MAFSM 2007
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A Simple Water Balance for a Constructed Shallow Wetland Storm Water BMP

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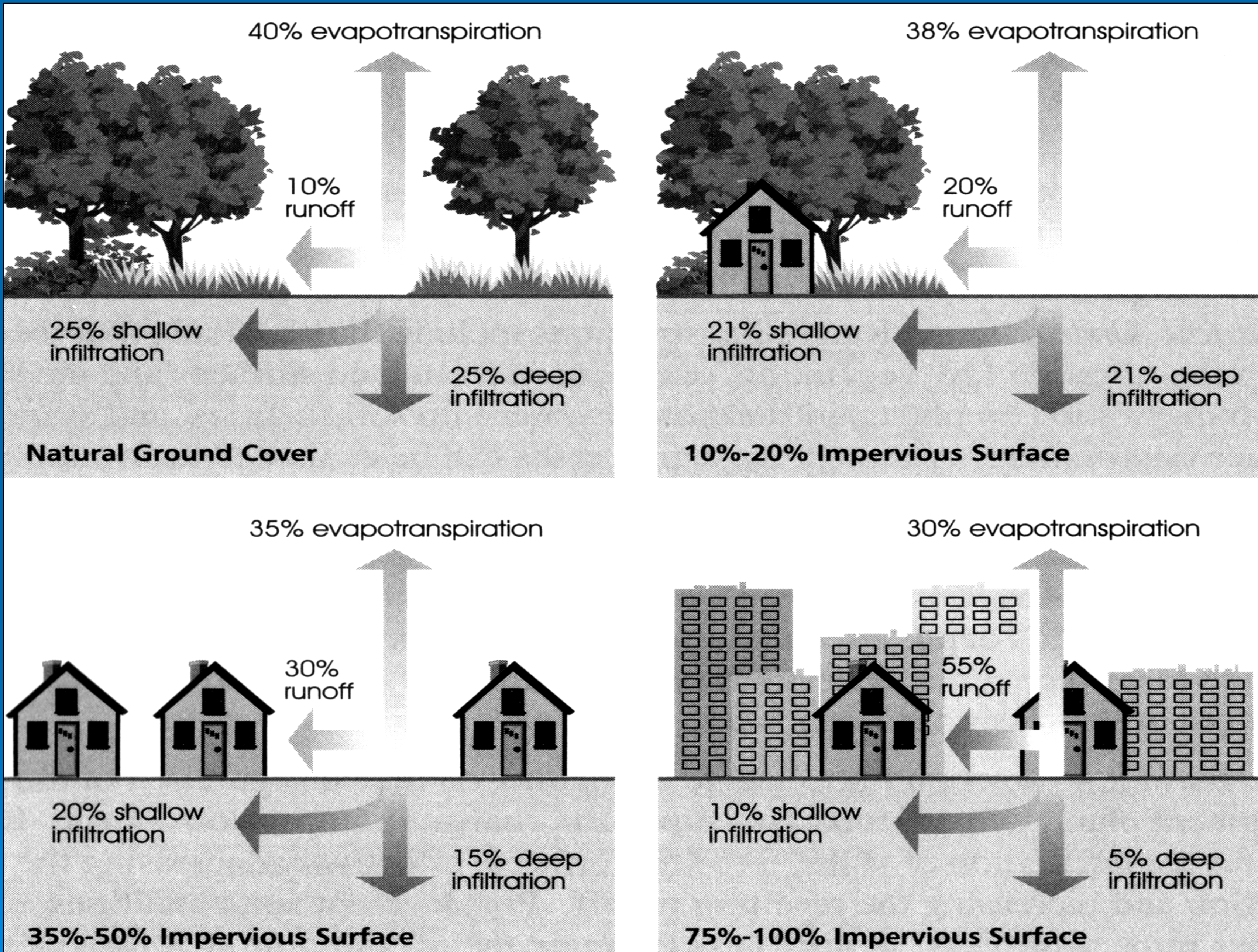

40% evapotranspiration
10% runoff
25% shallow infiltration
25% deep infiltration
Natural Ground Cover
38% evapotranspiration
20% runoff
21% shallow infiltration
21% deep infiltration
10%-20% Impervious Surface
35% evapotranspiration
30% runoff
20% shallow infiltration
15% deep infiltration
35%-50% Impervious Surface
30% evapotranspiration
55% runoff
10% shallow infiltration
5% deep infiltration
75%-100% Impervious Surface

Performance Standards for Stormwater Management in Maryland

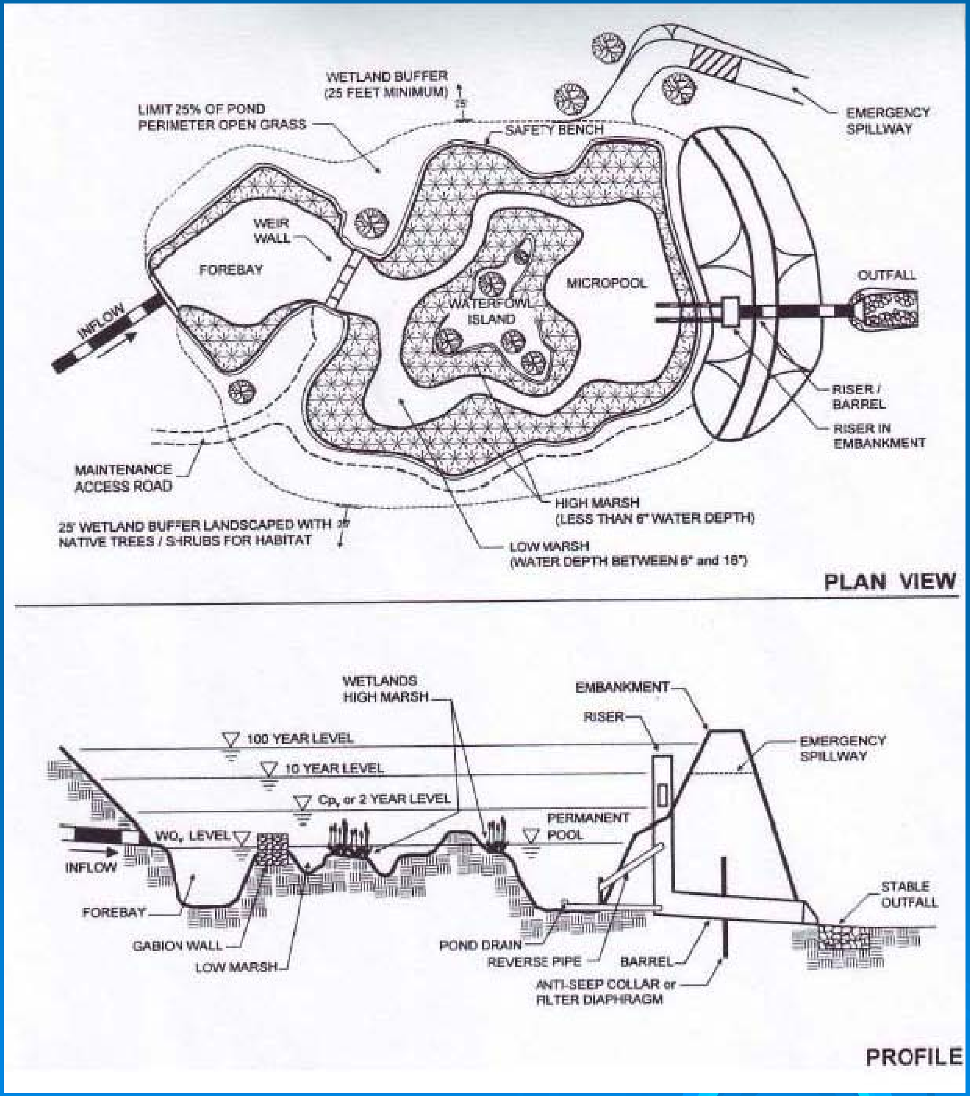
- Performance Standards
  - Prevent adverse impacts of stormwater runoff
  - Standards apply to construction disturbing 5,000 or more square feet
  - Water quality management provided by structural and /or non-structural BMPs
  - A selected BMP is presumed to comply with the performance standard if:
    - Sized to capture the prescribed water quality volume (WQ_v)
    - Designed according to the performance criteria outlined in ***2000 Maryland Stormwater Manual***
    - Constructed properly
    - Maintained regularly

Performance Standards for Stormwater Management in Maryland

Best Management Practices (BMPs)

- Structural BMP performance standard
  - Designed to remove
    - 80% of average annual post-development suspended solids load
    - 40% of the average annual total phosphorous load

Constructed Shallow Wetland



Constructed Shallow Wetland

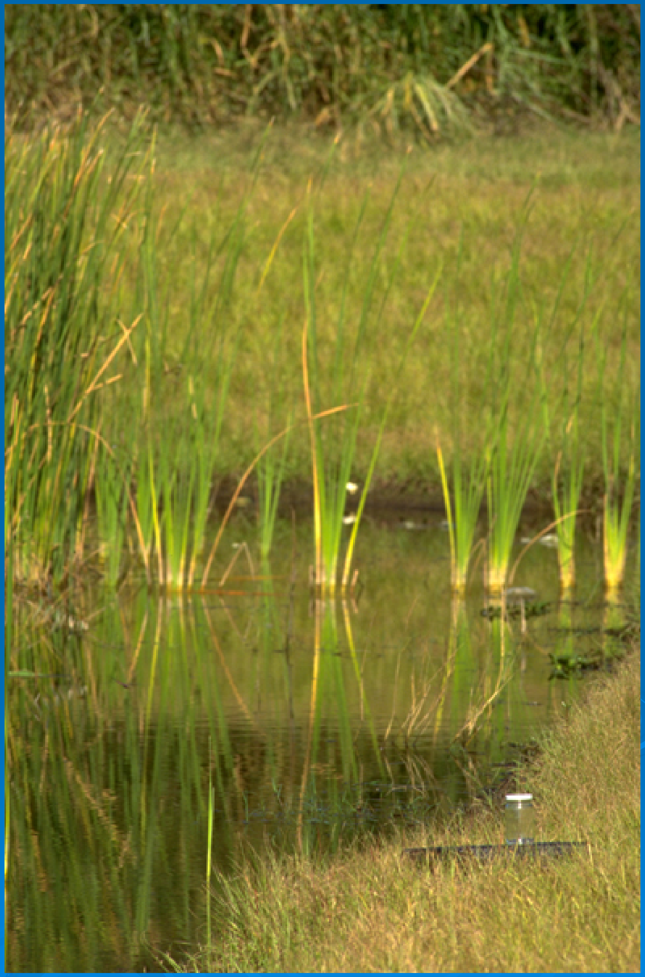
Advantages

- Provides wildlife and wetlands habitat
- Provides significant water quality improvement across a broad spectrum of constituents
- Provides control of channel erosion

Constructed Shallow Wetland

Limitations

- Aesthetics (swampy)
- Drowning hazard
- Mosquito breeding
- Slope limited
- Supplemental water demand
- Relatively large footprint
- Dam safety



Constructed Shallow Wetland

Targeted Constituents	Removal Effectiveness				
	Low		Medium		High
✓ Sediment					✓
✓ Nutrients			✓		
✓ Trash					✓
✓ Metals					✓
✓ Bacteria					✓
✓ Oil and Grease					✓
✓ Organics					✓

Constructed Shallow Wetland

Design parameters: sizing criteria

- Water quality volume (WQ_v)(acre-feet)

  - Storage required to capture and treat 90% of the average annual rainfall depth (P)

  - Eastern rainfall zone P=1.0”

  - Western rainfall zone P=0.9”

Constructed Shallow Wetland

$$WQ_v=[(P)(Rv)(A)]/12$$

WQ_v = Water Quality Volume (ac. ft.)

P = 90% of the Average Annual Rainfall (in.)

Rv = Volumetric Runoff Coefficient

A = Site Area (acres)

Constructed Shallow Wetland

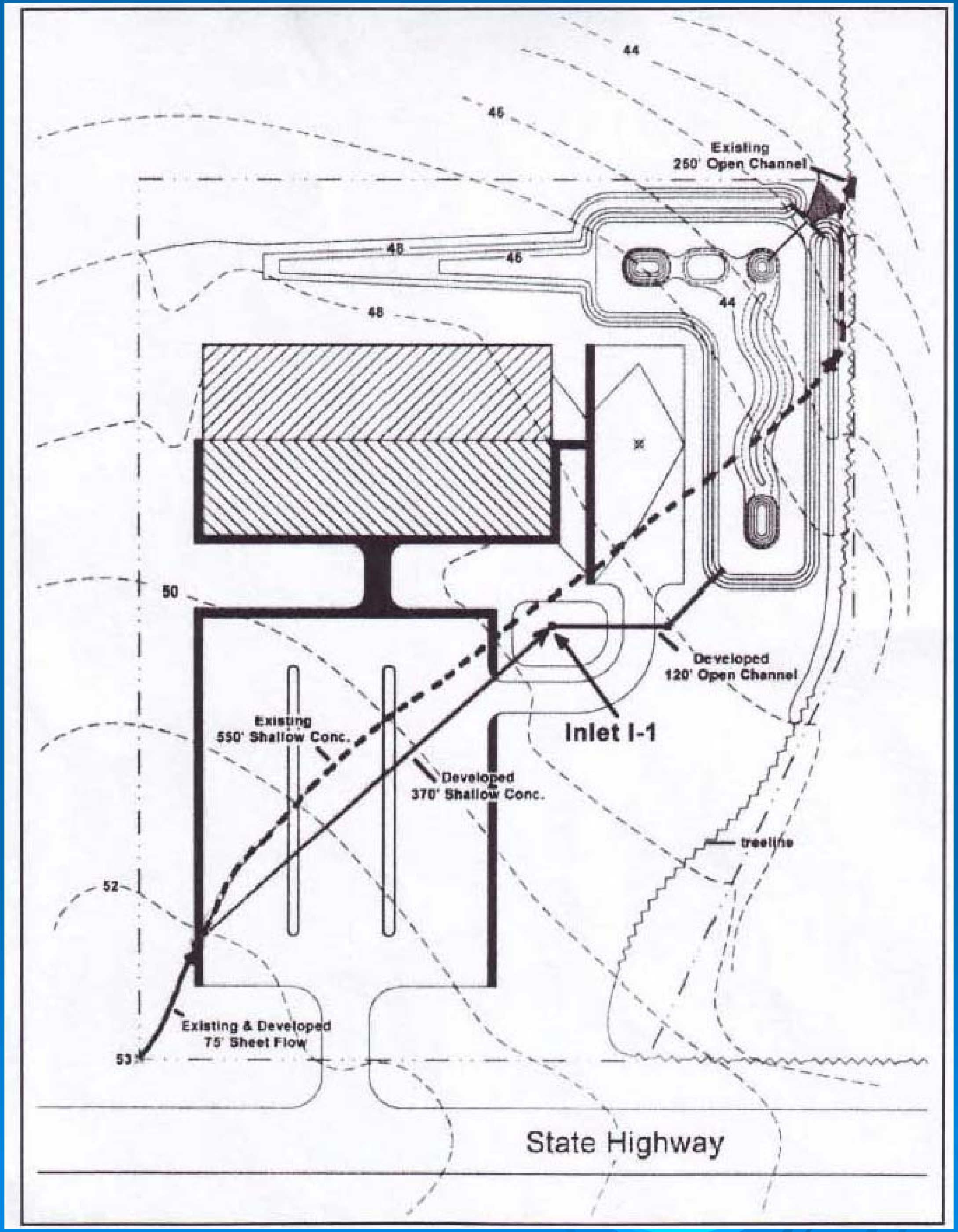
Design Parameters: sizing criteria (cont.)

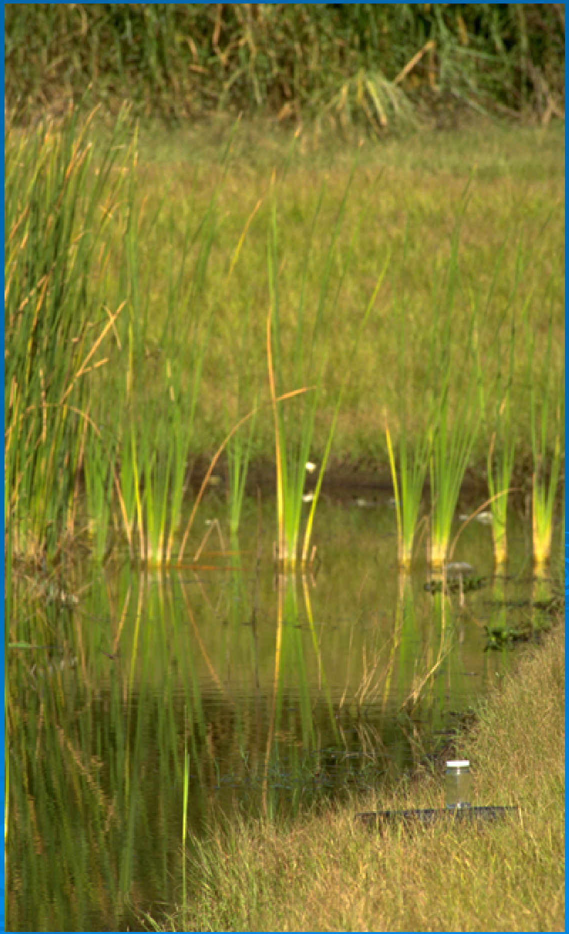
- Wetland treatment criteria
  - Surface area
    - 1.5% of drainage catchment
  - Micropool + Forebay
    - 25% of WQ_V
    - minimum depth: 4 feet
  - High marsh
    - 35% of total surface area
    - water depth: 6 inches or less
  - Low marsh
    - 65% of total surface area
    - water depth: 6 to 18 inches

Shallow Wetland

Design Example

Clevenger Community Center





Shallow Wetland – Design Example Clevenger Community Center[1]

Site Drainage Area	5.3 acres
Total Impervious Area	1.94 acres
Existing Ground Elevation at Outfall	44.5’ NGVD
Seasonal High Water Table	41.0’ NGVD
Rainfall Zone (P)	1”

[1]Design Example 1 – Appendix C; *2000 Maryland Stormwater Design Manual*, Maryland Department of the Environment

Shallow Wetland – Design Example
Site Data

Drainage Area	5.3 acres
Post Developed Conditions CN	74
2-yr. Design Rainfall Event	3.3”
2-yr. Design Storm Runoff	1.1”
Water Quality Volume (WQ_v)	0.167 ac-ft
Groundwater Recharge Volume (Re_v)	0.0456 ac-ft
Surface Area of Wetland (minimum 1.5% of drainage area to BMP)	0.0795 acres

Shallow Wetland – Design Example
Wetland Configuration

	Design	Provided
Surface Area of Wetland	3463 SF	5950 SF
Deep Water Zone (depth $\geq$ 4')	1326 CF	1950 CF
High Marsh (depth $\leq$ 6")	1212 SF	2160 SF
Low Marsh (depth 6" to 18")[1]	1039 SF	2040 SF
Total Marsh	2251 SF	4200 SF
Deep Water Zone (depth $\geq$ 4')[2]	-	1750 SF

[1]Estimated: Total marsh area less high marsh area

[2]Estimated: Total surface area of wetland less total marsh area

Shallow Wetland – Design Example

Evaporation Rates for Maryland Ponds

	April	May	June	July	August	September
Evaporation (ft.)	0.36	0.44	0.52	0.54	0.46	0.35

Maximum Drawdown

Volume of Runoff (2-year storm)	1.1”
2-year Rainfall (P)	3.3”/0.275’
Runoff Efficiency (E)	0.33
Inflow	0.48 ac-ft
Maximum Monthly Evaporation (July)	0.54’
Evaporation Volume	0.074 ac-ft

Inflow > Outflow (Evap)

Shallow Wetland – Water Balance

The hydrologic balance for wetland surface can be defined as:

$$P + R_i - R_o - E_s - T_s - I = \Delta S$$

P is direct precipitation

R_i is runoff from the site

R_o is outflow from the wetland

E_s is evaporation from the wetland open water surface

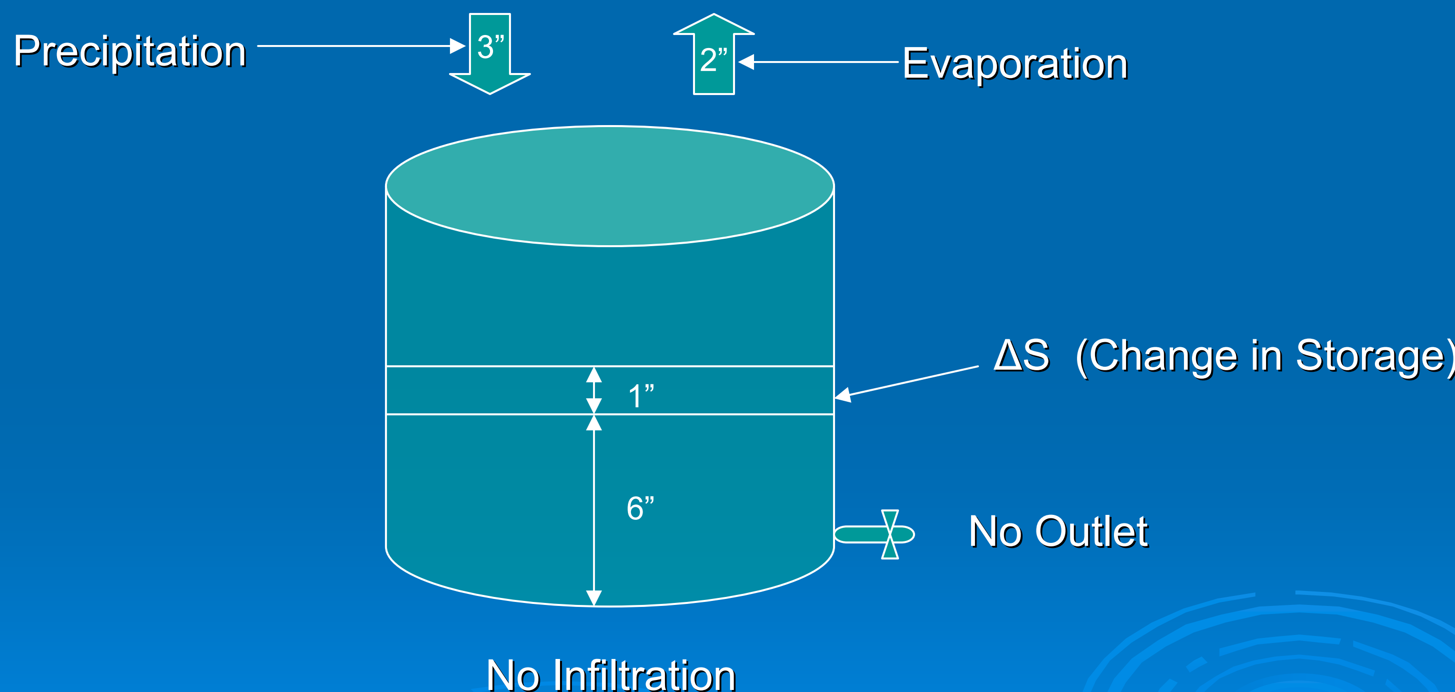
T_s is transportation from wetland vegetation

I is infiltration

ΔS is the change of storage in the wetlands

Shallow Wetland – Water Balance

Simple Water Balance for a Pond



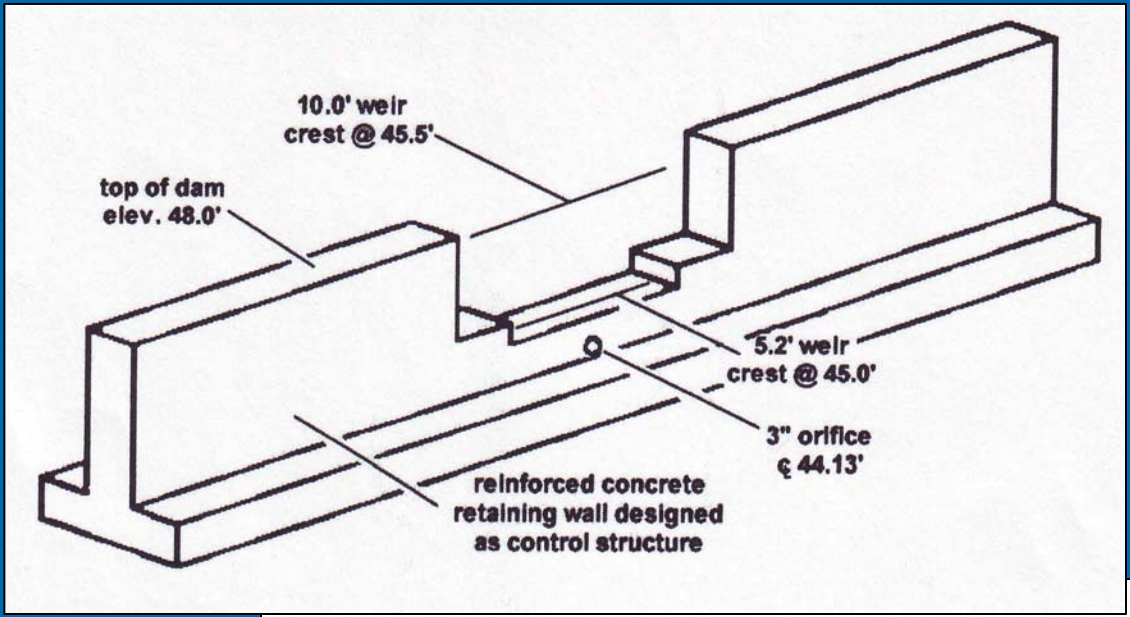
Shallow Wetland – Water Balance

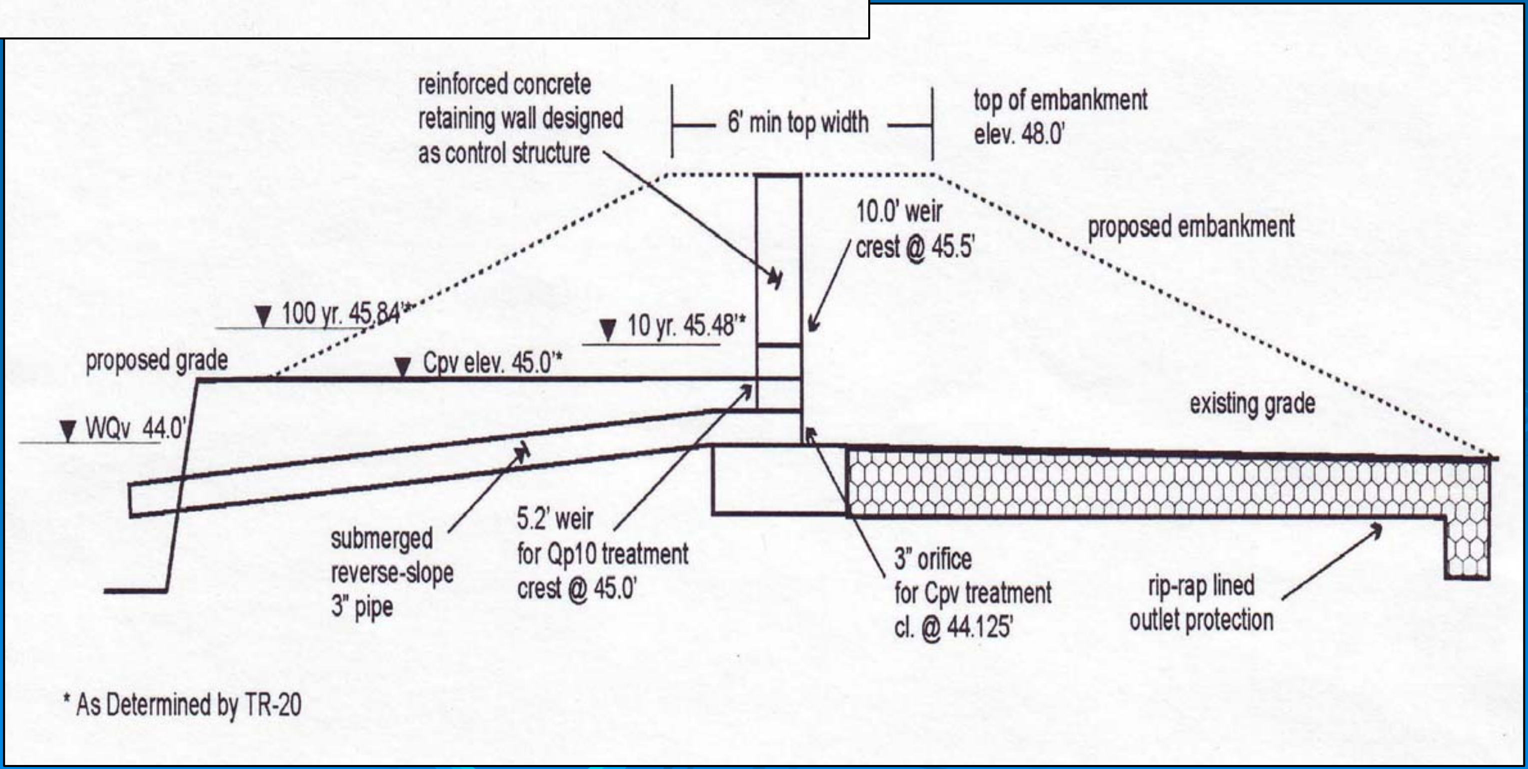
Stage-Storage Data

Elevation	Δ Storage	Storage (cubic feet)	Storage (acre-feet)
40.0	0.0	0.0	0.0
41.0	372.0	372.0	0.0085
42.0	665.0	1,037.0	0.0238
43.0	1,428.0	2,465.0	0.0566
44.0	3,990.0	6,455.0	0.1482
45.0	11,200.0	17,665.0	0.4055
45.5	8,478.0	26,133.0	0.5999
46.0	8,987.0	35,120.0	0.8062
47.0	19,530.0	54,650.0	1.2546
48.0	21,646.0	76,296.0	1.7515

Shallow Wetland

Control Structure and Centerline of Dam





Shallow Wetland – Water Balance

Stage - Discharge Data

Elevation	Total Discharge
44.00	0.00
44.25	0.085
44.50	0.150
44.75	0.194
45.00	0.229
45.50	5.70
46.00	27.08
47.00	102.54
48.00	206.29

Shallow Wetland – Water Balance

Evapotranspiration

The evaporation from all water, soil, snow, ice, vegetative and other surfaces, plus transpiration.

Potential Evapotranspiration

Evapotranspiration if there is adequate soil moisture supply at all times.

Method of Estimation of Potential Evapotranspiration

Thornthwaite's Equation: This equation is based on air temperature (heat index) with an adjustment made for daylight hours.

$$ET_a = 1.6c\left[\frac{10t_c}{TE}\right]^a$$

ETa = Adjusted Evapotranspiration (cm/month)

tc = Temprature Degree C

$\text{Heat Index} = (t_c / 5)^{1.514}$

TE = Thornthwaite's temprature efficiency Index $= \sum_{1}^{12} \text{Heat Index}$

$a = 0.000000675\, TE^3 - 0.00000771\, TE^2 + 0.01792\, TE + 0.49239$

c = Daylight Adjustment Factor

Shallow Wetland – Water Balance

Potential Evapotranspiration Estimation using Thornthwaite's Equation
Charles County, MD

Month	Mean Monthly Temprature (deg F)	Mean Monthly Temprature (deg C)	Monthly Heat Index	Unadjusted Evapotranspiration (cm/month)	Day Light Adjustment Lat. 38.5	Adjusted Evapotranspiration (cm/month)	Adjusted Evapotranspiration (in/month)
January	35.0	1.7	0.190	0.24	0.849	0.21	0.08
February	38.5	3.6	0.611	0.74	0.836	0.62	0.24
March	46.6	8.1	2.080	2.41	1.030	2.48	0.98
April	55.8	13.2	4.359	4.90	1.076	5.41	2.13
May	63.9	17.7	6.792	7.50	1.189	9.24	3.64
June	71.6	22.0	9.423	10.27	1.182	12.72	5.01
July	75.8	24.3	10.977	11.90	1.202	14.96	5.89
August	74.4	23.6	10.450	11.35	1.146	13.32	5.24
September	68.3	20.2	8.260	9.05	1.023	9.39	3.70
October	57.6	14.2	4.868	5.45	0.963	5.25	2.07
November	48.4	9.1	2.481	2.85	0.839	2.39	0.94
December	39.2	4.0	0.713	0.86	0.822	0.71	0.28

Shallow Wetland – Water Balance

Clevenger Community Center

Constructed Shallow Wetland

(Average Precipitation)

Month		Mean Monthly Precipitation (inches)	Mean Monthly Runoff (inches)	Mean Monthly Runoff (cu. Feet)	Open Water Evaporation (Evap.) (inches)	Potential Evapo-Tanspiration (ET) (inches)	Combined Losses (Evap.+ ET) (cu. feet)	Begining of Month Storage (cu. feet)	Net Inflow/Loss (cu. feet)	Outflow from Structure (cu. feet)	Change in Storage (cu. feet)	Deficit/Surplus
January		3.42	1.14	21932								
February		2.85	0.95	18277								
March		3.96	1.32	25395								
April	Growing Season	3.11	1.04	19944	4.32	2.13	8306	6455	11639	10368	1271	Surplus
May		4.13	1.38	26486	5.28	3.64	10513	7726	15973	10368	5605	Surplus
June		3.81	1.27	24434	6.24	5.01	12673	13331	11761	10368	1393	Surplus
July		4.12	1.37	26422	6.48	5.89	13402	14724	13020	10368	2652	Surplus
August		4.6	1.53	29500	5.52	5.24	11496	17375	18004	10368	7636	Surplus
September		4.31	1.44	27640	4.2	3.70	8644	25011	18996	10368	8628	Surplus
October		3.36	1.12	21548								
November		3.21	1.07	20586								
December		3.16	1.05	20265								

Shallow Wetland – Water Balance

Clevenger Community Center
Constructed Shallow Wetland
(Below Average Precipitation)

Month		Mean Monthly Precipitation (inches)	Mean Monthly Runoff (inches)	40% of Mean Monthly Runoff (cu. Feet)	Open Water Evaporation (Evap.) (inches)	Potential Evapo-Tanspiration (ET) (inches)	Combined Evap.+ ET (cu. feet)	Begining of Month Storage (cu. feet)	Net Inflow/Loss (cu. feet)	Outflow from Structure (cu. feet)	End of Month Storage (cu. feet)	Change in Storage (cu. feet)	Deficit/Surplus
January		3.42	1.14	8773									
February		2.85	0.95	7311									
March		3.96	1.32	10158									
April	Growing Season	3.11	1.04	7978	4.32	2.13	8306	6455	-328	0	6127	-328	Deficit
May		4.13	1.38	10594	5.28	3.64	10513	6127	82	0	6209	82	Deficit
June		3.81	1.27	9773	6.24	5.01	12673	6209	-2899	0	3309	-2899	Deficit
July		4.12	1.37	10569	6.48	5.89	13402	3309	-2833	0	476	-2833	Deficit
August		4.6	1.53	11800	5.52	5.24	11496	476	304	0	780	304	Deficit
September		4.31	1.44	11056	4.2	3.70	8644	780	2412	0	3193	2412	Deficit
October		3.36	1.12	8619									
November		3.21	1.07	8234									
December		3.16	1.05	8106									

Shallow Wetland – Design Example
Worst Case Drawdown

Maximum Monthly Evaporation	0.54 ft
Average Evaporation per Day	0.017 ft/day
Evaporation over 45 Days	0.78 ft
Normal Pool – WQ_v at Elev. 44.0 feet	6455 cu. ft.
Worst Case Draw at Elev. 43.2 feet	3263 cu. ft.

Shallow Wetland – Water Balance

Clevenger Community Center

Constructed Shallow Wetland

(Below Average Precipitation)

Month		Mean Monthly Precipitation (inches)	Mean Monthly Runoff (inches)	40% of Mean Monthly Runoff (cu. Feet)	Open Water Evaporation (Evap.) (inches)	Potential Evapo-Tanspiration (ET) (inches)	Combined Evap.+ ET (cu. feet)	Begining of Month Storage (cu. feet)	Net Inflow/Loss (cu. feet)	Outflow from Structure (cu. feet)	End of Month Storage (cu. feet)	Change in Storage (cu. feet)	Deficit/Surplus
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August	Growing Season	4.6	1.53	11800	5.52	5.24	11496	476	304	0	780	304	Deficit
September	Growing Season	4.31	1.44	11056	4.2	3.70	8644	780	2412	0	3193	2412	Deficit
October		3.36	1.12	8619									
November		3.21	1.07	8234									
December		3.16	1.05	8106									

Shallow Wetland – Water Balance

RESULTS AND CONCLUSIONS

- Single month (runoff – evaporation), simple water budget example is supported by the extended growing season water balance
- Extended, worst case, simple water budget indicates a water deficit at the end of the 45 day period.
- Extended growing season water balance approach with 40% mean monthly runoff indicates a water deficit in all months with possible winter months recovery
- In any extended period of insufficient precipitation/runoff – a source of supplemental water will be necessary to support the wetland vegetation.


Questions?