Wetland Hydrology

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Wetland Hydrology

USACE Definition

"…all hydrologic characteristics of areas that are periodically inundated or have soils saturated to the surface at some time during the growing season."

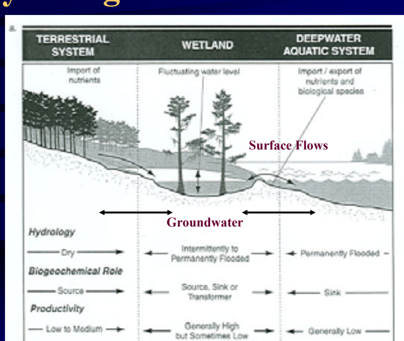
Hydrology is the single most important determinant of the establishment and maintenance of specific wetland types and processes (oxidation and reduction)

Unique Physicochemical Conditions

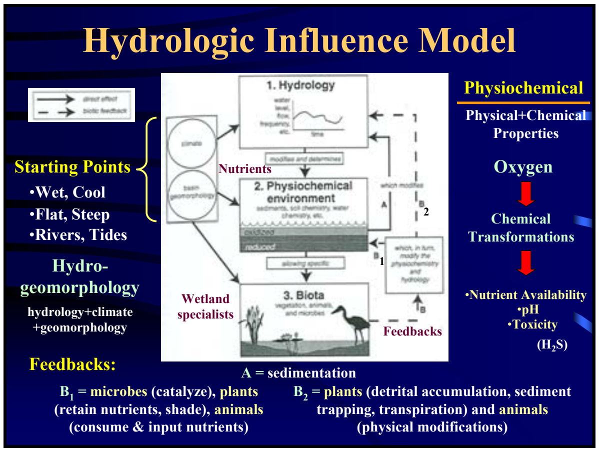
Hydrologic Zones:

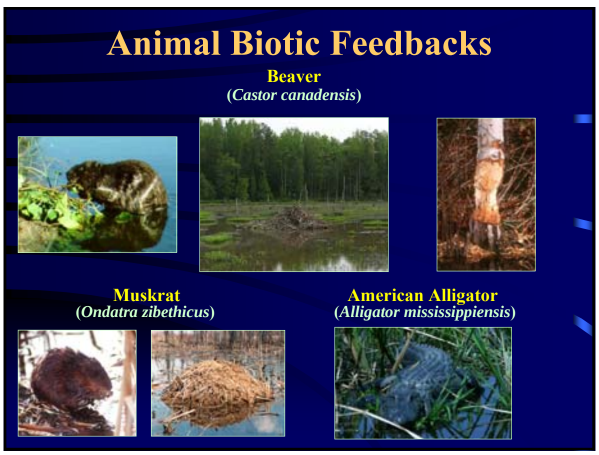
I	Permanently inundated	100%	IV	Seasonally	12.6–25%
II	Semi-permanently	76–99%	V	Irregularly	5–12.5%
III	Regularly	26–75%	VI	Intermittingly	<5%

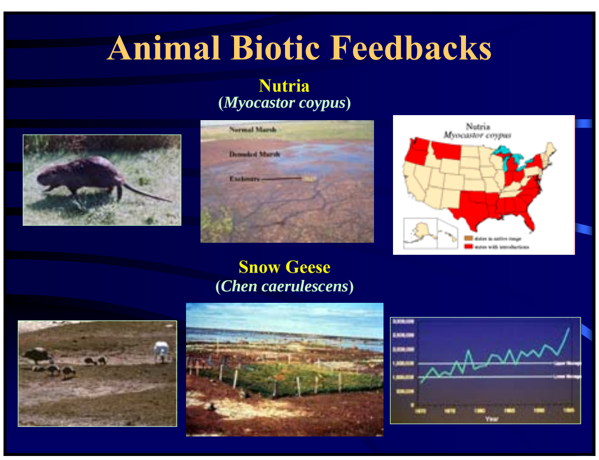
Hydrologic Flows & Processes

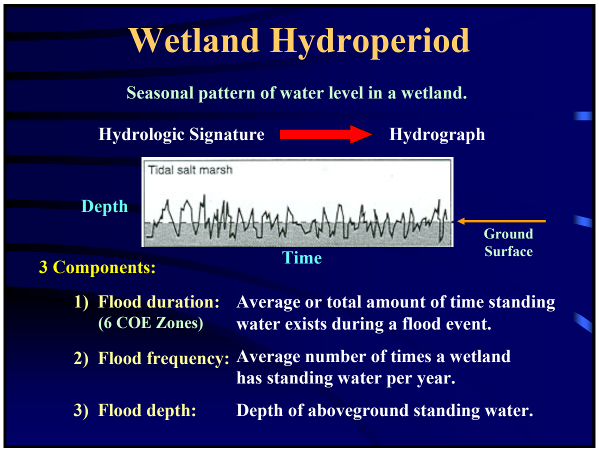


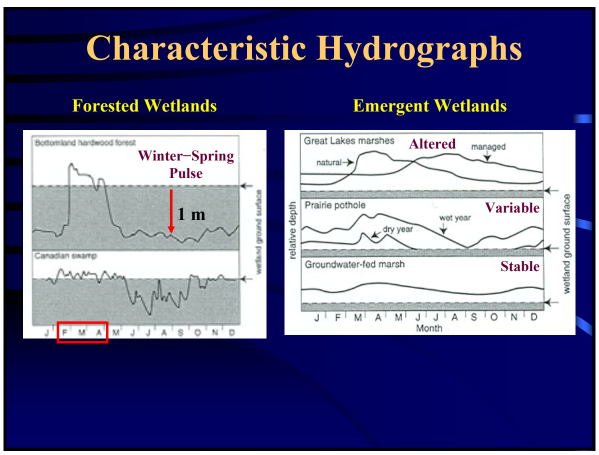
Note: Differences between terrestrial, wetland, and deepwater systems.

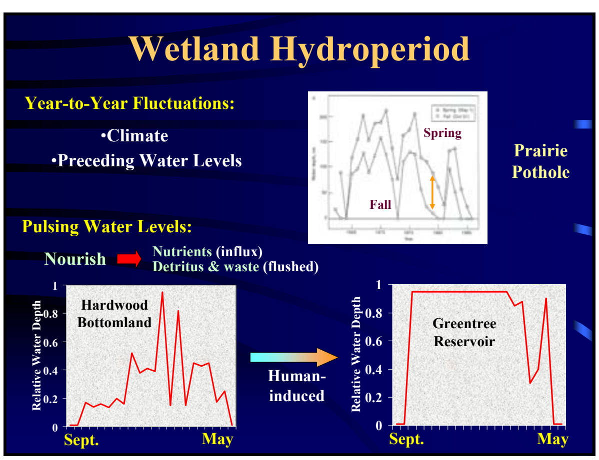

Hydrologic Influence Model
Starting Points
•Wet, Cool
•Flat, Steep
•Rivers, Tides
Hydro-
geomorphology
hydrology+climate
+geomorphology
1. Hydrology
Nutrients
2. Physiochemical environment
3. Biota
Wetland specialists
Feedbacks
Physiochemical
Physical+Chemical Properties
Oxygen
Chemical Transformations
•Nutrient Availability
•pH
•Toxicity
(H2S)
Feedbacks:
A = sedimentation
B1 = microbes (catalyze), plants (retain nutrients, shade), animals (consume & input nutrients)
B2 = plants (detrital accumulation, sediment trapping, transpiration) and animals (physical modifications)


Animal Biotic Feedbacks
Beaver
(Castor canadensis)
Muskrat
(Ondatra zibethicus)
American Alligator
(Alligator mississippiensis)


Animal Biotic Feedbacks
Nutria
(Myocastor coypus)
Normal Marsh
Denuded Marsh
Nutria
Myocastor coypus
Snow Geese
(Chen caerulescens)


Wetland Hydroperiod
Seasonal pattern of water level in a wetland.
Hydrologic Signature
Hydrograph
Tidal salt marsh
Depth
Time
Ground Surface
3 Components:
1) Flood duration: Average or total amount of time standing water exists during a flood event.
(6 COE Zones)
2) Flood frequency: Average number of times a wetland has standing water per year.
3) Flood depth: Depth of aboveground standing water.


Characteristic Hydrographs
Forested Wetlands
Emergent Wetlands
Bottomland hardwood forest
Winter–Spring Pulse
1 m
Canadian swamp
wetland ground surface
J F M A M J J A S O N D
Great Lakes marshes
Altered
natural
managed
Prairie pothole
Variable
dry year
wet year
Groundwater-fed marsh
Stable
relative depth
wetland ground surface
Month


Wetland Hydroperiod
Year-to-Year Fluctuations:
•Climate
•Preceding Water Levels
Spring
Fall
Prairie Pothole
Pulsing Water Levels:
Nourish
Nutrients (influx)
Detritus & waste (flushed)
Hardwood Bottomland
Relative Water Depth
Sept.
May
Human-induced
Greentree Reservoir
Relative Water Depth
Sept.
May

Wetland Water Budget

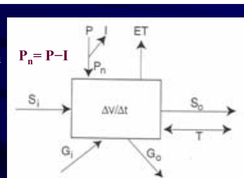
Quantification of all hydrologic inputs and outputs.

$$\frac{\Delta V}{\Delta t} = P_n + S_i + G_i - ET - S_o - G_o \pm T$$

P_n = net precipitation

S_i = surface inflows (sheet, stream flow)

G_i = groundwater inflow



ET = evapotranspiration

S_o = surface outflows

G_o = groundwater outflows

T = tidal inflow (+) & outflow (−)

I = Interception

ΔV/Δt = Change in volume of water storage per unit time

Wetland Water Budget

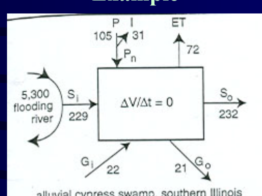
Example

P = 105 cm/yr

I = 31 cm/yr

S_i = 229 cm/yr

G_i = 22 cm/yr



ET = 72 cm/yr

S_o = 232 cm/yr

G_o = 21 cm/yr

T = 0

1) Calculate net precipitation

$$P_n = P - I = 105 - 31 = 74 \quad cm/yr$$

2) Calculate ΔV/Δt

$$\frac{\Delta V}{\Delta t} = P_n + S_i + G_i - ET - S_o - G_o \pm T = 74 + 229 + 22 - 72 - 232 - 21 = 0 \quad cm/yr$$

Renewal Rate & Residence Time

Renewal Rate: Turnover rate of the water in a wetland

How rapidly is water <u>replaced</u> in a wetland?

Drive biochemical processes!

Residence Time: Average time that water remains in a wetland. *(Turnover time or detention time)*

$$R_t = \frac{V}{Q_t}$$

V = average volume of water in wetland (depth x surface area)

Q_t = total inflow rate = $(P_n + S_i + G_i)_t$

Residence Time vs. Productivity

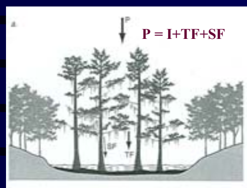
As residence time decreases, productivity in wetlands often increases

i.e., turnover increases wetland productivity

Turnover Time

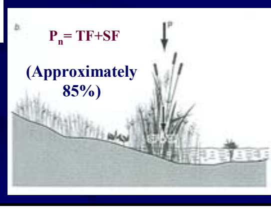
- Atmosphere (9 d)
- River (12−20 d)
- Oceans (3,100 yrs)

Hydrologic Pathways
Precipitation



Throughfall (TF)
Water passes through vegetation to wetland

Stemflow (SF)
Water intercepts vegetation & passes to wetland via stem



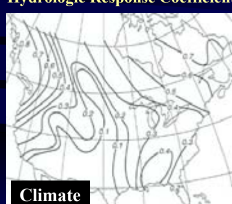
Interception (I)

Water retained in vegetation
- Total amt of precipitation
- Intensity of precipitation
- Vegetation morphology
- Vegetation strata

Hydrologic Pathways
Surface Flow: Overland Runoff

Nonchannelized sheet flow usually following rainfall and spring thaw or as tides rise

Hydrologic Response Coefficient



Percent of precipitation that becomes surface runoff

Tennessee ~35%

Rational Runoff Coefficient
Considers Land Use!

		C	
Urban			
	Business District	0.75–0.95	
	Residential	0.30–0.50	
Rural			
	Sandy Pasture	0.15	
	Loamy Cultivated	0.40	0.35 ↓
	Loamy Woodland	0.30	

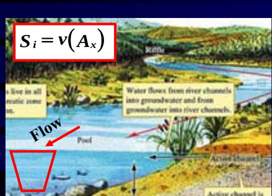
$$S_i = c(I \times A)$$

S_i = runoff to wetland (m^3/s)

A = watershed area (km^2)
I = rainfall intensity (mm/hr)

Hydrologic Pathways
Surface Flow: Streamflow

Channelized water flow into a wetland



Overbank Flow Probability
On average, the chance of bankfull discharge in a year.

$P(\bar{x}_{RI}) = (\bar{x}_{RI})^{-1}$ $= (1.5)^{-1} = 67\%$

Bankfull Discharge
When water begins to flow over its bank into the floodplain

Recurrence Interval
Average duration that a river floodplain experiences bankfull discharge.

$\bar{x}_{RI}$ = 1.5 yrs

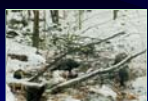
Hydrologic Pathways

Groundwater

Subsurface flow of water into or out of a wetland

1) Discharge Wetland: Water table of surrounding landscape is <u>higher</u> than water in wetland.

Water Flows into the Wetland ⇒ Water table loses Water



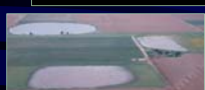
Hydrologic Pathways

Groundwater

Subsurface flow of water into or out of a wetland

2) Recharge Wetland: Water table of surrounding landscape is <u>below</u> water in a wetland.

Water Flows out of Wetland ⇒ Water table gains Water



Darcy's Law

$$G = k(A_x)s$$

G = flow rate of groundwater

k = soil permeability

s = hydraulic gradient (slope of water table)

A_x = groundwater cross-sectional area perpendicular to the direction of flow

Hydrologic Pathways

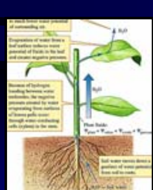
Evapotranspiration

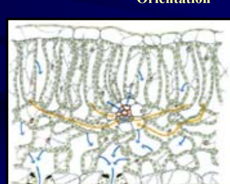
Combined water loss from evaporation and transpiration

Evaporation: Water that vaporizes from water or soil in a wetland.

Transpiration: Water loss through vascular plants generally at the stomata of leaves.

- Leaf-surface Area
- Orientation
- Protected Stomata
- Lipid Cuticle





Does wetland vegetation increase or decrease water loss from a wetland?

Ecological Monographs 51:403-427

Water Resources Research 2:443-453

Hydrologic Pathways

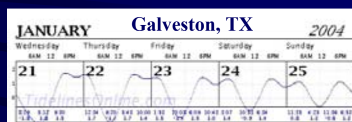
Estuarine Wetlands
Tides

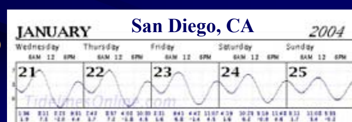
Gravitational Pull of Moon > Sun on Oceans

Types

A) Frequency
- •Semi-diurnal (two)
- •Diurnal (one)

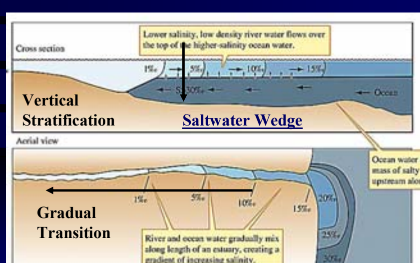
B) Magnitude
- •Spring ⟷ (full, new)
- •Neap ↳ (1st,3rd)





Hydrologic Pathways

Estuarine Wetlands
Saltwater Wedge



Salinity is negatively related with depth and distance from the ocean

Human Influences

Saltwater Intrusion

Stressors: submergence, saline soils/water, soil anoxia

Specific Effects of Hydrology on Wetlands

1) Vegetative Species Composition and Richness

Results in unique vegetation (zones) related to duration of soil anoxia and may increase or decrease species richness.

Flowthrough & dynamic hydrology w/ spatial heterogeneity → "pulses"

2) Primary Productivity

Depends on nutrient availability and generally is greatest in flowthrough systems with periodic drawdowns.

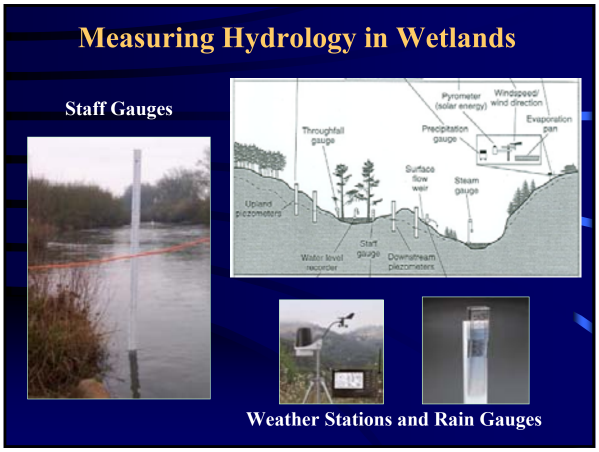
Allochthonous (out) + Autochthnous (in) Sources

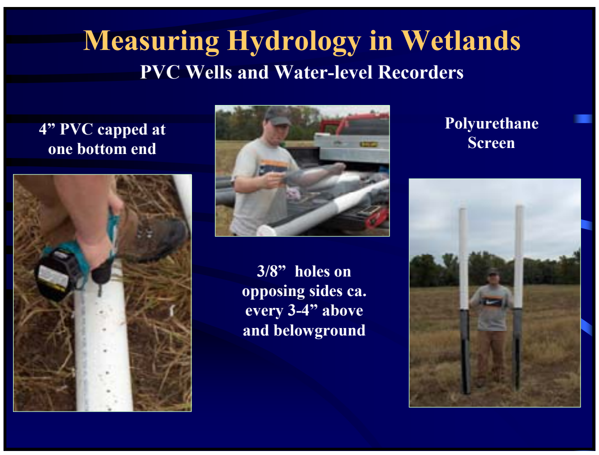
3) Organic Accumulation and Export

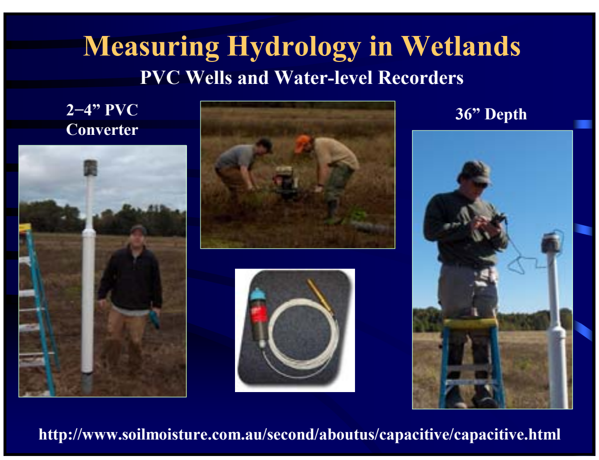
Accumulation greatest in stagnant, semi-permanently flooded wetlands (sinks) and export greatest in flowthrough with high primary productivity (sources, see #3).

Decomposition maximized when aerobic.

4) Nutrient Cycling
- •Nutrient Availability — When primary productivity & decomp high
- •Nutrient Transformations — Oxidized to reduced, solubility & pH


Measuring Hydrology in Wetlands
Staff Gauges
Weather Stations and Rain Gauges


Measuring Hydrology in Wetlands
PVC Wells and Water-level Recorders
4" PVC capped at one bottom end
3/8" holes on opposing sides ca. every 3-4" above and belowground
Polyurethane Screen


Measuring Hydrology in Wetlands
PVC Wells and Water-level Recorders
2–4" PVC Converter
36" Depth
http://www.soilmoisture.com.au/second/aboutus/capacitive/capacitive.html