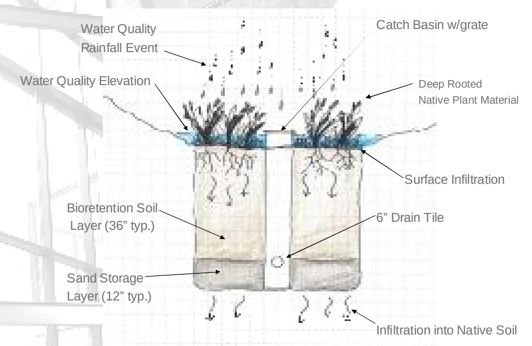
Modeling Bioretention Basins to Meet Water Quality Drawdown Requirements

Standard Bioretention Basin Detail



Ohio EPA Regulations

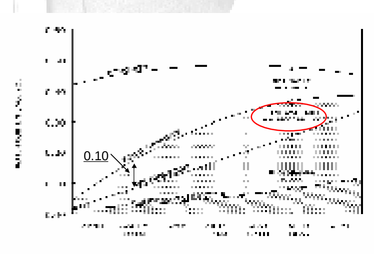
+ Bioretention Basin
  - 40 hour drawdown time
  - No more than half the volume can drain from the basin within 1/3 of the time or 13.3 hours.
+ Common interpretation is that the surface of the bioretention cell must drawdown the water quality volume in 40 hours.
  - Soil must have a very low permeability (0.25 in/hr)
  - Increased vertical storage and smaller surface area
  - Problems with plant survivability
+ Alternative analysis looks at the volume of water that the receiving stream receives in 40 hours since the main focus of the Ohio EPA water quality regulation is to reduce stream erosion.

Bioretention Soil Characteristics

+ Permeability
  - Soil Mixes
    - Kurtz Bros. Cleveland, Bio-swale #2 mix, 3.9 in/hr
    - Minnesota mix, 70% sand/30% sphagnum peat moss, 4-6 in/hr
    - NC State mix, 85% sand, 6% peat, 9% fines, 2 in/hr

Field Capacity

+ Definition
  - It is defined as the amount of water held in the soil after free drainage has ceased. The difference in water content between the field capacity and wilting point is the amount of water available for evapotranspiration.

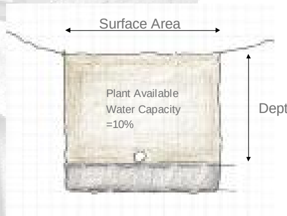


Source: http://msw.cecs.ucf.edu/AndFiles/hlp2.html

Step 1

+ Determine the volume of runoff lost to evapotranspiration
  - Assumptions
    - Water content of soil at wilting point prior to rainfall event
    - Bioretention basin properly maintained
    - Sandy Loam Soil - field capacity = 10% (see soil moisture retention chart)
  - Calculate the volume of soil from the surface to the invert of drain tile and multiply by 10% to determine potential loss of water volume to evapotranspiration
    - Assumes plant material can develop sufficient root depth to invert of drain tile.

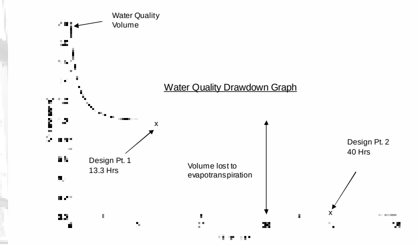
Evapotranspiration Loss Detail



Potential Evapotranspiration
= Surface area * depth * plant available water capacity

Check #1

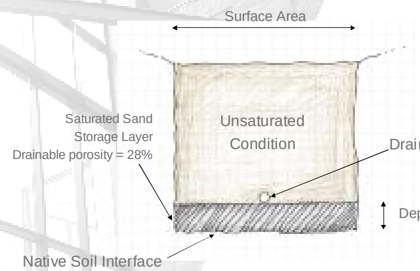
+ If water lost to evapotranspiration is greater than 50% of the water quality volume, then the drawdown curve meets the two design points, 50% in no more than 13.3 hours and 100% in 40 hours.



Step 2

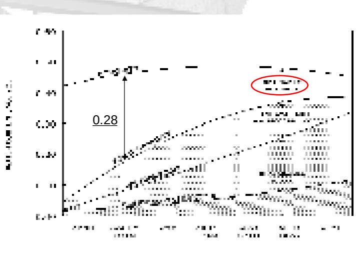
+ Calculate Groundwater Recharge Volume
  - If water lost to evapotranspiration is less than 50% of the water quality volume, EPA water quality criteria has not been met, therefore determine volume lost to groundwater recharge.
    - Saturated storage layer below drain tile is where the groundwater recharge volume is stored
    - The volume of recharge would be the drainable porosity of the storage layer. For sand the drainable porosity is approximately 28% of the volume (see chart)
    - Assumptions
      - Drainable porosity of soil above invert of drain tile has passed through drain and discharged to receiving stream
      - Permeability of native soil is sufficient enough for the drainable porosity of the storage layer to drain before next rainfall event
      - Root depth of plant materials may extend into storage zone enhancing the concept of the drainable porosity being removed before the next rainfall event

Groundwater Recharge Detail



Potential Recharge = Surface area * depth * drainable porosity

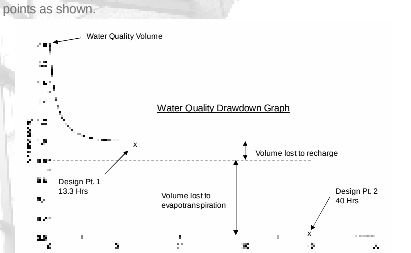
Soil Moisture Retention Parameters



Source: http://msw.cecs.ucf.edu/AndFiles/hlp2.html

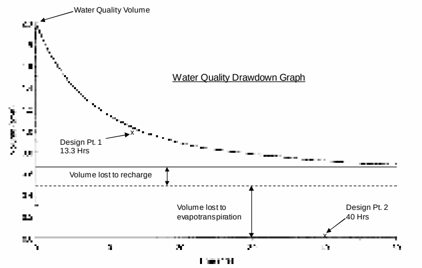
Check #2

+ If volume of runoff lost to evapotranspiration and groundwater recharge is greater than 50% of the water quality volume, the resulting drawdown curve meets the two design points as shown.



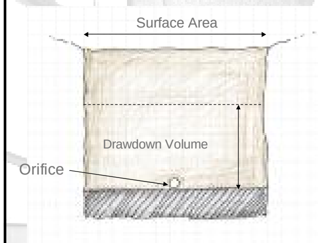
Step 3

+ If volume of runoff lost to evapotranspiration and groundwater recharge is still less than 50% of the water quality volume
  - Provide a water quality drawdown graph of the remaining water quality volume, similar to the procedure for a wet basin.



Drawdown Detail

Remaining Water Quality Volume = Total water quality volume
- field capacity
- groundwater recharge



Drawdown volume is equal to remaining water quality volume times the drainable porosity of the bioretention soil mix with the drain tile modeled as an orifice to model the drawdown time

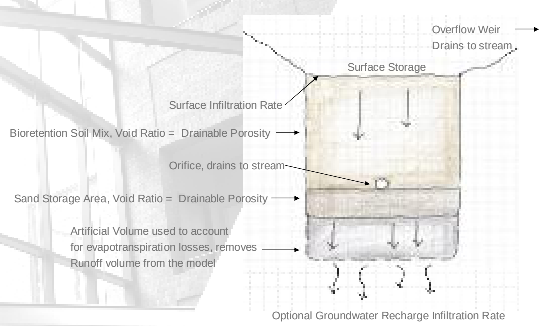
Example Problem

+ 2 acre medium density residential area (38% impervious) tributary to a bioretention basin
  - Surface Area of Bioretention Cell
    - Assume 5% of impervious area or 1655 square feet
  - Depth of Bioretention Soil
    - Assume 3' with a 1' sand storage layer, w/drain tile @ 3'
  - Water Quality Volume
    - 1481 ft^3 using ASCE equation
  - Field Capacity Losses
    - (3' x 1655 ft^2 x 0.10) = 497 ft^3
  - Infiltration Losses
    - (1' x 1655 ft^2 x 0.28) = 463 ft^3
  - Total Losses = 960 ft^3 > 50% of 1481 ft^3
    - Water Quality Criteria Met, Drawdown Graph not required

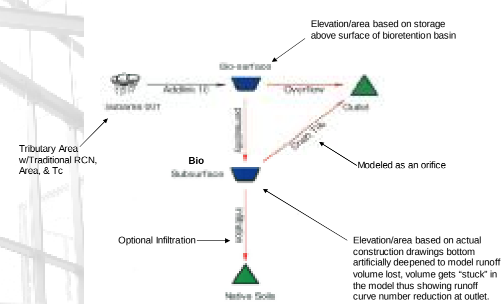
Modeling Larger Single-event Storms

+ Volume of runoff lost with water quality calculation can be used to reduce post-developed runoff volume
  - Reduces critical storm
  - Reduces size of detention basins
  - Decreases peak flow rates

Larger Single-event Rainfall Model Schematic



Larger Single-event Rainfall Model



Modeling a Water Quality Rainfall Event

EMHT

+ Develop a Water Quality Event Hydrograph
  - Use a TR-20 type model
    - PondPack, HydroCad, Intellisolve, TR-20 for DOS, etc.
  - Rainfall Event
    - 2-hr duration, 0.75" rainfall event per Ohio EPA
  - Use a Huff or Bulletin 71 Rainfall Distribution
    - 0-10 square mile drainage area
    - 50% probability curve
    - 1st Quartile, 2-hr storm
  - Calculate Water Quality Runoff Coefficient
    - Use ASCE Equation
      - $C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$
      - i = percent impervious
      - Assume surface of bioretention cell is impervious
  - Calculate Water Quality Volume
    - WQv = CPA/12 (ac-ft)
    - P = 0.75"
    - A= Area in Acres

Step 1

EMHT

+ Develop a Water Quality Event Hydrograph (continued)
  - Calculate Equivalent Runoff Curve Number
    - Using standard composite RCN numbers for the tributary area produces a very small runoff volume due to the initial abstraction taking away a significant portion of the runoff during a 0.75" rainfall event, 0.41" for a RCN of 83.
    - Artificially calibrate the RCN to produce a runoff volume equal to the water quality volume. A common value for residential area may be a RCN of 92-95.
    - Only to be used for water quality event simulations
  - Time of Concentration
    - TR-55 method or storm sewer calculations
  - Watershed Area
    - From site tributary area map

Step 2

EMHT

+ Determine Peak Water Quality Event Elevation
  - Route water quality event hydrograph calculated in Step 1 to surface of bioretention basin
  - Use the peak flow rate into the soil as the primary outlet determined in Step 2
  - Water quality elevation
    - Add 20% to peak water surface elevation to account for sediment storage

Water Quality Event Detail

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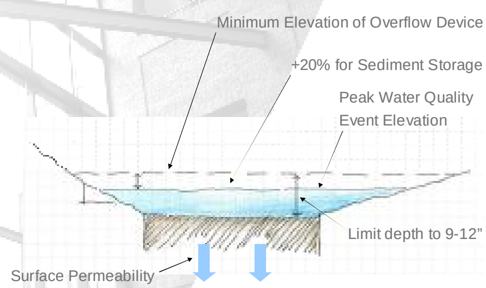

Future Considerations

EMHT

+ Better field capacity/volume reduction information
+ Attenuation of flow using TR-20 type models
+ Continuous simulation models
  - Show a significant reduction in impervious runoff on a yearly basis
  - Used to model mitigation of groundwater recharge in the Darby watershed, Central Ohio
    - Ohio EPA approved the RECARGA model from the University of Wisconsin as a bioretention groundwater recharge mitigation tool in the Darby watershed

Questions?

EMHT

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