The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

Online Course on Natural Treatment Systems: Introduction to Natural Wetlands

Introduction to natural wetlands

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Contents

What is a wetland?

Various definitions exist, depending on the focus: environmental, ecological, regulatory, …

Broadest definition: Transition area between dry lands (uplands) and deeply flooded lands (aquatic systems)

Ramsar definition: A wetland is an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6m

!! Because of temporal and biological variability, there is no absolute hydrological demarcation!!

What is a wetland?

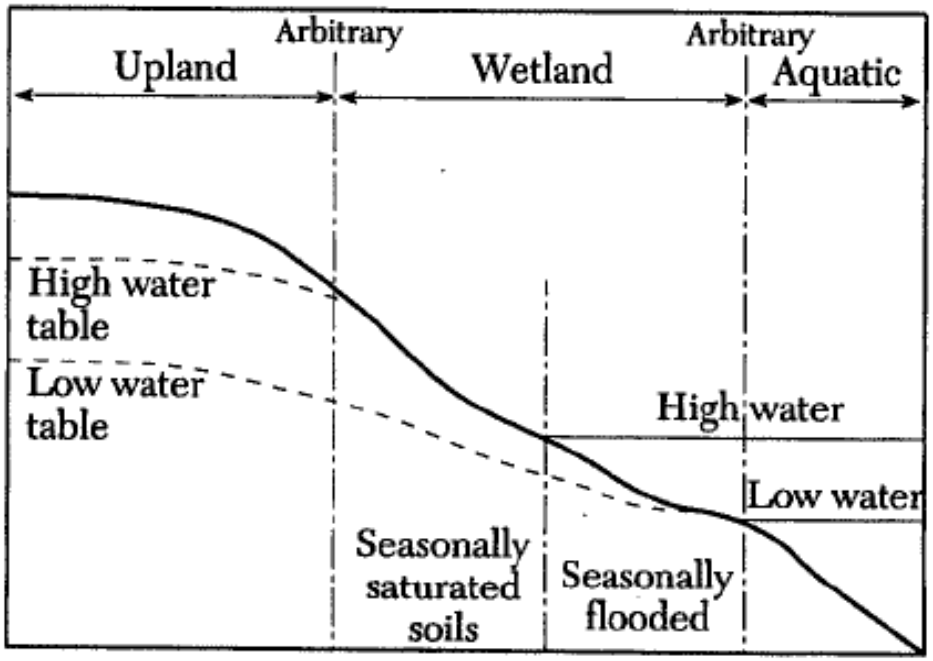


Figure 1.1. Wetlands are transitional areas between uplands, where excessive water is not a factor for plant growth, and aquatic ecosystems, where flooding excludes rooted, emergent vegetation (Kadlec & Knight 1996).

Also called "ecotone"

Source: IWA Scientific and Technical Report No 8 (2000)

Types of wetlands

1. Saltwater

- marine
- estuarine
- lagoonar
- salt lake

2. Freshwater

- riverine
- lacustrine
- palustrine

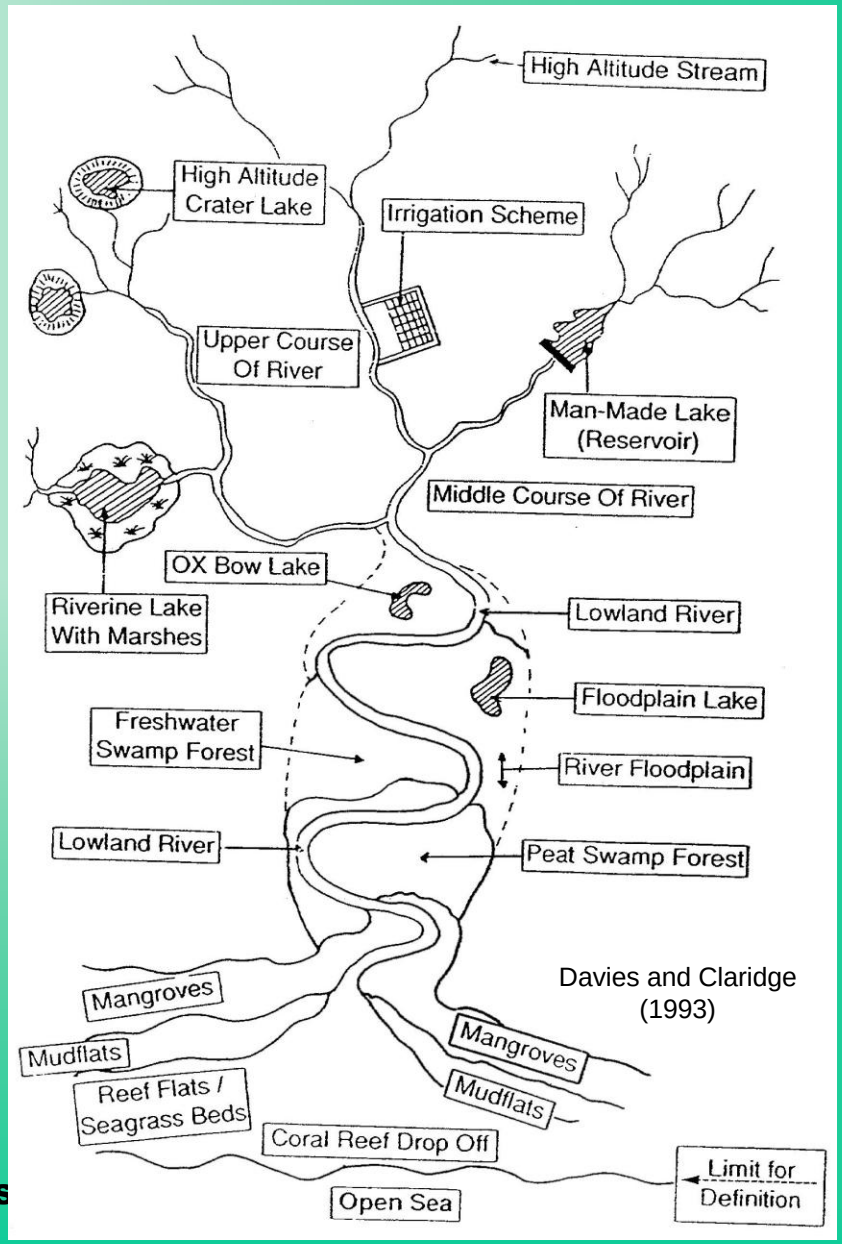
3. Artificial

- aquaculture/mariculture
- agriculture
- salt exploitation
- urban/industrial
- water-storage areas

Types of wetlands

- Different wetland types occur along the river basin, from upstream to downstream

- Each wetland type has its own typical vegetation



Examples

Mangroves

Examples

Raised bog

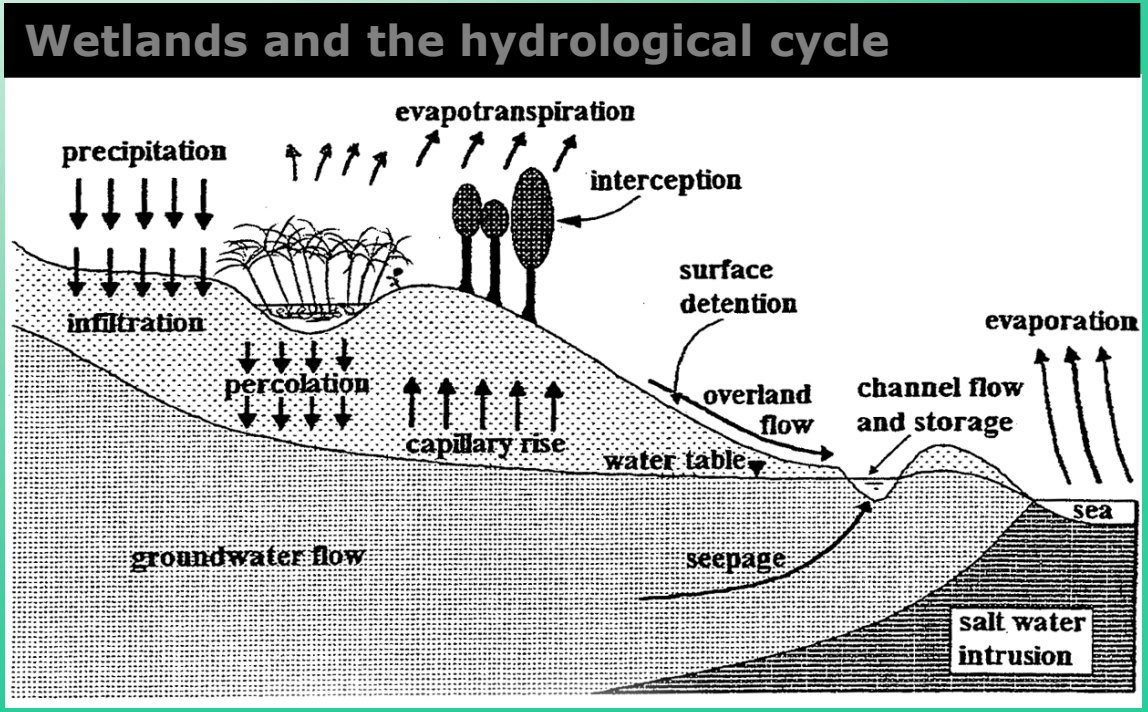
Examples

Lacustrine wetland with reed vegetation

Natural functions of wetlands

1. Climatic effects:

- Global warming amelioration by carbon fixation and CO_2 balance
- Important component of the hydrological cycle
- Micro-climate influences (wetlands have cooling effect)



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Natural functions of wetlands

2. Biodiversity functions:

- Ecosystem diversity
- Habitat diversity
- Species and population diversity
- Link between terrestrial and aquatic ecosystems
- Diverse species assemblages
- Highly diverse microbiological activity
- Large genetic pool
- Wetlands as connectors

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Natural functions of wetlands

3. Habitat functions:

- Wildlife habitats
  - Fish feeding and breeding grounds
  - Bird feeding and breeding grounds
- Terrestrial / aquatic habitats
- Protects biodiversity and gene pools

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Natural functions of wetlands

4. Hydrological and hydraulic functions:

- Coastal erosion protection and flood defense
- Catchment dynamics, impact on:
  - groundwater recharge
  - water holding capacity
  - continued stream and river flow
  - flood protection

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Natural functions of wetlands

5. Water quality functions:

- Particulates filtration
- Nutrient stripping
- Biodegradation of toxic compounds
- Heavy metal stripping and accumulation
- Waste water treatment

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Structural components

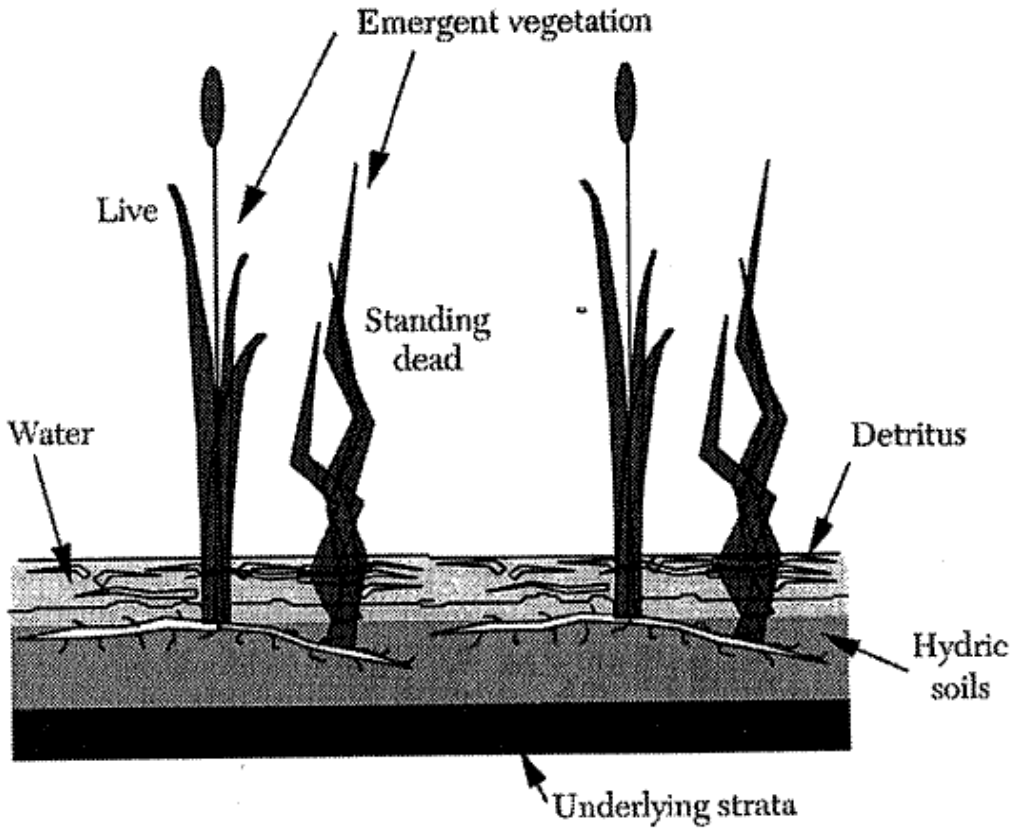


Figure 1.2. Structural components of a wetland.

Source: IWA Scientific and Technical Report No 8 (2000)

Hydrology – water regime

Two important concepts: **hydroperiod** and **depth of flooding**

→ Most influential to determine wetland type

→ Affects soil pH, oxygen concentration, nutrient cycling etc.

Hydroperiod = duration of flooded or saturated soil conditions

Depth of flooding = water depth

Hydrology – water regime

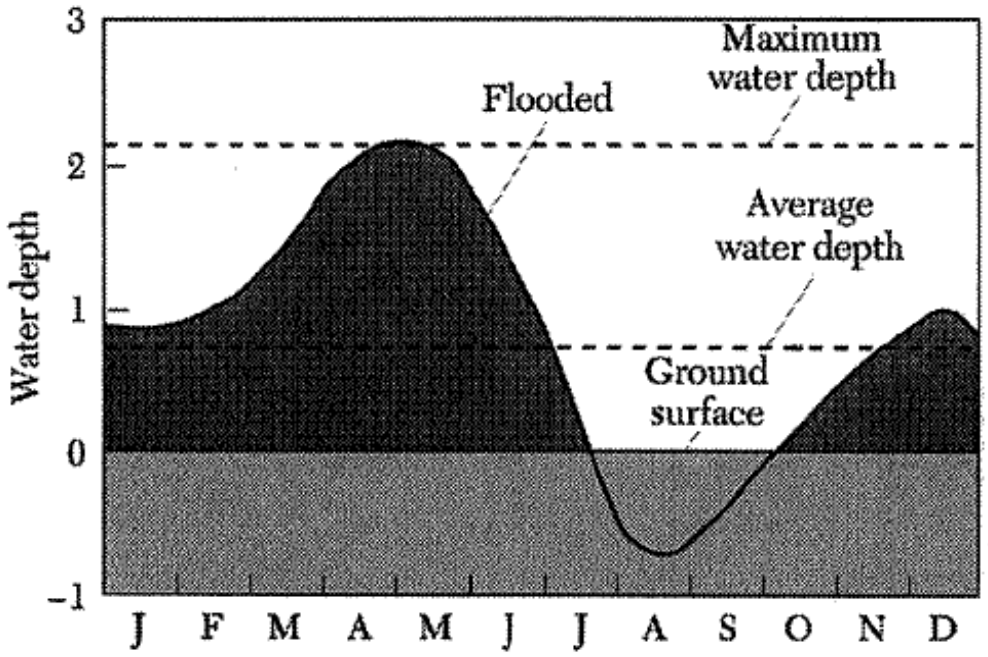


Figure 1.3. Components of wetland hydroperiod and water regime (Kadlec & Knight 1996). Hydroperiod = 9/12 = 75%; average depth = 0.8; maximum depth = 2.2.

Source: IWA Scientific and Technical Report No 8 (2000)

Hydrology – Water budget

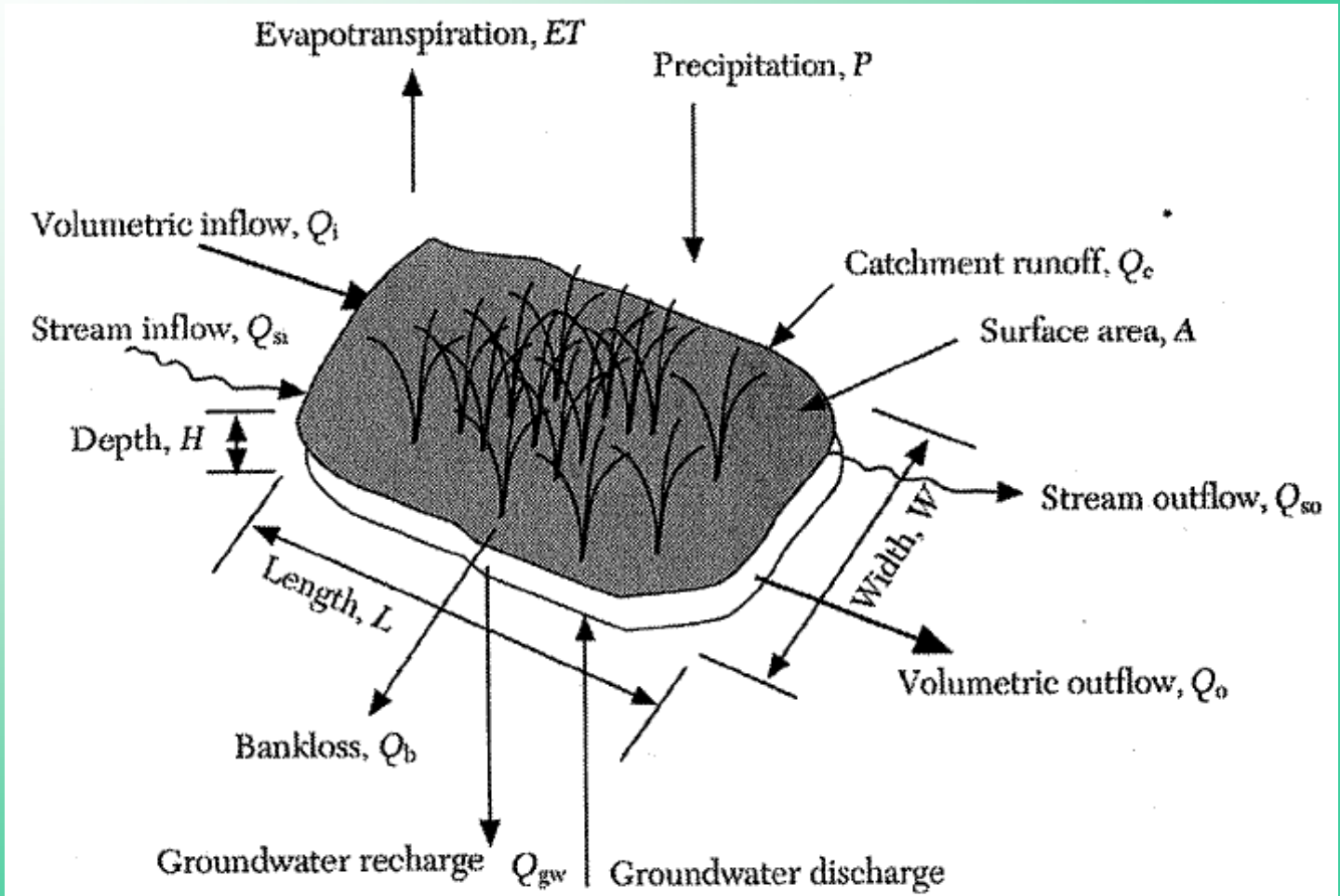


Figure 1.4. Components of the water budget and associated terminology.

Source: IWA Scientific and Technical Report No 8 (2000)

Hydrology – Water budget

In constructed wetlands, following components are normally absent:

- catchment runoff (surrounded by dikes)
- stream inflow (only inflow of wastewater)
- groundwater recharge (isolated by means of clay or plastic liner)
- groundwater discharge (isolated by means of clay or plastic liner)

Wastewater treatment wetland: fairly constant inflow
Storm water treatment wetland: peak flows and dry periods

Hydrology – Water budget

One important concept: **detention time**

= average time water stays inside the wetland

= average time water needs to flow from the inlet to the outlet

Why is this important? The longer wastewater stays inside the system, the more time there is for bacteria to degrade pollutants and for plants to take up nutrients → better treatment efficiency.

Detention time (days) = storage volume (m^3) / flow rate (m^3/day)

Soils - formation

Flooding → strongly reduced penetration of oxygen

Litter fall → high oxygen demand for degradation of organic material

RESULT:
Anaerobic conditions → very slow degradation of organic material

RESULT:
Accumulation of organic material (as peat)

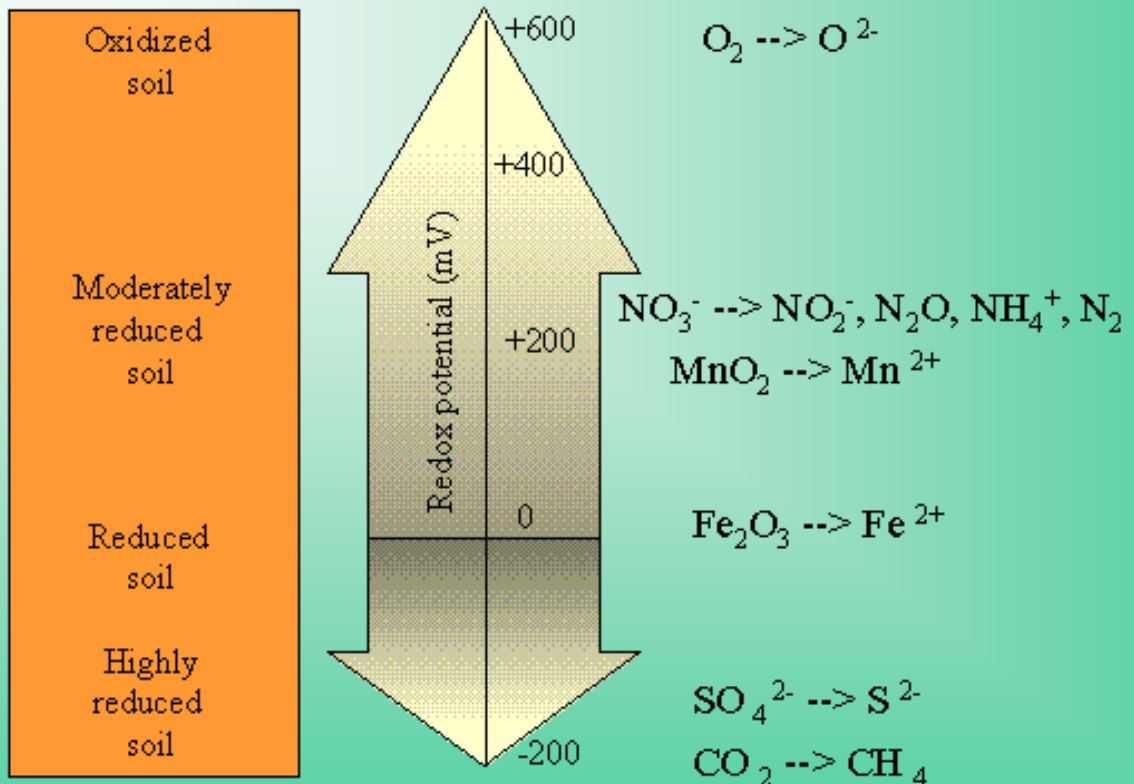
Soils - formation

In warm-climate freshwater marshes: up to 1.4 cm/year
In northern bogs: up to 1.1 mm/year (less productive wetlands!)

In constructed wetlands additional material accumulates when particles (organic and inorganic) from the wastewater settle to the bottom.

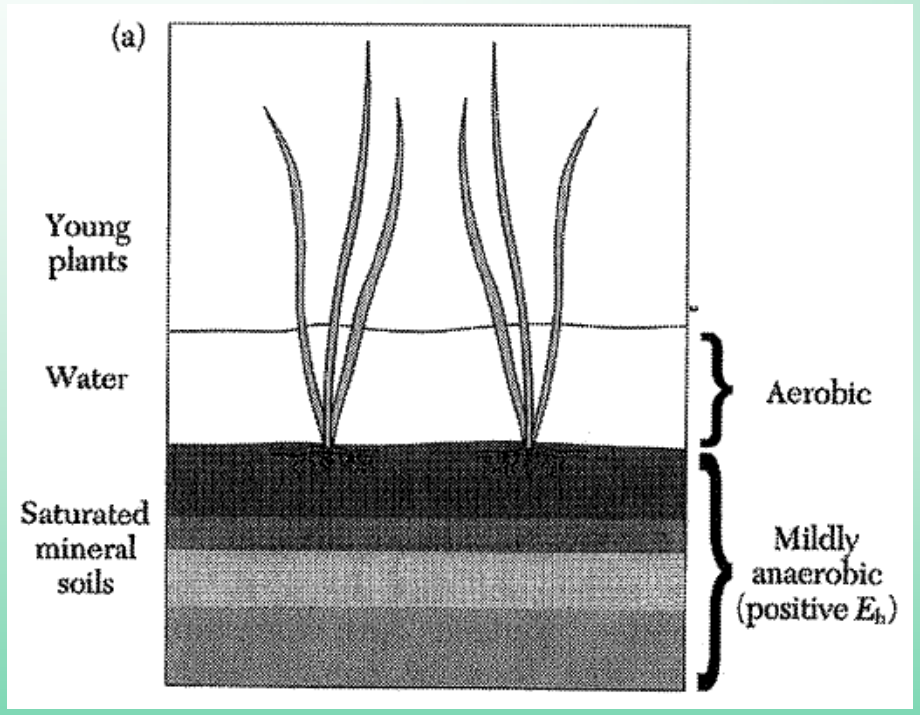
Soils – Redox conditions

Example Of The Range In Redox Potentials In Waterlogged Soils And The Location In The Redox Range Where The Various Electron Acceptors Are Active



To refresh your memory, see: http://en.wikipedia.org/wiki/Redox and: http://en.wikipedia.org/wiki/Redox_potential

Soils – Redox conditions



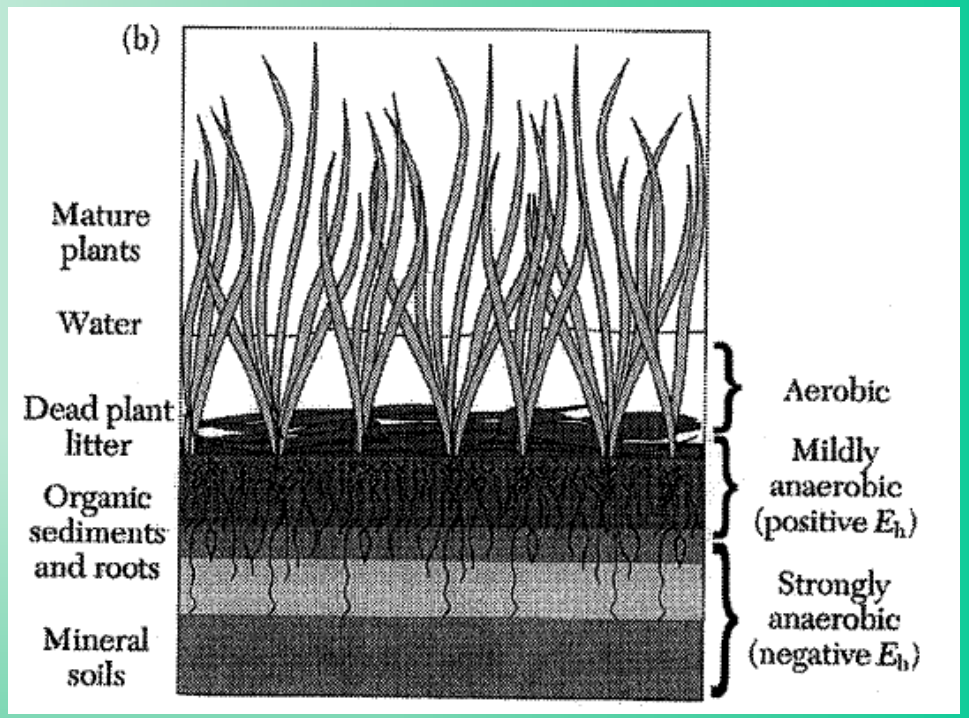


Figure 1.5. Stages in the maturation of constructed wetland soils: (a) newly planted, (b) mature (Kadlec & Knight 1996).

Source: IWA Scientific and Technical Report No 8 (2000)

Soils – microbial processes

Bacteria have important roles in the Carbon (C), Nitrogen (N) and Sulfur (S) cycles

Activity of bacteria depends on:
- concentrations of pollutants
- redox conditions
- pH
- temperature

Details of the different cycles are given later.

Vegetation - components

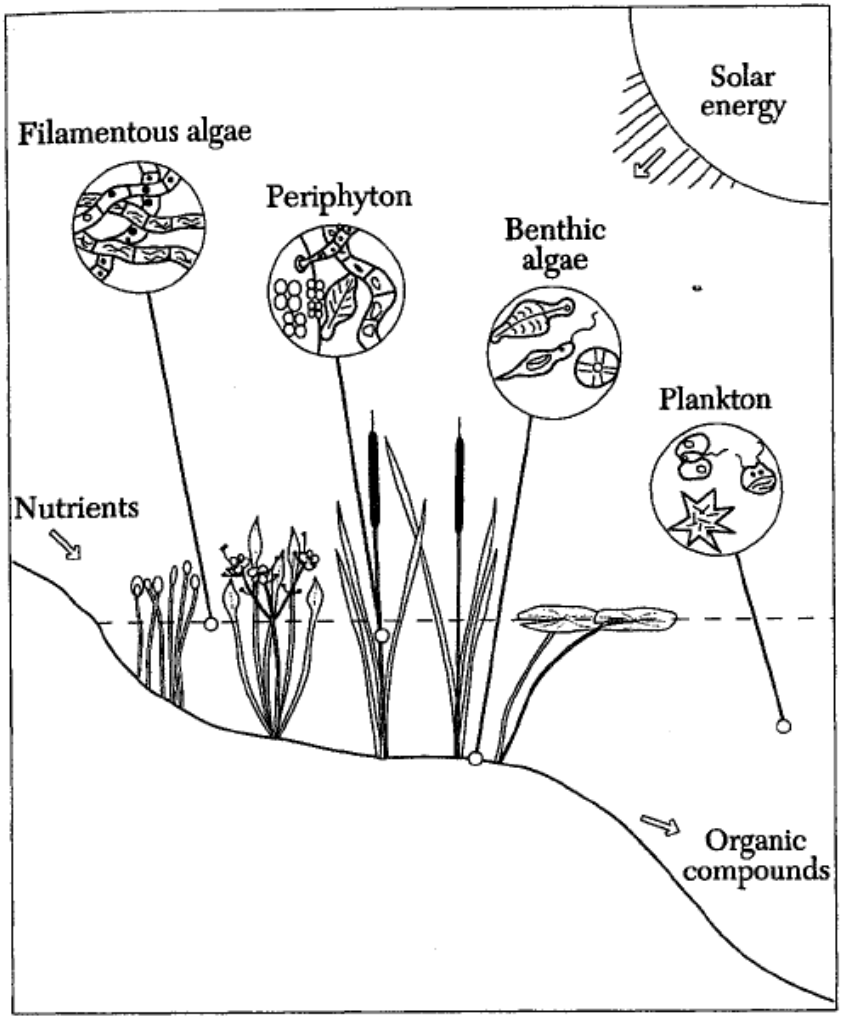


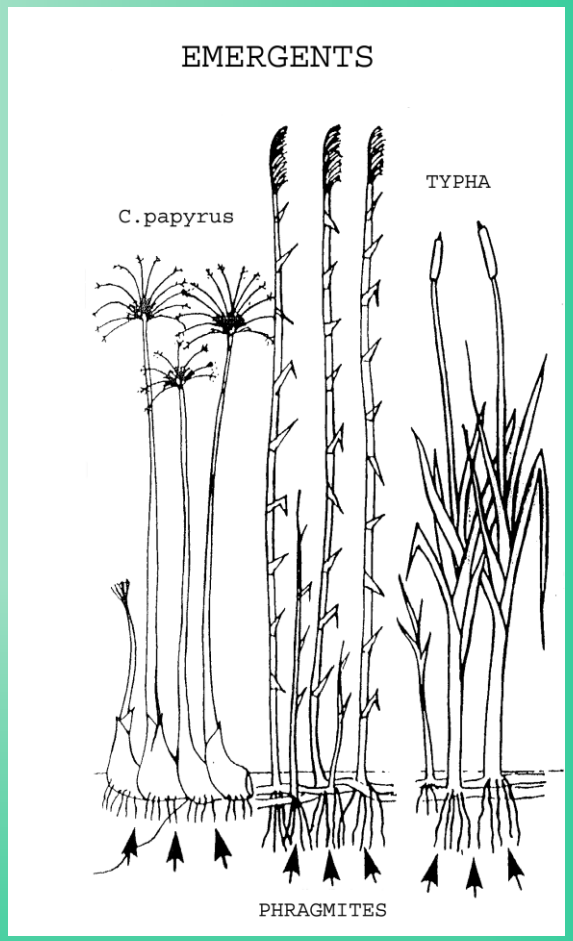
Figure 1.6. Algae and macrophytes in treatment wetlands (Kadlec & Knight 1996).

Source: IWA Scientific and Technical Report No 8 (2000)

Vegetation – emergent plants

- Emergent plant communities are composed of robust herbaceous plants that are normally anchored to the substrate and whose shoots emerge from the water to more than a metre in height.

- Example: *Cyperus papyrus*



(Denny, P.; 1987)

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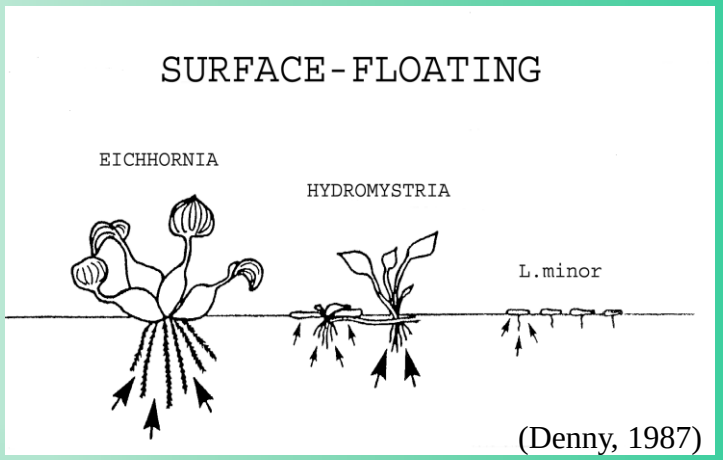
Vegetation – surface-floating plants

- true surface-floating vegetation is composed of *obligate acropleustophytes,* i.e. plants that are specifically designed to float on the water surface



(Denny, 1987)

- Example: duckweeds (*Lemnaceae*)

- Water hyacinth (*Eichhornia crassipes*)

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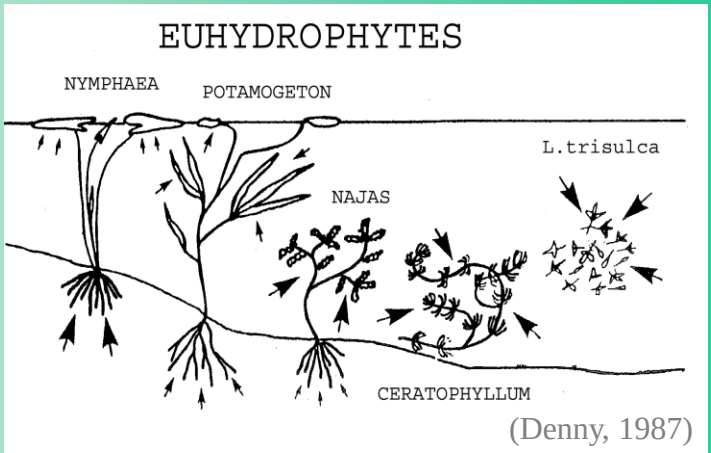
Vegetation – euhydrofytes

- Euhydrophytes are true water plants that have lost many of the terrestrial characteristics and acquired some very specific adaptations to the water environment. They are either floating-leaved or submerged



(Denny, 1987)

- Example: the water lilies (*Nymphaea* sp.)

- bed of submerged *Potamogeton* sp.

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Vegetation

Understanding ecological properties of plants is essential for successful design.

For example:

- some plants provide better shading → less growth of algae
- some plants provide high carbon input → "food" for bacteria
- some plants have more stems/roots → better filtration

One stubborn but (partially) incorrect myth: plants are important for treatment because of direct uptake and sequestration of pollutants

→ Plant uptake only important during growth season (and thus relatively more important in tropical conditions)

→ Plant uptake only important in low-loaded wetlands

Fauna

Flagellates, ciliates, amoeba, invertebrates are contributing to nutrient cycling and removal (integral part of the food web); exact role and importance however still not very clear

Some animals are unwanted:

- beavers and musk rats: wastewater disappears through tunnels; also feed on young plants
- dear, elk, wild pigs: can destroy plants when foraging
- bottom-foraging fish: can resuspend settled particles (this is called “bioturbation”
- insects: can cause damage to plants

Fauna - illustration

1. Samples were taken from the upper 15cm of five subsurface-flow wetlands in Belgium.

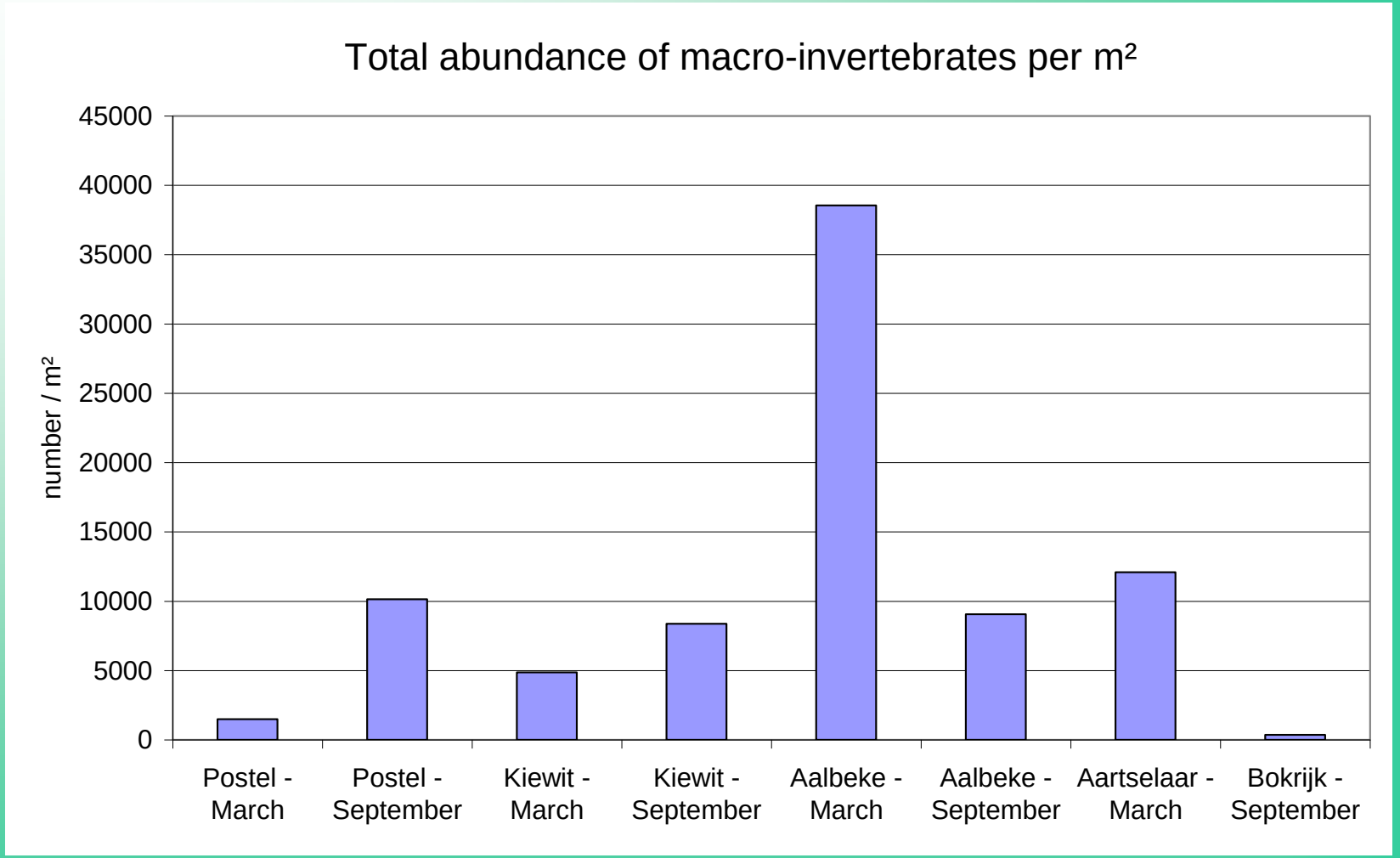
2. Samples were washed and sieved and macro-invertebrates (animals > 500 µm) were collected

3. Macro-invertebrate groups were identified and counted

4. Total abundances are shown in the next slide → stresses the importance of fauna in wetlands!

5. Main groups encountered: Diptera (flies and midges), Oligochaeta (bristle worms), Crustacea, Mollusca

Fauna - illustration



Rousseau (2002), unpublished results