

USER'S
MANUAL

***Water Quality Capture
Optimization and
Statistics Model
(WQ-COSM) v2.0***

October 2012 Edition

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Introduction

Water Quality Capture Optimization Statistical Model (WQ-COSM) is a Windows-based computer program that uses recorded rainfall data from the National Climatic Data Center (NCDC) and information about the catchment's hydrologic parameters to help the user determine the water quality capture volume (WQCV) and the maximized WQCV for any type of stormwater treatment facility (i.e., structural Best Management Practice (BMP)) that captures runoff in temporary storage basin (vessel) for mitigating of hydrologic changes caused by urbanization and also treats its water quality through sedimentation, biological uptake of pollutants and/or filtration/infiltration.

This program replaces a DOS based program called PondRisk (ref.: Guo, James C.Y. (1986). *PONDRISK Computer Model for Determination of Maximized Detention Volume*, Dept. of Civil Engineering, U. of Colorado Denver, Denver, Colorado). WQ-COSM provides a modern user interface and adds additional functionality that was not available in PondRisk. WQ-COSM computes runoff using continuous runoff simulation using either Rational Method or Horton's infiltration method and calculates the WQCV based on the runoff simulation.

WQCV is an integral part of any BMP that remove significant portions of pollutants from the majority of runoff events and helps mitigate the hydrologic changes caused by urbanization. These BMPs differ from flow-through BMPs that do not have a WQCV and do not mitigate the effects of increased stormwater runoff peaks and volumes that result from urbanization. Flow-through BMPs are primarily used to remove gross pollutants consisting of floating trash and coarse sediment, but for the most part, do not remove fine sediment and associated pollutants, bacteria, and dissolved constituents in significant amounts. A WQCV is a part of the following types of BMPs:

- Total storage for an Extended Detention Basin (i.e., dry) basin (EDB)
- Surcharge storage above the permanent pool of a Retention Pond (i.e., wet) pond (RP)
- Surcharge storage above the permanent pool of Wetland Basin (WB)
- Above or upstream of a Media Filters (MF)
- Above of upstream of a Rain Gardens (RG), sometimes called bio-retention cell.

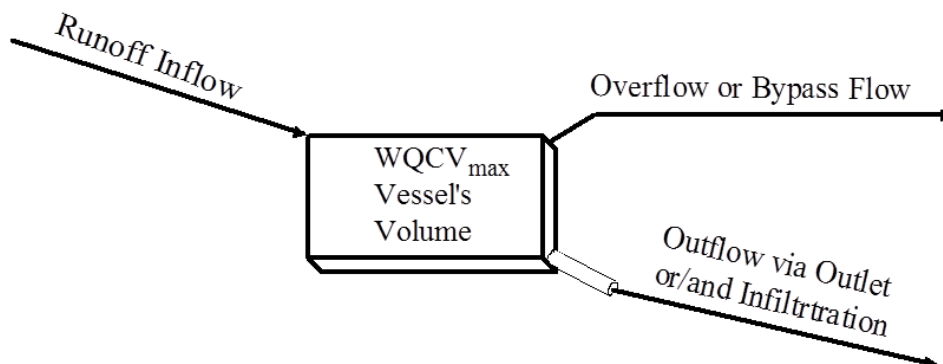
WQ-COSM is implemented as two programs, a user interface and the math engine. The user interface collects information from the user, generates properly formatted input files for the math engine and displays the results after the math engine has successfully processed the information in the input file.

The math engine performs the following basic tasks:

1. Processes the continuous rainfall data and identifies individual storms after excluding small, non-runoff producing, and user-defined large outlier storms. Reports statistical results for the entire and filtered rainfall data.

2. Processes the accepted continuous rainfall data to develop a continuous runoff record for each time increment in the filtered rainfall record. Reports statistical results of the resultant runoff data set. Optional output lists summary data for each individual storm.
3. Routes the continuous runoff data through a series of increasing basin (vessel) sizes (i.e., through a series of increasing WQCV basins) to develop data on runoff volumes and number of storms captured by each vessel size. Reports the percent and the total runoff volume, the percent of all runoff captured (i.e., volume-based approach) and the percent of individual storms captured in total (i.e., event-based approach) by various WQCV basin (vessel) sizes.
4. Finds the point of diminishing return in WQCV vessel size for the capture of total runoff volumes and for the capture of individual storms. Reports both.

The size (i.e., volume) of the WQCV vessel, or basin, is dependent on the runoff that results over time from the tributary catchment (step 2 above) and the time it takes to empty a brim-full WQCV vessel (i.e., the rate of discharge from the vessel) when there is no runoff entering it. The routing of runoff (step 3 above) through a WQCV basin (vessel) is illustrated in Figure 1.



Note: The discharge rate through the outlet is equal to $[(WQCV_{max}) / (\text{Drain Time})]$

Figure 1. Routing Runoff through a WQCV Basin (Vessel).

For more information on the underlying methodology of the math model, the user is referred to the following sources: (Guo and Urbonas, 2002), (Urbonas, Guo, and Tucker 1990) and *Description of the WQ-COSM Computer Model to Generate a Capture Volume for Stormwater BMPS* (2011).

Installing WQ-COSM

WQ-COSM is distributed as freeware as a Microsoft Installer package (*.msi). To install WQ-COSM, simply double-click on the *WQ-COSM.msi* installer. During the installation process you will be prompted to select an installation type. The 'Typical' install option needs to be selected. If you receive a warning message from your virus protection software that this is an unknown model, we suggest that you select the option to proceed with the installation.

WQ-COSM can be uninstalled using the 'Add/Remove Programs' dialog in Windows or by re-running the installer and selecting the 'Uninstall' option.

Using WQ-COSM

To use WQ-COSM, on your computer go to 'Start->All Programs->UWRI Programs' and click on 'WQ-COSM.' This will launch the user interface (see Figure 2) and open up a new WQ-COSM project.

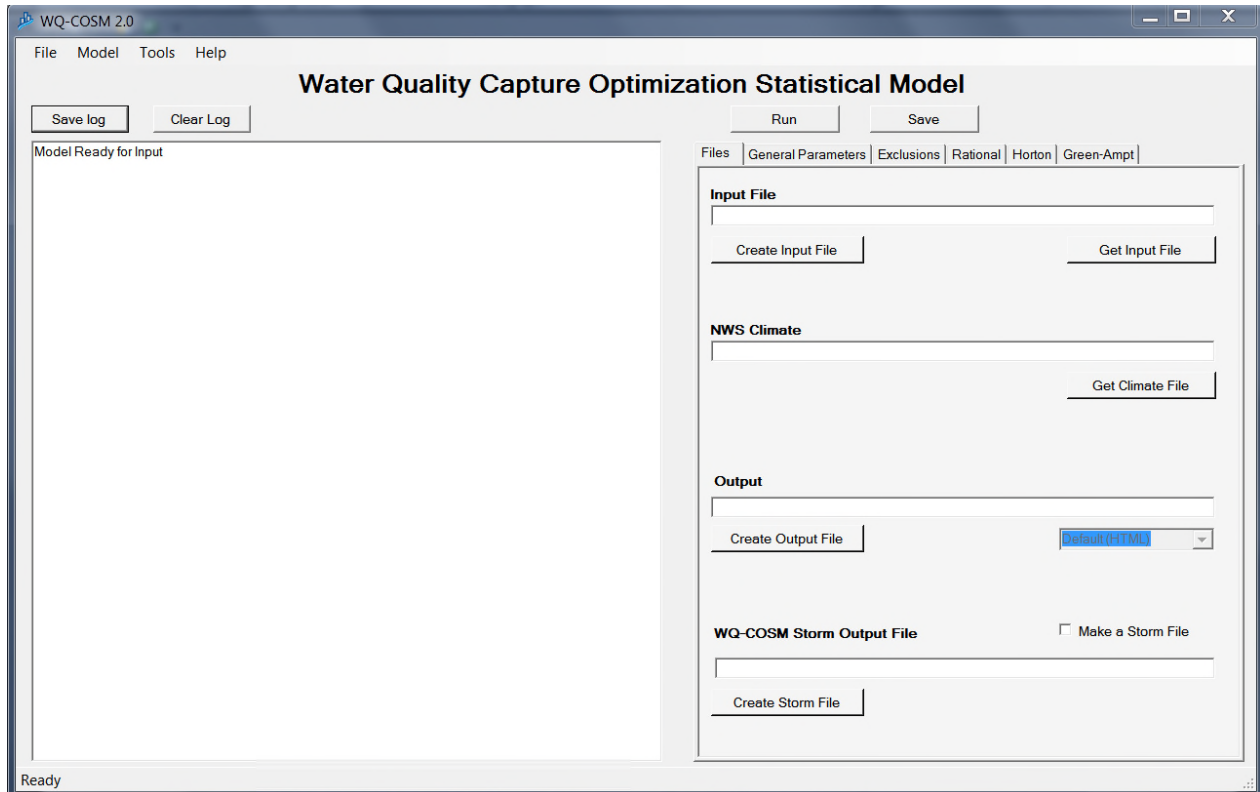


Figure 2. WQ-COSM primary user interface.

The left-hand side of the interface displays the log of the steps performed by the software. You can save this log for analysis in the future should you encounter problems and you can also clear the log shown on the interface. Two buttons are provided for the user to implement each.

The right-hand side of the interface is used for data entry. You will note that there are six tabs near the top (see Figure 3).

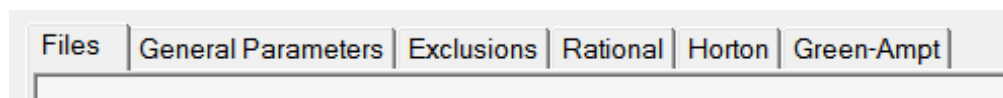


Figure 3. Tabs on the user interface seen when the program is started.

Regardless of the tab selected, whenever any entry field is selected by the user, a brief description of the field is provide in the area at the very bottom left-hand side of the interface.

'Files' Tab

Under this tab you can enter the file names and their locations/directory on your computer. You will need to enter file names for "**Input File**", "**NWS Climate**" and "**Output**".

Input File: If you have a WQ-COSM project that was saved in the past, it can be opened by entering the file name and the directory stream, or by searching for it using *Get Input File* button below and to the right of the input file field. WQ-COSM input files projects are stored have a *.qvin extension. It is essentially a text file with sections delimited by [SectionName] and parameters defined one per line using 'param=value' syntax (see [Creating and Editing Input Files without the Use of the Interface](#) section of this manual).

You can create new files by pressing the *Create Input File* button below and to the left of the file input field. The program will automatically assign the extensions when you are creating new files (*.qvin for the '**Input File**' and *.html for the '**Output**'), so do not enter them.

The '**Output**' file has to have the html extension in order to view the output. Future versions of WQ-COSM may offer other options. Also, this file will be overwritten each time the model runs, unless the user specifies a new file name for the subsequent run.

NWS Climate: The continuous rainfall data file should be in the National Climatic Data Center (NCDC) format and have the comma separated values (*.csv). These data files can be obtained from NCDC operated by NOAA. In 2012 the NCDC changed the way the data are presented in these files, however WQ-COSM will recognize both the old format and the new format. When you download data from NCDC, request the associated station and location information. You can enter the downloaded '**NSW Climate**' file for the project by clicking on the *Get Climate File* button below and to the right of the NSW Climate entry field.

WQ-COSM will assign a data processing time-step for performing continuous simulations of runoff equal the one used in the downloaded NCDC rainfall file.

Output: Entering the '**WQ-COSM Storm Output File**' is optional and is needed only when the 'Make a Storm File' box is checked. This file will contain the *.csv file containing summary information for every Individual storm identified by the program. This file can be viewed and used with spreadsheet programs such as Excel or imported into other software of your choosing.

Run and Save Buttons: To run the current WQ-COSM project, press the **Run** button. To save the input you just created or modified, press the **Save** button. Assuming all input parameters are within the expected range, the WQ-COSM math engine will be called. Any messages from the WQ-COSM math engine will be displayed on the left hand side of the screen. If the math engine completes successfully, a window will be launched where you can view the results file. You will be prompted to save your input before closing the run.

'General Parameters' Tab

The user interface under this Tab is depicted in Figure 4 and asks for the following information:

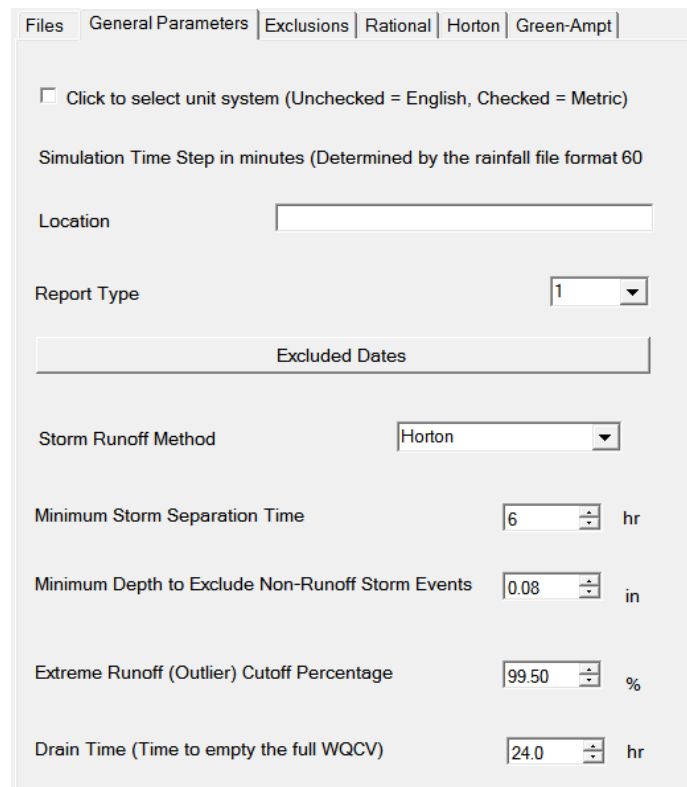


Figure 4. Data entry user interface for 'General Parameter'.

- **Unit system.** If this box is left unchecked, the default unit system of Standard US units will be used. The only parameter that differs is “inches”.
- **Location:** Enter the location of the project, study area, region or any other descriptor. This does not affect data processing and is used only for user information.

Report Type: Choose one of the three types of reports you want the program to produce, namely:

1 = Type 1 report that has WQCV and Rainfall/Runoff Statistics and also provides a table of all WQCVs calculated by both *Volume Capture Ratio* and *Event Capture Ratio* methods, and displays the maximized capture volumes for each method. User may copy and paste the tables generated for subsequent analysis or generation of figure using Excel or other software.

2 = Type 2 report that has a complete list of individual storms identified by the program along with the summary of rainfall and runoff depths, durations, and storm separations. It contains same information as the csv file generated when you request 'WQ-COSM Storm Output File' described earlier, but in html format.

3 = Type 3 report that contains, in html format, a table of all storms processed by the WQ-COSM program that includes *total precipitation, runoff, storm duration, time the storm starts and dry period separating the start of the storm and the end of the previous storm*. Water quality capture information is not a part of this report.

- **Storm Runoff Method:** Choose one of three runoff methods to convert rainfall depths to runoff depths for each of the time increments in the filtered rainfall record. The three methods available are *Rational*, *Horton* and *Green-Ampt*. Depending on the method you chose, the required parameter input fields will appear on its respective Tab.
- **Minimum Storm Separation Time:** Minimum time in hours between consecutive rainfall events (i.e., end of one storm and beginning of the next one) that marks the start of a new storm. Typically between 3 - 24 hours (default = 6-hours).
- **Minimum Depth to Exclude No-Runoff Storm Events:** Minimum total storm depth (inches or mm) for inclusion in the runoff and WQCV analysis. It is used to exclude non-runoff producing storms. State-of-practice for urban runoff suggests total minimum storm depths between 0.06 and 0.12 in. (default = 0.08 inches) is needed to produce runoff.
- **Extreme Runoff (Outlier) Cutoff Percentage:** The upper percentile of all individual storms to use in WQCV analysis. This excludes large outlier storms (program default = 99.5%). Storms above this percentile value are not used in finding the Maximized WQCV (i.e., the point of diminishing return capture volume)
- **Drain Time (Time to empty the full WQCV):** Emptying time for the brim-full WQCV to be totally emptied out (in hours) when there is no inflow. This typically range between 12 and 96 hours and depends on the type of BMP being analyzed and meteorological region (default = 24 hours).
- **Excluded dates:** Clicking on the **Excluded Dates** button launches the Tab 'Exclusions'.

'Exclusions' Tab

Using this Tab opens parameter fields that allow you to specify a season to exclude from all the years of record or specific dates to exclude from the analysis of the continuous precipitation record. For example, you may want to exclude precipitation data from a winter snow season which has completely different precipitation-runoff dynamic from rainfall. Or, you may want to exclude specific dates that may have questionable or bad data. If no dates are specified, WQ-COSM will use all of the precipitation data in the **NWS Climate** file.

'Rational' Tab

If **Rational** is specified in the **Storm Runoff Method** field under the **General Parameters** Tab, the parameter entry fields for this runoff estimating method will be available under the **Rational** Tab. For this runoff method, the only parameter that you will need to fill in is the **Rational 'C'** coefficient. This is the simplest runoff estimating method and result is relatively linear runoff output that does not account for variations in storm depth, antecedent precipitation and drying time between storms. However, a table of suggested **Rational Runoff Coefficient 'C'** may be found in Appendix A.

'Horton' Tab

If **Horton** is specified in the **Storm Runoff Method** field under the **General Parameters** Tab, the parameter entry fields for this runoff estimating method will be available under the **Horton** Tab. For this runoff method you will need to fill out the following fields:

- **Initial Infiltration Rate:** The initial infiltration rate in inches per hour (mm/hr.) (no default recommended). Suggested values for various soil types may be found in Appendix A.
- **Final Infiltration Rate:** The final infiltration rate in inches per hour (mm/hr.) (no default recommended). Suggested values for various soil types may be found in Appendix A.
- **Infiltration Decay Rate:** The infiltration decay rate in 1.0/hr units (no default recommended). Suggested values for various soil types may be found in Appendix A.
- **Imperviousness:** The imperviousness of the basin in percent (no default recommended).
- **Pervious Depress Storage:** The maximum pervious depression storage for the basin in inches (mm) (recommended default = 0.4 in (1 mm)). Suggested values for various soil types may be found in Appendix A.
- **Impervious Depression Storage:** The maximum impervious depression storage for the basin in inches (mm) (recommended default = 0.1 in (0.25 mm)). Suggested values for various soil types may be found in Appendix A.
- **Drying Time:** The time required for the basin to recover its infiltration and depression storage capacity that may vary from 1 to 14 days (recommended default = 3 to 5 days). Suggested values for various soil types may be found in Appendix A.

'Green-Ampt' Tab

If **Green-Ampt** is specified in the **Storm Runoff Method** field under the **General Parameters** Tab, the parameter entry fields for this runoff estimating method will be available under the **Green-Ampt** Tab. For this runoff method you will need to fill out the following fields:

- **Imperviousness:** The imperviousness of the basin in percent (no default recommended).
- **Pervious Depress Storage:** The maximum pervious depression storage for the basin in inches (mm) (recommended default = 0.4 in (1 mm)). Suggested values for various soil types may be found in Appendix A.
- **Impervious Depression Storage:** The maximum impervious depression storage for the basin in inches (mm) (recommended default = 0.1 in (0.25 mm)). Suggested values for various soil types may be found in Appendix A.
- **Drying Time:** The time required for the basin to recover its infiltration and depression storage capacity that may vary from 1 to 14 days (recommended default = 3 to 5 days). Suggested values for various soil types may be found in Appendix A.
- **Average Capillary Suction:** The initial infiltration rate in inches per hour (mm/hr.) depends on soil type (no default recommended). Suggested values for various soil types may be found in Appendix A.

- **Saturated Conductivity:** The final infiltration rate in inches per hour (mm/hr.) depends on soil type (no default recommended). Suggested values may be found in Appendix A.
- **Maximum Soil Moisture Deficit:** It is a non-dimensional fraction difference between soil porosity and the actual moisture content (no default recommended). Suggested values by soil type may be found in Appendix A.

Creating and Editing Input Files without the Use of the Interface

Users may also choose to create or edit WQ-COSM input files using tools other than the Pond Risk User Interface. The required syntax for input files is provided below. First two lines of entry define the location of the output file and the NCDC rainfall file. All the subsequent lines are used to define the input parameters by entering or changing the values to the right of the equal sign. A sample input file (*.qvin) is shown below to the user to follow. However, to run the file, the user will have to call the WQ-COSM program using Windows “Start” button.

[WQCOSMUI]

```
outputFile=C:\Users\Username\Documents\supdirectory1\subdirectory2\subdirectory3\filename.htm
rainfallFile=C:\Users\ Username\Documents\supdirectory1\subdirectory2\subdirectory3\rainfall
file.csv
```

[WQCOSM]

```
COOPID=
cutoffPercent=99.5
drainTime=40
excludeDates=
location=Denver Stapleton
minStormDepth=0.08
reportType=1
simulationType=CONTINUOUS
stormSepTime=360
timeStep=60
```

[HortonBasin]

```
dryingTime=3
finalInfRate=0.1
impervDepStg=0.1
imperviousness=90
infDecayRate=3
initInfRate=2
pervDepStg=0.4
```

APPENDIX – A

Ranges in Rainfall Losses for Rational, Horton’s and Green Ampt Methods

Rational Runoff Coefficient ‘C’. This coefficient varies with soil type and degree of effective imperviousness of the catchment between 0.0 and 1.0. Based on EPS’s Nationwide Urban Runoff Program Data from over 60 different sites in United States and the follow-up analysis performed by the Urban Drainage and Flood Control District (UDFCD) in the Denver Region, Table A1 offers suggested values when selecting values of C for use with WQ-COSM.

Table A1. Runoff Coefficient as a Function of Total Imperviousness

Percentage Imperviousness	Runoff Coefficient by NRCS Hydrologic Soil Groups		
	C & D	B	A
0%	0.04	0.02	0.00
10%	0.11	0.06	0.00
20%	0.17	0.12	0.06
30%	0.22	0.18	0.13
40%	0.28	0.23	0.19
50%	0.34	0.29	0.25
60%	0.41	0.37	0.33
70%	0.49	0.45	0.42
80%	0.60	0.57	0.54
90%	0.73	0.71	0.69
100%	0.89	0.89	0.89

Horton’s Method Parameters. WQ-COSM uses the integrated form of Horton’s equation to find rainfall losses on pervious surfaces during continuous simulation, namely:

$$F_t = f_o * t + \frac{f_i - f_o}{a} * (1 - e^{-at})$$

in which,

- f = infiltration rate (in/hr),
- f_o = final infiltration rate (in/hr),
- f_i = initial infiltration rate (in/hr),
- e = natural logarithm base,
- a = decay coefficient (1/hour),
- t = time (hours)

Horton’s Initial Infiltration Rate varies with the types of soil. Typically used values range from 0.2 to 10.0 inches per hour (5 to 25 mm/h). Table A2 contains initial infiltration rates suggested for use with WQ-COSM and are based on ones originally suggested by Akan (1993), and others.

Table A2. Horton's Initial Infiltration by Soil Type

Soil Type	(in/hr)	(mm/hr)
Dry sandy soils with little or no vegetation	5.0	127
Dry loam soils with little or no vegetation	3.0	76.2
Dry clay soils with little or no vegetation	1.0	25.4
Dry sandy soils with dense vegetation	10.0	254
Dry loam soils with dense vegetation	6.0	152
Dry clay soils with dense vegetation	2.0	51
Moist sandy soils with little or no vegetation	1.7	43
Moist loam soils with little or no vegetation	1.0	25
Moist clay soils with little or no vegetation	0.3	7.6
Moist sandy soils with dense vegetation	3.3	84
Moist loam soils with dense vegetation	2.0	5.1
Moist clay soils with dense vegetation	0.7	18

Horton's Final Infiltration Rate also varies with the types of soil. Table A3 contains final infiltration rates suggested by Akan (1993), and others:

Table A3. Horton's Final Infiltration Rate by Soil Type

Soil Type	Final Infiltration Rate	
	(in/hr)	(mm/hr)
Clay loam, silty clay loam, sandy clay, silty clay, clay	0.01 - 0.08	0.25 - 2.0
Sandy clay loam	0.06 - 0.12	1.57 - 3.1
Silt loam, loam	0.15 - 0.30	3.8 - 7.6
Sandy loam	0.43 - 0.86	11 - 22
Loamy sand	1.2 - 2.4	30 - 60
Sand, ,	4.7 - 9.3	119 - 236

The final infiltration rate is the saturated hydraulic conductivity rate of the soil.

Horton's Infiltration Decay Rate can vary considerably. Values typically in use by modelers range from 2 to 6/hr (0.00056 to 0.00167/sec). Because there is little sensitivity in final results after the value of 3/hr is used, it is recommended a value of 3/hr be used with WQ-COSM for NRDC Soil Groups B, C and D and a value of 2/hr for Soil Group A.

Impervious Surface Depression Storage can also vary considerably depending on the type of the surface and its condition. Water stored in depressions on impervious areas is lost through evaporation.

Typical values in use by modelers range from 0.04 to 0.12 inches (1 to 3 mm). A value of 0.08 inches (2 mm) is recommended for use with WQ-COSM. See Table A4 for recommendations.

Pervious Depression Storage, in inches or millimeters, has to be filled up before runoff begins and is subject to both infiltration and evaporation. For grassed urban surfaces this ranges from 0.2 to 0.5 inches (6 to 13 mm) and a value 0.3 to 0.4 inches (8 to 10 mm) is recommended for use with WQ-COSM. See Table A4 for recommendations.

Table A4. Pervious and Impervious Surface Depression (Retention) Losses.

	Land Cover	Range	Recommended
Pervious Surfaces	Impervious:		
	Large paved areas	0.05 - 0.15	0.1
	Roofs-flat	0.1 - 0.3	0.1
	Roofs-sloped	0.05 - 0.1	0.05
Impervious Surfaces	Lawn grass	0.2 - 0.5	0.35
	Wooded areas and open fields	0.2 - 0.6	0.4

Drying Time used by modelers typically varies from 1 to 14 days, depending on local climate during the rainfall seasons. Table A5 lists drying times offered for your consideration.

Table A5. Drying times for use in continuous simulations with Horton's and Green-Ampt.

Climate/Region	Drying time in days (typically used)
Arid regions	1 to 2 (1)
Semi- Arid regions	2 to 4 (3)
Midwest, East and SE USA	3 to 8 (5)
Very Humid and prolonged precipitation regions	7 to 14 (10)

Green-Ampt Method Parameters. The Green-Ampt equation was suggested by Mein-Larson (1973) and operates in two-stages. First it predicts the volume of water that will infiltrate before the surface becomes saturated. After that infiltration capacity is predicted. The following algorithm describes these two stages:

Stage 1: When $F < F_s$; then $f = i$

$$\text{if } i > K_s; \text{ then } F_s = (S_u * IMD) / f$$

Stage 2: Otherwise $f = F_p$

$$\text{in which, } F_p = K_s * (1 + S_u * IMD / F)$$

in which:

f = infiltration rate, ft/sec

F_p = infiltration capacity, ft/sec

i = rainfall intensity, ft/sec

F = cumulative infiltration volume, this event, ft

F_s = cumulative infiltration volume required to cause surface saturation, ft

* S_u = average capillary suction at the wetting front, ft water

* IMD = initial moisture deficit, ft/ft

* K_s = saturated hydraulic conductivity of soil, ft/sec

Note: * denotes parameters to be entered by the user.

Pervious Depress Storage: Same as for Horton's described above.

Impervious Surface Depression Storage: Same as for Horton's described above.

Drying Time: Same as Horton's described above.

Saturated Conductivity: Saturated hydraulic conductivity is similar to the **Horton's Final Infiltration Rate** described above. Table A6 lists values for your consideration.

Average Capillary Suction: The average capillary suction in inches (mm) of water. It may be the most difficult parameter to quantify accurately. It can be derived from soil moisture conductivity data. Table A6 lists values for your consideration.

Maximum Soil Moisture Deficit: This is the most sensitive parameter of all of the user inputs for the Green-Ampt method. It is non-dimensional fraction difference between soil porosity and the actual moisture content. Table A6 lists values offered for your consideration.

Table A6. Suggested values for Saturated Conductivity, Average Capillary Suction and Maximum Soil Moisture. (Ref. Maidment (1993) and Rawls, et. al. (1983).

	Average Capillary Suction		Saturated Hydraulic Conductivity		Maximum (Initial) Moisture Deficit	
	in	mm	in/hr	mm/hr	East Coast	West Coast
Sand	1.93	49.0	4.74 - 9.27	120 - 236	0.346	0.404
Loamy sand	2.4	61.0	1.18 - 2.35	30.0 - 59.7	0.312	0.382
Sandy loam	4.33	110	0.43 - 0.86	10.9 - 21.8	0.246	0.358
Loam	3.5	88.9	0.13 - 0.52	3.3 - 13.2	0.193	0.346
Silt loam	6.69	57.9	0.26 - 0.27	6.6 - 6.7	0.171	0.368
Sandy clay loam	8.66	220	0.06 - 0.12	1.57 - 3.1	0.143	0.25
Clay loam	8.27	104	0.04 - 0.08	1.0 - 2.0	0.146	0.267
Silty clay loam	10.6	269	0.04 - 0.08	1.0 - 2.0	0.105	0.263
Sandy clay	9.45	240	0.02 - 0.05	0.5 - 1.3	0.091	0.191
Silty clay	11.4	290	0.02 - 0.04	0.5 - 1.0	0.092	0.229
Clay	12.6	320	0.01 - 0.02	0.25 - 0.5	0.079	0.203

NOTE: Saturated hydraulic conductivity, or permeability, values differed between two sources used. Values from Rawls were about 50% of the values from Maidment. Both values are represented as a range.

References

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