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AECOM

Use of Lysimeters to Estimate Site-Specific Soil Standards for PFAS

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Former Air Force Base, Texas

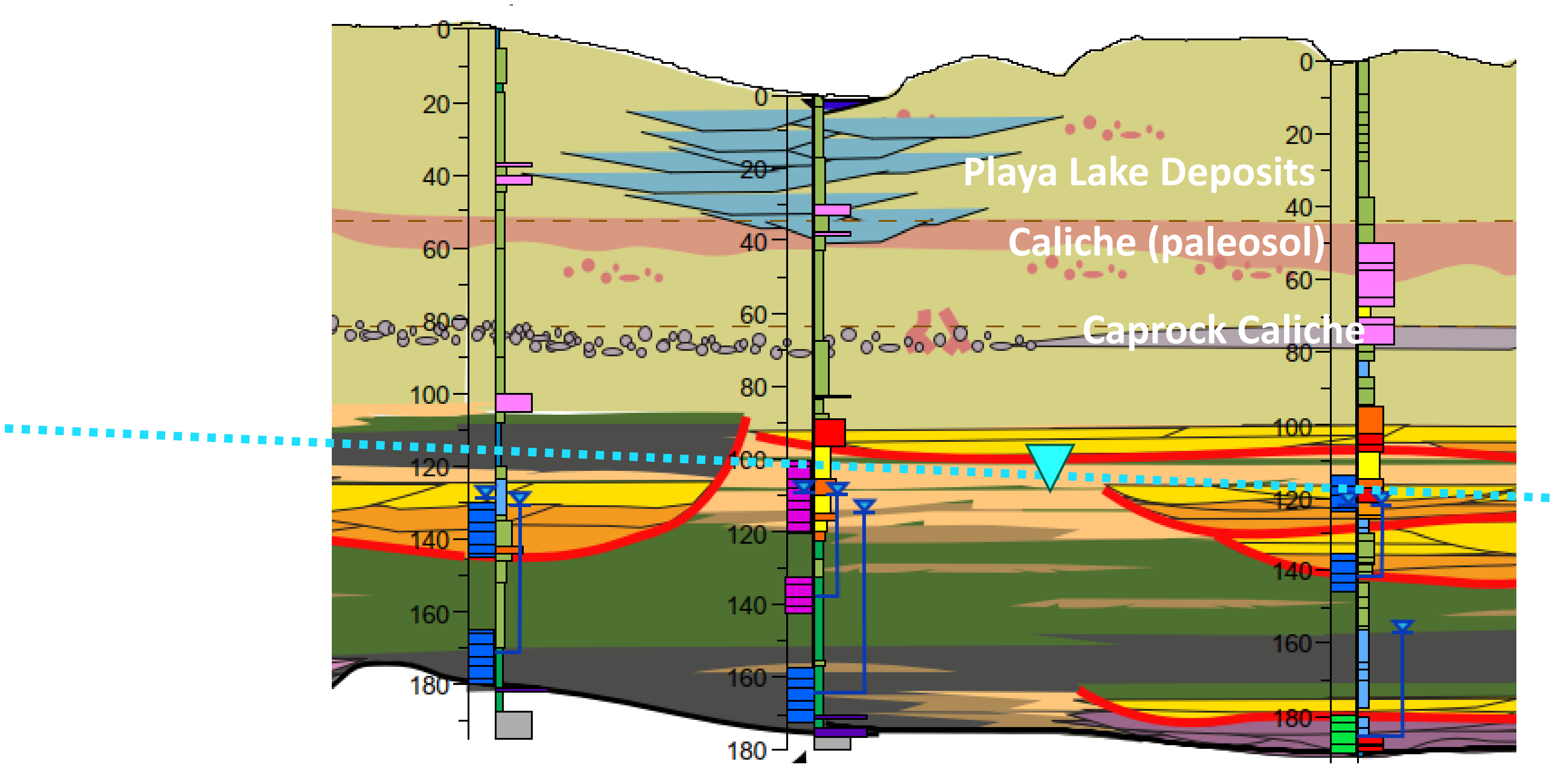
- Historic use of AFFF
  - Fire Training Area
  - Fire Station
- Affected Property Assessment (APA)
  - Metrics on soil impacts
  - Specific COCs
  - Volume/depth of impacts

PFHxS in Soil – Fire Training Area - Plan

PFHxS in Soil – Fire Training Area - Isometric

Conceptual Site Model

- Southern High Plains
- Average yearly rainfall = 19 inches (semiarid)
- Hydrology dominated by playa lakes
- Site-specific geology
  - Aeolian
  - Caprock caliche
  - Fluvial Deposits



Predictive Integrated Stratigraphic Modeling (PRISM®) Cross-Section

Project Objective

- Calculate site-specific, leach-based soil standards for PFAS compounds (Protective Concentration Levels [PCLs])
- Techniques: Texas Risk Reduction Program (TRRP)
  - Tier 1: ‘Default’ - uses generic input values
  - Tier 2: ‘Site-specific’ - allows use of some site-specific input values
  - Tier 3: ‘Modified’ – evaluation method that deviates from Tier 1/2

IMPORTANT POINTS:

- Tier 1/2 techniques utilize partitioning factors derived using EPA EPI Suite™ - Estimation Program Interface and EPA Risk Assessment Guidance for Superfund (RAGS) techniques.
- Even if RAGS appropriate, published partitioning values for PFAS are highly variable (e.g., log K_{oc} ranges from 1.15 to 4.5 for PFHxS; ITRC, 2023)

Project Approach

- Utilize lysimeters to perform a Tier 3 TRRP analysis to develop site-specific PCLs for PFAS
  - Eliminate uncertainty with physicochemical properties
  - Develop ‘area of concern’ (AOC) – specific values
  - Estimate soil-water partition coefficient (Ksw) and utilize within the TRRP calculation process (RAGS)

Preparation

Scope of Work

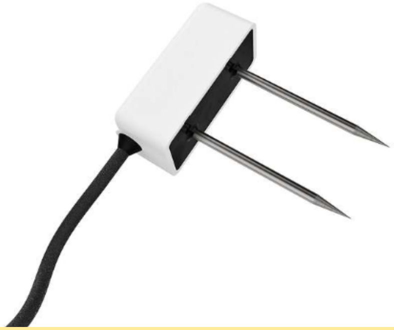
- Twenty dual chamber lysimeters
  - Fire Station, Fire Training Area
  - Locations exceed Tier 1 standards
- Depth
  - Phase 1 – ~20 feet bgs; 11 lysimeters
  - Phase 2 – ~6 to 10 feet bgs; 9 lysimeters
- Sampling
  - PFAS in soil
  - FOC, grain size, pH, conductivity, cation and anion exchange capacities


Field Assembly

Porewater Collection

- Loss of lysimeter vacuum
  - Desiccation of silica flour; numerous rewetting procedures
- Phase 2
  - Shallower depth
  - Soil moisture sensors

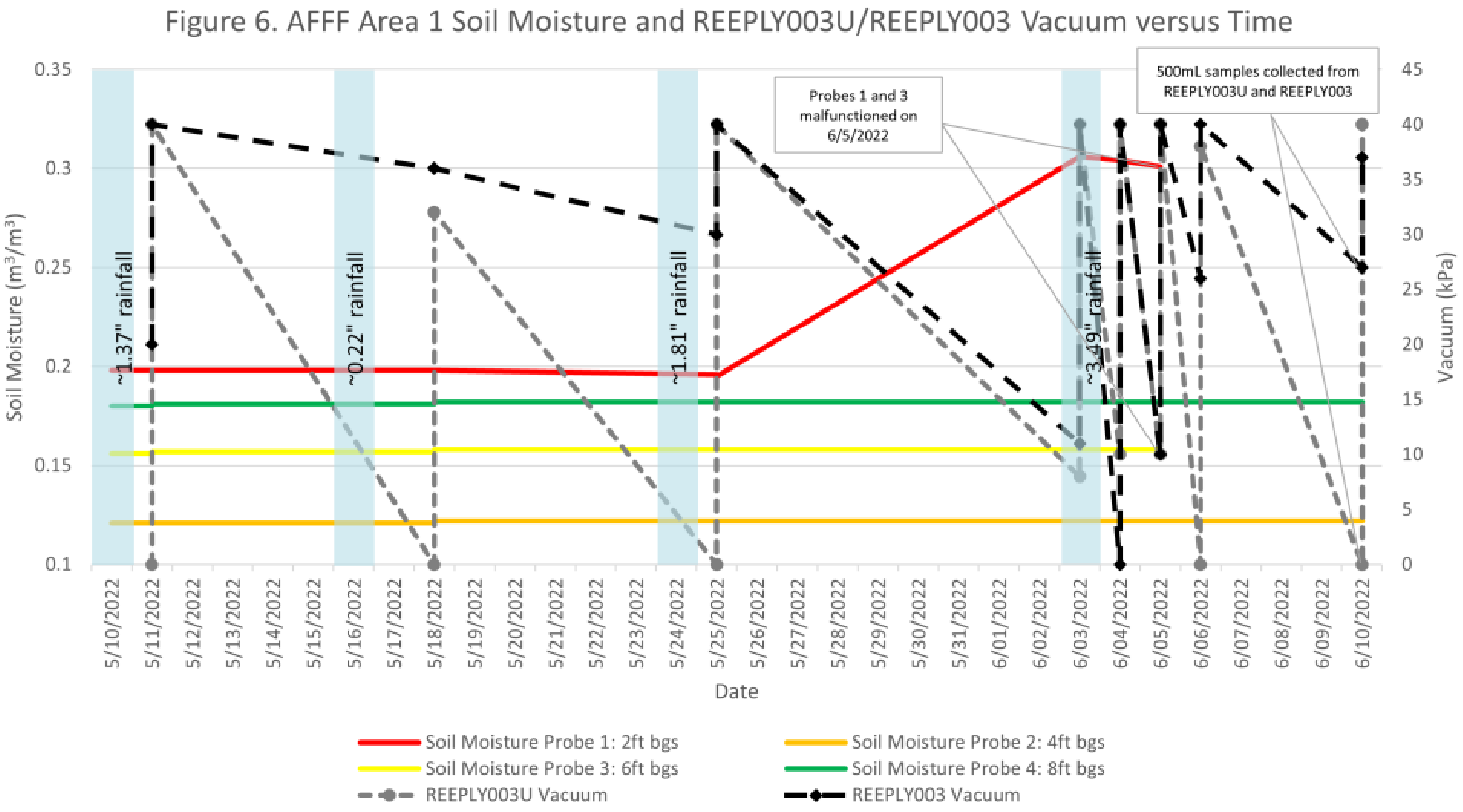
Silica flour mixing



IMPORTANT POINT:
Arid conditions at the Site limited porewater sample collection, encouraging a modified installation approach and additional monitoring procedures to improve chances of successful sample collection

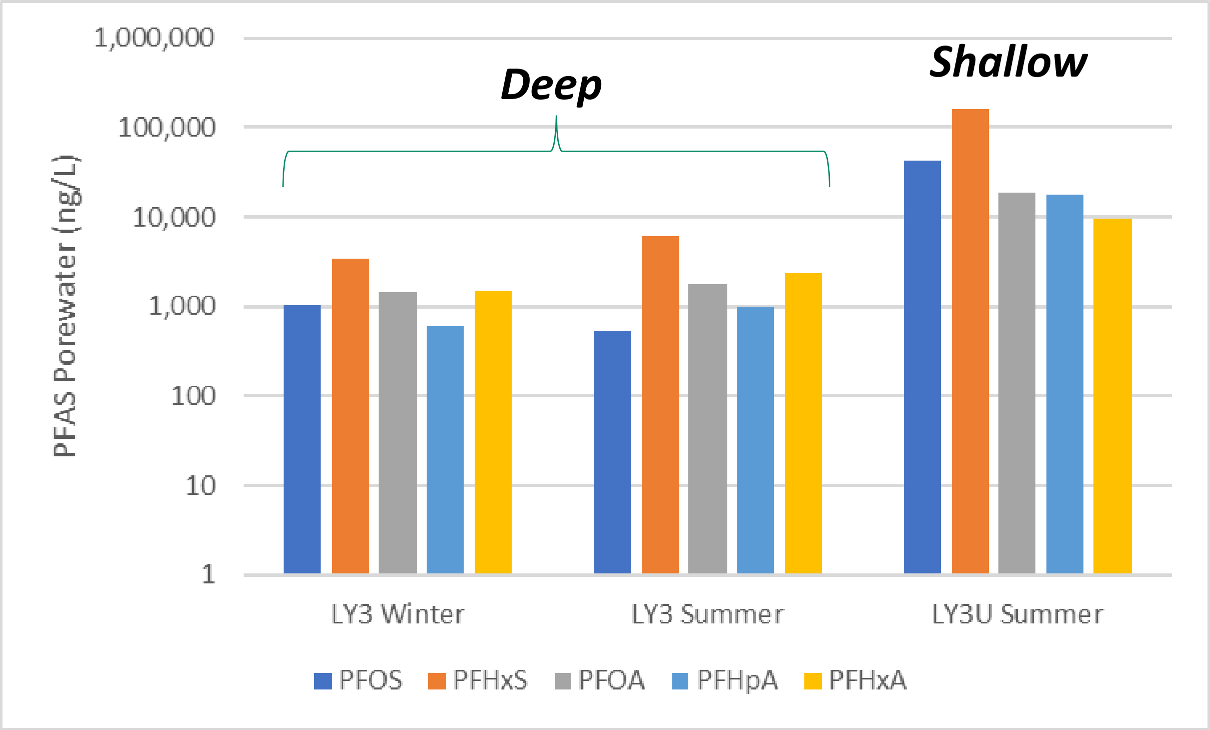
Soil Moisture Monitoring

- Soil moisture and vacuum
  - No moisture increases in deeper intervals
  - Difficulty maintaining vacuum
  - Samples collected following rain events
- Seven porewater samples from five lysimeters
  - 12-month sampling interval (June 2021 to June 2022)
  - 4 deep (Phase 1); 3 shallow (Phase 2)

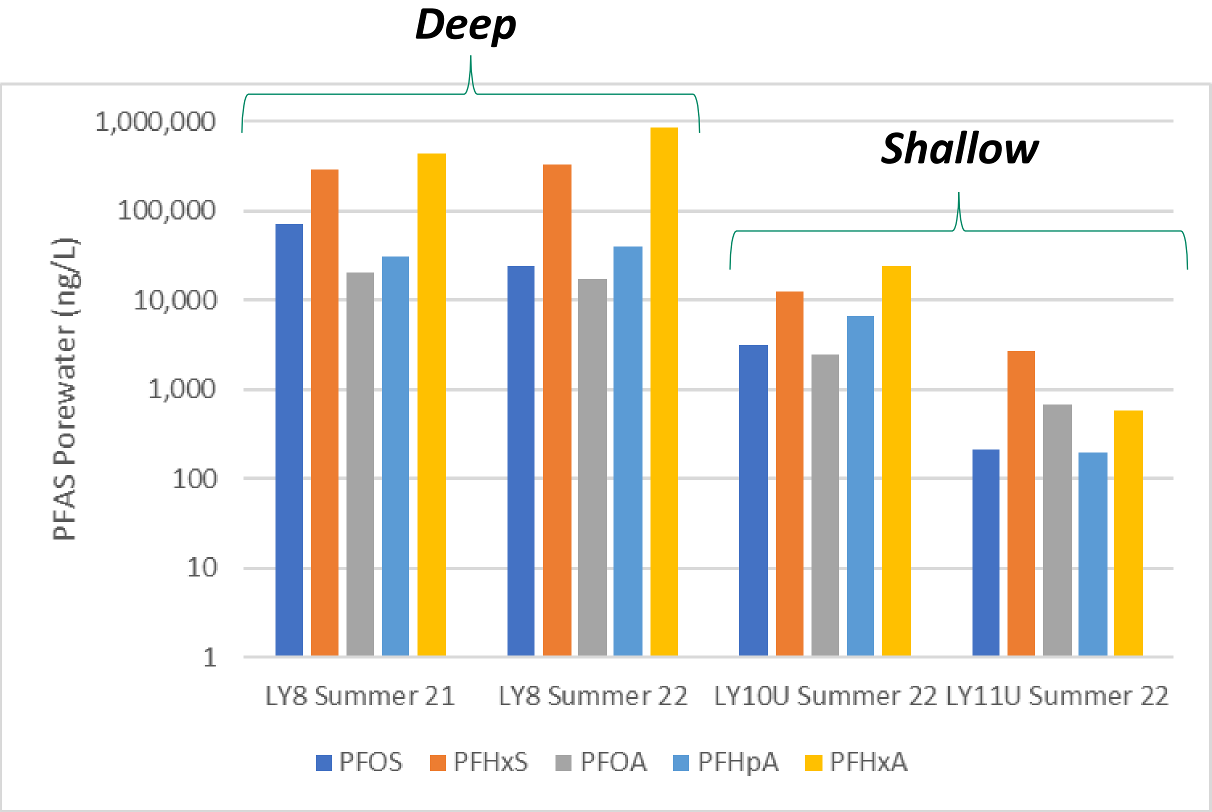


Soil Moisture and Lysimeter Vacuum

Lysimeter Porewater Results



Fire Station



Fire Training Area

Site-Specific Standard Calculation – Method #1

- Tier 2 PCL
  - Calculate site-specific $^{GW}Soil_{Ing}$ PCL using standards TCEQ TRRP procedures
- Result: **Five of five locations exceeded comparison level**

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TCEQ TRRP Tier 2 Soil-to-Groundwater PCL Calculator

Reference Name:	Soil-to-GW	*Sample Reference #:*		*Date of Calculation:*	September 30, 2022
octane Sulfonate (PFOS)	*Comments:*	CAS #1763-23-1 (PFOS in ERPIMS)			

PCL Calculation - General Solution

Calculates soil clean-up concentration which is protective of groundwater for the given Groundwater PCL requirement using Eqn. 1

$$^{GW}Soil = \frac{\text{Critical GW PCL x Lateral Dilution Factor}}{\text{COC Soil-leachate Partition Factor}} \cdot \frac{\text{Distance from Top of Affected Soil to GW}}{\text{Thickness of Affected Soil}}$$

$$^{GW}Soil = \frac{GW\ PCL \cdot LDF}{K_{SW}} \cdot \frac{L_2}{L_1}$$

(Eqn. 1)

COC Soil-Leachate Partition Factor

Calculates the Tier 2 value of the COC partition factor from affected vadose zone source zone into soil water (leachate)

$$\text{COC Soil - Leachate Partition Factor} = \frac{\text{Soil bulk density}}{\text{Soil vol. water content} + (\text{soil - water partition coeff. x Soil bulk density}) + (\text{Henry's Law const. x Soil vol. air content})}$$

$$K_{SW} = \frac{\rho_b}{\theta_{ws} + \boxed{K_d}\,\rho_b + \boxed{H'}\,\theta_{as}}$$

(Eqn. 3)

NOTE: Only ONE (1) K_d is used

nput EITHER: Log K_{oc}/K_d OR *Inorg* K_d

IMPORTANT POINT:

TRRP-selected physicochemical parameters utilized for partitioning

Site-Specific Standard Calculation – Method #2

- Anderson (2021) Method
  - If measured porewater from lysimeter is greater than 'porewater comparison level', soil will leach to groundwater
    - LDF – leachate dilution factor; calculated from Tier 2 PCL equations
- Result: **Four of five locations exceed comparison level**

$$\text{Porewater comparison level} = {}^{GW}GW_{Ing}\,PCL{*}LDF \qquad \text{Equation 1}$$

Leachate Dilution Factor Calculation

Calculates the Tier 2 value for the dilution factor of a COC in vadose zone leachate that is mixed with groundwater

$$\text{Lateral Dilution Factor} = 1 + \frac{\text{GW Darcy Velocity x GW Mixing Zone Thickness}}{\text{Net Infiltration Rate x Length of Affected Soil in Direction of GW flow}}$$

$$LDF = 1 + \frac{U_{gw}\delta_{gw}}{I_f W_s} \qquad \text{(Eqn. 2)}$$

NOTE: GW Mixing Zone Thickness (δ_{gw}) can not be greater than Aquifer Thickness (b_{gw}). Calculator selects correct value.

TCEQ TRRP Equation

Site-Specific Standard Calculation – Method #3

Lysimeter soil and porewater results used to calculate soil-leachate partition factor (Ksw) (Tier 3)

Ksw Calculation

$$K_{sw}\left[\frac{\left(\frac{mg}{L}-H_2O\right)}{\left(\frac{mg}{kg}-soil\right)}\right]=\frac{\rho_b}{\theta_{ws}+K_d\rho_d+H'\theta_{as}}$$

$$\frac{C_w}{C_t}=\frac{\rho_b}{\theta_{ws}+K_d\rho_d+H'\theta_{as}}$$

Where:
Cw = leachate concentration (mg/L) [from lysimeter]
Ct = soil concentration (mg/kg) [from soil at lysimeter location]

GWSoil PCL Calculation

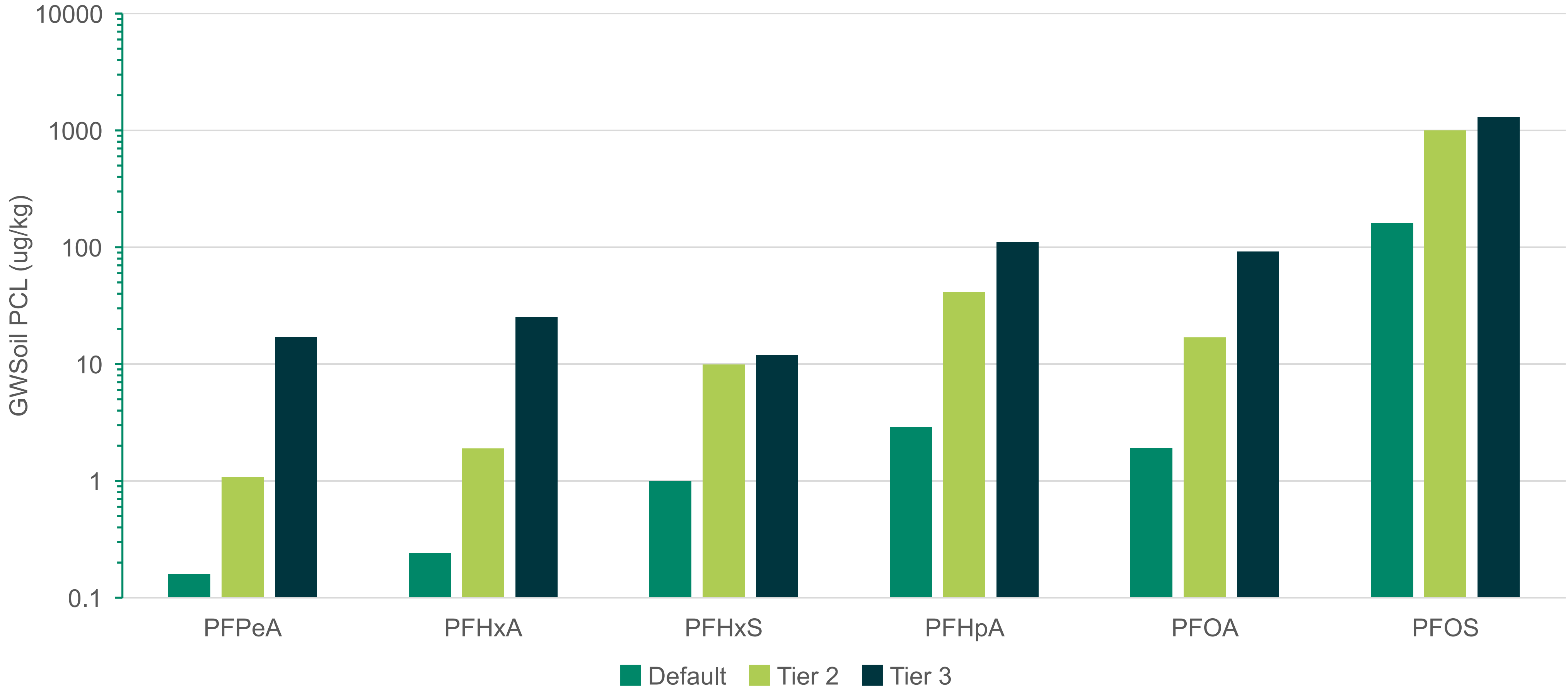
$$GW_{Soil}=\frac{(Groundwater_{PCL})LDF}{K_{sw}}\cdot\frac{L_2}{L_1}$$

$$GW_{Soil}=\frac{(Groundwater_{PCL})LDF}{\frac{C_w}{C_t}}\cdot\frac{L_2}{L_1}$$

Result: **<u>Four of five locations exceed comparison level</u>**

IMPORTANT POINT:
L2/L1 ratio accounts for additional sorption between impacted soil and water table

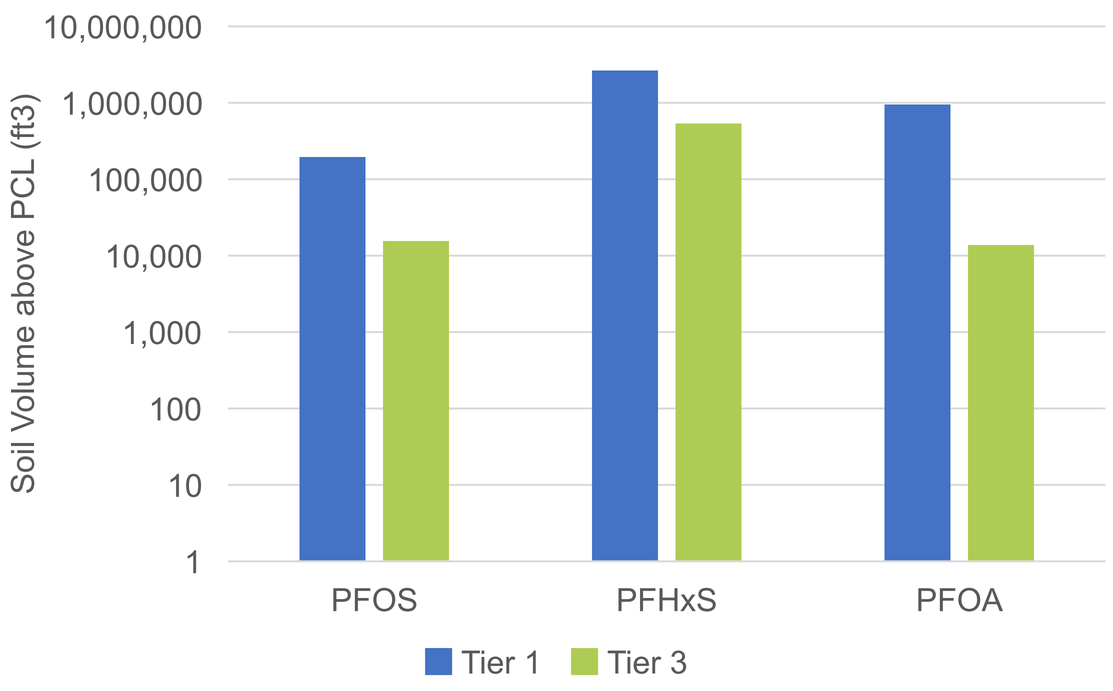
$^{GW}Soil_{Ing}$ Comparison

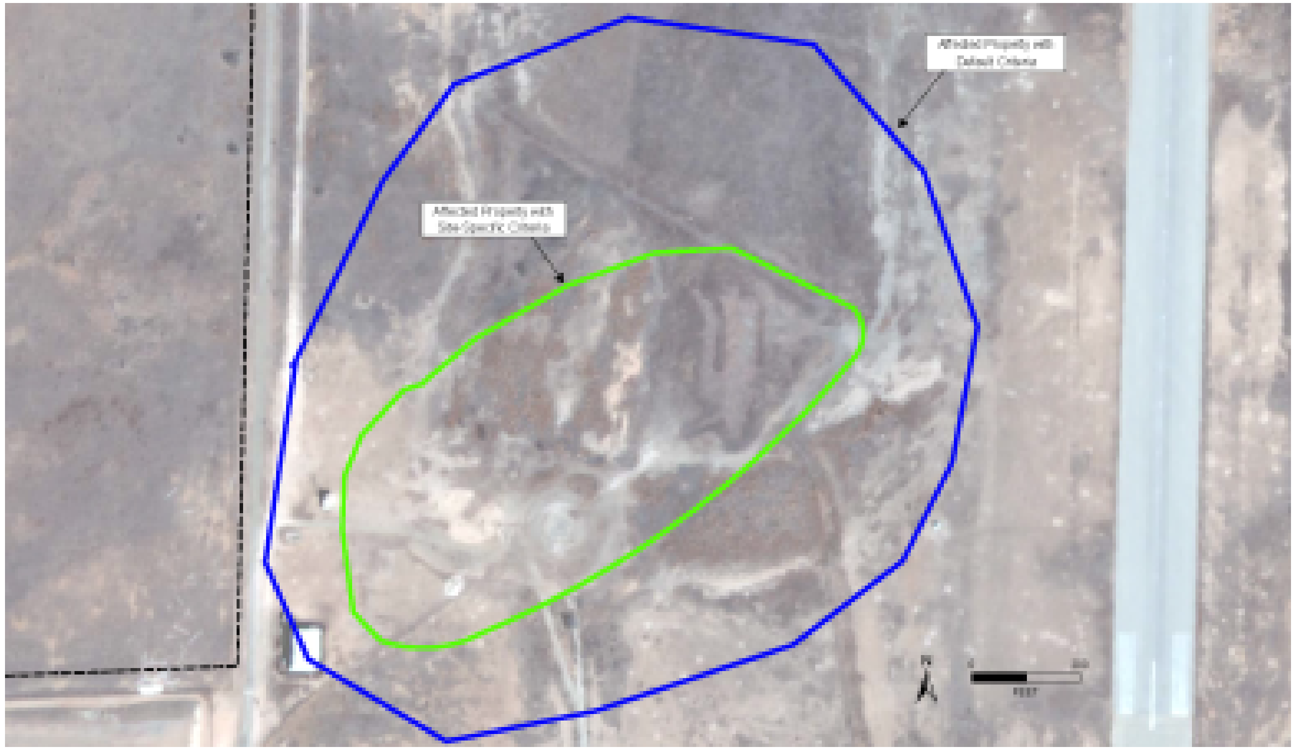


IMPORTANT POINT:

Lysimeter data and Tier 3 analysis resulted in higher $^{GW}Soil_{Ing}$ standards for all PFAS COCs.

Project Implications





Extent of PFHxS in Soil > PCL – Tier 1 and Tier 3

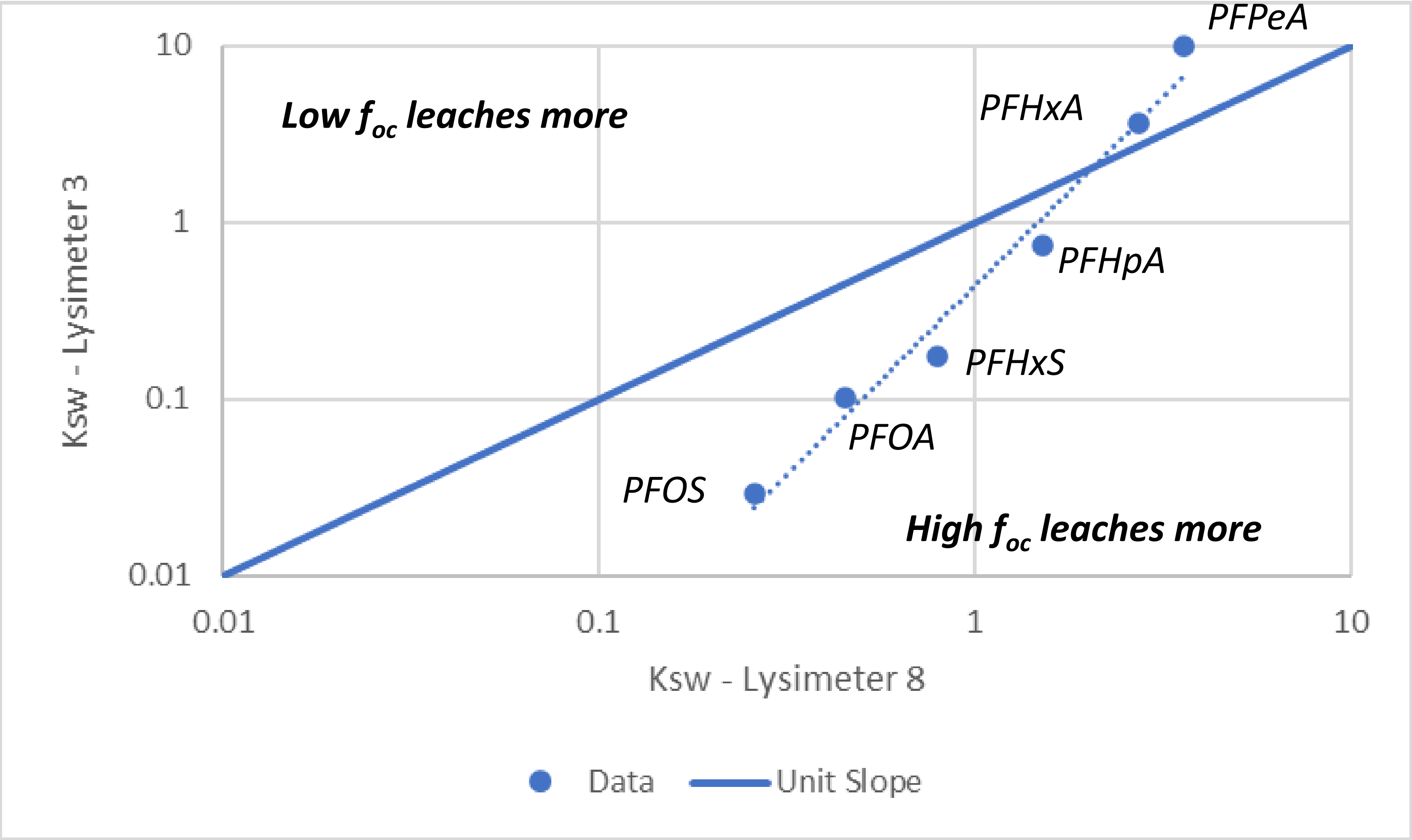
IMPORTANT POINT:
Significantly less soil requiring remediation using Tier 3 methods

Soil Parameters

Parameter	Units	LY3 – Fire Station	LY8 – Fire Training Area
Gravel	%	0	3.8
Sand	%	62.3	35.6
Silt	%	31.2	40.8
Clay	%	6.5	19.8
Anion Exchange Capacity	meq/100g	40.6	43
Cation Exchange Capacity	meq/100g	10.8	7.47
pH	SU	8.34	8.69
Fraction Organic Carbon	g/g	**0.00385**	**0.0347**
Electrical Conductivity	ds/m	0.24	0.36

IMPORTANT POINT:
Fraction organic carbon (FOC) only parameter significantly different between locations.

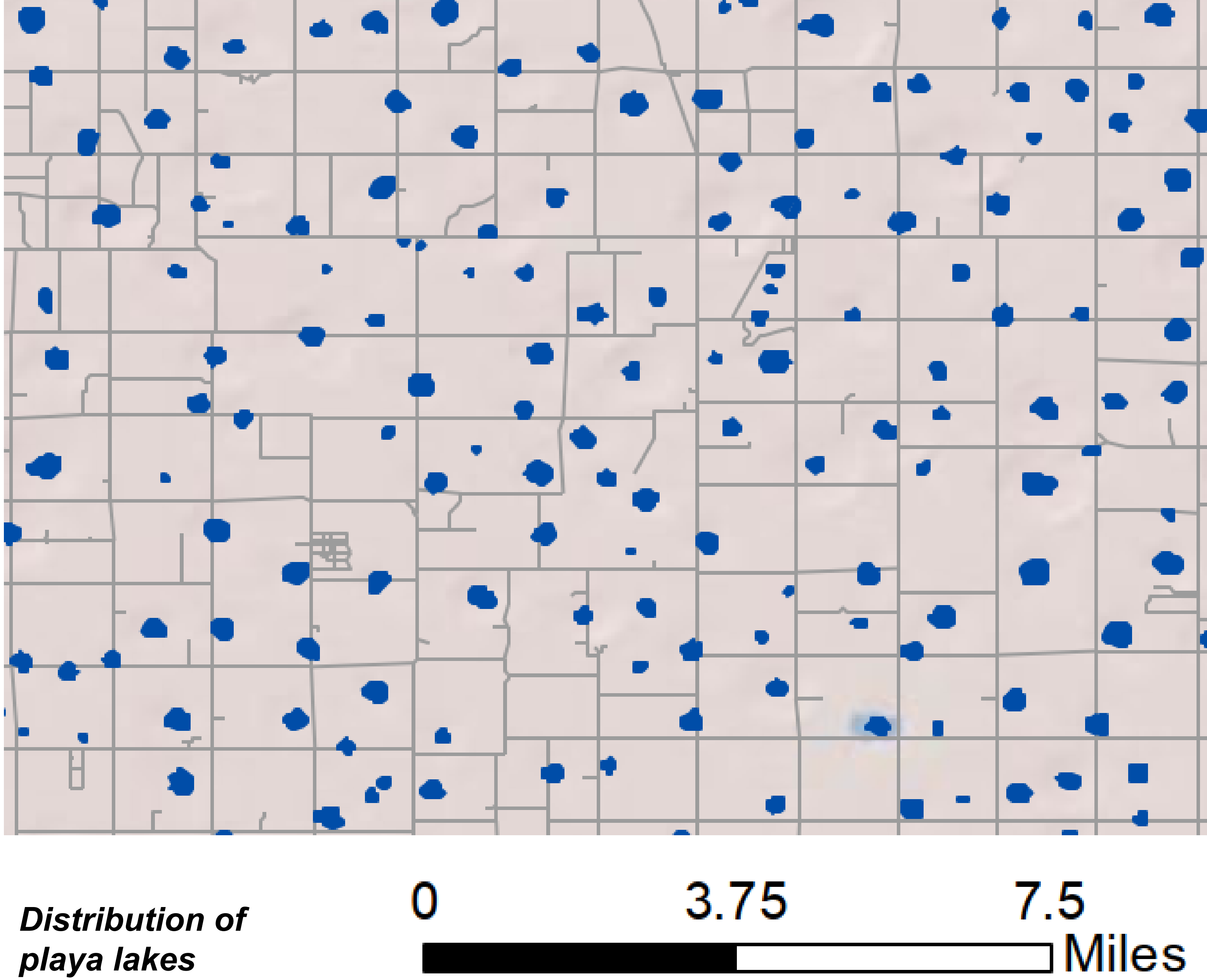
Partitioning Comparison



IMPORTANT POINT:
Sulfonates preferentially leach more at higher FOC; Low molecular weight carboxylates preferentially leach less at higher FOC

Lessons Learned

- Tier 3 approach accepted by TCEQ
  - Significantly less volume requiring remediation
- Lysimeter preparation and installation
  - Gas-rated fittings
  - Silica flour preparation
    - Rewetting procedures
  - Moisture sensors
- Site hydrology
  - Arid
  - Deep water table



Distribution of playa lakes

Source: Playa Lakes Joint Venture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