Stormwater Infiltration Basin Design

Design Considerations and Example Projects

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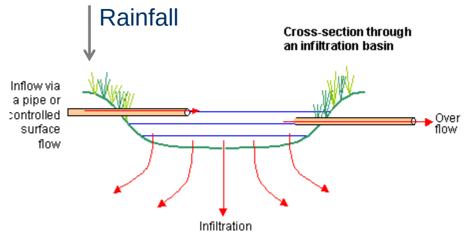
Overview of Webinar

- Background Information
- Regulatory requirements
  - Legal outlining
  - Guidance
- Advantages and Disadvantages
- Design Considerations
- Design volume determination
- Basin location and site constraints
  - Examples
- Maintenance Requirements

http://www.elibrary.dep.state.pa.us/dsweb/Get/Rendition-760907/index.htm

Definition and Purpose

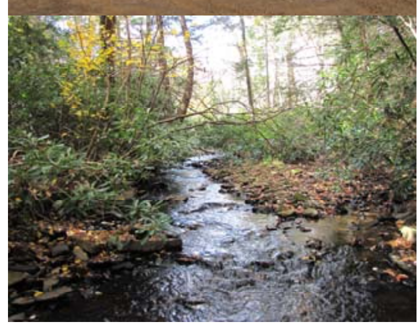
- Open -shallow basin
- Temporarily store design runoff volume
- Treatment via exfiltration through bottom (and sides)
- Variations of design include]
  - Infiltration trenches
  - Underground infiltration systems
  - Dry wells
- Pollutant removal via physical, chemical and biological processes
- Peak flows are reduced
- Highly efficient treatment
- Typically aggressively vegetated bottom



http://www.ciria.com/suds/infiltration_devices.htm

Advantages

- Very effective pollutant removal
- Mimics natural hydrology
  - Increase in groundwater recharge
  - Promotes base flow in streams
- Net runoff volume is lower
- Reduced peak flows
- Helps to manage thermal impacts from runoff
- Good BMP in urban settings
- Stand alone or treatment chain
- Can be aesthetic
- No standing water if working properly



Disadvantages

- DA limitations in many states
- Best use on more permeable soils
- Clearance from confining layers required
- Very high permeability and high pollutant loads – groundwater contamination without pre-treating
- Not for industrial pollutants, pesticides petroleum, etc.
- High sediment loads may limit their use – clogging of pore space
- Relatively high failure rates compared to other BMPs

Regulatory Requirements

- Regulations vary by state and municipality
  - Soil requirements/ LSS
  - Site inspection check list
  - Permeability specs
- Legal outlining to break out defining parameters
- Suggests scoping meetings with agency
- Projects presented here are in NC
  - Requirements even different now

Best Management Practices Manual | PC-28 Infiltration Basin

PC-28 INFILTRATION BASIN

Reference: Maryland Stormwater Design Manual.

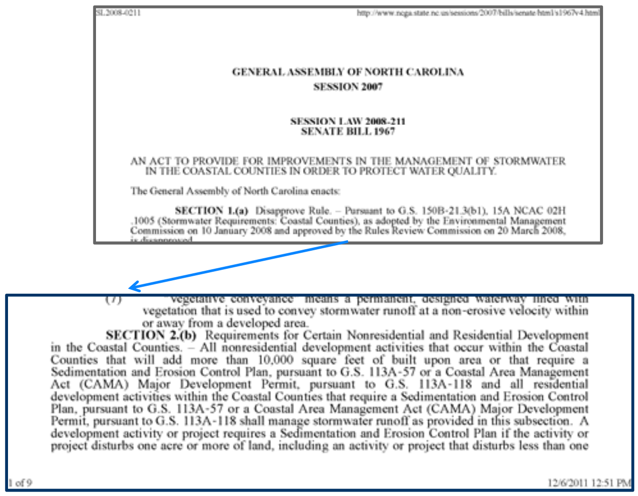
BMP Objectives

- ☐ Perimeter Control
- ☐ Slope Protection
- ☐ Borrow and Stockpiles
- ☒ Drainage Areas
- ☒ Sediment Trapping
- ☐ Stream Protection
- ☒ Temporary Stabilizing
- ☒ Permanent Stabilizing

http://itd.idaho.gov/enviro/storm%20water/BMP/PDF%20Files%20for%20BMP/Chapter%205/PC-28%20%20Infiltration%20Basin.pdf

Legal Outlining - Example

- Statutory Code
- Administrative Code
- Agency interpretation
  - **Manuals interpret for you but check the law itself**
  - **Some Codes specifically call out the BMP manual**
- Broad to Narrow


SL2008-0211 http://www.ncga.state.nc.us/sessions/2007/bills/senate/html/s1967v4.html

GENERAL ASSEMBLY OF NORTH CAROLINA
SESSION 2007

SESSION LAW 2008-211
SENATE BILL 1967

AN ACT TO PROVIDE FOR IMPROVEMENTS IN THE MANAGEMENT OF STORMWATER IN THE COASTAL COUNTIES IN ORDER TO PROTECT WATER QUALITY.

The General Assembly of North Carolina enacts:

SECTION 1.(a) Disapprove Rule. – Pursuant to G.S. 150B-21.3(b1), 15A NCAC 02H .1005 (Stormwater Requirements: Coastal Counties), as adopted by the Environmental Management Commission on 10 January 2008 and approved by the Rules Review Commission on 20 March 2008, is disapproved.

(7) "Vegetative conveyance" means a permanent, designed waterway lined with vegetation that is used to convey stormwater runoff at a non-erosive velocity within or away from a developed area.

SECTION 2.(b) Requirements for Certain Nonresidential and Residential Development in the Coastal Counties. – All nonresidential development activities that occur within the Coastal Counties that will add more than 10,000 square feet of built upon area or that require a Sedimentation and Erosion Control Plan, pursuant to G.S. 113A-57 or a Coastal Area Management Act (CAMA) Major Development Permit, pursuant to G.S. 113A-118 and all residential development activities within the Coastal Counties that require a Sedimentation and Erosion Control Plan, pursuant to G.S. 113A-57 or a Coastal Area Management Act (CAMA) Major Development Permit, pursuant to G.S. 113A-118 shall manage stormwater runoff as provided in this subsection. A development activity or project requires a Sedimentation and Erosion Control Plan if the activity or project disturbs one acre or more of land, including an activity or project that disturbs less than one

1 of 9 12/6/2011 12:51 PM

http://www.ncga.state.nc.us/sessions/2007/bills/senate/html/s1967v4.html

Design Considerations – Examples From Various States

State	Max DA	Infiltration - Ksat	Soil Parameters	Clearence	Drawdown	Other Comments
Michigan	<50 ac	0.52	clay max 30%	4' SHWT or Bedrock	48 hrs	Pre-treatment and in a chain
Idaho	< 5 ac	Unspecified	HSG A or B	4'	48 hrs	Dewatering system normally reqd Referenced Maryland manual
Minnesota	5 - 50 ac	0.2 in/hr		3' SHWT or Confining	72 hrs	r **Must have cold climate suitability**
Riverside Co, CA	50 ac	0.5 in/hr	Not on C and D HSG	5' SHWT or Confining	48 hrs	Underdrain required
New Jersey	NA	0.5 in.hr	HSG A and B only		72 hrs	Different regs for GW recharge, SS and Surface, vs. WQ needs **Field or lab soil test required** **Setbacks for basement seepage and flooding considered** 6" sand layer must be placed on bottom

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html

Design Considerations – Cold Climates

- Frost Line may render infiltration basins not feasable
- Some proprietary sub-grade systems will work when others do not (MN BMP Manual)
- Chloride problems →High salt runoff
- Spring snowmelt → high runoff volume
- Problems with freeze
  - Ice forming on top of & within the system
  - MN suggest keeping basin dry prior to freeze in fall

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html

Design Considerations - Overview

- Design Storm
  - SA - Coastal NC – 1.5” P
- Siting is critical due to:
  - Limitation of soils
  - **Clearance from SHWT**
  - Building foundations, creation of seeps, potential slope failures
- Maximum drainage area
  - NC – 2.0 Ac In Volume
- Targeted sediment and pollutant efficiency
- Longitudinal and cross slope

NCDENR Stormwater BMP Manual Chapter Revised: 07-23-09

16. Infiltration Devices

Description
Infiltration devices are trenches or basins that fill with stormwater runoff and allow the water to exfiltrate, i.e., exit the device by infiltrating into the soil.

Regulatory Credits		Feasibility Considerations	
Pollutant Removal			
85%	Total Suspended Solids	High	Land Requirement
30%	Total Nitrogen	Med-High	Cost of Construction
35%	Total Phosphorus	Med	Maintenance Burden
Water Quantity		Small-Med	Treatable Basin Size
possible	Peak Runoff Attenuation	High	Possible Site Constraints
yes	Runoff Volume Reduction	Med-High	Community Acceptance

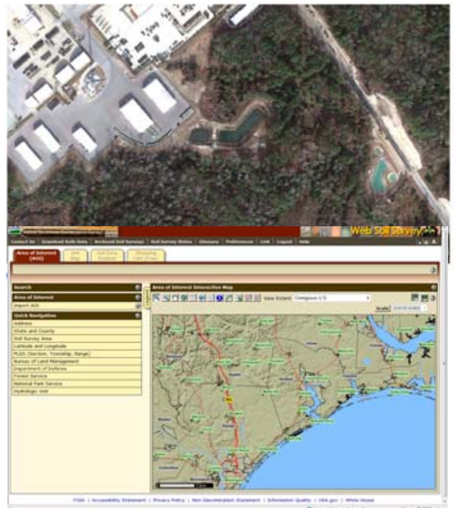
Major Design Elements

	Required by the NC Administrative Rules of the Environmental Management Commission. Other specifications may be necessary to meet the stated pollutant removal requirements.
1	Sizing shall take into account all runoff at ultimate build-out including off-site drainage.
2	Side slopes stabilized with vegetation shall be no steeper than 3:1.
3	BMP shall be located in a recorded drainage easement with a recorded access easement to a public ROW.
4	If the BMP is used for sedimentation and erosion control during construction, it must be cleaned out and returned to the design state.
5	The design shall be located a minimum of 30 feet from surface waters, and 50 feet from Class SA waters.
6	The design shall be located a minimum of 100 feet from water supply wells.
7	The bottom shall be a minimum of 2 feet above the seasonal high water table.
8	Volume in excess of the treatment volume, as determined from the design storm, shall bypass the device. (also see 16.3.9)
9	Volume in excess of the treatment volume, as determined from the design storm, shall be evenly distributed across a minimum 30 feet long vegetated filter strip. (A 50-ft filter is required in some locations.) (also see 16.3.9)
10	The storage volume must completely draw down to the seasonally high water table under seasonally high water conditions within 5 days.
11	Soils must have a minimum infiltration rate of 0.52 inches per hour to be suitable for infiltration.
12	Device must not be sited on fill material. (also see 16.3.2)
13	Trenches must be shallower than their largest surface dimension to prevent categorization as an "injection well."

Infiltration Devices 16-1 July 2007

Site Inspection - Desktop

- Aerial photos
  - Provide a wealth of information on veg ty
- Topographic Map
  - Best locations for basin often on the brea grade
  - Stay away from artificial/ altered areas
- **Soil Maps**
  - **NRCS Web Soil Survey**
  - Soils Maps (if you have them)
  - Saturated soils tell you NO from the desk
  - Utility interactioins
  - As-builts
- Other sources
  - Utility interactioins
  - As-builts



Appropriate Soils

- Soils should be well drained
- No underlying confinement layers
- Sandy soils in coastal zones are ideal – avoid clay
- Minimum 0.52"/ hr value (more on Ksat later)
- Any foreign smell in soils must be investigated before siting basin
- Extremely high permeability avoided depending on source of runoff

http://slowwatermovement.blogspot.com/2010/09/urban-seep-soil-science.html

ASCE | KNOWLEDGE & LEARNING — Hydraulic Conductivity

- Darcy's Law - Ksat values
  - NC – Min. 0.52"/hr rate
- Constant head permeability test
- NC – LSS required and Soils Report
- Double ring infiltrometer test
- We use lowest value to be conservative

Water Reading	change in water level	Chamber C.F.	clock time (min)	Elapsed Time (min)	(hr)	Q (cm3/hr)	K (cm/hr)	K (in/hr)	K gal/ft2/day
21.8	0.0	105.0	0.0						
21.2	0.6	105.0	1.0	1.00	0.017	3780.0	5.4284	2.1372	31.975
20.7	0.5	105.0	2.0	1.00	0.017	3150.0	4.5236	1.7810	26.646
20.3	0.4	105.0	3.0	1.00	0.017	2520.0	3.6189	1.4248	21.317
20.1	0.2	105.0	4.0	1.00	0.017	1260.0	1.8095	0.7124	10.658
19.7	0.4	105.0	5.0	1.00	0.017	2520.0	3.6189	1.4248	21.317
19.4	0.3	105.0	6.0	1.00	0.017	1890.0	2.7142	1.0686	15.988
19.1	0.3	105.0	7.0	1.00	0.017	1890.0	2.7142	1.0686	15.988
18.8	0.3	105.0	8.0	1.00	0.017	1890.0	2.7142	1.0686	15.988
						Final Ksat	2.714	1.069	15.988

Water Reading	change in water level	Chamber C.F.	clock time (min)	Elapsed Time (min)	(hr)	Q (cm3/hr)	K (cm/hr)	K (in/hr)	K gal/ft2/day
30.5	0.0	105.0	0.5						
30.3	0.2	105.0	1.5	1.00	0.017	1260.0	1.7123	0.6741	10.086
30.1	0.2	105.0	2.5	1.00	0.017	1260.0	1.7123	0.6741	10.086
29.9	0.2	105.0	3.5	1.00	0.017	1260.0	1.7123	0.6741	10.086
29.8	0.1	105.0	4.5	1.00	0.017	630.0	0.8562	0.3371	5.043
29.6	0.2	105.0	5.5	1.00	0.017	1260.0	1.7123	0.6741	10.086
29.5	0.1	105.0	6.5	1.00	0.017	630.0	0.8562	0.3371	5.043
29.4	0.1	105.0	7.5	1.00	0.017	630.0	0.8562	0.3371	5.043
29.3	0.1	105.0	8.5	1.00	0.017	630.0	0.8562	0.3371	5.043
						Final Ksat	0.856	0.337	5.043

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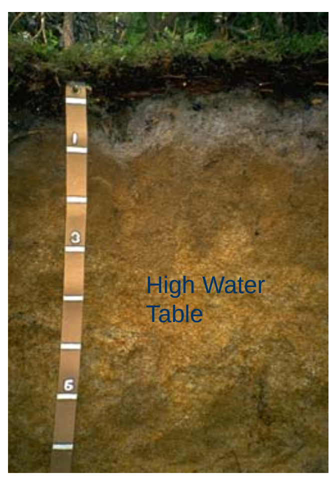
- **It governs site elevations in lowlands!!**
- Often have to use location where planners anticipate a structure or parkign
- NC – Min 2' Clearence
- Pays to perform preliminary inspection
  - **Investigate all feasible locales**
- Be familiar with mottling and hydric indicators
- Up to 1' can be fill on sites where you have no option



http://soils.cals.uidaho.edu/SoilORDERS/spodosols_07.htm

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Proximity to Wetlands

- Check the regulatory guidance in your State/municipality
- Generally challenging to locate near wetlands
  - Wetland soils not normally high enough permeability
  - Lack clearance of SHWT

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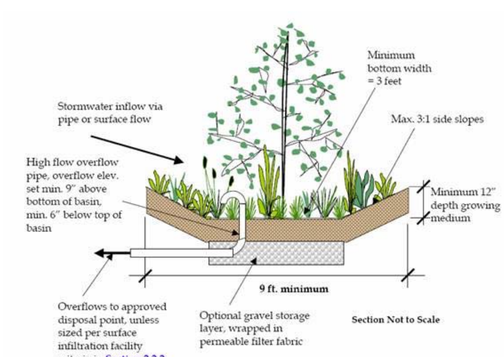
Basin Sizing

- Treatment volume or Capture volume
  - State and local BMP manuals require various methods
  - Typically size for entire volume
- Drawdown considerations
  - Varies by state and local regs
  - Use minimum Ksat or half value
  - Some regs require drawdown device for maintenance
- Max 2.0 ac-in per basin for our projects in (NC)



http://www.cityofsandy.com

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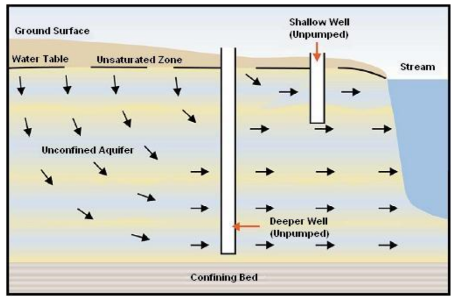
Other limiting factors

- Proximity to Buildings –
  - foundation stability
  - Saturation of basements (not a problems in lowlands)
- Karst/limestone geology
- Challenges in cold climates



http://www.omafra.gov.on.ca/english/environment/facts/06-113.htm

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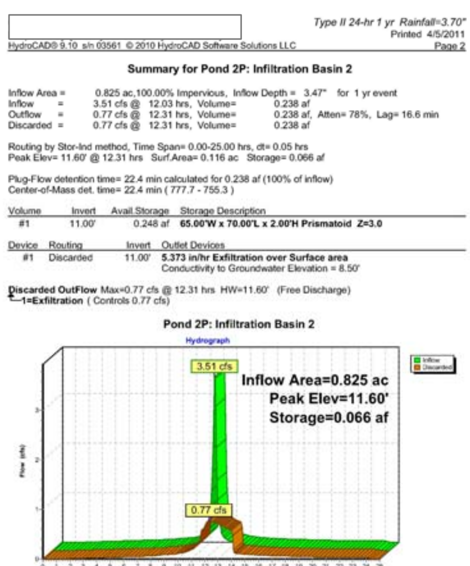
Modeling

- Though not always required, we validate with models
- Hydrocad is a simple, good tool for this purpose
- Provides check of:
  - Drawdown time
  - Attenuation of peak flow
  - Max ponding depth



Type II 24-hr 1 yr Rainfall=3.70"
Printed 4/5/2011
HydroCAD® 9.10 s/n 03561 © 2010 HydroCAD Software Solutions LLC Page 2

Summary for Pond 2P: Infiltration Basin 2

Inflow Area = 0.825 ac,100.00% Impervious, Inflow Depth = 3.47" for 1 yr event
Inflow = 3.51 cfs @ 12.03 hrs, Volume= 0.238 af
Outflow = 0.77 cfs @ 12.31 hrs, Volume= 0.238 af, Atten= 78%, Lag= 16.6 min
Discarded = 0.77 cfs @ 12.31 hrs, Volume= 0.238 af

Routing by Stor-Ind method, Time Span= 0.00-25.00 hrs, dt= 0.05 hrs
Peak Elev= 11.60' @ 12.31 hrs Surf.Area= 0.116 ac Storage= 0.066 af

Plug-Flow detention time= 22.4 min calculated for 0.238 af (100% of inflow)
Center-of-Mass det. time= 22.4 min (777.7 - 755.3)

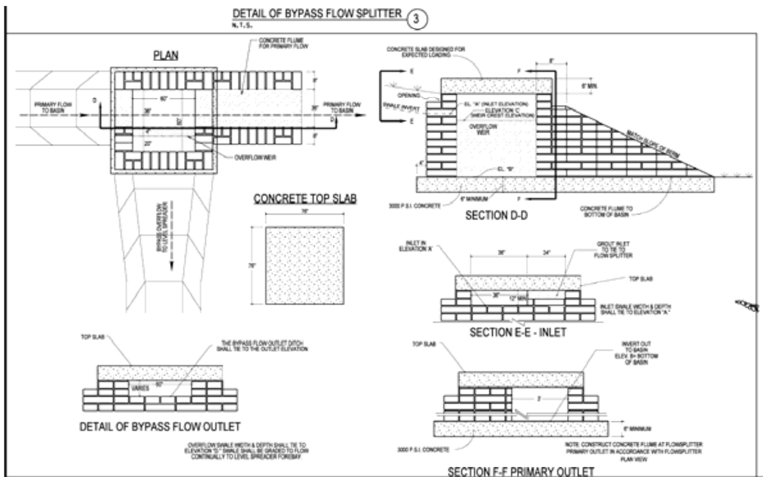
Volume	Invert	Avail.Storage	Storage Description
#1	11.00'	0.248 af	**65.00'W x 70.00'L x 2.00'H Prismatoid Z=3.0**

Device	Routing	Invert	Outlet Devices
#1	Discarded	11.00'	**5.373 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 8.50'

Discarded OutFlow Max=0.77 cfs @ 12.31 hrs HW=11.60' (Free Discharge)
└1=**Exfiltration** (Controls 0.77 cfs)

Pond 2P: Infiltration Basin 2

Bypass Large Events



- Bypasses may be inline or offline
- 10 yr ? Depends on the agency
- If open channel conveyances
  - Use max pond depth

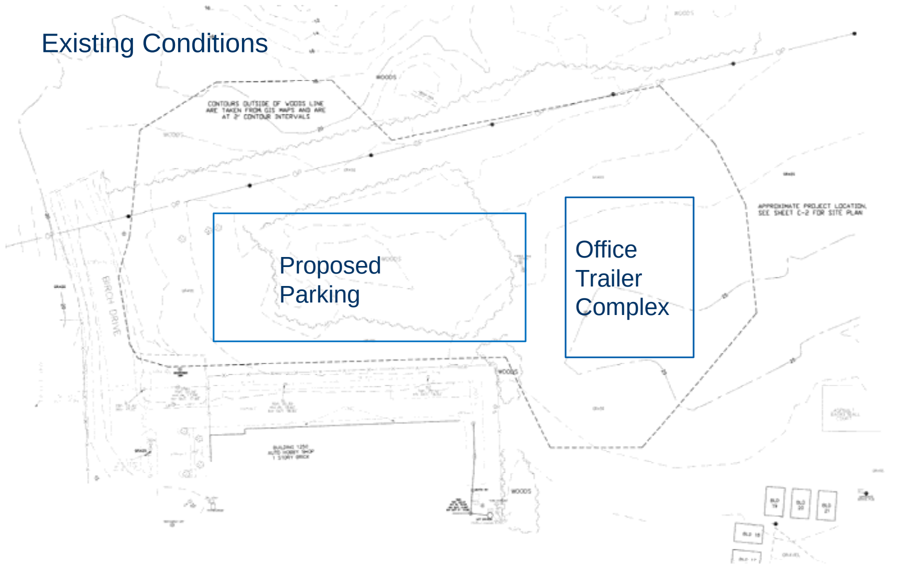
- Piped runoff is easier to "split"
  Many examples available

Permit Applications

- Use a **CHECK LIST**
  - **Even better – use agency check list!**
- Legible and logical
- Concise
- Scoping meeting head off confusion
- Tell a clear "story"
- Extra dims save review effort
- Notate primary change or increase
- Constraints identified
- Quality maps, calcs and images

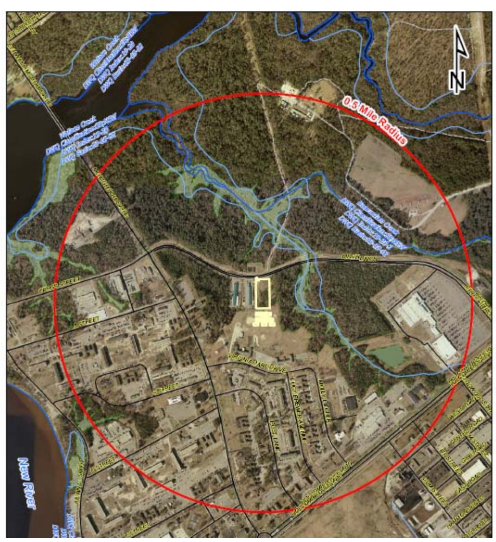
Examples of Constraints - Project A

Existing Conditions



Examples of Constraints - Project A

Class of receiving water and wetland proximity

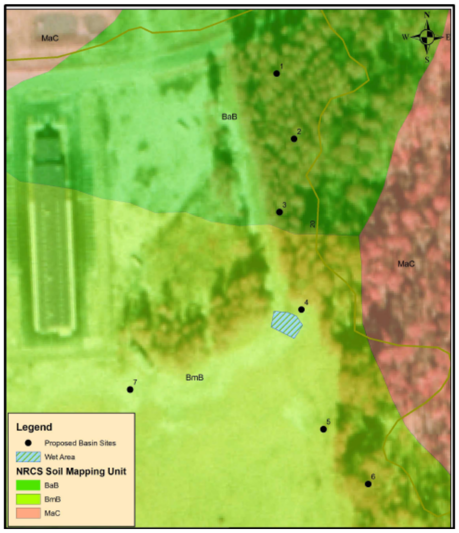


Examples of Constraints - Project A

Soils Map

Examples of Constraints - Project A

LSS Investigation



Examples of Constraints - Project A

- Soils Report - Findings

  Locations 4, 5 7 are out

- Basin 1,2,3 and 6 are appropriate sites

Depth to Seasonal High Water Table

During the field investigation, the depth to the seasonal high water table (SHWT) was determined through the use of field indicators for redoximorphic features or the presence of saturated soil. Table 3 presents the soil borings and the determination of the SHWT.

Table 3 Boring and Depth to SHWT

Boring #	SHWT Determination (inches below Surface)
Basin 1	46
Basin 2	>48
Basin 3	>48
Basin 4	30
Basin 5	24 (Perched)
Basin 6	>48
Basin 7	26

Basin 4, 5 and 7 have clayey soil occurring at or near the surface and this clay affects the depth of the SHWT. While Basin 4 didn't show any indicators of wetness until 30 inches there was an area close to Basin 4 (See Figure 1) that at the time of the investigation was rutted, had cattails growing and standing water. A boring at the center of this wet area indicated a massive clay layer at the surface and a perched water table at 10 inches. Likewise, Basin 5 had a massive clay layer extending down to 24 inches with a

Soils Testing - A

- Ksat

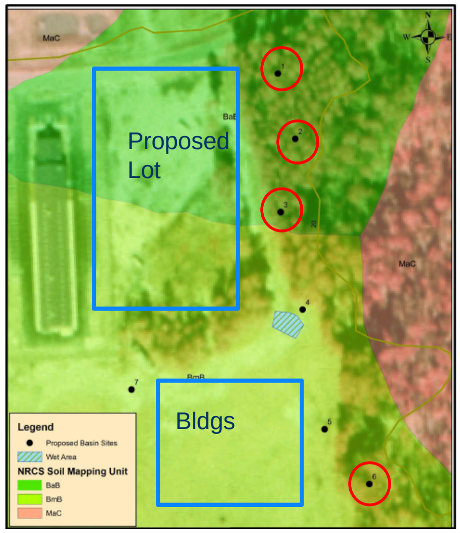
Multiple saturated hydraulic conductivity tests were performed at each proposed infiltration basin. The results for each test are shown below in Table 4. Data sheets for each hydraulic conductivity tests are also attached. At each basin location, the geometric mean was taken and is presented in Table 4. The geometric mean was calculated instead of the arithmetic mean, as it tends to dampen the effect of very high or low values, which might bias the arithmetic mean if a straight average was calculated.

Table 4 Results of Saturated Hydraulic Conductivity Tests and Geometric Mean

Test Location	Test Number	Test Depth (inches)	Measured K_{SAT} (in/hr)	Geometric Mean (in/hr)
Basin 1	1	12.2	1.92	2.43
	2	13.0	4.04	
	3	11.8	1.85	
Basin 2	1	13.8	1.06	1.21
	2	13.4	1.63	
	3	14.2	1.04	
Basin 3	1	11.4	1.92	2.88
	2	12.6	4.68	
	3	12.2	3.26	
Basin 4	1	12.6	1.59	0.24
	2	12.6	0.12	
	3	13.4	0.07	
Basin 5	1	25.6	0.22	0.15
	2	24.8	0.11	
Basin 6	1	17.3	1.31	1.18
	2	14.2	1.07	
Basin 7	1	11.8	1.07	0.60
	2	12.6	0.34	

Examples of Constraints - Project A

- Summary of Constraints at A
- Elevation is not a problem
- Only sites on the N end will work
- Wetlands not a problem
- Temporary trailer sites will have a long conveyance



Basin Sizing - A

- Requirements

Infiltration Basin A

Drainge Area (Sf)	146362
Imp Area (sf)	51836
(A) Drainage Area (Ac)	3.36
(I_A) Imp Fraction	0.35
(R_D)Rainfall Depth Per State SWP(in)	1

Basin A

Designed By: BMD
Date:

Step 1: Determine Runoff Volume
Simple Method

a. $Rv = .05 + .9(I_A)$ = Rv (post) = .05+.9*.67 = 0.37
Rv (pre) = .05+.9*0 = 0.05

b. $V = 3630 \times R_D \times R_V \times A$

Post V=3630 *1.5*0.37 *3.36 V (Post) = 4498 cf

Min. Treatment Vol (Post - Pre)= 4498 cf

Treatment Vol in Ac-in 1.24 ac-in

Step 2: Determine Surface Area- Min.

(K) Infiltration Rate (in/hr)	2.16
(T) Intended Days to Infiltrate (days)	2

a. $A = \frac{V}{2 * (K * T)}$ = A=7039/(2*(2.61*2))

Min SA of Basin = 520.6 sf

Basin Sizing - A

Example Spread Sheet Cont'd:

Basin Volume

Depth to Exist grount to SHWT (ft) 4.33 -From DWQ Soil Scientist Approved Depth

Existing Ground Elevation	20.50	Bypass Weir Elevation	20.40
Design Storage Elevation	20.40	Flow Splitter - Inlet Elevation	20.90
Bottom Elevation	18.30	Flow Splitter - Bypass Flow Outlet	19.50
Flow Splitter - Outlet to Basin Elev.	18.50	Top of Berm Elevation	21.50

Max Excavation Depth 2.33 * Must set invert to min of 0.4 above existing

Storage Depth 2.10

Surface Area Required (Avg of Top and Bottom SA) 2142

Top Width @ Storage Elev	49.6	Top Length @ Storage	79.6
Bottom Width	37	Bottom Length	67.0

Target Area	2140 sf
Actual Area Top =	3948 sf
Actual Area Bottom =	2479 sf
Avg Surface Area =	3214 sf
Volume of Basin (Depth*SA) =	6749 cf

4. Calculation of Volumetric Flow Rate of Infitration and Drawdown

Q from infiltration: *Q is actually the Darcian Flow Rate

Area (sf)	(K) in/hr	Q (infiltration) =
2479	2.16	0.12 cfs

$$Q = A \cdot (K) \cdot \text{Conversion} = cfs$$

$$\text{Example Calculation of } Q: \text{Surface Area} = 4556\,sf \qquad (K) = 3.94\,in/hr$$

$$4556\,sf \cdot \frac{3.94\,in}{hr} \cdot \frac{1\,ft}{12\,in} \cdot \frac{1\,hr}{3600\,s} = 0.42\,cfs$$

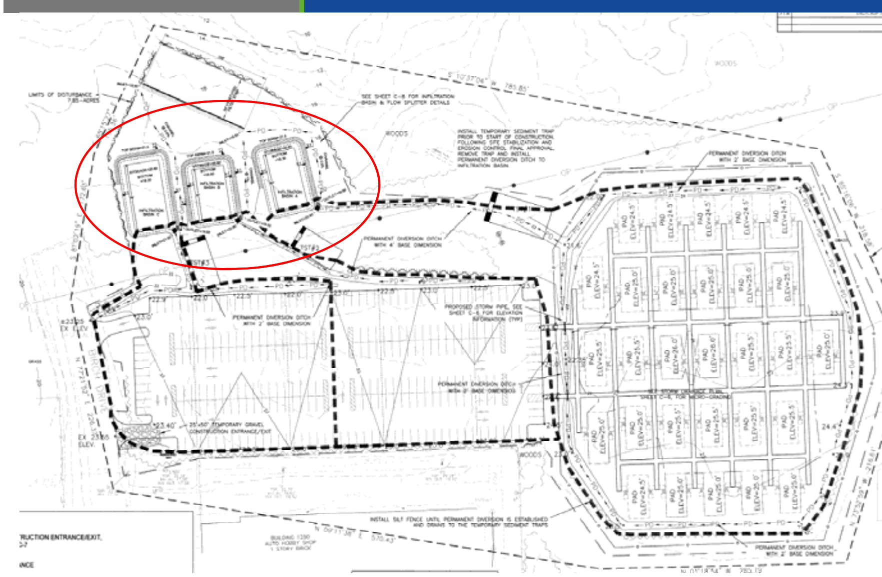
Drawdown Time for Treatment Volume

$$\text{Example Calculation}: \; Q = 0.42cfs \quad V = 3458cf$$

$$\frac{V}{Q} = T \;\therefore\; \frac{3458\,ft^3}{1} \cdot \frac{1s}{0.42\,ft^3} \cdot \frac{1hr}{3600s} = 2.1hrs = .089days$$

Volume (cf)	Q	Drawdown Time for Design Vol: Hours	Days
6749	0.12	15.1	0.63

Proposed - A



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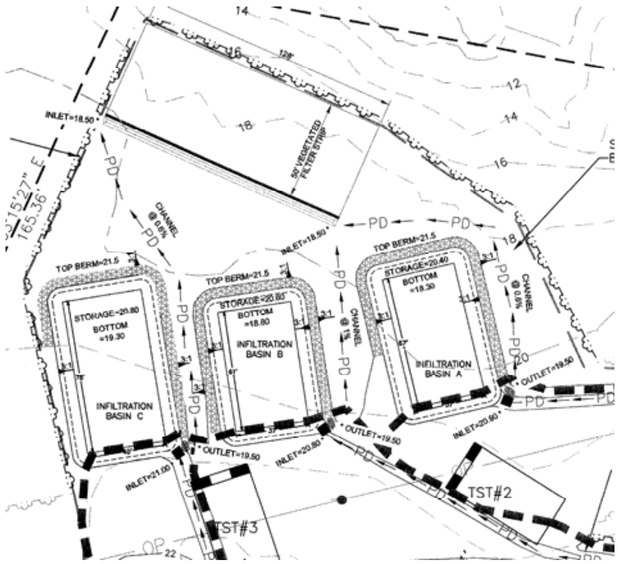
Proposed - A



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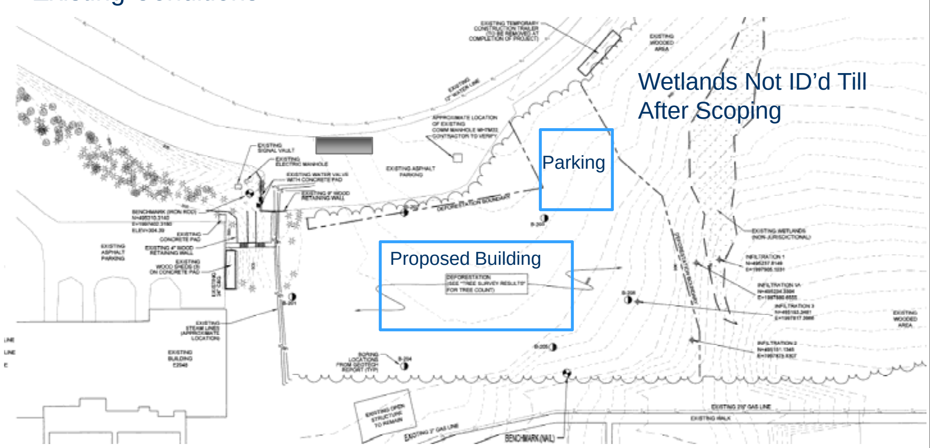
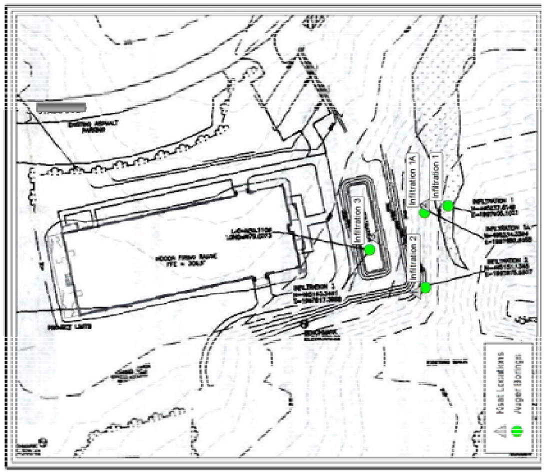
Examples of Constraints - Project B

Existing Conditions



Soil Borings Locations- Project B

- Pinched by wetlands
- Elevation is not a problem
- Slope should have high Ksat



Project B – Ksat and SHWT

Table 2 presents each boring with a soil series determination. Determination of soil series was made through a comparison of soil boring descriptions to the Natural Resources Conservation Service (NRCS) Official Series Description (OSD) for the soil series that were mapped by the NRCS for this site.

Table 2 - Soil Series Determination and Depth to SHWT

Boring #	Soil Series Determination	SHWT Determination (inches below surface)
Infiltration 1	Johnston	6
Infiltration 1A	Blaney	24
Infiltration 2	Blaney	60+
Infiltration 3	Blaney	60+

Table 3 presents the saturated hydraulic conductivity for each infiltration basin as well as a moderation factor to get an area infiltration rate for each proposed infiltration basin.

Table 3 - Results of Saturated Hydraulic Conductivity Tests

Soil Type	Test Location	Test Depth (in)	Measured K_{SAT} (in/hr)	75% of K_{SAT} (in/hr)
Blaney	1	15	11.311	8.48
Blaney	2	14	19.103	14.33
Blaney	3a	37	10.205	7.65
Blaney	3b	12	32.676	24.51

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Project B - Sizing

- Requirements

Drainge Area (Sf)	70825
Imp Area (sf)	39853
(A) Drainage Area (Ac)	**1.626**
(I_A) Imp Fraction	**0.56**
(R_D)Rainfall Depth Per State SWP(in)	**1**

Designed By: BMD
Date:

Step 1: Determine Runoff Volume
Simple Method

a. $Rv = .05 + .9(I_A)$ = Rv (post) = .05+.9*.56 = 0.56
Rv (pre) = .05+.9*0 = 0.05

b. $V = 3630 \times R_D \times R_V \times A$
Post V=3630 *1.0*0.67 *.6273 V (Post) = 3284 cf

Min. Treatment Vol =	**3284 cf**

Treatment Vol in Ac-in 0.90 ac-in

Required Volume for 2.5X to Not Bypass or Filter	**8210 cf**

Step 2: Determine Surface Area- Min.

(K) Infiltration Rate (in/hr)	12.26
(T) Intended Days to Infiltrate (days)	2

*Half the K value from the Soils Report

a. $A = \frac{V}{2 * (K * T)}$ = A=3799/(2*(5.66*2))

Min SA of Basin =	**67.0 sf**

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Project B - Proposed

- 2X Sized

Basin Volume

Depth to Exist grount to SHWT (ft)	5.00	-From soils report		
Existing Ground Elevation	302.00	Elevation at Soil Boring		
Design Storage Elevation	304.30			
Bottom Elevation	301.40		Overflow Weir Elevation	304.30
Basin Inlet Elevation	301.40		Top of Berm Elevation	305.00
Max Excavation Depth	3.00	299.00 ft. elev. using site 3		
Storage Depth	2.90			2.90
Surface Area Required (Avg of Top and Bottom SA)				2
Top Width @ Storage Elev	37.4		Top Length @ Storage Elev	113.4
Bottom Width	20		Bottom Length	96.0

Target Area	0 sf
Surface Area Storage =	**4241 sf**
Surface Area Bottom =	**1920 sf**
Avg Surface Area =	**3081 sf**
Volume of Basin (Depth*SA) =	**8934 cf**
Exceed Required Volume by	**2.72 X**

4. Calculation of Volumetric Flow Rate of Infitration and Drawdown

Q from infiltration: *Q is actually the Darcian Flow Rate

Area (sf)	(K) in/hr	**Q (infiltration) =**	**0.54 cfs**
1920	12.255		

$Q = A \cdot (K) \cdot \; Conversion = cfs$

$Example Calculation\; of\; Q: SurfaceArea = 3184\, sf \qquad (K) = 2.42\, in/hr$

$3184\, sf \cdot \frac{2.42\, in}{hr} \cdot \frac{1\, ft}{12\, in} \cdot \frac{1\, hr}{3600 s} = 0.18\, cfs$

Drawdown Time for Treatment Volume

$Example\; Calculation: \; Q = 0.18 cfs \quad V = 3184 cf$

$\frac{V}{Q} = T \; \therefore \; \frac{3184\, ft^3}{1} \cdot \frac{1s}{0.18\, ft^3} \cdot \frac{1hr}{3600s} = 2.1hrs = .049 days$

Volume (cf)	Q	Drawdown Time for Design Vol Hours	Days
8934	**0.54**	**4.6**	**0.19**

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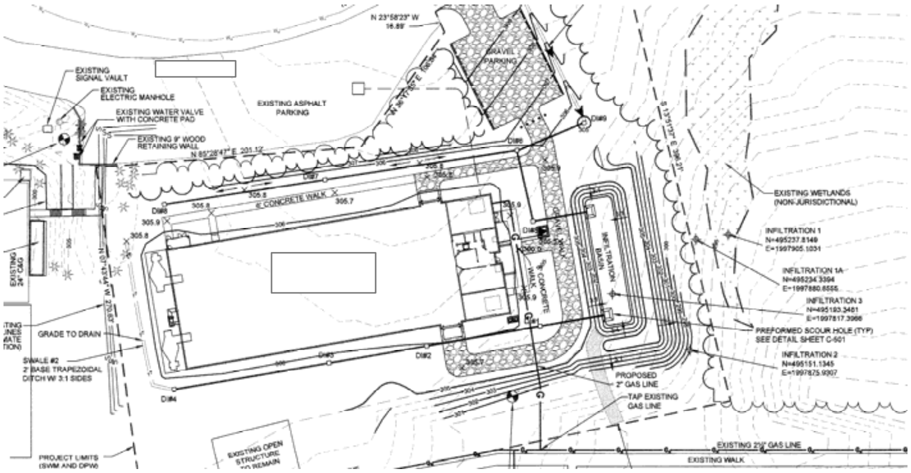

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Constructability and Maintenance

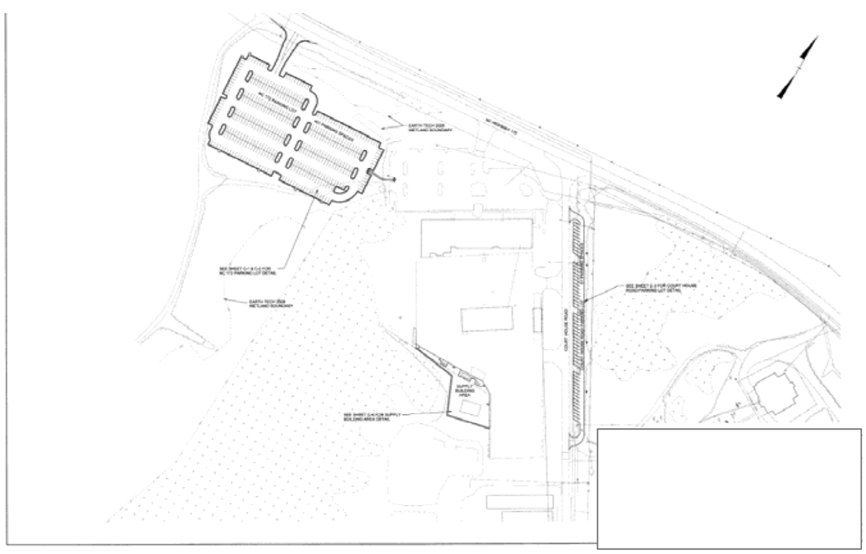
- Swales to nowhere
- **Flat slope and sandy soil**
- Inlets and outlets - **Erosion**
- Compaction due to equipment
- Poor oversight
- **Clogging**

Check maintenance requirements of your agency.

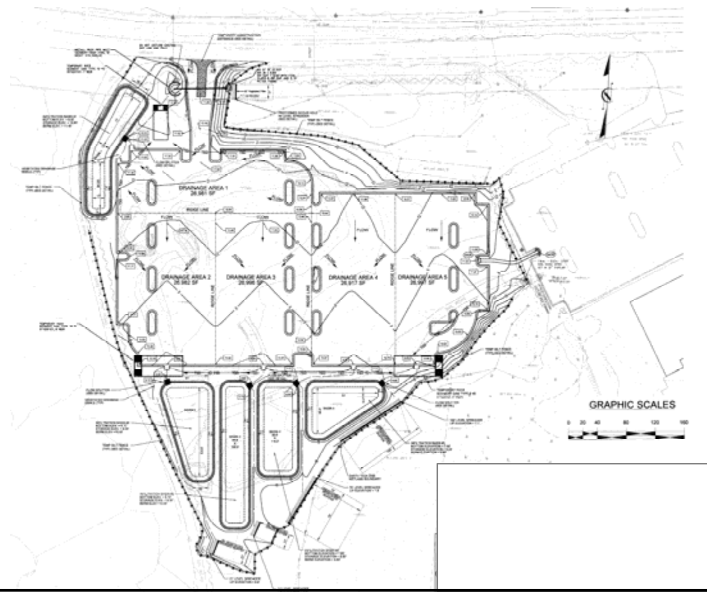
Reference Information

- Check your local and state guidance availability first
- http://www.stormwaterpa.org/assets/media/BMP_manual/chapter_6/Chapter_6-4-2.pdf
- http://dnr.wi.gov/runoff/stormwater/InfStdsTools/Technical_Note.pdf
- http://portal.ncdenr.org/web/wq/ws/su/bmp-ch16
- http://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.5.pdf
- http://itd.idaho.gov/enviro/storm%20water/BMP/PDF%20Files%20for%20BMP/Chapter%205/PC-28%20%20Infiltration%20Basin.pdf
- Groundwater mounding beneath infiltration basin: http://pubs.usgs.gov/sir/2010/5102/

Extra Materials - Examples



Extra Materials - Examples



Extra Materials - Examples

- Tough Scenario
  - Low Density but a bridge…

Extra Materials - Examples

- Capture and treat HD area within LD project
- Good stewardship