Composite and Discrete Sampling to Attain Risk-Based Site Characterization Objectives - A Case History

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October 2002: San Diego, California; 13th Annual West Coast Conference on Contaminated Soils, Sediments and Water; Presentation titled “Composite and Discrete Sampling to Attain Risk-Based Site Characterization Objectives – A Case History”.

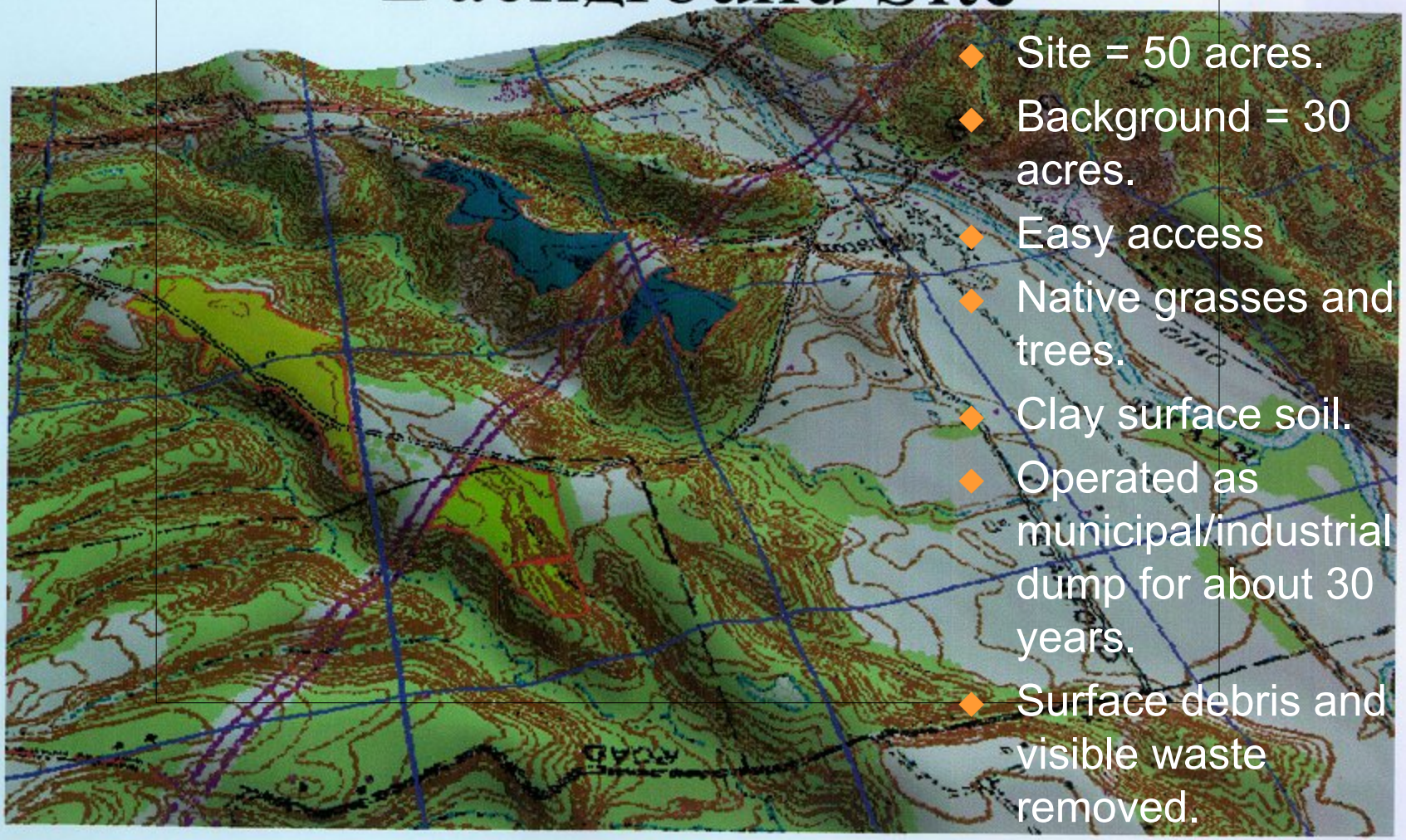
About this presentation

- Case history of a site characterization which utilized both composite and discrete surface soil sampling with the intended purpose to calculate average chemical concentrations for subdivided areas.
- The average concentration of 157 chemicals representing 13 areas were calculated.
- The sampling plan was driven by the need to to make risk-based decisions.
- Sampling plan was prepared following the DQO process.
- Discussion is limited to site surface soil.

Concluding Remark

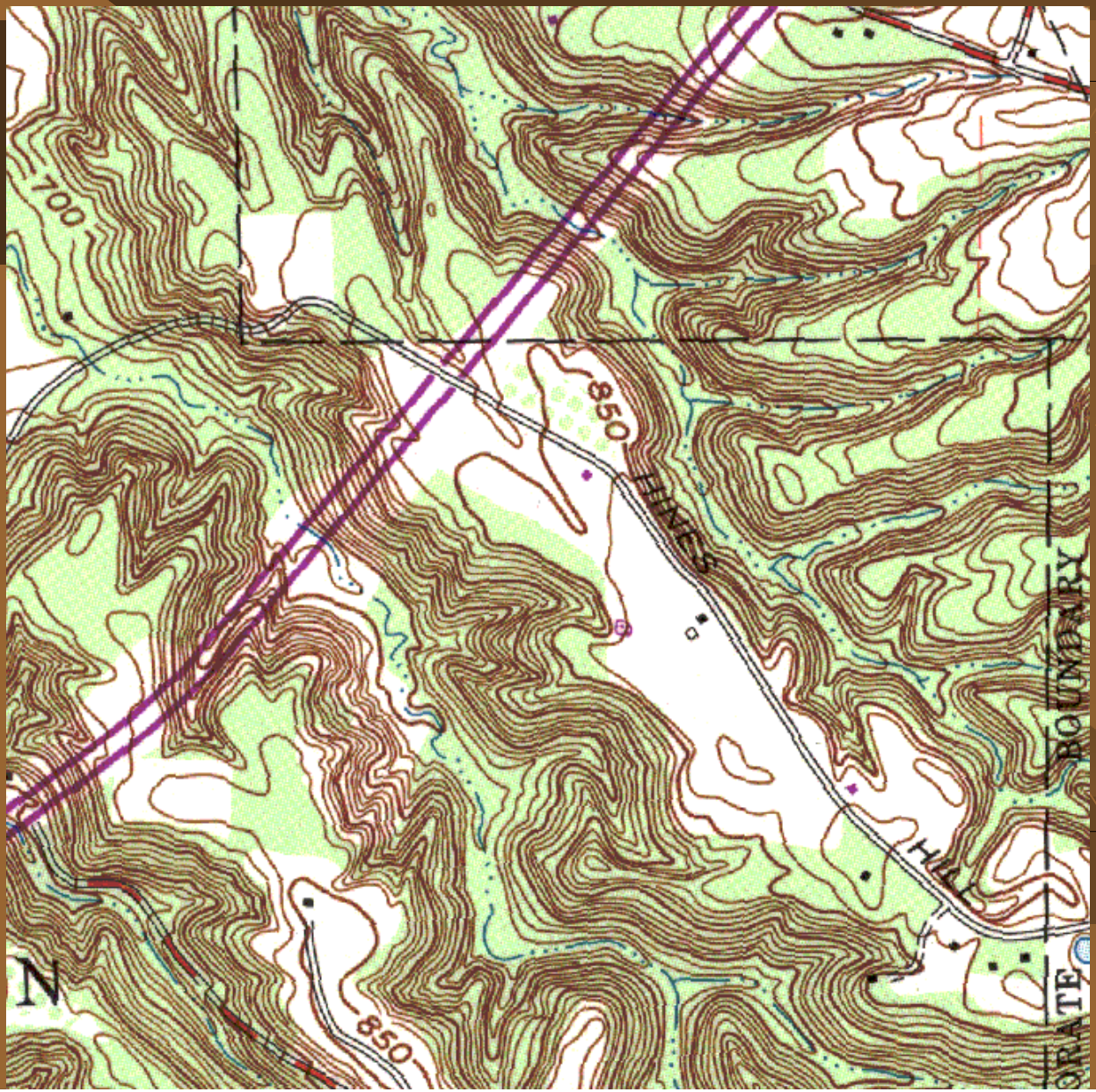
Composite Samples more efficiently characterized the surface soils than did individual point samples.

Krejci Site and its associated Background Site



- Site = 50 acres.
- Background = 30 acres.
- Easy access
- Native grasses and trees.
- Clay surface soil.
- Operated as municipal/industrial dump for about 30 years.
- Surface debris and visible waste removed.

Krejci Site



- Large number of chemicals may be present at any location in unknown quantities.
- These could exist without visible trace.

Objectives

1. Reasonably assure that a threat to human health is not present if no contamination is discovered at the site.

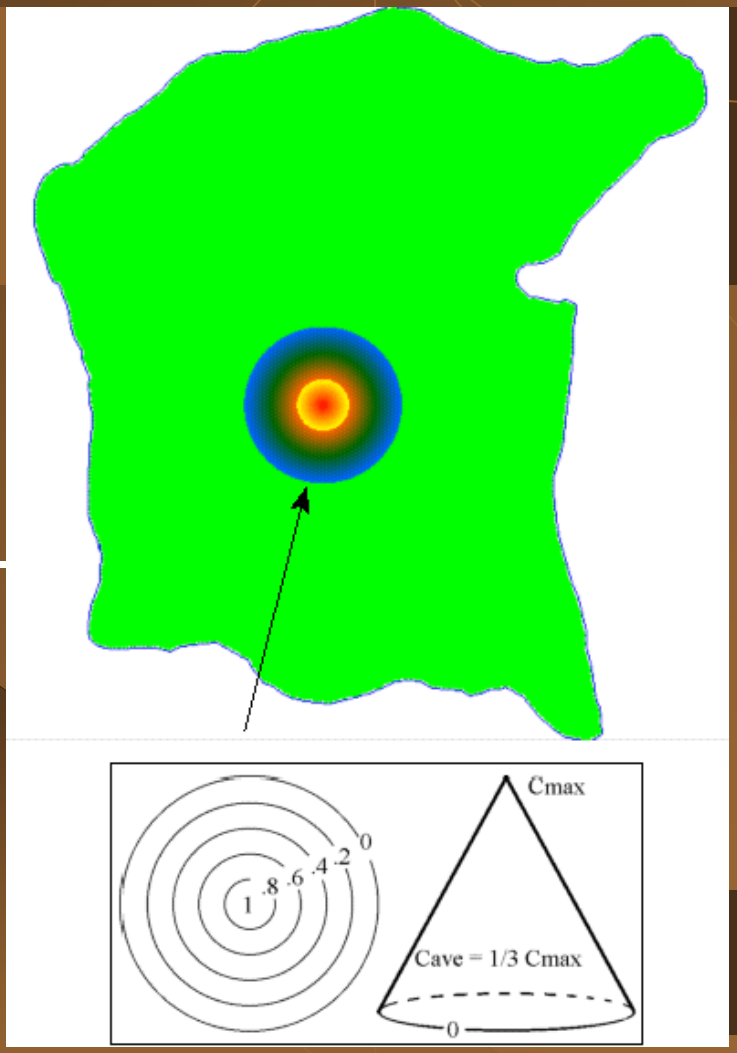
2. Acquire data that is adequate for human health risk assessment.

Conceptual Risk Model

- Created to aid in identifying data needs
- Assumptions were made permitting calculation of minimally acceptable average chemical concentration values for the site.

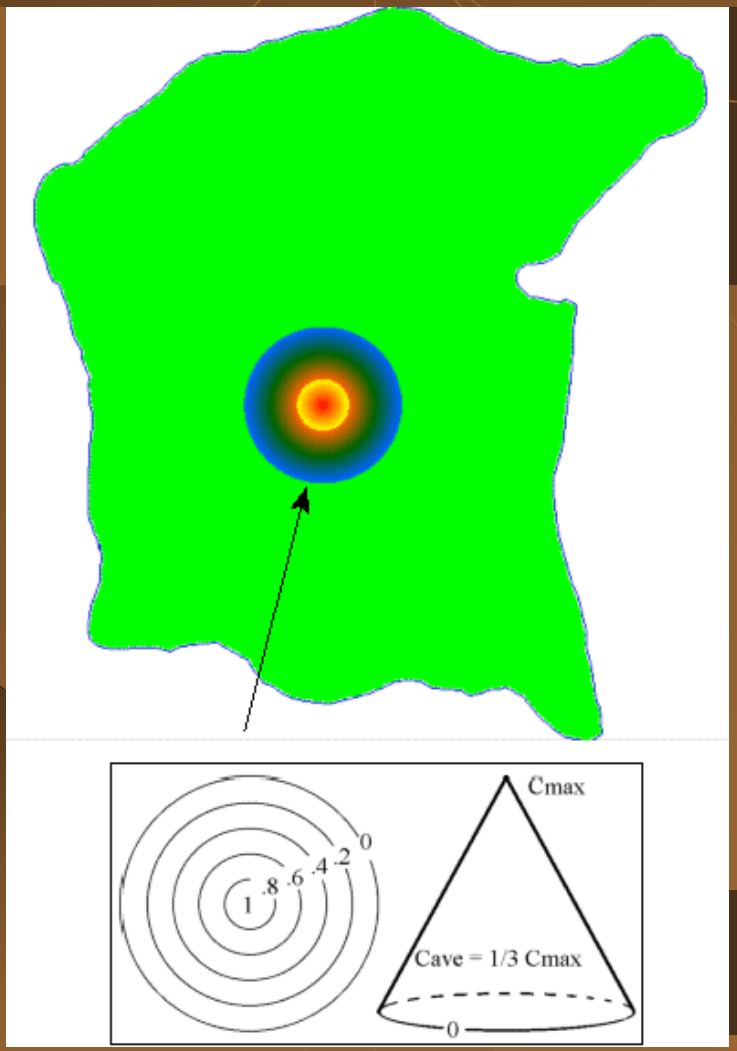
Conceptual Hot Spot Model

- Contaminant distributions described by circular hot spots.
- Maximum concentration in the center.
- Decreasing concentration with increasing radial distance.
- Hot Spot Average (C_{ave}) = $C_{Max}/3$
- Site Average = C_{ave} x $Area_{hs}/Area_{site}$



Consequential Hot Spot

Smallest hot spot that would cause the average site concentration to be unacceptable.



What is the area of the smallest hot spot that would cause the allowable concentration to be exceeded?

$$A_{HotSpot} = A_{Site} \times \frac{C_{allowable}}{C_{HotSpotAverage}}$$

How large is the detectable region of the hot spot?

$$A_d = A_{hotspot} \times (1 - \frac{C_d}{C_{\max}})$$

Where:

C_d is the detection limit of the analytical method

C_{max} is the maximum concentration of the chemical

A_d is the detectable area of the hot spot.

Statistics

$$\alpha = q^{N}$$

Where:

α is the probability of no success in N trials

q is the probability of no success in 1 trial. This is $1-A_d/A_{site}$

How many samples are required to detect a hot spot that causes an unacceptable average site concentration?

Assuming random selection of sampling locations:

$$N = \frac{\log(\alpha)}{\log\left(1 - 3 \times \frac{C_{allowable}}{C_{\max}} \times \left(1 - z\left(\frac{C_{allowable}}{C_{\max}}\right)^2\right)\right)}$$

Where:

N = number of samples required.

α = probability of having no successes in N trials.

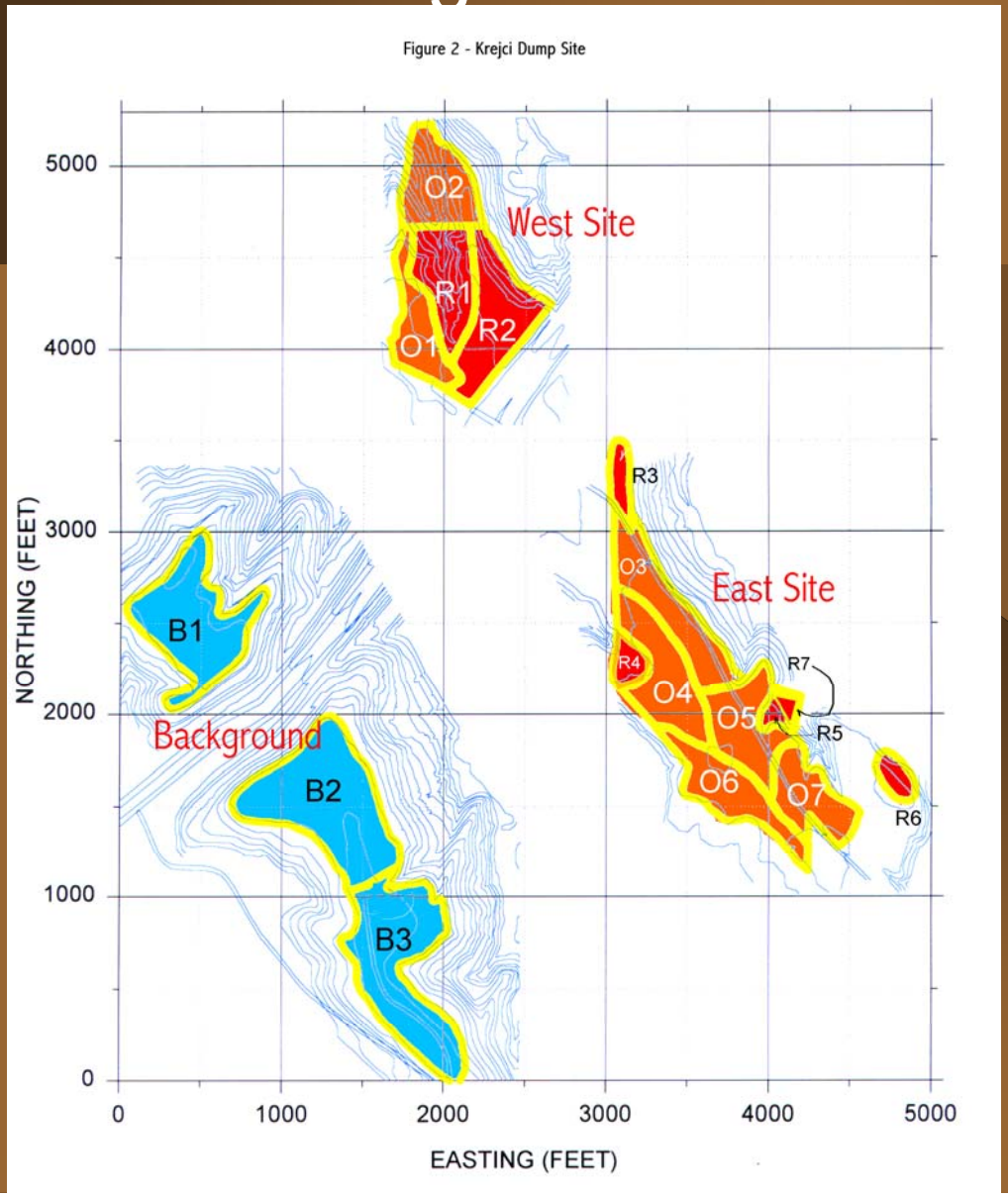
$Z = C_d / C_{allowable}$

Representing the hot spot in the average.

The derived equation only assures that contamination will be detected if an unacceptable condition exists.

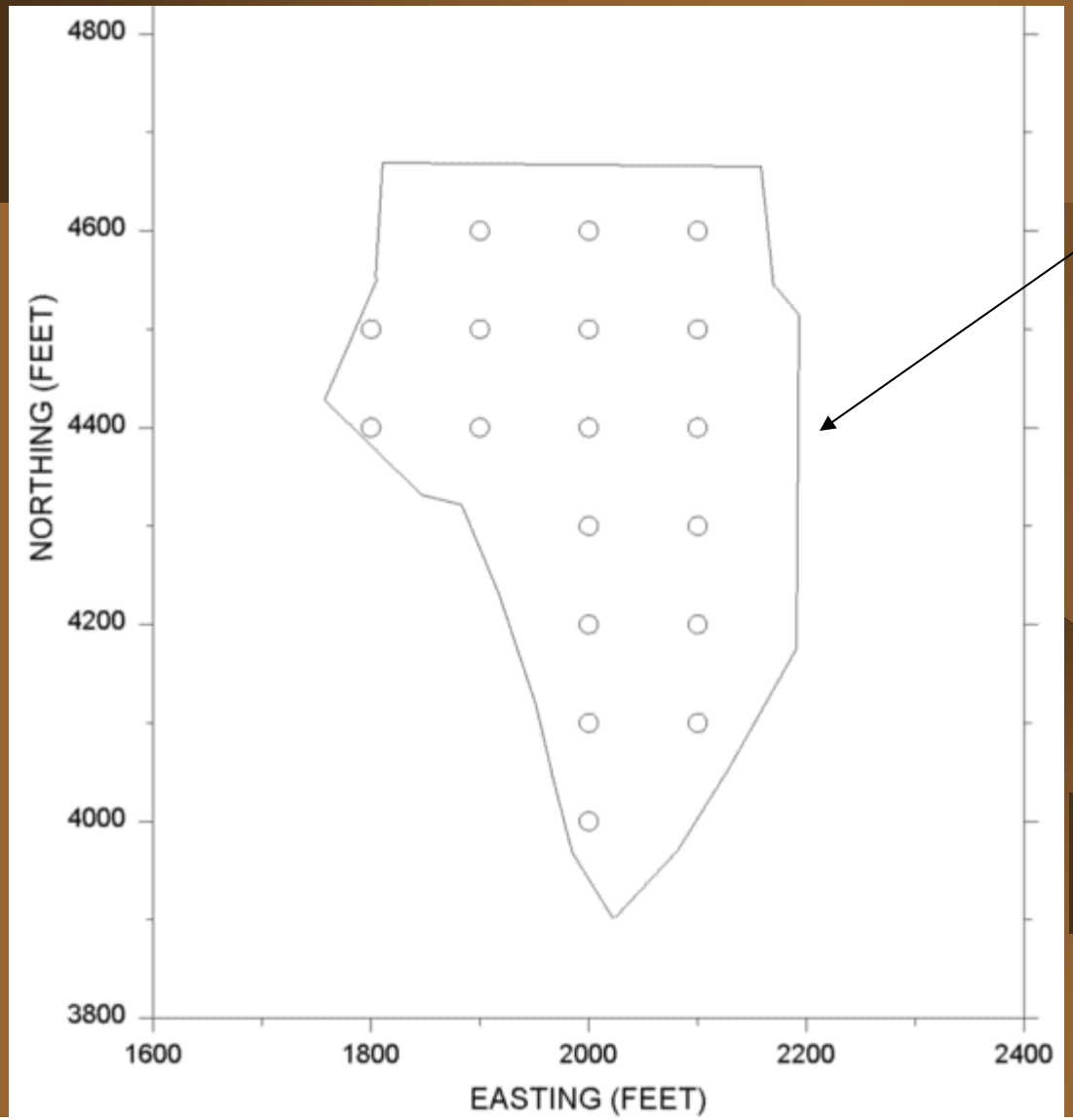
A more awkward equation was derived to permit the calculation of the number of samples needed to assure representation of the hot spot.

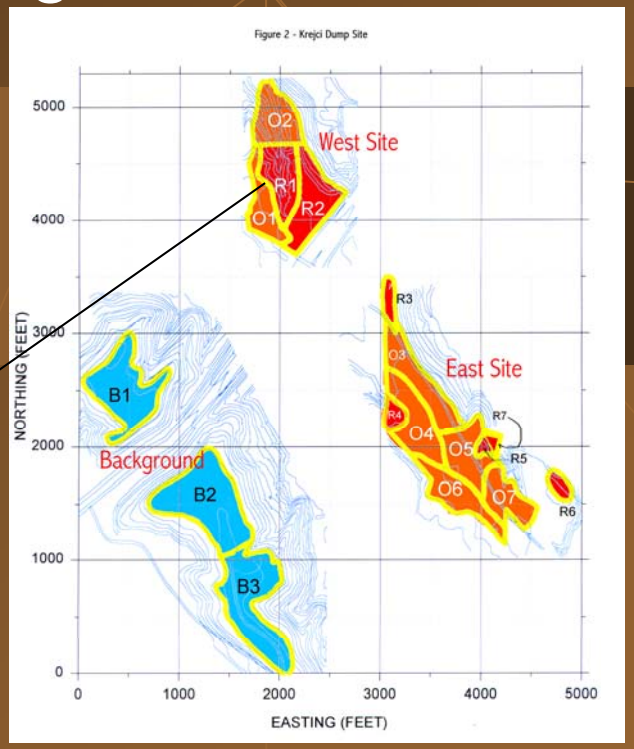
Subdividing the site.



- It was desired to focus attention on areas thought most likely to be contaminated.
- It was also desired to characterize surface soil contamination separately for each site drainage area.
- This resulted in subdividing The Site into 13 areas of concern AOC's and subdividing the Background site into 3 AOC's.

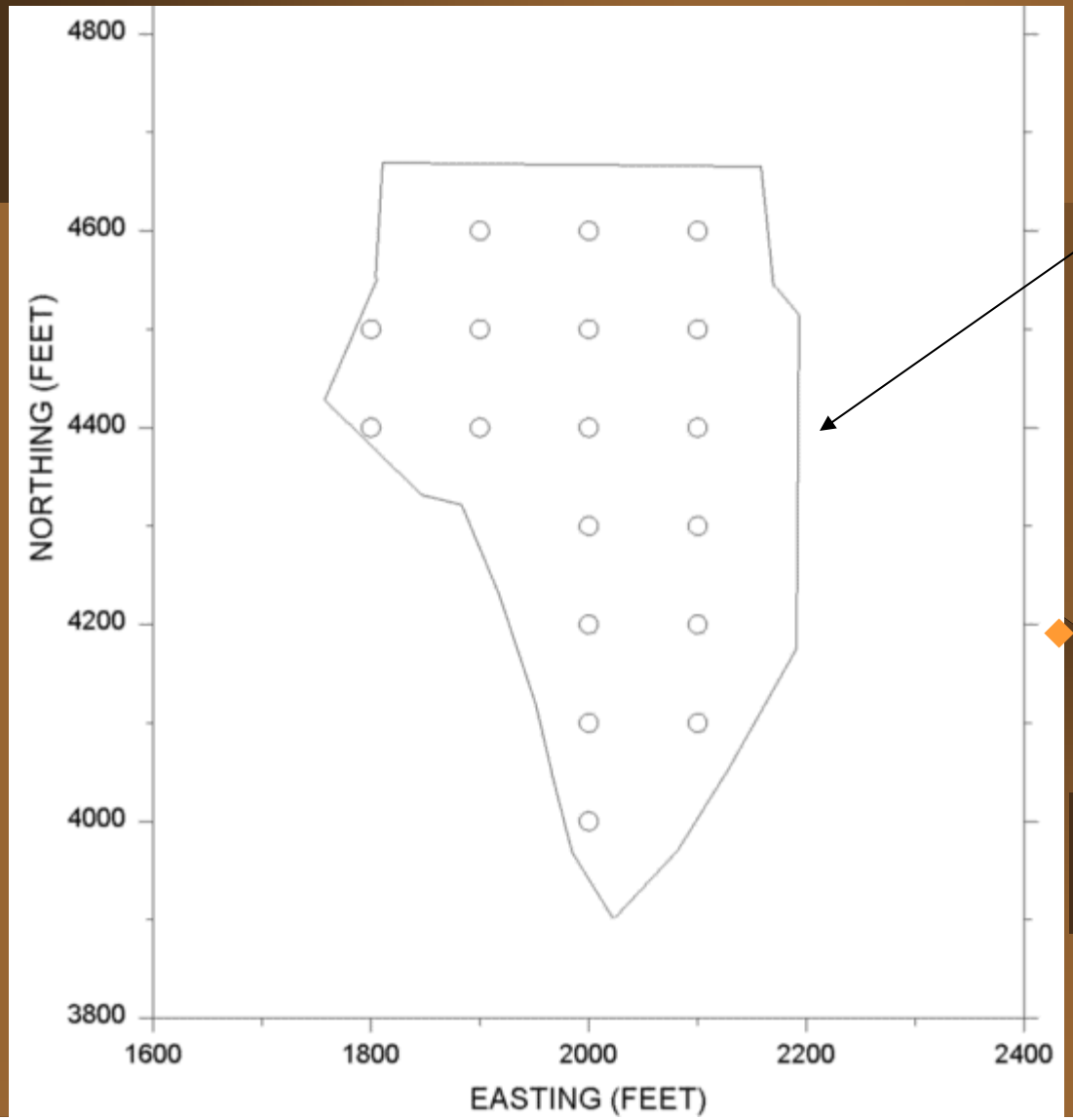
Example of discrete sampling grid - 100 ft centers - H1

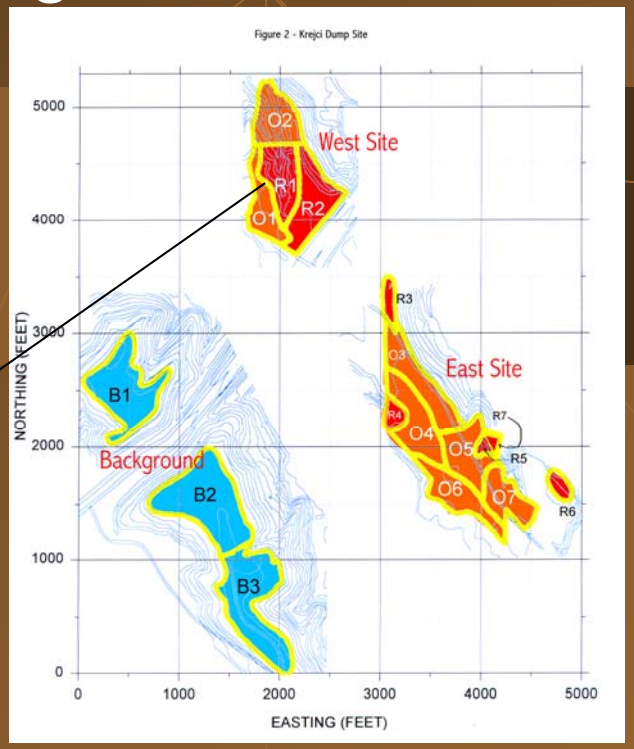




- Discrete samples were collected at 100 ft grid points in areas thought most likely to exhibit high levels of contamination. These numbered areas are prefixed by R.

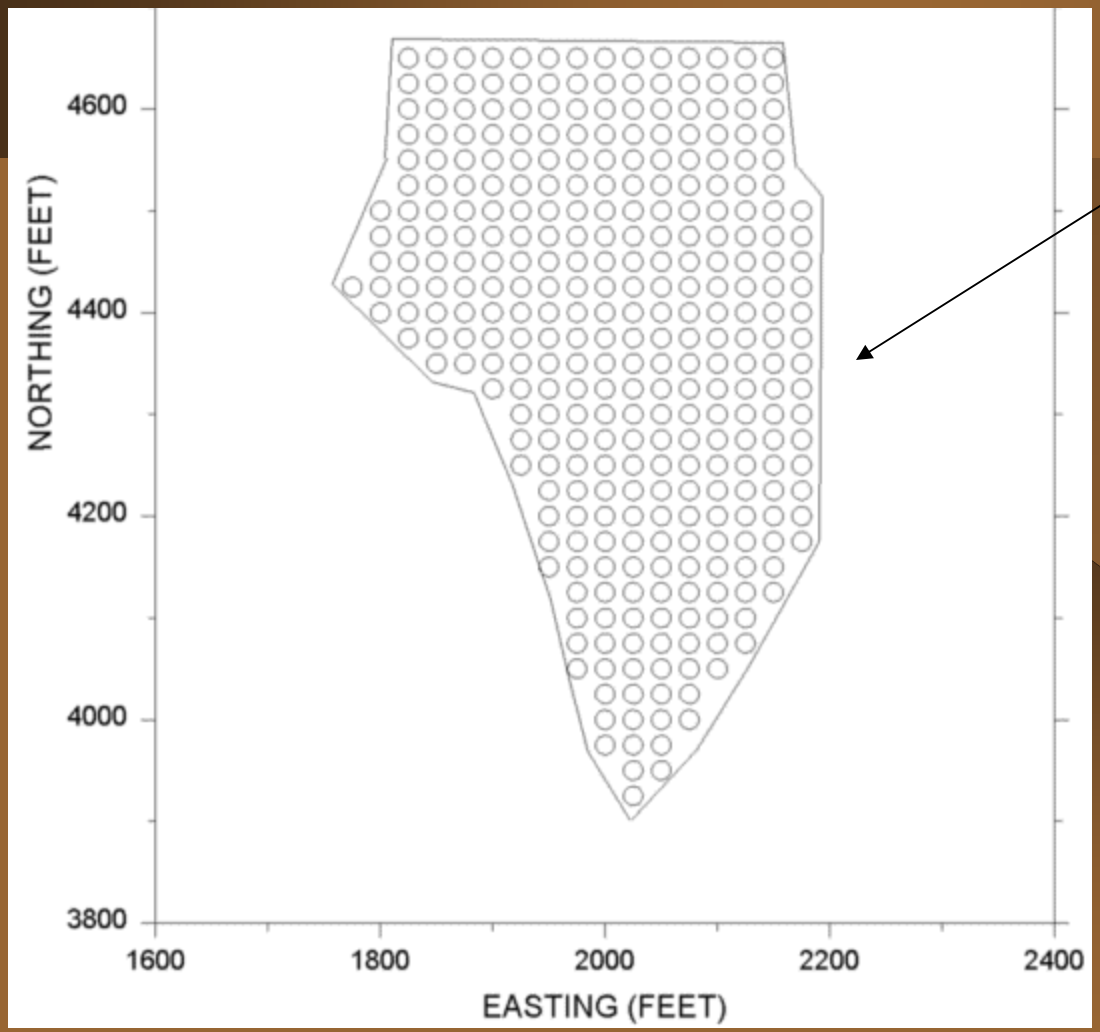
Example of discrete sampling grid - 100 ft centers - H1

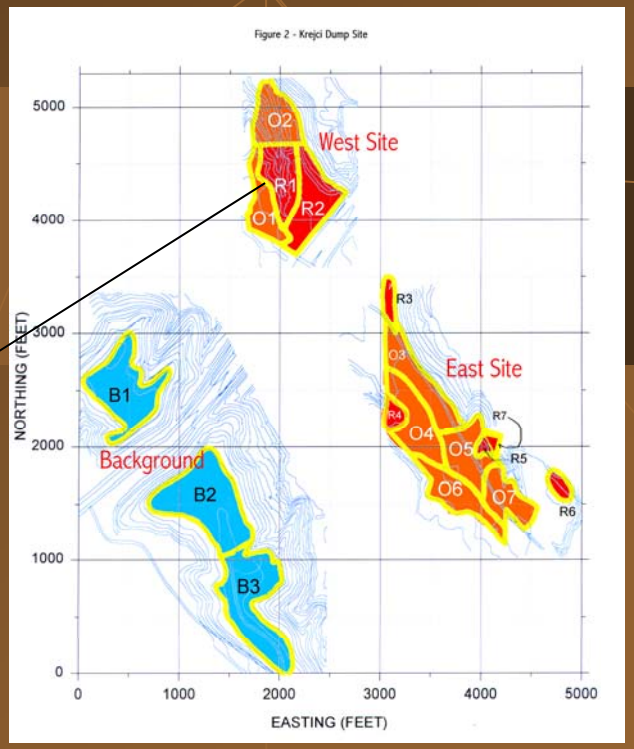




- Discrete samples were collected at 200 ft grid points in background areas and Site areas thought less likely to exhibit high levels of contamination. These are prefixed by B and O respectively.

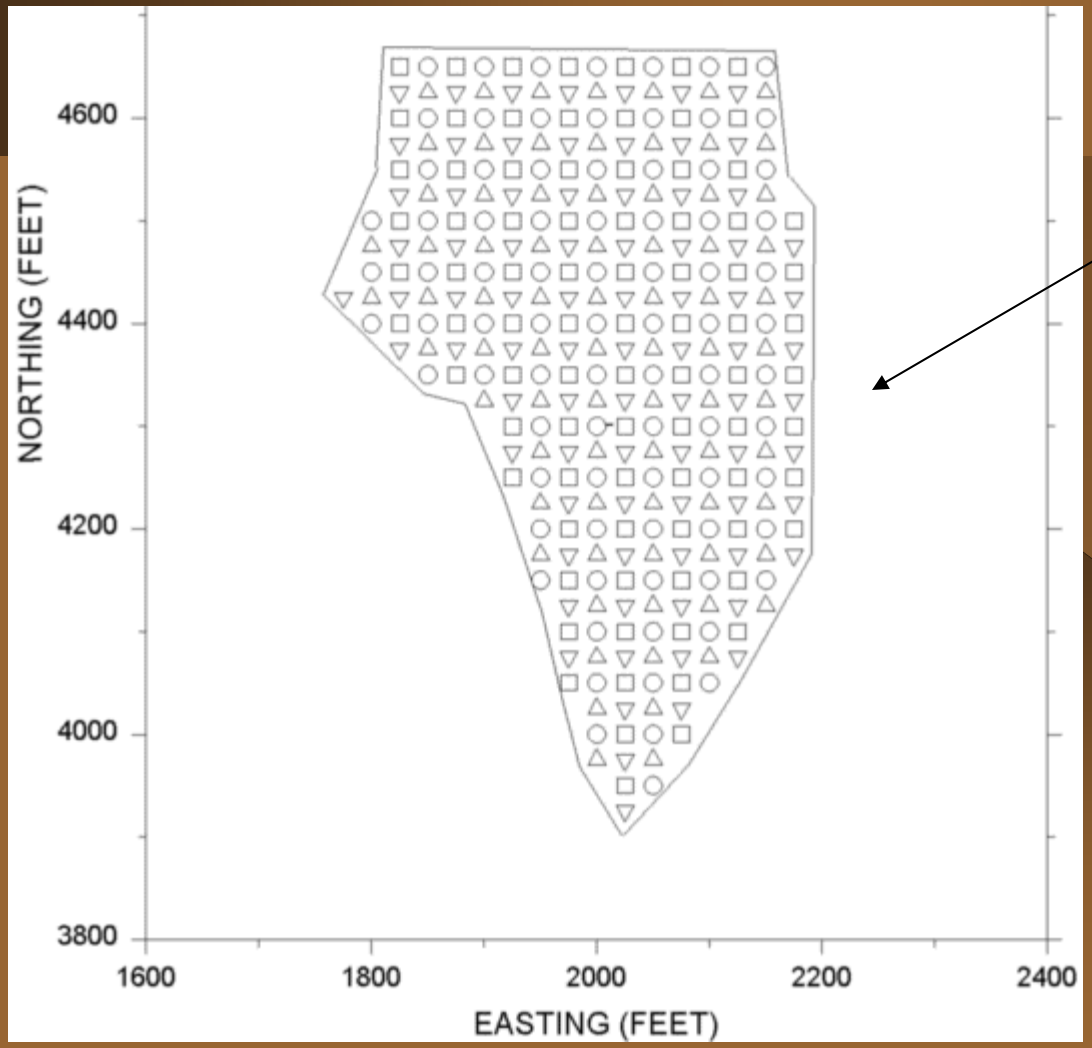
Example of PCB screening locations - 25 ft grid - H1

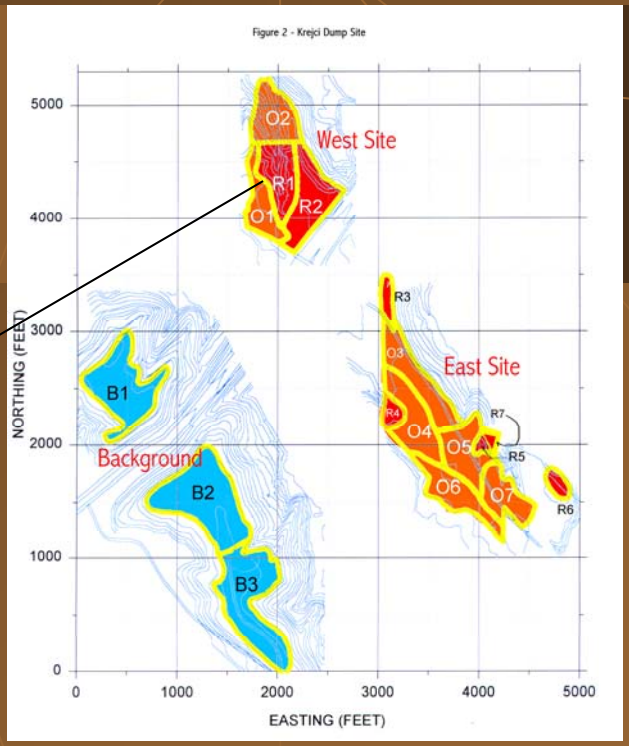




- PCB screening was conducted at discrete locations on a 25 ft grid in R areas and a 50 ft grid in O areas.

Example of the Composite Sampling Scheme - quadruplicate samples - 50 ft centers.

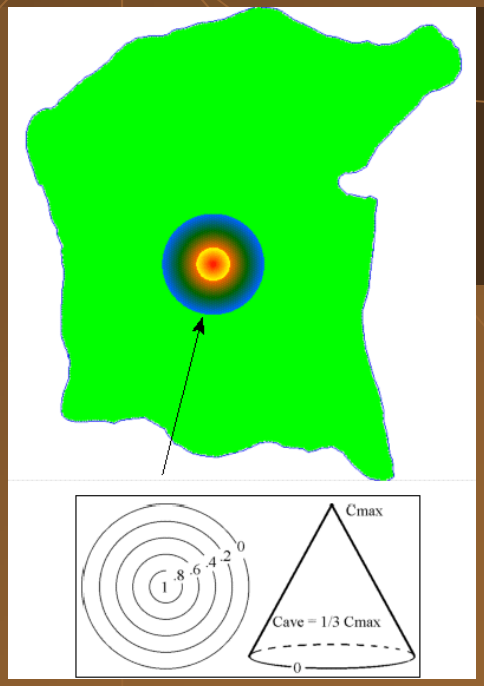




- Quadruplicate or Octuplicate composite samples were collected to represent each area.

Expectations

More likely that composite samples will result in higher estimates of AOC average chemical concentrations than discrete samples.



EXAMPLE

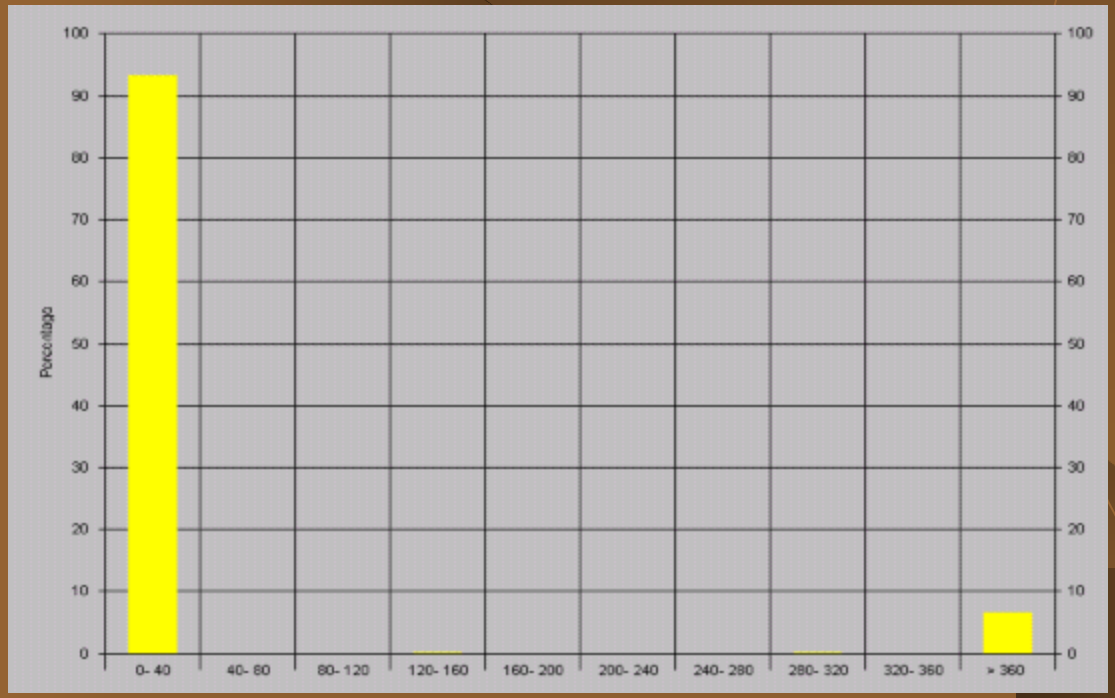
Assume that the significant hot spot is 6 percent of the site area.

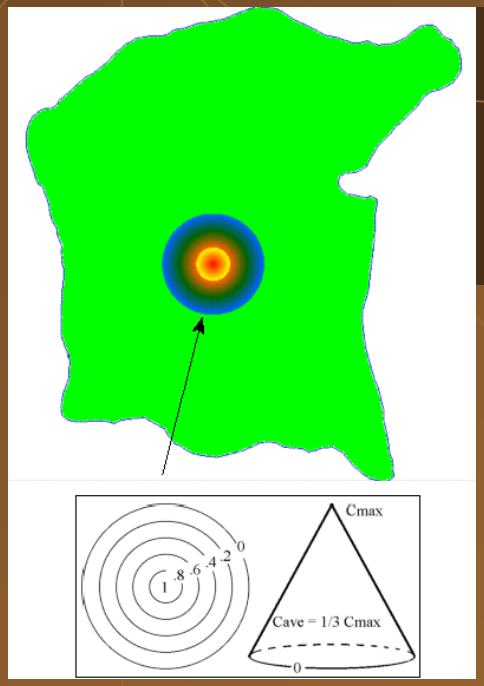
Assume maximum concentration is 10000

Site average concentration is 200.

Contaminant Distribution

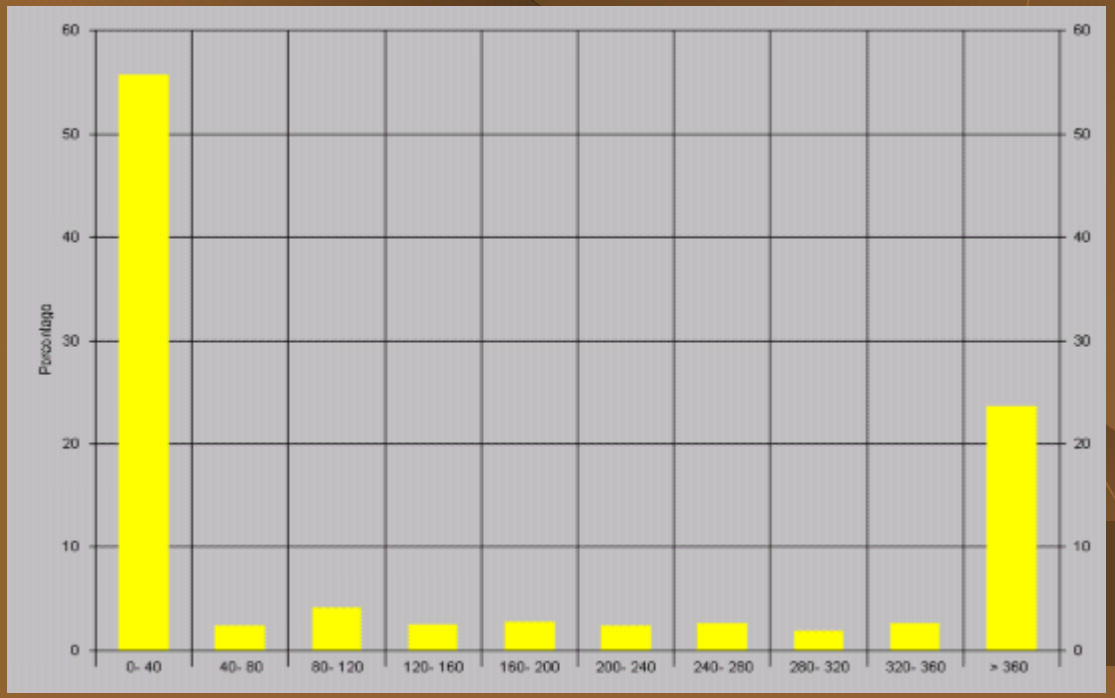
One sample collected per episode and 1000 sampling episodes.

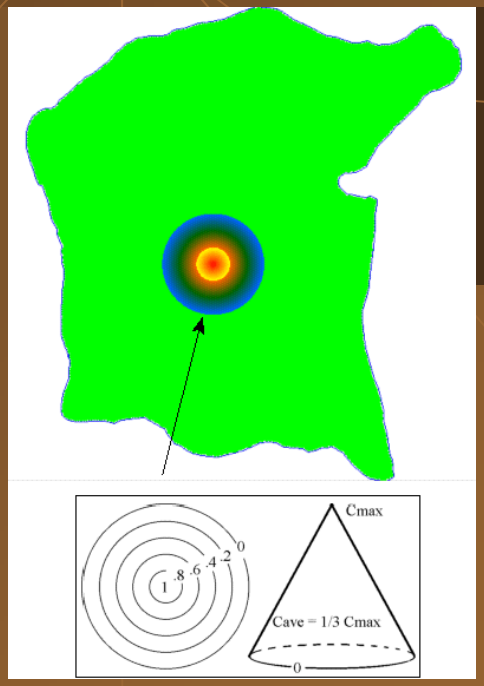




Contaminant Distribution

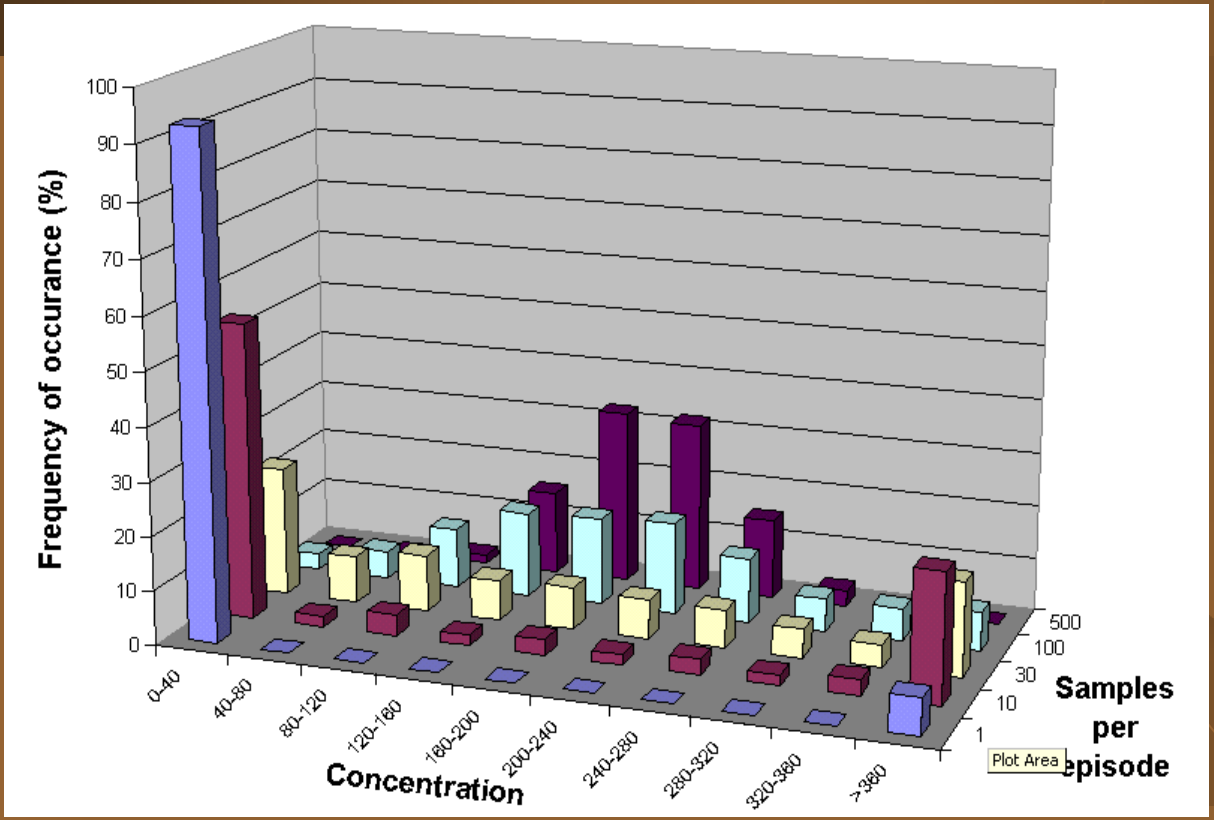
Ten samples collected per episode and 1000 sampling episodes

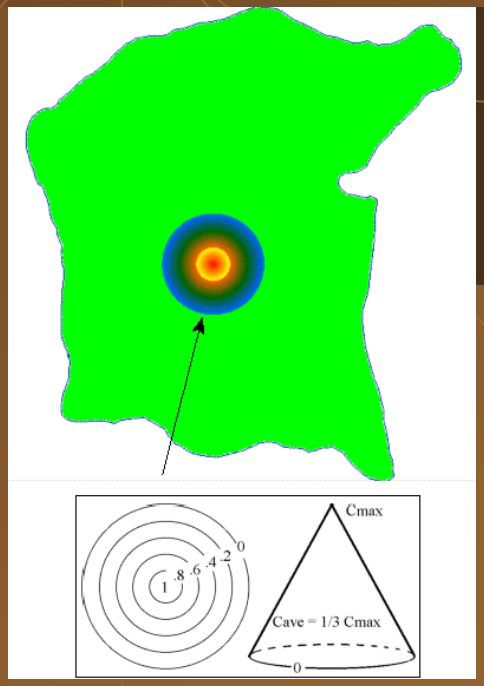




Contaminant Distribution

N samples collected per episode and
1000 sampling episodes

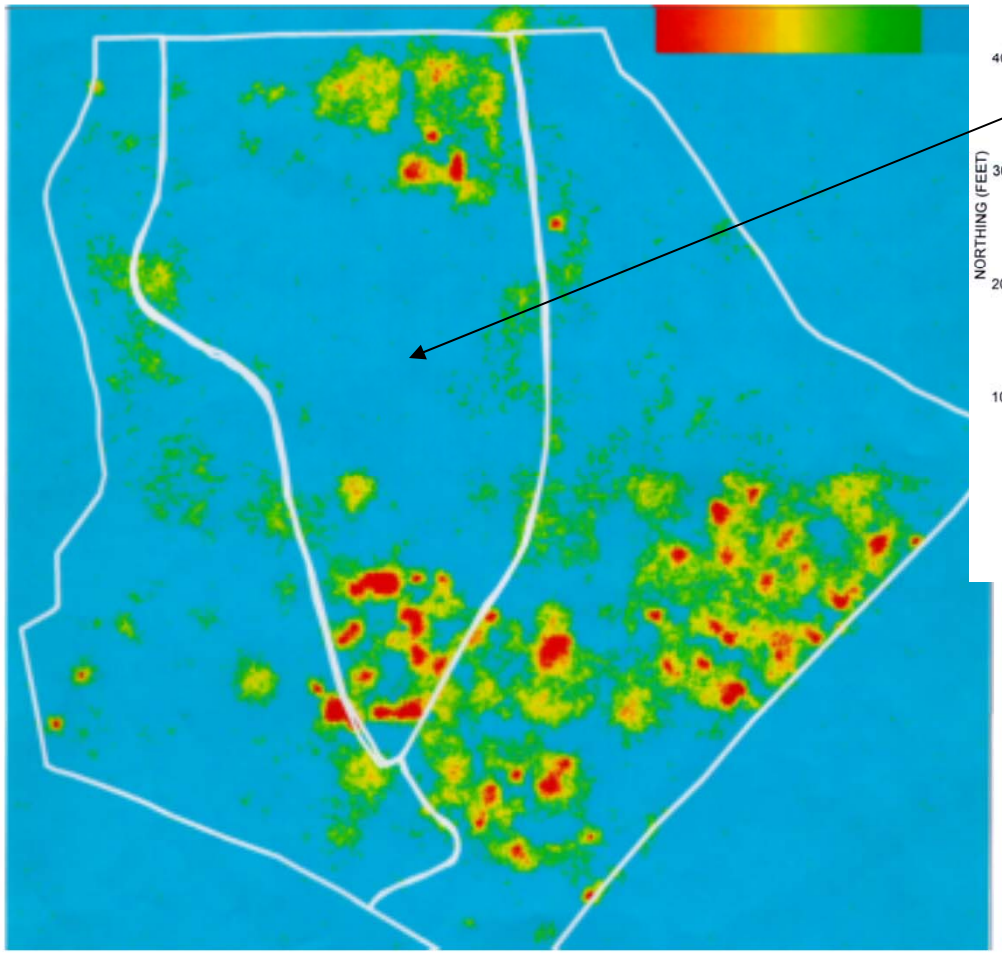


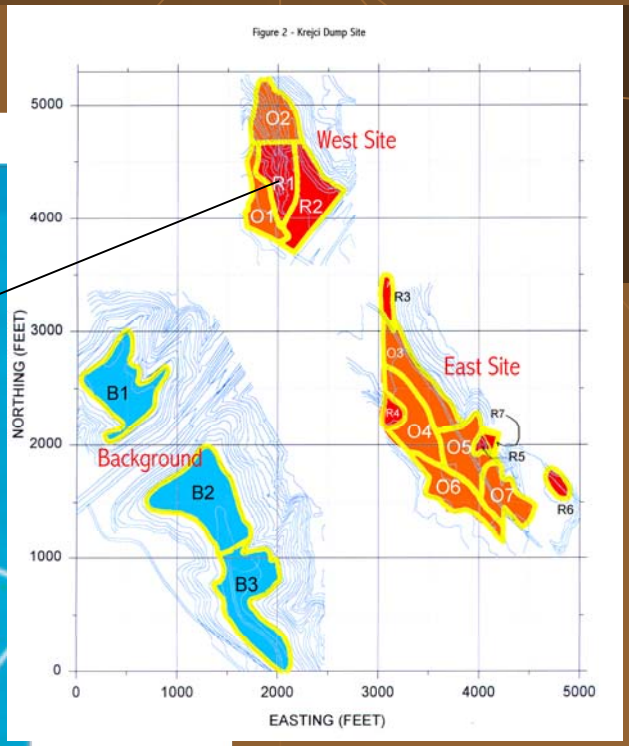


Comparison of Lead Subunit Averages from Point and Composite Samples			
Subunit	**Area (ft^2/1000)**	**Average Concentration calculated from Point Samples (mg/Kg) with Corresponding Number of samples shown in Parentheses.**	**Average Concentration calculated from Composite Samples (mg/Kg) with Number of Samples in Parentheses and Total Number of Specimens in Brackets.***
R1	200	**2789** (18)	2145 (8) [640]
R2	266	1128 (27)	**1217** (8) [851]
R3	51	20 (3)	**37** (4) [82]
R4	49	122 (5)	**136** (8) [157]
R5	24	970 (4)	**6116** (8) [77]
R6	41	132 (4)	**171** (4) [66]
O1	167	415 (3)	**736** (8) [134]
O2	203	71 (5)	**83** (4) [81]
O3	245	132 (6)	**506** (4) [98]
O4	240	366 (6)	**372** (4) [96]
O5	203	194 (5)	**1463** (4) [81]
O6	198	239 (6)	**727** (8) [158]
O7	163	**857** (4)	856 (4) [65]
B1	368	42 (8)	**47** (4) [147]
B2	475	56 (10)	56 (4) [190]

Comparison of Aroclor 1254 Subunit Averages from Point and Composite Samples			
Subunit	**Area (ft^2/1000)**	**Average Concentration calculated from Point Samples (mg/Kg) with Corresponding Number of samples shown in Parentheses.**	**Average Concentration calculated from Composite Samples (mg/Kg) with Number of Samples in Parentheses and Total Number of Specimens in Brackets.***
R1	200	**12.9** (18)	5.3 (8) [640]
R2	266	16.4 (22)	**27.7** (8) [851]
R3	51	0.6 (3)	**1.3** (4) [82]
R4	49	1.2 (5)	**68.6** (8) [157]
R5	24	4.7 (2)	**43.2** (8) [77]
O1	167	0.6 (4)	**17.0** (8) [134]
O2	203	0.1 (5)	**1.0** (4) [81]
O3	245	1.5 (6)	**2.7** (4) [98]
O4	240	3.0 (6)	**3.1** (4) [96]
O5	203	1.9 (5)	**2.1** (4) [81]
O6	198	0.7 (5)	**1.7** (8) [158]
O7	163	**0.8** (4)	0.7 (4) [65]

Composite sampling was also used to evaluate completeness of site characterization



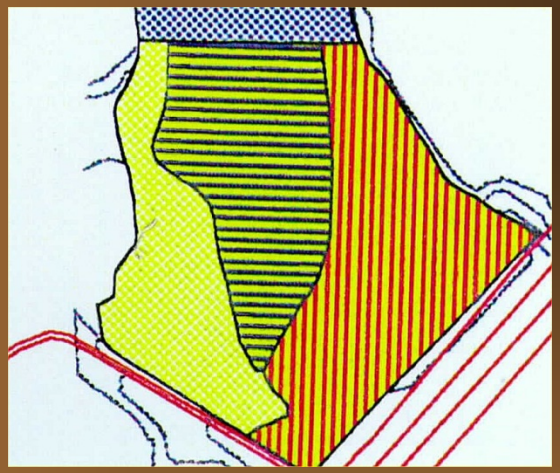


Summary

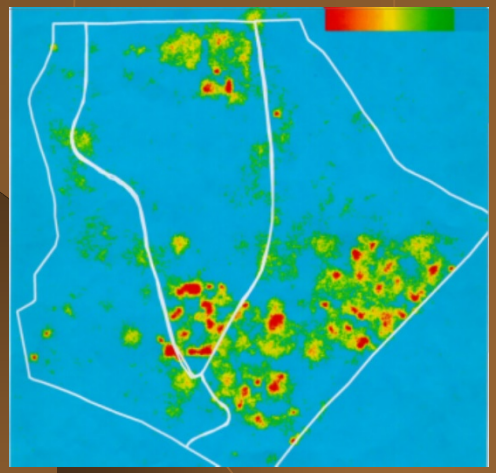
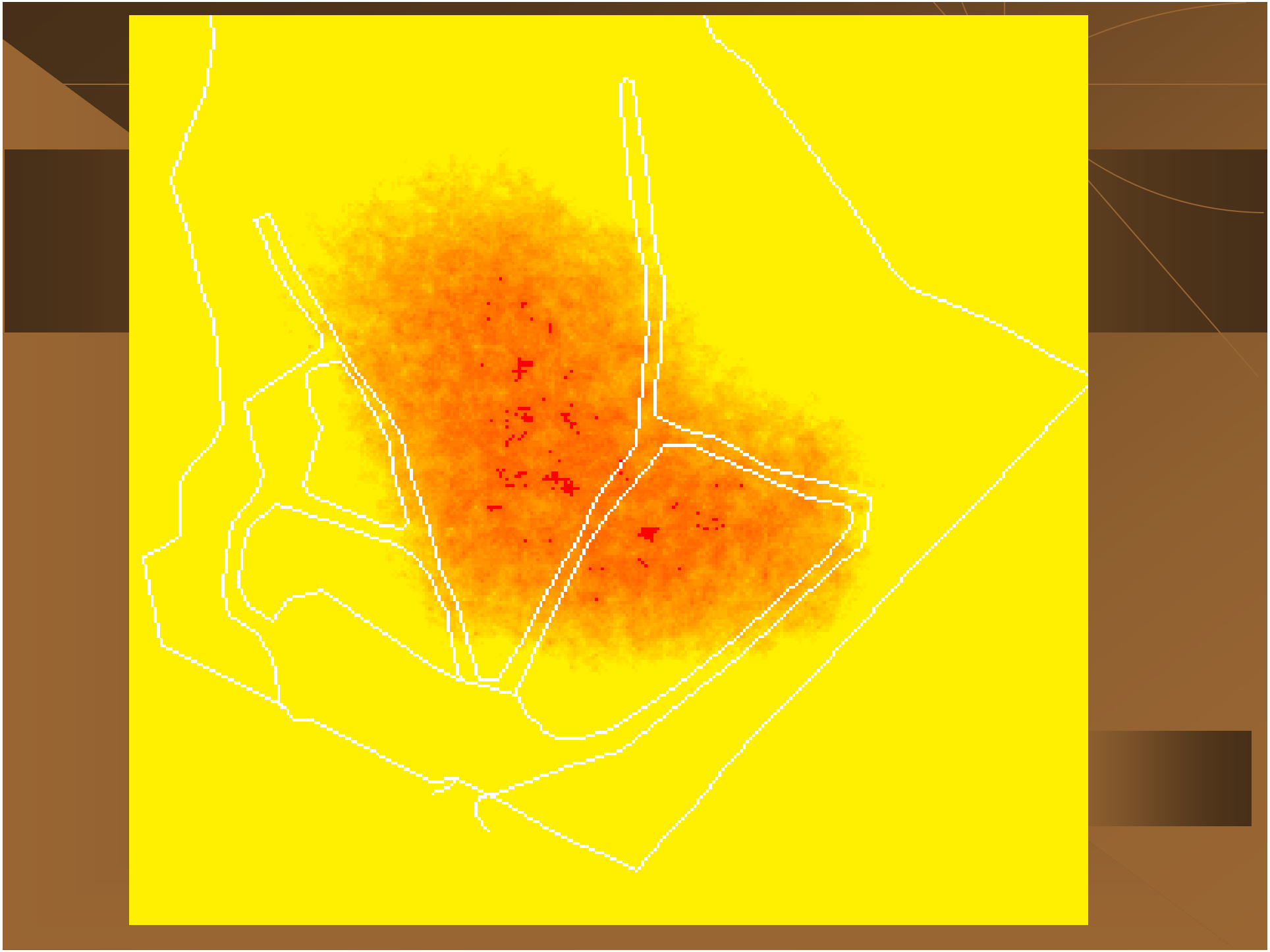
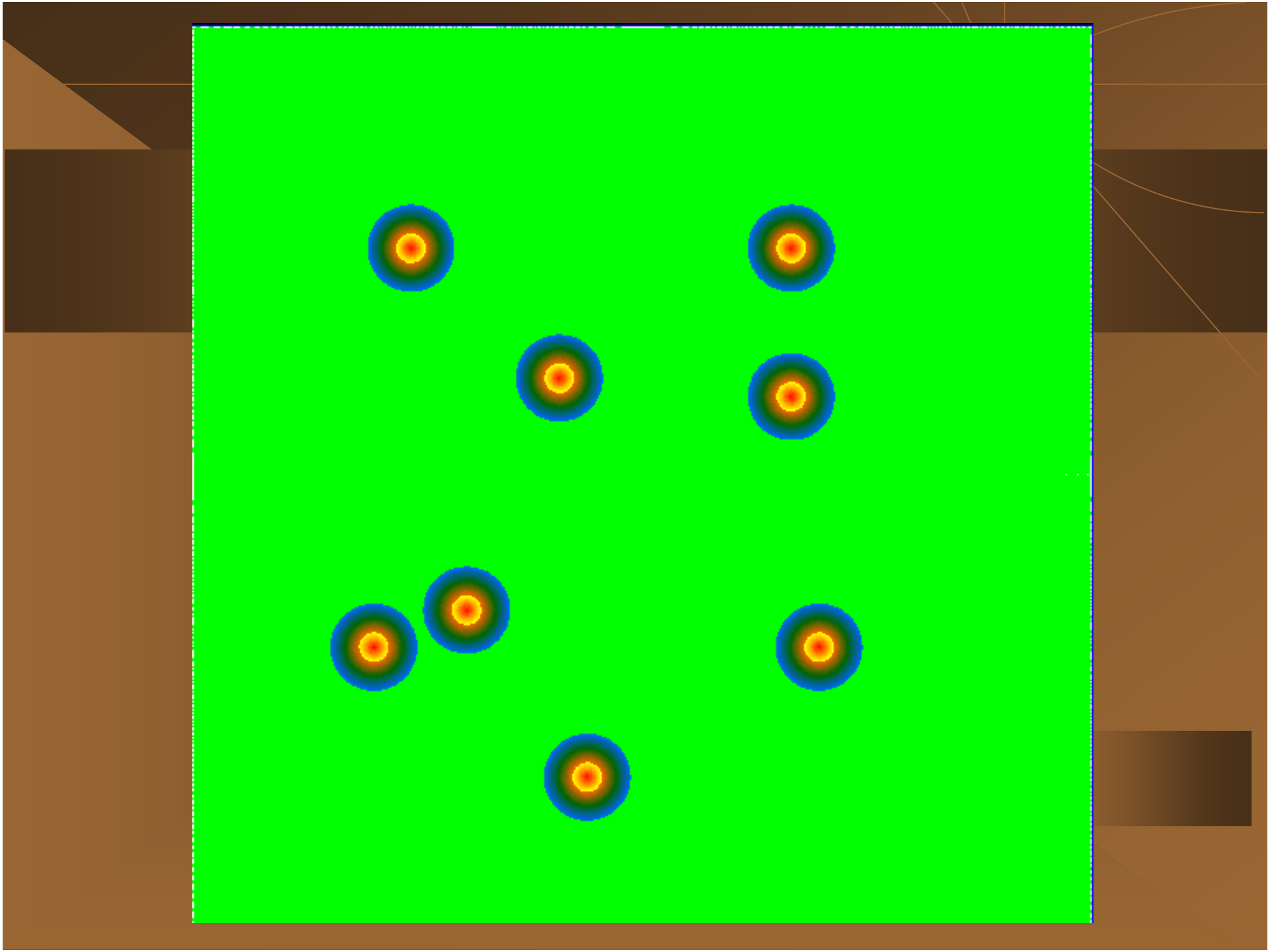
- Risk-based data needs were developed for The Site.
- Undiscovered contamination is not expected to present an unacceptable risk to human health.
- Composite and discrete sampling resulted in data that was adequate for use in risk assessment.
- Composite sampling provided a check on the adequacy of discrete sampling and modeled distributions.
- Average chemical concentrations were greater when calculated using composite sample data.

Concluding Remark

Composite Samples more efficiently characterized the surface soils at the Krejci Dump Site than did individual point samples.



Mean =18 mg/kg
24 samples 1625 specimens



Mean =11 mg/kg
44 samples 300 screenings