



# Cost Comparisons of Phytotechnologies to Other Remedial Approaches

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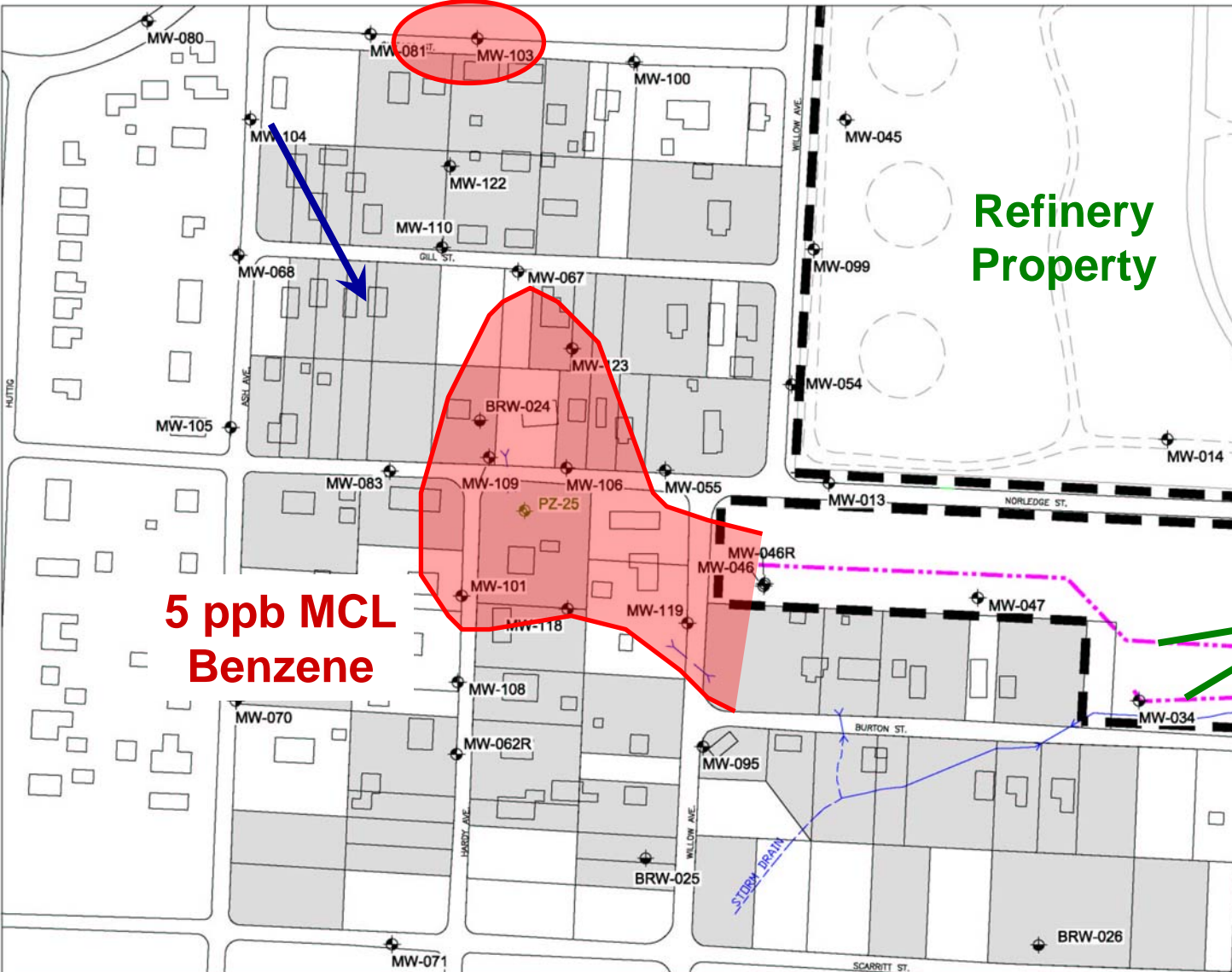
## OVERVIEW

1. Case Study Background
2. Net Present Valuation vs. Total Life Cycle
3. Influence Factors and Weighted Probabilities of Occurrence
4. Rate of Return on (Research) Investment

# Case Study Background

- **Site Conditions:**
  - **Neighborhood properties** adjacent to a former petroleum refinery
  - Groundwater impacted with **gasoline range organics (BTEX)**
  - Portion of groundwater treated using **horizontal 3-phase extraction**
  - Groundwater 5-13 ft bgs; silty clay;  **$5 \times 10^{-6}$  cm/s**
- **Issues:**
  - **Extraction efficiency low** (low hydraulic conductivity = low recoveries)
  - **Refinery property undergoing redevelopment**
  - **Reduce the disturbance** to the local community (minimize sound, safety risks, heavy equipment traffic)
  - **Provide some value** to the community for these under-utilized properties
- **Phytotechnology Option:**
  - Create bird / butterfly gardens (**“Phytoscapes”**) using vegetation that can promote rhizodegradation and control hydraulics

# Site Map



**Lots available for Phytoscapes**

**Refinery Property**

**Phase 1 Horizontal Wells**



# Phytoscapes

## Concept Borrowed from BP Retail



### Phytoscaped Retail Site

**Phytoscapes:**  
Landscapes that incorporate phytoremediation species to **clean up or prevent** environmental liabilities (small leaks and spills)

# Plant Screening Experiments

## Pure Gasoline Injections

Examined various deep-rooted species (naturalizing and landscape); monitored survivability over time

Injected pure gasoline (+/- 10% oxygenates) at various volumes

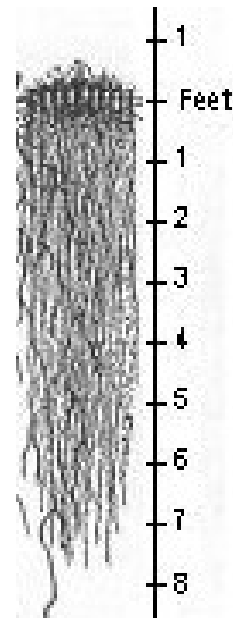
Irrigated with pure gasoline (various volumes)



Confirmed roots growing through soil (yellow)

Clean topsoil

Clayey soil



Sub-irrigation only source of water

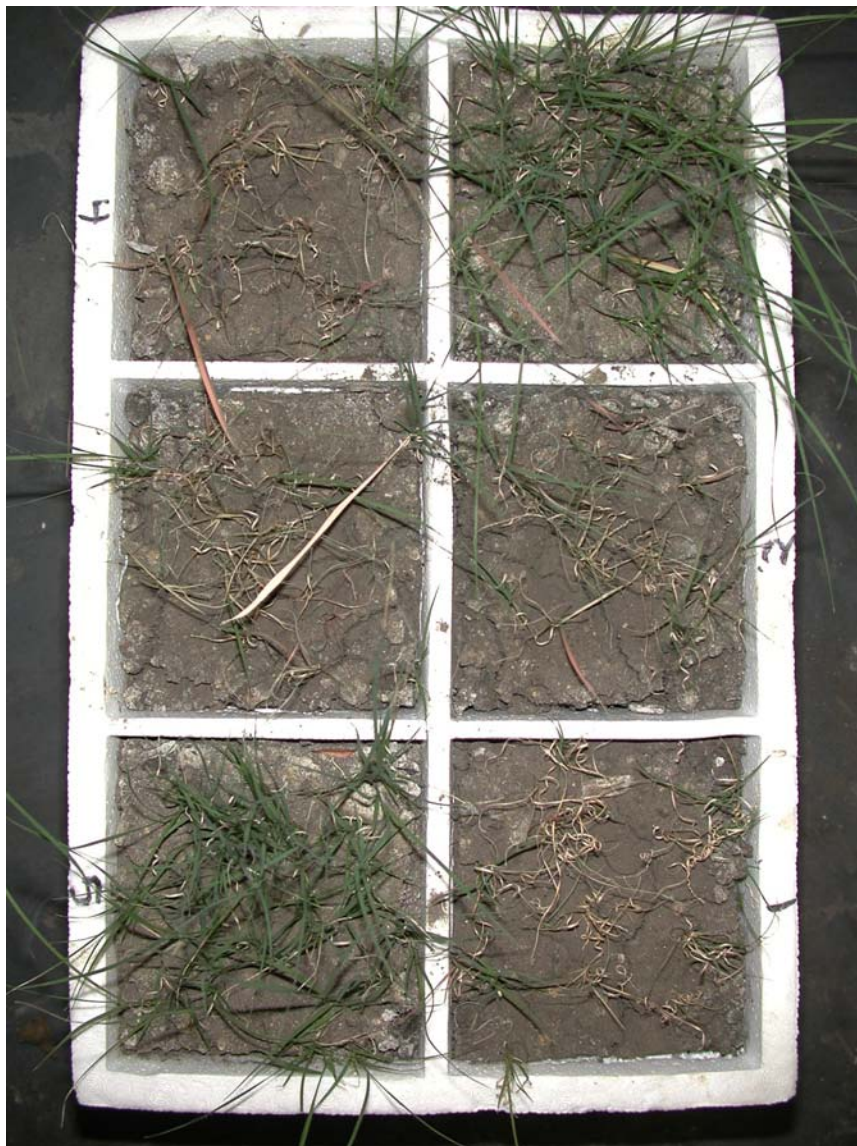
1 L total soil volume



# Gasoline Testing Results

## Not Only Tolerate, But Remediate

45 mls per 1 L cell (7.5% by wgt)



### Final Soil Concentrations:

Unplanted Control Pots (not shown):

- BTEX 1,875 ug/kg
- MTBE 2,700 ug/kg

Planted Pots: Bottom Soil Layer

- BTEX 46 ug/kg (ND, 11, ND, 35)
- MTBE 50 ug/kg

**orders of magnitude lower**

# Gasoline Toxicity Results

## Tolerant Species

- 3 out of 3 Buffalo grasses (*Buchloe dactyloides* spp.)
- MOST** ornamental clump grasses (*Andropogon*, *Bouteloua*, *Elymus*, *Miscanthus*, *Pennisetum*, *Saccharum*,...)
- 1 of 1 Columbine (*Aquilegia canadensis*)
- 1 of 2 Coneflowers (*Echinacea* sp.)
- 2 of 2 Blazingstars (*Liatris* sp.)
- 3 of 3 Hollies (*Ilex* sp.)
- 1 of 1 Mugo pine (*Pinus mugo*)
- 2 of 3 Viburnums (*Viburnum* sp.)

## Intolerant Species

- 2 of 3 Goldenrods (*Solidago* sp.)
- 2 of 2 Indigos (*Baptista* sp.)
- 1 of 2 Asters (*Aster* sp.)
- 1 of 1 Golden Alexanders (*Zizia aurea*)
- 1 of 1 Cardinal flower (*Lobelia cardinalis*)
- 1 of 2 Daylilies (*Hemerocallis* sp.)
- 4 of 5 Junipers (*Juniperus* sp.)
- 1 of 1 Japanese yew (*Taxus x Media*)
- 1 of 1 Emerald arborvitae (*Thuja occidentalis*)

## Uses:

- Prevention and Remediation

## Uses:

- Leak Detection?

See Poster









# Total Life Cycle Cost Comparison

- **Option 1: Horizontal 3-Phase (H3P) Extraction System**
  - Capital (installation) **\$1,000k**
  - OM&M = \$150k per year for 5 years **\$ 750k**
  - **TOTAL Life Cycle Cost** **\$1,750k**
- **Option 2: Plant Hydraulic Barrier (Phyto) System**
  - Capital (research and development) **\$ 110k**
    - Includes pilot test, standard (1<sup>o</sup>) + additional (2<sup>o</sup>) monitoring
  - Capital (installation) **\$ 200k**
  - OM&M (establishment) = \$45k year 1, \$25k year 2 **\$ 70k**
  - OM&M = \$10k per year thereafter for 8 years **\$ 80k**
  - **TOTAL Life Cycle Cost** **\$ 460k**
- **Cost Savings (Value Added)** **\$1,290k**
- **“Does not consider the time-value of money... economics are not realistic”**

# Net Present Valuation (NPV)

## Cost Comparison

- **Option 1: Horizontal 3-Phase (H3P) Extraction System**
  - Capital (\$1,000k installation **now**)
  - OM&M (\$150k/yr for 5 years **future**)
  - **TOTAL NPV (2.5% Rate)** **\$1,603k**
- **Option 2: Plant Hydraulic Barrier (Phyto) System**
  - Capital (\$110k R&D **spent already**)
  - Capital (\$200k installation **now**)
  - OM&M (\$75k for 2 years establishment **future**)
  - OM&M (\$10k/yr for 8 years after establishment **future**)
  - **TOTAL NPV (2.5% Rate)** **\$ 416k**
- **Cost Savings (Value Added)** **\$1,187k**
- **“Still not a fair comparison...Option 1 could be anything outlandish...artificially creates a clear-cut decision”**



# Other Influencing Factors

## Quantifiables to Non-Quantifiables

- Quantifiables:**

- Capital and O&M costs, legal fees, risk assessments, reporting requirements, length of project

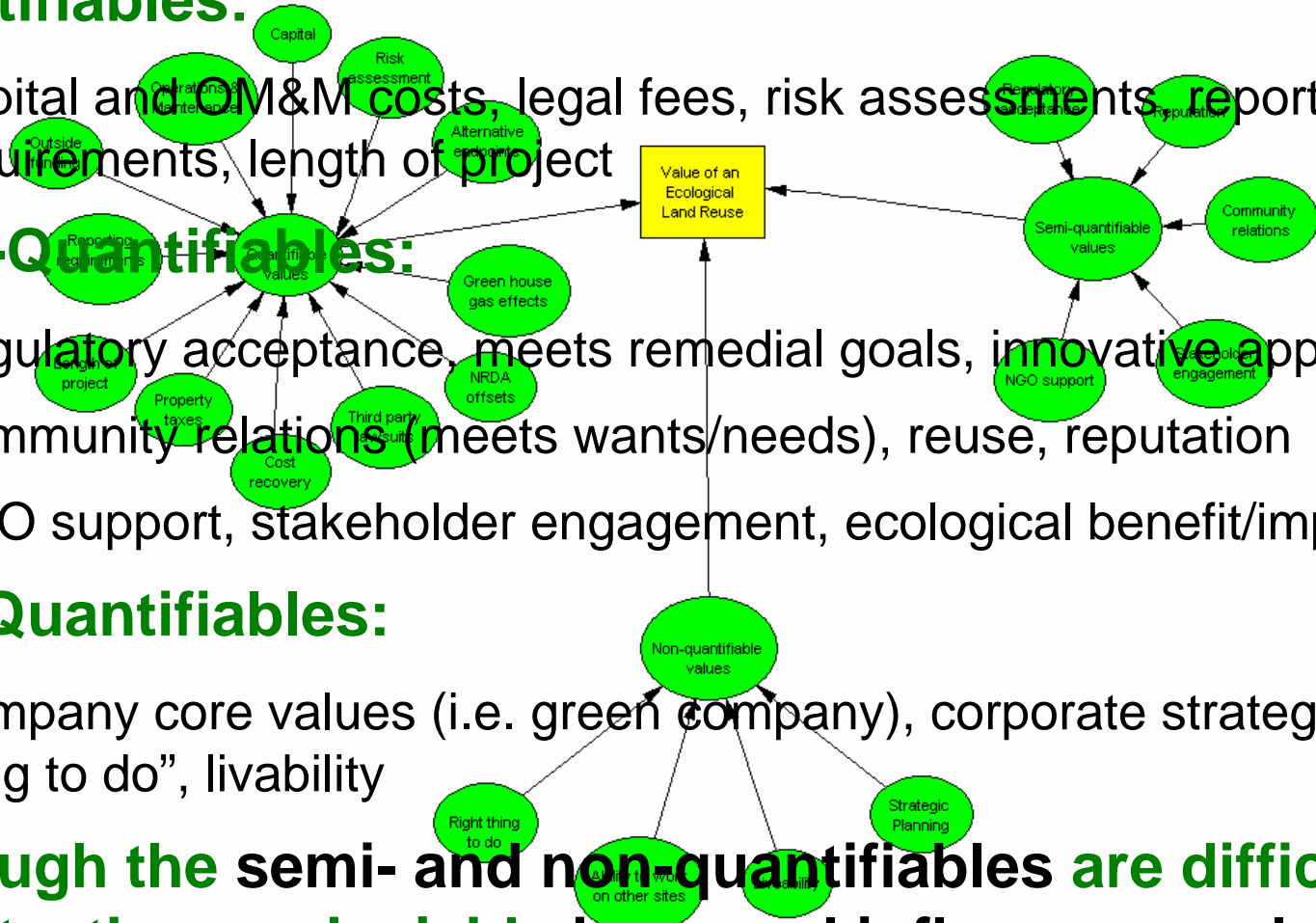
- Semi-Quantifiables:**

- Regulatory acceptance, meets remedial goals, innovative approaches
- Community relations (meets wants/needs), reuse, reputation
- NGO support, stakeholder engagement, ecological benefit/impact

- Non-Quantifiables:**

- Company core values (i.e. green company), corporate strategy, “right thing to do”, livability

**Although the semi- and non-quantifiables are difficult to value, they undeniably have real influence on clean up options**



# Weighted Probability of Occurrence

Influencing Factors	H3P Extract		Phyto	
<b>Quantifiables</b>				
Financials (Net Present Valuations)	+ 0%	(0%)	+100%	(100%)
<b>Semi-Quantifiables</b>				
Meet Remedial Goals (Track Records)	+50%	(50%)	- 50%	(50%)
Innovative Approach (Univ. Involved)	- 5%	(45%)	+ 5%	(55%)
Beneficial Reuse (Fits Local Plan)	- 10%	(35%)	+ 10%	(65%)
Ecological Enhancement (Want/Need)	- 5%	(30%)	+ 5%	(70%)
<b>Non-Quantifiables</b>				
Livability (Complaints of H3P System)	- 10%	(20%)	+ 10%	(80%)
Corporate Strategy (Reuse)	- 5%	(15%)	+ 5%	(85%)

# Weighted Probability of Occurrence Cost Comparison

- **Option 1: Horizontal 3-Phase (H3P) Extraction System**
  - TOTAL NPV **\$1,603k**
  - Weighted Probability of Occurrence **x 15%**
- **Option 2: Plant Hydraulic Barrier (Phyto) System**
  - TOTAL NPV **+\$ 416k**
  - Weighted Probability of Occurrence **x 85%**
- **Weighted NPV Options Baseline** **\$ 594k**
- **ACTUAL: Plant Hydraulic Barrier (Phyto) System**
  - TOTAL NPV (100% weighted) **- \$ 416k**
- **Cost Savings (Value Added)** **\$ 178k**
- **“Very defensible accounting approach...rigorous (yet simple) process”**



# Additional Value “Tips the Scales”

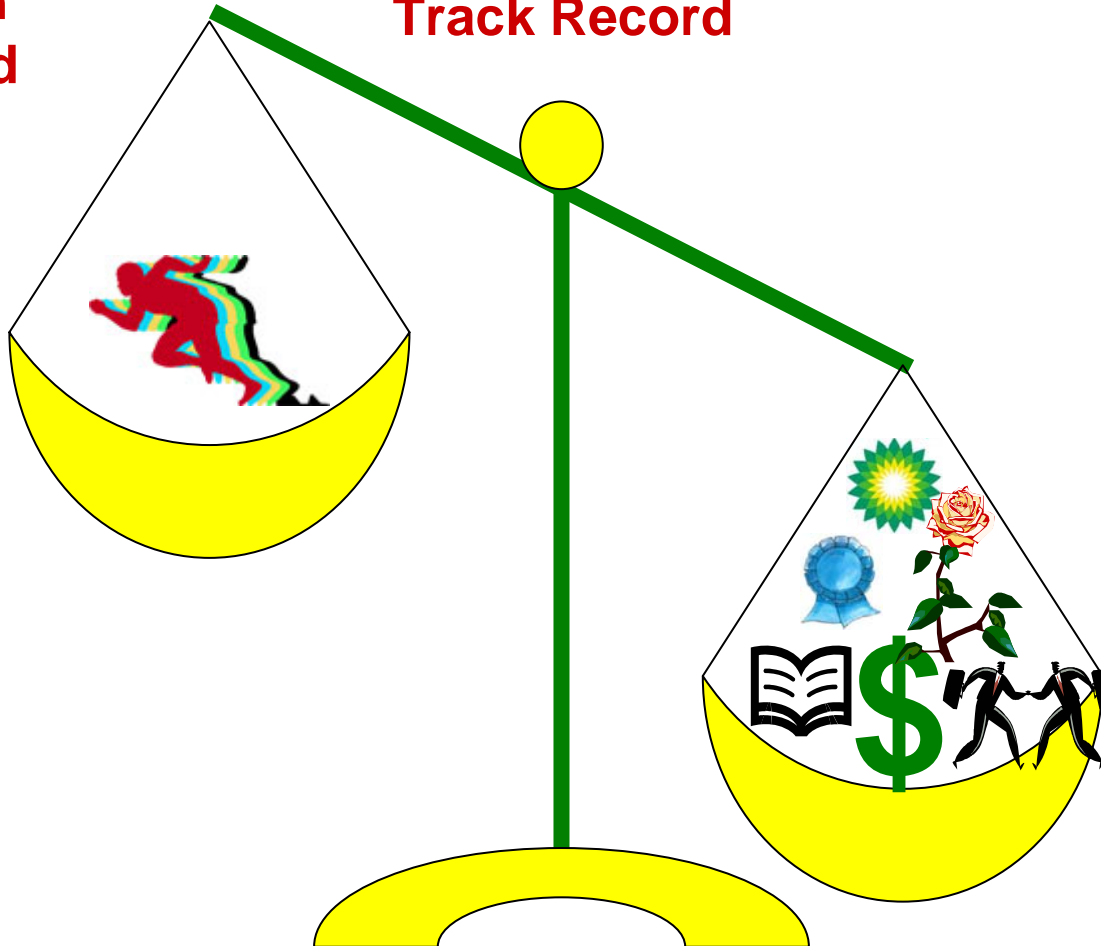
## Semi- and Non-Quantifiables

Option #1 – H3P

Option #2 – Phyto

Remediation  
Track Record

Financials  
approximately “in balance” with  
Track Record



Financials

+ Educational

+ Stakeholder  
Engagement

+ Ecological

+ Reputation

+ Corporate  
Values

# Justifying R&D

## Pilot Study Costs of \$110k



**Weather Parameters / Sap Flow**

## Planting

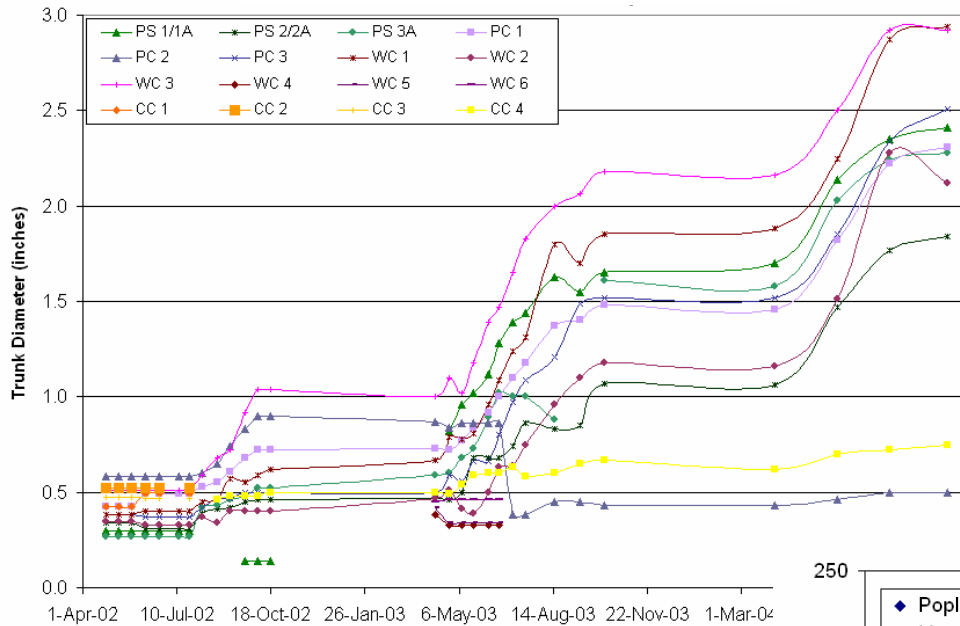




# Pilot Study

## Other Components

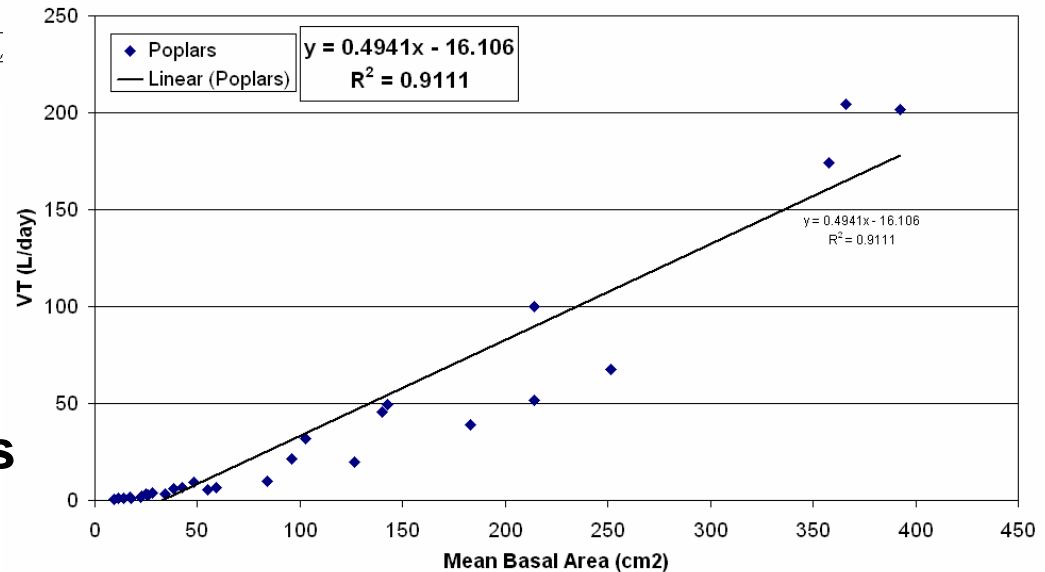
### Growth Assessment



### Tissue Analyses



### ET Data Analyses





# Rate of Return on Investment

- **Research Investment to conduct phyto pilot: \$110k**
  - **Not known up front** whether it would prove successful
  - **Compete against capital projects** (revenue-generating)
- **Concept of a Rate of Return (RoR):**
  - If you invest \$1, you **want to get back more** than \$1 in revenue
  - Common industry practice uses a **hurdle RoR**, i.e. 15% (\$1.15 back)
  - A project that **does not exceed hurdle usually will not get funded**
- **How do you incorporate this into remediation?**
  - Generally, **remediation is only a cost-center** (no revenue generated)
  - But, there is a **cost savings** in using alternative approaches
  - **Use the NPV and weighted outcomes to include semi- and non-quantifiables**

# Rate of Return on Investment

- Option 1: H3P System Total NPV x Weighting **\$240k**
- Option 2: Phyto System Total NPV x Weighting **+\$354k**
- **Weighted NPV Options Baseline** **\$594k**
- **ACTUAL: Phyto System Total NPV** **-\$416k**
- **Cost Savings (Value Added)** **\$178k**
- Phyto R&D Investment **\$110k**
- Rate of Return on Investment

$$\text{RoR} = \frac{\$178\text{k} - \$110\text{k}}{\$110\text{k}} \times 100\% = 62\% !!$$

# Conclusions and Recommendations

- **Corporate Perspective**

- Economics of remediation evaluated on a **common accounting basis**
- Use **net present valuation** over life cycle costs
- Use **probabilities of occurrence** to weight options
- Demonstrate a beneficial **rate of return on investment**

- **Benefits of this to the Site Owners**

- Provides **justification** to spend on remediation
- Advocate **semi- and non-quantifiable influencing factors** to managers and regulators alike (step through the **holistic thought process**, “**tell the whole story**”)

- **Benefits of this to the Environmental Consulting Community**

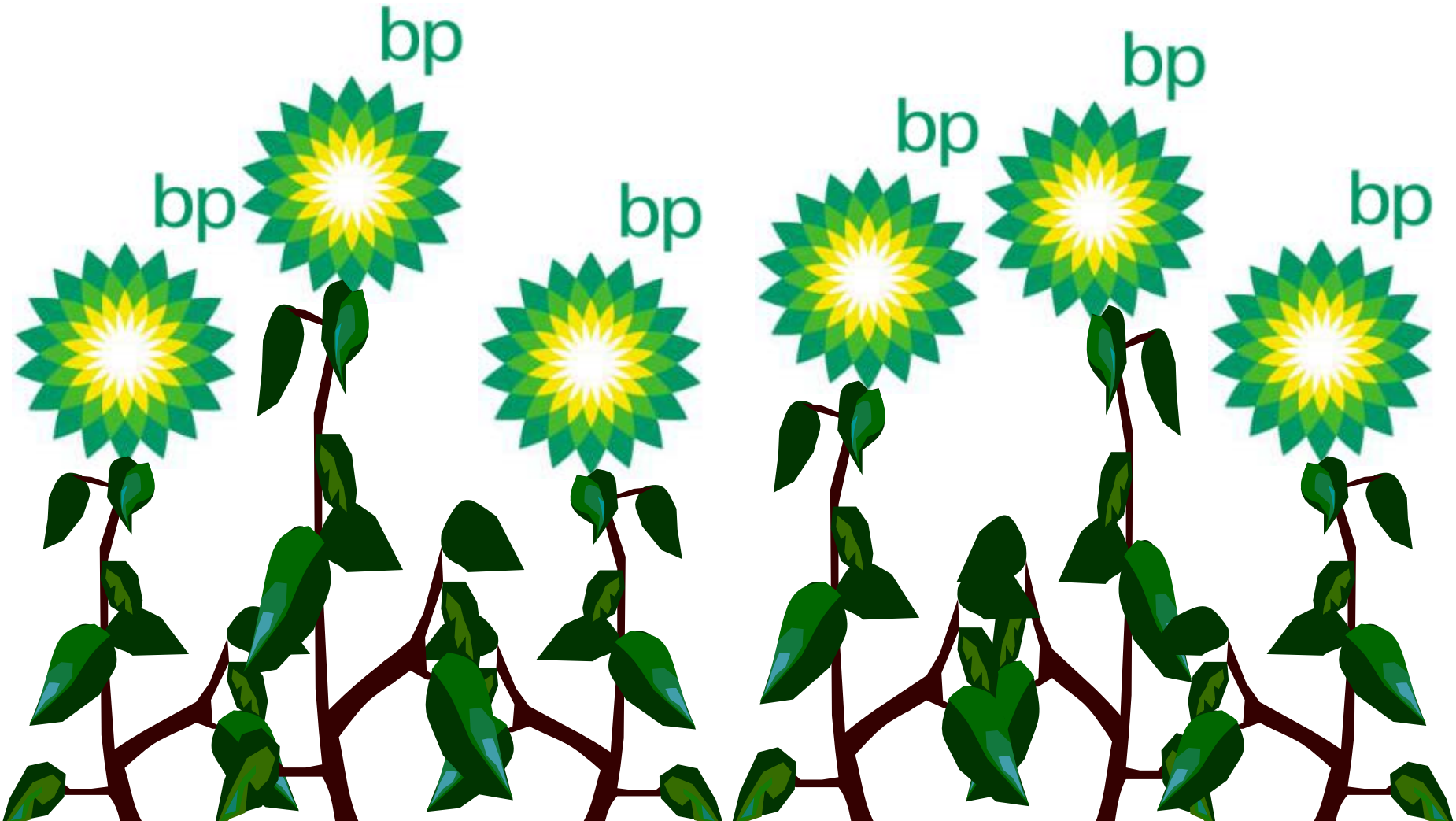
- Puts the **economics in terms that site owners understand**
- Keeps it realistic (**believable and credible**)

- **Benefits of this to the Academic Community**

- Provides justification to **secure R&D funding from site owners**



# QUESTIONS !!!



**Better Process**