ARUP

Rhynland Energy

Moraga Storage LLC - ZOVL (Oakham, MA)

Stormwater Management Report

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1.1 General Information

- **Project Address:** 358 Coldbrook Rd Oakham, MA 01068
- **Existing Land Use/Zoning:** Agricultural and Rural Residential District
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1.2 Executive Summary

This Stormwater Management Report was prepared in accordance with the Massachusetts Department of Environmental Protection (MassDEP) Stormwater Management Handbook on behalf of Rhynland Energy. The report examines the changes in drainage that can be expected as the result of the proposed battery energy storage site (BESS) development located at 358 Coldbrook Road in the Town of Oakham in Worcester County, Massachusetts (herein referred to as the 'Site').

Figure 1-1: Site Locus Map

The proposed project consists of 74 battery units with associated utility connections, and site improvements including electrical equipment, concrete pads, access driveways, and stormwater drainage infrastructure.

The stormwater management system for this site has been designed utilizing Best Management Practices (BMPs) and Low Impact Design (LID) to be in general compliance with the stormwater management standards outlined in the Massachusetts Stormwater Handbook. The proposed project will provide pollutant reduction by way of proprietary stormwater treatment devices, and peak runoff attenuation by way of reducing impervious coverage, maintaining existing drainage patterns, and the implementation of dry detention basins. The project will also provide erosion and sedimentation control drawings in accordance with the Erosion and Sedimentation Guidelines: A Guide for Planners, Designers, and Municipal Officials during the demolition and construction periods, as well as long term stabilization of the site.

Peak runoff to the Site's design points have been reduced in the post development conditions. A summary of the pre- and post-development conditions peak runoff rates for the 2-, 10-, and 100-year are shown in **Table 1-1** below.

The design detailed in this report is further supported by the site development drawings prepared by Arup dated March 18th, 2025, provided in **Appendix M**.

Table 1-1: Peak Runoff Rate Summary (cfs)

	2-year			**10-year**			**100-year**		
	Pre	**Post**	**Δ**	**Pre**	**Post**	**Δ**	**Pre**	**Post**	**Δ**
DP-1	8.51	5.10	-3.41	15.58	8.81	-6.77	27.16	16.35	-10.81
DP-2	13.60	10.99	-2.61	25.27	23.37	-1.9	44.43	43.24	-1.19

2. Site Conditions

2.1 Existing Site Description

The existing parcel is approximately 42.85 acres and the proposed limit of disturbance is 17.9 acres. The entire Town of Oakham is designated as an "Agricultural and Rural Residential District" as indicated on the "Zoning Map of Oakham, Massachusetts" prepared in March 1972. The site is bordered to the east by Coldbrook Road, and to the north, south, and west by rural, vegetated land.

The site is the location of a former automobile salvage storage facility that today is comprised mostly of forest, marsh, and unmaintained developed area. Additionally, a Massachusetts Electric d/b/a National Grid maintained power line easement passes through the northeastern portion of the site. A paved road provides access to the Site from Coldbrook Road. At the end of the access road there is an abandoned one-story, two bay service garage, an attached one-story office or reception building, and a separate shed. Much of the site is covered by unpaved access roads and former car storage areas which are becoming overgrown with shrubs and herbaceous vegetation.

The western portion of the Site is generally level, but includes small manmade drainage channels, mounds, depressions, and berms. In the northeast portion, the topography gradually slopes down in a northeasterly direction. In the southeast portion, there is a steep decline that becomes shallower going eastward.

2.1.1 Soil Conditions

According to the USDA Natural Resources Conservation Service (NRCS) Web Soil Survey, the main soil types onsite are hydrologic soil group (HSG) types C and D. See **Table 2-1** for all soil types onsite and their corresponding hydrologic soil group per Web Soil Survey (see **Appendix C**).

During our initial screening of the site, it was determined that the groundwater elevation has a depth of about 19-27" below grade per the USDA Web Soil Survey. Per the Massachusetts Stormwater Handbook, a vertical separation of 2' is required between groundwater and the bottom of our stormwater system. Furthermore, since the site is comprised mostly of C and D soils - infiltration on the Site was deemed not suitable. The design will instead implement surface detention basins with impermeable liners to accommodate the peak flow mitigation requirements.

Table 2-1: NRCS Soil Survey

Map Unit Symbol	Map Unit Name	Rating	HSG
910C	Woodbridge-Paxton association, 3 to 15 percent slopes, extremely stony	Moderately well drained	C/D
918B	Ridgebury-Whitman association, 0 to 8 percent slopes, extremely stony	Poorly drained	D
927C	Montauk-Scituate-Canton association, 3 to 15 percent slopes, extremely stony	Well drained	C

2.1.2 Wetland Information

The Site contains multiple wetland resource areas, primarily classified as Bordering Vegetated Wetlands (BVWs). The site contains 6,600 linear feet of BVW per field delineation by Epsilon on July 21, 2023 and March 26, 2024 and approved by the Oakham Conservation Commission through an Order of Resource Area Delineation (ORAD) in December 2024.

The proposed development aims to limit the amount of disturbance to these existing wetland systems to the maximum extent feasible. Under the Massachusetts Wetland Protection Act (WPA), a BVW has a 100-foot Buffer Zone extending from its edge - project work within the 100-foot Buffer Zone includes: grading, stormwater drainage infrastructure, battery and associated utility installation, paved access roadway, gravel walkways, and a proposed noise wall. The WPA does not have strict performance standards for buffer zone work, and the Town of Oakham does not have a wetlands protection bylaw or wetland delineation methodology that differs from the state methodology – therefore, no additional mitigation is required for work within this buffer zone.

Practical alternatives were explored to avoid direct BVW impact, but in order to access the rear of the site – a proposed access road crossing in the area of BVW Flag Series W6 & W7 was determined to be necessary. This disturbance totals to approximately 800 SF of temporary disturbance and 385 SF of permanent wetland fill. Per the WPA, work proposed directly within a BVW must meet specific performance standards as outlined in 310 CMR 10.55 and 310 CMR 10.53(1). The permanent alteration will be replaced at a 1:1 or greater ratio in area and function and be hydrologically connected to the original BVW, maintain similar or improved wetland functions, and use native plantings and appropriate soil conditions.

Additionally, while Isolated Vegetated Wetlands (IVWs) are present, they do not meet the criteria for Isolated Land Subject to Flooding (ILSF) under the WPA. Nevertheless, no work is proposed in these areas.

Indirect impacts from stormwater discharges will be mitigated through the use of sedimentation and erosion control measures during construction as well as BMPs and an Operation & Maintenance Plan once the site is fully constructed and stabilized.

Supplemental information regarding the existing wetlands is provided in **Appendix L**.

2.1.3 Environmental Concerns

According to the most current mapping on MassGIS, there are no Areas of Critical Environmental Concern (ACEC), Outstanding Resource Water (ORW), or Environmental Communities/Populations mapped within the Site. Additionally, there are no mapped Priority and Estimated Habitats, nor any Vernal pools located on the Site.

The western portion of the site is located within Zone A, Zone B, and Zone C of the Surface Water Supply Protection Area. The proposed project includes access roadway improvements within the Zone C area; however, no stormwater discharges are proposed in the overlay areas. All stormwater from the improved roadway areas will be managed in accordance with the MassDEP Stormwater Standards, ensuring that runoff is directed to appropriate treatment and discharge locations outside of the protection areas. As no new stormwater discharges are occurring within the protection areas, the project does not impact water quality or require additional stormwater mitigation measures for that area.

2.1.4 FEMA Flood Zones

According to the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM), map number 2503240005B, effective April 3, 1984, the site is not located in a FEMA floodplain. See **Appendix B**.

2.2 Proposed Site Description

The proposed project consists of 74 battery units with associated utility connections, and site improvements including electrical equipment, concrete pads, access driveways, and stormwater drainage infrastructure. The site has been designed to maintain existing topography and mimic existing drainage patterns to the maximum extent feasible.

The only impervious surfaces proposed to be constructed are access roads and small concrete pads for utility equipment. Once operational, vehicular access to the project will be limited to infrequent maintenance visits. The proposed improvements will result in 117,065 SF of impervious area. A total of approximately 778,380 square feet or 17.9 acres of disturbed area is anticipated, including lay-down and staging areas, and construction activities associated with the project. All work will take place within the proposed property limits. The impervious surfaces defined above will be kept to the minimum practical. This design gives preference to proposed drainage infrastructure, low impact development, and maintains existing grade, as much as practical.

BESS sites are complicated in nature due to their intricate ownership structures, phased construction processes, and need for extensive coordination with local utilities and regulatory authorities. Specifically for this site, additional information will be provided at future phases of design once a contractor has been procured and local utility owners have been engaged. Due to these complexities, the project will provide construction period pollution prevention plans and erosion and sedimentation control plans, long-term pollution prevention plans, and identification of post-construction drainage system owners and parties responsible for O&M in a subsequent design phase.

3. Stormwater Management

3.1 Design Criteria & Stormwater Methodology

To strengthen community resilience and prepare for the impacts of climate change, the Massachusetts Environmental Policy Act (MEPA) Interim Protocol has been established. This protocol includes the efforts of the Resilient Massachusetts Action Team (RMAT), which is advancing the "Climate Resilience Design Standards and Guidelines" project. The design standards for extreme precipitation incorporate an increase factor based on the project's design life. A percent increase is applied to the National Oceanic and Atmospheric Administration (NOAA) medial values. The project has a design life of approximately 20 years which follows the Mid-Century precent increases. All values are listed in

Table 3-1 below and NOAA rainfall data can be found in **Appendix K**.

Table 3-1: Rainfall Depths

Frequency (24-hr Duration)	2-year	10-year	25-year	100-year
NOAA Atlas 14 Present Baseline 24hr Rainfall (inches)	3.06	4.74	5.79	7.41
Mid-Century (2030/2050) (in)	3.9	6.0	7.4	9.4

The peak runoff discharges for existing and proposed conditions were analyzed using the Soil Conservation Service (SCS) methodology. Values for area, curve number and time of concentration were calculated for existing and proposed conditions. Values of time of concentration (Tc) were determined for existing and proposed conditions based on land cover and slope of the flow path, using methods outlined in the SCS methodology. The minimum Tc used in TR-55 is 0.1 hour. For this study, a 24-hour SCS Type III standard rainfall was used to determine the peak flow rate to the point of discharge from the site. The pre- and post-development runoff rates discharged from the site were ultimately computed using the Autodesk Stormwater & Sanitary Analysis (SSA) computer program.

Water Quality Volume ("WQV") for the site will be calculated assuming that the concrete equipment pads are impervious cover and gravel surfaces are pervious cover.

3.2 Existing Conditions

3.2.1 Existing Development Collection and Conveyance

The existing condition did not include any drainage infrastructure. Stormwater flows predominantly from west to east and north to south across the site via overland flow.

The project site is split between the Ware and the Quaboag sub-watersheds within the larger Chicopee watershed.

The portion of the site that drains to DP-2 is within the Quaboag River sub-watershed. The Quaboag River originates at Quaboag Pond and flows through the towns of Brookfield, West Brookfield, and Warren, Massachusetts. As Quaboag Pond has an established Total Maximum Daily Load (TMDL) for phosphorus, developments and stormwater discharges within its watershed are subject to a 30% total phosphorus loading removal requirement to address issues like algal blooms and excessive aquatic plant growth.

3.2.2 Existing Watersheds and Design Point Information

The pre-development drainage conditions were delineated into two (2) sub-catchment areas that drain to two (2) design points:

- <u>Design Point 1 (DP-1):</u> Sub-catchment E1
- <u>Design Point 2 (DP-</u>2): Sub-catchment E2

The entire site is part of the larger Chicopee River Watershed, but the site is split between two sub-watersheds. Sub-catchment E1 drains to DP-1, which is part of the Ware River sub-watershed. Sub-catchment E2 drains to DP-2, which is part of the Quaboag River sub-watershed.

Refer to the Pre-Development Conditions Watershed Map in **Appendix D** for a depiction of the pre-development watersheds, flow paths, and design points for the site.

Table 3-2 below illustrates the calculated pre-development conditions peak rates of runoff.

Table 3-2: Existing Conditions Peak Runoff Rates (cfs)

Point of Analysis	2-Year Storm	10-Year Storm	100-Year Storm
DP-1	8.51	15.58	27.16
DP-2	13.60	25.27	44.43

3.3 Proposed Conditions

3.3.1 Proposed Development Collection and Conveyance

Natural drainage patterns will be maintained throughout the site to the maximum extent practicable so that the proposed hydrologic conditions will closely match existing conditions.

Drainage catchment areas and stormwater calculations presented herein are based on the 30% Site Civil Plans and represent a conceptual design intended to demonstrate engineering feasibility and regulatory compliance. As site grading and BMP selection are refined during subsequent design phases, drainage catchment boundaries and stormwater calculations will be updated accordingly. This iterative process is consistent with standard engineering practice and does not alter the project's commitment to full compliance with the Massachusetts Stormwater Management Standards and applicable watershed-specific requirements.

The site has been designed with a conventional drainage system. The site's impervious runoff is directed to a series of catch basins and manholes which capture and convey stormwater runoff via underground pipe system which is conveyed to two (2) proposed proprietary treatment devices for pre-treatment. In order to meet the TMDL requirement noted in **Section 3.2.1**, the project is proposing the use of two (2) proprietary Jellyfish filters downstream of the pre-treatment devices. These devices will be appropriately sized by the manufacturer to achieve the required phosphorus reduction. Additionally, these units have been sized by the manufacturer to avoid scouring of sediment and oils in the device during the 100-year storm. Supporting documentation demonstrating compliance with the relevant treatment requirements is provided in **Appendix F**.

The majority of the Site's flows discharge to two (2) dry detention basins upstream of their respective design points in order to capture and attenuate peak flows prior to discharge. See **Section 3.4** for additional information on how the project meets the Massachusetts Stormwater Standards.

A noted, the proposed dry detention basins have been designed without an infiltration component due to high groundwater levels and the presence of low-permeability soils. To prevent infiltration and ensure long-term stability, these basins will include an impermeable liner. Given the high groundwater conditions, buoyancy of the liner may be a concern. During the detailed design phase, buoyancy calculations will be conducted to assess potential uplift forces. If necessary, anchoring or other stabilization measures will be incorporated into the final design to prevent displacement and ensure long-term performance.

The proposed subsurface storm drainage collection system is designed to convey at minimum the 25-year design storm event throughout the site. Storm drainage pipes were sized based on calculated design flows using the Autodesk Storm and Sanitary Analysis with the TR-20 methodology.

3.3.2 Proposed Watersheds and Design Point Information

The proposed conditions drainage patterns maintain the same design points as existing, but are broken into four (4) sub-catchments:

- Design Point 1 (DP-1): Sub-catchments P1 and P2
  - Runoff from sub-catchments P1 and P2 is treated by the proposed water quality unit/hydrodynamic separator and Jellyfish Filter before being released to the proposed dry detention basin (Pond1) for attenuation prior to discharge.

- Design Point 2 (DP-2): Sub-catchments P3 and P4
  - Sub-catchment P3 contains no impervious area. Runoff from this area flows directly to DP-2 via a stormwater conveyance channel. While no attenuation or treatment is provided for these flows, they are still included in the peak flow analysis.
  - Runoff from sub-catchment P4 is treated by a proposed water quality unit/hydrodynamic separator and a Jellyfish Filter before being released to the proposed dry detention basin (Pond2) for attenuation prior to discharge.

Refer to the Post-Development Conditions Watershed Map in **Appendix D** for a depiction of the post-development watersheds, flow paths, and design points for the site.

Table 3-3 below illustrates the calculated post-development conditions peak rates of runoff.

Table 3-3: Proposed Conditions Peak Runoff Rates (cfs)

Point of Analysis	2-Year Storm	10-Year Storm	100-Year Storm
DP-1	5.10	8.81	16.35
DP-2	10.99	23.37	43.24

3.3.3 Gravel Access Road Drainage System

The 12/16/2025 Site Plan Alternative plan proposes a gravel access road intended to support construction and long-term O&M of the facility. The access road is located outside the fenced Battery Energy Storage System (BESS) facility and is not intended to function as an impervious surface. At the 30% design stage, the gravel access road is treated as a pervious surface for stormwater management purposes. Runoff from the access road will be managed using Best Management Practice (BMP)-based conveyance, including a crowned road section with vegetated and/or stone-lined swales to promote infiltration, sediment attenuation, and non-erosive flow conveyance. Catch basins and piped drainage elements shown along the access road on the 30% site plans are conceptual placeholders only, included to demonstrate potential low-point control and continuity of drainage. During subsequent design phases, these structures are expected to be replaced in whole or in part with swales and other non-structural BMPs, subject to final grading and detailed drainage analysis. The access road drainage system is intended to function independently from the BESS facility stormwater basins, except where localized conditions necessitate controlled discharge for stability or regulatory compliance. Final drainage configuration will be confirmed during detailed design.

3.4 Stormwater Management Standards

In accordance with the Massachusetts Stormwater Handbook, the following stormwater management standards are provided. The proposed stormwater management system has been designed to comply with the currently approved Massachusetts Stormwater Standards as outlined in the MassDEP Stormwater Handbook. It is acknowledged that proposed revisions to the Stormwater Standards are under review but have not yet been formally adopted. While these updates are not yet enforceable, the design has incorporated aspects of the proposed changes where feasible to align with anticipated future requirements. If the updated Stormwater Standards are adopted prior to project approval, a review of the final approved regulations against the current design will be conducted to determine any necessary modifications to ensure compliance.

Stormwater runoff from impervious areas within the fenced BESS facility will be collected, treated, and managed in accordance with applicable Stormwater Standards, including peak flow attenuation and water quality treatment. The stormwater management system has been designed to ensure no adverse impacts to downstream resources and to maintain pre-development hydrologic conditions to the maximum extent practicable. The gravel access road proposed in the 12/16/2025 Site Plan Alternative plan does not require treatment for Total Suspended Solids (TSS) under the Stormwater Handbook; however, erosion control, stabilization, and non-erosive conveyance are incorporated into the design through BMP-based drainage measures.

3.4.1 Standard 1 – No New Untreated Discharge

The Massachusetts Stormwater Handbook states that no new stormwater conveyances may discharge untreated stormwater directly to or cause erosions in wetlands or waters of the Commonwealth. The project treats all stormwater runoff from impervious areas via proprietary treatment devices on-site prior to discharge.

Additionally, to prevent erosion and sedimentation, BMPs and associated pipes and other conveyances must be properly designed and installed in accordance with Volume 2 of the Massachusetts Stormwater Handbook. A downstream analysis has been completed to confirm that the proposed outfalls are non-erosive.

3.4.2 Standard 2 – Peak Rate Attenuation

The Massachusetts Stormwater Handbook states that stormwater management systems shall be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates. The proposed development discharge rates are below the existing rates. A summary of the existing and proposed discharge rates has been listed in **Section 3.3** of this report and Autodesk Storm and Sanitary outputs can be found in **Appendix I**.

Two (2) surface detention basins with impermeable liners will be implemented to accommodate the peak flow mitigation requirements The detention basins will completely drain within 48 hours after the end of a storm. Sizing calculations are shown in **Appendix H**.

3.4.3 Standard 3 – Recharge

Due to potentially high groundwater conditions and site soil conditions as noted in **Section 2.1.1**, groundwater recharge was deemed as not feasible as the systems will not be able to achieve adequate separation from groundwater. However, opportunity for groundwater recharge is provided through the landscaped areas on site.

3.4.4 Standard 4 –Water Quality

The required water quality volume equals 1.0 inch of runoff times the total impervious area of the post-development project site for a discharge. As noted in **Sections 2.1.1** and **3.4.3**, infiltration was deemed not feasible on this site, therefore stormwater quality will be improved through the proposed water quality units and ultimately long-term operation and maintenance plans. The proprietary water quality units will capture and treat runoff from the impervious surfaces prior to discharge.These units have been sized by the manufacturer to avoid scouring of sediment and oils in the device during the 100-year storm.

As noted in **Section 3.2.1**, there is an established Total Maximum Daily Load (TMDL) for phosphorus, so stormwater discharges within the Quaboag sub-watershed are subject to a 30% total phosphorus removal requirement. To meet this standard at the current 30% design stage, phosphorus removal within the Quaboag drainage area is addressed conceptually through a combination of:

1. Vegetated and/or stone-lined swales providing soil contact and infiltration
2. Distributed BMP-based treatment along drainage flow paths
3. Structural treatment measures (e.g., proprietary Jellyfish Filter filtration systems) where required to supplement non-structural BMP performance

The proposed treatment devices have been sized to meet the required water quality flow (QWf) and bypass flows from greater storm events. See **Appendix F** for water quality calculations and supporting documentation from the manufacturer. Final phosphorus load calculations, BMP sizing, and allocation between structural and non-structural controls will be completed during detailed design once final grading and drainage catchment areas are established.

The Massachusetts Stormwater Handbook also requires systems to be designed to remove 80% of the average annual post-development Total Suspended Solids (TSS). According to the automated calculations, the proposed treatment train results in 96% TSS removal across the Site. The TSS removal calculations were completed using the automated Excel spreadsheet from the MassDEP website. TSS removal calculations and material from the manufacturer is included in **Appendix G**.

3.4.5 Standard 5 – Land Uses with Higher Potential Pollutant Loads (LUHPPLs)

This proposed battery storage facility is not considered a Land Use with Higher Potential Pollutant Loads. Therefore, Standard 5 does not apply.

3.4.6 Standard 6 – Critical Areas

There are no Areas of Critical Environmental Concern located on the project site.

As noted in **Section 2.1.3**, the western portion of the site is located within Zone A, Zone B, and Zone C of the Surface Water Supply Protection Area. The proposed project includes access roadway improvements within the Zone C area; however, no stormwater discharges are proposed in the overlay areas. All stormwater from the improved roadway areas will be managed in accordance with the MassDEP Stormwater Standards, ensuring that runoff is directed to appropriate treatment and discharge locations outside of the protection areas. As no new stormwater discharges are occurring within the protection areas, the project does not impact water quality or require additional stormwater mitigation measures for that area. Regardless, the stormwater management system for this project is still designed for the more stringent the 1-inch runoff depth for the calculated water quality treatment volume.

3.4.7 Standard 7 – Redevelopment

The Site is not considered a redevelopment or infill project so Standard 6 does not apply.

3.4.8 Standard 8 – Construction Period Pollution Prevention and Erosion and Sedimentation Control

The project has provided erosion and sedimentation control drawings for the demolition and construction periods and will provide a separate report regarding long term stabilization of the site at a subsequent design phase. A construction phasing plan will be established after the bidding phase for this project when a contractor has been selected at which time the Stormwater Pollution Prevention Plan will be prepared and submitted.

Because the Project will disturb more than one (1) acre of land, a Notice of Intent will be submitted to the Environmental Protection Agency (EPA) for coverage under the National Pollution Discharge Elimination

System (NPDES) Construction General Permit. As part of this application the Applicant is required to prepare a Stormwater Pollution Prevention Plan (SWPPP) and implement the measures in the SWPPP. The SWPPP, which is to be kept on site, includes erosion and sediment controls (stabilization practices and structural practices), temporary and permanent stormwater management measures, Contractor inspection schedules and reporting of all SWPPP features, materials management, waste disposal, off-site vehicle tracking, spill prevention and response, sanitation, and non-stormwater discharges

The soil erosion and sediment control measures that will be proposed as part of this project include erosion control barriers like geotextile silt fences and compost filter socks, stabilization practices, phased construction sequencing, and a construction entrance. The 12/16/2025 Site Plan Alternative gravel access road will also be constructed to prevent sediment transport, rutting, or channelized flow during and after construction. Construction BMPs must be maintained. Construction period pollution prevention and erosion and sediment control shall meet the requirements for the most current EPA Construction General Permit (CGP) for all projects requiring coverage under the CGP. A project-specific Stormwater Pollution Prevention Plan (SWPPP) will be prepared prior to construction and updated as necessary to reflect final drainage design. See details below.

Short Term Erosion Control:

The proposed erosion and sedimentation controls consider the specific characteristics of the site and the anticipated construction activities. They have been designed in accordance with the latest MassDEP Guidelines for Soil Erosion and Sediment Control.

Construction Entrances:

Construction entrances will be utilized to remove sediment from construction vehicle tires and prevent it from being tracked onto adjoining paved roadway areas. Maintain the pad in a condition that will prevent tracking and washing of sediment onto paved surfaces. Place additional clean gravel on top of gravel that has become silted or remove the silted gravel and replace the gravel to the depth removed with clean gravel, as conditions warrant. Remove immediately all sediment spilled, dropped, washed, or tracked onto paved surfaces.

Erosion Control Barriers:

Prior to any construction activity, barriers will be placed at the downgradient limits of construction and adjacent to the wetlands. Barriers will be inspected at least once a week and within 24 hours after the end of a storm generating a discharge. Barriers will be maintained until the contributing disturbed areas are stabilized.

Inlet Protection:

Prior to any construction activity, inlet protection will be placed at the downgradient catch basins and inlets. Inlet protection should be inspected at least once a week and within 24 hours after the end of a storm generating a discharge. Inlet protection will be maintained until the contributing disturbed areas are restored.

Stockpile Management:

The topsoil stockpiles which will be idle for at least 30 days will be stabilized with temporary seed and mulch no later than 7 days from the last use. Small stockpiles may be covered with impervious tarps or erosion control matting in lieu of seeding and mulching. A geotextile silt fence or hay bale barrier will be installed around the stockpile area approximately 10 feet from the proposed toe of the slope. Inspect temporary stockpiles at the end of each workday to ensure that tarps are in place and secured.

3.4.9 Standard 9 – Operation and Maintenance Plan

A post-construction Stormwater Operation and Maintenance (O&M) Plan, which identifies required inspection and maintenance activities for structural stormwater BMPs is provided in **Appendix J**. The owner shall be responsible for construction operation and maintenance of the site.

3.4.10 Standard 10 – Prohibition of Illicit Discharges

No illicit discharges as outlined in Massachusetts Stormwater Handbook are proposed as part of this project.

4. Summary

In summary, the proposed stormwater management system design, illustrated within the site development drawings prepared by Arup meets the standards set forth in the Massachusetts Stormwater Handbook. The proposed development results in an increase in impervious area when compared to existing conditions. To manage the increase in runoff associated with the increase in impervious area, the project includes the utilization of two dry detention basins for peak flow mitigation. As outlined in the tables above, the proposed stormwater management system as designed will provide a decrease in peak rates of runoff from the proposed facility for the 2-, 10-, and 100-year storm events. The project has been designed to the greatest extent feasible to maintain existing site hydrology. As a result, the proposed project will not result in any adverse conditions to the surrounding areas and properties. Supporting documentation and stormwater-related computations are contained in the Appendices of this report.

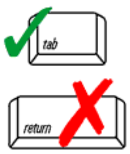
Appendix A: MassDEP Stormwater Checklist

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.



A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

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[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

COMMONWEALTH OF MASSACHUSETTS
B. DEREK ANDERSON
CIVIL
NO. 47556
REGISTERED PROFESSIONAL ENGINEER

B. Derek Anderson 2/28/2025

Signature and Date

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

☒ New development

☐ Redevelopment

☐ Mix of New Development and Redevelopment

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

☐ No disturbance to any Wetland Resource Areas

☒ Site Design Practices (e.g. clustered development, reduced frontage setbacks)

☐ Reduced Impervious Area (Redevelopment Only)

☐ Minimizing disturbance to existing trees and shrubs

☐ LID Site Design Credit Requested:

- ☐ Credit 1
- ☐ Credit 2
- ☐ Credit 3

☐ Use of “country drainage” versus curb and gutter conveyance and pipe

☐ Bioretention Cells (includes Rain Gardens)

☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)

☐ Treebox Filter

☐ Water Quality Swale

☒ Grass Channel

☐ Green Roof

☐ Other (describe): ______________________

Standard 1: No New Untreated Discharges

☒ No new untreated discharges

☒ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth

☐ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

Standard 2: Peak Rate Attenuation

☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.

☒ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.

☒ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

☐ Soil Analysis provided.

☐ Required Recharge Volume calculation provided.

☐ Required Recharge volume reduced through use of the LID site Design Credits.

☐ Sizing the infiltration, BMPs is based on the following method: Check the method used.

  ☐ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

☐ Runoff from all impervious areas at the site discharging to the infiltration BMP.

☐ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:

  ☐ Site is comprised solely of C and D soils and/or bedrock at the land surface

  ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000

  ☐ Solid Waste Landfill pursuant to 310 CMR 19.000

  ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.

☐ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.

☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

Standard 3: Recharge (continued)

☐ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☐ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☐ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

- ☐ is within the Zone II or Interim Wellhead Protection Area
- ☐ is near or to other critical areas
- ☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)
- ☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☒ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

Standard 4: Water Quality (continued)

☒ The BMP is sized (and calculations provided) based on:

- ☒ The ½" or 1" Water Quality Volume or
- ☒ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☒ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☒ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☐ Critical areas and BMPs are identified in the Stormwater Report.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☐ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☐ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☐ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control (continued)

☒ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☐ The project is ***not*** covered by a NPDES Construction General Permit.

☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.

☒ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

Standard 9: Operation and Maintenance Plan

☒ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:

- ☐ Name of the stormwater management system owners;
- ☐ Party responsible for operation and maintenance;
- ☒ Schedule for implementation of routine and non-routine maintenance tasks;
- ☒ Plan showing the location of all stormwater BMPs maintenance access areas;
- ☒ Description and delineation of public safety features;
- ☒ Estimated operation and maintenance budget; and
- ☒ Operation and Maintenance Log Form.

☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:

- ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
- ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

Standard 10: Prohibition of Illicit Discharges

☐ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;

☐ An Illicit Discharge Compliance Statement is attached;

☒ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.

Appendix B: FEMA Firm Panel

KEY TO MAP

500-Year Flood Boundary
100-Year Flood Boundary
Zone Designations*
100-Year Flood Boundary
500-Year Flood Boundary

ZONE B
ZONE A1
ZONE A5
ZONE B

Base Flood Elevation Line With Elevation In Feet** — 513
Base Flood Elevation in Feet Where Uniform Within Zone** — (EL 987)
Elevation Reference Mark — RM7×
Zone D Boundary
River Mile — •M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index To Map Panels.

INITIAL IDENTIFICATION:
AUGUST 2, 1974

FLOOD HAZARD BOUNDARY MAP REVISIONS:
AUGUST 20, 1976

FLOOD INSURANCE RATE MAP EFFECTIVE:
APRIL 3, 1984

FLOOD INSURANCE RATE MAP REVISIONS:

Refer to the FLOOD INSURANCE RATE MAP EFFECTIVE date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program, at (800) 638-6620.

APPROXIMATE SCALE
800 0 800 FEET

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
OAKHAM,
MASSACHUSETTS
WORCESTER COUNTY

PANEL 5 OF 15
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
250324 0005 B

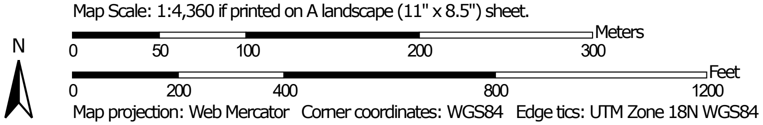
EFFECTIVE DATE:
APRIL 3, 1984

Federal Emergency Management Agency

Appendix C: NRCS Soil Survey & Environmental Data

Hydrologic Soil Group—Worcester County, Massachusetts, Northwestern Part

Map Scale: 1:4,360 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Worcester County, Massachusetts, Northwestern Part
Survey Area Data: Version 18, Aug 27, 2024

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Oct 15, 2020—Oct 31, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Water		0.1	0.1%
910C	Woodbridge-Paxton association, 3 to 15 percent slopes, extremely stony	C/D	55.0	87.5%
918B	Ridgebury-Whitman association, 0 to 8 percent slopes, extremely stony	D	6.4	10.2%
927C	Montauk-Scituate-Canton association, 3 to 15 percent slopes, extremely stony	C	1.4	2.2%
Totals for Area of Interest			**62.8**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

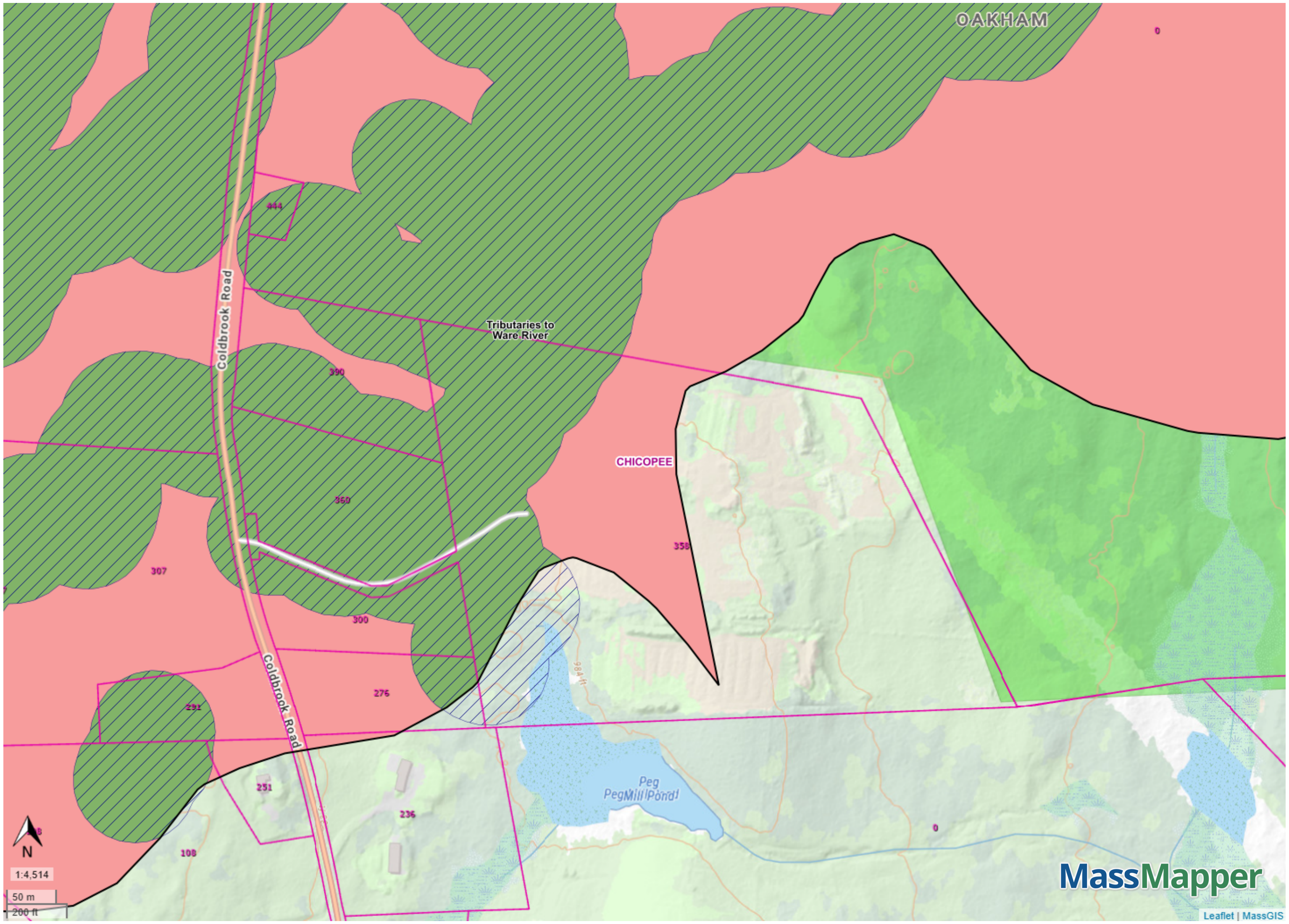
Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Surface Water Supply



DEP 2013 Boundaries for Tributaries thereto Watersheds

Labels

Major Watersheds

Property Tax Parcels

Detailed Features

Zone A

Zone B

Zone C

Surface Water Supply Watersheds

- Surface Water (Active or Inactive)
- Emergency Surface Water
- Rhode Island Source

Phone
(203) 262-9328

Telefax
(203) 264-3414

WHITE PLAINS, N.Y.
(914) 946-4850

SOILTESTING, INC.

90 DONOVAN ROAD - OXFORD, CONN. 06478-1028

GEOTECHNICAL / ENVIRONMENTAL SUBSURFACE INVESTIGATIONS - Test Borings - Core Drilling
Monitoring Wells - Recovery Wells - Direct Push/Probe Sampling
UNDERPINNING - HELICAL PILES - SOIL NAILS

January 6, 2025

Rhyland Energy
750 Lexington Ave.
New York NY 10022
Attn.: Jon O'Hara

Re: 300 Coldbrook Road G226-3040-24
Oakham MA

Dear Mr. O'Hara,

Attached please find the Test Boring Logs and location plan for work in Oakham MA along with our invoice.

If you have any questions, please do not hesitate to contact us.

Very truly yours,

James A. DeAngelis
President

SOILTESTING, INC.

TO: Rhyland Energy
DATE: 6-Jan-25
ADDRESS: 750 Lexington Ave., New York NY 10022
SITE LOCATION: 300 Coldbrook Rd., Oakham MA
REPORT SENT TO: Jon O'Hara
SAMPLES SENT TO: Storage (Max 60 days)

90 Donovan Road
Oxford, Connecticut 06478-1028
203-262-9328

Branch Office:
White Plains, New York 10607
914-946-4850

JOB NO.

G226-3040-24

SOILTESTING, INC.
90 DONOVAN RD.
OXFORD, CT 06478
CT (203) 262-9328
NY (914) 946-4850

CLIENT:	Rhyland Energy	SHEET 1 OF 1	
		HOLE NO.	B-1
PROJECT NO.	G226-3040-24		
PROJECT NAME	Subsurface Investigations	BORING LOCATIONS	Per Plan
FOREMAN - DRILLER	SD/dw		
LOCATION	300 Coldbrook Road Oakham MA		
INSPECTOR		OFFSET	

	CASING	SAMPLER	CORE BAR		
TYPE	HSA	SS		DATE START	12/23/24
SIZE I.D.	4 ¼"	1 3/8"		DATE FINISH	12/23/24
HAMMER WT.		140#	BIT	SURFACE ELEV.	
HAMMER FALL		30"		GROUND WATER ELEV.	

GROUND WATER OBSERVATIONS
AT none FT AFTER 0 HOURS
AT__FT AFTER__HOURS

DEPTH	CASING BLOWS PER FOOT	SAMPLE NO	Type	PEN	REC	DEPTH @ BOT	BLOWS PER 6 IN ON SAMPLER (FORCE ON TUBE) 0 - 6	6 - 12	12- 18	CORE TIME PER FT (MIN)	DENSITY OR CONSIST / MOIST	STRATA CHANGE DEPTH / ELEV	FIELD IDENTIFICATION OF SOIL REMARKS INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.
		1	ss	24"	10"	2'0"	2	2			loose	4"	Topsoil
							3	3			moist		Brn F-M SAND & SILT
		2	ss	24"	2"	4'0"	3	4			loose		
							3	3			moist		Same
5													
		3	ss	24"	24"	7'0"	4	6			compact		
							7	8			moist		Same, (gry)
		4	ss	24"	24"	9'0"	5	7			compact		
							6	9			moist	9'6"	Same, (gry)
10		5	ss	1"	0"	9'7"	50/1"				dense/dry	9'7"	Poss Bedrock, Auger Refusal
													EOB 9'7"
15													
20													
25													
30													
35													
40													

NOTE: Subsoil conditions revealed by this investigation represent conditions at specific locations and may not represent conditions at other locations or times.

GROUND SURFACE TO ________FT. USED ______________CASING THEN _______ CASING TO _______FT. **HOLE NO. B-1**

A = AUGER UP = UNDISTURBED PISTON T = THINWALL V = VANE TEST
WOR = WEIGHT OF RODS WOH = WEIGHT OF HAMMER & RODS C = COARSE
SS = SPLIT TUBE SAMPLER H.S.A. = HOLLOW STEM AUGER M = MEDIUM
PROPORTIONS USED: TRACE = 0 - 10% LITTLE = 10 - 20% SOME = 20 - 35% AND =35 - 50% F = FINE

SOILTESTING, INC. **90 DONOVAN RD.** **OXFORD, CT 06478** **CT (203) 262-9328** **NY (914) 946-4850**	CLIENT: **Rhyland Energy**		SHEET 1 OF 1 HOLE NO. B-2
	PROJECT NO. **G226-3040-24**		
	PROJECT NAME **Subsurface Investigations**		BORING LOCATIONS Per Plan
FOREMAN - DRILLER **SD/dw**	LOCATION **300 Coldbrook Road Oakham MA**		
INSPECTOR			OFFSET 5' South

	CASING	SAMPLER	CORE BAR
TYPE	HSA	SS	
SIZE I.D.	4 ¼"	1 3/8"	
HAMMER WT.		140#	BIT
HAMMER FALL		30"	

GROUND WATER OBSERVATIONS
AT 10 FT AFTER 0 HOURS
AT ___FT __ AFTER__HOURS

DATE START 12/23/24
DATE FINISH 12/23/24
SURFACE ELEV.
GROUND WATER ELEV.

DEPTH	CASING BLOWS PER FOOT	SAMPLE NO	Type	PEN	REC.	DEPTH @ BOT	BLOWS PER 6 IN ON SAMPLER (FORCE ON TUBE) 0 - 6	6 - 12	12 - 18	CORE TIME PER FT (MIN)	DENSITY OR CONSIST / MOIST	STRATA CHANGE DEPTH / ELEV	FIELD IDENTIFICATION OF SOIL REMARKS INCL. COLOR, LOSS OF WASH WATER, SEAMS IN ROCK, ETC.
		1	ss	24"	14"	2'0"	4	7			compact	6"	Topsoil
							8	6			dry		Brn F-M SAND & SILT, lit F gravel
		2	ss	24"	20"	4'0"	10	14			compact		
							15	12			dry		Same
5													
		3	ss	24"	10"	7'0"	5	8			compact		
							21	38			dry		Gry F-M SAND & SILT, some F gravel
		4	ss	24"	18"	9'0"	41	26			v dense		
							31	17			dry		Same
10													
		5	ss	24"	18"	12'0"	12	14			compact		
							15	20			wet		Same
15													
		6	ss	24"	6"	16'8"	8	12			compact	16'6"	
							17	50/2"			dry	17'	Partially weathered Bedrock or Boulder fragments
													EOB 17' Auger Refusal
20													
25													
30													
35													
40													

NOTE: Subsoil conditions revealed by this investigation represent conditions at specific locations and may not represent conditions at other locations or times.

GROUND SURFACE TO ________FT. USED ______________CASING THEN _______ CASING TO _______FT. **HOLE NO. B-2**

A = AUGER UP = UNDISTURBED PISTON T = THINWALL V = VANE TEST
WOR = WEIGHT OF RODS WOH = WEIGHT OF HAMMER & RODS C = COARSE
SS = SPLIT TUBE SAMPLER H.S.A. = HOLLOW STEM AUGER M = MEDIUM
PROPORTIONS USED: TRACE = 0 - 10% LITTLE = 10 - 20% SOME = 20 - 35% AND =35 - 50% F = FINE

SOILTESTING, INC.
90 DONOVAN RD.
OXFORD, CT 06478
CT (203) 262-9328
NY (914) 946-4850

CLIENT: **Rhynland Energy**

SHEET 1 OF 1

PROJECT NO. **G226-3040-24**

PROJECT NAME **300 Coldbrook Road**

BORING/PERCOLATION TEST
LOCATION #: B-2

TECHNICIAN: SD

LOCATION **Oakham MA**

INSPECTOR

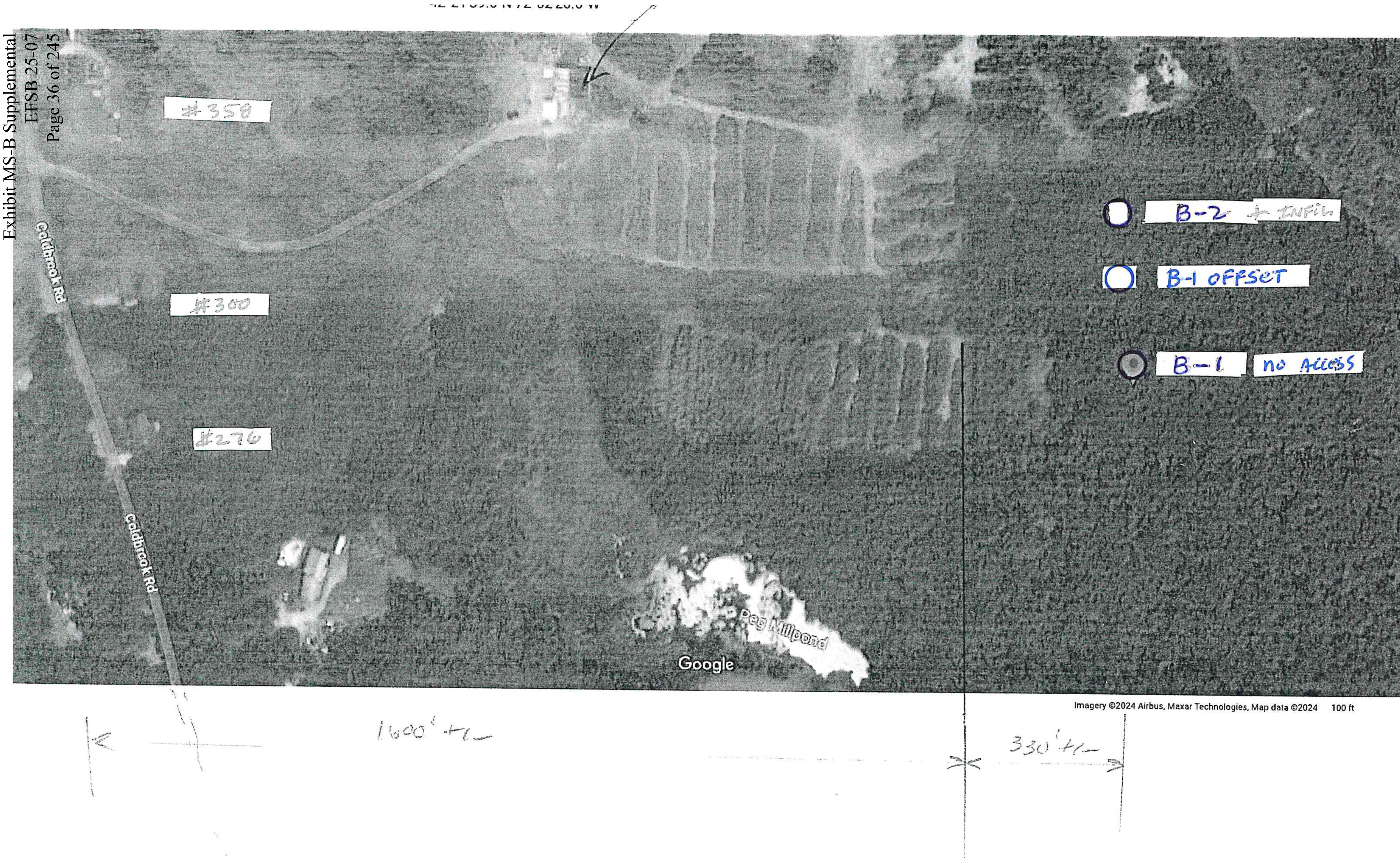
PERCOLATION TEST

OFFSET

DATE START 12/23/24
DATE FINISH 12/23/24

CASING DIAMETER: 4"
OVERALL CASING LENGTH: 78"
CASING STICK-UP (A.G. Surface): 6"
ADJACENT OBSERVATION WELL GROUNDWATER LEVEL READING: N/A
DEPTH TO GROUNDWATER LEVEL ______ DATE/TIME N/A
PRESOAK DATE:

Time	Water Level from Top of Casing	Notes
1:05PM	48"	Intial Full
2:05PM	49"	
3:05PM	49 3/4"	
3:10PM	48"	2nd Fill
4:10PM	48 3/4"	
		Percolation Rate = 3/4" per hour

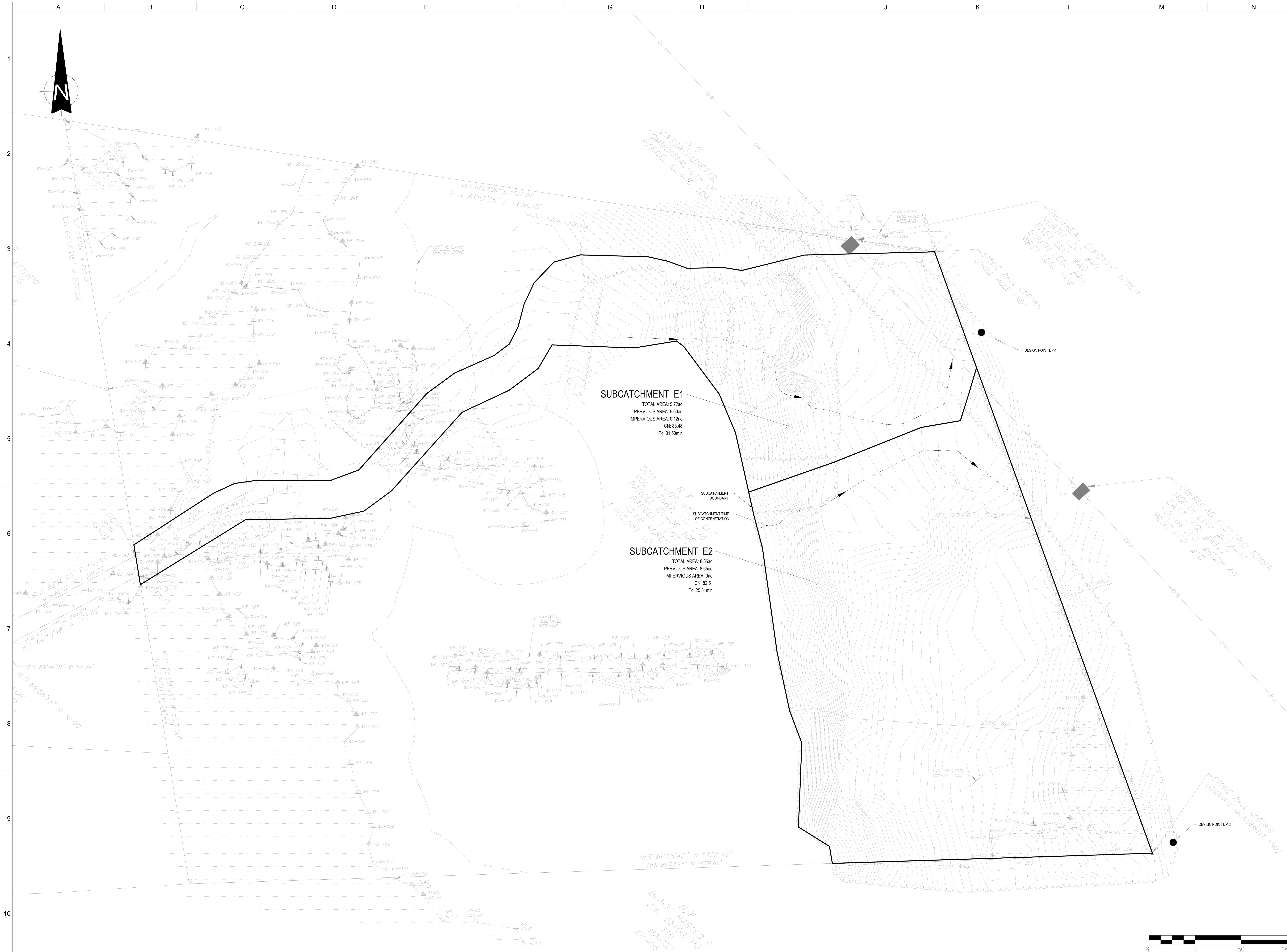


DEACON ALLEN DRIVE

(BEHIND) 300 COLD BROOK RD, OAKHAM MASS

Appendix D: Pre & Post Development Catchment Maps

PLOT TIME: 3/13/2025 4:04 PM
PLOT BY: Reese Smith



Issue	Date	Revisions
A	9/22/23	DRAFT ISSUED FOR REVIEW
B	9/28/23	CONSTRAINT MAPPING
C	8/21/24	10% DESIGN SUBMISSION
D	9/13/24	30% DESIGN DRAFT
E	11/01/24	ISSUED FOR ISO-NE SIS APPLICATION
F	02/28/2025	30% DESIGN
G	03/18/2025	30% DESIGN REVISION

ARUP

60 State Street , Boston, MA
02109, United States

www.arup.com

Client
MORAGA STORAGE LLC

Job Title
MORAGA STORAGE
ZOVL - Oakham, MA

Seal

NOT FOR CONSTRUCTION

Drawing Title
EXISTING SUBCATCHMENT MAP

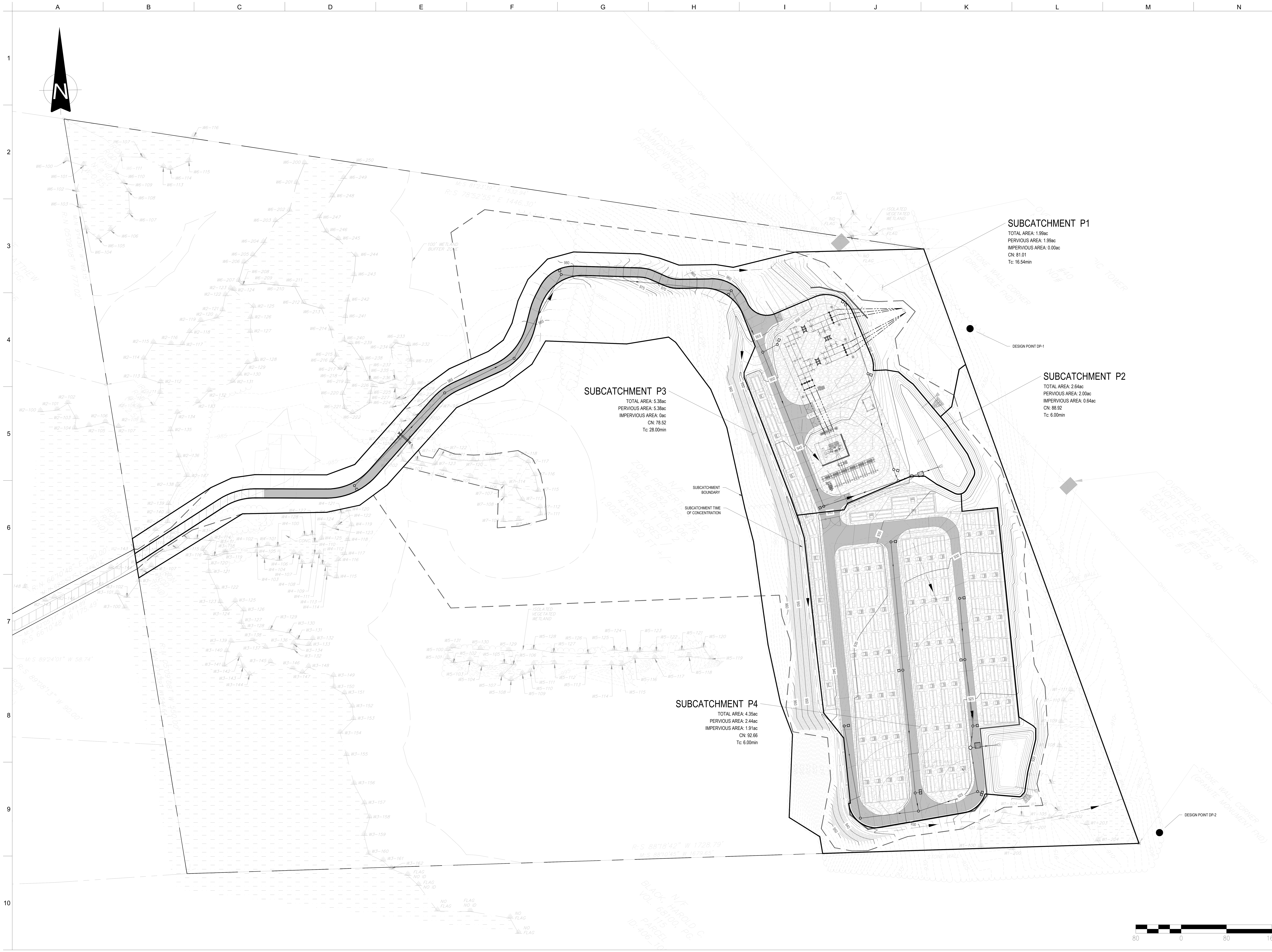
Scale: 1" = 80'

File Name: SUBCATCH-PRE_R1.DWG

Drawing Status: 30% DESIGN DRAWINGS

Job No	Drawing No	Issue
296229-00		G

PLOT TIME: 3/19/2025 1:51 PM
PLOT BY: Reese Smith



Issue	Date	Revisions
A	9/22/23	DRAFT ISSUED FOR REVIEW
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C	8/21/24	10% DESIGN SUBMISSION
D	9/13/24	30% DESIGN DRAFT
E	11/01/24	ISSUED FOR ISO-NE SIS APPLICATION
F	02/28/2025	30% DESIGN
G	03/18/2025	30% DESIGN REVISION

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Client

MORAGA STORAGE LLC

Job Title

MORAGA STORAGE
ZOVL - Oakham, MA

Seal

NOT FOR CONSTRUCTION

Drawing Title

PROPOSED SUBCATCHMENT MAP

Scale
1" = 80'

File Name
SUBCATCH-POST.DWG

Drawing Status
30% DESIGN DRAWINGS

Job No	Drawing No	Issue
296229-00		G

Appendix E: Pipe Sizing Calculations

Moraga Storage LLC - ZOVL
358 Coldbrook Road
Oakham, MA
Arup Job Number: 296229
3/18/2025

Rational Pipe Sizing Calculations

Design Period Storm:		25	Year	Design Period Intensity		7.4	in/hr	<<RMAT Mid-Century Rainfall									
LOCATION		IMPERVIOUS			PERVIOUS			SUM CA	Tc (min)	I (in/hr)	Q (cfs)	D (in)	S (ft/ft)	Material	n	Q Full (cfs)	V Full (fps)
FROM	TO	A	C	CA	A	C	CA										
DP-1																	
CB-1	MH-1	0.14	0.95	0.14	0.00	0.30	0.00	0.14	6	7.4	1.01	8	0.030	HDPE	0.012	2.27	6.50
MH-1	MH-2	0.14	0.95	0.14	0.00	0.30	0.00	0.14	6	7.4	1.01	8	0.006	HDPE	0.012	1.01	2.90
MH-2	MH-3	0.14	0.95	0.14	0.00	0.30	0.00	0.14	6	7.4	1.01	8	0.007	HDPE	0.012	1.07	3.07
CB-2	MH-4	0.12	0.95	0.11	0.00	0.30	0.00	0.11	6	7.4	0.82	8	0.013	HDPE	0.012	1.46	4.19
MH-3	MH-4	0.14	0.95	0.14	0.00	0.30	0.00	0.14	6	7.4	1.01	8	0.017	HDPE	0.012	1.70	4.88
MH-4	MH-5	0.26	0.95	0.25	0.00	0.30	0.00	0.25	6	7.4	1.84	8	0.048	HDPE	0.012	2.87	8.22
CB-3	MH-5	0.12	0.95	0.12	0.00	0.30	0.00	0.12	6	7.4	0.86	8	0.010	HDPE	0.012	1.31	3.75
MH-5	MH-7	0.38	0.95	0.36	0.00	0.30	0.00	0.36	6	7.4	2.70	8	0.050	HDPE	0.012	2.93	8.39
CB-4	MH-6	0.08	0.95	0.07	0.05	0.30	0.01	0.09	6	7.4	0.64	8	0.008	HDPE	0.012	1.17	3.35
MH-6	MH-7	0.08	0.95	0.07	0.05	0.30	0.01	0.09	6	7.4	0.64	8	0.006	HDPE	0.012	1.04	2.98
MH-7	MH-8	0.46	0.95	0.44	0.05	0.30	0.01	0.45	6	7.4	3.33	12	0.026	HDPE	0.012	6.22	7.92
CB-5	MH-8	0.21	0.95	0.20	0.16	0.30	0.05	0.25	6	7.4	1.83	12	0.010	HDPE	0.012	3.86	4.91
MH-8	MH-12	0.67	0.95	0.64	0.21	0.30	0.06	0.70	6	7.4	5.16	18	0.007	HDPE	0.012	9.52	5.39
HDS-1	JFV-1	0.74	0.95	0.71	1.23	0.30	0.37	1.07	6	7.4	7.95	24	0.006	HDPE	0.012	18.98	6.04
JFV-1	POND1	0.74	0.95	0.71	1.23	0.30	0.37	1.07	6	7.4	7.95	24	0.005	HDPE	0.012	17.33	5.52
CB-6	MH-9	0.01	0.95	0.01	0.00	0.30	0.00	0.01	6	7.4	0.05	8	0.013	HDPE	0.012	1.46	4.19
MH-9	MH-10	0.01	0.95	0.01	0.00	0.30	0.00	0.01	6	7.4	0.05	8	0.006	HDPE	0.012	1.00	2.86
CB-7	MH-10	0.00	0.95	0.00	0.55	0.30	0.17	0.17	6	7.4	1.24	12	0.013	HDPE	0.012	4.32	5.49
MH-10	MH-11	0.01	0.95	0.01	0.55	0.30	0.17	0.17	6	7.4	1.28	12	0.030	HDPE	0.012	6.69	8.51
CB-8	MH-11	0.06	0.95	0.06	0.47	0.30	0.14	0.20	6	7.4	1.51	12	0.010	HDPE	0.012	3.86	4.91
MH-11	MH-12	0.07	0.95	0.07	1.02	0.30	0.31	0.38	6	7.4	2.79	24	0.007	HDPE	0.012	19.76	6.29
MH-12	HDS-1	0.74	0.95	0.71	1.50	0.30	0.45	1.15	6	7.4	8.55	24	0.005	HDPE	0.012	17.84	5.68

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DP-2																		
CB-9	MH-13	0.16	0.95	0.16	0.14	0.30	0.04	0.20	6	7.4	1.46	8	0.025	HDPE	0.012	2.07	5.93	
MH-13	MH-14	0.16	0.95	0.16	0.14	0.30	0.04	0.20	6	7.4	1.46	12	0.009	HDPE	0.012	3.66	4.66	
MH-14	MH-18	0.16	0.95	0.16	0.14	0.30	0.04	0.20	6	7.4	1.46	12	0.040	HDPE	0.012	7.72	9.83	
CB-10	MH-15	0.19	0.95	0.18	0.15	0.30	0.05	0.23	6	7.4	1.67	8	0.025	HDPE	0.012	2.07	5.93	
MH-15	MH-16	0.19	0.95	0.18	0.15	0.30	0.05	0.23	6	7.4	1.67	12	0.009	HDPE	0.012	3.64	4.64	
CB-11	MH-16	0.19	0.95	0.18	0.30	0.30	0.09	0.27	6	7.4	1.98	8	0.025	HDPE	0.012	2.07	5.93	
MH-16	MH-17	0.38	0.95	0.36	0.45	0.30	0.14	0.49	6	7.4	3.65	18	0.008	HDPE	0.012	10.18	5.76	
CB-12	MH-17	0.38	0.95	0.36	0.34	0.30	0.10	0.47	6	7.4	3.45	12	0.025	HDPE	0.012	6.10	7.77	
MH-17	MH-18	0.76	0.95	0.72	0.79	0.30	0.24	0.96	6	7.4	7.10	18	0.009	HDPE	0.012	10.80	6.11	
MH-18	MH-22	0.92	0.95	0.88	0.93	0.30	0.28	1.16	6	7.4	8.56	18	0.008	HDPE	0.012	10.18	5.76	
CB-16	MH-22	0.38	0.95	0.36	0.34	0.30	0.10	0.46	6	7.4	3.39	12	0.025	HDPE	0.012	6.10	7.77	
MH-22	HDS-2	1.30	0.95	1.23	1.27	0.30	0.38	1.61	6	7.4	11.95	18	0.020	HDPE	0.012	16.09	9.11	
CB-13	MH-19	0.21	0.95	0.20	0.29	0.30	0.09	0.28	6	7.4	2.10	12	0.025	HDPE	0.012	6.10	7.77	
MH-19	MH-20	0.21	0.95	0.20	0.29	0.30	0.09	0.28	6	7.4	2.10	12	0.009	HDPE	0.012	3.66	4.66	
CB-14	MH-20	0.19	0.95	0.18	0.33	0.30	0.10	0.28	6	7.4	2.05	8	0.025	HDPE	0.012	2.07	5.93	
MH-20	MH-21	0.39	0.95	0.37	0.62	0.30	0.19	0.56	6	7.4	4.15	18	0.010	HDPE	0.012	11.49	6.50	
CB-15	MH-21	0.22	0.95	0.21	0.21	0.30	0.06	0.27	6	7.4	2.02	8	0.025	HDPE	0.012	2.07	5.93	
MH-21	HDS-2	0.62	0.95	0.59	0.83	0.30	0.25	0.83	6	7.4	6.18	18	0.020	HDPE	0.012	16.09	9.11	
HDS-2	JFV-2	1.92	0.95	1.82	2.10	0.30	0.63	2.45	6	7.4	18.13	24	0.012	HDPE	0.012	26.85	8.55	
JFV-2	POND2	1.92	0.95	1.82	2.10	0.30	0.63	2.45	6	7.4	18.13	24	0.006	HDPE	0.012	18.98	6.04	

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Appendix F: Water Quality Calculations

Moraga Storage LLC - ZOVL
358 Coldbrook Road
Oakham, MA
Arup Job Number: 296229
March 18, 2025

Water Quality Volume (WQV) Calculation

DRY POND 1

Catch Basin #1 (CB-1)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000225	sq mi	
WQF =	0.174	cfs	

Catch Basin #2 (CB-2)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000183	sq mi	
WQF =	0.141	cfs	
Total WQF =	0.316	cfs	CBs #1-2

Catch Basin #3 (CB-3)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000191	sq mi	
WQF =	0.148	cfs	
Total WQF =	0.464	cfs	CBs #1-3

Catch Basin #4 (CB-4)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000118	sq mi	
WQF =	0.091	cfs	
Total WQF =	0.555	cfs	CBs #1-4

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Catch Basin #5 (CB-5)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000328	sq mi	
WQF =	0.254	cfs	
Total WQF =	0.809	cfs	CBs #1-5

Catch Basin #6 (CB-6)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000010	sq mi	
WQF =	0.008	cfs	

Catch Basin #7 (CB-7)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000004	sq mi	
WQF =	0.003	cfs	
Total WQF =	0.011	cfs	CBs #6-7

Catch Basin #8 (CB-8)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000101	sq mi	
WQF =	0.078	cfs	
Total WQF =	0.089	cfs	CBs #6-8

Hydrodynamic Separator #1 (HDS-1)

Total WQF =	0.90	cfs	CBs #1-8

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DRY POND 2

Catch Basin #9 (CB-9)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table
A (impervious area) =	0.000255	sq mi
WQF =	0.197	cfs

Catch Basin #10 (CB-10)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table
A (impervious area) =	0.000296	sq mi
WQF =	0.229	cfs

Catch Basin #11 (CB-11)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table
A (impervious area) =	0.000291	sq mi
WQF =	0.225	cfs

Catch Basin #12 (CB-12)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000600	sq mi	
WQF =	0.464	cfs	
Total WQF =	1.116	cfs	CBs #9-12

Catch Basin #13 (CB-13)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table
A (impervious area) =	0.000325	sq mi
WQF =	0.251	cfs

Catch Basin #14 (CB-14)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches

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Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000291	sq mi	
WQF =	0.225	cfs	
Total WQF =	0.476	cfs	CBs #13-14

Catch Basin #15 (CB-15)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000348	sq mi	
WQF =	0.269	cfs	
Total WQF =	0.746	cfs	CBs #13-15

Catch Basin #16 (CB-16)

WQF = (qu) x (A) x (WQV)

WQV =	1.0	inches	
Qu =	774.0	csm/in based on time of concentration of 6 minutes (0.1 hours) per table	
A (impervious area) =	0.000587	sq mi	
WQF =	0.455	cfs	
Total WQF =	1.571	cfs	CBs #9-12, 16

Hydrodynamic Separator #2 (HDS-2)

Total WQF =	2.32	cfs	CBs #9-16

Prepared By:
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Appendix G: TSS Removal

TSS Removal Calculation Worksheet

Location: Subcatchment P1

A BMP[1]	B TSS Removal Rate[1]	C Starting TSS Load*	D Amount Removed (B*C)	E Remaining Load (C-D)
Proprietary Pretreatment Practice (HDS-1)	0.80	1.00	0.80	0.20
Proprietary Treatment Practice (JFV-1)	0.80	0.20	0.16	0.04

Total TSS Removal = 96%

Project: 296229
Prepared By: Arup
Date: 3/18/2025

*Equals remaining load from previous BMP (E) which enters the BMP

Prepared By:
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TSS Removal Calculation Worksheet

Location: Subcatchment P2

A BMP[1]	B TSS Removal Rate[1]	C Starting TSS Load*	D Amount Removed (B*C)	E Remaining Load (C-D)
Proprietary Pretreatment Practice (HDS-2)	0.80	1.00	0.80	0.20
Proprietary Treatment Practice (JFV-2)	0.80	0.20	0.16	0.04

Total TSS Removal = 96%

Project: 296229
Prepared By: Arup
Date: 3/18/2025

*Equals remaining load from previous BMP (E) which enters the BMP

Prepared By:
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6.6.2 Total Phosphorus

Total phosphorus and orthophosphate phosphorous (ortho phosphorous) were analyzed for 21 of the sampled storm events. These results are shown in Tables 13 and 14.

Influent EMCs for total phosphorus ranged from 0.0806 mg/L to 1.7500 mg/L with a mean of 0.4711 mg/L and a median of 0.3380 mg/L. Corresponding effluent EMCs for total phosphorus ranged from 0.030mg/L to 0.1730 mg/L with a mean of 0.0836 mg/L and a median of 0.0915 mg/L.

Influent EMCs for ortho phosphorous ranged from 0.0100 mg/L to 0.0360 mg/L with a mean of 0.0179 mg/L and a median of 0.0150 mg/L. Corresponding effluent EMCs for ortho phosphorous ranged from 0.0100 mg/L to 0.0541 mg/L with a mean of 0.0192 mg/L and a median of 0.0160 mg/L.

Table 13. Total Phosphorus Results

Total Phosphorus								
Event ID	**Sample Type**	**Influent result (mg/L)**	**Method reporting limit (MRL) (mg/L)**	**Influent load (g)**	**Effluent result (mg/L)**	**Method reporting limit (MRL) (mg/L)**	**Effluent load (g)**	**Individual storm reduction (RE) (%)**
4/7/2017	Comp.	0.7060	0.0100	44.3	0.0920	0.0100	5.8	87.0
4/12/2017	Comp.	0.3380	0.0100	33.0	0.0760	0.0100	7.4	77.5
4/19/2017	Comp.	0.5000	0.0100	9.0	0.0360	0.0100	0.7	92.8
4/26/2017	Comp.	0.5040	0.0100	22.0	0.0420	0.0100	1.8	91.7
5/13/2017	Comp.	0.2560	0.0100	25.0	0.1100	0.0100	10.7	57.0
5/16/2017	Comp.	0.0940	0.0100	16.3	0.0420	0.0100	7.3	55.3
6/8/2017	Comp.	0.2560	0.0100	22.9	0.1040	0.0100	9.3	59.4
6/15/2017	Comp.	0.3620	0.0100	37.6	0.0520	0.0100	5.4	85.6
3/8/2018	Comp.	1.7500	0.0100	163.1	0.1300	0.0100	12.1	92.6
3/14/2018	Comp.	0.6520	0.0100	69.7	0.0940	0.0100	10.1	85.6
3/16/2018	Comp.	0.0820	0.0100	1.8	0.0300	0.0100	0.7	63.4
3/22/2018	Comp.	0.3640	0.0100	40.9	0.0720	0.0100	8.1	80.2
3/27/2019	Comp.	0.2260	0.0500	39.5	0.0699	0.0500	12.2	69.1
4/5/2019	Peak	0.3370	0.0500	1.7	0.0915	0.0500	0.5	72.8
4/13/2019	Peak	0.2490	0.0500	95.9	0.0870	0.0500	33.5	65.1
5/18/2019	Peak	1.0900	0.2500	122.7	0.1730	0.0500	19.5	84.1
12/7/2019	Comp.	0.3350	0.0500	89.9	0.1050	0.0500	28.2	68.7
12/11/2019	Comp.	0.0806	0.0500	8.5	0.0523	0.0500	5.5	35.1
12/19/2019	Comp.	0.2110	0.0500	37.1	0.0925	0.0500	16.2	56.2
3/30/2020	Peak	1.0500	0.0500	126.0	0.0921	0.0500	11.1	91.2
4/20/2020	Peak	0.4510	0.0500	27.9	0.1120	0.0500	6.9	75.2
Min		0.0806	0.0100	1.7	0.0300	0.0100	0.5	35.1
Max		1.7500	0.2500	163.1	0.1730	0.0500	33.5	92.8
Mean		0.4711	0.0367	49.3	0.0836	0.0271	10.1	73.6
Median		0.3380	0.0100	37.1	0.0915	0.0100	8.1	75.2
Sum				1034.9			213.0	

Table 21. Basic Treatment TSS results

Total Suspended Solids (TSS)									
Event ID	Sample Type	Influent result (mg/L)	Method reporting limit (MRL) (mg/L)	Influent load (kg)	Effluent result (mg/L)	Method reporting limit (MRL) (mg/L)	Effluent load (kg)	Basic Criteria 1 20-100 mg/l Eff. conc. ≤ 20mg/l	Basic Criteria 2 100-200 mg/l ≥80% RE (%) [a]
3/20/2017	Comp.	51.2	2.0	6.8	19.4	2.1	2.6	19.4	
3/21/2017	Comp.	102.0	2.0	7.1	22.0	2.0	1.5		78.4
4/7/2017	Comp.	201.0	2.0	12.6	30.8	2.0	1.9		84.6
4/12/2017	Comp.	108.0	2.0	10.6	24.4	2.0	2.4		77.4
4/19/2017	Comp.	452.0	2.0	8.2	44.6	2.1	0.8		77.7
4/26/2017	Comp.	257.0	2.3	11.2	10.0	2.4	0.4		95.0
5/13/2017	Comp.	66.0	2.0	6.4	33.2	2.0	3.2	33.2	
5/16/2017	Comp.	24.0	2.0	4.2	6.8	2.0	1.2	6.8	
6/8/2017	Comp.	73.6	2.0	6.6	16.8	2.0	1.5	16.8	
6/15/2017	Comp.	134.0	2.5	13.9	10.4	2.0	1.1		92.2
3/8/2018	Comp.	755.0	3.3	70.4	47.2	2.0	4.4		76.4
3/14/2018	Comp.	181.0	5.0	19.4	27.0	5.0	2.9		85.1
3/16/2018	Comp.	19.0	5.0	0.4	ND	5.0	0.1		
3/22/2018	Comp.	224.0	5.0	25.1	20.0	5.0	2.2		90.0
3/27/2019	Comp.	94.0	5.0	16.4	11.0	5.0	1.9	11.0	
4/5/2019	Peak	171.0	5.0	0.9	23.0	5.0	0.1		86.5
4/13/2019	Peak	117.0	5.0	45.0	25.0	5.0	9.6		78.6
5/18/2019	Peak	254.0	5.0	28.6	20.0	5.0	2.3		90.0
12/7/2019	Comp.	200.0	5.0	53.7	17.0	5.0	4.6		91.5
12/11/2019	Comp.	13.0	5.0	1.4	10.0	5.0	1.1		
12/19/2019	Comp.	91.0	5.0	16.0	31.0	5.0	5.4	31.0	
3/30/2020	Peak	605.0	5.0	72.6	51.0	5.0	6.1		74.5
4/20/2020	Peak	210.0	5.0	13.0	29.0	5.0	1.8		85.5
Min		13.0	2.0	0.4	5.0	2.0	0.1	6.8	74.5
Max		755.0	5.0	72.6	51.0	5.0	9.6	33.2	95.0
Mean		191.4	3.7	19.6	23.2	3.6	2.6	19.7	84.2
Median		134.0	5.0	12.6	22.0	5.0	1.9	18.1	85.1
Lower 95% for RE [b]									82.0
Sum				450.4			59.2		

[a] Influent TSS concentrations capped at 200 mg/L for Basic Criteria 2 RE calculation purposes
[b] confidence interval calculated using TAPE bootstrap confidence interval calculator

WASHINGTON STATE DEPARTMENT OF ECOLOGY

January 2021

GENERAL USE LEVEL DESIGNATION FOR BASIC (TSS) AND PHOSPHORUS TREATMENT For Contech Environmental Solutions Jellyfish® Filter

Ecology's Decision:

1. Based on Contech Environmental Solution's application submissions, Ecology hereby issues a General use level designation (GULD) for Basic (TSS) and Phosphorus Treatment for Contech's Jellyfish® Filter:
   - Sized at a hydraulic loading rate of no greater than 0.21 gpm/sf filter surface for hi-flo cartridges and 0.11 gpm/sf filter surface for draindown cartridges

Table 1. Jellyfish® cartridge hydraulic loading rates and sediment capture capacity[1] associated with various filter cartridge sizes.

Cartridge Length	Design Treatment Flow Rate	Design Sediment Mass Loading Capacity
15 inches	Hi-Flo 22 gpm Draindown 11 gpm	Hi-Flo 35 lbs Draindown 17 lbs
27 inches	Hi-Flo 40 gpm Draindown 20 gpm	Hi-Flo 63 lbs Draindown 31 lbs
40 inches	Hi-Flo 60 gpm Draindown 30 gpm	Hi-Flo 93 lbs Draindown 46 lbs
54 inches	Hi-Flo 80 gpm Draindown 40 gpm	Hi-Flo 125 lbs Draindown 63 lbs

[1] Design sediment mass loading capacity based on laboratory testing using silica sediment.

2. Ecology approves Jellyfish® Filter units at the design treatment flow rates shown in Table 1. Total Jellyfish Filter system design treatment capacity is the sum of the design treatment capacity of individual cartridges and must equal or exceed the water quality design flow rate. Calculate the water quality design flow rate that must be treated by an individual treatment system using the following procedures:
   - Western Washington: For treatment installed upstream of detention or retention, the water quality design flow rate is the peak 15-minute flow rate as calculated using the latest version of the Western Washington Hydrology Model or other Ecology-approved continuous runoff model.
   - Eastern Washington: For treatment installed upstream of detention or retention, the water quality design flow rate is the peak 15-minute flow rate as calculated using one of the three methods described in Chapter 2.7.6 of the 2019 Stormwater Management Manual for Eastern Washington (SWMMEW) or local manual.
   - Entire State: For treatment installed downstream of detention, the water quality design flow rate is the full 2-year release rate of the detention facility.
3. The GULD has no expiration date but may be amended or revoked by Ecology.

<u>Ecology's Conditions of Use:</u>

Jellyfish® Filter units shall comply with the following conditions:

1. Design, assemble, install, operate, and maintain Jellyfish® Filter units in accordance with Contech's applicable manuals and documents and this Ecology Decision.
2. Contech uses sediment-loading capacity, in conjunction with the water quality design flow rate, to determine the target maintenance interval.
3. Jellyfish® Filters shall conform to specifications submitted to and approved by Ecology.
4. Maintenance: The required inspection/maintenance interval for stormwater treatment devices is often dependent on the efficiency of the device and the degree of pollutant loading from a particular drainage basin. Therefore, Ecology does not endorse or recommend a "one size fits all" maintenance cycle for a particular model/size of manufactured filter treatment device.
   - The Jellyfish® Filter is designed for a target maintenance interval of 12 months. Maintenance includes floatable trash, debris, and oil removal; sediment removal; and the rinsing or replacement of filter cartridges.
   - A Jellyfish® Filter tested in Dundee, OR averaged a 3.2 month maintenance interval. Construction activities were ongoing in the drainage basin and near the monitoring site during the first two years of the study. Monitoring personnel observed significant amounts of roadway sediments and organic debris in the runoff, and TSS concentrations were higher than typical for roadway runoff. The runoff that occurred during the study may be unusual, and the maintenance interval the Jellyfish® Filter required may not be indicative of other, more typical, sites.

- Owner/s operators must inspect Jellyfish® Filter systems for a minimum of twelve months from the start of post-construction operation to determine site-specific inspection/maintenance schedules and requirements. Owners/operators must conduct inspections monthly during the wet season, and every other month during the dry season. (According to the SWMMWW, the wet season in westerns Washington is October 1 to April 30. According to the SWMMEW, the wet season in eastern Washington is October 1 to June 30.) After the first year of operation, owners/operators must conduct inspections based on the findings during the first year of inspections.
- Conduct inspections by qualified personnel, follow manufacturer's guidelines, and use methods capable of determining either a decrease in treated effluent flow rate and/or a decrease in pollutant removal ability.

5. Install the Jellyfish® Filter in such a manner such that flows exceeding the maximum operating rate of the system are bypassed and will not resuspend captured sediment.
6. Discharges from the Jellyfish® Filter units shall not cause or contribute to water quality standards violations in receiving waters.

Applicant: CONTECH Engineered Solutions

Applicant's Address: 11835 NE Glenn Widing Dr
Portland, OR 97220

Application Documents:

- *Jellyfish® Filter Dundee, OR, General Use Level Designation Technical Evaluation Report*, Prepared by CONTECH Engineered Solutions, December 28, 2020
- Application Letter for CULD for Jellyfish Filter - Basic Treatment, Phosphorus Treatment, and Oil Treatment, dated April 27, 2012.
- Letter from Imbrium Systems dated September 4, 2012 regarding the draft CULD/PULD document.
- *TAPE Analysis of Jellyfish Filter UF Field Study Data*, prepared by Stormwater Management Services, LLC.
- *TARP Field Test Performance Monitoring of a Jellyfish Filter JF4-2-1. Performance Monitoring Report for JF4-2-1* Prepared By: University of Florida, Engineering School of Sustainable Infrastructure and Environment (ESSIE), University of Florida, Gainesville, FL 32611. Final Version: 01 November 2011.
- *Jellyfish Filter Systems Evaluation Report in Consideration for Pilot Level Designation (PLD) for Imbrium Systems Corporation*, by Gary R. Minton, PhD, PE, with Resource Planning Associates in Seattle, Washington May 7, 2008 (updated July 1, 2008).

- *NJCAT Technology Verification, Jellyfish Fine Sediment Filter*, by the New Jersey Corporation for Advanced Technology (NJCAT) Program Imbrium Systems Corporation, June 2008

Applicant's Use Level Request:

- General use level designation as a Basic (TSS) and Phosphorus Treatment device in accordance with Ecology's 2019 Stormwater Management Manual for Western Washington.

Applicant's Performance Claims:

Based on results from a laboratory and field-testing, the applicant claims the Jellyfish® Filter, operating at a hydraulic loading rate of no more than 0.21 gpm/sf for hi-flo cartridges and 0.11 gpm/sf for draindown cartridges, is able to remove:

- 80% of total suspended solids (TSS) for influent concentrations greater than 100 mg/L and achieve a 20 mg/L effluent for influent concentrations less than 100 mg/L.
- 50% of total phosphorus for influent concentrations 0.1 to 0.5 mg/L

Recommendations:

Ecology finds that:

- Contech Engineered Solutions has shown Ecology, through laboratory and field testing, that the Jellyfish® Filter is capable of attaining Ecology's Basic (TSS) and Total Phosphorus treatment goals.

Findings of Fact:

<u>Field Testing 2017-2020</u>
Contech completed field testing in Dundee, OR on a Jellyfish® Filter unit containing six 54-inch hi-flo cartridges and one 54-inch draindown cartridge. This combination of cartridges resulted in a design flow capacity of 520 gpm (1.16 cfs). Since Contech conducted the field evaluation they contracted with Herrera Environmental Consultants to provide third party oversight.

- The field evaluation was completed between March 2017 and April 2020. Throughout the evaluation a total of 23 individual storm events (18 flow-weighted composite samples and 5 peak flow grab samples) were sampled to evaluate system performance. All sampled events met the TAPE sampling event qualification criteria, while 21 of the 23 events met the influent requirements for TSS and/or total phosphorus. Peak flows during these 21 events ranged from 26% to 106% of the design treatment capacity of 520 gpm, with a mean peak flow rate of 67% of design.
- Of the 23 TAPE qualified events, 21 met the requirements for TSS analysis (16 flow weighted composite; 5 peak flow grab samples). Influent concentrations ranged from 24 mg/L to 755 mg/L, with a mean concentration of 208 mg/L. Concentrations that exceeded the upper end of TAPE influent range were capped at 200 mg/L prior to calculating the pollutant removal efficiency. For all samples with influent concentrations greater than 100 mg/L the bootstrap estimate of the lower 95 percent confidence limit (LCL95) of the mean TSS reduction was 82%, meeting the 80% performance goal for Basic Treatment. The TAPE bootstrap calculator could not be used on samples with influent concentrations

between 20 mg/L to 100 mg/L due to the limited number of events available (n=6). For these events the mean and median effluent TSS concentrations were 19.7 and 18.1 mg/L respectively, again meeting the 20 mg/L effluent goal for Basic Treatment.

- Of the 23 TAPE qualified events, 18 met the requirements for total phosphorus analysis (13 flow-weighted composite; 5 peak flow grab samples). Influent concentrations ranged from 0.211 mg/L to 1.75 mg/L, with a mean concentration of 0.535 mg/L. Concentrations that exceeded the upper end of TAPE influent range were capped at 0.5 mg/L prior to calculating the pollutant removal efficiency. The LCL 95 mean percent removal goal was 70.1%, meeting the 50% performance goal for Phosphorus Treatment.
- Median particle sized distribution results from three samples showed 20% of sediment >250 µm, 31% of sediment between 62.5 to 250 µm, and 51% of sediment <62.5 µm. This demonstrates the influent to the Jellyfish consisted of primarily silt-sized particles (3.9 to 62.5 µm) and is thus representative of Pacific Northwest Stormwater.
- Contech encountered several unanticipated events and challenges that disrupted the sampling and/or resulted in lost data: the Jellyfish was taken offline twice to avoid atypical sediment loading that was the result of construction within the drainage basin; monitoring was suspended to repair or replace equipment that was damaged from vandalism and extreme weather; and, a cyber-attack on Contech storage drives resulted in a loss of approximately 15% of non-sampled flow and precipitation data.

<u>Field Testing 2010-2011</u>

Results (second-generation membrane filtration cartridges) – University of Florida (Gainesville, FL) installed and tested a Jellyfish JF4-2-1. The University conducted monitoring of the system from May 28, 2010 to June 27, 2011, with runoff from 15.01 inches of rainfall. The monitoring followed the Technology Acceptance Reciprocity Partnership (TARP) field test protocol, per the guidelines of the New Jersey Department of Environmental Projection (NJDEP). The New Jersey Corporation for Advanced Technology (NJCAT), on May 14, 2012 certified the Jellyfish Filter for 80 percent TSS removal.

- The JF4-2-1 operating at a maximum treatment flow rate of 200 gpm provided a median total suspended solids (TSS) removal of 89 percent, and a median suspended sediment concentration (SSC) removal of 99 percent. Influent TSS concentrations ranged from 16.3 to 261.0 mg/L. TSS concentrations in the range of 20-100 mg/L were reduced to less than 20 mg/L for 16 of 17 events. Average TSS removal for influent TSS between 100-200 mg/L was 90 percent.

- Other median pollutant removals included: total phosphorus, 59 percent; total nitrogen, 51 percent; total copper, 90 percent; and total zinc 70 percent.

- Total oil and grease influent concentrations ranged from 0.2 to 4.1 mg/L, with a median removal efficiency of 62 percent.

- No maintenance was required or carried out during the 13-month monitoring period. Curves of head loss versus flow rate were nearly identical for the system with fresh cartridges (beginning of monitoring) and dirty cartridges (end of monitoring period). The sump and filter cartridges captured 166 pounds of dry basis particulate matter.

- Runoff treated by the JF4-2-1 was from a nearby parking lot (approximately 75 percent pavement and 25 percent planting islands). Depending on storm event intensity and wind direction, the drainage area varied from 0.12 to 0.20 acres.

Laboratory Testing and Results

Imbrium conducted testing at the Monteco Limited Research & Development Centre (RDC) in Mississauga, Ontario with third party testing oversight provided by Prof. James Li of Ryerson University in Toronto. The laboratory set-up used a single cartridge fitted into a tank sized to be 1/7 the volume of a full-scale 7-cartridge Jellyfish Filter system. Based on the lab test results:

- A Jellyfish Filter system fitted with a single Jellyfish cartridge or multiple Jellyfish cartridges can remove greater than 86% Sil-Co-Sil 106 (mean particle size 22 microns) within a 95% confidence interval of +/- 1.3% at the system's 100% operating rate with influent sediment concentrations ranging from 100 to 300 mg/L. For systems using 12-inch diameter cartridges, each cartridge containing 91filtration tentacles of 54-inch length, the 100% operating rate is 50 gpm per cartridge operating at 12 inches driving head (i.e., 0.66 gpm/ft2). Each (of the) 91 filtration tentacles is composed of three 18-inch long segments for a total length of 54 inches with 76 ft2 of surface area (first generation membrane filtration cartridges).
- Test runs at 100 mg/L influent concentration resulted in effluent concentrations ranging from 12 to 21 mg/L. Ten of the 11 test runs had effluent less than 20 mg/L (as required for Basic Treatment).
- Sampling of effluent found an average D90 of about 14 microns indicating the Jellyfish Filter System is capable of removing most particles above 15 microns.

Other Jellyfish Filter Related Issues Recommended to be Addressed by the Company:

1. Conduct hydraulic testing to obtain information about maintenance requirements on a site with runoff that is more typical of the Pacific Northwest.

Technology Description: Download at: http://www.conteches.com/products/stormwater-management/treatment/jellyfish-filter

Contact Information:

Applicant:	Jeremiah Lehman Contech Engineered Solutions, LLC. 11815 Glenn Widing Dr Portland, OR 97220 (503) 258-3136 jlehman@conteches.com
Applicant website:	www.conteches.com

Ecology web link: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

Ecology: Douglas C. Howie, P.E.
Department of Ecology
Water Quality Program
(360) 407-6444
douglas.howie@ecy.wa.gov

Revision History

Date	**Revision**
August 2008	PULD granted
January 2012	PULD Extension granted
September 2012	CULD for Basic treatment; PULD for Oil and Phosphorus treatment.
January 2013	Modifications to format document in line with other Use Level Documents, Changes dates for QAPP, TER, and Expiration
August 2014	Revised contact information and due dates for QAPP, TER, and expiration
March 2015	Revised Contact Information to Contech from Imbrium
November 2016	Revised Contech contact information
March 2018	Revised TER delivery and Expiration dates, Changed text from Imbrium to Contech in selected locations
April 2019	Revised TER delivery and Expiration dates
September 2020	Revised TER delivery and Expiration dates
January 2021	GULD Granted

CONTECH ENGINEERED SOLUTIONS

Estimated Net Annual Solids Load Reduction Based on the Rational Rainfall Method

CASCADE separator™

ZOVL - Moraga Storage

Oakham, MA

HDS 2

AREA	4.02	acres	CASCADE MODEL	CS-6	
WEIGHTED C	0.48		PARTICLE SIZE	110	microns
TC	6.00	minutes			

Rainfall Intensity[1] (in/hr)	Percent Rainfall Volume[1]	Hydraulic Loading Rate (gpm/ft2)	Removal Efficiency (%)	Incremental Removal (%)
0.08	37.6%	2.45	100.0	37.6
0.16	22.6%	4.90	100.0	22.6
0.24	11.9%	7.35	100.0	11.9
0.32	7.6%	9.80	100.0	7.6
0.40	4.3%	12.25	100.0	4.3
0.48	2.3%	14.70	98.1	2.3
0.56	1.8%	17.15	95.8	1.7
0.64	1.4%	19.60	93.5	1.3
0.72	0.9%	22.05	91.2	0.8
0.80	1.2%	24.50	88.9	1.0
0.88	1.5%	26.96	86.6	1.3
0.96	0.9%	29.41	84.3	0.8
1.04	0.4%	31.86	82.0	0.3
1.12	0.4%	34.31	79.7	0.3
1.20	0.6%	36.76	77.3	0.4
1.28	0.3%	39.21	75.0	0.2
1.36	0.2%	41.66	72.7	0.1
1.44	0.9%	44.11	70.4	0.6
1.52	0.6%	46.56	68.1	0.4
1.60	0.4%	49.01	65.8	0.3
1.80	0.2%	55.14	60.1	0.1
2.00	0.9%	61.26	54.3	0.5
				96.6
			Removal Efficiency Adjustment[2] =	0.0%
			Predicted % Annual Rainfall Treated =	98.8%
			Predicted Net Annual Load Removal Efficiency =	96.6%

1 - Based on 13 years of 15 minute precipitation data for Station 0666, Birch Hill Dam, Worcester County, MA

2 - Reduction due to use of 60-minute data for a site that has a time of concentration less than 30-minutes.

CONTECH ENGINEERED SOLUTIONS

Estimated Net Annual Solids Load Reduction
Based on the Rational Rainfall Method

CASCADE separator™

ZOVL - Moraga Storage
Oakham, MA
HDS 1

AREA	2.02	acres	CASCADE MODEL	CS-4	
WEIGHTED C	0.50		PARTICLE SIZE	110	microns
TC	6.00	minutes			

Rainfall Intensity[1] (in/hr)	Percent Rainfall Volume[1]	Hydraulic Loading Rate (gpm/ft2)	Removal Efficiency (%)	Incremental Removal (%)
0.08	37.6%	2.89	100.0	37.6
0.16	22.6%	5.77	100.0	22.6
0.24	11.9%	8.66	100.0	11.9
0.32	7.6%	11.54	100.0	7.6
0.40	4.3%	14.43	98.3	4.3
0.48	2.3%	17.32	95.6	2.2
0.56	1.8%	20.20	92.9	1.7
0.64	1.4%	23.09	90.2	1.2
0.72	0.9%	25.97	87.5	0.8
0.80	1.2%	28.86	84.8	1.0
0.88	1.5%	31.75	82.1	1.2
0.96	0.9%	34.63	79.3	0.7
1.04	0.4%	37.52	76.6	0.3
1.12	0.4%	40.40	73.9	0.3
1.20	0.6%	43.29	71.2	0.4
1.28	0.3%	46.17	68.5	0.2
1.36	0.2%	49.06	65.8	0.1
1.44	0.9%	51.95	63.1	0.6
1.52	0.6%	54.83	60.4	0.3
1.60	0.4%	57.72	57.6	0.2
1.80	0.2%	64.93	50.9	0.1
2.00	0.9%	72.15	44.1	0.4
				95.8

Removal Efficiency Adjustment[2] =	0.0%
Predicted % Annual Rainfall Treated =	98.8%
Predicted Net Annual Load Removal Efficiency =	95.8%

1 - Based on 13 years of 15 minute precipitation data for Station 0666, Birch Hill Dam, Worcester County, MA

2 - Reduction due to use of 60-minute data for a site that has a time of concentration less than 30-minutes.

Appendix H: BMP Sizing

Moraga Storage LLC - ZOVL
358 Coldbrook Road
Oakham, MA
Arup Job Number: 296229
March 18, 2025

Basin Sizing Calculations

Basin: Pond1

Basin Requirements:
Percentage of WQV Required for New Development = 100%
Total Impervious Area = 44,339 SF
Required WQV = 1" x Impervious Area = 3,695 CF
Areq = Surface area required for bottom of basin = 0.066 * required WQV = 244 SF

Proposed Basin Size:
Bottom of basin surface area = 6,139 SF
1ft depth area = 7,523 SF
2ft depth area = 8,975 SF
3ft depth area = 10,478 SF
Top of basin surface area = 12,037 SF
A = Average surface area top and bottom of basin = 9,088 SF
Dponding = ponding depth = 3 FT
V = Static storage volume = A * Dponding = 27,264 CF

Basin: Pond2

Basin Requirements:
Percentage of WQV Required for New Development = 100%
Total Impervious Area = 83,027 SF
Required WQV = 1" x Impervious Area = 6,919 CF
Areq = Surface area required for bottom of basin = 0.066 * required WQV = 457 SF

Proposed Basin Size:
Bottom of basin surface area = 3,429 SF
1ft depth area = 4,209 SF
2ft depth area = 5,080 SF
3ft depth area = 6,015 SF
4ft depth area = 7,019 SF
Top of basin surface area = 8,092 SF
A = Average surface area top and bottom of basin = 5,761 SF
Dponding = ponding depth = 4 FT
V = Static storage volume = A * Dponding = 23,042 CF

Appendix H: BMP Sizing

Moraga Storage LLC - ZOVL
358 Coldbrook Road
Oakham, MA
Arup Job Number: 296229
March 18, 2025

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Percentage of WQV Required for New Development = 100%
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Top of basin surface area = 8,092 SF
A = Average surface area top and bottom of basin = 5,761 SF
Dponding = ponding depth = 4 FT
V = Static storage volume = A * Dponding = 23,042 CF

Appendix I: Pre & Post Development SSA Model Outputs

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Autodesk® Storm and Sanitary Analysis 2016 - Version 13.0.94 (Build 0)
-----------------------------------------------------------------------------------------

*******************
Project Description
*******************
File Name ................ ZOVL_PreDevelopment_r2.SPF


****************
Analysis Options
****************
Flow Units ............... cfs
Subbasin Hydrograph Method. SCS TR-20
Time of Concentration...... SCS TR-55
Storage Node Exfiltration.. Constant rate, projected area
Starting Date ............ MAY-06-2024 00:00:00
Ending Date .............. MAY-09-2024 00:00:00
Report Time Step ......... 00:04:00


*************
Element Count
*************
Number of rain gages ...... 1
Number of subbasins ....... 2
Number of nodes ........... 2
Number of links ........... 0


****************
Raingage Summary
****************
Gage                Data                Data       Recording
ID                  Source              Type        Interval
                                                         min
------------------------------------------------------------
Rain Gage-01        2YR 24HR (Future)   CUMULATIVE      1.00


****************
Subbasin Summary
****************
Subbasin                Total
                         Area
ID                        ft²
------------------------------
Catch-E1            249040.01
Catch-E2            376753.49


************
Node Summary
************
Node                Element             Invert   Maximum    Ponded    External
ID                  Type             Elevation     Elev.      Area      Inflow
                                            ft        ft       ft²
------------------------------------------------------------------------------
DP-1                OUTFALL               0.00      0.00      0.00
DP-2                OUTFALL               0.00      0.00      0.00


**************************        Volume        Depth
Runoff Quantity Continuity       acre-ft       inches
**************************     ---------      -------
Total Precipitation ......         4.612        3.852
Surface Runoff ...........         0.011        0.009
```

```
Continuity Error (%) .....        -0.001


**************************        Volume        Volume
Flow Routing Continuity          acre-ft      Mgallons
**************************      ---------     ---------
External Inflow ..........         0.000         0.000
External Outflow .........         2.622         0.855
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.000         0.000
Continuity Error (%) .....         0.000


******************************************
Composite Curve Number Computations Report
******************************************
```

Subbasin Catch-E1

Soil/Surface Description	Area (ft²)	Soil Group	CN
Woods, Fair	142163.41	D	79.00
Paved parking & roofs	5256.97	D	98.00
Dirt roads	101619.58	D	89.00
Composite Area & Weighted CN	249039.97		83.48

Subbasin Catch-E2

Soil/Surface Description	Area (ft²)	Soil Group	CN
Woods & grass combination, Fair	349096.58	D	82.00
Dirt roads	27656.87	D	89.00
Composite Area & Weighted CN	376753.45		82.51

```
***************************************************
SCS TR-55 Time of Concentration Computations Report
***************************************************

Sheet Flow Equation
-------------------

        Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

        Where:

        Tc = Time of Concentration (hrs)
        n  = Manning's Roughness
        Lf = Flow Length (ft)
        P  = 2 yr, 24 hr Rainfall (inches)
        Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation
----------------------------------

        V  = 16.1345 * (Sf^0.5) (unpaved surface)
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)
```

Where:

Tc = Time of Concentration (hrs)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation

$$V = (1.49 * (R^{(2/3)}) * (Sf^{0.5})) / n$$
$$R = Aq / Wp$$
$$Tc = (Lf / V) / (3600 \text{ sec/hr})$$

Where:

Tc = Time of Concentration (hrs)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft^2)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's Roughness

Subbasin Catch-E1

Sheet Flow Computations

	Subarea A	Subarea B	Subarea C
Manning's Roughness:	0.30	0.80	0.80
Flow Length (ft):	40.00	35.00	25.00
Slope (%):	7.50	6.00	12.00
2 yr, 24 hr Rainfall (in):	3.00	3.00	3.00
Velocity (ft/sec):	0.13	0.05	0.07
Computed Flow Time (minutes):	4.99	10.74	6.22

Shallow Concentrated Flow Computations

	Subarea A	Subarea B	Subarea C
Flow Length (ft):	384.00	264.00	61.00
Slope (%):	9.50	3.00	3.50
Surface Type:	Woodland	Woodland	Unpaved
Velocity (ft/sec):	1.54	0.87	3.02
Computed Flow Time (minutes):	4.16	5.06	0.34
Total TOC (minutes):	31.50		

Subbasin Catch-E2

Sheet Flow Computations

	Subarea A	Subarea B	Subarea C
Manning's Roughness:	0.80	0.80	0.80
Flow Length (ft):	39.00	25.00	37.00
Slope (%):	11.00	16.00	25.00
2 yr, 24 hr Rainfall (in):	3.00	3.00	3.00
Velocity (ft/sec):	0.07	0.08	0.10
Computed Flow Time (minutes):	9.19	5.54	6.35

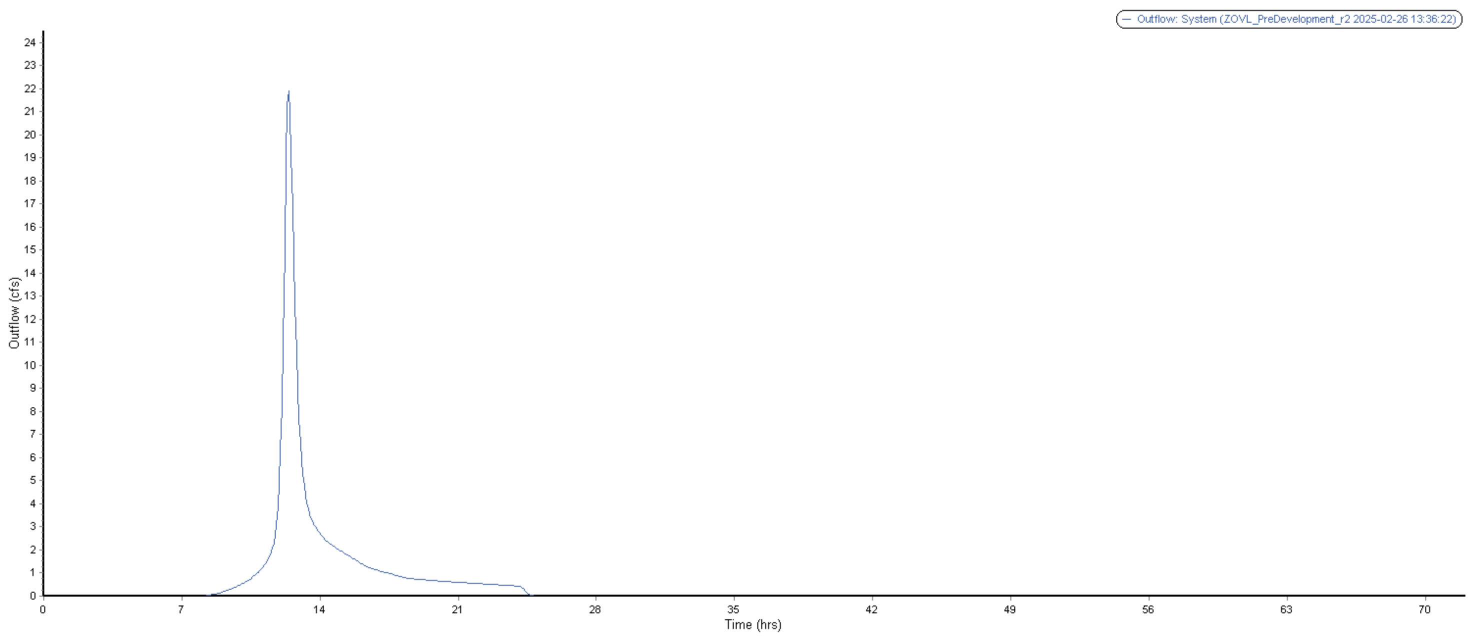
Shallow Concentrated Flow Computations

	Subarea A	Subarea B	Subarea C
Flow Length (ft):	21.00	170.00	232.00
Slope (%):	14.50	5.00	5.00
Surface Type:	Woodland	Unpaved	Woodland
Velocity (ft/sec):	1.90	3.61	1.12
Computed Flow Time (minutes):	0.18	0.78	3.45
Total TOC (minutes):	25.51		

****
Subbasin Runoff Summary
****

Subbasin ID	Total Precip in	Total Runoff in	Peak Runoff cfs	Weighted Curve Number	Time of Concentration days	Time of Concentration hh:mm:ss
Catch-E1	3.90	2.24	8.51	83.480	0	00:31:30
Catch-E2	3.90	2.16	13.60	82.510	0	00:25:30

Analysis began on: Wed Feb 26 13:26:04 2025
Analysis ended on: Wed Feb 26 13:26:13 2025
Total elapsed time: 00:00:09


Outflow: System (ZOVL_PreDevelopment_r2 2025-02-26 13:36:22)
Outflow (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
0
7
14
21
28
35
42
49
56
63
70
Time (hrs)

```
Autodesk® Storm and Sanitary Analysis 2016 - Version 13.0.94 (Build 0)
------------------------------------------------------------------------------------------

*******************
Project Description
*******************
File Name ................ ZOVL_PreDevelopment_r2.SPF


****************
Analysis Options
****************
Flow Units ............... cfs
Subbasin Hydrograph Method. SCS TR-20
Time of Concentration...... SCS TR-55
Storage Node Exfiltration.. Constant rate, projected area
Starting Date ............ MAY-06-2024 00:00:00
Ending Date .............. MAY-09-2024 00:00:00
Report Time Step ......... 00:04:00


*************
Element Count
*************
Number of rain gages ...... 1
Number of subbasins ....... 2
Number of nodes ........... 2
Number of links ........... 0


****************
Raingage Summary
****************
Gage                Data                Data       Recording
ID                  Source              Type        Interval
                                                            min
------------------------------------------------------------
Rain Gage-01        10YR 24HR (Future)  CUMULATIVE      1.00


****************
Subbasin Summary
****************
Subbasin                Total
                         Area
ID                        ft²
------------------------------
Catch-E1            249040.01
Catch-E2            376753.49


************
Node Summary
************
Node                Element             Invert   Maximum    Ponded    External
ID                  Type             Elevation     Elev.      Area      Inflow
                                            ft        ft       ft²
------------------------------------------------------------------------------
DP-1                OUTFALL               0.00      0.00      0.00
DP-2                OUTFALL               0.00      0.00      0.00


**************************         Volume         Depth
Runoff Quantity Continuity        acre-ft        inches
**************************       ---------       -------
Total Precipitation ......           7.096         5.927
Surface Runoff ...........           0.020         0.017
```

```
Continuity Error (%) .....        -0.001


**************************        Volume       Volume
Flow Routing Continuity          acre-ft     Mgallons
**************************      ---------    ---------
External Inflow ..........         0.000        0.000
External Outflow .........         4.883        1.591
Initial Stored Volume ....         0.000        0.000
Final Stored Volume ......         0.000        0.000
Continuity Error (%) .....         0.000


******************************************
Composite Curve Number Computations Report
******************************************
```

```
--------------------
Subbasin Catch-E1
--------------------
```

Soil/Surface Description	Area (ft²)	Soil Group	CN
Woods, Fair	142163.41	D	79.00
Paved parking & roofs	5256.97	D	98.00
Dirt roads	101619.58	D	89.00
Composite Area & Weighted CN	249039.97		83.48

```
--------------------
Subbasin Catch-E2
--------------------
```

Soil/Surface Description	Area (ft²)	Soil Group	CN
Woods & grass combination, Fair	349096.58	D	82.00
Dirt roads	27656.87	D	89.00
Composite Area & Weighted CN	376753.45		82.51

```
***************************************************
SCS TR-55 Time of Concentration Computations Report
***************************************************

Sheet Flow Equation
-------------------

        Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

        Where:

        Tc = Time of Concentration (hrs)
        n  = Manning's Roughness
        Lf = Flow Length (ft)
        P  = 2 yr, 24 hr Rainfall (inches)
        Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation
----------------------------------

        V  = 16.1345 * (Sf^0.5) (unpaved surface)
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)
```

```
        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)

Channel Flow Equation
---------------------

        V  = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
        R  = Aq / Wp
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        R  = Hydraulic Radius (ft)
        Aq = Flow Area (ft²)
        Wp = Wetted Perimeter (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)
        n  = Manning's Roughness

--------------------
Subbasin Catch-E1
--------------------

Sheet Flow Computations
-----------------------
                                              Subarea A          Subarea B          Subarea C
        Manning's Roughness:                       0.30               0.80               0.80
        Flow Length (ft):                         40.00              35.00              25.00
        Slope (%):                                 7.50               6.00              12.00
        2 yr, 24 hr Rainfall (in):                 3.00               3.00               3.00
        Velocity (ft/sec):                         0.13               0.05               0.07
        Computed Flow Time (minutes):              4.99              10.74               6.22

Shallow Concentrated Flow Computations
--------------------------------------
                                              Subarea A          Subarea B          Subarea C
        Flow Length (ft):                        384.00             264.00              61.00
        Slope (%):                                 9.50               3.00               3.50
        Surface Type:                          Woodland           Woodland            Unpaved
        Velocity (ft/sec):                         1.54               0.87               3.02
        Computed Flow Time (minutes):              4.16               5.06               0.34
=================================================================================================
        Total TOC (minutes):                      31.50
=================================================================================================


--------------------
Subbasin Catch-E2
--------------------

Sheet Flow Computations
-----------------------
                                              Subarea A          Subarea B          Subarea C
        Manning's Roughness:                       0.80               0.80               0.80
        Flow Length (ft):                         39.00              25.00              37.00
        Slope (%):                                11.00              16.00              25.00
        2 yr, 24 hr Rainfall (in):                 3.00               3.00               3.00
        Velocity (ft/sec):                         0.07               0.08               0.10
        Computed Flow Time (minutes):              9.19               5.54               6.35

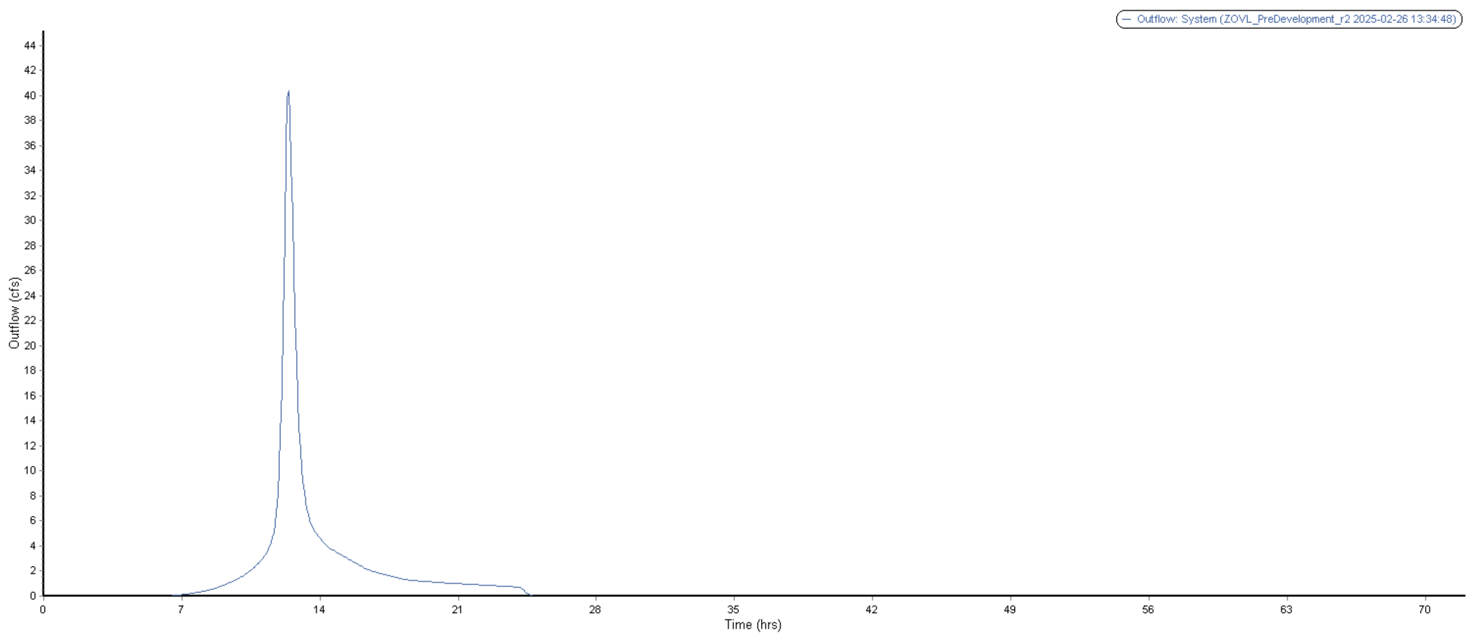
Shallow Concentrated Flow Computations
```

	Subarea A	Subarea B	Subarea C
Flow Length (ft):	21.00	170.00	232.00
Slope (%):	14.50	5.00	5.00
Surface Type:	Woodland	Unpaved	Woodland
Velocity (ft/sec):	1.90	3.61	1.12
Computed Flow Time (minutes):	0.18	0.78	3.45
Total TOC (minutes):	25.51		

****
Subbasin Runoff Summary
****

Subbasin ID	Total Precip in	Total Runoff in	Peak Runoff cfs	Weighted Curve Number	Time of Concentration days	Time of Concentration hh:mm:ss
Catch-E1	6.00	4.14	15.58	83.480	0	00:31:30
Catch-E2	6.00	4.04	25.27	82.510	0	00:25:30

Analysis began on: Wed Feb 26 13:27:07 2025
Analysis ended on: Wed Feb 26 13:27:16 2025
Total elapsed time: 00:00:09


Outflow: System (ZOVL_PreDevelopment_r2 2025-02-26 13:34:48)
Outflow (cfs)
Time (hrs)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
0
7
14
21
28
35
42
49
56
63
70

```
Autodesk® Storm and Sanitary Analysis 2016 - Version 13.0.94 (Build 0)
-----------------------------------------------------------------------------------------

*******************
Project Description
*******************
File Name ................ ZOVL_PreDevelopment_r2.SPF


****************
Analysis Options
****************
Flow Units ............... cfs
Subbasin Hydrograph Method. SCS TR-20
Time of Concentration...... SCS TR-55
Storage Node Exfiltration.. Constant rate, projected area
Starting Date ............ MAY-06-2024 00:00:00
Ending Date .............. MAY-09-2024 00:00:00
Report Time Step ......... 00:04:00


*************
Element Count
*************
Number of rain gages ...... 1
Number of subbasins ....... 2
Number of nodes ........... 2
Number of links ........... 0


****************
Raingage Summary
****************
Gage                Data                Data       Recording
ID                  Source              Type        Interval
                                                         min
------------------------------------------------------------
Rain Gage-01        100YR 24HR (Future) CUMULATIVE      1.00


****************
Subbasin Summary
****************
Subbasin                Total
                         Area
ID                        ft²
------------------------------
Catch-E1            249040.01
Catch-E2            376753.49


************
Node Summary
************
Node                Element            Invert  Maximum    Ponded    External
ID                  Type            Elevation    Elev.      Area      Inflow
                                           ft       ft       ft²
-------------------------------------------------------------------------------
DP-1                OUTFALL              0.00     0.00      0.00
DP-2                OUTFALL              0.00     0.00      0.00


**************************         Volume         Depth
Runoff Quantity Continuity       acre-ft        inches
**************************      ---------       -------
Total Precipitation ......         11.117         9.286
Surface Runoff ...........          0.036         0.030
```

```
Continuity Error (%) .....        -0.001


*************************        Volume        Volume
Flow Routing Continuity          acre-ft      Mgallons
*************************       ---------     ---------
External Inflow ..........         0.000         0.000
External Outflow .........         8.748         2.851
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.000         0.000
Continuity Error (%) .....         0.000


******************************************
Composite Curve Number Computations Report
******************************************

--------------------
Subbasin Catch-E1
--------------------
                                                             Area         Soil
Soil/Surface Description                                    (ft²)         Group          CN
-------------------------------------------------------------------------------------------
Woods, Fair                                             142163.41            D        79.00
Paved parking & roofs                                     5256.97            D        98.00
Dirt roads                                              101619.58            D        89.00
Composite Area & Weighted CN                            249039.97                     83.48

--------------------
Subbasin Catch-E2
--------------------
                                                             Area         Soil
Soil/Surface Description                                    (ft²)         Group          CN
-------------------------------------------------------------------------------------------
Woods & grass combination, Fair                         349096.58            D        82.00
Dirt roads                                               27656.87            D        89.00
Composite Area & Weighted CN                            376753.45                     82.51


***************************************************
SCS TR-55 Time of Concentration Computations Report
***************************************************

Sheet Flow Equation
-------------------

        Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

        Where:

        Tc = Time of Concentration (hrs)
        n  = Manning's Roughness
        Lf = Flow Length (ft)
        P  = 2 yr, 24 hr Rainfall (inches)
        Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation
----------------------------------

        V  = 16.1345 * (Sf^0.5) (unpaved surface)
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)
```

Where:

Tc = Time of Concentration (hrs)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation

$$V = (1.49 * (R^{(2/3)}) * (Sf^{0.5})) / n$$
$$R = Aq / Wp$$
$$Tc = (Lf / V) / (3600 \text{ sec/hr})$$

Where:

Tc = Time of Concentration (hrs)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's Roughness

Subbasin Catch-E1

Sheet Flow Computations

	Subarea A	Subarea B	Subarea C
Manning's Roughness:	0.30	0.80	0.80
Flow Length (ft):	40.00	35.00	25.00
Slope (%):	7.50	6.00	12.00
2 yr, 24 hr Rainfall (in):	3.00	3.00	3.00
Velocity (ft/sec):	0.13	0.05	0.07
Computed Flow Time (minutes):	4.99	10.74	6.22

Shallow Concentrated Flow Computations

	Subarea A	Subarea B	Subarea C
Flow Length (ft):	384.00	264.00	61.00
Slope (%):	9.50	3.00	3.50
Surface Type:	Woodland	Woodland	Unpaved
Velocity (ft/sec):	1.54	0.87	3.02
Computed Flow Time (minutes):	4.16	5.06	0.34

Total TOC (minutes):	31.50

Subbasin Catch-E2

Sheet Flow Computations

	Subarea A	Subarea B	Subarea C
Manning's Roughness:	0.80	0.80	0.80
Flow Length (ft):	39.00	25.00	37.00
Slope (%):	11.00	16.00	25.00
2 yr, 24 hr Rainfall (in):	3.00	3.00	3.00
Velocity (ft/sec):	0.07	0.08	0.10
Computed Flow Time (minutes):	9.19	5.54	6.35

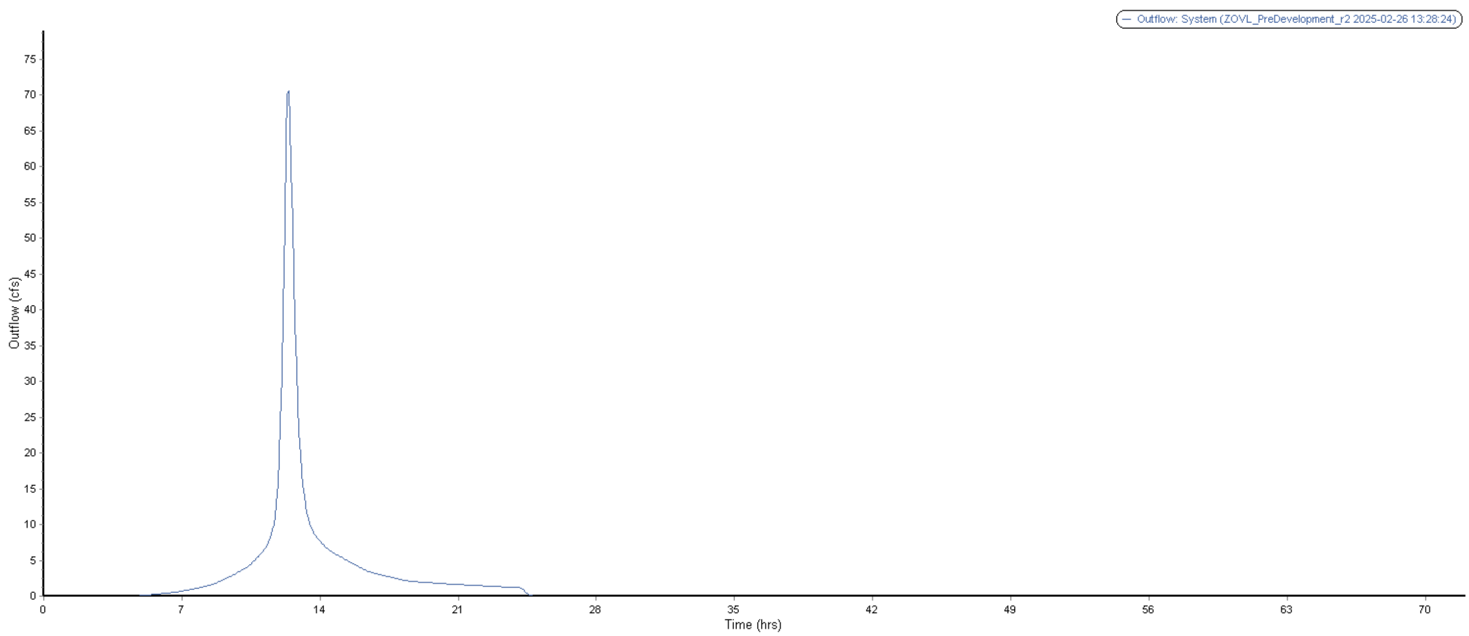
Shallow Concentrated Flow Computations

	Subarea A	Subarea B	Subarea C
Flow Length (ft):	21.00	170.00	232.00
Slope (%):	14.50	5.00	5.00
Surface Type:	Woodland	Unpaved	Woodland
Velocity (ft/sec):	1.90	3.61	1.12
Computed Flow Time (minutes):	0.18	0.78	3.45
Total TOC (minutes):	25.51		

****
Subbasin Runoff Summary
****

Subbasin ID	Total Precip in	Total Runoff in	Peak Runoff cfs	Weighted Curve Number	Time of Concentration days	Time of Concentration hh:mm:ss
Catch-E1	9.40	7.38	27.16	83.480	0	00:31:30
Catch-E2	9.40	7.26	44.43	82.510	0	00:25:30

Analysis began on: Wed Feb 26 13:28:14 2025
Analysis ended on: Wed Feb 26 13:28:23 2025
Total elapsed time: 00:00:09


Outflow: System (ZOVL_PreDevelopment_r2 2025-02-26 13:28:24)
Outflow (cfs)
Time (hrs)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
0
7
14
21
28
35
42
49
56
63
70

```
Autodesk® Storm and Sanitary Analysis 2016 - Version 13.0.94 (Build 0)
-----------------------------------------------------------------------------------------

*******************
Project Description
*******************
File Name ................ ZOVL_PostDevelopment_r1.SPF


****************
Analysis Options
****************
Flow Units ............... cfs
Subbasin Hydrograph Method. SCS TR-20
Time of Concentration...... SCS TR-55
Link Routing Method ....... Hydrodynamic
Storage Node Exfiltration.. Constant rate, projected area
Starting Date ............ MAY-06-2024 00:00:00
Ending Date .............. MAY-09-2024 00:00:00
Report Time Step .......... 00:04:00


*************
Element Count
*************
Number of rain gages ...... 1
Number of subbasins ....... 4
Number of nodes ........... 10
Number of links ........... 12


****************
Raingage Summary
****************
Gage                Data                Data       Recording
ID                  Source              Type        Interval
                                                              min
------------------------------------------------------------
Rain Gage-01        2YR 24HR (Future)   CUMULATIVE      1.00


****************
Subbasin Summary
****************
Subbasin                Total
                         Area
ID                        ft²
------------------------------
Catch-P1             86824.66
Catch-P2            115184.55
Catch-P3            234457.05
Catch-P4            189338.22


************
Node Summary
************
Node                Element               Invert   Maximum    Ponded    External
ID                  Type               Elevation     Elev.      Area      Inflow
                                              ft        ft       ft²
------------------------------------------------------------------------------
Jun-02-Out2         JUNCTION              916.00    920.33      0.00
Jun-03-Out2         JUNCTION              916.00    999.00   1000.00
Jun-04-Out2         JUNCTION              916.00    921.50      0.00
Jun-05-Out1         JUNCTION              935.00    999.00   1000.00
Jun-06-Out1         JUNCTION              935.00    937.75      0.00
Jun-07-Out1         JUNCTION              935.00    939.00      0.00
```

DP-1	OUTFALL	0.00	936.00	0.00
DP-2	OUTFALL	0.00	917.50	0.00
Stor-02-POND2	STORAGE	916.00	921.00	10000.00
Stor-04-POND1	STORAGE	935.00	939.00	10000.00

****
Link Summary
****

Link ID	From Node	To Node	Element Type	Length ft	Slope %	Manning's Roughness
Link-01-RipRap-2	Jun-03-Out2	Jun-04-Out2	CHANNEL	15.0	33.3333	0.0330
Link-02-Surface-2	Jun-04-Out2	DP-2	CHANNEL	10.0	5.0000	0.0200
Link-03-RipRap1	Jun-05-Out1	Jun-07-Out1	CHANNEL	12.0	25.0000	0.0330
Link-04-Surface1	Jun-07-Out1	DP-1	CHANNEL	30.0	3.3333	0.0200
Orifice-01-2yr-2	Stor-02-POND2	Jun-02-Out2	ORIFICE			
Orifice-02-10yr-2	Stor-02-POND2	Jun-02-Out2	ORIFICE			
Orifice-03-OutletPipe2	Jun-02-Out2	Jun-04-Out2	ORIFICE			
Orifice-04-2yr-1	Stor-04-POND1	Jun-06-Out1	ORIFICE			
Orifice-05-10yr-1	Stor-04-POND1	Jun-06-Out1	ORIFICE			
Orifice-06-OutletPipe1	Jun-06-Out1	Jun-07-Out1	ORIFICE			
Weir-02-100yr-2	Stor-02-POND2	Jun-03-Out2	WEIR			
Weir-04-100yr-1	Stor-04-POND1	Jun-05-Out1	WEIR			

****
Cross Section Summary
****

Link ID	Shape	Depth/ Diameter ft	Width ft	No. of Barrels	Cross Sectional Area ft²	Full Flow Hydraulic Radius ft	Design Flow Capacity cfs
Link-01-RipRap-2	TRAPEZOIDAL	0.50	10.00	1	4.25	0.42	61.79
Link-02-Surface-2	RECT_OPEN	2.00	10.00	1	20.00	1.43	421.47
Link-03-RipRap1	TRAPEZOIDAL	0.50	10.00	1	4.25	0.42	53.51
Link-04-Surface1	RECT_OPEN	2.00	10.00	1	20.00	1.43	344.13

************************** Runoff Quantity Continuity **************************	Volume acre-ft	Depth inches
Total Precipitation	4.612	3.852
Surface Runoff	0.012	0.010
Continuity Error (%)	-0.001	

************************** Flow Routing Continuity **************************	Volume acre-ft	Volume Mgallons
External Inflow	0.000	0.000
External Outflow	2.883	0.940
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

```
*****************************************
Composite Curve Number Computations Report
*****************************************
```

Subbasin Catch-P1

Soil/Surface Description	Area (ft²)	Soil Group	CN
Woods, Fair	28528.90	D	79.00
Woods & grass combination, Fair	58295.76	D	82.00
Composite Area & Weighted CN	86824.66		81.01

Subbasin Catch-P2

Soil/Surface Description	Area (ft²)	Soil Group	CN
Paved parking & roofs	27947.90	D	98.00
Meadow, non-grazed	33451.85	D	78.00
Gravel roads	53784.80	D	91.00
Composite Area & Weighted CN	115184.55		88.92

Subbasin Catch-P3

Soil/Surface Description	Area (ft²)	Soil Group	CN
Woods, Fair	121539.49	D	79.00
Meadow, non-grazed	112917.56	D	78.00
Composite Area & Weighted CN	234457.05		78.52

Subbasin Catch-P4

Soil/Surface Description	Area (ft²)	Soil Group	CN
Paved parking & roofs	83026.68	D	98.00
Meadow, non-grazed	20512.93	D	78.00
Gravel roads	85798.65	D	91.00
Composite Area & Weighted CN	189338.26		92.66

```
**************************************************
SCS TR-55 Time of Concentration Computations Report
**************************************************
```

Sheet Flow Equation

```
Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where:

Tc = Time of Concentration (hrs)
n  = Manning's Roughness
Lf = Flow Length (ft)
P  = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)
```

Shallow Concentrated Flow Equation

```
V  = 16.1345 * (Sf^0.5) (unpaved surface)
```

```
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)

Channel Flow Equation
---------------------

        V  = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
        R  = Aq / Wp
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        R  = Hydraulic Radius (ft)
        Aq = Flow Area (ft²)
        Wp = Wetted Perimeter (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)
        n  = Manning's Roughness

--------------------
Subbasin Catch-P1
--------------------

Sheet Flow Computations
-----------------------
                                       Subarea A          Subarea B          Subarea C
        Manning's Roughness:                0.40               0.00               0.00
        Flow Length (ft):                 100.00               0.00               0.00
        Slope (%):                          7.00               0.00               0.00
        2 yr, 24 hr Rainfall (in):          3.00               3.00               3.00
        Velocity (ft/sec):                  0.12               0.00               0.00
        Computed Flow Time (minutes):      13.44               0.00               0.00

Shallow Concentrated Flow Computations
--------------------------------------
                                       Subarea A          Subarea B          Subarea C
        Flow Length (ft):                 305.00               0.00               0.00
        Slope (%):                         10.80               0.00               0.00
        Surface Type:                   Woodland           Woodland           Woodland
        Velocity (ft/sec):                  1.64               0.00               0.00
        Computed Flow Time (minutes):       3.10               0.00               0.00
================================================================================================
        Total TOC (minutes):               16.54
================================================================================================


--------------------
Subbasin Catch-P2
--------------------

        User-Defined TOC override (minutes):      6.00

--------------------
```

```
Subbasin Catch-P3
--------------------

Sheet Flow Computations
-----------------------
                                              Subarea A           Subarea B           Subarea C
        Manning's Roughness:                       0.40                0.00                0.00
        Flow Length (ft):                        100.00                0.00                0.00
        Slope (%):                                 4.00                0.00                0.00
        2 yr, 24 hr Rainfall (in):                 3.00                3.00                3.00
        Velocity (ft/sec):                         0.10                0.00                0.00
        Computed Flow Time (minutes):             16.81                0.00                0.00

Shallow Concentrated Flow Computations
--------------------------------------
                                              Subarea A           Subarea B           Subarea C
        Flow Length (ft):                        342.00              178.00              270.00
        Slope (%):                                 7.50                7.00                5.00
        Surface Type:                     Grass pasture            Woodland            Woodland
        Velocity (ft/sec):                         1.92                1.32                1.12
        Computed Flow Time (minutes):              2.97                2.25                4.02

Channel Flow Computations
-------------------------
                                              Subarea A           Subarea B           Subarea C
        Manning's Roughness:                       0.02                0.00                0.00
        Flow Length (ft):                        974.00                0.00                0.00
        Channel Slope (%):                         1.70                0.00                0.00
        Cross Section Area (ft²):                  5.00                0.00                0.00
        Wetted Perimeter (ft):                     6.33                0.00                0.00
        Velocity (ft/sec):                         8.30                0.00                0.00
        Computed Flow Time (minutes):              1.96                0.00                0.00
================================================================================================
        Total TOC (minutes):                      28.00
================================================================================================


--------------------
Subbasin Catch-P4
--------------------

        User-Defined TOC override (minutes):      6.00

***********************
Subbasin Runoff Summary
***********************
```

Subbasin ID	Total Precip in	Total Runoff in	Peak Runoff cfs	Weighted Curve Number	Time of Concentration days	hh:mm:ss
Catch-P1	3.90	2.04	3.51	81.010	0	00:16:32
Catch-P2	3.90	2.72	8.14	88.920	0	00:06:00
Catch-P3	3.90	1.85	6.91	78.520	0	00:28:00
Catch-P4	3.90	3.09	14.77	92.660	0	00:06:00

```
******************
Node Depth Summary
******************
```

Node ID	Average Depth Attained ft	Maximum Depth Attained ft	Maximum HGL Attained ft	Time of Max Occurrence days	hh:mm	Total Flooded Volume acre-in	Total Time Flooded minutes	Retention Time hh:mm:ss

Jun-02-Out2	0.04	0.59	916.59	0	12:23	0	0	0:00:00
Jun-03-Out2	0.00	0.00	916.00	0	00:00	0	0	0:00:00
Jun-04-Out2	0.01	0.13	916.13	0	12:29	0	0	0:00:00
Jun-05-Out1	0.00	0.00	935.00	0	00:00	0	0	0:00:00
Jun-06-Out1	0.03	0.39	935.39	0	12:34	0	0	0:00:00
Jun-07-Out1	0.01	0.08	935.08	0	12:34	0	0	0:00:00
DP-1	0.00	0.00	0.00	0	00:00	0	0	0:00:00
DP-2	0.00	0.00	0.00	0	00:00	0	0	0:00:00
Stor-02-POND2	0.12	2.98	918.98	0	12:29	0	0	0:00:00
Stor-04-POND1	0.08	1.39	936.39	0	12:34	0	0	0:00:00

****
Node Flow Summary
****

Node ID	Element Type	Maximum Lateral Inflow cfs	Peak Inflow cfs	Time of Peak Inflow Occurrence days	hh:mm	Maximum Flooding Overflow cfs	Time of Peak Flooding Occurrence days hh:mm
Jun-02-Out2	JUNCTION	0.00	4.12	0	12:29	0.00	
Jun-03-Out2	JUNCTION	0.00	0.00	0	00:00	0.00	
Jun-04-Out2	JUNCTION	0.00	4.14	0	12:35	0.00	
Jun-05-Out1	JUNCTION	0.00	0.00	0	00:00	0.00	
Jun-06-Out1	JUNCTION	0.00	1.74	0	12:34	0.00	
Jun-07-Out1	JUNCTION	0.00	1.74	0	12:34	0.00	
DP-1	OUTFALL	3.50	5.10	0	12:16	0.00	
DP-2	OUTFALL	6.90	10.99	0	12:24	0.00	
Stor-02-POND2	STORAGE	14.65	14.65	0	12:08	0.00	
Stor-04-POND1	STORAGE	8.07	8.07	0	12:08	0.00	

****
Storage Node Summary
****

Storage Node ID	Maximum Ponded Volume 1000 ft³	Maximum Ponded Volume (%)	Time of Max Ponded Volume days hh:mm	Average Ponded Volume 1000 ft³	Average Ponded Volume (%)	Maximum Storage Node Outflow cfs	Maximum Exfiltration Rate cfm	Time of Max. Exfiltration Rate hh:mm:ss	Total Exfiltrated Volume 1000 ft³
Stor-02-POND2	13.886	49	0 12:29	0.480	2	4.12	0.00	0:00:00	0.000
Stor-04-POND1	9.852	27	0 12:34	0.552	2	1.74	0.00	0:00:00	0.000

****
Outfall Loading Summary
****

Outfall Node ID	Flow Frequency (%)	Average Flow cfs	Peak Inflow cfs

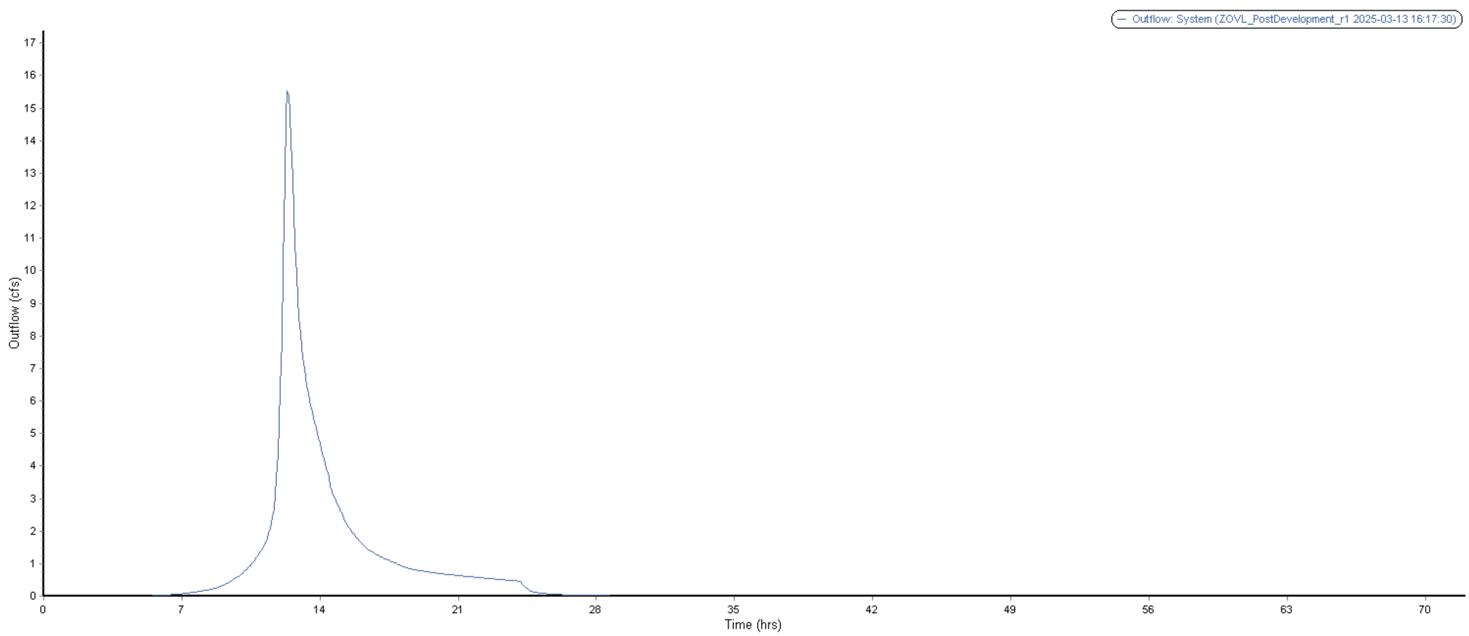
DP-1	46.14	0.34	5.10
DP-2	38.24	0.85	10.99
System	42.19	1.20	15.52

****
Link Flow Summary
****

Link ID	Element Type	Time of Peak Flow Occurrence days hh:mm	Maximum Velocity Attained ft/sec	Length Factor	Peak Flow during Analysis cfs	Design Flow Capacity cfs	Ratio of Maximum /Design Flow	Ratio of Maximum Flow Depth	Total Time Surcharged minutes	Reported Condition
Link-01-RipRap-2	CHANNEL	0 00:00	0.00	1.00	0.00	61.79	0.00	0.13	0	Calculated
Link-02-Surface-2	CHANNEL	0 12:29	3.49	1.00	4.12	421.47	0.01	0.06	0	Calculated
Link-03-RipRap1	CHANNEL	0 00:00	0.00	1.00	0.00	53.51	0.00	0.08	0	Calculated
Link-04-Surface1	CHANNEL	0 12:34	2.33	1.00	1.74	344.13	0.01	0.04	0	Calculated
Orifice-01-2yr-2	ORIFICE	0 12:29			4.12					
Orifice-02-10yr-2	ORIFICE	0 00:00			0.00					
Orifice-03-OutletPipe2	ORIFICE	0 12:35			4.14					
Orifice-04-2yr-1	ORIFICE	0 12:34			1.74					
Orifice-05-10yr-1	ORIFICE	0 00:00			0.00					
Orifice-06-OutletPipe1	ORIFICE	0 12:34			1.74					
Weir-02-100yr-2	WEIR	0 00:00			0.00			0.00		
Weir-04-100yr-1	WEIR	0 00:00			0.00			0.00		

****
Highest Flow Instability Indexes
****
All links are stable.

Analysis began on: Thu Mar 13 16:17:16 2025
Analysis ended on: Thu Mar 13 16:17:29 2025
Total elapsed time: 00:00:13


Outflow: System (ZOVL_PostDevelopment_r1 2025-03-13 16:17:30)
Outflow (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Time (hrs)
0
7
14
21
28
35
42
49
56
63
70

Autodesk® Storm and Sanitary Analysis 2016 - Version 13.0.94 (Build 0)

****
Project Description
****

File Name .... ZOVL_PostDevelopment_r1.SPF

****
Analysis Options
****

Flow Units .... cfs
Subbasin Hydrograph Method. SCS TR-20
Time of Concentration...... SCS TR-55
Link Routing Method .... Hydrodynamic
Storage Node Exfiltration.. Constant rate, projected area
Starting Date MAY-06-2024 00:00:00
Ending Date MAY-09-2024 00:00:00
Report Time Step 00:04:00

****
Element Count
****

Number of rain gages 1
Number of subbasins 4
Number of nodes 10
Number of links 12

****
Raingage Summary
****

Gage ID	Data Source	Data Type	Recording Interval min
Rain Gage-01	10YR 24HR (Future)	CUMULATIVE	1.00

****
Subbasin Summary
****

Subbasin ID	Total Area ft²
Catch-P1	86824.66
Catch-P2	115184.55
Catch-P3	234457.05
Catch-P4	189338.22

****
Node Summary
****

Node ID	Element Type	Invert Elevation ft	Maximum Elev. ft	Ponded Area ft²	External Inflow
Jun-02-Out2	JUNCTION	916.00	920.33	0.00	
Jun-03-Out2	JUNCTION	916.00	999.00	1000.00	
Jun-04-Out2	JUNCTION	916.00	921.50	0.00	
Jun-05-Out1	JUNCTION	935.00	999.00	1000.00	
Jun-06-Out1	JUNCTION	935.00	937.75	0.00	
Jun-07-Out1	JUNCTION	935.00	939.00	0.00	

DP-1	OUTFALL	0.00	936.00	0.00
DP-2	OUTFALL	0.00	917.50	0.00
Stor-02-POND2	STORAGE	916.00	921.00	10000.00
Stor-04-POND1	STORAGE	935.00	939.00	10000.00

****
Link Summary
****

Link ID	From Node	To Node	Element Type	Length ft	Slope %	Manning's Roughness
Link-01-RipRap-2	Jun-03-Out2	Jun-04-Out2	CHANNEL	15.0	33.3333	0.0330
Link-02-Surface-2	Jun-04-Out2	DP-2	CHANNEL	10.0	5.0000	0.0200
Link-03-RipRap1	Jun-05-Out1	Jun-07-Out1	CHANNEL	12.0	25.0000	0.0330
Link-04-Surface1	Jun-07-Out1	DP-1	CHANNEL	30.0	3.3333	0.0200
Orifice-01-2yr-2	Stor-02-POND2	Jun-02-Out2	ORIFICE			
Orifice-02-10yr-2	Stor-02-POND2	Jun-02-Out2	ORIFICE			
Orifice-03-OutletPipe2	Jun-02-Out2	Jun-04-Out2	ORIFICE			
Orifice-04-2yr-1	Stor-04-POND1	Jun-06-Out1	ORIFICE			
Orifice-05-10yr-1	Stor-04-POND1	Jun-06-Out1	ORIFICE			
Orifice-06-OutletPipe1	Jun-06-Out1	Jun-07-Out1	ORIFICE			
Weir-02-100yr-2	Stor-02-POND2	Jun-03-Out2	WEIR			
Weir-04-100yr-1	Stor-04-POND1	Jun-05-Out1	WEIR			

****
Cross Section Summary
****

Link ID	Shape	Depth/ Diameter ft	Width ft	No. of Barrels	Cross Sectional Area ft²	Full Flow Hydraulic Radius ft	Design Flow Capacity cfs
Link-01-RipRap-2	TRAPEZOIDAL	0.50	10.00	1	4.25	0.42	61.79
Link-02-Surface-2	RECT_OPEN	2.00	10.00	1	20.00	1.43	421.47
Link-03-RipRap1	TRAPEZOIDAL	0.50	10.00	1	4.25	0.42	53.51
Link-04-Surface1	RECT_OPEN	2.00	10.00	1	20.00	1.43	344.13

************************** Runoff Quantity Continuity **************************	Volume acre-ft	Depth inches
Total Precipitation	7.096	5.927
Surface Runoff	0.022	0.018
Continuity Error (%)	-0.001	

************************** Flow Routing Continuity **************************	Volume acre-ft	Volume Mgallons
External Inflow	0.000	0.000
External Outflow	5.176	1.687
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

****
Composite Curve Number Computations Report
****

Subbasin Catch-P1

Soil/Surface Description	Area (ft^2)	Soil Group	CN
Woods, Fair	28528.90	D	79.00
Woods & grass combination, Fair	58295.76	D	82.00
Composite Area & Weighted CN	86824.66		81.01

Subbasin Catch-P2

Soil/Surface Description	Area (ft^2)	Soil Group	CN
Paved parking & roofs	27947.90	D	98.00
Meadow, non-grazed	33451.85	D	78.00
Gravel roads	53784.80	D	91.00
Composite Area & Weighted CN	115184.55		88.92

Subbasin Catch-P3

Soil/Surface Description	Area (ft^2)	Soil Group	CN
Woods, Fair	121539.49	D	79.00
Meadow, non-grazed	112917.56	D	78.00
Composite Area & Weighted CN	234457.05		78.52

Subbasin Catch-P4

Soil/Surface Description	Area (ft^2)	Soil Group	CN
Paved parking & roofs	83026.68	D	98.00
Meadow, non-grazed	20512.93	D	78.00
Gravel roads	85798.65	D	91.00
Composite Area & Weighted CN	189338.26		92.66

****
SCS TR-55 Time of Concentration Computations Report
****

Sheet Flow Equation

```
Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where:

Tc = Time of Concentration (hrs)
n  = Manning's Roughness
Lf = Flow Length (ft)
P  = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)
```

Shallow Concentrated Flow Equation

```
V  = 16.1345 * (Sf^0.5) (unpaved surface)
```

```
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)

Channel Flow Equation
---------------------

        V  = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
        R  = Aq / Wp
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        R  = Hydraulic Radius (ft)
        Aq = Flow Area (ft²)
        Wp = Wetted Perimeter (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)
        n  = Manning's Roughness

--------------------
Subbasin Catch-P1
--------------------

Sheet Flow Computations
-----------------------
                                       Subarea A           Subarea B           Subarea C
        Manning's Roughness:                0.40                0.00                0.00
        Flow Length (ft):                 100.00                0.00                0.00
        Slope (%):                          7.00                0.00                0.00
        2 yr, 24 hr Rainfall (in):          3.00                3.00                3.00
        Velocity (ft/sec):                  0.12                0.00                0.00
        Computed Flow Time (minutes):      13.44                0.00                0.00

Shallow Concentrated Flow Computations
--------------------------------------
                                       Subarea A           Subarea B           Subarea C
        Flow Length (ft):                 305.00                0.00                0.00
        Slope (%):                         10.80                0.00                0.00
        Surface Type:                   Woodland            Woodland            Woodland
        Velocity (ft/sec):                  1.64                0.00                0.00
        Computed Flow Time (minutes):       3.10                0.00                0.00
===============================================================================================
        Total TOC (minutes):               16.54
===============================================================================================


--------------------
Subbasin Catch-P2
--------------------

        User-Defined TOC override (minutes):      6.00

--------------------
```

Subbasin Catch-P3

Sheet Flow Computations

	Subarea A	Subarea B	Subarea C
Manning's Roughness:	0.40	0.00	0.00
Flow Length (ft):	100.00	0.00	0.00
Slope (%):	4.00	0.00	0.00
2 yr, 24 hr Rainfall (in):	3.00	3.00	3.00
Velocity (ft/sec):	0.10	0.00	0.00
Computed Flow Time (minutes):	16.81	0.00	0.00

Shallow Concentrated Flow Computations

	Subarea A	Subarea B	Subarea C
Flow Length (ft):	342.00	178.00	270.00
Slope (%):	7.50	7.00	5.00
Surface Type:	Grass pasture	Woodland	Woodland
Velocity (ft/sec):	1.92	1.32	1.12
Computed Flow Time (minutes):	2.97	2.25	4.02

Channel Flow Computations

	Subarea A	Subarea B	Subarea C
Manning's Roughness:	0.02	0.00	0.00
Flow Length (ft):	974.00	0.00	0.00
Channel Slope (%):	1.70	0.00	0.00
Cross Section Area (ft^2):	5.00	0.00	0.00
Wetted Perimeter (ft):	6.33	0.00	0.00
Velocity (ft/sec):	8.30	0.00	0.00
Computed Flow Time (minutes):	1.96	0.00	0.00

Total TOC (minutes): 28.00

Subbasin Catch-P4

User-Defined TOC override (minutes): 6.00

Subbasin Runoff Summary

Subbasin ID	Total Precip in	Total Runoff in	Peak Runoff cfs	Weighted Curve Number	Time of Concentration days hh:mm:ss
Catch-P1	6.00	3.88	6.67	81.010	0 00:16:32
Catch-P2	6.00	4.73	13.77	88.920	0 00:06:00
Catch-P3	6.00	3.63	13.66	78.520	0 00:28:00
Catch-P4	6.00	5.14	23.88	92.660	0 00:06:00

Node Depth Summary

Node ID	Average Depth Attained ft	Maximum Depth Attained ft	Maximum HGL Attained ft	Time of Max Occurrence days hh:mm	Total Flooded Volume acre-in	Total Time Flooded minutes	Retention Time hh:mm:ss

Jun-02-Out2	0.07	2.84	918.84	0	12:21	0	0	0:00:00
Jun-03-Out2	0.06	0.07	916.07	0	12:23	0	0	0:00:00
Jun-04-Out2	0.01	0.24	916.24	0	12:21	0	0	0:00:00
Jun-05-Out1	0.00	0.00	935.00	0	00:00	0	0	0:00:00
Jun-06-Out1	0.05	0.74	935.74	0	12:33	0	0	0:00:00
Jun-07-Out1	0.01	0.11	935.11	0	12:33	0	0	0:00:00
DP-1	0.00	0.00	0.00	0	00:00	0	0	0:00:00
DP-2	0.00	0.00	0.00	0	00:00	0	0	0:00:00
Stor-02-POND2	0.18	4.01	920.01	0	12:21	0	0	0:00:00
Stor-04-POND1	0.14	2.25	937.25	0	12:32	0	0	0:00:00

****
Node Flow Summary
****

Node ID	Element Type	Maximum Lateral Inflow cfs	Peak Inflow cfs	Time of Peak Inflow Occurrence days	Time of Peak Inflow Occurrence hh:mm	Maximum Flooding Overflow cfs	Time of Peak Flooding Occurrence days	Time of Peak Flooding Occurrence hh:mm
Jun-02-Out2	JUNCTION	0.00	9.75	0	12:21	0.00		
Jun-03-Out2	JUNCTION	0.00	0.01	0	12:21	0.00		
Jun-04-Out2	JUNCTION	0.00	9.75	0	12:21	0.00		
Jun-05-Out1	JUNCTION	0.00	0.00	0	00:00	0.00		
Jun-06-Out1	JUNCTION	0.00	3.08	0	12:32	0.00		
Jun-07-Out1	JUNCTION	0.00	3.08	0	12:33	0.00		
DP-1	OUTFALL	6.65	8.81	0	12:16	0.00		
DP-2	OUTFALL	13.65	23.37	0	12:23	0.00		
Stor-02-POND2	STORAGE	23.77	23.77	0	12:08	0.00		
Stor-04-POND1	STORAGE	13.68	13.68	0	12:08	0.00		

****
Storage Node Summary
****

Storage Node ID	Maximum Ponded Volume 1000 ft³	Maximum Ponded Volume (%)	Time of Max Ponded Volume days hh:mm	Average Ponded Volume 1000 ft³	Average Ponded Volume (%)	Maximum Storage Node Outflow cfs	Maximum Exfiltration Rate cfm	Time of Max. Exfiltration Rate hh:mm:ss	Total Exfiltrated Volume 1000 ft³
Stor-02-POND2	20.577	73	0 12:21	0.728	3	9.76	0.00	0:00:00	0.000
Stor-04-POND1	17.325	48	0 12:32	1.001	3	3.08	0.00	0:00:00	0.000

****
Outfall Loading Summary
****

Outfall Node ID	Flow Frequency (%)	Average Flow cfs	Peak Inflow cfs

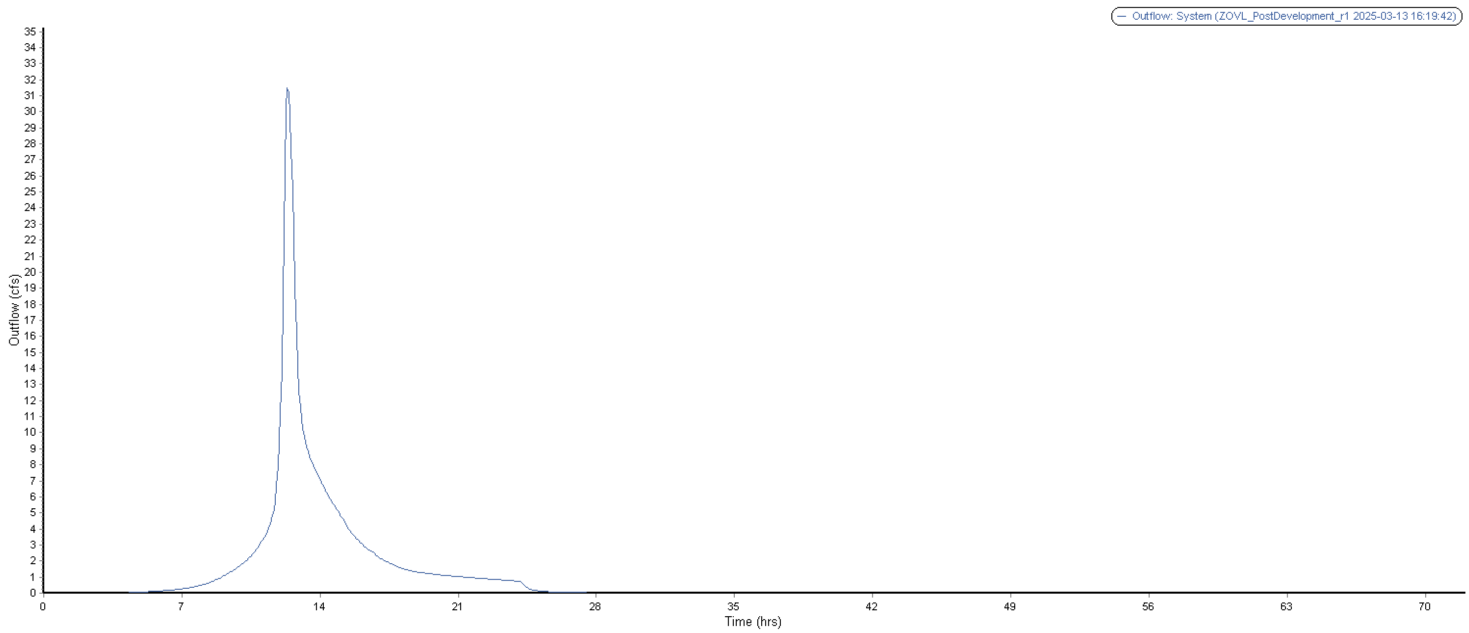
DP-1	49.49	0.57	8.81
DP-2	40.46	1.45	23.37
System	44.97	2.02	31.46

****
Link Flow Summary
****

Link ID	Element Type	Time of Peak Flow Occurrence days hh:mm	Maximum Velocity Attained ft/sec	Length Factor	Peak Flow during Analysis cfs	Design Flow Capacity cfs	Ratio of Maximum /Design Flow	Ratio of Maximum Flow Depth	Total Time Surcharged minutes	Reported Condition
Link-01-RipRap-2	CHANNEL	0 00:00	0.00	1.00	0.00	61.79	0.00	0.24	0	Calculated
Link-02-Surface-2	CHANNEL	0 12:21	4.62	1.00	9.75	421.47	0.02	0.11	0	Calculated
Link-03-RipRap1	CHANNEL	0 00:00	0.00	1.00	0.00	53.51	0.00	0.11	0	Calculated
Link-04-Surface1	CHANNEL	0 12:33	2.89	1.00	3.08	344.13	0.01	0.05	0	Calculated
Orifice-01-2yr-2	ORIFICE	0 12:07			4.15					
Orifice-02-10yr-2	ORIFICE	0 12:21			6.87					
Orifice-03-OutletPipe2	ORIFICE	0 12:21			9.75					
Orifice-04-2yr-1	ORIFICE	0 12:18			2.21					
Orifice-05-10yr-1	ORIFICE	0 12:32			0.95					
Orifice-06-OutletPipe1	ORIFICE	0 12:33			3.08					
Weir-02-100yr-2	WEIR	0 12:21			0.01			0.01		
Weir-04-100yr-1	WEIR	0 00:00			0.00			0.00		

****
Highest Flow Instability Indexes
****
All links are stable.

Analysis began on: Thu Mar 13 16:19:27 2025
Analysis ended on: Thu Mar 13 16:19:41 2025
Total elapsed time: 00:00:14


Outflow: System (ZOVL_PostDevelopment_r1 2025-03-13 16:19:42)
Outflow (cfs)
Time (hrs)
0
7
14
21
28
35
42
49
56
63
70

Autodesk® Storm and Sanitary Analysis 2016 - Version 13.0.94 (Build 0)

****
Project Description
****

File Name .... ZOVL_PostDevelopment_r1.SPF

****
Analysis Options
****

Flow Units .... cfs
Subbasin Hydrograph Method. SCS TR-20
Time of Concentration...... SCS TR-55
Link Routing Method .... Hydrodynamic
Storage Node Exfiltration.. Constant rate, projected area
Starting Date MAY-06-2024 00:00:00
Ending Date MAY-09-2024 00:00:00
Report Time Step 00:04:00

****
Element Count
****

Number of rain gages 1
Number of subbasins 4
Number of nodes 10
Number of links 12

****
Raingage Summary
****

Gage ID	Data Source	Data Type	Recording Interval min
Rain Gage-01	100YR 24HR (Future)	CUMULATIVE	1.00

****
Subbasin Summary
****

Subbasin ID	Total Area ft²
Catch-P1	86824.66
Catch-P2	115184.55
Catch-P3	234457.05
Catch-P4	189338.22

****
Node Summary
****

Node ID	Element Type	Invert Elevation ft	Maximum Elev. ft	Ponded Area ft²	External Inflow
Jun-02-Out2	JUNCTION	916.00	920.33	0.00	
Jun-03-Out2	JUNCTION	916.00	999.00	1000.00	
Jun-04-Out2	JUNCTION	916.00	921.50	0.00	
Jun-05-Out1	JUNCTION	935.00	999.00	1000.00	
Jun-06-Out1	JUNCTION	935.00	937.75	0.00	
Jun-07-Out1	JUNCTION	935.00	939.00	0.00	

DP-1	OUTFALL	0.00	936.00	0.00
DP-2	OUTFALL	0.00	917.50	0.00
Stor-02-POND2	STORAGE	916.00	921.00	10000.00
Stor-04-POND1	STORAGE	935.00	939.00	10000.00

****
Link Summary
****

Link ID	From Node	To Node	Element Type	Length ft	Slope %	Manning's Roughness
Link-01-RipRap-2	Jun-03-Out2	Jun-04-Out2	CHANNEL	15.0	33.3333	0.0330
Link-02-Surface-2	Jun-04-Out2	DP-2	CHANNEL	10.0	5.0000	0.0200
Link-03-RipRap1	Jun-05-Out1	Jun-07-Out1	CHANNEL	12.0	25.0000	0.0330
Link-04-Surface1	Jun-07-Out1	DP-1	CHANNEL	30.0	3.3333	0.0200
Orifice-01-2yr-2	Stor-02-POND2	Jun-02-Out2	ORIFICE			
Orifice-02-10yr-2	Stor-02-POND2	Jun-02-Out2	ORIFICE			
Orifice-03-OutletPipe2	Jun-02-Out2	Jun-04-Out2	ORIFICE			
Orifice-04-2yr-1	Stor-04-POND1	Jun-06-Out1	ORIFICE			
Orifice-05-10yr-1	Stor-04-POND1	Jun-06-Out1	ORIFICE			
Orifice-06-OutletPipe1	Jun-06-Out1	Jun-07-Out1	ORIFICE			
Weir-02-100yr-2	Stor-02-POND2	Jun-03-Out2	WEIR			
Weir-04-100yr-1	Stor-04-POND1	Jun-05-Out1	WEIR			

****
Cross Section Summary
****

Link ID	Shape	Depth/ Diameter ft	Width ft	No. of Barrels	Cross Sectional Area ft²	Full Flow Hydraulic Radius ft	Design Flow Capacity cfs
Link-01-RipRap-2	TRAPEZOIDAL	0.50	10.00	1	4.25	0.42	61.79
Link-02-Surface-2	RECT_OPEN	2.00	10.00	1	20.00	1.43	421.47
Link-03-RipRap1	TRAPEZOIDAL	0.50	10.00	1	4.25	0.42	53.51
Link-04-Surface1	RECT_OPEN	2.00	10.00	1	20.00	1.43	344.13

Runoff Quantity Continuity	Volume acre-ft	Depth inches
Total Precipitation	11.117	9.286
Surface Runoff	0.038	0.032
Continuity Error (%)	-0.001	

Flow Routing Continuity	Volume acre-ft	Volume Mgallons
External Inflow	0.000	0.000
External Outflow	9.060	2.952
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

```
*****************************************
Composite Curve Number Computations Report
*****************************************

--------------------
Subbasin Catch-P1
--------------------
                                                         Area          Soil
Soil/Surface Description                                 (ft²)         Group          CN
-----------------------------------------------------------------------------------------
Woods, Fair                                           28528.90             D       79.00
Woods & grass combination, Fair                       58295.76             D       82.00
Composite Area & Weighted CN                          86824.66                     81.01

--------------------
Subbasin Catch-P2
--------------------
                                                         Area          Soil
Soil/Surface Description                                 (ft²)         Group          CN
-----------------------------------------------------------------------------------------
Paved parking & roofs                                 27947.90             D       98.00
Meadow, non-grazed                                    33451.85             D       78.00
Gravel roads                                          53784.80             D       91.00
Composite Area & Weighted CN                         115184.55                     88.92

--------------------
Subbasin Catch-P3
--------------------
                                                         Area          Soil
Soil/Surface Description                                 (ft²)         Group          CN
-----------------------------------------------------------------------------------------
Woods, Fair                                          121539.49             D       79.00
Meadow, non-grazed                                   112917.56             D       78.00
Composite Area & Weighted CN                         234457.05                     78.52

--------------------
Subbasin Catch-P4
--------------------
                                                         Area          Soil
Soil/Surface Description                                 (ft²)         Group          CN
-----------------------------------------------------------------------------------------
Paved parking & roofs                                 83026.68             D       98.00
Meadow, non-grazed                                    20512.93             D       78.00
Gravel roads                                          85798.65             D       91.00
Composite Area & Weighted CN                         189338.26                     92.66


**************************************************
SCS TR-55 Time of Concentration Computations Report
**************************************************

Sheet Flow Equation
-------------------

        Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

        Where:

        Tc = Time of Concentration (hrs)
        n  = Manning's Roughness
        Lf = Flow Length (ft)
        P  = 2 yr, 24 hr Rainfall (inches)
        Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation
----------------------------------

        V  = 16.1345 * (Sf^0.5) (unpaved surface)
```

```
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)

Channel Flow Equation
---------------------

        V  = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
        R  = Aq / Wp
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        R  = Hydraulic Radius (ft)
        Aq = Flow Area (ft²)
        Wp = Wetted Perimeter (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)
        n  = Manning's Roughness

--------------------
Subbasin Catch-P1
--------------------

Sheet Flow Computations
-----------------------
                                       Subarea A           Subarea B           Subarea C
        Manning's Roughness:                0.40                0.00                0.00
        Flow Length (ft):                 100.00                0.00                0.00
        Slope (%):                          7.00                0.00                0.00
        2 yr, 24 hr Rainfall (in):          3.00                3.00                3.00
        Velocity (ft/sec):                  0.12                0.00                0.00
        Computed Flow Time (minutes):      13.44                0.00                0.00

Shallow Concentrated Flow Computations
--------------------------------------
                                       Subarea A           Subarea B           Subarea C
        Flow Length (ft):                 305.00                0.00                0.00
        Slope (%):                         10.80                0.00                0.00
        Surface Type:                   Woodland            Woodland            Woodland
        Velocity (ft/sec):                  1.64                0.00                0.00
        Computed Flow Time (minutes):       3.10                0.00                0.00
===============================================================================================
        Total TOC (minutes):               16.54
===============================================================================================


--------------------
Subbasin Catch-P2
--------------------

        User-Defined TOC override (minutes):      6.00

--------------------
```

```
Subbasin Catch-P3
--------------------

Sheet Flow Computations
-----------------------
                                              Subarea A           Subarea B           Subarea C
        Manning's Roughness:                       0.40                0.00                0.00
        Flow Length (ft):                        100.00                0.00                0.00
        Slope (%):                                 4.00                0.00                0.00
        2 yr, 24 hr Rainfall (in):                 3.00                3.00                3.00
        Velocity (ft/sec):                         0.10                0.00                0.00
        Computed Flow Time (minutes):             16.81                0.00                0.00

Shallow Concentrated Flow Computations
--------------------------------------
                                              Subarea A           Subarea B           Subarea C
        Flow Length (ft):                        342.00              178.00              270.00
        Slope (%):                                 7.50                7.00                5.00
        Surface Type:                     Grass pasture            Woodland            Woodland
        Velocity (ft/sec):                         1.92                1.32                1.12
        Computed Flow Time (minutes):              2.97                2.25                4.02

Channel Flow Computations
-------------------------
                                              Subarea A           Subarea B           Subarea C
        Manning's Roughness:                       0.02                0.00                0.00
        Flow Length (ft):                        974.00                0.00                0.00
        Channel Slope (%):                         1.70                0.00                0.00
        Cross Section Area (ft²):                  5.00                0.00                0.00
        Wetted Perimeter (ft):                     6.33                0.00                0.00
        Velocity (ft/sec):                         8.30                0.00                0.00
        Computed Flow Time (minutes):              1.96                0.00                0.00
===============================================================================================
        Total TOC (minutes):                      28.00
===============================================================================================


--------------------
Subbasin Catch-P4
--------------------

        User-Defined TOC override (minutes):      6.00

***********************
Subbasin Runoff Summary
***********************
```

Subbasin ID	Total Precip in	Total Runoff in	Peak Runoff cfs	Weighted Curve Number	Time of Concentration days	Time of Concentration hh:mm:ss
Catch-P1	9.40	7.07	11.90	81.010	0	00:16:32
Catch-P2	9.40	8.05	22.76	88.920	0	00:06:00
Catch-P3	9.40	6.76	25.10	78.520	0	00:28:00
Catch-P4	9.40	8.51	38.43	92.660	0	00:06:00

```
******************
Node Depth Summary
******************
```

Node ID	Average Depth Attained ft	Maximum Depth Attained ft	Maximum HGL Attained ft	Time of Max Occurrence days	Time of Max Occurrence hh:mm	Total Flooded Volume acre-in	Total Time Flooded minutes	Retention Time hh:mm:ss

Jun-02-Out2	0.12	3.97	919.97	0	12:17	0	0	0:00:00
Jun-03-Out2	3.34	5.14	921.14	0	12:17	0	0	0:00:00
Jun-04-Out2	0.02	0.39	916.39	0	12:17	0	0	0:00:00
Jun-05-Out1	2.49	3.07	938.07	0	12:28	0	0	0:00:00
Jun-06-Out1	0.09	1.65	936.65	0	12:28	0	0	0:00:00
Jun-07-Out1	0.01	0.18	935.18	0	12:28	0	0	0:00:00
DP-1	0.00	0.00	0.00	0	00:00	0	0	0:00:00
DP-2	0.00	0.00	0.00	0	00:00	0	0	0:00:00
Stor-02-POND2	0.26	5.42	921.42	0	12:17	1.15	26	0:00:00
Stor-04-POND1	0.22	3.28	938.28	0	12:28	0	0	0:00:00

****
Node Flow Summary
****

Node ID	Element Type	Maximum Lateral Inflow cfs	Peak Inflow cfs	Time of Peak Inflow Occurrence days	hh:mm	Maximum Flooding Overflow cfs	Time of Peak Flooding Occurrence days	hh:mm
Jun-02-Out2	JUNCTION	0.00	11.44	0	12:17	0.00		
Jun-03-Out2	JUNCTION	0.00	7.37	0	12:17	0.00		
Jun-04-Out2	JUNCTION	0.00	18.81	0	12:17	0.00		
Jun-05-Out1	JUNCTION	0.00	1.90	0	12:28	0.00		
Jun-06-Out1	JUNCTION	0.00	4.69	0	12:28	0.00		
Jun-07-Out1	JUNCTION	0.00	6.59	0	12:28	0.00		
DP-1	OUTFALL	11.84	16.35	0	12:17	0.00		
DP-2	OUTFALL	24.99	43.24	0	12:20	0.00		
Stor-02-POND2	STORAGE	38.22	38.22	0	12:08	23.41	0	12:10
Stor-04-POND1	STORAGE	22.65	22.65	0	12:08	0.00		

****
Storage Node Summary
****

Storage Node ID	Maximum Ponded Volume 1000 ft³	Maximum Ponded Volume (%)	Time of Max Ponded Volume days	hh:mm	Average Ponded Volume 1000 ft³	Average Ponded Volume (%)	Maximum Storage Node Outflow cfs	Maximum Exfiltration Rate cfm	Time of Max. Exfiltration Rate hh:mm:ss	Total Exfiltrated Volume 1000 ft³
Stor-02-POND2	28.081	100	0	12:10	1.147	4	18.81	0.00	0:00:00	0.000
Stor-04-POND1	27.827	77	0	12:28	1.596	4	6.59	0.00	0:00:00	0.000

****
Outfall Loading Summary
****

Outfall Node ID	Flow Frequency (%)	Average Flow cfs	Peak Inflow cfs

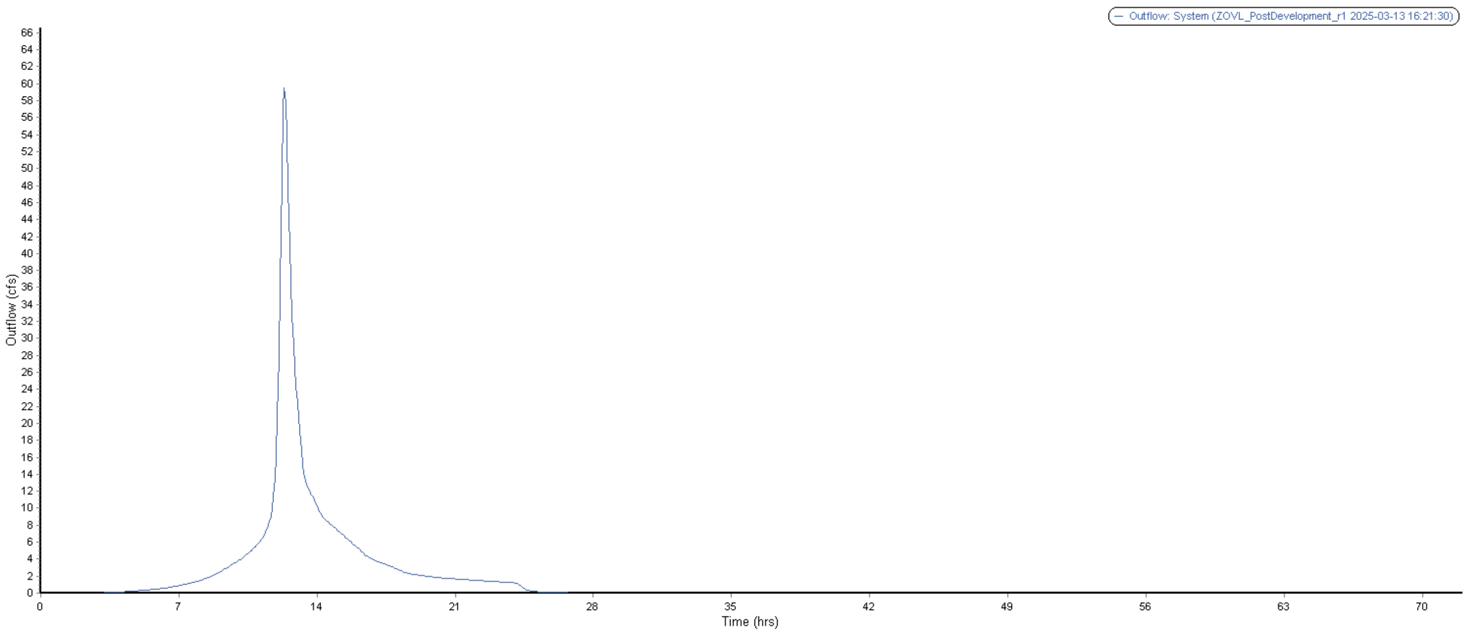
DP-1	52.29	0.95	16.35
DP-2	42.23	2.43	43.24
System	47.26	3.38	59.45

****
Link Flow Summary
****

Link ID	Element Type	Time of Peak Flow Occurrence days hh:mm	Maximum Velocity Attained ft/sec	Length Factor	Peak Flow during Analysis cfs	Design Flow Capacity cfs	Ratio of Maximum /Design Flow	Ratio of Maximum Flow Depth	Total Time Surcharged minutes	Reported Condition
Link-01-RipRap-2	CHANNEL	0 12:17	3.51	1.00	7.37	61.79	0.12	0.54	0	Calculated
Link-02-Surface-2	CHANNEL	0 12:17	5.62	1.00	18.81	421.47	0.04	0.17	0	Calculated
Link-03-RipRap1	CHANNEL	0 12:28	2.07	1.00	1.90	53.51	0.04	0.25	0	Calculated
Link-04-Surface1	CHANNEL	0 12:28	3.83	1.00	6.59	344.13	0.02	0.09	0	Calculated
Orifice-01-2yr-2	ORIFICE	0 11:57			4.15					
Orifice-02-10yr-2	ORIFICE	0 12:17			8.23					
Orifice-03-OutletPipe2	ORIFICE	0 12:17			11.44					
Orifice-04-2yr-1	ORIFICE	0 12:27			2.22					
Orifice-05-10yr-1	ORIFICE	0 12:28			2.47					
Orifice-06-OutletPipe1	ORIFICE	0 12:28			4.69					
Weir-02-100yr-2	WEIR	0 12:17			7.37			1.00		
Weir-04-100yr-1	WEIR	0 12:28			1.90			0.28		

****
Highest Flow Instability Indexes
****
All links are stable.

Analysis began on: Thu Mar 13 16:21:14 2025
Analysis ended on: Thu Mar 13 16:21:29 2025
Total elapsed time: 00:00:15


Outflow: System (ZOVL_PostDevelopment_r1 2025-03-13 16:21:30)
Outflow (cfs)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
0
7
14
21
28
35
42
49
56
63
70
Time (hrs)

Appendix J: Operations and Maintenance Plan

Moraga Storage LLC - ZOVL
Stormwater Management Systems
Operations and Maintenance Plan

RESPONSIBLE PARTY DURING CONSTRUCTION: TBD

RESPONSIBLE PARTY POST CONSTRUCTION: TBD

Construction Phase

During the construction phase, all erosion control devices and measures shall be maintained in accordance with the final record plans, local/state approvals and conditions, and the EPA General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities, if applicable. Additionally, the maintenance of all erosion / siltation control measures during construction shall be the responsibility of the general contractor. Upon proper notice to the property owner, the Town/City or its authorized designee shall be allowed to enter the property at a reasonable time and in a reasonable manner for the purposes of inspection. Due to the complex nature of the project, a more detailed description of the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan before any land disturbance begins.

Long-term Pollution Prevention Plan

Standard 4 requires the development of suitable practices for source control and pollution prevention. These measures must be identified in a long-term pollution prevention plan in a subsequent design phase. The long-term pollution prevention plan shall include the proper procedures for the following:

- good housekeeping;
- storing materials and water products inside or under cover;
- vehicle washing;
- routine inspections and maintenance of stormwater BMPs;
- spill prevention and response;
- maintenance of lawns, gardens, and other landscapes areas;
- storage and use of fertilizers, herbicides, and pesticides;
- pet waste management;
- operation and management of septic systems; and
- proper management of de-icing chemicals and snow.

The long-term pollution prevention plan shall provide that sand piles be contained and stabilized to prevent the discharge of sand to wetlands or water bodies, and, where feasible, covered. If a Total Maximum Daily Load (TMDL) has been developed that indicates that the use of fertilizers containing nutrients must be reduced, the long-term pollution prevention plan shall also include nutrient management.

Post Development Controls

Once construction is completed, the post development stormwater controls for the following items are to be operated and maintained in compliance with the procedures set in this report (note that the continued implementation of these procedures shall be the responsibility of the Owner or its assignee):

1. Catch Basins, Manholes and Piping;
2. Proprietary Water Quality Treatment Devices;
3. Outlet Control Structures;
4. Stormwater Detention Basin.

Refer to the 30% Drawings to see the location of all stormwater BMPs. All BMPs have been placed in locations with sufficient maintenance access that will be responsibility of the Owner.

BMP ID: Catch Basins, Manholes and Piping.

Inspection Schedule:

- *At least annually.*

Inspection Description:

- *Open covers or inlet grates as applicable. Identify if there is any damage to the structure or connections to pipes or obstruction to flow and verify that a clear flow path exists. Check concrete encasement and adjacent paving for apparent structural soundness, damage, and signs of settlement. Inspect for evidence of pollutants.*

- *Note type of debris. Note existing water, debris and silt levels relative to a fixed point (such as the floor of the structure).*

- *Repair any damaged structures or pipe connections or obstructions to flow (such as silt and debris). Accumulated sediment and hydrocarbons present must be removed and properly disposed of off-site in accordance with local, state, federal, and other applicable requirements. Remove any silt or debris as required, but at least when sediment reaches within 6-inches of the inlet or outlet pipes.*

Public Safety Features:
Site is fenced off and will not be accessible to the public.

Operation and Maintenace Budget:
At this stage of the project, specific details regarding the party or parties responsible for operation and maintenance, as well as the estimated operation and maintenance budget and funding sources, are not yet available. This project is currently in the permitting phase, and ownership and operational responsibilities will be determined at a later date. However, we have provided rough magnitude costs based on data from the Rhode Island Stormwater Design and Installation Standards Manual (2011):

- *$1/gal to dewater and remove sludge*
- *$66/ton sediment dump fee*
- *$800/trip-day transport underground dredge materials*

STORM WATER MANAGEMENT SYSTEM OPERATIONS AND MAINTENANCE PLAN

CATCH BASINS, MANHOLES AND PIPING

Name of Inspector: ____________________ Title of Inspector: _______________

Inspector's Signature: __________________

Inspection Date	Satisfactory			Location	Maintenance Needed and Description	Implementation Date of Maintenance
	Yes	No	N/A			

BMP ID: Proprietary Water Quality Treatment Device

Inspection Schedule:

- *Quarterly inspection is recommended for the first year after installation. The frequency of inspections after the first year can be determined by observing the in the system. At minimum, every 6 months to meet certification requirements.*

- *Additionally, the device must be cleaned out when either pollutant removal capacity is reduced by 50% or more, or when 50% or more of the pollutant storage capacity is filled or displaced.*

Inspection Description:

- *Note the depth of sediment in the sump, 12 inches or greater will require maintenance to remove and dispose of in an environmentally friendly manner. If there is trash, debris, or oil, it should be removed as well.*

- *In dry weather conditions, there should be no standing water on the deck, if there is standing water in the backwash pool, this indicates that the filter cartridges must be rinsed.*

- *In wet weather conditions, observe the rate and movement of water in the unit. Note the depth of water above deck elevation within the maintenance access wall or inlet bay. Observe the amount of standing water on the deck. There should not be any beyond the backwash pool.*

- *Any appreciated sediment on the deck should be removed.*

- *If necessary, remove and rinse the individual cartridges to extend the life of the filter. If a cartridge is deemed unusable, replace it. Any missing pieces on the deck or the rest of the system should be replaced as well.*

Maintenance Schedule:

- *Varies based on the results of the inspection. If the filter is well maintained by the owner, cartridges should last 3-5 years.*

Public Safety Features:

Site is fenced off and will not be accessible to the public.

Operation and Maintenace Budget:

At this stage of the project, specific details regarding the party or parties responsible for operation and maintenance, as well as the estimated operation and maintenance budget and funding sources, are not yet available. This project is currently in the permitting phase, and ownership and operational responsibilities will be determined at a later date. However, we have provided rough magnitude costs based on data from the Rhode Island Stormwater Design and Installation Standards Manual (2011):

- *$1 per gallon of water to dewater and remove sludge*
- *$66 per ton sediment dump fee*

- *$800 per trip per day to transport underground dredge materials (minimum 2-4 trips per day for estimation)*

According to the supplier, it is estimated that it would cost $6.600 to replace all cartridges in the filter.

Additional Notes:
Inspection is required immediately after an upstream oil, fuel, or other chemical spill.

STORM WATER MANAGEMENT SYSTEM OPERATIONS AND MAINTENANCE PLAN

PROPRIETARY TREATMENT DEVICE

Name of Inspector: ____________________ Title of Inspector: ________________

Inspector's Signature: ___________________

Inspection Date	Satisfactory			Location	Maintenance Needed and Description	Implementation Date of Maintenance
	Yes	No	N/A			

BMP ID: Outlet Control Structures

Inspection Schedule:

- *At least annually.*

Inspection Description:

- *Condition of rip-rap area should be cleared of all sediment deposits and invasive plant species.*
- *Inspect for damage (e.g. erosion, cracks, spalling, seepage/ weeps, failure, animal burrows). Damage and deterioration of the area shall be repaired immediately.*
- *Note any overgrown/ dead vegetation preventing or impeding access by maintenance personnel or equipment.*

Public Safety Features:
Site is fenced off and will not be accessible to the public.

Operation and Maintenace Budget:
At this stage of the project, specific details regarding the party or parties responsible for operation and maintenance, as well as the estimated operation and maintenance budget and funding sources, are not yet available. This project is currently in the permitting phase, and ownership and operational responsibilities will be determined at a later date.

STORM WATER MANAGEMENT SYSTEM OPERATIONS AND MAINTENANCE PLAN

OUTLET CONTROL STRUCTURES

Name of Inspector: ____________________ Title of Inspector: _______________

Inspector's Signature: __________________

Inspection Date	Satisfactory			Location	Maintenance Needed and Description	Implementation Date of Maintenance
	Yes	No	N/A			

BMP ID: Stormwater Detention Basin

Inspection Schedule:
At least annually.

Inspection Description:

Note any apparent high-water marks such as a debris line or discolored vegetation relative to a fixed point.

Note level of silt, sand or debris in bottom of basins relative to a fixed point.

Note type of debris. Inspect for evidence of pollutants.

Remove sediment from the forebay and basin as necessary. Wait until floor of the basin is thoroughly dry before removing sediment. At a minimum remove sediment accumulation immediately after construction and every five years after that.

Remove trash and debris and dispose of in an environmentally acceptable manner.

Remove excess vegetation from basin. Revegetate as needed.

Maintenance Schedule:
Twice a year: mow the buffer area, side slopes, and basin bottom. Remove trash and debris, grass clippings and accumulated organic matter.

Additional Notes:
If standing water is observed for longer than 72 hours after a storm event, a pump should be placed in the basin and discharged to the downstream manhole. After the system is dewatered it should be observed by a Professional Engineer, who should provide an opinion as to why the basin is not draining and provide recommendations to restore storage capacity to the system.

STORM WATER MANAGEMENT SYSTEM OPERATIONS AND MAINTENANCE PLAN

STORMWATER DETENTION BASIN

Name of Inspector: ____________________ Title of Inspector: ________________

Inspector's Signature: ___________________

Inspection Date	Satisfactory			Location	Maintenance Needed and Description	Implementation Date of Maintenance
	Yes	No	N/A			

CASCADE
separator®

The Cascade Separator®

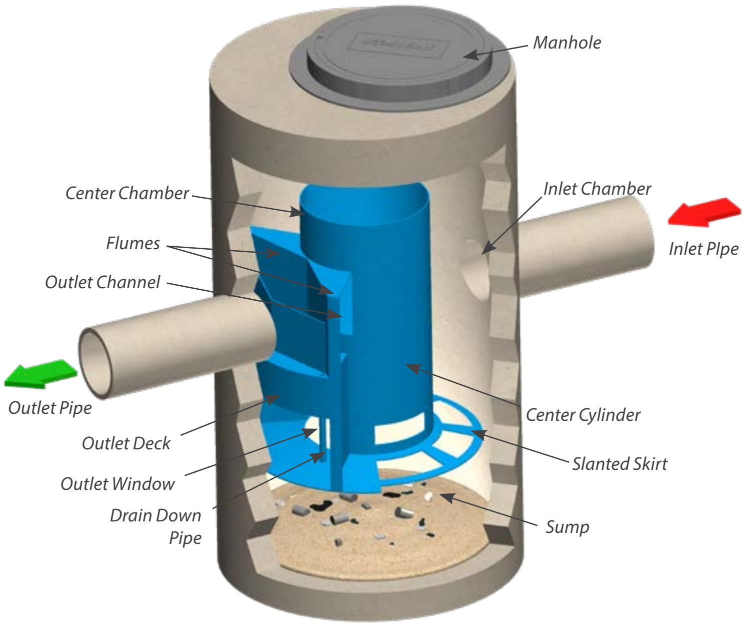
Advanced Sediment Capture Technology

The **Cascade Separator®** is the newest innovation in stormwater treatment from Contech. The Cascade Separator was developed by Contech's stormwater experts using advanced modeling tools and Contech's industry leading stormwater laboratory.

This innovative hydrodynamic separator excels at sediment capture and retention while also removing hydrocarbons, trash, and debris from stormwater runoff. What makes the Cascade Separator unique is the use of opposing vortices that enhance particle settling and a unique skirt design that allows for sediment transport into the sump while reducing turbulence and resuspension of previously captured material. These two factors allow the Cascade Separator to treat high flow rates in a small footprint, resulting in an efficient and economical solution for any site.

Learn More:
www.ContechES.com/cascade

FEATURE	BENEFIT
Unique skirt design & opposing vortices	Superior TSS removal; reduced system size and costs
Inlet area accepts wide range of inlet pipe angles	Design and installation flexibility
Accepts multiple inlet pipes	Eliminates the need for separate junction structure
Grate inlet option	Eliminates the need for a separate grate inlet structure
Internal bypass	Eliminates the need for a separate bypass structure
Clear access to sump and stored pollutants	Fast, easy maintenance



CASCADE MAINTENANCE

Cascade provides unobstructed access to stored pollutants, making it easy to maintain using a vacuum truck, with no requirement to enter the unit.

An efficient and economical solution

CONTECH® ENGINEERED SOLUTIONS