Mine Reclamation Applications of a New Water Budget Model: Wetbud

W. Lee Daniels

Dept. of Crop & Soil Environmental Sciences

http://www.landrehab.org/WETBUD

Who's doing what?

Zach Agioutantis, Univ. of Kentucky -- Programmer & MODFLOW

W. Lee Daniels, Virginia Tech -- Program coordinator & gadfly

Ben Hiza, Old Dominion University – Julie Metz models / groundwater

Stephen Stone, Old Dominion University – Huntley Meadows models

Tess Thompson, Virginia Tech – Surface water & ET estimators

Rich Whittecar, Old Dominion University – Groundwater & MODFLOW

Previous Graduate Students: Kerby Dobbs, Matt Gloe, John McCleod, Eric Neuhaus, O. Waverly Parks, Candice Piercy, Tracy Thornton, Cal Smith

Research Associates/Specialists: Dan Evans, Katie Haering, Sara Klopf and Laura Lehman.

Objectives

- **Review brief history of "water budgeting issues" for wetland creation in the mid-Atlantic region of the USA.**

- **Describe the development and basic structure of our new water budget model – Wetbud**

- **Provide an overview of Wetbud's data requirements, functions and outputs that are potentially useful for mining applications.**

Aylett Sand & Gravel Mine in October 1998

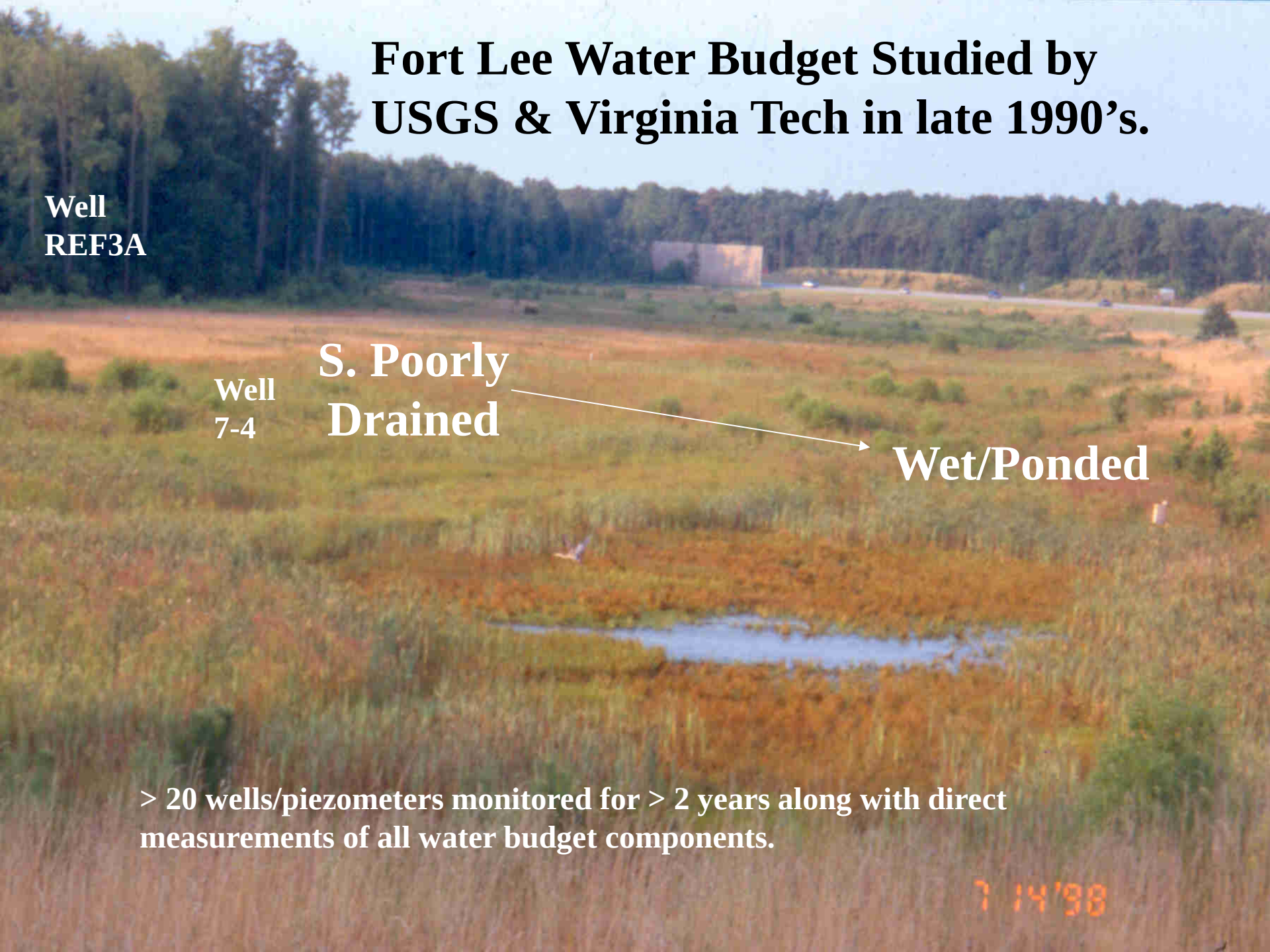
Results in Daniels et al. (ASMR 2002)

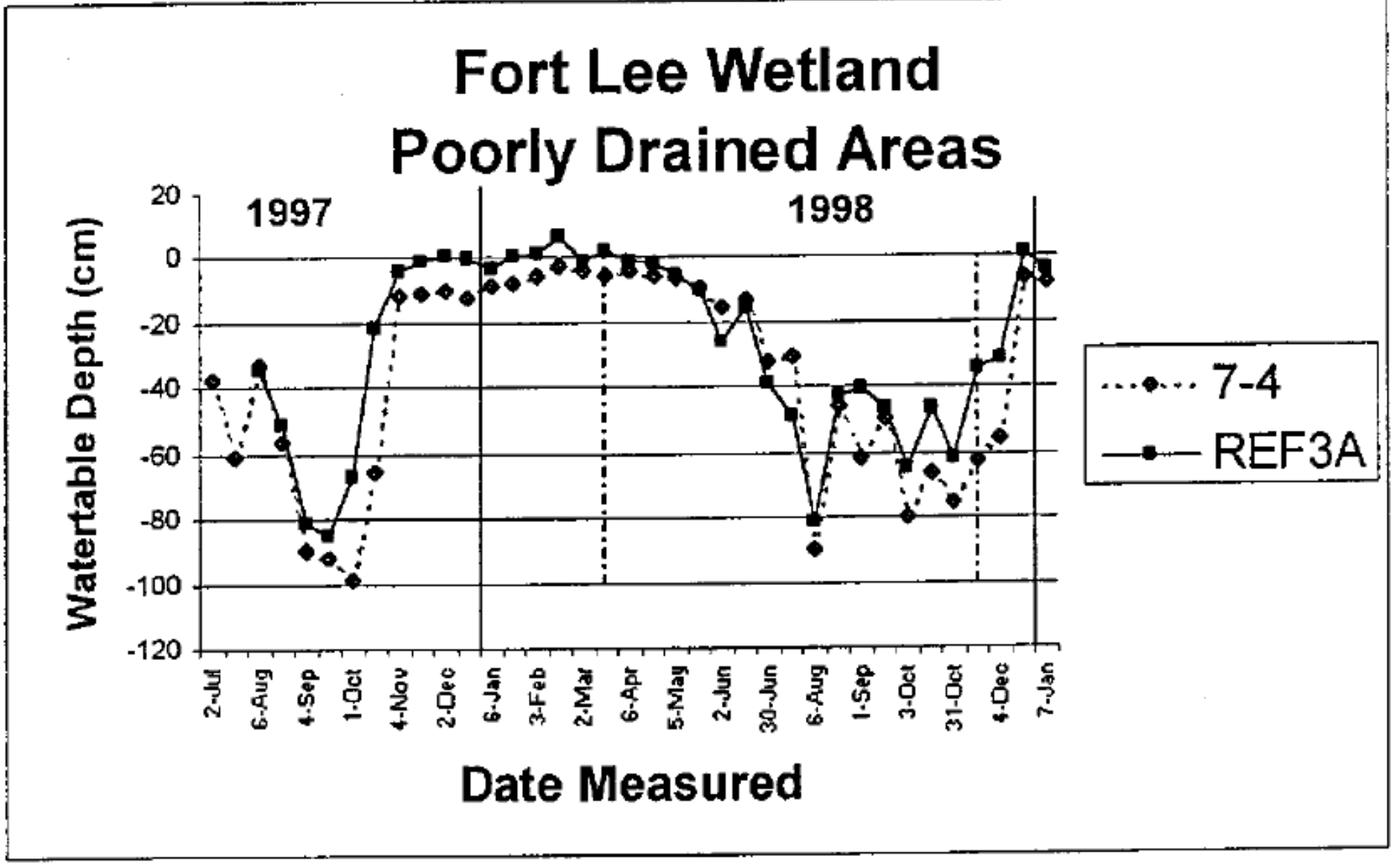
Western portion of site in April of 1999 following revegetation. Site was chosen as potential for building created wetlands for mitigation of impacts to widening of US 460 (never happened).

Created Wetland Water Budgeting

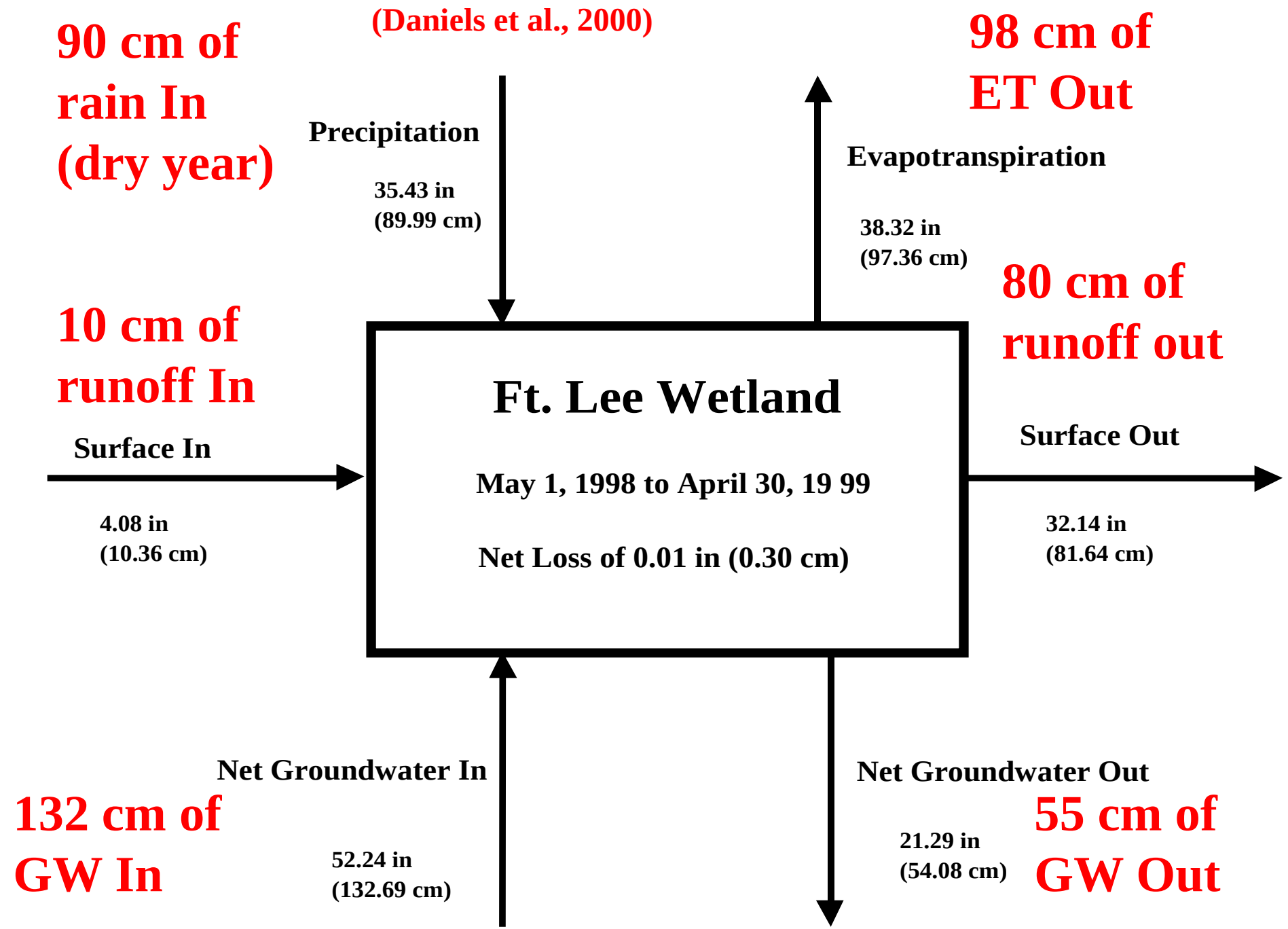
- **Wide variation in water budgeting approaches among agencies and consultants.**

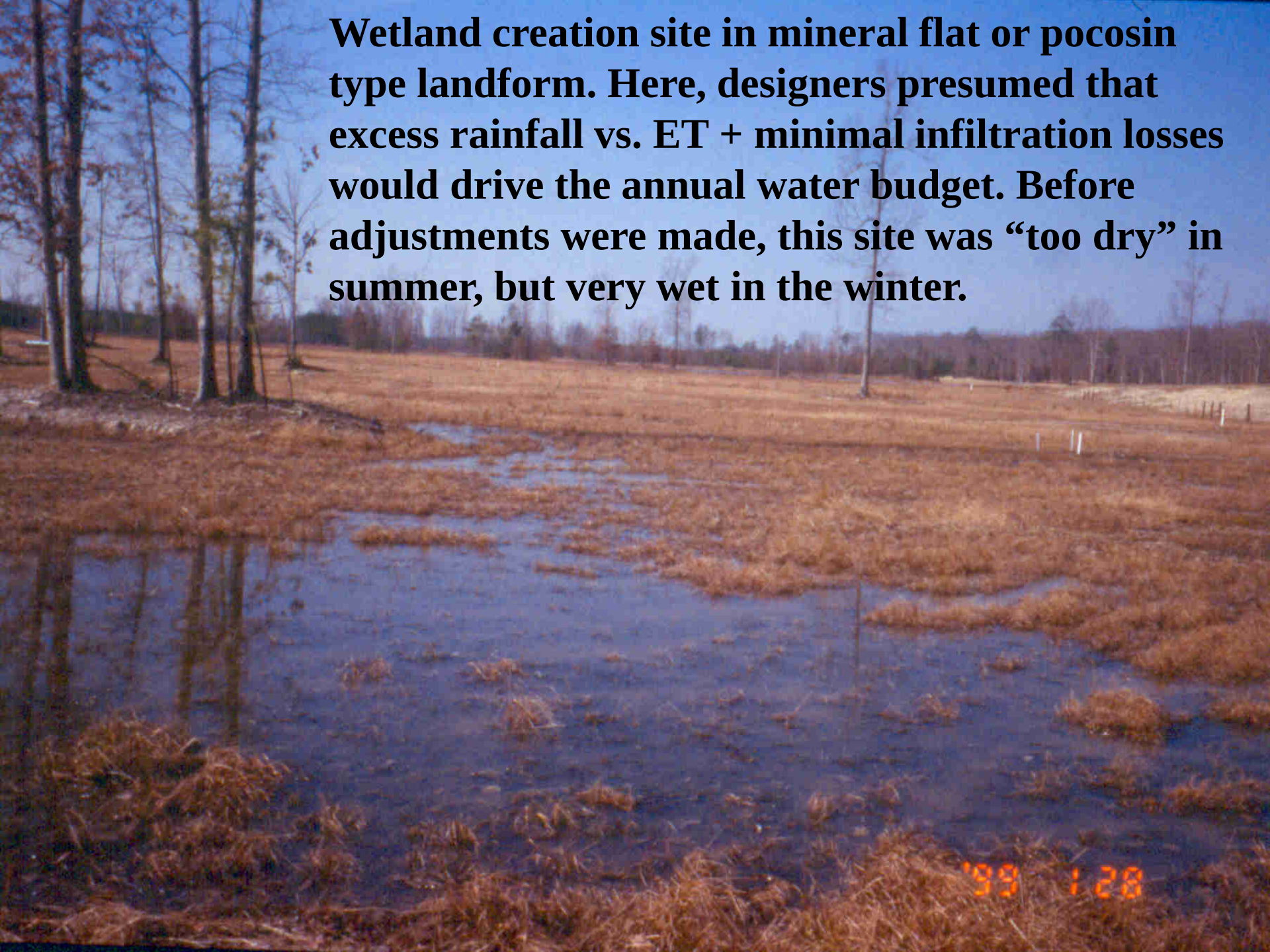
- **Many agencies follow and/or recommend variations of the "Pierce Approach" whereby ground water flux is presumed minimal, ET is estimated via Thornthwaite, runoff additions are estimated via SCS/NRCS Runoff Curve Number Method, water is presumed to be detained over the site via a berm, and water level is controlled via an outlet, etc.**


Fort Lee Water Budget Studied by USGS & Virginia Tech in late 1990's.
Well REF3A
Well 7-4
S. Poorly Drained
Wet/Ponded
> 20 wells/piezometers monitored for > 2 years along with direct measurements of all water budget components.
7 14'98



Hydroperiod of created soil vs native soil at Ft. Lee; the mitigation site soil was dominated by fac upland vegetation. Only ~20% of the site was characterized by this type of hydroperiod.

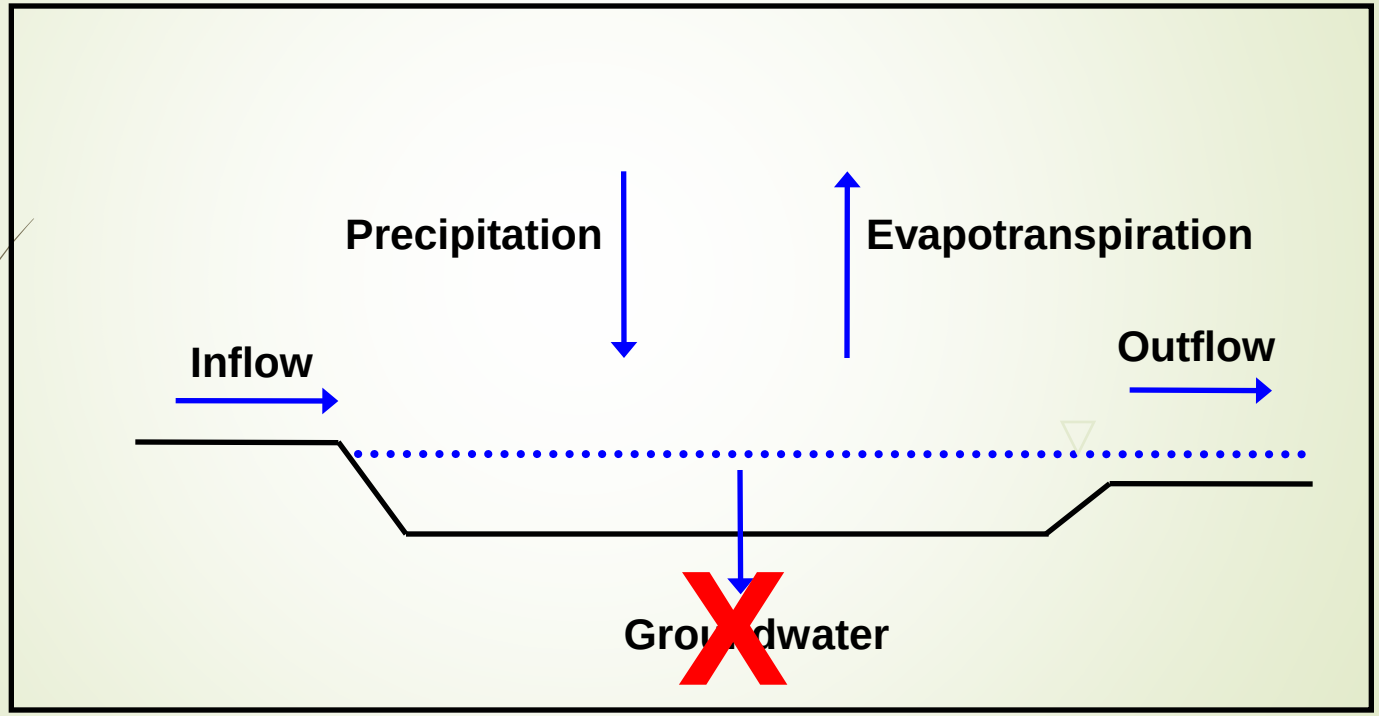

90 cm of rain In (dry year)
(Daniels et al., 2000)
98 cm of ET Out
Precipitation
35.43 in (89.99 cm)
Evapotranspiration
38.32 in (97.36 cm)
80 cm of runoff out
10 cm of runoff In
Ft. Lee Wetland
Surface In
May 1, 1998 to April 30, 19 99
Surface Out
4.08 in (10.36 cm)
Net Loss of 0.01 in (0.30 cm)
32.14 in (81.64 cm)
Net Groundwater In
Net Groundwater Out
132 cm of GW In
52.24 in (132.69 cm)
21.29 in (54.08 cm)
55 cm of GW Out



Wetland creation site in mineral flat or pocosin type landform. Here, designers presumed that excess rainfall vs. ET + minimal infiltration losses would drive the annual water budget. Before adjustments were made, this site was “too dry” in summer, but very wet in the winter.

A commonly employed “simple” way to create a mitigation wetland is to create a perched system

Can work on hilltops with low permeability intentionally compacted subsoils



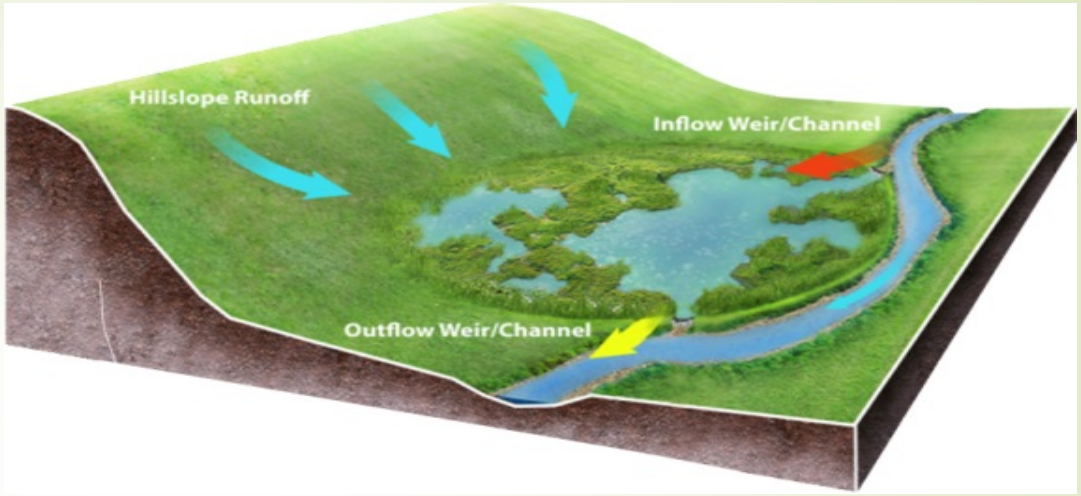
assume negligible

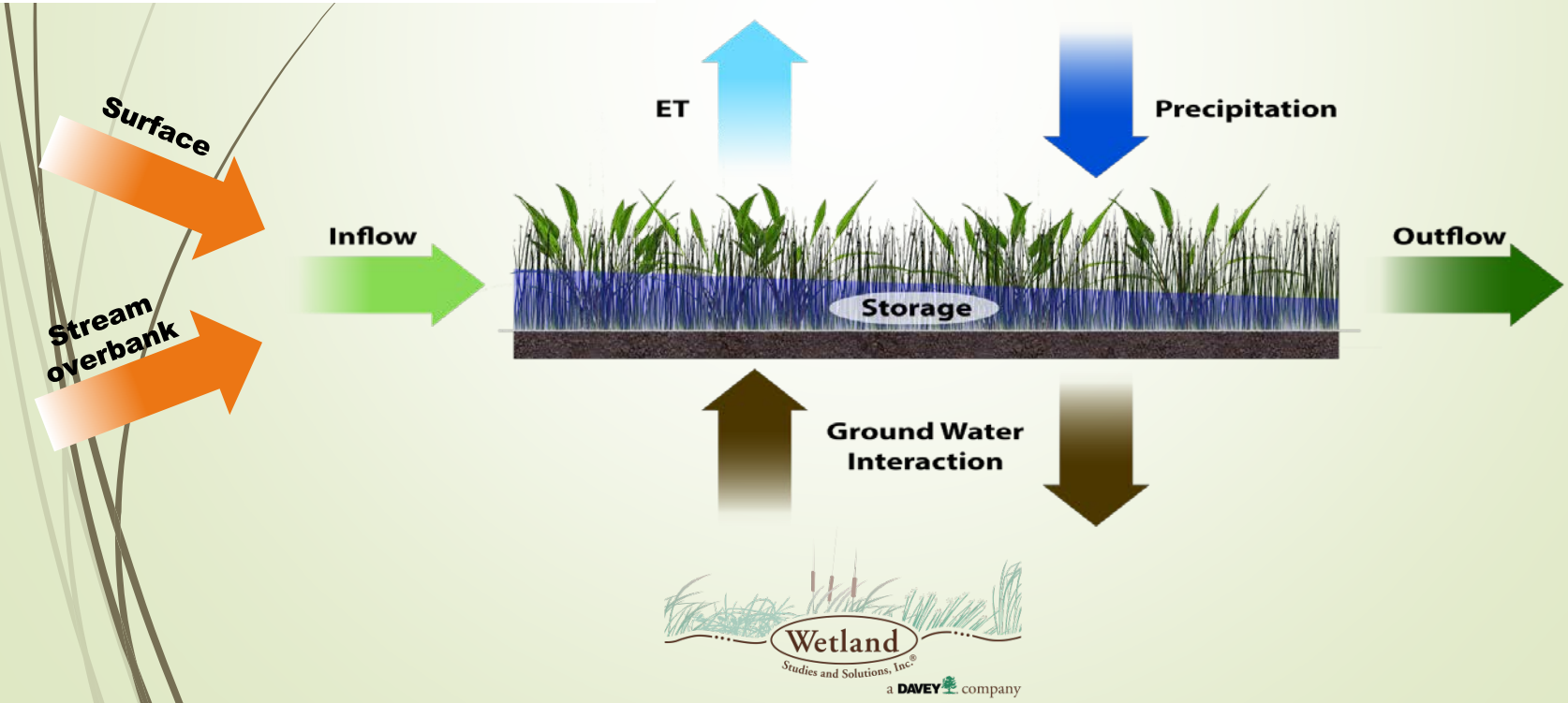
Surface soil from an anonymous 3-year old mitigation wetland.

Note massive structure in surface breaking to firm plates at about 20 cm. This is the “traffic pan” that was designed to perch the water table, but also led to extremely dry summer conditions.

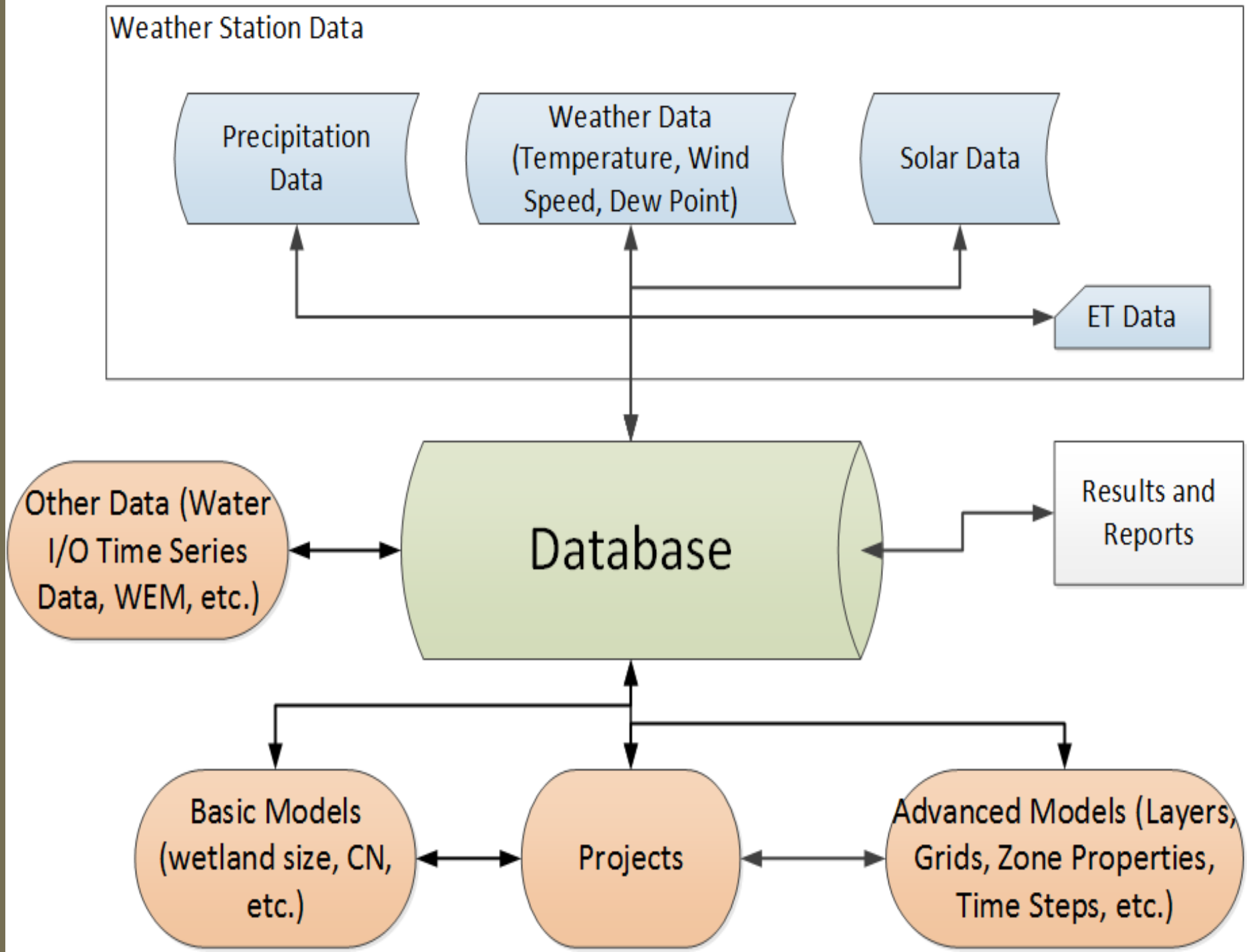
Water Budget Model Issues Addressed by Wetbud

- "Bath Tub" vs. Sloped Systems
- Vegetative Flow Resistance
- Groundwater Inputs vs. data?
- Overbank Flow Contribution
- Which Precipitation Data?
- Variations in ET Estimators
- Complex topography



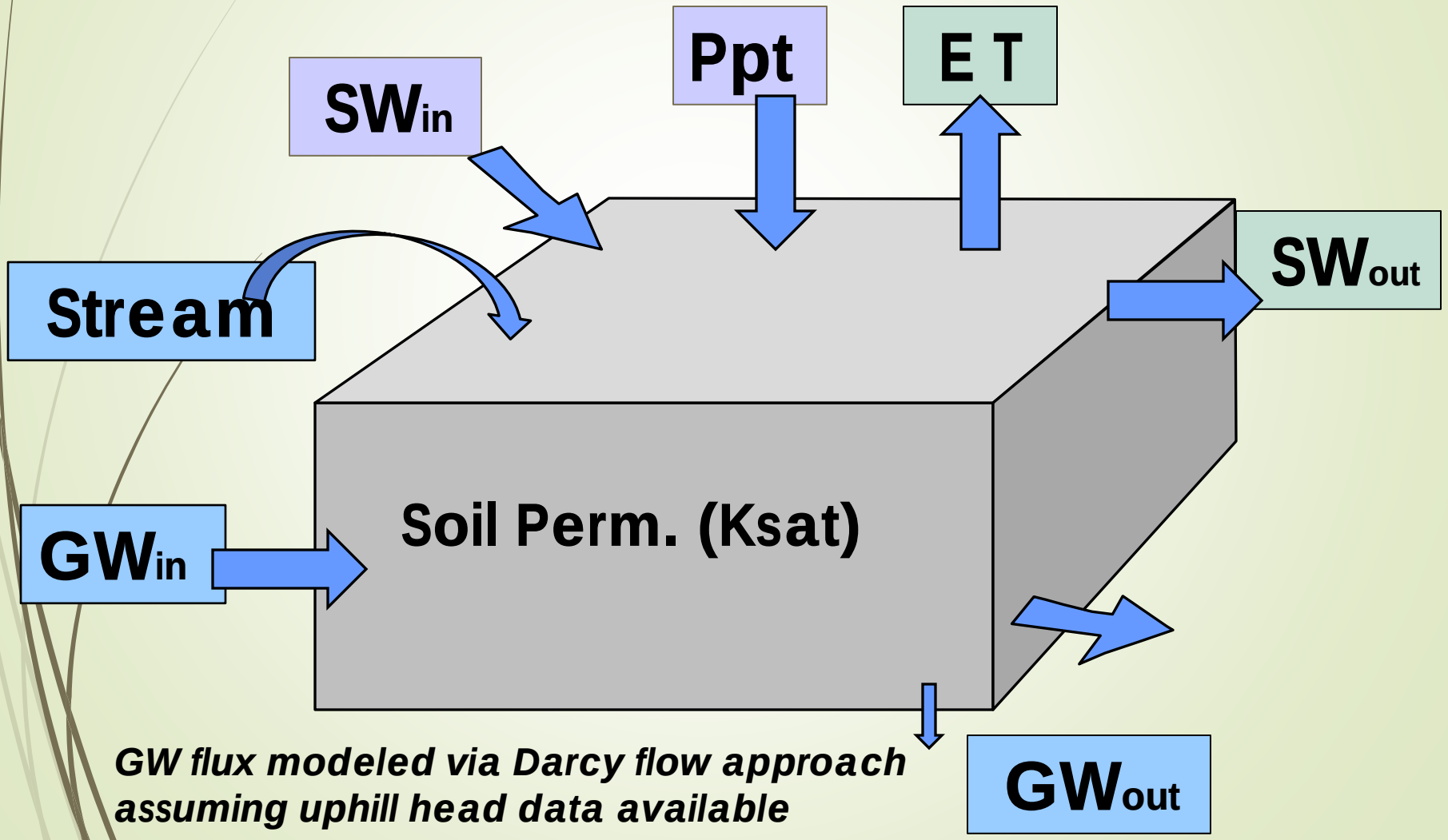


Wetbud is mass balance based water budget model that runs in a PC environment (No Mac versions yet!)


Weather Station Data
Precipitation Data
Weather Data (Temperature, Wind Speed, Dew Point)
Solar Data
ET Data
Other Data (Water I/O Time Series Data, WEM, etc.)
Database
Results and Reports
Basic Models (wetland size, CN, etc.)
Projects
Advanced Models (Layers, Grids, Zone Properties, Time Steps, etc.)

Wetbud Basic Version

Wetbud is a design tool for wetland creation



```
GSOD Dry/Normal/Wet year calculations. Procedure version 2014-11-22
Precipitation Data based on NOAA/GSOD Station: 724010
Wet / Dry / Normal Splits based on WETS Station: VA7201
Data set examined: From year: 1973
Data set examined:   To year: 2014
User input: Minimum accepted year: 1973
Dry Year Maximum Precipitation (in): 39.56
Wet Year Minimum Precipitation (in): 46.79
Records in the 30% Dry split (sorted by precipitation): 9
Year in the 30% Dry split: 1:2001-->32.29
Year in the 30% Dry split: 2:1997-->34.03
...
Records in the 40% Normal split  (sorted by precipitation): 13
Year in the 40% Normal split: 1:1981-->39.91
Year in the 40% Normal split: 2:1986-->41.75
...
Records in the 30% Wet split (sorted by precipitation): 20
Year in the 30% Wet split: 1:1977-->46.86
Year in the 30% Wet split: 2:1983-->47.56
Year in the 30% Wet split: 3:2004-->48.33
...
-------------------------------------
Starting calculations for the Dry year
Records in the 30% Dry split: 9
Median in the 30% Dry split: 5
Checking year: 1976 in slot: 5
Dry Spring Check: Score for Month: 3 is 1
Dry Spring Check: Score for Month: 4 is 1
Dry Spring Check: Score for Month: 5 is 1
Dry Spring Check: Score for Month: 6 is 1
Dry Spring Check: Total Score: 4
Spring is Dry: Year Accepted: 1976
-----------------------------------------
Starting calculations for the Normal year
Records in the 40% Normal split: 13
Median in the 40% Normal split: 7
Checking year: 1990 in slot: 7
Normal Spring Check: Score for Month: 3 is 2
Normal Spring Check: Score for Month: 4 is 2
Normal Spring Check: Score for Month: 5 is 2
Normal Spring Check: Score for Month: 6 is 3
Normal Spring Check: Total Score: 9
Spring is Normal: Year Accepted: 1990
-------------------------------------
```

Wetbud will auto download either nearest or chosen NOAA weather station data and then choose the typical Wet, Dry and Normal years out of the last 30 via an internal algorithm that has been accepted by USCOE and VA DEQ.

Wetbud

Projects Parameters Basic Models Advanced Models Reports Utilities Help

Project Wizard

Note that this is another created wetland in a sand & gravel mine. Designers here ignored GW and most of it turned into an open water system

Wetbud is freeware and available for download at www.landrehab.org/WETBUD

Current Project: None

01.04.00.69 c:\wetbud\wetbud2.fdb

Basic Model via the Wizard

- **Automatically downloads nearest applicable weather station data (30 years) in Virginia from 15 pre-selected locations and populates ppt and ET estimators for W-N-D years. Will download other data for other states, but "data clean-up" is required.**

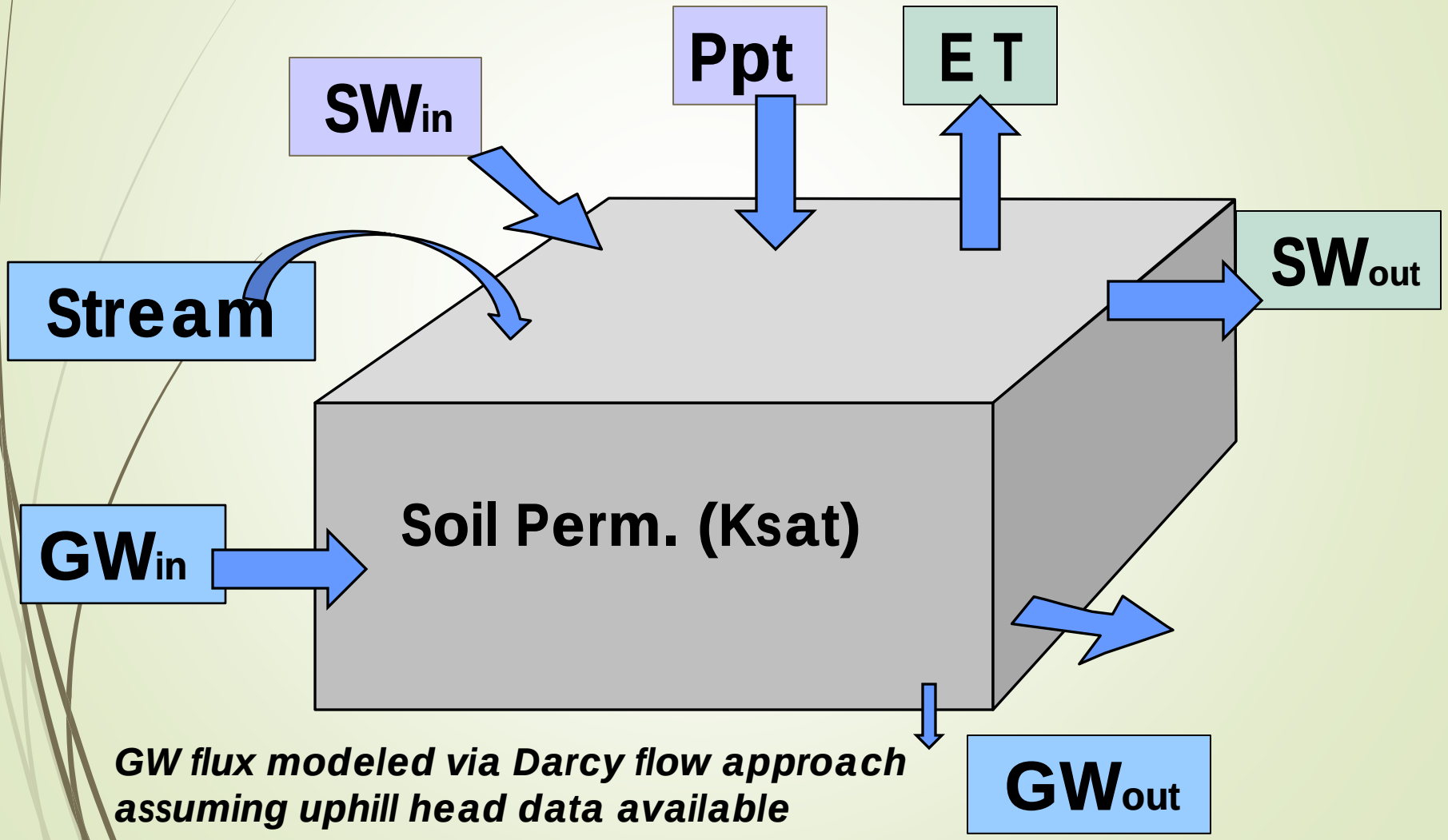
- **In Wizard mode, assumes no overbank and GW input; assumes GW losses at 1"/month.**

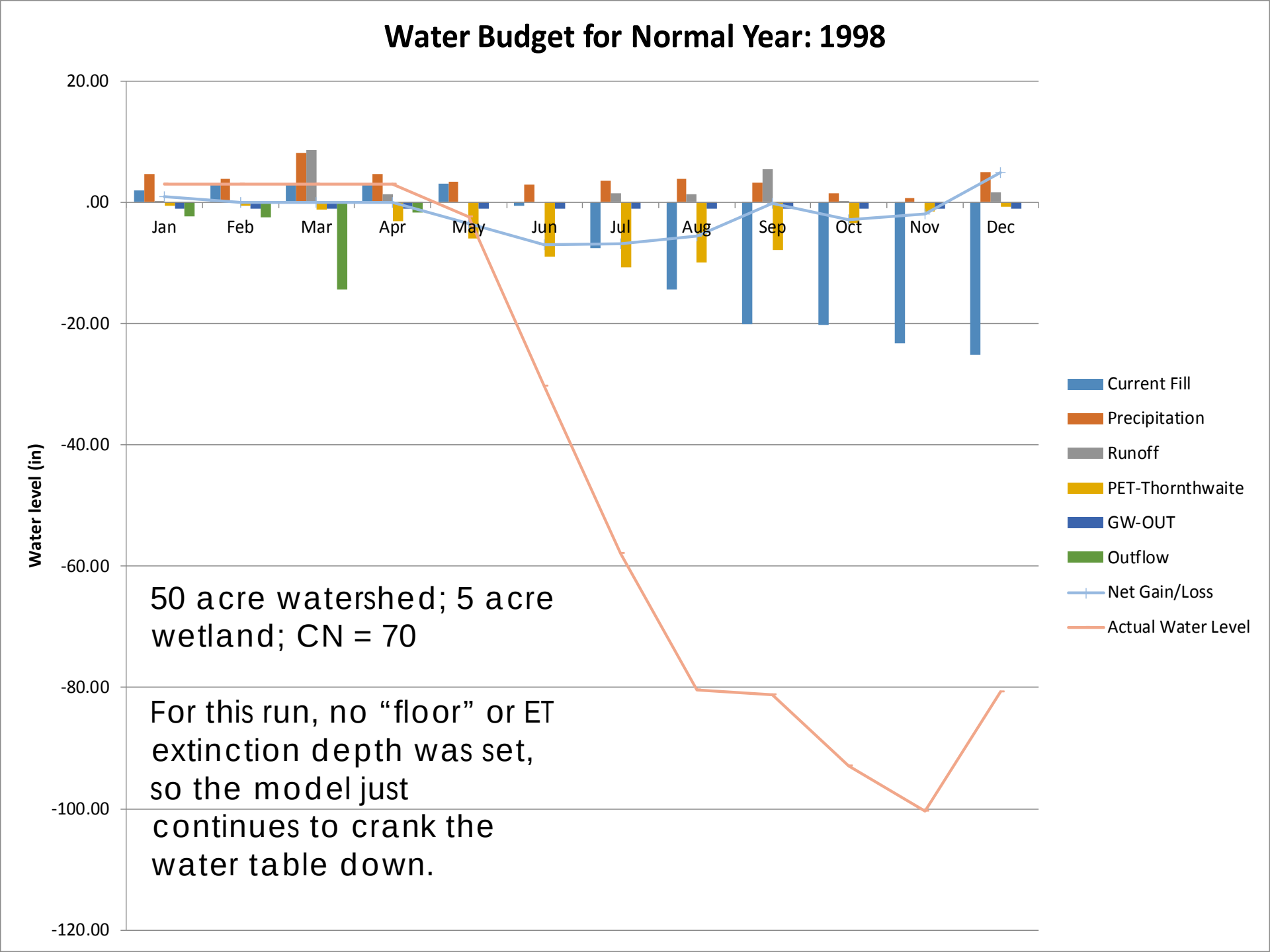
- **User inputs wetland and watershed size and runoff CN.**

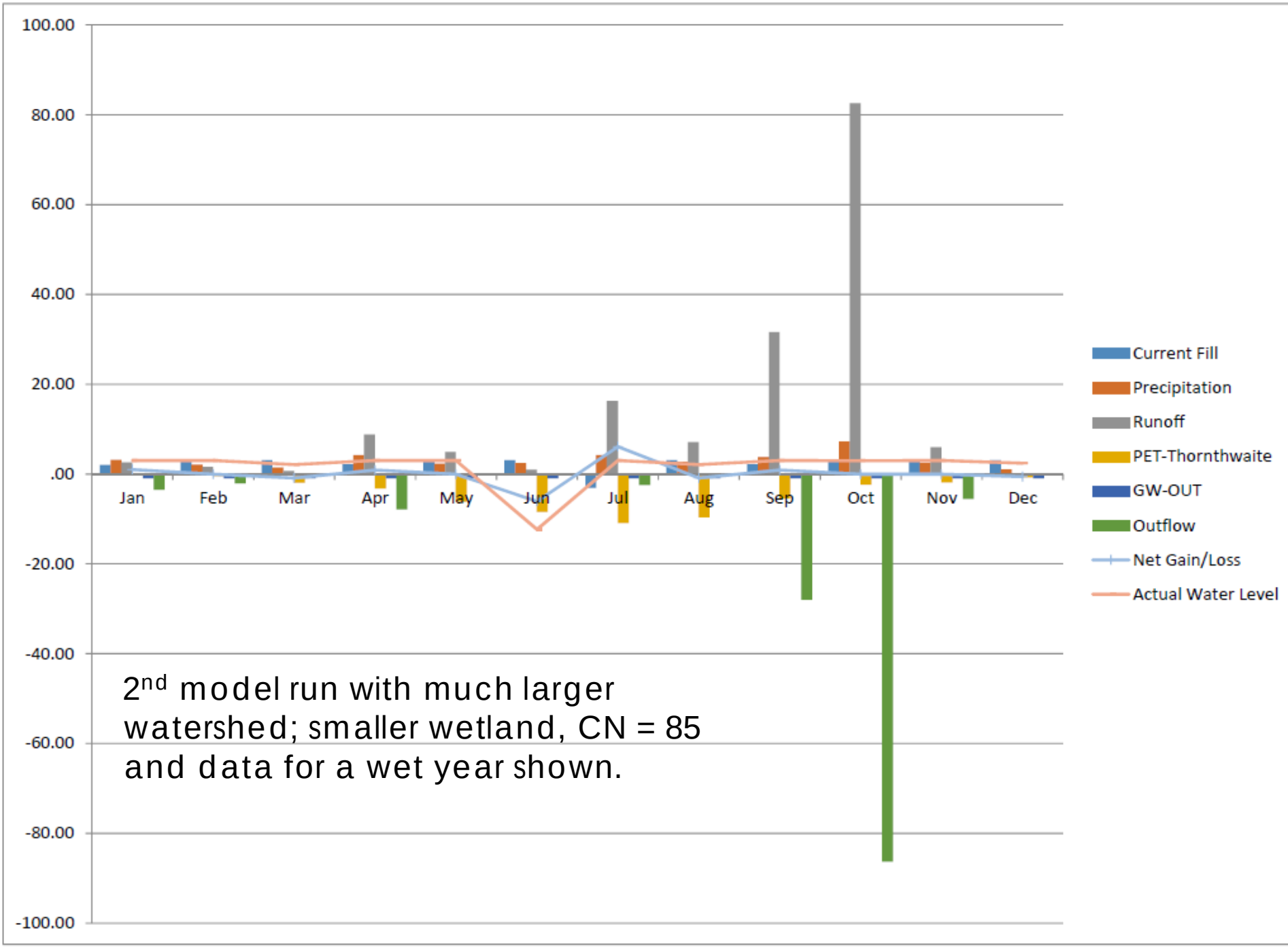
- **Model runs in < 5 minutes once simple inputs are made. Daily time-step but results are charted monthly.**

Wetbud Basic Version

Wetbud is a design tool for wetland creation




Water Budget for Normal Year: 1998
20.00
.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
Water level (in)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Current Fill
Precipitation
Runoff
PET-Thornthwaite
GW-OUT
Outflow
Net Gain/Loss
Actual Water Level
50 acre watershed; 5 acre wetland; CN = 70
For this run, no “floor” or ET extinction depth was set, so the model just continues to crank the water table down.


100.00
80.00
60.00
40.00
20.00
.00
-20.00
-40.00
-60.00
-80.00
-100.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Current Fill
Precipitation
Runoff
PET-Thornthwaite
GW-OUT
Outflow
Net Gain/Loss
Actual Water Level
2nd model run with much larger watershed; smaller wetland, CN = 85 and data for a wet year shown.

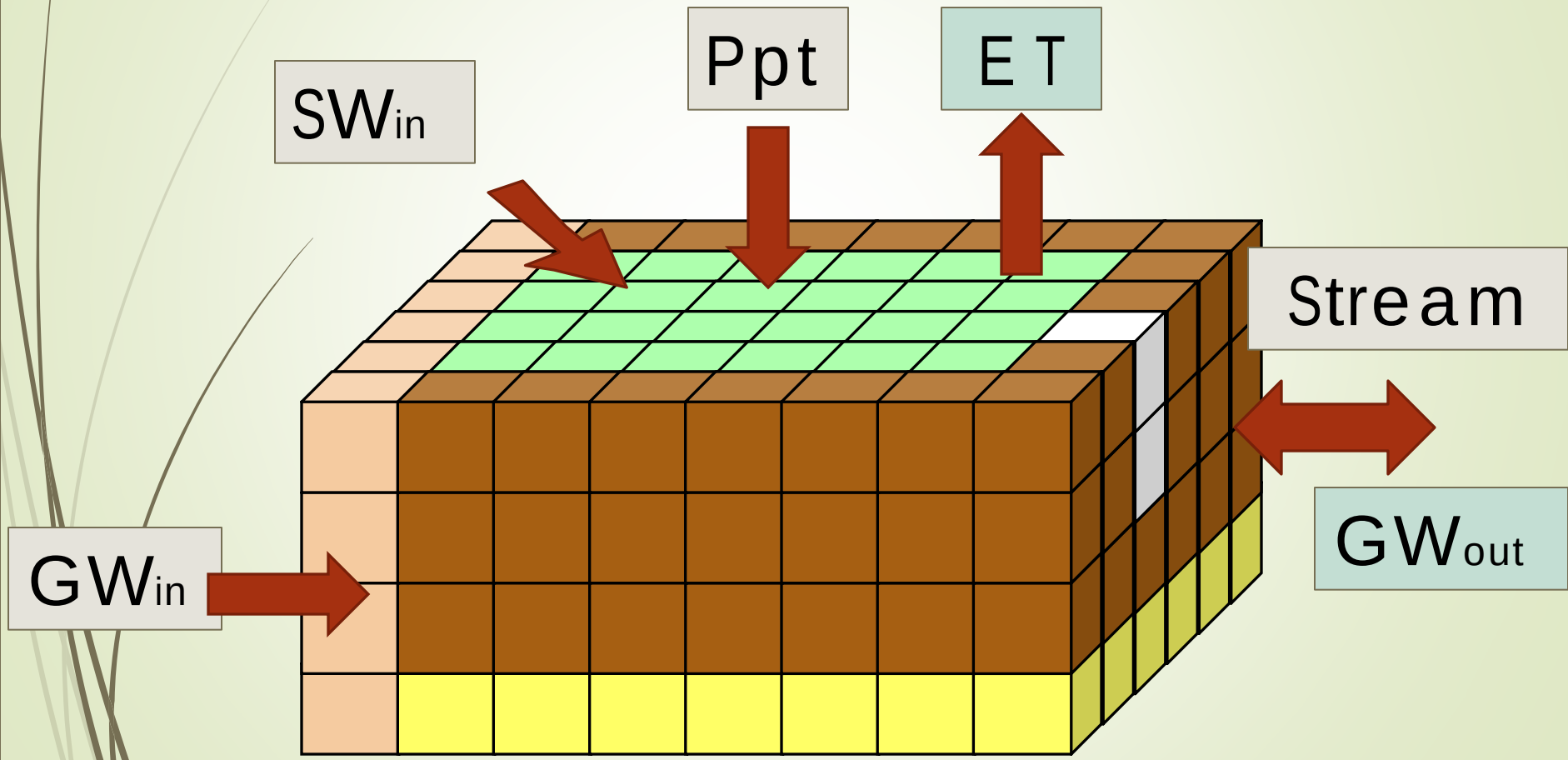
Wetbud Advanced Version

Allows for 3-D modeling including multiple water/soil/substrate layers, slopes, variable wetland topography, etc.

Incorporates more rigorous groundwater flux modeling via MODFLOW (basic model uses a simplified Darcy approach)

Generates daily models of water surface topography in 3D or for any cross-section. Will generate detailed hydroperiod prediction for any location in wetland.

WetBud – Advanced Version



Model and Component Validation & Calibration

Huntley Meadows – Fairfax
(detailed ET x 4 and GW studies)

Northfork Bank – Haymarket
(basic model + overbank flow)

Cedar Run 3 – W. of Quantico

Others at Julie Metz, Bender Farms, Pocahontas, etc.

Wetland Studies and Solutions, Inc.®
a DAVEY company

Advanced Model Output for Project: PSF_Example

Code	Description
1_Lyr_Ex	Example with a singl
5_Lyr_Ex	Includes vegetation
5_Lyr_Ex_2	copy-Includes veget

Charts | Import Results

Layer

Row: 24/50

24

Column: 25/41

25

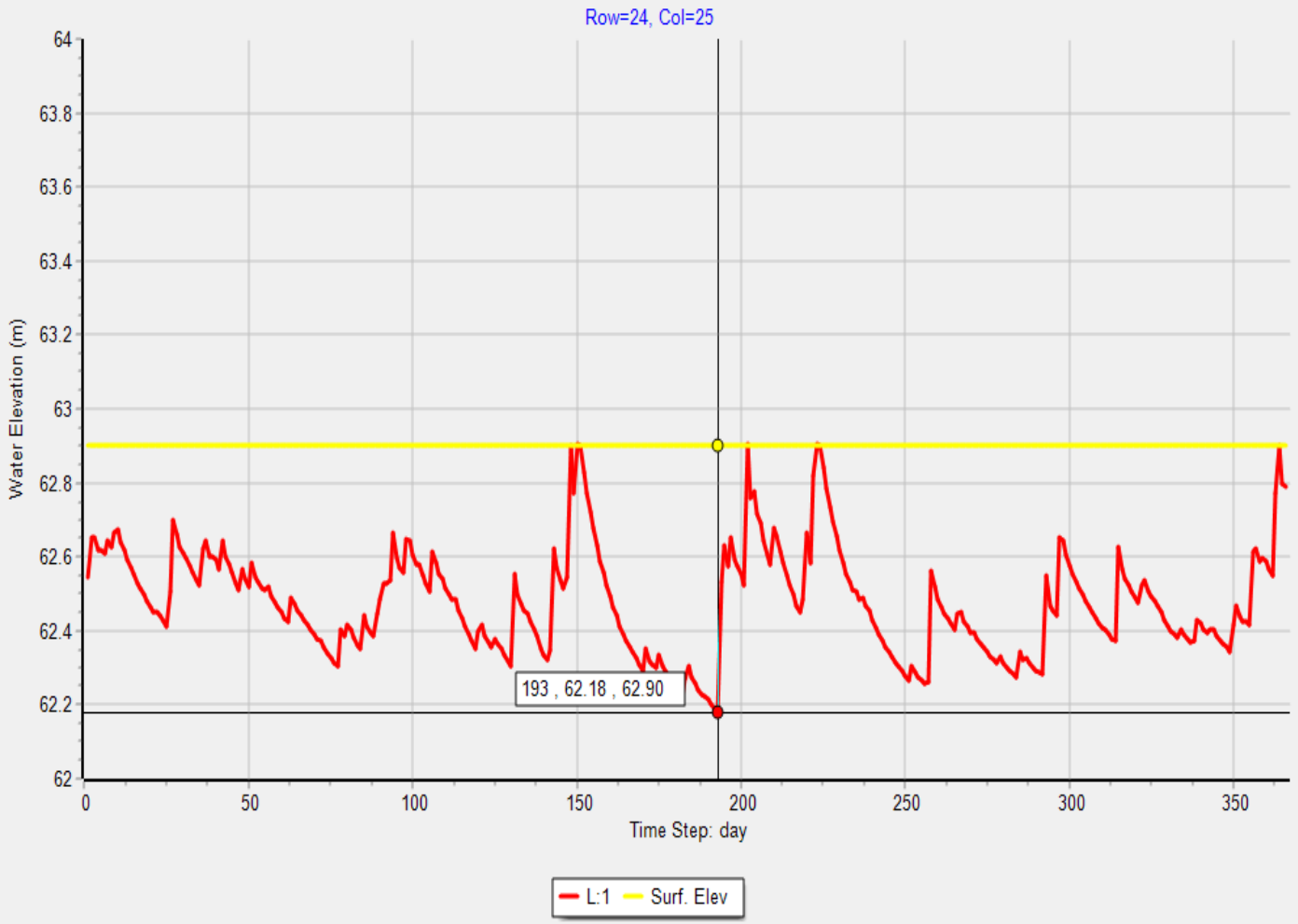
Time Step

1

Color Scale

Close

Head vs Time Step | Head along Row | Head along Col | Head at Mon. Points | Grids



1 line(s) generated

Chart Current Layer ONLY

Auto Update Chart

Do NOT Apply Preset Chart Settings

Chart Surface Elevation

Generate Chart

Export

Useful Mining Applications

- **Will automatically download NOAA weather data from nearest station (need to clean up zeros etc.)**
- **Built in algorithm will choose W-N-D years from last 30 years of complete data**
- **Automatically calculates monthly (Thornthwaite) or daily (Penman) ET**

Useful Mining Applications

- **Will run simple CN driven runoff estimates for receiving basins or you can add custom hydrograph data**
- **Internal model (Wem) will generate 30-year estimates of water table fluctuations if you can provide 6 months to 1 year of daily data for an upgradient “good responsive well”**
- **Of course, it will also generate a wetland water budget!**

Where do I get Wetbud?

- The latest versions is always available at www.landrehab.org/WETBUD
- The download is simple, but you need to wait while it loads and processes.
- You will also see a database program called “Firebird” being installed; that’s ok.

Acknowledgments

- **Funds for various portions of this research were provided by Wetland Studies and Solutions Inc. and the Peterson Family Foundation.**

- **Thanks to all the students, post-docs and research staff cited in this talk. Too many to list!**

- **I particularly want to thank Jim Perry (VIMS) for his input over the past 20 years.**