An Ecological Framework for Reviewing Compensatory Mitigation: Plan Review

Part 4 of 4: "Red Flag" Review for Hydrology and Soils in Palustrine Systems

Presented by:

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P.E., P.W.S., P.W.D., LEED® AP

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Purpose of the Red Flag Review - To Find:

- Fatal Flaws or Assumptions
- Areas that need more explanation/analysis
- Constructability Issues
- Areas that need enhanced inspection, testing or measurement
- Areas that need more clarity to ensure proper implementation (most people look at the drawing – not the words)

REMEMBER: The Plan designer likely knows more than you about the site and project.

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Our “Hot Buttons” Today:
Things the Plan Reviewer should ask

- **Q1.** Do you agree with Basis of the Design Target Hydrograph or Reference Hydrograph?

- **Q2.** Does the water budget model mimic the site’s design and landscape position?

- **Q3.** Are the water budget components scientifically estimated?

- **Q4.** Is there resiliency in the system to account for the extreme variability in the data input and *(lack of)* precision of the model?

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Q1. Do you agree with Basis of the Design Target Hydrograph or Reference Hydrograph?

- This is the major determinate -type of wetlands you restore or create.

- Does it provide a depth, duration, and timing (i.e. seasonality) of water for the desired type of Wetlands?

- Is it from a reference wetlands – Go look at it! Regardless – ask:
  - Is it the same type you want to restore/create?
  - Is it in the same landscape position, physiographic province?
  - Is there enough data to determine the desired variability from Wet to Normal to Dry Years?
  - Are we using this data as a design goal with the appropriate precipitation data?
  - How was it established? Use St. Paul District Guidance 2018-1 as a comparison

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Sources for Target Hydrology and Performance Standards

- Lee Daniels (VT) and Rich Whittecar (ODU) are developing a library of Hydrographs as part of a grant from the Resource Protection Group, Inc. to use with WetBud.
  - http://www.wetlands.com/wetland-research-initative/
  - http://www.landrehab.org/WETBUD

US Army Corps of Engineers ®
St. Paul District

ST. PAUL DISTRICT REGULATORY BRANCH

ORIGINATOR: STEVE EGGERS
NUMBER: 2018-1
GEOGRAPHIC AREA: MINNESOTA AND WISCONSIN
ISSUED: ___ 2018

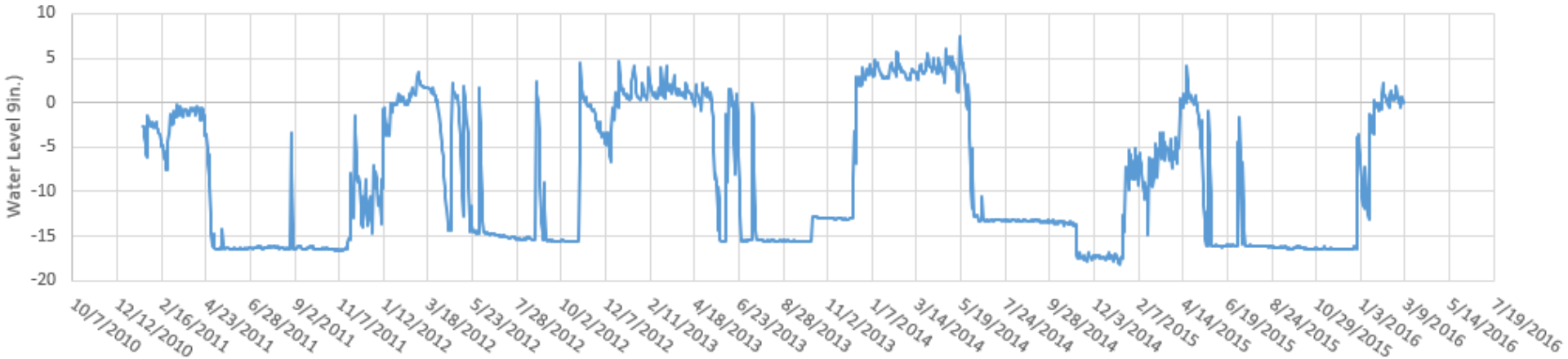
Guidance on Target Hydrology and Performance Standards for Compensatory Mitigation Sites—Version 6.0

Target Hydrographs – Narrative and Reference Site Examples

- *PFO1A:* Ground water within 12 inches of the surface for a minimum of 12.5% of the growing season (27 days)
  - Issues – only has min depth - no max inundation depth, no timing, no allowable variability
- Better Example from St. Paul 2018-01

C. **Hardwood Swamps, Shrub-Carrs and Alder Thickets (Mineral Soils).** *Hydrology shall consist of a water table 12 inches or less below the soil surface, to inundation up to 6 inches in depth, for a minimum of 28 consecutive days, or two periods of 14 or more consecutive days, during the growing season under normal and wetter than normal hydrological conditions (per Sprecher and Warne 2000). Inundation greater than 6 inches in depth during the growing season shall not occur except following the 10-year, 24-hour—or greater—precipitation events. Duration of inundation greater than 6 inches depth shall be less than 14 consecutive days. An exception can be made for sites with hummocky microtopography—hollows between hummocks can have standing water depths up to 12 inches for extended duration.*

- Reference Well data (before conversion into a Target Hydrograph):

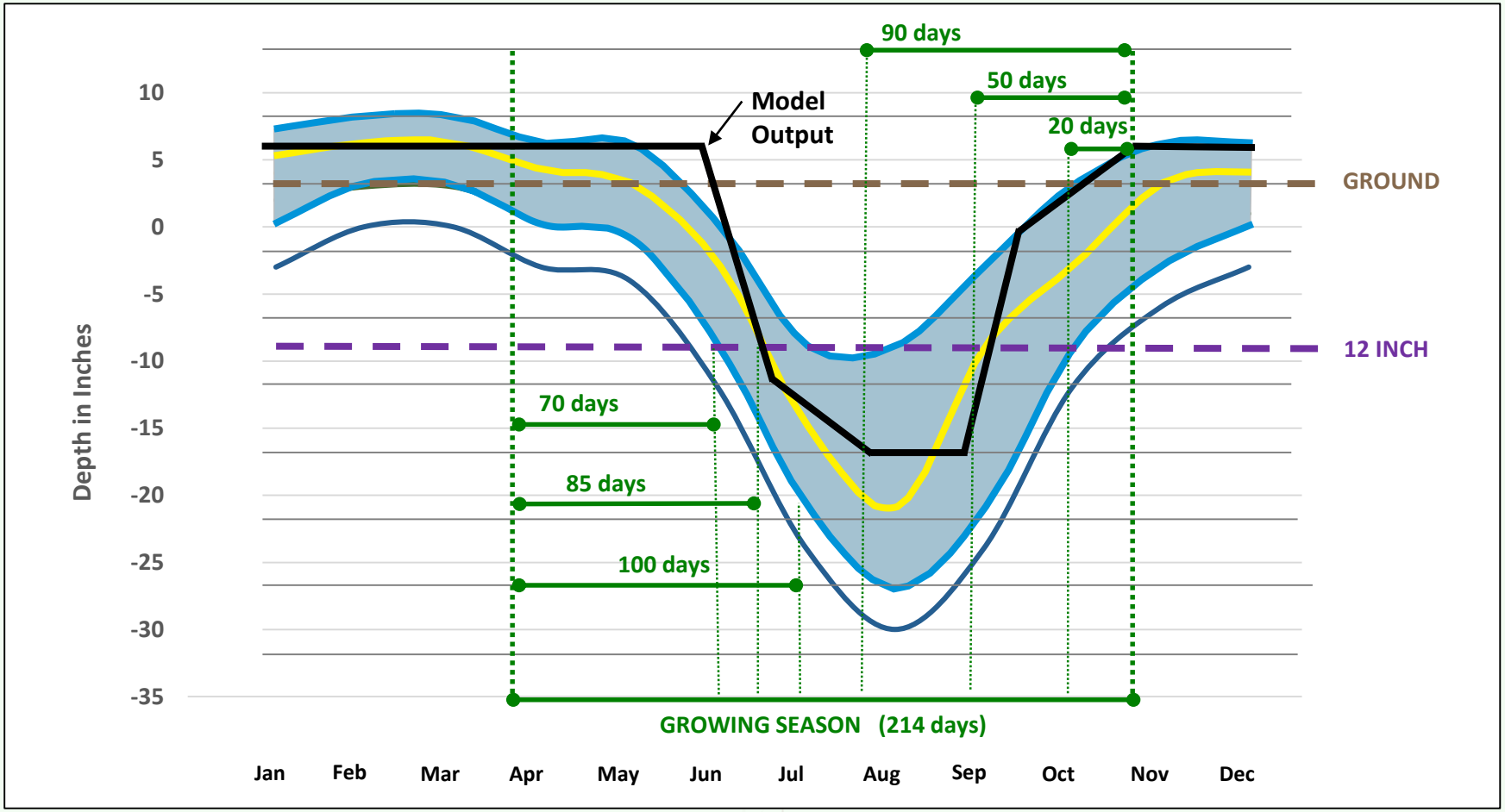


Target Hydrograph vs. Water Budget Model Output

- Cowardin Classification PFO 1B
- Location: Prince William County, VA
- Novitzki System: Surface Water Depression

Normal Year

- Physiographic Province: Piedmont
- Growing season start: April 1
- Growing season end: November 1



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Purpose of Water Budget

- Tool to estimate the depth, duration, and timing of water in a wetlands – hydrograph

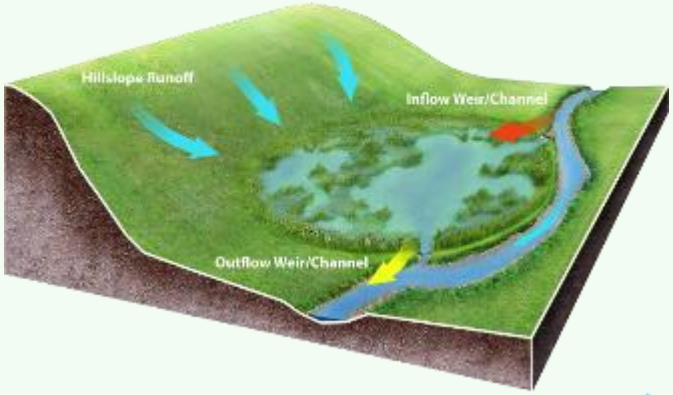
- Goal is to develop a design that has a water budget with a hydrograph similar to your reference hydrograph or design hydrograph

- Assist in the design of a resilient system capable of using adaptation management

Understand the data and calculation limitations!

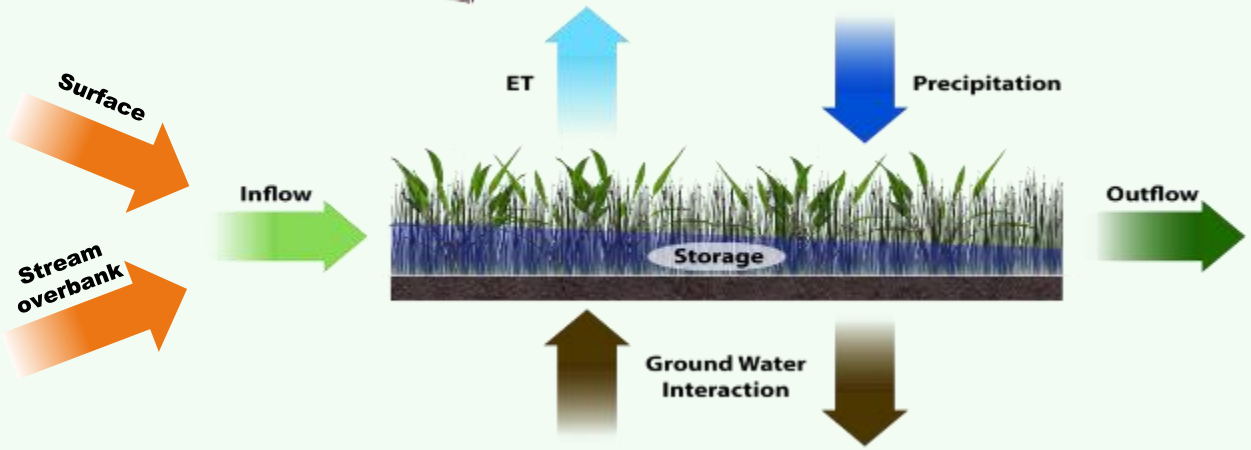
Wetland Water Budget

$$P + S_I + OB + G_I - ET - S_O - G_O = S_t$$



Where:

P = Precipitation
S_I = Surface-water Input
OB = Overbank flow
G_I = Ground-water input
ET = Evapotranspiration
S_O = Surface-water output
G_O = Ground-water output
S_t = Net potential storage



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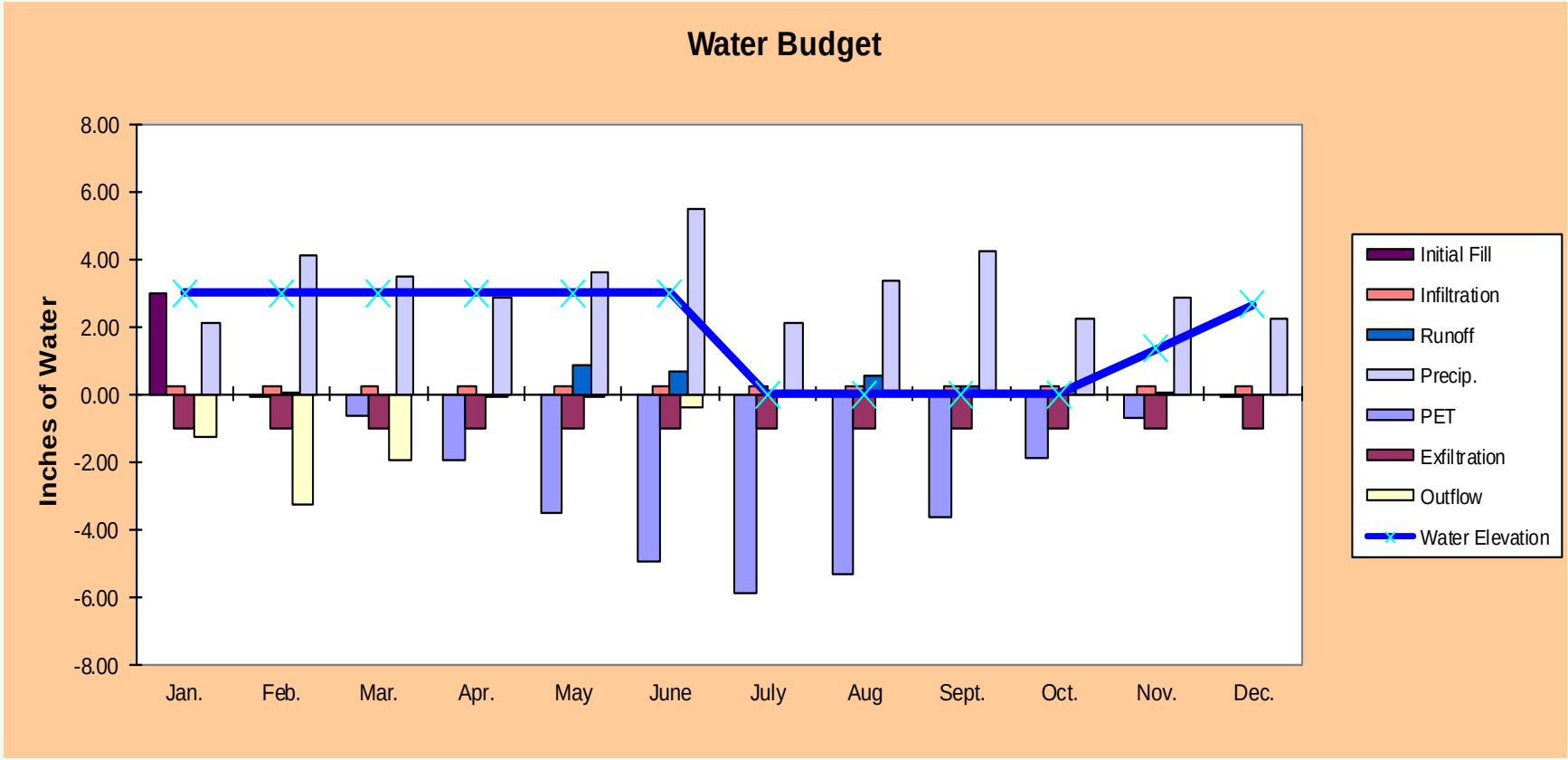
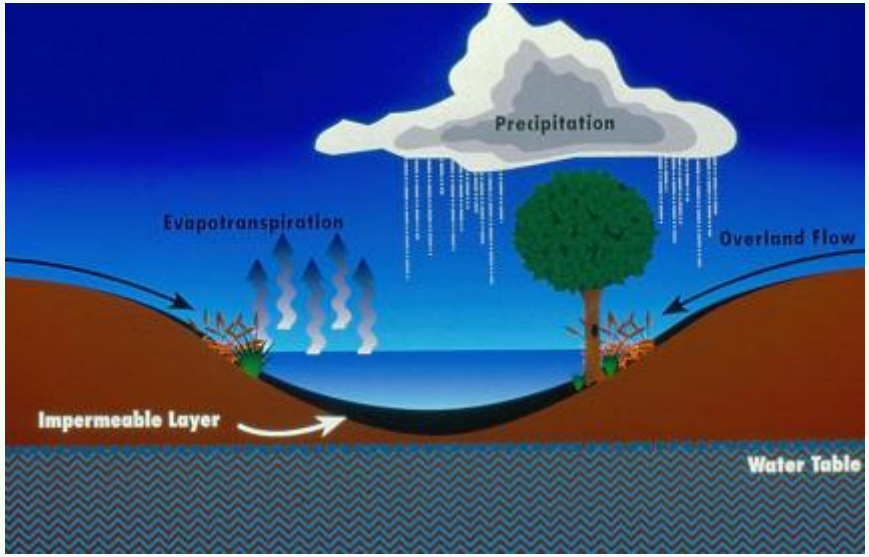
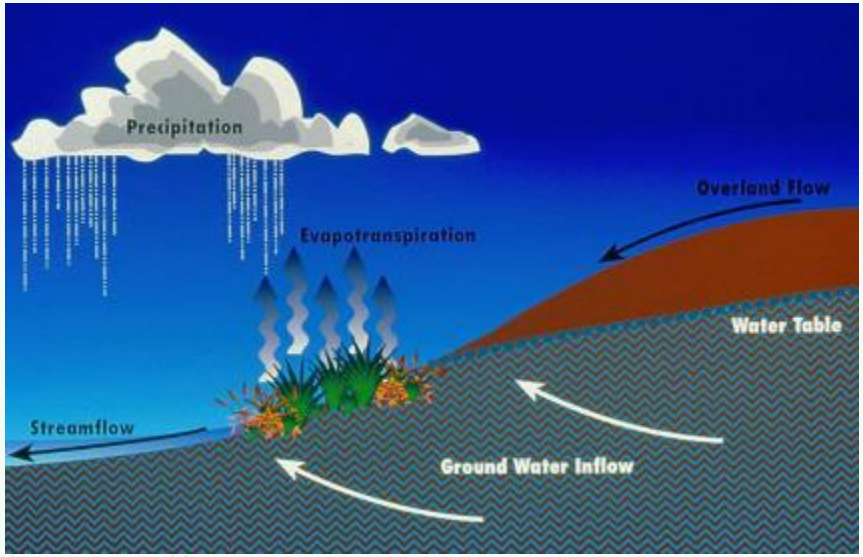
Hydrograph: A Visual Representation of the Water Budget



Q2. Does the proposed model mimic the site's design and landscape position?

- Model must represent the landscape position and water source - Novitzki (1979,1982) and Pierce (2015)
- Models simplify the complexity of real wetlands – add common sense and experience
- Ex: Cannot use the same model for a Surface water depression Wetlands (left) vs. a Ground-water depression wetlands (right) (Pierce 2015)



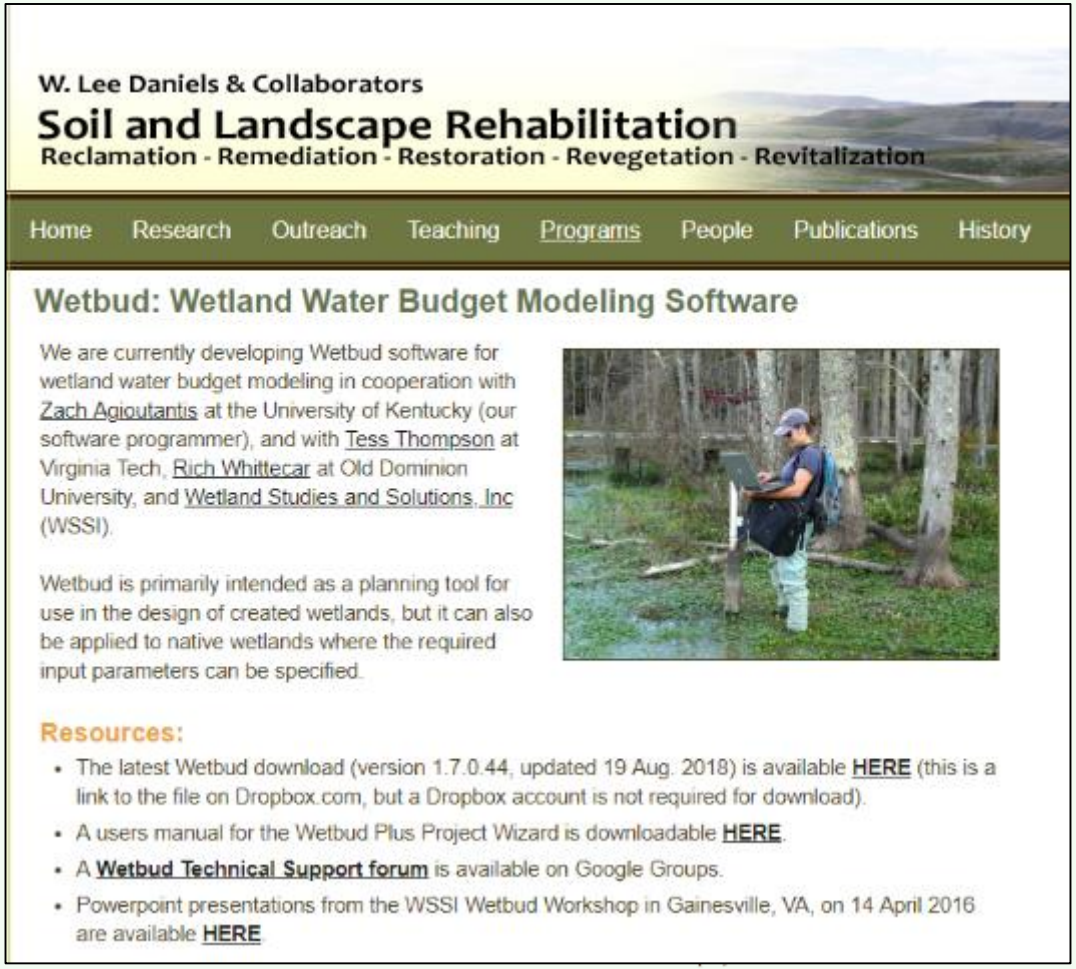


Suggested waterbudget methodologies

- "Pierce" Method:

  Gary J. Pierce. 2015. *Wetland Mitigation: Planning Hydrology, Vegetation and Soils for Constructed Wetlands*. Mallory N. Gilbert and Robert J. Pierce contributing editors. Wetland Training Institute, Inc. Glenwood, New Mexico. xvi+352 pp.

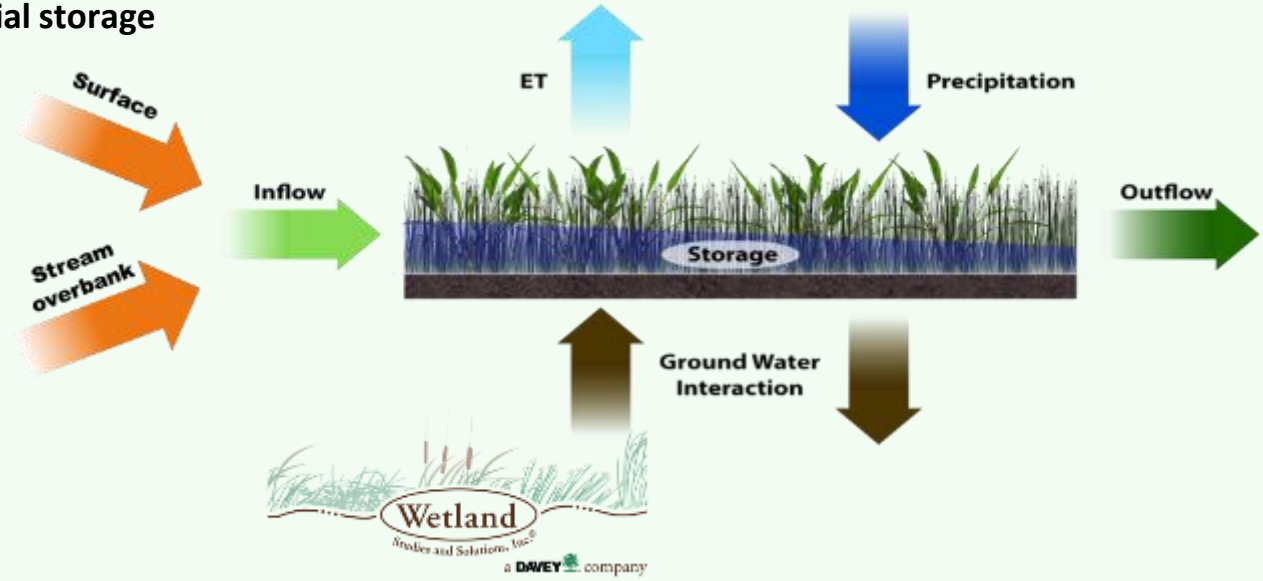
- Wetbud - http://www.landrehab.org/WETBUD



Q3. Are the water budget components scientifically estimated?

$$P + S_I + OB + G_I - ET - S_O - G_O = S_t$$

- **Where:**
- **P = Precipitation**
- **S_I = Surface-water Input**
- **OB = Overbank flow**
- **G_I = Ground-water input**
- **ET = Evapotranspiration**
- **S_O = Surface-water output**
- **G_O = Ground-water output**
- **S_t = Net potential storage**



Precipitation (P) – do you agree with what the designer used?

- Goal - Estimate future "P" using historic data (climate Change?)
- Use a logically located weather station
- Account for variability looking at WND:
  - Wet Year
  - Normal Year
  - Dry Year

- Analyze distribution within year as well as in total year
- Best Professional Judgement (BPJ)

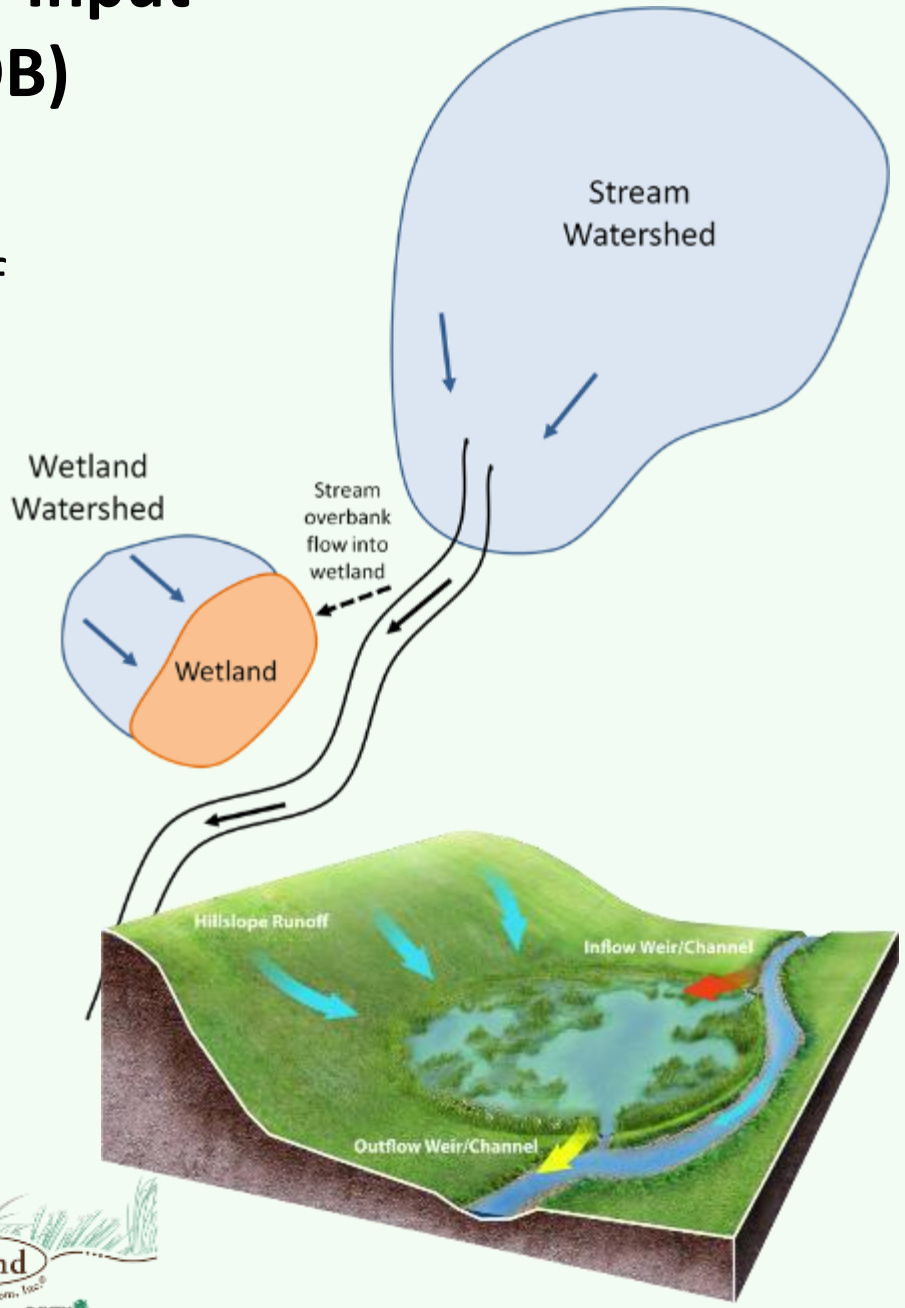
or

Statistical Approach with WETS – such as developed by Dr. George Rich Whittecar, Jr. at Old Dominion University

Did they model Surface Water Input (S_I) and Overbank Flow (OB) appropriately?

Surface water inflows can be runoff from the wetland watershed or overbank flows from an adjacent stream.

- Direct measurement:
  - USGS Gauge Data (https://waterdata.usgs.gov/nwis)
- Small Springs and Streams:
  - V-Notch Weirs
- Models:
  - TR-55 (my preference)
  - Rational Method
  - SWMM
  - HEC-HMS



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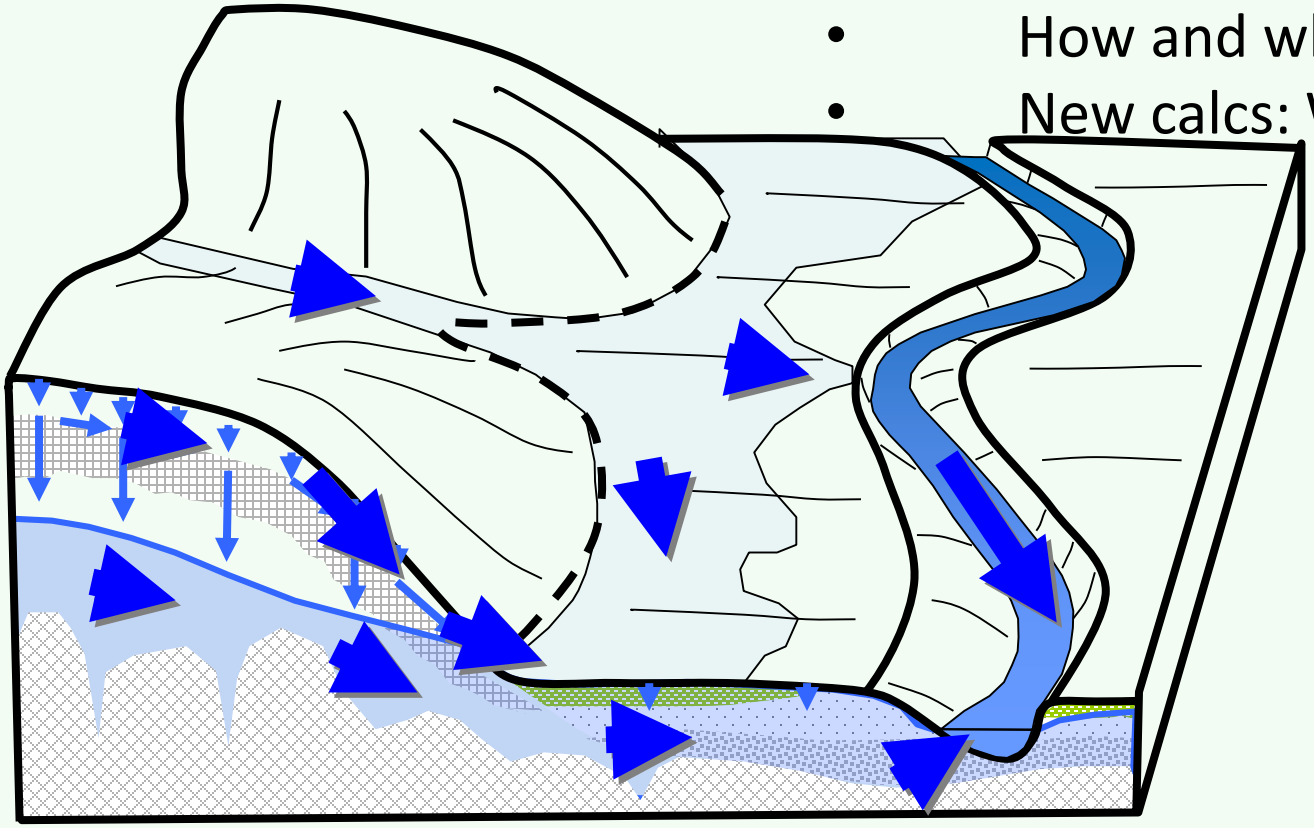
How was Groundwater Input (G_I) estimated?

- Landscape and Geology
- How and where GW used
- New calcs: WND and W_{em}



Piedmont Wetlands: the interface between uplands, groundwater, and surface water

Graphics Courtesy of Rich Whitecarr, ODU

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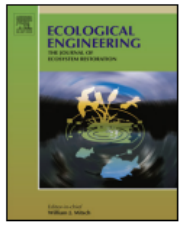

Use of the Effective Monthly Recharge model to assess long-term water-level fluctuations in and around groundwater-dominated wetlands

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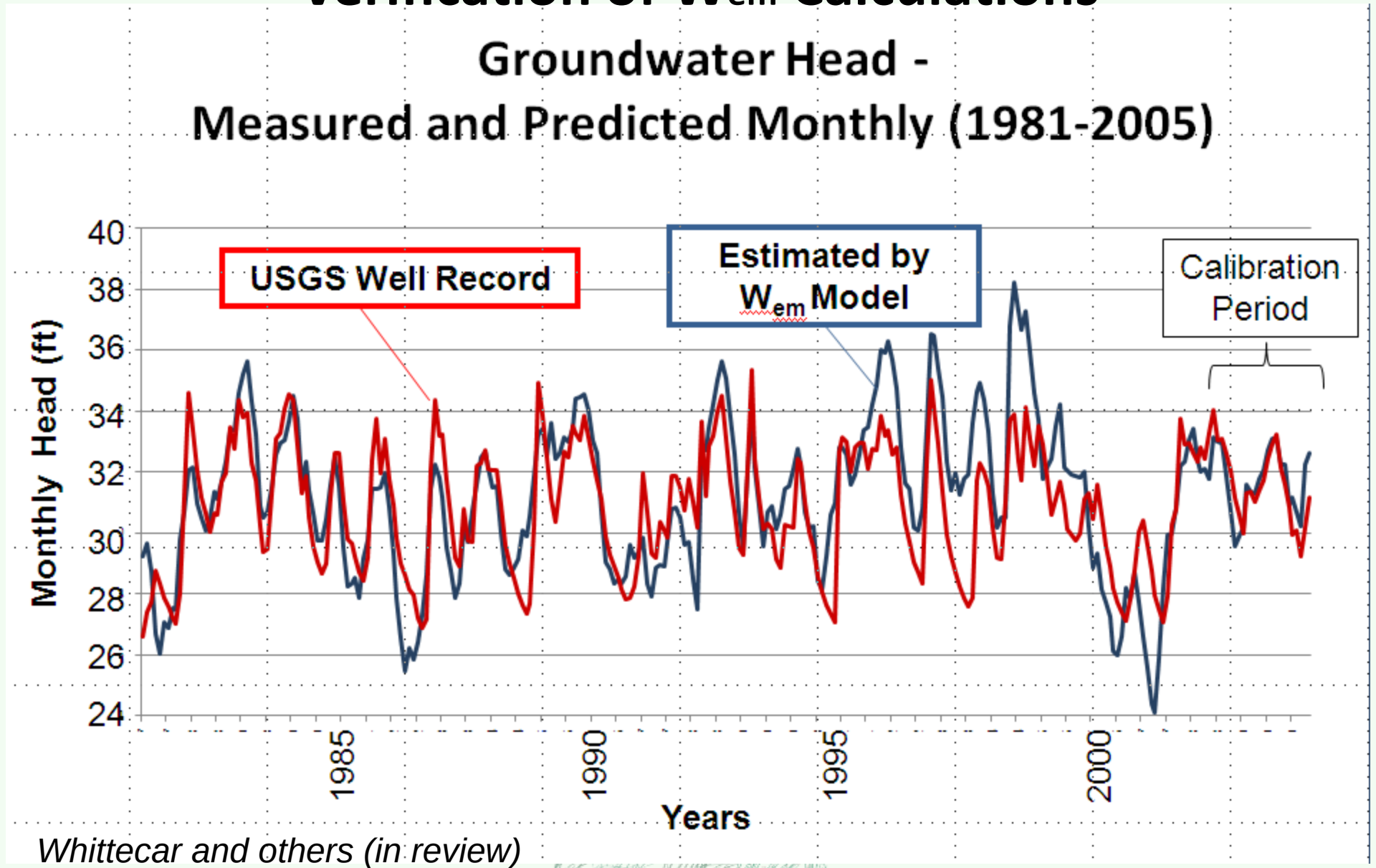
ABSTRACT

Effective Monthly Recharge (W_{em}) calculations use historical weather data to estimate monthly-scale water level changes in precipitation-and-groundwater-driven wetlands. This time-weighted water-budget procedure relates first-of-the-month hydraulic heads measured in a monitoring well or small pond with precipitation and evapotranspiration data for preceding months and generates a regression equation used to estimate historic water levels. This study developed an enhanced procedure more robust than used with previous W_{em} studies. Two data sets of water-table fluctuations in humid-temperate southeastern Virginia (U.S.A.) allowed verification of the model procedure—a 30-year record from a shallow well maintained by the U.S.G.S., and a 6.5-year record from a mitigation wetland measured before and after construction. Analyses of Predicted Heads and Observed Heads at both sites indicate that the W_{em} model can replicate reasonably the seasonal patterns of water-table fluctuations and the range of values of hydraulic heads at a monthly scale. Within the limitations set by the assumptions of the procedure and the range of water fluctuations during the calibration period, W_{em} calculations may be used to generate synthetic hydrographs for periods with appropriate weather data. Analyses of two sites in Missouri and Nebraska (U.S.A.) suggest that the W_{em} procedure may prove useful also in climatic regions with relatively strong seasonal forcing, but additional testing is needed to verify the range of model applicability. These reconstructions could support long-term decisions in the management of wildlife habitats or design of mitigation wetlands.

Verification of W_{em} Calculations



Whittecar and others (in review)

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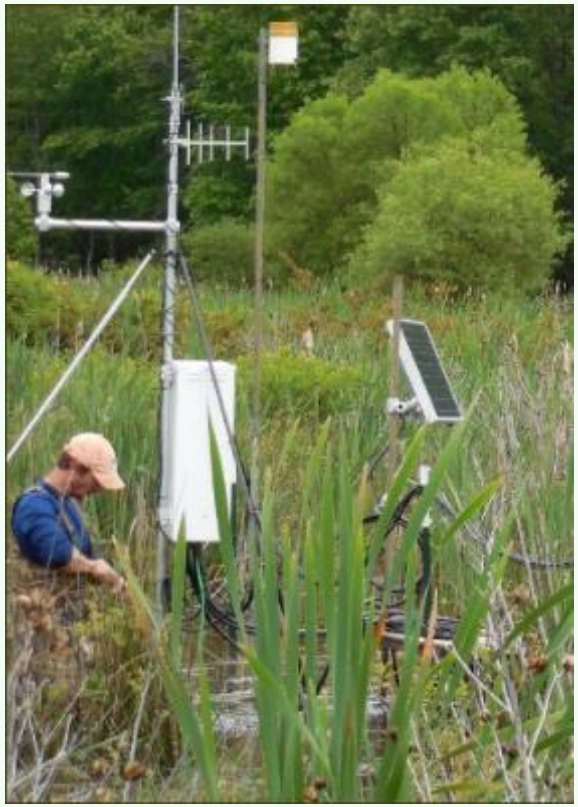
PET vs. ET

- Potential evapotranspiration (PET) is the evapotranspiration (ET) rate when water supply is unlimited- i.e., when there is ample water.
- I will use PET and ET interchangeably – which some may say is “sloppy”.
- PET is expected to overestimate ET when soils are not flooded or saturated – so it is likely conservative for wetlands construction purposes



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Evapotranspiration (ET) Discussion

- Need to estimate future “ET” using historic data
- Account for variability looking at WND:
  - Wet Year
  - Normal Year
  - Dry Year
- Some say “no suitable models exist”
- Carter et al (1970): ET in wetlands = 0.53 to 5.40 x Evaporation
- Kadlec and Knight (1996): ET = 0.7 to 0.9 x Pan Evapo. (0.8 commonly used)
- Hammer (1992): Emergent plants in pond reduce ET to 0.8/0.9 Pan Evap
- PET may overestimate ET in drier conditions

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Evapotranspiration (ET) Discussion, cont.

- Few ET estimation methods use readily available data
- VT/ODU/WSSI/RPG research ongoing (see Stephen Stone Thesis, 2017 and Huntly Meadow reports): https://www.wetlands.com/rfp-2-wri
- Methods that use typically available data:
  - Penman-Monteith (Jensen et al 1990) – uses many data variables
  - Thornthwaite (1948, 1955) – just needs mean monthly temp.

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Evapotranspiration (ET) Opinions

- Penman better estimate – but you need very good/detailed data set to use it (Daniels and Thompson, VT, 2018 personal emails)
- Thornthwaite developed to be used on a regional basis – gives approx. for a given latitude (Daniels, VT, 2018 personal emails)
- Thornthwaite underpredicted ET (as estimated by Bowmen's R) by as much as 50% in summer at Ft. Lee, VA mitigation site (Daniels, personal emails on VT/USGS study)
- Pierce (text pg. 98-99) recommends Thornthwaite – based on data availability

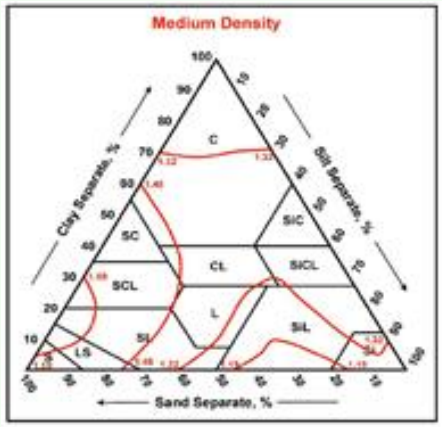
The Plan Reviewer Questions for ET

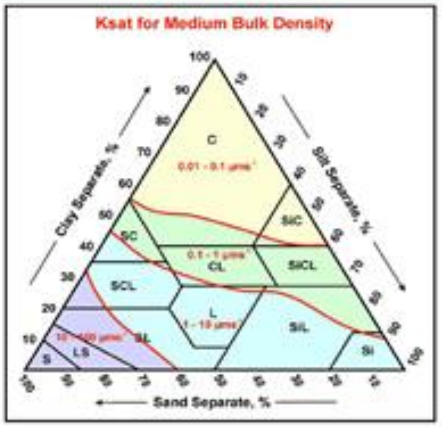
- What was used?
- Does the model account for the lack of precision of this value?
- Ex: Comparison for Dulles, 1974 weather data:

Normal (1974)			
Month	Rainfall	Penman-MontiethPET	Thornthwaite
Jan	4.45	1.16	0.24
Feb	1.03	1.77	0.04
Mar	3.10	3.30	0.93
Apr	2.23	4.49	2.19
May	5.67	4.63	3.44
Jun	6.15	4.59	4.38
Jul	2.42	5.83	5.63
Aug	5.31	4.53	5.14
Sep	4.65	3.77	3.51
Oct	0.70	3.34	1.68
Nov	1.51	2.33	0.89
Dec	5.85	1.29	0.23
Total	43.07	41.03	28.30

Groundwater Out (G_o) and Infiltration/Permeability/Saturated Hydraulic Conductivity (K_{sat})

- I am using Infiltration/Permeability/Saturated Hydraulic Conductivity (K_{sat}) inerchangeably
- Hydraulic Conductivity (K_{sat}) is used in today's technical literature – but much reference sources (NRCS) use Permeability or Infiltration rate.
- To estimate G_o we need to know K_{sat}
- See Pierce pg. 101 for a six step protocol





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Problems with Measuring Infiltration

- "For solution of real problems, the choice of the appropriate *K* requires judgement. It is seldom possible to make an evaluation closer than the nearest decimal place; therefore design decisions….should allow for such variations (Sowers, pg. 98, 1979)

- There is no accurate way to calculate or measure this rate for even moderately large areas… (Pierce, pg. 99, 2015)

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Common Field and Lab measurements of K_{sat}

- Soil Texture/Bulk Density relations from NRCS
- Single Ring Infiltrometer – mixes K_{vert} and K_{hor}
- Falling Head/Rising Head well tests
- Double Ring Infiltrometers
  - ASTM D3385 12/24-inch standard Mini turf tech version
  - ASTM D5093 – Sealed Double ring (5ft/12 ft) – 10^{-7} cm/sec and slower (seal removes Evaporation influence)
- Precision (aka Johnson) Permeameter
- Flexible Wall Permeameter (lab) – ASTM D508
  - Must mimic compaction/moisture content

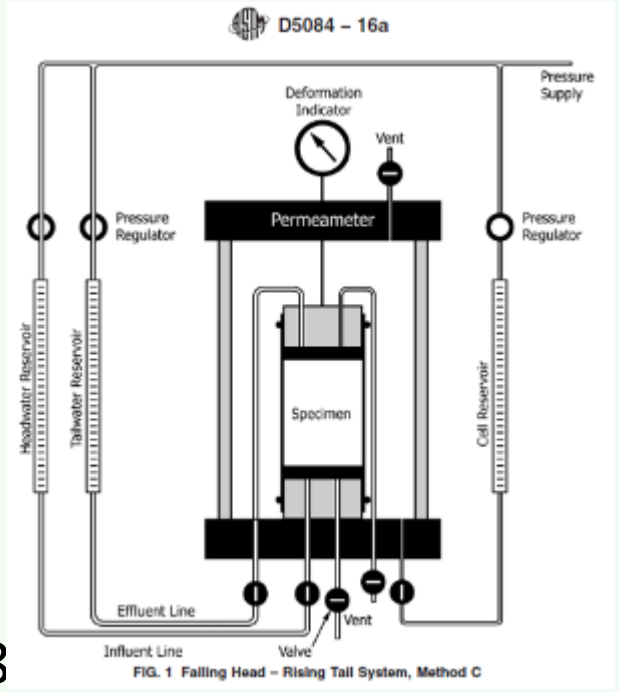
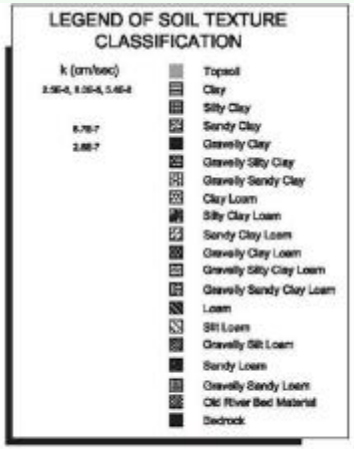


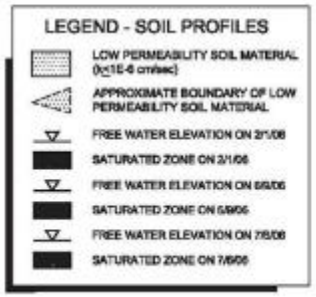
FIG. 1 Falling Head – Rising Tail System, Method C

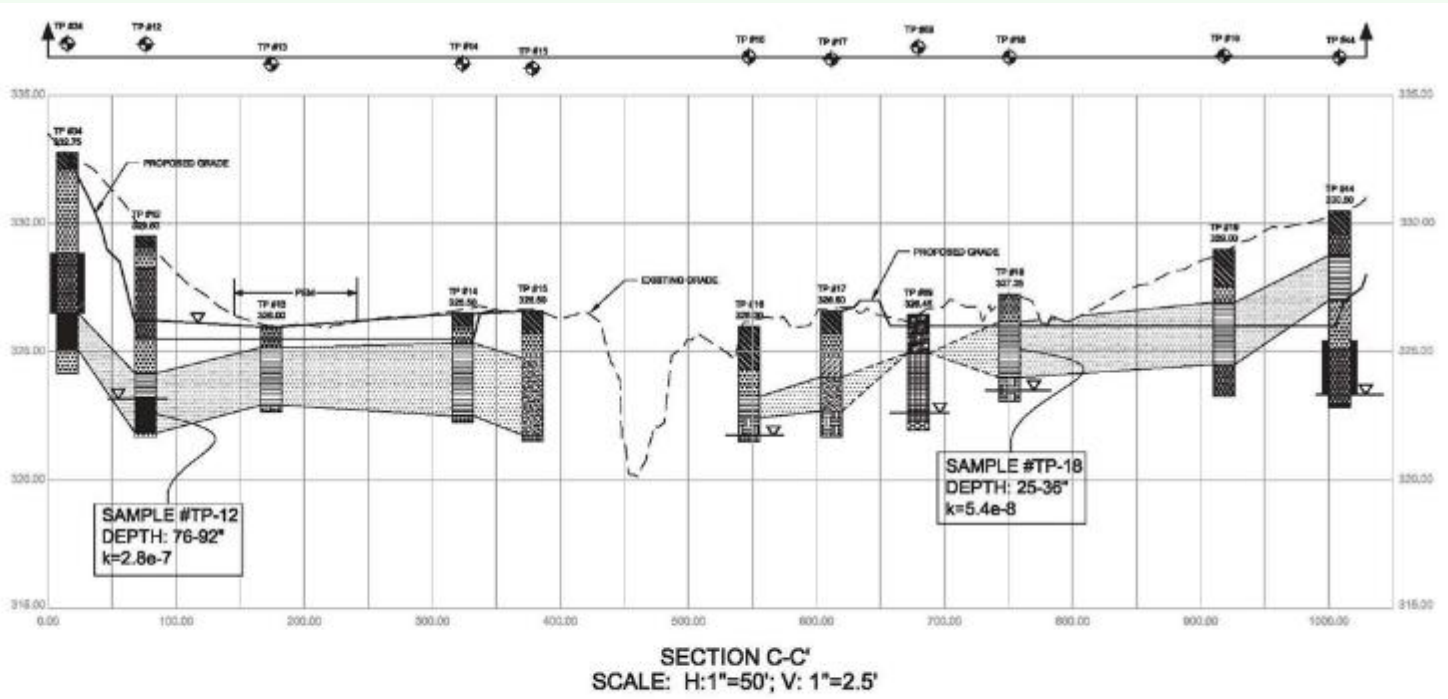
Plan Reviewer Questions for K_{sat}

- Has the waterbudget evaluated the sensitivity of the design to the likely Order of Magnitude variability of the K_{sat} ?

- Does Grading Plan consider where the soils type are vs. grading plan?







SECTION C-C'
SCALE: H:1"=50'; V: 1"=2.5'

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Additional Plan Reviewer Question for K_{sat}

- Is the K_{sat} utilized logical based on soil type?
  - Classic error of using 10^{-6} cm/sec regardless of soil type – *Reservoir story….*
  - How was it determined? Require documentation
  - Did someone look at the soil and assess/test K_{sat}? FEEL THEM!!

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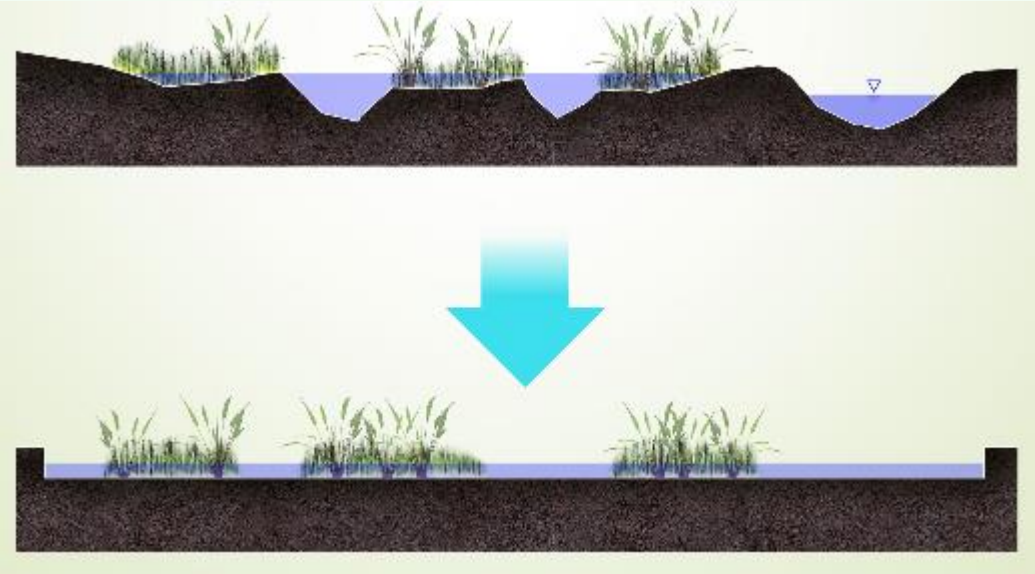
Surface Water: Storage (S_t) and Outflow (S_o)

- $S_o = P + S_I + OB + G_I - ET - S_t - G_O$
- Can the Outflow (S_o) system handle large storm events (i.e. 100 year or greater?)
- S_t is calculated from the design grading plan topography and outlet weir invert elevation
- Does the Grading Plan reflect the S_t used?
- Are the selected plant species reflective of the expected water regimes?



Q4. Is there resiliency in the system to account for the extreme variability in the data input and (lack of) precision of the model?

- Waterbudgets are not going to be exact – and weather patterns vary.
- Most Inputs/outputs will vary +/-50%, some by Order of Magnitude! – use Sensitivity Analysis to demonstrate design resiliency
- Need to be able to easily adjust design if the site is too wet/dry – Adaptive management

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Conclusion of "Red Flag" Review for Hydrology and Soils

- If we get the waterbudget correct – the desired wetlands and soils usually follow…(proper plant selection and soil handling, make it even better!)

- So success is more likely to occur if the plan reviewer can confirm that:

  - **The Design Target Hydrograph is representative of the type of wetlands desired;**

  - **The water budget model mimic the site's design and landscape position;**

  - **The model utilizes scientifically estimated components <u>for this site</u>; and**

  - **There is resiliency in the system's design to account for the extreme variability in the data input and lack of precision of the model – and that adaptive management techniques are easily applied to achieve success if the initial target hydrograph is not achieved.**

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Thank you for your attention