ATTACHMENT B

ENGINEERED ARTIFICIAL TURF LANDFILL FINAL COVER ALTERNATE

US Ecology
Wayne Disposal, Inc.
Belleville, Michigan

Engineered Artificial Turf Landfill Cover Equivalency Demonstration

November 2021

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1.0 PURPOSE

CTI and Associates, Inc. has prepared this report to demonstrate the equivalency of Engineered Artificial Turf Landfill Cover (EATLC) system to the traditional cover system as shown in the permitted drawings titled "Wayne Disposal, Inc. Site No. 2 Master Cell VI-F&G". Final cover requirements specified by Code of Federal Regulations (CFR) §264.310 require the final cover to in part:

- Provide long-term minimization of migration of liquids through the closed landfill
- Promote drainage of the cover
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

In addition to prescriptive requirements for the final cover over a hazardous waste landfill, Michigan Administrative Code R 299.9619(6)(a) also states the owner or operator can: Substitute an equivalent design which shall include a flexible membrane liner component with a minimum thickness of 1 mm (40 mil), depending on the type of material selected, and demonstrates to the director that it provides equivalent environmental protection.

The following sections will demonstrate that EATLC provides similar or better performance to the current prescribed final cover system. This demonstration compares the following key characteristics:

- Minimizing Maintenance
- Minimizing Infiltration
- Minimizing Erosion Potential
- Promotion of Surface Water Runoff
- Resisting Damage from Settlement
- Promoting Slope Stability

2.0 CONFIGURATION OF THE FINAL COVER SYSTEM

2.1 PERMITTED COVER SYSTEM

The current cover system that has been permitted for the site consists of the following components (from bottom to top):

- Leveling Layer - 1-ft (min)
- Geosynthetic clay liner (GCL)
- HDPE geomembrane - 40-mil textured
- Double-Sided Geocomposite
- Protective Soil - 2.5-ft
- Topsoil - 0.5-ft
- Vegetation

Figure 1 below depicts the details of the final cover system based on the permit design.

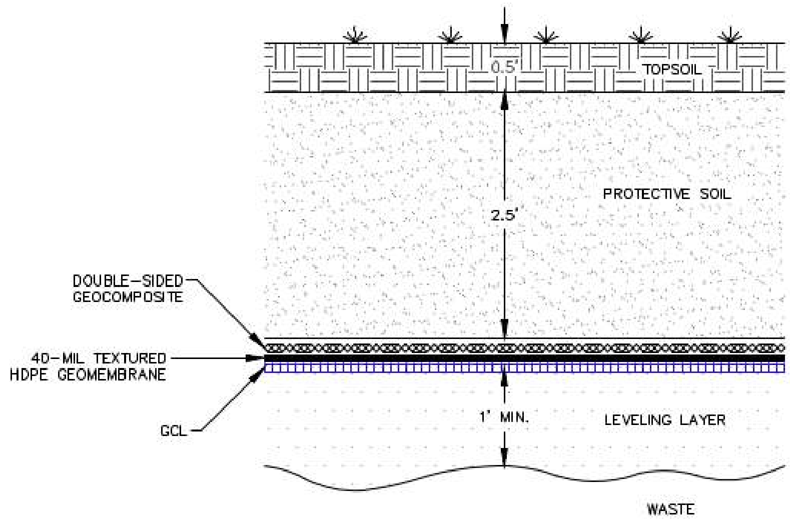


Figure 1 - Permitted Final Cover System

2.2 Engineered Artificial Turf Landfill Cover System

The Engineered Artificial Turf Landfill Cover system will consist of the following components (from bottom to top):

- Leveling Layer - 1-ft (min)
- Geosynthetic Clay Liner (Two layers)
- HDPE Geomembrane - 40-mil textured
- Engineered Artificial Turf
- Sand Infill - 0.5-inch

Figure 2 below depicts the details of the final cover system based on the proposed EATLC design. Additional details of the EATLC system as part of the final cover system are included in **Attachment A**. Photos of the top and underside of the EATLC are presented in **Figure 3 and 4**, respectively.

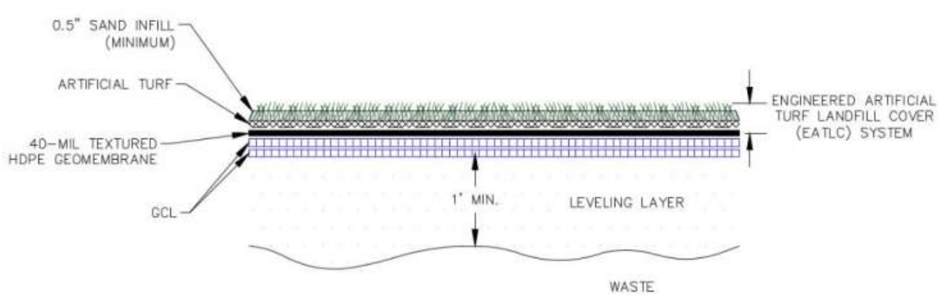


Figure 2 – Engineered Artificial Turf Landfill Cover System

Figure 3 - View of engineered artificial turf with sand infill and textured geomembrane

Figure 4 - Underside view of engineered artificial turf and textured geomembrane

3.0 EQUIVALENCY DEMONSTRATION

3.1 SUMMARY

This demonstration generally applies to alternative covers consisting of engineered artificial turf. However, all the specific data cited is reflective of ClosureTurf, a commercially available product manufactured by WatershedGeo designed specifically for landfill cover systems. It is to date perhaps the best known and best studied system. Other similar systems exist and as they are developed and come to market are likely to behave similarly and have similar properties. WDI will evaluate other similar systems at the time of the final cover installation based on specifications and the data provided by manufacturers. The selected products shall provide equivalent functions and performance as demonstrated in this report.

This demonstration shows that based on all the key and relevant criteria evaluated, engineered artificial turf landfill cover systems have been demonstrated to perform at least as well as traditional cover systems. **Table 1** below shows a summary of these specific criteria. The remainder of the document provides detail to support the conclusions in **Table 1**. Drawings and details depicting EATLC used in the final cover system at WDI are contained in **Attachment A**.

Table 1 – Comparison of Engineered Artificial Turf Landfill Cover to Conventional Cover

Category		Criterion for Evaluation	Equivalency of **EATLC** to Conventional Cover			
				EATLC		Conventional Cover
Incl. 40 mil min Geomembrane [per R 299.9619(6)(a)]			✓	40 mil		40 mil (typ)
Minimize	Maint-enance	Turf resilience	✓	Permanent, no mowing, no reseeding		Continual mowing and upkeep
		Slope stability	✓	Critical interface is FML/GCL/GCL/Soil		Critical interface is FML/GCL/Soil
		Static factor of safety (sat. cond)	✓	1.9-2.4 (typ) – slope 4:1		1.3 – 1.5 (typ) - max. slope 4:1
	Erosion	Annual estimated erosion amount	✓	<0.5 tons per acre per year		Up to 2 tons per acre per year
		Resistance to shear forces	✓	Limiting flow velocity is >11 ft/s		Limiting flow velocity 5 ft/s (without turf reinforcement mats)
	Infiltra-tion	Storm water leakage into landfill	✓	0.000 in/day (per HELP Model)		0.000 in/day (per HELP model)
		Reduce ponding potential	✓	Min. slopes ≥ 4% (easy to observe ponding)		Min. slopes ≥ 4%
Promote Runoff		Subsurface drainage capacity	✓	No need (all drainage managed on surface)		Limited by geocomposite capacity
		Runoff curve number	✓	92-95 (typ)		<90 (typ)
		Cover retains water	✓	Infiltration layer eliminated		Infiltration layer holds water
Resist Damage from Settlement		Rutting and deformation of cover	✓	Low potential, subgrade stays dry		Higher potential, subgrade retains water
		Time to complete repairs	✓	Hours		Days to repair/ weeks for new media

3.2 MAINTENANCE

The vegetative/infiltration layer in traditional cover systems typically requires a number of significant maintenance activities through closure and post-closure of the landfill. These can include:

- Mowing/excess vegetation removal
- Establishment/reestablishment of vegetation
- Erosion protection/repair
- Desiccation repair
- Addressing burrowing animals/burrow repair
- Settlement/Ponding
- Silt/sedimentation removal from drainage channels

By contrast, one of the biggest advantages of engineered artificial turf landfill cover systems is it greatly reduces the maintenance efforts making for a more protective barrier because it is more likely to remain intact throughout the closure/post-closure period.

EATLC has the following maintenance related properties:

- It does not require mowing
- Panels can be replaced more easily and within a matter of hours
- Resistance to erosion
- Resistance to damage from animals
- Settlement is more easily spotted and repaired
- Negligible sedimentation runoff

The technical aspects of these items are detailed more fully below.

3.2.1 Design Life

The engineered turf blades of engineered turf are specifically designed to resist the damaging effects of prolonged ultraviolet exposure. The design lifetime of the complete cover system is represented by the half-life of when half of the tensile strength of the synthetic turf fibers is reached from UV degradation. For ClosureTurf, Watershed Geo has conducted UV performance testing over the past several years at a testing facility in New River, Arizona and at some of the original closure turf installation locations (Pensacola, Florida and Jena, Louisiana). Independent performance assessments indicate that the half-life (50% retained tensile strength) of the UV exposed HDPE grass blades is in excess of 100 years. See Figure 7 of the report included as part of **Attachment B**. The extrapolated service life is expected to be on the order of 200 years or greater, based upon the minimum required tensile strength.

The other components of the EATLC system also have design lives well over 100 years. Both the geomembrane and the geotextile backing component of engineered turf are shielded from UV exposure by the turf fibers and the infill sand and resist degradation. This results in extending the design life in comparison to exposed materials, so those protected components are expected to have a design life of several hundred years.

3.2.2 Veneer Stability

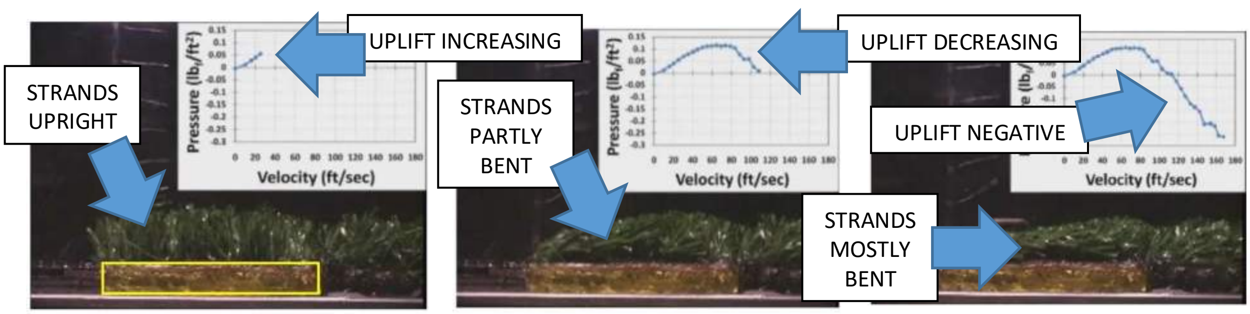
Sliding of the soil cover on top of the geomembrane in a traditional cover system is a potential design concern. This is especially true after major storm events if the drainage system between the soil and geomembrane is not properly designed. For EATLC, the thick soil component is removed, eliminating the potential for seepage forces to build up providing for greater stability. For the proposed design at WDI, the critical interfaces are the same for both systems, that is FML/GCL, GCL/GCL, and GCL/Soil. By eliminating the soil veneer, greater stability and steeper slopes with the same factor of safety are achievable.

Veneer stability analyses were performed to compare each cover system by determining the required interface friction angle for the critical interface(s) and demonstrate the stability of the final cover soils over the cap/cover system geosynthetics. The longest and steepest slope was chosen to be analyzed for minimum interface shear strength requirements, and the following two conditions were checked: Static Unsaturated and Static Saturated. The results of this analysis are given in **Attachment C**. The analyses indicate that the factors of safety are well above the minimum required values for both conditions.

3.2.3 Wind Uplift

A related concern for EATLC is wind uplift. The geotextile/turf layer is designed to be installed on top of the geomembrane and remain in place without anchoring it to the geomembrane below. It relies on interface friction and overlying sand ballast to remain immobile.

The Georgia Tech Research Institute conducted 2D, full scale wind tunnel tests to evaluate ClosureTurf under several wind speeds to evaluate aerodynamic properties and potential for uplift. The experiment measured the aerodynamic forces acting on the permeable upper turf layer and evaluated the wind speed in relation to the sand ballast. The purpose of the ballast is twofold: 1) Prevent liftoff and 2) Prevent tangential motion along the interface between the turf material and the geomembrane underlayment resulting from aerodynamic lift and drag acting on the turf layer. The testing performed determined the sand ballast requirements needed to counteract the uplift pressure. Illustration of the test and the results are depicted in **Figure 5** below. Interestingly, maximum uplift occurs at around 50 mph before the uplift begins to drop and become negative. This is due to the grass blades bending over, breaking the suction force resulting in a downward force due to drag. The maximum uplift corresponds to approximately 0.12 psf. This is much less than the downward force created by 0.5 in of sand which is approximately 4.5 psf.



V_{inf} = 25 ft/sec = 17 mph V_{inf} = 110 ft/sec = 75 mph V_{inf} = 170 ft/sec = 115 mph

Figure 5 – Wind tunnel testing results

The wind tunnel testing compared uplift pressure at both the interior and along the edge of the samples. Maximum uplift pressure was observed along the edge. At 66 mph, which represents the historical peak wind gust for Detroit based on the available wind data from the National Climatic Data Center, the minimum sand ballast required was 0.2 in. Additional details are contained in **Attachment D.**

3.2.4 Rutting

For conventional soil covers, the soil infiltration layer holds water during the wetter portions of the year. When this occurs in areas that require routine access or areas along access road alignments can experience rutting from vehicles and possibly even foot traffic.

Engineered artificial turf was evaluated by another 3rd party consultant (SGI) for subgrade integrity where ground pressure from heavy equipment was evaluated in relation to maintaining the integrity of the engineered artificial turf landfill cover components. Results showed that when the subgrade is protected by EATLC, including the sand infill, the subgrade can handle equipment with tire pressures up to 60 psi on 3H:1V slopes and up to 90 psi on relatively flat slopes with no appreciable damage to the engineered turf of the subgrade. This evaluation is contained in **Attachment E**.

3.2.5 Ponding/Settlement Repairs

For a conventional cover system, settlement may lead to ponding on the surface and local saturation of infiltration layer. Because of the resulting soft subgrade, repairs may be delayed due to difficulties getting the necessary heavy equipment to the area and/or risking additional damage to the cover system from rutting and erosion from the equipment. As shown in **Figure 6**, excessive settlement can also affect the performance of the underlying geosynthetics which may or may not be apparent at the surface. Vegetated cover soils can obscure the ability to inspect for geosynthetic defects or anomalies resulting from excessive settlement. The presence of the vegetated soil layer also hinders the ability to implement repairs, in the event that the corrective measures are necessary since it must be fully over excavated to make repairs which can require significant effort and delay repairs even more. Finally, once the repairs are made, it may take several weeks to reestablish vegetation before the repair is fully implemented. Total time for repairs is likely measured in weeks perhaps to more than a month.

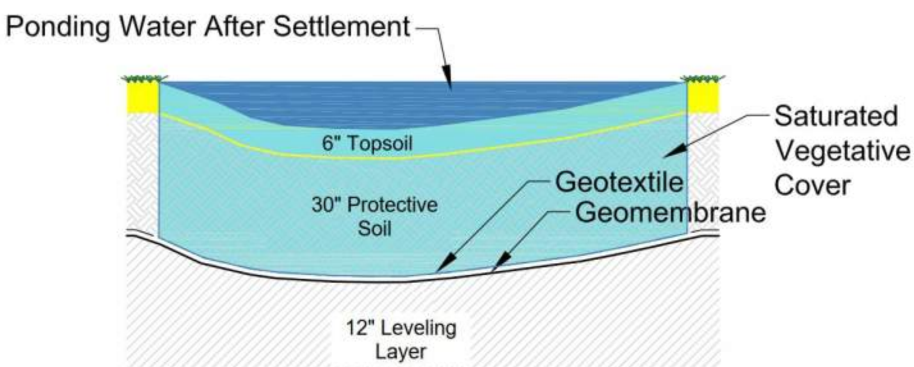


Figure 6 – Repairs to conventional cover

In contrast, repair of settlement in areas where engineered artificial turf landfill cover is utilized can be addressed much more quickly as depicted in **Figure 7**. Because there is no soil component, the potential for soft subgrade is minimized and the geosynthetic components can be readily accessed and inspected. Any ponded water can be pumped and removed, the geosynthetics removed to reveal the settlement area, the depressed area filled with soil to bring it back up to grade, and the area quickly seamed and repaired. There is no need to reseed the area. Total time for repair can likely be measured in hours.

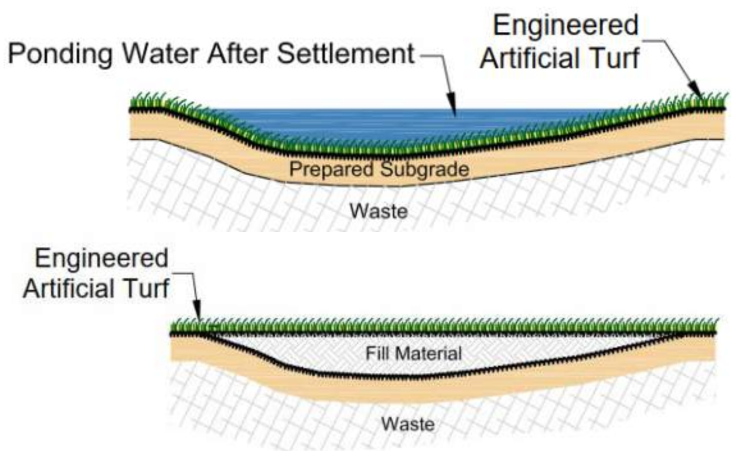


Figure 7 – Repairs to Engineered Artificial Turf Landfill Cover

3.3 EROSION

For a conventional cover system, the ability to resist erosion is primarily related to the establishment (and retention) of adequate vegetation. It can be difficult to establish and maintain adequate vegetation across the full extent of a landfill. Extended periods of drought can quickly transition to high intensity downpours.

The vegetative/infiltration soil layer is the primary component of the conventional cover system which is subject to erosion. On-site soils that are likely to be used for this layer consist primarily of a combination of silt, clay, and sand particles in various proportions. Erosional stability of these individual particles is influenced by soil adhesion, vegetative cover, and internal friction. Erosion of the vegetative soil layer cannot be entirely arrested since some of the stability parameters vary over time and various climatic conditions. Silt loams, loams, fine sands and sandy loams are the most detachable soil particles (Morgan, 2005) which make up a large percentage of vegetative soil.

Based on the current design, the estimated annual rate of soil erosion (discharge) from the conventional vegetative cover system is predicted to range up to 1.3 tons per acre, per year (USE 2021). Also, significant, additional erosion could occur during a single, extreme storm event potentially resulting in damage to the engineered soil components requiring and costly repairs. Additionally, perimeter channels within a conventional cover can become laden with sediments which can be detrimental to vegetation in that zone and can lead to water quality concerns, erosion rills, and an increasingly complex maintenance program to maintain adequate vegetation.

Engineered artificial turf landfill cover is designed to essentially eliminate this potential by eliminating the vegetative/infiltration soil layer. The EATLC system does have a 0.5-in thick specified infill sand layer that is spread within the engineered artificial turf layer which is used for ballast and for UV protection of the underlying geotextile backing of the engineered artificial turf components. However, in comparison to traditional cover, the sand infill is much less erodible. It consists of a coarse-grained sand meeting specific standards tested for resistance to erosion. Stability of the sand aggregates is influenced by internal friction and turf strand reinforcement which are static properties and allow for the potential for soil erosion to be minimized by design.

Watershed Geo has completed extensive hydraulic testing to evaluate the sand infill's performance under various surface water conditions. The summary of this testing program is included in **Attachment F** and the sand infill specifications developed from this testing is included in **Attachment G**. Sand infill that conforms to these specifications is expected to experience minimal sand movement under the design surface water conditions.

3.4 Infiltration Equivalency

By design, the vegetated soil layer is intended to act as a large sponge which soaks up precipitation during storm events and provides a moisture reservoir for the vegetation. However, one of the undesirable consequences of the sponge action is that each time the soil layer becomes saturated (during prolonged storm events), the soil layer will slowly release or seep a steady flow of water across the underlying cover membrane for several days after the storm event. Subsequently, the opportunity for water leakage through any cover membrane defects is extended. Therefore, the presence of the vegetated soil layer inadvertently prolongs an undesirable window of opportunity where leakage might occur.

Alternative engineered artificial turf landfill cover systems perform similar to or better than the prescribed traditional cover systems in terms of infiltration (Carlson, et al., 2019). The primary reasons for this are 1) The geomembrane material is itself designed to be essentially impermeable and 2) Because they don't have a soil component that could potentially hold water, synthetic turf cover systems like ClosureTurf have a much smaller hydraulic head over the geomembrane layer driving infiltration in comparison to traditional cover systems. The full technical paper cited is provided in **Attachment H**.

The final cover systems described in Section 2.0 were each modeled in the USEPA's Hydrologic Evaluation of Landfill Performance (HELP) Model. The results showed that EATLC compared to the current permitted traditional cover system produced similar rates and sheds much more water than a traditional cover system. The analysis shows that both cover systems allow for negligible flow through the geosynthetic composite cover. The EATLC system meets the criteria from a hydrologic standpoint of being at least as protective as the permitted cover system. Complete results for the entire simulation period are included in **Attachment I**.

3.5 Surface Water Considerations

The use of an engineered artificial turf landfill cover system allows the landfill to manage a larger volume of surface water with similar or smaller annual infiltration compared to a traditional cover system. For a traditional cover system, benches and berms are designed to intercept long flow paths of runoff and prevent rill erosion. With engineered artificial turf, the cover system isn't subjected to this same rill erosion even for long flow lengths. This allows for the removal of mid-slope features and the EATLC is then able to utilize surface flow as the primary means of conveyance. Without these intercept features and with the higher run-off coefficients, the cover system will discharge faster and minimize the time that surface water is flowing on the geomembrane liner. The complete technical paper that compares the hydrologic performance of engineered artificial turf to a traditional cover system is included in **Attachment J**.

A surface water analysis was performed for the use of EATLC. The currently permitted design was updated to account for the properties of EATLC. For example, the design run-off curve number for EATLC is 95, compared to 84 for the traditional cover system. Compared to the traditional final cover system the downslope channels and almost all of the diversion berms in the landfill expansion area were removed. The only berms that remain are along select locations of the perimeter of the landfill to route runoff to ditches and storm sewer inlets. Plans showing the location of the remaining berms are included in **Attachment A**. The runoff velocity and flow depths in some downstream ditches also increased. To handle this, the ditches receiving sheet flow from EATLC areas will be lined with engineered artificial turf. The height of the containment berms on the outside edge of the perimeter channels are being increased or channel lining modified, as necessary, to accommodate the higher runoff volumes. Also, some culverts increased in size to transmit the increased flows. The complete surface water analysis is included in **Attachment K**. The EATLC stormwater management system is shown on Figures 1 and 2 in Attachment K-1.5.

The run-off water quality characteristics, including turbidity (total suspended solids), for a traditional cover system tend to degrade during high intensity precipitation events, because of increased flow rates and increased erosional shear forces on the vegetative soils. The turbidity water quality related to an EATLC system remains clear throughout a wide spectrum of high intensity storm events since the manufactured sand infill lacks fine silt or clay particles and has been engineered to specifically resist the range of expected erosional forces.

Concerns regarding other potential water quality considerations (nitrates, BOD, fertilizers, etc.) are also eliminated with an EATLC system.

3.6 Additional Considerations

In addition to the technical considerations, there are other considerations for the use of engineered artificial turf landfill cover.

3.6.1 Aesthetics

Figure 8 – Engineered artificial turf options

The engineered artificial turf component is available in a variety of colors to better blend in with adjacent topography and vegetation. It can be installed with a random pattern to look more natural as shown in **Figure 8.**

3.6.2 Carbon Footprint

Based on a 2012 study, the CO_2 footprint of engineered artificial turf systems are only 20% of the traditional multilayered cover systems (Koerner, 2012). This is largely due to greatly reducing truck and equipment traffic and the ability to install engineered artificial turf approximately 50% faster than conventional cover. This process is depicted in **Figure 9**. This also increases safety for both onsite personnel and offsite motorists sharing the road with haul trucks.

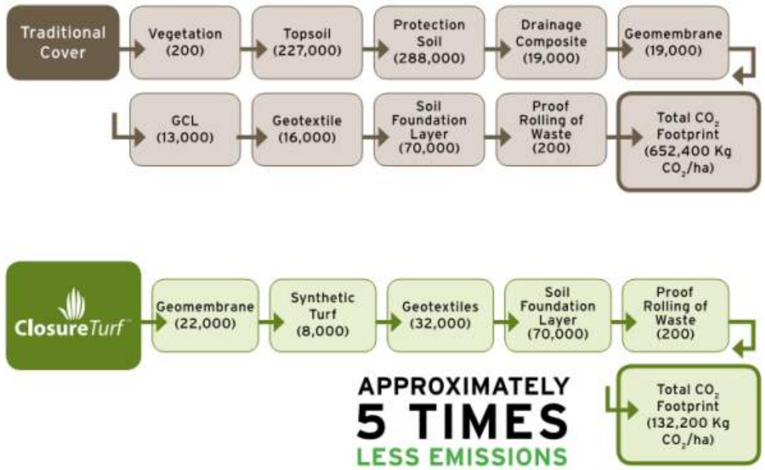


Figure 9 – CO_2 footprint traditional vs. ClosureTurf

3.6.3 Renewable Energy

Engineered artificial turf landfill cover systems can also be leveraged to be better locations for renewable energy projects. Lowered maintenance costs are perhaps the most noticeable advantage where mowing can be eliminated, erosion potential is very low, and repairs are more easily performed where needed. In some cases, maintenance requirements like mowing can make projects cost prohibitive.

Figure 10 – Example of renewable energy project where maintenance could be reduced using EATLC

4.0 REFERENCES

Carlson, C. P., Zhu, M. & Ebrahimi, A., 2019. *Hydrologic Performance of Synthetic Turf Cover Systems and Their Equivalency to Prescriptive Cover Systems.* Houston, Industrial Fabrics Association International, p. 8.

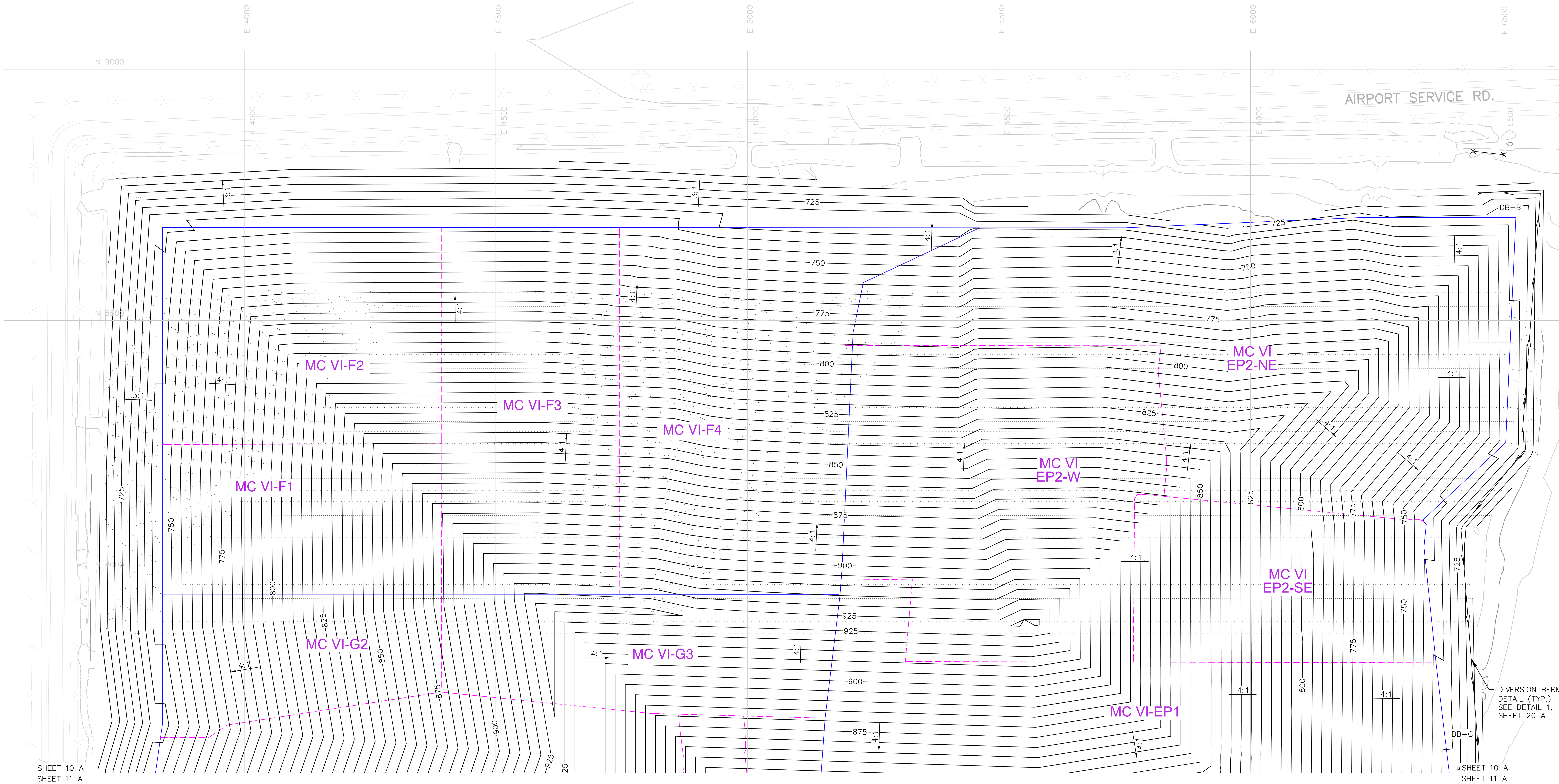
Koerner, R. M., 2012. Traditional vs. Exposed Geomembrane Landfill Covers. *Geosynthetics*, 1 October, pp. 34-41.

Morgan, R. P. C., 2005. *Soil Erosion and Conservation.* 3rd ed ed. Malden, MA: Blackwell Pub.

USE, 2021. 2021 WDI Permit Modification, Calculation A-6.9

Attachment A

Drawings



LEGEND

500	EXISTING MAJOR CONTOURS
	EXISTING MINOR CONTOURS
500	TOP OF FINAL COVER MAJOR CONTOURS
	TOP OF FINAL COVER MINOR CONTOURS
	EXISTING VEGETATION
	GRADE BREAK
	SUBCELL BOUNDARY
	CELL BOUNDARY
1 / 20 A	DIVERSION BERM

NOTES:

1. THE BASE MAP WAS CREATED USING AN AERIAL DRONE SURVEY PROVIDED BY DRONEVIEW TECHNOLOGIES, DATED DECEMBER 10, 2020. UPDATED WITH DRONE AERIAL SURVEY DATED APRIL 2, 2021.
2. DIVERSION BERMS ARE SLOPED AT 2% UNLESS OTHERWISE NOTED.

N

0 100 200

SCALE IN FEET

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CHECKED BY:	CAB
APPROVED BY:	XZ

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REV	DATE	REVISION DESCRIPTION	DRN	APP
1	10/08/21	SUBCELLS G4-G7 REVISIONS; FINAL GRADE MODIFICATIONS; MISCELLANEOUS CHANGES	WRG	XZ

WAYNE DISPOSAL, INC. SITE NO. 2 - MASTER CELL VI-F&G
VAN BUREN TOWNSHIP, WAYNE COUNTY, MICHIGAN

ENGINEERED TURF STORM WATER MANAGEMENT AND SEDIMENTATION PLAN (1 OF 2)

PROJECT NUMBER 1218070017

SCALE 1" = 100'

DRAWING NO 10 A

SHEET 10 A
SHEET 11 A

LEGEND

500	EXISTING MAJOR CONTOURS
	EXISTING MINOR CONTOURS
500	TOP OF FINAL COVER MAJOR CONTOURS
	TOP OF FINAL COVER MINOR CONTOURS
	EXISTING VEGETATION
	GRADE BREAK
	SUBCELL BOUNDARY
	CELL BOUNDARY
1 / 20 A	DIVERSION BERM

NOTES:

1. THE BASE MAP WAS CREATED USING AN AERIAL DRONE SURVEY PROVIDED BY DRONEVIEW TECHNOLOGIES, DATED DECEMBER 10, 2020. UPDATED WITH DRONE AERIAL SURVEY DATED APRIL 2, 2021.
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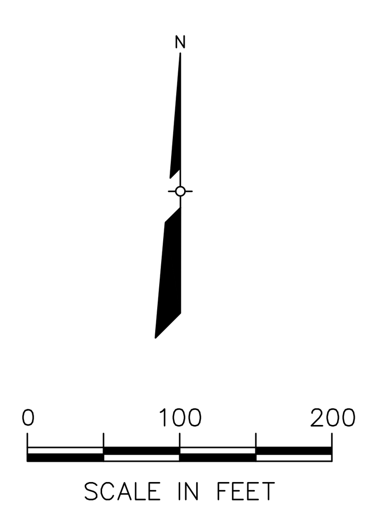

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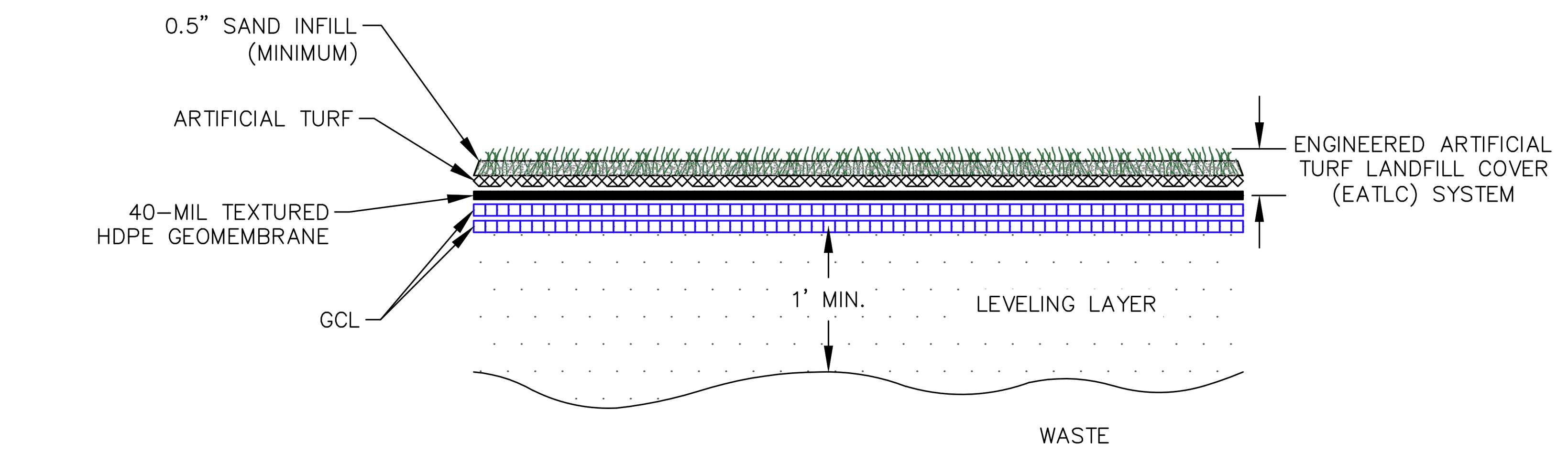
CHECKED BY: CAB
APPROVED BY: XZ

REV	DATE	REVISION DESCRIPTION	DRN	APP
1	10/08/21	SUBCELLS G4-G7 REVISIONS; FINAL GRADE MODIFICATIONS; MISCELLANEOUS CHANGES	WRG	XZ

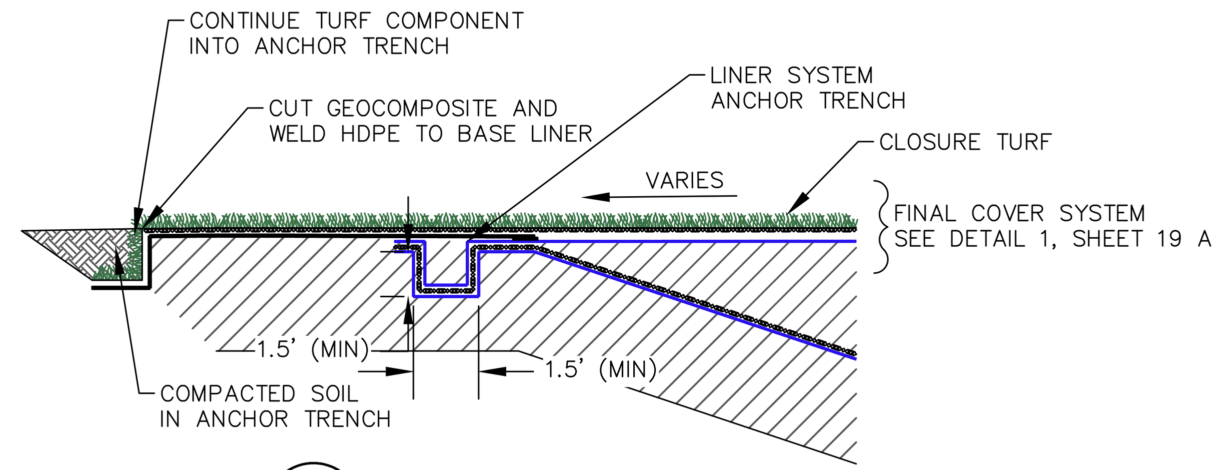
WAYNE DISPOSAL, INC. SITE NO. 2 - MASTER CELL VI-F&G
VAN BUREN TOWNSHIP, WAYNE COUNTY, MICHIGAN

ENGINEERED TURF STORM WATER MANAGEMENT AND SEDIMENTATION PLAN (2 OF 2)

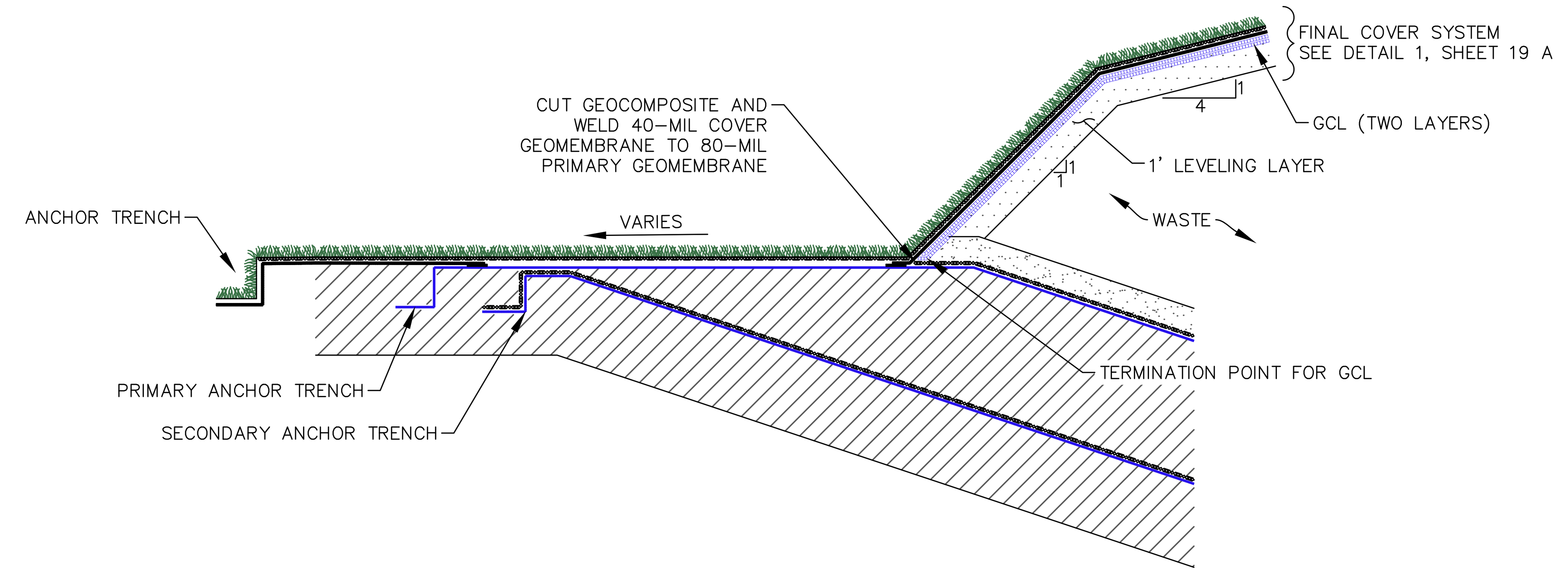
PROJECT NUMBER 1218070017
SCALE 1" = 100'
DRAWING NO 11 A



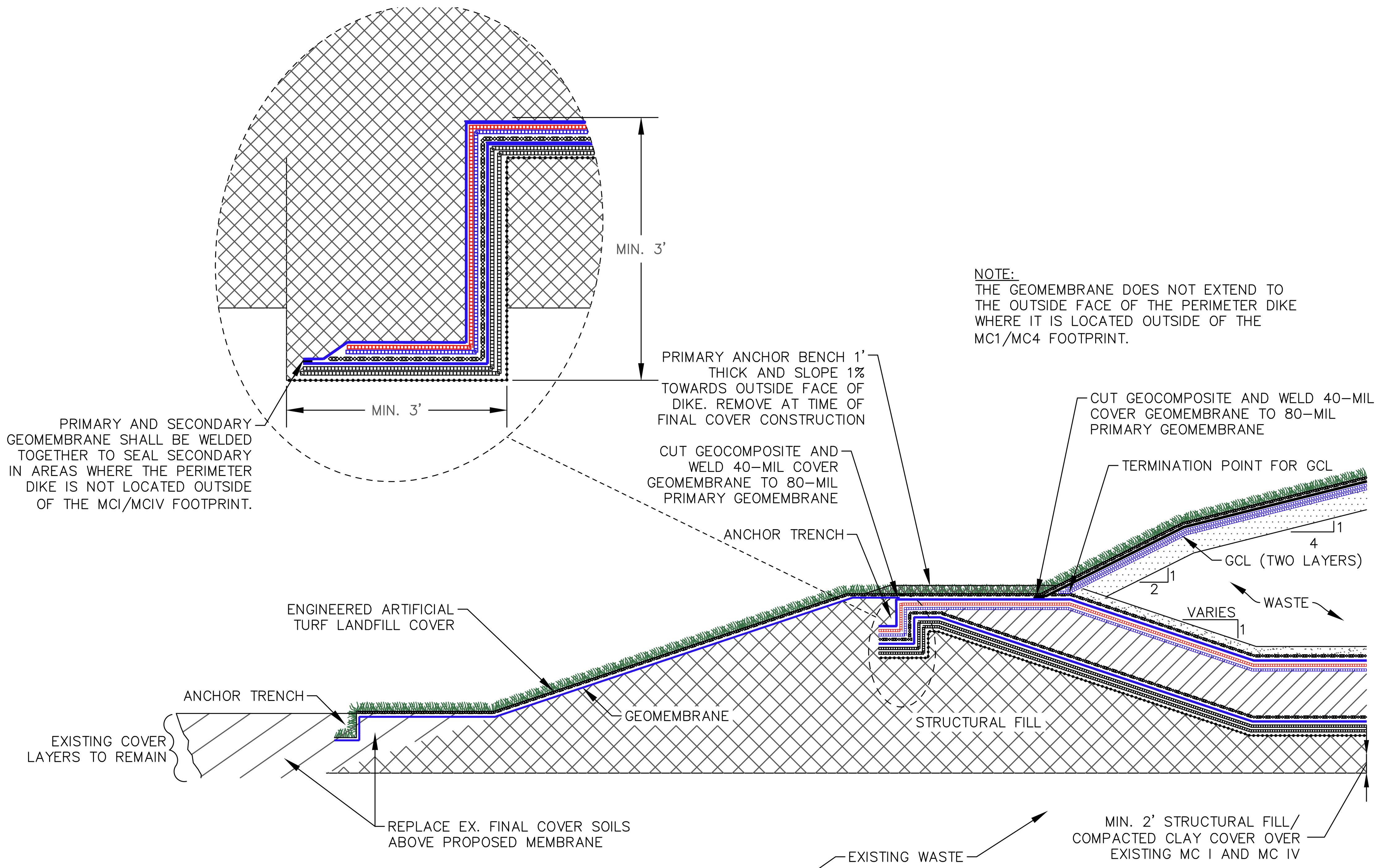
1 / 19 A **FINAL COVER SYSTEM**
NOT TO SCALE



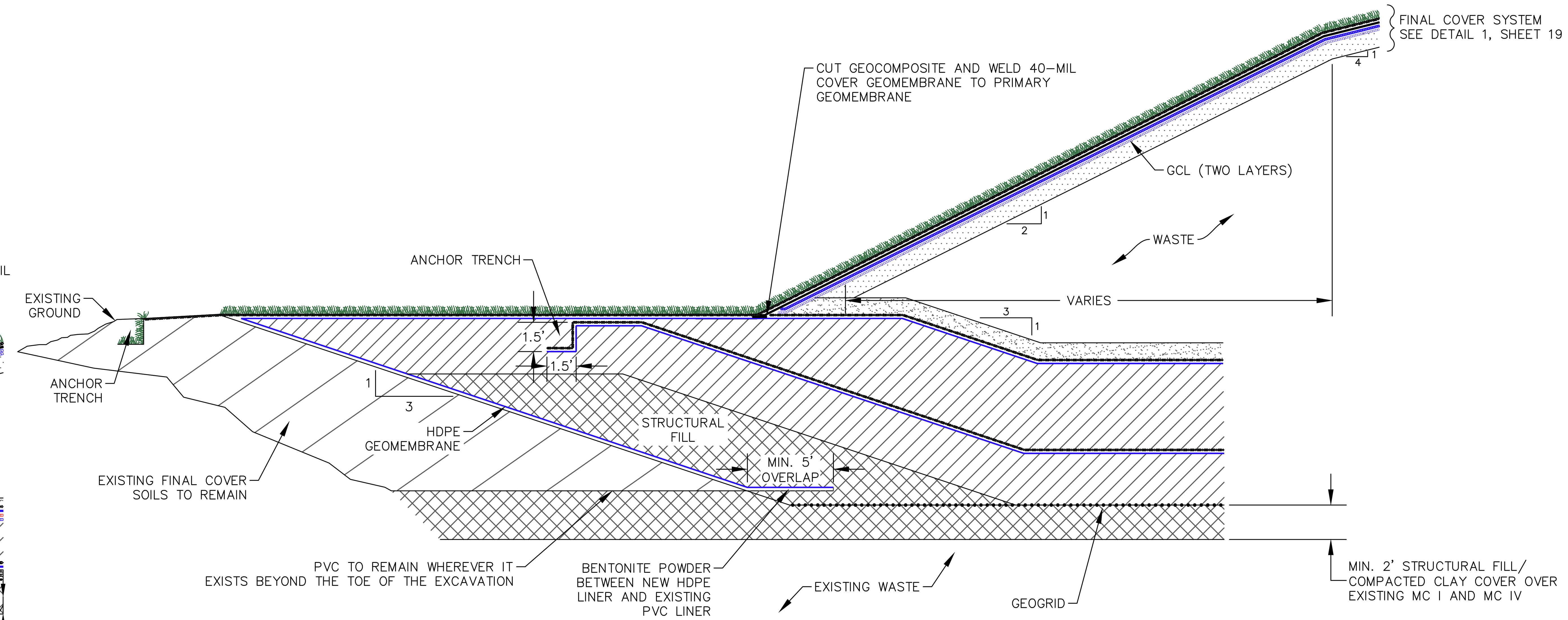
2 / 19 A **ANCHOR TRENCH**
NOT TO SCALE



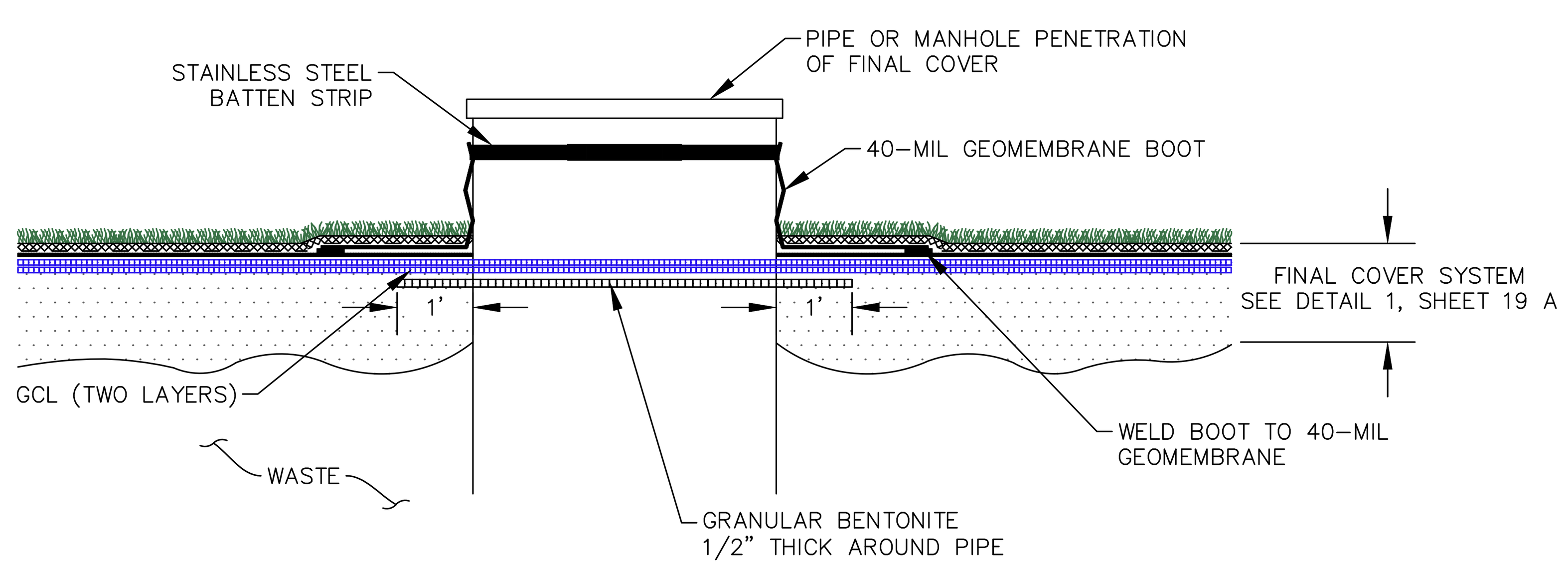
2 / 19 A **FINAL COVER TIE-IN DETAIL MC VI-AN, AS, C & D**
NOT TO SCALE



3 / 19 A **DIKE AND COVER TIE-IN DETAIL (TYP.) MC VI-F, MC VI-G, & EAST SIDE OF MC VI-E**
NOT TO SCALE



4 / 19 A **DIKE AND COVER TIE-IN DETAIL NORTH SIDE OF MC VI-E**
NOT TO SCALE



5 / 19 A **FINAL COVER PENETRATION DETAIL (TYP.)**
NOT TO SCALE

DATE:	10/08/21
DESIGNED BY:	LEH
DRAWN BY:	WRG
CHECKED BY:	CAB
APPROVED BY:	XZ

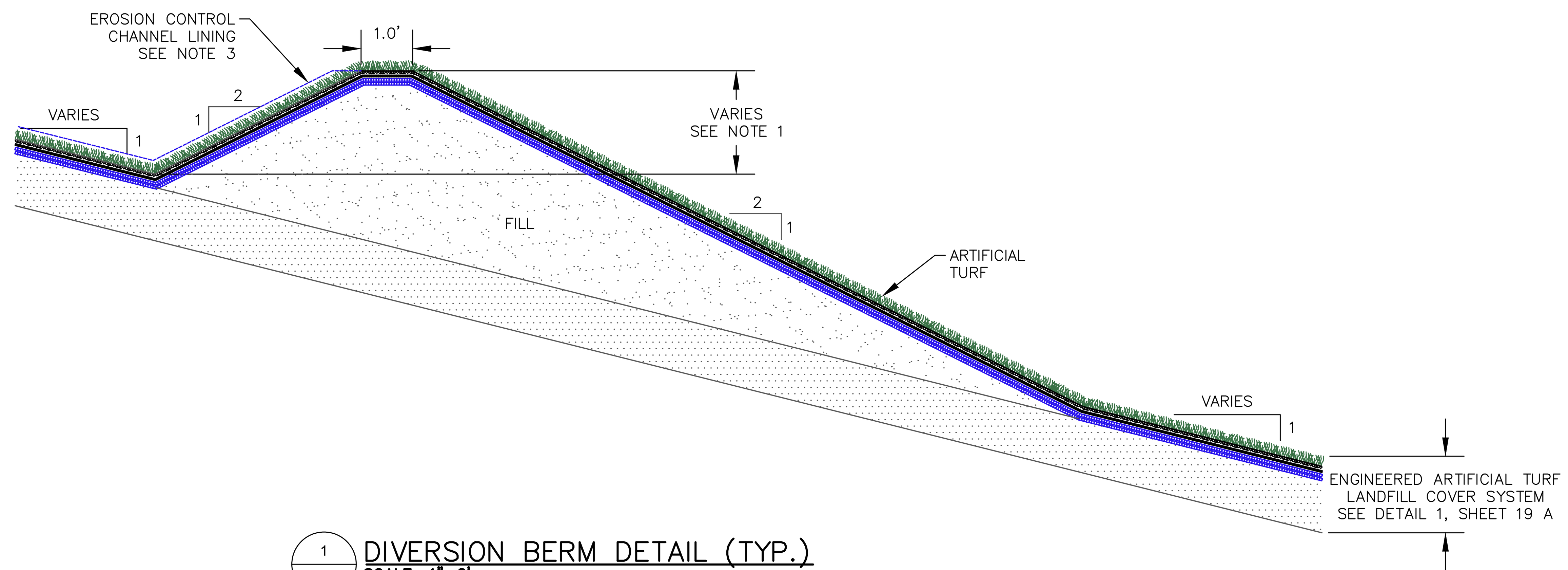
CTI and Associates, Inc.
28001 Cabot Drive, Ste. 250
Novi, Michigan 48377
248.486.5100 (fax)248.486.5050
www.cticompanies.com

REV	DATE	REVISION DESCRIPTION	DRN	APP
1	10/08/21	SUBCELLS G4-G7 REVISIONS; FINAL GRADE MODIFICATIONS; MISCELLANEOUS CHANGES	WRG	XZ

WAYNE DISPOSAL, INC. SITE NO. 2 - MASTER CELL VI-F&G
VAN BUREN TOWNSHIP, WAYNE COUNTY, MICHIGAN

ENGINEERED TURF FINAL COVER DETAILS

PROJECT NUMBER 1218070017
SCALE AS SHOWN
DRAWING NO 19 A



1 / 20 A **DIVERSION BERM DETAIL (TYP.)**
SCALE: 1"=2'

NOTE:

1. ALL DIVERSION BERMS TO BE 2FT HIGH (MINIMUM).
2. DIVERSION BERM SLOPE TO BE 2% UNLESS NOTED OTHERWISE ON DRAWINGS.
3. DIMENSIONS AND CONFIGURATION OF DIVERSION BERMS WILL BE DETERMINED BY THE EROSION CONTROL CHANNEL LINING CHOSEN. CHANNEL AND OUTLET ENERGY DISSIPATER DESIGN TO BE COMPLETED PRIOR TO CONSTRUCTION.

DATE:	10/08/21
DESIGNED BY:	LEH
DRAWN BY:	WRG
CHECKED BY:	CAB
APPROVED BY:	XZ

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REVISIONS

REV	DATE	REVISION DESCRIPTION	DRN	APP
1	10/08/21	SUBCELLS G4-G7 REVISIONS; FINAL GRADE MODIFICATIONS; MISCELLANEOUS CHANGES	WRG	XZ

WAYNE DISPOSAL, INC. SITE NO. 2 - MASTER CELL VI-F&G
VAN BUREN TOWNSHIP, WAYNE COUNTY, MICHIGAN

ENGINEERED TURF STORMWATER MANAGEMENT SYSTEM DETAILS

PROJECT NUMBER 1218070017
SCALE AS SHOWN
DRAWING NO 20 A

Attachment B

Design Life of ClosureTurf

Technical Note

DESIGN LIFE OF CLOSURETURF®

The ClosureTurf® Final Cover System is projected to last well over one hundred (100) years, provided it is installed and maintained in accordance with Watershed Geosynthetics' standard specifications. This duration exceeds the current post-closure regulatory period of 30 years by more than 3 times. During that time, the average maintenance cost of the ClosureTurf system will be roughly 10 to 20% of the cost for maintenance of a traditional soil cover system.

CLOSURETURF COMPONENTS

To better understand system longevity, it is helpful to break down the system into its components and explain the function of each component. A cross-section of the ClosureTurf system is shown in Figure 1 to aid the discussion.

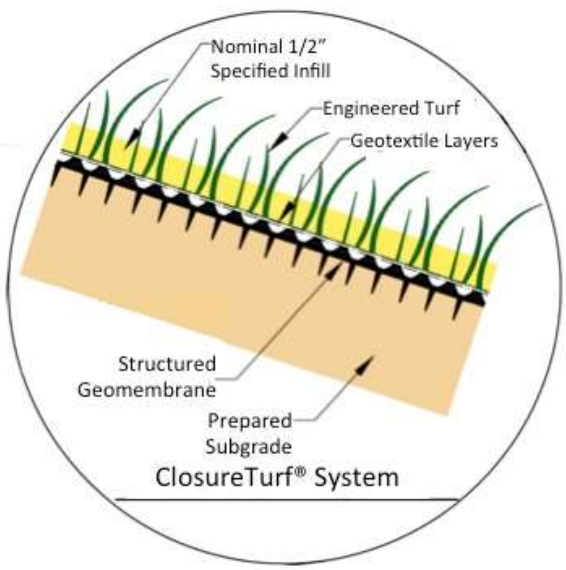

Figure 1. ClosureTurf® Cross-Section

Starting at the prepared subgrade and moving vertically through the cross-section of the system, the first component is the structured geomembrane. The structural geomembrane layer creates an impermeable hydraulic barrier providing the actual environmental containment. Moving upward through the cross-section, the second component is the engineered turf layer. The engineered turf layer is comprised of two distinct parts: (1) a double-layer woven geotextile backing with enhanced ultraviolet (UV) resistance; and (2) polyethylene turf fibers (or yarns) tufted into the woven

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geotextiles. The third, and final, component of the ClosureTurf system is the specified infill. The specified infill is an angular, specifically graded sand resting on the geotextile backing and within the individual turf fibers of the engineered turf layer.

UV Protection

The geomembrane is covered by the engineered turf and sand protecting the geomembrane from UV exposure. Based upon research by Geosynthetic Institute (GSI) [Koerner et al., 2011 and Koerner et al., 2012], a covered geomembrane has an expected lifetime (i.e., a half-life) of several hundred years. The sand infill and turf fibers provide UV shielding of the geotextile backing of the engineered synthetic turf. With the sand infill in place, the geotextile backing will remain intact and in place covering the structured geomembrane, allowing the geomembrane to realize its full design life. The sole component of the ClosureTurf system exposed to UV is the turf fibers.

Longevity of Turf Fibers

Longevity of the turf fibers dictates the design life of the ClosureTurf system. UV longevity testing on the turf fibers indicates the half-life is projected to be over two hundred years, as presented in Attachment 1, Literature Review and Assessment of ClosureTurf UV Longevity prepared by Geosyntec Consultants. At year 100, the turf fibers are projected to have approximately 60% of the original tensile strength. The average tensile strength of virgin turf fibers is approximately 35 lbs per fiber. Therefore, the tensile strength at year 100 is projected to be approximately 20 lbs per fiber, which is significantly greater than the estimated minimum tensile strength necessary for the turf fibers to perform in application (i.e., approximately 2.5 to 3.5 lbs per fiber). Turf fiber tensile strength values over time compared to the required service value are presented in Figure 2.

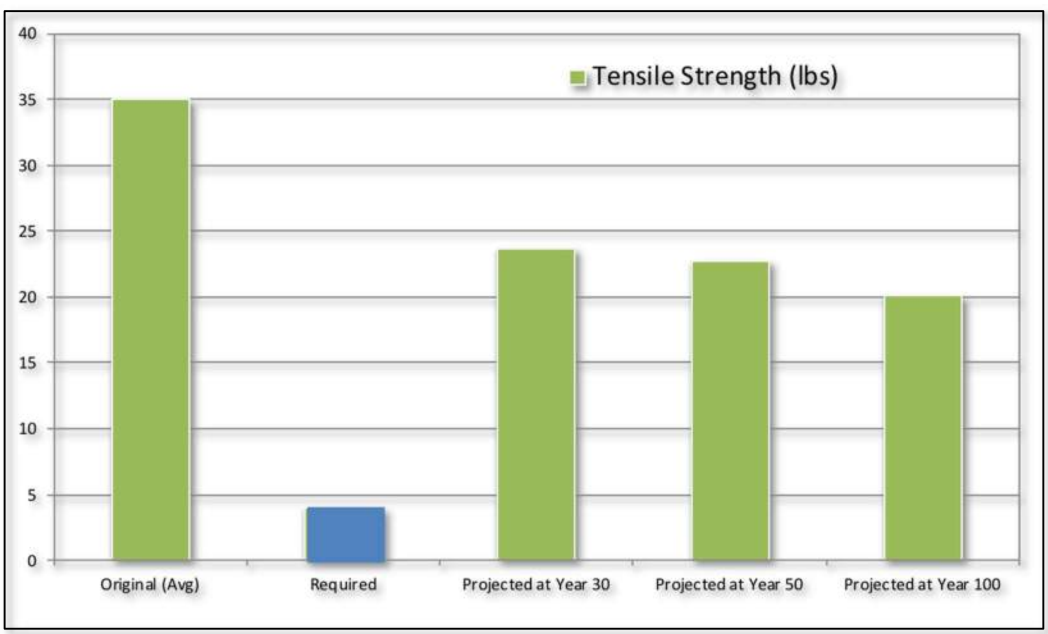

Figure 2. ClosureTurf® Fiber Tensile Strength

Field samples of turf fibers have been collected and tested for tensile strength at an independent laboratory. Samples were collected at two ClosureTurf installations, the LaSalle-Grant Landfill in Louisiana and the Saufley Field Road Landfill in Florida. The field sample turf exposure times ranged from five to eight years. The retained tensile strength of the turf field samples was compared with the laboratory UV testing results in New River, Arizona, as presented in Figure 3. Field performance of the engineered turf tensile strength matches or exceeds results from laboratory testing of UV exposure.

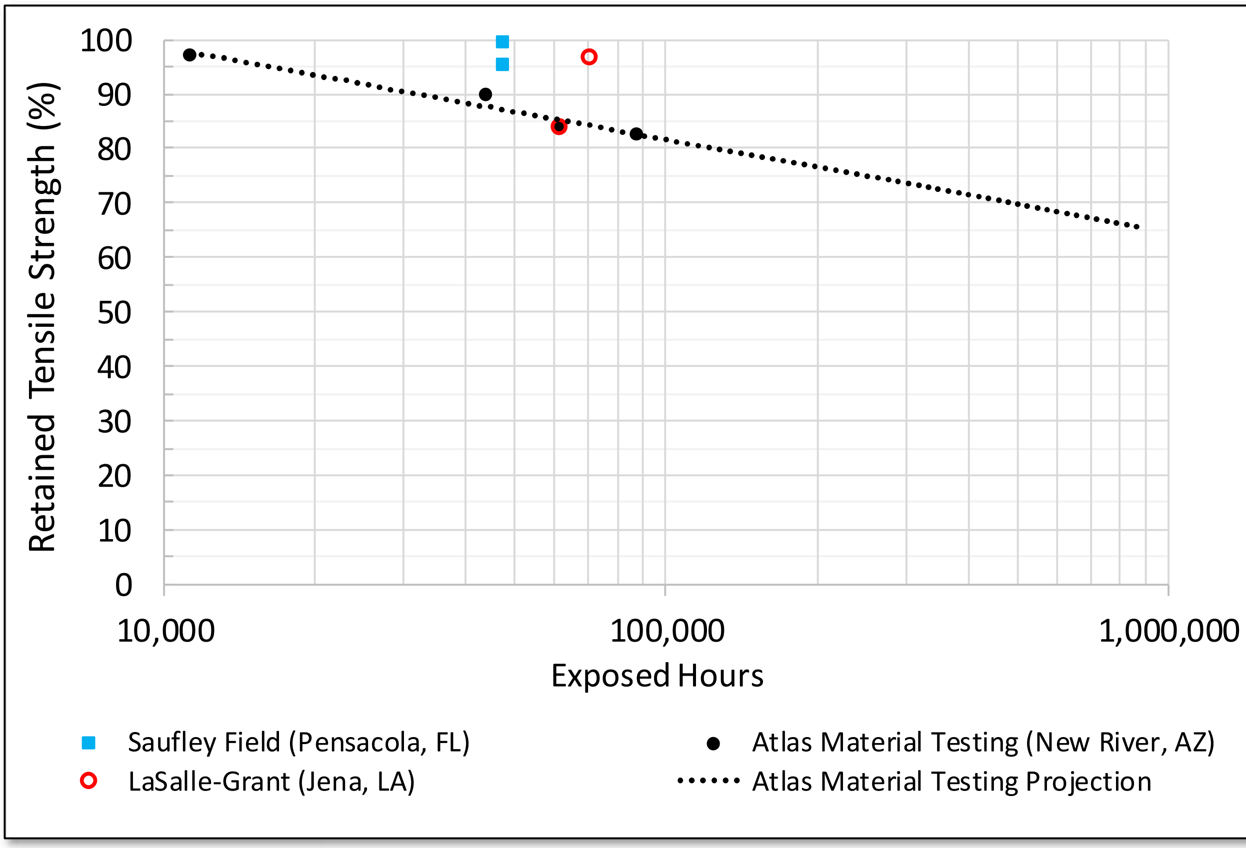

Figure 3. ClosureTurf® Fiber Tensile Strength, Field Performance

Maintenance Cost

As with any closure system, regular maintenance activities are required with the ClosureTurf system. Standard maintenance activities include, primarily, periodic visual inspection (e.g., once per quarter or once per year) and localized sand placement to cover exposed geotextile backing, as needed, at five-year intervals. The average maintenance cost for the system will typically be 10 to 20% of the cost for maintenance of a traditional soil cover system. Watershed Geosynthetic's experience with existing ClosureTurf installations suggests an average budgetary amount for maintenance is $150 to $250 per acre per year. As a comparison, a typical soil cover system has an estimated average maintenance cost of $1,200 to $1,500 per acre per year.

References

Koerner, R.M., Hsuan, G.Y., and Koerner G.R. (2011), "Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions," GRI White Paper #6, Original: June 7, 2005 Updated: February 8, 2011.

Koerner, R.M., Koerner G.R., Hsuan, G.Y., and Wong, W.K. (2012), "Lifetime Prediction of Laboratory UV Exposed Geomembranes: Part I - Using a Correlation Factor," GRI White Paper #42, January 3, 2012.

LIMITATIONS

Attachment 1

Literature Review and Assessment of ClosureTurf® UV Longevity

Geosyntec consultants

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15 May 2015

José Urrutia, P.E.
Vice President of Engineering
Watershed Geosynthetics
11400 Atlantis Place, Suite 200
Alpharetta, GA 30022

Subject: Literature Review and Assessment of ClosureTurf® UV Longevity

Dear Mr. Urrutia:

Watershed Geosynthetics, Inc. (Watershed) has patented an alternative landfill closure system termed, ClosureTurf®. ClosureTurf® consists of high-density polyethylene (HDPE) grass blades tufted through a polypropylene (PP) geotextile backing which overlies Super Gripnet®, an HDPE or linear low-density polyethylene (LLDPE) geomembrane manufactured by AGRU America Inc. The addition of a layer of sand ballast during installation completes the system. The sand ballast provides cover for the lower portion of the HDPE grass blades, the PP geotextile backing, and the Super Gripnet® (Figure 1). The ClosureTurf® system, therefore, is a "hybrid" closure system in the sense that it is neither a traditional soil cover or an exposed geomembrane. ClosureTurf® has been used to close a number of landfills throughout the United States. A select list of sites where it has been used is shown in Table 1. Applications extend to other facilities as well, such as capping of coal ash ponds.

Watershed has requested that Geosyntec Consultants, Inc. (Geosyntec) provide an assessment of the longevity of the ClosureTurf® system with regard to UV degradation. Since ClosureTurf® has elements (i.e., the HDPE grass blades) that are permanently exposed to UV radiation, this assessment will be particularly focused on the exposed portion of the system. However, the UV longevity of the PP geotextile backing and HDPE geomembrane will also be addressed by reference.

Geosyntec's approach to this assessment has been to conduct a literature review of pertinent documents available (journal papers, white papers, presentations, etc.), distill the results of the review, and perform limited analysis. This report concludes with a summary of the review and analysis along with brief discussion for recommendations.

EXECUTIVE SUMMARY

The UV longevity assessment of the ClosureTurf® system (Figure 1) began with a literature review. In general, relatively little published information was discovered regarding exposed HDPE grass blade degradation. The information that is available consists of retained tensile strength test results of HDPE grass blades after exposure (1, 5, 7 and 10 years) at a field test facility in New River, Arizona (Watershed, 2014). Extrapolation of this data by Watershed (2014) resulted in a prediction of 65% retained tensile strength after 100 years of service. In addition, Richgels *et al* (2015) published half-life (i.e., 50% retained tensile strength) predictions of exposed HDPE grass blades using a laboratory data release from the Geosynthetics Institute (GSI) on HDPE geomembrane strips exposed to UV lamp irradiation. Richgels *et al* (2015) obtains an upper bound and lower bound half-life predictions of 247 years and 176 years, respectively. Extrapolation of the field data from New River, Arizona yielded a half-life of 216 years.

Geosyntec checked the calculations shown in Richgels *et al* (2015) and obtained 277 years and 214 years for the upper and lower bound estimates of HDPE grass blade half-life. Differences in the results between Geosyntec and Richgels *et al* (2015) are attributed to rounding. Geosyntec attempted to repeat these calculations for actual performance requirements (i.e., 12.5% of original tensile strength) of the HDPE grass blades rather than a randomly assigned half-life, however the predictions resulted in service lives that were too lengthy to be reasonable. The most likely explanation is that the laboratory data has not degraded enough to allow for service life predictions using 12.5% retained tensile strength. Future data releases from GSI will aid in providing more accurate predictions below the half-life.

Based on Richgels *et al* (2015) predictions, as well as the prediction given in Watershed (2014) it appears that the half-life of the HDPE grass blades exposed to Arizona-like conditions is on the order of 100 years. These results are promising; however additional field test data is needed to improve the half-life predictions, particularly since half-life predictions for exposed HDPE geomembrane are also approximately 100 years (Koerner *et al*, 2015). Understanding the differences in weathering between HDPE grass blades in a synthetic turf and an HDPE geomembrane will provide additional insight into the similar half-life predictions of the two geosynthetics. Finally, the service life of the HDPE grass blades in the ClosureTurf® system should ideally be based on its performance requirements rather than a half-life which will result in a longer service life prediction.

In addition to the HDPE grass blades, there are two unexposed elements of the ClosureTurf® system: (i) the PP geotextile backing for turf component; and (ii) the Super Gripnet® which consist of a HDPE geomembrane (see Figure 1).

Watershed has incorporated UV degradation inhibitors into the PP geotextile backing which, according to Watershed has lead to an improvement in UV resistance by a factor of 14 over the original prediction of 65% retained tensile strength after 100 years (Watershed, 2014). Koerner (2011) has estimated that covered HDPE geomembrane will have a half-life of 446 years at 20 degrees Celsius and 265 years at 25 degrees Celsius.

Therefore, the most critical component of the ClosureTurf® appears to be the exposed HDPE grass blades when it comes to UV degradation. However, degradation of the HDPE grass blades to unserviceable levels can be remediated by replacement of the turf component of the ClosureTurf® system.

BACKGROUND AND LITERATURE REVIEW SUMMARY

In total, Geosyntec has reviewed approximately 40 technical documents to date. The database is a combination of documents provided to Geosyntec by Watershed as well as documents collected by Geosyntec. A complete reference list of the documents in the database can be made available upon request.

In general, relatively little information was found on the topic of exposed HDPE grass blades with respect to degradation due to UV radiation. The documents that were obtained and reviewed are listed below.

1. Field test data provided by Watershed from the New River, Arizona testing facility on the HDPE grass blades (Watershed, 2014).

2. Testing results (Atlas-MTS) discussing the UV longevity of polyethylene and polypropylene grass used for outdoor European athletic facilities.

3. Technical paper by Richgels, *et al.* (2015a) published in the conference proceedings for Geosynthetics 2015 in Portland, Oregon.

4. Presentation by Richgels., C. at the Geosynthetics Conference for 2015 in Portland, Oregon (Richgels, 2015b).

5. Presentation by Diguilio, D. at the Northern New England SWANA Conference on 25 September 2013 (Diguilio, 2013).

The following documents on the topic of HDPE Geomembrane degradation due to UV exposure were reviewed and found to contain useful information regarding this assessment.

1. Geosynthetic Research Institute (GRI) White Paper #6 (Koerner *et al*., 2011). This white paper contained degradation data (% retained strength and elongation) on laboratory aged samples of 1.5 mm HDPE geomembrane. Aging was completed using a UV Fluorescent device per ASTM D7238 at 70 degrees Celsius (^{o}C).

2. Geosynthetic Institute (GSI) webinar presentation by Koerner *et al*., (2015). This presentation contained a slide that compared predicted (laboratory vs. field) half-life of geomembranes of various resins, including HDPE, as well as a suggestion for estimating lower bound half-life.

3. Journal paper authored by Rowe *et al*. (2010) published in the Journal of Geotechnical and Geoenvironmental Engineering.

DISCUSSION OF DOCUMENTS AND DATA

The data from the New River, AZ testing facility on the artificial grass component of ClosureTurf® (Watershed, 2014) appears to be the only data set of its kind in our compiled database. The data consists of tensile property testing from field samples exposed to the Arizona environment at approximate exposure periods of 1, 5, 7 and 10 years. At each of the four exposure periods, 20 samples were tested for a total of 80 tests. The average values for tensile strength retained at each corresponding time period is 97%, 90%, 84% and 83%, respectively (Figure 2).

One additional data point was found in the Atlas-MTS document. That data point indicated that approximately 90% of tensile strength of polyethylene grass would be available after 20 years of field exposure assuming average European climatic conditions (temperature, irradiance, etc.). However, the average European irradiance is approximately one-half to one-third that of Arizona (Figure 3) notwithstanding temperature effects. Therefore, the Atlas-MTS data point will be consistent with the data from the New River, AZ facility in the 7 to 10 year time frame once adjusted for the relative levels of exposure and temperature between Europe and Arizona. As such, this data point will not extend the exposure duration covered by the New River, AZ data.

The paper and corresponding presentation by Richgels (2015a, 2015b) utilized the laboratory data released from the GSI on UV degradation of HDPE samples to make upper and lower bound estimates of the field half-life of the HDPE grass blades. The upper bound method utilizes Arrhenius modeling of lab data to project exposure times at half-life to site temperatures combined with ratios of UV irradiance between the laboratory lamp and monthly average irradiance at New River, AZ to develop half-life loss per month. A similar procedure using a linear extrapolation (rather than Arrhenius) was demonstrated for a lower bound estimate. The Watershed (2014) field data set was plotted in between the upper and lower bound estimates. This method is further discussed in the section below titled, "HDPE Grass Blade Service Life Calculations".

Koerner *et al*. (2011) discusses the UV longevity of both exposed and unexposed geomembranes made from various resins, including HDPE based on GSI's laboratory testing program. This document is particularly useful in regard to the ClosureTurf® elements that are considered non-exposed (i.e., the PP geotextile backing for the turf component and the underlying HDPE geomembrane).

The presentation by Koerner *et al*. (2015) includes estimates of half-life of exposed HDPE geomembranes as well as a recommendation for linear data extrapolation as a lower bound limit that was implemented by Richgels (2015b).

PERFORMANCE REQUIREMENTS

The definition of service life of an HDPE (or other resin) geosynthetic (grass blades and geotextiles/geomembranes) typically invokes the half-life criteria. However, the half-life criteria is arbitrary and while useful as a general indicator for comparison it does not directly relate to any aspect of field performance for ClosureTurf® or any other geosynthetic. Therefore it is more appropriate to define the service life in terms of field requirements placed on the material.

HDPE Grass Blades

For the case of the HDPE grass blades on the ClosureTurf® system, tensile strength requirements fall in the range of 2.5 to 3.5 lbs, based on applied loads of pullout forces from equipment operation and water runoff forces (Diguilo, 2013). The ClosureTurf® HDPE grass blades are manufactured with 20 lbs. of tensile strength immediately following the process (Diguilo, 2013). Therefore, without considering a factor of safety, the required tensile strength of the HDPE grass blade is equal to approximately 12.5% to 17.5% of original strength capacity.

PP Geotextile Backing and HDPE Geomembrane

Performance requirements for the PP geotextile backing and HDPE geomembrane depend on more site-specific parameters (e.g., steepness of slopes, seismicity, etc.) than the HDPE grass blades. Therefore until a parametric study is completed which will define the performance requirements over a range of expected conditions, the half-life will have to be used as a benchmark for degradation of the PP geotextile and HDPE geomembrane.

HDPE GRASS BLADE SERVICE LIFE CALCULATIONS

In order to develop a prediction for the longevity of the HDPE grass blades with respect to UV degradation, Geosyntec implemented the method found in Richgels (2015a, 2015b) for two levels of retained tensile strength. The first level is the 50% of tensile strength, or half-life, criterion that is commonly used as a benchmark for geosynthetic service life. Geosyntec performed this calculation to compare our results with the results presented by Richgels (2015a, 2015b). Once the half-life estimates were calculated, Geosyntec attempted to repeat the calculations using a retained tensile strength of 12.5% of an HPDE grass blade.

Half-Life Estimation (50% of Retained Strength)

The assessment utilized by Richgels (2015a, 2015b) begins with a laboratory data release from GSI (Figure 4). The data includes retained tensile strength of HDPE samples that have been incubated under a UV lamp at elevated temperatures, which accelerates the UV weathering process in accordance with ASTM D7238.

As mentioned, the GSI data includes samples tested at three elevated temperatures: (i) 80 degrees Celsius (^{o}C); (ii) 70^{o}C; and (iii) 60^{o}C. The testing program appears to have originally included only the 70^{o}C data, with the 80 ^{o}C and 60^{o}C testing added at a later date (therefore, weathering is not as advanced). The 70^{o}C data set has reached approximately 66%, while the 80^{o}C and 60^{o}C data sets have reached approximately 78% and 86%, respectively. Nonetheless, logarithmic extrapolations to 50% retained strength were performed for each data set. The amount of exposure time (on a log scale) corresponding to the 50% retained strength plotted vs. the inverse of the corresponding temperature (80^{o}C, 70^{o}C and 60^{o}C) is shown in Figure 5. Figure 5 allows for extrapolation to find the laboratory exposure time required to achieve 50% retained strength at temperatures lower than the test temperatures (i.e., actual field temperatures).

Once the curve is defined relating any temperature to a level of laboratory lamp exposure, the remaining task is to develop a relationship between laboratory exposure and field exposure for a particular site. In this case, the testing site in New River, AZ where Watershed has performed tests on HDPE grass blades, was selected.

Richgels (2015a, 2015b) presents monthly averages at the site for: (i) peak turf temperature; and (ii) irradiance as a fraction of the laboratory lamp irradiance. Using these two values for a given month combined with the Arrhenius model, an estimate of half-life loss per month is obtained. Summation of the half-life lost per month over a year yields the annual half-life loss. The inverse of the annual half-life loss is the predicted half-life in years. Using this method, Richgels obtains a half-life of approximately 247 years, while Geosyntec obtained a half-life of 277 years using the same data (Table 2). The difference is attributable to rounding errors in the logarithmic projections.

Following the suggestion of Koerner *et al*. (2015), Richgels (2015b) treated the results of the half-life mentioned above as an upper bound estimate. For the lower bound estimate, Koerner *et al*. (2015) suggests performing a linear extrapolation of the laboratory data to lower field temperatures, rather than using the Arrhenius model.

With the linear extrapolation, the ratio of monthly irradiance to laboratory lamp irradiance is scaled linearly to calculate the number of months required to reach half-life at 80C, 70C and 60C. Linear extrapolations per month are made from the elevated temperatures to the corresponding peak turf temperature in that month. The resulting half-life loss per month is summed to obtained half-life loss per year. The inverse of that result is the half-life in years. Richgels (2015b) calculates a half-life of 176 years using this linear model. Geosyntec's calculation using the same data resulted in a half-life of 214 years (Table 3 and Figure 6). The difference in the calculations is approximately the same as with the calculation using the Arrhenius (logarithmic) model.

Figure 7 shows the calculated upper (Arrhenius - logarithmic) and lower (linear) bound curves calculated by Richgels (2015b) along with the field data on the HDPE grass blades provided by Watershed (2014). As shown in Figure 7, the trend line fit to the field data falls in between the upper and lower bound curves produced by Richgels (2015b). Note that the first point from the field data at approximately 1 year is omitted from the trend line. This is because the first data point is assumed to be within the anti-oxidant phase of degradation rather than the polymer oxidation stage as suggested by Rowe *et al*. (2010). Additional discussion regarding the stages of degradation for polyolefin materials can be found in CUR 243 (2012).

Service Life Estimation Based on Performance Requirements (12.5% of Retained Strength)

Geosyntec repeated the calculations discussed above for the estimation of half-life, but extrapolated the GSI laboratory data down to 12.5% rather than 50% at 80C, 70C and 60C. Upper bound

(Arrhenius – logarithmic) and lower bound (linear) estimates were 2,500 years and 2,043 years, respectively.

These estimates of service life are simply too large to be reasonable. A likely explanation is that the samples tested at 80C, 70C and 60C have not degraded enough to produce accurate predictions at 12.5% retained strength. As previously mentioned, the data for 80C has reached 78% retained strength; the data for 70C has reached 66% retained strength; and the data for 60C has reached 86% retained strength. Therefore, the extrapolation for each of these data sets to 50% retained strength will be much more accurate than extrapolations to 12.5%. In addition, small uncertainties in log-based extrapolations will greatly influence results.

For these reasons, it is not practical or useful at this time to quantitatively assess service life in terms of actual performance requirements when those requirements are substantially below the half-life. There is some value, however in a qualitative use of performance requirements in comparisons with half-life estimates (i.e., to establish the factor of safety remaining at 50% degradation).

SUMMARY AND CONCLUSIONS

Geosyntec's literature review of approximately 40 documents yielded few sources of UV degradation data for exposed HDPE grass blades. Relevant data that was found included the field test data from the New River, AZ testing facility provided by Watershed (2014) and one data point from Atlas-MTS. The Atlas-MTS data point indicated that HDPE grass blades in average European climatic conditions would retain approximately 90% of its original strength after 20 years of field exposure. Taking into account the differences in temperature and UV irradiance between New River, AZ and European averages, the data point is consistent with the New River, AZ test data in the 7 to 10 year range.

Following the method presented in Richgels (2015a, 2015b) for HDPE grass blades, Geosyntec calculated an upper bound half-life of 277 years compared with Richgels 247 years using the Arrhenius (semi-log) extrapolations to site temperatures and ratio of laboratory lamp to field irradiance. Geosyntec calculated a lower bound half-life based on linear temperature extrapolations, as suggested by Koerner *et al*. (2015), of 214 years compared with 176 years obtained by Richgels (2015b). The differences between Geosyntec and Richgels calculations were attributed to rounding. As shown in Figure 7, the field data from New River, AZ suggests a half-life of 216 years when considering only the last three data points (i.e., polymer oxidation stage).

Another prediction of HDPE grass blade degradation is included in Watershed (2014) using the same (New River, AZ) field data. That prediction of retained tensile strength at 100 years of service life is 65%.

Therefore, it appears that the half-life of the HDPE grass blades will be on the order of 100 years based on the existing field data set and extrapolation methods found in the literature and presented herein. The results are promising; however additional field test data is needed to improve the half-life prediction, particularly since the half-life predictions for exposed HDPE geomembranes are also approximately 100 years (Koerner, 2015). Half-life predictions presented herein will also need to be revisited when additional labratory data is released from the GSI testing program.

Geosyntec attempted to calculate the service life of the HDPE grass blades using 12.5% of retained strength, rather than an arbitrarily assigned half-life. However, the calculation resulted in unreasonably long service life. This result is likely due to uncertainties in extrapolating the laboratory data released from GSI down to the 12.5% retained strength level. The data release has degraded to 78%, 66% and 86% for the 80 °C, 70 °C, and 60 °C test temperatures. Therefore, extrapolations to 50% may be warranted while extrapolations to 12.5% may not be until additional lab data is available. That being said, it should be recognized that half-life, or 50% of retained strength, has a factor of safety of 2.8 to 4.0 when considering the tensile capacity performance requirements of HDPE grass blades.

With regard to the unexposed elements of the ClosureTurf® system, Watershed (2014) indicates that the retained tensile strength of the PP geotextile backing prior to the addition of UV inhibitors is 65% after 100 years. This estimate is based on exhumed samples of the geotextile from the LaSalle-Grant Landfill in Louisiana. According to Watershed (2014), the addition of proprietary UV inhibitors to the PP geotextile backing has led to an improvement in UV resistance by a factor of 14. The final geosynthetic in the ClosureTurf® system is the covered HDPE geomembrane. Koerner (2011) estimates that the half-life of a covered HDPE geomembrane is 446 years at 20C, and 265 years at 25C. Furthermore, the degradation of the unexposed elements of the ClosureTurf® system invoke the half-life criteria. As discussed with regard the exposed HPDE grass blades, actual performance requirements should ideally be used to determine system longevity. However, the existing testing programs need to be allowed to degrade further before projections to lower values are made.

It is worth reiterating that applications of ClosureTurf® in areas of the United States where the UV irradiance and the temperatures are lower will result in longer half-life predictions than discussed above. In some cases (e.g., the Northeastern States), the differences will likely be quite large when compared with Arizona.

Finally, once UV degradation of the most susceptible component of ClosureTurf® (i.e., the exposed HDPE grass blades) does result in a tensile break, replacement of the HDPE grass and PP geotextile backing can be performed.

CLOSING

Geosyntec appreciates the opportunity to assist Watershed in the development of its ClosureTurf® products. Questions and comments may be directed to either of the undersigned at 678-202-9500.

Sincerely,

Will Tanner, P.E.
Project Engineer

Ming Zhu, Ph.D., P.E.
Senior Engineer

Attachments: References
Tables
Figures

Copies to: Bill Gaffigan (Geosyntec)
Mike Ayers (Watershed)

REFERENCES

Atlas Materials Testing Solutions, (Atlas-MTS). "Artificial Grass Yarns – Improving Sports Performance".

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TABLES

Table 1. Selected Sites where ClosureTurf® has been Installed.

Select ClosureTurf® Installations				
Installation	**Type**	**Acres**	**State**	**Year**
Progressive - Weatherford	Public – MSW	8.5	Texas	2010
Progressive - Timberland	Public - MSW	4	Louisiana	2011
Crazy Horse (Salinas SWA – Monterey)	City – MSW	65	California	2012
Saufley Landfill (Escambia)	Public – C&D	22.5	Florida	2012
Georgia Pacific	Independent	70	Georgia	2013
Berkeley County Landfill	City - MSW	12	South Carolina	2013
Lanchester Landfill (Chester)	City - MSW	7	Pennsylvania	2013
Tangipahoa Parish	City – MSW	22	Louisiana	2013
Sandtown – (Berkeley County)	City – MSW	4	Delaware	2013
Si-County Landfill	EPA – Region 6	5	Texas	2014
Holcim Cement Landfill (Kiln Dust)	Independent	46	New York	2015

Table 2. HDPE Grass Blade Upper Bound Half-Life Calculations (Geosyntec)

Month	UV Lamp On[1] (hrs/day)	Peak Turf Temp[2] (C)	Peak Turf Temp (K)	Peak Turf Temp (1/K)	Reaction Rate[3]	Lab Half-Life[4] (lamp hrs)	Field Equivalent[5] (days)	Field Equivalent[6] (months)	Half Life Loss per Month[7]
January	4.00	27.99	301.14	0.0033	-15.67	6385286	1596322	51494	1.94196E-05
February	4.94	27.96	301.11	0.0033	-15.67	6401982	1296604	46307	2.15949E-05
March	6.13	33.94	307.09	0.0033	-15.11	3632197	593012	19129	5.22755E-05
April	6.94	40.58	313.73	0.0032	-14.50	1983742	285945	9531	0.000104915
May	7.25	51.21	324.36	0.0031	-13.58	792646	109330	3527	0.000283544
June	7.31	61.52	334.67	0.0030	-12.75	344593	47124	1571	0.00063662
July	6.94	66.82	339.97	0.0029	-12.34	228887	32993	1064	0.000939599
August	7.00	64.80	337.95	0.0030	-12.50	267230	38176	1273	0.000785841
September	6.94	59.43	332.58	0.0030	-12.91	406208	58553	1889	0.000529439
October	5.88	47.74	320.89	0.0031	-13.88	1062504	180852	5834	0.000171411
November	4.56	36.38	309.53	0.0032	-14.88	2899472	635501	21183	4.72069E-05
December	3.69	24.68	297.83	0.0034	-15.99	8826208	2393548	77211	1.29515E-05
Lab	20							**Yearly Half-life Loss[8]**	0.003604818
								Half-life[9] (years)	277.41

Notes:

(1) UV Lamp On (hours per day) is given in Richgels (2015a, 2015b).
(2) Peak Turf Temps for New River, AZ given in Richgels (2015a, 2015b).
(3) Reaction Rate is calculated from the regression curve shown in Figure 4 for the upper bound (logarithmic) case.
(4) Lab half-life in hours is equal to 1/e^(Reaction Rate).
(5) Field equivalent (days) is calculated by dividing the lab half-life in hours by the UV lamp on hours per day.
(6) Field equivalent in days is converted to months using the given days in that particular month.
(7) Half-life loss per month is the inverse of the corresponding field equivalent in months.
(8) The yearly half-life loss is the sum of each individual months half-life loss.
(9) The half-life in years is the inverse of the yearly half-life loss.

Table 3. HDPE Grass Blade Lower Bound Half-Life Calculations (Geosyntec)

Month	UV Lamp On[1] (hours/day)	Months @ 80 C[2]	Months @ 70 C[2]	Months @ 60 C[2]	Peak Turf Temp[3] (C.)	Half-life Months (from Regression)	Half-life Loss per month
January	4.00	692	1507	3078	27.99	6948	0.000143933
February	4.94	620	1352	2761	27.96	6256	0.000159849
March	6.13	452	984	2010	33.94	4059	0.00024637
April	6.94	412	898	1834	40.58	3213	0.000311281
May	7.25	382	832	1698	51.21	2248	0.000444747
June	7.31	391	852	1740	61.52	1580	0.000633027
July	6.94	399	869	1775	66.82	1237	0.00080834
August	7.00	395	861	1759	64.80	1371	0.000729293
September	6.94	412	898	1834	59.43	1826	0.000547629
October	5.88	471	1026	2095	47.74	3070	0.000325779
November	4.56	627	1365	2788	36.38	5321	0.000187929
December	3.69	750	1635	3339	24.68	7945	0.000125871
Lab	20					**Yearly Half-life Loss**	0.00466405
						Half-life (years)	214.41

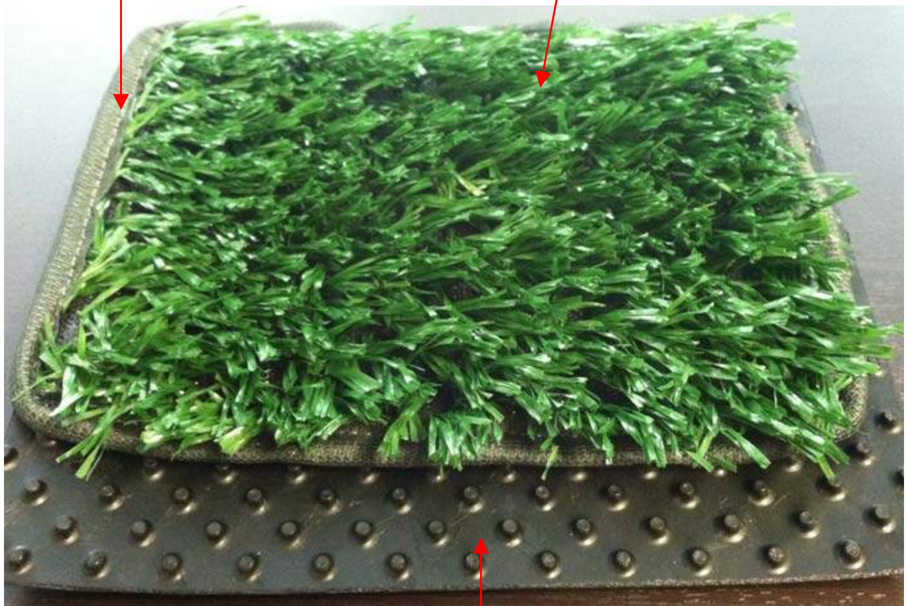
Notes:

(1) UV Lamp On (hours per day) is given in Richgels (2015a, 2015b).

(2) The months required at each temperature is calculated using the regressions from Figure 4 for each temperature, projected down to half-life, then dividing the lamp-hours at half-life by the UV lamp on hours per day for a given month. Once this calculation is done for 80, 70 and 60 C, a linear regression (as shown in Figure 5) is used to obtain the half-life months at the corresponding peak turf temp.

(3) Peak turf temperatures given in Richgels (2015a, 2015b).

FIGURES



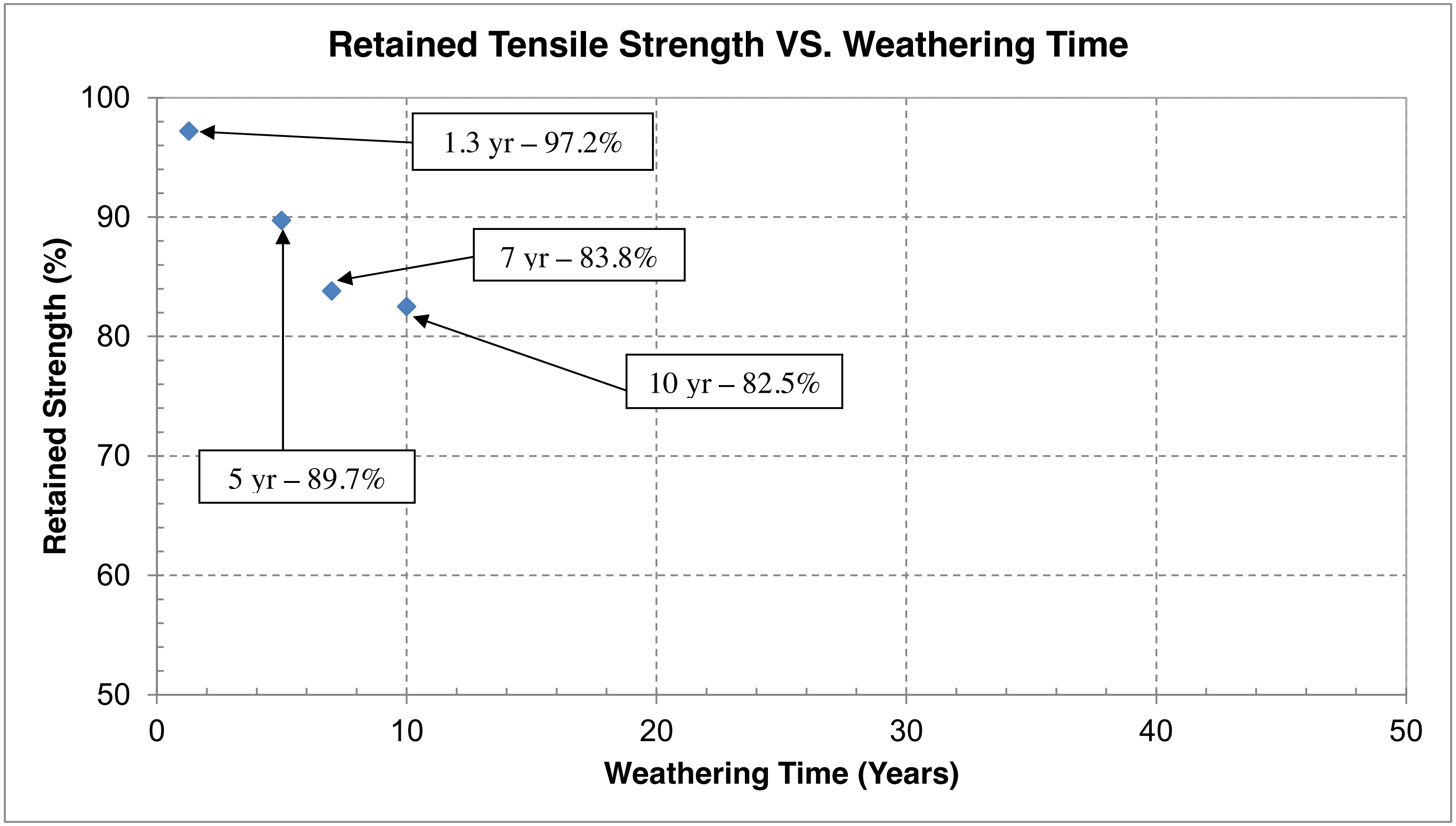
Note: The sand ballast infill is not shown in the sample photo on the left, but is shown in a field application photo on the right.

ClosureTurf® Components
Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 1

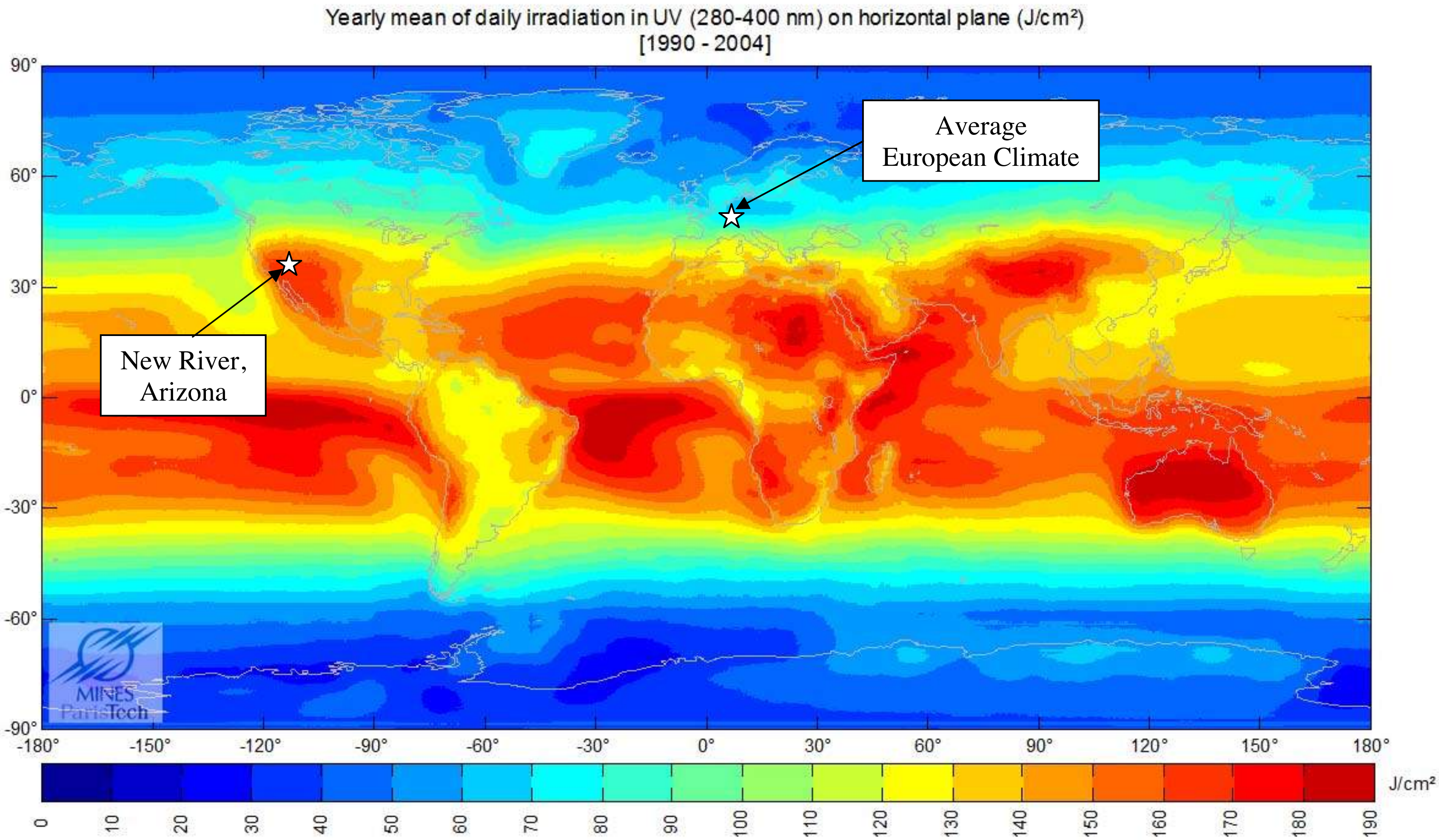
Kennesaw, GA | 23-April-2015



Notes:

1. The first data point at Weathering Time of 1.3 years is considered to be within the initial stage of UV degradation (i.e., anti-oxidant depletion), rather than polymer oxidation which is represented by the final three data points.
2. Each data point represents the average result of 20 tensile break tests.

Field Test Data (Watershed, 2014) **New River, AZ Atlas Testing Facility** Watershed Geosynthetics – ClosureTurf® UV Assessment		
Geosyntec consultants		Figure **2**
Kennesaw, GA	25-April-2015	



$1\ J/cm^2 = 4.755\ ft\text{-}lbs/in^2$

Yearly Irradiation in the Ultraviolet Range

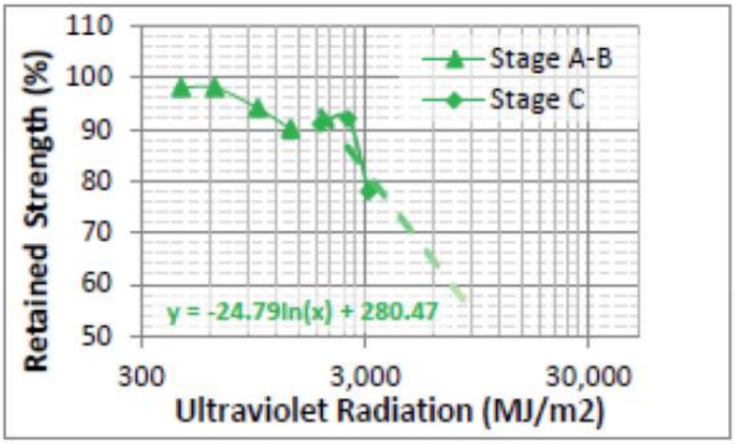
Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

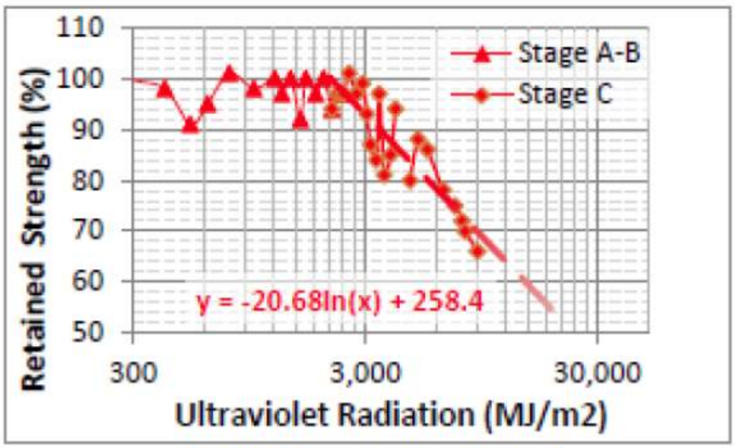
Figure 3

Kennesaw, GA

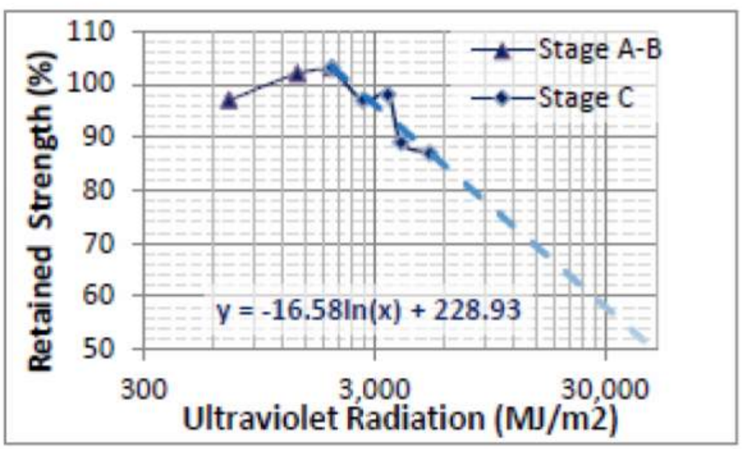
23-April-2015



a) 80°C Temperature Dataset

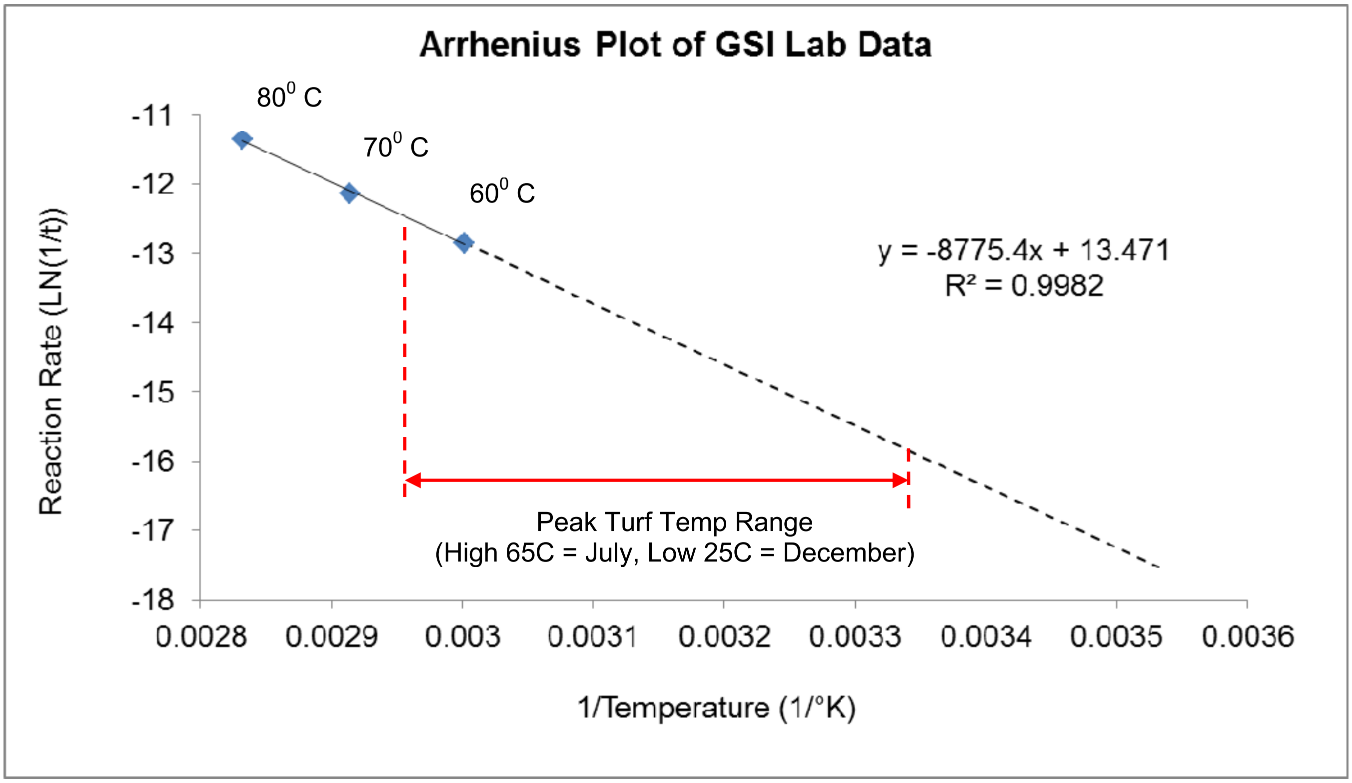


b) 70°C Temperature Dataset



c) 60°C Temperature Dataset

GSI Data Release - Three Stage Oxidation of HDPE for Different Temperatures Watershed Geosynthetics – ClosureTurf® UV Assessment	
Geosyntec consultants	Figure 4
Kennesaw, GA 23-April-2015	



Note: Richgels (2015b) mentions that the use of peak turf temperature is conservative since it only occurs for approximately one hour per day.

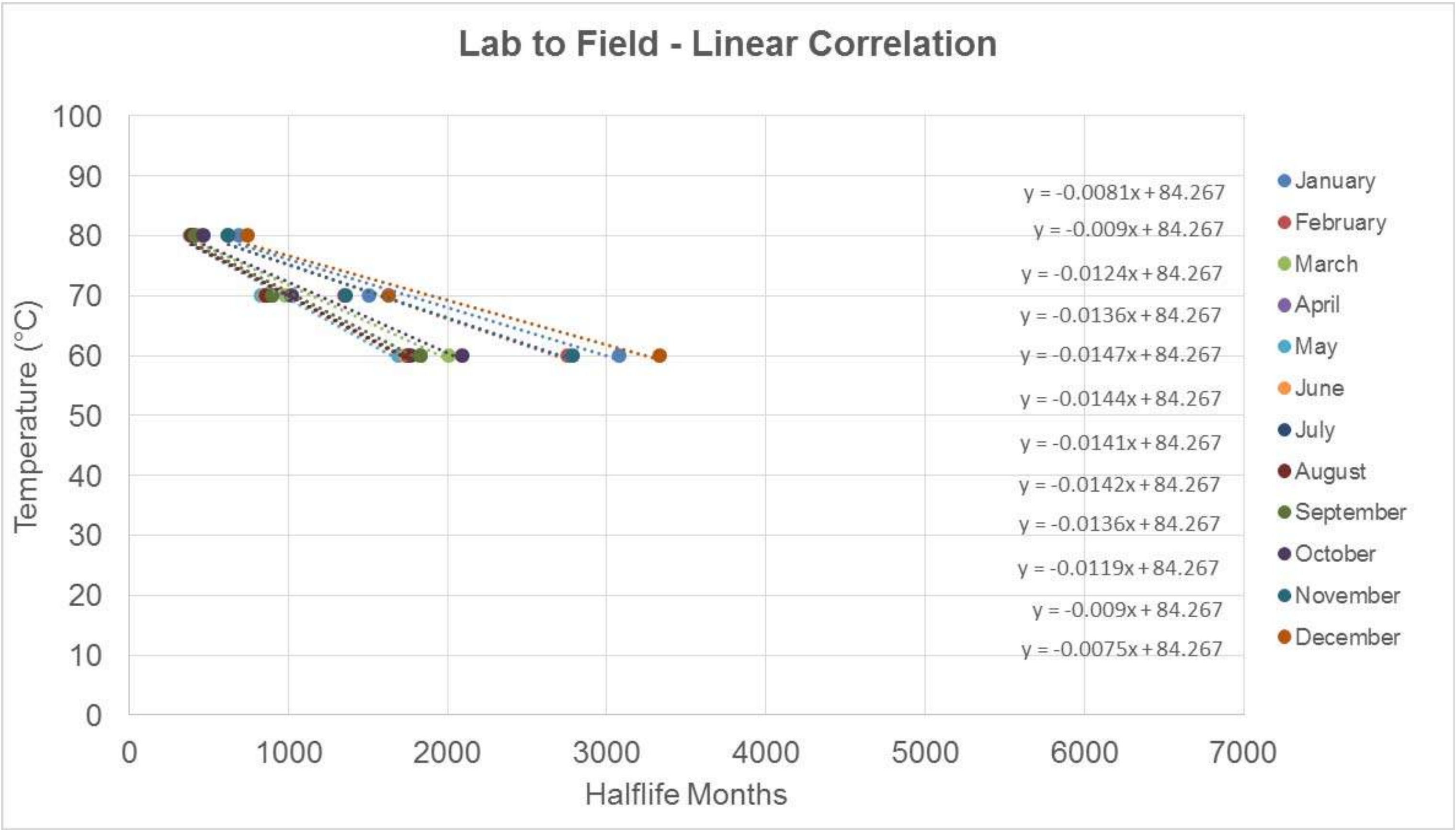
Arrhenius Plot of Lab Data

Watershed Geosynthetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 5

Kennesaw, GA | 23-April-2015



Note: Each month was projected down to the peak turf temperature given in Table 3 to get the half-life months. The inverse of half-life months is half-life loss per month. The sum of all the half-life losses for each month in a year is the yearly half-life loss, the inverse of which is the half-life.

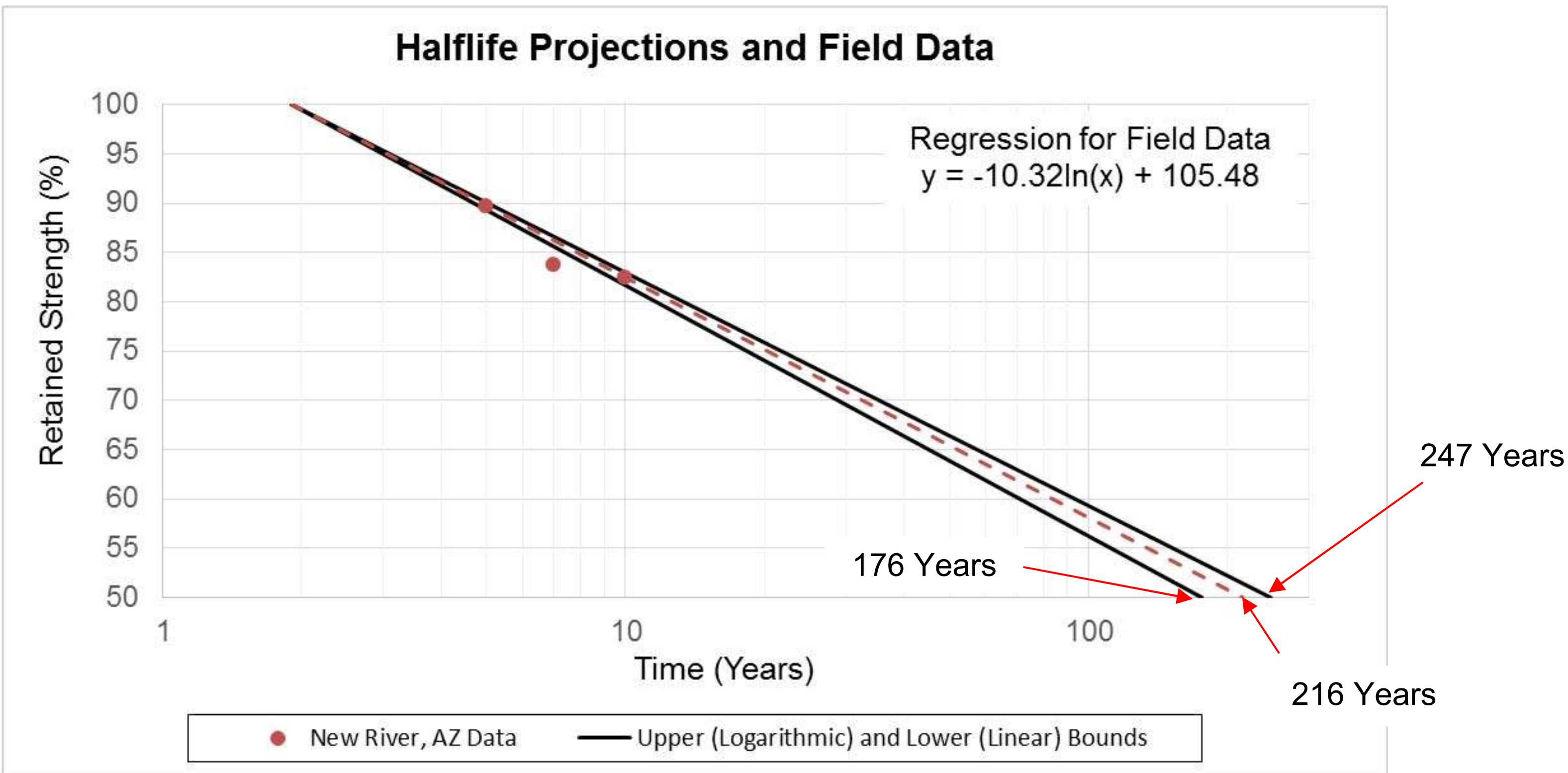
Linear Extrapolations for Half-life Months

Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure 6

Kennesaw, GA | 23-April-2015



Note: Geosyntec calculated an upper bound half-life of 277 years and a lower bound half-life of 214 years using the same data and method. Difference between Geosyntec and Richgels calculations are attributed to rounding.

Halflife Projections (Richgels, 2015a, 2015b)
Upper and Lower Bound Estimates
Watershed Geosythetics – ClosureTurf® UV Assessment

Geosyntec consultants

Figure **7**

Kennesaw, GA | 23-March-2015

Attachment C

Veneer Stability Analysis

Objective:

Determine the minimum drained and undrained strength parameters (friction angle and cohesion/adhesion), necessary to obtain the appropriate factors of safety for cover system stability, specifically for the proposed engineered turf system.

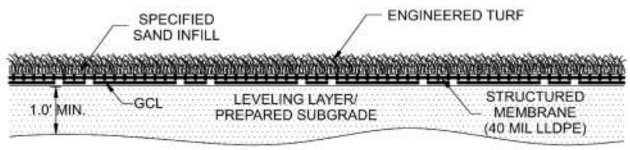


Figure 1. Cross Section (Typical ClosureTurf Cover)

Method:

Use methods outlined in journal paper *Influence Of Water Flow On The Stability Of Geosynthetic-Soil Layered Systems On Slopes* by Giroud et. al. for calculations of static stability. Seismic conditions are not evaluated because the facility is not located in a historically seismic active area.

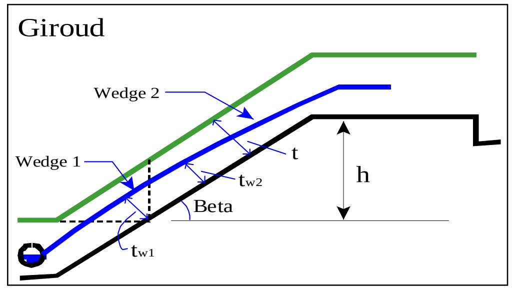


Figure 2. Variable Definitions

Figure 1 depicts Wayne Disposal proposed cover system design using engineered turf
Figure 2 shows variables assumed in Giroud's method

Calculations: Condition 1 - Static Unsaturated

Assume: the following conditions:

- No geosynthetic reinforcements
- No tension allowed in geosynthetics (T=0)
- No interface adhesion
- Geotextile/turf thickness is 0.5 mm
- GCL is two (2) 0.25 mm layers
- ClosureTurf and sand infill are fully interlocked and do not represent a critical interface.

Given: Soil conditions, liner system design, and slope geometry

Slope Geometry

Slope Angle (b)		4 :1 =	14.04	degrees
Slope Height (h)	205	ft		

Engineered Turf Material Properties

	Turf/GTX	Sand Infill	Wt. Avg.	
Thickness (t)	0.002	0.042	0.043	ft (GTX is 0.5 mm (assumed)/sand infill is 0.5 in typ.)
Dry Unit Weight (γ_d)	135.5	105.0	106.2	pcf (turf based on vendor info, sand is conservatively assumed)
` field cond. (w_F)	N/A	15.0	15.0	% (field moisture of sand conservatively assumed)
Unit Weight - field cond. (γ_T)	135.5	120.8	121.3	pcf
Specific Gravity (G_S)	N/A	2.65	2.65	(sand conservatively assumed)
Saturated Moisture (w_{SAT})	N/A	21.7	21.7	%
Saturated Unit Weight (γ_{SAT})	135.5	127.8	128.1	pcf
Buoyant Unit Weight (γ_B)	73.1	65.4	65.7	pcf
Total Normal Stress (σ)	0.22	5.03	5.25	pcf (total normal stress of ClosureTurf)
Shear Strength - both (ϕ) , (c)	25	deg,	0	psf (internal friction angle for sand, conservatively assumed)

Determine: The factor of safety (FS_A) against sliding of the engineered components along interfaces between materials above FML

where:
$$FS_A = \frac{\gamma_t (t - t_w) + \gamma_b t_w}{\gamma_t (t - t_w) + \gamma_{sat} t_w}\frac{\tan\delta_A}{\tan\beta} + \frac{a_A/\sin\beta}{\gamma_t (t - t_w) + \gamma_{sat} t_w} + \frac{\gamma_t (t - t_w^*) + \gamma_b t_w^*}{\gamma_t (t - t_w) + \gamma_{sat} t_w}\frac{t}{h}\frac{\sin\phi}{2\sin\beta\,\cos\beta\,\cos(\beta+\phi)} + \frac{c\,t/h}{\gamma_t (t - t_w) + \gamma_{sat} t_w}\frac{\cos\phi}{\sin\beta\,\cos(\beta+\phi)} + \frac{T/h}{\gamma_t (t - t_w) + \gamma_{sat} t_w}$$

δ_A = interface friction angle between engineered components above FML
a_A = adhesion between engineered components above FML
T = geosynthetic tension above the slip surface
t_w = thickness of flow in Wedge 2 (see Figure 2)
t^*_w = thickness of flow in Wedge 1 (see Figure 2)
(All other variables previously defined)

Determine: The factor of safety (FS_B) against sliding of the engineered components along interfaces between materials below FML

where:
$$FS_B = \frac{\tan\delta_B}{\tan\beta} + \frac{a_B/\sin\beta}{\gamma_t (t - t_w) + \gamma_{sat} t_w} + \frac{\gamma_t (t - t_w^*) + \gamma_b t_w^*}{\gamma_t (t - t_w) + \gamma_{sat} t_w}\frac{t}{h}\frac{\sin\phi}{2\sin\beta\cos\beta\cos(\beta+\phi)} + \frac{ct/h}{\gamma_t (t - t_w) + \gamma_{sat} t_w}\frac{\cos\phi}{\sin\beta\,\cos(\beta+\phi)} + \frac{T/h}{\gamma_t (t - t_w) + \gamma_{sat} t_w}$$

δ_B = interface friction angle between engineered components above FML
a_B = adhesion between engineered components above FML
(All other variables previously defined)

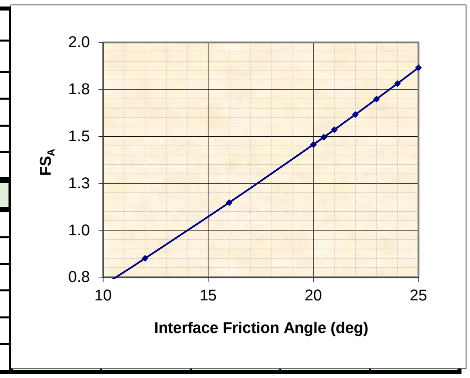
Calculations: Cover Condition 1 - Static Unsaturated (continued)

The first term quantifies the contribution of the interface friction angle to stability. The second term quantifies the contribution of the interface adhesion to stability. The third and fourth terms quantify the contribution of the toe buttressing effect, which results from the shear strength of the soil located at the toe of the slope above the slip surface. Both terms depend on the soil internal friction angle, whereas only the fourth term depends on the soil cohesion. The fifth term quantifies the contribution to the factor of safety of any tension in the geosynthetics located above the slip surface (which may include one or more geosynthetics specifically used as reinforcement).

Required angle of friction (δ) to obtain a FS_A and FS_B equal to 1.5 under unsaturated conditions is tabulated as follows:

Factor of Safety Above FML (FS_A)

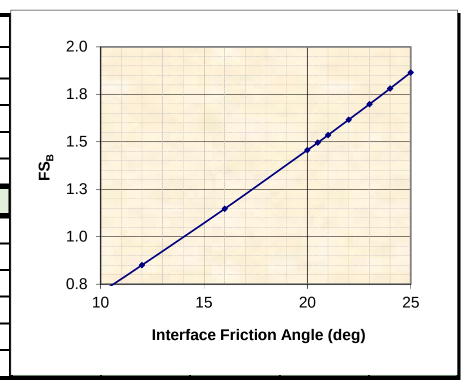
Interface Strength Param.		Water on slope		
δ_A (deg)	a_A (psf)	t_w (ft)	t^*_w (ft)	FS_A
10	0	0	0	0.71
12	0	0	0	0.85
16	0	0	0	1.15
20	0	0	0	1.46
20.5	0	0	0	1.50
21	0	0	0	1.54
22	0	0	0	1.62
23	0	0	0	1.70
24	0	0	0	1.78
25	0	0	0	1.87
26	0	0	0	1.95



► δ_A @ FS=1.5 20.5 deg ==> use 20.5 deg for spec. (check against other conditions)

Factor of Safety Below FML (FS_B)

Interface Strength Param.		Water on slope		
δ_B (deg)	a_B (psf)	t_w (ft)	t^*_w (ft)	FS_B
10	0	0	0	0.71
12	0	0	0	0.85
16	0	0	0	1.15
20	0	0	0	1.46
20.5	0	0	0	1.50
21	0	0	0	1.54
22	0	0	0	1.62
23	0	0	0	1.70
24	0	0	0	1.78
25	0	0	0	1.87
26	0	0	0	1.95



► δ_B @ FS=1.5 20.5 deg ==> use 20.5 deg for spec. (check against other conditions)

Calculations: Cover Condition 2 - Static Saturated

Determine: *The static factor of safety for $FS_{A\,\&\,B}$ assuming varying depth of surface water on top of the engineered turf modeling surface water depths from sheet and/or shalllow concentrated flow on top of the cover system. ClosureTurf does not have a subsurface drainage layer; therefore, evaluation of seepage induced pressure in the cover system is not applicable. The manufacturer of ClosureTurf has demonstrated that erosion of the sand infill is very unlikely under the anticipated flow conditions (See Attachment A) and flow will generally occur on top of the sand infill where relative permeability is much higher. Because of the shallow depth of sand infill, flow characteristics, and resistance to erosion, seepage forces within the sand can be neglected. Under these conditions, the first two terms in the stability equation reduce to:*

$$FS_{A\&B} = \frac{a}{(\gamma_t - \gamma_w)z}\frac{2}{\sin(2\beta)} + [cot\beta]tan\delta + \ldots.$$

The factor of safety should meet or exceed 1.1 under saturated conditions. Because seepage forces are neglected, there is no need to distiguish between the interfaces above or below the impermeable membrane. Assume minimum shear strength parameters δ and a are equal to values from analysis for Cover Condition 1. It should be noted that this analysis also assumes no apparent adhesion is present in the interface. This assumption is extremely conservative because each of the critical interfaces (GM/GCL/GCL/soil) all involve cohesive materials which likley will be present under wet conditoins. Any appreciable measureable apparent adhesion will make the materials inherently stable under their own

Assume: The following conditions:

- No geosynthetic reinforcements
- No tension allowed in geosynthetics (T=0)
- No interface adhesion
- Geotextile/turf thickness is 0.5 mm
- GCL is two (2) 0.25 mm layers
- ClosureTurf and sand infill are fully interlocked and do not represent a critical interface.
- Critical interface(s) are between the GM/GCL/GCL/subgrade soil
- Seepage forces are negligible and are not considered

Given: Soil conditions, liner system design, and slope geometry

Slope Geometry

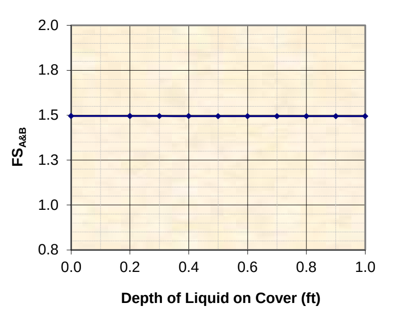
Slope Angle (b)	4 :1 =	14.04	degrees
Slope Height (h)	205 ft		

ClosureTurf Material Properties

	Turf/GTX	Sand Infill	Wtd. Avg.	
Thickness (t)	0.002	0.042	0.043	ft (GTX is 0.5 mm (assumed)/sand infill is 0.5 in typ.)
Dry Unit Weight (γ_d)	135.5	105.0	106.2	pcf (turf based on vendor info, sand is conservatively assumed)
Moisture - field cond. (w_F)	N/A	15.00	15.0	% (field moisture of sand conservatively assumed)
Unit Weight - field cond. (γ_T)	135.5	120.8	121.3	
Specific Gravity (G_S)	N/A	2.65	2.65	(sand conservatively assumed)
Saturated Moisture (w_{SAT})	N/A	21.7	21.7	%
Saturated Unit Weight (γ_{SAT})	135.5	127.8	128.1	pcf
Buoyant Unit Weight (γ_B)	73.1	65.4	65.7	pcf
Shear Strength - both (ϕ) , (c)	25 deg,		0	psf (internal friction angle for sand, conservatively assumed)

Factor of Safety Above FML ($FS_{A\&B}$)

Interface Strength Param.		Water on slope		
δ_A (deg)	a_A (psf)	t_w (ft)	t^*_w (ft)	FS_B
20.5	0	0.00	0.00	1.50
20.5	0	0.20	0.20	1.50
20.5	0	0.20	0.20	1.50
20.5	0	0.30	0.30	1.50
20.5	0	0.40	0.40	1.50
20.5	0	0.50	0.50	1.49
20.5	0	0.60	0.60	1.49
20.5	0	0.70	0.70	1.49
20.5	0	0.80	0.80	1.49
20.5	0	0.90	0.90	1.49
20.5	0	1.00	1.00	1.49



► $FS_{A\&B}$ reqd≥ 1.1 ==> minimum $FS_{A\&B}$ equals 1.49 with saturated sand infill ==> OK

Results: Tabular Summary of Analyses

Component	Controlling Analysis	Minimum Interface Shear Strength Parameters (Peak)*				
		ϕ (deg)	c (psf)	δ_A (deg)	δ_B (deg)	a (psf)
Sand Infill	Static Unsaturated, Minimum FS = 1.5	25	0	-	-	-
All geosynthetic and soil interfaces above FML	Static Unsaturated, Minimum FS = 1.5	-	-	20.5	-	0
All geosynthetic and soil interfaces below FML	Static Unsaturated, Minimum FS = 1.5	-	-	-	20.5	0

*Minimum specifications assume no cohesion/adhesion. Laboratory testing of the components over the range of normal stresses to be encountered in the field may result in a Mohr-Coloumb failure envelope suggesting a nonzero value for cohesion/adhesion. In such cases, the friction angle may be lower than that specified and still be acceptable as long as the actual shear strength for the materials is greater than the envelop developed with the minimum specification noted above.

Conclusions:

The proposed engineered turf cover system for WDI was evaluated for shallow translational/veneer failures along the geosynthetic components parallel to the slope. Worst case cross sections were utilized as noted in the analyses. Minimum factors of safety are based on typical industry standard values which were used to develop minimum strength parameters for each of the components. The minimum specifications noted above are within the range of reasonable characteristics for the materials involved. Therefore, the minimum specifications calculated are acceptable.

Attachment D

Wind Uplift Evaluation

July 8, 2010

Mr. Michael R. Ayres, P.E.
Closure Turf, LCC
3005 Breckinridge Blvd.
Duluth, GA 30096

Subject: **Aerodynamic Evaluations of Closure Turf Ground Cover Materials**

References: **1: Contract # AGR DTD 5/14/10**

Dear Mr. Ayres and Closure Turf LCC affiliates:

The Georgia Tech Research Institute is pleased to submit the attached Report, covering the period from May 14 to July 8, 2010, in fulfillment of Reference. This document details the tasks and analysis made on contracted work performed by the GTRI Aerospace, Transportation and Advanced Systems Laboratory and its team members on Phase I of the Project entitled "Aerodynamic Evaluations of Closure Turf Ground Cover Materials".

We look forward to continuation of this work for/with Closure Turf, LCC upon the adoption of Phase II activities related to aerodynamic investigation of Closure Turf Material or other desired evaluations.

Sincerely,

Graham M. Blaylock
Principal Investigator

Aerodynamic Evaluations of Closure Turf Ground Cover

Phase I REPORT

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Introduction

GTRI has been contracted by Closure Turf, LCC to **experimentally evaluate the aerodynamic properties and ballast requirements** of a novel synthetic ground-cover system under a range of wind speed conditions (V_{inf}). The Closure Turf Material was tested full-scale in **GTRI's subsonic Model Test Facility (MTF) wind tunnel** wherein the normal force loading (lb_f/ft^2) and the shear stress (lb_f/ft^2) were determined for a suitable section of the material. The turf material was tested in two configurations, one representing the perimeter of the turf installation (Fig 5) and the 2nd at a representative interior section (Fig 6). Both installations were evaluated on a **flat level surface**. The installation is shown in Figures 1a-d below.

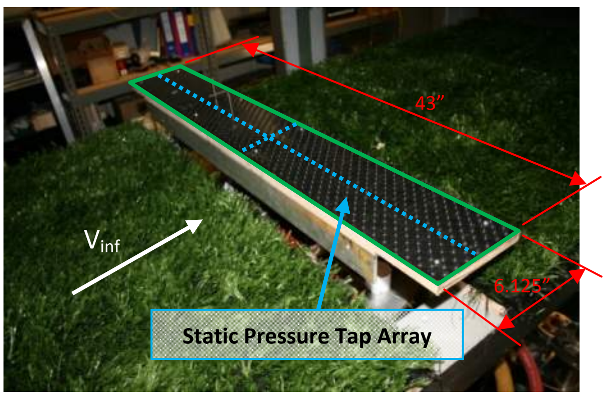


Figure 1a – Model Before Final Turf Layer

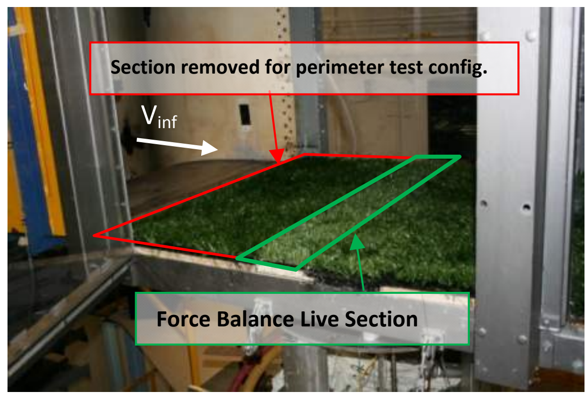


Figure 1b – Turf Installed & Model Lowered

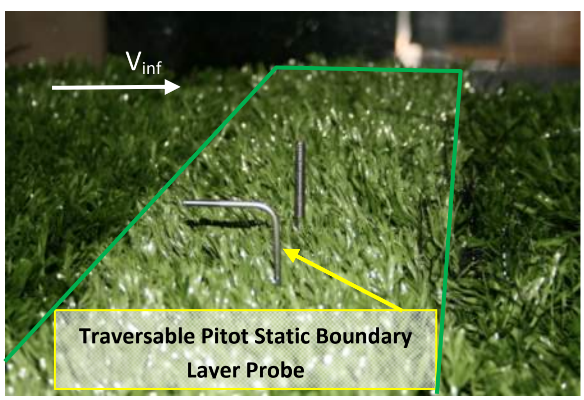


Figure 1c - Pitot Static Boundary Layer Probe

Figure 1d – Full Installation Looking Downstream

Program Description

Closure Turf system - The Closure Turf ground cover system consists of two independent layers. The first layer is a **geomembrane** to cap the upper soil layer. This is then covered with a **geotextile** turf layer (Fig 2a and 2b)

Geomembrane Layer -The impermeable geomembrane is made from Agru 50-mil LLDPE Super Gripnet® material and is used to cap the terrain being covered. It has an array of spikes to interface to the soil below and an array of studs to interface with the turf covering above. Throughout the testing and subsequent analysis of the Closure Turf system, **it was assumed that the geomembrane will be sufficiently installed to prevent movement of that layer.**

Geotextile Turf Layer – This component is designed to be installed on top of the geomembrane. The turf is intended to remain in place without an anchoring system linking it to the geomembrane below. It relies on the interface friction and sand ballast added on top of the turf to ensure that it remains immobile under all environmental conditions. It is constructed of two permeable sheets of woven HDPE mesh material which are linked together with synthetic blades of grass that are looped through the two HDPE substrates (Fig 2a).

Figure 2a – Closure Turf Synthetic Ground Cover System

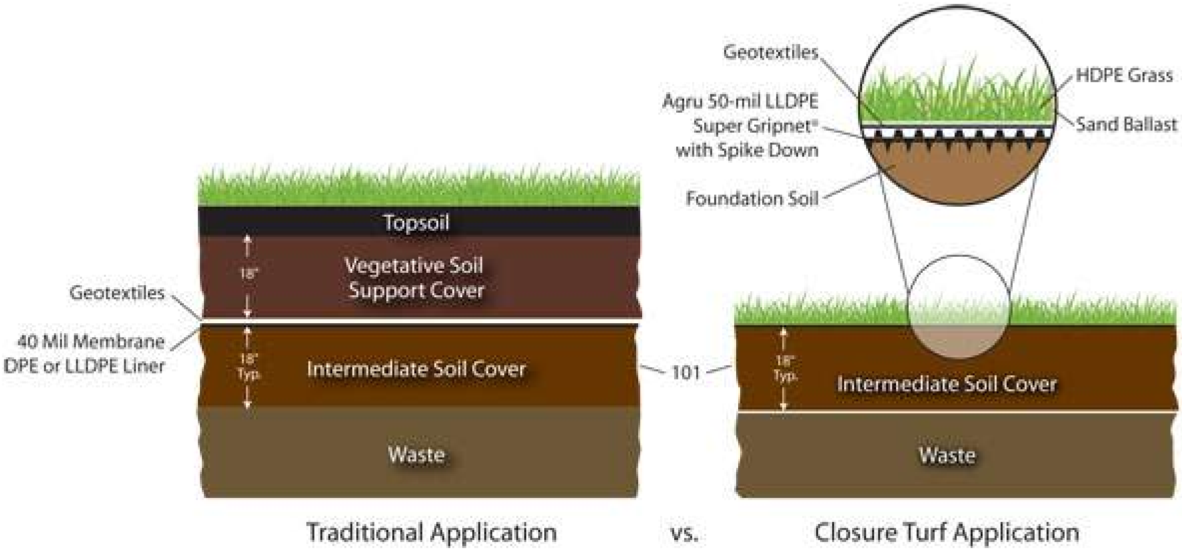


Figure 2b – Installation of Closure Turf

Purpose – The scope of this program was to conduct a full-scale wind tunnel test and experimentally isolate and measure the aerodynamic forces acting on a section of the permeable upper geotextile turf layer alone as installed above the impermeable geomembrane. The wind tunnel install configuration would simulate a wide range of wind speeds flowing over a **flat and level terrain installation** of the Closure Turf ground cover system (Fig 1a-d). The sand ballast requirements needed to counteract the resulting aerodynamic forces could then be determined. The purpose of the ballast is twofold. It serves to prevent both lift-off and tangential motion of the turf material along the geomembrane underlayment **resulting from aerodynamic lift and drag acting on the turf layer**.

Methodology

Model Design – The model represented a full-scale 2D section of the Closure Turf material with a 6.125" chord (stream-wise dimension) with a width of 43" that spanned the tunnel wall to wall. This area constituted the live balance section upon which the total sum of all aerodynamic forces could be measured by a 6 component force balance located under the test section. The model consisted of 4 layers listed below from the lower to uppermost turf layer

1) ¾" Furniture grade plywood support base – This incorporated several pressure taps on the underside in order to measure the ambient pressure (P_{amb}) to determine the vertical force (F_{amb}) due to pressure acting upward on the lower surface of the model.
2) Foam Filler Layer – This represented the soil layer surrounding the lower geomembrane spikes.
3) Impermeable Goemembrane Layer – This was fixed rigidly to the base. An array of static pressure taps was installed on the upper side of this layer, shown schematically in Fig. 1a. These

pressures were integrated numerically to determine the force (F_{geo}) due to pressure acting down on the membrane.

4) Geotextile Turf Layer – The turf was first mounted to a thin wire support frame to maintain the geometry and to provide a safety measure to prevent material from dislodging in the tunnel. The frame was then mounted rigidly on top of the lower construction flush with the top of the geomembrane upper surface studs.

Pitot Static Boundary Layer Probe – In general, pressure variation through the height of the boundary layer is due to viscous forces which cause deficits in the total pressure as the bounding flat and level surface is approached. The static pressure remains constant. However, the unique characteristics of the flexible and permeable turf layer warranted investigating the boundary layer formation on the Closure Turf system. To accomplish this, a traverse system was built into the model to actuate a Pitot static probe vertically through the boundary layer (Fig 1c). This allows the measurement of the total and static pressure as a function of the probe height, defined as h = 0" at the upper surface of the turf HDPE woven mesh. From these measurements the flow velocity distribution was determined. This characterizes the shape of the boundary layer which is by its nature a transition from the no slip condition at the surface ($V = 0$) to free stream conditions ($V = V_{inf}$). The characteristics of this boundary layer profile such as the BL thickness, the height required for the flow to reach free stream velocity, provide valuable insight into the observed results.

Force Balance – An under floor 6 component force balance was utilized to measure the aerodynamic lift (L) and the total drag (D) of the model. These forces were transmitted to the balance through a vertical strut which mounted to the underside of the model base. It should be noted that these forces represent the total sum of all pressure distributions acting on the model resolved vertically and tangentially. As such the isolated vertical force acting on just the turf layer (L_{turf}) is found by Equation 1.

$$L_{turf} = L - L_{amb} + L_{geo} \qquad \text{(Eq 1)}$$

Under the confines of this program, it was not feasible to separate the drag acting on just the turf from skin friction and pressure drag acting on the geomembrane. That being the case, the total drag as measured from the force balance was taken as the drag acting on the turf. This results in a conservative overestimation of the actual turf drag force present.

Installation Conditions – Two installation conditions were examined separately. To more accurately simulate the actual installation conditions, both geomembrane and turf layers were installed upstream and downstream of the balance live model (Fig 1b and 1d). This represents an **interior** condition and in this case the model was located approximately 18" inboard of the **perimeter**. It was also suspected that the perimeter, if unaccounted for, could lead to a worse case situation. To determine the nature of this the upstream turf was removed leaving just the geomembrane as a stand in for a typical surface soil roughness that could be expected at the edge of a real world installation. This left the model mounted turf exposed at the leading edge.

Results and Discussion

These results represent the required thickness of sand for the Closure Turf system as installed on **flat and level terrain**. The density of the sand was provided by Closure Turf. If a different material density is to be used as ballast, the results can be recalculated via Equation 2.

In all cases, **the driving parameter for the depth of the sand is tangential slip due to the aerodynamic formation of shear stress**. The sand ballast requirements have been illustrated in Figures 5 and 6 for several assumed representative interface coefficients of static friction (μ_s). The **minimum** required sand ballast height is found by Equation 2.

$$h_{sand}(in) = \frac{1}{\rho_{sand}}\left(\frac{\tau}{\mu_s} + P\right)\frac{12in}{ft} \qquad \text{(Eq 2)}$$

Where:

$$\rho_{sand} = Weight\ Density\ of\ Ballast(sand) = 110\ \frac{lb_f}{ft^3}$$

$$\tau = \frac{D}{Area} = Shear\ Stress, \frac{lb_f}{ft^2}$$

$$P = \frac{L_{turf}}{Area} = Normal\ Force\ Loading, \frac{lb_f(+tve\ up)}{ft^2}$$

The measured data for determining the sand depth are shown in Table I and Table II and plotted in Figures 5 and 6 for the perimeter and interior configurations respectively. The last column of each table gives the resulting sand height requirement, based on Equation 2, for μ_s = 0.93. This value was determined independently from the efforts of this program by Closure Turf affiliates and supplied for use in this analysis.

Perimeter Condition (PC) – The ballast requirement resulting from this configuration are substantially greater than the interior condition. For the given μ_s =0.93 a **minimum** sand height of 0.4" or 3.6 lb_f/ft^2 is needed to provide the ballast based on the resulting shear at 175 ft/s. The lifting pressure will be satisfied by this loading as shown in Figure 4. It should be noted that the required ballast height due to uplift goes from positive to negative at around 115 ft/s. There are several factors contributing to these results.

PC Boundary Layer (BL) – The profile for the perimeter condition is shown in Figure 4 (Red Curve). One characteristic to note is that the boundary layer thickness reaches 99% of free stream velocity at a height of approximately 2". This subjects the turf to up to 89% of the total free stream based on a max vertical blade height of 1.25". This has several resulting effects which can be followed in Figures 3a to 3f. The cascade of effects proceeds as follows.

The blades are subject to higher velocities and thus higher increasing drag as the wind speed increases. The higher drag increases the bending of the blades back onto the mesh substrate. The effect of this has 2 **counteracting effects on the net lift**. At lower velocities (Fig3a-b) the blades are bent slightly with the flow being deflected and accelerated of over the perimeter as shown by the tufts. This flow acceleration increases the **local** velocity and lowers the local static pressure **below** that of free stream static which creates the pressure differential building up in 3a and b Additionally, in this installation, the perimeter exposes the gap between the turf and the geomembrane which allows for some uplift pressure recovery beneath the turf. However, as the free stream velocity increases, the drag is increased further by virtue of greater velocity exposure in the relatively thin boundary layer, the bending angle of the turf also increases (Fig 3b-c). This bending produces an increasing down force reaction which starts to counteract the suction created by the local flow acceleration. Simultaneously, the slightly reduced turf profile geometry (caused by the increased bending) shown in Figure 3c-d begins to reduce the relative local flow acceleration and thus also reduces the suction. This continues until the net vertical force becomes zero at about 110 ft/s (Fig 3d) and continues to decrease through Figure 3f.

Interior Condition (IC) – This condition owes its behavior to the formation of a drastically different boundary layer than the perimeter as shown by the blue profile in Figure 4. Compared to the Perimeter profile it is 25% thicker with no measurable velocity until the height is greater than 50% of the turf length (0.75”). The blades thusly experience a maximum velocity of 45% of free stream. This reduces the drag acting on the turf layer. Furthermore, the static pressure remains constant as a function of height through the BL which effectively prevents the formation of a pressure differential on the flat and level permeable turf membrane.

The cause for the deficient boundary layer is created by longer flow paths over a given surface and all boundaries grow in thickness and increase in turbulence with increasing distance. In the case of Closure Turf, the interaction of the flow with the flexible blades causes this growth to occur quite rapidly. The distance producing the profile in Fig 4 was 18” however, the effect of the growing boundary layer can be seen even in the perimeter condition development in Figures 3a –f. The Model section (highlighted in yellow) is 6.125” wide. It is clearly seen that little to no defection occurs in the turf at a distance just over 6 inches behind the perimeter edge. Thus the boundary layer at further distances than 18” and greater from the perimeter can be expected to have minimal interaction with the turf. Figure 6 shows these results by producing measurements requiring minimal ballast.

<u>Final Comments and Executive Summary</u>

GTRI was contracted by Closure Turf to determine the effective required ballast in terms of sand thickness needed to counteract the aerodynamic forces versus wind velocity acting on a permeable geotextile synthetic turf ground covering material that is to be overlaid onto an impermeable geomembrane underlayment. *It was found that in both perimeter and interior loading conditions, the shear acting on the material serves as the more demanding factor for determining the ballast.*

- **The resulting measurements represent the forces acting on the permeable Turf Layer *only*. The impermeable geomembrane layer was to be assumed immobile as a founding assumption of this program**

- **If it is determined that the static interface friction coefficient (μ_s) between the soil and the lower side of the membrane is lower than that occurring between the turf and the membrane upper surface studs, the lower μ_s should be used in Equation 2 to recalculate the sand depth required by shear. The same shear data given in Tables I & II will apply because, as discussed within the methodology section, the measured shear could not be feasibly separated between the two layers independently and thus represents their combined effect.**
- **The sand ballast depths represented in Figures 5 & 6 and Tables I & II are the Minimum depths required, the proper factor of safety has been left to be determined by Closure Turf, LCC and the authorized building permit issuing agencies.**
- **The perimeter of the turf installation is much more demanding than interior sections.**
- **All measurements were made on a rigidly constrained system. It was not within the scope of this investigation to determine what dynamic effects might occur, including gusts or erosion of sand ballast or any possible unstable perturbations.**
- **All configurations consisted of flat and level terrain installation.**
- **All calculations and measurements assume that the blade length is increased to account for any added ballast material. This is to ensure that the installation matches the conditions as tested.**

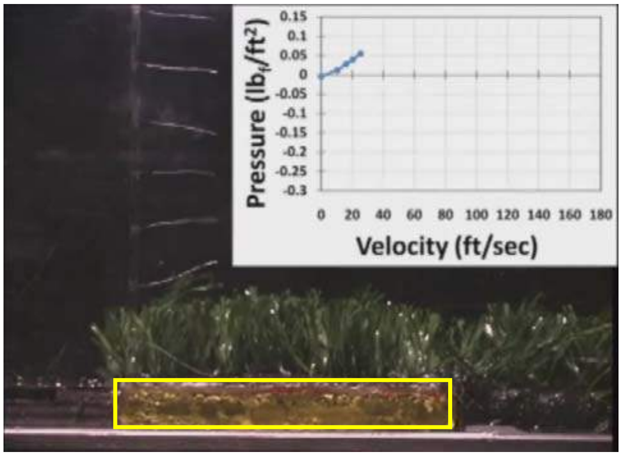


Figure 3a: Vinf = 25 ft/sec

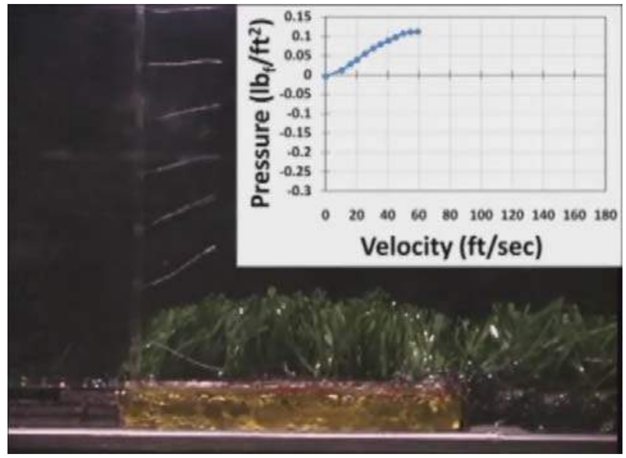


Figure 3b: Vinf = 60 ft/sec

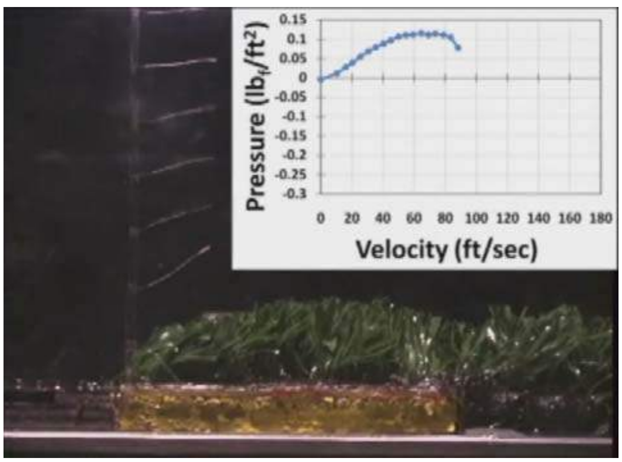


Figure 3c: Vinf = 90 ft/sec

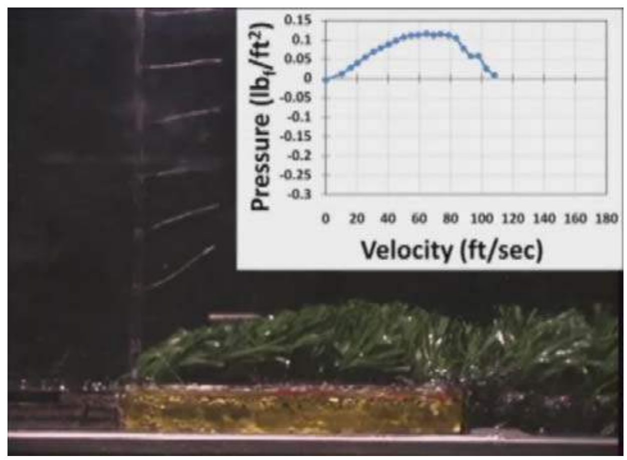


Figure 3d: Vinf = 110 ft/sec

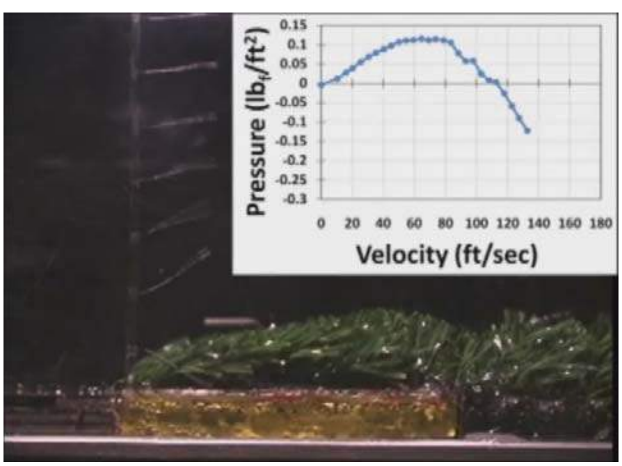


Figure 3e: Vinf = 135 ft/sec

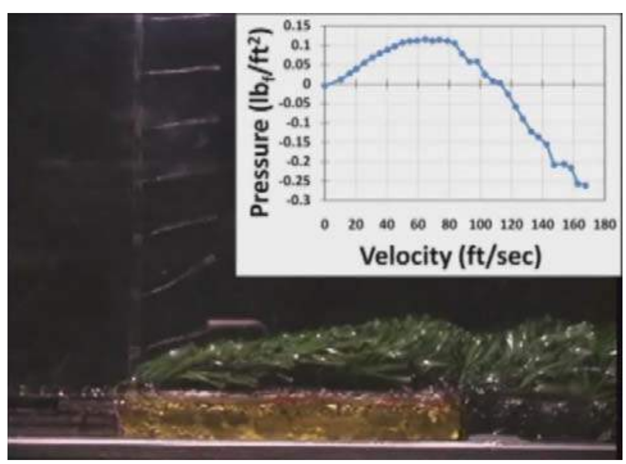


Figure 3f: Vinf = 170 ft/sec

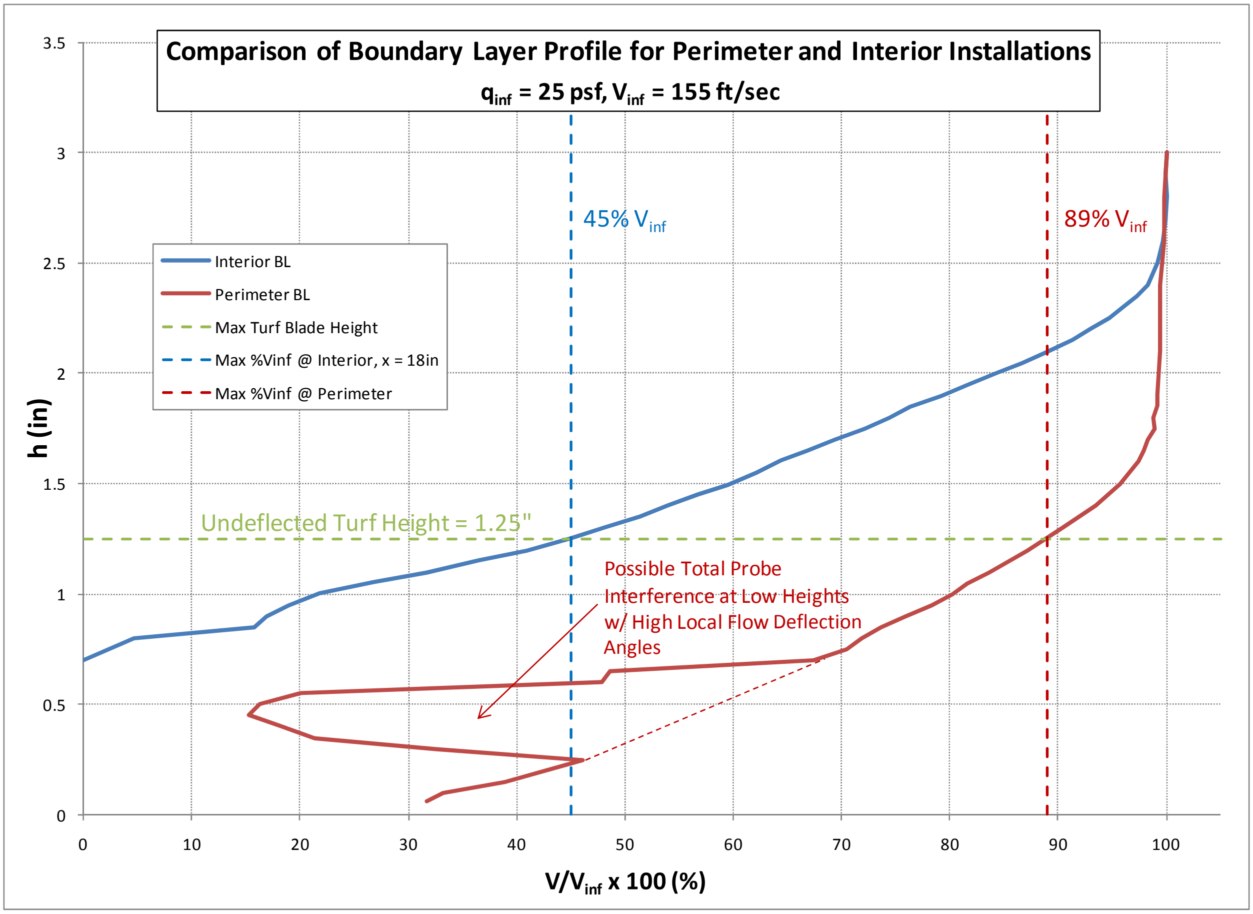


Figure 4 – Non-Dimensional Boundary Layer Profiles for Perimeter and Interior Installations

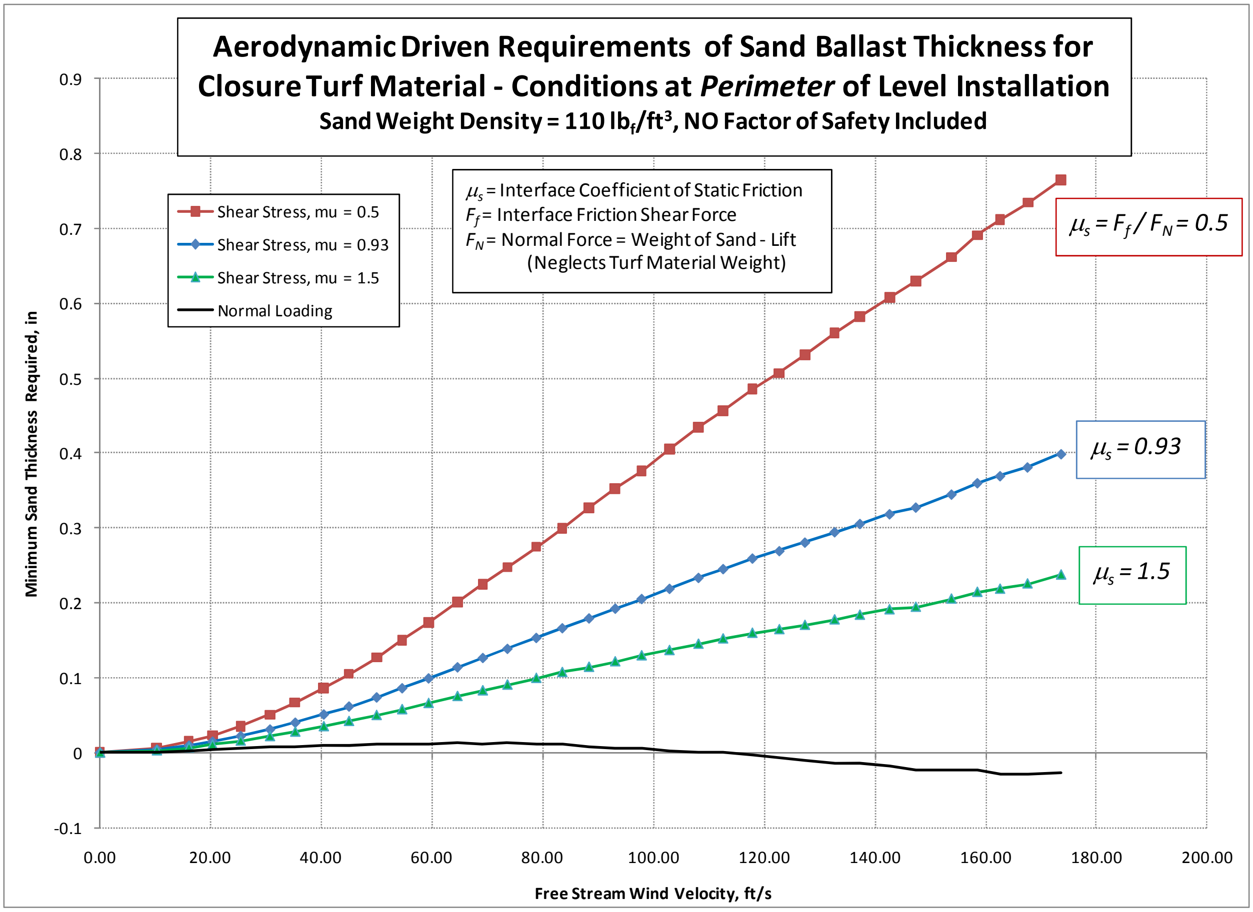


Figure 5 – Sand Ballast Minimum Requirement at the *Perimeter* of Turf Installation

Table I - Perimeter Installation				
Wind Speed (*ft/s*)	Wind Speed (*mi/hr*)	Turf Normal Force Loading (lb_f/ft^2)	Turf Shear Stress ($\mathrm{lb_f/ft^2}$)	Sand Height Due to Shear (*in*)
0.00	0.00	0	0	0
10.26	6.99	0.011689	0.023784	0.0040651
16.06	10.95	0.027798	0.053106	0.009262
20.31	13.84	0.039396	0.086922	0.0144939
25.40	17.32	0.054936	0.136103	0.0219582
30.70	20.93	0.06927	0.198423	0.0308322
35.26	24.04	0.078777	0.266915	0.0399035
40.42	27.56	0.088429	0.351918	0.0509275
44.97	30.66	0.096783	0.434606	0.0615383
49.97	34.07	0.10646	0.529776	0.0737576
54.57	37.21	0.110561	0.630469	0.0860165
59.36	40.47	0.111817	0.741903	0.099225
64.58	44.03	0.115373	0.865046	0.1140578
69.15	47.15	0.111526	0.975305	0.1265718
73.60	50.18	0.114496	1.076528	0.1387694
78.82	53.74	0.111457	1.204017	0.1533926
83.52	56.94	0.104976	1.320714	0.1663744
88.34	60.23	0.077354	1.458158	0.1794835
93.08	63.46	0.057303	1.588598	0.192597
97.86	66.72	0.058201	1.697814	0.2055063
102.89	70.15	0.024978	1.844449	0.2190825
108.12	73.72	0.007601	1.985703	0.2337562
112.58	76.76	0.002646	2.090641	0.2455251
117.87	80.37	-0.026041	2.237684	0.2596441
122.74	83.69	-0.058742	2.352732	0.2695721
127.36	86.84	-0.089852	2.479185	0.2810115
132.72	90.49	-0.122289	2.627843	0.2949108
137.29	93.61	-0.135769	2.734267	0.305924
142.65	97.26	-0.155489	2.863465	0.3189279
147.40	100.50	-0.208034	2.98848	0.3278602
153.84	104.89	-0.206002	3.134988	0.3452676
158.51	108.08	-0.21588	3.274285	0.3605298
162.63	110.88	-0.256805	3.392572	0.3699406
167.59	114.26	-0.261535	3.496667	0.3816351
173.66	118.41	-0.23928	3.626641	0.3993092

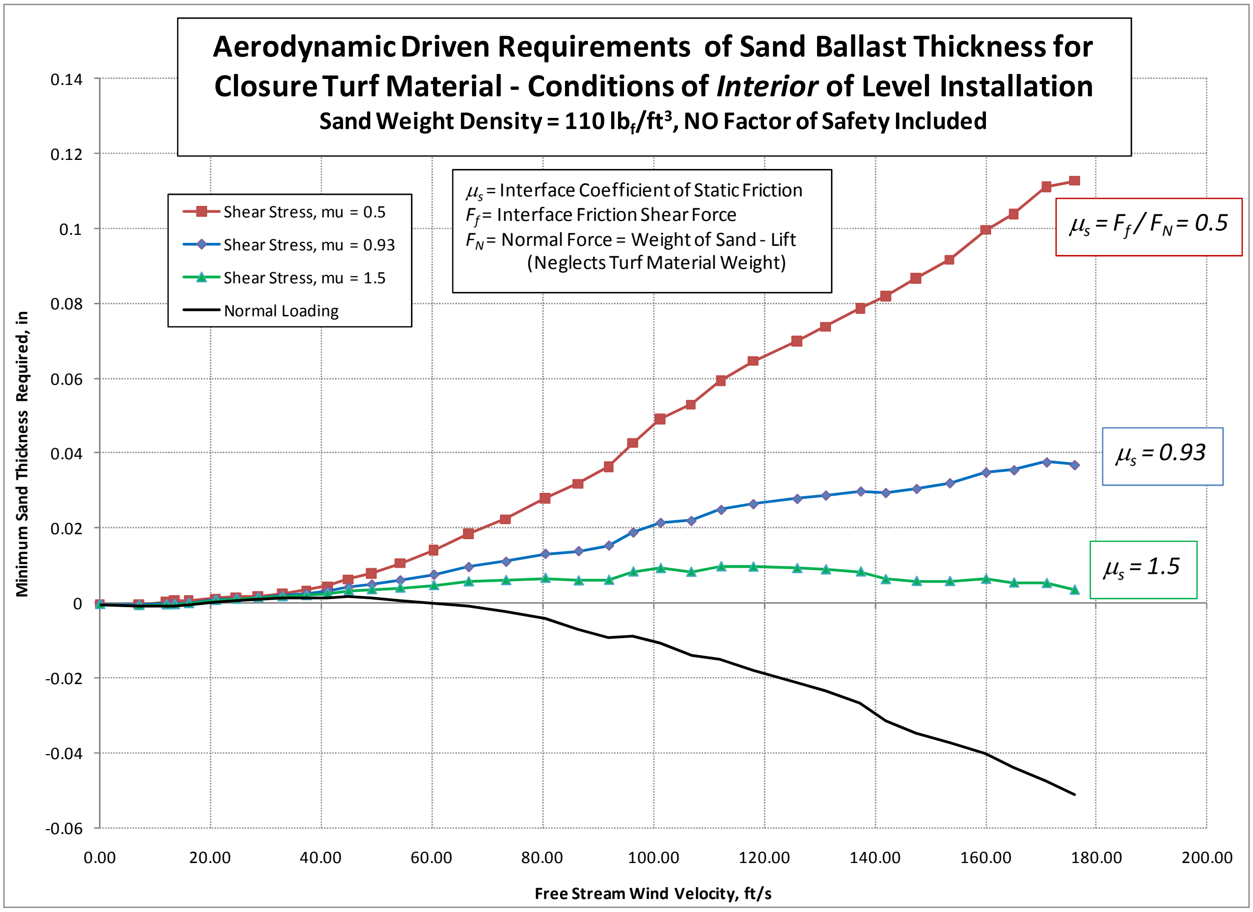


Figure 6 – Minimum Sand Ballast Requirement in the *Interior* of Turf Installation

Table I - Interior Installation				
Wind Speed (ft/s)	Wind Speed (mi/hr)	Turf Normal Force Loading (lb_f/ft^2)	Turf Sheer Stress (lb_f/ft^2)	Sand Height Due to Shear (*in*)
0.00	0.00	-0.00419	0.000471	0
7.07	4.82	-0.00858	0.002819	-0.000605326
12.02	8.20	-0.00858	0.005658	-0.000272305
13.47	9.18	-0.009201	0.006927	-0.000191194
16.05	10.94	-0.005314	0.005174	2.72117E-05
20.91	14.26	0.003753	0.0034	0.000808245
24.64	16.80	0.006062	0.004099	0.00114213
28.56	19.47	0.009925	0.003388	0.001480147
32.94	22.46	0.011669	0.005393	0.001905592
37.27	25.41	0.011221	0.009767	0.002369798
41.09	28.01	0.013608	0.013502	0.003068321
44.90	30.61	0.015886	0.02088	0.004182285
49.08	33.47	0.011842	0.03072	0.004895374
54.21	36.96	0.006407	0.045273	0.006009561
60.31	41.12	-0.000648	0.064883	0.007540218
66.57	45.39	-0.006394	0.087581	0.009575904
73.32	49.99	-0.019878	0.112271	0.01100111
80.43	54.84	-0.037311	0.146631	0.013129826
86.42	58.92	-0.06477	0.178237	0.013841748
91.90	62.66	-0.083261	0.208285	0.01534924
96.30	65.66	-0.081403	0.236369	0.018846242
101.24	69.02	-0.097454	0.273298	0.021427071
106.76	72.79	-0.129489	0.30751	0.021945482
112.17	76.48	-0.138401	0.341067	0.024909568
117.97	80.43	-0.163997	0.378085	0.026459565
125.89	85.83	-0.193612	0.417441	0.027845377
131.07	89.36	-0.215792	0.445855	0.028758761
137.38	93.67	-0.245542	0.482763	0.029842691
141.88	96.73	-0.289393	0.520185	0.029448623
147.46	100.54	-0.317409	0.555461	0.030530279
153.47	104.64	-0.340708	0.59023	0.032067045
159.99	109.08	-0.369093	0.641021	0.034928388
165.05	112.53	-0.4029	0.677722	0.035545455
170.96	116.56	-0.437374	0.727691	0.037646121
176.00	120.00	-0.469865	0.751682	0.036915842

Attachment E

ClosureTurf Integrity Study

SGI TESTING SERVICES
A GEORGIA LIMITED LIABILITY COMPANY

8 July 2010

Mr. Jose Urrutia
Closure Turf, LLC
3005 Breckinridge Blvd., Suite 240
Duluth, Georgia 3096

Subject: Evaluation of Drivability
Light Weight Construction Equipment on
Closure Turf™ System

Dear Mr. Urrutia,

DEFINITION OF CLOSURE TURF™ SYSTEM

As shown in Figure 1, the installed Closure Turf™ system from top to bottom consists of:

- A thin sand layer;
- Artificial grass with geotextile down;
- Agru 50-mil Super Gripnet with spike sides down; and
- Subgarde (foundation) soil.

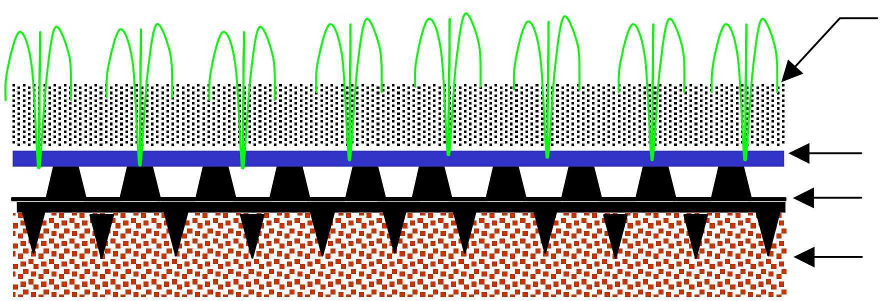


Figure 1. Cross-section of the Closure Turf system

MAIL TO: SGI TESTING SERVICES, LLC
P.O. BOX 2427
LILBURN, GA 30048-2427

FACILITY LOCATION
4405 INTERNATIONAL BLVD., SUITE B-117
NORCROSS, GA 30093

WEB SITE: WWW.INTERACTIONSPECIALISTS.COM
PHONE: 770.931.8222 FAX: 770.931.8240

DEFINITION OF POST-CONSTRUCTION DRIVABILITY

Drivability of rubber-tired construction equipment (RTCE) on the Closure Turf™ system is a rather broad subject including: (i) stability - potential sliding (shear failure) within the Turf Closure system; (ii) bearing capacity of the subgrade soil; (iii) localized settlement after construction due to waste decomposing and compression under gravity force; and (iv) rut depth. The purpose of this report is to evaluate the stability within the Turf Closure system and bearing capacity of the subgrade soil.

STABILITY

As shown in Figure 2, when a RTCE moves at a constant speed on the Closure Turf system, its gravity load is transferred to the Closure Turf system through the tire-soil contact.

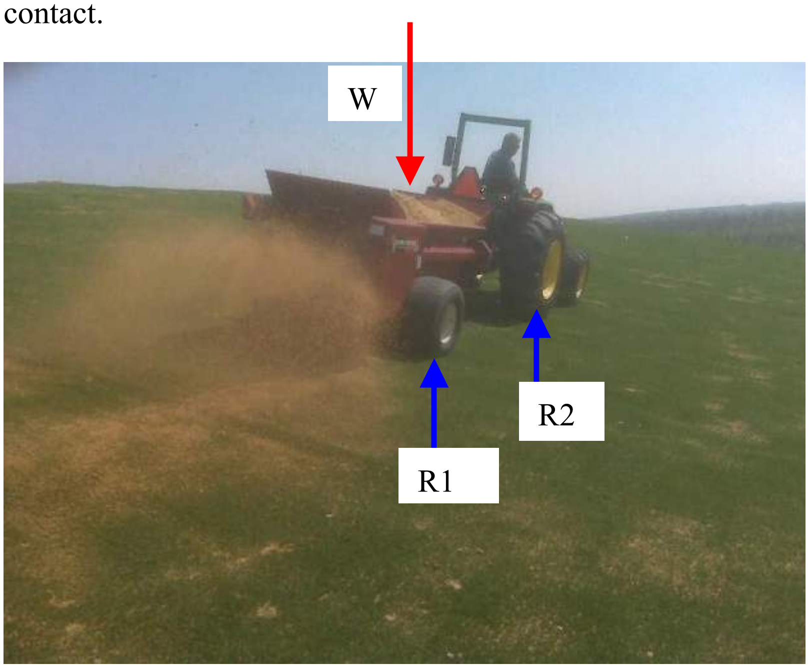


Figure 2. Rubber-tired construction equipment on the Closure Turf system.

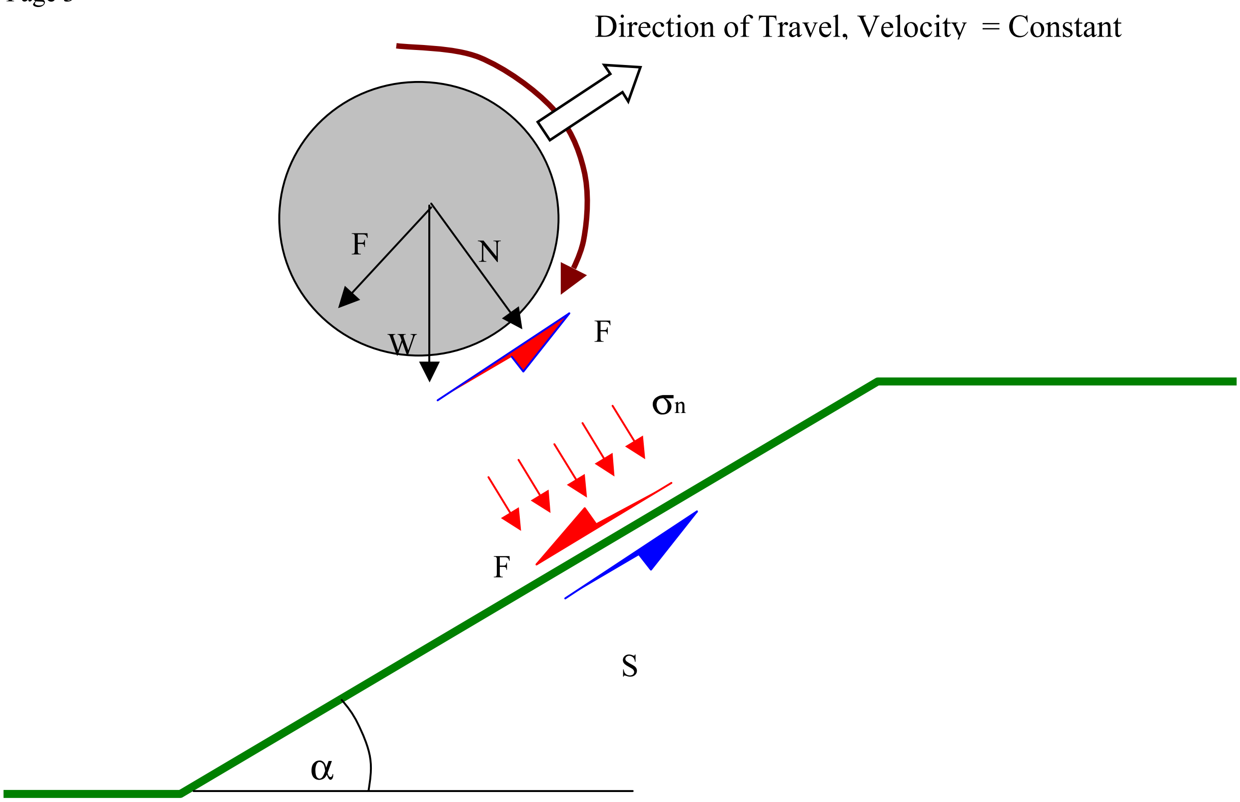


Figure 3. Tire-soil contact loading conditions on a slope. (NOTE: not to scale).

Assuming the gravity force of RTCE is evenly distributed to four tires, the contact normal stress at the tire-sand contact area as shown in Figure 3 can be estimated by the following equation:

$$\sigma_n = \frac{W \cos\alpha}{4A} \qquad (1)$$

where:

α = the slope angle;

σ_n = contact normal stress between the tire and sand;

W = total gravity force of equipment; and

A = contact area between a tire and sand layer.

Assuming: (i) the tire-soil contact area is approximately equivalent to a 10 inch diameter circular area and (ii) the total weight of a RTCE is 8000 lbs, then the contact normal stress in the unit of psi is:

$$\sigma_n = \frac{8000\cos\alpha}{4(3.14)(5^2)} = 25.5\cos\alpha \qquad (2)$$

Equation (2) is also applicable to a level surface by setting $\alpha = 0$. This gives the maximum contact normal stress of 25.5 psi. It is noted that the tire-sand contact normal stress over a 10-inch diameter area is much higher than the overburden pressure of 1 inch thick cover sand. Therefore, it is necessary to evaluate the stability of the Closure Turf system in the tire-sand contact area under the high normal stress conditions. The shear strength parameters for this localized stability analysis should be determined from the interface direct shear tests at high normal stresses (2000 to 5000 psf). Based on the test results in Attachment 1, the peak friction angle and adhesion of the sand/artificial grass/Agru 50-mil Super Gripnet LLDPE geomemebrane system is 34 degree and 39 psf, respectively for the normal stress range of 2000 to 5000 psf. Under the drained conditions (i.e., no pore pressure induced by RTCE), neglecting the adhesion for the conservative reason, the safety factor (FS) against the localized shear failure within the tire-soil contact area is:

$$FS = \frac{A\sigma_n \tan\delta}{0.25(W)\sin\alpha} \qquad (3)$$

where:

α = the slope angle;

σ_n = contact normal stress between the tire and sand;

δ = the peak friction angle of the Closure Turf system;

W = total gravity force of equipment; and

A = contact area between a tire and sand layer.

Substituting Equation (1) into (3), Equation (3) is reduced to:

$$FS = \frac{\tan\delta}{\tan\alpha} \tag{4}$$

For the given Closure Turf system, the peak friction angle is constant. It is obvious that FS decreases with increasing the slope angle. Based on the information provided by Closure Turf LLC, the maximum allowable slope angle is 18 degree (3:1 slope).

At $\alpha = 18.4$ degree,

$$FS = \frac{\tan 34}{\tan 18} = 2.0 \tag{5}$$

This indicates that there is sufficient shear resistance in the Closure Turf system against the localized shear failure within the tire-soil area. It is not expected the localized internal shear failure to occur within the tire-soil contact area of Closure Turf system when it subjected to the gravity force from a typical lightweight RTCE traveling at a constant velocity.

BEARING CAPACITY

For a given RTCE, W and A are constant, therefore the maximum contact normal stress occurs when the RTCE travels on the level surface (Equation 1). The contact normal stress is transferred to the subgade soil as shown in Figure 4.

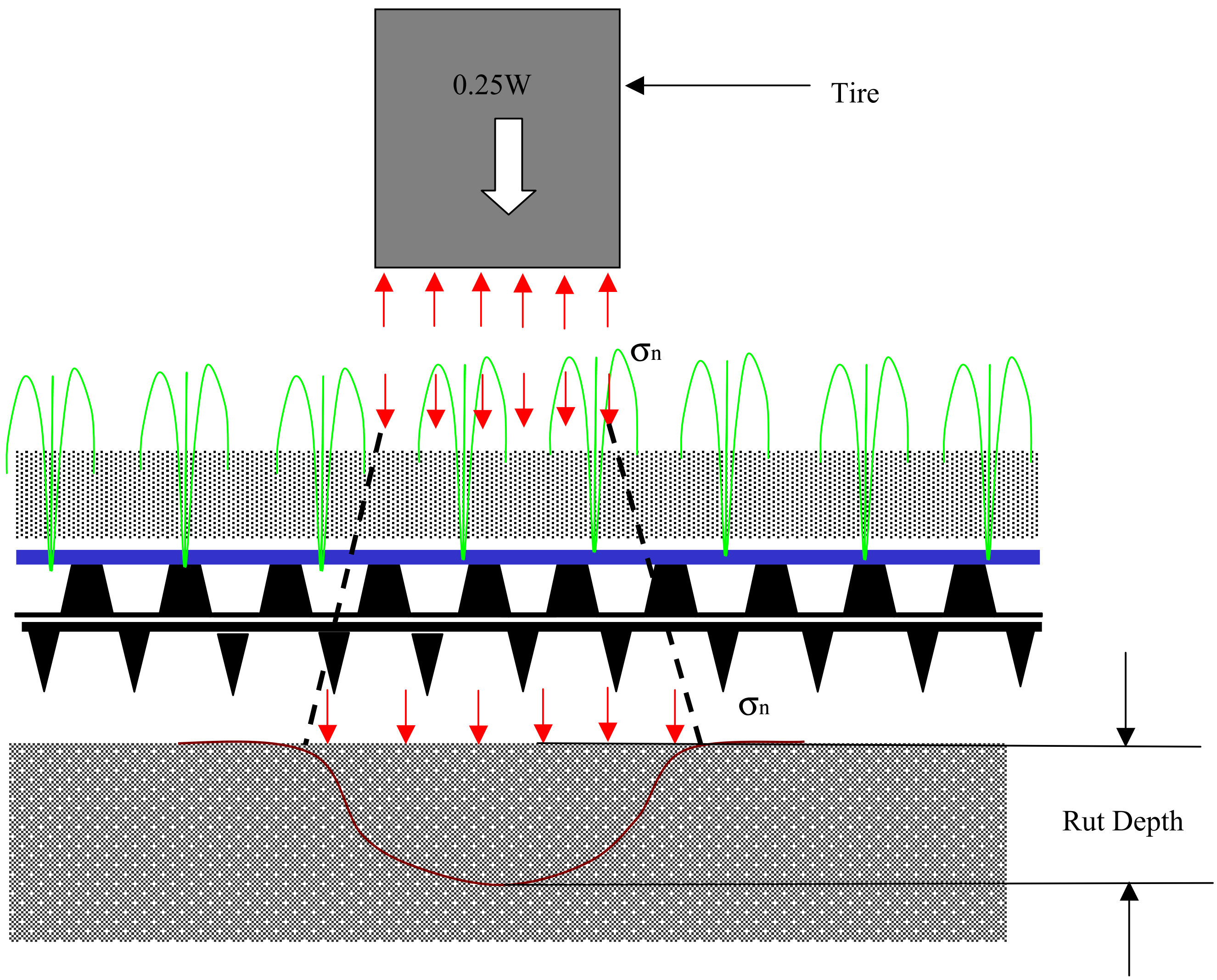


Figure 4. Normal stress acting on top of the subgrade (foundation) soil

Based on soil mechanics, the contact load (0.25W) distributes to a larger area as depth increases (depth starting from the top surface of the cover sand). However, due to the fact that the cover sand layer is only 1 inch thick, and the artificial grass and geomembrane are flexible, the load spreading angle (factor) is insignificant. The normal stress transferred to the top of subgrade soil is considered the same as the tire-sand contact stress for the conservative reason.

As shown previously (Equation 2), assuming (i) the tire-soil contact area is approximately a 10 inch diameter circular area and (ii) the total weight of a RTCE is 8000 lbs, then the maximum contact normal stress is:

$$\sigma_n = \frac{8000\cos\alpha}{4(3.14)(5^2)} = 25.5\,psi \qquad (6)$$

Under the action of tire-sand contact normal stress over the contact area (10 in diameter), there are two major concerns:

- Excessive rut depth, which is not defined for the Closure Turf system at the present time. Generally speaking, the subgrade soil settles and rut forms when it is subjected a normal stress. As number of vehicle passes increases, the rut depth increases. Eventually the surface may reach such a condition that driving is difficult if the accumulated pass is larger than some critical number. Therefore, for the given type of equipment (W and A are fixed), one way to reduce rut depth is to limit the number of passes. This may be achieved by not driving over the same area when a significant rut depth is already developed. The other way is to compact subgrade soil to high density to improve the stiffness for the subgrade soil.

- Bearing capacity failure because the contact normal stress is greater than the bearing capacity of the subgrade soil.

In the case of soft subgrade soil (worst case), the bearing capacity is estimated by the following equation:

$$q_u = c_u N_C \qquad (7)$$

where:

c_u = undrained shear strength of soft subgrade soil

N_c = bearing capacity factor (6.2 for a circular loading area)

$$q_u = 6.2c_u \tag{8}$$

For the soft subgrade soil, the safety factor against bearing capacity failure is:

$$FS = \frac{6.2c_u}{\sigma_n} \tag{9}$$

Typically, the acceptable bearing capacity safety factor is 2.0. The required undrained shear strength for the subgrade soil is,

$$c_u \geq \frac{2(25.5)}{6.2} = 8.2\,psi \tag{10}$$

The value of c_u can be estimated from the widely used CBR value for soft subgrade soil with CBR < 5 using the following equation (Giroud and Noiray 1981):

$$c_u = 4.3CBR \tag{11}$$

Substituting Equation 11 into 10 gives the following equation:

$$CBR \geq 1.9 \tag{12}$$

Therefore, under the action of the gravity force from a typical RTCE (W = 8000 lbs, A = 79 square inch), the required minimum CBR value for the subgrade is 2. In reality, a well-compacted subgarde soil for the Closure Turf system should have a CBR value significantly higher than 2. It is expected that a well-compacted subgarde soil layer (SM or SC, typically used as subgarde soil for the landfill cover system) should have sufficient bearing capacity to support the lightweight RTCE.

CLOSURE

SGI appreciates the opportunity to provide technical services to Closure Turf, LLC. Should you have any questions regarding the attached document(s), or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

REFERENCES

Giroud, J.P., and Noiray, L. (1981) "Geotextile-reinforced unpaved road design." Journal of Geotechnical Engineering 107(9), 1233-1254.

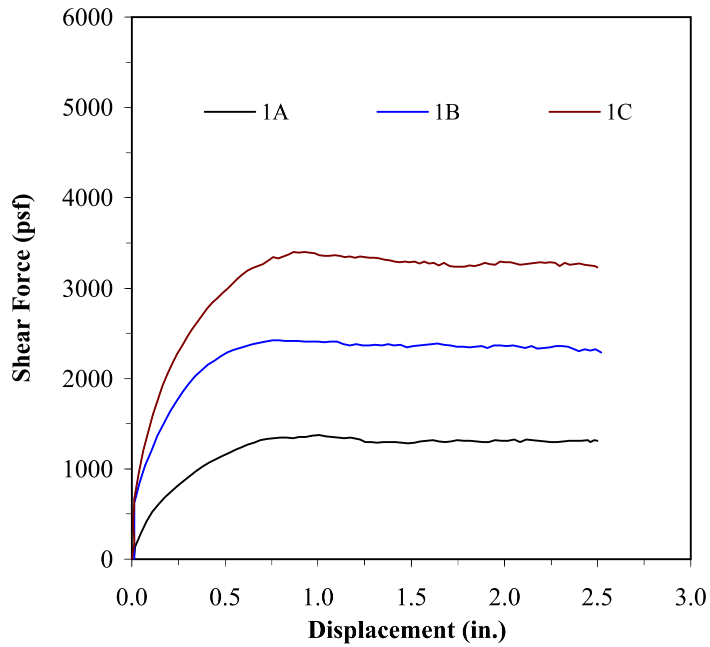
NOTES:
(1) Unless otherwise noted in the test results the sample(s)/specimen(s) were prepared in accordance with the applicable test standards or generally accepted sampling procedures.
(2) Contaminated/chemical samples and all related laboratory generated waste (i.e., test liquids, PPE, absorbents, etc.) will be returned to the client or designated representative(s), at the client's cost, within 60 days following the completion of the testing program, unless special arrangements for proper disposal are made with SGI.
(3) Materials that are not contaminated will be discarded after test specimens and archived specimens are obtained. Archived specimens will be discarded 30 days after the completion of the testing program, unless long-term storage arrangements are specifically made with SGI.
(4) The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. The reported results are submitted for the exclusive use of the client to whom they are addressed.

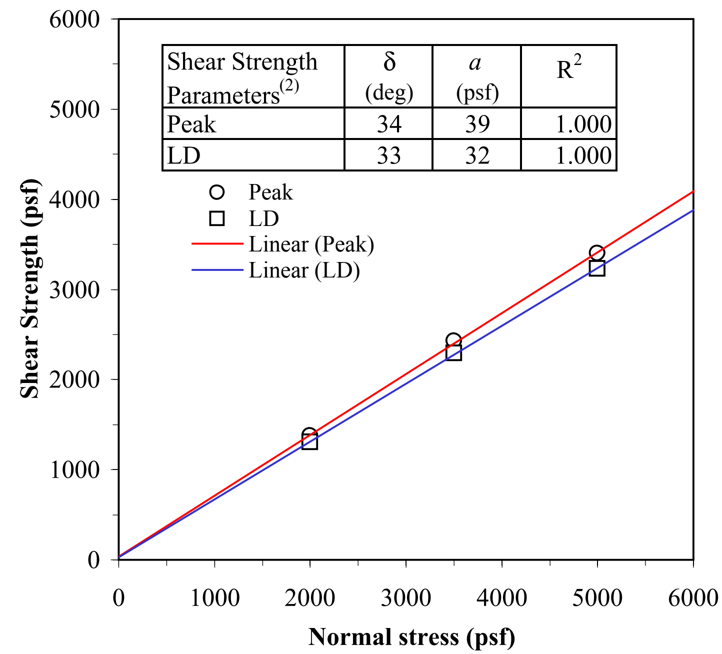
ATTACHMENT 1

INTERFACE DIRECT SHEAR TEST RESULTS

CLOSURETURF LLC -LANDFILL COVER SYSTEM
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand nominally compacted
Artificial grass with grass side (green yarns) up/
Agru 50 mil LLDPE Super Gripnet geomembrane with studs side up/
Lower Shear Box: Concrete sand





Shear Strength Parameters(2)	δ (deg)	*a* (psf)	R^2
Peak	34	39	1.000
LD	33	32	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Lower Soil			Upper Soil			GCL		Shear Strengths		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_{LD} (psf)	
1A	12 x 12	2000	0.04	10	24	-	-	-	-	-	-	-	-	-	-	1376	1308	(1)
1B	12 x 12	3500	0.04	20	24	-	-	-	-	-	-	-	-	-	-	2425	2291	(1)
1C	12 x 12	5000	0.04	50	24	-	-	-	-	-	-	-	-	-	-	3400	3233	(1)

NOTES:
(1) Sliding (i.e., shear failure) occurred at the interface between the cover (upper) sand and artificial grass.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF TEST:	6/21/2010
FIGURE NO.	C-1
PROJECT NO.	SGI10007
DOCUMENT NO.	
FILE NO.	

Attachment F

Evaluation of Sand Infill Criteria for ClosureTurf

Technical Note

EVALUATION OF SAND INFILL CRITERIA FOR CLOSURETURF®

Fine aggregate infill (sand) is one component of the ClosureTurf® three component system. An extensive testing program was implemented to evaluate the criteria and performance properties for the sand infill in the ClosureTurf system. The program included large scale performance testing by an independent third party laboratory, TRI Environmental (TRI) at the Denver Downs Research facility in Greeneville, South Carolina. A description of the testing procedures and results are provided in this document.

SAND INFILL FUNCTION

The sand infill component of ClosureTurf is utilized as a protective layer for the geotextile backing of the engineered turf component. The polypropylene geotextile backing material contains ultraviolet (UV) radiation degradation inhibitors protecting it against UV damage. Sand infill functions as an additional protective layer against UV degradation of the geotextile backing. Optimal sand infill performance occurs with minimal sand movement.

TRI tested sand infill mobilization in ClosureTurf in general accordance with ASTM D 6460, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion* and ASTM D 6459 *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion*. The results of the testing were also analyzed in accordance with each Standard to quantify infill mobilization during tested conditions. Photographs of tested sands are provided as Attachment A.

SAND INFILL LARGE SCALE HYDRAULICS TESTING

The TRI large-scale hydraulic testing (ASTM D 6460) was conducted in a rectangular flume having a 0.10 ft/ft slope. The subgrade was a loamy soil over which ClosureTurf with a ½ inch sand infill was installed following installation guidelines. Water is supplied to the facility by gravity flow and controlled and measured through upstream sluice gates as presented in Figure 1.

A test consists of measuring infill thickness, opening the sluice gates a predetermined amount allowing overtopping flow on the ClosureTurf for a period of 30 minutes, closing the sluice gate to stop overtopping flow and measuring infill depth to evaluate sand loss. The test procedure is repeated a minimum of four times with increasing overtopping flow amounts or until enough sand infill has been removed to expose the majority of the geotextile backing.

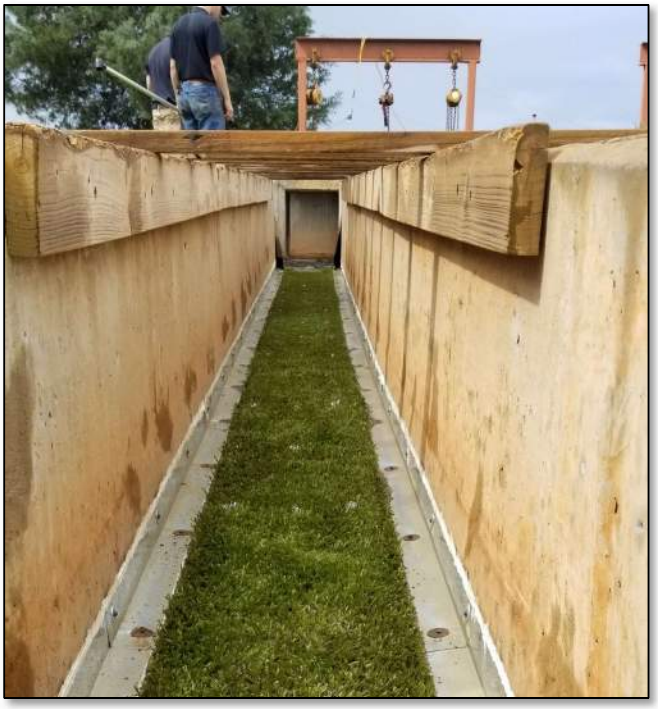


Figure 1. ClosureTurf® TRI Flume Test Installation

Reported test results include sand infill loss during each 30-minute overtopping period and the corresponding hydraulic shear stress during the 30-minute test period. The testing was conducted on six different sand infills having a range of grain size distributions, fine aggregate angularities and specific gravities. Sand infill angularity and specific gravity are presented in Table 1. Tested sand infill grain size distributions are presented in Figure 2. Hydraulic shear stress results are presented in Figure 3.

Table 1. Tested Sand Infill Angularity and Specific Gravity

Test Sand No.	Fine Aggregate Angularity (FAA) (%) (ASTM C 1252 / AASHTO T 304) (Method A)	Bulk Specific Gravity, Dry (SG) (ASTM C 128 / AASHTO T 84)
1	47.2	2.64
2	40.5	2.60
3	43.1	2.59
4	45.7	2.64
5	47.1	2.85
6	43.7	1.96

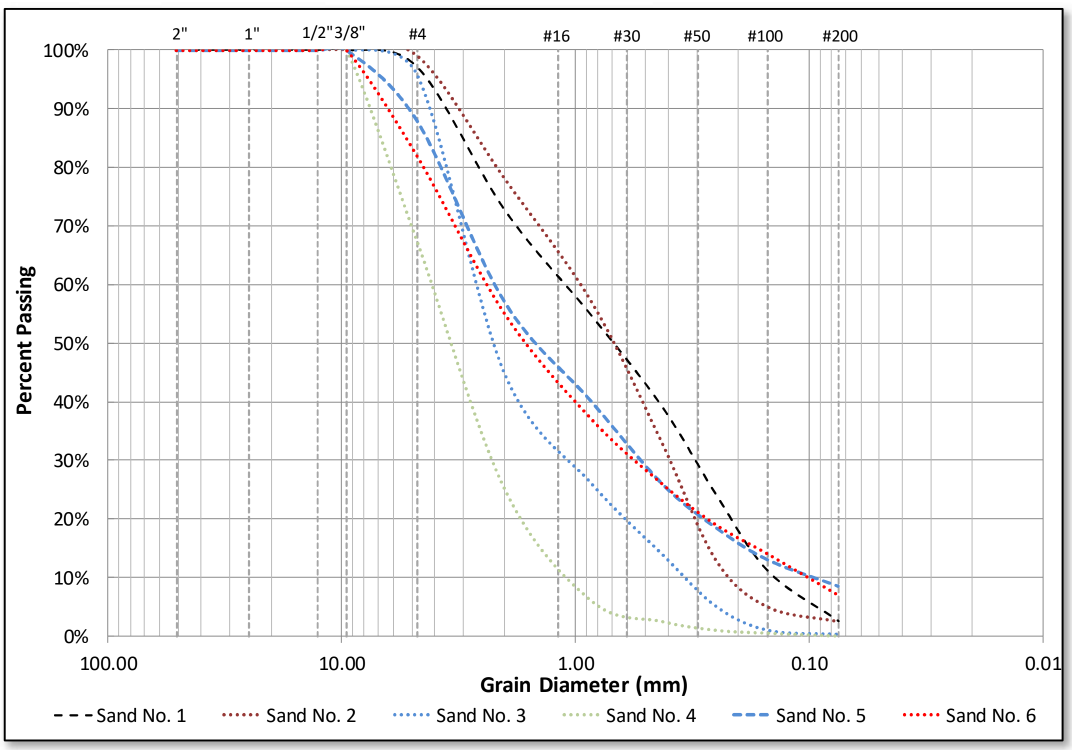


Figure 2. Tested Sand Infill Grain Size Distributions (ASTM C 136 / AASHTO T 27)

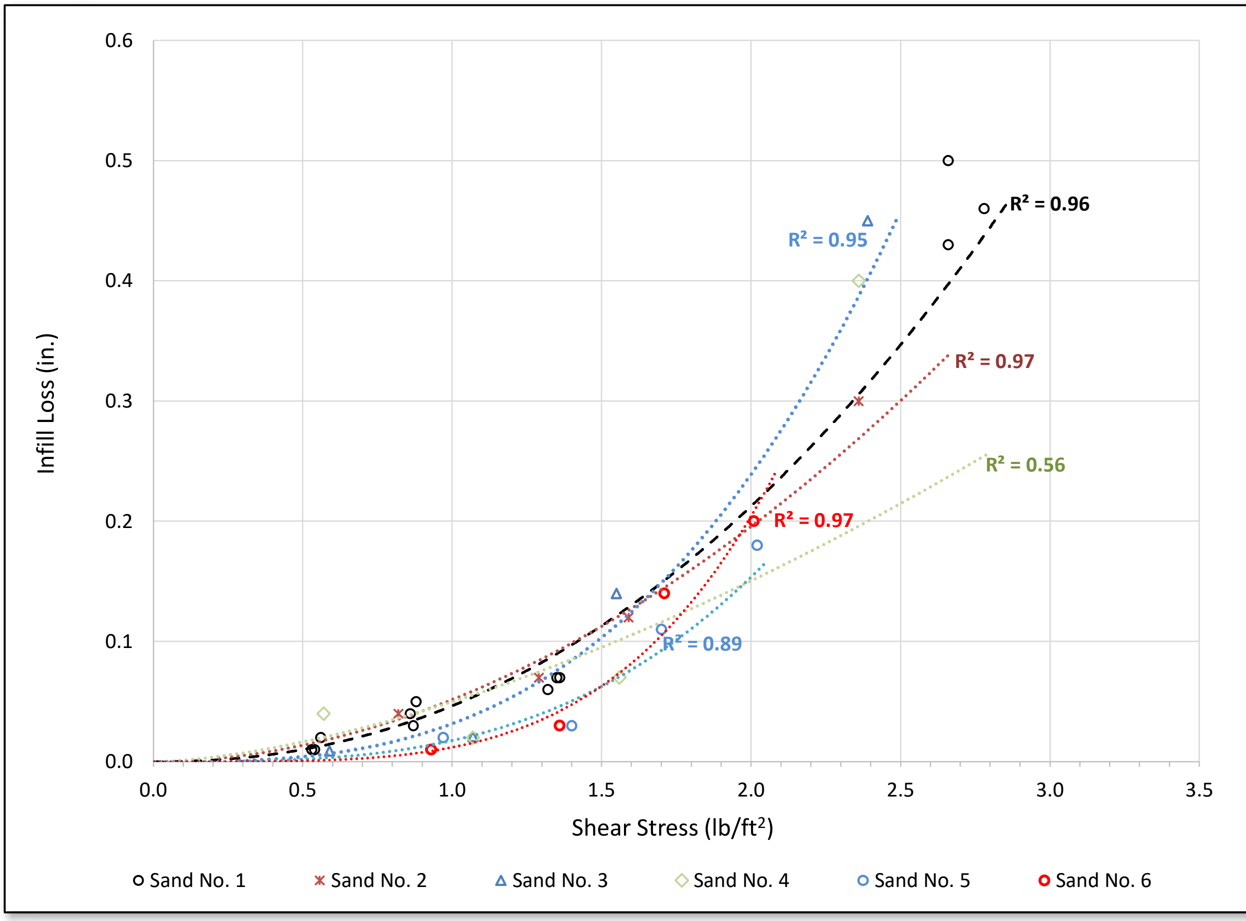
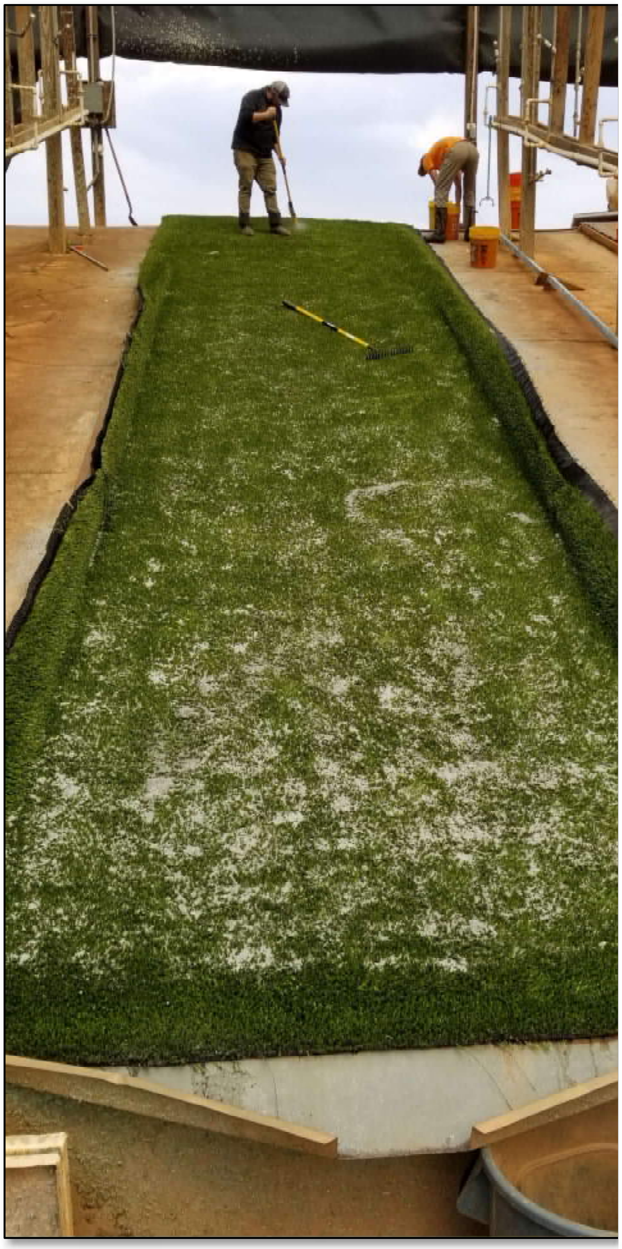


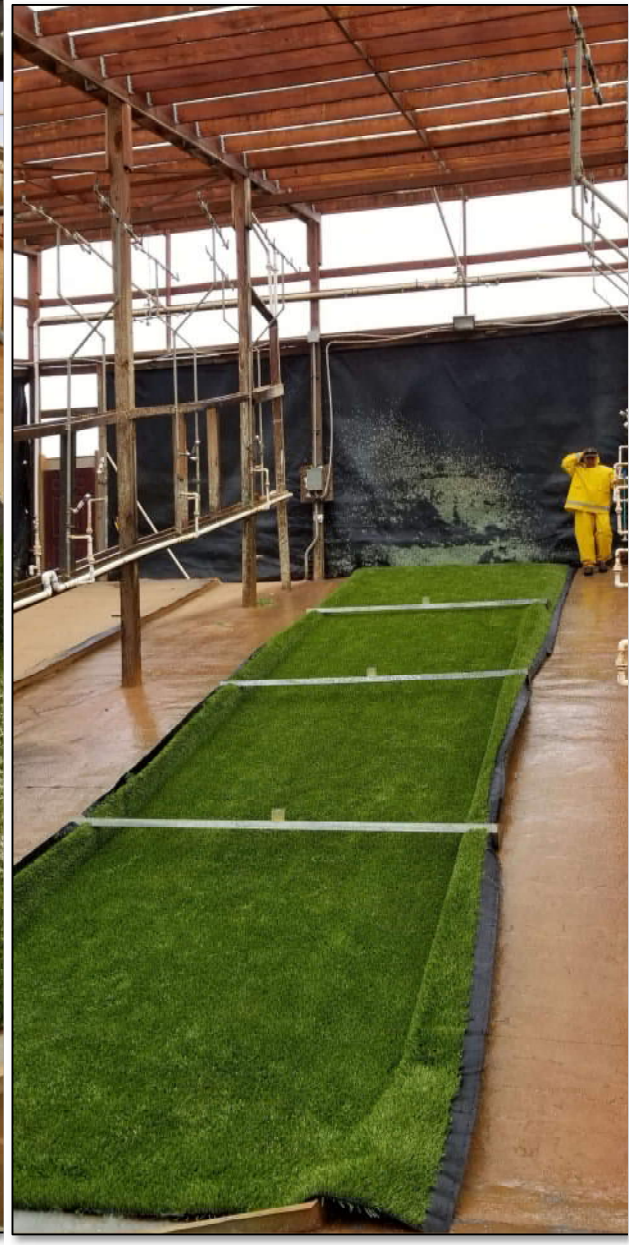
Figure 3. Infill Loss Due to Hydraulic Shear

SAND INFILL LARGE SCALE RAINFALL EROSION TESTING

The TRI large-scale rainfall erosion testing (ASTM D 6459) was conducted on a rectangular plot measuring 40 feet by 8 feet (length x width) and having a 0.33 ft/ft slope. The subgrade was a loamy soil over which ClosureTurf with a ½ inch sand infill was installed following installation guidelines as presented in Figure 4a. Artificial rainfall is produced by ten "rain trees" arranged around the perimeter of the test slope. Each rain tree has four sprinkler heads atop a 15 ft. riser pipe. The rainfall system produces target rainfall intensities of 2-, 4-and 6-inches per hour at pre-calibrated rain drop size distributions for a period of 20 minutes per intensity resulting in a one hour test. Testing in progress is presented in Figure 4b. All runoff was collected during testing to quantify sediment mobilization. Incremental infill losses are presented in Table 2.



(a) Infill Installation



(b) Testing in Progress

Figure 4. ClosureTurf® TRI Rainfall Erosion Testing

Table 2. Tested Sand Infill Rainfall Erosion Results

Test Sand No.	Rainfall Intensity (in./hr)	Incremental Infill Loss (%)
1	2.0	0.01
1	4.0	0.02
1	6.1	0.04
3	2.0	0.00
3	4.2	0.00
3	6.1	0.00
4	2.1	0.00
4	4.1	0.00
4	6.0	0.00

Based on the TRI large scale rainfall erosion and hydraulic shear test results and sand infill material properties, a sand infill specification was developed as summarized in Figure 5 and as appears in the WatershedGeo CSI specification, SECTION 31 05 16, *ClosureTurf® SAND INFILL COMPONENT*.

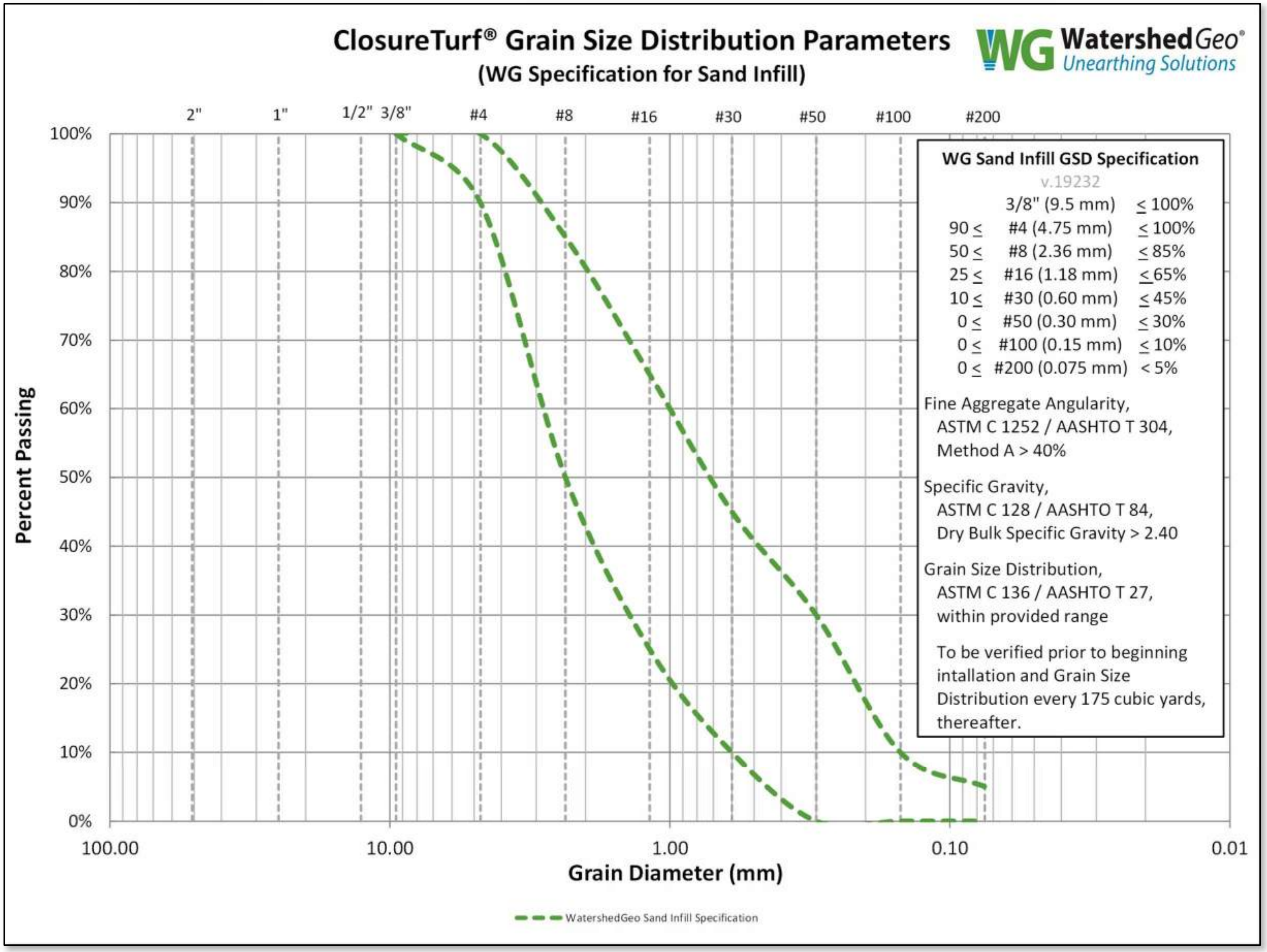


Figure 5. ClosureTurf® Sand Infill Specification

Attachment A

Figure A1. Tested Sand No. 1

Figure A2. Tested Sand No. 2

Figure A3. Tested Sand No. 3

Figure A4. Tested Sand No. 4

Figure A5. Tested Sand No. 5

Figure A6. Tested Sand No. 6

LIMITATIONS

ClosureTurf® is a U.S. registered trademark which designates a product from Watershed Geosynthetics LLC. This product is the subject of issued U.S. and foreign patents and/or pending U.S. and foreign patent applications. All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, this information should not be used or relied upon for any specific application without independent professional examination and verification of its accuracy, suitability and applicability. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Watershed Geosynthetics LLC as to the effects of such use or the results to be obtained, nor does Watershed Geosynthetics LLC assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.

Attachment G

ClosureTurf Sand Infill Component Specification

This ClosureTurf® Specification document has been prepared to provide the Owner, Design Engineer, Construction Quality Assurance Professional of Record, and the Contractor / Installer with a general guidance specification. All information, recommendations and suggestions appearing in this specification concerning the use of our products are based upon experience, tests and data believed to be reliable; however, this information should not be used or relied upon for any specific application without independent professional examination and verification of its accuracy, suitability and applicability. The independent professional shall edit this document to suit the site-specific project design criteria. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Watershed Geosynthetics LLC as to the effects of such use or the results to be obtained, nor does Watershed Geosynthetics LLC assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. ClosureTurf® is a U.S. registered trademark which designates a product from Watershed Geosynthetics LLC. This product is the subject of issued U.S. and foreign patents and/or pending U.S. and foreign patent applications. Nothing herein is to be construed as permission to grant license or as a recommendation to infringe any patent.

SECTION 31 05 16

ClosureTurf® SAND INFILL COMPONENT

PART 1: GENERAL

1.01 SUMMARY

A. Section Includes:

Specifications for approved Sand Infill Component of the patented ClosureTurf® System.

1.02 RELATED SECTIONS

Section 31 23 13 - Subgrade preparation (Upper 6 inches of subgrade only)

Section 01 42 00 - References and Definitions

Section 01 60 00 - ClosureTurf® Product Specification

Section 01 60 00 - ClosureTurf® MicroDrain® Product Specification

Section 01 60 01 - ClosureTurf® MicroSpike® Product Specification

Section 01 73 19 - ClosureTurf® Installation Specification

Section 31 05 16 - ClosureTurf® Sand Infill Specification

Section 03 49 01 - Alternate HydroBinder® Infill Specification

Section 23 51 23 - ClosureTurf® HDPE Pressure Relief Valve Specification

PART 2: PRODUCTS

2.01 DESCRIPTION

Sand Infill Component of the ClosureTurf® System shall meet the fine aggregate angularity, specific gravity and grain size distribution as specified by WatershedGeo in this Specification.

A. Fine aggregate angularity shall be tested in accordance with ASTM C 1252 / AASHTO T 304, *Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading). Method A.* Method A uncompacted void content shall be greater than or equal to 40%.

B. Sand infill specific gravity shall be tested in accordance with ASTM C 128 / AASHTO T 84, *Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate.* Bulk oven-dry specific gravity shall be greater than or equal to 2.40.

C. Sand infill grain size distribution shall be tested in accordance with ASTM C 136 / AASHTO T 27, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.* The grain size distribution shall be as prescribed in Table 1 and presented in Figure 1.

Table 1. Sand Infill Grain Size Distribution

		3/8" (9.5 mm)	≤	100%
90%	≤	#4 (4.75 mm)	≤	100%
50%	≤	#8 (2.36 mm)	≤	85%
25%	≤	#16 (1.18 mm)	≤	65%
10%	≤	#30 (0.60 mm)	≤	45%
0	≤	#50 (0.30 mm)	≤	30%
0	≤	#100 (0.15 mm)	≤	10%
0	≤	#200 (0.075 mm)	≤	5%

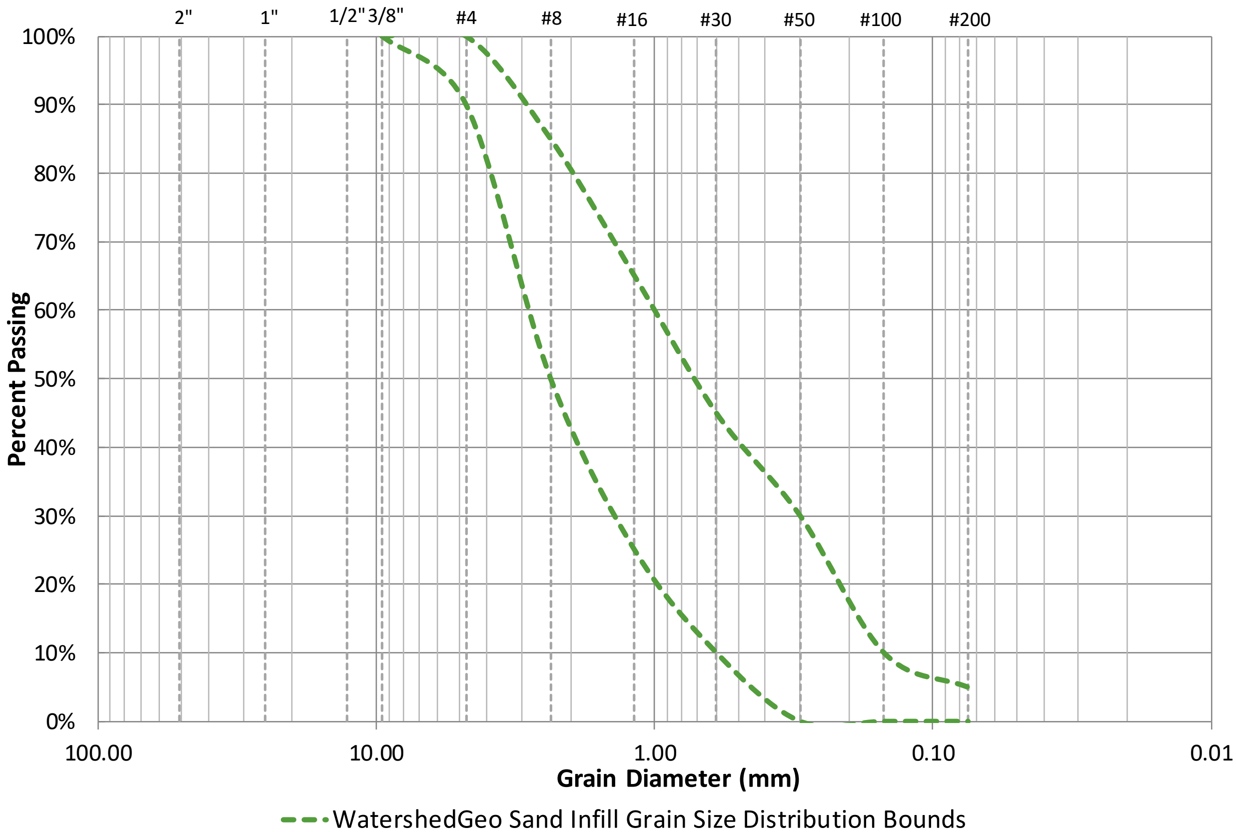


Figure 1: ClosureTurf® Specified Infill Grain Size Distribution

D. Documentation of sand infill conformance with ASTM C 136 / AASHTO T 27, ASTM C 128 / AASHTO T 84 and ASTM C 1252 / AASHTO T 304 shall be submitted to the specified CQA personnel.

E. Subsequent to initial verification of specification conformance, sand infill shall have grain size distribution conformance verified and documented for each 175 cubic yards to be installed.

PART 3: EXECUTION:

Not Used. See Section 01 73 19 ClosureTurf® Installation Specifications.

END OF SECTION

Attachment H

ClosureTurf Case Study

DESIGN AND INSTALLATION OF A GEOSYNTHETIC FINAL COVER UTILIZING ARTIFICIAL TURF IN LOUISIANA

R. C. de Abreu[1], and J. Franklin[2],

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[2]*President, Franklin Engineers & Consultants, L.L.C., 2734 Sunrise Boulevard, Suite 308, Pearland, Texas 77584, U.S.A.; PH +1 281 205 8415; email: jfranklin@feandcllc.com*

ABSTRACT

The Tangipahoa Regional Solid Waste Facility (Tangipahoa RSWF), located in Independence, Louisiana, U.S.A., has recently installed a relatively new type of geosynthetic final cover consisting of a linear low-density polyethylene (LLDPE) structured geomembrane and an artificial turf tufted into geotextiles. This system, branded as ClosureTurf™, was utilized to close two disposal cells of the Municipal Solid Waste (MSW) landfill. The two closed cells occupy an area of approximately 8 hectares. A geosynthetic final cover was selected for closing the cells instead of the more traditional earthen cover due to the poor quality of the available local soils: highly erodible silty clays and low pH topsoils. The synthetic cover system consisted of two layers of woven geotextiles with tufted UV-resistant polyethylene grass that was laid over a 50-mil LLDPE structured drainage geomembrane and in-filled with sand. The role of the sand was to act as ballast to the system. The design of the final cover system considered the acting forces on the geosynthetic materials such as self-weight, ballast pressure, wind suction, and landfill gas pressure. The system has some advantages over other types of synthetic covers such as the minimization of the necessity for anchoring and a more natural and pleasant look. The authors of this paper, who evaluated, designed, and provided quality control services during installation the final cover for the facility, are currently evaluating the performance of both, the synthetic final cover and the surficial gas system (SGS) installed in 2013..

Keywords: landfill, geosynthetics, landfill cover, final cover, synthetic cover, gas system

1 INTRODUCTION

Conventional landfills are designed throughout the world under the premise of encapsulating solid wastes within a contained and controlled space in order to avoid the migration of potential contaminants from the waste to the environment (de Abreu 2003). Under this concept, low-permeability barriers are constructed on the bottom and on the top of the landfill to minimize the release of contaminants to the water, air, and natural soils. The top barrier, known as the final cover, is designed to minimize the infiltration of rain and snow as well as to avoid the uncontrolled escape of gases generated by the biological and chemical decomposition of the refuse, while being resistant to weathering and other internal and external elements.

Final cover systems for municipal solid waste landfills in the United States are regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA) and specific regulations from each state. The State of Louisiana regulations (ERC 2014) require that final cover systems for municipal solid waste landfills be composed of a recompacted clay layer with thickness of at least 60 cm and hydraulic conductivity lower than $1x10^{-7}$ cm/s, overlain with a geomembrane approved by the environmental state agency (the Louisiana Department of Environmental Quality - LDEQ). In areas where slopes are steeper than 1(V):4(H), the geomembrane is not required. A minimum of 15 cm of topsoil capable of support vegetative grow is required to be placed as the top part of the cover. Alternative design for landfill final covers, including the utilization of exposed geomembranes, is also considered by the LDEQ as long as the alternative cover is capable of providing equivalent or superior performance when compared to the traditional cover. It is important to note that, although regulations often prescribe the minimum component layers that the final cover must have, it is usually necessary to design additional layers for the successful installation and performance of the cover. According to Koerner (1998) and Qian et al. (2002), additional components of a final cover may include a gas collection layer, a surface water drainage layer, and a protection layer.

Exposed geomembranes have been used as landfill cover in the United States for more than 15 years. The use of exposed geomembranes as final cover offers several advantages when compared to traditional covers, including easier installation, less maintenance, airspace savings, and overall cost savings (de Abreu and Franklin 2014). Main concerns regarding the use of exposed geomembranes by environmental regulatory agencies are weathering and wind uplift. Others concerns may include aesthetics, increase in surface water run-off, potential for physical damage, and eventual seepages more difficult to be detected. On the other hand, traditional covers may suffer from stability issues, such as differential settlement causing cracks and increasing the hydraulic conductivity of the low-permeability clay layer, soil erosion, and veneer sliding of layers. Figure 1 presents a visual comparison between the components of a traditional and an exposed geomembrane final cover. The figure depicts the minimum layers thicknesses as required by the State of Louisiana.

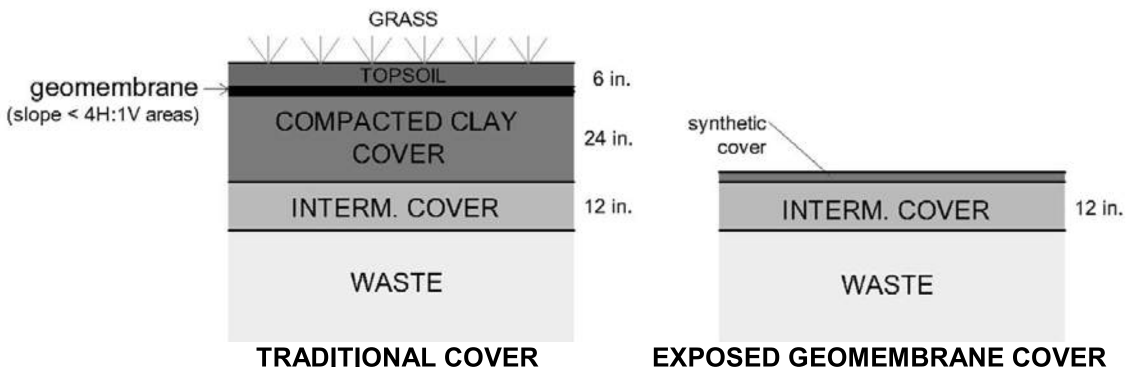

Figure 1. Comparison between components of traditional and exposed geomembrane final covers as regulated by the State of Louisiana

2 FINAL COVER FOR THE TANGIPAHOA REGIONAL SOLID WASTE FACILITY

2.1 Description of the Artificial Turf Final Cover System (Richgels et al. 2012)

The final design of the final cover system for the Tangipahoa RSWF utilized a "hybrid" final cover system, branded as "ClosureTurf^{TM}". This system consists of a structured geomembrane protected from the effects of weathering by an artificial grass component. The artificial grass "mechanically erosion-resistant" layer is manufactured with high density polyethylene (HDPE) artificial grass tufts sewn into a double layer 203 g/m^2 polypropylene (PP) woven geotextile. This artificial turf layer is placed over a 1.27 mm linear low density polyethylene (LLDPE) structured geomembrane (SGM) with raised 3.3 mm studs on the top surface and 4.4 mm spikes on the bottom surface. Both the stud and spike components are built into the structured geomembrane sheet using a calendared flat die extrusion process versus a blown film process for textured geomembrane.

The artificial turf component is anchored in place over the structured geomembrane with ballasting sand. Use of anchoring trenches is limited to final cover terminations and those required for the convenience of the installation in contrast to the extensive anchoring required for regular exposed geomembranse.

Figure 2 presents a schematic of the artificial turf system used at the Tangipahoa RSWF.

2.2 The Facility

The Tangipahoa RSWF is a permitted municipal solid waste landfill located in south Louisiana, approximately 90 km northwest of the city of New Orleans. The landfill is owned by the Tangipahoa Parish Government and has been in operation by the municipality since 1987. It currently disposes of approximately 550 t of waste daily. Twelve disposal cells were constructed for waste disposal along the years. Cells 1 through 9 were closed according the regulations of the time. Cells 10 and 11 were closed in November 2013 using the artificial turf final cover system described in the previous section. The total area of Cells 10 and 11 is approximately 9 hectares.

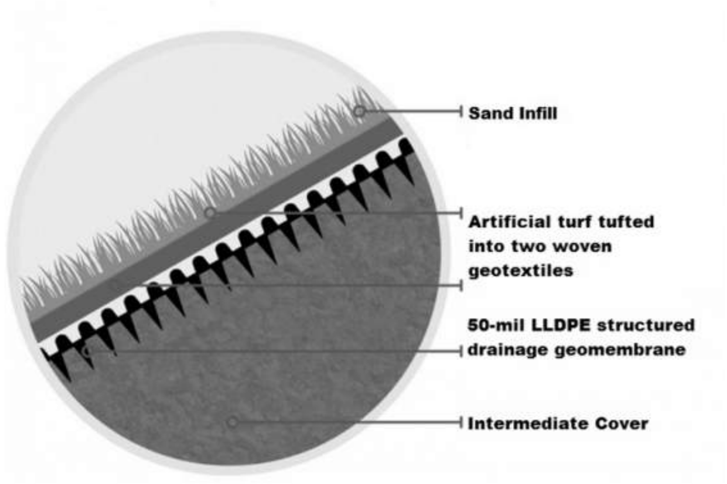

Figure 2. Schematic of the artificial turf final cover system utilized at the Tangipahoa RSWF

Several considerations were made to utilize an alternative final cover system for Cells 10 and 11 of the facility, including the limited availability of in-situ soils required for a low-permeability traditional cover, poor in-situ topsoils with low pH, steep slopes (1V:3H), and the high costs and difficulty maintaining the existing cover. The engineering consultants and local government officials performed a cost-benefit analysis, while considering different types of alternative final covers. The artificial turf system was selected as the best alternative for closing the two cells. Approval for the facility to install the artificial turf final cover system was granted by the Louisiana Department of Environmental Quality in August 2011. The main construction and installation activities occurred between August and November 2013.

3 DESIGN CONSIDERATIONS

3.1 Weathering

Weathering is one of the main concerns when utilizing an exposed geomembrane as the final cover. Exposure to ultraviolet light can reduce the service life of the geoemembrane by reducing the strength resistance and other mechanical properties. It is important to note that in the final cover system utilized for the Tangipahoa RSWF, the geomembrane is protected from weathering since it is overlaid with the artificial grass component and the sand. Nevertheless, the artificial grass component, which is made of HDPE, would be exposed to precipitation, erosional forces, and ultraviolet light.

According to Koerner (2012), all geosynthetics have made great progress in their formulations and manufacturing in the last 25 years and exposed lifetime of 30 years or greater is currently achievable, even in hot climates, in accordance with laboratory studies conducted by the Geosynthetic Institute (GSI). It is interesting to note that artificial turf has been used in soccer and football fields exposed to elements throughout the world for decades with success.

Tensile strength testing was performed on the artificial grass yarns by SGI Testing Services of Georgia (SGI 2009). Samples were weathered under field conditions in the Arizona Desert for 5 and 7 years in accordance with ASTM G147/2002 and ASTM G7/2005. According to the tensile strength results of the SGI report, the average retained strength for the 5-year and 7-year samples were equal to 89.7% and 83.8%, respectively. Preliminary extrapolated data for 30 year-exposure would result in a retained tensile strength equal to 58.7%, according to SGI. This would correspond to a tensile strength of 53 N per yarn, which is 3 to 4 times greater than the tensile strength indicated by the manufacturer to resist run-off and equipment forces.

3.2 Wind Uplift

Another valid concern regarding the use of exposed geomembranes is wind uplift due to development of suction forces at the geomembrane surface, as explained by Giroud (1995). These suction forces are directly proportional to the wind speed and must be counterbalanced to prevent the failure of the geomembrane. This consideration was extremely important since the facility is located in an area prone to hurricanes, known as the Atlantic Hurricane Belt. However, as discussed by Jones Edmunds (2010), the artificial turf final cover system is “a three-dimensional structure that alters the boundary layer forces at the surface”. This alteration of forces occurs due to the porous nature of the material and the increase in the aerodynamic conditions due to the turf blades, which bend and react against the wind. Therefore, the standard uplift conditions and calculations for exposed geomembranes clearly do not apply.

The forces generated at the surface of the artificial turf system were evaluated by the Georgia Tech Research Institute through aerodynamic testing (GTRI 2010). The artificial turf cover system was full-scaled tested in a subsonic wind tunnel wherein the normal force loading and the shear stress for different wind speeds were determined under two different conditions: one representing the perimeter of turf installation (without anchoring) and the other representing an interior section. Both configurations were tested under a flat horizontal surface. The results have shown that 1.0 cm of sand with unit weight equal to 17 kN/m^3 would be enough to counteract the uplift forces of wind speeds of approximately 190 km/h (no safety factor included). The perimeter installation configuration represented the worst condition.

In accordance with ASCE Standard 7-10 (2010), “Minimum Design Loads for Buildings and Other Structures”, the wind speed correspondent to a recurrence interval of 50 years is approximately 150 km/h at the site location. For a recurrence interval of 100 years, the wind speed is approximately 170 km/h. A wind speed of 185 km/h was utilized for the wind uplift verification of the artificial turf cover system during the design phase. The safety factor for wind uplift was calculated by using the data generated from the wind tunnel testing and for the site conditions and cell configurations of the facility. The calculated safety factor against wind uplift was equal to approximately 1.6, when a sand thickness of 1.3 cm was considered.

3.3 Cover Veneer Slope Stability

The analysis of cover veneer stability for the artificial turf final cover system basically follows the equations of limit equilibrium forces involved in a finite length slope of uniform cover soil with horizontal seepage buildup as presented by Koerner (1998) and Qian et al. (2002). Three interfaces were analysed against imminent failure: the interface between sand and the artificial turf, the interface between the geotextile of the artificial turf and the LLDPE geomembrane, and the interface between the LLDPE geomembrane and underneath intermediate cover. The friction angles between interfaces assumed for design were obtained based on product-specific interface friction laboratory testing performed by SGI Testing Services, LLC.

Interface friction angles obtained through testing were approximately 35° (peak) /33° (residual) for the interface between the sand and the artificial turf component, 43° (peak)/38° (residual) for the interface between the geotextile of the artificial turf component and the LLDPE geomembrane, and 38° (peak)/34° (residual) for the interface between the spiked side of the LLDPE geomembrane and the soil.

All three analysed cases resulted in safety factors greater than 2.0, with the interface between the geomembrane and soil representing the weakest interface for the project.

3.4 Erosion

One of the main goals of utilizing a synthetic final cover in the project was to reduce the erosion, since the in-situ clayey soils available at the facility were very silty and sandy in nature. However, despite the fact that the artificial turf system used in the project was primarily composed of synthetic components, it requires a sand layer to act as ballast against uplift. This sand layer would be subject to weather conditions, including severe precipitation events, which are not uncommon in Louisiana. Therefore, the capability of this sand layer to resist erosion forces also required verification for the project.

An analysis using the Universal Soil Loss Equation – USLE (Qing et al. 2002) was performed for a critical section of the project, showing that the average annual soil loss would be 2.7 t/ha, which is approximately 4 times lower than the maximum acceptable annual soil loss rate of 11 t/ha. The results indicate that minor erosion may occur along time and post-closure care may likely be needed regarding replacing the lost sand, since its function as ballast is vital part of the stability of the cover as presented on Section 3.3 of this article.

3.5 Surface Water Drainage Design

Another concern regarding the use of a synthetic final cover was that the volume and flow of surface water run-off were expected to increase significantly since storm water infiltration would be practically negligible. In addition, the designers aimed to significantly decrease the surface water run-off velocities in order to minimize the loss of sand.

The surface water drainage design limited sheet flow run-off to lengths equal or lower than 60 m. Diversion and perimeter berms were constructed on the existing slopes in order to limit the sheet flow run-off to that distance. Diversion and perimeter berms were typically 1 m tall and routed the surface water to let-down channels typically 3 to 5 m wide.

A hydraulic shear analysis was conducted to verify if the sand component would be removed at places where concentrated flow would occur (typically at the diversion/perimeter berms and let-down channels). The results showed that sand would be removed at relatively low shear stress values (as low as 29 Pa), which would be acceptable for the locations under sheet flow and diversion berms, but not at the perimeter berms and let-down channels. A cemented sand mix (3 sand:1 cement) was then utilized instead of sand at the perimeter berms and let-down channels in order to improve the shear strength of those drainage components. It was proven that the cemented sand mix utilized would be capable of resisting shear stresses as high as 700 Pa, which is much greater than the shear stresses at perimeter berms and let-downs.

3.6 Gas System Design

The gas system design concept utilized at the Tangipahoa RSWF has been coined as “Surficial Gas System” (SGS) design. This concept was specially developed for use with the artificial turf system. In a traditional gas system design, vertical extraction wells (VEWs) are drilled or horizontal gas collectors (HGCs) are installed into the waste mass to extract gas. VEW depths can vary greatly. They can be as shallow as 6 m and as deep as 60 m. HGCs are typically installed to depths that can vary anywhere from 2 to 6 m deep. In a traditional gas system, the purpose of the extraction devices is to capture the landfill gas within the waste mass.

The SGS design employs a slightly different approach to gas extraction. For the SGS design, perforated pipes are installed underneath the surface of the artificial turf system and near the surface of the intermediate cover to induce a vacuum. These gas extraction devices are referred to as surficial gas collectors (SGCs). In this approach, vacuum is induced underneath the geomembrane for the purpose of collecting the LFG using preferential pathways. Since the SGS is near the surface of the landfill, the vacuum induced within the waste mass is minimal; therefore, landfill gas will travel preferential pathways to the surface and eventually encounter the vacuum produced by the SGCs. At the Tangipahoa RSWF, perforated HDPE pipes were installed underneath the surface of the artificial turf system and on top of the intermediate cover. Since the facility already had a traditional gas system in place at certain areas, the gas system design was slightly modified for those areas. Perforated HDPE pipes with 10-cm diameter were utilized as collectors in the areas where a gas system was not in place, but 5-cm diameter pipes were used in areas where typical gas system components were already installed. The SGS is a very new gas system design concept, so the designers conservatively opted for larger pipes in areas without an existing gas system in place. The spacing of the SGCs was approximately 30 to 60 m apart, which is very similar to the spacing of extraction devices installed as part of a traditional gas system.

In order to monitor the vacuum distribution underneath the artificial turf system, sample ports were installed in key locations. These sample ports do not necessarily need to be included in the artificial turf system design; however, the designers felt that the vacuum distribution information obtained through the installation and monitoring of those sample ports would be beneficial to future design considerations.

The final component of the SGS design is the installation of pressure relief valves (PRVs). The purpose of the PRVs is to relieve gas pressure build-up beneath the artificial turf system that may occur during an unexpected outage of the blower/flare skid. This is a very important component of the gas system design because unanticipated high gas pressures can cause stability failure of the artificial turf system.

4 PERFORMANCE EVALUATION

The facility and the designers are currently evaluating the performance of the installed artificial turf final cover system. At the time this article was written, five months passed since installation of the system at the Tangipahoa RSWF.

4.1 Visual Performance

The facility is currently performing visual inspections to evaluate if any additional measures regarding extra maintenance or minor repairs are needed in the first months immediately following installation of the system. So far, no major problems have been observed.

The sand infill has been resisting erosion throughout the area even after intense precipitation events. The exception is the locations where the sand infill layer was deliberated installed with more than 2 cm in thickness. However, in those areas, the remaining sand thickness was at least greater than 1 cm, which is required by the design.

It has been also observed that there is a propensity for birds to peck the yarns of the artificial turf. Although the artificial turf does not naturally attract birds, the existence of birds at the facility or at the facility’s adjacencies can pose a risk to the integrity of the turf component and shall be managed under the permitted bird control practices. In the specific case of the Tangipahoa RSWF, sound guns have been effectively used as bird control measure.

The only minor issue observed so far at the recently completed project, was that in a small area at the top of the landfill (approximately 20 m^2 in size), some water was found to be trapped inside an overlap seam of the geomembrane component. The facility, designers, and product representatives have been closely monitoring that area. It appears that the area with water has not increased in size along time even after intense rainfall events, which suggests that the water is not due to a leakage in the geomembrane. Other possible explanations for the presence of water at that location are the evapotranspitration of the clay and storm water trapped during construction migrating to that area.

4.2 Surface Water Run-Off Quality Performance

The designed surface water drainage system appears to be effectively handling rainfall flows by adequately routing precipitation run-off to its final destination. In addition, the designers intend to monitor the quality of the water run-off to verify if any modifications can be made to the storm water treatment system of the facility. The facility, which is located near a tributary of Lake Pontchartrain, have been for several years required to treat run-off storm water in order to reduce its turbidity before discharging off-site.

It seems intuitive that the water quality of an area with a synthetic cover would be superior that an area with clay cover, especially regarding turbidity. In order to quantify the beneficial effect of the installation of the artificial turf cover system installed at Tangipahoa RSWF, the writers developed a water monitoring program in which storm water run-off samples would be collected and analyzed from two distinct areas: one with only artificial turf cover system installed and, the other, with only intermediate cover. Other than the type of cover installed, both areas are approximately 2 hectares in size, have similar characteristics, and are located at the Tangipahoa RSWF. The analysed parameters include Turbidity, Total Suspended Solids (TSS), pH, Total Organic Carbon (TOC), and Total Recorable Iron (TRI).

Only one sampling event has been performed so far, so a final conclusion cannot be drawn at the present time. Table 1 presents the result of the first sampling event. As it can be seen, a preliminary comparison of the results shows that the artificial turf system cover lead to better water quality than a clayey intermediate cover for the parameters analysed.

Table 1: Water Quality Results for First Sampling Event

Parameter	Area with Intermediate Cover	Area with Artificial Turf System
Turbidity (NTU)	371	11
TSS (mg/L)	349	< 4
pH	6.5	7.3
TOC (mg/L)	174	1
TRI (mg/L)	16	0.5

4.3 Gas System Monitoring Performance

The Tangipahoa RSWF is the only landfill in the country with a surficial gas system (SGS) and a typical gas system in place in a same area. For this reason, the writers performed a 3-month evaluation of the gas system under three different operational scenarios. For the first month the system was evaluated with both the typical gas system and the SGS operating at the same time (Full Gas Collection and Control System - GCCS). In the second month, only the extraction capability of the SGS was evaluated by turning off the typical GCCS (SGS Only). In the third month the extraction capability of the typical gas system was evaluated operating by itself (Typical GCCS Only). The criteria that we used to evaluate the performance of the gas system in each operating scenario were the landfill gas extraction rate and the pressure distribution observed at the sample ports.

Figure 3 displays the Landfill Gas Extraction Rate Comparison Chart with each operating scenario. It should be noted that the first reading obtained in the Full-GCCS Scenario appears to be low because field personnel were able to increase the gas extraction rates due to the presence of the geomembrane that limits air intrusion. It can also be inferred that the first reading from the Typical-GCCS Only Scenario appeared to be higher than normal because this scenario followed the SGS-Only Scenario. It is expected that the SGS-Only operational scenario will typically lead to lower vacuum distribution throughout the pipe network in accordance with the standard operating parameters that would be used in a typical gas collection and control system.

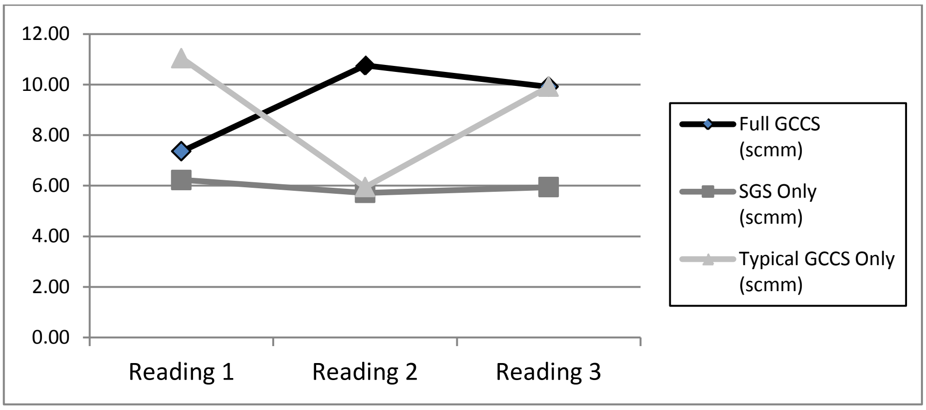

Figure 3. Landfill Gas Extraction Comparison Chart

As can be seen from Figure 3, the Typical-GCCS Only and Full-GCCS operating scenarios have similar flow rates at the end of the evaluation period; while, in the SGS-Only scenarios, LFG extraction rates were lower than both. We believe that there is the possibility that the gas extraction rate could more closely reflect the extraction rates of the other operational scenarios if more time was allowed. We believe that it could possibly take more time for the gas to establish preferential pathways to the SGS for extraction.

Figure 4 includes information on the second criterion, pressure distribution that was assessed as part of this evaluation. As expected, the vacuum distribution underneath the artificial turf system was lower than the other operating scenarios. As previously mentioned, this design premise includes preferential pathways; therefore, the amount of positive pressure throughout the network will be greater. It should be noted that the positive pressures were relatively small (0.4 cm·H_2O or less). For this reason, it may be inferred that these pressures might not to be a major concern.

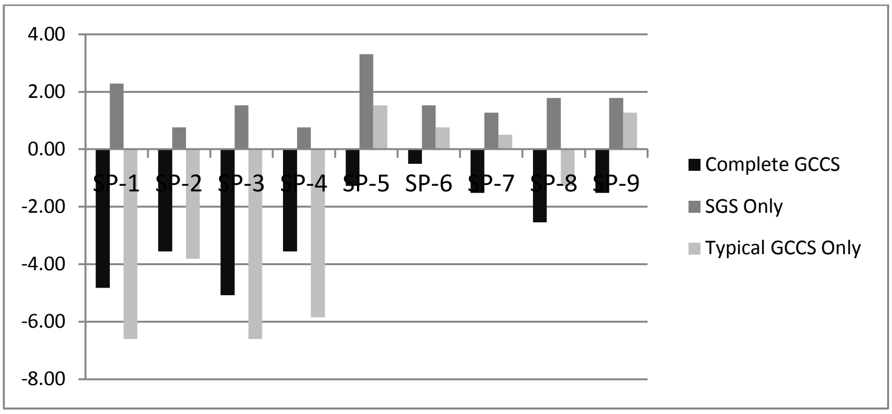

Figure 4. Landfill Gas Pressure Comparison Chart (in cm·H_2O units)

5 CONCLUSION

Based on the investigation performed during the design phase, visual observations conducted during installation, and performance evaluation of the final cover installed at the Tangipahoa Regional Solid Waste Facility, the writers believe that the artificial turf cover system is a viable technology for utilization as final cover system for solid waste landfills. Specifically, it is a strong option for landfills that only have available highly erodible soils or poor topsoils.

Regarding the gas system installed at the facility, based on the data shown, the writers believe that the Surficial Gas System (SGS) is also a viable design concept to employ when high demand or mitigation of landfill gas migration is not a requirement. However, the need for additional data is warranted. The writers plan to perform a more long-term evaluation of all of the operational scenarios to obtain more definitive results on the performance of the SGS design concept.

6 ACKNOWLEDGEMENTS

The writers would like to thank the Tangipahoa Parish Government for allowing the publication of the information contained in this article and to Watershed Geosynthetics for their support in the design, installation, and post-construction phases of the project.

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Attachment I

Hydrologic Evaluation of Landfill

Performance (HELP) Model Analysis

HELP Model Comparison
Engineered Turf / Traditional Cover
November 2021

Prepared by:

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CALCULATION SHEET

Client:	US Ecology – Wayne Disposal	Project No.:			
Project:	Engineered Turf Equivalency Demonstration Report	Calculated By:	JLM	Date:	10/01/21
Calculation	HELP Model – Cover Comparison	Checked By:	XZ	Date:	10/06/21
		Approved By:		Date:	

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2.1. HELP Model Parameters 1
2.2. Model Assumptions 2
2.3. Standard Soil Cover System Material Textures 3
2.4. Engineered Turf Cover System Material Textures 3
3.0 Results 3
4.0 Conclusions 4

Attachments

Attachment A: Final Cover Comparison Calculations
Attachment B1: Standard Permitted Cover System HELP Model Output
Attachment B2: Engineered Turf Cover System HELP Model Output
Attachment C: Climate Data Information

CALCULATION SHEET

Client:	US Ecology – Wayne Disposal	Project No.:			
Project:	Engineered Turf Equivalency Demonstration Report	Calculated By:	JLM	Date:	10/01/21
Calculation	HELP Model – Cover Comparison	Checked By:	XZ	Date:	10/06/21
		Approved By:		Date:	

1.0 OBJECTIVE

CTI & Associates has prepared this report to demonstrate the hydrologic equivalency of engineered turf to the traditional cover system requirements specified by Code of Federal Regulations (CFR) §264.310 which in part requires the final cover to in part

- Provide long-term minimization of migration of liquids through the closed landfill
- Promote drainage of the cover
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

In addition to prescriptive requirements for the final cover over a hazardous waste landfill, Michigan Administrative Code R 299.9619(6)(a) also states the owner or operator can: Substitute an equivalent design which shall include a flexible membrane liner component with a minimum thickness of 1 mm (40 mil), depending on the type of material selected, and demonstrates to the director that it provides equivalent environmental protection.

ClosureTurf, which is an engineered turf designed to be used for landfill cover systems, already includes the 40 mil minimum geomembrane. It is the most developed and tested of the commercially available engineered turf products and is the subject of this comparison. Other aspects of environmental protection can be demonstrated through various performance demonstrations. To demonstrate the hydrologic performance of ClosureTurf, the Hydrologic Evaluation of Landfill Performance (HELP) Model, was used to compare the amount of percolation through the cover system expected for each system.

2.0 FINAL COVER COMPARISON METHODOLOGY

The HELP Model was developed by USEPA specifically to compare the hydrologic performance of different cover designs while considering a variety of environmental, soil, and design variables (Schroeder et al., 1994). Version 4.0.1 was used for this evaluation. The results of the HELP Model provide a detailed look at daily, monthly, and annual contact water amounts expected to be generated for a given cover design. Therefore, the efficacy of each cover evaluated can be directly compared by the amount of contact water generated. A detailed engineering manual discussing the basis for the model is available online at the following location: https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model. Updated information on version 4.0 from USEPA used in this analysis can be found here: https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model.

2.1. HELP MODEL PARAMETERS

The HELP Model requires four different types of climate data to execute including: evapotranspiration, precipitation, temperature, and solar radiation. Each data group is based on a specific location and can either be synthetically generated using the HELP Model or manually entered. For this analysis, the most important parameter is precipitation because it directly correlates to the amount of contact water generated. For all four groups, the program was used to generate 100 years of synthetic data based on the default database associated with the closest weather station to the site, Detroit Metro Airport, which is approximately 12 miles east of the site. The synthetic precipitation data was back checked with the National Oceanic and Atmospheric Administration's (NOAA) Summary of Monthly Normals for precipitation to determine if the actual climate values were consistent with the model data. It was determined that they were in good agreement for purposes of this analysis. This comparison is included in the calculations in **Attachment A**.

The remaining model parameters included site geometry and material characteristics. A standard of one acre was used for each analysis. Representavie slope lengths and grades were also used as depicted in the summary Tables 1 and 2. With the exception of the cover system materials modeled, all other inputs into the model were held constant to facilitate a fair comparison. For purposes of the comparison, each final cover system was input into the model and the amount of contact water measured after 100 years was compared. The model presents peak daily results and average annual results over the 100-year simulation period. Input parameters are included in the output files contained in **Attachments B1** and **B2**. Climate data are included in **Attachment C**.

2.2. MODEL ASSUMPTIONS

The following assumptions were made in performing the HELP Model Analysis. For reference, the HELP Model User's Guide For Version 4 can be found online at: https://www.epa.gov/land-research/help-40-user-manual.

- The geosynthetics materials are assumed to be constructed with good quality workmanship and in accordance with the project CQA Plan. An industry standard defect area of 0.0001 m^2 was assumed in the analysis with a placement quality of "good". This represents one pinhole-type defect and four pinhole installation defects per acre. Both designs include a 40 mil geomembrane underlain by a GCL. Geomembrane hydraulic conductivity was modeled as 4.0×10^{-13} cm/sec while GCL hydraulic conductivity was modeled as 3.0×10^{-9} cm/sec

- The initial water contents of all layers were manually set equal to the default HELP specified field capacity of the material, which represents the water content of the material after a prolonged period of gravity drainage. However, it should be noted that for the purpose of calculating hydraulic flow through the landfill system, the HELP Model conservatively assumes that all barrier layers (final cover barrier layer) are saturated.

- The HELP Model was utilized to synthetically generate temperature, precipitation, evapotranspiration, and solar radiation data based on Detroit Metro, Michigan. The evaporative zone depth was conservatively reduced from the default value based on the given cover system.

- The HELP Model results are independent of the landfill area. A one acre area was considered for the analysis. Therefore, cover system leakage results are presented as cubic feet per acre per time period (annual or daily). Results were converted to gallons per acre per time period using the conversion factor listed below:

$$\frac{ft^3}{time\ period} \times \frac{7.48\ gallons}{ft^3} \times \frac{time\ period}{\#\ of\ days}$$

2.3. Standard Soil Cover System Material Textures

Cover materials for the OAC prescribed Standard Soil Cover System used in the HELP Model were modeled as follows:

- The Infiltration Layer was modeled consistent with past analyses as follows:
  - Porosity: 0.471
  - Wilting Point: 0.21
  - Saturated Hydraulic Conductivity: 5.0×10^{-4} cm/sec.
- The geocomposite drainage Layer was modeled as HELP default texture 20 with effective saturated hydraulic conductivity of 10 cm/s.

2.4. Engineered Turf Cover System Material Textures

The engineered turf was modeled as recommended by the manufacturer of ClosureTurf and based on the published characteristics of the materials.

- The sand infill material was modeled as follows:
  - Porosity: 0.437
  - Wilting Point: 0.024
  - Saturated Hydraulic Conductivity: 2.5×10^{-2} cm/sec
- The lateral drainage characteristics were modeled with an effective Saturated Hydraulic Conductivity of 31.6 cm/s.

3.0 Results

The HELP model output files for the required and proposed cover systems are provided in Appendix B. The key results of the HELP Model comparison depicting the hydraulic performance of each cover system are included in Table 1 and Table 2 below. Note that these results are presented for comparative purposes and may not represent accurate estimates of actual leakage through the constructed cover system.

Table 1: Rainfall/Runoff/Infiltration of standard cover system versus Engineered Turf Cover System

Final Cover Systems	Slope	Slope Length (ft)	Average Annual Precipitation (in)	Average Annual Runoff (in)	Average Annual Perc. Through Membrane (in)
Permitted Cover System	4%	625	31.7	2.6	1E-6
Engineered Turf	4%	625	31.7	8.0	1E-6
Permitted Cover System	25%	200	31.7	3.1	5E-7
Engineered Turf	25%	820	31.7	7.9	1E-6

Table 2: Hydraulic Performance of Permitted Cover System versus Engineered Turf Cover System

Final Cover Systems	Slope	Slope Length (ft)	Average Daily Leakage Rate (Gal/Acre/Day)	Peak Daily Leakage Rate (Gal/Acre/Day)	Average Annual Leakage Rate (Gal/Acre/Year)
Permitted Cover System	4%	625	7.2E-5	7.1E-4	0.03
Engineered Turf	4%	625	8.1E-5	4.4E-4	0.03
Permitted Cover System	25%	200	3.8E-5	2.6E-4	0.02
Engineered Turf	25%	820	8.6E-5	2.3E-4	0.03

4.0 CONCLUSIONS

The results in Table 1 and Table 2 provide a side-by-side comparison of the §264.310 traditional permitted design standard versus engineered turf which shows that the proposed alternate cover system will result in similar rates and sheds much more water than a traditional cover system. Although percolation rates are mathematically different, this likely is due to limitations in the model for handling such small values relative to the overall resolution of the model. In any case, it shows that both cover systems allow for negligible flow through the geosynthetic composite cover. From a hydrologic standpoint, the proposed alternate material meets the criteria for being at least as protective to the environment as the permitted cover system.

Attachment A
Final Cover Comparison Calculations

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Novi, MI 48377
Tel. (248) 486-5100

USE/WDI

Final Cover Comparison
2021 WDI Permit Mod

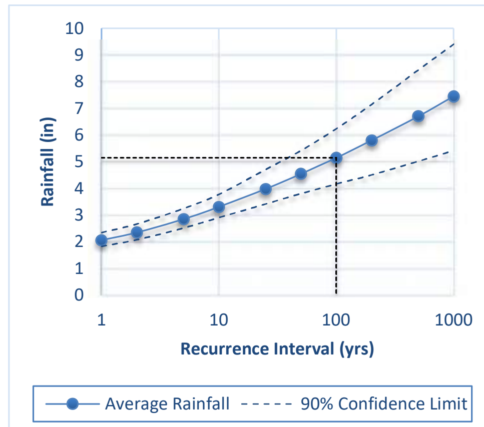
JOB	1208070066		
SHT NO	1	OF	3
CALC BY	JLM	DATE	10/03/21
CHK BY	XZ	DATE	

Review climate data for the site and determine total normal precip, monthly extreme values, and 100 yr/24 hr storm based on local NOAA Data

National Environmental Satellite, Data, and Information Service: Climate Normals 1981-2010
Station Data: DETROIT MET. AIRPORT, MI US USW00094847 Lat 42.2313° N Long -83.3308° W

Normal Precipitation

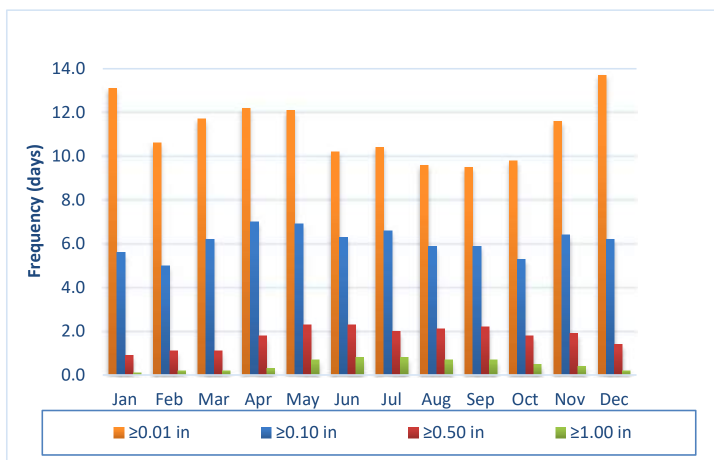
Month	Rainfall (in)	Snowfall (in)	Extreme Daily Rainfall.* (in)	Year	24-hr Storm Duration Rainfall Recurrence Interval (yr)	Precip. (in)
Jan	1.96	12.5	2.06	11/2020		0
Feb	2.02	10.2	2.41	09/1876	1	2.06
Mar	2.28	6.9	1.97	30/2017	2	2.35
Apr	2.90	1.7	3.58	20/2000	5	2.85
May	3.38	0.0	2.56	26/1968	10	3.31
Jun	3.52	0.0	3.07	06/1903	25	3.98
Jul	3.37	0.0	4.74	31/1925	50	4.55
Aug	3.00	0.0	4.57	11/2014	100	5.15
Sep	3.27	0.0	3.71	11/2000	200	5.8
Oct	2.52	0.1	3.29	Mar-54	500	6.71
Nov	2.79	1.5	2.59	22/1909	1000	7.45
Dec	2.46	9.6	2.17	21/1967		
Year	33.47	42.50				



*Extreme data from 1874 through 2021

Frequency Distribution for Daily Precipitation (1981-2010)

Mth/Rain	≥0.01 in	≥0.10 in	≥0.50 in	≥1.00 in
Jan	13.1	5.6	0.9	0.1
Feb	10.6	5.0	1.1	0.2
Mar	11.7	6.2	1.1	0.2
Apr	12.2	7.0	1.8	0.3
May	12.1	6.9	2.3	0.7
Jun	10.2	6.3	2.3	0.8
Jul	10.4	6.6	2.0	0.8
Aug	9.6	5.9	2.1	0.7
Sep	9.5	5.9	2.2	0.7
Oct	9.8	5.3	1.8	0.5
Nov	11.6	6.4	1.9	0.4
Dec	13.7	6.2	1.4	0.2
Year	134.5	73.3	20.9	5.6



28001 Cabot Dr.
Novi, MI 48377
Tel. (248) 486-5100

USE/WDI

Final Cover Comparison
2021 WDI Permit Mod

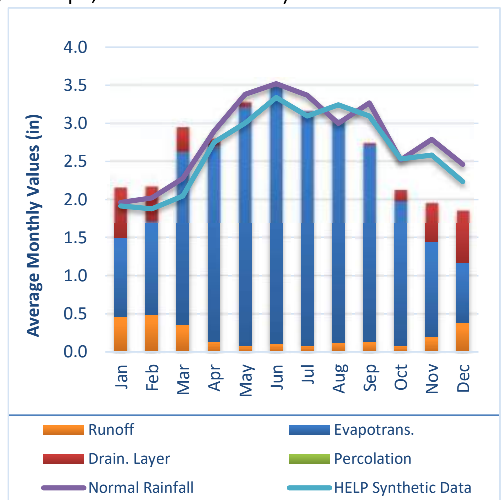
JOB	**1208070066**		
SHT NO	**2**	OF	**3**
CALC BY	**JLM**	DATE	**10/03/21**
CHK BY	**XZ**	DATE	

Compare climate data and HELP model results. Determine average daily precipitation, stormwater runoff, and leachate generation due to percolation through the infiltration layer based on HELP model data.

HELP Model Average Monthly Precipitation & Leachate Data

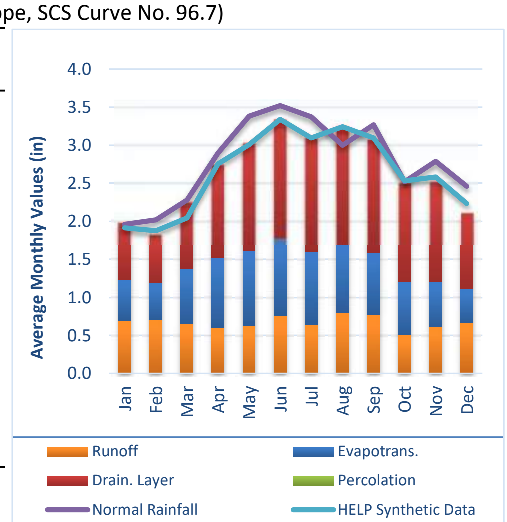
HELP Model - 100 yrs of Synthetic Weather Data - (Permitted Cover System, 1 Acre, 625 ft/4% slope, SCS Curve No. 90.0)

Average Month	Rainfall in	Runoff in	Evapotrans. in	Evap. Zone in	Drain. Layer in	Percolation in
Jan	1.91	0.457	1.038	0.344	0.660	0.000
Feb	1.88	0.488	1.217	0.332	0.464	0.000
Mar	2.05	0.350	2.274	0.305	0.327	0.000
Apr	2.76	0.137	2.564	0.283	0.092	0.000
May	3.01	0.083	3.125	0.275	0.067	0.000
Jun	3.34	0.101	3.386	0.268	0.013	0.000
Jul	3.10	0.084	3.059	0.258	0.016	0.000
Aug	3.24	0.124	2.912	0.267	0.007	0.000
Sep	3.10	0.128	2.582	0.280	0.030	0.000
Oct	2.53	0.084	1.890	0.293	0.149	0.000
Nov	2.58	0.196	1.245	0.322	0.514	0.000
Dec	2.24	0.387	0.790	0.340	0.678	0.000
Year	31.73	2.62	26.08		3.02	0.000
Peak Daily	2.40	2.20			0.342	0.000



HELP Model - 100 yrs of Synthetic Weather Data - (CT Cover System, 1 Acre, 625 ft/4% slope, SCS Curve No. 96.7)

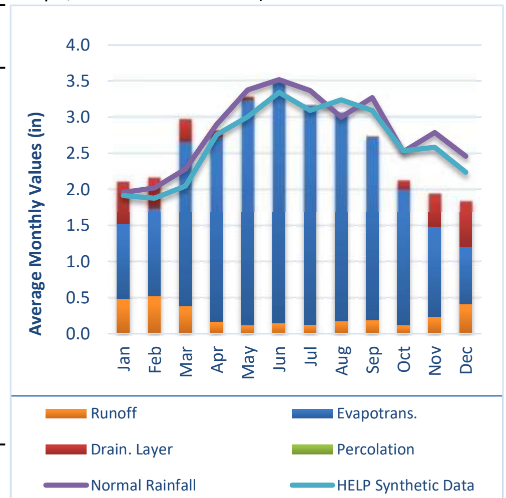
Average Month	Rainfall in	Runoff in	Evapotrans. in	Evap. Zone in	Drain. Layer in	Percolation in
Jan	1.91	0.698	0.536	0.130	0.750	0.000
Feb	1.88	0.707	0.481	0.100	0.637	0.000
Mar	2.05	0.655	0.726	0.088	0.871	0.000
Apr	2.76	0.597	0.923	0.080	1.223	0.000
May	3.01	0.624	0.986	0.076	1.419	0.000
Jun	3.34	0.762	1.008	0.079	1.569	0.000
Jul	3.10	0.640	0.964	0.076	1.496	0.000
Aug	3.24	0.800	0.894	0.075	1.550	0.000
Sep	3.10	0.777	0.811	0.072	1.487	0.000
Oct	2.53	0.505	0.697	0.073	1.299	0.000
Nov	2.58	0.612	0.586	0.081	1.320	0.000
Dec	2.24	0.664	0.449	0.111	0.998	0.000
Year	31.73	8.04	9.06		14.62	0.000
Peak Daily	2.4	2.44			0.591	0.000



	USE/WDI	JOB 1208070066			
28001 Cabot Dr.	Final Cover Comparison	SHT NO	3	OF	3
Novi, MI 48377	2021 WDI Permit Mod	CALC BY	JLM	DATE	10/03/21
Tel. (248) 486-5100		CHK BY	XZ	DATE	

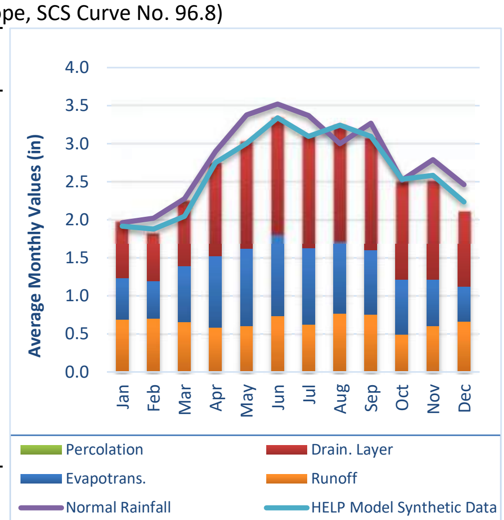
HELP Model - 100 yrs of Synthetic Weather Data - (Permit Cover System, 1 Acre, 200 ft/4:1 slope, SCS Curve No. 90.9)

Average Month	Rainfall in	Runoff in	Evapotrans. in	Evap. Zone in	Drain. Layer in	Percolation in
Jan	1.91	0.486	1.037	0.350	0.585	0.000
Feb	1.88	0.519	1.217	0.339	0.430	0.000
Mar	2.05	0.383	2.272	0.311	0.316	0.000
Apr	2.76	0.169	2.552	0.288	0.090	0.000
May	3.01	0.122	3.105	0.279	0.052	0.000
Jun	3.34	0.149	3.357	0.272	0.009	0.000
Jul	3.10	0.123	3.030	0.262	0.010	0.000
Aug	3.24	0.177	2.881	0.269	0.001	0.000
Sep	3.10	0.186	2.535	0.283	0.013	0.000
Oct	2.53	0.119	1.880	0.296	0.126	0.000
Nov	2.58	0.242	1.241	0.325	0.461	0.000
Dec	2.24	0.415	0.790	0.344	0.635	0.000
Year	31.73	3.09	25.90		2.73	0.000
Peak Daily	2.40	2.21			0.250	0.000



HELP Model - 100 yrs of Synthetic Weather Data - (CT Cover System, 1 Acre, 820 ft/4:1 slope, SCS Curve No. 96.8)

Average Month	Rainfall in	Runoff in	Evapotrans. in	Evap. Zone in	Drain. Layer in	Percolation in
Jan	1.91	0.693	0.542	0.344	0.749	0.000
Feb	1.88	0.705	0.486	0.332	0.632	0.000
Mar	2.05	0.653	0.736	0.305	0.867	0.000
Apr	2.76	0.586	0.939	0.283	1.222	0.000
May	3.01	0.602	1.020	0.275	1.407	0.000
Jun	3.34	0.733	1.068	0.268	1.537	0.000
Jul	3.10	0.622	1.001	0.258	1.477	0.000
Aug	3.24	0.768	0.945	0.267	1.531	0.000
Sep	3.10	0.754	0.848	0.280	1.473	0.000
Oct	2.53	0.496	0.721	0.293	1.283	0.000
Nov	2.58	0.603	0.609	0.322	1.300	0.000
Dec	2.24	0.663	0.461	0.340	0.990	0.000
Year	31.73	7.88	9.38		14.47	0.000
Peak Daily	2.40	2.44			0.642	0.000



Conclusions:

Overall, the HELP synthetic data correlates well with the available monthly climate normals data from NOAA. It underpredicts rainfall by a little over an inch. As the primary objective of the HELP model is to demonstrate the Engineered Turf cover system has an equivalent or better hydrologic performance compared to the permitted soil cover system, this HELP model is sufficient for comparison purposes.

The final cover comparison shows that the Engineered Turf barrier used in the alternate cover system prevents infiltration as effectively as the permitted cover which is to say the both effectively prevent infiltration when installed properly. The biggest difference as illustrated by the results is the soil component of the traditional cover holds a large portion of the surface water while the engineered turf sheds that water.

R 299.9619(6)(a) states the owner or operator can substitute an equivalent design which shall include a flexible membrane liner component with a minimum thickness of 1 mm (40 mil), depending on the type of material selected, and demonstrates to the director that it provides equivalent environmental protection. ClosureTurf includes the geomembrane, it also offers equivalent environmental protection as it relates surface water infiltration and percolation through the cover system.

Attachment B1
Standard Permitted Cover System HELP Model Output

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: MC Cell VI-F&G Permit Cover **Simulated On:** 10/7/2021 9:02

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
WDI Veg/Infiltration Layer
Material Texture Number 43

Thickness	=	36	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.3422	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-04	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
Drainage Net (0.5 cm)
Material Texture Number 20

Thickness	=	0.2	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.01	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E+01	cm/sec
Slope	=	25	%
Drainage Length	=	200	ft

Layer 3
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 4
Type 3 - Barrier Soil Liner

Bentonite (High)
Material Texture Number 17

Thickness	=	0.25	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-09	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	90.9	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	5.958	inches
Upper Limit of Evaporative Storage	=	8.478	inches
Lower Limit of Evaporative Storage	=	3.78	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	12.509	inches
Total Initial Water	=	12.509	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	42.18	Degrees
Maximum Leaf Area Index	=	1	
Start of Growing Season (Julian Date)	=	90	days
End of Growing Season (Julian Date)	=	216	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	72	%
Average 3rd Quarter Relative Humidity	=	80	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for Belleville, Michigan

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.913949	1.878746	2.045516	2.755274	3.005731	3.34107
3.096216	3.243099	3.096181	2.533399	2.583786	2.235743

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
29.7	30.4	42.7	54.8	68.5	78.1
81.5	79	68.8	56.2	44	31.5

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Average Annual Totals Summary

Title: MC Cell VI-F&G Permit Cover
Simulated on: 10/7/2021 9:08

	Average Annual Totals for Years 1 - 100*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	31.73	[3.35]	115,175.2	100.00
Runoff	3.091	[1.284]	11,219.0	9.74
Evapotranspiration	25.898	[2.765]	94,009.5	81.62
Subprofile1				
Lateral drainage collected from Layer 2	2.7348	[1.3]	9,927.5	8.62
Percolation/leakage through Layer 4	0.000001	[0]	0.0018	0.00
Average Head on Top of Layer 3	0.0001	[0.0001]	---	---
Water storage				
Change in water storage	0.0053	[0.8627]	19.2	0.02

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: MC Cell VI-F&G Permit Cover
Simulated on: 10/7/2021 9:08

	Peak Values for Years 1 - 100*	
	(inches)	(cubic feet)
Precipitation	2.40	8,721.4
Runoff	2.208	8,016.0
Subprofile1		
Drainage collected from Layer 2	0.2504	909.1
Percolation/leakage through Layer 4	0.000000	0.0000
Average head on Layer 3	0.0038	---
Maximum head on Layer 3	0.0075	---
Location of maximum head in Layer 2	0.00 (feet from drain)	
Other Parameters		
Snow water	4.1439	15,042.2
Maximum vegetation soil water	0.4231 (vol/vol)	
Minimum vegetation soil water	0.2100 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: MC Cell VI-F&G Permit Cover
Simulated on: 10/7/2021 9:08
Simulation period: 100 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	12.8479	0.3569
2	0.0024	0.0120
3	0.0000	0.0000
4	0.1875	0.7500
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: MC Cell VI-F&G Permit Cover **Simulated On:** 10/7/2021 13:59

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
WDI Veg/Infiltration Layer
Material Texture Number 43

Thickness	=	36	inches
Porosity	=	0.471	vol/vol
Field Capacity	=	0.342	vol/vol
Wilting Point	=	0.21	vol/vol
Initial Soil Water Content	=	0.3368	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E-04	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
Drainage Net (0.5 cm)
Material Texture Number 20

Thickness	=	0.2	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.01	vol/vol
Effective Sat. Hyd. Conductivity	=	1.00E+01	cm/sec
Slope	=	4	%
Drainage Length	=	625	ft

Layer 3
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 4
Type 3 - Barrier Soil Liner

Bentonite (High)
Material Texture Number 17

Thickness	=	0.25	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-09	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	90	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	18	inches
Initial Water in Evaporative Zone	=	5.842	inches
Upper Limit of Evaporative Storage	=	8.478	inches
Lower Limit of Evaporative Storage	=	3.78	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	12.315	inches
Total Initial Water	=	12.315	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	42.18	Degrees
Maximum Leaf Area Index	=	1	
Start of Growing Season (Julian Date)	=	90	days
End of Growing Season (Julian Date)	=	216	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	72	%
Average 3rd Quarter Relative Humidity	=	80	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for Belleville, Michigan

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.913949	1.878746	2.045516	2.755274	3.005731	3.34107
3.096216	3.243099	3.096181	2.533399	2.583786	2.235743

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
29.7	30.4	42.7	54.8	68.5	78.1
81.5	79	68.8	56.2	44	31.5

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Average Annual Totals Summary

Title: MC Cell VI-F&G Permit Cover
Simulated on: 10/7/2021 14:03

	Average Annual Totals for Years 1 - 100*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	31.73	[3.35]	115,175.2	100.00
Runoff	2.619	[1.205]	9,507.1	8.25
Evapotranspiration	26.082	[2.845]	94,677.7	82.20
Subprofile1				
Lateral drainage collected from Layer 2	3.0205	[1.3803]	10,964.5	9.52
Percolation/leakage through Layer 4	0.000001	[0]	0.0035	0.00
Average Head on Top of Layer 3	0.0023	[0.001]	---	---
Water storage				
Change in water storage	0.0071	[0.8521]	25.9	0.02

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: MC Cell VI-F&G Permit Cover
Simulated on: 10/7/2021 14:03

	Peak Values for Years 1 - 100*	
	(inches)	(cubic feet)
Precipitation	2.40	8,721.4
Runoff	2.198	7,978.9
Subprofile1		
Drainage collected from Layer 2	0.3421	1,241.6
Percolation/leakage through Layer 4	0.000000	0.0001
Average head on Layer 3	0.0944	---
Maximum head on Layer 3	0.1881	---
Location of maximum head in Layer 2	1.51	(feet from drain)
Other Parameters		
Snow water	4.1439	15,042.2
Maximum vegetation soil water	0.4108	(vol/vol)
Minimum vegetation soil water	0.2100	(vol/vol)

Final Water Storage in Landfill Profile at End of Simulation Period

Title: MC Cell VI-F&G Permit Cover
Simulated on: 10/7/2021 14:03
Simulation period: 100 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	12.8297	0.3564
2	0.0106	0.0530
3	0.0000	0.0000
4	0.1875	0.7500
Snow water	0.0000	---

Attachment B2
Engineered Turf Cover System HELP Model Output

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title: MC Cell VI-F&G Engineered Turf **Simulated On:** 10/7/2021 16:03

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
Engineered Turf
Material Texture Number 44

Thickness	=	0.5	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.024	vol/vol
Effective Sat. Hyd. Conductivity	=	2.50E-02	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
Studded Drainage Layer
Material Texture Number 123

Thickness	=	0.13	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.01	vol/vol
Effective Sat. Hyd. Conductivity	=	3.16E+01	cm/sec
Slope	=	25	%
Drainage Length	=	820	ft

Layer 3
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 4
Type 3 - Barrier Soil Liner

Bentonite (High)
Material Texture Number 17

Thickness	=	0.5	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-09	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	96.8	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	0.5	inches
Initial Water in Evaporative Zone	=	0.012	inches
Upper Limit of Evaporative Storage	=	0.218	inches
Lower Limit of Evaporative Storage	=	0.012	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	0.388	inches
Total Initial Water	=	0.388	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	42.18	Degrees
Maximum Leaf Area Index	=	1	
Start of Growing Season (Julian Date)	=	90	days
End of Growing Season (Julian Date)	=	216	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	72	%
Average 3rd Quarter Relative Humidity	=	80	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for Belleville, Michigan

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.913949	1.878746	2.045516	2.755274	3.005731	3.34107
3.096216	3.243099	3.096181	2.533399	2.583786	2.235743

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
29.7	30.4	42.7	54.8	68.5	78.1
81.5	79	68.8	56.2	44	31.5

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Average Annual Totals Summary

Title: MC Cell VI-F&G Engineered Turf
Simulated on: 10/7/2021 16:09

	Average Annual Totals for Years 1 - 100*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	31.73	[3.35]	115,175.2	100.00
Runoff	7.879	[1.761]	28,601.5	24.83
Evapotranspiration	9.378	[1.156]	34,041.5	29.56
Subprofile1				
Lateral drainage collected from Layer 2	14.4711	[1.3463]	52,530.2	45.61
Percolation/leakage through Layer 4	0.000001	[0]	0.0042	0.00
Average Head on Top of Layer 3	0.0008	[0.0001]	---	---
Water storage				
Change in water storage	0.0006	[0.5254]	2.1126	0.00

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: MC Cell VI-F&G Engineered Turf
Simulated on: 10/7/2021 16:10

	Peak Values for Years 1 - 100*	
	(inches)	(cubic feet)
Precipitation	2.40	8,721.4
Runoff	2.440	8,855.5
Subprofile1		
Drainage collected from Layer 2	0.6423	2,331.7
Percolation/leakage through Layer 4	0.000000	0.0000
Average head on Layer 3	0.0125	---
Maximum head on Layer 3	0.0250	---
Location of maximum head in Layer 2	0.00 (feet from drain)	
Other Parameters		
Snow water	4.1439	15,042.2
Maximum vegetation soil water	0.4370 (vol/vol)	
Minimum vegetation soil water	0.0240 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: MC Cell VI-F&G Engineered Turf
Simulated on: 10/7/2021 16:10
Simulation period: 100 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	0.0702	0.1404
2	0.0013	0.0100
3	0.0000	0.0000
4	0.3749	0.7499
Snow water	0.0000	---

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 4.0 BETA (2018)
DEVELOPED BY USEPA NATIONAL RISK MANAGEMENT RESEARCH LABORATORY

Title:	MC Cell VI-F&G Engineered Turf	**Simulated On:**	10/7/2021 16:47

Layer 1
Type 1 - Vertical Percolation Layer (Cover Soil)
Engineered Turf
Material Texture Number 44

Thickness	=	0.5	inches
Porosity	=	0.437	vol/vol
Field Capacity	=	0.062	vol/vol
Wilting Point	=	0.024	vol/vol
Initial Soil Water Content	=	0.024	vol/vol
Effective Sat. Hyd. Conductivity	=	2.50E-02	cm/sec

Layer 2
Type 2 - Lateral Drainage Layer
Studded Drainage Layer
Material Texture Number 123

Thickness	=	0.13	inches
Porosity	=	0.85	vol/vol
Field Capacity	=	0.01	vol/vol
Wilting Point	=	0.005	vol/vol
Initial Soil Water Content	=	0.01	vol/vol
Effective Sat. Hyd. Conductivity	=	3.16E+01	cm/sec
Slope	=	4	%
Drainage Length	=	625	ft

Layer 3
Type 4 - Flexible Membrane Liner
HDPE Membrane
Material Texture Number 35

Thickness	=	0.04	inches
Effective Sat. Hyd. Conductivity	=	2.00E-13	cm/sec
FML Pinhole Density	=	1	Holes/Acre
FML Installation Defects	=	1	Holes/Acre
FML Placement Quality	=	3	Good

Layer 4
Type 3 - Barrier Soil Liner

Bentonite (High)
Material Texture Number 17

Thickness	=	0.5	inches
Porosity	=	0.75	vol/vol
Field Capacity	=	0.747	vol/vol
Wilting Point	=	0.4	vol/vol
Initial Soil Water Content	=	0.75	vol/vol
Effective Sat. Hyd. Conductivity	=	3.00E-09	cm/sec

Note: Initial moisture content of the layers and snow water were computed as nearly steady-state values by HELP.

General Design and Evaporative Zone Data

SCS Runoff Curve Number	=	96.7	
Fraction of Area Allowing Runoff	=	100	%
Area projected on a horizontal plane	=	1	acres
Evaporative Zone Depth	=	0.5	inches
Initial Water in Evaporative Zone	=	0.012	inches
Upper Limit of Evaporative Storage	=	0.218	inches
Lower Limit of Evaporative Storage	=	0.012	inches
Initial Snow Water	=	0	inches
Initial Water in Layer Materials	=	0.388	inches
Total Initial Water	=	0.388	inches
Total Subsurface Inflow	=	0	inches/year

Note: SCS Runoff Curve Number was calculated by HELP.

Evapotranspiration and Weather Data

Station Latitude	=	42.18	Degrees
Maximum Leaf Area Index	=	1	
Start of Growing Season (Julian Date)	=	90	days
End of Growing Season (Julian Date)	=	216	days
Average Wind Speed	=	9	mph
Average 1st Quarter Relative Humidity	=	70	%
Average 2nd Quarter Relative Humidity	=	72	%
Average 3rd Quarter Relative Humidity	=	80	%
Average 4th Quarter Relative Humidity	=	77	%

Note: Evapotranspiration data was obtained for Belleville, Michigan

Normal Mean Monthly Precipitation (inches)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
1.913949	1.878746	2.045516	2.755274	3.005731	3.34107
3.096216	3.243099	3.096181	2.533399	2.583786	2.235743

Note: Precipitation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Normal Mean Monthly Temperature (Degrees Fahrenheit)

Jan/Jul	Feb/Aug	Mar/Sep	Apr/Oct	May/Nov	Jun/Dec
29.7	30.4	42.7	54.8	68.5	78.1
81.5	79	68.8	56.2	44	31.5

Note: Temperature was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49
Solar radiation was simulated based on HELP V4 weather simulation for:
Lat/Long: 42.18/-83.49

Average Annual Totals Summary

Title: MC Cell VI-F&G Engineered Turf
Simulated on: 10/7/2021 16:52

	Average Annual Totals for Years 1 - 100*			
	(inches)	[std dev]	(cubic feet)	(percent)
Precipitation	31.73	[3.35]	115,175.2	100.00
Runoff	8.042	[1.78]	29,191.4	25.35
Evapotranspiration	9.064	[1.106]	32,901.7	28.57
Subprofile1				
Lateral drainage collected from Layer 2	14.6223	[1.3618]	53,078.9	46.09
Percolation/leakage through Layer 4	0.000001	[0]	0.0040	0.00
Average Head on Top of Layer 3	0.0036	[0.0003]	---	---
Water storage				
Change in water storage	0.0009	[0.5232]	3.2043	0.00

* Note: Average inches are converted to volume based on the user-specified area.

Peak Values Summary

Title: MC Cell VI-F&G Engineered Turf
Simulated on: 10/7/2021 16:53

	Peak Values for Years 1 - 100*	
	(inches)	(cubic feet)
Precipitation	2.40	8,721.4
Runoff	2.440	8,855.5
Subprofile1		
Drainage collected from Layer 2	0.5917	2,147.8
Percolation/leakage through Layer 4	0.000000	0.0001
Average head on Layer 3	0.0517	---
Maximum head on Layer 3	0.1032	---
Location of maximum head in Layer 2	0.50 (feet from drain)	
Other Parameters		
Snow water	4.1439	15,042.2
Maximum vegetation soil water	0.4370 (vol/vol)	
Minimum vegetation soil water	0.0240 (vol/vol)	

Final Water Storage in Landfill Profile at End of Simulation Period

Title: MC Cell VI-F&G Engineered Turf
Simulated on: 10/7/2021 16:53
Simulation period: 100 years

	Final Water Storage	
Layer	(inches)	(vol/vol)
1	0.1003	0.2005
2	0.0013	0.0100
3	0.0000	0.0000
4	0.3750	0.7500
Snow water	0.0000	---

Attachment C
Climate Data Information

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Monthly Normals 1981-2010

Generated on 10/03/2021

National Centers for Environmental Information
151 Patton Avenue
Asheville, North Carolina 28801

Current Location: Elev: 631 ft. Lat: 42.2313° N Lon: -83.3308° W
Station: **DETROIT METROPOLITAN AIRPORT, MI US USW00094847**

Temperature (°F)																						
Mean							Cooling Degree Days Base (above)						Heating Degree Days Base (above)				Mean Number of Days					
Month	Daily Max	Daily Min	Mean	Long Term Max Std Dev	Long Term Min Std Dev	Long Term Avg Std Dev	55	57	60	65	70	72	55	57	60	65	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
01	32.0	19.1	25.6	4.7	5.7	5.1	-7777	-7777	0	0	0	0	913	975	1068	1223	0.0	0.0	1.6	15.7	26.7	2.0
02	35.2	21.0	28.1	4.1	4.3	4.1	-7777	-7777	-7777	-7777	0	0	753	809	893	1033	0.0	0.0	2.0	10.6	24.3	0.8
03	45.8	28.6	37.2	3.8	3.0	3.3	6	4	2	-7777	-7777	0	558	618	709	862	0.0	0.0	10.3	3.5	20.3	-7777
04	59.1	39.4	49.2	3.1	2.4	2.6	47	34	20	6	1	-7777	220	266	342	479	0.0	0.0	23.8	0.1	5.6	0.0
05	69.9	49.4	59.7	3.8	3.4	3.5	186	145	97	42	13	7	42	63	108	208	0.0	0.4	30.7	0.0	0.2	0.0
06	79.3	59.5	69.4	2.7	2.4	2.4	434	376	291	167	75	50	2	4	9	35	-7777	2.4	30.0	0.0	0.0	0.0
07	83.4	63.9	73.6	2.7	2.3	2.3	578	516	423	271	137	95	0	-7777	-7777	2	-7777	4.5	31.0	0.0	0.0	0.0
08	81.4	62.6	72.0	2.7	2.6	2.6	527	465	373	225	103	68	-7777	-7777	1	8	0.0	2.5	31.0	0.0	0.0	0.0
09	74.0	54.7	64.4	2.8	1.9	2.2	294	244	175	84	29	16	14	23	44	104	0.0	0.5	30.0	0.0	0.0	0.0
10	61.6	43.3	52.4	3.0	2.8	2.8	69	49	27	8	2	1	148	190	261	397	0.0	0.0	27.3	0.0	1.9	0.0
11	48.8	34.3	41.5	3.7	2.9	3.1	8	4	1	-7777	0	0	412	468	555	704	0.0	0.0	13.2	0.9	12.5	0.0
12	36.1	24.1	30.1	5.1	5.2	5.0	1	-7777	-7777	0	0	0	773	834	927	1082	0.0	0.0	2.6	10.5	23.9	0.7
Summary	58.9	41.7	50.3	3.5	3.2	3.2	2150	1837	1409	803	360	237	3835	4250	4917	6137	0.0	10.3	233.5	41.3	115.4	3.5

-7777: a non-zero value that would round to zero

Empty or blank cells indicate data is missing or insufficient occurrences to compute value

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Monthly Normals
1981-2010

Generated on 10/03/2021

National Centers for Environmental Information
151 Patton Avenue
Asheville, North Carolina 28801

Current Location: Elev: 631 ft. Lat: 42.2313° N Lon: -83.3308° W

Station: **DETROIT METROPOLITAN AIRPORT, MI US USW00094847**

Precipitation (in.)								
	Totals	**Mean Number of Days**				**Precipitation Probabilities Probability that precipitation will be equal to or less than the indicated amount**		
	Means	**Daily Precipitation**				**Monthly Precipitation vs. Probability Levels**		
Month	**Mean**	**>= 0.01**	**>= 0.10**	**>= 0.50**	**>= 1.00**	**0.25**	**0.50**	**0.75**
01	1.96	13.1	5.6	0.9	0.1	1.28	1.80	2.80
02	2.02	10.6	5.0	1.1	0.2	0.89	1.83	3.02
03	2.28	11.7	6.2	1.1	0.2	1.46	2.15	3.18
04	2.90	12.2	7.0	1.8	0.3	2.11	2.72	3.85
05	3.38	12.1	6.9	2.3	0.7	2.20	3.00	4.61
06	3.52	10.2	6.3	2.3	0.8	2.35	3.37	4.91
07	3.37	10.4	6.6	2.0	0.8	2.43	3.22	4.38
08	3.00	9.6	5.9	2.1	0.7	1.60	3.07	4.19
09	3.27	9.5	5.9	2.2	0.7	1.74	2.86	4.28
10	2.52	9.8	5.3	1.8	0.5	1.56	2.15	3.54
11	2.79	11.6	6.4	1.9	0.4	1.78	2.68	3.31
12	2.46	13.7	6.2	1.4	0.2	1.61	2.39	2.91
Summary	33.47	134.5	73.3	20.9	5.6	21.01	31.24	44.98

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U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Monthly Normals
1981-2010
Generated on 10/03/2021

National Centers for Environmental Information
151 Patton Avenue
Asheville, North Carolina 28801

Current Location: Elev: 631 ft. Lat: 42.2313° N Lon: -83.3308° W
Station: **DETROIT METROPOLITAN AIRPORT, MI US USW00094847**

Snow (in.)												
	Totals	Mean Number of Days									Snow Probabilities Probability that snow will be equal to or less than the indicated amount	
	Means	Snowfall >= Thresholds					Snow Depth >= Thresholds				Monthly Snow vs. Probability Levels Values derived from the incomplete gamma distribution.	
Month	Snowfall Mean	0.01	1.0	3.0	5.00	10.00	1	3	5	10	.25	.50	.75
01	12.5	10.4	3.7	1.1	0.4	0.2	17.4	11.0	5.9	1.3	7.0	9.9	17.9
02	10.2	8.3	3.2	1.2	0.4	0.0	12.7	7.5	3.7	0.9	4.9	9.0	14.6
03	6.9	5.4	2.1	0.7	0.3	0.0	5.6	3.1	1.6	0.0	3.4	5.8	9.7
04	1.7	1.6	0.4	0.2	0.1	0.0	0.5	0.3	0.1	0.0	0.0	0.6	2.0
05	-7777	-7777	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.1	0.2	-7777	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1.5	2.3	0.5	-7777	0.0	0.0	1.0	0.2	0.0	0.0	0.1	0.9	2.2
12	9.6	8.5	3.2	0.9	0.4	0.0	8.7	5.4	3.4	0.3	4.9	7.8	13.2
Summary	42.5	36.7	13.1	4.1	1.6	0.2	45.9	27.5	14.7	2.5	20.3	34.0	59.6

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U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Monthly Normals
1981-2010
Generated on 10/03/2021

National Centers for Environmental Information
151 Patton Avenue
Asheville, North Carolina 28801

Current Location: Elev: 631 ft. Lat: 42.2313° N Lon: -83.3308° W
Station: **DETROIT METROPOLITAN AIRPORT, MI US USW00094847**

Growing Degree Units (Monthly)

Base	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
40	10	12	84	298	609	882	1043	992	731	390	132	21
45	3	3	41	185	456	732	888	837	581	254	66	9
50	1	1	17	100	310	582	733	682	433	144	26	3
55	-7777	-7777	6	47	186	434	578	527	294	69	8	1
60	0	-7777	2	20	97	291	423	373	175	27	1	-7777
Growing Degree Units for Corn (Monthly)												
50/86	3	6	48	163	352	576	713	671	449	202	57	8

Growing Degree Units (Accumulated Monthly)

Base	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
40	10	22	106	404	1013	1895	2938	3930	4661	5051	5183	5204
45	3	6	47	232	688	1420	2308	3145	3726	3980	4046	4055
50	1	2	19	119	429	1011	1744	2426	2859	3003	3029	3032
55	0	0	6	53	239	673	1251	1778	2072	2141	2149	2150
60	0	0	2	22	119	410	833	1206	1381	1408	1409	1409
Growing Degree Units for Corn (Monthly Accumulated)												
50/86	3	9	57	220	572	1148	1861	2532	2981	3183	3240	3248

Note: For corn, temperatures below 50 are set to 50, and temperatures above 86 are set to 86.

-7777: a non-zero value that would round to zero.

Empty or blank cells indicate data is missing or insufficient occurrences to compute value.

NOAA Atlas 14, Volume 8, Version 2 DETROIT METRO AP
Station ID: 20-2103
Location name: Detroit, Michigan, USA*
Latitude: 42.2314°, Longitude: -83.3308°
Elevation:
Elevation (station metadata): 631 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.312 (0.271-0.367)	0.369 (0.319-0.434)	0.463 (0.400-0.545)	0.543 (0.466-0.642)	0.656 (0.544-0.794)	0.745 (0.604-0.909)	0.835 (0.654-1.04)	0.929 (0.698-1.18)	1.06 (0.763-1.36)	1.15 (0.812-1.50)
10-min	0.457 (0.396-0.537)	0.540 (0.468-0.635)	0.678 (0.585-0.799)	0.795 (0.682-0.939)	0.960 (0.797-1.16)	1.09 (0.884-1.33)	1.22 (0.958-1.52)	1.36 (1.02-1.72)	1.55 (1.12-1.99)	1.69 (1.19-2.20)
15-min	0.557 (0.483-0.655)	0.658 (0.570-0.774)	0.827 (0.714-0.974)	0.970 (0.832-1.15)	1.17 (0.972-1.42)	1.33 (1.08-1.62)	1.49 (1.17-1.85)	1.66 (1.25-2.10)	1.88 (1.36-2.43)	2.06 (1.45-2.68)
30-min	0.764 (0.662-0.898)	0.902 (0.781-1.06)	1.13 (0.979-1.34)	1.33 (1.14-1.57)	1.61 (1.34-1.95)	1.83 (1.48-2.24)	2.05 (1.61-2.55)	2.29 (1.72-2.90)	2.60 (1.88-3.36)	2.85 (2.01-3.71)
60-min	0.974 (0.844-1.14)	1.15 (0.996-1.35)	1.45 (1.25-1.71)	1.70 (1.46-2.01)	2.07 (1.72-2.51)	2.36 (1.92-2.89)	2.66 (2.09-3.31)	2.97 (2.24-3.77)	3.40 (2.46-4.39)	3.73 (2.63-4.87)
2-hr	1.18 (1.03-1.38)	1.40 (1.22-1.63)	1.76 (1.53-2.06)	2.08 (1.79-2.44)	2.53 (2.11-3.05)	2.89 (2.36-3.51)	3.26 (2.58-4.04)	3.66 (2.77-4.61)	4.20 (3.06-5.39)	4.62 (3.28-5.98)
3-hr	1.31 (1.15-1.53)	1.55 (1.35-1.80)	1.95 (1.69-2.27)	2.29 (1.98-2.68)	2.80 (2.35-3.37)	3.20 (2.63-3.89)	3.63 (2.88-4.48)	4.08 (3.10-5.12)	4.70 (3.44-6.01)	5.19 (3.69-6.69)
6-hr	1.55 (1.36-1.79)	1.80 (1.58-2.08)	2.24 (1.96-2.60)	2.64 (2.29-3.06)	3.21 (2.72-3.85)	3.69 (3.05-4.45)	4.19 (3.35-5.14)	4.73 (3.63-5.91)	5.48 (4.04-6.97)	6.07 (4.36-7.78)
12-hr	1.80 (1.59-2.07)	2.06 (1.82-2.37)	2.53 (2.22-2.90)	2.94 (2.57-3.39)	3.57 (3.05-4.26)	4.09 (3.41-4.92)	4.65 (3.75-5.68)	5.26 (4.06-6.53)	6.11 (4.54-7.74)	6.80 (4.91-8.65)
24-hr	2.06 (1.83-2.35)	2.35 (2.08-2.67)	2.85 (2.52-3.25)	3.31 (2.91-3.78)	3.98 (3.42-4.71)	4.55 (3.81-5.42)	5.15 (4.17-6.24)	5.80 (4.51-7.15)	6.71 (5.02-8.44)	7.45 (5.42-9.41)
2-day	2.35 (2.10-2.66)	2.69 (2.40-3.04)	3.27 (2.90-3.70)	3.78 (3.34-4.29)	4.52 (3.89-5.29)	5.12 (4.30-6.04)	5.75 (4.68-6.90)	6.42 (5.02-7.85)	7.35 (5.54-9.16)	8.09 (5.93-10.2)
3-day	2.58 (2.31-2.90)	2.93 (2.62-3.30)	3.54 (3.15-3.99)	4.06 (3.60-4.60)	4.82 (4.16-5.61)	5.44 (4.58-6.38)	6.08 (4.96-7.25)	6.75 (5.30-8.21)	7.69 (5.81-9.53)	8.42 (6.20-10.5)
4-day	2.78 (2.49-3.12)	3.14 (2.82-3.53)	3.76 (3.36-4.23)	4.30 (3.82-4.85)	5.07 (4.38-5.88)	5.70 (4.81-6.66)	6.34 (5.19-7.55)	7.03 (5.53-8.52)	7.97 (6.04-9.85)	8.71 (6.43-10.9)
7-day	3.29 (2.97-3.67)	3.69 (3.32-4.12)	4.36 (3.91-4.88)	4.94 (4.41-5.54)	5.77 (5.00-6.64)	6.43 (5.45-7.46)	7.11 (5.84-8.40)	7.82 (6.18-9.41)	8.79 (6.70-10.8)	9.55 (7.09-11.8)
10-day	3.75 (3.39-4.17)	4.18 (3.77-4.65)	4.90 (4.41-5.46)	5.51 (4.93-6.16)	6.39 (5.55-7.31)	7.08 (6.02-8.18)	7.79 (6.42-9.15)	8.52 (6.76-10.2)	9.52 (7.28-11.6)	10.3 (7.68-12.7)
20-day	5.10 (4.63-5.62)	5.61 (5.09-6.19)	6.46 (5.84-7.14)	7.16 (6.44-7.95)	8.15 (7.11-9.23)	8.91 (7.62-10.2)	9.69 (8.02-11.3)	10.5 (8.35-12.4)	11.5 (8.87-14.0)	12.3 (9.26-15.1)
30-day	6.27 (5.71-6.89)	6.87 (6.25-7.56)	7.86 (7.13-8.65)	8.66 (7.82-9.57)	9.75 (8.53-11.0)	10.6 (9.07-12.0)	11.4 (9.47-13.2)	12.2 (9.78-14.4)	13.3 (10.3-16.0)	14.1 (10.6-17.2)
45-day	7.79 (7.12-8.53)	8.56 (7.81-9.37)	9.76 (8.88-10.7)	10.7 (9.70-11.8)	12.0 (10.5-13.4)	12.9 (11.1-14.6)	13.8 (11.5-15.8)	14.6 (11.7-17.2)	15.7 (12.1-18.8)	16.5 (12.5-20.0)
60-day	9.13 (8.36-9.96)	10.1 (9.20-11.0)	11.5 (10.5-12.6)	12.6 (11.4-13.8)	14.0 (12.3-15.6)	15.0 (12.9-16.9)	16.0 (13.3-18.2)	16.8 (13.5-19.6)	17.9 (13.8-21.3)	18.6 (14.1-22.5)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical

Attachment J

Hydraulic Performance of **Synthetic Turf Cover Systems**

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Hydrologic Performance of Synthetic Turf Cover Systems and Their Equivalency to Prescriptive Cover Systems

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ABSTRACT

Synthetic turf cover systems have gained popularity as a viable final cover system alternative to traditional soil-geosynthetic cover systems for various reasons (e.g., less material required, quicker installation, and less maintenance). Federal and state regulations commonly require that the design engineers demonstrate alternative cover systems perform equivalently with the prescribed traditional cover system. This paper presents a comparison between the calculated hydrologic performance of traditional and synthetic turf cover systems for two state regulations; one for municipal solid waste (MSW) landfills and one for hazardous waste landfills. The results of these analyses showed that synthetic turf cover systems have larger annual runoff and drainage collection with similar or smaller annual infiltration through the geomembrane when compared to the traditional cover systems. Therefore, the synthetic turf cover systems perform similar to or better than the prescribed traditional cover systems in terms of infiltration.

INTRODUCTION

Synthetic turf cover systems are a relatively new geosynthetic product that typically consist of the following layers (from bottom to top) [WatershedGeo, 2018]: (i) a structured linear-low density polyethylene (LLDPE) or high density polyethylene (HDPE) geomembrane, which includes studs on the top to act as a drainage layer and spikes on the bottom to increase the interface shear strength of the system; (ii) an engineered turf protective layer, consisting of HDPE grass blades attached to woven geotextiles; and (iii) a thin layer (12.5-mm. thick minimum) of specified infill, which is usually clean sand primarily used for ballasting and protecting the engineered turf and the structured geomembrane. Figure 1 shows a typical detail for a synthetic turf cover system.

Because synthetic turf cover systems typically require less material, are generally quicker to install, and are expected to require less maintenance after installation [WatershedGeo, 2018], they have gained popularity as a viable alternative to the traditional soil-geosynthetic cover system. Federal and state regulations commonly require that the design engineers demonstrate alternative cover systems perform equivalently in terms of infiltration compared to the prescribed traditional cover system. This paper presents a comparison between the calculated hydrologic performance of prescribed traditional cover systems and alternative synthetic turf cover systems to evaluate the hydrologic equivalency of the synthetic turf cover systems for two case studies.

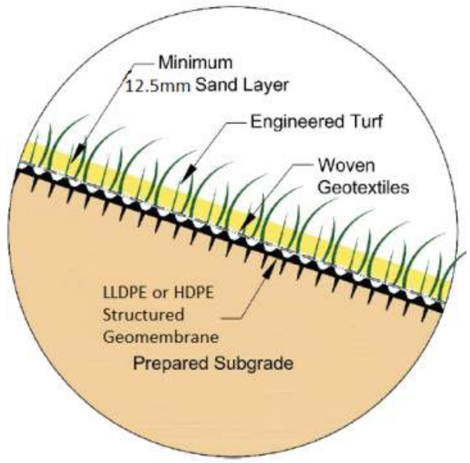

Figure 1. Typical synthetic turf cover system detail [WatershedGeo, 2018]

CASE STUDIES

The case studies examined in this paper represent two state regulations for MSW and hazardous waste landfills with varying slope angles and lengths.

Case Study 1: Indiana MSW Landfill. The first case study examines the Indiana state regulations for MSW landfills. A generic site in Indianapolis, Indiana was considered for this case study. As per Section 22-6(b)(8) of the 329 IAC 10 regulations [Indiana General Assembly, 2004], the slopes of the final cover system must not be less than 4 percent nor greater than 33 percent. Therefore, a 33-percent slope with a 18.3-m slope length and a 4-percent slope with 30.5-m slope length, were considered. Figure 2 shows a comparison between the prescribed traditional soil-geosynthetic cover system and the alternative synthetic turf cover systems for Case Study 1.

As per Section 22-6(b) of the 329 IAC 10 regulations [Indiana General Assembly, 2004], the final cover system for new or existing MSW landfills that have a composite bottom liner and a leachate collection system must consist of the following layers (from bottom to top): (i) a 0.3-m thick methane gas venting layer with a hydraulic conductivity of 1×10^{-3} cm/sec or more; (ii) a 0.6-m thick soil barrier layer with a hydraulic conductivity of 1×10^{-6} cm/sec or less; (iii) a 1.5-mm thick HDPE geomembrane; (iv) a 0.3-m thick drainage layer with a hydraulic conductivity of 1×10^{-3} cm/sec or more; (v) a 0.45-m thick protective layer consisting of earthen material; and (vi) a 0.15-m thick vegetative layer consisting of earthen material that is capable of sustaining vegetation.

For this case study, two alternative synthetic turf cover systems were considered: (i) a synthetic turf cover system that replaces all layers above the soil barrier layer; and (ii) a synthetic turf cover system that replaces all layers above the methane gas venting layer. For both alternatives, the synthetic turf cover system was modeled with the following layers (from bottom to top): (i) a 1.5-mm thick HDPE textured geomembrane; (ii) a 3.3-mm thick studded drainage layer that is part of the HDPE geomembrane; and (iii) 25-mm thick sand infill and engineered turf.

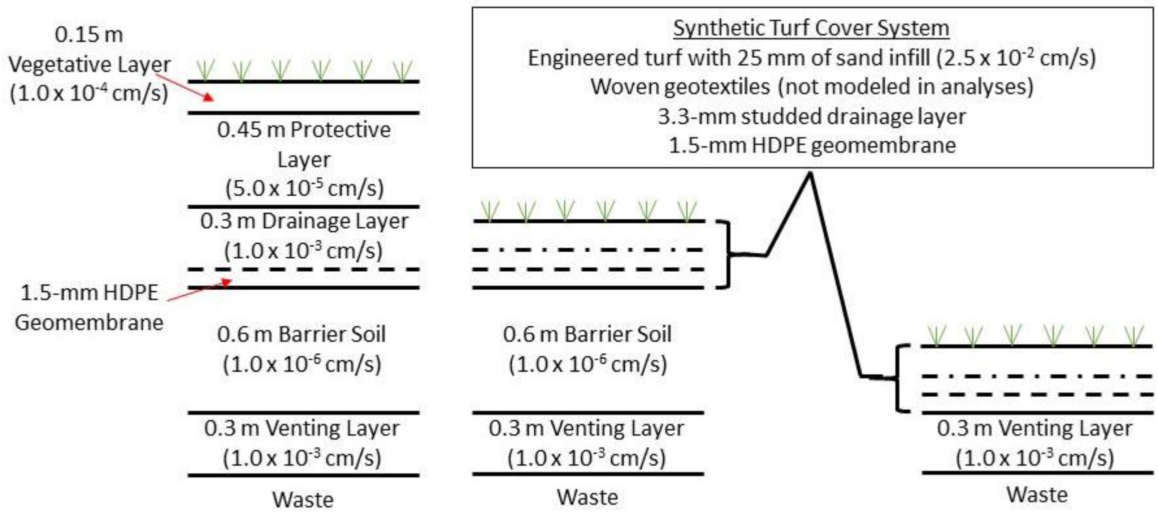

Figure 2. Prescriptive soil-geosynthetic cover system (left) and alternative synthetic turf cover systems with (center) and without (right) a barrier soil for Case Study 1

Case Study 2: Texas Hazardous Waste Landfill. The second case study examines the Texas state and federal regulations for hazardous waste landfills. A generic site in Houston, Texas was considered for this case study. The Texas Commission on Environmental Quality (TCEQ) in Section 335.174(a) of the Texas Administrative Code [TCEQ, 1996] and the U.S. Environmental Protection Agency (USEPA) in Section 264.310(a) of Subpart N of Title 40 [USEPA, 2017] provide design-based requirements for the design of final cover systems of industrial solid waste and municipal hazardous waste landfills. Details for final cover systems that satisfy these design-based requirements are provided by the USEPA [1989]. Maximum and minimum slopes of 33 percent and 3 percent with slope lengths of 19.8 m and 30.5 to 152.4 m, respectively, were considered for Case Study 2. Figure 3 shows a comparison between the prescribed traditional soil-geosynthetic cover system and the alternative synthetic turf cover systems considered for Case Study 2.

As per USEPA [1989], the prescribed traditional soil-geosynthetic cover system for Case Study 2 was modeled with the following layers (from bottom to top): (i) a 0.6-m thick compacted clay liner with a hydraulic conductivity of 1×10^{-7} cm/sec or less; (ii) a 1.5-mm thick HDPE geomembrane; (iii) a 7.6-mm thick geocomposite drainage layer, equivalent in hydraulic conductivity to a 0.3-m thick granular drainage layer with a hydraulic conductivity of 1×10^{-2} cm/sec or more; (iv) a 0.45-m thick protective layer consisting of earthen material; and (vi) a 0.15-m thick vegetative layer consisting of earthen material that is capable of sustaining vegetation. An intermediate/daily cover layer with a thickness of 0.15 m was also modeled below the compacted clay liner.

For this case study, two alternatives were considered for the synthetic turf cover system: (i) the synthetic turf cover system that replaces all layers above the compacted clay liner; and (ii) the synthetic turf cover system that replaces all layers above the compacted clay liner and replaces the compacted clay liner with a 7.6-mm thick geosynthetic clay liner. For both alternatives, the synthetic turf cover system was modeled with the following layers (from bottom to top): (i) a 1.5-mm thick HDPE textured geomembrane; (ii) a 3.3-mm thick studded drainage layer that is part of the HDPE geomembrane; and (iii) 12.5-mm thick sand infill and engineered turf.

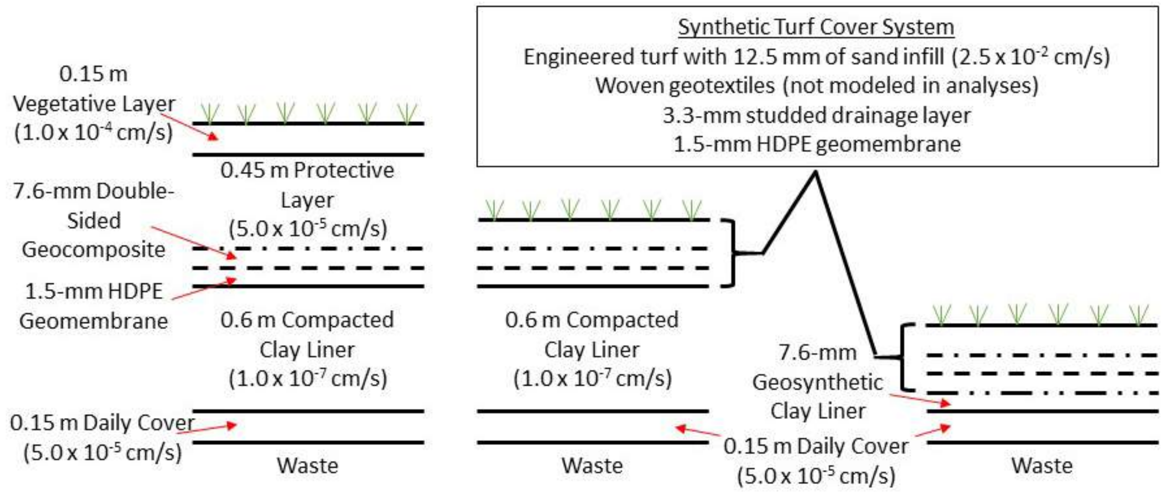

Figure 3. Prescriptive soil-geosynthetic cover system (left) and alternative synthetic turf cover systems with a compacted clay liner (center) and geosynthetic clay liner (right) for Case Study 2

ANALYSIS METHODOLOGY

The calculations for the hydrologic evaluation of the cover systems presented in this paper were modeled using the Hydrologic Evaluation of Landfill Performance (HELP) software, Version 3.07, developed for the USEPA [Schroeder et al., 1994a and 1994b]. The HELP program is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of a landfill's cover and/or liner systems. The program accepts climate, soil, and design data, and uses a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, evaporation, soil moisture storage, and lateral drainage.

Climatic Data. The evaporative zone depth is defined as the maximum depth from which water may be removed by evapotranspiration. This depth affects the storage of water near the surface and directly impacts the computations for evapotranspiration and runoff [Schroeder et al., 1994a and 1994b]. For vegetated surfaces, the evaporative zone depth should be equal to the expected average depth of root penetration. For the traditional cover systems, the evaporative zone depths were selected as approximately 0.5 and 0.6 m for Case Studies 1 and 2 respectively, using the HELP default values. The evaporative zone depth for the alternative synthetic turf cover systems were selected as the combined thickness of the sand infill, engineered turf, and studded drainage layers (i.e., 28.3 and 15.8 mm for Case Studies 1 and 2, respectively).

Synthetic precipitation data for a 100-year modeling period were generated using the synthetic weather generator in HELP and site specific precipitation data from the National Oceanic and Atmospheric Administration (NOAA) precipitation frequency data server. Synthetic daily temperature, solar radiation, and relative humidity data were also generated for a 100-year modeling period for the closest default locations available in the HELP program.

Cover System Properties. Table 1 shows the properties used for the cover system components for Case Studies 1 and 2. The default properties available in the HELP database were used for porosity, field capacity, and wilting point. As noted in Table 1, the hydraulic conductivities of the cover system components correspond to either prescribed limits, typical values, or manufacturer-specified values. Case Study 2 considers long-term site conditions and thus, the hydraulic conductivities of the drainage layers are expected to decrease due to degradation, clogging, and/or creep of the drainage layers. Therefore, the hydraulic conductivities in Case Study 2 have been reduced by a factor of 2.4 to account for some creep, delayed intrusion, particulate clogging, and biological clogging and a factor of safety of 1.5. The reduction factor of 2.4 was developed from available technical literature [Giroud et al., 2000] and is typical for cover systems. Although a reduction factor could also be used for the granular drainage layer in Case Study 1, it was not considered for the analyses presented in this paper.

The geomembrane components of the prescribed and alternative cover systems were modeled to contain one hole per 0.004 km^2 and have good installation quality. For the calculations, each hole was modeled with an area of 1 cm^2 as recommended by Giroud and Bonaparte [1989]. A 100 percent runoff from precipitation on the cover systems was allowed in the HELP models; however, it should be controlled to prevent excessive erosion of the final cover system.

Table 1. Cover system properties used in HELP models

Component	Case Study (1)	Layer Thickness	Total Porosity (2)	Field Capacity (2)	Wilting Point (2)	Saturated Hydraulic Conductivity (cm/sec)	HELP Material Texture # (2)	HELP Layer Type
Vegetative Cover Layer	1, 2	0.15 m	0.471	0.342	0.210	1.0×10^{-4} (3)	12	Vertical Percolation
Protective Soil Layer	1, 2	0.45 m	0.471	0.342	0.210	5.0×10^{-5} (3)	12	Vertical Percolation
Granular Drainage Layer (4)	1	0.3 m	0.457	0.083	0.033	1.0×10^{-3} (5)	3	Drainage Layer
Double-Sided Geocomposite Drainage Layer	2	7.6 mm	0.850	0.010	0.005	11.84 (4.93) (6)(7)	20	Drainage Layer
HDPE Geomembrane	1, 2	1.5 mm	-	-	-	2.0×10^{-13} (7)	35	Geomembrane
Engineered Turf (8)	1	25 mm	0.437	0.062	0.024	2.5×10^{-2}	2	Vertical Percolation
	2	12.5 mm						
Woven Geotextile (8)	1, 2	-	-	-	-	-	-	Not Modeled
Studded Drainage Layer for Textured HDPE Geomembrane (8)	1, 2	3.3 mm	0.850	0.010	0.005	75.76 (31.57) (6)	20	Drainage Layer
Textured HDPE Geomembrane (with spike down) (8)	1, 2	1.5 mm	-	-	-	2.0×10^{-13} (7)	35	Geomembrane
Soil Barrier Layer (9)	1	0.6 m	0.427	0.418	0.367	1.0×10^{-6} (5)	16	Barrier Soil
Methane Gas Venting Layer (4)	1	0.3 m	0.457	0.083	0.033	1.0×10^{-3} (5)	3	Vertical Percolation
Compacted Clay Liner	2	0.6 m	0.427	0.418	0.367	1.0×10^{-7} (5)	16	Barrier Soil
Geosynthetic Clay Liner	2	7.6 mm	0.750	0.747	0.400	5.0×10^{-9} (7)	17	Barrier Soil
Daily/Intermediate Cover (9)	2	0.15 m	0.427	0.418	0.367	5.0×10^{-5} (3)	16	Vertical Percolation

Notes:
(1) Case study identifies for which case study or studies the cover system component was used.
(2) Values shown for total porosity, field capacity, and wilting point correspond to the default values for the selected HELP material texture number.
(3) Hydraulic conductivity values selected based on typical values.
(4) Drainage and methane gas venting layers are modeled with properties typical of filter sands.
(5) Hydraulic conductivity values selected based on minimum design requirements.
(6) Hydraulic conductivity values within the parentheses represent the long-term hydraulic conductivities with a reduction factor of 2.4 applied.
(7) Hydraulic conductivity values selected based on typical values from manufacturers.
(8) Properties for synthetic turf cover system layers were selected based on manufacturers design guidelines [WatershedGeo, 2018].
(9) Soil barrier layer and daily/intermediate cover are modeled with properties typical of compacted clays.

Output Data. The HELP program calculated and output the average annual rates for surface runoff, stormwater collected through the drainage layer, and infiltration through the geomembrane and the average hydraulic head over the geomembrane during the peak daily rainfall event. The average annual rates were calculated for a modeled area of 0.004 km^2 while the average hydraulic head over the geomembrane was calculated for the specified drainage lengths. All calculations considered a 100-yr modeling period. The values calculated for these parameters in the alternative synthetic turf cover systems were compared to the calculated values for the prescribed traditional cover systems and used to evaluate the equivalency of the alternative synthetic turf cover systems.

ANALYSIS RESULTS

Case Study 1. Table 2 presents the calculated average annual rates for runoff, drainage collected, and infiltration and the average hydraulic head over the geomembrane for the traditional and alternative cover systems examined in Case Study 1.

The calculated average annual rates for runoff and drainage collected for both alternative synthetic turf cover systems are approximately 3,000 L/day and 5,600 L/day for the modeled area, respectively, which are larger than the calculated rates for the traditional soil-geosynthetic cover system (i.e., approximately 2,200 L/day and 1,600 L/day for the modeled area, respectively). The alternative synthetic turf cover systems have much less material above the drainage layer (0.03 m) and a higher hydraulic conductivity for the drainage layer (approximately 76 cm/sec) than the traditional cover system (0.6 m and 1.0×10^{-3} cm/sec) and thus, store less water, have a shorter path to the drainage layer, and are able to more quickly convey water collected on the drainage layer. The average annual infiltration rates calculated for both alternative synthetic turf cover systems in this case study are less than the rates calculated for the traditional soil-geosynthetic cover system for both slopes modeled. This observation can predominantly be attributed to the significantly larger calculated hydraulic head over the geomembrane for the traditional soil-geosynthetic cover system (i.e., approximately 18 to 91 cm) compared to the calculated values for the alternative synthetic turf cover systems (i.e., less than 0.1 cm). The use of a barrier soil layer beneath the synthetic turf cover system does not affect the calculated average annual rates for runoff and drainage collected, as expected, but does reduce the calculated average annual infiltration rates by approximately two orders of magnitude.

Table 2. Results for Case Study 1 (reported values are for the modeled area of 0.004 km^2)

Final Cover Alternative	Slope (%)	Slope Length (m)	Barrier Soil Layer	Average Annual Runoff Rate (L/day)	Average Annual Rate of Drainage Collected (L/day)	Average Annual Infiltration Rate through Cover (cm/day)	Average Hydraulic Head over Geomembrane (cm)
Soil-Geosynthetic	33.0	18.3	Yes	2,277	1,623	4.5E-06	18.39
	4.0	30.5	Yes	2,183	1,682	5.3E-05	91.29
Synthetic Turf	33.0	18.3	Yes	2,997	5,634	1.9E-09	0.01
			No	2,997	5,634	1.9E-07	0.02
	4.0	30.5	Yes	3,006	5,568	1.3E-08	0.03
			No	3,006	5,567	2.0E-06	0.03

Case Study 2. The calculated average annual rates for runoff, drainage collected, and infiltration and the average hydraulic head over the geomembrane for the traditional and alternative cover systems examined in Case Study 2 are presented in Table 3.

Like Case Study 1, the alternative synthetic turf cover systems have larger calculated average annual rates for runoff (approximately 2,700 to 2,900 L/day for the modeled area) and drainage collected (approximately 7,600 to 7,800 L/day for the modeled area) than the rates calculated for the soil-geosynthetic cover system (approximately 1,500 to 2,100 L/day and approximately 1,600 to 2,000 L/day for the modeled area, respectively). However, for slope angles of 33 and 3 percent with slope lengths of 19.8 and 30.5 m, respectively, the calculated average annual infiltration rates for the alternative synthetic turf and traditional soil-geosynthetic cover systems are approximately equal. If the slope length for the slope with an angle of 3 percent is increased to 152.4 m, the calculated average annual infiltration rate for the traditional soil-geosynthetic cover system increases by approximately an order of magnitude while the calculated rates for the alternative synthetic turf cover systems do not significantly change. This increase in the calculated average annual infiltration rate for the traditional cover system with the increase in the slope length is likely the result of the drainage layer being unable to convey the water in the cover system for the longer drainage path, as evident by the much larger calculated average hydraulic head (increase from 0.23 cm to 39.46 cm). The use of a geosynthetic clay liner with the alternative synthetic turf cover system in place of the compacted clay liner does not affect the calculated average annual rates for runoff and drainage collected, as expected, but does slightly reduce the calculated average annual infiltration rates because of the lower hydraulic conductivity for the geosynthetic clay liner.

Table 3. Results for Case Study 2 (reported values are for the modeled area of 0.004 km^2)

Final Cover Alternative	Slope (%)	Slope Length (m)	Barrier Soil Layer	Average Annual Runoff Rate (L/day)	Average Annual Rate of Drainage Collected (L/day)	Average Annual Infiltration Rate through Cover (cm/day)	Average Hydraulic Head over Geomembrane (cm)
Soil-Geosynthetic	33.0	19.8	Compacted Clay	2,052	1,585	1.9E-09	0.04
	3.0	30.5	Compacted Clay	1,770	1,785	9.6E-09	0.23
		152.4	Compacted Clay	1,467	2,037	9.4E-08	39.46
Synthetic Turf	33.0	19.8	Compacted Clay	2,708	7,760	1.9E-09	0.01
			GCL	2,708	7,760	1.9E-09	0.01
	3.0	30.5	Compacted Clay	2,736	7,715	7.7E-09	0.08
			GCL	2,736	7,715	3.8E-09	0.08
		152.4	Compacted Clay	2,940	7,599	1.9E-08	1.30
			GCL	2,940	7,599	5.8E-09	1.30

SUMMARY AND CONCLUSIONS

The calculated hydrologic performance of synthetic turf cover systems and traditional soil-geosynthetic cover systems were compared for two case studies that considered different state regulations, landfill types, and slope angles and lengths. Average annual rates for surface runoff, stormwater collected through the drainage layer, and infiltration through the geomembrane and the average hydraulic head over the geomembrane during the peak daily rainfall event were calculated and output by the HELP computer program. The hydrologic equivalency of alternative synthetic turf cover systems to the prescribed traditional soil-geosynthetic cover systems was evaluated by comparing the output data from HELP for the cover systems.

For the two case studies presented in this paper, the alternative synthetic turf cover systems had greater calculated average annual runoff and drainage collection compared to the prescribed traditional cover system because they have a thinner layer for infiltration into the drainage layer and a drainage layer with a higher hydraulic conductivity. The average annual rates of infiltration calculated for the alternative synthetic turf cover systems were approximately equal to or less than the rates calculated for the corresponding prescribed traditional cover systems as a result of the lower calculated average hydraulic heads over the geomembrane components in the alternative synthetic turf cover systems. For Case Study 1, where a granular drainage layer is prescribed for the traditional soil-geosynthetic cover system, or Case Study 2, with the longer drainage slope length, the calculated average hydraulic heads over the geomembrane component in the alternative synthetic turf cover systems are much lower. Based on the results of analyses presented in this paper, the synthetic turf cover systems are considered equivalent compared to the prescribed traditional cover systems in terms of infiltration.

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Attachment K

Surface Water Analysis

ATTACHMENT K

SURFACE WATER MANAGEMENT SYSTEM DESIGN CALCULATIONS

Attachment

K-1	**Surface Water Management System Design Approach**
K-2	**Surface Water Diversion Berm Analysis**
K-3	**Surface Water Ditch Analysis**
K-4	**Culvert Analysis**
K-5	**Storm Sewer Analysis**
K-6	**Sedimentation Basin Analysis**

ATTACHMENT K-1

SURFACE WATER MANAGEMENT SYSTEM DESIGN APPROACH

CALCULATION SHEET

Client: US Ecology - Wayne Disposal	Project No.: 1218070017		
Project: 2021 WDI Permit Modification Application	Calculated By: LEH	Date: 11/04/2021
	Checked By: TCR	Date: 11/04/2021
Calculation: SW Management System Design Approach -Engineered Turf	Approved By: XZ	Date: 11/04/2021

Surface Water Management System Design Approach -Engineered Turf

Objective

Summarize the surface water management system design approach, assumptions, and hydrologic parameters to be used in the analysis of the Wayne Disposal Inc. (WDI) surface water management system.

Design Criteria, Assumptions, and Methodology

1. The WDI surface water management system will consist of diversion berms, ditches, culverts, storm sewers, surface water infiltration, the North Sedimentation Basin (NSB), and the South Sedimentation Basin (SSB).
2. The surface water management system is designed in accordance with Rule 299.9619(6)(b).
3. The channels and basin are designed to collect and control the 25-yr, 24-hr storm event and to manage the 100-yr, 24-hr storm event with no off-site flooding.
4. Use rainfall data from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 8, Version 2. The 25-yr, 24-hour storm event is 3.95 inches, and the 100-yr, 24-hr storm event is 5.12 inches, see Attachment K-1.1.
5. Use storm distribution MSE-3 from the Atlas 14 rainfall for Midwest and Southeast States. See Attachment K-1.2.
6. Conservatively assume hydrologic soil group D to calculate the run-off curve number for existing areas outside of MC VI and perimeter berms without the engineered turf cover. Hydrologic soil group D soils have a high runoff potential when thoroughly wet and typically have clayey textures and less than 50 percent sand.
7. Run-off curve numbers for existing areas will be chosen using Table 2-2 of Technical Release 55 (TR-55) Assume a cover type of “Fair Pasture”, CN of 84, for existing areas without engineered turf as well as adjacent areas except MC I. Assume a cover type of “Good Pasture”, CN of 80, represents the existing established final cover vegetation on MC I. A curve number of 98 represents pond areas. See Attachment K-1.3.
8. Run-off curve number for engineered artificial turf landfill cover, such as Closure Turf, areas will be taken from Watershed Geo’s design guideline Table 2, CN of 95 represents normal rainfall events. See Attachment K-1.4.
9. Use HydroCAD to evaluate the surface water run-off and management features including the diversion berms, channels, and culverts. HydroCAD is based largely on hydrologic techniques developed by the SCS combined with other hydrologic and hydraulic calculations. For a given rainfall event, these techniques are used to generate hydrographs throughout a watershed. Storage-Indication-Translation Method routing techniques were used to route surface water through the surface water management system. The antecedent moisture condition specifies the moisture level in the ground immediately prior to the storm. A value of "2" for normal conditions is used in the analyses.
10. Times of concentration were computed by HydroCAD using methodology developed by the SCS. A maximum sheet flow length of 200 ft was used prior to transitioning to shallow

concentrated flow.

11. Use the Storm Water Management Model (SWMM) to evaluate the performance of storm sewers in the SSB watershed. SWMM is a dynamic rainfall-runoff simulation model developed by USEPA used for single event or long-term simulation of runoff quantity and quality from primarily urban areas. SWMM contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through a drainage system network of pipes, channels, storage/treatment units and diversion structures. It has been widely used throughout the world for planning, analysis, and design related to storm water runoff, combined and sanitary sewers, and other drainage systems.
12. Surface water management system design is based on future final closure conditions with the use of engineered artificial turf on MC VI.

Calculation

The North Sedimentation Basin (NSB) receives runoff from portions of MC IV, MC VI, MC VII, MC IX, MC X and MC XI consisting of a watershed area of approximately 287.6 acres. The conveyance structures in the NSB watershed include a detention pond, ditches, diversion berms and culverts.

The South Sedimentation Basin (SSB) receives runoff from portions of MC VI, MC I, MC X, and MC XI, and portions of the entrance area, and the wastewater treatment plant. The total area of the SSB watershed is approximately 102.3 acres. The storm water conveyance structures in the SSB watershed include a detention pond, ditches, culverts, catch basins, and storm sewers.

The lined pond receives runoff from primarily paved areas. The conveyance structures in the lined pond watershed consist of a storage basin, catch basins and storm sewers. The watershed area draining to the Lined Pond is reduced from conditions during site operations, therefore, the Lined Pond is anticipated to continue to provide adequate capacity to manage the runoff as originally designed and permitted. The lined pond was not reanalyzed in these calculations.

The proposed subbasin delineations and surface water management feature labels are provided in Attachment K-1.5. HydroCAD analyses were done separately for the NSB and the SSB watersheds. HydroCAD and SWMM model outputs are provided in Attachment K-1.6. Additional model inputs and output are discussed in the calculations related to the surface water management system components identified below.

Diversion Berms: Diversion berms are used to direct surface water run-off from landfill sideslopes to perimeter ditches. Design calculations are provided in Attachment K-2

Ditches: Ditches are used to route surface water run-off around the landfill and to sedimentation basins. Design calculations are provided in Attachment K-3

Culverts: Culverts are required to convey surface water run-off under access roads and through berms within the site. Existing and proposed culverts are evaluated in Attachment K-4

Storm Sewer: A network of storm sewers, catch basins, and manholes is used to route surface water run-off from a portion of the site to the SSB. The storm sewer analysis is discussed in Attachment K-5

Sedimentation Basins: – Sedimentation basins on site will contain surface water prior to discharge off-site. The sedimentation basin analysis is provided in Attachment K-6

The Attachments to K-1 are summarized as follows:

K-1.1	Rainfall Data
K-1.2	Storm Distribution Data
K-1.3	Curve Number Data
K-1.4	Closure Turf Design Guide Excerpts
K-1.5	Surface Water Management Figures
K-1.6	Surface Water Model Output

Conclusion

The model outputs and above information is used in the design of the surface water management features in the following surface water management system calculations.

Reference

1. "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, volume 2, Version 3, G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley, National Weather Service, Silver Spring, Maryland, 2004. Location: Van Buren Twp, Michigan, Lat. 42.223, Long. -83.5226.
2. Urban Hydrology for Small Watersheds, TR-55. June 1986, United States Department of Agriculture (USDA).

ATTACHMENT K-1.1

RAINFALL DATA

NOAA Atlas 14, Volume 8, Version 2
Location name: Van Buren Twp, Michigan, USA*
Latitude: 42.223°, Longitude: -83.5226°
Elevation: 699.8 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.321 (0.267-0.392)	0.379 (0.314-0.464)	0.475 (0.393-0.582)	0.556 (0.457-0.684)	0.670 (0.532-0.844)	0.759 (0.589-0.965)	0.850 (0.637-1.10)	0.943 (0.677-1.24)	1.07 (0.738-1.44)	1.17 (0.783-1.59)
10-min	0.470 (0.390-0.575)	0.555 (0.460-0.679)	0.696 (0.575-0.853)	0.814 (0.670-1.00)	0.981 (0.779-1.24)	1.11 (0.863-1.41)	1.24 (0.932-1.61)	1.38 (0.992-1.82)	1.57 (1.08-2.11)	1.71 (1.15-2.32)
15-min	0.573 (0.476-0.701)	0.676 (0.561-0.828)	0.848 (0.702-1.04)	0.993 (0.817-1.22)	1.20 (0.951-1.51)	1.36 (1.05-1.72)	1.52 (1.14-1.96)	1.68 (1.21-2.22)	1.91 (1.32-2.57)	2.08 (1.40-2.83)
30-min	0.767 (0.638-0.938)	0.907 (0.752-1.11)	1.14 (0.942-1.40)	1.34 (1.10-1.64)	1.61 (1.28-2.04)	1.83 (1.42-2.33)	2.06 (1.54-2.66)	2.29 (1.64-3.02)	2.60 (1.80-3.50)	2.84 (1.91-3.87)
60-min	0.970 (0.806-1.19)	1.15 (0.950-1.40)	1.44 (1.19-1.77)	1.70 (1.40-2.09)	2.07 (1.65-2.61)	2.36 (1.83-3.01)	2.66 (2.00-3.46)	2.98 (2.15-3.94)	3.42 (2.36-4.61)	3.76 (2.53-5.12)
2-hr	1.17 (0.980-1.42)	1.38 (1.16-1.68)	1.75 (1.45-2.12)	2.06 (1.70-2.52)	2.52 (2.02-3.17)	2.89 (2.26-3.66)	3.27 (2.47-4.22)	3.68 (2.66-4.84)	4.24 (2.95-5.69)	4.68 (3.17-6.33)
3-hr	1.30 (1.09-1.58)	1.53 (1.28-1.85)	1.93 (1.61-2.34)	2.28 (1.89-2.77)	2.79 (2.25-3.51)	3.21 (2.53-4.06)	3.66 (2.78-4.70)	4.13 (3.00-5.41)	4.79 (3.35-6.40)	5.31 (3.61-7.14)
6-hr	1.55 (1.30-1.85)	1.79 (1.51-2.15)	2.23 (1.87-2.68)	2.62 (2.19-3.16)	3.21 (2.61-4.01)	3.70 (2.93-4.66)	4.22 (3.23-5.41)	4.79 (3.52-6.25)	5.59 (3.94-7.44)	6.24 (4.27-8.33)
12-hr	1.81 (1.53-2.15)	2.06 (1.74-2.45)	2.51 (2.12-2.99)	2.92 (2.45-3.50)	3.55 (2.91-4.41)	4.08 (3.26-5.11)	4.66 (3.59-5.93)	5.28 (3.90-6.85)	6.17 (4.39-8.16)	6.89 (4.75-9.15)
24-hr	2.07 (1.77-2.45)	2.35 (2.00-2.77)	2.83 (2.41-3.36)	3.28 (2.77-3.90)	3.95 (3.26-4.87)	4.52 (3.63-5.60)	5.12 (3.97-6.47)	5.78 (4.30-7.43)	6.71 (4.80-8.80)	7.46 (5.18-9.83)
2-day	2.35 (2.02-2.76)	2.68 (2.30-3.15)	3.25 (2.78-3.82)	3.75 (3.19-4.43)	4.49 (3.71-5.46)	5.09 (4.11-6.25)	5.73 (4.46-7.15)	6.40 (4.79-8.15)	7.34 (5.28-9.54)	8.09 (5.65-10.6)
3-day	2.58 (2.22-3.01)	2.92 (2.51-3.41)	3.51 (3.01-4.11)	4.03 (3.43-4.73)	4.78 (3.97-5.79)	5.40 (4.37-6.59)	6.05 (4.73-7.51)	6.73 (5.05-8.53)	7.68 (5.55-9.94)	8.44 (5.92-11.0)
4-day	2.78 (2.40-3.23)	3.13 (2.70-3.64)	3.73 (3.21-4.35)	4.26 (3.64-4.99)	5.03 (4.18-6.07)	5.66 (4.59-6.88)	6.31 (4.95-7.82)	7.01 (5.27-8.86)	7.97 (5.77-10.3)	8.74 (6.15-11.4)
7-day	3.29 (2.85-3.80)	3.68 (3.19-4.26)	4.34 (3.75-5.03)	4.92 (4.22-5.72)	5.74 (4.79-6.87)	6.41 (5.22-7.74)	7.10 (5.60-8.74)	7.83 (5.92-9.83)	8.84 (6.43-11.3)	9.63 (6.82-12.4)
10-day	3.75 (3.26-4.32)	4.17 (3.63-4.81)	4.89 (4.23-5.64)	5.50 (4.74-6.38)	6.38 (5.34-7.59)	7.08 (5.79-8.51)	7.81 (6.17-9.55)	8.56 (6.50-10.7)	9.60 (7.01-12.2)	10.4 (7.40-13.4)
20-day	5.09 (4.46-5.82)	5.61 (4.90-6.41)	6.46 (5.63-7.40)	7.17 (6.22-8.24)	8.17 (6.86-9.61)	8.95 (7.35-10.6)	9.74 (7.74-11.8)	10.6 (8.06-13.1)	11.7 (8.56-14.7)	12.5 (8.94-16.0)
30-day	6.26 (5.50-7.12)	6.87 (6.03-7.82)	7.86 (6.87-8.96)	8.67 (7.54-9.92)	9.77 (8.23-11.4)	10.6 (8.75-12.5)	11.5 (9.13-13.8)	12.3 (9.42-15.1)	13.4 (9.88-16.8)	14.2 (10.2-18.1)
45-day	7.79 (6.87-8.83)	8.55 (7.53-9.69)	9.75 (8.56-11.1)	10.7 (9.35-12.2)	12.0 (10.1-13.9)	12.9 (10.7-15.1)	13.8 (11.0-16.5)	14.7 (11.3-17.9)	15.8 (11.6-19.7)	16.5 (11.9-21.0)
60-day	9.14 (8.08-10.3)	10.0 (8.87-11.3)	11.5 (10.1-13.0)	12.6 (11.0-14.3)	14.0 (11.8-16.1)	15.0 (12.4-17.5)	15.9 (12.7-18.9)	16.8 (12.9-20.4)	17.9 (13.2-22.2)	18.6 (13.5-23.5)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.
Please refer to NOAA Atlas 14 document for more information.

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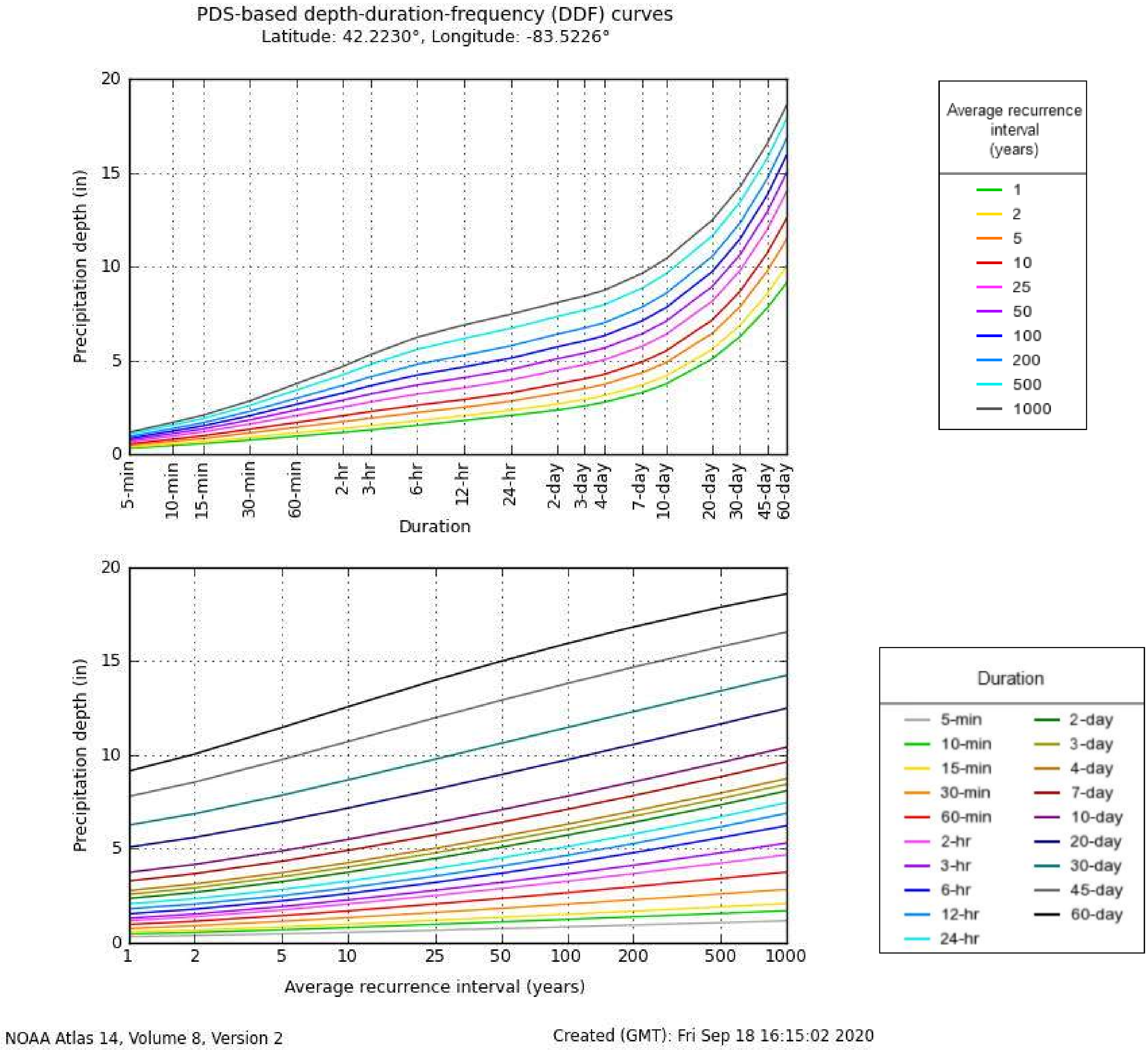
PF graphical



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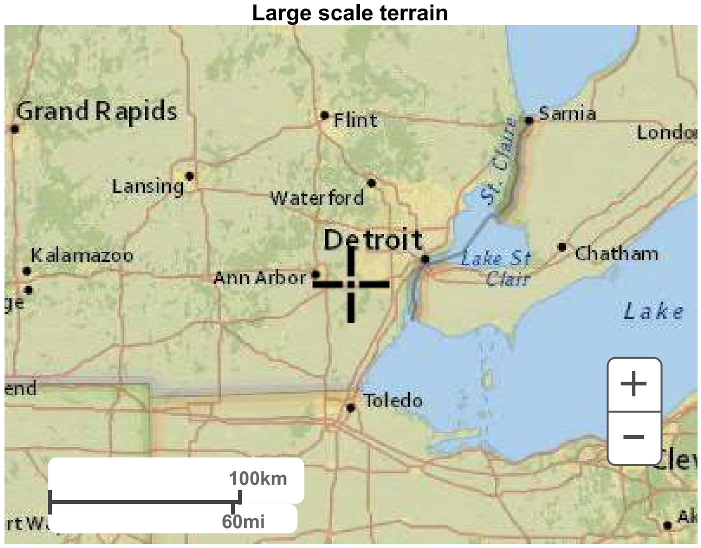
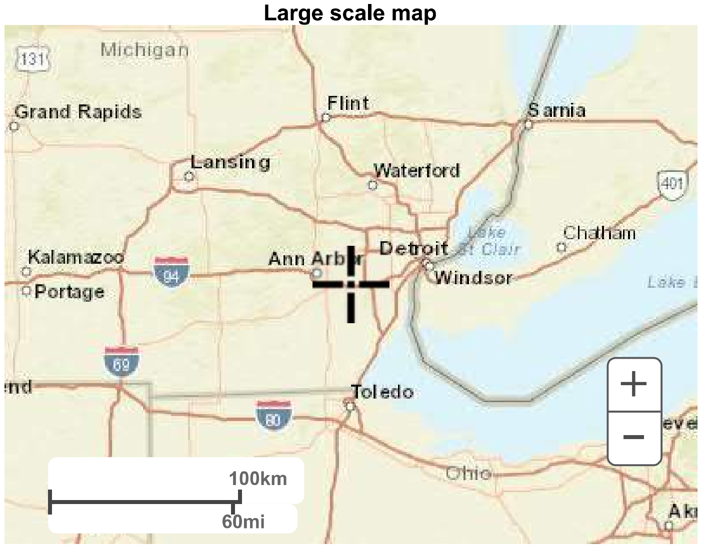
Maps & aerials

Small scale terrain

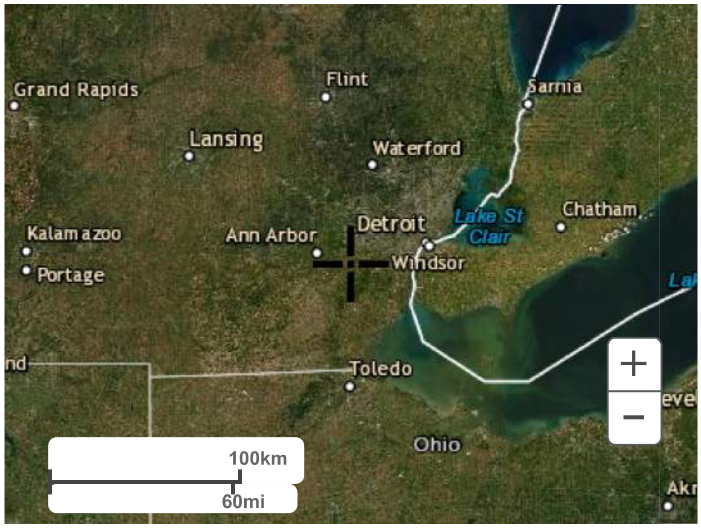
Large scale terrain



Large scale map



Large scale aerial



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National Weather Service
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Disclaimer

ATTACHMENT K-1.2

STORM DISTRIBUTION DATA

NOAA Atlas 14 rainfall for Midwest and Southeast states

Compiled by William Merkel and Helen Fox Moody, updated April 29, 2015

Statistics for NOAA Atlas 14 100-year 24-hour rainfall by state and county

Background

NOAA released volumes 8 and 9 of Atlas 14 for the midwest and southeast United States respectively on Monday April 22, 2013. Precipitation-frequency data are available from NOAA Atlas 14 for both annual and partial duration series at the NWS website http://hdsc.nws.noaa.gov/hdsc/pfds/. GIS data for the 100-year 24-hour partial duration rainfall were downloaded and prepared. State and county maps were overlayed on the GIS to derive statistics on a county basis. The GIS Spatial Analyst command Zonal Statistics as Table was used to generate minimum, maximum, range (difference between maximum and minimum), mean, and standard deviation of the 100-year 24-hour rainfall.

Considerable study of the NOAA 14 data (2006) for the Ohio Valley and neighboring states has been completed both by the Water Quality and Quantity Technology Development Team and by hydraulic engineers in the respective state offices and some procedures have been developed to prepare rainfall databases for the WinTR-55 and EFH-2 computer programs and for developing rainfall distributions to replace the Types II and III which were used in the past. Similar procedures are expected to be used in the midwest and southeast states (which border the Ohio Valley NOAA 14 area) due to similar climatic and topographic characteristics.

Instructions

Preparation of rainfall databases

The midwest and southeast states covered by NOAA Atlas 14 volumes 8 and 9 (except for Colorado) have rainfall data included in the WinTR-55 rainfall database by county or by parish in Louisiana. These same data are also included in rainfall data files used with the EFH-2 computer program. One option for users of these computer programs is to visit the NOAA 14 web site and download data at specific project sites. To save user's time and considering that users may not have internet access at all times, rainfall databases and data files are expected to be developed for these states. Whereas the current files are generally based on TP-40 (1961), data from NOAA Atlas 14 will be substituted.

The first step in this process is to develop maximum, minimum, range, and mean of the 100-year 24-hour rainfall by state and county or parish. This has been done by Bill Merkel and Helen Fox Moody . In states where there is enough topographic relief to product orographic effects in the rainfall amounts, such as Virginia, 100-year 24-hour rainfall could vary by up to 5 inches in a single county. To address this situation, if the rainfall varied more than 1.5 inches within a county, the county was split in two or more parts, each having a set of rainfall values in the rainfall database.

Some of the midwest and southeast states have all counties with less than 1.5 inch variation. Other states have several counties with more than 1.5 inches of variation.

If a county is to be split, use the following procedure:

- Split the county along some boundary such that the range of the 100-year 24-hour rainfall of each part is less than 1.5 inches.
- Start with a state/county GIS shapefile and digitize the boundary.
- In split counties, generate the statistics for each part (min, max, range, and mean).
- Select a representative point location in each county or part of split counties. Find a point in the county (or part of county) where the 100-year 24-hour rainfall is equal (or within 0.05 inch) of the mean county value. Record this latitude and longitude.
- Open the NOAA Atlas 14 web site and download the csv (comma separated variable) file for that location. Use the 1-year through 100-year 24-hour rainfall values at this location in the WinTR-55 rainfall database and the EFH-2 rainfall data file. A GIS layer will be developed with the set of locations in each state.
- Bill and Helen will assist any state with these steps if requested.

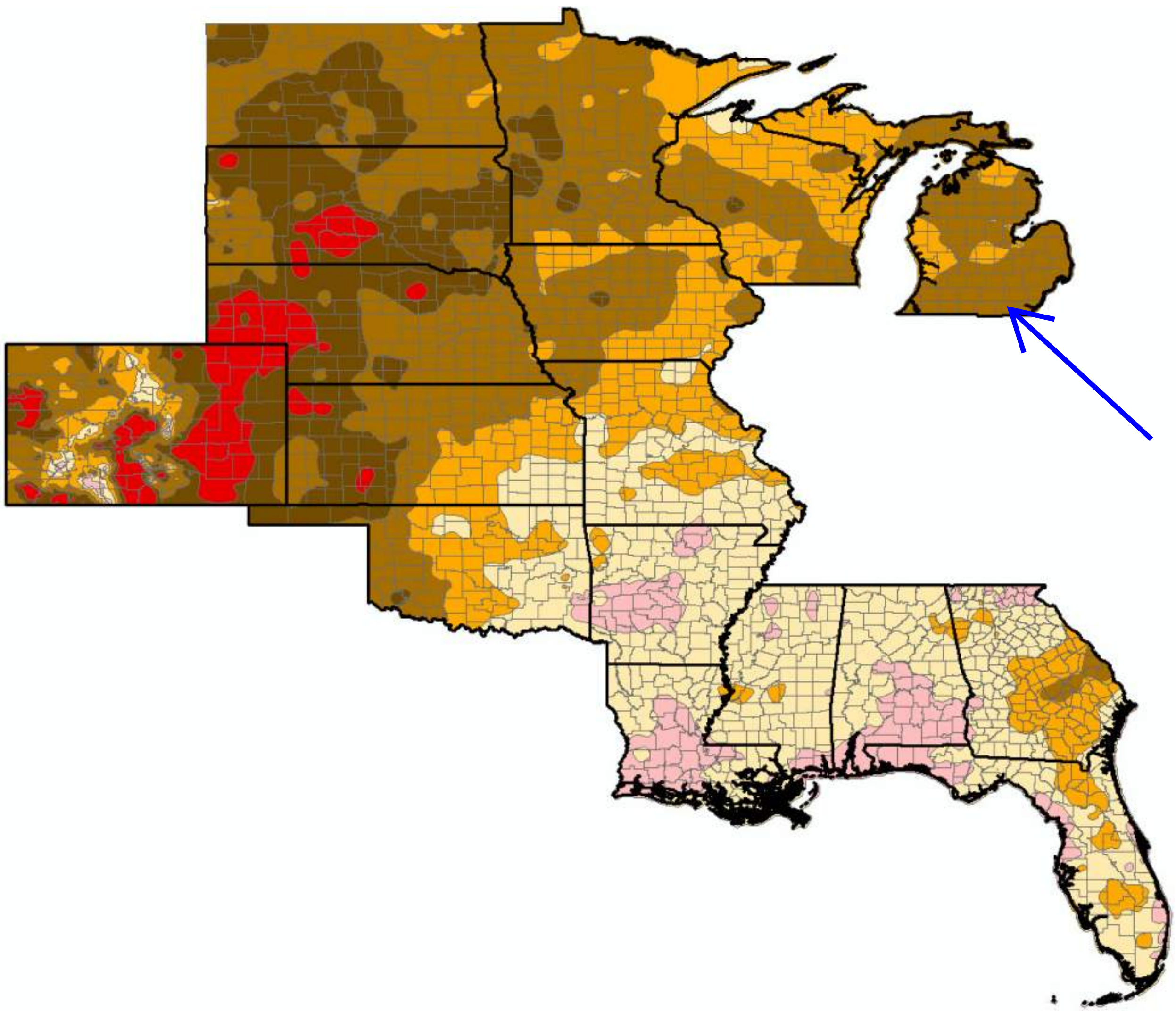
Development of rainfall distributions

The latest draft of Part 630 Chapter 4 Storm Rainfall and Distribution includes the procedures that will be used to develop rainfall distributions for the midwest and southeast states. The purpose of the rainfall distribution is to include all the rainfall amounts at shorter durations in the 24-hour rainfall distribution. For example, for a 25-year 24-hour storm, the 25-year 5-minute rainfall, 25-year 10-minute, rainfall, etc are included within the 24-hour distribution. This is accomplished by placing the 5-minute rainfall in the center (12 hours) and each larger duration being centered at 12 hours. The 60-minute rainfall is located between 11.5 and 12.5 hours. The 2-hour rainfall is located from 10 to 12 hours, etc.

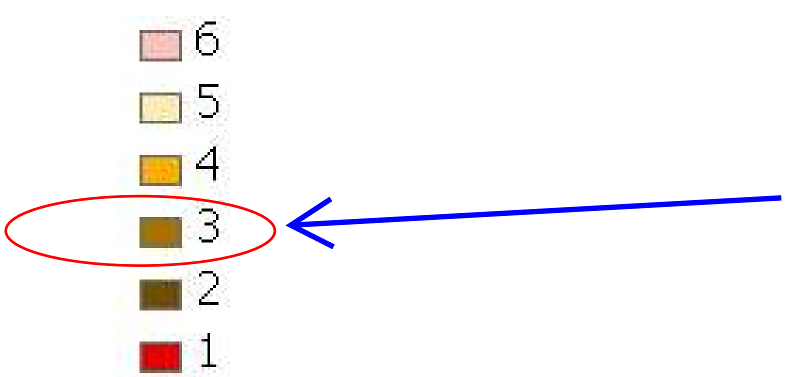
A map has been generated with the ratio of the 60-minute rainfall to the 24-hour rainfall for the 25-year values. In preliminary analyses, this ratio varies from a low value of 0.32 to a high value of 0.75. A rainfall distribution map has 6 rainfall distributions. Based on this ratio, areas within a range of values will be included as a rainfall distribution region. They are named MSE 1, MSE 2, through MSE 6 (MSE is abbreviated from midwest/southeast states). The range of ratio of 60-minute to 24-hour rainfall is in the following table.

Rainfall Distribution Name	Minimum 60-min/24-hour	Maximum 60-min/24-hour
MSE 1	0.58	0.75
MSE 2	0.53	0.58
MSE 3	0.48	0.53
MSE 4	0.43	0.48
MSE 5	0.38	0.43
MSE 6	0.32	0.38

For reference, the 60-minute to 24-hour ratio for the Type II rainfall distribution is 0.45 and the ratio for the Type III is 0.40. Based on the NOAA Atlas 14 data, rainfall distributions less intense, of similar intensity, and more intense than the Types II and III are being used.



Tentative rainfall distribution regions (based on GIS analysis).



Distribution region 1 has the most intense rainfall distribution and region 6 has the least intense rainfall distribution. In preliminary tests, regions 1 and 2 have peak discharges similar to the New Mexico 60 and 65 rainfall distributions (significantly higher than the Type II). Region 4 has peak discharges similar to the Type II rainfall distributions. Region 5 has peak discharges similar to the Type III rainfall distribution. Region 6 has peak discharges less than the Type III rainfall distribution.

Some may question whether to drop the Type II, Type III, and New Mexico rainfall distributions based on these preliminary conclusions. The Type II does not have any documentation remaining on specifically how it was developed and what data were used to develop it. We do not have documentation on the New Mexico rainfall distributions (there may be some documentation saved in the New Mexico state office). The Type III has significant documentation remaining and is based on data from TP-40 and NWS Hydro-35 report. The tentative rainfall distributions (map above) above are based on NOAA 14 data and similar procedures were used to develop rainfall distributions for the Ohio Valley and New York/New England states.

The map above is based entirely on the GIS data and does not consider state or county boundaries. When adjusting the map to fit state desires, the boundaries may be adjusted to follow county/parish boundaries. It is simpler for the field office staff to use a single rainfall distribution in a county. Two general choices have been used in states. One is to select the rainfall distribution that makes up the largest percentage of land area. The other choice is to select the more conservative rainfall distribution that is present in a county. For example, if a county is divided between rainfall distribution MSE 3 and MSE 4, then assign rainfall distribution MSE 3. Whichever choice is made, it is recommended to be consistent for all counties in a state.

Yet several states have chosen to follow the rainfall distributions as defined on the map above. This means that a single county may have more than one rainfall distribution and the user must read the map to determine which rainfall distribution to use.

ATTACHMENT K-1.3

CURVE NUMBER DATA

Table 2-2a Runoff curve numbers for urban areas [1/]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2/]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3/]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4/]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5/]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-2d Runoff curve numbers for arid and semiarid rangelands [1/]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition [2/]	A [3/]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and I_a, = 0.2S. For range in humid regions, use table 2-2c.
2 Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
3 Curve numbers for group A have been developed only for desert shrub.

ATTACHMENT K-1.4

CLOSURE TURF DESIGN GUIDE EXCERPTS

5.0 Hydrology

5.1 ClosureTurf® Hydrology Parameters

Currently, many regulatory agencies are requiring run-off curve numbers (RCN) of 95-98 of a typical landfill closure. ClosureTurf's RCN should be calculated between 92 and 95. This number was derived by TRI Environmental, Inc. and Colorado State University Hydraulics Laboratory in separate tests. Table 2 below shows the typical TR-55 design parameters for Hydrology using ClosureTurf®.

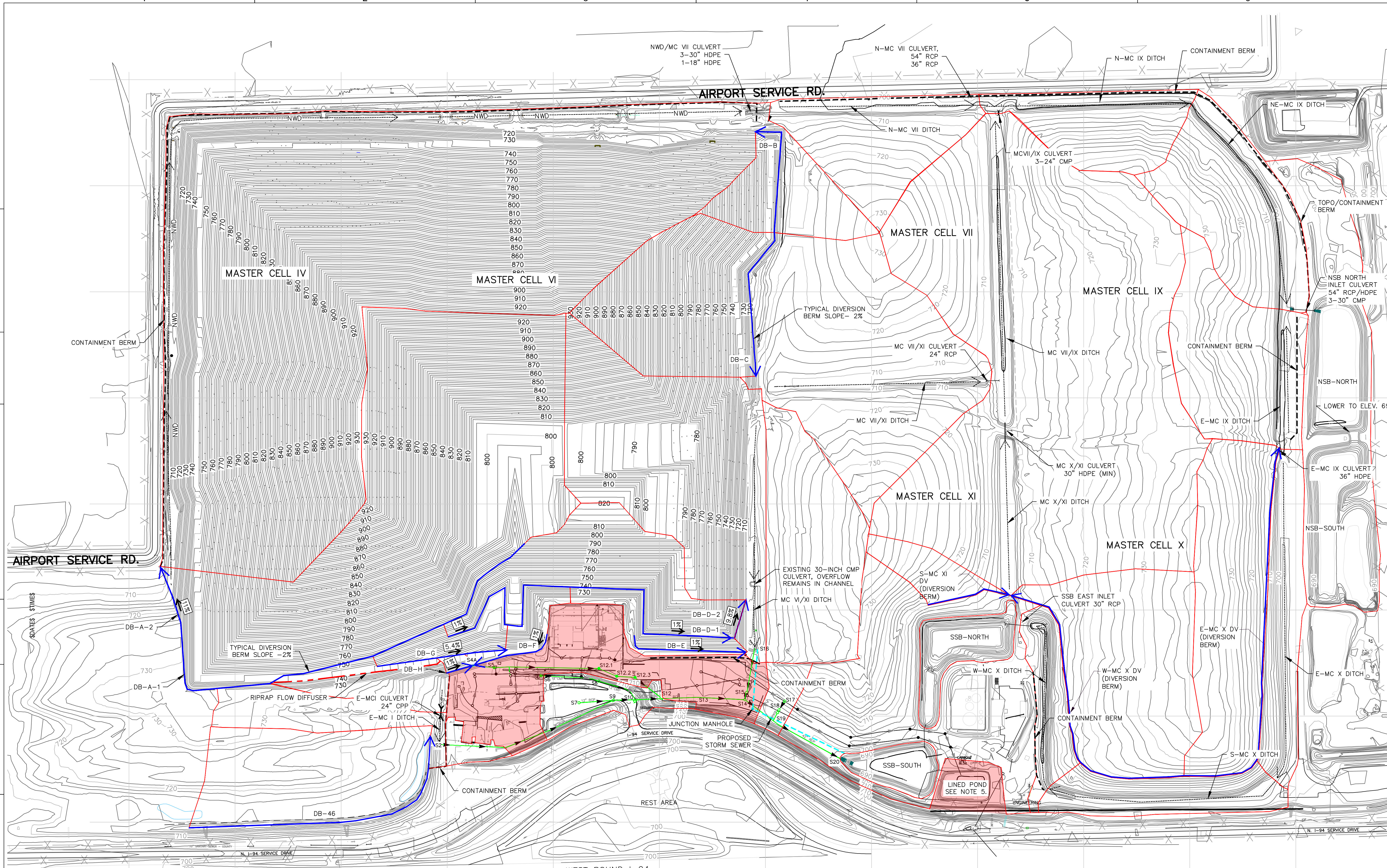
Closure Turf® Hydrology		
	TR-55 Data	
	Curve Number Depends on Rain Intensity	92[1] - 95
Sheet Flow	Manning's n	
	Slopes >10%	0.12
	Slopes <10%	0.22
	Flow Length	100'-300' dependent on Manning's n until a depth of not more than 0.1 foot is attained in the 2yr 24hr rainfall
	2yr-24hr Rain	SCS
	Land Slope	design
Shallow Concentrated Flow	Flow Length	design
	Slope	design
	Surface (paved/unpaved)	Paved
	X-Sect Area	ft^2
Channel Flow	Wetted Perimeter	Linear Feet
	Channel Slope	ft/ft
	Manning's n	0.03[2]
	Flow Length	design

1. RCN ranging from 92 in High Intensity Rainfalls to 95 in normal rainfall events.
2. Manning's n for channel flow will vary with depth of flow.

Table 2: ClosureTurf® TR-55 Data

ATTACHMENT K-1.5

SURFACE WATER MANAGEMENT FIGURES



NOTES:

1. THE BASE MAP WAS CREATED USING AN AERIAL SURVEY TAKEN IN DECEMBER, 2020 BY WDI.
2. THE DESIGN SURFACE SHOWN REPRESENTS THE MCVI FINAL GRADES – 2021 REDESIGN BY CTI.
3. CONVEYANCE SYSTEMS ARE DESIGNED TO COLLECT AND CONTROL THE RUNOFF FROM AT LEAST A 25-YR, 24-HR STORM AND MANAGE A 100-YR, 24-HR STORM.
4. SURFACE WATER MANAGEMENT SYSTEM DESIGN INFORMATION FOR ENGINEERED TURF FINAL COVER PROVIDED IN APPENDIX K. ALTERNATE CONFIGURATIONS AND MATERIALS THAT MEET DESIGN CRITERIA MAY BE UTILIZED.
5. THIS EXPANSION REDUCES THE DRAINAGE AREA TO THE LINED POND. THEREFORE THE DESIGN OF THE LINED POND, LINED POND SEWER, AND ASSOCIATED DRAINAGE AREA WILL CONTINUE TO FUNCTION AS ORIGINALLY DESIGNED AND IS NOT PART OF THE SSB DRAINAGE AREA.

0 200 400
SCALE IN FEET

LEGEND

500 EXISTING MAJOR CONTOURS
EXISTING MINOR CONTOURS
DIVERSION BERM
WATERSHED BOUNDARY
DITCH FLOW PATH
DIVERSION BERM
RIPRAP FLOW DIFFUSER
SOUTH SEDIMENTATION BASIN STORM SEWER
LINED POND STORM SEWER
CULVERT
CATCH BASIN, CURB STYLE
CATCH BASIN INLET
STORM MANHOLE COVER
LINED POND WATERSHED (NOT MODELED)
CONTAINMENT BERM
PROPOSED STORM SEWER
PROPOSED CATCH BASIN/MANHOLE

DATE: 10/28/21
DESIGNED BY: LEH
DRAWN BY: LEH
CHECKED BY: TCR
APPROVED BY: XZ

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Novi, Michigan 48377
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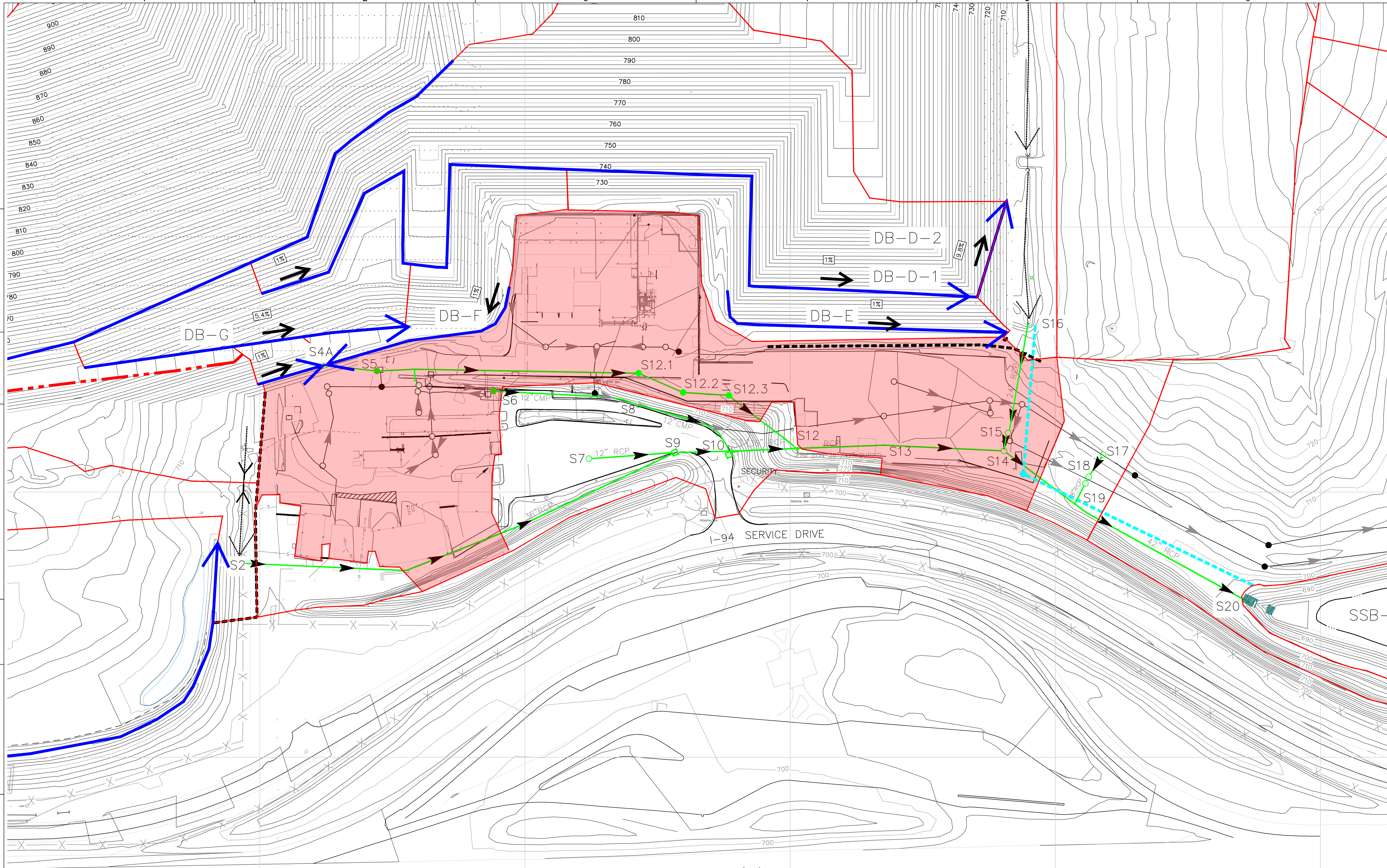
www.cticompanies.com

REV | DATE | REVISION DESCRIPTION | DRN | APP

WAYNE DISPOSAL, INC. SITE NO. 2 - MASTER CELL VI-F&G
VAN BUREN TOWNSHIP, WAYNE COUNTY, MICHIGAN

SUBWATERSHED MAP - ENGINEERED TURF

PROJECT NUMBER 1218070017
SCALE AS NOTED
DRAWING NO K-1.5
FIGURE 1



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N

0 80 160

SCALE IN FEET

LEGEND

- 500 EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- WATERSHED BOUNDARY
- DITCH FLOW PATH
- DIVERSION BERM
- DOWNSLOPE CHANNEL
- SOUTH SEDIMENTATION BASIN STORM SEWER
- LINED POND STORM SEWER
- CULVERT
- CATCH BASIN, CURB STYLE
- CATCH BASIN INLET
- STORM MANHOLE COVER
- LINED POND WATERSHED (NOT MODELED)
- CONTAINMENT BERM
- PROPOSED STORM SEWER
- PROPOSED CATCH BASIN/MANHOLE

DATE:	10/28/21
DESIGNED BY:	LEH
DRAWN BY:	LEH
CHECKED BY:	TCR
APPROVED BY:	XZ

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www.cticompanies.com

REV	DATE	REVISION DESCRIPTION	DRN	APP

REVISIONS

WAYNE DISPOSAL, INC. SITE NO. 2 - MASTER CELL VI-F&G
VAN BUREN TOWNSHIP, WAYNE COUNTY, MICHIGAN

STORM SEWER SYSTEM PLAN - ENGINEERED TURF

PROJECT NUMBER 1218070017

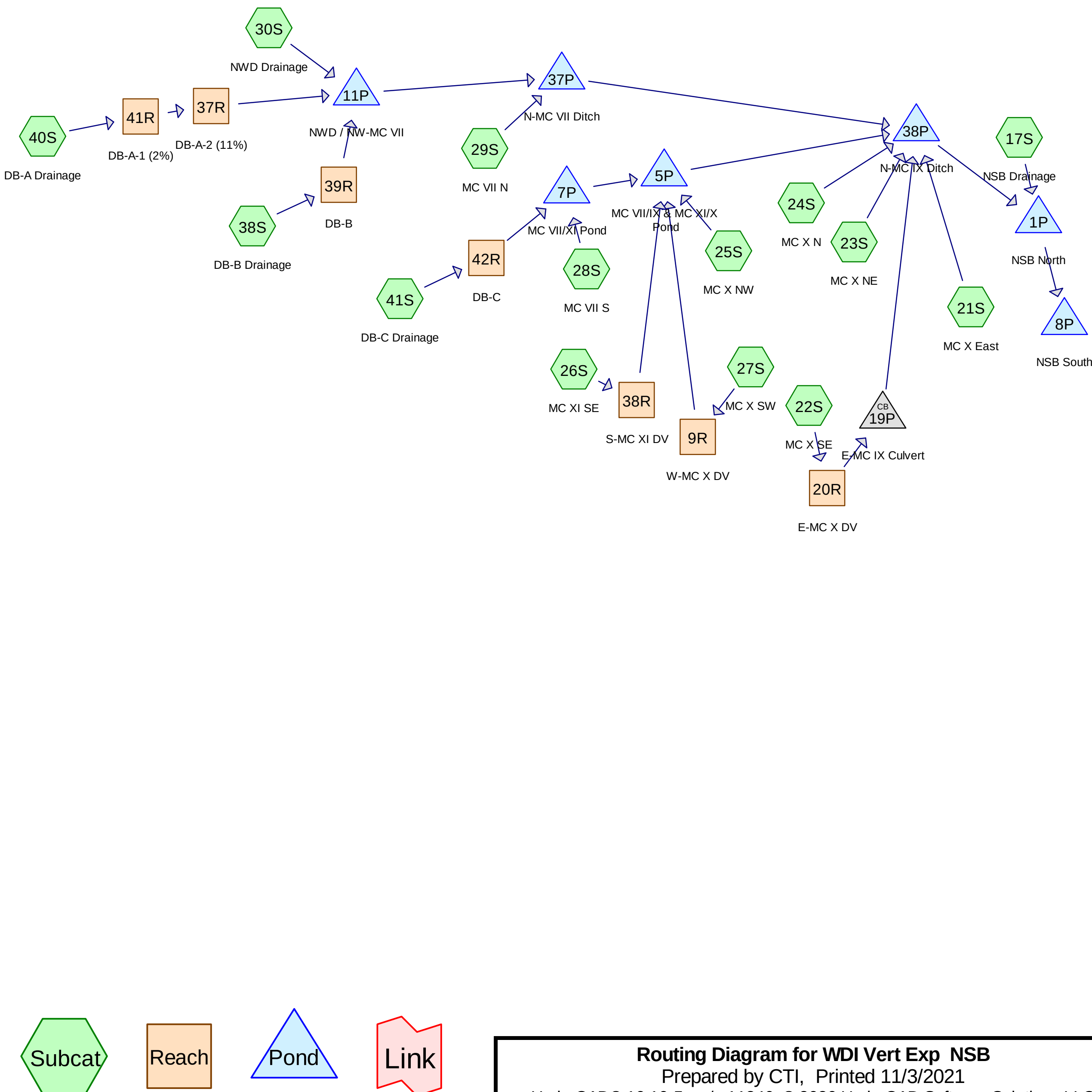
SCALE AS SHOWN

DRAWING NO K-1.5 FIGURE 2

ATTACHMENT K-1.6

SURFACE WATER MODEL OUTPUT

North Sedimentation Basin (NSB) HYDROCAD OUTPUT – 25-yr, 24-hr



Routing Diagram for WDI Vert Exp NSB
Prepared by CTI, Printed 11/3/2021
HydroCAD® 10.10-5a s/n 11246 © 2020 HydroCAD Software Solutions LLC

Time span=0.00-36.00 hrs, dt=0.04 hrs, 901 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 17S: NSB Drainage Runoff Area=483,100 sf 0.00% Impervious Runoff Depth=3.38"
Tc=0.0 min CN=95 Runoff=76.09 cfs 3.125 af

Subcatchment 21S: MC X East Runoff Area=443,100 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=650' Slope=0.0370 '/' Tc=21.2 min CN=84 Runoff=25.66 cfs 1.973 af

Subcatchment 22S: MC X SE Runoff Area=527,091 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=240' Slope=0.0540 '/' Tc=15.5 min CN=84 Runoff=35.62 cfs 2.347 af

Subcatchment 23S: MC X NE Runoff Area=435,600 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=440' Slope=0.0590 '/' Tc=15.3 min CN=84 Runoff=29.79 cfs 1.939 af

Subcatchment 24S: MC X N Runoff Area=282,100 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=310' Slope=0.0930 '/' Tc=11.7 min CN=84 Runoff=21.63 cfs 1.256 af

Subcatchment 25S: MC X NW Runoff Area=2,437,500 sf 8.04% Impervious Runoff Depth=2.41"
Flow Length=820' Slope=0.0380 '/' Tc=23.0 min CN=85 Runoff=139.97 cfs 11.253 af

Subcatchment 26S: MC XI SE Runoff Area=95,200 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=405' Slope=0.0770 '/' Tc=13.4 min CN=84 Runoff=6.90 cfs 0.424 af

Subcatchment 27S: MC X SW Runoff Area=600,400 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=240' Slope=0.0400 '/' Tc=17.5 min CN=84 Runoff=38.28 cfs 2.673 af

Subcatchment 28S: MC VII S Runoff Area=923,419 sf 4.21% Impervious Runoff Depth=2.41"
Flow Length=1,070' Tc=20.9 min CN=85 Runoff=55.61 cfs 4.263 af

Subcatchment 29S: MC VII N Runoff Area=349,700 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=560' Slope=0.0390 '/' Tc=19.5 min CN=84 Runoff=21.14 cfs 1.557 af

Subcatchment 30S: NWD Drainage Runoff Area=3,609,746 sf 5.58% Impervious Runoff Depth=3.38"
Flow Length=886' Slope=0.2500 '/' Tc=7.2 min CN=95 Runoff=438.24 cfs 23.354 af

Subcatchment 38S: DB-B Drainage Runoff Area=96,773 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=378' Slope=0.2500 '/' Tc=6.4 min CN=95 Runoff=12.09 cfs 0.626 af

Subcatchment 40S: DB-A Drainage Runoff Area=1,755,927 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=1,150' Tc=7.8 min CN=95 Runoff=209.40 cfs 11.360 af

Subcatchment 41S: DB-C Drainage Runoff Area=487,859 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=381' Slope=0.2500 '/' Tc=6.4 min CN=95 Runoff=60.97 cfs 3.156 af

Reach 9R: W-MC X DV Avg. Flow Depth=1.37' Max Vel=3.22 fps Inflow=38.28 cfs 2.673 af
n=0.025 L=1,400.0' S=0.0050 '/' Capacity=91.23 cfs Outflow=33.14 cfs 2.673 af

Reach 20R: E-MC X DV Avg. Flow Depth=1.49' Max Vel=4.71 fps Inflow=35.62 cfs 2.347 af
n=0.025 L=1,780.0' S=0.0100 '/' Capacity=68.87 cfs Outflow=30.87 cfs 2.347 af

Reach 37R: DB-A-2 (11%) Avg. Flow Depth=1.71' Max Vel=21.33 fps Inflow=187.20 cfs 11.360 af
n=0.020 L=125.2' S=0.1097 '/' Capacity=837.73 cfs Outflow=186.68 cfs 11.360 af

Reach 38R: S-MC XI DV Avg. Flow Depth=0.66' Max Vel=3.70 fps Inflow=6.90 cfs 0.424 af
n=0.025 L=750.0' S=0.0180 '/' Capacity=57.72 cfs Outflow=6.40 cfs 0.424 af

Reach 39R: DB-B Avg. Flow Depth=0.89' Max Vel=5.83 fps Inflow=12.09 cfs 0.626 af
n=0.020 L=598.0' S=0.0200 '/' Capacity=99.84 cfs Outflow=11.29 cfs 0.626 af

Reach 41R: DB-A-1 (2%) Avg. Flow Depth=2.37' Max Vel=11.26 fps Inflow=209.40 cfs 11.360 af
n=0.020 L=2,146.0' S=0.0200 '/' Capacity=357.63 cfs Outflow=187.20 cfs 11.360 af

Reach 42R: DB-C Avg. Flow Depth=1.65' Max Vel=8.75 fps Inflow=60.97 cfs 3.156 af
n=0.020 L=724.0' S=0.0200 '/' Capacity=99.84 cfs Outflow=57.27 cfs 3.156 af

Pond 1P: NSB North Peak Elev=693.90' Storage=2,241,101 cf Inflow=198.30 cfs 65.232 af
Outflow=90.59 cfs 20.210 af

Pond 5P: MC VII/IX & MC XI/X Pond Peak Elev=703.18' Storage=433,061 cf Inflow=235.45 cfs 21.504 af
24.0" Round Culvert x 3.00 n=0.025 L=30.0' S=0.0033 '/' Outflow=59.68 cfs 19.337 af

Pond 7P: MC VII/XI Pond Peak Elev=707.93' Storage=74,866 cf Inflow=98.14 cfs 7.419 af
Outflow=65.39 cfs 7.155 af

Pond 8P: NSB South Peak Elev=686.98' Storage=1,395,115 cf Inflow=90.59 cfs 20.210 af
Outflow=0.00 cfs 0.000 af

Pond 11P: NWD / NW-MC VII Peak Elev=710.46' Storage=549,996 cf Inflow=580.45 cfs 35.340 af
Outflow=139.72 cfs 35.340 af

Pond 19P: E-MC IX Culvert Peak Elev=704.16' Inflow=30.87 cfs 2.347 af
36.0" Round Culvert n=0.012 L=72.0' S=0.0365 '/' Outflow=30.87 cfs 2.347 af

Pond 37P: N-MC VII Ditch Peak Elev=702.15' Storage=132,671 cf Inflow=157.63 cfs 36.897 af
Outflow=145.32 cfs 35.255 af

Pond 38P: N-MC IX Ditch Peak Elev=699.67' Storage=362,060 cf Inflow=263.71 cfs 62.107 af
Outflow=195.50 cfs 62.107 af

Total Runoff Area = 287.592 ac Runoff Volume = 69.305 af Average Runoff Depth = 2.89"
96.52% Pervious = 277.574 ac 3.48% Impervious = 10.018 ac

Summary for Subcatchment 17S: NSB Drainage

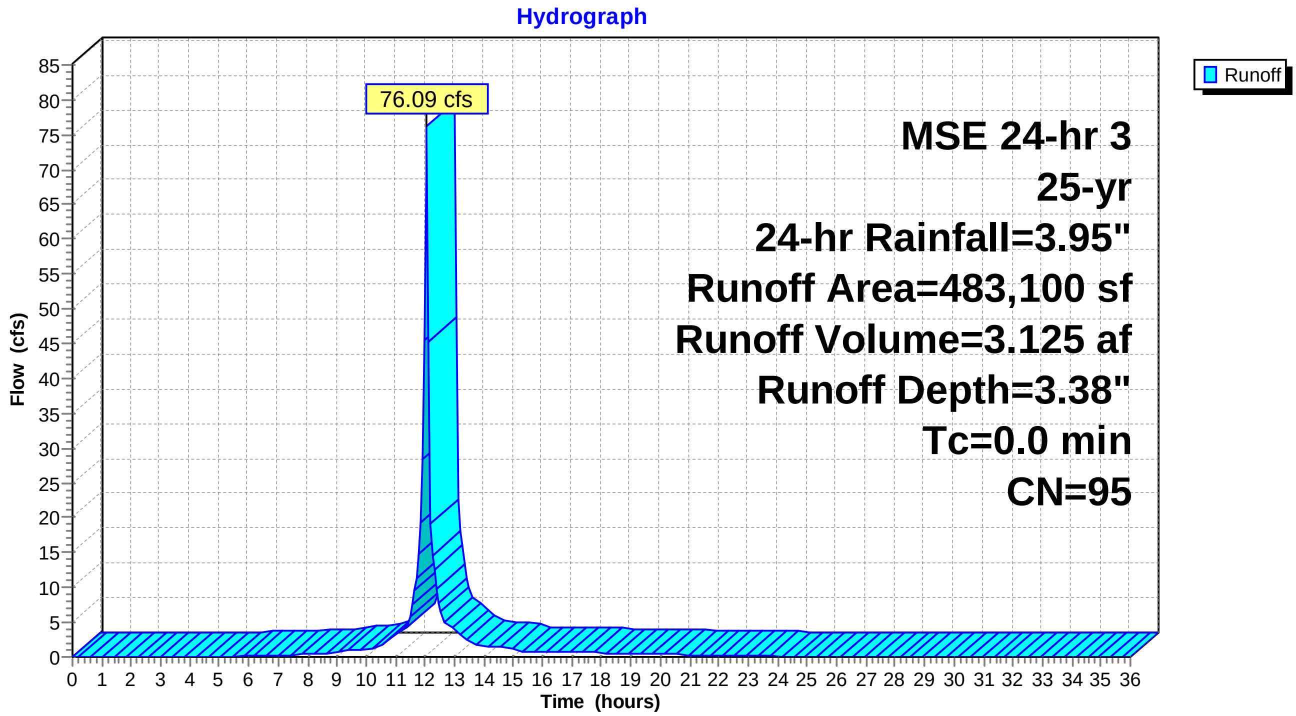
Drainage area is pond area and land area
Land area = 483,100 - 111,900 = 371,200

Runoff = 76.09 cfs @ 12.06 hrs, Volume= 3.125 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
111,900	84	50-75% Grass cover, Fair, HSG D
371,200	98	Water Surface, 0% imp, HSG D
483,100	95	Weighted Average
483,100		100.00% Pervious Area

Subcatchment 17S: NSB Drainage



Summary for Subcatchment 21S: MC X East

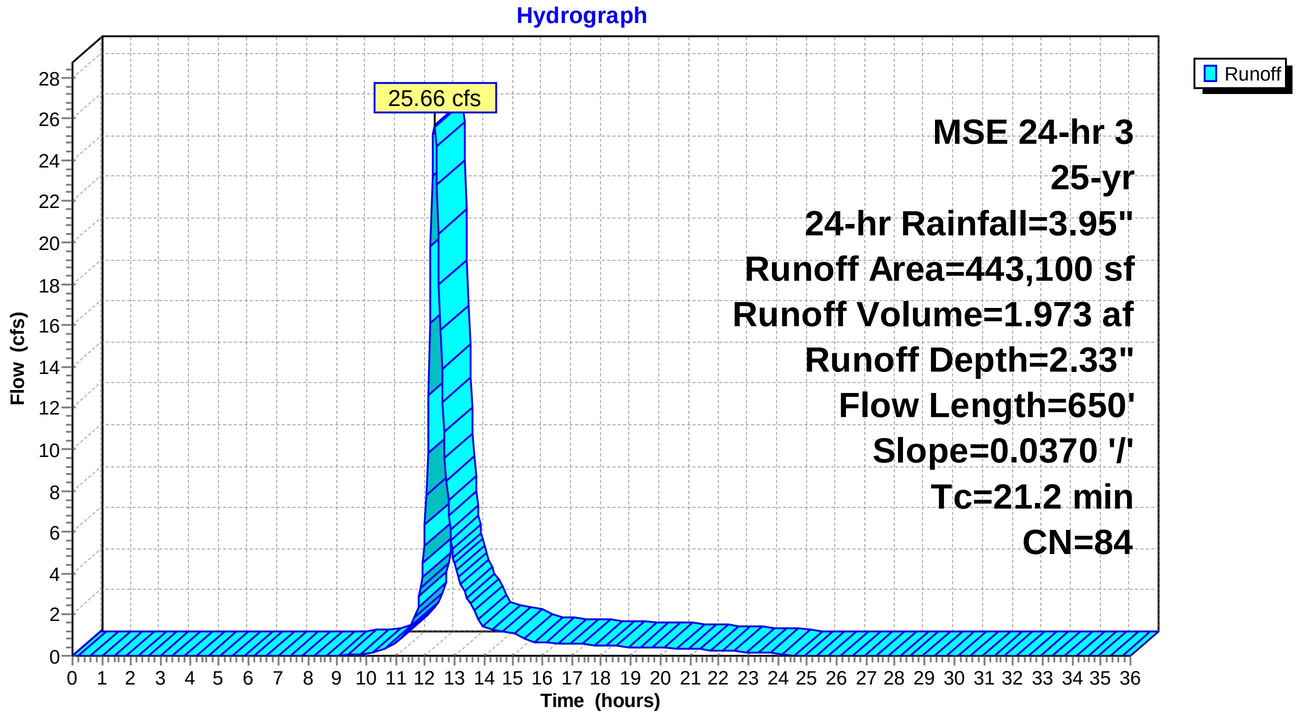
Runoff = 25.66 cfs @ 12.31 hrs, Volume= 1.973 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
443,100	84	50-75% Grass cover, Fair, HSG D
443,100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.6	200	0.0370	0.21		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
5.6	450	0.0370	1.35		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.2	650	Total			

Subcatchment 21S: MC X East



Summary for Subcatchment 22S: MC X SE

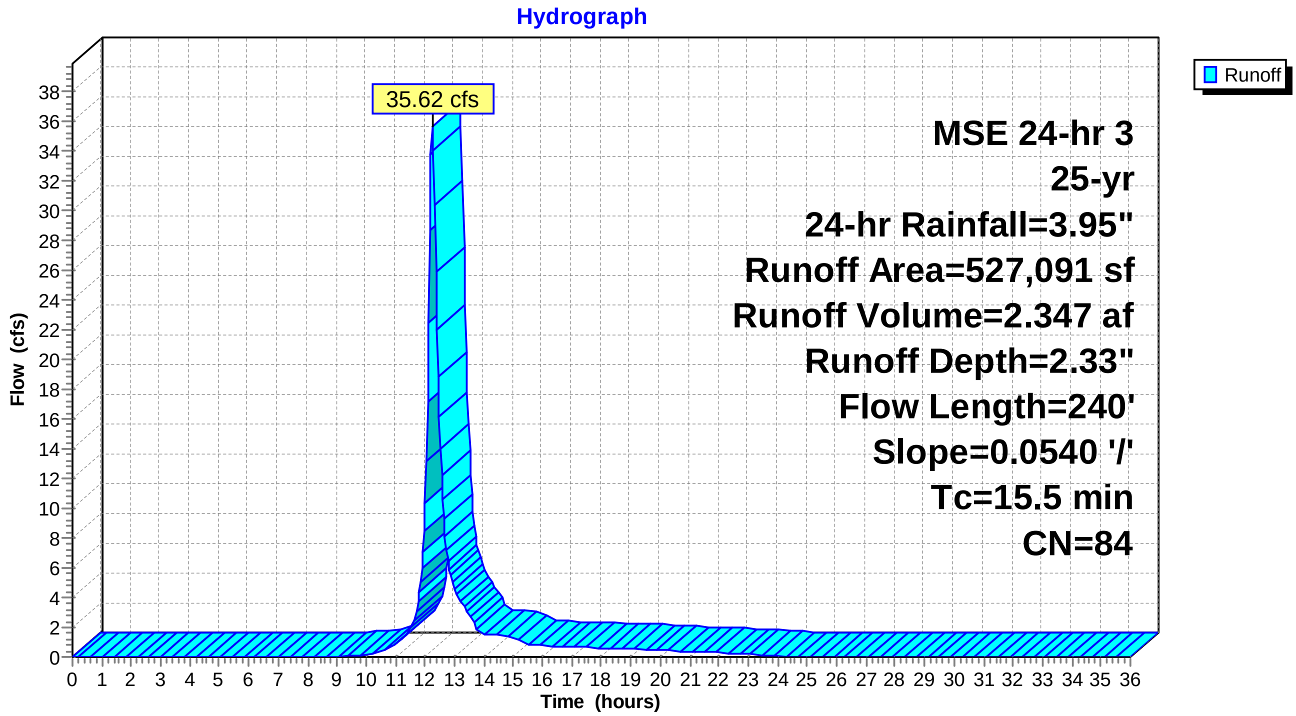
Runoff = 35.62 cfs @ 12.24 hrs, Volume= 2.347 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
527,091	84	50-75% Grass cover, Fair, HSG D
527,091		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.5	240	0.0540	0.26		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 22S: MC X SE



Summary for Subcatchment 23S: MC X NE

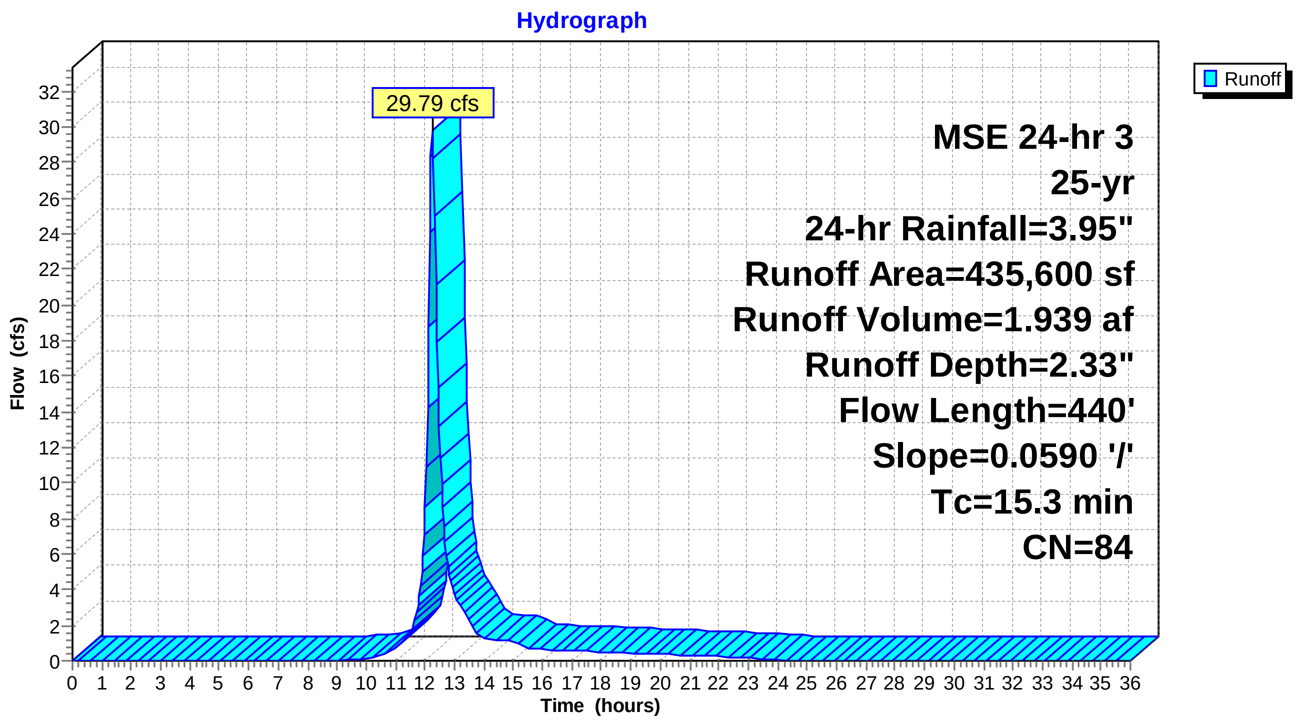
Runoff = 29.79 cfs @ 12.24 hrs, Volume= 1.939 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
435,600	84	50-75% Grass cover, Fair, HSG D
435,600		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.9	200	0.0590	0.26		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
2.4	240	0.0590	1.70		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
15.3	440	Total			

Subcatchment 23S: MC X NE



Summary for Subcatchment 24S: MC X N

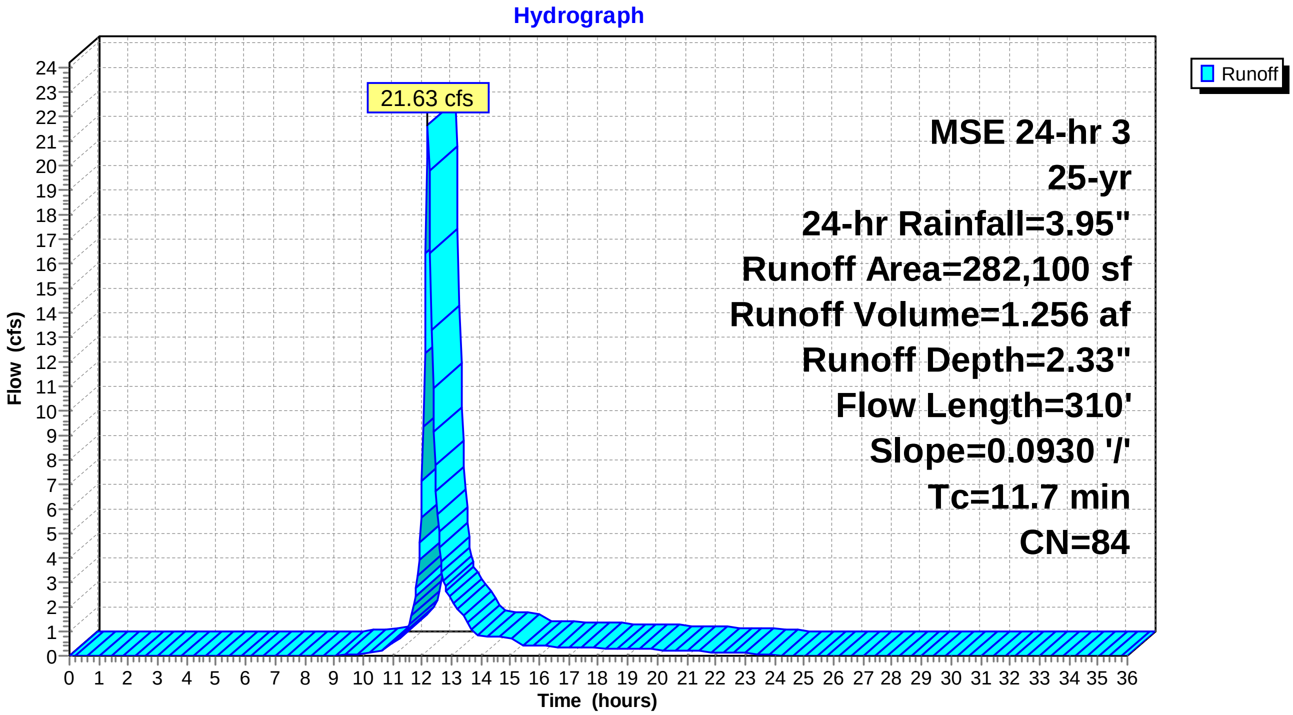
Runoff = 21.63 cfs @ 12.20 hrs, Volume= 1.256 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
282,100	84	50-75% Grass cover, Fair, HSG D
282,100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.8	200	0.0930	0.31		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
0.9	110	0.0930	2.13		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
11.7	310	Total			

Subcatchment 24S: MC X N



Summary for Subcatchment 25S: MC X NW

Drainage area is pond area and land area
Land area = 2,437,500 - 196,000 = 2,241,500

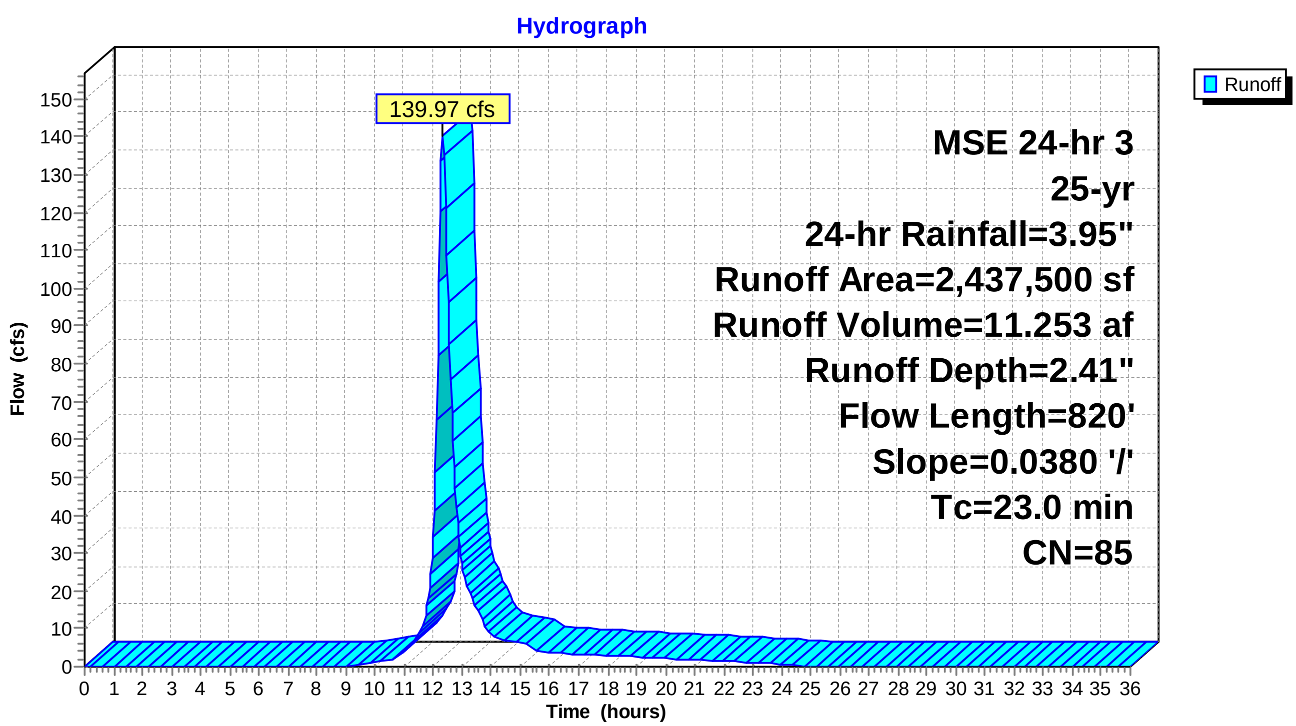
Runoff = 139.97 cfs @ 12.33 hrs, Volume= 11.253 af, Depth= 2.41"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
196,000	98	Water Surface, HSG D
2,241,500	84	50-75% Grass cover, Fair, HSG D
2,437,500	85	Weighted Average
2,241,500		91.96% Pervious Area
196,000		8.04% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.4	200	0.0380	0.22		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
7.6	620	0.0380	1.36		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
23.0	820	Total			

Subcatchment 25S: MC X NW



Summary for Subcatchment 26S: MC XI SE

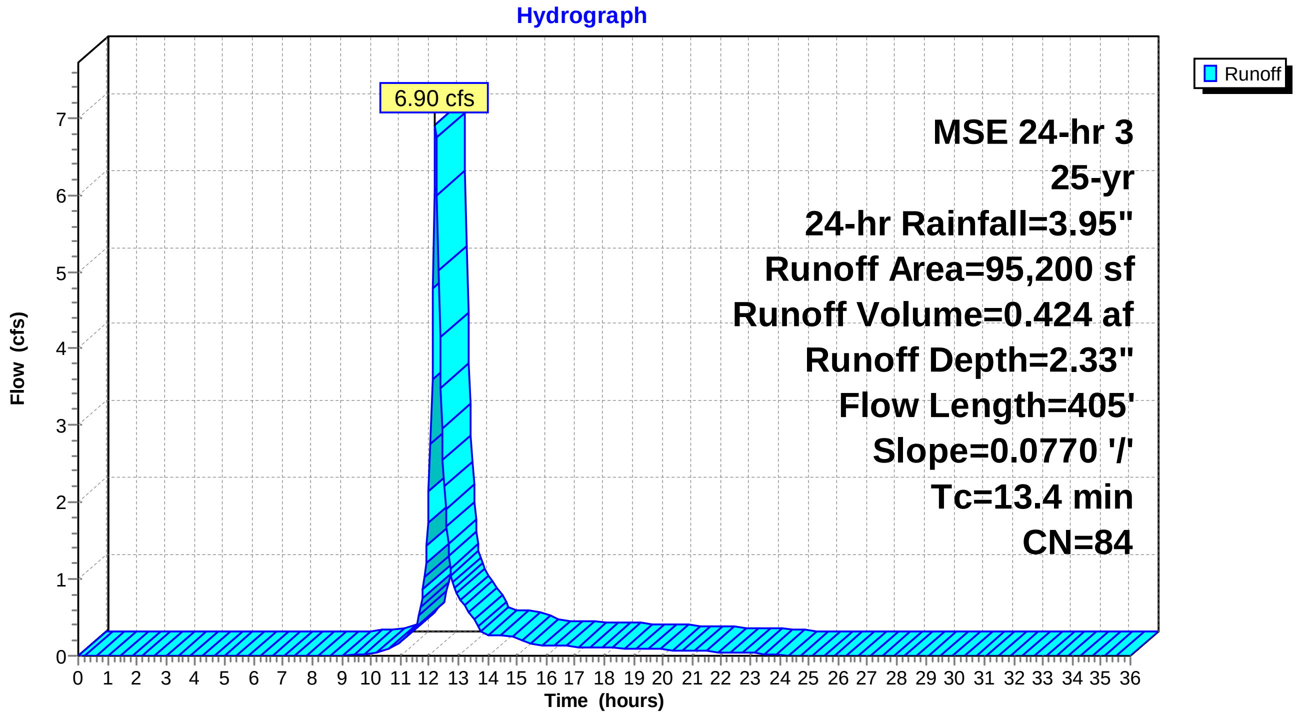
Runoff = 6.90 cfs @ 12.22 hrs, Volume= 0.424 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
95,200	84	50-75% Grass cover, Fair, HSG D
95,200		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	200	0.0770	0.29		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
1.8	205	0.0770	1.94		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.4	405	Total			

Subcatchment 26S: MC XI SE



Summary for Subcatchment 27S: MC X SW

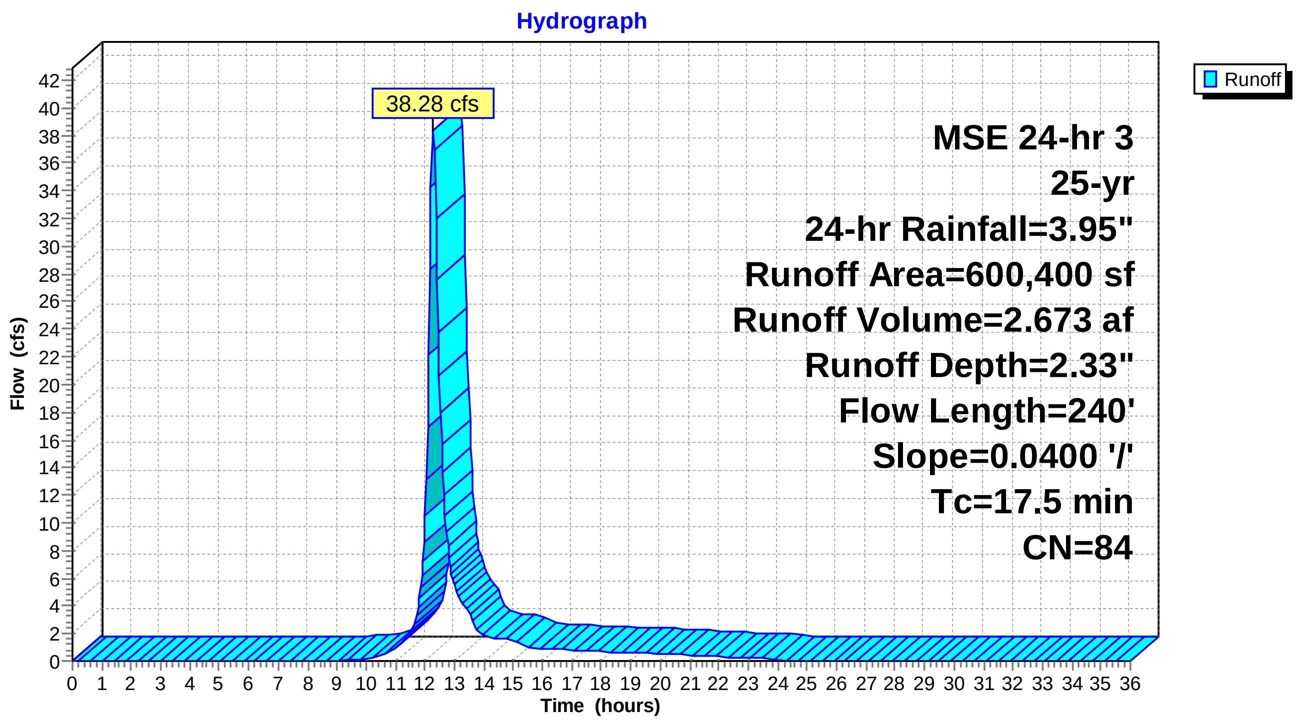
Runoff = 38.28 cfs @ 12.26 hrs, Volume= 2.673 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
600,400	84	50-75% Grass cover, Fair, HSG D
600,400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.5	240	0.0400	0.23		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 27S: MC X SW



Summary for Subcatchment 28S: MC VII S

Drainage area is pond area and land area
Land area = 998,400 - 38,900 = 959,500

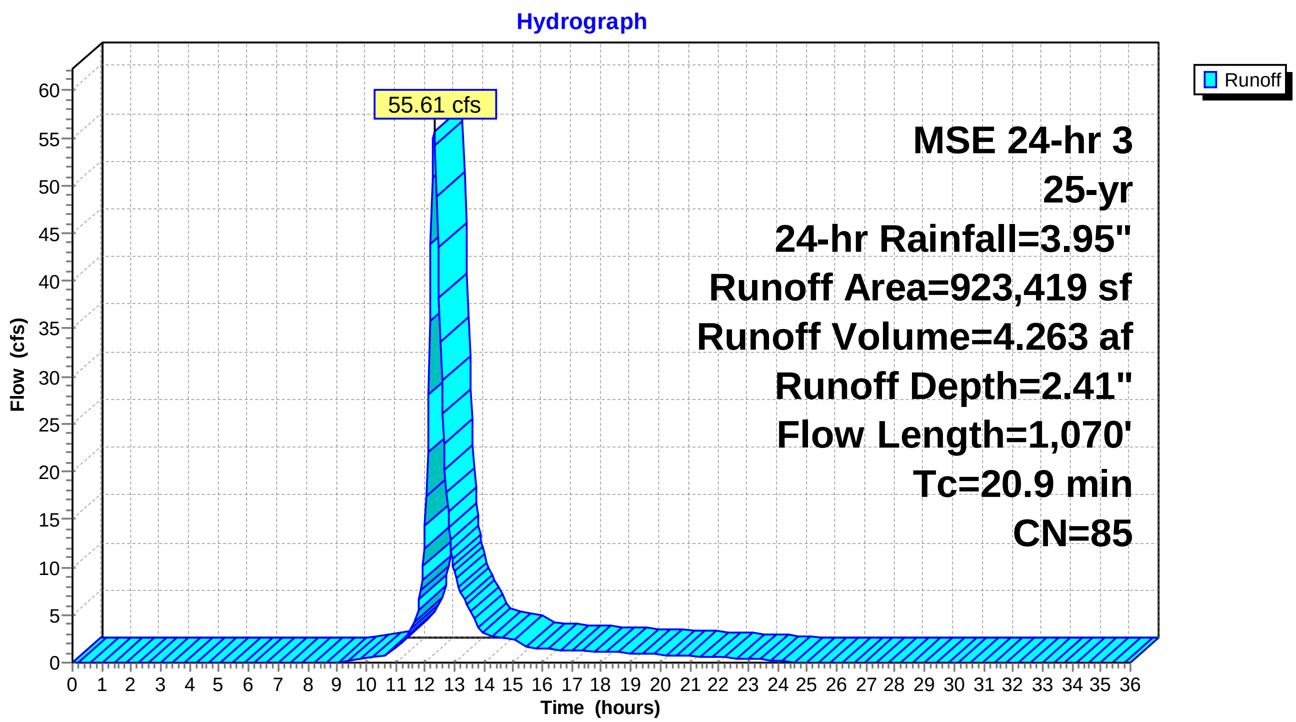
Runoff = 55.61 cfs @ 12.31 hrs, Volume= 4.263 af, Depth= 2.41"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
38,900	98	Water Surface, HSG D
884,519	84	50-75% Grass cover, Fair, HSG D
923,419	85	Weighted Average
884,519		95.79% Pervious Area
38,900		4.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.9	200	0.0300	0.20		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
2.3	170	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.7	700	0.0140	7.03	84.40	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.025 Earth, clean & winding
20.9	1,070	Total			

Subcatchment 28S: MC VII S



Summary for Subcatchment 29S: MC VII N

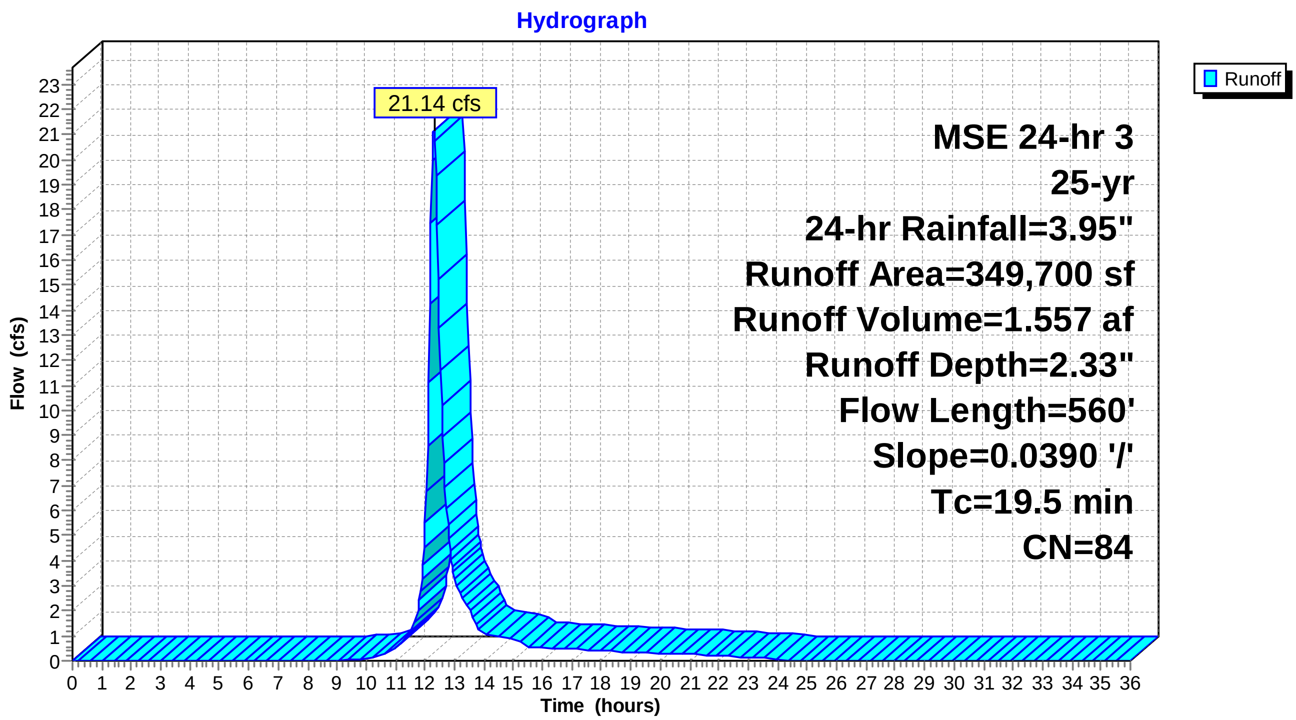
Runoff = 21.14 cfs @ 12.29 hrs, Volume= 1.557 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
349,700	84	50-75% Grass cover, Fair, HSG D
349,700		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.2	200	0.0390	0.22		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
4.3	360	0.0390	1.38		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
19.5	560	Total			

Subcatchment 29S: MC VII N



Summary for Subcatchment 30S: NWD Drainage

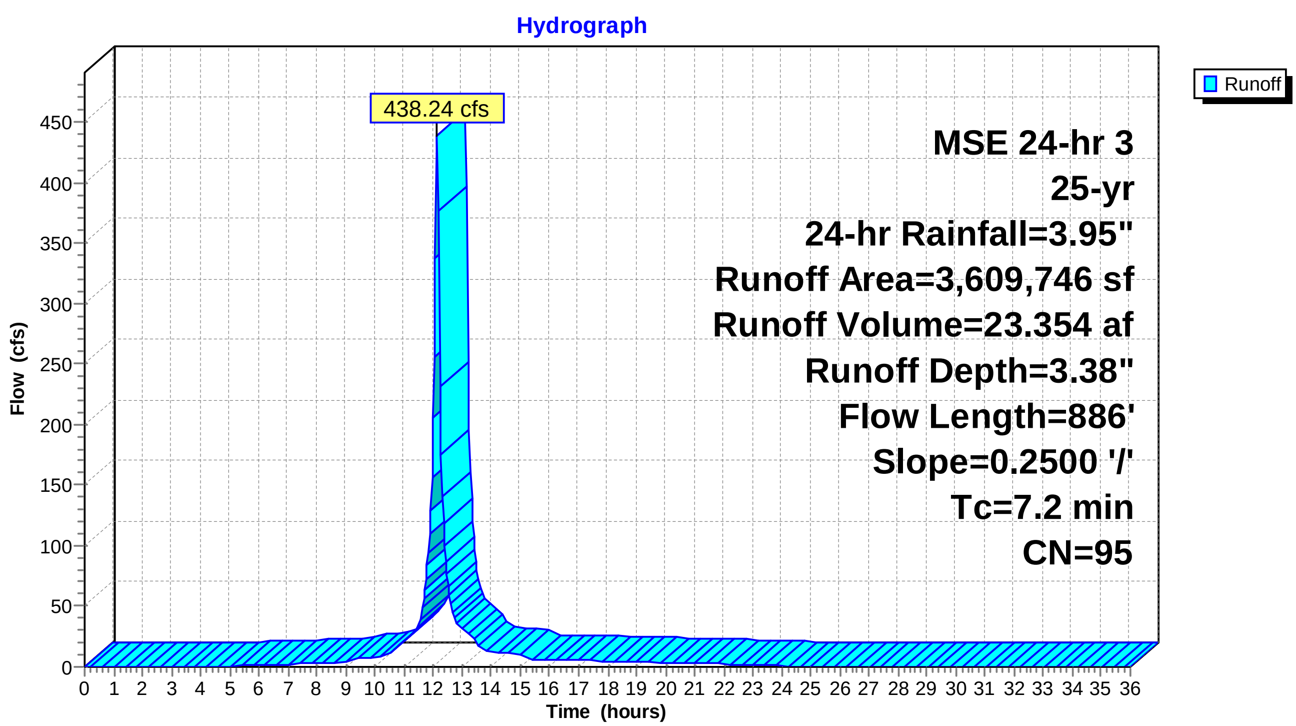
Runoff = 438.24 cfs @ 12.14 hrs, Volume= 23.354 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
	201,500	98	Water Surface, HSG D
*	3,408,246	95	Closure Turf
	3,609,746	95	Weighted Average
	3,408,246		94.42% Pervious Area
	201,500		5.58% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
1.1	686	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
7.2	886	Total			

Subcatchment 30S: NWD Drainage



Summary for Subcatchment 38S: DB-B Drainage

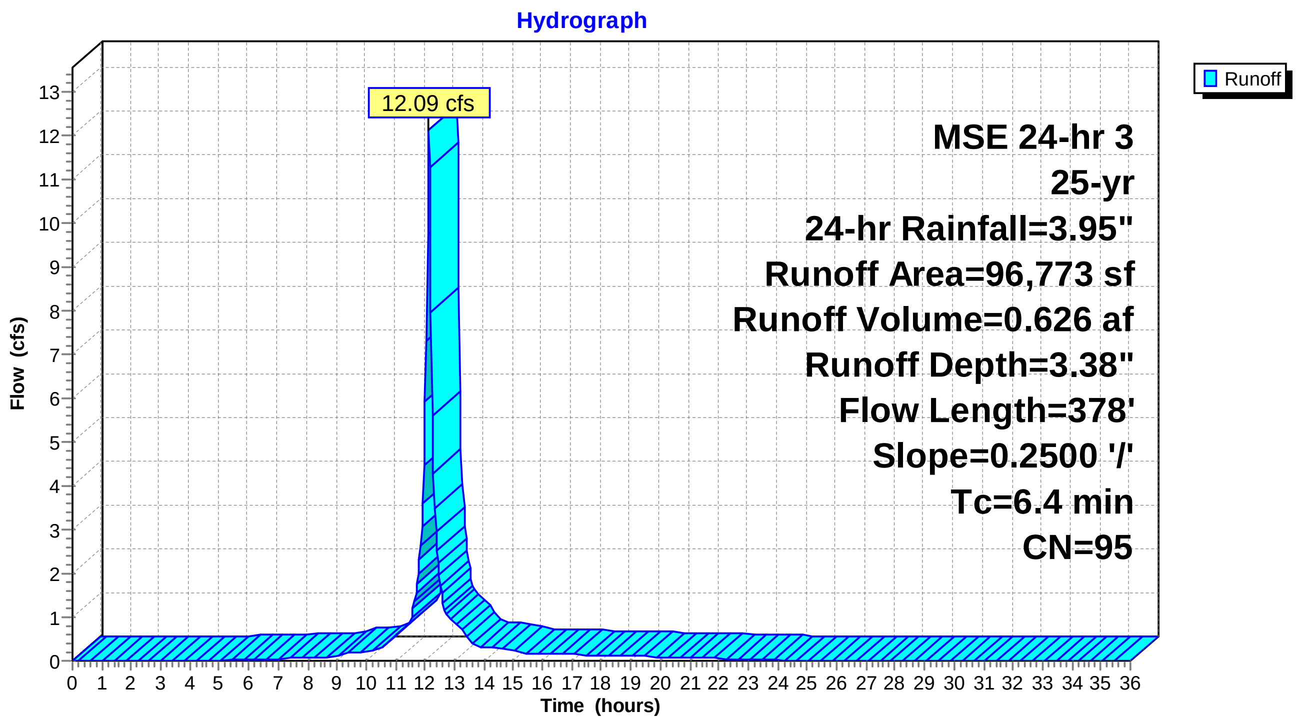
Runoff = 12.09 cfs @ 12.13 hrs, Volume= 0.626 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	96,773	95	Closure Turf
	96,773		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.3	178	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
6.4	378	Total			

Subcatchment 38S: DB-B Drainage



Summary for Subcatchment 40S: DB-A Drainage

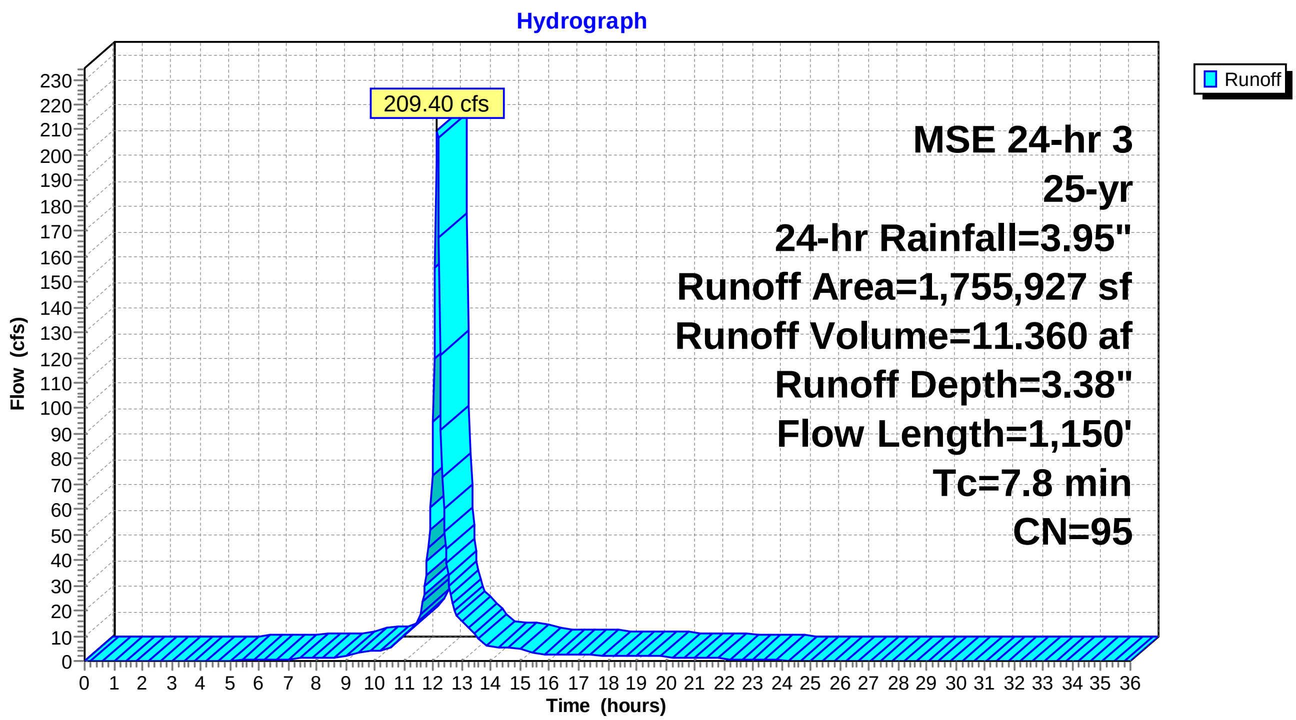
Runoff = 209.40 cfs @ 12.15 hrs, Volume= 11.360 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	1,755,927	95	Closure Turf
	1,755,927		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.5	313	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.8	189	0.0400	4.06		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.4	400	0.0400	14.86	178.32	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.020
0.0	48	0.1600	29.72	356.64	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.020
7.8	1,150	Total			

Subcatchment 40S: DB-A Drainage



Summary for Subcatchment 41S: DB-C Drainage

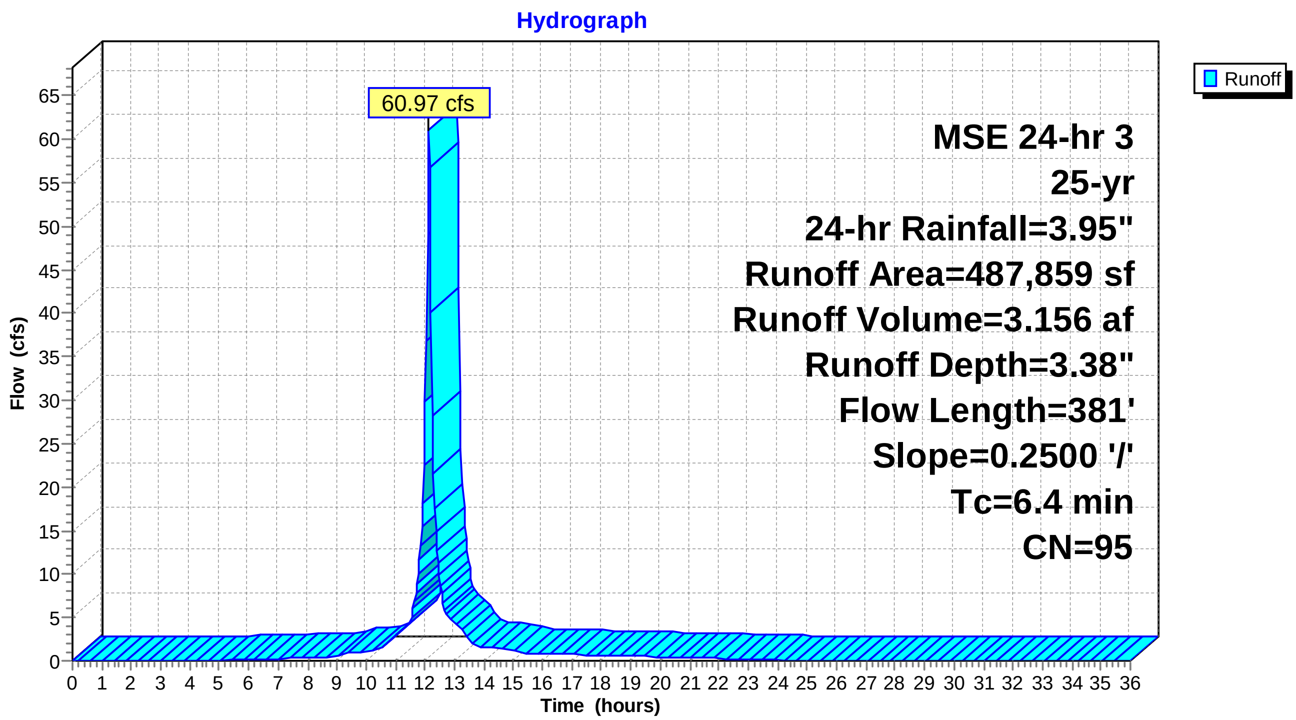
Runoff = 60.97 cfs @ 12.13 hrs, Volume= 3.156 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	487,859	95	Closure Turf
	487,859		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.3	181	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
6.4	381	Total			

Subcatchment 41S: DB-C Drainage



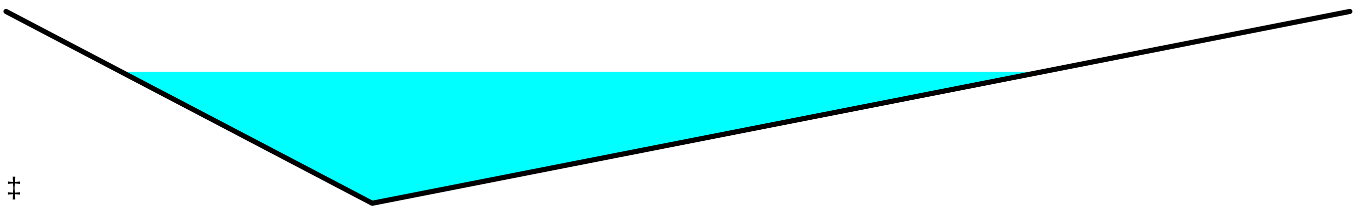
Summary for Reach 9R: W-MC X DV

Inflow Area = 13.783 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 38.28 cfs @ 12.26 hrs, Volume= 2.673 af
Outflow = 33.14 cfs @ 12.47 hrs, Volume= 2.673 af, Atten= 13%, Lag= 12.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 3.22 fps, Min. Travel Time= 7.2 min
Avg. Velocity = 0.88 fps, Avg. Travel Time= 26.6 min

Peak Storage= 14,417 cf @ 12.35 hrs
Average Depth at Peak Storage= 1.37' , Surface Width= 15.05'
Bank-Full Depth= 2.00' Flow Area= 22.0 sf, Capacity= 91.23 cfs

0.00' x 2.00' deep channel, n= 0.025 Earth, clean & winding
Side Slope Z-value= 3.0 8.0 '/' Top Width= 22.00'
Length= 1,400.0' Slope= 0.0050 '/'
Inlet Invert= 713.00', Outlet Invert= 706.00'



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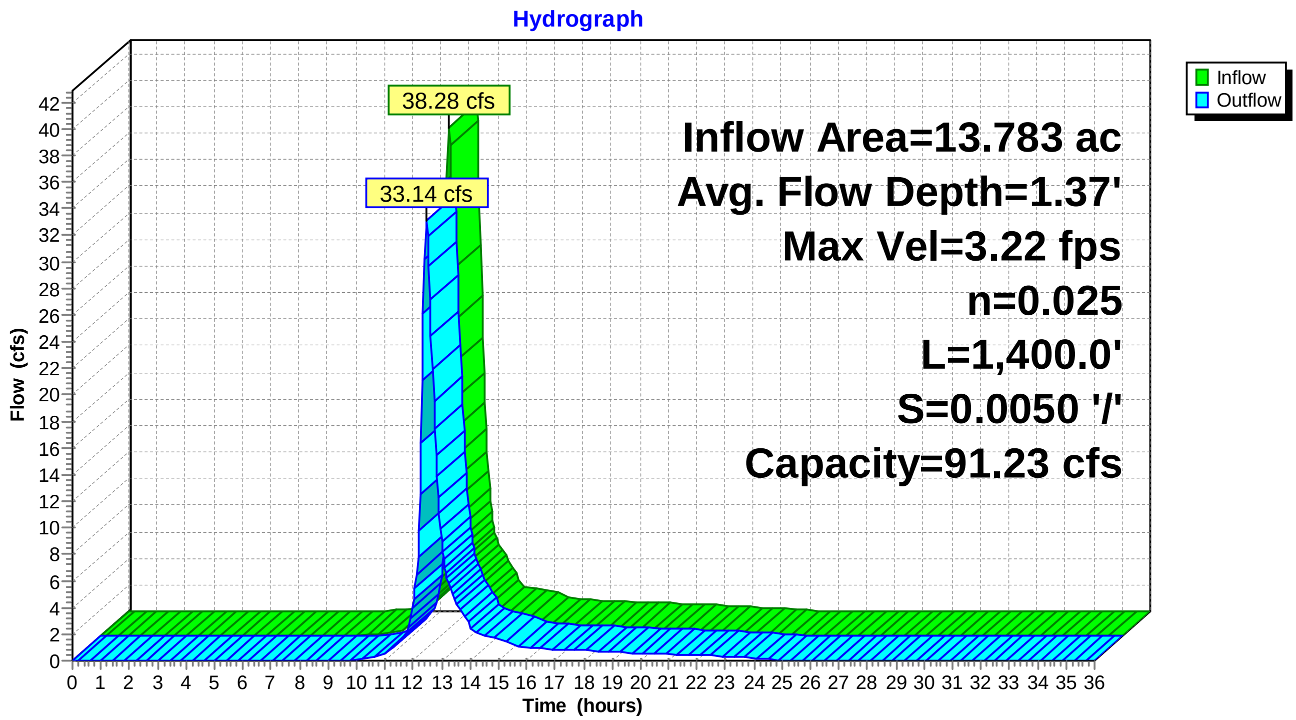
Reach 9R: W-MC X DV



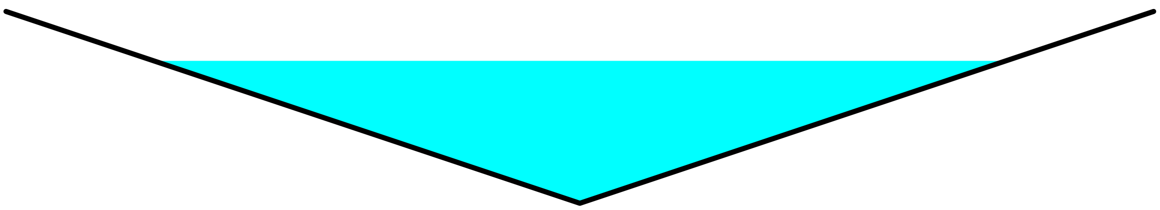
Summary for Reach 20R: E-MC X DV

Inflow Area = 12.100 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 35.62 cfs @ 12.24 hrs, Volume= 2.347 af
Outflow = 30.87 cfs @ 12.42 hrs, Volume= 2.347 af, Atten= 13%, Lag= 10.7 min

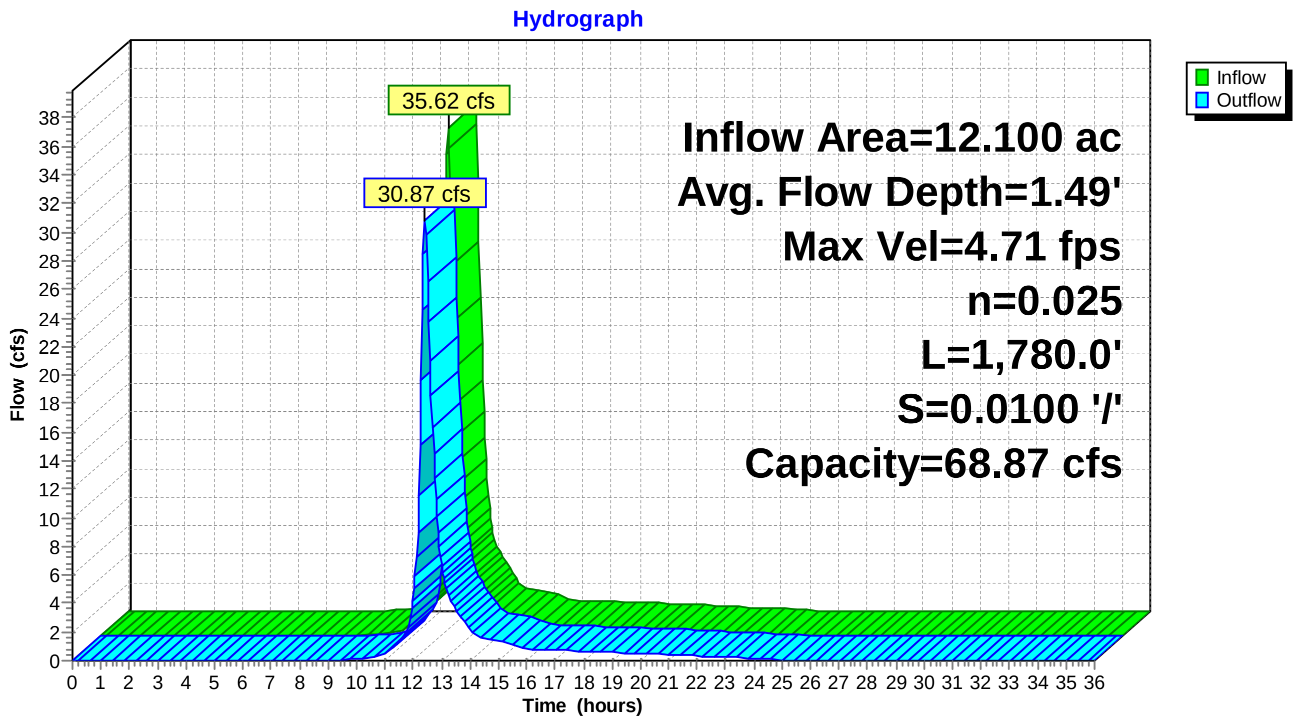
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 4.71 fps, Min. Travel Time= 6.3 min
Avg. Velocity = 1.33 fps, Avg. Travel Time= 22.3 min

Peak Storage= 11,776 cf @ 12.32 hrs
Average Depth at Peak Storage= 1.49' , Surface Width= 8.91'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 68.87 cfs

0.00' x 2.00' deep channel, n= 0.025 Earth, clean & winding
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 1,780.0' Slope= 0.0100 '/'
Inlet Invert= 723.00', Outlet Invert= 705.20'



Reach 20R: E-MC X DV



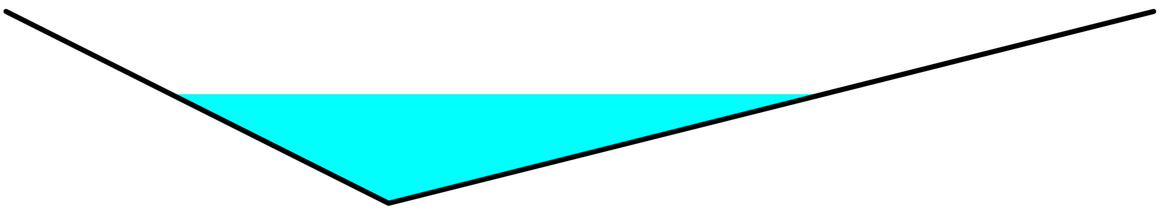
Summary for Reach 37R: DB-A-2 (11%)

Inflow Area = 40.311 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 187.20 cfs @ 12.23 hrs, Volume= 11.360 af
Outflow = 186.68 cfs @ 12.24 hrs, Volume= 11.360 af, Atten= 0%, Lag= 0.2 min

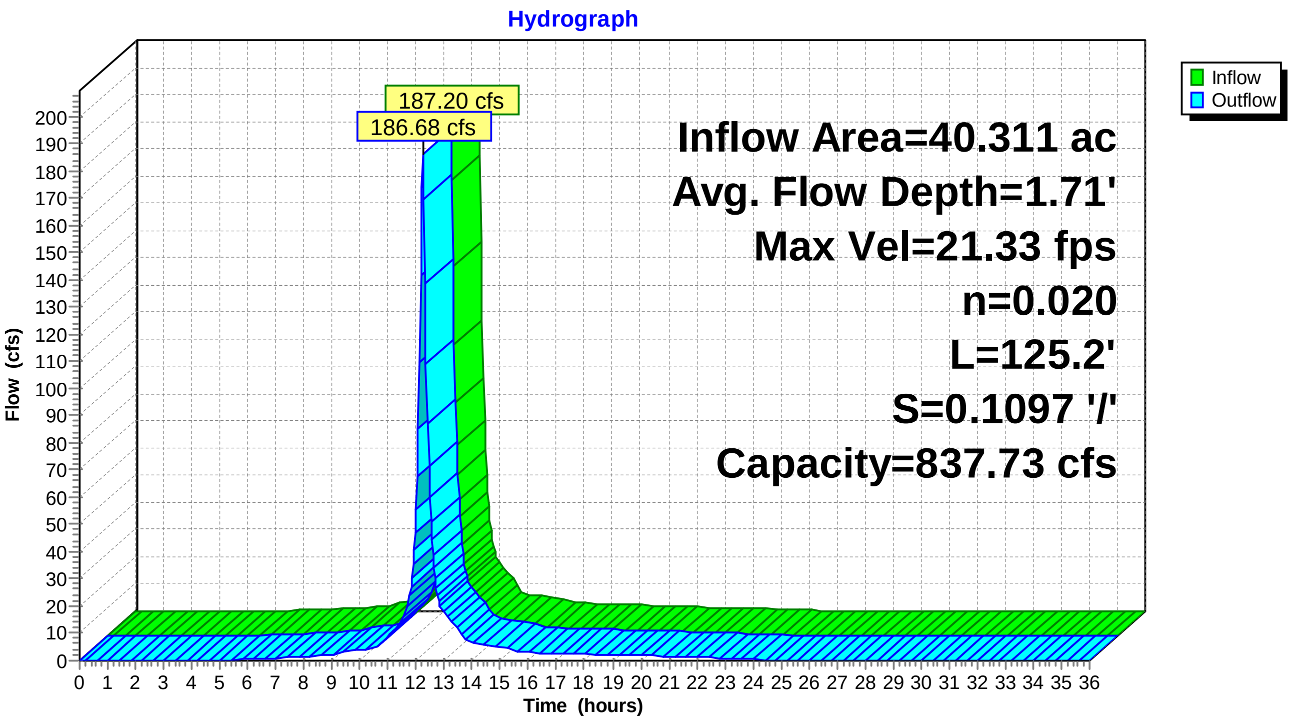
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 21.33 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 6.40 fps, Avg. Travel Time= 0.3 min

Peak Storage= 1,099 cf @ 12.24 hrs
Average Depth at Peak Storage= 1.71' , Surface Width= 10.26'
Bank-Full Depth= 3.00' Flow Area= 27.0 sf, Capacity= 837.73 cfs

0.00' x 3.00' deep channel, n= 0.020
Side Slope Z-value= 2.0 4.0 '/' Top Width= 18.00'
Length= 125.2' Slope= 0.1097 '/'
Inlet Invert= 728.00', Outlet Invert= 714.26'



Reach 37R: DB-A-2 (11%)



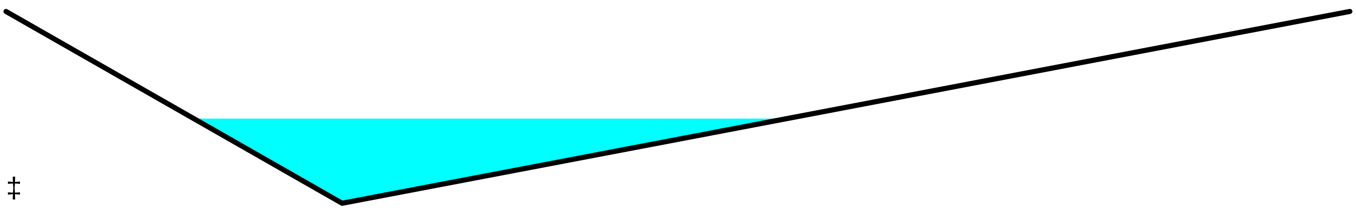
Summary for Reach 38R: S-MC XI DV

Inflow Area = 2.185 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 6.90 cfs @ 12.22 hrs, Volume= 0.424 af
Outflow = 6.40 cfs @ 12.32 hrs, Volume= 0.424 af, Atten= 7%, Lag= 6.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 3.70 fps, Min. Travel Time= 3.4 min
Avg. Velocity = 1.26 fps, Avg. Travel Time= 9.9 min

Peak Storage= 1,310 cf @ 12.26 hrs
Average Depth at Peak Storage= 0.66' , Surface Width= 5.29'
Bank-Full Depth= 1.50' Flow Area= 9.0 sf, Capacity= 57.72 cfs

0.00' x 1.50' deep channel, n= 0.025 Earth, clean & winding
Side Slope Z-value= 2.0 6.0 '/' Top Width= 12.00'
Length= 750.0' Slope= 0.0180 '/'
Inlet Invert= 719.00', Outlet Invert= 705.50'



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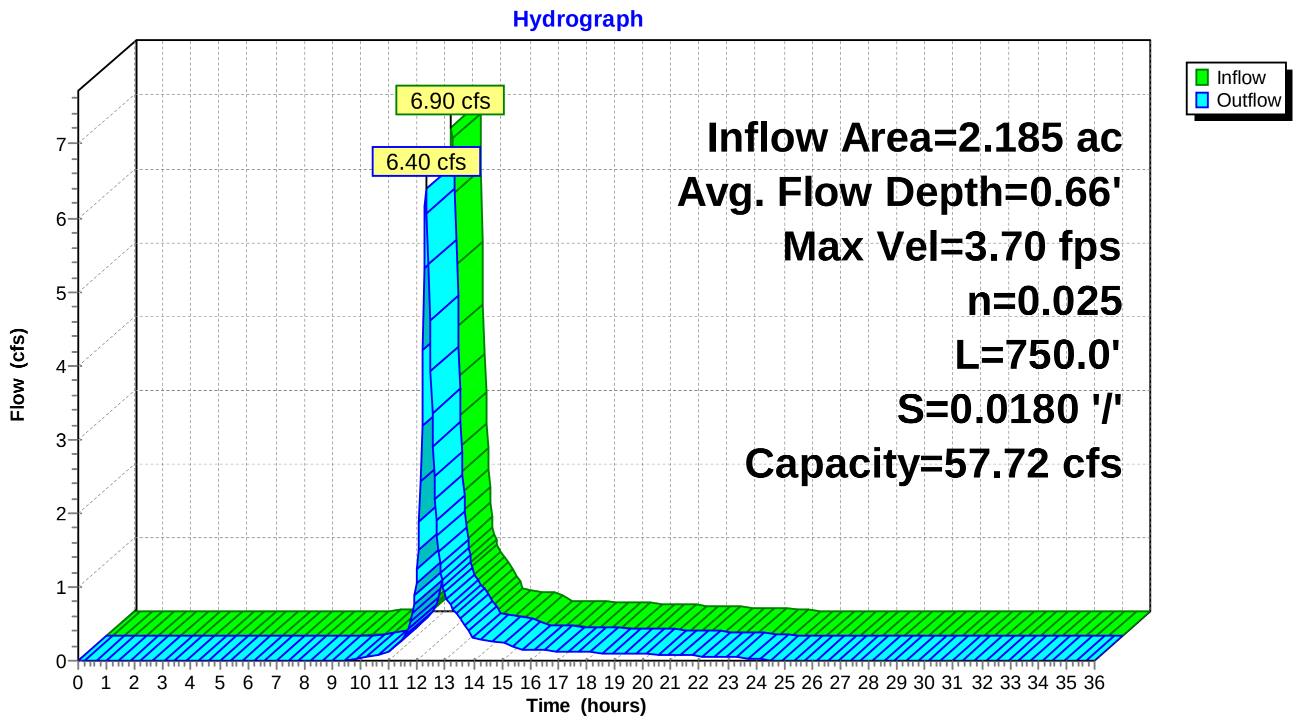
Reach 38R: S-MC XI DV



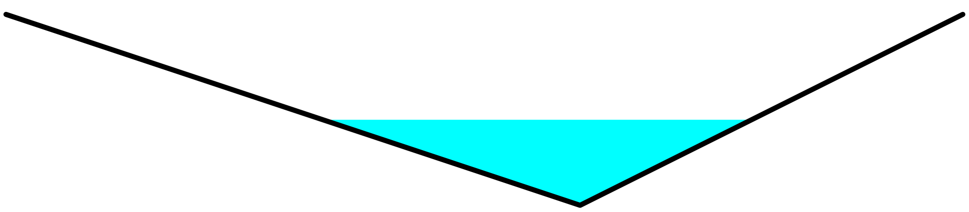
Summary for Reach 39R: DB-B

Inflow Area = 2.222 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 12.09 cfs @ 12.13 hrs, Volume= 0.626 af
Outflow = 11.29 cfs @ 12.18 hrs, Volume= 0.626 af, Atten= 7%, Lag= 3.1 min

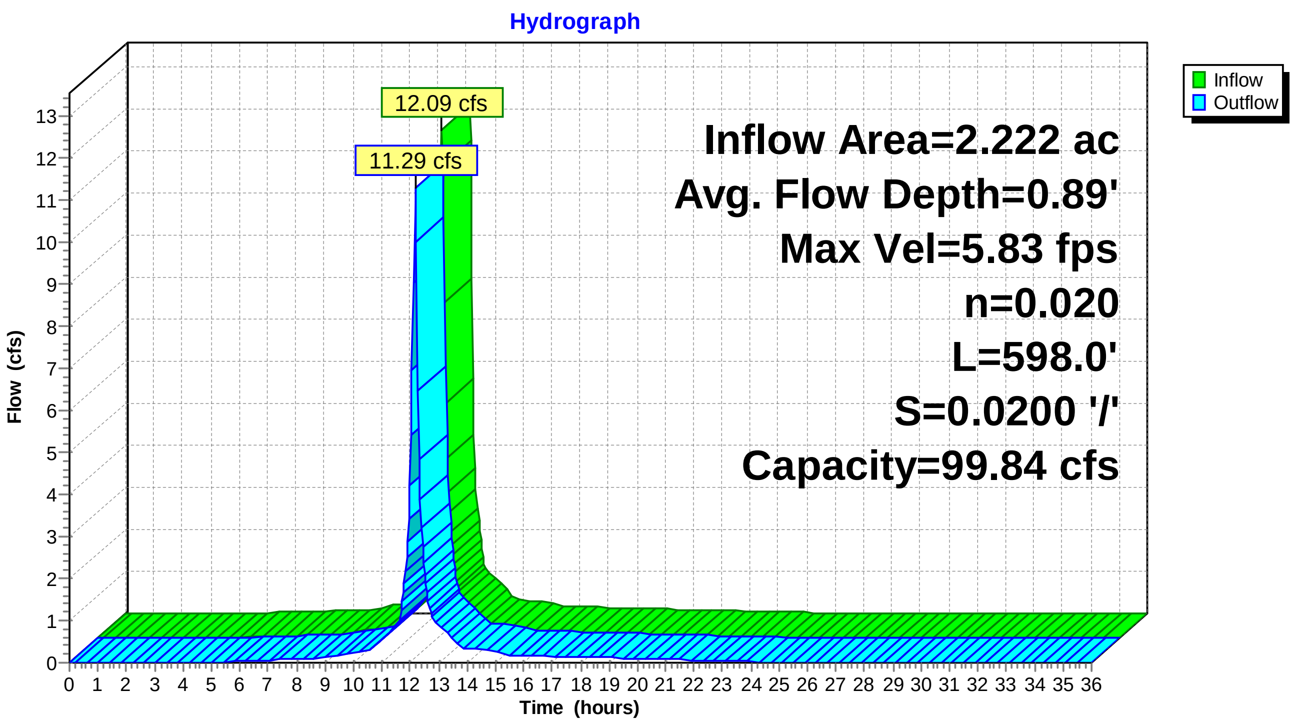
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 5.83 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.88 fps, Avg. Travel Time= 5.3 min

Peak Storage= 1,194 cf @ 12.15 hrs
Average Depth at Peak Storage= 0.89' , Surface Width= 4.47'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 99.84 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 3.0 2.0 '/' Top Width= 10.00'
Length= 598.0' Slope= 0.0200 '/'
Inlet Invert= 725.96', Outlet Invert= 714.00'



Reach 39R: DB-B



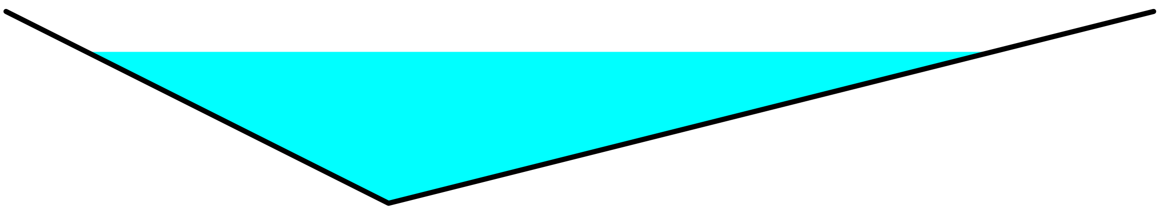
Summary for Reach 41R: DB-A-1 (2%)

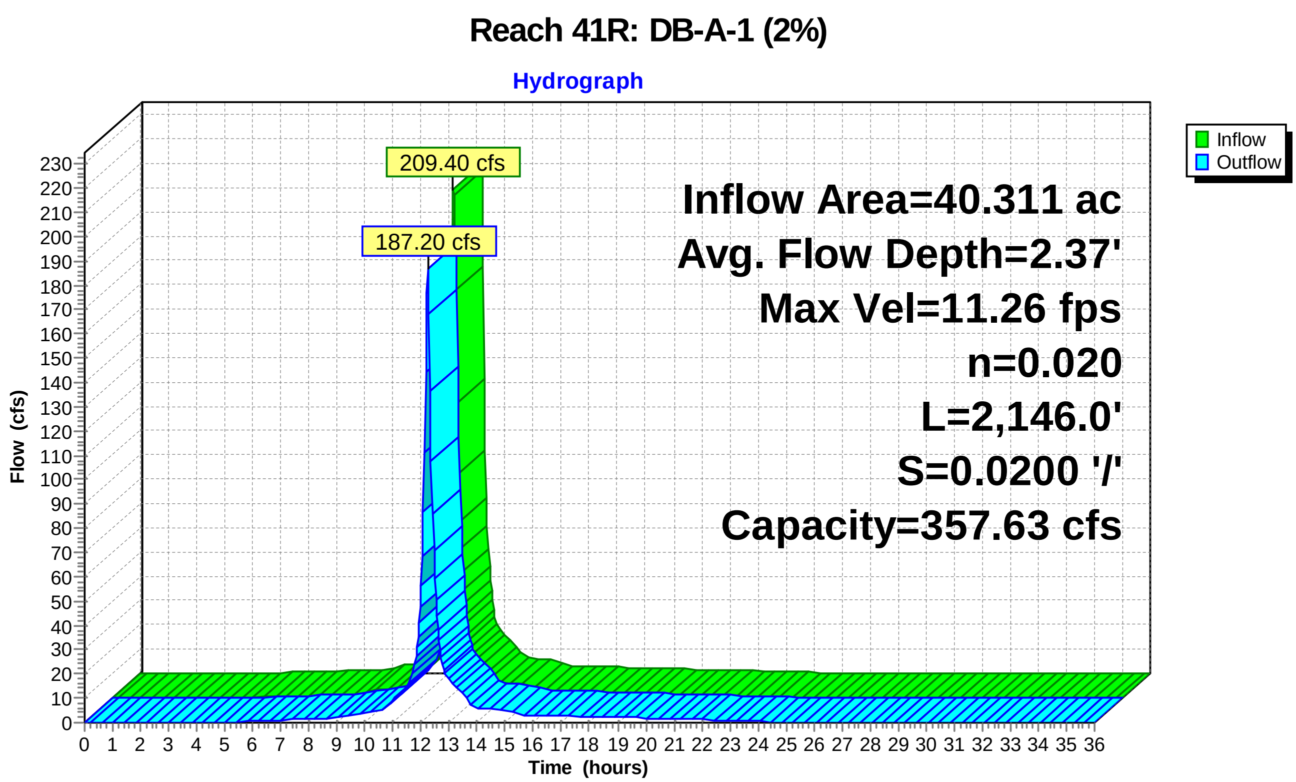
Inflow Area = 40.311 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 209.40 cfs @ 12.15 hrs, Volume= 11.360 af
Outflow = 187.20 cfs @ 12.23 hrs, Volume= 11.360 af, Atten= 11%, Lag= 5.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 11.26 fps, Min. Travel Time= 3.2 min
Avg. Velocity = 3.27 fps, Avg. Travel Time= 10.9 min

Peak Storage= 36,121 cf @ 12.18 hrs
Average Depth at Peak Storage= 2.37' , Surface Width= 14.22'
Bank-Full Depth= 3.00' Flow Area= 27.0 sf, Capacity= 357.63 cfs

0.00' x 3.00' deep channel, n= 0.020
Side Slope Z-value= 2.0 4.0 '/' Top Width= 18.00'
Length= 2,146.0' Slope= 0.0200 '/'
Inlet Invert= 770.92', Outlet Invert= 728.00'





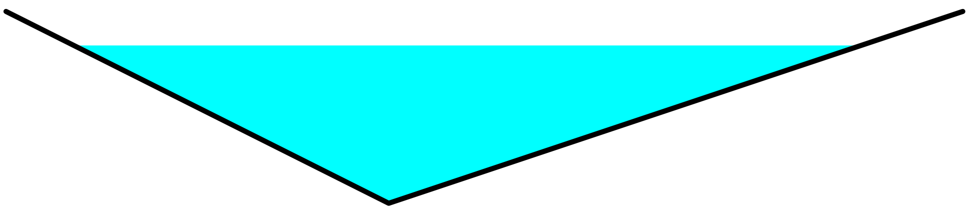
Summary for Reach 42R: DB-C

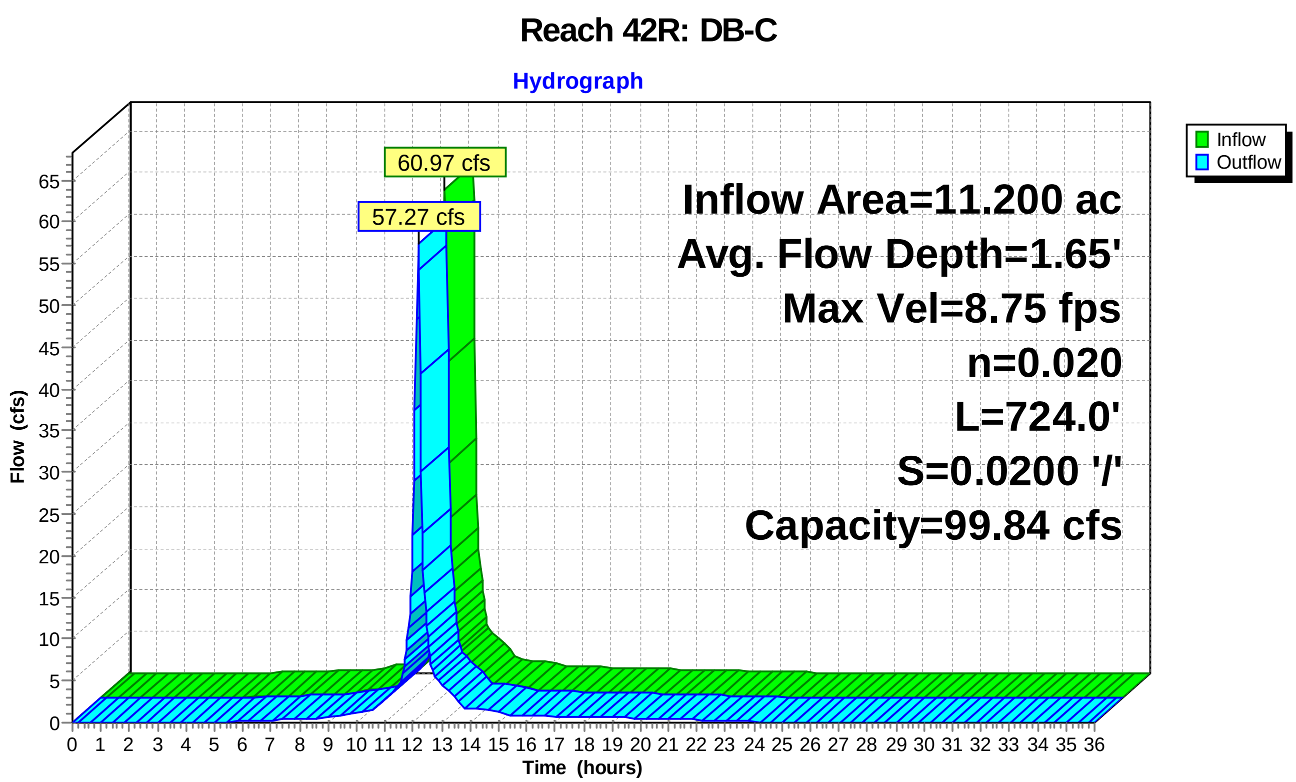
Inflow Area = 11.200 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 60.97 cfs @ 12.13 hrs, Volume= 3.156 af
Outflow = 57.27 cfs @ 12.17 hrs, Volume= 3.156 af, Atten= 6%, Lag= 2.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 8.75 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 2.75 fps, Avg. Travel Time= 4.4 min

Peak Storage= 4,904 cf @ 12.15 hrs
Average Depth at Peak Storage= 1.65' , Surface Width= 8.23'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 99.84 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 2.0 3.0 '/' Top Width= 10.00'
Length= 724.0' Slope= 0.0200 '/'
Inlet Invert= 726.48', Outlet Invert= 712.00'





Summary for Pond 1P: NSB North

Inflow Area = 287.592 ac, 3.48% Impervious, Inflow Depth = 2.72" for 25-yr, 24-hr event
Inflow = 198.30 cfs @ 13.28 hrs, Volume= 65.232 af
Outflow = 90.59 cfs @ 15.44 hrs, Volume= 20.210 af, Atten= 54%, Lag= 129.6 min
Primary = 90.59 cfs @ 15.44 hrs, Volume= 20.210 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Starting Elev= 674.00' Surf.Area= 53,100 sf Storage= 144,600 cf
Peak Elev= 693.90' @ 15.44 hrs Surf.Area= 152,081 sf Storage= 2,241,101 cf (2,096,501 cf above start)

Plug-Flow detention time= 359.0 min calculated for 16.871 af (26% of inflow)
Center-of-Mass det. time= 195.9 min (1,059.6 - 863.7)

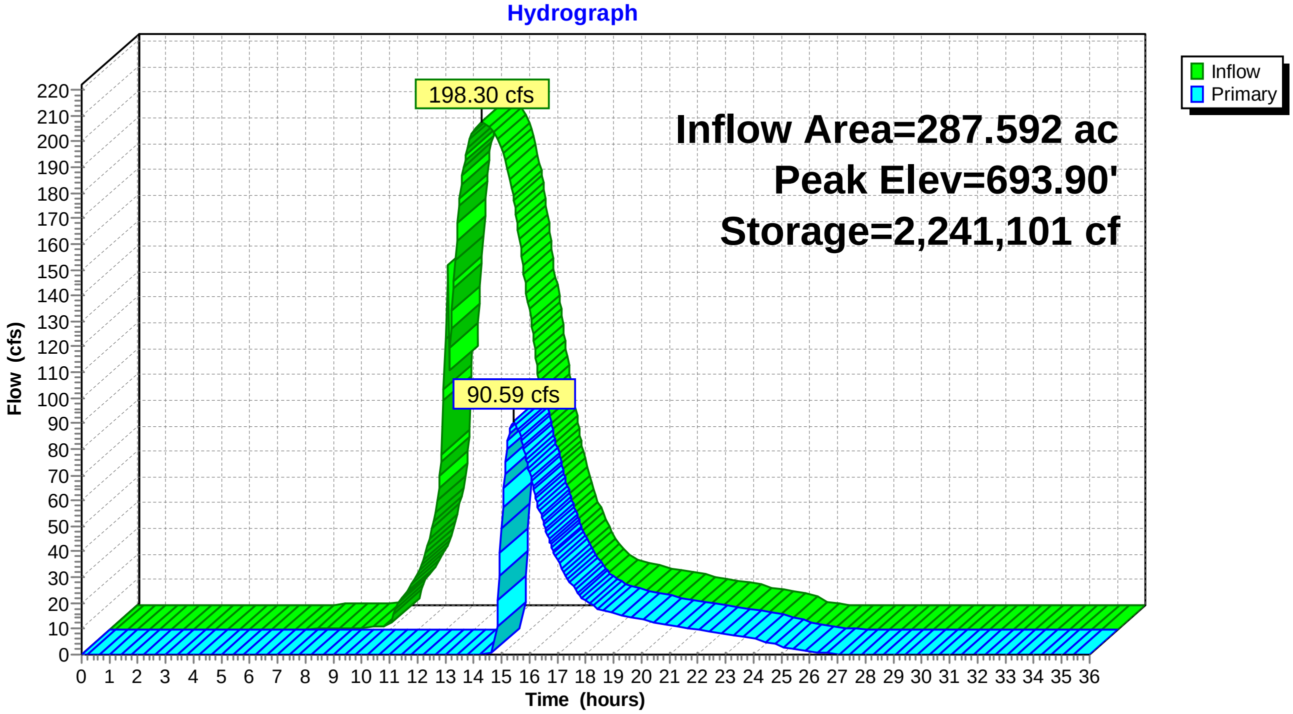
Volume	Invert	Avail.Storage	Storage Description
#1	668.00'	2,910,320 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
668.00	1,200	0	0
670.00	12,400	13,600	13,600
674.00	53,100	131,000	144,600
680.00	87,600	422,100	566,700
690.00	135,200	1,114,000	1,680,700
694.00	152,508	575,416	2,256,116
695.00	158,400	155,454	2,411,570
698.00	174,100	498,750	2,910,320

Device	Routing	Invert	Outlet Devices
#1	Primary	693.00'	**40.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=90.20 cfs @ 15.44 hrs HW=693.90' (Free Discharge)
└─**1=Broad-Crested Rectangular Weir** (Weir Controls 90.20 cfs @ 2.50 fps)

Pond 1P: NSB North



Summary for Pond 5P: MC VII/IX & MC XI/X Pond

MC X/XI Culverts do not restrict flow in ditch (have more capacity than outlet on north end) therefore they are not modeled.

Inflow Area = 104.325 ac, 5.17% Impervious, Inflow Depth = 2.47" for 25-yr, 24-hr event
Inflow = 235.45 cfs @ 12.37 hrs, Volume= 21.504 af
Outflow = 59.68 cfs @ 13.02 hrs, Volume= 19.337 af, Atten= 75%, Lag= 39.1 min
Primary = 59.68 cfs @ 13.02 hrs, Volume= 19.337 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Starting Elev= 697.10' Storage= 0 cf
Peak Elev= 703.18' @ 13.02 hrs Surf.Area= 154,176 sf Storage= 433,061 cf

Plug-Flow detention time= 117.6 min calculated for 19.337 af (90% of inflow)
Center-of-Mass det. time= 74.9 min (890.0 - 815.1)

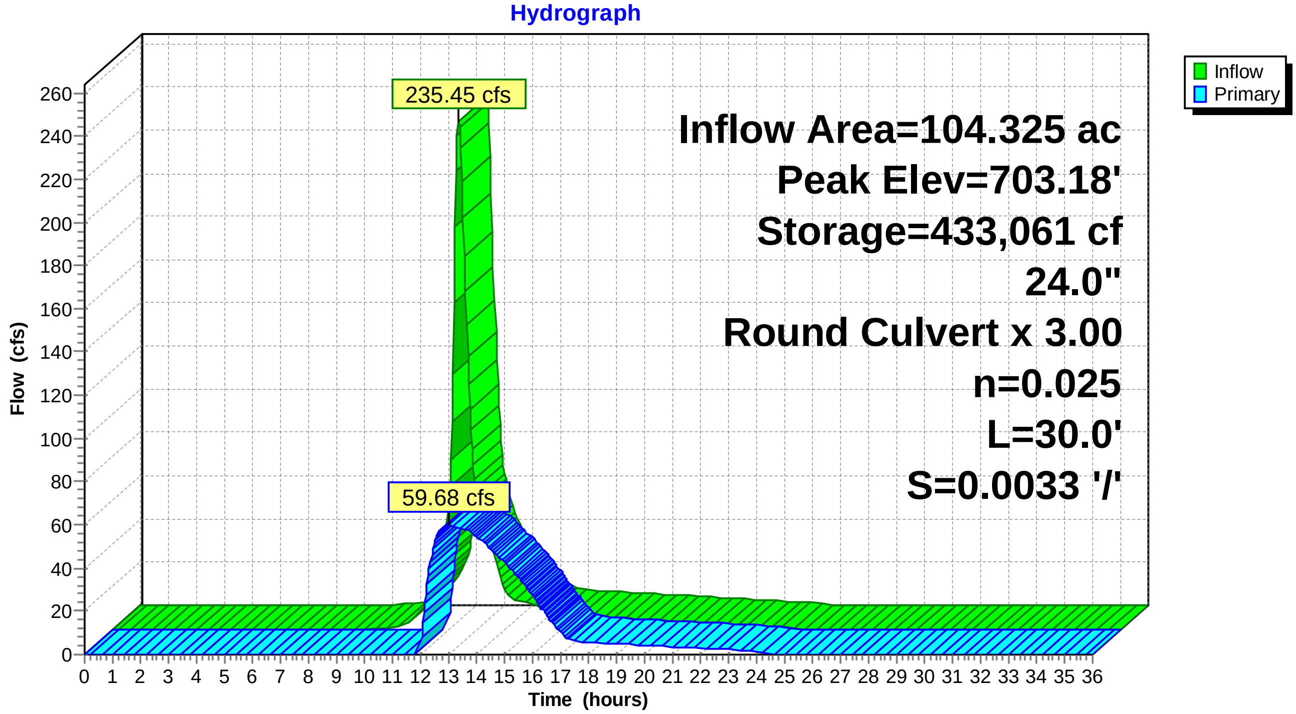
Volume	Invert	Avail.Storage	Storage Description
#1	698.00'	925,600 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
698.00	13,000	0	0
700.00	55,300	68,300	68,300
702.00	137,000	192,300	260,600
704.00	166,000	303,000	563,600
706.00	196,000	362,000	925,600

Device	Routing	Invert	Outlet Devices
#1	Primary	697.10'	**24.0" Round Culvert X 3.00** L= 30.0' CMP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 697.10' / 697.00' S= 0.0033 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf

Primary OutFlow Max=59.67 cfs @ 13.02 hrs HW=703.18' TW=700.41' (Fixed TW Elev= 700.41')
└─**1=Culvert** (Inlet Controls 59.67 cfs @ 6.33 fps)

Pond 5P: MC VII/IX & MC XI/X Pond



Summary for Pond 7P: MC VII/XI Pond

Inflow Area = 32.398 ac, 2.76% Impervious, Inflow Depth = 2.75" for 25-yr, 24-hr event
Inflow = 98.14 cfs @ 12.20 hrs, Volume= 7.419 af
Outflow = 65.39 cfs @ 12.40 hrs, Volume= 7.155 af, Atten= 33%, Lag= 11.8 min
Primary = 65.39 cfs @ 12.40 hrs, Volume= 7.155 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 707.93' @ 12.40 hrs Surf.Area= 37,935 sf Storage= 74,866 cf

Plug-Flow detention time= 41.0 min calculated for 7.147 af (96% of inflow)
Center-of-Mass det. time= 22.3 min (815.3 - 793.0)

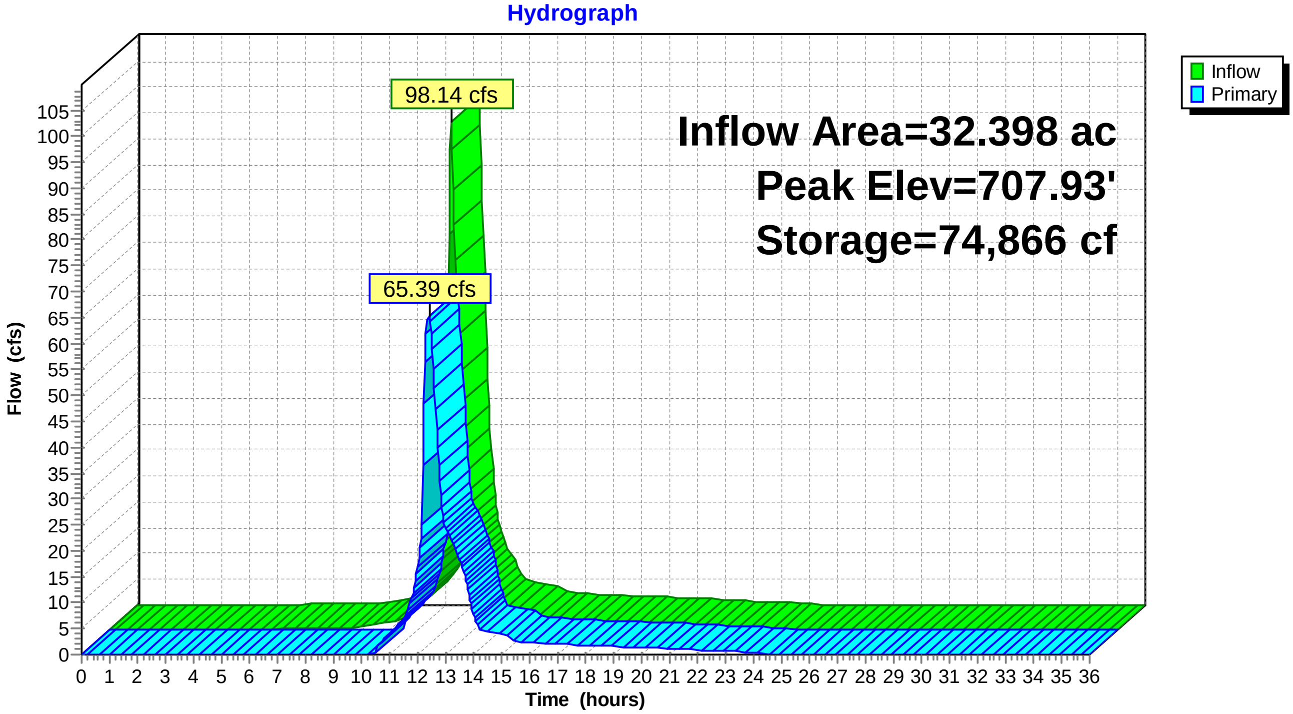
Volume	Invert	Avail.Storage	Storage Description
#1	700.00'	200,200 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
700.00	0	0	0
702.00	1,450	1,450	1,450
704.00	5,200	6,650	8,100
706.00	12,750	17,950	26,050
708.00	38,900	51,650	77,700
710.00	83,600	122,500	200,200

Device	Routing	Invert	Outlet Devices
#1	Primary	700.30'	**24.0" Round Culvert** L= 40.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 700.30' / 699.40' S= 0.0225 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 3.14 sf
#2	Primary	707.00'	**16.0' long x 25.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=65.28 cfs @ 12.40 hrs HW=707.93' TW=704.55' (Fixed TW Elev= 704.55')
—**1=Culvert** (Inlet Controls 27.79 cfs @ 8.85 fps)
—**2=Broad-Crested Rectangular Weir** (Weir Controls 37.49 cfs @ 2.53 fps)

Pond 7P: MC VII/XI Pond



Summary for Pond 8P: NSB South

Inflow Area = 287.592 ac, 3.48% Impervious, Inflow Depth = 0.84" for 25-yr, 24-hr event
Inflow = 90.59 cfs @ 15.44 hrs, Volume= 20.210 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

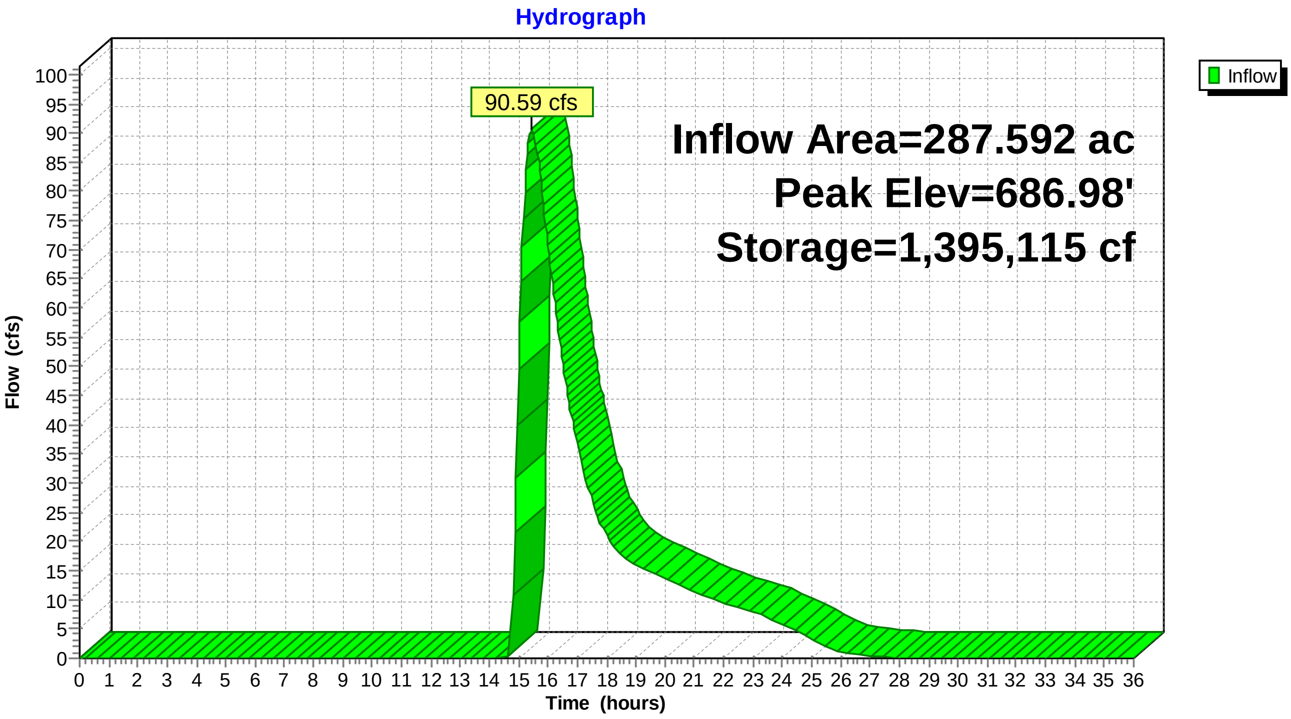
Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Starting Elev= 680.00' Surf.Area= 98,500 sf Storage= 514,800 cf
Peak Elev= 686.98' @ 36.00 hrs Surf.Area= 153,774 sf Storage= 1,395,115 cf (880,315 cf above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= (not calculated: no outflow)

Volume	Invert	Avail.Storage	Storage Description
#1	672.00'	2,867,350 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
672.00	30,200	0	0
680.00	98,500	514,800	514,800
690.00	177,700	1,381,000	1,895,800
694.00	203,900	763,200	2,659,000
695.00	212,800	208,350	2,867,350

Pond 8P: NSB South



Summary for Pond 11P: NWD / NW-MC VII

Inflow Area = 125.401 ac, 3.69% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 580.45 cfs @ 12.15 hrs, Volume= 35.340 af
Outflow = 139.72 cfs @ 12.48 hrs, Volume= 35.340 af, Atten= 76%, Lag= 19.6 min
Primary = 139.72 cfs @ 12.48 hrs, Volume= 35.340 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 710.46' @ 12.48 hrs Surf.Area= 160,032 sf Storage= 549,996 cf

Plug-Flow detention time= 38.5 min calculated for 35.340 af (100% of inflow)
Center-of-Mass det. time= 38.5 min (808.6 - 770.1)

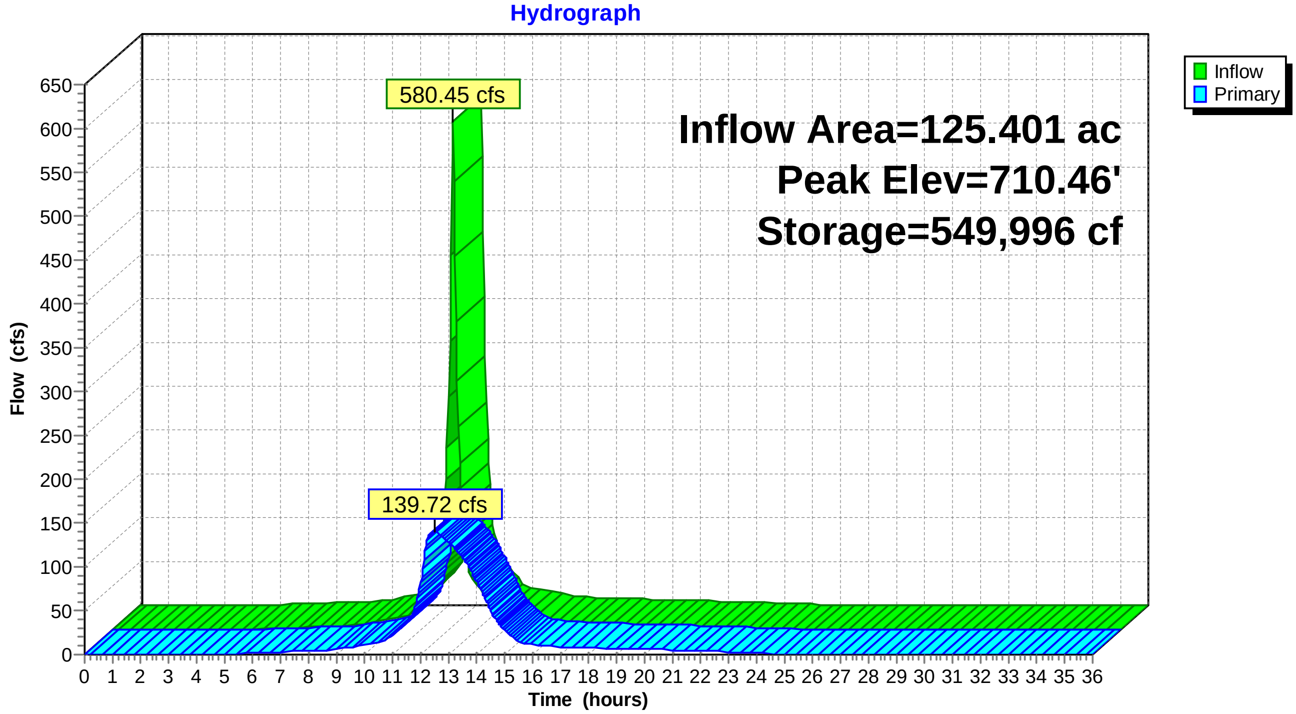
Volume	Invert	Avail.Storage	Storage Description
#1	704.30'	827,625 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
704.30	0	0	0
706.00	68,500	58,225	58,225
708.00	102,200	170,700	228,925
710.00	147,500	249,700	478,625
712.00	201,500	349,000	827,625

Device	Routing	Invert	Outlet Devices
#1	Primary	704.30'	**30.0" Round 30" HDPE Culverts X 3.00** L= 125.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 704.30' / 699.00' S= 0.0424 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 4.91 sf
#2	Primary	704.30'	**18.0" Round 18" HDPE Culverts** L= 125.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 704.30' / 699.00' S= 0.0424 '/' Cc= 0.900 n= 0.012, Flow Area= 1.77 sf

Primary OutFlow Max=139.72 cfs @ 12.48 hrs HW=710.46' TW=702.65' (Fixed TW Elev= 702.65')
1=30" HDPE Culverts (Inlet Controls 124.09 cfs @ 8.43 fps)
2=18" HDPE Culverts (Inlet Controls 15.63 cfs @ 8.84 fps)

Pond 11P: NWD / NW-MC VII



Summary for Pond 19P: E-MC IX Culvert

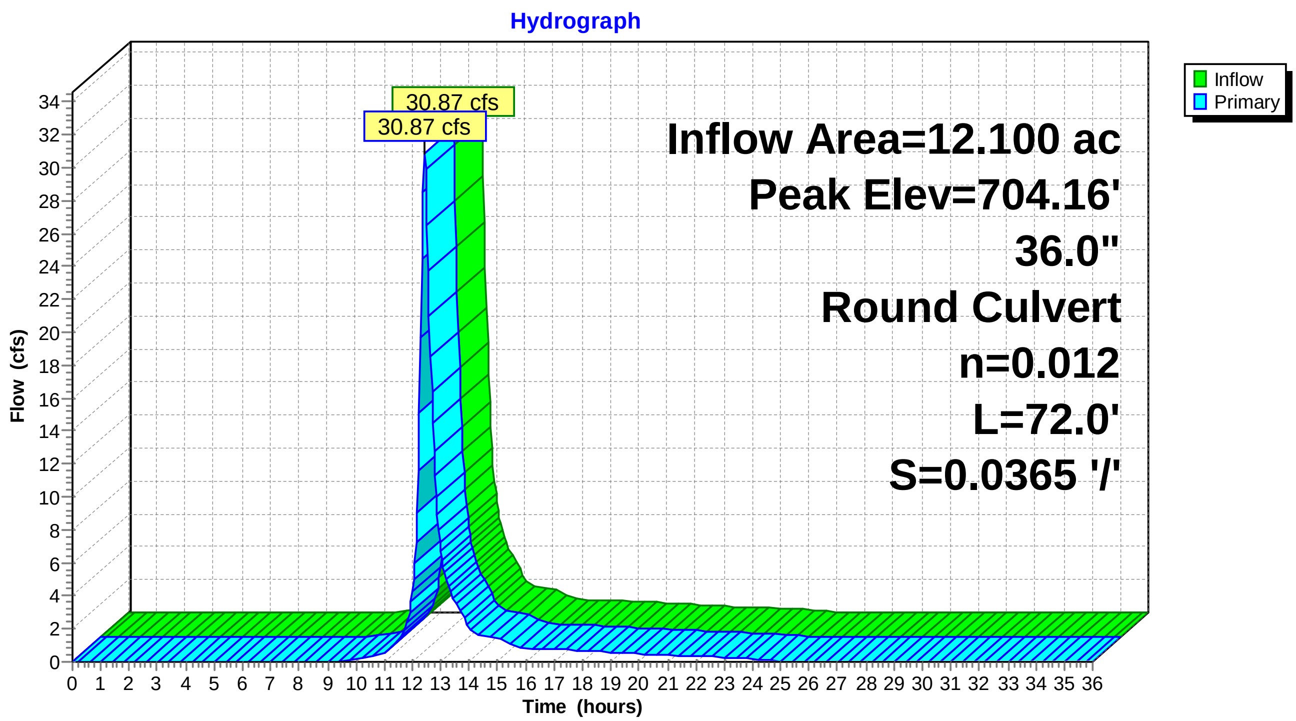
Inflow Area = 12.100 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 30.87 cfs @ 12.42 hrs, Volume= 2.347 af
Outflow = 30.87 cfs @ 12.42 hrs, Volume= 2.347 af, Atten= 0%, Lag= 0.0 min
Primary = 30.87 cfs @ 12.42 hrs, Volume= 2.347 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 704.16' @ 12.42 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	701.82'	**36.0" Round Culvert** L= 72.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 701.82' / 699.19' S= 0.0365 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 7.07 sf

Primary OutFlow Max=30.66 cfs @ 12.42 hrs HW=704.15' TW=698.17' (Fixed TW Elev= 698.17')
↑**1=Culvert** (Inlet Controls 30.66 cfs @ 5.20 fps)

Pond 19P: E-MC IX Culvert



Summary for Pond 37P: N-MC VII Ditch

Inflow Area = 133.429 ac, 3.47% Impervious, Inflow Depth = 3.32" for 25-yr, 24-hr event
Inflow = 157.63 cfs @ 12.35 hrs, Volume= 36.897 af
Outflow = 145.32 cfs @ 12.66 hrs, Volume= 35.255 af, Atten= 8%, Lag= 18.5 min
Primary = 145.32 cfs @ 12.66 hrs, Volume= 35.255 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 702.15' @ 12.66 hrs Surf.Area= 38,774 sf Storage= 132,671 cf

Plug-Flow detention time= 40.8 min calculated for 35.255 af (96% of inflow)
Center-of-Mass det. time= 18.4 min (827.2 - 808.7)

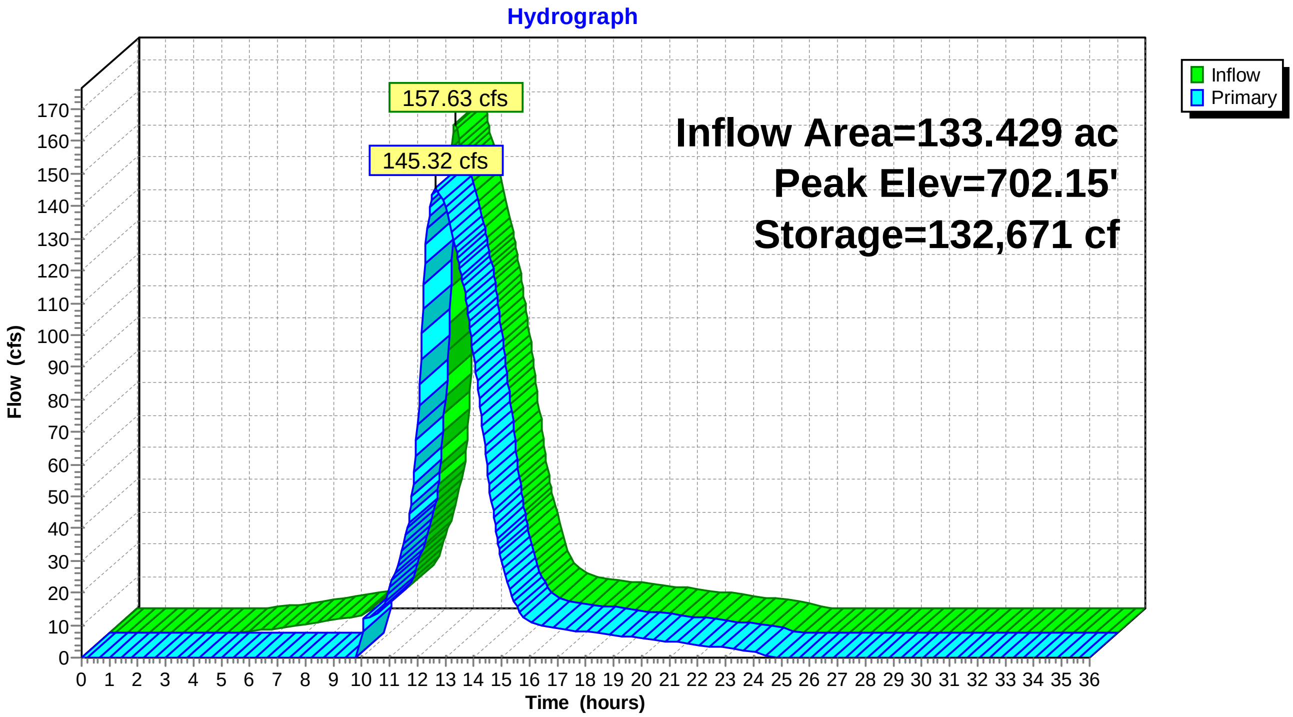
Volume	Invert	Avail.Storage	Storage Description
#1	696.77'	167,201 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
696.77	0	0	0
697.00	2,561	295	295
698.00	14,817	8,689	8,984
699.00	26,696	20,757	29,740
700.00	30,510	28,603	58,343
701.00	34,346	32,428	90,771
702.00	38,204	36,275	127,046
703.00	42,106	40,155	167,201

Device	Routing	Invert	Outlet Devices
#1	Primary	696.77'	**54.0" Round 54" Culvert** L= 42.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 696.77' / 696.61' S= 0.0038 '/' Cc= 0.900 n= 0.012, Flow Area= 15.90 sf
#2	Primary	696.77'	**36.0" Round 36" Culvert** L= 42.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 696.77' / 696.61' S= 0.0038 '/' Cc= 0.900 n= 0.012, Flow Area= 7.07 sf

Primary OutFlow Max=145.29 cfs @ 12.66 hrs HW=702.15' TW=700.42' (Fixed TW Elev= 700.42')
1=54" Culvert (Inlet Controls 100.59 cfs @ 6.32 fps)
2=36" Culvert (Inlet Controls 44.71 cfs @ 6.32 fps)

Pond 37P: N-MC VII Ditch



Summary for Pond 38P: N-MC IX Ditch

Inflow Area = 276.502 ac, 3.62% Impervious, Inflow Depth = 2.70" for 25-yr, 24-hr event
Inflow = 263.71 cfs @ 12.41 hrs, Volume= 62.107 af
Outflow = 195.50 cfs @ 13.40 hrs, Volume= 62.107 af, Atten= 26%, Lag= 59.4 min
Primary = 195.50 cfs @ 13.40 hrs, Volume= 62.107 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 699.67' @ 13.40 hrs Surf.Area= 156,098 sf Storage= 362,060 cf

Plug-Flow detention time= 23.9 min calculated for 62.107 af (100% of inflow)
Center-of-Mass det. time= 23.9 min (868.9 - 845.0)

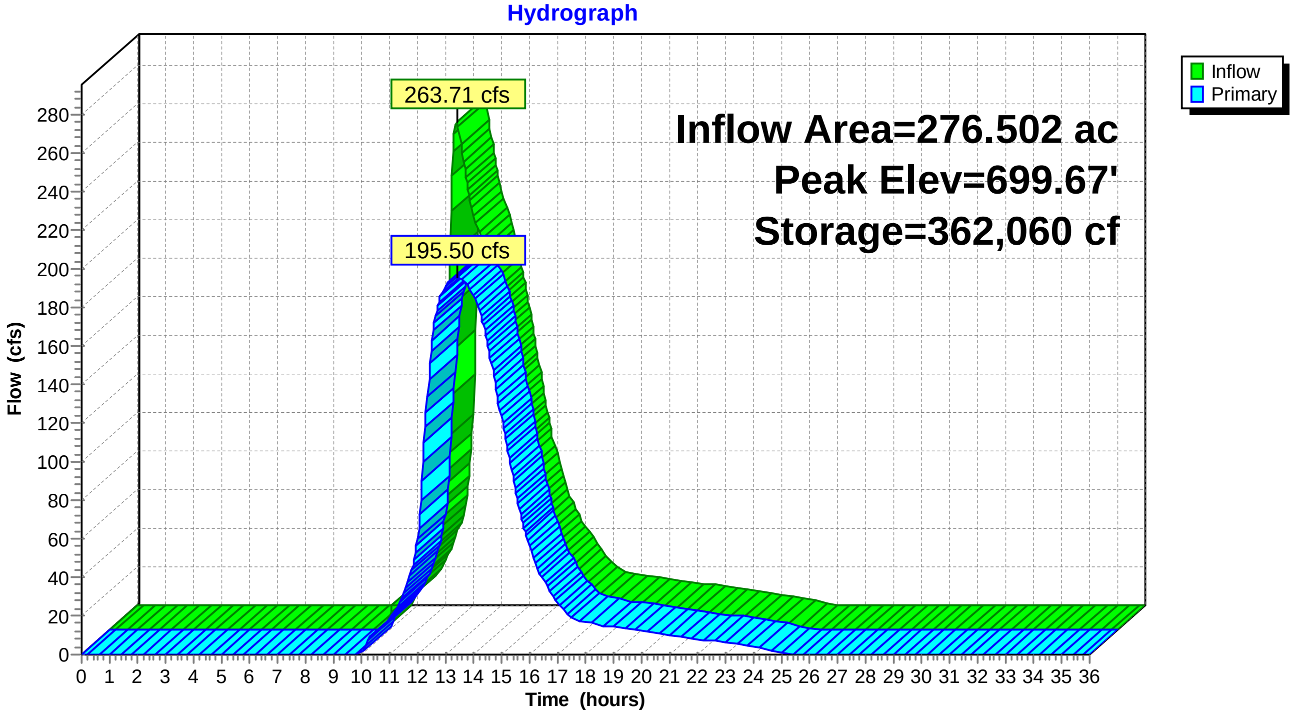
Volume	Invert	Avail.Storage	Storage Description
#1	694.90'	799,720 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
694.90	0	0	0
695.00	350	18	18
696.00	27,524	13,937	13,955
698.00	103,447	130,971	144,926
700.00	166,382	269,829	414,755
702.00	218,583	384,965	799,720

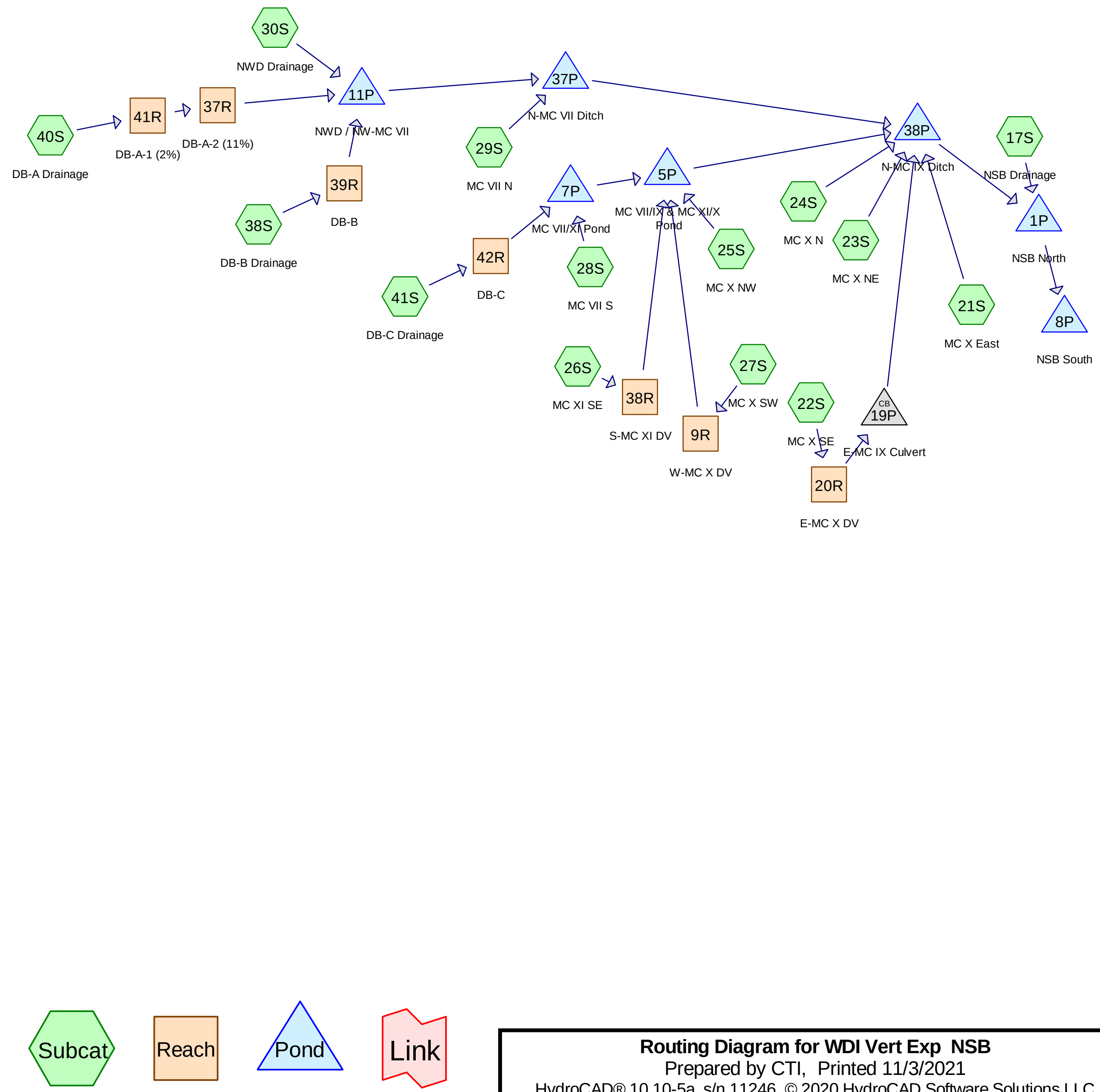
Device	Routing	Invert	Outlet Devices
#1	Primary	694.96'	**30.0" Round 30" Culvert X 3.00** L= 110.0' CMP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 694.96' / 694.96' S= 0.0000 '/' Cc= 0.900 n= 0.025, Flow Area= 4.91 sf
#2	Primary	694.90'	**54.0" Round 54" Culvert** L= 110.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 694.90' / 690.50' S= 0.0400 '/' Cc= 0.900 n= 0.012, Flow Area= 15.90 sf

Primary OutFlow Max=195.50 cfs @ 13.40 hrs HW=699.67' TW=694.18' (Fixed TW Elev= 694.18')
1=30" Culvert (Barrel Controls 73.86 cfs @ 5.02 fps)
2=54" Culvert (Inlet Controls 121.64 cfs @ 7.65 fps)

Pond 38P: N-MC IX Ditch



North Sedimentation Basin (NSB) HYDROCAD OUTPUT – 100-yr, 24-hr



Routing Diagram for WDI Vert Exp NSB
Prepared by CTI, Printed 11/3/2021
HydroCAD® 10.10-5a s/n 11246 © 2020 HydroCAD Software Solutions LLC

Time span=0.00-36.00 hrs, dt=0.04 hrs, 901 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 17S: NSB Drainage Runoff Area=483,100 sf 0.00% Impervious Runoff Depth=4.54"
Tc=0.0 min CN=95 Runoff=100.06 cfs 4.194 af

Subcatchment 21S: MC X East Runoff Area=443,100 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=650' Slope=0.0370 '/' Tc=21.2 min CN=84 Runoff=37.02 cfs 2.865 af

Subcatchment 22S: MC X SE Runoff Area=527,091 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=240' Slope=0.0540 '/' Tc=15.5 min CN=84 Runoff=51.29 cfs 3.409 af

Subcatchment 23S: MC X NE Runoff Area=435,600 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=440' Slope=0.0590 '/' Tc=15.3 min CN=84 Runoff=42.88 cfs 2.817 af

Subcatchment 24S: MC X N Runoff Area=282,100 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=310' Slope=0.0930 '/' Tc=11.7 min CN=84 Runoff=31.08 cfs 1.824 af

Subcatchment 25S: MC X NW Runoff Area=2,437,500 sf 8.04% Impervious Runoff Depth=3.48"
Flow Length=820' Slope=0.0380 '/' Tc=23.0 min CN=85 Runoff=200.20 cfs 16.224 af

Subcatchment 26S: MC XI SE Runoff Area=95,200 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=405' Slope=0.0770 '/' Tc=13.4 min CN=84 Runoff=9.92 cfs 0.616 af

Subcatchment 27S: MC X SW Runoff Area=600,400 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=240' Slope=0.0400 '/' Tc=17.5 min CN=84 Runoff=55.18 cfs 3.883 af

Subcatchment 28S: MC VII S Runoff Area=923,419 sf 4.21% Impervious Runoff Depth=3.48"
Flow Length=1,070' Tc=20.9 min CN=85 Runoff=79.50 cfs 6.146 af

Subcatchment 29S: MC VII N Runoff Area=349,700 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=560' Slope=0.0390 '/' Tc=19.5 min CN=84 Runoff=30.49 cfs 2.261 af

Subcatchment 30S: NWD Drainage Runoff Area=3,609,746 sf 5.58% Impervious Runoff Depth=4.54"
Flow Length=886' Slope=0.2500 '/' Tc=7.2 min CN=95 Runoff=577.59 cfs 31.341 af

Subcatchment 38S: DB-B Drainage Runoff Area=96,773 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=378' Slope=0.2500 '/' Tc=6.4 min CN=95 Runoff=15.94 cfs 0.840 af

Subcatchment 40S: DB-A Drainage Runoff Area=1,755,927 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=1,150' Tc=7.8 min CN=95 Runoff=276.01 cfs 15.245 af

Subcatchment 41S: DB-C Drainage Runoff Area=487,859 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=381' Slope=0.2500 '/' Tc=6.4 min CN=95 Runoff=80.36 cfs 4.236 af

Reach 9R: W-MC X DV Avg. Flow Depth=1.58' Max Vel=3.54 fps Inflow=55.18 cfs 3.883 af
n=0.025 L=1,400.0' S=0.0050 '/' Capacity=91.23 cfs Outflow=48.58 cfs 3.883 af

Reach 20R: E-MC X DV Avg. Flow Depth=1.71' Max Vel=5.17 fps Inflow=51.29 cfs 3.409 af
n=0.025 L=1,780.0' S=0.0100 '/' Capacity=68.87 cfs Outflow=45.35 cfs 3.409 af

Reach 37R: DB-A-2 (11%) Avg. Flow Depth=1.91' Max Vel=22.89 fps Inflow=249.56 cfs 15.245 af
n=0.020 L=125.2' S=0.1097 '/' Capacity=837.73 cfs Outflow=248.96 cfs 15.245 af

Reach 38R: S-MC XI DV Avg. Flow Depth=0.76' Max Vel=4.07 fps Inflow=9.92 cfs 0.616 af
n=0.025 L=750.0' S=0.0180 '/' Capacity=57.72 cfs Outflow=9.30 cfs 0.616 af

Reach 39R: DB-B Avg. Flow Depth=0.99' Max Vel=6.25 fps Inflow=15.94 cfs 0.840 af
n=0.020 L=598.0' S=0.0200 '/' Capacity=99.84 cfs Outflow=14.87 cfs 0.840 af

Reach 41R: DB-A-1 (2%) Avg. Flow Depth=2.64' Max Vel=12.10 fps Inflow=276.01 cfs 15.245 af
n=0.020 L=2,146.0' S=0.0200 '/' Capacity=357.63 cfs Outflow=249.56 cfs 15.245 af

Reach 42R: DB-C Avg. Flow Depth=1.83' Max Vel=9.38 fps Inflow=80.36 cfs 4.236 af
n=0.020 L=724.0' S=0.0200 '/' Capacity=99.84 cfs Outflow=75.77 cfs 4.236 af

Pond 1P: NSB North Peak Elev=694.52' Storage=2,335,715 cf Inflow=231.01 cfs 91.828 af
Outflow=197.60 cfs 46.806 af

Pond 5P: MC VII/IX & MC XI/X Pond Peak Elev=704.55' Storage=656,914 cf Inflow=344.55 cfs 30.839 af
24.0" Round Culvert x 3.00 n=0.025 L=30.0' S=0.0033 '/' Outflow=72.88 cfs 28.672 af

Pond 7P: MC VII/XI Pond Peak Elev=708.37' Storage=93,554 cf Inflow=134.54 cfs 10.382 af
Outflow=97.21 cfs 10.117 af

Pond 8P: NSB South Peak Elev=693.48' Storage=2,553,632 cf Inflow=197.60 cfs 46.806 af
Outflow=0.00 cfs 0.000 af

Pond 11P: NWD / NW-MC VII Peak Elev=711.78' Storage=784,815 cf Inflow=773.35 cfs 47.427 af
Outflow=157.20 cfs 47.427 af

Pond 19P: E-MC IX Culvert Peak Elev=705.10' Inflow=45.35 cfs 3.409 af
36.0" Round Culvert n=0.012 L=72.0' S=0.0365 '/' Outflow=45.35 cfs 3.409 af

Pond 37P: N-MC VII Ditch Peak Elev=702.65' Storage=152,731 cf Inflow=183.24 cfs 49.688 af
Outflow=165.20 cfs 48.047 af

Pond 38P: N-MC IX Ditch Peak Elev=700.54' Storage=507,634 cf Inflow=330.31 cfs 87.634 af
Outflow=227.98 cfs 87.634 af

Total Runoff Area = 287.592 ac Runoff Volume = 95.902 af Average Runoff Depth = 4.00"
96.52% Pervious = 277.574 ac 3.48% Impervious = 10.018 ac

Summary for Subcatchment 17S: NSB Drainage

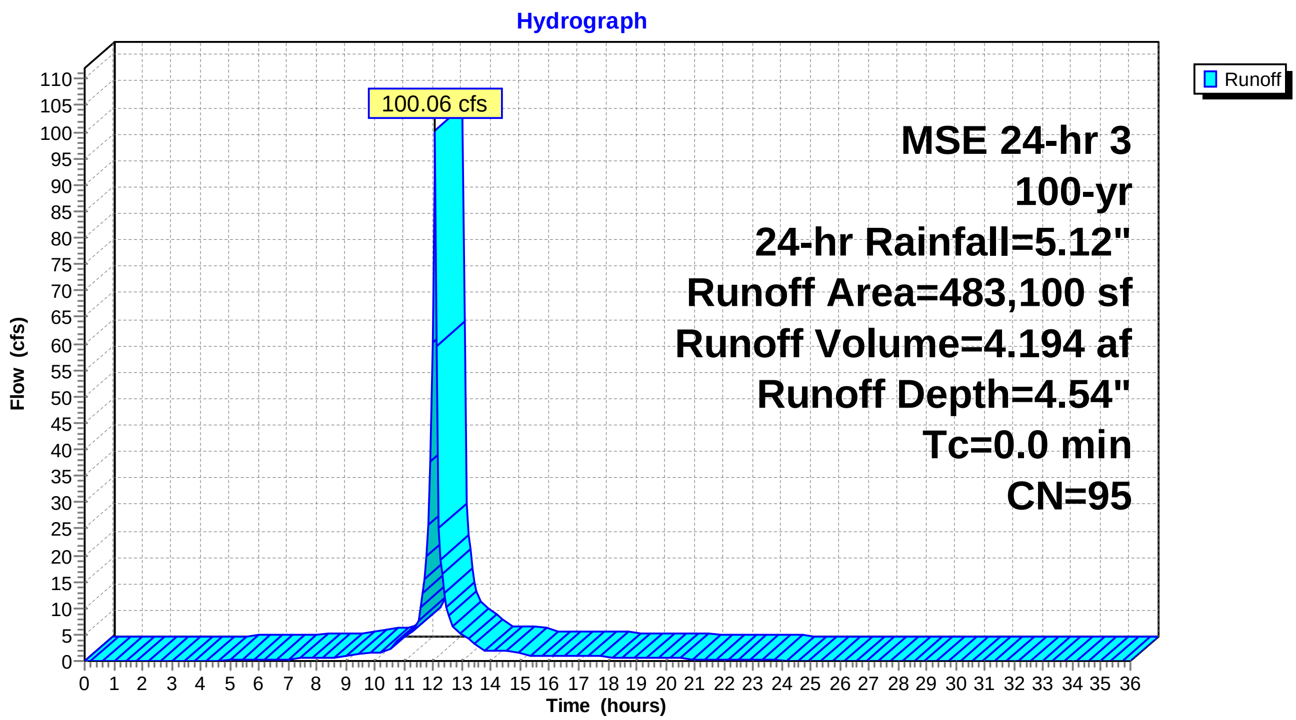
Drainage area is pond area and land area
Land area = 483,100 - 111,900 = 371,200

Runoff = 100.06 cfs @ 12.06 hrs, Volume= 4.194 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
111,900	84	50-75% Grass cover, Fair, HSG D
371,200	98	Water Surface, 0% imp, HSG D
483,100	95	Weighted Average
483,100		100.00% Pervious Area

Subcatchment 17S: NSB Drainage



Summary for Subcatchment 21S: MC X East

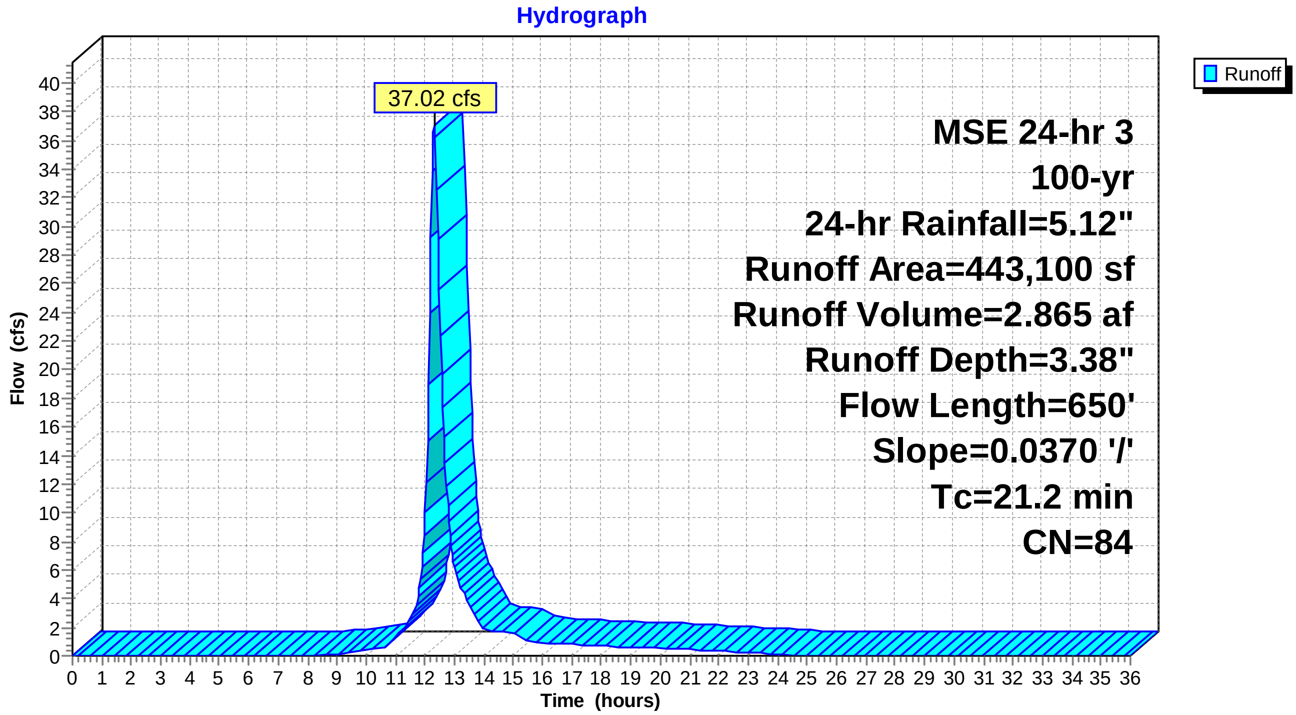
Runoff = 37.02 cfs @ 12.31 hrs, Volume= 2.865 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
443,100	84	50-75% Grass cover, Fair, HSG D
443,100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.6	200	0.0370	0.21		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
5.6	450	0.0370	1.35		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.2	650	Total			

Subcatchment 21S: MC X East



Summary for Subcatchment 22S: MC X SE

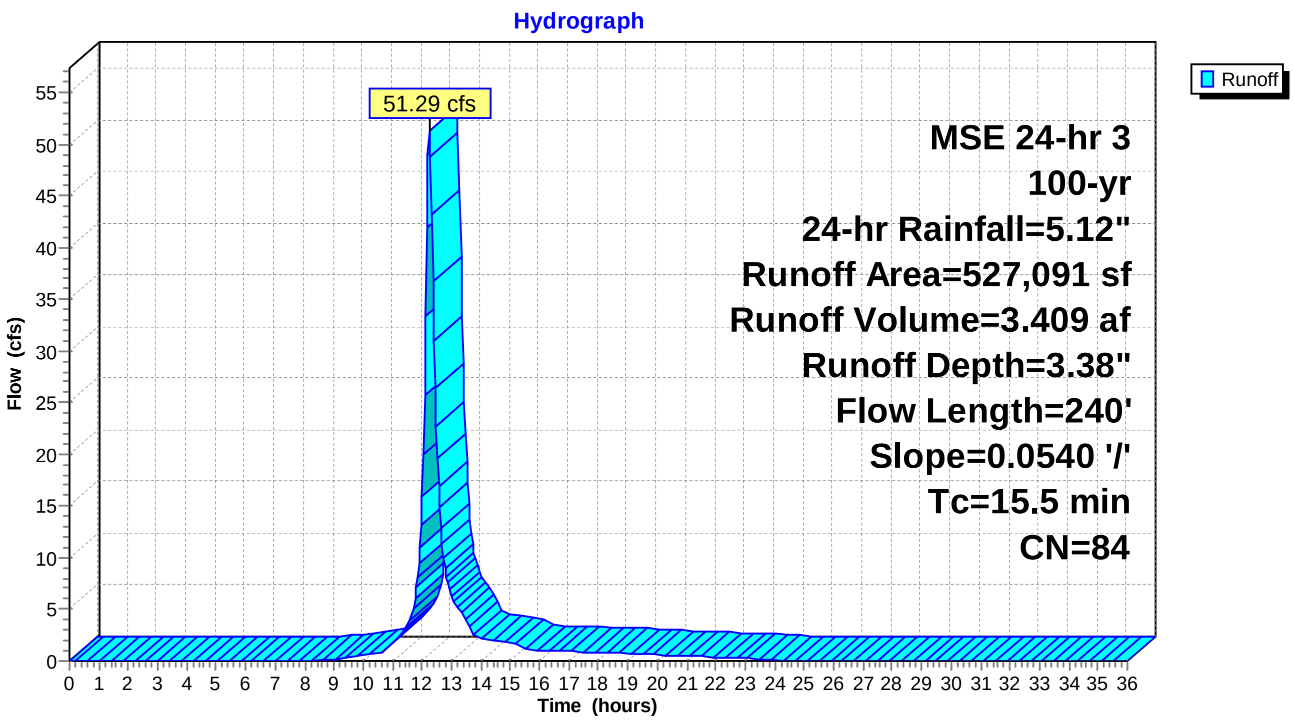
Runoff = 51.29 cfs @ 12.24 hrs, Volume= 3.409 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
527,091	84	50-75% Grass cover, Fair, HSG D
527,091		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.5	240	0.0540	0.26		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 22S: MC X SE



Summary for Subcatchment 23S: MC X NE

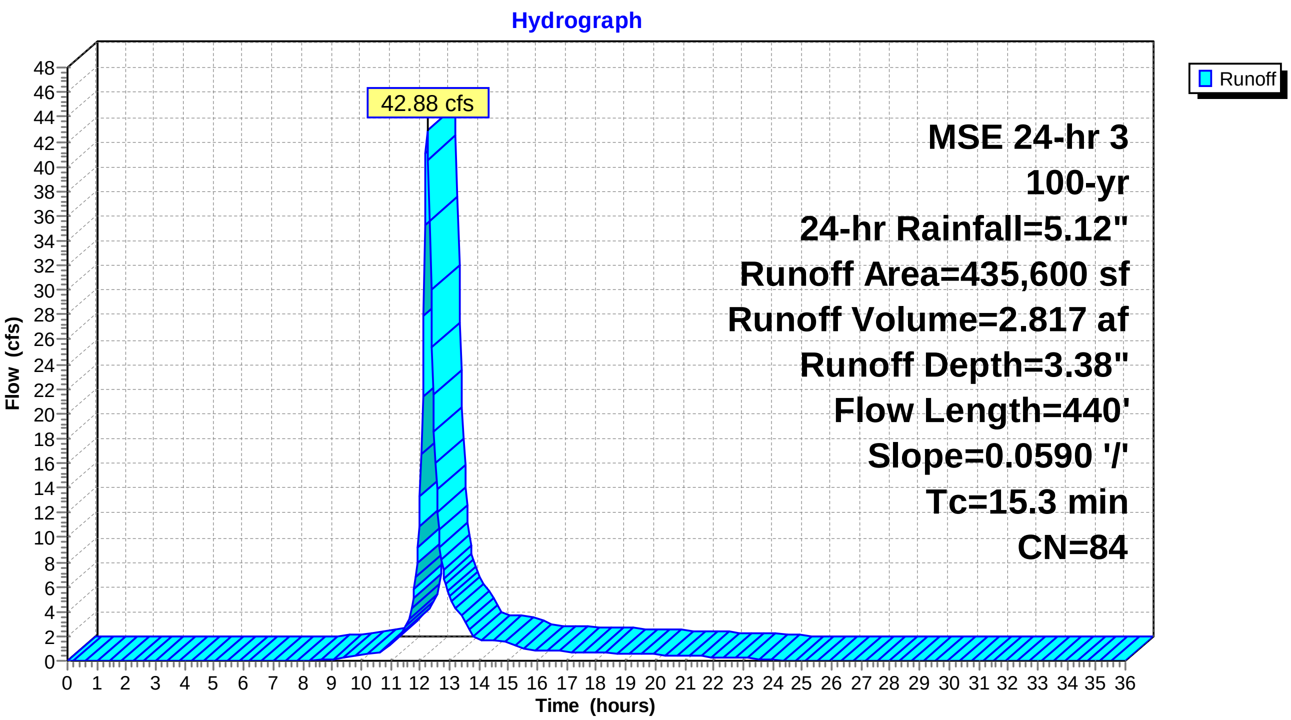
Runoff = 42.88 cfs @ 12.24 hrs, Volume= 2.817 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
435,600	84	50-75% Grass cover, Fair, HSG D
435,600		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.9	200	0.0590	0.26		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
2.4	240	0.0590	1.70		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
15.3	440	Total			

Subcatchment 23S: MC X NE



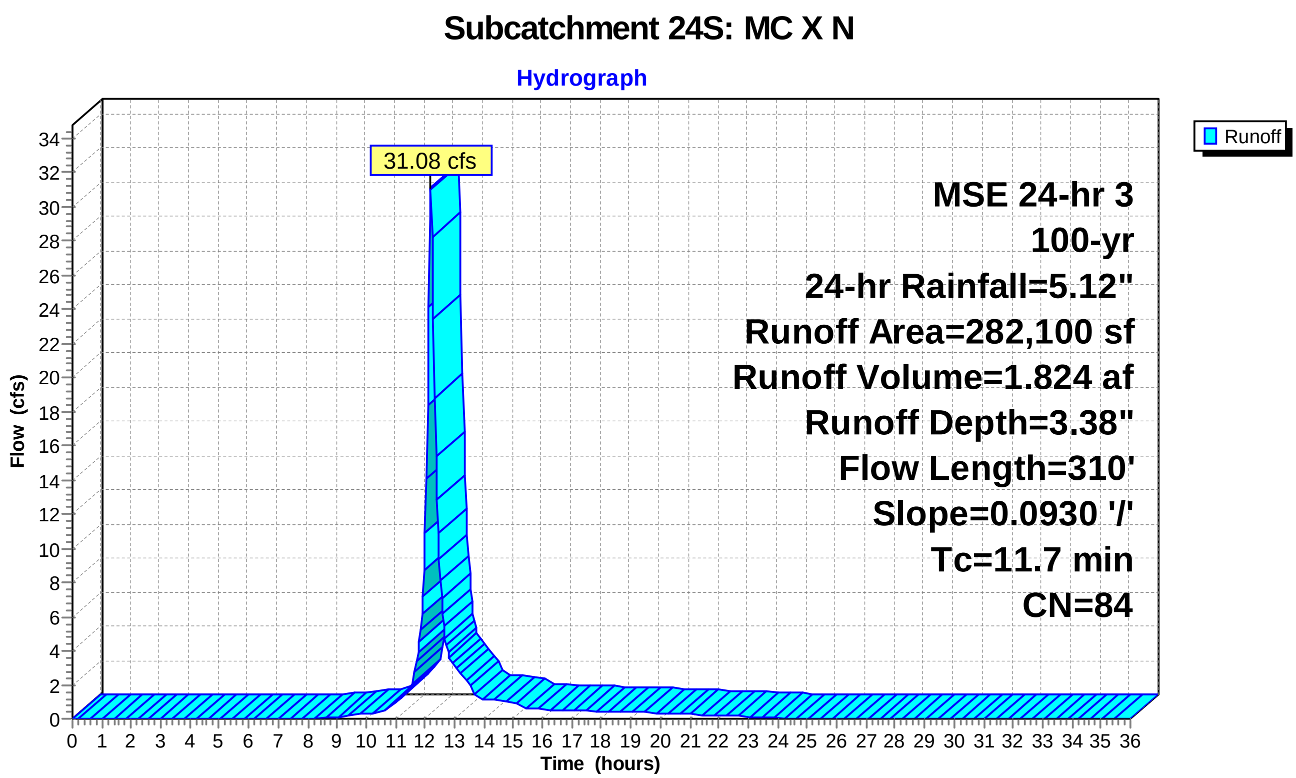
Summary for Subcatchment 24S: MC X N

Runoff = 31.08 cfs @ 12.19 hrs, Volume= 1.824 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
282,100	84	50-75% Grass cover, Fair, HSG D
282,100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.8	200	0.0930	0.31		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
0.9	110	0.0930	2.13		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
11.7	310	Total			



Summary for Subcatchment 25S: MC X NW

Drainage area is pond area and land area
Land area = 2,437,500 - 196,000 = 2,241,500

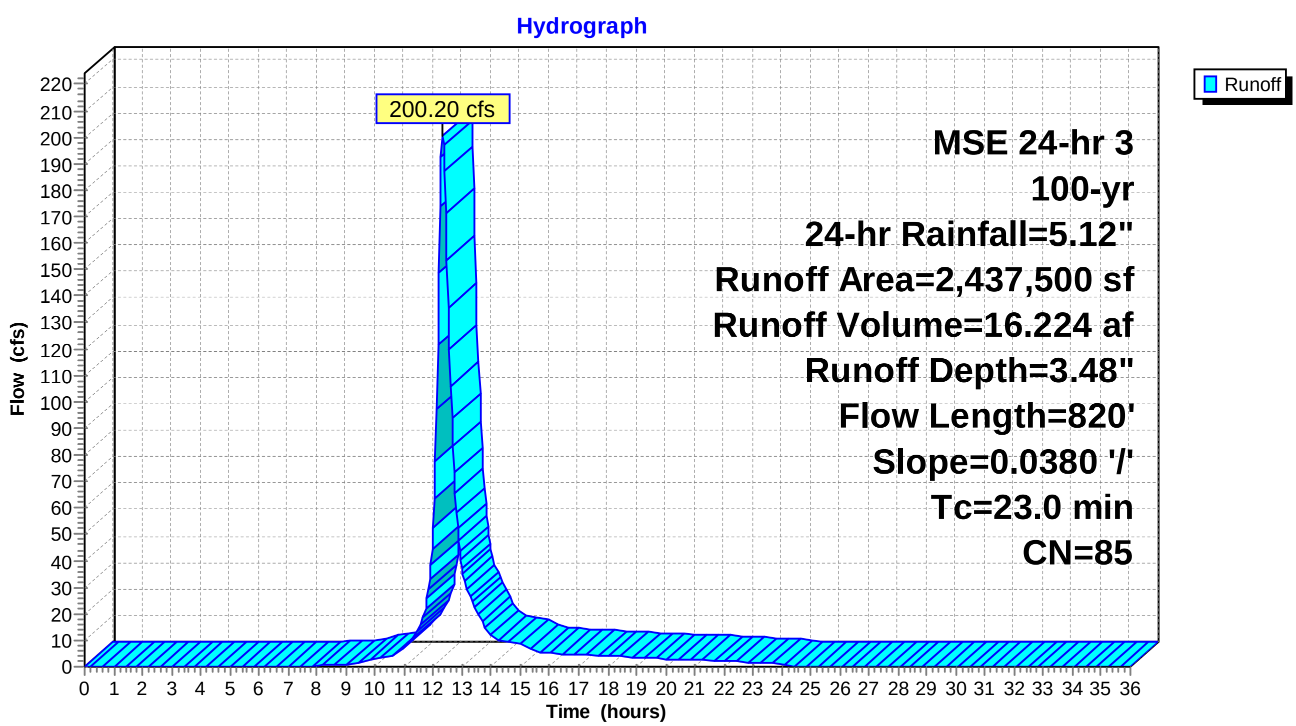
Runoff = 200.20 cfs @ 12.33 hrs, Volume= 16.224 af, Depth= 3.48"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
196,000	98	Water Surface, HSG D
2,241,500	84	50-75% Grass cover, Fair, HSG D
2,437,500	85	Weighted Average
2,241,500		91.96% Pervious Area
196,000		8.04% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.4	200	0.0380	0.22		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
7.6	620	0.0380	1.36		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
23.0	820	Total			

Subcatchment 25S: MC X NW



Summary for Subcatchment 26S: MC XI SE

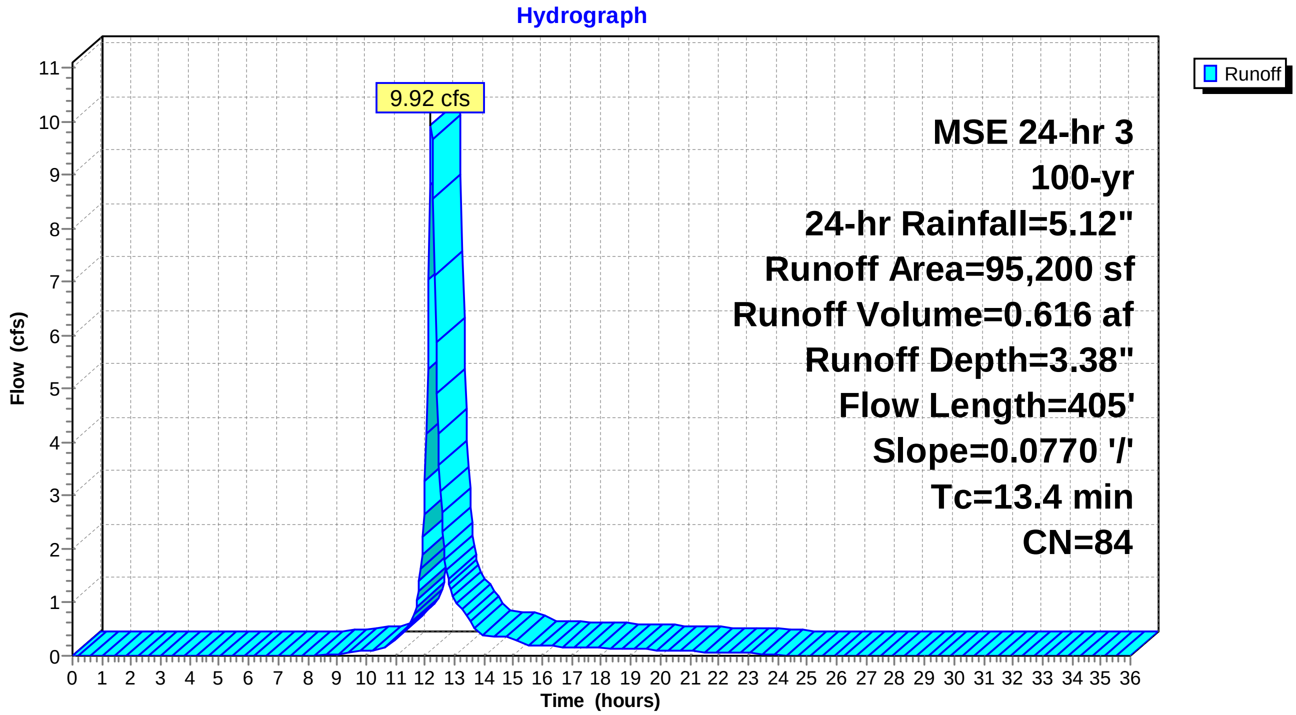
Runoff = 9.92 cfs @ 12.21 hrs, Volume= 0.616 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
95,200	84	50-75% Grass cover, Fair, HSG D
95,200		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.6	200	0.0770	0.29		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
1.8	205	0.0770	1.94		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.4	405	Total			

Subcatchment 26S: MC XI SE



Summary for Subcatchment 27S: MC X SW

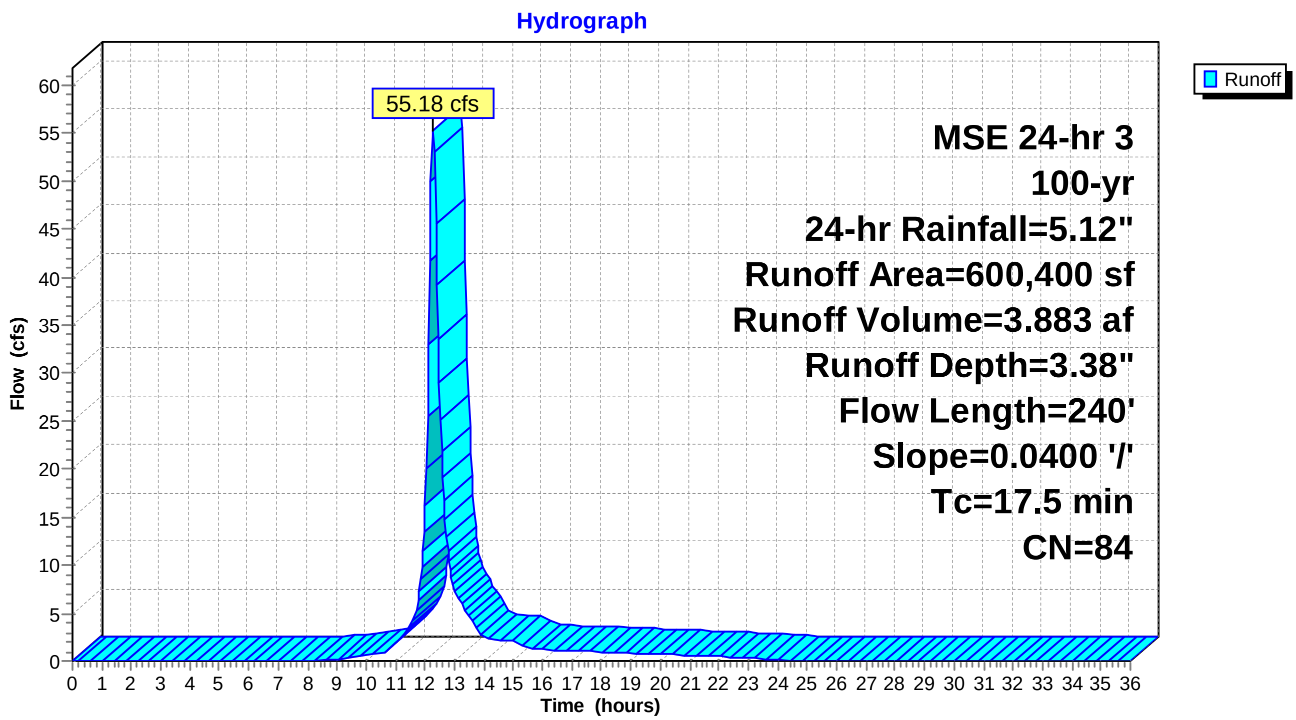
Runoff = 55.18 cfs @ 12.26 hrs, Volume= 3.883 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
600,400	84	50-75% Grass cover, Fair, HSG D
600,400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.5	240	0.0400	0.23		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 27S: MC X SW



Summary for Subcatchment 28S: MC VII S

Drainage area is pond area and land area
Land area = 998,400 - 38,900 = 959,500

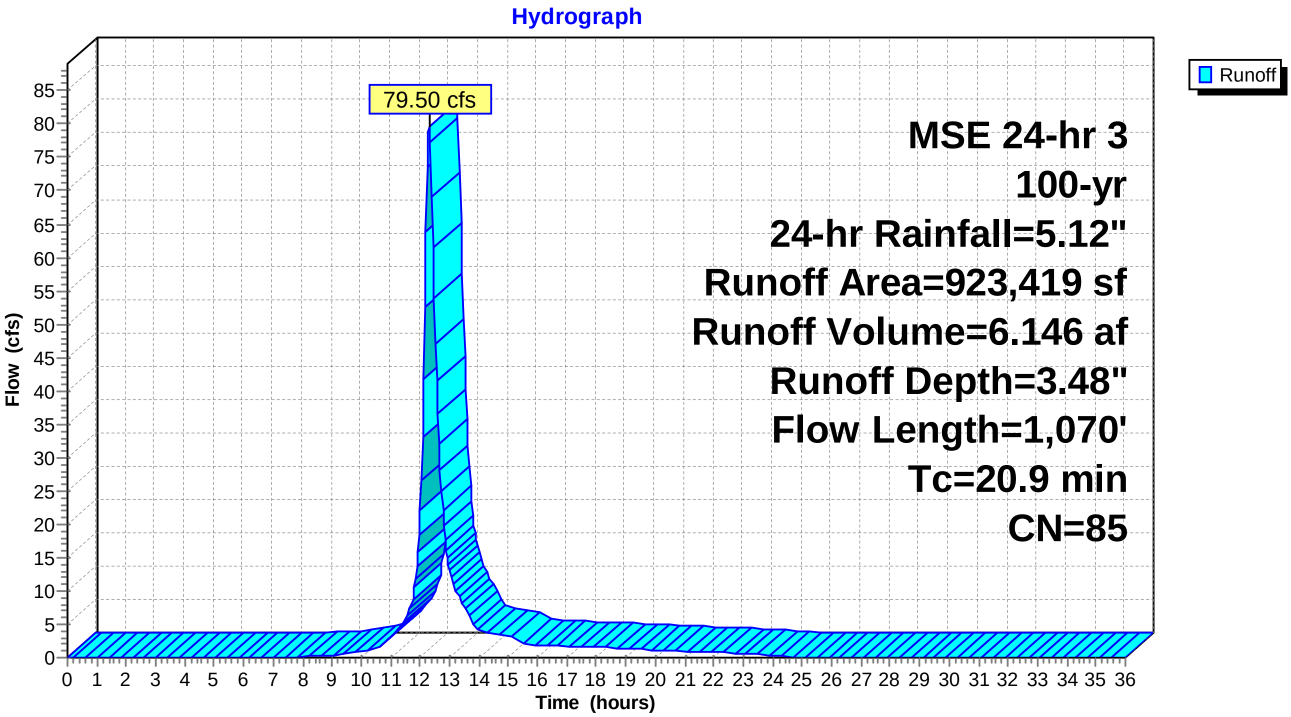
Runoff = 79.50 cfs @ 12.30 hrs, Volume= 6.146 af, Depth= 3.48"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
38,900	98	Water Surface, HSG D
884,519	84	50-75% Grass cover, Fair, HSG D
923,419	85	Weighted Average
884,519		95.79% Pervious Area
38,900		4.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.9	200	0.0300	0.20		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
2.3	170	0.0300	1.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.7	700	0.0140	7.03	84.40	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.025 Earth, clean & winding
20.9	1,070	Total			

Subcatchment 28S: MC VII S



Summary for Subcatchment 29S: MC VII N

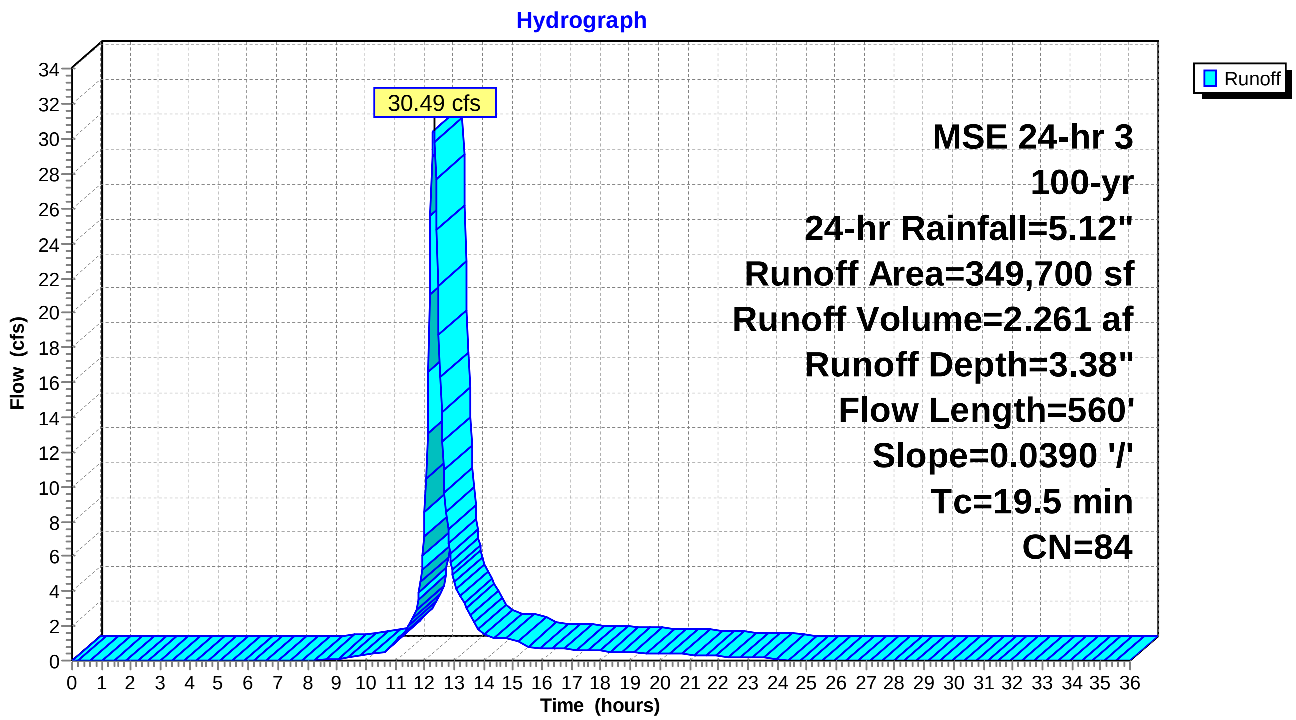
Runoff = 30.49 cfs @ 12.29 hrs, Volume= 2.261 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
349,700	84	50-75% Grass cover, Fair, HSG D
349,700		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.2	200	0.0390	0.22		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
4.3	360	0.0390	1.38		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
19.5	560	Total			

Subcatchment 29S: MC VII N



Summary for Subcatchment 30S: NWD Drainage

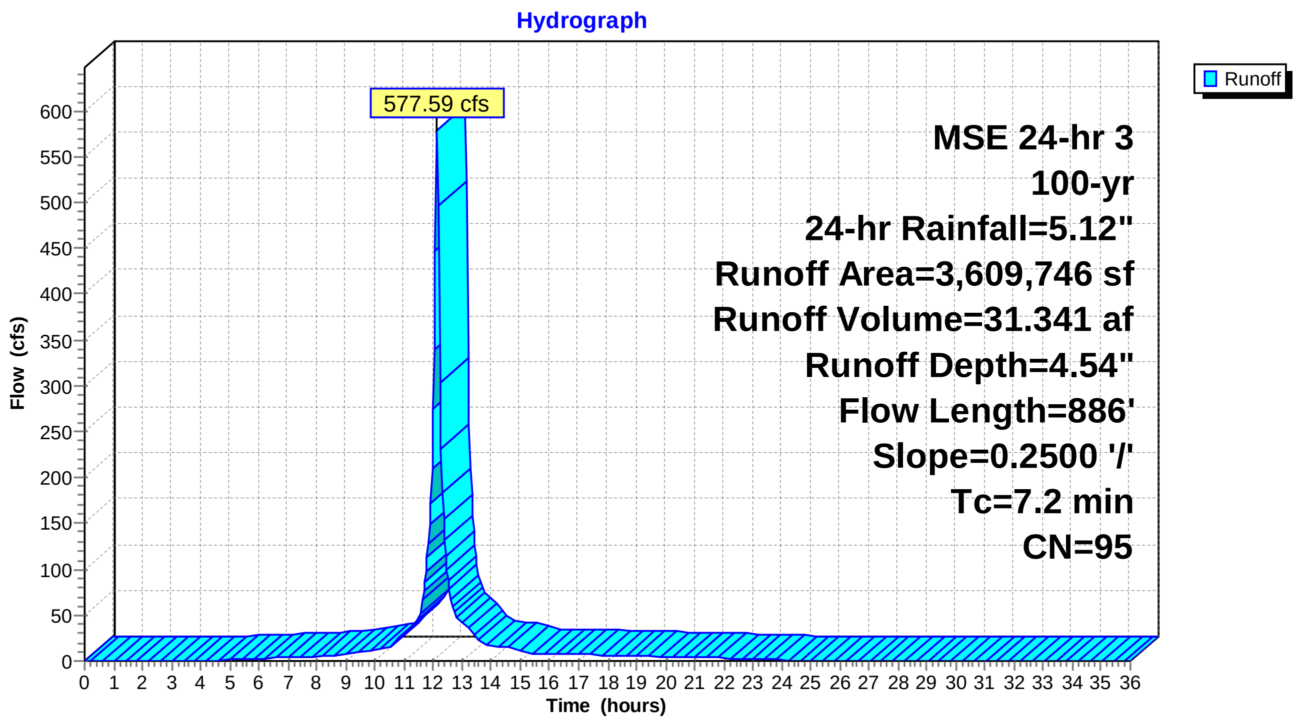
Runoff = 577.59 cfs @ 12.14 hrs, Volume= 31.341 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
	201,500	98	Water Surface, HSG D
*	3,408,246	95	Closure Turf
	3,609,746	95	Weighted Average
	3,408,246		94.42% Pervious Area
	201,500		5.58% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
1.1	686	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
7.2	886	Total			

Subcatchment 30S: NWD Drainage



Summary for Subcatchment 38S: DB-B Drainage

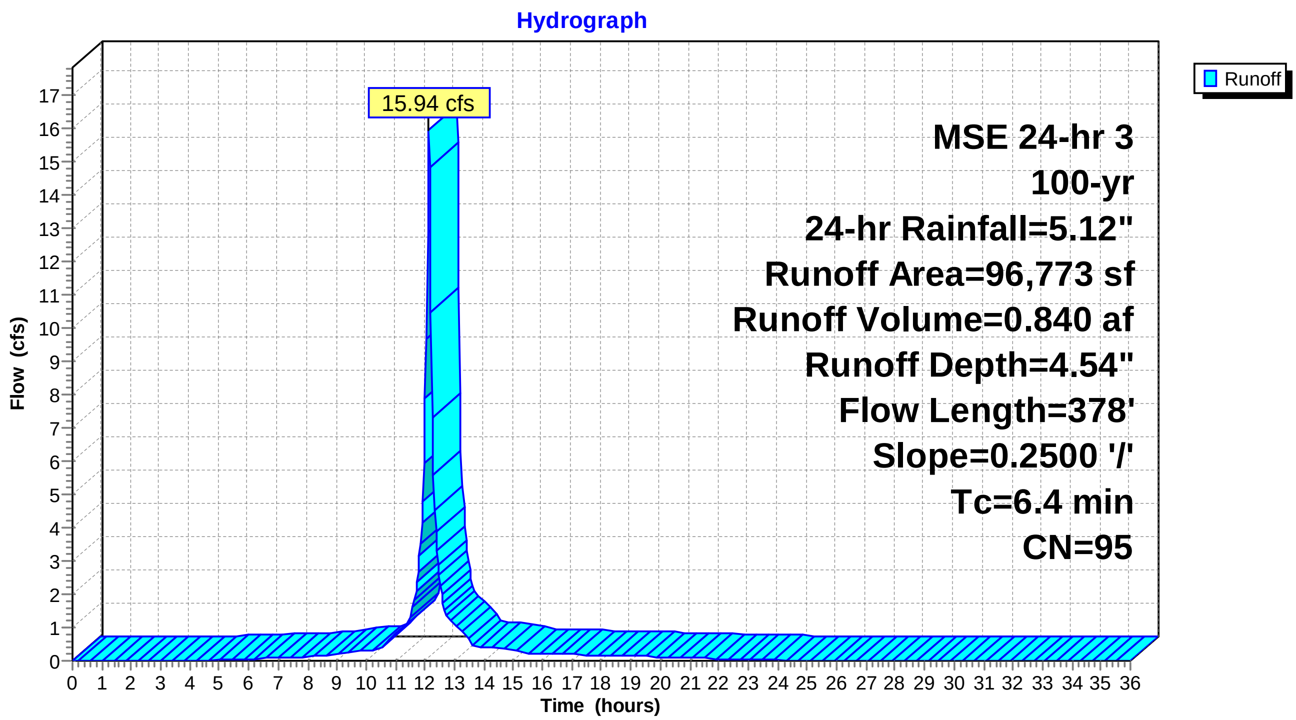
Runoff = 15.94 cfs @ 12.13 hrs, Volume= 0.840 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	96,773	95	Closure Turf
	96,773		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.3	178	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
6.4	378	Total			

Subcatchment 38S: DB-B Drainage



Summary for Subcatchment 40S: DB-A Drainage

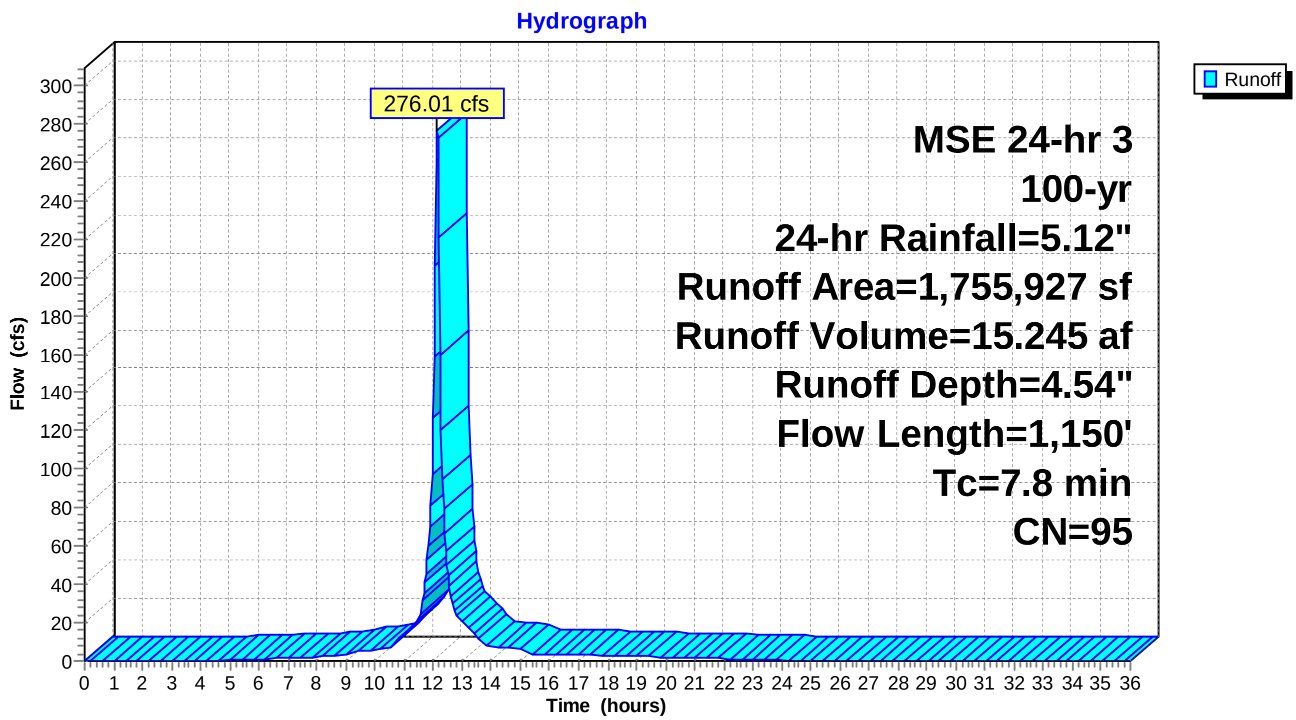
Runoff = 276.01 cfs @ 12.15 hrs, Volume= 15.245 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	1,755,927	95	Closure Turf
	1,755,927		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.5	313	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.8	189	0.0400	4.06		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.4	400	0.0400	14.86	178.32	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.020
0.0	48	0.1600	29.72	356.64	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.020
7.8	1,150	Total			

Subcatchment 40S: DB-A Drainage



Summary for Subcatchment 41S: DB-C Drainage

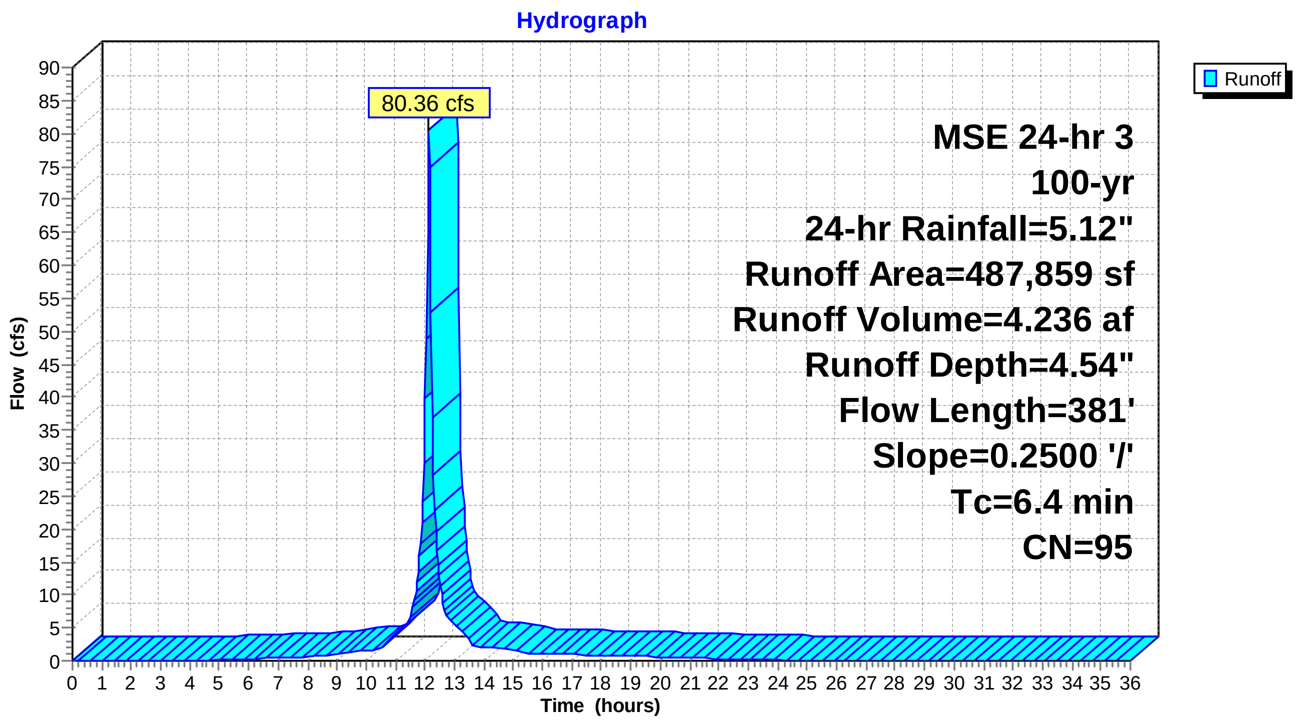
Runoff = 80.36 cfs @ 12.13 hrs, Volume= 4.236 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	487,859	95	Closure Turf
	487,859		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.3	181	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
6.4	381	Total			

Subcatchment 41S: DB-C Drainage



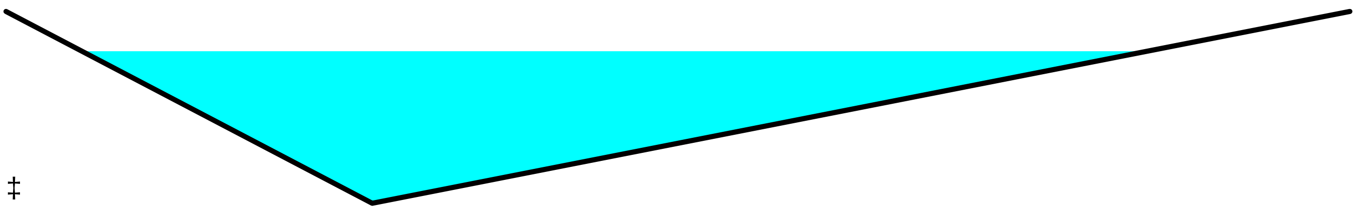
Summary for Reach 9R: W-MC X DV

Inflow Area = 13.783 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 55.18 cfs @ 12.26 hrs, Volume= 3.883 af
Outflow = 48.58 cfs @ 12.45 hrs, Volume= 3.883 af, Atten= 12%, Lag= 11.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 3.54 fps, Min. Travel Time= 6.6 min
Avg. Velocity = 0.94 fps, Avg. Travel Time= 24.7 min

Peak Storage= 19,274 cf @ 12.34 hrs
Average Depth at Peak Storage= 1.58' , Surface Width= 17.40'
Bank-Full Depth= 2.00' Flow Area= 22.0 sf, Capacity= 91.23 cfs

0.00' x 2.00' deep channel, n= 0.025 Earth, clean & winding
Side Slope Z-value= 3.0 8.0 '/' Top Width= 22.00'
Length= 1,400.0' Slope= 0.0050 '/'
Inlet Invert= 713.00', Outlet Invert= 706.00'



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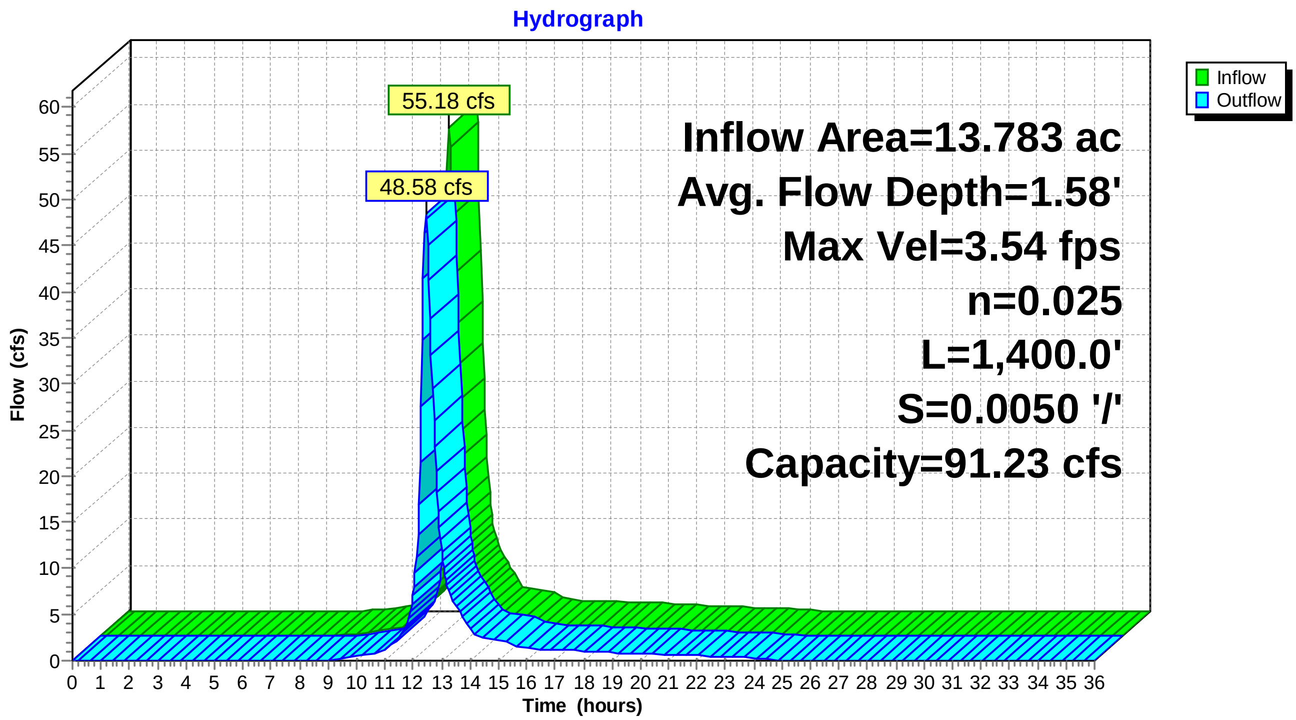
Reach 9R: W-MC X DV



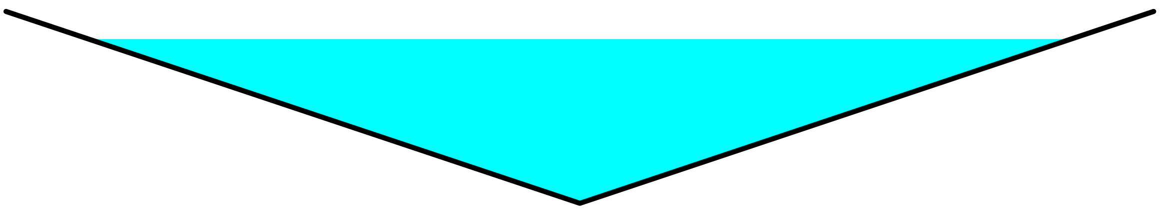
Summary for Reach 20R: E-MC X DV

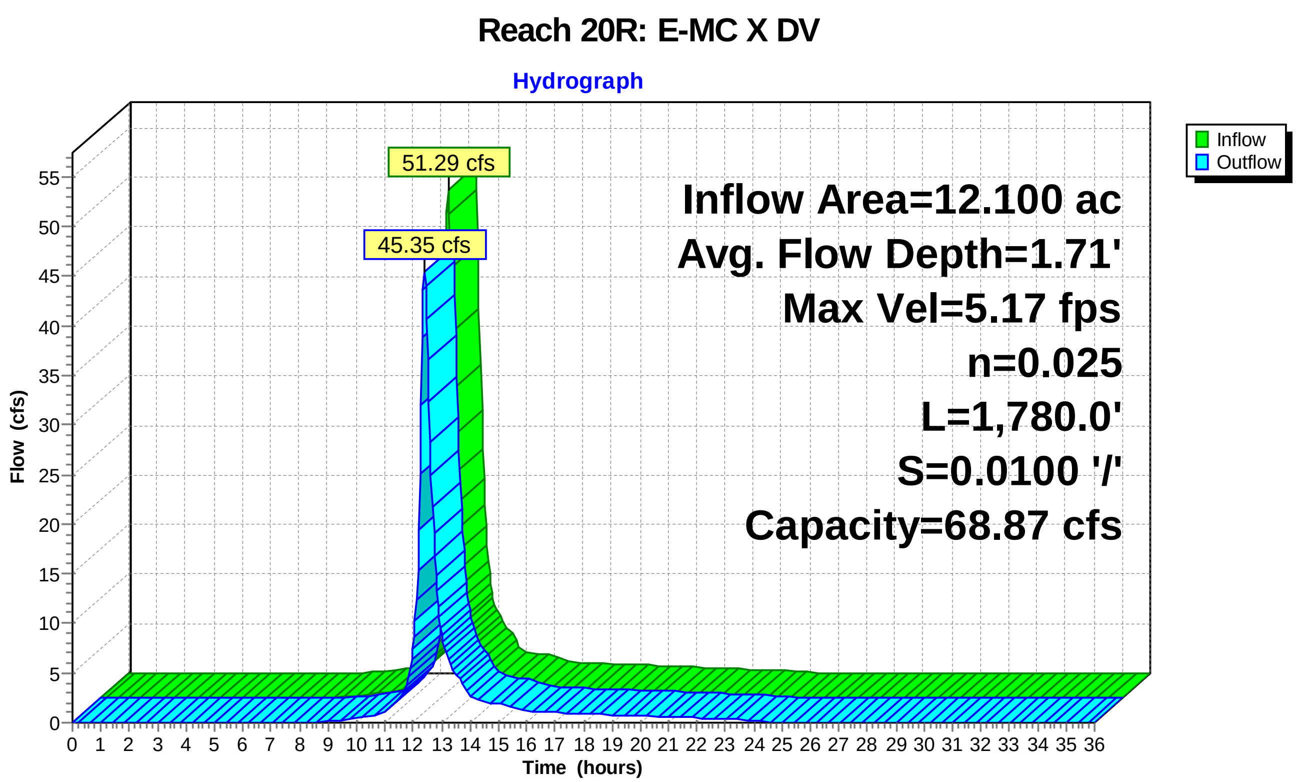
Inflow Area = 12.100 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 51.29 cfs @ 12.24 hrs, Volume= 3.409 af
Outflow = 45.35 cfs @ 12.40 hrs, Volume= 3.409 af, Atten= 12%, Lag= 9.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 5.17 fps, Min. Travel Time= 5.7 min
Avg. Velocity = 1.43 fps, Avg. Travel Time= 20.7 min

Peak Storage= 15,697 cf @ 12.31 hrs
Average Depth at Peak Storage= 1.71' , Surface Width= 10.29'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 68.87 cfs

0.00' x 2.00' deep channel, n= 0.025 Earth, clean & winding
Side Slope Z-value= 3.0 '/' Top Width= 12.00'
Length= 1,780.0' Slope= 0.0100 '/'
Inlet Invert= 723.00', Outlet Invert= 705.20'





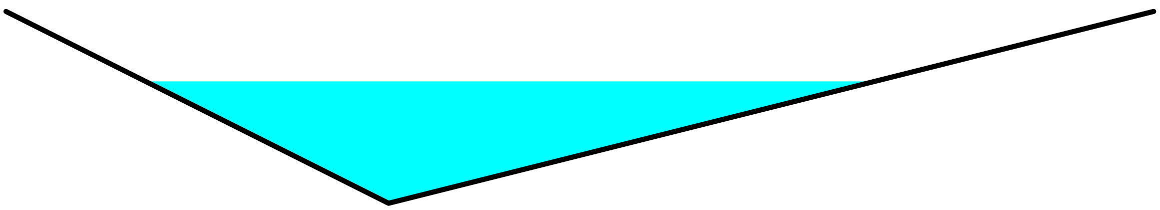
Summary for Reach 37R: DB-A-2 (11%)

Inflow Area = 40.311 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 249.56 cfs @ 12.23 hrs, Volume= 15.245 af
Outflow = 248.96 cfs @ 12.23 hrs, Volume= 15.245 af, Atten= 0%, Lag= 0.2 min

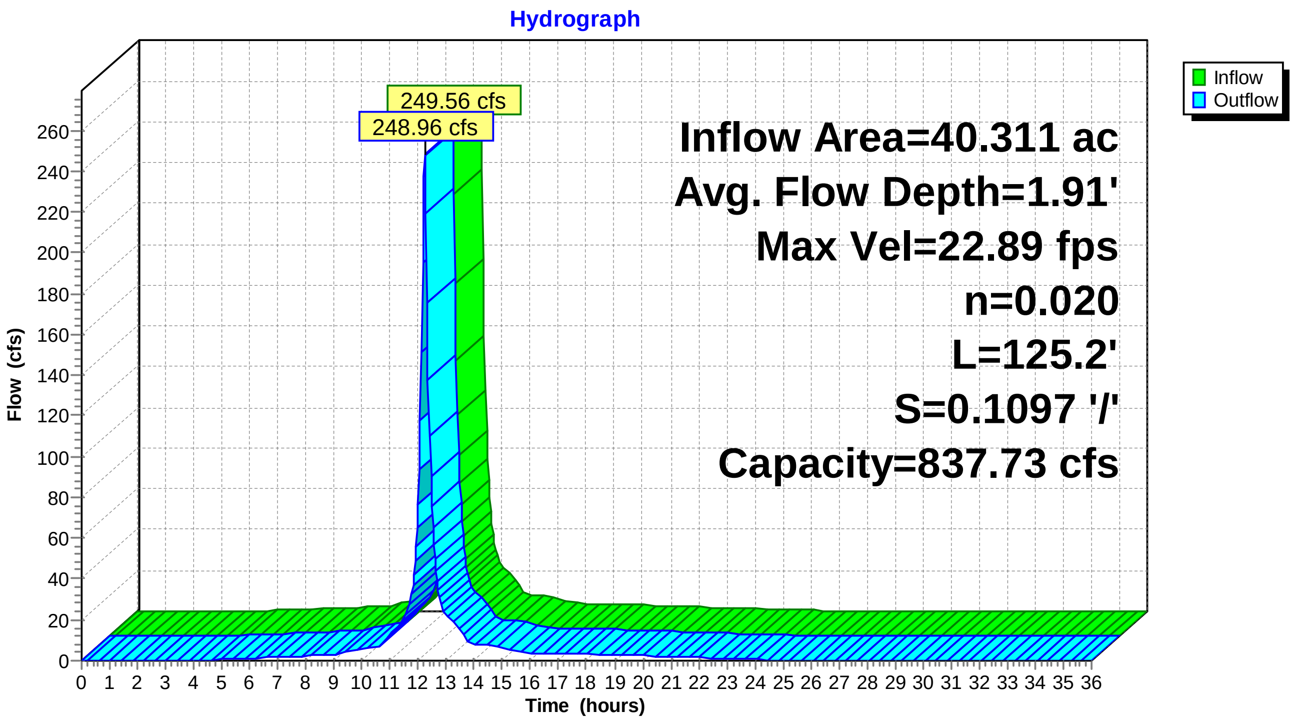
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 22.89 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 6.86 fps, Avg. Travel Time= 0.3 min

Peak Storage= 1,364 cf @ 12.23 hrs
Average Depth at Peak Storage= 1.91' , Surface Width= 11.43'
Bank-Full Depth= 3.00' Flow Area= 27.0 sf, Capacity= 837.73 cfs

0.00' x 3.00' deep channel, n= 0.020
Side Slope Z-value= 2.0 4.0 '/' Top Width= 18.00'
Length= 125.2' Slope= 0.1097 '/'
Inlet Invert= 728.00', Outlet Invert= 714.26'



Reach 37R: DB-A-2 (11%)



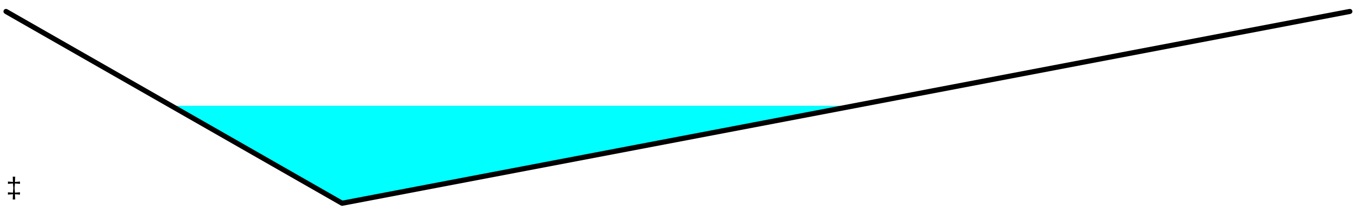
Summary for Reach 38R: S-MC XI DV

Inflow Area = 2.185 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 9.92 cfs @ 12.21 hrs, Volume= 0.616 af
Outflow = 9.30 cfs @ 12.30 hrs, Volume= 0.616 af, Atten= 6%, Lag= 5.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 4.07 fps, Min. Travel Time= 3.1 min
Avg. Velocity = 1.35 fps, Avg. Travel Time= 9.3 min

Peak Storage= 1,733 cf @ 12.25 hrs
Average Depth at Peak Storage= 0.76' , Surface Width= 6.08'
Bank-Full Depth= 1.50' Flow Area= 9.0 sf, Capacity= 57.72 cfs

0.00' x 1.50' deep channel, n= 0.025 Earth, clean & winding
Side Slope Z-value= 2.0 6.0 '/' Top Width= 12.00'
Length= 750.0' Slope= 0.0180 '/'
Inlet Invert= 719.00', Outlet Invert= 705.50'



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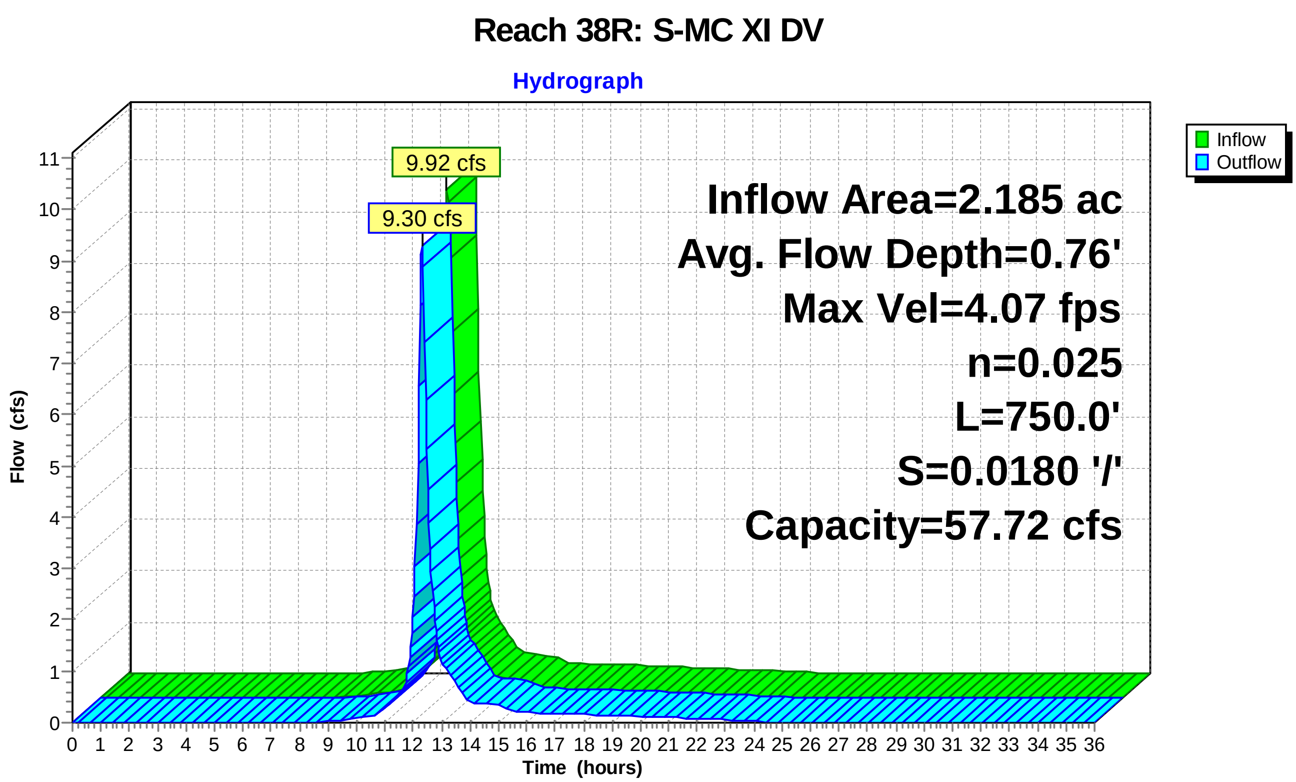


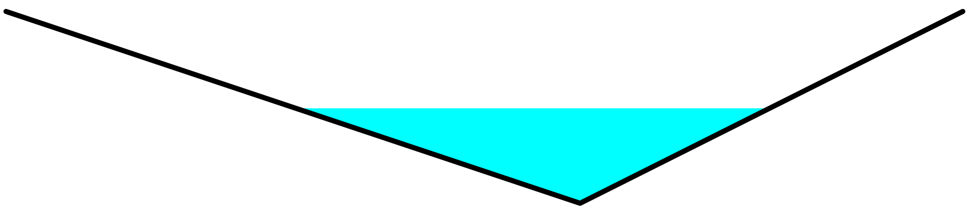
Summary for Reach 39R: DB-B

Inflow Area = 2.222 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 15.94 cfs @ 12.13 hrs, Volume= 0.840 af
Outflow = 14.87 cfs @ 12.18 hrs, Volume= 0.840 af, Atten= 7%, Lag= 2.8 min

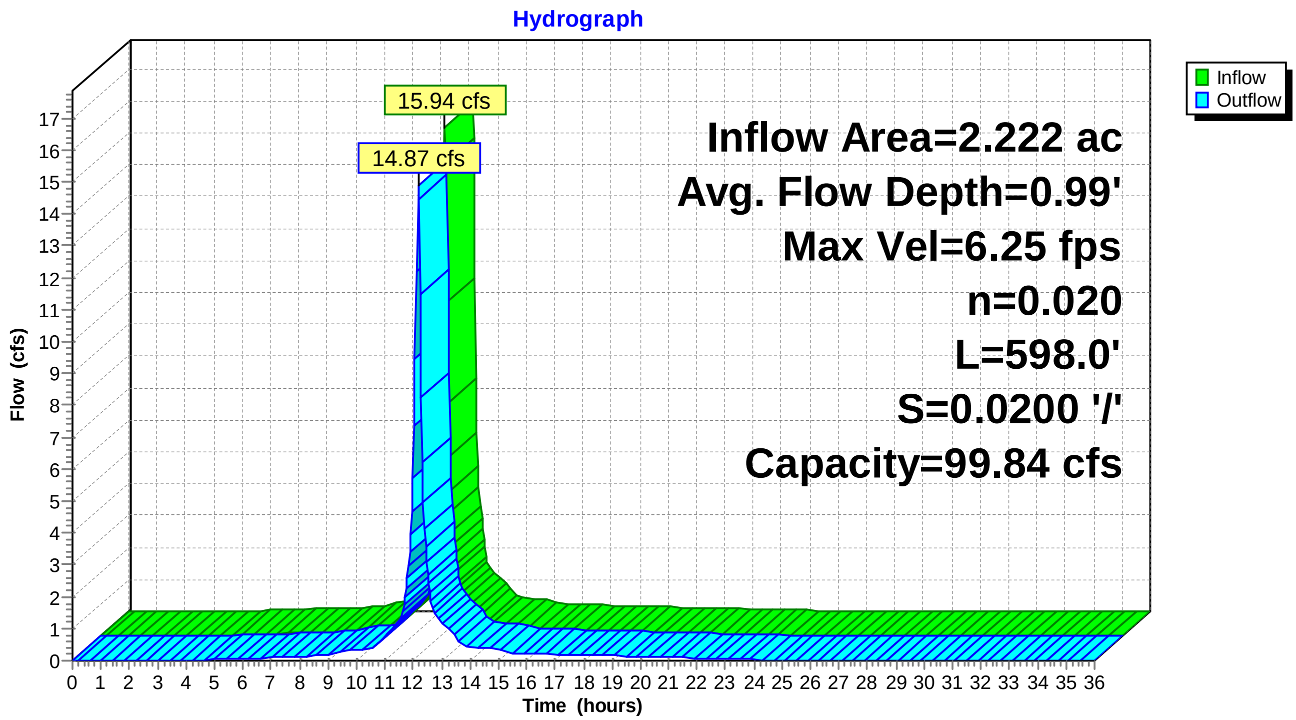
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 6.25 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 2.01 fps, Avg. Travel Time= 5.0 min

Peak Storage= 1,473 cf @ 12.15 hrs
Average Depth at Peak Storage= 0.99' , Surface Width= 4.96'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 99.84 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 3.0 2.0 '/' Top Width= 10.00'
Length= 598.0' Slope= 0.0200 '/'
Inlet Invert= 725.96', Outlet Invert= 714.00'



Reach 39R: DB-B



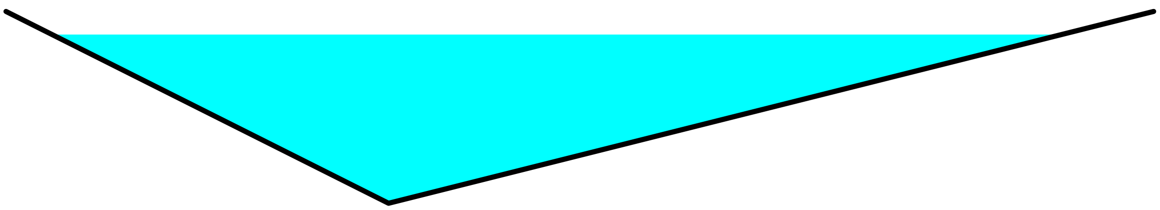
Summary for Reach 41R: DB-A-1 (2%)

Inflow Area = 40.311 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 276.01 cfs @ 12.15 hrs, Volume= 15.245 af
Outflow = 249.56 cfs @ 12.23 hrs, Volume= 15.245 af, Atten= 10%, Lag= 4.8 min

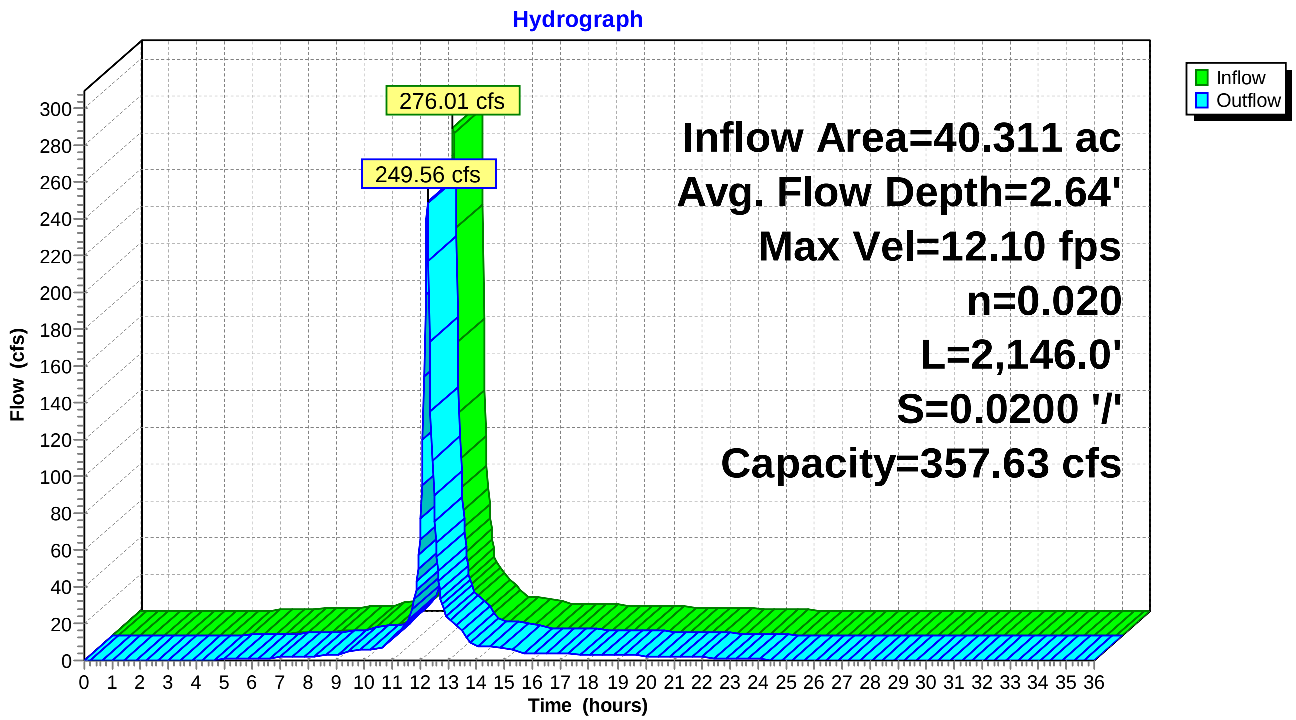
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 12.10 fps, Min. Travel Time= 3.0 min
Avg. Velocity = 3.51 fps, Avg. Travel Time= 10.2 min

Peak Storage= 44,774 cf @ 12.18 hrs
Average Depth at Peak Storage= 2.64' , Surface Width= 15.83'
Bank-Full Depth= 3.00' Flow Area= 27.0 sf, Capacity= 357.63 cfs

0.00' x 3.00' deep channel, n= 0.020
Side Slope Z-value= 2.0 4.0 '/' Top Width= 18.00'
Length= 2,146.0' Slope= 0.0200 '/'
Inlet Invert= 770.92', Outlet Invert= 728.00'



Reach 41R: DB-A-1 (2%)



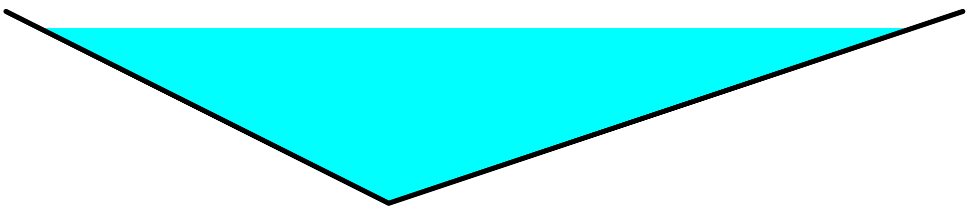
Summary for Reach 42R: DB-C

Inflow Area = 11.200 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 80.36 cfs @ 12.13 hrs, Volume= 4.236 af
Outflow = 75.77 cfs @ 12.17 hrs, Volume= 4.236 af, Atten= 6%, Lag= 2.2 min

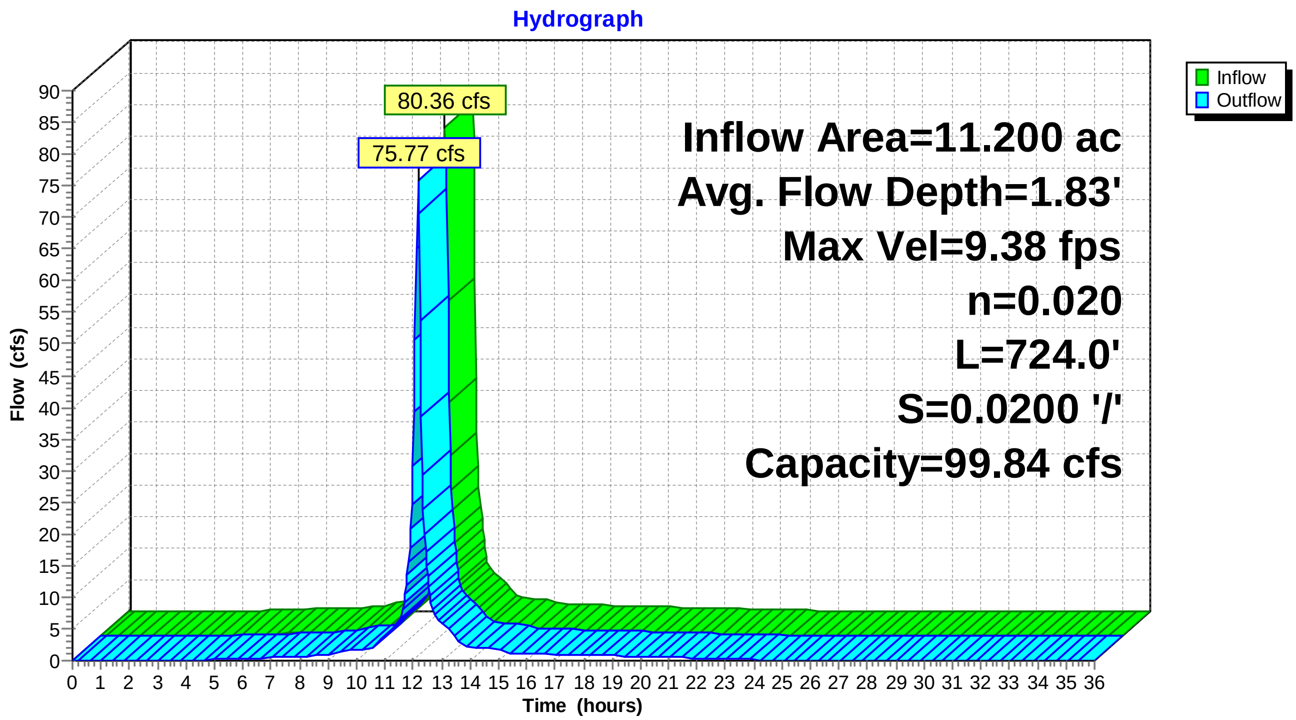
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Max. Velocity= 9.38 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 2.95 fps, Avg. Travel Time= 4.1 min

Peak Storage= 6,046 cf @ 12.15 hrs
Average Depth at Peak Storage= 1.83' , Surface Width= 9.14'
Bank-Full Depth= 2.00' Flow Area= 10.0 sf, Capacity= 99.84 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 2.0 3.0 '/' Top Width= 10.00'
Length= 724.0' Slope= 0.0200 '/'
Inlet Invert= 726.48', Outlet Invert= 712.00'



Reach 42R: DB-C



Summary for Pond 1P: NSB North

Inflow Area = 287.592 ac, 3.48% Impervious, Inflow Depth = 3.83" for 100-yr, 24-hr event
Inflow = 231.01 cfs @ 13.47 hrs, Volume= 91.828 af
Outflow = 197.60 cfs @ 14.93 hrs, Volume= 46.806 af, Atten= 14%, Lag= 87.6 min
Primary = 197.60 cfs @ 14.93 hrs, Volume= 46.806 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Starting Elev= 674.00' Surf.Area= 53,100 sf Storage= 144,600 cf
Peak Elev= 694.52' @ 14.93 hrs Surf.Area= 155,553 sf Storage= 2,335,715 cf (2,191,115 cf above start)

Plug-Flow detention time= 251.0 min calculated for 43.438 af (47% of inflow)
Center-of-Mass det. time= 130.0 min (1,002.1 - 872.1)

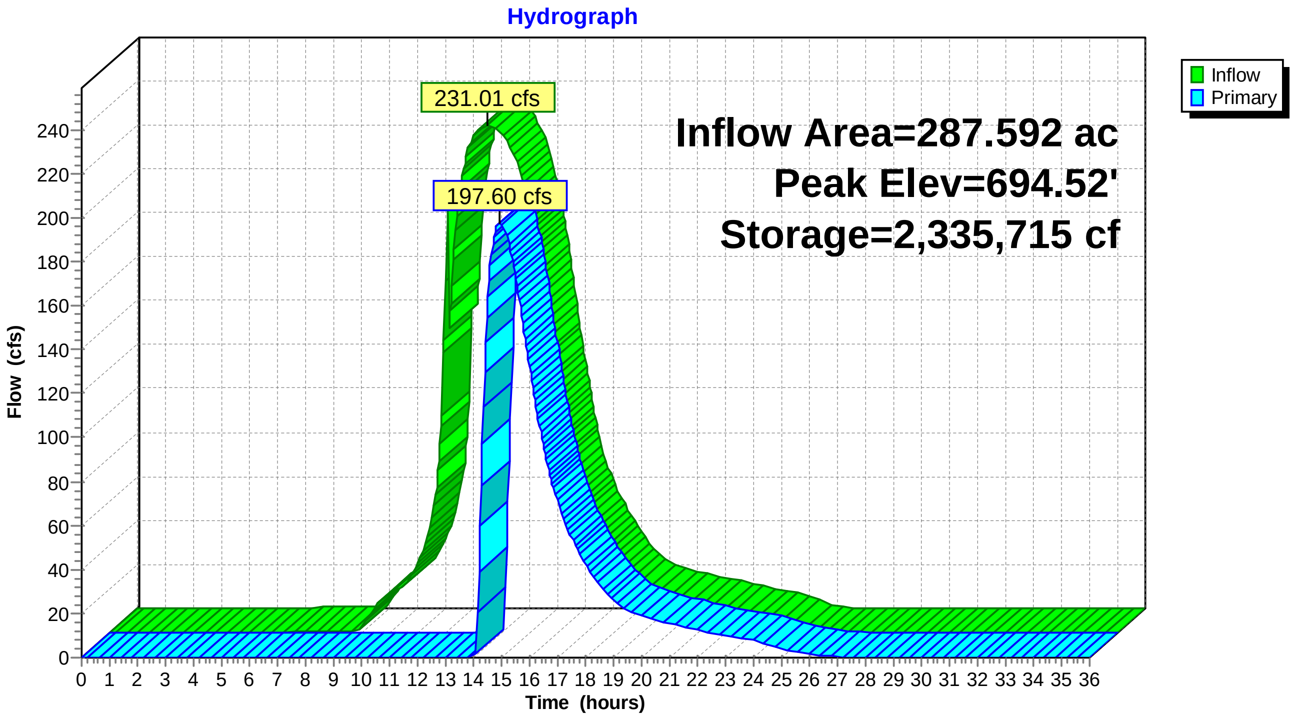
Volume	Invert	Avail.Storage	Storage Description
#1	668.00'	2,910,320 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
668.00	1,200	0	0
670.00	12,400	13,600	13,600
674.00	53,100	131,000	144,600
680.00	87,600	422,100	566,700
690.00	135,200	1,114,000	1,680,700
694.00	152,508	575,416	2,256,116
695.00	158,400	155,454	2,411,570
698.00	174,100	498,750	2,910,320

Device	Routing	Invert	Outlet Devices
#1	Primary	693.00'	**40.0' long x 20.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=196.80 cfs @ 14.93 hrs HW=694.52' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 196.80 cfs @ 3.24 fps)

Pond 1P: NSB North



Summary for Pond 5P: MC VII/IX & MC XI/X Pond

MC X/XI Culverts do not restrict flow in ditch (have more capacity than outlet on north end) therefore they are not modeled.

Inflow Area = 104.325 ac, 5.17% Impervious, Inflow Depth = 3.55" for 100-yr, 24-hr event
Inflow = 344.55 cfs @ 12.36 hrs, Volume= 30.839 af
Outflow = 72.88 cfs @ 13.06 hrs, Volume= 28.672 af, Atten= 79%, Lag= 42.2 min
Primary = 72.88 cfs @ 13.06 hrs, Volume= 28.672 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Starting Elev= 697.10' Storage= 0 cf
Peak Elev= 704.55' @ 13.06 hrs Surf.Area= 174,228 sf Storage= 656,914 cf

Plug-Flow detention time= 126.8 min calculated for 28.640 af (93% of inflow)
Center-of-Mass det. time= 94.6 min (902.1 - 807.5)

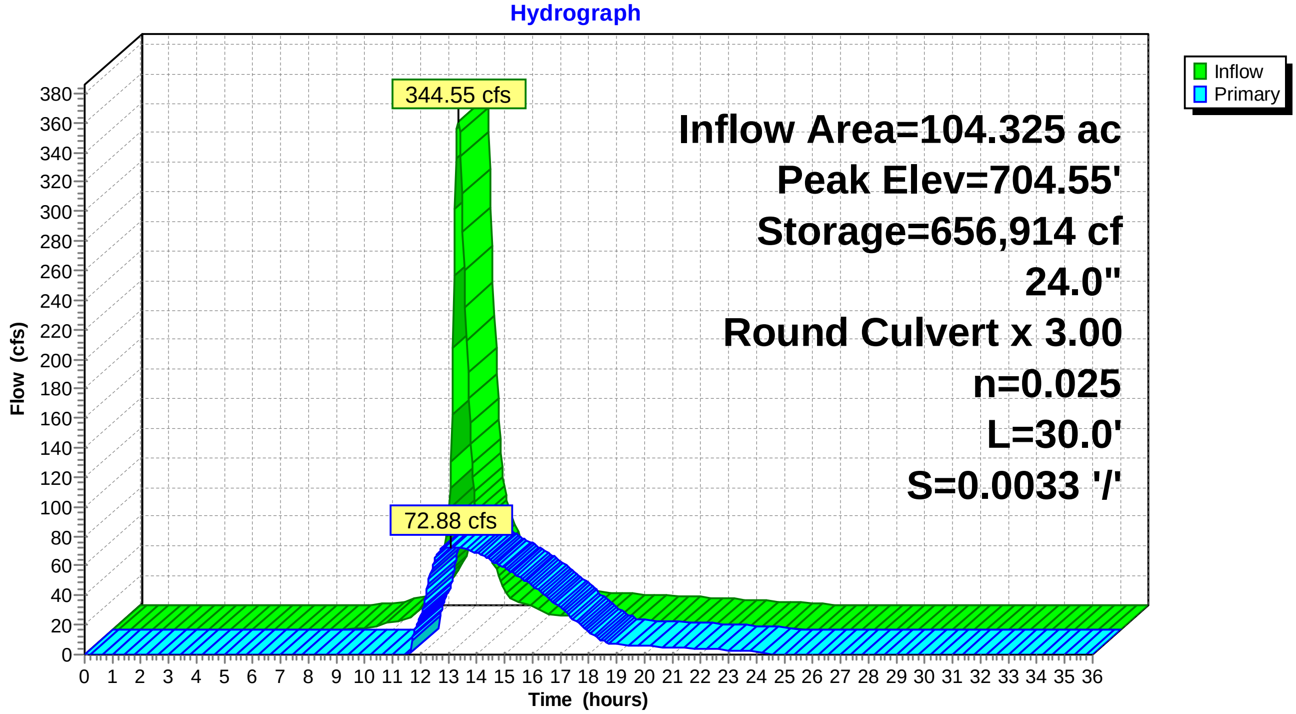
Volume	Invert	Avail.Storage	Storage Description
#1	698.00'	925,600 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
698.00	13,000	0	0
700.00	55,300	68,300	68,300
702.00	137,000	192,300	260,600
704.00	166,000	303,000	563,600
706.00	196,000	362,000	925,600

Device	Routing	Invert	Outlet Devices
#1	Primary	697.10'	**24.0" Round Culvert X 3.00** L= 30.0' CMP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 697.10' / 697.00' S= 0.0033 '/' Cc= 0.900 n= 0.025 Corrugated metal, Flow Area= 3.14 sf

Primary OutFlow Max=72.88 cfs @ 13.06 hrs HW=704.55' TW=700.41' (Fixed TW Elev= 700.41')
└─**1=Culvert** (Inlet Controls 72.88 cfs @ 7.73 fps)

Pond 5P: MC VII/IX & MC XI/X Pond



Summary for Pond 7P: MC VII/XI Pond

Inflow Area = 32.398 ac, 2.76% Impervious, Inflow Depth = 3.85" for 100-yr, 24-hr event
Inflow = 134.54 cfs @ 12.20 hrs, Volume= 10.382 af
Outflow = 97.21 cfs @ 12.37 hrs, Volume= 10.117 af, Atten= 28%, Lag= 10.2 min
Primary = 97.21 cfs @ 12.37 hrs, Volume= 10.117 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 708.37' @ 12.37 hrs Surf.Area= 47,137 sf Storage= 93,554 cf

Plug-Flow detention time= 34.6 min calculated for 10.106 af (97% of inflow)
Center-of-Mass det. time= 20.6 min (807.7 - 787.1)

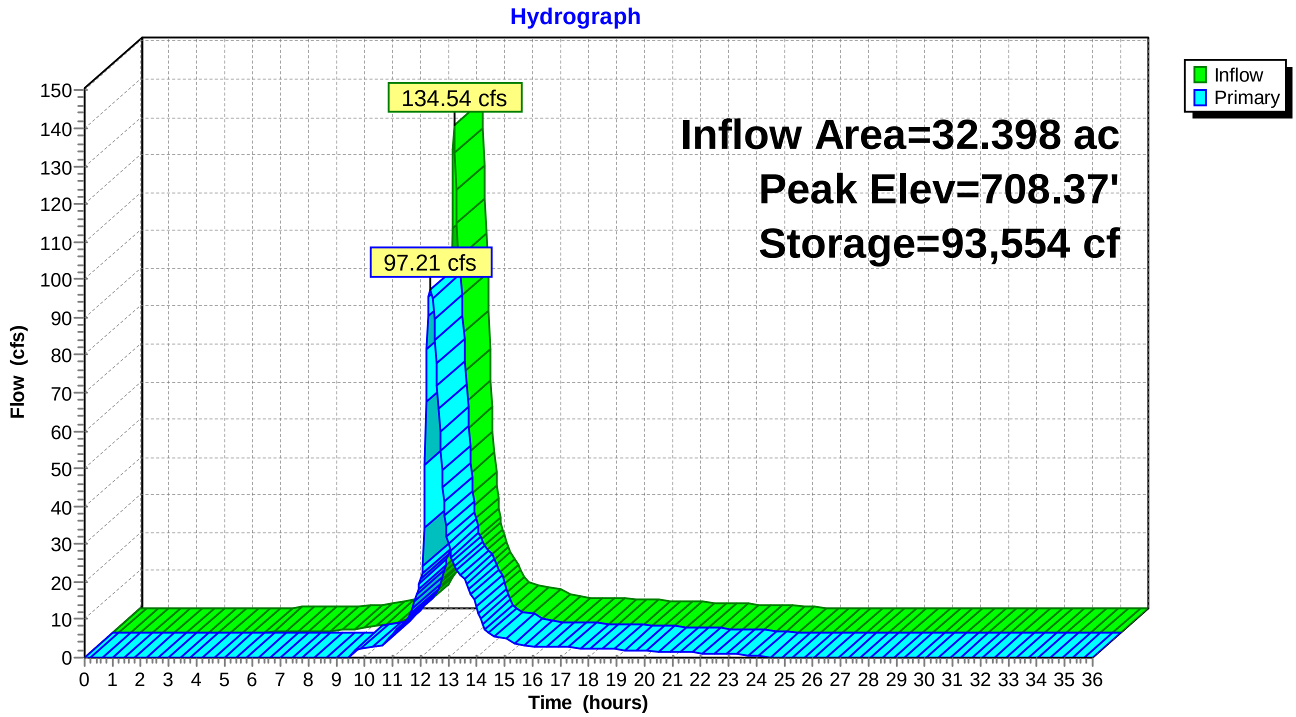
Volume	Invert	Avail.Storage	Storage Description
#1	700.00'	200,200 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
700.00	0	0	0
702.00	1,450	1,450	1,450
704.00	5,200	6,650	8,100
706.00	12,750	17,950	26,050
708.00	38,900	51,650	77,700
710.00	83,600	122,500	200,200

Device	Routing	Invert	Outlet Devices
#1	Primary	700.30'	**24.0" Round Culvert** L= 40.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 700.30' / 699.40' S= 0.0225 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 3.14 sf
#2	Primary	707.00'	**16.0' long x 25.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63

Primary OutFlow Max=96.96 cfs @ 12.37 hrs HW=708.37' TW=704.55' (Fixed TW Elev= 704.55')
1=Culvert (Inlet Controls 29.55 cfs @ 9.41 fps)
2=Broad-Crested Rectangular Weir (Weir Controls 67.41 cfs @ 3.09 fps)

Pond 7P: MC VII/XI Pond



Summary for Pond 8P: NSB South

Inflow Area = 287.592 ac, 3.48% Impervious, Inflow Depth = 1.95" for 100-yr, 24-hr event
Inflow = 197.60 cfs @ 14.93 hrs, Volume= 46.806 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

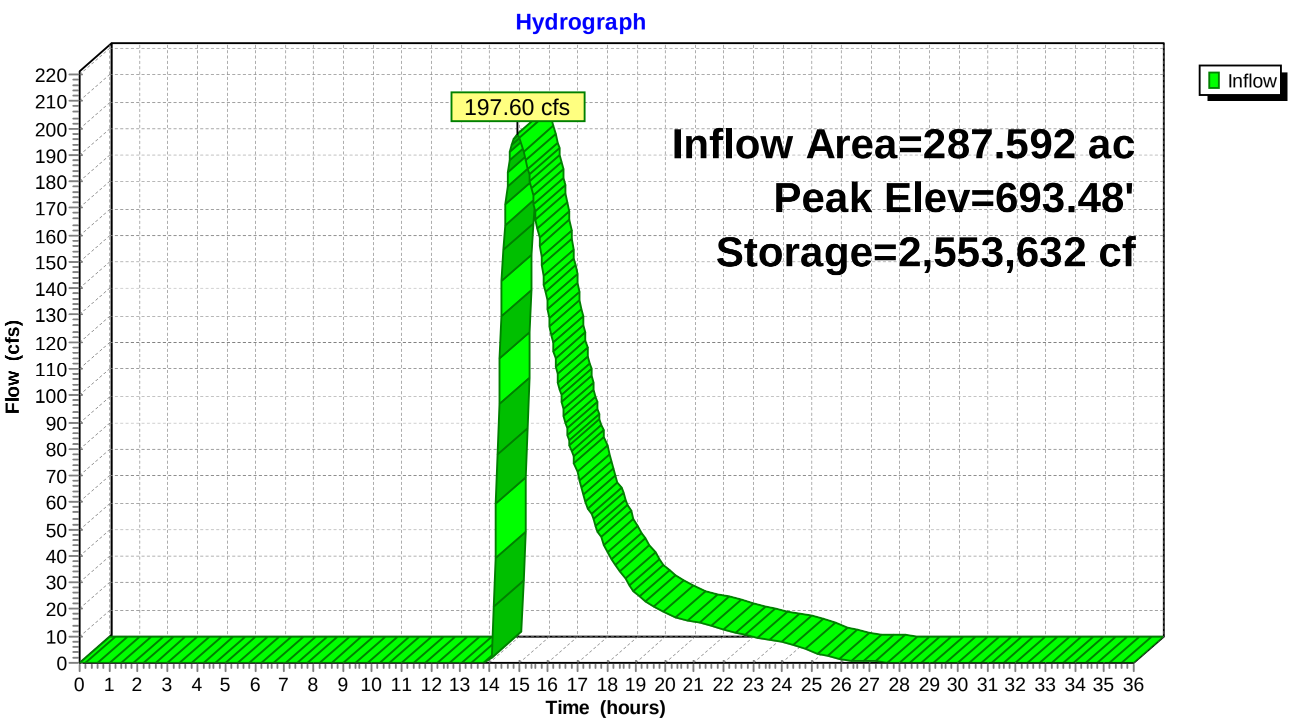
Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Starting Elev= 680.00' Surf.Area= 98,500 sf Storage= 514,800 cf
Peak Elev= 693.48' @ 36.00 hrs Surf.Area= 200,487 sf Storage= 2,553,632 cf (2,038,832 cf above start)

Plug-Flow detention time= (not calculated: initial storage exceeds outflow)
Center-of-Mass det. time= (not calculated: no outflow)

Volume	Invert	Avail.Storage	Storage Description
#1	672.00'	2,867,350 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
672.00	30,200	0	0
680.00	98,500	514,800	514,800
690.00	177,700	1,381,000	1,895,800
694.00	203,900	763,200	2,659,000
695.00	212,800	208,350	2,867,350

Pond 8P: NSB South



Summary for Pond 11P: NWD / NW-MC VII

Inflow Area = 125.401 ac, 3.69% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 773.35 cfs @ 12.15 hrs, Volume= 47.427 af
Outflow = 157.20 cfs @ 12.52 hrs, Volume= 47.427 af, Atten= 80%, Lag= 21.9 min
Primary = 157.20 cfs @ 12.52 hrs, Volume= 47.427 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 711.78' @ 12.52 hrs Surf.Area= 195,680 sf Storage= 784,815 cf

Plug-Flow detention time= 47.1 min calculated for 47.374 af (100% of inflow)
Center-of-Mass det. time= 47.0 min (811.6 - 764.6)

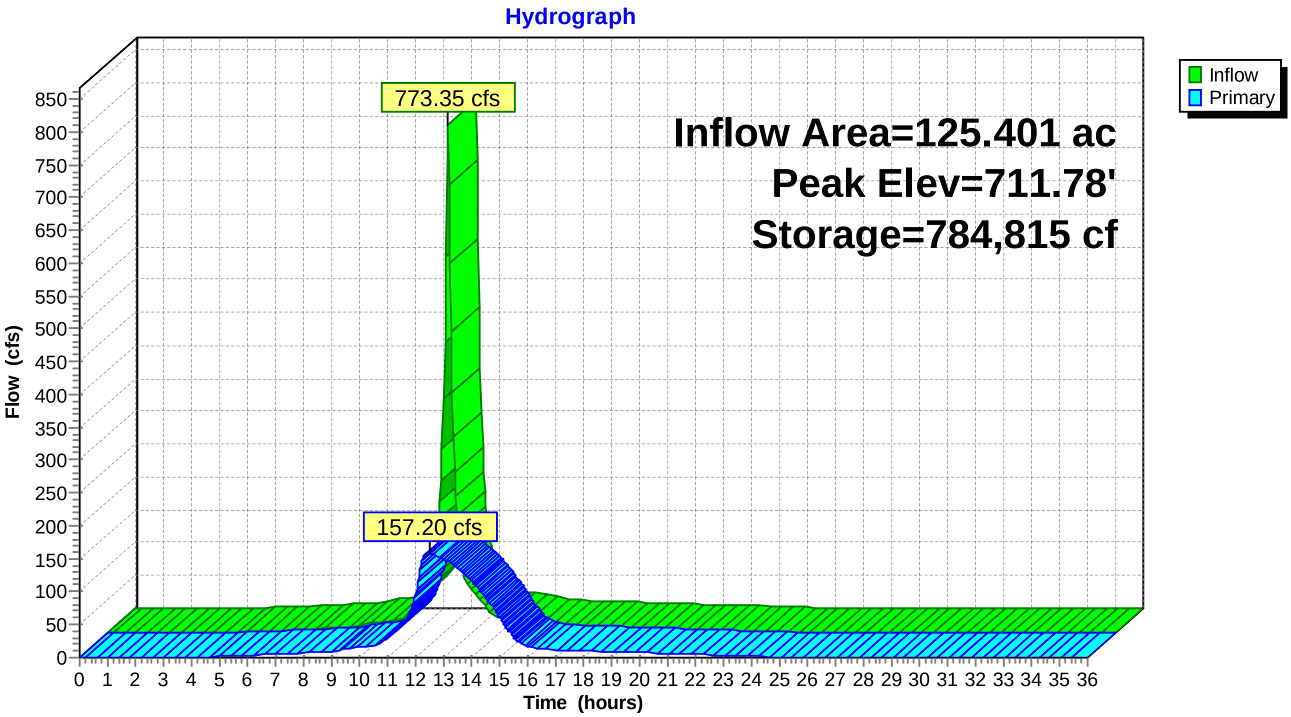
Volume	Invert	Avail.Storage	Storage Description
#1	704.30'	827,625 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
704.30	0	0	0
706.00	68,500	58,225	58,225
708.00	102,200	170,700	228,925
710.00	147,500	249,700	478,625
712.00	201,500	349,000	827,625

Device	Routing	Invert	Outlet Devices
#1	Primary	704.30'	**30.0" Round 30" HDPE Culverts X 3.00** L= 125.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 704.30' / 699.00' S= 0.0424 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 4.91 sf
#2	Primary	704.30'	**18.0" Round 18" HDPE Culverts** L= 125.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 704.30' / 699.00' S= 0.0424 '/' Cc= 0.900 n= 0.012, Flow Area= 1.77 sf

Primary OutFlow Max=157.20 cfs @ 12.52 hrs HW=711.78' TW=702.65' (Fixed TW Elev= 702.65')
1=30" HDPE Culverts (Inlet Controls 139.77 cfs @ 9.49 fps)
2=18" HDPE Culverts (Inlet Controls 17.43 cfs @ 9.86 fps)

Pond 11P: NWD / NW-MC VII



Summary for Pond 19P: E-MC IX Culvert

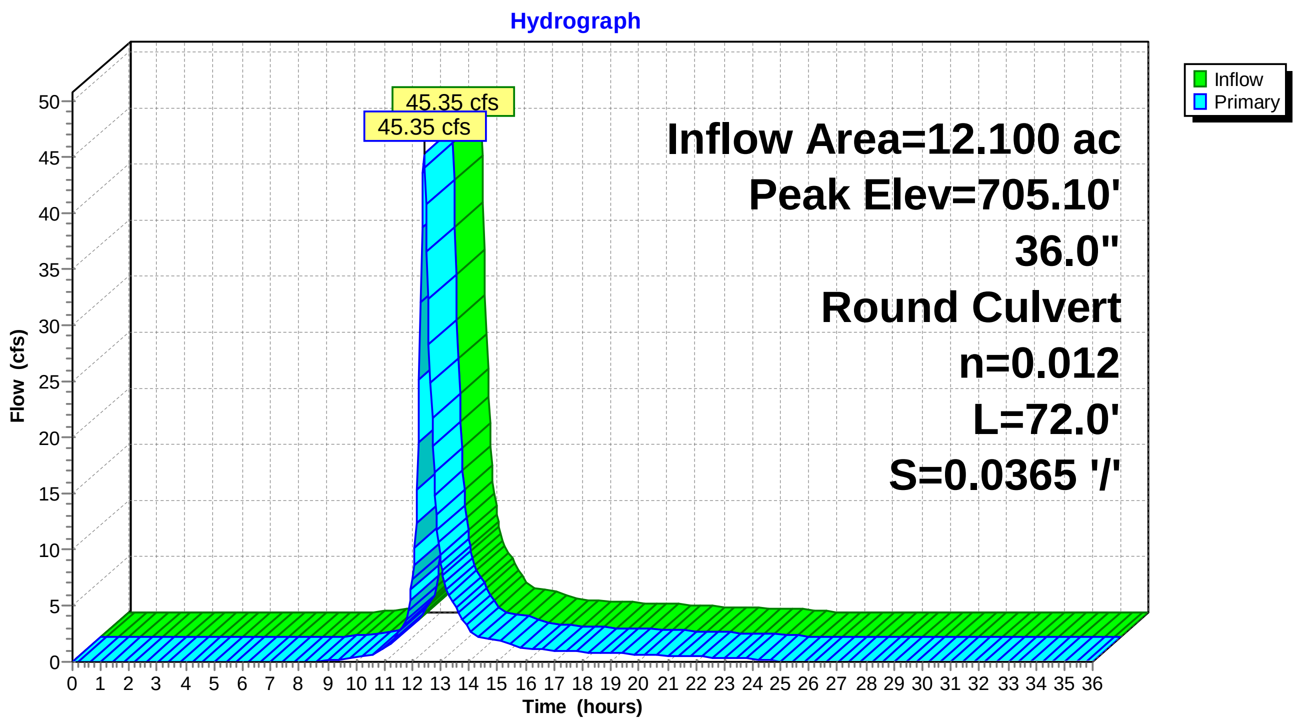
Inflow Area = 12.100 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 45.35 cfs @ 12.40 hrs, Volume= 3.409 af
Outflow = 45.35 cfs @ 12.40 hrs, Volume= 3.409 af, Atten= 0%, Lag= 0.0 min
Primary = 45.35 cfs @ 12.40 hrs, Volume= 3.409 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 705.10' @ 12.40 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	701.82'	**36.0" Round Culvert** L= 72.0' CPP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 701.82' / 699.19' S= 0.0365 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 7.07 sf

Primary OutFlow Max=45.25 cfs @ 12.40 hrs HW=705.09' TW=698.17' (Fixed TW Elev= 698.17')
└─**1=Culvert** (Inlet Controls 45.25 cfs @ 6.40 fps)

Pond 19P: E-MC IX Culvert



Summary for Pond 37P: N-MC VII Ditch

Inflow Area = 133.429 ac, 3.47% Impervious, Inflow Depth = 4.47" for 100-yr, 24-hr event
Inflow = 183.24 cfs @ 12.33 hrs, Volume= 49.688 af
Outflow = 165.20 cfs @ 12.69 hrs, Volume= 48.047 af, Atten= 10%, Lag= 21.4 min
Primary = 165.20 cfs @ 12.69 hrs, Volume= 48.047 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 702.65' @ 12.69 hrs Surf.Area= 40,743 sf Storage= 152,731 cf

Plug-Flow detention time= 34.4 min calculated for 47.993 af (97% of inflow)
Center-of-Mass det. time= 17.7 min (828.9 - 811.3)

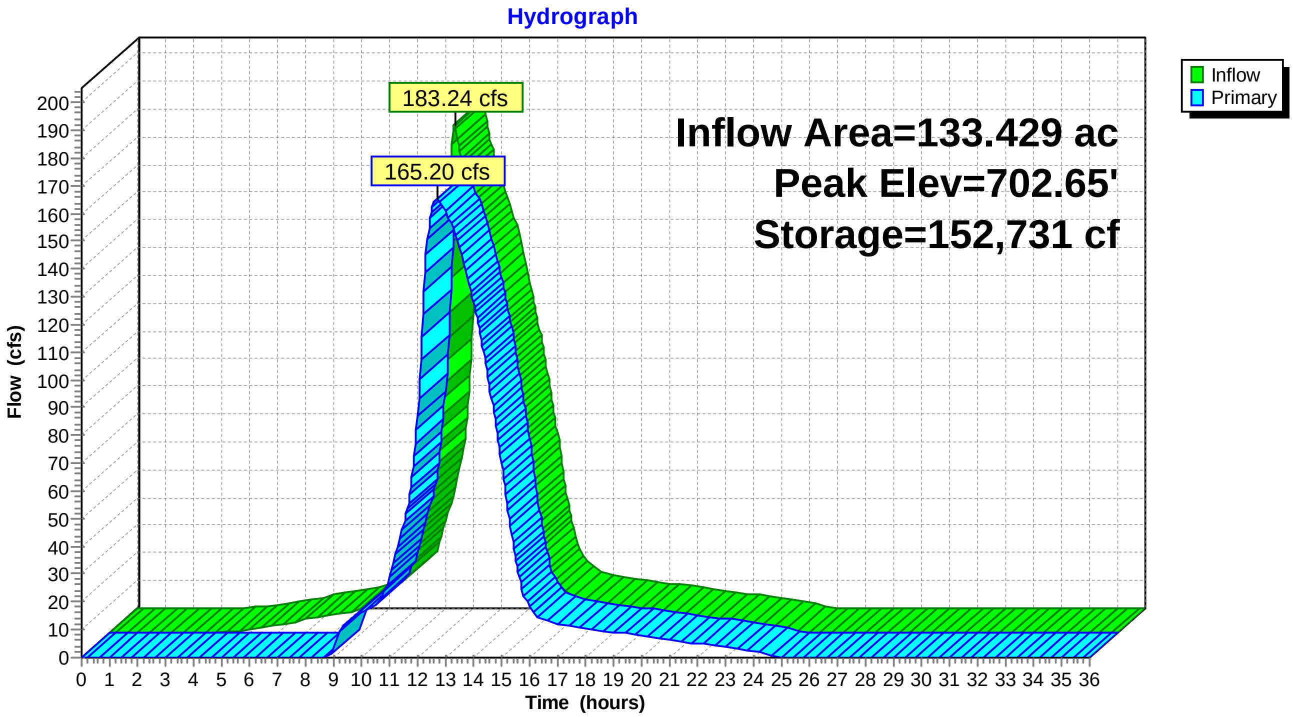
Volume	Invert	Avail.Storage	Storage Description
#1	696.77'	167,201 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
696.77	0	0	0
697.00	2,561	295	295
698.00	14,817	8,689	8,984
699.00	26,696	20,757	29,740
700.00	30,510	28,603	58,343
701.00	34,346	32,428	90,771
702.00	38,204	36,275	127,046
703.00	42,106	40,155	167,201

Device	Routing	Invert	Outlet Devices
#1	Primary	696.77'	**54.0" Round 54" Culvert** L= 42.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 696.77' / 696.61' S= 0.0038 '/' Cc= 0.900 n= 0.012, Flow Area= 15.90 sf
#2	Primary	696.77'	**36.0" Round 36" Culvert** L= 42.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 696.77' / 696.61' S= 0.0038 '/' Cc= 0.900 n= 0.012, Flow Area= 7.07 sf

Primary OutFlow Max=165.18 cfs @ 12.69 hrs HW=702.65' TW=700.42' (Fixed TW Elev= 700.42')
1=54" Culvert (Inlet Controls 114.36 cfs @ 7.19 fps)
2=36" Culvert (Inlet Controls 50.83 cfs @ 7.19 fps)

Pond 37P: N-MC VII Ditch



Summary for Pond 38P: N-MC IX Ditch

Inflow Area = 276.502 ac, 3.62% Impervious, Inflow Depth = 3.80" for 100-yr, 24-hr event
Inflow = 330.31 cfs @ 12.37 hrs, Volume= 87.634 af
Outflow = 227.98 cfs @ 13.60 hrs, Volume= 87.634 af, Atten= 31%, Lag= 74.0 min
Primary = 227.98 cfs @ 13.60 hrs, Volume= 87.634 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.04 hrs
Peak Elev= 700.54' @ 13.60 hrs Surf.Area= 180,365 sf Storage= 507,634 cf

Plug-Flow detention time= 27.8 min calculated for 87.634 af (100% of inflow)
Center-of-Mass det. time= 27.8 min (877.7 - 849.9)

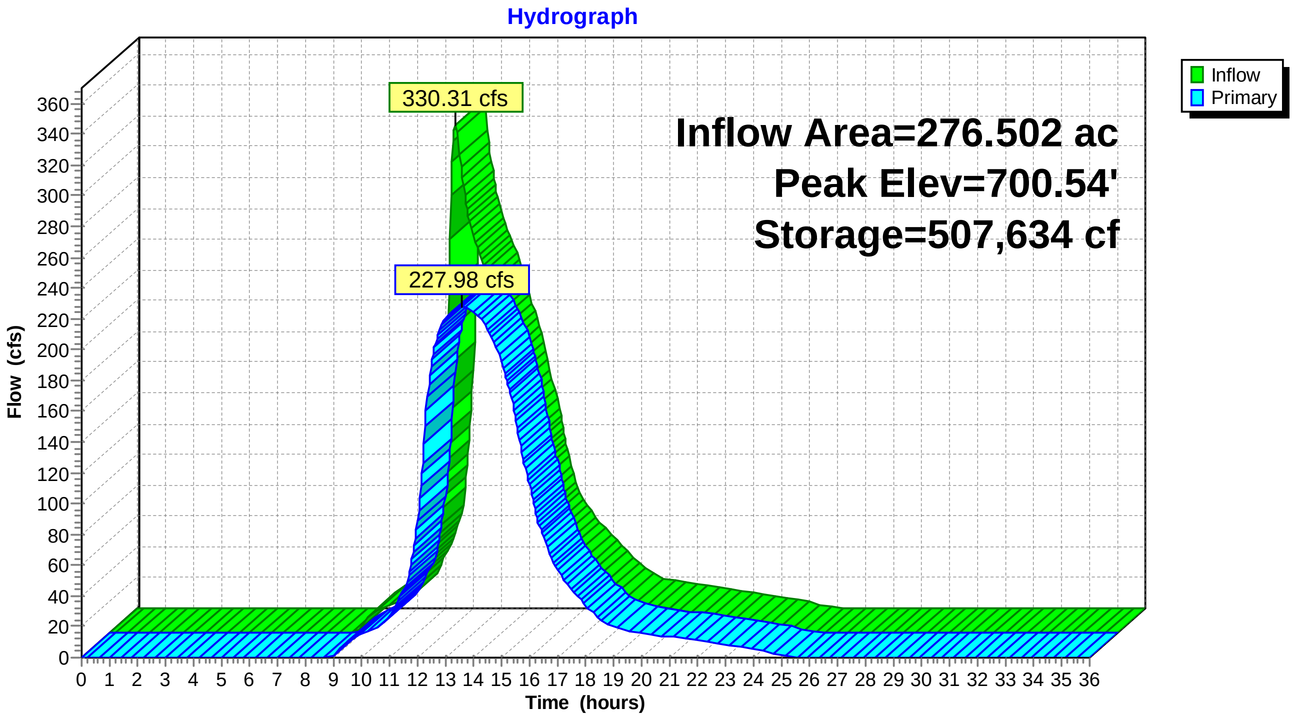
Volume	Invert	Avail.Storage	Storage Description
#1	694.90'	799,720 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
694.90	0	0	0
695.00	350	18	18
696.00	27,524	13,937	13,955
698.00	103,447	130,971	144,926
700.00	166,382	269,829	414,755
702.00	218,583	384,965	799,720

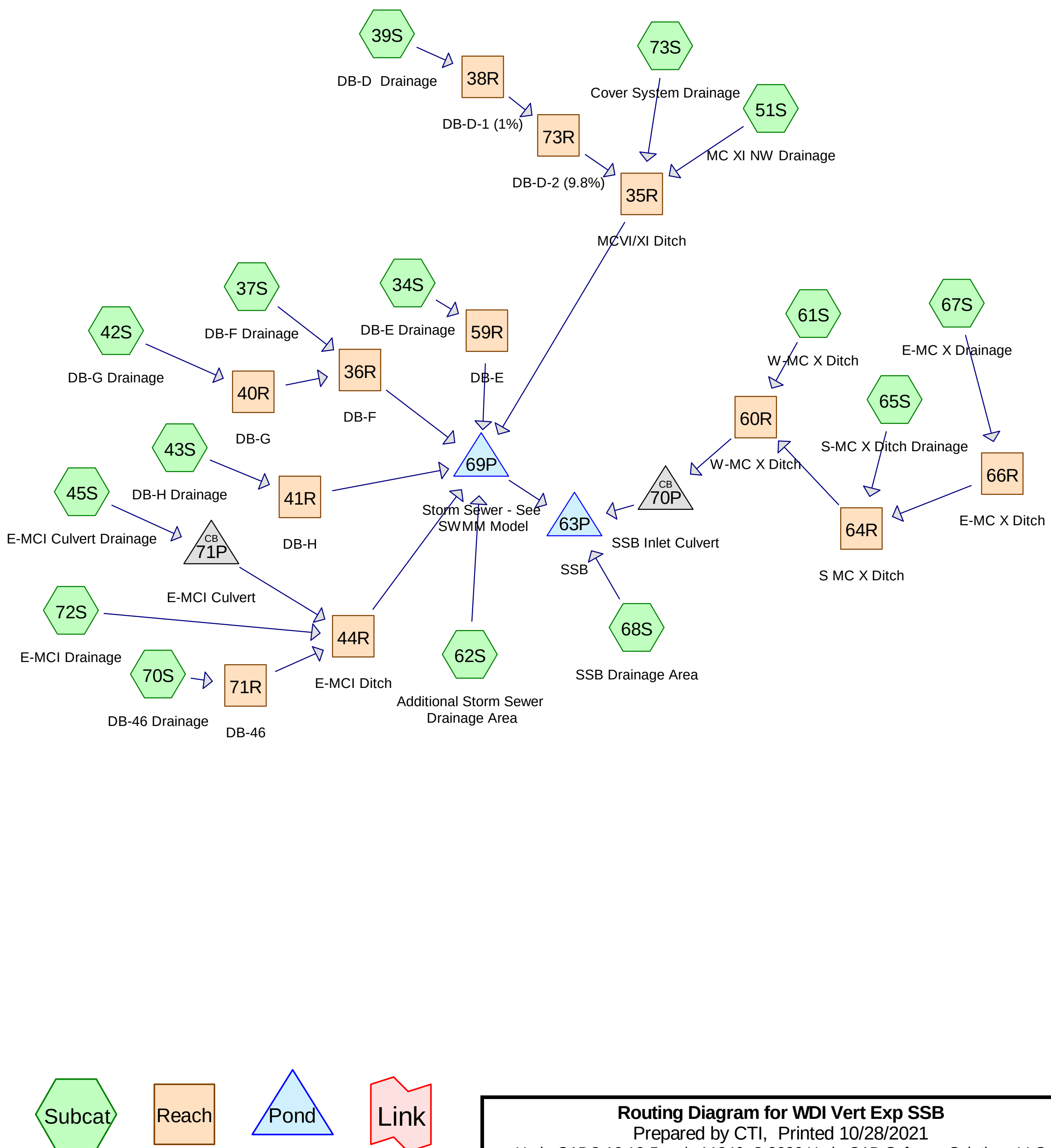
Device	Routing	Invert	Outlet Devices
#1	Primary	694.96'	**30.0" Round 30" Culvert X 3.00** L= 110.0' CMP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 694.96' / 694.96' S= 0.0000 '/' Cc= 0.900 n= 0.025, Flow Area= 4.91 sf
#2	Primary	694.90'	**54.0" Round 54" Culvert** L= 110.0' RCP, sq.cut end projecting, Ke= 0.500 Inlet / Outlet Invert= 694.90' / 690.50' S= 0.0400 '/' Cc= 0.900 n= 0.012, Flow Area= 15.90 sf

Primary OutFlow Max=227.98 cfs @ 13.60 hrs HW=700.54' TW=694.18' (Fixed TW Elev= 694.18')
1=30" Culvert (Barrel Controls 87.07 cfs @ 5.91 fps)
2=54" Culvert (Inlet Controls 140.91 cfs @ 8.86 fps)

Pond 38P: N-MC IX Ditch



South Sedimentation Basin (SSB) HYDROCAD OUTPUT – 25-yr, 24-hr



Routing Diagram for WDI Vert Exp SSB
Prepared by CTI, Printed 10/28/2021
HydroCAD® 10.10-5a s/n 11246 © 2020 HydroCAD Software Solutions LLC

Time span=0.00-36.00 hrs, dt=0.02 hrs, 1801 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 34S: DB-E Drainage Runoff Area=86,500 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=476' Tc=3.4 min CN=95 Runoff=12.17 cfs 0.560 af

Subcatchment 37S: DB-F Drainage Runoff Area=63,437 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=280' Tc=5.0 min CN=95 Runoff=8.55 cfs 0.410 af

Subcatchment 39S: DB-D Drainage Runoff Area=384,155 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=62' Slope=0.2500 '/' Tc=2.4 min CN=95 Runoff=55.79 cfs 2.485 af

Subcatchment 42S: DB-G Drainage Runoff Area=82,915 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=52' Slope=0.2500 '/' Tc=2.1 min CN=95 Runoff=12.16 cfs 0.536 af

Subcatchment 43S: DB-H Drainage Runoff Area=8,958 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=77' Tc=9.3 min CN=95 Runoff=1.01 cfs 0.058 af

Subcatchment 45S: E-MCI Culvert Drainage Runoff Area=136,608 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=667' Tc=22.3 min CN=84 Runoff=7.72 cfs 0.608 af

Subcatchment 51S: MC XI NW Drainage Runoff Area=464,875 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=480' Slope=0.0520 '/' Tc=16.5 min CN=84 Runoff=30.74 cfs 2.070 af

Subcatchment 61S: W-MC X Ditch Runoff Area=141,400 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=150' Slope=0.2500 '/' Tc=5.8 min CN=84 Runoff=14.01 cfs 0.629 af

Subcatchment 62S: Additional Storm Sewer Runoff Area=237,200 sf 100.00% Impervious Runoff Depth=3.72"
Tc=0.0 min CN=98 Runoff=35.48 cfs 1.686 af

Subcatchment 65S: S-MC X Ditch Drainage Runoff Area=205,200 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=160' Slope=0.3300 '/' Tc=5.4 min CN=84 Runoff=20.59 cfs 0.914 af

Subcatchment 67S: E-MC X Drainage Runoff Area=253,500 sf 0.00% Impervious Runoff Depth=2.33"
Flow Length=110' Slope=0.2500 '/' Tc=4.5 min CN=84 Runoff=26.56 cfs 1.129 af

Subcatchment 68S: SSB Drainage Area Runoff Area=900,800 sf 23.12% Impervious Runoff Depth=2.59"
Flow Length=400' Slope=0.0730 '/' Tc=13.7 min CN=87 Runoff=71.50 cfs 4.465 af

Subcatchment 70S: DB-46 Drainage Runoff Area=455,500 sf 0.00% Impervious Runoff Depth=2.00"
Flow Length=450' Slope=0.0350 '/' Tc=19.1 min CN=80 Runoff=24.00 cfs 1.743 af

Subcatchment 72S: E-MCI Drainage Runoff Area=177,527 sf 0.00% Impervious Runoff Depth=2.00"
Flow Length=1,086' Tc=33.4 min CN=80 Runoff=6.83 cfs 0.679 af

Subcatchment 73S: Cover System Drainage Runoff Area=858,183 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=1,385' Tc=9.7 min CN=95 Runoff=95.79 cfs 5.552 af

Reach 35R: MCVI/XI Ditch Avg. Flow Depth=1.66' Max Vel=7.73 fps Inflow=162.49 cfs 10.107 af
n=0.020 L=290.0' S=0.0100 '/' Capacity=1,123.17 cfs Outflow=161.20 cfs 10.107 af

Reach 36R: DB-F Avg. Flow Depth=1.15' Max Vel=4.95 fps Inflow=20.35 cfs 0.947 af
n=0.020 L=402.0' S=0.0100 '/' Capacity=85.77 cfs Outflow=19.72 cfs 0.947 af

Reach 38R: DB-D-1 (1%) Avg. Flow Depth=1.58' Max Vel=6.10 fps Inflow=55.79 cfs 2.485 af
n=0.020 L=1,851.0' S=0.0100 '/' Capacity=155.51 cfs Outflow=45.12 cfs 2.485 af

Reach 40R: DB-G Avg. Flow Depth=0.69' Max Vel=8.20 fps Inflow=12.16 cfs 0.536 af
n=0.020 L=610.0' S=0.0540 '/' Capacity=199.31 cfs Outflow=11.80 cfs 0.536 af

Reach 41R: DB-H Avg. Flow Depth=0.38' Max Vel=2.35 fps Inflow=1.01 cfs 0.058 af
n=0.020 L=127.1' S=0.0100 '/' Capacity=85.74 cfs Outflow=1.00 cfs 0.058 af

Reach 44R: E-MCI Ditch Avg. Flow Depth=1.87' Max Vel=3.51 fps Inflow=37.12 cfs 3.031 af
n=0.025 L=250.0' S=0.0041 '/' Capacity=129.69 cfs Outflow=36.98 cfs 3.031 af

Reach 59R: DB-E Avg. Flow Depth=0.94' Max Vel=4.32 fps Inflow=12.17 cfs 0.560 af
n=0.020 L=576.5' S=0.0100 '/' Capacity=85.81 cfs Outflow=11.41 cfs 0.560 af

Reach 60R: W-MC X Ditch Avg. Flow Depth=1.02' Max Vel=2.42 fps Inflow=22.31 cfs 2.672 af
n=0.025 L=833.0' S=0.0024 '/' Capacity=326.61 cfs Outflow=21.03 cfs 2.672 af

Reach 64R: S MC X Ditch Avg. Flow Depth=2.07' Max Vel=2.77 fps Inflow=23.26 cfs 2.042 af
n=0.025 L=1,110.0' S=0.0027 '/' Capacity=103.29 cfs Outflow=17.73 cfs 2.042 af

Reach 66R: E-MC X Ditch Avg. Flow Depth=1.26' Max Vel=1.81 fps Inflow=26.56 cfs 1.129 af
n=0.030 L=1,500.0' S=0.0025 '/' Capacity=145.10 cfs Outflow=14.40 cfs 1.129 af

Reach 71R: DB-46 Avg. Flow Depth=1.00' Max Vel=3.70 fps Inflow=24.00 cfs 1.743 af
n=0.025 L=200.0' S=0.0100 '/' Capacity=152.89 cfs Outflow=23.88 cfs 1.743 af

Reach 73R: DB-D-2 (9.8%) Avg. Flow Depth=1.02' Max Vel=14.29 fps Inflow=45.12 cfs 2.485 af
n=0.020 L=187.0' S=0.0980 '/' Capacity=486.88 cfs Outflow=44.84 cfs 2.485 af

Pond 63P: SSB Inflow=298.73 cfs 23.524 af
Primary=298.73 cfs 23.524 af

Pond 69P: Storm Sewer - See SWMM Model Inflow=215.54 cfs 16.388 af
Primary=215.54 cfs 16.388 af

Pond 70P: SSB Inlet Culvert Peak Elev=690.92' Inflow=21.03 cfs 2.672 af
30.0" Round Culvert n=0.012 L=113.0' S=-0.0012 '/' Outflow=21.03 cfs 2.672 af

Pond 71P: E-MCI Culvert Peak Elev=705.52' Inflow=7.72 cfs 0.608 af
24.0" Round Culvert n=0.012 L=80.0' S=0.0025 '/' Outflow=7.72 cfs 0.608 af

Total Runoff Area = 102.313 ac Runoff Volume = 23.524 af Average Runoff Depth = 2.76"
90.00% Pervious = 92.086 ac 10.00% Impervious = 10.227 ac

Summary for Subcatchment 34S: DB-E Drainage

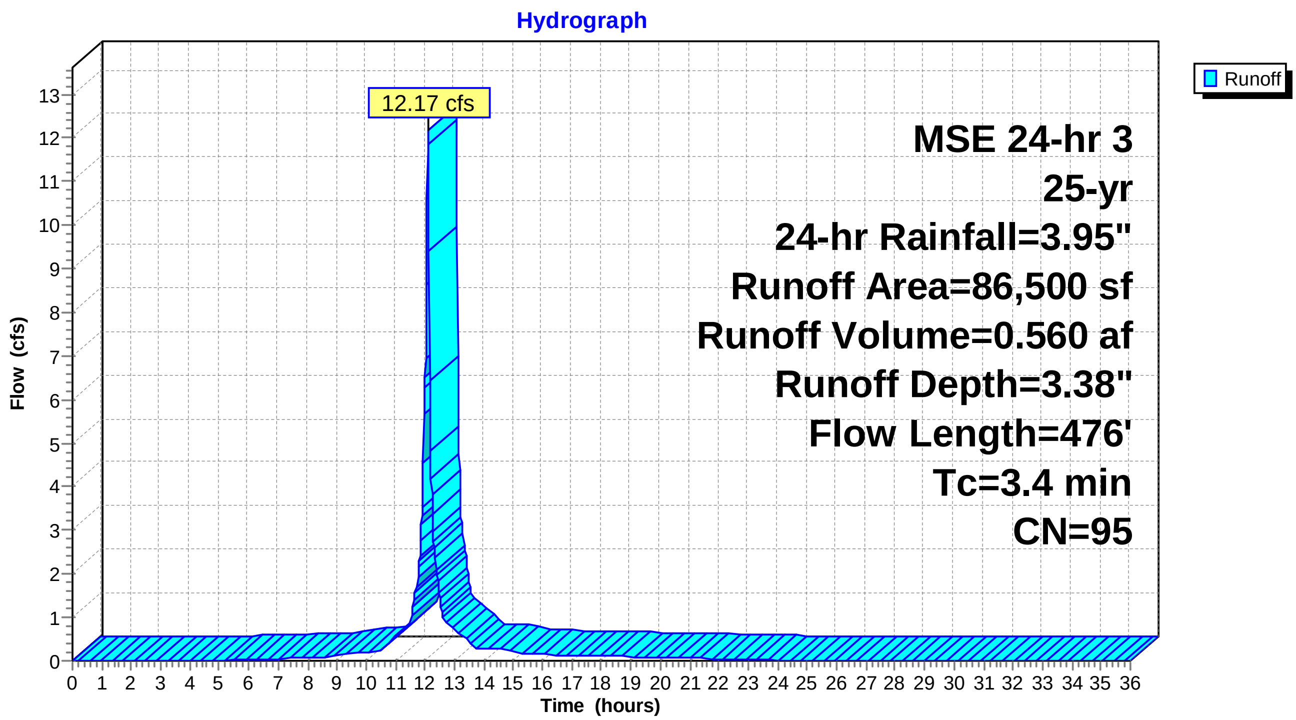
Runoff = 12.17 cfs @ 12.10 hrs, Volume= 0.560 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	86,500	95	Closure Turf
	86,500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.5	66	0.2500	0.44		**Sheet Flow,** n= 0.120 P2= 2.35"
0.9	410	0.0100	7.43	89.16	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.020
3.4	476	Total			

Subcatchment 34S: DB-E Drainage



Summary for Subcatchment 37S: DB-F Drainage

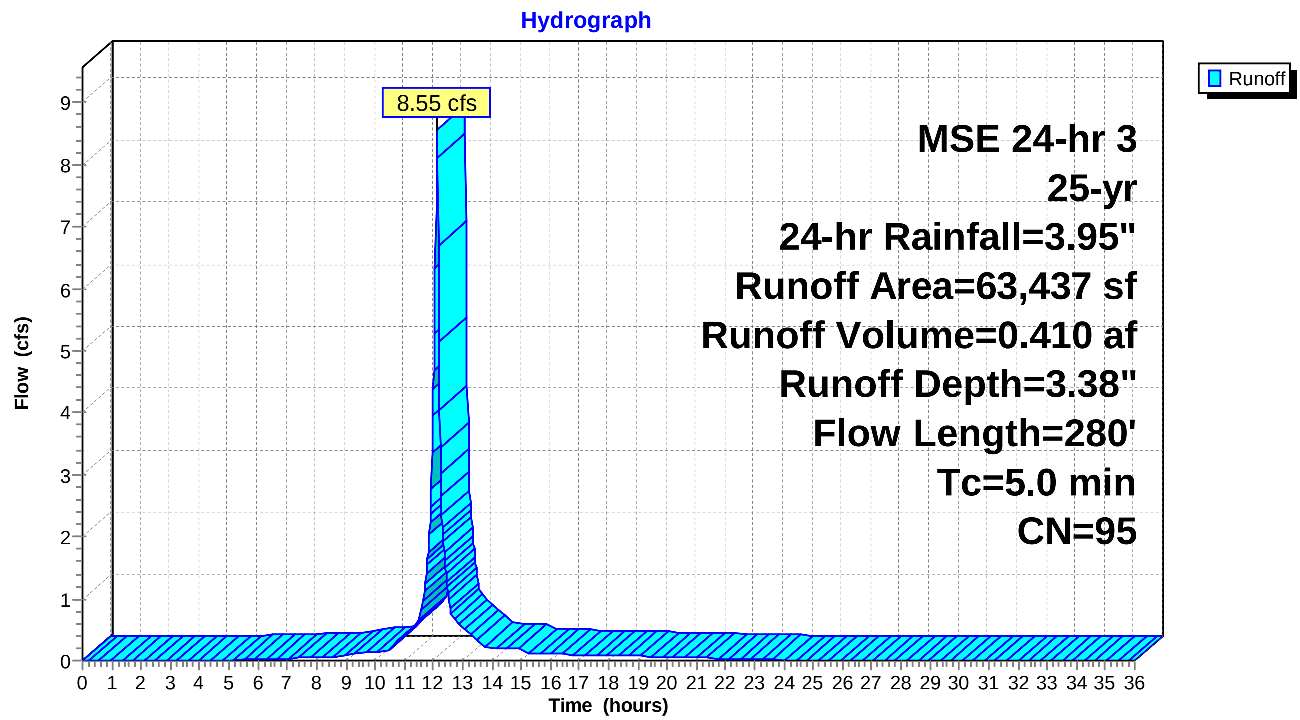
Runoff = 8.55 cfs @ 12.12 hrs, Volume= 0.410 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	63,437	95	Closure Turf
	63,437		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.5	65	0.2500	0.44		**Sheet Flow,** n= 0.120 P2= 2.35"
2.5	215	0.0050	1.44		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
5.0	280	Total			

Subcatchment 37S: DB-F Drainage



Summary for Subcatchment 39S: DB-D Drainage

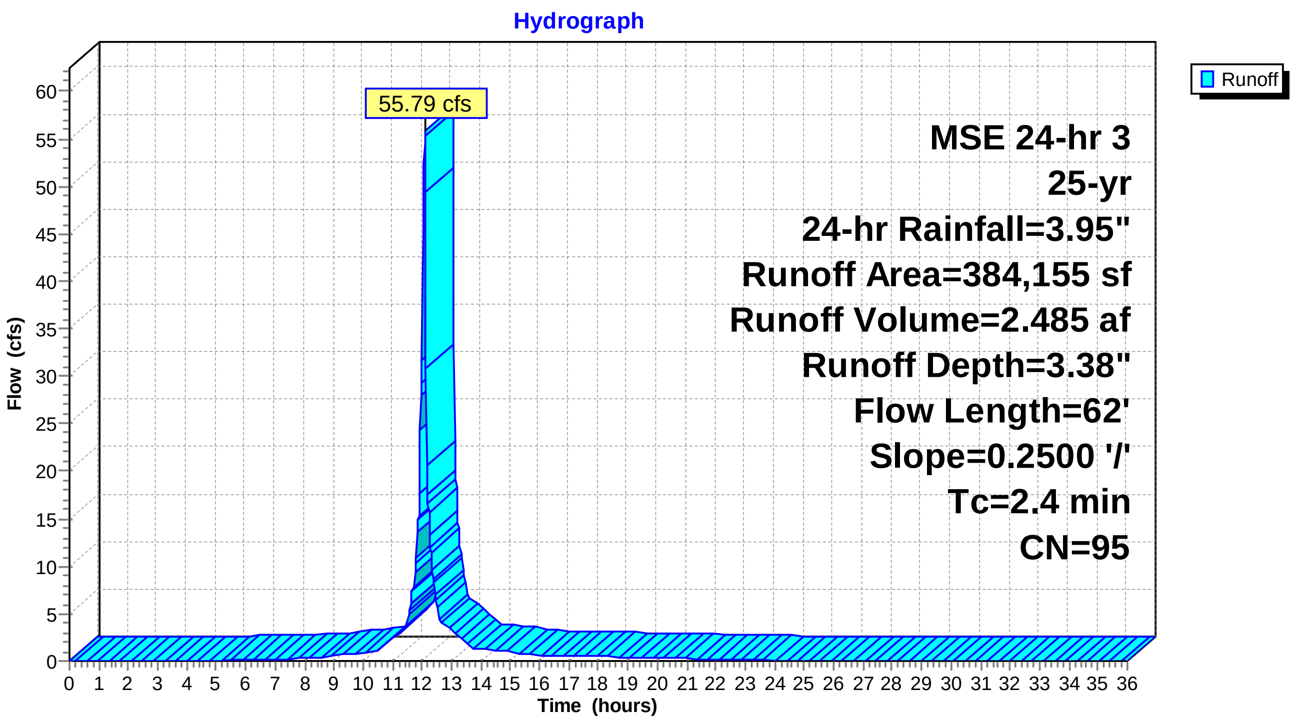
Runoff = 55.79 cfs @ 12.09 hrs, Volume= 2.485 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	384,155	95	Closure Turf
	384,155		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.4	62	0.2500	0.43		**Sheet Flow,** n= 0.120 P2= 2.35"

Subcatchment 39S: DB-D Drainage



Summary for Subcatchment 42S: DB-G Drainage

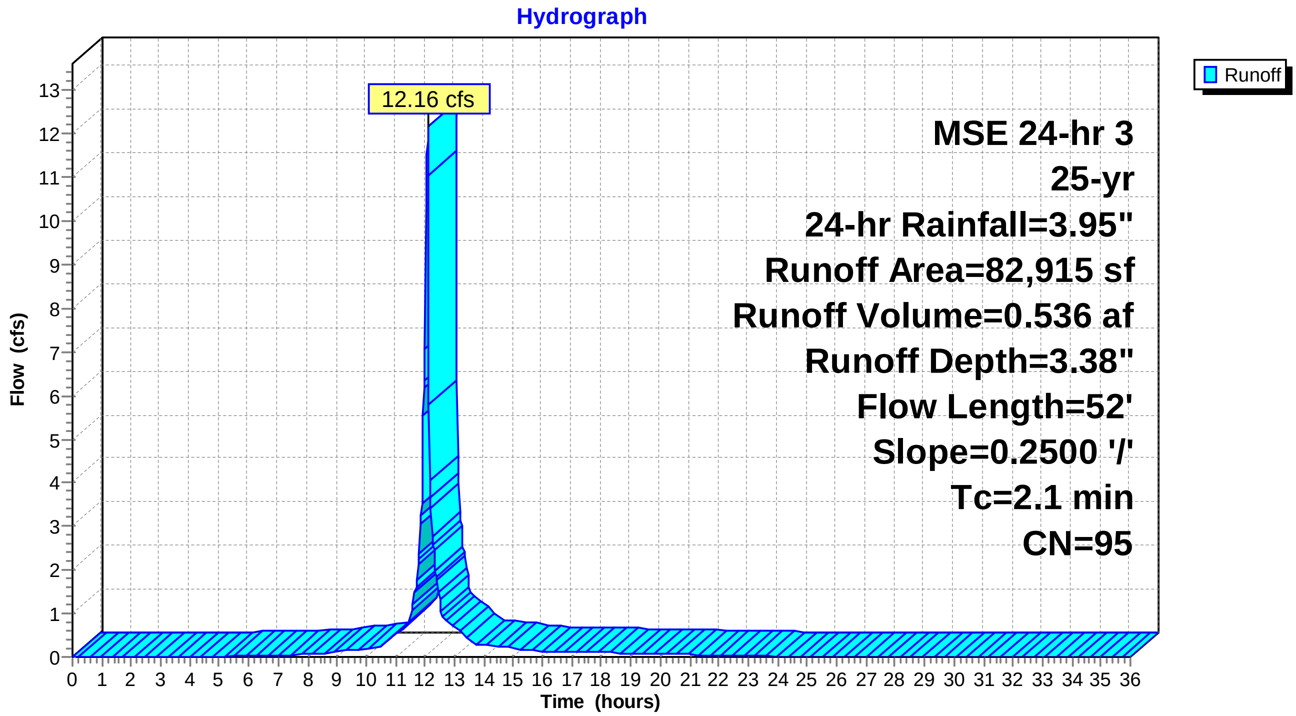
Runoff = 12.16 cfs @ 12.09 hrs, Volume= 0.536 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	82,915	95	Closure Turf
	82,915		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.1	52	0.2500	0.42		**Sheet Flow,** n= 0.120 P2= 2.35"

Subcatchment 42S: DB-G Drainage



Summary for Subcatchment 43S: DB-H Drainage

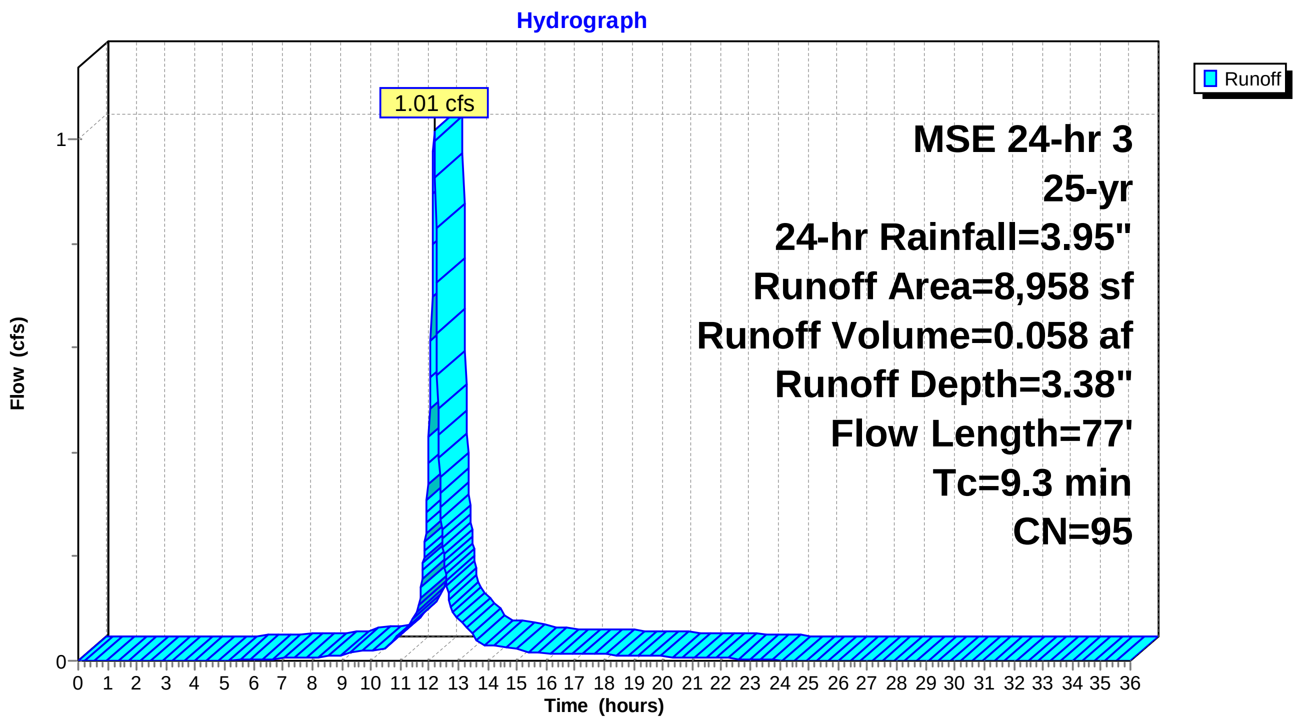
Runoff = 1.01 cfs @ 12.16 hrs, Volume= 0.058 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	8,958	95	Closure Turf
	8,958		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	29	0.0100	0.06		**Sheet Flow,** n= 0.220 P2= 2.35"
1.7	48	0.3300	0.46		**Sheet Flow,** n= 0.120 P2= 2.35"
9.3	77	Total			

Subcatchment 43S: DB-H Drainage



Summary for Subcatchment 45S: E-MCI Culvert Drainage

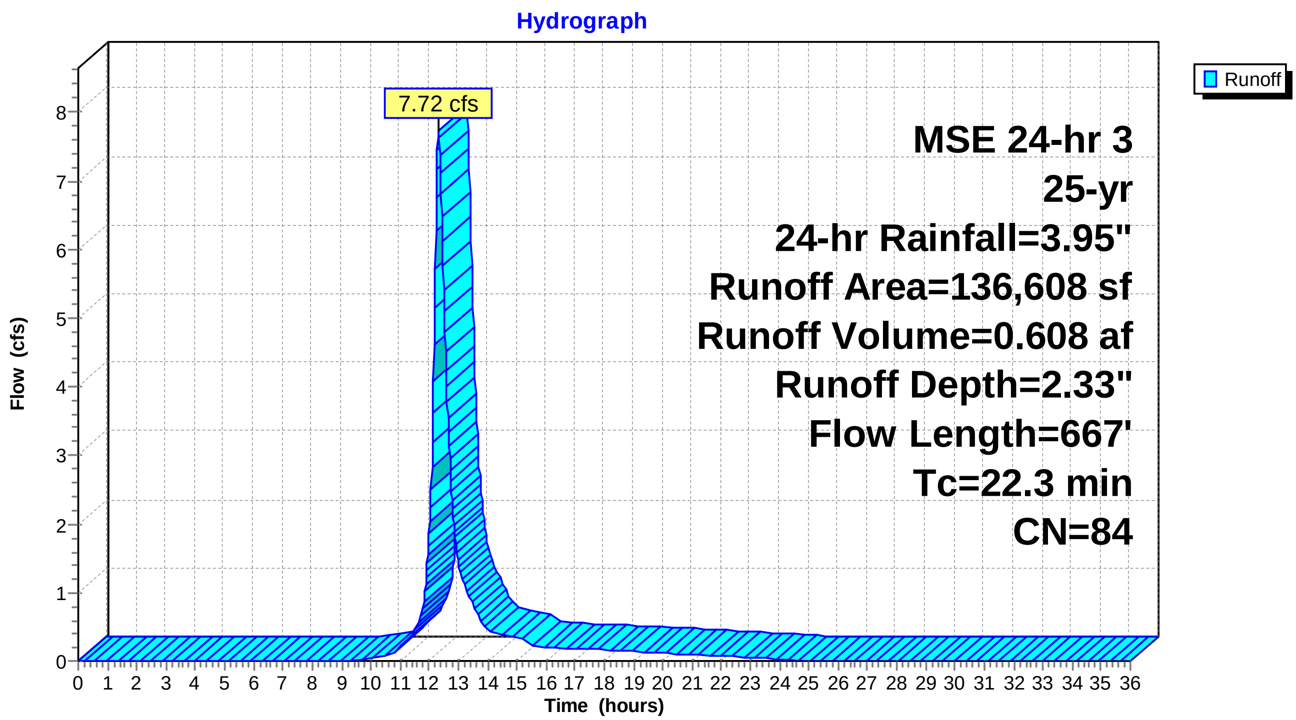
Runoff = 7.72 cfs @ 12.32 hrs, Volume= 0.608 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
	104,100	80	>75% Grass cover, Good, HSG D
*	32,508	95	Closure Turf
	136,608	84	Weighted Average
	136,608		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.2	32	0.0100	0.06		**Sheet Flow, Closure turf** n= 0.220 P2= 2.35"
1.6	35	0.3300	0.36		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
8.2	133	0.0800	0.27		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
4.3	467	0.0670	1.81		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
22.3	667	Total			

Subcatchment 45S: E-MCI Culvert Drainage



Summary for Subcatchment 51S: MC XI NW Drainage

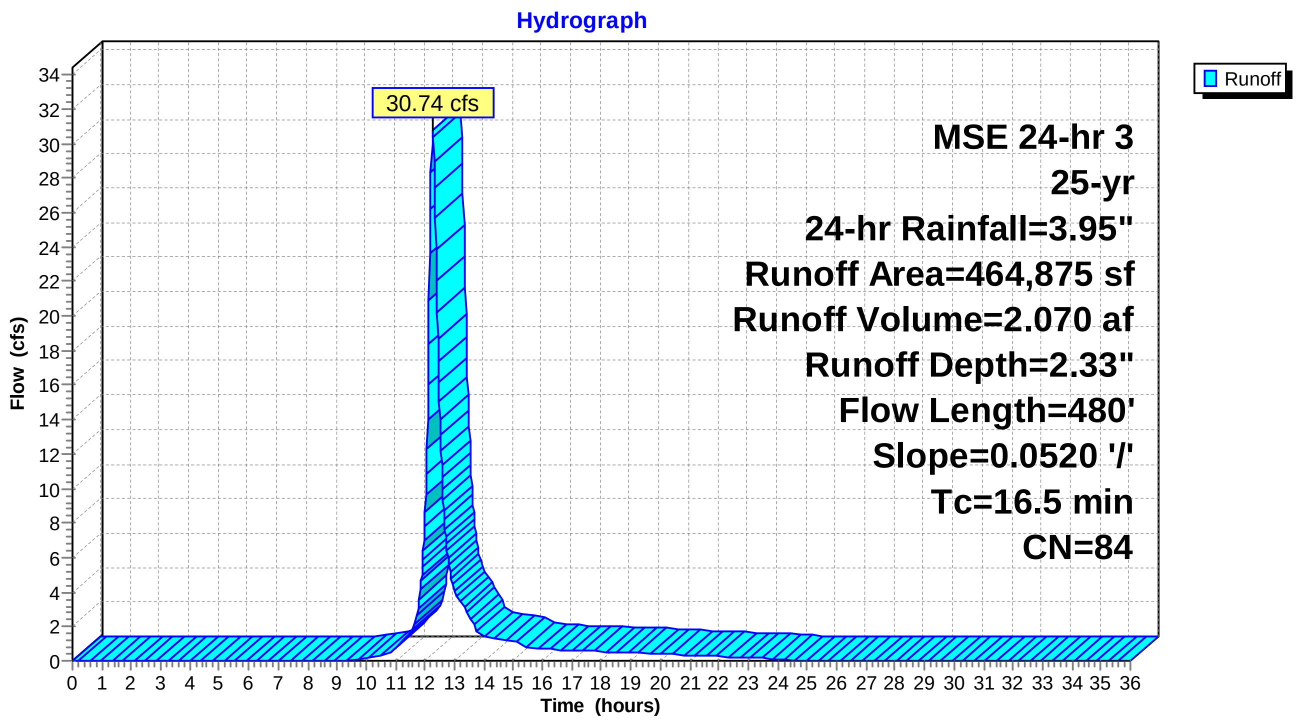
Runoff = 30.74 cfs @ 12.25 hrs, Volume= 2.070 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
464,875	84	50-75% Grass cover, Fair, HSG D
464,875		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.6	200	0.0520	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
2.9	280	0.0520	1.60		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
16.5	480	Total			

Subcatchment 51S: MC XI NW Drainage



Summary for Subcatchment 61S: W-MC X Ditch

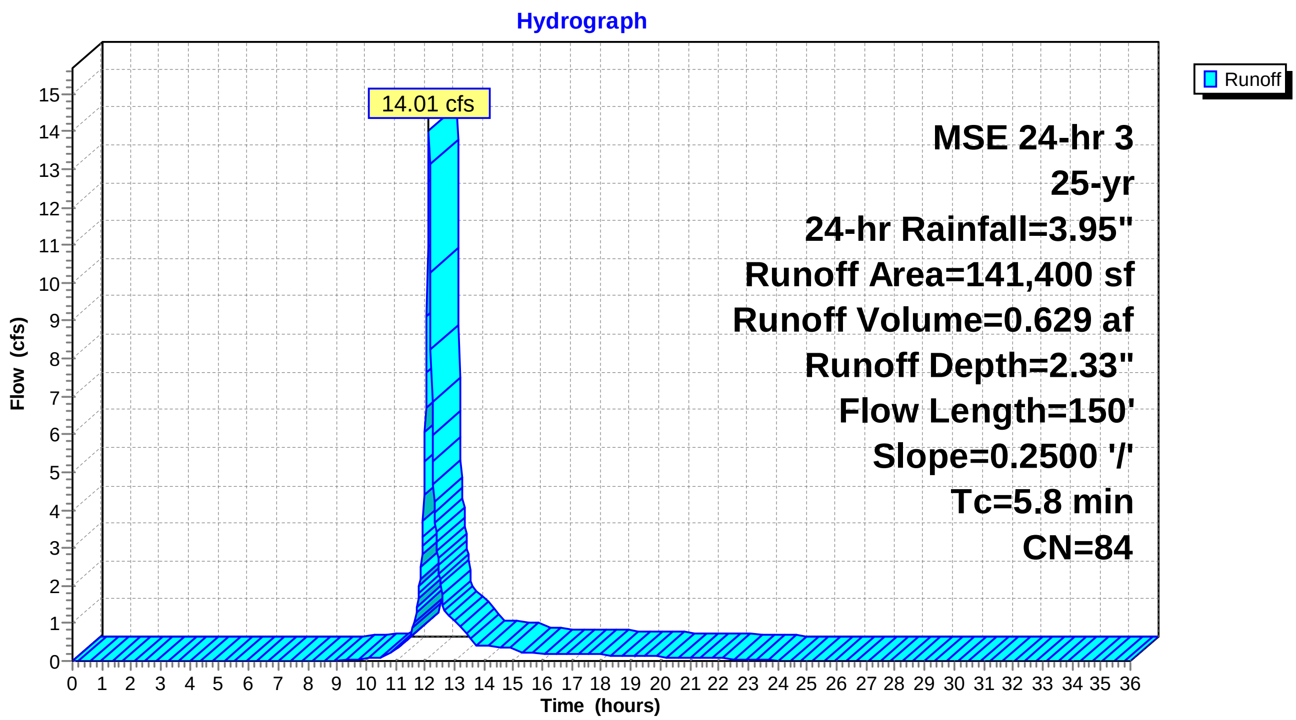
Runoff = 14.01 cfs @ 12.13 hrs, Volume= 0.629 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
141,400	84	50-75% Grass cover, Fair, HSG D
141,400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	150	0.2500	0.43		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 61S: W-MC X Ditch



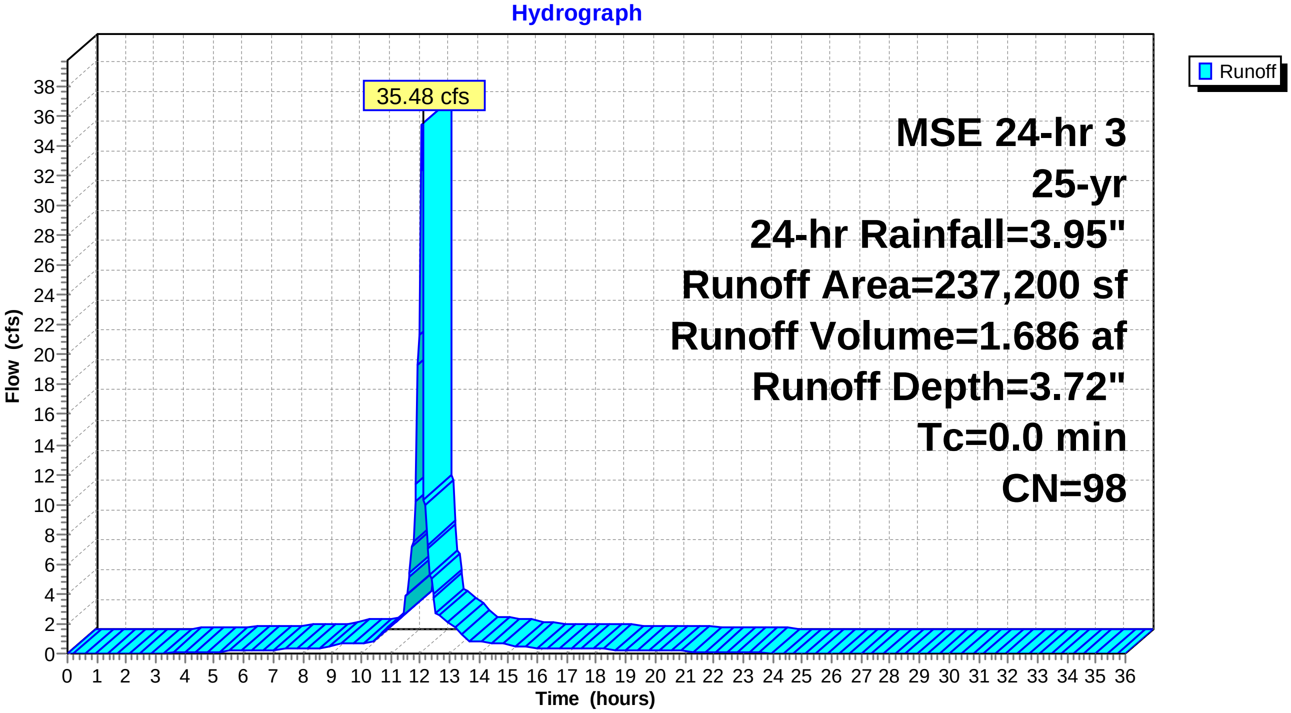
Summary for Subcatchment 62S: Additional Storm Sewer Drainage Area

Runoff = 35.48 cfs @ 12.08 hrs, Volume= 1.686 af, Depth= 3.72"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
237,200	98	Paved parking, HSG D
237,200		100.00% Impervious Area

Subcatchment 62S: Additional Storm Sewer Drainage Area



Summary for Subcatchment 65S: S-MC X Ditch Drainage

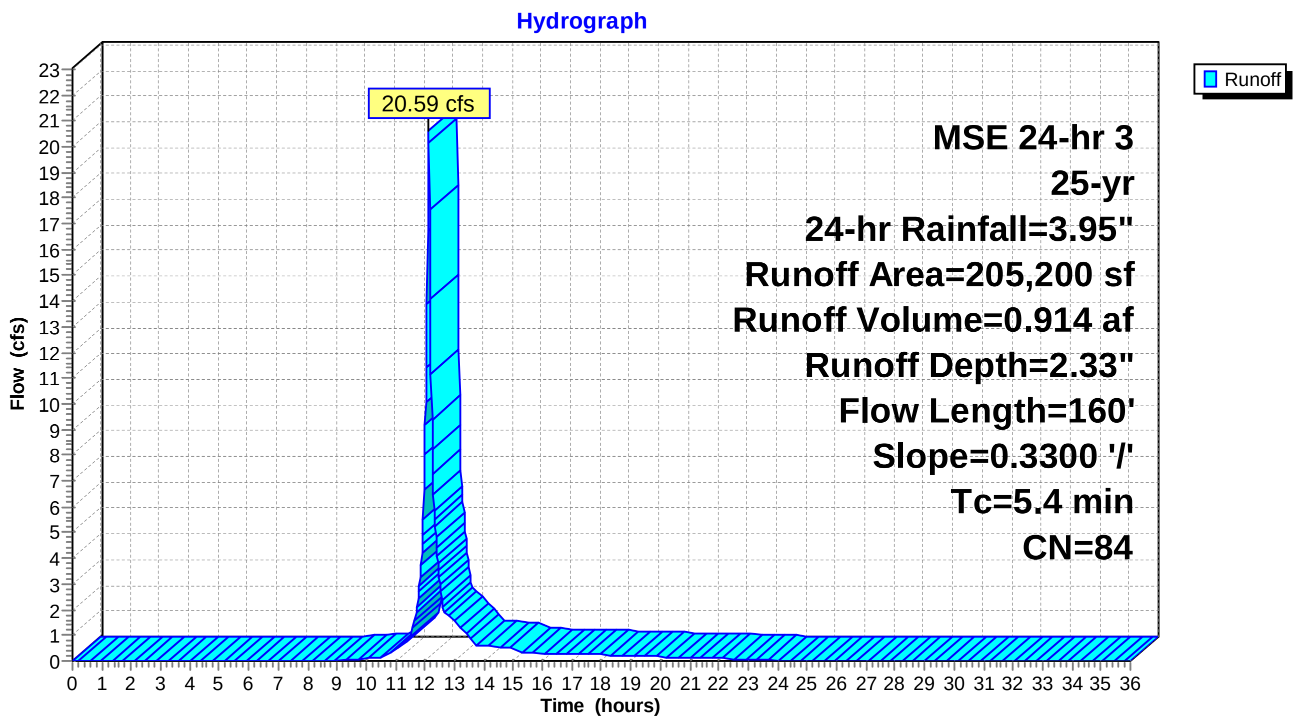
Runoff = 20.59 cfs @ 12.13 hrs, Volume= 0.914 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
205,200	84	50-75% Grass cover, Fair, HSG D
205,200		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	160	0.3300	0.49		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 65S: S-MC X Ditch Drainage



Summary for Subcatchment 67S: E-MC X Drainage

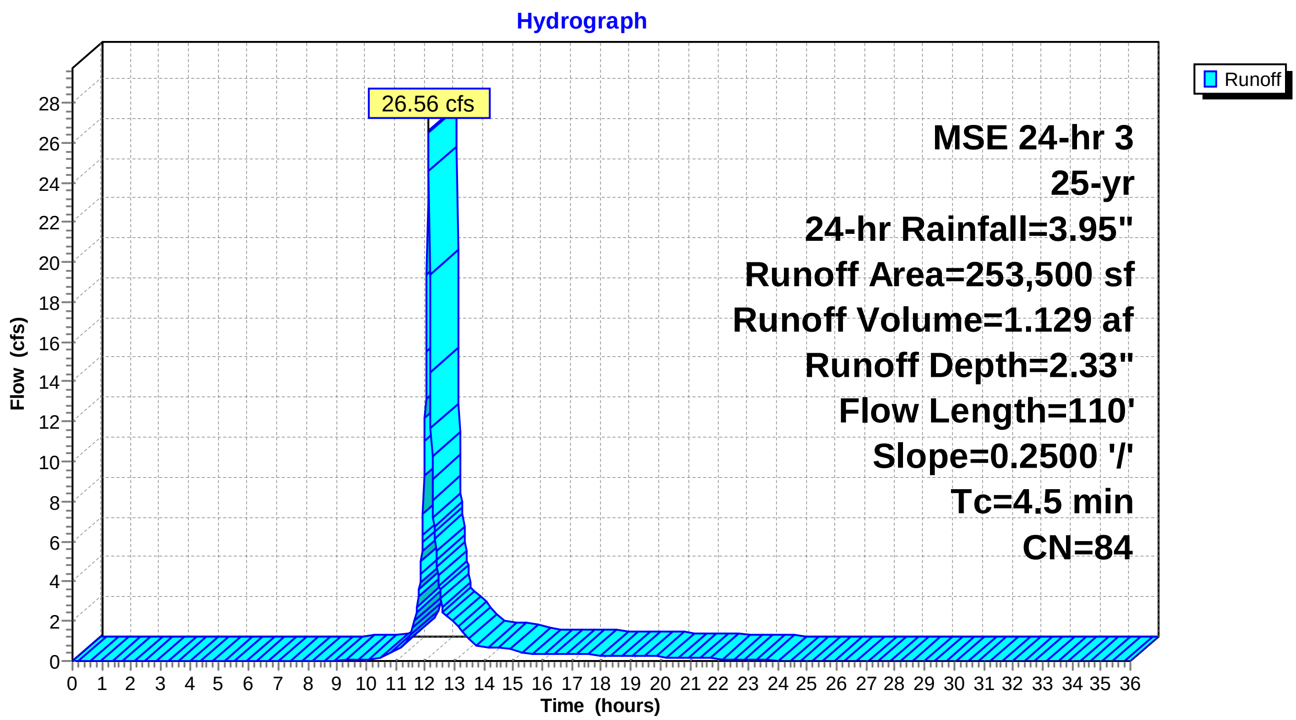
Runoff = 26.56 cfs @ 12.12 hrs, Volume= 1.129 af, Depth= 2.33"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
253,500	84	50-75% Grass cover, Fair, HSG D
253,500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.5	110	0.2500	0.41		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 67S: E-MC X Drainage



Summary for Subcatchment 68S: SSB Drainage Area

Total area is 900,800 sf
Pond area is 208,300 sf
Therefore, surrounding area is 692,500 sf (900,800 - 208,300)

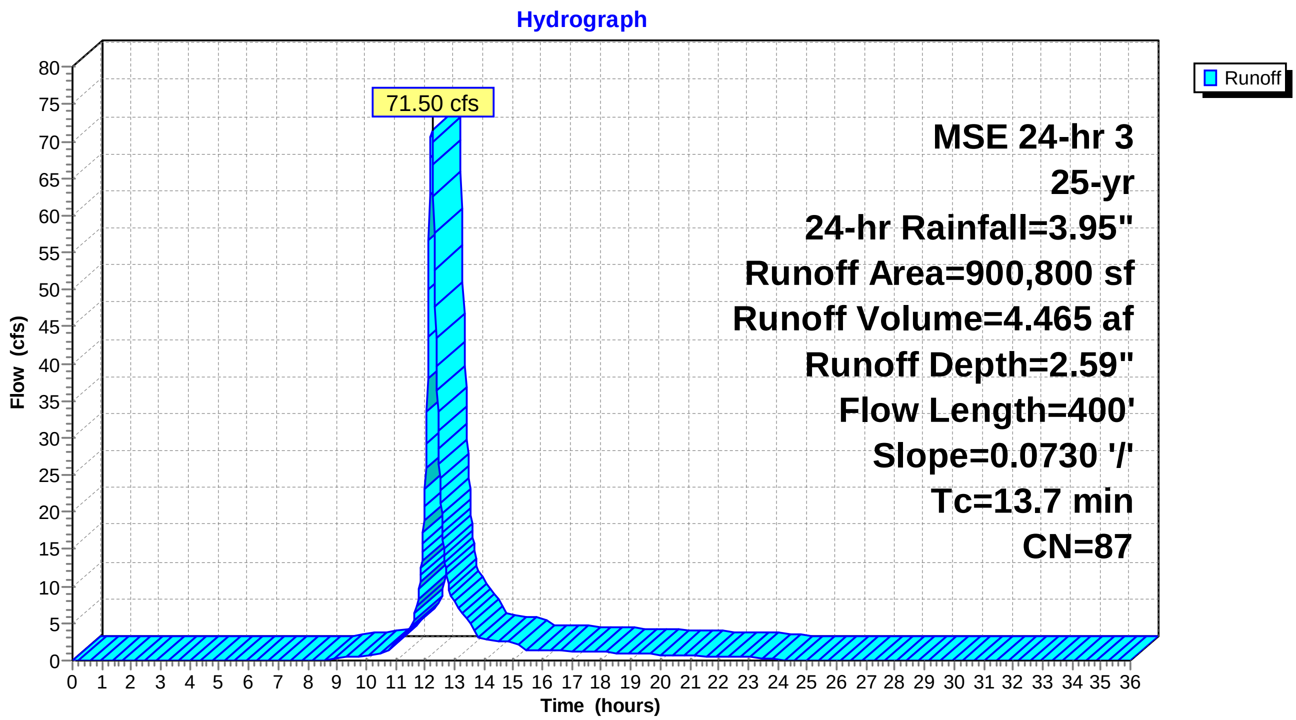
Runoff = 71.50 cfs @ 12.22 hrs, Volume= 4.465 af, Depth= 2.59"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
692,500	84	50-75% Grass cover, Fair, HSG D
208,300	98	Water Surface, HSG D
900,800	87	Weighted Average
692,500		76.88% Pervious Area
208,300		23.12% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.9	200	0.0730	0.28		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
1.8	200	0.0730	1.89		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.7	400	Total			

Subcatchment 68S: SSB Drainage Area



Summary for Subcatchment 70S: DB-46 Drainage

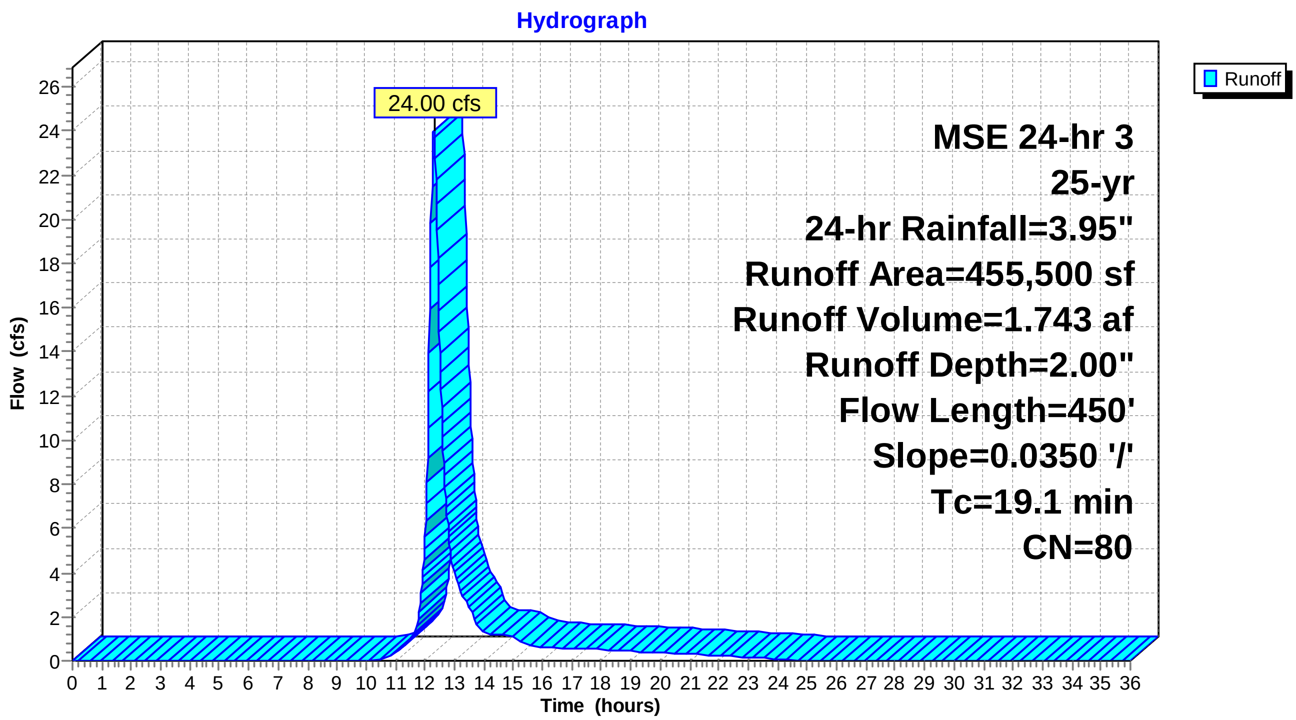
Runoff = 24.00 cfs @ 12.29 hrs, Volume= 1.743 af, Depth= 2.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
455,500	80	>75% Grass cover, Good, HSG D
455,500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.9	200	0.0350	0.21		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
3.2	250	0.0350	1.31		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
19.1	450	Total			

Subcatchment 70S: DB-46 Drainage



Summary for Subcatchment 72S: E-MCI Drainage

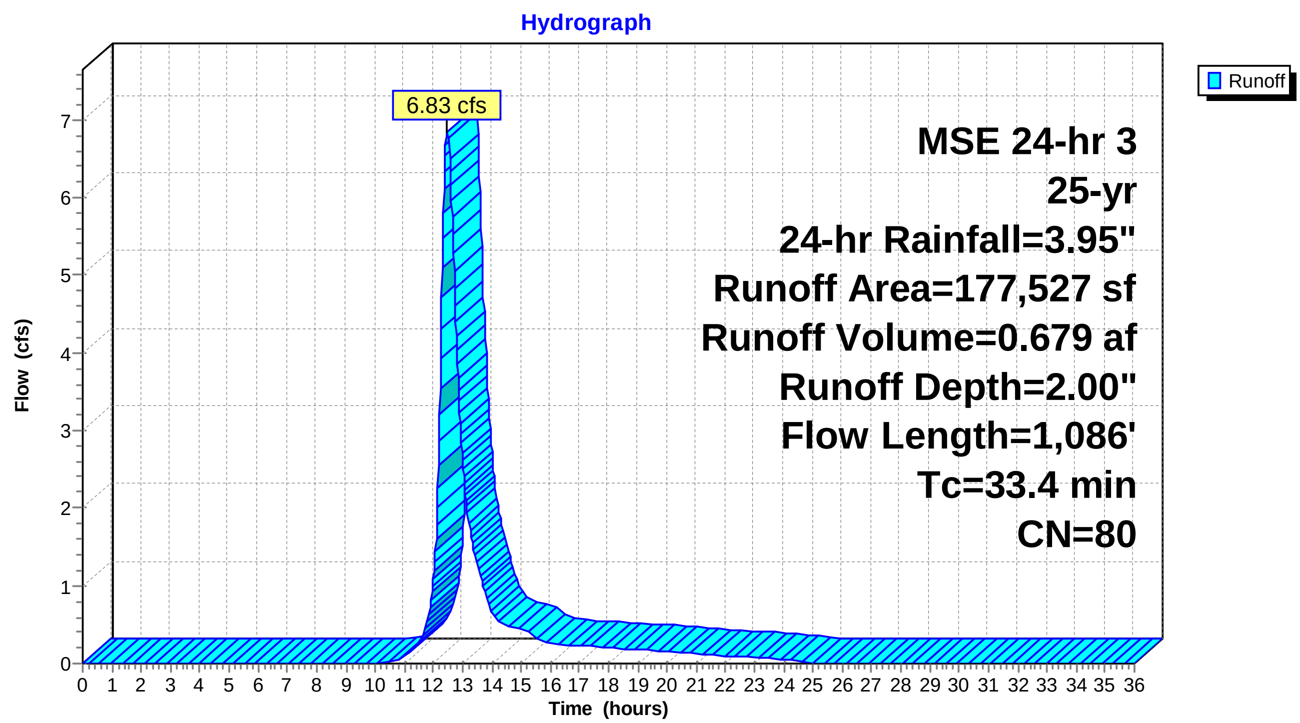
Runoff = 6.83 cfs @ 12.48 hrs, Volume= 0.679 af, Depth= 2.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

Area (sf)	CN	Description
177,527	80	>75% Grass cover, Good, HSG D
177,527		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
19.9	200	0.0200	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
10.8	640	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.7	246	0.0488	1.55		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
33.4	1,086	Total			

Subcatchment 72S: E-MCI Drainage



Summary for Subcatchment 73S: Cover System Drainage

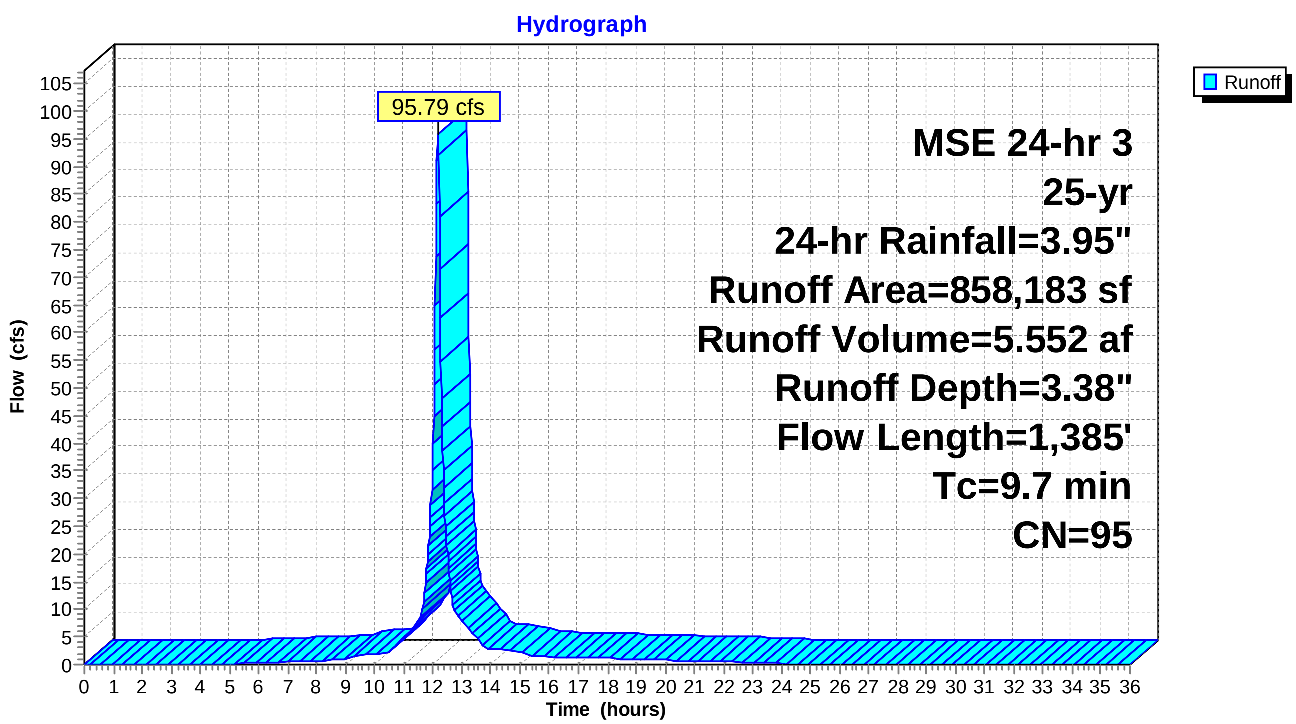
Runoff = 95.79 cfs @ 12.17 hrs, Volume= 5.552 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 25-yr, 24-hr Rainfall=3.95"

	Area (sf)	CN	Description
*	858,183	95	Closure Turf
	858,183		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.5	321	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
2.7	626	0.0360	3.85		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.4	238	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
9.7	1,385	Total			

Subcatchment 73S: Cover System Drainage



Summary for Reach 35R: MCVI/XI Ditch

Inflow Area = 39.192 ac, 0.00% Impervious, Inflow Depth = 3.09" for 25-yr, 24-hr event
Inflow = 162.49 cfs @ 12.19 hrs, Volume= 10.107 af
Outflow = 161.20 cfs @ 12.21 hrs, Volume= 10.107 af, Atten= 1%, Lag= 1.1 min

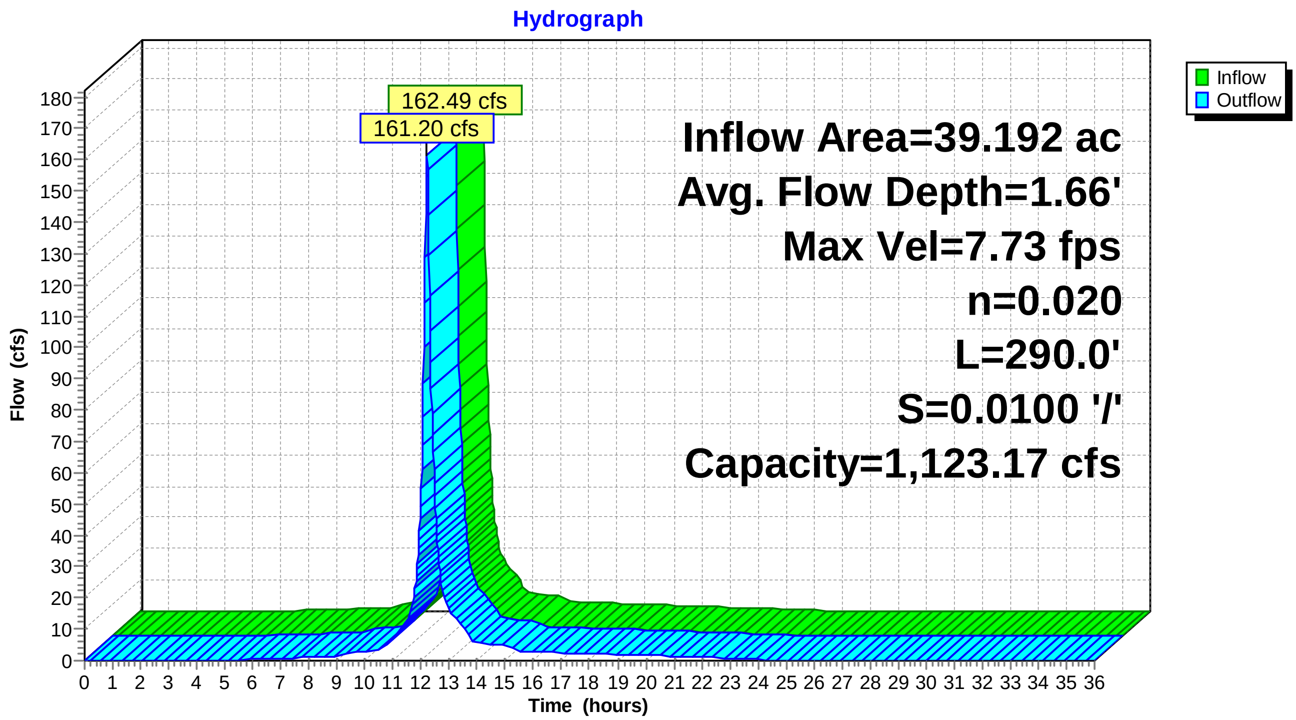
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 7.73 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.88 fps, Avg. Travel Time= 2.6 min

Peak Storage= 6,075 cf @ 12.20 hrs
Average Depth at Peak Storage= 1.66' , Surface Width= 19.27'
Bank-Full Depth= 4.00' Flow Area= 88.0 sf, Capacity= 1,123.17 cfs

6.00' x 4.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 '/' Top Width= 38.00'
Length= 290.0' Slope= 0.0100 '/'
Inlet Invert= 700.15', Outlet Invert= 697.26'

‡

Reach 35R: MCVI/XI Ditch



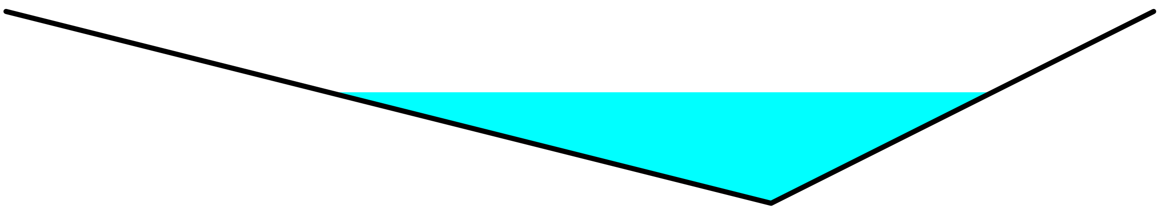
Summary for Reach 36R: DB-F

Inflow Area = 3.360 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 20.35 cfs @ 12.12 hrs, Volume= 0.947 af
Outflow = 19.72 cfs @ 12.16 hrs, Volume= 0.947 af, Atten= 3%, Lag= 2.2 min

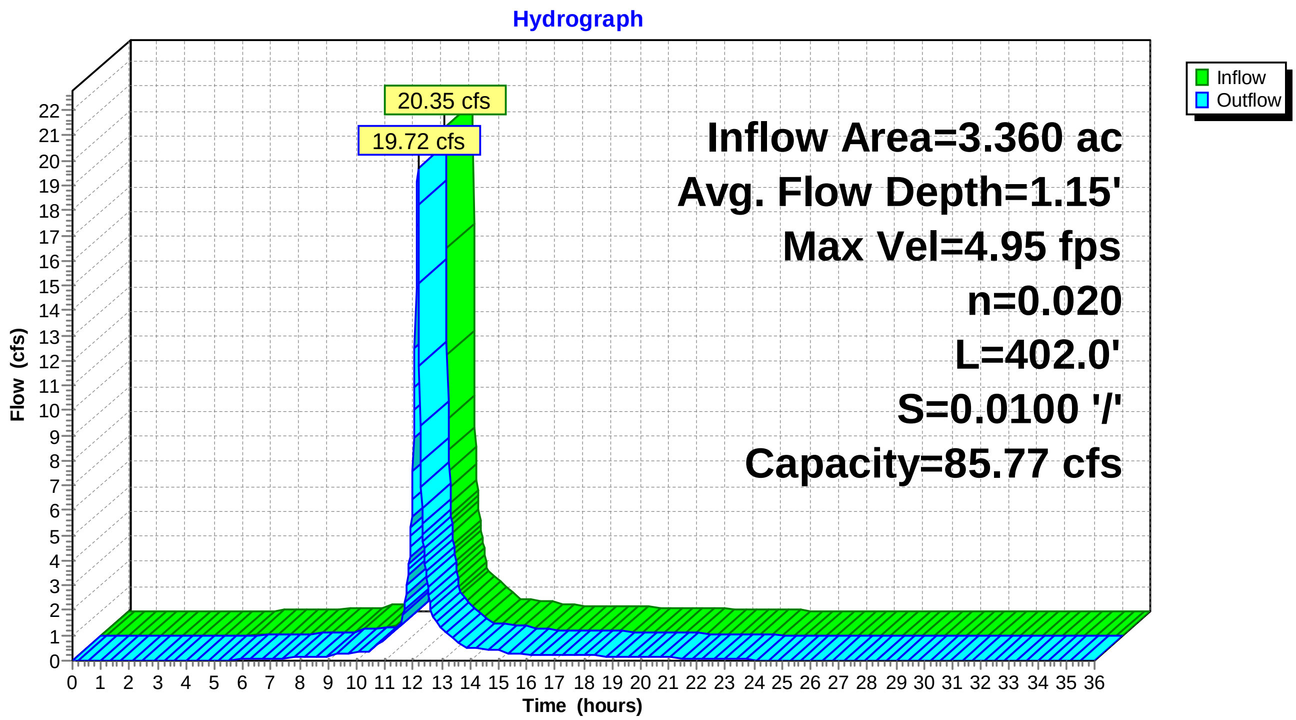
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 4.95 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 1.53 fps, Avg. Travel Time= 4.4 min

Peak Storage= 1,608 cf @ 12.13 hrs
Average Depth at Peak Storage= 1.15' , Surface Width= 6.93'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 85.77 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 402.0' Slope= 0.0100 '/'
Inlet Invert= 712.02', Outlet Invert= 708.00'



Reach 36R: DB-F



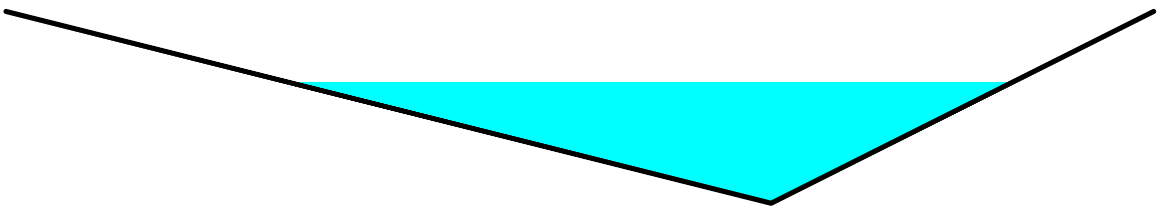
Summary for Reach 38R: DB-D-1 (1%)

Inflow Area = 8.819 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 55.79 cfs @ 12.09 hrs, Volume= 2.485 af
Outflow = 45.12 cfs @ 12.21 hrs, Volume= 2.485 af, Atten= 19%, Lag= 6.9 min

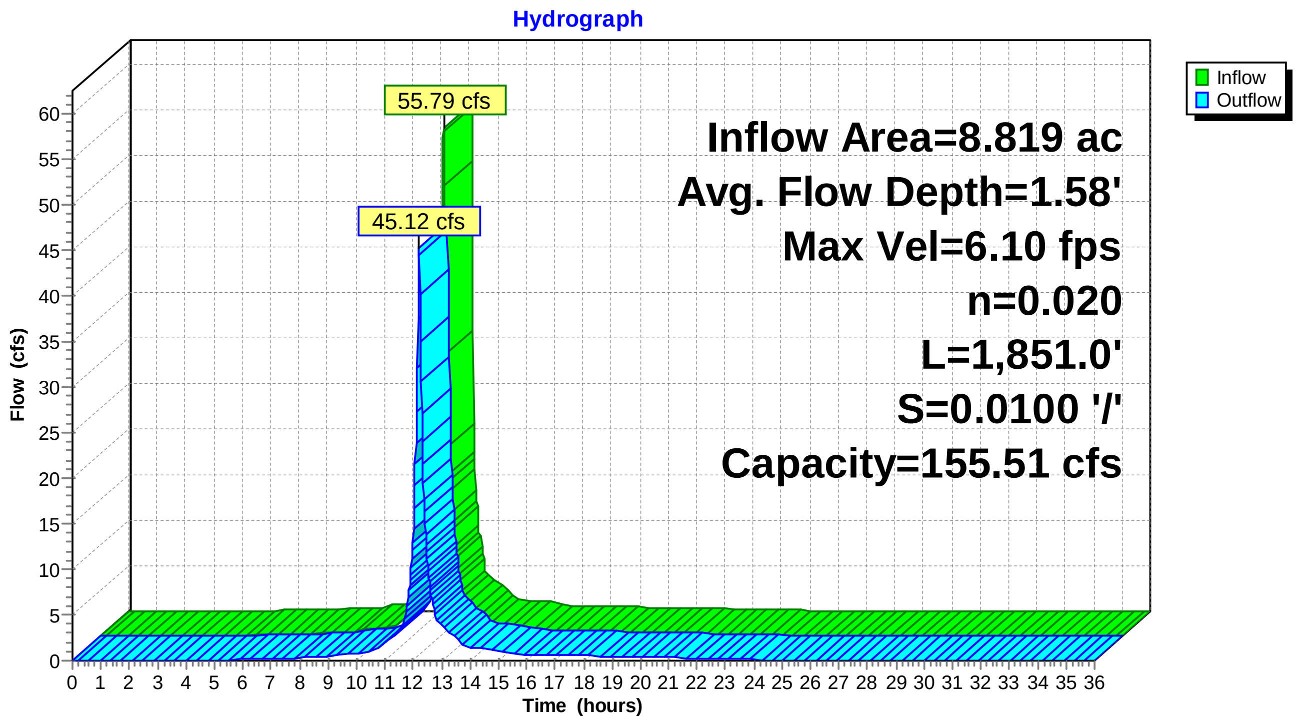
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 6.10 fps, Min. Travel Time= 5.1 min
Avg. Velocity = 1.68 fps, Avg. Travel Time= 18.4 min

Peak Storage= 13,810 cf @ 12.12 hrs
Average Depth at Peak Storage= 1.58' , Surface Width= 9.46'
Bank-Full Depth= 2.50' Flow Area= 18.8 sf, Capacity= 155.51 cfs

0.00' x 2.50' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 15.00'
Length= 1,851.0' Slope= 0.0100 '/'
Inlet Invert= 744.85', Outlet Invert= 726.34'



Reach 38R: DB-D-1 (1%)



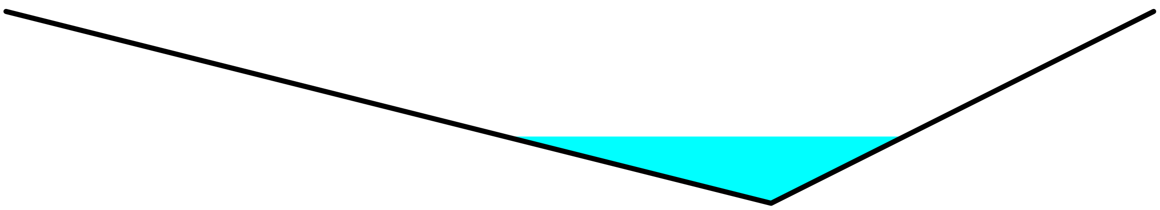
Summary for Reach 40R: DB-G

Inflow Area = 1.903 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 12.16 cfs @ 12.09 hrs, Volume= 0.536 af
Outflow = 11.80 cfs @ 12.12 hrs, Volume= 0.536 af, Atten= 3%, Lag= 1.7 min

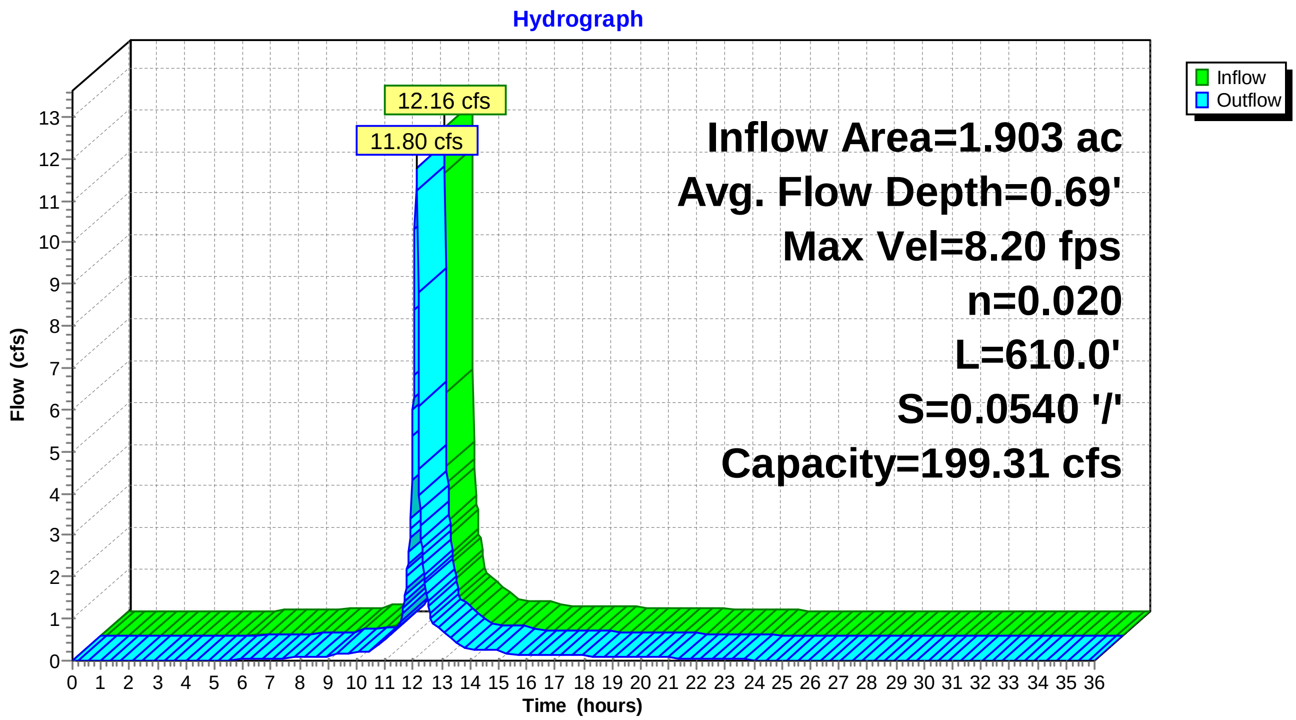
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 8.20 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 2.60 fps, Avg. Travel Time= 3.9 min

Peak Storage= 879 cf @ 12.10 hrs
Average Depth at Peak Storage= 0.69' , Surface Width= 4.16'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 199.31 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 610.0' Slope= 0.0540 '/'
Inlet Invert= 762.04', Outlet Invert= 729.10'



Reach 40R: DB-G



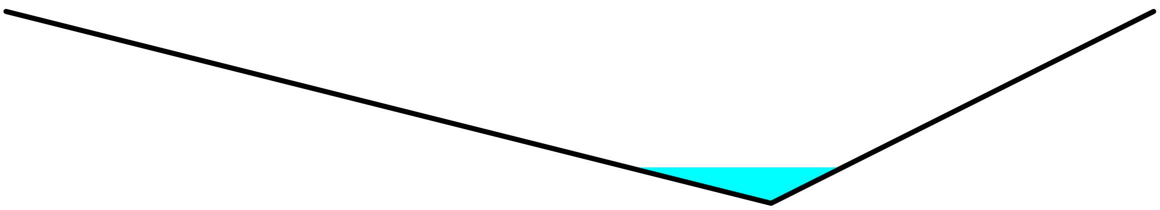
Summary for Reach 41R: DB-H

Inflow Area = 0.206 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 1.01 cfs @ 12.16 hrs, Volume= 0.058 af
Outflow = 1.00 cfs @ 12.19 hrs, Volume= 0.058 af, Atten= 1%, Lag= 1.6 min

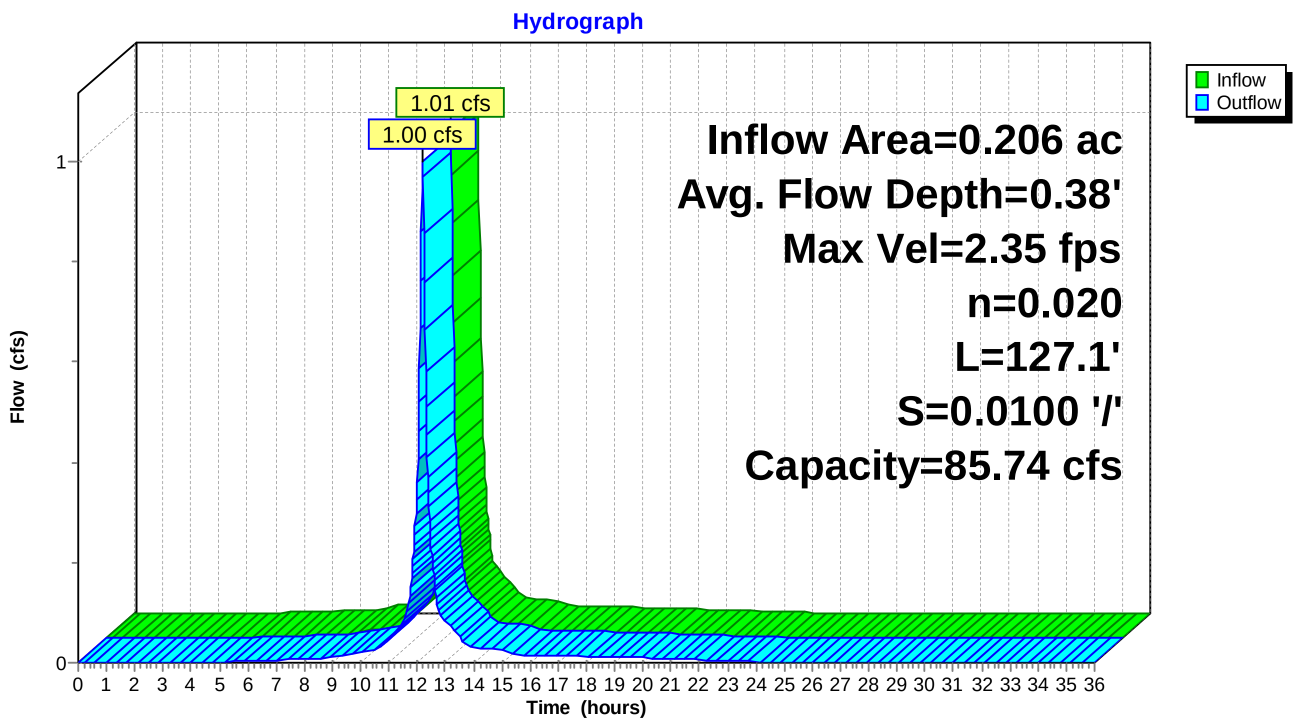
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 2.35 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 0.81 fps, Avg. Travel Time= 2.6 min

Peak Storage= 54 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.38' , Surface Width= 2.26'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 85.74 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 127.1' Slope= 0.0100 '/'
Inlet Invert= 707.69', Outlet Invert= 706.42'



Reach 41R: DB-H



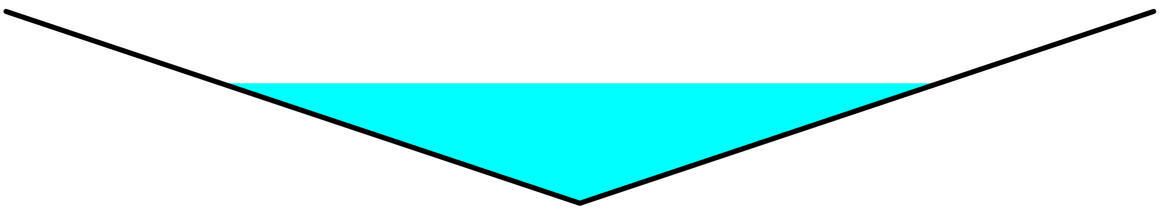
Summary for Reach 44R: E-MCI Ditch

Inflow Area = 17.668 ac, 0.00% Impervious, Inflow Depth = 2.06" for 25-yr, 24-hr event
Inflow = 37.12 cfs @ 12.33 hrs, Volume= 3.031 af
Outflow = 36.98 cfs @ 12.37 hrs, Volume= 3.031 af, Atten= 0%, Lag= 2.2 min

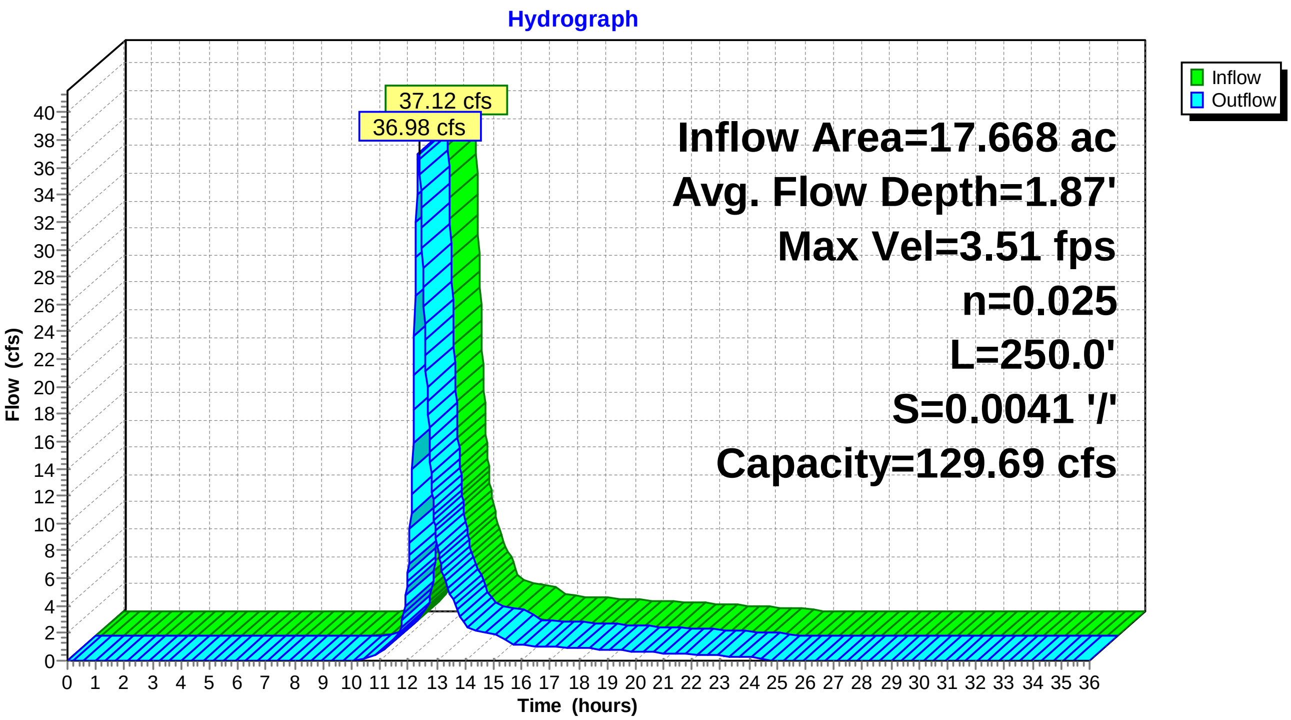
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 3.51 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 1.27 fps, Avg. Travel Time= 3.3 min

Peak Storage= 2,634 cf @ 12.35 hrs
Average Depth at Peak Storage= 1.87' , Surface Width= 11.24'
Bank-Full Depth= 3.00' Flow Area= 27.0 sf, Capacity= 129.69 cfs

0.00' x 3.00' deep channel, n= 0.025
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 250.0' Slope= 0.0041 '/'
Inlet Invert= 702.00', Outlet Invert= 700.98'



Reach 44R: E-MCI Ditch



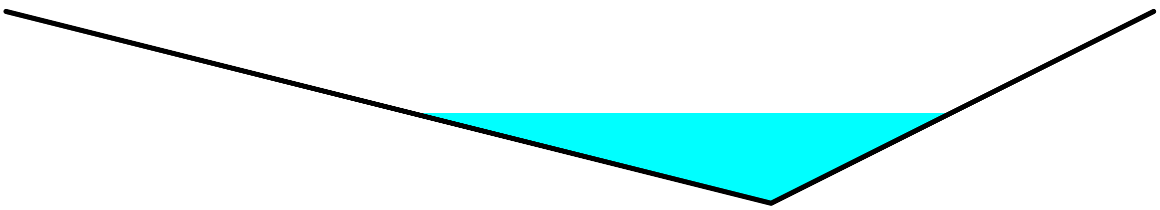
Summary for Reach 59R: DB-E

Inflow Area = 1.986 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 12.17 cfs @ 12.10 hrs, Volume= 0.560 af
Outflow = 11.41 cfs @ 12.16 hrs, Volume= 0.560 af, Atten= 6%, Lag= 3.4 min

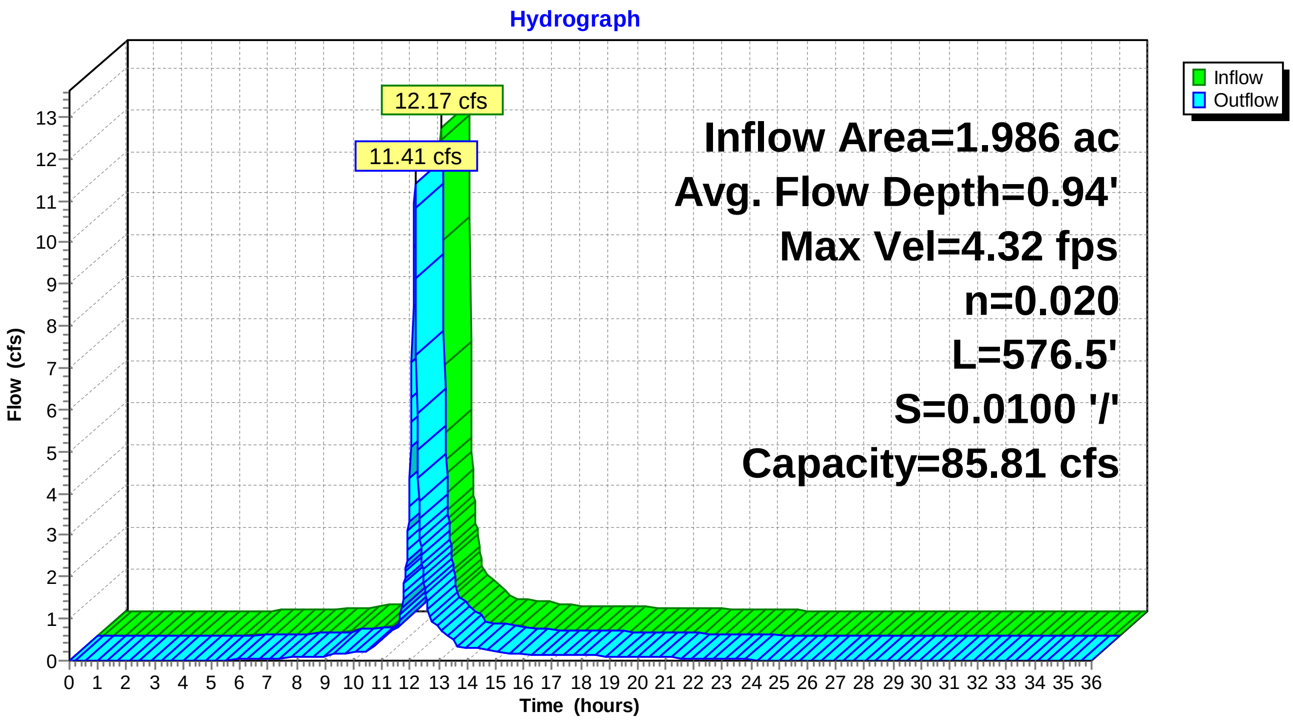
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 4.32 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 1.34 fps, Avg. Travel Time= 7.2 min

Peak Storage= 1,530 cf @ 12.12 hrs
Average Depth at Peak Storage= 0.94' , Surface Width= 5.64'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 85.81 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 576.5' Slope= 0.0100 '/'
Inlet Invert= 718.00', Outlet Invert= 712.23'



Reach 59R: DB-E



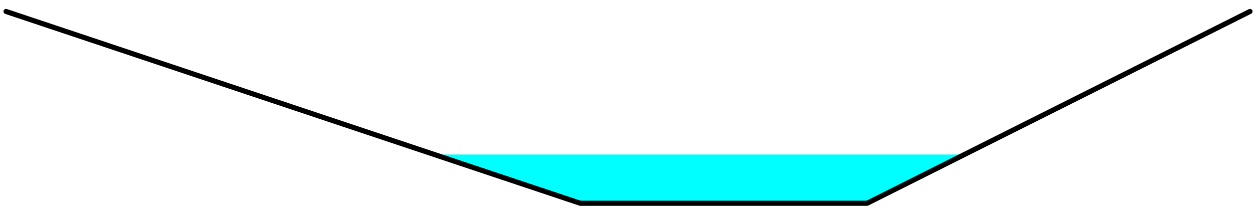
Summary for Reach 60R: W-MC X Ditch

Inflow Area = 13.776 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 22.31 cfs @ 12.28 hrs, Volume= 2.672 af
Outflow = 21.03 cfs @ 12.42 hrs, Volume= 2.672 af, Atten= 6%, Lag= 8.5 min

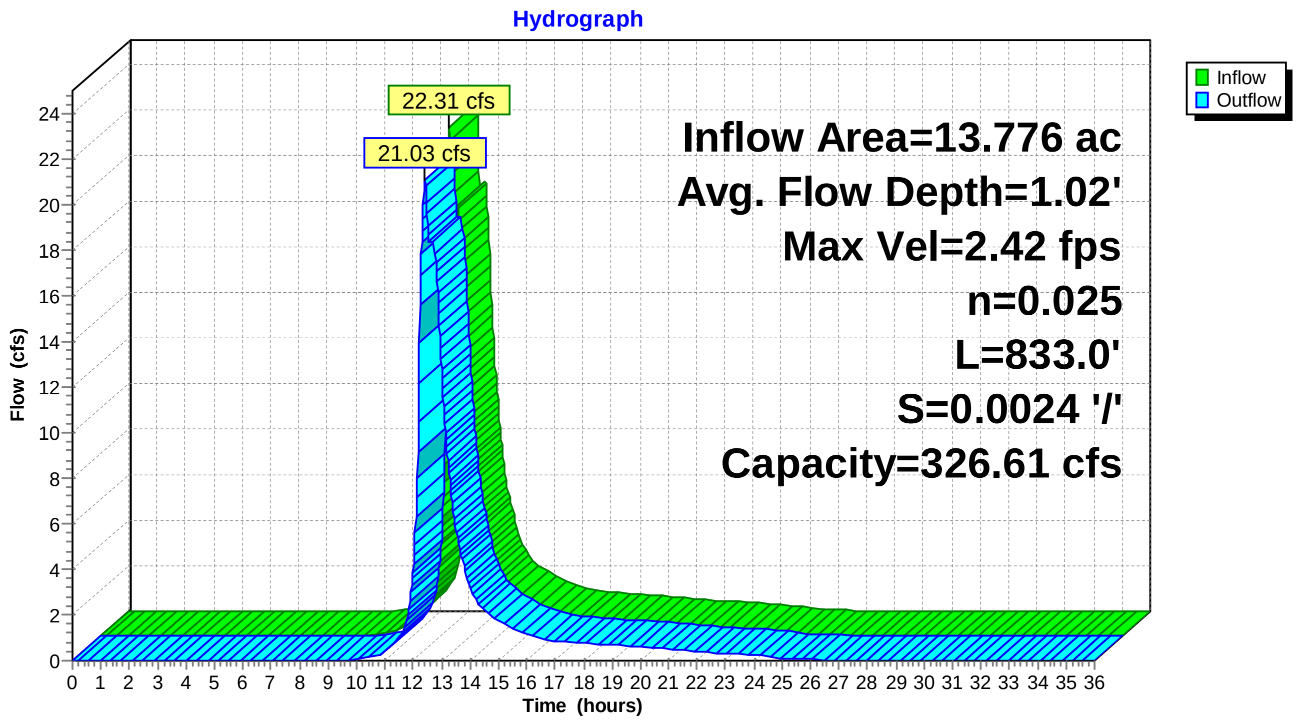
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 2.42 fps, Min. Travel Time= 5.7 min
Avg. Velocity = 0.65 fps, Avg. Travel Time= 21.5 min

Peak Storage= 7,250 cf @ 12.32 hrs
Average Depth at Peak Storage= 1.02' , Surface Width= 11.09'
Bank-Full Depth= 4.00' Flow Area= 64.0 sf, Capacity= 326.61 cfs

6.00' x 4.00' deep channel, n= 0.025
Side Slope Z-value= 3.0 2.0 '/' Top Width= 26.00'
Length= 833.0' Slope= 0.0024 '/'
Inlet Invert= 691.00', Outlet Invert= 689.00'



Reach 60R: W-MC X Ditch



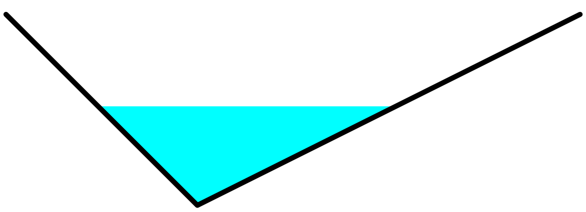
Summary for Reach 64R: S MC X Ditch

Inflow Area = 10.530 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 23.26 cfs @ 12.13 hrs, Volume= 2.042 af
Outflow = 17.73 cfs @ 12.29 hrs, Volume= 2.042 af, Atten= 24%, Lag= 9.8 min

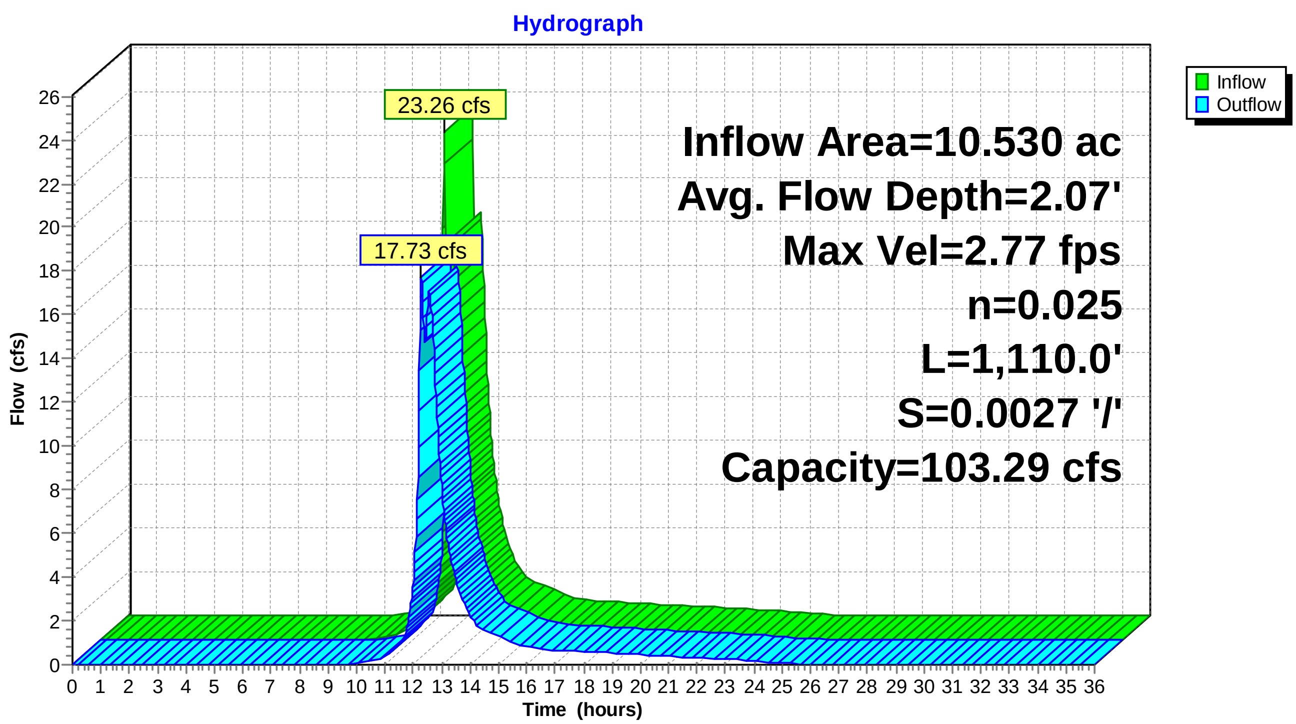
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 2.77 fps, Min. Travel Time= 6.7 min
Avg. Velocity = 0.84 fps, Avg. Travel Time= 22.1 min

Peak Storage= 7,133 cf @ 12.18 hrs
Average Depth at Peak Storage= 2.07' , Surface Width= 6.21'
Bank-Full Depth= 4.00' Flow Area= 24.0 sf, Capacity= 103.29 cfs

0.00' x 4.00' deep channel, n= 0.025
Side Slope Z-value= 1.0 2.0 '/' Top Width= 12.00'
Length= 1,110.0' Slope= 0.0027 '/'
Inlet Invert= 694.00', Outlet Invert= 691.00'



Reach 64R: S MC X Ditch



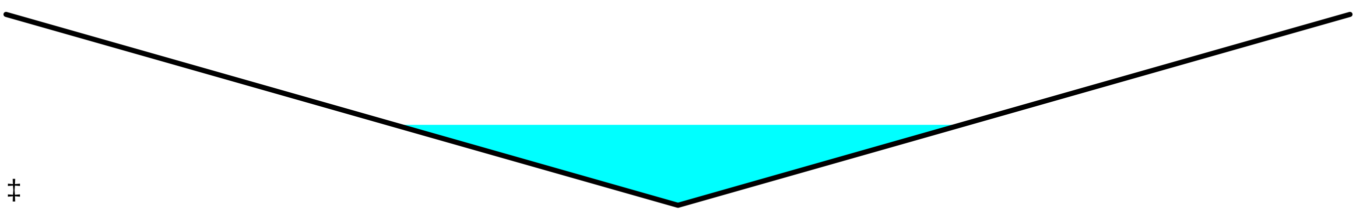
Summary for Reach 66R: E-MC X Ditch

Inflow Area = 5.820 ac, 0.00% Impervious, Inflow Depth = 2.33" for 25-yr, 24-hr event
Inflow = 26.56 cfs @ 12.12 hrs, Volume= 1.129 af
Outflow = 14.40 cfs @ 12.41 hrs, Volume= 1.129 af, Atten= 46%, Lag= 17.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 1.81 fps, Min. Travel Time= 13.8 min
Avg. Velocity = 0.50 fps, Avg. Travel Time= 50.2 min

Peak Storage= 11,979 cf @ 12.18 hrs
Average Depth at Peak Storage= 1.26' , Surface Width= 12.64'
Bank-Full Depth= 3.00' Flow Area= 45.0 sf, Capacity= 145.10 cfs

0.00' x 3.00' deep channel, n= 0.030 Stream, clean & straight
Side Slope Z-value= 5.0 '/' Top Width= 30.00'
Length= 1,500.0' Slope= 0.0025 '/'
Inlet Invert= 697.80', Outlet Invert= 694.00'



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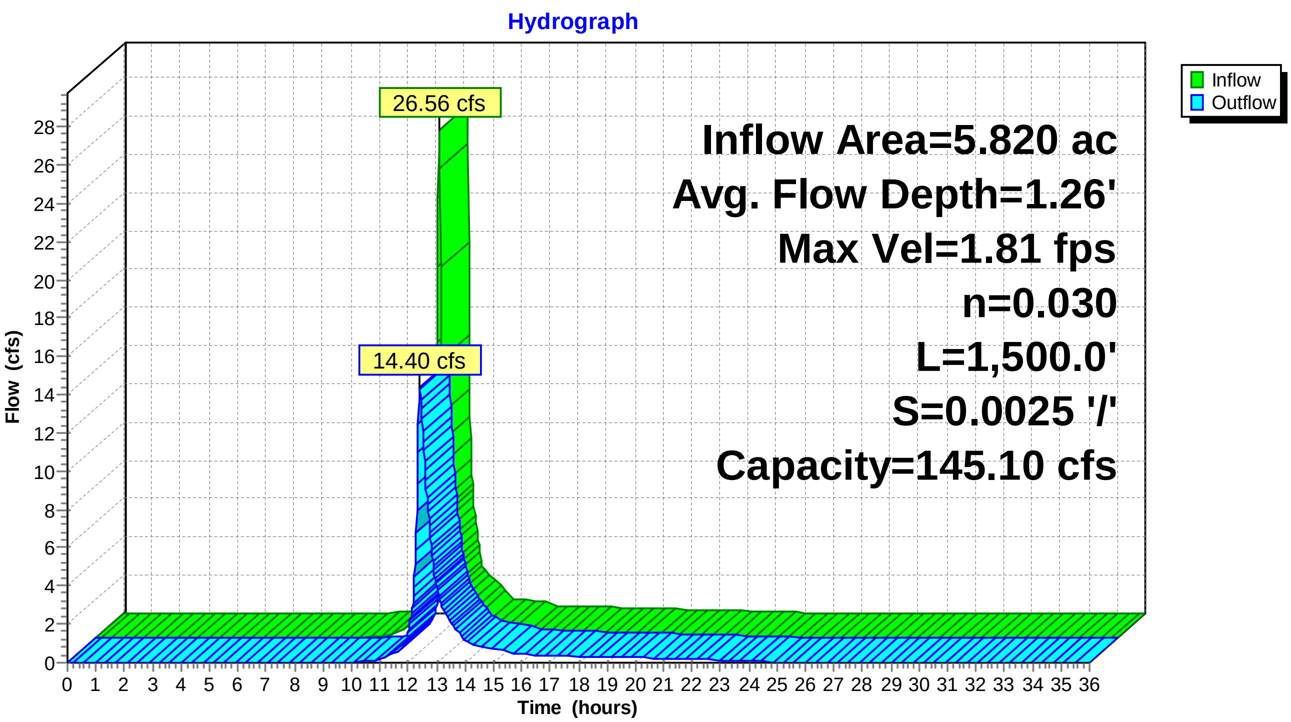
Reach 66R: E-MC X Ditch



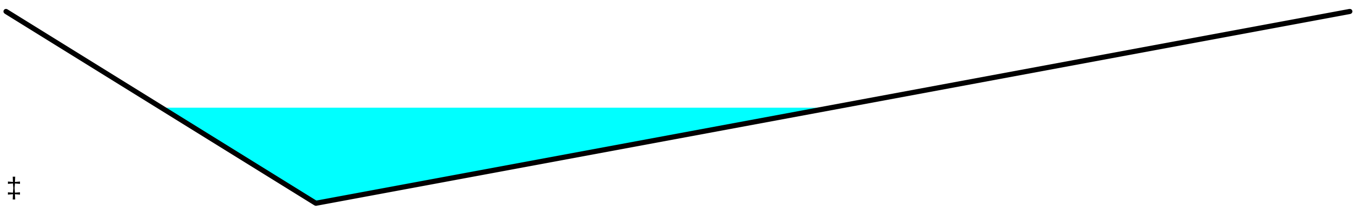
Summary for Reach 71R: DB-46

Inflow Area = 10.457 ac, 0.00% Impervious, Inflow Depth = 2.00" for 25-yr, 24-hr event
Inflow = 24.00 cfs @ 12.29 hrs, Volume= 1.743 af
Outflow = 23.88 cfs @ 12.31 hrs, Volume= 1.743 af, Atten= 0%, Lag= 1.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 3.70 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 1.40 fps, Avg. Travel Time= 2.4 min

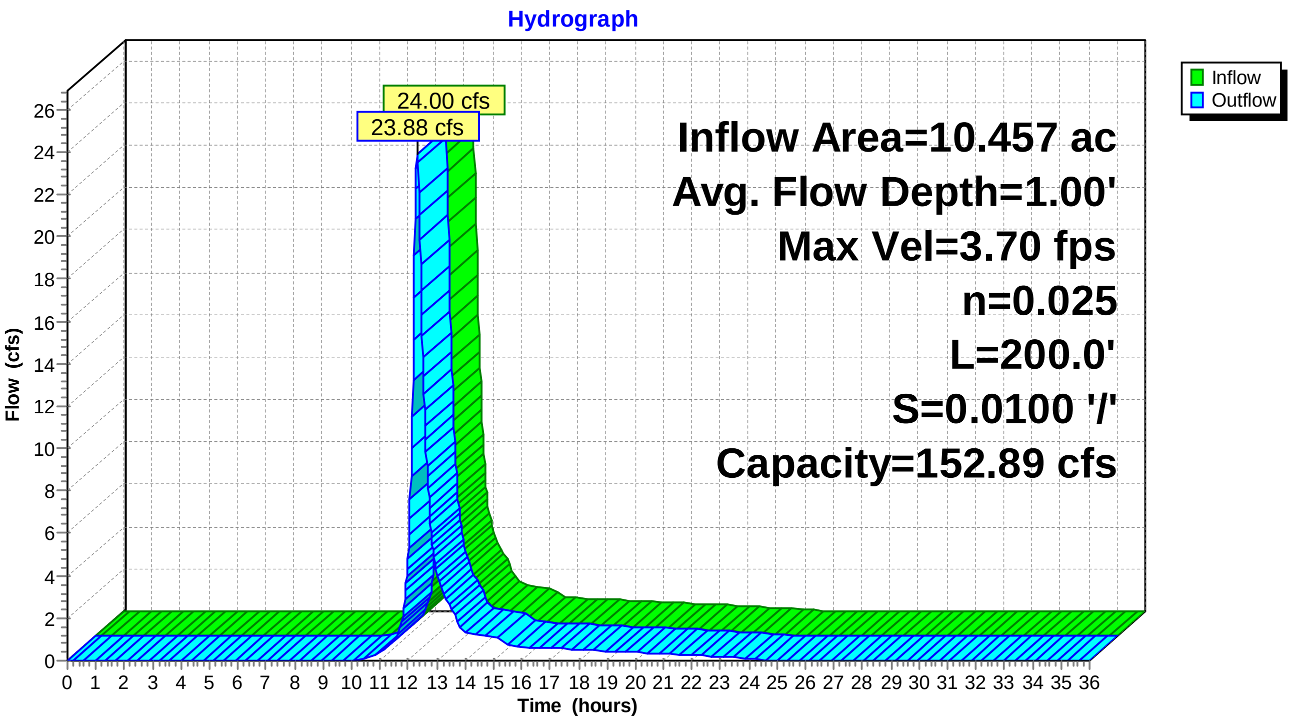
Peak Storage= 1,294 cf @ 12.30 hrs
Average Depth at Peak Storage= 1.00' , Surface Width= 12.97'
Bank-Full Depth= 2.00' Flow Area= 26.0 sf, Capacity= 152.89 cfs

0.00' x 2.00' deep channel, n= 0.025
Side Slope Z-value= 3.0 10.0 '/' Top Width= 26.00'
Length= 200.0' Slope= 0.0100 '/'
Inlet Invert= 703.00', Outlet Invert= 701.00'



‡

Reach 71R: DB-46



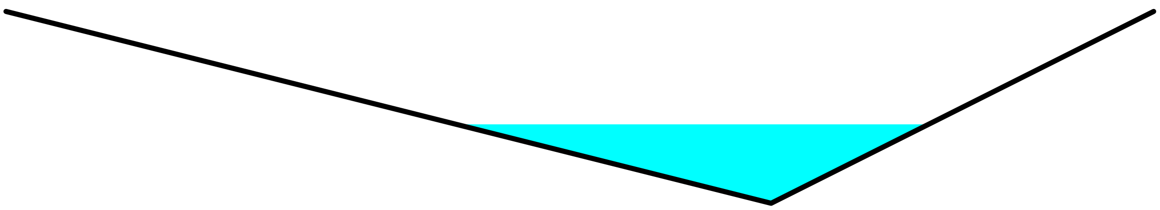
Summary for Reach 73R: DB-D-2 (9.8%)

Inflow Area = 8.819 ac, 0.00% Impervious, Inflow Depth = 3.38" for 25-yr, 24-hr event
Inflow = 45.12 cfs @ 12.21 hrs, Volume= 2.485 af
Outflow = 44.84 cfs @ 12.21 hrs, Volume= 2.485 af, Atten= 1%, Lag= 0.4 min

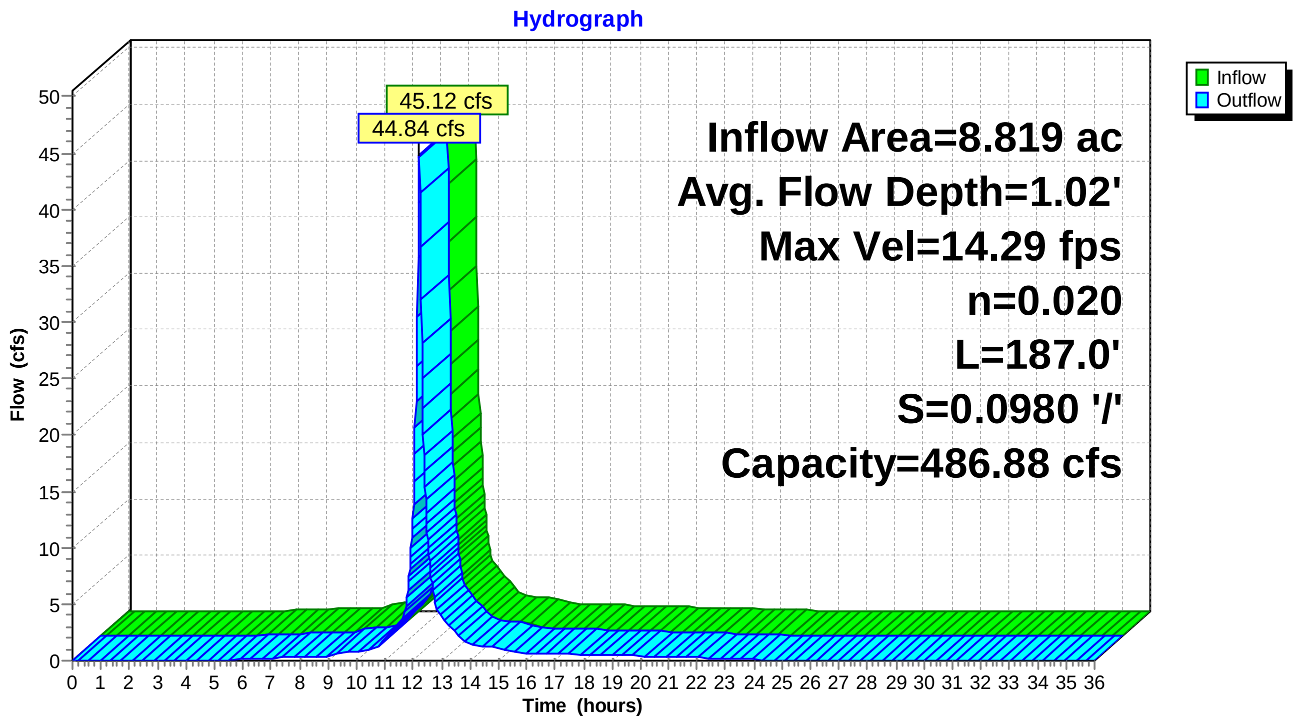
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 14.29 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 4.18 fps, Avg. Travel Time= 0.7 min

Peak Storage= 589 cf @ 12.21 hrs
Average Depth at Peak Storage= 1.02' , Surface Width= 6.15'
Bank-Full Depth= 2.50' Flow Area= 18.8 sf, Capacity= 486.88 cfs

0.00' x 2.50' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 15.00'
Length= 187.0' Slope= 0.0980 '/'
Inlet Invert= 726.33', Outlet Invert= 708.00'



Reach 73R: DB-D-2 (9.8%)

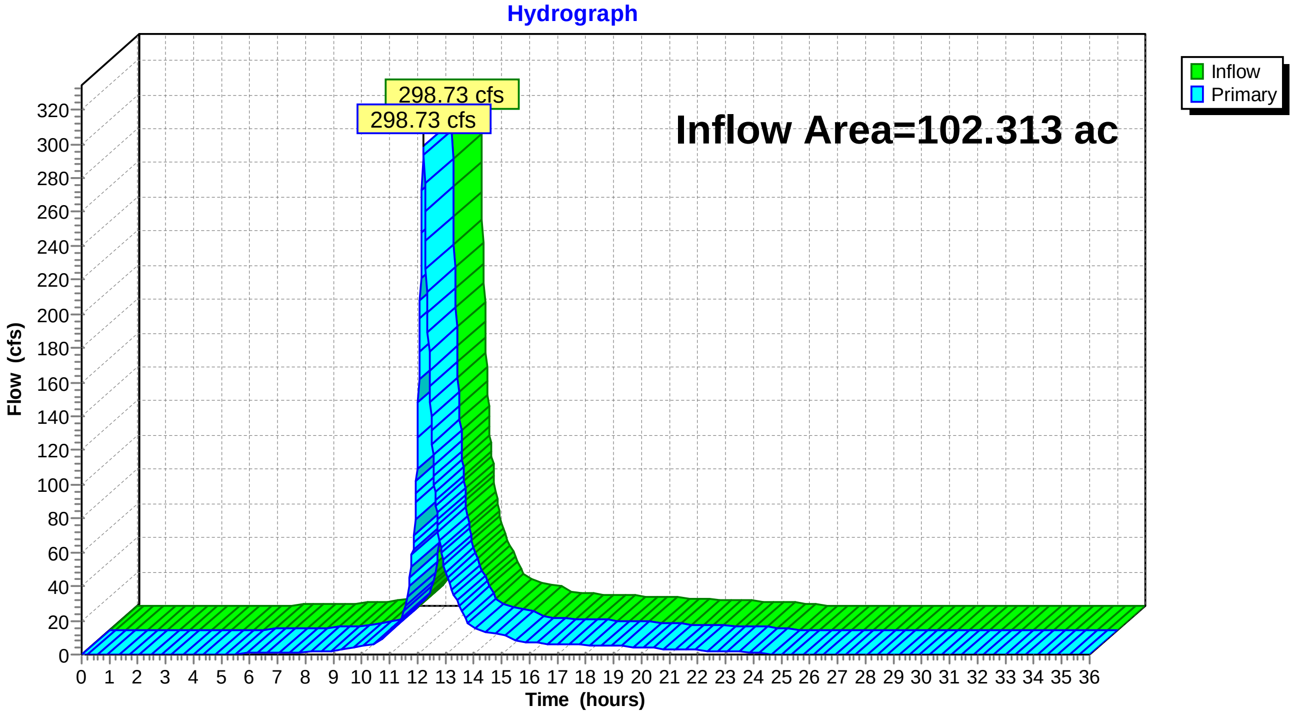


Summary for Pond 63P: SSB

Inflow Area = 102.313 ac, 10.00% Impervious, Inflow Depth = 2.76" for 25-yr, 24-hr event
Inflow = 298.73 cfs @ 12.21 hrs, Volume= 23.524 af
Primary = 298.73 cfs @ 12.21 hrs, Volume= 23.524 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs

Pond 63P: SSB

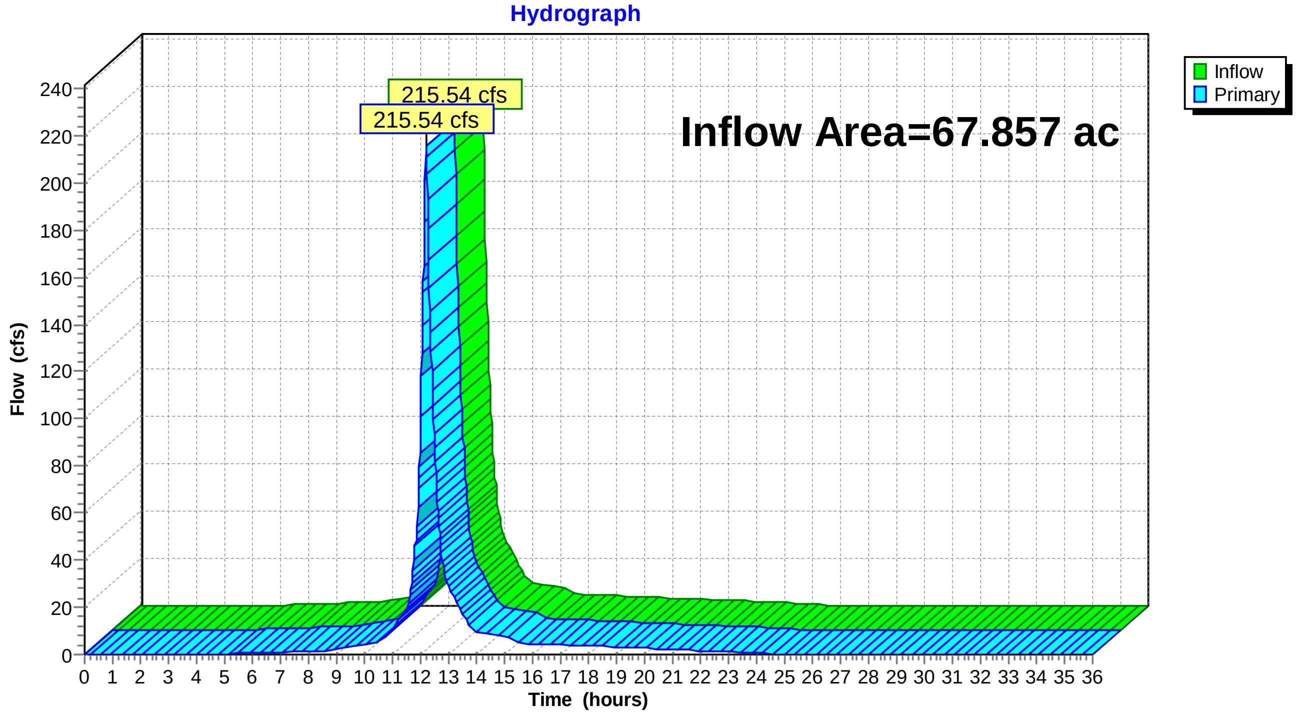


Summary for Pond 69P: Storm Sewer - See SWMM Model

Inflow Area =	67.857 ac,	8.02% Impervious, Inflow Depth = 2.90"		for 25-yr, 24-hr event
Inflow =	215.54 cfs @	12.20 hrs, Volume=	16.388 af	
Primary =	215.54 cfs @	12.20 hrs, Volume=	16.388 af,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs

Pond 69P: Storm Sewer - See SWMM Model



Summary for Pond 70P: SSB Inlet Culvert

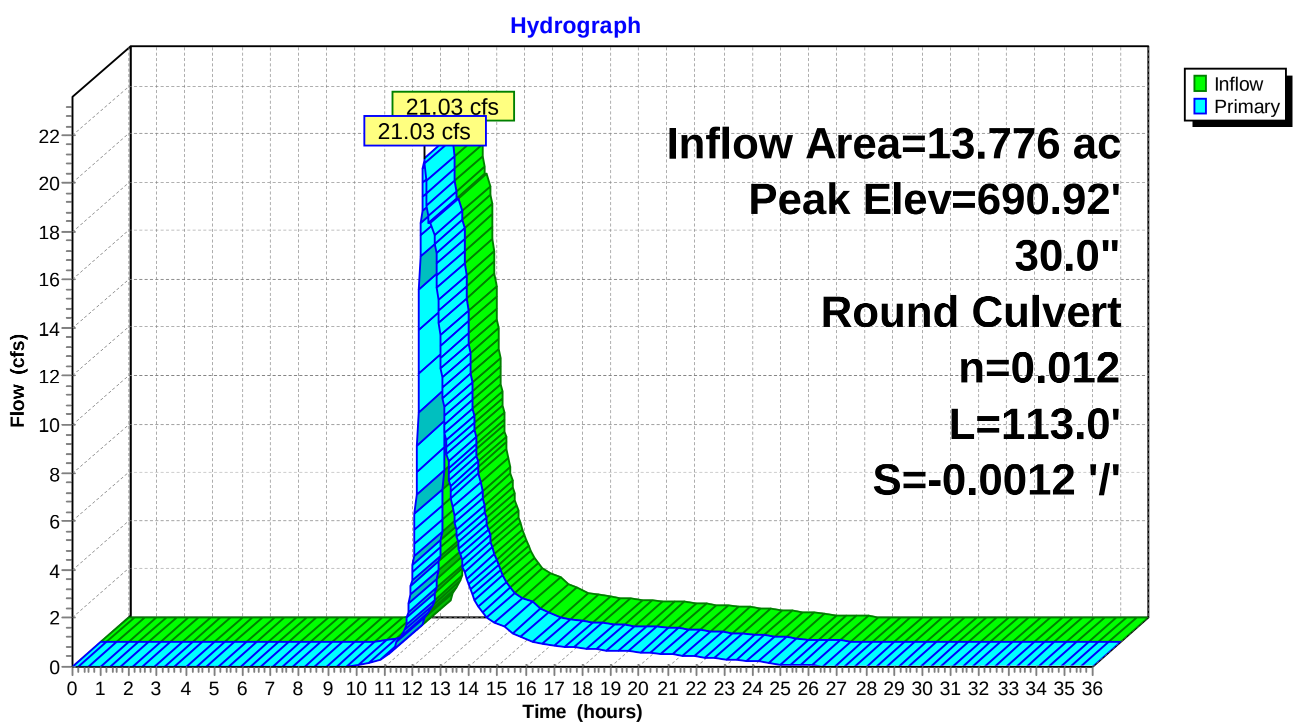
Inflow Area =	13.776 ac,	0.00% Impervious,	Inflow Depth = 2.33"	for 25-yr, 24-hr event
Inflow =	21.03 cfs @	12.42 hrs, Volume=	2.672 af	
Outflow =	21.03 cfs @	12.42 hrs, Volume=	2.672 af,	Atten= 0%, Lag= 0.0 min
Primary =	21.03 cfs @	12.42 hrs, Volume=	2.672 af	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Peak Elev= 690.92' @ 12.42 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	688.14'	**30.0" Round Culvert** L= 113.0' RCP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 688.01' / 688.14' S= -0.0012 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 4.91 sf

Primary OutFlow Max=21.03 cfs @ 12.42 hrs HW=690.92' (Free Discharge)
↑—**1=Culvert** (Barrel Controls 21.03 cfs @ 4.62 fps)

Pond 70P: SSB Inlet Culvert



Summary for Pond 71P: E-MCI Culvert

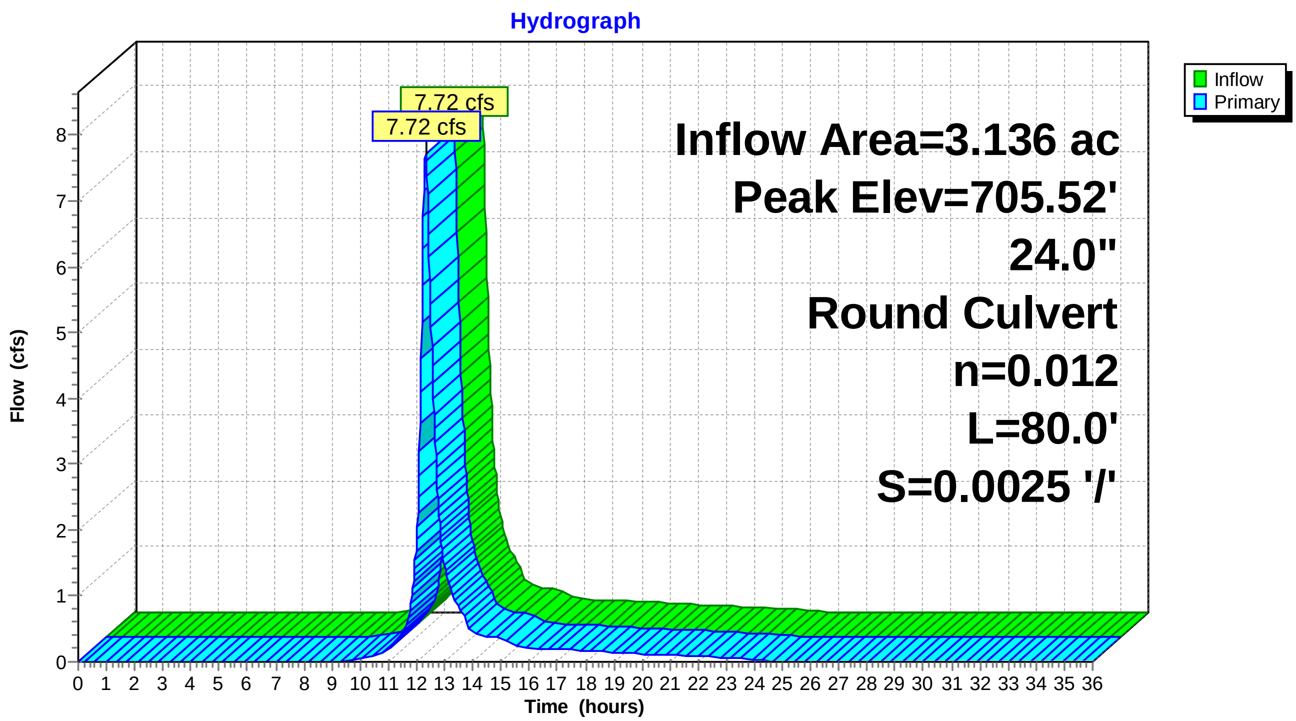
Inflow Area =	3.136 ac,	0.00% Impervious, Inflow Depth = 2.33"	for 25-yr, 24-hr event
Inflow =	7.72 cfs @	12.32 hrs, Volume=	0.608 af
Outflow =	7.72 cfs @	12.32 hrs, Volume=	0.608 af, Atten= 0%, Lag= 0.0 min
Primary =	7.72 cfs @	12.32 hrs, Volume=	0.608 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Peak Elev= 705.52' @ 12.32 hrs

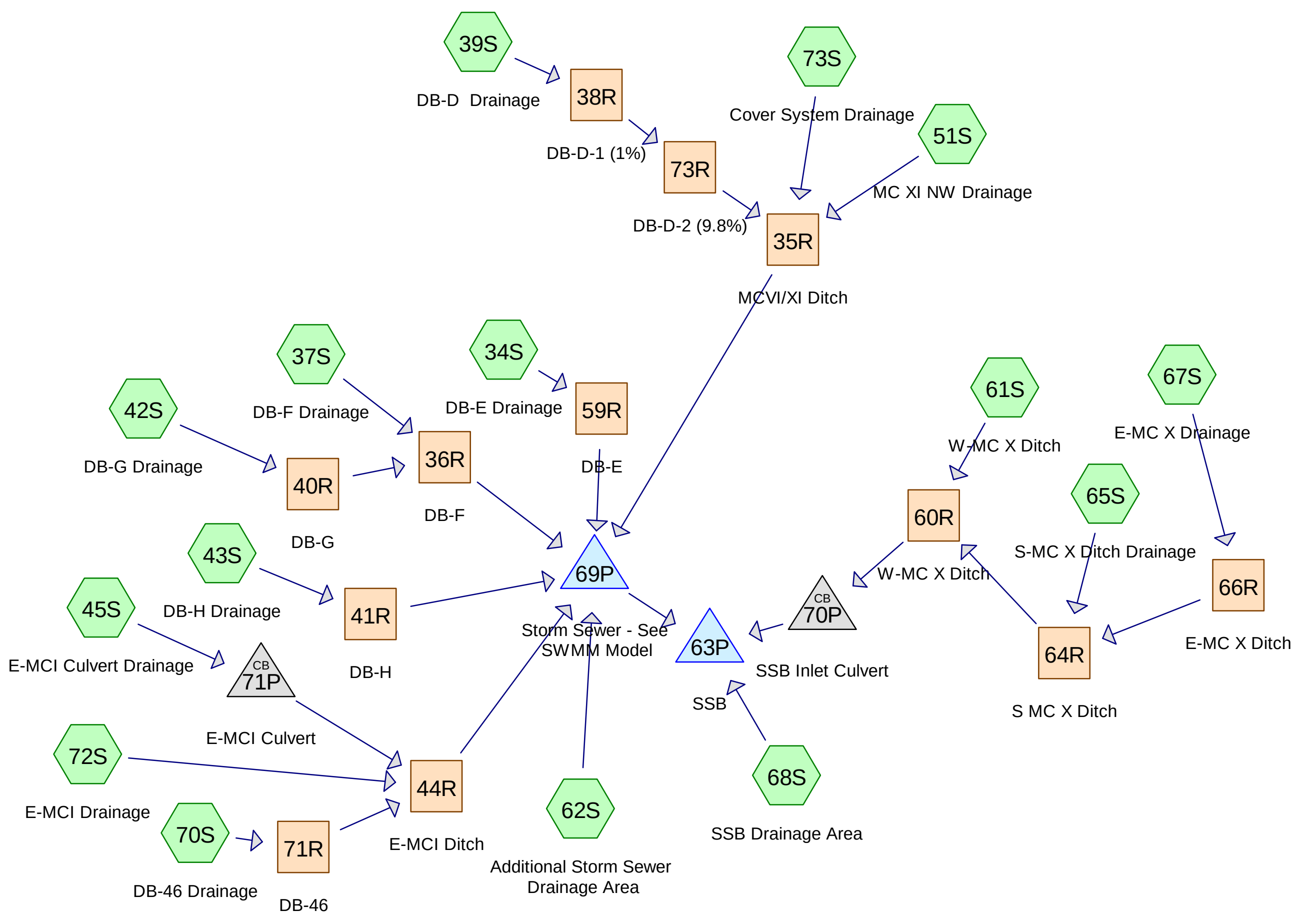
Device	Routing	Invert	Outlet Devices
#1	Primary	703.00'	**24.0" Round Culvert** L= 80.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 703.00' / 702.80' S= 0.0025 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

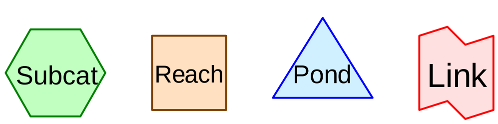
Primary OutFlow Max=7.72 cfs @ 12.32 hrs HW=705.52' TW=705.10' (Fixed TW Elev= 705.10')
1=Culvert (Inlet Controls 7.72 cfs @ 2.46 fps)

Pond 71P: E-MCI Culvert



South Sedimentation Basin (SSB) HYDROCAD OUTPUT – 100-yr, 24-hr





Routing Diagram for WDI Vert Exp SSB
Prepared by CTI, Printed 10/28/2021
HydroCAD® 10.10-5a s/n 11246 © 2020 HydroCAD Software Solutions LLC

Time span=0.00-36.00 hrs, dt=0.02 hrs, 1801 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 34S: DB-E Drainage Runoff Area=86,500 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=476' Tc=3.4 min CN=95 Runoff=16.02 cfs 0.751 af

Subcatchment 37S: DB-F Drainage Runoff Area=63,437 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=280' Tc=5.0 min CN=95 Runoff=11.26 cfs 0.551 af

Subcatchment 39S: DB-D Drainage Runoff Area=384,155 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=62' Slope=0.2500 '/' Tc=2.4 min CN=95 Runoff=73.42 cfs 3.335 af

Subcatchment 42S: DB-G Drainage Runoff Area=82,915 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=52' Slope=0.2500 '/' Tc=2.1 min CN=95 Runoff=16.00 cfs 0.720 af

Subcatchment 43S: DB-H Drainage Runoff Area=8,958 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=77' Tc=9.3 min CN=95 Runoff=1.34 cfs 0.078 af

Subcatchment 45S: E-MCI Culvert Drainage Runoff Area=136,608 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=667' Tc=22.3 min CN=84 Runoff=11.15 cfs 0.883 af

Subcatchment 51S: MC XI NW Drainage Runoff Area=464,875 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=480' Slope=0.0520 '/' Tc=16.5 min CN=84 Runoff=44.30 cfs 3.006 af

Subcatchment 61S: W-MC X Ditch Runoff Area=141,400 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=150' Slope=0.2500 '/' Tc=5.8 min CN=84 Runoff=19.95 cfs 0.914 af

Subcatchment 62S: Additional Storm Sewer Runoff Area=237,200 sf 100.00% Impervious Runoff Depth=4.88"
Tc=0.0 min CN=98 Runoff=46.10 cfs 2.216 af

Subcatchment 65S: S-MC X Ditch Drainage Runoff Area=205,200 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=160' Slope=0.3300 '/' Tc=5.4 min CN=84 Runoff=29.42 cfs 1.327 af

Subcatchment 67S: E-MC X Drainage Runoff Area=253,500 sf 0.00% Impervious Runoff Depth=3.38"
Flow Length=110' Slope=0.2500 '/' Tc=4.5 min CN=84 Runoff=37.89 cfs 1.639 af

Subcatchment 68S: SSB Drainage Area Runoff Area=900,800 sf 23.12% Impervious Runoff Depth=3.68"
Flow Length=400' Slope=0.0730 '/' Tc=13.7 min CN=87 Runoff=100.19 cfs 6.342 af

Subcatchment 70S: DB-46 Drainage Runoff Area=455,500 sf 0.00% Impervious Runoff Depth=3.00"
Flow Length=450' Slope=0.0350 '/' Tc=19.1 min CN=80 Runoff=35.98 cfs 2.612 af

Subcatchment 72S: E-MCI Drainage Runoff Area=177,527 sf 0.00% Impervious Runoff Depth=3.00"
Flow Length=1,086' Tc=33.4 min CN=80 Runoff=10.27 cfs 1.018 af

Subcatchment 73S: Cover System Drainage Runoff Area=858,183 sf 0.00% Impervious Runoff Depth=4.54"
Flow Length=1,385' Tc=9.7 min CN=95 Runoff=126.33 cfs 7.451 af

Reach 35R: MCVI/XI Ditch Avg. Flow Depth=1.92' Max Vel=8.39 fps Inflow=220.71 cfs 13.793 af
n=0.020 L=290.0' S=0.0100 '/' Capacity=1,123.17 cfs Outflow=218.94 cfs 13.793 af

Reach 36R: DB-F Avg. Flow Depth=1.28' Max Vel=5.30 fps Inflow=26.83 cfs 1.271 af
n=0.020 L=402.0' S=0.0100 '/' Capacity=85.77 cfs Outflow=26.17 cfs 1.271 af

Reach 38R: DB-D-1 (1%) Avg. Flow Depth=1.76' Max Vel=6.57 fps Inflow=73.42 cfs 3.335 af
n=0.020 L=1,851.0' S=0.0100 '/' Capacity=155.51 cfs Outflow=60.90 cfs 3.335 af

Reach 40R: DB-G Avg. Flow Depth=0.77' Max Vel=8.78 fps Inflow=16.00 cfs 0.720 af
n=0.020 L=610.0' S=0.0540 '/' Capacity=199.31 cfs Outflow=15.58 cfs 0.720 af

Reach 41R: DB-H Avg. Flow Depth=0.42' Max Vel=2.52 fps Inflow=1.34 cfs 0.078 af
n=0.020 L=127.1' S=0.0100 '/' Capacity=85.74 cfs Outflow=1.32 cfs 0.078 af

Reach 44R: E-MCI Ditch Avg. Flow Depth=2.18' Max Vel=3.88 fps Inflow=55.28 cfs 4.514 af
n=0.025 L=250.0' S=0.0041 '/' Capacity=129.69 cfs Outflow=55.06 cfs 4.514 af

Reach 59R: DB-E Avg. Flow Depth=1.05' Max Vel=4.64 fps Inflow=16.02 cfs 0.751 af
n=0.020 L=576.5' S=0.0100 '/' Capacity=85.81 cfs Outflow=15.09 cfs 0.751 af

Reach 60R: W-MC X Ditch Avg. Flow Depth=1.29' Max Vel=2.75 fps Inflow=34.54 cfs 3.881 af
n=0.025 L=833.0' S=0.0024 '/' Capacity=326.61 cfs Outflow=32.84 cfs 3.881 af

Reach 64R: S MC X Ditch Avg. Flow Depth=2.44' Max Vel=3.09 fps Inflow=34.39 cfs 2.966 af
n=0.025 L=1,110.0' S=0.0027 '/' Capacity=103.29 cfs Outflow=27.51 cfs 2.966 af

Reach 66R: E-MC X Ditch Avg. Flow Depth=1.48' Max Vel=2.01 fps Inflow=37.89 cfs 1.639 af
n=0.030 L=1,500.0' S=0.0025 '/' Capacity=145.10 cfs Outflow=22.01 cfs 1.639 af

Reach 71R: DB-46 Avg. Flow Depth=1.16' Max Vel=4.09 fps Inflow=35.98 cfs 2.612 af
n=0.025 L=200.0' S=0.0100 '/' Capacity=152.89 cfs Outflow=35.82 cfs 2.612 af

Reach 73R: DB-D-2 (9.8%) Avg. Flow Depth=1.15' Max Vel=15.43 fps Inflow=60.90 cfs 3.335 af
n=0.020 L=187.0' S=0.0980 '/' Capacity=486.88 cfs Outflow=60.36 cfs 3.335 af

Pond 63P: SSB Inflow=416.80 cfs 32.845 af
Primary=416.80 cfs 32.845 af

Pond 69P: Storm Sewer - See SWMM Model Inflow=295.86 cfs 22.622 af
Primary=295.86 cfs 22.622 af

Pond 70P: SSB Inlet Culvert Peak Elev=692.17' Inflow=32.84 cfs 3.881 af
30.0" Round Culvert n=0.012 L=113.0' S=-0.0012 '/' Outflow=32.84 cfs 3.881 af

Pond 71P: E-MCI Culvert Peak Elev=705.97' Inflow=11.15 cfs 0.883 af
24.0" Round Culvert n=0.012 L=80.0' S=0.0025 '/' Outflow=11.15 cfs 0.883 af

Total Runoff Area = 102.313 ac Runoff Volume = 32.845 af Average Runoff Depth = 3.85"
90.00% Pervious = 92.086 ac 10.00% Impervious = 10.227 ac

Summary for Subcatchment 34S: DB-E Drainage

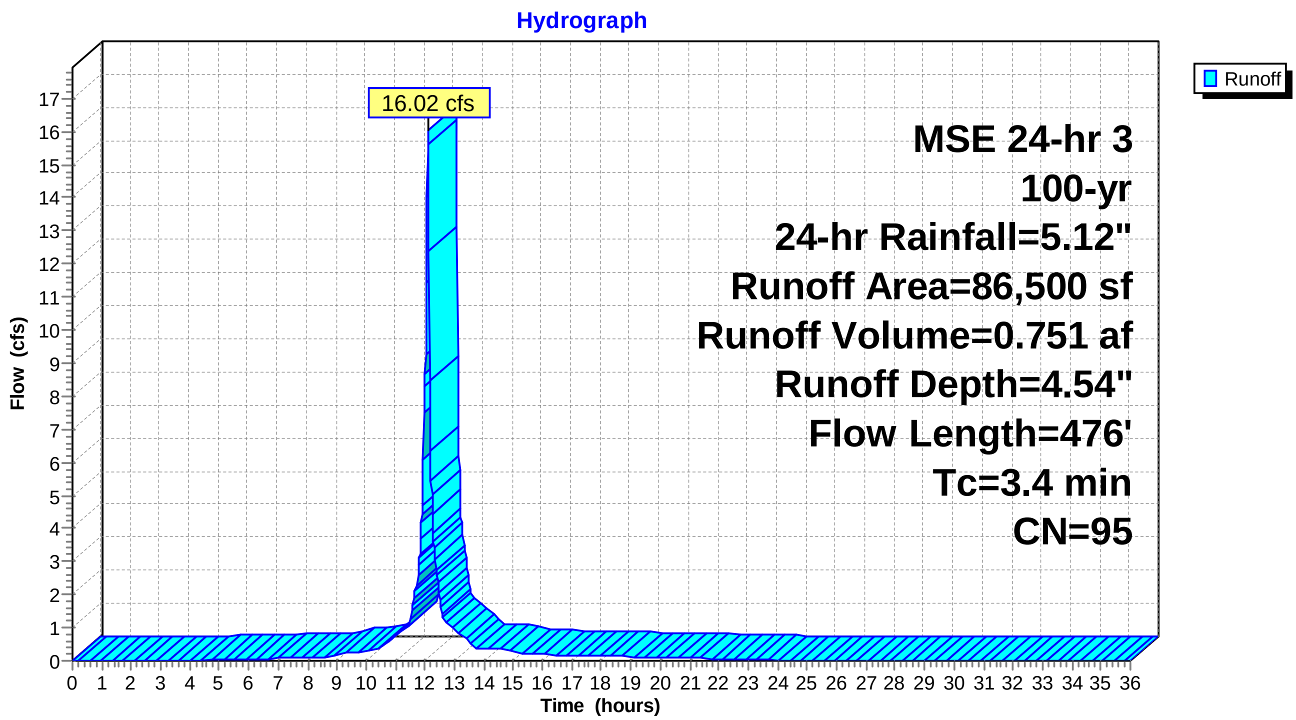
Runoff = 16.02 cfs @ 12.10 hrs, Volume= 0.751 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	86,500	95	Closure Turf
	86,500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.5	66	0.2500	0.44		**Sheet Flow,** n= 0.120 P2= 2.35"
0.9	410	0.0100	7.43	89.16	**Channel Flow,** Area= 12.0 sf Perim= 12.0' r= 1.00' n= 0.020
3.4	476	Total			

Subcatchment 34S: DB-E Drainage



Summary for Subcatchment 37S: DB-F Drainage

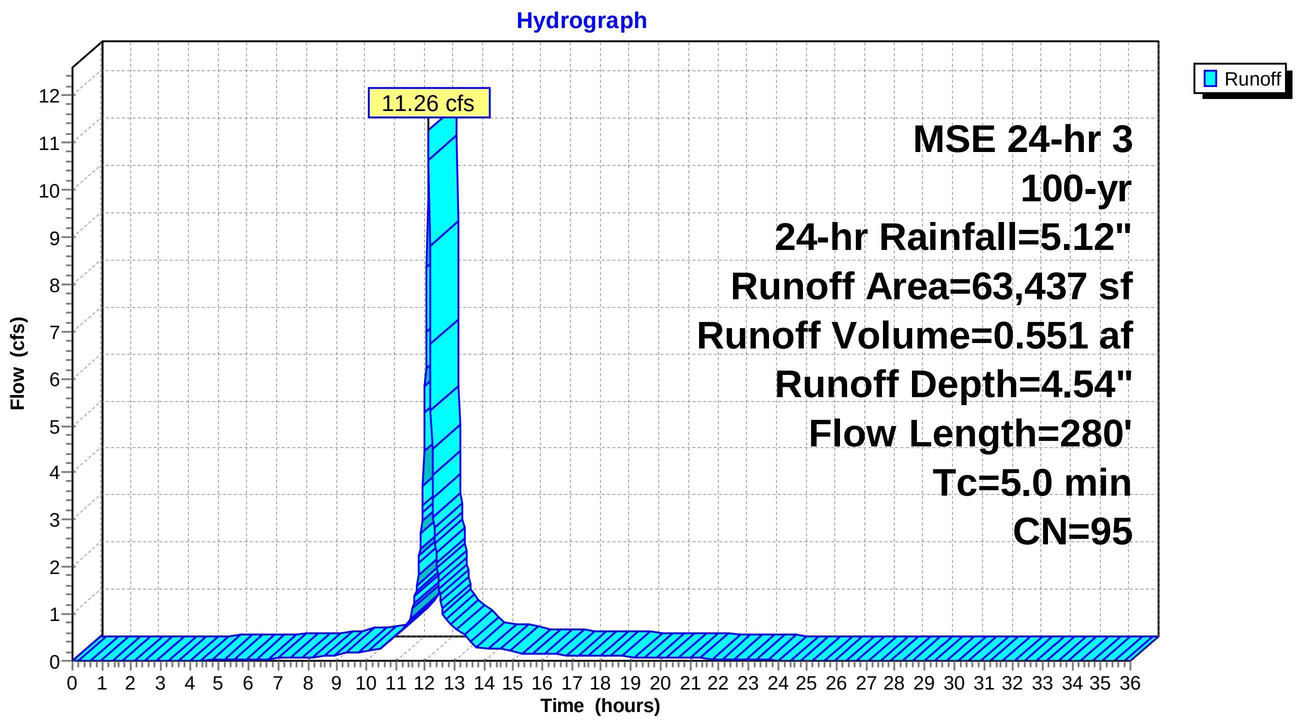
Runoff = 11.26 cfs @ 12.12 hrs, Volume= 0.551 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	63,437	95	Closure Turf
	63,437		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.5	65	0.2500	0.44		**Sheet Flow,** n= 0.120 P2= 2.35"
2.5	215	0.0050	1.44		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
5.0	280	Total			

Subcatchment 37S: DB-F Drainage



Summary for Subcatchment 39S: DB-D Drainage

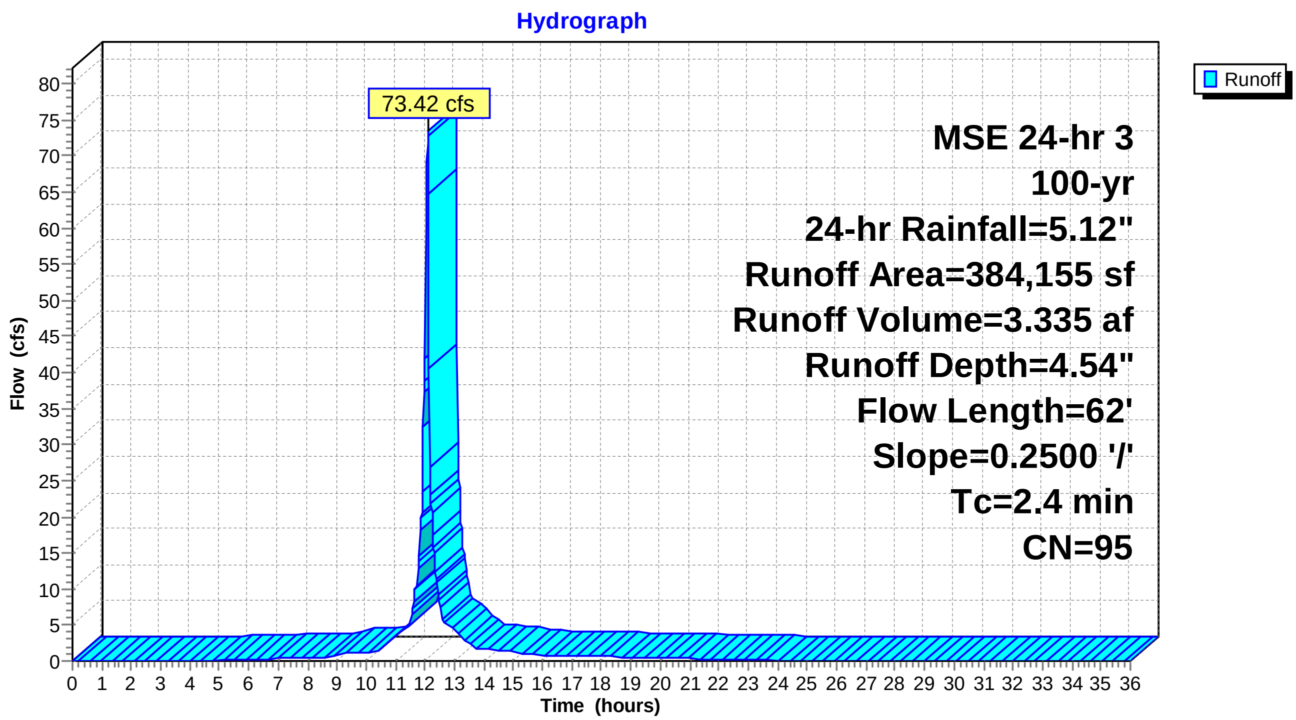
Runoff = 73.42 cfs @ 12.09 hrs, Volume= 3.335 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	384,155	95	Closure Turf
	384,155		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.4	62	0.2500	0.43		**Sheet Flow,** n= 0.120 P2= 2.35"

Subcatchment 39S: DB-D Drainage



Summary for Subcatchment 42S: DB-G Drainage

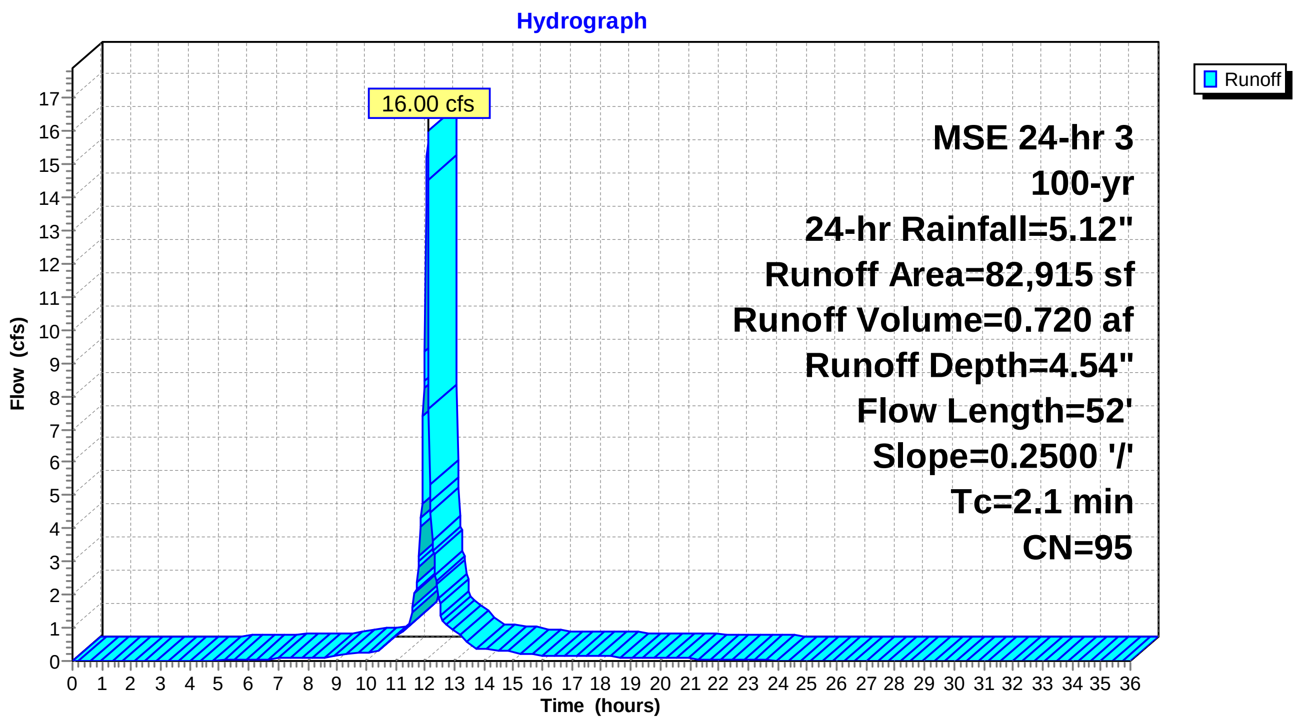
Runoff = 16.00 cfs @ 12.09 hrs, Volume= 0.720 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	82,915	95	Closure Turf
	82,915		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.1	52	0.2500	0.42		**Sheet Flow,** n= 0.120 P2= 2.35"

Subcatchment 42S: DB-G Drainage



Summary for Subcatchment 43S: DB-H Drainage

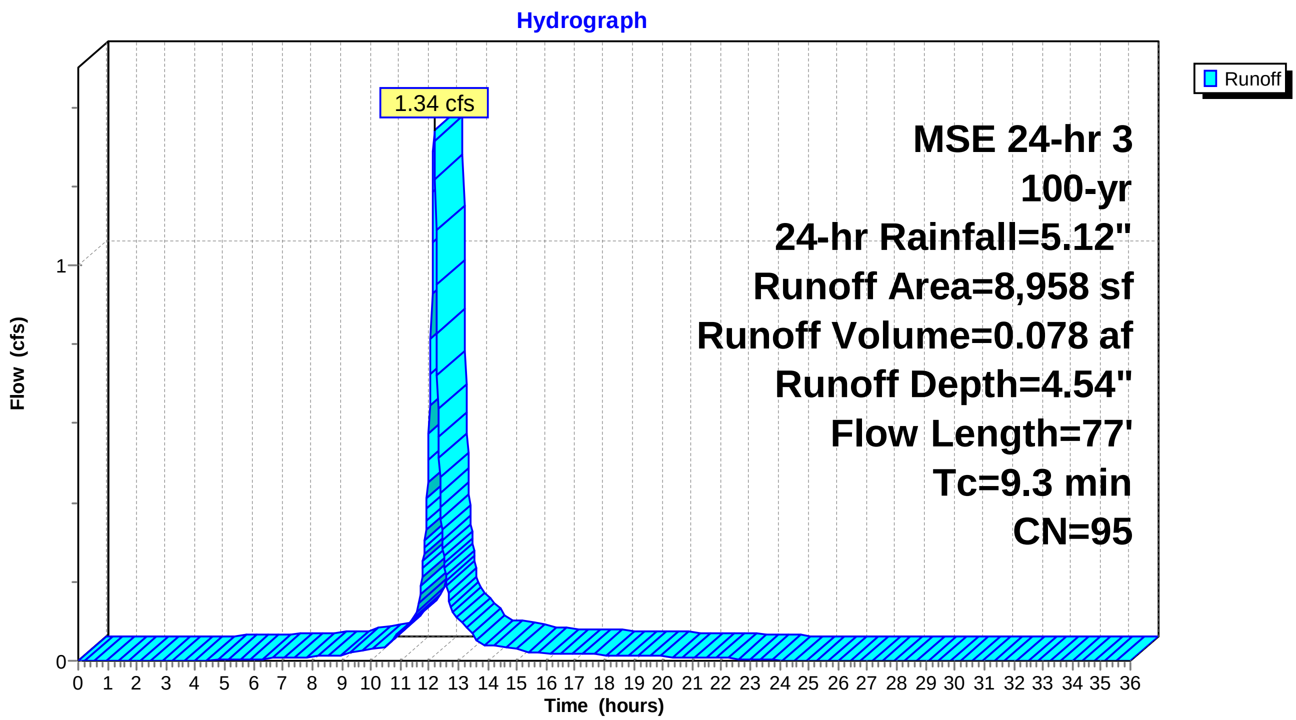
Runoff = 1.34 cfs @ 12.16 hrs, Volume= 0.078 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	8,958	95	Closure Turf
	8,958		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	29	0.0100	0.06		**Sheet Flow,** n= 0.220 P2= 2.35"
1.7	48	0.3300	0.46		**Sheet Flow,** n= 0.120 P2= 2.35"
9.3	77	Total			

Subcatchment 43S: DB-H Drainage



Summary for Subcatchment 45S: E-MCI Culvert Drainage

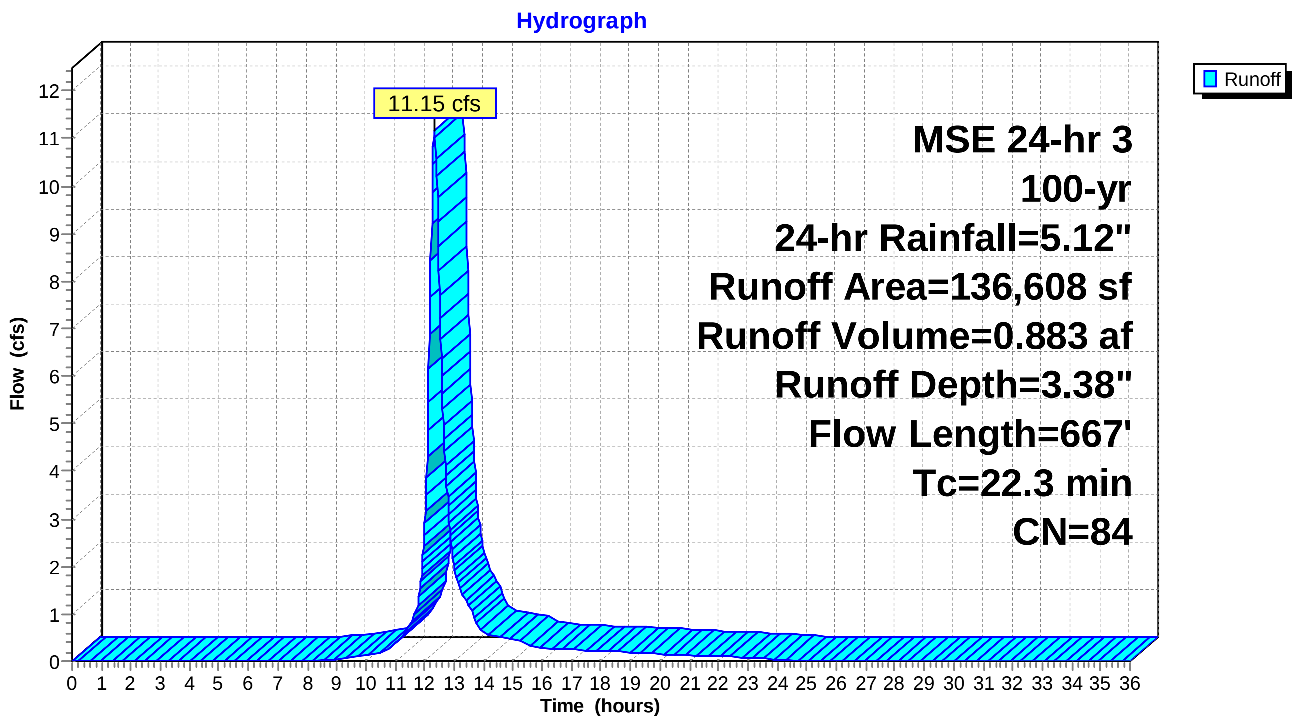
Runoff = 11.15 cfs @ 12.32 hrs, Volume= 0.883 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
	104,100	80	>75% Grass cover, Good, HSG D
*	32,508	95	Closure Turf
	136,608	84	Weighted Average
	136,608		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.2	32	0.0100	0.06		**Sheet Flow, Closure turf** n= 0.220 P2= 2.35"
1.6	35	0.3300	0.36		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
8.2	133	0.0800	0.27		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
4.3	467	0.0670	1.81		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
22.3	667	Total			

Subcatchment 45S: E-MCI Culvert Drainage



Summary for Subcatchment 51S: MC XI NW Drainage

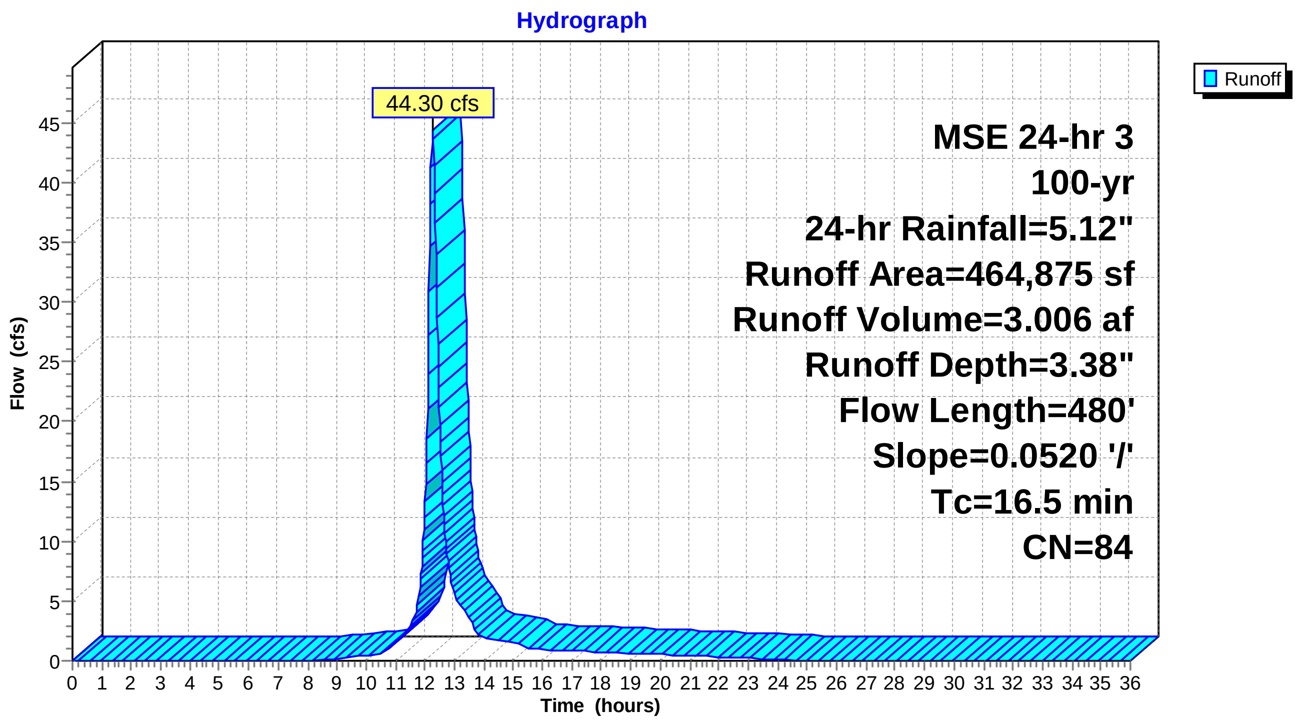
Runoff = 44.30 cfs @ 12.25 hrs, Volume= 3.006 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
464,875	84	50-75% Grass cover, Fair, HSG D
464,875		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.6	200	0.0520	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
2.9	280	0.0520	1.60		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
16.5	480	Total			

Subcatchment 51S: MC XI NW Drainage



Summary for Subcatchment 61S: W-MC X Ditch

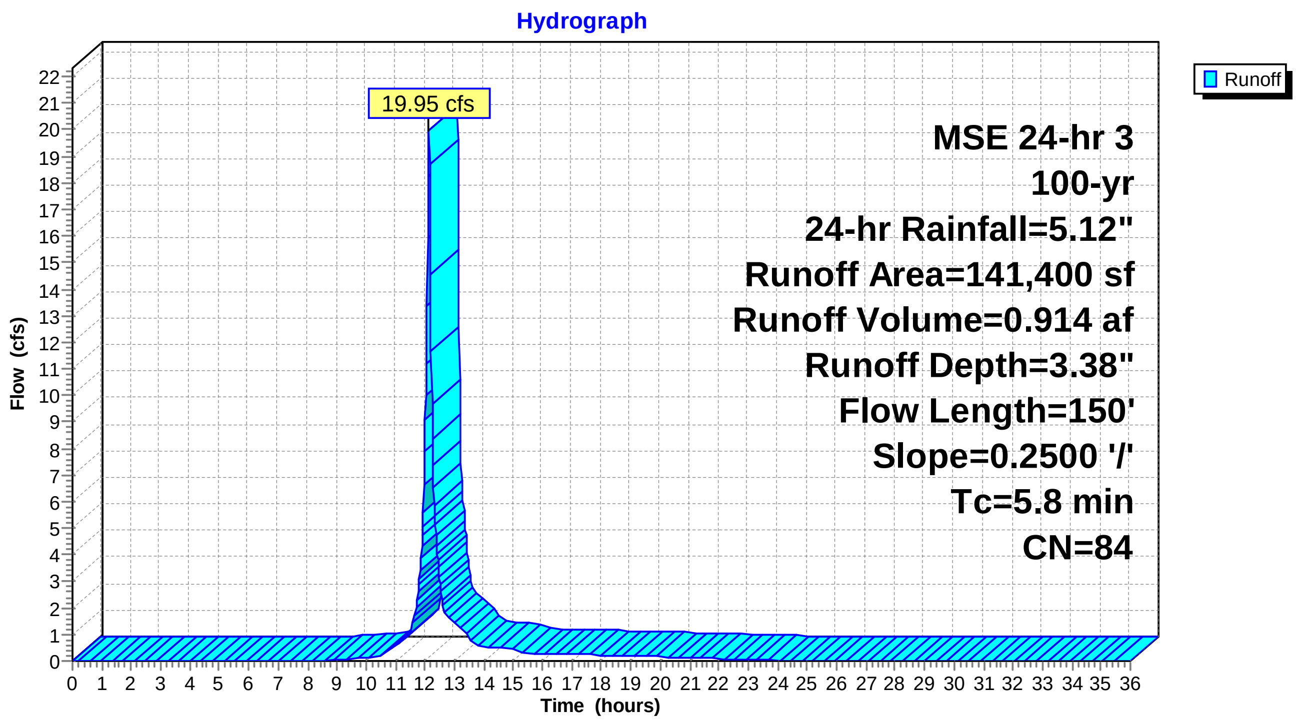
Runoff = 19.95 cfs @ 12.13 hrs, Volume= 0.914 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
141,400	84	50-75% Grass cover, Fair, HSG D
141,400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	150	0.2500	0.43		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 61S: W-MC X Ditch



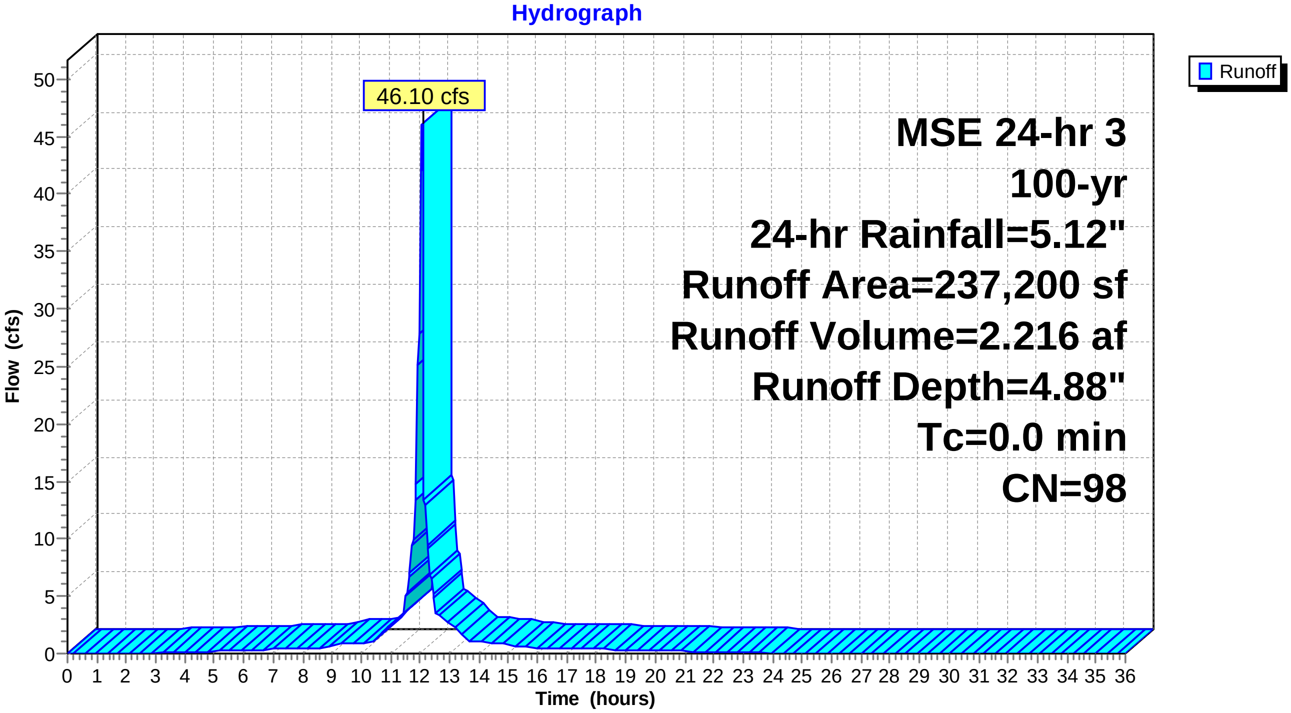
Summary for Subcatchment 62S: Additional Storm Sewer Drainage Area

Runoff = 46.10 cfs @ 12.08 hrs, Volume= 2.216 af, Depth= 4.88"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
237,200	98	Paved parking, HSG D
237,200		100.00% Impervious Area

Subcatchment 62S: Additional Storm Sewer Drainage Area



Summary for Subcatchment 65S: S-MC X Ditch Drainage

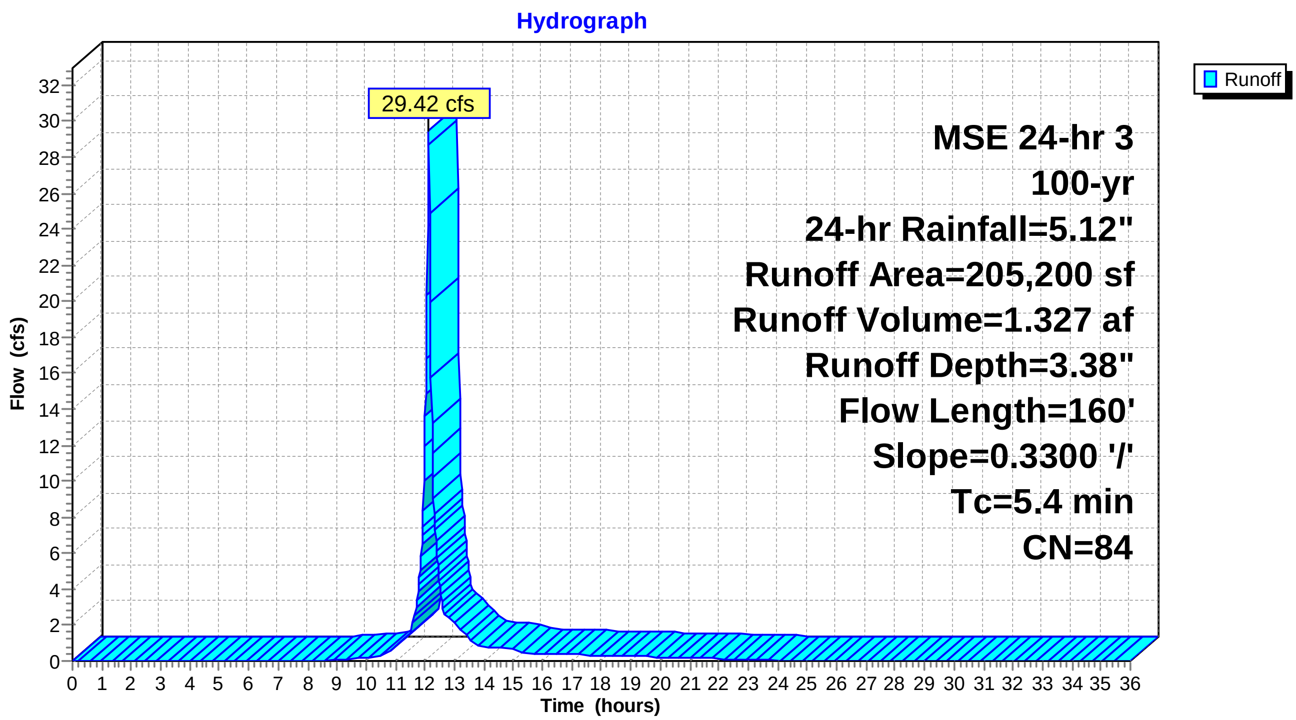
Runoff = 29.42 cfs @ 12.12 hrs, Volume= 1.327 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
205,200	84	50-75% Grass cover, Fair, HSG D
205,200		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	160	0.3300	0.49		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 65S: S-MC X Ditch Drainage



Summary for Subcatchment 67S: E-MC X Drainage

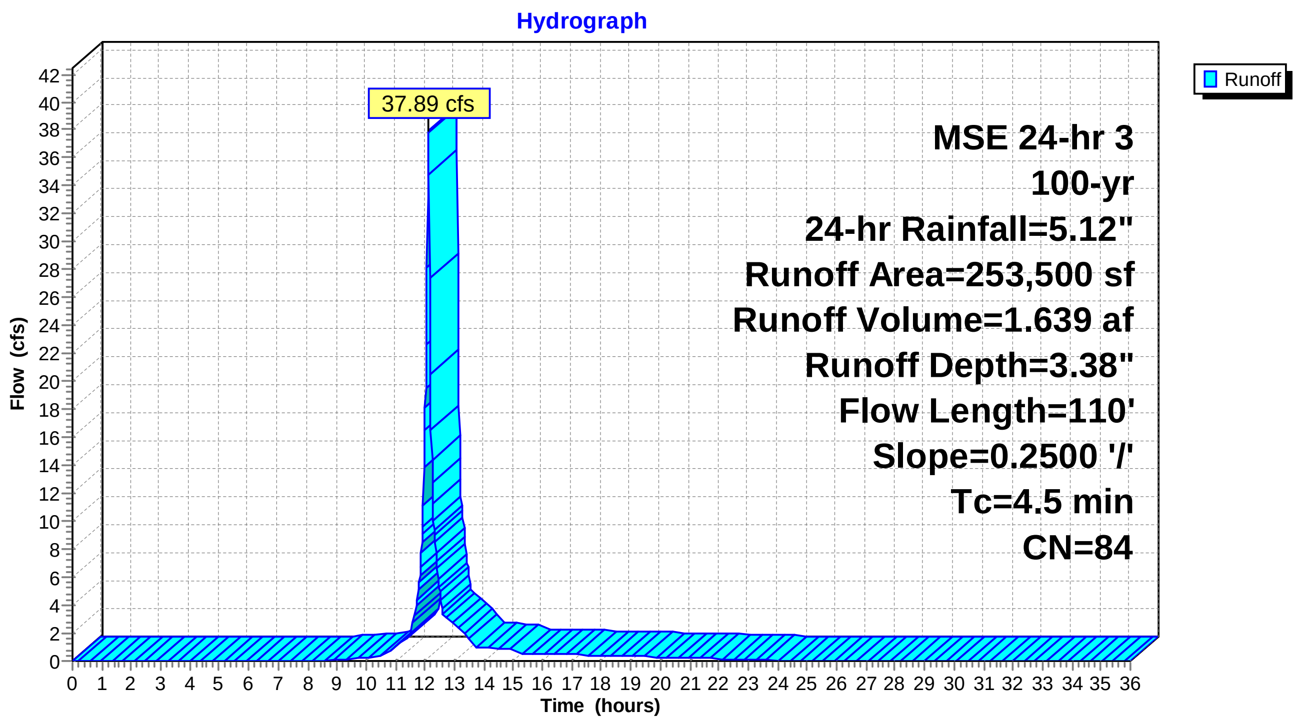
Runoff = 37.89 cfs @ 12.12 hrs, Volume= 1.639 af, Depth= 3.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
253,500	84	50-75% Grass cover, Fair, HSG D
253,500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.5	110	0.2500	0.41		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"

Subcatchment 67S: E-MC X Drainage



Summary for Subcatchment 68S: SSB Drainage Area

Total area is 900,800 sf
Pond area is 208,300 sf
Therefore, surrounding area is 692,500 sf (900,800 - 208,300)

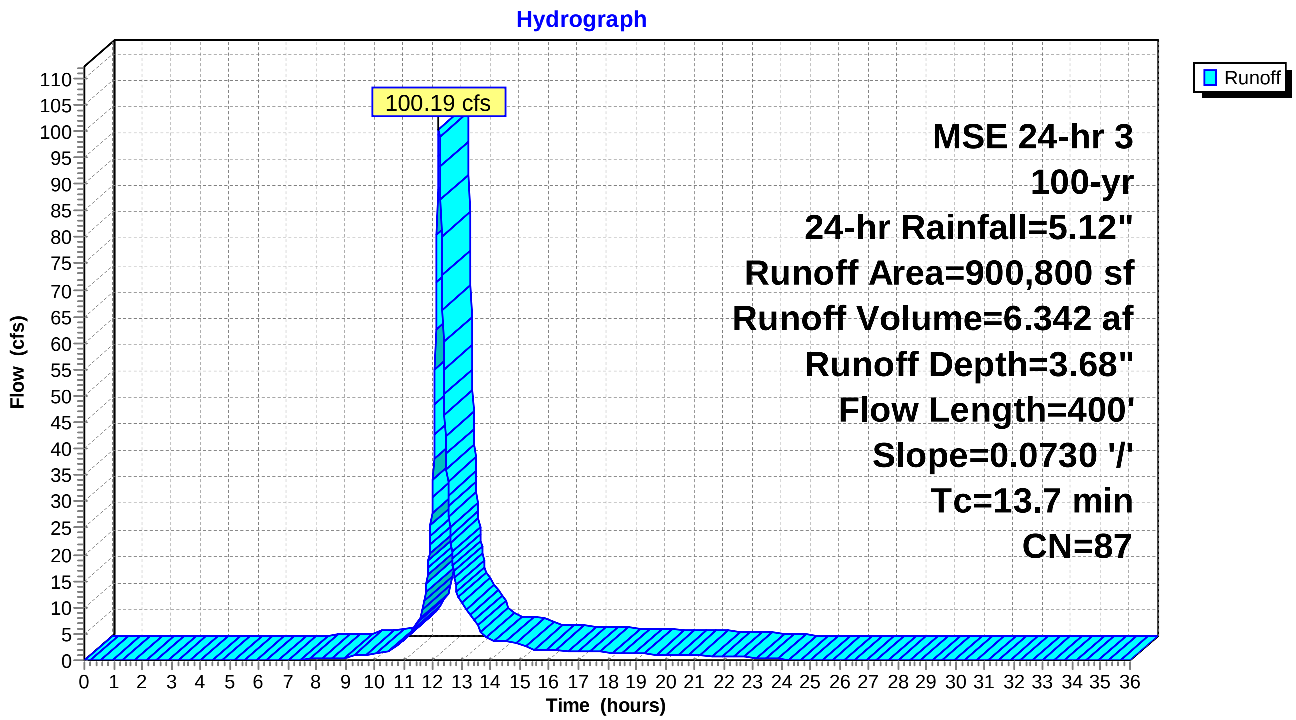
Runoff = 100.19 cfs @ 12.22 hrs, Volume= 6.342 af, Depth= 3.68"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
692,500	84	50-75% Grass cover, Fair, HSG D
208,300	98	Water Surface, HSG D
900,800	87	Weighted Average
692,500		76.88% Pervious Area
208,300		23.12% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.9	200	0.0730	0.28		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
1.8	200	0.0730	1.89		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
13.7	400	Total			

Subcatchment 68S: SSB Drainage Area



Summary for Subcatchment 70S: DB-46 Drainage

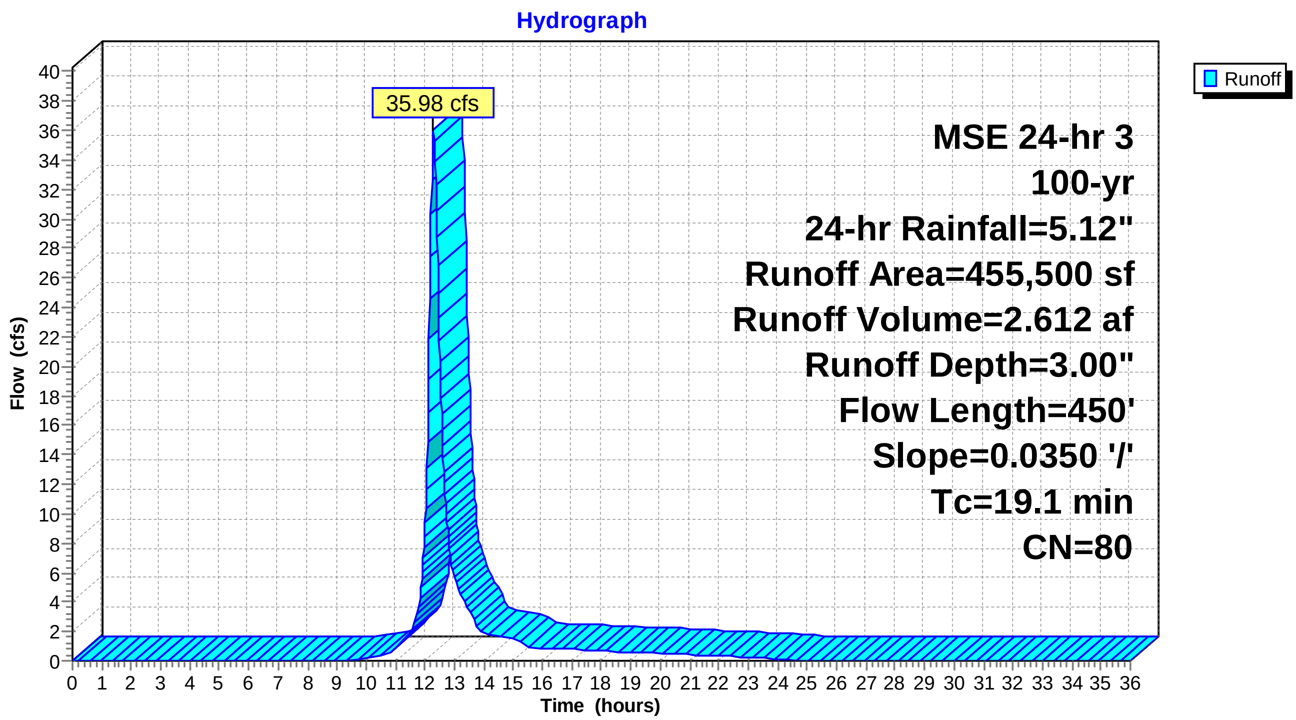
Runoff = 35.98 cfs @ 12.28 hrs, Volume= 2.612 af, Depth= 3.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
455,500	80	>75% Grass cover, Good, HSG D
455,500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.9	200	0.0350	0.21		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
3.2	250	0.0350	1.31		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
19.1	450	Total			

Subcatchment 70S: DB-46 Drainage



Summary for Subcatchment 72S: E-MCI Drainage

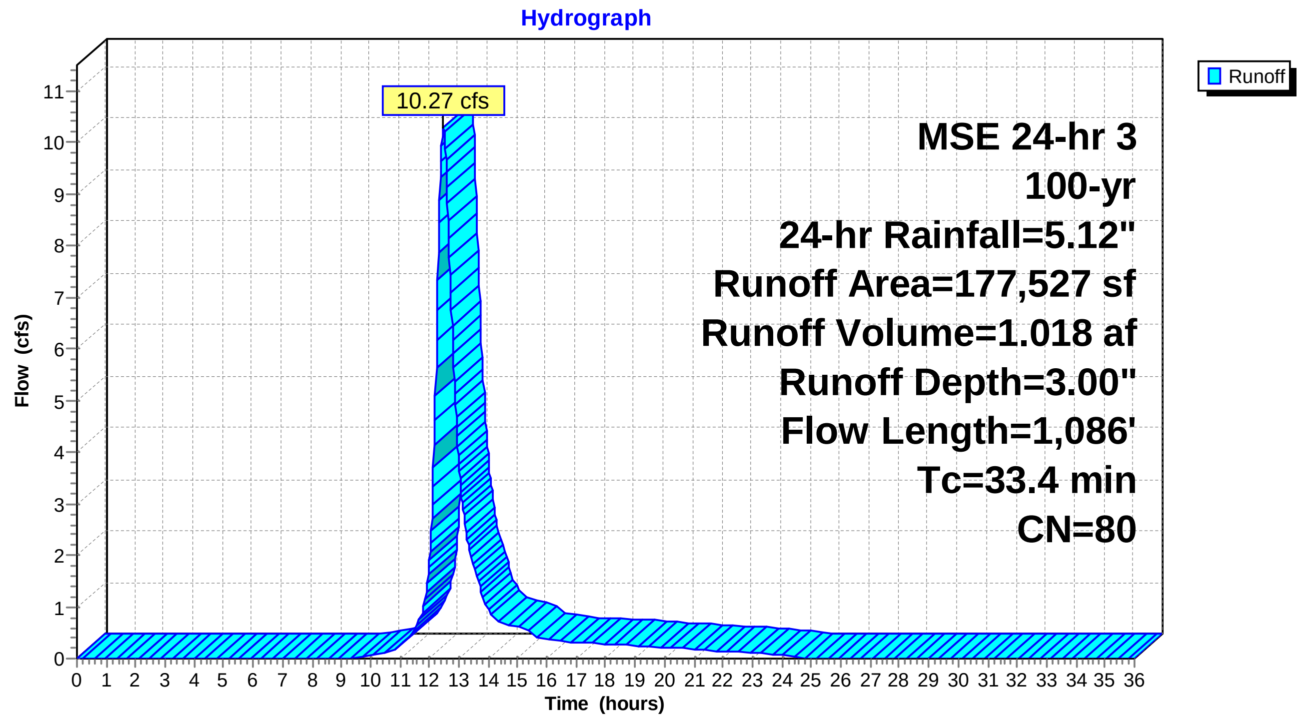
Runoff = 10.27 cfs @ 12.46 hrs, Volume= 1.018 af, Depth= 3.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

Area (sf)	CN	Description
177,527	80	>75% Grass cover, Good, HSG D
177,527		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
19.9	200	0.0200	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 2.35"
10.8	640	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.7	246	0.0488	1.55		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
33.4	1,086	Total			

Subcatchment 72S: E-MCI Drainage



Summary for Subcatchment 73S: Cover System Drainage

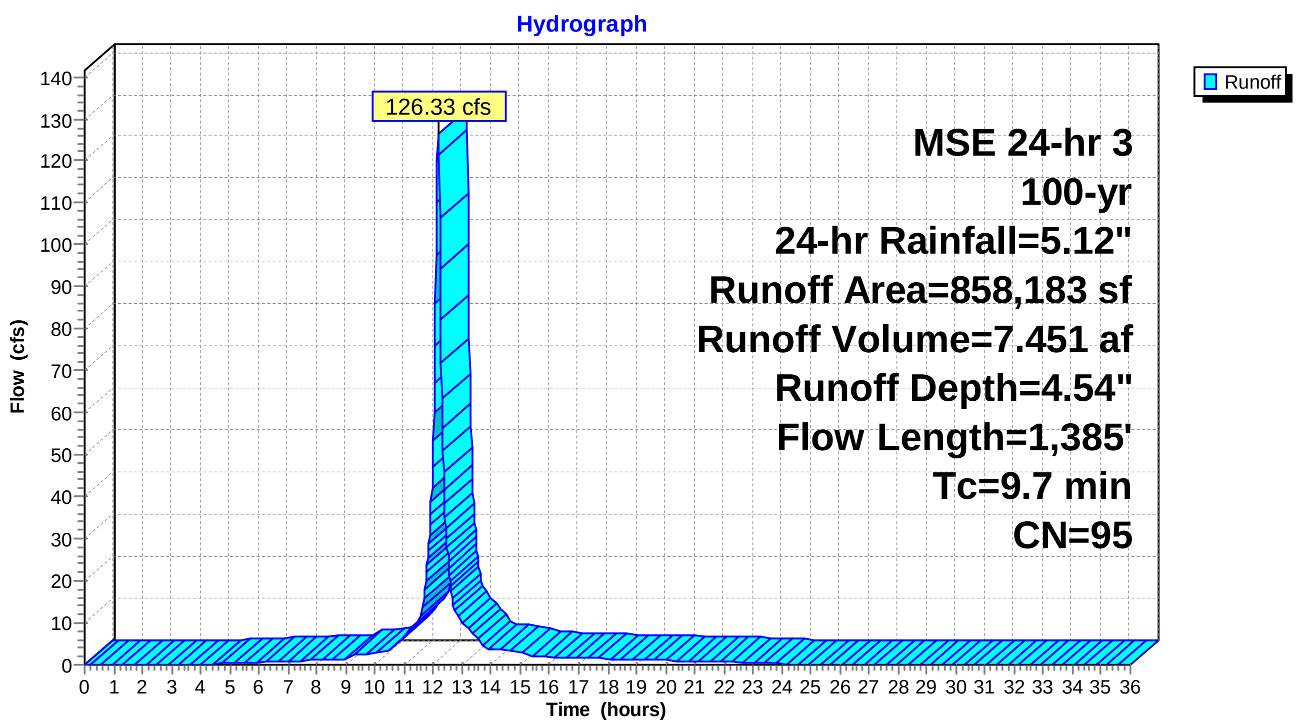
Runoff = 126.33 cfs @ 12.17 hrs, Volume= 7.451 af, Depth= 4.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
MSE 24-hr 3 100-yr, 24-hr Rainfall=5.12"

	Area (sf)	CN	Description
*	858,183	95	Closure Turf
	858,183		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	200	0.2500	0.55		**Sheet Flow,** n= 0.120 P2= 2.35"
0.5	321	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
2.7	626	0.0360	3.85		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.4	238	0.2500	10.15		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
9.7	1,385	Total			

Subcatchment 73S: Cover System Drainage



Summary for Reach 35R: MCVI/XI Ditch

Inflow Area = 39.192 ac, 0.00% Impervious, Inflow Depth = 4.22" for 100-yr, 24-hr event
Inflow = 220.71 cfs @ 12.19 hrs, Volume= 13.793 af
Outflow = 218.94 cfs @ 12.21 hrs, Volume= 13.793 af, Atten= 1%, Lag= 1.0 min

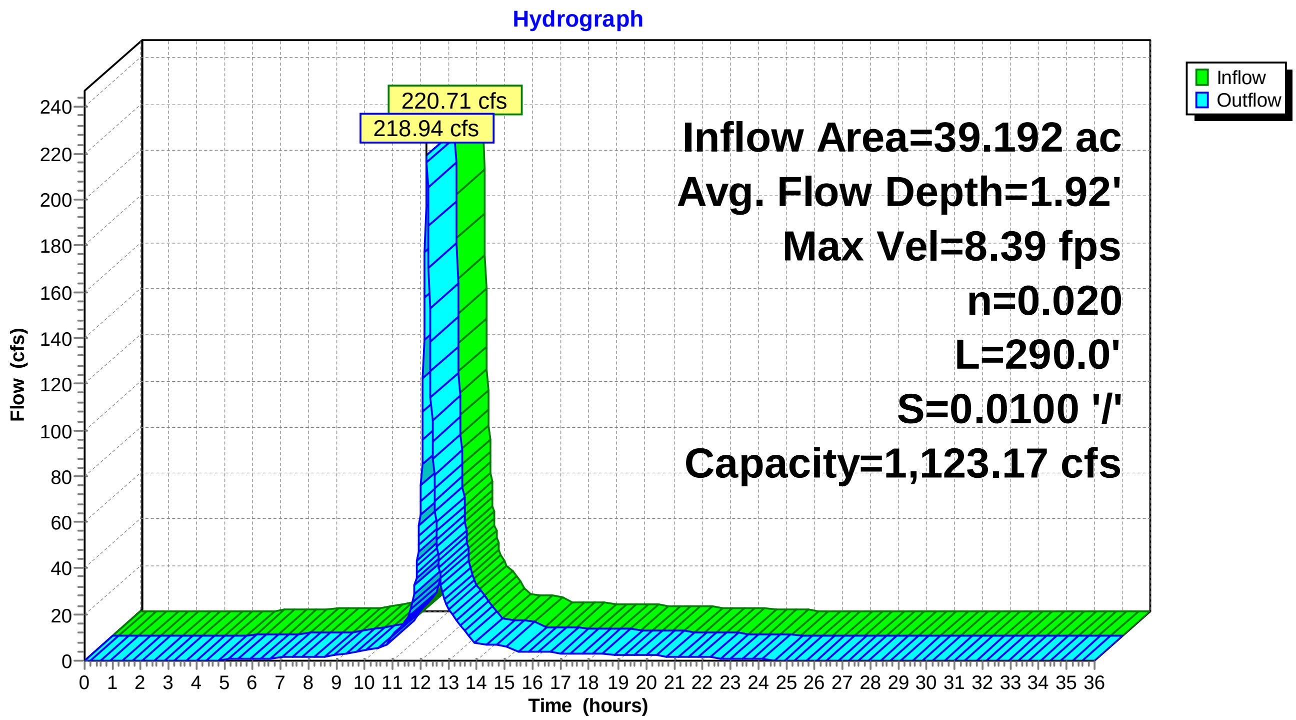
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 8.39 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 2.05 fps, Avg. Travel Time= 2.4 min

Peak Storage= 7,611 cf @ 12.20 hrs
Average Depth at Peak Storage= 1.92' , Surface Width= 21.35'
Bank-Full Depth= 4.00' Flow Area= 88.0 sf, Capacity= 1,123.17 cfs

6.00' x 4.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 '/' Top Width= 38.00'
Length= 290.0' Slope= 0.0100 '/'
Inlet Invert= 700.15', Outlet Invert= 697.26'

‡

Reach 35R: MCVI/XI Ditch



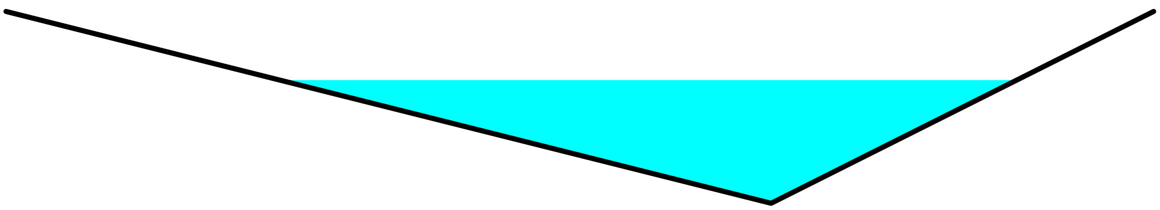
Summary for Reach 36R: DB-F

Inflow Area = 3.360 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 26.83 cfs @ 12.12 hrs, Volume= 1.271 af
Outflow = 26.17 cfs @ 12.15 hrs, Volume= 1.271 af, Atten= 2%, Lag= 2.1 min

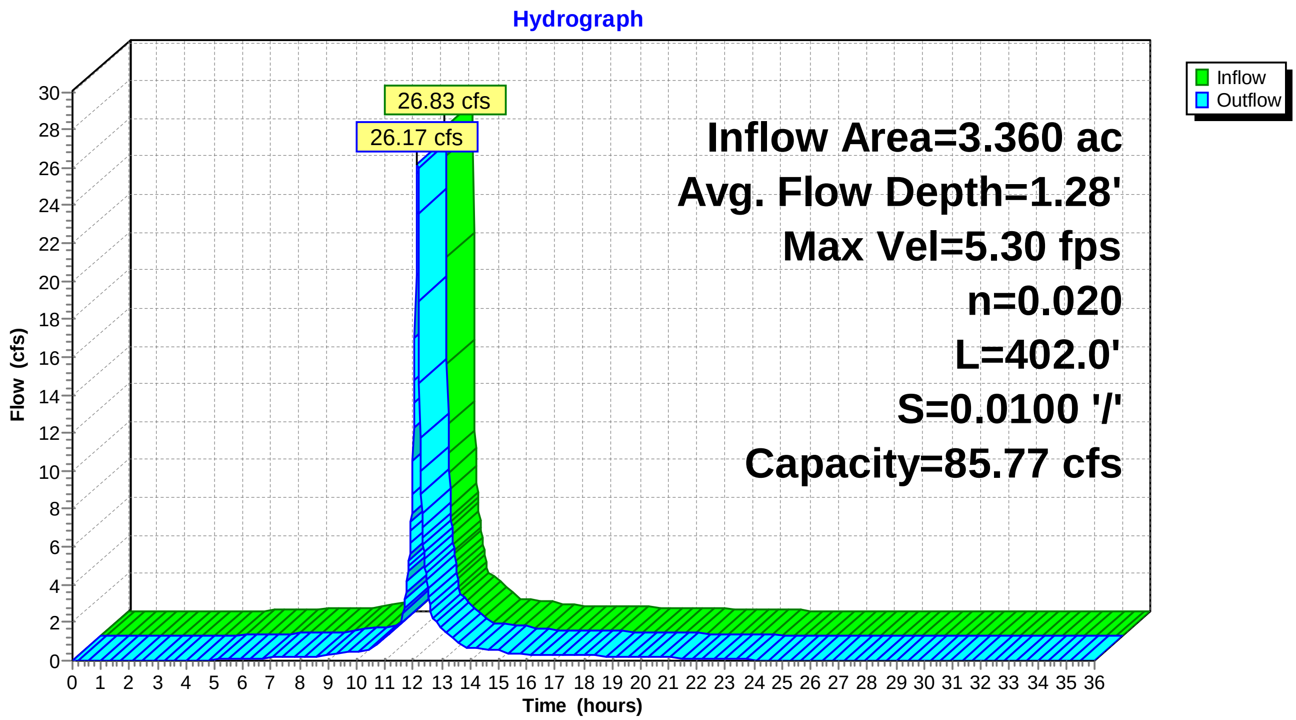
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 5.30 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 1.64 fps, Avg. Travel Time= 4.1 min

Peak Storage= 1,984 cf @ 12.13 hrs
Average Depth at Peak Storage= 1.28' , Surface Width= 7.70'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 85.77 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 402.0' Slope= 0.0100 '/'
Inlet Invert= 712.02', Outlet Invert= 708.00'



Reach 36R: DB-F



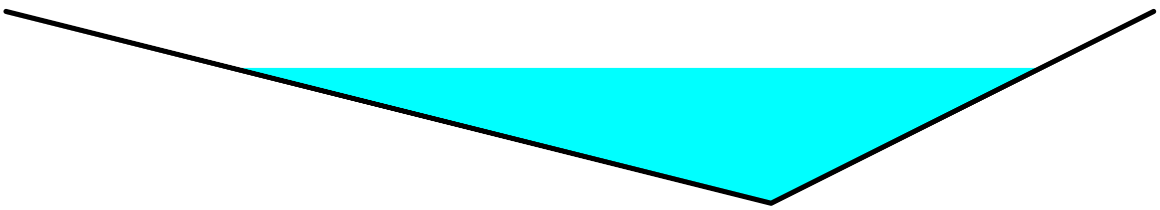
Summary for Reach 38R: DB-D-1 (1%)

Inflow Area = 8.819 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 73.42 cfs @ 12.09 hrs, Volume= 3.335 af
Outflow = 60.90 cfs @ 12.20 hrs, Volume= 3.335 af, Atten= 17%, Lag= 6.5 min

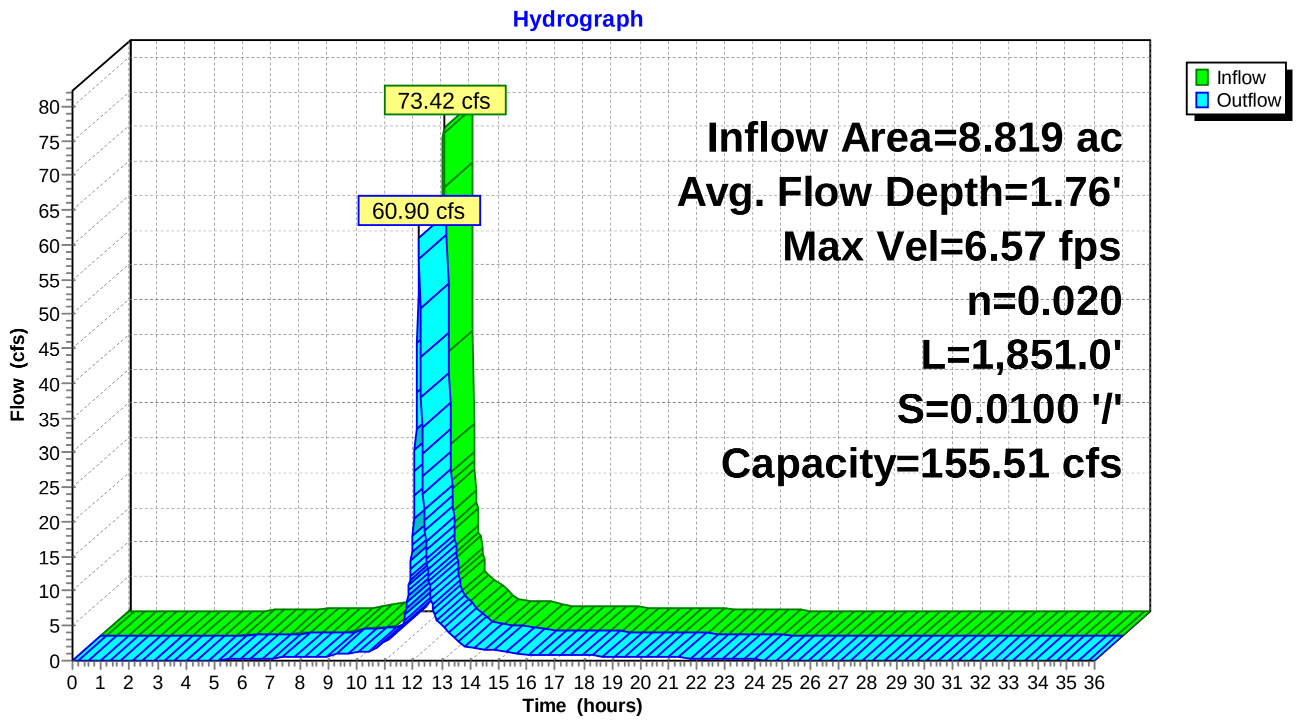
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 6.57 fps, Min. Travel Time= 4.7 min
Avg. Velocity = 1.80 fps, Avg. Travel Time= 17.2 min

Peak Storage= 17,225 cf @ 12.12 hrs
Average Depth at Peak Storage= 1.76' , Surface Width= 10.57'
Bank-Full Depth= 2.50' Flow Area= 18.8 sf, Capacity= 155.51 cfs

0.00' x 2.50' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 15.00'
Length= 1,851.0' Slope= 0.0100 '/'
Inlet Invert= 744.85', Outlet Invert= 726.34'



Reach 38R: DB-D-1 (1%)



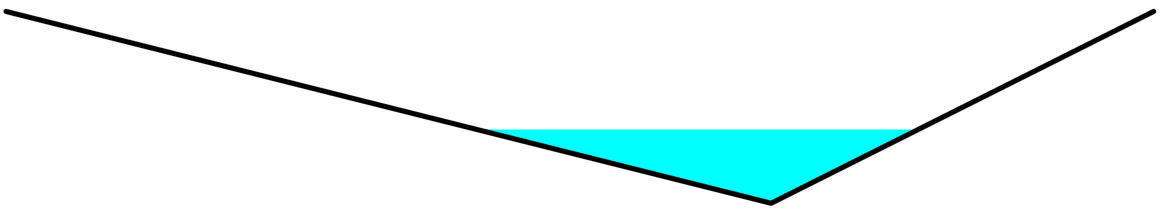
Summary for Reach 40R: DB-G

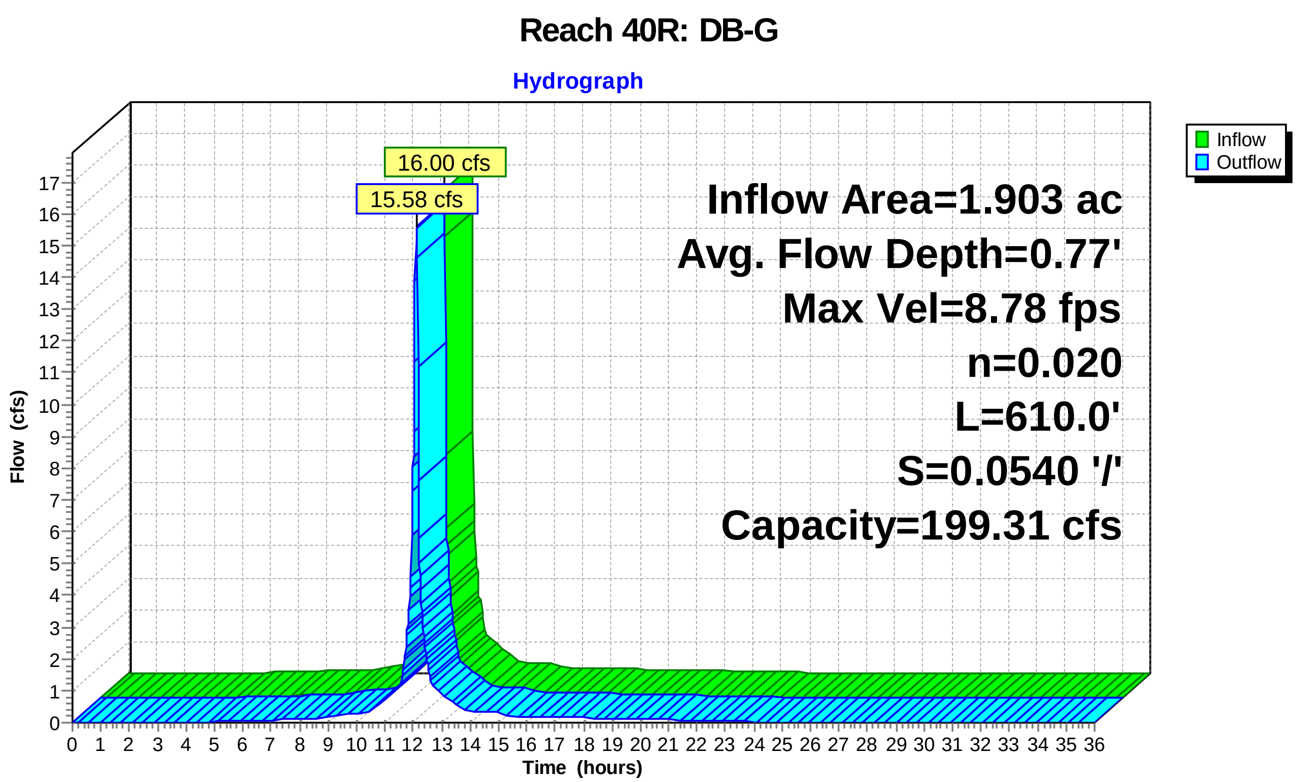
Inflow Area = 1.903 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 16.00 cfs @ 12.09 hrs, Volume= 0.720 af
Outflow = 15.58 cfs @ 12.12 hrs, Volume= 0.720 af, Atten= 3%, Lag= 1.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 8.78 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 2.78 fps, Avg. Travel Time= 3.7 min

Peak Storage= 1,083 cf @ 12.10 hrs
Average Depth at Peak Storage= 0.77' , Surface Width= 4.62'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 199.31 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 610.0' Slope= 0.0540 '/'
Inlet Invert= 762.04', Outlet Invert= 729.10'





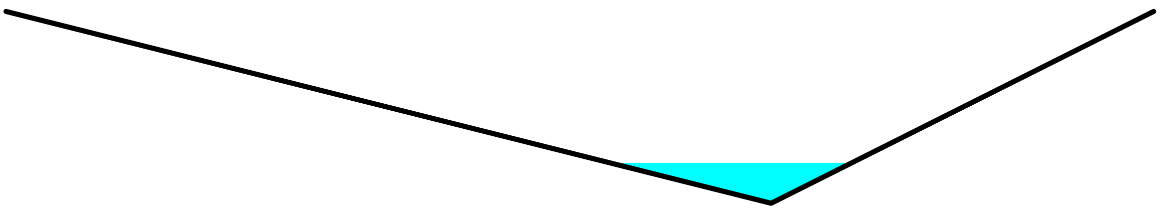
Summary for Reach 41R: DB-H

Inflow Area = 0.206 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 1.34 cfs @ 12.16 hrs, Volume= 0.078 af
Outflow = 1.32 cfs @ 12.19 hrs, Volume= 0.078 af, Atten= 1%, Lag= 1.5 min

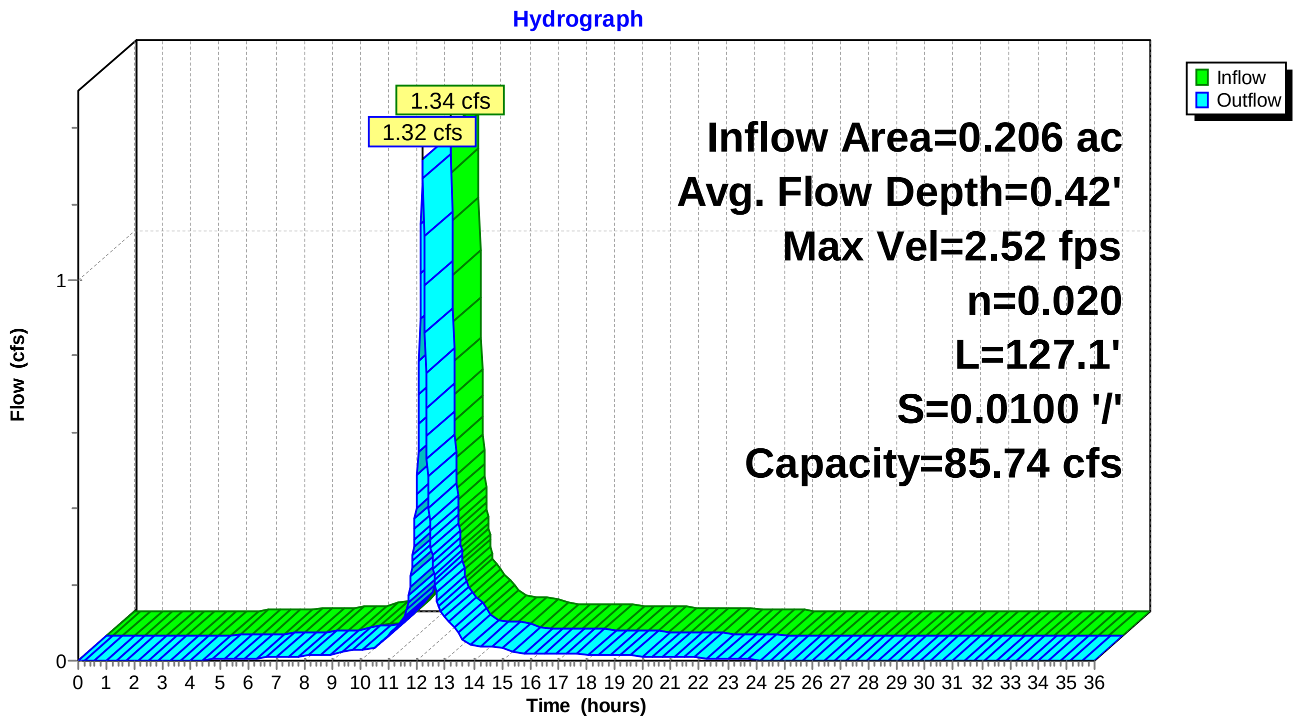
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 2.52 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 0.87 fps, Avg. Travel Time= 2.4 min

Peak Storage= 67 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.42' , Surface Width= 2.51'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 85.74 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 127.1' Slope= 0.0100 '/'
Inlet Invert= 707.69', Outlet Invert= 706.42'



Reach 41R: DB-H



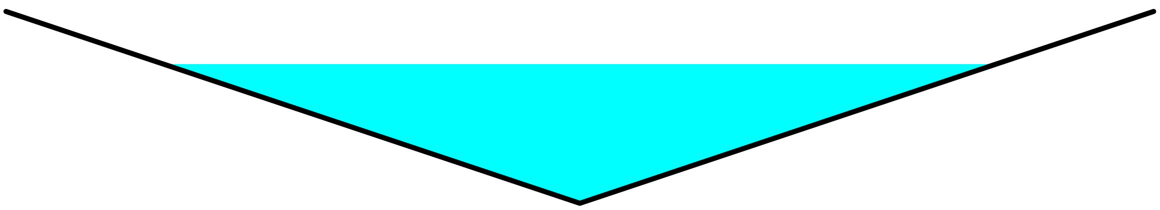
Summary for Reach 44R: E-MCI Ditch

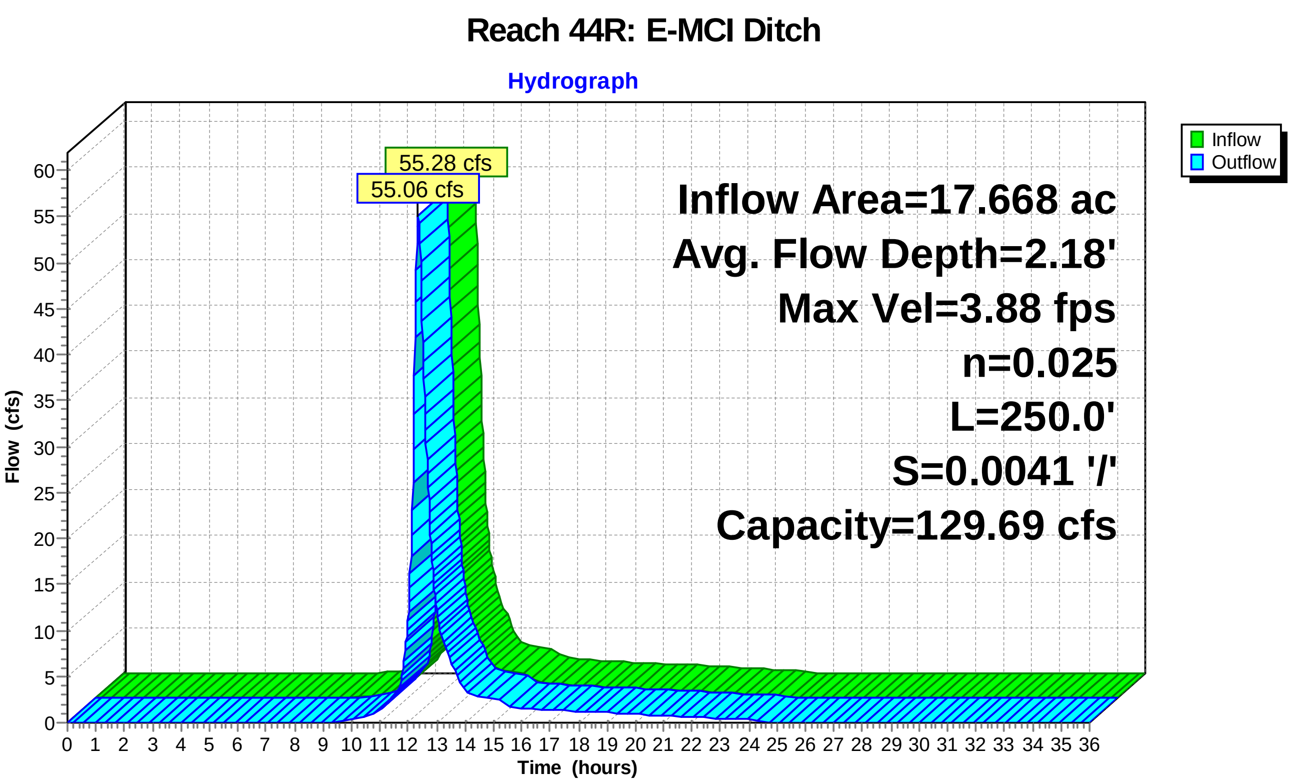
Inflow Area = 17.668 ac, 0.00% Impervious, Inflow Depth = 3.07" for 100-yr, 24-hr event
Inflow = 55.28 cfs @ 12.32 hrs, Volume= 4.514 af
Outflow = 55.06 cfs @ 12.36 hrs, Volume= 4.514 af, Atten= 0%, Lag= 2.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 3.88 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.36 fps, Avg. Travel Time= 3.1 min

Peak Storage= 3,552 cf @ 12.34 hrs
Average Depth at Peak Storage= 2.18' , Surface Width= 13.06'
Bank-Full Depth= 3.00' Flow Area= 27.0 sf, Capacity= 129.69 cfs

0.00' x 3.00' deep channel, n= 0.025
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 250.0' Slope= 0.0041 '/'
Inlet Invert= 702.00', Outlet Invert= 700.98'





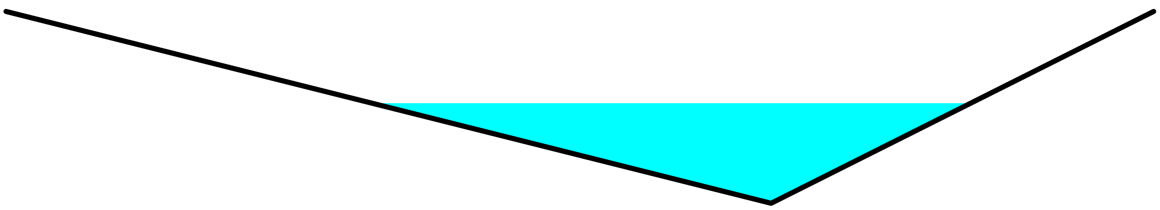
Summary for Reach 59R: DB-E

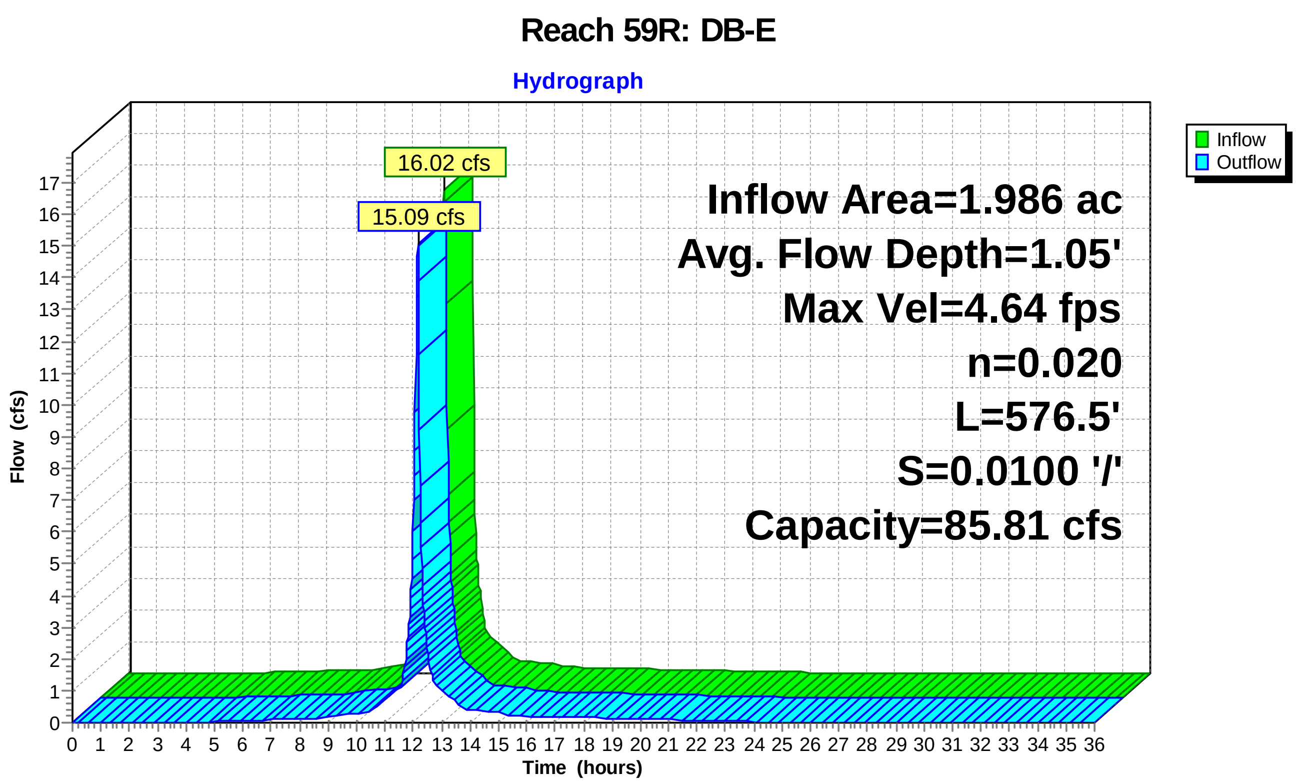
Inflow Area = 1.986 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 16.02 cfs @ 12.10 hrs, Volume= 0.751 af
Outflow = 15.09 cfs @ 12.15 hrs, Volume= 0.751 af, Atten= 6%, Lag= 3.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 4.64 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 1.43 fps, Avg. Travel Time= 6.7 min

Peak Storage= 1,891 cf @ 12.12 hrs
Average Depth at Peak Storage= 1.05' , Surface Width= 6.27'
Bank-Full Depth= 2.00' Flow Area= 12.0 sf, Capacity= 85.81 cfs

0.00' x 2.00' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 12.00'
Length= 576.5' Slope= 0.0100 '/'
Inlet Invert= 718.00', Outlet Invert= 712.23'





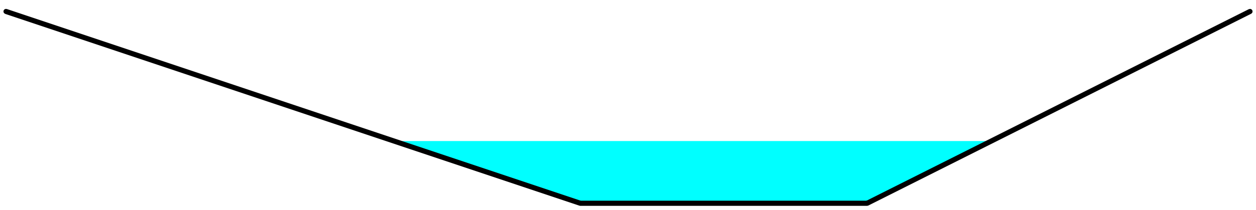
Summary for Reach 60R: W-MC X Ditch

Inflow Area = 13.776 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 34.54 cfs @ 12.26 hrs, Volume= 3.881 af
Outflow = 32.84 cfs @ 12.38 hrs, Volume= 3.881 af, Atten= 5%, Lag= 7.4 min

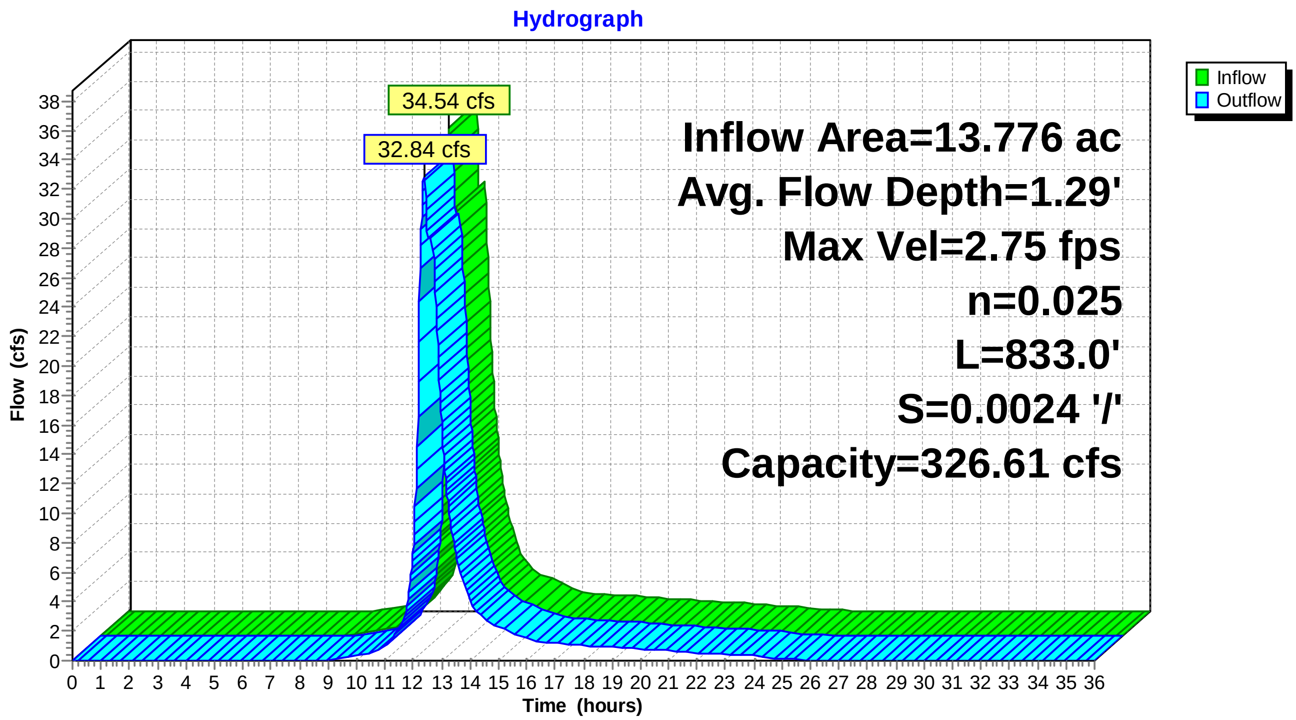
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 2.75 fps, Min. Travel Time= 5.0 min
Avg. Velocity = 0.70 fps, Avg. Travel Time= 19.8 min

Peak Storage= 9,941 cf @ 12.30 hrs
Average Depth at Peak Storage= 1.29' , Surface Width= 12.46'
Bank-Full Depth= 4.00' Flow Area= 64.0 sf, Capacity= 326.61 cfs

6.00' x 4.00' deep channel, n= 0.025
Side Slope Z-value= 3.0 2.0 '/' Top Width= 26.00'
Length= 833.0' Slope= 0.0024 '/'
Inlet Invert= 691.00', Outlet Invert= 689.00'



Reach 60R: W-MC X Ditch



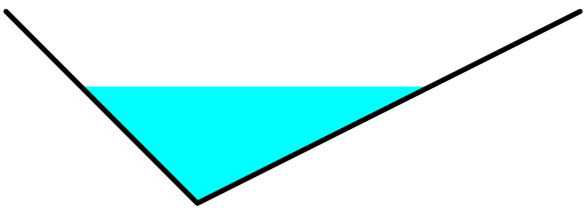
Summary for Reach 64R: S MC X Ditch

Inflow Area = 10.530 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 34.39 cfs @ 12.13 hrs, Volume= 2.966 af
Outflow = 27.51 cfs @ 12.28 hrs, Volume= 2.966 af, Atten= 20%, Lag= 8.9 min

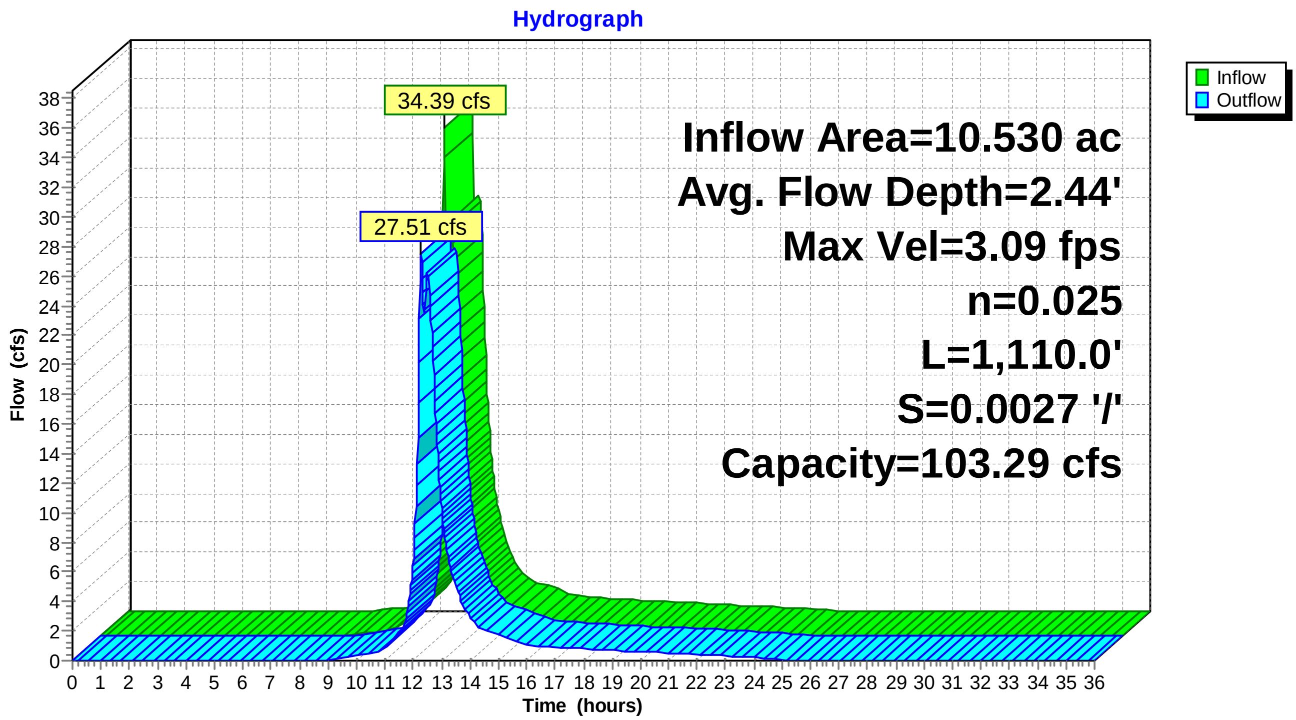
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 3.09 fps, Min. Travel Time= 6.0 min
Avg. Velocity = 0.90 fps, Avg. Travel Time= 20.5 min

Peak Storage= 9,877 cf @ 12.18 hrs
Average Depth at Peak Storage= 2.44' , Surface Width= 7.31'
Bank-Full Depth= 4.00' Flow Area= 24.0 sf, Capacity= 103.29 cfs

0.00' x 4.00' deep channel, n= 0.025
Side Slope Z-value= 1.0 2.0 '/' Top Width= 12.00'
Length= 1,110.0' Slope= 0.0027 '/'
Inlet Invert= 694.00', Outlet Invert= 691.00'



Reach 64R: S MC X Ditch



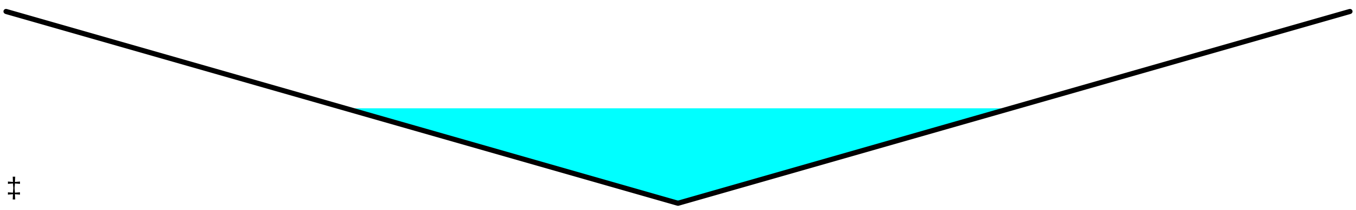
Summary for Reach 66R: E-MC X Ditch

Inflow Area = 5.820 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 37.89 cfs @ 12.12 hrs, Volume= 1.639 af
Outflow = 22.01 cfs @ 12.39 hrs, Volume= 1.639 af, Atten= 42%, Lag= 16.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 2.01 fps, Min. Travel Time= 12.4 min
Avg. Velocity = 0.54 fps, Avg. Travel Time= 46.6 min

Peak Storage= 16,442 cf @ 12.18 hrs
Average Depth at Peak Storage= 1.48' , Surface Width= 14.81'
Bank-Full Depth= 3.00' Flow Area= 45.0 sf, Capacity= 145.10 cfs

0.00' x 3.00' deep channel, n= 0.030 Stream, clean & straight
Side Slope Z-value= 5.0 '/' Top Width= 30.00'
Length= 1,500.0' Slope= 0.0025 '/'
Inlet Invert= 697.80', Outlet Invert= 694.00'



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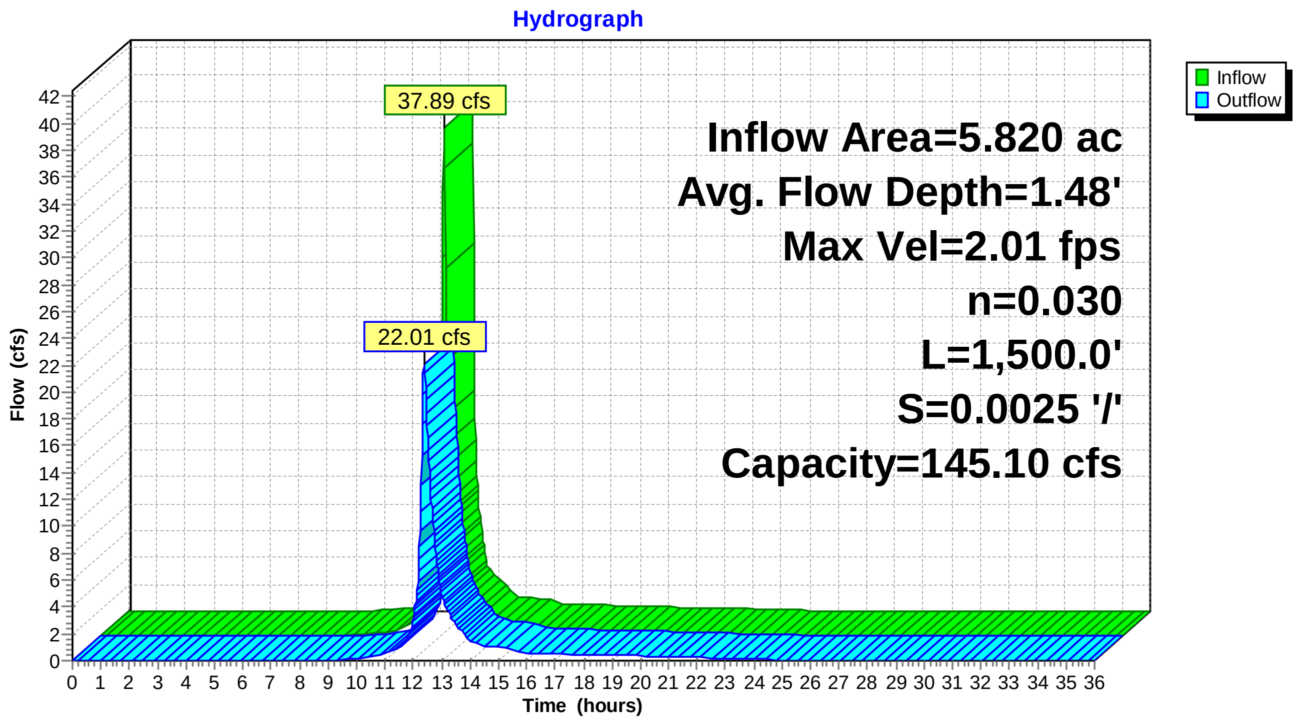
Reach 66R: E-MC X Ditch



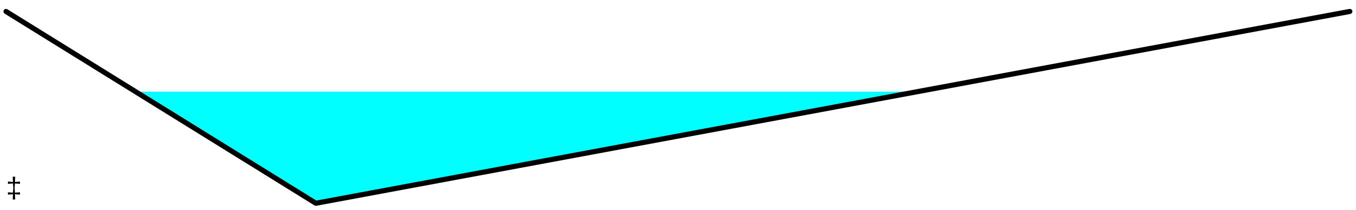
Summary for Reach 71R: DB-46

Inflow Area = 10.457 ac, 0.00% Impervious, Inflow Depth = 3.00" for 100-yr, 24-hr event
Inflow = 35.98 cfs @ 12.28 hrs, Volume= 2.612 af
Outflow = 35.82 cfs @ 12.31 hrs, Volume= 2.612 af, Atten= 0%, Lag= 1.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 4.09 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.52 fps, Avg. Travel Time= 2.2 min

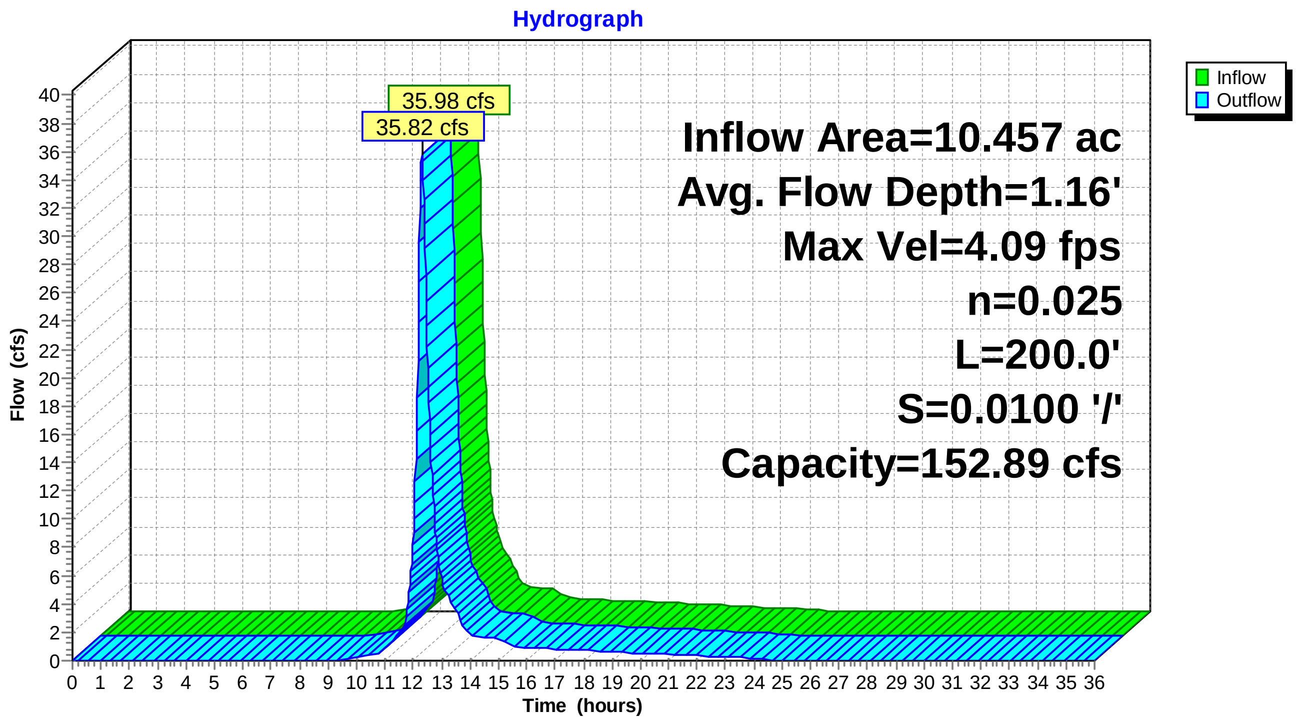
Peak Storage= 1,753 cf @ 12.29 hrs
Average Depth at Peak Storage= 1.16' , Surface Width= 15.10'
Bank-Full Depth= 2.00' Flow Area= 26.0 sf, Capacity= 152.89 cfs

0.00' x 2.00' deep channel, n= 0.025
Side Slope Z-value= 3.0 10.0 '/' Top Width= 26.00'
Length= 200.0' Slope= 0.0100 '/'
Inlet Invert= 703.00', Outlet Invert= 701.00'



‡

Reach 71R: DB-46



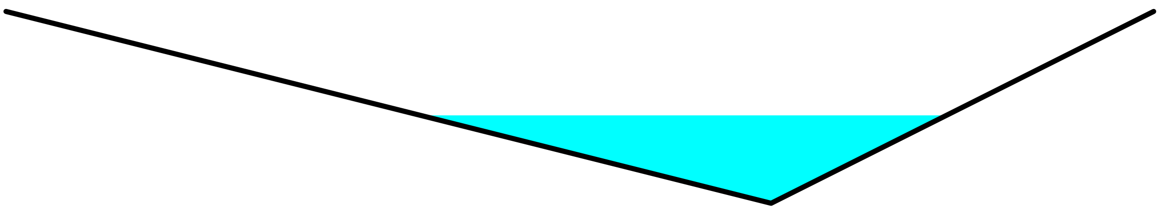
Summary for Reach 73R: DB-D-2 (9.8%)

Inflow Area = 8.819 ac, 0.00% Impervious, Inflow Depth = 4.54" for 100-yr, 24-hr event
Inflow = 60.90 cfs @ 12.20 hrs, Volume= 3.335 af
Outflow = 60.36 cfs @ 12.21 hrs, Volume= 3.335 af, Atten= 1%, Lag= 0.3 min

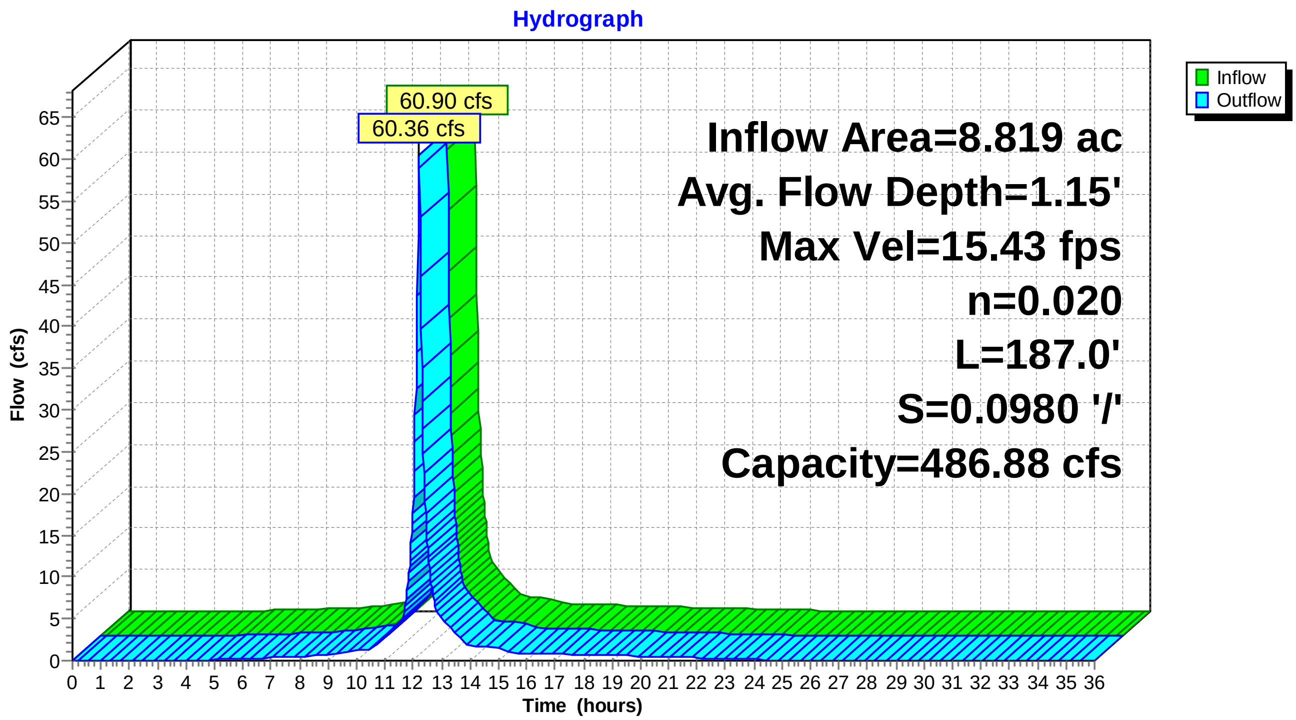
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Max. Velocity= 15.43 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 4.47 fps, Avg. Travel Time= 0.7 min

Peak Storage= 736 cf @ 12.20 hrs
Average Depth at Peak Storage= 1.15' , Surface Width= 6.87'
Bank-Full Depth= 2.50' Flow Area= 18.8 sf, Capacity= 486.88 cfs

0.00' x 2.50' deep channel, n= 0.020
Side Slope Z-value= 4.0 2.0 '/' Top Width= 15.00'
Length= 187.0' Slope= 0.0980 '/'
Inlet Invert= 726.33', Outlet Invert= 708.00'



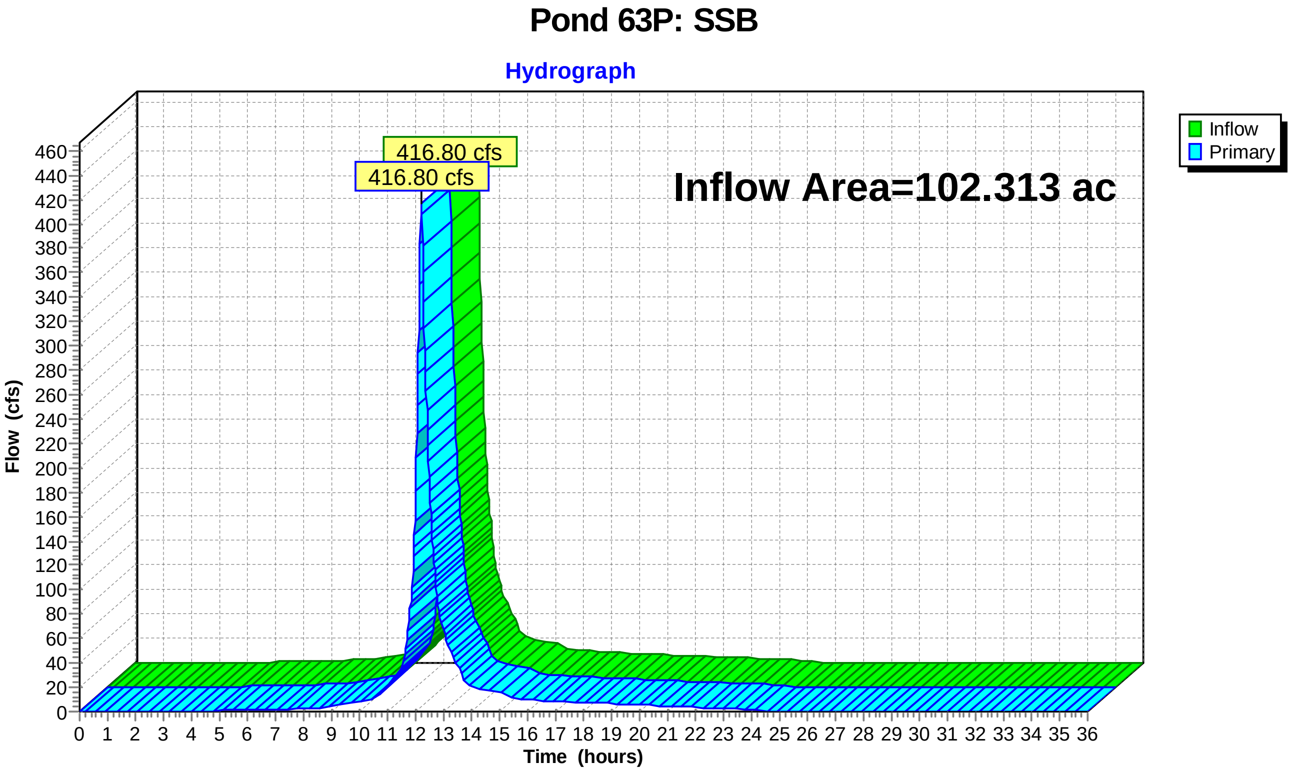
Reach 73R: DB-D-2 (9.8%)



Summary for Pond 63P: SSB

Inflow Area = 102.313 ac, 10.00% Impervious, Inflow Depth = 3.85" for 100-yr, 24-hr event
Inflow = 416.80 cfs @ 12.20 hrs, Volume= 32.845 af
Primary = 416.80 cfs @ 12.20 hrs, Volume= 32.845 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs

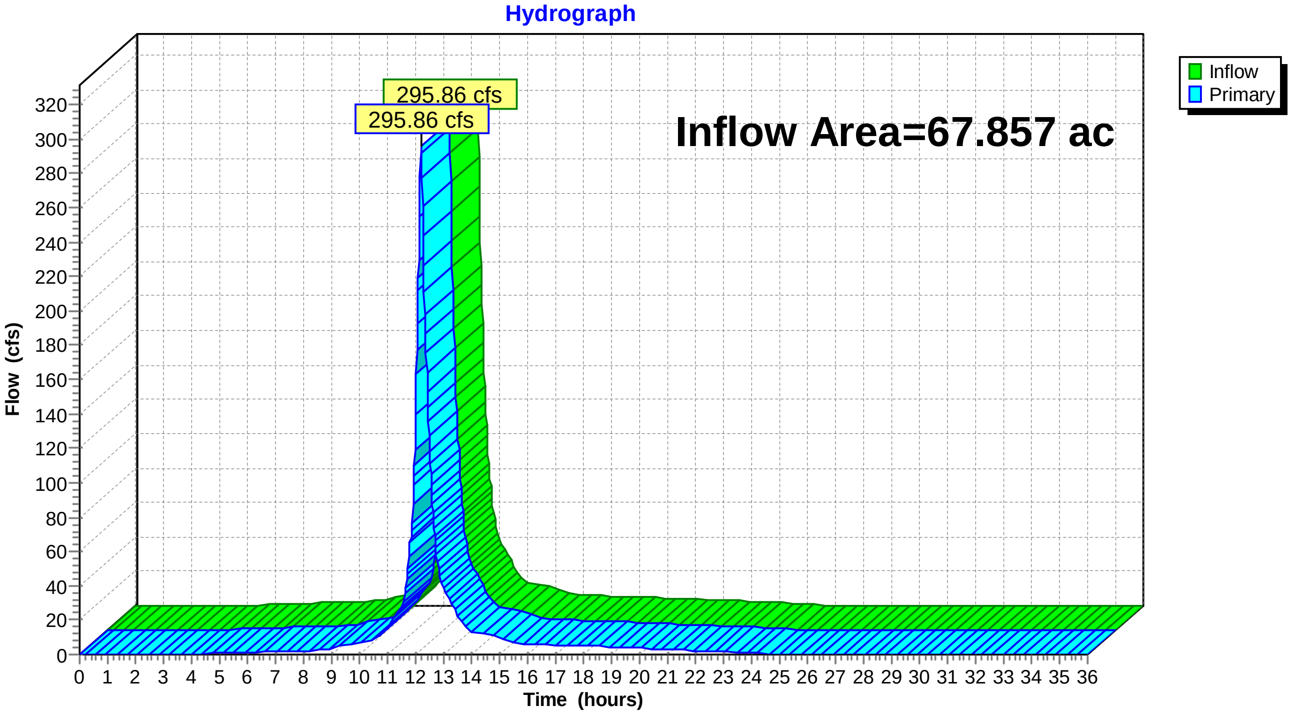


Summary for Pond 69P: Storm Sewer - See SWMM Model

Inflow Area =	67.857 ac,	8.02% Impervious, Inflow Depth = 4.00"	for 100-yr, 24-hr event	
Inflow =	295.86 cfs @	12.19 hrs, Volume=	22.622 af	
Primary =	295.86 cfs @	12.19 hrs, Volume=	22.622 af,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs

Pond 69P: Storm Sewer - See SWMM Model



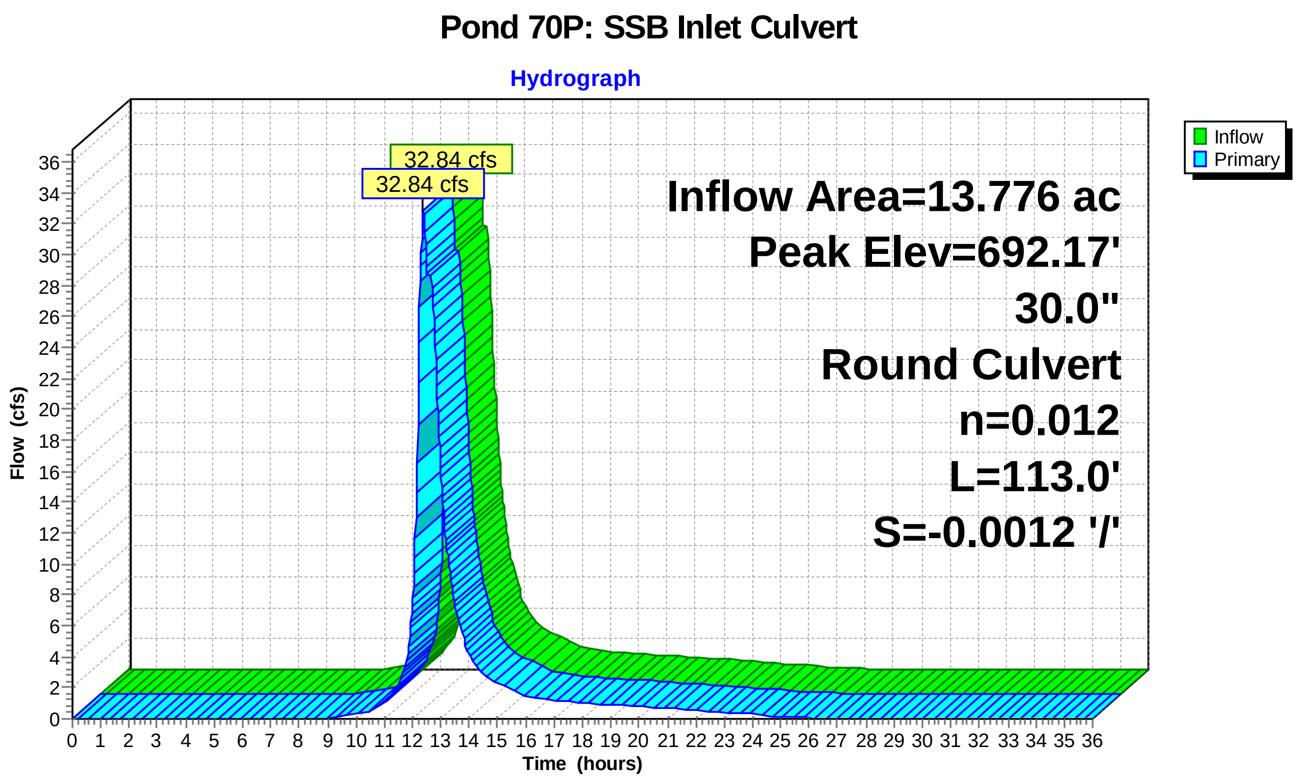
Summary for Pond 70P: SSB Inlet Culvert

Inflow Area =	13.776 ac,	0.00% Impervious, Inflow Depth =	3.38"	for 100-yr, 24-hr event
Inflow =	32.84 cfs @	12.38 hrs, Volume=	3.881 af	
Outflow =	32.84 cfs @	12.38 hrs, Volume=	3.881 af,	Atten= 0%, Lag= 0.0 min
Primary =	32.84 cfs @	12.38 hrs, Volume=	3.881 af	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Peak Elev= 692.17' @ 12.38 hrs

Device	Routing	Invert	Outlet Devices
#1	Primary	688.14'	**30.0" Round Culvert** L= 113.0' RCP, end-section conforming to fill, Ke= 0.500 Inlet / Outlet Invert= 688.01' / 688.14' S= -0.0012 '/' Cc= 0.900 n= 0.012 Concrete pipe, finished, Flow Area= 4.91 sf

Primary OutFlow Max=32.80 cfs @ 12.38 hrs HW=692.17' (Free Discharge)
└─**1=Culvert** (Barrel Controls 32.80 cfs @ 6.68 fps)



Summary for Pond 71P: E-MCI Culvert

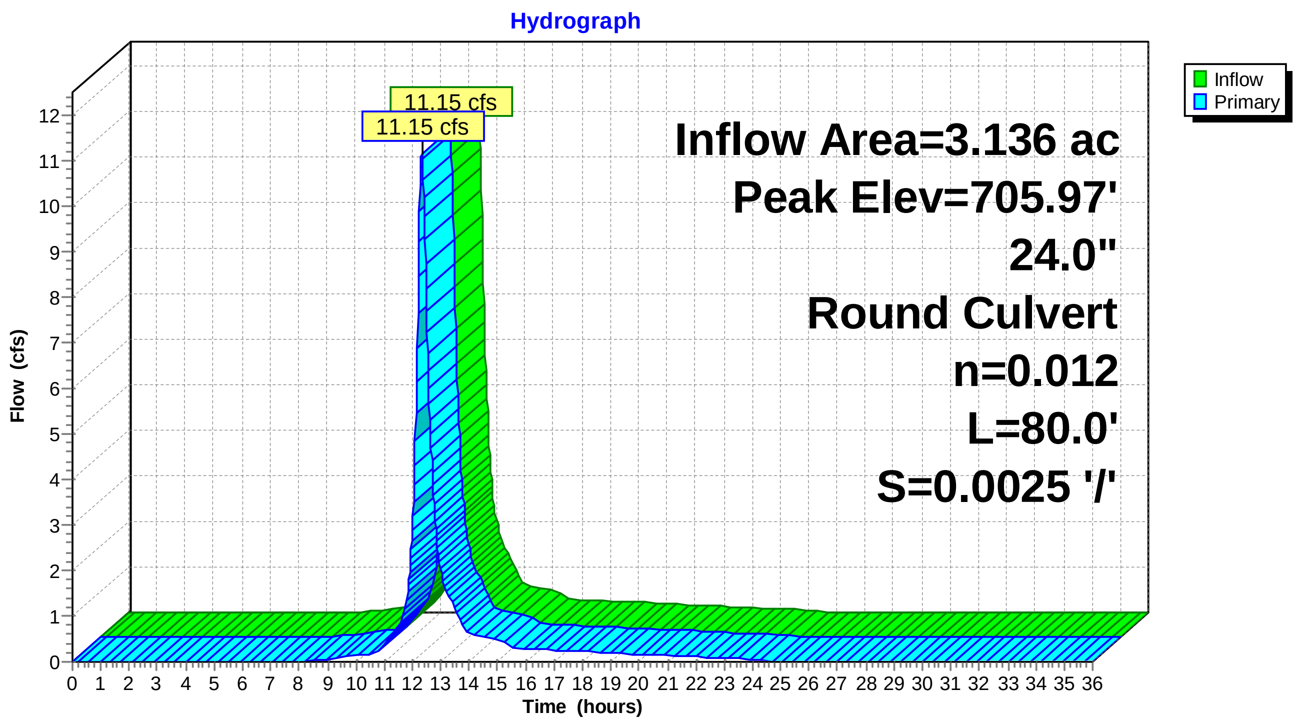
Inflow Area = 3.136 ac, 0.00% Impervious, Inflow Depth = 3.38" for 100-yr, 24-hr event
Inflow = 11.15 cfs @ 12.32 hrs, Volume= 0.883 af
Outflow = 11.15 cfs @ 12.32 hrs, Volume= 0.883 af, Atten= 0%, Lag= 0.0 min
Primary = 11.15 cfs @ 12.32 hrs, Volume= 0.883 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.02 hrs
Peak Elev= 705.97' @ 12.32 hrs

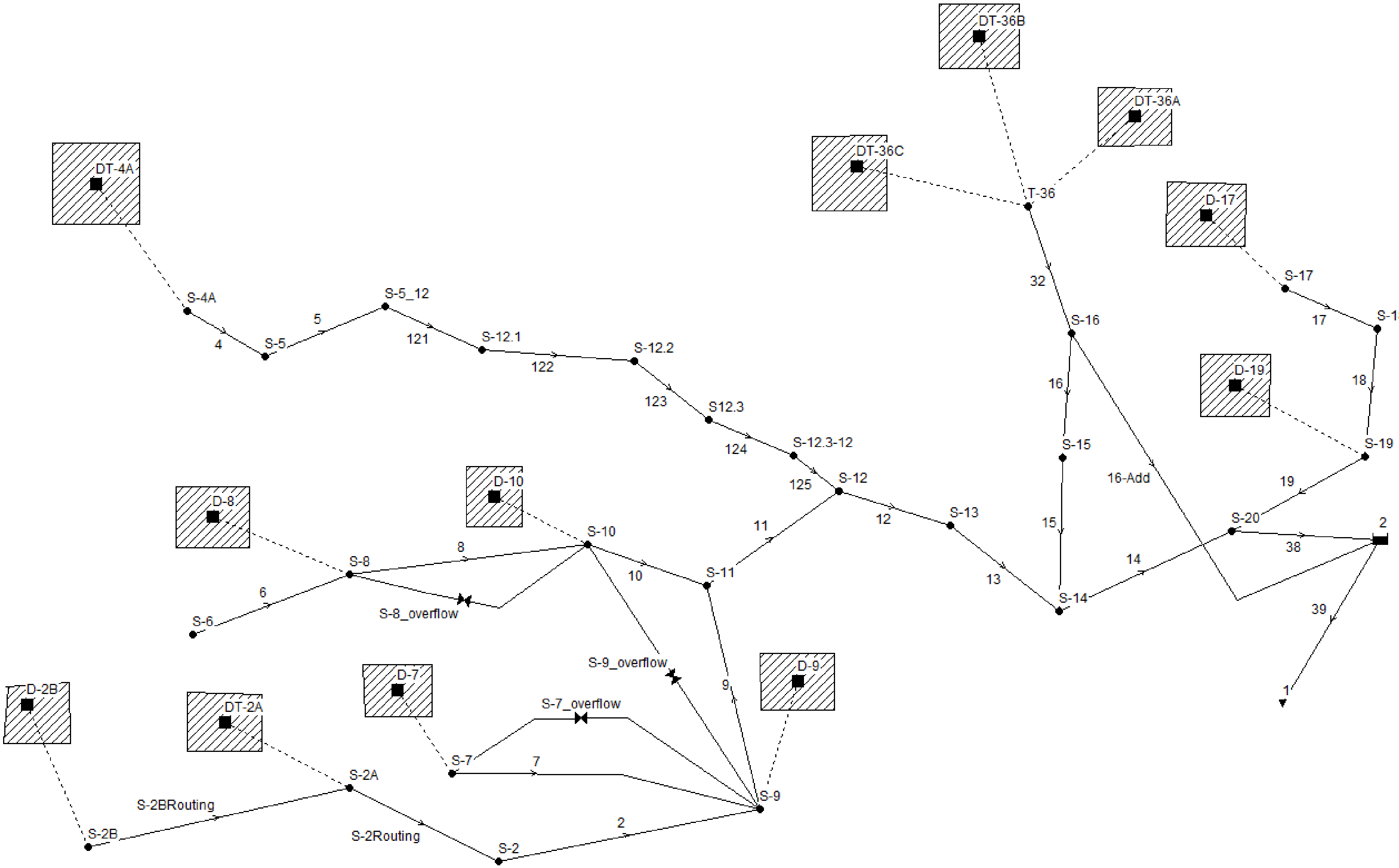
Device	Routing	Invert	Outlet Devices
#1	Primary	703.00'	**24.0" Round Culvert** L= 80.0' CPP, projecting, no headwall, Ke= 0.900 Inlet / Outlet Invert= 703.00' / 702.80' S= 0.0025 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 3.14 sf

Primary OutFlow Max=11.15 cfs @ 12.32 hrs HW=705.97' TW=705.10' (Fixed TW Elev= 705.10')
└**1=Culvert** (Inlet Controls 11.15 cfs @ 3.55 fps)

Pond 71P: E-MCI Culvert



South Sedimentation Basin (SSB) SWMM OUTPUT – 25-yr, 24-hr



DT-36B
DT-36A
DT-36C
T-36
DT-4A
D-17
32
S-17
S-4A
S-5_12
S-16
17
S-18
5
4
S-5
121
S-12.1
S-12.2
D-19
122
16
18
123
S12.3
S-12.3-12
S-15
S-19
124
125
S-12
16-Add
19
D-10
D-8
S-13
11
S-10
12
15
S-20
2
8
S-8
14
38
10
S-11
13
6
S-14
S-6
S-8_overflow
39
S-9_overflow
D-9
D-7
9
1
D-2B
DT-2A
S-7_overflow
S-7
7
S-2A
S-9
S-2BRouting
2
S-2B
S-2Routing
S-2

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.015)

WARNING 02: maximum depth increased for Node S-7
WARNING 02: maximum depth increased for Node S-8
WARNING 02: maximum depth increased for Node S-9
WARNING 02: maximum depth increased for Node T-36
WARNING 02: maximum depth increased for Node S-5_12

****
Element Count
****

Number of rain gages 2
Number of subcatchments ... 12
Number of nodes 28
Number of links 31
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
TS1	MSE3-100yr,24hr	INTENSITY	6 min.
MSE3	MSE-25yr,24hr	INTENSITY	6 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
D-10	0.51	17.00	100.00	2.6000	MSE3	S-10
D-17	2.11	1200.00	0.00	5.8100	MSE3	S-17
D-19	0.38	600.00	0.00	1.5000	MSE3	S-19
DT-2A	6.80	250.00	13.00	7.0000	MSE3	S-2A
DT-4A	3.60	1100.00	100.00	25.0000	MSE3	S-4A
D-7	1.09	40.00	100.00	2.0000	MSE3	S-7
D-8	0.51	115.00	100.00	0.0700	MSE3	S-8
D-9	0.32	13.00	100.00	1.6000	MSE3	S-9
DT-36B	19.70	1265.00	100.00	25.0000	MSE3	T-36
DT-36A	10.60	1180.00	0.00	5.0000	MSE3	T-36
DT-36C	10.80	2240.00	100.00	25.0000	MSE3	T-36
D-2B	10.90	1340.00	0.00	4.1000	MSE3	S-2B

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
S-2	JUNCTION	686.25	16.20	100.0	
S-4A	JUNCTION	693.34	15.00	0.0	
S-5	JUNCTION	692.01	7.50	0.0	
S-6	JUNCTION	695.71	3.20	0.0	
S-7	JUNCTION	694.09	5.45	0.0	
S-8	JUNCTION	694.73	5.00	0.0	
S-9	JUNCTION	684.57	14.00	660.0	
S-10	JUNCTION	691.90	4.80	2100.0	
S-11	JUNCTION	685.67	15.65	0.0	
S-12	JUNCTION	686.18	16.25	0.0	
S-13	JUNCTION	685.57	15.90	0.0	
S-14	JUNCTION	685.88	16.34	0.0	
S-15	JUNCTION	687.52	14.09	0.0	
S-16	JUNCTION	697.26	10.74	100.0	
S-17	JUNCTION	695.46	4.70	0.0	
S-18	JUNCTION	694.60	5.40	0.0	
S-19	JUNCTION	690.98	9.26	0.0	
S-20	JUNCTION	685.98	10.00	0.0	
T-36	JUNCTION	709.00	7.74	0.0	
S-5_12	JUNCTION	691.07	4.50	0.0	
S-12.1	JUNCTION	688.83	16.84	0.0	
S-12.2	JUNCTION	688.47	17.98	0.0	
S12.3	JUNCTION	688.30	14.93	0.0	
S-12.3-12	JUNCTION	686.56	4.00	0.0	
S-2A	JUNCTION	700.20	3.00	0.0	
S-2B	JUNCTION	710.90	2.00	0.0	
1	OUTFALL	690.00	1.00	0.0	
2	STORAGE	671.00	25.00	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
2	S-2	S-9	CONDUIT	855.0	0.0211	0.0130

4	S-4A	S-5	CONDUIT	100.0	0.1800	0.0130
5	S-5	S-5_12	CONDUIT	147.0	0.6395	0.0130
6	S-6	S-8	CONDUIT	275.0	0.3564	0.0130
7	S-7	S-9	CONDUIT	163.0	2.1600	0.0130
8	S-8	S-10	CONDUIT	205.0	1.3562	0.0130
9	S-9	S-11	CONDUIT	122.0	0.2049	0.0130
10	S-10	S-11	CONDUIT	19.0	0.6842	0.0130
11	S-11	S-12	CONDUIT	107.0	-0.4766	0.0130
12	S-12	S-13	CONDUIT	165.0	0.3697	0.0130
13	S-13	S-14	CONDUIT	226.0	-0.3009	0.0130
14	S-14	S-20	CONDUIT	166.0	0.0602	0.0130
15	S-15	S-14	CONDUIT	35.0	0.7715	0.0130
16	S-16	S-15	CONDUIT	210.0	2.9775	0.0130
17	S-17	S-18	CONDUIT	49.0	0.0204	0.0130
18	S-18	S-19	CONDUIT	14.0	0.3571	0.0130
19	S-19	S-20	CONDUIT	43.0	12.5869	0.0130
32	T-36	S-16	CONDUIT	900.0	0.9712	0.0250
38	S-20	2	CONDUIT	414.0	0.0725	0.0130
39	2	1	CONDUIT	400.0	0.1250	0.0130
121	S-5_12	S-12.1	CONDUIT	350.0	0.6400	0.0130
122	S-12.1	S-12.2	CONDUIT	110.0	0.3273	0.0120
123	S-12.2	S12.3	CONDUIT	100.0	0.1700	0.0120
124	S12.3	S-12.3-12	CONDUIT	120.0	1.4502	0.0120
125	S-12.3-12	S-12	CONDUIT	26.0	1.4617	0.0130
S-2Routing	S-2A	S-2	CONDUIT	250.0	0.3000	0.0250
S-2BRouting	S-2B	S-2A	CONDUIT	1340.0	0.7985	0.0250
16-Add	S-16	2	CONDUIT	500.0	0.2520	0.0130
S-9_overflow	S-9	S-10	WEIR			
S-8_overflow	S-8	S-10	WEIR			
S-7_overflow	S-7	S-9	WEIR			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
2	CIRCULAR	3.00	7.07	0.75	3.00	1	9.68
4	CIRCULAR	3.00	7.07	0.75	3.00	1	28.30
5	CIRCULAR	3.50	9.62	0.88	3.50	1	80.45
6	CIRCULAR	1.00	0.79	0.25	1.00	1	2.13
7	CIRCULAR	1.00	0.79	0.25	1.00	1	5.24
8	CIRCULAR	1.00	0.79	0.25	1.00	1	4.15

9	CIRCULAR	3.00	7.07	0.75	3.00	1	30.19
10	CIRCULAR	1.00	0.79	0.25	1.00	1	2.95
11	CIRCULAR	3.00	7.07	0.75	3.00	1	46.05
12	CIRCULAR	3.50	9.62	0.88	3.50	1	61.17
13	CIRCULAR	3.50	9.62	0.88	3.50	1	55.19
14	CIRCULAR	3.50	9.62	0.88	3.50	1	24.69
15	CIRCULAR	2.00	3.14	0.50	2.00	1	19.87
16	CIRCULAR	2.00	3.14	0.50	2.00	1	39.04
17	CIRCULAR	1.50	1.77	0.38	1.50	1	1.50
18	CIRCULAR	1.50	1.77	0.38	1.50	1	6.28
19	CIRCULAR	1.50	1.77	0.38	1.50	1	37.27
32	TRAPEZOIDAL	7.74	334.00	4.08	80.30	1	4993.90
38	CIRCULAR	3.50	9.62	0.88	3.50	1	27.08
39	CIRCULAR	1.00	0.79	0.25	1.00	1	1.26
121	CIRCULAR	4.50	15.90	1.13	4.50	1	157.32
122	CIRCULAR	3.00	7.07	0.75	3.00	1	41.34
123	CIRCULAR	3.00	7.07	0.75	3.00	1	29.79
124	CIRCULAR	4.00	12.57	1.00	4.00	1	187.39
125	CIRCULAR	3.00	7.07	0.75	3.00	1	80.64
S-2Routing	TRIANGULAR	3.00	39.00	1.46	26.00	1	163.53
S-2BRouting	TRIANGULAR	2.00	26.00	0.99	26.00	1	137.03
16-Add	CIRCULAR	2.50	4.91	0.63	2.50	1	20.59

```
*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ YES
  Water Quality .......... NO
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... DYNWAVE
```

```
Surcharge Method ......... EXTRAN
Starting Date ............ 06/14/2019 00:00:00
Ending Date .............. 06/16/2019 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:02:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 01:00:00
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.005000 ft

*********************
Control Actions Taken
*********************


**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......        22.160         3.950
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         3.573         0.637
Surface Runoff ...........        18.497         3.297
Final Storage ............         0.126         0.022
Continuity Error (%) .....        -0.165


**************************        Volume        Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......        18.512         6.032
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........         0.000         0.000
Flooding Loss ............         0.000         0.000
Evaporation Loss .........         0.000         0.000
Exfiltration Loss ........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......        18.513         6.033
Continuity Error (%) .....        -0.007
```

```
  **************************
  Time-Step Critical Elements
  **************************
  None

  ********************************
  Highest Flow Instability Indexes
  ********************************
  Link 125 (2)
  Link 11 (1)

  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :     0.50 sec
  Average Time Step           :     1.00 sec
  Maximum Time Step           :     1.00 sec
  Percent in Steady State     :     0.21
  Average Iterations per Step :     2.01
  Percent Not Converging      :     0.09
  Time Step Frequencies       :
      1.000 -  0.871 sec      :    99.79 %
      0.871 -  0.758 sec      :     0.16 %
      0.758 -  0.660 sec      :     0.01 %
      0.660 -  0.574 sec      :     0.01 %
      0.574 -  0.500 sec      :     0.03 %

  ***************************
  Subcatchment Runoff Summary
  ***************************
```

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
D-10	3.95	0.00	0.00	0.00	3.96	0.00	3.96	0.05	2.88	1.003
D-17	3.95	0.00	0.00	1.29	0.00	2.62	2.62	0.15	10.27	0.663
D-19	3.95	0.00	0.00	1.29	0.00	2.62	2.62	0.03	1.90	0.663
DT-2A	3.95	0.00	0.00	1.35	0.51	2.05	2.56	0.47	16.49	0.649
DT-4A	3.95	0.00	0.00	0.00	3.96	0.00	3.96	0.39	22.64	1.003
D-7	3.95	0.00	0.00	0.00	3.96	0.00	3.96	0.12	6.11	1.002
D-8	3.95	0.00	0.00	0.00	3.96	0.00	3.96	0.05	2.93	1.003

D-9	3.95	0.00	0.00	0.00	3.96	0.00	3.96	0.03	1.79	1.002
DT-36B	3.95	0.00	0.00	0.00	3.96	0.00	3.96	2.12	93.93	1.001
DT-36A	3.95	0.00	0.00	1.29	0.00	2.61	2.61	0.75	34.50	0.661
DT-36C	3.95	0.00	0.00	0.00	3.96	0.00	3.96	1.16	65.43	1.003
D-2B	3.95	0.00	0.00	1.54	0.00	2.36	2.36	0.70	31.20	0.598

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	Time of Max Occurrence hr:min	Reported Max Depth Feet
S-2	JUNCTION	0.56	12.05	698.30	0	12:21	12.05
S-4A	JUNCTION	0.13	1.73	695.07	0	12:21	1.72
S-5	JUNCTION	0.10	3.05	695.06	0	12:21	3.03
S-6	JUNCTION	0.00	0.00	695.71	0	12:22	0.00
S-7	JUNCTION	0.22	3.95	698.04	0	12:13	3.88
S-8	JUNCTION	0.04	0.98	695.71	0	12:21	0.97
S-9	JUNCTION	2.12	11.28	695.85	0	12:21	11.28
S-10	JUNCTION	0.09	3.61	695.51	0	12:21	3.61
S-11	JUNCTION	1.04	9.77	695.44	0	12:21	9.76
S-12	JUNCTION	0.53	8.85	695.03	0	12:21	8.84
S-13	JUNCTION	1.12	9.08	694.65	0	12:21	9.08
S-14	JUNCTION	0.76	8.26	694.14	0	12:21	8.25
S-15	JUNCTION	0.83	8.14	695.66	0	12:21	8.13
S-16	JUNCTION	0.26	7.53	704.79	0	12:22	7.52
S-17	JUNCTION	0.63	2.39	697.85	0	12:12	2.39
S-18	JUNCTION	1.17	2.67	697.27	0	12:12	2.67
S-19	JUNCTION	0.34	1.72	692.70	0	12:20	1.72
S-20	JUNCTION	0.56	6.68	692.66	0	12:21	6.67
T-36	JUNCTION	0.13	1.89	710.89	0	12:12	1.88
S-5_12	JUNCTION	0.11	3.98	695.05	0	12:21	3.97
S-12.1	JUNCTION	0.16	9.88	698.71	0	12:11	6.21
S-12.2	JUNCTION	0.18	8.32	696.79	0	12:11	6.56
S12.3	JUNCTION	0.14	6.85	695.15	0	12:11	6.73
S-12.3-12	JUNCTION	0.31	8.47	695.03	0	12:21	8.47
S-2A	JUNCTION	0.26	1.75	701.95	0	12:20	1.75
S-2B	JUNCTION	0.11	1.09	711.99	0	12:15	1.08
1	OUTFALL	0.00	0.00	690.00	0	00:00	0.00
2	STORAGE	8.70	11.64	682.64	2	00:00	11.64

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days	Time of Max Occurrence hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal	Flow Balance Error Percent
S-2	JUNCTION	0.00	35.93	0	12:20	0	1.17	-0.004
S-4A	JUNCTION	22.64	22.64	0	12:12	0.388	0.388	0.214
S-5	JUNCTION	0.00	22.56	0	12:12	0	0.387	-0.236
S-6	JUNCTION	0.00	0.00	0	12:21	0	1.16e-06	0.480 gal
S-7	JUNCTION	6.11	6.11	0	12:12	0.117	0.117	0.239
S-8	JUNCTION	2.93	2.93	0	12:12	0.0549	0.0549	0.004
S-9	JUNCTION	1.79	38.81	0	12:21	0.0344	1.33	0.156
S-10	JUNCTION	2.88	5.71	0	12:11	0.0549	0.11	-0.108
S-11	JUNCTION	0.00	41.29	0	12:23	0	1.44	0.039
S-12	JUNCTION	0.00	47.97	0	12:22	0	2	-0.034
S-13	JUNCTION	0.00	47.97	0	12:22	0	1.82	0.060
S-14	JUNCTION	0.00	95.18	0	12:22	0	4.49	-0.000
S-15	JUNCTION	0.00	47.50	0	12:31	0	2.66	0.007
S-16	JUNCTION	0.00	185.26	0	12:12	0	4.02	-0.302
S-17	JUNCTION	10.27	10.27	0	12:12	0.15	0.15	0.046
S-18	JUNCTION	0.00	10.27	0	12:12	0	0.15	0.084
S-19	JUNCTION	1.90	12.17	0	12:12	0.0271	0.177	0.019
S-20	JUNCTION	0.00	98.93	0	12:21	0	4.66	0.000
T-36	JUNCTION	193.86	193.86	0	12:12	4.03	4.03	0.293
S-5_12	JUNCTION	0.00	22.95	0	12:12	0	0.388	-0.060
S-12.1	JUNCTION	0.00	17.40	0	12:09	0	0.388	-0.025
S-12.2	JUNCTION	0.00	13.36	0	12:48	0	0.388	-0.016
S12.3	JUNCTION	0.00	13.90	0	12:48	0	0.388	-0.024
S-12.3-12	JUNCTION	0.00	20.79	0	11:59	0	0.562	0.070
S-2A	JUNCTION	16.49	41.86	0	12:14	0.474	1.18	0.245
S-2B	JUNCTION	31.20	31.20	0	12:12	0.7	0.7	-0.409
1	OUTFALL	0.00	0.00	0	00:00	0	0	0.000 gal
2	STORAGE	0.00	146.55	0	12:21	0	6.03	0.000

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
S-11	JUNCTION	0.52	2.665	5.885
S-12	JUNCTION	0.86	5.349	7.401
S-13	JUNCTION	0.98	5.584	6.816
S-14	JUNCTION	0.82	4.389	8.081
S-15	JUNCTION	0.62	2.648	5.952
S-17	JUNCTION	0.07	0.245	2.305
S-20	JUNCTION	0.79	3.179	3.321
S-12.1	JUNCTION	0.41	5.384	6.956
S-12.2	JUNCTION	0.66	5.317	9.663
S12.3	JUNCTION	0.57	2.846	8.084
S-12.3-12	JUNCTION	0.74	4.471	0.000

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CFS
2	584.124	19	0	0	805.992	26	2 00:00	0.00

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CFS	Max Flow CFS	Total Volume 10^6 gal
1	0.00	0.00	0.00	0.000
System	0.00	0.00	0.00	0.000

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
2	CONDUIT	35.69	0 12:22	5.05	3.69	1.00
4	CONDUIT	22.56	0 12:12	5.83	0.80	0.60
5	CONDUIT	22.95	0 12:12	7.35	0.29	0.94
6	CONDUIT	0.00	0 12:21	0.01	0.00	0.49
7	CONDUIT	5.63	0 12:12	7.31	1.08	1.00
8	CONDUIT	2.84	0 12:11	4.20	0.69	0.99
9	CONDUIT	39.10	0 12:23	5.53	1.30	1.00
10	CONDUIT	5.37	0 12:12	6.84	1.82	1.00
11	CONDUIT	41.30	0 12:23	5.84	0.90	1.00
12	CONDUIT	47.97	0 12:22	4.99	0.78	1.00
13	CONDUIT	47.97	0 12:22	4.99	0.87	1.00
14	CONDUIT	95.18	0 12:22	9.89	3.85	1.00
15	CONDUIT	47.50	0 12:30	15.12	2.39	1.00
16	CONDUIT	47.50	0 12:31	15.12	1.22	1.00
17	CONDUIT	10.27	0 12:12	6.08	6.85	0.91
18	CONDUIT	10.27	0 12:12	6.42	1.64	0.85
19	CONDUIT	12.33	0 12:12	7.55	0.33	0.95
32	CONDUIT	185.26	0 12:12	5.64	0.04	0.38
38	CONDUIT	98.93	0 12:21	10.57	3.65	0.94
39	CONDUIT	0.00	0 00:00	0.00	0.00	0.00
121	CONDUIT	17.40	0 12:09	4.28	0.11	0.94

122	CONDUIT	13.36	0	12:48	3.92	0.32	1.00
123	CONDUIT	13.90	0	12:48	4.90	0.47	1.00
124	CONDUIT	15.52	0	12:48	2.19	0.08	1.00
125	CONDUIT	22.16	0	11:59	3.75	0.27	1.00
S-2Routing	CONDUIT	35.93	0	12:20	3.48	0.22	0.51
S-2BRouting	CONDUIT	26.99	0	12:15	2.28	0.20	0.70
16-Add	CONDUIT	47.70	0	12:22	9.89	2.32	0.95
S-9_overflow	WEIR	0.00	0	00:00			0.00
S-8_overflow	WEIR	0.00	0	00:00			0.00
S-7_overflow	WEIR	0.00	0	00:00			0.00

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
		---------- Fraction of Time in Flow Class ----------								
2	1.00	0.02	0.00	0.00	0.97	0.00	0.00	0.01	0.49	0.00
4	1.00	0.00	0.00	0.00	0.01	0.00	0.00	0.99	0.00	0.00
5	1.00	0.00	0.00	0.00	0.53	0.47	0.00	0.00	0.00	0.00
6	1.00	0.00	0.95	0.00	0.04	0.00	0.00	0.00	0.74	0.00
7	1.00	0.01	0.00	0.00	0.01	0.00	0.00	0.97	0.01	0.00
8	1.00	0.00	0.00	0.00	0.02	0.11	0.00	0.87	0.12	0.00
9	1.00	0.01	0.02	0.00	0.97	0.00	0.00	0.00	0.00	0.00
10	1.00	0.00	0.00	0.00	0.01	0.00	0.00	0.98	0.00	0.00
11	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.03	0.00
12	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.04	0.00
13	1.00	0.01	0.02	0.00	0.53	0.00	0.45	0.00	0.02	0.00
14	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.39	0.00
15	1.00	0.02	0.00	0.00	0.02	0.00	0.00	0.96	0.00	0.00
16	1.00	0.00	0.00	0.00	0.01	0.00	0.00	0.98	0.00	0.00
17	1.00	0.18	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00
18	1.00	0.18	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00
19	1.00	0.02	0.58	0.00	0.40	0.00	0.00	0.00	0.81	0.00
32	1.00	0.00	0.00	0.00	0.01	0.00	0.00	0.98	0.01	0.00
38	1.00	0.02	0.00	0.00	0.00	0.00	0.00	0.98	0.00	0.00
39	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	1.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.98	0.00
122	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.96	0.00
123	1.00	0.00	0.00	0.00	0.80	0.19	0.00	0.00	0.01	0.00

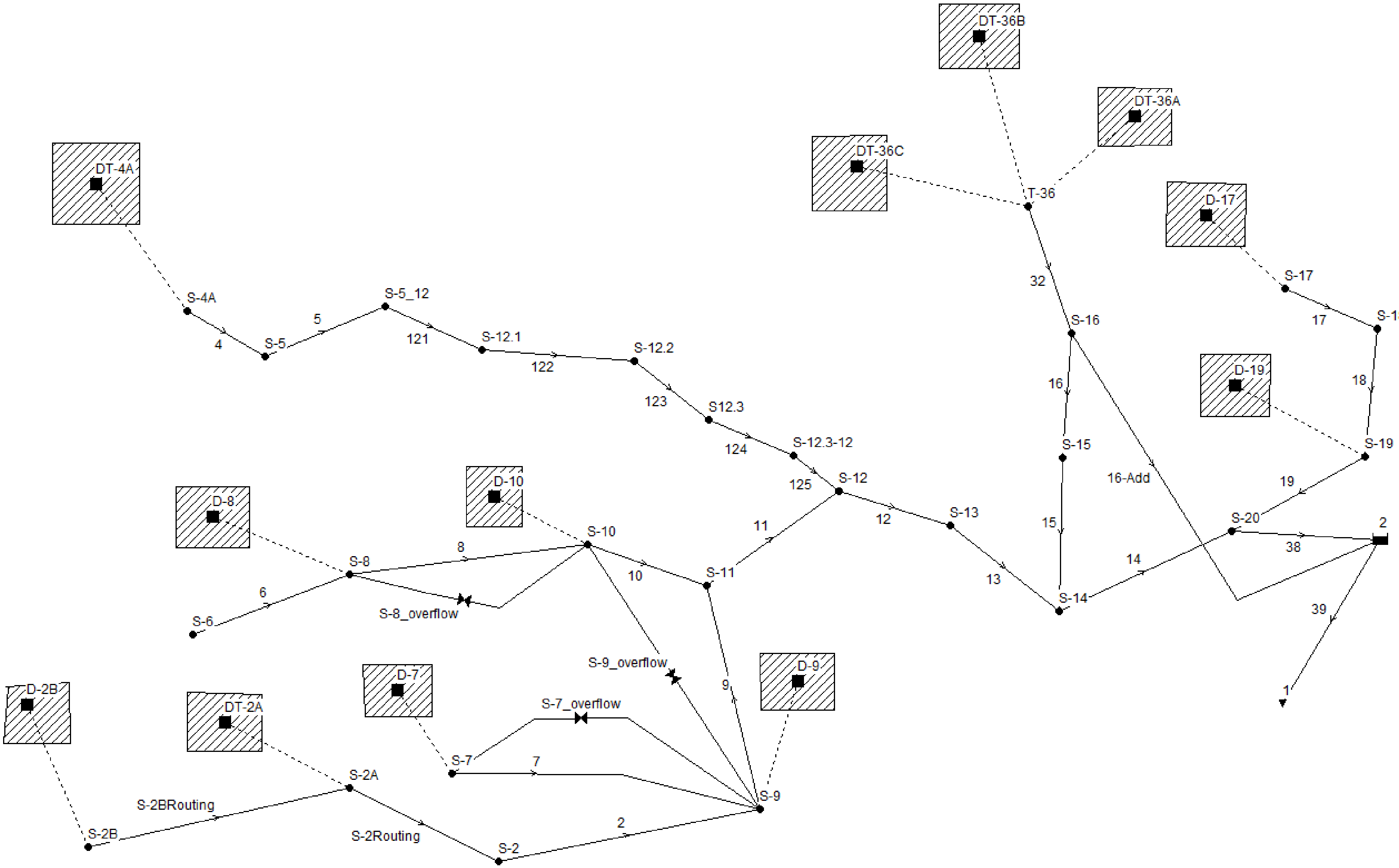
124	1.00	0.00	0.00	0.00	0.83	0.17	0.00	0.00	0.86	0.00
125	1.00	0.01	0.00	0.00	0.96	0.03	0.00	0.00	0.62	0.00
S-2Routing	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
S-2BRouting	1.00	0.00	0.18	0.00	0.82	0.00	0.00	0.00	0.82	0.00
16-Add	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00

****
Conduit Surcharge Summary
****

Conduit	--------- Hours Full -------- Both Ends	Upstream	Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
2	1.00	1.01	1.01	1.04	0.89
5	0.01	0.01	0.23	0.01	0.01
7	0.34	0.34	0.65	0.04	0.04
8	0.01	0.01	0.52	0.01	0.01
9	1.08	1.08	1.23	0.34	0.34
10	0.50	0.53	0.52	0.18	0.11
11	0.97	0.97	1.23	0.01	0.01
12	0.86	0.86	0.98	0.01	0.01
13	0.82	0.82	0.98	0.01	0.01
14	0.79	0.85	0.79	1.42	0.79
15	0.85	0.93	0.85	1.03	0.85
16	0.71	0.71	0.74	0.74	0.71
17	0.01	0.07	0.01	0.71	0.01
18	0.01	0.01	0.01	0.13	0.01
19	0.01	0.01	2.71	0.01	0.01
38	0.01	0.79	0.01	1.35	0.01
121	0.01	0.01	0.41	0.01	0.01
122	0.64	0.64	0.66	0.01	0.01
123	0.66	0.66	0.68	0.01	0.01
124	0.57	0.57	0.74	0.01	0.01
125	0.88	0.88	0.97	0.01	0.01
16-Add	0.01	0.69	0.01	0.71	0.01

Analysis begun on: Sat Oct 9 15:20:26 2021
Analysis ended on: Sat Oct 9 15:20:32 2021
Total elapsed time: 00:00:06

South Sedimentation Basin (SSB) SWMM OUTPUT – 100-yr, 24-hr


DT-36B
DT-36A
DT-36C
T-36
DT-4A
D-17
32
S-17
S-16
S-18
17
S-4A
S-5_12
5
4
S-5
121
S-12.1
S-12.2
122
16
D-19
18
123
S12.3
124
S-12.3-12
S-15
S-19
125
S-12
16-Add
19
D-10
D-8
S-10
11
S-13
12
15
S-20
2
8
S-8
38
14
10
S-11
13
6
S-14
S-6
S-8_overflow
39
S-9_overflow
D-9
9
D-7
D-2B
DT-2A
1
S-7_overflow
S-7
7
S-2A
S-9
S-2BRouting
2
S-2B
S-2Routing
S-2

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.015)

WARNING 02: maximum depth increased for Node S-7
WARNING 02: maximum depth increased for Node S-8
WARNING 02: maximum depth increased for Node S-9
WARNING 02: maximum depth increased for Node T-36
WARNING 02: maximum depth increased for Node S-5_12

****
Element Count
****
Number of rain gages 2
Number of subcatchments ... 12
Number of nodes 28
Number of links 31
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
TS1	MSE3-100yr,24hr	INTENSITY	6 min.
MSE3	MSE3-100yr,24hr	INTENSITY	6 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
D-10	0.51	17.00	100.00	2.6000	MSE3	S-10
D-17	2.11	1200.00	0.00	5.8100	MSE3	S-17
D-19	0.38	600.00	0.00	1.5000	MSE3	S-19
DT-2A	6.80	250.00	13.00	7.0000	MSE3	S-2A
DT-4A	3.60	1100.00	100.00	25.0000	MSE3	S-4A
D-7	1.09	40.00	100.00	2.0000	MSE3	S-7
D-8	0.51	115.00	100.00	0.0700	MSE3	S-8
D-9	0.32	13.00	100.00	1.6000	MSE3	S-9

DT-36B	19.70	1265.00	100.00	25.0000	MSE3	T-36
DT-36A	10.60	1180.00	0.00	5.0000	MSE3	T-36
DT-36C	10.80	2240.00	100.00	25.0000	MSE3	T-36
D-2B	10.90	1340.00	0.00	4.1000	MSE3	S-2B

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
S-2	JUNCTION	686.25	16.20	100.0	
S-4A	JUNCTION	693.34	15.00	0.0	
S-5	JUNCTION	692.01	7.50	0.0	
S-6	JUNCTION	695.71	3.20	0.0	
S-7	JUNCTION	694.09	5.45	0.0	
S-8	JUNCTION	694.73	5.00	0.0	
S-9	JUNCTION	684.57	14.00	660.0	
S-10	JUNCTION	691.90	4.80	2100.0	
S-11	JUNCTION	685.67	15.65	0.0	
S-12	JUNCTION	686.18	16.25	0.0	
S-13	JUNCTION	685.57	15.90	0.0	
S-14	JUNCTION	685.88	16.34	0.0	
S-15	JUNCTION	687.52	14.09	0.0	
S-16	JUNCTION	697.26	10.74	100.0	
S-17	JUNCTION	695.46	4.70	0.0	
S-18	JUNCTION	694.60	5.40	0.0	
S-19	JUNCTION	690.98	9.26	0.0	
S-20	JUNCTION	685.98	10.00	0.0	
T-36	JUNCTION	709.00	7.74	0.0	
S-5_12	JUNCTION	691.07	4.50	0.0	
S-12.1	JUNCTION	688.83	16.84	0.0	
S-12.2	JUNCTION	688.47	17.98	0.0	
S12.3	JUNCTION	688.30	14.93	0.0	
S-12.3-12	JUNCTION	686.56	4.00	0.0	
S-2A	JUNCTION	700.20	3.00	0.0	
S-2B	JUNCTION	710.90	2.00	0.0	
1	OUTFALL	690.00	1.00	0.0	
2	STORAGE	671.00	25.00	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
2	S-2	S-9	CONDUIT	855.0	0.0211	0.0130
4	S-4A	S-5	CONDUIT	100.0	0.1800	0.0130
5	S-5	S-5_12	CONDUIT	147.0	0.6395	0.0130
6	S-6	S-8	CONDUIT	275.0	0.3564	0.0130
7	S-7	S-9	CONDUIT	163.0	2.1600	0.0130
8	S-8	S-10	CONDUIT	205.0	1.3562	0.0130
9	S-9	S-11	CONDUIT	122.0	0.2049	0.0130
10	S-10	S-11	CONDUIT	19.0	0.6842	0.0130
11	S-11	S-12	CONDUIT	107.0	-0.4766	0.0130
12	S-12	S-13	CONDUIT	165.0	0.3697	0.0130
13	S-13	S-14	CONDUIT	226.0	-0.3009	0.0130
14	S-14	S-20	CONDUIT	166.0	0.0602	0.0130
15	S-15	S-14	CONDUIT	35.0	0.7715	0.0130
16	S-16	S-15	CONDUIT	210.0	2.9775	0.0130
17	S-17	S-18	CONDUIT	49.0	0.0204	0.0130
18	S-18	S-19	CONDUIT	14.0	0.3571	0.0130
19	S-19	S-20	CONDUIT	43.0	12.5869	0.0130
32	T-36	S-16	CONDUIT	900.0	0.9712	0.0250
38	S-20	2	CONDUIT	414.0	0.0725	0.0130
39	2	1	CONDUIT	400.0	0.1250	0.0130
121	S-5_12	S-12.1	CONDUIT	350.0	0.6400	0.0130
122	S-12.1	S-12.2	CONDUIT	110.0	0.3273	0.0120
123	S-12.2	S12.3	CONDUIT	100.0	0.1700	0.0120
124	S12.3	S-12.3-12	CONDUIT	120.0	1.4502	0.0120
125	S-12.3-12	S-12	CONDUIT	26.0	1.4617	0.0130
S-2Routing	S-2A	S-2	CONDUIT	250.0	0.3000	0.0250
S-2BRouting	S-2B	S-2A	CONDUIT	1340.0	0.7985	0.0250
16-Add	S-16	2	CONDUIT	500.0	0.2520	0.0130
S-9_overflow	S-9	S-10	WEIR			
S-8_overflow	S-8	S-10	WEIR			
S-7_overflow	S-7	S-9	WEIR			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
2	CIRCULAR	3.00	7.07	0.75	3.00	1	9.68
4	CIRCULAR	3.00	7.07	0.75	3.00	1	28.30
5	CIRCULAR	3.50	9.62	0.88	3.50	1	80.45
6	CIRCULAR	1.00	0.79	0.25	1.00	1	2.13
7	CIRCULAR	1.00	0.79	0.25	1.00	1	5.24
8	CIRCULAR	1.00	0.79	0.25	1.00	1	4.15
9	CIRCULAR	3.00	7.07	0.75	3.00	1	30.19
10	CIRCULAR	1.00	0.79	0.25	1.00	1	2.95
11	CIRCULAR	3.00	7.07	0.75	3.00	1	46.05
12	CIRCULAR	3.50	9.62	0.88	3.50	1	61.17
13	CIRCULAR	3.50	9.62	0.88	3.50	1	55.19
14	CIRCULAR	3.50	9.62	0.88	3.50	1	24.69
15	CIRCULAR	2.00	3.14	0.50	2.00	1	19.87
16	CIRCULAR	2.00	3.14	0.50	2.00	1	39.04
17	CIRCULAR	1.50	1.77	0.38	1.50	1	1.50
18	CIRCULAR	1.50	1.77	0.38	1.50	1	6.28
19	CIRCULAR	1.50	1.77	0.38	1.50	1	37.27
32	TRAPEZOIDAL	7.74	334.00	4.08	80.30	1	4993.90
38	CIRCULAR	3.50	9.62	0.88	3.50	1	27.08
39	CIRCULAR	1.00	0.79	0.25	1.00	1	1.26
121	CIRCULAR	4.50	15.90	1.13	4.50	1	157.32
122	CIRCULAR	3.00	7.07	0.75	3.00	1	41.34
123	CIRCULAR	3.00	7.07	0.75	3.00	1	29.79
124	CIRCULAR	4.00	12.57	1.00	4.00	1	187.39
125	CIRCULAR	3.00	7.07	0.75	3.00	1	80.64
S-2Routing	TRIANGULAR	3.00	39.00	1.46	26.00	1	163.53
S-2BRouting	TRIANGULAR	2.00	26.00	0.99	26.00	1	137.03
16-Add	CIRCULAR	2.50	4.91	0.63	2.50	1	20.59

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

```
****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ YES
  Water Quality .......... NO
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... DYNWAVE
Surcharge Method ......... EXTRAN
Starting Date ............ 06/14/2019 00:00:00
Ending Date .............. 06/16/2019 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:02:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 01:00:00
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.005000 ft


*********************
Control Actions Taken
*********************

**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......        28.723         5.120
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         3.894         0.694
Surface Runoff ...........        24.756         4.413
Final Storage ............         0.126         0.022
Continuity Error (%) .....        -0.186
```

```
**************************        Volume         Volume
Flow Routing Continuity         acre-feet      10^6 gal
**************************       ---------      ---------
Dry Weather Inflow .......           0.000          0.000
Wet Weather Inflow .......          24.776          8.074
Groundwater Inflow .......           0.000          0.000
RDII Inflow ..............           0.000          0.000
External Inflow ..........           0.000          0.000
External Outflow .........           0.000          0.000
Flooding Loss ............           0.001          0.000
Evaporation Loss .........           0.000          0.000
Exfiltration Loss ........           0.000          0.000
Initial Stored Volume ....           0.000          0.000
Final Stored Volume ......          24.777          8.074
Continuity Error (%) .....          -0.006


***************************
Time-Step Critical Elements
***************************
None


********************************
Highest Flow Instability Indexes
********************************
Link 125 (2)
Link 11 (1)
Link 12 (1)


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     0.49 sec
Average Time Step           :     1.00 sec
Maximum Time Step           :     1.00 sec
Percent in Steady State     :     0.21
Average Iterations per Step :     2.02
Percent Not Converging      :     0.18
```

Time Step Frequencies :

1.000 - 0.871 sec	:	99.53 %
0.871 - 0.758 sec	:	0.13 %
0.758 - 0.660 sec	:	0.10 %
0.660 - 0.574 sec	:	0.19 %
0.574 - 0.500 sec	:	0.05 %

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Imperv Runoff in	Perv Runoff in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
D-10	5.12	0.00	0.00	0.00	5.13	0.00	5.13	0.07	3.84	1.003
D-17	5.12	0.00	0.00	1.39	0.00	3.69	3.69	0.21	14.53	0.721
D-19	5.12	0.00	0.00	1.39	0.00	3.69	3.69	0.04	2.67	0.721
DT-2A	5.12	0.00	0.00	1.48	0.67	2.94	3.60	0.67	25.47	0.704
DT-4A	5.12	0.00	0.00	0.00	5.14	0.00	5.14	0.50	29.68	1.003
D-7	5.12	0.00	0.00	0.00	5.13	0.00	5.13	0.15	8.16	1.003
D-8	5.12	0.00	0.00	0.00	5.13	0.00	5.13	0.07	3.90	1.003
D-9	5.12	0.00	0.00	0.00	5.13	0.00	5.13	0.04	2.39	1.003
DT-36B	5.12	0.00	0.00	0.00	5.13	0.00	5.13	2.74	127.89	1.002
DT-36A	5.12	0.00	0.00	1.40	0.00	3.68	3.68	1.06	52.43	0.719
DT-36C	5.12	0.00	0.00	0.00	5.14	0.00	5.14	1.51	86.41	1.003
D-2B	5.12	0.00	0.00	1.69	0.00	3.38	3.38	1.00	48.82	0.661

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	Time of Max Occurrence hr:min	Reported Max Depth Feet
S-2	JUNCTION	0.73	16.03	702.28	0	12:23	16.03
S-4A	JUNCTION	0.17	13.39	706.73	0	12:11	4.37
S-5	JUNCTION	0.15	7.50	699.51	0	12:11	5.54
S-6	JUNCTION	0.03	3.20	698.91	0	12:12	2.93

S-7	JUNCTION	0.26	5.13	699.22	0	12:12	5.12
S-8	JUNCTION	0.08	3.93	698.66	0	12:16	3.91
S-9	JUNCTION	2.26	13.91	698.48	0	12:18	13.91
S-10	JUNCTION	0.15	6.37	698.27	0	12:21	6.37
S-11	JUNCTION	1.17	12.24	697.91	0	12:18	12.23
S-12	JUNCTION	0.66	11.20	697.38	0	12:14	11.14
S-13	JUNCTION	1.24	11.23	696.80	0	12:14	11.17
S-14	JUNCTION	0.87	10.12	696.00	0	12:14	10.07
S-15	JUNCTION	0.92	9.90	697.42	0	12:18	9.89
S-16	JUNCTION	0.35	9.68	706.94	0	12:25	9.67
S-17	JUNCTION	0.66	3.04	698.50	0	12:11	3.03
S-18	JUNCTION	1.21	2.98	697.58	0	12:12	2.97
S-19	JUNCTION	0.38	4.16	695.14	0	12:12	4.15
S-20	JUNCTION	0.66	8.24	694.22	0	12:14	8.23
T-36	JUNCTION	0.16	2.19	711.19	0	12:12	2.18
S-5_12	JUNCTION	0.16	9.43	700.50	0	12:11	6.43
S-12.1	JUNCTION	0.23	10.01	698.84	0	12:11	8.66
S-12.2	JUNCTION	0.26	9.32	697.79	0	12:11	8.95
S12.3	JUNCTION	0.22	9.10	697.40	0	12:14	9.04
S-12.3-12	JUNCTION	0.43	10.84	697.40	0	12:14	10.78
S-2A	JUNCTION	0.29	2.18	702.38	0	12:23	2.18
S-2B	JUNCTION	0.13	1.29	712.19	0	12:14	1.29
1	OUTFALL	0.00	0.00	690.00	0	00:00	0.00
2	STORAGE	10.37	13.84	684.84	2	00:00	13.84

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days	Time of Max Occurrence hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal	Flow Balance Error Percent
S-2	JUNCTION	0.00	56.45	0	12:16	0	1.67	-0.201
S-4A	JUNCTION	29.68	29.68	0	12:12	0.502	0.502	0.260
S-5	JUNCTION	0.00	29.70	0	12:11	0	0.501	-0.395
S-6	JUNCTION	0.00	1.91	0	12:12	0	0.00089	0.421
S-7	JUNCTION	8.16	8.16	0	12:12	0.152	0.152	0.158
S-8	JUNCTION	3.90	3.90	0	12:12	0.0711	0.072	0.401
S-9	JUNCTION	2.39	49.04	0	12:17	0.0446	1.87	0.108

S-10	JUNCTION	3.84	12.09	0	12:14	0.0711	0.163	-0.033
S-11	JUNCTION	0.00	53.23	0	12:29	0	2.02	0.025
S-12	JUNCTION	0.00	60.41	0	12:17	0	2.74	-0.030
S-13	JUNCTION	0.00	60.41	0	12:17	0	2.51	0.040
S-14	JUNCTION	0.00	107.78	0	12:22	0	5.87	-0.002
S-15	JUNCTION	0.00	49.09	0	12:48	0	3.37	0.005
S-16	JUNCTION	0.00	255.03	0	12:12	0	5.32	0.192
S-17	JUNCTION	14.53	14.53	0	12:12	0.212	0.212	0.027
S-18	JUNCTION	0.00	14.53	0	12:12	0	0.212	0.060
S-19	JUNCTION	2.67	17.20	0	12:12	0.0381	0.25	0.013
S-20	JUNCTION	0.00	115.83	0	12:14	0	6.12	-0.000
T-36	JUNCTION	266.74	266.74	0	12:12	5.31	5.31	-0.192
S-5_12	JUNCTION	0.00	30.02	0	12:11	0	0.503	-0.106
S-12.1	JUNCTION	0.00	30.31	0	12:11	0	0.503	0.004
S-12.2	JUNCTION	0.00	30.31	0	12:11	0	0.503	-0.023
S12.3	JUNCTION	0.00	30.33	0	12:11	0	0.503	-0.043
S-12.3-12	JUNCTION	0.00	30.40	0	12:11	0	0.732	0.068
S-2A	JUNCTION	25.47	65.88	0	12:13	0.666	1.67	0.486
S-2B	JUNCTION	48.82	48.82	0	12:12	1	1	-0.416
1	OUTFALL	0.00	0.00	0	00:00	0	0	0.000 gal
2	STORAGE	0.00	167.17	0	12:20	0	8.07	0.000

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
S-4A	JUNCTION	0.43	10.392	1.608
S-5	JUNCTION	0.47	3.350	0.000
S-6	JUNCTION	0.51	2.200	0.000
S-11	JUNCTION	0.77	5.137	3.413
S-12	JUNCTION	1.17	7.699	5.051
S-13	JUNCTION	1.30	7.726	4.674
S-14	JUNCTION	1.13	6.248	6.222
S-15	JUNCTION	0.90	4.405	4.195
S-17	JUNCTION	0.15	0.886	1.664
S-20	JUNCTION	1.11	4.740	1.760

S-5_12	JUNCTION	0.52	4.927	0.000
S-12.1	JUNCTION	0.69	5.509	6.831
S-12.2	JUNCTION	0.96	6.315	8.665
S12.3	JUNCTION	0.82	5.098	5.832
S-12.3-12	JUNCTION	1.05	6.836	0.000

****
Node Flooding Summary
****

Flooding refers to all water that overflows a node, whether it ponds or not.

Node	Hours Flooded	Maximum Rate CFS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 gal	Maximum Ponded Depth Feet
S-5	0.01	10.57	0 12:11	0.000	0.000
S-6	0.01	1.83	0 12:12	0.000	0.000
S-10	0.51	12.09	0 12:14	0.025	1.571

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CFS
2	782.511	26	0	0	1078.843	35	2 00:00	0.00

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CFS	Max Flow CFS	Total Volume 10^6 gal
1	0.00	0.00	0.00	0.000

System	0.00	0.00	0.00	0.000

****

Link Flow Summary

****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
2	CONDUIT	45.74	0 12:34	6.47	4.73	1.00
4	CONDUIT	29.70	0 12:11	6.16	1.05	1.00
5	CONDUIT	30.02	0 12:11	6.94	0.37	1.00
6	CONDUIT	1.91	0 12:12	2.50	0.90	1.00
7	CONDUIT	5.96	0 12:09	7.58	1.14	1.00
8	CONDUIT	2.75	0 12:08	4.09	0.66	1.00
9	CONDUIT	48.55	0 12:32	6.87	1.61	1.00
10	CONDUIT	7.20	0 12:42	9.17	2.44	1.00
11	CONDUIT	53.23	0 12:29	7.53	1.16	1.00
12	CONDUIT	60.41	0 12:17	6.28	0.99	1.00
13	CONDUIT	60.41	0 12:17	6.28	1.09	1.00
14	CONDUIT	107.78	0 12:22	11.20	4.36	1.00
15	CONDUIT	49.09	0 12:48	15.63	2.47	1.00
16	CONDUIT	49.09	0 12:48	15.62	1.26	1.00
17	CONDUIT	14.53	0 12:12	8.24	9.68	0.99
18	CONDUIT	14.54	0 12:12	8.32	2.32	0.96
19	CONDUIT	17.36	0 12:11	9.82	0.47	1.00
32	CONDUIT	255.03	0 12:12	5.56	0.05	0.53
38	CONDUIT	115.83	0 12:14	12.21	4.28	0.96
39	CONDUIT	0.00	0 00:00	0.00	0.00	0.00
121	CONDUIT	30.31	0 12:11	3.98	0.19	1.00
122	CONDUIT	30.31	0 12:11	4.29	0.73	1.00
123	CONDUIT	30.33	0 12:11	4.69	1.02	1.00
124	CONDUIT	30.40	0 12:11	2.42	0.16	1.00
125	CONDUIT	30.59	0 12:11	4.33	0.38	1.00
S-2Routing	CONDUIT	56.45	0 12:16	3.72	0.35	0.83
S-2BRouting	CONDUIT	42.55	0 12:14	2.56	0.31	0.82
16-Add	CONDUIT	54.67	0 12:25	11.25	2.65	0.97
S-9_overflow	WEIR	3.13	0 12:18			0.82
S-8_overflow	WEIR	0.00	0 00:00			0.00

S-7_overflow	WEIR	4.04	0	12:12	0.61

****
Flow Classification Summary
****

Conduit	Adjusted /Actual Length	---------- Fraction of Time in Flow Class ---------- Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
2	1.00	0.02	0.00	0.00	0.97	0.00	0.00	0.01	0.48	0.00
4	1.00	0.00	0.00	0.00	0.01	0.00	0.00	0.98	0.00	0.00
5	1.00	0.00	0.00	0.00	0.53	0.47	0.00	0.00	0.00	0.00
6	1.00	0.00	0.92	0.00	0.07	0.00	0.00	0.00	0.73	0.00
7	1.00	0.01	0.00	0.00	0.02	0.00	0.00	0.97	0.01	0.00
8	1.00	0.00	0.00	0.00	0.03	0.12	0.00	0.85	0.13	0.00
9	1.00	0.00	0.02	0.00	0.98	0.00	0.00	0.00	0.00	0.00
10	1.00	0.00	0.00	0.00	0.02	0.00	0.00	0.98	0.00	0.00
11	1.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.03	0.00
12	1.00	0.01	0.00	0.00	0.99	0.00	0.00	0.00	0.03	0.00
13	1.00	0.01	0.02	0.00	0.54	0.00	0.44	0.00	0.02	0.00
14	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.38	0.00
15	1.00	0.02	0.00	0.00	0.03	0.00	0.00	0.96	0.00	0.00
16	1.00	0.00	0.00	0.00	0.02	0.00	0.00	0.98	0.00	0.00
17	1.00	0.15	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00
18	1.00	0.16	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00
19	1.00	0.02	0.55	0.00	0.43	0.00	0.00	0.00	0.83	0.00
32	1.00	0.00	0.00	0.00	0.02	0.00	0.00	0.98	0.02	0.00
38	1.00	0.02	0.00	0.00	0.00	0.00	0.00	0.98	0.00	0.00
39	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	1.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.97	0.00
122	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.95	0.00
123	1.00	0.00	0.00	0.00	0.73	0.26	0.00	0.00	0.01	0.00
124	1.00	0.00	0.00	0.00	0.87	0.12	0.00	0.00	0.86	0.00
125	1.00	0.01	0.00	0.00	0.96	0.03	0.00	0.00	0.58	0.00
S-2Routing	1.00	0.00	0.00	0.00	0.01	0.00	0.00	0.99	0.00	0.00
S-2BRouting	1.00	0.00	0.16	0.00	0.84	0.00	0.00	0.00	0.84	0.00
16-Add	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
2	1.31	1.33	1.33	1.37	1.19
4	0.43	0.43	0.47	0.02	0.01
5	0.52	0.52	0.58	0.01	0.01
6	0.51	0.51	0.57	0.01	0.01
7	0.63	0.63	0.94	0.05	0.05
8	0.57	0.57	0.76	0.01	0.01
9	1.41	1.41	1.59	0.58	0.58
10	0.75	0.76	0.77	0.63	0.51
11	1.29	1.29	1.59	0.43	0.01
12	1.17	1.17	1.30	0.01	0.01
13	1.13	1.13	1.30	0.45	0.01
14	1.11	1.16	1.11	1.82	1.11
15	1.16	1.25	1.16	1.30	1.11
16	1.02	1.02	1.07	1.07	1.02
17	0.01	0.15	0.01	0.90	0.01
18	0.01	0.06	0.01	0.21	0.01
19	0.55	0.55	3.42	0.01	0.01
38	0.01	1.11	0.01	1.74	0.01
121	0.52	0.52	0.69	0.01	0.01
122	0.90	0.90	0.96	0.01	0.01
123	0.96	0.96	0.97	0.01	0.01
124	0.82	0.82	1.05	0.01	0.01
125	1.20	1.20	1.29	0.01	0.01
S-2BRouting	0.01	0.01	0.28	0.01	0.01
16-Add	0.01	1.00	0.01	1.02	0.01

Analysis begun on: Sat Oct 9 15:15:01 2021
Analysis ended on: Sat Oct 9 15:15:07 2021
Total elapsed time: 00:00:06

ATTACHMENT K-2

SURFACE WATER DIVERSION BERM ANALYSIS

CALCULATION SHEET

Client: US Ecology - Wayne Disposal	Project No.: 1218070017	
Project: 2021 WDI Permit Modification Application	Calculated By: LEH	Date: 11/04/2021
Calculation: Surface Water Diversion Berm Analysis -Engineered Turf	Checked By: TCR	Date: 11/04/2021
	Approved By: XZ	Date: 11/04/2021

Surface Water Diversion Berm Analysis -Engineered Turf

Objective

Design the diversion berms to direct surface water run-off from landfill slopes to perimeter ditches. Diversion berms are designed to a depth and slope to provide sufficient capacity.

Design Criteria, Assumptions, and Methodology

1. Diversion berm locations are shown on the Figure provided in Attachment K-1.5.
2. Diversion berms will collect and control the run-off from the 25-yr, 24-hr storm event with a minimum of 0.5 ft of freeboard. The berms will manage flow from the 100-yr, 24-hr storm event with no offsite flooding.
3. Diversion berm slopes will typically be sloped at 2 percent, but will vary at certain locations due to site conditions.
4. Diversion berm channels will be triangular in shape.
5. The interior-side channel slope of the diversion berm channel will vary depending on the final cover slope. Conservatively use the typical maximum slope for the diversion berms modeled.
6. Diversion berms will be lined with engineered artificial turf landfill cover, such as Closure Turf.
7. The design of the diversion berms is based on the berms at each slope with largest drainage area. This will result in a standard berm sized for the maximum design flow for each channel slope. Unique diversion berm locations and configurations are also modeled.

Calculation

The critical diversion berms considered in this analysis are as follows:

- DB-A-1, Berm at 2% slope with largest immediate drainage area.
- DB-A-2, Berm at 11% slope with largest immediate drainage area.
- DB-D-1, Berm at 1% slope with largest immediate drainage area.
- DB-D-2, Berm at 9.8% slope with largest immediate drainage area.
- DB-G, Berm at 5.4% slope with largest immediate drainage area.
- DB-46, Existing berm with unique drainage configuration.
- W-MC X DV, existing berm with unique drainage configuration.
- E-MC X DV, existing berm with unique drainage configuration.
- S-MC X DV, existing berm with unique drainage configuration.

Diversion berm designs are based on the HydroCAD model output provided in Attachment K-1.6. Diversion berm designs are summarized in Table K-2.1 below.

CALCULATION SHEET

Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Surface Water Diversion Berm Analysis -Engineered Turf
Project No.: 1218070017
Calculated By: LEH Date: 11/04/2021
Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Conclusion

The proposed diversion berms, described above, will safely collect and control the design storm event. Diversion berm locations and cross sections may be modified depending on site conditions at closure, as long as design requirements are met.

CALCULATION SHEET
Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Surface Water Diversion Berm Analysis -Engineered Turf

Project No.: 1218070017
Calculated By: LEH Date: 11/04/2021
Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Table K-2.1: Diversion Berm Summary

Diversion Berm Modeled	Additional Diversion Berms Represented in Design	Diversion Berm Design					Peak Flow (25-yr, 24-hr Storm)		
		Watershed Drainage Area (ac.)	Design Slope (%)	Channel Sideslopes <Max> (H:V)	Design Depth (ft)	Channel Lining	Flow Rate (cfs)	Flow Depth (ft)	Flow Velocity (ft/sec)
DB-A-1	DB-B and DB-C	40.3; See Note 3	2.0%	4:1 / 2:1	3.0	Engineered Turf	209.4	2.37	11.26
DB-A-2	--	40.3	11.0%	4:1 / 2:1	3.0	Engineered Turf	187.2	1.71	21.33
DB-D-1	DB-E, DB-F, and DB-H	8.8; See Note 4	1.0%	4:1 / 2:1	2.5	Engineered Turf	55.8	1.58	6.10
DB-D-2	--	8.8	9.8%	4:1 / 2:1	2.5	Engineered Turf	45.1	1.02	14.29
DB-G	--	1.9	5.4%	4:1 / 2:1	2.0	Engineered Turf	12.2	0.69	8.20
DB-46	--	10.5	1.0%	10:1 / 3:1	2.0	Grass (existing)	24.0	1.00	3.70
W-MC X DV	--	13.8	Varies (0.5% min)	3:1 / 8:1	2.0	Grass (existing)	38.3	1.37	3.22
E-MC X DV	--	12.1	1.0%	3:1 / 3:1	2.0	Grass (existing)	35.6	1.49	4.71
S-MC XI DV	--	2.2	1.8%	6:1 / 2:1	1.5	Grass (existing)	6.9	0.66	3.70

Notes:
1. All diversion channels are triangular in shape and formed by the construction of a berm on the final cover grades.
2. Diversion berm locations, cross section, and slopes may be modified based on site conditions at time of construction, as long as design requirements are met.
3. Actual watershed drainage area for DB-A-1 is 37.8 ac.
4. Actual watershed drainage area for DB-D-1 is 8.3 ac.

ATTACHMENT K-3

SURFACE WATER DITCH ANALYSIS

CALCULATION SHEET

Client: US Ecology - Wayne Disposal	Project No.: 1218070017		
Project: 2021 WDI Permit Modification Application	Calculated By: LEH	Date: 11/04/2021	
Calculation: Surface Water Ditch Analysis -Engineered Turf	Checked By: TCR	Date: 11/04/2021	
	Approved By: XZ	Date: 11/04/2021	

Surface Water Ditch Analysis -Engineered Turf

Objective

Design ditches to convey surface water run-off at the site.

Design Criteria, Assumptions, and Methodology

1. Ditch locations are shown on the Figure provided in Attachment K-1.5.
2. Ditch labels describe the ditch location with respect to the Master Cell (MC) locations.
3. Ditches will collect and control the run-off from the 25-yr, 24-hr storm event with a minimum freeboard of 0.5 feet and manage run-off from the 100-yr, 24-hr storm event with no offsite flooding.
4. Ditch cross section and slopes will vary depending on the location within the site.
5. Ditches around the perimeter of MC VI will be lined with engineered artificial turf landfill cover, such as closure turf or hydroturf. Other ditches will be vegetated.
6. Erosion protection will be provided, as needed, at:
   a. Locations where the ditch changes directions,
   b. Locations with grass ditch lining where the maximum flow velocity is greater than 5.0 fps, and
   c. Culvert inlet and outlet locations with grass ditch lining.
7. Ditch label typically indicates the location, e.g., ditch MC VII/XI is located between MC VII and MC XI.
8. Ditches that are restricted by downstream culverts are modeled as ponds to account for water storage during storm events. This affects the following ditches:
   a. NWD restricted by culvert NWD/MC VII Culvert,
   b. N-MC VII ditch restricted by culvert N-MC VII;
   c. N-MV IX and NE MC-IX ditches restricted by the NSB North Inlet culvert;
   d. MC VII/XI ditch restricted by culvert MC VII/XI,
   e. MC VII/IX and MC X/XI ditches restricted by culvert MC VII/IX
9. All but two of the ditches are existing on-site ditches. Only ditches S-MC VI and N-MC VI are new proposed ditches. Some ditches include grading modifications in the form of containment berms, as shown in the drawings. The lining of ditch MC VI/XI will be changed to engineered turf.

Calculation

Ditch design is based on the HydroCAD model output provided in Attachment K-1.6. Ditch designs are summarized in Table K-3.1 below. Ditches along the perimeter of the site that need to maintain containment on the outbound edge of the site have a minimum containment berm elevation identified in the table.

Conclusion

The proposed ditches, described above and in the table below, will safely transmit the design storm event. Ditch cross sections and slopes may be modified depending on site conditions at closure as long as design requirements are met.

CALCULATION SHEET
Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Surface Water Ditch Analysis -Engineered Turf

Project No.: 1218070017
Calculated By: LEH Date: 11/04/2021
Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Table K-3.1: Ditch Design Summary

Drainage Ditch Label	Channel Design							Peak Flow (25-yr, 24-hr)			
	Design Slope (%)	Channel Shape	Channel Sideslopes (H:V)	Req. Berm Elev. (ft)	Channel Bottom Width (ft)	Design Depth <Min.> (ft)	Channel Lining	Flow Rate (cfs)	Flow Depth (ft)	Peak Elev. (ft)	Flow Velocity (ft/sec)
North Sedimentation Basin (NSB) Subwatershed											
NWD (north & west of MC IV and VI) - Modeled as pond	Varies	Trapezoidal	2:1 (max)	712.0	Varies	Varies	Engineered Turf	580.5	6.2 (max)	710.5	NA
N-MC VII – Modeled as pond	Varies	Trapezoidal	2:1 (max)	703.0	Varies	Varies	Engineered Turf	157.6	5.4 (max)	702.2	NA
MC VII/XI -Modeled as pond	Varies	Triangular	2:1 (max)	707.0 (spillway)	--	Varies	Grass	98.1	7.9 (max)	707.9	NA
MC X/XI and MC VII/IX Modeled as pond	Varies	Trapezoidal	2:1 (max)	706.0	Varies	Varies	Grass	235.5	6.1 (max)	703.2	NA
N-MC IX , NE-MC-IX, and E-MC IX– Modeled as pond	Varies	Trapezoidal	2:1 (max)	702.0	Varies	Varies	Grass	263.7	4.8 (max)	699.7	NA
South Sedimentation Basin (SSB) Subwatershed											
E-MC X	0.25%	Triangular	5:1 / 5:1	--	--	3.0	Grass	26.6	1.26	--	1.81
S-MC X	0.27%	Triangular	1:1 / 2:1	--	--	4.0	Grass	23.3	2.07	--	2.77
W- MC X	0.24%	Trapezoidal	3:1 / 2:1	--	6.0	4.0	Grass	22.3	1.02	--	2.42
E-MC I	0.41%	Triangular	3:1	--	--	3.0	Grass	37.1	1.87	--	3.51
MC VI/XI	1.0%	Trapezoidal	4:1	--	6.0	4.0	Engineered Turf	162.5	1.66	--	7.73

Notes:
1. Ditches modeled as ponds do not include flow velocity.
2. Ditch slopes that vary are, at a minimum, sloped to drain.
3. Ditch configuration may be changed as long as design criteria are met.

ATTACHMENT K-4

CULVERT ANALYSIS

CALCULATION SHEET

Client: US Ecology - Wayne Disposal | Project No.: 1218070017
Project: 2021 WDI Permit Modification Application | Calculated By: LEH Date: 11/04/2021
Calculation: Culvert Analysis -Engineered Turf | Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Culvert Analysis -Engineered Turf

Objective

Analyze existing culverts to remain in place and proposed culverts for final cover conditions to convey surface water through ditches and into sedimentation basins.

Design Criteria, Assumptions, and Methodology

1. This analysis is primarily of existing culvert pipes, changes from existing conditions are noted.
2. Culvert locations are shown on the Figure provided in Attachment K-1.5.
3. Culvert labels describe the ditch location with respect to the Master Cell (MC) locations.
4. South Sedimentation Basin storm sewer pipes and inlets are addressed in Appendix K-5.
5. Culverts will collect and control flow from the 25-yr, 24-hr storm event and manage run-off from the 100-yr, 24-hr storm event with no offsite flooding.
6. Culverts will consist or Reinforced Concrete Pipe (RCP), Corrugated Metal Pipe (CMP), or Smooth Lined Corrugated HDPE Pipe (CPP). A Manning's No. of 0.012 is used to represent RCP and CPP, while a value of 0.025 is used to represent CMP.
7. The tailwater depth input for each culvert was based on the downstream channel flow depth for the design storm event.
8. Riprap or other materials, such as permanent turf reinforcement mat, will be used at culvert inlets and outlets.
9. Alternate culvert pipe materials, sizes, and configurations that meet design criteria may be used.
10. Culverts NWD-MC VII, MC VII/IX, and E-MC VI/XI restrict flow, and are modeled as ponds to account for water storage during storm events.

Calculation

Culvert design is based on the HydroCAD model output provided in Attachment K-1.6. Culvert designs are summarized in Table K-4.1 below.

Conclusion

The culverts described in the table below, will safely transmit the design storm event. Alternate culvert slopes, materials, and dimensions that meet design requirements may be used.

CALCULATION SHEET

Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Culvert Analysis -Engineered Turf

Project No.: 1218070017
Calculated By: LEH Date: 11/04/2021
Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Table K-4.2
Culvert Summary

Culvert Label (new/existing)	Number and Type of Culvert	Min. Pipe Dia. (in.)	Design Slope (%)	Approx. Design Length (ft)	Approx. Inlet Invert Elev. (ft)	Total Watershed Area (ac.)	Peak Flow Rate <25-yr, 24-hr> (cfs)	Head-water Elev. (ft)
North Sedimentation Basin (NSB) Watershed								
NWD / MC VII (new)	3/CPP 1/CPP	30” 18”	4.24	125.0	704.3	125.4	139.72	710.46
N-MC VII (existing)	1/RCP 1/RCP	54” 36”	0.38	42	696.8	133.4	145.32	702.15
MC VII/IX (existing)	3/CMP	24”	0.33	30	697.1	104.3	59.68	703.18
MC VII/XI (existing see note 2)	1/RCP	24”	2.25	40	700.3	32.4	65.39	707.93
N-MC IX (existing)	1/RCP 3/CMP	54” 30”	4.00 0.0	110.0	695.0	276.5	194.51	699.65
E-MC IX (existing)	1/CPP	36”	3.65	72	701.8	12.1	30.87	704.16
South Sedimentation Basin (SSB) Watershed								
E-MC I (new, see note 3)	1/CPP	24”	0.25	80	703.0	3.1	7.72	705.52
SSB East Inlet (existing)	1/RCP	30”	0.12	113	688.1	13.8	21.03	690.92

Notes:
1. Culvert MC X/XI was not modeled due to the location upstream of the restrictive MC VII/IX culvert.
2. Under existing conditions at culvert MC VII/XI, if the upstream ditch overtops the containment berm, the flow will route to the same location as the culvert output. This is an acceptable flow path, the model indicates the overflow velocity is less than 3 fps, therefore vegetation will prevent erosion.
3. The existing culvert for the access road to MC I will be replaced with the designed culvert.
4. Alternate culvert pipe materials, sizes, and configurations that meet design criteria may be used.

ATTACHMENT K-5

STORM SEWER ANALYSIS

CALCULATION SHEET	
Client: US Ecology - Wayne Disposal	Project No.: 1218070017
Project: 2021 WDI Permit Modification Application	Calculated By: TCR Date: 11/04/2021
Calculation: Storm Sewer Analysis	Checked By: WL Date: 11/04/2021
	Approved By: XZ Date: 11/04/2021

Storm Sewer Analysis

Objective

Evaluate the capacity of the existing South Sedimentation Basin (SSB) storm sewer to collect and control the design storm event under final closure conditions with an engineered artificial turf cover.

Design Criteria, Assumptions, and Methodology

1. Storm Sewer routes surface water run-off to the SSB. The layout is shown on the Figure provided in Attachment K-1.5.
2. The storm sewer will collect and control run-off from the 25-yr, 24-hr storm event and manage the 100-yr, 24-hr storm event with no offsite flooding.
3. The existing storm sewer layout is reflected in the "Storm Water Management System Evaluation Report" prepared by CTI, Revised February 2021. Changes to the existing storm sewer layout are identified below.
4. Grading as shown in the drawings.

Calculation

The existing storm sewer includes revisions to accommodate the surface water flows from the expansion. The changes include the following:

A. S-1 Inlet: Remove the existing inlet
B. S-3 Inlet: Remove the existing inlet
C. S-4A Inlet: Extend the existing S-4 inlet vertically to new design grades.
D. Install a new 30-inch storm sewer pipe from the S-16 inlet location to the SSB. Inlet invert 697.26, slope 0.25% minimum. Alternate configuration, piping, or channels with sufficient flow capacity may be used.

The SWMM model was used to evaluate the revised storm sewer system for final cover conditions. SWMM model inputs and outputs are provided in Attachment K-1.6. A summary of flooding output is provided in Table K-6.6.1 below.

Conclusion

The revised storm sewer will safely collect and control the 25-yr, 24-hour storm event with no flooding and will manage the 100-yr, 24-hr storm event with no offsite flooding.

CALCULATION SHEET

Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Storm Sewer Analysis

Project No.: 1218070017
Calculated By: TCR Date: 11/04/2021
Checked By: WL Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Table K-6.6.1: Storm Sewer Summary 100-yr, 24-hr Flooding/Overflow

Junction	Description	Drainage Area	Flooding Depth/Volume	Comments
S-5, & S-6	Manholes	MC-1 and Expansion	None	Incidental volume, does not exceed manhole.
S-10	Drop Inlet	Site Entrance Area	1.57 ft (25,000 gal)	Flood volume will be contained within S-10 inlet drainage area, See Note 1.

Notes:

1. Flooding at S-10 up to approximately elev. 698.4 (1.7 ft above inlet) will remain on-site within the S-10 drainage area. The flooding depth at S-10 is based on a 2,100 sf area to model increased storage depths in the area of S-10. At elev. 698.4, there is approx. 3,670 cf (27,450 gal) of surface water storage in the area of S-10.

ATTACHMENT K-6

SEDIMENTATION BASIN ANALYSIS

CALCULATION SHEET

Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Sedimentation Basin Analysis -Engineered Turf

Project No.: 1218070017
Calculated By: LEH Date: 11/04/2021
Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Sedimentation Basin Analysis -Engineered Turf

Objective

Evaluate the storage capacity of the existing North Sedimentation Basin (NSB) and South Sedimentation Basin (SSB) for final landfill cover conditions with engineered turf.

Design Criteria, Assumptions, and Methodology

1. The site includes three storm water sedimentation basins, NSB, SSB, and the Lined Pond. After a storm event, the NSB storm water is pumped to the SSB. The storm water in SSB and the Lined Pond are treated separately prior to discharge off-site.
2. The subwatershed draining to the existing EGLE approved Lined Pond and related storm sewer system is reduced under final conditions. Therefore, the Lined Pond has sufficient capacity for the design storm event, and revised calculations are not included herein.
3. At WDI the Sedimentation Basins are design to store the entire 100-yr, 24-hr storm event with no discharge off site. From Attachment K-1.1 the 100-yr, 24-hr storm rainfall is 5.12 inches.
4. Both NSB and SSB consist of two separate areas connected by a spillway for the NSB and culvert for the SSB. The NSB South area is divided into two parts by a berm within the basin. The spillway between NSB north and NSB south will be made deeper for final conditions, as shown in Attachment K-1.5.
5. From the HydroCAD output provided in Attachment K-1.6, the total design storm run-off volume is as follows:
    a. 91.83 ac-ft for the NSB, use 91.8 ac-ft
    b. 32.85 ac-ft for the SSB, use 32.9 ac-ft
6. The NSB and SSB locations are shown in Attachment K-1.5.

Calculation

Sedimentation basin volumes are estimated using topography and as-built data. Sedimentation Basin design information is summarized in Table K-6.1, below.

Conclusion

The North Sedimentation Basin (NSB) and the South Sedimentation Basin (SSB) have sufficient capacity to store the entire 100-yr, 24-hr design storm event with over 1 ft of freeboard.

CALCULATION SHEET

Client: US Ecology - Wayne Disposal
Project: 2021 WDI Permit Modification Application
Calculation: Sedimentation Basin Analysis -Engineered Turf

Project No.: 1218070017
Calculated By: LEH Date: 11/04/2021
Checked By: TCR Date: 11/04/2021
Approved By: XZ Date: 11/04/2021

Table K-6.1: Sedimentation Basin Design Summary
(at assumed final site conditions)

Location	NSB North	NSB South	SSB North	SSB South
Top of Berm (no freeboard) Elev.	695		695	
Basin Bottom Elev.	670	672/668	673	670
Pond Connection / Elev.	Spillway / 693.0		60” Dia. Culvert / 684	
Total Storage Volume Available (with 1-ft freeboard)	115.9 ac-ft		53.8 ac-ft	
100-yr, 24-hr Storm Run-off Vol.	91.8 ac-ft		32.9 ac-ft	