Determining the Effectiveness of the Villanova Bio-Infiltration Traffic Island in Infiltrating Annual Runoff

by

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A Thesis
Submitted to the
Department of Civil and Environmental Engineering
of Villanova University
in Partial Requirements for the Degree of
Master of Civil Engineering

Villanova University
Villanova, Pa
May 2003

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Full Title of Thesis: Determining the Effectiveness of the Villanova Bio-Infiltration Traffic Island in Infiltrating Annual Runoff

Date of Submission: May 31, 2003

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Acknowledgements

I would first like to thank Dr. Traver for all of his help from the beginning to the end. I'd also like to thank the DEP for the funding of this project and the food that went on my table during my tenure as a poor grad student. Dr. Andrea Welker was of assistance with the soil classification and assistance on the theory of infiltration. Thanks also go out to Tyler Ladd for the work he did before I got here, and his continuing work along the way, to Bill Heasom for his helping surveying the drainage area and his continuous insight on the project. Clay Emerson was a big help in constructing the model, and giving insight on the thesis writing experience. Thanks also to George Pappas for his help in the installation of the monitoring equipment.

Abstract

Urbanization, with its increase in impervious surface and resulting pollutant loads, causes several degrading effects on downstream watersheds. Stormwater Management criteria have changed to include reduction in volume, thus causing infiltration to become a more widely used practice. The Villanova Bio-Infiltration Traffic Island, funded through a Pennsylvania Department of Environmental Protection Growing Greener Grant, was built to infiltrate storm runoff for small events, while allowing larger storms to flow into the existing storm sewer. Data was collected from the site for one year. The outflow, including infiltration, was modeled using a combination of spreadsheets and HEC-HMS. The results from this model, along with historical rain gauge data from Chadd's Ford, PA were used to project the long term effectiveness of the traffic island The two most important factors in design, volume and infiltration rates, were varied to determine how sensitive each factor is in performance.

Since most annual precipitation comes from small storms, the Villanova Bio-Infiltration Traffic Island was able to capture and infiltrate 69% of the yearly runoff. The amount of runoff captured was found to be directly related to the hydraulic conductivity of the soil, and the surface storage volume of the infiltration bed. Recommendations for future studies include the effects of the system on water quality and the surrounding soil.

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Introduction

This thesis is a study of a bio-infiltration traffic island and its effectiveness to meet changing stormwater management design criteria. The traffic island's performance for specified storm events is examined, and the amount of annual runoff captured by the system is predicted. The study focused on an existing traffic island that was retrofitted to create a bio-infiltration traffic island. The design would capture and infiltrate the first inch of runoff, while allowing larger storms to bypass into the exiting storm sewer system. The study also examines the applicability of current hydrologic tools in modeling the system. Funding for the project came from a Growing Greener grant from the Pennsylvania Department of Environmental Protection.

Urban storm runoff creates several degrading effects on river systems. Changing of the urban landscape by filling and grading of the surface, as well as collecting runoff in impervious pipes and channels, bypasses the natural infiltration process (Lawrence, et al 1996). Combined with the loss of vegetation, runoff travels faster through the watershed. These faster travel times increase peak flows to the receiving waters. Large amounts of impervious surface also decrease the amount of evaporation in the system (EPA 2002). Impervious surface does not allow for infiltration to occur, also creating a higher peak flows and volume of runoff (Lawrence, et al 1996). Base flows are lowered and the soil moisture is reduced (Barbosa and Hvitved-Jacobsen 2001). Streams flowing in areas with as little as 10% impervious surface cover suffer stream channel destabilization, a rise in water temperature, and a reduction of the quality and diversity of life in the stream. Channels widen due to the increase in erosion and sedimentation transport. In drought periods, the loss of infiltration and groundwater recharge causes base flows to decrease as well (EPA 2002).

Urban activities also lead to an increase of the pollutant load to the watershed. Runoff from impervious surfaces, especially highway runoff from vehicle traffic, imposes external pollutant loads entering the watershed (Barbosa and Hvitved-Jacobsen 2001). Fertilizers and other chemicals can also make their way onto grass and other pervious surfaces and be transported into streams. Airborne deposition of pollutants from industry will also add to the pollutant load. The increased storm runoff will transport these pollutants into the receiving surface waters (Lawrence, et al 1996).

The engineering community has realized a need for new methods to deal with urban stormwater issues. In a guidance document published by the EPA, new runoff management strategies are to minimize the amount of directly connected impervious surfaces. The document also encourages the use of infiltration and the prevention of pollutant runoff by separating pollutants from runoff before their discharge into natural receiving water bodies (EPA 2002). Congress passed into law Phase 2 of the NPDES Storm Water program. This requires the use of appropriate combinations of Best Management Practice strategies using both structural and nonstructural methods for all new construction in populated areas, and for the remediation of existing problems. The legislation encourages the use of storage practices along with vegetative and infiltration practices to meet runoff and pollutant standards (Federal Register 2000). The measures also mandate adequate long-term operation and maintenance controls.

The state of Pennsylvania, through the implementation of Act 167, has developed a more specified approach to storm water management. Act 167 was enacted as a stormwater management planning tool in 1978. From 1978 until recently, the laws only focused on peak flows (Pa Dep 2002). The act is now being used as the vehicle to implement new stormwater management policies. The state's Department of Environmental Protection's policy encourages the use of Best Management Practices (BMP's) that protect and maintain the existing conditions in streams, with particular attention to water quality issues in special protection streams. It provides a uniform approach to post-construction stormwater management. The policy emphasizes groundwater recharge through infiltration, water quality treatment, and discharge and rate control. The goal is to replicate the infiltration and runoff characteristics of the site, prior to development. The policy also emphasizes the need to minimize impervious cover and the use of innovative storm water BMP's that provide infiltration and water quality treatment (Pa Dep 2002). The Bio-infiltration Traffic Island is designed for infiltration and water quality improvement.

These measures, along with insight from engineers, have created a shift towards using infiltration as a means to ameliorate stormwater problems and to meet regulatory goals. The new focus is on volume. The strategy now is to focus on smaller storms, which make up most of the annual precipitation volume. Storms of one inch or less can make up roughly 80% of annual rainfall volume. Infiltration structures would be designed to capture and infiltrate the small storms, while allowing runoff from extreme events to bypass the system and flow into a BMP designed for a larger storm. No infiltration BMP would be designed to infiltrate the 100 year storm, as spatial and economic constraints would prevent this. As early as 1991, the need to use infiltration as a means to control storm runoff had been identified (Whipple 1991). An infiltration BMP is designed to promote the interception of runoff to reduce the total volume, peak flows, contaminant transport, and to promote ground water recharge (Lawrence, et al 1996).

Ideally, an infiltration practice would utilize large areas of pervious, vegetated cover to closely recreate the natural infiltration process of the land. This would provide a slow infiltration process and make use of the humic root zone and its biochemical processes to remove pollutants and protect groundwater (Mikklesen, et al 1996). Vegetation would also recreate evapo-transpiration. This, however, is not as practical within an urban landscape due to space restrictions. The strategy is to take relatively large amounts of runoff and collect it into a relatively small area. These structures would infiltrate the runoff at a higher rate than a natural green surface. Several devices would be built throughout the construction site, instead of trying to infiltrate all of the site's runoff within one structure. Examples of infiltration BMP's include grassed swales, filter strips, rock bed infiltration trenches and pits, exfiltration trenches, infiltration basins and porous pavement (EPA 2002). Constraints of using infiltration include steep land slopes, highly erodible soils, active clays, and high groundwater tables. The possibility of ground water contamination is also an important factor. High moisture content of the soil can also decrease performance of the system (Lawrence, et al 1996).

The resulting effects of urbanization on storm water, with its increases in peak flows and total volume, have been shown to cause harmful effects even for smaller storms (Lawrence, et al 1996). For contaminant control, storm water quality impacts are primarily related to the initial portion of the rainfall (Lawrence, et al 1996). The largest portion of non-point source pollution comes from the accumulation from frequent small storms over the course of a year. This load comes from what is referred to as the "first flush" of the storm, where pollutants are washed from the surface by the initial portion of the rain event. Lawrence, et. al recommends the target volume for an infiltration practice be less than a one year storm (Lawrence, et al 1996). By doing this, an infiltration practice can act as an effective means of pollution source control (Mikklesen, et al 1996). The underlying soil and rock strata can act as a pollutant trap. Pollutants are treated by chemical removal due to sorption and precipitation of the pollutant onto aquifer solids (Lee and Jones 1998). Organic pollutants can also undergo bio-transformations into less harmful substances. The sorption properties are dependent on the characteristics of the underlying material (Lee and Jones 1998). Silts and clays offer high sorption rates, but have low infiltration rates. Consequentially, sands and gravels have low sorption properties, but offer high infiltration capacities (Lee and Jones 1998). The transport of sediments into the infiltration area over time can clog the pores in the soil, thus reducing the effect of the system (Lee and Jones 1998).

Examining the pollutants that might enter an infiltration facility is also important. Biological degradation of streams can be attributed to the presence of hydrocarbons. Most hydrocarbons in storm runoff occur in particulate form (Whipple 1991). The particulate matter can then be removed during the infiltration process. The removal of organic solids is largely dependent on the organic carbon content of the soil. Higher total organic carbon levels tend to lead to a higher capacity for the removal of dissolved organics. This capacity will change over time due to the coating of soil particles by the removed organics (Lee and Jones 1998). Nitrogen and phosphorous levels are less of a concern for possible drinking water contamination (Mikklesen, et al 1996). Concentrations infiltrating into the ground would not exceed drinking water standards. It is also important to examine any possible connection between the groundwater and surface water (Lee and Jones 1998). Should the groundwater exfiltrate into any surface water, the possible pollution due to metals must be examined (Mikklesen, et al 1996). Metals such as lead, copper, and cadmium all have health risks (Whipple 1991). Most metals occur in particulate form and are removed during the infiltration process (Whipple 1991). The use of salts on pavement in the winter can lead to higher concentrations of salts in the runoff and ultimately in the groundwater. This could impair the use of the groundwater for domestic water supply purposes (Lee and Jones 1998).

Since both hydrocarbons and metals occur in particulate form and can be easily removed, no large groundwater risk is present. However, with the deposition of these substances on the soil particles, over time, the soil can become contaminated (Mikklesen, et al 1996). This would especially create a problem if many infiltration practices were used within the same area. Long-term maintenance of the system would need to be done. The soil might need to be removed or cleaned. To further reduce any groundwater risk, the runoff can be diverted into a separate basin where particulate matter would settle. The run off would then flow into another basin where the infiltration would occur (Whipple 1991).

Another key factor in the removal of pollutants is the vegetation of the area. Vegetation will increase the capture of runoff through evapo-transpiration. The infiltrating water should pass through a humic root layer to screen absorbable and degradable pollutants (Mikklesen, et al 1996). Surface vegetation will enhance interception and infiltration capacity as well (Lawrence, et al 1996). Vegetation must be chosen to survive cycles of different water conditions and extended periods of dryness (Barbosa and Hvitved 2001).

The Villanova Bio-infiltration Traffic Island was designed to capture and infiltrate the first inch of runoff, including the first flush of pollutants. The 1.2-acre drainage area is roughly half impervious cover from parking areas, with the other half being grass cover. The drainage area was defined by surveying the area and creating a topographical map. Monitoring instruments were installed to record the pond depth, precipitation data, and outflow. Combining the survey data with the instrumental data, a model of the drainage area and traffic island was created using HEC-HMS to calculate the amount of runoff infiltrated for a given storm event. Two models were created. The first modeled the original design. The second modeled the traffic island after the addition of a v-notch weir, which also doubled the storage capacity. The model was calibrated based upon this data. Later storms were used for verification. For a given storm depth, the models calculated the amount of runoff produced by the watershed, the amount captured by the traffic island, and the amount of outflow. Rain gauge data taken from the National Weather Service at Chadd's Ford, Pa was used to predict the annual amount of runoff captured by the system for each storm model. Recommendations for future studies, as well as design and construction recommendations, are included.

Design and Construction

Design Overview

This study focuses on a retrofitted bio-infiltration traffic island and its drainage area on the campus of Villanova University. The watershed is located at the headwaters of the Darby River, located in southeast Pennsylvania. Based upon a survey of the area, the drainage area is 1.2 acres and is 50% impervious. The BMP was designed to capture and infiltrate runoff for storms around one inch, which would include roughly 80% of the annual runoff for the region.

The traffic island is located at the bottom of the drainage area. An overhead view of the traffic island is shown (Figure 1). Runoff enters the traffic island through two cuts made in the curb and through a pipe connecting from a storm sewer inlet. One cut was placed where a storm drain inlet had been located. The inlet was filled and paved, which can be seen at the right of the figure. Placement of the other cut was determined by observing the flow of water across the pavement, illustrated in Figure 2. Runoff then travels across a rip-rap lined channel onto the surface of the infiltration bed. The traffic island is connected to the storm sewer system through a 12-in corrugated plastic pipe, where runoff is redirected from the storm sewer onto the surface of the infiltration bed. A wall was constructed within the inlet to divert the water. Later, a steel plate V-notch weir was attached to the top of the wall for more accurate discharge measurements. The addition of the V-notch weir also increased the storage capacity of the traffic island. Figure 3 represents a cross sectional sketch of the system.

Flow that enters through the storm sewer inlet is diverted into the traffic island for small storms. When full, flow goes over the wall and into the storm sewer system. The illustration also shows the location of two monitoring wells created during construction and the covering of the other storm inlet. To create the infiltration bed, the original soil was excavated and then sifted with the sand to provide a more porous surface layer. The soil was mixed to create a 1:1 sand/soil ratio. The made soil was then returned to the basin. Vegetation was planted on the surface of the basin. To prevent erosion until the plants grew, a layer of mulch was also laid onto the surface. Monitoring instruments were put in place in March 2002. A more detailed look at the construction process can be found in Appendix A.

Site survey

During the summer of 2002, with the help of Bill Heasom and Tyler Ladd, the drainage area was defined based upon a survey. Baselines were done every five feet within the traffic island and every 25 feet outside. Elevations were then taken to produce a contour map of the traffic island and the entire surrounding area. Contours were drawn every 1/2 foot. From the contour map, the drainage area was defined. Figure 4 below shows the drainage area, which was found to be 1.2 acres in area.

Figure 1: Plan view of Traffic Island. (Heasom 2002).

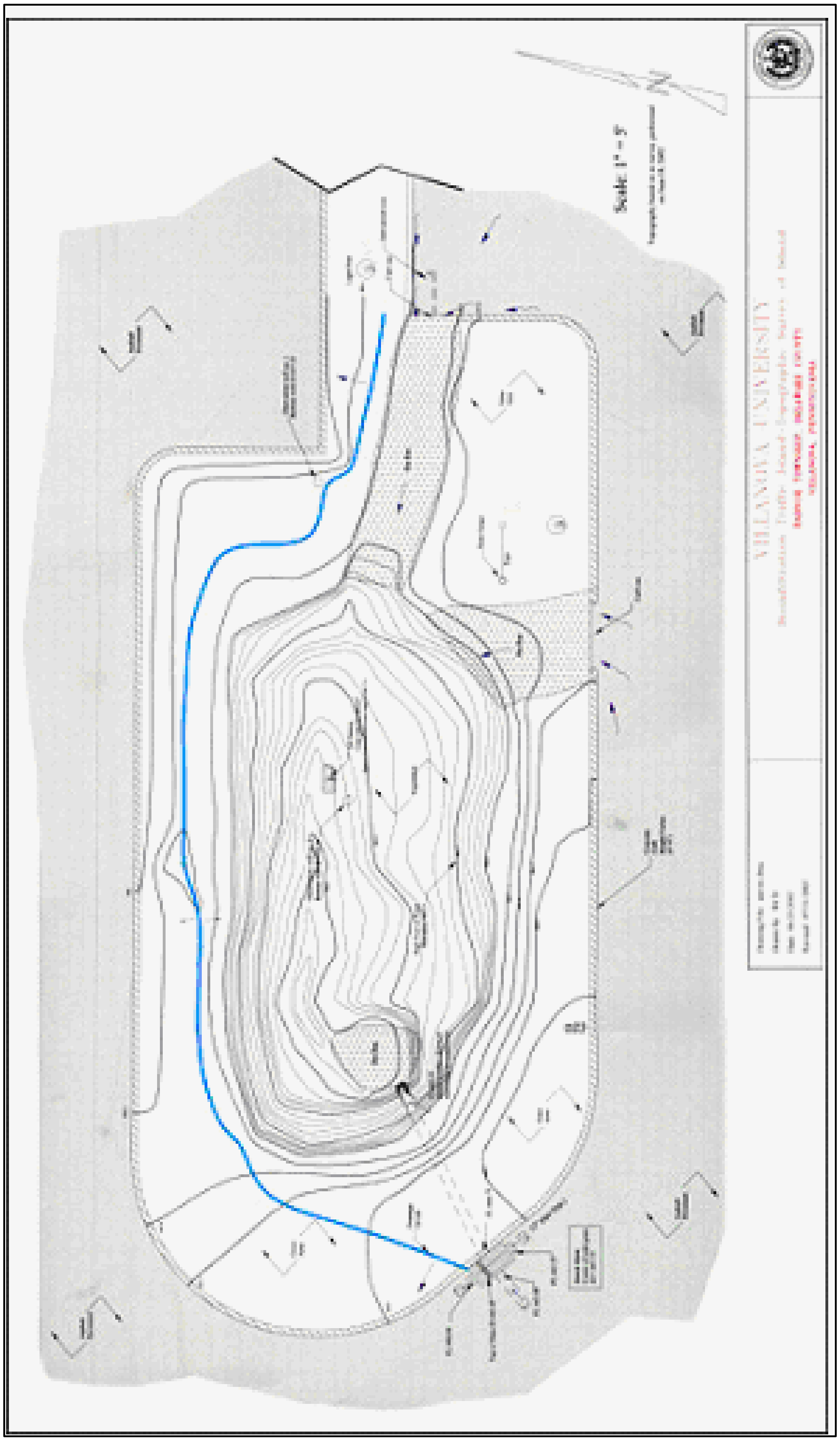


Figure 2: Determining location of curb cuts. (Ladd, 2001)

Figure 3: Cross sectional sketch of Traffic Island

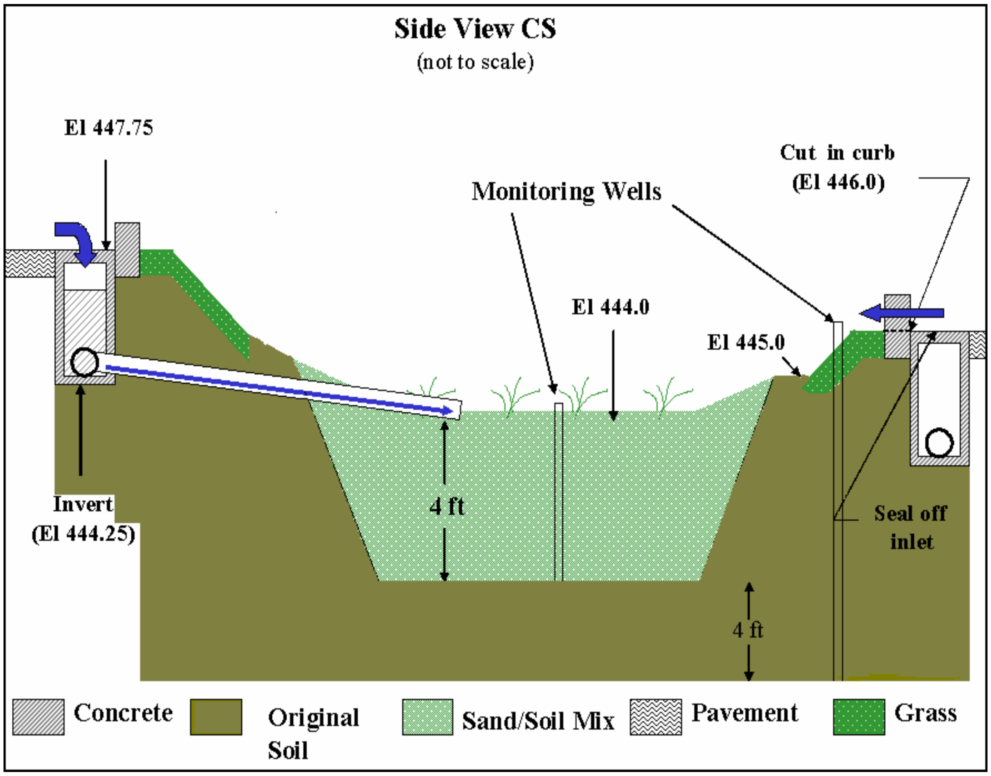
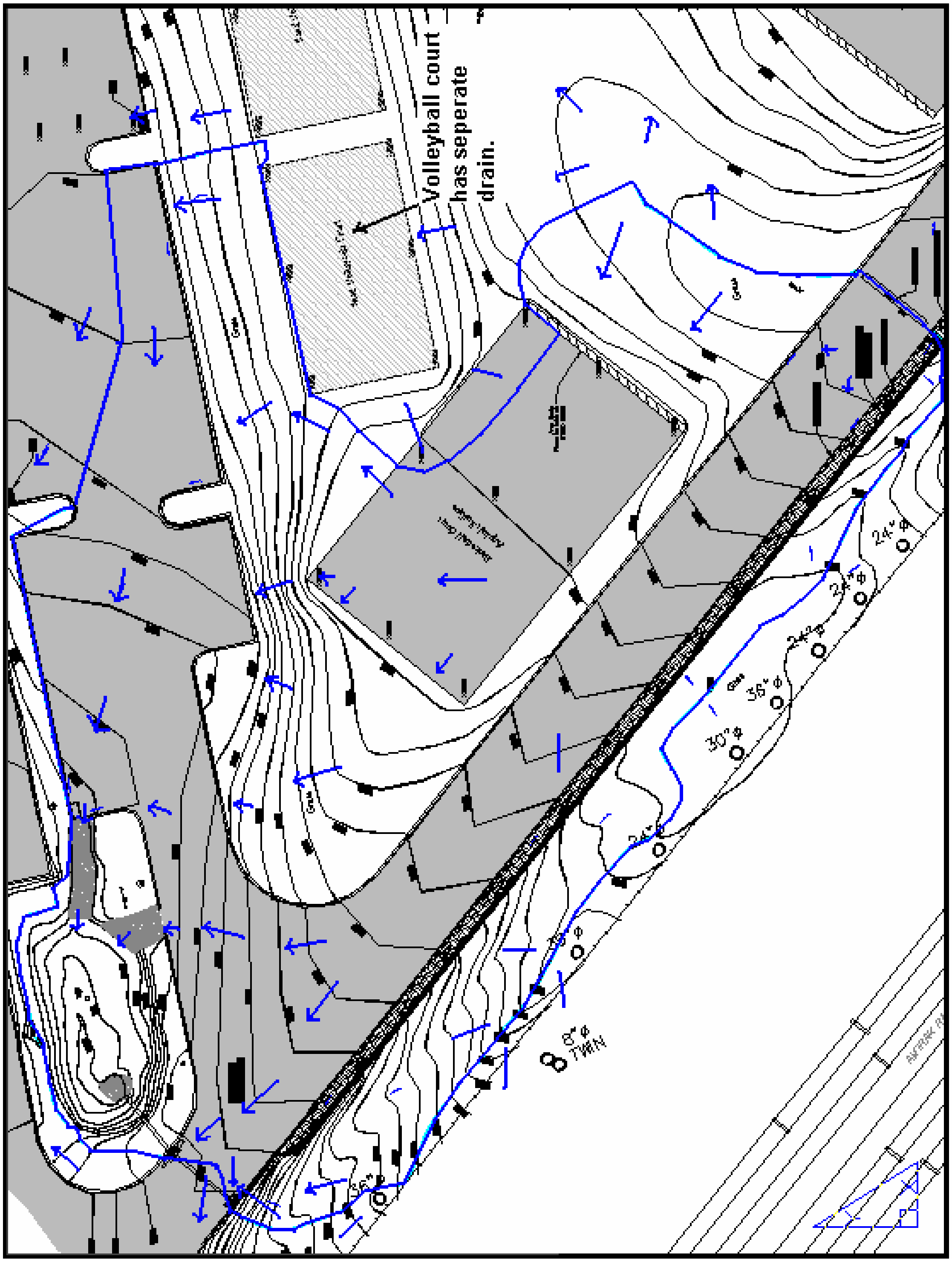


Fig 4 Drainage area (Heasom 2002)



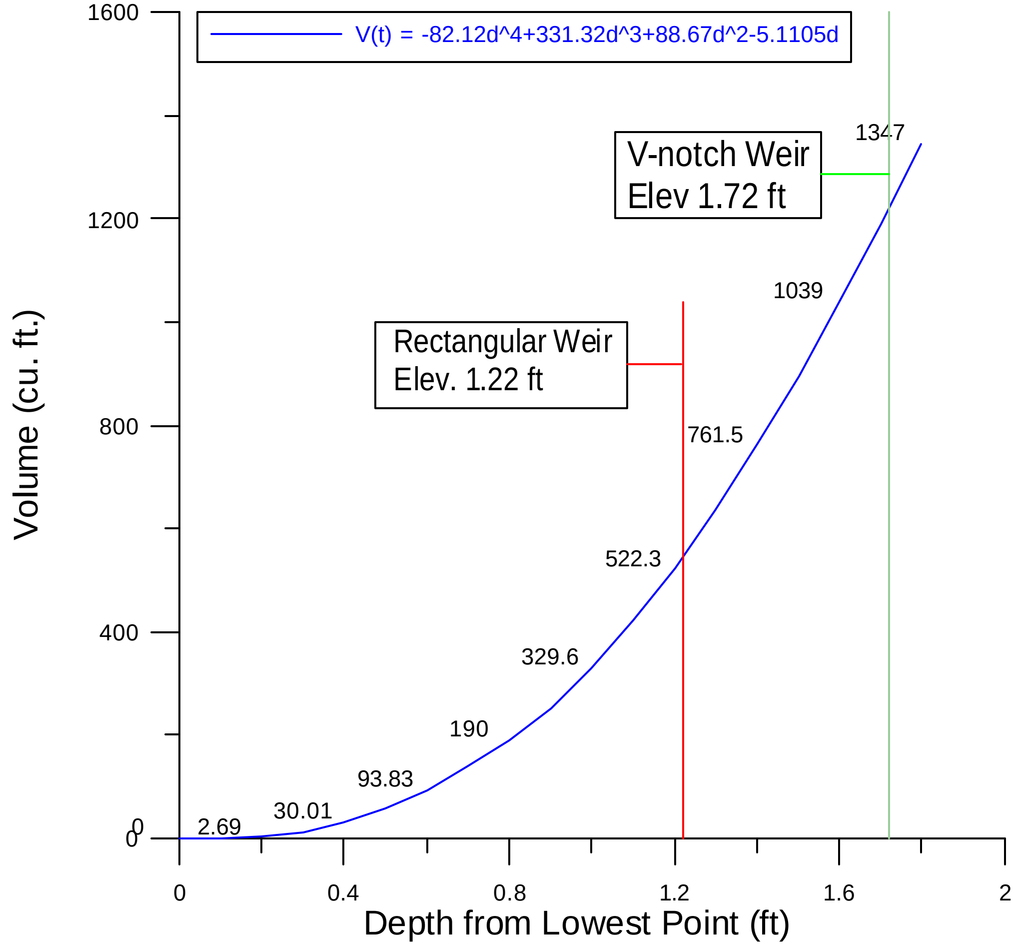
To determine a volume versus depth relationship, the contours inside the traffic island were drawn at 0.1-ft intervals. Using AutoCAD, the areas enclosed by each contour were calculated. The areas for two contour lines were averaged to produce an incremental volume. Starting with the lowest elevation of 444.2 ft, each incremental volume is added at 0.1-ft increments to calculate the total surface volume of the traffic island (Table 1).

Table 1: Calculating surface volume for 0.1 ft increments in elevation.

Contour	**Depth**	**Area Enclosed**	**Perimeter**	**Increment of volume**	**Total Volume**
(ft)	(ft)	(ft^2)	(ft)	(ft^3)	(ft^3)
444.2	0.0	0.00	0.00	0.00	0.00
444.3	0.1	9.66	21.99	0.48	0.48
444.4	0.2	34.48	45.60	2.21	2.69
444.5	0.3	140.13	74.79	8.73	11.42
444.6	0.4	231.70	83.67	18.59	30.01
444.7	0.5	320.83	95.27	27.63	57.64
444.8	0.6	402.98	101.08	36.19	93.83
444.9	0.7	472.88	105.21	43.79	137.62
445.0	0.8	574.06	115.11	52.35	189.97
445.1	0.9	687.41	120.99	63.07	253.04
445.2	1.0	843.12	128.88	76.53	329.57
445.3	1.1	963.96	133.11	90.35	419.92
445.4	1.2	1083.37	140.05	102.37	522.29
445.5	1.3	1197.98	145.70	114.07	636.36
445.6	1.4	1304.35	150.01	125.12	761.47
445.7	1.5	1394.03	154.05	134.92	896.39
445.8	1.6	1465.04	156.77	142.95	1039.35
445.9	1.7	1536.19	161.56	150.06	1189.41
446.0	1.8	1611.64	165.72	157.39	1346.80

Plotting volume versus pond depth, the points fit along a relatively smooth curve. The parabolic shape of the basin was the basis for the attempt to fit the volume curve to a quadratic shape. However, the regression curve did not fit well for lower depths, actually causing negative volumes. The data did, however, fit well to a polynomial function to the 4^{th} power. The plot of the data is shown below in Figure 5, along with the regression equation relating volume and depth of the basin.

Fig 5: Volume vs. Depth Relationship for Traffic Island



Weirs

The original design had a rectangular weir located with an elevation of 445.42 ft., corresponding to a depth of 1.22 ft. in the traffic island. To make incremental volume calculations more accurate, the weir in the storm inlet was fitted with a sharp-crested V-notch weir. The weir was also added to increase the storage capacity of the traffic island. Design was done according to ASTM D 5242-92: Standard Test Method for Open-Channel Flow Measurement of Water with Thin-Plate Weirs (ASTM 1996). The weir was constructed with a 90 degree notch, and a 45 degree bevel on the downstream side. The vertex of the notch is located at an elevation of 445.92 ft. This would correspond to a depth of 1.72 feet within the traffic island.

The addition of the plate not only ensures accuracy of discharge measurements, but also increases the storage capacity of the traffic island. According to the data, the amount of surface volume with the original design only came out to be about 550 cubic feet. This would correspond to a volume of 0.13 inches over the watershed. After installing the V-notch weir, this storage capacity increases to about 1220 cubic feet. This corresponds to a volume of 0.29 inches over the watershed.

Infiltration Bed

A sieve analysis was performed on the native soil, the sand to be added, and the final mix. The analysis was done according to ASTM D422. Atterberg limits tests were also run on the soil (ASTM 4318). The existing soil was then classified as a ML, the sand being a SP, and the mixed fill being SM, according to the Unified Soil Classification System. Classification was done using ASTM D248. Calculations of the soil tests are included in Appendix B. A soil sample was taken from the grass area above the traffic island in September 2002. The moisture content was found to be 0.20 and the porosity was estimated at 0.46.

The 50/50 mix was then added back into the traffic island to create the 4-foot deep infiltration bed. The preliminary design was to capture one inch or runoff, stored in the voids of the infiltration bed and in the basin on the surface. The estimated volume of the filled area was 4130 cubic feet. At a best estimate, the sand would have porosity around 0.50. This would create a void space volume of around 2000 cubic feet within the fill. Combining this with the approximated 2250 cubic feet of volume in the surface of the pond, and using the size of the drainage area (1.2 ac), the storage capacity of the traffic island was 4150 cu. Ft or 1.00 in over the watershed.

The sifted soil was then added back into the traffic island, covered with mulch, and vegetation was planted. The final step was to add the monitoring equipment. Figure 6 shows the traffic island after the retrofit was complete.

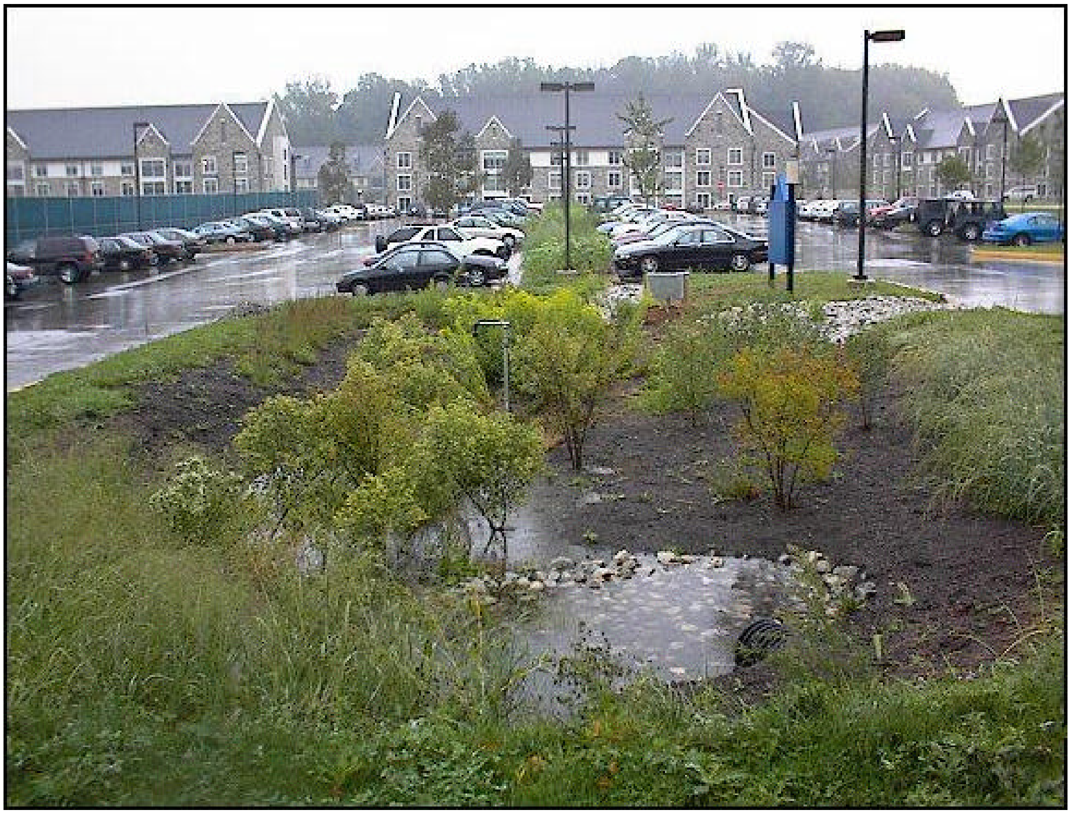
Vegetation

Selecting the vegetation used for the traffic island was as much an experiment as the study itself. Vegetation must survive both prolonged saturated and drought conditions. Plants chosen for the traffic island are commonly found in the coastal tidal areas and sand dunes of Southern New Jersey (Leeds, Chuck. Personal Correspondence 2003). Below is a list of the plants used in the traffic island, with both the scientific name and common name (Table 2).

Table 2: List of Traffic Island Vegetation (Leeds 2003)

Species Name	**Common Name**	**Species Name**	**Common Name**
Grasses		**Woody Plants**	
Ammophila Breviligulata	American Beach Grass	Photinia melanocarpa	Back Chokeberry
Panicum amarum	Coastal Panic Grass	Baccharis halimifolia	Goundsel Tree
Panicum virgatum	Switch Grass	Ilex verticillata	Winterberry
Schizachyrium scoparium	Little Bluestem	Iva fretescens	Marsh Elder
Herbs		Prunus maritima	Beach Plum
Solidago sempervirens	Seaside Goldenrod		

Fig 6: Photo of TI during storm event, with vegetation and equipment. (Prokop 2002)



Monitoring Equipment

Equipment was placed on site to record precipitation, water surface elevation, and to detect any standing water within the monitoring wells. The data logger used was the American Sigma 950 Flow meter along with a 60-kHz ultrasonic transducer. The transducer was mounted to a steel pipe and placed above the pond. A concrete pad was placed to create a level surface under the sensor, helping to reduce any possible echo loss (Fig 1). Pad elevation is 0.23 ft above the lowest point in the traffic island. Inside the two monitoring wells, pressure transducers were placed to record the water table elevation. The rain gauge was fixed to the top of an education sign located next to the traffic island. All data was recorded at five-minute intervals.

Model Setup and Calibration

Overview

HEC-HMS 2.2.0, a publicly distributed hydrological modeling program offered by the US Army Corps of Engineers was used to model the traffic island and its watershed (Hydrologic Engineering Center 2002). The NRCS unit hydrograph and soil cover complex methods were used to calculate and route the runoff from the drainage area. Within the traffic island, storage indication routing was used. Outflow and storage relationships for the traffic island are developed using a spreadsheet.

Two models were created of the system. The first model represents the traffic island with its original design. The second model represents the traffic island after the installation of the V-notch weir. All storms before December 1, 2002 are included in the first model, while all storms after that are incorporated in the second model. Each model was calibrated based upon precipitation and water surface elevation data from the traffic island basin. For each of the runs, the data from the precipitation gauge was imported into HMS and entered as a precipitation gauge. Storms occurring after 03/20/03 were used for model verification.

To create and calibrate the model, data was taken from 12 storms occurring between September 2002 and March, 2003. Storm depths ranged from 0.22 in up to 2.64 in. For each storm, precipitation data, water surface elevation, and groundwater table data were recorded. The pressure transducer located in the monitoring well never recorded any depth throughout the entire data collection period. Therefore, this measurement was not used in any of the modeling process. Each of the storm events is listed below (Table 3) in increasing precipitation depth. .

Table 3: Storm Data used for Model Calibration

Date	P (in)	Date	P (in)
10/10/02	0.22	10/16/02	1.38
10/04/02	0.33	11/11/02	1.50
11/05/02	0.54	10/29/02	1.52
12/20/02	0.91	03/20/03	1.84
10/25/02	1.09	09/26/02	2.36
01/01/03	1.18	10/10/02	2.64

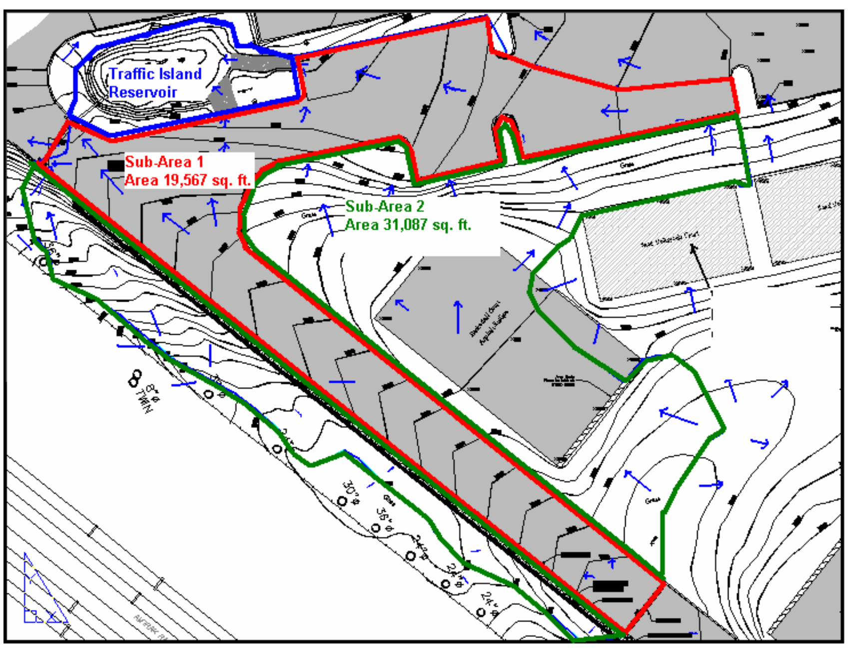
Precipitation for the October 10th storm was split into two parts. Between 1:00 a.m. and 3:00 a.m., 0.22 in. of rain fell. No other precipitation was recorded until 9:20 a.m. During this 6-hour gap, water that had collected within the traffic island had begun infiltrating. This initial burst of precipitation was separated from the rest of the storm event so that the initial abstraction ratio of the impervious surface could be determined. For the study, the first part of the October 10th precipitation was referred to as Part A, and the second part was referred to as Part B.

The SCS Curve number method was used to calculate runoff. Within the model, the drainage area, curve number, and initial abstraction ratio must be entered. To construct the unit hydrograph, a lag time for each sub-area must be entered as well. The storage vs. outflow relationship needed for the storage indication routing is dependent upon two variables: infiltration rate and weir flow. In order to construct this table, an infiltration rate and an approximate weir coefficient must be found.

Drainage areas

The drainage area is divided into two sub-areas. Sub-area 1 (19, 567 sq. ft.) represents the directly connected impervious surface in the watershed. The basketball court is not included within this sub-area. Runoff from the basketball court flows onto grass before flowing into the traffic island. Because it is disconnected, and some infiltration can occur on the surface, it is included in Sub-area 2. Sub-area 2 (31, 087 sq. ft.) included the basketball court, and all grassy areas of the watershed. Drainage areas are calculated based upon the data from the survey. The traffic island itself is modeled as a reservoir, illustrated in Fig 7. Sub-area 1 flows directly into the traffic island, so no reach routing was needed. Sub-are 2 flows onto Sub-area 1, but the distance and resulting time elements would be insignificant. Thus, no routing was used for Sub-area 2 either. The sub-area is modeled as if it flowed directly into the traffic island.

Figure 7: Dividing Drainage Area



Infiltration Rates

To create the reservoir storage vs. outflow table, the infiltration rate was combined with the weir flow. For small storms, only infiltration occurs. By creating the table solely for infiltration outflow, the model was run for small events, where no weir flow was present. These runs were done in order to calibrate the curve number and initial abstraction values for the first sub-area. Upon calibration of these parameters, larger storms were run through the model to calibrate the weir coefficient for the rectangular weir. Because the V-notch weir was constructed to ASTM standards, no calibration was performed for its discharge coefficient. After knowing the discharge coefficients, each storm even was run again to calibrate the curve number and initial abstraction ratio for the second sub-area. The final model is a result of the average curve number values for the second-sub area from each of the storms.

For this model, the infiltration rate is defined as the change in water surface elevation versus time. Data is taken from the end of the storm, where precipitation has ended and only infiltration occurs. The ultrasonic level recordings for each time step are used to do this. In all of the storms, the water surface elevation decreased at a fairly linear rate. The slope of this line is used as the infiltration rate of the storm. Table 4 illustrates how the infiltration rates for the storms were calculated. The depth values were taken from the data at hourly increments. When the data recorded 1.20 ft of depth, the values were placed in the table. The table lists the depth values with t=0 and depth = 1.2 ft. For the 9/26 storm, the water surface elevation began to rise after more precipitation started to fall. For this reason, the depth values stop higher than the other storms. With the 10/4 and 11/5 storms, the depth never rose to 1.20 ft, so the highest values are used.

For modeling purposes, three infiltration rates were used. Storms prior to October 16th were modeled with in infiltration rate of 0.40 in/hr. The storms on October 16th and October 25th were modeled with in infiltration rate of 0.30 in/hr, and all of the following storms were modeled with an infiltration rate of 0.22 in/hr.

The infiltration rate was used to calculate the outflow for a given depth within the reservoir, when water surface elevation was less than the weir elevation. Within the model, the elevation/storage/outflow table was selected. The outflow table is developed for a storm event, based upon its observed infiltration rate, the elevation of the weir, and the discharge relationship for that weir.

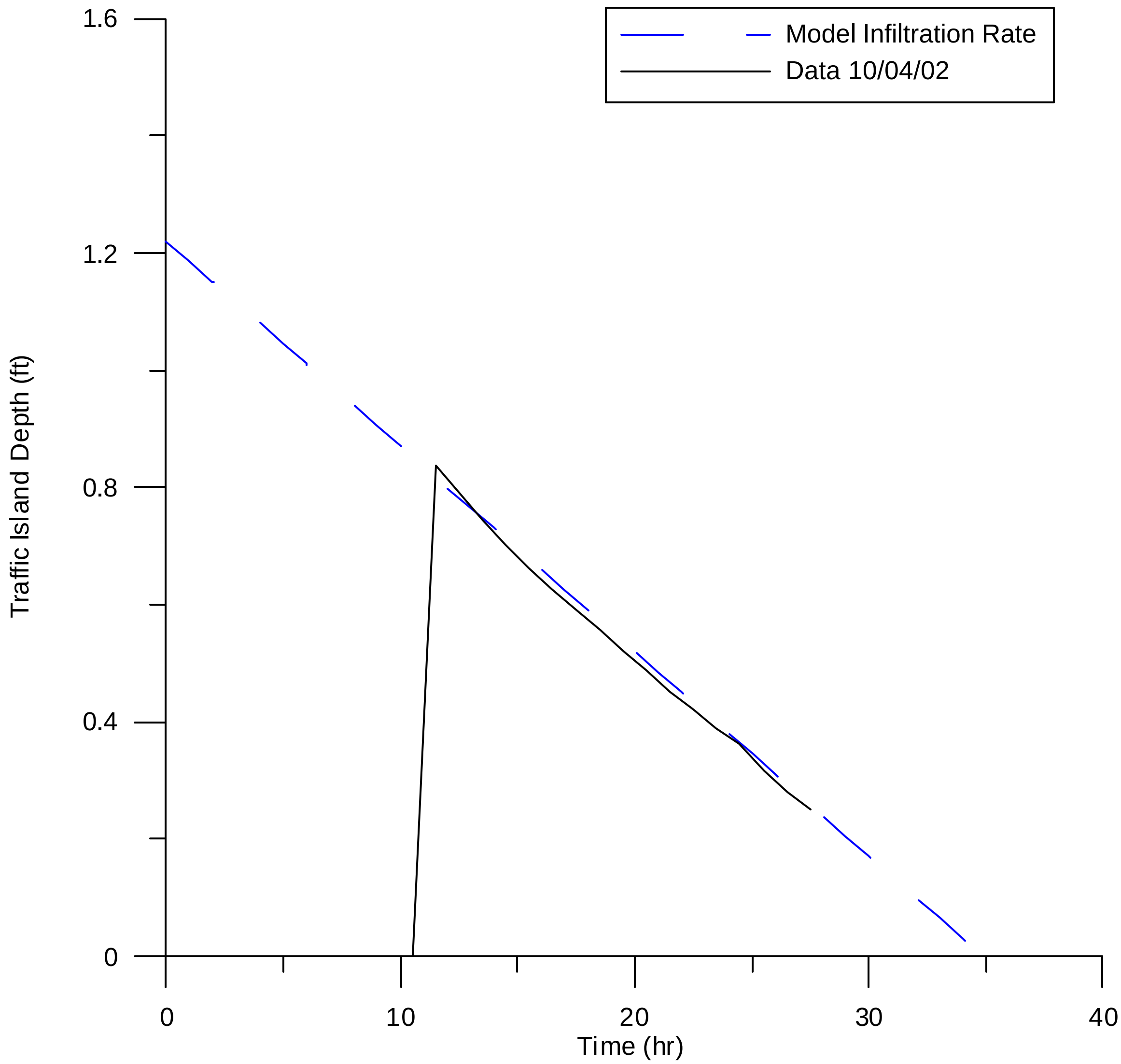
Storms on October 10th, October 4th, and November 5th, 2002 were all completely captured by the traffic island. In each of these events, the water surface elevation never rose above the weir. The elevation/storage/outflow table was first calculated for these storms. Runs were done on these events. The outflow values for weir flow were calibrated later. The process is done in an excel spreadsheet, with columns for time, depth, volume and outflow.

Table 4: Calculating Infiltration Rates for Storm Events

Time (hr)	26-Sep	4-Oct	10-Oct	16-Oct	25-Oct	29-Oct	5-Nov	11-Nov	20-Dec	1-Jan	30-Mar
0.00	1.19		1.20	1.20	1.21	1.20		1.20	1.20	1.19	1.20
1.00	1.16		1.17	1.18	1.19	1.18		1.19	1.18	1.17	1.19
2.00	1.12		1.15	1.16	1.17	1.17	1.17	1.18	1.16	1.15	1.16
3.00	1.09		1.12	1.14	1.15	1.15	1.15	1.17	1.15	1.14	1.15
4.00	1.05		1.09	1.12	1.12	1.14	1.14	1.15	1.12	1.12	1.14
5.00	1.02		1.06	1.10	1.09	1.12	1.12	1.13	1.10	1.10	1.13
6.00	0.98		1.02	1.08	1.07	1.10	1.10	1.11	1.08	1.09	1.11
7.00	0.91		0.99	1.06	1.04	1.08	1.08	1.09	1.06	1.08	1.08
8.00	0.89		0.96	1.04	1.02	1.06	1.06	1.09	1.04	1.04	1.06
9.00	0.85	0.84	0.92	1.01	1.00	1.03	1.04	1.08	1.02	1.00	1.04
10.00	0.82	0.78	0.89	0.99	0.98	1.02	1.03	1.06	1.00	0.98	1.02
11.00	0.79	0.74	0.85	0.96	0.96	0.99	1.01	1.04	0.96	0.96	0.99
12.00	0.76	0.70	0.81	0.94	0.94	0.98	1.00	1.02	0.96	0.94	0.97
13.00	0.72	0.66	0.77	0.91	0.92	0.98	0.99	0.99	0.95	0.92	0.94
14.00	0.69	0.62	0.74	0.89	0.89	0.97	0.98	0.97	0.94	0.91	0.92
15.00		0.59	0.70	0.84	0.88	0.95	0.96	0.94	0.93	0.91	0.89
16.00		0.55	0.66	0.81	0.85	0.94	0.94	0.92	0.91	0.88	0.87
17.00		0.52	0.63	0.78	0.82	0.92	0.92	0.90	0.89	0.86	0.84
18.00		0.48	0.60	0.75	0.79	0.90	0.90	0.88	0.87	0.84	0.80
19.00		0.45	0.57	0.73	0.77	0.89	0.89	0.86	0.86	0.81	0.76
20.00		0.42	0.53	0.70	0.74	0.87	0.81	0.84	0.82	0.79	0.73
21.00		0.38	0.50	0.67	0.71	0.85	0.85	0.82	0.81	0.77	0.70
22.00		0.35	0.48	0.65	0.68	0.83	0.83	0.80	0.79	0.75	0.68
23.00		0.31	0.45	0.64	0.66	0.82	0.82	0.78	0.76	0.72	0.66
24.00		0.28	0.41	0.62	0.63	0.79	0.80	0.76	0.74	0.70	0.63
25.00		0.25	0.38	0.60	0.61	0.77	0.78	0.74	0.72	0.68	0.61
26.00			0.34	0.58	0.59	0.75	0.76	0.72	0.71	0.66	0.59
27.00			0.31	0.56	0.54	0.74	0.74	0.70	0.68	0.64	0.58
28.00			0.27	0.53	0.50	0.72	0.73	0.69	0.66	0.62	0.57
29.00			0.23	0.50	0.48	0.70	0.70	0.66	0.65	0.60	0.55
30.00				0.48	0.47	0.65	0.68	0.64	0.63	0.58	0.52
31.00				0.45	0.44	0.61	0.65	0.62	0.60	0.56	0.49
32.00				0.43	0.41	0.59	0.63	0.61	0.58	0.53	0.47
33.00				0.39	0.40	0.58	0.61	0.59	0.56	0.51	0.44
34.00				0.37	0.38	0.58	0.60	0.57	0.54	0.48	0.42
35.00				0.34	0.36	0.57	0.58	0.53	0.51	0.46	0.37
36.00				0.31	0.34	0.56	0.56	0.50	0.50		0.33
37.00				0.27	0.31	0.54	0.55	0.48	0.48		0.30
38.00				0.24	0.29	0.53	0.54	0.47	0.46		
39.00					0.26	0.52	0.53	0.44	0.44		
40.00						0.51	0.52	0.43	0.45		
Slope (ft/hr)	-0.037	-0.036	-0.034	-0.025	-0.025	-0.018	-0.018	-0.020	-0.019	-0.021	-0.025
I (in/hr)	**0.44**	**0.43**	**0.41**	**0.30**	**0.30**	**0.22**	**0.21**	**0.24**	**0.23**	**0.25**	**0.30**

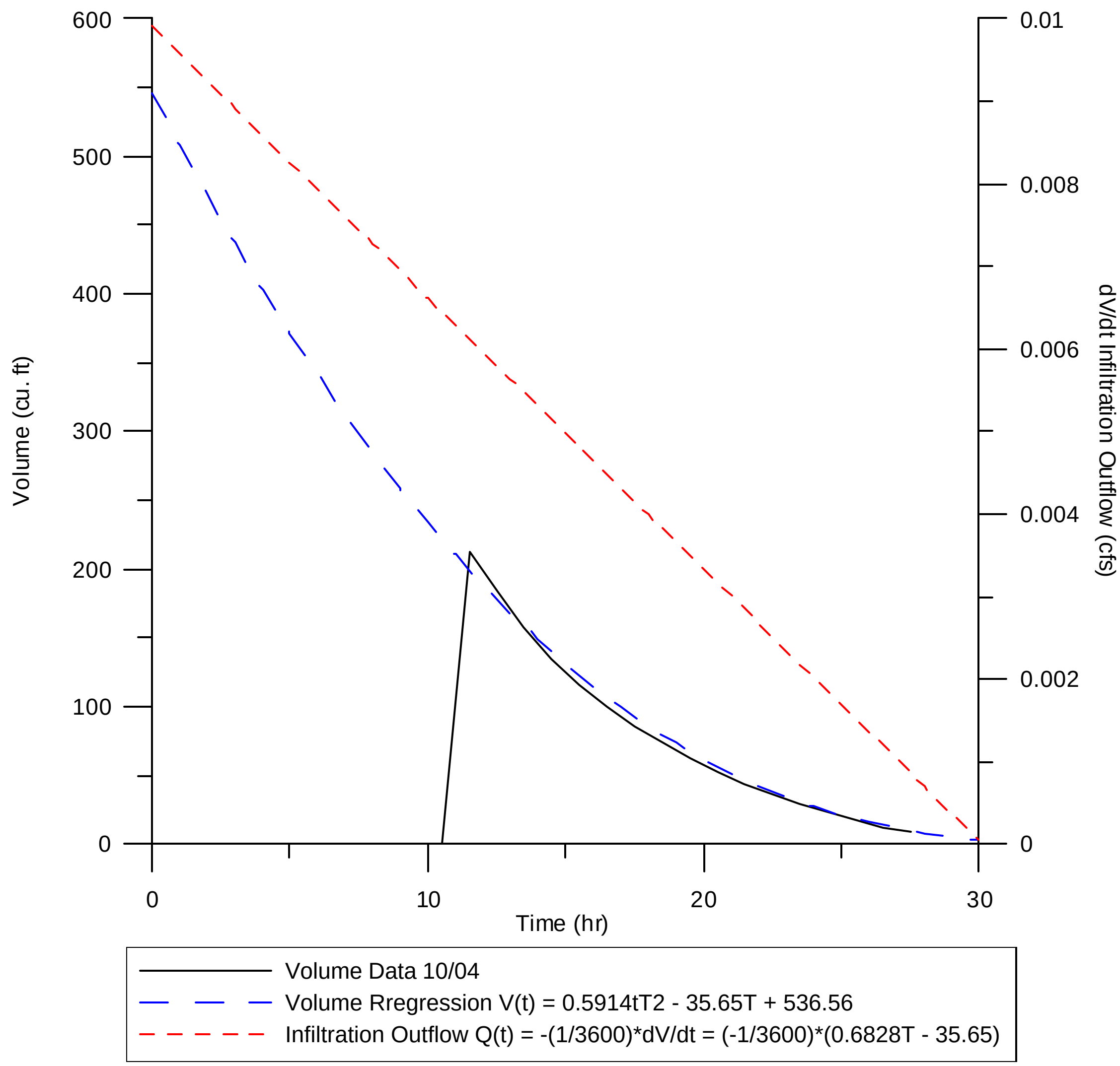
The model requires that a relationship between depth, storage and outflow be entered. Knowing the infiltration rate, a depth versus time relationship can be easily plotted. This depth versus time relationship must be converted into an outflow versus depth relationship. The infiltration rate for the storm was plotted as a function of time. The line was created with a max depth equal to the elevation of the weir. Using the infiltration rate as the slope, depths were calculated at one-hour increments. An illustration of this is shown below for an infiltration rate of 0.40 in/hr (Fig 8).

Figure 8: Depth vs. Time for I = 0.40 in/hr



At t=0, the depth of the reservoir is 1.22 ft. This represents the traffic island being full, where any additional runoff would escape over the weir. Using the depth vs. volume relationship from the survey data, each of those depths were converted to a volume. Thus, for a given infiltration rate, a volume vs. time relationship can be predicted. This is illustrated below (Fig 9).

Fig 9: Volume vs. Time for I = 0.40 in/hr



Also shown on Figure 9 is a regression function created from the volume vs. time curve. The derivative of this function was used as the outflow due to infiltration. For I= 0.40 in/hr, this comes out to be 1.0684t-33.85. The outflow is calculated at hourly increments. Thus, for a given time step, a depth, volume, and outflow value is known. This is presented in tabular form below (Table 5). The function result is in cubic feet per hour. This is converted into a cubic feet per second value. Volume values are converted from cubic feet to acre-feet. HMS requires the storage value to be entered in acre-feet.

Table 5: Developing Storage/Elevation/Outflow Table for I = 0.40 in/hr

Time (hr)	Depth	Volume (cu. ft)	Storage (ac. Ft)	dV/dt (ft^3/hr)	Infiltration Outflow (cfs)
0	1.22	545.4	0.012522	35.65	0.0099028
1	1.185	507.8	0.011659	34.467	0.0095742
2	1.15	471.7	0.010828	33.284	0.0092457
3	1.115	436.9	0.010030	32.102	0.0089171
4	1.08	403.5	0.009264	30.919	0.0085886
5	1.045	371.7	0.008532	29.736	0.00826
6	1.01	341.2	0.007833	28.553	0.0079314
7	0.975	312.2	0.007167	27.37	0.0076029
8	0.94	284.6	0.006534	26.188	0.0072743
9	0.905	258.5	0.005934	25.005	0.0069458
10	0.87	233.8	0.005367	23.822	0.0066172
11	0.835	210.5	0.004833	22.639	0.0062887
12	0.8	188.7	0.004331	21.456	0.0059601
13	0.765	168.2	0.003861	20.274	0.0056316
14	0.73	149.1	0.003423	19.091	0.005303
15	0.695	131.3	0.003015	17.908	0.0049744
16	0.66	114.9	0.002638	16.725	0.0046459
17	0.625	99.8	0.002291	15.542	0.0043173
18	0.59	85.9	0.001973	14.36	0.0039888
19	0.555	73.3	0.001683	13.177	0.0036602
20	0.52	61.9	0.001421	11.994	0.0033317
21	0.485	51.6	0.001185	10.811	0.0030031
22	0.45	42.5	0.000975	9.6284	0.0026746
23	0.415	34.4	0.000790	8.4456	0.002346
24	0.38	27.3	0.000627	7.2628	0.0020174
25	0.345	21.2	0.000487	6.08	0.0016889
26	0.31	16.0	0.000368	4.8972	0.0013603
27	0.275	11.7	0.000269	3.7144	0.0010318
28	0.24	8.2	0.000188	2.5316	0.0007032
29	0.205	5.4	0.000124	1.3488	0.0003747
30	0.17	3.3	0.000075	0.166	4.611E-05

This process was repeated. The first process is described above. It was also performed for the original weir and infiltration rates of 0.30 and 0.22 in/hr. The fourth process was for the V-notch weir and an infiltration rate of 0.22 in/hr. Printouts of the Excel spreadsheets used to create each of the tables are located in Appendix C. The volumes vs. time and infiltration outflow values are listed in Table 6. It also shows each storm's infiltration rate and weir elevation.

Table 6: Storm Data for Modeling

Date	P (in)	Inf. (in/hr)	Weir D	Storage Vol. vs. Time	Inf. Outflow
9/26	2.36	0.40	1.22	$0.5432t^2$-33.85t+536.24	1.0684t-33.85
10/04	0.33	0.40	1.22	$0.5432t^2$-33.85t+536.24	1.0684t-33.85
10/10	0.22	0.40	1.22	$0.5432t^2$-33.85t+536.24	1.0684t-33.85
10/10	2.64	0.40	1.22	$0.5432t^2$-33.85t+536.24	1.0684t-33.85
10/16	1.38	0.30	1.22	$0.303t^2$-25.465t+536.4	0.604t-25.465
10/25	1.09	0.30	1.22	$0.303t^2$-25.465t+536.4	0.604t-25.465
10/29	1.52	0.22	1.22	$0.1622t^2$-18.66+536.17	0.3244t-18.66
11/05	0.54	0.22	1.22	$0.1622t^2$-18.66+536.17	0.3244t-18.66
11/11	1.50	0.22	1.22	$0.1622t^2$-18.66+536.17	0.3244t-18.66
12/20	0.91	0.22	1.72	$0.179t^2$-29.502t+1220.2	0.358t-29.502
01/01	1.18	0.22	1.72	$0.179t^2$-29.502t+1220.2	0.358t-29.502
03/20	1.84	0.22	1.72	$0.179t^2$-29.502t+1220.2	0.358t-29.502

Now that the reservoir was created, the model can be run for small storms (P<0.6 in). The next step is to calibrate the curve number, initial abstraction ratio and lag time values for the sub-areas. The curve number for Sub-area 1 was selected as 98, the standard SCS curve number for pavement. For small storms, it was assumed that all of the runoff leading into the traffic island came from the directly connected impervious surfaces. Taking the data from the storm on October 5th, the initial abstraction ratio was calibrated to match the real data. By doing this, the initial loss of the impervious surface area was determined to be 0.06 in. This is the same depth estimated for depression storage on impervious surfaces (Tholin and Keifer 1960). An illustration of this is shown below, with the depth of water in the reservoir being shown for both the model run and the recorded data (Fig 10).

Lag time calibration was accomplished by observing the data from a storm on September 27th. This was chosen because of the intensity and brevity of the rainfall. In the data, the time from the peak of the rainfall to the peak of the water surface elevation was 20 minutes. This value represents the lag time for the entire watershed. Due to the relative small size of the watershed, the difference in lag times between the two sub-areas would be small and less sensitive. Therefore, the same 20-minute value was used for both sub-areas. Fig 11 shows the storm data from September 27th.

Fig 10: Calibrating Impervious Surface Parameters

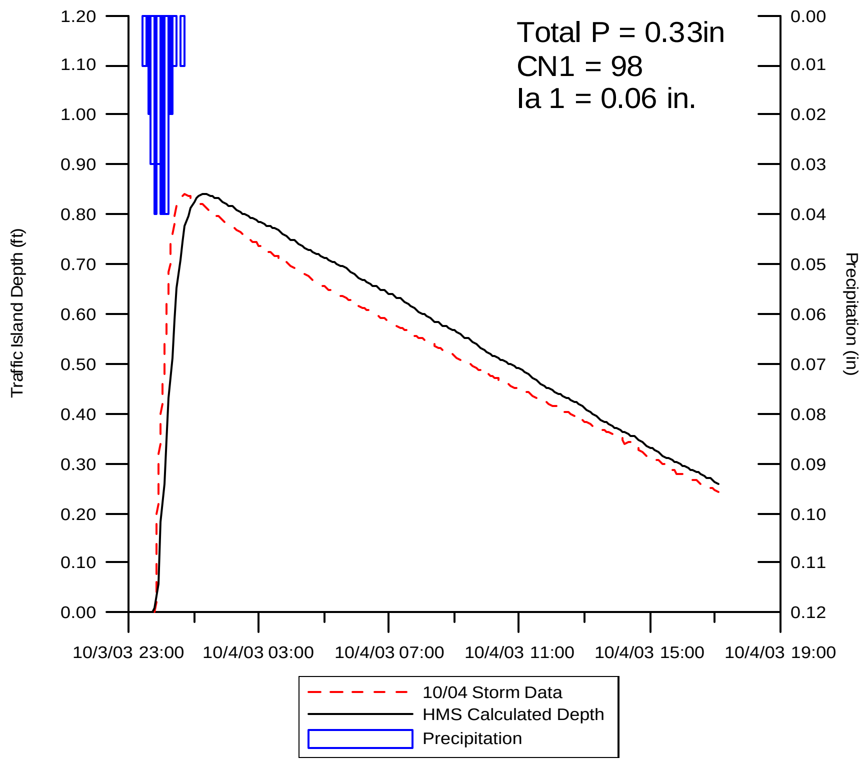
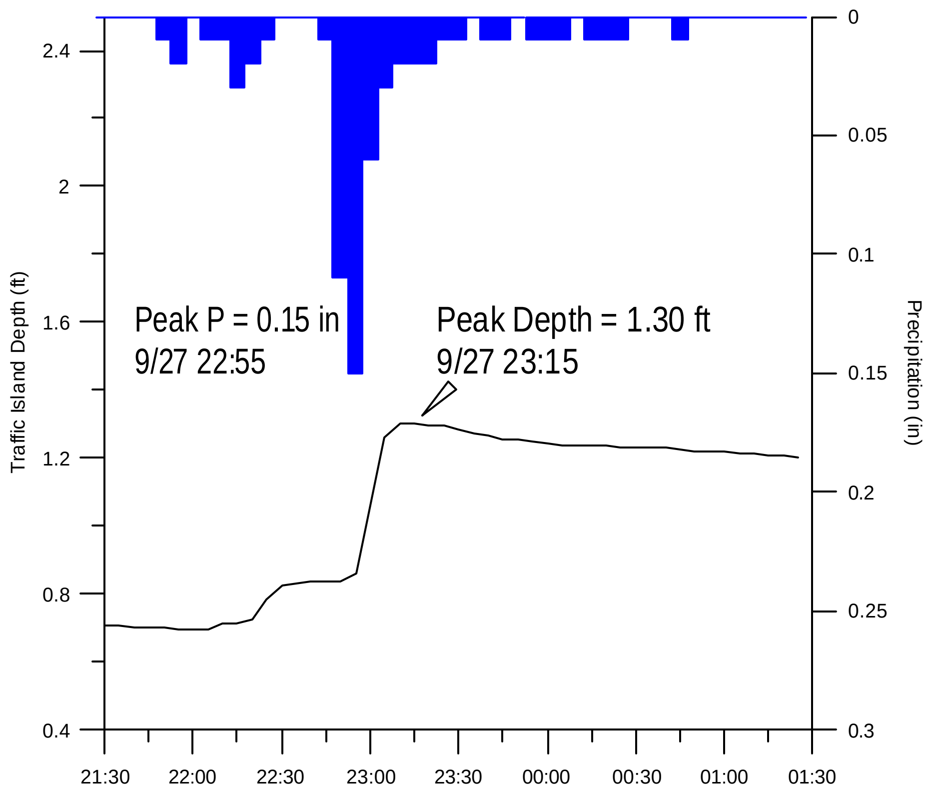


Figure 11: Determining Lag Time



The next parameter to model is the weir coefficient for the rectangular weir. When the traffic island fills, any additional runoff flows over the weir. Outflow values within the reservoir table must include the infiltration plus weir flow. The infiltration outflow is assumed to be the same as the outflow calculated for the highest depth without weir flow (d = 1.22 or 1.72ft). Taking the infiltration outflow values calculated previously, the elevation/outflow table is extended to depths where weir flow would occur.

For the original design, the wall was modeled as a rectangular weir. The standard equation for weir flow is $Q = 2/3\ (2g)^{1/2}\ C_d\ L\ H^{3/2}$, where Q is flow in cfs, C_d is the coefficient of discharge, L is the length of the weir in feet, g is the gravitational constant (32.2 ft/s^2), and H is the head over the weir in feet. Weir length is 2.0 ft, the length of the weir from the survey data. Taking the data from the storm on October 25th, the model was run using the parameters already calculated and calibrated. The curve number for Sub-area 1 was 98, with an initial abstraction of 0.06 in. The curve number for Sub-area 2 was set to 80. The initial abstraction was left blank, thus using the default SCS value. The model was run using a range of C_d values until the total amount of runoff that flowed over the weir in the model equaled the total amount from the recorded data. Weir head was said to be the difference between the water surface elevation and the weir elevation (d – 1.22 ft). For each five minute interval, the discharge rate was calculated by the head at that time. Multiplying the flow by 300, the total volume in cubic feet for that time step was calculated. Summing all of the volume calculations over the length of time the weir had head, the total volume of runoff flowing over the weir for the entire storm event was calculated. This was converted from cubic feet to inches of runoff over the watershed.

For the storm on Oct 25th, 1.09 inches of rain produced 0.32 inches of runoff in the traffic island. With the C_d being 0.75, the total amount of runoff that flowed over the weir was 0.12 inches. The HMS model calculated this to be 0.13 inches.

The second design was modeled as a V-notch weir. Due to the accuracy of the V-notch weir, no calibration was necessary. The weir equations used and their respective coefficients are listed below (Table 7).

Table 7: Weir Equations Used in Modeling

Rectangular Weir	V-notch Weir
$Q = 2/3\ (2g)^{1/2}\ C_d\ L\ H^{3/2}$	$Q = C_d\ 8/15\ (2g)^{0.5} \tan(\Theta/2)\ H^{5/2}$
Cd = 0.75	Cd = 0.58
L = 2	Θ = 90

The final parameter to calibrate is the curve number for Sub-area 2. The initial abstraction ratio was left at the default for the SCS method. Storms were run individually to find the curve number that would best fit the data. The best fit was determined when the total outflow over the weir in the model matched the total outflow from the observed data. Table 8 shows each of the storm events for the rectangular weir, the total amount of runoff produced, the best curve number for the event, and the total amount of weir overflow. The CN A2 column is the curve number that best fit the data. Runoff is reported as the amount of runoff calculated within the model. Error is reported as the difference between the weir overflow in the model and from the recorded data. For the storms on October 16th and for Part B of October 10th, the curve number could not be fit to exactly match the calculations. The values listed are the closest the model could simulate the actual data. A graphical representation of each calibrated storm can be found in Appendix D.

Table 8: Calibrating Sub-area 2 CN for Rectangular Weir

				Weir Overflow (in)		
Storm	P (in)	CN A2	Runoff (in)	Recorded	Model	Error
10-Oct A	0.22	**	0.03	--	--	--
4-Oct	0.33	**	0.06	--	--	--
5-Nov	0.54	83	0.13	--	--	--
25-Oct	1.09	81	0.41	0.20	0.20	0.00
16-Oct	1.38	60	0.43	0.15	0.26	0.11
11-Nov	1.50	87	0.82	0.58	0.57	-0.01
29-Oct	1.52	90	0.92	0.63	0.66	0.03
26-Sep	2.36	75	1.17	0.89	0.90	0.01
10-Oct B	2.64	65	1.14	0.54	0.67	0.13

For Part A of October 10th and the October 4th storm, the curve number for Sub-area two is irrelevant. For storm depths of this magnitude, all of the runoff comes from the directly connected impervious surface. No runoff comes from the grass area. Thus, the curve number for storms less than 0.5 in is not applicable. These storms were omitted from averaging the curve number. For the first two storms, as well as the November 5th storm, the traffic island never filled entirely. The weir flow columns are just left blank in this table. The final three storms (12/20, 01/01, 03/20), are with the V-notch weir in place. For these events, the model was run the same as the rectangular weir storms. Results for the calibration are listed below (Table 9).

Table 9: Calibrating Sub-area 2 for V-notch Weir

				Weir Overflow (in)		
Storm	P (in)	CN A2	Runoff (in)	Recorded	Model	Error
20-Dec	0.91	88	0.39	0.04	0.03	-0.01
1-Jan	1.18	89	0.61	0.18	0.17	-0.01
20-Mar	1.84	81	0.93	0.48	0.48	0

Taking the average of all of the curve numbers from tables 8 and 9, the average curve number for the 10 storms is 80. Each of the storm events was then rerun with this curve number. The results of the runs are shown for both the rectangular weir model (Table 10), and the V-notch weir model (Table 11).

Table 10: Calibrated Model Results for Rectangular Weir

				Weir Overflow (in)		
Storm	P (in)	CN A2	Runoff (in)	Recorded	Model	Error
10-Oct	0.22	**	0.03	--	--	--
14-Oct	0.33	**	0.06	--	--	--
5-Nov	0.54	80	0.13	--	--	--
25-Oct	1.09	80	0.41	0.20	0.19	-0.01
16-Oct	1.38	80	0.43	0.15	0.39	0.24
11-Nov	1.50	80	0.82	0.58	0.41	-0.17
29-Oct	1.52	80	0.92	0.63	0.41	-0.22
26-Sep	2.36	80	1.17	0.89	1.04	0.15
10-Oct	2.64	80	1.14	0.54	1.15	0.61

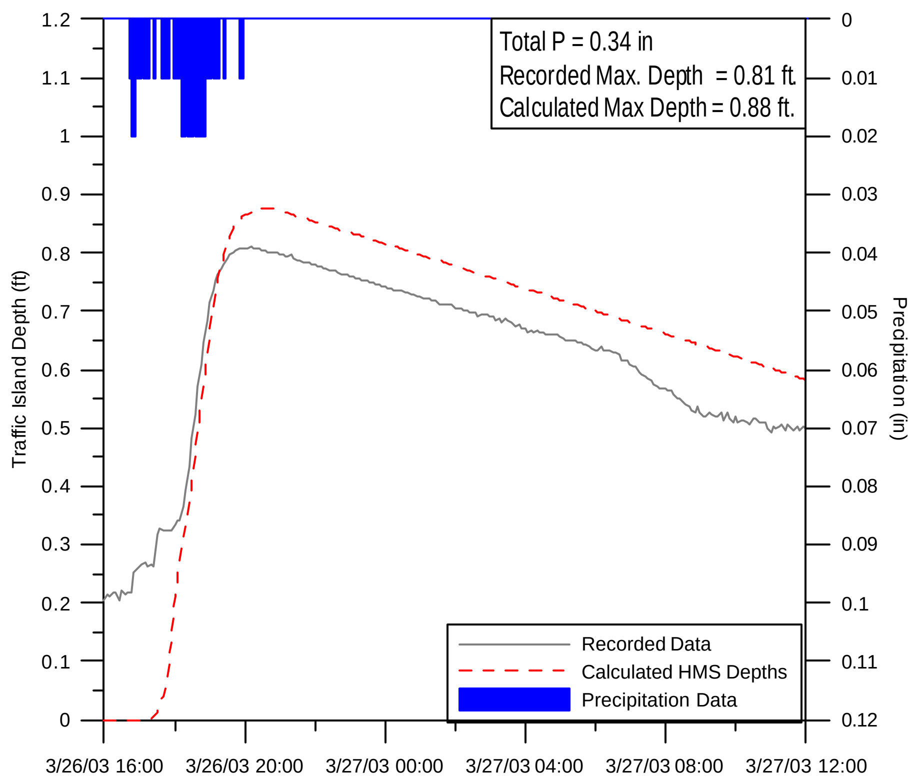
Table 11: Calibrated Model Results for V-notch Weir

				Weir Overflow (in)		
Storm	P (in)	CN A2	Runoff (in)	Recorded	Model	Error
20-Dec	0.91	80	0.39	0.04	0.00	-0.04
1-Jan	1.18	80	0.61	0.18	0.02	-0.16
20-Mar	1.84	80	0.93	0.48	0.46	-0.02

Model Verification

Data from a storm on March 26th, 2003 was used to verify the model. On that day, the total precipitation depth was 0.34 in. This is almost exactly the same amount of precipitation that fell on October 4th, 2002 (0.33 in). Running the calibrated model with the precipitation data, the output from the HMS model compared to the recorded data is shown below (Fig 12).

Figure 12: First Storm Calibration 3/25/03



The model slightly over-predicts the amount of runoff produced by the storm. The maximum depth of the traffic island was recorded as 0.81 ft. HMS calculated the maximum depth to be 0.88 ft. The October 4th storm had a maximum depth of 0.84 ft. Below is a table comparing the two storms and their HMS outputs (Table 12).

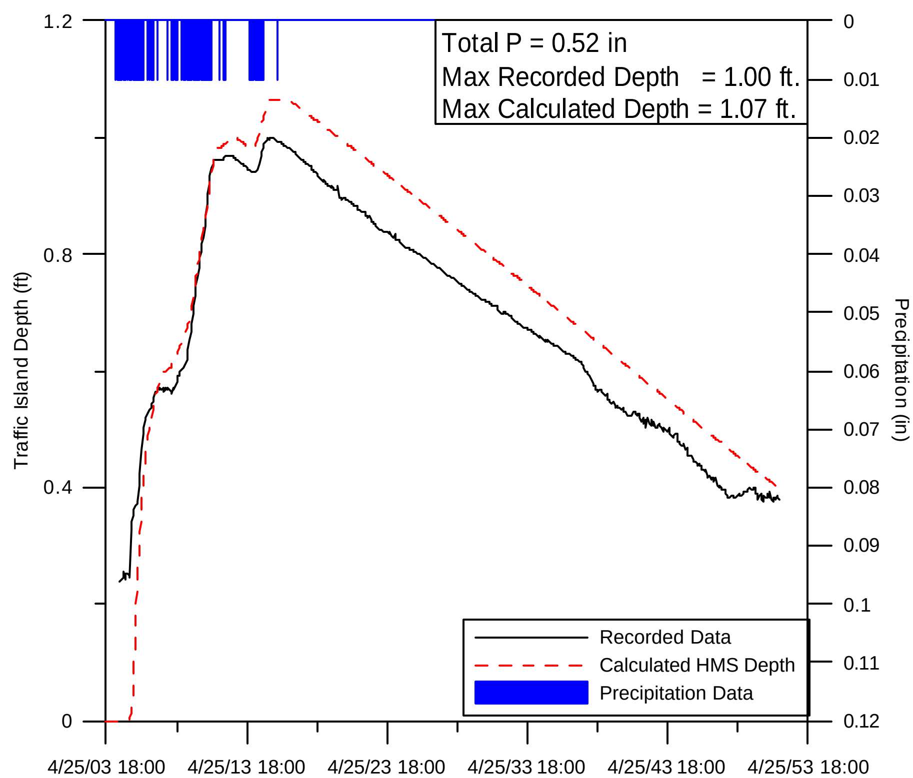
Table 12: Comparing Storms of Similar Depth

Storm	P(in)	Recorded Max D (ft)	Calculated Max D (ft)	Percent Error
4-Oct	0.33	0.84	0.84	0.0
26-mar	0.34	0.81	0.88	8.6

Volume values are calculated using the regression equation from the survey data, as mentioned before. For each storm, the peak volume is an estimate of the total amount of runoff that was produced during the event. For the storm on March 26th, the max volume of 195 cubic feet in the recorded data represents 0.05 in. of runoff across the entire watershed. The 241 cubic feet from the HMS computations represents 0.06 in. of runoff across the watershed.

A second verification can be made using the precipitation data from April 25th, 2003. The total precipitation depth for this storm was 0.52 in. The model was run using the same 0.22 in/hr infiltration rate used in the calibration process. Running the model, the recorded depth and the calculated depth are shown below (Fig 13).

Figure 13: Second Verification Storm (04/25/03)



In this storm event, the maximum depth of the traffic island was measured to be 1.00 ft. The model calculated the maximum depth to be 1.07 ft. The model over-estimated the depth of stormwater within the traffic island by 7%.

BMP Effectiveness

Precipitation Data

Annual precipitation data from a National Weather Service rain gauge located in Chadd's Ford, PA was used to project the effectiveness of the Villanova Bio-infiltration Traffic Island. This rain gauge was chosen based upon its proximity to the research site. Both the traffic island and the rain gauge are located in Delaware County, PA. Daily precipitation records were used from 1948-2001. The total number of days on record was 17,772 (48.7 years). The total amount of precipitation recorded over the entire period of record was 2193.51 in. This averages out to 45.05 in. annually.

Procedure

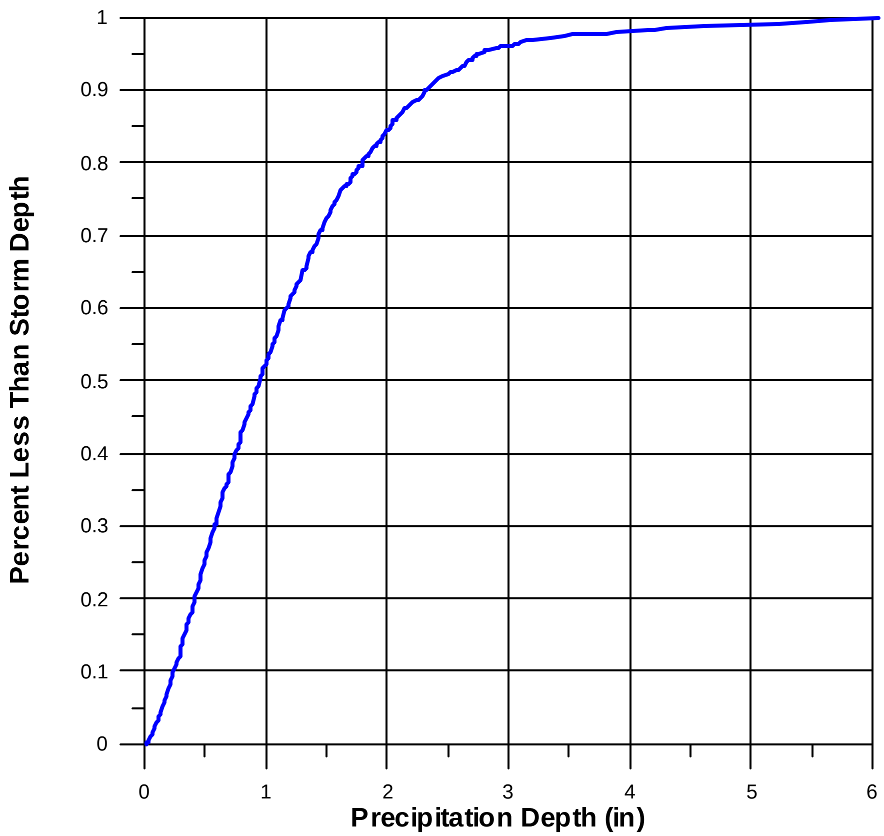
The precipitation data was used to create a total mass curve. The steps in creating this curve are illustrated in Table 13, below. Each of the daily precipitation totals were sorted based upon total precipitation depth in Column A. Column B shows the total number of times the storm depth occurred within the period of data. Column C is the product of Columns A and B. This represents the total amount of mass that came from storms of that depth. Column D shows the cumulative mass that has been summed up to that storm depth. Taking that mass and dividing by the sum of all of the storm events (2195.51 in), Column E is calculated. This represents the percentage of rainfall that is less than or equal to that given storm depth. These values were calculated for each different precipitation total found in the data, ranging from 0.01 in. up to 6.05 in. The table shows what these values are for selected storm depths. The spreadsheet is located in Appendix E.

Table 13: Creating Mass Curve from Rain Gauge Data

A	B	C	D	E
P (in)	Frequency	P*F (in)	Cum Mass	% Total
0.25	64	16	229.35	0.10
0.50	34	17	557.28	0.25
0.75	20	15	877.41	0.40
1.00	10	10	1148.38	0.52
1.50	8	12	1587.1	0.72
2.00	6	12	1853.15	0.84
3.10	2	6.2	2120.69	0.97
6.05	1	6.05	2193.51	1.00

Columns A and D were plotted (Fig 14) showing how a vast majority of annual precipitation comes from smaller storms. The graph illustrates how a vast majority of the annual precipitation comes from storms less than 2.00 inches.

Fig 14: Chadd's Ford Daily Precipitation Data



The graph shows how 52% of all of the precipitation at the site was 1.00 in or smaller. Theoretically, if a BMP were designed to capture and treat the first inch of precipitation, then at least 52% of the annual runoff of the site would be treated. Also, the first inch of every other storm above one inch would be treated raising the total further. This was the basis for the design of the traffic island. Originally, the traffic island was designed to capture and infiltrate the first inch of runoff. To estimate the actual amount of runoff the traffic island would infiltrate over the course of a year, the amount of annual runoff must first be estimated.

Runoff Computation

As before, the precipitation data was sorted based upon total storm depth. The model was run for each of the storm depths on record. Precipitation data for the model was entered into HMS as a user-defined hyetograph. Durations for the hypothetical storms were determined based upon the data recorded from the traffic island rain gauge on site. For all storms less than or equal to 0.5 inches, the duration was 3 hours. A duration of 6 hours was used when the precipitation depth was between 0.51 and 1.00 in, 12 hours for depths between 1.01 and 1.50 inches, 18 hours for depths between 1.51 and 2.00 inches, and a duration of 24 hours for all storm depths greater than 2.00 inches. The storm depth was distributed so that approximately half of the precipitation fell within the middle third of the storm, with the remaining precipitation being distributed over the first and last thirds. Examples of various storm depths and durations are shown below (Table 14). All of the user-created hyetographs are listed in Appendix F...

Table 14: Example Hyetographs of Hypothetical Storms

Depth (in)	0.25	0.75
Time (hr)	P (in)	P (in)
1	0.06	0.10
2	0.13	0.11
3	0.06	0.17
4		0.17
5		0.10
6		0.10

When the model was run for a particular storm depth, the assumption was made that the total runoff produced would be the same for all storms of the same precipitation depth. Similar to the precipitation totals, the total amount of runoff for all storms of a given depth was said to be the amount of runoff produced by the model run multiplied by the frequency of the storm. There are four designations of runoff quantities, the first being the "pre-development" conditions. The second quantity calculated is "post-development." This represents the amount of runoff produced in the drainage area. This is what was leaving the watershed after development, but before the construction of the traffic island. The third value is the amount of runoff leaving the watershed after the original construction of the traffic island. This was when the traffic island had the rectangular weir. The final runoff computation was for the V-notch weir. This represents what leaves the traffic island after the addition of the V-notch weir.

Pre-development

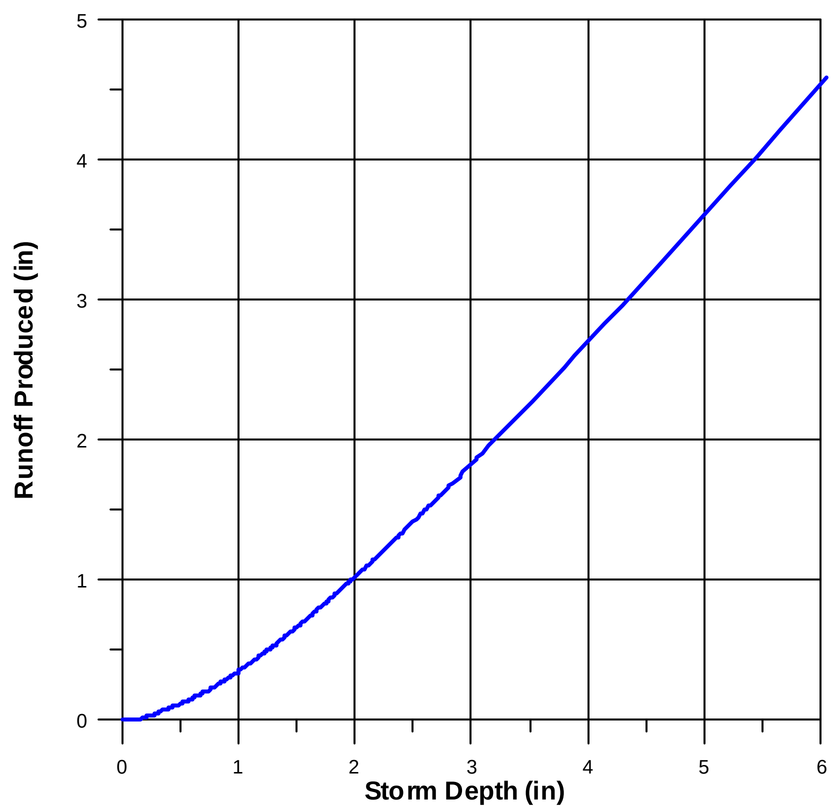
As with any BMP, the goal is to return the runoff of a site to a pre-development state. Normally this is done in the design of a developing area. With this site, development had already taken place. The goal is to see if a retrofit can reduce the runoff close to the pre-development state. To estimate what a "pre-construction" runoff curve would be, the drainage area was modeled as a single sub-area. Using the SCS runoff equation, the amount of runoff from the drainage area was calculated for each of the storm depths on record. The area was modeled as a forest, in poor condition with B class soils (curve number of 66). Similar to the graph constructed with the precipitation data, the storm depth was multiplied by the number of times it occurred. With this, the drainage area would have produced 70.83 in. of runoff during the entire period of data, coming out to an average annual runoff volume of only 1.45 in.

Post-development

To model the current conditions of the drainage area, and to estimate what would leave the site without the construction of the traffic island, the model was run for various storm depths in the same manner as stated before. The total amount of runoff was calculated for all 48 years of data by multiplying the amount of runoff calculated for a storm event by the frequency of that event. Adding all of those values for all of the storm depths, a total runoff of 753.10 in was calculated. Runoff values were taken from the output summary table of the reservoir in HMS. The total inflow to the reservoir would be the total amount of runoff that entered the traffic island; therefore, this value was used to express the total runoff from the watershed. This would represent the amount of runoff that would leave the drainage area without any BMP present.

Dividing the total amount of runoff for the entire period of record by the number of years, an annual average of 15.47 inches is calculated. Thus, in a given year, an average of 45.05 inches of precipitation produces 15.47 inches of runoff. The amount of runoff produced was plotted versus storm depth, shown in Fig 15. Note: All of the graphs end with the highest recorded value from the rain gauge data. Larger storms (100-yr events), would not fall onto this graph. The focus of this design is on smaller storms. While larger storms are of importance, the traffic island is not designed to handle extreme events.

Fig 15: Post-development Runoff before Traffic Island

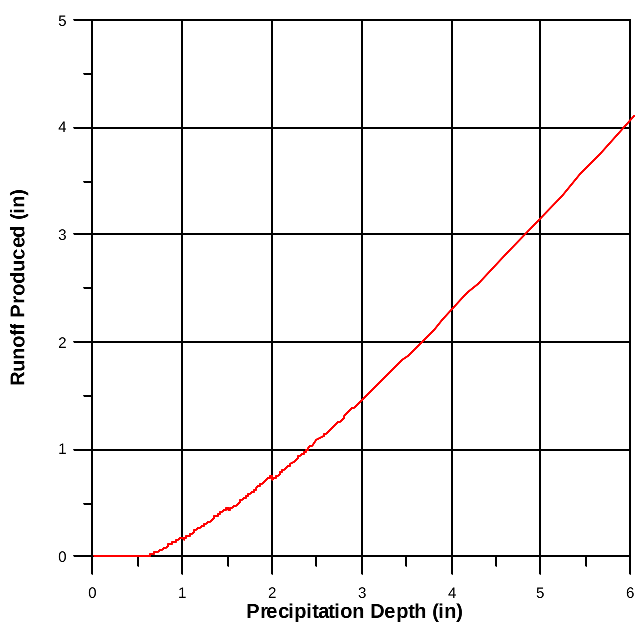


Rectangular Weir

The same process was done for each of the two BMP models created. The first model was for the original design (rectangular weir). An infiltration rate of 0.22 in/hr was assumed for this process. This was chosen because it was the smallest of the three observed infiltration rates, thus providing a more conservative estimate of its effectiveness. The same curve numbers, lag times, and weir coefficient was used. For the traffic island models, the runoff was defined as the total amount of flow over the weir for the event. The computed water surface elevation was used to calculate the incremental flow for each time step on an Excel spreadsheet. Flow values are in cfs. The model was run with five-minute time steps. Each flow value was multiplied by 300 seconds to give a total volume for that five-minute interval. The sum of all of the incremental volumes is the total outflow volume. This is the amount of water that leaves the watershed after the addition of the traffic island. As before, the amount of runoff for a particular storm depth was assumed to be the same for all storms of the same depth. The same user-entered hyetographs were used.

For the rectangular weir model, a total of 392.01 inches of runoff left the watershed during the entire period of data. This corresponds to an annual average of 8.05 inches. The graph below shows the amount of runoff for the traffic island as a function of storm depth. The runoff from the drainage area without the traffic island is also plotted (Fig 16). For all storm depths, the amount of runoff leaving the site with the BMP present is less than the amount would be if no BMP were present. Before, runoff started leaving the site after only 0.12 in. of precipitation had fallen. With the traffic island present, no runoff was observed until after 0.60 in. of precipitation had fallen.

Fig 16: Comparing Rectangular Weir

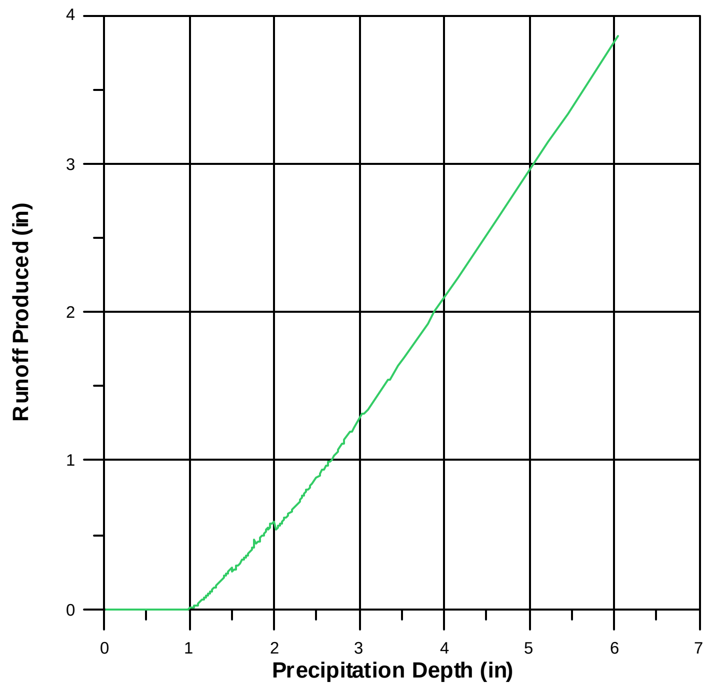


There is a slight discontinuity in the runoff curve for the traffic island model at storm depths of 1.00, 1.50, and 2.00 inches. This is due to the change in the rainfall distribution at these points. At depths less than 1.00 in., the precipitation is distributed over a 6-hour time period, while depths above 1.00 in. are distributed over a 12-hour time period. A storm depth of 1.00 inches is distributed over 6 hours, and 0.18 in. of runoff flows over the rectangular weir. For the storm depth of 1.01 inches (12-hr distribution), 0.16 inches of runoff are produced. Even though more rain fell, less runoff was produced. This illustrates how the intensity of the rainfall can influence the traffic island effectiveness. For the storm of 1.00 in, the rainfall intensity was higher than the storm of 1.01 inches. The slower rainfall intensity allows more runoff to infiltrate while the traffic island is filling. The discontinuity in the graph is a result of the intensity and duration of the storm changing. In reality, the actual intensity and duration of the storm events on record will vary from storm to storm. The intensities and durations used in this analysis are just assumptions. Actual results may vary. Storms of the same depth will produce slightly higher and lower runoff results. The values in this analysis are just approximations of what an average value would be for all storms of a given storm depth. Overall, the discontinuity does not change the overall shape of the runoff curve.

V-notch weir

The same process was run for the V-notch weir model. With this model, the maximum storage volume of the traffic island is more than double the volume for the rectangular weir. Higher infiltration capacities are expected. In the V-notch weir model, the same 753.10 in. of runoff passed through the traffic island. Taking the total from all of the storms, the total runoff leaving the site in the V-notch model was 231.98 inches. This comes out to an average annual volume of 4.76 in. of runoff annually. The average annual amount of runoff before the installation of the traffic island was 15.47 in. annually. This means that the traffic island captured and infiltrated 10.71 inches of runoff per year. The plot of the runoff curve from the model per storm depth is listed below (Fig 17). The runoff curve with no BMP present is also presented.

Fig 17: Runoff Curve for V-notch Weir Model



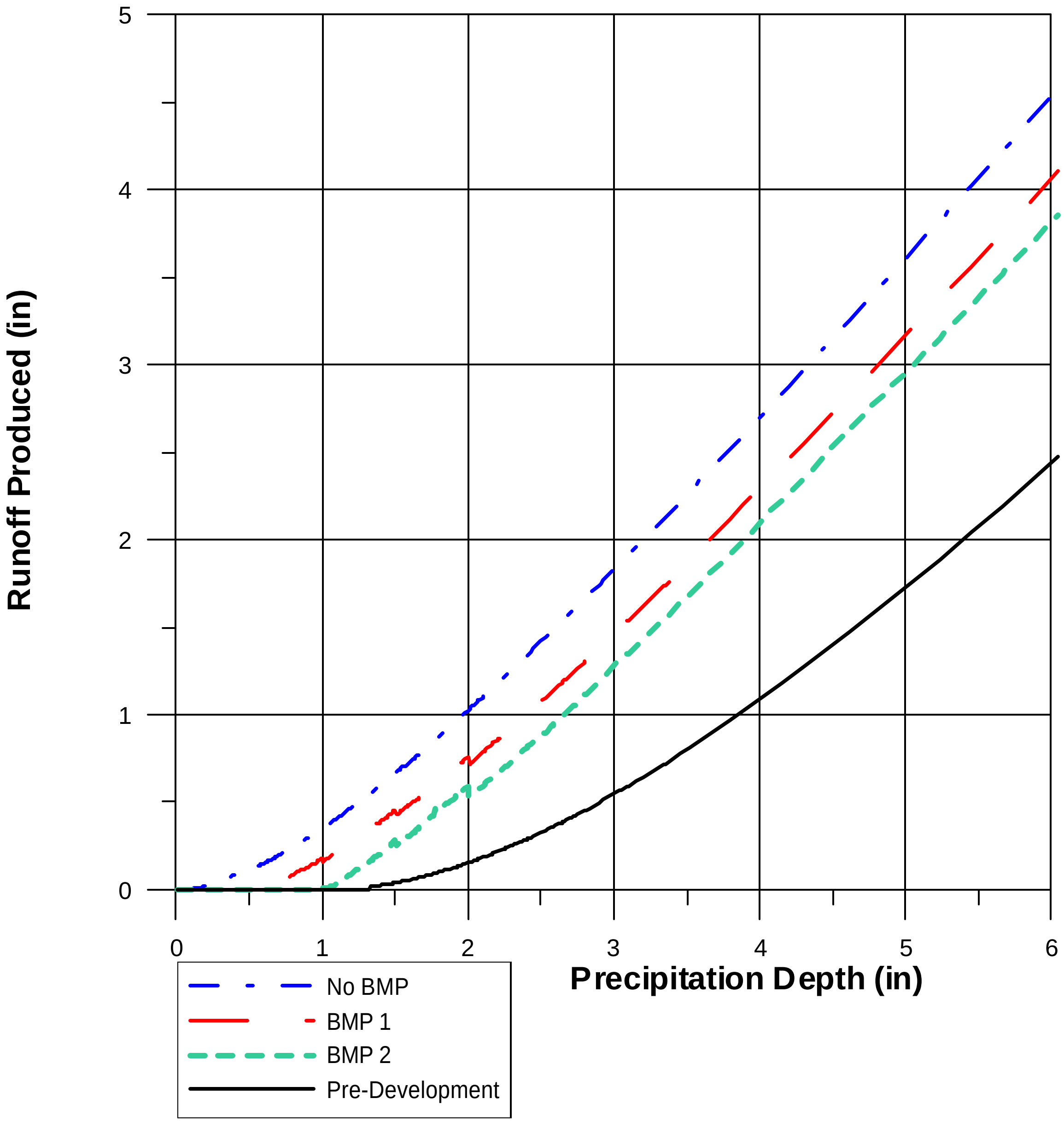
As before, runoff would normally start to be produced after only 0.12 in. of precipitation. With the original rectangular weir present, runoff would start to leave the site after 0.60 in. of precipitation. After adding the V-notch weir, 1.00 in. of rain has to fall before any runoff leaves the system. So, for all storms less than 1.00 in. in depth, the traffic island captures all of the runoff.

The discontinuity in the runoff curve is present with the V-notch runoff curve, just like the Rectangular weir curve. As before, this is the result of the changing rainfall intensity. The runoff values are just approximates, as the data only reports total storm depth for the entire day.

Overall Effectiveness

The runoff curves of all the different model runs were plotted on the same graph to illustrate the changing effectiveness of the system (Fig 18). The No BMP curve shows the runoff coming from the drainage area, flowing into the traffic island. This represents what would leave the site if the traffic island were not there. The BMP 1 curve represents the runoff leaving the site after the construction of the traffic island, and the BMP 2 curve shows the runoff leaving the site after the addition of the V-notch weir. Also included is the pre-development runoff curve.

Fig 18: Runoff vs. Storm Depth Comparison



As the graph shows, the amount of runoff leaving the site decreases as the infiltration capacity of the traffic island increases. However, both traffic island designs fall short of re-creating the pre-development state. Overall effectiveness can be measured by taking the total amount of runoff captured as a ratio of the total amount of runoff produced by the drainage area. The amount captured was defined as the difference of the amount of runoff produced by the drainage area and the amount of runoff flowing over the weir. In the case of the rectangular weir, the drainage area produces 15.47 inches of runoff annually. The traffic island allows 8.05 inches of runoff to flow out of the system. This means that the traffic island captured 7.42 inches of runoff. As a ratio, 48% of the annual runoff is captured by the traffic island. For the V-notch weir model, the traffic island allows 4.76 inches of runoff to flow out of the system. This produces a ratio of 69%. The values are also listed below (Table 15).

Table 15: Annual BMP Effectiveness

Model	Rect Weir	V-notch Weir
Runoff Before Traffic Island (in)	15.47	15.47
Runoff after Traffic Island (in)	8.05	4.76
Runoff Infiltrated (in)	7.42	10.71
% Runoff Infiltrated (in)	48%	69%
Pre-Construction Runoff (in)	1.45	1.45

Peak Flows

The traffic island was also analyzed for its effectiveness in reducing peak flows for large events. The models were run for the 2-100 yr storms. Precipitation data for these runs was taken from TP-40 sheets.. Total storm depths were taken from the curve. Storm depths of 3.4, 5.0, 6.0, 7.2, and 8.5 in were used for the 2, 10, 25, 50 and 100-yr events, respectively. For the meteorological model, the SCS Type II distribution was applied to each storm depth. For the Pre-Development condition, the model only had one drainage area. Peak flows were read directly from the drainage area summary table in HMS. The peak flow from the drainage area without the traffic island was defined as the peak inflow to the reservoir in the rectangular weir model. For peak traffic island outflow in the rectangular weir and v-notch weir model, the peak depth was used. Using the weir equations, the peak outflows were calculated.

Table 16: Peak Flows for Extreme Events

	Peak Flows (cfs)				
Model Run	**2-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Without BMP	1.74	3.32	3.81	4.26	4.97
Rect. Weir	1.66	3.27	3.73	4.21	4.90
V-notch Weir	1.46	2.48	2.80	3.15	3.75
Pre-Development	0.36	1.27	1.59	1.92	2.39

Overall, the rectangular weir design had no significant effect on reducing peak flows. Although the total amount of runoff was reduced, the peak flows were almost the same with or without the BMP present. Peak flows did decrease somewhat with the V-notch weir in place, but were still greater than the pre-development condition.

Discussion

Factors that control the amount of inflow into the traffic island include the amount of impervious surface, land use, soil cover, and land slopes within the watershed. The volume, intensity and frequency of the rainfall also affect the amount of runoff produced. The outflow from the traffic island is determined by two factors: the surface storage volume and infiltration rate of the soil. Within this study, the land use of the drainage area was already fixed. Nothing could be done to change the inflow to the traffic island. The rest of this study looks into how the traffic island variables (infiltration rate and volume) affect its overall performance.

Varying Infiltration Rates

As discussed earlier, the rate at which the runoff infiltrated into the traffic island varied during the data collection. During the study, the infiltration rate was defined as the change in water surface elevation with respect to time. The water surface elevation decreased at a fairly linear rate for all storm events. Generally, the infiltration rate was higher at the beginning of the study. The first few storm events saw this rate to be around 0.42 in/hr. After a period of time, the rate came to a constant rate, around 0.22 in/hr. While the exact reason for this change is unknown, several possibilities exist. During the summer of 2002, there was a severe drought in the area. The infiltration rates in September and early October might have been higher due to the lower moisture content of the soil. After November 1, there was considerable precipitation in the area. The moisture content of the soil was higher during this period, so a slower infiltration rate is to be expected. One way to examine this was to observe the number of dry days before a storm event. Unfortunately, no clear pattern could be found by doing this.

Another factor that might affect the infiltration rate would be a redistribution of soil particles. Some scouring and erosion was visible on the surface of the traffic island, particularly along the flow paths from the curb cuts to the bottom of the basin. With each precipitation event, soil is moved. The traffic island was constructed about a year before the first storm events used in this study. Over time, the heavier particles on the surface might have settled some. This would have created a surface layer different from the rest of the infiltration bed.

During the study period, the highest infiltration rate observed was 0.42 in/hr. The lowest infiltration rate observed was 0.18 in/hr. Converting this to cm/hr, the infiltration rate ranged from 0.46-1.07 cm/hr. Using the standard Green-Ampt parameters (Rawls, et. Al. 1983), a relation between the infiltration rate and the hydraulic conductivity of the soil might be possible. For a sandy loam ($n = 0.46$), the hydraulic conductivity is 1.09 cm/hr. For a silt loam ($n = 0.50$), the hydraulic conductivity is 0.65 cm/hr. The observed infiltration rates fall within a range between the two values. The hydraulic conductivity of the sandy loam is the upper bound, and the hydraulic conductivity of the silt loam is the lower bound.

The lower infiltration rates were indicative of a soil with higher silt contents. The higher infiltration rates were indicative of a soil with a higher sand content. When the traffic island was constructed, the native soil was mixed with pure sand. The native soil had a higher silt content. One possibility is that, through the particle size redistribution, the top of the traffic island is has separated, with a silt layer on top of the sandy layer. Since the silt layer would have the lower hydraulic conductivity, it would act as a control for the infiltration rate. This change in the surface layer would be the cause for the decrease in the infiltration rate. Although the porosity of the soil will affect the storage capacity of the traffic island, the hydraulic conductivity will control the rate at which the water flows into the void spaces. Generally, the hydraulic conductivity of the soil will provide an estimate of what the infiltration rate would be. The hydraulic conductivity may change over time. If a soil is mixed, like with the present traffic island, the lower hydraulic conductivity of the two soils should be used for conservative design estimates.

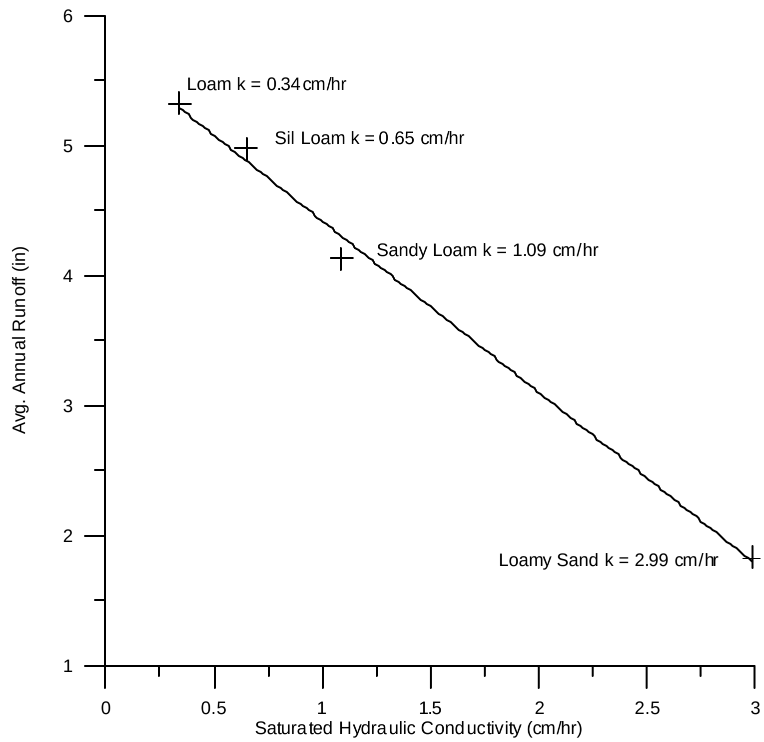
To examine how the infiltration rate might affect yearly runoff values, the model was run with varying infiltration rates. Using Green-Ampt saturated hydraulic conductivity parameters, infiltration rates were used for various soil classes. Hydraulic conductivities were converted from cm/hr to in/hr, and imported into the excel spreadsheets in the same way the original model was constructed. The model was run for a loamy sand (k = 2.99 cm/hr), a sandy loam (k = 1.09 cm/hr), silt loam (0.26 cm/hr), and a loam (0.14 cm/hr). Rather than running the model for every storm depth from the rain gauge data, the precipitation values were rounded to the nearest 0.1 in. The model was run for that storm depth, and assumed the same for all precipitation values within that range. The v-notch weir was used in modeling. Thus, holding volume constant, the effect of the infiltration rate was determined. The total average annual runoff computations are located below (Table 17).

Table 17: Varying Infiltration Rates

Soil Type	**K (cm/hr)**	**Infiltration Rate (in/hr)**	**Avg Annual Runoff (in))**
Loamy Sand	2.99	1.18	**1.83**
Sandy Loam	1.09	0.43	**4.13**
Silt Loam	0.65	0.26	**4.98**
Loam	0.34	0.13	**5.33**

As Table 18 shows, the average annual runoff leaving the traffic island varies as the infiltration rate varies. As the infiltration rate increases, so does the infiltration depth. Plotting annual runoff versus infiltration rate, the points form a straight line relationship.

Figure 19: Decreasing Runoff as a Function of Hydraulic Conductivity



Effects of previous storms

The amount of time between storm events does factor into the effectiveness of the traffic island. Precipitation may occur within a period of a few hours, but the runoff can stay on the surface of the traffic island for up for an extended period. When precipitation fell on January 3rd, 2003, the runoff took four days to completely infiltrate. During the data collection at the site, there were two storms where a significant amount of runoff was still standing within the traffic island at the start of the storm. Between 1:40 pm on 9/26 and 6:50 am on 9/27, 2.36 inches of rain fell. This caused there to be 0.72 feet of water in the traffic island when precipitation started falling again at 9:45 pm. Treating this new rainfall as a new storm event, the precipitation data was run through the model for the rectangular weir. An infiltration rate of 0.40 in/hr was used, the same as the 9/26 event. Using the model, the 0.64 inches of precipitation created 0.18 inches of runoff. Since this event was modeled as a new event, the drainage area had recovered all of its infiltration capacity. This may not be the actual amount of runoff produced within the drainage area for this event, since it had rained the day before, and the soil may not have fully recovered its infiltration capacity. Fifteen hours had passed from the end of the previous rainfall and the beginning of the second rainfall. This gap was assumed to be large enough to model the second precipitation as a separate storm event.

Applying the weir equation to the recorded water surface elevation, 0.10 in. of runoff flowed over the weir. Using the HMS output, 0.09 inches of runoff flowed over the weir. Thus, for

0.64 inches of precipitation, 0.10 inches of runoff left the site. Had the traffic island been completely dry, only 0.02 inches of runoff would flow over the weir. Thus, another factor in the effectiveness of the traffic island is the frequency of precipitation. If the traffic island is already partially full from another storm event, it will infiltrate less for the second event.

Volume

The surface storage capacity of the traffic island is another important factor on its performance. Also, the volume of the traffic island is the easiest factor to change and control during the design process. The V-notch weir was placed six inches above the previous weir. This elevation was chosen because it would provide the maximum amount of storage capacity for the traffic island. At this elevation, the water surface would extend back into the rip-rap inlet channels. Had the weir been placed any higher, the water surface would back into the parking lot. Thus, for the current conditions, the traffic island cannot store any more water on the surface. Although impossible with the current topography, the traffic island model was run to look at what would happen if we again added six inches to the weir elevation. The same volume vs. depth relationship was used, and the same infiltration rate (0.22 in/hr) from the original models was used. In developing the storage/outflow curve, the same v-notch weir equation was also used. This was an attempt to model a hypothetical basin with the same shape and larger depth.

Comparing the three traffic island models, the first model (rectangular weir) had a maximum surface storage volume of about 550 cubic feet (0.13 in.) before weir flow would occur. The present traffic island model has about 1220 cubic feet (0.29 in) of volume. Adding 0.5 ft to the weir elevation, and using the same volume vs. depth relationship, the hypothetical model would have a maximum storage volume of about 2050 cubic feet (0.49 in). Adding 0.5 feet in each case approximately doubles the maximum storage capacity.

A separate basin model was created to simulate the hypothetical traffic island. To better compare results, the same infiltration rate (0.22 in/hr) from the previous model runs was used. The storage/outflow table included a v-notch weir with the notch having an elevation of 2.22 ft above the bottom of the basin. The Chadd’s Ford rain gauge data was used again. The model was run for each of the storm depths on record. Multiplying the outflow by the frequency of the storm depth, the total amount of runoff from the site for each storm depth was known. The sum of all of the runoff values was divided by the number of years of data to produce the average annual runoff for the hypothetical design. With the hypothetical traffic island present, the average annual runoff would decrease to 2.74 in. This is a 42% decrease from the present design (4.76 in).

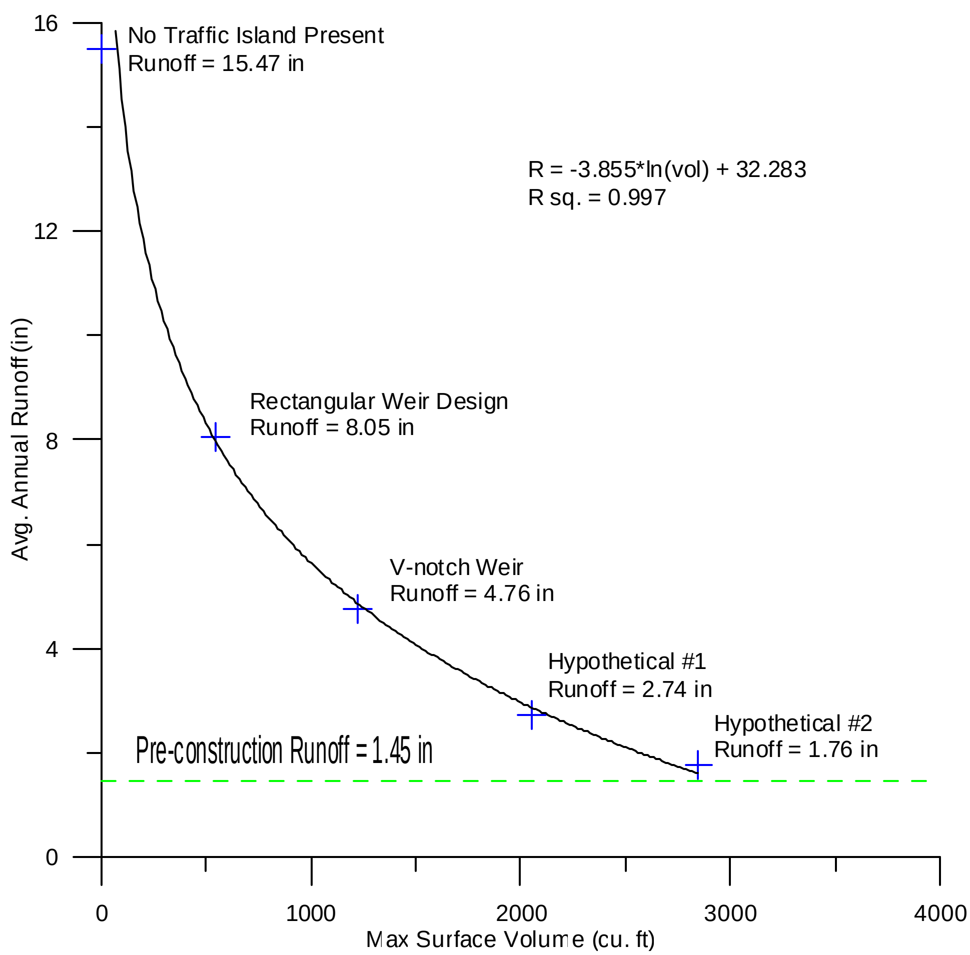
To further speculate how volume would affect the runoff totals, another six inches were added to the weir elevation. Following the same process as above, the average annual runoff for the second hypothetical traffic island design was calculated. The results from the rectangular weir, v-notch weir, and both hypothetical designs are shown below (Table 18).

Table 18: Hypothetical Design Results

Model	Weir Elev	Max Vol	Avg R (in)
BMP 1	1.22	550	**8.05**
BMP 2	1.72	1220	**4.76**
Hypothetical 1	2.22	2050	**2.74**
Hypothetical 2	2.72	2850	**1.79**
Pre-Development			**1.45**

With the first hypothetical design in place, the post-construction runoff of 15.47 inches is reduced to 2.74 inches. This means 12.73 inches of runoff would be infiltrated annually. This would also mean that 82% of the annual runoff would be captured and infiltrated. With the second hypothetical design, 88% of the annual runoff would be infiltrated.

Figure 20: Traffic Island Volume vs. Annual Runoff



To further illustrate the effect volume has on annual runoff, the runoff calculations for each of the models were plotted as a function of traffic island volume (Fig 20). As the graph shows, the extra benefit of added volume decreases as the traffic island gets larger and larger. At some point, an optimal volume would exist. The extra cost of excavation, or the availibily of space might put constraints on the size of the traffic island.

Impervious Surface

Another observation made during the model calibration dealt with the impervious surface percentage in the watershed. Through the site survey, the drainage area was found to be roughly 50% impervious. However, a portion of that impervious surface came from the basketball court. The court was slightly sloped, so that runoff travels off the pavement, and across a small grass area before flowing onto the parking lot. By doing this, the amount of runoff was reduced. Original attempts in modeling the area as 50% impervious overestimated the runoff flowing into the traffic island. Because of this, the drainage area was only modeled with the directly connected impervious surface in the one sub-area. By disconnecting the impervious surface, the runoff has a chance to infiltrate some within the drainage area. This will reduce the total volume of runoff at the site.

Conclusions

The Villanova Bio-Infiltration Traffic Island was originally designed to infiltrate the first inch of runoff from each storm event. This volume was calculated based on the storage space within the voids of the infiltration bed including the surface volume. The design, however, failed to reach this target depth only capturing the first 0.16 in. of runoff. The decrease in effectiveness is due to the infiltration process itself. Runoff enters the traffic island faster than it infiltrates into the soil. Thus, the voids within the infiltration bed are never completely filled. When the surface storage reaches its maximum depth, additional runoff flows over the weir into the storm sewer.

The elevation of the diversion weir was raised to increase the surface storage of the traffic island. After the addition of the v-notch weir, the traffic island infiltrates the first 0.34 in. of runoff for each storm event. Due to the fact that most of the annual precipitation comes from small storms, the traffic island was able to reduce the yearly runoff by 69%.

Factors that effect the performance of a bio-infiltration traffic island include the hydraulic conductivity of the soil, and the overall surface volume of the BMP. When the volume of the traffic island increased, the amount of runoff captured increased.

Design Recommendations

The size of the traffic island should be determined by the target infiltration volume. This would be accomplished by creating enough surface storage volume to hold the target infiltration depth.

Although the infiltration rate of the soil can greatly affect the total decrease of runoff, natural processes of time will reduce the hydraulic conductivity of the surface of the traffic island. Sediment flowing into the traffic island, along with biological matter and erosion of the traffic island itself, will cause the surface layer to change over time. The accumulation of finer particles will decrease the hydraulic conductivity. The traffic island was originally designed with a fill material with a higher hydraulic conductivity. Over time, the additional infiltration capacity by mixing the soil decreased to a steady level. The added effectiveness from the higher hydraulic conductivity would be lost over time.

A large portion of the construction costs of the traffic island came from the sifting of the two soil types. As observed, the benefit of this decreased over time. If the traffic island were constructed in a high clay content soil, the need to mix the soil would be greater. However, in soils where the hydraulic conductivities are relatively higher, the need to add the sand is not required. The traffic island could be constructed just by excavating the soil and making a larger pond. Further testing of this concept needs to be conducted.

One possible way to regain the higher infiltration rate is to disturb the surface layer. By loosening the surface layer, the water would move through the system faster, thus allowing more runoff to infiltrate. Tilling the surface layer could become part of a routine maintenance sequence to keep the traffic island working at its maximum potential.

Due to the relatively small decrease in peak flows, a traffic island could not be used as the sole BMP for a site. The traffic island could be used in combination with a standard detention basin. The traffic island would remove a large amount of the volume for daily flows, but the detention basin would handle peak flows from larger storms. The overall volume leaving the site would decrease significantly, while still decreasing peak flows for extreme events. Also, due to its relatively low construction costs, a traffic island could be added to an existing detention basin. The cumulative effects of several traffic islands over a watershed have yet to be determined. Traffic islands in series could infiltrate most all of the annual runoff.

Future Studies

Future studies concerning the effectiveness of the traffic island should include:

- Construction of several traffic islands with varying surface volumes and soil types to further examine their effects on traffic island performance.
- Water quality analysis of the infiltrated runoff to identify any benefits or flaws of the system.
- Long term sampling of the soil to study possible water quality effects of particulate matter adhering to soil particles and to examine their effect on infiltration rates.
- Changing maintenance measures, including raking and tilling, to determine the exact cause for the change in infiltration rates and to maximize the traffic island's infiltration potential.

References

1. ASTM (2003). "Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)." D2487-00, W. Conshohocken, PA.

2. ASTM (2003). "Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils." D4318-00, W. Conshohocken, PA.

3. ASTM (1996). "Standard Test Method for Open-Channel Flow Measurement of Water with Thin-Plate Weirs." D5242-92, W. Conshohocken, PA.

4. ASTM (2002). "Standard Test Method for Particle-Size Analysis of Soils." D422-63, W. Conshohocken, PA.

5. Barbosa, Ana Estela, and Hvitved-Jacobsen, Thorkild. (2001). "Infiltration Pond Design for Highway Runoff Treatment in Semiarid Climates." J. Environmental Eng., ASCE, 127 (11), 1014-1022.

6. E.P.A. (2002). "National Management Measures to Control Nonpoint Source Pollution from Urban Areas—Draft." Washington, DC.

7. Federal Register (200). 64 FR 68722.

8. HEC-HMS reference manual; release 2.2.0. (2002). Hydrologic Engineering Center, Davis, Ca

9. Lawrence, A.I., Marsalek, J., Ellis, J.B., and Urbonas, B. (1996). "Stormwater detention & BMP's." J. Hydraulic Research/De Recherches Hydrauliques. Int. Assoc for Hydraulic Research., 34 (6), 79 9-813.

10. Lee, G. Fred, and Jones-Lee (1998) "Development of Appropriate Stormwater Infiltration BMP's: Part 1—Potential Water Quality Impacts, Monitoring and Efficacy Evaluation." Proceedings, Ground Water Protection Council 98 Annual Forum.

11. Mikkelsen, P.S., Jacobsen, P., and Fujita, S. (1996). "Infiltration Practice for control of Urban Stormwater." J. Hydraulic Research/De Recherches Hydrauliques., Int. Assoc for Hydraulic Research, Netherlands., 34 (6), 827-840.

12. National Weather Service…..Chadd's Ford Rain Gauge Data

13. Pennsylvania DEP (2002). Comprehensive Stormwater Management Policy. Document No. 392-0300-002. September 28, 2002.

14. Rawls, W.J., Brakensiek, D.L.(1983). "Green-Ampt Infiltration Parameters from Soils Data," J. Hydraulic Div., ASCE, 109 (1), 318-333.

15. Strecker, Eric W., Urbonas, Ben R., Jones, Jonathan E., and Clary, Jane K. (2001). "Determining Urban Storm Water BMP Effectiveness." J. Water Resources Planning and Management, ASCE, 127 (3), 144-149.

16. Tholin, A.L. and Keifer, C.J. (1960). "Hydrology of Urban Runoff. Trans.", ASCE. Vol 125: `308-1379.

17. TP-40: Rainfall Frequency Atlas of the US 1961). Weather Bureau Technical Paper No. 40. Washington, DC.

18. Traver, Robert G. (2001) "Chadd's Form Daily Precipitation Data". Unpublished paper:

19. Whipple, William. (1991). "Best Management Practices for Storm Water and Infiltration Control." Water Resources Bulletin., AWRA., 27 (6), 895-902.

Appendix A: Construction Photographs

A1: Excavation of native soil. Curb cut placement is determined by flow of water across surface.

A2: Completion of excavation.

A3: Storm sewer inlet is blocked, and inlet pipe is added.

A4: Native soil to be added to sand.

A5: Storm sewer inlet on north end of traffic island is filled. The grate is later paved over, diverting flow into the traffic island.

A6: Made soil is being added back into traffic island to form the infiltration bed.

A7: Monitoring well is placed within infiltration bed.

A8: Mulch is placed on top of the soil to prevent erosion until the vegetation grows in. Rip rap is placed along flow paths to further reduce erosion.

A9: Completed Traffic Island with vegetation and monitoring equipment.

A10: Snowfall on 01/22/02.

A11: Two days later, rain melts the snow and fills the traffic island.

A12: Within 24 hrs, most of the runoff infiltrates.

A13: 48 hrs later, all of the runoff has infiltrated.

Appendix B: Soil Sieve Analysis

Native Soil

Soil
Wash
Dray Mass before wash 479.06 g
Dry Mass after wash 207.52 g

Sieve analysis on Native Soil

Sieve #	Opening Size (mm)	Cumulative wt Retained (g)	% Retained	% Passing
4	4.76	12.3	2.57%	97.43%
10	2	33.25	6.94%	93.06%
20	0.85	66.48	13.88%	86.12%
40	0.43	100.82	21.05%	78.95%
100	0.15	161.63	33.74%	66.26%
200	0.075	200.65	41.88%	**58.12%**
Pan		207.52		

Sieve analysis on Sand

Sample weight 459.53 g

Sieve #	Opening Size (mm)	Cumulative wt Retained (g)	% Retained	% Passing
4	4.76	16.73	3.64%	96.36%
10	2	71.08	15.47%	84.53%
20	0.85	182.82	39.78%	60.22%
40	0.43	333.17	72.50%	27.50%
100	0.15	453.32	98.65%	1.35%
200	0.075	458.7	99.82%	**0.18%**
Pan		459.53		

Projected Sieve analysis on Fill

**Assume 100 g of sand is added to 100 g of original soil

Total mass 200 g

Sieve #	Sand	Original Soil	Mix	% Retained	% Passing
4	3.64	2.57	6.21	3.10%	96.90%
10	15.47	6.94	22.41	11.20%	88.80%
20	39.78	13.88	53.66	26.83%	73.17%
40	72.50	21.05	93.55	46.77%	53.23%
100	98.65	33.74	132.39	66.19%	33.81%
200	99.82	41.88	141.70	70.85%	29.15%

Appendix C: Watershed Models

Appendix C contains the spreadsheets used to input the storage-elevation-outflow tables for the reservoir in HMS. The table on the right is the actual values used in HMS. The table on the left contains the process in calculating those values.

The first three spreadsheets (C-1, C-2, C-3), represent the rectangular weir model with the varying infiltration rates (0.22, 0.30, 0.40 in/hr, respectively). This is followed by the outflow table for the v-notch weir model (C-4). The next four tables (C-5, C-6, C-7, C-8) were used when the hydraulic conductivity of the soil was changed. The final two tables (C-9, C-10) are the hypothetical traffic island models used to predict the effect of changing volume. .

C1: Rectangular Weir 0.40 in/hr

Original Weir Elev. 1.22 ft
Inf Rate 0.40 in/hr

Time (hr)	Depth	Volume	Storage (ac. Ft)	dV/dt	Outflow
0	1.22	545.4	0.012522	35.65	0.0099028
1	1.18667	509.6	0.011699	34.467	0.0095742
2	1.15333	475.0	0.010905	33.284	0.0092457
3	1.12	441.8	0.010142	32.102	0.0089171
4	1.08667	409.8	0.009407	30.919	0.0085886
5	1.05333	379.1	0.008703	29.736	0.00826
6	1.02	349.7	0.008029	28.553	0.0079314
7	0.98667	321.7	0.007385	27.37	0.0076029
8	0.95333	295.0	0.006771	26.188	0.0072743
9	0.92	269.5	0.006187	25.005	0.0069458
10	0.88667	245.4	0.005633	23.822	0.0066172
11	0.85333	222.5	0.005109	22.639	0.0062887
12	0.82	201.0	0.004614	21.456	0.0059601
13	0.78667	180.7	0.004148	20.274	0.0056316
14	0.75333	161.7	0.003711	19.091	0.005303
15	0.72	143.9	0.003303	17.908	0.0049744
16	0.68667	127.3	0.002923	16.725	0.0046459
17	0.65333	111.9	0.002570	15.542	0.0043173
18	0.62	97.7	0.002244	14.36	0.0039888
19	0.58667	84.7	0.001944	13.177	0.0036602
20	0.55333	72.8	0.001670	11.994	0.0033317
21	0.52	61.9	0.001421	10.811	0.0030031
22	0.48667	52.1	0.001196	9.6284	0.0026746
23	0.45333	43.3	0.000994	8.4456	0.002346
24	0.42	35.5	0.000815	7.2628	0.0020174
25	0.38667	28.6	0.000657	6.08	0.0016889
26	0.35333	22.6	0.000519	4.8972	0.0013603
27	0.32	17.4	0.000400	3.7144	0.0010318
28	0.28667	13.1	0.000300	2.5316	0.0007032
29	0.25333	9.4	0.000217	1.3488	0.0003747
30	0.22	6.5	0.000149	0.166	4.611E-05
31	0.18667	4.2	0.000096		
32	0.15333	2.5	0.000056		
33	0.12	1.2	0.000028		
34	0.08667	0.4	0.000010		
35	0.05333	0.0	0.000001		
36	0.02		0.000000		

Elevation	Storage	Outflow
0.00	0	0
0.22	0.00014	0.00004
0.25	0.000217	0.000375
0.29	0.000300	0.000703
0.32	0.000400	0.001032
0.35	0.000519	0.001360
0.39	0.000657	0.001689
0.42	0.000815	0.002017
0.45	0.000994	0.002346
0.49	0.001196	0.002675
0.52	0.001421	0.003003
0.55	0.001670	0.003332
0.59	0.001944	0.003660
0.62	0.002244	0.003989
0.65	0.002570	0.004317
0.69	0.002923	0.004646
0.72	0.003303	0.004974
0.75	0.003711	0.005303
0.79	0.004148	0.005632
0.82	0.004614	0.005960
0.85	0.005109	0.006289
0.89	0.005633	0.006617
0.92	0.006187	0.006946
0.95	0.006771	0.007274
0.99	0.007385	0.007603
1.02	0.008029	0.007931
1.05	0.008703	0.008260
1.09	0.009407	0.008589
1.12	0.010142	0.008917
1.15	0.010905	0.009246
1.19	0.011699	0.009574
1.22	0.012522	0.009903
1.24	0.013029	0.032566
1.26	0.013547	0.074003
1.28	0.014075	0.127662
1.30	0.014614	0.191205
1.32	0.015162	0.26328
1.34	0.015721	0.342976
1.36	0.016289	0.429623
1.38	0.016867	0.522703
1.40	0.017454	0.621798
1.50	0.020531	1.197051
1.60	0.023823	1.886813
1.70	0.027306	2.67449
1.80	0.030952	3.549143
1.90	0.034727	4.502851
2.00	0.038593	5.529533

C2: Rectangular Weir 0.3 in/hr

Time (hr)	Depth	Volume	Storage (ac. Ft)	dV/dt	Outflow
0	1.22	545.4	0.012522	25.465	0.007074
1	1.195	518.4	0.011902	24.861	0.006906
2	1.17	492.2	0.011299	24.257	0.006738
3	1.145	466.6	0.010712	23.653	0.006570
4	1.12	441.8	0.010142	23.049	0.006403
5	1.095	417.7	0.009588	22.445	0.006235
6	1.07	394.3	0.009052	21.841	0.006067
7	1.045	371.7	0.008532	21.237	0.005899
8	1.02	349.7	0.008029	20.633	0.005731
9	0.995	328.6	0.007543	20.029	0.005564
10	0.97	308.2	0.007074	19.425	0.005396
11	0.945	288.5	0.006622	18.821	0.005228
12	0.92	269.5	0.006187	18.217	0.005060
13	0.895	251.3	0.005769	17.613	0.004893
14	0.87	233.8	0.005367	17.009	0.004725
15	0.845	217.0	0.004982	16.405	0.004557
16	0.82	201.0	0.004614	15.801	0.004389
17	0.795	185.7	0.004262	15.197	0.004221
18	0.77	171.0	0.003926	14.593	0.004054
19	0.745	157.1	0.003607	13.989	0.003886
20	0.72	143.9	0.003303	13.385	0.003718
21	0.695	131.3	0.003015	12.781	0.003550
22	0.67	119.5	0.002743	12.177	0.003383
23	0.645	108.3	0.002486	11.573	0.003215
24	0.62	97.7	0.002244	10.969	0.003047
25	0.595	87.8	0.002017	10.365	0.002879
26	0.57	78.6	0.001804	9.761	0.002711
27	0.545	69.9	0.001606	9.157	0.002544
28	0.52	61.9	0.001421	8.553	0.002376
29	0.495	54.5	0.001250	7.949	0.002208
30	0.47	47.6	0.001092	7.345	0.002040
31	0.445	41.3	0.000947	6.741	0.001873
32	0.42	35.5	0.000815	6.137	0.001705
33	0.395	30.2	0.000694	5.533	0.001537
34	0.37	25.5	0.000585	4.929	0.001369
35	0.345	21.2	0.000487	4.325	0.001201
36	0.32	17.4	0.000400	3.721	0.001034
37	0.295	14.1	0.000324	3.117	0.000866
38	0.27	11.2	0.000256	2.513	0.000698
39	0.245	8.6	0.000199	1.909	0.000530
40	0.22	6.5	0.000149	1.305	0.000363
41	0.195	4.7	0.000108	0.701	0.000195
42	0.17	3.3	0.000075	0.097	0.000027
43	0.145	2.1	0.000048	0	0.000000
44	0.12	1.2	0.000028	0	0.000000
45	0.095	0.6	0.000014	0	0.000000
46	0.07	0.2	0.000004	0	0.000000
47	0.045	0.0	0.000000	0	0.000000
48	0.02	0.0	0.000000	0	0.000000
49	0	0.0	0.000000	0	0.000000

Elevation	Storage	Outflow
0	0	0.000000
0.17	0.000075	0.000027
0.195	0.000108	0.000195
0.22	0.000149	0.000363
0.245	0.000199	0.000530
0.27	0.000256	0.000698
0.295	0.000324	0.000866
0.32	0.000400	0.001034
0.345	0.000487	0.001201
0.37	0.000585	0.001369
0.395	0.000694	0.001537
0.42	0.000815	0.001705
0.445	0.000947	0.001873
0.47	0.001092	0.002040
0.495	0.00125	0.002208
0.52	0.001421	0.002376
0.545	0.001606	0.002544
0.57	0.001804	0.002711
0.595	0.002017	0.002879
0.62	0.002244	0.003047
0.645	0.002486	0.003215
0.67	0.002743	0.003383
0.695	0.003015	0.003550
0.72	0.003303	0.003718
0.745	0.003607	0.003886
0.77	0.003926	0.004054
0.795	0.004262	0.004221
0.82	0.004614	0.004389
0.845	0.004982	0.004557
0.87	0.005367	0.004725
0.895	0.005769	0.004893
0.92	0.006187	0.005060
0.945	0.006622	0.005228
0.97	0.007074	0.005396
0.995	0.007543	0.005564
1.02	0.008029	0.005731
1.045	0.008532	0.005899
1.07	0.009052	0.006067
1.095	0.009588	0.006235
1.12	0.010142	0.006403
1.145	0.010712	0.006570
1.17	0.011299	0.006738
1.195	0.011902	0.006906
1.22	0.012522	0.007074
1.24	0.013029	0.029736
1.26	0.013547	0.071174
1.28	0.014075	0.124833
1.3	0.014614	0.188376
1.32	0.015162	0.260451
1.34	0.015721	0.340147
1.36	0.016289	0.426794
1.38	0.016867	0.519874
1.4	0.017454	0.618968
1.5	0.020531	1.194222
1.6	0.023823	1.883984
1.7	0.027306	2.671661

C3: Rectangular Weir 0.22 in/hr

Time (hr)	Depth	Volume	Storage (ac. Ft)	dV/dt	Outflow
0	1.22	545.4	0.012522	18.66	0.00518
1	1.20	525.6	0.012066	18.335	0.00509
2	1.18	506.1	0.011618	18.011	0.00500
3	1.17	487.0	0.011180	17.686	0.00491
4	1.15	468.3	0.010750	17.362	0.00482
5	1.13	450.0	0.010330	17.038	0.00473
6	1.11	432.0	0.009918	16.713	0.00464
7	1.09	414.5	0.009516	16.389	0.00455
8	1.07	397.4	0.009122	16.064	0.00446
9	1.06	380.6	0.008738	15.740	0.00437
10	1.04	364.3	0.008362	15.416	0.00428
11	1.02	348.3	0.007996	15.091	0.00419
12	1.00	332.8	0.007639	14.767	0.00412
13	0.98	317.6	0.007291	14.442	0.00401
14	0.96	302.8	0.006952	14.118	0.00392
15	0.95	288.5	0.006622	13.794	0.00383
16	0.93	274.5	0.006302	13.469	0.00374
17	0.91	260.9	0.005990	13.145	0.00365
18	0.89	247.7	0.005687	12.820	0.00356
19	0.87	234.9	0.005393	12.496	0.00347
20	0.85	222.5	0.005109	12.172	0.00338
21	0.84	210.5	0.004833	11.847	0.00329
22	0.82	198.9	0.004566	11.523	0.00320
23	0.80	187.7	0.004308	11.198	0.00311
24	0.78	176.8	0.004059	10.874	0.00302
25	0.76	166.3	0.003818	10.55	0.00293
26	0.74	156.2	0.003586	10.225	0.00284
27	0.73	146.5	0.003363	9.9012	0.00275
28	0.71	137.1	0.003148	9.5768	0.00266
29	0.69	128.1	0.002941	9.2524	0.00257
30	0.67	119.5	0.002743	8.928	0.00248
31	0.65	111.2	0.002553	8.6036	0.00239
32	0.63	103.3	0.002371	8.2792	0.00230
33	0.62	95.7	0.002197	7.9548	0.00221
34	0.60	88.5	0.002031	7.6304	0.00212
35	0.58	81.6	0.001873	7.306	0.00202
36	0.56	75.1	0.001723	6.9816	0.00193
37	0.54	68.8	0.001580	6.6572	0.00184
38	0.52	62.9	0.001445	6.3328	0.00175
39	0.51	57.4	0.001317	6.0084	0.00166
40	0.49	52.1	0.001196	5.684	0.00157
41	0.47	47.1	0.001082	5.3596	0.00148
42	0.45	42.5	0.000975	5.0352	0.00139
43	0.43	38.1	0.000875	4.7108	0.00130
44	0.41	34.0	0.000781	4.3864	0.00128
45	0.40	30.2	0.000694	4.062	0.00112
46	0.38	26.7	0.000613	3.7376	0.00103
47	0.36	23.4	0.000538	3.4132	0.00094
48	0.34	20.4	0.000469	3.0888	0.00085
49	0.32	17.7	0.000406	2.7644	0.00076
50	0.30	15.2	0.000348	2.44	0.00067
51	0.29	12.9	0.000296	2.1156	0.00058
52	0.27	10.8	0.000248	1.7912	0.00049
53	0.25	9.0	0.000206	1.4668	0.000407

Elevation	Storage	Outflow
0	0	0.000000
0.175	0.000081	0.000047
0.1933333	0.000106	0.0001371
0.2116667	0.000135	0.0002272
0.23	0.000168	0.0003173
0.2483333	0.000206	0.0004074
0.2666666	0.000248	0.0004975
0.285	0.000296	0.0005876
0.3033333	0.000348	0.0006777
0.3216666	0.000406	0.0007678
0.34	0.000469	0.000858
0.3583333	0.000538	0.0009481
0.3766666	0.000613	0.0010382
0.395	0.000694	0.0011283
0.4133333	0.0007813	0.0012184
0.4316666	0.000875	0.0013085
0.45	0.0009752	0.001399
0.4683333	0.0010821	0.001489
0.4866667	0.0011959	0.001579
0.505	0.0013168	0.001669
0.5233333	0.0014448	0.001759
0.5416666	0.0015802	0.001849
0.56	0.001723	0.001939
0.5783333	0.0018733	0.002029
0.5966666	0.0020314	0.002120
0.615	0.0021973	0.002210
0.6333333	0.0023711	0.002300
0.6516666	0.0025529	0.002390
0.67	0.0027429	0.002480
0.6883333	0.0029411	0.002570
0.7066666	0.0031476	0.002660
0.725	0.0033625	0.002750
0.7433333	0.0035859	0.002840
0.7616666	0.0038179	0.002931
0.78	0.0040586	0.003021
0.7983333	0.0043079	0.003111
0.8166666	0.0045660	0.003201
0.835	0.0048329	0.003291
0.8533333	0.0051087	0.003381
0.8716666	0.0053935	0.003471
0.89	0.0056871	0.003561
0.9083333	0.0059898	0.003651
0.9266667	0.0063015	0.003742
0.945	0.0066223	0.003832
0.9633333	0.0069521	0.003922
0.9816666	0.0072910	0.004012
1	0.0076391	0.004102
1.0183333	0.0079962	0.004192
1.0366666	0.008362	0.004282
1.055	0.0087377	0.004372
1.0733333	0.009122	0.004462
1.0916666	0.009516	0.004553
1.11	0.009918	0.004643
1.12833333	0.010330	0.004733

54	0.23	7.3	0.000168	1.1424	0.000317
55	0.21	5.9	0.000135	0.818	0.000227
56	0.19	4.6	0.000106	0.4936	0.000137
57	0.18	3.5	0.000081	0.1692	0.000047

1.14666667	0.010750	0.004823
1.165	0.011180	0.004913
1.18333333	0.011618	0.005003
1.20166667	0.012066	0.005093
1.22	0.012522	0.0053
1.24	0.013029	0.02799802
1.26	0.013547	0.06949969
1.28	0.014075	0.12324236
1.3	0.014614	0.18688414
1.4	0.017454	0.61814647
1.5	0.020531	1.19429487
1.6	0.023823	1.88512893
1.7	0.027306	2.67403093
1.8	0.030952	3.55004439
1.9	0.034727	4.50523564
2	0.038593	5.53351389

C4: V-notch Weir 0.22 in/hr

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
0	1.72	1220.7	0.028024	29.502	0.008195
1	1.70	1192.1	0.027366	29.144	0.008096
2	1.68	1163.7	0.026714	28.786	0.007996
3	1.67	1135.5	0.026067	28.428	0.007897
4	1.65	1107.6	0.025426	28.07	0.007797
5	1.63	1079.9	0.024792	27.712	0.007698
6	1.61	1052.5	0.024163	27.354	0.007598
7	1.59	1025.4	0.023541	26.996	0.007499
8	1.57	998.6	0.022925	26.638	0.007399
9	1.56	972.1	0.022316	26.28	0.007300
10	1.54	945.9	0.021714	25.922	0.007201
11	1.52	919.9	0.021119	25.564	0.007101
12	1.50	894.3	0.020531	25.206	0.007002
13	1.48	869.0	0.019950	24.848	0.006902
14	1.46	844.0	0.019376	24.49	0.006803
15	1.45	819.4	0.018811	24.132	0.006703
16	1.43	795.1	0.018252	23.774	0.006604
17	1.41	771.1	0.017702	23.416	0.006504
18	1.39	747.5	0.017159	23.058	0.006405
19	1.37	724.2	0.016625	22.7	0.006306
20	1.35	701.2	0.016098	22.342	0.006206
21	1.34	678.7	0.015580	21.984	0.006107
22	1.32	656.5	0.015070	21.626	0.006007
23	1.30	634.6	0.014569	21.268	0.005908
24	1.28	613.1	0.014075	20.91	0.005808
25	1.26	592.0	0.013591	20.552	0.005709
26	1.24	571.3	0.013115	20.194	0.005609
27	1.23	550.9	0.012648	19.836	0.005510
28	1.21	531.0	0.012189	19.478	0.005411
29	1.19	511.4	0.011739	19.12	0.005311
30	1.17	492.2	0.011299	18.762	0.005212
31	1.15	473.3	0.010867	18.404	0.005112
32	1.13	454.9	0.010444	18.046	0.005013
33	1.12	436.9	0.010030	17.688	0.004913
34	1.10	419.2	0.009625	17.33	0.004814
35	1.08	402.0	0.009229	16.972	0.004714
36	1.06	385.1	0.008842	16.614	0.004615
37	1.04	368.7	0.008464	16.256	0.004516
38	1.02	352.6	0.008095	15.898	0.004416
39	1.01	337.0	0.007736	15.54	0.004317
40	0.99	321.7	0.007385	15.182	0.004217
41	0.97	306.8	0.007044	14.824	0.004118
42	0.95	292.3	0.006711	14.466	0.004018
43	0.93	278.3	0.006388	14.108	0.003919
44	0.91	264.6	0.006074	13.75	0.003819
45	0.90	251.3	0.005769	13.392	0.003720
46	0.88	238.4	0.005473	13.034	0.003621
47	0.86	225.9	0.005186	12.676	0.003521
48	0.84	213.8	0.004907	12.318	0.003422
49	0.82	202.0	0.004638	11.96	0.003322
50	0.80	190.7	0.004377	11.602	0.003223
51	0.79	179.7	0.004126	11.244	0.003123
52	0.77	169.1	0.003883	10.886	0.003024
53	0.75	158.9	0.003648	10.528	0.002924
54	0.73	149.1	0.003423	10.17	0.002825
55	0.71	139.6	0.003205	9.812	0.002726

Elevation	Storage	Outflow
0	0.000000	0.000000
0.216667	0.000143	0.000041
0.235	0.000178	0.000140
0.253333	0.000217	0.000239
0.271667	0.000261	0.000339
0.29	0.000309	0.000438
0.308333	0.000363	0.000538
0.326667	0.000423	0.000637
0.345	0.000487	0.000737
0.363333	0.000558	0.000836
0.381667	0.000635	0.000936
0.4	0.000717	0.001035
0.418333	0.000806	0.001134
0.436667	0.000902	0.001234
0.455	0.001004	0.001333
0.473333	0.001113	0.001433
0.491667	0.001228	0.001532
0.51	0.001351	0.001632
0.528333	0.001481	0.001731
0.546667	0.001618	0.001831
0.565	0.001763	0.001930
0.583333	0.001916	0.002029
0.601667	0.002076	0.002129
0.62	0.002244	0.002228
0.638333	0.002420	0.002328
0.656667	0.002604	0.002427
0.675	0.002796	0.002527
0.693333	0.002997	0.002626
0.711667	0.003205	0.002726
0.73	0.003423	0.002825
0.748333	0.003648	0.002924
0.766667	0.003883	0.003024
0.785	0.004126	0.003123
0.803333	0.004377	0.003223
0.821667	0.004638	0.003322
0.84	0.004907	0.003422
0.858333	0.005186	0.003521
0.876667	0.005473	0.003621
0.895	0.005769	0.003720
0.913333	0.006074	0.003819
0.931667	0.006388	0.003919
0.95	0.006711	0.004018
0.968333	0.007044	0.004118
0.986667	0.007385	0.004217
1.005	0.007736	0.004317
1.023333	0.008095	0.004416
1.041667	0.008464	0.004516
1.06	0.008842	0.004615
1.078333	0.009229	0.004714
1.096667	0.009625	0.004814
1.115	0.010030	0.004913
1.133333	0.010444	0.005013
1.151667	0.010867	0.005112
1.17	0.011299	0.005212
1.188333	0.011739	0.005311
1.206667	0.012189	0.005411
1.225	0.012648	0.005510

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
56	0.69	130.5	0.002997	9.454	0.002626
57	0.68	121.8	0.002796	9.096	0.002527
58	0.66	113.4	0.002604	8.738	0.002427
59	0.64	105.4	0.002420	8.38	0.002328
60	0.62	97.7	0.002244	8.022	0.002228
61	0.60	90.4	0.002076	7.664	0.002129
62	0.58	83.4	0.001916	7.306	0.002029
63	0.57	76.8	0.001763	6.948	0.001930
64	0.55	70.5	0.001618	6.59	0.001831
65	0.53	64.5	0.001481	6.232	0.001731
66	0.51	58.9	0.001351	5.874	0.001632
67	0.49	53.5	0.001228	5.516	0.001532
68	0.47	48.5	0.001113	5.158	0.001433
69	0.46	43.7	0.001004	4.8	0.001333
70	0.44	39.3	0.000902	4.442	0.001234
71	0.42	35.1	0.000806	4.084	0.001134
72	0.40	31.2	0.000717	3.726	0.001035
73	0.38	27.6	0.000635	3.368	0.000936
74	0.36	24.3	0.000558	3.01	0.000836
75	0.35	21.2	0.000487	2.652	0.000737
76	0.33	18.4	0.000423	2.294	0.000637
77	0.31	15.8	0.000363	1.936	0.000538
78	0.29	13.5	0.000309	1.578	0.000438
79	0.27	11.4	0.000261	1.22	0.000339
80	0.25	9.4	0.000217	0.862	0.000239
81	0.24	7.7	0.000178	0.504	0.000140
82	0.22	6.2	0.000143	0.146	0.000041

Elevation	Storage	Outflow
1.243333	0.013115	0.005609
1.261667	0.013591	0.005709
1.28	0.014075	0.005808
1.298333	0.014569	0.005908
1.316667	0.015070	0.006007
1.335	0.015580	0.006107
1.353333	0.016098	0.006206
1.371667	0.016625	0.006306
1.39	0.017159	0.006405
1.408333	0.017702	0.006504
1.426667	0.018252	0.006604
1.445	0.018811	0.006703
1.463333	0.019376	0.006803
1.481667	0.019950	0.006902
1.5	0.020531	0.007002
1.518333	0.021119	0.007101
1.536667	0.021714	0.007201
1.555	0.022316	0.007300
1.573333	0.022925	0.007399
1.591667	0.023541	0.007499
1.61	0.024163	0.007598
1.628333	0.024792	0.007698
1.646667	0.025426	0.007797
1.665	0.026067	0.007897
1.683333	0.026714	0.007996
1.701667	0.027366	0.008096
1.72	0.028024	0.008195
1.74	0.028747	0.008335
1.76	0.029477	0.008989
1.78	0.030212	0.010382
1.8	0.030952	0.012684
1.82	0.031698	0.016037
1.84	0.032449	0.020566
1.86	0.033204	0.026382
1.88	0.033964	0.033590
1.9	0.034727	0.042285
1.92	0.035494	0.052559
1.94	0.036265	0.064495
1.96	0.037038	0.078176
1.98	0.037814	0.093679
2	0.038593	0.111079
2.025	0.039568	0.135604
2.05	0.040546	0.163340
2.075	0.041526	0.194413
2.1	0.042506	0.228950
2.2	0.046421	0.404067
2.4	0.054043	0.953831
2.5	0.057633	1.340759

C5: Loam (k = 0.34 cm/hr)

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
0	1.72	1220.7	0.028024	18.023	0.005006
1	1.71	1203.3	0.027623	17.8892	0.004969
2	1.70	1185.9	0.027224	17.7554	0.004932
3	1.69	1168.6	0.026827	17.6216	0.004895
4	1.68	1151.4	0.026433	17.4878	0.004858
5	1.66	1134.3	0.026040	17.354	0.004821
6	1.65	1117.3	0.025650	17.2202	0.004783
7	1.64	1100.4	0.025261	17.0864	0.004746
8	1.63	1083.6	0.024875	16.9526	0.004709
9	1.62	1066.9	0.024492	16.8188	0.004672
10	1.61	1050.2	0.024110	16.685	0.004635
11	1.60	1033.7	0.023731	16.5512	0.004598
12	1.59	1017.3	0.023355	16.4174	0.004560
13	1.57	1001.0	0.022980	16.2836	0.004523
14	1.56	984.8	0.022609	16.1498	0.004486
15	1.55	968.7	0.022239	16.016	0.004449
16	1.54	952.8	0.021873	15.8822	0.004412
17	1.53	936.9	0.021509	15.7484	0.004375
18	1.52	921.2	0.021147	15.6146	0.004337
19	1.51	905.5	0.020788	15.4808	0.004300
20	1.50	890.0	0.020432	15.347	0.004263
21	1.49	874.6	0.020078	15.2132	0.004226
22	1.47	859.3	0.019728	15.0794	0.004189
23	1.46	844.2	0.019380	14.9456	0.004152
24	1.45	829.1	0.019034	14.8118	0.004114
25	1.44	814.2	0.018692	14.678	0.004077
26	1.43	799.4	0.018352	14.5442	0.004040
27	1.42	784.8	0.018016	14.4104	0.004003
28	1.41	770.2	0.017682	14.2766	0.003966
29	1.40	755.8	0.017351	14.1428	0.003929
30	1.39	741.5	0.017023	14.009	0.003891
31	1.37	727.4	0.016698	13.8752	0.003854
32	1.36	713.3	0.016376	13.7414	0.003817
33	1.35	699.5	0.016057	13.6076	0.003780
34	1.34	685.7	0.015741	13.4738	0.003743
35	1.33	672.1	0.015428	13.34	0.003706
36	1.32	658.6	0.015119	13.2062	0.003668
37	1.31	645.2	0.014812	13.0724	0.003631
38	1.30	632.0	0.014508	12.9386	0.003594
39	1.28	618.9	0.014208	12.8048	0.003557
40	1.27	606.0	0.013911	12.671	0.003520
41	1.26	593.1	0.013617	12.5372	0.003483
42	1.25	580.5	0.013326	12.4034	0.003445
43	1.24	567.9	0.013038	12.2696	0.003408
44	1.23	555.5	0.012754	12.1358	0.003371
45	1.22	543.3	0.012472	12.002	0.003334
46	1.21	531.2	0.012194	11.8682	0.003297
47	1.20	519.2	0.011920	11.7344	0.003260
48	1.18	507.4	0.011648	11.6006	0.003222
49	1.17	495.7	0.011380	11.4668	0.003185
50	1.16	484.2	0.011115	11.333	0.003148
51	1.15	472.8	0.010853	11.1992	0.003111
52	1.14	461.5	0.010595	11.0654	0.003074
53	1.13	450.4	0.010340	10.9316	0.003037
54	1.12	439.5	0.010089	10.7978	0.002999
55	1.11	428.6	0.009840	10.664	0.002962

Elevation	Storage	Outflow
0	0.000000	0.000000
0.23	0.000159	0.000026
0.24	0.000181	0.000063
0.25	0.000204	0.000100
0.26	0.000229	0.000138
0.27	0.000256	0.000175
0.28	0.000285	0.000212
0.29	0.000315	0.000249
0.30	0.000348	0.000286
0.31	0.000383	0.000323
0.33	0.000419	0.000361
0.34	0.000458	0.000398
0.35	0.000498	0.000435
0.36	0.000541	0.000472
0.37	0.000586	0.000509
0.38	0.000634	0.000546
0.39	0.000683	0.000584
0.40	0.000735	0.000621
0.41	0.000789	0.000658
0.43	0.000846	0.000695
0.44	0.000904	0.000732
0.45	0.000966	0.000769
0.46	0.001030	0.000807
0.47	0.001096	0.000844
0.48	0.001165	0.000881
0.49	0.001237	0.000918
0.50	0.001311	0.000955
0.52	0.001388	0.000992
0.53	0.001467	0.001030
0.54	0.001549	0.001067
0.55	0.001634	0.001104
0.56	0.001722	0.001141
0.57	0.001813	0.001178
0.58	0.001906	0.001215
0.59	0.002002	0.001253
0.60	0.002101	0.001290
0.62	0.002204	0.001327
0.63	0.002308	0.001364
0.64	0.002416	0.001401
0.65	0.002527	0.001438
0.66	0.002641	0.001476
0.67	0.002758	0.001513
0.68	0.002878	0.001550
0.69	0.003001	0.001587
0.70	0.003127	0.001624
0.72	0.003257	0.001661
0.73	0.003389	0.001699
0.74	0.003525	0.001736
0.75	0.003663	0.001773
0.76	0.003805	0.001810
0.77	0.003950	0.001847
0.78	0.004099	0.001884
0.79	0.004250	0.001922
0.81	0.004405	0.001959
0.82	0.004563	0.001996
0.83	0.004724	0.002033
0.84	0.004889	0.002070

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
56	1.10	418.0	0.009595	10.5302	0.002925
57	1.08	407.4	0.009354	10.3964	0.002888
58	1.07	397.1	0.009116	10.2626	0.002851
59	1.06	386.8	0.008881	10.1288	0.002814
60	1.05	376.8	0.008649	9.995	0.002776
61	1.04	366.8	0.008421	9.8612	0.002739
62	1.03	357.0	0.008196	9.7274	0.002702
63	1.02	347.4	0.007975	9.5936	0.002665
64	1.01	337.9	0.007757	9.4598	0.002628
65	0.99	328.5	0.007542	9.326	0.002591
66	0.98	319.3	0.007331	9.1922	0.002553
67	0.97	310.3	0.007123	9.0584	0.002516
68	0.96	301.4	0.006918	8.9246	0.002479
69	0.95	292.6	0.006717	8.7908	0.002442
70	0.94	284.0	0.006519	8.657	0.002405
71	0.93	275.5	0.006325	8.5232	0.002368
72	0.92	267.2	0.006134	8.3894	0.002330
73	0.91	259.0	0.005946	8.2556	0.002293
74	0.89	251.0	0.005761	8.1218	0.002256
75	0.88	243.1	0.005580	7.988	0.002219
76	0.87	235.3	0.005402	7.8542	0.002182
77	0.86	227.7	0.005228	7.7204	0.002145
78	0.85	220.3	0.005057	7.5866	0.002107
79	0.84	213.0	0.004889	7.4528	0.002070
80	0.83	205.8	0.004724	7.319	0.002033
81	0.82	198.8	0.004563	7.1852	0.001996
82	0.81	191.9	0.004405	7.0514	0.001959
83	0.79	185.1	0.004250	6.9176	0.001922
84	0.78	178.5	0.004099	6.7838	0.001884
85	0.77	172.1	0.003950	6.65	0.001847
86	0.76	165.8	0.003805	6.5162	0.001810
87	0.75	159.6	0.003663	6.3824	0.001773
88	0.74	153.5	0.003525	6.2486	0.001736
89	0.73	147.6	0.003389	6.1148	0.001699
90	0.72	141.9	0.003257	5.981	0.001661
91	0.70	136.2	0.003127	5.8472	0.001624
92	0.69	130.7	0.003001	5.7134	0.001587
93	0.68	125.4	0.002878	5.5796	0.001550
94	0.67	120.1	0.002758	5.4458	0.001513
95	0.66	115.1	0.002641	5.312	0.001476
96	0.65	110.1	0.002527	5.1782	0.001438
97	0.64	105.3	0.002416	5.0444	0.001401
98	0.63	100.6	0.002308	4.9106	0.001364
99	0.62	96.0	0.002204	4.7768	0.001327
100	0.60	91.5	0.002101	4.643	0.001290
101	0.59	87.2	0.002002	4.5092	0.001253
102	0.58	83.0	0.001906	4.3754	0.001215
103	0.57	79.0	0.001813	4.2416	0.001178
104	0.56	75.0	0.001722	4.1078	0.001141
105	0.55	71.2	0.001634	3.974	0.001104
106	0.54	67.5	0.001549	3.8402	0.001067
107	0.53	63.9	0.001467	3.7064	0.001030
108	0.52	60.4	0.001388	3.5726	0.000992
109	0.50	57.1	0.001311	3.4388	0.000955
110	0.49	53.9	0.001237	3.305	0.000918

Elevation	Storage	Outflow
0.85	0.005057	0.002107
0.86	0.005228	0.002145
0.87	0.005402	0.002182
0.88	0.005580	0.002219
0.89	0.005761	0.002256
0.91	0.005946	0.002293
0.92	0.006134	0.002330
0.93	0.006325	0.002368
0.94	0.006519	0.002405
0.95	0.006717	0.002442
0.96	0.006918	0.002479
0.97	0.007123	0.002516
0.98	0.007331	0.002553
0.99	0.007542	0.002591
1.01	0.007757	0.002628
1.02	0.007975	0.002665
1.03	0.008196	0.002702
1.04	0.008421	0.002739
1.05	0.008649	0.002776
1.06	0.008881	0.002814
1.07	0.009116	0.002851
1.08	0.009354	0.002888
1.10	0.009595	0.002925
1.11	0.009840	0.002962
1.12	0.010089	0.002999
1.13	0.010340	0.003037
1.14	0.010595	0.003074
1.15	0.010853	0.003111
1.16	0.011115	0.003148
1.17	0.011380	0.003185
1.18	0.011648	0.003222
1.20	0.011920	0.003260
1.21	0.012194	0.003297
1.22	0.012472	0.003334
1.23	0.012754	0.003371
1.24	0.013038	0.003408
1.25	0.013326	0.003445
1.26	0.013617	0.003483
1.27	0.013911	0.003520
1.28	0.014208	0.003557
1.30	0.014508	0.003594
1.31	0.014812	0.003631
1.32	0.015119	0.003668
1.33	0.015428	0.003706
1.34	0.015741	0.003743
1.35	0.016057	0.003780
1.36	0.016376	0.003817
1.37	0.016698	0.003854
1.39	0.017023	0.003891
1.40	0.017351	0.003929
1.41	0.017682	0.003966
1.42	0.018016	0.004003
1.43	0.018352	0.004040
1.44	0.018692	0.004077
1.45	0.019034	0.004114
1.46	0.019380	0.004152

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
111	0.48	50.8	0.001165	3.1712	0.000881
112	0.47	47.7	0.001096	3.0374	0.000844
113	0.46	44.9	0.001030	2.9036	0.000807
114	0.45	42.1	0.000966	2.7698	0.000769
115	0.44	39.4	0.000904	2.636	0.000732
116	0.43	36.8	0.000846	2.5022	0.000695
117	0.41	34.4	0.000789	2.3684	0.000658
118	0.40	32.0	0.000735	2.2346	0.000621
119	0.39	29.8	0.000683	2.1008	0.000584
120	0.38	27.6	0.000634	1.967	0.000546
121	0.37	25.5	0.000586	1.8332	0.000509
122	0.36	23.6	0.000541	1.6994	0.000472
123	0.35	21.7	0.000498	1.5656	0.000435
124	0.34	19.9	0.000458	1.4318	0.000398
125	0.33	18.3	0.000419	1.298	0.000361
126	0.31	16.7	0.000383	1.1642	0.000323
127	0.30	15.2	0.000348	1.0304	0.000286
128	0.29	13.7	0.000315	0.8966	0.000249
129	0.28	12.4	0.000285	0.7628	0.000212
130	0.27	11.2	0.000256	0.629	0.000175
131	0.26	10.0	0.000229	0.4952	0.000138
132	0.25	8.9	0.000204	0.3614	0.000100
133	0.24	7.9	0.000181	0.2276	0.000063
134	0.23	6.9	0.000159	0.0938	0.000026

Elevation	Storage	Outflow
1.47	0.019728	0.004189
1.49	0.020078	0.004226
1.50	0.020432	0.004263
1.51	0.020788	0.004300
1.52	0.021147	0.004337
1.53	0.021509	0.004375
1.54	0.021873	0.004412
1.55	0.022239	0.004449
1.56	0.022609	0.004486
1.57	0.022980	0.004523
1.59	0.023355	0.004560
1.60	0.023731	0.004598
1.61	0.024110	0.004635
1.62	0.024492	0.004672
1.63	0.024875	0.004709
1.64	0.025261	0.004746
1.65	0.025650	0.004783
1.66	0.026040	0.004821
1.68	0.026433	0.004858
1.69	0.026827	0.004895
1.70	0.027224	0.004932
1.71	0.027623	0.004969
1.72	0.028024	0.005006
1.8	0.030952	0.009496
1.9	0.034727	0.039097
2	0.038593	0.107890
2.1	0.042506	0.225761
2.2	0.046421	0.400878
2.3	0.050285	0.640369
2.4	0.054043	0.950642
2.5	0.057633	1.337571
3	0.070629	4.602029

C6: Silt Loam (k = 0.65 cm/hr)

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
0	1.72	1220.7	0.028024	34.176	0.00949
1	1.70	1187.4	0.027259	33.6962	0.009360
2	1.68	1154.4	0.026502	33.2164	0.009227
3	1.66	1121.8	0.025753	32.7366	0.009094
4	1.63	1089.5	0.025011	32.2568	0.008960
5	1.61	1057.6	0.024278	31.777	0.008827
6	1.59	1026.0	0.023554	31.2972	0.008694
7	1.57	994.8	0.022838	30.8174	0.008560
8	1.55	964.0	0.022131	30.3376	0.008427
9	1.53	933.7	0.021434	29.8578	0.008294
10	1.51	903.7	0.020746	29.378	0.008161
11	1.49	874.2	0.020068	28.8982	0.008027
12	1.46	845.1	0.019400	28.4184	0.007894
13	1.44	816.4	0.018742	27.9386	0.007761
14	1.42	788.2	0.018095	27.4588	0.007627
15	1.40	760.5	0.017458	26.979	0.007494
16	1.38	733.2	0.016832	26.4992	0.007361
17	1.36	706.4	0.016216	26.0194	0.007228
18	1.34	680.1	0.015612	25.5396	0.007094
19	1.31	654.2	0.015019	25.0598	0.006961
20	1.29	628.9	0.014437	24.58	0.006828
21	1.27	604.1	0.013867	24.1002	0.006695
22	1.25	579.7	0.013309	23.6204	0.006561
23	1.23	555.9	0.012762	23.1406	0.006428
24	1.21	532.6	0.012227	22.6608	0.006295
25	1.19	509.8	0.011704	22.181	0.006161
26	1.17	487.5	0.011193	21.7012	0.006028
27	1.14	465.8	0.010694	21.2214	0.005895
28	1.12	444.6	0.010207	20.7416	0.005762
29	1.10	423.9	0.009732	20.2618	0.005628
30	1.08	403.8	0.009269	19.782	0.005495
31	1.06	384.2	0.008819	19.3022	0.005362
32	1.04	365.1	0.008381	18.8224	0.005228
33	1.02	346.5	0.007955	18.3426	0.005095
34	0.99	328.5	0.007542	17.8628	0.004962
35	0.97	311.1	0.007141	17.383	0.004829
36	0.95	294.1	0.006752	16.9032	0.004695
37	0.93	277.7	0.006376	16.4234	0.004562
38	0.91	261.9	0.006012	15.9436	0.004429
39	0.89	246.5	0.005660	15.4638	0.004296
40	0.87	231.7	0.005320	14.984	0.004162
41	0.85	217.5	0.004992	14.5042	0.004029
42	0.82	203.7	0.004677	14.0244	0.003896
43	0.80	190.5	0.004373	13.5446	0.003762
44	0.78	177.8	0.004081	13.0648	0.003629
45	0.76	165.6	0.003801	12.585	0.003496
46	0.74	153.9	0.003533	12.1052	0.003363
47	0.72	142.7	0.003276	11.6254	0.003229
48	0.70	132.0	0.003031	11.1456	0.003096
49	0.68	121.8	0.002797	10.6658	0.002963
50	0.65	112.1	0.002574	10.186	0.002829
51	0.63	102.9	0.002362	9.7062	0.002696
52	0.61	94.1	0.002161	9.2264	0.002563
53	0.59	85.9	0.001971	8.7466	0.002430
54	0.57	78.0	0.001791	8.2668	0.002296
55	0.55	70.6	0.001622	7.787	0.002163

Elevation	Storage	Outflow
0	0.000000	0.000000
0.205892	0.0001251	3.06E-05
0.227218	0.0001626	0.000164
0.248543	0.0002062	0.000297
0.269869	0.0002561	0.00043
0.291194	0.0003127	0.000564
0.312520	0.0003763	0.000697
0.333845	0.0004473	0.00083
0.355171	0.0005259	0.000964
0.376496	0.0006124	0.001097
0.397822	0.0007071	0.00123
0.419147	0.0008103	0.001363
0.440472	0.0009223	0.001497
0.461798	0.0010432	0.00163
0.483123	0.0011734	0.001763
0.504449	0.0013131	0.001897
0.525774	0.0014625	0.00203
0.547100	0.0016217	0.002163
0.568425	0.0017912	0.002296
0.589751	0.0019709	0.00243
0.611076	0.0021611	0.002563
0.632402	0.0023621	0.002696
0.653727	0.0025739	0.002829
0.675052	0.0027967	0.002963
0.696378	0.0030307	0.003096
0.717703	0.003276	0.003229
0.739029	0.0035327	0.003363
0.760354	0.0038011	0.003496
0.781680	0.0040811	0.003629
0.803005	0.0043729	0.003762
0.824331	0.0046765	0.003896
0.845656	0.0049922	0.004029
0.866982	0.0053199	0.004162
0.888307	0.0056597	0.004296
0.909633	0.0060117	0.004429
0.930958	0.0063758	0.004562
0.952283	0.0067523	0.004695
0.973609	0.007141	0.004829
0.994934	0.007542	0.004962
1.016260	0.0079554	0.005095
1.037585	0.008381	0.005228
1.058911	0.008819	0.005362
1.080236	0.0092693	0.005495
1.101562	0.0097318	0.005628
1.122887	0.0102066	0.005762
1.144213	0.0106935	0.005895
1.165538	0.0111926	0.006028
1.186864	0.0117037	0.006161
1.208189	0.0122268	0.006295
1.229514	0.0127619	0.006428
1.250840	0.0133087	0.006561
1.272165	0.0138673	0.006695
1.293491	0.0144374	0.006828
1.314816	0.0150191	0.006961
1.336142	0.0156121	0.007094
1.357467	0.0162163	0.007228
1.378793	0.0168316	0.007361

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
56	0.53	63.7	0.001462	7.3072	0.002030
57	0.50	57.2	0.001313	6.8274	0.001897
58	0.48	51.1	0.001173	6.3476	0.001763
59	0.46	45.4	0.001043	5.8678	0.001630
60	0.44	40.2	0.000922	5.388	0.001497
61	0.42	35.3	0.000810	4.9082	0.001363
62	0.40	30.8	0.000707	4.4284	0.001230
63	0.38	26.7	0.000612	3.9486	0.001097
64	0.36	22.9	0.000526	3.4688	0.000964
65	0.33	19.5	0.000447	2.989	0.000830
66	0.31	16.4	0.000376	2.5092	0.000697
67	0.29	13.6	0.000313	2.0294	0.000564
68	0.27	11.2	0.000256	1.5496	0.000430
69	0.25	9.0	0.000206	1.0698	0.000297
70	0.23	7.1	0.000163	0.59	0.000164
71	0.21	5.5	0.000125	0.1102	0.000031

Elevation	Storage	Outflow
1.400118	0.0174578	0.007494
1.421444	0.0180947	0.007627
1.442769	0.0187422	0.007761
1.464094	0.0194001	0.007894
1.485420	0.0200681	0.008027
1.506745	0.0207462	0.008161
1.528071	0.021434	0.008294
1.549396	0.0221313	0.008427
1.570722	0.022838	0.00856
1.592047	0.0235537	0.008694
1.613373	0.0242782	0.008827
1.634698	0.0250113	0.00896
1.656024	0.0257527	0.009094
1.677349	0.0265021	0.009227
1.698675	0.0272591	0.00936
1.720000	0.0280237	0.009493
1.8	0.030952	0.013983
1.9	0.034727	0.034090
2	0.038593	0.102884
2.1	0.042506	0.220755
2.2	0.046421	0.395872
2.3	0.050285	0.635363
2.4	0.054043	0.945636
2.5	0.057633	1.332564
3	0.070629	4.597022

C7: Sandy Loam (k = 1.09 cm/hr)

Time (hr)	Depth (ft)	Volume (ft^3)	Storage (Ac. Ft)	dV/dt (ft^3/hr)	Outflow (cfs)
0	1.72	1220.7	0.028024	57.81	0.016058
1	1.68	1165.0	0.026746	56.4336	0.015676
2	1.65	1110.3	0.025489	55.0572	0.015294
3	1.61	1056.6	0.024256	53.6808	0.014911
4	1.58	1003.9	0.023046	52.3044	0.014529
5	1.54	952.3	0.021862	50.928	0.014147
6	1.51	901.9	0.020704	49.5516	0.013764
7	1.47	852.6	0.019574	48.1752	0.013382
8	1.43	804.6	0.018472	46.7988	0.013000
9	1.40	757.9	0.017400	45.4224	0.012617
10	1.36	712.5	0.016357	44.046	0.012235
11	1.33	668.5	0.015346	42.6696	0.011853
12	1.29	625.8	0.014367	41.2932	0.011470
13	1.26	584.6	0.013419	39.9168	0.011088
14	1.22	544.7	0.012505	38.5404	0.010706
15	1.18	506.4	0.011624	37.164	0.010323
16	1.15	469.5	0.010777	35.7876	0.009941
17	1.11	434.0	0.009964	34.4112	0.009559
18	1.08	400.1	0.009185	33.0348	0.009176
19	1.04	367.7	0.008441	31.6584	0.008794
20	1.00	336.8	0.007731	30.282	0.008412
21	0.97	307.4	0.007056	28.9056	0.008029
22	0.93	279.5	0.006416	27.5292	0.007647
23	0.90	253.1	0.005810	26.1528	0.007265
24	0.86	228.2	0.005238	24.7764	0.006882
25	0.83	204.7	0.004700	23.4	0.006500
26	0.79	182.8	0.004196	22.0236	0.006118
27	0.75	162.3	0.003726	20.6472	0.005735
28	0.72	143.2	0.003288	19.2708	0.005353
29	0.68	125.5	0.002882	17.8944	0.004971
30	0.65	109.2	0.002508	16.518	0.004588
31	0.61	94.3	0.002164	15.1416	0.004206
32	0.58	80.6	0.001851	13.7652	0.003824
33	0.54	68.2	0.001567	12.3888	0.003441
34	0.50	57.1	0.001311	11.0124	0.003059
35	0.47	47.1	0.001082	9.636	0.002677
36	0.43	38.3	0.000880	8.2596	0.002294
37	0.40	30.6	0.000703	6.8832	0.001912
38	0.36	23.9	0.000549	5.5068	0.001530
39	0.33	18.2	0.000418	4.1304	0.001147
40	0.29	13.4	0.000308	2.754	0.000765
41	0.25	9.5	0.000218	1.3776	0.000383
42	0.22	6.3	0.000146	0.0012	0.000000

Elevation	Storage	Outflow
0	0.000000	0.000000
0.218031	0.0001458	0.0000003
0.253793	0.0002179	0.000383
0.289554	0.0003081	0.000765
0.325315	0.000418	0.001147
0.361076	0.000549	0.00153
0.396837	0.0007026	0.001912
0.432598	0.0008799	0.002294
0.468360	0.0010823	0.002677
0.504121	0.0013109	0.003059
0.539882	0.0015667	0.003441
0.575643	0.0018508	0.003824
0.611404	0.0021641	0.004206
0.647165	0.0025075	0.004588
0.682927	0.0028818	0.004971
0.718688	0.0032876	0.005353
0.754449	0.0037256	0.005735
0.790210	0.0041964	0.006118
0.825971	0.0047004	0.0065
0.861732	0.0052381	0.006882
0.897493	0.0058098	0.007265
0.933255	0.0064158	0.007647
0.969016	0.0070562	0.008029
1.004777	0.0077313	0.008412
1.040538	0.008441	0.008794
1.076299	0.0091852	0.009176
1.112060	0.009964	0.009559
1.147822	0.0107771	0.009941
1.183583	0.0116243	0.010323
1.219344	0.0125052	0.010706
1.255105	0.0134195	0.011088
1.290866	0.0143666	0.01147
1.326627	0.0153461	0.011853
1.362388	0.0163573	0.012235
1.398150	0.0173995	0.012617
1.433911	0.018472	0.013
1.469672	0.0195738	0.013382
1.505433	0.0207042	0.013764
1.541194	0.021862	0.014147
1.576955	0.0230462	0.014529
1.612717	0.0242558	0.014911
1.648478	0.0254894	0.015294
1.684239	0.0267458	0.015676
1.720000	0.0280237	0.016058
1.8	0.030952	0.004489
1.9	0.034727	0.034090
2	0.038593	0.102884
2.1	0.042506	0.220755
2.2	0.046421	0.395872
2.3	0.050285	0.635363
2.4	0.054043	0.945636
2.5	0.057633	1.332564

C8: Loamy Sand (k = 2.99 cm/hr)

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft^3)	(Ac. Ft)	(ft^3/hr)	(cfs)
0	1.72	1220.7	0.028024	157.34	0.043706
1	1.62	1070.3	0.024570	147.18	0.040883
2	1.52	927.6	0.021296	137.02	0.038061
3	1.43	793.8	0.018223	126.86	0.035239
4	1.33	669.7	0.015374	116.7	0.032417
5	1.23	555.9	0.012762	106.54	0.029594
6	1.13	453.0	0.010400	96.38	0.026772
7	1.03	361.3	0.008295	86.22	0.023950
8	0.94	281.0	0.006450	76.06	0.021128
9	0.84	211.9	0.004864	65.9	0.018306
10	0.74	153.9	0.003533	55.74	0.015483
11	0.64	106.5	0.002445	45.58	0.012661
12	0.54	69.2	0.001589	35.42	0.009839
13	0.44	41.2	0.000946	25.26	0.007017
14	0.35	21.5	0.000494	15.1	0.004194
15	0.25	9.0	0.000206	4.94	0.001372

Elevation	Storage	Outflow
0	0.000000	0.000000
0.248543	0.0002062	0.001372
0.346640	0.0004935	0.004194
0.444738	0.0009458	0.007017
0.542835	0.0015891	0.009839
0.640932	0.0024455	0.012661
0.739029	0.0035327	0.015483
0.837126	0.0048645	0.018306
0.935223	0.0064501	0.021128
1.033320	0.0082949	0.02395
1.131417	0.0103999	0.026772
1.229514	0.0127619	0.029594
1.327612	0.0153735	0.032417
1.425709	0.0182234	0.035239
1.523806	0.0212956	0.038061
1.621903	0.0245704	0.040883
1.720000	0.0280237	0.0437056
1.8	0.030952	0.048195
1.9	0.034727	0.077796
2	0.038593	0.146589
2.1	0.042506	0.264461
2.2	0.046421	0.439578
2.3	0.050285	0.679068
2.4	0.054043	0.989341
2.5	0.057633	1.376270
3	0.070629	4.640728

C9: Weir Elev. 2.22 ft

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft3)	(Ac. Ft)	(ft3/hr)	(cfs)
0	2.22	2056.02	0.0472	37.528	0.010424
1	2.201667	2024.93	0.04649	37.1932	0.010331
2	2.183333	1993.77	0.04577	36.8584	0.010238
3	2.165	1962.55	0.04505	36.5236	0.010145
4	2.146667	1931.28	0.04434	36.1888	0.010052
5	2.128333	1899.98	0.04362	35.854	0.009959
6	2.11	1868.67	0.0429	35.5192	0.009866
7	2.091667	1837.34	0.04218	35.1844	0.009773
8	2.073333	1806.03	0.04146	34.8496	0.00968
9	2.055	1774.73	0.04074	34.5148	0.009587
10	2.036667	1743.47	0.04002	34.18	0.009494
11	2.018333	1712.25	0.03931	33.8452	0.009401
12	2	1681.1	0.03859	33.5104	0.009308
13	1.981667	1650.01	0.03788	33.1756	0.009215
14	1.963333	1619.01	0.03717	32.8408	0.009122
15	1.945	1588.11	0.03646	32.506	0.009029
16	1.926667	1557.31	0.03575	32.1712	0.008936
17	1.908333	1526.62	0.03505	31.8364	0.008843
18	1.89	1496.07	0.03434	31.5016	0.00875
19	1.871667	1465.65	0.03365	31.1668	0.008657
20	1.853333	1435.39	0.03295	30.832	0.008564
21	1.835	1405.28	0.03226	30.4972	0.008471
22	1.816667	1375.34	0.03157	30.1624	0.008378
23	1.798333	1345.59	0.03089	29.8276	0.008285
24	1.78	1316.03	0.03021	29.4928	0.008192
25	1.761667	1286.66	0.02954	29.158	0.008099
26	1.743333	1257.5	0.02887	28.8232	0.008006
27	1.725	1228.56	0.0282	28.4884	0.007913
28	1.706667	1199.85	0.02754	28.1536	0.00782
29	1.688333	1171.38	0.02689	27.8188	0.007727
30	1.67	1143.14	0.02624	27.484	0.007634
31	1.651667	1115.16	0.0256	27.1492	0.007541
32	1.633333	1087.44	0.02496	26.8144	0.007448
33	1.615	1059.98	0.02433	26.4796	0.007355
34	1.596667	1032.8	0.02371	26.1448	0.007262
35	1.578333	1005.9	0.02309	25.81	0.007169
36	1.56	979.295	0.02248	25.4752	0.007076
37	1.541667	952.982	0.02188	25.1404	0.006983
38	1.523333	926.971	0.02128	24.8056	0.00689
39	1.505	901.269	0.02069	24.4708	0.006797
40	1.486667	875.883	0.02011	24.136	0.006704
41	1.468333	850.816	0.01953	23.8012	0.006611
42	1.45	826.077	0.01896	23.4664	0.006518
43	1.431667	801.669	0.0184	23.1316	0.006425
44	1.413333	777.599	0.01785	22.7968	0.006332
45	1.395	753.871	0.01731	22.462	0.006239
46	1.376667	730.491	0.01677	22.1272	0.006146
47	1.358333	707.462	0.01624	21.7924	0.006053
48	1.34	684.789	0.01572	21.4576	0.00596

Elevation	Storage	Outflow
0	0	0
0.1666667	7.07E-05	8.44E-06
0.185	9.39E-05	0.000101
0.2033333	0.000121	0.000194
0.2216667	0.000152	0.000287
0.24	0.000188	0.00038
0.2583333	0.000228	0.000473
0.2766667	0.000273	0.000566
0.295	0.000324	0.000659
0.3133333	0.000379	0.000752
0.3316667	0.00044	0.000845
0.35	0.000506	0.000938
0.3683333	0.000578	0.001031
0.3866667	0.000657	0.001124
0.405	0.000741	0.001217
0.4233333	0.000832	0.00131
0.4416667	0.000929	0.001403
0.46	0.001033	0.001496
0.4783333	0.001143	0.001589
0.4966667	0.001261	0.001682
0.515	0.001386	0.001775
0.5333333	0.001518	0.001868
0.5516667	0.001657	0.001961
0.57	0.001804	0.002054
0.5883333	0.001959	0.002147
0.6066667	0.002121	0.00224
0.625	0.002291	0.002333
0.6433333	0.002469	0.002426
0.6616667	0.002656	0.002519
0.68	0.00285	0.002612
0.6983333	0.003053	0.002705
0.7166667	0.003264	0.002798
0.735	0.003483	0.002891
0.7533333	0.003711	0.002984
0.7716667	0.003948	0.003077
0.79	0.004194	0.00317
0.8083333	0.004448	0.003263
0.8266667	0.004711	0.003356
0.845	0.004982	0.003449
0.8633333	0.005263	0.003542
0.8816667	0.005553	0.003635
0.9	0.005851	0.003728
0.9183333	0.006159	0.003821
0.9366667	0.006475	0.003914
0.955	0.006801	0.004007
0.9733333	0.007136	0.0041
0.9916667	0.00748	0.004193
1.01	0.007833	0.004286
1.0283333	0.008195	0.004379
1.0466667	0.008566	0.004472

Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft3)	(Ac. Ft)	(ft3/hr)	(cfs)
49	1.321667	662.476	0.01521	21.1228	0.005867
50	1.303333	640.527	0.0147	20.788	0.005774
51	1.285	618.946	0.01421	20.4532	0.005681
52	1.266667	597.736	0.01372	20.1184	0.005588
53	1.248333	576.901	0.01324	19.7836	0.005495
54	1.23	556.444	0.01277	19.4488	0.005402
55	1.211667	536.366	0.01231	19.114	0.005309
56	1.193333	516.672	0.01186	18.7792	0.005216
57	1.175	497.363	0.01142	18.4444	0.005123
58	1.156667	478.441	0.01098	18.1096	0.00503
59	1.138333	459.909	0.01056	17.7748	0.004937
60	1.12	441.767	0.01014	17.44	0.004844
61	1.101667	424.018	0.00973	17.1052	0.004751
62	1.083333	406.663	0.00934	16.7704	0.004658
63	1.065	389.702	0.00895	16.4356	0.004565
64	1.046667	373.137	0.00857	16.1008	0.004472
65	1.028333	356.968	0.00819	15.766	0.004379
66	1.01	341.196	0.00783	15.4312	0.004286
67	0.991667	325.82	0.00748	15.0964	0.004193
68	0.973333	310.84	0.00714	14.7616	0.0041
69	0.955	296.257	0.0068	14.4268	0.004007
70	0.936667	282.069	0.00648	14.092	0.003914
71	0.918333	268.276	0.00616	13.7572	0.003821
72	0.9	254.877	0.00585	13.4224	0.003728
73	0.881667	241.87	0.00555	13.0876	0.003635
74	0.863333	229.255	0.00526	12.7528	0.003542
75	0.845	217.029	0.00498	12.418	0.003449
76	0.826667	205.191	0.00471	12.0832	0.003356
77	0.808333	193.739	0.00445	11.7484	0.003263
78	0.79	182.67	0.00419	11.4136	0.00317
79	0.771667	171.981	0.00395	11.0788	0.003077
80	0.753333	161.671	0.00371	10.744	0.002984
81	0.735	151.735	0.00348	10.4092	0.002891
82	0.716667	142.171	0.00326	10.0744	0.002798
83	0.698333	132.976	0.00305	9.7396	0.002705
84	0.68	124.145	0.00285	9.4048	0.002612
85	0.661667	115.675	0.00266	9.07	0.002519
86	0.643333	107.562	0.00247	8.7352	0.002426
87	0.625	99.8008	0.00229	8.4004	0.002333
88	0.606667	92.3877	0.00212	8.0656	0.00224
89	0.588333	85.3175	0.00196	7.7308	0.002147
90	0.57	78.5855	0.0018	7.396	0.002054
91	0.551667	72.1862	0.00166	7.0612	0.001961
92	0.533333	66.1143	0.00152	6.7264	0.001868
93	0.515	60.3642	0.00139	6.3916	0.001775
94	0.496667	54.9299	0.00126	6.0568	0.001682
95	0.478333	49.8054	0.00114	5.722	0.001589
96	0.46	44.9842	0.00103	5.3872	0.001496
97	0.441667	40.4599	0.00093	5.0524	0.001403

Elevation	Storage	Outflow
1.065	0.008946	0.004565
1.0833333	0.009336	0.004658
1.1016667	0.009734	0.004751
1.12	0.010142	0.004844
1.1383333	0.010558	0.004937
1.1566667	0.010983	0.00503
1.175	0.011418	0.005123
1.1933333	0.011861	0.005216
1.2116667	0.012313	0.005309
1.23	0.012774	0.005402
1.2483333	0.013244	0.005495
1.2666667	0.013722	0.005588
1.285	0.014209	0.005681
1.3033333	0.014704	0.005774
1.3216667	0.015208	0.005867
1.34	0.015721	0.00596
1.3583333	0.016241	0.006053
1.3766667	0.01677	0.006146
1.395	0.017307	0.006239
1.4133333	0.017851	0.006332
1.4316667	0.018404	0.006425
1.45	0.018964	0.006518
1.4683333	0.019532	0.006611
1.4866667	0.020107	0.006704
1.505	0.02069	0.006797
1.5233333	0.02128	0.00689
1.5416667	0.021877	0.006983
1.56	0.022482	0.007076
1.5783333	0.023092	0.007169
1.5966667	0.02371	0.007262
1.615	0.024334	0.007355
1.6333333	0.024964	0.007448
1.6516667	0.025601	0.007541
1.67	0.026243	0.007634
1.6883333	0.026891	0.007727
1.7066667	0.027545	0.00782
1.725	0.028204	0.007913
1.7433333	0.028868	0.008006
1.7616667	0.029538	0.008099
1.78	0.030212	0.008192
1.7983333	0.03089	0.008285
1.8166667	0.031574	0.008378
1.835	0.032261	0.008471
1.8533333	0.032952	0.008564
1.8716667	0.033647	0.008657
1.89	0.034345	0.00875
1.9083333	0.035046	0.008843
1.9266667	0.035751	0.008936
1.945	0.036458	0.009029

Time	Depth	Volume	Storage	dV/dt	Outflow		Elevation	Storage	Outflow
(hr)	(ft)	(ft3)	(Ac. Ft)	(ft3/hr)	(cfs)				
98	0.423333	36.2257	0.00083	4.7176	0.00131		1.9633333	0.037167	0.009122
99	0.405	32.2746	0.00074	4.3828	0.001217		1.9816667	0.037879	0.009215
100	0.386667	28.5993	0.00066	4.048	0.001124		2	0.038593	0.009308
101	0.368333	25.1925	0.00058	3.7132	0.001031		2.0183333	0.039308	0.009401
102	0.35	22.0464	0.00051	3.3784	0.000938		2.0366667	0.040025	0.009494
103	0.331667	19.1532	0.00044	3.0436	0.000845		2.055	0.040742	0.009587
104	0.313333	16.5048	0.00038	2.7088	0.000752		2.0733333	0.041461	0.00968
105	0.295	14.0928	0.00032	2.374	0.000659		2.0916667	0.04218	0.009773
106	0.276667	11.9086	0.00027	2.0392	0.000566		2.11	0.042899	0.009866
107	0.258333	9.94355	0.00023	1.7044	0.000473		2.1283333	0.043618	0.009959
108	0.24	8.18859	0.00019	1.3696	0.00038		2.1466667	0.044336	0.010052
109	0.221667	6.63449	0.00015	1.0348	0.000287		2.165	0.045054	0.010145
110	0.203333	5.27181	0.00012	0.7	0.000194		2.1833333	0.045771	0.010238
111	0.185	4.09089	9.4E-05	0.3652	0.000101		2.2016667	0.046486	0.010331
112	0.166667	3.08183	7.1E-05	0.0304	8.44E-06		2.22	0.0472	0.010424
							2.3	0.050285	0.192009
							2.4	0.054043	0.623274
							2.5	0.057633	1.199425
							2.6	0.06099	1.890262
							2.7	0.064045	2.679168
							2.8	0.066723	3.555186
							2.9	0.068946	4.510382
							3	0.070629	5.538665

C10: Weir Elev. 2.72 ft

Time	Depth	Volume	Storage	dV/dt	Outflow		Elevation	Storage	Outflow
(hr)	(ft)	(ft3)	(Ac. Ft)	(ft3/hr)	(cfs)		0	0	0
0	2.72	2814.5	0.064613	37.284	0.010357		0.19	0.000101	0.002345
1	2.70	2791.9	0.064093	37.075	0.010299		0.208333	0.000129	0.0024031
2	2.68	2768.7	0.063560	36.866	0.010241		0.226667	0.000162	0.0024611
3	2.67	2744.9	0.063014	36.657	0.010183		0.245	0.000199	0.0025192
4	2.65	2720.6	0.062457	36.448	0.010124		0.263333	0.00024	0.0025772
5	2.63	2695.9	0.061889	36.239	0.010066		0.281667	0.000287	0.0026353
6	2.61	2670.7	0.061310	36.03	0.010008		0.3	0.000338	0.0026933
7	2.59	2645.0	0.060721	35.821	0.009950		0.318333	0.000395	0.0027514
8	2.57	2618.9	0.060121	35.612	0.009892		0.336667	0.000457	0.0028094
9	2.56	2592.4	0.059512	35.403	0.009834		0.355	0.000525	0.0028675
10	2.54	2565.4	0.058894	35.194	0.009776		0.373333	0.000599	0.0029256
11	2.52	2538.1	0.058267	34.985	0.009718		0.391667	0.000679	0.0029836
12	2.50	2510.5	0.057633	34.776	0.009660		0.41	0.000765	0.0030417
13	2.48	2482.5	0.056990	34.567	0.009602		0.428333	0.000857	0.0030997
14	2.46	2454.2	0.056340	34.358	0.009544		0.446667	0.000956	0.0031578
15	2.45	2425.5	0.055683	34.149	0.009486		0.465	0.001062	0.0032158
16	2.43	2396.6	0.055019	33.94	0.009428		0.483333	0.001175	0.0032739
17	2.41	2367.4	0.054349	33.731	0.009370		0.501667	0.001294	0.0033319
18	2.39	2338.0	0.053673	33.522	0.009312		0.52	0.001421	0.00339
19	2.37	2308.3	0.052992	33.313	0.009254		0.538333	0.001555	0.0034481
20	2.35	2278.5	0.052306	33.104	0.009196		0.556667	0.001696	0.0035061
21	2.34	2248.4	0.051616	32.895	0.009138		0.575	0.001845	0.0035642
22	2.32	2218.1	0.050920	32.686	0.009079		0.593333	0.002002	0.0036222
23	2.30	2187.7	0.050222	32.477	0.009021		0.611667	0.002167	0.0036803
24	2.28	2157.1	0.049519	32.268	0.008963		0.63	0.002339	0.0037383
25	2.26	2126.3	0.048813	32.059	0.008905		0.648333	0.002519	0.0037964
26	2.24	2095.5	0.048105	31.85	0.008847		0.666667	0.002708	0.0038544
27	2.23	2064.5	0.047394	31.641	0.008789		0.685	0.002904	0.0039125
28	2.21	2033.4	0.046681	31.432	0.008731		0.703333	0.003109	0.0039706
29	2.19	2002.3	0.045966	31.223	0.008673		0.721667	0.003323	0.0040286
30	2.17	1971.1	0.045250	31.014	0.008615		0.74	0.003545	0.0040867
31	2.15	1939.8	0.044532	30.805	0.008557		0.758333	0.003775	0.0041447
32	2.13	1908.5	0.043814	30.596	0.008499		0.776667	0.004014	0.0042028
33	2.12	1877.2	0.043095	30.387	0.008441		0.795	0.004262	0.0042608
34	2.10	1845.9	0.042376	30.178	0.008383		0.813333	0.004518	0.0043189
35	2.08	1814.6	0.041657	29.969	0.008325		0.831667	0.004784	0.0043769
36	2.06	1783.3	0.040938	29.76	0.008267		0.85	0.005058	0.004435
37	2.04	1752.0	0.040220	29.551	0.008209		0.868333	0.005341	0.0044931
38	2.02	1720.8	0.039503	29.342	0.008151		0.886667	0.005633	0.0045511
39	2.01	1689.6	0.038788	29.133	0.008093		0.905	0.005934	0.0046092
40	1.99	1658.5	0.038074	28.924	0.008034		0.923333	0.006244	0.0046672
41	1.97	1627.5	0.037361	28.715	0.007976		0.941667	0.006563	0.0047253
42	1.95	1596.5	0.036651	28.506	0.007918		0.96	0.006892	0.0047833
43	1.93	1565.7	0.035943	28.297	0.007860		0.978333	0.007229	0.0048414
44	1.91	1535.0	0.035238	28.088	0.007802		0.996667	0.007575	0.0048994
45	1.90	1504.4	0.034536	27.879	0.007744		1.015	0.007931	0.0049575
46	1.88	1473.9	0.033837	27.67	0.007686		1.033333	0.008295	0.0050156
47	1.86	1443.6	0.033141	27.461	0.007628		1.051667	0.008669	0.0050736
48	1.84	1413.5	0.032449	27.252	0.007570		1.07	0.009052	0.0051317
49	1.82	1383.5	0.031761	27.043	0.007512		1.088333	0.009443	0.0051897

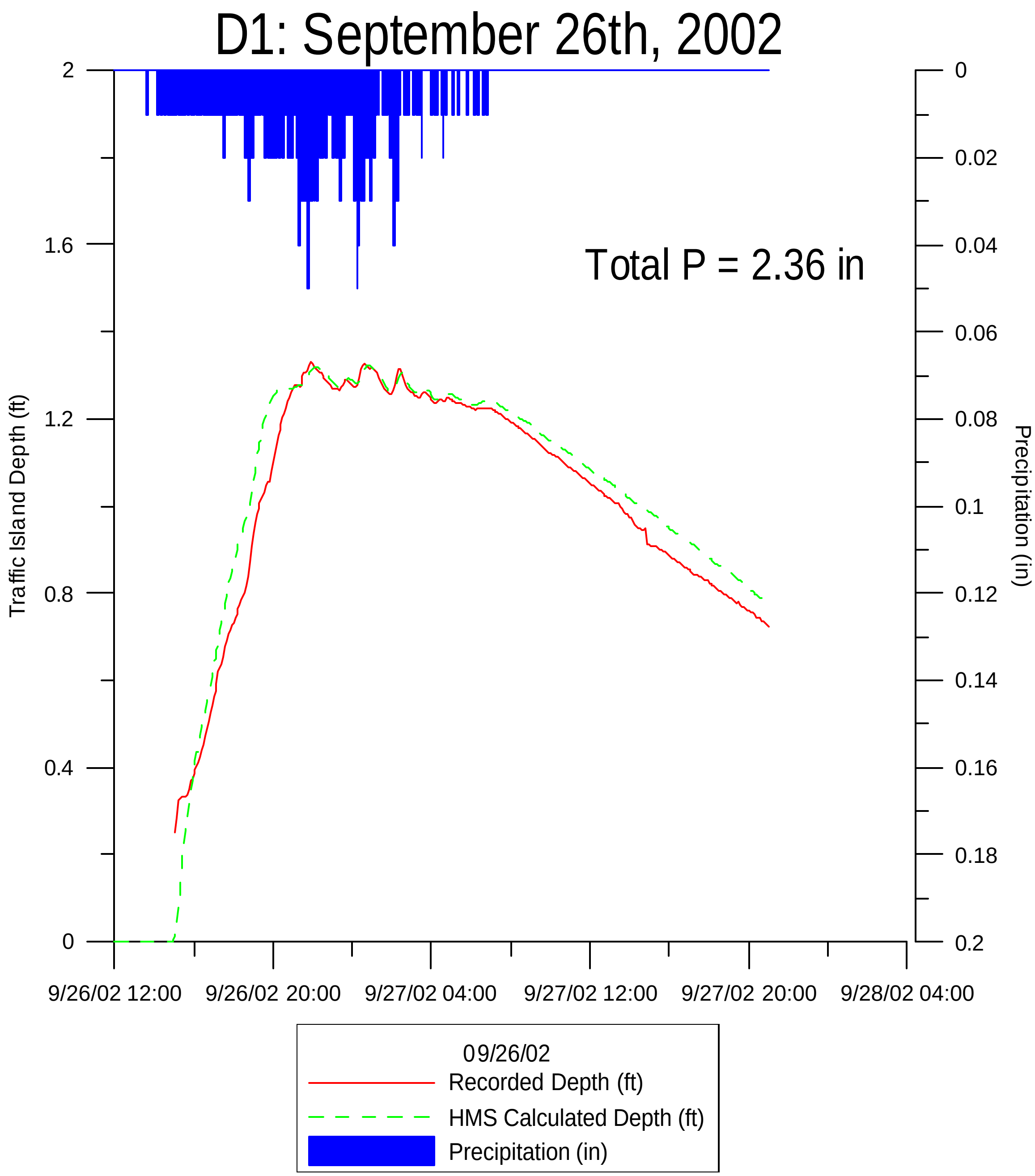
Time	Depth	Volume	Storage	dV/dt	Outflow		Elevation	Storage	Outflow
(hr)	(ft)	(ft3)	(Ac. Ft)	(ft3/hr)	(cfs)		0	0	0
50	1.80	1353.7	0.031076	26.834	0.007454		1.106667	0.009844	0.0052478
51	1.79	1324.1	0.030396	26.625	0.007396		1.125	0.010254	0.0053058
52	1.77	1294.6	0.029721	26.416	0.007338		1.143333	0.010673	0.0053639
53	1.75	1265.4	0.029050	26.207	0.007280		1.161667	0.011101	0.0054219
54	1.73	1236.4	0.028385	25.998	0.007222		1.18	0.011538	0.00548
55	1.71	1207.7	0.027724	25.789	0.007164		1.198333	0.011984	0.0055381
56	1.69	1179.1	0.027069	25.58	0.007106		1.216667	0.012438	0.0055961
57	1.68	1150.8	0.026419	25.371	0.007048		1.235	0.012901	0.0056542
58	1.66	1122.8	0.025775	25.162	0.006989		1.253333	0.013373	0.0057122
59	1.64	1095.0	0.025137	24.953	0.006931		1.271667	0.013854	0.0057703
60	1.62	1067.4	0.024505	24.744	0.006873		1.29	0.014343	0.0058283
61	1.60	1040.2	0.023879	24.535	0.006815		1.308333	0.014841	0.0058864
62	1.58	1013.2	0.023260	24.326	0.006757		1.326667	0.015347	0.0059444
63	1.57	986.5	0.022647	24.117	0.006699		1.345	0.015862	0.0060025
64	1.55	960.1	0.022042	23.908	0.006641		1.363333	0.016384	0.0060606
65	1.53	934.0	0.021442	23.699	0.006583		1.381667	0.016915	0.0061186
66	1.51	908.2	0.020851	23.49	0.006525		1.4	0.017454	0.0061767
67	1.49	882.8	0.020266	23.281	0.006467		1.418333	0.018001	0.0062347
68	1.47	857.6	0.019688	23.072	0.006409		1.436667	0.018556	0.0062928
69	1.46	832.8	0.019118	22.863	0.006351		1.455	0.019118	0.0063508
70	1.44	808.3	0.018556	22.654	0.006293		1.473333	0.019688	0.0064089
71	1.42	784.1	0.018001	22.445	0.006235		1.491667	0.020266	0.0064669
72	1.40	760.3	0.017454	22.236	0.006177		1.51	0.020851	0.006525
73	1.38	736.8	0.016915	22.027	0.006119		1.528333	0.021442	0.0065831
74	1.36	713.7	0.016384	21.818	0.006061		1.546667	0.022042	0.0066411
75	1.35	690.9	0.015862	21.609	0.006003		1.565	0.022647	0.0066992
76	1.33	668.5	0.015347	21.4	0.005944		1.583333	0.02326	0.0067572
77	1.31	646.5	0.014841	21.191	0.005886		1.601667	0.023879	0.0068153
78	1.29	624.8	0.014343	20.982	0.005828		1.62	0.024505	0.0068733
79	1.27	603.5	0.013854	20.773	0.005770		1.638333	0.025137	0.0069314
80	1.25	582.5	0.013373	20.564	0.005712		1.656667	0.025775	0.0069894
81	1.24	562.0	0.012901	20.355	0.005654		1.675	0.026419	0.0070475
82	1.22	541.8	0.012438	20.146	0.005596		1.693333	0.027069	0.0071056
83	1.20	522.0	0.011984	19.937	0.005538		1.711667	0.027724	0.0071636
84	1.18	502.6	0.011538	19.728	0.005480		1.73	0.028385	0.0072217
85	1.16	483.6	0.011101	19.519	0.005422		1.748333	0.02905	0.0072797
86	1.14	464.9	0.010673	19.31	0.005364		1.766667	0.029721	0.0073378
87	1.13	446.7	0.010254	19.101	0.005306		1.785	0.030396	0.0073958
88	1.11	428.8	0.009844	18.892	0.005248		1.803333	0.031076	0.0074539
89	1.09	411.4	0.009443	18.683	0.005190		1.821667	0.031761	0.0075119
90	1.07	394.3	0.009052	18.474	0.005132		1.84	0.032449	0.00757
91	1.05	377.6	0.008669	18.265	0.005074		1.858333	0.033141	0.0076281
92	1.03	361.3	0.008295	18.056	0.005016		1.876667	0.033837	0.0076861
93	1.02	345.5	0.007931	17.847	0.004958		1.895	0.034536	0.0077442
94	1.00	330.0	0.007575	17.638	0.004899		1.913333	0.035238	0.0078022
95	0.98	314.9	0.007229	17.429	0.004841		1.931667	0.035943	0.0078603
96	0.96	300.2	0.006892	17.22	0.004783		1.95	0.036651	0.0079183
97	0.94	285.9	0.006563	17.011	0.004725		1.968333	0.037361	0.0079764
98	0.92	272.0	0.006244	16.802	0.004667		1.986667	0.038074	0.0080344
99	0.91	258.5	0.005934	16.593	0.004609		2.005	0.038788	0.0080925

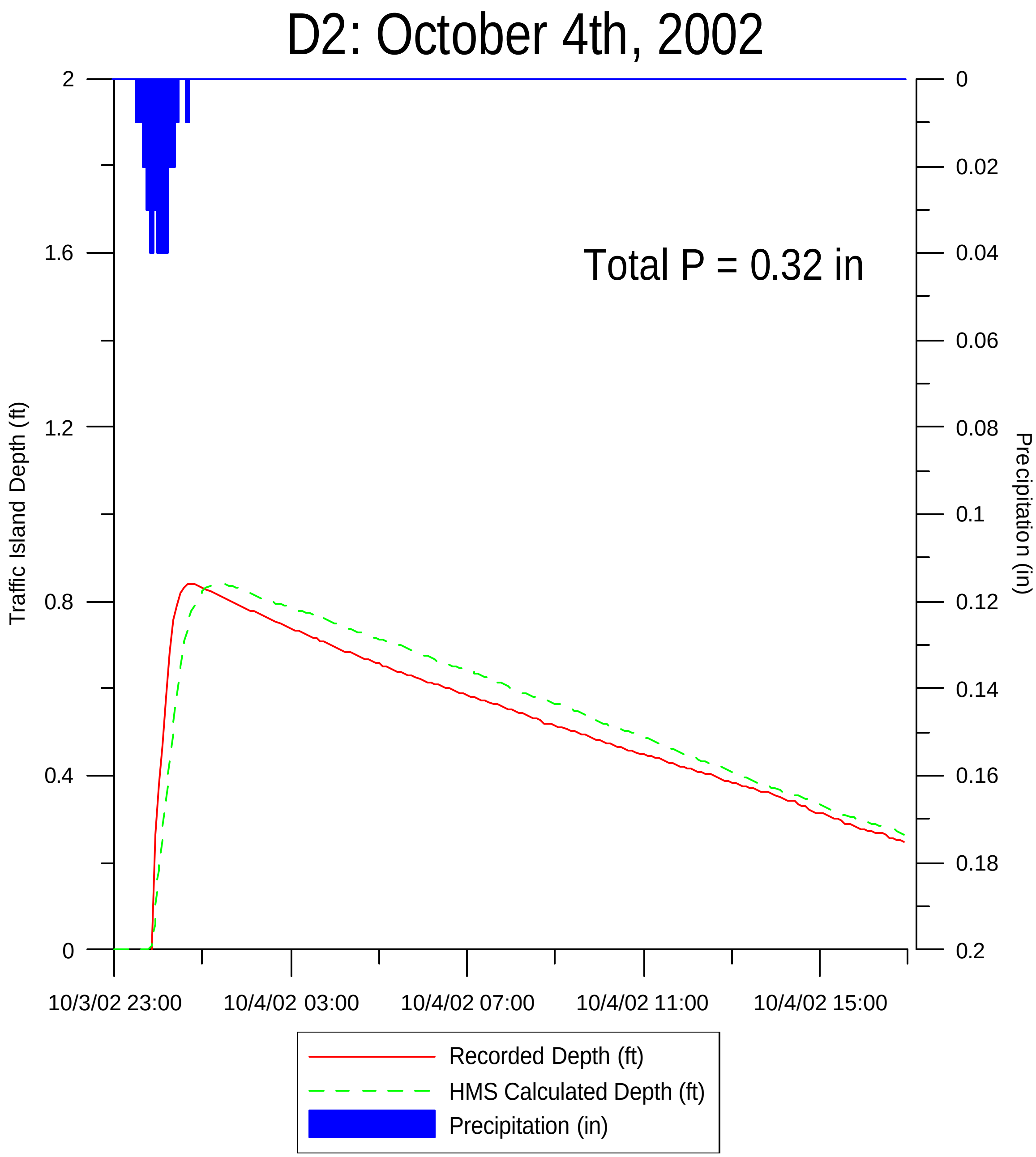
Time	Depth	Volume	Storage	dV/dt	Outflow
(hr)	(ft)	(ft3)	(Ac. Ft)	(ft3/hr)	(cfs)
100	0.89	245.4	0.005633	16.384	0.004551
101	0.87	232.7	0.005341	16.175	0.004493
102	0.85	220.3	0.005058	15.966	0.004435
103	0.83	208.4	0.004784	15.757	0.004377
104	0.81	196.8	0.004518	15.548	0.004319
105	0.80	185.7	0.004262	15.339	0.004261
106	0.78	174.9	0.004014	15.13	0.004203
107	0.76	164.4	0.003775	14.921	0.004145
108	0.74	154.4	0.003545	14.712	0.004087
109	0.72	144.7	0.003323	14.503	0.004029
110	0.70	135.4	0.003109	14.294	0.003971
111	0.69	126.5	0.002904	14.085	0.003913
112	0.67	117.9	0.002708	13.876	0.003854
113	0.65	109.7	0.002519	13.667	0.003796
114	0.63	101.9	0.002339	13.458	0.003738
115	0.61	94.4	0.002167	13.249	0.003680
116	0.59	87.2	0.002002	13.04	0.003622
117	0.58	80.4	0.001845	12.831	0.003564
118	0.56	73.9	0.001696	12.622	0.003506
119	0.54	67.7	0.001555	12.413	0.003448
120	0.52	61.9	0.001421	12.204	0.003390
121	0.50	56.4	0.001294	11.995	0.003332
122	0.48	51.2	0.001175	11.786	0.003274
123	0.47	46.3	0.001062	11.577	0.003216
124	0.45	41.7	0.000956	11.368	0.003158
125	0.43	37.4	0.000857	11.159	0.003100
126	0.41	33.3	0.000765	10.95	0.003042
127	0.39	29.6	0.000679	10.741	0.002984
128	0.37	26.1	0.000599	10.532	0.002926
129	0.36	22.9	0.000525	10.323	0.002868
130	0.34	19.9	0.000457	10.114	0.002809
131	0.32	17.2	0.000395	9.905	0.002751
132	0.30	14.7	0.000338	9.696	0.002693
133	0.28	12.5	0.000287	9.487	0.002635
134	0.26	10.5	0.000240	9.278	0.002577
135	0.25	8.6	0.000199	9.069	0.002519
136	0.23	7.0	0.000162	8.86	0.002461
137	0.21	5.6	0.000129	8.651	0.002403
138	0.19	4.4	0.000101	8.442	0.002345
139	0.17	3.3	0.000077	8.233	0.002287
140	0.15	2.5	0.000056	8.024	0.002229
141	0.14	1.7	0.000039	7.815	0.002171
142	0.12	1.1	0.000026	7.606	0.002113
143	0.10	0.7	0.000015	7.397	0.002055
144	0.08	0.3	0.000007	7.188	0.001997

Elevation	Storage	Outflow
2.023333	0.039503	0.0081506
2.041667	0.04022	0.0082086
2.06	0.040938	0.0082667
2.078333	0.041657	0.0083247
2.096667	0.042376	0.0083828
2.115	0.043095	0.0084408
2.133333	0.043814	0.0084989
2.151667	0.044532	0.0085569
2.17	0.04525	0.008615
2.188333	0.045966	0.0086731
2.206667	0.046681	0.0087311
2.225	0.047394	0.0087892
2.243333	0.048105	0.0088472
2.261667	0.048813	0.0089053
2.28	0.049519	0.0089633
2.298333	0.050222	0.0090214
2.316667	0.05092	0.0090794
2.335	0.051616	0.0091375
2.353333	0.052306	0.0091956
2.371667	0.052992	0.0092536
2.39	0.053673	0.0093117
2.408333	0.054349	0.0093697
2.426667	0.055019	0.0094278
2.445	0.055683	0.0094858
2.463333	0.05634	0.0095439
2.481667	0.05699	0.0096019
2.5	0.057633	0.00966
2.518333	0.058267	0.0097181
2.536667	0.058894	0.0097761
2.555	0.059512	0.0098342
2.573333	0.060121	0.0098922
2.591667	0.060721	0.0099503
2.61	0.06131	0.0100083
2.628333	0.061889	0.0100664
2.646667	0.062457	0.0101244
2.665	0.063014	0.0101825
2.683333	0.06356	0.0102406
2.701667	0.064093	0.0102986
2.72	0.064613	0.0103567
2.8	0.066723	0.177925
2.9	0.068946	0.600903
3	0.070629	1.170543
3.2	0.072025	2.643961

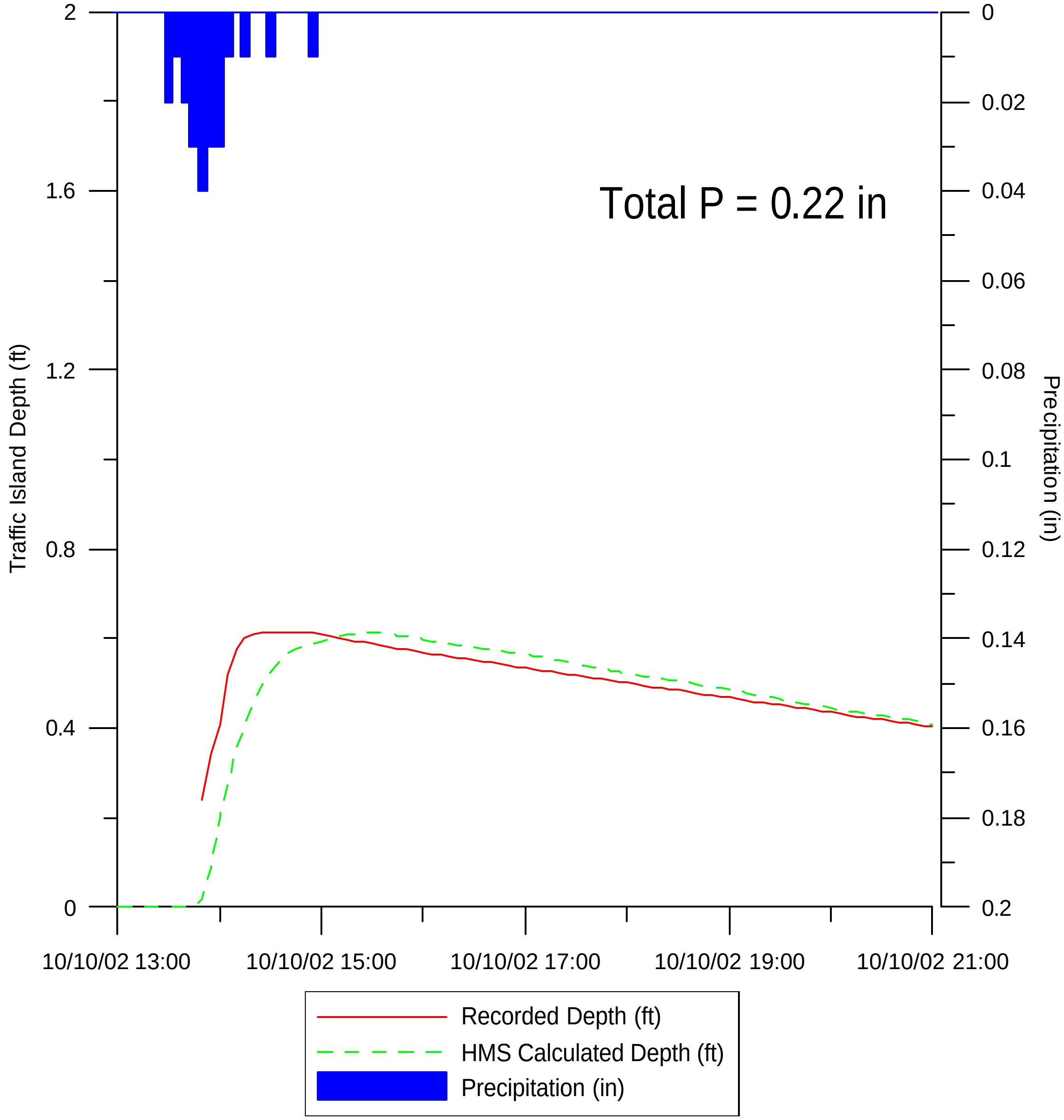
Appendix D: Storm Data for Calibration

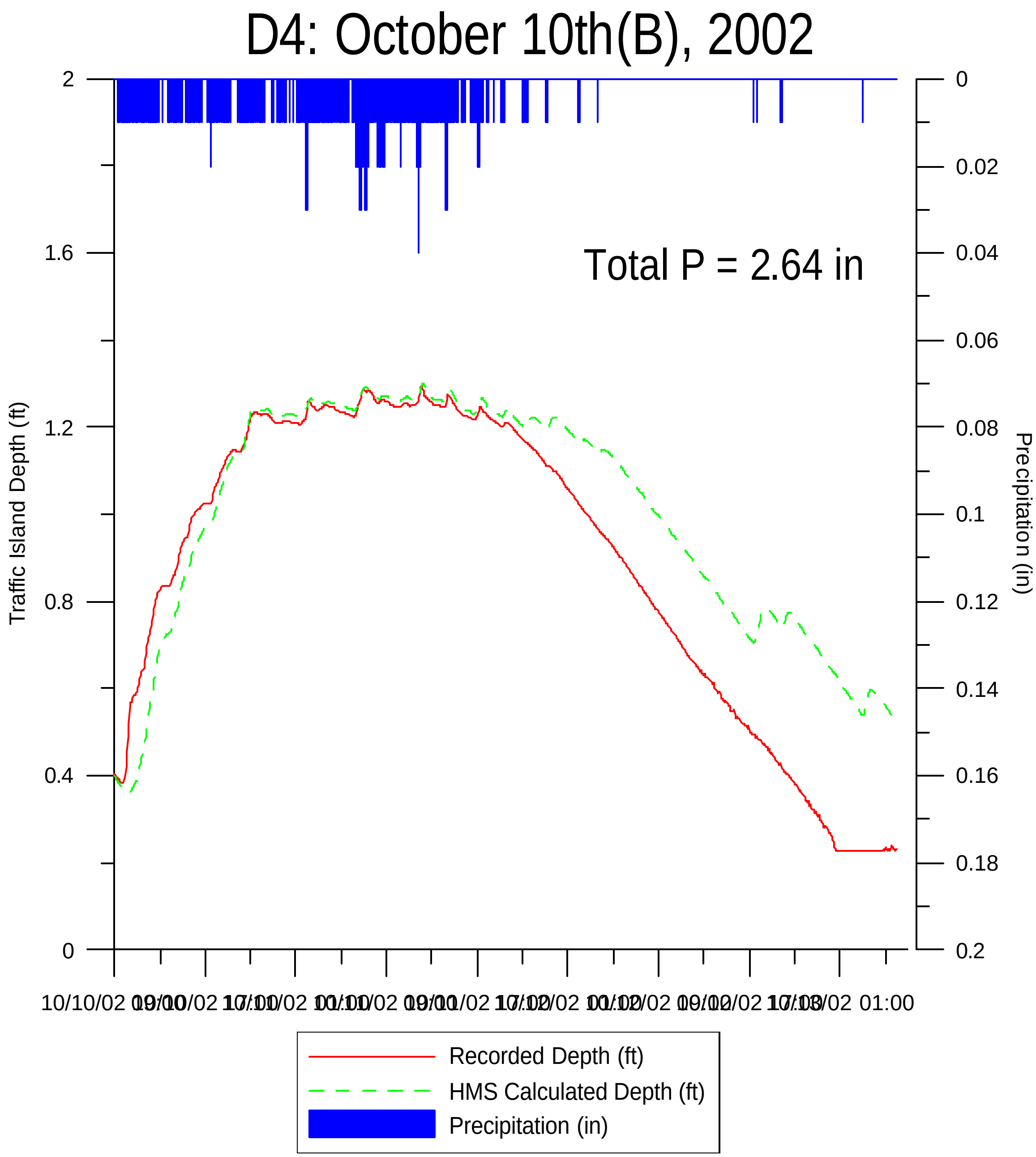
Appendix D contains a graphical representation of the calibration runs for each of the twelve storms used in the process. Starting with the earliest storm (09/26/02) and ending with the latest (03/20/03). Calibration was done based on calculating the volume of runoff flowing over the weir. The graphs show the recorded water surface elevation in the traffic island versus the calculated water surface elevation in the model.

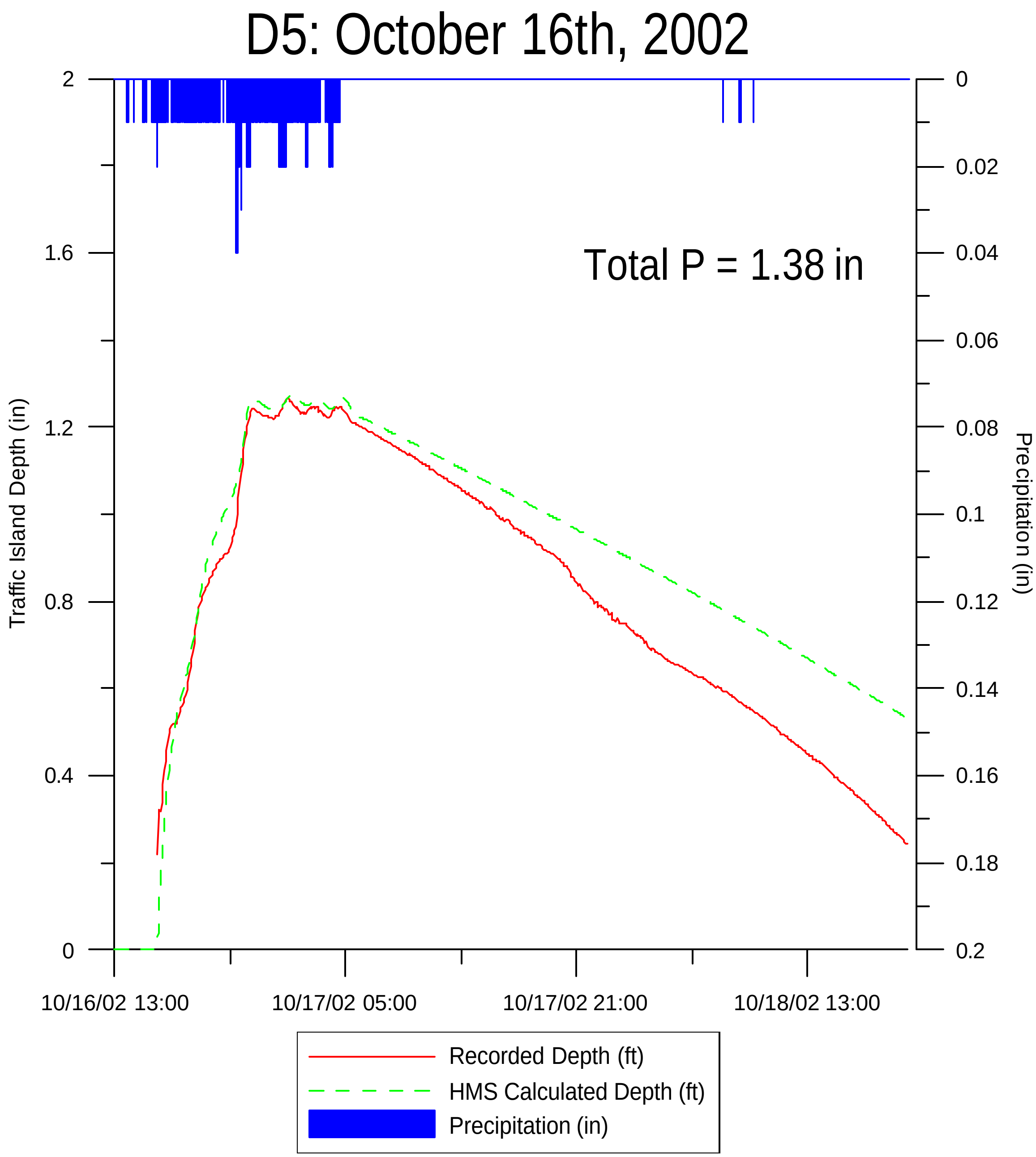

D1: September 26th, 2002
Total P = 2.36 in
Traffic Island Depth (ft)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
9/26/02 12:00
9/26/02 20:00
9/27/02 04:00
9/27/02 12:00
9/27/02 20:00
9/28/02 04:00
09/26/02
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)

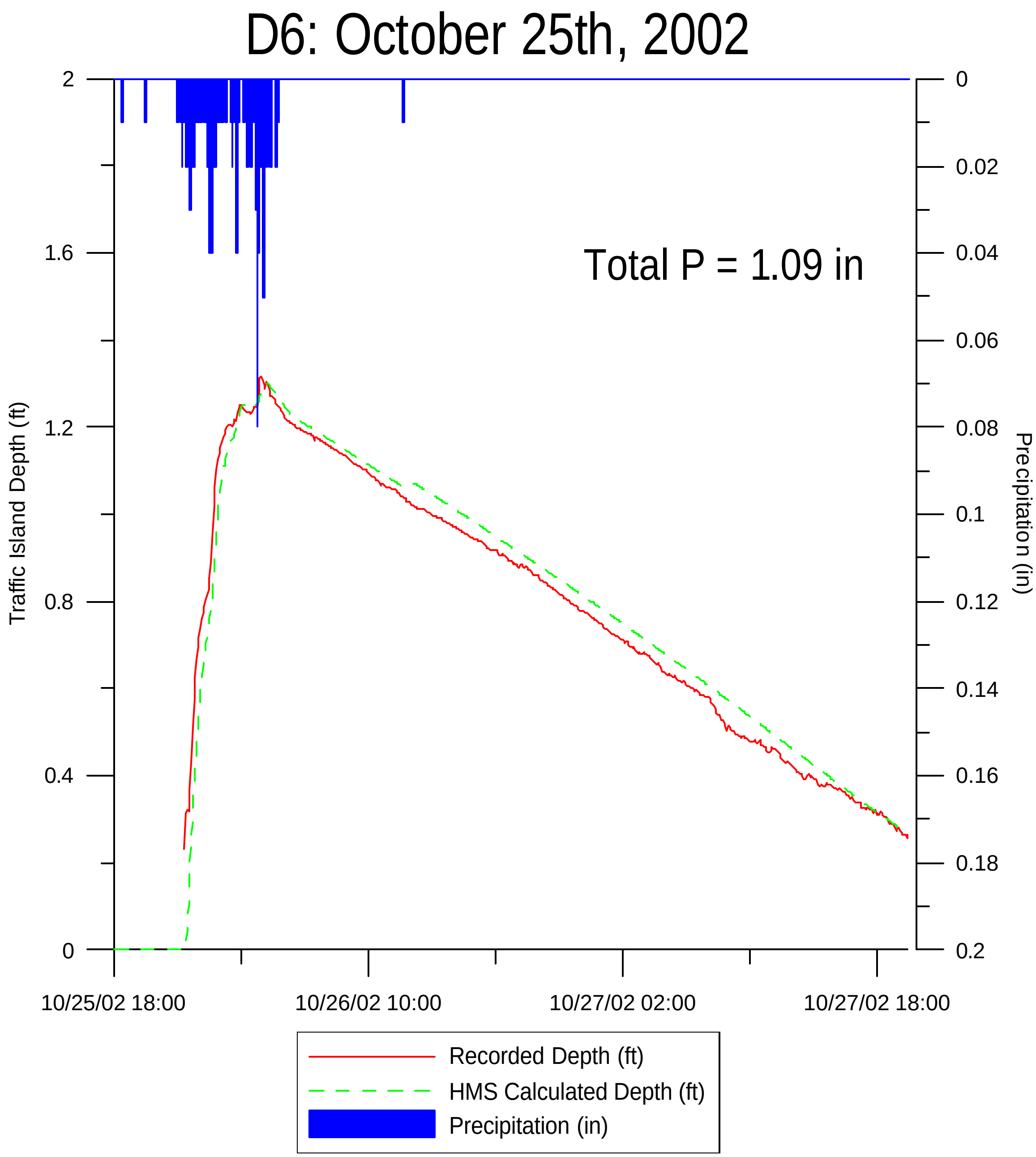

D2: October 4th, 2002
Total P = 0.32 in
Traffic Island Depth (ft)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10/3/02 23:00
10/4/02 03:00
10/4/02 07:00
10/4/02 11:00
10/4/02 15:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)

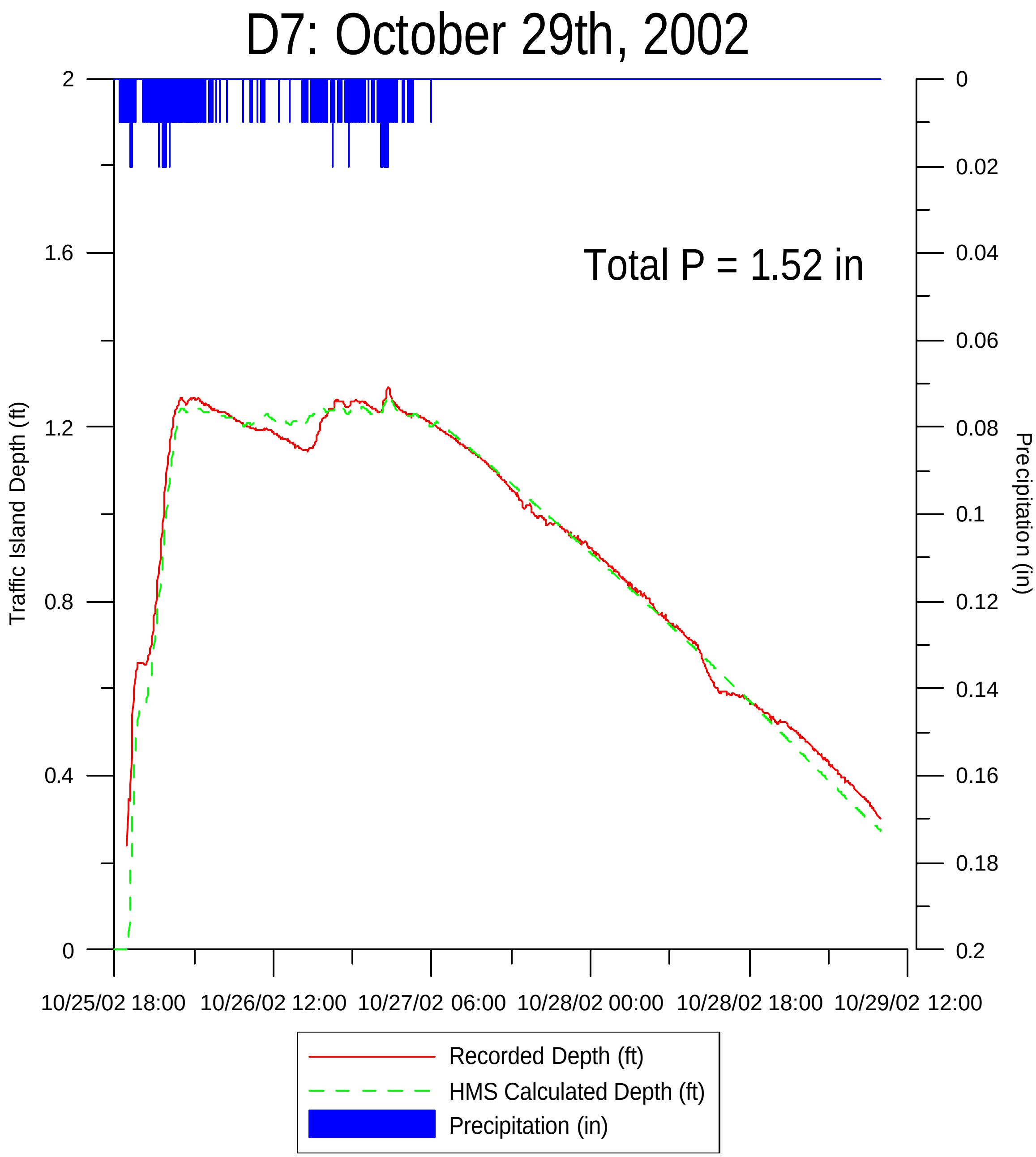
D3: October 10th(A), 2002



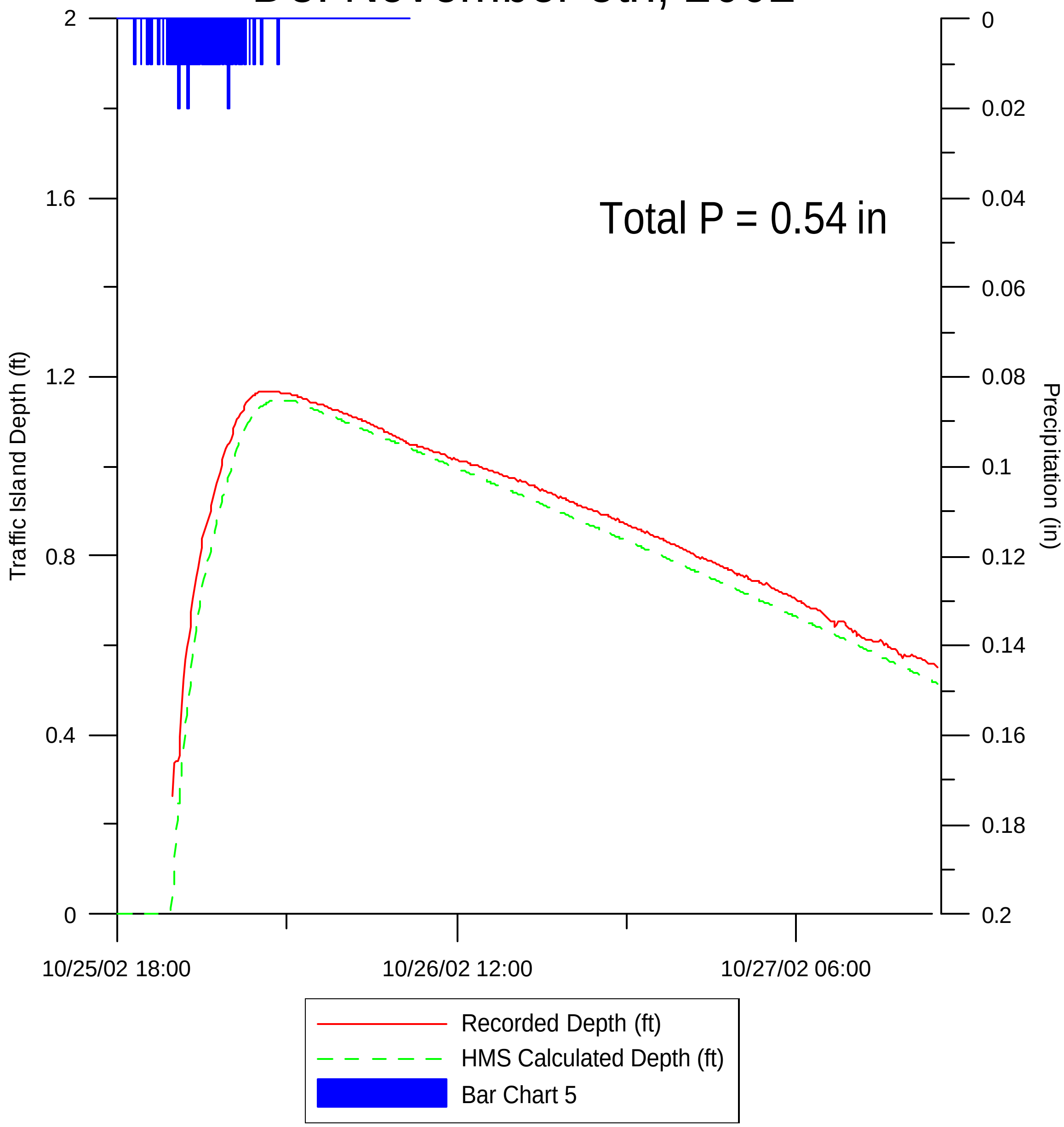

D4: October 10th(B), 2002
Total P = 2.64 in
Traffic Island Depth (ft)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10/10/02 09:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)

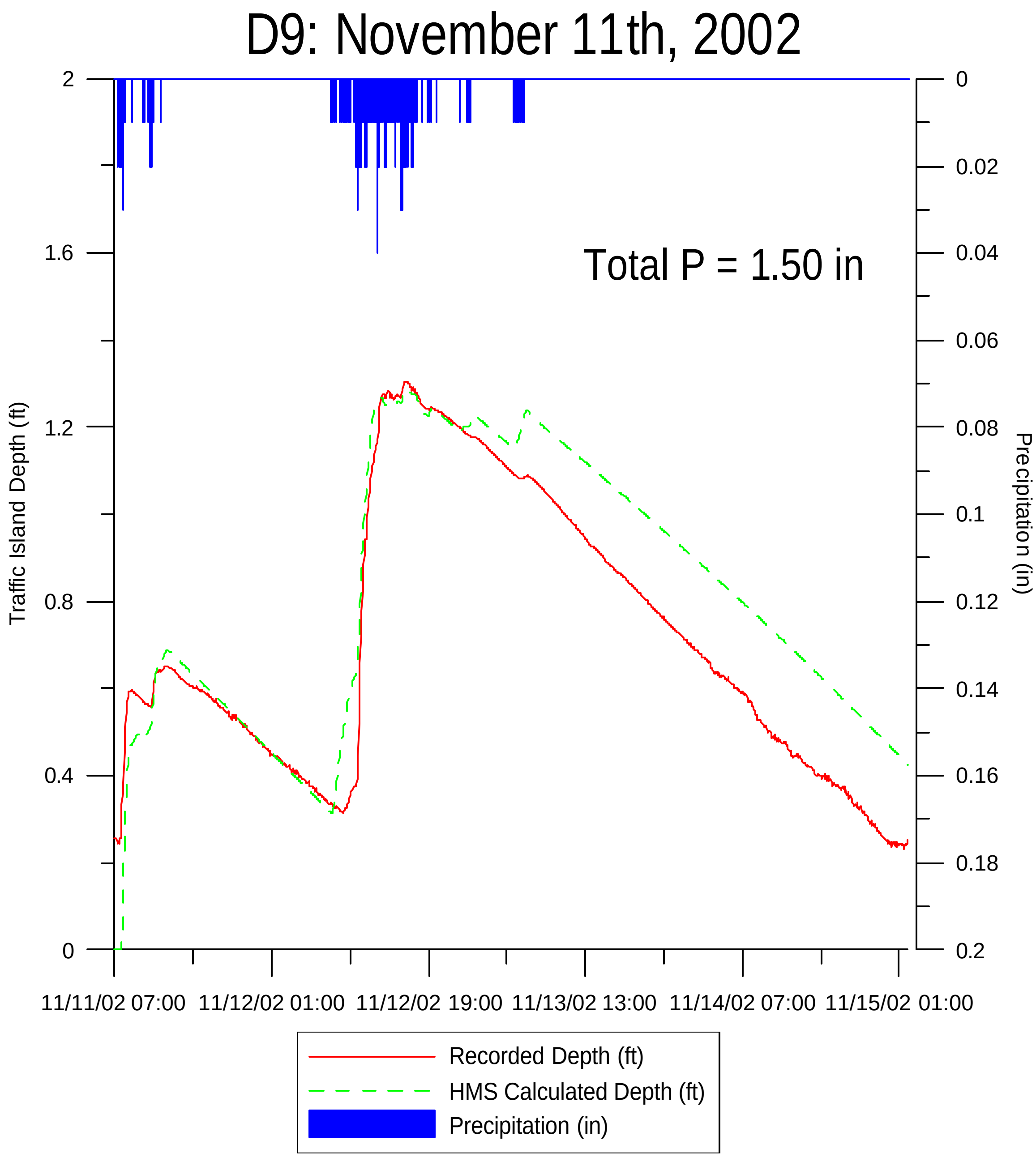

D5: October 16th, 2002
Total P = 1.38 in
Traffic Island Depth (in)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10/16/02 13:00
10/17/02 05:00
10/17/02 21:00
10/18/02 13:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)

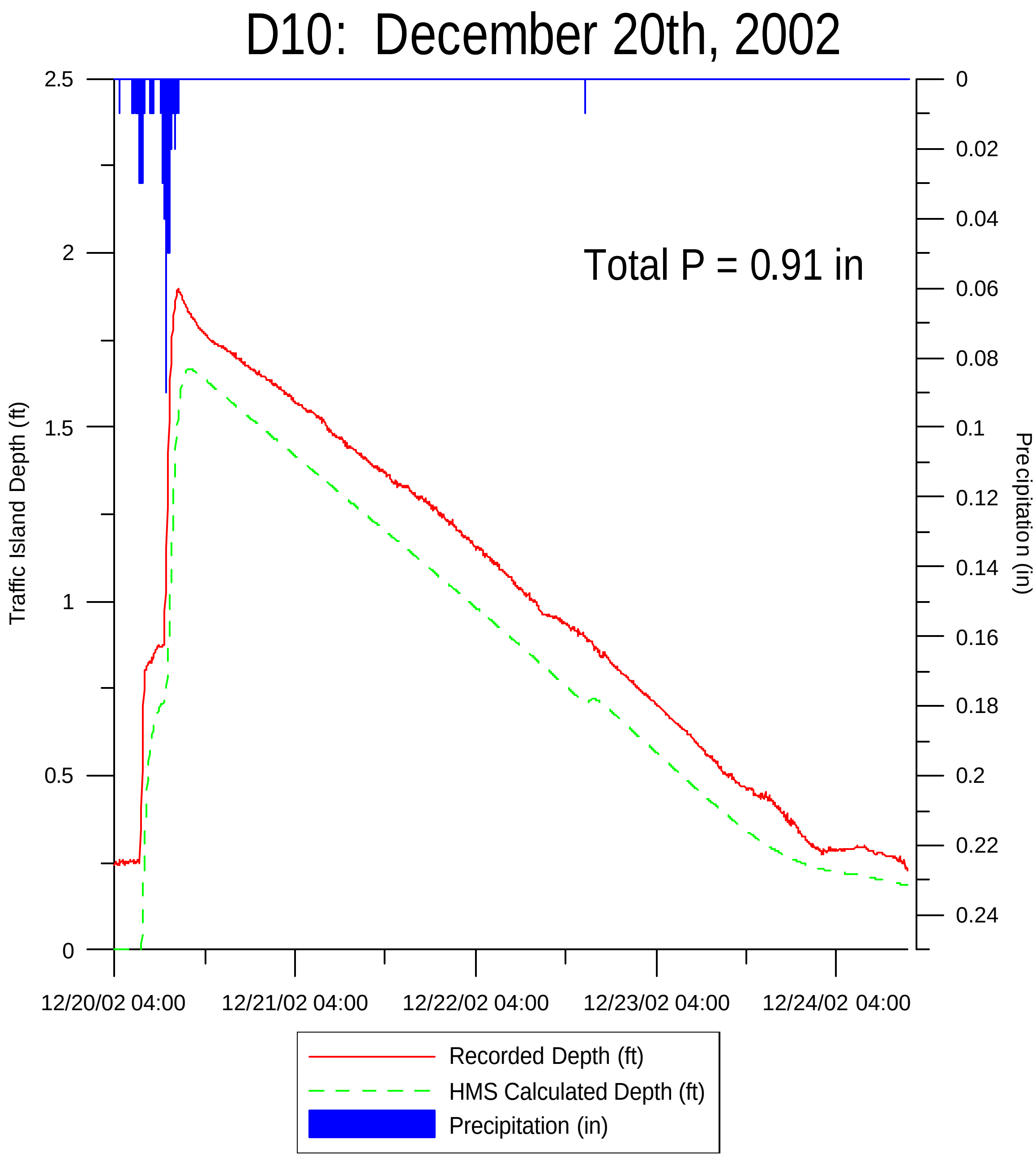

D6: October 25th, 2002
Total P = 1.09 in
Traffic Island Depth (ft)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10/25/02 18:00
10/26/02 10:00
10/27/02 02:00
10/27/02 18:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)


D7: October 29th, 2002
Total P = 1.52 in
Traffic Island Depth (ft)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
10/25/02 18:00
10/26/02 12:00
10/27/02 06:00
10/28/02 00:00
10/28/02 18:00
10/29/02 12:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)

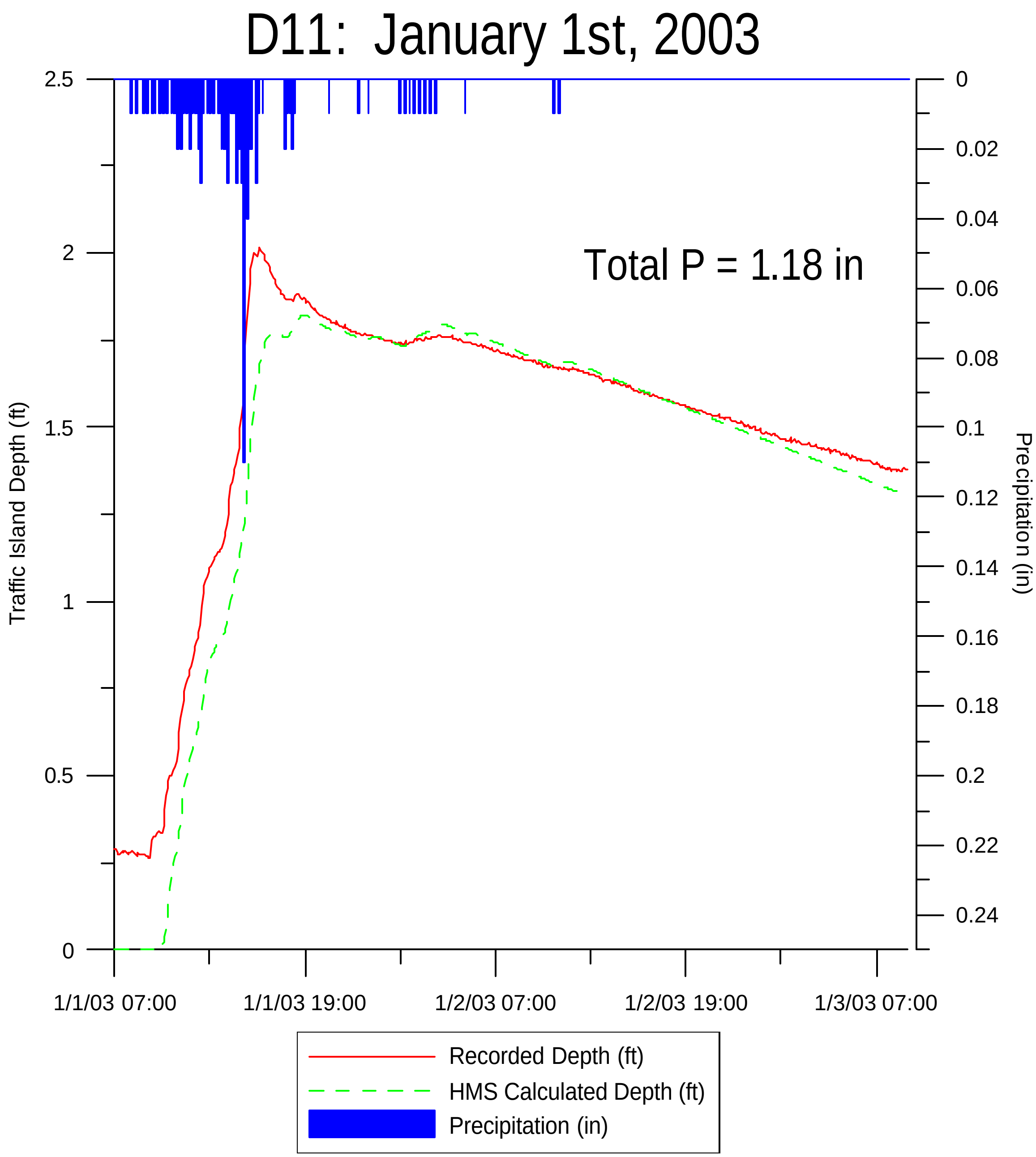
D8: November 5th, 2002



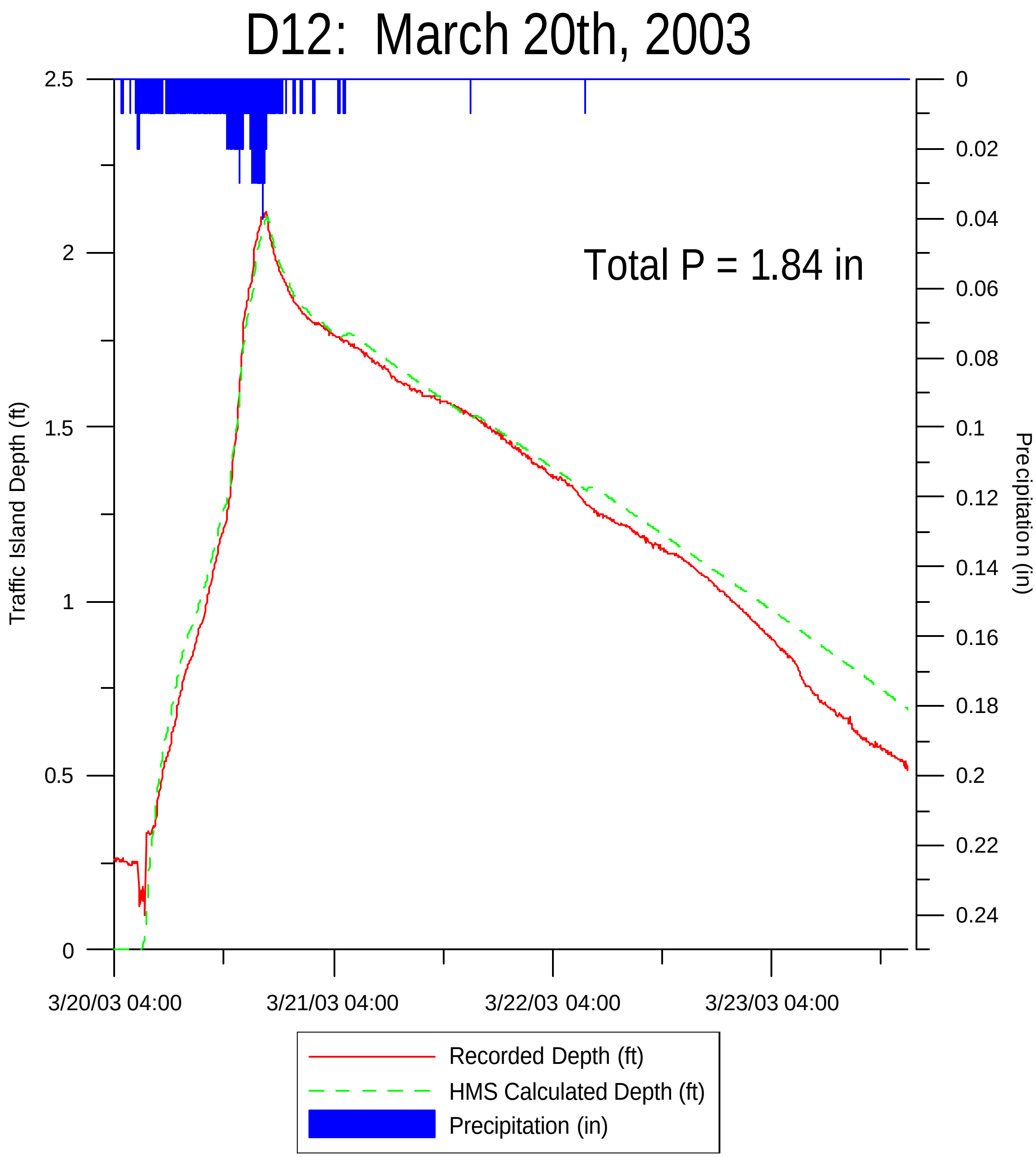

D9: November 11th, 2002
Total P = 1.50 in
Traffic Island Depth (ft)
Precipitation (in)
2
1.6
1.2
0.8
0.4
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
11/11/02 07:00
11/12/02 01:00
11/12/02 19:00
11/13/02 13:00
11/14/02 07:00
11/15/02 01:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)



D10: December 20th, 2002
Total P = 0.91 in
Traffic Island Depth (ft)
Precipitation (in)
2.5
2
1.5
1
0.5
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
12/20/02 04:00
12/21/02 04:00
12/22/02 04:00
12/23/02 04:00
12/24/02 04:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)



D11: January 1st, 2003
Total P = 1.18 in
Traffic Island Depth (ft)
Precipitation (in)
2.5
2
1.5
1
0.5
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
1/1/03 07:00
1/1/03 19:00
1/2/03 07:00
1/2/03 19:00
1/3/03 07:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)


D12: March 20th, 2003
Total P = 1.84 in
Traffic Island Depth (ft)
Precipitation (in)
2.5
2
1.5
1
0.5
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
3/20/03 04:00
3/21/03 04:00
3/22/03 04:00
3/23/03 04:00
Recorded Depth (ft)
HMS Calculated Depth (ft)
Precipitation (in)

Appendix F: BMP Effectiveness Study Data

F1: Chadd's Ford Rain Gauge Data for BMP Effectiveness Study

17772 Days Recorded				Total Precip =	2193.51					
48.69 yrs				Avg. Annual P =	45.05					
P (in)	Frequency	P*F (in)	Cum Mass	% Total		P (in)	Frequency	P*F (in)	Cum Mass	% Total
0.01	59	0.59	0.59	0.00		1.38	2	2.76	1485.89	0.68
0.02	162	3.24	3.83	0.00		1.39	3	4.17	1490.06	0.68
0.03	130	3.90	7.73	0.00		1.40	7	9.80	1499.86	0.68
0.04	139	5.56	13.29	0.01		1.41	5	7.05	1506.91	0.69
0.05	191	9.55	22.84	0.01		1.42	2	2.84	1509.75	0.69
0.06	104	6.24	29.08	0.01		1.43	13	18.59	1528.34	0.70
0.07	91	6.37	35.45	0.02		1.44	7	10.08	1538.42	0.70
0.08	116	9.28	44.73	0.02		1.45	9	13.05	1551.47	0.71
0.09	70	6.30	51.03	0.02		1.46	1	1.46	1552.93	0.71
0.10	153	15.30	66.33	0.03		1.47	4	5.88	1558.81	0.71
0.11	48	5.28	71.61	0.03		1.48	10	14.80	1573.61	0.72
0.12	86	10.32	81.93	0.04		1.49	1	1.49	1575.10	0.72
0.13	46	5.98	87.91	0.04		1.50	8	12.00	1587.10	0.72
0.14	65	9.10	97.01	0.04		1.51	4	6.04	1593.14	0.73
0.15	111	16.65	113.66	0.05		1.52	2	3.04	1596.18	0.73
0.16	64	10.24	123.90	0.06		1.53	5	7.65	1603.83	0.73
0.17	55	9.35	133.25	0.06		1.54	5	7.70	1611.53	0.73
0.18	61	10.98	144.23	0.07		1.55	7	10.85	1622.38	0.74
0.19	35	6.65	150.88	0.07		1.56	5	7.80	1630.18	0.74
0.20	92	18.40	169.28	0.08		1.57	5	7.85	1638.03	0.75
0.21	47	9.87	179.15	0.08		1.58	2	3.16	1641.19	0.75
0.22	67	14.74	193.89	0.09		1.59	2	3.18	1644.37	0.75
0.23	46	10.58	204.47	0.09		1.60	6	9.60	1653.97	0.75
0.24	37	8.88	213.35	0.10		1.62	10	16.20	1670.17	0.76
0.25	64	16.00	229.35	0.10		1.63	4	6.52	1676.69	0.76
0.26	33	8.58	237.93	0.11		1.64	1	1.64	1678.33	0.77
0.27	33	8.91	246.84	0.11		1.65	4	6.60	1684.93	0.77
0.28	34	9.52	256.36	0.12		1.66	1	1.66	1686.59	0.77
0.29	35	10.15	266.51	0.12		1.67	2	3.34	1689.93	0.77
0.30	89	26.70	293.21	0.13		1.68	1	1.68	1691.61	0.77
0.31	29	8.99	302.20	0.14		1.69	2	3.38	1694.99	0.77
0.32	57	18.24	320.44	0.15		1.70	9	15.30	1710.29	0.78
0.33	33	10.89	331.33	0.15		1.71	3	5.13	1715.42	0.78
0.34	27	9.18	340.51	0.16		1.72	2	3.44	1718.86	0.78
0.35	51	17.85	358.36	0.16		1.73	1	1.73	1720.59	0.78
0.36	26	9.36	367.72	0.17		1.74	3	5.22	1725.81	0.79
0.37	25	9.25	376.97	0.17		1.75	3	5.25	1731.06	0.79
0.38	32	12.16	389.13	0.18		1.76	3	5.28	1736.34	0.79
0.39	18	7.02	396.15	0.18		1.77	4	7.08	1743.42	0.79
0.40	52	20.80	416.95	0.19		1.78	1	1.78	1745.20	0.80
0.41	21	8.61	425.56	0.19		1.79	1	1.79	1746.99	0.80

0.42	41	17.22	442.78	0.20		1.80	7	12.60	1759.59	0.80
0.43	30	12.90	455.68	0.21		1.81	4	7.24	1766.83	0.81
0.44	25	11.00	466.68	0.21		1.82	1	1.82	1768.65	0.81
0.45	38	17.10	483.78	0.22		1.83	2	3.66	1772.31	0.81
0.46	25	11.50	495.28	0.23		1.84	2	3.68	1775.99	0.81
0.47	36	16.92	512.20	0.23		1.85	4	7.40	1783.39	0.81
0.48	34	16.32	528.52	0.24		1.86	2	3.72	1787.11	0.81
0.49	24	11.76	540.28	0.25		1.87	1	1.87	1788.98	0.82
0.50	34	17.00	557.28	0.25		1.88	4	7.52	1796.50	0.82
0.51	19	9.69	566.97	0.26		1.90	4	7.60	1804.10	0.82
0.52	19	9.88	576.85	0.26		1.91	1	1.91	1806.01	0.82
0.53	27	14.31	591.16	0.27		1.92	3	5.76	1811.77	0.83
0.54	32	17.28	608.44	0.28		1.93	2	3.86	1815.63	0.83
0.55	26	14.30	622.74	0.28		1.94	1	1.94	1817.57	0.83
0.56	24	13.44	636.18	0.29		1.95	4	7.80	1825.37	0.83
0.57	23	13.11	649.29	0.30		1.96	1	1.96	1827.33	0.83
0.58	20	11.60	660.89	0.30		1.97	4	7.88	1835.21	0.84
0.59	9	5.31	666.20	0.30		1.98	3	5.94	1841.15	0.84
0.60	28	16.80	683.00	0.31		2.00	6	12.00	1853.15	0.84
0.61	23	14.03	697.03	0.32		2.01	1	2.01	1855.16	0.85
0.62	29	17.98	715.01	0.33		2.02	1	2.02	1857.18	0.85
0.63	23	14.49	729.50	0.33		2.03	4	8.12	1865.30	0.85
0.64	20	12.80	742.30	0.34		2.04	4	8.16	1873.46	0.85
0.65	26	16.90	759.20	0.35		2.05	4	8.20	1881.66	0.86
0.66	15	9.90	769.10	0.35		2.06	1	2.06	1883.72	0.86
0.67	13	8.71	777.81	0.35		2.07	1	2.07	1885.79	0.86
0.68	10	6.80	784.61	0.36		2.08	2	4.16	1889.95	0.86
0.69	12	8.28	792.89	0.36		2.10	3	6.30	1896.25	0.86
0.70	32	22.40	815.29	0.37		2.11	1	2.11	1898.36	0.87
0.71	11	7.81	823.10	0.38		2.12	4	8.48	1906.84	0.87
0.72	24	17.28	840.38	0.38		2.13	1	2.13	1908.97	0.87
0.73	17	12.41	852.79	0.39		2.15	4	8.60	1917.57	0.87
0.74	13	9.62	862.41	0.39		2.16	2	4.32	1921.89	0.88
0.75	20	15.00	877.41	0.40		2.17	2	4.34	1926.23	0.88
0.76	12	9.12	886.53	0.40		2.20	2	4.40	1930.63	0.88
0.77	9	6.93	893.46	0.41		2.21	3	6.63	1937.26	0.88
0.78	15	11.70	905.16	0.41		2.24	2	4.48	1941.74	0.89
0.79	10	7.90	913.06	0.42		2.25	1	2.25	1943.99	0.89
0.80	34	27.20	940.26	0.43		2.26	1	2.26	1946.25	0.89
0.81	11	8.91	949.17	0.43		2.27	2	4.54	1950.79	0.89
0.82	21	17.22	966.39	0.44		2.29	2	4.58	1955.37	0.89
0.83	8	6.64	973.03	0.44		2.30	5	11.50	1966.87	0.90
0.84	10	8.40	981.43	0.45		2.31	2	4.62	1971.49	0.90
0.85	16	13.60	995.03	0.45		2.32	1	2.32	1973.81	0.90
0.86	9	7.74	1002.77	0.46		2.33	1	2.33	1976.14	0.90
0.87	8	6.96	1009.73	0.46		2.35	3	7.05	1983.19	0.90
0.88	13	11.44	1021.17	0.47		2.36	2	4.72	1987.91	0.91
0.89	5	4.45	1025.62	0.47		2.37	1	2.37	1990.28	0.91

0.90	24	21.60	1047.22	0.48		2.38	2	4.76	1995.04	0.91
0.91	10	9.10	1056.32	0.48		2.40	3	7.20	2002.24	0.91
0.92	9	8.28	1064.60	0.49		2.41	2	4.82	2007.06	0.91
0.93	10	9.30	1073.90	0.49		2.43	1	2.43	2009.49	0.92
0.94	6	5.64	1079.54	0.49		2.45	4	9.80	2019.29	0.92
0.95	25	23.75	1103.29	0.50		2.50	1	2.50	2021.79	0.92
0.96	9	8.64	1111.93	0.51		2.53	2	5.06	2026.85	0.92
0.97	7	6.79	1118.72	0.51		2.54	1	2.54	2029.39	0.93
0.98	14	13.72	1132.44	0.52		2.57	1	2.57	2031.96	0.93
0.99	6	5.94	1138.38	0.52		2.58	2	5.16	2037.12	0.93
1.00	10	10.00	1148.38	0.52		2.60	2	5.20	2042.32	0.93
1.01	9	9.09	1157.47	0.53		2.62	1	2.62	2044.94	0.93
1.02	9	9.18	1166.65	0.53		2.64	1	2.64	2047.58	0.93
1.03	11	11.33	1177.98	0.54		2.65	3	7.95	2055.53	0.94
1.04	6	6.24	1184.22	0.54		2.66	2	5.32	2060.85	0.94
1.05	13	13.65	1197.87	0.55		2.67	1	2.67	2063.52	0.94
1.06	8	8.48	1206.35	0.55		2.70	1	2.70	2066.22	0.94
1.07	5	5.35	1211.70	0.55		2.71	2	5.42	2071.64	0.94
1.08	10	10.80	1222.50	0.56		2.72	1	2.72	2074.36	0.95
1.09	5	5.45	1227.95	0.56		2.73	1	2.73	2077.09	0.95
1.10	20	22.00	1249.95	0.57		2.74	1	2.74	2079.83	0.95
1.11	8	8.88	1258.83	0.57		2.75	2	5.50	2085.33	0.95
1.12	16	17.92	1276.75	0.58		2.80	2	5.60	2090.93	0.95
1.13	4	4.52	1281.27	0.58		2.81	1	2.81	2093.74	0.95
1.14	5	5.70	1286.97	0.59		2.83	1	2.83	2096.57	0.96
1.15	18	20.70	1307.67	0.60		2.90	1	2.90	2099.47	0.96
1.16	1	1.16	1308.83	0.60		2.91	1	2.91	2102.38	0.96
1.17	8	9.36	1318.19	0.60		2.93	1	2.93	2105.31	0.96
1.18	4	4.72	1322.91	0.60		3.04	1	3.04	2108.35	0.96
1.19	2	2.38	1325.29	0.60		3.05	1	3.05	2111.40	0.96
1.20	17	20.40	1345.69	0.61		3.09	1	3.09	2114.49	0.96
1.21	3	3.63	1349.32	0.62		3.10	2	6.20	2120.69	0.97
1.22	6	7.32	1356.64	0.62		3.15	1	3.15	2123.84	0.97
1.23	5	6.15	1362.79	0.62		3.20	1	3.20	2127.04	0.97
1.24	5	6.20	1368.99	0.62		3.34	1	3.34	2130.38	0.97
1.25	9	11.25	1380.24	0.63		3.35	1	3.35	2133.73	0.97
1.26	4	5.04	1385.28	0.63		3.46	1	3.46	2137.19	0.97
1.27	7	8.89	1394.17	0.64		3.52	1	3.52	2140.71	0.98
1.28	5	6.40	1400.57	0.64		3.80	1	3.80	2144.51	0.98
1.29	2	2.58	1403.15	0.64		3.89	1	3.89	2148.40	0.98
1.30	20	26.00	1429.15	0.65		4.15	1	4.15	2152.55	0.98
1.31	1	1.31	1430.46	0.65		4.20	1	4.20	2156.75	0.98
1.32	2	2.64	1433.10	0.65		4.30	1	4.30	2161.05	0.99
1.33	4	5.32	1438.42	0.66		4.62	1	4.62	2165.67	0.99
1.34	5	6.70	1445.12	0.66		5.23	1	5.23	2170.90	0.99
1.35	14	18.90	1464.02	0.67		5.45	2	10.90	2181.80	0.99
1.36	7	9.52	1473.54	0.67		5.66	1	5.66	2187.46	1.00
1.37	7	9.59	1483.13	0.68		6.05	1	6.05	2193.51	1.00

E2: User-entered Hyetographs for HMS Runs

T (hr)	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
1	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
2	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08
3	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04

T (hr)	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30
1	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.08
2	0.08	0.09	0.09	0.09	0.10	0.11	0.11	0.11	0.12	0.13	0.13	0.13	0.14	0.14	0.14
3	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.08	0.08

T (hr)	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.45
1	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.13
2	0.15	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19
3	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.13

T (hr)	0.46	0.47	0.48	0.49	0.50
1	0.13	0.13	0.14	0.14	0.14
2	0.20	0.20	0.20	0.21	0.21
3	0.13	0.14	0.14	0.14	0.15

T (hr)	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.64	0.65
1	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09
2	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
3	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15
4	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15
5	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
6	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08

T (hr)	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80
1	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11
2	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11
3	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.18
4	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.18
5	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11
6	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11

T (hr)	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95
1	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.14
2	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14
3	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20
4	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20
5	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14
6	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13

T (hr)	0.96	0.97	0.98	0.99	1.00
1	0.14	0.14	0.14	0.14	0.14
2	0.14	0.14	0.14	0.15	0.15
3	0.20	0.21	0.21	0.21	0.21
4	0.20	0.20	0.21	0.21	0.21
5	0.14	0.14	0.14	0.14	0.15
6	0.14	0.14	0.14	0.14	0.14

T (hr)	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15
1	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
3	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05
4	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14
6	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26
7	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26
8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14
9	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
10	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
11	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
12	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

T (hr)	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30
1	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
3	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06
4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
5	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
6	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27
7	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
8	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
9	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06
10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
11	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
12	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

T (hr)	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.38	1.39	1.40	1.41	1.42	1.43	1.44	1.45
1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07
3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
4	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
5	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
6	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.29
7	0.27	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
8	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
9	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
10	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
11	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
12	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07

T (hr)	1.46	1.47	1.48	1.49	1.50
1	0.07	0.07	0.07	0.07	0.07
2	0.07	0.07	0.07	0.07	0.07
3	0.07	0.07	0.07	0.07	0.07
4	0.07	0.07	0.07	0.08	0.08
5	0.16	0.17	0.17	0.17	0.17
6	0.29	0.29	0.29	0.29	0.29
7	0.29	0.29	0.29	0.29	0.29
8	0.16	0.16	0.17	0.17	0.17
9	0.07	0.07	0.07	0.07	0.08
10	0.07	0.07	0.07	0.07	0.07
11	0.07	0.07	0.07	0.07	0.07
12	0.07	0.07	0.07	0.07	0.07

T (hr)	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.58	1.59	1.60	1.62	1.63	1.64	1.65	1.66
1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07
3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
4	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
5	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
6	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
7	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
8	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
9	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21
10	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.21
11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
12	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
13	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
14	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
15	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
16	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
17	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07
18	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07

T (hr)	1.67	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.75	1.76	1.77	1.78	1.79	1.80	1.81
1	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08
2	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08
3	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
4	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08
5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
6	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
7	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
9	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
10	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
12	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
13	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
14	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
15	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
16	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08
17	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08
18	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

T (hr)	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.90	1.91	1.92	1.93	1.94	1.95	1.96	1.97
1	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
3	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
4	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09
6	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
7	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
8	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
9	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
10	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
12	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
14	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
15	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
16	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
17	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
18	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

T (hr)	2.01	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.10	2.11	2.12	2.13	2.15	2.16
1	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
3	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
4	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
6	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
7	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
8	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
9	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
11	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
12	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
13	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
14	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
15	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
16	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
17	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
18	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
19	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07
20	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07
21	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
22	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
23	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
24	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

T (hr)	2.17	2.20	2.21	2.24	2.25	2.26	2.27	2.29	2.30	2.31	2.32	2.33	2.35	2.36
1	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
3	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
4	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
5	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
6	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08
7	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08
8	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08
9	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10
10	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
11	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
12	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
13	0.26	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
14	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
15	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
16	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
17	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10
18	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
19	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08
20	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08
21	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08
22	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
23	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
24	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

T (hr)	2.37	2.38	2.40	2.41	2.43	2.45	2.50	2.53	2.54	2.57	2.58	2.60	2.62	2.64
1	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
3	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
4	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
6	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
7	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
8	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
9	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
12	0.27	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
13	0.27	0.27	0.27	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
14	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
15	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
16	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
17	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
18	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
19	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
20	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
21	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
22	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
23	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
24	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

T (hr)	2.65	2.66	2.67	2.70	2.71	2.72	2.73	2.74	2.75	2.80	2.81	2.83	2.90	2.91
1	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
2	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
3	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
4	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
5	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
6	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10
7	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10
8	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10
9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.13
10	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13
11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13
12	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.30	0.30
13	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.30	0.30
14	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13
15	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13
16	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.13
17	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.13
18	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10
19	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10
20	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
21	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
22	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
23	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
24	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09

T (hr)	2.93	3.04	3.05	3.09	3.10	3.15	3.20	3.34	3.35	3.46	3.52	3.80	3.89	4.15
1	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12
2	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12
3	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12
4	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.13	0.13
5	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.13
6	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.14
7	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.14
8	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.13	0.14
9	0.13	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
10	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
11	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
12	0.30	0.31	0.31	0.31	0.31	0.32	0.32	0.33	0.33	0.34	0.34	0.37	0.37	0.40
13	0.30	0.31	0.31	0.31	0.31	0.32	0.32	0.33	0.33	0.34	0.34	0.37	0.37	0.40
14	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
15	0.13	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
16	0.13	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
17	0.13	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.18	0.18	0.20
18	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.14
19	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.14
20	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.13	0.14
21	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.13	0.13
22	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12
23	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12
24	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12

T (hr)	4.20	4.30	4.62	5.23	5.45	5.66	6.05
1	0.12	0.13	0.14	0.15	0.17	0.18	0.18
2	0.13	0.14	0.14	0.16	0.17	0.18	0.18
3	0.13	0.14	0.14	0.16	0.17	0.18	0.18
4	0.13	0.14	0.14	0.16	0.17	0.18	0.18
5	0.13	0.14	0.14	0.16	0.17	0.18	0.18
6	0.14	0.14	0.14	0.16	0.17	0.18	0.18
7	0.14	0.14	0.14	0.16	0.17	0.18	0.18
8	0.14	0.14	0.15	0.16	0.17	0.18	0.18
9	0.20	0.20	0.23	0.26	0.26	0.27	0.30
10	0.20	0.20	0.23	0.26	0.27	0.27	0.30
11	0.20	0.20	0.23	0.26	0.27	0.27	0.30
12	0.40	0.41	0.45	0.51	0.52	0.54	0.63
13	0.40	0.41	0.45	0.51	0.52	0.53	0.63
14	0.20	0.20	0.23	0.26	0.27	0.27	0.30
15	0.20	0.20	0.23	0.26	0.27	0.27	0.30
16	0.20	0.20	0.23	0.26	0.26	0.27	0.30
17	0.20	0.20	0.23	0.26	0.26	0.27	0.29
18	0.14	0.14	0.14	0.16	0.17	0.18	0.18
19	0.14	0.14	0.14	0.16	0.17	0.18	0.18
20	0.14	0.14	0.14	0.16	0.17	0.18	0.18
21	0.13	0.14	0.14	0.16	0.17	0.18	0.18
22	0.13	0.14	0.14	0.16	0.17	0.18	0.18
23	0.13	0.14	0.14	0.16	0.17	0.18	0.18
24	0.13	0.13	0.14	0.16	0.17	0.18	0.18