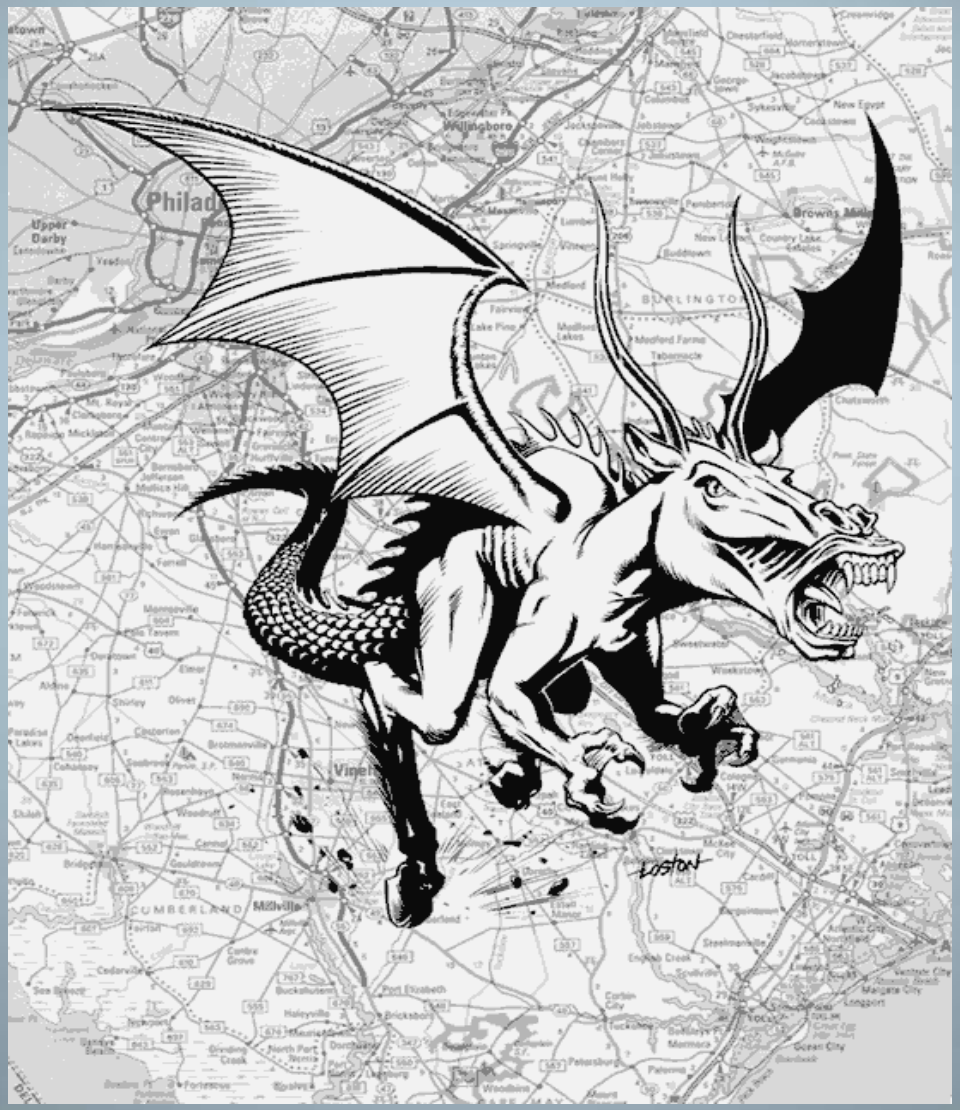
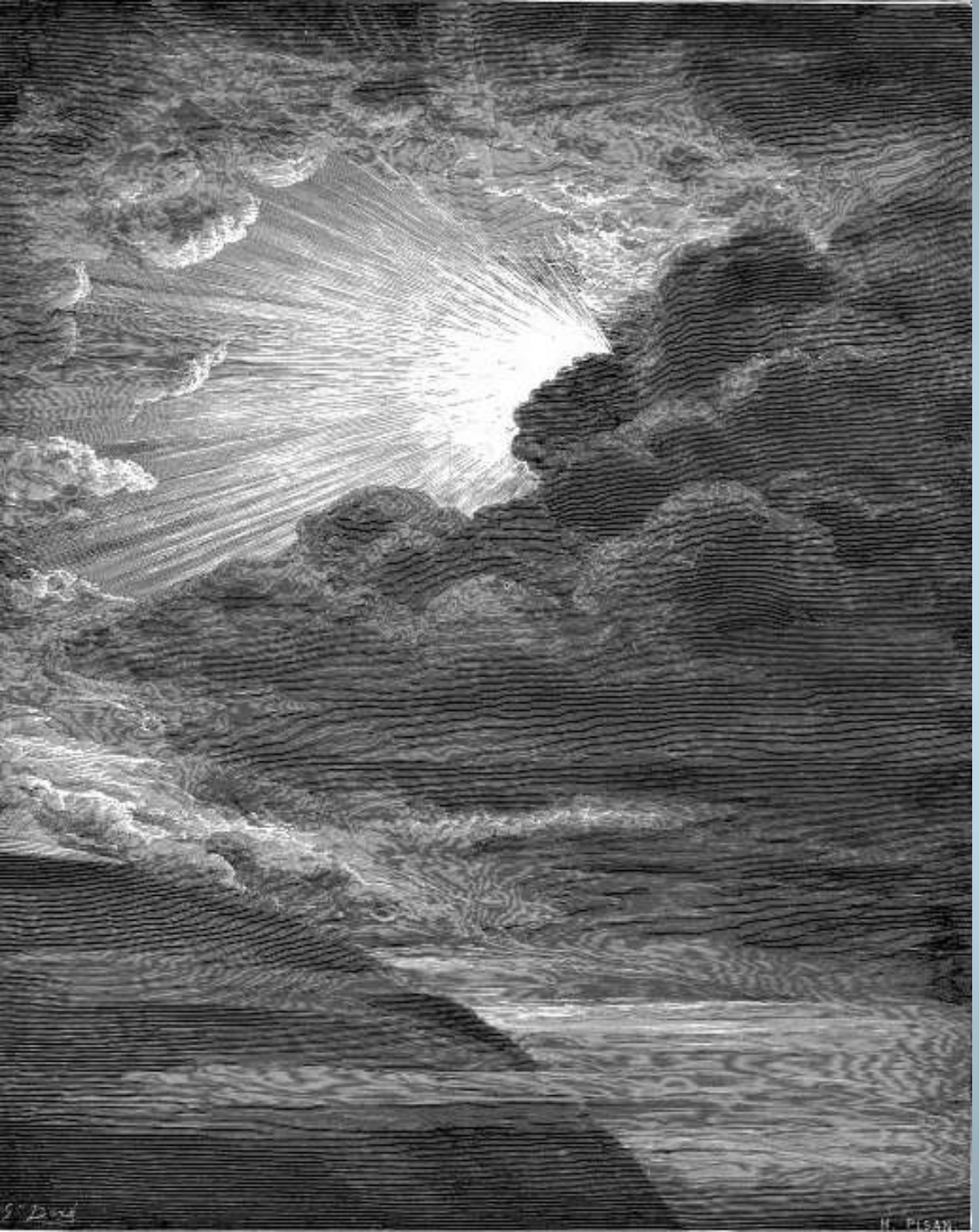
Non-Human Water Supply
- Or -

Evapotranspiration:

The Parameter from Hell





Let's Shed a Little Light on the Subject

Hydrologic Cycle

Output:

1. Evaporation & Transpiration

Input : Precipitation

2. Surface Runoff

3. Groundwater Recharge

- *No light to see it*
- *Too small a space to be there*
- *Moves too slow to observe*

How easy is it to determine the four parts of the Hydrologic Cycle?

Precipitation

Evapotranspiration

Surface Runoff

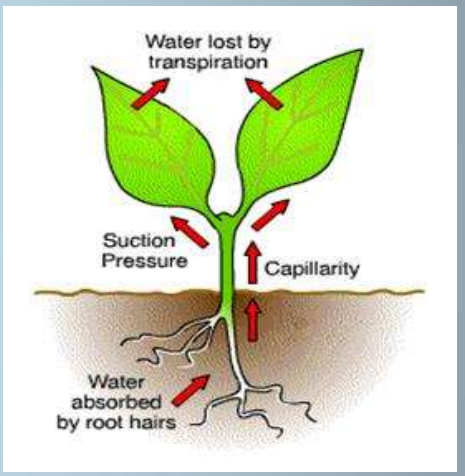
Groundwater Recharge

Why is determining evapotranspiration such a *bear* ?

Evapotranspiration is really two things – Evaporation & Transpiration

Similarity

- conversion of liquid water to water vapor
- transfer from ground to atmosphere



Contrast

- Evaporation is a physical process involving weather factors ***on*** the surface (uses surface water)
- Transpiration is a botanical process involving plant physiological, soil and weather processes ***beneath*** and ***above*** the surface (uses groundwater)

Development of Evapotranspiration Equations: Unchecked variable growth

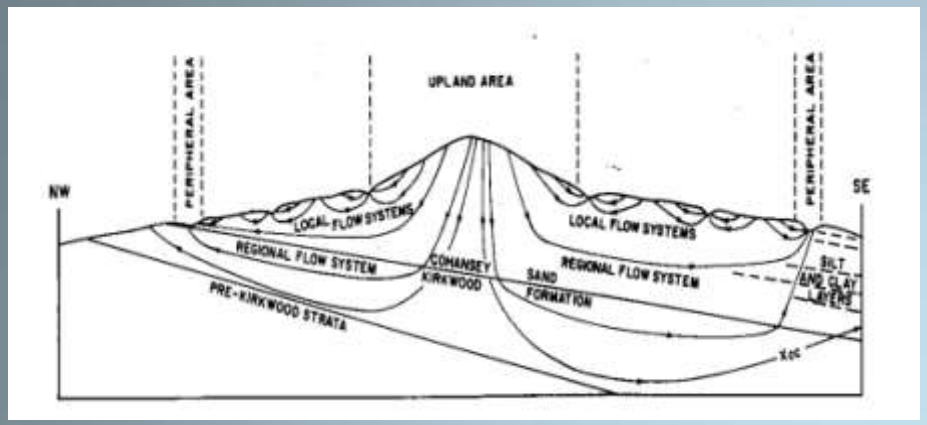
Dalton's Equation (1801)

$$E = c(e_s - e_a)$$

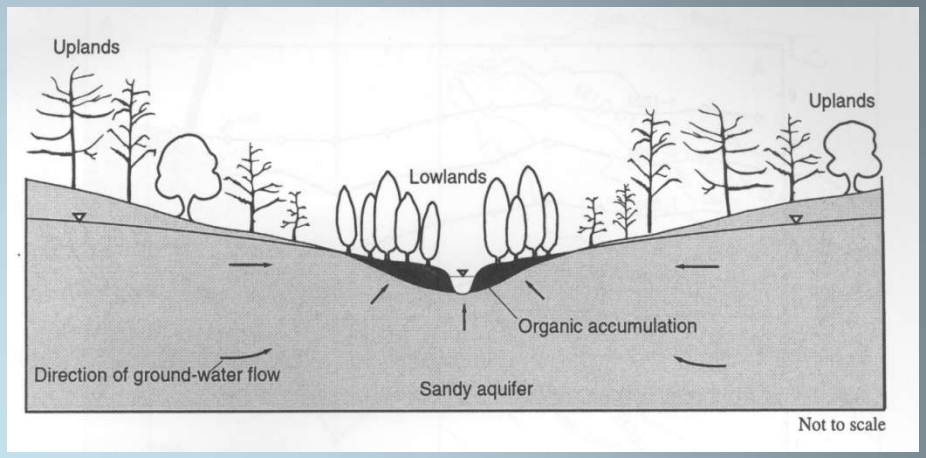
Penman-Monteith Equation (1965)

$$E = \frac{\Delta * (K + L) + \rho_a * c_a * C_{at} * e^*_a * (1 - W_a)}{\rho_w * \lambda_v * [\Delta + \gamma * (1 + C_{at} / C_{can})]}$$

Hydrologic Conceptual Models of Kirkwood –Cohansey Aquifer in NJ Pine Barrens



E.C. Rhodehamel (1970)



E.Modica (1998)

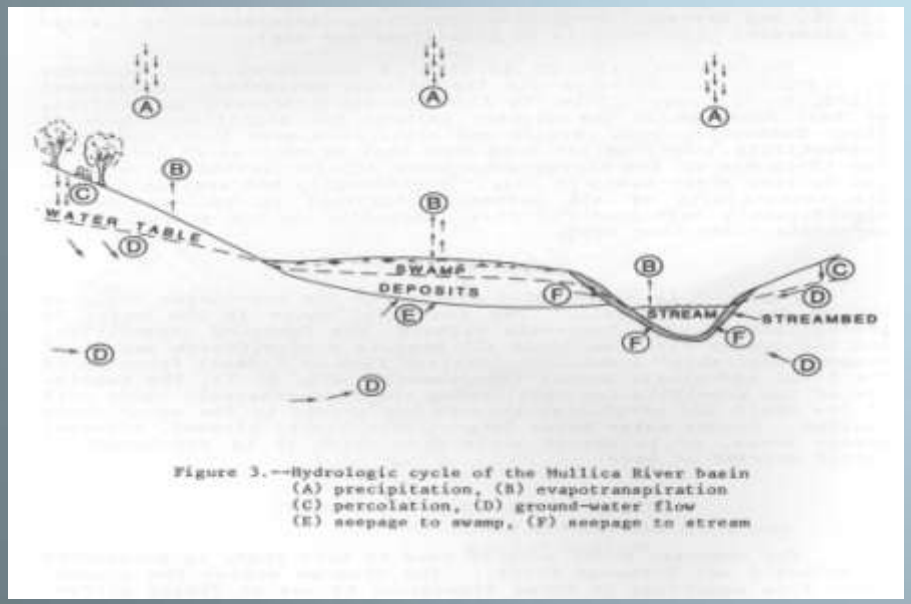
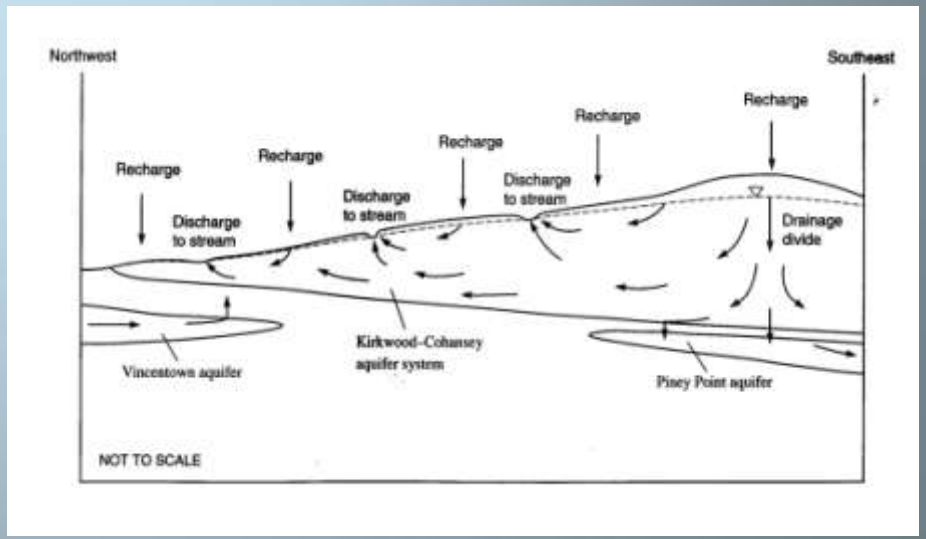


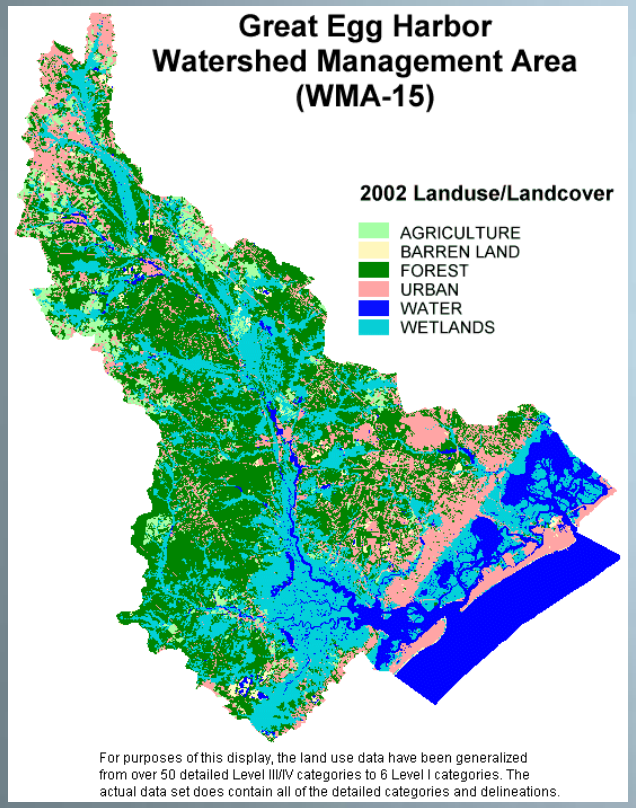
Figure 3.--Hydrologic cycle of the Mullica River basin
(A) precipitation, (B) evapotranspiration
(C) percolation, (D) ground-water flow
(E) seepage to swamp, (F) seepage to stream

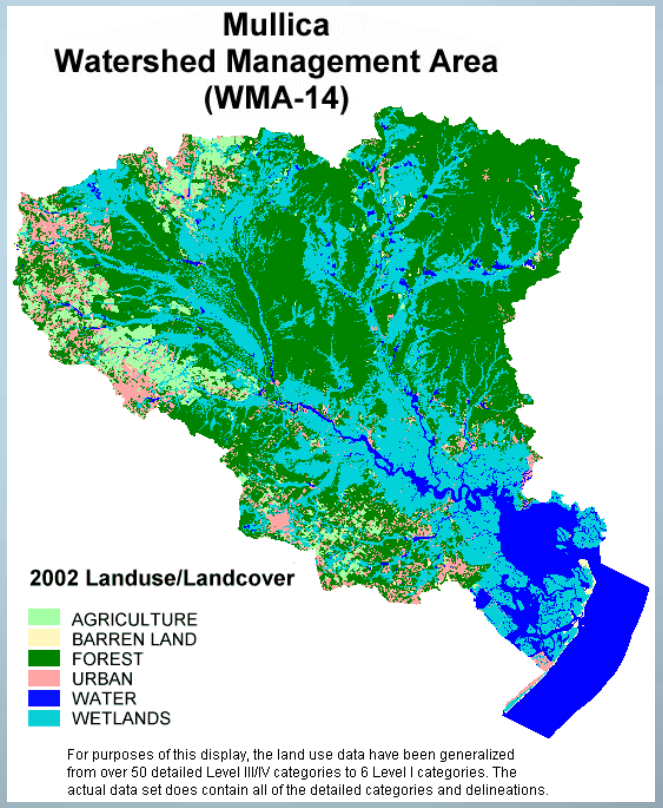
A.W. Harbaugh & C.L. Tilley (1984)



E. Modica (1996)

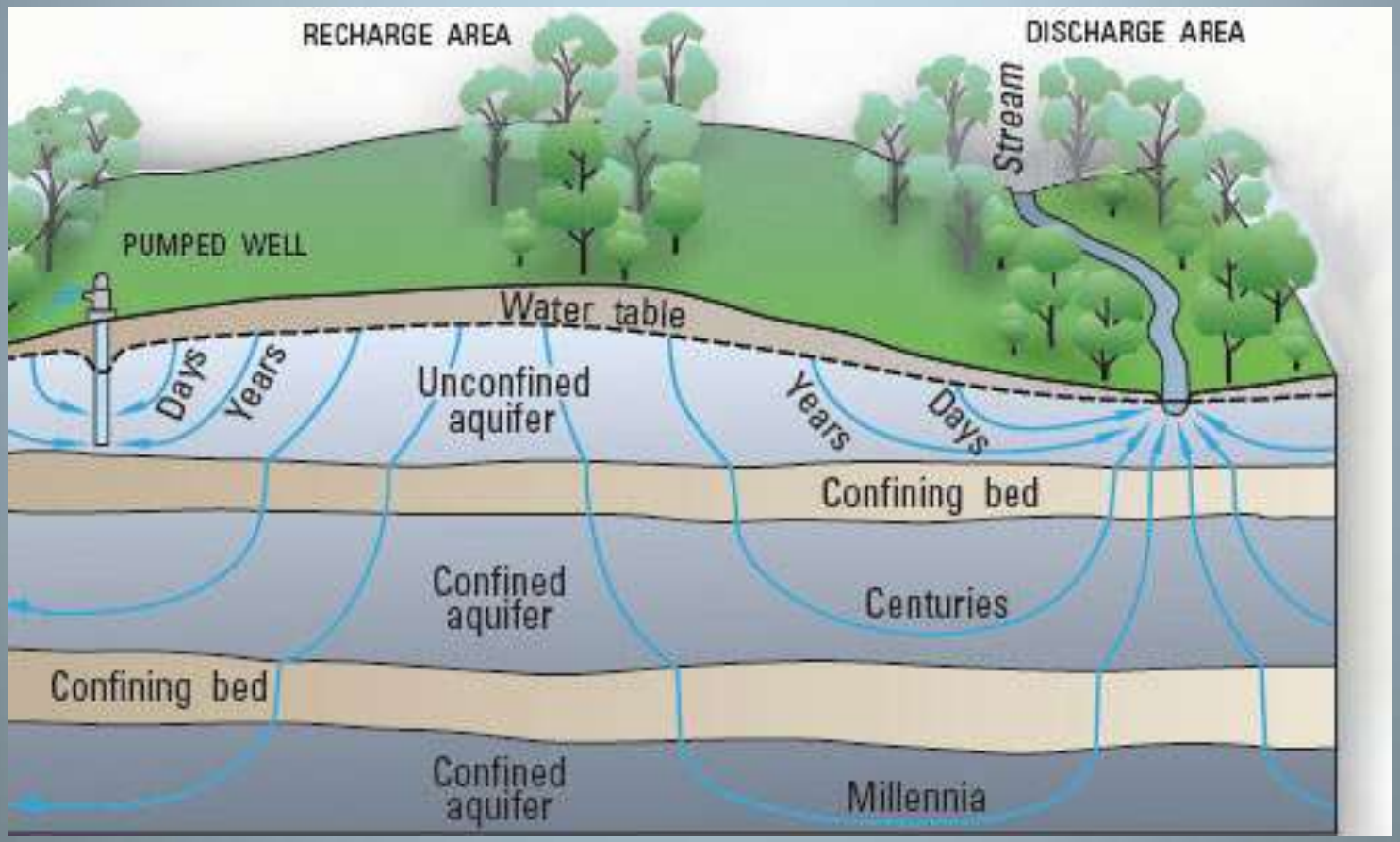
Pine Barrens Land Use in Selected Watershed Management Areas





The Nature of Pine Barrens Discharge Zones

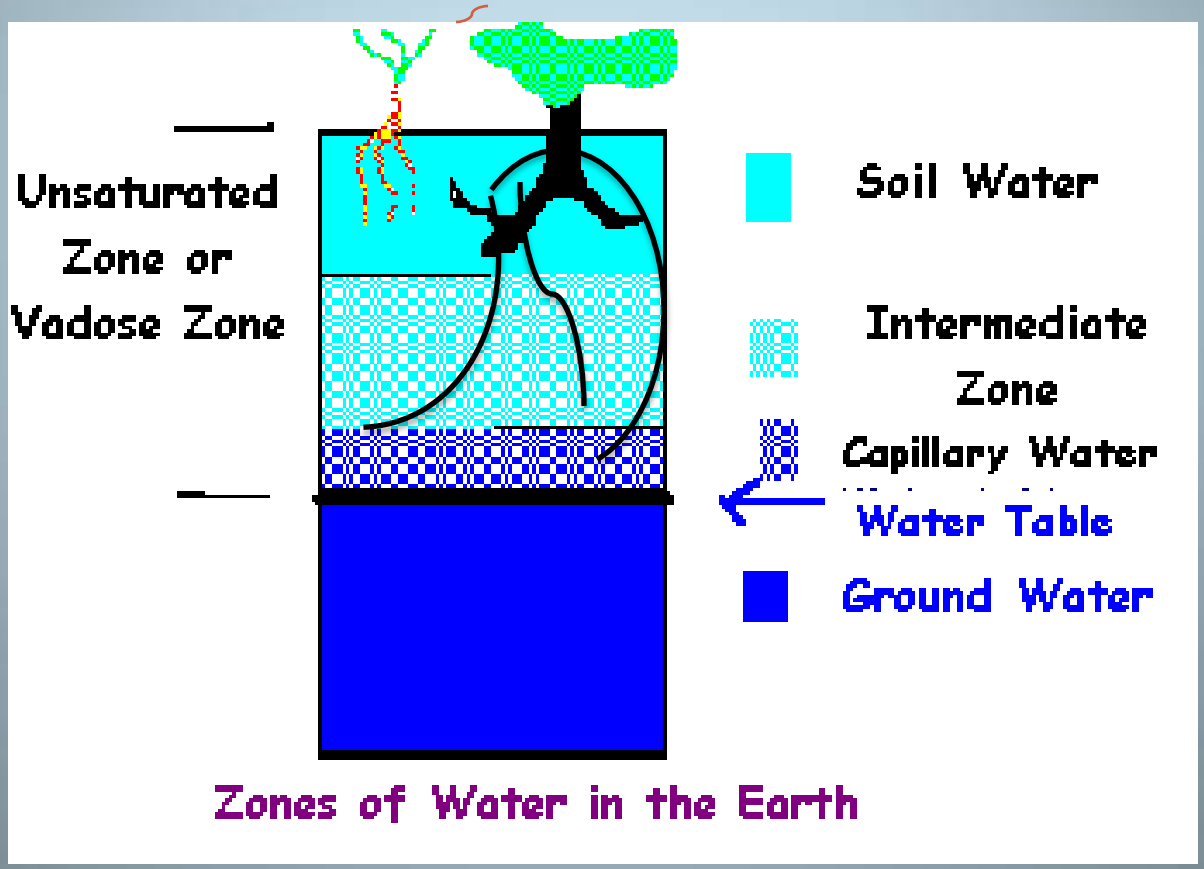
The Traditional View : Discharge into Streams



The Nature of Pine Barrens Discharge Zones

Wetlands Transpiration : A Second Flowpath

Roots tap capillary fringe/water table consuming groundwater



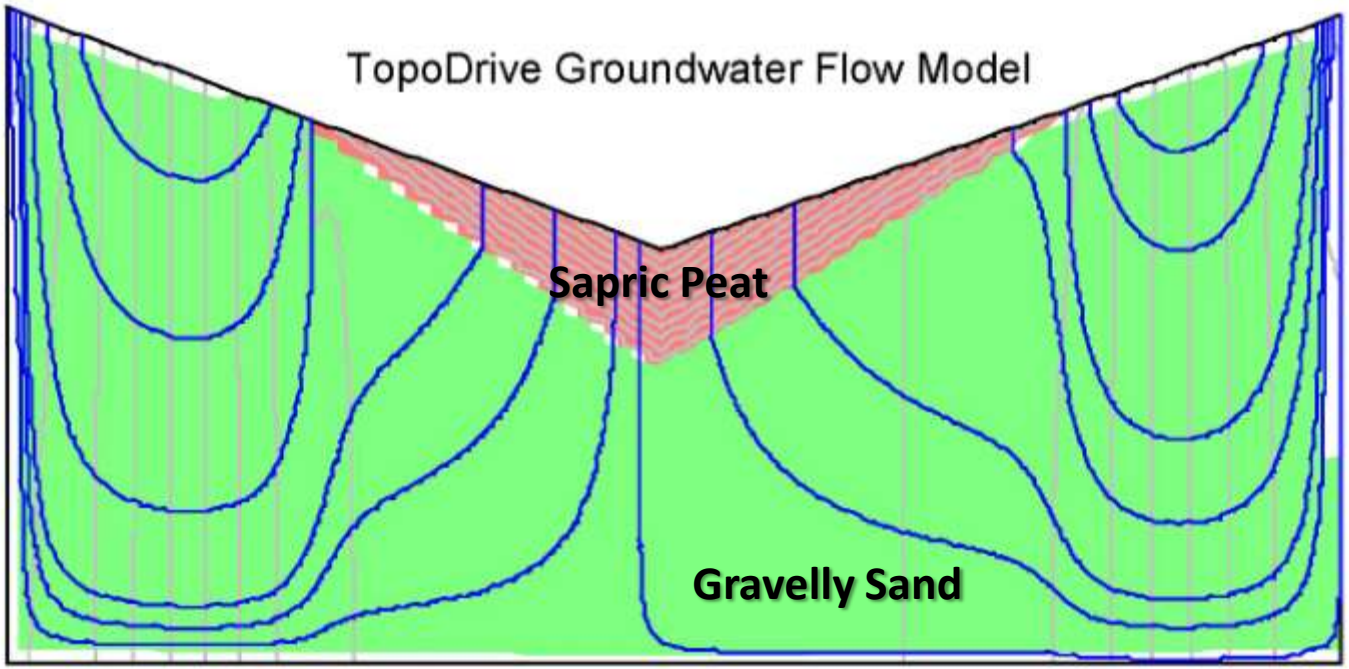
The Nature of Pine Barrens Discharge Zones

- **Muck Soils from 1 to 10 feet thick**
- **Upper Muck (i.e., fibric peat) very permeable while Lower Muck (sapric peat) impermeable**

Material	Hydraulic Conductivity
	Ft/day
Fibric Peat[1]	>4.27
SapricPeat[1]	<.034
Kirkwood-Cohansey[2]	78.81

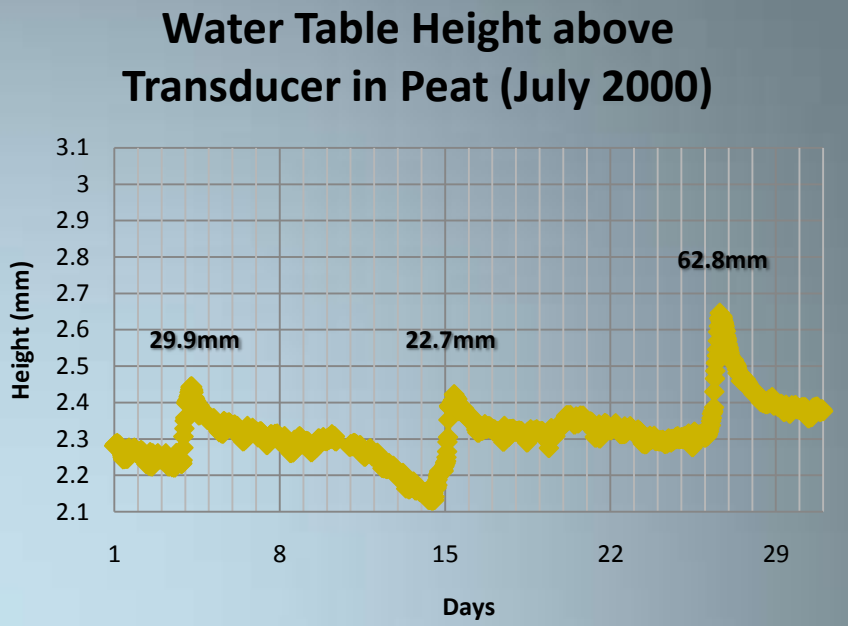
1 D.H.Boelter & E.S.Verry (1977)
2 R.L.Walker, P.A.Reilly & K.M.Watson (2008)

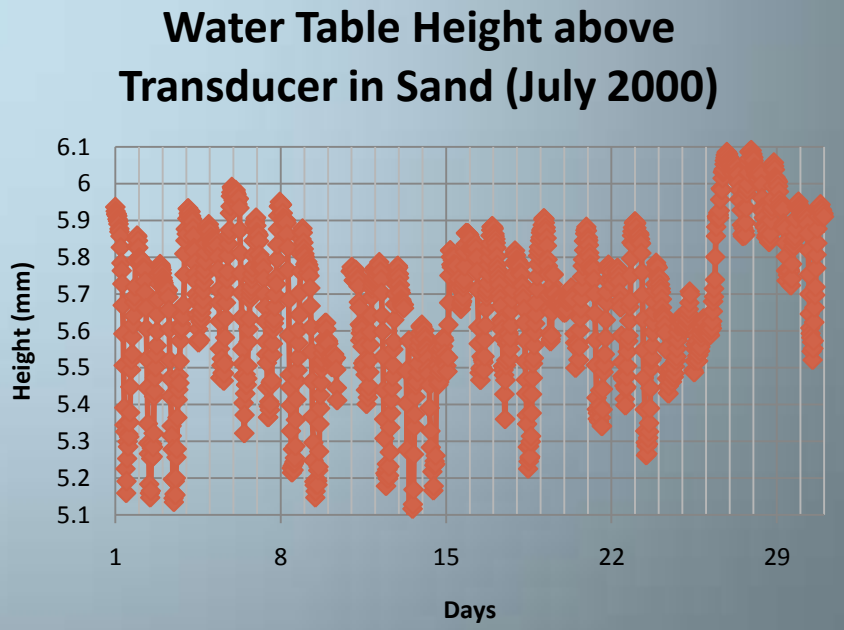
Flow Pattern Alteration due to Sapric Peat



Groundwater discharge refracted toward vertical when entering sapric peat.

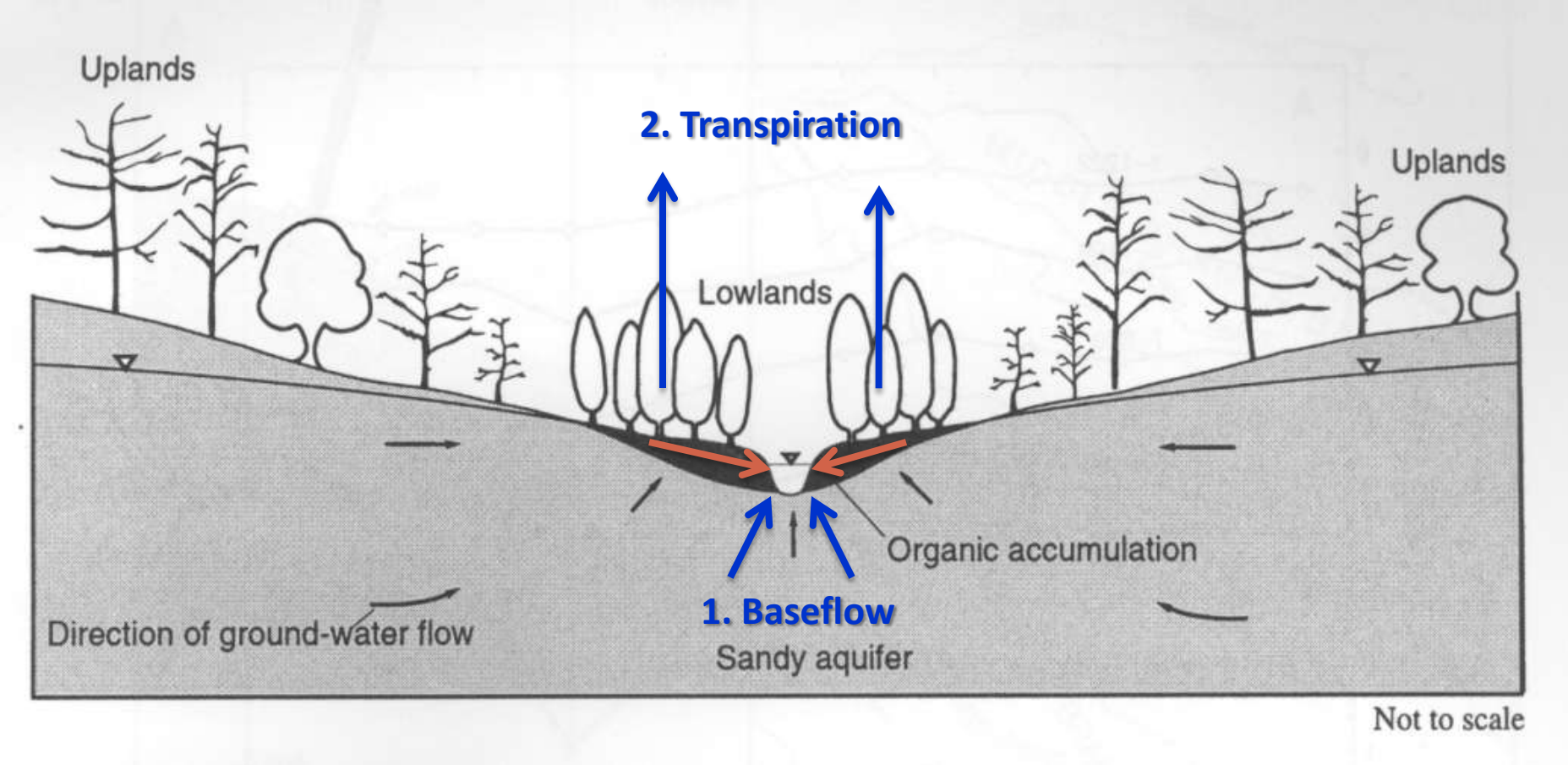
Semi-Independent Water Table Fluctuations in Cedar Bog





The Nature of Pine Barrens Discharge Zones

Wetlands have 2 outputs: Baseflow & Transpiration



Modified from E.Modica (1996)

Pine Barrens Water Budget (E.C. Rhodehamel, 1979)

	Parameter	Cm/yr	Percent
Input	Precipitation	114.4	100
Output	Interception	15.0	13.1
Output	ET (undrained depressions)	2.3	2.0
Output	ET (soils & groundwater)	39.9	34.9
Output	Direct Runoff	6.4	5.6
Output	Groundwater Discharge	50.8	44.6

ET Calculations (%) based on Ballard (1979)
Forest 30.6%
Wetlands 65.5%

Evapotranspiration Calculation based on Ballard Study (1979)

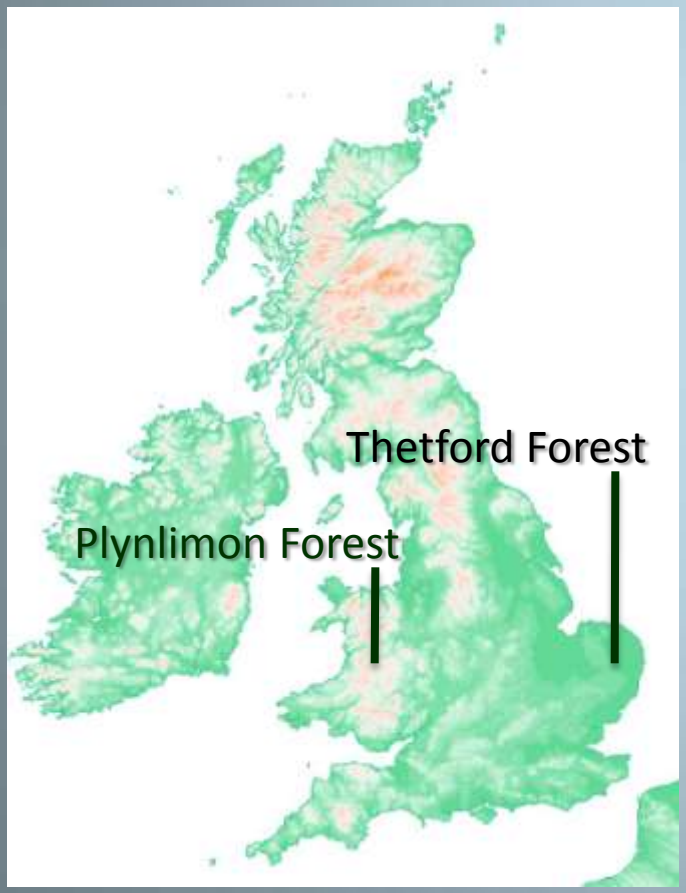
	Acreage		ET (MGD)*		PPT (MGD)	
WMA	Forest	Wetland	Forest	Wetland	Forest	Wetland
Barnegat Bay	147438	89380	452	587	1477	895
Mullica	186300	135423	571	890	1866	1356
Great Egg Harbor	145467	110208	446	724	1457	1104

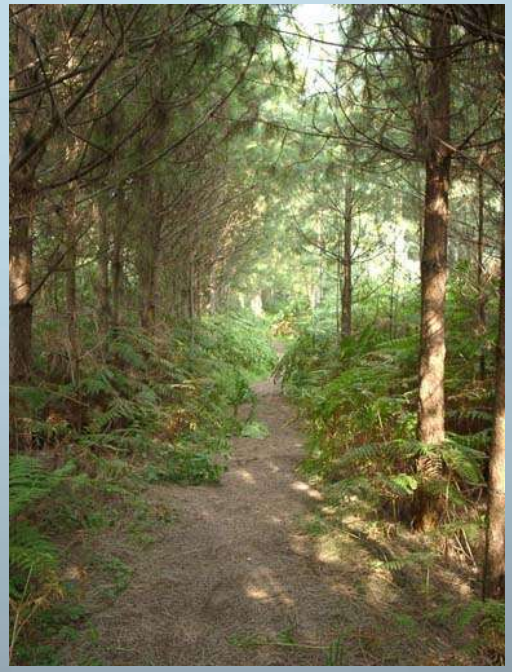
ET/PPT

Forest	Wetland
30.6%	65.5%

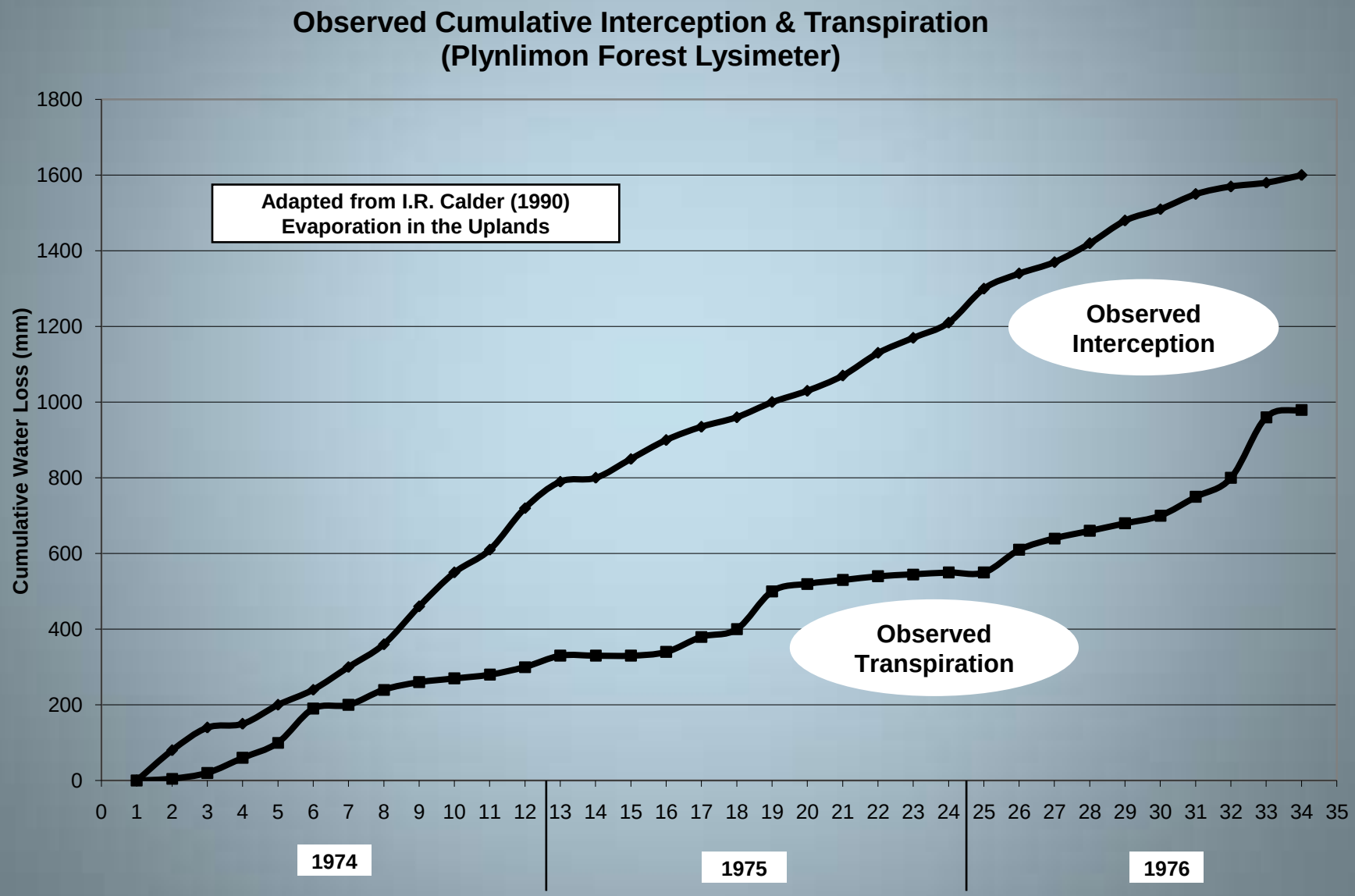
•Based on J.T. Ballard (1979) ET values for upland (35cm/growing season) and lowland forests (75cm/growing season)

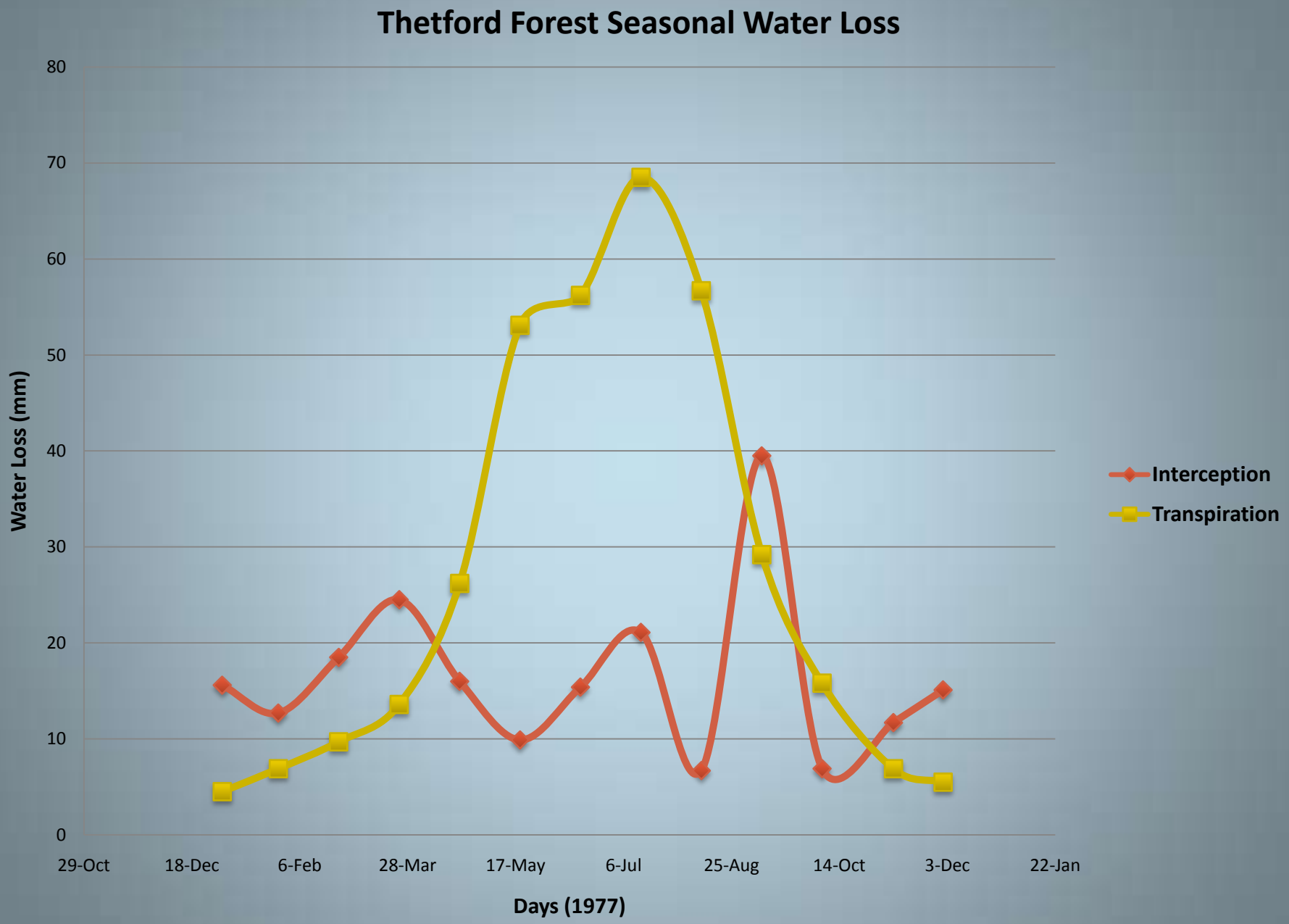
What is known about transpiration rates anywhere?





Distinguishing Evaporation from Transpiration




Thetford Forest Seasonal Water Loss
80
70
60
50
40
30
20
10
0
Water Loss (mm)
29-Oct
18-Dec
6-Feb
28-Mar
17-May
6-Jul
25-Aug
14-Oct
3-Dec
22-Jan
Days (1977)
Interception
Transpiration

Transpiration Rates of Forest Species

Species	Common Name	Average Transpiration	Indicator Categories	
			NE	SE
Liriodendron tulipifera	Tulip Poplar	7.28	FACU	FAC
Liriodendron tulipifera	Tulip Poplar	8.49	FACU	FAC
Liriodendron tulipifera	Tulip Poplar	7.03	FACU	FAC
Quercus alba	White Oak	10.24	FACU-	FACU
Quercus rubra	Red Oak	8.66	FACU-	FACU
Quercus rubra	Red Oak	5.84	FACU-	FACU
Quercus rubra	Red Oak	8.97	FACU-	FACU
Acer saccharum	Sugar Maple	8.79	FACU-	FACU-
Acer negundo	Box-elder	4.61	FAC+	FACW
Plantanus occidentalis	Sycamore	6.34	FACW-	FACW-
Pinus taeda	Loblolly Pine	3.35	FAC-	FAC
Pinus taeda	Loblolly Pine	3.66	FAC-	FAC
Clethra alnifolia	Sweet Pepperbush	7.01	FAC+	FACW
Ilex glabra	Inkberry	11.60	FACW-	FACW
Myrica cerifera	Southern Bayberry	7.78	FAC	FAC+
Gordonia lasianthus	Loblolly Bay	12.80	No	FACW

in./growing season

P.J. Kramer & J.S. Boyer, 1995. Water Relations of Plants and Soils

Indicator category designations from NRCS Plants Database

But who knows anything about transpiration rates in Pine Barrens Wetlands?

Kirkwood-Cohansey Project Cooperators

Conclusions

Existing models of the Kirkwood-Cohansey aquifer in the NJ Pine Barrens oversimplify groundwater flow by assuming that wetlands discharge only into streams.

Cedar bog transpiration is a second source for groundwater discharge.

Muck soils beneath cedar bogs refract groundwater discharge toward transpiring plants and away from streams.

Transpiration rates in cedar bogs and hardwood swamps are not well known and require further research in order to make groundwater flow models more precise.

Well water withdrawal from the Kirkwood-Cohansey aquifer deprives streams and adjacent wetlands of needed water.

Thank You
11 6 '06