Modeling Bioretention Basins to Meet Water Quality Drawdown Requirements

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)
  - 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.

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

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 saturated 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 zone to drain before next rainfall event.
    - Root depth of plant materials may extend into storage zone enhancing the drainable porosity of the storage zone being removed before the next rainfall event.

Groundwater Recharge Detail

Potential Recharge = Surface area * depth * drainable porosity

Soil Moisture Retention Parameters

- For 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.

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

Water Quality Drawdown Graph

Volume lost to recharge

Design Pt. 1
40 Hrs

Volume lost to evapotranspiration

Design Pt. 2
13.3 Hrs

Water Quality Volume

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
- Assume 5% of impervious area or 1655 square feet
- Depth of Bioretention Soil
- Assume 3' with a 1' sand storage layer, with drain tile @ 3'
- Water Quality Volume
  - 1481 ft³ using ASCE equation
- Field Capacity Losses
  - (3' x 1655 ft² x 0.10) = 497 ft³
- Infiltration Losses
  - (1' x 1655 ft² x 0.28) = 463 ft³
- Total Losses = 960 ft³ > 50% of 1481 ft³
- 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
- Reduce critical storm
- Reduce size of detention basins
- Decreases peak flow rates

Larger Single-event Rainfall Model Schematic

Surface Infiltration Rate
- Orifice, drains to stream

Optional Groundwater Recharge Infiltration Rate
- Optional infiltration modeled as an orifice

Hypothetical area with ponded runoff
- Tributary area with traditional RCN, Area, & Tc
- Optional infiltration
- Bioretention soil mix, void ratio = drainable porosity
- Surface storage, void ratio = drainable porosity
- Sand storage area, void ratio = drainable porosity
- Surface storage
- Drainage basin to stream
- Optional groundwater recharge infiltration rate
- Optional infiltration modeled as an orifice

Elevations based on storage above surface of bioretention basin
- Elevation/area based on actual construction drawings
- Tributary area with ponded runoff artificially deepened to model runoff volume loss, volume gets "stuck" in the model thus showing runoff curve number reduction at outlet.
Modeling a Water Quality Rainfall Event

Step 1

- 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. 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

- 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

Future Considerations

- 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 watersheds

Questions?

Contact Information
Doug Turney, P.E.
Evans, Mechwart, Hambleton, & Tilton Inc.
5500 New Albany Road
Columbus, Ohio 43054
614-775-4213
dturney@emht.com