In situ Selenium Control: results of field lysimeter study

West Virginia Mine Drainage Task Force

26 March 2013

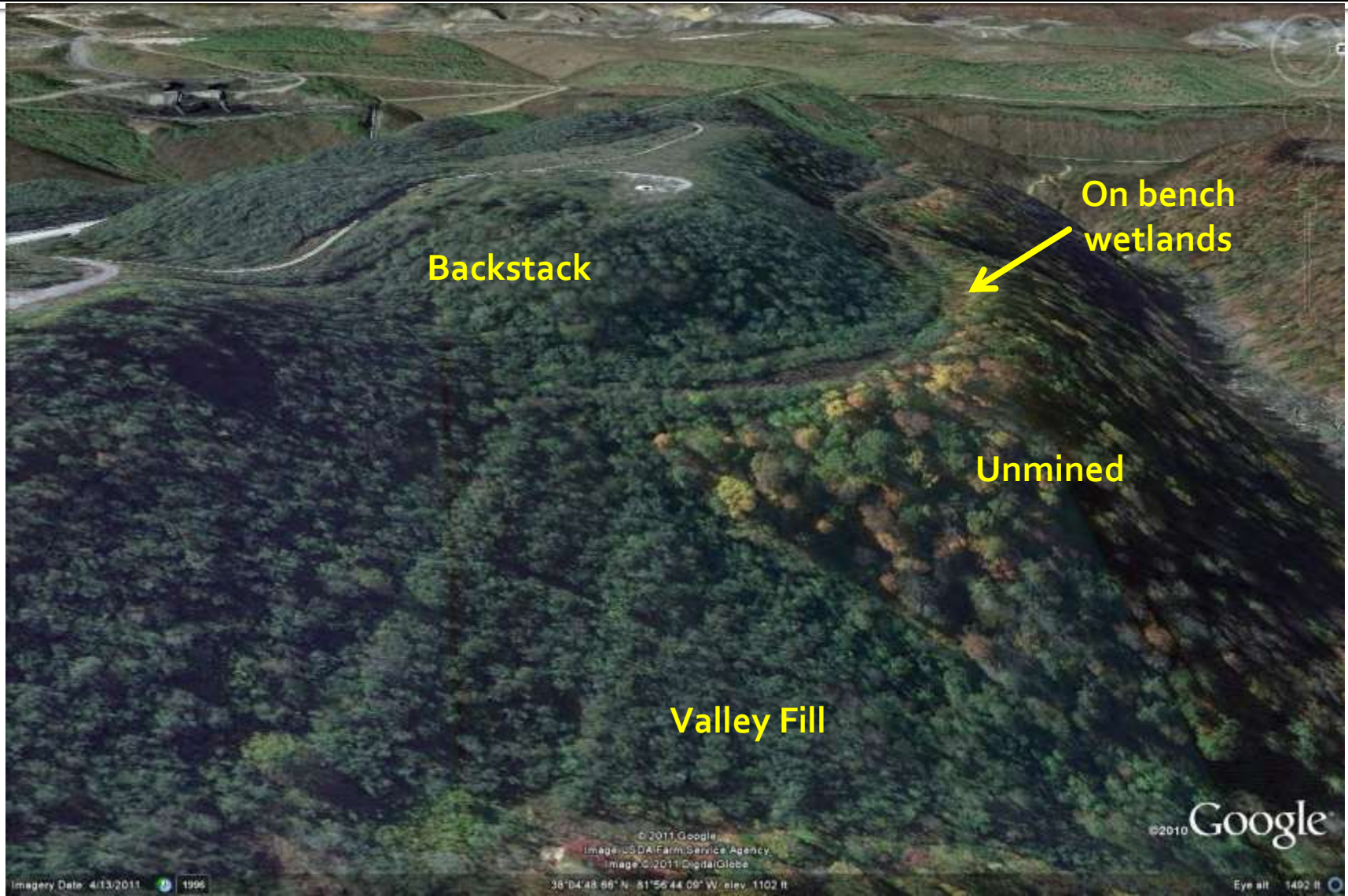**Paul Ziemkiewicz**
Joe Donovan
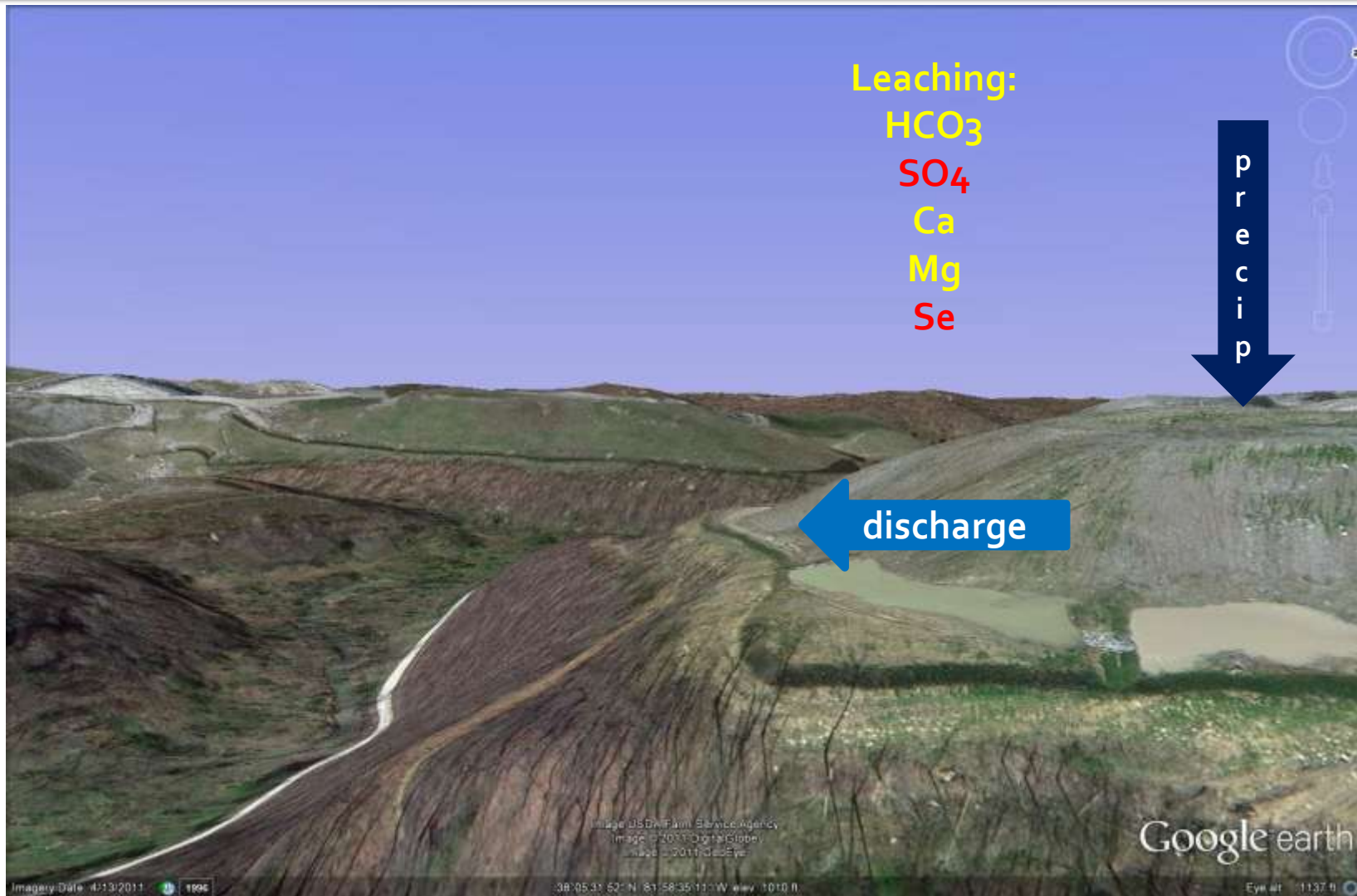West Virginia University Water Research Institute
Morgantown WV

Typical mountaintop mine:
Oldest mining (1985) in foreground
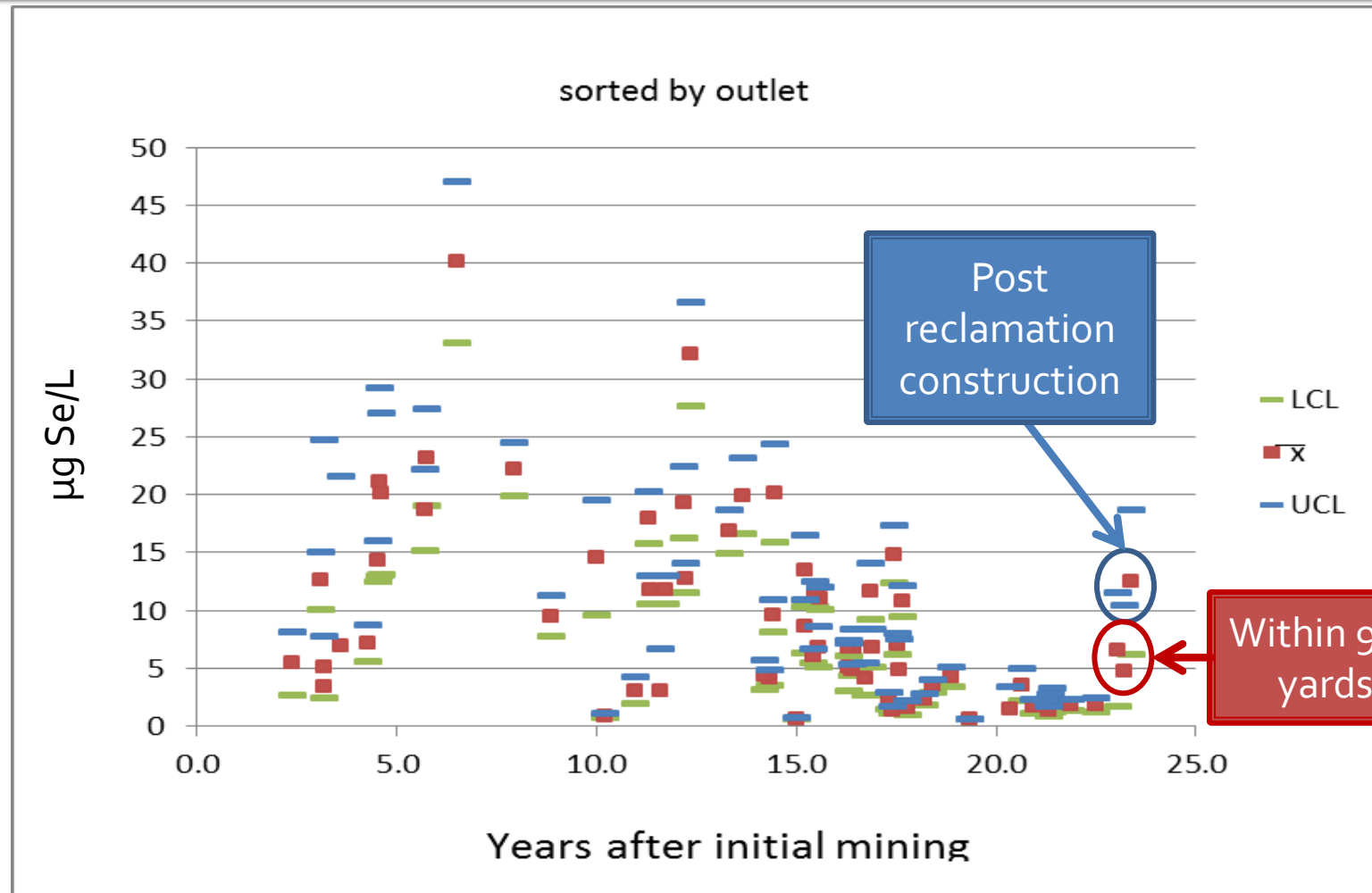
Mountaintop mining: Nomenclature

Southern WV mountaintop mining: Infiltration, leaching and discharge

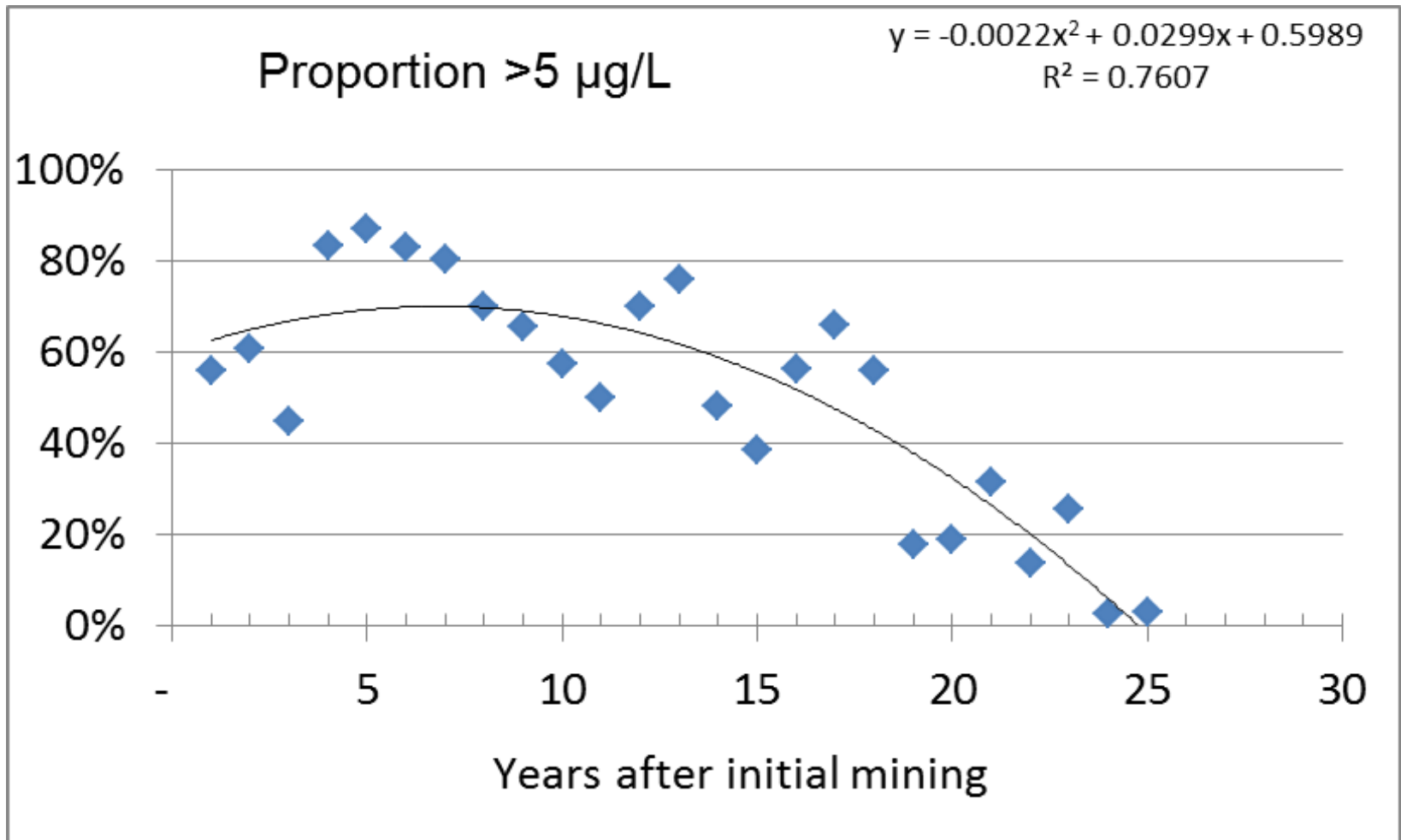Leaching:
HCO$_3$
SO$_4$
Ca
Mg
Se

precip

discharge

5,388 data points sorted by permit-95% confidence intervals

sorted by outlet

5,388 data points sorted by age class-95% confidence intervals

Field observations sorted by age class
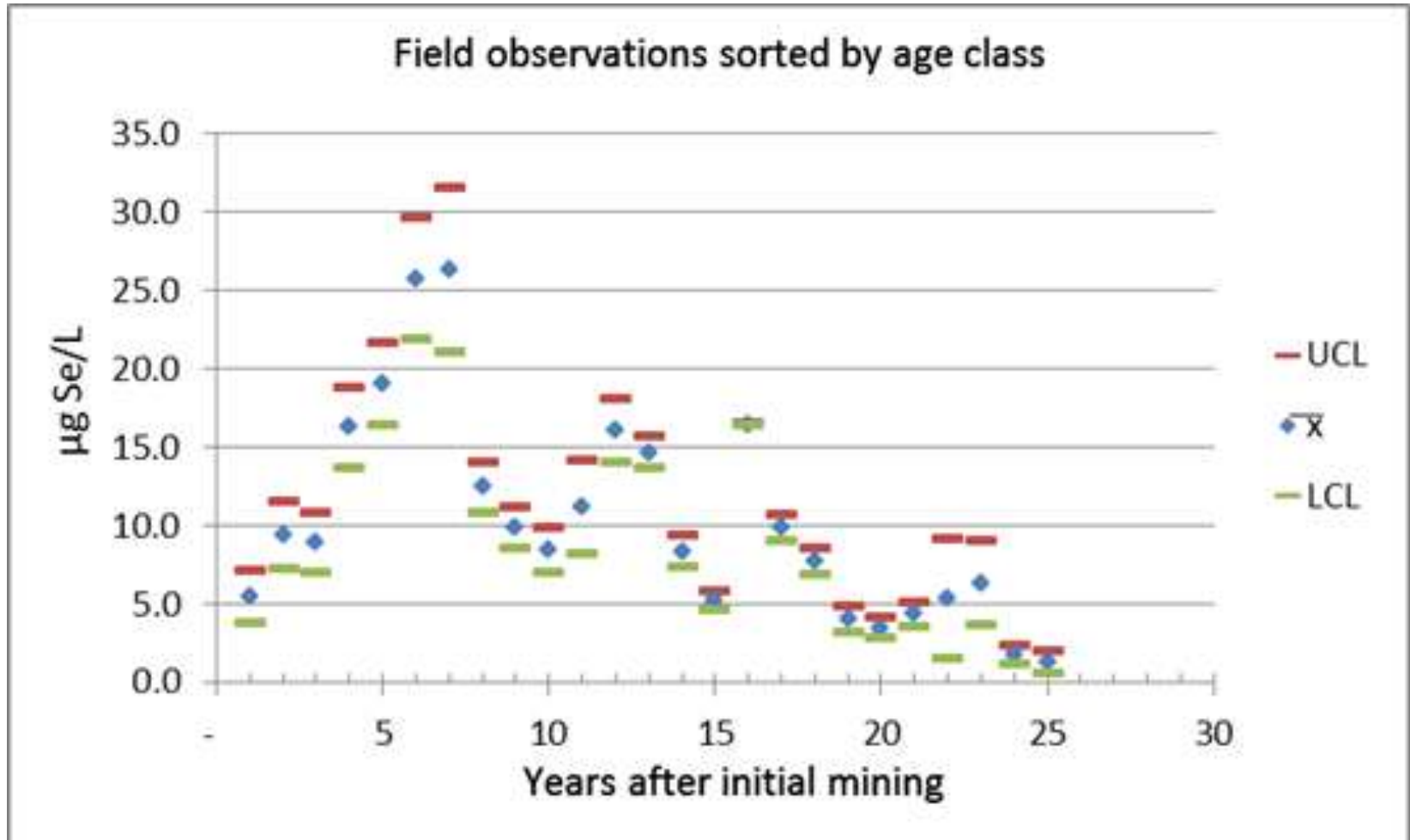
97% of outlet samples were in compliance by year 25

Lab study: FeOOH removed about 40% of selenium
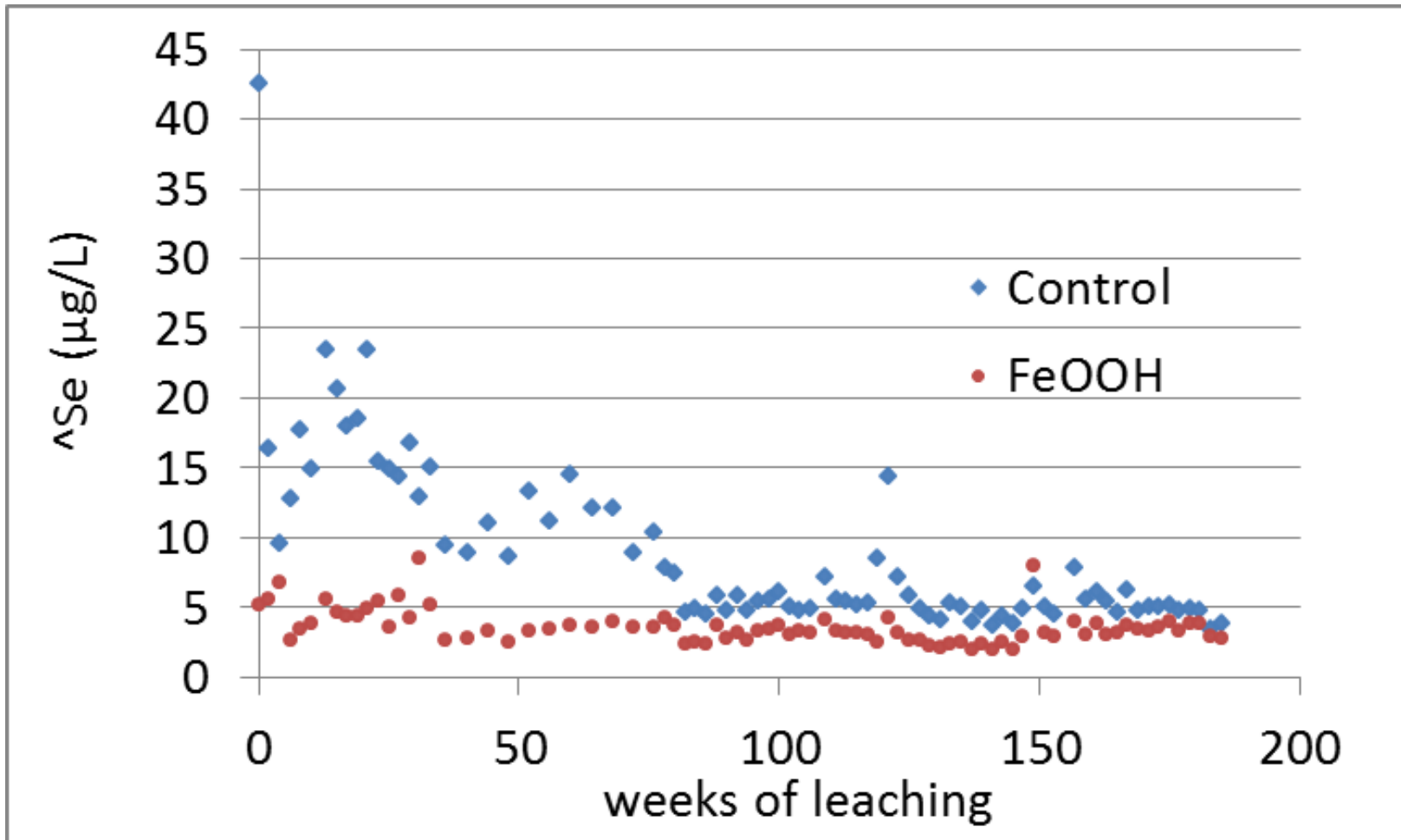
Selenium weathering model

Overburden   **Mine Spoil**   **Discharge**

25-40% inorganic Se

Se^{2-}, Se^0? oxidation

Mobile forms: SeO_3^{2-} oxidizes to SeO_4^{2-} (slow)

Leaching

Mobile selenium SeO_3^{2-}, SeO_4^{2-}

60-75% organically bound and other immobile Se forms

Internal seques-tration e.g. SeO_3^{2-} + FeOOH

Not subject to oxidation/ mobilization

Immobile selenium

What can be done to enhance FeOOH Sequestration?
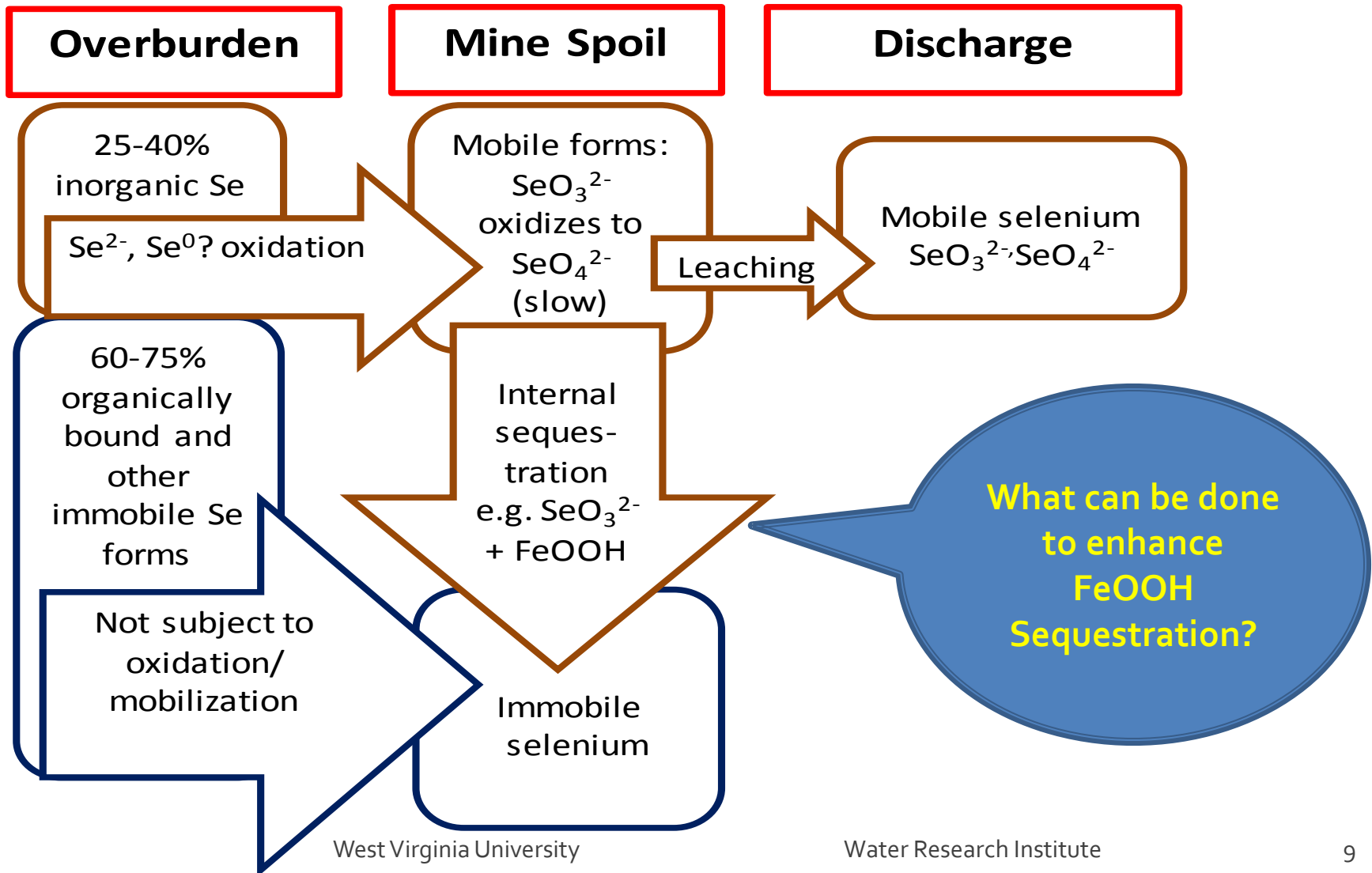
In situ Selenium Control: two year results

30 x 60 ton lysimeters at Hobet 21

What is a lysimeter?
A very large, outdoor humidity cell
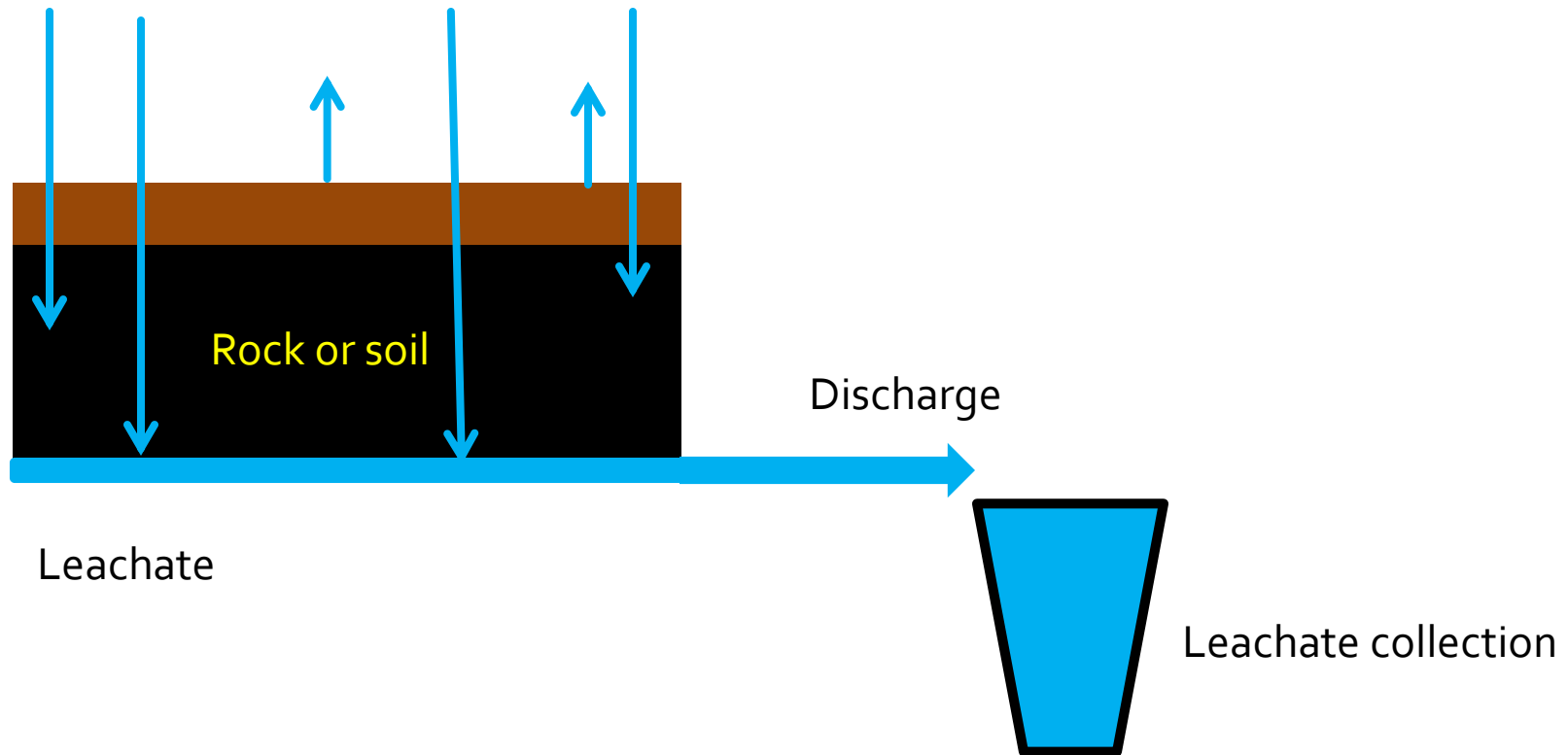
Natural or induced precipitation
and evaporation/transpiration

Rock or soil

Discharge

Leachate

Leachate collection

Lysimeter layout and cross section
16 x 24 x (4-6) ft

ferrihydrite storage

lysimeter cells

underdrains

tank gallery

a)

rear wall

7.3 m

51 mm PVC drain

to tanks

4.9 m
front wall

b)

topsoil

waste rock
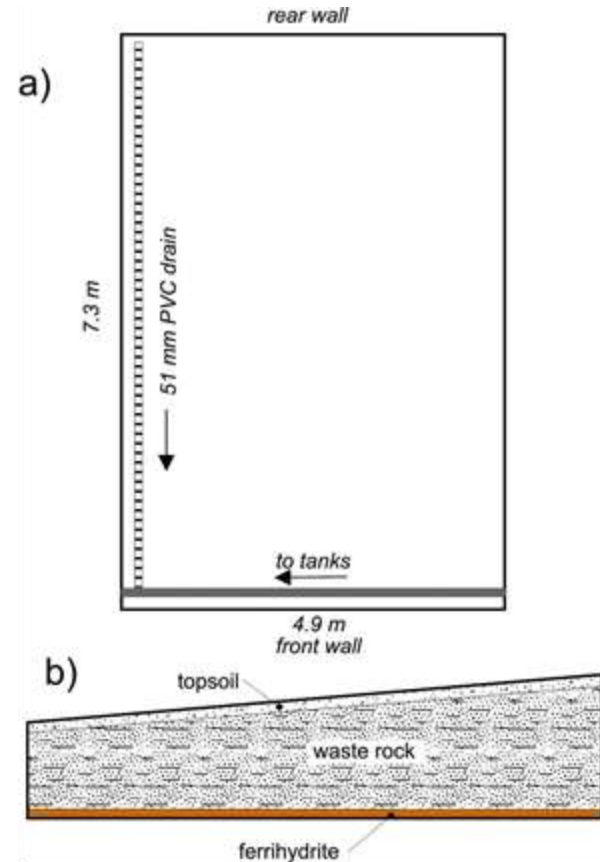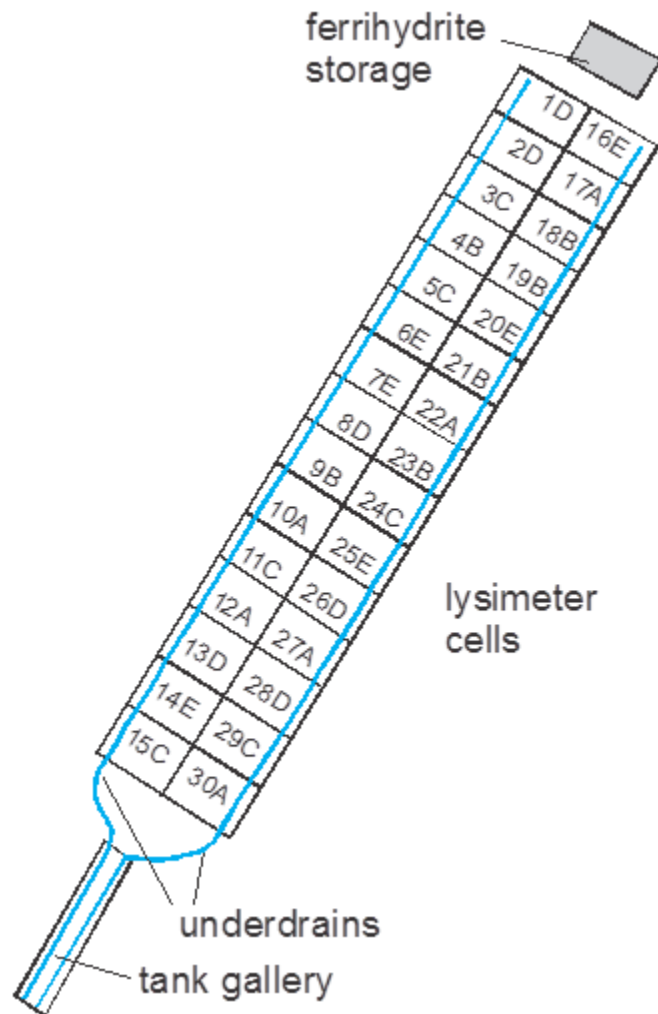
ferrihydrite

Ferrihydrite layer for Se sorption

Treatment:
- A – control (0%) ferrihydrite (6 lysimeters)
- B – 0.25 in. (0.2%) ferrihydrite (6 lysimeters)
- C – 2.25 in. (1.5%) ferrihydrite (6 lysimeters)
- D – 9 in. (6%) ferrihydrite (6 lysimeters)
- E – 18 in. (12%) ferrihydrite (6 lysimeters)

Lysimeter showing plastic liner and drain line

Placing organic shale over ferrihydrite

Leachate collection tanks

Results after two years

Treatment
FeOOH layer thickness:

A - control
B - 0.25 in.
C - 2.25 in.
D - 9 in.
E - 18 in.
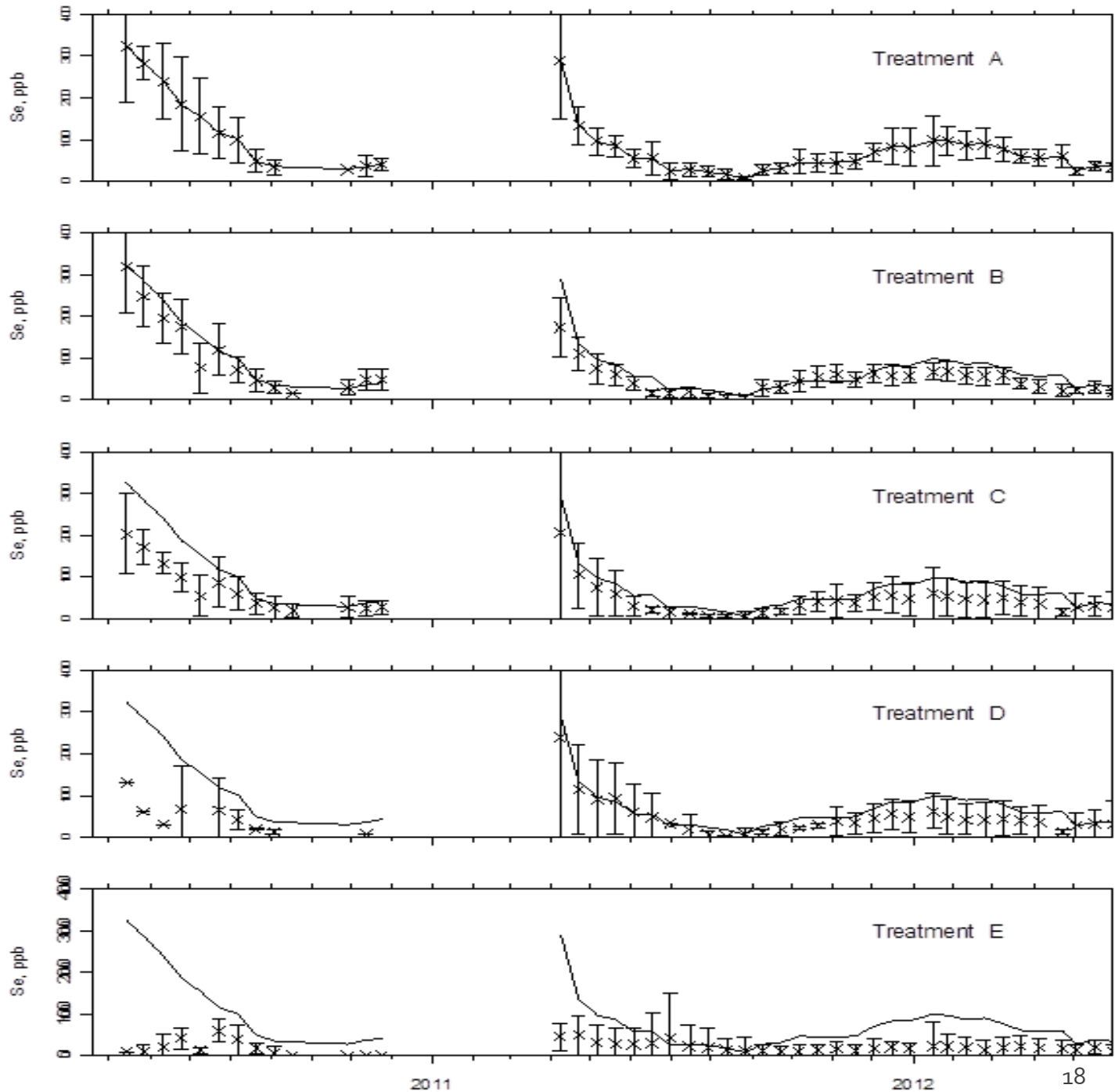
Cumulative Se removal
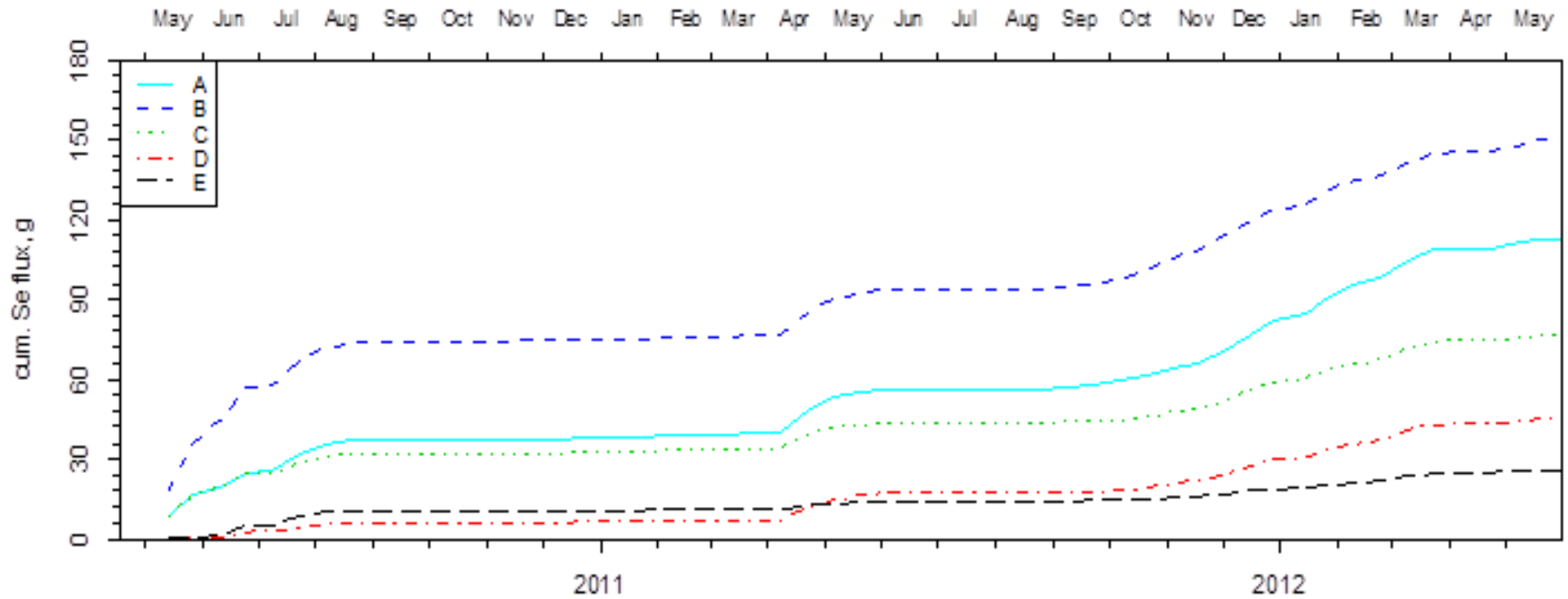
FeOOH layer thickness				
0 in.	0.25 in.	2.25 in.	9 in.	18 in.

	0 in.	0.25 in.	2.25 in.	9 in.	18 in.
avg Se conc	83	66	52	45	20
% Se removal		20%	37%	45%	76%

In situ Selenium Control: Practical implications

Selective Handling with FeOOH Addition

Southern WV mountaintop mining: Infiltration, leaching and discharge

Leaching:
HCO$_3$
SO$_4$
Ca
Mg
Se

precip

discharge
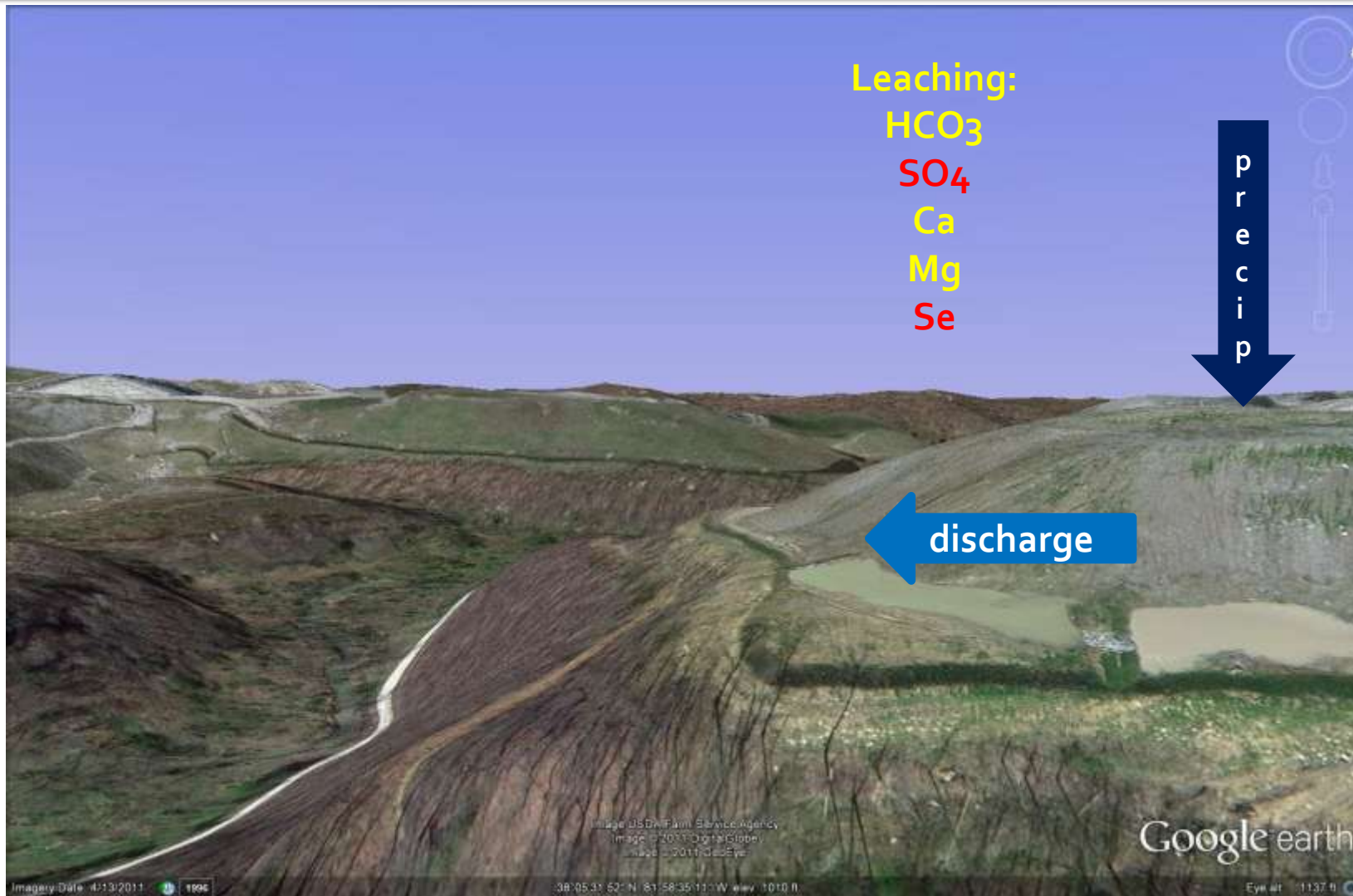
X-sec. Backfill showing special handling cell over ferrihydrite layer

Special handling cell for AMD control

Precipitation

organic shale

Estimated FeOOH required per permit with three selective handling cells

FeOOH Requirement

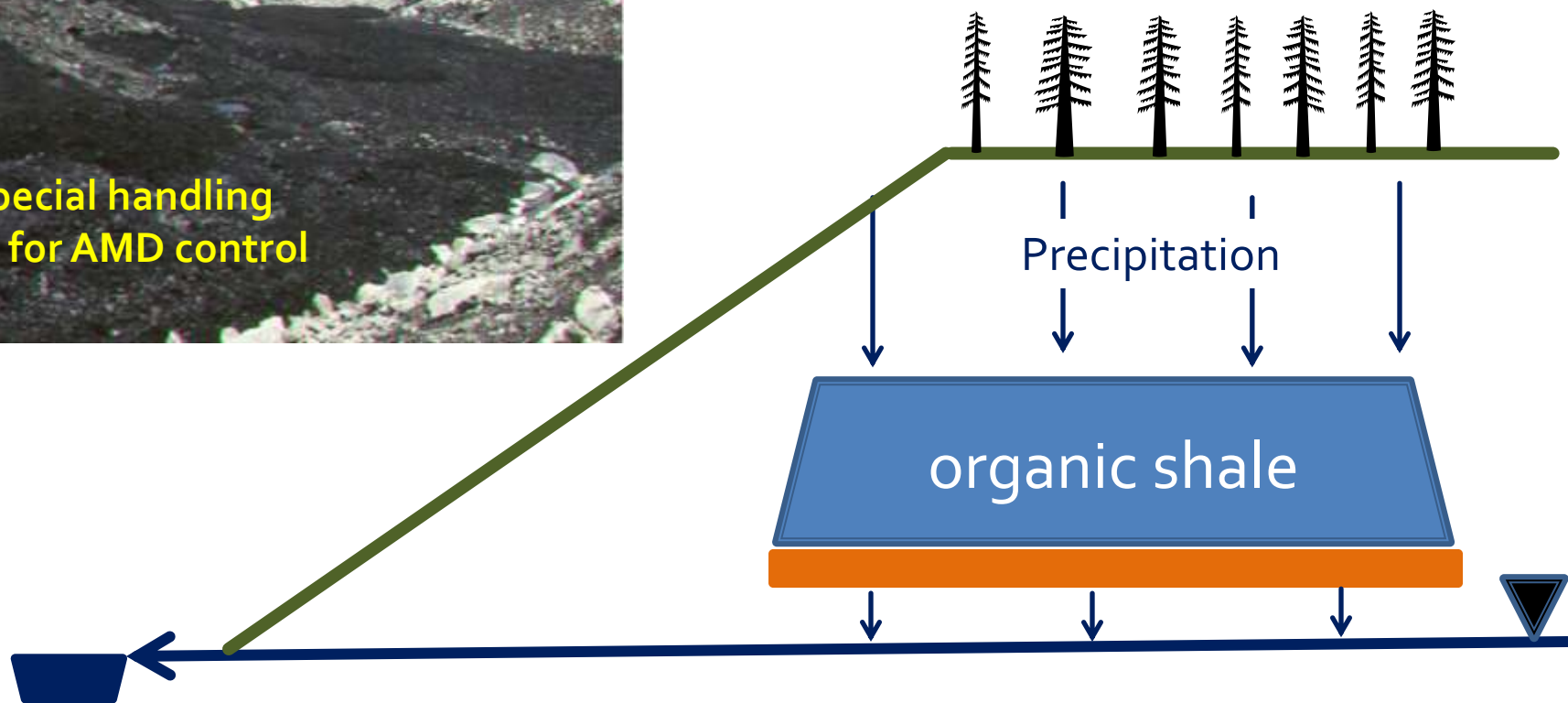|		
permit area	150	ha
permit area	371	ac
	19.3	ac squared
coal thickness	8	ft
OB/coal ratio	10	OB/coal
OB thickness	80	ft
OB volume	47,942,794	cu yd
OB mass	21,792,179	tons
organic shale	2,179,218	tons
cell volume	641	ac ft
cell height	30	ft
combined cell area	21.4	ac
cells/permit	3	
each cell	7.1	ac
FeOOH density	1.75	tons/cu yd
FeOOH layer	1.5	ft
FeOOH volume	51,727	cu yd
FeOOH mass	90,522	tons/permit

Perfectly square 371 acre permit
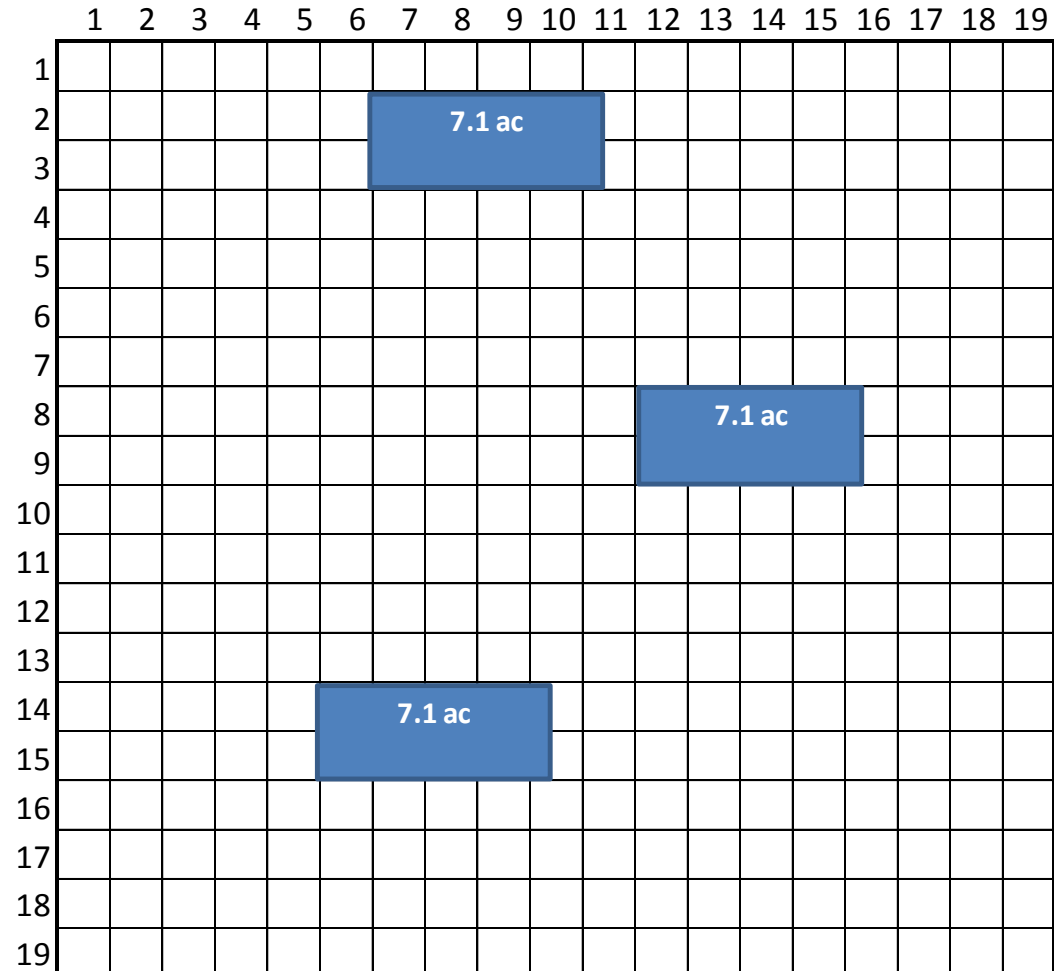
Estimated effect of selective handling with 18 in. FeOOH

WITHOUT FEOOH

Permit area

A. area under cells	21.4	ac
B. area not under cells	345.6	ac
C. total area	371.3	ac

net infiltration — 1.37 gpm/ac

A. area under cells	29	gpm
B. area not under cells	474	gpm
C. total area	509	gpm

Se concentration

% removal	0%	
A. area under cells	300	µg/L
B. area not under cells	0.5	µg/L

Se load

A. area under cells	0.1055	lbs/day
B. area not under cells	0.0028	lbs/day
C. total area	0.1084	lbs/day

net Se concentration — 17.8 µg/L

WITH FEOOH

Permit area

A. area under cells	21.4	ac
B. area not under cells	349.9	ac
C. total area	371.3	ac

net infiltration — 1.37 gpm/ac

A. area under cells	29	gpm
B. area not under cells	479	gpm
C. total area	509	gpm

Se concentration

% removal	76%	
A. area under cells	72	µg/L
B. area not under cells	0.5	µg/L

Se load

A. area under cells	0.0253	lbs/day
B. area not under cells	0.0029	lbs/day
C. total area	0.0282	lbs/day

net Se concentration — 4.6 µg/L

Factors controlling Se concentration at outfall

- Control of selenium in special handling cells
  - FeOOH application
  - Control will likely be less than 100%
  - Minimization of water movement through shale: compaction, configuration...
- Dilution with low selenium ground water
- Surface water, maybe

Key factors:

- Se mass balance in overburden

- OB Se cutoff for selective handling

- Can the high Se rock be selectively handled?
  - Degree of Se segregation in overburden
- FeOOH cost
  - Development of low cost source of FeOOH

Accurate estimates of FeOOH addition rates and performance will need:

- Relationship between Se concentration in major spoil types and leachate concentrations e.g. convert mg Se/kg to μg Se/L

- "Background" leachate Se concentrations from non-organic shale spoils

- Is Se removal proportional to FeOOH layer thickness or is removal hydraulically controlled?

  - Will 1.5 ft. of FeOOH provide the same removal performance with 5 or 30 ft. of overlying, organic shale?

Questions?

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