Groundwater Remediation Using Engineered Wetlands

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Casper, Wyoming

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A case study –
British Petroleum,
Wyoming Casper

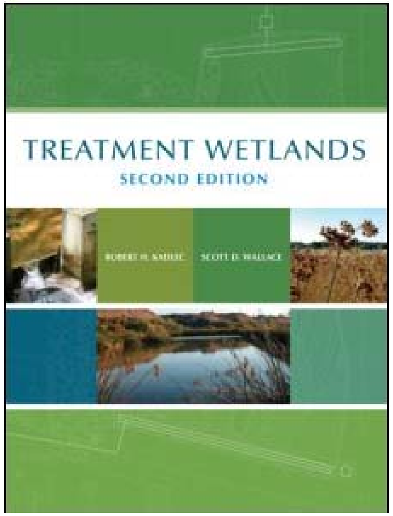
Introduction

Who we are

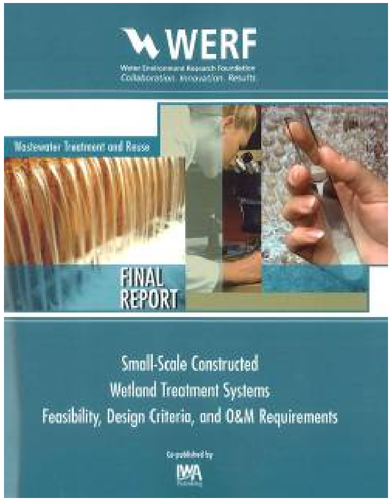
- North American Wetland Engineering (1997)
- Jacques Whitford (2007)
- Stantec (2009)
- Canadian/American environmental consulting firm
  - Design engineering
  - Full in-house CAD, construction observation
  - Wastewater operations
- National and International Experience
- Pilot testing facility
- *Treatment Wetlands, 2nd Edition*, Kadlec and Wallace

Engineered Wetland Design

Treatment Wetlands, Second Edition
Primary textbook in the world for engineered wetland design
(Kadlec & Wallace, 2008)

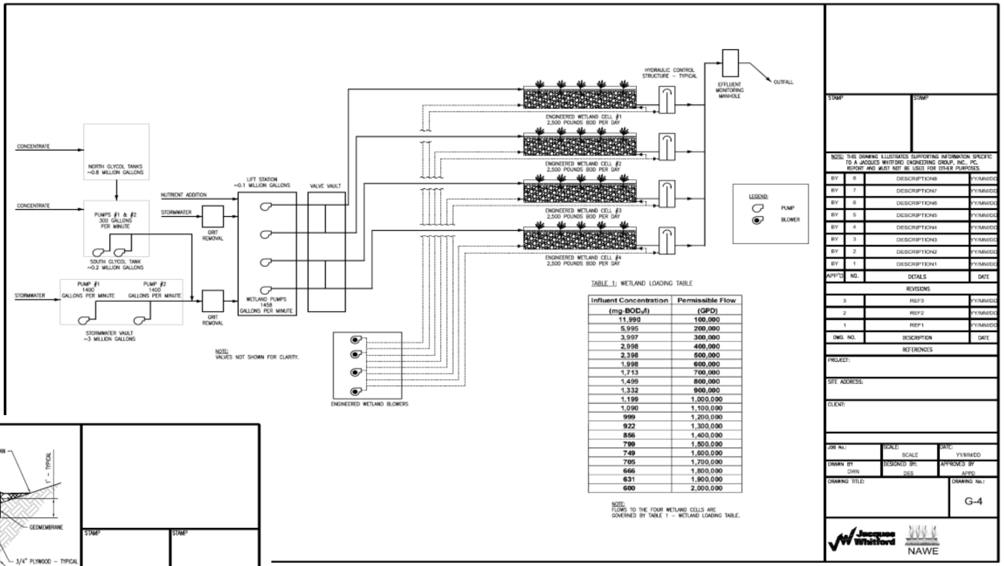


Small Scale Constructed Wetland Systems
Water Environment Research Foundation
(Wallace & Knight, 2006)

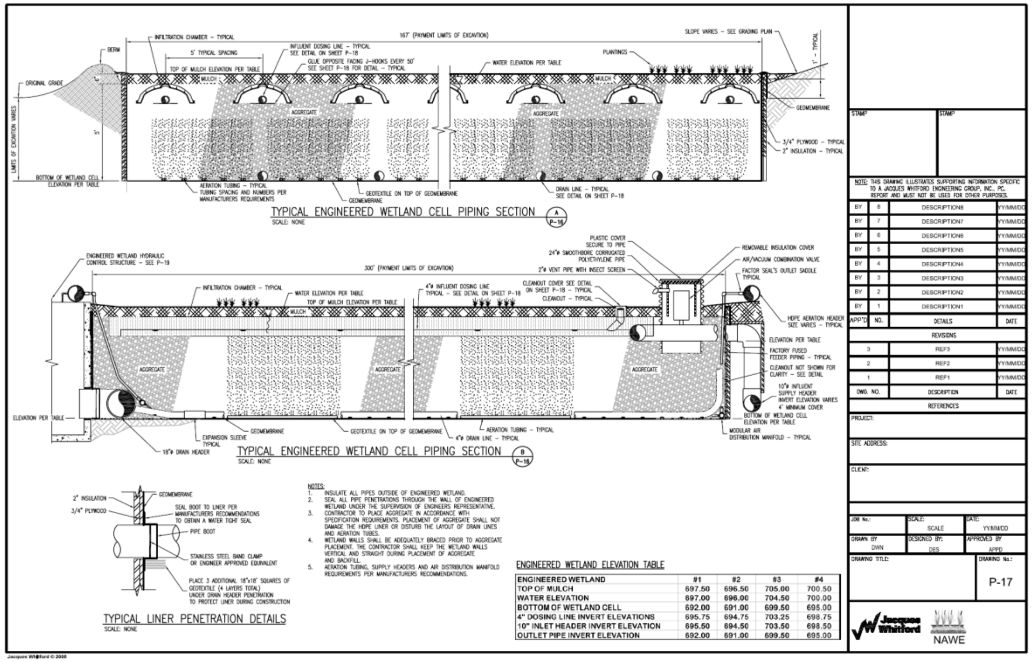


Process Design Engineers

HSSF Process



Influent Concentration	Permissible Flow
(mg-BOD$_5$/l)	(GPD)
11,990	100,000
5,995	200,000
3,997	300,000
2,998	400,000
2,398	500,000
1,998	600,000
1,713	700,000
1,499	800,000
1,332	900,000
1,199	1,000,000
1,090	1,100,000
999	1,200,000
922	1,300,000
856	1,400,000
799	1,500,000
749	1,600,000
705	1,700,000
666	1,800,000
631	1,900,000
600	2,000,000



ENGINEERED WETLAND	#1	#2	#3	#4
TOP OF MULCH	697.50	696.50	705.00	700.50
WATER ELEVATION	697.00	696.00	704.50	700.00
BOTTOM OF WETLAND CELL	692.00	691.00	699.50	695.00
4" DOSING LINE INVERT ELEVATIONS	695.75	694.75	703.25	698.75
10" INLET HEADER INVERT ELEVATION	695.50	694.50	703.50	698.50
OUTLET PIPE INVERT ELEVATION	692.00	691.00	699.50	695.00

Vertical Sub Surface Flow Wetland Design

Industrial Overview

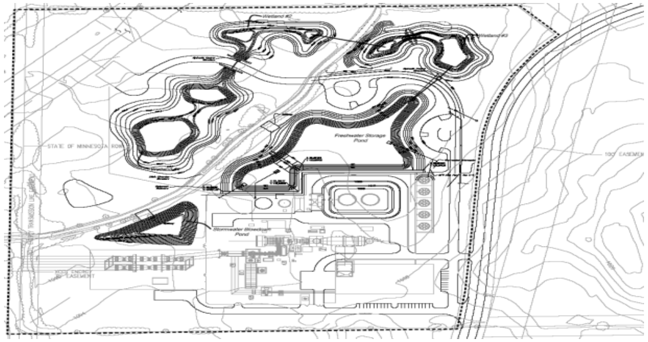
Treatment for complex waste streams

- Oil and Gas Downstream Refining
- Mining
- Transportation/Airport
- Food Processing
- Contaminated Groundwater
- Solid Waste

Industrial Projects

Buffalo International Airport, NY
Deicing fluid treatment using Wetlands

Schilling Farm, MN
TCE contaminated soil



Minnesota Municipal Power Agency
Storm water harvesting and reuse using wetlands – Cooling water

Wellsville , New York
Engineered wetland petroleum hydrocarbon remediation project for BP (1,090 m^3/day)

Engineered Wetlands

- Engineered to optimize biodegradation of organic contaminants
- Designed with Forced Bed Aeration™ to increase aerobic biodegradation rates
- Equipped with reactive media to adsorb contaminants
- Characterized by controlled hydraulic loading designs

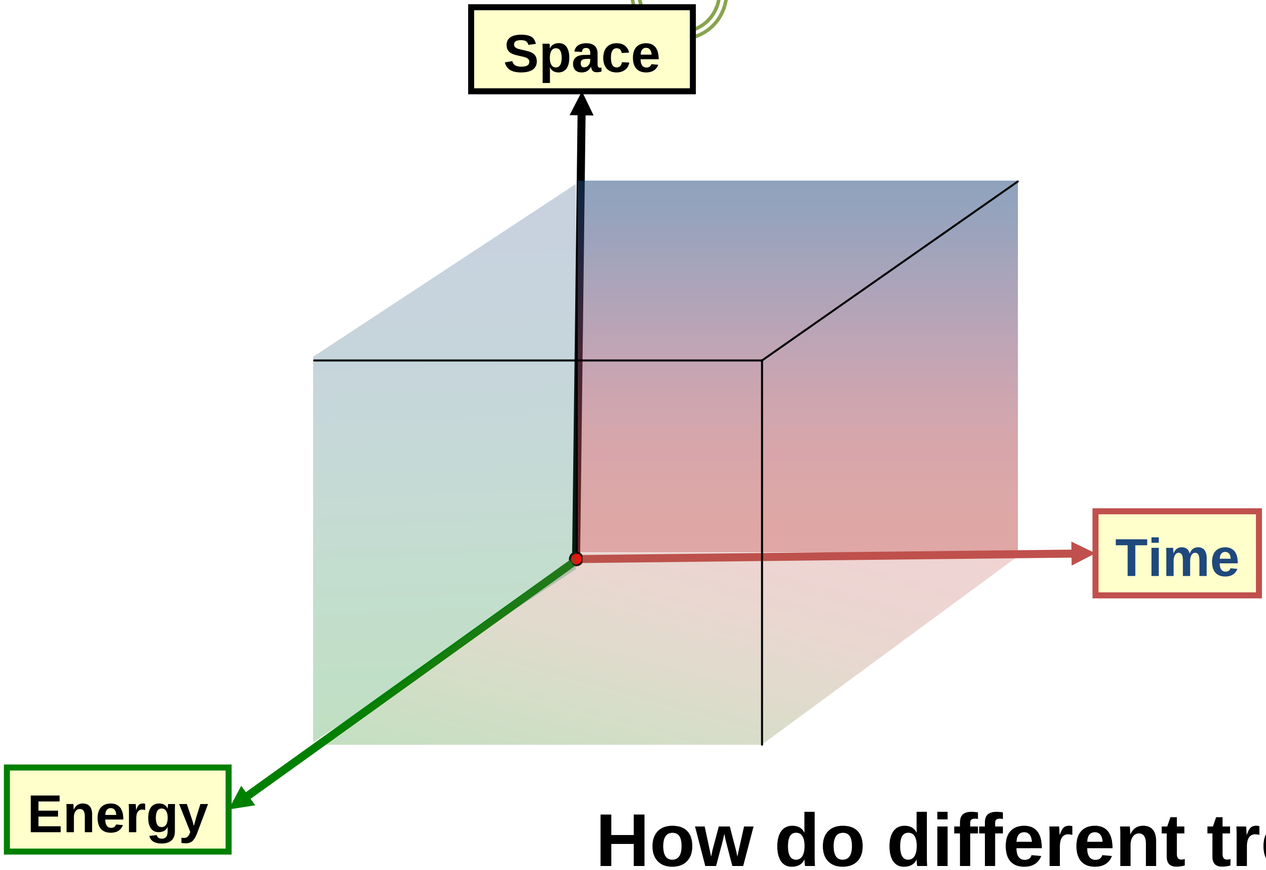
Types of Wetlands

- Free Water Surface (FWS)
- Horizontal Subsurface Flow (HSSF)
- Vertical Subsurface Flow (VSSF)
- Tidal Flow (TF)

Engineered Wetlands

- Aerated (cold climates) ← NAWE
- fill-and-drain (warm climates)
- reactive media (ammonia, phosphorus, etc)
- industrial wastewaters

Treatment Process Selection

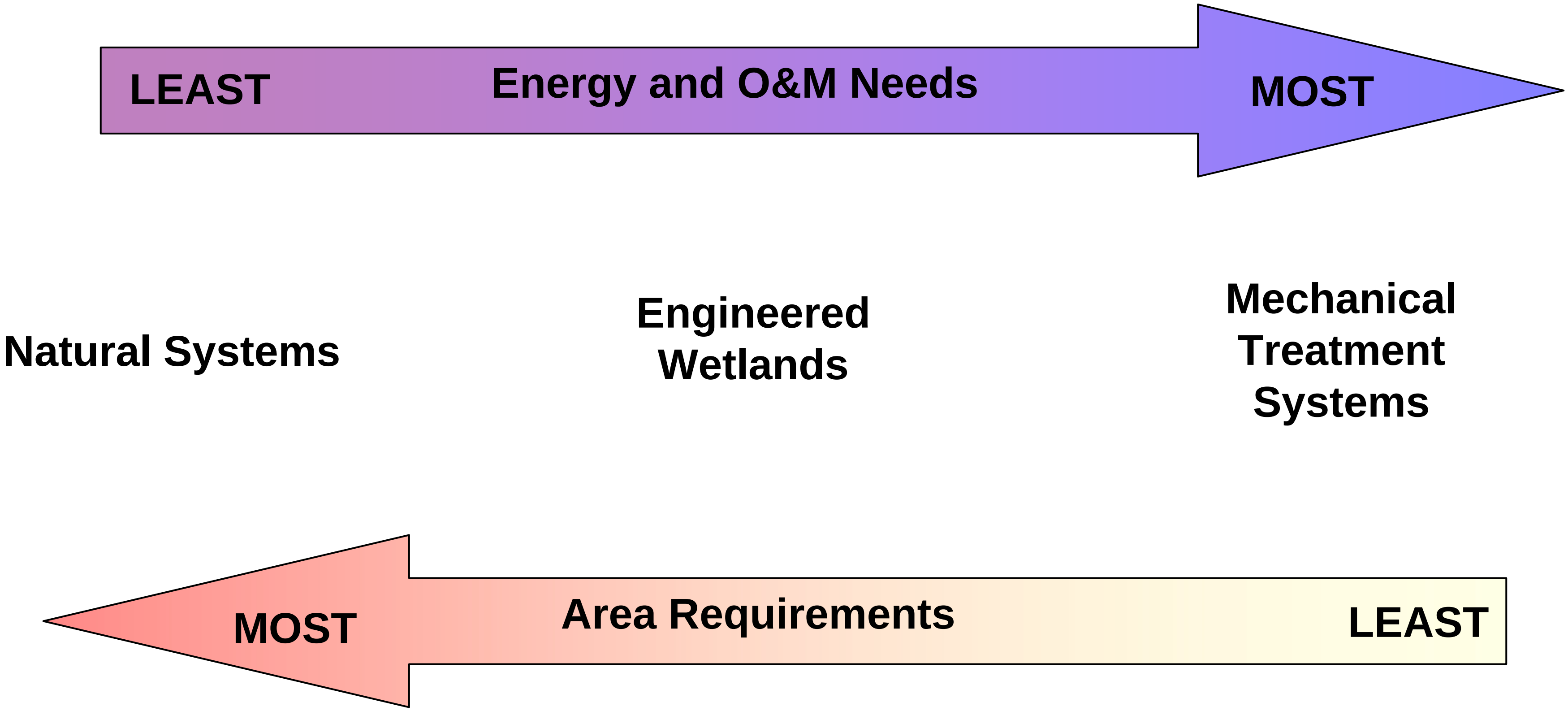


How do different treatment options address these criteria?

Wetland Treatment Chemistry

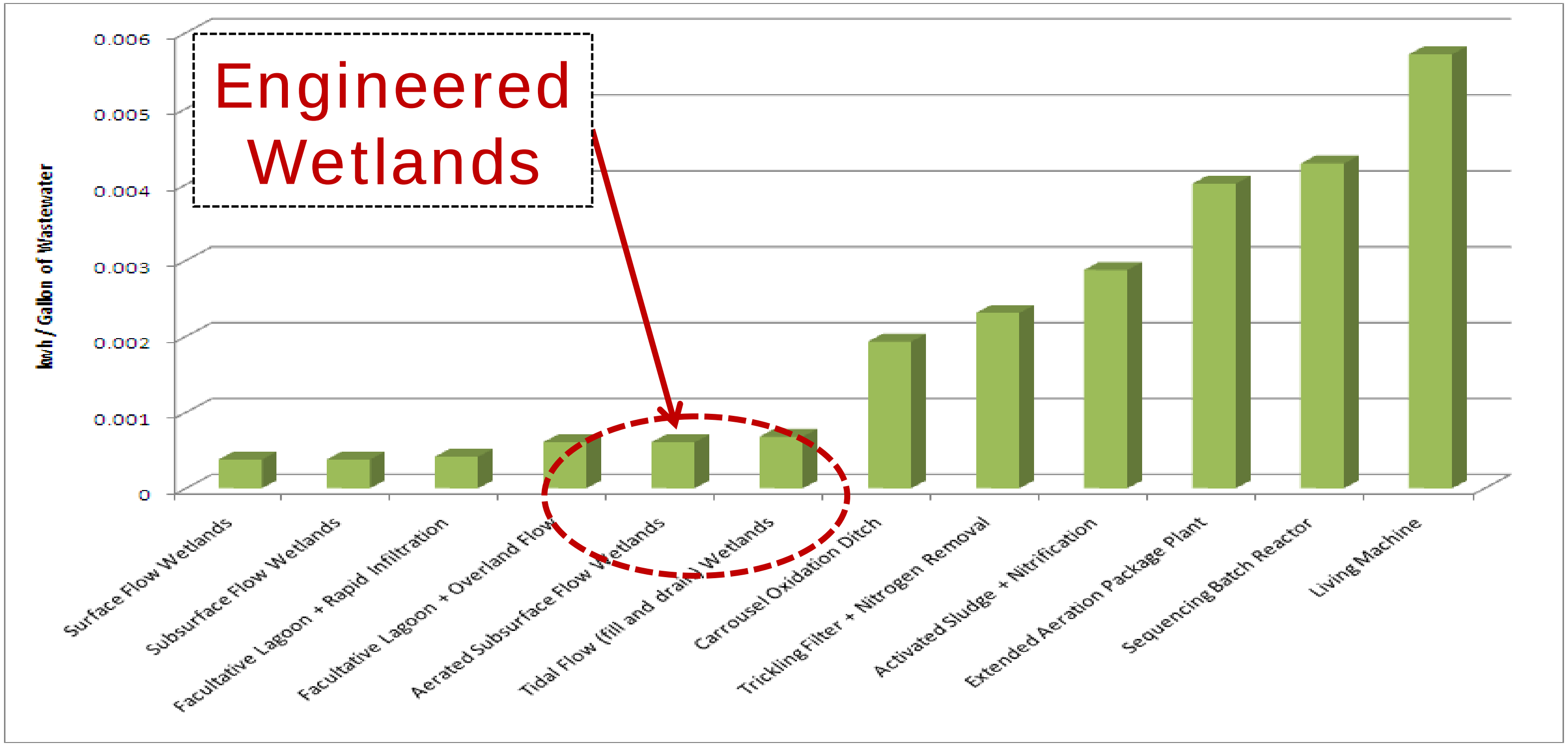
- Aerobic wetlands
  - Fe, Mn
- Sulfate reducing wetlands
  - Cu, Cr, Ni, Mo, As etc…
- Alkalinity-adding wetlands
- BOD, COD
- Nitrification and de-nitrification processes
- Naphthenic acids ***
- TCE, DCE,
- LNAPL, BTEX, Hydrocarbons, PAH,
- Salts
  - Wetlands are biological treatment reactors; will not remove salts unless thermodynamically favorable

Natural vs. Mechanical Systems



Selecting treatment options

- There is a trade-off between land and mechanical complexity:



Free water surface wetlands

Olentangy River Wetland Research Park
Ohio State University

Vertical subsurface flow engineered wetland

Horizontal subsurface flow engineered wetland

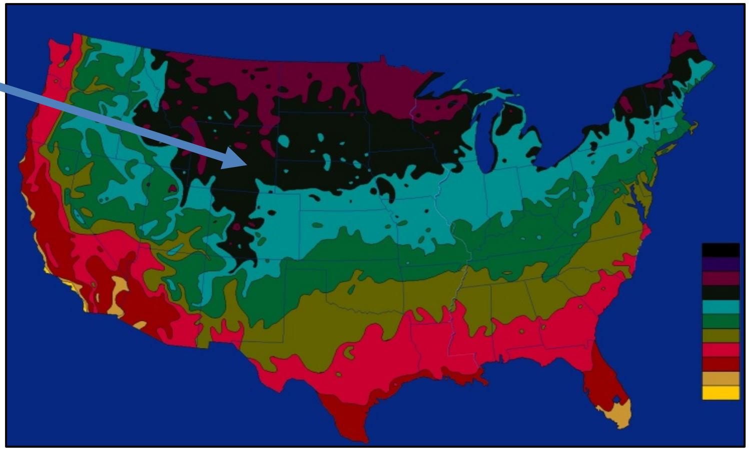
Wetlands & Remediation

- Oxidizing wetland environment
  - Oxidation & precipitation of iron, managanese
  - Degradation of TPH and other organics
  - Ammonia
- Reducing wetland environment
  - Reductive dehalogenation for chlorinated solvents
  - Reduction of sulfates (sulfide preciptation of copper, nickel, etc.)

BP Casper Refinery Site

- Operated 1908 to 1991
- Estimated 30 million gallons of hydrocarbons had leaked in a shallow alluvial aquifer (113,550 m3)
- Since 1981, 37,000 m^3 of LNAPL has been recovered.
- Wide range in annual temperature
- Record high: 40 °C
- Record low: -40 °C

Largest remediation wetland in North America - 2006

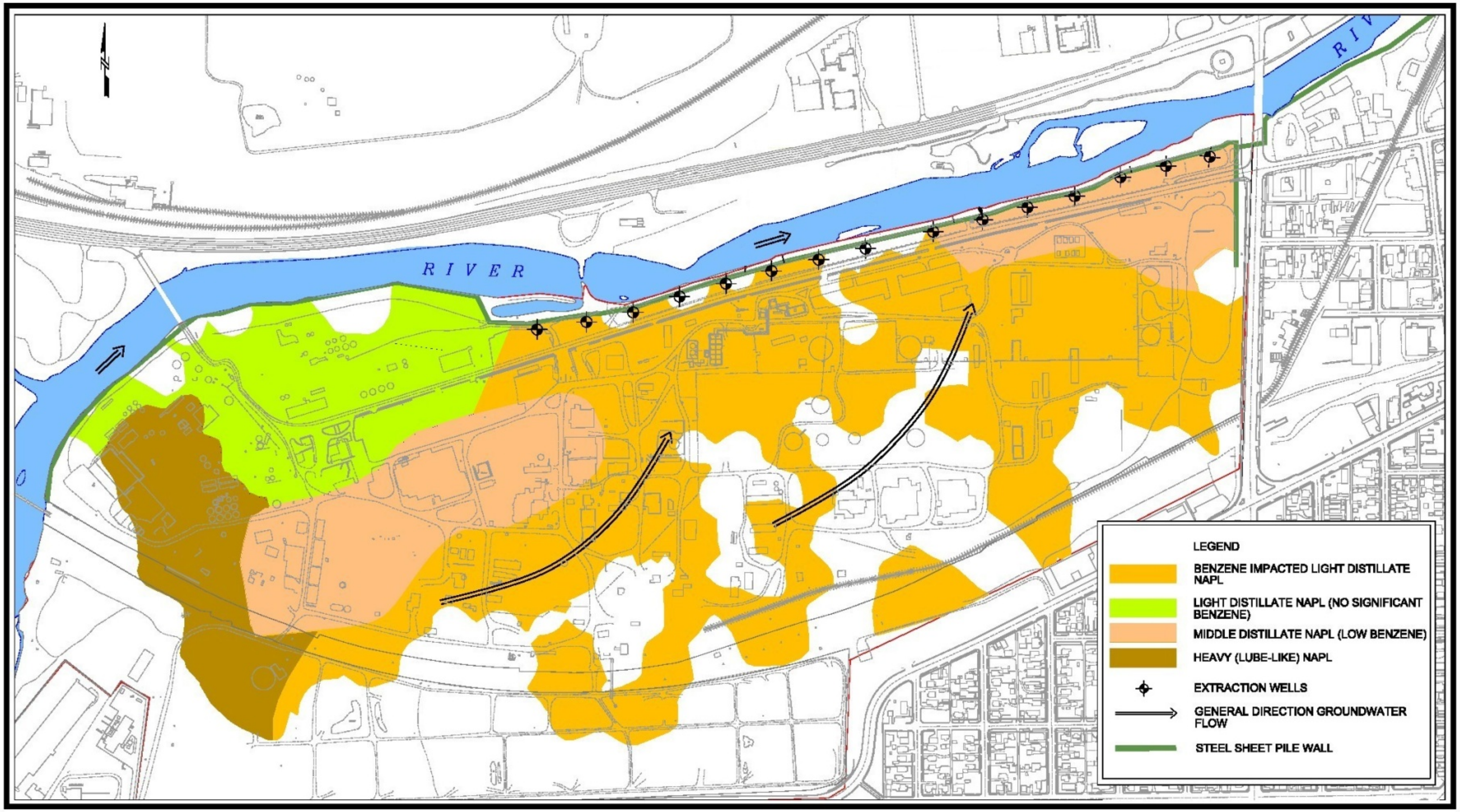


BP Refinery: Casper, Wyoming

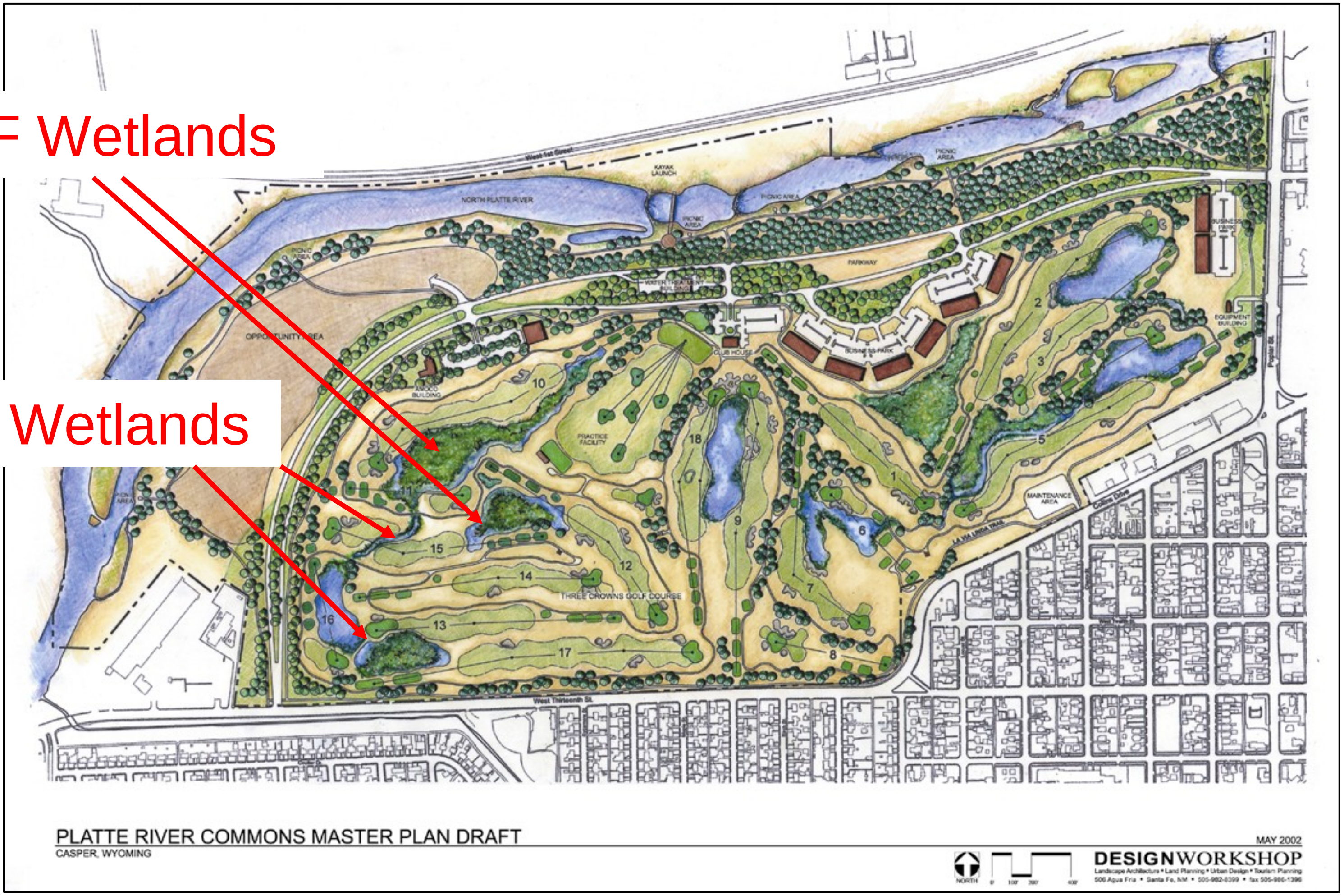
- Benzene and iron remediation over long timeframe (50 to 100 years)
- Design flow rate: 1.6 MGD or 6000m3/day

Parameter	Influent Concentration (mg/L)	Required Effluent Concentration (mg/L)
Benzene	1.5	<0.05
Total iron	>6	<2

LNAPL distribution



Former refinery site reuse plan

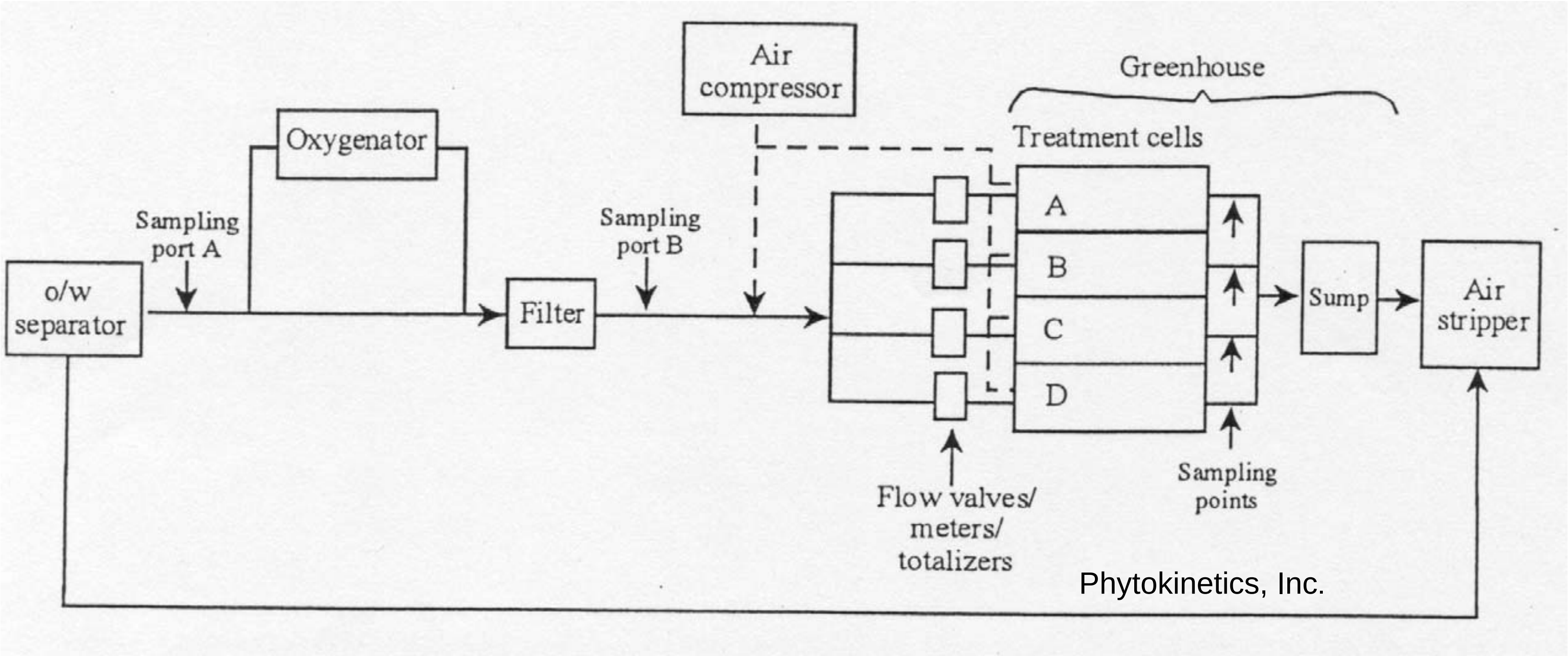


Petroleum Hydrocarbons

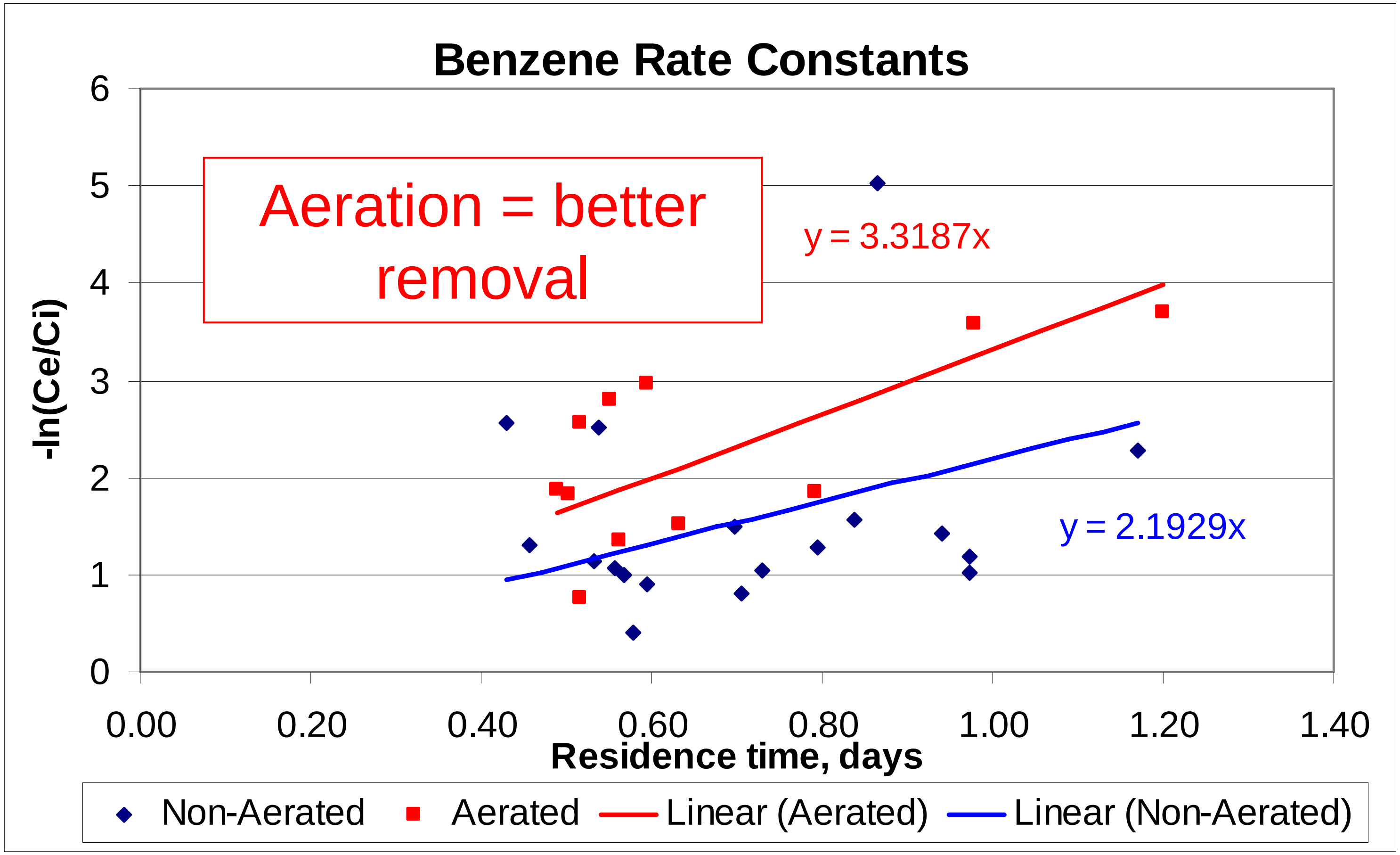
- Pilot-scale system designed and operated for BP in Casper, Wyoming, USA
- Former refinery with petroleum hydrocarbon-contaminated groundwater
- Pilot-system operated under aerated and non-aerated conditions
- Effect of insulation also studied
- Results used to design full-scale system treating 6000 m^3/d

Casper Pilot

- 4 cells
- Vertical upward flow
- With and without aeration
- With and without wetland sod

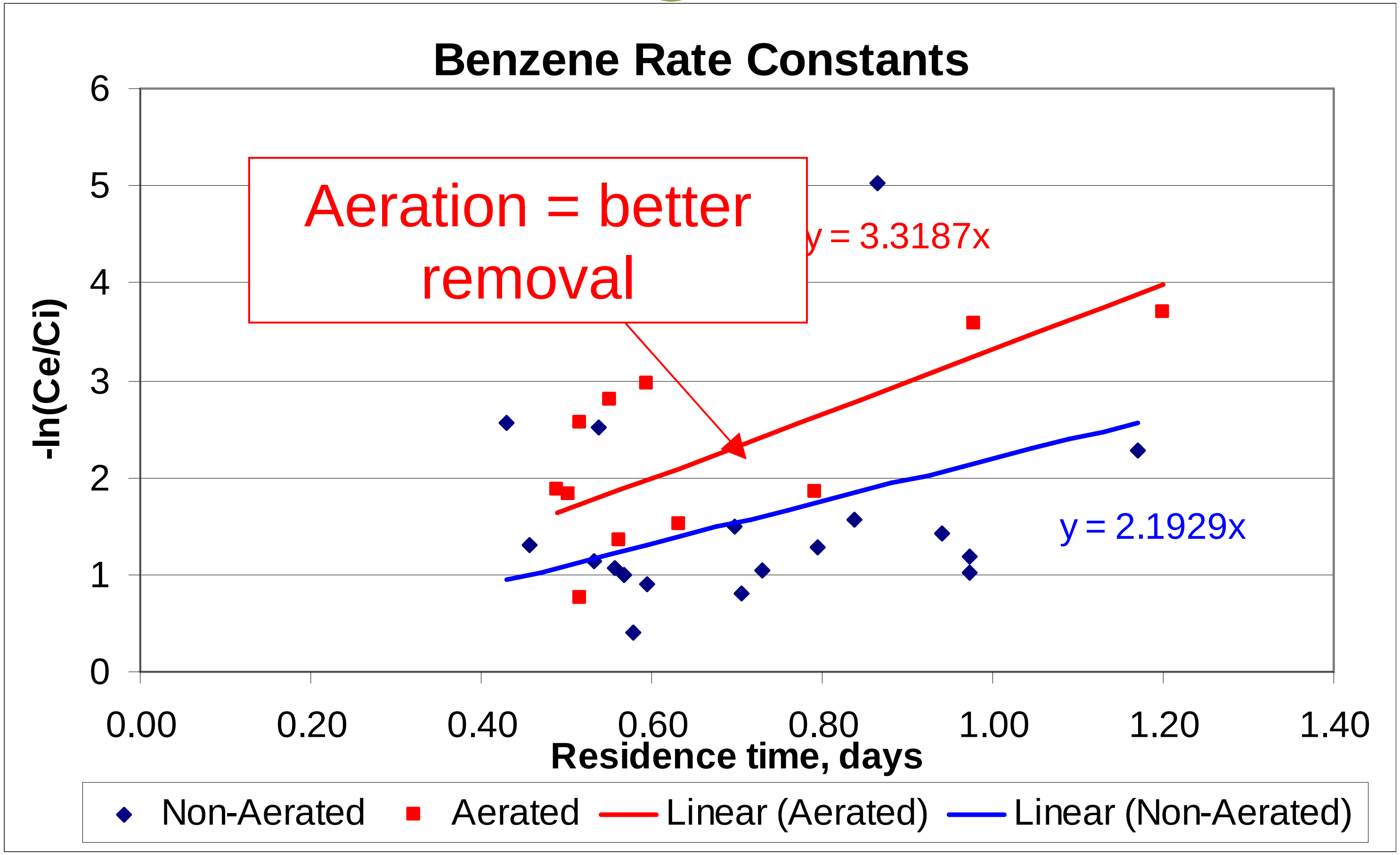


Pilot results: aerated vs. non-aerated

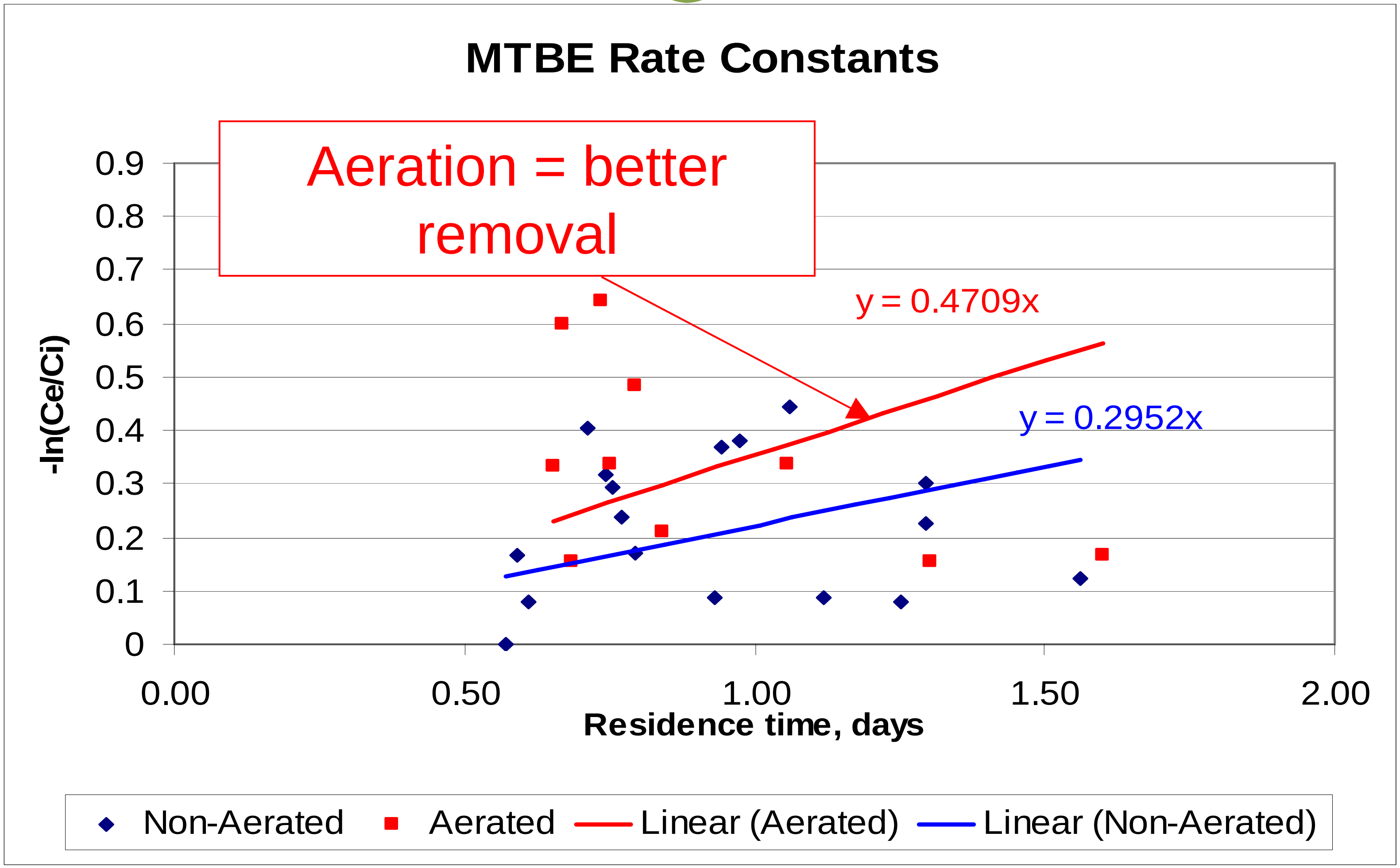


Area: 10 acres → 3.3 acres

Pilot Results: Benzene



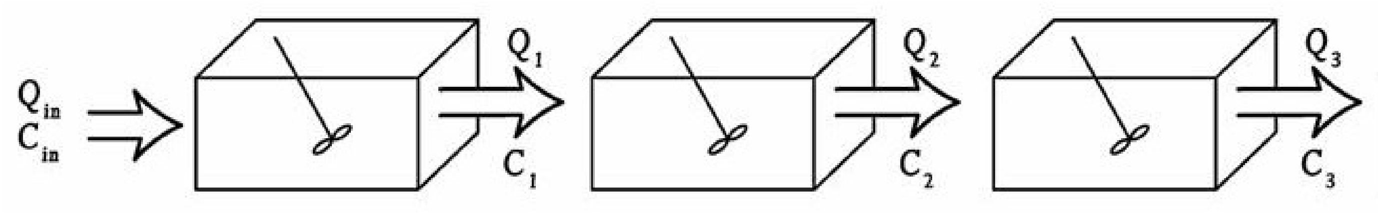
Pilot Results: MTBE



Casper Rate Coefficients

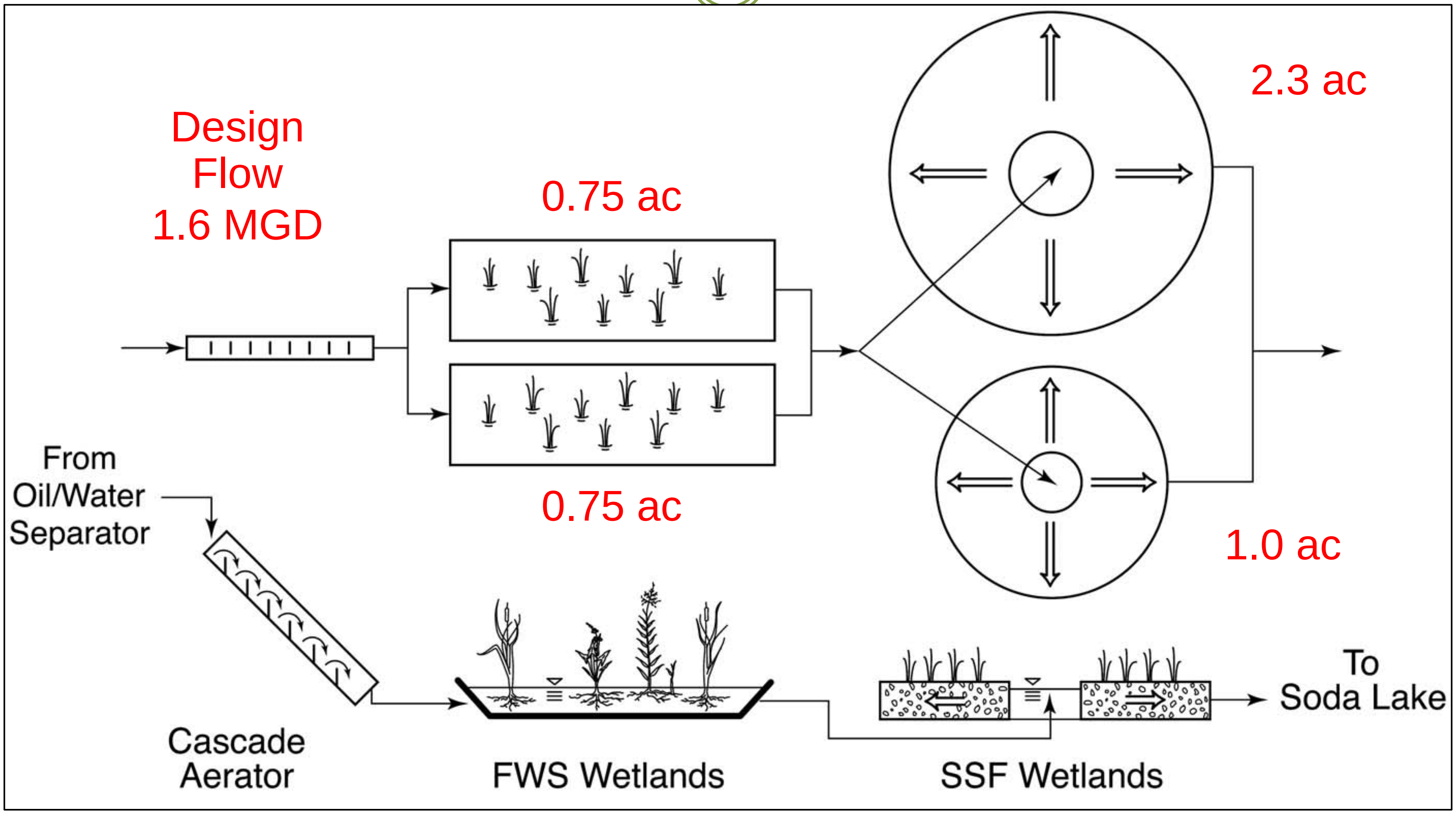
k_A, m/yr, based on 3 TIS

	Aeration		No Aeration	
Compound	Wetland Mulch	No Mulch	Wetland Mulch	No Mulch
Benzene	518	456	317	226
BTEX	356	311	257	244
TPH	1058	965	725	579
MTBE	64	60	35	22



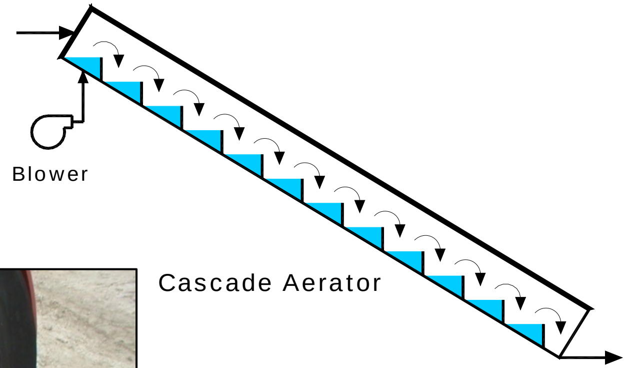
Wallace & Kadlec, 2005

Full scale treatment system



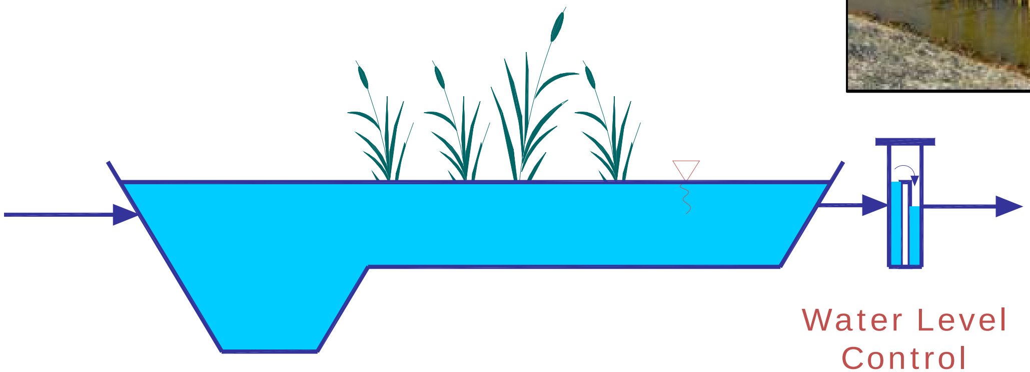
Cascade aerator

- Oxidize Fe^{2+} to Fe^{3+}
- Benzene stripping reduces concentration to ~ 0.1 to 0.8 mg/L

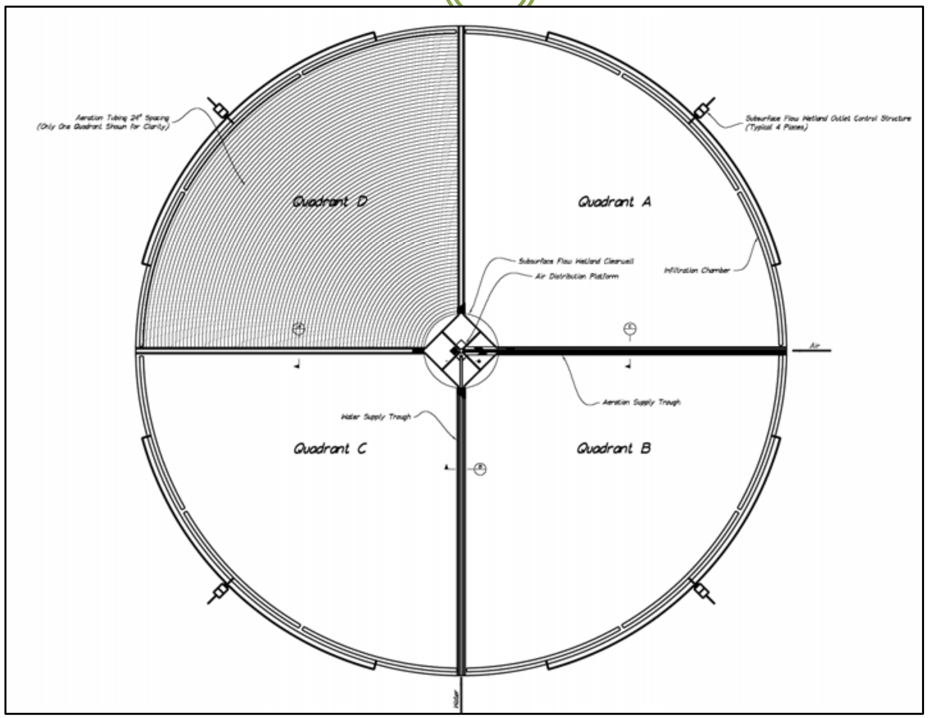


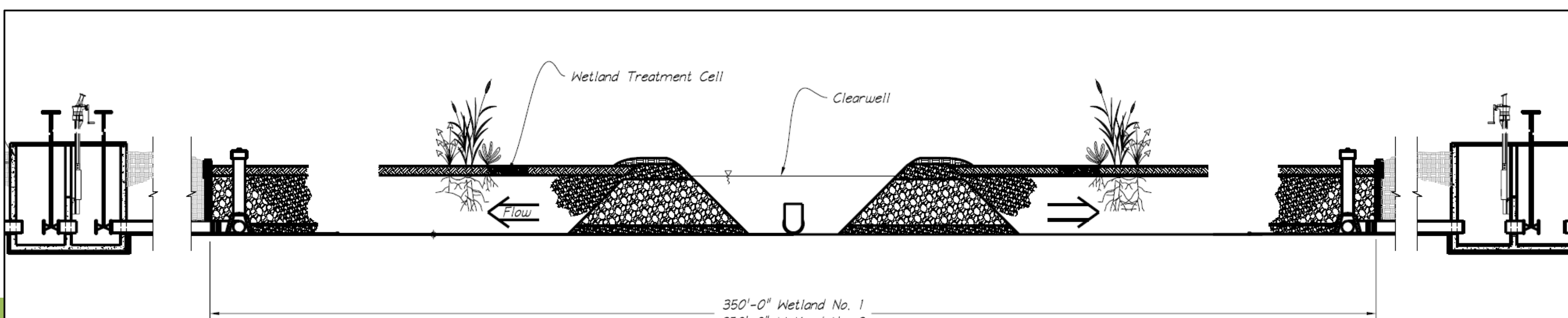
Free water surface wetlands

- Iron sedimentation
- Deep zones for sludge removal



HSSF engineered wetland



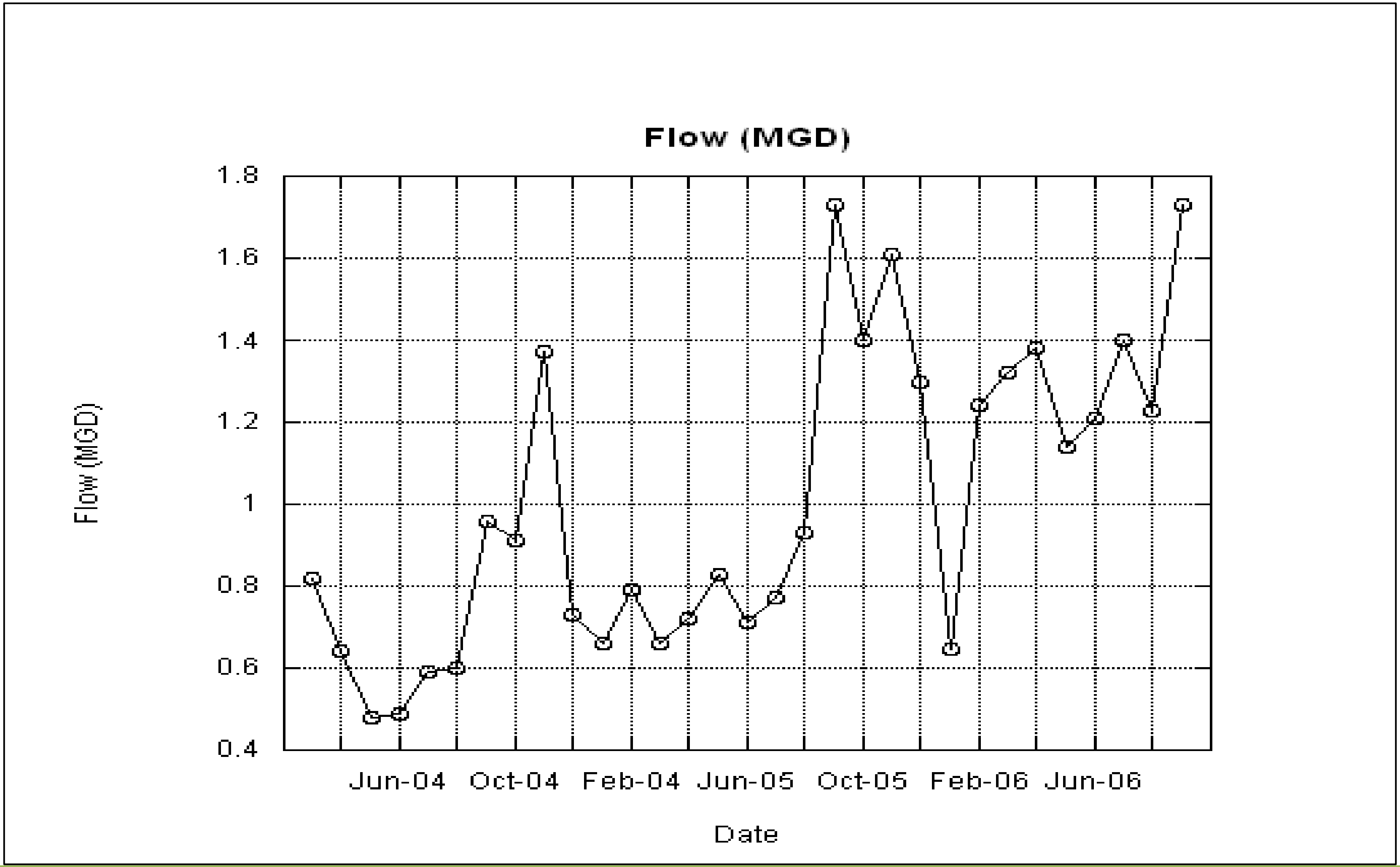


Forced Bed Aeration™

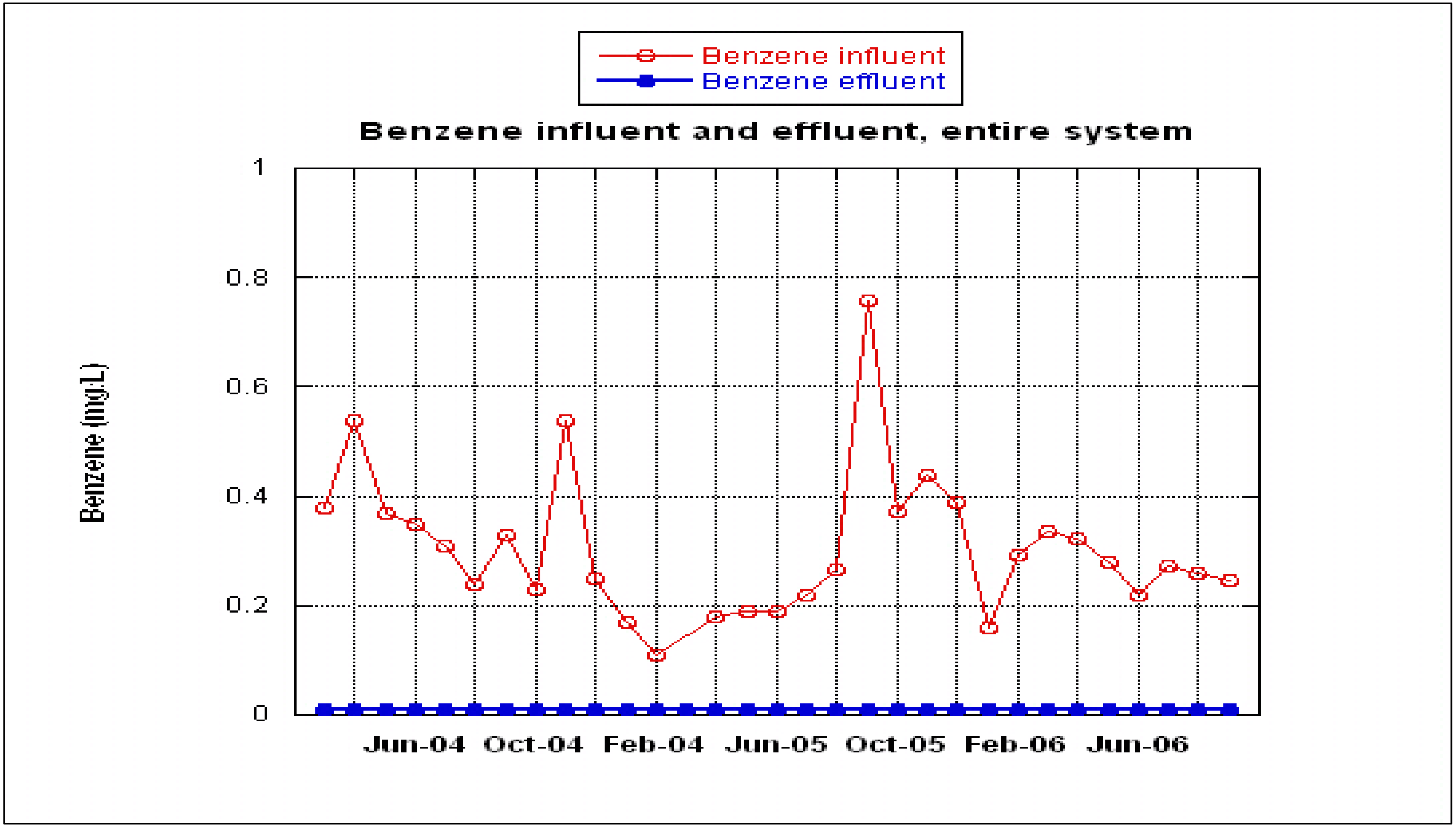
HSSF engineered wetland construction

HSSF engineered wetland

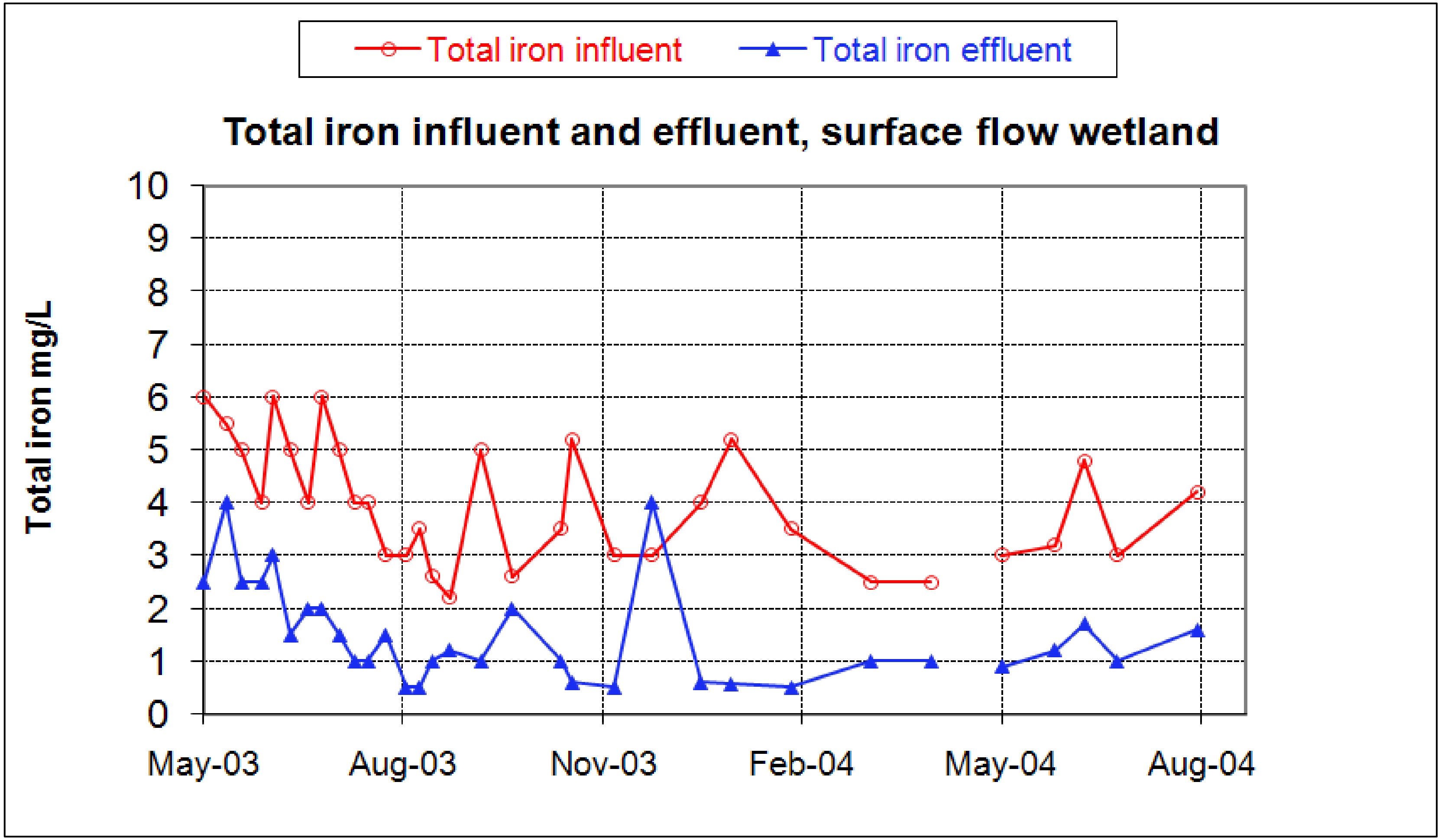
Approaching design flow 2004-2006



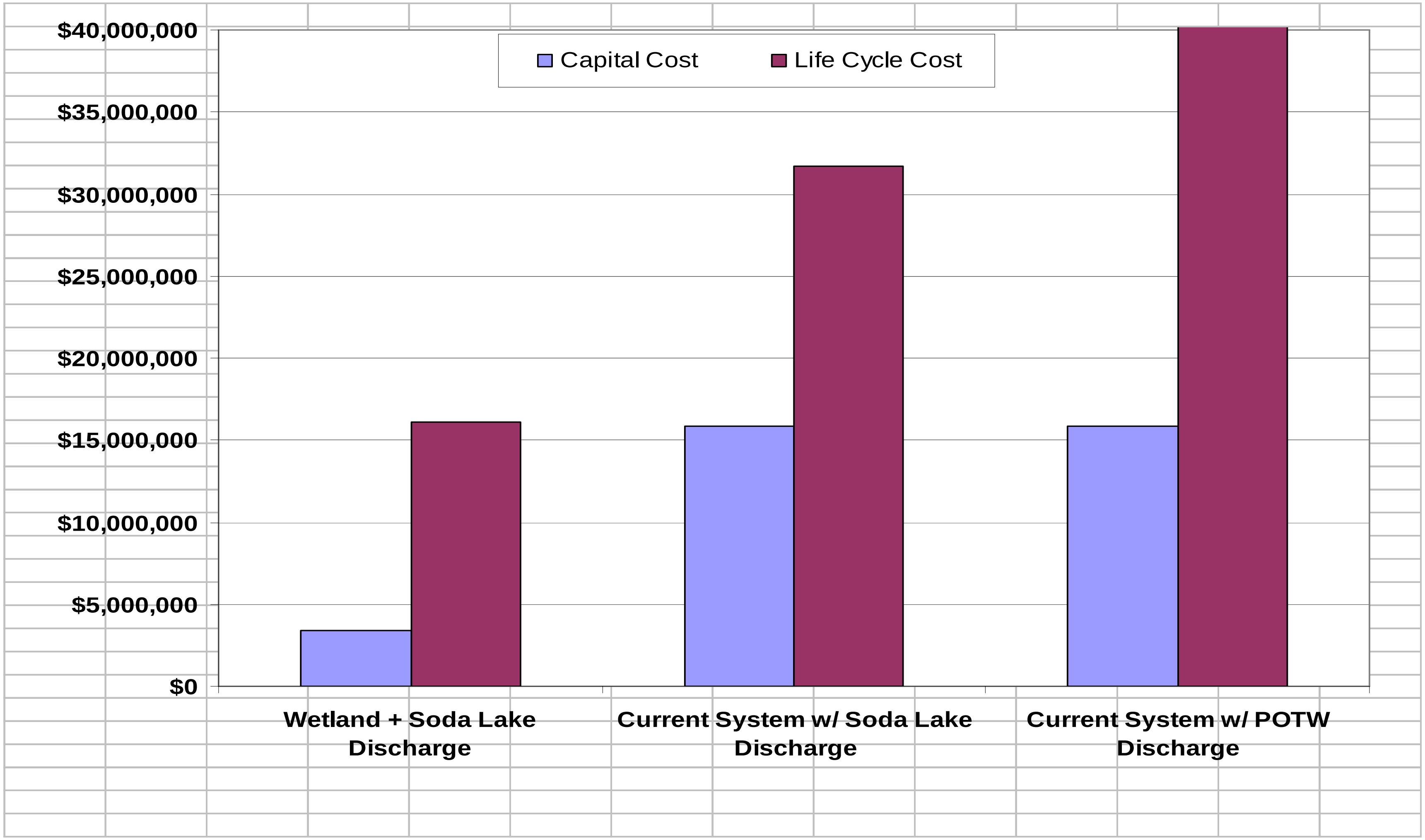
Benzene data: 2004-2006



Total iron data: 2003-2004



Cost savings to BP: significant



Conclusion

- Construction of an Engineered Wetland saved BP over $12.5 million compared to a conventional plant

Wetland	Air stripping &Catalytic oxidation
$3.4 million	$15.9 Million

- Anticipated to save $15.7 million in Operating costs over the next 50 years.
- Currently treats 6000m3/day of contaminated groundwater.
- Is now a terrific amenity to the community.

Casper site 2006

Questions?