WETLAND HYDROLOGY
Basic terms & concepts

Hydrology - most important determinant for establishing and maintenance of specific types of wetlands and wetland processes
- despite its importance not thoroughly investigated
- watershed approach

Wetlands are very sensitive to changes in their regular pattern of water storage and movement
Water level fluctuation => perturbation in wetland structure

CONTROL OF WETLAND HYDROLOGY BY BIOTIC PROCESSES
- peat building
- sediment trapping
- water shading and transpiration by plants
- beaver dams
- "gator holes"

HYDROLOGY - a science that deals with occurrence, distribution and movement of water
HYDROLOGIC CYCLE - a central concept in hydrology

HYDROLOGIC CYCLE

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Volume (total) x 1,000,000</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>1370</td>
<td>97.25</td>
</tr>
<tr>
<td>Ice Caps and Glaciers</td>
<td>29</td>
<td>2.05</td>
</tr>
<tr>
<td>Groundwater</td>
<td>9.5</td>
<td>0.68</td>
</tr>
<tr>
<td>Lakes</td>
<td>0.125</td>
<td>0.01</td>
</tr>
<tr>
<td>Soils/Moisture</td>
<td>0.065</td>
<td>0.005</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>0.013</td>
<td>0.001</td>
</tr>
<tr>
<td>Streams and Rivers</td>
<td>0.0017</td>
<td>0.0002</td>
</tr>
</tbody>
</table>
**WATER BUDGET**

- the general balance between inflows, storage and outflows
- mass balance equation:

  \[ \Delta V = P_n + S_i + G_i - ET - S_o - G_o \ (\pm T) \]

  (not all the wetlands have the equal proportions of all these components)

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**WETLAND HYDROPERIOD**

- wetland "signature" -- seasonal pattern of the water level of a wetland
- flood duration
- flood frequency

- primary determinants of wetland's hydroperiod are its position on landscape (slope, flat, depression) and its source of water
- HGM (hydrogeomorphic) functional assessment approach (Brinson & Rheinhardt 1996, Ecological Applications 6:69-76)

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**WATER BUDGET**

\[ \Delta V = P_n + S_i + G_i - ET - S_o - G_o \ (\pm T) \]

Ideally, all components of the water budget should be measured

One of the components of water budgets is frequently calculated as the residual of the budget equation. The residual contains the sum of all errors from all other components.

**Precipitation (P)** - the main input of water to the earth's surface;
- liquid (rainfall and drizzle)
- solid (snow) for some wetlands the only source of water

Permanently flooded wetlands occur where \( P > ET \)
Precipitation (P) - cont.

Fate of precipitation: interception (I), stem flow (SF) and throughfall (TF)

\[
P = I + TF + SF \\
P_n = P - I \\
P_n = SF + TF
\]

Interception - in forests 5-35 %, emergent wetlands similar

Measurements of precipitation: point measurements - raingage (manual or recording)

Rainfall is not regularly distributed in space and time

Error from extrapolation from a single gauge station to the whole wetland area may be as high as 75%

Snow - water equivalent (equivalent water depth of melted snow)

300 mm fresh snow = 25 mm rain

Fog

Precipitation (P) - cont.

WMO - standard water gauge in each member country

Estimating precipitation from cloud brightness (GOES = Geostationary Operational Environmental Satellite data; VISSR = Visual Infrared Spin Scan Radiometer) - ground station required for data calibration

Climadiagrams (Heinrich Walter)

Climadiagrams are brief summaries of average climatic variables and their time course.

The diagrams display monthly averages for temperature and precipitation over a year. 20 mm of monthly precipitation (right ordinate) equal 10°C average temperature (left ordinate). When the precipitation curve undercuts the temperature curve, the area in between them is dotted (every 2 mm) indicating dry season. When the precipitation curve supercedes the temperature curve, vertical lines are plotted for each month (with tic marks every 2 mm) indicating moist season.

All diagrams are designed in a uniform pattern, illustrated by the following sample:

1. Country name, station location and elevation, station name
2. The length of the observation period for temperature and precipitation respectively
3. Annual average of temperature and annual precipitation sum
4. (red) Temperature curve
5. (blue) Precipitation time series
6. Indication of frost periods
7. Mean daily max. temperature of the warmest month
8. Mean daily min. temperature of the coldest month

http://www.zoolex.org/walter.html
SURFACE INFLOW AND OUTFLOW:

\[ S = P \cdot A \cdot R_p \]

- **S** = surface runoff
- **P** = average precipitation in a watershed
- **A** = area of watershed
- **R_p** = hydrologic response coefficient, \( R_p \) is a lump term that takes into account the surface roughness and slope of a catchment, travel time of flow, and any other factor that is going to control how fast the rainwater becomes a surface flow. This variable is estimated by checking some reference sites (residential area, forest, pasture), measuring stream discharge, rainfall intensity for a number of storms, the area of a catchment, and solving \( R_p \) for that particular catchment. If the catchment of interest varies in land cover, the individual parts are then averaged to provide an estimate of \( R_p \).
GROUNDWATER INFLOW AND OUTFLOW:

Discharge wetland - GW moving into wetland
Recharge wetland - GW moving out of wetland into aquifer

The flow of groundwater into, through and out of a wetland described by an
equation called:

Darcy's law  \( G = k \cdot a \cdot s \),

- \( G \) = flow rate of groundwater (m³/day),
- \( k \) = hydraulic conductivity (m/d; cm/s),
- \( a \) = cross-sectional area,
- \( s \) = hydraulic gradient (delta h/delta x)

- the rate of flow of water is proportional to the hydraulic conductivity or
  permeability and hydraulic gradient

Hydraulic conductivity (k)
- the capacity of a soil to transmit water. It varies for different types of wetland
  sometimes by several orders of magnitude.
- differences in hydraulic conductivity between saturated and unsaturated soils; in
  saturated soils \( k \) depends on the geometry of pore spaces
  - \( k \) (m/d):
    - Peat 500-1
    - Clay 0.001-0.1
    - Sand 30-5000
- when calculating the GW flow, we assume that the whole area has the same \( k \)

- How to measure:
  - lab tests
  - auger hole method:
    - pump - depletion model
    - fill - recharge model
**Hydraulic gradient**
- slope of water (piezometric surface, potentiometric surface)
- measured in number of water table wells related to known datum (elevation)
- water table wells (slotted plastic pipe) serve for identifying the elevation of the water table surface (hydraulic head)
- at least two water table wells needed to quantify the direction of GW flow

From Georgia Tech website

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**Evapotranspiration (ET)**
Water removed from soil/water by evaporation together with water passing through plants as transpiration

Evaporation measured in:
- Evaporation pans (evaporation depends on the pan design)
- Class A pans commonly used in National Weather Service stations

Evaporation depends on:
1) solar radiation (major source of heat)
2) temperature of air and evaporating surface
   - higher air T - more water vapor it can hold
   - tropical areas - higher moisture
3) saturation deficit of the air - the amount of water that can be taken by the air before it gets saturated
4) wind speed
5) evaporating surface
Three approaches to estimating ET:

1) Mass transfer or water vapor flux
   Rate of evapotranspiration proportional to the difference between vapor pressure at the water (leaf) surface and the vapor pressure in the overlaying air.

2) Energy Balance (heat balance)

3) Empirical relationships based on both approaches
   (the use of meteorological constants and measurements available from meteorological stations)
   Penman's-Monteith, Thornthwaite, Hammer and Kadlec, etc.

Difference between evaporation from free-water surface and wetland evapotranspiration

ET from wetland ranges from 0.54 to 5.3 times pan evaporation depending on plant species - different stomatal conductance

Lysimeter - soil block with a plant population enclosed in a container; loss of water through evapotranspiration is measured as a change in total weight

From the GSF - Inst. Of Ecol. Web site

An ocean TIDE refers to the cyclic rise and fall of seawater.

The moon is the primary factor controlling the temporal rhythm and height of tides. At the location on the Earth closest to the moon, seawater is drawn toward the moon because of the greater strength of gravitational attraction. On the opposite side of the Earth, another tidal bulge is produced away from the moon.

The second factor controlling tides on the Earth's surface is the sun's gravity. The height of the average solar tide is about 50% the average lunar tide.

TIDES (From Tides web site)
TYPES OF TIDES

The geometric relationship of moon and sun to locations on the Earth's surface results in creation of three different types of tides.

- Northern Gulf of Mexico and SE Asia
- Atlantic coasts of the US and Europe
- West coast of Canada and the US

Question:

How do the different components of the water balance control salinity in marshes?

- GW age
- P/ET
- GW flux

Marsh Salinity
- Low
- Med
- High

Source rock

A Wetland Water Balance Study of Northern Belizean Marshes

Candice Constantine, Jose Constantine, Greg Pasternack, University of California-Davis
Values for the components of the water budget were obtained from field measurements of precipitation, evapotranspiration and water depth changes.

Difficulties with delineating the watershed areas
Assumption of a negligible surface water inflow

\[
\text{Change in storage} = P - ET + dGW
\]

Net precipitation volume: \( P \times \text{marsh area} \)
Net ET: \( ET \times \text{marsh area covered by vegetation} \)
Net E: \( E (\text{data from Belize Meteorol. Service}) \times \text{marsh area without vegetation} \)

Wet x Dry season (J une-J anuary; February-April)

Results from water balance calculations; negative values = outputs; positive values = inputs
Preliminary conclusions

1) GW serves as a net-source during the wet season and as a net-sink during the dry season for all study site marshes
2) GW is a larger source for the high salinity marsh than for a medium salinity marsh
3) GW mixing may be the source of salinity in northern Belizean marshes (Candice & Jose)
4) High ET is a major source of salinity in northern Belizean marshes (Greg)
5) Cation data from all water sources are necessary to resolve this