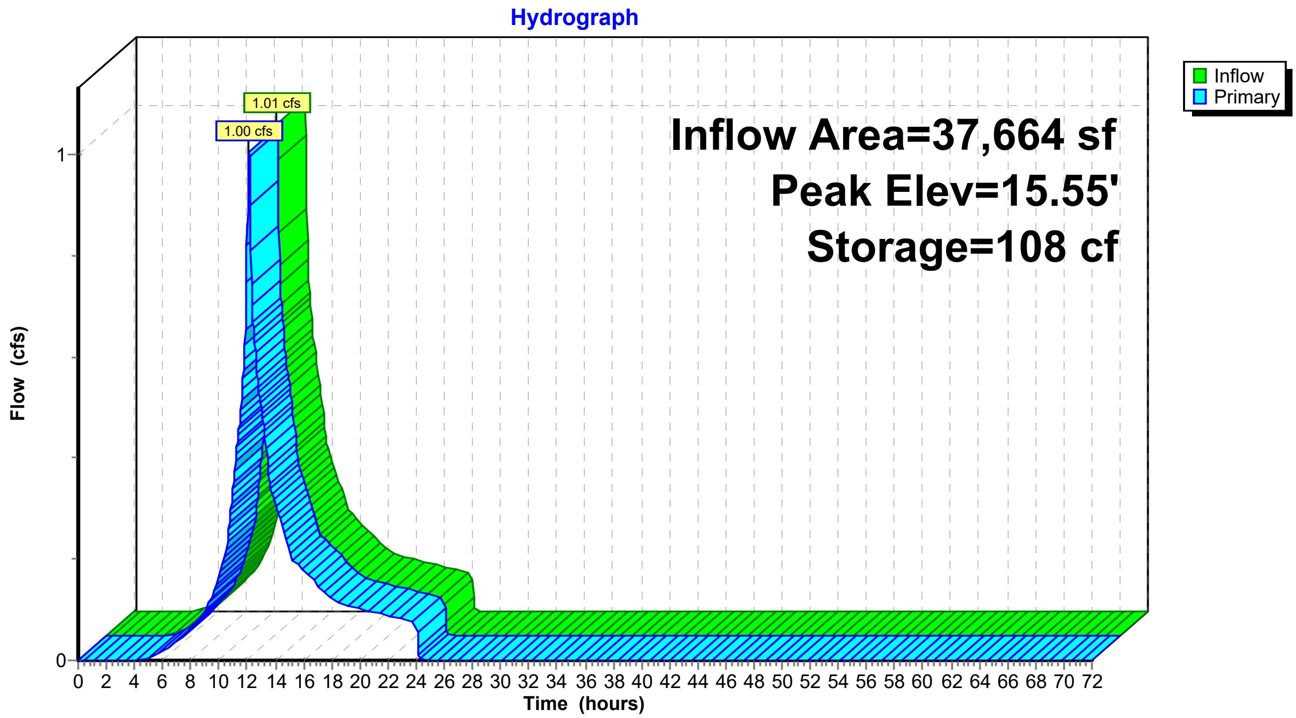
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	196 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	196	0	0
16.00	196	196	196

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.99 cfs @ 12.13 hrs HW=15.55' (Free Discharge)
└**1=Orifice/Grate** (Orifice Controls 0.70 cfs @ 3.57 fps)
└**2=Orifice/Grate** (Weir Controls 0.29 cfs @ 0.73 fps)

Pond GI-9A: Green Infrastructure



Summary for Pond GI-9B: Green Infrastructure

[81] Warning: Exceeded Pond BYP9B by 0.09' @ 12.65 hrs

Inflow Area = 30,173 sf, 18.18% Impervious, Inflow Depth = 4.43" for 100 year - current event
Inflow = 0.97 cfs @ 12.13 hrs, Volume= 11,140 cf
Outflow = 0.96 cfs @ 12.14 hrs, Volume= 11,140 cf, Atten= 1%, Lag= 0.9 min
Primary = 0.96 cfs @ 12.14 hrs, Volume= 11,140 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.55' @ 12.14 hrs Surf.Area= 571 sf Storage= 312 cf

Plug-Flow detention time= 6.3 min calculated for 11,140 cf (100% of inflow)
Center-of-Mass det. time= 6.2 min (834.4 - 828.2)

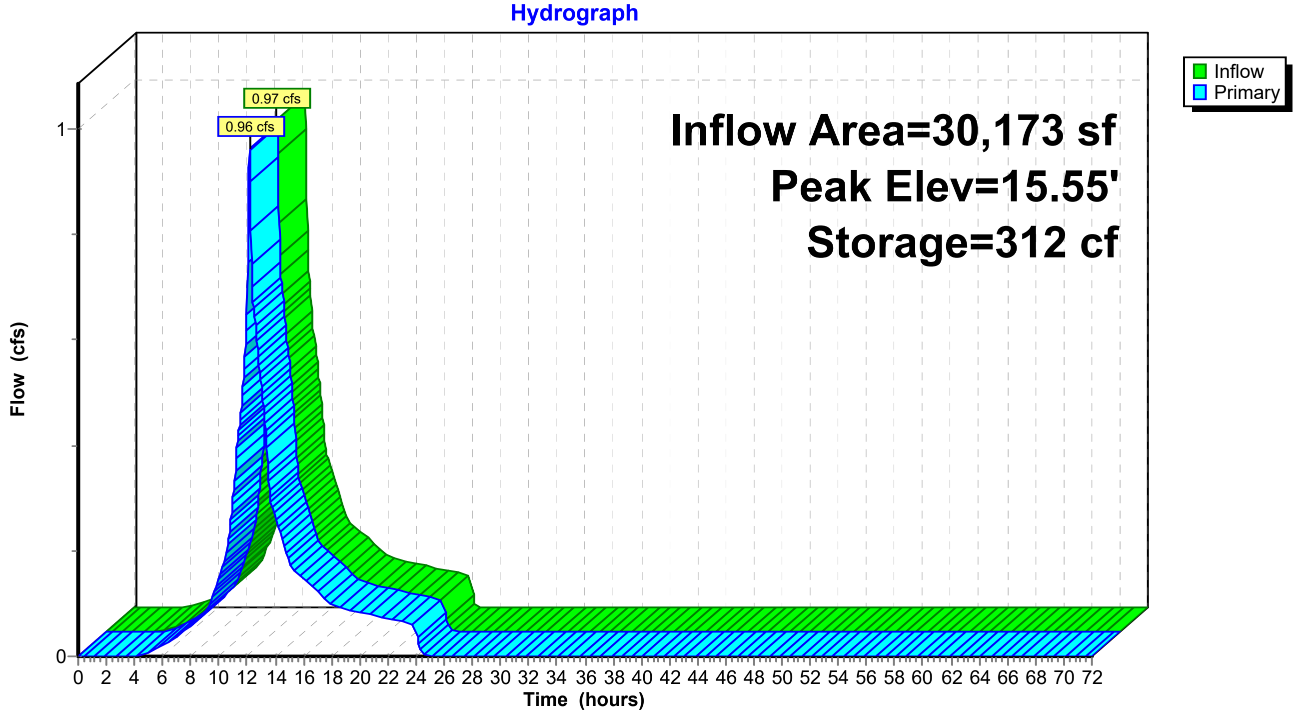
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	571 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	571	0	0
16.00	571	571	571

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.96 cfs @ 12.14 hrs HW=15.55' (Free Discharge)
1=Orifice/Grate (Orifice Controls 0.70 cfs @ 3.56 fps)
2=Orifice/Grate (Weir Controls 0.26 cfs @ 0.70 fps)

Pond GI-9B: Green Infrastructure



Summary for Pond UG-1: North Baseball Field

Inflow Area = 249,220 sf, 8.70% Impervious, Inflow Depth = 5.95" for 100 year - current event
Inflow = 36.98 cfs @ 12.13 hrs, Volume= 123,473 cf
Outflow = 3.16 cfs @ 13.33 hrs, Volume= 122,784 cf, Atten= 91%, Lag= 72.3 min
Primary = 3.16 cfs @ 13.33 hrs, Volume= 122,784 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.70' @ 13.33 hrs Surf.Area= 126,247 sf Storage= 65,522 cf

Plug-Flow detention time= 347.5 min calculated for 122,698 cf (99% of inflow)
Center-of-Mass det. time= 345.6 min (1,159.5 - 813.9)

Volume	Invert	Avail.Storage	Storage Description
#1A	11.00'	46,200 cf	**248.17'W x 508.72'L x 1.83'H Field A** 231,453 cf Overall - 77,454 cf Embedded = 153,999 cf x 30.0% Voids
#2A	11.00'	77,454 cf	**ADS_StormTech SC-310 +Cap** x 5254 Inside #1 Effective Size= 28.9"W x 16.0"H => 2.07 sf x 7.12'L = 14.7 cf Overall Size= 34.0"W x 16.0"H x 7.56'L with 0.44' Overlap 74 Rows of 71 Chambers
		123,654 cf	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	12.50'	**5.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=3.16 cfs @ 13.33 hrs HW=11.70' (Free Discharge)
—**1=Orifice/Grate** (Orifice Controls 3.16 cfs @ 4.02 fps)
—**2=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond UG-1: North Baseball Field - Chamber Wizard Field A

Chamber Model = ADS_StormTechSC-310 +Cap (ADS StormTech®SC-310 with cap length)
Effective Size= 28.9"W x 16.0"H => 2.07 sf x 7.12'L = 14.7 cf
Overall Size= 34.0"W x 16.0"H x 7.56'L with 0.44' Overlap

34.0" Wide + 6.0" Spacing = 40.0" C-C Row Spacing

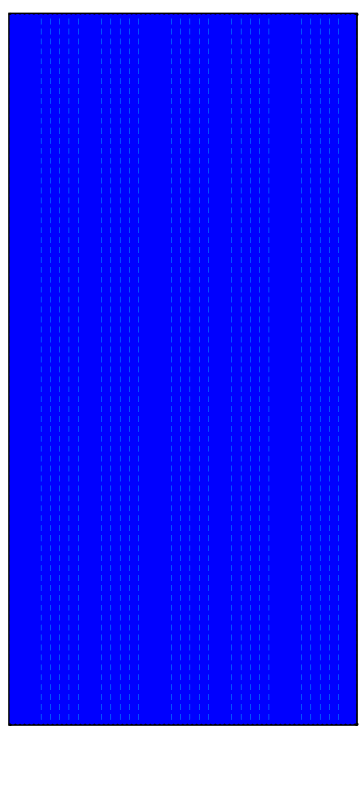
71 Chambers/Row x 7.12' Long +0.60' Cap Length x 2 = 506.72' Row Length +12.0" End Stone x 2 = 508.72' Base Length
74 Rows x 34.0" Wide + 6.0" Spacing x 73 + 12.0" Side Stone x 2 = 248.17' Base Width
16.0" Chamber Height + 6.0" Cover = 1.83' Field Height

5,254 Chambers x 14.7 cf = 77,454.3 cf Chamber Storage

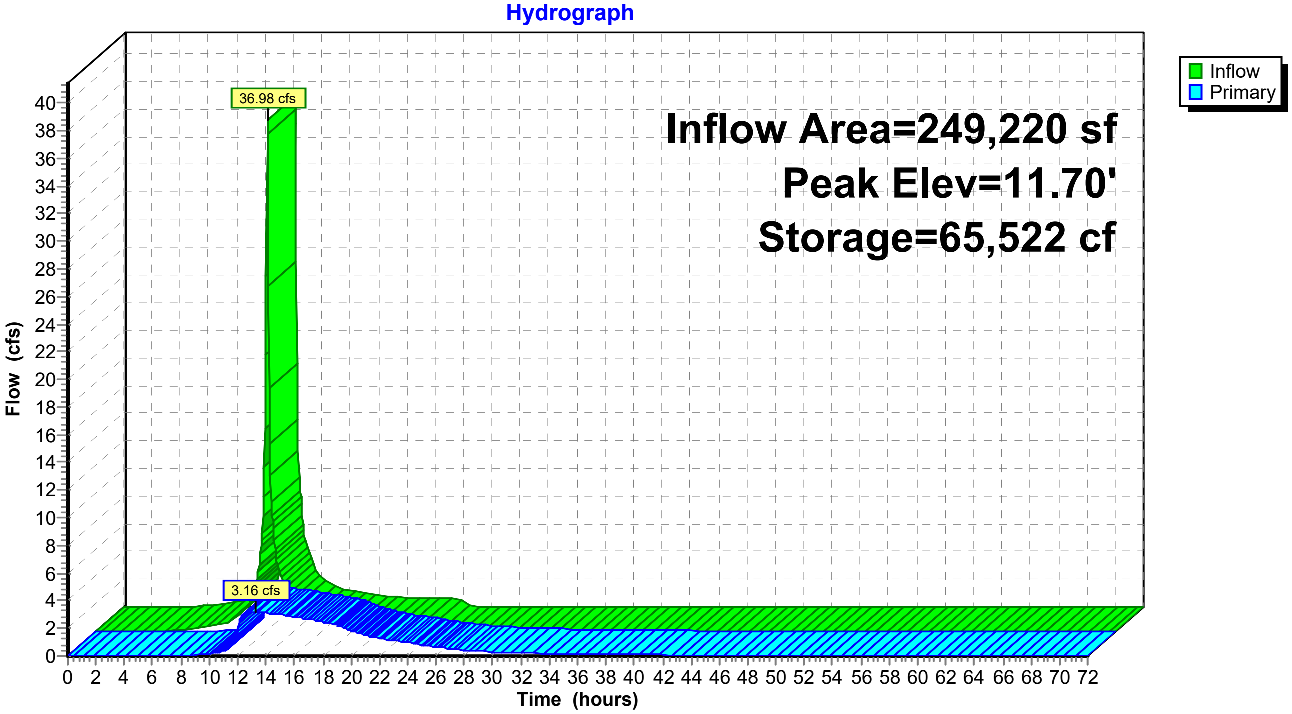
231,453.5 cf Field - 77,454.3 cf Chambers = 153,999.2 cf Stone x 30.0% Voids = 46,199.8 cf Stone Storage

Chamber Storage + Stone Storage = 123,654.0 cf = 2.839 af
Overall Storage Efficiency = 53.4%
Overall System Size = 508.72' x 248.17' x 1.83'

5,254 Chambers
8,572.4 cy Field
5,703.7 cy Stone



Pond UG-1: North Baseball Field



Summary for Pond UG-2: Central Soccer Field

Inflow Area = 404,841 sf, 31.43% Impervious, Inflow Depth = 6.42" for 100 year - current event
Inflow = 62.67 cfs @ 12.13 hrs, Volume= 216,544 cf
Outflow = 4.22 cfs @ 13.64 hrs, Volume= 215,884 cf, Atten= 93%, Lag= 90.7 min
Primary = 4.22 cfs @ 13.64 hrs, Volume= 215,884 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 10.24' @ 13.64 hrs Surf.Area= 118,120 sf Storage= 116,809 cf

Plug-Flow detention time= 393.6 min calculated for 215,734 cf (100% of inflow)
Center-of-Mass det. time= 391.4 min (1,227.1 - 835.7)

Volume	Invert	Avail.Storage	Storage Description
#1A	9.00'	58,829 cf	**253.25'W x 466.42'L x 3.00'H Field A** 354,360 cf Overall - 158,263 cf Embedded = 196,097 cf x 30.0% Voids
#2A	9.00'	158,263 cf	**ADS_StormTech SC-740 +Cap** x 3445 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 53 Rows of 65 Chambers
		217,092 cf	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Primary	9.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	10.50'	**5.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=4.22 cfs @ 13.64 hrs HW=10.24' (Free Discharge)
—**1=Orifice/Grate** (Orifice Controls 4.22 cfs @ 5.37 fps)
—**2=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond UG-2: Central Soccer Field - Chamber Wizard Field A

Chamber Model = ADS_StormTechSC-740 +Cap (ADS StormTech®SC-740 with cap length)
Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf
Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap

51.0" Wide + 6.0" Spacing = 57.0" C-C Row Spacing

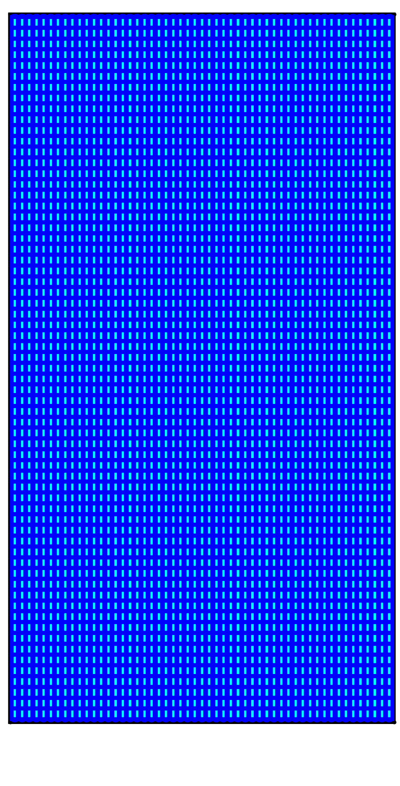
65 Chambers/Row x 7.12' Long +0.81' Cap Length x 2 = 464.42' Row Length +12.0" End Stone x 2 = 466.42' Base Length
53 Rows x 51.0" Wide + 6.0" Spacing x 52 + 12.0" Side Stone x 2 = 253.25' Base Width
30.0" Chamber Height + 6.0" Cover = 3.00' Field Height

3,445 Chambers x 45.9 cf = 158,263.4 cf Chamber Storage

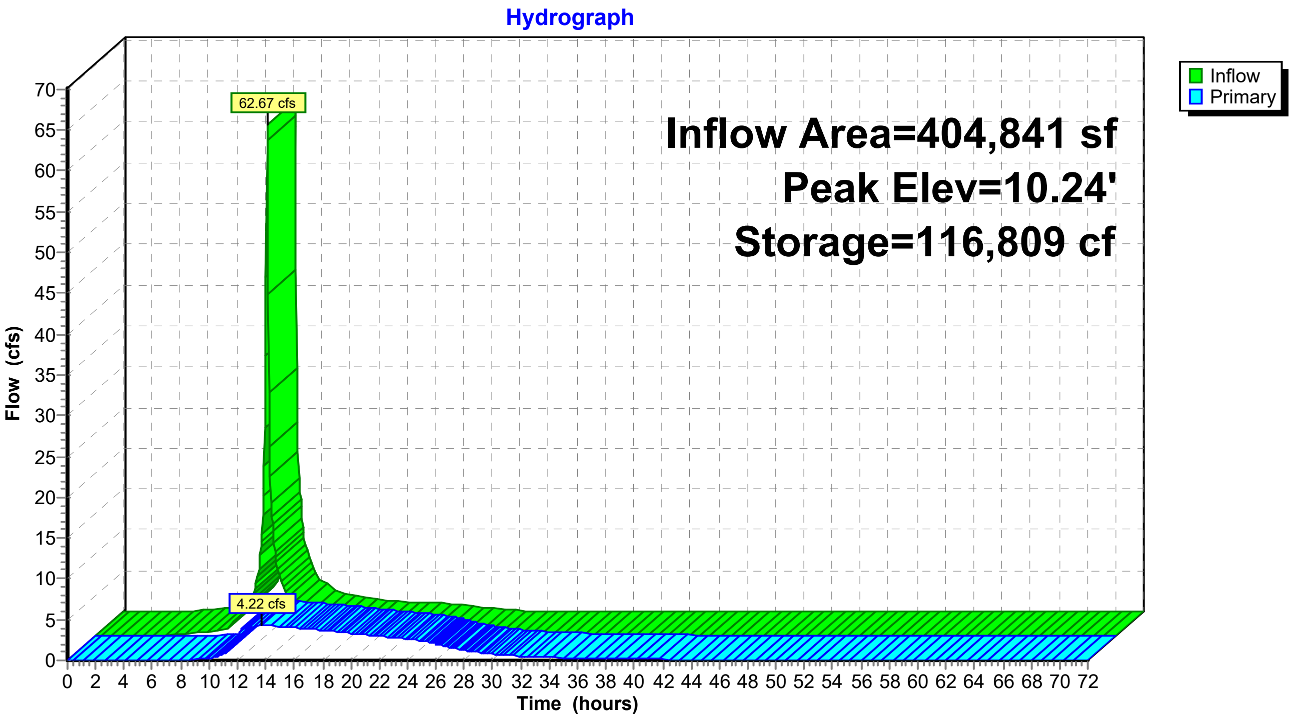
354,360.1 cf Field - 158,263.4 cf Chambers = 196,096.7 cf Stone x 30.0% Voids = 58,829.0 cf Stone Storage

Chamber Storage + Stone Storage = 217,092.4 cf = 4.984 af
Overall Storage Efficiency = 61.3%
Overall System Size = 466.42' x 253.25' x 3.00'

3,445 Chambers
13,124.4 cy Field
7,262.8 cy Stone



Pond UG-2: Central Soccer Field



Summary for Pond UG-3: Central LL System (Maximized)

Inflow Area = 1,117,522 sf, 30.42% Impervious, Inflow Depth = 6.34" for 100 year - current event
Inflow = 170.39 cfs @ 12.13 hrs, Volume= 590,879 cf
Outflow = 18.05 cfs @ 13.11 hrs, Volume= 590,836 cf, Atten= 89%, Lag= 59.0 min
Primary = 18.05 cfs @ 13.11 hrs, Volume= 590,836 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 10.34' @ 13.11 hrs Surf.Area= 188,580 sf Storage= 291,586 cf

Plug-Flow detention time= 379.2 min calculated for 590,836 cf (100% of inflow)
Center-of-Mass det. time= 379.1 min (1,207.8 - 828.7)

Volume	Invert	Avail.Storage	Storage Description
#1A	8.00'	191,361 cf	**338.08'W x 557.79'L x 5.50'H Field A** 1,037,187 cf Overall - 399,317 cf Embedded = 637,871 cf x 30.0% Voids
#2A	8.75'	399,317 cf	**ADS_StormTech MC-3500 d +Cap** x 3619 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 47 Rows of 77 Chambers Cap Storage= +14.9 cf x 2 x 47 rows = 1,400.6 cf
		590,678 cf	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Primary	8.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	9.50'	**5.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=18.05 cfs @ 13.11 hrs HW=10.34' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 5.79 cfs @ 7.37 fps)
└─**2=Sharp-Crested Rectangular Weir** (Weir Controls 12.26 cfs @ 3.00 fps)

Pond UG-3: Central LL System (Maximized) - Chamber Wizard Field A

Chamber Model = ADS_StormTechMC-3500 d +Cap (ADS StormTech®MC-3500 d rev 03/14 with Cap volume)
Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf
Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap
Cap Storage= +14.9 cf x 2 x 47 rows = 1,400.6 cf

77.0" Wide + 9.0" Spacing = 86.0" C-C Row Spacing

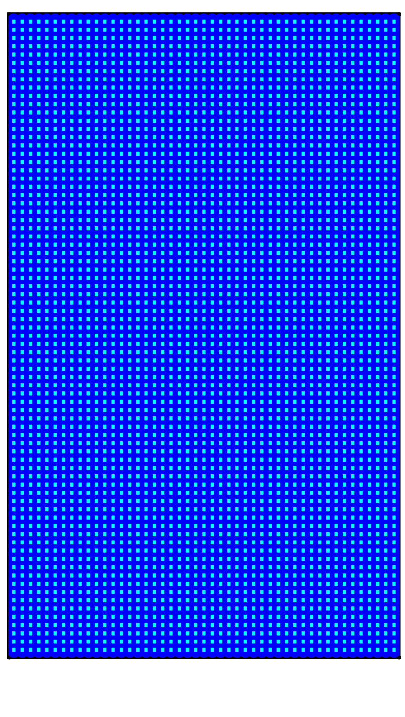
77 Chambers/Row x 7.17' Long +1.85' Cap Length x 2 = 555.79' Row Length +12.0" End Stone x 2 = 557.79' Base Length
47 Rows x 77.0" Wide + 9.0" Spacing x 46 + 12.0" Side Stone x 2 = 338.08' Base Width
9.0" Base + 45.0" Chamber Height + 12.0" Cover = 5.50' Field Height

3,619 Chambers x 110.0 cf + 14.9 cf Cap Volume x 2 x 47 Rows = 399,316.7 cf Chamber Storage

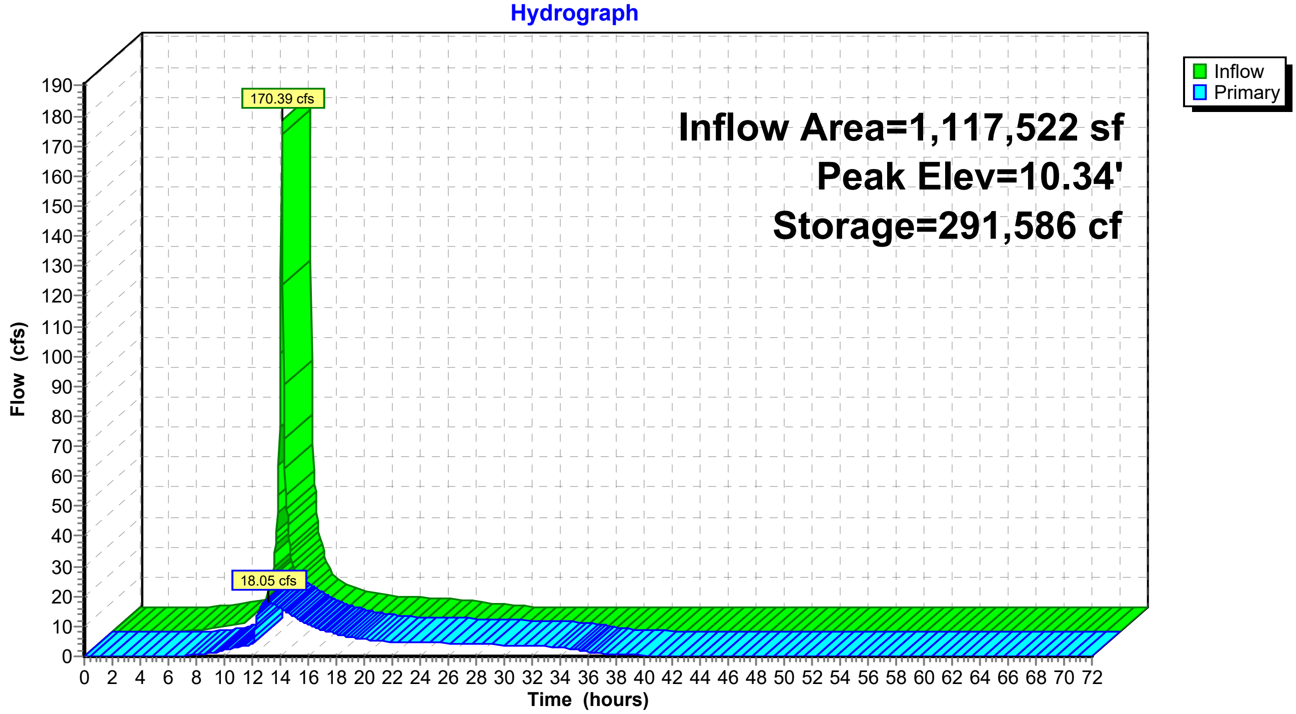
1,037,187.3 cf Field - 399,316.7 cf Chambers = 637,870.6 cf Stone x 30.0% Voids = 191,361.2 cf Stone Storage

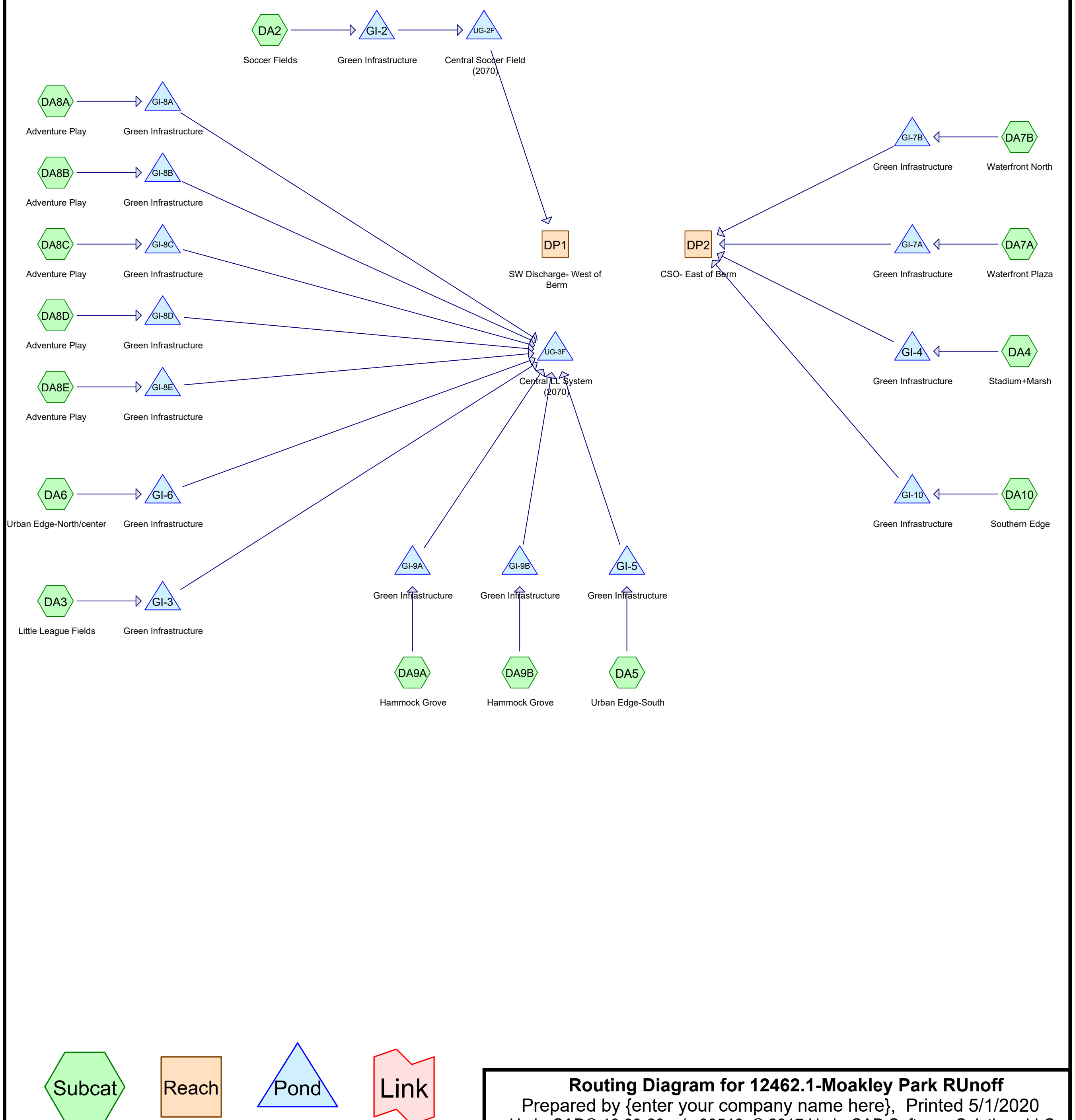
Chamber Storage + Stone Storage = 590,677.9 cf = 13.560 af
Overall Storage Efficiency = 56.9%
Overall System Size = 557.79' x 338.08' x 5.50'

3,619 Chambers
38,414.3 cy Field
23,624.8 cy Stone



Pond UG-3: Central LL System (Maximized)





Routing Diagram for 12462.1-Moakley Park RUnoff
Prepared by {enter your company name here}, Printed 5/1/2020
HydroCAD® 10.00-20 s/n 00546 © 2017 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
213,708	74	>75% Grass cover, Good, HSG C (DA3)
1,430,722	80	>75% Grass cover, Good, HSG D (DA10, DA2, DA4, DA5, DA6, DA7A, DA7B, DA8A, DA8B, DA8C, DA8D, DA8E, DA9A, DA9B)
60,000	98	Turf Field (DA4)
743,980	98	Unconnected pavement, HSG D (DA10, DA2, DA3, DA4, DA5, DA6, DA7A, DA7B, DA8A, DA8B, DA8C, DA8D, DA8E, DA9A, DA9B)
2,448,410	**85**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
0	HSG A	
0	HSG B	
213,708	HSG C	DA3
2,174,702	HSG D	DA10, DA2, DA3, DA4, DA5, DA6, DA7A, DA7B, DA8A, DA8B, DA8C, DA8D, DA8E, DA9A, DA9B
60,000	Other	DA4
2,448,410		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	Su Nu
0	0	213,708	1,430,722	0	1,644,430	>75% Grass cover, Good	
0	0	0	0	60,000	60,000	Turf Field	
0	0	0	743,980	0	743,980	Unconnected pavement	
0	**0**	**213,708**	**2,174,702**	**60,000**	**2,448,410**	**TOTAL AREA**	

Time span=0.00-72.00 hrs, dt=0.05 hrs, 1441 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

SubcatchmentDA10: Southern Edge Runoff Area=89,040 sf 21.95% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=20.46 cfs 69,926 cf

SubcatchmentDA2: Soccer Fields Runoff Area=404,841 sf 31.43% Impervious Runoff Depth=9.95"
Tc=6.0 min CN=86 Runoff=96.03 cfs 335,692 cf

SubcatchmentDA3: Little League Fields Runoff Area=351,836 sf 39.26% Impervious Runoff Depth=9.56"
Tc=6.0 min CN=83 Runoff=81.55 cfs 280,199 cf

SubcatchmentDA4: Stadium+Marsh Runoff Area=389,731 sf 48.29% Impervious Runoff Depth=10.34"
Tc=6.0 min CN=89 Runoff=94.20 cfs 335,729 cf

SubcatchmentDA5: Urban Edge-South Runoff Area=178,043 sf 31.71% Impervious Runoff Depth=9.95"
Tc=6.0 min CN=86 Runoff=42.23 cfs 147,632 cf

SubcatchmentDA6: Urban Runoff Area=354,554 sf 29.27% Impervious Runoff Depth=9.56"
Tc=6.0 min UI Adjusted CN=83 Runoff=82.18 cfs 282,363 cf

SubcatchmentDA7A: Waterfront Plaza Runoff Area=154,470 sf 45.37% Impervious Runoff Depth=10.21"
Tc=6.0 min CN=88 Runoff=37.12 cfs 131,416 cf

SubcatchmentDA7B: Waterfront North Runoff Area=292,806 sf 20.13% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=67.28 cfs 229,949 cf

SubcatchmentDA8A: Adventure Play Runoff Area=26,649 sf 12.91% Impervious Runoff Depth=9.29"
Tc=6.0 min UI Adjusted CN=81 Runoff=6.07 cfs 20,632 cf

SubcatchmentDA8B: Adventure Play Runoff Area=21,545 sf 24.73% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=4.95 cfs 16,920 cf

SubcatchmentDA8C: Adventure Play Runoff Area=15,823 sf 23.97% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=3.64 cfs 12,426 cf

SubcatchmentDA8D: Adventure Play Runoff Area=34,949 sf 27.15% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=8.03 cfs 27,446 cf

SubcatchmentDA8E: Adventure Play Runoff Area=66,286 sf 18.42% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=15.23 cfs 52,056 cf

SubcatchmentDA9A: Hammock Grove Runoff Area=37,664 sf 5.01% Impervious Runoff Depth=9.16"
Tc=6.0 min UI Adjusted CN=80 Runoff=8.49 cfs 28,738 cf

SubcatchmentDA9B: Hammock Grove Runoff Area=30,173 sf 18.18% Impervious Runoff Depth=9.42"
Tc=6.0 min UI Adjusted CN=82 Runoff=6.93 cfs 23,696 cf

Reach DP1: SW Discharge-West of Berm Inflow=4.53 cfs 332,130 cf
Outflow=4.53 cfs 332,130 cf

Reach DP2: CSO- East of Berm Inflow=207.43 cfs 767,019 cf
Outflow=207.43 cfs 767,019 cf

Pond GI-10: Green Infrastructure Peak Elev=11.51' Storage=3,077 cf Inflow=20.46 cfs 69,926 cf
Outflow=20.41 cfs 69,926 cf

Pond GI-2: Green Infrastructure Peak Elev=12.00' Storage=26,508 cf Inflow=96.03 cfs 335,692 cf
Outflow=90.44 cfs 335,692 cf

Pond GI-3: Green Infrastructure Peak Elev=11.97' Storage=28,344 cf Inflow=81.55 cfs 280,199 cf
Outflow=71.87 cfs 280,199 cf

Pond GI-4: Green Infrastructure Peak Elev=11.99' Storage=26,634 cf Inflow=94.20 cfs 335,729 cf
Outflow=87.08 cfs 335,729 cf

Pond GI-5: Green Infrastructure Peak Elev=11.82' Storage=10,690 cf Inflow=42.23 cfs 147,632 cf
Outflow=40.73 cfs 147,632 cf

Pond GI-6: Green Infrastructure Peak Elev=11.99' Storage=21,462 cf Inflow=82.18 cfs 282,363 cf
Outflow=75.85 cfs 282,363 cf

Pond GI-7A: Green Infrastructure Peak Elev=11.74' Storage=12,682 cf Inflow=37.12 cfs 131,416 cf
Outflow=35.09 cfs 131,416 cf

Pond GI-7B: Green Infrastructure Peak Elev=12.00' Storage=12,280 cf Inflow=67.28 cfs 229,949 cf
Outflow=65.23 cfs 229,949 cf

Pond GI-8A: Green Infrastructure Peak Elev=10.89' Storage=318 cf Inflow=6.07 cfs 20,632 cf
Outflow=5.94 cfs 20,632 cf

Pond GI-8B: Green Infrastructure Peak Elev=11.07' Storage=596 cf Inflow=4.95 cfs 16,920 cf
Outflow=4.74 cfs 16,920 cf

Pond GI-8C: Green Infrastructure Peak Elev=10.76' Storage=301 cf Inflow=3.64 cfs 12,426 cf
Outflow=3.30 cfs 12,426 cf

Pond GI-8D: Green Infrastructure Peak Elev=11.24' Storage=1,228 cf Inflow=8.03 cfs 27,446 cf
Outflow=8.02 cfs 27,446 cf

Pond GI-8E: Green Infrastructure Peak Elev=11.36' Storage=1,725 cf Inflow=15.23 cfs 52,056 cf
Outflow=15.23 cfs 52,056 cf

Pond GI-9A: Green Infrastructure Peak Elev=11.17' Storage=230 cf Inflow=8.49 cfs 28,738 cf
Outflow=8.53 cfs 28,841 cf

Pond GI-9B: Green Infrastructure Peak Elev=11.15' Storage=657 cf Inflow=6.93 cfs 23,696 cf
Outflow=6.86 cfs 23,696 cf

Pond UG-2F: Central Soccer Field (2070) Peak Elev=1.44' Storage=206,606 cf Inflow=90.44 cfs 335,692 cf
Outflow=4.53 cfs 332,130 cf

Pond UG-3F: Central LL System (2070) Peak Elev=2.56' Storage=489,904 cf Inflow=239.33 cfs 892,212 cf
Outflow=23.10 cfs 891,395 cf

Total Runoff Area = 2,448,410 sf Runoff Volume = 1,994,819 cf Average Runoff Depth = 9.78"
67.16% Pervious = 1,644,430 sf 32.84% Impervious = 803,980 sf

Summary for Subcatchment DA10: Southern Edge

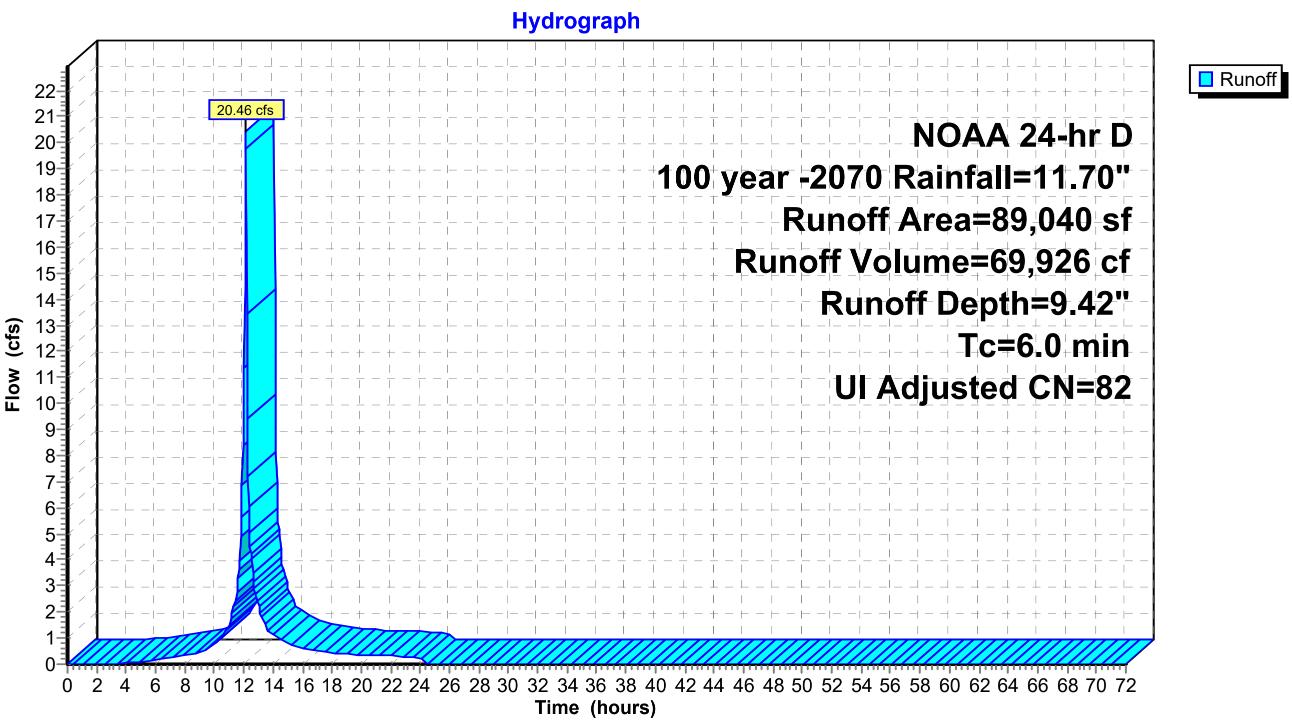
Runoff = 20.46 cfs @ 12.13 hrs, Volume= 69,926 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
69,498	80		>75% Grass cover, Good, HSG D
19,542	98		Unconnected pavement, HSG D
89,040	84	82	Weighted Average, UI Adjusted
69,498			78.05% Pervious Area
19,542			21.95% Impervious Area
19,542			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA10: Southern Edge



Summary for Subcatchment DA2: Soccer Fields

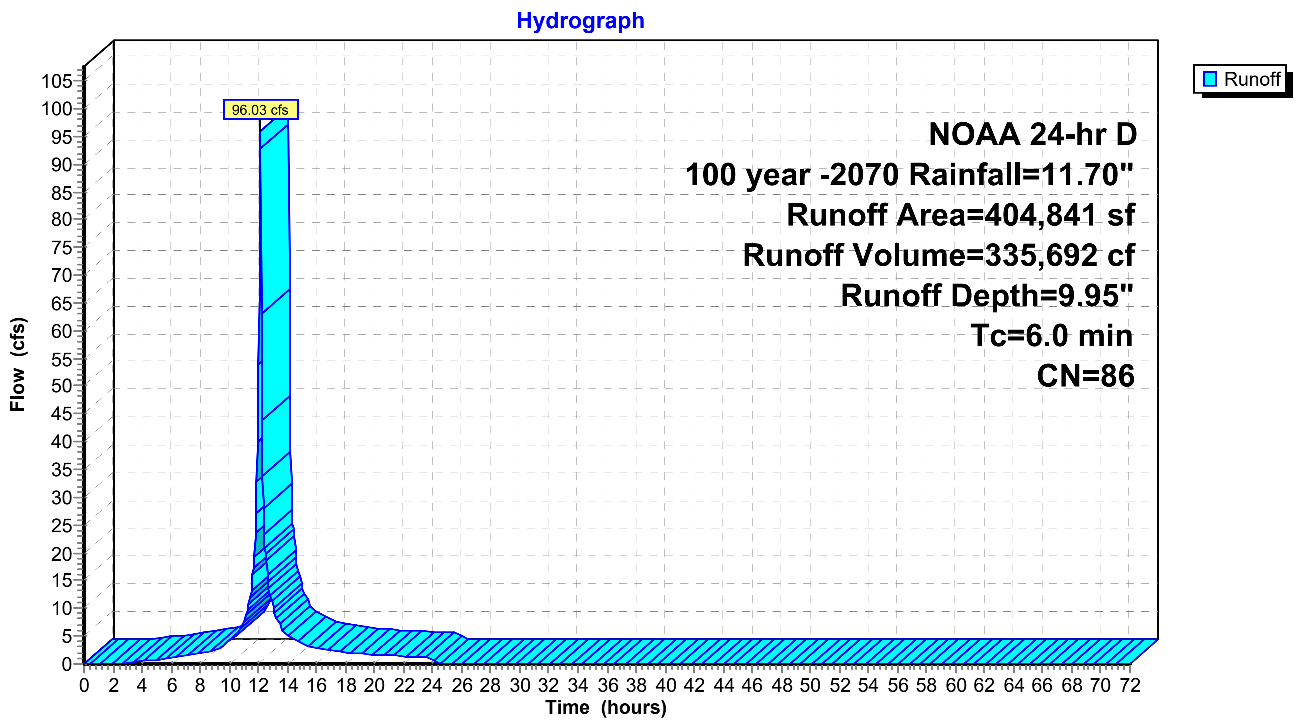
Runoff = 96.03 cfs @ 12.13 hrs, Volume= 335,692 cf, Depth= 9.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Description
277,607	80	>75% Grass cover, Good, HSG D
127,234	98	Unconnected pavement, HSG D
404,841	86	Weighted Average
277,607		68.57% Pervious Area
127,234		31.43% Impervious Area
127,234		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA2: Soccer Fields



Summary for Subcatchment DA3: Little League Fields

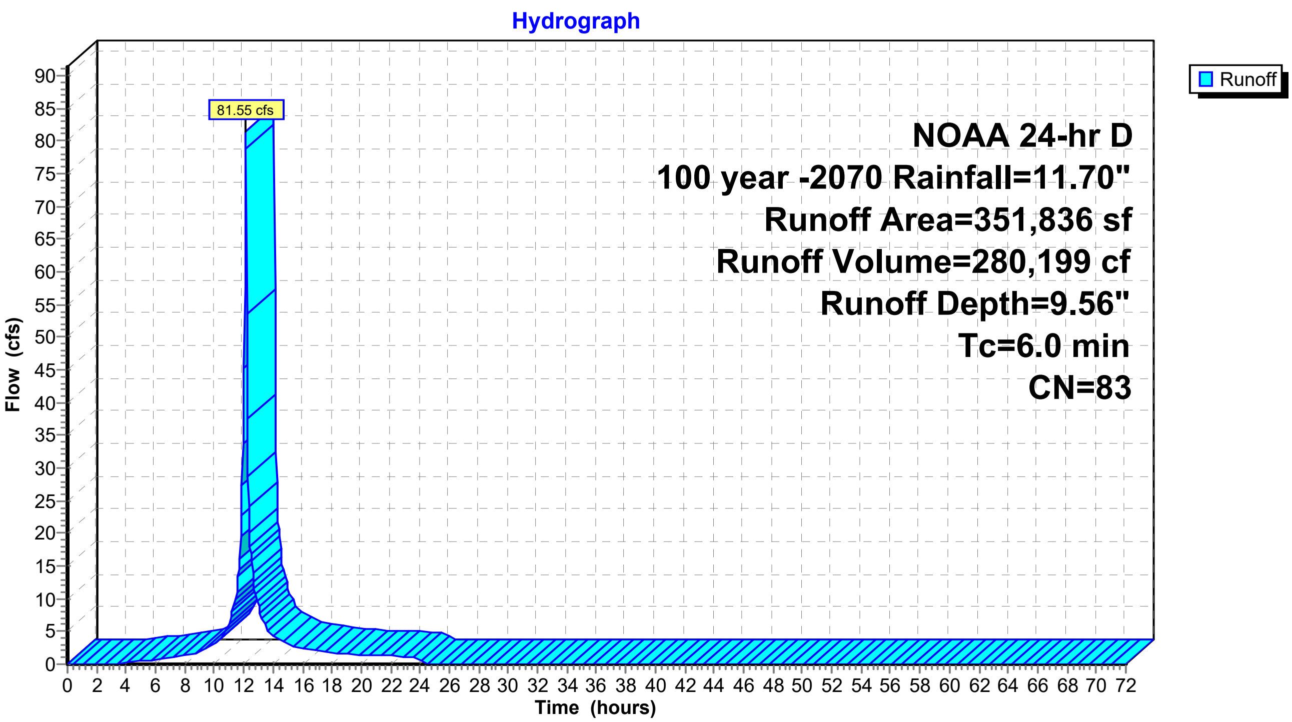
Runoff = 81.55 cfs @ 12.13 hrs, Volume= 280,199 cf, Depth= 9.56"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Description
213,708	74	>75% Grass cover, Good, HSG C
138,128	98	Unconnected pavement, HSG D
351,836	83	Weighted Average
213,708		60.74% Pervious Area
138,128		39.26% Impervious Area
138,128		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA3: Little League Fields



Summary for Subcatchment DA4: Stadium+Marsh

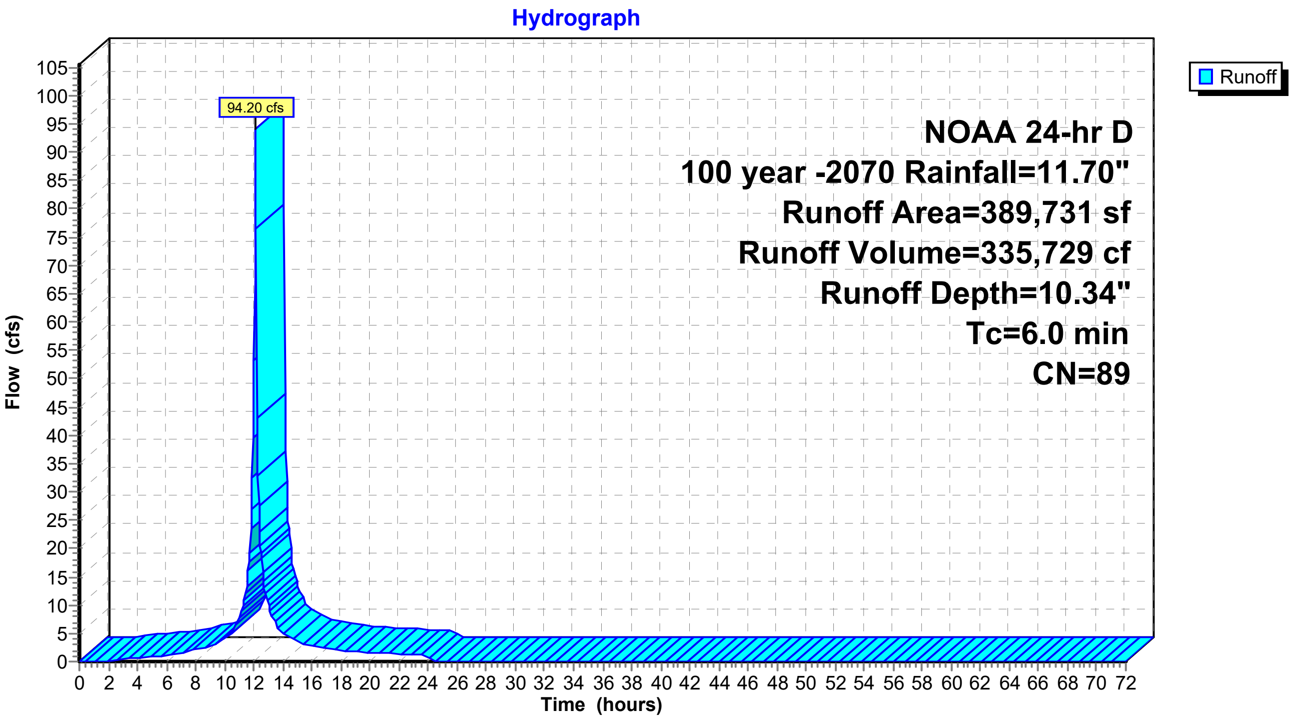
Runoff = 94.20 cfs @ 12.13 hrs, Volume= 335,729 cf, Depth=10.34"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

	Area (sf)	CN	Description
	201,539	80	>75% Grass cover, Good, HSG D
	128,192	98	Unconnected pavement, HSG D
*	60,000	98	Turf Field
	389,731	89	Weighted Average
	201,539		51.71% Pervious Area
	188,192		48.29% Impervious Area
	128,192		68.12% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA4: Stadium+Marsh



Summary for Subcatchment DA5: Urban Edge-South

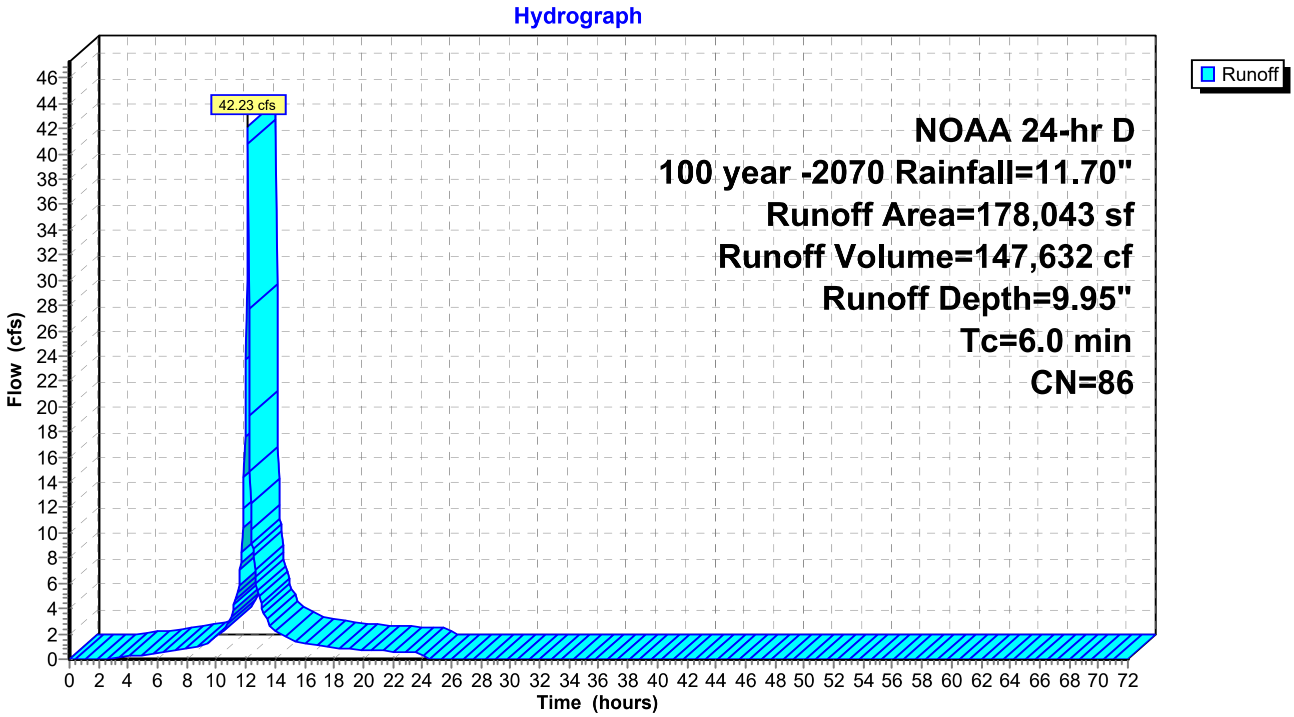
Runoff = 42.23 cfs @ 12.13 hrs, Volume= 147,632 cf, Depth= 9.95"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Description
121,587	80	>75% Grass cover, Good, HSG D
56,456	98	Unconnected pavement, HSG D
178,043	86	Weighted Average
121,587		68.29% Pervious Area
56,456		31.71% Impervious Area
56,456		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA5: Urban Edge-South



Summary for Subcatchment DA6: Urban Edge-North/center

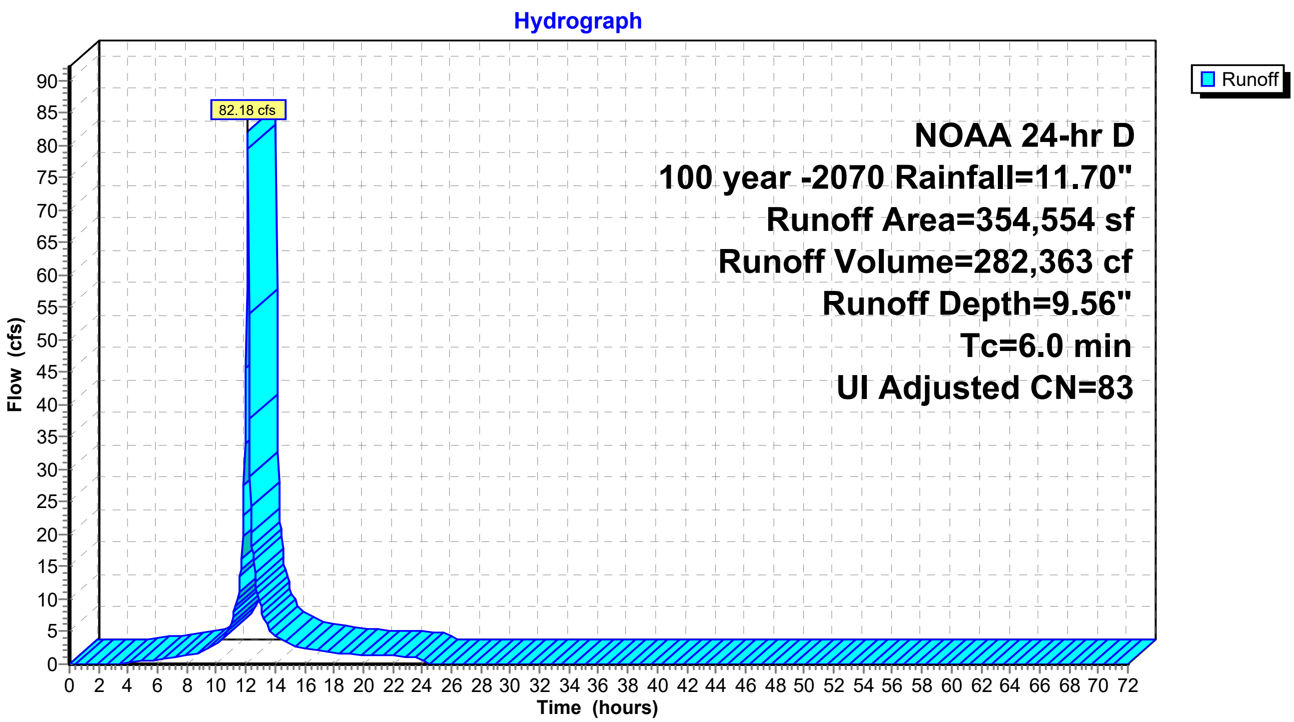
Runoff = 82.18 cfs @ 12.13 hrs, Volume= 282,363 cf, Depth= 9.56"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
250,786	80		>75% Grass cover, Good, HSG D
103,768	98		Unconnected pavement, HSG D
354,554	85	83	Weighted Average, UI Adjusted
250,786			70.73% Pervious Area
103,768			29.27% Impervious Area
103,768			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA6: Urban Edge-North/center



Summary for Subcatchment DA7A: Waterfront Plaza

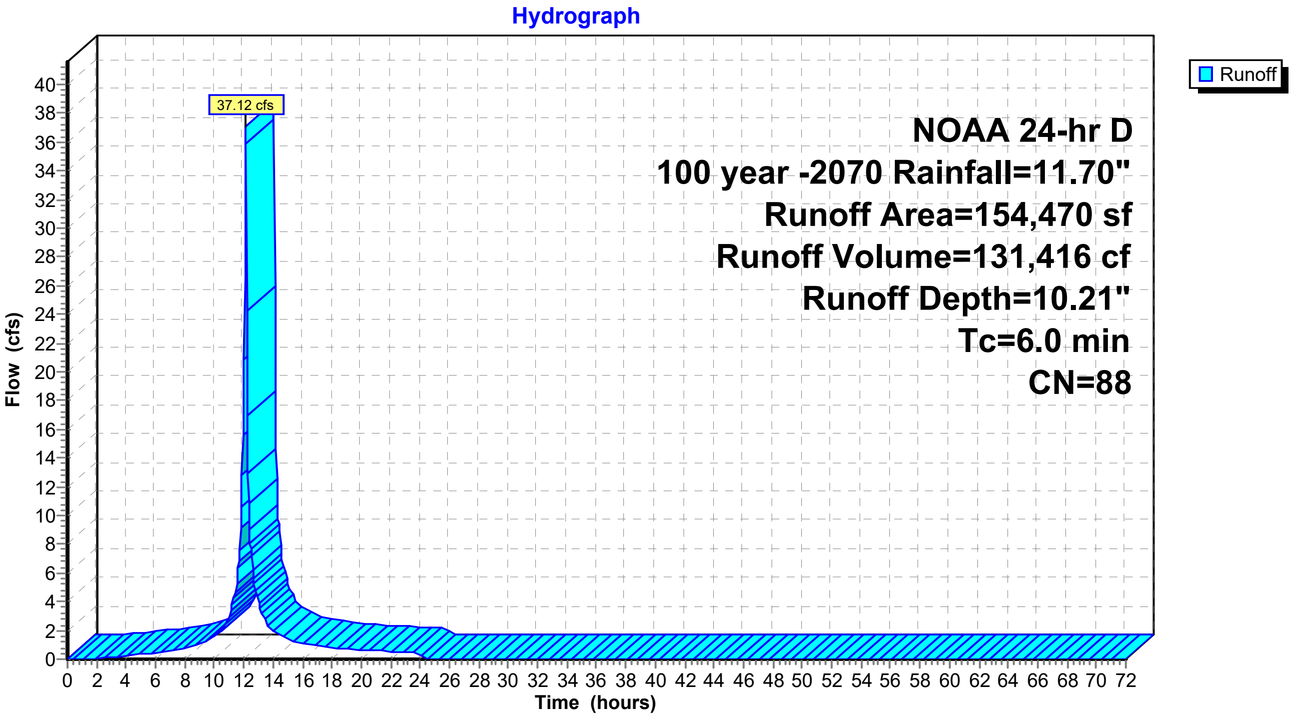
Runoff = 37.12 cfs @ 12.13 hrs, Volume= 131,416 cf, Depth=10.21"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Description
84,388	80	>75% Grass cover, Good, HSG D
70,082	98	Unconnected pavement, HSG D
154,470	88	Weighted Average
84,388		54.63% Pervious Area
70,082		45.37% Impervious Area
70,082		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA7A: Waterfront Plaza



Summary for Subcatchment DA7B: Waterfront North

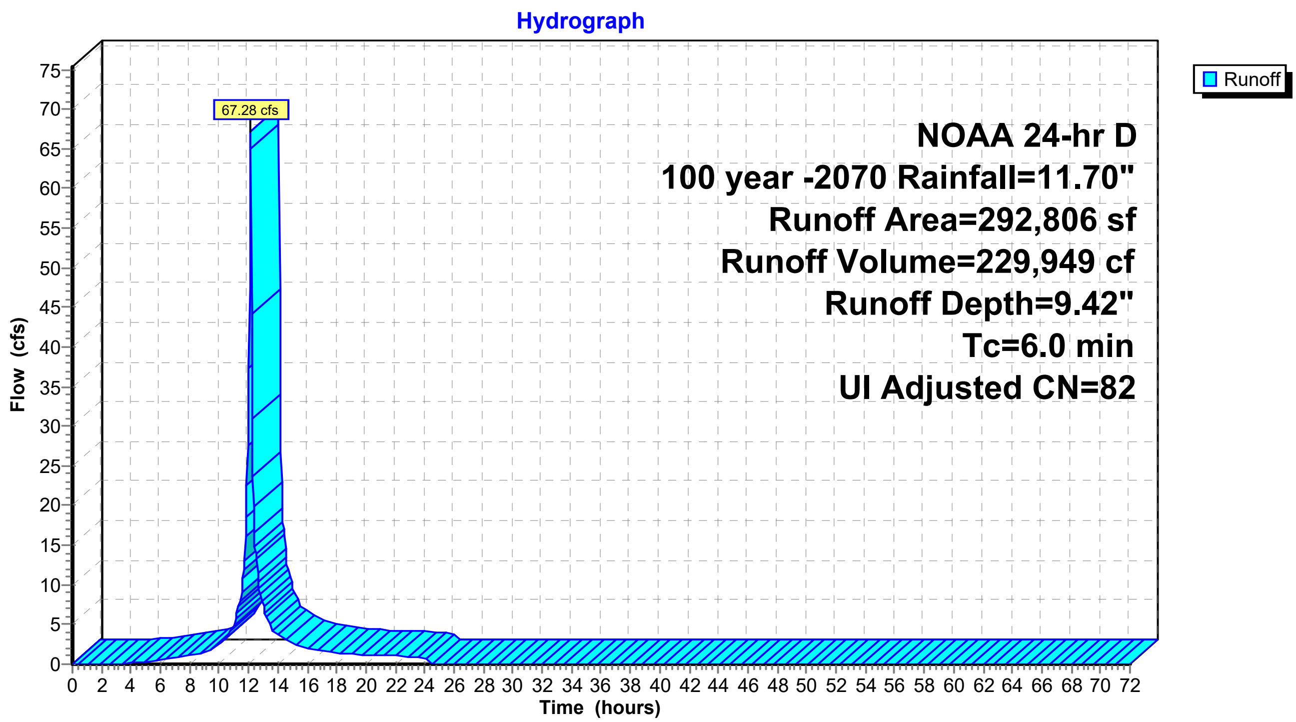
Runoff = 67.28 cfs @ 12.13 hrs, Volume= 229,949 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
233,860	80		>75% Grass cover, Good, HSG D
58,946	98		Unconnected pavement, HSG D
292,806	84	82	Weighted Average, UI Adjusted
233,860			79.87% Pervious Area
58,946			20.13% Impervious Area
58,946			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA7B: Waterfront North



Summary for Subcatchment DA8A: Adventure Play

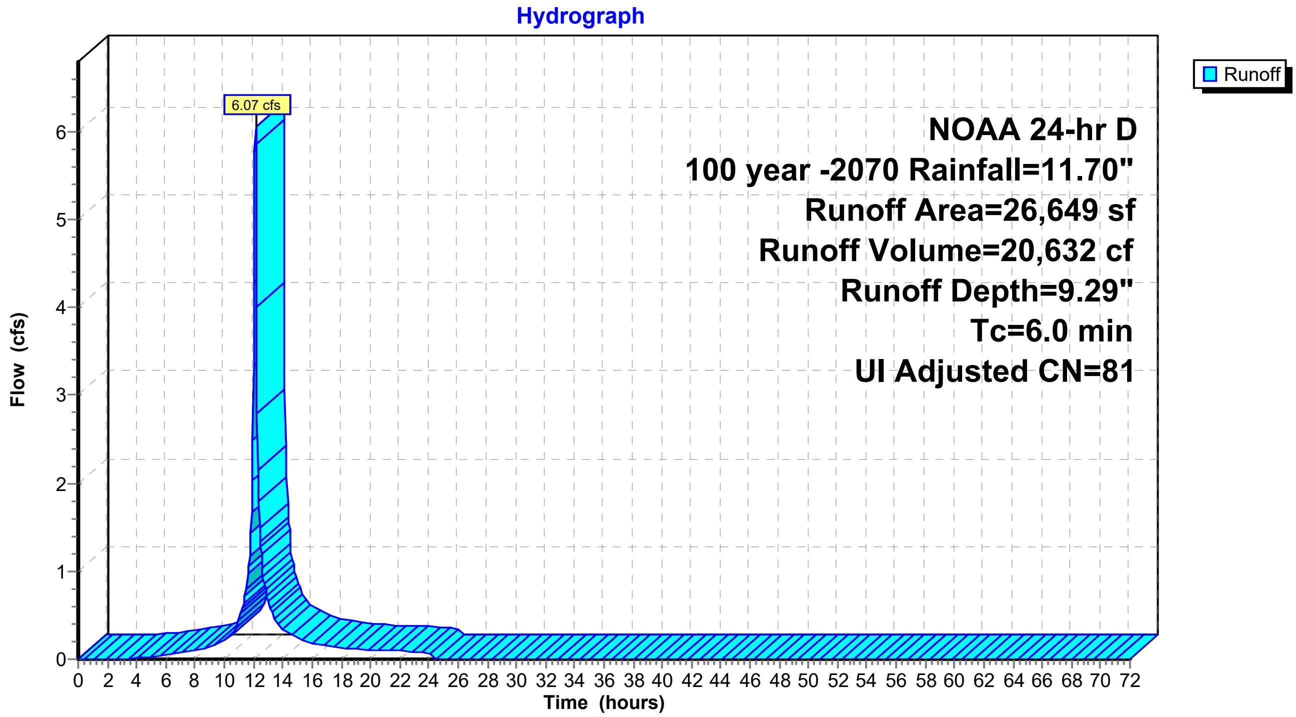
Runoff = 6.07 cfs @ 12.13 hrs, Volume= 20,632 cf, Depth= 9.29"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
23,208	80		>75% Grass cover, Good, HSG D
3,441	98		Unconnected pavement, HSG D
26,649	82	81	Weighted Average, UI Adjusted
23,208			87.09% Pervious Area
3,441			12.91% Impervious Area
3,441			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8A: Adventure Play



Summary for Subcatchment DA8B: Adventure Play

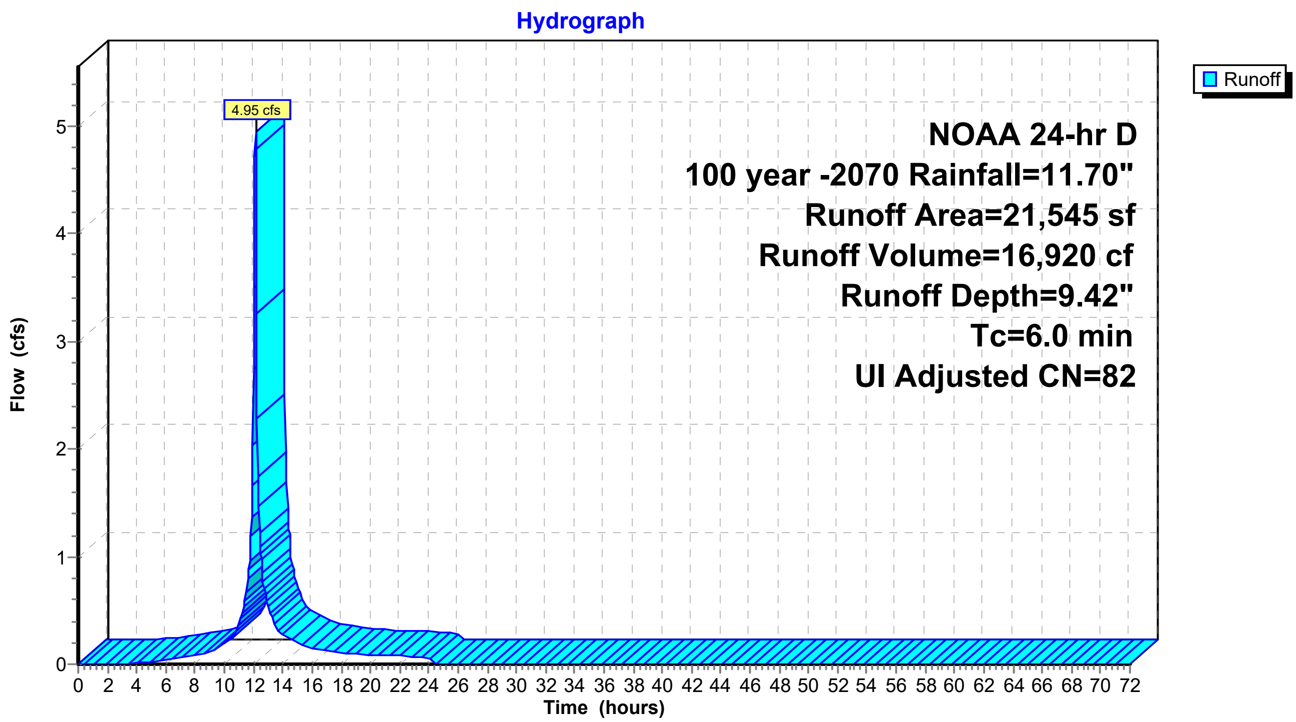
Runoff = 4.95 cfs @ 12.13 hrs, Volume= 16,920 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
16,216	80		>75% Grass cover, Good, HSG D
5,329	98		Unconnected pavement, HSG D
21,545	84	82	Weighted Average, UI Adjusted
16,216			75.27% Pervious Area
5,329			24.73% Impervious Area
5,329			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8B: Adventure Play



Summary for Subcatchment DA8C: Adventure Play

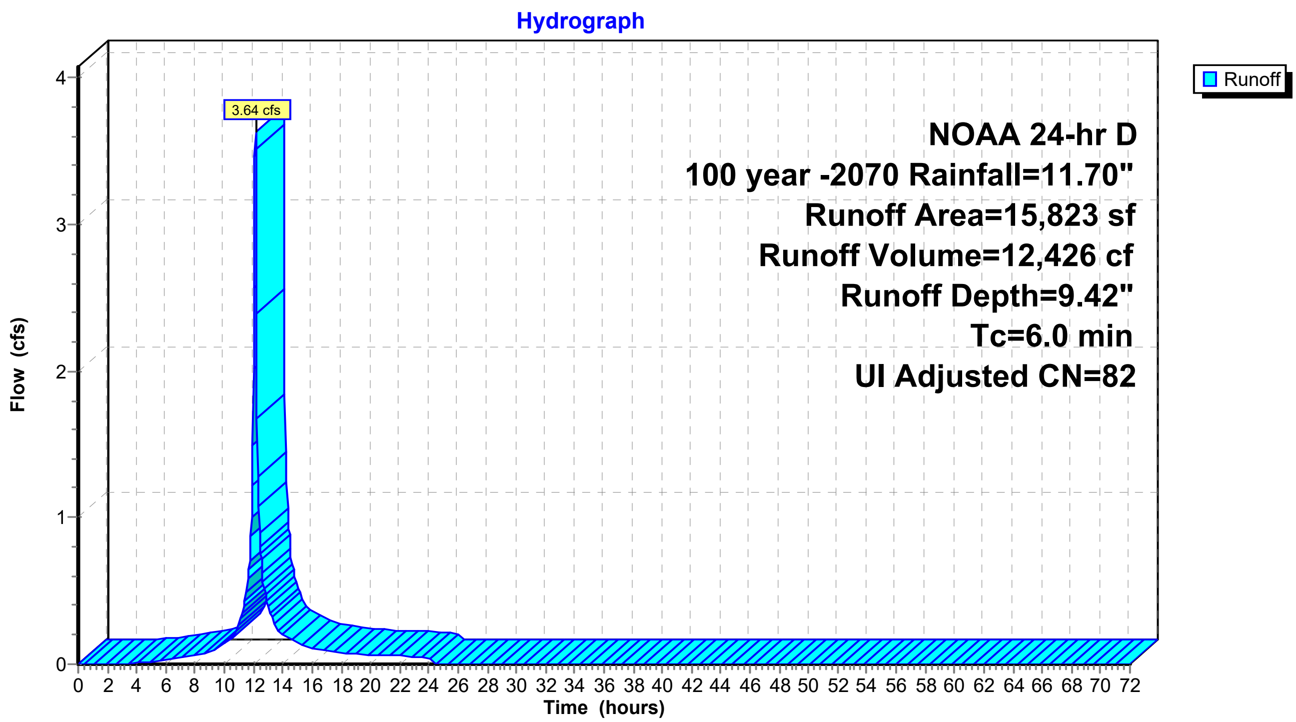
Runoff = 3.64 cfs @ 12.13 hrs, Volume= 12,426 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
12,030	80		>75% Grass cover, Good, HSG D
3,793	98		Unconnected pavement, HSG D
15,823	84	82	Weighted Average, UI Adjusted
12,030			76.03% Pervious Area
3,793			23.97% Impervious Area
3,793			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8C: Adventure Play



Summary for Subcatchment DA8D: Adventure Play

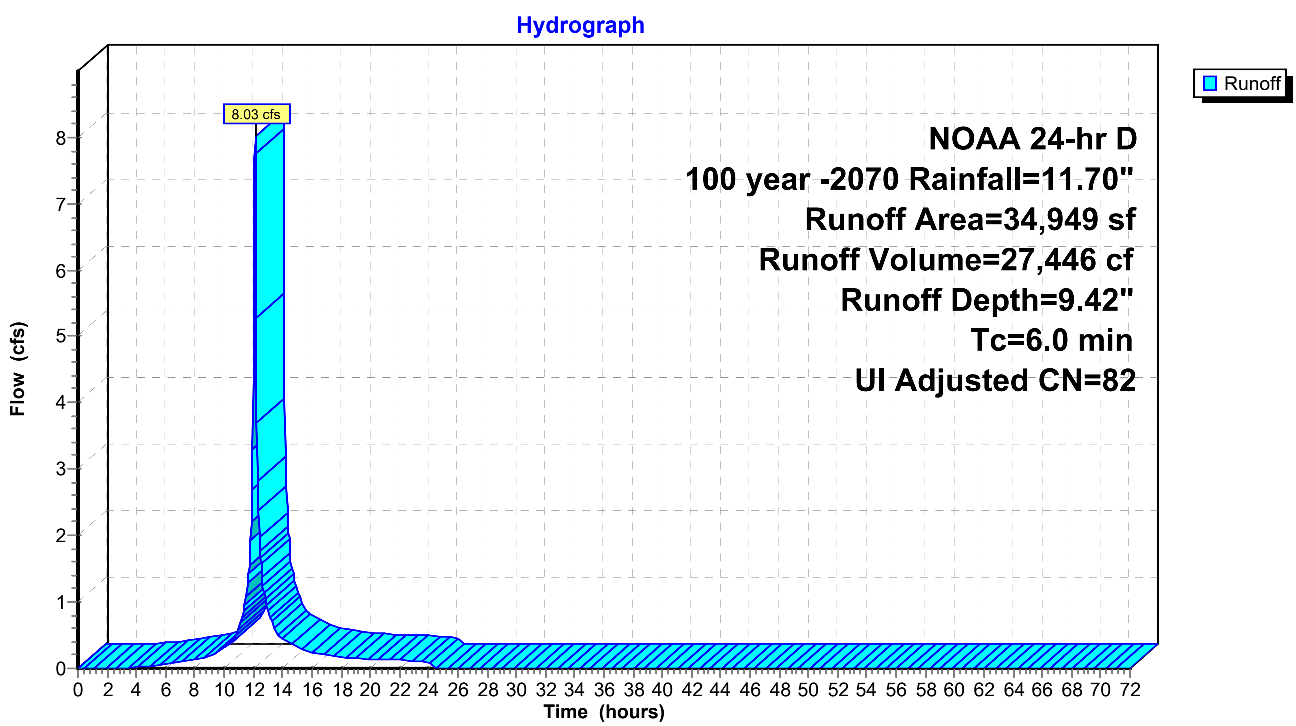
Runoff = 8.03 cfs @ 12.13 hrs, Volume= 27,446 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
25,461	80		>75% Grass cover, Good, HSG D
9,488	98		Unconnected pavement, HSG D
34,949	85	82	Weighted Average, UI Adjusted
25,461			72.85% Pervious Area
9,488			27.15% Impervious Area
9,488			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8D: Adventure Play



Summary for Subcatchment DA8E: Adventure Play

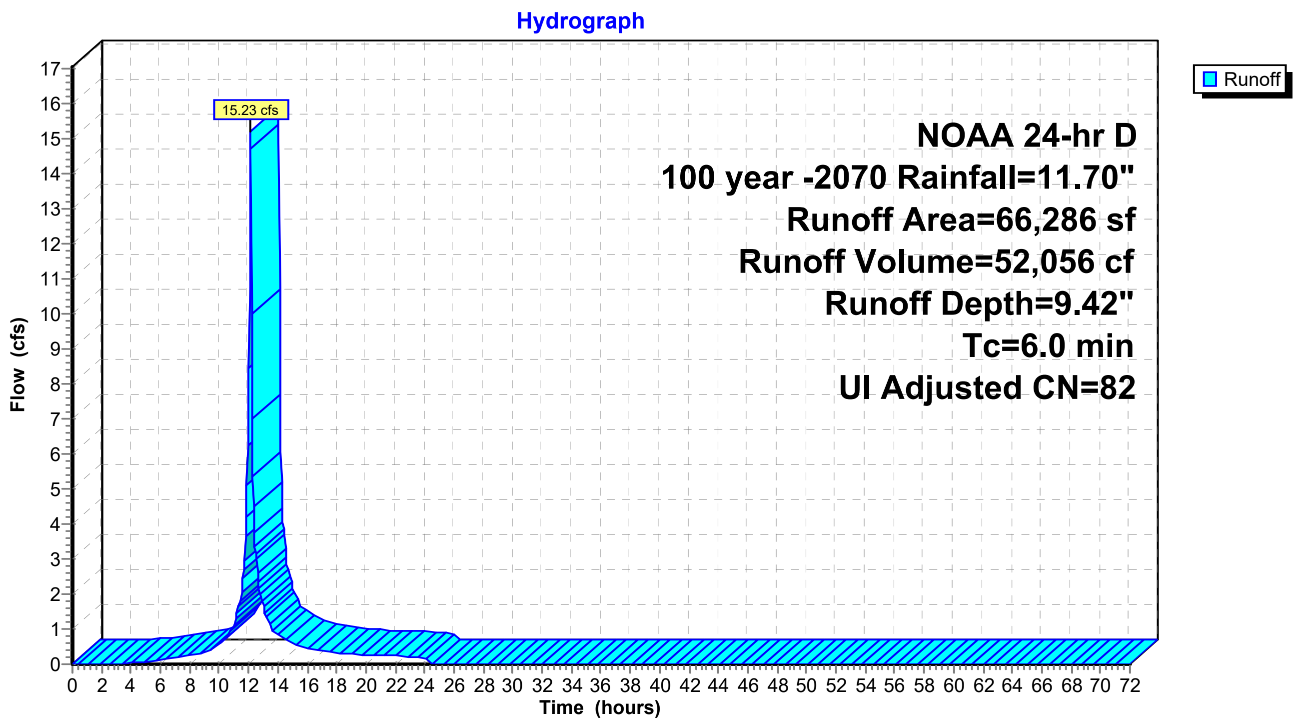
Runoff = 15.23 cfs @ 12.13 hrs, Volume= 52,056 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
54,076	80		>75% Grass cover, Good, HSG D
12,210	98		Unconnected pavement, HSG D
66,286	83	82	Weighted Average, UI Adjusted
54,076			81.58% Pervious Area
12,210			18.42% Impervious Area
12,210			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA8E: Adventure Play



Summary for Subcatchment DA9A: Hammock Grove

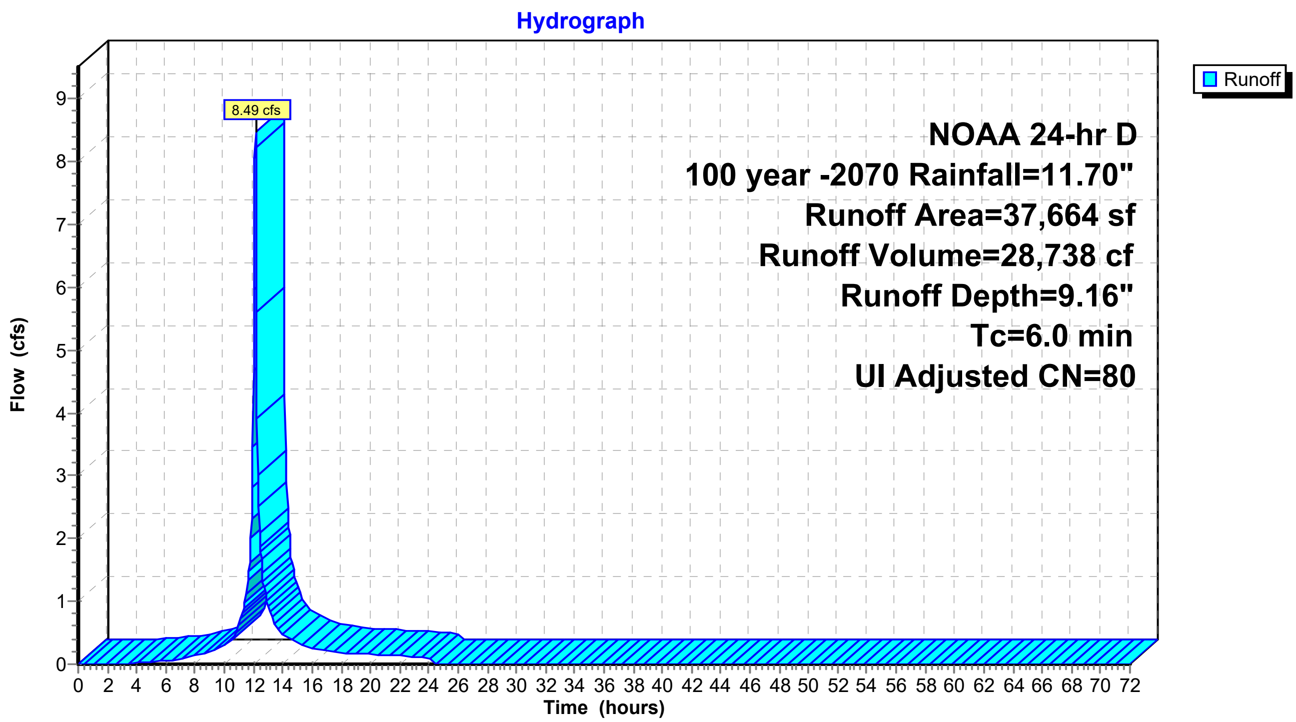
Runoff = 8.49 cfs @ 12.13 hrs, Volume= 28,738 cf, Depth= 9.16"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
35,778	80		>75% Grass cover, Good, HSG D
1,886	98		Unconnected pavement, HSG D
37,664	81	80	Weighted Average, UI Adjusted
35,778			94.99% Pervious Area
1,886			5.01% Impervious Area
1,886			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA9A: Hammock Grove



Summary for Subcatchment DA9B: Hammock Grove

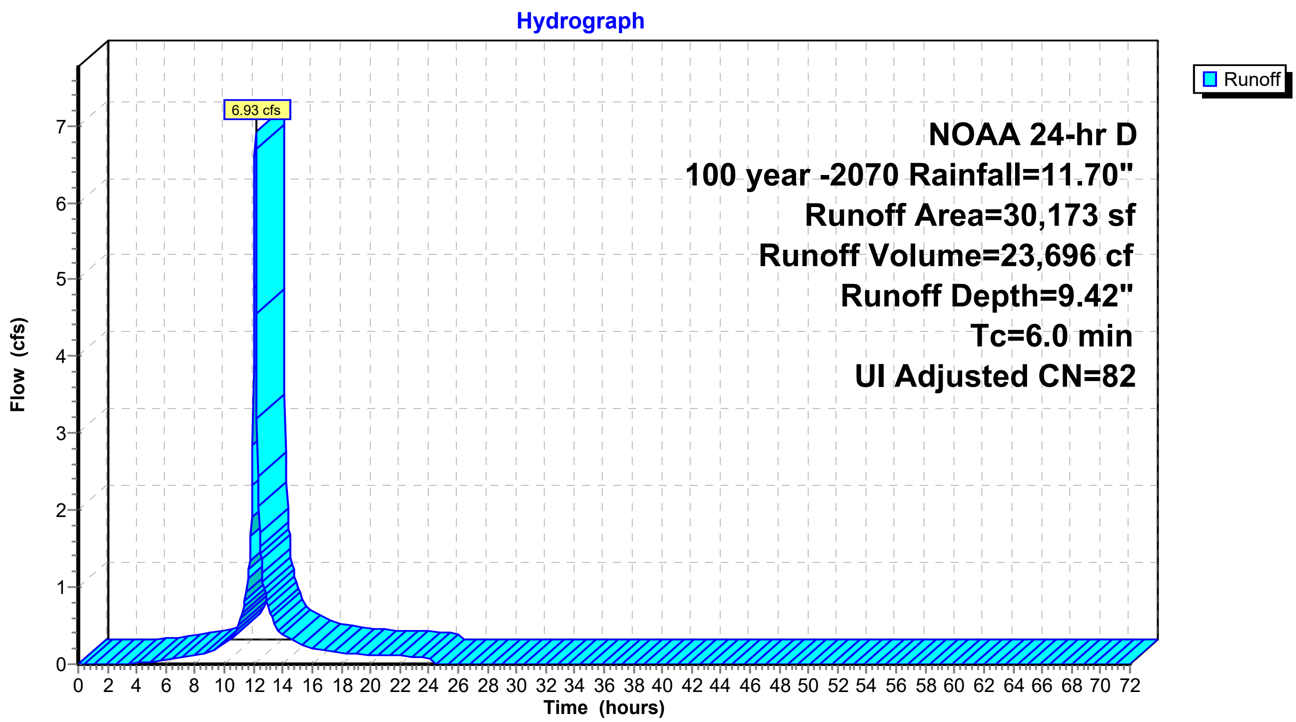
Runoff = 6.93 cfs @ 12.13 hrs, Volume= 23,696 cf, Depth= 9.42"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year -2070 Rainfall=11.70"

Area (sf)	CN	Adj	Description
24,688	80		>75% Grass cover, Good, HSG D
5,485	98		Unconnected pavement, HSG D
30,173	83	82	Weighted Average, UI Adjusted
24,688			81.82% Pervious Area
5,485			18.18% Impervious Area
5,485			100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA9B: Hammock Grove



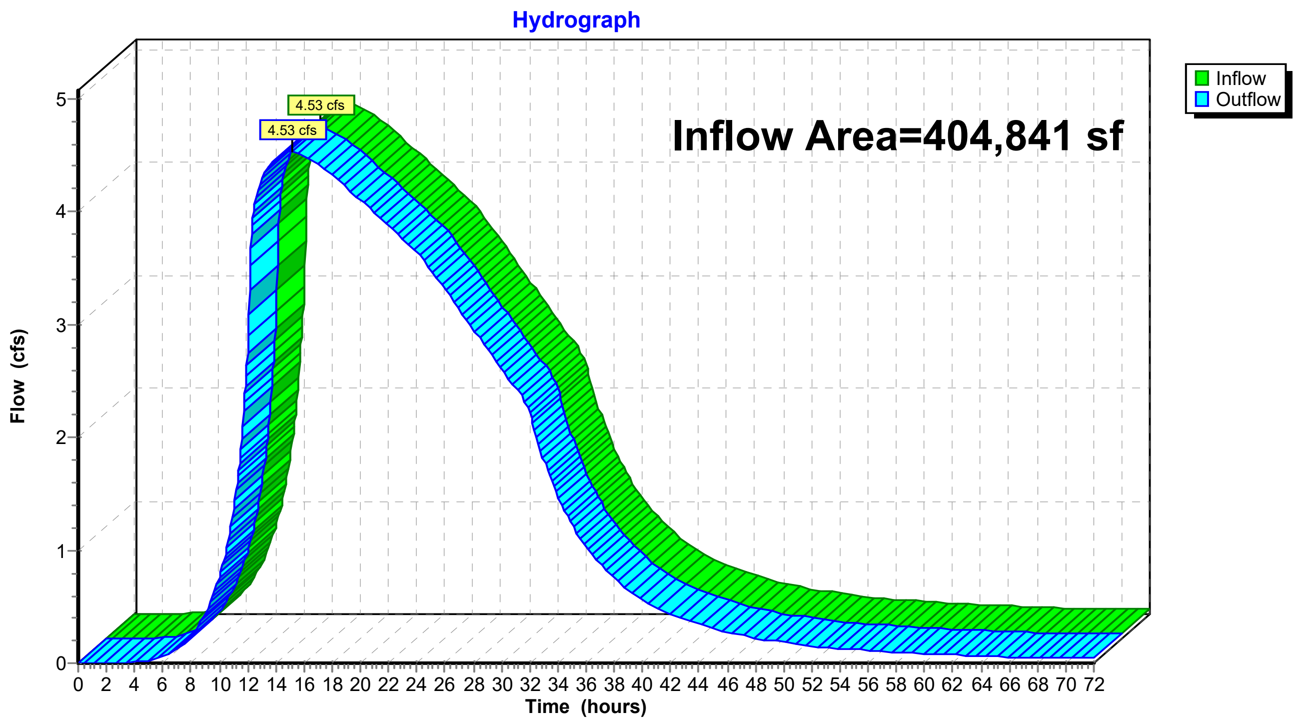
Summary for Reach DP1: SW Discharge- West of Berm

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	404,841 sf,	31.43% Impervious,	Inflow Depth > 9.84"	for 100 year -2070 event
Inflow =	4.53 cfs @	15.13 hrs, Volume=	332,130 cf	
Outflow =	4.53 cfs @	15.13 hrs, Volume=	332,130 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Reach DP1: SW Discharge- West of Berm



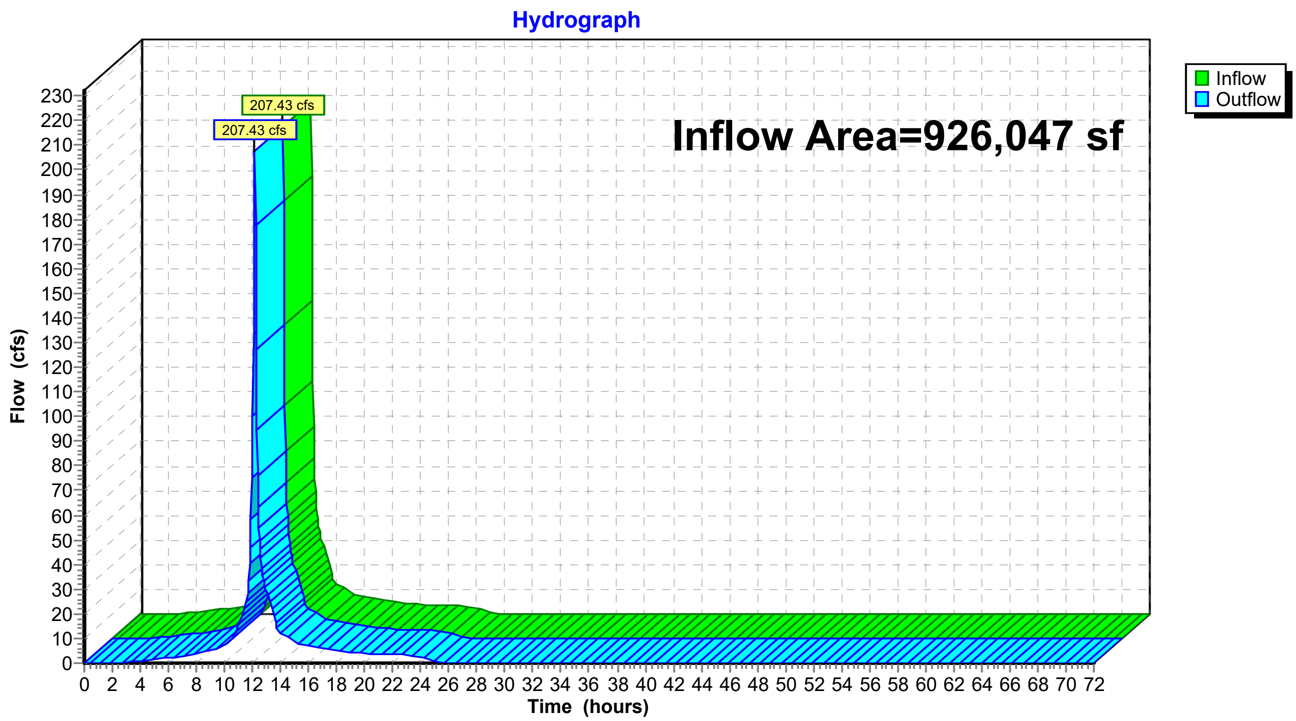
Summary for Reach DP2: CSO- East of Berm

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	926,047 sf,	36.37% Impervious,	Inflow Depth = 9.94"	for 100 year -2070 event
Inflow =	207.43 cfs @	12.15 hrs, Volume=	767,019 cf	
Outflow =	207.43 cfs @	12.15 hrs, Volume=	767,019 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

Reach DP2: CSO- East of Berm



Summary for Pond GI-10: Green Infrastructure

Inflow Area = 89,040 sf, 21.95% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 20.46 cfs @ 12.13 hrs, Volume= 69,926 cf
Outflow = 20.41 cfs @ 12.14 hrs, Volume= 69,926 cf, Atten= 0%, Lag= 0.7 min
Primary = 20.41 cfs @ 12.14 hrs, Volume= 69,926 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.51' @ 12.14 hrs Surf.Area= 2,036 sf Storage= 3,077 cf

Plug-Flow detention time= 15.1 min calculated for 69,877 cf (100% of inflow)
Center-of-Mass det. time= 15.1 min (805.1 - 790.0)

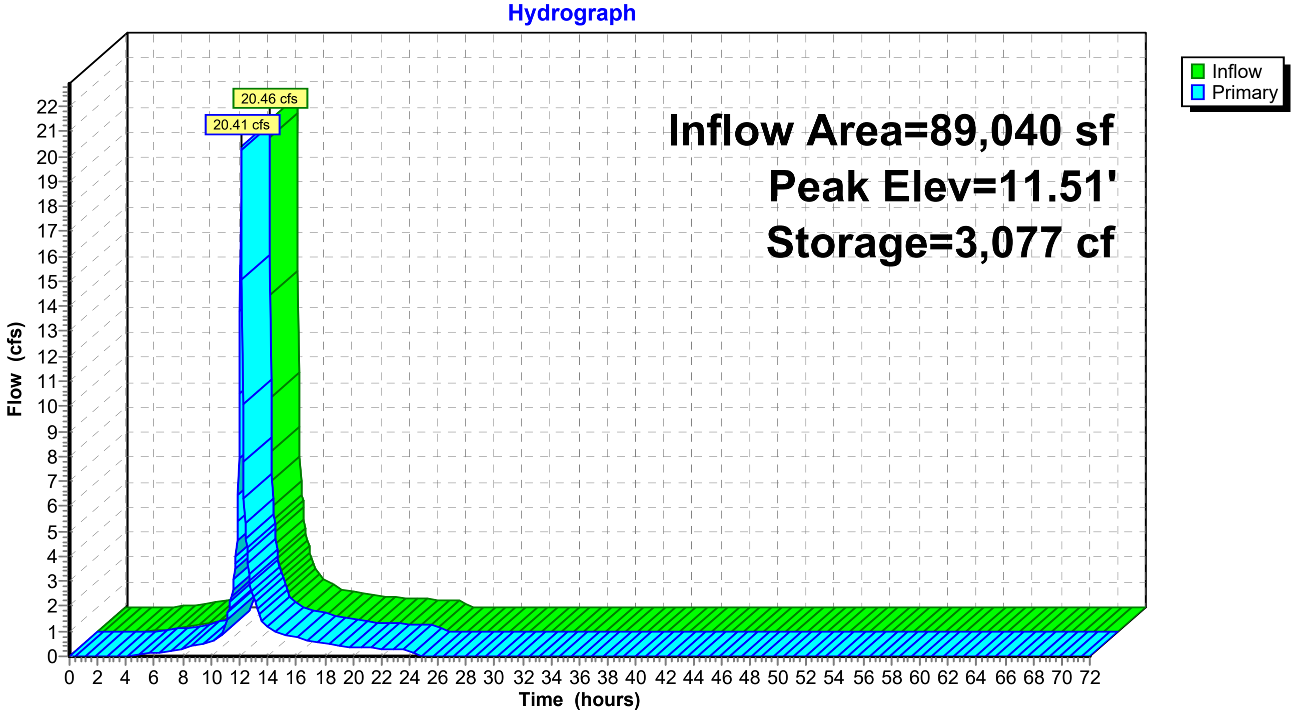
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	4,072 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	2,036	0	0
11.00	2,036	2,036	2,036
12.00	2,036	2,036	4,072

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=19.78 cfs @ 12.14 hrs HW=11.50' (Free Discharge)
├─**1=Broad-Crested Rectangular Weir** (Weir Controls 18.62 cfs @ 1.86 fps)
└─**2=Orifice/Grate** (Orifice Controls 1.16 cfs @ 5.90 fps)

Pond GI-10: Green Infrastructure



Summary for Pond GI-2: Green Infrastructure

Inflow Area = 404,841 sf, 31.43% Impervious, Inflow Depth = 9.95" for 100 year -2070 event
Inflow = 96.03 cfs @ 12.13 hrs, Volume= 335,692 cf
Outflow = 90.44 cfs @ 12.15 hrs, Volume= 335,692 cf, Atten= 6%, Lag= 1.5 min
Primary = 90.44 cfs @ 12.15 hrs, Volume= 335,692 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 12.00' @ 12.15 hrs Surf.Area= 13,254 sf Storage= 26,508 cf

Plug-Flow detention time= 17.5 min calculated for 335,459 cf (100% of inflow)
Center-of-Mass det. time= 17.6 min (797.5 - 779.8)

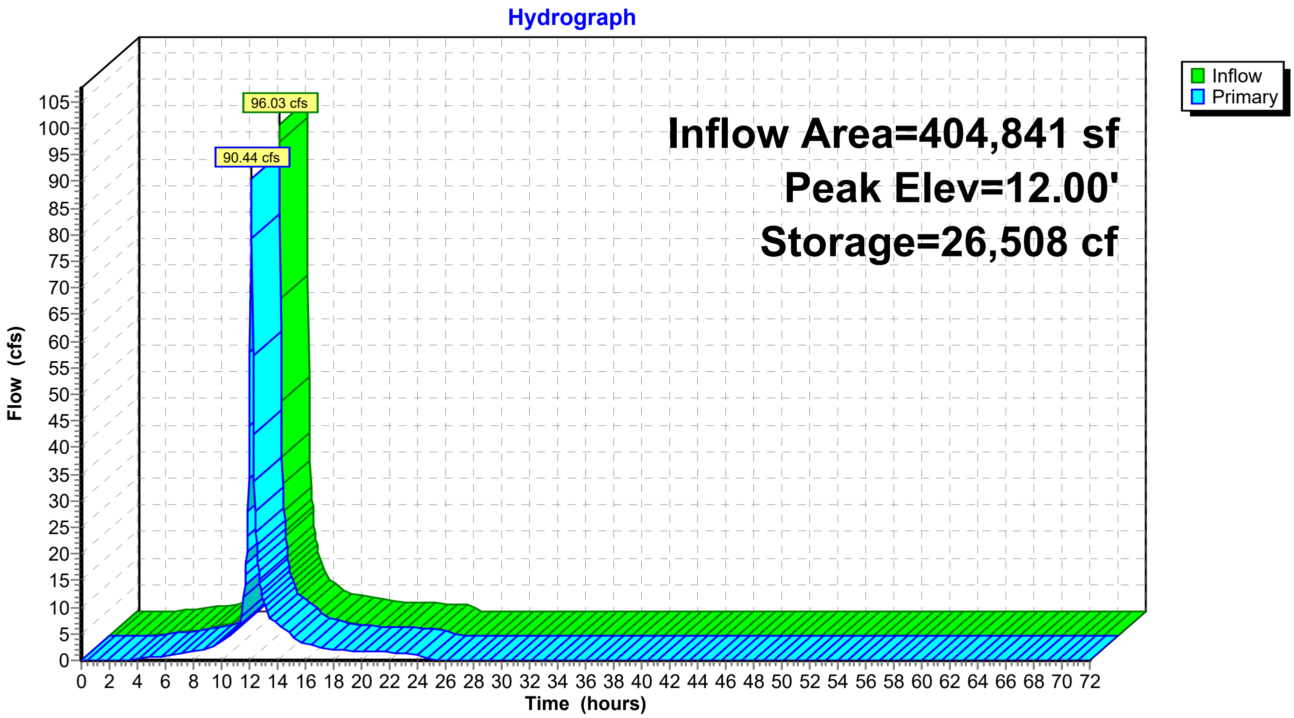
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	26,508 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	13,254	0	0
11.00	13,254	13,254	13,254
12.00	13,254	13,254	26,508

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**30.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=89.79 cfs @ 12.15 hrs HW=12.00' (Free Discharge)
—**1=Broad-Crested Rectangular Weir** (Weir Controls 79.11 cfs @ 2.65 fps)
—**2=Orifice/Grate** (Orifice Controls 5.34 cfs @ 6.80 fps)
—**3=Orifice/Grate** (Orifice Controls 5.34 cfs @ 6.80 fps)

Pond GI-2: Green Infrastructure



Summary for Pond GI-3: Green Infrastructure

Inflow Area = 351,836 sf, 39.26% Impervious, Inflow Depth = 9.56" for 100 year -2070 event
Inflow = 81.55 cfs @ 12.13 hrs, Volume= 280,199 cf
Outflow = 71.87 cfs @ 12.17 hrs, Volume= 280,199 cf, Atten= 12%, Lag= 2.3 min
Primary = 71.87 cfs @ 12.17 hrs, Volume= 280,199 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.97' @ 12.17 hrs Surf.Area= 14,388 sf Storage= 28,344 cf

Plug-Flow detention time= 13.2 min calculated for 280,199 cf (100% of inflow)
Center-of-Mass det. time= 12.9 min (800.5 - 787.6)

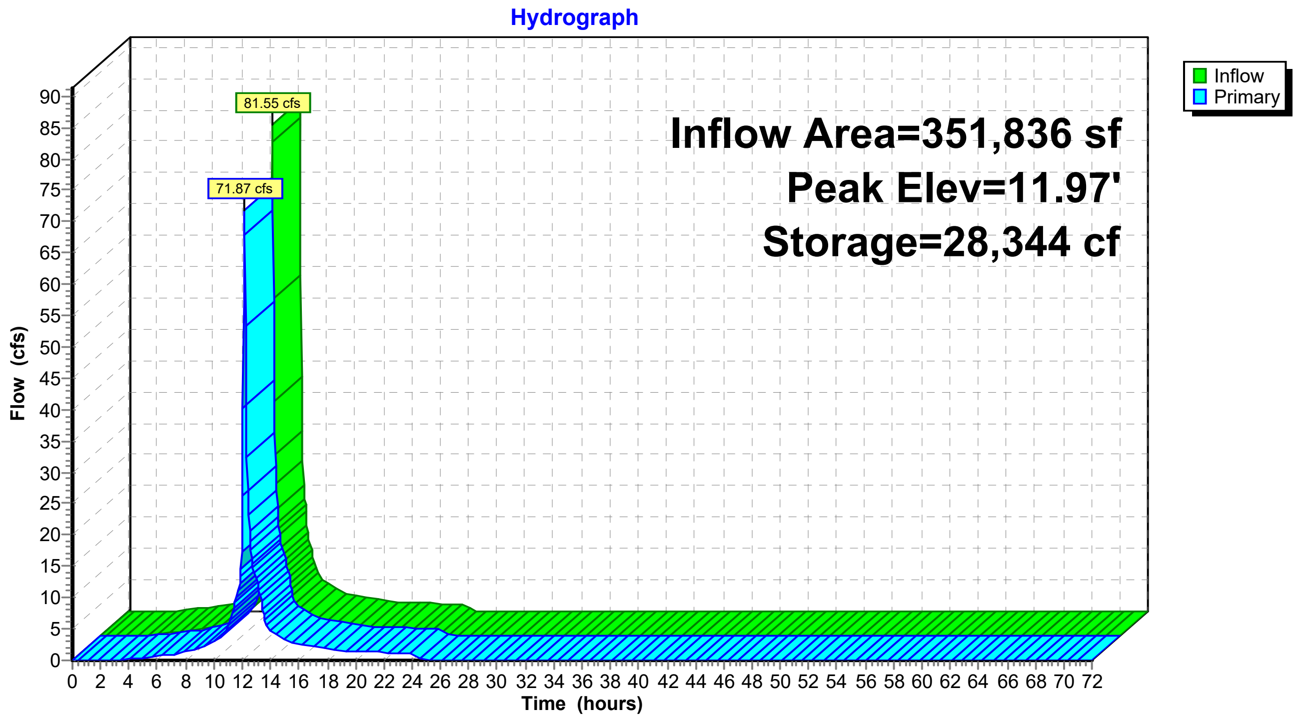
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	28,776 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	14,388	0	0
11.00	14,388	14,388	14,388
12.00	14,388	14,388	28,776

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#4	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#5	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=70.03 cfs @ 12.17 hrs HW=11.95' (Free Discharge)
├─**1=Broad-Crested Rectangular Weir** (Weir Controls 48.92 cfs @ 2.58 fps)
├─**2=Orifice/Grate** (Orifice Controls 5.28 cfs @ 6.72 fps)
├─**3=Orifice/Grate** (Orifice Controls 5.28 cfs @ 6.72 fps)
├─**4=Orifice/Grate** (Orifice Controls 5.28 cfs @ 6.72 fps)
└─**5=Orifice/Grate** (Orifice Controls 5.28 cfs @ 6.72 fps)

Pond GI-3: Green Infrastructure



Summary for Pond GI-4: Green Infrastructure

Inflow Area = 389,731 sf, 48.29% Impervious, Inflow Depth = 10.34" for 100 year -2070 event
Inflow = 94.20 cfs @ 12.13 hrs, Volume= 335,729 cf
Outflow = 87.08 cfs @ 12.16 hrs, Volume= 335,729 cf, Atten= 8%, Lag= 1.8 min
Primary = 87.08 cfs @ 12.16 hrs, Volume= 335,729 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.99' @ 12.16 hrs Surf.Area= 13,353 sf Storage= 26,634 cf

Plug-Flow detention time= 11.3 min calculated for 335,496 cf (100% of inflow)
Center-of-Mass det. time= 11.4 min (782.8 - 771.4)

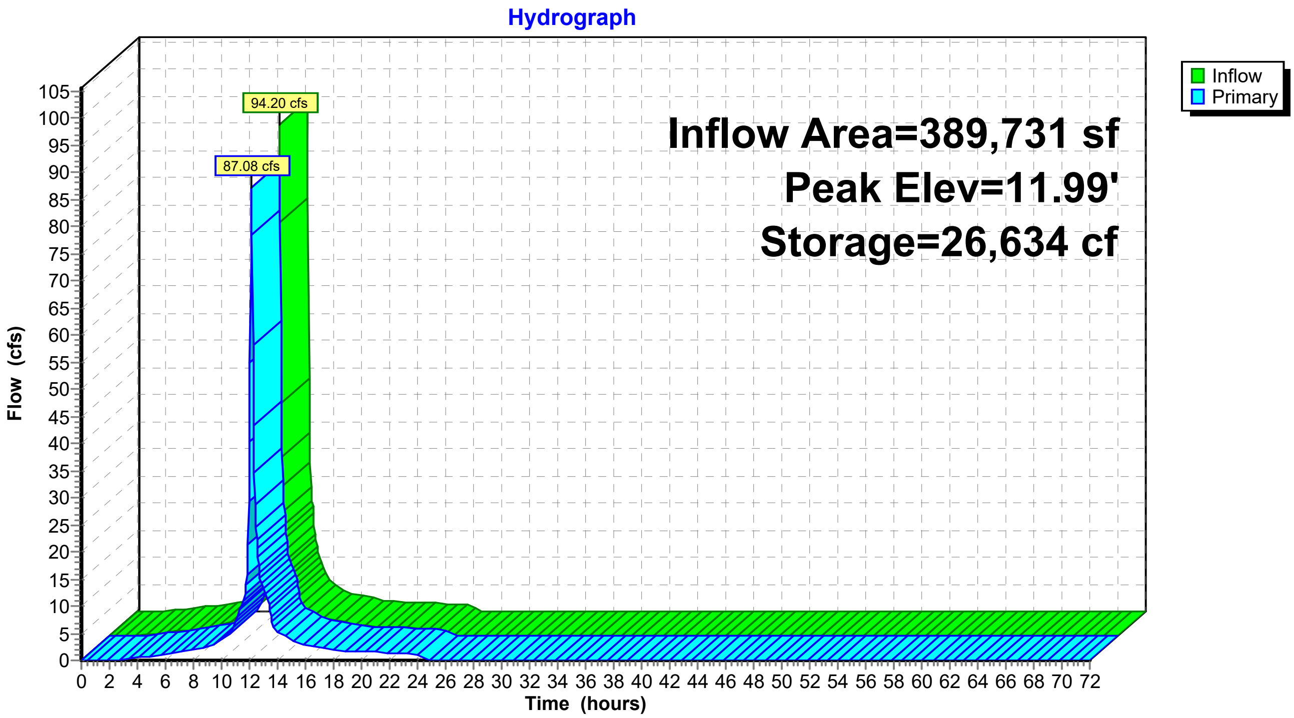
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	26,706 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	13,353	0	0
11.00	13,353	13,353	13,353
12.00	13,353	13,353	26,706

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**25.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#4	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#5	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=85.87 cfs @ 12.16 hrs HW=11.98' (Free Discharge)
1=Broad-Crested Rectangular Weir (Weir Controls 64.58 cfs @ 2.63 fps)
2=Orifice/Grate (Orifice Controls 5.32 cfs @ 6.78 fps)
3=Orifice/Grate (Orifice Controls 5.32 cfs @ 6.78 fps)
4=Orifice/Grate (Orifice Controls 5.32 cfs @ 6.78 fps)
5=Orifice/Grate (Orifice Controls 5.32 cfs @ 6.78 fps)

Pond GI-4: Green Infrastructure



Summary for Pond GI-5: Green Infrastructure

Inflow Area = 178,043 sf, 31.71% Impervious, Inflow Depth = 9.95" for 100 year -2070 event
Inflow = 42.23 cfs @ 12.13 hrs, Volume= 147,632 cf
Outflow = 40.73 cfs @ 12.15 hrs, Volume= 147,632 cf, Atten= 4%, Lag= 1.2 min
Primary = 40.73 cfs @ 12.15 hrs, Volume= 147,632 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.82' @ 12.15 hrs Surf.Area= 5,881 sf Storage= 10,690 cf

Plug-Flow detention time= 38.0 min calculated for 147,530 cf (100% of inflow)
Center-of-Mass det. time= 38.2 min (818.0 - 779.8)

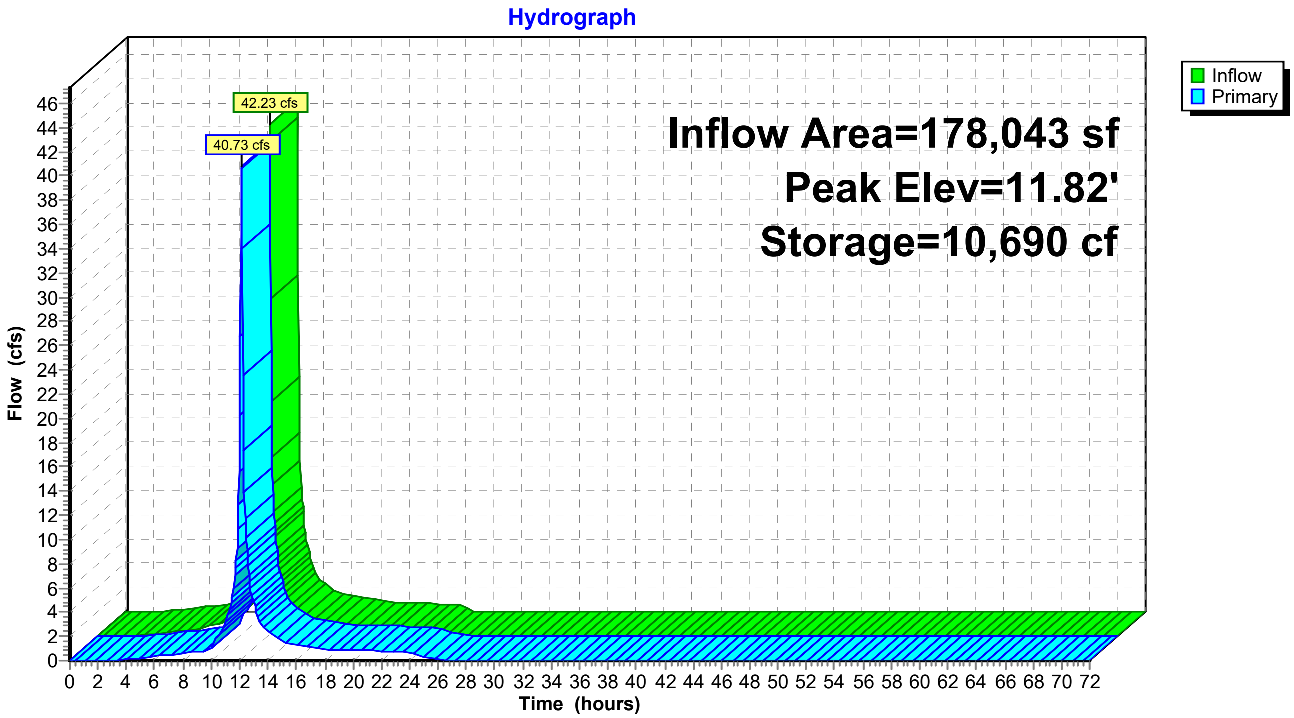
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	11,762 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	5,881	0	0
11.00	5,881	5,881	5,881
12.00	5,881	5,881	11,762

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=40.45 cfs @ 12.15 hrs HW=11.81' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 39.18 cfs @ 2.41 fps)
└─**2=Orifice/Grate** (Orifice Controls 1.27 cfs @ 6.48 fps)

Pond GI-5: Green Infrastructure



Summary for Pond GI-6: Green Infrastructure

Inflow Area = 354,554 sf, 29.27% Impervious, Inflow Depth = 9.56" for 100 year -2070 event
Inflow = 82.18 cfs @ 12.13 hrs, Volume= 282,363 cf
Outflow = 75.85 cfs @ 12.16 hrs, Volume= 282,363 cf, Atten= 8%, Lag= 1.8 min
Primary = 75.85 cfs @ 12.16 hrs, Volume= 282,363 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.99' @ 12.16 hrs Surf.Area= 10,809 sf Storage= 21,462 cf

Plug-Flow detention time= 10.5 min calculated for 282,167 cf (100% of inflow)
Center-of-Mass det. time= 10.6 min (798.1 - 787.6)

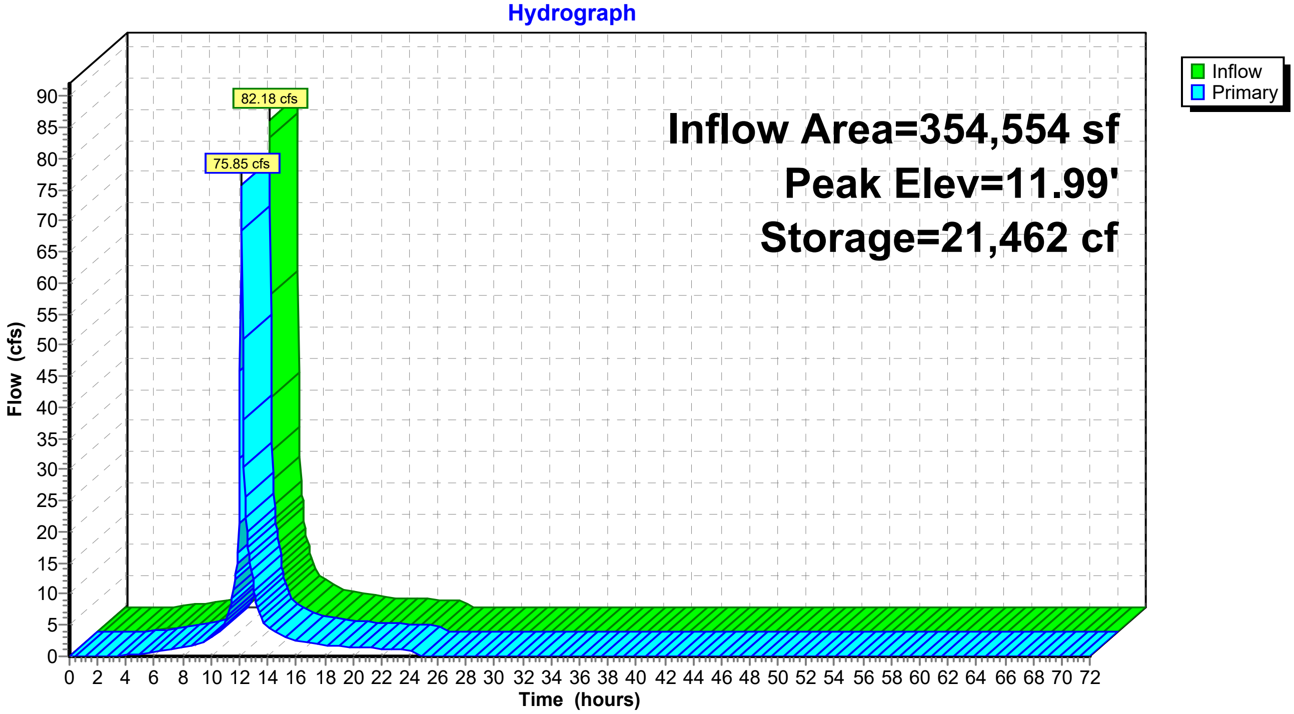
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	21,618 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	10,809	0	0
11.00	10,809	10,809	10,809
12.00	10,809	10,809	21,618

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**18.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**18.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=74.63 cfs @ 12.16 hrs HW=11.97' (Free Discharge)
├─**1=Broad-Crested Rectangular Weir** (Weir Controls 50.74 cfs @ 2.61 fps)
├─**2=Orifice/Grate** (Orifice Controls 11.94 cfs @ 6.76 fps)
└─**3=Orifice/Grate** (Orifice Controls 11.94 cfs @ 6.76 fps)

Pond GI-6: Green Infrastructure



Summary for Pond GI-7A: Green Infrastructure

Inflow Area = 154,470 sf, 45.37% Impervious, Inflow Depth = 10.21" for 100 year -2070 event
Inflow = 37.12 cfs @ 12.13 hrs, Volume= 131,416 cf
Outflow = 35.09 cfs @ 12.15 hrs, Volume= 131,416 cf, Atten= 5%, Lag= 1.5 min
Primary = 35.09 cfs @ 12.15 hrs, Volume= 131,416 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.74' @ 12.15 hrs Surf.Area= 7,300 sf Storage= 12,682 cf

Plug-Flow detention time= 50.1 min calculated for 131,324 cf (100% of inflow)
Center-of-Mass det. time= 50.4 min (824.7 - 774.3)

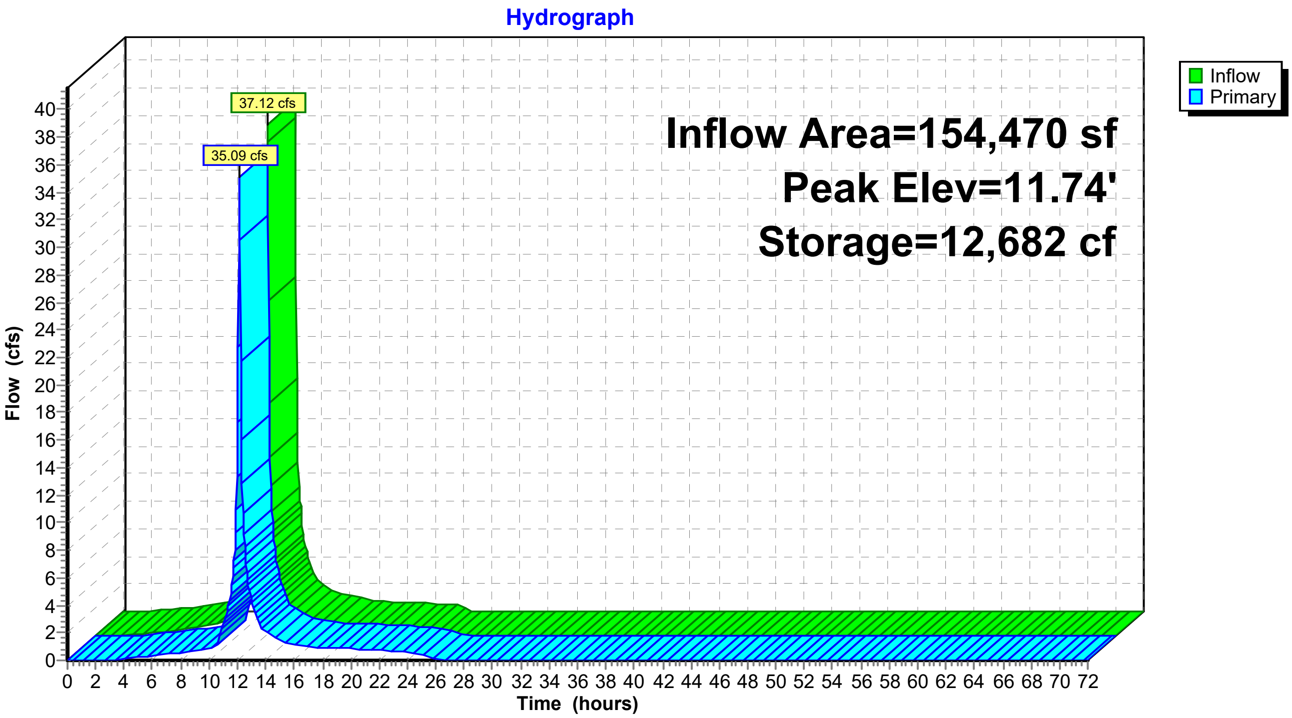
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	14,600 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	7,300	0	0
11.00	7,300	7,300	7,300
12.00	7,300	7,300	14,600

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=34.95 cfs @ 12.15 hrs HW=11.74' (Free Discharge)
1=Broad-Crested Rectangular Weir (Weir Controls 33.71 cfs @ 2.29 fps)
2=Orifice/Grate (Orifice Controls 1.25 cfs @ 6.34 fps)

Pond GI-7A: Green Infrastructure



Summary for Pond GI-7B: Green Infrastructure

Inflow Area = 292,806 sf, 20.13% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 67.28 cfs @ 12.13 hrs, Volume= 229,949 cf
Outflow = 65.23 cfs @ 12.15 hrs, Volume= 229,949 cf, Atten= 3%, Lag= 1.2 min
Primary = 65.23 cfs @ 12.15 hrs, Volume= 229,949 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 12.00' @ 12.15 hrs Surf.Area= 6,140 sf Storage= 12,280 cf

Plug-Flow detention time= 8.2 min calculated for 229,789 cf (100% of inflow)
Center-of-Mass det. time= 8.2 min (798.2 - 790.0)

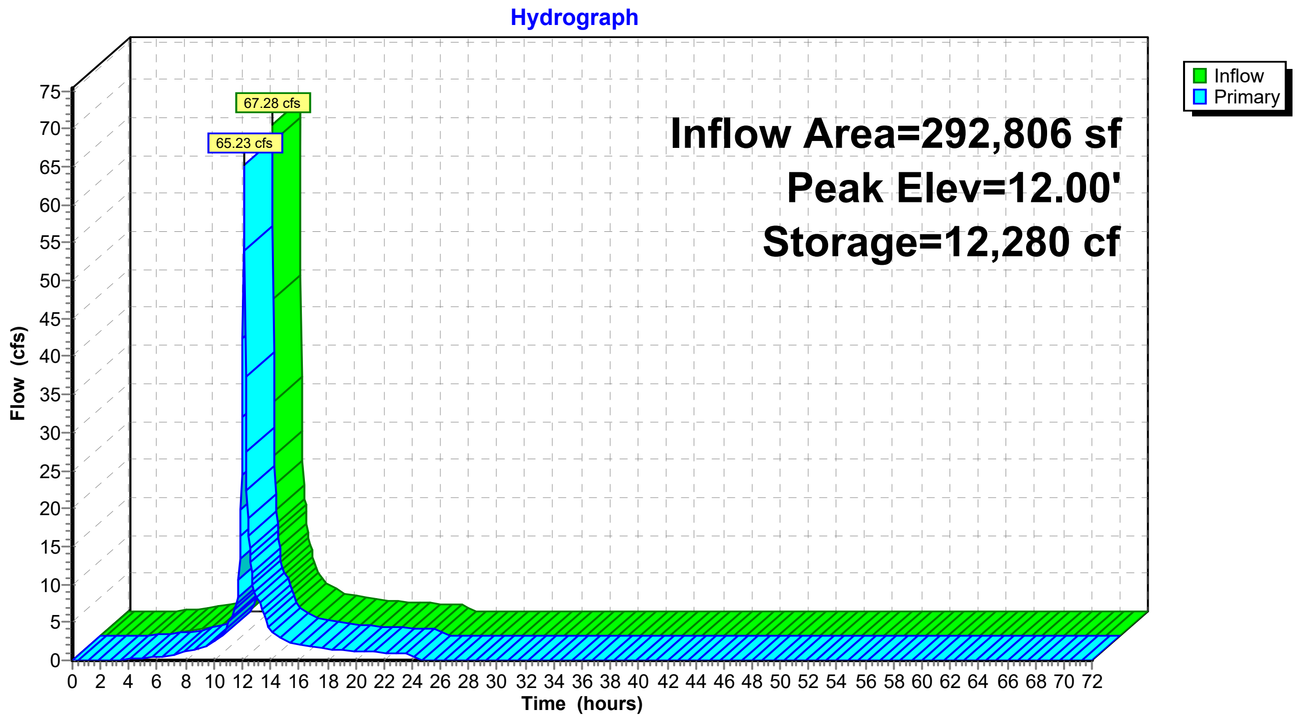
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	12,280 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	6,140	0	0
11.00	6,140	6,140	6,140
12.00	6,140	6,140	12,280

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#4	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=64.66 cfs @ 12.15 hrs HW=12.00' (Free Discharge)
—**1=Broad-Crested Rectangular Weir** (Weir Controls 52.64 cfs @ 2.64 fps)
—**2=Orifice/Grate** (Orifice Controls 5.34 cfs @ 6.80 fps)
—**3=Orifice/Grate** (Orifice Controls 5.34 cfs @ 6.80 fps)
—**4=Orifice/Grate** (Orifice Controls 1.34 cfs @ 6.80 fps)

Pond GI-7B: Green Infrastructure



Summary for Pond GI-8A: Green Infrastructure

Inflow Area = 26,649 sf, 12.91% Impervious, Inflow Depth = 9.29" for 100 year -2070 event
Inflow = 6.07 cfs @ 12.13 hrs, Volume= 20,632 cf
Outflow = 5.94 cfs @ 12.14 hrs, Volume= 20,632 cf, Atten= 2%, Lag= 0.9 min
Primary = 5.94 cfs @ 12.14 hrs, Volume= 20,632 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 10.89' @ 12.14 hrs Surf.Area= 358 sf Storage= 318 cf

Plug-Flow detention time= 1.5 min calculated for 20,617 cf (100% of inflow)
Center-of-Mass det. time= 1.5 min (793.9 - 792.4)

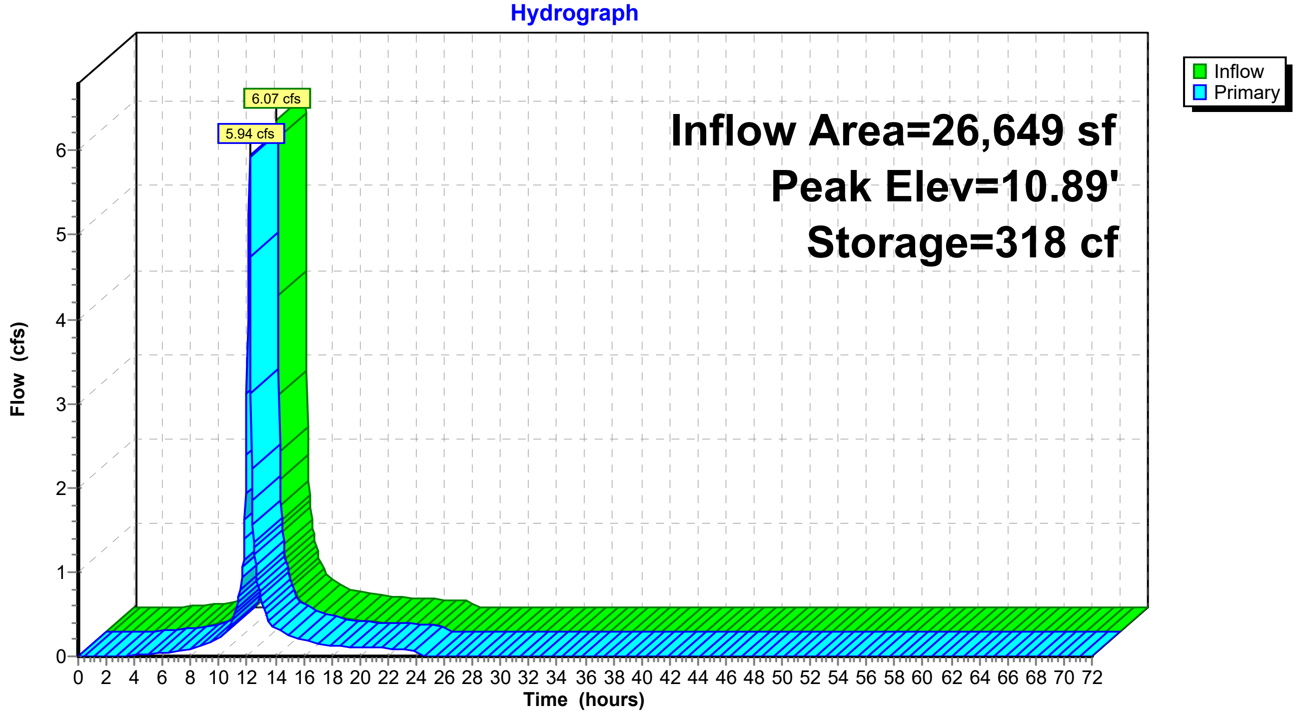
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	716 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	358	0	0
11.00	358	358	358
12.00	358	358	716

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**12.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=5.83 cfs @ 12.14 hrs HW=10.87' (Free Discharge)
1=Broad-Crested Rectangular Weir (Controls 0.00 cfs)
2=Orifice/Grate (Orifice Controls 3.53 cfs @ 4.49 fps)
3=Orifice/Grate (Orifice Controls 2.31 cfs @ 3.18 fps)

Pond GI-8A: Green Infrastructure



Summary for Pond GI-8B: Green Infrastructure

Inflow Area = 21,545 sf, 24.73% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 4.95 cfs @ 12.13 hrs, Volume= 16,920 cf
Outflow = 4.74 cfs @ 12.15 hrs, Volume= 16,920 cf, Atten= 4%, Lag= 1.5 min
Primary = 4.74 cfs @ 12.15 hrs, Volume= 16,920 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.07' @ 12.16 hrs Surf.Area= 555 sf Storage= 596 cf

Plug-Flow detention time= 2.8 min calculated for 16,908 cf (100% of inflow)
Center-of-Mass det. time= 2.8 min (792.9 - 790.0)

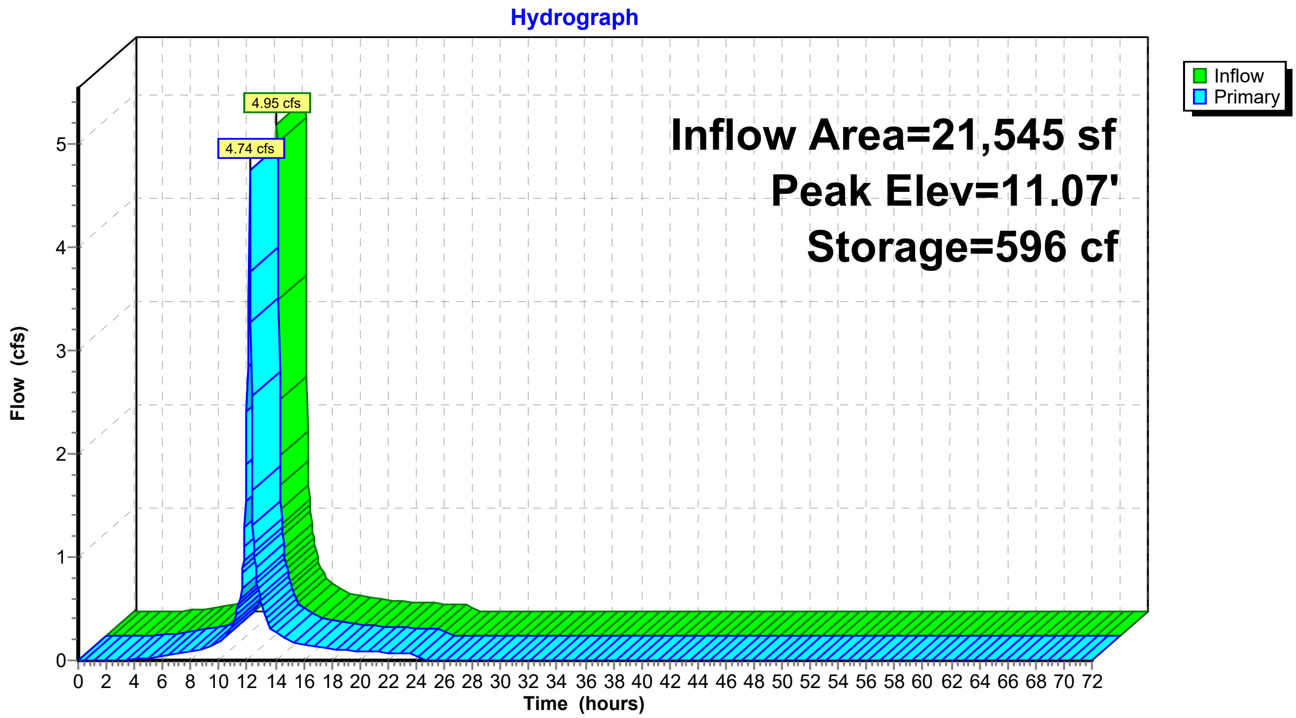
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	1,110 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	555	0	0
11.00	555	555	555
12.00	555	555	1,110

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=4.65 cfs @ 12.15 hrs HW=11.06' (Free Discharge)
1=Broad-Crested Rectangular Weir (Weir Controls 0.75 cfs @ 0.61 fps)
2=Orifice/Grate (Orifice Controls 3.90 cfs @ 4.96 fps)

Pond GI-8B: Green Infrastructure



Summary for Pond GI-8C: Green Infrastructure

Inflow Area = 15,823 sf, 23.97% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 3.64 cfs @ 12.13 hrs, Volume= 12,426 cf
Outflow = 3.30 cfs @ 12.16 hrs, Volume= 12,426 cf, Atten= 9%, Lag= 1.8 min
Primary = 3.30 cfs @ 12.16 hrs, Volume= 12,426 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 10.76' @ 12.16 hrs Surf.Area= 395 sf Storage= 301 cf

Plug-Flow detention time= 2.1 min calculated for 12,418 cf (100% of inflow)
Center-of-Mass det. time= 2.1 min (792.2 - 790.0)

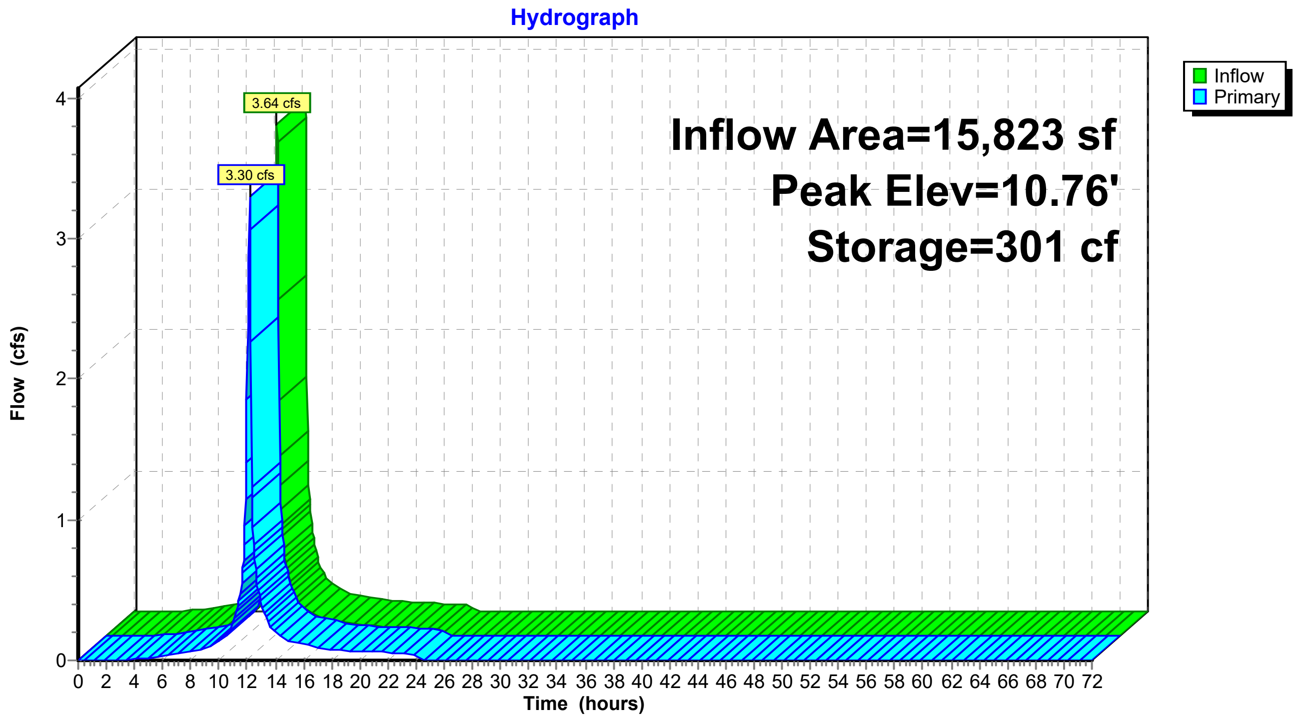
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	790 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	395	0	0
11.00	395	395	395
12.00	395	395	790

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=3.26 cfs @ 12.16 hrs HW=10.74' (Free Discharge)
├─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)
└─**2=Orifice/Grate** (Orifice Controls 3.26 cfs @ 4.15 fps)

Pond GI-8C: Green Infrastructure



Summary for Pond GI-8D: Green Infrastructure

Inflow Area = 34,949 sf, 27.15% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 8.03 cfs @ 12.13 hrs, Volume= 27,446 cf
Outflow = 8.02 cfs @ 12.14 hrs, Volume= 27,446 cf, Atten= 0%, Lag= 0.5 min
Primary = 8.02 cfs @ 12.14 hrs, Volume= 27,446 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.24' @ 12.14 hrs Surf.Area= 988 sf Storage= 1,228 cf

Plug-Flow detention time= 5.4 min calculated for 27,427 cf (100% of inflow)
Center-of-Mass det. time= 5.4 min (795.4 - 790.0)

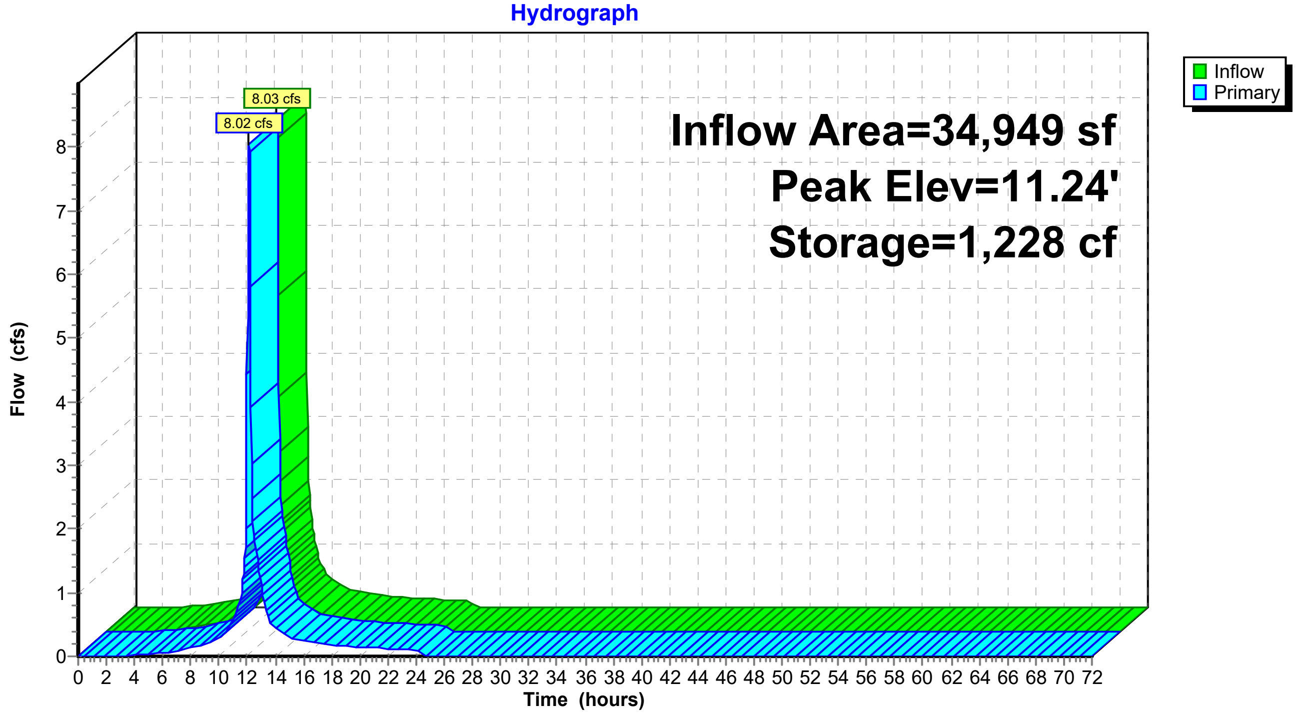
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	1,976 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	988	0	0
11.00	988	988	988
12.00	988	988	1,976

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=7.74 cfs @ 12.14 hrs HW=11.24' (Free Discharge)
└—**1=Broad-Crested Rectangular Weir** (Weir Controls 5.64 cfs @ 1.20 fps)
└—**2=Orifice/Grate** (Orifice Controls 1.05 cfs @ 5.35 fps)
└—**3=Orifice/Grate** (Orifice Controls 1.05 cfs @ 5.35 fps)

Pond GI-8D: Green Infrastructure



Summary for Pond GI-8E: Green Infrastructure

Inflow Area = 66,286 sf, 18.42% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 15.23 cfs @ 12.13 hrs, Volume= 52,056 cf
Outflow = 15.23 cfs @ 12.14 hrs, Volume= 52,056 cf, Atten= 0%, Lag= 0.5 min
Primary = 15.23 cfs @ 12.14 hrs, Volume= 52,056 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.36' @ 12.14 hrs Surf.Area= 1,272 sf Storage= 1,725 cf

Plug-Flow detention time= 4.6 min calculated for 52,020 cf (100% of inflow)
Center-of-Mass det. time= 4.7 min (794.7 - 790.0)

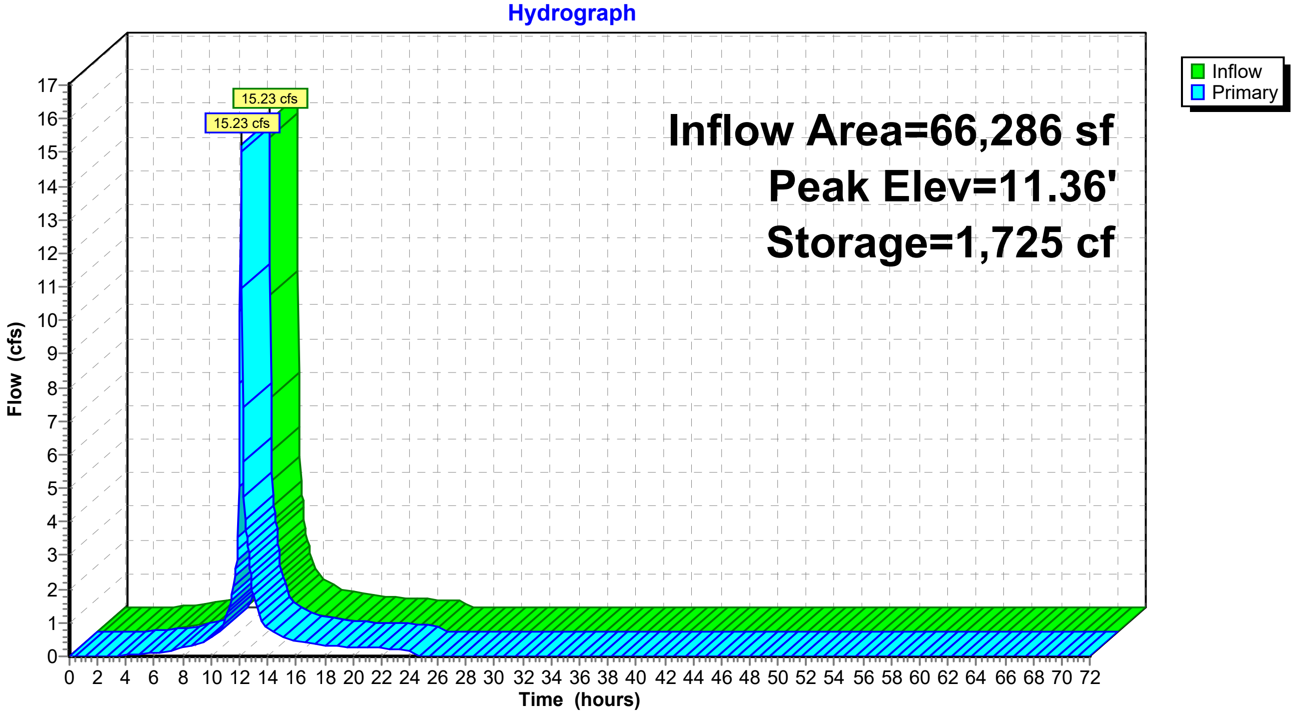
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	2,544 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	1,272	0	0
11.00	1,272	1,272	1,272
12.00	1,272	1,272	2,544

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=14.70 cfs @ 12.14 hrs HW=11.35' (Free Discharge)
1=Broad-Crested Rectangular Weir (Weir Controls 10.31 cfs @ 1.49 fps)
2=Orifice/Grate (Orifice Controls 4.39 cfs @ 5.58 fps)

Pond GI-8E: Green Infrastructure



Summary for Pond GI-9A: Green Infrastructure

[88] Warning: Qout>Qin may require smaller dt or Finer Routing

Inflow Area = 37,664 sf, 5.01% Impervious, Inflow Depth = 9.16" for 100 year -2070 event
Inflow = 8.49 cfs @ 12.13 hrs, Volume= 28,738 cf
Outflow = 8.53 cfs @ 12.13 hrs, Volume= 28,841 cf, Atten= 0%, Lag= 0.0 min
Primary = 8.53 cfs @ 12.13 hrs, Volume= 28,841 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 11.17' @ 12.13 hrs Surf.Area= 196 sf Storage= 230 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 0.4 min (795.2 - 794.8)

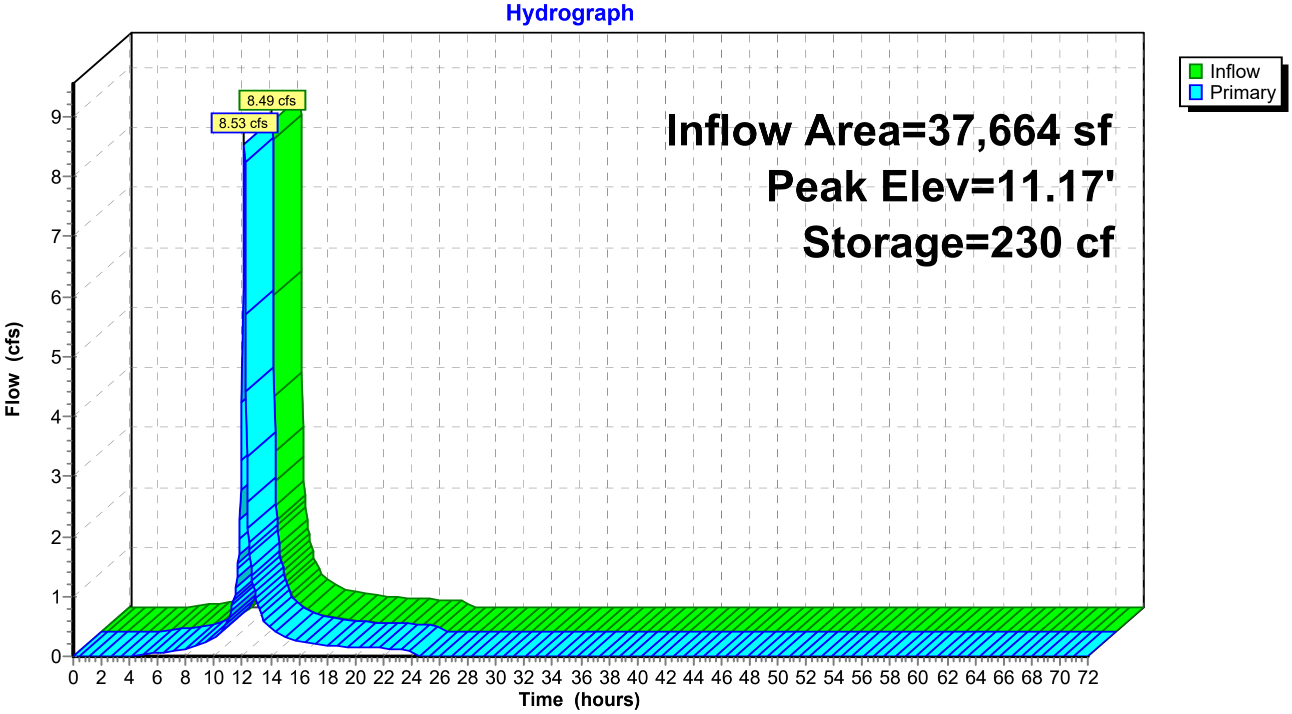
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	392 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	196	0	0
11.00	196	196	196
12.00	196	196	392

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Primary	10.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=8.19 cfs @ 12.13 hrs HW=11.16' (Free Discharge)
—**1=Broad-Crested Rectangular Weir** (Weir Controls 3.11 cfs @ 0.97 fps)
—**2=Orifice/Grate** (Orifice Controls 4.07 cfs @ 5.18 fps)
—**3=Orifice/Grate** (Orifice Controls 1.02 cfs @ 5.18 fps)

Pond GI-9A: Green Infrastructure



Summary for Pond GI-9B: Green Infrastructure

Inflow Area = 30,173 sf, 18.18% Impervious, Inflow Depth = 9.42" for 100 year -2070 event
Inflow = 6.93 cfs @ 12.13 hrs, Volume= 23,696 cf
Outflow = 6.86 cfs @ 12.13 hrs, Volume= 23,696 cf, Atten= 1%, Lag= 0.0 min
Primary = 6.86 cfs @ 12.13 hrs, Volume= 23,696 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 11.15' @ 12.13 hrs Surf.Area= 571 sf Storage= 657 cf

Plug-Flow detention time= 2.6 min calculated for 23,679 cf (100% of inflow)
Center-of-Mass det. time= 2.6 min (792.7 - 790.0)

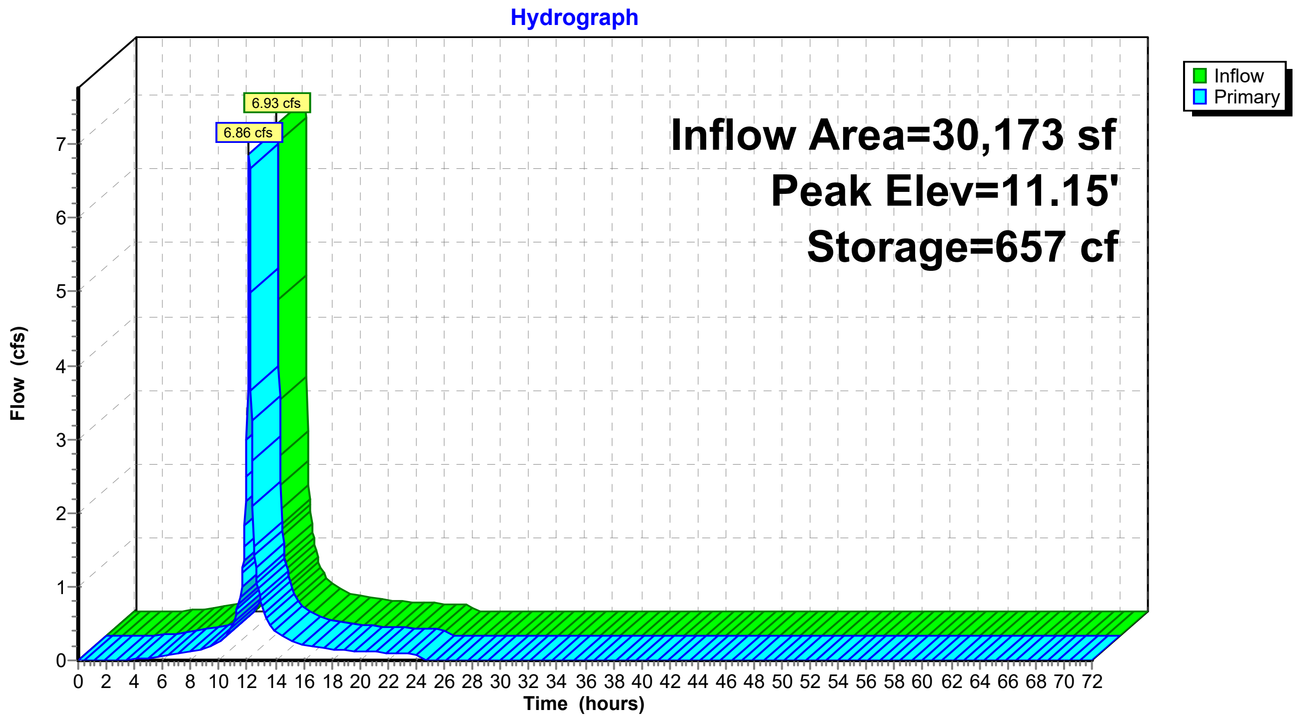
Volume	Invert	Avail.Storage	Storage Description
#1	10.00'	1,142 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
10.00	571	0	0
11.00	571	571	571
12.00	571	571	1,142

Device	Routing	Invert	Outlet Devices
#1	Primary	11.00'	**20.0' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32
#2	Primary	10.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=6.64 cfs @ 12.13 hrs HW=11.14' (Free Discharge)
1=Broad-Crested Rectangular Weir (Weir Controls 2.60 cfs @ 0.92 fps)
2=Orifice/Grate (Orifice Controls 4.04 cfs @ 5.14 fps)

Pond GI-9B: Green Infrastructure



Summary for Pond UG-2F: Central Soccer Field (2070)

Inflow Area = 404,841 sf, 31.43% Impervious, Inflow Depth = 9.95" for 100 year -2070 event
Inflow = 90.44 cfs @ 12.15 hrs, Volume= 335,692 cf
Outflow = 4.53 cfs @ 15.13 hrs, Volume= 332,130 cf, Atten= 95%, Lag= 178.7 min
Primary = 4.53 cfs @ 15.13 hrs, Volume= 332,130 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 1.44' @ 15.13 hrs Surf.Area= 183,286 sf Storage= 206,606 cf

Plug-Flow detention time= 619.5 min calculated for 331,900 cf (99% of inflow)
Center-of-Mass det. time= 613.9 min (1,411.4 - 797.5)

Volume	Invert	Avail.Storage	Storage Description
#1A	0.00'	91,086 cf	**319.75'W x 573.22'L x 3.00'H Field A** 549,858 cf Overall - 246,239 cf Embedded = 303,620 cf x 30.0% Voids
#2A	0.00'	246,239 cf	**ADS_StormTech SC-740 +Cap** x 5360 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 67 Rows of 80 Chambers
		337,324 cf	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Primary	0.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	1.50'	**5.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=4.53 cfs @ 15.13 hrs HW=1.44' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 4.53 cfs @ 5.77 fps)
└─**2=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond UG-2F: Central Soccer Field (2070) - Chamber Wizard Field A

Chamber Model = ADS_StormTechSC-740 +Cap (ADS StormTech®SC-740 with cap length)
Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf
Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap

51.0" Wide + 6.0" Spacing = 57.0" C-C Row Spacing

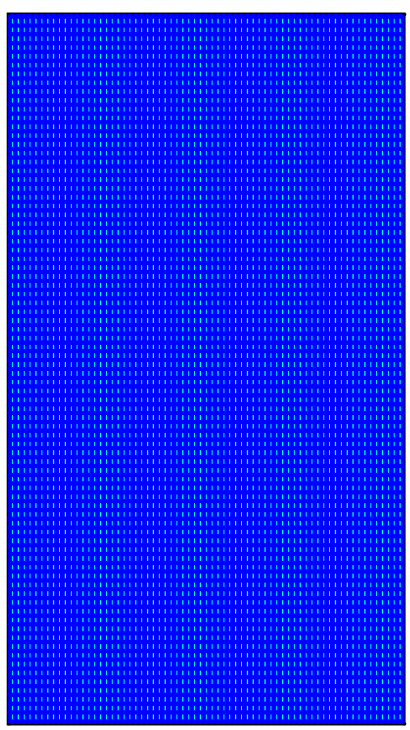
80 Chambers/Row x 7.12' Long +0.81' Cap Length x 2 = 571.22' Row Length +12.0" End Stone x 2 = 573.22' Base Length
67 Rows x 51.0" Wide + 6.0" Spacing x 66 + 12.0" Side Stone x 2 = 319.75' Base Width
30.0" Chamber Height + 6.0" Cover = 3.00' Field Height

5,360 Chambers x 45.9 cf = 246,238.5 cf Chamber Storage

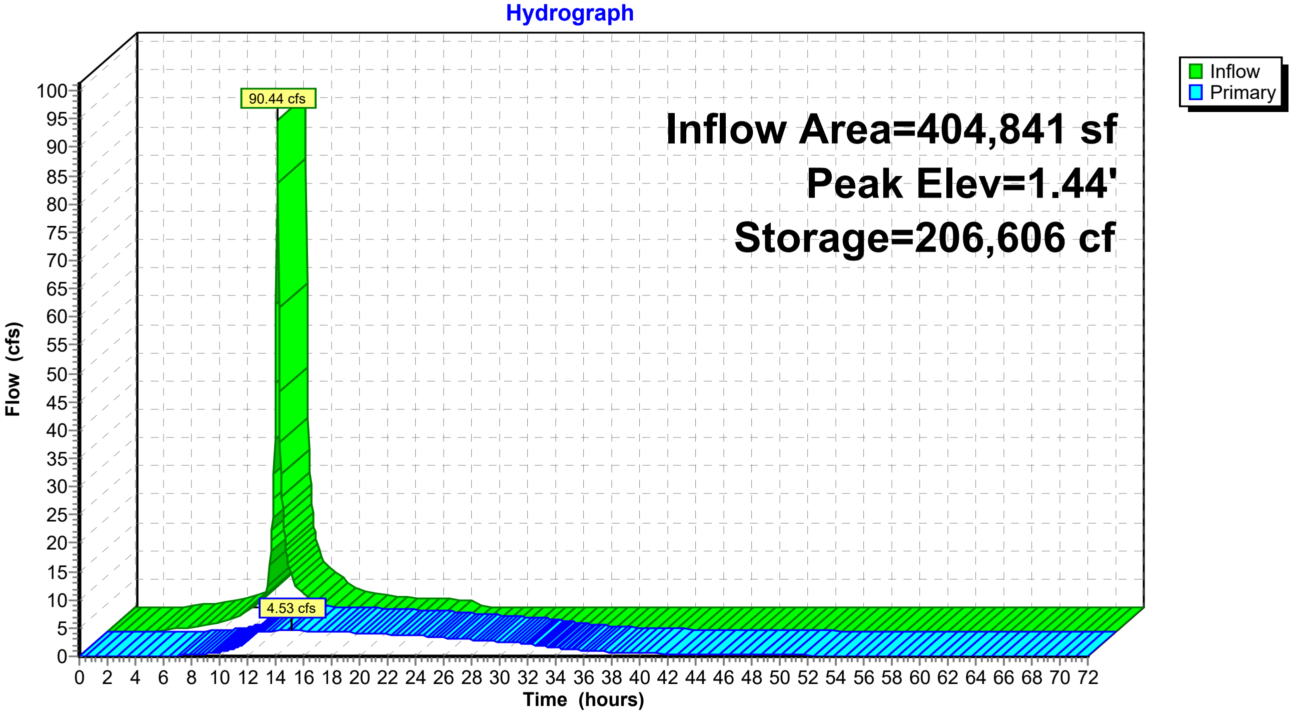
549,858.1 cf Field - 246,238.5 cf Chambers = 303,619.6 cf Stone x 30.0% Voids = 91,085.9 cf Stone Storage

Chamber Storage + Stone Storage = 337,324.4 cf = 7.744 af
Overall Storage Efficiency = 61.3%
Overall System Size = 573.22' x 319.75' x 3.00'

5,360 Chambers
20,365.1 cy Field
11,245.2 cy Stone



Pond UG-2F: Central Soccer Field (2070)



Summary for Pond UG-3F: Central LL System (2070)

Inflow Area = 1,117,522 sf, 30.42% Impervious, Inflow Depth = 9.58" for 100 year -2070 event
Inflow = 239.33 cfs @ 12.15 hrs, Volume= 892,212 cf
Outflow = 23.10 cfs @ 13.42 hrs, Volume= 891,395 cf, Atten= 90%, Lag= 76.0 min
Primary = 23.10 cfs @ 13.42 hrs, Volume= 891,395 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 2.56' @ 13.42 hrs Surf.Area= 286,156 sf Storage= 489,904 cf

Plug-Flow detention time= 522.2 min calculated for 891,395 cf (100% of inflow)
Center-of-Mass det. time= 521.5 min (1,322.8 - 801.4)

Volume	Invert	Avail.Storage	Storage Description
#1A	0.00'	289,990 cf	**388.25'W x 737.04'L x 5.50'H Field A** 1,573,857 cf Overall - 607,225 cf Embedded = 966,632 cf x 30.0% Voids
#2A	0.75'	607,225 cf	**ADS_StormTech MC-3500 d +Cap** x 5508 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 54 Rows of 102 Chambers Cap Storage= +14.9 cf x 2 x 54 rows = 1,609.2 cf
		897,214 cf	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Primary	0.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	1.50'	**5.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=23.09 cfs @ 13.42 hrs HW=2.56' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 6.05 cfs @ 7.70 fps)
└─**2=Sharp-Crested Rectangular Weir** (Weir Controls 17.05 cfs @ 3.36 fps)

Pond UG-3F: Central LL System (2070) - Chamber Wizard Field A

Chamber Model = ADS_StormTechMC-3500 d +Cap (ADS StormTech®MC-3500 d rev 03/14 with Cap volume)
Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf
Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap
Cap Storage= +14.9 cf x 2 x 54 rows = 1,609.2 cf

77.0" Wide + 9.0" Spacing = 86.0" C-C Row Spacing

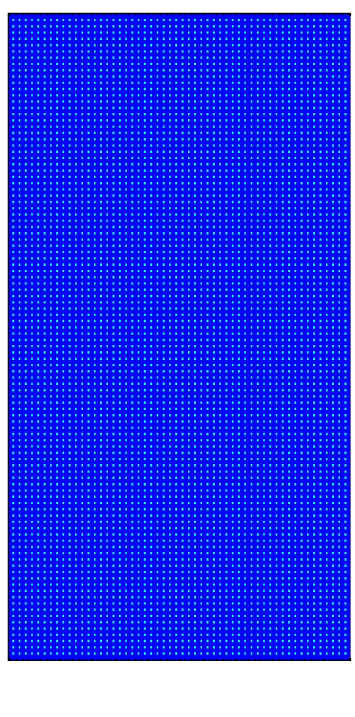
102 Chambers/Row x 7.17' Long +1.85' Cap Length x 2 = 735.04' Row Length +12.0" End Stone x 2 = 737.04' Base Length
54 Rows x 77.0" Wide + 9.0" Spacing x 53 + 12.0" Side Stone x 2 = 388.25' Base Width
9.0" Base + 45.0" Chamber Height + 12.0" Cover = 5.50' Field Height

5,508 Chambers x 110.0 cf + 14.9 cf Cap Volume x 2 x 54 Rows = 607,224.5 cf Chamber Storage

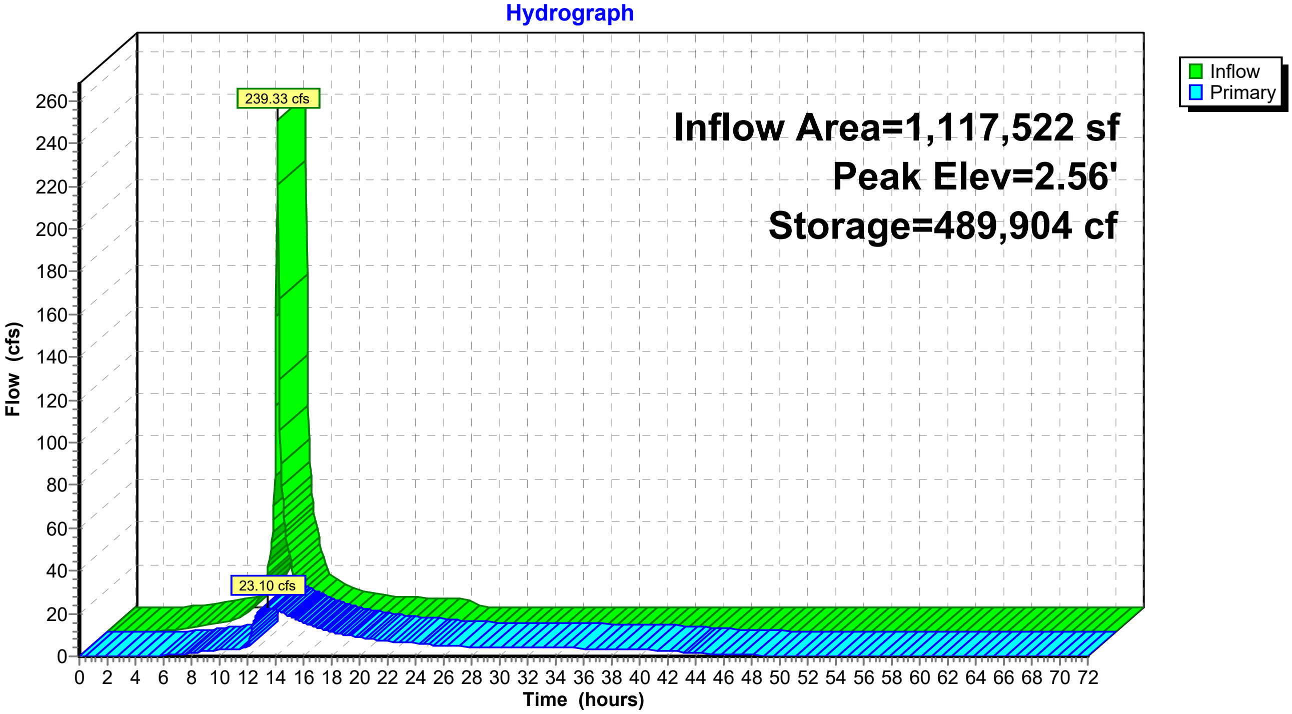
1,573,856.8 cf Field - 607,224.5 cf Chambers = 966,632.2 cf Stone x 30.0% Voids = 289,989.7 cf Stone Storage

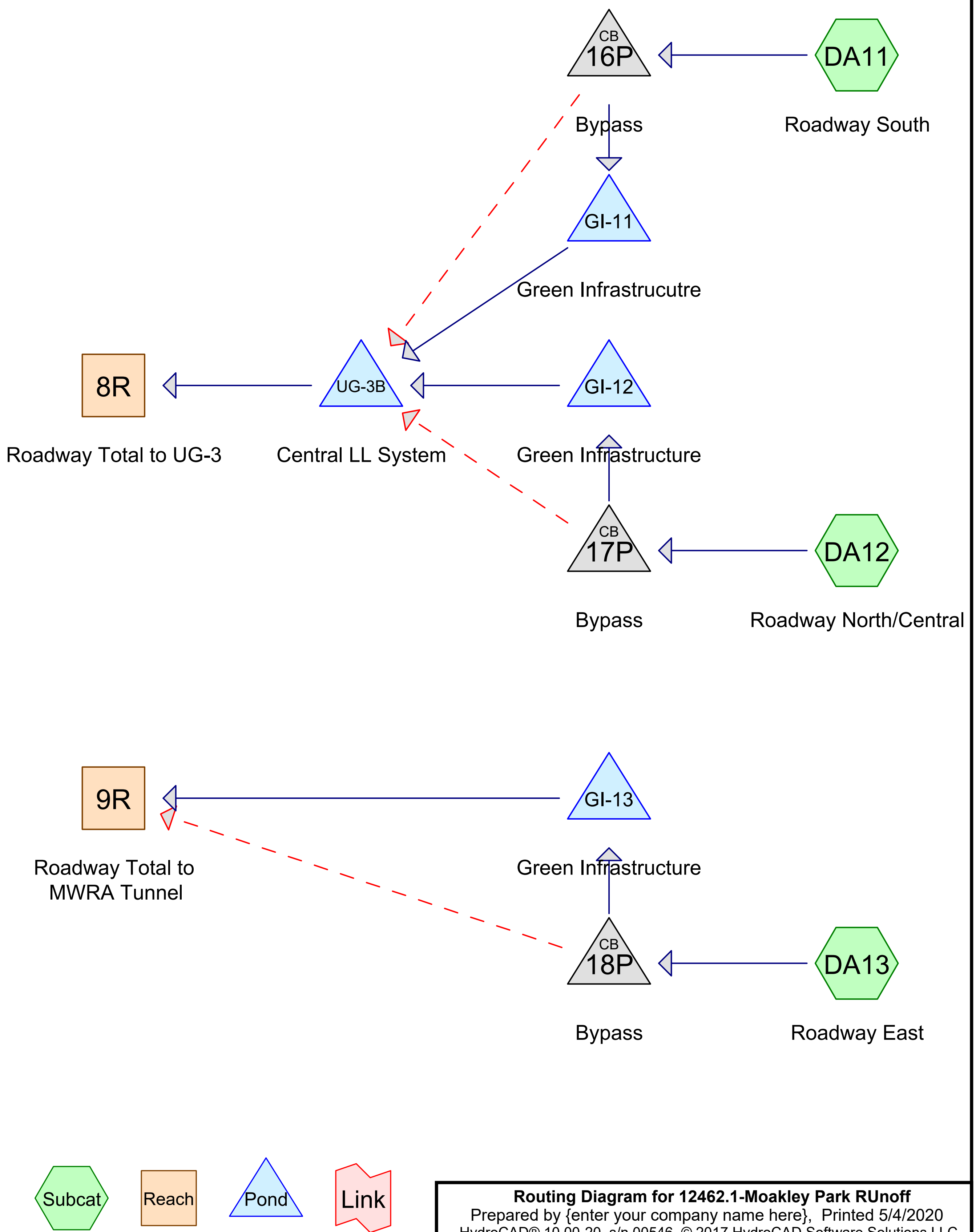
Chamber Storage + Stone Storage = 897,214.2 cf = 20.597 af
Overall Storage Efficiency = 57.0%
Overall System Size = 737.04' x 388.25' x 5.50'

5,508 Chambers
58,291.0 cy Field
35,801.2 cy Stone



Pond UG-3F: Central LL System (2070)





Routing Diagram for 12462.1-Moakley Park RUnoff
Prepared by {enter your company name here}, Printed 5/4/2020
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Area Listing (selected nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
133,349	98	Impervious, HSG D (DA11, DA12, DA13)
133,349	**98**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
0	HSG A	
0	HSG B	
0	HSG C	
133,349	HSG D	DA11, DA12, DA13
0	Other	
133,349		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	Subcatchment Numbers
0	0	0	133,349	0	133,349	Impervious	DA11, DA12, DA13
0	**0**	**0**	**133,349**	**0**	**133,349**	**TOTAL AREA**	

Time span=0.00-72.00 hrs, dt=0.05 hrs, 1441 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

SubcatchmentDA11: Roadway South Runoff Area=21,993 sf 100.00% Impervious Runoff Depth=7.85"
Tc=6.0 min CN=98 Runoff=3.78 cfs 14,387 cf

SubcatchmentDA12: Roadway Runoff Area=61,916 sf 100.00% Impervious Runoff Depth=7.85"
Tc=6.0 min CN=98 Runoff=10.65 cfs 40,504 cf

SubcatchmentDA13: Roadway East Runoff Area=49,440 sf 100.00% Impervious Runoff Depth=7.85"
Tc=6.0 min CN=98 Runoff=8.51 cfs 32,343 cf

Reach 8R: Roadway Total to UG-3 Inflow=3.13 cfs 52,251 cf
Outflow=3.13 cfs 52,251 cf

Reach 9R: Roadway Total to MWRA Tunnel Inflow=8.04 cfs 32,298 cf
Outflow=8.04 cfs 32,298 cf

Pond 16P: Bypass Peak Elev=16.18' Inflow=3.78 cfs 14,387 cf
Primary=1.03 cfs 11,848 cf Secondary=2.76 cfs 2,539 cf Outflow=3.78 cfs 14,387 cf

Pond 17P: Bypass Peak Elev=16.51' Inflow=10.65 cfs 40,504 cf
Primary=3.23 cfs 33,591 cf Secondary=7.42 cfs 6,914 cf Outflow=10.65 cfs 40,504 cf

Pond 18P: Bypass Peak Elev=16.25' Inflow=8.51 cfs 32,343 cf
Primary=4.24 cfs 29,397 cf Secondary=4.26 cfs 2,946 cf Outflow=8.51 cfs 32,343 cf

Pond GI-11: Green Infrastrucutre Peak Elev=15.57' Storage=1,299 cf Inflow=1.03 cfs 11,848 cf
Outflow=0.99 cfs 11,843 cf

Pond GI-12: Green Infrastructure Peak Elev=15.88' Storage=5,671 cf Inflow=3.23 cfs 33,591 cf
Outflow=2.39 cfs 33,591 cf

Pond GI-13: Green Infrastructure Peak Elev=15.75' Storage=3,854 cf Inflow=4.24 cfs 29,397 cf
Outflow=3.90 cfs 29,352 cf

Pond UG-3B: Central LL System Peak Elev=9.68' Storage=17,599 cf Inflow=13.26 cfs 54,886 cf
Outflow=3.13 cfs 52,251 cf

Total Runoff Area = 133,349 sf Runoff Volume = 87,234 cf Average Runoff Depth = 7.85"
0.00% Pervious = 0 sf 100.00% Impervious = 133,349 sf

Summary for Subcatchment DA11: Roadway South

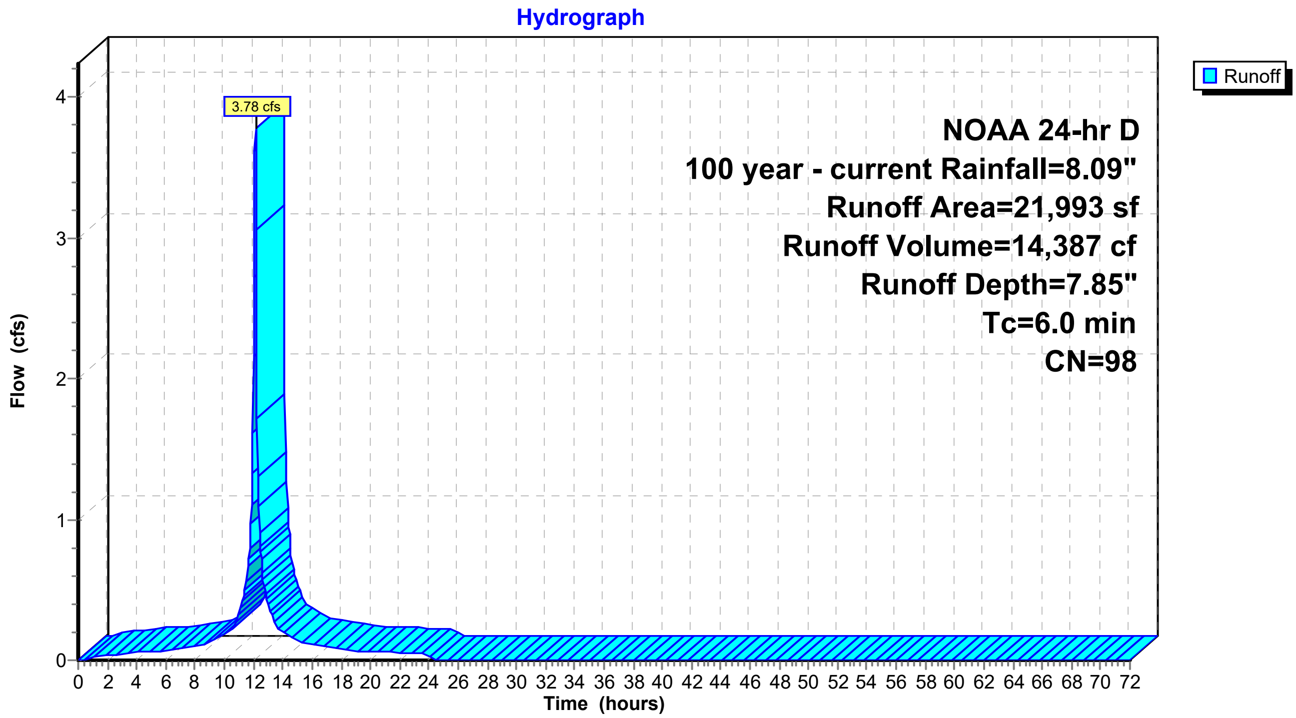
Runoff = 3.78 cfs @ 12.13 hrs, Volume= 14,387 cf, Depth= 7.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	21,993	98	Impervious, HSG D
	21,993		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA11: Roadway South



Summary for Subcatchment DA12: Roadway North/Central

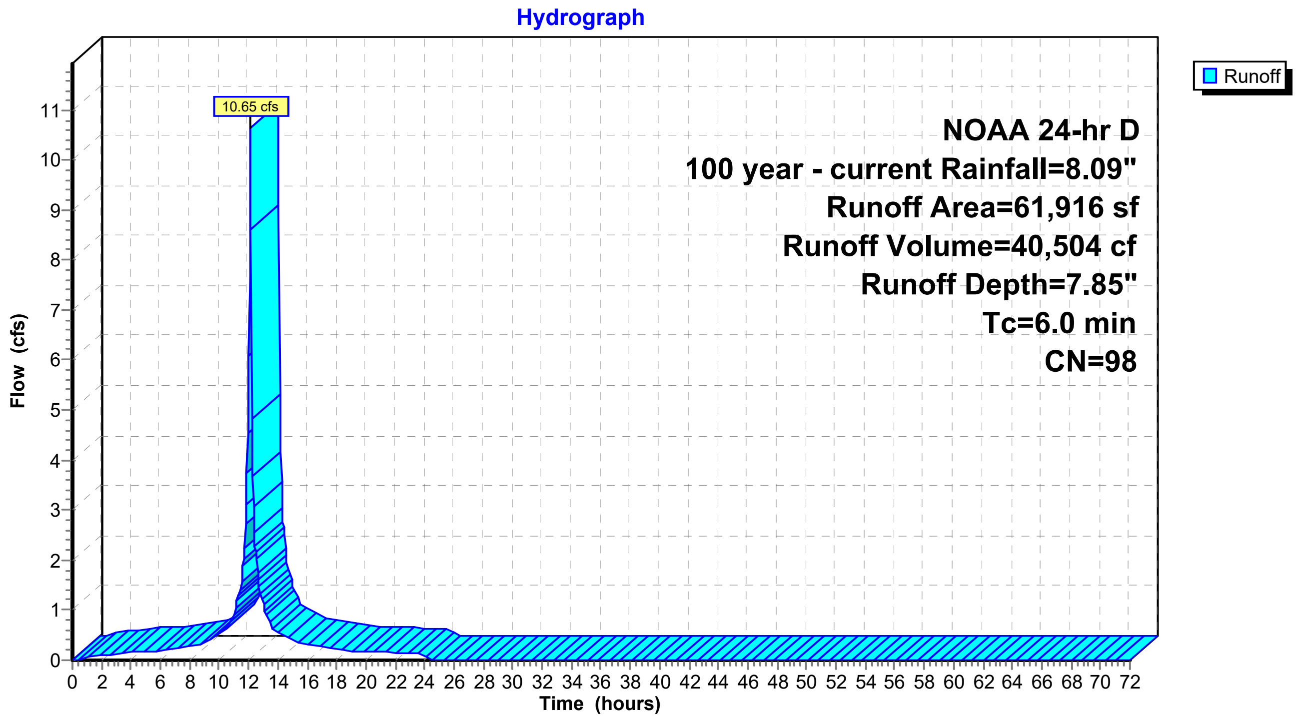
Runoff = 10.65 cfs @ 12.13 hrs, Volume= 40,504 cf, Depth= 7.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	61,916	98	Impervious, HSG D
	61,916		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA12: Roadway North/Central



Summary for Subcatchment DA13: Roadway East

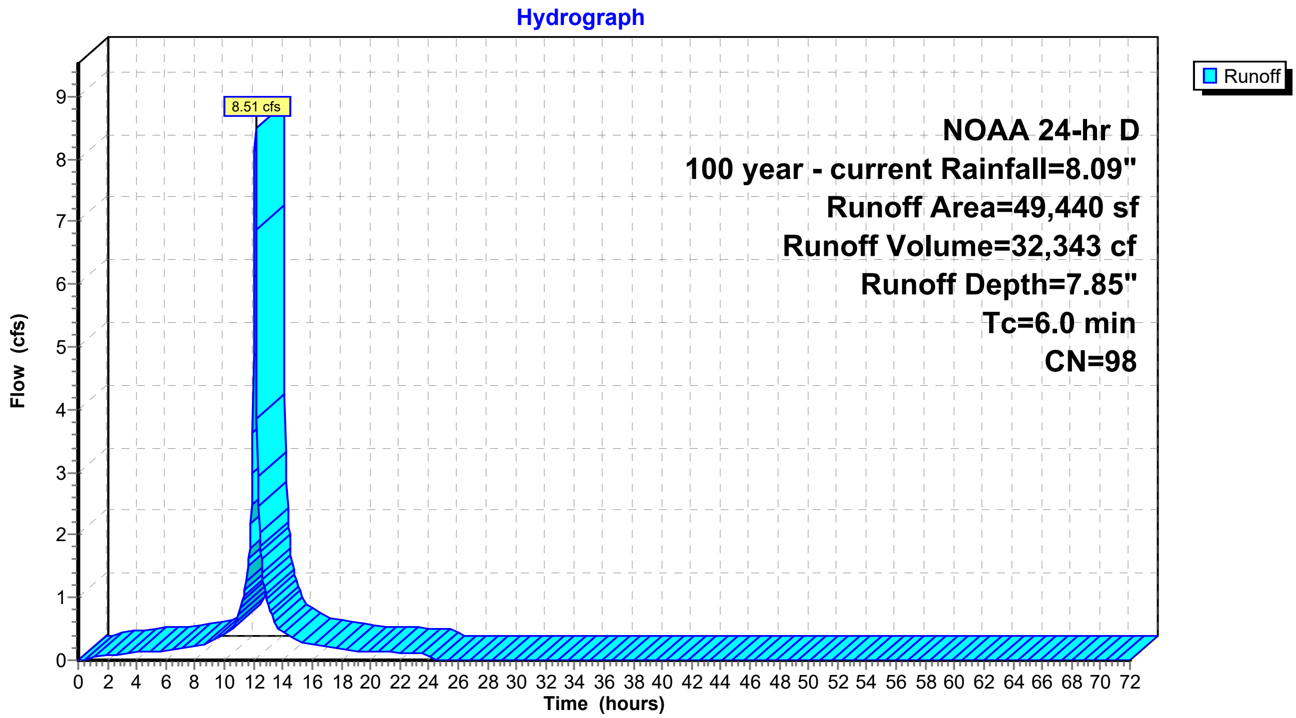
Runoff = 8.51 cfs @ 12.13 hrs, Volume= 32,343 cf, Depth= 7.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
NOAA 24-hr D 100 year - current Rainfall=8.09"

	Area (sf)	CN	Description
*	49,440	98	Impervious, HSG D
	49,440		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment DA13: Roadway East

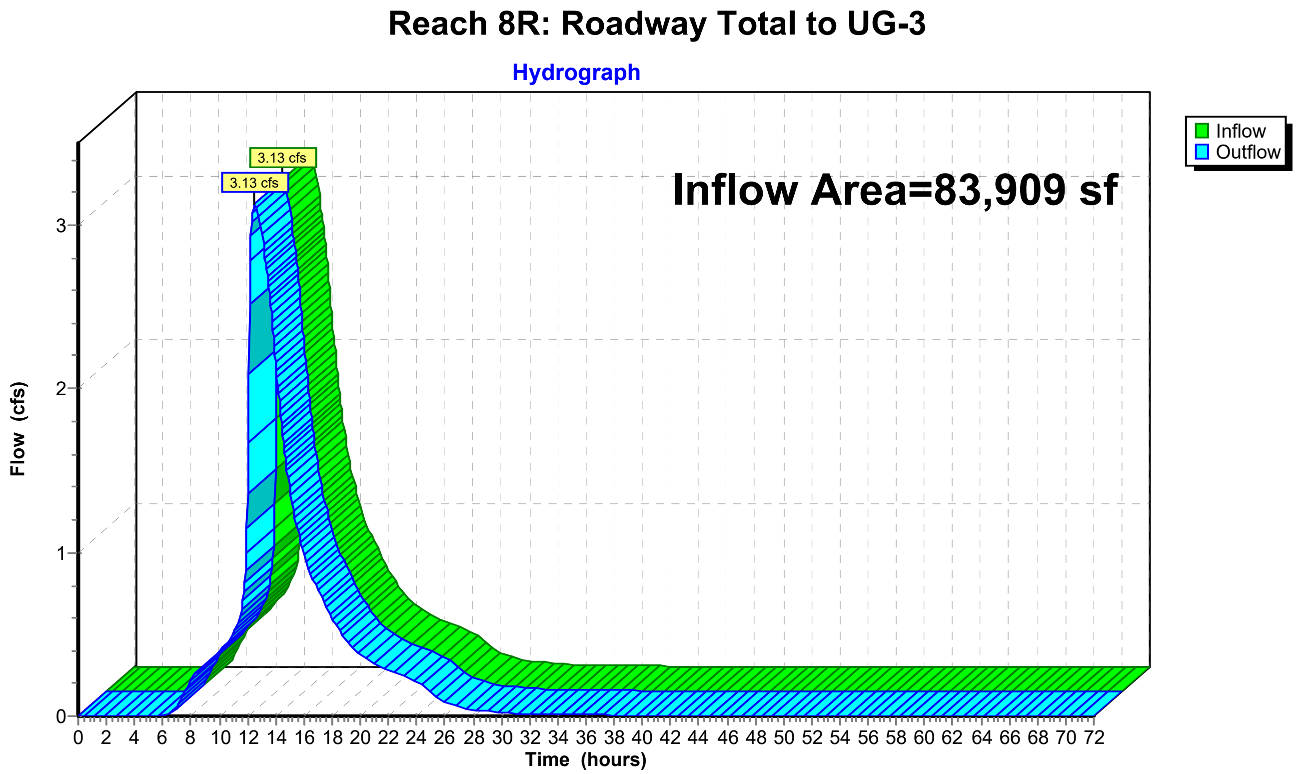


Summary for Reach 8R: Roadway Total to UG-3

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 83,909 sf,100.00% Impervious, Inflow Depth = 7.47" for 100 year - current event
Inflow = 3.13 cfs @ 12.54 hrs, Volume= 52,251 cf
Outflow = 3.13 cfs @ 12.54 hrs, Volume= 52,251 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs

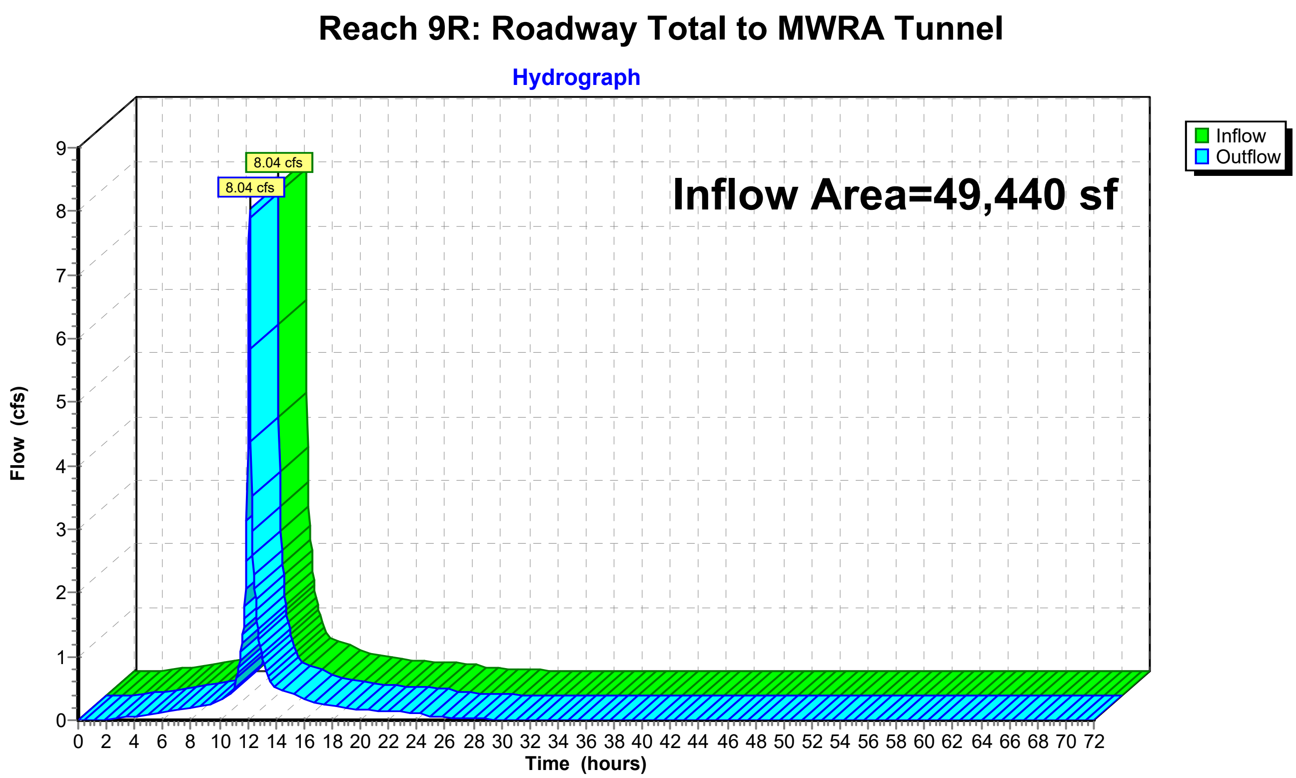


Summary for Reach 9R: Roadway Total to MWRA Tunnel

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 49,440 sf,100.00% Impervious, Inflow Depth = 7.84" for 100 year - current event
Inflow = 8.04 cfs @ 12.13 hrs, Volume= 32,298 cf
Outflow = 8.04 cfs @ 12.13 hrs, Volume= 32,298 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs



Summary for Pond 16P: Bypass

[57] Hint: Peaked at 16.18' (Flood elevation advised)

Inflow Area =	21,993 sf,100.00% Impervious,	Inflow Depth = 7.85"	for 100 year - current event	
Inflow =	3.78 cfs @	12.13 hrs, Volume=	14,387 cf	
Outflow =	3.78 cfs @	12.13 hrs, Volume=	14,387 cf,	Atten= 0%, Lag= 0.0 min
Primary =	1.03 cfs @	12.13 hrs, Volume=	11,848 cf	
Secondary =	2.76 cfs @	12.13 hrs, Volume=	2,539 cf	

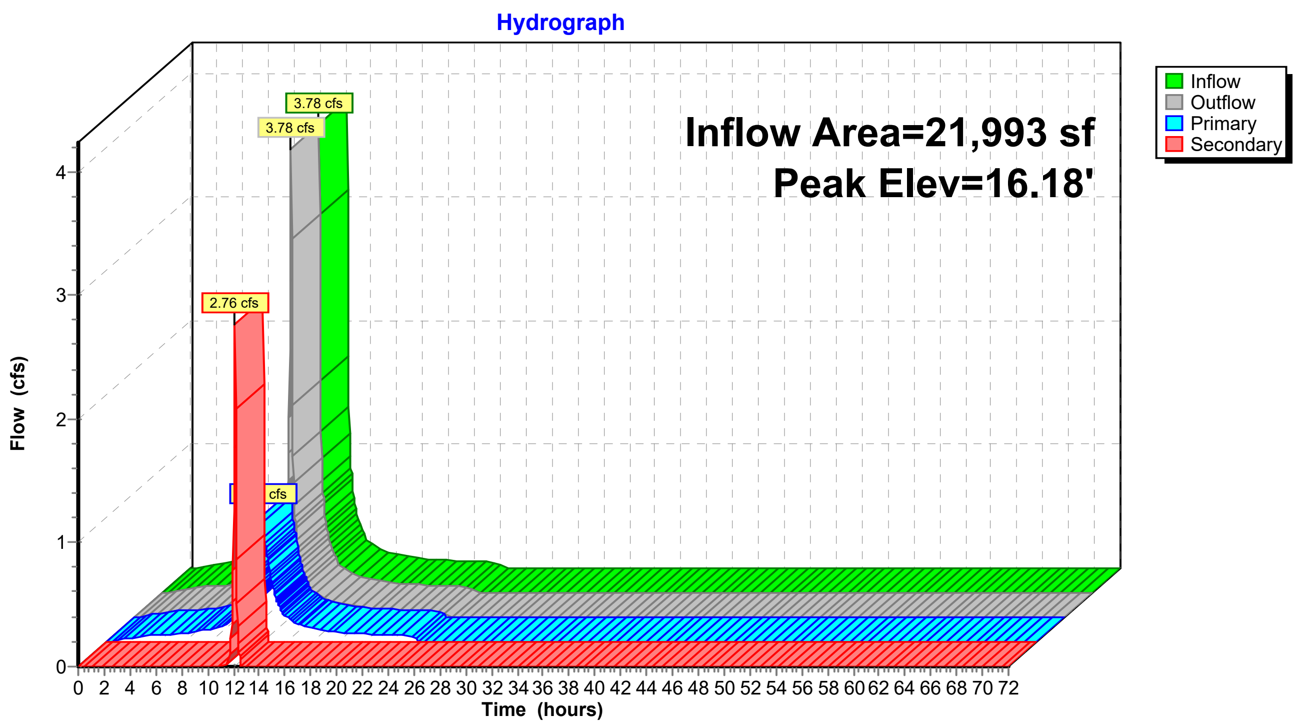
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.18' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.40'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=1.01 cfs @ 12.13 hrs HW=16.15' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 1.01 cfs @ 5.17 fps)

Secondary OutFlow Max=2.62 cfs @ 12.13 hrs HW=16.15' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 2.62 cfs @ 2.95 fps)

Pond 16P: Bypass



Summary for Pond 17P: Bypass

[57] Hint: Peaked at 16.51' (Flood elevation advised)

Inflow Area =	61,916 sf,100.00% Impervious,	Inflow Depth = 7.85"	for 100 year - current event	
Inflow =	10.65 cfs @	12.13 hrs, Volume=	40,504 cf	
Outflow =	10.65 cfs @	12.13 hrs, Volume=	40,504 cf,	Atten= 0%, Lag= 0.0 min
Primary =	3.23 cfs @	12.13 hrs, Volume=	33,591 cf	
Secondary =	7.42 cfs @	12.13 hrs, Volume=	6,914 cf	

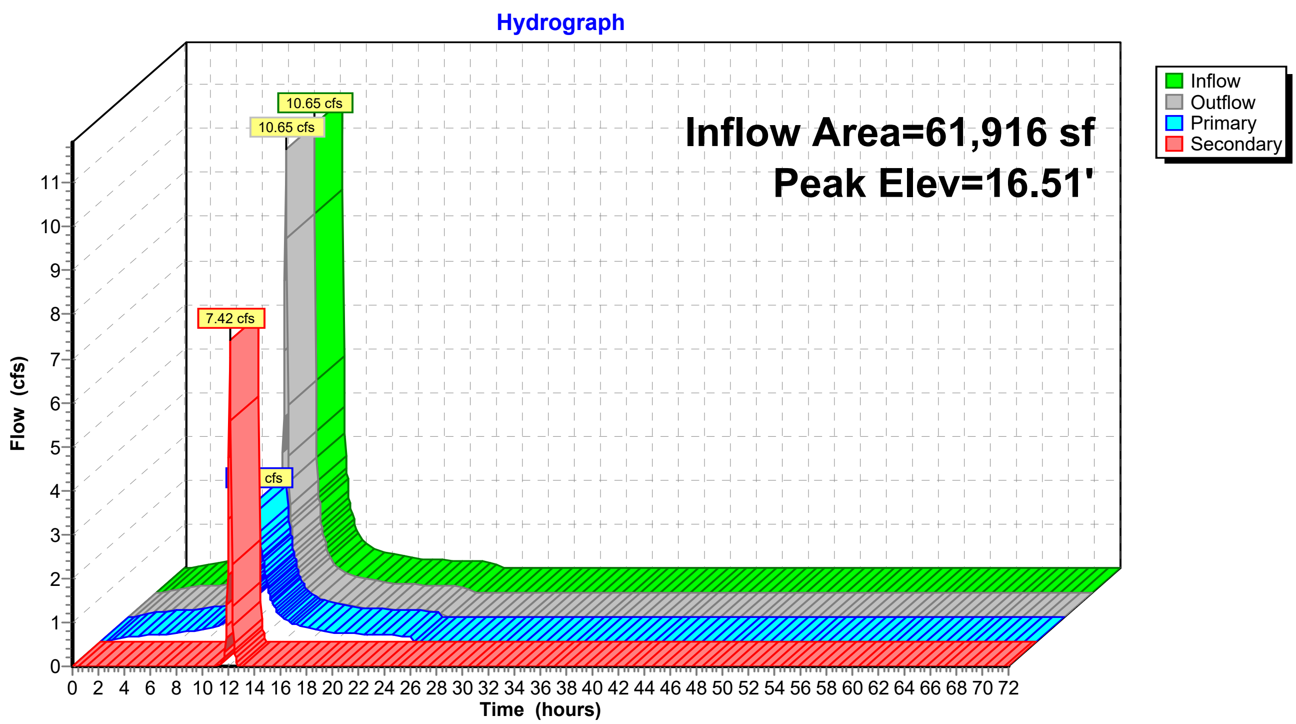
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.51' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**10.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.30'	**24.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=3.19 cfs @ 12.13 hrs HW=16.47' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 3.19 cfs @ 5.84 fps)

Secondary OutFlow Max=7.04 cfs @ 12.13 hrs HW=16.47' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 7.04 cfs @ 3.68 fps)

Pond 17P: Bypass



Summary for Pond 18P: Bypass

[57] Hint: Peaked at 16.25' (Flood elevation advised)

Inflow Area = 49,440 sf,100.00% Impervious, Inflow Depth = 7.85" for 100 year - current event
Inflow = 8.51 cfs @ 12.13 hrs, Volume= 32,343 cf
Outflow = 8.51 cfs @ 12.13 hrs, Volume= 32,343 cf, Atten= 0%, Lag= 0.0 min
Primary = 4.24 cfs @ 12.13 hrs, Volume= 29,397 cf
Secondary = 4.26 cfs @ 12.13 hrs, Volume= 2,946 cf

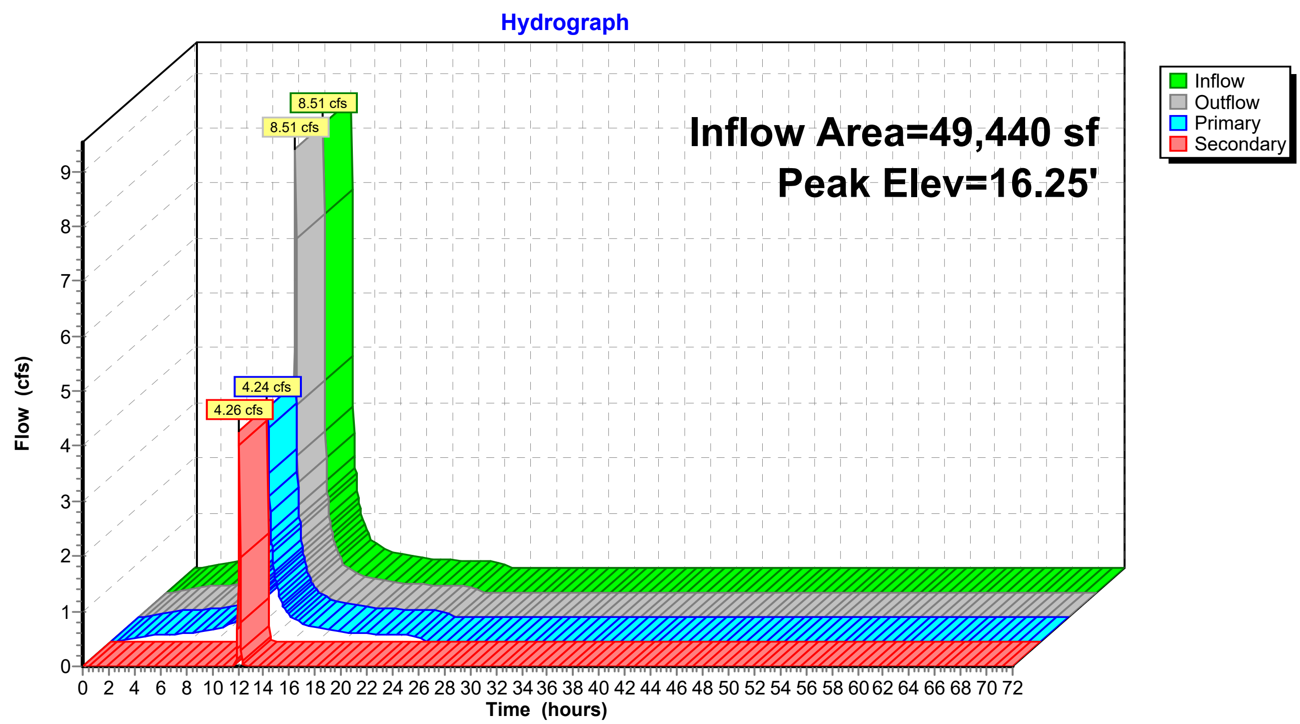
Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 16.25' @ 12.13 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**12.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Secondary	15.25'	**18.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=4.16 cfs @ 12.13 hrs HW=16.21' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 4.16 cfs @ 5.30 fps)

Secondary OutFlow Max=4.00 cfs @ 12.13 hrs HW=16.21' (Free Discharge)
└─**2=Orifice/Grate** (Orifice Controls 4.00 cfs @ 3.34 fps)

Pond 18P: Bypass



Summary for Pond GI-11: Green Infrastrucutre

[81] Warning: Exceeded Pond 16P by 0.31' @ 13.10 hrs

Inflow Area = 21,993 sf,100.00% Impervious, Inflow Depth = 6.46" for 100 year - current event
Inflow = 1.03 cfs @ 12.13 hrs, Volume= 11,848 cf
Outflow = 0.99 cfs @ 12.17 hrs, Volume= 11,843 cf, Atten= 4%, Lag= 2.5 min
Primary = 0.99 cfs @ 12.17 hrs, Volume= 11,843 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.57' @ 12.17 hrs Surf.Area= 2,291 sf Storage= 1,299 cf

Plug-Flow detention time= 58.9 min calculated for 11,835 cf (100% of inflow)
Center-of-Mass det. time= 60.1 min (805.3 - 745.2)

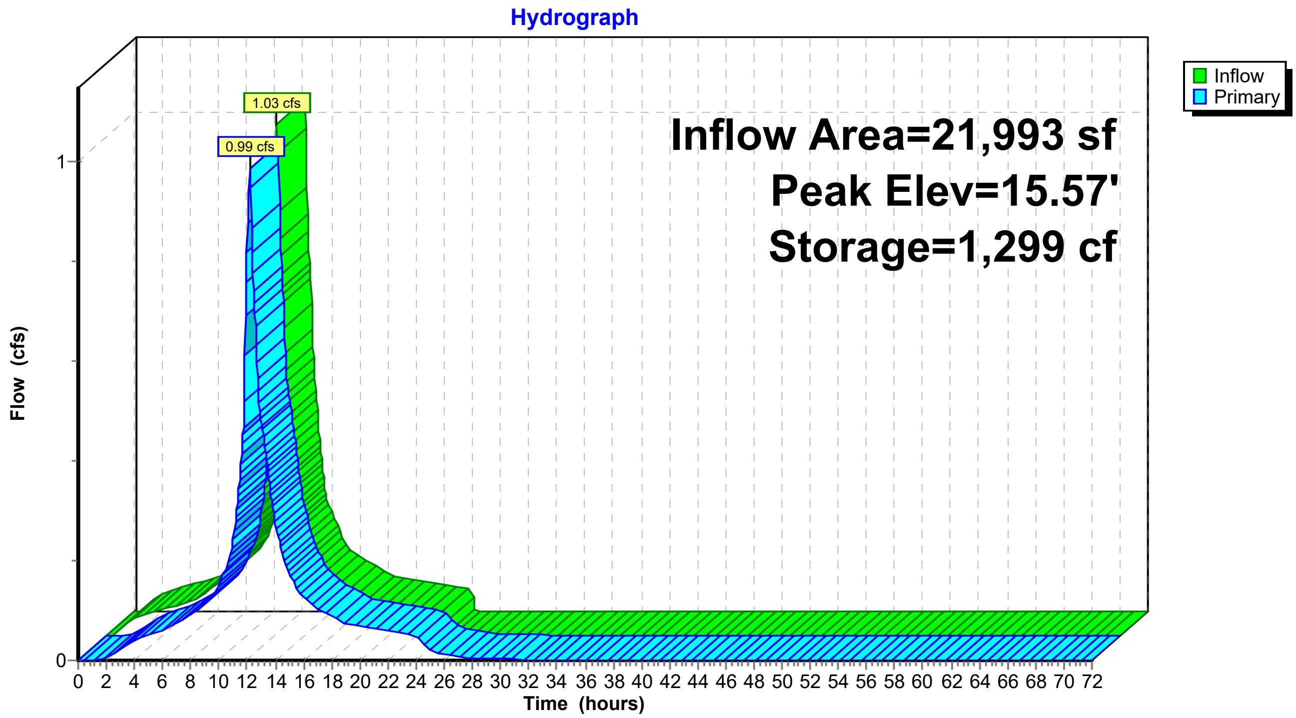
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	2,291 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	2,291	0	0
16.00	2,291	2,291	2,291

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Vert. Orifice/Grate** C= 0.600
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=0.98 cfs @ 12.17 hrs HW=15.57' (Free Discharge)
1=Orifice/Grate (Orifice Controls 0.53 cfs @ 2.71 fps)
2=Orifice/Grate (Weir Controls 0.45 cfs @ 0.84 fps)

Pond GI-11: Green Infrastrucutre



Summary for Pond GI-12: Green Infrastructure

[81] Warning: Exceeded Pond 17P by 0.49' @ 12.80 hrs

Inflow Area = 61,916 sf,100.00% Impervious, Inflow Depth = 6.51" for 100 year - current event
Inflow = 3.23 cfs @ 12.13 hrs, Volume= 33,591 cf
Outflow = 2.39 cfs @ 12.29 hrs, Volume= 33,591 cf, Atten= 26%, Lag= 9.7 min
Primary = 2.39 cfs @ 12.29 hrs, Volume= 33,591 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.88' @ 12.29 hrs Surf.Area= 6,450 sf Storage= 5,671 cf

Plug-Flow detention time= 60.6 min calculated for 33,591 cf (100% of inflow)
Center-of-Mass det. time= 59.8 min (804.9 - 745.1)

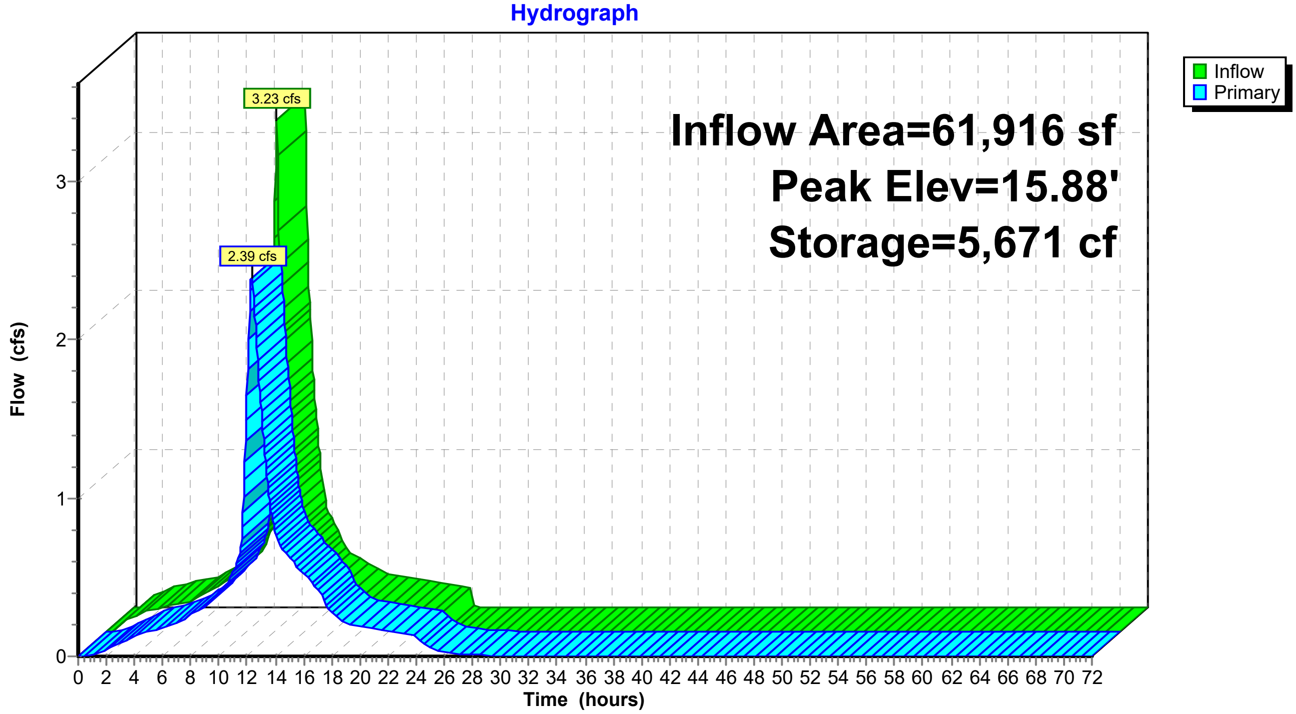
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	6,450 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	6,450	0	0
16.00	6,450	6,450	6,450

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	15.50'	**24.0" W x 24.0" H Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=2.38 cfs @ 12.29 hrs HW=15.88' (Free Discharge)
—**1=Orifice/Grate** (Orifice Controls 0.89 cfs @ 4.51 fps)
—**2=Orifice/Grate** (Orifice Controls 1.50 cfs @ 1.98 fps)

Pond GI-12: Green Infrastructure



Summary for Pond GI-13: Green Infrastructure

[81] Warning: Exceeded Pond 18P by 0.39' @ 13.60 hrs

Inflow Area = 49,440 sf,100.00% Impervious, Inflow Depth = 7.14" for 100 year - current event
Inflow = 4.24 cfs @ 12.13 hrs, Volume= 29,397 cf
Outflow = 3.90 cfs @ 12.18 hrs, Volume= 29,352 cf, Atten= 8%, Lag= 3.0 min
Primary = 3.90 cfs @ 12.18 hrs, Volume= 29,352 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 15.75' @ 12.18 hrs Surf.Area= 5,150 sf Storage= 3,854 cf

Plug-Flow detention time= 81.1 min calculated for 29,332 cf (100% of inflow)
Center-of-Mass det. time= 81.7 min (825.1 - 743.4)

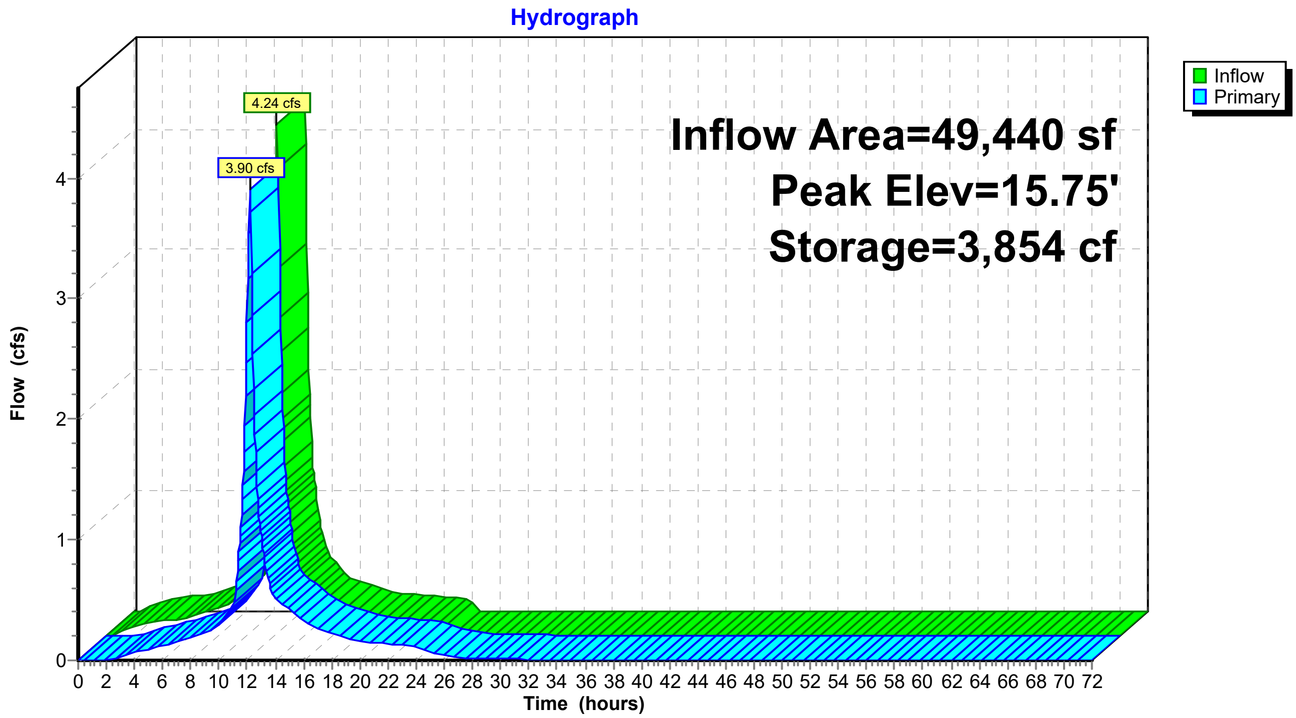
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	5,150 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	5,150	0	0
16.00	5,150	5,150	5,150

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**6.0" Vert. Orifice/Grate** C= 0.600
#2	Primary	15.50'	**24.0" x 24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=3.87 cfs @ 12.18 hrs HW=15.75' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.67 cfs @ 3.39 fps)
└─**2=Orifice/Grate** (Weir Controls 3.20 cfs @ 1.62 fps)

Pond GI-13: Green Infrastructure



Summary for Pond UG-3B: Central LL System

Inflow Area = 83,909 sf,100.00% Impervious, Inflow Depth = 7.85" for 100 year - current event
Inflow = 13.26 cfs @ 12.13 hrs, Volume= 54,886 cf
Outflow = 3.13 cfs @ 12.54 hrs, Volume= 52,251 cf, Atten= 76%, Lag= 24.7 min
Primary = 3.13 cfs @ 12.54 hrs, Volume= 52,251 cf

Routing by Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.05 hrs
Peak Elev= 9.68' @ 12.54 hrs Surf.Area= 17,552 sf Storage= 17,599 cf

Plug-Flow detention time= 146.1 min calculated for 52,214 cf (95% of inflow)
Center-of-Mass det. time= 114.5 min (905.9 - 791.4)

Volume	Invert	Avail.Storage	Storage Description
#1A	8.00'	18,113 cf	**130.25'W x 134.76'L x 5.50'H Field A** 96,539 cf Overall - 36,161 cf Embedded = 60,378 cf x 30.0% Voids
#2A	8.75'	36,161 cf	**ADS_StormTech MC-3500 d +Cap** x 324 Inside #1 Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap 18 Rows of 18 Chambers Cap Storage= +14.9 cf x 2 x 18 rows = 536.4 cf
		54,274 cf	Total Available Storage

Storage Group A created with Chamber Wizard

Device	Routing	Invert	Outlet Devices
#1	Primary	8.50'	**12.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=3.13 cfs @ 12.54 hrs HW=9.68' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 3.13 cfs @ 3.98 fps)

Pond UG-3B: Central LL System - Chamber Wizard Field A

Chamber Model = ADS_StormTechMC-3500 d +Cap (ADS StormTech®MC-3500 d rev 03/14 with Cap volume)
Effective Size= 70.4"W x 45.0"H => 15.33 sf x 7.17'L = 110.0 cf
Overall Size= 77.0"W x 45.0"H x 7.50'L with 0.33' Overlap
Cap Storage= +14.9 cf x 2 x 18 rows = 536.4 cf

77.0" Wide + 9.0" Spacing = 86.0" C-C Row Spacing

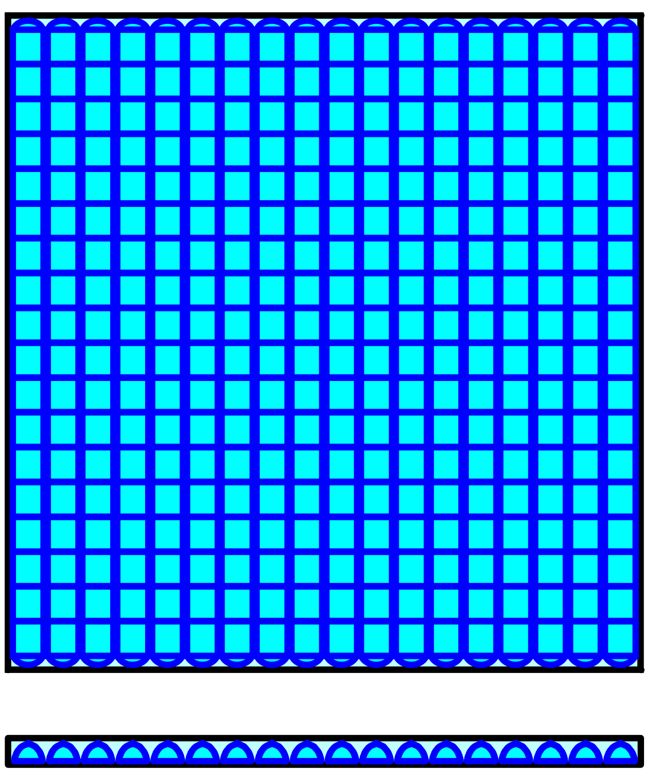
18 Chambers/Row x 7.17' Long +1.85' Cap Length x 2 = 132.76' Row Length +12.0" End Stone x 2 = 134.76' Base Length
18 Rows x 77.0" Wide + 9.0" Spacing x 17 + 12.0" Side Stone x 2 = 130.25' Base Width
9.0" Base + 45.0" Chamber Height + 12.0" Cover = 5.50' Field Height

324 Chambers x 110.0 cf + 14.9 cf Cap Volume x 2 x 18 Rows = 36,160.8 cf Chamber Storage

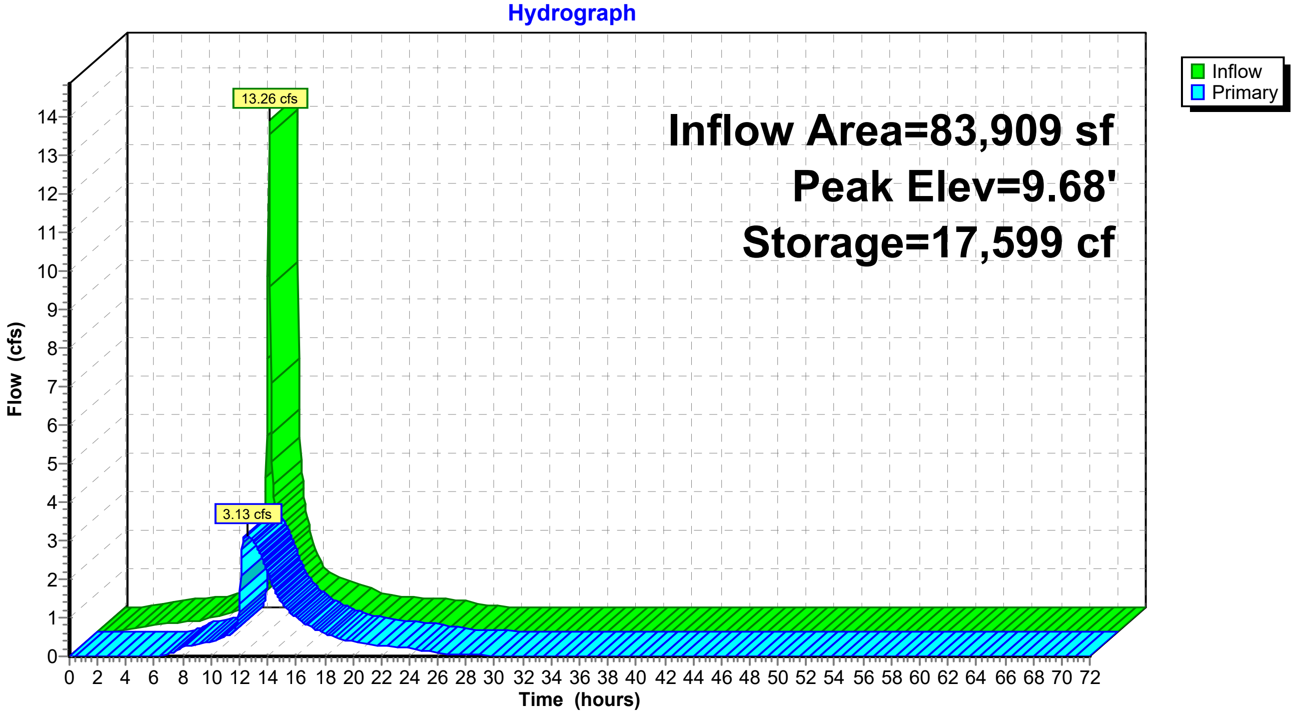
96,538.7 cf Field - 36,160.8 cf Chambers = 60,377.9 cf Stone x 30.0% Voids = 18,113.4 cf Stone Storage

Chamber Storage + Stone Storage = 54,274.2 cf = 1.246 af
Overall Storage Efficiency = 56.2%
Overall System Size = 134.76' x 130.25' x 5.50'

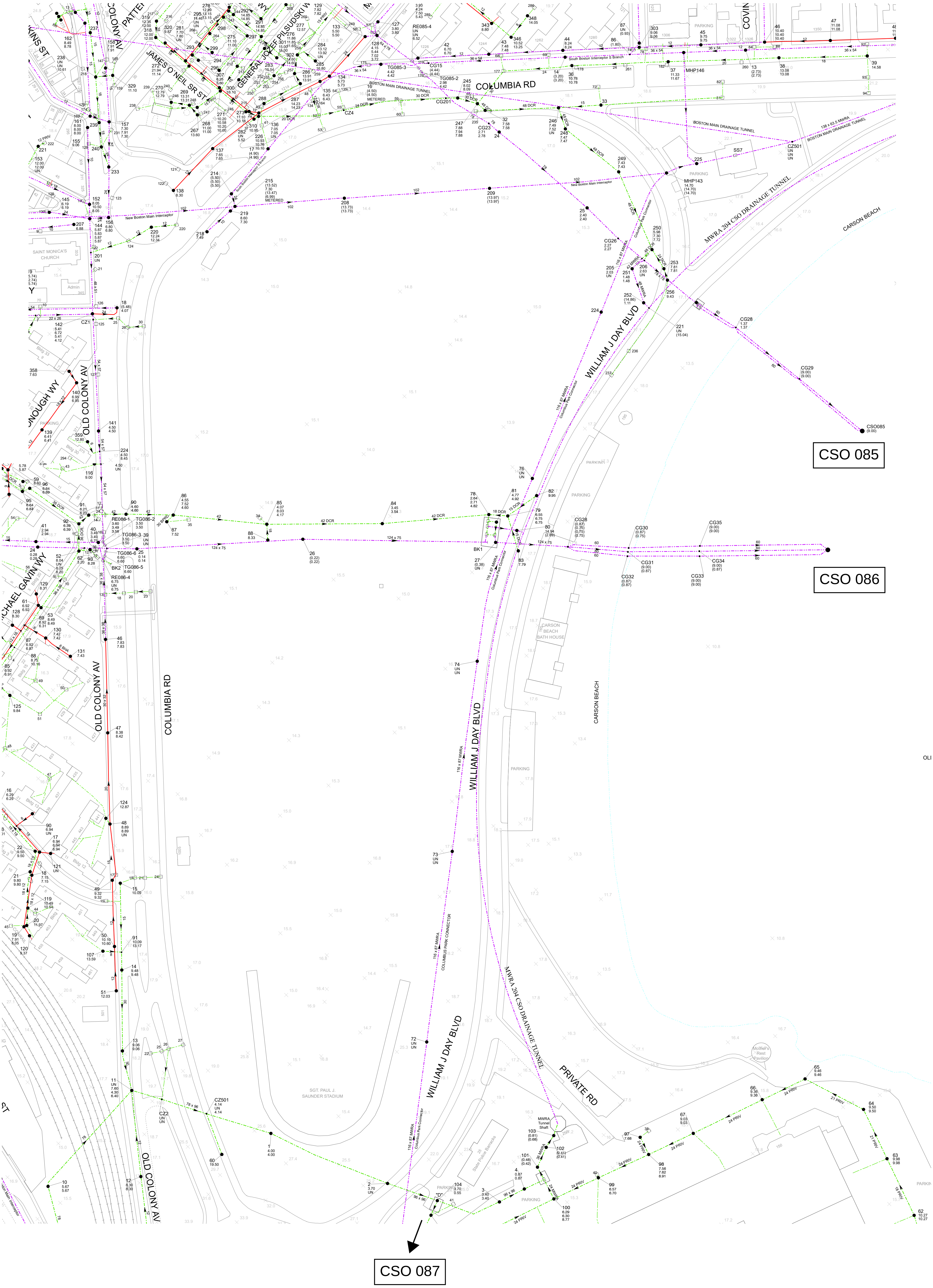
324 Chambers
3,575.5 cy Field
2,236.2 cy Stone



Pond UG-3B: Central LL System



APPENDIX E: RECORD MWRA/BWSC DOCUMENTATION



CSO 085
CSO 086
CSO 087
COLUMBIA RD
WILLIAM J DAY BLVD
OLD COLONY AV
PRIVATE RD
CARSON BEACH
BOSTON MAIN DRAINAGE TUNNEL
MWRA 204 CSO DRAINAGE TUNNEL
New Boston Main Interceptor
South Boston Interceptor S Branch
SAINT MONICA'S CHURCH
CARSON BEACH BATH HOUSE
SGT. PAUL J. SAUNDER STADIUM
PARKING

South Boston CSO and Stormwater Control Strategy

Storm Size	Control Objective
Up to 1-Year Storm ~2.8" of rain in 24 hrs	Capture all CSO and stormwater in tunnel from outfalls BOS081 to BOS086. Capture all stormwater from outfall BOS087.
1- to 5-Year Storm 2.8- 4" of rain in 24 hrs	Capture all CSO and stormwater from BOS081 to BOS086. After taking in first flush from BOS087, close gate to divert BOS087 stormwater to BWSC's Morrissey Boulevard Stormdrain.
5- to 25-Year Storm >4" of rain in 24 hrs	Close BOS081- BOS087 stormwater gates. Dedicate tunnel to capturing CSO up to tunnel storage capacity (25-year, 24-hour storm).

MASSACHUSETTS WATER RESOURCES AUTHORITY
Charlestown Navy Yard
100 First Avenue
Boston, Massachusetts 02129

Telephone: (617) 242-6000
Facsimile: (617) 788-4899

Frederick A. Laskey
Executive Director

February 03, 2011

John P. Sullivan, P.E.
Chief Engineer
Boston Water & Sewer Commission
980 Harrison Avenue,
Roxbury, MA 02119

**SUBJECT: North Dorchester Bay CSO Storage Tunnel
BWSC and DCR CSO and Stormwater Flows to NDB Pumping Station**

Dear Mr. Sullivan:

This correspondence is in response to your request concerning the volume of DCR stormwater estimated to be captured by the North Dorchester CSO Storage Tunnel and its impacts to BWSC flows and wholesale charge from MWRA.

BWSC combined sewer overflows and BWSC and DCR separate stormwater flows that now drain to the North Dorchester Bay (NDB) beaches via the six remaining BWSC outfalls (BOS081, 082, 084, 085, 086 and 087) will be captured by the NDB tunnel and pumped <u>after each storm</u> to the local BWSC system for handling at Columbus Park and treatment at Deer Island. Capturing and pumping these CSO and stormwater flows (pump station flows will be metered) will increase the volume of flow measured at Columbus Park Headworks for the calculation of wholesale rate to BWSC.

<u>Separate Stormwater and Combined Sewer Areas</u>

The separate stormwater area is roughly bounded by Columbia Road to the north, Pleasure Bay to the east, the beaches and the Bayside Expo property to the south, and Dorchester Avenue to the west. While this area primarily includes city and state parks and parkways, including Moakley Park and the green space along Day Boulevard, it also includes developed areas in North Dorchester tributary to Outfall BOS087, 21 acres of the Old Colony Housing Project (though not the entire development), and most of the Bayside Expo and nearby Shaw's Supermarket parking lots.

See Table 1 for separate storm drain areas tributary to each outfall downstream of the CSO regulators. There are approximately 262 acres served by separate storm drains owned by BWSC (155 acres) and DCR (107 acres) that drain to the six outfalls <u>downstream of the CSO regulators</u> (we understand there are no longer any active CSO regulators associated with Outfall BOS087, which now discharges stormwater only). There are approximately 292 acres that drain to BWSC combined sewers upstream of the regulators.

Typical Year CSO and Separate Stormwater Volumes

See Table 2 for design storm and typical year CSO and separate stormwater volumes to each of seven outfalls (note: flows to Outfall BOS083 are now diverted to Outfall BOS084, and Outfall BOS083 is permanently closed). Stormwater flows to Outfall BOS087 will be diverted to the NDB tunnel up to the 1-year, 24-hour storm (2.79 inches) and, with the exception of approximately 1 million gallons first flush, will be diverted to the Morrissey Boulevard storm drain and Savin Hill Cove in storms greater than the 1-year, 24-hour storm. In a typical year, the tunnel is predicted to capture up to 7.94 million gallons of BWSC CSO and up to 143.84 million gallons of BWSC and DCR separate stormwater.

BWSC and DCR Stormwater Portions

See Table 1 for BWSC and DCR stormwater drainage areas and runoff coefficients. From these values, the portion of BWSC stormwater volume is calculated to be 73% and the portion of DCR stormwater volume is calculated to be 27%. This ratio is expected to be a reasonable apportionment of stormwater runoff generation across a range of storm sizes, except for very large storms that cause street gutter flows in the elevated areas of South Boston served by combined sewers to bypass or inundate catch basin inlets, allowing "excess" runoff from these combined areas to reach the BWSC catch basins along Columbia Road.

Infiltration in BWSC and DCR Storm Drains

The pumping station at Conley Terminal will also routinely pump low flows that collect in the tunnel during dry weather. These flows are expected to primarily be infiltration (groundwater) into tributary storm drains that are owned and operated by BWSC and DCR, but may also include minor infiltration into the NDB tunnel itself. The project design assumes 300 gpm (157 million gallons per year) infiltration rate. Since the source of most of this flow is the tributary BWSC and DCR storm drains, it may be reasonable to assume the same BWSC 73% and DCR 27% split, even though the flow is dependent on length and condition of the drain pipes and groundwater level, not land area or runoff coefficient.

Predicted Tunnel Flows from BWSC and DCR Sources

Typical year annual and average daily flows of infiltration, CSO and stormwater are presented in the table below.

Tunnel Flow Component	BWSC		DCR		Total Pumped	
	MG/day	MG/year	MG/day	MG/year	MG/day	MG/year
Infiltration	0.31	114.57	0.12	42.38	0.43	156.95
CSO	0.02	7.94	-	-	0.02	7.94
Stormwater	0.29	105.00	0.11	38.84	0.39	143.84
Total	0.62	227.51	0.23	81.22	0.84	308.73

Predicted Increase in Total Measured Flow and Sewer Charges

There are two flow numbers used in the rate calculation for each community:
1. Percent share of average daily flow (over the whole calendar year) used for calculation of MWRA O&M charge; and
2. Percent share of peak-month average daily flow (highest of the 12 monthly averages) used for calculation of 25% of MWRA capital charge.

	CY2008	CY2009
Average Daily Flow	95.86 MGD	92.06 MGD
Peak-Month Average Daily Flow	121.92 MGD	103.12 MGD

BWSC sources only (100% CSO, 73% infiltration and 73% stormwater)
227.51 MG/(92.06 MGD x 365) = <u>0.68% increase in total measured BWSC flow</u>

Based on the FY11 unit cost for the flow-based component of the sewer rate (flow based unit costs developed using BWSC's CY 07/08/09 actual average daily and peak monthly flows), which is $1,703 per million gallons, the additional charge to BWSC for the added BWSC flow (only) would be approximately $1,703/MG x 227.51MG = $387,450 <u>in a typical year</u>.

BWSC and DCR sources (all flows to tunnel and pumping station)
308.73 MG/(92.06 MGD x 365) = <u>0.92% increase in total measured BWSC flow</u>

The additional charge to BWSC for the added BWSC and DCR flow would be approximately $1,703/MG x 308.73MG = $525,767 <u>in a typical year</u>.

If you would like to discuss this correspondence in more detail, I am available at your convenience.

Sincerely,

Michael J. Hornbrook
Chief Operating Officer

cc: Vincent G. Mannering, Executive Director, BWSC
Fred Laskey, Executive Director, MWRA
Kathy Soni, MWRA

Attachments: Table 1-Breakdown of BWSC/DCR Stormwater Areas/Runoff
Table 2-CSO/Stormwater Flows

TABLE 1. BREAKDOWN OF BWSC AND DCR STORMWATER TO NDB TUNNEL

	BWSC			DCR					
Outfall	Area (ac.)	Runoff Coefficient C	Area x C (1)	Area (ac.)	Runoff Coefficient C (2)	Area x C(1)	Total AxC	%BWSC	%DCR
BOS081	3.01	0.65	1.96	7.14	0.65	4.64	6.60	30	70
BOS082	1.93	0.65	1.25	4.82	0.65	3.13	4.39	29	71
BOS083	0.73	0.65	0.47	1.09	0.65	0.71	1.18	40	60
BOS084	3.75	0.65	2.44	5.31	0.65	3.45	5.89	41	59
BOS085	9.77	0.65	6.35	27.64	0.38	10.45	16.80	38	62
BOS086	19.6	0.65	12.74	35.68	0.17	6.21	18.95	67	33
BOS087	116	0.65	75.66	25.71	0.37	9.51	85.17	89	11
Total	155	0.65	101	107	0.35	38.1	139	73	27

Notes:
(1) Volume of stormwater tributary to outfall is proportional to the area times the runoff coefficient.
(2) For outfalls BOS085 to BOS087, the C value indicated for DCR represents a weighted average of multiple runoff areas with differing C values.

Table 2: CSO and Separate Stormwater Flows to North Dorchester Bay Storage Tunnel (From NDB SEIR, April 2004.)

Regulator	CSO Volume (MG)							
	3-month LT	3-month HT	1-year LT	1-year HT	2-year LT	2-year HT	5-year LT	5-year HT
RE081-2	0.14	0.03	0.39	0.22	0.63	0.53	0.88	0.74
RE082-2	0.19	0.10	0.65	0.65	1.26	1.36	1.94	2.01
RE083-1	0.04	0.05	0.22	0.25	0.41	0.43	0.67	0.69
RE084-3	0.00	0.00	0.24	0.14	0.79	0.87	1.49	1.63
RE084-6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RE085-4	0.00	0.00	0.00	0.01	0.37	0.47	0.91	1.09
RE086-1	0.00	0.00	0.15	0.05	0.43	0.46	0.81	0.90
RE086-8	0.00	0.00	1.71	0.00	2.35	0.26	5.28	1.40
Total	0.37	0.19	3.36	1.32	6.24	4.37	11.99	8.47
Average of HT, LT	0.28		2.34		5.31		10.23	

Outfall	SW Volume (MG)					
	3-month	1-Year	2-Year	5-Year	10-Year	25-Year
BOS081	0.44	0.68	0.81	1.09	1.34	1.54
BOS082	0.42	0.66	0.82	1.13	1.39	1.60
BOS083	0.07	0.11	0.13	0.17	0.21	0.24
BOS084	0.33	0.51	0.62	0.84	1.02	1.17
BOS085	0.83	1.30	1.57	2.17	2.68	3.15
BOS086	0.81	1.26	1.54	2.14	2.64	3.10
BOS087	3.67	5.96	7.10	9.58	11.64	13.34
Total	6.57	10.48	12.59	17.12	20.92	24.14
Total Without BOS087	2.90	4.52	5.49	7.54	9.28	10.80

Outfall	ANNUAL SIMULATION		
	Activations	CSO Volume (MG)	SW Volume (MG)
BOS081	21	1.98	9.28
BOS082	17	3.27	9.15
BOS083	13	1.02	1.47
BOS084	7	1.06	7.07
BOS085	1	0.16	17.85
BOS086	4	0.45	17.41
BOS087	0	0.00	81.61
Total		7.94	143.84
Total Without BOS087		7.94	62.23

Note: BOS087 stormwater volumes include separation of RE087-1.

REVISED CONCEPTUAL PLAN

STOSS LANDSCAPE URBANISM

- GRADING, CONNECTIVITY, EDGE CONDITIONS, SOILS, PHASING PLAN AND COST ESTIMATES

BOSTON PARKS & RECREATION
Martin J. Walsh, Mayor

MOAKLEY PARK

Sub-Task 1.4 Landscape Resilience Design
and Engineering Refinements + Costs
September 3, 2020

STOSS

Mayor Martin J. Walsh

MOAKLEY PARK

FINAL LANDSCAPE DESIGN PACKAGE

- DESIGN OVERVIEW
  - Principles
  - Conceptual Framework
  - 3-Part Park
    - City Edge
    - Core + Crest
    - Coast
  - Site Systems
  - Play Typologies

- FINAL RENDERINGS
  - Aerials:
    - Overview from NW
    - Waterfront
    - Stadium
  - Section-Perspectives
    - Waterfront Coastal Landscape
    - Waterfront Plaza
    - City Edge

- PLANS
  - Phase 1 Plan
  - Pre-Schematic Grading Plan
  - Pre-Schematic Soils Plan

RESILIENT Protecting the residential communities inland of Moakley from future flood events and climate change impacts.

ACTIVE Retaining and enhancing Moakley as a key active recreational amenity for South Boston and the entire city through elevated ball fields, a revamped stadium, and destination sport courts and play areas with improved stormwater management.

DIVERSE Develop a wide-range of programming that includes play elements for various ages and abilities, events spaces for large performances and small community gatherings, as well as passive areas for nature walks, picnicing and lounging.

INCLUSIVE Creating equitable access to Boston's greatest natural resource.

ACCESSIBLE Increase the linkages between these communities, points of access and the park, the harbor and the islands beyond. Access points into the park are located at key intersections with adjacent neighborhoods.

SAFE Provide an environment that can be relaxing and enjoyable for visitors through all hours of the day and all season of the year. Visibility and sight lines can be maintained through strategic planting, enhanced lighting, and thoughtfully placed programming. Designated routes for pedestrians, cyclists, and joggers, as well as specific program for people with limited mobility will avoid conflicts between various park users.

CONCEPTUAL FRAMEWORK
3-PART PARK

CITY EDGE

CREST + CORE

COAST

+

+

+

STOSS

STOSS

STOSS

STOSS

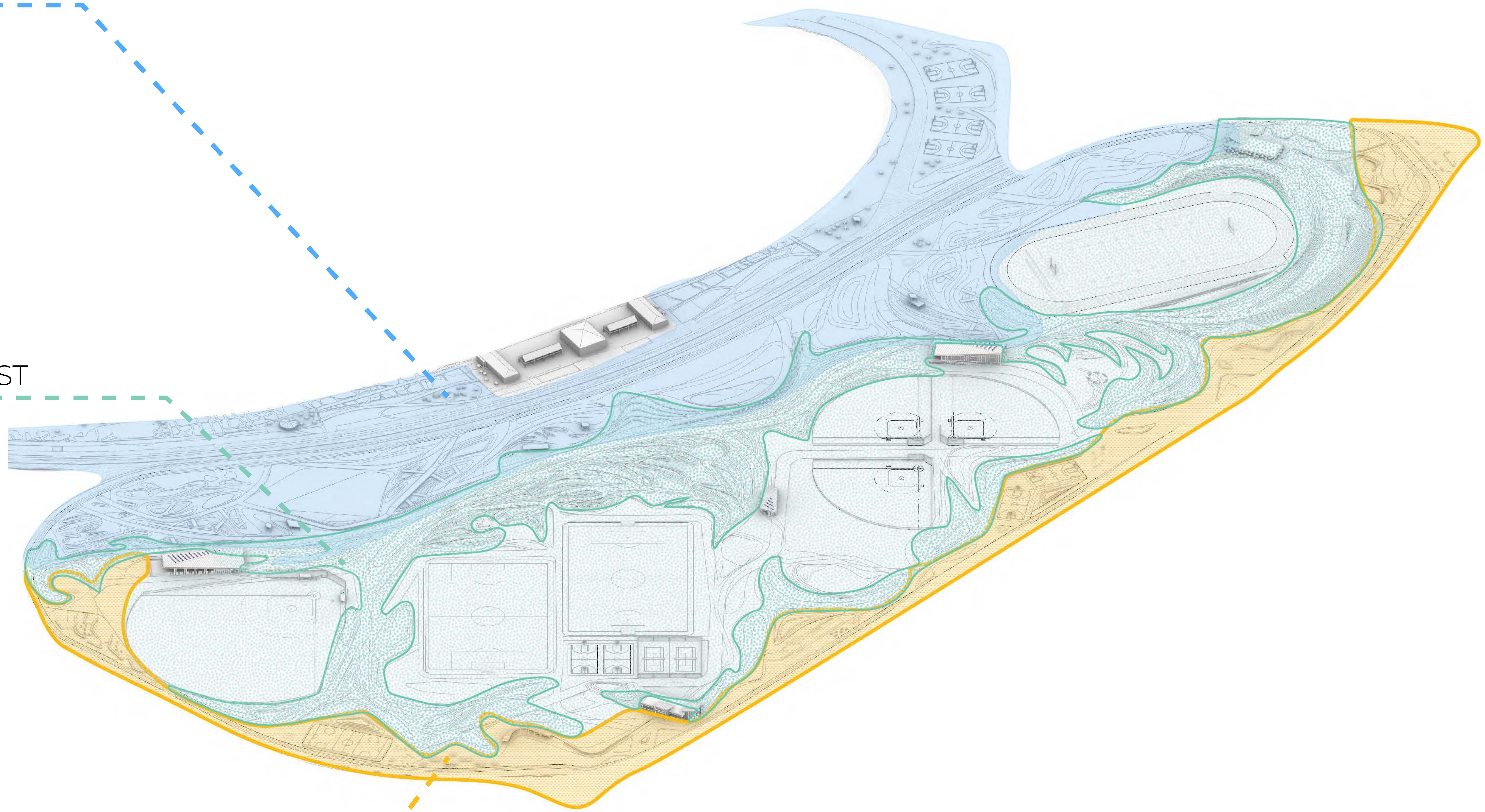
STOSS

CONCEPTUAL FRAMEWORK
3-PART PARK

COAST

CORE + CREST

CITY



STOSS

SITE SYSTEMS

- OVERVIEW
- PROGRAM
- CIRCULATION
- PLANTING
- STORMWATER
- COASTAL FLOODING

MOAKLEY PARK
OVERVIEW

SITE SYSTEMS
PROGRAM: PLAY

SITE SYSTEMS
PROGRAM : SPORTS

SITE SYSTEMS
PROGRAM : EVENTS

SITE SYSTEMS

PROGRAM : COMMUNITY + GATHERING

SITE SYSTEMS
PROGRAM : ECOLOGY

SITE SYSTEMS

PROGRAM : BUILDINGS + STRUCTURES

STOSS

SITE SYSTEMS

PROGRAM : COMPOSITE

SITE SYSTEMS

CIRCULATION : PRIMARY

STOSS

SITE SYSTEMS

CIRCULATION : SECONDARY

STOSS

SITE SYSTEMS

CIRCULATION : COMPOSITE

STOSS

SITE SYSTEMS

CIRCULATION: RUNNING LOOPS

STOSS

SITE SYSTEMS

COASTAL FLOOD MANAGEMENT: 9" SLR + 1% STORM

STOSS

SITE SYSTEMS

COASTAL FLOOD MANAGEMENT: 21" SLR + 1% STORM

SITE SYSTEMS

COASTAL FLOOD MANAGEMENT: 40" SLR + 1% STORM

STOSS

SITE SYSTEMS

COASTAL FLOOD MANAGEMENT: 2070 MHHW

SITE SYSTEMS
STORMWATER : SURFACE

STOSS

SITE SYSTEMS

STORMWATER : SUBSURFACE

STOSS

SITE SYSTEMS
PLANTING : EXISTING

STOSS

SITE SYSTEMS
PLANTING : STRUCTURE

SITE SYSTEMS

PHASE 1: PRESERVED TREES

STOSS

CITY EDGE

- OVERVIEW / PROGRAM
- SITE CONNECTIONS
- PROGRAM VARIATIONS

CITY EDGE
OVERVIEW

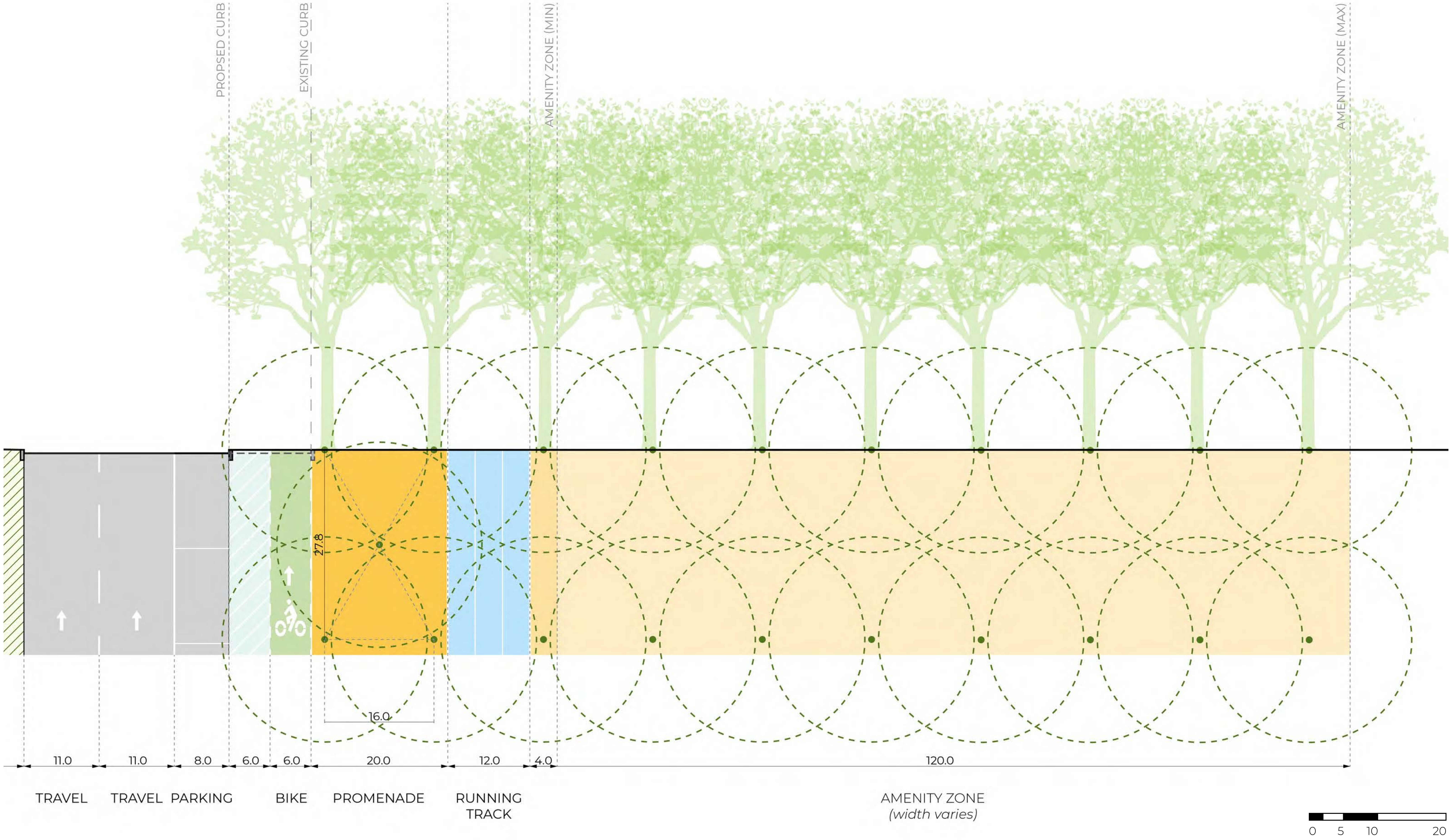
STOSS

CITY EDGE
SITE CONNECTIONS

CITY EDGE
TYPICAL CONDITION

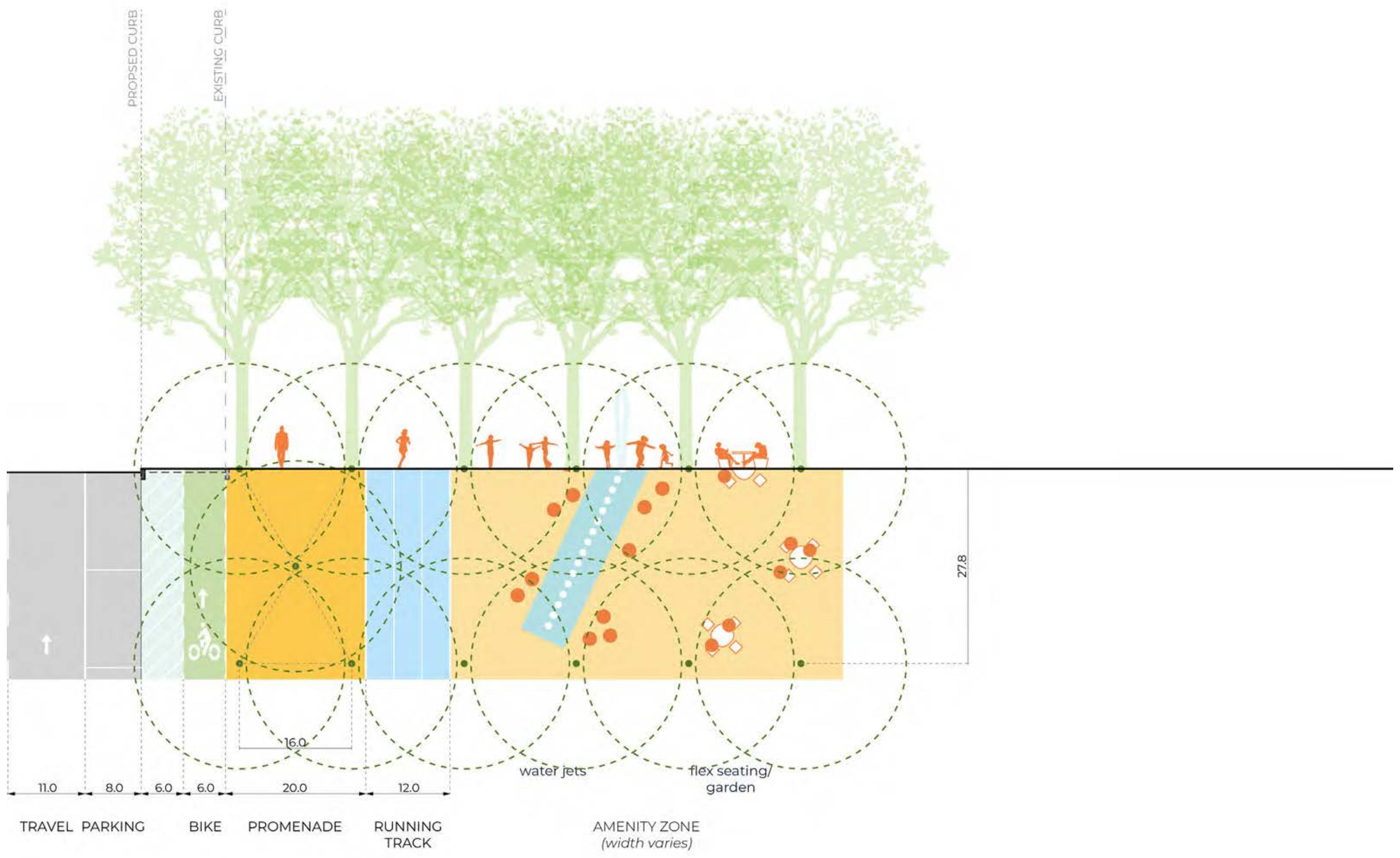
PROMENADE: 20.0'
RUNNING TRACK: 12.0'

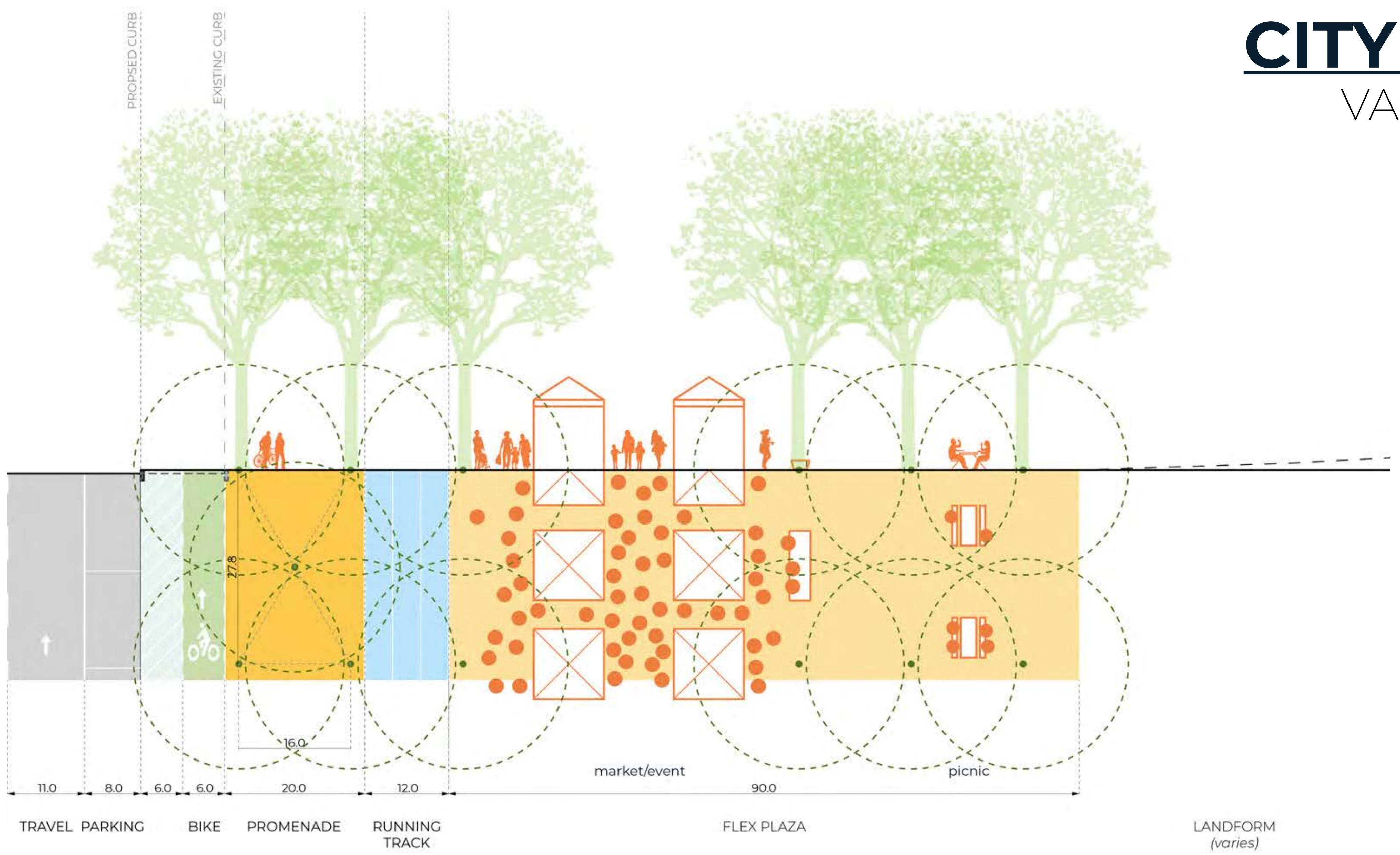
TREES: ~30' DIAMETER
SPACING: 16' ON CENTER

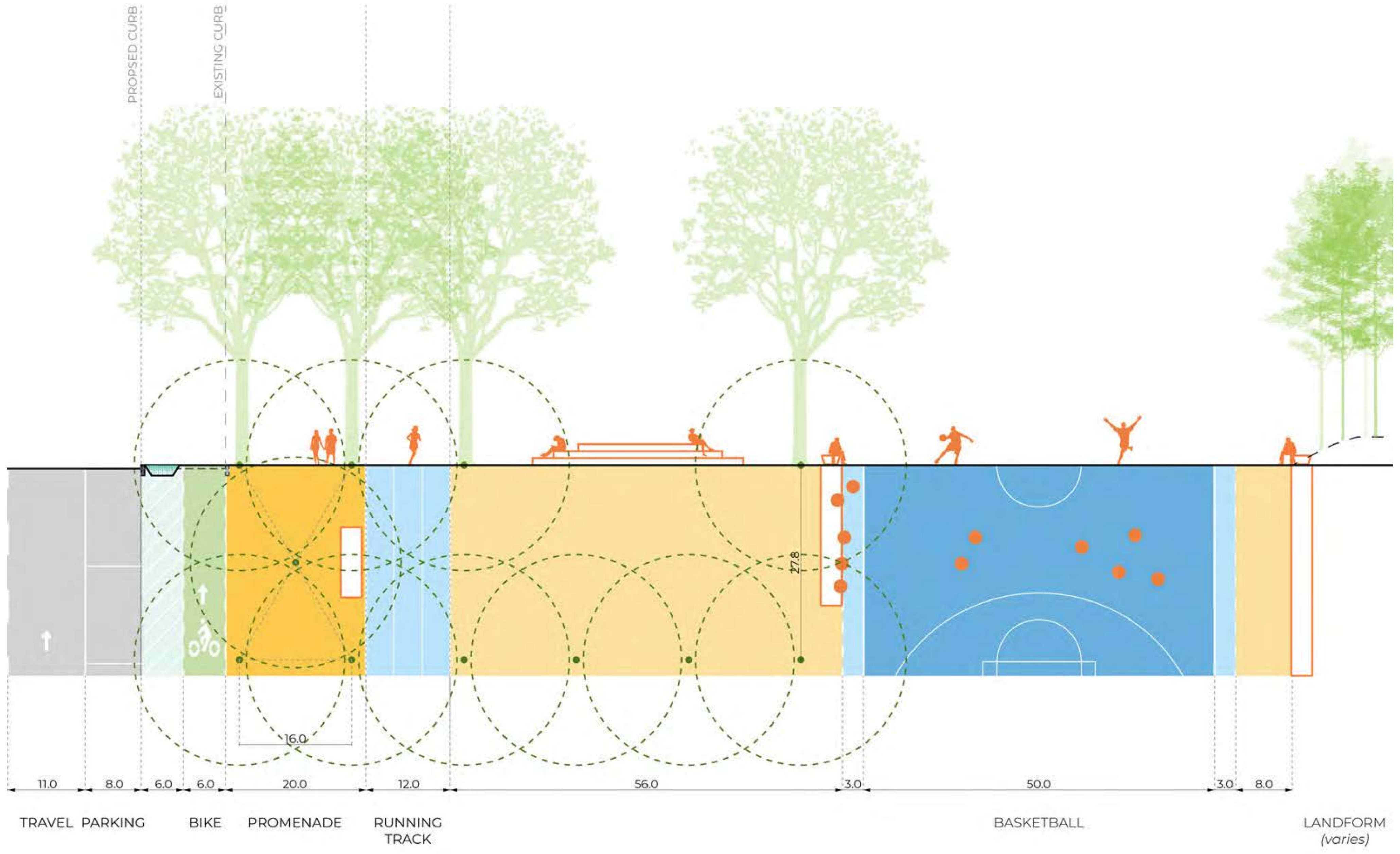


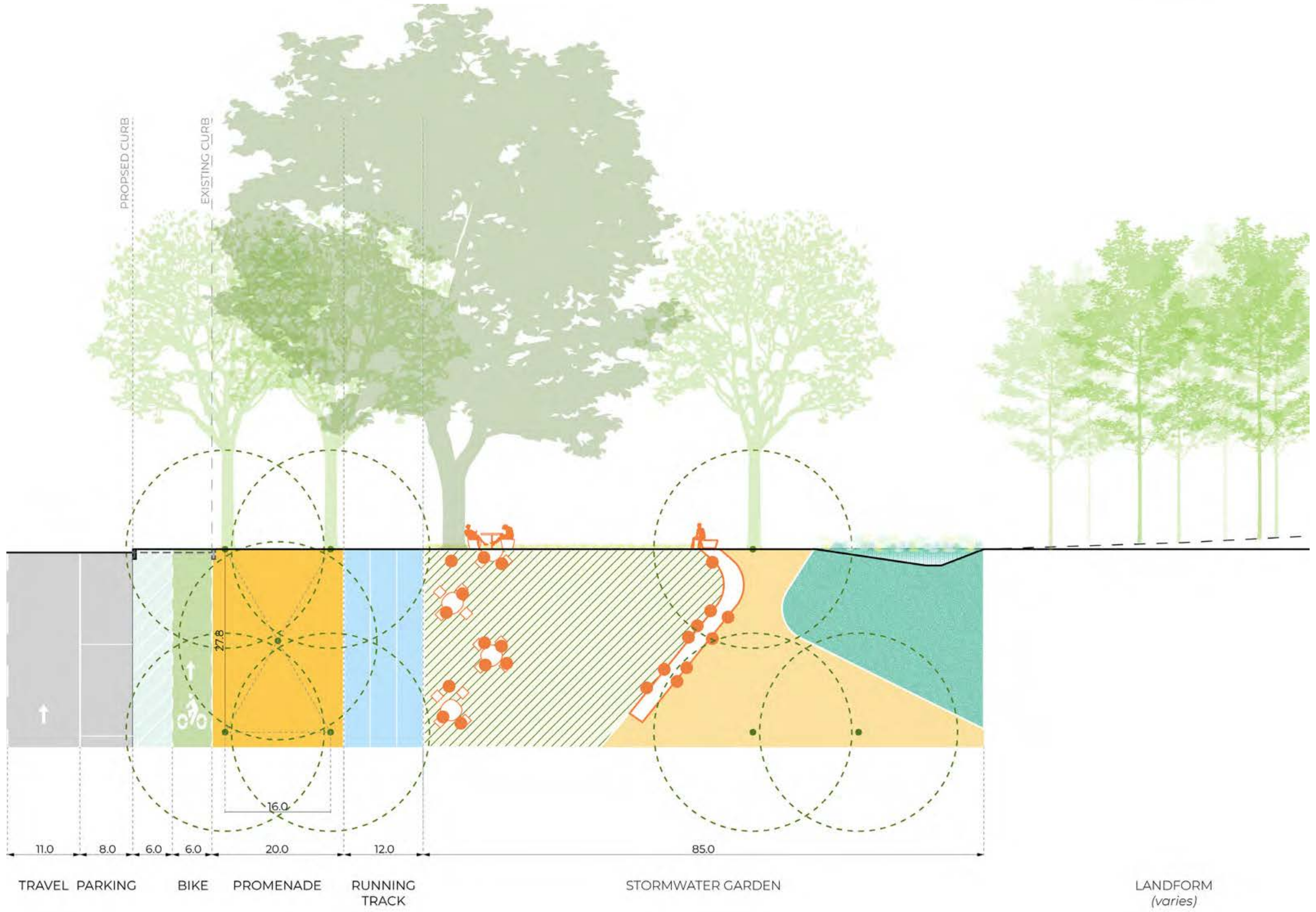
STOSS

CITY EDGE
VARIATIONS









STOSS

CORE + CREST

- OVERVIEW
- ADVENTURE PLAY
- GROVE
- STADIUM

CORE+CREST
OVERVIEW

ADVENTURE PLAY
OVERVIEW

STOSS

GROVE
OVERVIEW

STADIUM + SLEDDING HILL
OVERVIEW

COASTAL PARK

- OVERVIEW
- WATERFRONT PLAZA

COASTAL PARK
OVERVIEW

STOSS

COASTAL PARK
WATERFRONT PLAZA

FINAL RENDERINGS

- AERIAL RENDERINGS
- SECTION PERSPECTIVES

AERIAL RENDERINGS

VIEW FROM NORTHWEST - EXISTING PREBLE CIRCLE

AERIAL RENDERINGS

VIEW FROM NORTHWEST - PROPOSED ENTRY PLAZAS

AERIAL RENDERINGS

VIEW FROM NORTH OVERLOOKING COASTAL LANDSCAPE - DAY BLVD OPEN

AERIAL RENDERINGS

VIEW FROM NORTH OVERLOOKING COASTAL LANDSCAPE - DAY BLVD CLOSED

AERIAL RENDERINGS

VIEW FROM SOUTHWEST OVERLOOKING STADIUM + SLEDDING HILL

SECTION PERSPECTIVE
WATERFRONT COASTAL LANDSCAPE

STOSS

SECTION PERSPECTIVE

WATERFRONT PLAZA - EVENTS/FESTIVAL

STOSS

SECTION PERSPECTIVE

CITY EDGE / STORMWATER MEADOWS / COURTS + FIELDS

STOSS

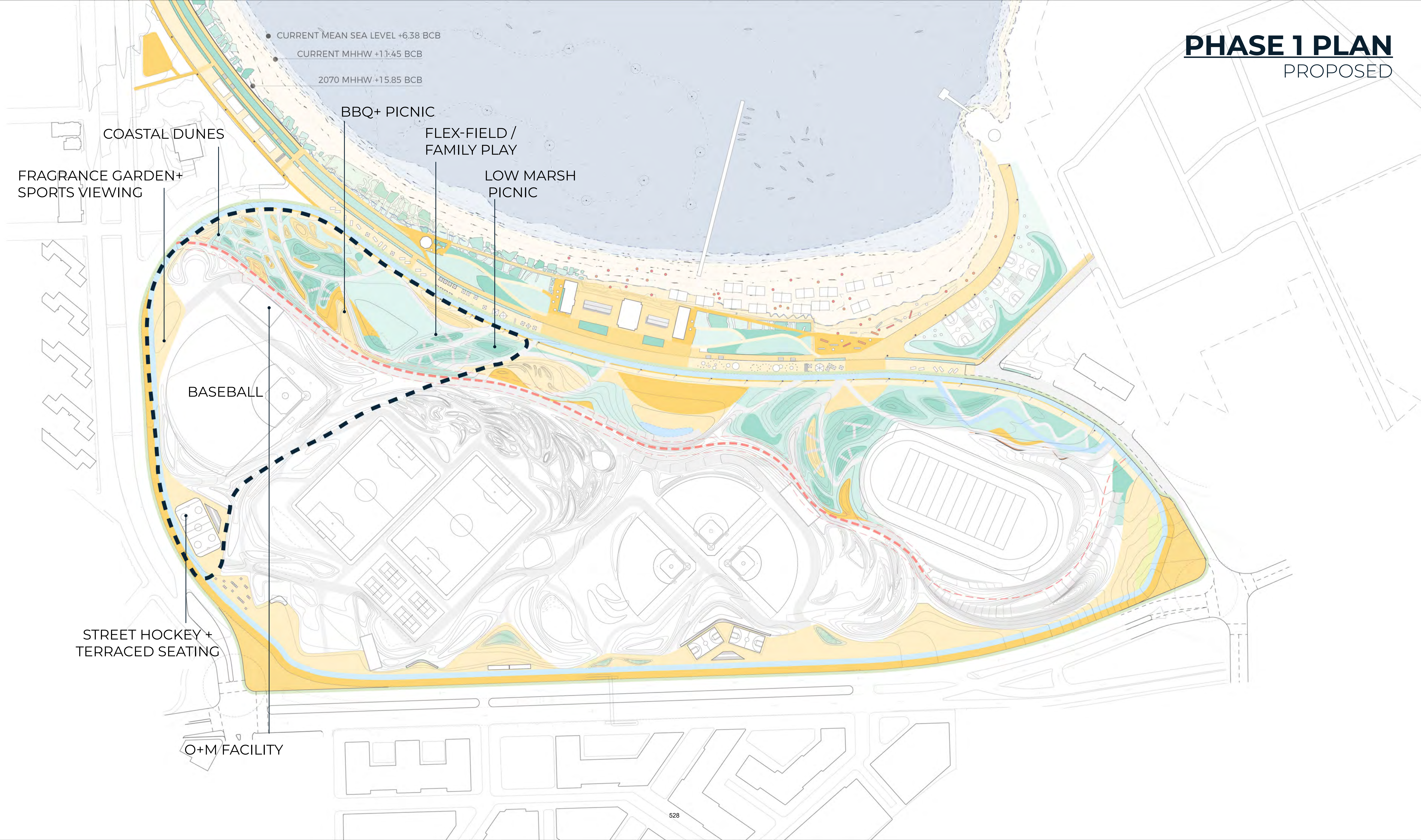
PLANS

- PHASE 1 PLAN
- PRE-SCHEMATIC PLAN

PHASE 1 PLAN
EXTENTS

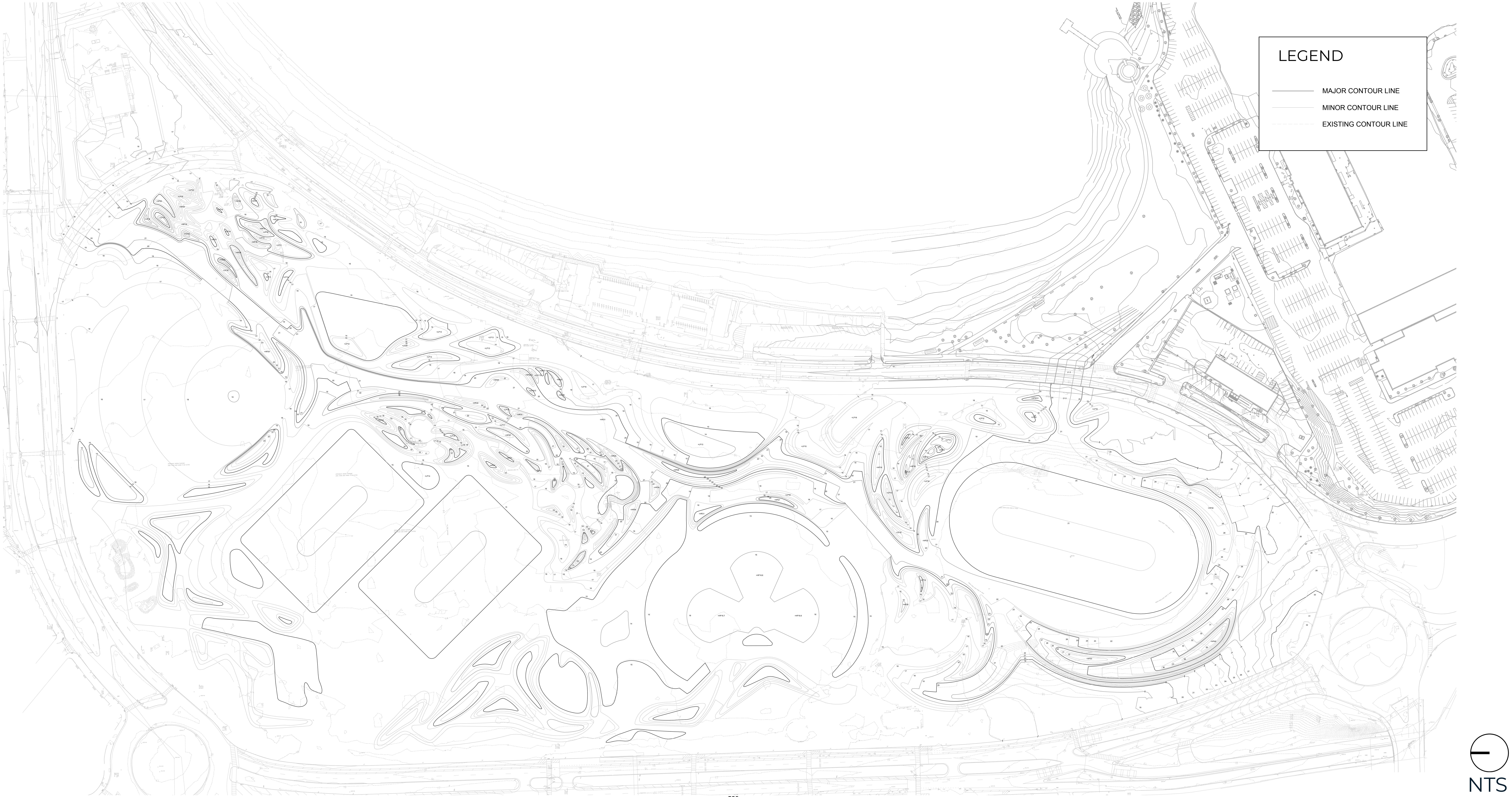
STOSS

PHASE 1 PLAN
PROPOSED



STOSS

PRE-SCHEMATIC GRADING PLAN



STOSS

*SEE SUB-TASK 3.2 PRE-SCHEMATIC SET FOR DETAILED GRADING AND SITE SECTIONS

PRE-SCHEMATIC SOIL PLAN

STOSS

*SEE SUB-TASK 3.2 PRE-SCHEMATIC SET FOR DETAILED GRADING AND SITE SECTIONS

ID #	Description	Overall Cost		% of Total Fee
1.0	**Waterfront (BPRD)**	**$**	**22,836,119**	**14.5%**
1.01	BBQ & Picnic at Waterfront Plaza	$	790,451	3.5%
1.02	BBQ & Picnic (Dunes)	$	354,951	1.6%
1.03	Waterfront Plaza / Amphitheater	$	4,211,127	18.4%
1.04	Water Features/Fountain	$	2,206,500	9.7%
1.05	Marsh	$	1,972,796	8.6%
1.06	Beachfront Flex Field	$	359,467	1.6%
1.07	Play/Fitness	$	351,750	1.5%
1.08	Shelters	$	360,000	1.6%
1.09	Promenade & Running Track	$	4,630,492	20.3%
1.10	Electrical Service	$	150,000	0.7%
1.11	Pathways	$	1,241,910	5.4%
1.12	Tree Planting	$	750,000	3.3%
1.13	Earthwork	$	5,456,676	23.9%
~~**2.0**~~	~~**Waterfront (DCR / MassDOT)**~~	~~**$**~~	~~**-**~~	~~**0.0%**~~
2.01	Promenade	$	-	
2.02	Beach Nourishment	$	-	
2.03	Structures	$	-	
2.04	Dune Restoration	$	-	
2.05	Harborwalk	$	-	
2.06	Basketball	$	-	
2.07	Beer Garden	$	-	
2.08	Lighting	$	-	
3.0	**Urban Edge Improvements**	**$**	**23,853,775**	**15.2%**
3.01	North Entry Plaza	$	3,942,618	16.5%
3.02	South Entry Plaza	$	3,963,917	16.6%
3.03	Street Hockey & Seating	$	399,425	1.7%
3.04	Fragrance Gardens	$	1,088,250	4.6%
3.05	Leisure Play & Water Garden	$	380,339	1.6%
3.06	Basketball & Fitness Clusters	$	681,560	2.9%
3.07	Promenade & Running Track	$	4,931,365	20.7%
3.08	Skate Park	$	3,350,000	14.0%
3.09	Interactive Play/Active Play	$	1,785,687	7.5%
3.10	Electrical Service	$	310,000	1.3%
3.11	Miscellaneous Landscaping/Features	$	1,700,000	7.1%
3.12	Earthwork	$	1,320,615	5.5%
4.0	**General Landscape**	**$**	**12,553,774**	**8.0%**
4.01	Landscaping/Planting	$	4,650,000	37.0%
4.02	Pathways	$	179,598	1.4%
4.03	Earthwork	$	7,724,176	61.5%
5.0	**Grove**	**$**	**3,558,376**	**2.3%**
5.01	Custom/Integrated Furniture	$	300,000	8.4%
5.02	Grove	$	1,700,000	47.8%
5.03	Electrical Service	$	100,000	2.8%
5.04	Pathways	$	160,067	4.5%
5.05	Earthwork	$	1,298,309	36.5%
6.0	**Adventure Play**	**$**	**8,084,464**	**5.1%**
6.01	Woodland/Adventure Play	$	5,125,520	63.4%
6.02	Electrical Service	$	130,000	1.6%
6.03	Pathways	$	212,464	2.6%
6.04	Earthwork	$	2,616,480	32.4%
7.0	**Stadium & Parking**	**$**	**16,055,903**	**10.2%**
7.01	Stadium Demolition	$	459,000	2.9%
7.02	New Field Construction	$	3,387,765	21.1%
7.03	Sledding Hill / Overlook	$	622,500	3.9%
7.04	Seating	$	144,000	0.9%
7.05	Parking Garage	$	-	0.0%
7.06	Electrical Service	$	97,500	0.6%
7.07	Miscellaneous Landscaping/Features	$	84,000	0.5%
7.08	Pathways	$	592,431	3.7%
7.09	Earthwork	$	10,668,707	66.4%
8.0	**Fields & Athletics**	**$**	**10,130,028**	**6.4%**
8.01	Baseball Field	$	2,239,958	22.1%
8.02	Multi-Use Fields (Soccer)	$	1,824,000	18.0%
8.03	Little League Fields	$	1,555,323	15.4%
8.04	Basketball/Tennis	$	830,560	8.2%
8.05	Electrical Service	$	107,500	1.1%
8.06	Pathways	$	580,599	5.7%
8.07	Mounds/Landscape Areas	$	136,267	1.3%
8.08	Earthwork	$	2,855,821	28.2%
9.0	**Flood Management**	**$**	**11,034,305**	**7.0%**
9.01	Berm and Barrier Wall	$	3,300,000	29.9%
9.02	Pathways	$	180,079	1.6%
9.03	Landscape/Planting	$	298,444	2.7%
9.04	Earthwork	$	7,255,781	65.8%
10.0	**Buildings and Structures**	**$**	**14,059,000**	**8.9%**
10.01	Maintenance & Operations (Primary)	$	4,181,348	29.7%
10.02	Community Building	$	2,874,303	20.4%
10.03	Sports Headquarters	$	1,118,000	8.0%
10.04	Event Space	$	3,744,303	26.6%
10.05	Welcome Center / Maintenance & Operations	$	1,871,045	13.3%
10.06	Comfort Stations	$	270,000	1.9%
11.0	**Sitewide Improvements**	**$**	**34,939,987**	**22.2%**
11.01	Earthwork	$	18,736,200	53.6%
11.02	Stormwater	$	7,314,100	20.9%
11.03	Dewatering	$	3,000,000	8.6%
11.04	Site Utilities	$	5,000,000	14.3%
11.05	Emergency Access - 20 ft	$	375,687	1.1%
11.06	Wayfinding Signage	$	214,000	0.6%
11.07	Water Fountains	$	300,000	0.9%
	SUBTOTAL FOR SITE AND BUILDING COSTS	**$**	**157,106,000**	
	Mobilization and Site Preparation (5%)	$	7,856,000	
	General Conditions, Bonding, Insurance & Fees (15%)	$	23,566,000	
	Construction Subtotal (No Contingency)	$	188,528,000	
	Estimating Contingency (20%)	$	37,706,000	
	Construction Subtotal (With Contingency)	**$**	**226,234,000**	
	Cost Escalation Contingency (5% per annum by phase)	$	72,380,000	
	TOTAL CONSTRUCTION COST WITH MARKUPS AND CONTINGENCIES	$	298,614,000	

ID #	Description	Overall Cost	% of Total Fee
1.0	**Waterfront (BPRD)**	**$ 22,836,119**	**14.5%**
1.01	BBQ & Picnic at Waterfront Plaza	$ 790,451	3.5%
1.02	BBQ & Picnic (Dunes)	$ 354,951	1.6%
1.03	Waterfront Plaza / Amphitheater	$ 4,211,127	18.4%
1.04	Water Features/Fountain	$ 2,206,500	9.7%
1.05	Marsh	$ 1,972,796	8.6%
1.06	Beachfront Flex Field	$ 359,467	1.6%
1.07	Play/Fitness	$ 351,750	1.5%
1.08	Shelters	$ 360,000	1.6%
1.09	Promenade & Running Track	$ 4,630,492	20.3%
1.10	Electrical Service	$ 150,000	0.7%
1.11	Pathways	$ 1,241,910	5.4%
1.12	Tree Planting	$ 750,000	3.3%
1.13	Earthwork	$ 5,456,676	23.9%
~~**2.0**~~	~~**Waterfront (DCR / MassDOT)**~~	~~**$ -**~~	~~**0.0%**~~
2.01	Promenade	$ -	
2.02	Beach Nourishment	$ -	
2.03	Structures	$ -	
2.04	Dune Restoration	$ -	
2.05	Harborwalk	$ -	
2.06	Basketball	$ -	
2.07	Beer Garden	$ -	
2.08	Lighting	$ -	
3.0	**Urban Edge Improvements**	**$ 23,853,775**	**15.2%**
3.01	North Entry Plaza	$ 3,942,618	16.5%
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3.06	Basketball & Fitness Clusters	$ 681,560	2.9%
3.07	Promenade & Running Track	$ 4,931,365	20.7%
3.08	Skate Park	$ 3,350,000	14.0%
3.09	Interactive Play/Active Play	$ 1,785,687	7.5%
3.10	Electrical Service	$ 310,000	1.3%
3.11	Miscellaneous Landscaping/Features	$ 1,700,000	7.1%
3.12	Earthwork	$ 1,320,615	5.5%
4.0	**General Landscape**	**$ 12,553,774**	**8.0%**
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6.0	**Adventure Play**	**$ 8,084,464**	**5.1%**
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7.0	**Stadium & Parking**	**$ 16,055,903**	**10.2%**
7.01	Stadium Demolition	$ 459,000	2.9%
7.02	New Field Construction	$ 3,387,765	21.1%
7.03	Sledding Hill / Overlook	$ 622,500	3.9%
7.04	Seating	$ 144,000	0.9%
7.05	Parking Garage	$ -	0.0%
7.06	Electrical Service	$ 97,500	0.6%
7.07	Miscellaneous Landscaping/Features	$ 84,000	0.5%
7.08	Pathways	$ 592,431	3.7%
7.09	Earthwork	$ 10,668,707	66.4%
8.0	**Fields & Athletics**	**$ 10,130,028**	**6.4%**
8.01	Baseball Field	$ 2,239,958	22.1%
8.02	Multi-Use Fields (Soccer)	$ 1,824,000	18.0%
8.03	Little League Fields	$ 1,555,323	15.4%
8.04	Basketball/Tennis	$ 830,560	8.2%
8.05	Electrical Service	$ 107,500	1.1%
8.06	Pathways	$ 580,599	5.7%
8.07	Mounds/Landscape Areas	$ 136,267	1.3%
8.08	Earthwork	$ 2,855,821	28.2%
9.0	**Flood Management**	**$ 11,034,305**	**7.0%**
9.01	Berm and Barrier Wall	$ 3,300,000	29.9%
9.02	Pathways	$ 180,079	1.6%
9.03	Landscape/Planting	$ 298,444	2.7%
9.04	Earthwork	$ 7,255,781	65.8%
10.0	**Buildings and Structures**	**$ 14,059,000**	**8.9%**
10.01	Maintenance & Operations (Primary)	$ 4,181,348	29.7%
10.02	Community Building	$ 2,874,303	20.4%
10.03	Sports Headquarters	$ 1,118,000	8.0%
10.04	Event Space	$ 3,744,303	26.6%
10.05	Welcome Center / Maintenance & Operations	$ 1,871,045	13.3%
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11.01	Earthwork	$ 18,736,200	53.6%
11.02	Stormwater	$ 7,314,100	20.9%
11.03	Dewatering	$ 3,000,000	8.6%
11.04	Site Utilities	$ 5,000,000	14.3%
11.05	Emergency Access - 20 ft	$ 375,687	1.1%
11.06	Wayfinding Signage	$ 214,000	0.6%
11.07	Water Fountains	$ 300,000	0.9%

SUBTOTAL FOR SITE AND BUILDING COSTS	**$ 157,106,000**
Mobilization and Site Preparation (5%)	$ 7,856,000
General Conditions, Bonding, Insurance & Fees (15%)	$ 23,566,000
Construction Subtotal (No Contingency)	$ 188,528,000
Estimating Contingency (20%)	$ 37,706,000
year 3 cost appreciation (total)	$ 72,183,348
year 6 cost appreciation (total)	$ 118,684,168
year 9 cost appreciation (total)	$ 107,746,296
Construction Subtotal (With Contingency)	**$ 226,234,000**
Cost Escalation Contingency (5% per annum by phase)	$ 72,380,000
TOTAL CONSTRUCTION COST WITH MARKUPS AND CONTINGENCIES	**$ 298,614,000**

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
1	**Waterfront (BPRD)**	490,251 SQ FT					
1.01	**BBQ & Picnic at Waterfront Plaza**						
		Furniture - Picnic Area	15	EA	$ 3,500	$ 52,500	
		Furniture - Barbeque Grills	15	EA	$ 600	$ 9,000	
		Concrete Paving	667	SY	$ 75	$ 50,000	
		Gravel Base, 8" d	296	CY	$ 42	$ 12,451	
		Loam and Seed	6,000	SF	$ 6	$ 36,000	
		Shrubs	6,000	SF	$ 35	$ 210,000	
		Trash Enclosure	1	LS	$ 8,000	$ 8,000	
		Speciality Lighting	1	Allow.	$ 300,000	$ 300,000	
		Pedestrian Lighting at Plaza	15	EA	$ 7,500	$ 112,500	
					TOTAL	**$ 790,451**	
1.02	**BBQ & Picnic (Dunes)**						
		Furniture - Bench at path	20	EA	$ 5,000	$ 100,000	
		Furniture - Picnic Area	15	EA	$ 4,500	$ 67,500	
		Furniture - Barbeque Grills	15	EA	$ 600	$ 9,000	
		Concrete Paving	667	SY	$ 75	$ 50,000	
		Gravel Base, 8" d	296	CY	$ 42	$ 12,451	
		Landscape/Planting	6,000	SF	$ 8	$ 48,000	
		Trash Enclosure	1	LS	$ 8,000	$ 8,000	
		Dunes + Picnic Area Lighting	1	Allow.	$ 60,000	$ 60,000	
					TOTAL	**$ 354,951**	
1.03	**Waterfront Plaza / Amphitheater**						
		Plaza Paving	25,000				
		Precast Concrete Pavers	25,000	SF	$ 60	$ 1,500,000	
		Gravel Base, 8" d	741	CY	$ 42	$ 31,127	
		Ampitheater	20,000	SF	$ 50	$ 1,000,000	Customized Product
		Furniture - Custom	30	LS	$ 6,000	$ 180,000	
		Furniture - Plaza Custom	30	LS	$ 8,000	$ 240,000	
		Loam and Seed	20,000	SF	$ 8	$ 160,000	
		Herbaceous and Shrub Planting	10,000	SF	$ 35	$ 350,000	
		Electrical Service - Amphitheater Event	1	LS	$ 30,000	$ 30,000	
		Electrical Conduit & Wiring - Amphitheater	1	LS	$ 20,000	$ 20,000	
		Amphitheater Lighting	2,000	LF	$ 350	$ 700,000	
					TOTAL	**$ 4,211,127**	
1.04	**Water Features/Fountain**						
		Water Feature	5,000	SF		$ 2,000,000	estimate from Fluidity
		Water Connection	1	LS	$ 30,000	$ 30,000	
		Electrical Connection	1	LS	$ 15,000	$ 15,000	
		Splash Pad Vault + Backflow Prev.	1	LS	$ 30,000	$ 30,000	
		Cast-In-Place Concrete Paving - 4" Depth	556	SY	$ 85	$ 47,222	
		Gravel Borrow at Conc. Paving (8" depth)	122	CY	$ 35	$ 4,278	
		Water Feature Lighting	1	LS	$ 80,000	$ 80,000	
					TOTAL	**$ 2,206,500**	
1.05	**Marsh**						
		Marsh planting	126,110	SF			
		Upper Marsh (6')	63,055	LS	$ 680,000	$ 680,000	

		Lower Marsh (3')	63,055	LS	$ 375,000	$ 375,000	
		12 - 24" dia. Riprap (or other) (24" depth)	1,000	CY	$ 135	$ 135,000	
		Mounds/Grass	11,662	SF	$ 8	$ 93,296	
		Boardwalk	4,000	SF	$ 115	$ 460,000	
		Furniture	20	LS	$ 3,500	$ 70,000	
		Interpretive Signage	5	EA	$ 1,500	$ 7,500	
		Conservation Area Fencing	2,240	LF	$ 50	$ 112,000	
		Marsh lighting at boardwalk	1	LS	$ 40,000	$ 40,000	Assumes a recessed light at 6-ft intervals along 440 LF of boardwalk
					TOTAL	**$ 1,972,796**	
1.06	**Beachfront Flex Field**						
		Loam and Seed	30,000	SF	$ 8	$ 240,000	increased sf here, adjust other items as needed
		Fine Grading	3,333	SY	$ 5	$ 16,667	
		Light Compaction	3,333	SY	$ 7	$ 23,333	
		Rootzone Mix @ 8"d	741	CY	$ 60	$ 44,467	
		Drain Inlets / Clean Out	6	EA	$ 1,500	$ 9,000	
		Drainage Structures	1	EA	$ 6,000	$ 6,000	
		12" Collector Drains at Fields	200	LF	$ 30	$ 6,000	
		2" Flat Drains at Fields	2,000	LF	$ 7	$ 14,000	
					TOTAL	**$ 359,467**	
1.07	**Play/Fitness**						
		Adult Fitness Equipment	4	EA	$ 18,500	$ 74,000	
		PIP Surfacing w/ 4" Rubber, Gravel Base	5,555	SF	$ 50	$ 277,750	
					TOTAL	**$ 351,750**	
1.08	**Shelters**						
		Shade Shelter-BBQ & Picnic (Dunes)	6	EA	$ 60,000	$ 360,000	
					TOTAL	**$ 360,000**	
1.09	**Promenade & Running Track**						
		Promenade	61,020	SF			
		Integral Colored Concrete Paving (4")	2,258	SY	$ 80	$ 180,619	
		Gravel Base, 8" d	1,507	CY	$ 42	$ 63,312	
		Bike Lane	48,636				
		Bituminous Concrete Pavement (3")	908	TON	$ 150	$ 136,181	
		Gravel Base, 8" d for Bit. Pavement	1,201	CY	$ 42	$ 50,463	
		Color Sealcoat	48,636	SF	$ 2	$ 97,272	
		Running Track (12 feet width) Track Surfac	3,980	SY	$ 40	$ 159,200	
		Bituminous Concrete Pavement - (4")	99	TONS	$ 120	$ 11,887	
		Gravel Borrow - (12")	147	CY	$ 50	$ 7,370	Unit price increase due to area size
		Buffer Planting	19,440	SF	$ 14	$ 272,160	
		Tree Planting (28 feet apart)	231	EA	$ 5,000	$ 1,157,143	
		Structural Soil	43,971	CY	$ 39	$ 1,714,886	
		Furniture - Plaza Bench	60	EA	$ 8,000	$ 480,000	
		Bollards with LED Lighting	150	EA	$ 2,000	$ 300,000	
					TOTAL	**$ 4,630,492**	
1.1	**Electrical Service**						
		Electrical Service	1	LS	$ 50,000	$ 50,000	
		Electrical Conduit & Wiring	1	LS	$ 100,000	$ 100,000	
					TOTAL	**$ 150,000**	
1.11	**Pathways**						

		Emergency Access - 20 ft	7,900	SF			
		Bituminous Concrete Pavement (4")	147	TON	$ 150	$ 22,120	
		Gravel Base, 12" d for Bit. Pavement	293	CY	$ 42	$ 12,289	
		Primary Paths - 20 ft	4,880	SF			
		Bituminous Concrete Pavement (4")	91	TON	$ 150	$ 13,664	
		Gravel Base, 12" d for Bit. Pavement	181	CY	$ 50	$ 9,037	Unit price increase due to area size
		Secondary Paths - 12 ft	52,824	SF			
		Bituminous Concrete Pavement (3")	986	TON	$ 150	$ 147,907	
		Gravel Base, 8" d for Bit. Pavement	1,305	CY	$ 42	$ 54,808	
		Tertiary Paths - 6 ft	6,960	SF			
		Bituminous Concrete Pavement (3")	130	TON	$ 150	$ 19,488	
		Gravel Base, 8" d for Bit. Pavement	172	CY	$ 50	$ 8,597	Unit price increase due to area size
		Custom Aggregates/Colors at key locations	1	Allow.	$ 300,000	$ 300,000	Allowance for custom aggregates/colors
		Lighting at Emergency, Primary, Secondary	70	EA	$ 7,500	$ 525,000	
		Furniture - Bench at Primary and Secondar	26	EA	$ 5,000	$ 129,000	180 foot interval
					TOTAL	**$ 1,241,910**	
1.12	**Tree Planting**						
		Tree Planting	150	EA	$ 5,000	$ 750,000	
					TOTAL	**$ 750,000**	
1.13	**Earthwork**						
	Dune and BBQ Area	Imported Lightweight Fill	17,211	CY	$ 129	$ 2,220,219	
		Imported Topsoil (Loam)	9,476	CY	$ 29	$ 274,804	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	7,113	Ton	$ 65	$ 462,345	
		T&D Group C Soils	1,016	Ton	$ 130	$ 132,080	
		T&D Group D Soils	2,032	Ton	$ 260	$ 528,320	
	Waterfront Plaza Area	Imported Lightweight Fill	1,433	CY	$ 129	$ 184,857	
		Imported Topsoil (Loam)	1,823	CY	$ 29	$ 52,867	
		T&D Group A Soils	1,832	Ton	$ 40	$ 73,280	
		T&D Group B Soils	1,221	Ton	$ 65	$ 79,365	
		T&D Group C Soils	0	Ton	$ 130	$ -	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Marsh Area	Imported Lightweight Fill	5,333	CY	$ 129	$ 687,957	
		Imported Topsoil (Loam)	3,472	CY	$ 29	$ 100,688	
		T&D Group A Soils	1,908	Ton	$ 40	$ 76,320	
		T&D Group B Soils	273	Ton	$ 65	$ 17,745	
		T&D Group C Soils	3,271	Ton	$ 130	$ 425,230	
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Skate Park Area	Imported Lightweight Fill	13	CY	$ 129	$ 1,677	
		Imported Topsoil (Loam)	1,583	CY	$ 29	$ 45,907	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	1,431	Ton	$ 65	$ 93,015	
		T&D Group C Soils	0	Ton	$ 130	$ -	
		T&D Group D Soils	0	Ton	$ 260	$ -	
					TOTAL	**$ 5,456,676**	

0	0						

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
2	**Waterfront (BPRD)**						
2.01	**Promenade**						
		Decking - promenade		SY	$ -	$ -	
		Gravel Base (8" depth)		CY	$ -	$ -	
		Railings		LF	$ -	$ -	
					$ -	$ -	
					$ -	$ -	
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					TOTAL	**$ -**	
2.02	**Beach Nourishment**						
					$ -	$ -	
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					TOTAL	**$ -**	
2.03	**Structures**						
					TOTAL	**$ -**	
2.04	**Dune Restoration**						
					TOTAL	**$ -**	
2.05	**Harborwalk**						
					TOTAL	**$ -**	
2.06	**Basketball**						
					TOTAL	**$ -**	
2.07	**Beer Garden**						
					TOTAL	**$ -**	
2.08	**Lighting**						
					TOTAL	**$ -**	
#REF!	**#REF!**						
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						TOTAL	**$ -**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
3	**Urban Edge Improvements**						
3.01	**North Entry Plaza**	**45,133 SQ FT**					
		Precast Concrete Pavers	20,000	SF	$ 65	$ 1,300,000	
		Gravel Base, 8" d	494	CY	$ 42	$ 20,751	
		Precast Concrete Pavers (vehicular)	15,000	SF	$ 75	$ 1,125,000	
		Gravel Base, 12" d	556	CY	$ 42	$ 23,333	
		Water Feature	2,000	SF	$ 100	$ 200,000	
		Water Connection	1	LS	$ 30,000	$ 30,000	
		Electrical Connection	1	LS	$ 15,000	$ 15,000	
		Splash Pad Vault + Backflow Prev.	1	LS	$ 30,000	$ 30,000	
		Cast-In-Place Concrete Paving - 4" Dep	222	SY	$ 85	$ 18,889	
		Gravel Borrow at Conc. Paving (8" dep	49	CY	$ 50	$ 2,444	Unit price increase due to area size
		Furniture - Bench	10	EA	$ 8,000	$ 80,000	
		Furniture - Plaza Custom	20	EA	$ 10,000	$ 200,000	
		Herbaceous and Shrub Planting	8,000	SF	$ 35	$ 280,000	
		Trash Receptacle/Recycling	6	EA	$ 1,200	$ 7,200	
		Stage/Shelter	1	LS	$ 150,000	$ 150,000	
		Pedestrian Lighting at Plaza	20	EA	$ 7,500	$ 150,000	
		Catenary Lighting	1	LS	$ 100,000	$ 100,000	
		Catenary Poles	10	EA	$ 5,000	$ 50,000	
		Stage Lighting	1	LS	$ 80,000	$ 80,000	
		Water Feature Lighting	1	LS	$ 80,000	$ 80,000	
					TOTAL	**$ 3,942,618**	
3.02	**South Entry Plaza**	**56,596 SQ FT**					
		Precast Concrete Pavers	25,000	SF	$ 65	$ 1,625,000	
		Gravel Base, 8" d	618	CY	$ 42	$ 25,939	
		Precast Concrete Pavers	20,000	SF	$ 75	$ 1,500,000	
		Gravel Base, 12" d (Vehicular)	741	CY	$ 42	$ 31,111	
		Water Feature	1,000	SF	$ 100	$ 100,000	
		Water Connection	1	LS	$ 30,000	$ 30,000	
		Electrical Connection	1	LS	$ 15,000	$ 15,000	
		Splash Pad Vault + Backflow Prev.	1	LS	$ 30,000	$ 30,000	
		Cast-In-Place Concrete Paving - 4" Dep	111	SY	$ 85	$ 9,444	
		Gravel Borrow at Conc. Paving (8" dep	24	CY	$ 50	$ 1,222	Unit price increase due to area size
		Furniture - Bench	10	EA	$ 8,000	$ 80,000	
		Furniture - Plaza Custom	20	EA	$ 10,000	$ 200,000	
		Trash Receptacle/Recycling	6	EA	$ 1,200	$ 7,200	
		Mounds/Grass	10,500	SF	$ 8	$ 84,000	
		Pedestrian Lighting at Plaza	10	EA	$ 7,500	$ 75,000	
		Catenary Lighting	1	LS	$ 100,000	$ 100,000	
		Catenary Poles	10	EA	$ 5,000	$ 50,000	
					TOTAL	**$ 3,963,917**	
3.03	**Street Hockey & Seating**	**15,760 SQ FT**					
		Street Hockey Terraced Seating	1	LS	$ 20,000	$ 20,000	
		Loam and Seed	6,000	SF	$ 8	$ 48,000	
		Furniture/Bike Racks	15	EA	$ 6,000	$ 90,000	
		Custom Bench	1	LS	$ 10,000	$ 10,000	
		Fitness Equipment					
		Adult Fitness Equipment	3	EA	$ 18,500	$ 55,500	
		PIP Surfacing w/ 4" Rubber, Gravel Base	2,000	SF	$ 40	$ 80,000	
		BVCL Fence - 6' Height	1,279	LF	$ 75	$ 95,925	
					TOTAL	**$ 399,425**	
3.04	**Fragrance Gardens**	**13,352 SQ FT**					

		Sensory Garden - Herbaceous and Shrub P	14,350	SF	$ 35	$ 502,250	
		Custom Furniture	10	EA	$ 8,000	$ 80,000	
		Interpretive Signage	3	EA	$ 1,500	$ 4,500	
		Raised Planter/Seatwalls	850	LF	$ 590	$ 501,500	
					TOTAL	**$ 1,088,250**	
3.05	**Leisure Play & Water Garden**	**17,485 SQ FT**					
		Stormwater Garden	4,000	SF	$ 14	$ 56,000	
		Furniture - Flexible Seating	10	EA	$ 6,000	$ 60,000	
		Furniture - Chess Garden Tables	10	EA	$ 3,500	$ 35,000	
		Furniture - Custom Bench	5	EA	$ 10,000	$ 50,000	
		Bocce Court Surfacing	2,000	SF	$ 5	$ 10,000	
		Gravel Base (8" depth)	49	CY	$ 50	$ 2,450	Unit price increase due to area size
		Precast Concrete Curb	500	LF	$ 25	$ 12,500	
		PT Dasher Board	500	LF	$ 5	$ 2,500	
		Table Tennis	6	EA	$ 6,000	$ 36,000	
		Concrete Paving	889	SY	$ 75	$ 66,667	
		Gravel Base, 8" d	296	CY	$ 50	$ 14,822	
		Trash Receptacle/Recycling	2	EA	$ 1,200	$ 2,400	
		Loam and Seed	4,000	SF	$ 8	$ 32,000	
					TOTAL	**$ 380,339**	
3.06	**Basketball & Fitness Clusters**	**40,658 SQ FT**					
		Basketball (2)					
		Asphalt Paving (3" depth)	210	TON	$ 180	$ 37,800	
		Gravel Base, (8" depth for Bit. Conc. Path)	280	CY	$ 42	$ 11,760	
		Color Sealcoat at Courts	9,000	SF	$ 2	$ 18,000	
		Basketball Goal	4	EA	$ 6,000	$ 24,000	
		Rough & Fine Grading	1,300	SY	$ 5	$ 6,500	
		Fitness Equipment					
		Adult Fitness Equipment	3	EA	$ 18,500	$55,500	
		PIP Surfacing w/ 4" Rubber, Gravel Base	900	SF	$ 40	$36,000	
		Furniture	8	LS	$ 6,000	$ 48,000	
		Topography Seating	3,000	SF	$ 50	$ 150,000	Unit price increase due to area size
		Planting	15,000	SF	$ 8	$ 120,000	
		Mounds/Grass	13,000	SF	$ 8	$ 104,000	
		Furniture - Custom Bench	5	EA	$ 10,000	$ 50,000	
		Basketball - Terraced Seating	1	LS	$ 20,000	$ 20,000	
					TOTAL	**$ 681,560**	
3.07	**Promenade & Running Track**						
		Promenade	38,784	SF			
		Decomposed Granite with Binder	478	CY	$ 80	$ 38,267	
		Gravel Base, 8" d	958	CY	$ 42	$ 40,241	
		Steel edger or similar edging	6,000	LF	$ 15	$ 90,000	
		Bike Lane	39,216				
		Bituminous Concrete Pavement (3")	732	TON	$ 150	$ 109,805	
		Gravel Base, 8" d for Bit. Pavement	969	CY	$ 42	$ 40,689	
		Color Sealcoat	39,216	SF	$ 2	$ 78,432	
		Running Track (12 feet width) Track Surfac	4,260	SY	$ 40	$ 170,400	
		Bituminous Concrete Pavement - (4")	106	TONS	$ 120	$ 12,723	
		Gravel Borrow - (12")	158	CY	$ 50	$ 7,889	Unit price increase due to area size
		Buffer Planting	24,180	SF	$ 14	$ 338,520	
		Structural Soil	64,600	CY	$ 39	$ 2,519,400	
		Furniture - Bench	100	EA	$ 5,000	$ 500,000	
		Pedestrian Lighting at Promenade	65	EA	$ 9,000	$ 585,000	
		Interactive Lighting	1	Allow.	$ 400,000	$ 400,000	
					TOTAL	**$ 4,931,365**	

3.08	**Skate Park**						
		Concrete Skate Park	47,000	SF	$ 60	$ 2,820,000	
		Concrete Special Treatment	1	Allow.	$ 100,000	$ 100,000	Custom concrete luminous finish treatment
		Mounds/Grass	35,000	SF	$ 8	$ 280,000	
		Linear Lighting at Skate Park	8	EA	$ 7,500	$ 60,000	
		Skate Park - Terraced Seating	1	LS	$ 20,000	$ 20,000	
		Climbing Wall	1	Allow.	$ 50,000	$ 50,000	
		Tree Protection	1	Allow.	$ 20,000	$ 20,000	
					TOTAL	**$ 3,350,000**	
3.09	**Interactive Play/Active Play**	**39,700 SQ FT**					
		Standalone Equipment	1	LS	$ 450,000	$ 450,000	
		Landscape Boulders	160	TON	$ 420	$ 67,200	
		PIP Surfacing w/ 4" Rubber	10,000	SF	$ 40	$ 400,000	
		PIP Surfacing w/ 4" Rubber (4" Conc.below	14,000	SF	$ 40	$ 560,000	
		Concrete at PIP Surfacing Slopes	342	CY	$ 35	$ 11,978	
		Concrete Paving	1,111	SY	$ 75	$ 83,333	
		Gravel Base, 8" d	247	CY	$ 42	$ 10,376	
		Furniture Bench	10	EA	$ 5,000	$ 50,000	
		Furniture Other	8	EA	$ 6,000	$ 48,000	
		Planting	5,700	SF	$ 14	$ 79,800	
		Climbing Wall	1	LS	$ 25,000	$ 25,000	
					TOTAL	**$ 1,785,687**	
3.10	**Electrical Service**						
		Promenade Lighting					
		Electrical Service	1	LS	$ 50,000	$ 50,000	
		Electrical Conduit & Wiring	1	LS	$ 80,000	$ 80,000	
		Plaza Lighting					
		Electrical Service	1	LS	$ 100,000	$ 100,000	
		Electrical Conduit & Wiring	1	LS	$ 80,000	$ 80,000	
					TOTAL	**$ 310,000**	
3.11	**Miscellaneous Landscaping/Features**						
		Tree Planting	340	EA	$ 5,000	$ 1,700,000	
					TOTAL	**$ 1,700,000**	
3.12	**Earthwork**						
	Plaza Area (North)	Imported Lightweight Fill	628	CY	$ 129	$ 81,012	
		Imported Topsoil (Loam)	326	CY	$ 29	$ 9,454	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	260	Ton	$ 65	$ 16,900	
		T&D Group C Soils	0	Ton	$ 130	$ -	
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Plaza Area (South)	Imported Lightweight Fill	1,213	CY	$ 129	$ 156,477	
		Imported Topsoil (Loam)	2,032	CY	$ 29	$ 58,928	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	751	Ton	$ 65	$ 48,815	
		T&D Group C Soils	0	Ton	$ 130	$ -	
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Garden Area (North)	Imported Lightweight Fill	259	CY	$ 129	$ 33,411	
		Imported Topsoil (Loam)	691	CY	$ 29	$ 20,039	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	0	Ton	$ 65	$ -	
		T&D Group C Soils	207	Ton	$ 130	$ 26,910	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In

		T&D Group D Soils	0	Ton	$ 260	$ -	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
	Garden Area (West)	Imported Lightweight Fill	1,033	CY	$ 129	$ 133,257	
		Imported Topsoil (Loam)	527	CY	$ 29	$ 15,283	
		T&D Group A Soils	424	Ton	$ 40	$ 16,960	
		T&D Group B Soils	141	Ton	$ 65	$ 9,165	
		T&D Group C Soils	0	Ton	$ 130	$ -	
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Sports and Play Area (North)	Imported Lightweight Fill	1,294	CY	$ 129	$ 166,926	
		Imported Topsoil (Loam)	731	CY	$ 29	$ 21,199	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	613	Ton	$ 65	$ 39,845	
		T&D Group C Soils	613	Ton	$ 130	$ 79,690	
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Sports and Play Area (West)	Imported Lightweight Fill	1,512	CY	$ 129	$ 195,048	
		Imported Topsoil (Loam)	2,224	CY	$ 29	$ 64,496	
		T&D Group A Soils	1,467	Ton	$ 40	$ 58,680	
		T&D Group B Soils	210	Ton	$ 65	$ 13,650	
		T&D Group C Soils	419	Ton	$ 130	$ 54,470	
		T&D Group D Soils	0	Ton	$ 260	$ -	
					TOTAL	**$ 1,320,615**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
4	**General Landscape**						
4.01	**Landscaping/Planting**						
		Tree Planting	250	EA	$ 5,000	$ 1,250,000	
		Mounds/Grass	425,000	SY	$ 8	$ 3,400,000	
					TOTAL	**$ 4,650,000**	
4.02	**Pathways**						
		Secondary Paths - 12 ft	46,800	SF			
		Bituminous Concrete Pavement (3")	874	TON	$ 150	$ 131,040	
		Gravel Base, 8" d for Bit. Pavement	1,156	CY	$ 42	$ 48,558	
					TOTAL	**$ 179,598**	
4.03	**Earthwork**						
	General Landscaped Area	Imported Lightweight Fill	40,648	CY	$ 129	$ 5,243,592	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
		Imported Topsoil (Loam)	16,911	CY	$ 29	$ 490,419	
		T&D Group A Soils	4,415	Ton	$ 40	$ 176,600	
		T&D Group B Soils	13,045	Ton	$ 65	$ 847,925	
		T&D Group C Soils	2,680	Ton	$ 130	$ 348,400	
		T&D Group D Soils	2,374	Ton	$ 260	$ 617,240	
					TOTAL	**$ 7,724,176**	

assume there are standard benches at even intervals along the length of paths throughout the site

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
5	**Grove**	89,973 Sq-Ft					
5.01	**Custom/Integrated Furniture**						
		Swings and Hammock Poles	1	LS	$ 300,000	$ 300,000	
					TOTAL	**$ 300,000**	
5.02	**Grove**						
		Loam & Seed	50,000	SF	$ 6	$ 300,000	
		Tree Planting	120	EA	$ 5,000	$ 600,000	
		Mounds/Grass	25,000	SY	$ 8	$ 200,000	
		Furniture - Bench at Path	20	LS	$ 5,000	$ 100,000	
		Grove Tree Lighting	1	Allow.	$ 500,000	$ 500,000	
					TOTAL	**$ 1,700,000**	
5.03	**Electrical Service**						
		Electrical Service	1	LS	$ 50,000	$ 50,000	
		Electrical Conduit & Wiring	1	LS	$ 50,000	$ 50,000	
					TOTAL	**$ 100,000**	
5.04	**Pathways**						
		Secondary Paths - 12 ft	7,980	SF			
		Bituminous Concrete Pavement (3")	149	TON	$ 150	$ 22,344	
		Gravel Base, 8" d for Bit. Pavement	197	CY	$ 50	$ 9,857	Unit price increase due to area size
		Tertiary Paths - 6 ft	6,510	SF			
		Bituminous Concrete Pavement (3")	122	TON	$ 150	$ 18,228	
		Gravel Base, 8" d for Bit. Pavement	161	CY	$ 50	$ 8,041	Unit price increase due to area size
		Lighting at Secondary Pathways	11	EA	$ 7,500	$ 83,125	
		Furniture - Bench at Secondary Path	4	EA	$ 5,000	$ 18,472	180 foot interval
					TOTAL	**$ 160,067**	
5.05	**Earthwork**						
	Grove Area	Imported Lightweight Fill	6,584	CY	$ 129	$ 849,336	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
		Imported Topsoil (Loam)	3,007	CY	$ 29	$ 87,203	
		T&D Group A Soils	1,540	Ton	$ 40	$ 61,600	
		T&D Group B Soils	0	Ton	$ 65	$ -	
		T&D Group C Soils	2,309	Ton	$ 130	$ 300,170	
		T&D Group D Soils	0	Ton	$ 260	$ -	
					TOTAL	**$ 1,298,309**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
6	**Adventure Play**	161,262 Sq-Ft					
6.01	**Woodland/Adventure Play**						
		Play Structures	1	LS	$ 900,000	$ 900,000	
		Bridges, Canopy Walk	6	EA	$ 75,000	$ 450,000	
		Natural Play Elements	1	LS	$ 500,000	$ 500,000	
		Standalone Equipment	1	LS	$ 500,000	$ 500,000	
		Sensory Play	1	LS	$ 100,000	$ 100,000	
		Landscape Boulders	160	TON	$ 420	$ 67,200	
		PIP Surfacing w/ 4" Rubber	15,000	SF	$ 40	$ 600,000	
		PIP Surfacing w/ 4" Rubber (4" Conc.below)	5,000	SF	$ 40	$ 200,000	
		Concrete at PIP Surfacing Slopes	122	CY	$ 50	$ 6,111	
		Concrete Paving	1,111	SY	$ 75	$ 83,333	
		Gravel Base, 8" d	247	CY	$ 42	$ 10,376	
		Furniture - Bench	10	EA	$ 5,000	$ 50,000	
		Furniture - Other	8	EA	$ 8,000	$ 64,000	
		Stormwater Meadow	3,500	SF	$ 35	$ 122,500	
		Herbaceous and Shrub Planting	11,000	SF	$ 35	$ 385,000	
		Mounds/Grass	10,000	SY	$ 8	$ 80,000	
		Tree Planting	120	EA	$ 5,000	$ 600,000	
		Tree Protection	1	LS	$ 20,000	$ 20,000	
		Interpretive Signage	8	EA	$ 1,500	$ 12,000	
		Lighting	10	EA	$ 7,500	$ 75,000	
		Custom Lighting	1	Allow.	$ 300,000	$ 300,000	
					TOTAL	**$ 5,125,520**	
6.02	**Electrical Service**						
		Electrical Service	1	LS	$ 50,000	$ 50,000	
		Electrical Conduit & Wiring	1	LS	$ 80,000	$ 80,000	
					TOTAL	**$ 130,000**	
6.03	**Pathways**						
		Secondary Paths - 12 ft	10,260	SF			
		Bituminous Concrete Pavement (3")	192	TON	$ 150	$ 28,728	
		Gravel Base, 8" d for Bit. Pavement	253	CY	$ 42	$ 10,645	
		Tertiary Paths - 6 ft	9,600	SF			
		Bituminous Concrete Pavement (3")	179	TON	$ 150	$ 26,880	
		Gravel Base, 8" d for Bit. Pavement	237	CY	$ 42	$ 9,961	
		Lighting	15	EA	$ 7,500	$ 112,500	
		Furniture - Bench at Secondary Path	5	EA	$ 5,000	$ 23,750	180 foot interval
					TOTAL	**$ 212,464**	
6.04	**Earthwork**						
	Adventure Play Area	Imported Lightweight Fill	17,708	CY	$ 129	$ 2,284,332	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
		Imported Topsoil (Loam)	7,327	CY	$ 29	$ 212,483	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	1,841	Ton	$ 65	$ 119,665	
		T&D Group C Soils	0	Ton	$ 130	$ -	
					TOTAL	**$ 2,616,480**	

other elements to be included:
stormwater meadows
herbaceous and shrub planting

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
7	**Stadium & Parking**	293,303 SQ-FT					
7.01	**Stadium Demolition**						
		Temporary Construction Fence	1	LS	$ 20,000	$ 20,000	
		Erosion Controls	2,000	LF	$ 5	$ 10,000	Assumes full perimeter
		R&D Bleachers, Turf Field and Track	25	DAY	$ 12,000	$ 300,000	Based on daily rates for 2 excavators, loader, skid steers and laborers
		Disposal of concrete	3,400	CY	$ 35	$ 119,000	Includes bleachers, caissons, exterior walls, contingency for pathways, miscellaneous pads
		Miscellaneous Demolition	1	LS	$ 10,000	$ 10,000	
					TOTAL	**$ 459,000**	
7.02	**New Field Construction**						
		SYNTHETIC TURF FIELD					
		Synthetic Turf Field Leveling Stone - 1" Depth	160	CY	$ 45	$ 7,200	
		Synthetic Turf Field Drainage Stone - 14" Dep	1,165	CY	$ 45	$ 52,425	
		Drainage Fabric	10,070	SY	$ 2	$ 20,140	
		Compaction	10,070	SY	$ 7	$ 70,490	
		Synthetic Field Turf	90,620	SF	$ 3	$ 226,550	
		Infill 50/50 (Crumb Rubber)	90,620	SF	$ 2	$ 135,930	
		Field Perimeter Collector Pipe - 12"	1,660	LF	$ 35	$ 58,100	
		Field Lateral Drainage Pipe	6,000	LF	$ 8	$ 45,000	
		Synthetic Turf Installation	90,620	SF	$ 4	$ 362,480	
		Scoreboard Foundation/Reinstallation	1	EA	$ 8,000	$ 8,000	
		Goal Posts and Footings	2	EA	$ 7,500	$ 15,000	
		20' Safety Netting	350	LF	$ 100	$ 35,000	
		RUNNING TRACK					
		Track Surfacing	5,100	SY	$ 40	$ 204,000	
		Bituminous Concrete Pavement - 4" Depth	1,150	TONS	$ 120	$ 138,000	
		Gravel Borrow - 12" Depth	450	CY	$ 35	$ 15,750	
		6" Perimeter Channel Drain	1,300	LF	$ 45	$ 58,500	
		Field Athletic Features	1	LS	$ 50,000	$ 50,000	
		BVCL Fence - 4' Height	1,280	LF	$ 65	$ 83,200	
		BVCL Single Gate - 4' Height	2	EA	$ 1,500	$ 3,000	
		BVCL Double Gate - 4' Height	3	EA	$ 2,000	$ 6,000	
		DRAINAGE					
		Nyloplast Drain Inlets	5	EA	$ 1,800	$ 9,000	
		Concrete Catch Basins	2	EA	$ 4,000	$ 8,000	
		Concrete Drainage Manhole	1	EA	$ 4,000	$ 4,000	
		Drainage Pipe - 12"	1,200	LF	$ 35	$ 42,000	
		STADIUM BLEACHER AND STRUCTURE					
		Bleachers	1	Allow.	$ 500,000	$ 500,000	
		Lighting	1	Allow.	$ 300,000	$ 300,000	
		Bleacher Foundation	1	LS	$ 90,000	$ 90,000	
		IRRIGATION	1	LS	$ 120,000	$ 120,000	
		Precast Concrete Manhole	2	EA	$ 4,000	$ 8,000	
		Field Lighting System	8	EA	$ 88,000	$ 704,000	
		Handholes	8	EA	$ 1,000	$ 8,000	
					TOTAL	**$ 3,387,765**	
7.03	**Sledding Hill / Overlook**						
		Mounds/Grass	9,500	SY	$ 10	$ 95,000	
		Garden Planting at Info Building	5,000	SF	$ 14	$ 70,000	
		Tree Planting	90	EA	$ 5,000	$ 450,000	
		Interpretive Signage	5	EA	$ 1,500	$ 7,500	

					TOTAL	**$ 622,500**	
7.04	**Seating**						
		Furniture Bench	16	LS	$ 5,000	$ 80,000	
		Furniture Custom	8	LS	$ 8,000	$ 64,000	
					TOTAL	**$ 144,000**	
7.05	**Parking Garage**	Removed from project scope					
			0	LS	$ -	$ -	
					TOTAL	**$ -**	
7.06	**Electrical Service**						
		Electrical Cabinet	1	EA	$ 7,500	$ 7,500	
		Conduit and Wire	1	LS	$ 90,000	$ 90,000	
					TOTAL	**$ 97,500**	
7.07	**Miscellaneous Landscaping/Features**						
		Loam and Seed	10,500	SF	$ 8	$ 84,000	
					TOTAL	**$ 84,000**	
7.08	**Pathways**						
		Primary Paths - 18 ft	24,156	SF			
		Bituminous Concrete Pavement (4")	451	TON	$ 150	$ 67,637	
		Gravel Base, 12" d for Bit. Pavement	895	CY	$ 42	$ 37,576	
		Secondary Paths - 12 ft	18,276	SF			
		Bituminous Concrete Pavement (3")	341	TON	$ 150	$ 51,173	
		Gravel Base, 8" d for Bit. Pavement	451	CY	$ 42	$ 18,962	
		Lighting at Primary and Secondary Paths	45	EA	$ 7,500	$ 337,500	
		Furniture - Bench at Primary and Secondary I	16	EA	$ 5,000	$ 79,583	180 foot interval
					TOTAL	**$ 592,431**	
7.09	**Earthwork**						
	Stadium and Parking Area	Imported Lightweight Fill	62,642	CY	$ 129	$ 8,080,818	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
		Imported Topsoil (Loam)	18,486	CY	$ 29	$ 536,094	
		T&D Group A Soils	1,396	Ton	$ 40	$ 55,840	
		T&D Group B Soils	22,333	Ton	$ 65	$ 1,451,645	
		T&D Group C Soils	4,187	Ton	$ 130	$ 544,310	
		T&D Group D Soils	0	Ton	$ 260	$ -	
					TOTAL	**$ 10,668,707**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
8.00	**Fields & Athletics**	653,032 SQ-FT					
8.01	**Baseball Field**						
		Artificial Turf Baseball field					
		Mounds/Grass	2,056	SY	$ 8	$ 16,448	
		Fine Grading	14,470	SY	$ 5	$ 72,350	
		Light Compaction	14,470	SY	$ 7	$ 101,290	
		Drainage Stone @ 14"d	5,643	CY	$ 45	$ 253,935	
		Finishing Stone @ 1"d	386	CY	$ 45	$ 17,370	
		Drainage Fabric	14,470	SY	$ 2	$ 28,940	
		Synthetic Turf Surfacing	130,225	SF	$ 2	$ 260,450	
		Infill 50/50	130,225	SF	$ 2	$ 260,450	
		Installation of Turf	130,225	SF	$ 4	$ 520,900	
		4' Ht. Chainlink Fence	600	LF	$ 65	$ 39,000	
		Ball Netting System	800	LF	$ 100	$ 80,000	
		Concrete Mow Curb	1,433	LF	$ 25	$ 35,825	
		Goal Posts	2	EA	$ 8,000	$ 16,000	
		Dugout Roof Structure	2	EA	$ 20,000	$ 40,000	
		Player Bench	4	EA	$ 3,000	$ 12,000	
		Drain Inlets / Clean Out	4	EA	$ 1,500	$ 6,000	
		Drainage Structures	1	EA	$ 6,000	$ 6,000	
		12" Collector Drains at Fields	2,000	LF	$ 30	$ 60,000	
		12" Flat Drains at Fields	5,000	LF	$ 9	$ 45,000	
		Movable Pitching Mound	1	EA	$ 8,000	$ 8,000	
		Irrigation	1	LS	$ 40,000	$ 40,000	
		Lighting - Baseball	4	LS	$ 80,000	$ 320,000	
					TOTAL	**$ 2,239,958**	
8.02	**Multi-Use Fields (Soccer)**						
		Multi-Use Natural Turf - 2 Fields					
		Mounds/Grass	10,000	SY	$ 8	$ 80,000	
		Fine Grading	20,000	SY	$ 5	$ 100,000	
		Light Compaction	20,000	SY	$ 7	$ 140,000	
		Rootzone Mix @ 8"d	4,500	CY	$ 60	$ 270,000	
		Loam and Hydroseed	20,000	SY	$ 4	$ 80,000	
		Ball Netting System	800	LF	$ 100	$ 80,000	
		Concrete Mow Curb	800	LF	$ 25	$ 20,000	
		Bleachers	2	EA	$ 6,500	$ 13,000	
		Player Bench	4	EA	$ 3,000	$ 12,000	
		Soccer Goals/Equipment	4	EA	$ 5,000	$ 20,000	
		Irrigation	1	LS	$181,000	$ 181,000	
		Drain Inlets / Clean Out	12	EA	$ 1,500	$ 18,000	
		Drainage Structures	2	EA	$ 6,000	$ 12,000	
		12" Collector Drains at Fields	3,600	LF	$ 30	$ 108,000	
		2" Flat Drains at Fields	30,000	LF	$ 7	$ 210,000	
		Lighting - Multi-use	6	LS	$ 80,000	$ 480,000	

					TOTAL	$	1,824,000	
8.03	Little League Fields							
		Little League Natural Turf - 3 Fields						
		Fine Grading	15,768	SY	$ 5	$	78,840	
		Backstops	3	EA	$ 25,000	$	75,000	
		Infield Mix @ 4"d	345	SY	$ 34	$	11,730	
		3/8" peastone blanket	1,734	CY	$ 60	$	104,040	
		Rootzone Mix @ 8"d	2,928	CY	$ 84	$	245,952	
		Loam and Hydroseed	8,784	SY	$ 4	$	35,136	
		8' Ht. Chainlink Fence	285	LF	$ 85	$	24,225	
		Concrete Mow Curb	1,440	LF	$ 25	$	36,000	
		Bleachers	6	EA	$ 6,500	$	39,000	
		Player Bench	6	EA	$ 3,000	$	18,000	
		Dugout Roof Structure	6	EA	$ 20,000	$	120,000	
		Foul Poles	6	EA	$ 2,500	$	15,000	
		Irrigation	141,900	SF	$ 1	$	141,900	
		Drain Inlets / Clean Out	10	EA	$ 1,500	$	15,000	
		Drainage Structures	3	EA	$ 6,000	$	18,000	
		12" Collector Drains at Fields	1,500	LS	$ 30	$	45,000	
		2" Flat Drains at Fields	7,500	LS	$ 7	$	52,500	
		Lighting - Little League	6	LS	$ 80,000	$	480,000	
					TOTAL	$	1,555,323	
8.04	Basketball/Tennis							
		Tennis Courts (2)						
		Full Depth Asphalt Paving at Tennis Courts (3" Depth)	280	TON	$ 180	$	50,400	
		Gravel Borrow (8" Depth)	360	CY	$ 35	$	12,600	
		Color Sealcoat at Courts	14,500	SF	$ 2	$	29,000	
		New Tennis Nets and Posts	2	EA	$ 2,500	$	5,000	
		6' HT. BVCL Single Wide Gate	2	EA	$ 2,000	$	4,000	
		6' HT. BVCL Fence	700	LF	$ 75	$	52,500	
		Rough & Fine Grading	1,600	SY	$ 5	$	8,000	
		Player Bench	4	EA	$ 3,000	$	12,000	
		Basketball (2)						
		Asphalt Paving (3" depth)	210	TON	$ 180	$	37,800	
		Gravel Base, (8" depth for Bit. Conc. Path)	280	CY	$ 42	$	11,760	
		Color Sealcoat at Courts	9,000	SF	$ 2	$	18,000	
		Basketball Goal	4	EA	$ 6,000	$	24,000	
		6' HT. BVCL Single Wide Gate	2	EA	$ 2,000	$	4,000	
		6' HT. BVCL Fence	1,000	LF	$ 75	$	75,000	
		Rough & Fine Grading	1,300	SY	$ 5	$	6,500	
		Lighting - Basketball + Tennis	6	LS	$ 80,000	$	480,000	
		Player Bench	4	EA	$ 3,000	$	12,000	
					TOTAL	$	830,560	
8.05	Electrical Service							
		Electrical Cabinet	1	EA	$ 7,500	$	7,500	
		Electrical Conduit & Wiring	1	LS	$100,000	$	100,000	

					TOTAL	**$ 107,500**	
8.06	**Pathways**						
		Primary Paths - 20 ft	80,900	SF			
		Bituminous Concrete Pavement (4")	1,510	TON	$ 150	$ 226,520	
		Gravel Base, 12" d for Bit. Pavement	2,996	CY	$ 42	$ 125,844	
		Secondary Paths - 12 ft	38,736	SF			
		Bituminous Concrete Pavement (3")	723	TON	$ 150	$ 108,461	
		Gravel Base, 8" d for Bit. Pavement	957	CY	$ 42	$ 40,191	
		Furniture - Bench at Primary and Secondary Paths	16	EA	$ 5,000	$ 79,583	180 foot interval
					TOTAL	**$ 580,599**	
8.07	**Mounds/Landscape Areas**						
		Mounds/Grass	4,533	SY	$ 8	$ 36,267	
		Tree Planting	20	EA	$ 5,000	$ 100,000	
					TOTAL	**$ 136,267**	
8.08	**Earthwork**						
	Field 1	Imported Lightweight Fill	2,420	CY	$ 129	$ 312,180	Note that cut/fill overlap between the stormwater chambers and other project areas, particularly the fields, were accounted for in these calculations.
		Imported Topsoil (Loam)	2,014	CY	$ 29	$ 58,406	
		T&D Group A Soils	162	Ton	$ 40	$ 6,480	
		T&D Group B Soils	1,458	Ton	$ 65	$ 94,770	
		T&D Group C Soils	0	Ton	$ 130	$ -	
		T&D Group D Soils	0	Ton	$ 260	$ -	
	Field 2	Imported Lightweight Fill	1,594	CY	$ 129	$ 205,626	
		Imported Topsoil (Loam)	4,815	CY	$ 29	$ 139,635	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	476	Ton	$ 65	$ 30,940	
		T&D Group C Soils	0	Ton	$ 130	$ -	
		T&D Group D Soils	1,427	Ton	$ 260	$ 371,020	
	Field 3	Imported Lightweight Fill	7,110	CY	$ 129	$ 917,190	
		Imported Topsoil (Loam)	3,466	CY	$ 29	$ 100,514	
		T&D Group A Soils	0	Ton	$ 40	$ -	
		T&D Group B Soils	0	Ton	$ 65	$ -	
		T&D Group C Soils	3,896	Ton	$ 130	$ 506,480	
		T&D Group D Soils	433	Ton	$ 260	$ 112,580	
					TOTAL	**$ 2,855,821**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
9	**Flood Management**						
9.01	**Berm and Barrier Wall**						
		Steel Sheet Piles for Flood Protection Barri	2,000	LF	$ 1,650	$ 3,300,000	Assumes 2,000 LF of sheet piling Assumes 30 ft long sheets Assumes hot-rolled, steel sheeting Plus lightweight fill costs previously developed by N. Ames for the flood protection barrier
					TOTAL	**$ 3,300,000**	
9.02	**Pathways**						
		Secondary Paths - 20 ft	33,200	SF			
		Bituminous Concrete Pavement (3")	620	TON	$ 150	$ 92,960	
		Gravel Base, 8" d for Bit. Pavement	820	CY	$ 50	$ 41,008	Unit price increase due to area size
		Furniture - Bench at Secondary Paths	9	EA	$ 5,000	$ 46,111	180 foot interval
					TOTAL	**$ 180,079**	
9.03	**Landscape/Planting**						
		Mounds/Grass	18,556	SY	$ 8	$ 148,444	
		Tree Planting	30	EA	$ 5,000	$ 150,000	
					TOTAL	**$ 298,444**	
9.04	**Earthwork**						
	Flood Management Area	Imported Lightweight Fill	31,162	CY	$ 129	$ 4,019,898	In areas of 1-3' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1' of topsoil cover. In areas of 3-5' of fill, assume 1' of existing fill is excavated and replaced with lightweight fill with 1-2' of topsoil cover. In areas of >5' of fill, assume 2' of existing fill is excavated and replaced with 5' or more of lightweight fill with 2' of topsoil cover.
		Imported Topsoil (Loam)	10,602	CY	$ 29	$ 307,458	
		T&D Group A Soils	2,151	Ton	$ 40	$ 86,040	
		T&D Group B Soils	717	Ton	$ 65	$ 46,605	
		T&D Group C Soils	2,868	Ton	$ 130	$ 372,840	
		T&D Group D Soils	9,319	Ton	$ 260	$ 2,422,940	
					TOTAL	**$ 7,255,781**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
10.00	**Buildings and Structures**						
10.01	**Maintenance & Operations (Primary)**						
		Primary M&O Building	8,700	SF	$ 320	$ 2,784,000	
		(150 LF) Piles	75	PILE	$ 18,000	$ 1,350,000	
		(250 LF) Piles	0	PILE	$ 24,000	$ -	
		Pile Equipment Mobilization	0.38	%	$ 50,000	$ 18,939	fraction of total piles
		Pile Static Axial Load Test	0.38	%	$ 75,000	$ 28,409	fraction of total piles
					TOTAL	**$ 4,181,348**	
10.02	**Community Building**						
		Community Center/Day Care	5,500	SF	$ 360	$ 1,980,000	
		(150 LF) Piles	48	PILE	$ 18,000	$ 864,000	
		(250 LF) Piles	0	PILE	$ 24,000	$ -	
		Pile Equipment Mobilization	0.24	%	$ 50,000	$ 12,121	fraction of total piles
		Pile Static Axial Load Test	0.24	%	$ 75,000	$ 18,182	fraction of total piles
					TOTAL	**$ 2,874,303**	
10.03	**Sports Headquarters**						
		Sports HQ	2,600	SF	$ 430	$ 1,118,000	
		(150 LF) Piles	0	PILE	$ 18,000	$ -	
		(250 LF) Piles	0	PILE	$ 24,000	$ -	
		Pile Equipment Mobilization	0.00	%	$ 50,000	$ -	fraction of total piles
		Pile Static Axial Load Test	0.00	%	$ 75,000	$ -	fraction of total piles
					TOTAL	**$ 1,118,000**	
10.04	**Event Space**						
		Destination Restaurant/Event Building	5,700	SF	$ 500	$ 2,850,000	
		(150 LF) Piles	48	PILE	$ 18,000	$ 864,000	
		(250 LF) Piles	0	PILE	$ 24,000	$ -	
		Pile Equipment Mobilization	0.24	%	$ 50,000	$ 12,121	fraction of total piles
		Pile Static Axial Load Test	0.24	%	$ 75,000	$ 18,182	fraction of total piles
					TOTAL	**$ 3,744,303**	
10.05	**Welcome Center / Maintenance & Operations**						
		Admin/Welcome Center	3,800	SF	$ 360	$ 1,368,000	
		(150 LF) Piles	27	PILE	$ 18,000	$ 486,000	
		(250 LF) Piles	0	PILE	$ 24,000	$ -	
		Pile Equipment Mobilization	0.14	%	$ 50,000	$ 6,818	fraction of total piles
		Pile Static Axial Load Test	0.14	%	$ 75,000	$ 10,227	fraction of total piles
					TOTAL	**$ 1,871,045**	
10.06	**Comfort Stations**						
		Comfort Station	900	SF	$ 300	$ 270,000	
		(150 LF) Piles	0	PILE	$ 18,000	$ -	
		(250 LF) Piles	0	PILE	$ 24,000	$ -	
		Pile Equipment Mobilization	0.00	%	$ 50,000	$ -	fraction of total piles
		Pile Static Axial Load Test	0.00	%	$ 75,000	$ -	fraction of total piles
					TOTAL	**$ 270,000**	
0.00	**0.00**						

					$ -	$ -	
					TOTAL	**$ -**	

Item ID	Task Description	Construction Item	Quantity	Unit	Unit Price	Construction Cost	Notes
11	**Sitewide Improvements**						
11.01	**Earthwork**						
	Stormwater Chambers	Imported Topsoil (Loam)	30,800	CY	$ 29	$ 893,200	chambers.
		Imported Crushed Stone	15,400	CY	$ 34	$ 523,600	Assume 1' base of crushed stone
		T&D Group A Soils	44,350	Ton	$ 40	$ 1,774,000	
		T&D Group B Soils	16,000	Ton	$ 65	$ 1,040,000	
		T&D Group C Soil	52,980	Ton	$ 130	$ 6,887,400	
		T&D Group D Soils	29,300	Ton	$ 260	$ 7,618,000	
					TOTAL	**$ 18,736,200**	
11.02	**Stormwater**						
		Stormwater Meadow	65,200	SF	$ 6	$ 391,200	
		Stormwater Marsh/Wetland	28,600	SF	$ 10	$ 286,000	
		Porous Pavement	3,400	SF	$ 12	$ 40,800	
		Stormwater Corridor Trench	8,700	SF	$ 6	$ 52,200	
		Urban Edge Tree Plazas/Porous Pavement	18,500	SF	$ 12	$ 222,000	
		Add Alternate - Tree Plazas/Porous Pavement for Addit	9,700	SF	$ 12	$ 116,400	
		Add Alternate - Constructed Marsh for Additional Road	5,100	SF	$ 10	$ 51,000	
		24" HDPE Pipe	2,500	LF	$ 45	$ 112,500	
		12" HDPE	5,000	LF	$ 35	$ 175,000	
		4" HDPE Pipe (underdrainage)	6,000	LF	$ 20	$ 120,000	
		12" Flat drain (synth field)	5,000	LF	$ 20	$ 100,000	
		Deep sump and hooded catch basins	30	EA	$ 6,300	$ 189,000	
		4' Diameter Drain Manhole	20	EA	$ 4,500	$ 90,000	
		6' Diameter Drain Manhole/Outlet Control	10	EA	$ 7,000	$ 70,000	
		Area Drain	30	EA	$ 2,200	$ 66,000	
		Cleanout	20	EA	$ 600	$ 12,000	
		Subsurface Detention System	1	LS	$ 5,220,000	$ 5,220,000	
					TOTAL	**$ 7,314,100**	
11.03	**Dewatering**						
		Site Dewatering and Treatment	1	LS	$ 3,000,000	$ 3,000,000	
					TOTAL	**$ 3,000,000**	
11.04	**Site Utilities**						
		Utility Connections	1	LS	$ 5,000,000	$ 5,000,000	
					TOTAL	**$ 5,000,000**	
11.05	**Emergency Access - 20 ft**						
		Emergency Access - 20 ft	65,400	SF			
		Bituminous Concrete Pavement (4")	1,221	TON	$ 150	$ 183,120	
		Gravel Base, 12" d for Bit. Pavement	2,422	CY	$ 42	$ 101,733	
		Furniture - Bench at Emergency Access	18	EA	$ 5,000	$ 90,833	180 foot interval
					TOTAL	**$ 375,687**	
11.06	**Wayfinding Signage**						
		Backflow Preventer and Cabinet	3	LS	$ 8,000	$ 24,000	
		Connection to Existing Water Service	1	LS	$ 100,000	$ 100,000	
		Drinking Fountain w/ Bottle Filler	15	EA	$ 6,000	$ 90,000	
					TOTAL	**$ 214,000**	
11.07	**Water Fountains**						
			1	LS	$ 300,000	$ 300,000	
					TOTAL	**$ 300,000**	

LANDSCAPE RESILIENCE ENGINEERING

WESTON & SAMPSON

- CLIMATE STANDARD MEMORANDUM

WESTON & SAMPSON ENGINEERS, INC.
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Climate Design Parameters Report

September 2020

CITY OF
Boston
MASSACHUSETTS

Moakley Park Project

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Weston & Sampson Engineers, Inc. (Weston & Sampson) presents this Climate Design Parameters Report to inform the City of Boston Parks and Recreation Department on the resilient climate design adjustments recommended for the Joe Moakley Park project located in Boston, Massachusetts. Joe Moakley Park is commonly referred to as Moakley Park and this project will be referred to as "the Project". This report examines coastal, extreme precipitation, and extreme heat climate data and projections, based on the most current, peer-reviewed climate methodologies. Content presented should be used as climate parameters to inform design of the earthen berm flood barrier, stormwater management system, and park revitalization efforts moving forward.

1.0 PROJECT OVERVIEW

1.1 Project Assets + Useful Life

Useful Life is defined as the estimated average number of years before an asset will likely need reinvestment to continue to perform its intended function(s). For this project, we have identified the following components and their Useful Life.

A. Earthen Berm
    - Coastal flood management barrier
    - Useful Life = 50 years

B. Stormwater Management
    - Below-ground stormwater detention chambers
    - Useful Life = 50 years

C. Park Revitalization
    - Landscape modifications
    - Useful Life = 30 years

1.2 Climate Planning Horizon Selected for Design

The Planning Horizon is defined as the range of years used to determine the future climate event projections to be used in the design criteria.

Recommended Target Planning Horizon = 2070 (50 years)

1.3 Existing Site Conditions

The Flood Insurance Rate Map (FIRM) for Moakley Park is shown in Figure 1, detailing the general flood elevations for the Site. This FIRM indicates that the majority of the Site exists within FEMA Zone AE, with an elevation of 16.5 ft-Boston City Base (BCB) Datum. FEMA uses the NAVD88 datum to describe the various Zone elevations, and conversion to the BCB requires the addition of 6.46 ft to the NAVD88 elevation. In addition, a transect that cuts across the southern third of the Site is also shown on Figure 1. This FIRM was last updated in March of 2016. Zone AE is classified as a Special Flood Hazard Area, an area inundated by 1% annual-chance flooding and in which base flood elevations have been determined, as indicated on the FIRM.

The elevation of William J Day Boulevard (hereinafter the "Blvd") is slightly higher than the Site. While there is currently no earthen berm on-site, the height of the Blvd intercepts existing coastal flooding, such that the Site does not currently experience coastal flooding. Woods Hole Group is currently evaluating a Letter of Map Revision (LOMR) to redraw the FIRM to illustrate this flood protection the Blvd provides.

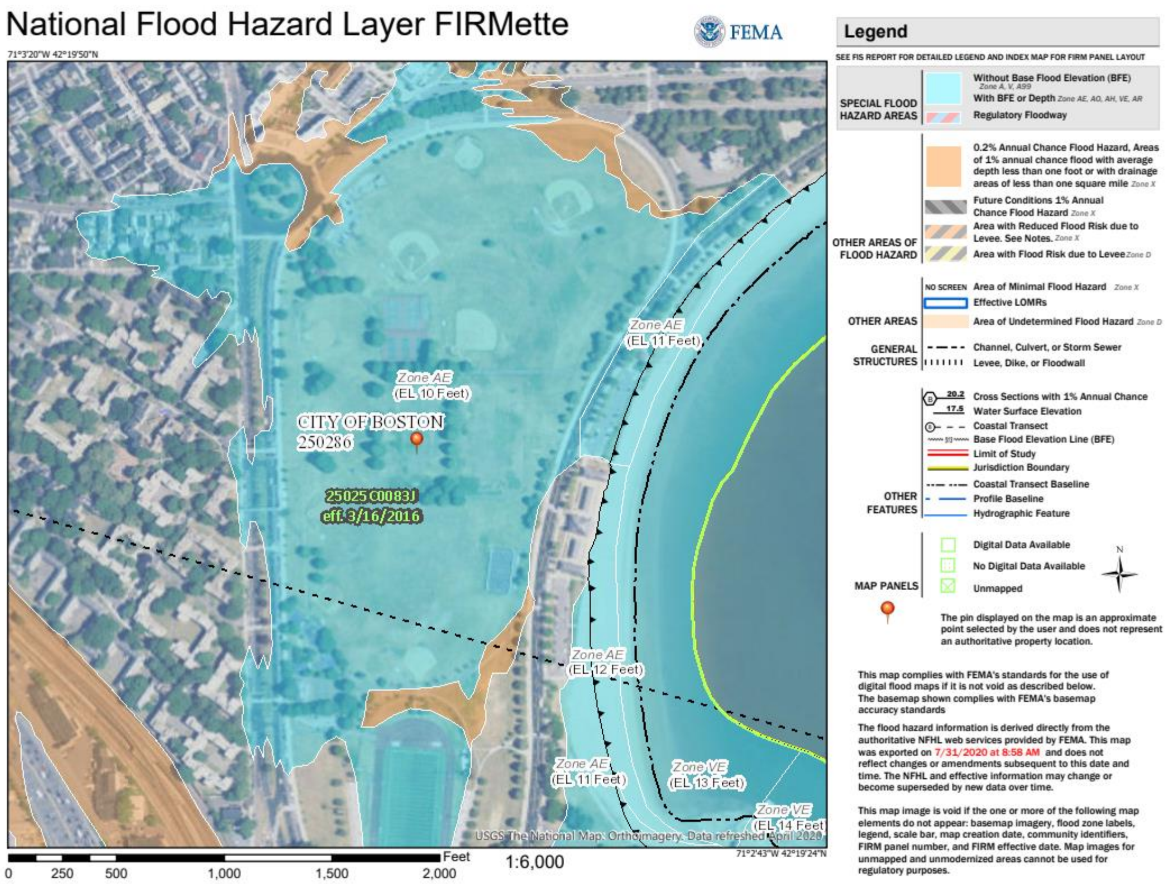

Figure 1. FEMA Flood Insurance Rate Map for the Moakley Park Site
Source: FEMA's National Flood Hazard Layer Viewer

1.4 Data Used for Climate Projections

This Climate Design Parameters Report uses existing, peer-reviewed methodologies for statistical climate data analysis. The design criteria and projections included in this report correspond to the best available science and projections for the Commonwealth and in the Boston area. The climate planning horizon and return period/confidence intervals proposed in this report were based on professional judgement and in accordance with recommendations and standards that are currently being developed state-wide, as part of implementation of the State Hazard Mitigation Climate Adaptation Plan (SHMCAP).

The source of coastal climate data and projections presented in this report was the Massachusetts Coastal Flood Risk Model (MC-FRM), a state-wide climate model developed by the Woods Hole Group (WHG) for MassDOT.

- Previously, resilient coastal climate design parameters have been based on the Boston Harbor Flood Risk Model (BH-FRM), published in 2016 by the (WHG) for the City of Boston. Since 2016, the MC-FRM has been developed to reflect the most current sea-level rise and storm surge projections, as well as updated climatology for the entire State.
- MC-FRM has not yet been publicly released, but Woods Hole Group was subcontracted by Stoss to provide MC-FRM data for present, 2030, 2050, and 2070 planning horizons.

Precipitation climate data and projections presented in this report were collected and analyzed using methodology outlined by the National Cooperative Highway Research Program (NCHRP) Final Report for "Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure," Project 15-61, 2019.

- Previously, resilient precipitation climate design parameters have been based on the Boston Water and Sewer Commission (BWSC) 2015 Report precipitation projections. The BWSC Report was not used as the primary informant for this report's design parameters due to the availability of more current climate data and projections, as well as data that is more site-specific.
- *Link to NCHRP Project 15-61 Report*: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP1561FinalReport.pdf
- The primary source for the baseline precipitation climate data was NOAA Atlas 14 Point Precipitation Frequency Estimates.
- The primary source for daily precipitation projections data was the Statistical Downscaled CMIP5 Climate and Hydrology Projections using Localized Constructed Analogs (LOCA).
    - *Link to LOCA data set*: https://gdo--dcp.ucllnl.org/
    - Group 1 Global Climate Models (GCMs) were used as per recommendation by the NCHRP 15-61 report.

The source of temperature climate data and projections presented in this report was the Multivariate Adaptive Constructed Analogs (MACA) data set.

- Previously, resilient climate design parameters for heat have been based on the Rossi et al., 2015 and Houser et al., 2015 temperature projections. Those sources were not used as the primary informant for this report's design parameters due to the availability of more current climate data and projections, as well as data that is site-specific to Moakley Park.
- *Link to MACA data set*: https://climate.northwestknowledge.net/MACA/data_portal.php

2.0 COASTAL CLIMATE ADJUSTMENT

2.1 Annual Exceedance Probability and Sea-level Rise

The MC-FRM water surface elevation projections for each annual exceedance probability, based on sea-level rise (SLR) projections for the 2030, 2050, and 2070 planning horizons are shown on Table 1. The water surface elevations presented are based on SLR projections for Northern Massachusetts (North of Cape Cod, Boston, etc.).

Water surface elevations are base flood elevations and do not include freeboard or wave action. 1 ft of freeboard is recommended for the design flood elevation (DFE). WHG has proposed beach nourishment to mitigate wave action, but if beach nourishment is not completed, wave heights are reported to be 2.3 ft from the MC-FRM. Hence, the recommended DFE is 21.6 ft-BCB, assuming 1 ft of freeboard on the 2070 of 20.6 ft-BCB (Table 1).

The 1% annual exceedance probability (AEP) is the design storm recommended for project assets. The climate planning horizon selected for design is 2070.

Table 1. MC-FRM Coastal Climate Projections Based on Sea-Level Rise

Annual Exceedance Probability (%)	Present – No SLR	2030 – 1.29 ft SLR	2050 – 2.49 ft SLR	2070 – 4.29 ft SLR
	Water Surface Elevation (ft-BCB)	Water Surface Elevation (ft-BCB)	Water Surface Elevation (ft-BCB)	Water Surface Elevation (ft-BCB)
0.1	17.4	18.5	20.4	22.1
0.2	17	18.1	20	21.7
0.5	16.5	17.5	19.3	21
1	16	17.1	18.9	20.6*
2	15.6	16.7	18.4	20.1
5	15.1	16.2	17.8	19
10	14.6	15.8	17.3	18.5
20	14.2	15.3	16.7	18.3
25	14	15.2	16.5	18.2

*Highlighted value corresponds to the water surface elevation for the 2070 1% design storm.

2.2 Tidal Projections for Dorchester Bay

The mean higher high water (MHHW) and mean high water (MHW) elevations projected at the Site are illustrated on Table 2. The elevation of William J Day Boulevard, which intercepts tidal flooding before it reaches the Site, is 0.5 ft higher than the Park (17 ft). Tidal flooding is not projected under regular tide conditions in the future, since the MHHW tidal elevation (15.9 ft-BCB) is below the elevation of the Blvd.

Table 2. Tidal Projections for Dorchester Bay

Tides	Present		2030		2050		2070	
	MHHW	MHW	MHHW	MHW	MHHW	MHW	MHHW	MHW
Elevation (ft-BCB)	11.5	11	12.8	12.4	14.1	13.6	15.9	15.4

3.0 EXTREME PRECIPITATION CLIMATE ADJUSTMENT

3.1 Storm Depth

The BWSC design standard uses the 10-yr 24-hour storm event, with a rainfall volume of 5.25 inches for design of stormwater infrastructure (BWSC, 2015).

The 25-yr (or 4%) recurrence interval (also known as return period) is recommended for stormwater management/drainage design and park revitalization. This interval is therefore the minimum design criteria. The planning horizon selected for design is 2070. Table 3 indicates the total storm depth data and projections for the present, 2030, 2050, and 2070 planning horizons. The NOAA Atlas 14 Point Precipitation Frequency Estimates and the LOCA data set were the primary sources used for the baseline and climate projections data.

The projected 2070 25-yr storm event equates to the present-day 100-yr storm event, as shown in Figure 2.

Table 3. Total Storm Depth (inches/24-hour)

Recurrence Interval	NOAA Atlas 14 Present Baseline	2030 Values	2050 Values	2070 Values
2-yr	3.3	3.4	3.8	3.8
5-yr	4.3	4.5	5.0	5.2
10-yr	5.1	5.5	6.1	6.5
25-yr	6.3	6.7	7.5	8.2*
50-yr	7.2	7.6	8.8	9.7
100-yr	8.1	8.6	10.1	11.2
200-yr	9.3	9.8	12.0	13.2
500-yr	11.1	12.0	15.3	16.8

*Highlighted value corresponds to the water surface elevation for the 2070 25-yr recurrence interval design storm.

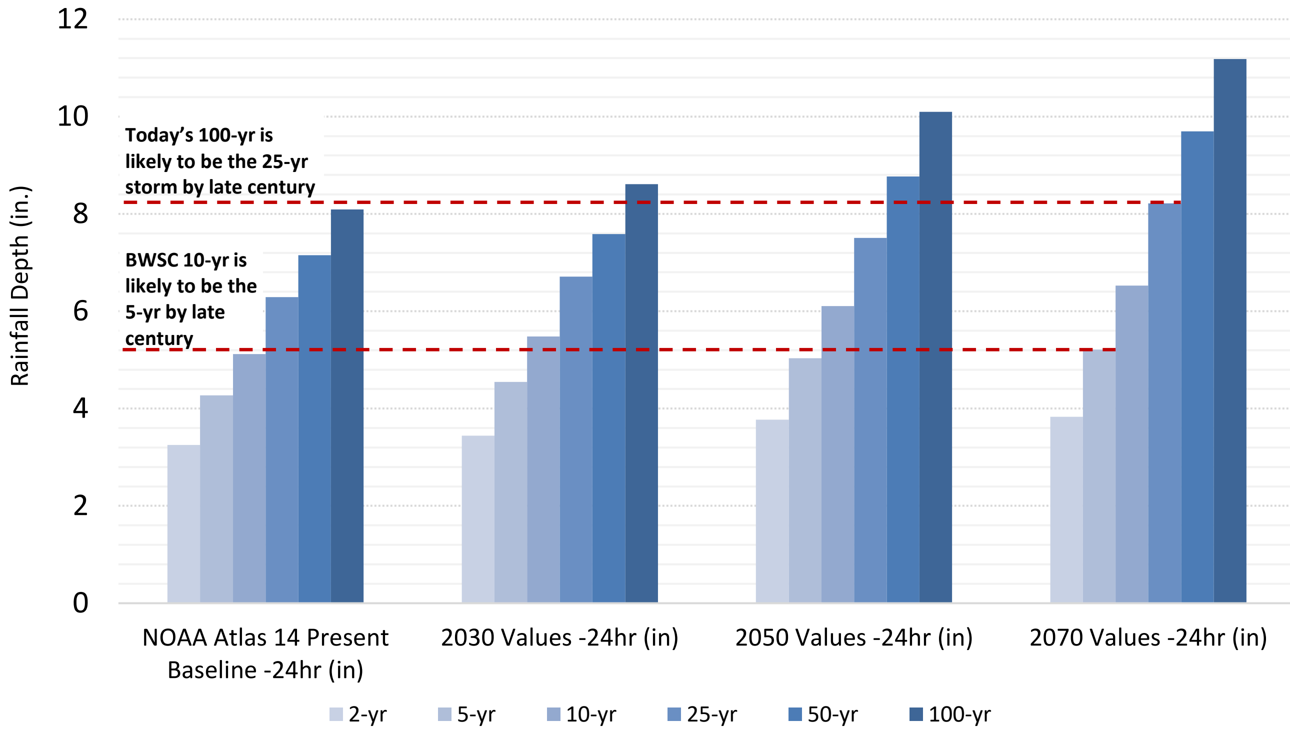

Figure 2. Projected Rainfall Depths by Return Period for Moakley Park

3.2 Peak Rainfall Intensity

The recommended precipitation design standard is the 25-year, 24-hr storm of 8.2 inches. Table 4 presents the hourly rainfall intensity data projections, calculated based on the 2070, 25-yr design storm. This design event corresponds to a total storm depth of 8.2 in/24-hr, with an hourly peak intensity of 2.05 inches/hour.

Table 4. Peak Hourly Rainfall Intensity for the 24-hour Design Storm

Duration (hour)	Ratio	Cumulative Depth (inches)	Hourly Peak Intensity (inches/hour)
0	0.00	0.00	0.00
1	0.01	0.08	0.08
2	0.02	0.16	0.08
3	0.03	0.25	0.09
4	0.04	0.35	0.10
5	0.06	0.46	0.11
6	0.07	0.59	0.13
7	0.09	0.74	0.15
8	0.11	0.93	0.19
9	0.15	1.20	0.26
10	0.19	1.55	0.35
11	0.25	2.05	0.50
12	0.50	4.10	2.05
13	0.75	6.15	2.05
14	0.81	6.65	0.50
15	0.85	7.01	0.36
16	0.89	7.27	0.26
17	0.91	7.46	0.19
18	0.93	7.61	0.15
19	0.94	7.74	0.13
20	0.96	7.85	0.11
21	0.97	7.95	0.10
22	0.98	8.04	0.09
23	0.99	8.13	0.08
24	1.00	8.20	0.07

4.0 EXTREME HEAT CLIMATE ADJUSTMENT

4.1 Extreme Heat

The temperature design criteria that are recommended for the project for the current, 2030 and 2070 planning horizons are presented on Table 5. The recommended climate planning horizon is 2070. MACA data were used to estimate these extreme heat climate projections.

Table 5. Temperature Projections				
End of Useful Life	Average Temperature (°F)	# of Days above 90°F	# of Days above 95°F	# of Days below 32°F
Baseline	60	6	0	98
2030	63	18	3	77
2070	67	43	16	45

Further Considerations

The extreme temperature climate projections presented in Table 5 are most relevant to design of park revitalization efforts. The vulnerable communities adjacent to the park (high percentage of low-income, minority, English-isolated households) are most at risk to heat impacts. Park revitalization has the opportunity to reduce the urban heat island effect present in the region. Examples of design considerations include increased tree canopy, reduce impervious surfaces, and green-infrastructure.

5.0 REFERENCES

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