

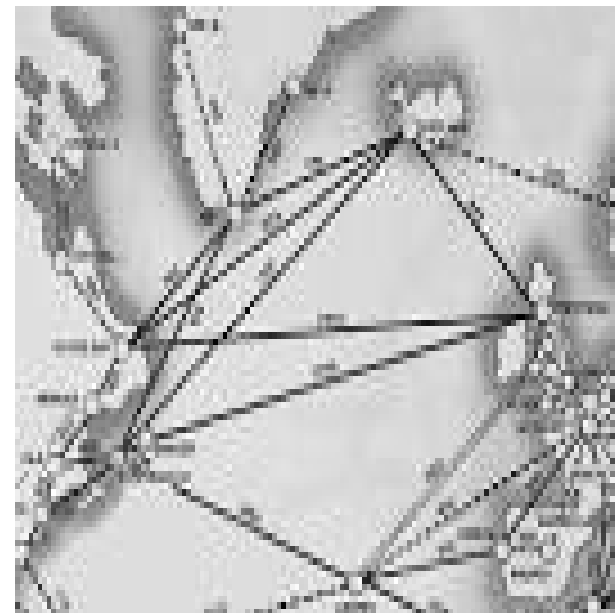


*PROOF-OF-CONCEPT EVALUATION  
VERIFICATION OF IN-SITU PHC REMEDIATION  
UNDER ACTUAL SITE BIOGEOCHEMICAL CONDITIONS*

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## *Presentation Outline*

- Site Description
- Summary of Pilot Study Process
- Evaluation Methods
  - Passive Additive Release
  - Low-Cost, Low-Risk Evaluation
  - Conservative and Repeatable Process
- Description of *BioStryke*<sup>®</sup> TPHenhanced<sup>™</sup>
- Summary of Results
- Case Study Examples
- Questions and Answers



# Site Description

## Loring AFB Argyle Pump Station

- One of 4 Pump Stations Supporting the Searsport Pipeline for over 40-years
- Conveyed JP Fuel from Portland Maine to the Loring AFB to Support WWII Efforts
- Post-War Efforts Pipeline Conveyed
  - Fuel Oils (Gas, Diesel, No 2/No 4)
  - Aviation Fuels (JP, JP-4)
  - Home Heating Fuel
- Decommissioned in 1991
- Utilization, Maintenance, and Housekeeping Resulted in Multiple Release of Various PHC's
- Dissolved Phase Plume, Smear Zone and Saturated Site Soil Contaminants
- Elevated Naturally Occurring Organic Mass



GOING



# Site History

## Loring AFB Argyle Pump Station

- Previous Remediation Strategy Included
- In-Situ Air Sparge /Vapor Extraction System (AS/VES) Installed 2001
- Remediation Goals Included
  - Removal of Soil PHC Vapors
  - Removal of Dissolve Phase Contaminants
  - Increase Groundwater Oxygen Levels to Support Aerobic Bioremediation
- Maine Department of Environmental Protection (MEDEP)
  - Ceased AS/VES Operations in 2006
  - Decreased Contaminant Removal and Increased Maintenance Costs
- Proof-of-Concept Evaluation Allowed in 2009
- Goal to Determine Efficacy of In-Situ Anaerobic PHC Degradation





# Proof-of-Concept Evaluation Loring AFB Argyle Pump Station



- Proof-of-Concept Evaluation Designed to Determine Efficacy of In-Situ Anaerobic Contaminant Destruction
- Proprietary Biostimulation Formulation
- Provided Metabolic Analog to Oxygen
- Remediation Goals Included
  - Destruction of Dissolved Phase Contaminants
  - Increased Bioavailability of Residual PHC Mass
  - Elimination of Above Ground Support
- **BioStryke® TPHenhanced™**
  - Proprietary Blend of Electron Acceptors
  - Leverages Existing Site Conditions
  - Biostimulates Native Microbial Populations
  - Eliminates Energy Costs; Nuisance Odors, Emissions, and Vapors



## *Evaluation Process Overview*

- On-Site Treatability Evaluation
  - Additive Deployed by Passive Release Units (PRS)
  - Selectively Permeable Wicking Fabric
  - Passive Additive Release Over-Time
  - No Long-Term Impact to Site Geochemistry
- PRS Deployment Units
  - PRS Unit is 5-feet long, 1-5/8<sup>th</sup> inch Circumference
  - Each unit contains 2 pounds of Additive
  - Suspended within Screened MW Interval
- Performance Evaluation
  - Groundwater Monitored & Sampled for Analytical Testing Throughout Proof-of-Concept Process
  - Additive Efficacy Determined by
    - Comparison of Baseline Data to that obtained from Multiple Rounds of Performance Monitoring, Sampling and Testing Events



- Established Performance Criteria
  - Minimum Criteria 50% Destruction
- PRS Extent of Impact
  - Minimal Area-of-**Influence** ( $\leq 1$  meter **AOI**)
  - Passive-Aggressively Amends GW Column
  - Biostimulates Native Microbial Populations
  - Effects Site Geochemistry Positively
- Low-Cost, Low-Risk
  - Confirm Biotic Pathway Exists On-Site
  - Eliminates Laboratory 'Jar-Effect'
  - Identify Future Evaluation Needs (Field/Lab)
  - Confirm Full-Scale Loading Demand Estimates
  - Model Full-Scale Impacts to Site Geochemistry





## *Pilot Study Program Protocols*

- Sample Collection Low-Flow Purge Protocols
- Non-Purge Removal Required
- Purging of GW Monitoring Well Adversely Skews Study Results
  - *Removes Amended Groundwater*
  - *Removes Biostimulated Microbial Population*
- Groundwater Monitored and Sampled
  - *Typically every 7-10 days*
  - *For this study replaced PRS units 7 times*
  - *13-week Evaluation Period*
- PRS Deployment Units are removed and Replaced After Completion of Each Monitoring/Sampling Event







## *Biostimulation as a Source Control Strategy*

### Anticipated Observations - Geochemical

- Increased Oxygen Reduction Potential (ORP)
- Reduced Production of Methanogenic Gasses and Conditions
- Rapid Utilization of Additive Components
- Increased Native Populations of Heterotrophic Petrophylic Microbials
- Enhanced Volatile Fatty Acid (VFA) Production
- Increased Contaminant Bioavailability
- Increased Rates of PHC Degradation in Direct Response to Additive Availability

## *Pilot Study Process Confirms Biostimulation as a Source Control Strategy*

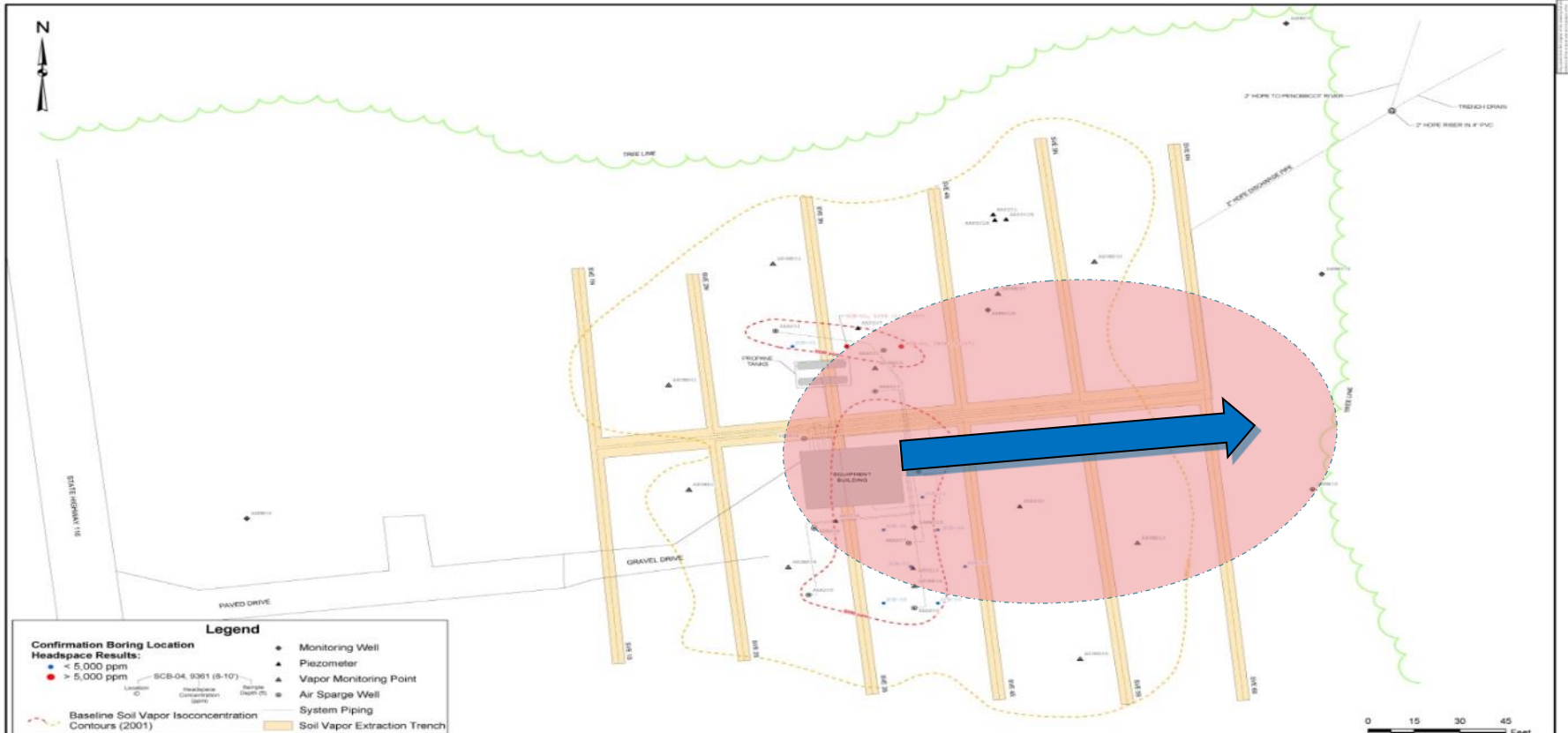
### Anticipated Observations - Contaminants

- Rapid Biodegradation of Dissolved Phase Petroleum Hydrocarbon Contaminants
- Increased Microbial Population Growth
- Increased Production of Volatile Fatty Acids (VFA's)
- Enhanced Flux (desorption) of PHC Residual Source Mass
- Increased Contaminant Bioavailability
- Enhanced Anaerobic Biodegradation
- No Fuel Consumption, Generation of Nuisance Emissions, Vapors, Noise
- Cost-Effective Remedial Performance with Less Environmental Impact = **GREEN**

- Former US Air Force Fire Training Facility
- Contaminants of Concern: BTEX, Naphthalene
- Gasoline and Diesel Range Organics (GRO/DRO)
- Volatile and Extractable Petroleum Hydrocarbons (VPH/EPH)
- Baseline [VPH/EPH] 5,713 mg/L and 1,746 mg/L, respectively.







Two Separate Residual Source Zones as identified by Soil Vapor and Soil Sample Analyses

(µg/L)	6-7-11	7-5-11	7-20-11	8-8-11	8-25-11	9-7-11	8-14-12	10-28-11
<b>Total VPH+EPH</b>	7,459	9,387	8,209	3,026	7,479	4,209	4,124	3,831
<b>Total BTEX</b>	1,355	1,284	1,406	351	4,730	1,027	958	1,015
<b>VPH</b>	5,713	5,614	5,456	2,213	6,778	3,792	3,833	3,582
<b>EPH</b>	1,746	3,773	2,753	813	701	417	291	249
<b>TPHENHANCED™</b>	<0.05	1,400	7,000	64	67	2,000	1,500	230

**Initially Observed Slight Increase in Bioavailability Followed By Return to Baseline  
 Week 4 Realized Significant Reduction in Dissolved Phase Contaminants with a  
 Concurrent Depletion of Biostimulating Additive**

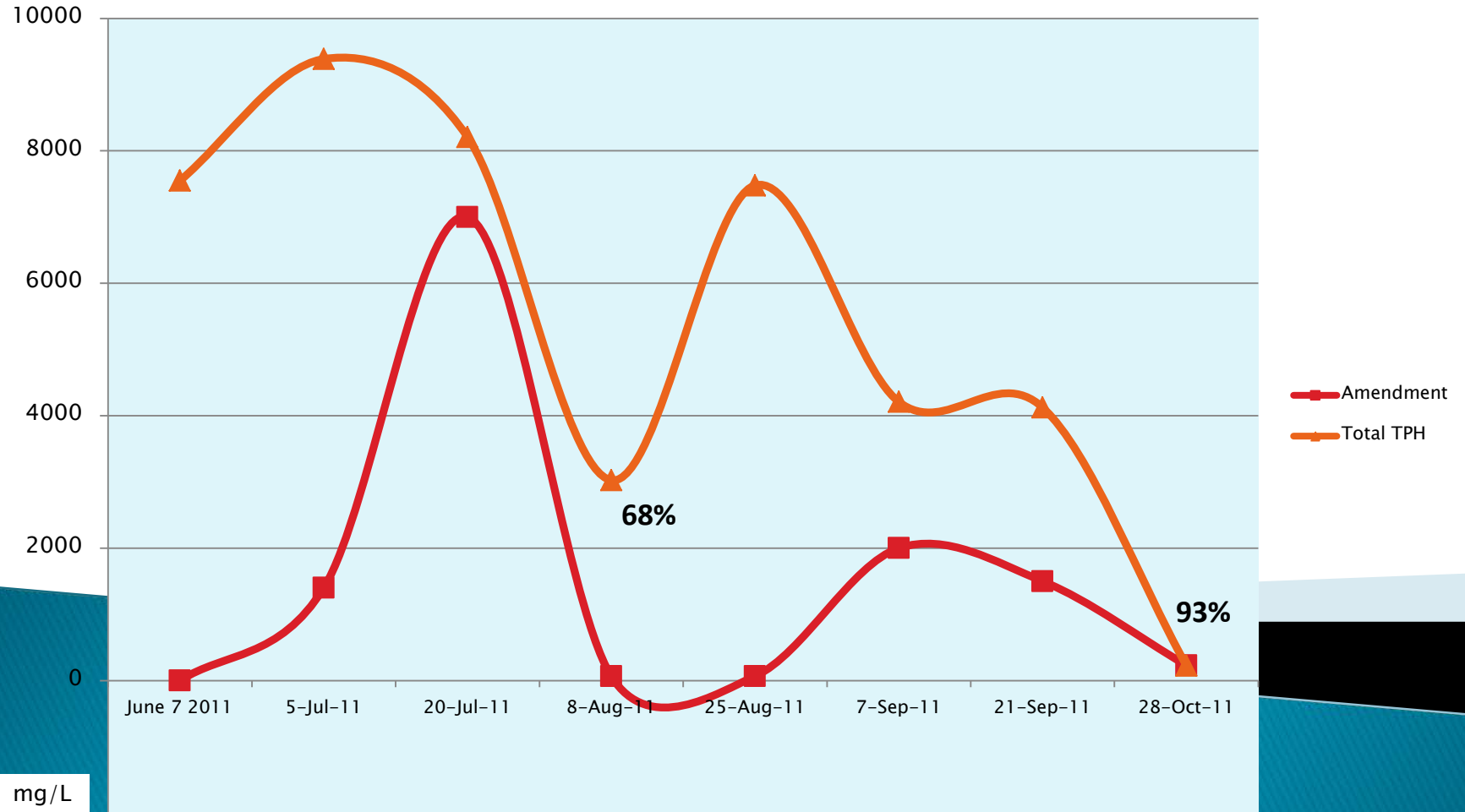
**Week 6 Realized Massive Desorption of Residual Source Mass Contaminants**

**Realized 93% Decrease in [EPH] and 60% Decrease in total [VPH/EPH]**

**99.8% Assimilation of TPH<sub>ENHANCED</sub>™ within 1 year to 13 mg/L**



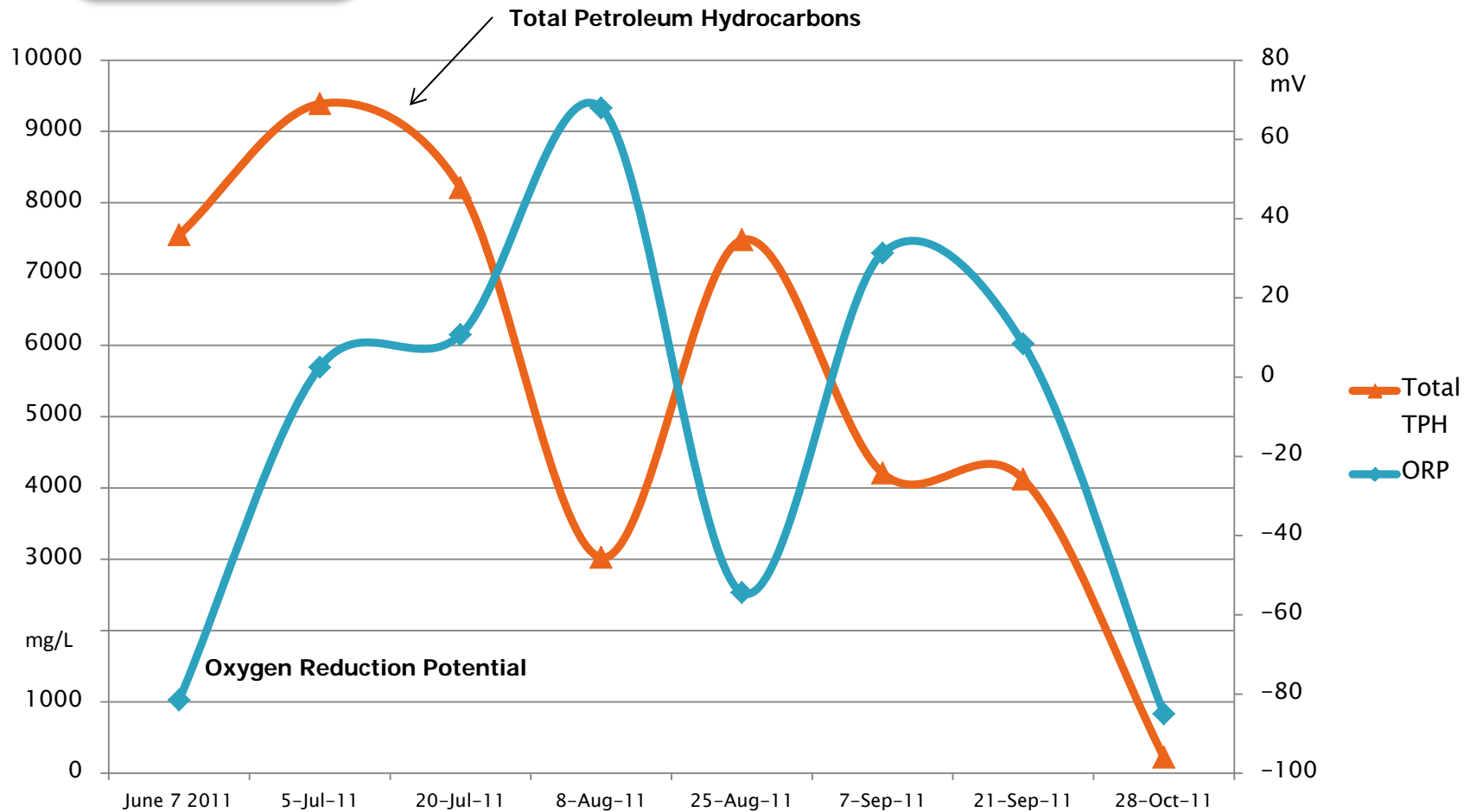
# BioStryke™ TPHenhanced® Pilot Study Former AFB Argyle Pump Station Pilot Study COC Results





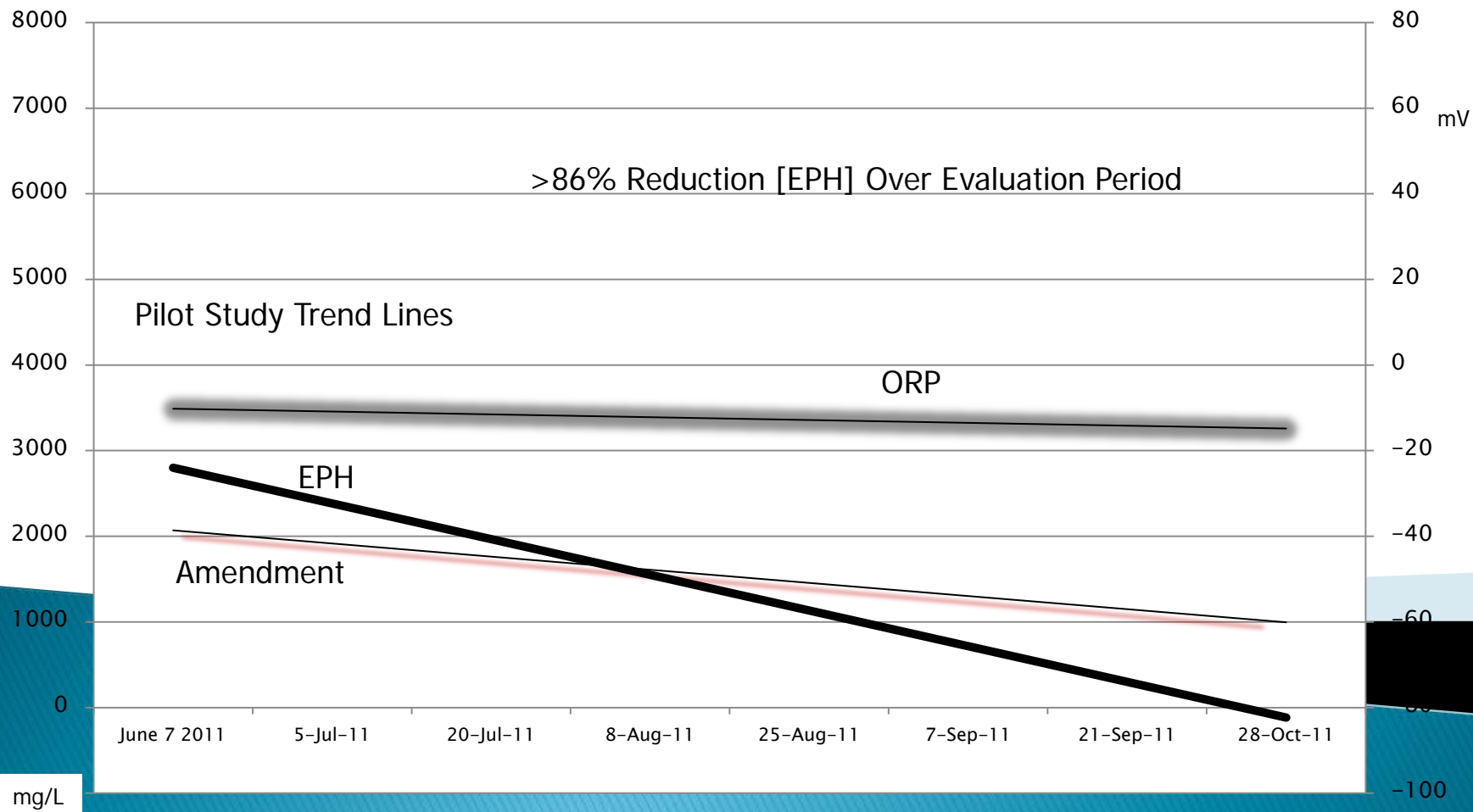


# BioStryke™ TPEnhanced® Pilot Study Maine DEP Former Loring AFB Argyle Pump Station Geochemical Results





# BioStryke™ TPHenhanced® Pilot Study Maine DEP Former Loring AFB Argyle Pump Station



(mg/L)	6-7-11	7-5-11	7-20-11	8-8-11	8-25-11	9-7-11	8-14-12	10-28-11
<b>pH</b>	6.2	5.88	6.31	7.27	6.09	6.46	6.59	6.67
<b>ORP</b>	-81.5	NA	10.7	67.9	-54.4	31.3	8.4	-84.7
<b>DO</b>	0.01	1.05	1.12	0.82	1.02	1.03	2.35	0.28
<b>Methane</b>	6,300	7,600	NA	3,500	4,500	5,100	4,200	4,200
<b>SO<sub>4</sub></b>	<1	<250	<1000	<20	<50	<200	1,000	<50

- pH Levels Remained Relatively Stable
- ORP Readings Indicate Periods of Enhanced Reducing Conditions
- Methane Production Decreased in Response to Additive Deployment
- Periods of Greatest PHC Biodegradation Concurrent with Elevated ORP
  - Pilot Study Demonstrated Efficacy of Anaerobic PHC Degradation as Source Control

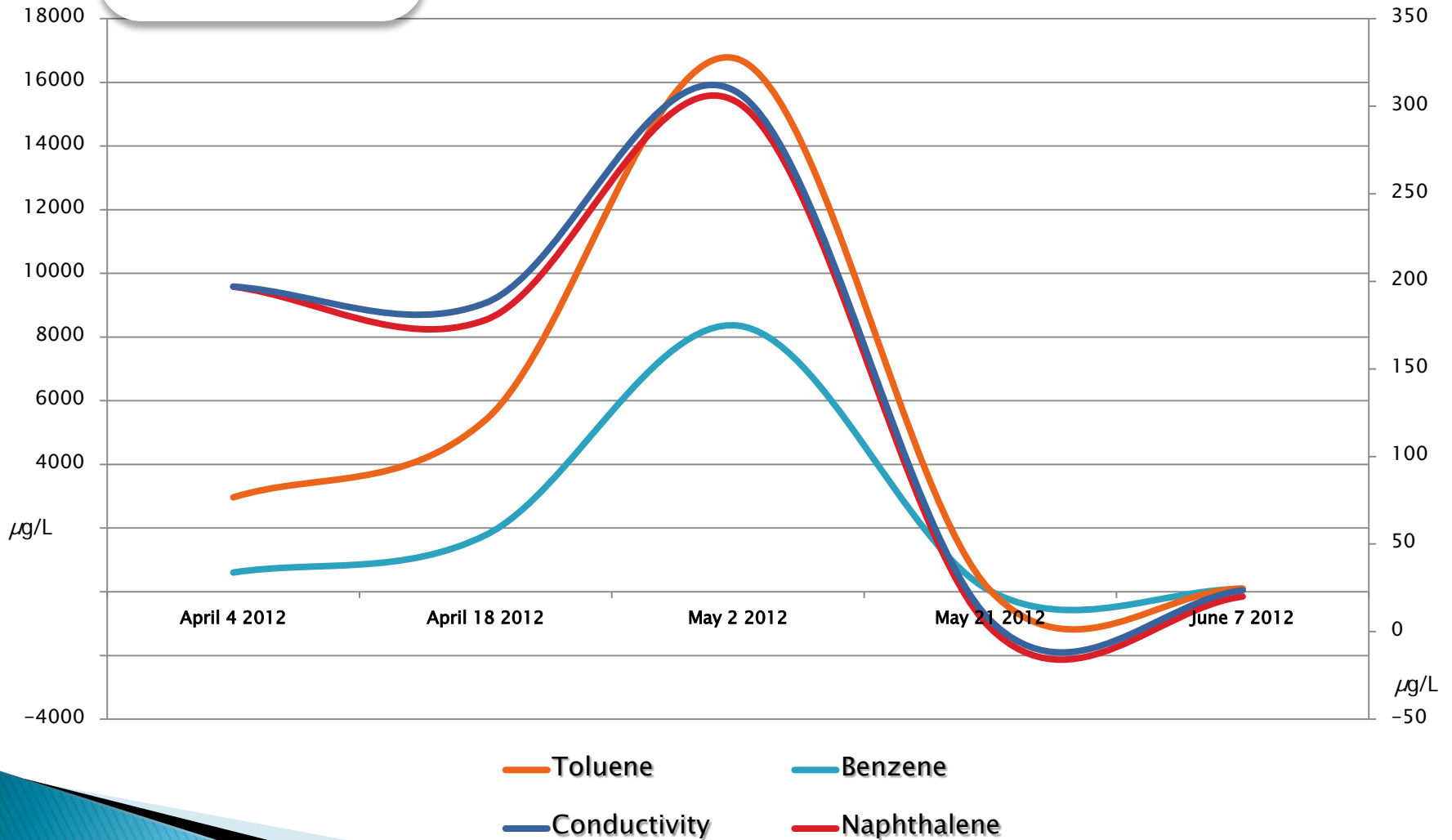


## Drum Pilot Study – Proof of Concept Chanute AFB Fire Training Facility

	April 4 (µg/L)	April 18 (µg/L)	May 2 (µg/L)	May 21 (µg/L)	Reduction	June 7 (µg/L)
Benzene	606	1,780	8,350	24.6	99.7%	92.3
Naphthalene	197	178	302	2.02	99.3%	19.7
Toluene	2,360	3,620	8,370	13.4	99.8%	8.4
1,2,4-TMB	282	224	843	4.13	99.5%	70.5
pH	NT	5.7	5.3	6.1	NA	6.7

- Placed Contaminated Saturated Soil Containing Residual Mass in 55-gal drum
- Contaminated Matrix Removed from Source Zone in Proposed Treatment Zone
- BioStryke® TPHenhanced™ Dosing rate = Full Scale Recommendation
- Initially Realized Massive Increase in Contaminant Bioavailability after 4-weeks
- Followed by > 99% Decrease in [PHCs] at weeks 7-8 of Evaluation Period
  - Rebound Observed Due to Additive Depletion

## Drum Pilot Study – Proof of Concept Chanute AFB Fire Training Facility



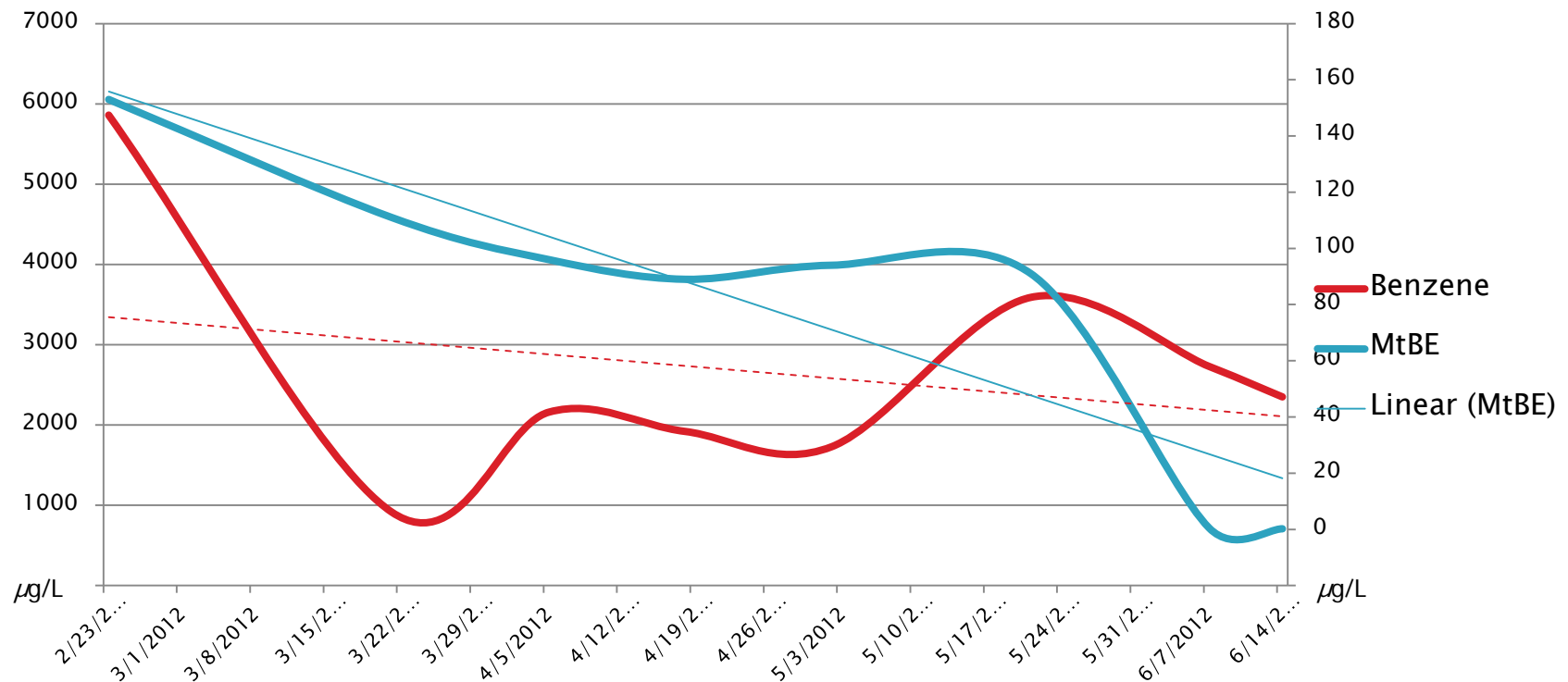
## Injection Pilot Study – Proof of Concept Test Area 1 - Chanute AFB Fire Training Facility

	Feb 23 (µg/L)	March 21 (µg/L)	April 5 (µg/L)	April 18 (µg/L)	May 2 (µg/L)	May 21, 2011
<b>Benzene</b>	5860	916	2160	1920	1730	3590
<b>Naphthalene</b>	26.6	2.36	26.8	14.6	5.5	5.5
<b>MtBE</b>	153	111	96	89	93	91.4
<b>Conductivity</b>	23.2	4.7	4.3	4.7	4.2	4.65
<b>pH</b>	8.1	7.3	7.5	7.6	7.4	7.9

- Multiple Point DPT Injection over 25 x 56-ft Impact Zone w 10-ft Thickness
- Two GW Monitoring Wells Located Proximate to Center of Treatment Zone
- Smear Zone at Capillary Fringe 2-3 feet thick; Continuous Residual Source Mass
- **BioStryke**® TPHenhanced™ Dosing Rate = Drum Study & Full Scale Applications
  - Concentrations of Benzene Initially Decreased 84.3%
  - Subsequently, Benzene Concentrations Decreased 70.5% over 10-week period
    - Concentrations of Naphthalene Decreased 79.3% during same period
      - Trending Decrease in Recalcitrant MtBE also Observed (39% decrease)



## Injection Pilot Study – Proof of Concept Chanute AFB Fire Training Facility



- **Pilot Study Confirms Cost-Effective Anaerobic PHC Destruction Possible**
  - **Pore Space Slurry Displacement Rate < 1.5% using 77 gallons/node**
  - **Estimate Additive Cost < \$4.00 per Treated Ton**



## BioStryke™ TPHenhanced® Pilot Study Maine DEP Former Loring AFB Argyle Pump Station Conclusions

- Innovative Anaerobic In-Situ Bioremediation Strategy
  - >90% Reduction [EPH] over 13-week evaluation period
  - >80% Reduction [BTEX] over 13-week evaluation period
  - >71% Reduction [VPH] by day 61; 45% Reduction over 13-week evaluation period
- Demonstrated Ability To Passive-Aggressively Enhance
  - Facultative Microbial Respiration, Contaminant Bioavailability & Biodegradation
- Evaluation Influenced by Contaminant Advection into Limited Treatment Zone
- Total Full-Scale Amendment Cost estimated < \$7 per ton
- Eliminating Aboveground Energy-Consuming Emissions-Generating Equipment
- BioStryke® TPHenhanced™ = Sustainable Green NAPL Source Control



## BioStryke™ TPHenhanced® Pilot Stud Locations

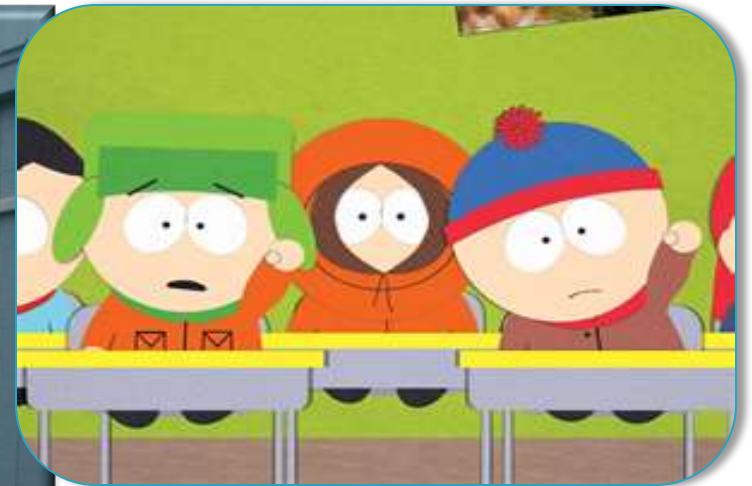
- **United States Air Force: Chanute AFB, Illinois (ongoing)**
  - Former Fire Training facility
  - Multiple Petroleum Contaminants
  - Between 200% – 400% increase in [dissolved] due to mass desorption
  - Between 35% and 115% Reduction in [Benzene] over 3-months for approximate 60% average destruction rate
- **Former Gas Station facility: Southern New Jersey, NJDEP (ongoing)**
- **Maine, New Hampshire, NJ, PA and New York Deployment Locations**
- **Former Fuel Distribution facility: London, Ontario, MOE (ongoing)**
  - Smear Zone and Vadose Zone TPH (GRO/DRO) Contaminants
  - Amendment deployment via subslab infiltration gallery
  - **>94%** destruction in GRO/DRO dissolved phase contaminants in 4-wks

### Confirmed Biotic Degradation Pathway Plausible w/ Significant PHC Decreases

- Low-Impact, Low-Risk w/ Minimal to *NO* Long-Term Impact to Site BioGeochemistry
- Performed on-Site Under Actual Site Geochemical Conditions Providing “*Go-no-Go*” Evaluation Process that is Conservative-Representative
- Provides Owners/Generators, Practitioners, & Regulators Added Confidence Prior to Commitment to any Additive Based Remedial Strategy
- Requires Scheduled, Consistent and Accurate Field Monitoring, Groundwater Sampling and Laboratory Analytical Testing
- Assists in Establishment of Full-Scale Amendment Demand , Rate of Assimilation, Treatment Timelines, and Full-Scale Additive Cost Estimates
  - Approved by Ministry of Ontario Environment, USAF, NASA, Numerous United State Environmental Regulatory Agencies, International



*Thank You ?? Questions ??*



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**Thank You**

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