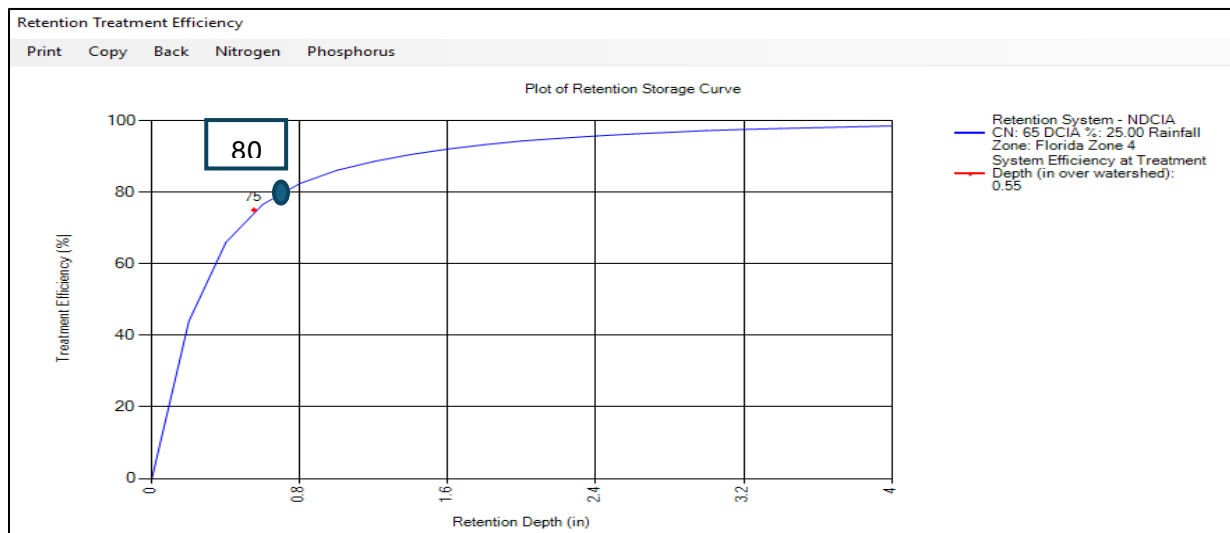


Annual Effectiveness for BMPs in Series

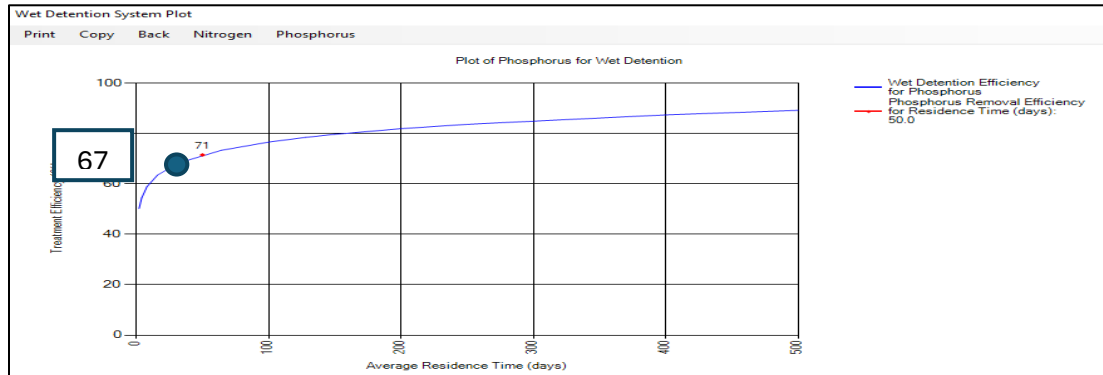
Included in this help section is information related Retention in series: When the runoff from a catchment enters one BMP and the discharge enters into another BMP without additional catchment flow, the BMPs are said to be in series for the catchment. Examples for retention BMPs in series are a pervious pavement followed by exfiltration and a rain garden followed by exfiltration. Without any additional runoff to the downstream BMP, the annual capture effectiveness is calculated from the total capture treatment depth of the two retention systems. The annual capture effectiveness as a function of treatment volume is shown in the Figure below (using “plot” button for example problem 3) as 75% removal at a treatment depth of 0.552 inches over the catchment. The applicant wishes to increase the removal to 80%. It was decided to use 0.5 acres of 4-inch-thick pervious concrete parking with 8 inches of #57 rock and 2 inches of pea rock in the reservoir. The pervious pavement with reservoir by itself (stand-alone) produces a treatment volume of 0.151 inches over the catchment and a capture volume of 33%.

The annual capture is a function of the cumulative treatment depth of 0.703 inches (or 0.552 + 0.151) with a capture volume of 80%. It is not the sum of the capture volumes from each BMP which is 108% (75+33). Obviously, you cannot capture more than 100%, nor can you capture the same water volume twice. The same result of 80% removal is calculated from the **Select Treatment Options Worksheet** using the “BMPs in Series” button. Do not forget to use the **configure catchment** button to “select multiple BMP” as the catchment configuration.

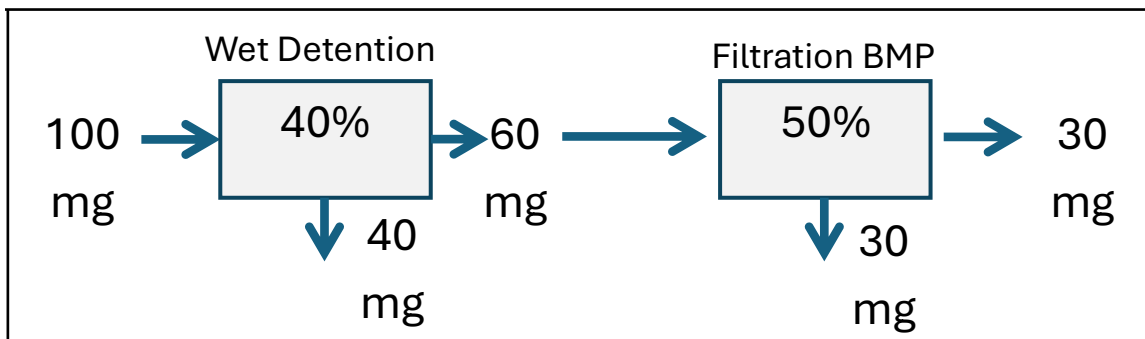


Wet detention in series: An example in series is the division of a wet pond into multiple cells sometimes called cascading ponds. Removal as a function of average annual residence time is shown in the Figure below (using “plot” button for example problem 4). If this wet detention pond were divided into two equal size ponds, the removal for one pond would be 67% TP (25 days average annual residence time). When the total pool volume is used, the removal at 50 days

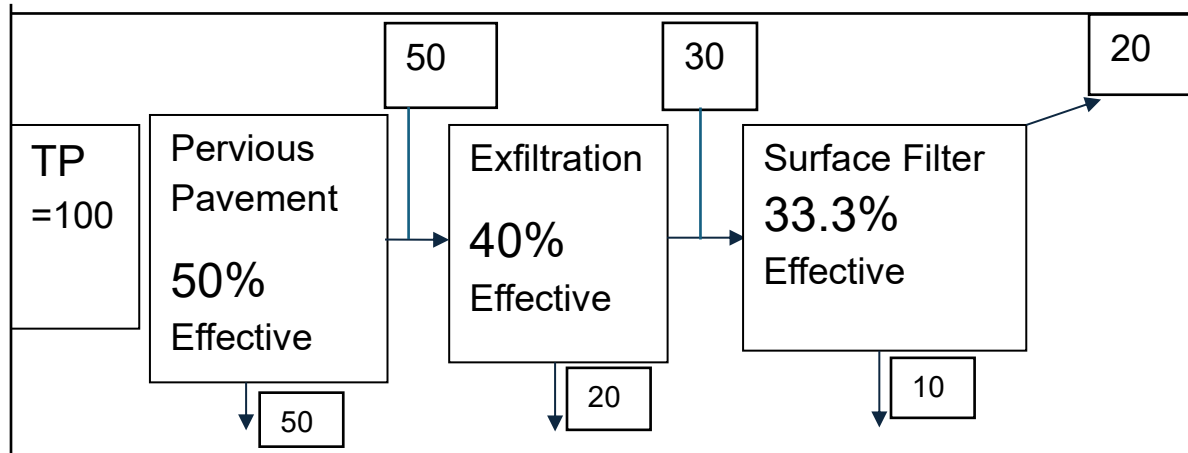
is 71%. Obviously, for two ponds of this example, the removal is not the sum of the two (67+67). The pollutant cannot be removed twice.



BMPs in Series for which the removal mechanisms are not the same or neither follows the same removal principles (example: not both retention and detention): An example is a wet pond followed by a filter in the same catchment. The wet pond removes 40% of TN and the filter removes 50% of the remaining TN. The following diagram illustrates the calculations. For this example, there is an overall 70% (40+30) removal of TN. The removal is not 90% (40+50).



Another example is pervious pavement directly connected to exfiltration and then a filter. Note there is no additional input between the BMPs and thus not a need for additional catchments.



$$\text{Removal \%} = 100 [1 - \{(1-0.5)(1-0.4)(1-.33)\}] = 100 [1-.20] = 80 \text{ and for "i"}$$

$$\text{BMPs: Overall \% Removal} = 100 [1 - \prod_i \{1 - (\text{BMP}_i/100)\}] \text{ for all "i".}$$

where: BMP_i = % removal for "i" BMP Series Efficiency Equation

