Technical Note for Sizing
Infiltration Basins and Bioretention Devices
To Meet State of Wisconsin Stormwater Infiltration Performance Standards

Table of Contents

PART 1. INTRODUCTION

This technical note includes several tools approved by the Wisconsin Department of Natural Resources to design infiltration basins and bioretention devices capable of meeting the state of Wisconsin stormwater infiltration performance standards contained in ss. NR 151.12(5)(c) and NR 151.24(5), Wis. Adm. Code. The purpose of this technical note is to describe where these tools can be found and how they are used. The Department of Natural Resources recognizes the existence of other models that estimate stormwater infiltration. These other models and tools may also be used to meet the state of Wisconsin infiltration performance standards if approved by the Department of Natural Resources.

The tools included in this technical note are:

- a chart for determining target stay-on depth;
- RECARGA, an infiltration model that can be used to determine the required effective infiltration area for infiltration basins and bioretention devices;
- a set of design charts, developed using RECARGA, which can be used to determine the required effective infiltration area for infiltration basins.

The University of Wisconsin-Madison Department of Civil Engineering developed the RECARGA model. The University of Wisconsin and Department of Natural Resources staff developed the other design charts included in this technical note.

To design an infiltration basin or bioretention device, one or more conservation practice standards must be used in conjunction with this technical note. These conservation practice standards include other important requirements relating to siting, dimensions, construction, operation and maintenance of infiltration practices. The applicable conservation practice standards include:

- ➢ DNR Conservation Practice Standard 1002, Site Evaluation for Stormwater Infiltration;
- ➢ DNR Conservation Practice Standard 1003, Infiltration Basin;
- ➢ DNR Conservation Practice Standard 1004, Bioretention for Infiltration;
- ➢ Wisconsin Department of Natural Resources Specification S100, Compost.

These conservation practice standards are posted on the following DNR Internet site:
http://dnr.wi.gov/runoff/stormwater/techstds.htm#Post

The designer will use Parts 2 and 3 of this technical note and the DNR Conservation Practice Standard 1003 to determine the required effective infiltration area for an infiltration basin. Part 5 of this technical note may also be used. To determine the effective infiltration area for a bioretention device, the designer will use Parts 2, 4 and 5 of this technical note in conjunction with DNR Conservation Practice Standard 1004. In addition, DNR Conservation Practice Standards 1002 and S100 apply to both devices.

This technical note also cross-references several digital files that can be used to size infiltration basins and bioretention devices. A list of these digital files is shown in Table 1. Note that some of the digital files will be used in designing both infiltration basins and bioretention devices while others are specific to only one of these practices. These digital files can be downloaded from the following DNR Internet site:
http://dnr.wi.gov/runoff/stormwater/techstds.htm#Post

Table 1. Directory of digital files referenced in this technical note.

File Content	Applicability	File Name
Technical note text	Infiltration Basins, Bioretention Devices	*Technical Note for Sizing Infiltration Devices.doc*
Target Stay-on Depth	Infiltration Basins, Bioretention Devices	*Target stay-on requirements.xls*
Silt loam soils, 3" pond depth	Infiltration Basins	*Chart1madsiltloam3.xls*
Loam soils, 6" pond depth	Infiltration Basins	*Chart2madloam6.xls*
Sand loam soils, 6" pond depth	Infiltration Basins	*Chart3madsandyloam6.xls*
Sand loam soils, 12" pond depth	Infiltration Basins	*Chart4madsandyloam12.xls*
Loamy sand soil, 6" pond depth	Infiltration Basins	*Chart5madloamysand6.xls*
Loamy sand soil, 12" pond depth	Infiltration Basins	*Chart6madloamysand12.xls*
Loamy sand soil, 18" pond depth	Infiltration Basins	*Chart7madloamysand18.xls*
Loamy sand soil, 24" pond depth	Infiltration Basins	*Chart8madloamysand24.xls*
Sand, 6" pond depth	Infiltration Basins	*Chart9madsand6.xls*
Sand, 12" pond depth	Infiltration Basins	*Chart10madsand12.xls*
Sand, 18" pond depth	Infiltration Basins	*Chart11madsand18.xls*
Sand, 24" pond depth	Infiltration Basins	*Chart12madsand24.xls*
RECARGA v. 2.3	Infiltration Basins, Bioretention Devices	*RECARGA_2_3.exe (In Recarga Folder)*
RECARGA User's Manual v. 2.3	Infiltration Basins, Bioretention Devices	*RECARGA 2p3 User's Guide.doc*

PART 2. DETERMINING THE TARGET STAY-ON DEPTH FOR INFILTRATION BASINS AND BIORETENTION DEVICES

Instructions. DNR Conservation Practice Standard 1003 (Infiltration Basin) and 1004 (Bioretention for Infiltration) define target stay-on as follows:

> *"The amount of infiltration required on an average annual basis. It is the portion of the annual rainfall (inches) on the development site that must be infiltrated on an annual basis to meet the infiltration goal."*

The target stay-on depth is a required input for the RECARGA model and the infiltration basin design charts included in this technical note. Consequently, the target stay-on depth must be known in order to use these tools to determine the effective infiltration area of either an infiltration basin or a bioretention device.

The target stay-on depth for a development site is a function of the pre-development infiltration for the site and that portion of the pre-development infiltration that must be retained on the site to meet the state requirement. This technical note includes a simple design chart incorporating these factors. The chart can be used to determine the target stay-on needed to meet the state infiltration goal. The chart is found in the file "*Target stay-on requirements.xls*" (See Table 1). This Microsoft Excel file contains two worksheet tabs: "Target Chart" and "Target Data". Open the worksheet tab entitled "Target Chart". The chart itself is titled "Chart 1. Target Stay-on Requirement". You do not need, and should not attempt to open or modify, the underlying target data.

Note: *State infiltration requirements are established in chapter NR 151, Wis. Adm. Code. Pursuant to NR 151.12(5)(c)1.a., the goal for residential development is to maintain 90% of the annual pre-development infiltration. Pursuant to NR 151.12(5)(c)2.b., the goal for non-residential sites is to retain 60% of the annual pre-development infiltration.*

Other parts of NR 151 (NR 151.12(5)(c)1. and NR 151.12(5)(c)2.) include alternative infiltration requirements based on infiltrating runoff from the 2-year, 24-hour design storm. Although the design storm approach can be used to fulfill the state requirement, this technical note does not address that method.

“Chart 1, Target Stay-on Requirement” is used to determine the annual infiltration requirement for any site, regardless of the management practice to be applied. This means it is applicable to both infiltration basins and bioretention devices.

The x-axis of Chart 1 is the pre-development curve number. The appropriate pre-development curve number should be taken from TR-55 unless the pre-developed land use is cropland. If the pre-developed land use is cropland, s. NR 151.12(5)(b) 1., Wis. Adm. Code identifies maximum pre-development curve numbers that can be used. These are reproduced in the following table.

Table 2. Maximum pre-development runoff curve numbers for cropland areas

Hydrologic Soil Group	***A***	***B***	***C***	***D***
Runoff Curve Number	***56***	***70***	***79***	***83***

***Note**: The curve numbers in this table represent mid-range values for soils under a good hydrologic condition where conservation practices are used.*

The y-axis of Chart 1 is the target stay-on depth (annual infiltration requirement), in inches/year, for the development area. There are three curves in the chart. One curve is for residential development, a second is for non-residential (including commercial) development and a third is for pre-development conditions. The example below explains how to use this chart to make the required determination.

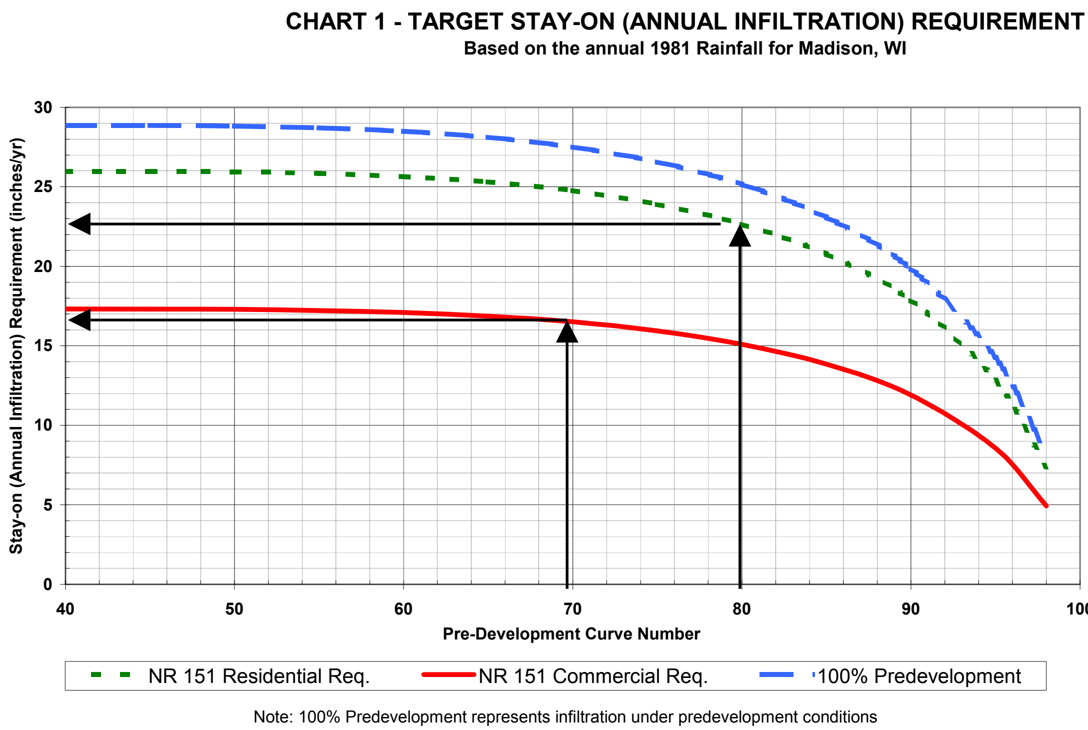
Chart 1 was developed using the annual rainfall sequence file for Madison, Wisconsin, 1981 (March 12 – December 2). This file may be used for statewide application until additional charts are prepared for other regional rainfalls. When additional charts are completed, they will be posted in this technical note.

Example. Figure 1 illustrates how the chart can be used to determine the annual infiltration requirement for a particular development:

- Locate the pre-development curve number on the x-axis.
- Move vertically to intersect the appropriate curve (residential or non-residential (commercial))
- Move horizontally to intersect the y-axis and determine the annual infiltration requirement.

For example, if the predevelopment curve number is 70 and the development site is non-residential (commercial), the annual infiltration requirement is 16.5 inches/year. If the predevelopment curve number is 80 and the development site is residential, the annual requirement is 22.5 inches/year.

Figure 1. Sample use of chart to determine the target stay-on requirement.



PART 3. DETERMINING THE EFFECTIVE INFILTRATION AREA REQUIREMENT FOR INFILTRATION BASINS

Instructions. In addition to target stay-on depth, other important parameters that affect the required effective infiltration area of an infiltration basin include:

- design infiltration rate of the native soil;
- design ponding depth in the basin;
- percent imperviousness of the development in the area tributary to the basin;
- post-development curve number of pervious areas in the area tributary to the basin.

A set of 12 design charts for infiltration basins was prepared using the RECARGA model. These are listed in Table 1 (example: *Chart5madloamysand6".xls*). Each chart represents a combination of design infiltration rate (K_d) and design ponding depth. The design infiltration rate (K_d) for each soil textural class is taken from DNR Conservation Practice Standard 1002, Site Evaluation for Stormwater Infiltration. DNR Conservation Practice Standard 1003 states that the ponding depth must infiltrate within the maximum allowable draw down period of 24 hours. This means that (Pond depth)/(K_d) must be equal to or less than 24 hours. Table 3 shows the combinations of design infiltration rates and ponding depths covered by the charts listed in Table 1. All infiltration basins were modeled using a rooting zone depth of 6 inches.

Each of the 12 charts includes several graphs corresponding to various percentages of imperviousness in the drainage area and the curve number of the pervious portion of the drainage area. In each chart, there are 6 imperviousness categories: 0%, 20%, 40%, 60%, 80%, and 100%. Each of the impervious categories is further refined based on the curve number of the pervious area. Two pervious area curve numbers are graphed: one graph depicts a pervious area curve number (CNp) of 60 and the other depicts a pervious area curve number (CNp) of 80.

To determine the area of an infiltration basin required to meet the annual infiltration requirement, the designer may use one of these prepared charts. If the designer wishes to determine the effective infiltration area for conditions that are not depicted on these charts, RECARGA may be used (See Part 5).

Table 3. Combinations of infiltration rates and ponding depths covered by Charts 1-12 listed in Table 1.

Soil Texture	Design Infiltration Rate (Kd), inches/hour	Basin Design Ponding Depth, inches
Silt loam	.13	3
Loam	.24	6
Sandy loam	.5	6
Sandy loam	.5	12
Loamy sand	1.63	6
Loamy sand	1.63	12
Loamy sand	1.63	18
Loamy sand	1.63	24
Sand	3.6	6
Sand	3.6	12
Sand	3.6	18
Sand	3.6.	24

After determining the target stay-on depth (see Part 2) and selecting the appropriate chart from Table 1, determine the preliminary effective infiltration area. This determination is preliminary because it may need to be increased to account for longitudinal slopes and the creation of infiltration cells within the infiltration basin. This correction process is described in DNR Conservation Practice Standard 1003, Infiltration Basin.

To determine the preliminary effective infiltration area required to meet the infiltration requirement, the required target stay-on depth is located on the y-axis of the design chart. Move horizontally to intersect the appropriate line depicting the % imperviousness and pervious area curve number. Drop down to the x-axis to find the infiltration basin area, which is expressed as a percent of the drainage area. Multiply this percentage by the size of the tributary area that will be served by the basin to determine the preliminary value for the effective infiltration area required to meet the state infiltration performance standard. Adjust the preliminary area as needed to account for the longitudinal slope and infiltration cell configuration, as described in DNR Conservation Standard 1003, Infiltration Basin.

In using these charts, it is acceptable to visually extrapolate within the same chart between the percent imperviousness graphs and also between the pervious area curve number graphs. However, it is not acceptable to extrapolate between charts (e.g. between charts 10 and 11).

Example. The site is 20 acres of cropland that will be converted to a mixed commercial & residential development. Assume the native soils in the area to be developed are silt loams and loams in soil hydrologic groups B and C with an average pre-development curve number of 75. Following development, the site will be 15 acres medium density residential and 5 acres commercial. A site investigation using DNR Conservation Practice Standard 1002, Site Evaluation for Stormwater Infiltration, concludes that the soil texture at the infiltration basin site is a sandy loam with a design infiltration rate of 0.5 in/hr. The post-development curve number for the pervious portions of the new urban development is anticipated to be 70, based on TR-55. The designer wants to maximize the pond depth, which would mean a depth of 12 inches could be accommodated based on an infiltration rate of .5 inches/hour and a maximum allowable drawdown time of 24 hours.

Step 1: Determine Overall Approach. The effective infiltration area needed for the runoff from residential areas will be determined and then added to the effective infiltration area needed for commercial areas. The sum of these two areas is the preliminary effective infiltration area. The preliminary effective infiltration area is then adjusted in accordance with DNR Conservation Practice Standard 1003, Infiltration Basin, to account for longitudinal slope and cell configuration.

Step 2: Determine Basin Component to Accommodate Residential Runoff. Two sub-steps are needed.

Sub-step 2A: Determine Target Stay-on Depth for Residential Component. The Target Stay-on Depth for the residential land use is determined using the file *Target stay-on requirements.xls.* The pre-development curve number is 75. The target stay-on depth for the residential portion of the basin is determined to be approximately 24 inches/year. Figure 2 illustrates this determination.

Sub-step 2B: Determine Preliminary Infiltration Area for Residential Component. The chart applicable to this site is *Chart4madsandyloam12".xls* (see list in Table 1.) In this example, assume an impervious area percentage of 40% for medium density residential and assume a curve number for pervious portions of the site to be 70. The target stay-on depth is 24 inches/year as determined in sub-step 2A. Using Chart 4, the facility must 1.2% of the 15-acre medium density residential area. Figure 3 illustrates this determination. The capacity needed for runoff from the residential area is therefore 7,840 square feet (43,560 * 15 * .012).

Step 3: Determine Basin Component to Accommodate Commercial Runoff. Two sub-steps are needed.

Sub-step 3A: Determine Target Stay-on Depth for Commercial Component. The Target Stay-on Depth for the commercial land use is determined using the file *Target stay-on requirements.xls.* The pre-development curve number is 75. The target stay-on depth for the commercial portion of the basin is approximately 16 inches/year. Figure 4 illustrates this determination

Sub-step 3B: Determine Preliminary Infiltration Area for Commercial Component. The chart applicable to this site is *Chart4madsandyloam12".xls* (see Table 1.) In using this chart, assume an impervious area percentage of 70% for commercial and assume that the curve number for pervious portions of the site is 70. The target stay-on depth is 16 inches/year as determined in sub-step 3A. Using Chart 4, the facility must be 0.5% of the 5 acres of commercial land use. Figure 5 illustrates this determination. The capacity needed for runoff from the commercial area is 1,089 square feet (43,560 * 5 * .005).

Step 4: Add the residential and commercial capacities to determine the preliminary effective infiltration area for a basin 12 inches deep. This area is 8,930 square feet (7,840 square feet for residential capacity + 1,089 square feet for commercial capacity). This area is used in conjunction with DNR Conservation Practice Standard 1003, Infiltration Basin, to determine the final effective infiltration area after needed adjustments are made for longitudinal slope and basin cell configurations.

Figure 2. Using Chart 1 to determine the target stay-on depth (inches/year) for the residential portion of the development area

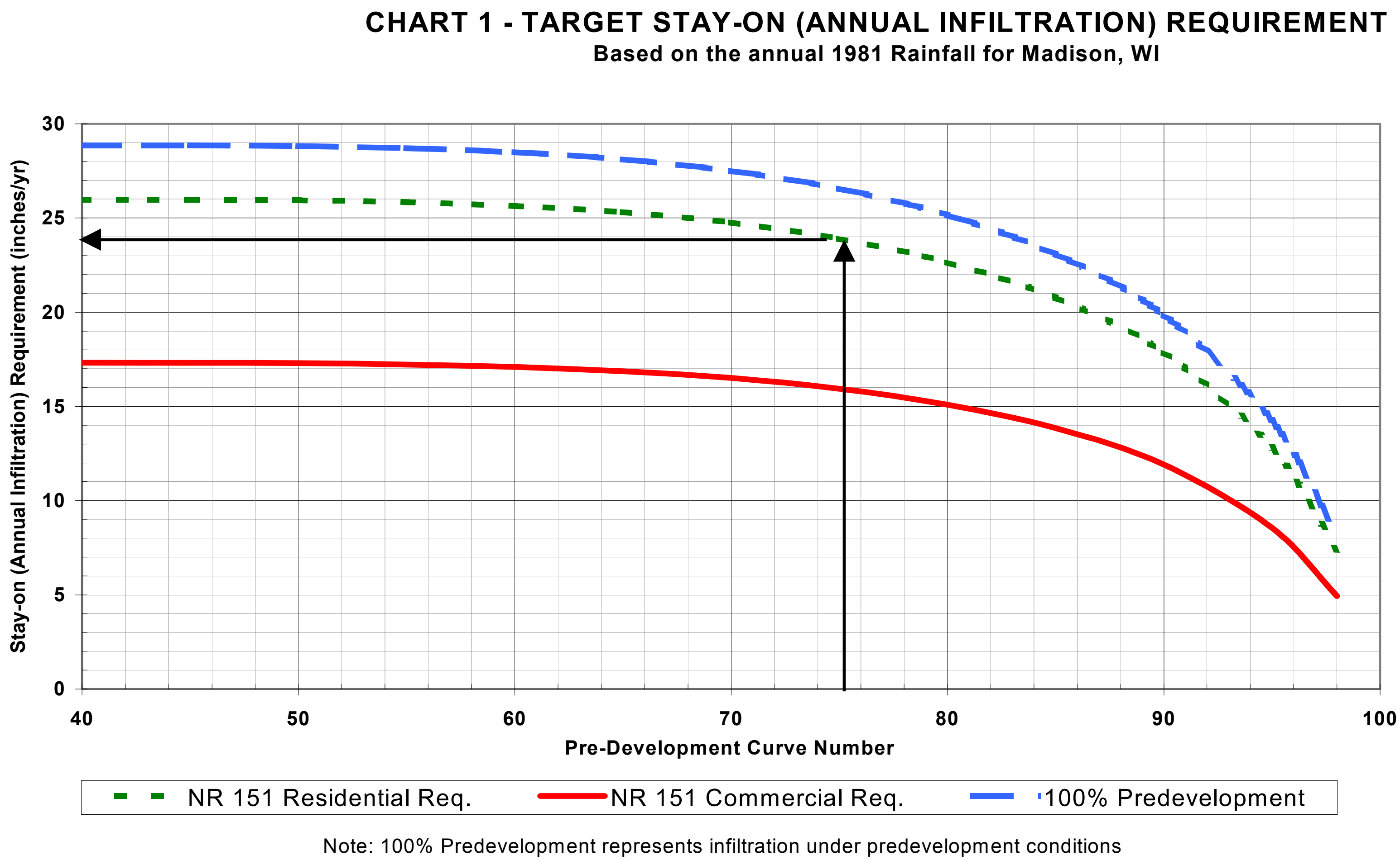


Figure 3. Using Chart 4 to determine the preliminary effective infiltration area needed to serve runoff from residential portion of drainage area

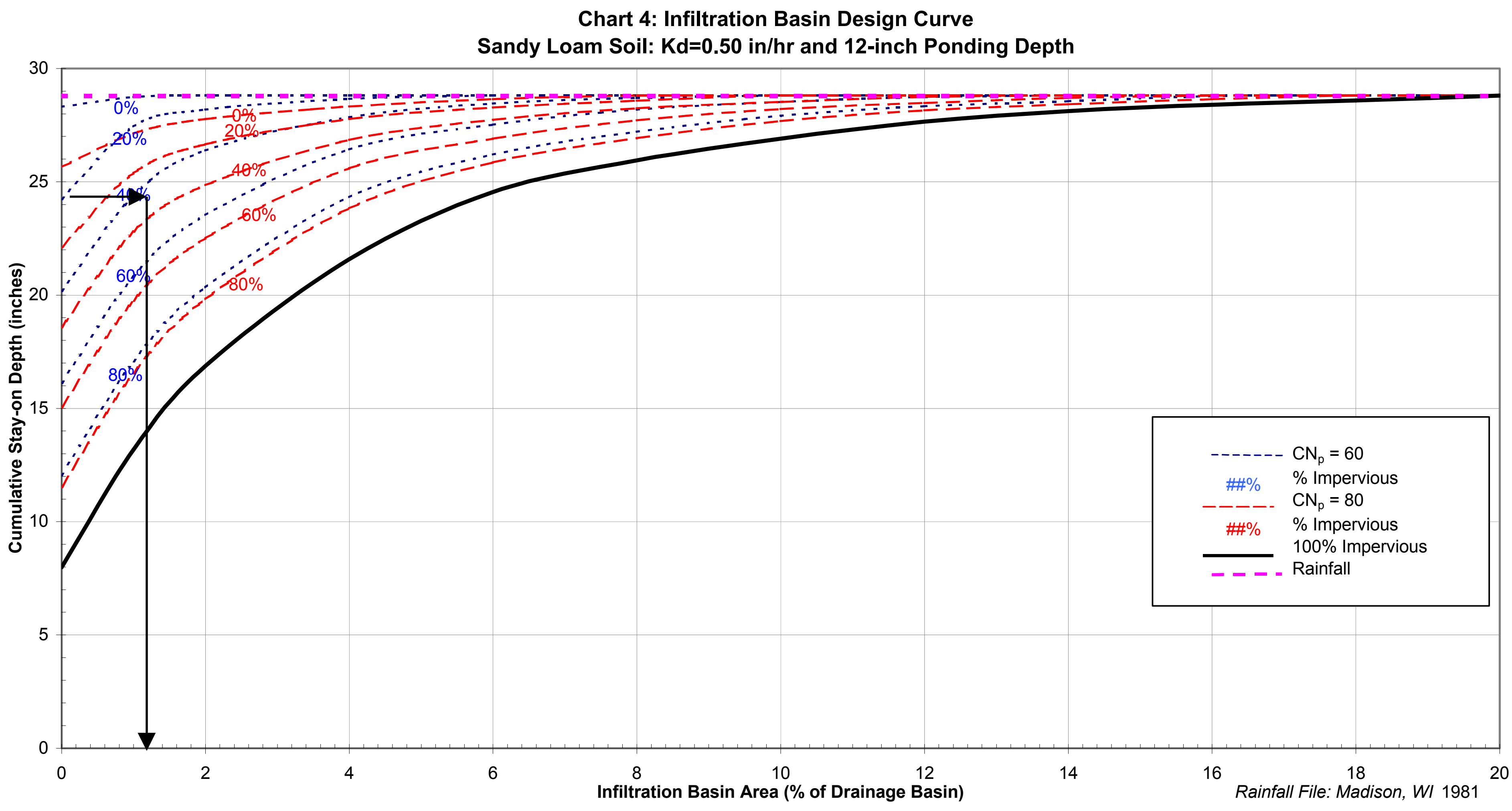


Figure 4. Using Chart 1 to determine the target stay-on depth (inches/year) for the commercial portion of the development area

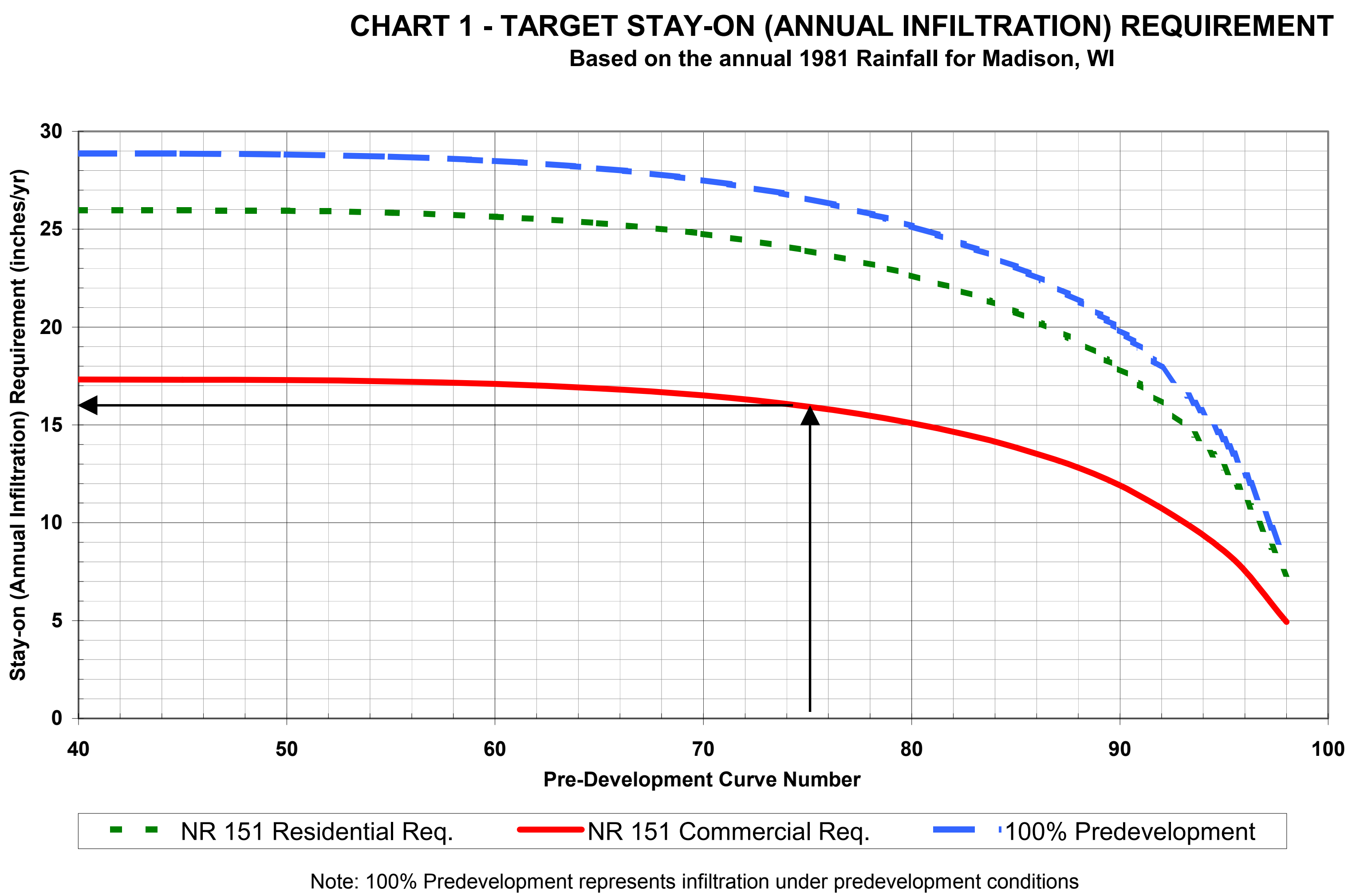
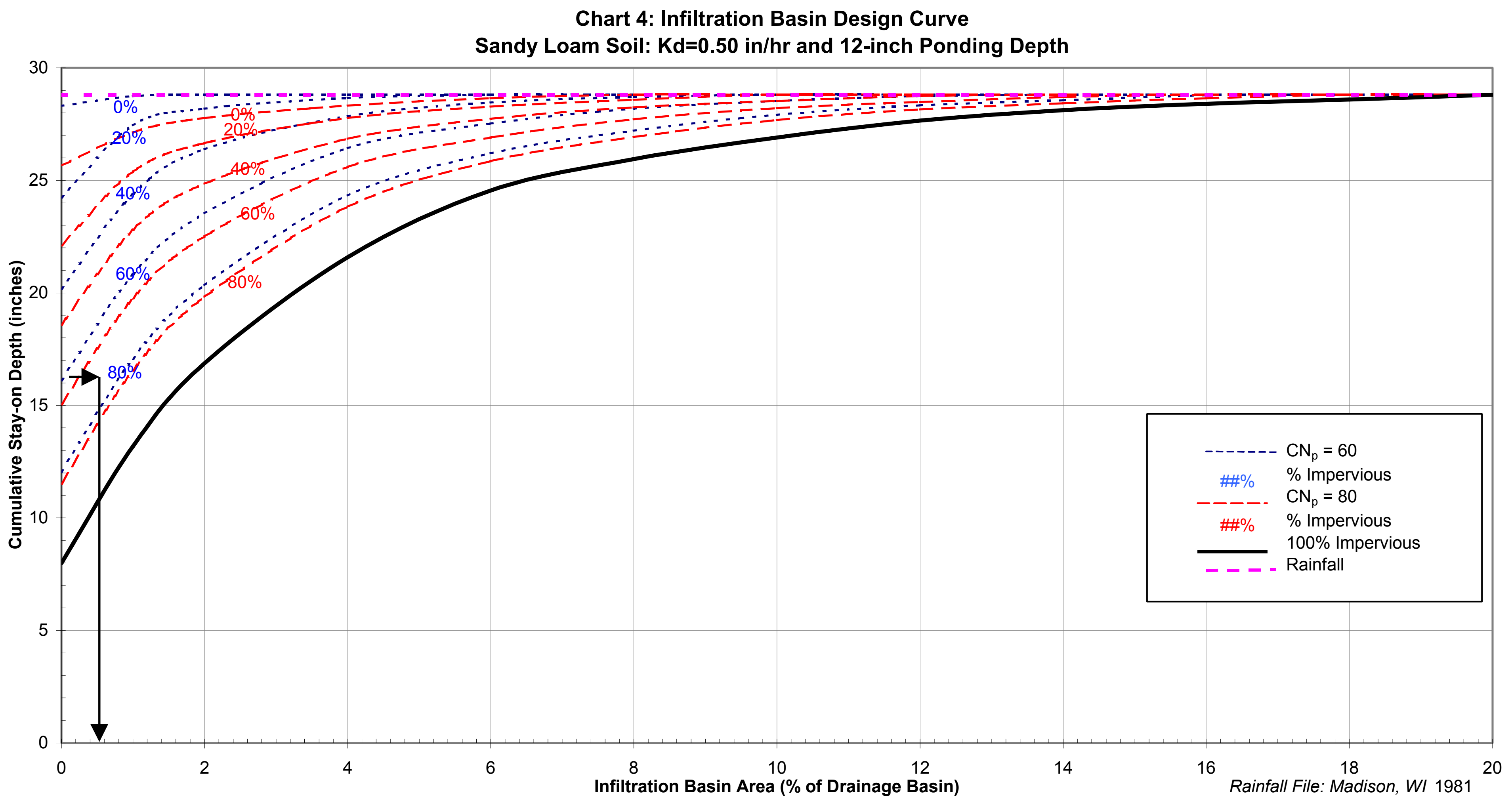


Figure 5. Using Chart 4 to determine the preliminary effective infiltration area to serve runoff from commercial portion of drainage area.



Part 4.
Determining the Effective Infiltration Area Requirement for Bioretention Devices

Determining the effective infiltration area of a bioretention device is more complicated than determining this area for an infiltration basin. Additional factors that affect infiltration dynamics include variation in the depth of the engineered soil, flow dynamics through the perforated underdrain and a variable sand/gravel storage layer. These additional factors require a more sophisticated modeling tool.

The RECARGA model referenced in Table 1 may be used to determine the required effective infiltration area of a bioretention device. The RECARGA model is discussed in Part 5.

Part 5. The RECARGA Model

The Water Resources Group at the University of Wisconsin Department of Civil and Environmental Engineering developed the RECARGA model. The model provides a design tool for evaluating the performance of bioretention devices, infiltration basins and rain gardens. Individual facilities with surface ponding, up to 3 distinct soil layers and optional underdrains can be modeled under user-specified precipitation and evaporation conditions. The model continuously simulates the movement of water throughout the facility (ponding zone, soil layers and underdrains), records the soil moisture and volume of water in each water budget term (infiltration, recharge, overflow, underdrain flow, evapotranspiration, etc.) at each time step and summarizes the results. The results of this model can be used to size facilities to meet specific performance objectives, such as reducing runoff volume or increasing recharge, and for analyzing the potential impacts of varying the design parameters.

The model uses the Green-Ampt infiltration model for initial infiltration into the soil surface and the van Genuchten relationship for drainage between soil layers. Input to the facility is calculated from user specified land cover data (percent impervious area, pervious area curve numbers and the area of the facility and tributary basin) using an initial abstraction equation (for impervious areas) or the TR-55 methodology for pervious areas. Underdrain flow is calculated using the orifice equation. The model also tracks continuous soil moisture and evapotranspiration between storm events. The user interface is intuitive and simple to use.

The model can be used in two modes: the original RECARGA simulation and the Facility Area Ratio Simulation.

> <u>RECARGA Simulation</u>. In this simulation the user enters data for estimated facility area, tributary area, percent imperviousness, pervious area curve number, design pond depth, design engineered soil depth, design engineered soil infiltration rate (default available), design storage layer depth, design storage layer infiltration rate (default available), design infiltration rate of native soil, underdrain flow rate, design rainfall file (default available) and regional evapo-transpiration data (default available).
>
> A simulation is run and basic water budget information is provided including the stay-on achieved. If the stay-on achieved is too high or too low, the simulation is run again with a different facility area chosen by the designer. This process is continued until the target stay-on is achieved. This can usually be accomplished in 3-4 model runs. This process should take about 2 minutes per model run (about 10 minutes total) at commonly available computing speeds. Slower processors will take longer.
>
> <u>Facility Area Ratio Simulation</u>. This simulation is a sub-routine run within RECARGA. It uses the same interface as the RECARGA model. Although it does not provide water budget output data, it does not require the user to go through an iterative process to determine the required facility area. This sub-routine performs the iteration for the user. Once the data is entered and the Facility Area Routine (FAR) is run, the program will provide the required facility area ratio. This percentage is then multiplied by the tributary area to calculate the required facility area. The input data is the same except that the user enters the target stay-on instead of the estimated facility area.

This process should take about 10 minutes for the model run at commonly available computing speeds. Slower processors will take longer.

The RECARGA model and the RECARGA User's Manual (Version 2.3) are referenced in Table 1. Both are available for downloading from the DNR Internet site. The User's Manual provides adequate guidance for using this design tool.

Note: The Water Resources Group has also prepared another tool called the Bioretention Nomograph and Worksheet Method. This method is based on RECARGA and as such is an approximation. The Department of Natural Resources does not authorize this tool for final practice design because determinations using the worksheet method may be 10-25% different than estimates produced by the model. However, the Bioretention Nomograph and Worksheet Method is valuable for quickly evaluating the effect that variation in design parameters has on required facility area. Although this worksheet method is not approved for final design and is not part of this technical note, DNR is making the method available as guidance on the DNR Internet site. It is a valuable learning tool and can be used, if desired, for preliminary sizing estimates.