Real World Application of LNAPL Transmissivity to a Late Stage/Mature LNAPL Plume Site

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LNAPL Recovery - When is Enough, Enough?

Introduction

- *Most Large-Scale Industrial Facilities Have Fully Developed LCSMs*
- *Risks Have Been Fully Defined*
- *Significant Quantities of LNAPL Have Been Recovered via Effectively Implemented Active Remediation Techniques*
- *Plumes are Mature and Stable*
- *When is Enough, Enough?*
- *Controlled Application of LNAPL Transmissivity (T_n) Could be the Answer*

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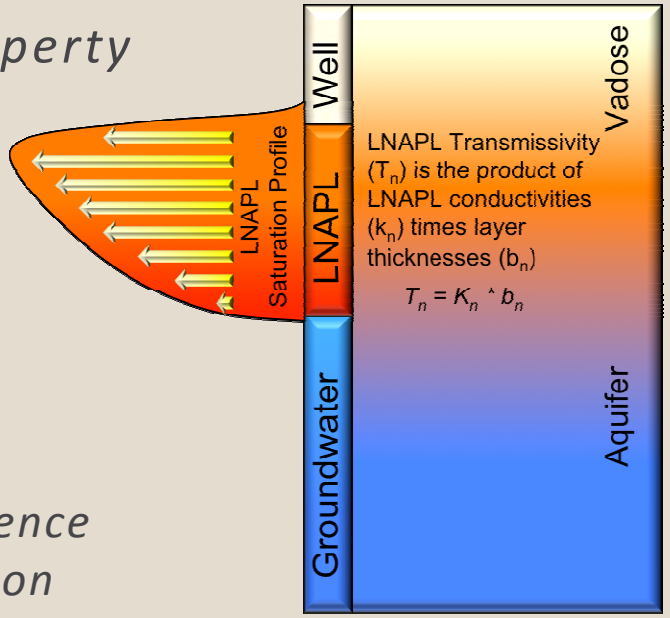
Overview

- *Introduction*
- *LNAPL Transmissivity – Definition, Measurement, Application*
- *Regulatory Considerations*
- *Real World Application at a Texas Refinery*
- *Summary*

An Ideal Metric

- *Collective Property*
  - *incorporates physical/chemical properties of the aquifer and of the LNAPL (e.g., permeability, viscosity)*
  - *incorporates LNAPL type (benzene versus bunker oil)*
  - *incorporates aquifer type (sand versus clay)*
- *Fundamental or Characteristic Property*
  - *repeatable for given conditions*
- *Saturation/Mass Driven*
  - *multiphase saturation distribution*
  - *varies directly with LNAPL mass*
- *Easily Measured*
  - *supported with multiple lines of evidence*
  - *obtained prior to or during remediation*

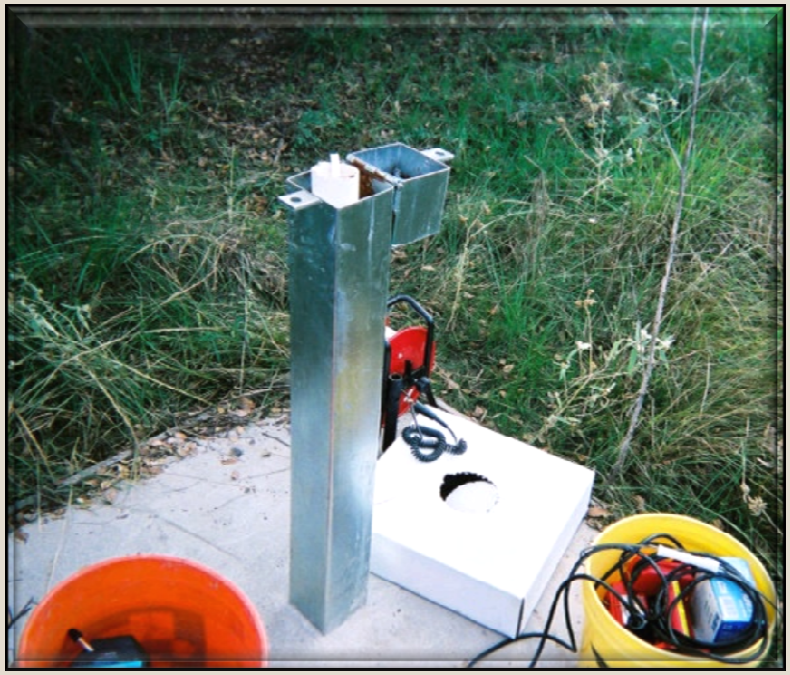


Measurement Techniques

- *New ASTM standard,*
  Standard Guide for Estimation of LNAPL Transmissivity
  (ASTM E2856-13)
- *Goals included:*
  - *Identification of Critical Assumptions and Best Practices*
  - *Standardization of Methods*
  - *Method Selection Criteria Matrix*
  - *Consistency of Calculations*
  - *Large Dataset of Comparable Values*
  - *Extend the Science and Practical Application*

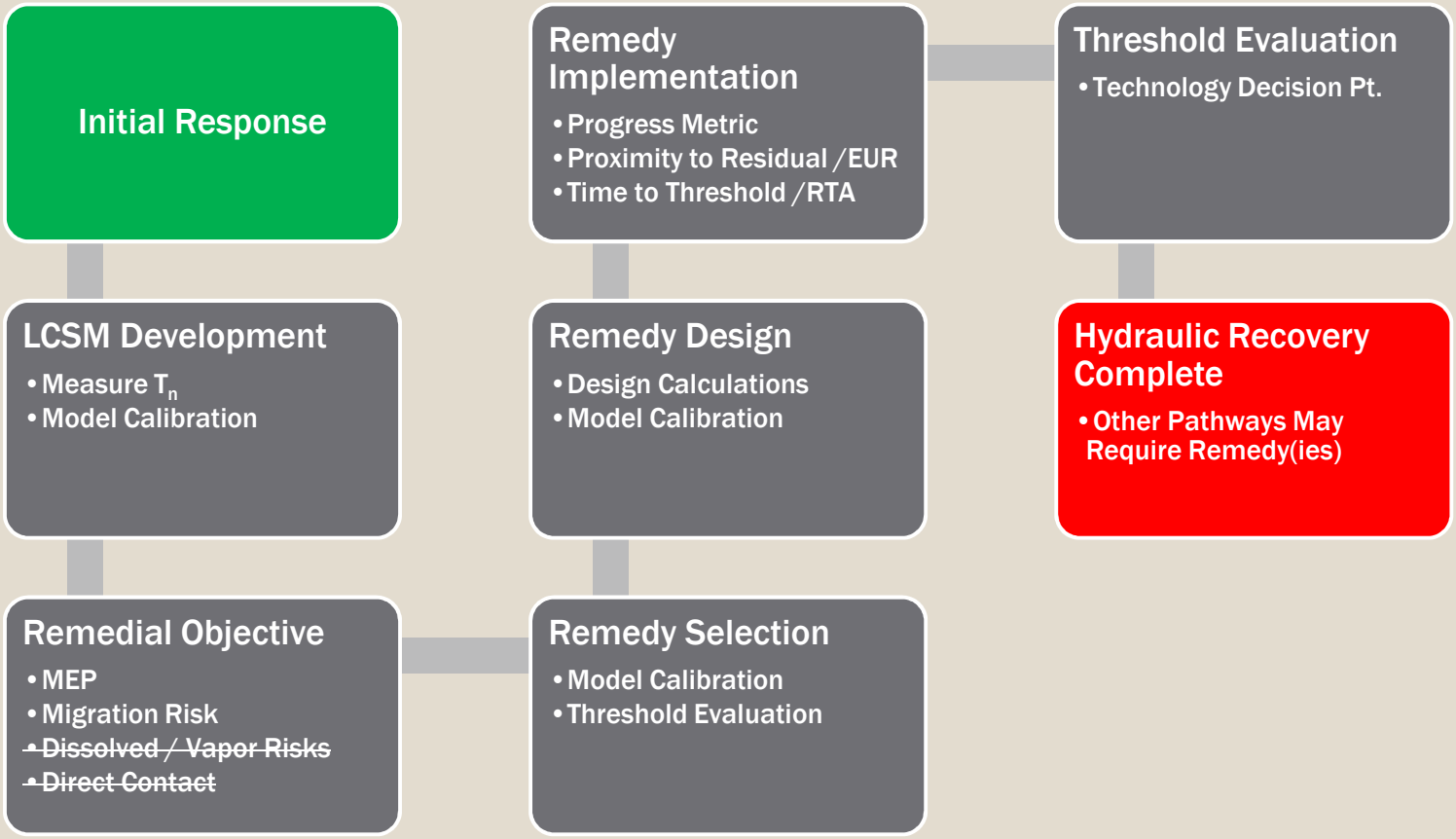
Measurement Techniques

- *Four Primary Measurement Methods (ASTM 2013)*
  - *Baildown/Slug Testing*
  - *Manual Skimming Testing*
  - *Recovery Data Analysis*
  - *Tracer Testing*



Application Through Project Life Cycle

LNAPL Transmissivity



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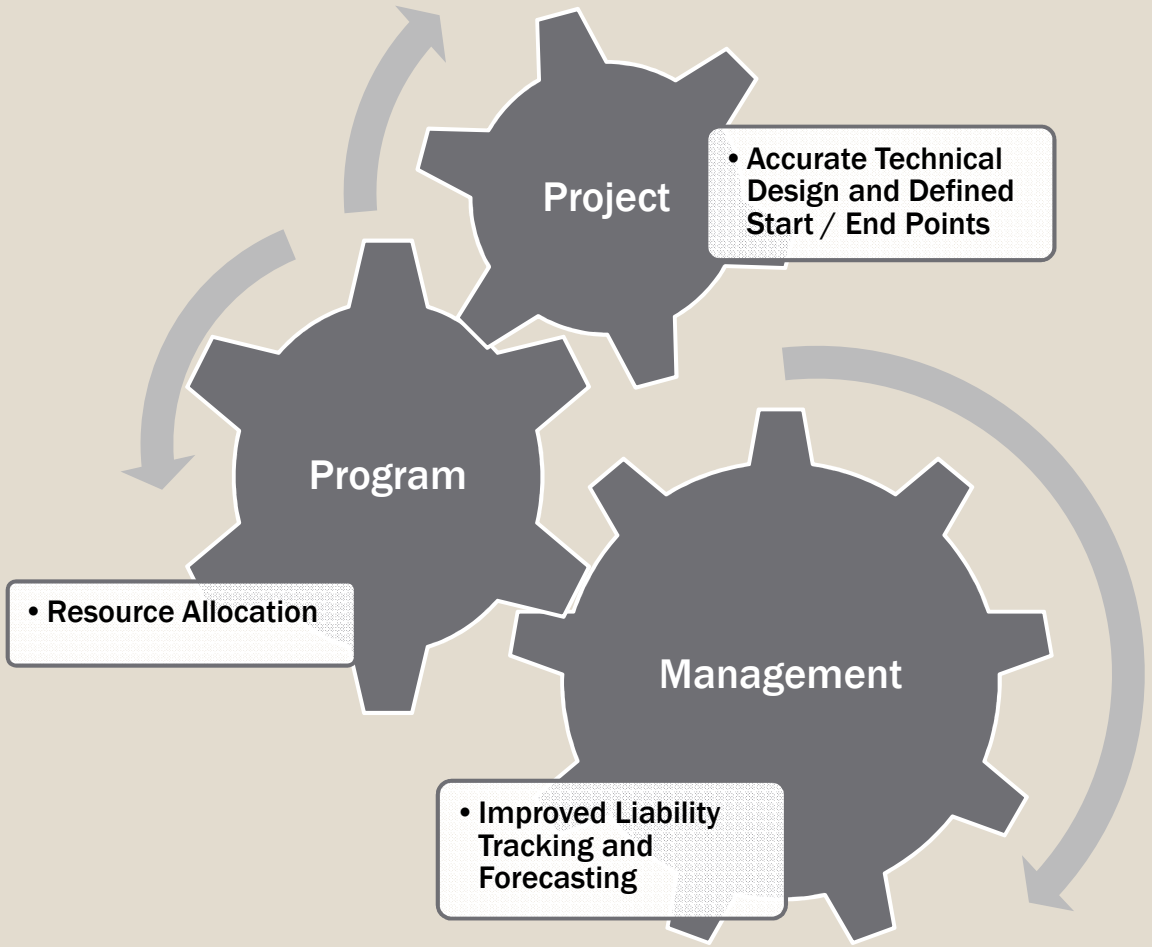
Strategic Application



TRRP-32, Risk-Based NAPL Management

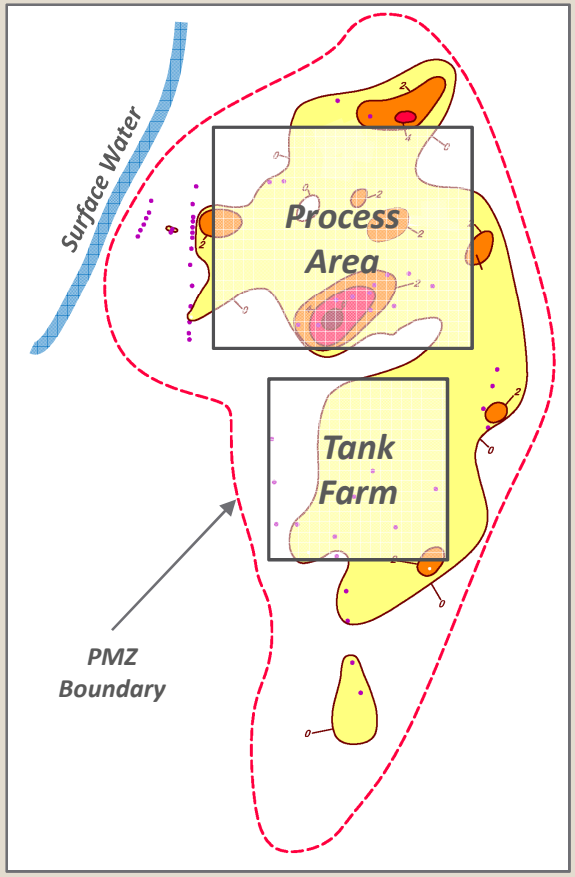
	STEP
STEP 1	Conduct NAPL Assessment
STEP 2	Identify NAPL Response Triggers
STEP 3	Determine NAPL Response Objectives and Endpoints
STEP 4	Develop NAPL Management Strategy
STEP 5	Implement NAPL Management Strategy and Evaluate NAPL Response Effectiveness

TRRP-32, Risk-Based NAPL Management

Endpoints (TRRP-32)	Migrating NAPL Zone Trigger	Recovery Only	• T_n time-series analysis
		Control (via TI)	• Model Calibration Parameter • Hydraulic Recoverability Metric
		Recovery	• T_n time-series analysis
	NAPL Contact w/ GW Zone Trigger	Recovery Only	• Design Parameter • "Readily Recoverable" Metric
Design	• Technology Selection Based on Hydraulic Recoverability of LNAPL • Model Calibration Parameter to Generate LNAPL Production Curves • Equipment Sizing, Volumetric Waste Mgmt. Plans • Fixed Base / Mobile Infrastructure Cost-Benefit Analysis		
Performance Evaluation	• Operational Performance Metric • Model Calibration Parameter • Hydraulic Recoverability Metric		

Implementation of T_n at a Texas Refinery

Real World Application



- Mature Hydraulic Recovery and Control System
- 56 Operating Recovery Wells in Compliance Plan
- LNAPL and Dissolved-Phase Plumes Stable
- Facility-Wide Plume Management Zone (PMZ)
- TRRP-32 Recovery Endpoint, "Recover Readily Recoverable NAPL Fraction"

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Implementation of T_n at a Texas Refinery

Real World Application

Average Well Total Depth (feet)	*40.8*
Average Depth to Groundwater (feet)	*32.5*
Number of Wells with Measurable NAPL	*57 (37.0%)*
Apparent NAPL Thickness Range (feet)	*0.01 - 7.89*
2013 Groundwater Recovery (gallons)	*11,719,192 (99.5%)*
2013 Hydrocarbon Recovery (gallons)	*57,363 (0.5%)*
Average Fluid Recovery Rate (gpm)	*18*
Aquifer Hydraulic Conductivity (feet/day)	*6.47*

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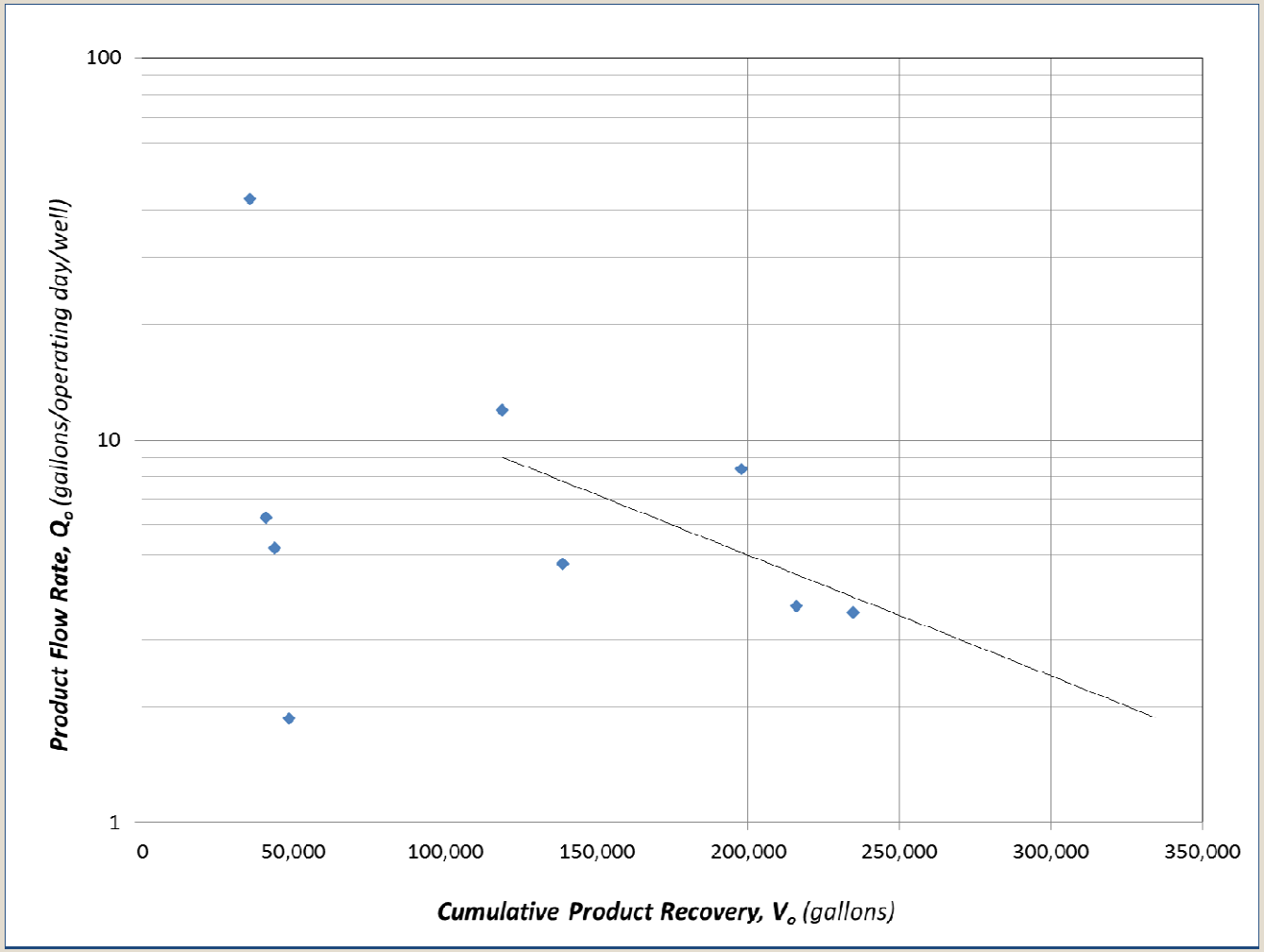
Implementation of T_n at a Texas Refinery

Real World Application



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Overview of SCOR™ Program

Real World Application

- *TCEQ-Approved SCOR™ Program, Based on LNAPL Transmissivity (shutdown, control, operation, and recharge)*
- *Hydraulic Control Wells to Remain Operational*
- *All Other Recovery Wells Evaluated for Shutdown Using LNAPL Transmissivity*
- *Combination of Annual Recovery-Based T_n and Short Term Test T_n (via baildown, manual skimming, ratio tests)*
- *Test of Operating Wells for T_n versus 0.1 and 0.5 feet^2/day Thresholds*
- *Operating Wells Must Requalify Each Year to Continue Operating*

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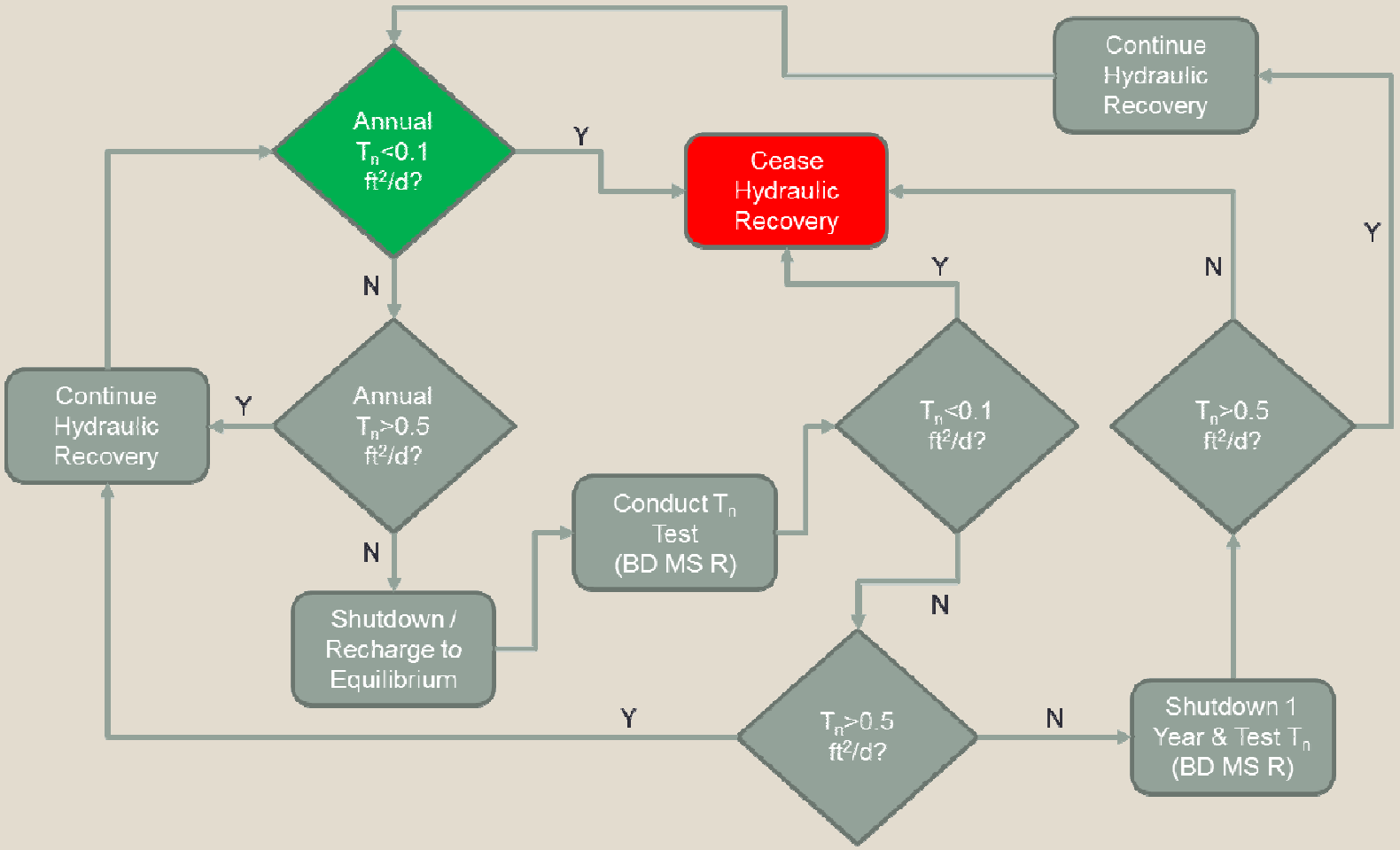
Overview of SCOR™ Program

Real World Application



Results of 2014 SCOR™ Plan Implementation

Real World Application

Wells Evaluated per 2013 Annual Recovery	**56**
Hydraulic Control Wells (continue operation)	22 (39%)
$T_n > 0.5$ ft²/day (continue operation)	6 (11%)
$T_n < 0.1$ ft²/day (shutdown)	11 (20%)
0.1 ft²/day $\leq T_n \leq 0.5$ ft²/day (short-term test)	17 (30%)
Wells Evaluated per Short-Term Test	**14**
$T_n > 0.5$ ft²/day (continue operation)	2

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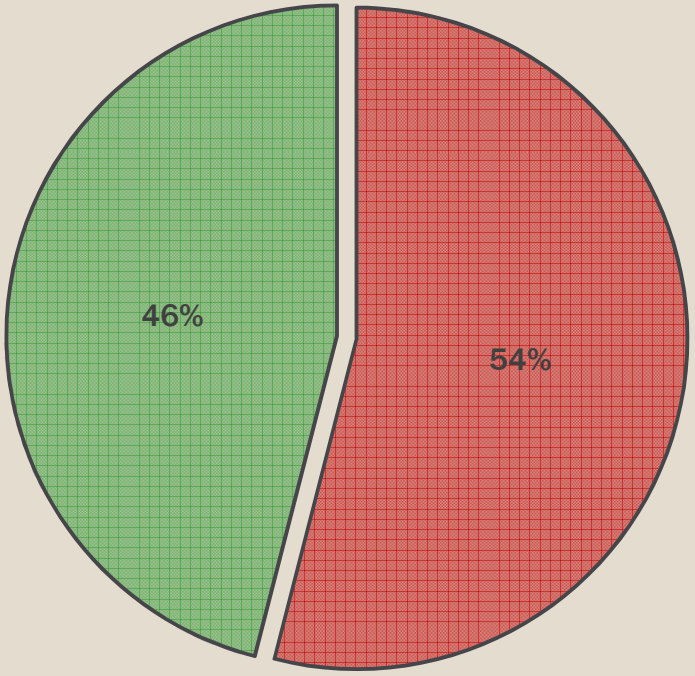
Results of 2014 SCOR™ Plan Implementation

Real World Application

Shut Down	
Shutdown Based on Annual T_n Evaluation	*11 (42%)*
Shutdown Based on Short-Term T_n Evaluation	*15 (58%)*
TOTAL	***26***



Operate	
Control Wells	*22 (42%)*
Continue Operation Based on Annual T_n Evaluation	*6 (58%)*
Continue Operation Based on Short-Term T_n Evaluation	*2 (58%)*
TOTAL	***30***

Total = 56 Recovery Wells

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Implementation of T_n at a Texas Refinery

Summary

- *LNAPL Transmissivity is an Ideal Leading, Progress, and **Endpoint** Metric*
- *Multiple Applications Throughout Project Life Cycle, Strategic Consideration at Program and Management Levels*
- *Defines "Readily Recoverable" and Answers the Question "When is Enough, Enough?"*
- *Application at this Texas Refinery Resulted in More Efficient Use of Available Resources and Optimization of the Existing Remediation System*

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Questions/Comments

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