Composite Sampling - A Case History of Site Characterization and Cleanup Verification – Krejci Dump Site

Dr. Mark C. Gemperline

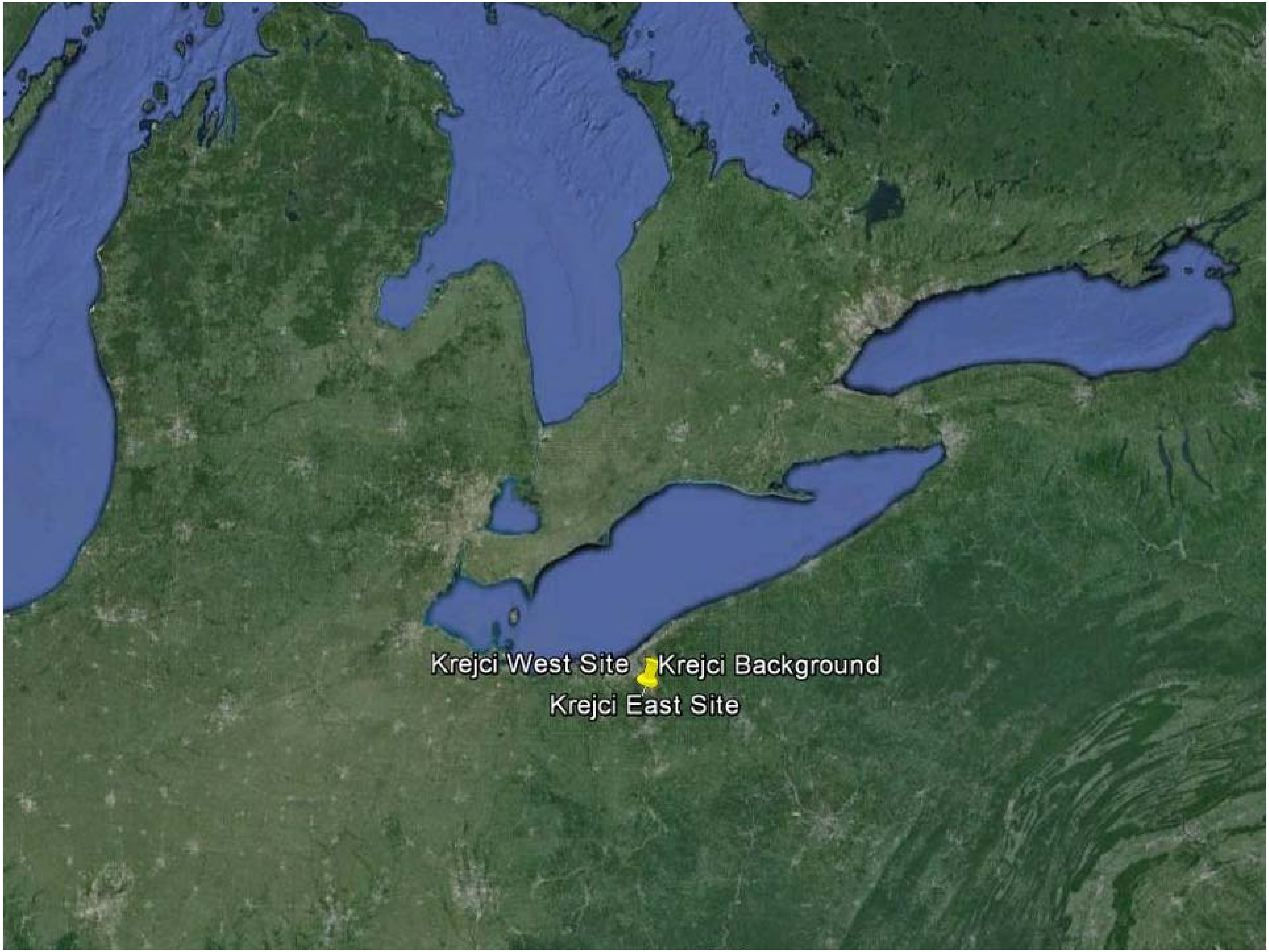
President,
MCG Geotechnical Engineering Inc.

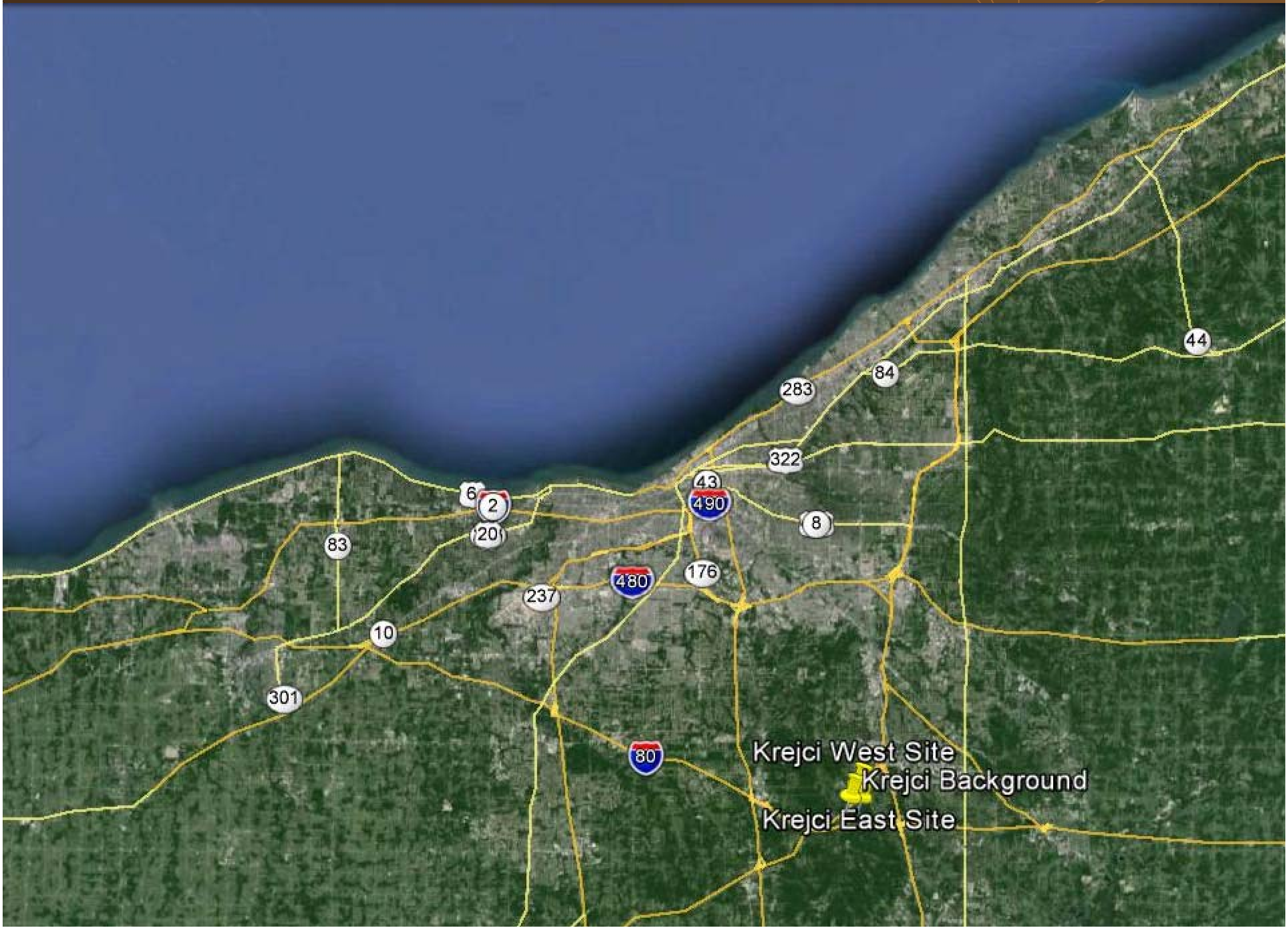
GSA Schedule Contract: GS-10F-0142X

email
MCG_Engineering@q.com
Web
*www.**mcggeotechnical**.com*

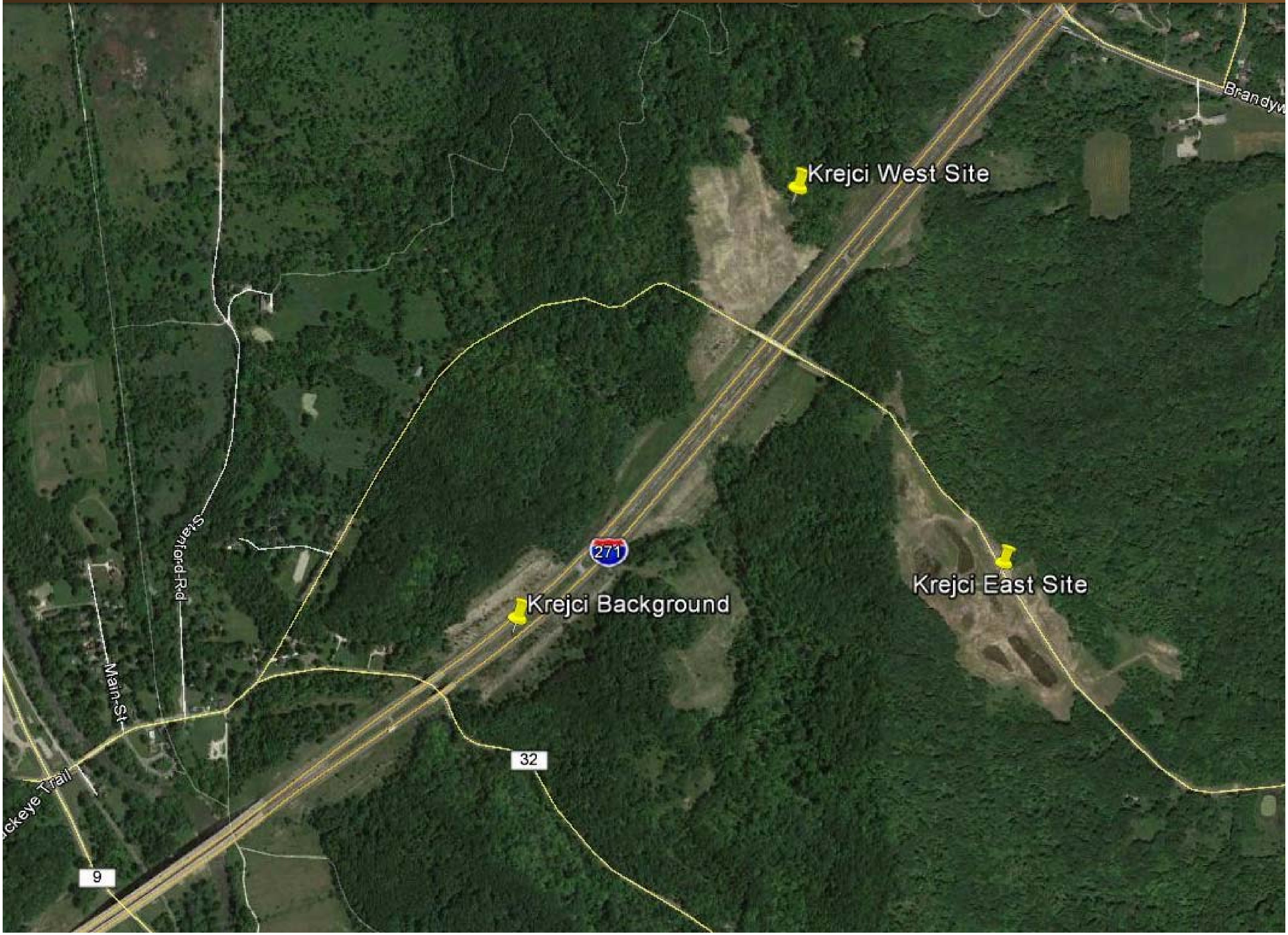
About This Presentation

- Describes the NPS Krejci Dump Site and how composite sampling was employed for both Characterization and Cleanup Verification.
- Also presents a few additional site investigations and lessons learned.

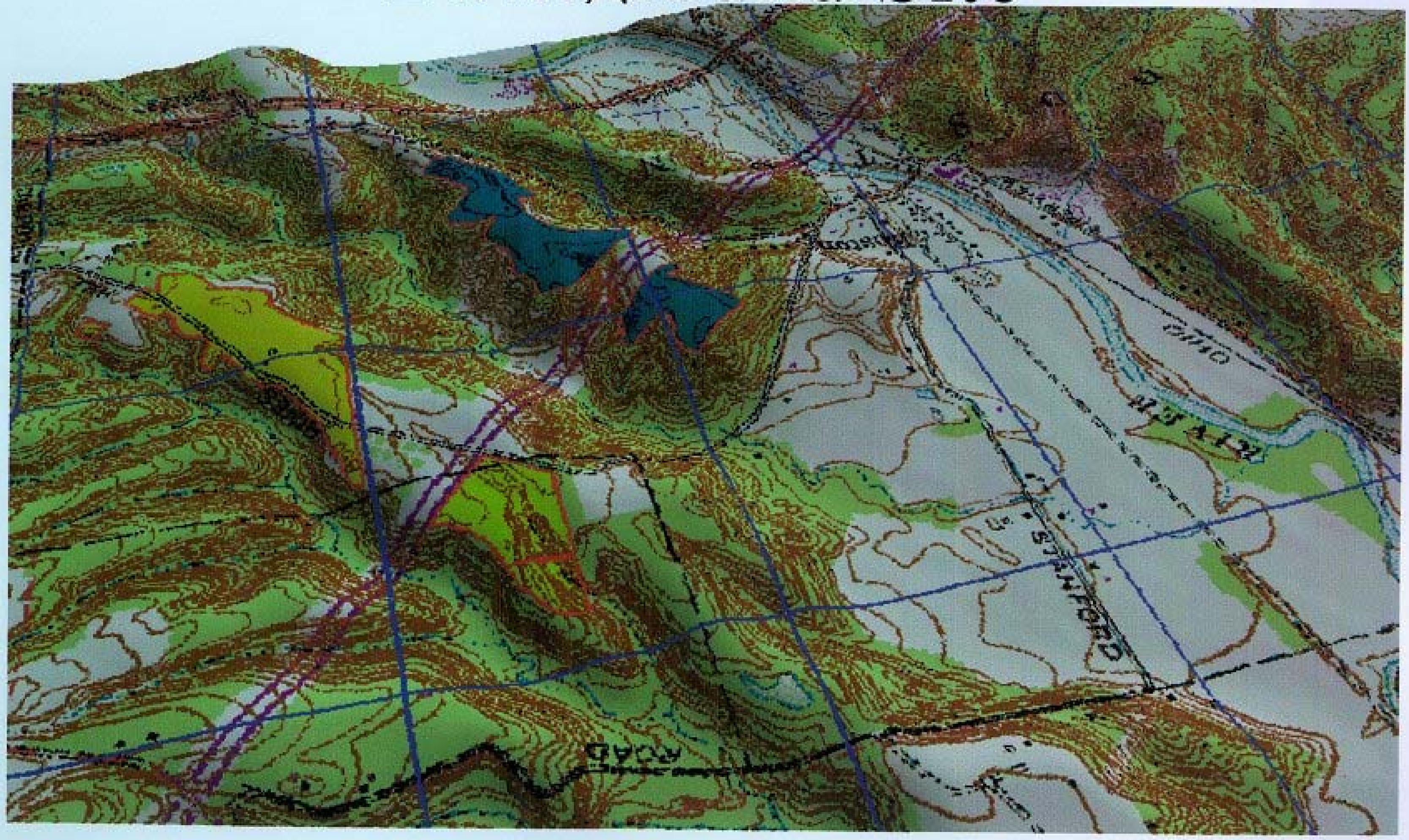

Krejci West Site
Krejci Background
Krejci East Site



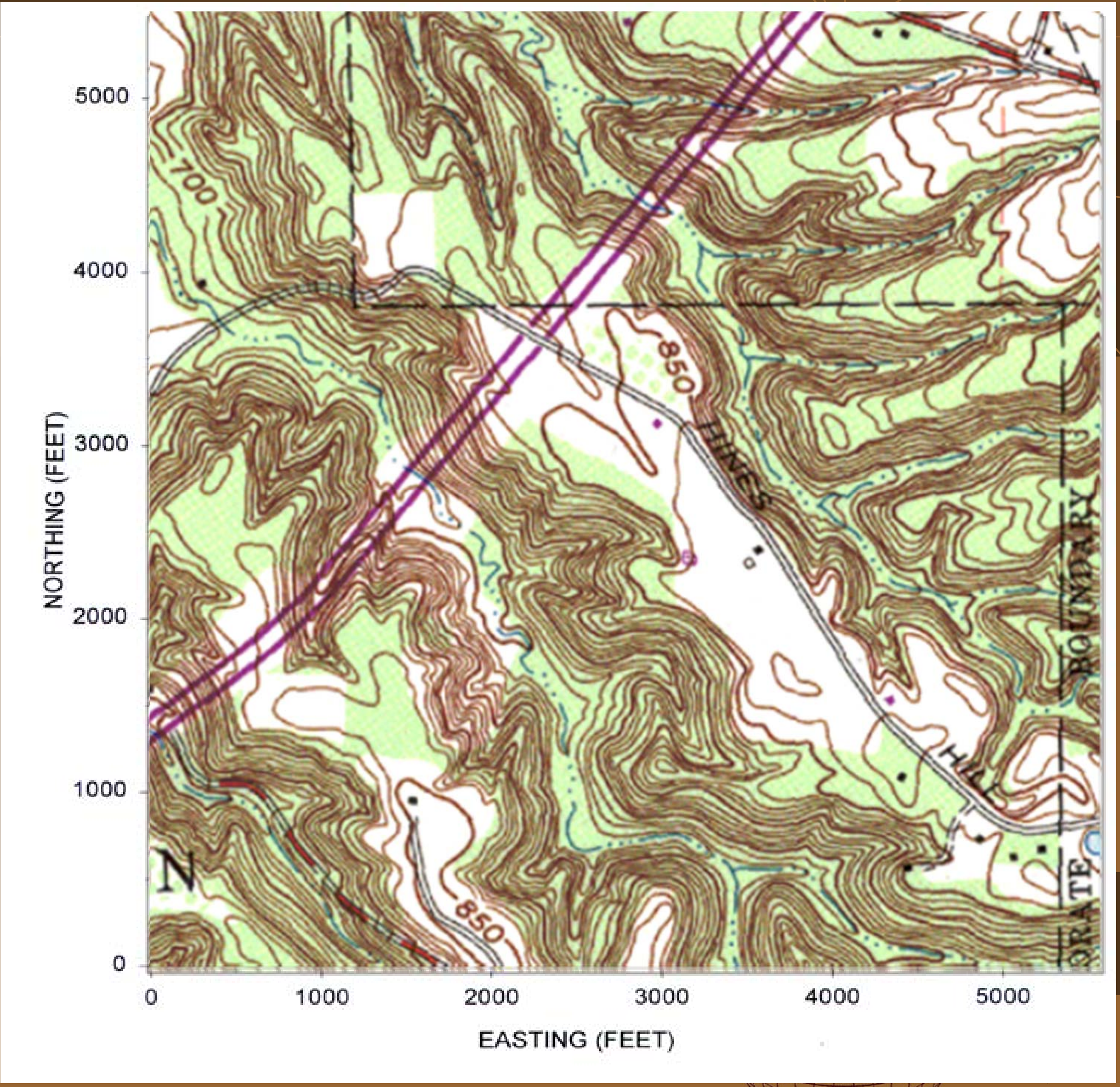
Krejci West Site
Krejci Background
Krejci East Site
283
84
44
322
43
490
6
2
8
20
83
480
176
237
10
301
80


Krejci West Site
Krejci Background
Krejci East Site
271
32
9
Stanford-Rd
Main-St
Buckeye Trail
Brandyw

Krejci Site and its associated Background Site



Location



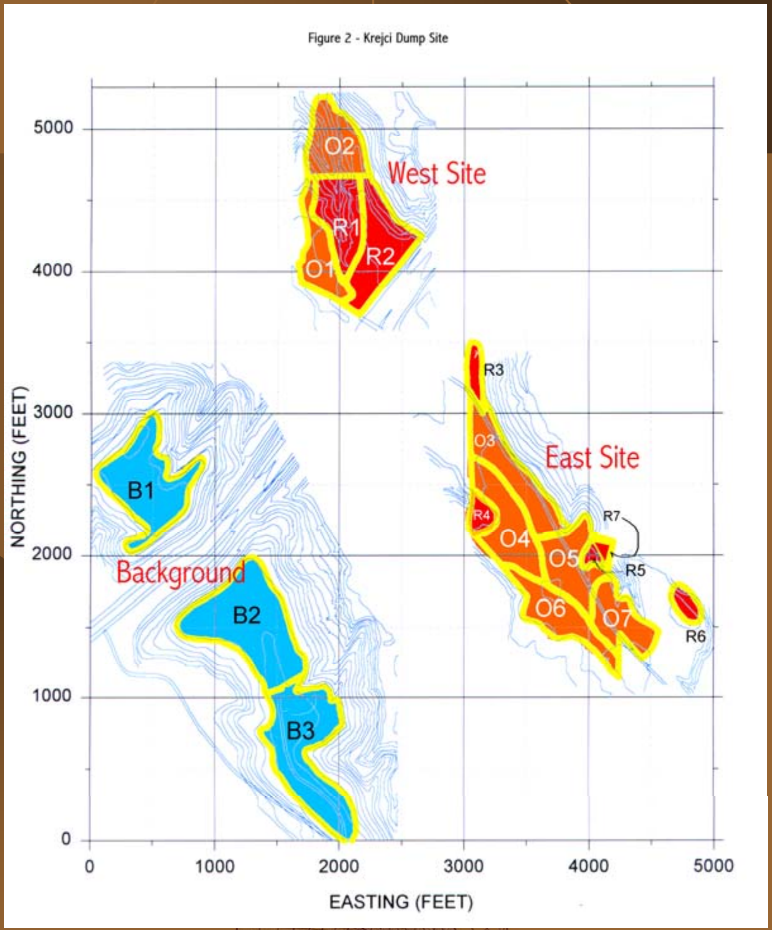
NORTHING (FEET)
EASTING (FEET)
0
1000
2000
3000
4000
5000
700
850
HINES
HILL
BOUNDARY
N

NPS Annexed the Dump Site in 1980

- The roughly 47-acre Site is a former municipal and industrial dump and salvage located within the Cuyahoga Valley National Park (Park) in Summit County, Ohio.
- During the years of operation from approximately 1950 to 1980, large volumes of solid and liquid waste materials were brought to the dump, where significant quantities of hazardous substances were released to the environment as a result of open dumping, spills, leaking containers, and burning.
- The United States purchased the land in 1980 for management by the Department of the Interior National Park Service (NPS).

The Krejci Dump Site

- The Site comprises two areas referred to the West Site (approximately 19 acres) and East Site (approximately 28 acres), located as shown on the next slide.




NOTICE
NO HUNTING
OR TRAPPING

MCG


Your
BANKAMERICARD
welcome here

MCG


12 18 '96

USEPA CERCLA Response

- In 1987, it was determined that the Site may constitute a threat to human health and the environment.
- In response to this determination, the U.S. Environmental Protection Agency (EPA) initiated an emergency removal action in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in June 1987.
- Staged Waste.
- Expended all available funds..


AREA
CLOSED
TO
VISITOR USE
DANGER
HAZARDOUS
WASTE


RG 0135
Please
DRIVE SAFELY

NPS Response Action

- In November 1988, NPS completed the removal of wastes staged during the initial EPA activity
- NPS also removed unconsolidated wastes remaining on the West Site.
- Large quantities of debris and contaminated soil remained.


11 5 '93

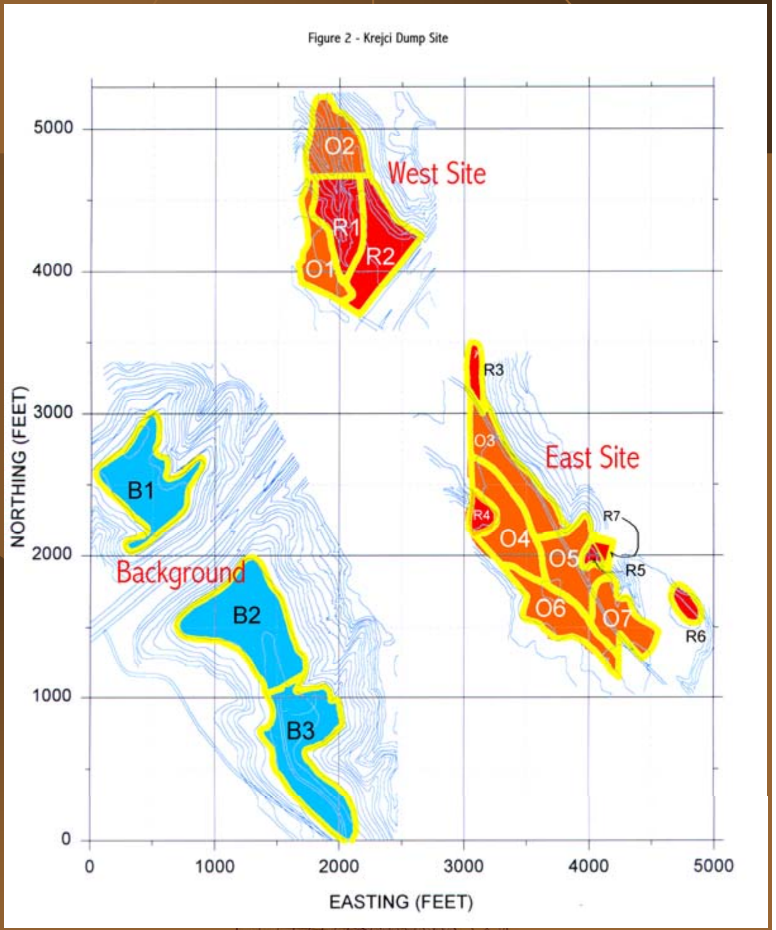

515 371 ST

DANGER
R&R
R&R


11.07.2005

CERCLA Remedial Investigation and Feasibility Study

- The Site comprises two areas referred to the West Site (approximately 19 acres) and East Site (approximately 28 acres), located as shown on the next slide.
- For the RI, the Site was divided into fourteen Areas of Concern (AOCs).
- The West Site consists of approximately 19 acres.
- The East Site consists of an estimated 28 acres.
- Initially it included the Boston Township right-of-way for Hines Hill Road.

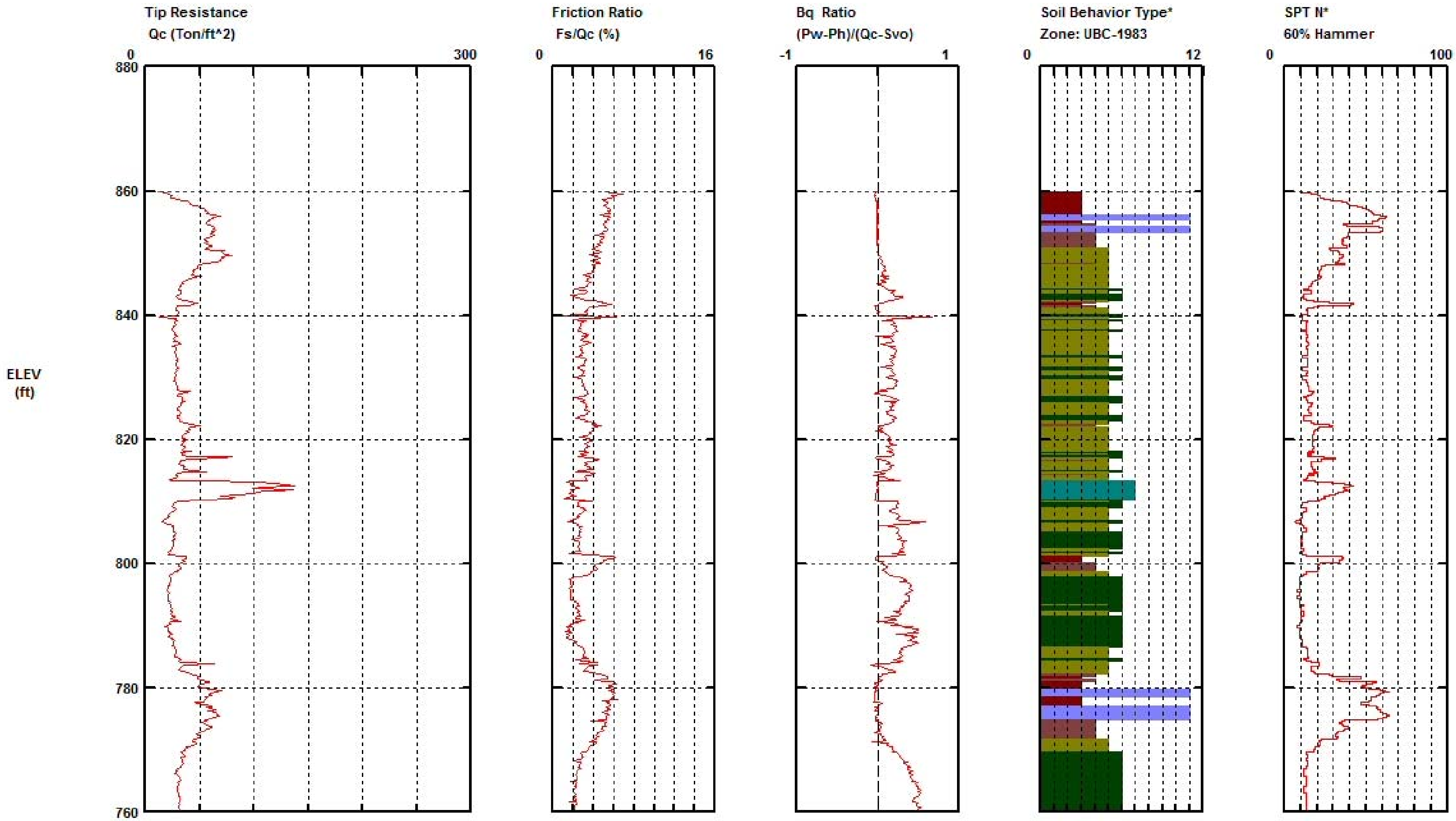


MCG

Krejci Cone Penetrometer Log

Operator: R.A.B./A.J.S.
Sounding: KRJA16
Cone Used: 361

CPT Date/Time: 11-14-94 08:17
Location: EAST-N2150 E3950
Job Number: KREJCI RI/FS



Maximum Depth = -758.30 feet

Depth Increment = 0.16 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Remedial Action

- Following the CERCLA Remedial Investigation and Feasibility Study (RI/FS), the Site Remedial Action (RA) was selected and set forth in the 2002 Record of Decision (ROD) issued by NPS.
- The ROD requires, among other things, that all debris and soils containing unacceptable levels of contaminants will be excavated and disposed off-site at appropriately licensed or permitted facilities.
- The ROD also established RGs for each identified Site contaminant.
- The ROD was incorporated into the Consent Decree (CD) negotiated with Ford Motor Company (Ford) and other Site responsible parties and entered by the U.S. District Court for the Northern District of Ohio (April 22, 2002).
- Under the terms of the Ford CD, Ford is implementing the RA, subject to NPS oversight, and in accordance with a Statement of Work (SOW), which sets forth additional RA implementation requirements.

Remedial Action

- Ford retained a contractor to conduct the cleanup.
- The Remedial Design (RD) Report and Remedial Action Work Plan (RAWP) detailing the RA design and implementation plans, respectively, were prepared on Ford's behalf and approved by NPS in 2005.
- Initial excavation began in October 2005.
- Various amendments were made to the RA documents.
- The only amendment to the Field Sampling Plan (FSP) was made on June 8, 2009.


09/25/2006


09/25/2006


CASE
09/25/2006


04 19 2006 11:24


VOLVO
CAT


06/21/2006


VOLVO
CAT
CAT 320C
6/21


2007/04/25


10/13/2006


2007/06/07


04.19.2006 11:25


2013/05/07

MCG


W Hines Hill Rd
© 2012 Google
381 ft
Google earth


N
© 2012 Google
562 ft
Google earth


2013/06/04

“We cannot solve today’s problems with the same level of thinking that created them”

ALBERT EINSTEIN
(1879 -1955)

RG Achievement Letter
Drafted August 2012

Four Sampling Events

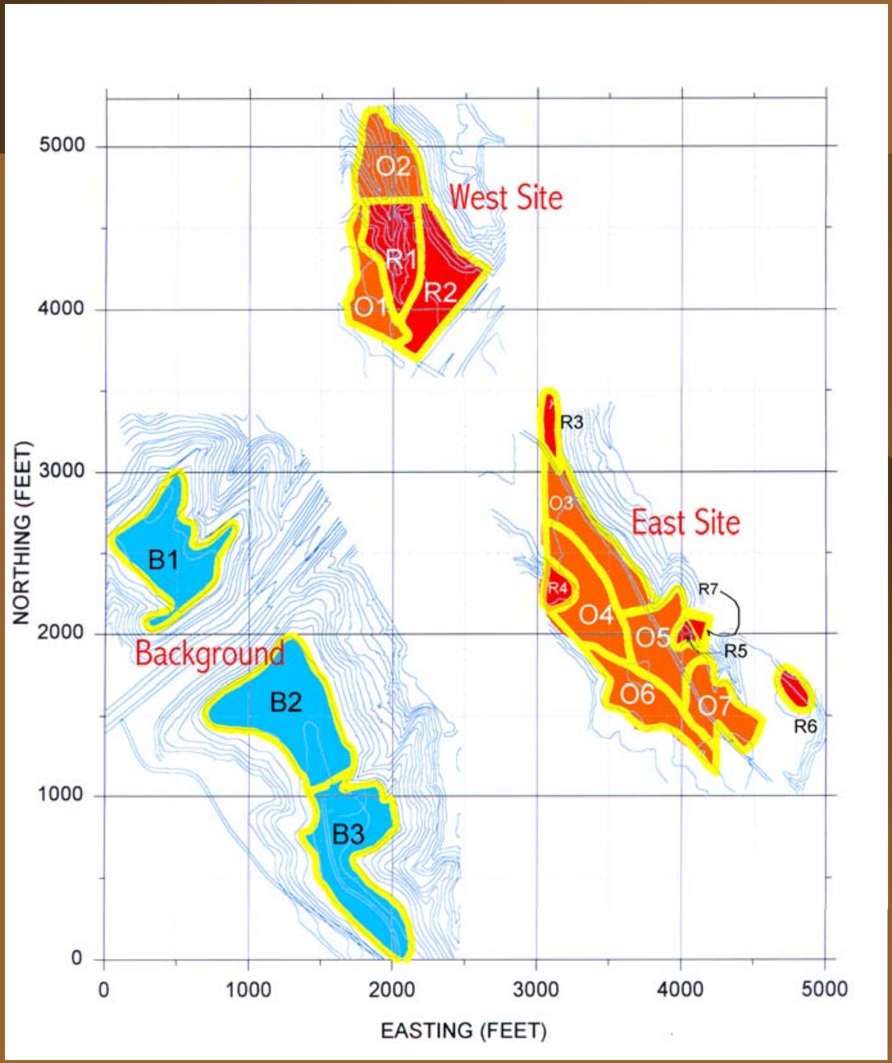
- **USEPA Emergency Response:** Characterized Surface Debris and waste during the Staging of Waste.
- **Remedial Investigation***: Obtain data sufficient to determine if the Site presents an unacceptable Human Health risk, and if necessary, to establish remediation goals and select a preferred alternative.
- **Final Design Investigation**: Obtain data necessary to better define the limits of the Site and refine the remedial action.
- **Cleanup Verification***: Obtain Data necessary to verify achievement of remediation goals.

Remedial Investigation

NPS SponsoredTeam

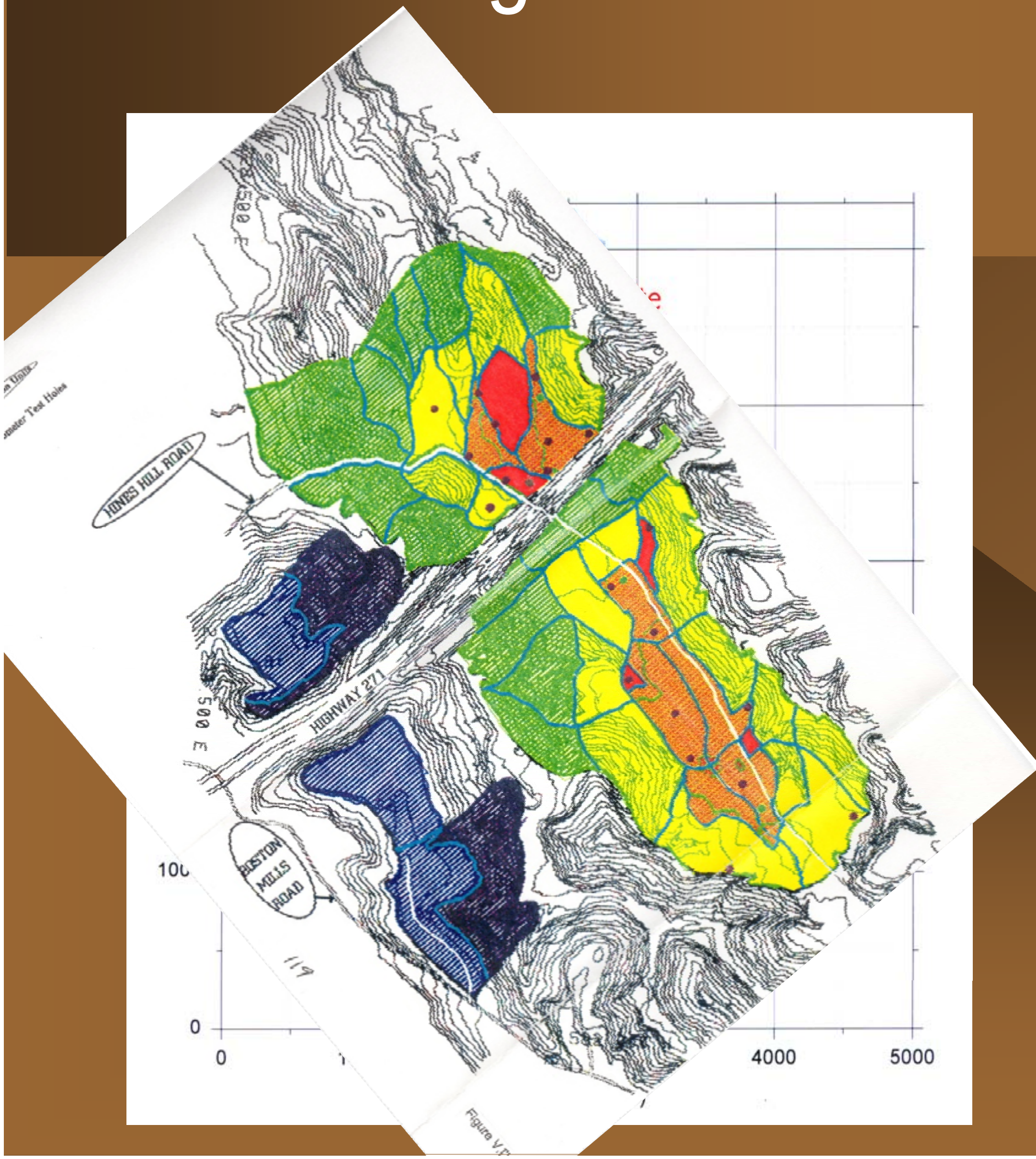
- Resource Manager*
- Geohydrologist/Site Characterization Specialist*
- Hydrologist
- Chemist
- Statistician
- Human Health Risk Assessor
- Ecological Risk Assessor
- Attorney*
- Ecology Specialist
- RCRA Specialist

Subdividing the site.



- The Site was divided into two areas of concern: The East and West Sites.
- These were subdivided to focus attention on specific drainages and areas of significant past use.
- A Background Site was also divided into areas.

Subdividing the site.



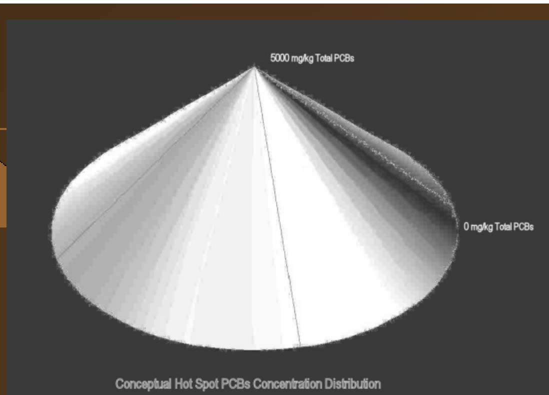
- Original Subdivisions
- Based on potential for Contaminant Transport
- Dioxin/Furan fallout
- Surface Water
- Not utilized, but spurred thoughts regarding “How Clean Is Clean” and Early Estimation of Remediation Goals.

Concept Used for Krejci Site

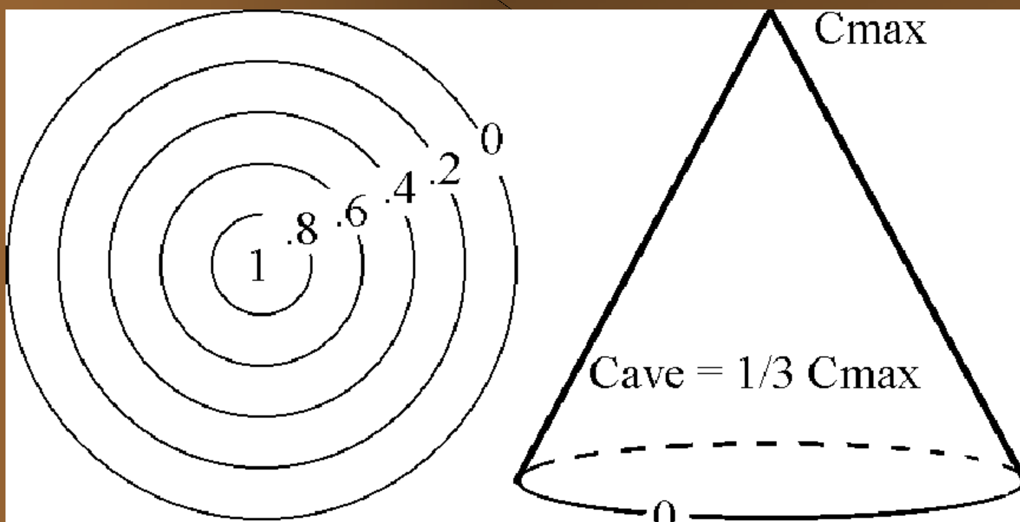
- Use Composite samples to provide a quantifiable level of confidence that what is missed is inconsequential to decision-making.
- Determine the project needs and use these needs to determine the number of increments that must be included in the sample.

Data Needed For Risk Assessments and Evaluation of Remediation Alternatives

- Risk calculations use estimates of mean concentrations within exposure areas.
- Risk assessment work plan prepared in the DQO stage.
    - Exposure areas defined
    - Equations and constants defined
    - Data needs defined
    - Data quality defined
- Potential Remediation Alternatives Developed Sufficiently to assess data needed for their evaluation.



Model Hot Spot



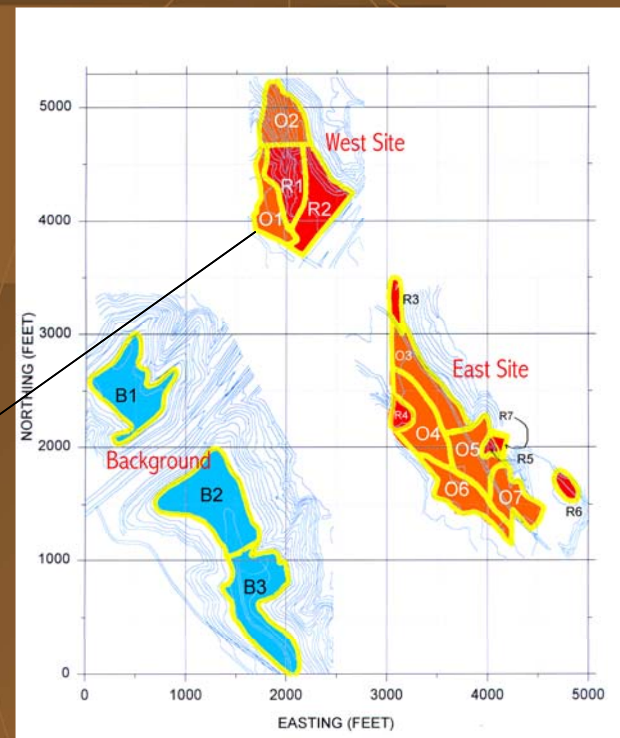
$$A_{HotSpot} = A_{Site} \times \frac{C_{allowable}}{C_{HotSpotAverage}}$$

Note that 98 percent of Soil was 75 micometer or smaller. Therefore: FE small.

However, Distributional Heterogeneity must be controlled.

Case History - Krejci Site – Cuyahoga Valley National Park

Primary Concern: Human Health Risk

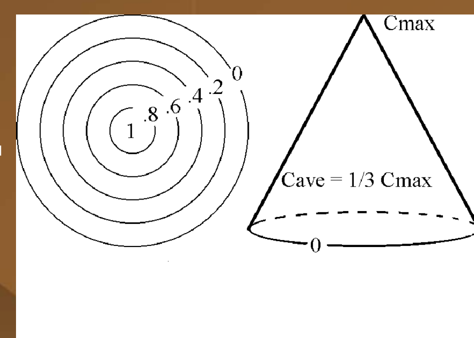


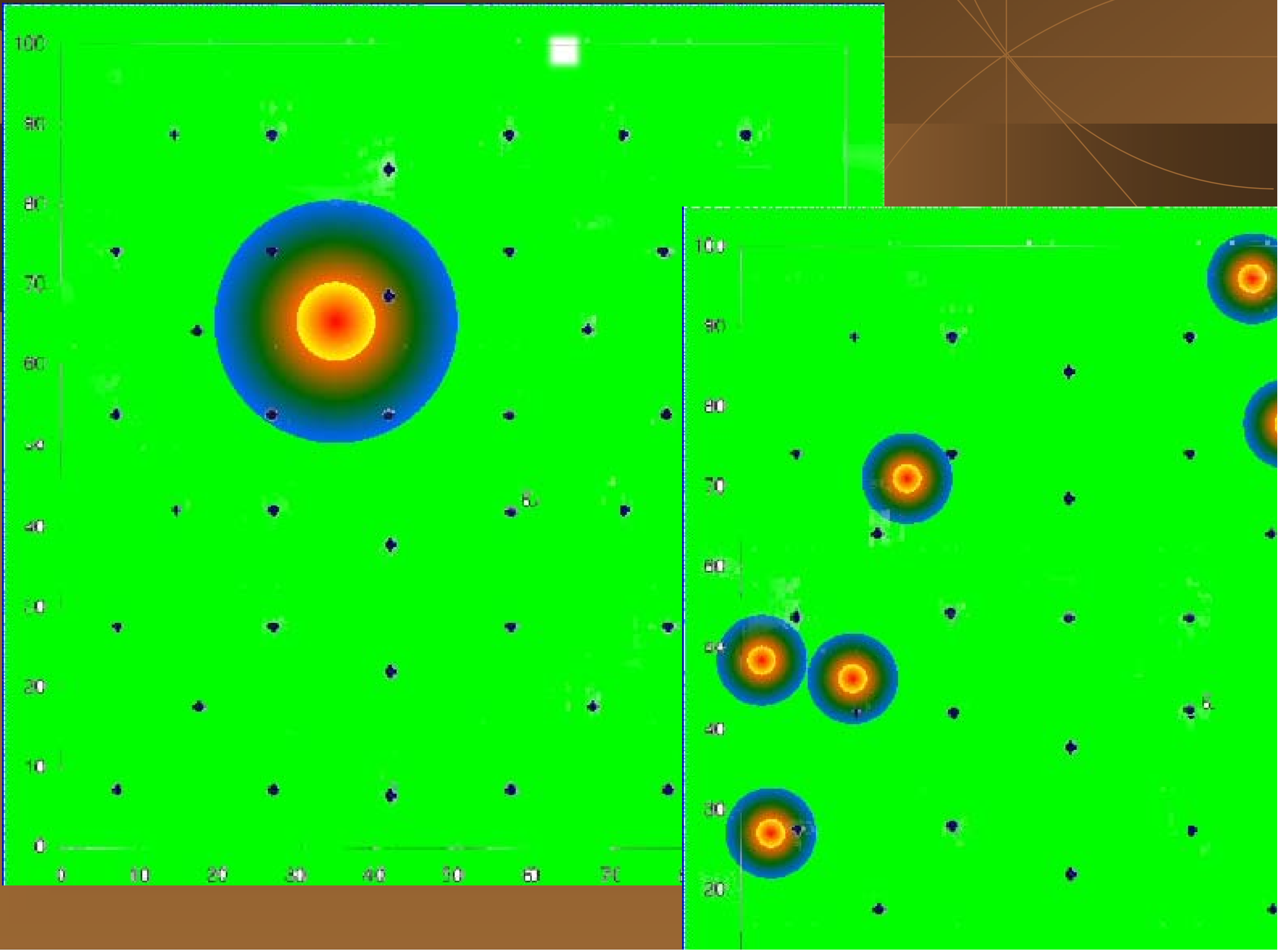
West Site

Human Health Risk Concern

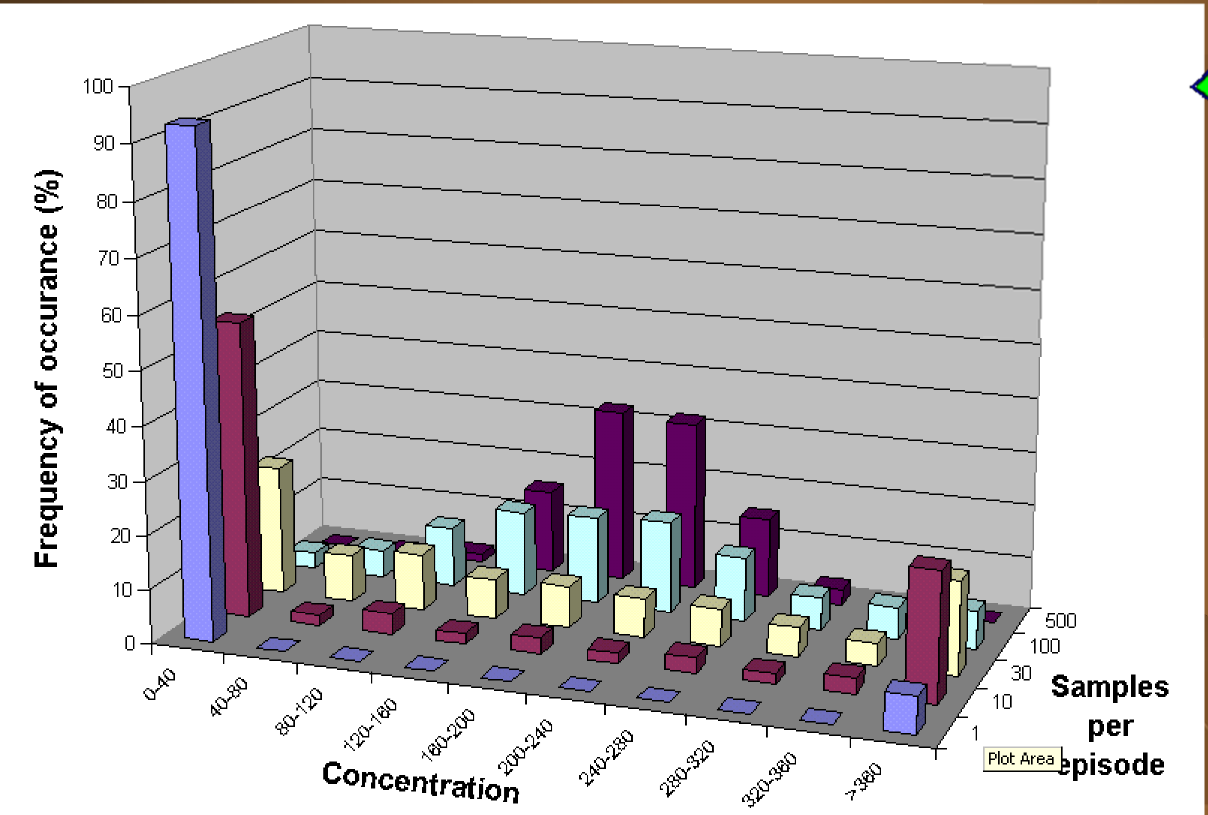
Risk evaluation suggested there is cause for concern if the area of contamination equals or exceeds 6 percent of the exposure area

West Site represents exposure area for recreational use scenario



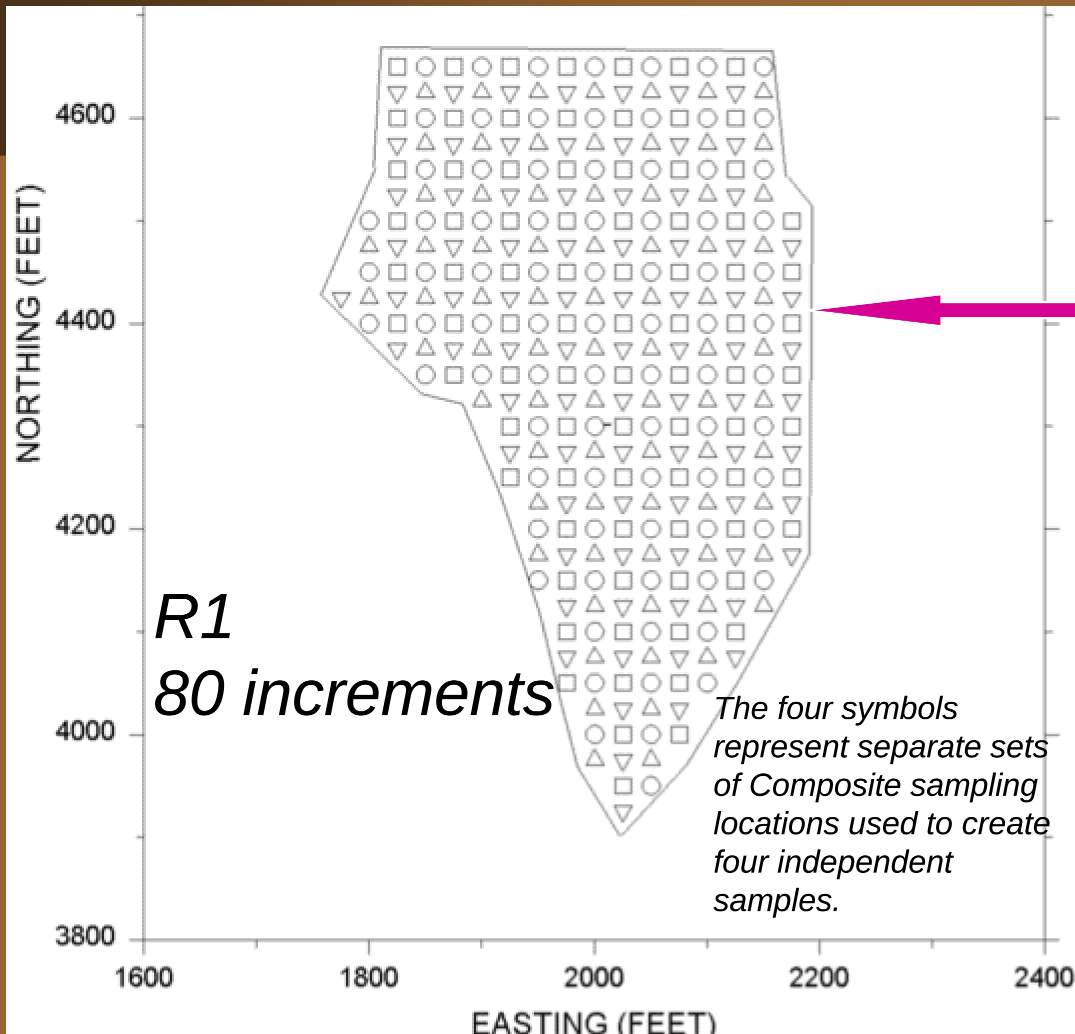


Simulated Contaminant Distributions

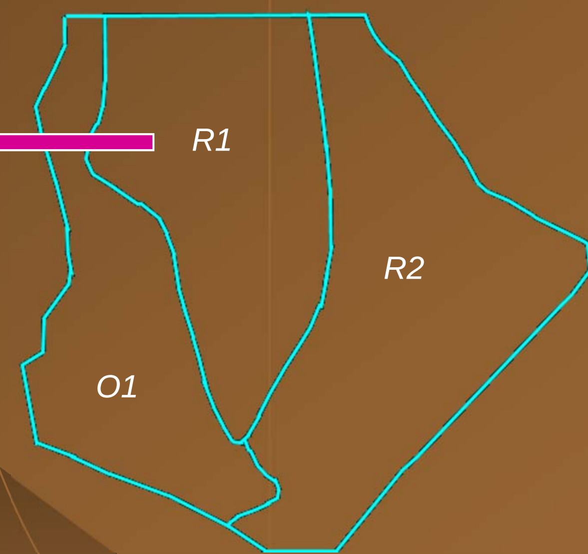


Distribution of 10000 sampling events using 1 through 500 increments per sample

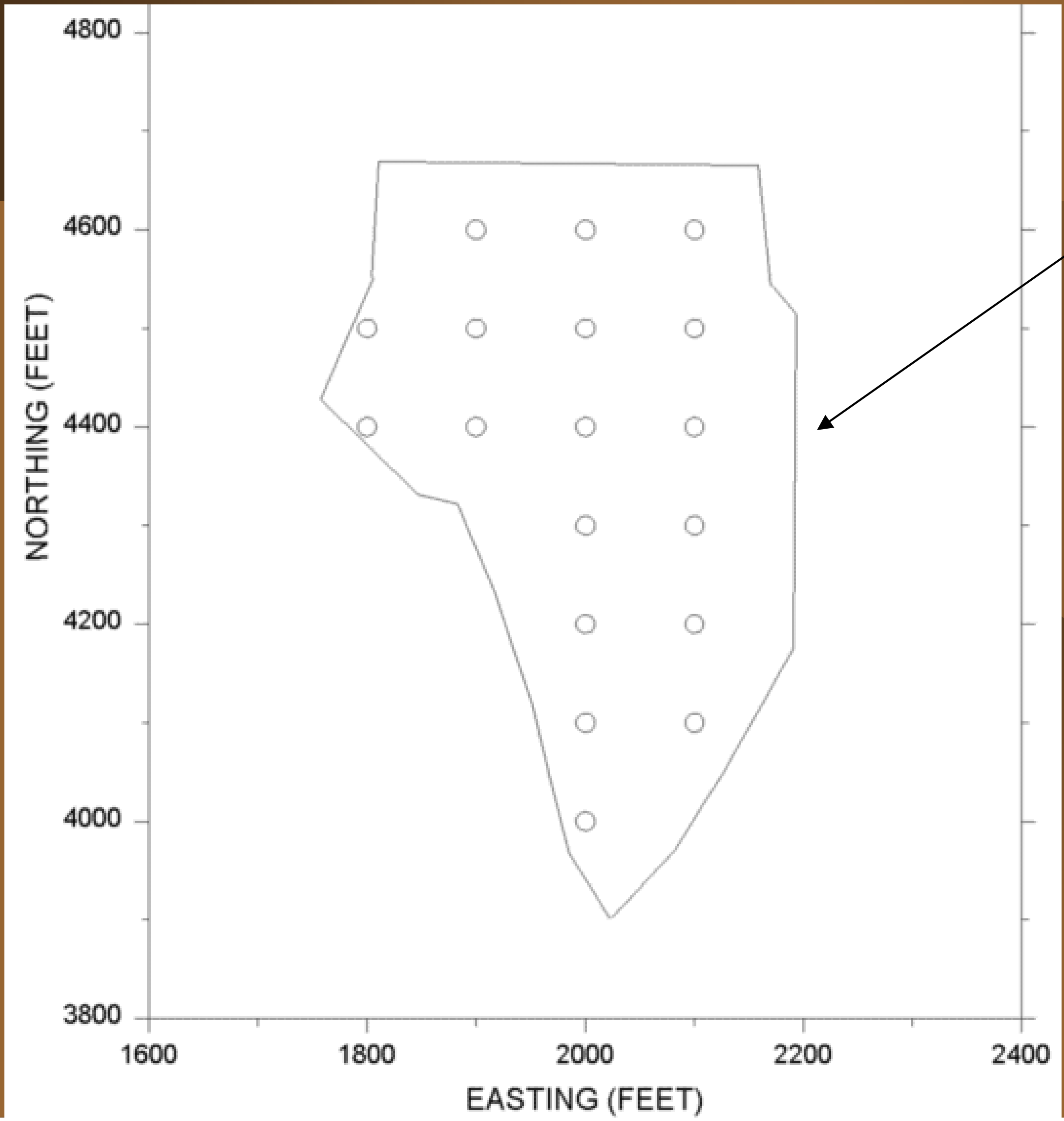
Sampling Scheme
quadruplicate samples - 25 ft grid.

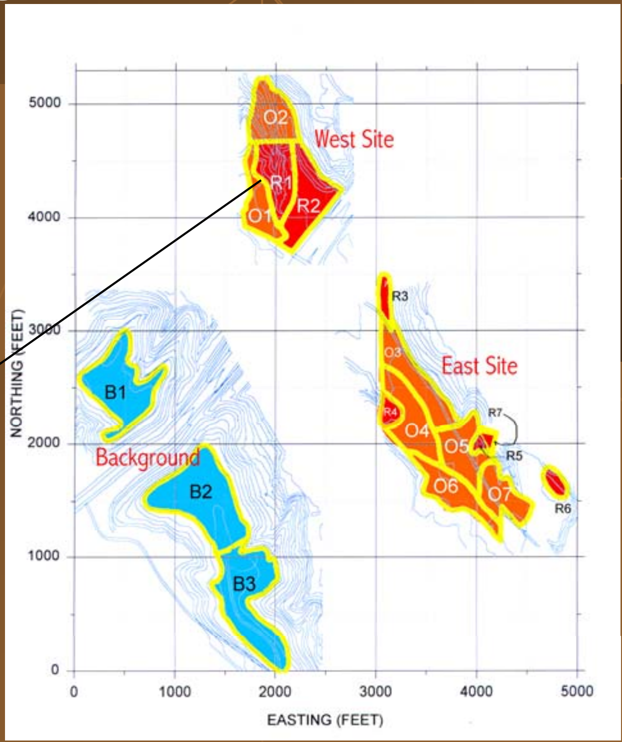


The four symbols represent separate sets of Composite sampling locations used to create four independent samples.



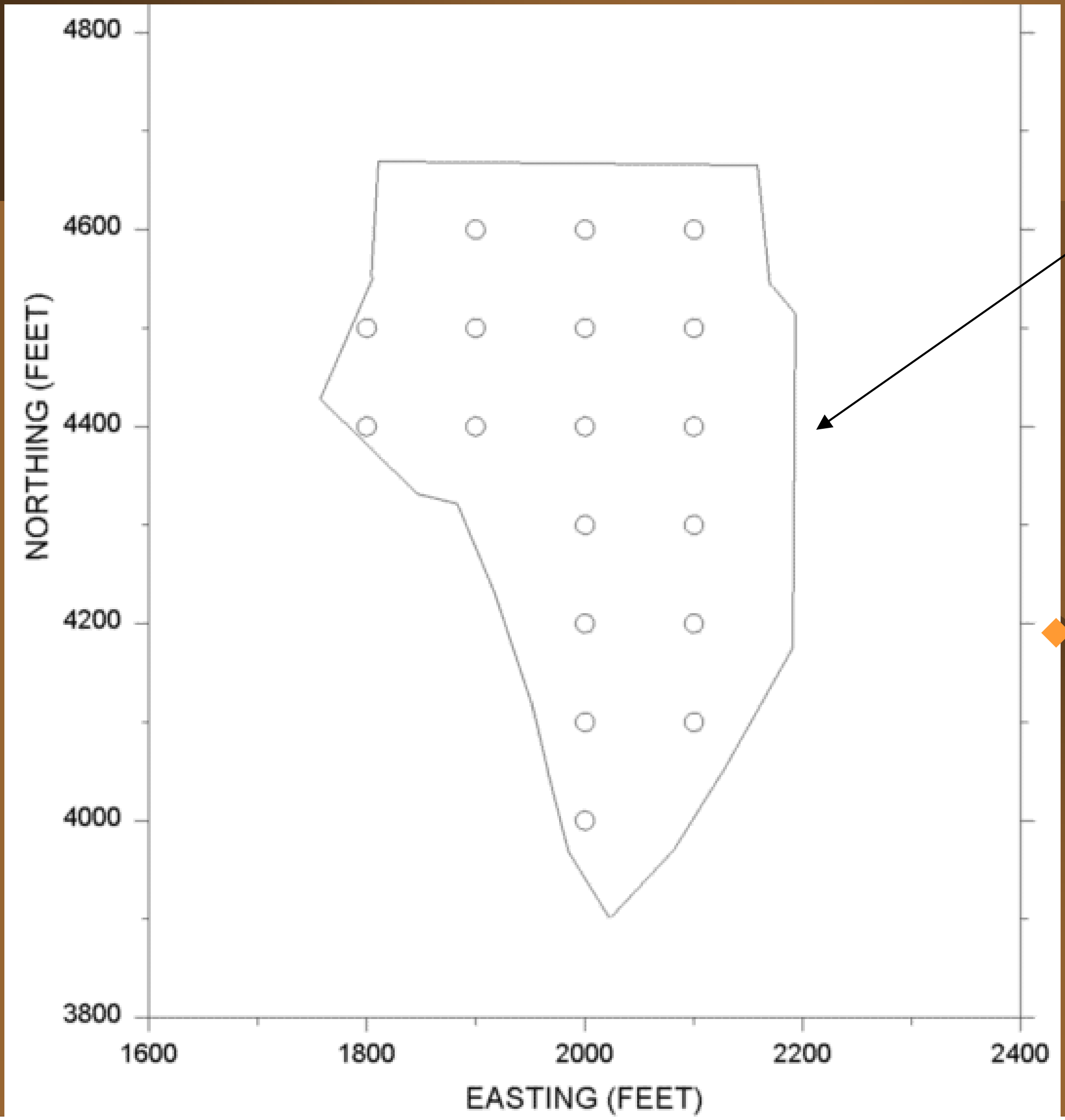
Example of Discrete Sampling Grid - 100 ft Centers – Red Areas

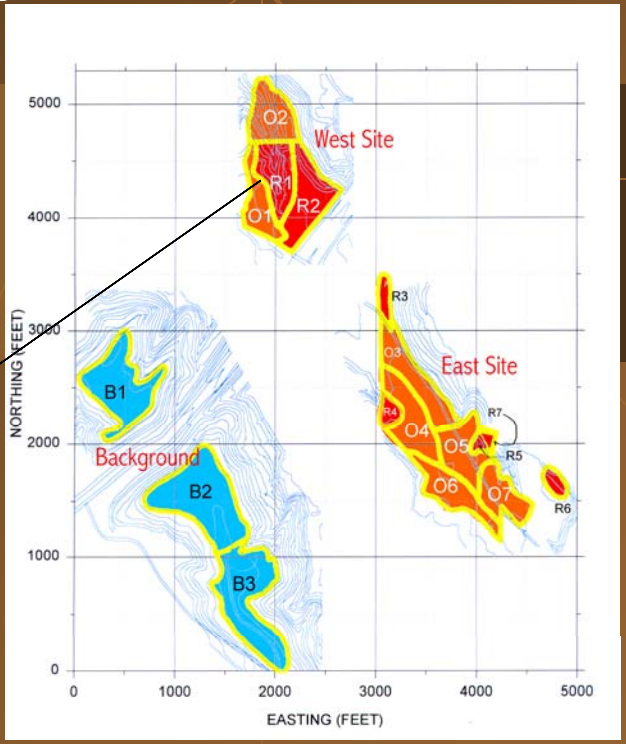




- Discrete samples were collected at 100 ft grid nodes in areas thought most likely to exhibit high levels of contamination. These numbered areas are prefixed by R.

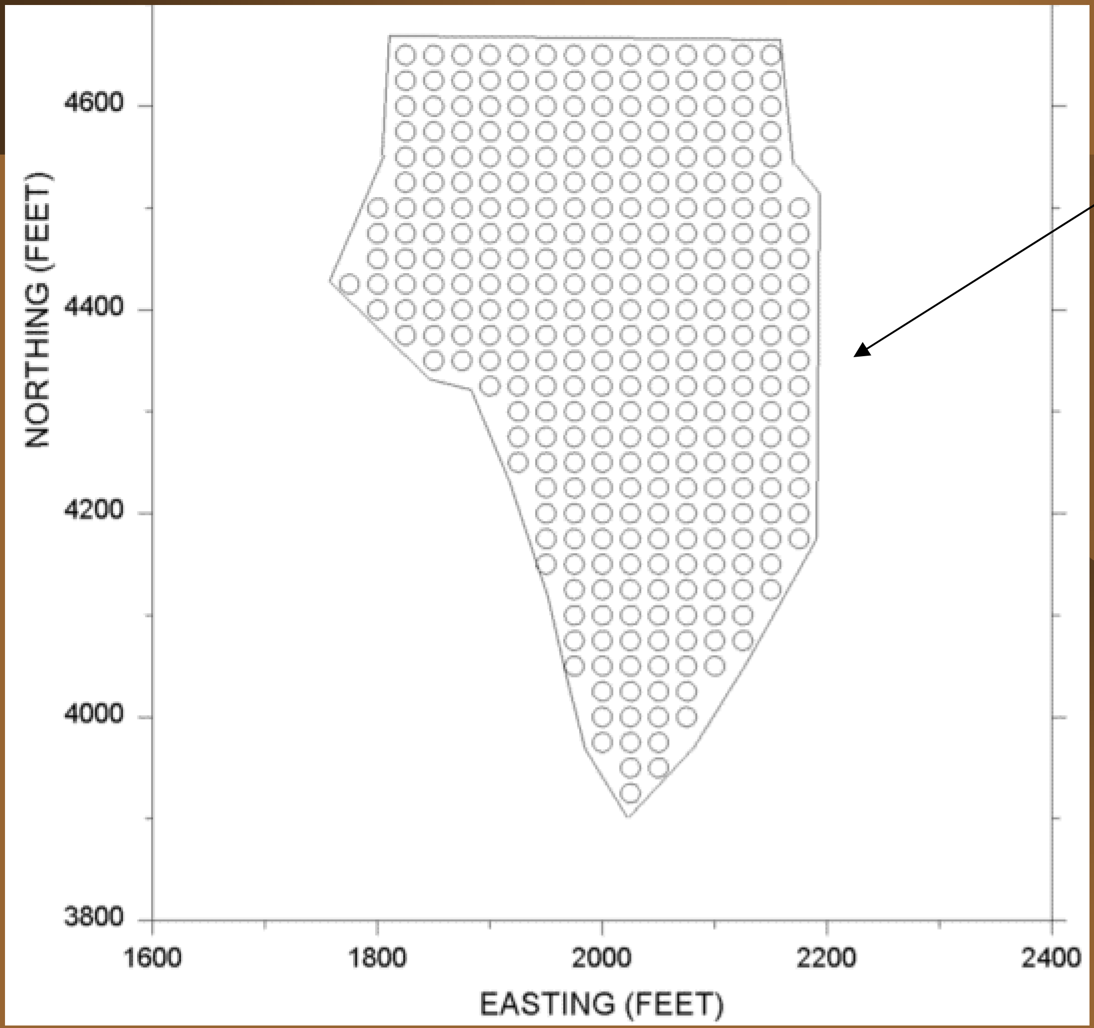
Example of Discrete Sampling Grid - 200 ft Centers – Orange and Blue

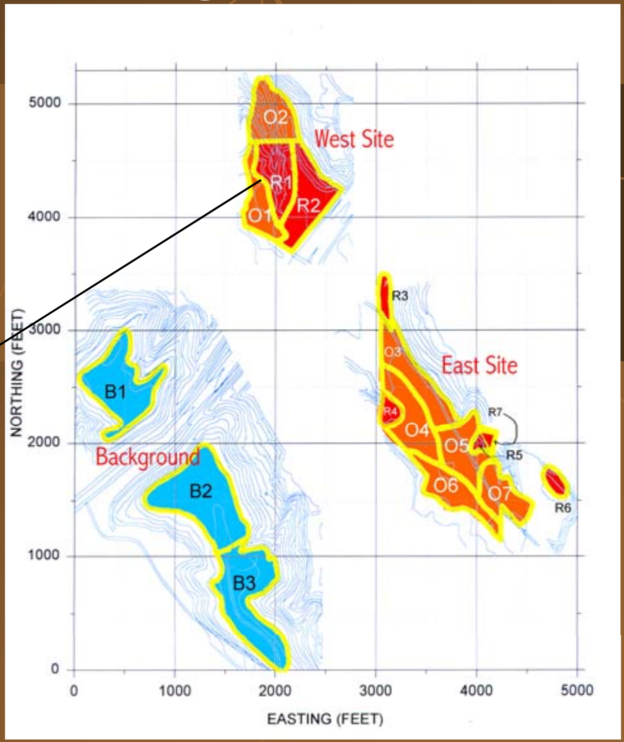




- Discrete samples were collected at 200 ft grid nodes in background areas and Site areas thought less likely to exhibit high levels of contamination. These are prefixed by B and O respectively.

Example of Discrete PCB screening locations - 25 ft grid - R1





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

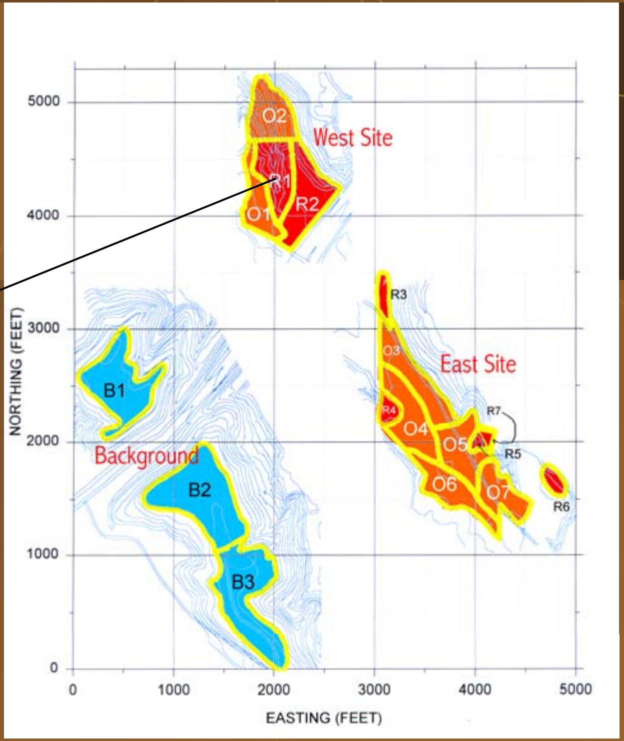
Comparison of PCBs Concentrations

Comparison of **PCBs** concentrations Discrete vs Multi-Increment Samples						
Subunit	Area	Number of Discrete Samples	Average Subunit Concentration	Number of Incremental Samples	Total number of Increments	Average Subunit Concentration
	(ft2/1000)		(mg/kg)			(mg/kg)
R1	200	18	**12.9**	8	640	5.3
R2	266	22	16.4	8	851	**27.7**
R3	51	3	0.6	4	82	**1.3**
R4	49	5	1.2	8	157	**68.6**
R5	24	2	4.7	8	77	**43.2**
O1	167	4	0.6	8	134	**17**
O2	203	5	0.1	4	81	**1**
O3	245	6	1.5	4	98	**2.7**
O4	240	6	3	4	96	**3.1**
O5	203	5	1.9	4	81	**2.1**
O6	198	5	0.7	8	158	**1.7**
O7	163	4	0.8	4	65	0.7
	46 acres	*85*	*8.2*	*72*	*2520*	*9.1*

Comparison of Lead Concentrations

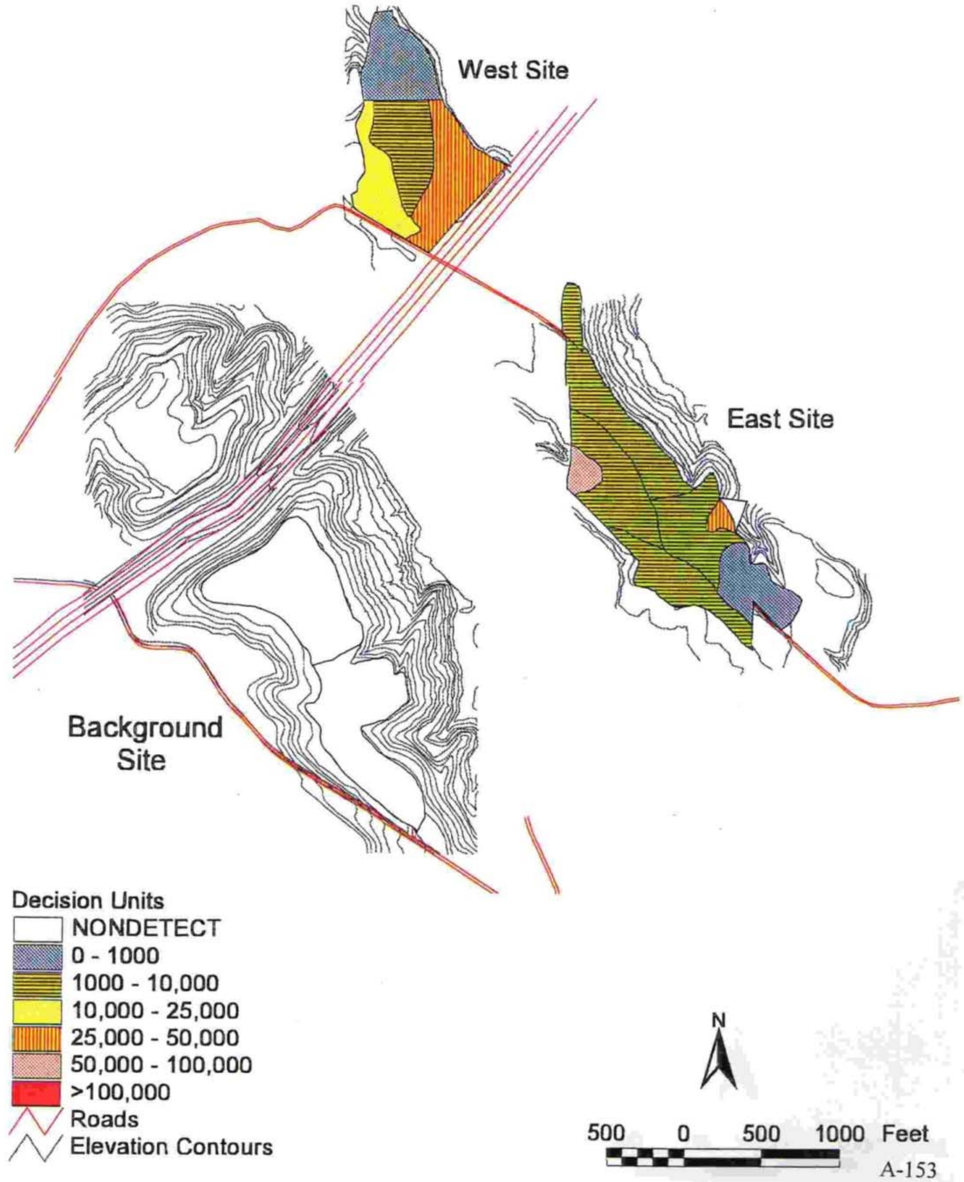
Comparison of **Lead** Concentrations Discrete vs Multi -Increment Samples						
Subunit	Area	Number of Discrete Samples	Average Subunit Concentration	Number of Incremental Samples	Total number of Increments	Average Subunit Concentration
	(ft2/1000)		(mg/kg)			(mg/kg)
R1	200	18	**2789**	8	640	2145
R2	266	27	1128	8	851	**1217**
R3	51	3	20	4	82	**37**
R4	49	4	122	8	157	**136**
R5	24	4	970	8	77	**6116**
R6	41	4	132	4	66	**171**
O1	167	3	415	8	134	**736**
O2	203	5	71	4	81	**83**
O3	245	6	132	4	98	**506**
O4	240	6	366	4	96	**372**
O5	203	5	194	4	81	**1463**
O6	198	6	239	8	158	**727**
O7	163	4	857	4	65	856
	46 acres	*95*	*646*	*72*	*2520*	*902*

Cokriged Screening and Laboratory PCBs



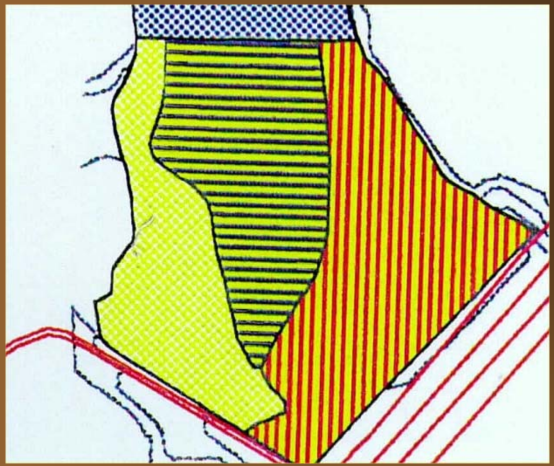
KREJCI SITES

Subunit Averages from Composite Samples
Analyte= Aroclor-1254. Units= PPB.



Comparison of PCBs Mean Concentrations

Composite Samples generally yielded higher estimates of mean contaminant concentrations.



Area Weighted

Mean =18 mg/kg

24 samples 1625 specimens

Numerical Average

Mean =11 mg/kg

44 samples 300 screenings

Comparison of Composite and Discrete Sample Estimates

Orange Area Mean PCBs

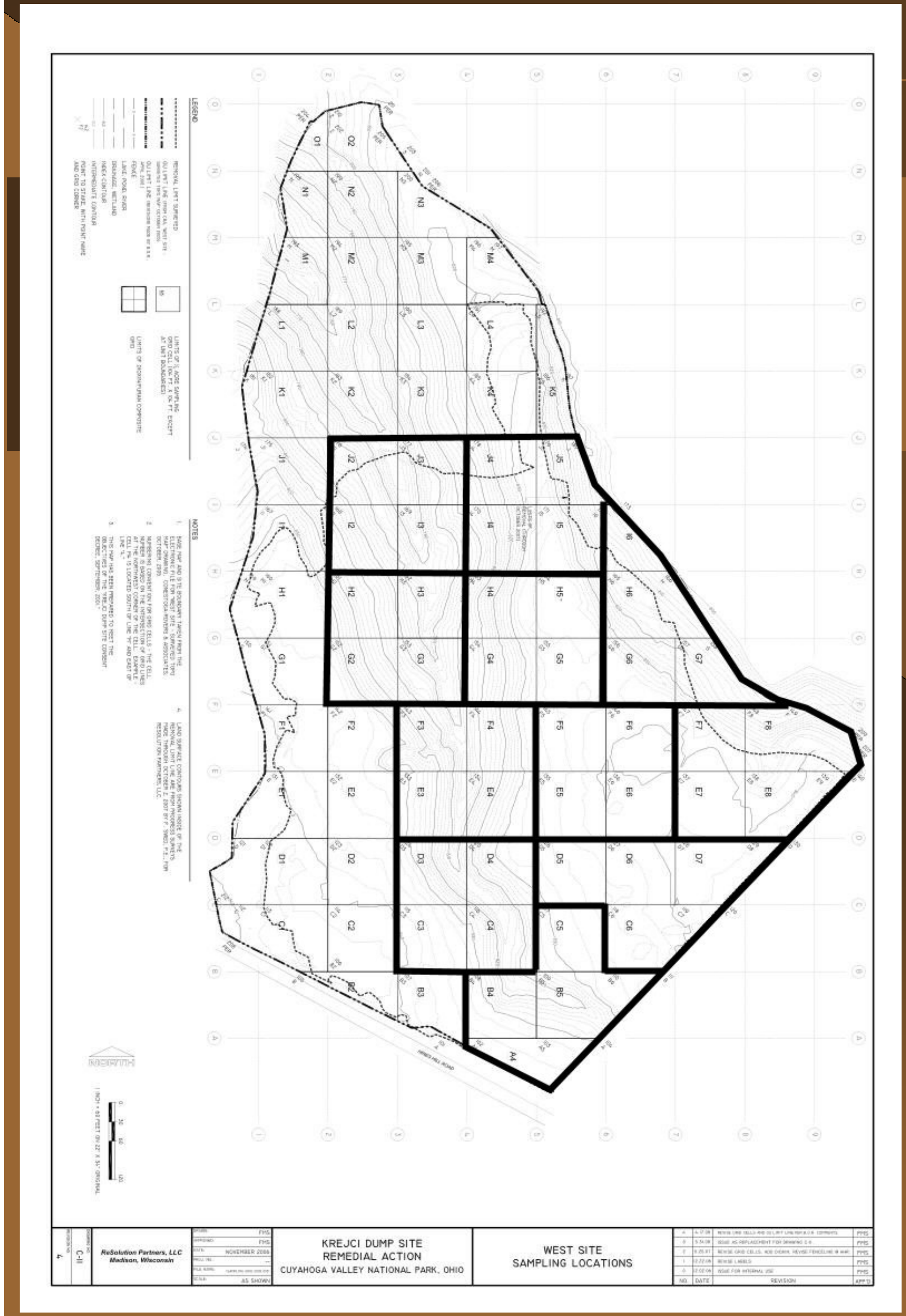
For Orange Areas (hot spots less common and smaller)

Composite	*Discrete*
Mean =4 mg/kg	Mean =1 mg/kg
36 samples 713 specimens	35 samples

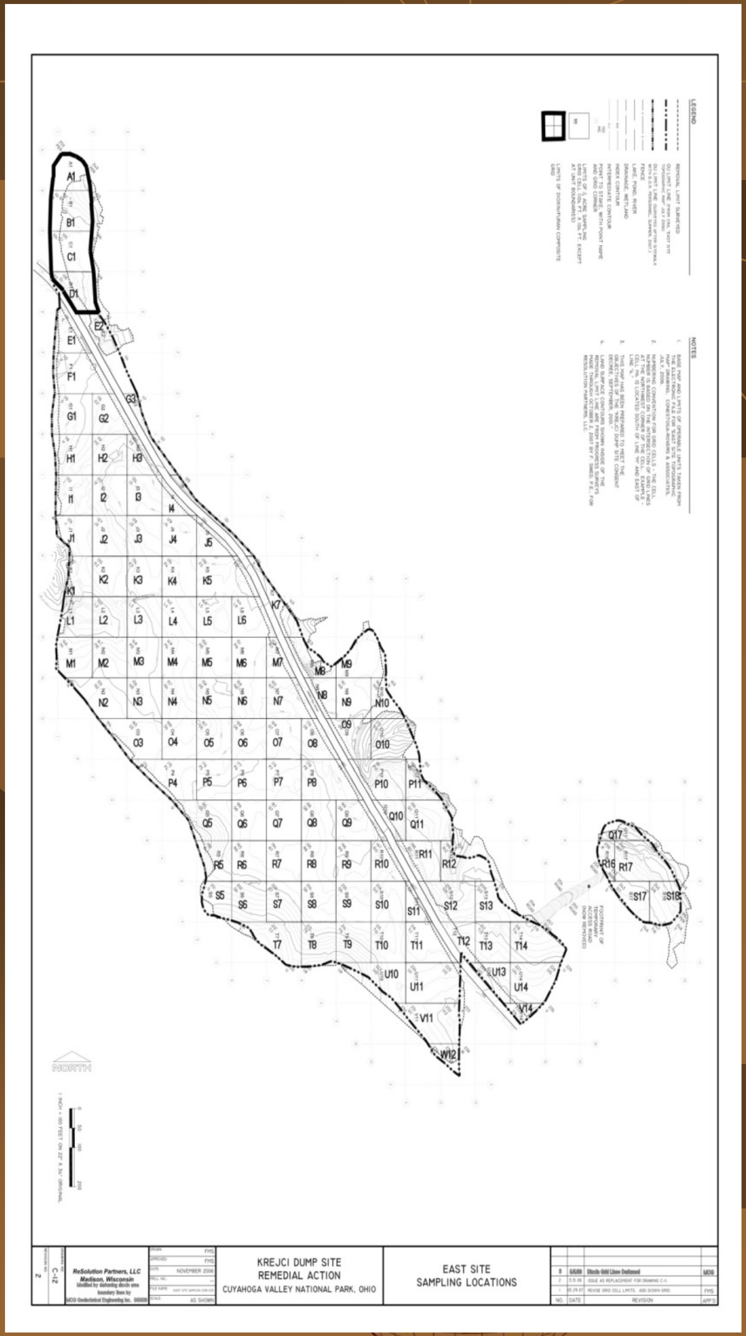
Cleanup Verification

Cleanup Verification

- Driven by the Need to Reduce Ecological Risk to an Acceptable Level.
- Park Exercised its Right to Special Consideration Under CERCLA by ensuring protection of all species at the individual rather than population level.
- Dioxin and Furan RGs based on Human Health Risk.
- RG - Background for TAL
- RG - Based on risk for Organic Compounds
- For the purpose of RA implementation, the Site was divided into 186 grids (76 on the West Site and 110 on the East Site) that are generally ¼-acre in size, located and identified as shown on the next slide.
- Twelve acres of the Site (48 grids) are subject to the dioxin/furan RG.



ReSolution Partners, LLC
Madison, Wisconsin
KREJCI DUMP SITE
REMEDIAL ACTION
CUYAHOGA VALLEY NATIONAL PARK, OHIO
WEST SITE
SAMPLING LOCATIONS



ReSolution Partners, LLC
Madison, Wisconsin
KREJCI DUMP SITE
REMEDIAL ACTION
CUYAHOGA VALLEY NATIONAL PARK, OHIO
EAST SITE
SAMPLING LOCATIONS

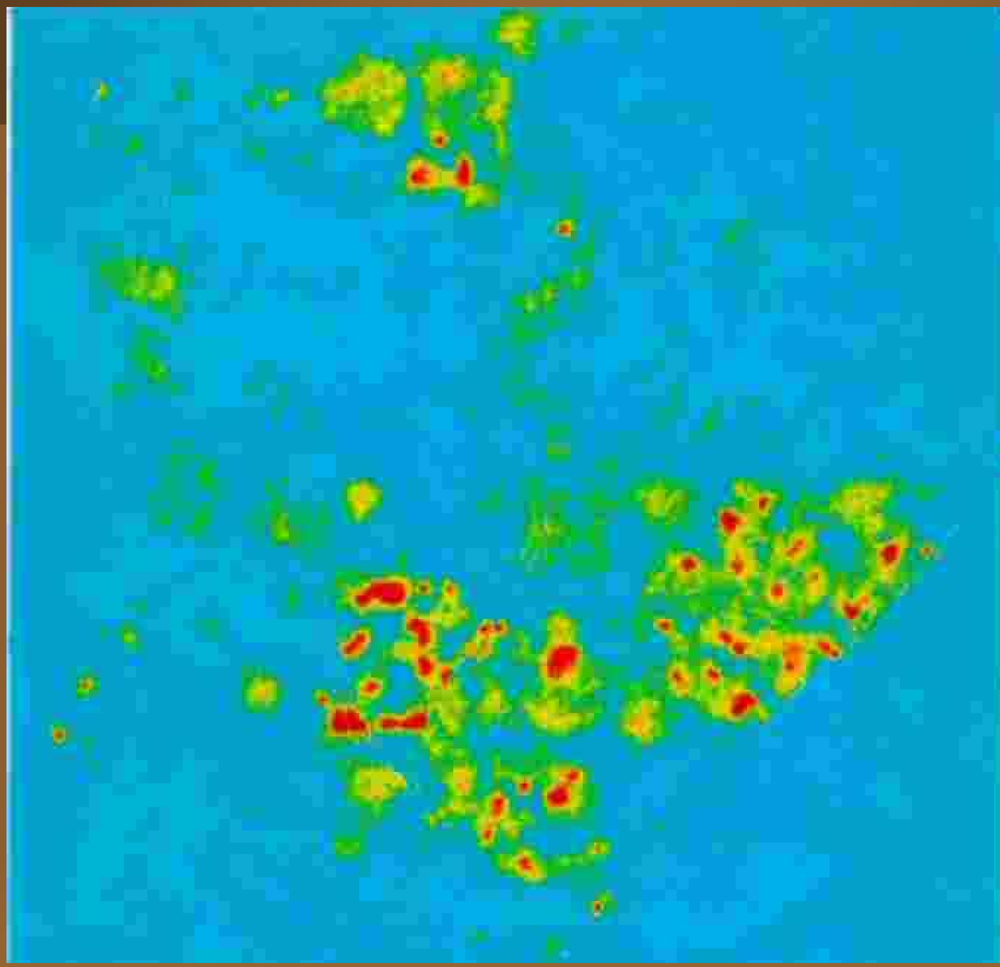
Cleanup Verification

- The CVS Plan provided that one sample comprised of approximately 40 increments of soil is collected to represent the surface of each ¼-acre grid.
- These samples were analyzed to determine the concentration of the Site contaminants listed in Appendix D, SOW, except for benzene and dioxins/furans.
- Samples for benzene analyses were collected from 40 discrete locations within each ¼-acre grid.
- Dioxin/furan samples (2,3,7,8-TCDD TEQ) were collected to represent the 12 identified one-acre dioxin/furan areas (or, alternatively, the individual ¼-acre grids within some of the 12 areas).

Cleanup Verification

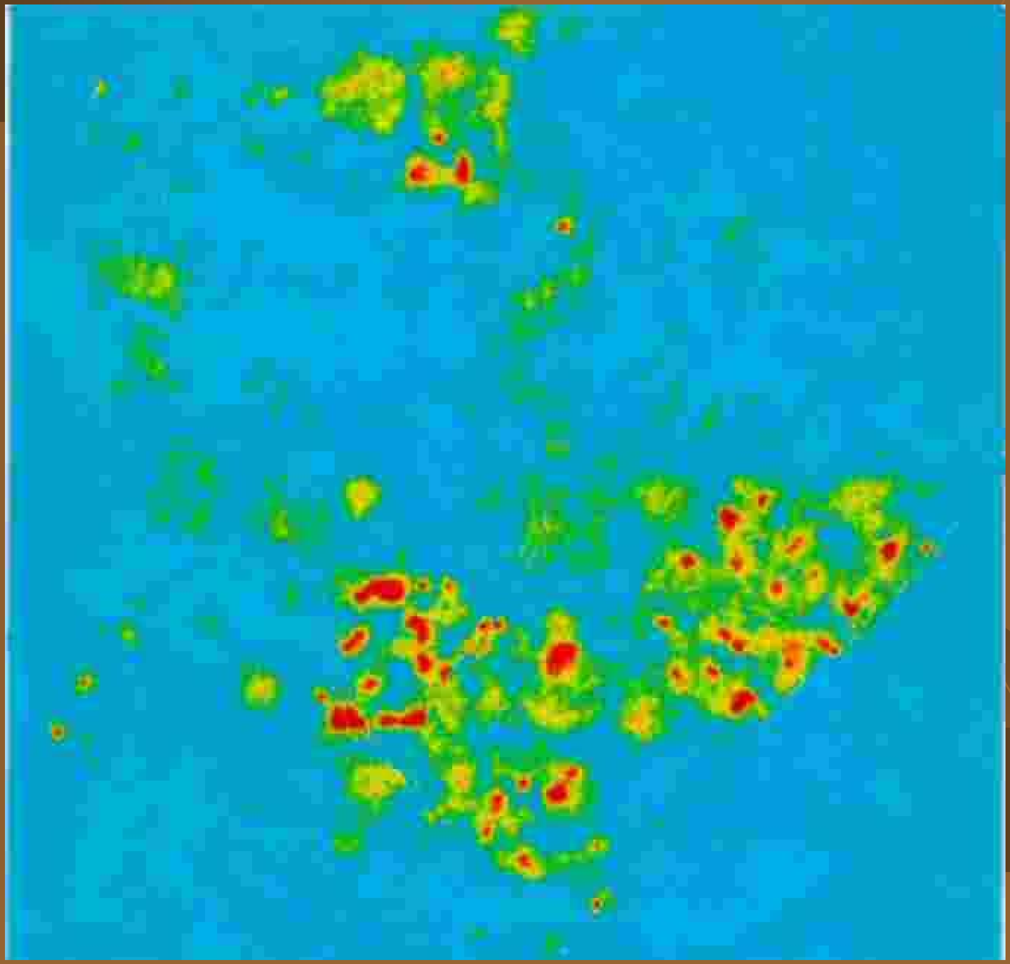
- Soils samples were submitted for laboratory analyses pursuant to QAPP protocols, and the resulting data were validated and entered into the Site database, also pursuant to established QAPP protocols.
- To ensure that soil sampling analyses were of the quality needed to limit the risk of erroneous decisions regarding attainment of RGs, the QAPP set forth criteria for evaluating the quality and usability of CVS data.
- More specifically, the QAPP established ten (10) measurement quality objectives (MQOs) by which the quality of CVS data can be evaluated.
- When CVS data routinely achieve applicable MQOs, these data are of sufficient quality to be used to verify whether Site grids have achieved the RGs.
- When CVS data fails to achieve MQOs, these data are assigned data qualifiers and are subject to additional evaluation to determine usability.
- Finally, usable data were compared with the RG for each applicable contaminant to verify that all RGs have been achieved in each grid.

Area (or Volume) Of Concern



The area (or volume) for which a representation of the mean is needed.

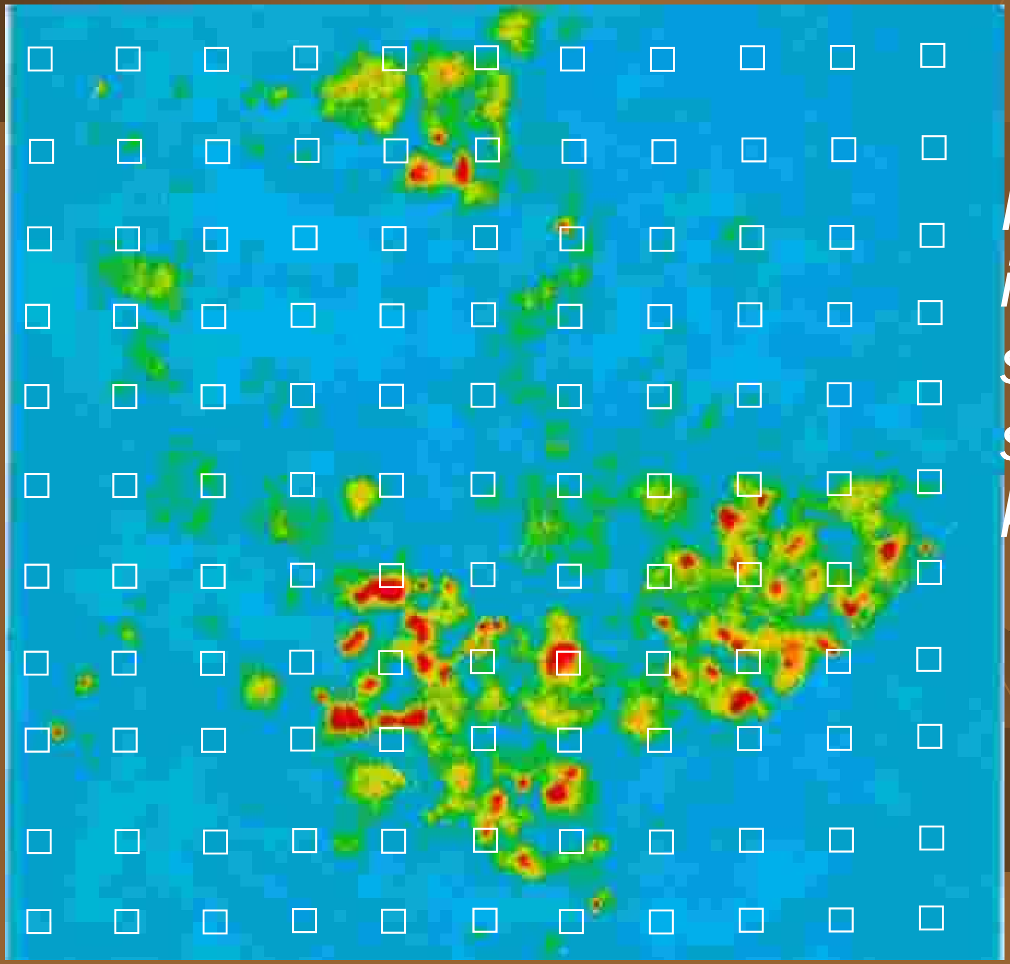
Area Of Concern for Risk Assessment



May be a home range for a wildlife receptor.

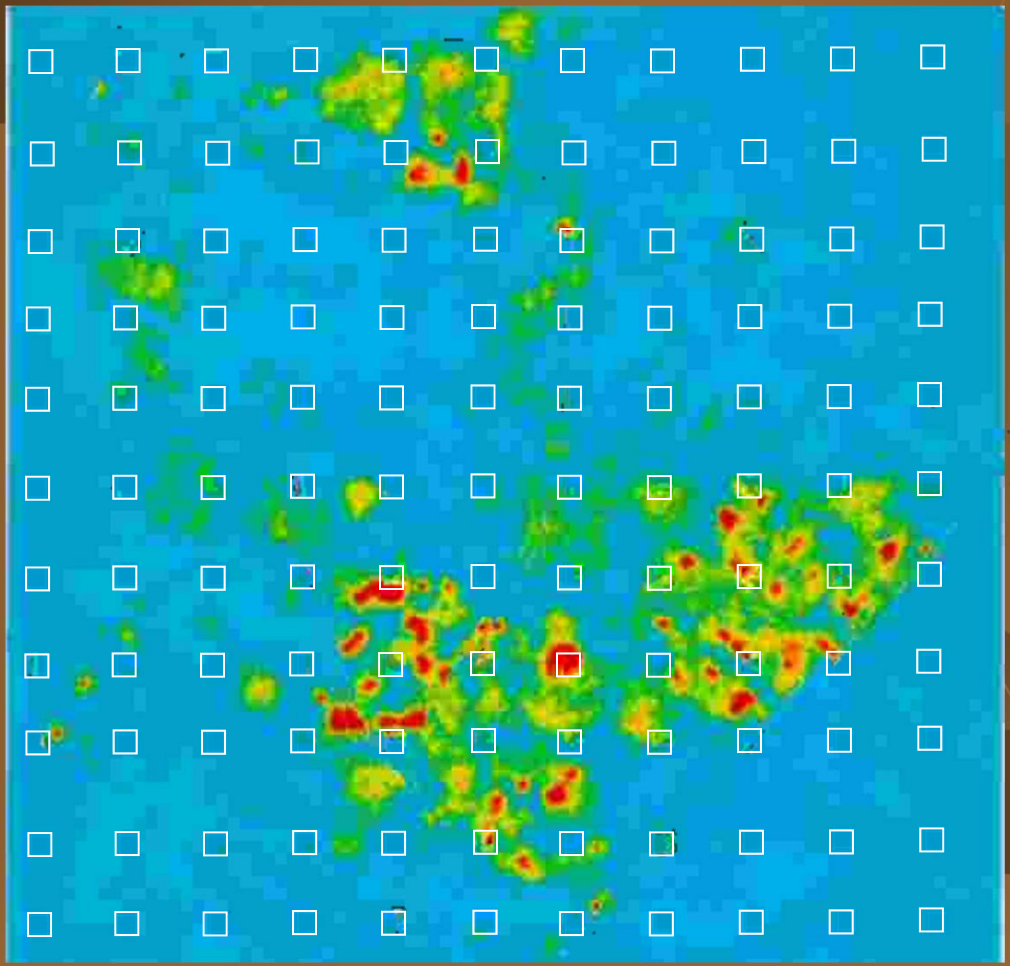
May be an exposure area for a human receptor.

How Many Increments are Needed?



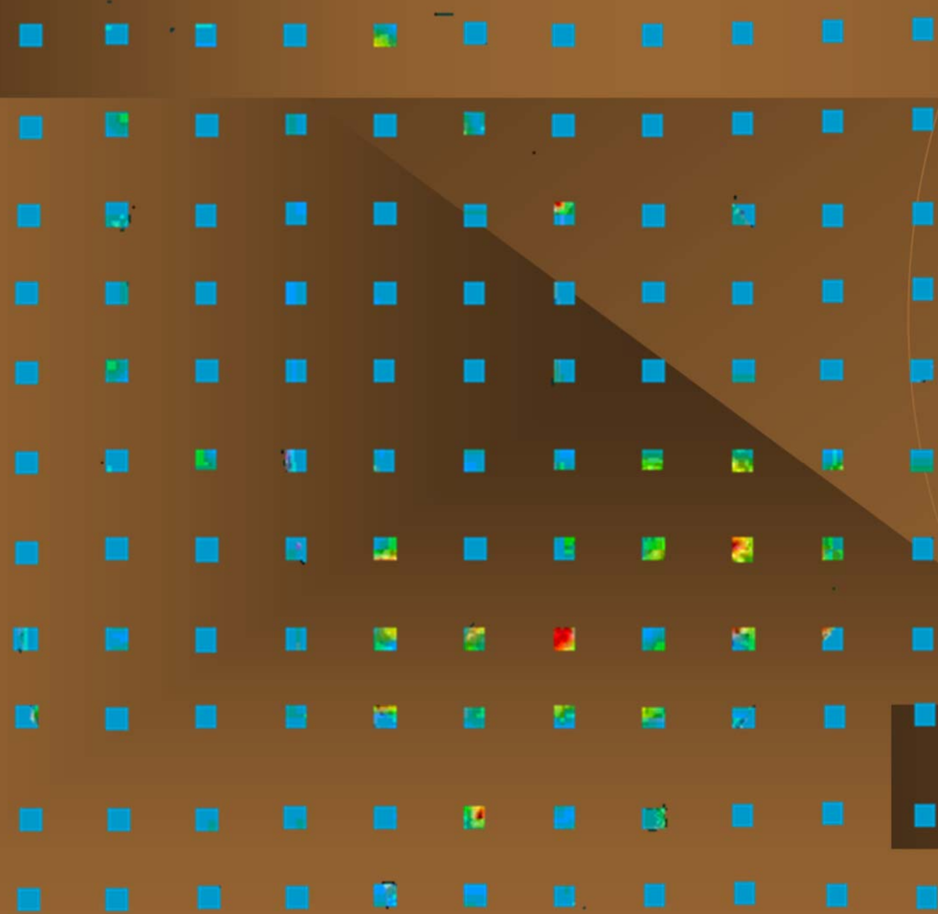
Include enough increments in the sample to be able to say "What we don't know won't hurt you."

Composite Sample Example



Example here shows 11x11 increment collection grid

Collect Increments from the Area of Concern



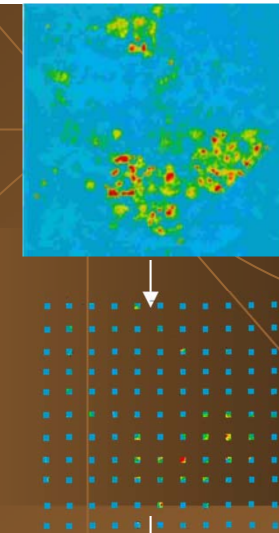
Equal mass increments are placed in a single sample container

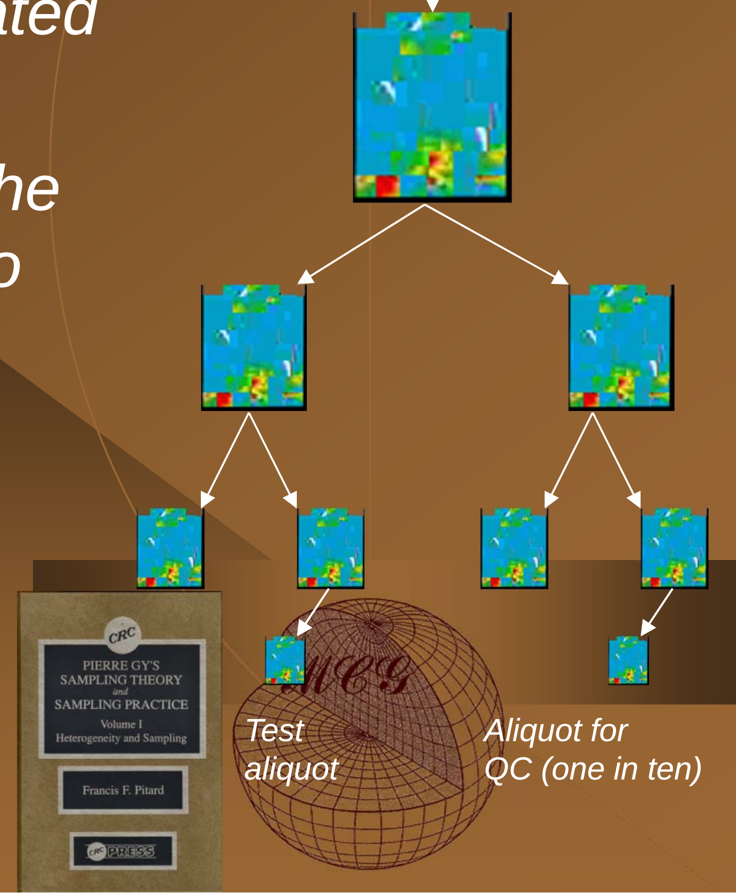
The Area is Represented Throughout the Aliquot Preparation Process

The sample is reduced in size by repeated Grinding-and-Splitting operations

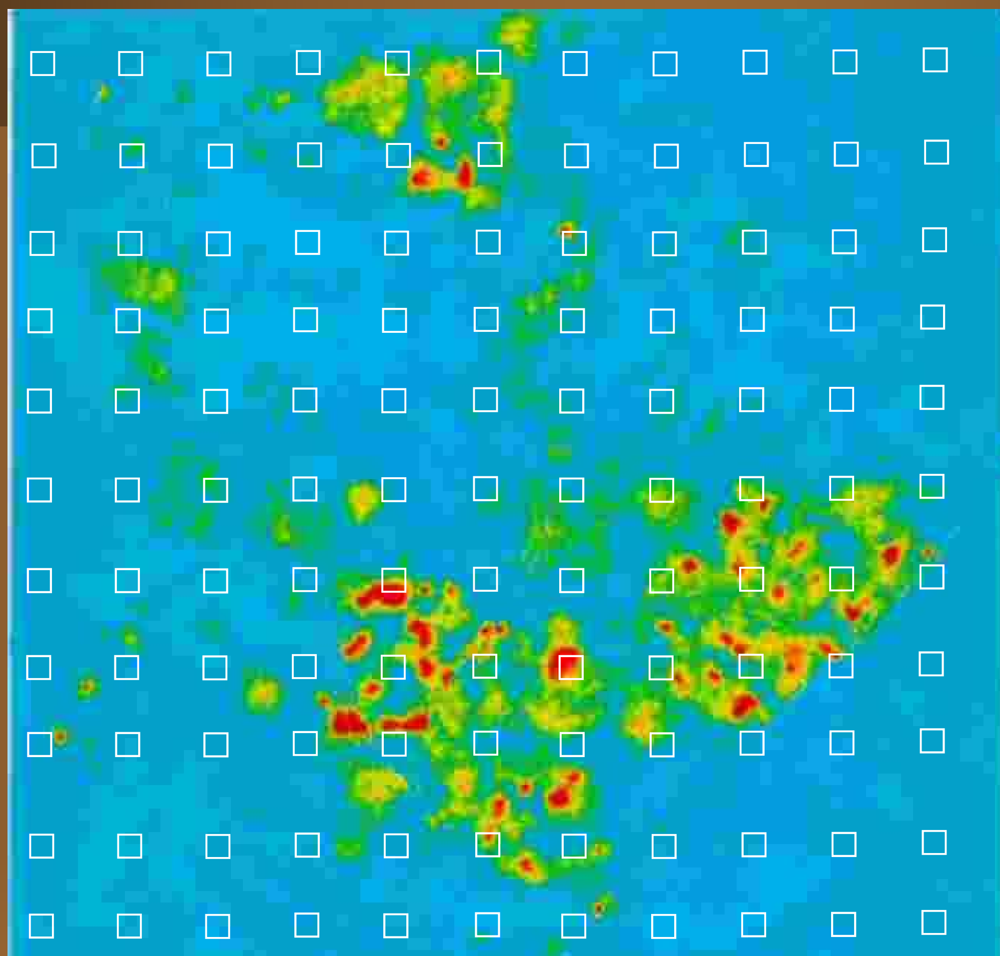
In each step of the splitting operation, the split from the previous step is ground so that the ratio of the mass of the largest particle to the mass of the sample remains constant (1/3% ~ FE=17%).

Iterations of Grinding-and-Splitting are repeated until the test aliquot mass is obtained.



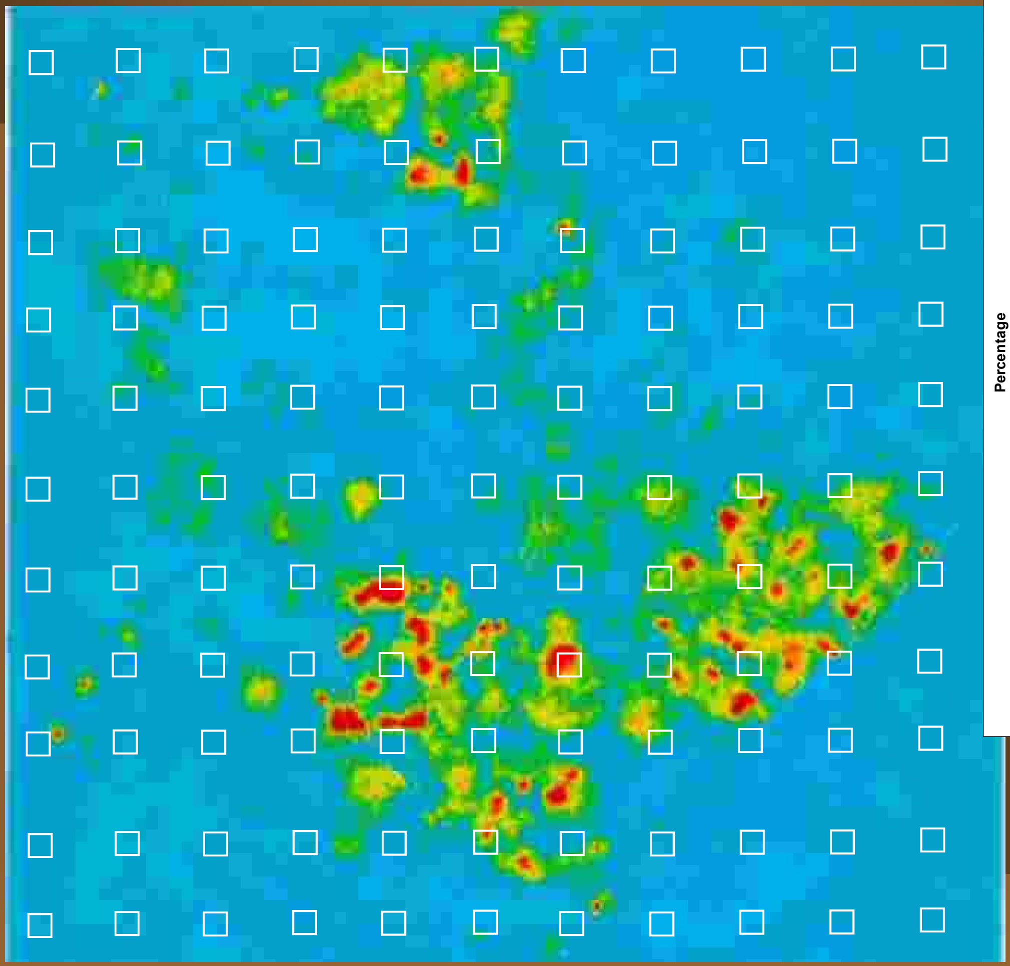


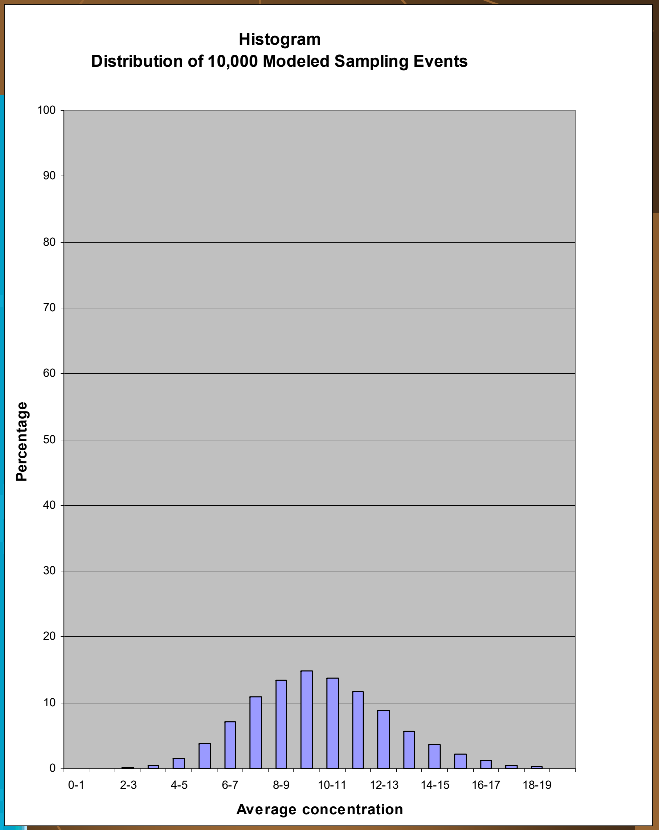
How Many Increments are Needed?



Enough to assure that underrepresented Contamination is Inconsequential

Example: Simulate 10000 Iterations of a Random 121-increment Sampling Event.

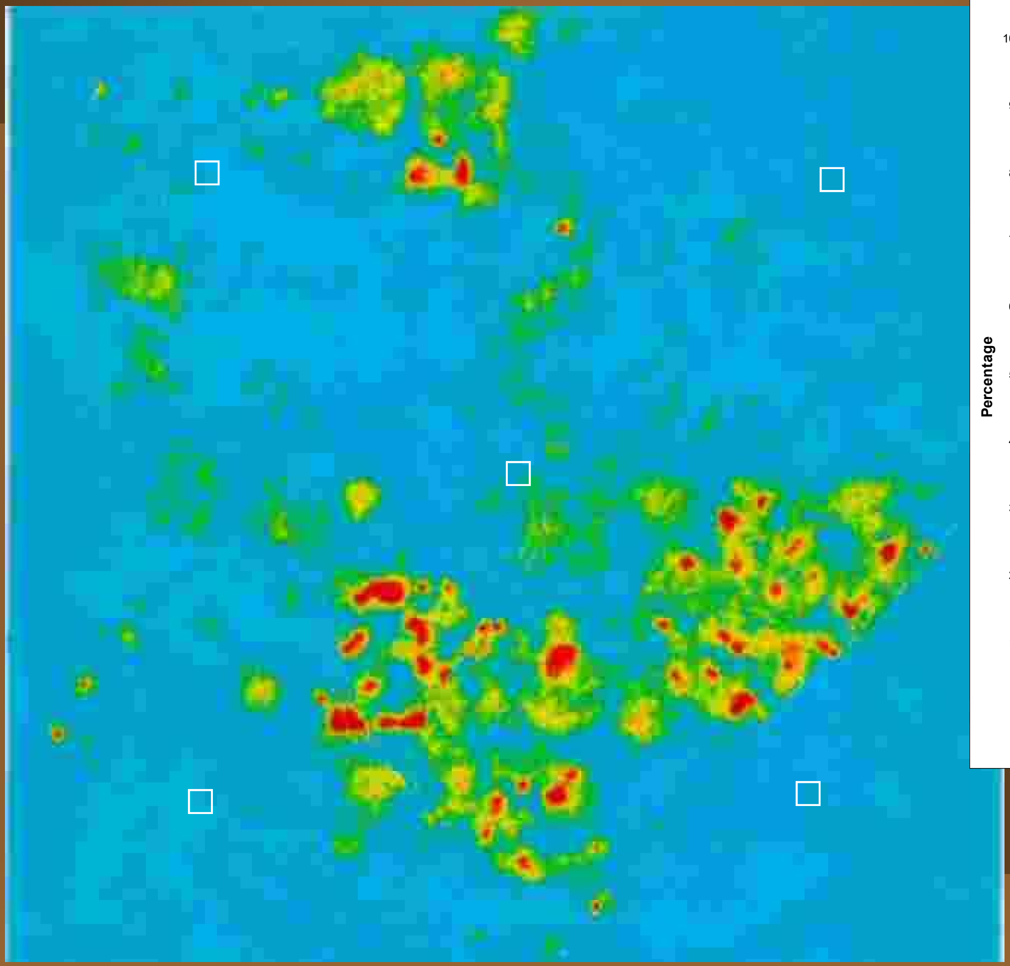


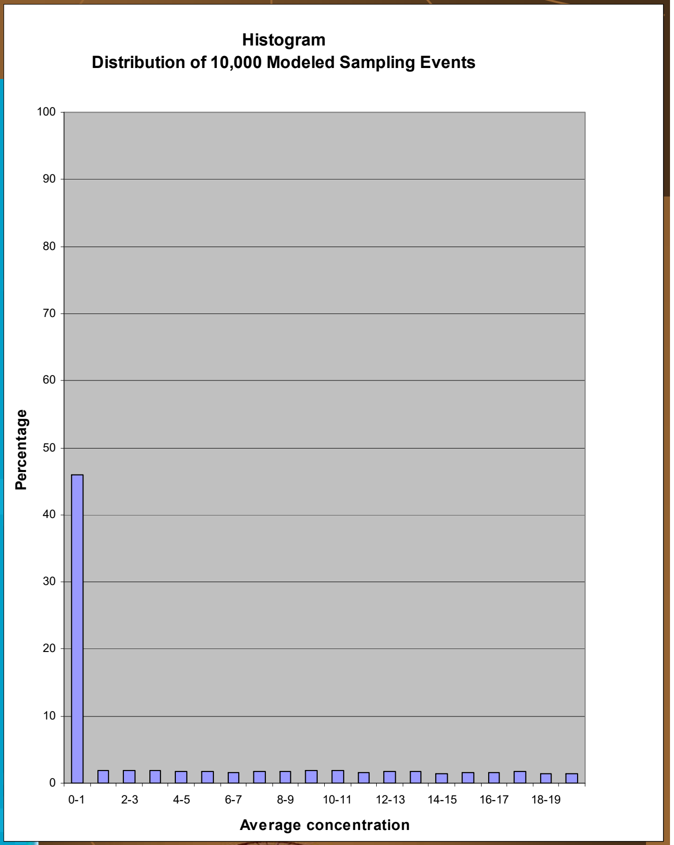


Distribution of Sample Concentrations

The narrow distribution of results suggests a good characterization is possible

Example: Now Simulate 10000 Iterations of a Random 5-increment Sampling Event.

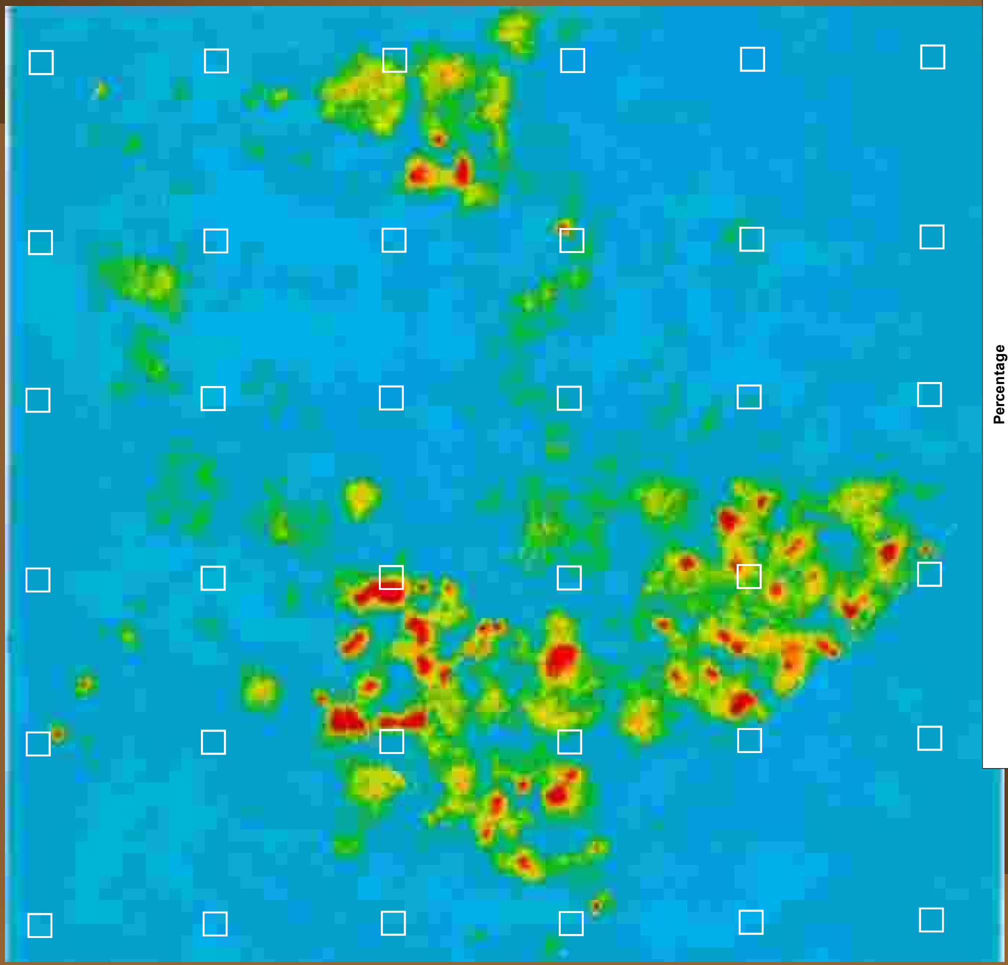


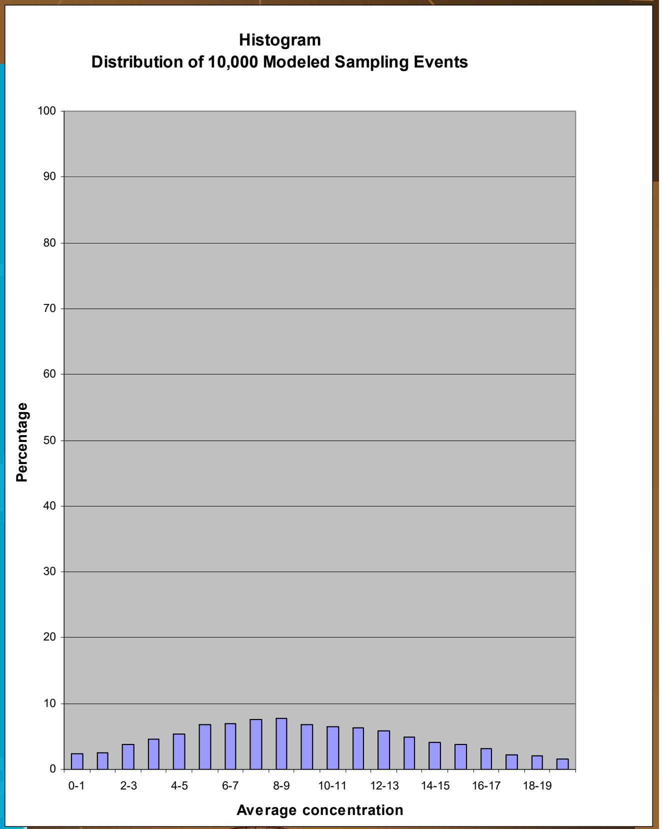


Distribution of Sample Concentrations

In this example contamination was completely missed nearly 50 percent of the time

Example: Now Simulate 10000 Iterations of a Random 36-increment Sampling Event.



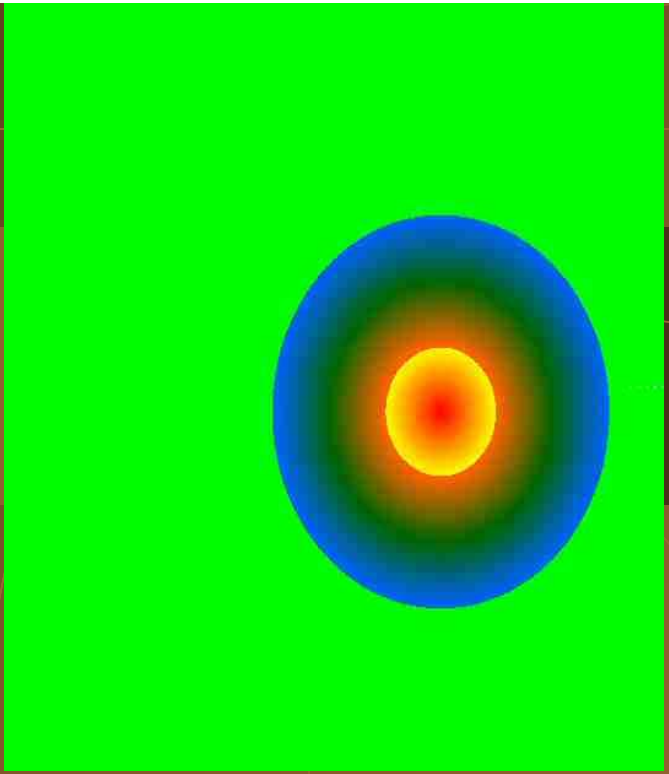


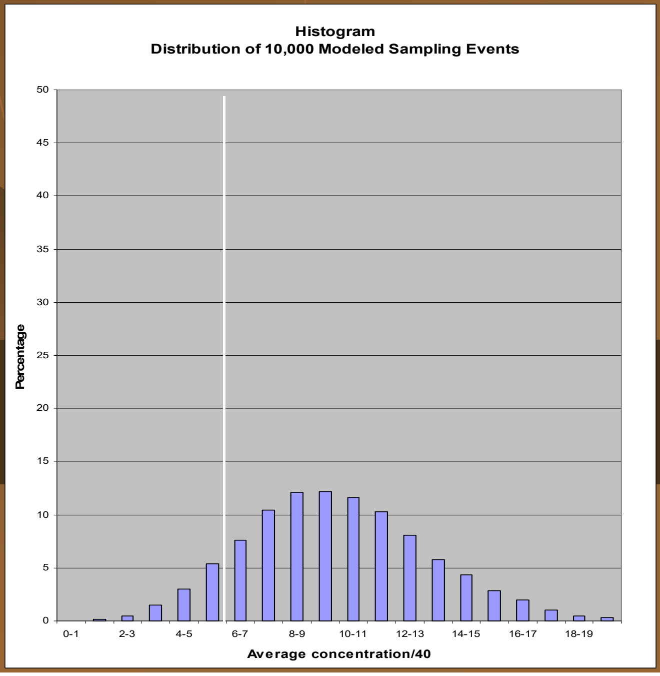
Distribution of Sample Concentrations

36 increments is a much better representation than 5.

Cleanup Verification

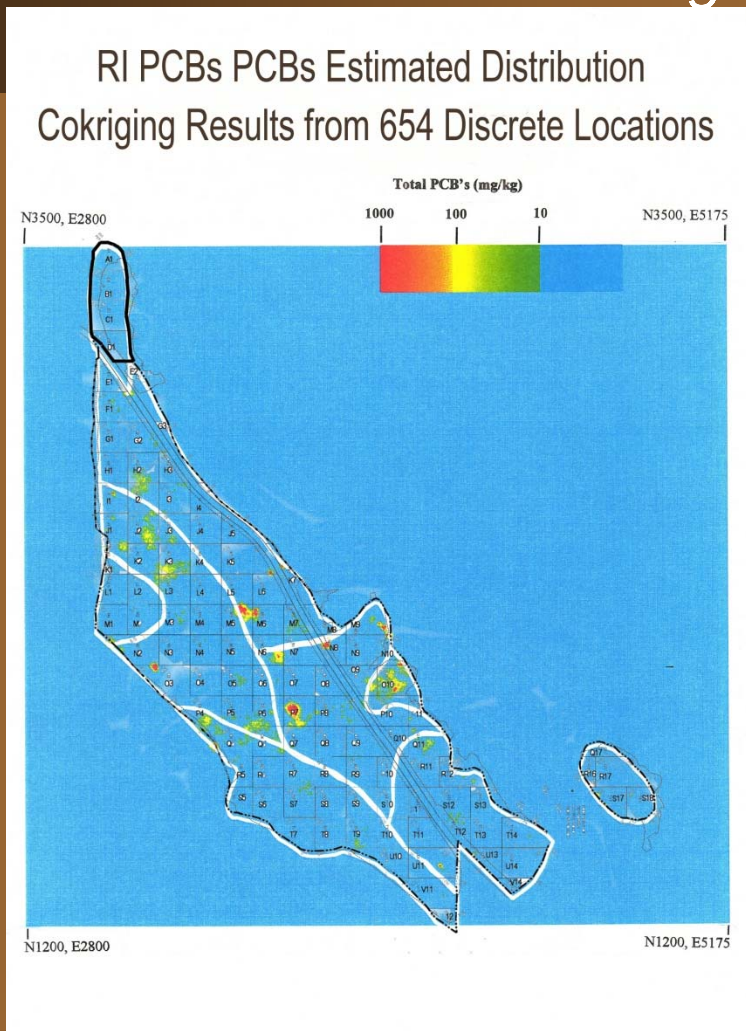
- Concern for ecological receptors controls sample plan design for cleanup verification
- A ¼-acre area is the home range for a local shrew requiring protection.
- The Composite sample must represent the smallest hot spot that would present an unacceptable threat to the shrew.
- Forty increments per ¼-acre were combined to form a single multi-increment sample for comparison to the remediation goal.



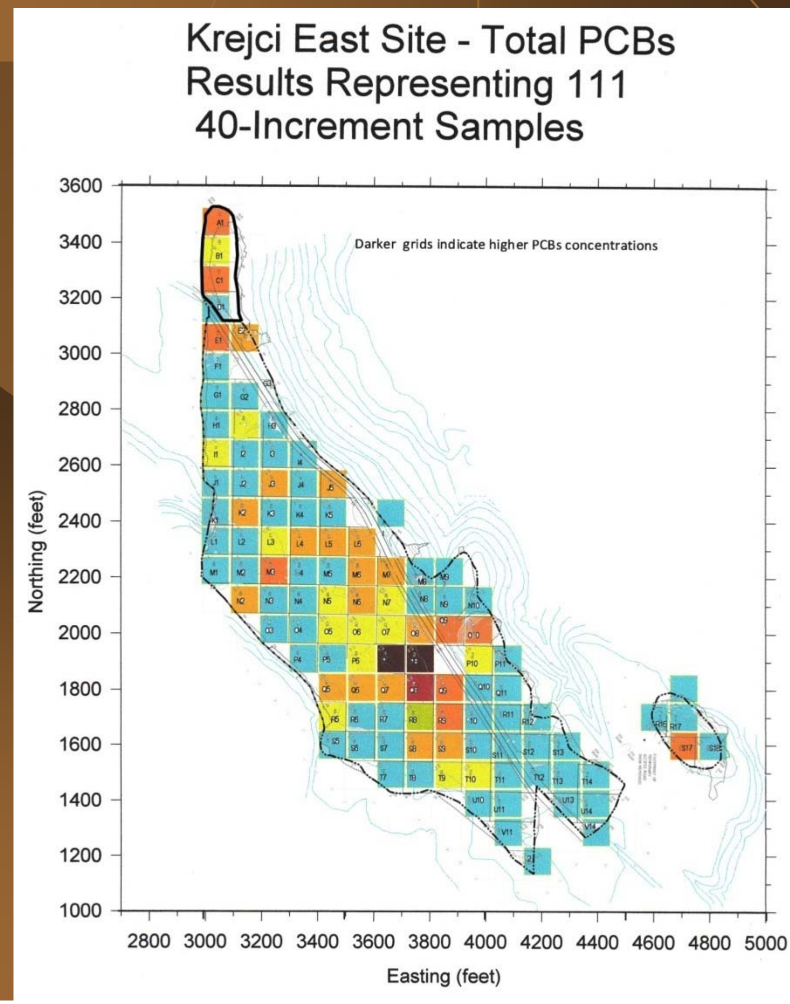


Example Results Following Initial Excavation

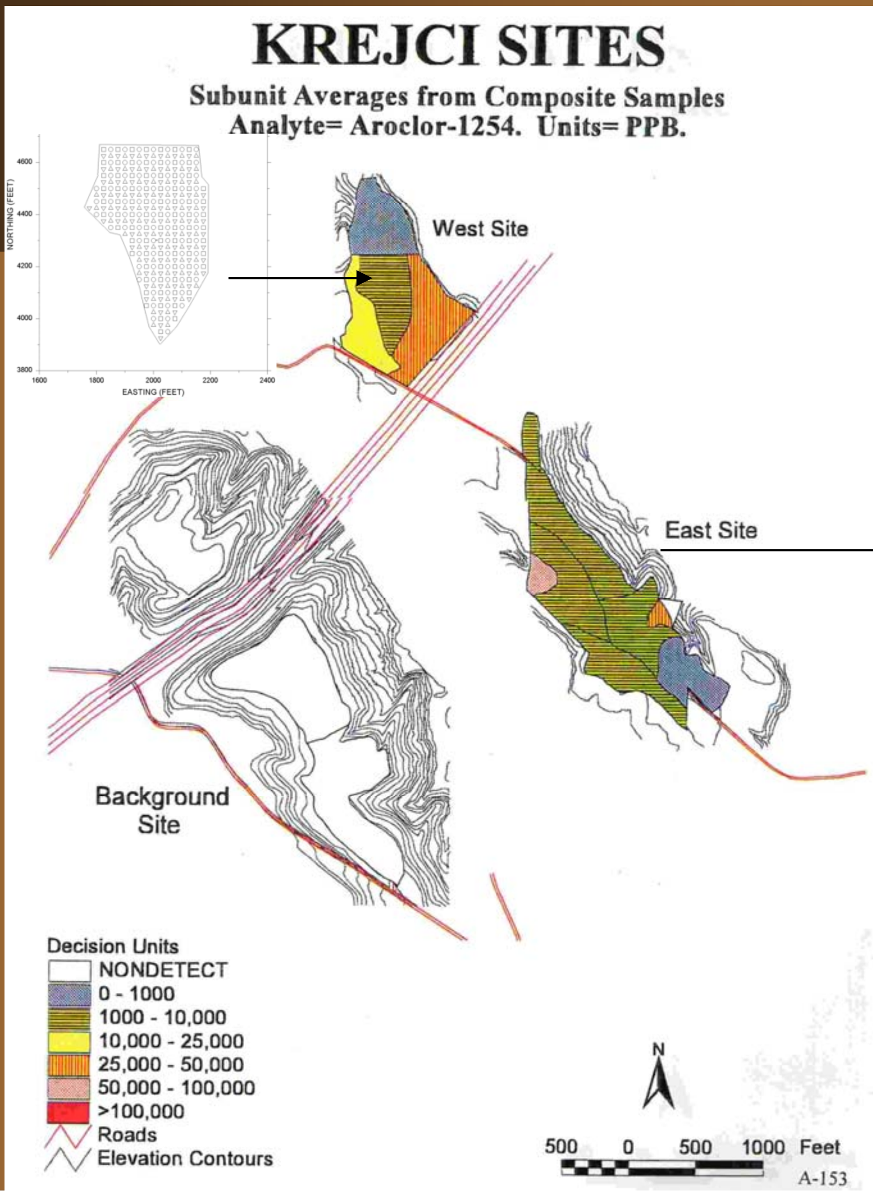
654 Discrete Samples (Cokriged) Results of Remedial Investigation



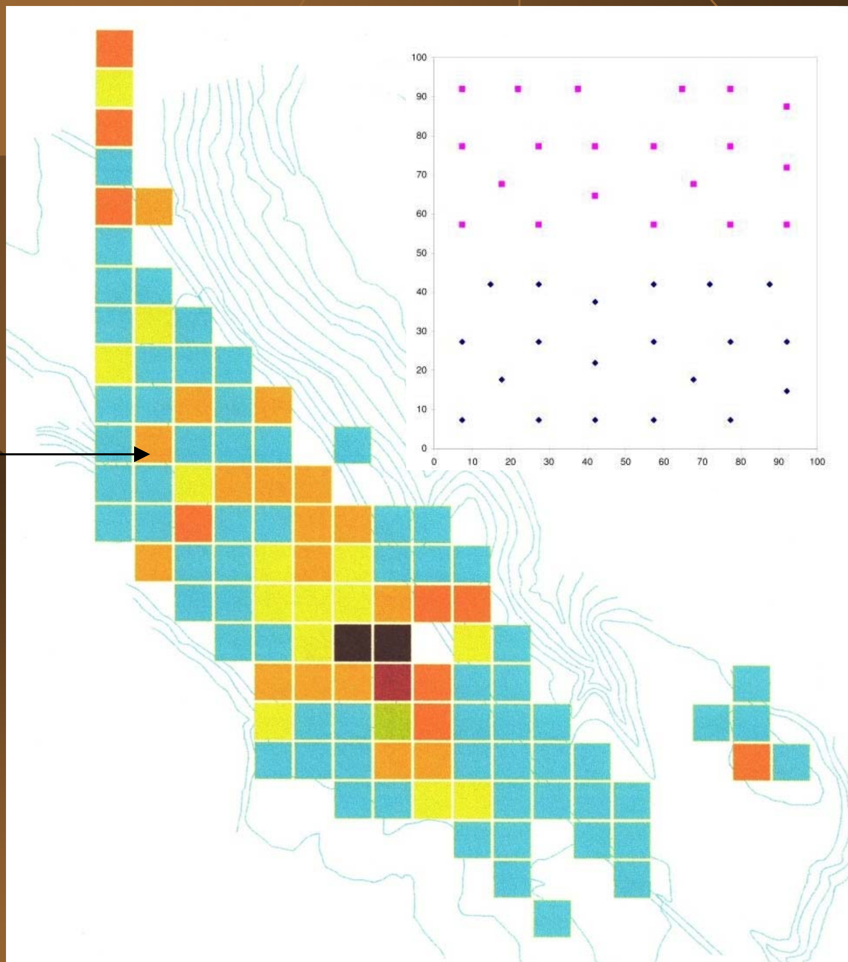
111 Composite Samples Following Partial Remediation



Example Results Following Initial Excavation

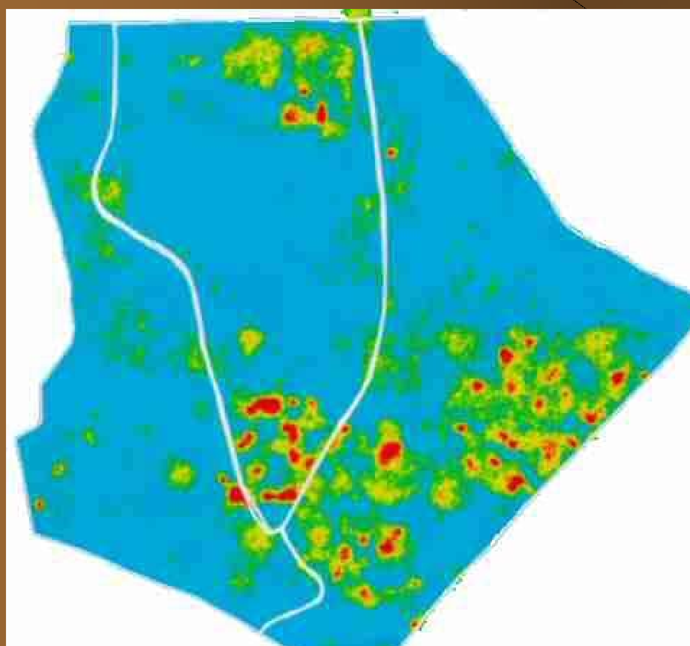


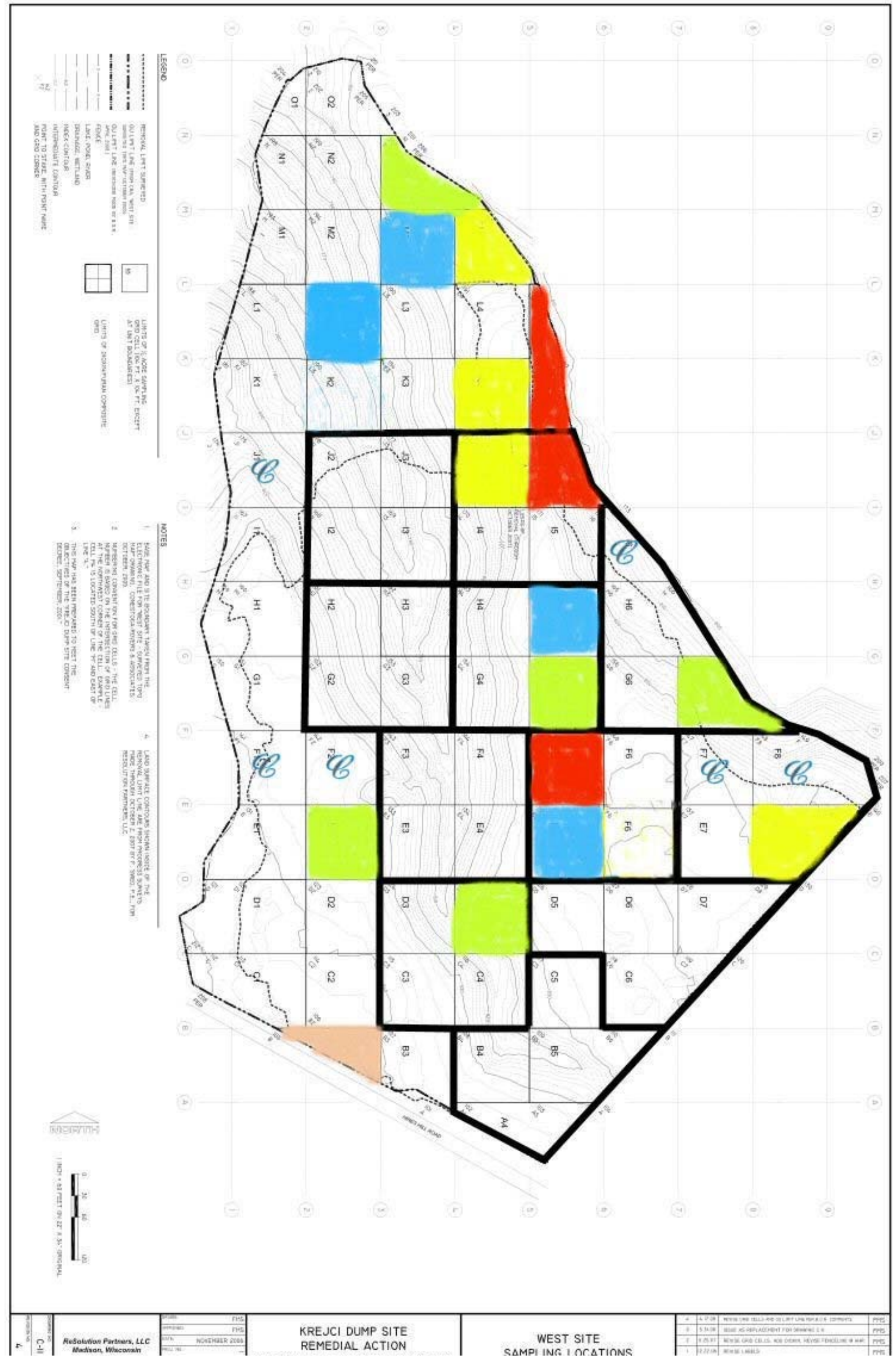
Following Partial Remediation

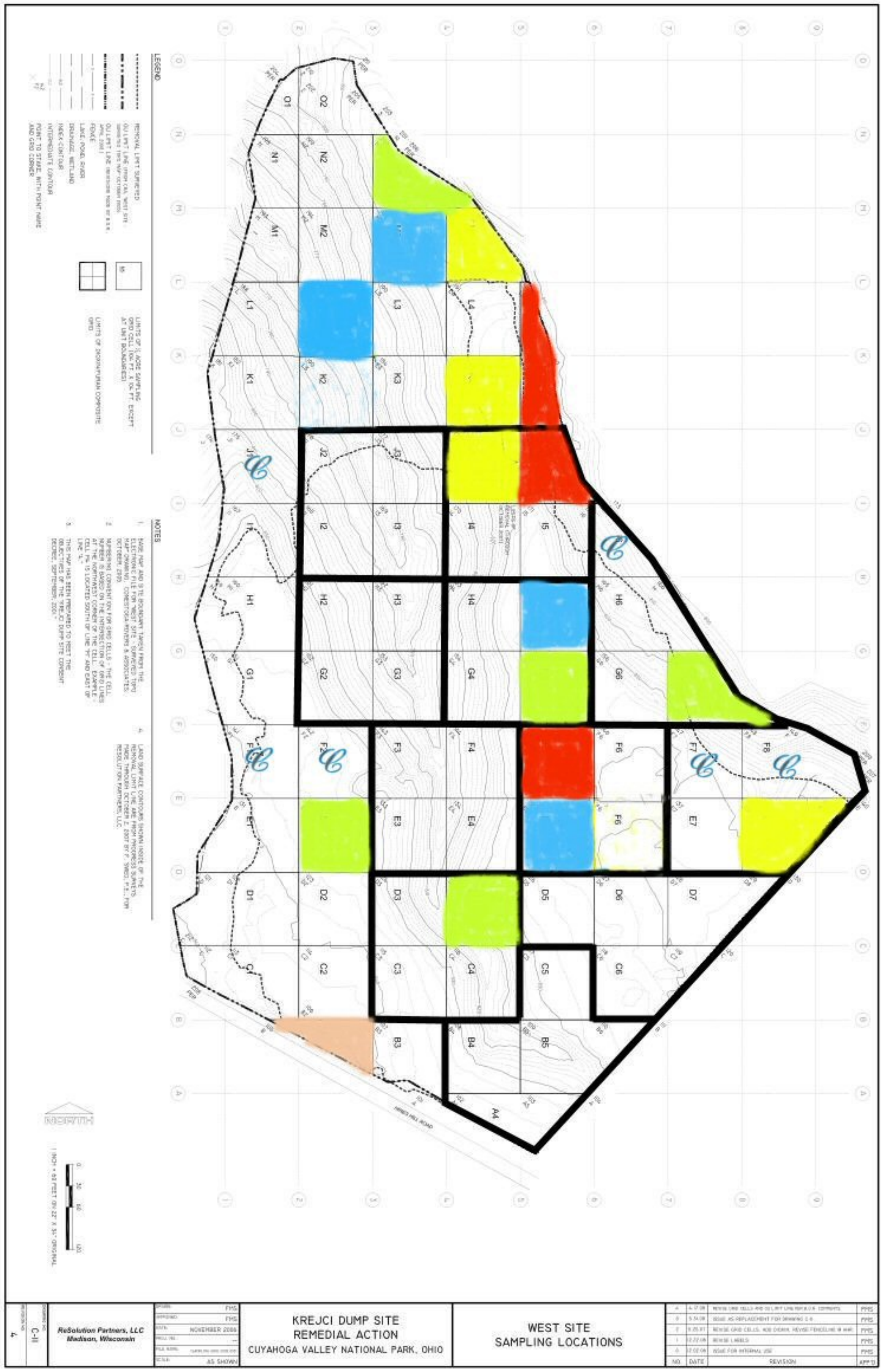


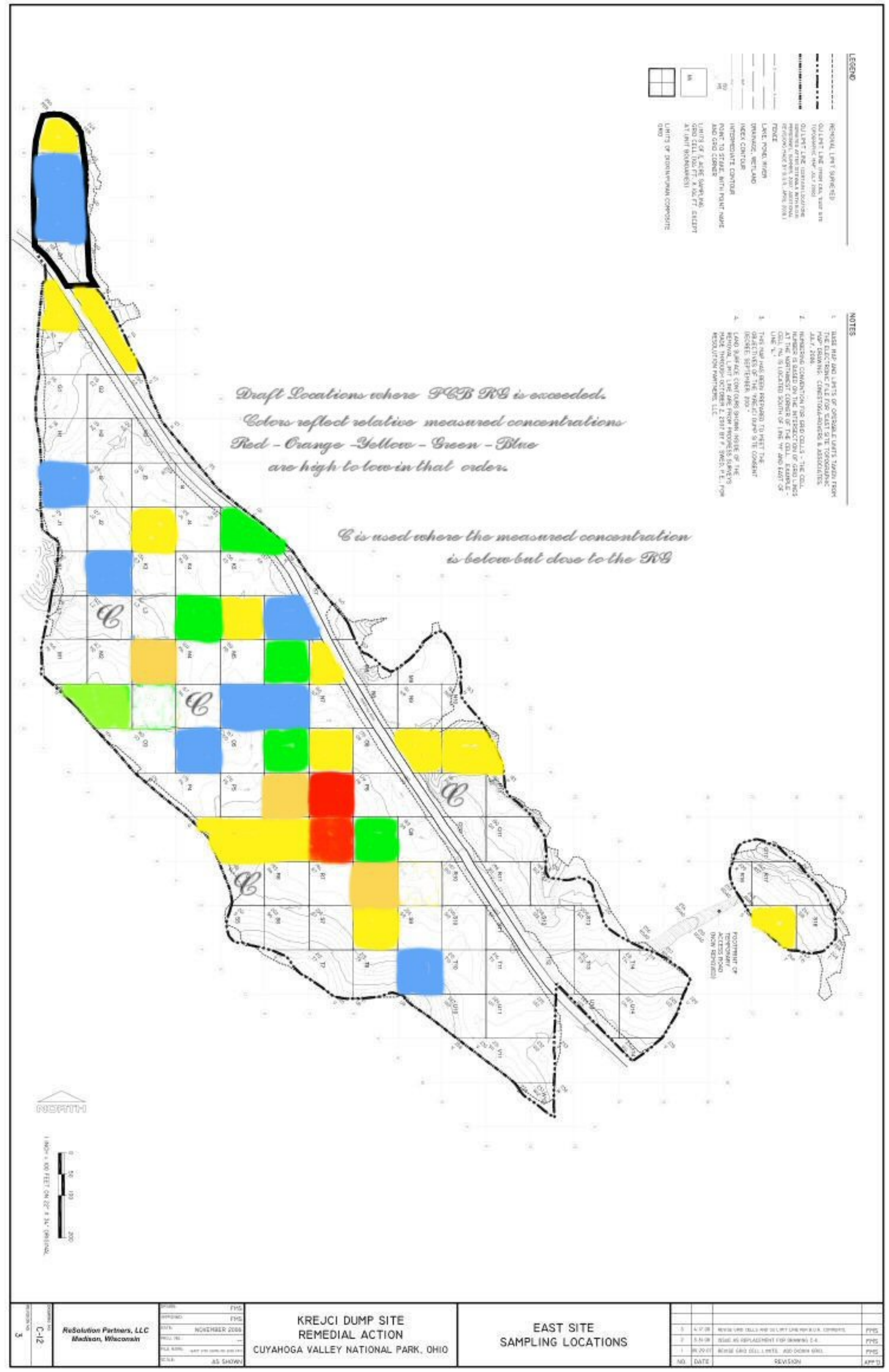
Colors depict differing concentrations

Compare RI to CVS Following Initial Excavation

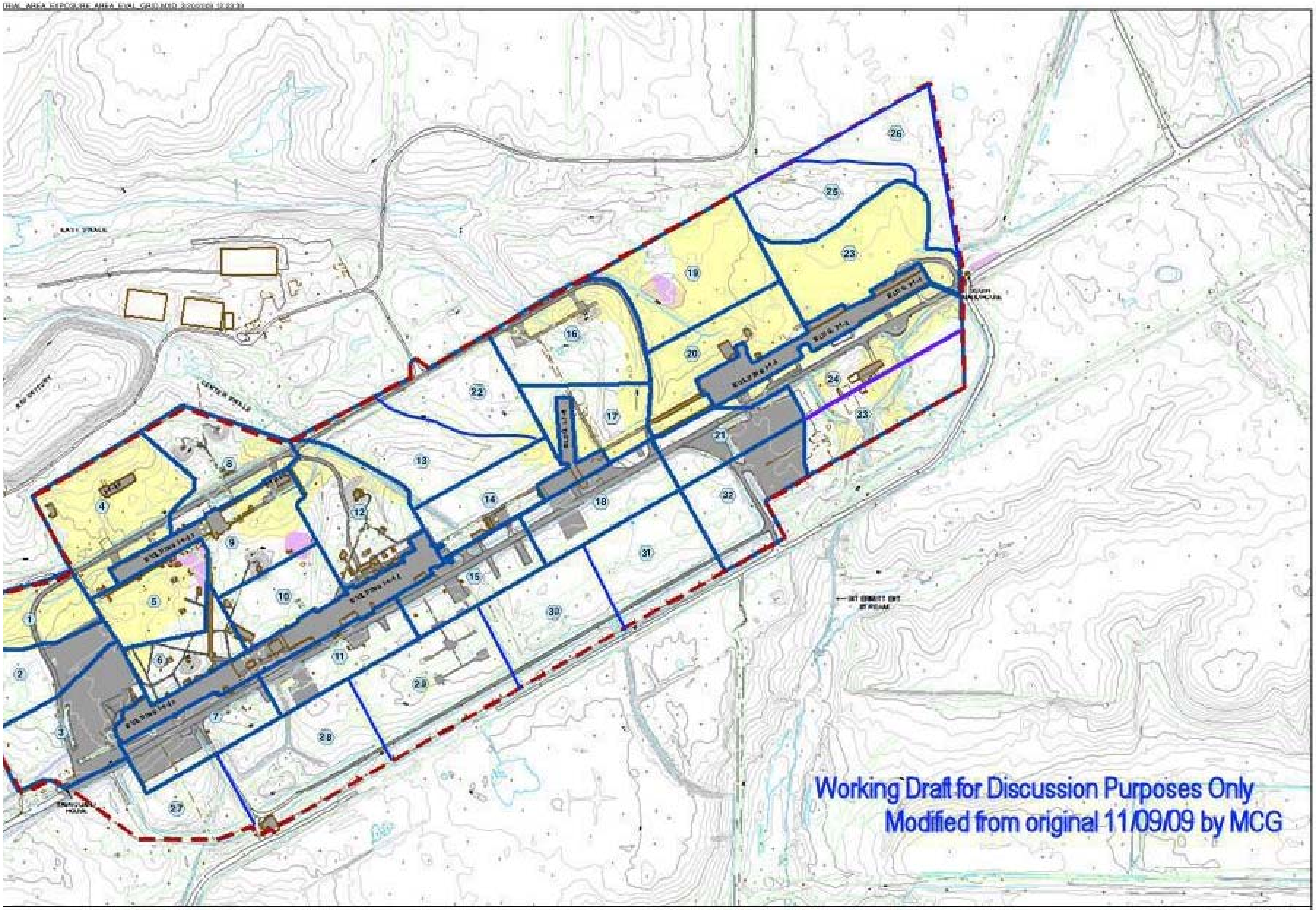





ReSolution Partners, LLC
Madison, Wisconsin
NOVEMBER 2006
AS SHOWN
KREJCI DUMP SITE
REMEDIAL ACTION
CUYAHOGA VALLEY NATIONAL PARK, OHIO
WEST SITE
SAMPLING LOCATIONS
C-II
NO.
DATE
REVISION
APP'D


Draft Locations where PCB RG is exceeded.
Colors reflect relative measured concentrations
Red – Orange –Yellow – Green – Blue
are high to low in that order.
C is used where the measured concentration
is below but close to the RG
ReSolution Partners, LLC
Madison, Wisconsin
NOVEMBER 2006
AS SHOWN
KREJCI DUMP SITE
REMEDIAL ACTION
CUYAHOGA VALLEY NATIONAL PARK, OHIO
EAST SITE
SAMPLING LOCATIONS
C-I2
NO.
DATE
REVISION
APP'D


Background
Track/Field Area
3.6 acres
Baseball/Soccer Field Area
2.7 acres
Background



e and
y

tion Limits, based on FD 1998
nd Remedial Design (As presented
007 meeting) and/or photo-documented
of FD confirmation samples

Proposed Soil Excavation Areas

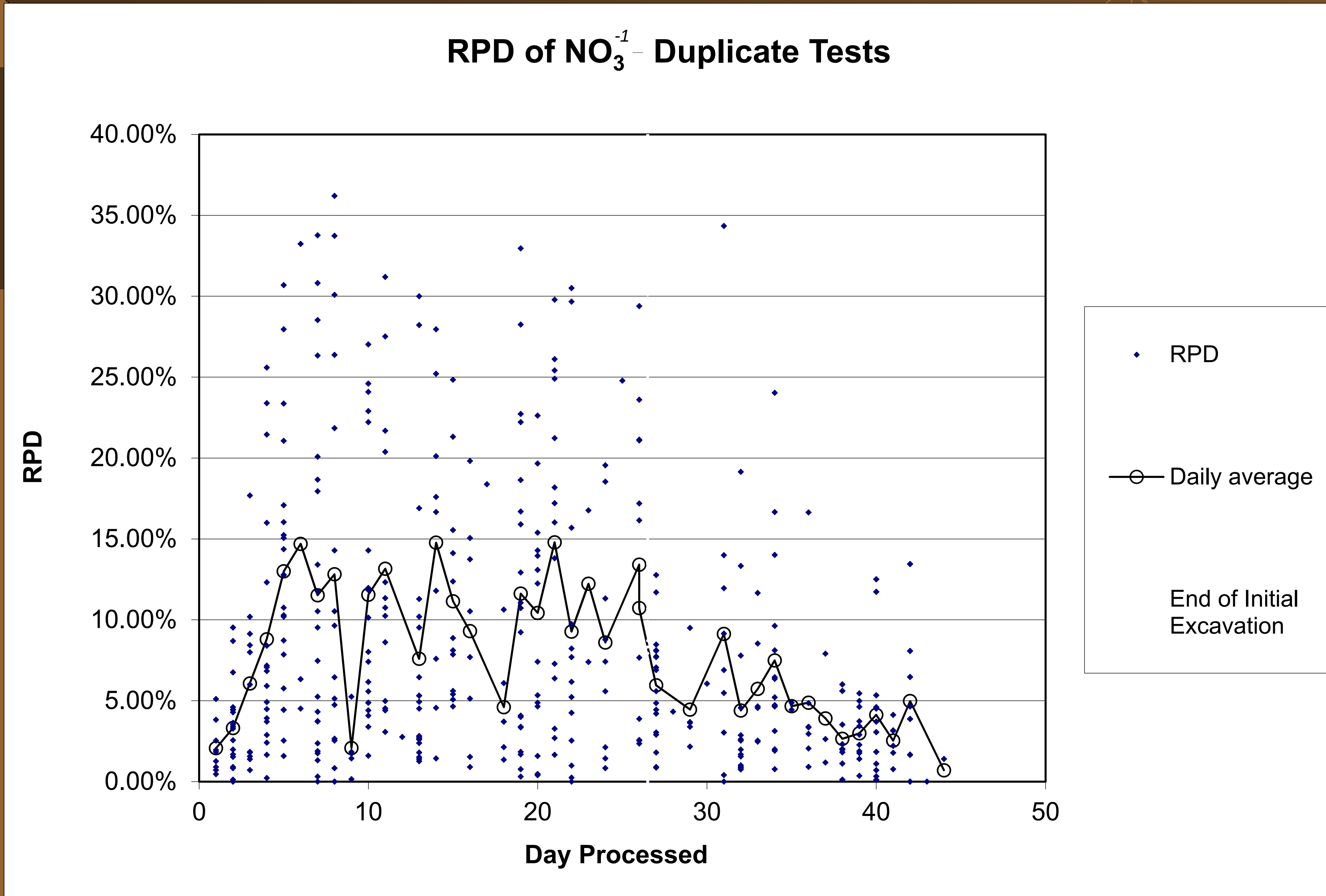
Exposure Area Evaluation Grid and Grid Zone Number

NOTES:

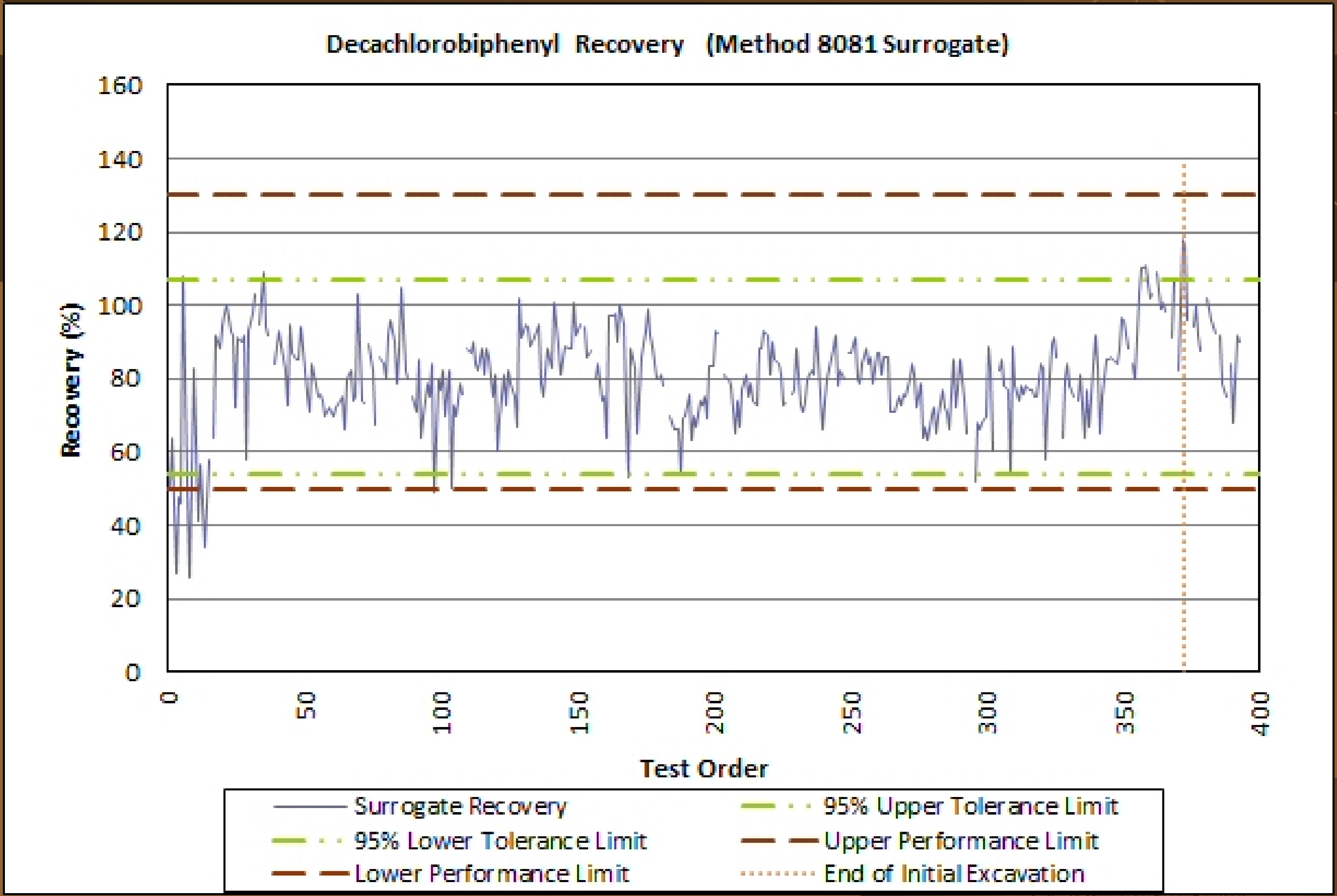
1. Topographic contours (one-foot interval) are from aerial photographs taken on February 28, 2001.
2. Grid coordinates are Illinois State Plane East, NAD83, US Survey Feet
3. The industrial area boundary coincides with the existing perimeter security fence, except at the Northern end of the area, where the boundary is shown along gravel access road where there is no fence.

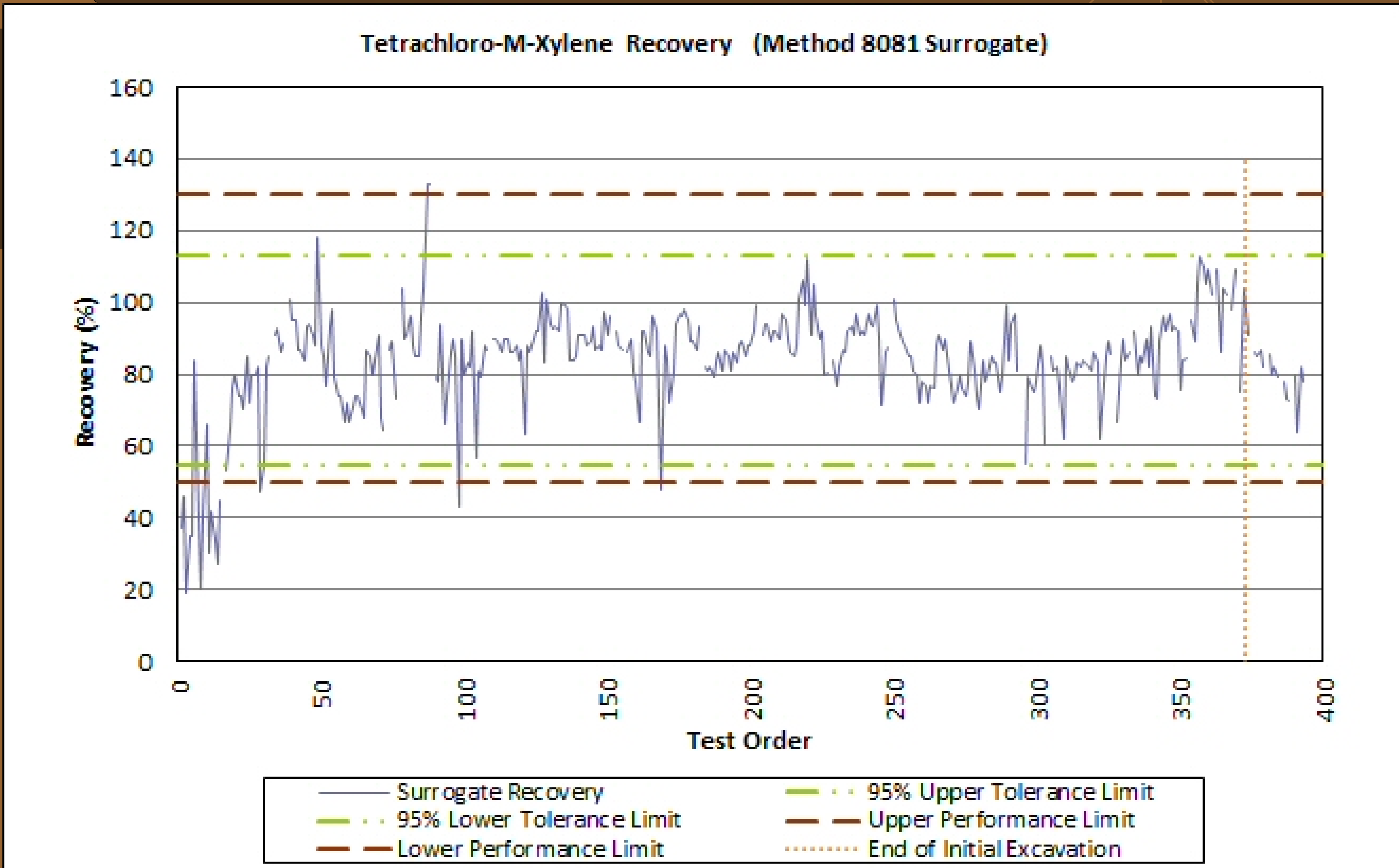
FIGURE 1
INDUSTRIAL AREA
EXPOSURE AREA
EVALUATION GRIDS
Crab Orchard NWR - PCB O.U.
Marion, IL
CH2MHILL

MCG

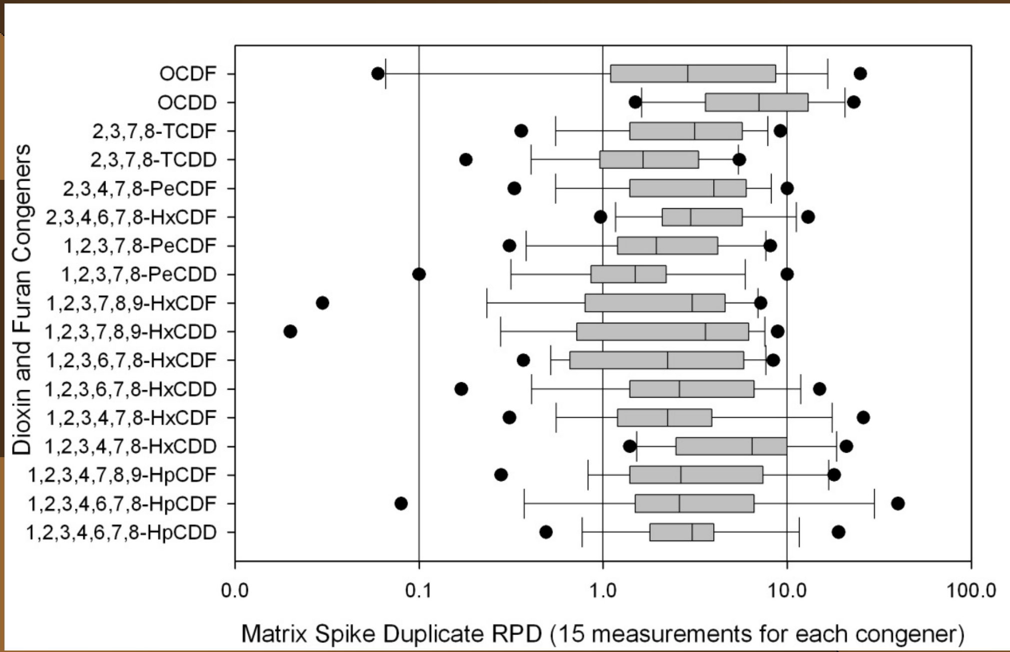


RPD of NO_3^{-1} Duplicate Tests
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
RPD
0
10
20
30
40
50
Day Processed
RPD
Daily average
End of Initial Excavation

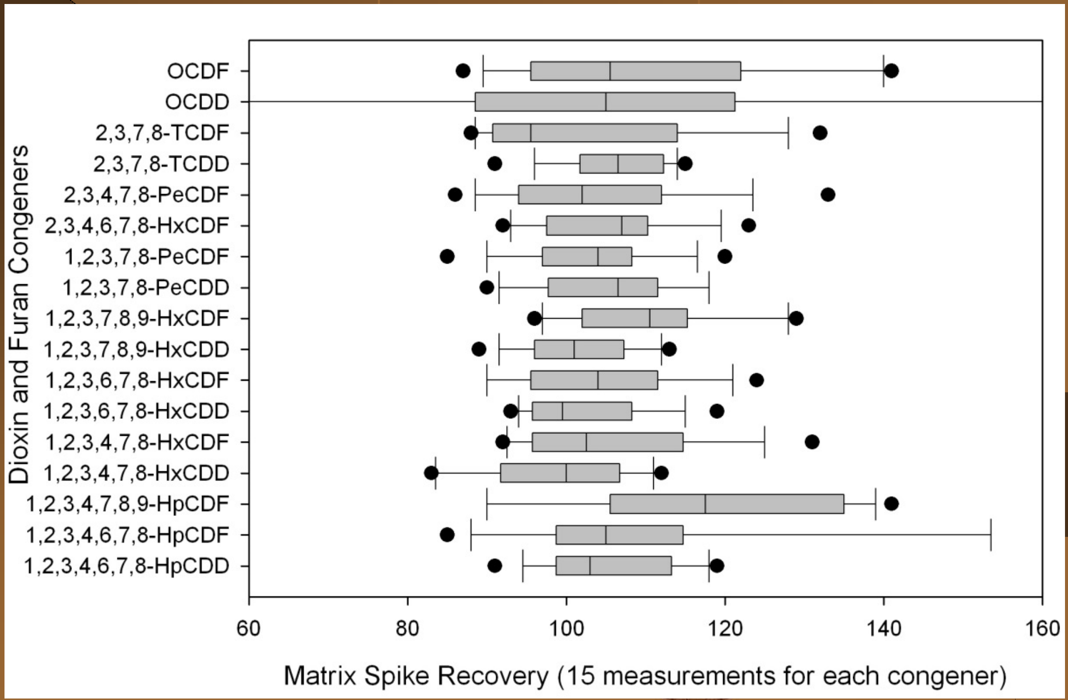

Decachlorobiphenyl Recovery (Method 8081 Surrogate)
Recovery (%)
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
Test Order
Surrogate Recovery
95% Upper Tolerance Limit
95% Lower Tolerance Limit
Upper Performance Limit
Lower Performance Limit
End of Initial Excavation



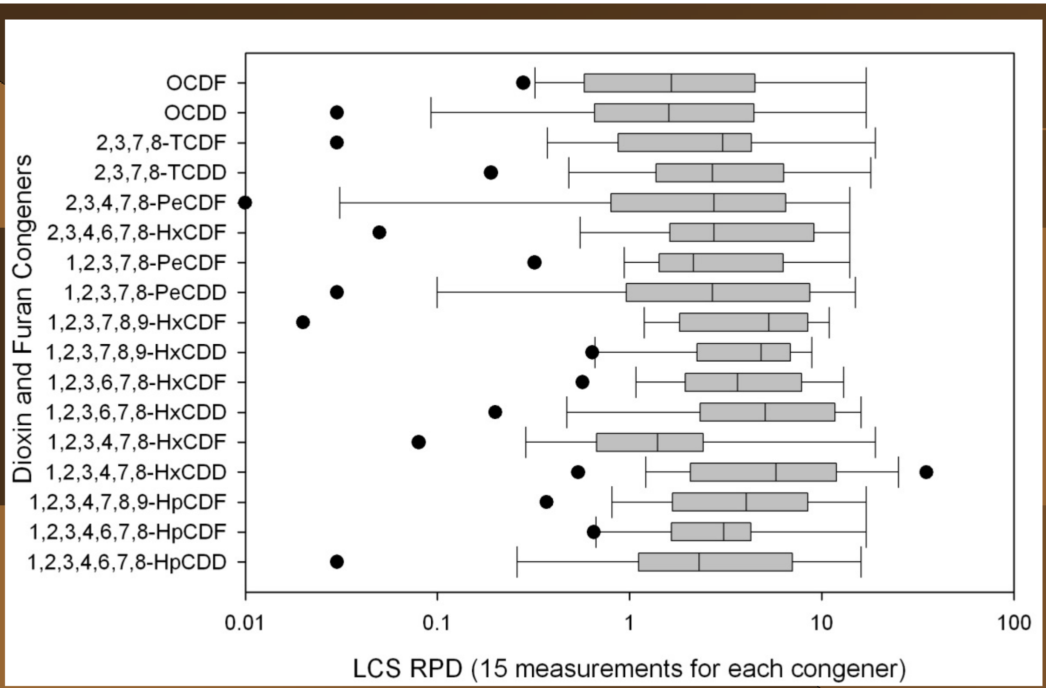
Tetrachloro-M-Xylene Recovery (Method 8081 Surrogate)
160
140
120
100
80
60
40
20
0
Recovery (%)
0
50
100
150
200
250
300
350
400
Test Order
Surrogate Recovery
95% Upper Tolerance Limit
95% Lower Tolerance Limit
Upper Performance Limit
Lower Performance Limit
End of Initial Excavation



Dioxin and Furan Congeners
OCDF
OCDD
2,3,7,8-TCDF
2,3,7,8-TCDD
2,3,4,7,8-PeCDF
2,3,4,6,7,8-HxCDF
1,2,3,7,8-PeCDF
1,2,3,7,8-PeCDD
1,2,3,7,8,9-HxCDF
1,2,3,7,8,9-HxCDD
1,2,3,6,7,8-HxCDF
1,2,3,6,7,8-HxCDD
1,2,3,4,7,8-HxCDF
1,2,3,4,7,8-HxCDD
1,2,3,4,7,8,9-HpCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,6,7,8-HpCDD
0.0
0.1
1.0
10.0
100.0
Matrix Spike Duplicate RPD (15 measurements for each congener)



Dioxin and Furan Congeners
OCDF
OCDD
2,3,7,8-TCDF
2,3,7,8-TCDD
2,3,4,7,8-PeCDF
2,3,4,6,7,8-HxCDF
1,2,3,7,8-PeCDF
1,2,3,7,8-PeCDD
1,2,3,7,8,9-HxCDF
1,2,3,7,8,9-HxCDD
1,2,3,6,7,8-HxCDF
1,2,3,6,7,8-HxCDD
1,2,3,4,7,8-HxCDF
1,2,3,4,7,8-HxCDD
1,2,3,4,7,8,9-HpCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,6,7,8-HpCDD
60
80
100
120
140
160
Matrix Spike Recovery (15 measurements for each congener)


Dioxin and Furan Congeners
OCDF
OCDD
2,3,7,8-TCDF
2,3,7,8-TCDD
2,3,4,7,8-PeCDF
2,3,4,6,7,8-HxCDF
1,2,3,7,8-PeCDF
1,2,3,7,8-PeCDD
1,2,3,7,8,9-HxCDF
1,2,3,7,8,9-HxCDD
1,2,3,6,7,8-HxCDF
1,2,3,6,7,8-HxCDD
1,2,3,4,7,8-HxCDF
1,2,3,4,7,8-HxCDD
1,2,3,4,7,8,9-HpCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,6,7,8-HpCDD
0.01
0.1
1
10
100
LCS RPD (15 measurements for each congener)

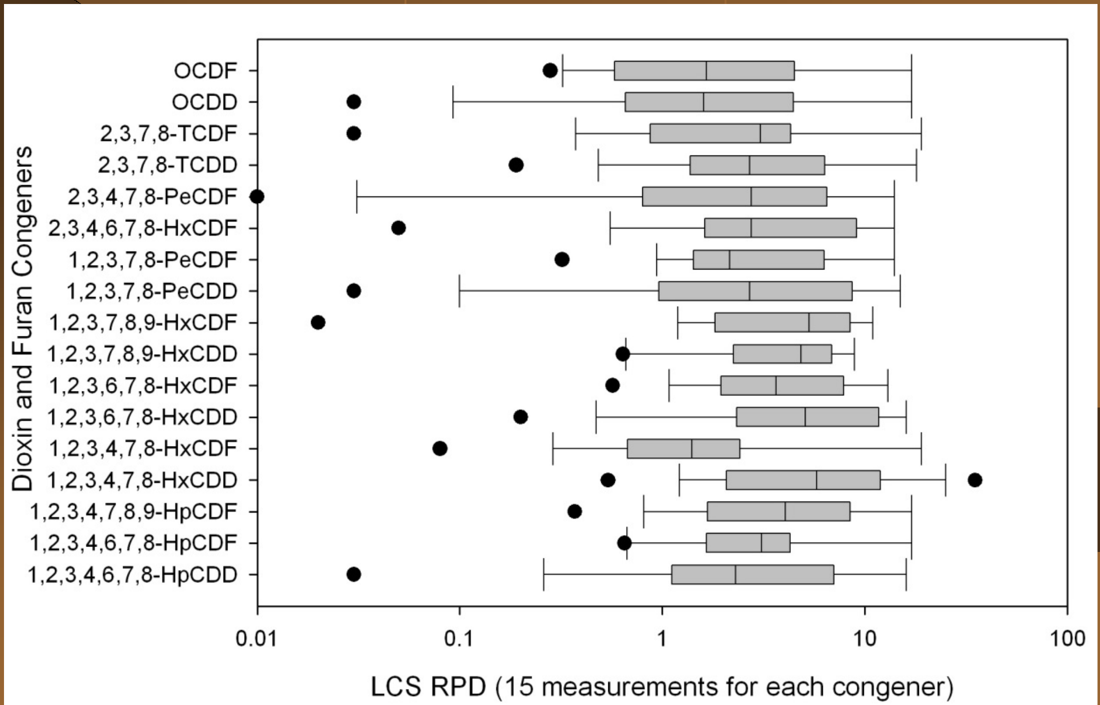

Dioxin and Furan Congeners
OCDF
OCDD
2,3,7,8-TCDF
2,3,7,8-TCDD
2,3,4,7,8-PeCDF
2,3,4,6,7,8-HxCDF
1,2,3,7,8-PeCDF
1,2,3,7,8-PeCDD
1,2,3,7,8,9-HxCDF
1,2,3,7,8,9-HxCDD
1,2,3,6,7,8-HxCDF
1,2,3,6,7,8-HxCDD
1,2,3,4,7,8-HxCDF
1,2,3,4,7,8-HxCDD
1,2,3,4,7,8,9-HpCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,6,7,8-HpCDD
0.01
0.1
1
10
100
LCS RPD (15 measurements for each congener)

Table Pb-1: Lead Data Quality Summary				
Laboratory Performance Criteria	Criteria	Measured	Comment	
Minimum LCS Recovery	greater than 80%	81%		
Minimum Matrix Spike Recovery	greater than 70%	77%		
Average LCS Recovery	N/A	90%		
Average Matrix Spike Recovery	N/A	95%		
Maximum LCS RPD	less than 20%	17%		
Maximum Laboratory Duplicate RPD	less than 20%	34%	high	
Average LCS RPD	N/A	3%		
Average Laboratory Duplicate RPD	N/A	8%		
Measurement Quality Objectives	Critera	Measured		
NPS CRM	Recovery greater than 169 mg/kg	Minimum Recovery =	169	mg/kg
EQIS CRM	Recovery greater than 166 mg/kg	Minimum Recovery =	161	mg/kg
CVS Split Analysis RPD	RPD less than 35%	Maximum RPD =	85	%
CRM Split Analysis RPD	RPD less than 35%	Maximum RPD =	9	%
Overall QC Indicator Measurements	Criteria	Measured		
NPS CRM "Made to" (Bias measure)	N/A	Average Recovery =	93.38	%
NPS Replicate Test (Precision measure)	N/A	Standard Deviation =	4.48	mg/kg
Data Quality Relative to Remediation Goals				
Tier 1 Remediation Goal	100	mg/kg		
Tier 2 Remediation Goal	none			
QC Derived reliance Level	108.3	mg/kg See Note 1		

Comments: All QC accuracy measurements for lead complied with related laboratory performance criteria and measurement quality objectives. Qualified laboratory precision is indicated by high maximum laboratory duplicate RPD (34%) and high CVS split RPDs. Good precision, however, is indicated by CRM split test results (maximum RPD = 9%) and by a low standard deviation (4.48 mg/kg) for repeated tests on the same sample relative to the expected mean (38.1 mg/kg). As desired, the derived reliance level (108.3 mg/kg) is greater than the remediation goal (100 mg/kg). Based on the foregoing, as well as a review of all QC data, it is concluded that the Lead CVS measurements are of acceptable quality and may be used to determine RG achievement.

Table Pb-2: Lead - NPS CRMs

Blind NPS CRM Results

Sample	Result	Analysis Date	Batch	Detect
BOR Sample 1-BOR 56	188	5/3/09	57226	Y
BOR SAMPLE 6-BOR 81	203	5/4/09	57400	Y
BOR Sample 4-BOR 82	169	5/8/09	57514	Y
BOR 83	193	5/27/09	57790	Y
BOR Sample 3-BOR 58	183	5/27/09	57790	Y
BOR 84	192	5/27/09	57848	Y
BOR Sample 7-BOR 105	186	5/27/09	57848	Y
BOR 85	180	6/5/09	58137	Y
BOR Sample 8-BOR 106	180	6/5/09	58137	Y
BOR 86	200	6/11/09	58213	Y
BOR 108	191	6/19/09	58563	Y
BOR 87	189	6/19/09	58563	Y
BOR 109	183	6/30/09	58729	Y
BOR 110	180	7/11/09	59382	Y
BOR Sample 9-BOR 107	194	7/24/09	59758	Y
BOR 111	177	7/30/09	59890	Y

CRMs		Vendor Supplied Information		
Mean	186.8	"Made to"		
Median	187.0	200	mg/kg	
Standard Deviation	8.8			
Sample Variance	77.3	Lower Acceptance Limit		
Kurtosis	0.0	169	mg/kg	
Skewness	0.0			
Range	34.0	Upper Acceptance Limit		
Minimum	169.0	204	mg/kg	
Maximum	203.0			
Sum	2988.0			
Count	16.0			
Largest(2)	200.0			
Smallest(2)	177.0			

Table Pb-3: Lead -NPS Replicate Tests on a Background Sample

Results of Replicate Analyses of a Single Sample

Sample	Result	Analysis Date	Batch	Detect
BOR 112	43.1	5/3/09	57226	Y
BOR 59	47.3	5/4/09	57400	Y
BOR 60	38.4	5/8/09	57514	Y
BOR 113	35	5/27/09	57790	Y
BOR 61	41.5	5/27/09	57790	Y
BOR 62	33.3	6/11/09	58213	Y
BOR 63	38.7	6/19/09	58563	Y
BOR 89	35.5	6/19/09	58563	Y
BOR 115	34.3	6/30/09	58729	Y
BOR 64	34	7/8/09	59165	Y
BOR 91	34.8	7/8/09	59165	Y
BOR 116	35.7	7/11/09	59382	Y
BOR 92	34	7/11/09	59382	Y
BOR 65	36.5	7/22/09	59623	Y
BOR 88	34.6	7/30/09	59890	Y
BOR 800	39.4	9/24/09	61415	Y
BOR-802	51	10/6/09	61791	Y
BOR 804	42.1	10/29/09	62501	Y
BOR-805	35.3	11/18/09	62992	Y
BOR-807	38.8	11/25/09	63216	Y
BOR-808	36.2	12/7/09	63406	Y
BOR 813	36.2	1/20/10	64129	Y
BOR 815	35.4	1/20/10	64207	Y
BOR-816	43.9	1/26/10	64334	Y
BOR-820	37.8	3/5/10	65037	Y

Replicate analyses of Single Sample	
Mean	38.112
Median	36.200
Standard Deviation	4.478
Sample Variance	20.052
Kurtosis	1.745
Skewness	1.428
Range	17.700
Minimum	33.300
Maximum	51.000
Sum	952.800
Count	25.000
Largest(2)	47.300
Smallest(2)	34.000

Table Pb-4: Lead NPS and EQIS Duplicates

Sample	Result	Analysis Date	Batch	Split	Result	Analysis Date	RPD
BOR 503	29.7	5/4/09	57400	ES-T11-080530	12.5	6/11/2009	82
BOR 506	15.4	5/8/09	57514	ES-S10-080523	11.1	6/11/2009	32
BOR 504	14.9	5/27/09	57790	ES-M05-080527	16.9	5/27/2009	13
BOR 507	22	6/5/09	58137	ES-O09-080610			
BOR 508	10.2	6/19/09	58563	ES-Q11-080606	25.4	5/8/2009	85
BOR 510	13.2	6/30/09	58729	OU-8HR-080605	16.3	5/3/2009	21
BOR 501	17.5	7/8/09	59165	WS-L04-080508	17.1	7/8/2009	2
BOR 505	51.7	7/22/09	59623	WS-K03-080509	48.6	7/8/2009	6
BOR 502	107	7/24/09	59758	WS-F05-080612	106	8/17/2009	1
BOR 509	11.3	7/24/09	59758	WS-E06-080613	11.4	7/24/2009	1
BOR 500	32.7	7/30/09	59890	WS-F01-080429	47.2	6/19/2009	36
BOR-809	11.1	12/14/09	63531	ES-K03-091103	12.1	11/25/2009	9
BOR-810	8.5	12/14/09	63531	ES-P07-091022	8.8	11/18/2009	3
BOR-811	9.5	12/14/09	63531	ES-R08-091021	8.7	11/18/2009	9
BOR 814	19.3	1/20/10	64129	ES-J05-091124	19.2	12/14/2009	1
BOR-818	12.2	3/5/10	65037	WS-F05-100111	9	1/26/2010	30
BOR-822	13.9	3/5/10	65037	ES-Q08-091228	10.7	1/20/2010	26
DUP-11	38	5/3/09	57100	ES-J03-080513	26.5	6/19/2009	36
DUP-17	20.3	5/4/09	57400	ES-F01-080529	18.9	5/8/2009	7
DUP-15	13.1	5/8/09	57514	ES-J02-080527	17.3	5/27/2009	28
DUP-18	38.4	5/8/09	57514	ES-J04-080530	25.8	5/27/2009	39
DUP-12	14.7	5/27/09	57790	ES-P06-080515	12.1	6/5/2009	19
DUP-16	19.8	5/27/09	57790	ES-P04-080528	16.5	6/5/2009	18
DUP-19	22.9	5/27/09	57848	ES-K05-080605	18.7	5/27/2009	20
DUP-13	13.5	6/5/09	58137	ES-T08-080522	11.4	6/11/2009	17
DUP-14	17.3	6/11/09	58213	ES-T10-080523	16.2	6/11/2009	7
DUP-3	42.9	6/19/09	58563	WS-C01-080501	44.3	6/19/2009	3
DUP-4	34.9	6/19/09	58563	WS-G01-080501	34.9	6/30/2009	0
DUP-5	38.6	6/30/09	58729	WS-I01-080501	38.9	6/30/2009	1
DUP-6	49.7	6/30/09	58729	WS-J01-080505	46.3	6/30/2009	7
DUP-7	38.2	7/8/09	59165	WS-M01-080505	36.8	7/8/2009	4

Table Pb-5: Lead EQIS CRMs

Results of Duplicate Analysis of EQIS CRMs

Sample	Result	Date	Batch	Detect	Average	RPD
ES-Z11-080605A	194	5/3/09	57100	Y		
ES-Z11-080605B	198	5/3/09	57100	Y	196.00	2.04
ES-Z09-080529A	198	5/4/09	57400	Y		
ES-Z09-080529B	202	5/4/09	57400	Y	200.00	2.00
ES-Z12-080606A	206	5/4/09	57400	Y		
ES-Z12-080606B	204	5/4/09	57400	Y	205.00	0.98
ES-Z05-080519A	175	5/8/09	57514	Y		
ES-Z05-080519B	179	5/8/09	57514	Y	177.00	2.26
ES-Z06-080520A	175	5/8/09	57514	Y		
ES-Z06-080520B	176	5/8/09	57514	Y	175.50	0.57
ES-Z07-080522A	182	5/27/09	57790	Y		
ES-Z07-080522B	188	5/27/09	57790	Y	185.00	3.24
ES-Z13-080610A	189	5/27/09	57848	Y		
ES-Z13-080610B	188	5/27/09	57848	Y	188.50	0.53
ES-Z10-080602A	189	6/5/09	58137	Y		
ES-Z10-080602B	179	6/5/09	58137	Y	184.00	5.43
ES-Z08-080527A	183	6/11/09	58213	Y		
ES-Z08-080527B	192	6/11/09	58213	Y	187.50	4.80
ES-Z14-080611A	182	6/19/09	58563	Y		
ES-Z14-080611B	187	6/19/09	58563	Y	184.50	2.71
ES-Z06-080520C	200	6/30/09	58729	Y		
ES-Z06-080520D	197	6/30/09	58729	Y	198.50	1.51
ES-Z05-080519C	184	7/8/09	59165	Y		
ES-Z05-080519D	179	7/8/09	59165	Y	181.50	2.75
ES-Z19-080624A	177	7/11/09	59382	Y		
ES-Z19-080624B	170	7/11/09	59382	Y	173.50	4.03
WS-Z17-080618A	167	7/11/09	59382	Y		
WS-Z17-080618B	169	7/11/09	59382	Y	168.00	1.19
WS-Z15-080613A	196	7/22/09	59623	Y		
WS-Z15-080613B	192	7/22/09	59623	Y	194.00	2.06
WS-Z18-080620A	194	7/22/09	59623	Y		
WS-Z18-080620B	192	7/22/09	59623	Y	193.00	1.04
WS-Z16-080617A	195	7/30/09	59890	Y		
WS-Z16-080617B	193	7/30/09	59890	Y	194.00	1.03
ES-Z22-091021A	173	11/18/09	62992	Y		
ES-Z22-091021B	174	11/18/09	62992	Y	173.50	0.58
ES-Z23-091022A	173	11/18/09	62992	Y		
ES-Z23-091022B	172	11/18/09	62992	Y	172.50	0.58
ES-Z24-091103A	193	11/25/09	63216	Y		
ES-Z24-091103B	186	11/25/09	63216	Y	189.50	3.69
ES-Z25-091104A	193	11/25/09	63216	Y		
ES-Z25-091104B	191	11/25/09	63216	Y	192.00	1.04
ES-Z26-091105A	180	12/7/09	63406	Y		
ES-Z26-091105B	177	12/7/09	63406	Y	178.50	1.68
ES-Z27-091106A	176	12/7/09	63406	Y		
ES-Z27-091106B	161	12/7/09	63406	Y	168.50	8.90
WS-Z29-091217A	197	1/6/10	63971	Y		
WS-Z29-091217B	191	1/6/10	63971	Y	194.00	3.09
WS-Z30-091230A	190	1/20/10	64129	Y		
WS-Z30-091230B	175	1/20/10	64129	Y	182.50	8.22

Table Pb-5: Lead EQIS CRMs (continued)

Results of Duplicate Analysis of EQIS CRMs

Sample	Result	Date	Batch	Detect	Average	RPD
WS-Z31-100107A	186	1/20/10	64207	Y		
WS-Z31-100107B	184	1/20/10	64207	Y	185.00	1.08
WS-Z32-100113A	184	1/26/10	64334	Y		
WS-Z32-100113B	175	1/26/10	64334	Y	179.50	5.01
ES-Z33-100225A	204	3/5/10	65037	Y		
ES-Z33-100225B	201	3/5/10	65037	Y	202.50	1.48

Analysis of EQIS CRMs		RPD of EQIS CRMs	
Mean	186	Mean	3
Median	187	Median	2
Standard Deviation	11	Standard Deviation	2
Sample Variance	113	Sample Variance	5
Kurtosis	-1	Kurtosis	2
Skewness	0	Skewness	2
Range	45	Range	8
Minimum	161	Minimum	1
Maximum	206	Maximum	9
Sum	10407	Sum	74
Count	56	Count	28
Largest(2)	204	Largest(2)	8
Smallest(2)	167	Smallest(2)	1

Table Pb-6: Lead Laboratory MS and LCS (Graph)

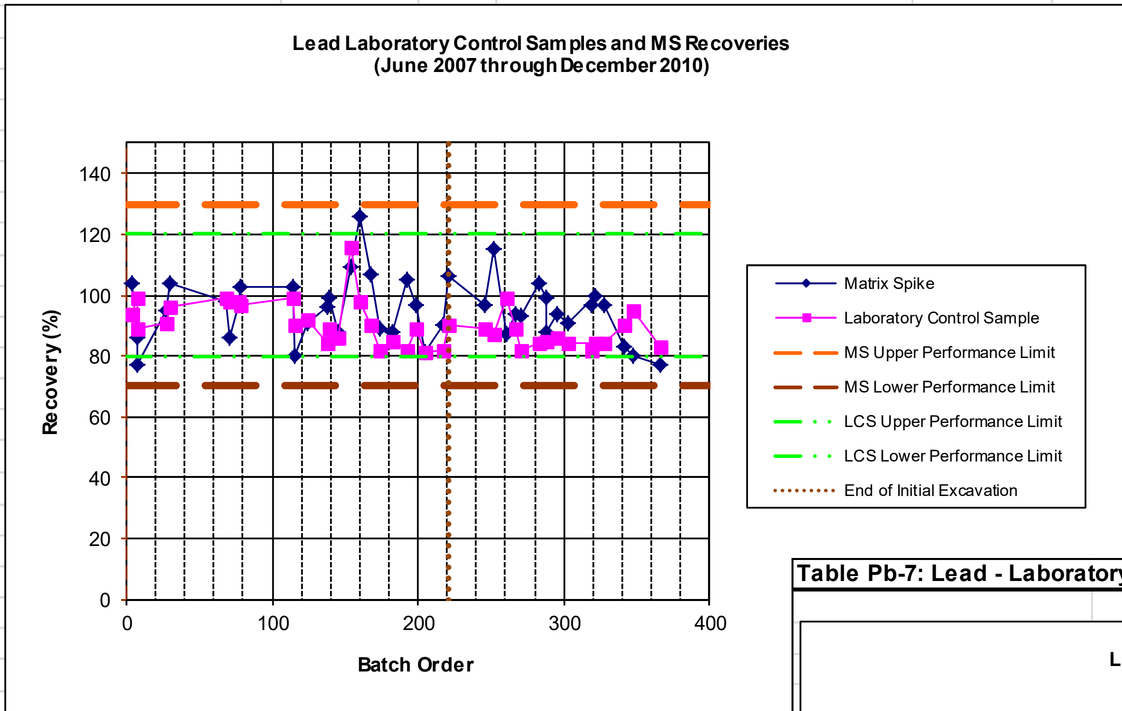
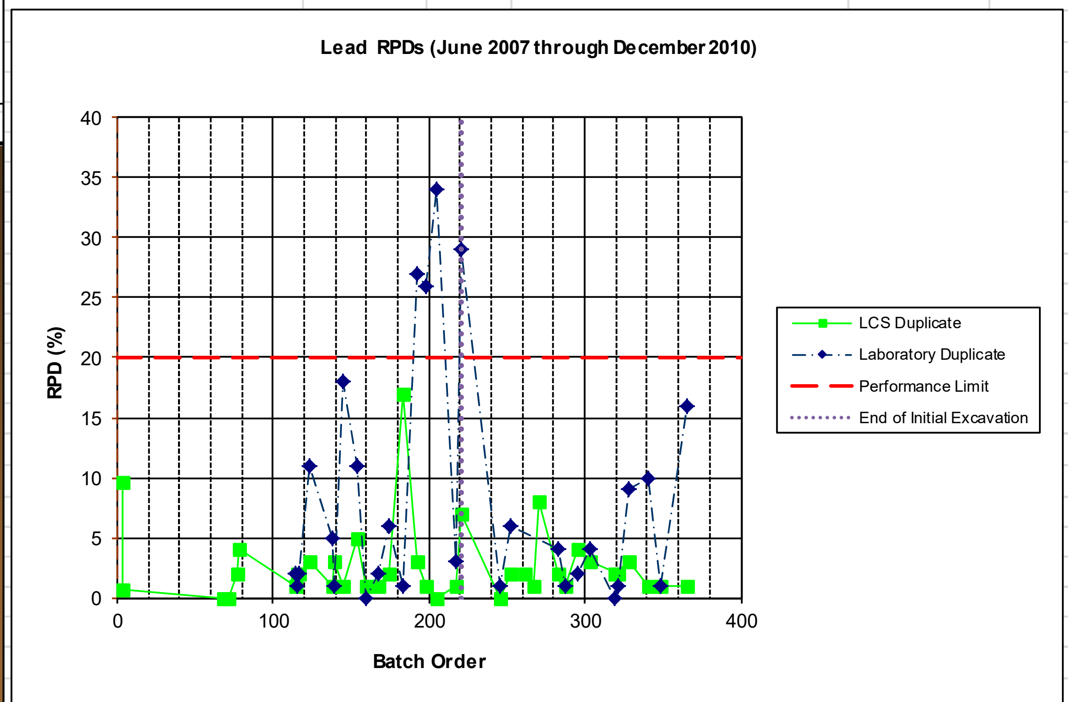
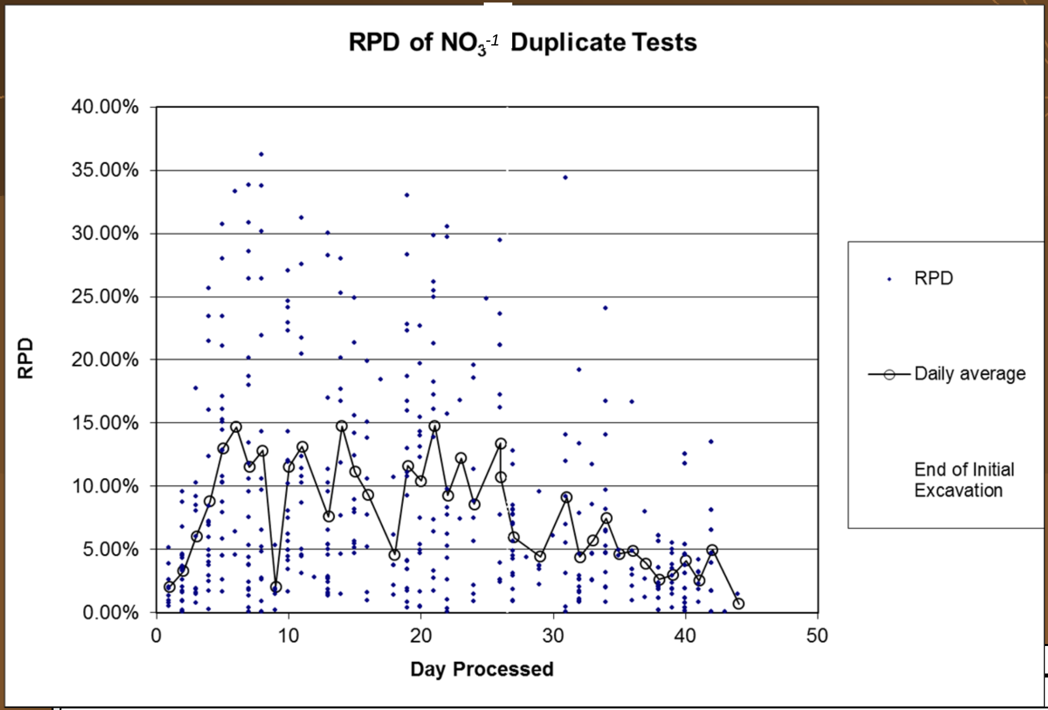
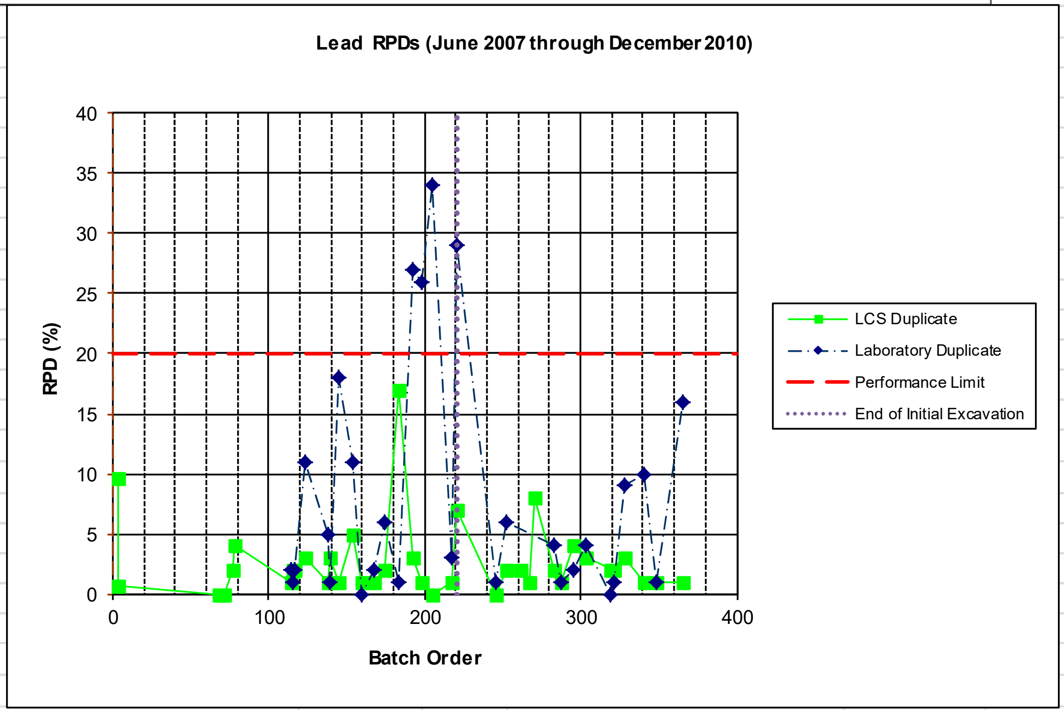


Table Pb-7: Lead - Laboratory Duplicates and LCS Duplicates (Graph)





RPD of NO_3^{-1} Duplicate Tests
RPD
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
0
10
20
30
40
50
Day Processed
RPD
Daily average
End of Initial Excavation



Lead RPDs (June 2007 through December 2010)
RPD (%)
40
35
30
25
20
15
10
5
0
0
100
200
300
400
Batch Order
LCS Duplicate
Laboratory Duplicate
Performance Limit
End of Initial Excavation

Other Important Lessons Learned:

- Always document, in painstaking detail, how you will use data before you collect it.
- Observational Method is not an excuse for not having a plan. Rather, requires plans be developed for all reasonable deviations from expectations.
- Soxtherm extraction of PCB’s was demonstrated to be more efficient than ultrasonic method.
- Microwave power variation, “cook time” and “Bomb” configuration variations, acids, grind time can all result in extreme differences in metal measurements.
- Weigh samples in both field, as received in lab, and after grinding and splitting steps.
- Mixing and stirring alone are never sufficient.
- Don’t trust that “clean fill” is clean..

Other Important Lessons Learned:

- Be sure to specify remediation goal in terms of "TEQ – 2,3,7,8 TCDD" not just the congener 2,3,7,8 TCDD.
- Specifying an RG based on risk weighted parameters is a very reasonable and expectedly better approach than specifying RG''s that are parameter specific.
- Don't accept that laboratories can't do better.
- Let "need" dictate quality requirements.
- "Professional Judgement" must be defensible.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Concluding Comments

- Composite samples provide a cost efficient means to acquire data for defensible risk assessment.
- Composite samples can economically represent many more locations than discrete samples and thereby provide better representations of average concentrations.
- Composite samples provides confidence that contaminants presenting unacceptable risks are discovered.