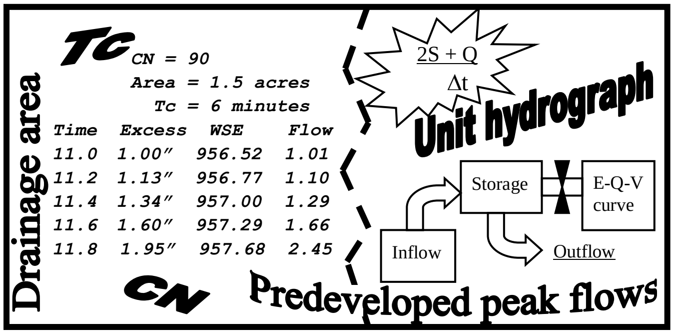
ACTIVITY: Detention Example for Spreadsheet

ST – 11



CITY OF KNOXVILLE

Description

The purpose of this stormwater treatment BMP is to give a detention example that shows the various types of information required and the level of detail. This example will use very complex spreadsheets to create a postdevelopment hydrograph, computing volumes and discharges for a rating curve, and detention basin routing. <u>Use of complex spreadsheets (as shown in this BMP) is neither required nor recommended.</u>

Approach

This BMP can be a potentially useful tool for some experienced stormwater designers. <u>The principal purpose of this BMP is to demonstrate the complexity of detention computations.</u> The potential user of this BMP is expected to be thoroughly familiar with the TR-55 publication "Urban Hydrology for Small Watersheds" (reference 175) and also the theory and practical application of detention routing. A description of detention requirements and NRCS methods are given within ST-10, Detention Computations. All hydrologic and hydraulic computations for stormwater detention facilities must be prepared and stamped by a registered engineer (licensed in the state of Tennessee) who is proficient in this field. Plans must show sufficient information to allow the builder to construct the detention structure correctly, and to verify that the as-built facility will operate as required.

<u>Warning:</u> -- Stormwater detention must be performed by a registered professional engineer with sufficient education and experience.

In Section 22.5-33 of the Knoxville Stormwater and Street Ordinance, hydrologic and hydraulic computations are required to be in accordance with NRCS methods. The NRCS Unit Hydrograph shall be used with average antecedent moisture conditions (AMC II) and Type II rainfall distribution, specified by Technical Release 55 (TR-55) publication from June 1986. The TR-55 publication ("Urban Hydrology for Small Watersheds") can be downloaded at:

http://www.wcc.nrcs.usda.gov/hydro/hydro-tools-models-tr55.html

Computational Software for NRCS Methods

This BMP (ST-11) represents one option available to the stormwater designer, which is to process a lot of complex equations by hand or by spreadsheet. However, the next BMP (ST-12) represents a second option: use commercially available and widely accepted software (such as HEC-1 or HEC-HMS) to generate hydrographs and then route the hydrographs through a detention basin outlet structure. Methods shown in this BMP can provide input data for the HEC-1 and HEC-HMS programs (as well as other types of stormwater detention software).

Software computations submitted for review to the City of Knoxville must include all necessary input data to reproduce the detention design, including details as needed to illustrate the outlet structure. Computations should be organized and neatly printed on standard 8.5" x 11" paper so that the results are easily referenced and located. The Knoxville Engineering Department may require verification of software programs that are unproved or not well-known in the Knoxville area.

The NRCS website has a DOS-based TR-55 program, with 6 menu choices closely matching the six chapters of the TR-55 publication. In addition, they are developing a windows-based TR-55 program. Neither of the TR-55 programs actually performs detention routing computations. The TR-55 programs provide an initial estimate of needed storage volumes for preliminary design. Use of the DOS-based TR-55 program is highly discouraged due to the large roundoff errors for small watersheds that are typical for most site developments.

Stormwater detention basins are designed in an iterative fashion. The basin volume and outlet structure configurations are chosen, then the design is actually tested by detention hydrograph routing. The resultant peak flows and peak water surface elevations are then compared to see if postdeveloped peak flow values have been reduced to the predeveloped peak flow values.

Spreadsheets for NRCS Hydrograph Routing

Although not recommended for complex types of structures, spreadsheets could potentially be used to generate hydrographs and then route hydrographs through very simple detention structures. An example is shown on Worksheets #1 through #8 (pages ST-11-10 to ST-11-21) for a dry detention basin with a typical outlet structure (orifices and weirs). These worksheets were generated in Microsoft® Excel 97 and can be downloaded from the BMP Manual website. These Excel spreadsheets can be adapted or reproduced using a knowledge of NRCS unit hydrographs and standard equations for computing volumes, orifice flow, weir flow and routing.

The eight worksheets (contained within three Excel spreadsheet files) are explained briefly for the benefit of professional engineers with design experience and a firm grasp of detention theory. The worksheets are not necessarily intended as an instructional tool for non-engineers. Input blocks in each worksheet are identified by heavy borders around each cell. Worksheet #2 should be examined closely, since it represents basic NRCS methods for estimating detention volumes even if a design engineer has other ways of actually routing the runoff hydrographs.

Worksheet #2 *(highly recommended as a starting point)*

Worksheets #4 and 5 *(useful to compute input data for HEC-1 and HEC-HMS)*

Worksheet	Excel file	File size	Essential functions
#1	ST11-CN.xls	27 kB	Determine CN & Tc
#2	ST11-EST.xls	33 kB	Detention volume initial estimates
#3	ST11-HRT.xls	~ 3320 kB	Computes NRCS unit hydrograph
#4	“ “ “	“ “	Computes surface areas and volumes
#5	“ “ “	“ “	Computes discharge rating curve
#6	“ “ “	“ “	Summary results of detention routing
#7	“ “ “	“ “	Backup file containing E-Q-V table
#8	“ “ “	“ “	Backup file to generate and route hydrograph

The third spreadsheet (ST11-HRT.xls) contains six worksheets that are all somewhat interrelated. It is a very large size for two basic reasons:

- The spreadsheet handles time increments of 0.02 hours over a period of 24 hours (which requires 1200 rows of computations in the basic routing function on Worksheet #8). The unit hydrograph is applied at time increments of 0.02 hours, for which 18 columns are used in conjunction with the 1200 rows.
- The spreadsheet computes an elevation-flow-volume table at elevation increments of 0.01 feet, and it then generates values for $2*S/\Delta + Q$ and for $2*S/\Delta - Q$. There are 1400 rows of computations set aside for this table, to allow a basin depth of up to 14 feet.

Because the third spreadsheet is so large, it may or may not automatically recalculate as the data is entered. It may be advantageous to change spreadsheet settings back and forth between automatic calculation and manual calculation. Under the menu item */Tools/Options/Calculation* are two buttons for *Calc Now* and for *Calc Sheet*. It is generally helpful to hit the *Calc Sheet* button for each sheet after filling in the data.

Most types of hydrology software (such as HEC-1 and Haestad Pondpack^{TM}) will have extremely efficient methods of dealing with matrices and selecting the best computational interval. For instance, it is not necessary to have a routing table for the portion of rainfall that occurs before the initial abstraction is satisfied (which occurs at 3.86 hours in the example problem). It is recommended that the design engineer should use commercially available software or public domain software if there is any concern over how a spreadsheet will function.

Worksheet #1

Computing CN and Tc

Page ST-11-10

The first spreadsheet (ST11-CN.xls) is a simple reproduction of the methods for determining CN and Tc using Chapters 2 and 3 of TR-55 publication (reference 175). Practicing engineers may already have a systematic way of determining CN and Tc which is acceptable. Table ST-10-1 lists typical values for CN; the preferred method for computing CN is to actually determine the area of different land covers (impervious surface, gravel, grass in good condition, etc) and then compute a weighted CN value. Detention basins are considered as impervious (with CN = 98). The spreadsheet also contains an adjustment for impervious areas that are not directly connected to a storm drainage system (typical for residential areas with less than 30% impervious area, with roof drains and driveways flowing onto grass areas). Preliminary design may require an average CN value for different types of land uses (such as residential ¼-acre lots, commercial property, etc), for which a typical % impervious area can be estimated.

Worksheet #2

Initial Detention Volume Estimates

Page ST-11-11

The second spreadsheet (ST11-EST.xls) is very useful for determining the necessary detention volume estimates, and it represents the minimum requirements for NRCS design as specified in the ordinance. The second spreadsheet is easily reproducible from the basic NRCS equations, condensing computations for peak discharge and detention storage volume estimates to a total of 6 inputs for the predeveloped and postdeveloped areas (A), curve numbers (CN) and times of concentration (Tc). Dashed areas of the spreadsheet contain coefficients for computing qu by interpolation of C0, C1 and C2 values. Various values and parameters include:

S = potential maximum retention after runoff begins (inches)

Ia = initial abstraction (inches)

P = 24-hour rainfall precipitation for a given storm (inches)

Q = total stormwater runoff (inches)

C0, C1, C2 = coefficients for computing qu from TR-55 publication Table F-1

A = drainage area (square miles)

qu = unit peak discharge (cfs per square mile per inch of rainfall)

Qi = postdeveloped graphical peak discharge (cubic feet per second)

Qo = predeveloped graphical peak discharge (cubic feet per second)

Vr = total runoff volume (acre-feet)

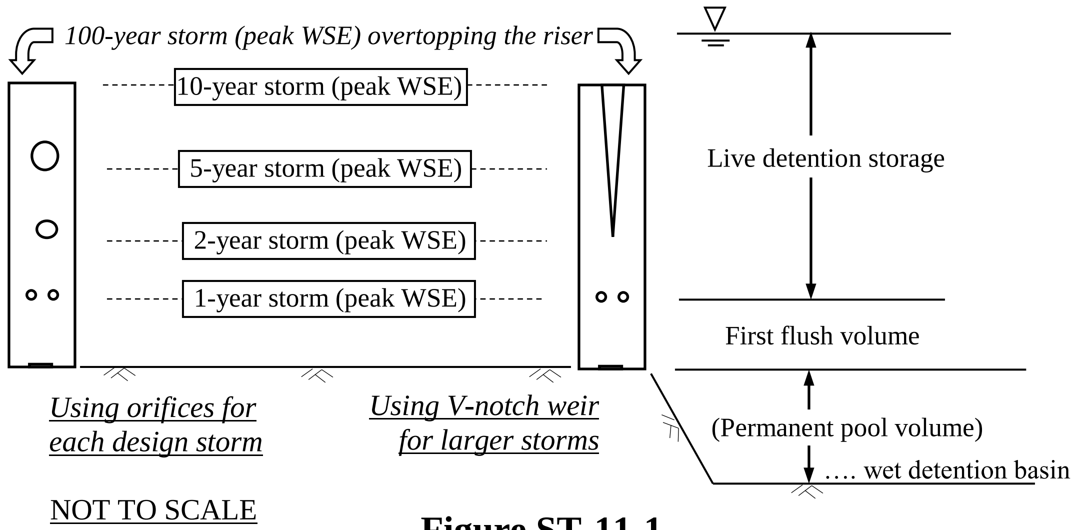


Figure ST-11-1
Typical Working Profile of Detention Basins

Vs = estimated detention storage volume needed (acre-feet or cubic feet)

Avg Qf = average outflow for the first flush volume (cubic feet per second)

The associated equations used in Worksheet #2 are:

$S = (1000/CN) - 10$

$Ia = 0.2 * S$

$Q = (P – Ia)^2 / (P + 0.8 * S)$

$qu = 10 \wedge (C0 + C1 * \log(Tc) + C2 * (\log(Tc))^2)$

$Qo = qu * A * Q * Fp$ (for predeveloped conditions)

$Qi = qu * A * Q * Fp$ (for postdeveloped conditions)

$Vr = Q * A / 12$

$Vs / Vr = 0.682 - 1.43 * (Qo/Qi) + 1.64 * (Qo/Qi)^2 - 0.804 * (Qo/Qi)^3$

$Vs = Vr (Vs / Vr)$

Avg Qf = FF volume / 86400 seconds

The term Fp (which is the pond adjustment factor) has been set equal to 1.0 within the spreadsheet for both predeveloped and postdeveloped conditions. Ponds, lakes or storage depressions usually do not occur in postdeveloped areas except for the detention basin itself (which is not counted for the pond adjustment factor).

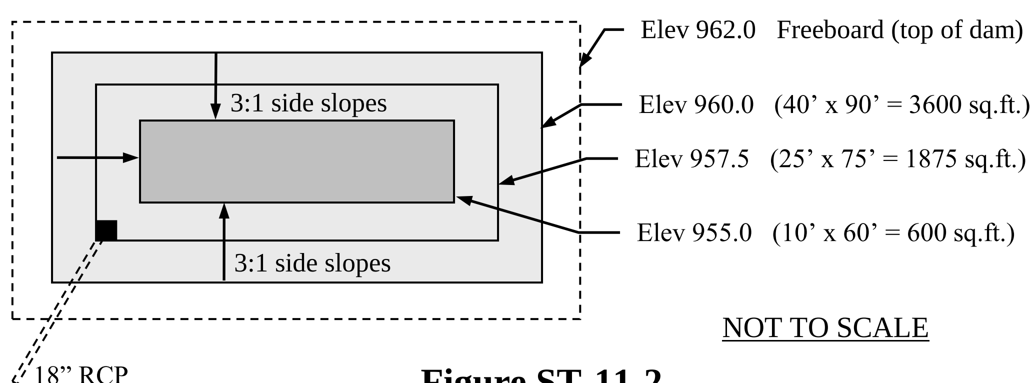


Figure ST-11-2
Estimated Volume for Example Problem

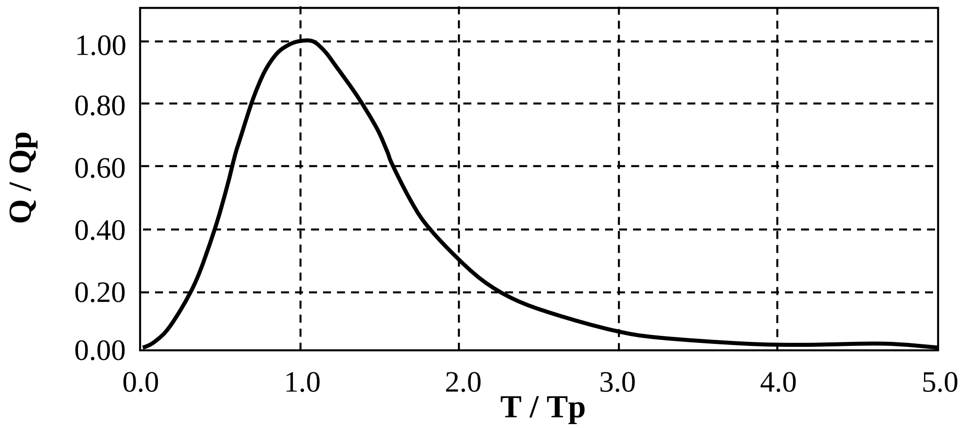


Figure ST-11-3
NRCS Unit Hydrograph

The estimated detention storage in Worksheet #2 is based upon each computed volume having the associated discharge outlet value equal to predeveloped peak flow for the specified design storm. This is most easily done by sizing an orifice or weir at the appropriate invert elevation (or often several orifices) as shown in Figure ST-11-1.

A carefully selected V-notch weir may satisfy more than one point on the required stage-storage-discharge curve (which is also called E-V-Q curve).

Initial volume estimates are adjusted due to first flush volume and 15% additional increase in storage volume.

Using the example shown in Worksheet #2, it would take 9223 cubic feet of volume to contain the 100-year storm. Assuming a ponded depth of 5 feet, the average surface area of the detention basin needs to be 1845 square feet. By selecting the length-width ratio of 3, the average area is computed to have dimensions of 25 feet by 75 feet. Then use a 3:1 side slope to compute the bottom surface area (2.5 feet lower) as 10 feet by 60 feet and the top surface area (2.5 feet higher) as 40 feet by 90 feet. This is shown in Figure ST-11-2. The initial estimate for the top of berm is elevation 962.0 to allow for changes as the outlet structure is modified, and for the 15% increase in storage volume as required in Section 22.5-31 of the Stormwater and Street Ordinance.

Worksheet #3

This portion of the spreadsheet is tabbed as NRCS UH. It computes the unit hydrograph, given the input parameters Tc, A, CN and P. An NRCS unit hydrograph with a peak attenuation factor of 484 has the shape shown in Figure ST-11-3. The column labeled UH (cfs) is used in Worksheet #8 to generate the actual hydrograph.

Computing the unit hydrograph

Page ST-11-12

The time of concentration is constrained to be exactly 6, 9, 12, 15 or 18 minutes for the purpose of simplifying the computational matrix in Worksheet #8. Do not use this spreadsheet if the time of concentration is not exactly 6, 9, 12, 15 or 18 minutes long. The typical time for a small postdeveloped project site is usually 0.1 hours (6 minutes). The formulas for Tp, Qp, UH and Incr Volume are shown on the worksheet. The recommended time increment for computing runoff (ΔD) is computed as Tp / 5; the time increment actually used in Worksheet #8 is 0.02 hours for all five allowable Tc values. The shape for the NRCS unit hydrograph is shown in Figure ST-11-3. The NRCS unit peak hydrograph rate used in the computations is at the ratio of T/Tp = 0.9, which is 99% of the actual peak value.

Worksheet #4

Computing storage volumes

Pages ST-11-13 and ST-11-14

This portion of the spreadsheet is tabbed as E-V. It computes the elevation-volume relationship using the conic formula at uniform 0.1' intervals; the formulas for interpolating areas and for computing the increment volumes are shown on the worksheet itself. The example worksheet contains input at elevations of 1' increments based on the specified 3:1 slope; in this case it is very easy to compute rectangular areas. The worksheet computes volumes between elevations 955.0 and 962.0 using 0.1' increments. This type of worksheet can be useful for HEC-1 and HEC-HMS data.

Worksheet #5

This portion of the spreadsheet (tabbed as E-V-Q) computes the discharge rating curve for up to ten combinations of orifices, weirs or user-input rating curves (typically submerged culverts). The control structures are selected as circular orifices in a square concrete riser, and are sized to approximately match the following rating curve taken from the initial size estimate on Worksheet #2:

Target outflow rates (with the estimated storage volumes)

1-year outflow should be approx 0.8 cfs	at 3691 cubic feet storage
2-year outflow should be approx 1.5 cfs	at 4878 cubic feet storage
5-year outflow should be approx 2.3 cfs	at 6005 cubic feet storage
10-year outflow should be approx 3.1 cfs	at 6962 cubic feet storage
25-year outflow should be approx 3.9 cfs	at 7901 cubic feet storage
100-year outflow should be approx 5.1 cfs	at 9223 cubic feet storage

(Iteration #1)

Selecting initial outlet structure configuration and computing E-V-Q curve

Pages ST-11-15 and ST-11-16

An initial outlet structure configuration (four orifices within a square concrete riser) discharges at the predevelopment flow rates and would be otherwise acceptable. However, the first flush storage volume does not have the right volume or drawdown storage time. So a second iteration will be needed.

- 4" orifice at invert 955.00
- 8" orifice at invert 957.85
- 6" orifice at invert 958.40
- 4" orifice at invert 959.20
- top of square concrete riser at 959.90 (total weir length of 8')

Between the elevations of 960.5 and 960.6, the culvert becomes the controlling feature for the outlet structure rather than the combination of orifices and weirs in columns 1 through 5. The culvert flows were input by hand but can also be easily computed using the submerged culvert equation shown in ST-10, Detention Computations. The formula used for unsubmerged circular weirs is:

$$Q = (\text{depth/diameter})^{1.83} \; 0.6 \; \pi \; (2g)^{0.5} \; (\text{diameter}/2)^{2.5}$$

Worksheet #6

This worksheet contains the overall summary of results. The user enters the beginning water surface elevation at time t = 0.00, and the remainder of the computations take place behind the scenes on Worksheet #8. The principal areas of interest on this worksheet are the final results: peak inflow and outflow times, peak inflow and outflow rates, peak water surface elevation, and the peak basin storage. In the example shown on the worksheets, the 10-year routed storm approximately meets the criteria of limiting outflows to predevelopment value of 3.1 cfs (from Worksheet #2). The complete results from the five design storms plus the 25-year storm are:

Return period	*Peak inflow*	*Peak outflow*	*Target*	*Peak WSE*	*Peak storage*
1-year	*3.49 cfs*	*0.65 cfs*	*0.8 cfs* ✓	*957.54*	*3068 cu.ft.*
2-year	*5.11 cfs*	*1.18 cfs*	*1.5 cfs* ✓	*958.28*	*4643 cu.ft.*
5-year	*6.73 cfs*	*2.36 cfs*	*2.3 cfs* ✓	*958.77*	*5881 cu.ft.*
10-year	*8.15 cfs*	*3.16 cfs*	*3.1 cfs* ✓	*959.15*	*6956 cu.ft.*
25-year	*9.56 cfs*	*3.84 cfs*	*3.9 cfs* ✓	*959.51*	*8068 cu.ft.*
100-year	*11.57 cfs*	*5.11 cfs*	*5.1 cfs* ✓	*959.97*	*9632 cu.ft.*

Route storm hydrograph and check results

(Iteration #1)

Page ST-11-17

These computed values substantially meet the requirements for detention, with minor variances up to 0.1 cfs over the allowable rate. However, the iteration #1 design does not include the controlled 24-hour release of the first flush volume (4500 cubic feet). Controlled release is accomplished by reducing bottom orifice to 1.25" (as explained in ST-10, Detention Computations). The next lowest orifice is relocated to elevation invert 958.20 to provide approximately 4500 cubic feet storage. Minor adjustments are made to other orifices and top of riser is raised 0.65' higher. The new configuration:

Adjust outlet to provide first flush volume and 24-hr drawdown time.

- 1.25" orifice at invert 955.00 (see ST-10 for sizing first flush release)
- 8" orifice at invert 958.20 (raised to provide 4500 cubic feet storage)
- 6" orifice at invert 958.50
- 4" orifice at invert 959.20
- top of square concrete riser at 960.55 (total weir length of 8')

(Iteration #2)

Adjusted outlet structure configuration

The complete results for the adjusted outlet structure for the six storms analyzed are:

Return period	*Peak inflow*	*Peak outflow*	*Target*	*Peak WSE*	*Peak storage*
1-year	*3.49 cfs*	*0.17 cfs*	*0.8 cfs* ✓	*958.39*	*4907 cu.ft.*
2-year	*5.11 cfs*	*1.20 cfs*	*1.5 cfs* ✓	*958.84*	*6071 cu.ft.*
5-year	*6.73 cfs*	*2.36 cfs*	*2.3 cfs* ✓	*959.34*	*7531 cu.ft.*
10-year	*8.15 cfs*	*3.16 cfs*	*3.1 cfs* ✓	*959.76*	*8899 cu.ft.*
25-year	*9.56 cfs*	*3.72 cfs*	*3.9 cfs* ✓	*960.15*	*10289 cu.ft.*
100-year	*11.57 cfs*	*5.15 cfs*	*5.1 cfs* ✓	*960.65*	*12248 cu.ft.*

(Iteration #2)

Route storm hydrograph and check results

Results are good!

Again, these results allow one or two storms to slightly exceed the allowable peak discharge rate as long as a few other storms are under the allowable peak discharge by a similar amount. The peak storage volume for the 100-year storm is adjusted by 15%, and the top of riser elevation adjusted accordingly. This adjustment (shown on page ST-10-8) by 0.43' places the new top of riser elevation at 960.98 (call it 961.00).

Adjust peak storage volume by 15% (as shown on page ST-10-8).

Worksheet #7

Only a portion of Worksheet #7 is reproduced as part of this example. Three sections of the detention basin are shown from 955.00 to 955.15 (at the bottom), 957.00 to 957.10 (in the middle), and 958.95 to 959.09 (at the top). This worksheet contains the overall detention routing curve by taking the E-Q-V information at increments of 0.01' and computing the values of $2S/\Delta t - Q$ and also $2S/\Delta t + Q$. This information is used in Worksheet #8 at each routing step to select new water surface elevation and volume.

(WS #7 – backup computations)

Page ST-11-18

Worksheet #8 - (generating inflow hydrograph)

This worksheet contains the largest amount of computations, and only a small portion of Worksheet #8 is reproduced as part of this example. The worksheet generates the inflow hydrograph and then routes the hydrograph through the detention basin with the NRCS

(WS #8 – backup

computations)

Type II cumulative rainfall distribution at increments of 0.1 hours. This information is used to compute cumulative total rainfall and cumulative total excess rainfall at increments of 0.02 hours, using the formula $Q = (P - 0.2 * S)^2 / (P + 0.8 * S)$ to determine total excess rainfall only after the initial abstraction S has been satisfied.

Pages ST-11-19 through ST-11-21

Page ST-11-19 shows three time intervals from Worksheet #8 (before the peak of the storm) that occur from 0.00 to 0.20 hours, from 7.00 to 7.20 hours, and from 10.00 to 10.22 hours. There is no inflow until the initial abstraction is satisfied at 3.86 hours; therefore there is no activity in the first time interval. At the second time interval, the inflow is 0.05 cfs, the outflow is 0.04 cfs, and the water surface is at 955.15. At the third time interval, the inflow is slightly larger than the outflow and the water surface is rising at a rate of 0.1' per hour.

Page ST-11-20 shows the peak time interval from 11.60 to 12.54 hours within Worksheet #8. The peak inflow rate of 8.15 cfs occurs at 11.94 hours (as reported on Worksheet #6) and the peak outflow rate of 3.16 cfs occurs at 12.10 hours.

Page ST-11-21 demonstrates how the inflow hydrograph is computed in Worksheet #8 by showing the time interval from 11.60 to 12.22 hours. First a matrix of flow values is created by multiplying incremental excess rainfall values by NRCS unit hydrograph flow ordinates. The overall matrix is based on a time ordinate from 0.00 hours to 25.00 hours, and the NRCS unit hydrograph time scale is from 0.00 hours to 0.32 hours in the particular instance where Tc is equal to 6 minutes. The value 0.0690 cfs comes from multiplying 0.1176 (the incremental excess rainfall for this row) times 0.5879 (the NRCS unit hydrograph flow for this column). The value of 0.0690 then corresponds to a time of 12.10 hours (11.88 hours + 0.22 hours UH delay). By summing the 17 boxes in a diagonal row as shown on page ST-11-21, the inflow hydrograph value of 3.285 cfs is obtained for a time of 12.10 hours. For different Tc values, time ordinates of the NRCS unit hydrograph will change. To compute inflow hydrograph for Tc value other than 6 minutes, matrix values are added in a different fashion other than the 45° diagonal stepwise pattern (as shown on page ST-11-21).

Worksheet #8 - (routing inflow hydrograph through detention basin)

The basic theory for detention routing is to compute what happens during a typical time interval Δt. The amount of storage increases if the inflow is greater than the outflow. In mathematical terms, the incremental change in storage is:

$$\Delta S = \Delta t \ (I_{AVG} - Q_{AVG})$$

This can be expanded to terms using adjacent time intervals 1 and 2 (where time 2 is later than time 1):

(Basic detention routing theory)

$$S_2 - S_1 = 0.5 \Delta t (I_1 + I_2) - 0.5 \Delta t (Q_1 + Q_2)$$

I_1 = Inflow at time interval 1
I_2 = Inflow at time interval 2
Q_1 = Outflow at time interval 1
Q_2 = Outflow at time interval 2
S_1 = Storage at time interval 1
S_2 = Storage at time interval 2

Multiplying each side by 2 and then dividing by Δt:

$$\left(\frac{2S_2}{\Delta t} + Q_2\right) = (I_1 + I_2) + \left(\frac{2S_1}{\Delta t} - Q_1\right) \qquad \textit{(equation A)}$$

This equation is arranged so that the unknown term is located on the left side, and the known terms are on the right side. The values for I_1 and I_2 are known throughout the time period of 0.00 to 24.00 hours. The terms S and Q are determined one step at a time. After computing the unknown term in equation A, the values of outflow (Q_2), storage (S_2), and elevation (WSE) are then taken from the tabulated detention rating curve in Worksheet #7. The following equation computes the next time step:

$$\left(\frac{2S_2}{\Delta t} - Q_2\right) = \left(\frac{2S_2}{\Delta t} + Q_2\right) - Q_2 - Q_2 \qquad \textit{(equation B)}$$

Look at page ST-11-20 (Worksheet #8) for the values at time 12.18 that have been previously computed. Then the first value for time 12.20 is computed by equation A using the two inflow values on page ST-11-20 and one value from page ST-11-18:

$$\left(\frac{2S_2}{\Delta t} + Q_2\right) = (I_1 + I_2) + \left(\frac{2S_1}{\Delta t} - Q_1\right) = 1.504 + 1.366 + 182.89 = 185.76$$

Interpolate the values on page ST-11-18 ……

Taking this value of 185.76 for $\left(\frac{2S_2}{\Delta t} + Q_2\right)$, corresponding values in Worksheet #7 on page ST-11-18 are:

Q = 2.94 cfs
S = 6576 cu.ft.
WSE = 959.02

…… to obtain the values for time = 12.20 hours on page ST-11-20.

Then using equation B with an extra decimal place to show the roundoff process:

$$\left(\frac{2S_2}{\Delta t} - Q_2\right) = \left(\frac{2S_2}{\Delta t} + Q_2\right) - Q_2 - Q_2 = 185.76 - 2.936 - 2.936 = 179.89$$

Hints for Complex Spreadsheets

<u>The main purpose of this BMP is to demonstrate the types of computations necessary to provide NRCS hydrographs and detention routing design.</u> The third Excel spreadsheet (ST11-HRT.xls) contains eight worksheets and is very cumbersome for some computers. The stormwater designer may want to use HEC-1, HEC-HMS or a commercially available software program. <u>Spreadsheets illustrated in this BMP should not be used by persons not familiar with hydrology and hydraulics.</u>

If using a complex spreadsheet, it is advantageous to change spreadsheet settings back and forth between automatic calculation and manual calculation under the menu item */Tools/Options/Calculation*. Also on this menu item are two buttons for *Calc Now* and for *Calc Sheet* to recompute worksheets individually and consecutively.

Conclusions

<u>There are many commercially available programs for stormwater detention routing with various input requirements.</u> It is recommended that the stormwater designer should learn to use a commercially available program or a government public domain software to perform stormwater detention computations. The next BMP (ST-12) shows the same example project using HEC-1 and HEC-HMS analysis. It is important to perform detention routing to verify that the initial design estimates are adequate, particularly since the NRCS volume estimate method within the TR-55 publication does not take into account the first flush volume requirements and the 15% additional storage volume requirements. Available detention space and configuration should be included into the project site at a very early stage in the design process.

References

153, 154, 158, 175, 180, 181, Knoxville Stormwater and Street Ordinance (see BMP Manual Chapter 10 for list)