# 4 HYDROLOGIC MODELING AND SIMULATION

## 4.1 INTRODUCTION

This chapter is intended to discuss simple, reliable hydrologic methods and models to quickly estimate volume control requirements, and to allow screening, selection, and approximate sizing of LID BMPs to achieve stormwater volume reduction goals to meet EISA Section 438. The methods and models presented have been used in numerous studies and are generally accepted by regulating authorities.

The purpose of water quantity and water quality modeling is to establish a means for the designer to visualize how water flows through a site, how much runoff is generated in a given sub-catchment, and determine how much water can be captured by a given BMP. This chapter will discuss background information about the design calculations set forth by the EPA Technical Guidance Manual, various hydrologic models to use for each design option and go through case studies applying hydrologic modeling and simulation.

For the purposes of the hydrologic analysis, the site design process is divided into three stages:

1) hydrologic analysis, in which the 95th percentile rainfall event is established, and the corresponding runoff volume for the developed and predevelopment condition are calculated;
2) site design, in which LID site design strategies are implemented to minimize increases in runoff volume resulting from development; and
3) application of BMPs to capture unavoidable runoff.

Standard hydrologic modeling and simulation reference tables are located in Appendix D, for reference to parameters described in this chapter.

## 4.2 DESIGN CALCULATIONS

The EPA Technical Guidance Manual for complying with EISA Section 438, *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act* (2009), provides a four step process to implement EISA Section 438 (Figure 4-1). Step 1 is to determine the applicability of the project of being over 5,000 square feet. Step 2 is to establish the design objective and analytical options; two (2) options are provided to meet the performance objective of preserving or restoring the hydrology of the site. Both options require the design, construction, and maintenance of stormwater management practices that manage rainfall on-site and prevent the off-site discharge of stormwater to the METF. Option 1 requires the management of all rainfall less than or equal to the $95^{th}$ percentile rainfall event Option 1 is a statistical determination of estimating the design retention volume between pre-development and post development conditions. Option 2 requires a detailed hydrologic analysis that uses site-specific and local conditions to demonstrate compliance. Option 2 encompasses continuous modeling techniques which call for a comparison of runoff volume between pre-development and post development conditions over a period of time (multiple storm events) using a period of record rainfall. Step 3 is a description of the representative design considerations and options for management of on-site stormwater; applying LID is the recommended design option to manage the required volume of stormwater determined in step 2. Step 4 is to finalize the site design and the cost estimate.

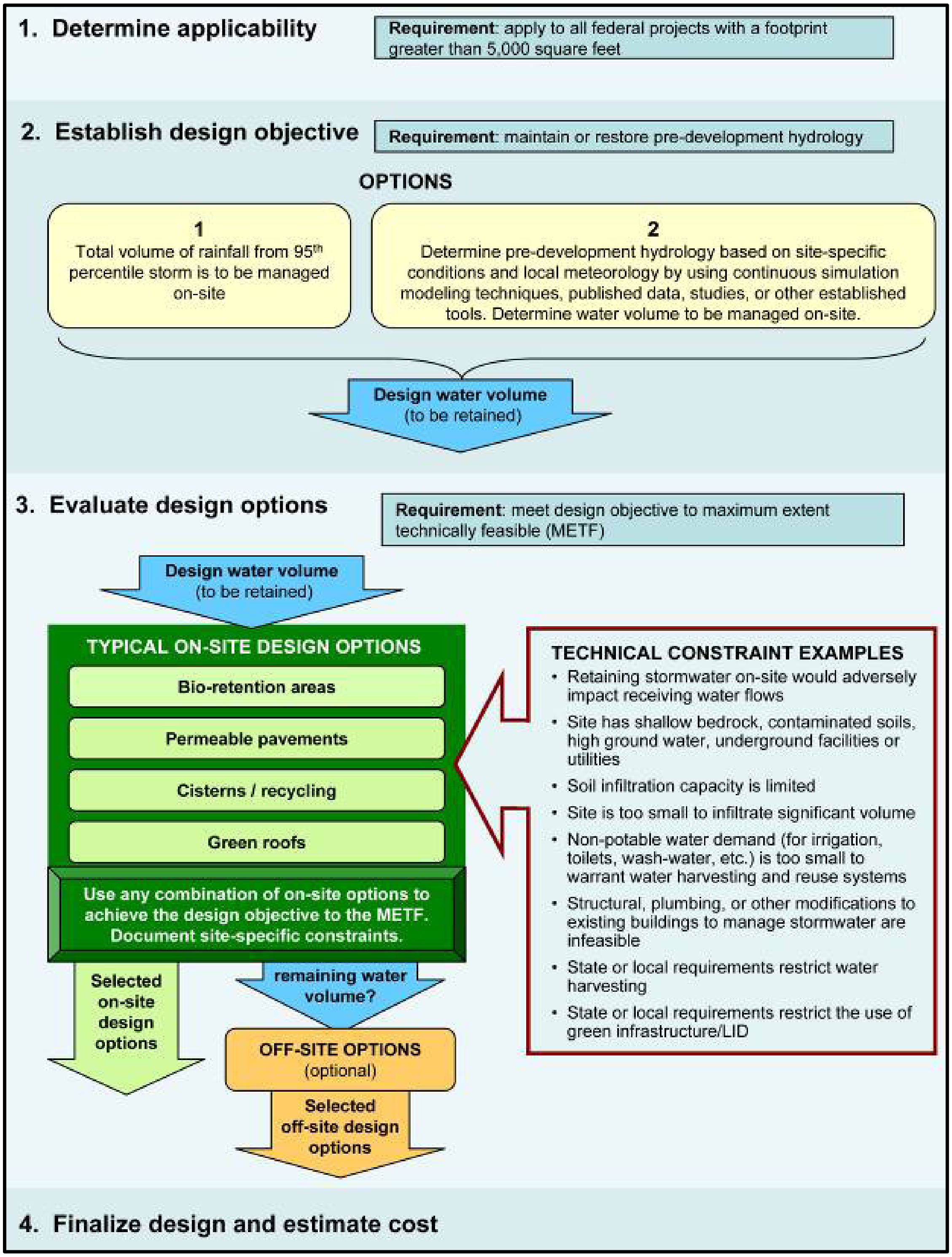



**Figure 4-1. Implementation of EISA Section 438**
(Source: EPA Technical Guidance Manual, 2009)

### 4.2.1 Option 1

Option 1 specifies the use of the 95th percentile rainfall event as the basis for the design storm calculation, Table 4-1; the difference in pre and post project volume of rainfall from 95th percentile storm is to be managed on-site. The 95th percentile rainfall event represents a daily rainfall volume, which on average will equal or exceed 95 percent of all daily rainfalls over a given period; at least 20-30 years. In more technical terms, the 95th percentile rainfall event is defined as the measured precipitation depth accumulated over a 24-hour period for the period of record that ranks as the 95th percentile rainfall depth based on the range of all daily event occurrences during this period. The 24-hour period is typically defined as 12:00:00 am to 11:59:59 pm. In general, at least a 20-30 year period of rainfall record is recommended for such an analysis. This raw data is readily available and collected by most airports across the country. Small rainfall events that are on tenth of an inch or less are excluded from the percentile analysis because this rainfall generally does not result in any measureable runoff due to absorption, interception, and evaporation by permeable, impermeable, and vegetated surfaces. Many stormwater modelers and hydrologists typically exclude rainfall events that are one tenth of an inch or less from calculations of rainfall events of any storm from their modeling analyses of rainfall event frequencies. The retention volumes for Option 1 are derived by taking the difference between estimating the pre- and post development runoff volumes for the 95% rainfall. However, this approach does not consider the effect of having series of multiple 24-hour rainfalls. This can be significant, particularly in climates with a greater average number of rainfall days per year, because the LID practices may take days or even weeks to dissipate the captured rainfall. Locations where it is not uncommon to have clusters of several days of rainfall either a dissipation time of more than 24 hours should be used with Option 1 or a continuous simulation as suggested for Option 2 of the EPA Technical Guidance Manual can be used.

**Table 4-1. 95th Percentile Storm Events for Select U.S. Cities**

| City | 95$^{th}$ Percentile Event Rainfall Total (in) | City | 95$^{th}$ Percentile Event Rainfall Total (in) |
|---|---|---|---|
| Atlanta, GA | 1.8 | Kansas City, MO | 1.7 |
| Baltimore, MD | 1.6 | Knoxville, TN | 1.5 |
| Boston, MA | 1.5 | Louisville, KY | 1.5 |
| Buffalo, NY | 1.1 | Minneapolis, MN | 1.4 |
| Burlington, VT | 1.1 | New York, NY | 1.7 |
| Charleston, WV | 1.2 | Salt Lake City, UT | 0.8 |
| Coeur D'Alene, ID | 0.7 | Phoenix, AZ | 1.0 |
| Cincinnati, OH | 1.5 | Portland, OR | 1.0 |
| Columbus, OH | 1.3 | Seattle, WA | 1.6 |
| Concord, NH | 1.3 | Washington, DC | 1.7 |
| Denver, CO | 1.1 | | |

(Source: Hirschman and Kosco, 2008)

### 4.2.2 Option 2

Option 2 of the EPA Technical Guidance Manual is a hydrologic analysis of pre-development site conditions to establish the base runoff characteristics. The designer compares the runoff characteristics resulting from the proposed development with those of the base runoff conditions. LID practices are incorporated and sized into the site plan such that the character of the post development runoff volume matches that of the base runoff conditions. The dissipation rate is an essential parameter for simulating the performance and determining the appropriate retention volume of LID practices. The relationship of the dissipation rate to the retention volume for LID practices is similar to the relationship between discharge rate and detention volume. However, the important difference between dissipation and discharge, other than how they occur, is that dissipation is much slower and is considered in terms of volume per day verses discharges, which are volume per second or per hour. The result is that a LID practice will take several days or even weeks to dissipate the retained water from a single rainfall. Therefore it is not unusual for another rainfall to occur before all the water from the previous rainfall has been dissipated.

The following is a discussion of possible modeling and simulation tools and methods that can be used to evaluate pre and post development site conditions, Table 4-1. The following sections discuss models of varying scales and capabilities to help guide planners, designers, surveyors, and construction engineers in selecting the proper tools for evaluating a particular site. The models are separated by those that would be most applicable for Option 1: Retain the difference between the pre and post project 95$^{th}$ Percentile Rainfall Volume, and those most applicable for Option 2: Site-Specific Continuous Hydrologic Simulation and Analysis. In addition, not all of these models have been used in the case studies due to time and financial limitations.

**Table 4-2. Possible Modeling and Simulation Tools and Methods**

| MODEL/METHOD | EISA OPTION | FEATURES |
|---|---|---|
| Rational Method | 1 | Computes peak water depths and volumes |
| SCS CN Method | 1 | Computes peak water depths and volumes |
| NRCS WinTR-55 (Model) | 1 | Computes temporally varying water runoff and volume |
| EPA SWMM (Model) | 1 | Computers temporally varying water and constituent runoff and volume |
| RVSM (Model) | 2 | Computes long-term runoff based on a 50 year period of record of precipitation |
| HSPF (Model) | 2 | Computes long-term temporally varying water and constituent runoff and volume |

## 4.3 STANDARD HYDROLOGIC MODELING AND SIMULATION TOOLS FOR OPTION 1

### 4.3.1 Rational Method

#### *4.3.1.1 Introduction*

The rational method is the most widely used method for the analysis of runoff response from small catchments. It has particular application to urban storm drainage, where it is used to calculate peak runoff rates for the design of storm sewers and small drainage structures (Ponce, 1989). The popularity of the rational method is attributed to its simplicity, although reasonable care is necessary in order to use the method correctly.

The rational method takes into account the following hydrologic characteristics or processes: 1) rainfall intensity; 2) rainfall duration; 3) rainfall frequency; 4) catchment area; 5) hydrologic abstractions; 6) runoff concentration; and 7) runoff diffusion.

In general, the rational method provides only a peak discharge, although in the absence of runoff diffusion it is possible to obtain an isosceles triangle shaped runoff hydrograph which can be used to compute runoff volume, Figure 4-2.

From Figure 4-2, $t_r$ is rainfall duration, $t_c$ is concentration time, $Q_e$ is equilibrium flow (maximum flow possible for a specified rainfall intensity), $I_e$ is effective rainfall intensity (Total rainfall minus all hydrologic abstractions).

The peak discharge is the product of: 1) runoff coefficient; 2) rainfall intensity; and 3) catchment area, with all the processes being lumped into these three parameters, Equation 4.1. Rainfall intensity contains information on rainfall duration and frequency. In turn, rainfall duration is related to concentration time, i.e., to the runoff concentration properties of the catchment. The runoff coefficient accounts for both hydrologic abstractions and runoff diffusion and may also be used to account for frequency. In this way, all the major hydrologic processes responsible for runoff response are embodied in the rational formula.

$$Q_p = CIA \tag{4.1}$$

Where, flow rate ($Q_p$) is cubic feet per second, rainfall intensity (I) is in inches per hour, catchment area (A) is in acres, and the runoff coefficient (C) is dimensionless.

The rational method does not take into account the following characteristics or processes: 1) spatial or temporal variations in either total or effective rainfall, 2) concentration time much greater than rainfall duration, and 3) a significant portion of runoff occurring in the form of streamflow. In addition, the rational method does not explicitly account for the catchment's antecedent moisture condition, although the latter may be implicitly accounted for by varying the runoff coefficient.

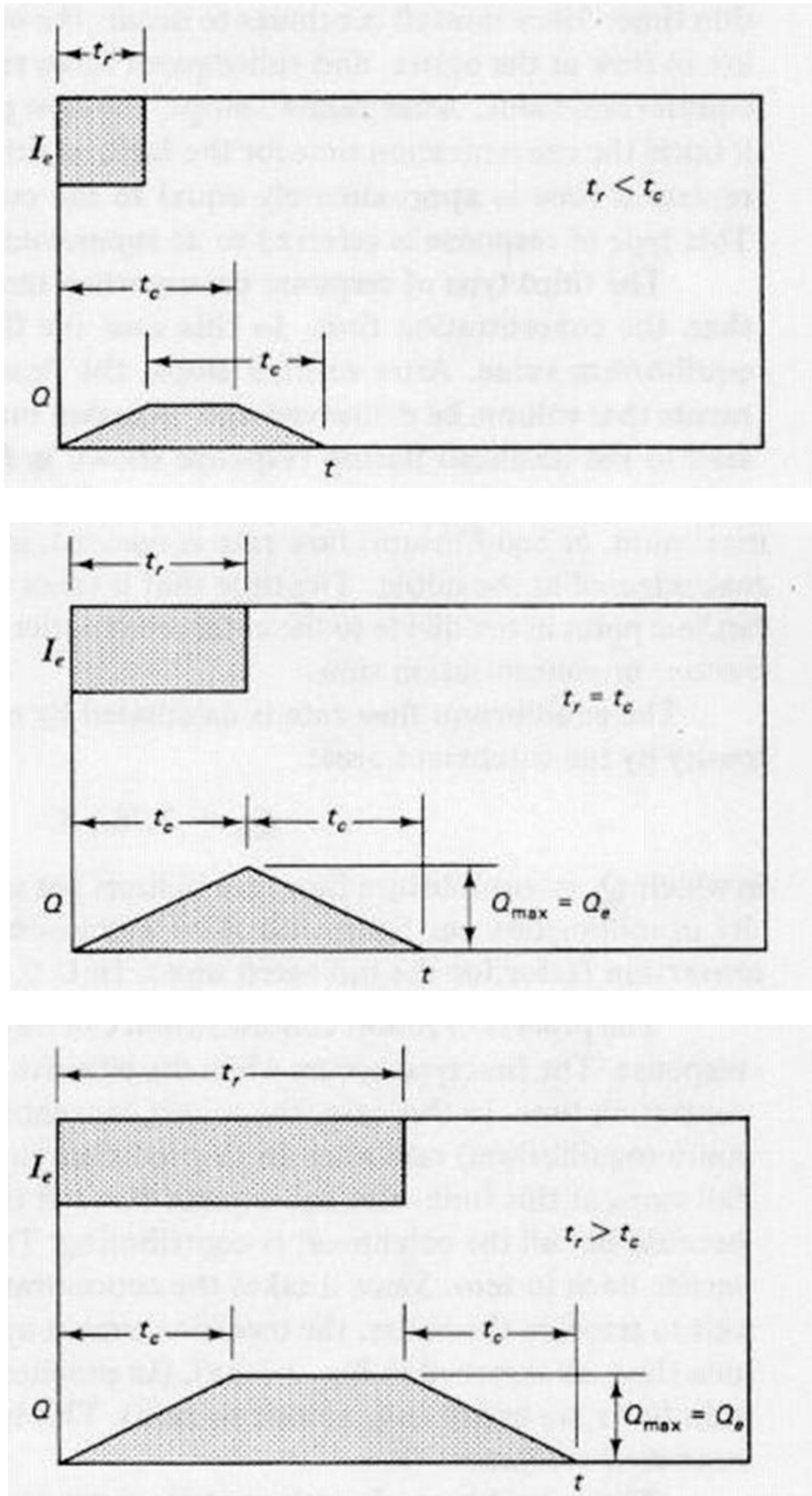



**Figure 4-2. Rational Method Hydrographs**
(Source: Ponce, 1989)

#### *4.3.1.2 Methodology*

The first requirement of the rational method is that the catchment be small. There is no consensus regarding the upper limit of a small catchment, however values ranging from 0.65 to 12.5 $km^2$ (0.2 to 4.5 $mi^2$) have been quoted in the literature. The current trend is to use 1.3 to 2.5 $km^2$ (0.5 to 0.9 $mi^2$) as the upper limit for the applicability of the rational method. Once the drainage boundary has been determined, the drainage area survey should also include: 1) land use and land use changes; 2) percentage of imperviousness; 3) characteristics of soil and vegetative cover that may affect the runoff coefficient; and 4) general magnitude of ground slopes and catchment gradient necessary to determine time of concentration.

Design values of runoff coefficients are usually a function of rainfall intensity and therefore of rainfall frequency. Higher values of runoff coefficient are applicable for higher values of rainfall intensity and return period, Appendix D, Tables D.1 to D.3.

With runoff coefficient, rainfall intensity, and catchment area determined, the peak discharge is calculated using Equation 4.1. The apparent simplicity of the procedure is misleading due to the range of possible runoff coefficients for each surface condition. Therefore the chosen C value is usually based on additional field information or designer's experience. The effect of frequency and/or antecedent moisture condition needs to be evaluated carefully.

### 4.3.2 SCS Runoff Curve Method

#### *4.3.2.1 Introduction*

The runoff curve number method is a procedure for hydrologic abstraction developed by the USDA Natural Resource Conservation Service (NRCS). In this method, runoff depth (i.e., effective rainfall depth) is a function of total rainfall depth and an abstractive parameter referred to as runoff curve number, curve number, or CN. The curve number varies in the range of 1 to 100, being a function of the following runoff producing catchment properties: 1) hydrologic soil type; 2) land use and treatment; 3) ground surface condition; and 4) antecedent moisture condition (Ponce, 1989).

The runoff curve number method was developed based on 24-h rainfall-runoff data. It limits itself to the calculation of runoff depth and does not explicitly take into account temporal variations of rainfall intensity. In the runoff curve number method, actual runoff is referred to as Q, and the potential runoff (total rainfall) is represented by P, with P being greater than or equal to Q. The actual retention after runoff begins is P minus Q. The potential retention (or potential maximum retention) is S, with S being greater than or equal to P minus Q.

The method is based on an assumption of proportionality between retention and runoff:

$$\frac{P-Q}{S}=\frac{Q}{P} \tag{4.2}$$

Where,

Q = Total runoff depth (inches)
P = Total rainfall depth (inches)
S = Maximum retention depth (inches)

This assumption states that the ratio of actual retention to potential retention is equal to the ratio of actual runoff to potential runoff. For practical applications, Equation 4.2 is improved by reducing the potential runoff by an amount equal to the initial abstraction. The initial abstraction consists mainly of interception, infiltration, and surface storage, all of which occur before runoff begins.

$$\frac{P-I_a-Q}{S}=\frac{Q}{P-I_a} \tag{4.3}$$

Where, $I_a$ is equal to initial abstraction. In the original development of the SCS Curve Number Method, the Intial Abstraction ration ($I_a$ /S) was assigned a value of 0.20.

Solving for Q and setting $I_a$ = 0.2S, results in the following runoff relationship:

$$Q=\frac{(P-0.2S)^2}{(P+0.8S)} \tag{4.4}$$

Which is subject to the restriction that P is greater than or equal to 0.2S.

Since potential maximum retention varies widely, it is more appropriate to express it in terms of a runoff curve number, an integer varying in the range of 1 to 100, in the following form:

$$S=\frac{1000}{CN}-10 \tag{4.5}$$

In which CN is dimensionless and S, 1000, and 10 are given in inches.

#### *4.3.2.2 Estimation of Runoff Curve Number (CN)*

For ungaged watersheds, estimates of CN are given in tables supplied by federal agencies and local city and county departments. Tables of runoff curve numbers for various hydrologic soil-cove complexes are widely available. The hydrologic soil-cover complex describes a specific combination of hydrologic soil group, land use and treatment, hydrologic surface condition, and antecedent moisture condition. All these have a direct bearing on the amount of runoff produced by a catchment. The hydrologic soil group describes the type of soil. The land use and treatment describes the type and condition of vegetative cover. The hydrologic condition refers to the ability of the catchment surface to enhance or impede direct runoff. The antecedent moisture condition accounts for the recent history of rainfall and consequently it is a measure of the amount of moisture stored by the catchment.

For hydrologic soil groups all the soils are classified into four hydrologic soil groups of distinct runoff producing properties. These groups are labeled A, B, C, or D. Group A consists of soils of low runoff potential having high infiltration rates even when wetted thoroughly. They are primarily deep, very well drained sands and gravels with a characteristically high rate of water transmission. Group B consists of soils with moderate infiltration rates when wetted thoroughly, primarily moderately deep to deep, moderately drained to well drainged, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. Group C consists of soils with slow infiltration rate when wetted thoroughly, primarily soils having a layer that impedes downward movement of water or soils of moderately fine to fine texture. These soils have a slow rate of water transmission. Group D consists of soils of high runoff potential, having very slow infiltration rates when wetted thoroughly. They are primarily clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay layer near the surface, and shallow soils overlying impervious material. These soils have a very slow rate of water transmission.

The effect of the surface condition of a watershed is evaluated by means of land use and treatment classes. Land use pertains to the watershed cover, including every kind of vegetation, litter and mulch, fallow (bare soil), as well as non-agricultural uses such as water surfaces (lakes, swamps, etc.), impervious surfaces (roads, roofs, etc.), and urban areas. Land treatment applies mainly to agricultural land uses however non-agricultural best management practices could be evaluated as well. The runoff curve number method distinguishes between cultivated lands, grasslands, and woods and forests.

The runoff curve number method has three levels of antecedent moisture, depending on the total rainfall in the 5 day period preceding a storm, Appendix D, Table D.4. The dry antecedent condition (AMC I) has the lowest runoff potential. The average antecedent moisture condition (AMC II) has an average runoff potential. The wet antecedent moisture condition (AMC III) has the highest runoff potential with the catchment practically saturated from previous storms.

Tables depicting average curve number values for various soils and land use and treatment conditions can be found in Appendix D, Tables D.5 to D.7.

Since this method will be demonstrated in the case studies to follow, the steps outlined below should be used in determining the required volume of water to manage.

- Determine project boundary
- Determine hydrologic soil group for the project area by reviewing the USDA soils database
- Determine existing condition landuse areas
- Estimate the runoff curve number for each existing condition landuse

- Compute the area weighted average runoff curve number for the existing condition landuse
- Determine the post project condition landuse areas
- Estimate the runoff curve number for each post project condition landuse
- Compute the area weighted average runoff curve number for the post project conditions
- Based on a 30 to 50 year period of daily rainfall, compute the 95$^{th}$ percentile storm depth
- Compute the existing condition runoff depth using the SCS curve number equation (Eq. 4.4)
- Compute the post project condition runoff depth using the SCS curve number equation
- Compute the volume of water to be managed by multiplying the difference in existing and post project condition runoff depth by the total catchment area

Once the volume of water to be managed has been computed then one can evaluate various LID practices to see which one or combinations will allow one to manage the required volume on site.

### 4.3.3 NRCS WinTR-55

#### *4.3.3.1 Introduction*

WinTR–55 is a single-event rainfall-runoff, small watershed hydrologic model. The model generates hydrographs from both urban and agricultural areas and at selected points along the stream system. Hydrographs are routed downstream through channels and/or reservoirs.
Multiple sub-areas can be modeled within the watershed (USDA, 2009).

#### *4.3.3.2 TR-55 Methodology*

The WinTR-55 method is a collection of simplified procedures developed by the NRCS to calculate peak discharges, flood hydrographs, and stormwater detention storage volumes in small and midsize urban watersheds. It consists of two main procedures: 1) a graphical method, and 2) a tabular method. The graphical method is used to calculate peak discharges, whereas the tabular method calculates flood hydrographs by using simplified routing procedures. These methods were developed based on information obtained from the SCS TR-20 hydrologic computer model. They are designed to be used in cases where their applicability can be clearly demonstrated, in lieu of more elaborate techniques. Whereas TR-55 does not specify watershed size, the graphical method is limited to catchments with concentration times in the range of 0.1 to 10.0 hours. Likewise, the tabular method is limited to catchments with concentration times of 0.1 to 2.0 hours.

Rainfall in TR-55 is described in terms of total rainfall depth and one of four standard 24 hour temporal rainfall distributions: type I, type IA, type II, and type III, Figure 4-2.

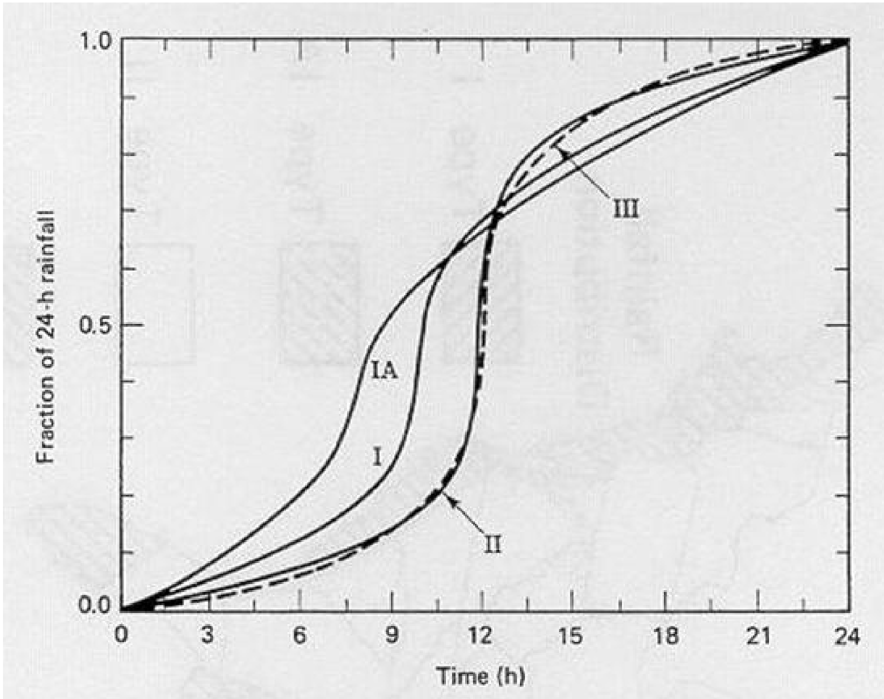



**Figure 4-3. SCS 24-Hour Rainfall Distribution**
(Source: Ponce, 1989)

Type I applies to California (south of the San Francisco Bay area) and Alaska; type IA applies to the Pacific Northwest and Northern California; type III applies to the Gulf Coast states; and type II applies everywhere else within the contiguous United States, Figure 4-3.

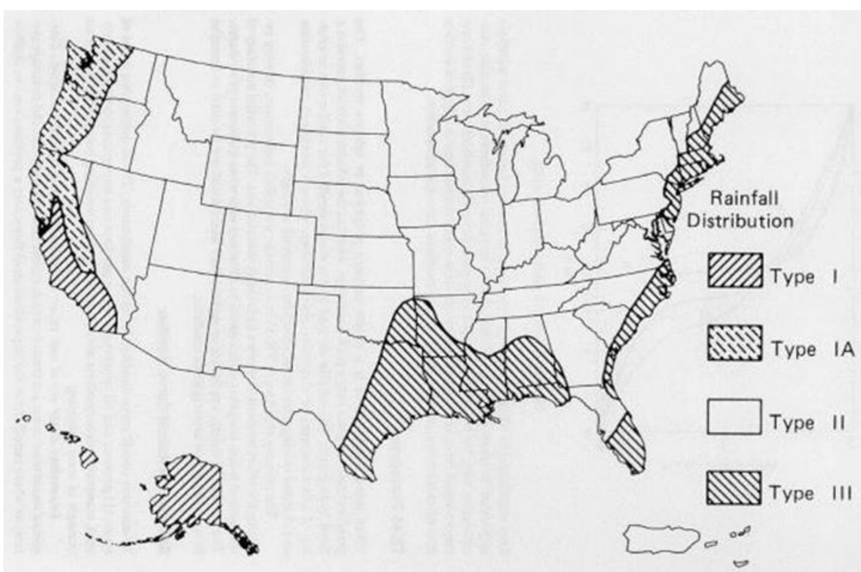



**Figure 4-4. Approximate Geographical Boundaries for SCS Rainfall Distribution**
(Source: Ponce, 1989)

The duration of these rainfall distributions is 24 hours. This constant duration was selected because most rainfall data is reported on a 24 hour basis. TR-55 uses the runoff curve number method to abstract total rainfall depth and calculate runoff depth. In addition, TR-55 includes procedures to determine concentration time for the following types of surface flow: 1) overland flow; 2) shallow concentrated flow; and 3) streamflow. Shallow concentrated flow is a type of surface flow of characteristics in between those of overland flow and streamflow (i.e. rill flow and gully flow).

#### *4.3.3.3 Model Overview*

A watershed consists of sub-areas (land areas) and reaches (major flow paths in the watershed). For each sub-area, a hydrograph is generated based on land and climate characteristics. Reaches are designated as either channel reaches, through which hydrographs are routed based on physical stream characteristics, or as storage reaches, through which hydrographs are routed based on reservoir storage and outlet characteristics. Sub-area and reach hydrographs are combined as needed to represent the accumulation of flow as water moves from the upland areas down through the watershed reach network. The watershed outlet represents the location at which all runoff from the watershed is accumulated.

In modeling LID practices with Win-TR-55, the infiltration and evapotranspiration are implicitly accounted for through the weighted curve number. As LID practices are introduced into the landscape then the user must be able to quantify the reduction in infiltration and evapotranspiration volume due to the project and how much infiltration capacity needs to be introduced into the project area with the LID practice in order to mitigate this loss in volume. There are a number of capabilities and limitations associated with this model, Table 4-3.

**Table 4-3. Win TR-55 Capabilities and Limitations**

| Variable | Limits |
|---|---|
| Minimum Area | Minimum area is 0.01 acre. Carefully examine results from sub-areas less than 1 acre. |
| Maximum Area | 25 square miles (6,500 ha) |
| Number of subwatersheds | 1 to 10 |
| Time of concentration for any sub-area | 0.1 hour <= Tc <= 10 hours |
| Number of reaches | 0 to 10 |
| Types of reaches | Channel or structure |
| Reach routing | Muskingum-Cunge |
| Structure routing | Storage-Indication |
| Structure types | Pipe or weir |
| Structure trial sizes | 1 to 3 |
| Rainfall depth | Default or user-defined 0 to 50 inches (0 to 1,270 mm) |
| Rainfall distributions | NRCS Type I, IA, II, III, NM60, NM65, NM70, NM75, or user-defined |
| Rainfall duration | 24-hour |
| Dimensionless unit hydrograph | Standard peak rate factor 484, or user-defined |
| Antecedent runoff condition | 2 (average) |

(Source: USDA, 2009)

In order to use WinTR-55, there is a minimum data requirement that needs to be met.

These data include:

- Project Identification Data
  - User
  - State
  - County
  - Project
  - Subtitle
- Dimensionless Unit Hydrograph
- Storm Data Source
- Rainfall Distribution Identifier
- Sub-area Entry and Summary
  - Sub-area Name
  - Sub-area Description
  - Sub-area Flows to Reach/Outlet
  - Area (ac. or sq. mi.)
  - Weighted curve number (CN)
  - Time of concentration (Tc)

Once the input data has been inserted and the model has been run, the File Display window, also referred to as the Report Viewer, displays various WinTR–55 reports, Table 4.3. This window opens after a WinTR–55 run. If there are any errors in the WinTR–55 run, this window opens with the Error File displayed. The user should carefully examine the error messages, and/or modify the input data to correct the errors.

In addition to the reports, there are hydrograph plotting options for sub-areas and reaches, Figure 4-5.

**Table 4-4. Win TR-55 Reports**

| Report Name | Description |
|---|---|
| Current data description | Lists the current user input data |
| Storm data | Lists the rainfall depth by rainfall return period information. Also shows Storm Data source, Rainfall Distribution, and the Dimensionless Unit Hydrograph. |
| Watershed Peak Table | Not available until an error-free WinTR-55 run is executed. Upon completion of an error-free WinTR-55 run, this option will give a listing of peak discharges, by reach, for each storm evaluated. |
| Hydrograph Peak/Peak Time Table | Not available until an error-free WinTR-55 run is executed. Upon completion of an error-free WinTR-55 run, this option gives a listing of peak discharge and time by sub-area or reach identifier, for each storm evaluated. |
| Structure Output Table | Not available until an error-free WinTR-55 run is executed. Upon completion of an error-free WinTR-55 run, this option gives a listing of peak flow (PF), storage volume (SV), and maximum stage (STG) for structures included in the WinTR-55 run. If there are no structures in the run, this table option is grayed out. |
| Sub-Area Summary Table | A listing by sub-area of drainage area, time of concentration, runoff curve number, receiving reach, and sub-area description. |
| Reach Summary Table | Identifies, by reach, the receiving reach, reach length, and routing method used. |
| Sub-Area Time of Concentration Details | A listing, by sub-area, of flow length, slope, Manning's n value, end area, wetted perimeter, velocity and travel time of concentration flow path segments along with the total time of concentration. |
| Sub-Area Land Use and Curve Number Details | A listing, by sub-area, of land use, hydrologic soil group, and area for each particular land use in a sub-area. Also lists the total area and weighted curve number for each sub-area. |
| Reach Channel Rating Details | Identifies, by reach, the reach length, Manning's n value used for that reach, friction slope, bottom width, and side slope. Also includes the computed channel rating for each reach. Channel ratings are in the WinTR-55 input data format: Stage-Flow-End Area. Rating tables also include top width and friction slope. |
| Structure Description | Provides a summary of the entered structure data by reach. If there are no structures in the run, this table option is grayed out. |
| Structure Rating Tables | Provides a summary of the computed structure ratings: stage, storage, and flow. If there are no structures in the run, this table option is grayed out. |

(Source: USDA, 2009)

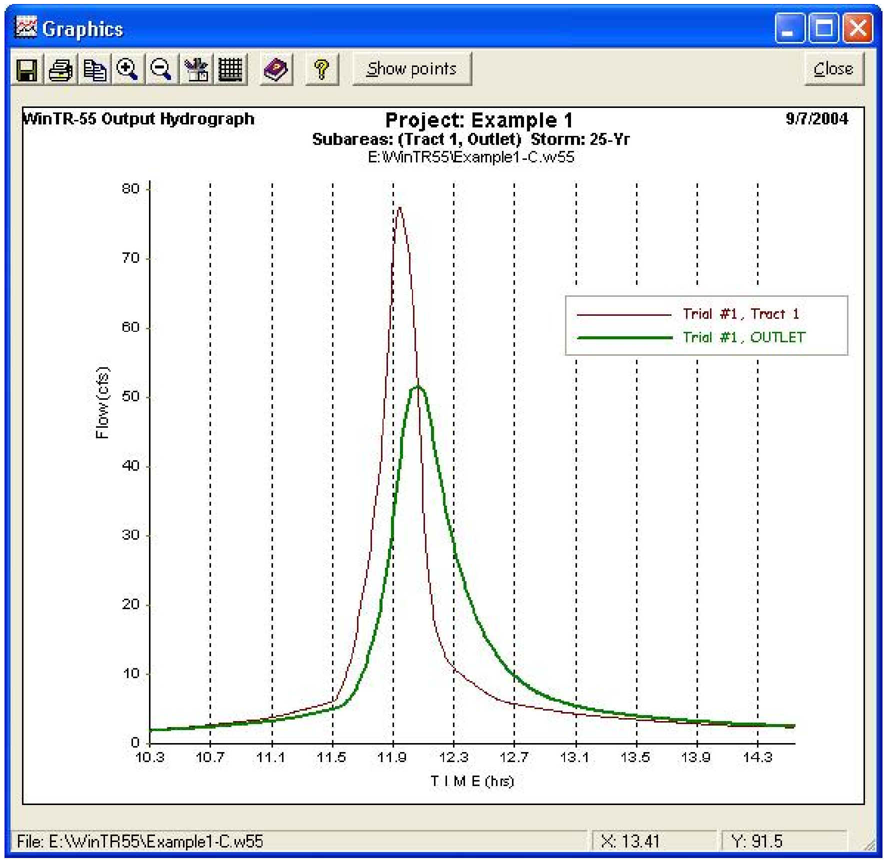



**Figure 4-5. Example Win TR-55 Hydrograph Plot**
(Source: USDA, 2009)

### 4.3.4 EPA SWMM

#### *4.3.4.1 Introduction*

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas (Rossman, 2010). The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

SWMM was first developed in 1971, and has since undergone several major upgrades since then. It continues to be widely used throughout the world for planning, analysis and design related to stormwater runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well. The current edition, Version 5, is a complete re-write of the previous release. Running under Windows, SWMM 5 provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses.

#### *4.3.4.2 Capabilities*

SWMM accounts for various hydrologic processes that produce runoff from urban areas. These include:

- time-varying rainfall
- evaporation of standing surface water
- snow accumulation and melting
- rainfall interception from depression storage
- infiltration of rainfall into unsaturated soil layers
- percolation of infiltrated water into groundwater layers
- interflow between groundwater and the drainage system
- nonlinear reservoir routing of overland flow
- runoff reduction via Low Impact Development (LID) controls.

Spatial variability in all of these processes is achieved by dividing a study area into a collection of smaller, homogeneous subcatchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between subcatchments, or between entry points of a drainage system.

SWMM also contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures. These include the ability to:

- handle drainage networks of unlimited size
- use a wide variety of standard closed and open conduit shapes as well as natural channels
- model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- utilize either kinematic wave or full dynamic wave flow routing methods
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels

In addition to modeling the generation and transport of runoff flows, SWMM can also estimate the production of pollutant loads associated with this runoff. The following processes can be modeled for any number of user-defined water quality constituents:

- dry-weather pollutant buildup over different land uses
- pollutant washoff from specific land uses during storm events
- direct contribution of rainfall deposition
- reduction in dry-weather buildup due to street cleaning
- reduction in washoff load due to BMPs
- entry of dry weather sanitary flows and user-specified external inflows at any point in the drainage system
- routing of water quality constituents through the drainage system
- reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels

In modeling LID practices with EPA SWMM, the infiltration and evapotranspiration are explicitly accounted for through the computation of infiltration and evapotranspiration. As LID practices are introduced into the landscape then the user will be able to better quantify the reduction in infiltration and evapotranspiration volume due to the project given the more explicit formulations and thus will be able to better determine infiltration capacity that needs to be accounted for with the LID practice in order to mitigate this loss in volume.

## 4.4 STANDARD HYDROLOGIC MODELING AND SIMULATION TOOLS FOR OPTION 2

### 4.4.1 The Retention Volume Simulation Model (RVSM)

#### *4.4.1.1 Introduction*

The RVSM simulates the pre-development conditions by modifying the runoff equation from the Curve Number Method found inTR-55 Runoff Equation (TR-55, equation 4.7) (Lemoine, 2011). Although the Curve Number Method is used in flow-based hydrology modeling, it is the closest method to being a volume-based model, because the method directly estimates a runoff volume. The method estimate runoff based on soil type and ground cover. Since the volume of rainwater retain, and not dissipated, in the soil and in depression storage of the previous day has the same effect as though it were part of the rainfall for the next day, the Runoff Equation from TR-55 can be modified to make it a continuous simulation. This modification involves adding to the rainfall volume of the current day, the rainfall retained in the soil and on the surface through depression storage from previous day less the estimate dissipation volume, Figure 4-6.

| | | | |
|---|---|---|---|
| $P_a =$ | $P + R_n$ | | **(4.6)** |
| $R_n =$ | $Pa - Qn - Q_d$ | | **(4.7)** |
| $Q_d \approx$ | $I_a$ | ....... *(Model Assumption)* | **(4,8)** |
| $I_a =$ | $0.2S$ | ....... *(eq. 2-2, TR-55)* | **(4,9)** |
| $S =$ | $(1000/CN) - 10$ | ....... *(eq. 2-4, TR-55)* | **(4.10)** |
| $Q_n =$ | $(P_a - 0.2S)^2 / (P_a + 0.8S)$ | ....... *(eq. 2-3, TR-55)* | **(4.11)** |

**P** = *24-Hour Precipitation*

$P_a$ = *Precipitation adjusted for retained moisture*

$R_n$ = *Retained moisture*

$Q_d$ = *Dissipation volume from infiltration, evapo-transpiration, and/or reuse*

$I_a$ = *Initial abstraction*

**S** = *Potential maximum retention after runoff begins*

**Qn** = *Pre-Development Runoff*

NOTE: All volumes are unit volumes of inches over the catchment area.)

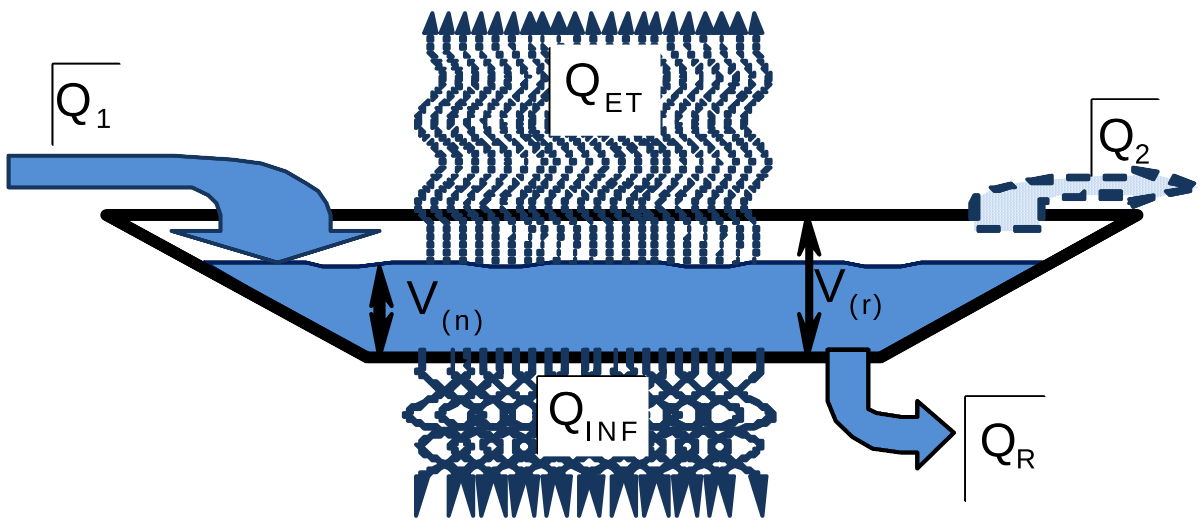



**Figure 4-6. RVSM Water Balance**

(Source: Lemoine, 2011)

The principle of continuity of volumes is used by the RVSM in simulating the performance of post-construction LID practices. Based on the continuity principle the retained volume is equal to the inflow volume minus the outflow volumes. The TR-55 Runoff Equation is used to calculate the inflow volume. The outflow volumes consist of; the infiltration volume, the evapo-transpiration volume, the reuse volume, and an overflow discharge volume when the LID retention capacity is exceeded. The RVSM groups the infiltration, evapo-transpiration, and reused volume into one variable called the dissipation rates.

The RVSM has four input variables: the pre-development curve number $CN_n$, the post-development curve number $CN_d$, the LID retention capacity $V_r$, and the dissipation rate $Q_D$.

Using those variables, the RVSM determines the number of occurrences when the discharge volume exceeded the 2-year runoff volume, and the number of occurrences when there is an overflow discharge of the LID practice based on the given retention capacity and dissipation rate. The goal is for the post-development discharge volume to “mimicking” the pre-development runoff volume. This goal is achieved by changing either the retention capacity or dissipation rate of the LID practice until the number of post-development discharge occurrences matches the pre-development occurrences. It is generally acknowledged that accelerated erosion occurs when the flow rate and frequency exceed the runoff from a 2-year rainfall. Therefore, the pre-development, 2-year runoff volume is used as the threshold for evaluating whether the post development discharge volume matches (mimics) the pre-development runoff volume.

#### *4.4.1.2 RVSM for Reuse Applications*

This same model can be used to evaluate the performance of reuse application. The model’s dissipation rate is the reuse rate. The reuse performance is measured by counting the number of days that there was sufficient retention volume to meet the demand for the retained water. The average availability is expressed as a percentage, calculated by dividing the number of days of available retention volume by the total number of days in the data set. This percentage provides an indication of whether and how much a supplemental source of water will be needed and how much. Various scenarios can be evaluated and this information used in a cost-benefit analysis to determine the optimum size retention tank.

The RVSM is created using a spreadsheet; however, a spreadsheet template has been created that can be used at any locality simply by inserting the 24-hour rainfall data and rainfall frequency data specific to that region. Once the appropriate local data has been input into the spreadsheet template, site specific evaluations and scenarios can be performed to estimate the required retention capacity and dissipation rate for LID practices. Alternatively the RVSM can be used to generate tables, charts and equations for use in designing LID practices anywhere within the local region.

### 4.4.2 EPA HSPF

#### *4.4.2.1 Introduction*

HSPF simulates for extended periods of time the hydrologic, and associated water quality, processes on pervious and impervious land surfaces and in streams and well-mixed impoundments. The model uses continuous rainfall and other meteorologic records to compute streamflow hydrographs and pollutographs (Bicknell et al, 2005). HSPF simulates interception soil moisture, surface runoff, interflow, base flow, snowpack depth and water content, snowmelt, evapotranspiration, ground-water recharge, dissolved oxygen, biochemical oxygen demand (BOD), temperature, pesticides, conservatives, fecal coliforms, sediment detachment and transport, sediment routing by particle size, channel routing, reservoir routing, constituent routing, pH, ammonia, nitrite-nitrate, organic nitrogen, orthophosphate, organic phosphorus, phytoplankton, and zooplankton. The program can simulate one or many pervious or impervious unit areas discharging to one or many river reaches or reservoirs. Frequency-duration analysis can be done for any time series. Any time step from 1 minute to 1 day that divides equally into 1 day can be used. Any period from a few minutes to hundreds of years may be simulated. HSPF is generally used to assess the effects of land-use change, reservoir operations, point or nonpoint source treatment alternatives, flow diversions, etc. Programs, available separately, support data preprocessing and postprocessing for statistical and graphical analysis of data saved to the Watershed Data Management (WDM) file.

#### *4.4.2.2 Conceptual Model Design*

To design a comprehensive simulation system, one must have a consistent means of representing the prototype; in our case, the real world. We view it as a set of constituents which move through a fixed environment and interact with each other. Water is one constituent; others are sediment, chemicals, etc. The motions and interactions are called processes.

The mathematical prototype is a continuum of constituents and processes. Simulation of such a system on a computer requires representation in a discrete fashion. In general, we do this by subdividing the prototype into "elements" which consist of "nodes" and "zones."

A node corresponds to a point in space. Therefore, a particular value of a spatially variable function can be associated with it, for example, channel flow rate and/or flow cross sectional area. A zone corresponds to a finite portion of the real world. It is usually associated with the integral of a spatially variable quantity, for example, storage in a channel reach. The relationship between zonal and nodal values is similar to that between the definite integral of a function and its values at the limits of integration.

An element is a collection of nodes and/or zones. We simulate the response of the land phase of the hydrological cycle using elements called "segments." A segment is a portion of the land assumed to have areally uniform properties. A segment of land with a pervious surface is called a "Pervious Land-segment" (PLS) and an impervious surface is called an “Impervious Land-segment” (ILS). A PLS or ILS has no nodes. In regards to stream or reservoir routing, we model a computational reach as a one dimensional element consisting of a single zone situated between two nodes. We simulate the flow rate and depth at the nodes; the zone is associated with storage.

#### *4.4.2.3 Pervious Land Segments*

A land segment is a subdivision of the simulated watershed. The boundaries are established according to the user's needs, but generally, a segment is defined as an area with similar hydrologic characteristics. For modeling purposes, water, sediment, and water quality constituents leaving the watershed move laterally to a downslope segment or to a reach/reservoir. A segment of land which has the capacity to allow enough infiltration to influence the water budget is considered pervious. In HSPF, PERLND (Pervious Land Segment) is the module that simulates the water quality and quantity processes which occur on a pervious land segment.

The primary module sections in PERLND simulate snow accumulation and melt, the water budget, sediment produced by land surface erosion, and water quality constituents by various methods. Other sections perform the auxiliary functions of correcting air temperature for use in snowmelt and soil temperature calculations, producing soil temperatures for estimating the outflow temperatures and influencing reaction rates in the agri-chemical sections, and determining outflow temperatures which influence the solubility of oxygen and carbon dioxide.

In modeling LID practices with HSPF, the PERLND segmentation is the primary module where the infiltration and evapotranspiration are explicitly accounted for through the computation of infiltration and evapotranspiration. As LID practices are introduced into the landscape then the user will be able to better quantify the reduction in infiltration and evapotranspiration volume due to the project given the more explicit formulations found within HSPF and thus will be able to better determine infiltration capacity that needs to be accounted for with the LID practice in order to mitigate this loss in volume.

#### *4.4.2.4 Impervious Land Segments*

In an impervious land segment, little or no infiltration occurs however, land surface processes do occur. Snow may accumulate and melt, and water may be stored or may evaporate. Various water quality constituents accumulate and are removed. Water, solids, and various pollutants flow from the segments by moving laterally to a downslope segment or to a reach/reservoir.

The HSPF IMPLND (Impervious Land Segment) module simulates a number of processes with many of them similar to the corresponding sections in the PERLND module. In fact, since sections snow and air temperature components perform functions that can be applied to pervious or impervious segments, they are shared by both modules.

#### *4.4.2.5 Streams and Reservoirs*

This module simulates the processes which occur in a single reach of open or closed channel or a completely mixed lake. For convenience, such a processing unit is referred to as a RCHRES. In keeping with the assumption of complete mixing, the RCHRES consists of a single zone situated between two nodes, which are the extremities of the RCHRES.

Flow through a RCHRES is assumed to be unidirectional. Water and other constituents which arrive from other RCHRES's and local sources enter the RCHRES through a single gate. Outflows may leave the RCHRES through one of several gates or exits. A RCHRES can have up to five outflow exits. Precipitation, evaporation, and other fluxes also influence the processes which occur in the RCHRES, but do not pass through the exits.

## 4.5 STORMWATER MANAGEMENT TECHNOLOGIES CASE STUDIES

### 4.5.1 Introduction

The purpose of this section is to demonstrate the application of the SCS Curve Number method for estimating the volume of water that needs to be managed for installations from different climatic zones and for different project design purposes using the Army LID Planning Tool. The SCS CN method was chosen due to its wide spread acceptance by watershed modelers and its flexibility in describing landscape parameters and features when modeling small catchments.

During the planning process, a general project boundary is typically determined. Using this project boundary or limit of disturbance, when available, to the engineer will evaluate the natural features that direct flow either to the area of interest or away from the area of interest. Once that has been done then man-made features, such as roads, drainage ditches, etc., need to be considered since they do alter the natural flow paths. After these features have been identified then the designer will need to delineate the catchment boundary, where the project will impact hydrology or increase runoff, using their best engineering judgement. In some cases, it may not be clear exactly how far out a boundary needs to go since the actual construction area may be small and the natural and man-made features may be sufficiently far away. In these cases, one needs to keep in mind that we are looking at the difference in existing and post project runoff conditions rather than absolute runoff depths so again some engineering judgement may need to be made in regards to how far out to set the catchment boundary. The consequences of setting the boundary too far away from the project site could cause the model to not be able to discern pre and post project differences accurately and thus cause the designer to either under design or over design the LID practices. In the case of over designing, this would cause an unnecessary increase in project cost. In the case of under designing, some local flooding may occur at the 95$^{th}$ percentile storm that otherwise should not occur.

Finally, this section demonstrates how different LID practices can be used in the design such that the water can be retained on site rather than allowed to runoff. The case studies presented here are hypothetical and are only meant to demonstrate estimating the EISA Section 438 volume requirement and applying LID BMPs to meet EISA.

### 4.5.2 Data Needs

The following sites were used in evaluating various LID Best Management Plans (BMPs): 1) Fort Drum; 2) Fort Hood; 3) Fort Benning; and 4) Fort Meade. The goal was to use sites that represented varying climatic regions in order to show the robustness of the LID BMPs to be used across the whole Department of Defense (DoD). In performing the LID analysis is was necessary to gather the following data:

- Land use/Land cover: The terms land use and land cover are often used interchangeably, but each term has its own unique meaning. *Land cover* refers to the characteristics and surface cover of Earth's surface, as represented by vegetation, water, bare earth, impervious surfaces, and other physical features of the land. Identification of land cover establishes the baseline information for activities like thematic mapping and change detection analysis. *Land use* refers to the activity, economic purpose, intended use, and/or management strategy placed on the land cover type(s) by human agents or land managers. Changes in intent or management practice likewise constitute land use change. When used together the phrase Land Use/Land Cover generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials.

- Digital Elevation Map (DEM): A DEM is a digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM). A DEM can be represented as a raster (a grid of squares) or as a triangular irregular network. For the LID analysis a minimum of 2-foot contour intervals (1-foot intervals are better) is necessary.

- Soil Texture Map: Soil texture is a soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil. Particles are grouped according to their size into what are called soil separates. At a minimum, the soil texture should be classified as sand, silt, or clay. A more detailed discussion of soil texture and possible soil amendments can be found in Chapter 3. Once the soil texture has been determined, then the hydrologic soil group (A, B, C, or D) can be ascertained and the appropriate infilatration rate (A=14.343 inches/day, B=9.743 inches/day, C=4.430 inches/day, and D=0.769 inches/day ) will be determined by the planning spreadsheet.

- Facilities Map: The facilities map should show basic man-made features associated with the selected installation (e.g., buildings, roads, parking lots, sewer/storm pipe systems, etc.)

- Precipitation: Precipitation is the quantity of water falling to earth at a specific place within a specified period of time. Precipitation can be in the form of rainfall or snow. For the LID analysis, 50 continuous years of 24-hour precipitation data is recommended.

For the case studies, the SCS Curve Number method was used in the hydrologic design of selected LID practices. In performing the hydrologic analysis, the following steps must be done:

- Evaluate existing soils (analysis) and surface features across project site.

- Determine the area (sq-ft / acres) of existing and planned: building foot print, parking, sidewalks, etc.

- Determine the area (sq-ft / acres) of existing vegetation features and the planned changes to the landscape.

- Compute changes in runoff volume from existing to planned site conditions.

- Evaluate LID practices appropriate for managing the change in runoff volume.

### 4.5.3 Fort Drum Case Study

#### *4.5.3.1 Background*

Fort Drum, New York is located in Western New York State, approximately 80 miles north of Syracuse, NY (Figure 4-7). Fort Drum gets 39 inches of rain per year. On average, there are 160 sunny days. The July high is around 80$^{o}$F and the January low is 10$^{o}$F.

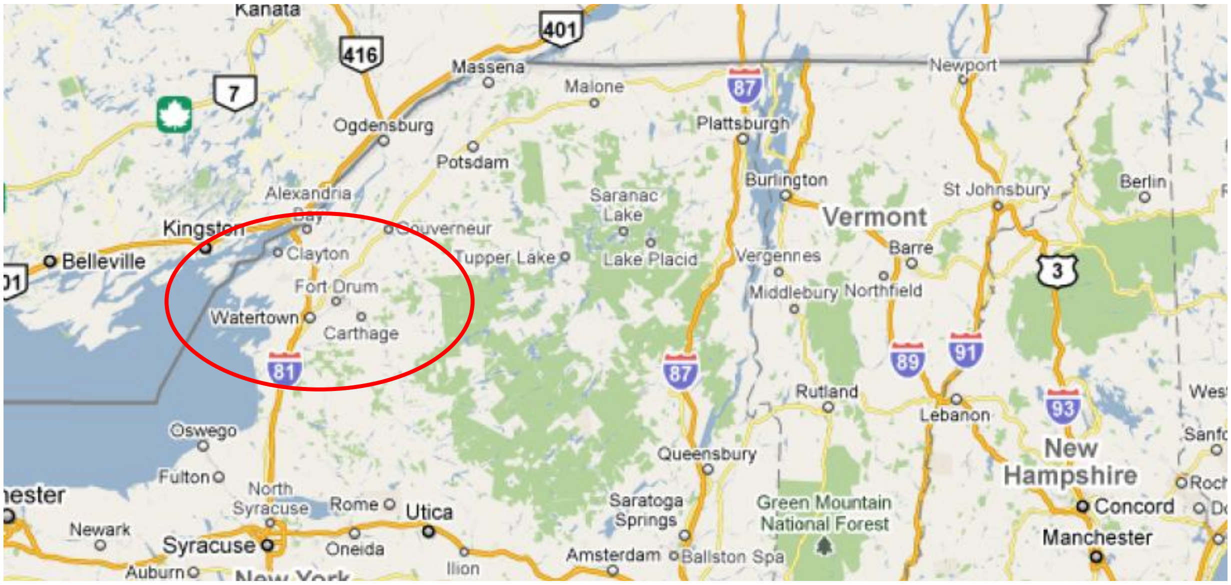



**Figure 4-7. Fort Drum, NY Location Map**

Fort Drum has been used as a military training site since 1908, however the Army's presence in the North Country may be traced back to the early 1800's. Today, Fort Drum consists of 107,265 acres. Its mission includes commanding active component units assigned to the installation, providing administrative and logistical support to tenant units, supporting tenant units, supporting active and reserve units from all services in training at Fort Drum, and planning and support for the mobilization and training of almost 80,000 troops annually. The Fort Drum installation can be seen in Figure 4-8.


**Figure 4-8. Fort Drum, NY Installation Area**

*4.5.3.2 Pre-Project Conditions*

For this case study, an existing housing site was selected for enlargement.

From a review of the USDA soils database, the predominant hydrologic soil group for the project site is Hydrologic Soil Group B. The existing land use consisted of Trees/Shrubs, Grassland, Lawns, and Existing Houses, Figure 4-9. By inputting the percent site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **61.6** (Figure 4-10).

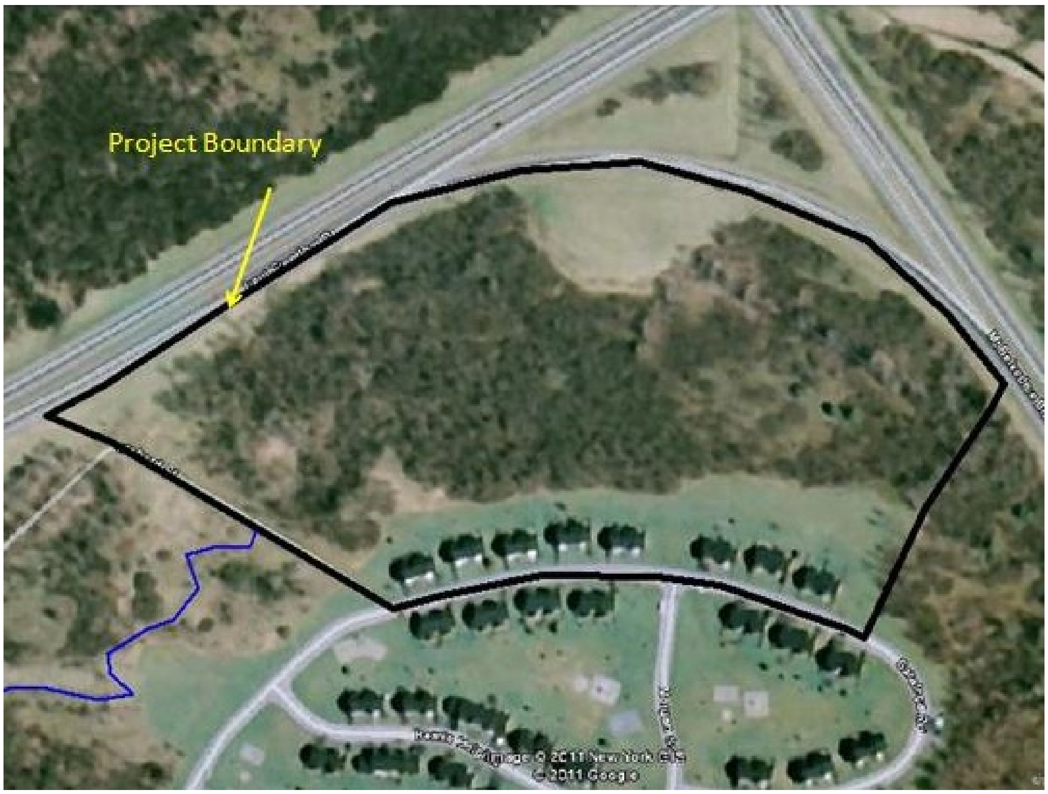



**Figure 4-9. Fort Drum, NY Project Site - Existing Landuse Conditions**

*4.5.3.3 Post-Project Conditions*

The post project land use, Figure 4-11, consisted of Lawn, Existing Houses, New Houses, Club House, Parking Lots, and Roads. By inputting the percent site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **74.9** (Figure 4-10).

SIMPLIFIED RUNOFF CURVE NUMBER METHOD

U.S. ARMY

ERDC

PRELIMINARY SELECTION AND SIZING OF LID PRACTICES

FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, EPA OPTION I

| | | | |
|---|---|---|---|
| DATE: | 14-Jun-11 | INSTALLATION: | Fort Drum, NY |
| PLANNER: | Bill Sproul | | |
| PROJECT NAME: | New Housing Development | | |
| PROJECT LOCATION: | Fort Drum | | |
| PROJECT AREA (acres): | 28.5 | 95% RAINFALL | 0.94 |

SELECT THE SITE'S GEN. SOIL TYPE: Sandy-Loam HSG = B

PRE-PROJECT

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | 60.7% | 60 |
| MEADOW | | |
| BRUSH & WEEDS (fair) | 18.7% | 56 |
| LAWN | 18.8% | 69 |
| ROADS & DRIVES (W*/C&G) | | |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | | |
| BUILDING ROOF | 1.8% | 98 |
| | | |
| | | |
| | | |
| | | |
| TOTAL % | 100.0% | |
| WEIGHTED AVERAGE CNn = | | 61.6 |

SELECTION OF OTHER LAND COVER TYPES

POST-PROJECT

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | | |
| MEADOW | | |
| BRUSH & WEEDS (fair) | | |
| LAWN | 77.8% | 69 |
| ROADS & DRIVES (W*/C&G) | 5.7% | 89 |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 4.4% | 98 |
| BUILDING ROOF | 12.1% | 98 |
| | | |
| | | |
| | | |
| | | |
| TOTAL % | 100.0% | |
| WEIGHTED AVERAGE CNd = | | 74.9 |

Pre-project: RUNOFF VOLUME (95% RAIN) = 0.037 ACRE-FEET; 1628 CUBIC FEET; 12180 GALLONS

Post-project: RUNOFF VOLUME (95% RAIN) = 0.048 ACRE-FEET; 2095 CUBIC FEET; 15672 GALLONS

MINIMUM RUNOFF RETENTION VOLUME TO COMPLY WITH EISA 438 VOLUME CONTROL REQUIREMENT

0.011 ACRE-FEET 467 CUBIC FEET 3,492 GALLONS

**Figure 4-10. Fort Drum Runoff Computations**


**Figure 4-11. Fort Drum, NY Project Site - Post-Project Landuse Conditions**

*4.5.3.4 Calculate EISA Volume Requirement*

The next step in the hydrologic design is to compute the 95$^{th}$ percentile storm. Based on an evaluation of a 50 year period of record of daily precipitation at Fort Drum, Figure 4-12, the 95$^{th}$ percentile storm was computed to be **0.94 inches**.

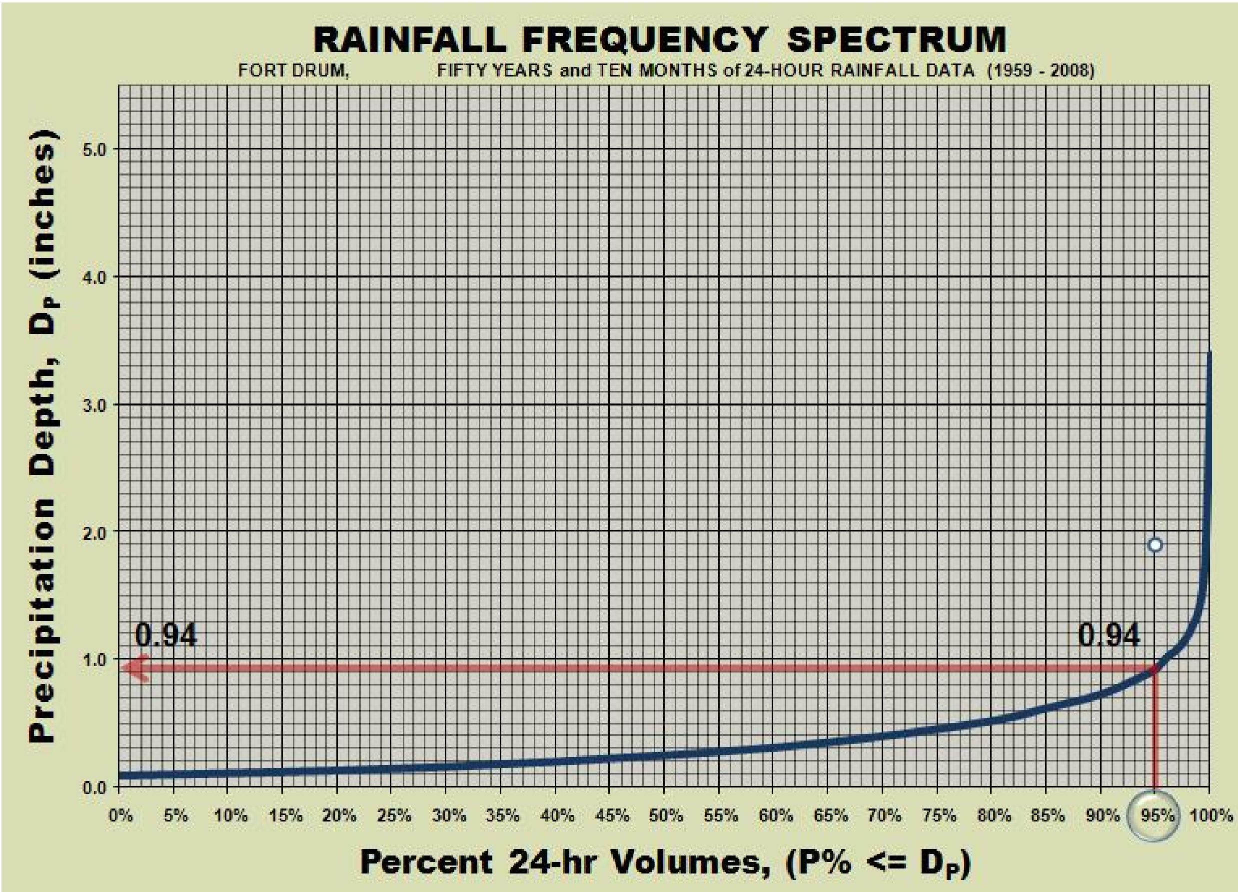



**Figure 4-12. Fort Drum, NY - 95th Percentile Storm Depth (Inches)**

At this point one is able to compute the peak runoff depths for both the existing and post project conditions using the SCS CN method. The peak runoff depths were computed to be 0.016 inches and 0.02 inches, respectively using the 95$^{th}$ percentile storm.

Once one computes the existing and post runoff depths then they are able to compute the amount of water that needs to be managed on the project site by multiplying the change in runoff depth by the site area, 28.5 acres. From this analysis, the Fort Drum project needs to manage **467 ft$^3$** of runoff, as computed in Figure 4-10.

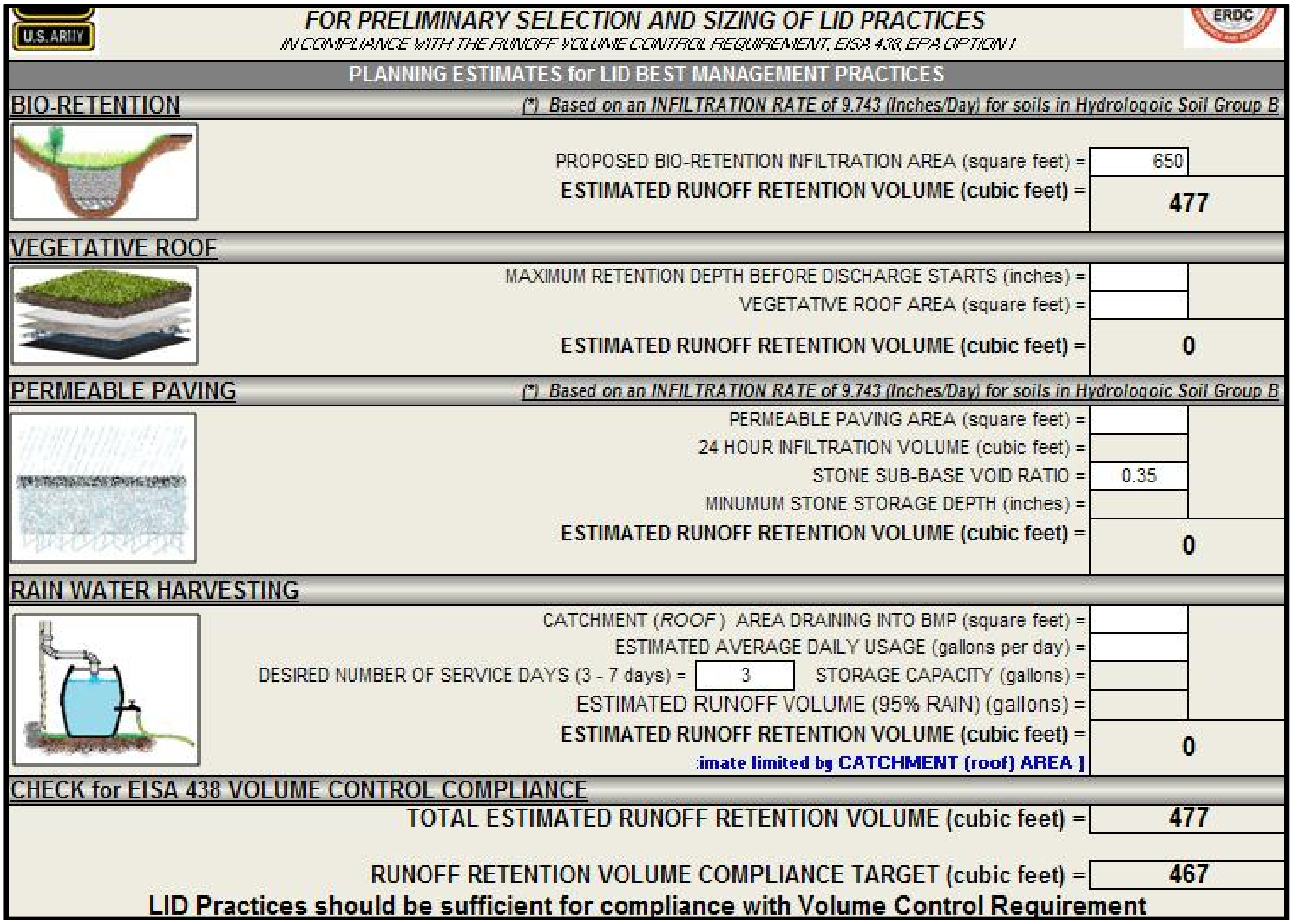
Input Parameters:
Site Area (A) = 28.5 acres
95$^{th}$ Storm (P) = 0.94 inches
Existing CN = 61.6
Post CN = 74.9

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad S = \frac{1000}{CN} - 10$$

Output:
Existing Q = 0.016 inches
Post Q = 0.02 inches

*4.5.3.5 Select LID BMPs to Manage EISA Volume*

The LID practice that was evaluated for this project was a bioswale, Figure 4-13. For this analysis, a Group B soil allows for 9.743 inches/day of water removed from the project site using this LID practice. Since this LID feature is an infiltration practice, it was determined that a bioswale area of 650 ft$^2$ (0.02 acres) was needed assuming a 24-hour dissipation time.


U.S. ARMY

ERDC

FOR PRELIMINARY SELECTION AND SIZING OF LID PRACTICES

*IN COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, EPA OPTION I*

PLANNING ESTIMATES for LID BEST MANAGEMENT PRACTICES

BIO-RETENTION — *(*) Based on an INFILTRATION RATE of 9.743 (Inches/Day) for soils in Hydrologic Soil Group B*

| | |
|---|---|
| PROPOSED BIO-RETENTION INFILTRATION AREA (square feet) = | 650 |
| **ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) =** | **477** |

VEGETATIVE ROOF

| | |
|---|---|
| MAXIMUM RETENTION DEPTH BEFORE DISCHARGE STARTS (inches) = | |
| VEGETATIVE ROOF AREA (square feet) = | |
| **ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) =** | **0** |

PERMEABLE PAVING — *(*) Based on an INFILTRATION RATE of 9.743 (Inches/Day) for soils in Hydrologic Soil Group B*

| | |
|---|---|
| PERMEABLE PAVING AREA (square feet) = | |
| 24 HOUR INFILTRATION VOLUME (cubic feet) = | |
| STONE SUB-BASE VOID RATIO = | 0.35 |
| MINUMUM STONE STORAGE DEPTH (inches) = | |
| **ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) =** | **0** |

RAIN WATER HARVESTING

| | |
|---|---|
| CATCHMENT (*ROOF*) AREA DRAINING INTO BMP (square feet) = | |
| ESTIMATED AVERAGE DAILY USAGE (gallons per day) = | |
| DESIRED NUMBER OF SERVICE DAYS (3 - 7 days) = 3 — STORAGE CAPACITY (gallons) = | |
| ESTIMATED RUNOFF VOLUME (95% RAIN) (gallons) = | |
| **ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) =** | **0** |

:imate limited by CATCHMENT (roof) AREA ]

CHECK for EISA 438 VOLUME CONTROL COMPLIANCE

| | |
|---|---|
| TOTAL ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = | **477** |
| RUNOFF RETENTION VOLUME COMPLIANCE TARGET (cubic feet) = | **467** |

**LID Practices should be sufficient for compliance with Volume Control Requirement**

**Figure 4-13. Fort Drum LID BMP Computations**

Since the Total Runoff Volume Retained (477 $ft^3$) exceeds the EISA Volume Requirement (467 $ft^3$), this project is expected to comply with EISA Section 438 using the selected LID BMPs.

### 4.5.4 Fort Hood Case Study

*4.5.4.1 Background*

Fort Hood is a United States military post located outside of Killeen, Texas (Figure 4-14). Fort Hood gets 32 inches of rain per year. The number of days with any measurable precipitation is 64. On average, there are 226 sunny days per year in Fort Hood. The July high is around 96°F and the January low is 34°F.

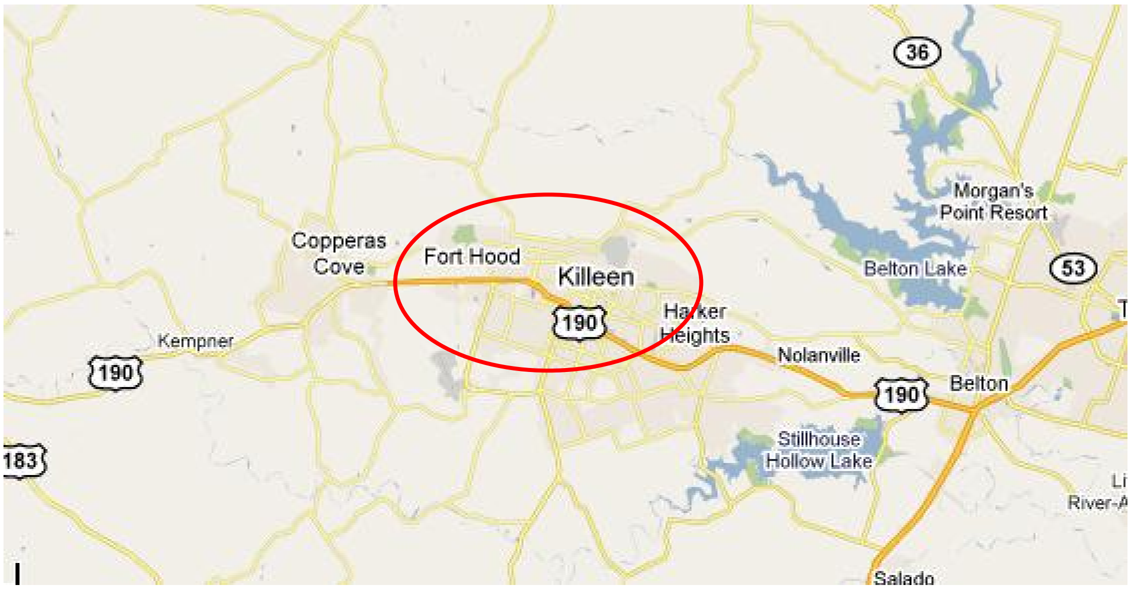



**Figure 4-14. Fort Hood, TX Vicinity Map**

The post is named after Confederate General John Bell Hood. It is located halfway between Austin and Waco, about 60 miles (97 km) from each, within the U.S. state of Texas. Its origin was the need for wide-open space to test and train with World War II tank destroyers. Today, Fort Hood has nearly 65,000 soldiers and family members and serves as a home for the following units: Headquarters III Corps; First Army Division West; the 1st Cavalry Division; 13th Sustainment Command (formerly 13th Corps Support Command); 89th Military Police Brigade; 504th Battlefield Surveillance Brigade; 21st Cavalry Brigade (Air Combat); Combat Aviation Brigade, 4th Infantry Division; and the 31st Air Defense Artillery Brigade. Fort Hood also includes Carl R. Darnall Army Medical Center and the Medical and Dental Activities as tenant units.

The Fort Hood installation can be seen in Figure 4-15.

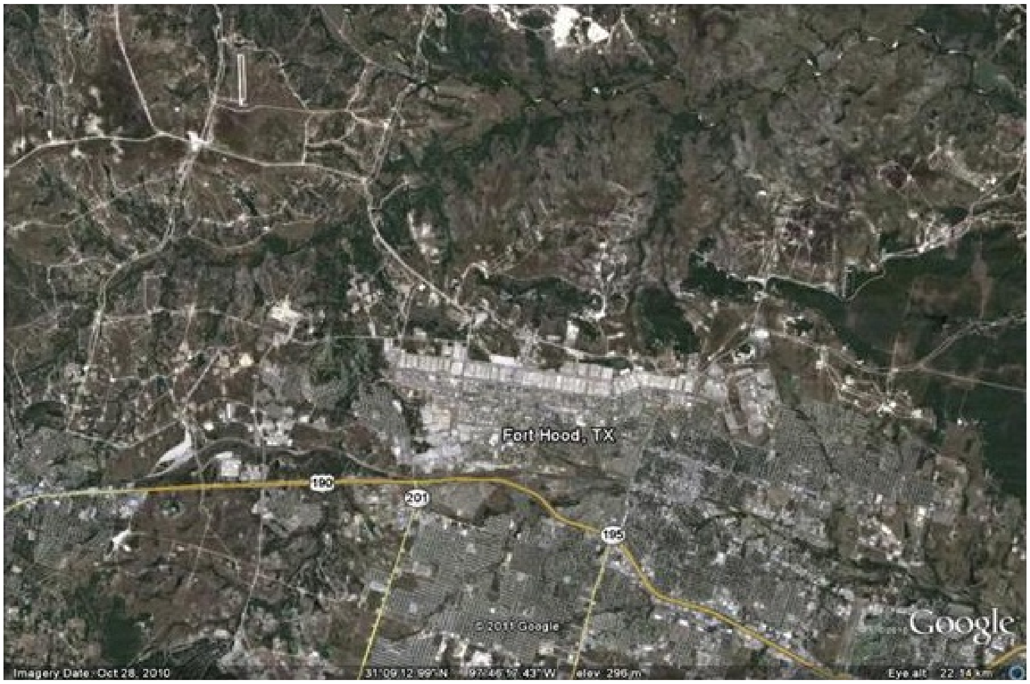



**Figure 4-15. Fort Hood, TX Installation Area**

### *4.5.4.2 Pre-Project Conditions*

For this demonstration project, four new buildings were added to the project site.

From a review of the USDA soils database, the predominant hydrologic soil group for the project site is Hydrologic Soil Group C. The existing land use consisted of Lawn, and Existing Buildings, Figure 4-16. By inputting the percent site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **81.8** (Figure 4-17).


**Figure 4-16. Fort Hood, TX Project Site - Existing Landuse Conditions**

| | | | |
|---|---|---|---|
| DATE: | 14-Jun-11 | INSTALLATION: | Fort Hood, Texas |
| PLANNER: | Bill Sproul | | |
| PROJECT NAME: | New Storage Units | | |
| ROJECT LOCATION: | Fort Hood | | |
| JECT AREA (acres): | 13.9 | 95% RAINFALL | 1.94 |

SELECT THE SITE'S GEN. SOIL TYPE: Silty-Loam HSG = C

| PRE-PROJECT LAND COVER | % of SITE | CN | | POST-PROJECT LAND COVER | % of SITE | CN |
|---|---|---|---|---|---|---|
| WOODED (fair) | | | | WOODED (fair) | | |
| MEADOW | | | | MEADOW | | |
| BRUSH & WEEDS (fair) | | | | BRUSH & WEEDS (fair) | | |
| LAWN | 82.7% | 79 | | LAWN | 74.7% | 79 |
| ROADS & DRIVES (W* /C&G) | 8.8% | 92 | | ROADS & DRIVES (W* /C&G) | 9.0% | 92 |
| ROADS & DRIVES (W /C&G) | | | | ROADS & DRIVES (W /C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | | | | PARKING, DRIVEWAYS & SIDEWALKS | | |
| BUILDING ROOF | 8.5% | 98 | | BUILDING ROOF | 16.3% | 98 |
| | | | SELECTION OF OTHER LAND COVER TYPES | | | |
| TOTAL % | 100.0% | | | TOTAL % | 100.0% | |
| WEIGHTED AVERAGE CNn = | | 81.8 | | WEIGHTED AVERAGE CNd = | | 83.3 |

| | | | | | |
|---|---|---|---|---|---|
| RUNOFF VOLUME (95% RAIN) = | 0.694 | ACRE-FEET | RUNOFF VOLUME (95% RAIN) = | 0.772 | ACRE-FE |
| 30227 CUBIC FEE | 226095 | GALLONS | 33647 CUBIC FEE | 251678 | GALLONS |

MINIMUM RUNOFF RETENTION VOLUME TO COMPLY WITH EISA 438 VOLUME CONTROL REQUIREMENT

0.079 ACRE-FEET 3,420 CUBIC FEET 25,583 GALLONS

**Figure 4-17. Fort Hood Runoff Computations**

### 4.5.4.3 Post-Project Conditions

The post project land use, Figure 4-18, consisted of Lawn, Existing Buildings, and New Buildings. By inputting the percent site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **83.3** (Figure 4-17).


**Figure 4-18. Fort Hood, TX Project Site - Post-Project Landuse Conditions**

### 4.5.4.4 *Calculate EISA Volume Requirement*

The next step in the hydrologic design is to compute the 95th percentile storm. Based on an evaluation of a 50 year period of record of daily precipitation at Fort Hood, Figure 4-19, the 95th percentile storm was computed to be **1.94 inches**.

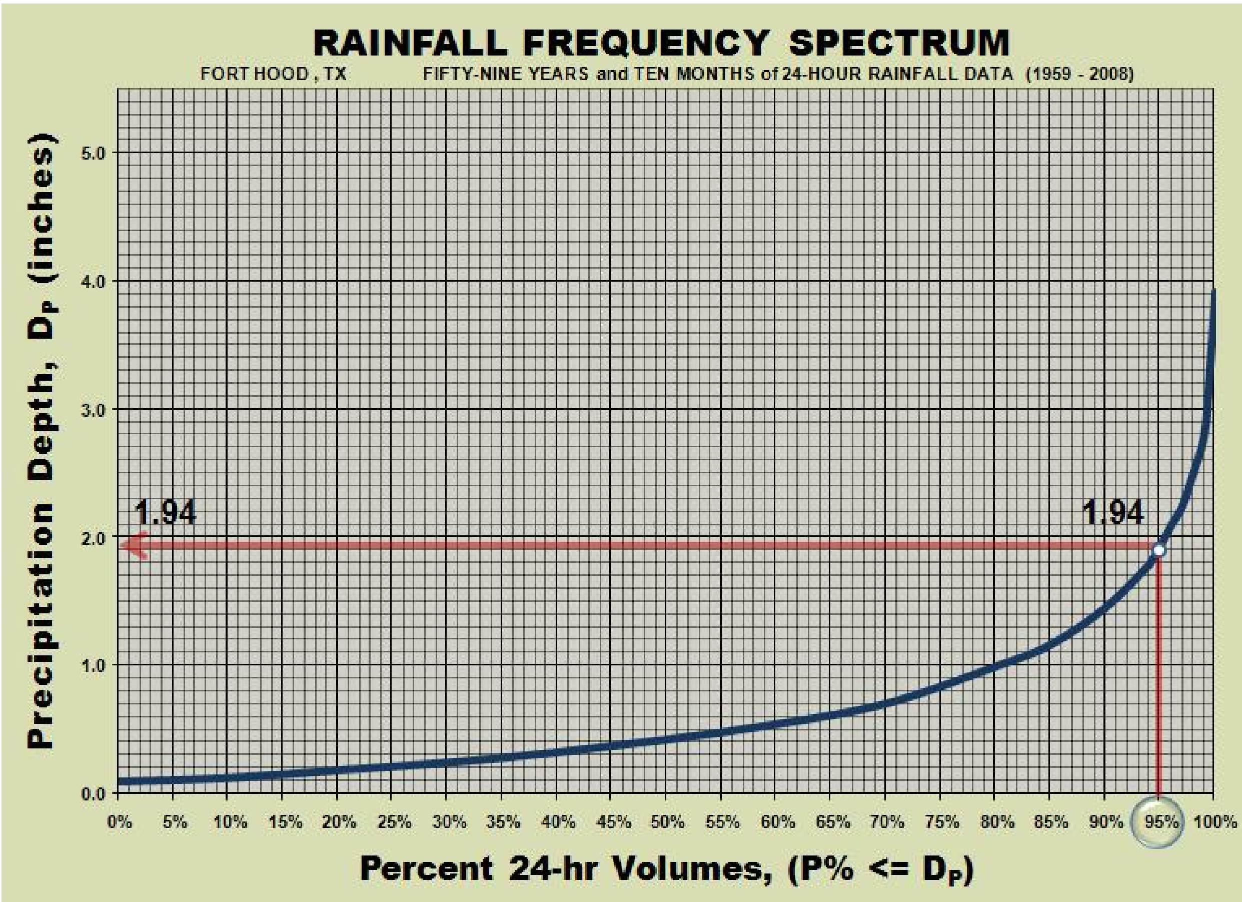



**Figure 4-19. Fort Hood, TX - 95th Percentile Storm Depth (Inches)**

At this point one is able to compute the peak runoff depths for both the existing and post project conditions using the SCS CN method. The peak runoff depths were computed to be 0.60 inches and 0.67 inches respectively using the 95th percentile storm.

Once one computes the existing and post runoff depths then they are able to compute the amount of water that needs to be managed on the project site by multiplying the change in runoff depth by the site area, 13.9 acres. From this analysis, the Fort Hood project needs to manage **3,420 ft$^3$** of runoff, as shown in Figure 4-17.

Input Parameters:
Site Area (A) = 13.9 acres
95th Storm (P) = 1.94 inches
Existing CN = 81.8
Post CN = 83.3

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad S = \frac{1000}{CN} - 10$$

Output:
Existing Q = 0.60 inches
Post Q = 0.67 inches

*4.5.4.5 Select LID BMPs to Manage EISA Volume*

The LID practice that was evaluated for this project was a series of rain gardens, Figure 4-20. For this analysis, a Group C soil allows for 4.43 inches/day of water removed from the project site using this LID practice. Since this LID feature is an infiltration practice, it was determined that a rain garden area of 16,500 ft$^2$ (0.38 acres) was needed assuming a 24-hour dissipation time.

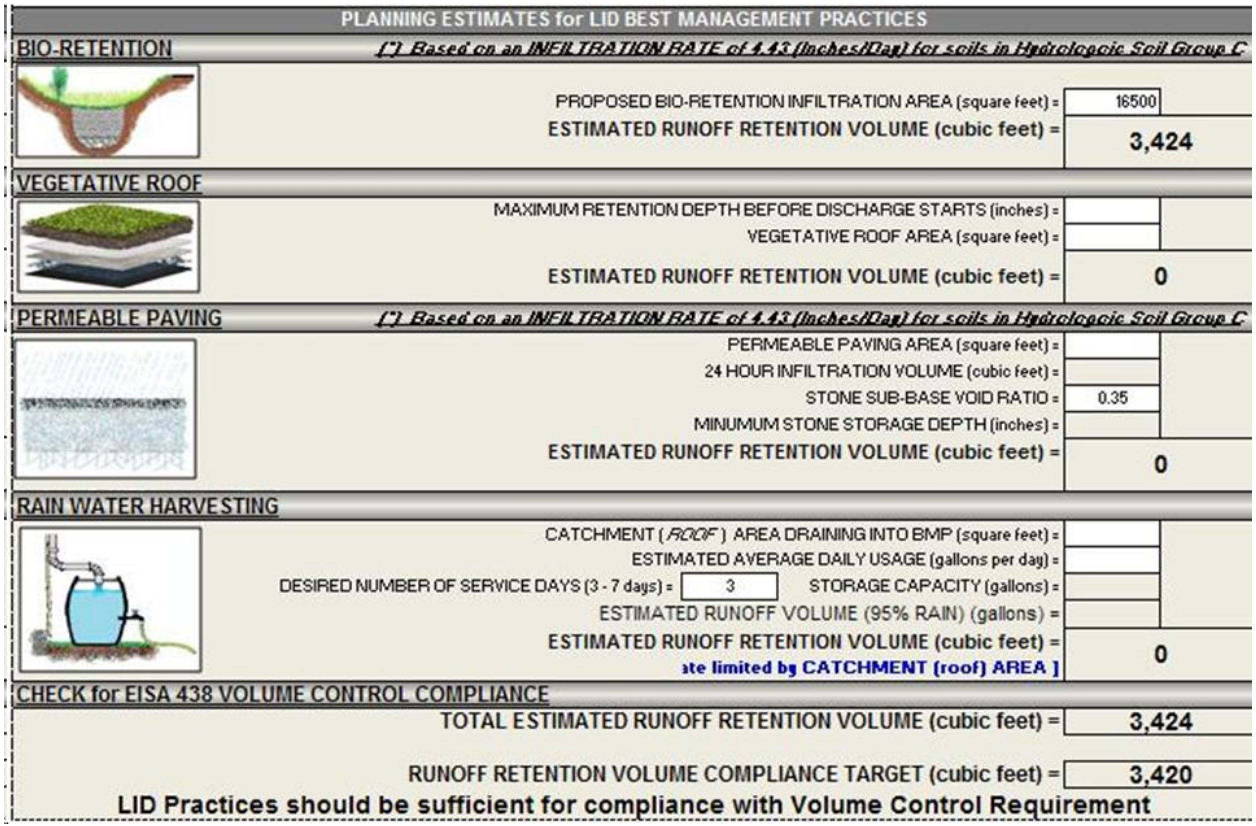



**Figure 4-20. Fort Hood LID BMP Computations**

Since the Total Runoff Volume Retained (3,424 ft$^3$) exceeds the EISA Volume Requirement (3,420 ft$^3$), this project is expected to comply with EISA Section 438 using the selected LID BMPs.

### 4.5.5 Fort Benning Case Study

#### *4.5.5.1 Background*

Fort Benning is a United States military post located outside of Columbus, GA (Figure 4-21). Columbus, GA, gets 49 inches of rain per year. The number of days with any measurable precipitation is 109. On average, there are 212 sunny days per year in Columbus, GA. The July high is around 92°F and the January low is 36°F.


**Figure 4-21. Fort Benning, GA Vicinity Map**

Fort Benning was established is 1918 and is named for Major General Henry L. Benning. It is south of Columbus, Georgia on U.S. highway 27. It has an active duty population of 34,834. This includes both reserve components. Fort Benning covers 73,533 hectares (181,626 acres) of land with 93% in west central Georgia and the remaining 7% in east central Alabama. Major portions of land lie in 3 counties: Muscogee and Chattahoochee Counties Georgia and Russell County in Alabama. There are about 124 hectares of open water, including ponds, streams, and rivers. The Chattahoochee River divides Fort Benning between Georgia and Alabama.

The Fort Benning installation can be seen in Figure 4-22.

**Figure 4-22. Fort Benning, GA Installation Area**

### *4.5.5.2 Pre-Project Conditions*

For this demonstration project, a new impervious parking lot was added to the project site.

From a review of the USDA soils database, the predominant hydrologic soil group for the project site is Hydrologic Soil Group C. The existing land use consisted of Grassland and Road, Figure 4-23. By inputting the percent site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **79.3** (Figure 4-24).


**Figure 4-23. Fort Benning, GA Project Site - Existing Landuse Conditions**

SIMPLIFIED RUNOFF CURVE NUMBER METHOD

*PRELIMINARY SELECTION AND SIZING OF LID PRACTICES*

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, EPA OPTION 1*

U.S. ARMY | ERDC

| | |
|---|---|
| DATE: | 14-Jun-11 |
| INSTALLATION: | Fort Benning, GA |
| PLANNER: | Bill Sproul |
| PROJECT NAME: | New Parking Lot |
| PROJECT LOCATION: | Fort Benning |
| PROJECT AREA (acres): | 16.1 |
| 95% RAINFALL | 1.88 |
| SELECT THE SITE'S GEN. SOIL TYPE: | Silty-Loam |
| HSG = | C |

PRE-PROJECT

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | | |
| MEADOW | | |
| BRUSH & WEEDS (fair) | | |
| LAWN | 97.5% | 79 |
| ROADS & DRIVES (W*/C&G) | 2.5% | 92 |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | | |
| BUILDING ROOF | | |
| | | |
| | | |
| | | |
| | | |
| TOTAL % | 100.0% | |
| WEIGHTED AVERAGE CNn = | | 79.3 |

RUNOFF VOLUME (95% RAIN) = 0.625 ACRE-FEET

27211 CUBIC FEET | 203538 GALLONS

SELECTION OF OTHER LAND COVER TYPES

POST-PROJECT

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | | |
| MEADOW | | |
| BRUSH & WEEDS (fair) | | |
| LAWN | 85.0% | 79 |
| ROADS & DRIVES (W*/C&G) | 15.0% | 92 |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | | |
| BUILDING ROOF | | |
| | | |
| | | |
| | | |
| | | |
| TOTAL % | 100.0% | |
| WEIGHTED AVERAGE CNd = | | 81.0 |

RUNOFF VOLUME (95% RAIN) = 0.708 ACRE-FEET

30851 CUBIC FEET | 230766 GALLONS

MINIMUM RUNOFF RETENTION VOLUME TO COMPLY WITH EISA 438 VOLUME CONTROL REQUIREMENT

0.084 ACRE-FEET | 3,640 CUBIC FEET | 27,228 GALLONS

**Figure 4-24. Fort Benning Runoff Computations**

### *4.5.5.3 Post-Project Conditions*

The post project land use (Figure 4-25), consisted of Grassland, Road, and New Parking Lot. By inputting the percent site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **81.0** (Figure 4-24).


**Figure 4-25. Fort Benning, GA Project Site - Post-project Landuse Conditions**

### *4.5.5.4 Calculate EISA Volume Requirement*

The next step in the hydrologic design is to compute the 95$^{th}$ percentile storm. Based on an evaluation of a 50 year period of record of daily precipitation at Fort Benning (Figure 4-26), the 95$^{th}$ percentile storm was computed to be **1.88 inches**.

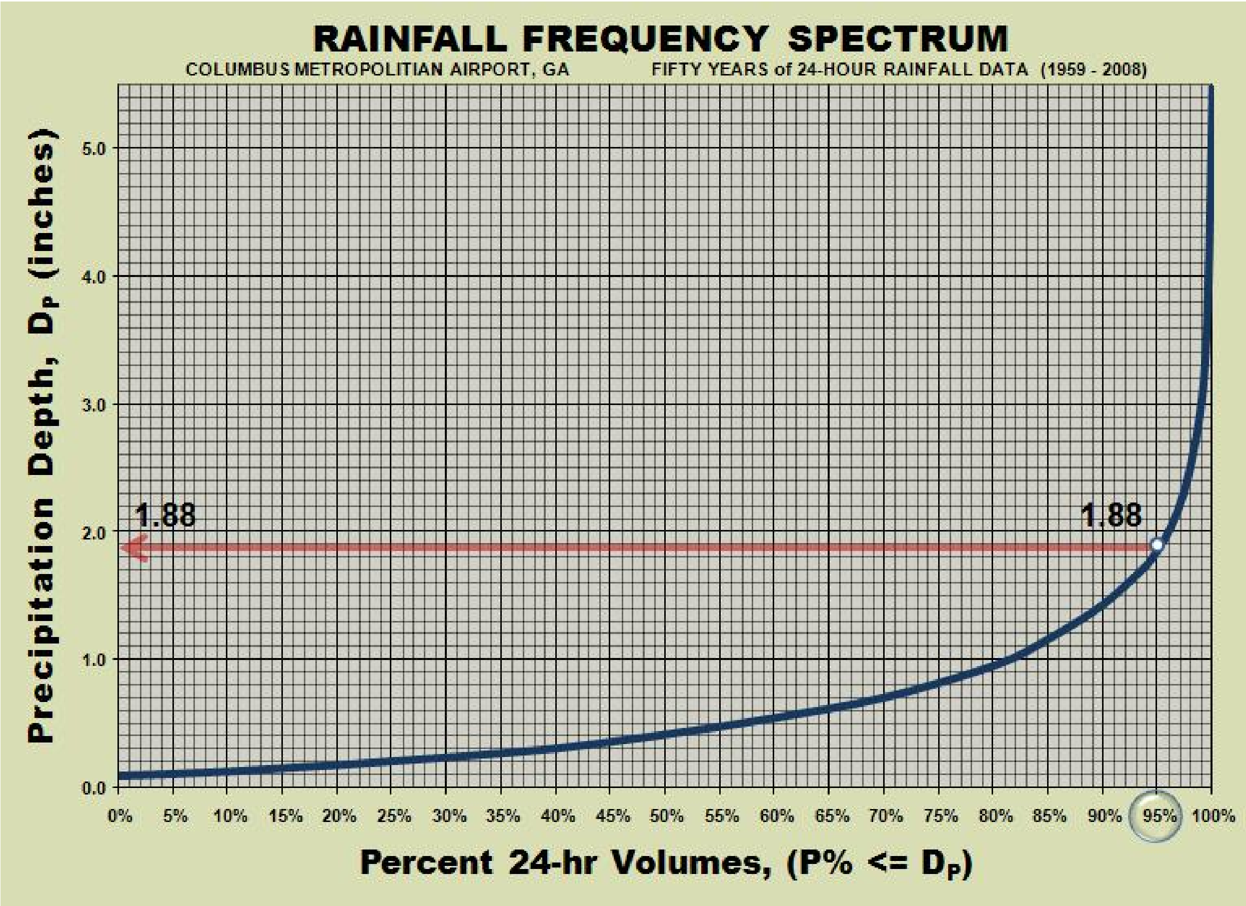



**Figure 4-26. Fort Benning, GA - 95th Percentile Storm Depth (Inches)**

Input Parameters:
Site Area (A) = 16.1 acres
95th Storm (P) = 1.88 inches
Existing CN = 79.3
Post CN = 81.0

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad S = \frac{1000}{CN} - 10$$

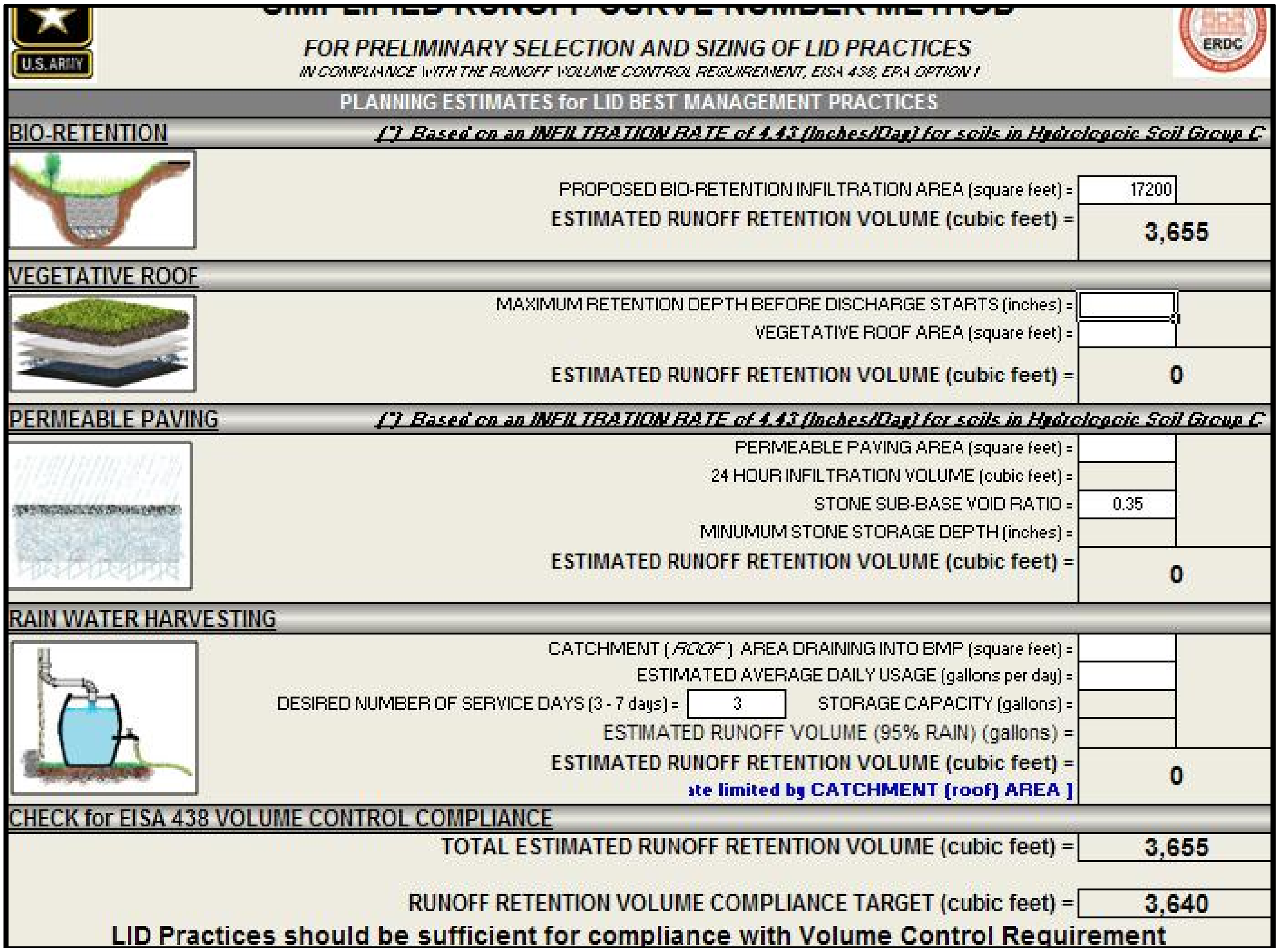
Output:
Existing Q = 0.46 inches
Post Q = 0.53 inches

At this point one is able to compute the peak runoff depths for both the existing and post project conditions using the SCS CN method. The peak runoff depths were computed to be 0.46 inches and 0.53 inches respectively using the 95th percentile storm.

Once one computes the existing and post project runoff depths, then they are able to compute the amount of water that needs to be managed on the project site by multiplying the change in runoff depth by the site area, 16.1 acres. From this analysis, the Fort Benning project needs to manage **3,640 $ft^3$** of runoff.

#### *4.5.5.5 Select LID BMPs to Manage EISA Volume*

The LID practice that was evaluated for this project was a bioswale, Figure 4-27. For this analysis, a Group C soil allows for 4.43 inches/day of water removed from the project site using this LID practice. Since this LID feature is an infiltration practice, it was determined that a bioswale of 17,200 ft2 (0.4 acres) was needed assuming a 24-hour dissipation time.


FOR PRELIMINARY SELECTION AND SIZING OF LID PRACTICES

IN COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, EPA OPTION I

PLANNING ESTIMATES for LID BEST MANAGEMENT PRACTICES

BIO-RETENTION — [*] Based on an INFILTRATION RATE of 4.43 (Inches/Day) for soils in Hydrologic Soil Group C

PROPOSED BIO-RETENTION INFILTRATION AREA (square feet) = 17200

ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 3,655

VEGETATIVE ROOF

MAXIMUM RETENTION DEPTH BEFORE DISCHARGE STARTS (inches) =

VEGETATIVE ROOF AREA (square feet) =

ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 0

PERMEABLE PAVING — [*] Based on an INFILTRATION RATE of 4.43 (Inches/Day) for soils in Hydrologic Soil Group C

PERMEABLE PAVING AREA (square feet) =

24 HOUR INFILTRATION VOLUME (cubic feet) =

STONE SUB-BASE VOID RATIO = 0.35

MINUMUM STONE STORAGE DEPTH (inches) =

ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 0

RAIN WATER HARVESTING

CATCHMENT ( ROOF ) AREA DRAINING INTO BMP (square feet) =

ESTIMATED AVERAGE DAILY USAGE (gallons per day) =

DESIRED NUMBER OF SERVICE DAYS (3 - 7 days) = 3 STORAGE CAPACITY (gallons) =

ESTIMATED RUNOFF VOLUME (95% RAIN) (gallons) =

ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 0

ate limited by CATCHMENT (roof) AREA ]

CHECK for EISA 438 VOLUME CONTROL COMPLIANCE

TOTAL ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 3,655

RUNOFF RETENTION VOLUME COMPLIANCE TARGET (cubic feet) = 3,640

LID Practices should be sufficient for compliance with Volume Control Requirement

**Figure 4-27. Fort Benning, GA LID BMP Computations**

Since the Total Runoff Volume Retained (3,655 ft$^3$) exceeds the EISA Volume Requirement (3,640 ft$^3$), this project is expected to comply with EISA Section 438 using the selected LID BMPs.

## 4.5.6 Fort Meade Case Study #1: AWG Headquarters Complex

### *4.5.6.1 Background*

Fort Meade is a United States military post located outside of Baltimore, MD (Figure 4-28). Fort Meade, MD, gets 44 inches of rain per year. The number of days with any measurable precipitation is 109. On average, there are 215 sunny days per year in Fort Meade, MD. The July high is around $88^{o}$F and the January low is $24^{o}$F.

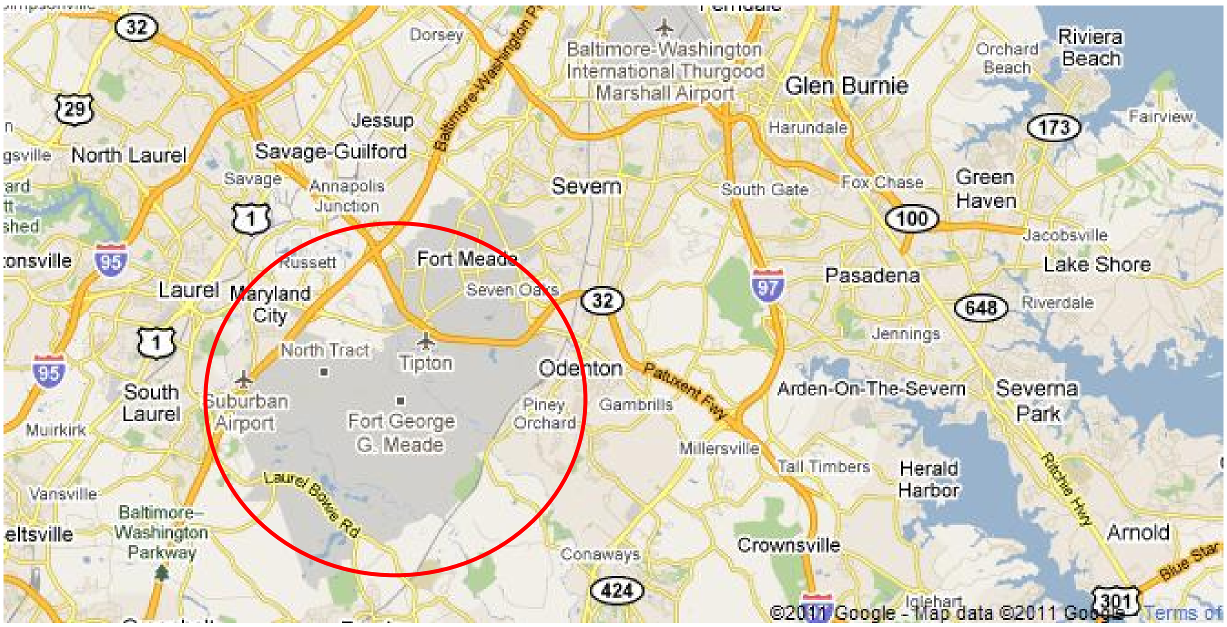


**Figure 4-28. Fort Meade, MD Vicinity Map**

Fort Meade became an active Army installation in 1917. Authorized by an Act of Congress in May 1917, it was one of 16 cantonments built for troops drafted for the war with the Central Powers in Europe. In August 1990, Fort Meade began processing Army Reserve and National Guard units from several states for the presidential call-up in support of Operation Desert Shield. In addition to processing reserve and guard units, Fort Meade sent two of its own active duty units, the 85th Medical Battalion and the 519th Military Police Battalion, to Saudi Arabia. In all, approximately 2,700 personnel from 42 units deployed from Fort Meade during Operation Desert Shield/Desert Storm.

The Fort Meade installation can be seen in Figure 4-29.

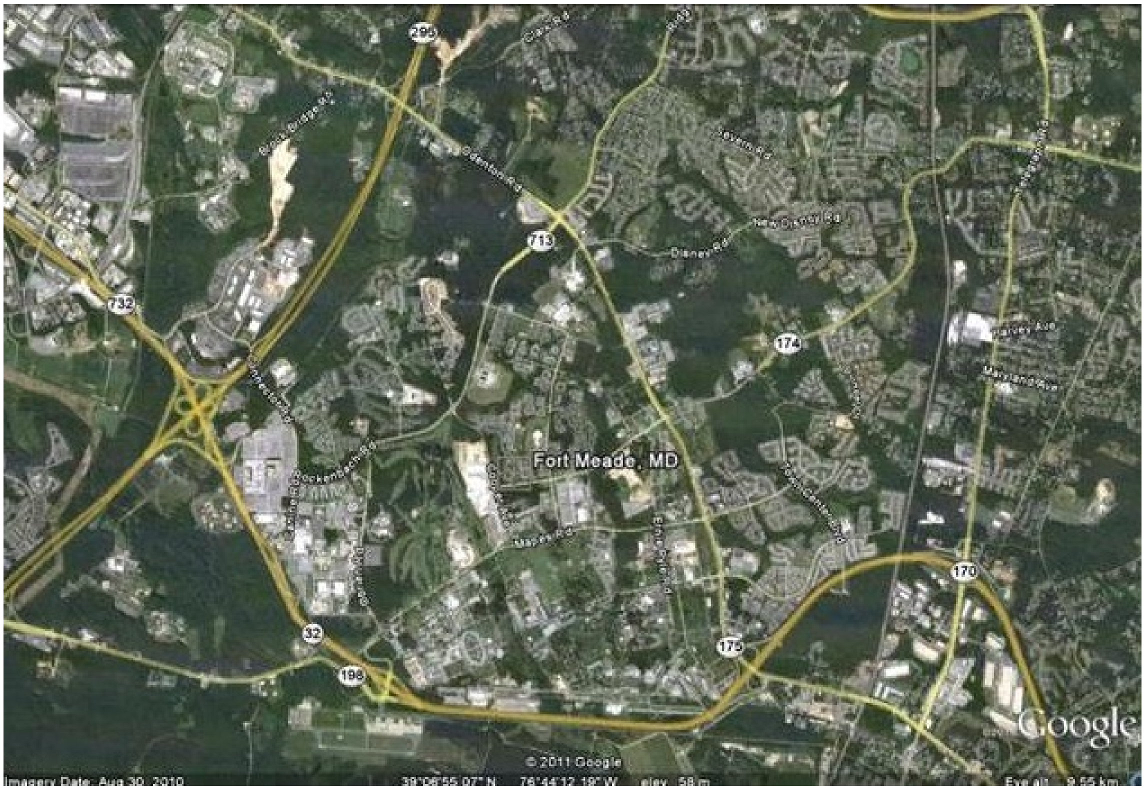



**Figure 4-29. Fort Meade, MD Installation Area**

### *4.5.6.2 Pre-Project Conditions*

This project includes a proposed Headquarters Building, Visitor Control Center, and associated roads and parking.

The existing 9.30 acre site, as shown in Figure 4-30 is predominantly meadow, with a small pocket of mature woods. There are a few abandoned buildings and associated pavement to be demolished as part of this project. There are no wetlands or streams within the site limits. Groundwater is not an issue; soil borings show the water table to be at least 15 feet below the ground surface. Based on a review of the USDA soils database, the predominant hydrologic soil group for the project site is Hydrologic Soil Group B, “Sandy Loam”.

By inputting the percent site area of each land use (Meadow, Woods, Building Roof, Parking/Driveways/Sidewalk) to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **62** (Figure 4-32).

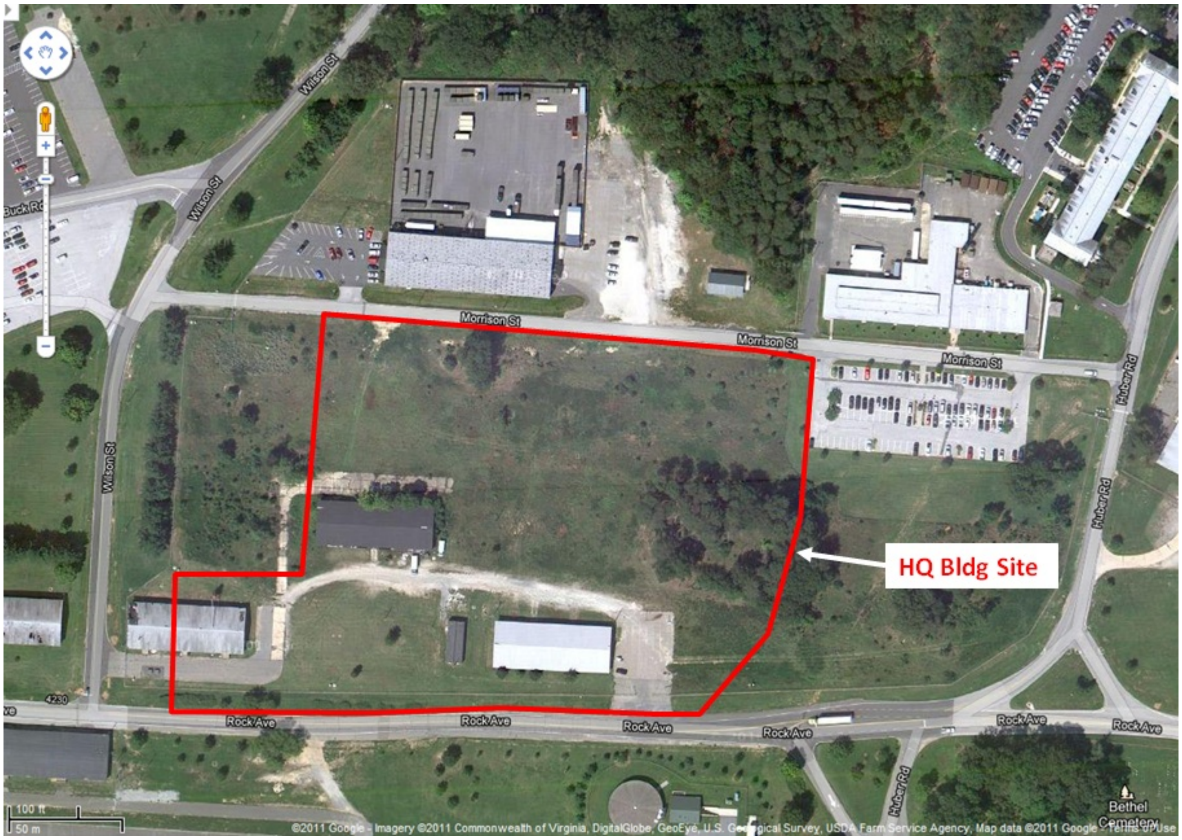



**Figure 4-30. Pre-Project Landuse Conditions**

### *4.5.6.3 Post-Project Conditions*

The proposed includes a 47,000 square foot Headquarters Building, a 2,900 square foot Visitor Control Center (VCC), and supporting facilities including parking, a loading dock, a maintenance drive, and a front drop off circle.

The post-project land use, Figure 4-31, consists of Grass, Building Roof, and Parking/Driveways/Sidewalks. By inputting the percent of site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average post-project CN is computed to be **80** (Figure 4-32).


**Figure 4-31. Post-Project Landuse Conditions**

LOW IMPACT DEVELOPMENT

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

*PRELIMINARY SELECTION AND SIZING OF STRUCTURAL LID PRACTICES*

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, MODIFIED EPA OPTION 2*

V 9.2 — PLANNING ESTIMATES for PRE & POST RUNOFF VOLUMES — Page 1 of 3

DATE: 5-Oct-2012 ARMY INSTALLATION: FORT MEADE

PLANNER: EEM

PROJECT NAME: AWG HEADQUARTERS COMPLEX

PROJECT LOCATION: ROCK AVE.

PROJECT AREA (acres): 9.3 95% RAINFALL 1.6 SELECT THE SITE'S OVERALL SOIL TYPE: Sandy-Loam HSG = B

| PRE-PROJECT LAND COVER | % of SITE | CN | | POST-PROJECT LAND COVER | % of SITE | CN |
|---|---|---|---|---|---|---|
| WOODED (fair) | 9.4% | 60 | | WOODED (fair) | | |
| MEADOW | 82.0% | 58 | | MEADOW | | |
| BRUSH & WEEDS (fair) | | | | BRUSH & WEEDS (fair) | | |
| LAWN | | | | LAWN | 61.0% | 69 |
| ROADS & DRIVES (W/C&G) | | | | ROADS & DRIVES (W/C&G) | | |
| ROADS & DRIVES (W/C&G) | | | | ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 4.6% | 98 | | PARKING, DRIVEWAYS & SIDEWALKS | 27.0% | 98 |
| BUILDING ROOF | 4.0% | 98 | | BUILDING ROOF | 12.0% | 98 |
| | | | SELECTION OF OTHER LAND COVER TYPES | | | |
| TOTAL % | 1 | | | TOTAL % | 1 | |
| WEIGHTED AVERAGE CNn = | | 62 | | WEIGHTED AVERAGE CNd = | | 80 |

**Figure 4-32. Pre-Project and Post-Project Curve Numbers**

#### *4.5.6.4 Calculate EISA Volume Requirement*

At this point one is able to calculate the EISA Volume Requirement for the project, using the inputs of Pre-Project CN, Post-Project CN, Site Area, and 95$^{th}$ percentile storm depth. For this example, instead of calculating the 95$^{th}$ percentile rainfall depth as in previous examples, the 95$^{th}$ percentile depth for Baltimore, MD, given in Table 4-1 of this guide (also in Table 1 of EPA's *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*) is used, **1.6 inches**.

The spreadsheet tool uses the SCS CN Method to compute the peak runoff volumes for both pre- and post-project conditions. The peak runoff volumes are computed to be 645 ft$^3$ and 11,672 ft$^3$, respectively. The difference between these volumes is the EISA Volume Requirement, which is the amount of runoff that needs to be retained on site using LID BMPs.

From this analysis, the Fort Meade project needs to manage **11,027 ft$^3$** of runoff, as shown in Figure 4-33.

Input Parameters:
Site Area (A) = 9.3 acres
95$^{th}$ Storm (P) = 1.6 inches
Existing CN = 62
Post CN = 80

Output:

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} x(A)$$

Q = Runoff Volume (ft$^3$)
Pre-Project Q = 645 ft$^3$
Post-Project Q = 11,672 ft$^3$
Difference in Q = 11,027 ft$^3$

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

*PRELIMINARY SELECTION AND SIZING OF STRUCTURAL LID PRACTICES*

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, MODIFIED EPA OPTION 2*

V 9.2 — PLANNING ESTIMATES for PRE & POST RUNOFF VOLUMES — Page 1 of 3

| | | | |
|---|---|---|---|
| DATE: | 5-Oct-2012 | ARMY INSTALLATION: | FORT MEADE |
| PLANNER: | EEM | | |
| PROJECT NAME: | AWG HEADQUARTERS COMPLEX | | |
| PROJECT LOCATION: | ROCK AVE. | | |
| PROJECT AREA (acres): | 9.3 | 95% RAINFALL | 1.6 |
| SELECT THE SITE'S OVERALL SOIL TYPE: | Sandy-Loam | HSG = | B |

**PRE-PROJECT**

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | 9.4% | 60 |
| MEADOW | 82.0% | 58 |
| BRUSH & WEEDS (fair) | | |
| LAWN | | |
| ROADS & DRIVES (WO/C&G) | | |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 4.6% | 98 |
| BUILDING ROOF | 4.0% | 98 |
| TOTAL % | 1 | |
| WEIGHTED AVERAGE CNn = | | 62 |
| RUNOFF VOLUME (95% RAIN) = | 0.01 | ACRE-FEET |
| 645 CUBIC FEET | 4828 | GALLONS |

SELECTION OF OTHER LAND COVER TYPES

**POST-PROJECT**

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | | |
| MEADOW | | |
| BRUSH & WEEDS (fair) | | |
| LAWN | 61.0% | 69 |
| ROADS & DRIVES (WO/C&G) | | |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 27.0% | 98 |
| BUILDING ROOF | 12.0% | 98 |
| TOTAL % | 1 | |
| WEIGHTED AVERAGE CNd = | | 80 |
| RUNOFF VOLUME (95% RAIN) = | 0.267949603 | ACRE-FEET |
| 11672 CUBIC FEET | 87306 | GALLONS |

**MINIMUM RUNOFF RETENTION VOLUME TO COMPLY WITH EISA 438 VOLUME CONTROL REQUIREMENT**

| | | |
|---|---|---|
| 0.25 ACRE-FEET | 11027 CUBIC FEET | 82478 GALLONS |

**Figure 4-33. Runoff Computations**

### *4.5.6.5 Select LID BMPs to Manage EISA Volume*

The LID practices chosen for this project to retain runoff is bioretention areas, concrete permeable pavers, and infiltration trenches (dry well). Figure 4-34 shows these proposed practices. Inputing the proposed surface area of each LID BMP in the spreadsheet, the volume of runoff retained is calculated, as shown in Figure 4-35. Summing these retention volumes (15947 $ft^3$ + 214 $ft^3$ + 1773 $ft^3$ + 1640 $ft^3$) gives a Total Volume Retained for the site, **19,574 $ft^3$**.

Since the Total Runoff Volume Retained (19,574 $ft^3$) exceeds the EISA Volume Requirement (11,027 $ft^3$), this project fulfills EISA Section 438 with the selected LID BMPs.

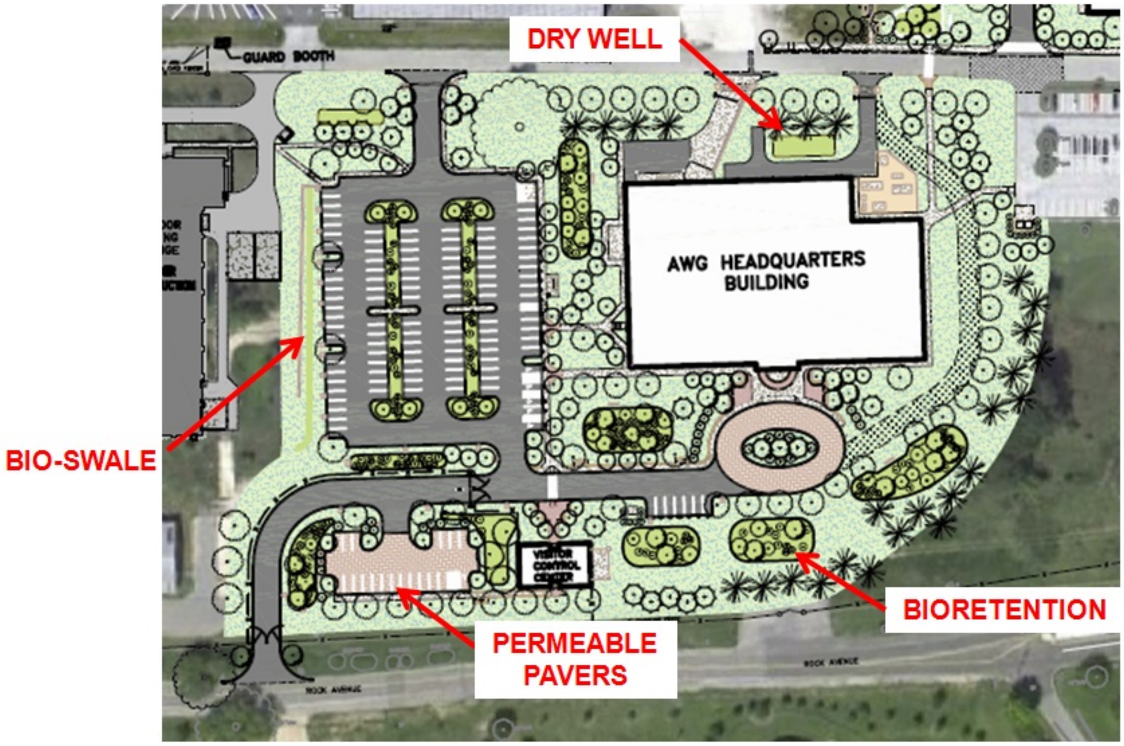
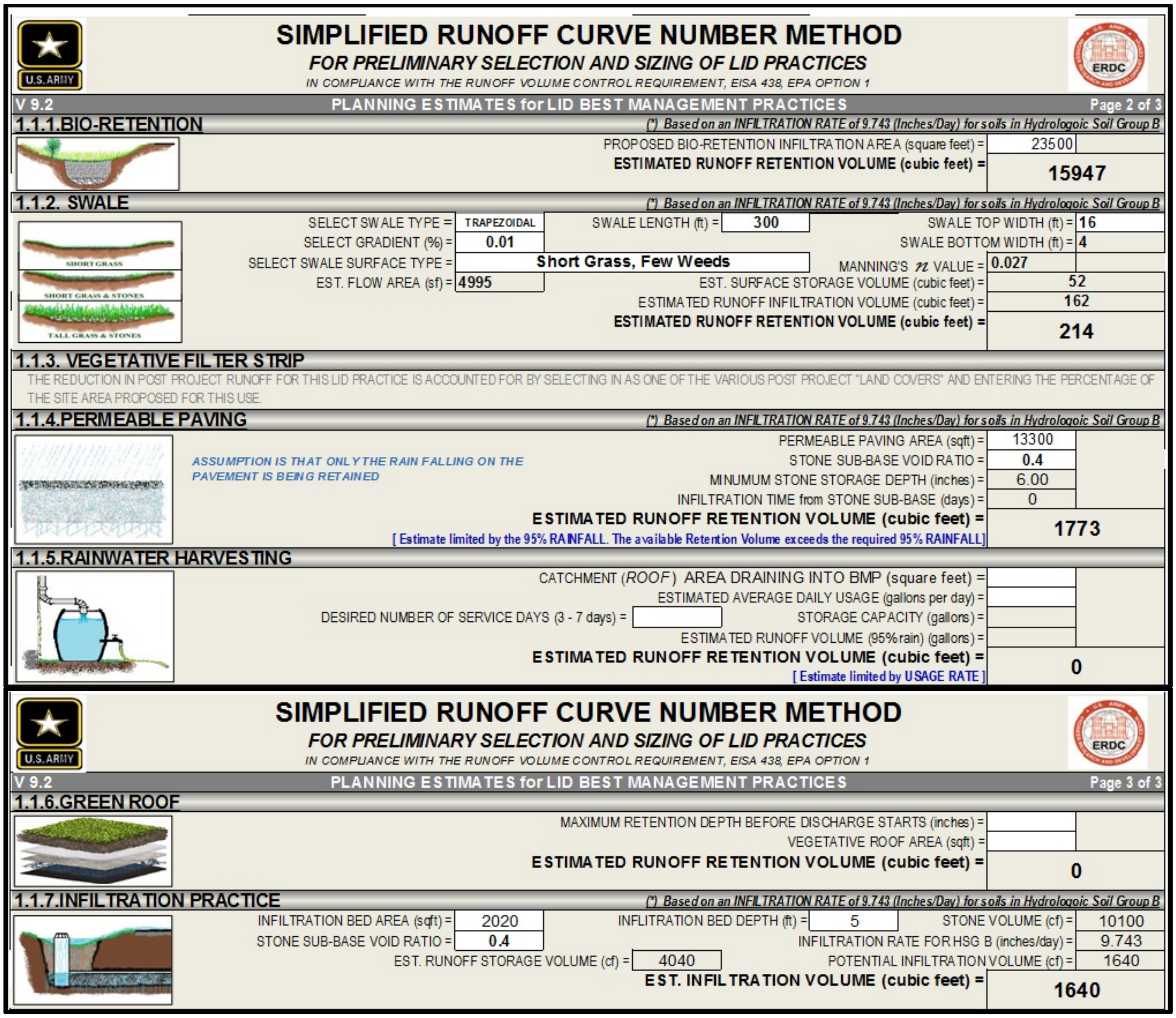



**Figure 4-34. Proposed LID BMPs Implemented**



**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

*FOR PRELIMINARY SELECTION AND SIZING OF LID PRACTICES*

*IN COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, EPA OPTION 1*

V 9.2 — PLANNING ESTIMATES for LID BEST MANAGEMENT PRACTICES — Page 2 of 3

**1.1.1.BIO-RETENTION** — *(*) Based on an INFILTRATION RATE of 9.743 (Inches/Day) for soils in Hydrologoic Soil Group B*

PROPOSED BIO-RETENTION INFILTRATION AREA (square feet) = 23500

**ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 15947**

**1.1.2. SWALE** — *(*) Based on an INFILTRATION RATE of 9.743 (Inches/Day) for soils in Hydrologoic Soil Group B*

SHORT GRASS / SHORT GRASS & STONES / TALL GRASS & STONES

SELECT SWALE TYPE = TRAPEZOIDAL; SWALE LENGTH (ft) = 300; SWALE TOP WIDTH (ft) = 16

SELECT GRADIENT (%) = 0.01; SWALE BOTTOM WIDTH (ft) = 4

SELECT SWALE SURFACE TYPE = Short Grass, Few Weeds; MANNING'S *n* VALUE = 0.027

EST. FLOW AREA (sf) = 4995; EST. SURFACE STORAGE VOLUME (cubic feet) = 52

ESTIMATED RUNOFF INFILTRATION VOLUME (cubic feet) = 162

**ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 214**

**1.1.3. VEGETATIVE FILTER STRIP**

THE REDUCTION IN POST PROJECT RUNOFF FOR THIS LID PRACTICE IS ACCOUNTED FOR BY SELECTING IN AS ONE OF THE VARIOUS POST PROJECT "LAND COVERS" AND ENTERING THE PERCENTAGE OF THE SITE AREA PROPOSED FOR THIS USE.

**1.1.4.PERMEABLE PAVING** — *(*) Based on an INFILTRATION RATE of 9.743 (Inches/Day) for soils in Hydrologoic Soil Group B*

*ASSUMPTION IS THAT ONLY THE RAIN FALLING ON THE PAVEMENT IS BEING RETAINED*

PERMEABLE PAVING AREA (sqft) = 13300

STONE SUB-BASE VOID RATIO = 0.4

MINUMUM STONE STORAGE DEPTH (inches) = 6.00

INFILTRATION TIME from STONE SUB-BASE (days) = 0

**ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 1773**

[ Estimate limited by the 95% RAINFALL. The available Retention Volume exceeds the required 95% RAINFALL]

**1.1.5.RAINWATER HARVESTING**

CATCHMENT (*ROOF*) AREA DRAINING INTO BMP (square feet) =

ESTIMATED AVERAGE DAILY USAGE (gallons per day) =

DESIRED NUMBER OF SERVICE DAYS (3 - 7 days) = ; STORAGE CAPACITY (gallons) =

ESTIMATED RUNOFF VOLUME (95%rain) (gallons) =

**ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 0**

[ Estimate limited by USAGE RATE ]

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

*FOR PRELIMINARY SELECTION AND SIZING OF LID PRACTICES*

*IN COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, EPA OPTION 1*

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**1.1.6.GREEN ROOF**

MAXIMUM RETENTION DEPTH BEFORE DISCHARGE STARTS (inches) =

VEGETATIVE ROOF AREA (sqft) =

**ESTIMATED RUNOFF RETENTION VOLUME (cubic feet) = 0**

**1.1.7.INFILTRATION PRACTICE** — *(*) Based on an INFILTRATION RATE of 9.743 (Inches/Day) for soils in Hydrologoic Soil Group B*

INFILTRATION BED AREA (sqft) = 2020; INFLITRATION BED DEPTH (ft) = 5; STONE VOLUME (cf) = 10100

STONE SUB-BASE VOID RATIO = 0.4; INFILTRATION RATE FOR HSG B (inches/day) = 9.743

EST. RUNOFF STORAGE VOLUME (cf) = 4040; POTENTIAL INFILTRATION VOLUME (cf) = 1640

**EST. INFILTRATION VOLUME (cubic feet) = 1640**

**Figure 4-35. LID BMP Computations**

### 4.5.7 Fort Meade Case Study #2: Vehicle Maintenance Facility

#### *4.5.7.1 Background*

Please see Section 4.5.6.1 for Fort Meade background information. It is referenced instead of copied here to minimize redundancy.

#### *4.5.7.2 Pre-Project Conditions*

This re-development project includes a proposed Vehicle Maintenace Facility and associated pavement for vehicle and supply storage.

The existing 3.0 acre site, as shown in Figure 4-36 is developed and mostly impervious, with an existing building and associated pavement. These will be demolished as part of this prior to constructing the Vehicle Maintenance Facility. The site area is surrounded by mature woods. The site drains to the northwest to an ephemeral stream. Groundwater is not an issue; soil borings show the water table to be at least 15 feet below the grouned surface. Based on a review of the USDA soils database, the predominant hydrologic soil group for the project site is Hydrologic Soil Group A, “Sandy”.

By inputting the percent site area of each land use (Building Roof, Parking/Driveway/Sidewalk, Grass) to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **87** (Figure 4-38).


**Figure 4-36. Pre-Project Landuse Conditions**

### *4.5.7.3 Post-Project Conditions*

The proposed includes a 14,000 square foot Vehicle Maintenace building with surrounding pavement for vehicle and supply storage. There is no POV parking requirement for this project; the existing parking lot south of the site will be used.

The post-project land use, Figure 4-37, consists of Grass, Building Roof, and Parking/Driveway/Sidewalks. By inputting the percent of site area of each land use to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average post-project CN is computed to be **90** (Figure 4-38).


**Figure 4-37. Post-Project Landuse Conditions**

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

***PRELIMINARY SELECTION AND SIZING OF STRUCTURAL LID PRACTICES***

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, MODIFIED EPA OPTION 2*

| V 9.2 | PLANNING ESTIMATES for PRE & POST RUNOFF VOLUMES | Page 1 of 3 |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| DATE: | 5-Oct-2012 | ARMY INSTALLATION: | FORT MEADE | | |
| PLANNER: | EEM | | | | |
| PROJECT NAME: | VEHICLE MAINTENANCE FACILITYY (VMF) | | | | |
| PROJECT LOCATION: | MORRISON STREET | | | | |
| PROJECT AREA (acres): | 3.0 | 95% RAINFALL | 1.6 | SELECT THE SITE'S OVERALL SOIL TYPE: Sandy | HSG = A |

| PRE-PROJECT LAND COVER | % of SITE | CN | | POST-PROJECT LAND COVER | % of SITE | CN |
|---|---|---|---|---|---|---|
| WOODED (fair) | | | | WOODED (fair) | | |
| MEADOW | | | | MEADOW | | |
| BRUSH & WEEDS (fair) | | | | BRUSH & WEEDS (fair) | | |
| LAWN | 23.0% | 49 | | LAWN | 16.0% | 49 |
| ROADS & DRIVES (WO/C&G) | | | | ROADS & DRIVES (WO/C&G) | | |
| ROADS & DRIVES (W/C&G) | | | | ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 59.0% | 98 | | PARKING, DRIVEWAYS & SIDEWALKS | 74.0% | 98 |
| BUILDING ROOF | 18.0% | 98 | | BUILDING ROOF | 10.0% | 98 |
| | | | SELECTION OF OTHER LAND COVER TYPES | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| TOTAL % | 1 | | | TOTAL % | 1 | |
| WEIGHTED AVERAGE CNn = | | 87 | | WEIGHTED AVERAGE CNd = | | 90 |

**Figure 4-38. Pre-Project and Post-Project Curve Numbers**

### *4.5.7.4 Calculate EISA Volume Requirement*

At this point one is able to calculate the EISA Volume Requirement for the project, using the inputs of Pre-Project CN, Post-Project CN, Site Area, and 95$^{th}$ percentile storm depth. For this example, instead of calculating the 95$^{th}$ percentile rainfall depth as in previous examples, the 95$^{th}$ percentile depth for Baltimore, MD, given in Table 4-1 of this guide (also in Table 1 of EPA's *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*) is used, **1.6 inches**.

The spreadsheet tool uses the SCS CN Method to compute the peak runoff volumes for both pre- and post-project conditions. The peak runoff volumes are computed to be 6,457 ft$^3$ and 8,407 ft$^3$, respectively. The difference between these volumes is the EISA Volume Requirement, which is the amount of runoff that needs to be retained on site using LID BMPs.

From this analysis, the Fort Meade project needs to manage **1,950 ft$^3$** of water, as shown in Figure 4-39.

Input Parameters:

Site Area (A) = 3.0 acres

95$^{th}$ Storm (P) = 1.6 inches

Existing CN = 87

Post CN = 90

Output:

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} x(A)$$

Q = Runoff Volume (ft$^3$)

Pre-Project Q = 6,457 ft$^3$

Post-Project Q = 8,407 ft$^3$

Difference in Q = 1,950 ft$^3$

U.S. ARMY

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

***PRELIMINARY SELECTION AND SIZING OF STRUCTURAL LID PRACTICES***

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, MODIFIED EPA OPTION 2*

ERDC

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DATE: 5-Oct-2012 — ARMY INSTALLATION: FORT MEADE

PLANNER: EEM

PROJECT NAME: VEHICLE MAINTENANCE FACILITYY (VMF)

PROJECT LOCATION: MORRISON STREET

PROJECT AREA (acres): 3.0 — 95% RAINFALL 1.6 — SELECT THE SITE'S OVERALL SOIL TYPE: Sandy — HSG = A

| PRE-PROJECT LAND COVER | % of SITE | CN | | POST-PROJECT LAND COVER | % of SITE | CN |
|---|---|---|---|---|---|---|
| WOODED (fair) | | | | WOODED (fair) | | |
| MEADOW | | | | MEADOW | | |
| BRUSH & WEEDS (fair) | | | | BRUSH & WEEDS (fair) | | |
| LAWN | 23.0% | 49 | | LAWN | 16.0% | 49 |
| ROADS & DRIVES (w/o/C&G) | | | | ROADS & DRIVES (w/o/C&G) | | |
| ROADS & DRIVES (w/C&G) | | | | ROADS & DRIVES (w/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 59.0% | 98 | | PARKING, DRIVEWAYS & SIDEWALKS | 74.0% | 98 |
| BUILDING ROOF | 18.0% | 98 | | BUILDING ROOF | 10.0% | 98 |
| | | | SELECTION OF OTHER LAND COVER TYPES | | | |
| TOTAL % | 1 | | | TOTAL % | 1 | |
| WEIGHTED AVERAGE CNn = | | 87 | | WEIGHTED AVERAGE CNd = | | 90 |
| RUNOFF VOLUME (95% RAIN) = | 0.15 | ACRE-FEET | | RUNOFF VOLUME (95% RAIN) = | 0.192990864 | ACRE-FEET |
| 6457 CUBIC FEET | 48297 | GALLONS | | 8407 CUBIC FEET | 62882 | GALLONS |

MINIMUM RUNOFF RETENTION VOLUME TO COMPLY WITH EISA 438 VOLUME CONTROL REQUIREMENT

| | | |
|---|---|---|
| 0.04 ACRE-FEET | 1950 CUBIC FEET | 14585 GALLONS |

**Figure 4-39. Runoff Computations**

### *4.5.7.5 Select LID BMPs to Manage EISA Volume*

The LID practices chosen for this project to retain runoff is bioretention areas, bio-swale, grass swale, and landscape infiltration. Figure 4-40 shows these proposed practices. Inputing the proposed surface area of each LID BMP in the spreadsheet, the volume of runoff retained is calculated, as shown in Figure 4-41. Summing these retention volumes (2719 $ft^3$ + 85 $ft^3$ + 741 $ft^3$) gives a Total Volume Retained for the site, **3545 $ft^3$**.

Since the Total Runoff Volume Retained (3545 $ft^3$) exceeds the EISA Volume Requirement (1950 $ft^3$), this project fulfills EISA Section 438 with the selected LID BMPs.

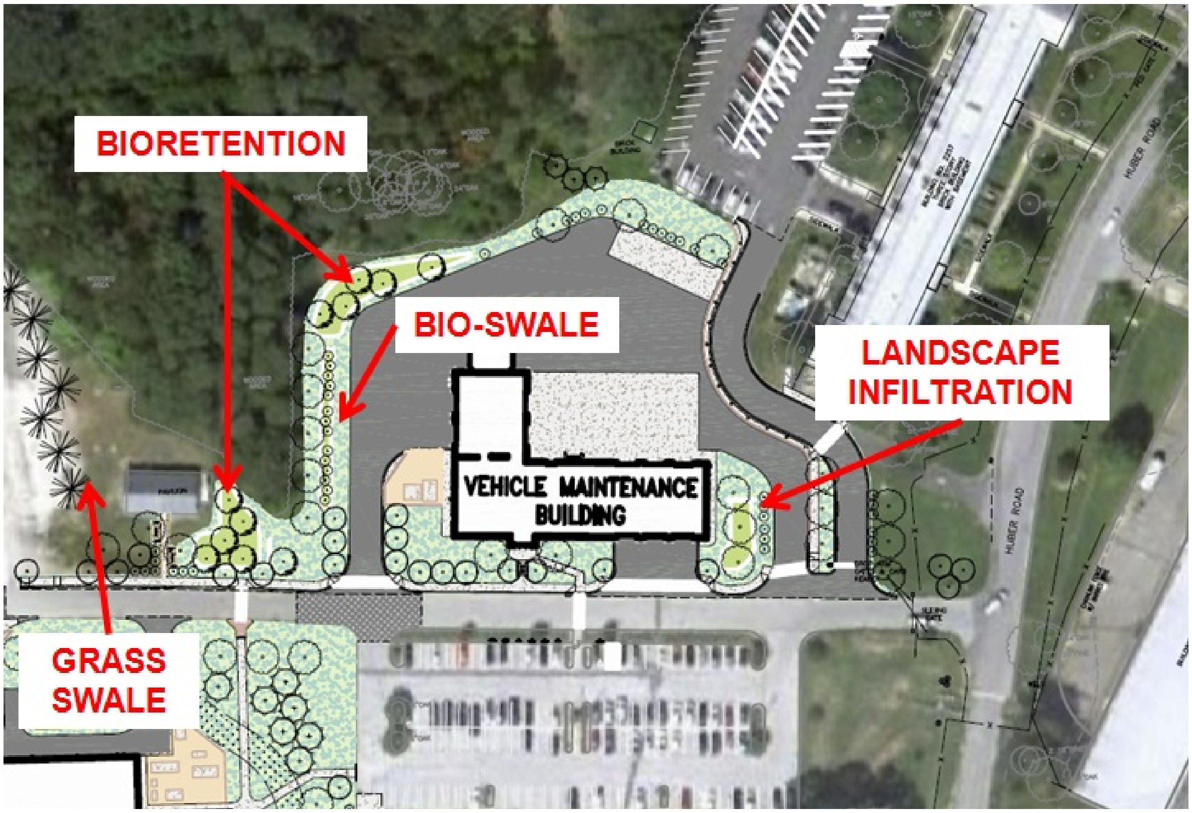


**Figure 4-40. Proposed LID BMPs Implemented**

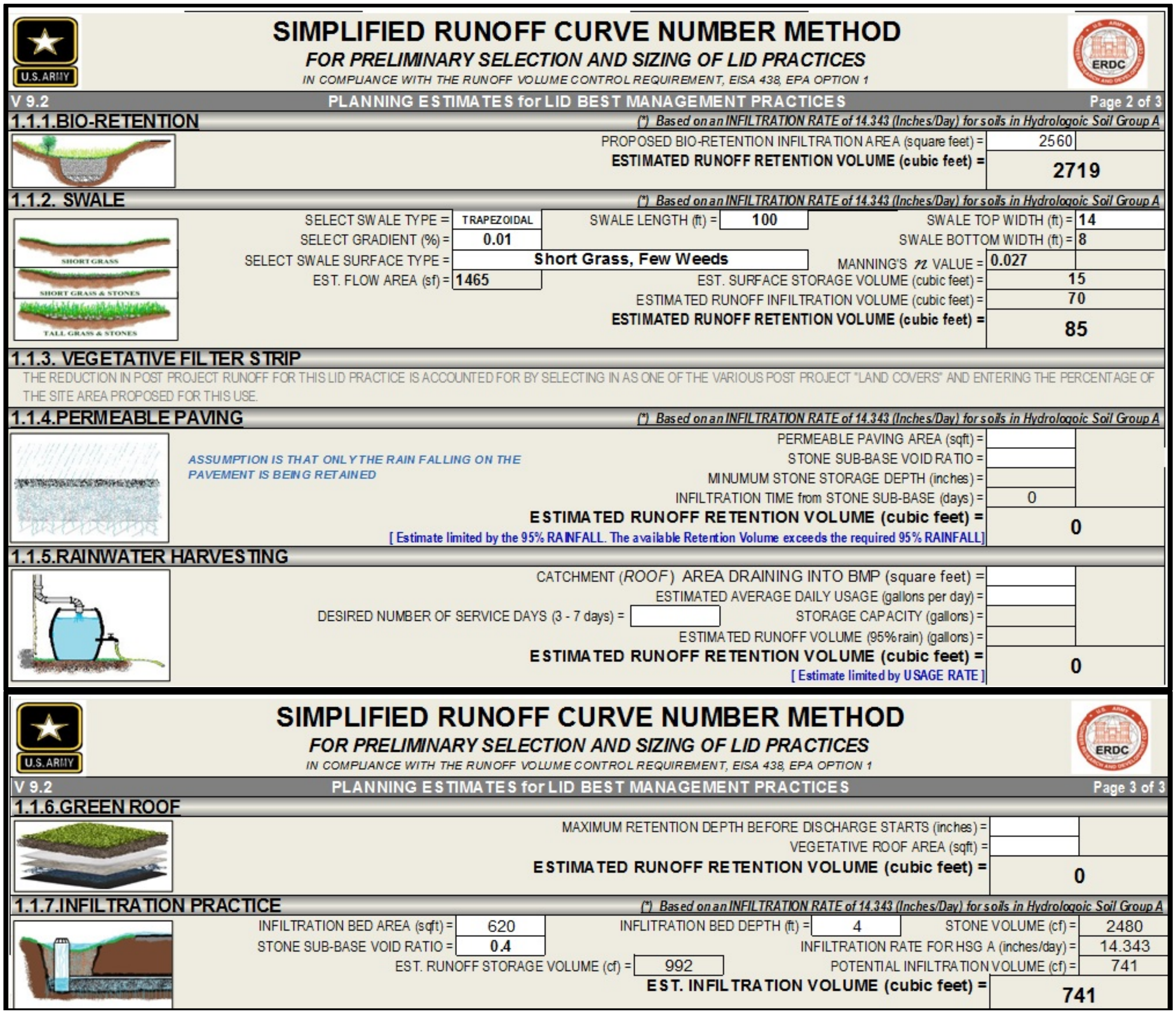


**Figure 4-41. LID BMP Computations**

Hydrologic modeling and simulation to meet the requirements of EISA Section 438 can be complemented by models and simulations that meet other regulatory requirements. As mentioned throughout the LID Technical User Guide, LID can be used to meet other regulatory requirements, such as state and local jurisdictions. Appendix E illustrates how LID and complementary modeling can be used to maximize compliance with regulations.

### 4.5.8 Fort Meade Case Study #3: DPW Building

#### *4.5.8.1 Background*

Please see Section 4.5.6.1 for Fort Meade background information. It is referenced instead of copied here to minimize redundancy.

#### *4.5.8.2 Pre-Project Conditions*

This re-development project includes a proposed Department of Public Works (DPW) Building with associated parking for POV and organizational vehicles and outdoor storage area.

The existing 3.30-acre site, as shown in Figure 4-42 is developed and mostly impervious, with a few grass islands that break up the pavement. An intermittent stream surrounded by woods divides the site in half. The site drains towards the stream which leaves the site through a culvert under 1st St. Groundwater is highly variable; a few feet below the ground in some places. Based on a review of the USDA soils database, the predominant hydrologic soil group for the project site is Hydrologic Soil Group C, "Silty Loam".

By inputting the percent site area of each land use (Parking/Driveway/Sidewalk, Lawn, Woods) to the spreadsheet tool, the estimated SCS curve number, CN, for each land use type is populated. Then the area weighted average pre-project CN is computed to be **91** (Figure 4-44).


**Figure 4-42. Pre-Project Landuse Conditions**

### *4.5.8.3 Post-Project Conditions*

The proposed includes a 15,000 square foot DPW Building with associated pavement for parking and outdoor storage.

The post-project land use, Figure 4-43, consists of Lawn, Building Roof, Woods, and Parking/Driveway/Sidewalks. By inputting the percent of site area of each land use to the spreadsheet tool, the estimated the SCS curve number, CN, for each land use type is populated. Then the area weighted average post-project CN is computed to be **89** (Figure 4-44).

Note that the post-project CN (89) is less than the pre-project CN (91). This makes sense because the project reduced the total impervious area of the site from pre-project conditions.

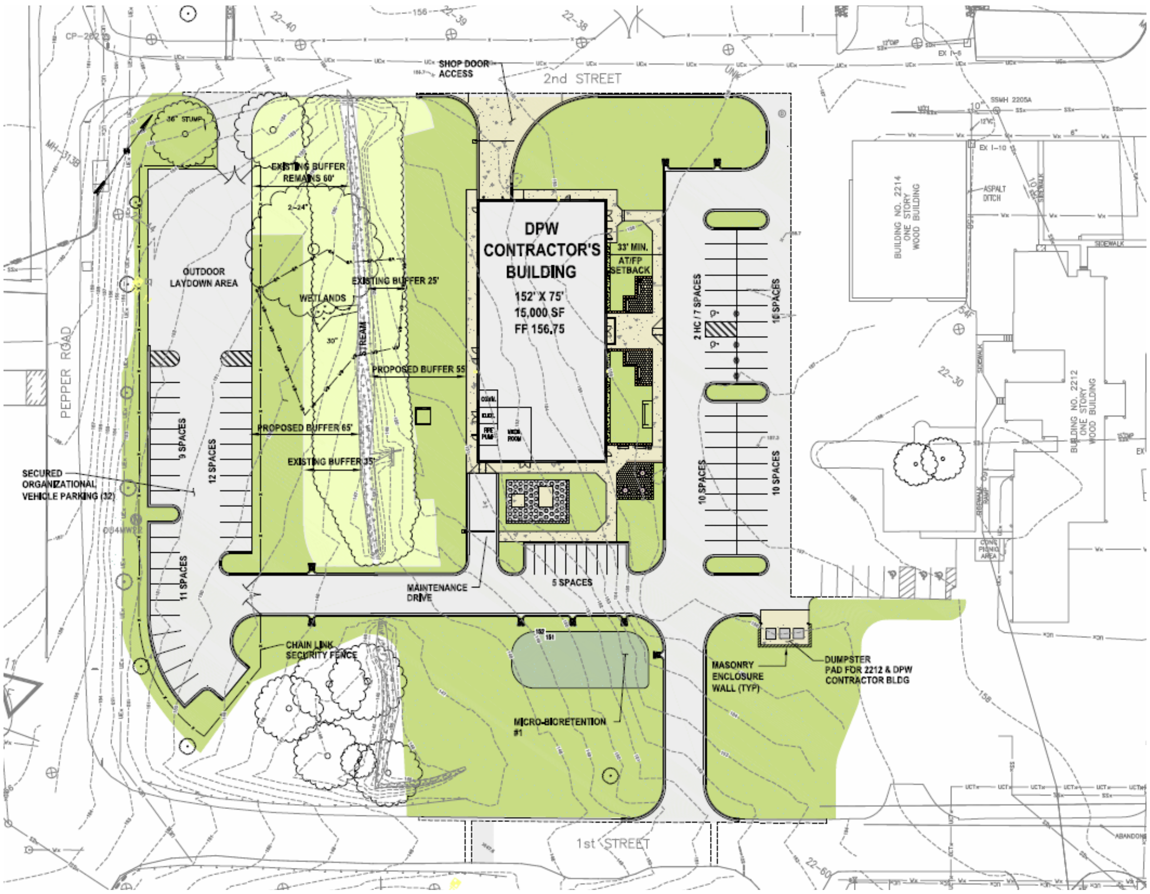


**Figure 4-43. Post-Project Landuse Conditions**

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

***PRELIMINARY SELECTION AND SIZING OF STRUCTURAL LID PRACTICES***

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, MODIFIED EPA OPTION 2*

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| | | | |
|---|---|---|---|
| DATE: | 5-Oct-2012 | ARMY INSTALLATION: | FORT MEADE |
| PLANNER: | EEM | | |
| PROJECT NAME: | DPW CONTRACTOR'S BUILDING | | |
| PROJECT LOCATION: | CHISHOLM AVE | | |
| PROJECT AREA (acres): | 3.3 | 95% RAINFALL | 1.6 |
| SELECT THE SITE'S OVERALL SOIL TYPE: | Silty-Loam | HSG = | C |

| PRE-PROJECT LAND COVER | % of SITE | CN | | POST-PROJECT LAND COVER | % of SITE | CN |
|---|---|---|---|---|---|---|
| WOODED (fair) | 10.0% | 73 | | WOODED (fair) | 10.0% | 73 |
| MEADOW | | | | MEADOW | | |
| BRUSH & WEEDS (fair) | | | | BRUSH & WEEDS (fair) | | |
| LAWN | 23.0% | 79 | | LAWN | 35.0% | 79 |
| ROADS & DRIVES (WO/C&G) | | | | ROADS & DRIVES (WO/C&G) | | |
| ROADS & DRIVES (W/C&G) | | | | ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 67.0% | 98 | | PARKING, DRIVEWAYS & SIDEWALKS | 47.0% | 98 |
| BUILDING ROOF | | | | BUILDING ROOF | 8.0% | 98 |
| | | | SELECTION OF OTHER LAND COVER TYPES | | | |
| TOTAL % | 1 | | | TOTAL % | 1 | |
| WEIGHTED AVERAGE CNn = | | 91 | | WEIGHTED AVERAGE CNd = | | 89 |

**Figure 4-44. Pre-Project and Post-Project Curve Numbers**

*4.5.8.4 Calculate EISA Volume Requirement*

At this point one is able to calculate the EISA Volume Requirement for the project, using the inputs of Pre-Project CN, Post-Project CN, Site Area, and 95th percentile storm depth. For this example, instead of calculating the 95th percentile rainfall depth as in previous examples, the 95th percentile depth for Baltimore, MD, given in Table 4-1 of this guide (also in Table 1 of EPA's *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*) is used, **1.6 inches**.

Input Parameters:
Site Area (A) = 3.3 acres
95th Storm (P) = 1.6 inches
Existing CN = 91
Post CN = 89

Output:

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} x(A)$$

Q = Runoff Volume ($ft^3$)
Pre-Project Q = 9,946 $ft^3$
Post-Project Q = 8,372 $ft^3$
Difference in Q = -1,574 $ft^3$

The spreadsheet tool uses the SCS CN Method to compute the peak runoff volumes for both pre- and post-project conditions. The peak runoff volumes are computed to be 9,946 $ft^3$ and 8,372 $ft^3$, respectively. The difference between these volumes is the EISA Volume Requirement, which is the amount of runoff that needs to be retained on site using LID BMPs.

Since the post-project CN is less than pre-project CN, the post-project runoff volume is also reduced from the pre-project volume, resulting in a negative value as the EISA Volume Requirement, **-1,574 $ft^3$**, as shown in Figure 4-45.

Since DoD defines the "pre-development" condition as "pre-project" (UFC 3-210-10), this redevelopment project results in an improved hydrologic condition (decrease in runoff volume), and no additional retention is need to comply with EISA.

**SIMPLIFIED RUNOFF CURVE NUMBER METHOD**

***PRELIMINARY SELECTION AND SIZING OF STRUCTURAL LID PRACTICES***

*FOR COMPLIANCE WITH THE RUNOFF VOLUME CONTROL REQUIREMENT, EISA 438, MODIFIED EPA OPTION 2*

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| | |
|---|---|
| DATE: | 5-Oct-2012 |
| ARMY INSTALLATION: | FORT MEADE |
| PLANNER: | EEM |
| PROJECT NAME: | DPW CONTRACTOR'S BUILDING |
| PROJECT LOCATION: | CHISHOLM AVE |
| PROJECT AREA (acres): | 3.3 |
| 95% RAINFALL | 1.6 |
| SELECT THE SITE'S OVERALL SOIL TYPE: | Silty-Loam |
| HSG = | C |

**PRE-PROJECT**

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | 10.0% | 73 |
| MEADOW | | |
| BRUSH & WEEDS (fair) | | |
| LAWN | 23.0% | 79 |
| ROADS & DRIVES (WO/C&G) | | |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 67.0% | 98 |
| BUILDING ROOF | | |
| TOTAL % | 1 | |
| WEIGHTED AVERAGE CNn = | | 91 |
| RUNOFF VOLUME (95% RAIN) = | 0.23 | ACRE-FEET |
| 9946 CUBIC FEET | 74396 | GALLONS |

**POST-PROJECT**

| LAND COVER | % of SITE | CN |
|---|---|---|
| WOODED (fair) | 10.0% | 73 |
| MEADOW | | |
| BRUSH & WEEDS (fair) | | |
| LAWN | 35.0% | 79 |
| ROADS & DRIVES (WO/C&G) | | |
| ROADS & DRIVES (W/C&G) | | |
| PARKING, DRIVEWAYS & SIDEWALKS | 47.0% | 98 |
| BUILDING ROOF | 8.0% | 98 |
| TOTAL % | 1 | |
| WEIGHTED AVERAGE CNd = | | 89 |
| RUNOFF VOLUME (95% RAIN) = | 0.1921921 | ACRE-FEET |
| 8372 CUBIC FEET | 62622 | GALLONS |

SELECTION OF OTHER LAND COVER TYPES

**MINIMUM RUNOFF RETENTION VOLUME TO COMPLY WITH EISA 438 VOLUME CONTROL REQUIREMENT**

| | | |
|---|---|---|
| -0.04 ACRE-FEET | -1574 CUBIC FEET | -11774 GALLONS |

**Figure 4-45. Runoff Computations**

### *4.5.8.5 Select LID BMPs to Manage EISA Volume*

Although EISA Section 438 is satisified, the project still had to comply with State of Maryland stormwater management requirements. The project used the following LID BMPs to fulfill State requirements:

Non-Structural LID BMPs: Protect Sensitive Areas, Reduce Impervious Surfaces, Riparian Buffer Restoration, and Reforestation.

Structural LID BMPs: Bioretention, Grass Swale, Vegetated Filter Strip.

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