Wetland technology for wastewater treatment and water quality improvement
I. Definitions

EARTH 444
BIOL 462

Ecological Engineering = Ecotechnology

"Design of sustainable natural and artificial ecosystems that integrate human society with its natural environment for the benefit of both" ***(S.E. Jorgensen 2009: Applications in Ecological Engineering, Elsevier)***

Ecology

- Commonly viewed as subset of biology
- theoretical ecology - evolutionary, systems, populations
- applied ecology - monitoring, assessing environmental impacts, managing natural resources
- ecological engineering has roots close to pure ecology (I.e. chemistry and chemical engineering)

Environmental Engineering

- ECOLOGICAL ENGINEERING ≠ ENVIRONMENTAL ENGINEERING
- environmental engineering, though uses scientific principles to solve pollution problems, usually involve energy and resource intensive operations (i.e. settling tanks, scrubbers, filters)

Biotechnology

- involves genetic manipulation to produce new strains and organisms to carry out specific functions
- ecotechnology uses existing species, communities, ecosystems

Synonyms or Subsets of Ecological Engineering

- phytoremediation
- synthetic ecology
- restoration ecology
- bioengineering
- sustainable agroecology
- habitat reconstruction
- ecosystem rehabilitation
- biomanipulation
- river restoration
- wetland restoration
- reclamation ecology
- ecohydrology

Phytoremediation

- The use of plants for removing toxic substances from contaminated soil or water
- e.g. wetlands/aquatic ecosystems
- e.g. soils (wet or dry)

Ecohydrology

- Use of a combination of ecological and hydrological principles to achieve sound environmental management

Classification of Ecotechnology

- 4 main classes of ecotechnology applications

1. TYPES OF APPLICATIONS

Application

- Ecosystems used to reduce or solve a pollution problem that otherwise would be harmful to other ecosystems

Examples

- Wetlands for diffuse pollution (open water wetlands)

2. TYPES OF APPLICATIONS

Application

- Ecosystems are imitated or copied to reduce or solve a problem

Examples

- Wetlands (root zone method)

3. TYPES OF APPLICATIONS

Application

- Ecosystems used for site recovery after major disturbance

Examples

- surface mine restoration; mine tailings; gravel pits and quarries; recovery of hazardous waste site

4. TYPES OF APPLICATIONS

Application	***Examples***
• Existing ecosystems are modified in an ecologically sound way to solve a problem	• biomanipulation; enhancement; integrated agriculture

Concepts of Ecological Engineering

- 1. SELF-DESIGN: self-organization of species shifts and food chain reorganizations in ecosystems adapting to change, human-induced or natural changes
- 2. SUSTAINABLE ECOSYSTEMS: once designed and created should sustain itself through self-design; should not depend on non-renewable fuel energies

Concepts of Ecological Engineering

- 3. ECOSYSTEM CONSERVATION:
  recognition of ecosystem values through ecological engineering provides greater justification to conserve natural ecosystems (i.e. flood control wetlands)
- 4. SYSTEMS APPROACH:works with whole ecosystems; synthesizes analytic experimental testing, modelling, cost-benefit analysis

Traditional vs. Ecological Engineering

Traditional Engineering	Ecological Engineering
Efficiency of function	Persistence of function
Seeks stability	Accepts change
Resists disturbance	Absorbs and recovers from change
Single acceptable outcome	More than one acceptable outcome
Spatially and temporally uniform	Spatially and temporally diverse
Predictable	Unpredictable
Heavy reliance on non-renewable energy	Maximum use of renewable energy
Rigid boundaries and edges	Flexible boundaries and edges
Unconcerned by production of waste materials from the design	Minimized production of waste

Wetland Ecotechnology

- **Habitat wetlands** - offset losses of natural wetlands
- **Wastewater and water quality improvement wetlands** - improve water quality
- **Flood control wetlands** - provide protection from flooding and erosion
- **Aquaculture wetlands** - production of food and fiber

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II. Background and History

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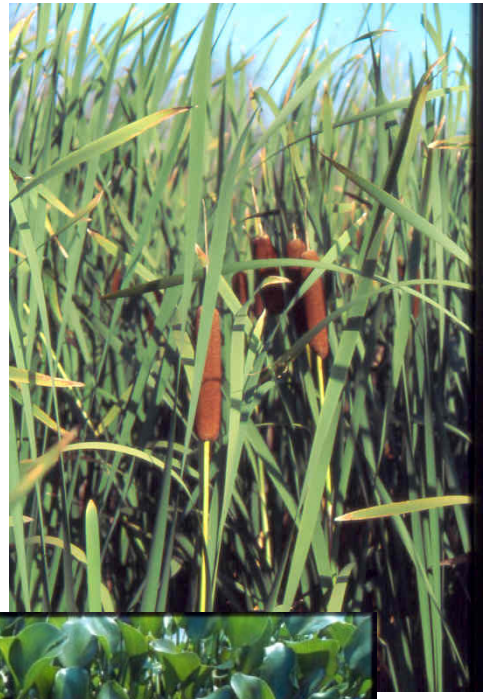
Wetland Technology as a Biological Treatment Method

- Käthe Seidel, Max Planck Institute, Germany in early 1950s
- investigated ability of aquatic macrophytes to grow in “polluted waters”; generally assumed they could grew only in clean water
- birth of wetland systems as biological treatment systems



History of Treatment Wetlands

- 1952-1970s – Germany: phenols and dairy wastewaters
- 1967-1972 – North Carolina: estuarine ponds/salt marsh
- 1971-1980s – Massachusetts, Michigan, NY., Florida, California- natural wetlands
- 1979-1980s – California, Florida, Ontario, Sask- engineered designs

State of Wetland Technology in Canada

- started in 1979: Listowel, ON and Humboldt, SK
- 100s of designs for all kinds of water quality issues - custom designs
  - fully operational
  - pilot-scale and demonstration sites
  - abandoned and destroyed
  - natural wetlands used
- mostly SF and SSF designs
- solely for water treatment and part of wetland system for other uses

(Courtesy of MOE)

Advantages of Wetland Technologies in Canada

- Great potential in wetland-rich Canada
- Conservation benefits - opportunity to reverse historical trend of wetland losses
- Non-traditional option that complements existing wastewater technologies
- Passive and above ground
- Low to no energy required
- Low to medium capital costs in comparison
- Low operation and maintenance costs
- Wide range of applications
- Numerous ancillary benefits

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III. Types of Systems

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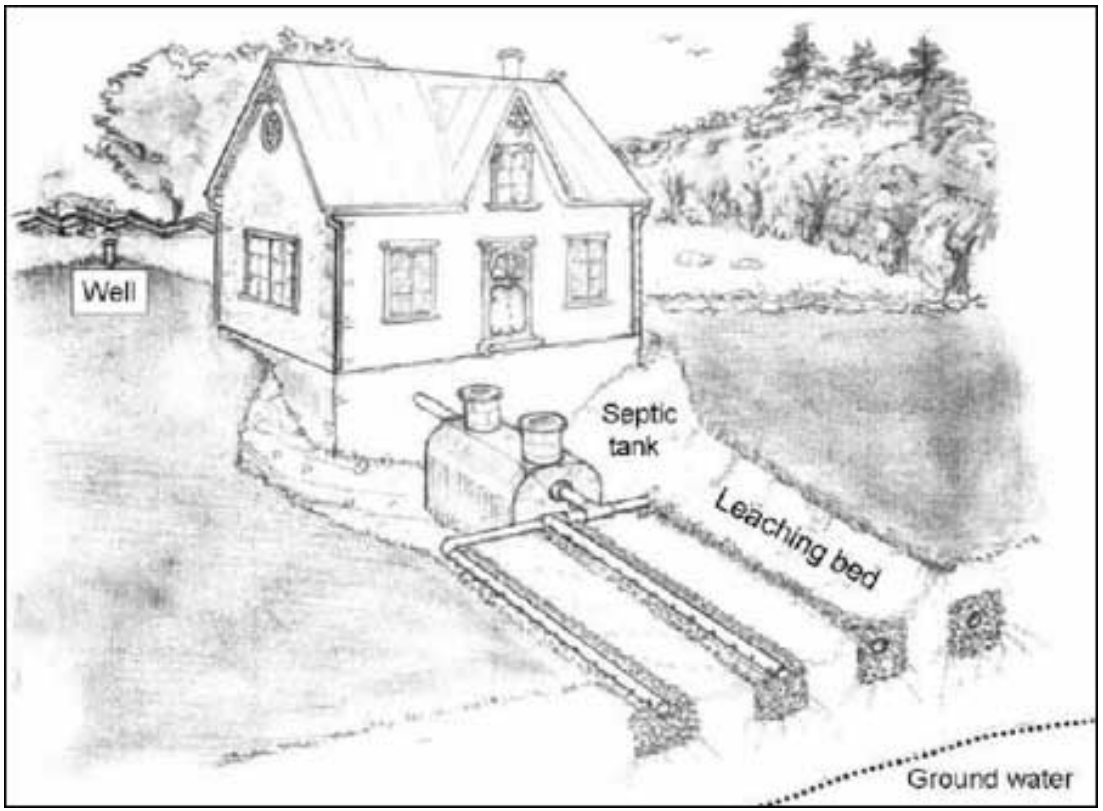
Kinds of Wastewater

- **Municipal -** dilute to concentrated mixture of urine, feces, paper, soaps, grease, household chemicals
- **Agricultural -** dilute to concentrated mixture of biodegradable compounds
- **Industrial -** dilute to concentrated mixture of biodegradable and nondegradable chemicals
- **Stormwaters -** dilute mixture of mineral and organic solids, dissolved salts

Upland Treatment Systems (Biological treatment)

- ***on-site infiltration*** **-** residential & community septic tanks & drain fields



Upland Treatment Systems

- ***slow-rate land infiltration*** **-** irrigation of vegetated land for polishing
- ***high-rate land infiltration*** **-** uses permeable soils for groundwater discharge

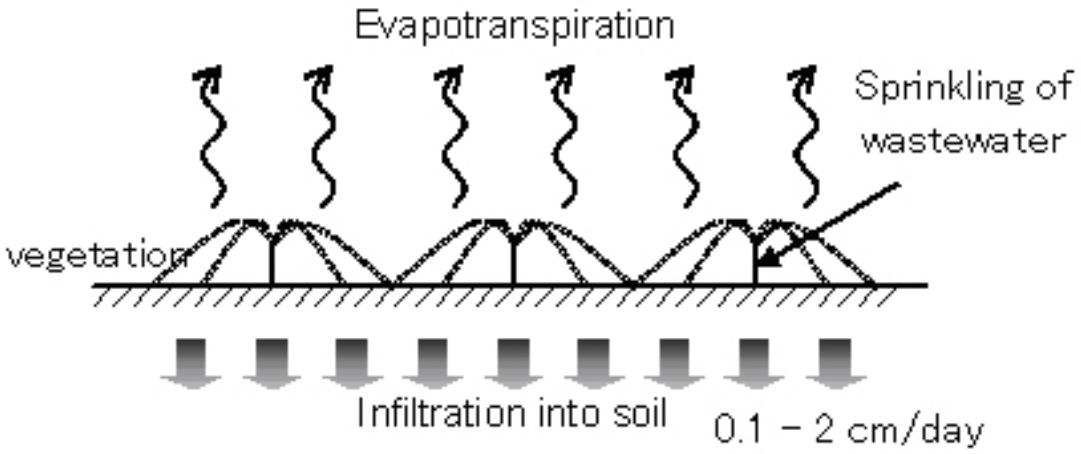


Fig. 1 Slow rate system

Upland Treatment Systems

- ***overland flow*** **-** uses low permeable soils, infiltration through surface vegetation

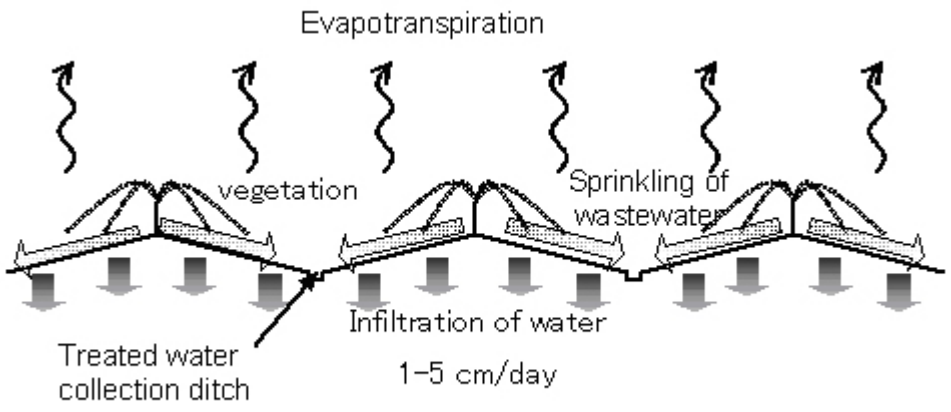


Fig. 2 Overland flow system

Aquatic & Wetland Systems

- ***Pond systems*** **-** stabilization ponds, designed with liners & forced aeration
- ***Floating aquatic plant systems*** **-** duckweed and water hyacinth
- ***Wetlands*** **-** natural, constructed surface flow & constructed subsurface flow systems

Wetland Types Used for Wastewater

- natural wetlands
  - bogs
  - fens*
  - swamps
  - marshes*
  - open water*
- constructed wetlands
  - surface flow (SF) wetlands
  - subsurface flow (SSF) wetlands
  - floating plant systems

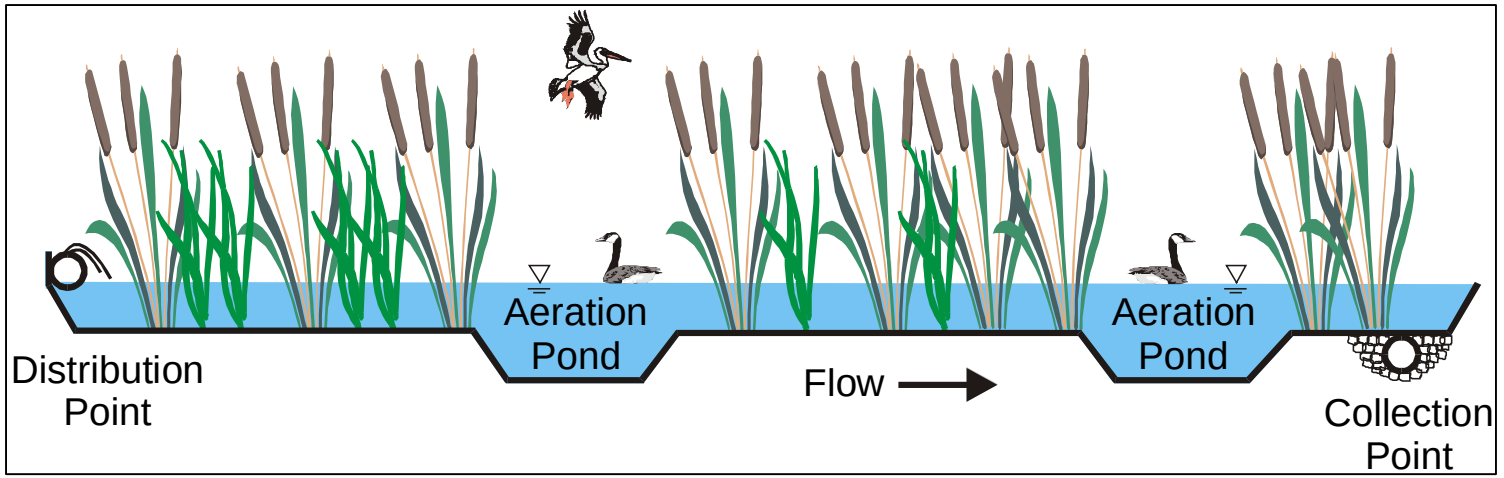
Is a Treatment Wetland an Option?

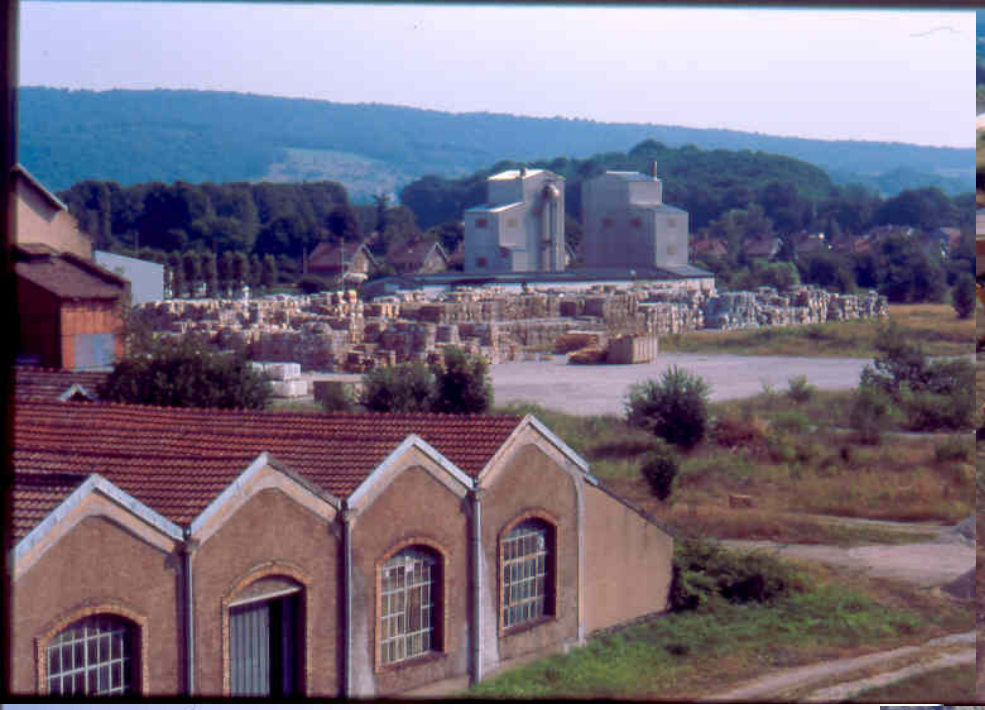
- Specify goals
- Designing for success: the wetland design and implementation procedures
- Evaluate performance and success: How & why?
  - lack of clear definition of success
  - need quantitative performance criteria and data
  - need regulatory guidelines
- Longer term operation, maintenance and monitoring
  - young technology and young systems
  - teach maintenance
  - develop cost-effective monitoring tools

Planning for the wetland option

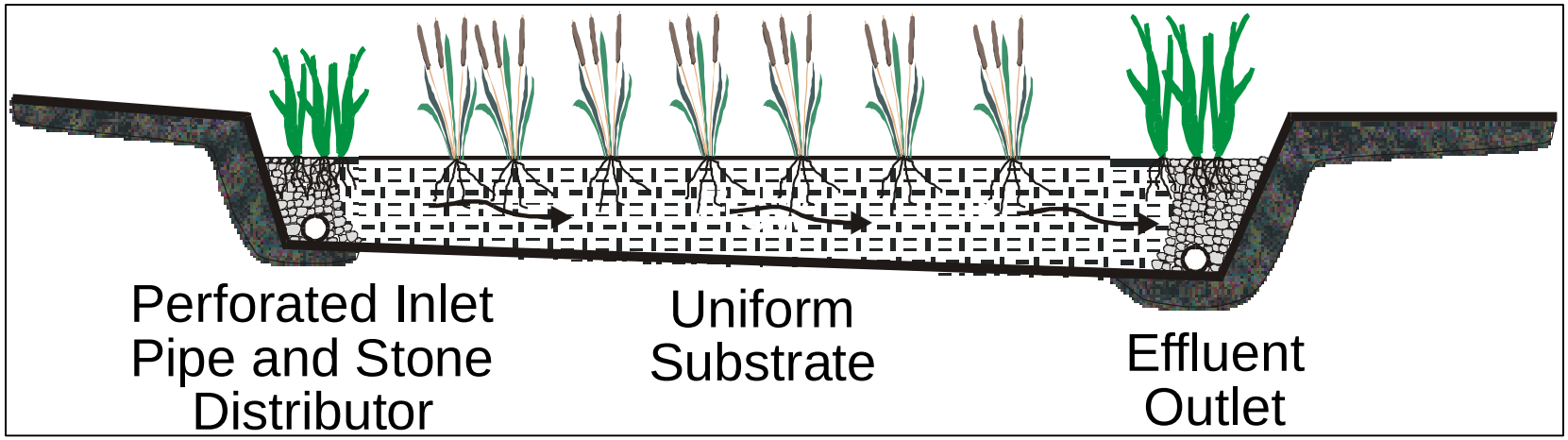
- Wastewater characterization
- Treatment Options: traditional and non-traditonal
- Wetland Alternatives
- Treatment Goals
- Regulatory Constraints
- Wetland Conceptual Plan

Surface Flow (Free-water) System

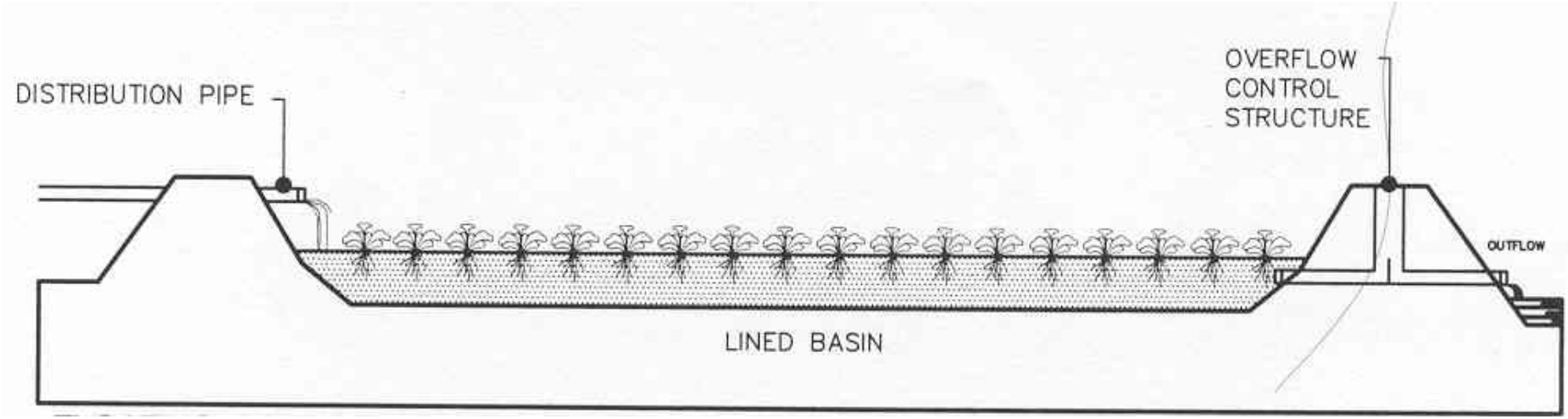


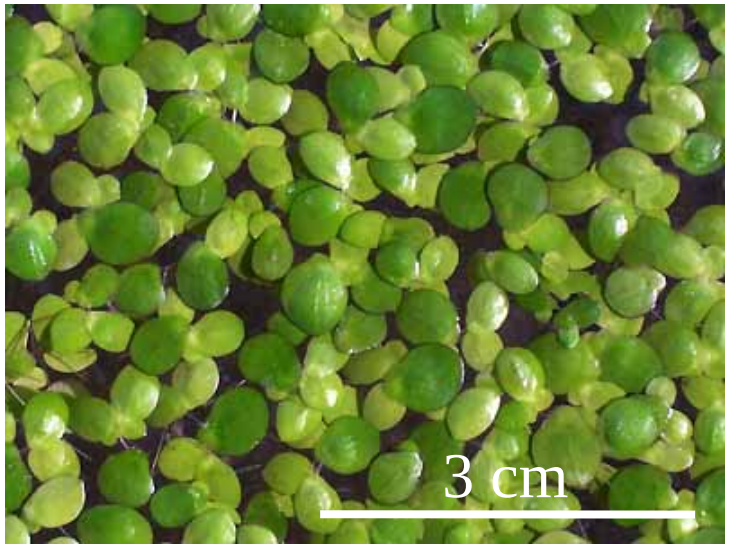


Subsurface Flow System



Free-Water/Floating Systems





Floating treatment wetlands

From: http://www.floatingislandinternational.com/wp-content/plugins/fii/casestudies/7.pdf

Near Brampton

(From Globe and Mail, Thursday, Sep. 22, 2011)