

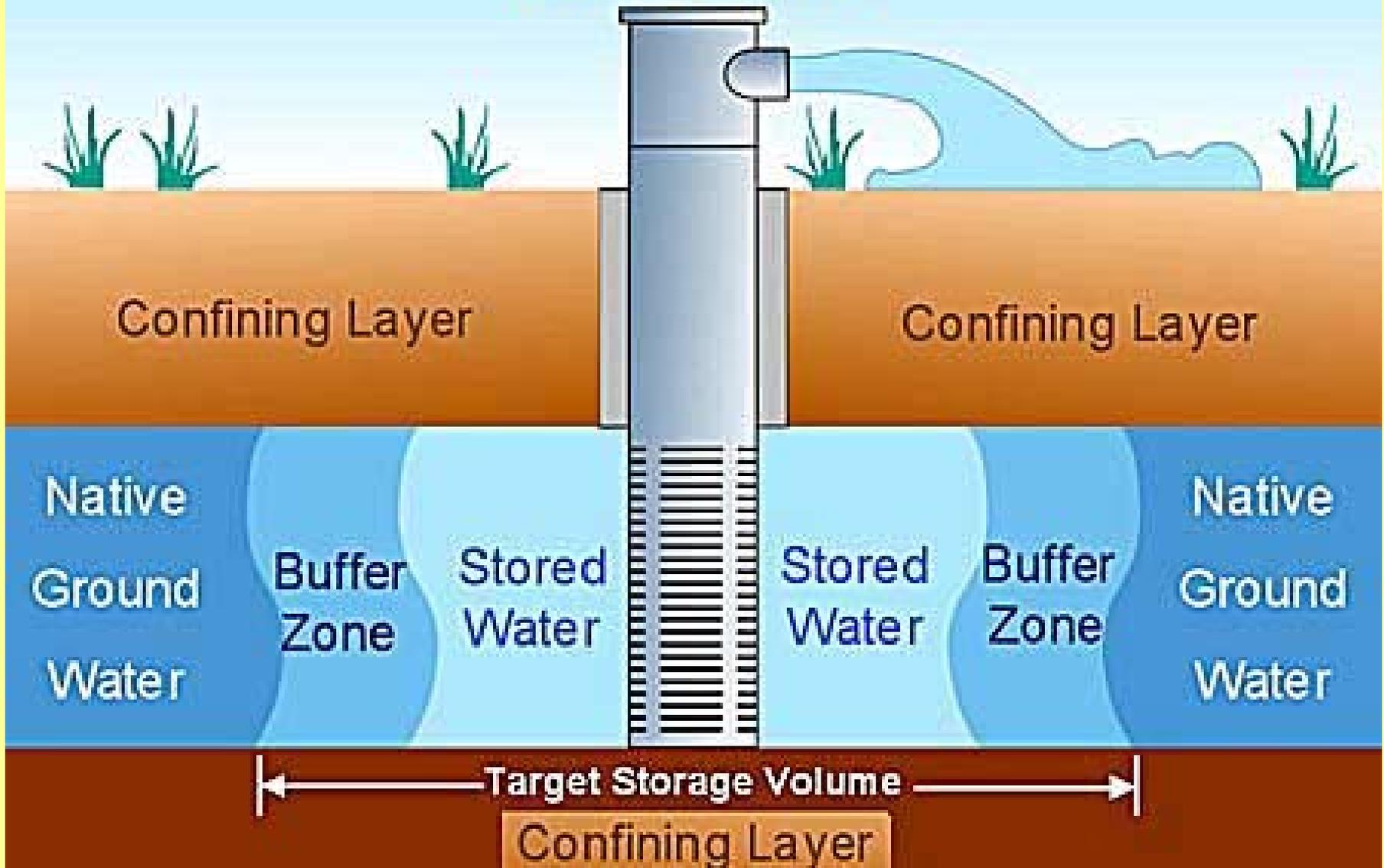
# DETERMINATION OF CHEMICAL BACKGROUND CONCENTRATIONS IN THE ENVIRONMENT IS DIFFICULT

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## ABUNDANCE AND MINERALOGICAL ASSOCIATIONS OF NATURALLY OCCURRING ARSENIC IN FLORIDA, USA

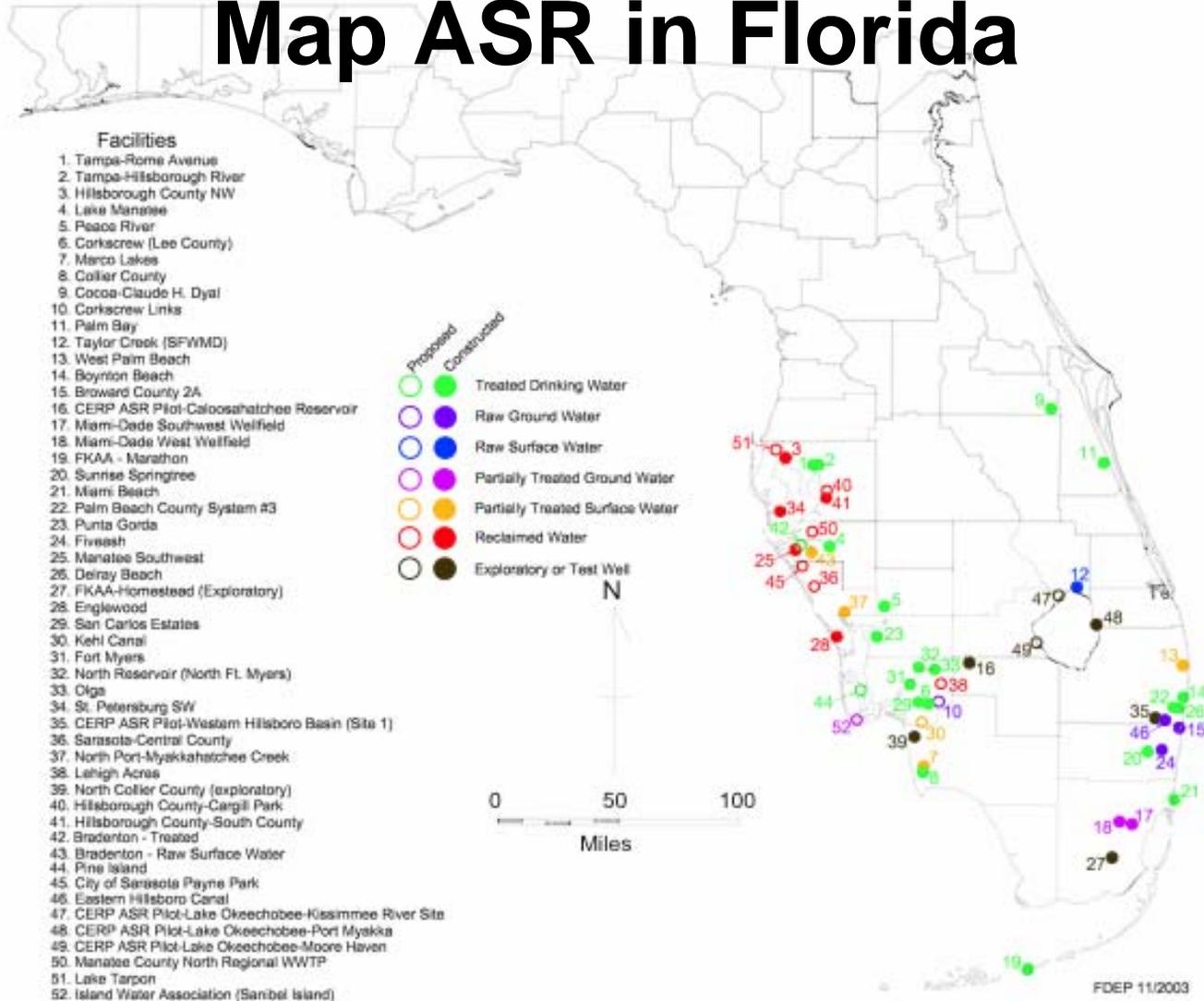


# ASR Well



# AQUIFER STORAGE AND RECOVERY FACILITIES IN FLORIDA

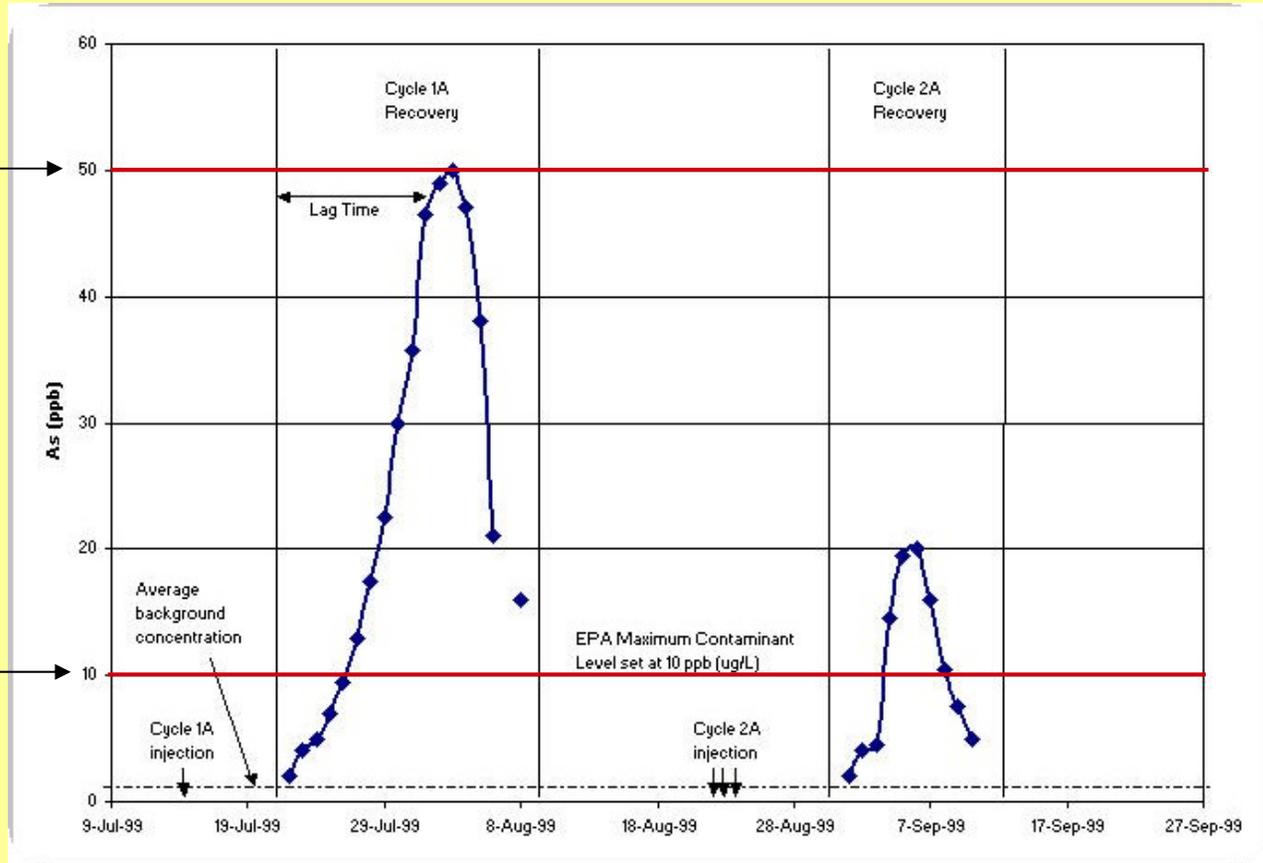
## Map ASR in Florida



# Arsenic recovery for two recharge/recovery cycles, Punta Gorda ASR

50  $\mu\text{g/L}$

10  $\mu\text{g/L}$



# WHERE IS THE ARSENIC COMING FROM?

Carbonate Minerals?

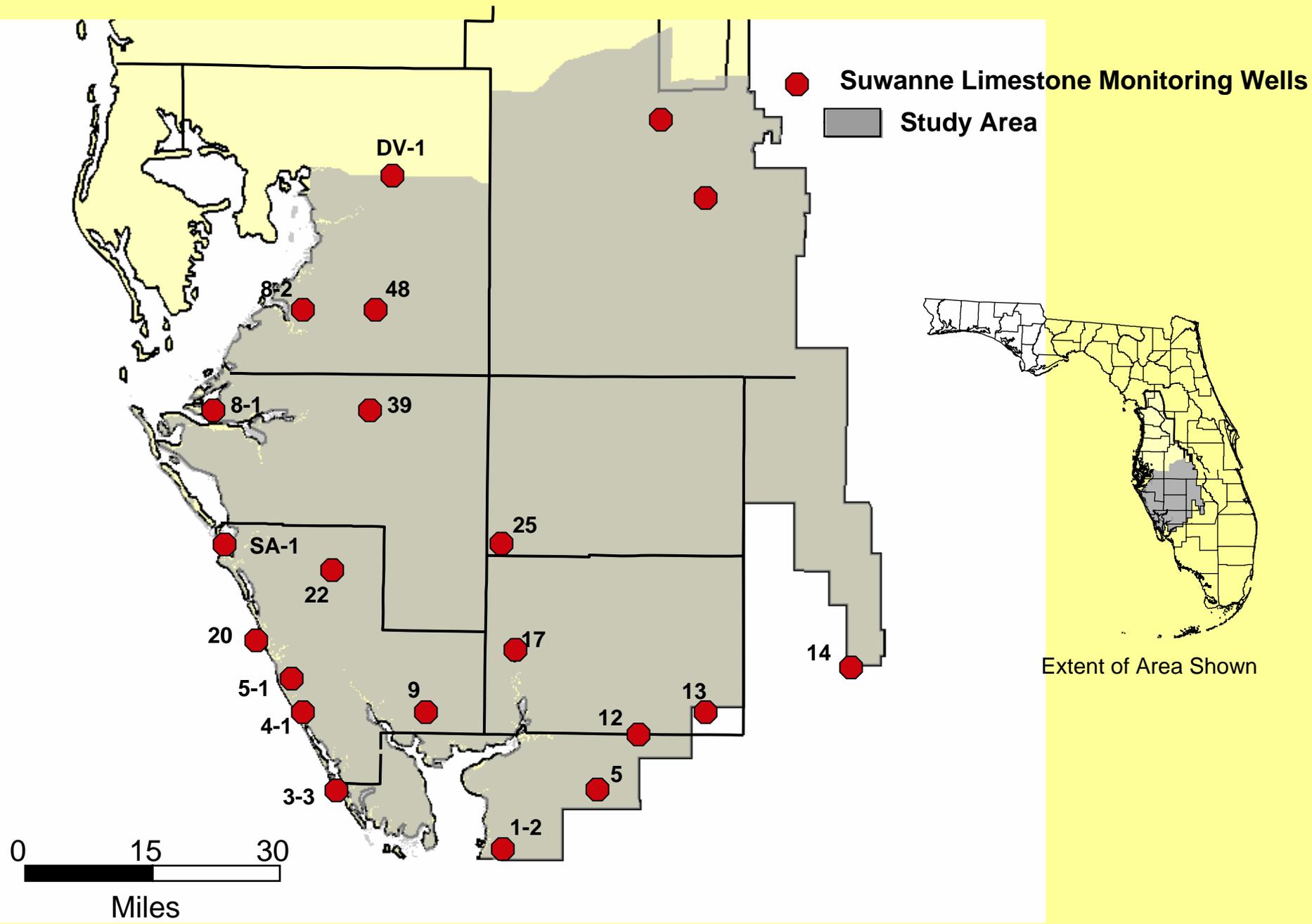
Sulfide Minerals?

Organic matter?

Iron Oxide?

Clay minerals?

## HOW MUCH ARSENIC IS THERE?



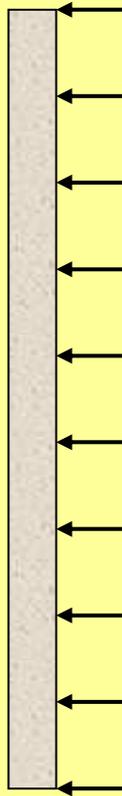
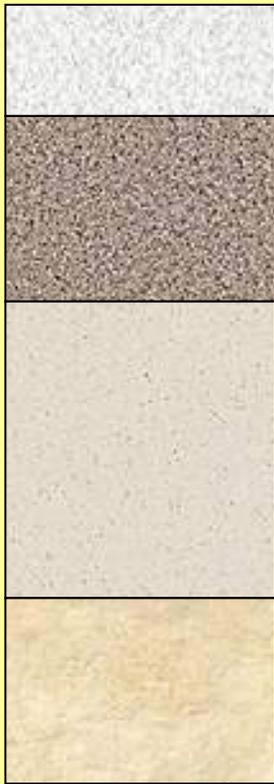
(From Price and Pichler, 2006)



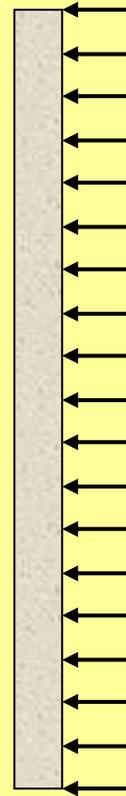
# SAMPLING STRATEGY 1

- Division of the rock sequence into fixed sampling intervals
- Sampling intervals depend on thickness of rock sequence and other factors, such as, how many samples can be taken, how many samples should be taken, how many samples can be analyzed.

# EXAMPLE



?



??

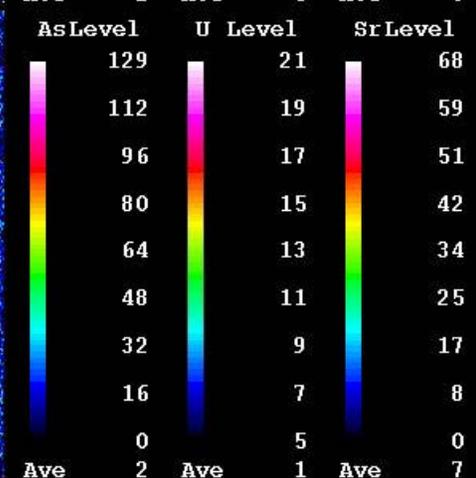
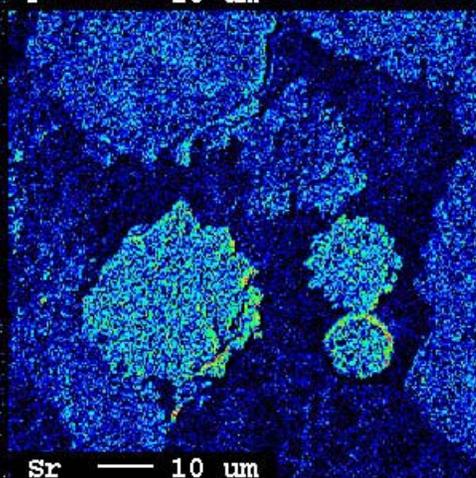
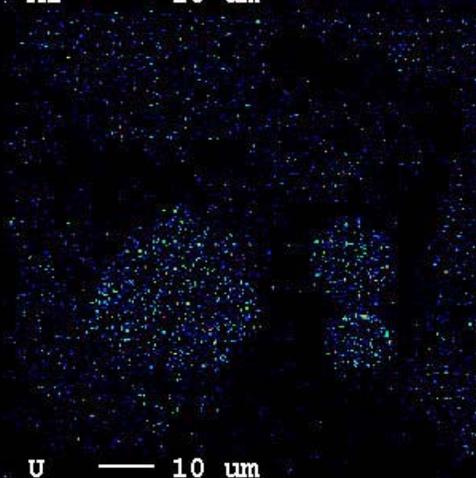
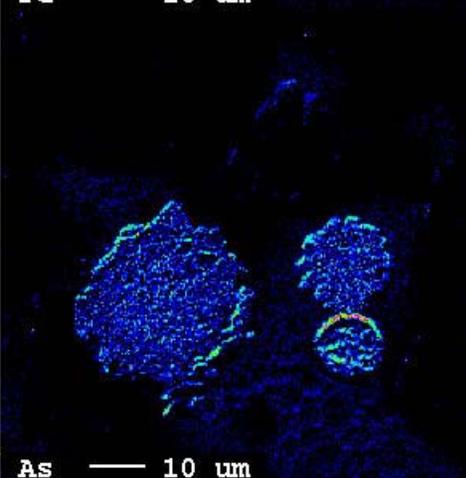
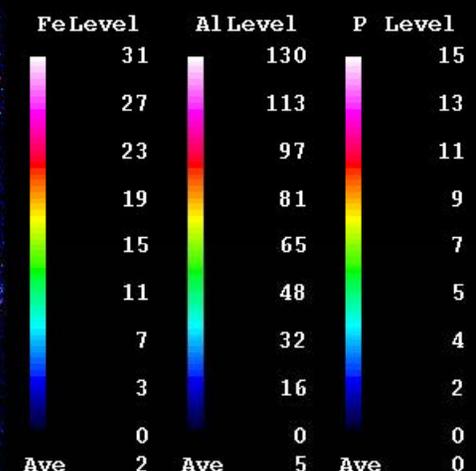
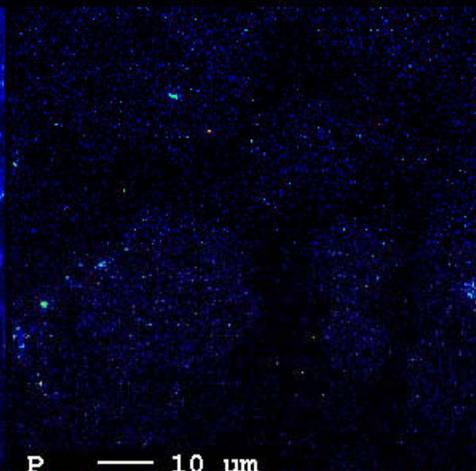
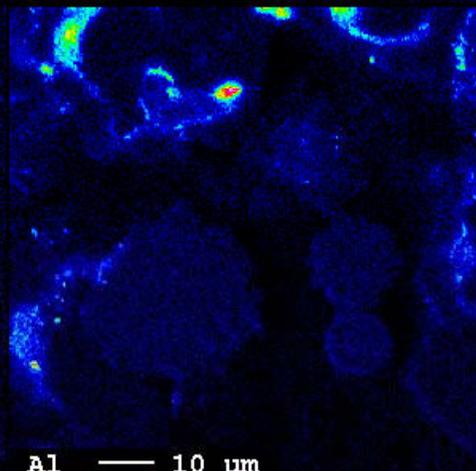
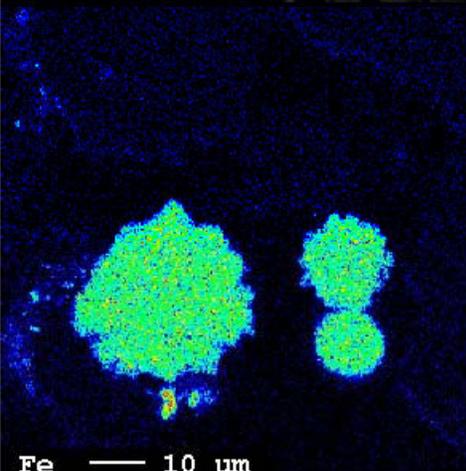
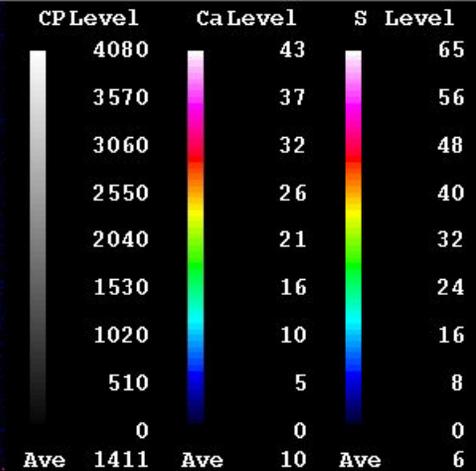
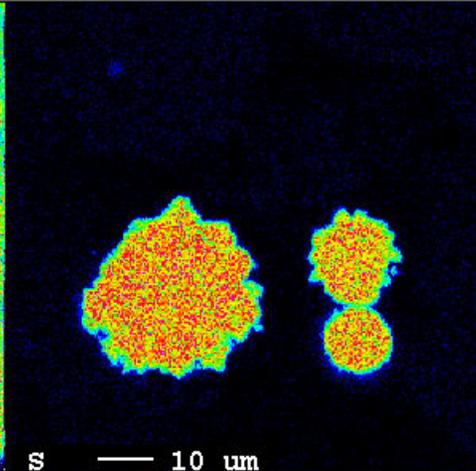
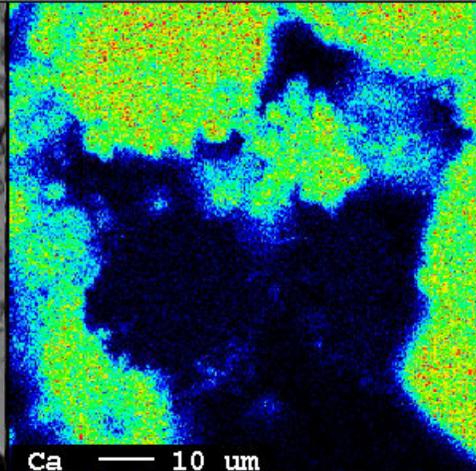
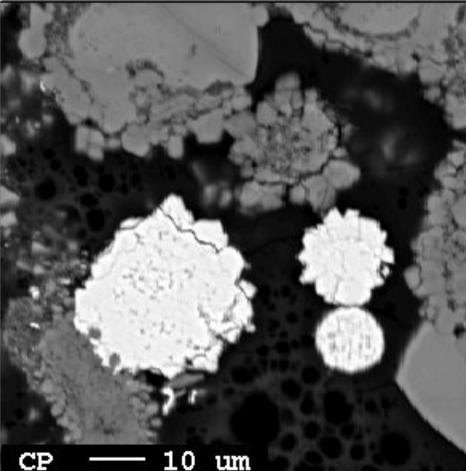


## SAMPLING STRATEGY 2

- Careful examination of core for areas that are unusual
- Sampling intervals depend on heterogeneity of rock sequence and other factors, such as, how many samples can be taken, how many samples should be taken, how many samples can be analyzed.

QuickTime™ and a  
TIFF (Uncompressed) decompressor  
are needed to see this picture.

**2000 X**



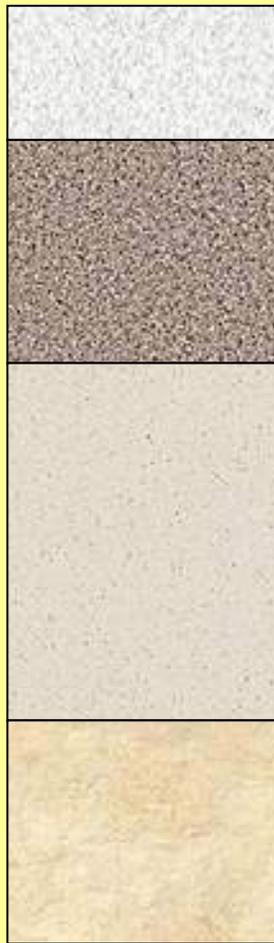
## SAMPLING STRATEGY 3

- A combination of interval and targeted samples
- Sampling intervals depend on thickness and heterogeneity of rock sequence and other factors, such as, how many samples can be taken, how many samples should be taken, how many samples can be analyzed.

**STRATEGY 1**

**STRATEGY 2**

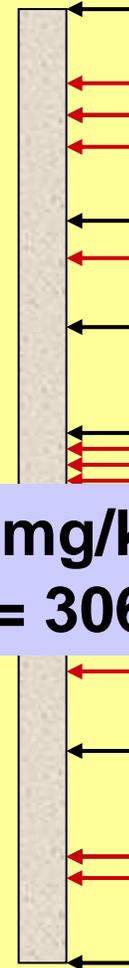
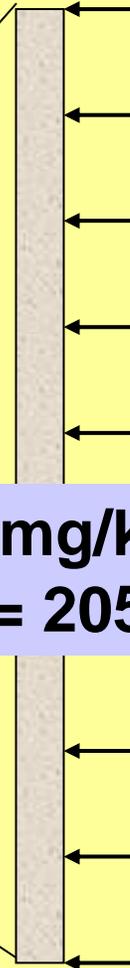
**STRATEGY 3**



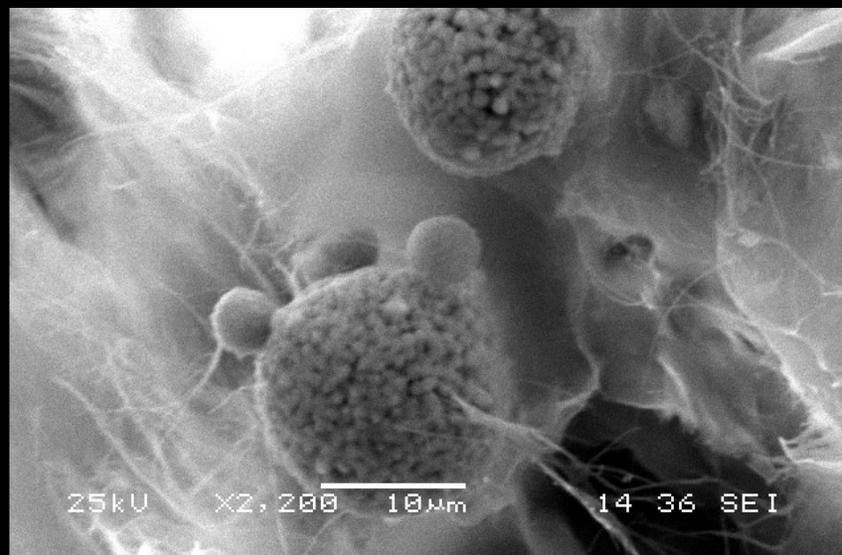
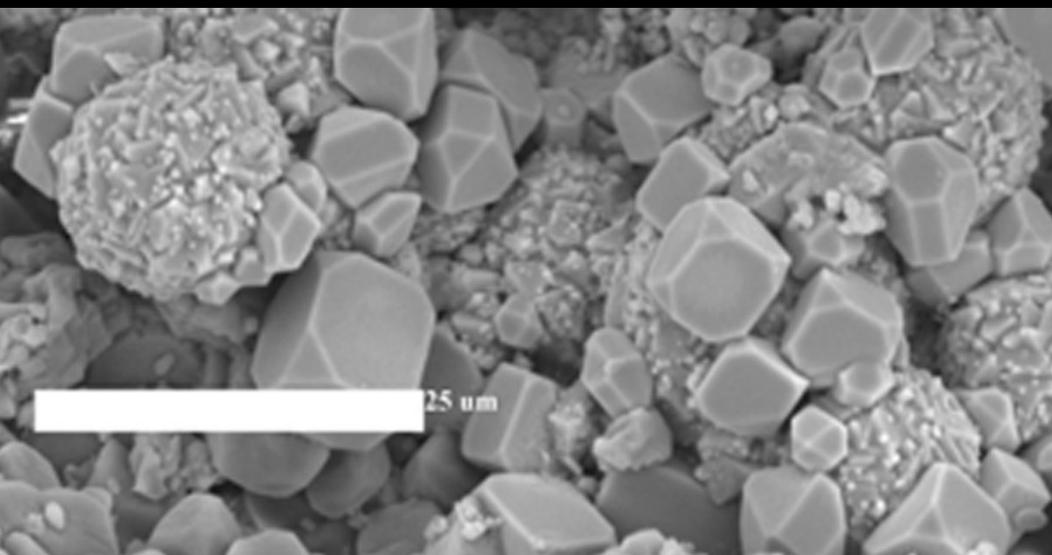
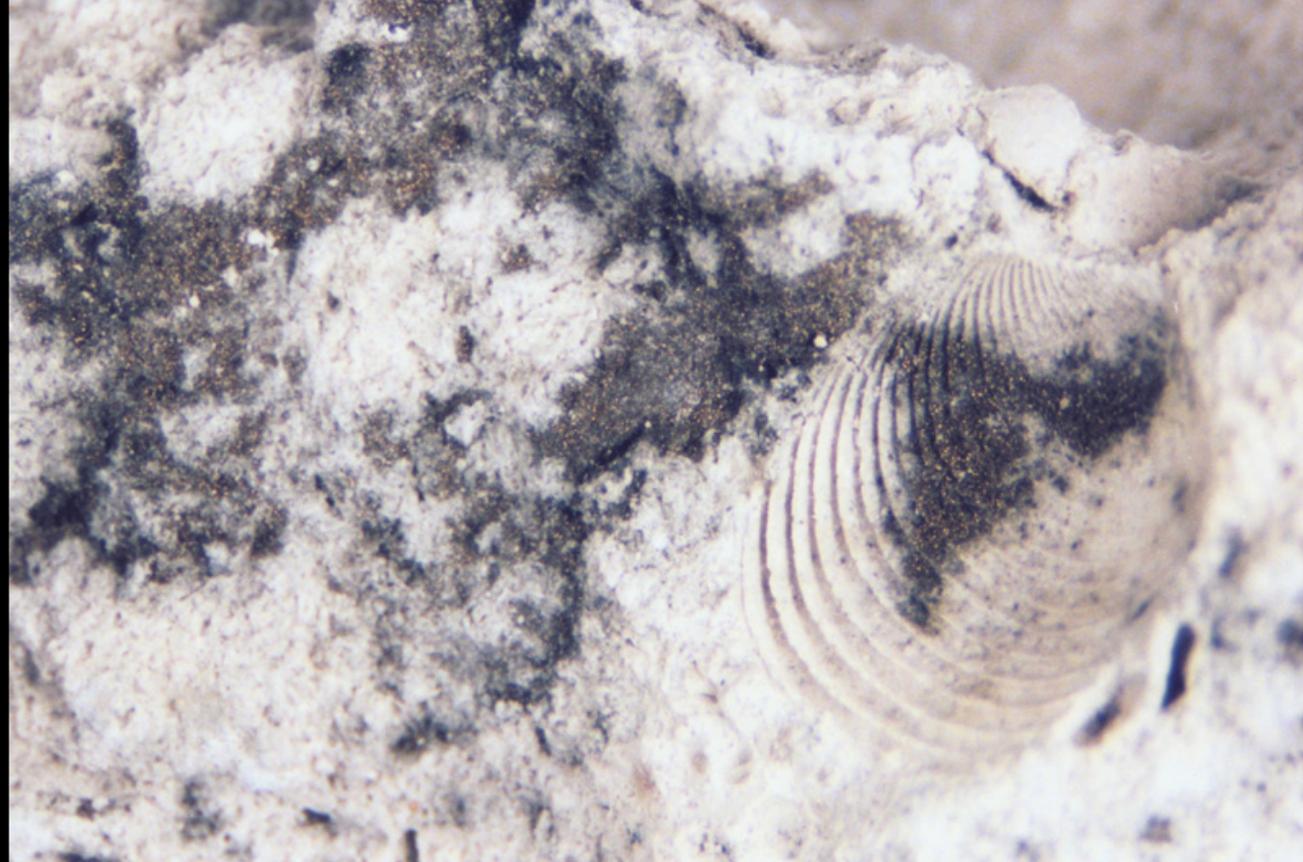
**1.7 mg/kg  
n = 205**

**9.5 mg/kg  
n = 101**

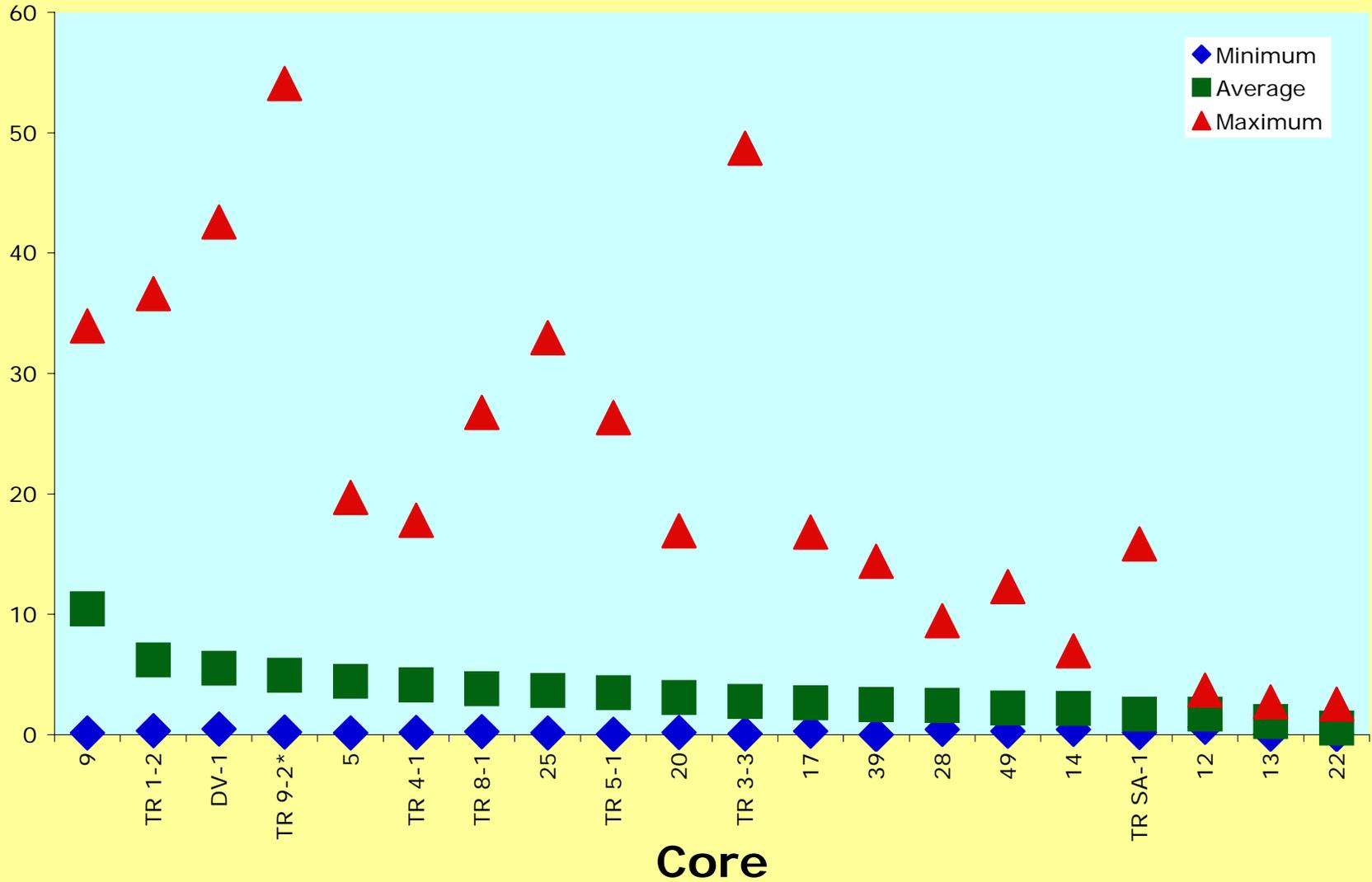
**3.5 mg/kg  
n = 306**



DV-249



# Average, Minimum and Maximum As Concentrations for Individual Cores



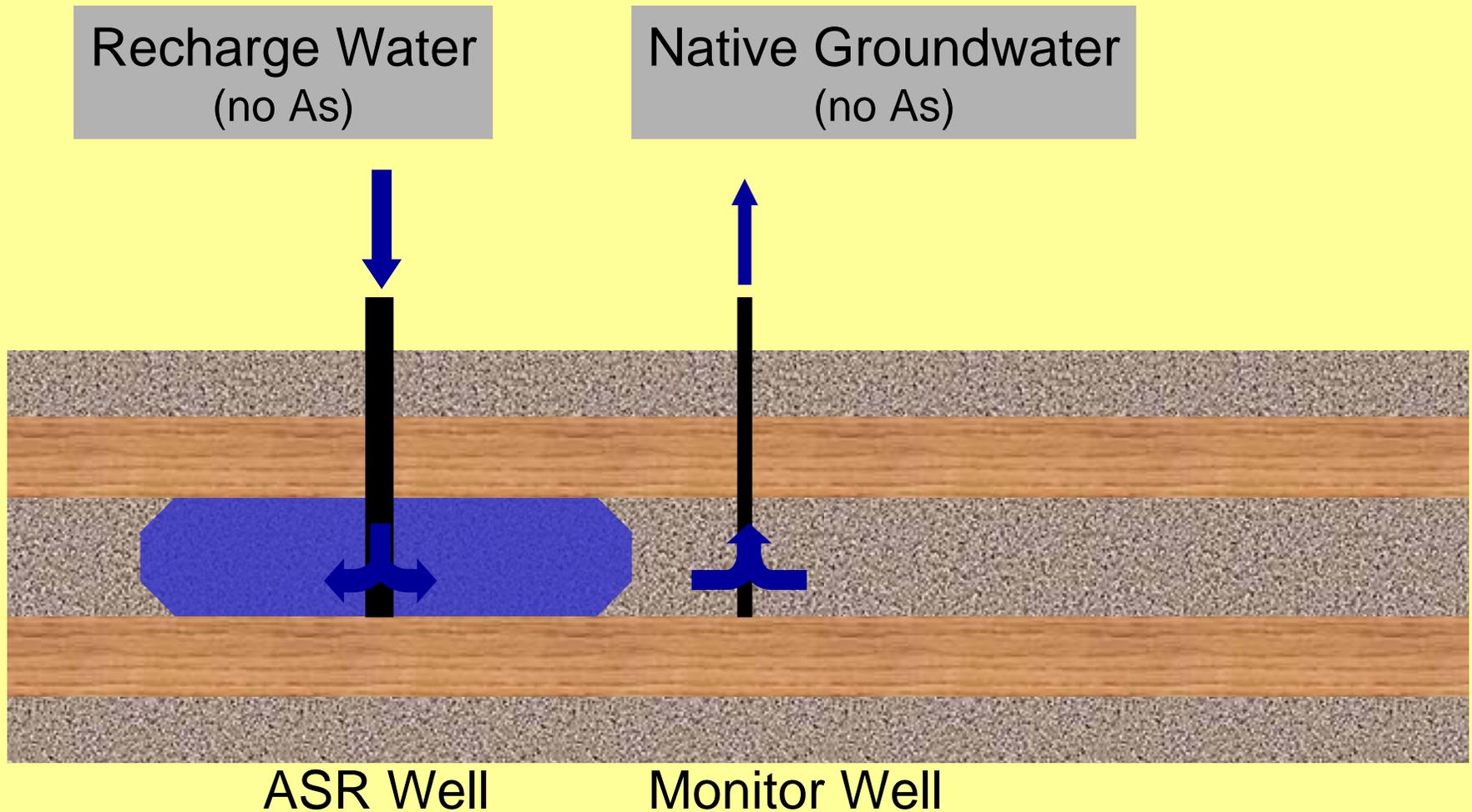
# THINGS WE KNOW

- Pyrite is the source of elevated As.
- Arsenic ubiquitous, but mostly in low concentrations.
- Arsenic associated almost exclusively with “targeted” samples
- Pyrite is not homogeneously distributed in the aquifer matrix and arsenic is not homogeneously distributed in pyrite.
- Pyrite is not stable in contact with the injected water.

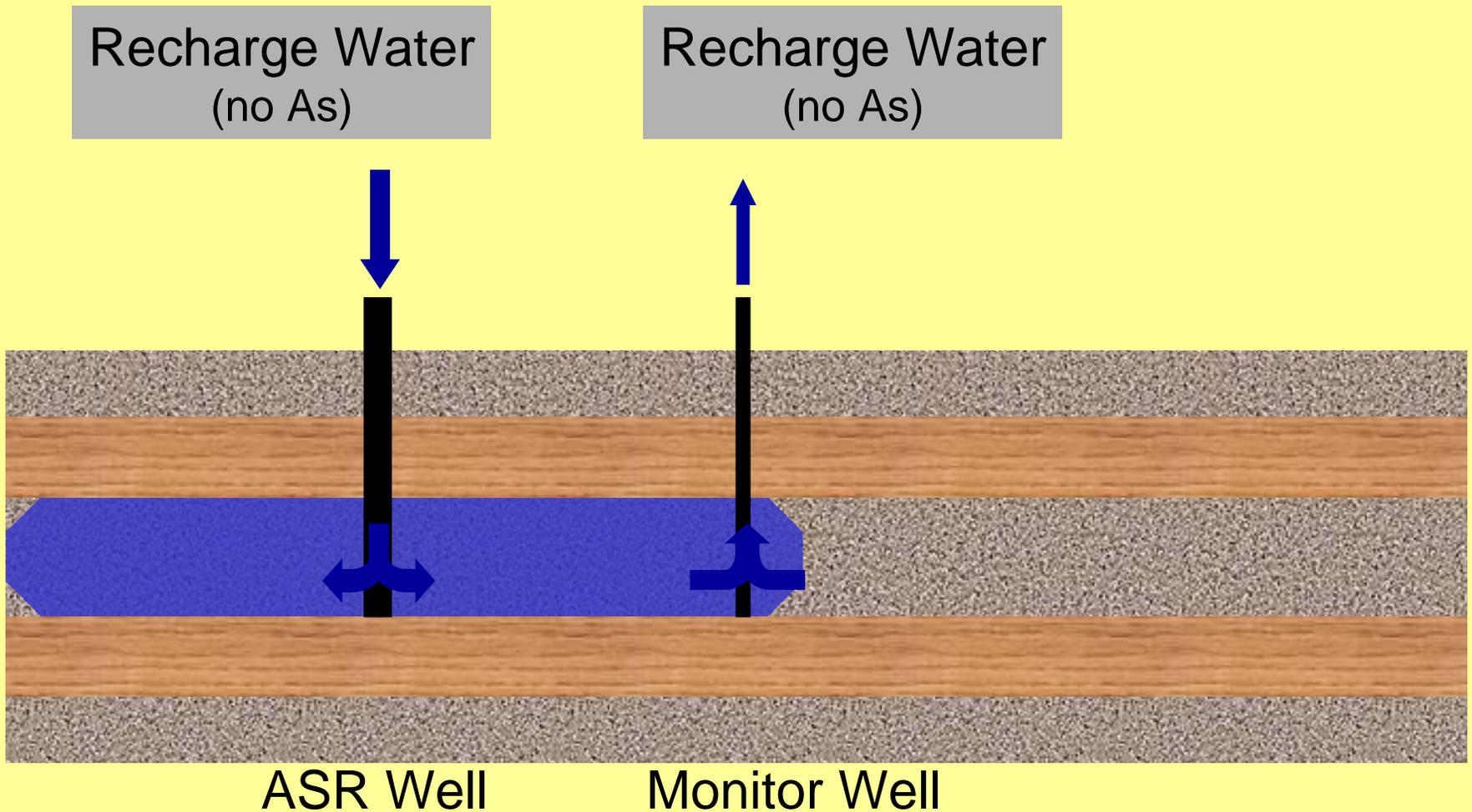
# **Why do we want/need to know?**

- **Where is the arsenic leached from the aquifer matrix?**
- **Could we remove the arsenic from the storage zone?**

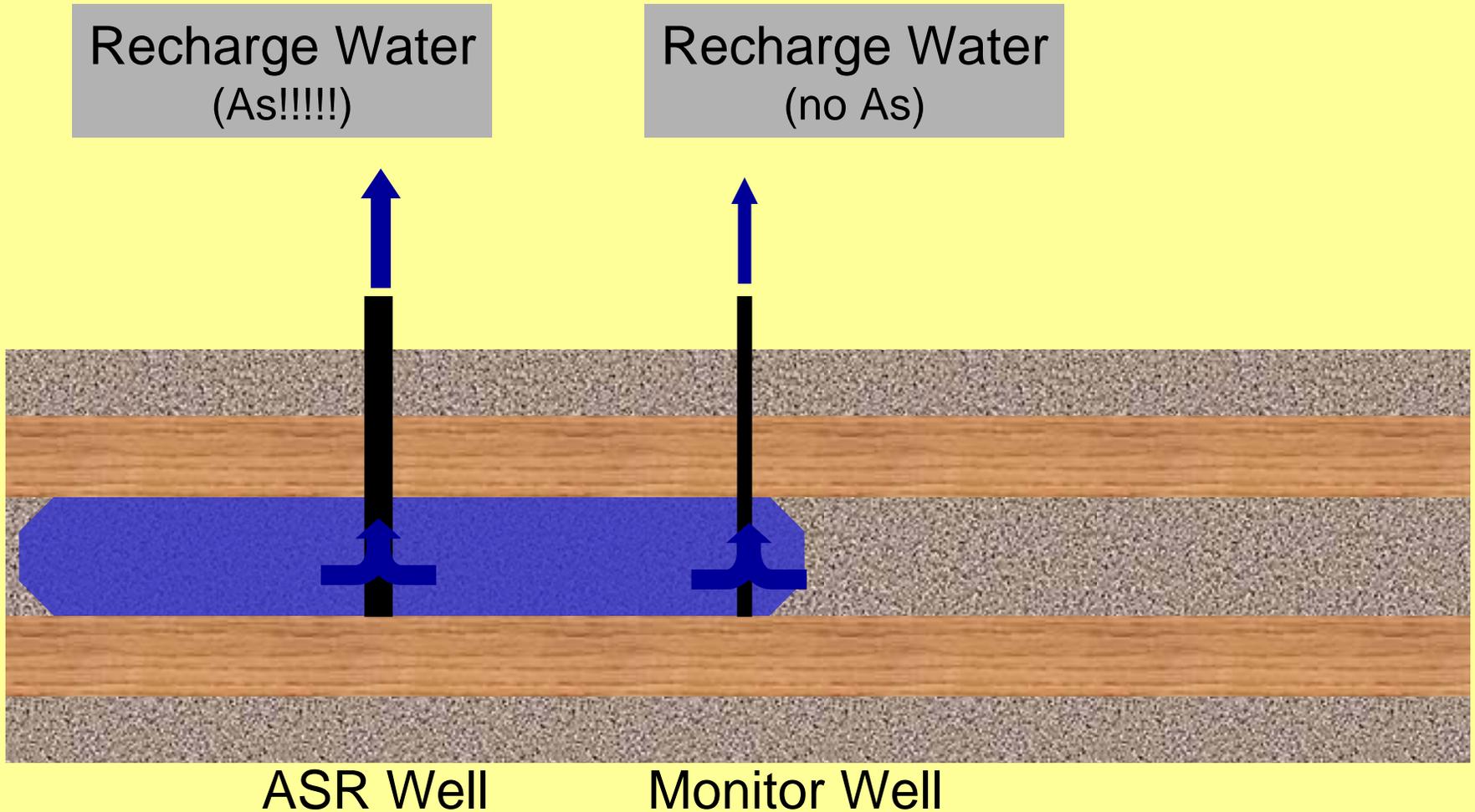
# Example: As behavior during ASR operation



# Example: As behavior during ASR operation



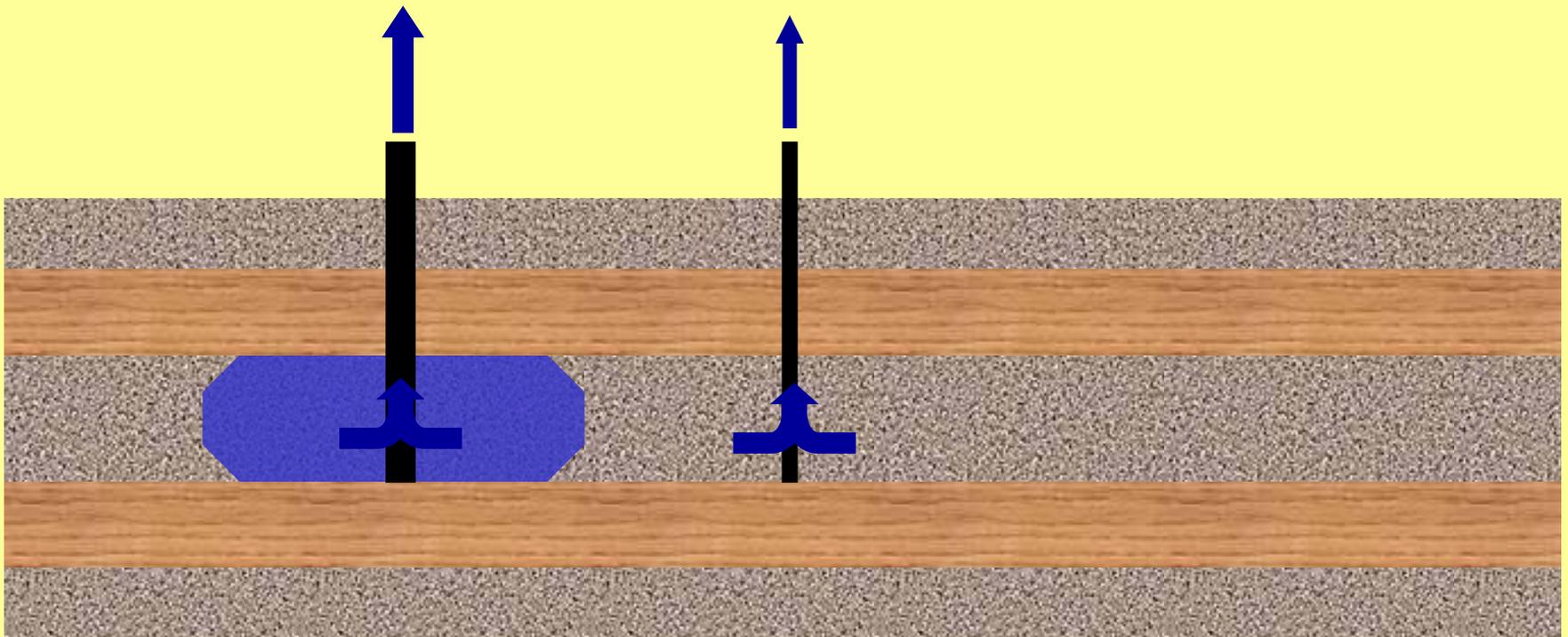
# Example: As behavior during ASR operation



# Example: As behavior during ASR operation

Recharge Water  
(As!!!!!!)

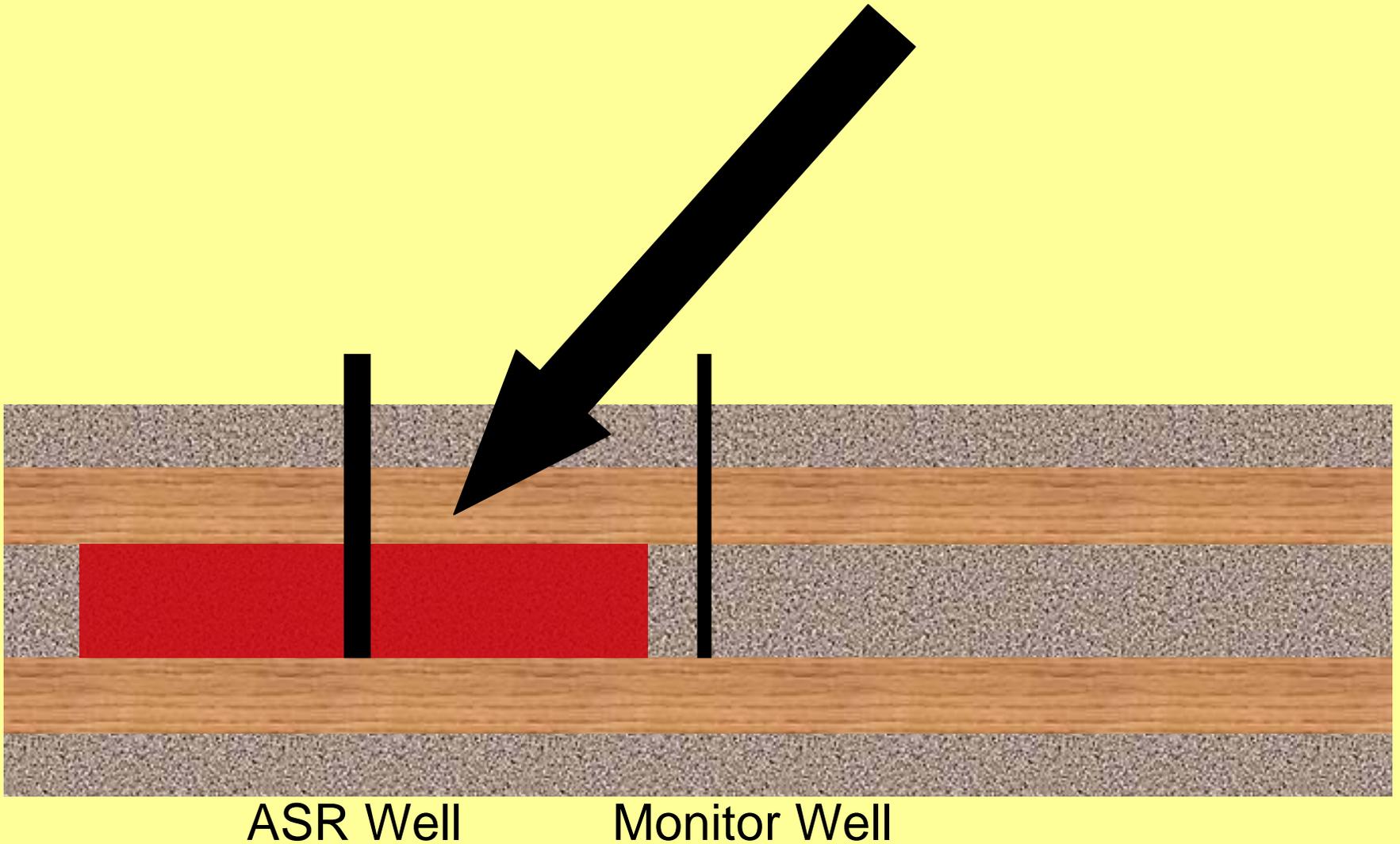
Native Groundwater  
(no As)



ASR Well

Monitor Well

**Answer: As is leached close to the ASR well??**



# Unfortunately the answer is no!

$$\% \text{ As released} = \frac{\text{As}(\mu\text{g/L}) * \text{porosity}}{C_{\text{As}}(\text{mg/kg}) * D(\text{g/cm}^3) * (1 - \text{porosity}) * 10}$$

$$C = 3.5 \text{ mg/kg}$$

$$D = 2.7 \text{ g/cm}^3$$

$$\text{porosity} = 0.3$$

$$\text{As (10 } \mu\text{g/L)} = 0.09 \%$$

**> 1000 Pore Volumes**

## WHAT DID WE LEARN?

**NATURE IS ALWAYS MORE  
COMPLICATED THAN WE THINK!**

**LOW-ARSENIC ROCKS CAN  
MAKE HIGH-ARSENIC WATER**

# WHAT WOULD I DO

- Start simple
- Quickly adapt an initial value(s)  
“An imperfect value is better than no value”
- Make errors on the safe side
- Allow the system to be dynamic -  
constant revisions

# Acknowledgments

- Roy Price
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