



## Lowry OU5

# *Remedial Progress Assessment*

February 2008



## Outline for Assessment

- Introduction
- Conceptual Model – Basis of Assessment
- Mitigation of Risk
  - Mass/Concentration/Risk Reduction Progress
  - Mechanisms for Removal
  - Challenging Areas for Future Remedial Focus
- Development of Cleanup Objectives
- Path to Closure – 2008 and Beyond



## Introduction: Lowry OU5 Remedial Progress Assessment

- Base Closed 1994
- Plume Delineation 1990-1999
- Interim Actions 1996-2002
  - BAHCS, SARS
  - Heritage Estates Soil Gas Mitigation
- Active Plume-wide Treatment 2003-2008
  - Treatability Studies
  - $\text{KMnO}_4$  Treatment – Phase 1 & 2 Injections
- Significant Cleanup Progress
  - Natural Attenuation, Interim Actions, and Active Remediation



## Introduction: Primary Focus of Assessment

- Remedial Assessment is focused on:
  - Remediation in the Main Plume
    - TCE (Carbon Tetrachloride) remedial efforts
  - Reduction of TCE concentrations
    - 1996 to Present
  - Evaluation of the Current Remedial Approach
    - Identify Point of Diminishing Returns for  $\text{KMnO}_4$
  - Closure Focus



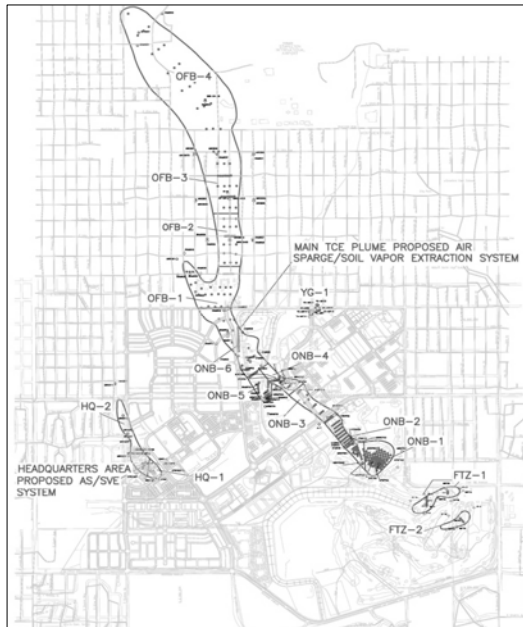
## Introduction: Closure Focus

- Protection of Human Health and Environment
  - OU5 Alluvial Plume: 89% Reduction of Potential Risk
  - On-base Indoor Air Pathway Cut
- Protection of Waters of the State
  - Significant declines in TCE Concentration and Mass throughout the plume
  - Alluvial Concentrations nearing risk-based cleanup levels in many parts of the plume
  - Natural Attenuation will likely be a Key Element of Closure



## Conceptual Model – Lowry OU5

- LAC/MDC Developed an Initial Conceptual Model for OU5 Based on:
  - Geology and Hydrogeology
  - Natural Fate Mechanisms for TCE
  - Constraints to Remediation
- Remediation Areas
  - Areas of similar conditions
  - Assist with development of approach and evaluation of progress

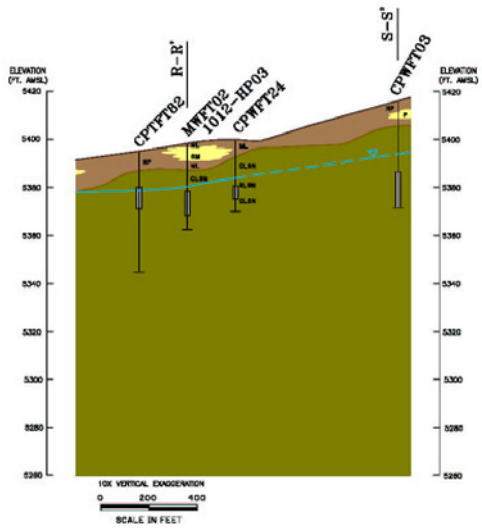


## Remediation Areas

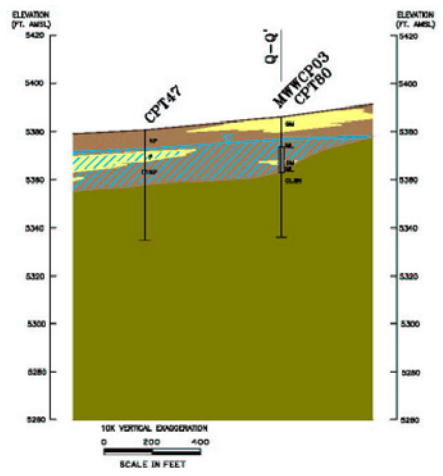


## Conceptual Model – Lowry OU5

- Determined TCE Mass Distribution
  - Input for remediation design (i.e., determining oxidant quantities for injection)
  - Provision of a baseline mass estimate against which to gauge remedial effectiveness and progress
- Methodology:
  - Using geologic cross-sections from the OU 5 RI Report, estimate volume of aquifer and percent sand vs. silt and/or clay for each remediation area
  - Using these volume and lithology estimates, and time specific groundwater chemical data, calculate mass of sorbed and dissolved TCE in each remediation area



**Area  
ONB-1**



**Area  
ONB-2**





## Conceptual Model – Provided Basis of Treatment

- Remedial Options Evaluation
  - Treatability Studies
    - Air Sparging,  $\text{KMnO}_4$  Injection, Ozone Sparging
- Selected Chemical Injection
  - Density
  - Persistence
  - Distribution
- Chemical Injection has been Performed Throughout the Main Plume
  - Direct Push Injections
  - Pressurized delivery of  $\text{KMnO}_4$  Solution
  - Primary Emphasis on Source Areas



## Conceptual Model – Basis of the Assessment

- Two Phases of  $\text{KMnO}_4$  injections
  - Site-wide (10/04) 404 locations, 120,000 lbs
  - On-base plumes (8/06) 366 locations, 44,000 lbs
  - Off-base plume (11/07) 299 locations, 99,000 lbs
- Samples collected semiannually
  - Performance, compliance, and closure networks
- Historical data: 1988 – present
  - Include OU5 RI, Supplemental RI, Interim actions monitoring, Plume area refinement study and current monitoring



## Risk Mitigation: Reduction in **TCE** **Concentrations**

- Significant Data (now in usable database)
  - Trend Plots
  - Significant Source Area near (BLDG 1432)
  - Remedial Success in OFR and other areas
    - Reduction in concentration up to 99% in some areas
  - Distribution of  $\text{KMnO}_4$  is Limited by Geologic Constraints
    - Alluvial Silt/Clay and Bedrock



## Risk Mitigation: Reduction in **TCE** **Concentrations...cont'd**

- Trends – significant concentration declines
  - On base: Bedrock - 15 wells monitored, 9 decreased  
Alluvial - 23 wells monitored, 21 decreased
  - Off base: Bedrock - 4 wells monitored, 2 decreased  
Alluvial - 13 wells monitored, 11 decreased
- Average Alluvial Concentration Decline  
= 86% to 94%
- MDC TCE half-life calculations
  - Treatment Decreased Half-life by Approximately 70%
    - Pre-remediation 5 +/- 2 yrs
    - Post-remediation 3 +/- 2 yrs



## Risk Mitigation: Reduction in **TCE** **Concentrations**...cont'd

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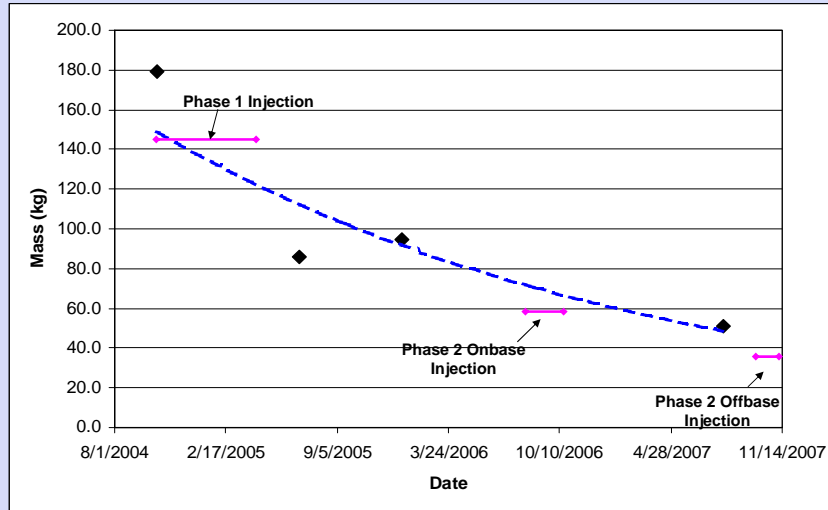


## Risk Mitigation: Reduction in **TCE Mass**

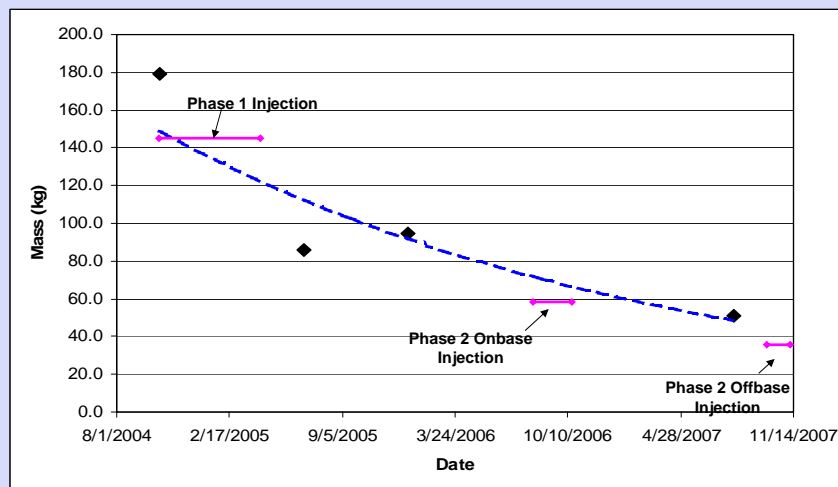
- Method for Measurement
  - Conceptual Model Mass
  - Mass at Several Monitoring Events
- Trends Allow for Validation of the Half-life Calculations
  - LAC Post-remediation Half-life of approximately 2 yrs
- Indicates a Total Mass Removal of Approximately 71% since Remediation was Initiated in Late 2004
  - Post-remediation period about 3 years



## TCE Mass Reduction - (Main Plume Alluvium)

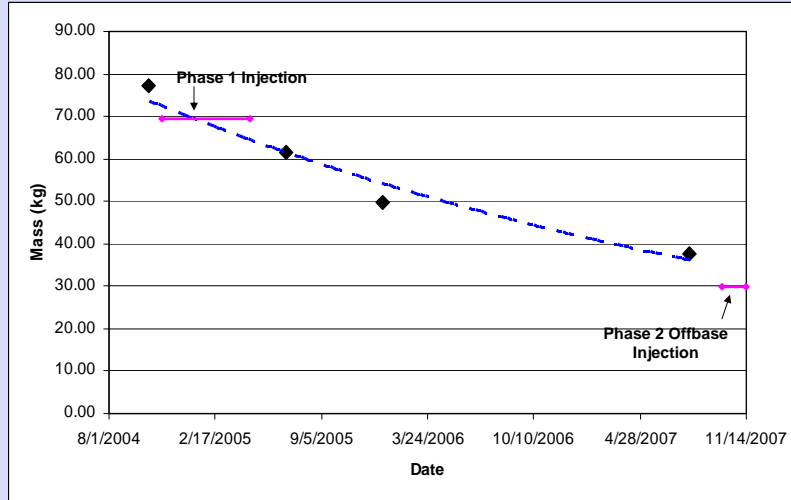


## TCE Mass Reduction - (On base)

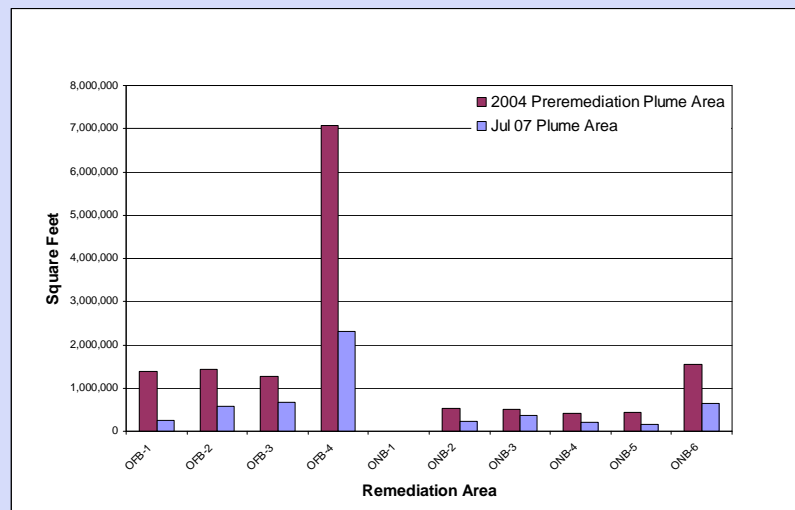




## TCE Mass Reduction - (Off base)



## Alluvial Plume Area Reduction





## TCE Reduction in **Plume Area and Mass**

Remediation Area	Percent Reduction in Plume Area	Preremediation	Jul 07	Percent Reduction in TCE Mass
		TCE Mass in Alluvium (kg)	TCE Mass in Alluvium (kg)	
OFB-1	81%	2.3	0.2	93%
OFB-2	60%	3.0	0.8	72%
OFB-3	47%	1.0	0.9	10%
OFB-4	67%	70.9	35.6	50%
ONB-1				
ONB-2	56%	48.7	6.0	88%
ONB-3	28%	10.6	2.0	81%
ONB-4	50%	2.7	0.8	69%
ONB-5	63%	32.2	3.8	88%
ONB-6	59%	7.4	1.2	84%
Total	63%	178.9	51.3	71%

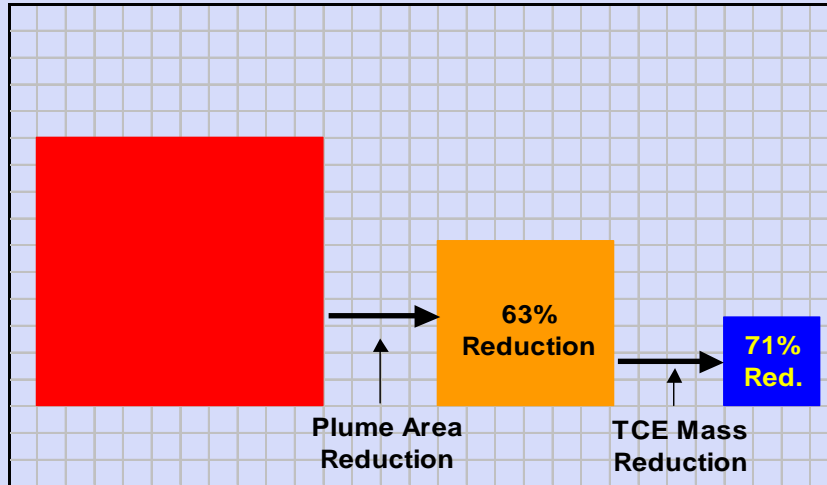


## Risk Mitigation: **Plume Area Reduction**

- Plume Area has been Reduced:
  - Overall Plume – 63% Reduction
  - Based on Original RI Plume Area vs. the Plume as Currently Mapped (July 07)
- Areal Extent as well as the TCE Concentrations in the plume can be Correlated to Risk Reduction
  - Population and Magnitude
- Crude Estimate (89%) of Risk Reduction Indicates Substantial Progress



## Estimated Total Risk Reduction – 89% (Site-wide)

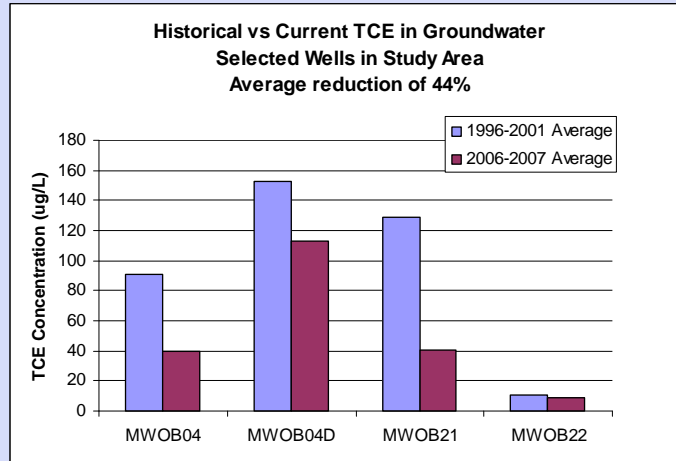


## 2007 Indoor Air Study

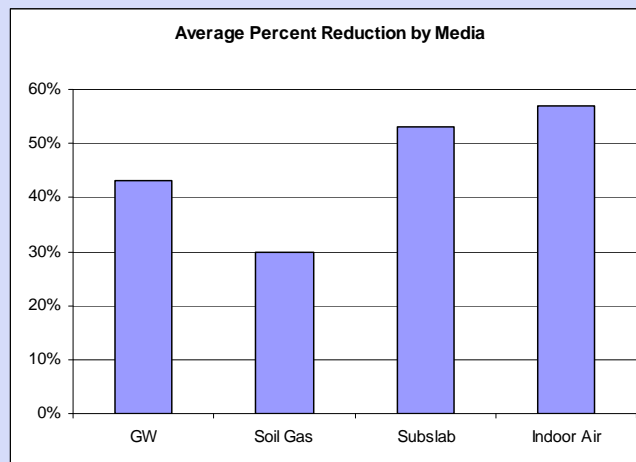
- Designed to assess changes in VOC concentrations in soil gas, subslab and indoor air with decreasing groundwater TCE concentrations
- Data compared to 1998 and 2001 indoor air studies, same houses and wells sampled where possible
- Groundwater data from 1996 to present evaluated



## Risk Mitigation: Preliminary Indoor Air Study Results - GW

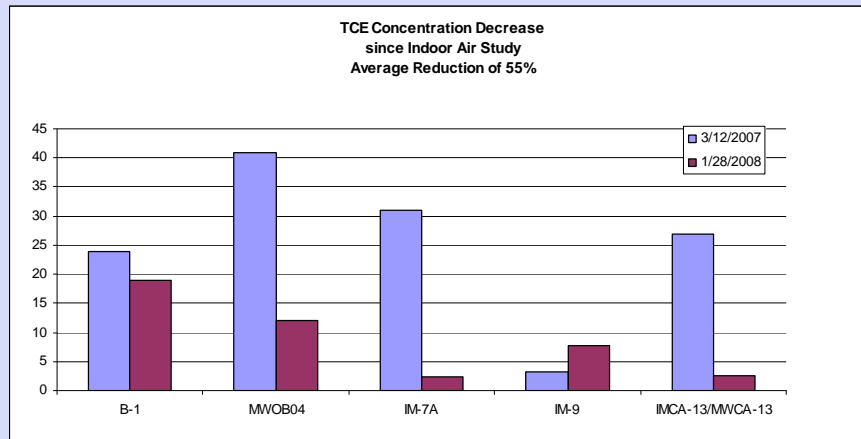


## Risk Mitigation: Preliminary Results of Indoor Air Study





## Risk Mitigation: Current GW Data for Indoor Air Study Area

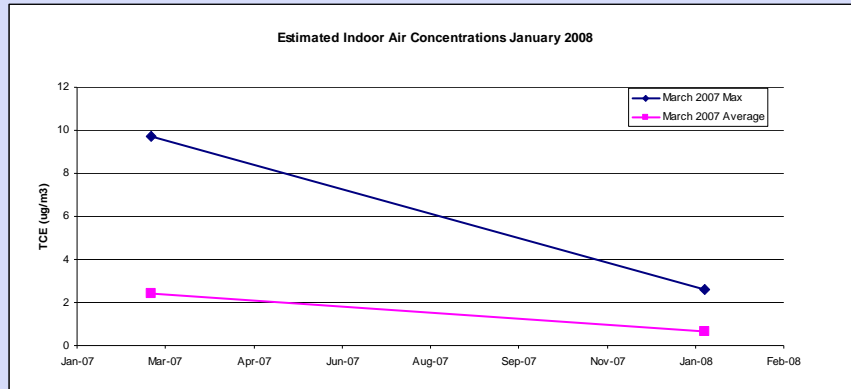


## Estimated Indoor Air Values

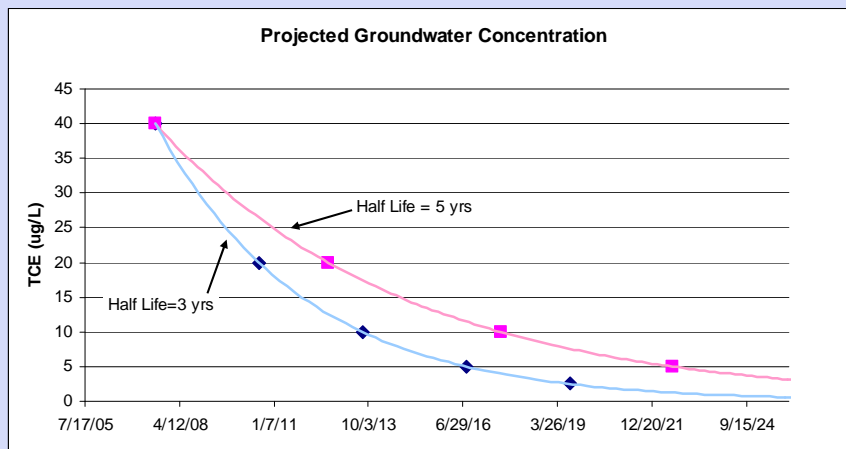
- Correlation was established during Indoor Air Study between decreases in groundwater and indoor air concentrations
  - Average decrease of 43% in GW gave 57% decrease in indoor air
- With new data from Jan 2008, an additional reduction in GW concentrations of 55% was observed
  - Correlated decrease in indoor air would be 72%



## Risk Mitigation: Estimated Indoor Air Concentration Plot



## Risk Mitigation: Going Forward





## Risk Mitigation: Mechanisms Contributing to Observed Progress

Why has Risk Mitigation been Successful?

- $\text{KMnO}_4$  Treatment (50%)
- Natural Attenuation (40%)
  - Includes:
    - Biodegradation/Abiotic Destruction (Likely Minor)
    - Dispersion/Dilution (Likely Secondary Removal Mechanism)
    - Volatilization (Likely Primary Removal Mechanism)
- Interim Actions (10%)
  - SARS
  - BAHCS
  - Heritage Estates Soil Vapor Mitigation



## Risk Mitigation Summary: Remedial Progress Assessment for Main Plume

- Remedial Efforts Resulted in Significant Progress Towards Closure:
  - Estimated Avg. Concentration Decline = 86 to 94% (Pre- and Post-remediation Decline)
  - Estimated TCE Mass Removal = 71% (Post-remediation)
  - Estimated Reduction in Plume Area = 63% (RI vs. Current)
  - Estimated Risk Reduction = 89% (RI vs. Current)
  - Indoor Air Concentrations are likely close to concentrations acceptable to CDPHE in Indoor Air Study Area



## Risk Mitigation Summary: Remedial Progress Assessment for Main Plume...cont'd

- Phase 1 and Phase 2  $\text{KMnO}_4$  Injections:
  - Were Successful in Mass Removal
  - Technology Showed Better Success when  $\text{KMnO}_4$  Concentration was High
  - $\text{KMnO}_4$  Decreased Half-life that can be Achieved through Natural Attenuation Processes
  - Clay/Silt Areas and Bedrock more difficult to treat



## Risk Mitigation: Challenging Areas for Future Remedial Focus

- Rebound
  - Mixed Results in Rebound Assessment
    - Moderate Rebound Near Source Areas
    - Little Rebound Away from Source Areas
- Technology Limitations (Delivery/Contact)
  - Alluvium
    - Diffusion-driven outcome in Silt areas
  - Bedrock
    - Moderate Success in Delivering  $\text{KMnO}_4$
- Carbon Tetrachloride Area
- Source Areas/Hot Spots (High Concentrations)



## Development of Cleanup Objectives – Closure Focus

- Closure Focus requires that we Identify “How Clean is Clean”
  - Data that indicate that protection of human health and the environment has been accomplished or will be achieved in a reasonable timeframe
  - Data that indicate that the cleanup can transition from active treatment to monitoring based on the estimated risk/natural attenuation
  - Data that indicate that “No Further Action” is warranted based on the estimated risk/natural attenuation



## Development of Cleanup Objectives – Risk-based Objective and/or ACL

- Default for TCE has been MCL – 5ppb
- Risk-based Cleanup
  - Calculate Exposure timeframe (i.e., 10 years)
  - Calculate declining exposure over time
  - Estimate exposure point concentration that is protective of human health
- ACL
  - Calculate GW concentration that can be used for NFA



## Summary: Development of Cleanup Objectives

- What do we need to do to understand risk at Lowry and develop cleanup criteria?
  - Prepare Indoor Air Study Report
  - Risk Calculations for Potential ACL endpoints
  - Evaluate Timeframe for Natural Attenuation to achieve Risk-based endpoint
  - Continue to assess the Success of treatment technologies
  - Develop a Path to Closure that is Risk Driven



## Lowry OU5: 2008 Scope of Work

Path to Closure Begins with 2008 Scope:

- A. Project Management/Database Management
- B. Semi-annual Sampling/GMP
- C. Remedial Progress Assessment
- D. Treatability Study Carbon Tet Area
- E. Chemical Injection – Main Plume
- F. Remedial Activities - HQ Plume
- G. Indoor Air/Risk Assessment Activities
- H. Development of Cleanup Objectives
- I. Well Abandonment
- J. Closure Activities



## Lowry OU5: 2008 Scope of Work...cont'd

### A) Project Management/Database Management

- Continued Efforts to Manage Sub-contractors and Closure
- Management of Data
  - Historical/Current Sampling Data
  - Mapping
  - Trend Analysis for Closure



## Lowry OU5: 2008 Scope of Work...cont'd

### B) Semi-annual Sampling/GMP

- July 2008 Sampling Event
  - Estimated at 70 Wells
  - Includes All Plumes
- January 2009 Sampling Event
  - Estimated at 60 Wells
  - Includes All Plumes
- Reporting



## Lowry OU5: 2008 Scope of Work...cont'd

### C) Remedial Progress Assessment

- 2008 Work Resulting From 2007 RPA:
  - Finalize Indoor Air Study Report
  - Develop Risk Calculations to Support NFA and Closure
    - Risk/Concentration Decline Model
    - Alternative Concentration Limits
    - Indoor Air Protection
- Continued Assessment of Results



## Lowry OU5: 2008 Scope of Work...cont'd

### D) Treatability Study

- BOS 100<sup>®</sup> Field Study
  - Carbon Tetrachloride Study Area
  - Work Plan
  - Field Injection Activities
  - Monitoring
    - Performance Monitoring
    - July 2008
    - January 2009
  - Report (expected Fall 2008)



## Remediation Progress: Carbon Tetrachloride Area

- Source area and prelim lateral extent defined 2004/2005
  - impacts >MCL observed in bedrock interval
  - CT Area underlies park/open space area
  - no direct exposure routes to human health
- Main Plume  $\text{KMnO}_4$  injections 2004 & 2006
  - no effect on CT
- Enhanced delineation of CT Area – 2006 ▶
  - Refined lateral extent
  - Confirmed impacts >MCL within bedrock only
  - Source mass localized in bedrock near well ETMW03



## Remediation Progress: Carbon Tetrachloride Area...cont'd

- Na Persulfate injections in source area – 2006
  - Time-concentration data indicate mass destruction then rebound ▶
- LAC Decision to Evaluate other Treatment Options
- Evaluation of alternative treatment – BOS 100®
  - Bench-scale study – in progress
  - Treatability study – field application Spring '08



## Lowry OU5: 2008 Scope of Work...cont'd

### E) Chemical Injection – Main Plume

- Northern Off-site Plume (OFB1 through OFB4): No Injections
  - 2007 Injection Assessment (July 2008)
  - Rebound/Closure Assessment (January 2009)
- ONB6: Hot Spot Treatment/Treatability Study
  - Approximately 50  $\text{KMnO}_4$  Injections in Hot Spots North of Carbon Tet Area
  - BOS 100<sup>®</sup> Treatment of Carbon Tet Area



## Lowry OU5: 2008 Scope of Work...cont'd

### E) Chemical Injection – Main Plume (cont.)

- ONB5: Remedial Options Assessment
  - $\text{KMnO}_4$  Treatment
  - BOS 100<sup>®</sup> Treatment
  - CAP Addendum Possible
  - Anticipated Remedial Activity in Late 2008
- ONB4: Hot Spot Treatment
  - Approximately 40  $\text{KMnO}_4$  Injections
- ONB3: No Injections



## Lowry OU5: 2008 Scope of Work...cont'd

### E) Chemical Injection – Main Plume (cont.)

- ONB2: Hot Spot Treatment
  - $\text{KMnO}_4$  Injections into Known Hot Spots
  - Approximately 100 Injection Points
- ONB1: Remedial Options Assessment
  - $\text{KMnO}_4$  Treatment
  - BOS 100<sup>®</sup> Treatment
  - Bioremediation
  - CAP Addendum Possible
  - Anticipated Remedial Activity in Late 2008



## Lowry OU5: 2008 Scope of Work...cont'd

### F) Remedial Activity - HQ Plume

- Remedial Options Assessment
  - $\text{KMnO}_4$  Treatment
  - BOS 100<sup>®</sup> Treatment
  - Anticipated Remedial Activity in Late 2008
- CAP Addendum Possible



## Lowry OU5: 2008 Scope of Work...cont'd

### G) Indoor Air/Risk Assessment Activities

- Indoor Air Report
  - Complete Report
  - Response to Comments
- Develop Risk/ Natural Attenuation Model
  - Baseline Risks from Previous Work
  - Risk/Indoor Air Association
  - Acceptable Exposure Point Concentration
  - Estimated Exposure Timeframe to Closure



## Lowry OU5: 2008 Scope of Work...cont'd

### H) Development of Cleanup Objectives

- Risk Input
- Negotiation with CDPHE
- ACL Support Calculations
- Public Meetings



## Lowry OU5: 2008 Scope of Work...cont'd

### I) Well Abandonment

- Well Abandonment Work Plan
- Approximate Number of Wells: 50



## Lowry OU5: 2008 Scope of Work...cont'd

### J) Closure Activities

- Oncoming Plumes
  - Request for No Action Determination
- Fire Training Zone Plumes
  - Request for No Further Action
- Compensatory Volume



## Path to Closure: Beyond 2008

- Continuous Assessment of Remedial Progress
- LAC Target: Active Treatment Completed 2010
  - Anticipated that 20ppb TCE can be shown to be Protective of Human Health (Off base)
  - Indoor Air Protection Accomplished through Treatment and IC's (On base)
- LAC Target: NFA for all areas by 2012
  - Long-term Monitoring Potential
  - Natural Attenuation Tail



## Summary

### Did we achieve Objectives of RPA?

- **Determine Progress of Main Plume Cleanup**
  - Yes, with Substantial Progress
- **Identify Challenges to Closure**
  - Yes, and 2008 Scope Reflects Active Approach to Closure
- **Initiate Discussion of Cleanup Objectives**
  - Yes, with Risk Calculations Planned for Early 2008
- **Present Revised Path to Closure and Scope/Schedule for 2008**
  - Yes, with anticipated Closure Point/Timeframe Identified