A Journey Through the World of Applied Aquatic Ecology

Stephen Lyon, Ph.D.

"The secrets of nature are in knowing their details"


MASSACHUSETTS.
N E W H A M P S H I R E
Lawrence
Lowell
Haverhill
ESSEX
Lynn
Salem
MIDDLESEX
WORCESTER
Worcester
BOSTON
Cambridge
Massachusetts Bay
A T L A N T I C
O C E A N
NORFOLK
PLYMOUTH
BRISTOL
Taunton
Fall River
New Bedford
Buzzards Bay
PROVIDENCE
Pawtucket
R H O D E
I S L A N D
Cape Cod Bay
BARNSTABLE
Nantucket Sound
DUKES
NANTUCKET
BOSTON and Vicinity

1973 – Woods Hole Oceanographic Institution

Dr. John Ryther
1922-2006

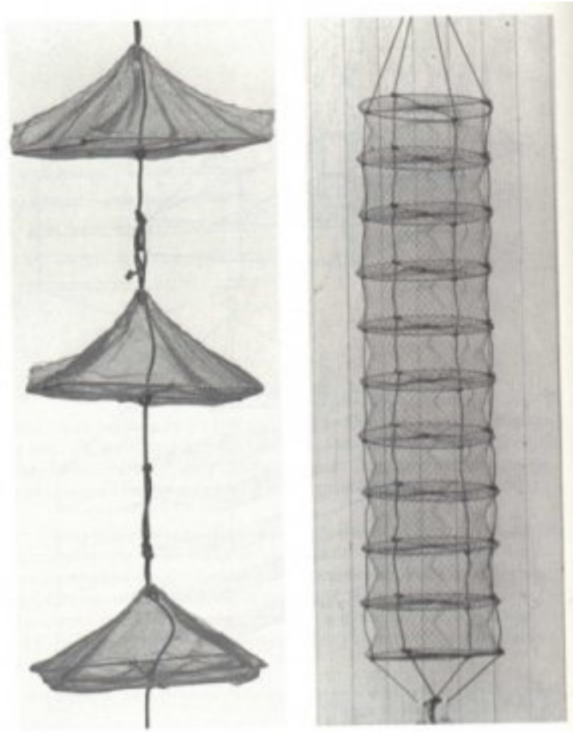
Sea Water

↓

Domestic Wastewater →

Marine Algae

→



Oysters raised in a rack culture

Tabor Academy, Marion, MA

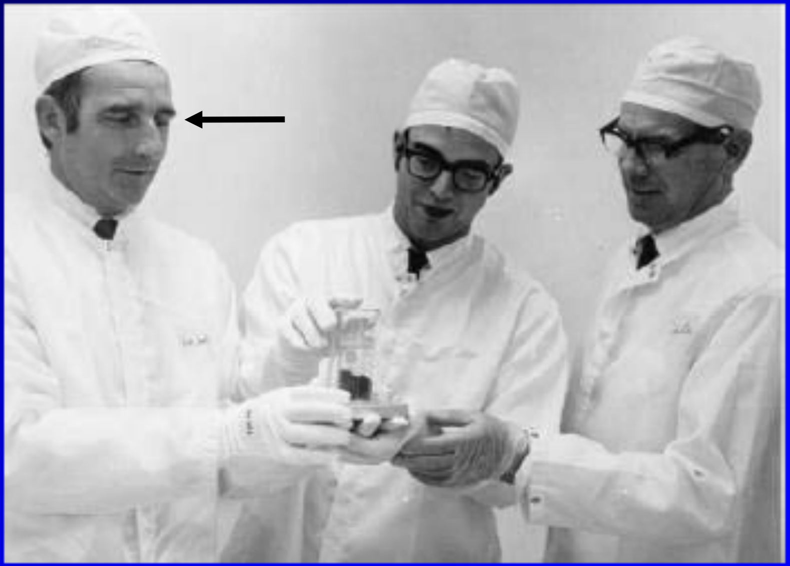
Humboldt State University, Arcata California

Uppsala University, Uppsala, Sweden

San Diego State University, San Diego, CA

University of California, Irvine

Returned lunar samples and carbonaceous chondrites



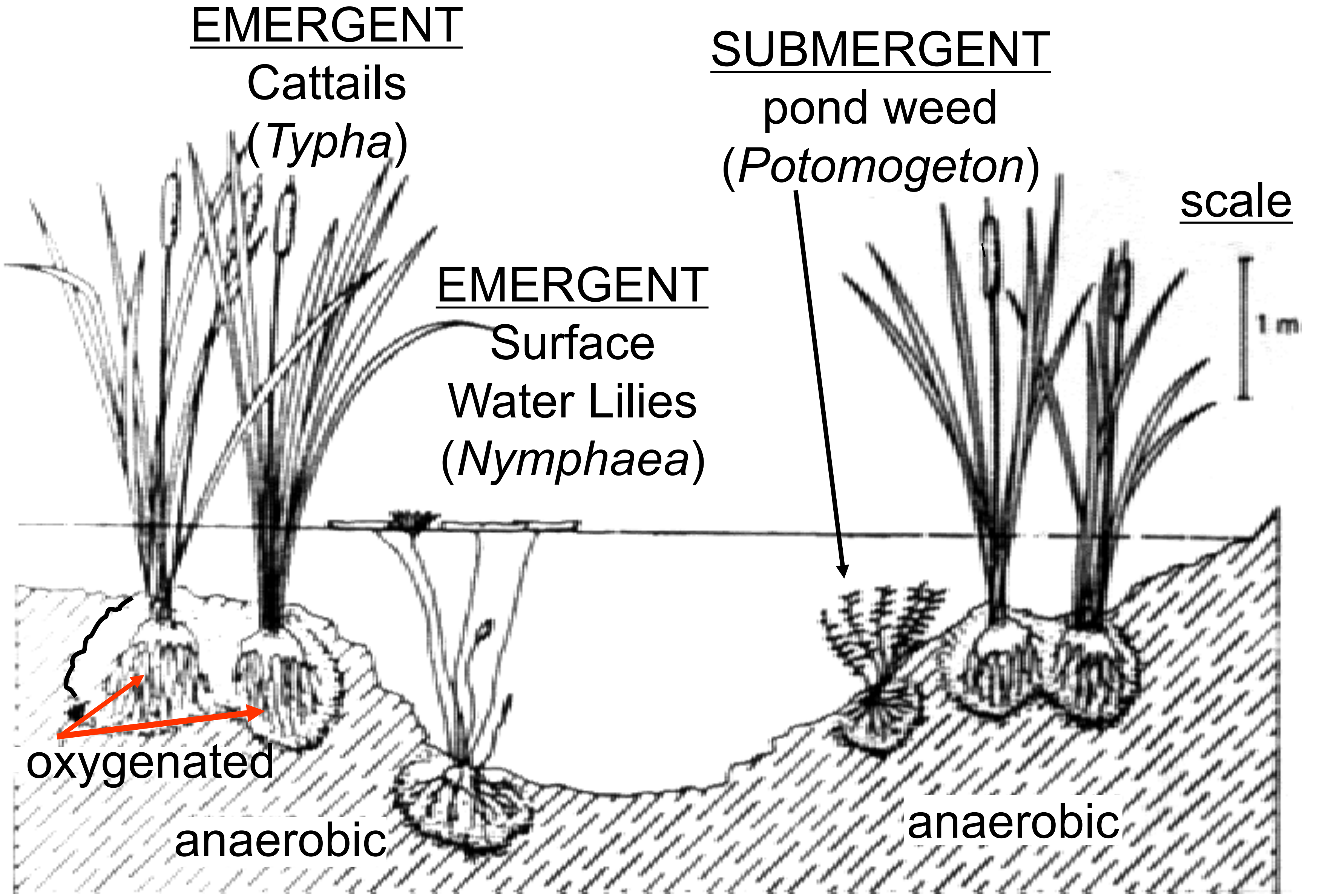
Ian Kaplan, Bill Schopf, John Smith: UCLA, 1971

- S and C concentration, isotopic composition, and effect of solar wind
- Searched for molecules of biological significance
- Proc. Apollo 11 Lunar Science Conf., 1970

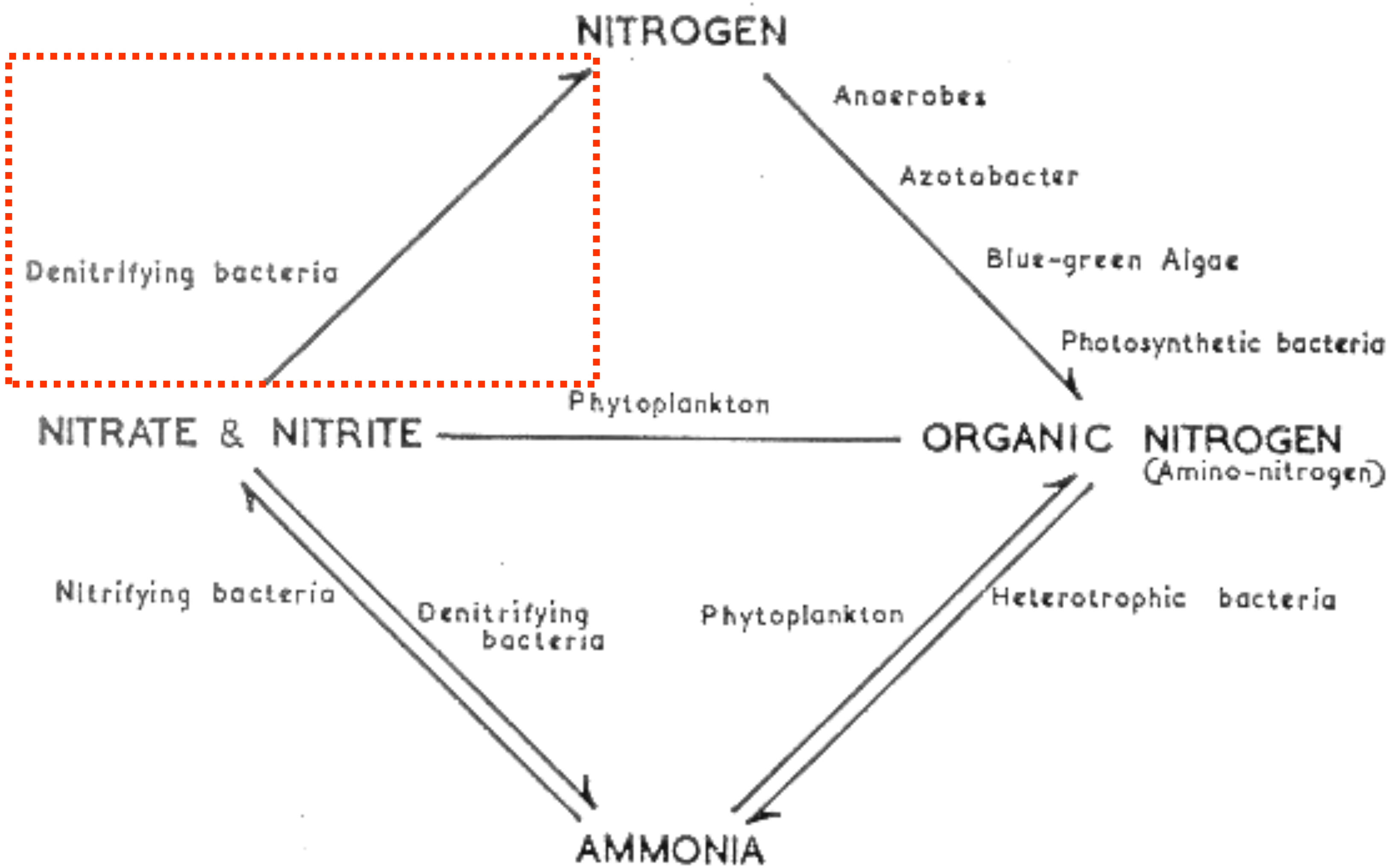
Charles Goldman – University of California, Davis, received the 2004 Alfred C. Redfield Lifetime Achievement Award from the American Society of Limnology and Oceanography (ASLO). The award recognizes and honors major, long-term achievements in the fields of limnology and oceanography including research, education, and service to the community and society.

Dr. Goldman worked on a project called

“An integrated Watershed Approach to Evaluate and Monitor Subalpine Landscapes“ that integrated the fields of **biology, ecology, limnology, fisheries, hydrology, geology, geochemistry, engineering, and environmental modeling in a multi-disciplinary program** designed to provide watershed managers and decision makers with innovative tools for environmental policy at Lake Tahoe.

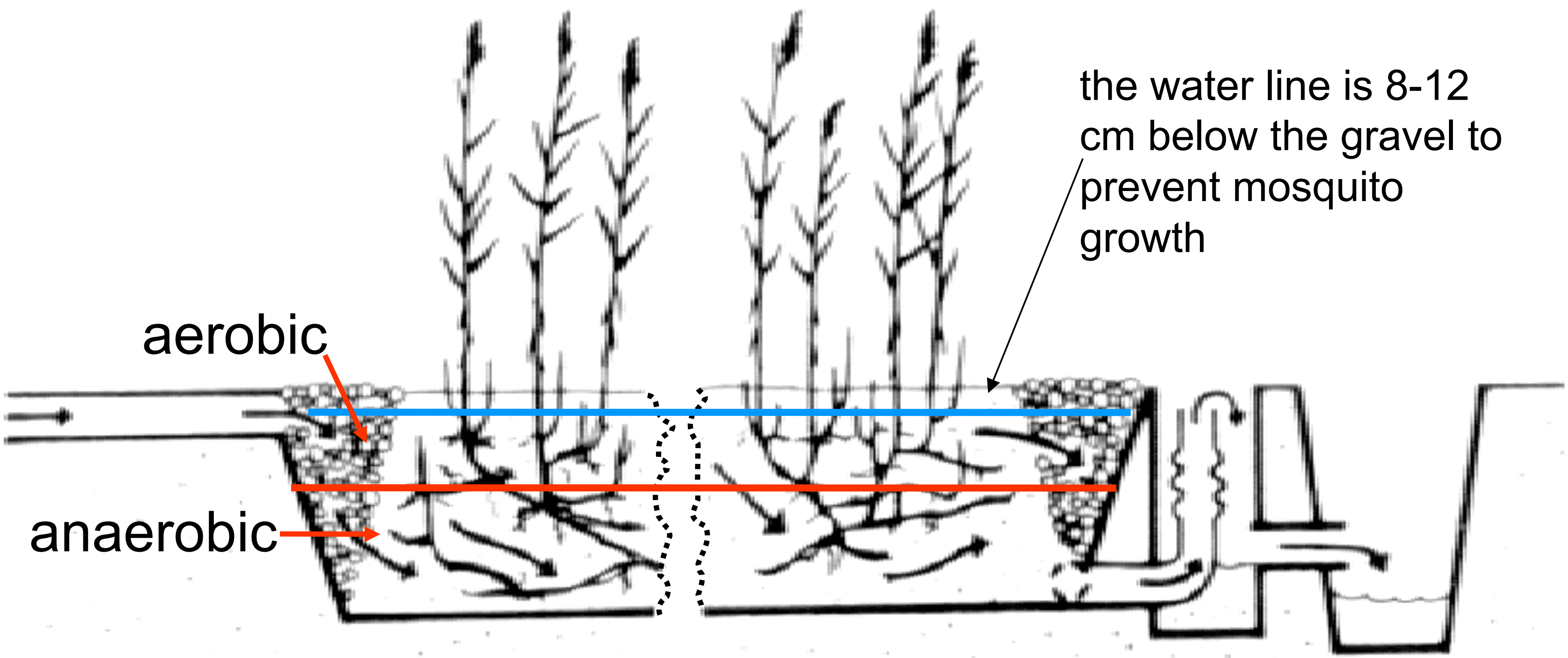


In a natural or open wetland the majority of treatment occurs as a function of microbial processes at the sediment/water interface



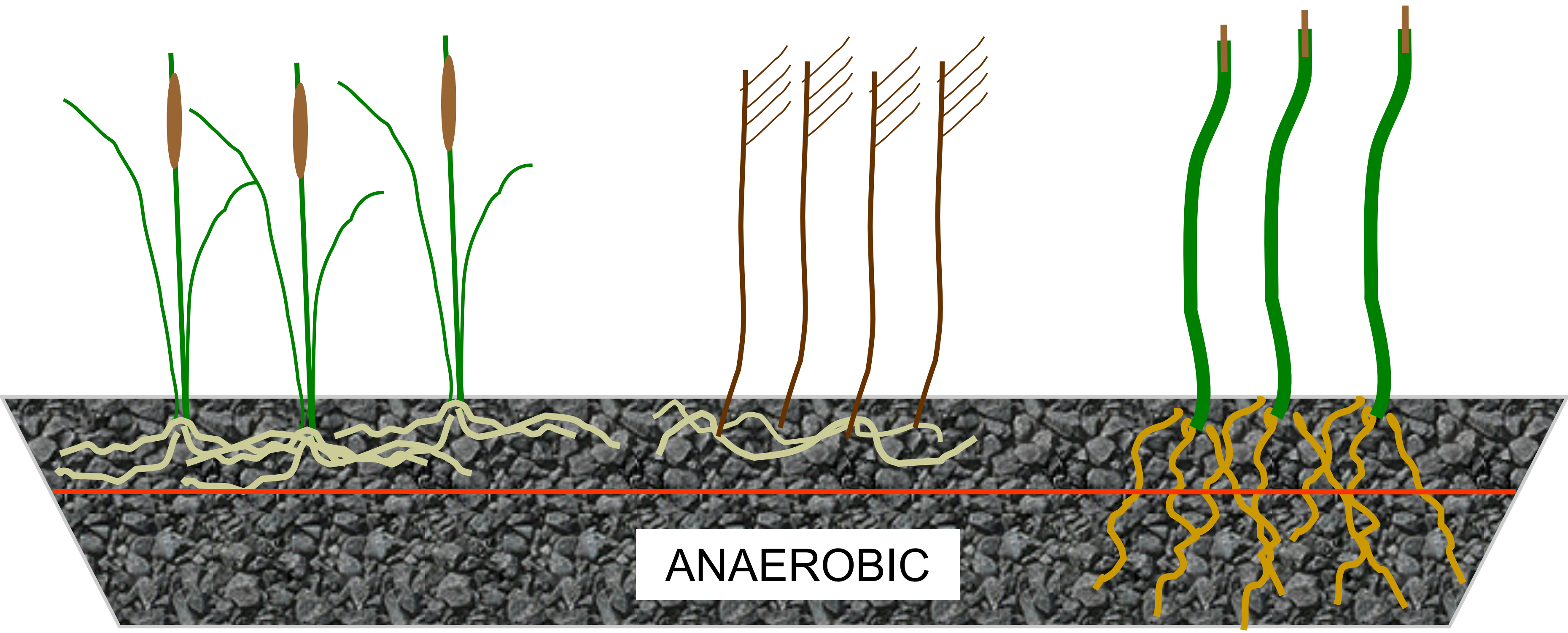
The Microbial Nitrogen Cycle

Profile of a horizontal subsurface flow constructed wetlands (SSF)

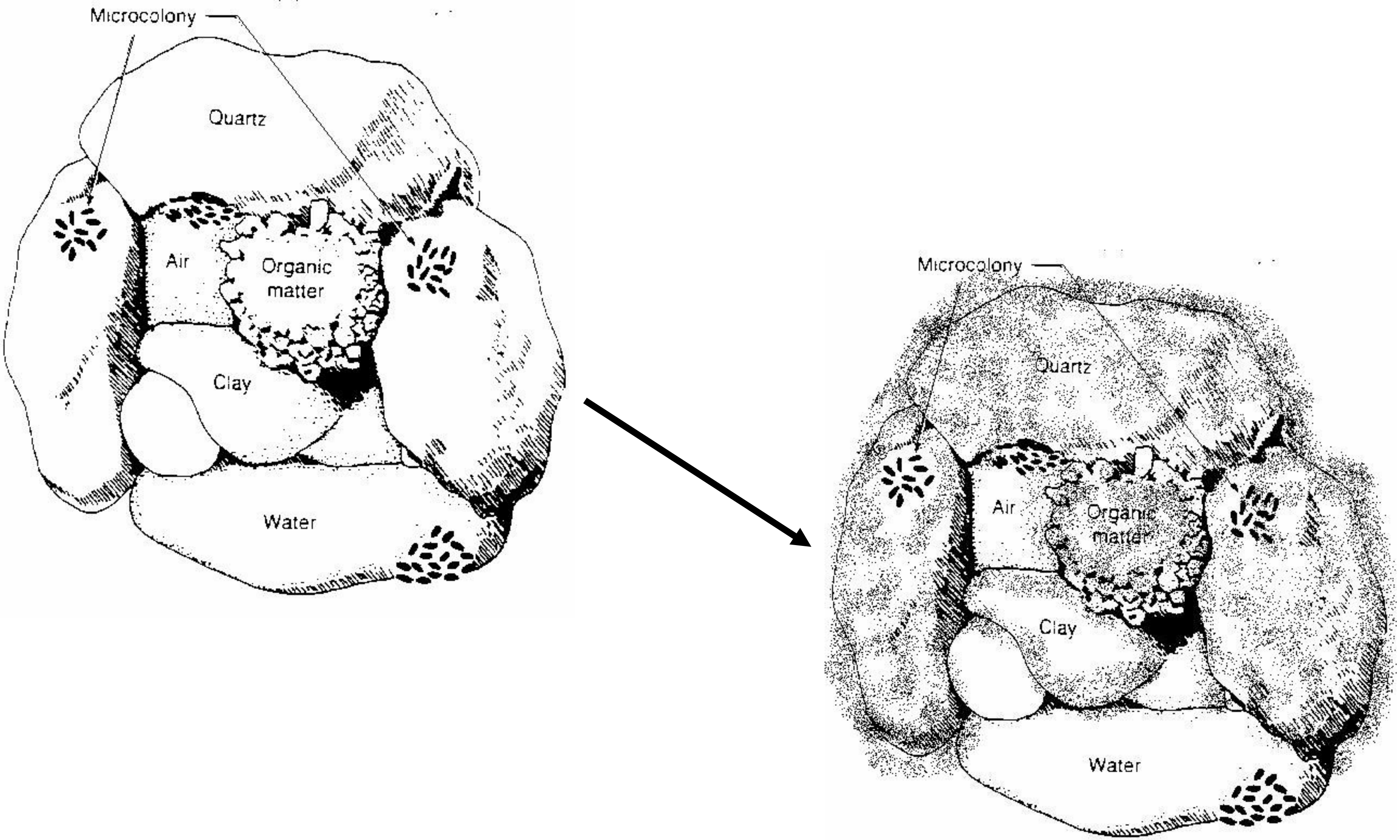


A gravel based SSF wetland increases the surface area one thousand fold compared to a traditional free surface constructed wetland.

Gravel-Based Subsurface Flow (SSF) Constructed Wetlands

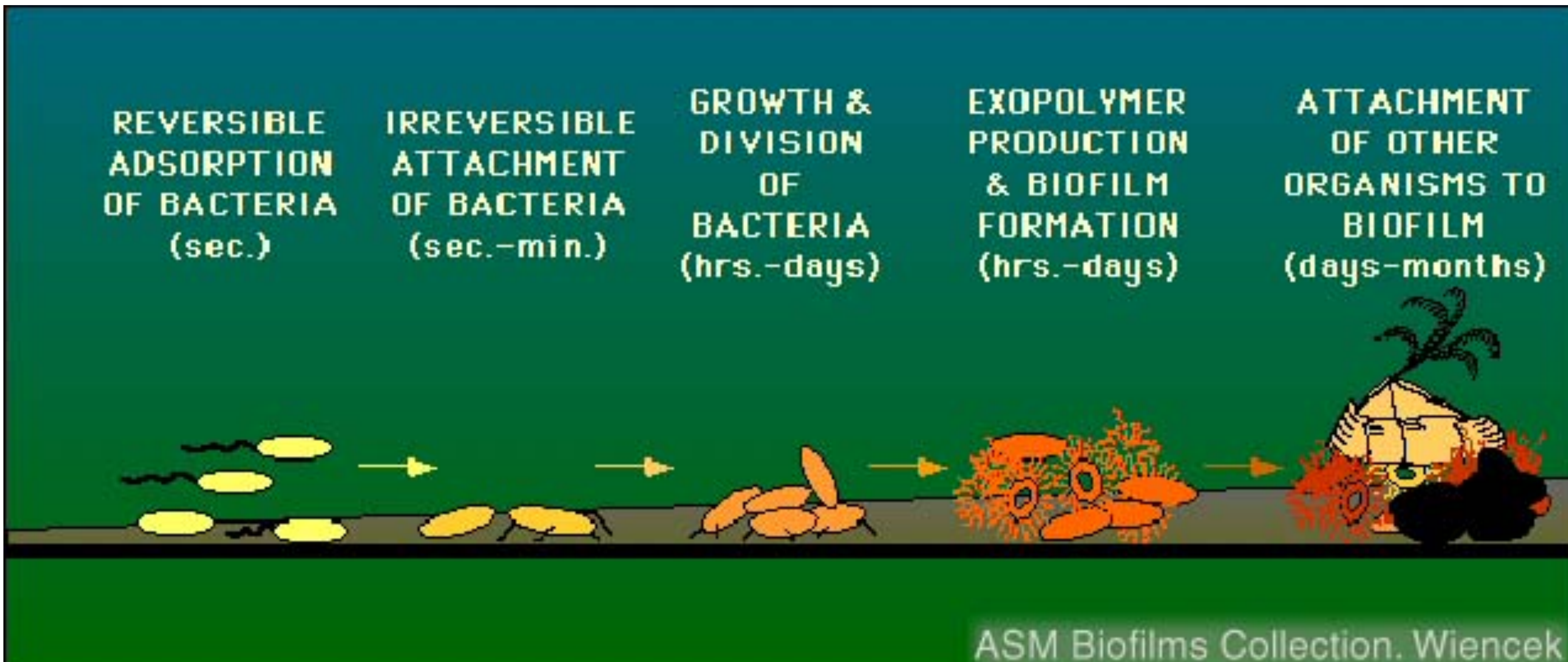


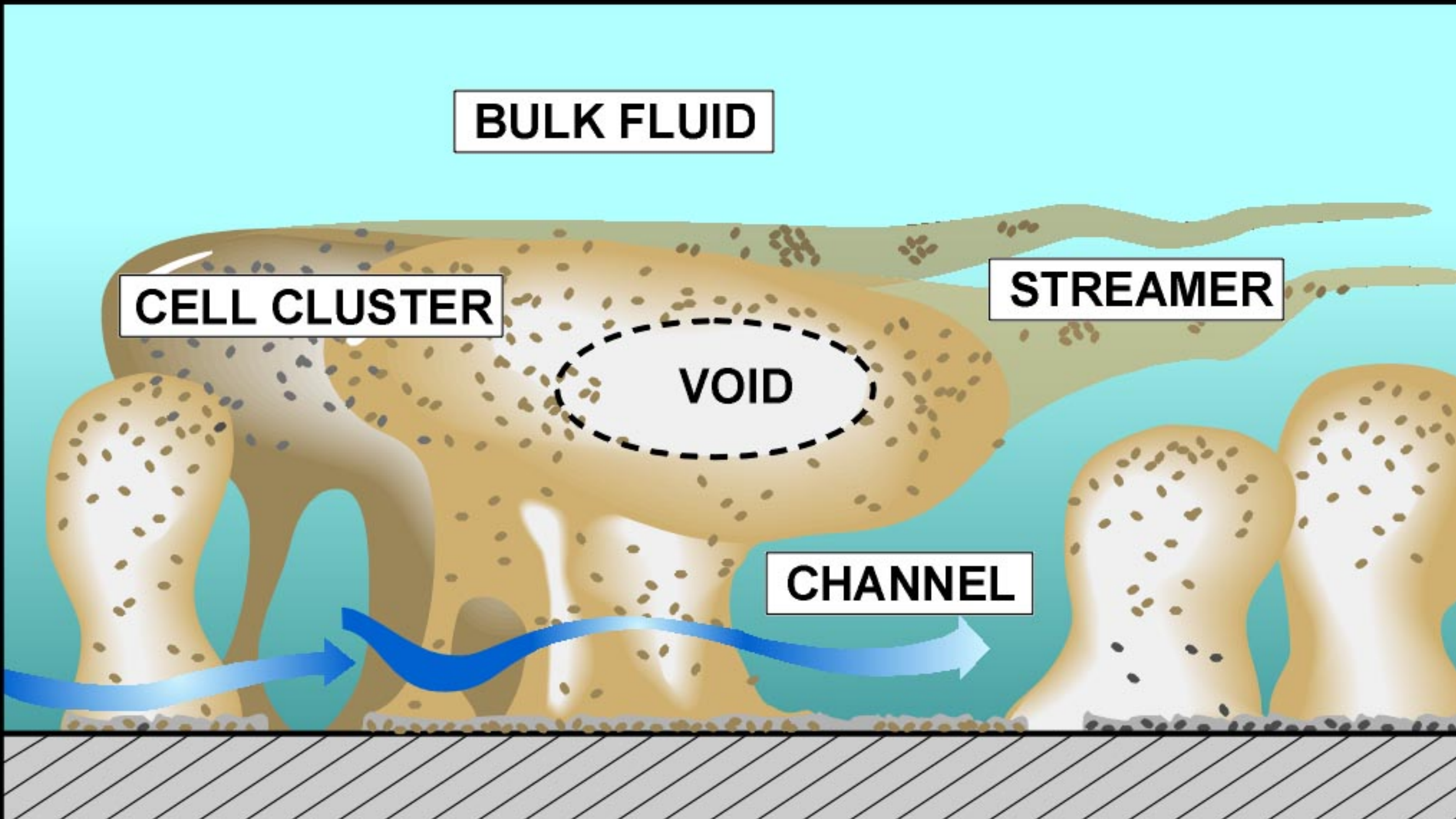
Cattail(*Typha*) Reed(*Phragmites*) Bulrush(*Schoenoplectus*)

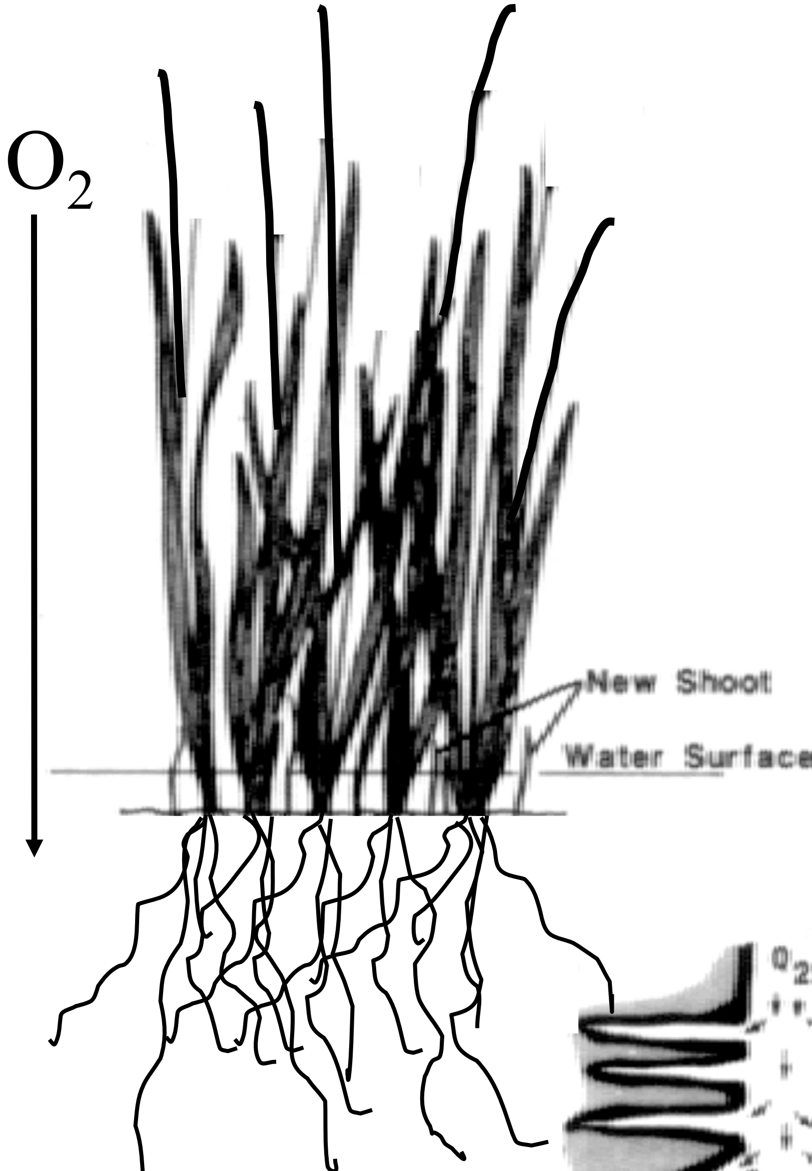


Development of Microbial Biofilm on a Solid Substrate - nitrification and denitrification occur within the biofilm

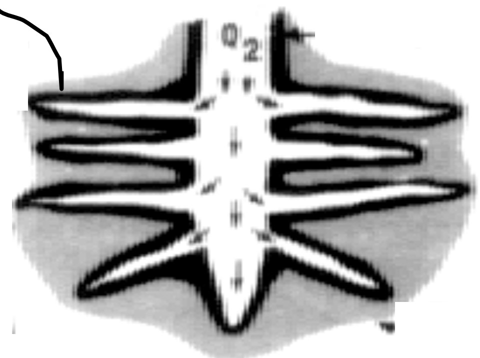
Biofilm Formation




BULK FLUID
CELL CLUSTER
STREAMER
VOID
CHANNEL
P. DIRCKX



oxidized zone



ROOT HAIR ENLARGED

translocation of oxygen from the shoots to the roots allows the formation of microaerobic zones

Data From Santee, CA 1980-1989

Constructed wetland planted with young bulrushes

(Santee, CA 1985)

Mature stand of constructed wetlands

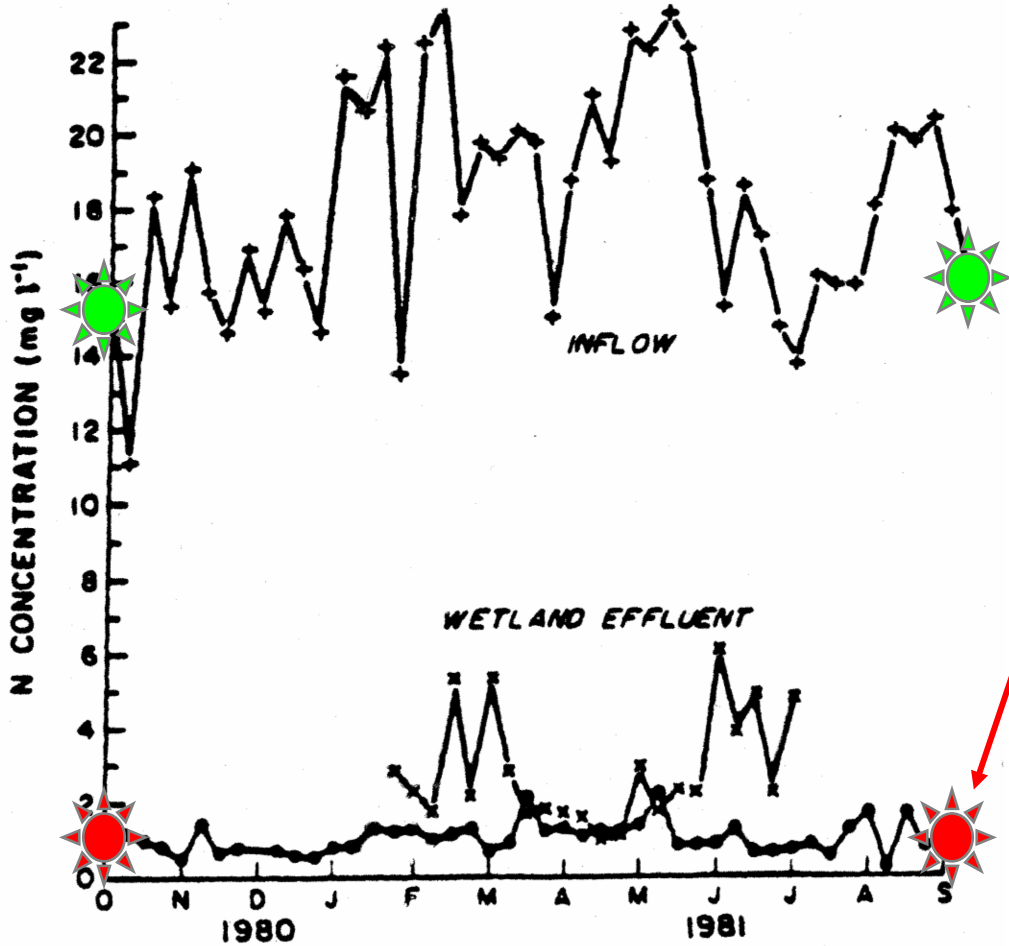


Fig. 2. Mean level of total nitrogen (TN) in the inflow to the artificial wetlands (+——+) as compared to the mean level of TN in the effluent of methanol-amended (●——●) and mulch-amended beds (×——×). Application rate for mulch-amended bed (plot 1E) was 8.4 cm day^{-1}. Application rate for methanol-amended beds (plots 1E and 2E) was 16.8 cm day^{-1}. Methanol:nitrate ratio was 6.8:1.

carbon addition to oxidized water can play a major role in denitrification

Carbon addition was crucial for the removal of nitrate

Nitrogen Removal in Artificial Wetlands. 1983. R.M. Gersberg et al. Water Research. 17, p.1009-1014.

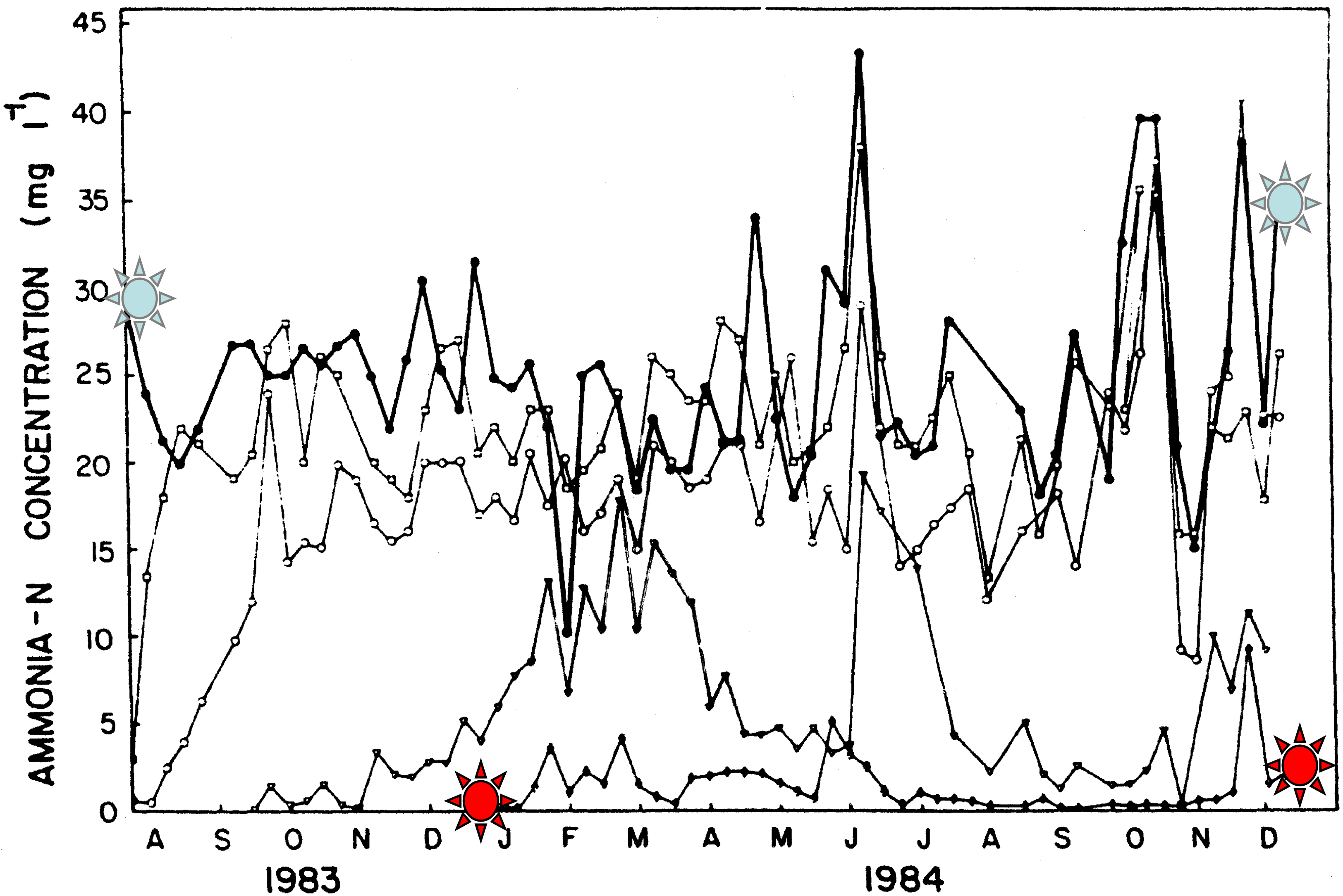


Fig. 2. Level of ammonia–N in the inflow (●—●) and effluent of the vegetated and unvegetated beds, at a primary wastewater application rate of 4.7 cm day^{-1}. ● Inflow; □ unvegetated; ○ cattails; ▽ reeds; ◇ bulrushes.

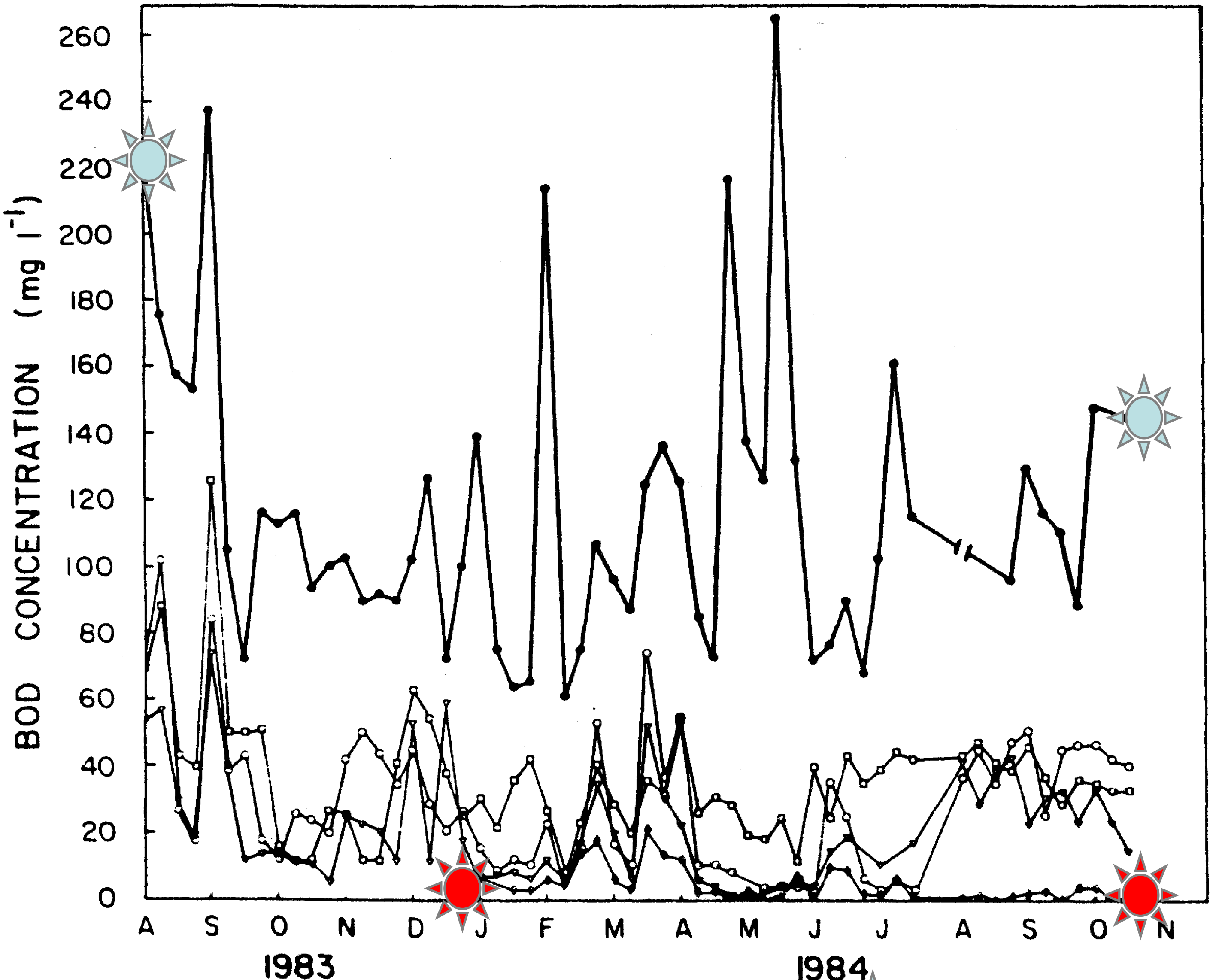


Fig. 3. Level of BOD_5 (biochemical oxygen demand) in the inflow (●—●) and effluent of the vegetated and unvegetated beds, at a primary wastewater application rate of 4.7 cm day^{-1}. ● Inflow; □ unvegetated; ○ cattails; ▽ reeds; ◇ bulrushes.

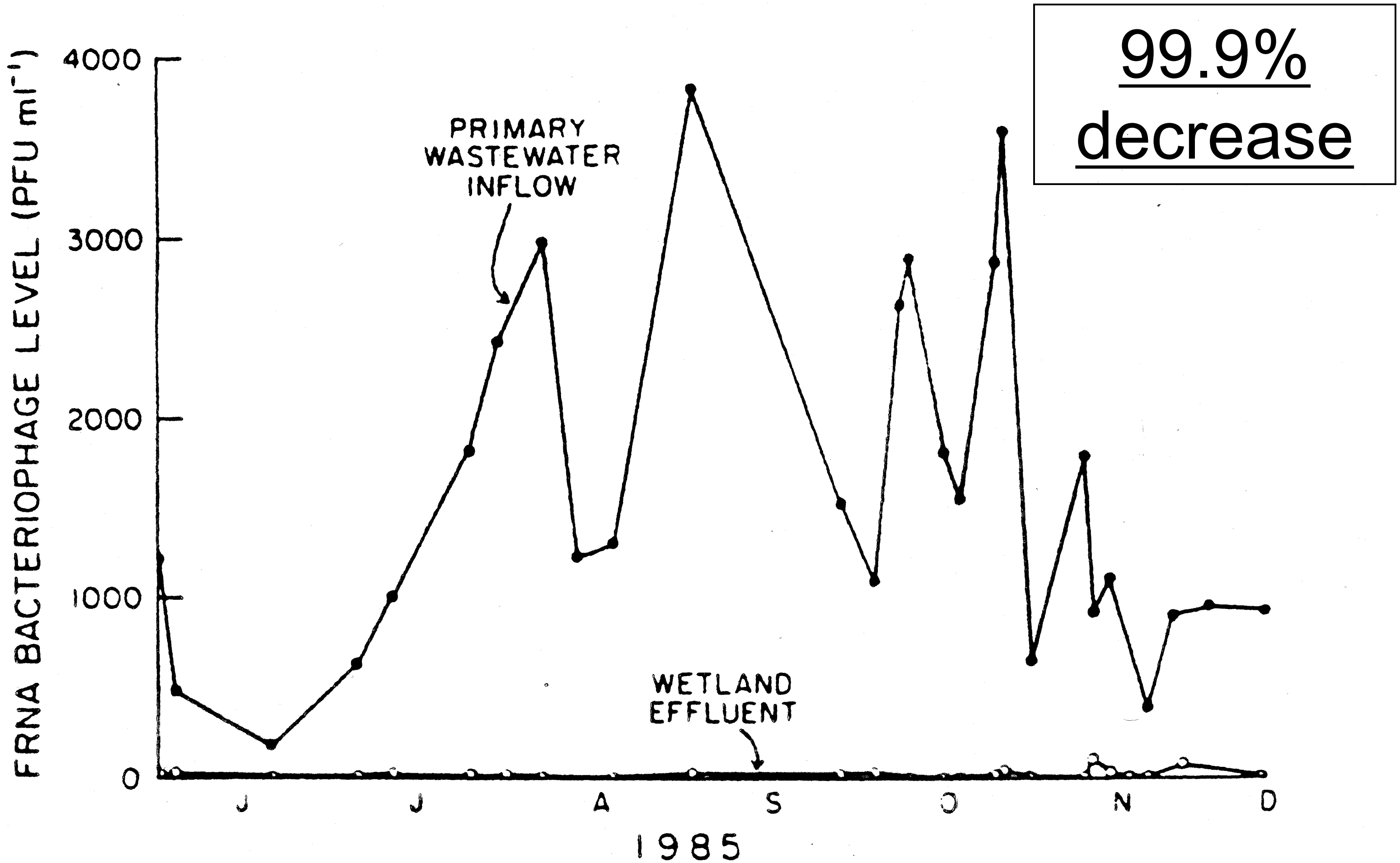
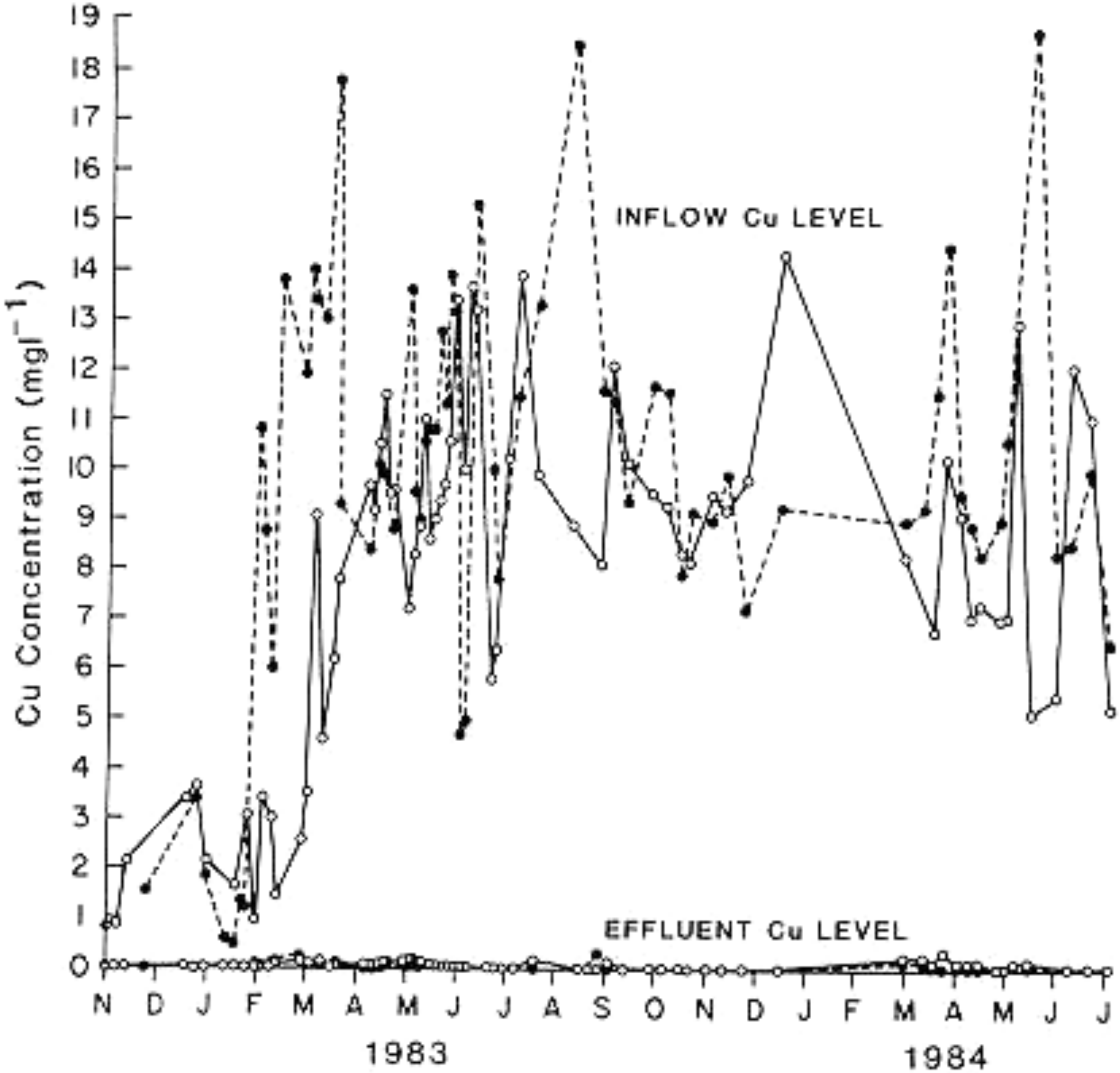


FIG. 1. Concentration of indigenous FRNA bacteriophages in applied primary municipal wastewater and in the wetland effluent. Effluent values represent the mean level for two vegetated (bulrush) beds at the hydraulic application rate of 5 cm per day from June to December 1985.



Removal of Cu by constructed wetlands

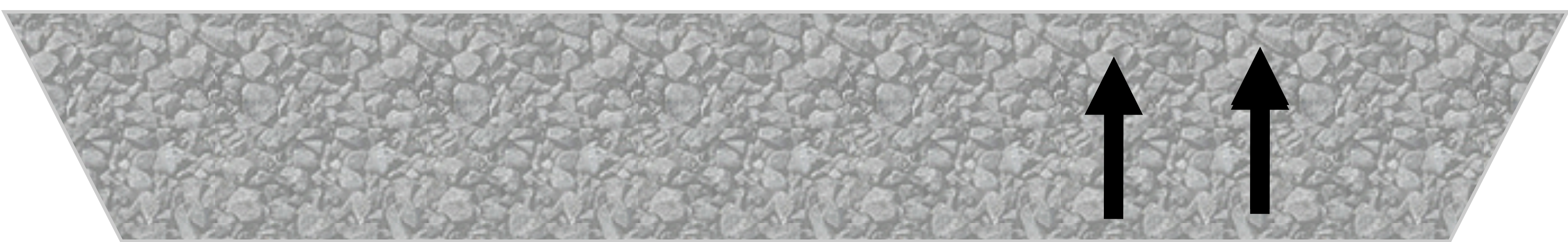
°=cattail

•= bulrush

residence time = 5.5 days

Dominant Mechanism

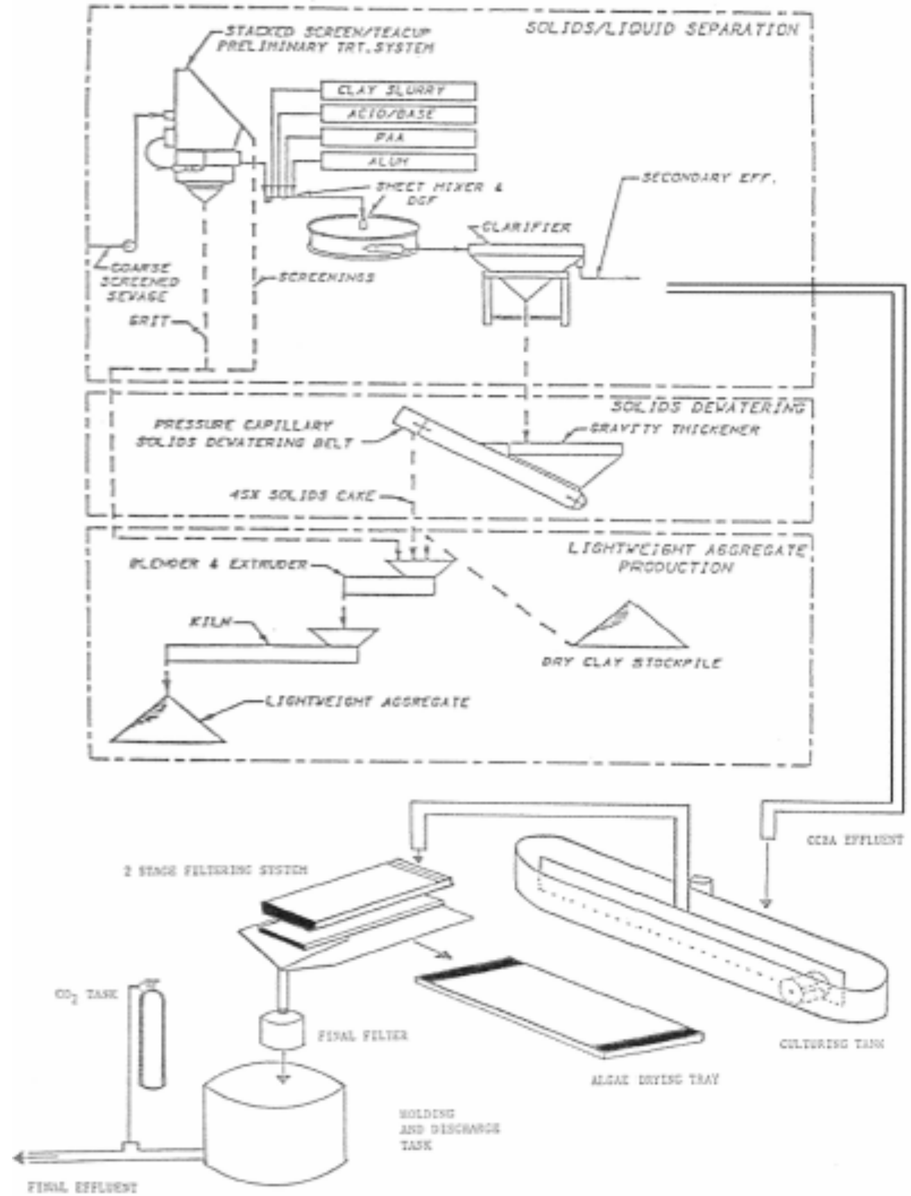
$$Cu^{+2} + H_2S = CuS_{(ppt)} + 2H^+$$



Hydrogen sulfide generated by the sulfate reducing bacteria

Complete Reclamation of Wastewater Using the CCBA-Spirulina Process

Role: Senior Staff Scientist 1981-89
(Spirulina Project-Principal Designer)

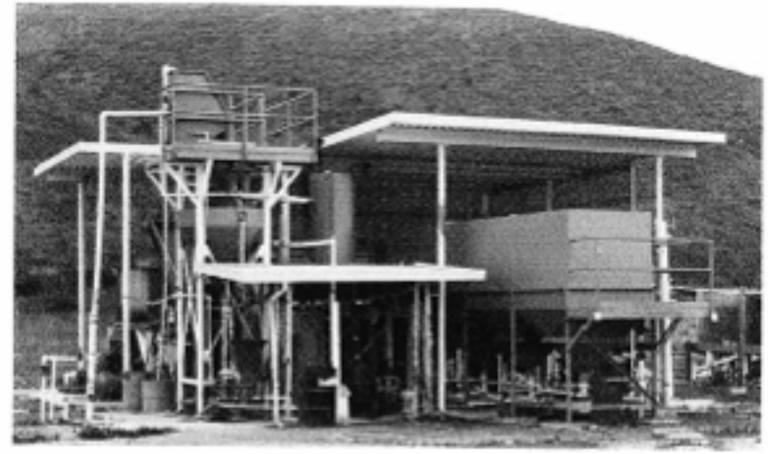


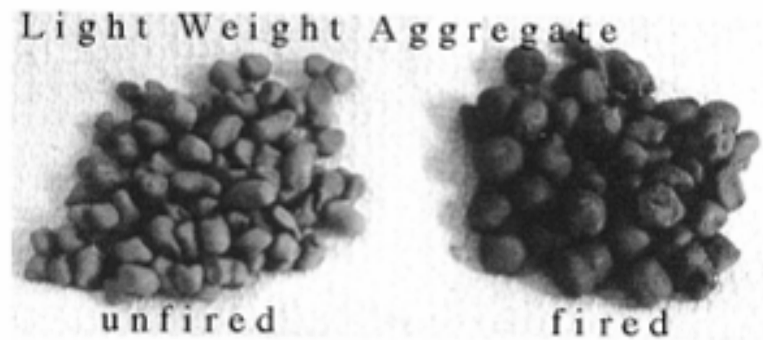
PROBLEM: Traditional wastewater treatment systems are expensive to construct and maintain. The prodlucts from these plants are nutrient laden water and large volumes of sludge. At present most sludge is disposed of in land fills or buried at sea. The cost of sludge handling and disposal accounts for a significant part of most water districts budget.

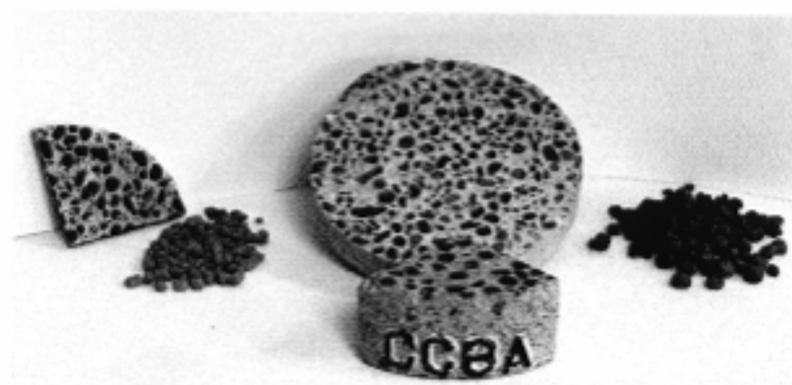
CONCEPT:

CCBA Project: The Coordinate Chemical Bonding and Adsorption (CCBA) Process is a physical-chemical treatment process that is modular, gravity fed and operates under all climatic conditions. The treatment time of a conventional system is about 24 hours. The CCBA Process treatment time is approximately 2 hours. The sludge formed from the process is mixed with clay and turned into pellets which are fired in a rotary kiln. These pellets can be used at light weight aggregate to be mixed with concrete. In addition to removing the standard components of wastewater, the CCBA Process is also very effective in removing heavy metals which precipitate out with the sludge. Once the sludge based pellets are fired, all metals are permanently bound in the clay matrix.

The CCBA pilot plant treated approximately 400,000 L/day that produced a high quality effluent and sludge was turned into light-weight aggregate that could be used in construction







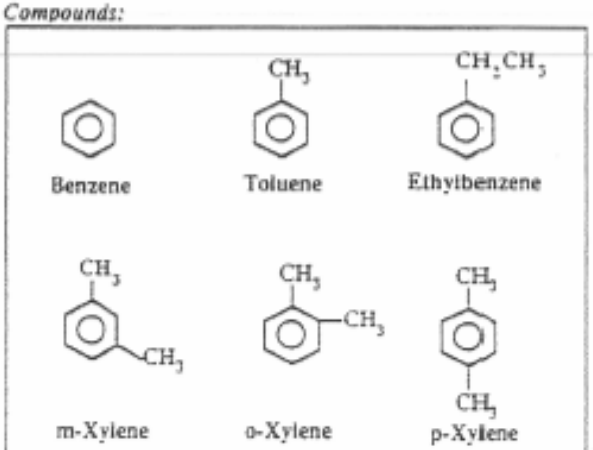
In-Situ Cleanup of Soil Contaminated by Leaking Underground Storage Tanks

Role: Research Assistant- 1989-1990- site construction and chemical analysis

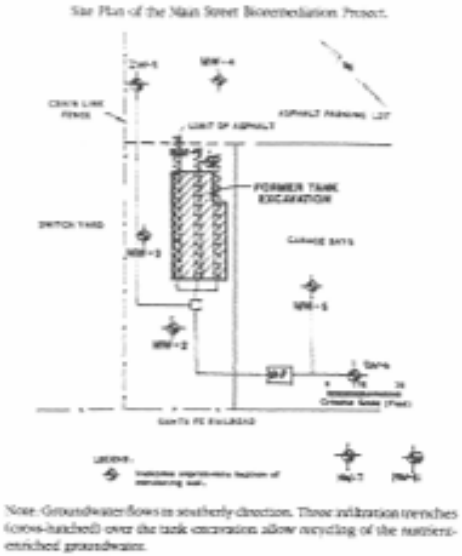
PROBLEM: Leaking underground storage tanks are one of the most common sources for the release of hazardous materials into soil and groundwater. The simple organic components of gasoline are easily broken down by soil bacteria. A class of compounds more resistant to bacterial degradation are referred to as BTEX (see figure below). Traditional methods for cleaning up these sites include incineration or landfilling the contaminated soil. The cost for this process if often very expensive (e.g. a single clean up of a gasoline station could cost $ 250,000). Once the contamination is discovered, there are legal mandates requiring some form of remedial action.

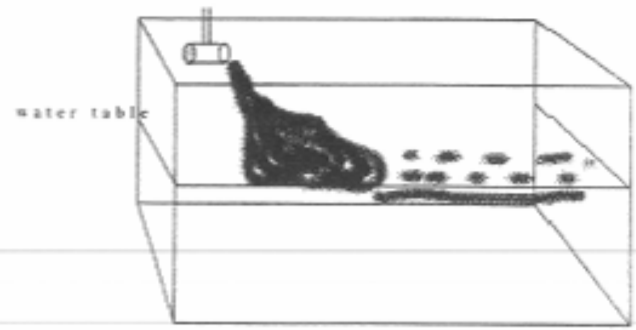
Aromatic Hydrocarbon Biodegradation in Ground Water (BTEX)

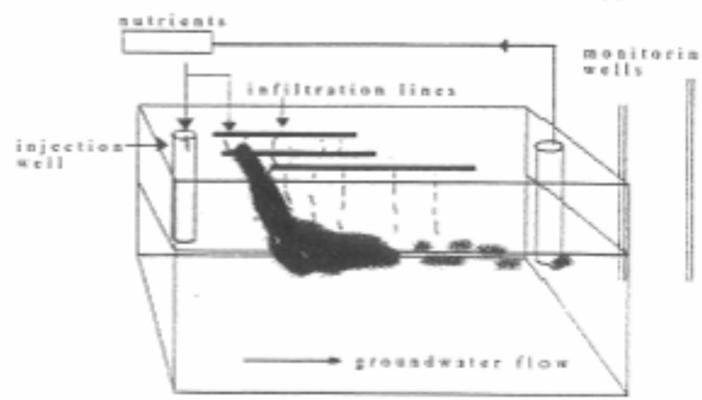
Compounds:



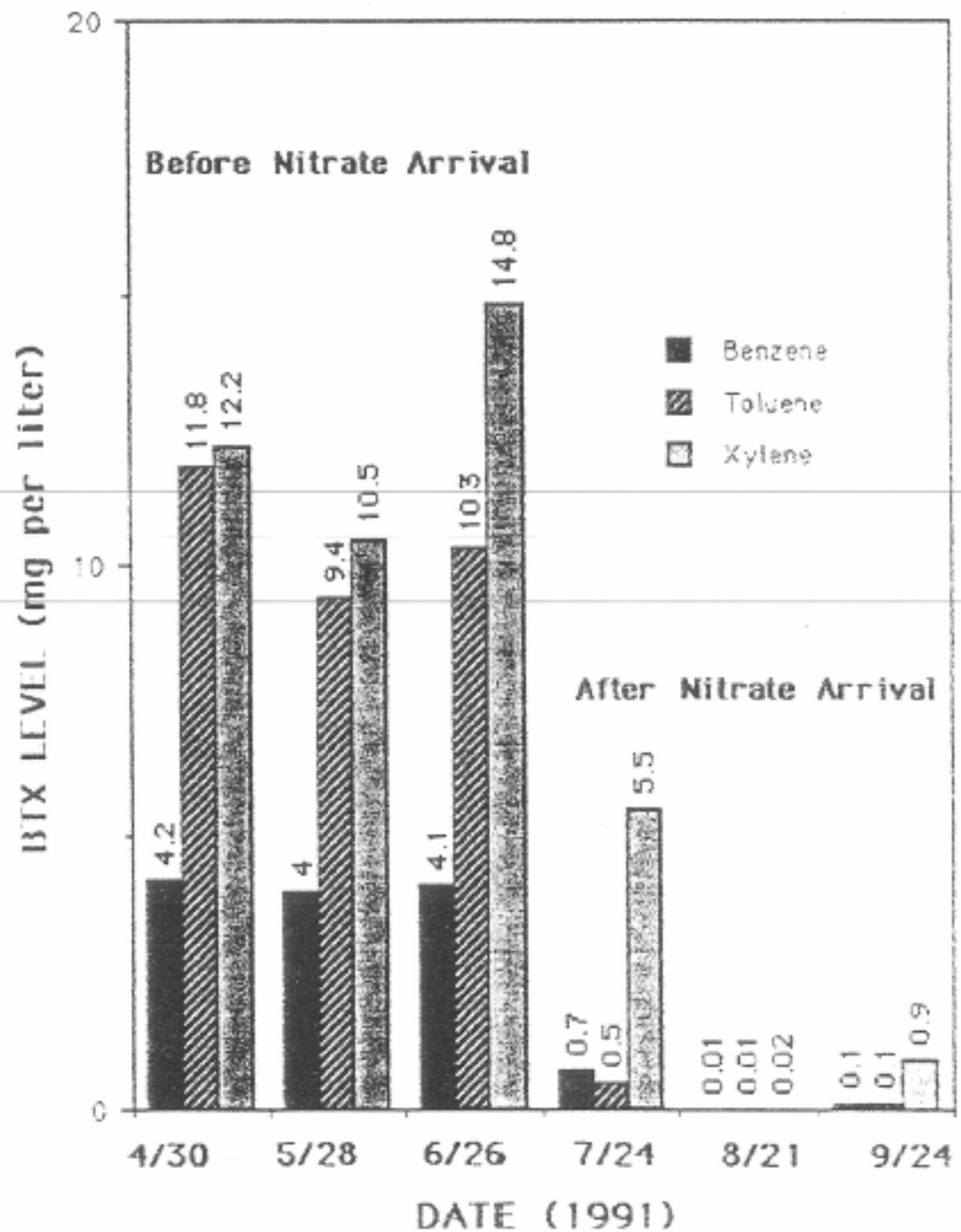
Schematic views of the remediation site



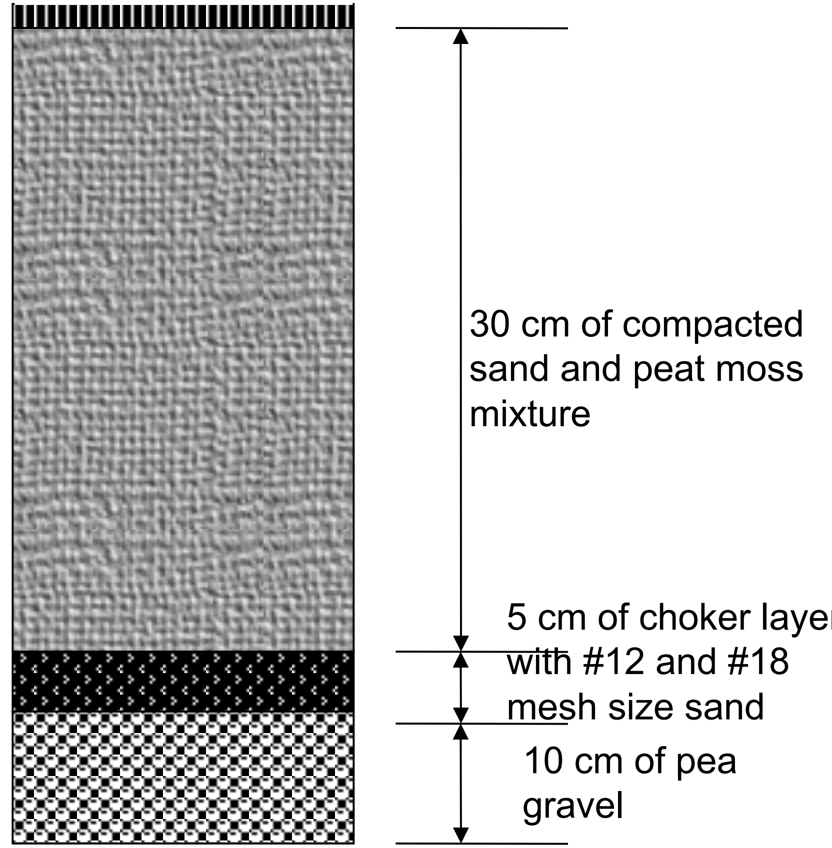




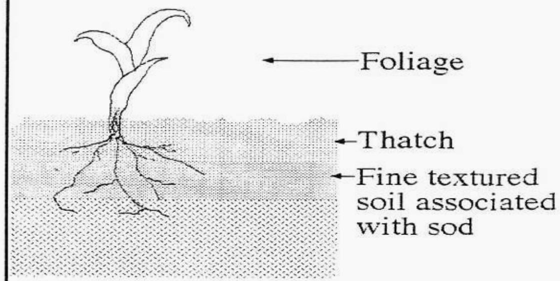
Level of Benzene, Toluene, and Xylenes before Nitrate Appearance and after the Arrival of Nitrate at Well MW-5.

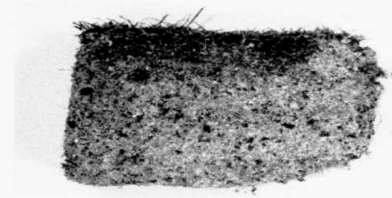


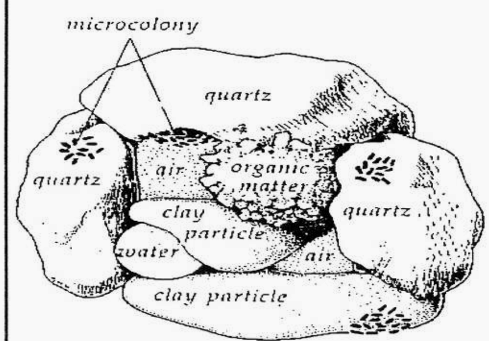
The Microbial Ecology of Black Plug Layer in Chemically Stressed Turf Grass Soils

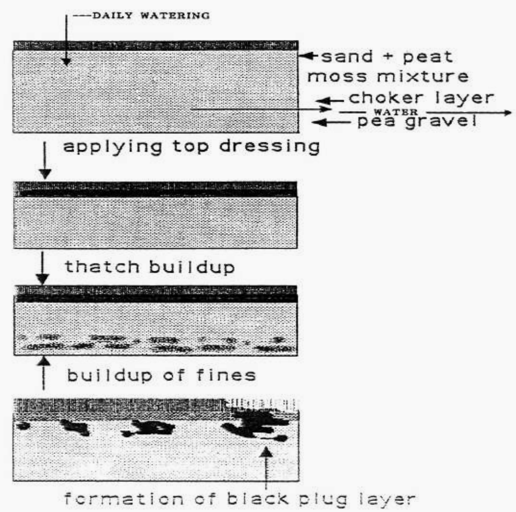


Profile of USGA green. The USGA soil mixture is 15% peat moss and 85% sand ranging in mesh size from 18 to 140.

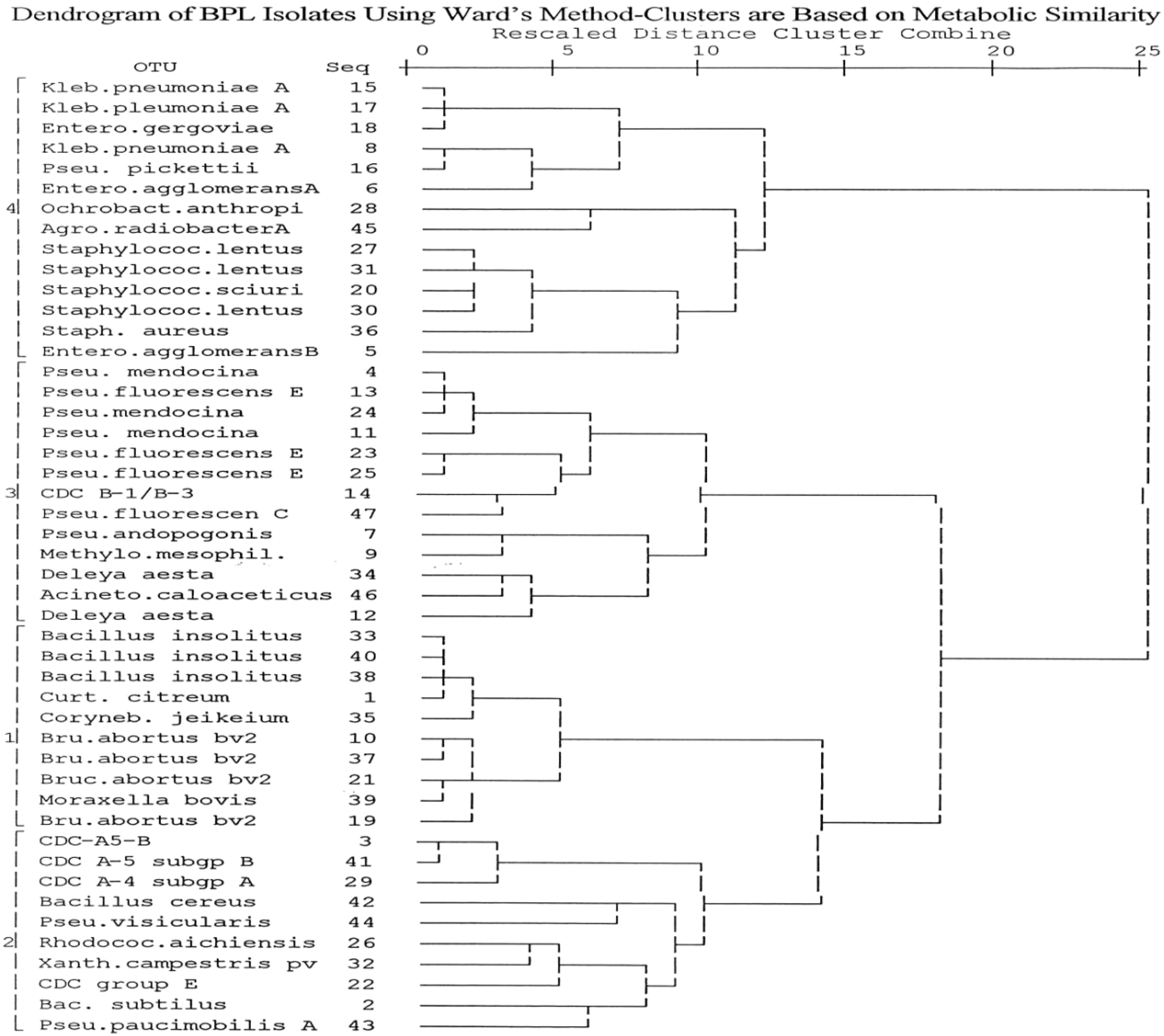






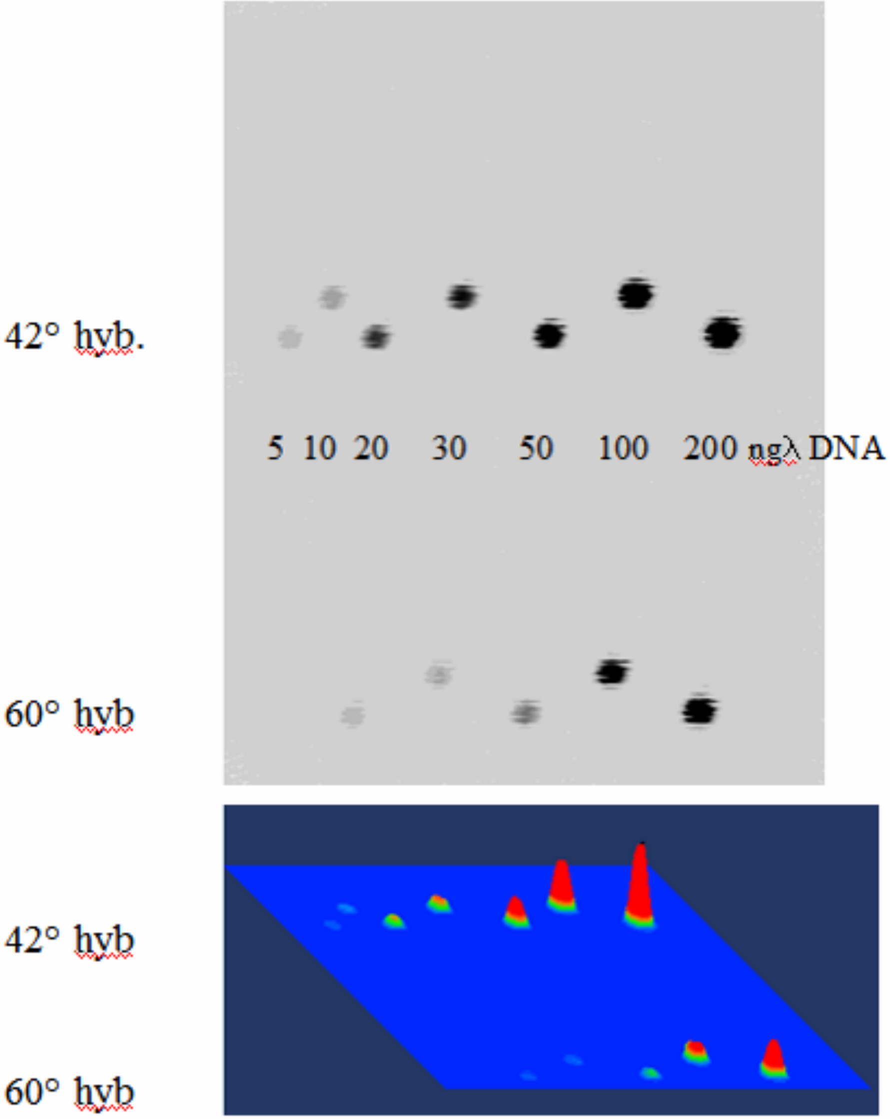


Three dimensional drawing of BPL based on cross section analysis



Profile of bacteria found at four different golf courses. The groupings are based on their ability to grow on different carbon sources

Tr-16 AMBIS scan 540 min



Quantitative species analysis using
“Reverse Sample Genome Probing”

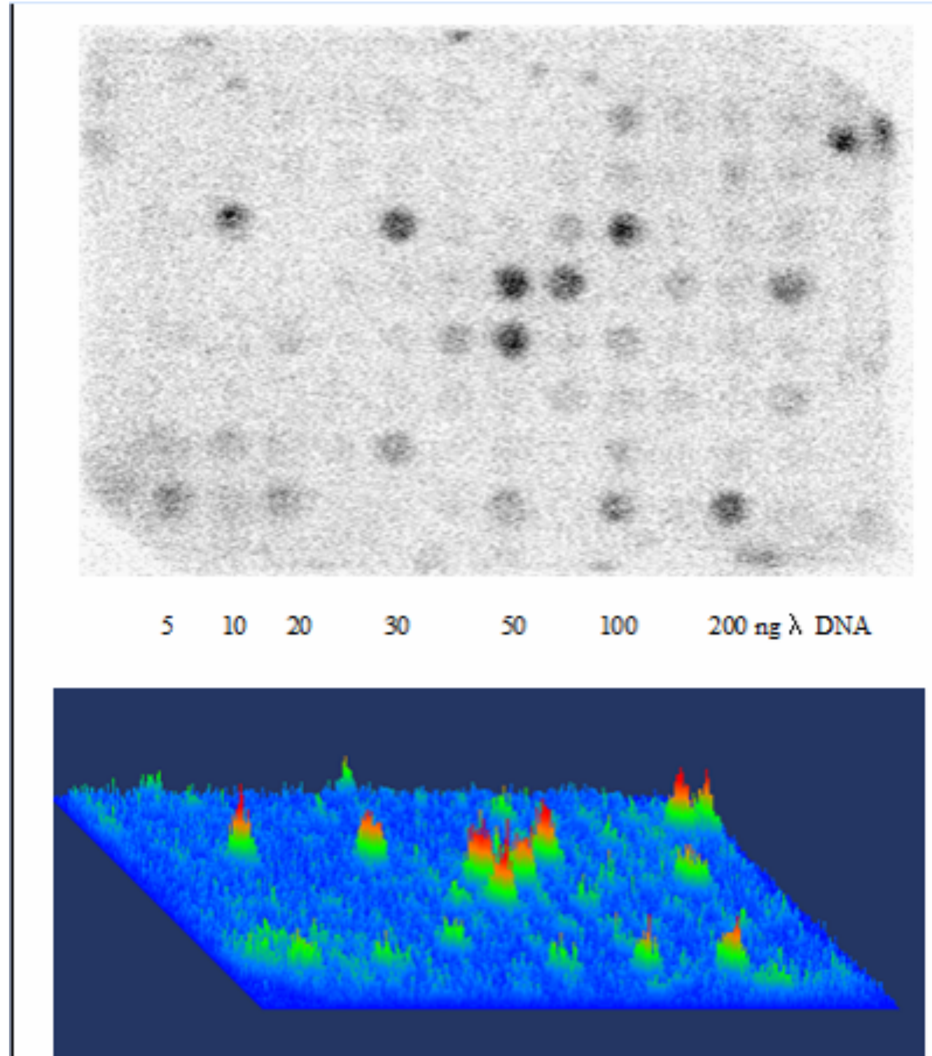
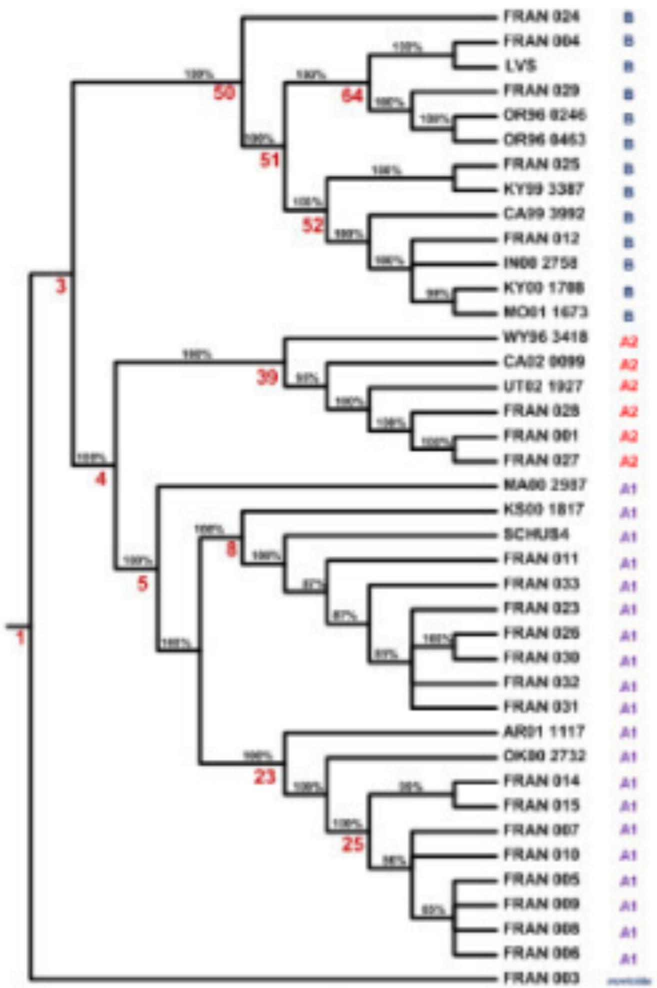
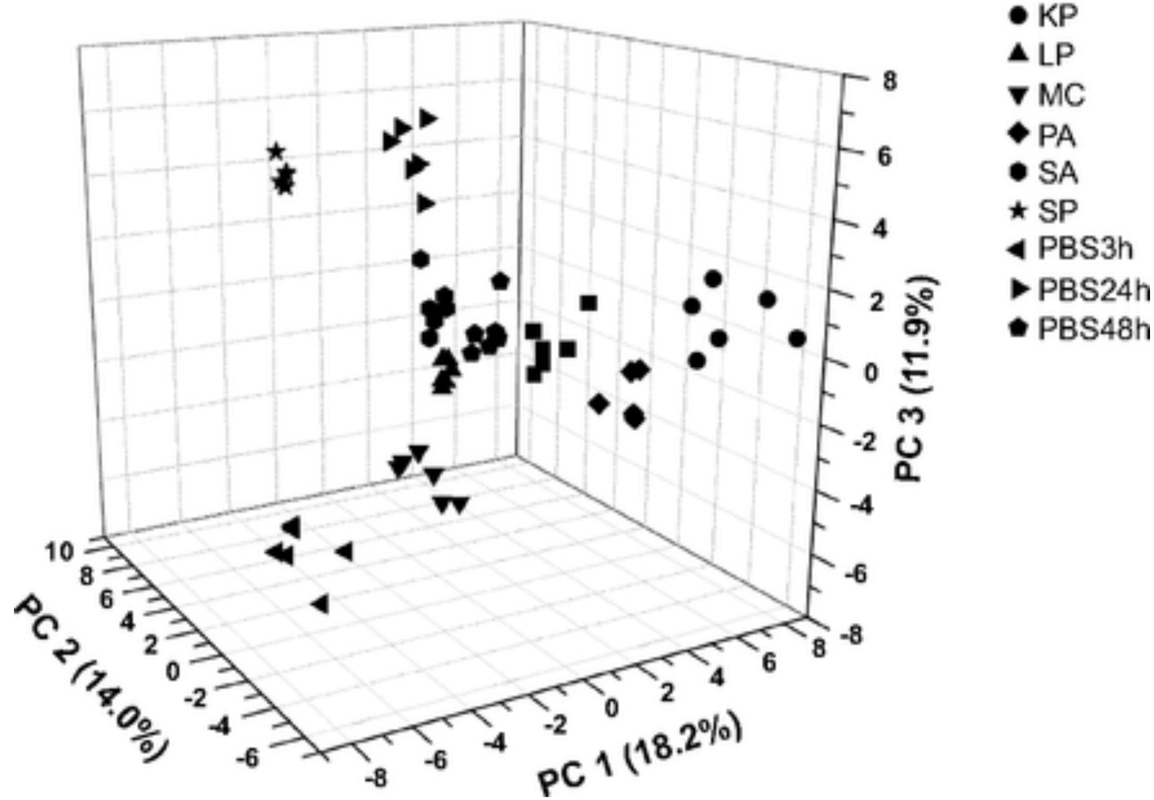


Figure 29b. Three dimensional perspective of RSJ-C showing relative high points of individual isolate DNA and λ DNA standards.

Hierarchical Cluster Analysis





Principal Components Analysis

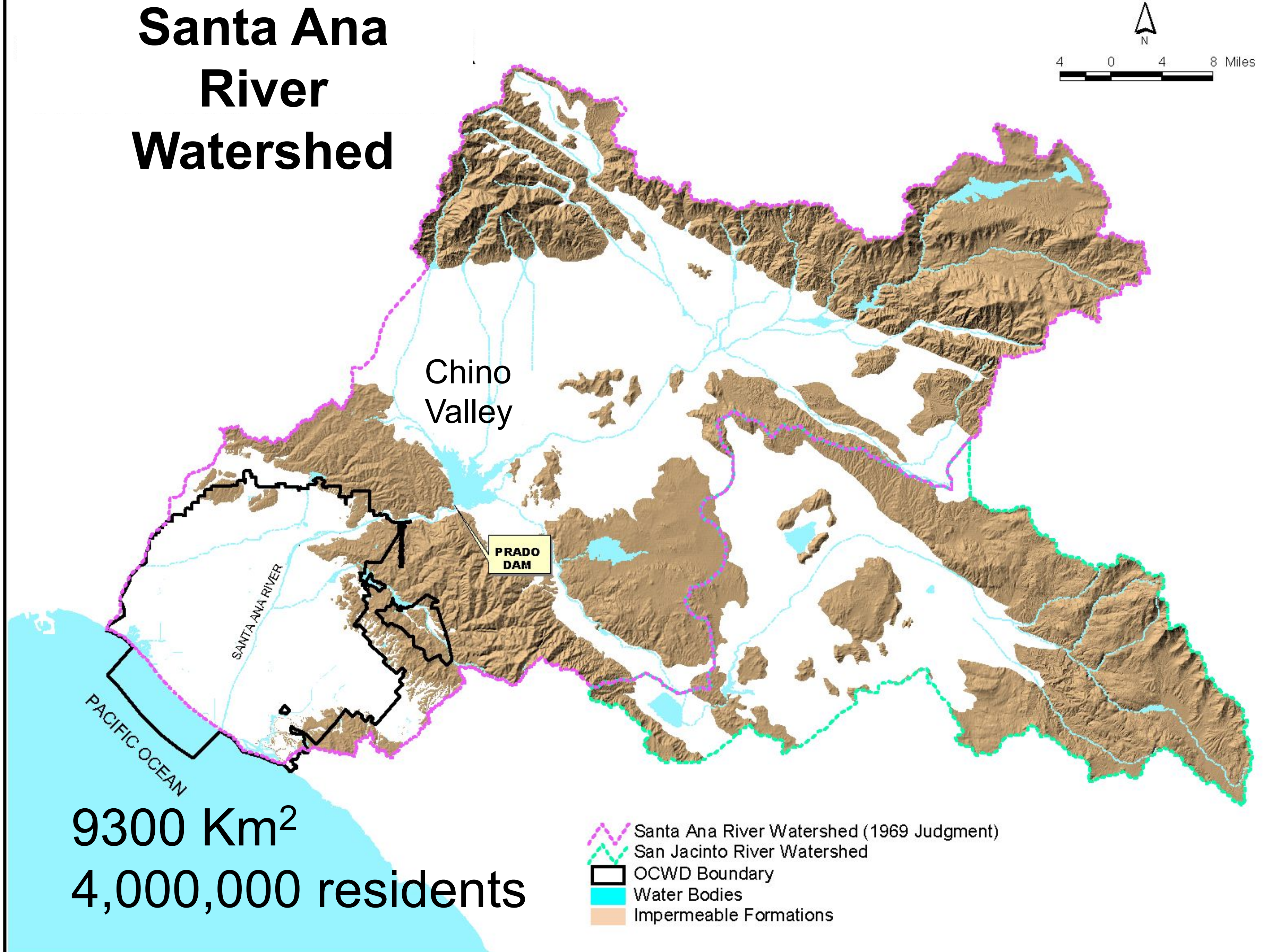
Lyon, S.R. 1999. “Multivariate Statistical Applications in Microbial Ecology.” In *Molecular Microbial Ecology Manual.* A.D.L. Akkermans, J.D. van Elsas and J.J. De Bruijn (eds). Kluwer Academic Publishers, Dordrecht, The Netherlands.

Orange County's Dairy Washwater Treatment Demonstration Project

Orange County Water District

Fountain Valley, CA

Santa Ana River Watershed



9300 Km^2

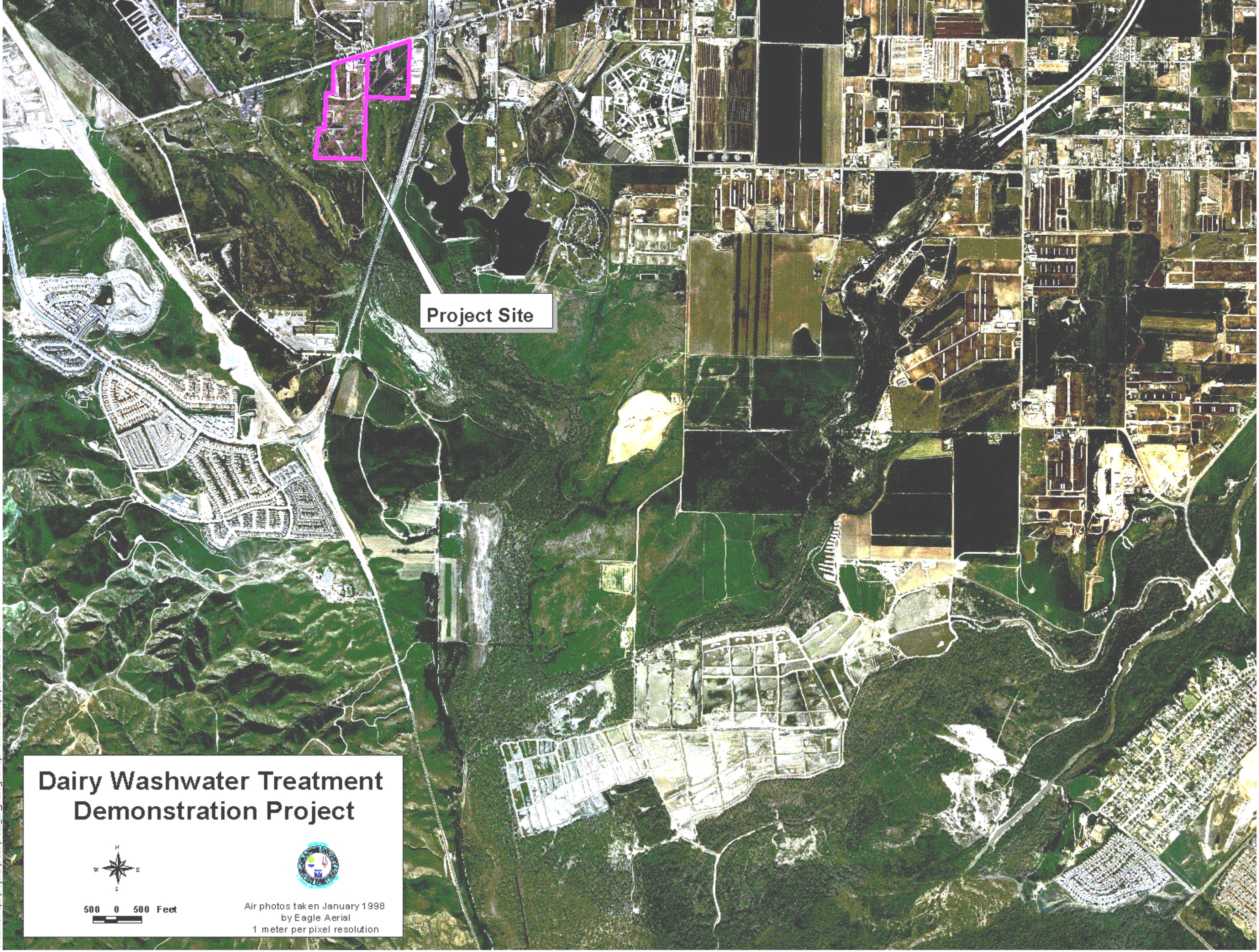
4,000,000 residents

- Water Quality for Orange County’s drinking water source
- Critical Habitat for endangered species
- Changes in the makeup of surface water and non-point source pollutants
- 101 Km^2, highest concentration of dairy cows in the world

Santa Ana River Threatened From Agricultural Nonpoint Source Runoff

- Over 386,000 cows
- Runoff of washwater & manure during storms

- Pollutants include nutrients TDS, pathogens, chemical & biological oxygen demand



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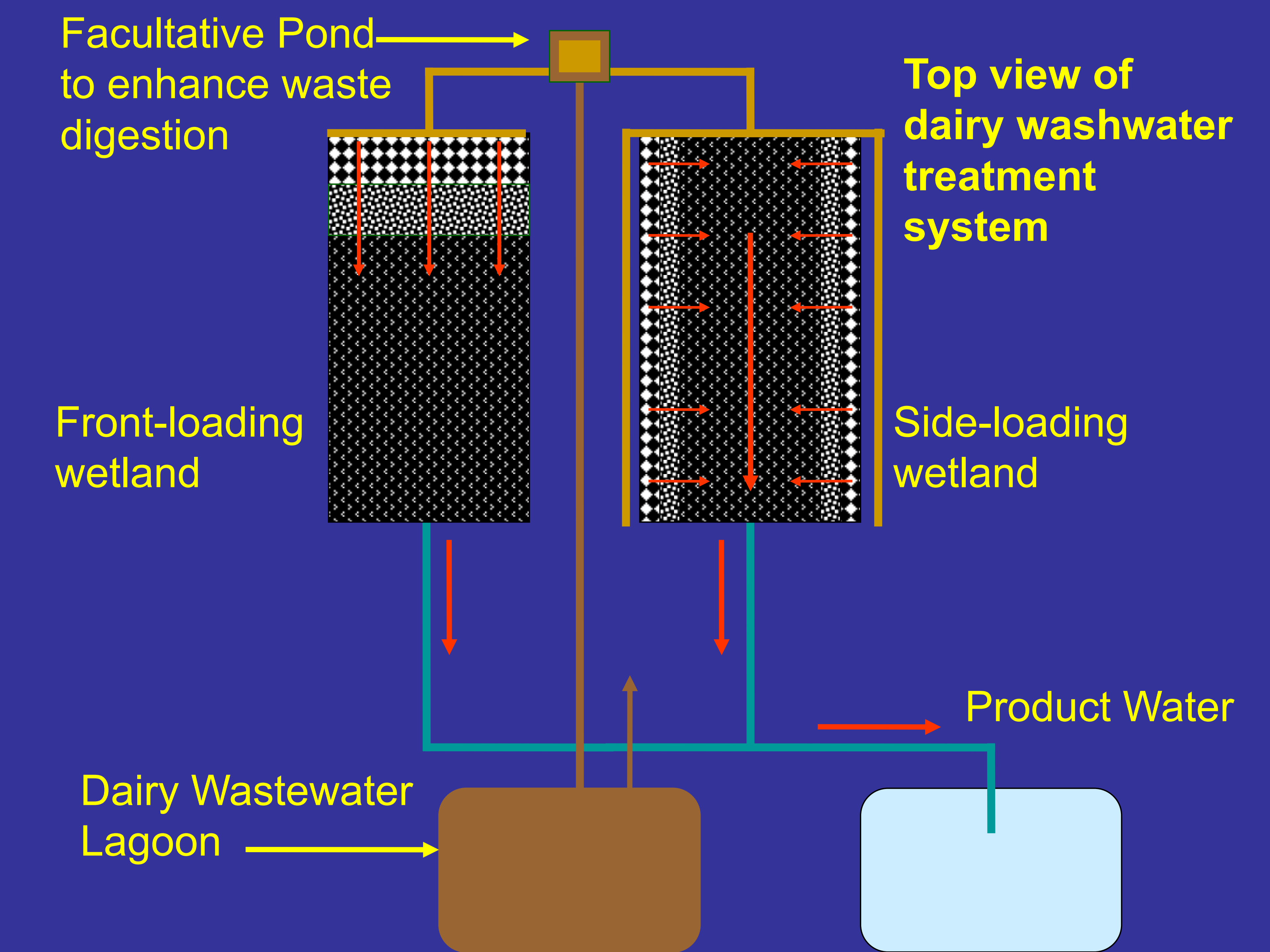
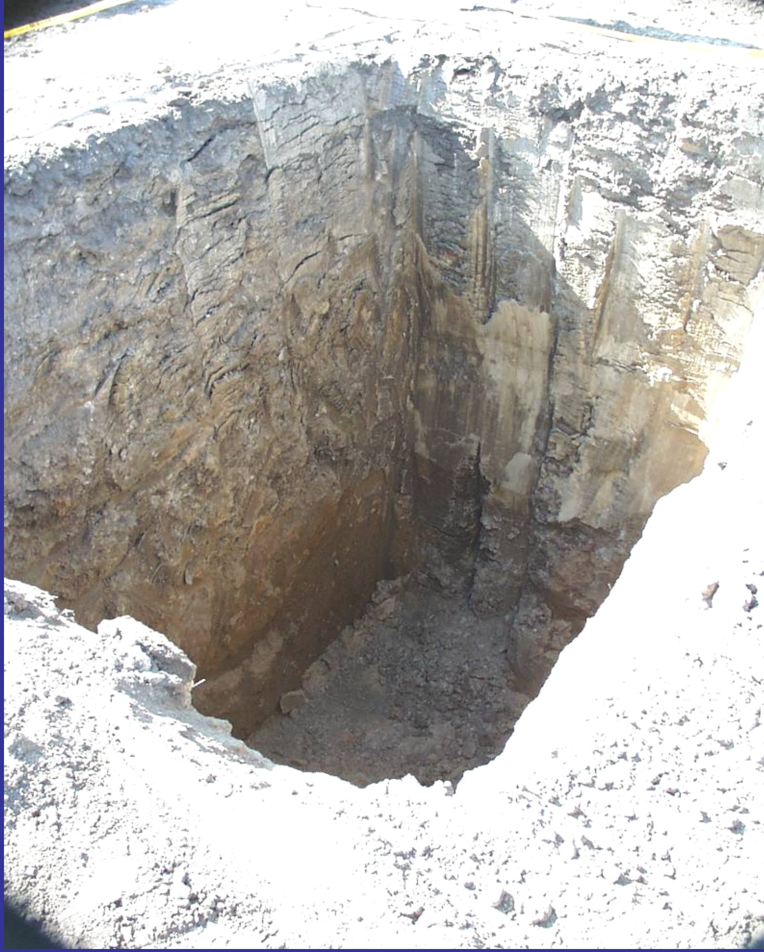

Facultative Pond to enhance waste digestion
Top view of dairy washwater treatment system
Front-loading wetland
Side-loading wetland
Product Water
Dairy Wastewater Lagoon

Site of constructed wetlands in Chino, CA before breaking ground in July 2000

Work in progress July 20, 2000

Excavation of the two wetland basins



2600 tons of pea gravel

Excavation of the facultative digestion pit (5 m deep)

Wetland basins were leveled with a 10 cm sand base and then covered with a PVC liner followed by a layer of geotextile

Sampling ports

Effluent collection box

OCWD crew filling in the basin with pea gravel

Constructed wetland prior to the addition of vegetation

Bulrushes harvested from the Prado wetlands and transplanted to the Dairy Demonstration Project

Side-loading constructed wetland

Front-loading constructed wetland

Dairy Washwater Treatment Demonstration Project

WE DRINK MILK WE LIKE CLEAN WATER

Dairy Washwater Demonstration Project

EPA United States Environmental Protection Agency

California EPA
RWQCB
Santa Ana Region

Dairy Producer Environmental Foundation

Orange County Water District — Since 1933 — A Tradition of Innovation

Chino Basin Watermaster

SWRCB

SAWPA

Inland Empire Utilities Agency

Participating Agencies

U.S. Dept. of Agriculture, Natural Resources Conservation Service
U.S. Salinity Laboratory
Inland Empire West Resource Conservation District
U.S. Geological Survey
University of California, Davis Cooperative Extension
South Coast Air Quality Management District
Northwest Mosquito & Vector Control District
Chino Basin Water Conservation District
Eastern Municipal Water District
Milk Producers Council
Western United Dairymen

Special thanks to the OCWD Prado and Forebay staffs for their tireless work in constructing this project.

Multiple Tours of Demonstration Projec

- USDA and US EPA
- Natural Resources Defense Council
- Orange County Grand Jury, and many others

Art Baggett, State Water Resources Control Board

Front-loading and Side-loading Wetlands, Summer 2001

Raw washwater and wetlands product water

Water Quality Highlights

- From July to September:
  - Total nitrogen decreased 25%
  - Suspended solids decreased 92%
  - BOD decreased 88%
- Samples analyzed in August achieved a 2-log removal in total coliforms and 3-log removal fecal coliforms

Provides habitat for Red-winged blackbirds and nesting Killdeers


CAT
CAT