Constructed Treatment Wetlands

Naval Facilities Engineering Service Center

Port Hueneme, California

Topics Covered - Constructed Treatment Wetlands

- Applicability to Navy
- Principles of Wetlands
- Mechanisms of Treatment
- Case Study - NAB Little Creek
- Planning and Implementation
- NFESC Points of Contact

Constructed Treatment Wetland Applications

- Installation restoration (IR) sites
  - Petroleum hydrocarbons
  - Landfill leachate
  - Metals
  - Groundwater & surface water runoff
- Municipal wastewater (remote troop locations)
- Stormwater runoff
- Deicing runoff
- Washracks
- Industrial effluents
- Sediments & Sludges (dredge spoils, O/W separators)

IR Site Contaminants

- Wetlands can be cost-effective where sites have high flows and moderate to low concentrations of:
  - Volatile Organics PPs
  - Semi-Volatile Organics PPs
  - Petroleum Hydrocarbons
  - Metals
  - Pesticides and Herbicides
  - PAHs
  - Chlorinated Solvents
  - Non-Chlorinated Solvents
- Groundwater and runoff treatment
- For high concentration priority pollutants, wetlands may be used as a secondary or tertiary process
- Particularly suited to sites where minimal O&M is desirable (e.g. BRAC facilities)

Principles

- What are wetlands?
- What are constructed treatment wetlands?
- How well-proven is the technology?
- Benefits (what can treatment wetlands do for me?)

Wetland Characteristics

- Shallow Standing Water and/or Saturated Soil for All or Part of the Year (Hydric Soils)
- Characteristic Vegetation Such As Reeds, Cattails, and Rushes
- Contaminant Removal via Physical, Chemical, and Biological Mechanisms
  - sedimentation, filtration, adsorption, volatilization
  - precipitation, photodegradation
  - microbial degradation, plant uptake and degradation

A Typical Wetland

A Typical Wetland

Constructed Treatment Wetlands Are:

- Man-made wetlands built in former upland areas
- Designed to intercept and remove pollutants from water
- Engineered to treat specific ranges of flows and contaminants

Influent Water + **Organics**, **Metals**, **Nutrients**, **Suspended solids** → **Constructed Wetlands** → **Cleaner Effluent**

Wetlands in a Desert

Treatment Wetlands - Condensed History

- Late 1800's to present – Wetlands used as wastewater discharge sites
- 1952 to 1979 – Research at Max Planck Inst.
- 1970's through 1980's – Numerous studies using natural and constructed wetlands and ponds
- 1988 – EPA formally recognized constructed wetlands technology by issuing a design manual
- An estimated 280 large-scale constructed wetlands presently being used for treatment in the US alone

Benefits of Treatment Wetlands

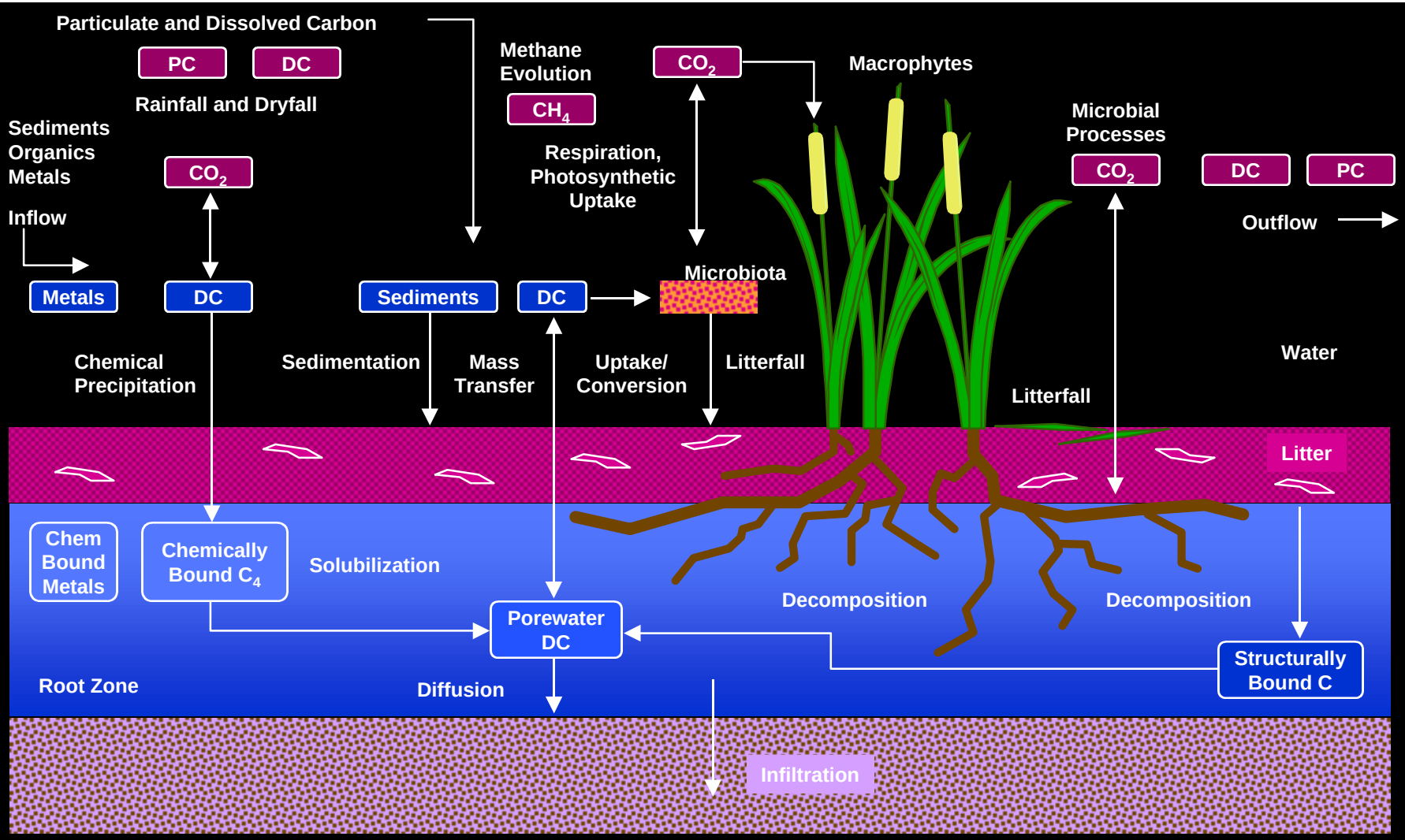
- Effective removal of a wide variety of contaminants
- Low O&M costs
- Compliance with water quality goals
- Protection of human health and the environment
- Reduction of flood hazard and erosion
- Enhanced community relations
- Conserves and enhances natural resources

Enhanced Natural Resources

Treatment Mechanisms

- Overview
- Organics
  - Typical Removal Efficiencies
  - Examples
- Metals
  - Typical Removal Efficiencies
  - Examples
- And the Rest (mixed contaminants)
  - Landfill Leachate
  - Wastewater
  - Stormwater

Contaminant Removal Mechanisms of Wetlands



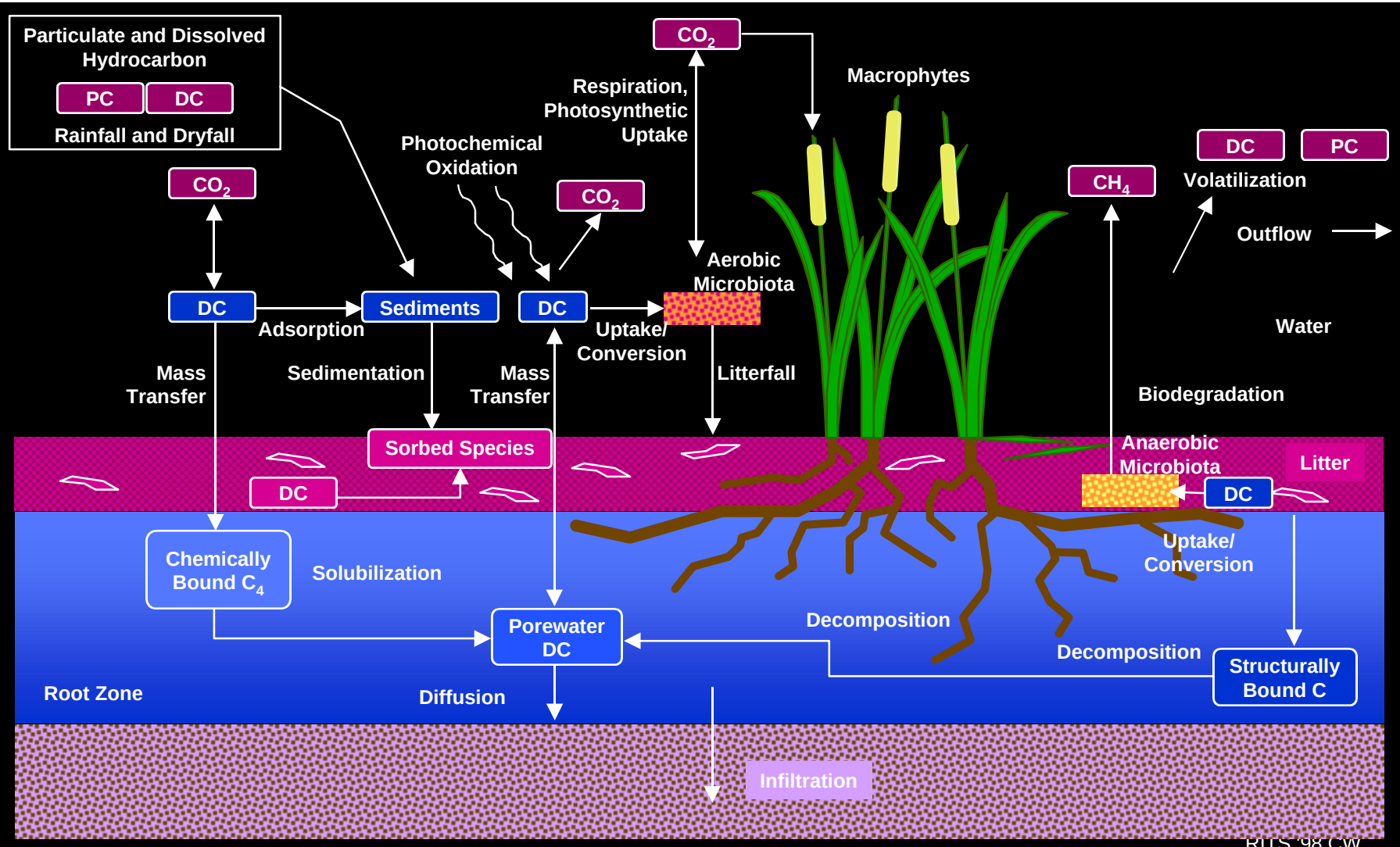
Treatment Wetland Organics Removal

- Wetlands treat petroleum hydrocarbons and other organics mainly via microbial degradation

- Organics typically treated using wetlands include:
    1. Fuels – gasoline, jet fuels, diesel
    2. Oil & Grease
    3. Pesticides, herbicides
    4. Phenol, many priority pollutants

- Treatment is broad-spectrum, though removal efficiency is compound-specific

Organics Removal Mechanisms



Hydrocarbon Removal Efficiencies

Contaminant Type:	Removal Efficiency (%)
Oil and grease	54 - 92
Phenols	63 - 81
Benzene, Toluene	99+
Ethylbenzene	99+
Naphthalene	86
Diethyl Phthalate	75
Benzoic acid	99

Constructed Wetlands for Hydrocarbon Treatment
Case Studies

Wetland	Flow Type	Hydrocarbon(s)	Influent	Removal Efficiency (%)
1. Amoco Refinery [1]	surface	Oil and grease Phenols TSS Total Chromium	2120 ug/L 80 ug/L 35.6 mg/L 400 ug/L	92 79 83 84
2. Tenneco Inc. [2]	subsurface	Oil and grease	-------	90
3. Surprise Arizona [2]	subsurface	Oil and grease	-------	54 - 92
4. Chevron Refinery [2]	surface	TSS	20 mg/L	45
5. Water Hyacinth [3]	surface	Phenol Benzene, Toluene Ethylbenzene Napthalene Diethyl Phthalate	------- ------- ------- ------- -------	81 > 99 > 99 86 75
6. New Mexico State U. [2]	subsurface	Benzoic acid	40 mg/L	99
7. Yanshan wetlands, Beijing, China [2]	surface	Oil and grease Phenols TSS	840 ug/L 27 ug/L 181 mg/L	65 63 77

[1] Moshiri, 1993. [2] Kadlec, 1995. [3] Tchobanoglous, 1991. Note: ------- indicates no data

Case Study: Amoco Refinery, Mandan, ND

- 41-acre wetland/pond system for treatment of 664,000 gal/day API separator hydrocarbon-laden wastewater and stormwater
- Wetland treatment of wastewater avoided 27 NPDES permit violations in 1990 alone
- Wetland/pond system cost $250K vs. $1M - $3M for traditional treatment systems (1972 dollars); O&M savings even greater
- Design included additional storage for process upsets, heavy storms, and snowmelt
- Numerous wildlife habitat benefits, recognition by regulators and environmental groups

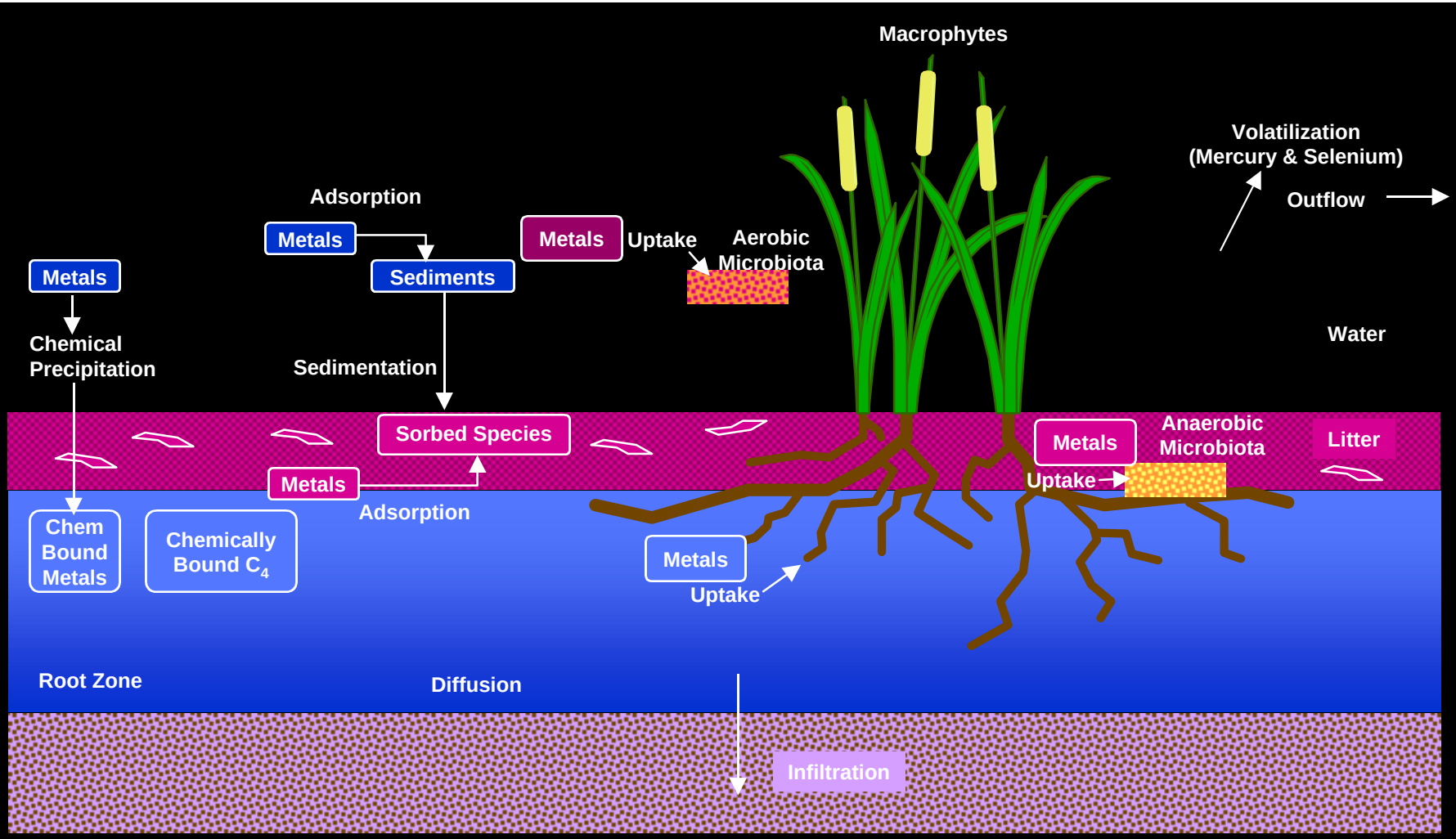
Jet Fuel in Groundwater Treatment

Jet Fuel in Groundwater Treatment

Treatment Wetland Metals Removal

- Metals are complexed via biological, chemical and physical mechanisms into insoluble forms
- Metals are eventually sorbed in the soil/sediment as biologically unavailable, stable complexes
- Removal efficiencies increase with increasing influent concentrations up to the point of plant and/or microbe toxicity
- Metals taken up by wetland plants concentrate in roots (lower amounts translocated to leaves/stems)

Metals Removal Mechanisms



Example: Metals Removal

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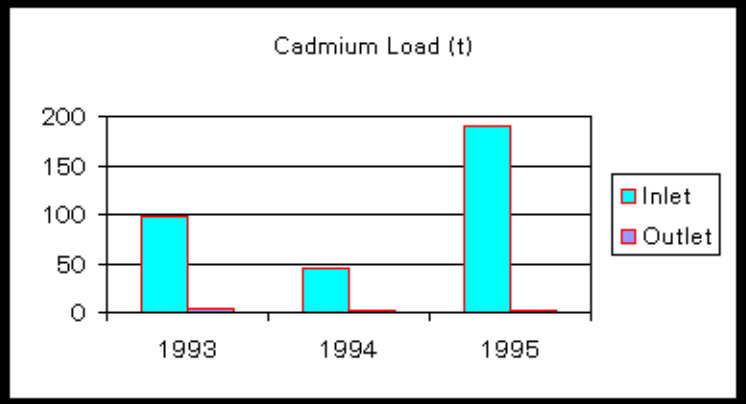
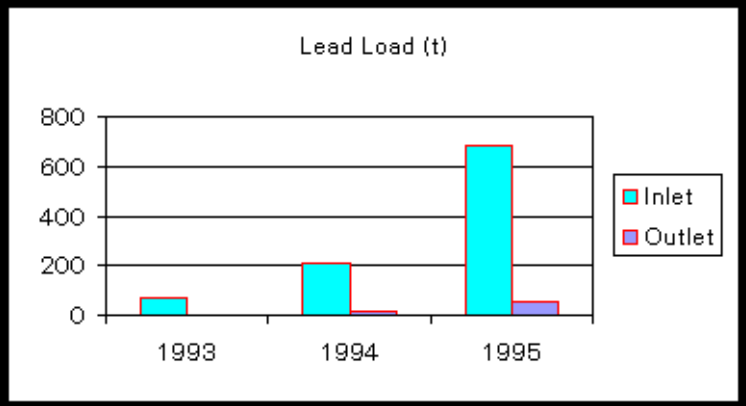
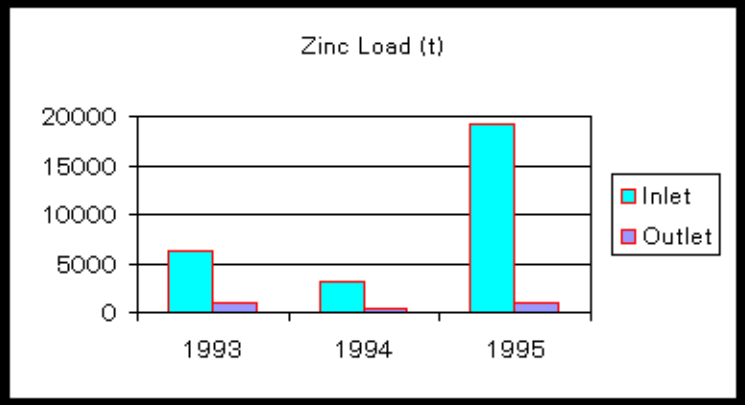






Landfill Leachate Contaminant Removal Efficiencies

Huneault Landfill[1]		Sarnia Landfill[2]		Tompkins Landfill[3]	
Boron	83%	Ammonia	52-98%	Ammonia	70%
Iron	94%	Nitrate	76-95%	BOD	65%
Lead	99%				
Zinc	55%				
BOD_5	87%				

Source: (1) http://www.computan.on.ca/~prodigal/peatfilt.htm
(2)http://www.computan.on.ca/~prodigal/landfill.htm
(3) Gerald A. Moshiri “Constructed Wetlands for Water Quality Improvement”

Wastewater Contaminant Removal Efficiencies

Pollutant	Influent Concentration	Removal Efficiency	Lower Limit
BOD	20 - 240 mg/L	50 - 96%	2 - 10 mg/L
Suspended Solids	20 - 380 mg/L	50 - 98%	2 - 10 mg/L
Ammonia Nitrogen	5 - 45 mg/L	Up to 95%	1 - 3 mg/L
Total Phosphorus	1 - 15 mg/L	Up to 90%	<1 mg/L
Metals	0.01 - 50 mg/L	50 - 99%	below detection
Coliforms	1500 - 68,000,000 cfu/100 mL	80 - 99%	<100 - 1000 cfu/100 ml

Source: Hammer, Constructed Wetlands for Wastewater Treatment, 1989; EPA NADB for Treatment Wetlands

Example: Wastewater Treatment Wetland

Arcata, CA Constructed Treatment Wetland

Renton, WA Sewage Treatment Plant Wetlands (1996)

Stormwater Treatment

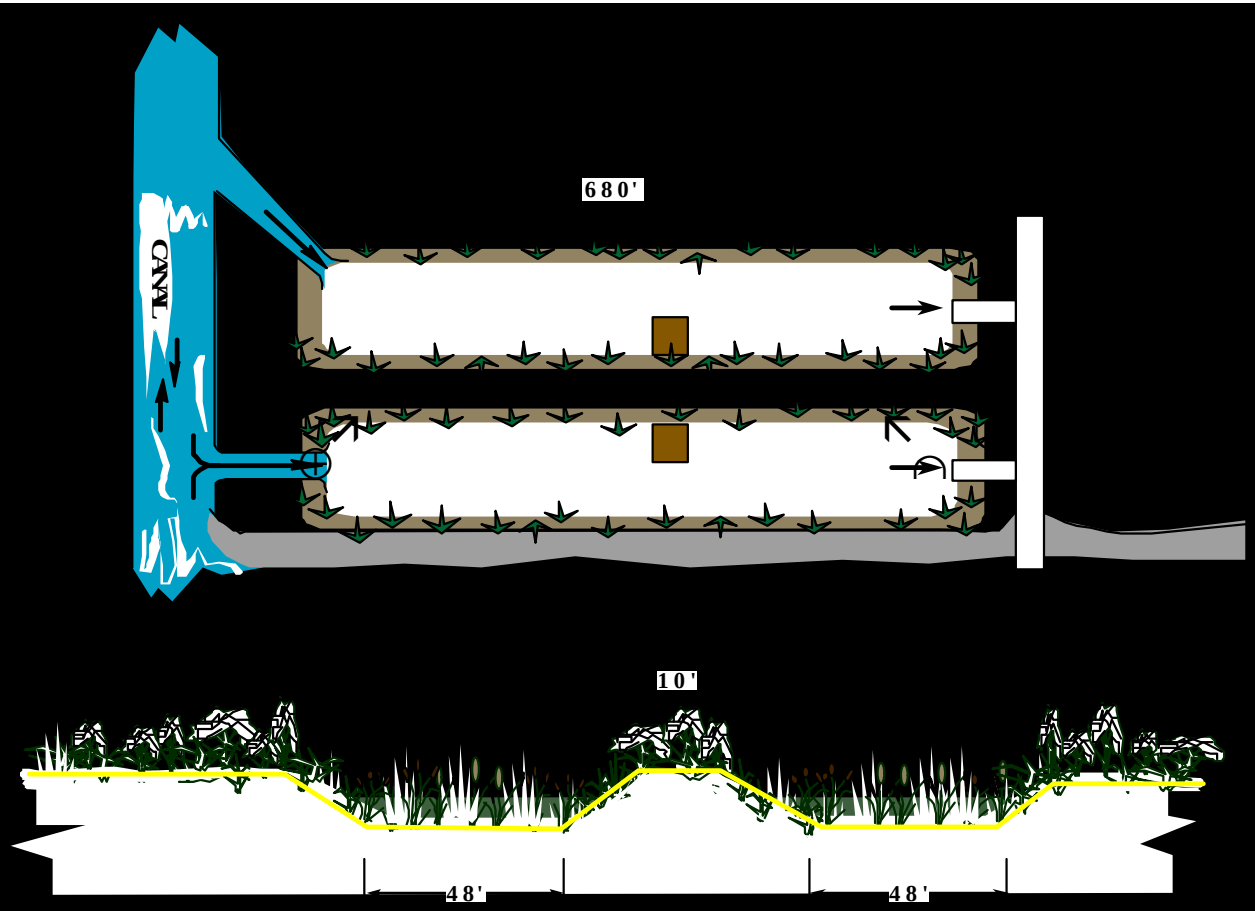
- Typically large volumes, low concentrations
- Wetlands naturally developed in part due to stormwater flows
- Contaminants include organics, nutrients, metals
- Wetlands treat mixed contaminants effectively by virtue of their complex structure

Example: (Fortuitous) Stormwater Treatment NCBC Port Hueneme, CA

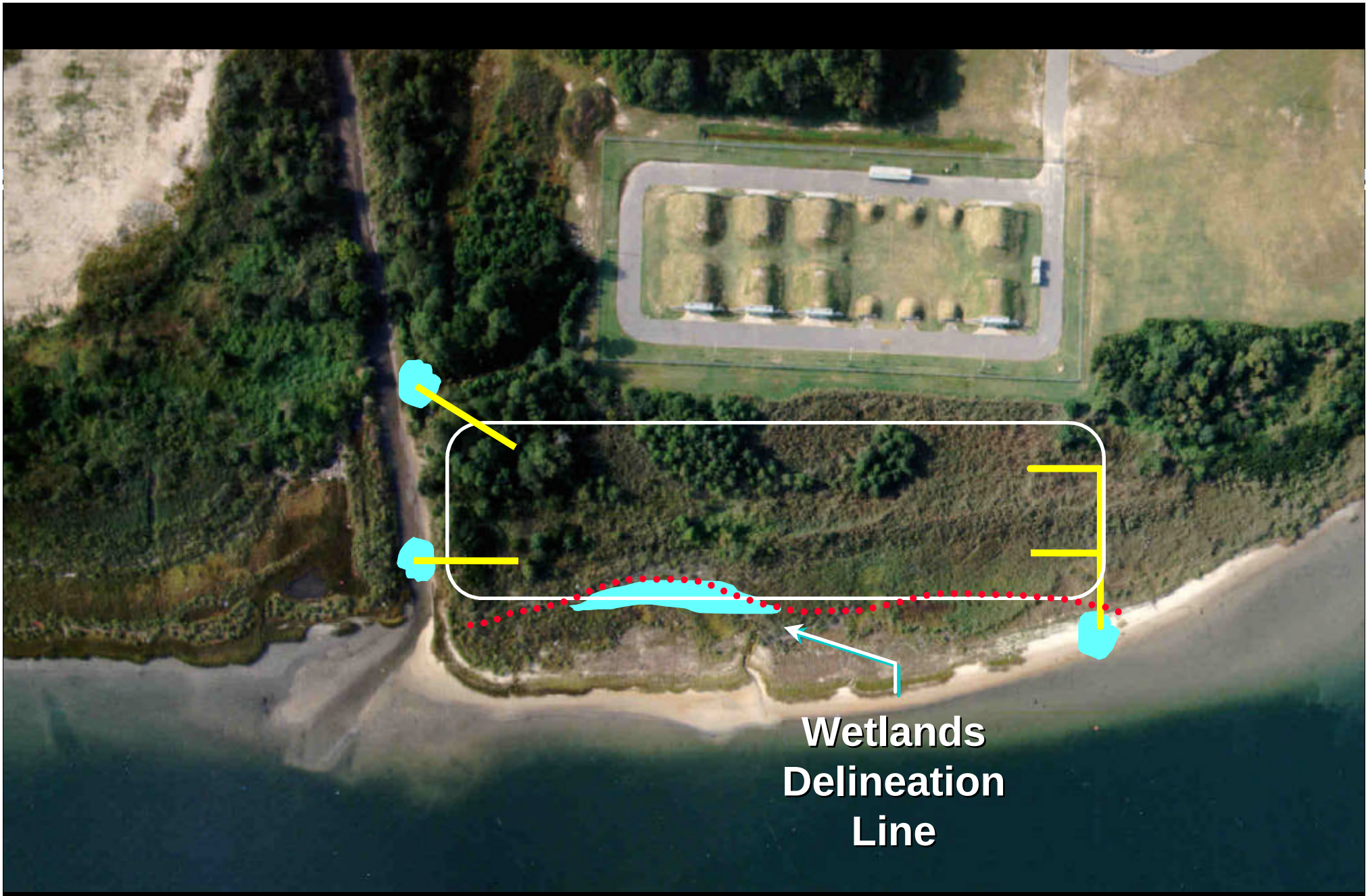
Case Study: NAB Little Creek Treatment Wetland

- Demonstration Treatment Wetland for Stormwater Treatment
- Tidally Influenced
- Contaminants Detected in
  - Runoff
  - Closed landfill adjacent to site
  - Sediments and Groundwater

Stormwater Treatment - NAB Little Creek Constructed Wetland Schematics

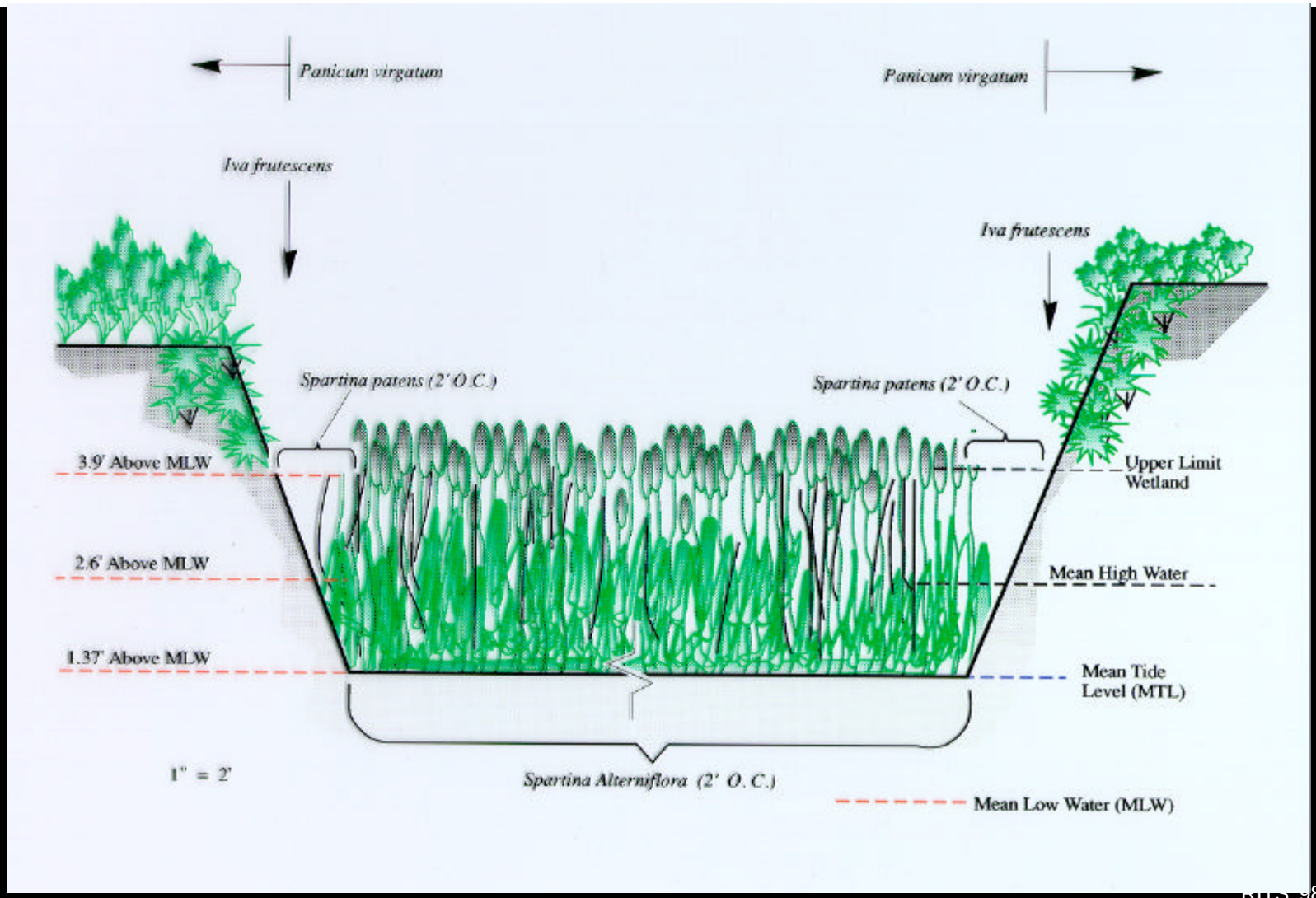


Tidally-Influenced Constructed Wetland System


Wetlands
Delineation
Line

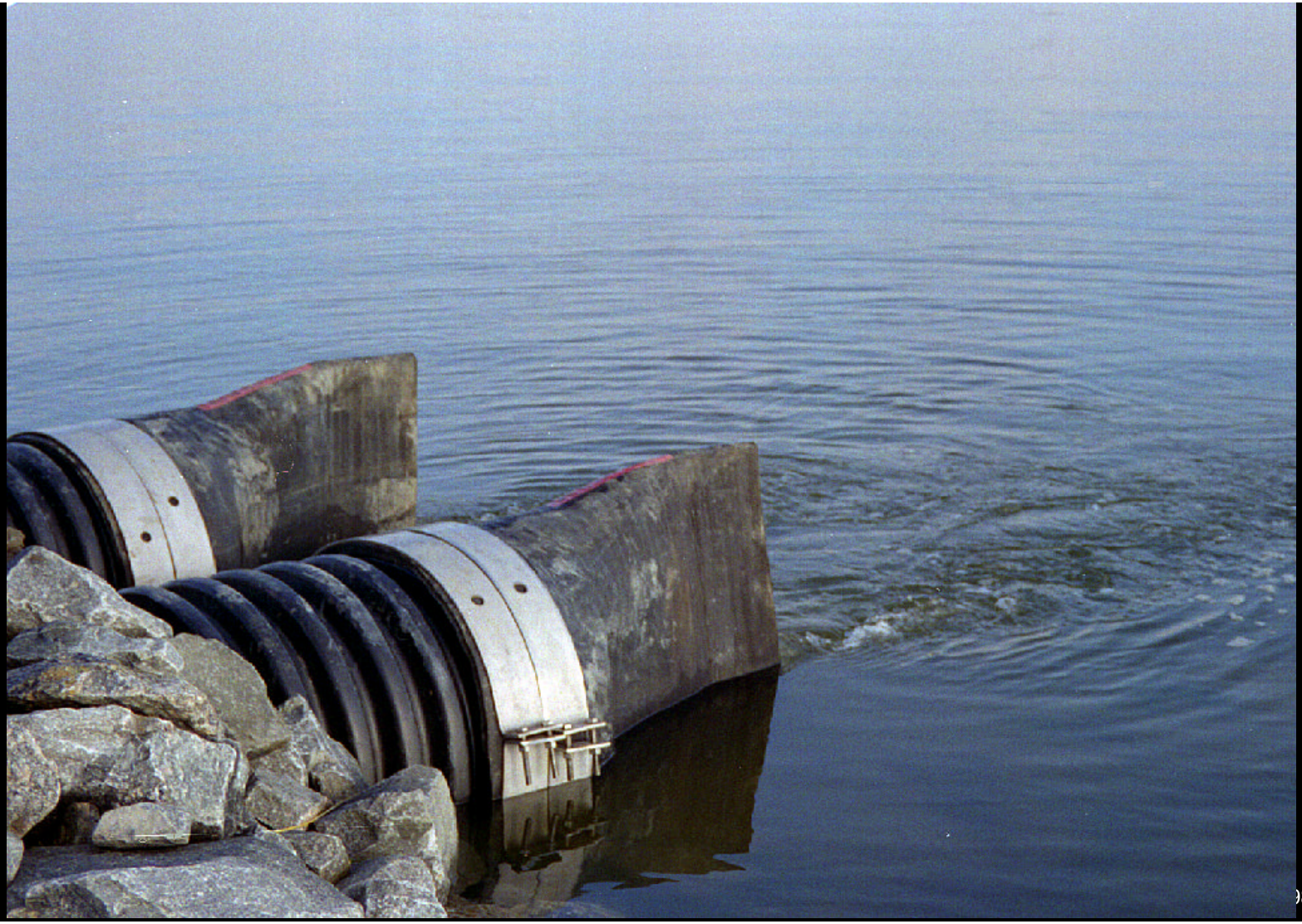
NAB Little Creek Wetland Construction

Cell Cross-Section



NAB Little Creek CW – Cell 1 Inlet

Outlet Check Valves



NAB Little Creek CW Startup – Summer '96

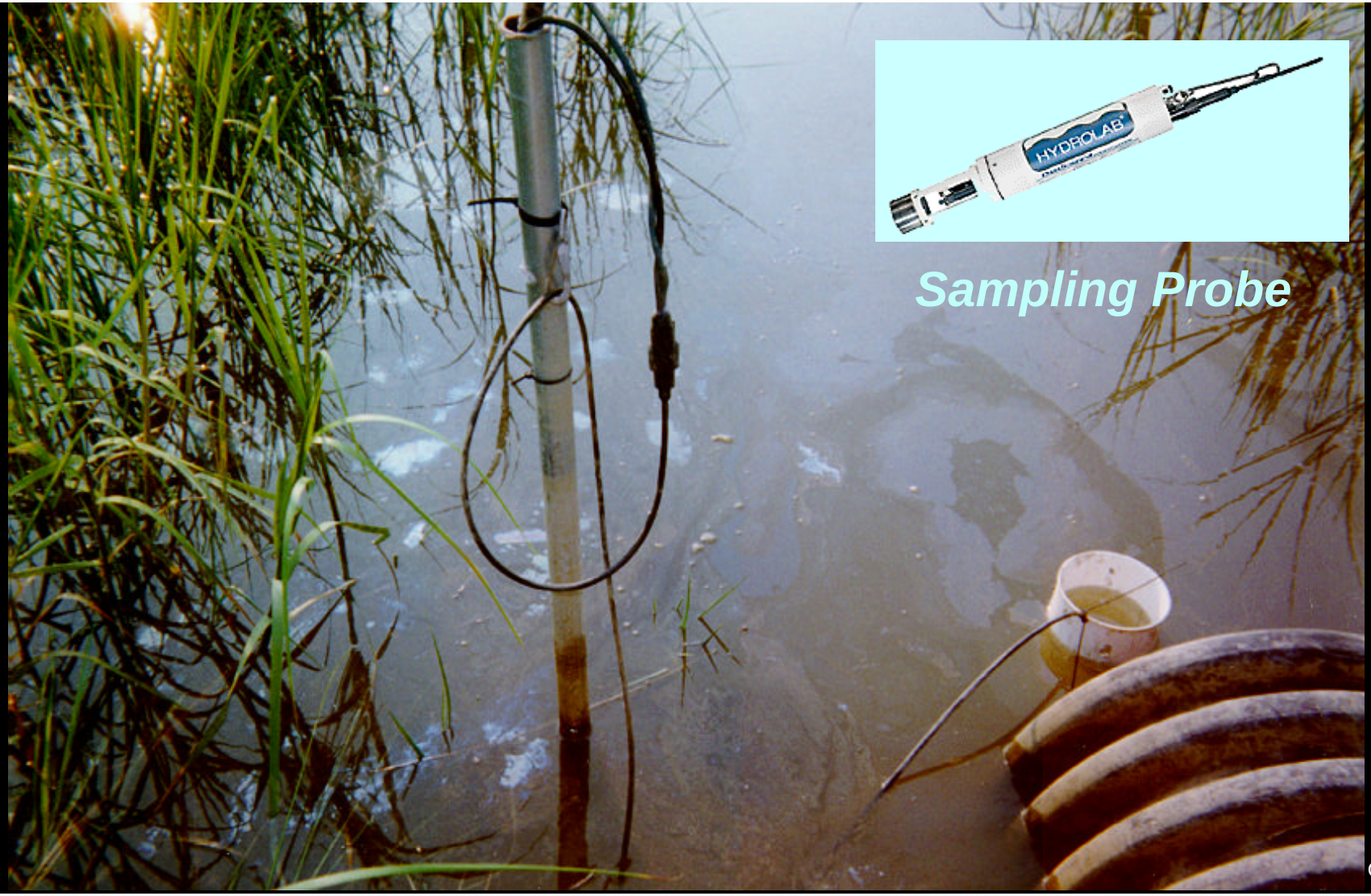
NAB Little Creek – Summer '97

NAB Little Creek – New Transplants

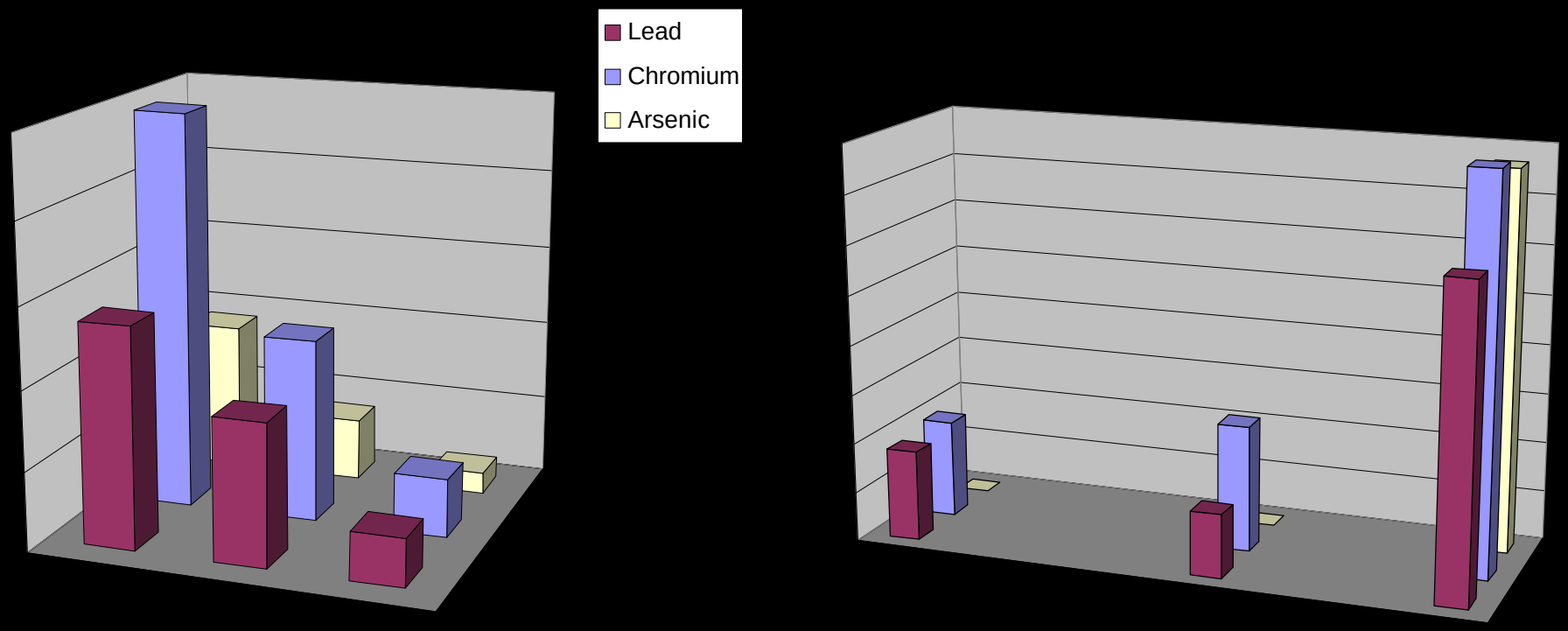
NAB Little Creek – One Year Growth

Solar Panel, Autosampler, and Monitoring Well

Sampling Probe at Cell Outlet



Metals Removal in Sediment



Costs of Constructed Wetland at NAB Little Creek – 2 Acres

Permitting	15 K
Design	58 K
Construction	125 K
Plants	9.6 K
Subtotal	207.6 K
Monitoring Equipment	29.2 K
Lab Analyses • 1995 18.5 K feasibility study • 1996 21 K startup monitoring • 1997 46 K quarterly monitoring	85.5 K
Total	313.8 K

Treatment Wetland Planning and Implementation

- Feasibility Considerations
- Design Considerations
- Permitting
- Implementation Steps
- Costs

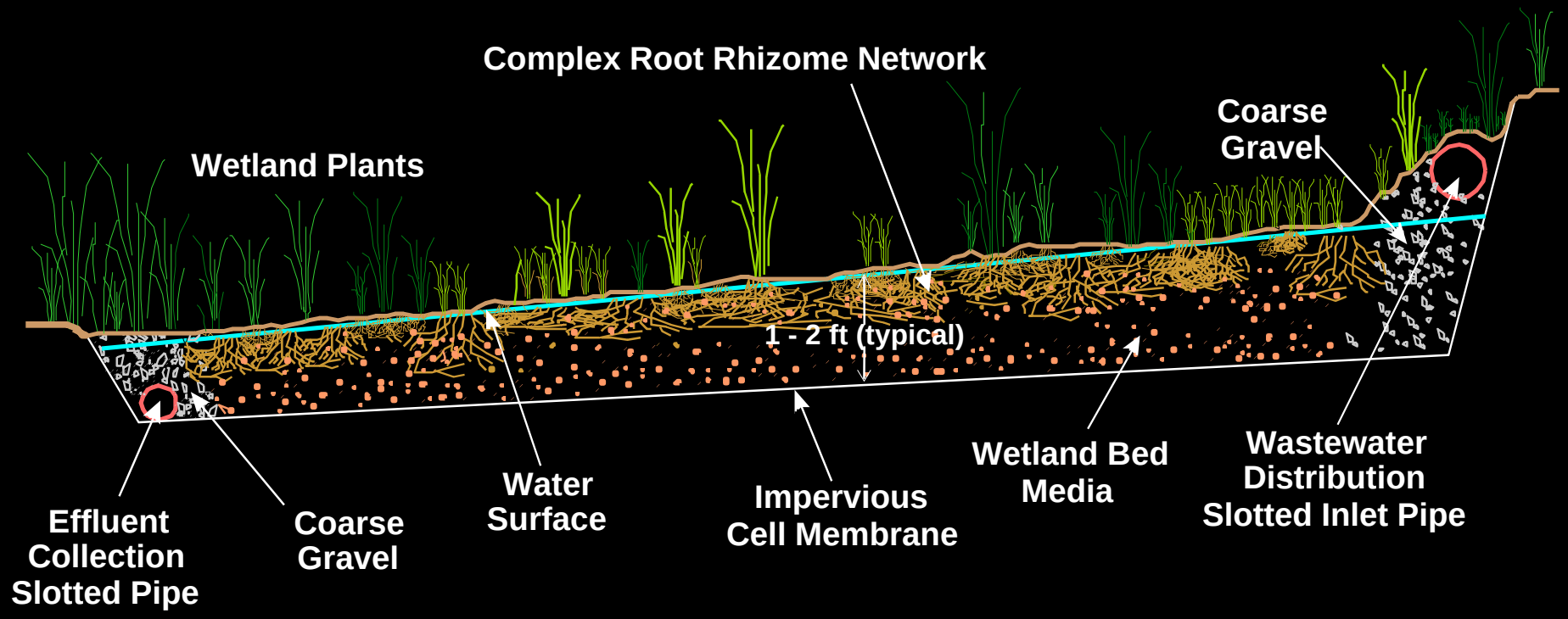
Feasibility of CWs at a Given Site

- Treatability
  - Contaminant types
  - Concentrations
- Flow (loading)
- Available land
  - Area
  - Topography
  - Geology/Soils
  - Proximity to source
- Funding/Permitting
- Timing
  - Permitting
  - Wetland development
- Practicality
  - Aesthetics
  - Nuisance control
  - Community acceptance

The Two Major Designs of Constructed Wetlands

- Surface Flow Wetlands
  - Water surface remains above the substrate
  - Water movement via laminar or quiescent flow
  - Treatment occurs in free water and infiltrated zones
- Subsurface Flow Wetlands
  - Constructed using a porous substrate material (gravel)
  - Water flows through the substrate
  - No open, standing water exists in this system, all treatment occurs in the infiltrated zone

Subsurface Flow Constructed Wetland



Design Considerations

- Type of wetland
  - Surface flow wetland
  - Subsurface flow wetland
- Retention time and area requirement (flow/loading)
  - General Rule of Thumb: 2-8 cm/day flow
  - General Rule of Thumb: 2-5% of watershed
  - Contaminant k
- Topography and Geology
- Hydrology
- Plant selection (volunteers, nursery stock)

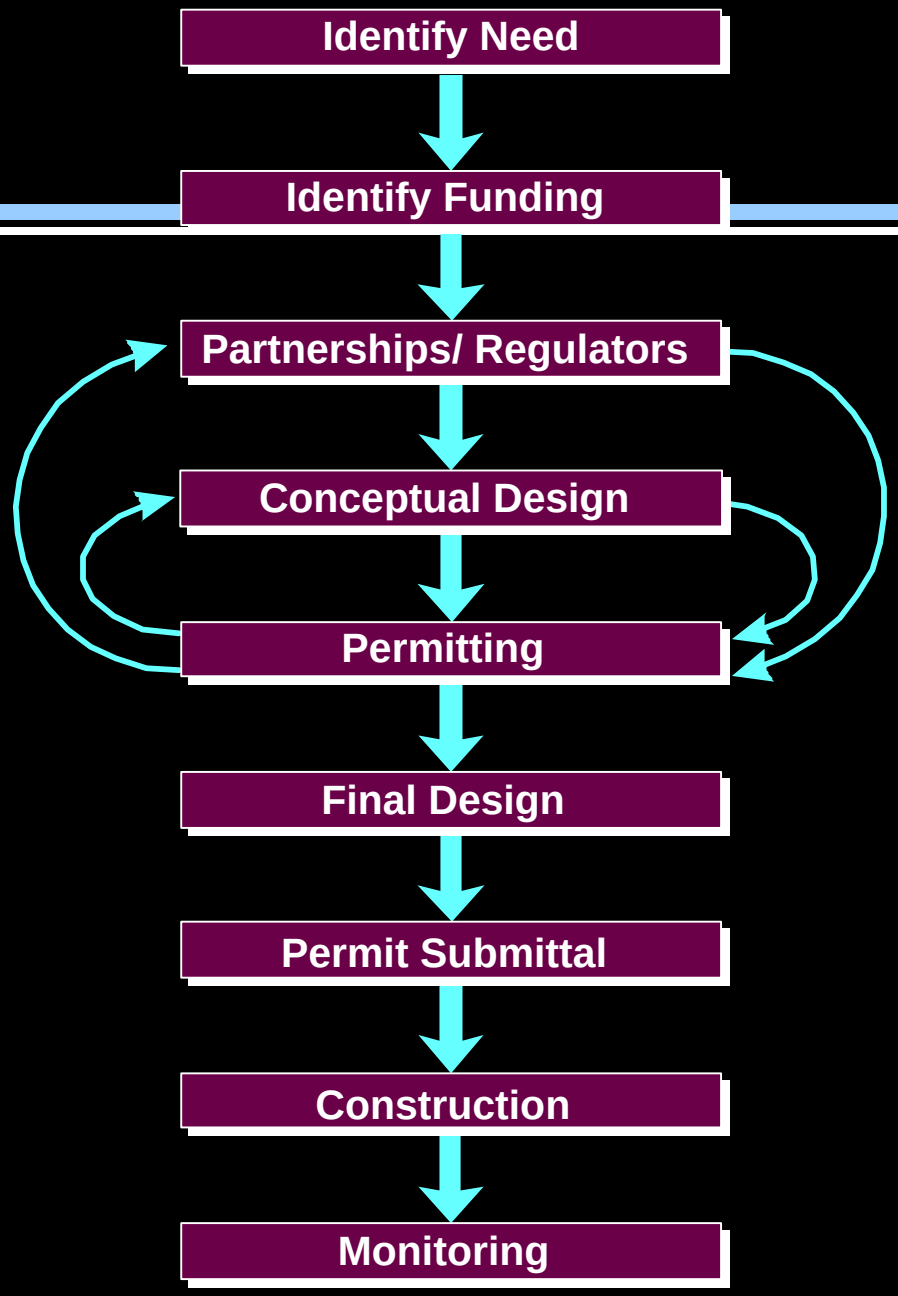
Design Considerations (Continued)

- Soils
  - Classification
  - Permeability
  - Organic Content
  - Cation Exchange Capacity
- Climate
  - Precipitation
  - Evapotranspiration
  - Temperature (seasonal extremes and averages)
  - Wind (speed/direction)

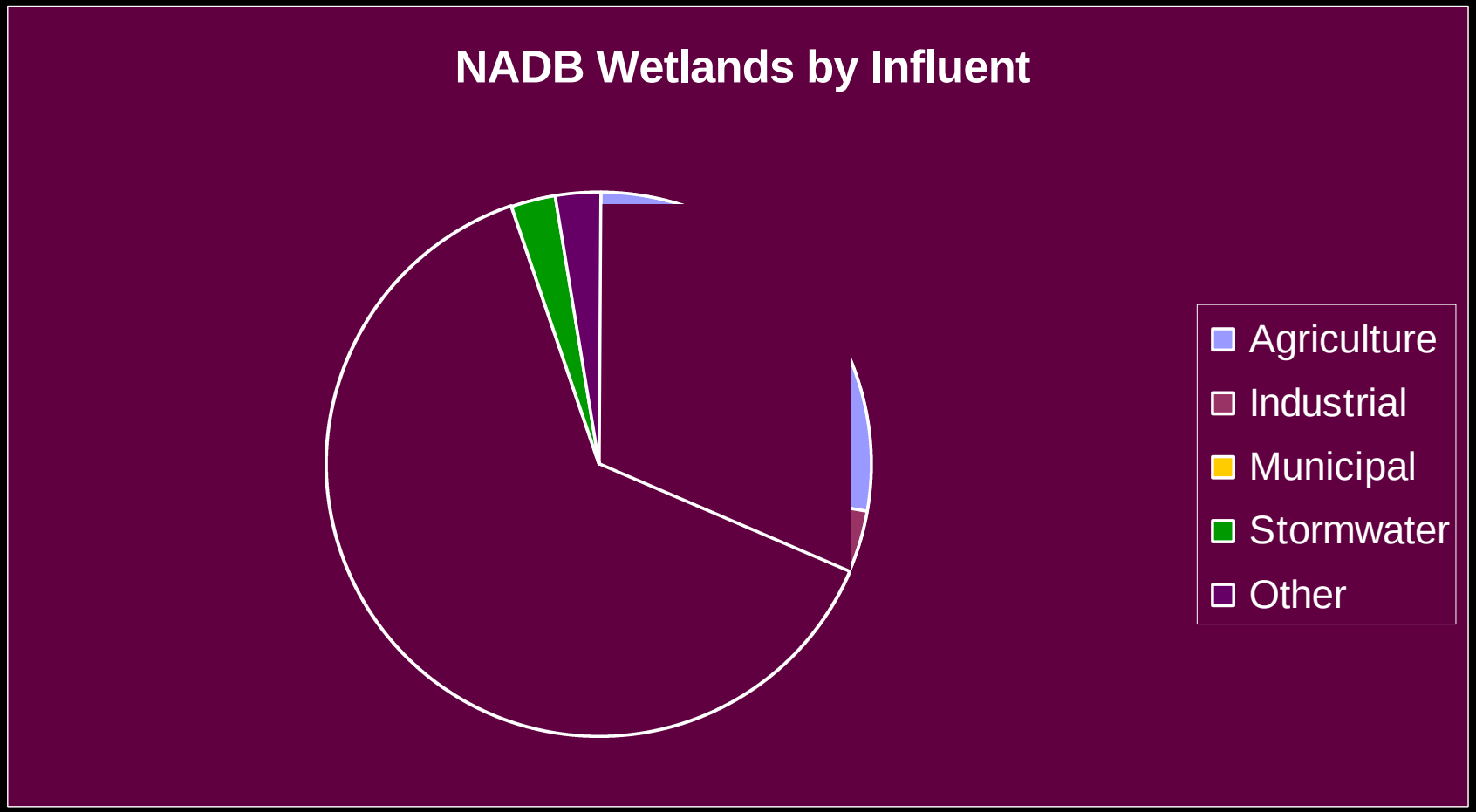
Permitting

- U. S. Army Corps of Engineers
- U. S. EPA
- State and Local Permits
- NPDES
- NEPA
- Community Groups
- Joint Permit Application Process

Implementation Steps



Constructed Treatment Wetland Applications in North America



Source: EPA Wetlands Treatment Database, 1994.

Constructed Treatment Wetlands in Database

Number of CWs	Over 300[1]
Size	<1 - 4000+ acres[1]
Flows	<100,000 gpd - 190 MGD[1]
Detention Times	1 -14 days[2]
Surface Flow Median Cost	**$13,200/acre[2]**
Subsurface Flow Median Cost	**$141,000/acre[2]**

Source: (1) EPA Treatment Wetlands Database, (2) Kadlec and Knight, 1996

Cost of Wetland vs. Conventional Treatment

	GAC	Chem/Prec	Wetland*
Capital	192-224K	310K	120K
O&M (10 years)	3-9M	1.7M	370K

- **Based on treatment of water at 300 gpm with 44 mg/L TPH over 10 years**
- **Wetland costs are based on the EPA Wetlands Treatment Database which includes cost data for 67 wetlands. These had an average cost of $1.5 M and an average size of 100 acres. The average O&M cost was $37K/year.**

GAC= Granular Activated Carbon

Chem/Prec = Chemical Precipitation

* Source: EPA Wetlands Treatment Database, 1994.

Constructed Wetland Technology Application Team

- Developing the tools necessary to implement wetland technology DoD-wide
- *Available Services*
  - In-House Consultation
  - Feasibility Analysis
  - Conceptual Design Support
  - Technical Library
  - Technology Application Guide
  - Construction/Contract Support
  - Technical Briefings

Points of Contact

- 805-982-1795 DSN: 551
- 805-982-1668
- 805-982-1618
- 805-982-1615
- 805-982-1184
- 805-982-1272

Web page: http://www.nfesc.navy.mil/enviro/wetlands/

Summary

- Constructed Treatment Wetlands can be used by the Navy for treatment of:
  - Contaminated Groundwater
  - Wastewater
  - Landfill Leachate
  - Stormwater Runoff
  - Sediments, Sludges, and other contaminated wet media
- Where suitable land is available, treatment wetland costs are often lower than other treatment options