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SMART CHARACTERIZATION - AN HRSC APPROACH FOR DETERMINING PREFERENTIAL PATHWAYS FOR COMPLEX SITES

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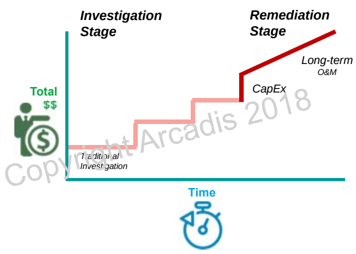
Outline

- Smart Characterization & Return on *Investigation*
- Stratigraphic Flux
- Precision vs Accuracy
- Source Characterization
- Case Study: Air Force Plant 4 (BAA 967)

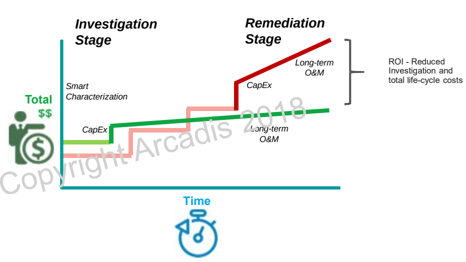
Smart Characterization

Its not just about more data, its what you do with the data that counts:

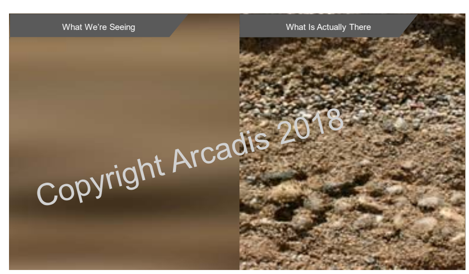
Return on *Investigation*

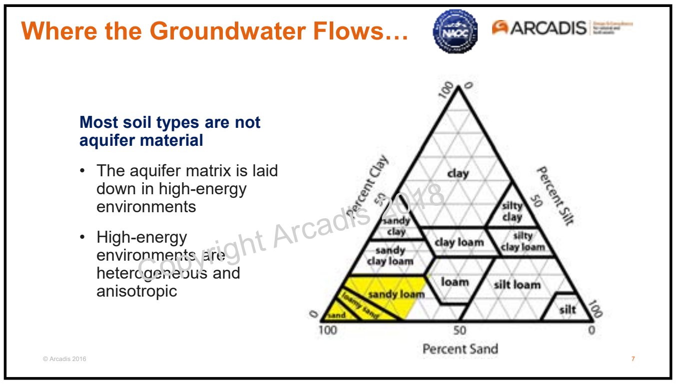


Return on *Investigation*



Moving From Conventional to Smart Characterization




Where the Groundwater Flows…
ARCADIS
Most soil types are not aquifer material
• The aquifer matrix is laid down in high-energy environments
• High-energy environments are heterogeneous and anisotropic
Percent Clay
Percent Silt
Percent Sand
clay
silty clay
sandy clay
silty clay loam
clay loam
sandy clay loam
loam
silt loam
sandy loam
loamy sand
sand
silt
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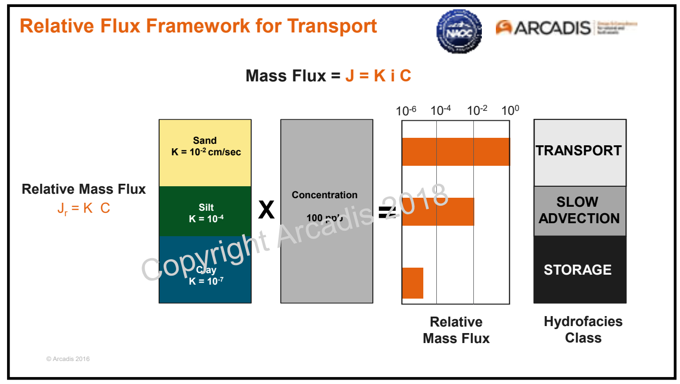
Relative Flux Framework for Transport
ARCADIS
Mass Flux = J = K i C
Relative Mass Flux
J_r = K C
Sand
K = 10^{-2} cm/sec
Silt
K = 10^{-4}
Clay
K = 10^{-7}
X
Concentration
100 µg/L
=
10^{-6} 10^{-4} 10^{-2} 10^{0}
Relative Mass Flux
TRANSPORT
SLOW ADVECTION
STORAGE
Hydrofacies Class
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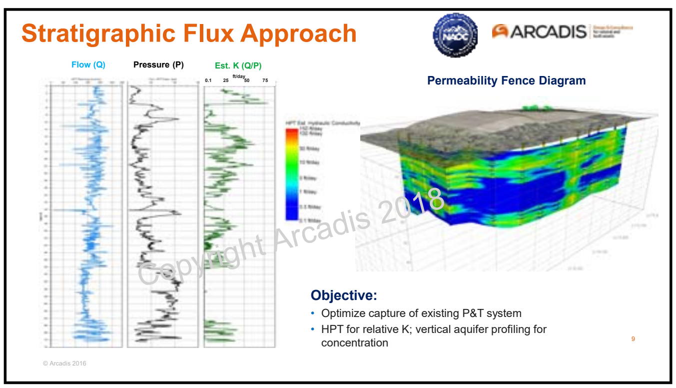
Stratigraphic Flux Approach
ARCADIS
Flow (Q)
Pressure (P)
Est. K (Q/P)
Permeability Fence Diagram
Objective:
• Optimize capture of existing P&T system
• HPT for relative K; vertical aquifer profiling for concentration
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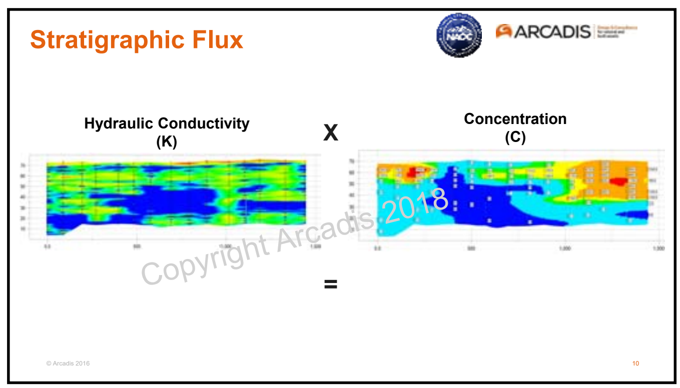
Stratigraphic Flux
ARCADIS
Hydraulic Conductivity (K)
X
Concentration (C)
=
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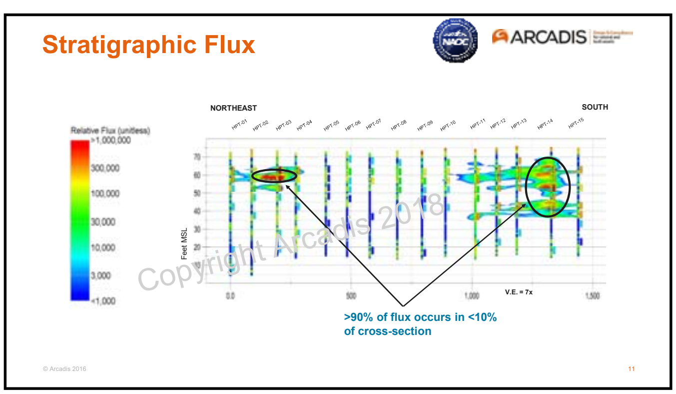
Stratigraphic Flux
ARCADIS
Relative Flux (unitless)
>1,000,000
300,000
100,000
30,000
10,000
3,000
<1,000
NORTHEAST
SOUTH
Feet MSL
V.E. = 7x
>90% of flux occurs in <10% of cross-section
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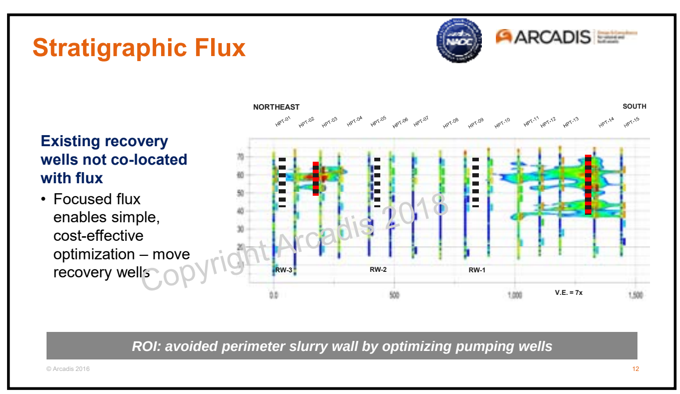
Stratigraphic Flux
ARCADIS
Existing recovery wells not co-located with flux
• Focused flux enables simple, cost-effective optimization – move recovery wells
NORTHEAST
SOUTH
RW-3
RW-2
RW-1
V.E. = 7x
ROI: avoided perimeter slurry wall by optimizing pumping wells
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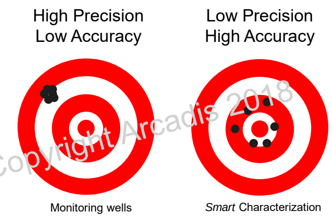
Precision vs. Accuracy

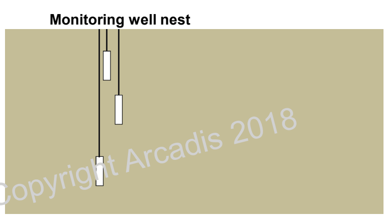
Precision: Is it repeatable?

Accuracy: Is it correct?

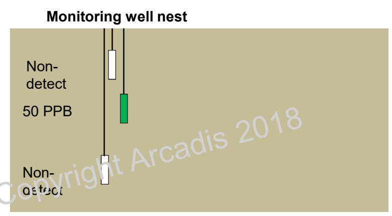
Precision vs. Accuracy



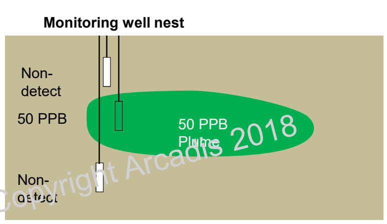
Precision vs. Accuracy



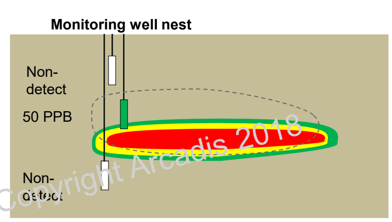
Precision vs. Accuracy



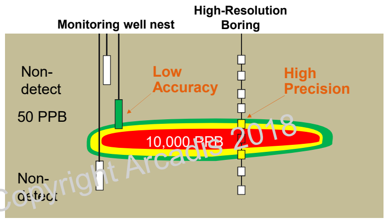
Precision vs. Accuracy



Precision vs. Accuracy

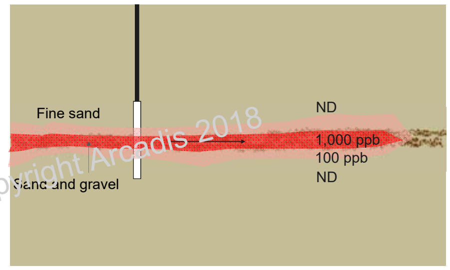


Precision vs. Accuracy



Precision vs. Accuracy

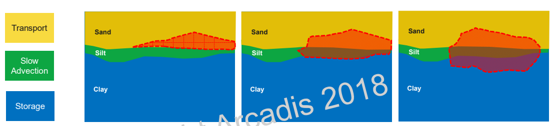
Install wells AFTER site characterization
- Same precision
- Better accuracy
- Less wells
- Less cost



Mass Distribution

Plume Maturity is Key

Plume Age: New | Moderate | Mature



Remediation: Easy | Moderately Hard | Difficult

Easy — Flux in transport zones:
- Typical leading edge
- Variety of treatment options available
- Minimal back-diffusion

Moderately Hard — Flux in transport /slow advection:
- Mature plume
- Mass flux associated with slow advection potentially significant
- Back Diffusion from silt ongoing issue

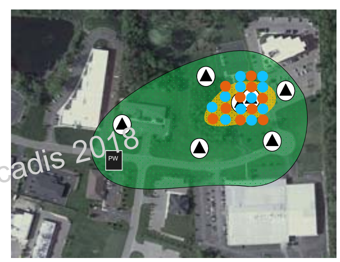
Difficult — Mass distributed across all hydrofacies:
- Typical source area
- Significant mass within diffusion dominant storage zones
- Intensive/aggressive treatment

Adaptive Approach

Adaptive grid of borings
- Mobile lab
- Adjust step-outs in real-time

High frequency sampling
- Focused on soil
- Groundwater for correlation

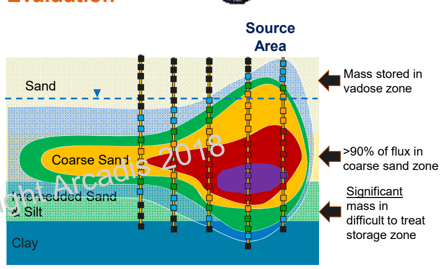
Characterization of stratigraphy & permeability
- Permeability profiling (HPT etc.)
- Sieve analysis



Flux-Based Source Evaluation

Whole core soil sampling:
- Vadose and saturated soil samples
- Quantitative results / COC speciation

Understand mass distribution and plume maturity



Mobile Laboratories

Courtesy: Triad Environmental Services, LLC

The appropriate mobile lab for a project depends on objective, scope and DQOs

- Screening level data vs certified data
- Required detection limits
- Number of samples vs. throughput
- COC list

Analytical Option	VOC Soil Reporting Limit	VOC Groundwater Reporting Limit	Typical Samples/Day/ Chemist	Advantages	Disadvantages
GC/MS Mobile Lab (Method 8260C)	[illegible] µg/kg	1-2 µg/L	20-30	NELAP certified labs; Ability to screen for other COCs	Highly impacted samples can slow production
DSITMS Mobile Lab (Method 8265)	100-200 µg/kg	2 µg/L	50-60	High throughput	COCs must be defined ahead of time, cannot distinguish between some isomers (e.g. cis vs trans-DCE)
Standard Fixed Lab (Method 8260B)	300 µg/kg (Methanol)	1 µg/L	24 hour turn	Stakeholders more familiar with fixed laboratory methods	Slow turnaround limits adaptability; Elevated soil detection limits with standard methanol preservation.

Partitioning Equation for Saturated Soils

$$C_t = C_w * [(K_{oc} * f_{oc}) + (\Theta_w/\rho_b)]$$

- Chemical and soil properties used to convert saturated soil data to equivalent groundwater concentrations
- Good approximation, not exact – GW concentrations influenced by several factors:
  - organic carbon content
  - chemical-specific carbon partitioning
  - soil porosity/moisture content
  - soil density

KEY: Use site-specific parameters for each hydrofacies

Parameter/Definition
C_t = bulk soil concentration
C_w = groundwater concentration
K_{oc} = organic carbon partition coefficient
f_{oc} = fraction of organic carbon
Θ_w = water filled soil porosity
ρ_b = dry bulk density

Soil Screening Guidance: Technical Background Document (U.S. EPA, 1996)

Air Force Plant 4

AFCEC Stratigraphic Flux Technical Demonstration

BAA ID 967

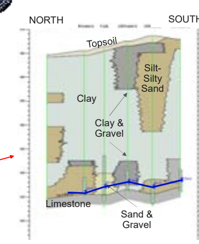
Air Force Plant 4, Chrome Pit 3

Fort Worth, Texas

- Barium chromate sludge disposal
- High concentrations of TCE and chromium
- Previous attempts at remediation unsuccessful
  - Excavation – significant mass remaining below former pit
  - ISCO – mobilized Cr

Challenging Conditions….

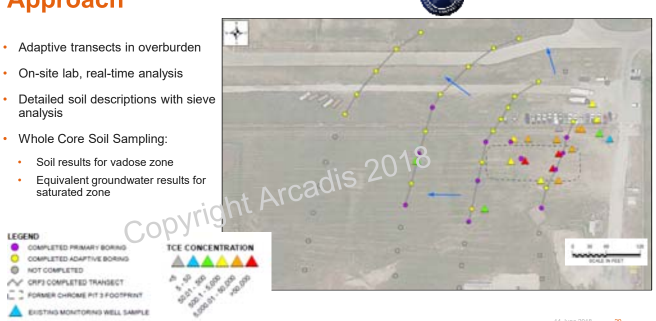
- High concentrations of TCE in dense low permeability clays/silts



- Pleistocene and Holocene alluvium
- Dense, poorly sorted
- limited saturated thickness
- shallow bedrock and saturated rubble zone

Approach

- Adaptive transects in overburden
- On-site lab, real-time analysis
- Detailed soil descriptions with sieve analysis
- Whole Core Soil Sampling:
  - Soil results for vadose zone
  - Equivalent groundwater results for saturated zone

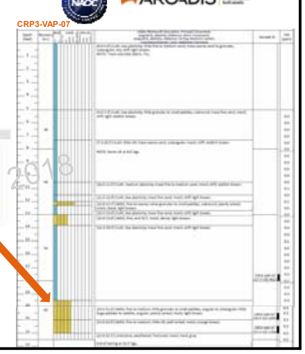


Hydrofacies Analysis

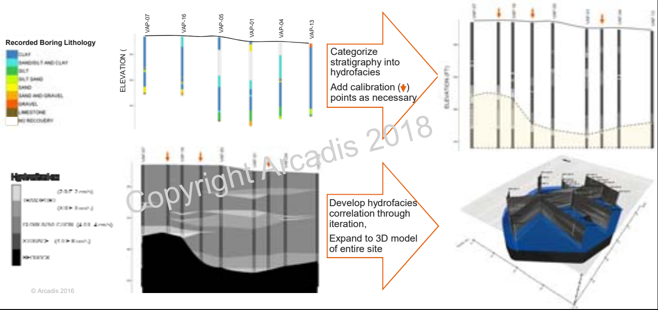
Geologic soil descriptions and sieve analysis to characterize hydrofacies.

Sieve results used to assign an average K to each hydrofacies unit:

Hydrofacies	Estimated K Range (cm/s)	Geometric Mean (cm/s)
Storage	10^{-5} to 10^{-7}	$4.0 X 10^{-6}$
Slow Advection	10^{-3} to 10^{-4}	$4.0 X 10^{-4}$
Transport	10^{-3}	$3.0 X 10^{-3}$
	10^{-2} to 10^{-1}	$2.0 X 10^{-2}$

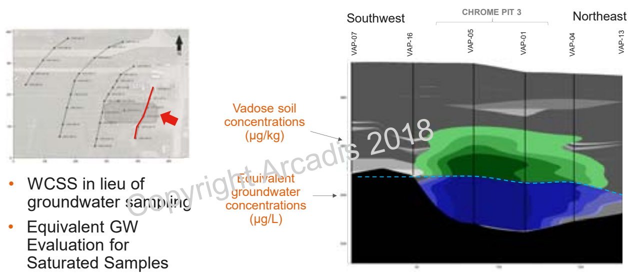


Hydrofacies Model Development



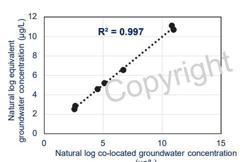
Whole Core Soil Sampling

- WCSS in lieu of groundwater sampling
- Equivalent GW Evaluation for Saturated Samples



Comparison of Equivalent Groundwater to Groundwater

- MDLs are used to lower detection limits
- Effective DL for TCE 20-40 µg/L



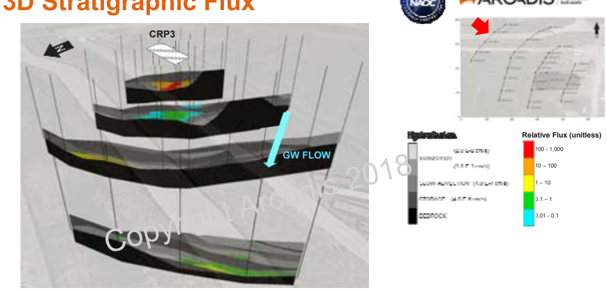
Comparison Type*	Depth (ft bgs)	Average TCE in Saturated Soil (µg/kg)*	Calculated Conversion Ratio**	Calculated Equivalent Groundwater (µg/L)	Co-located Groundwater (µg/L)
EQ GW to MW	27-31	10,800	6.1	66,000	50,800
EQ GW to MW	30-35	8,600	5.1	44,000	58,500
EQ GW to MW	27-32	114.8	6.1	700	824
EQ GW to VAP	[illegible]	30.1 J	5.8	180 J	167
EQ GW to VAP	35-37	<5.2	6.8	<35	14
EQ GW to VAP	25-30	<5.4	4.7	<25	13
EQ GW to VAP	40-40.5	16.2 J	6.1	98 J	93.3

EQ GW - Equivalent Groundwater Concentration
MW - Monitoring Well
VAP - Vertical Aquifer Profile Sample
* - Soil values are an average of samples collected within groundwater sample interval
** - Conversion ratio average of hydrofacies represented within groundwater sample interval

TCE Concentration

Clip hydrostratigraphic model at the water table for clarity:

3D Stratigraphic Flux



ROI – Identified complex flow pathways – focused monitoring/delineation/MNA

Key Takeaways – *Smart* Characterization

Four Key Elements of Smart Characterization
- Flux Based CSM
- Right tools
- Real-time, Adaptive
- Geologic interpretation

Key Takeaways – Geology is Critical

Real aquifers have fabric imprinted by the depositional environments

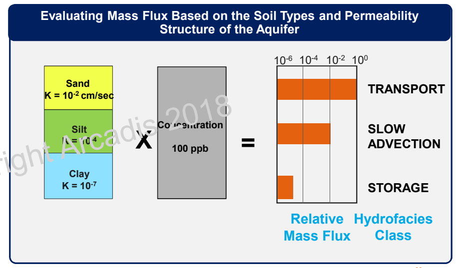
Groundwater flow is concentrated in the most permeable segments

Typically 90% of the flow occurs in 10% of the cross-sectional area

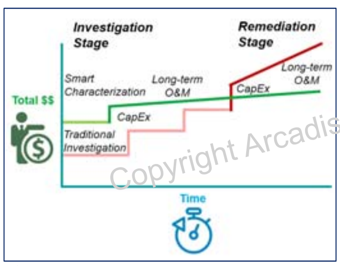
Key Takeaways – Relative flux

Build flux-based CSM by evaluating hydraulic conductivity and concentration in high-resolution

Classify hydrofacies based on transport potential



Takeaway – Smart Characterization



Better Conceptual Site Models in Less Time

Focused Remedy with Better Chance of Success

Less Cost Overall

Questions?

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