Adaptive Sampling and Analysis Techniques In Support of Precision Excavation

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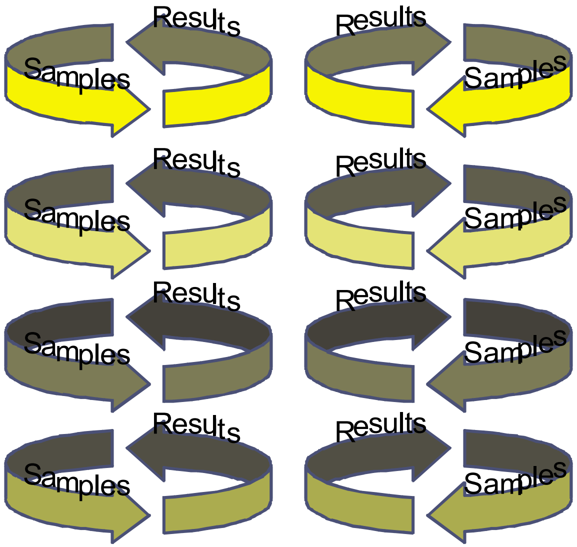
Sampling Programs Are Key Components of the Entire Environmental Restoration Process

***CERCLA** (Comprehensive Environmental Response, Compensation and Liability Act*

- Discovery; Preliminary Assessment (PA)
- Site Investigation (SI)
- Extended Site Investigation (ESI)
- Remedial Investigation/Feasibility Study (RI/FS)
- Remedial Action



***RCRA** (Resource Conservation and Recovery Act)*

- Discovery
- RCRA Facility Assessment (RFA)
- RCRA Facility Investigation (RFI)
- Corrective Measures Study (CMS)
- Corrective Measures Implementation (CMI)

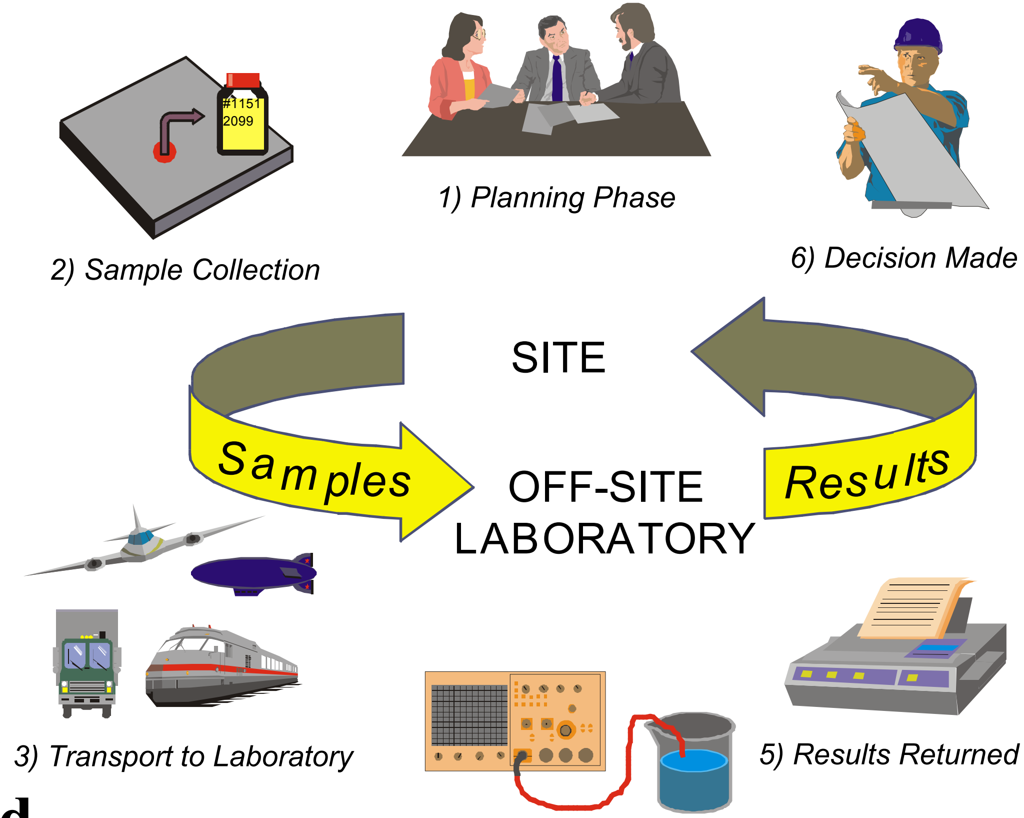
Standard Sampling and Analysis Programs Area Expensive

Characteristics:

- Preplanned Sampling;
- Off-Site Lab Analyses.

Problems:

- High cost per sample;
- Surprise results;
- Pressure to oversample;
- Multiple trips to the field.



1) Planning Phase

2) Sample Collection

6) Decision Made

SITE

Samples

OFF-SITE LABORATORY

Results

3) Transport to Laboratory

5) Results Returned

The Alternatives Go by Many Names…

- Observational Approach (geotechnical engineering)
- Adaptive Sampling and Analysis Programs (ANL)
- Expedited Site Characterization (ANL)
- Sequential sampling programs
- Directed sampling programs
- EPA Technology Innovation Office’s Triad Approach

…But All Share Common Themes:

- **Systematic Planning** (pulling together all information for a site to influence sampling program design, including specification of exactly what decision needs to be made)
- **Dynamic Work Plans** (emphasis not on sample numbers and locations, but on how these decisions will be supported in the field)
- **“Real-Time” Methods** (providing data quickly enough to influence the outcome of the program)

Adaptive Sampling and Analysis Programs Can Cut Costs Significantly

Characteristics:

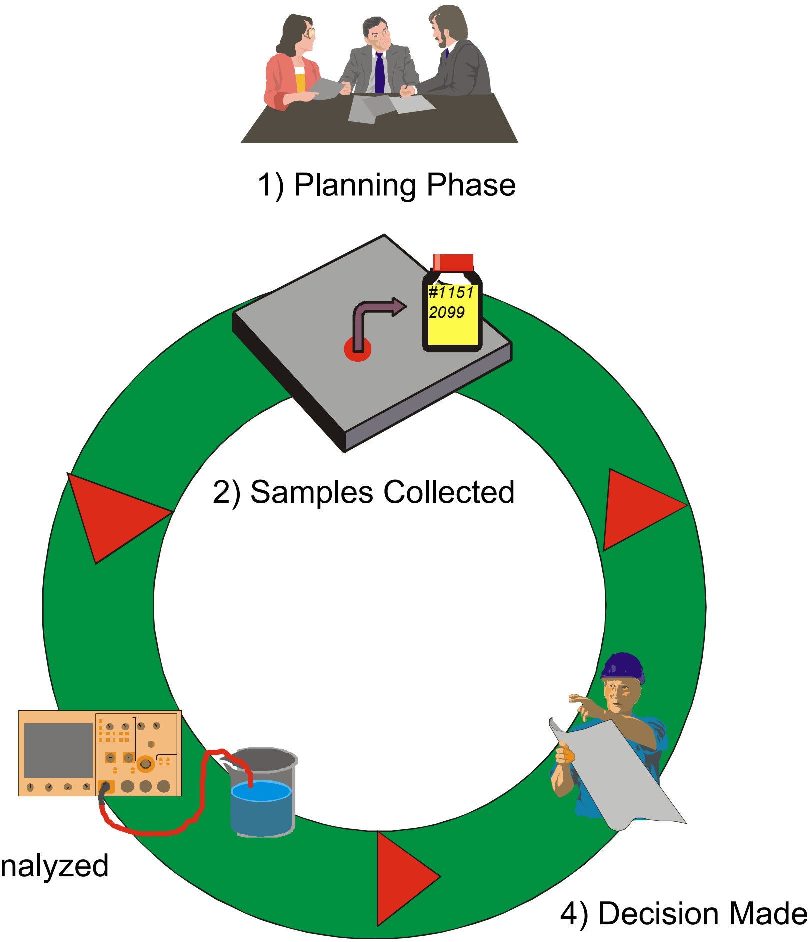
- Real-time sample analysis;
- Rapid field decision-making;

Advantages:

- Reduce cost per sample;
- Reduce # of samples;
- Reduce # of programs;
- Achieve better characterization.

Requirements:

- Real-time method;
- Decision support in the field.



1) Planning Phase

2) Samples Collected

3) Samples Analyzed

4) Decision Made

Real-Time Data Collection Methods are Becoming Increasingly Common

Discrete Samples
Direct Measurements

Scanning

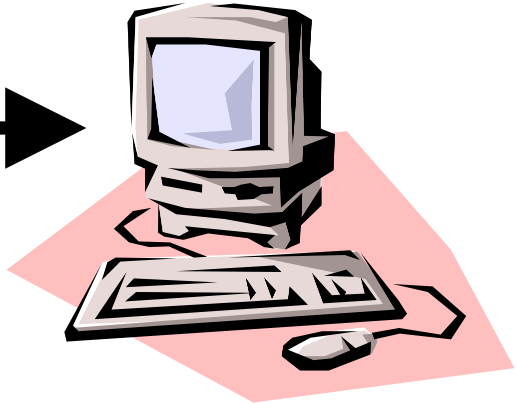
Interpolation……………………………………………...Interpretation

Adaptive Sampling and Analysis Program Decision Support

Base Maps

Geological Information

Sampling Data



Qualitative

- **Data Integration**
- **Data Management**
- **Data Visualization**
- **Data Dissemination**

Quantitative

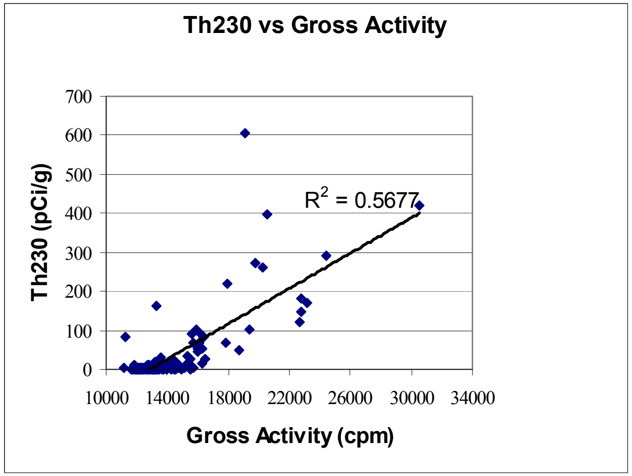
- **Contaminant Extent**
- **Where to Sample**
- **When to Stop**

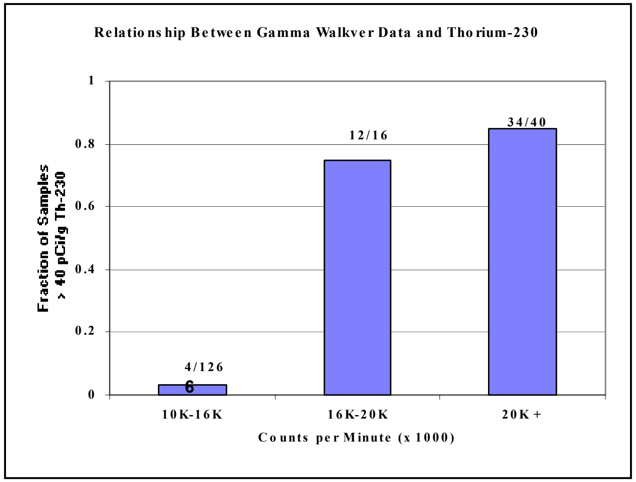
Joint Bayesian/Geostatistical Methods Provide One Approach for Guiding Discrete Sample Collection

- **Discrete sampling programs use limited data points to infer contamination status of large areas. Interpolation is key.**
- **A Bayesian approach is used to combine "soft" and "hard" data (Beta priors and posteriors for the probability of contamination being present above guidelines);**
- **Indicator geostatistics is used to interpolate from locations where samples have been taken to places where data is unavailable;**
- **Uncertainty handled in the context of EPA's DQOs and the probability of making Type I and II errors.**

Non-Parametric Techniques Are of Particular Value for Scanning Technologies

- Scanning technologies can provide 100% coverage of site surface/subsurface. Interpretation is key.
- Linear regression analysis not particularly useful, often observe poor “fit”.
- Non-parametric techniques focus on decision to be made and associated decision errors.
- Relatively immune to problems that plague linear regressions.





Adaptive Sampling Techniques Have Been Successfully Applied at a Number of Federal Sites

Sandia National Laboratories

- Chemical Waste Landfill
- Subsurface chromium contamination
- Estimation of contaminated soil volumes;
- Number of bores reduced by 40%, samples by 80%.

Kirtland Air Force Base

- RB-11 (Haliburton);
- Mixed waste burial trenches;
- Estimation of contaminated soil volumes;
- Number of bores reduced by 30%, samples by 50%.

Argonne National Laboratory

- 317 Area (Weston);
- Near surface VOC soil contamination;
- Estimation of extent;
- Number of samples reduced by 60%.

Brookhaven National Laboratory

- Glass Holes Area (CDM Federal);
- Subsurface mixed waste contamination;
- Estimation of contaminated soil volumes;
- Cost estimates for removal action reduced from $40M to $8M.

Fernald Site

- Soils program (Fluor Daniel Fernald);
- Radionuclide soil contamination;
- Support excavation design and execution;
- Expected to reduce $80M sampling to less than $40M.

Joliet Army Ammunition Plant

- TNT Production Lines (OHM);
- Surface TNT soil contamination;
- Estimation of contaminated soil volumes;
- Per sample costs reduced by 80%.

FUSRAP Painesville Site

- Whole site (BNI and SAIC);
- Mixed waste soil contamination;
- EE/CA support;
- Overall project savings estimated at $10M.

FUSRAP Ashland 2

- Whole site (ICF Kaiser);
- Radionuclide soil contamination;
- Precise excavation support;
- Overall project savings estimated at $10M.

Remediation Case Study: Ashland 2 FUSRAP Site

- Site used as a dumping ground for soils contaminated with Th-230, U-238, and Ra-226.
- Th-230 is the driver, with an action level of 30 pCi/g.
- Total excavation and disposal costs approximately $300 per cubic yard.
- RI/FS data sets included 341 soils samples from 116 soil bores.
- Existing soil volume estimate was 14,000 cubic yards. Re-analysis suggested a best estimate of 25,000 cubic yards, with a range of 3,000 to 46,000 cubic yards.

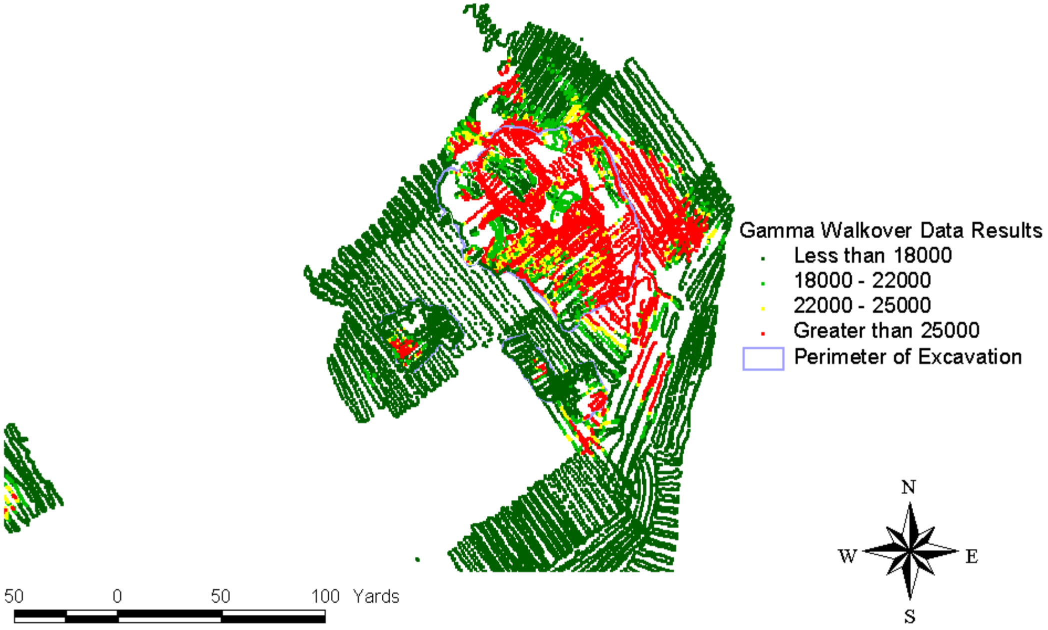
Precise Excavation Strategy for Ashland2

- Excavation designed for two foot lifts. Excavation footprints refined after each lift based on real-time results.
- Real-time data collection included:
  - Gamma scans logged with differentially corrected GPS system.
  - On-site gamma spectroscopy lab for quick turn-around of soil samples.
- Off-site alpha spectroscopy served as QA/QC for real-time results.
- 24 hour turn-around time target for new excavation footprints.
- Data integration and analysis through GIS and secure project support Web site.

Gamma Walkover Data Guided Excavation

- Gamma walkover dat collected, processed a disseminated daily.
- Gamma walkover dat divided surface into three categories: “clean”, “contaminate “uncertain”.
- Discrete samples with on-site gamma spec us for “uncertain” areas.
- On-going validation program allowed gros gamma trigger levels t be adjusted as needed

Gamma Walkover Data: Excavation Area (2 - 3 ft) Superimposed on Surficial Data (as of 8/08/98)



Effectiveness of the Precise Excavation Approach Can Be Measured by:

- **How “precise” was the excavation?**
- **What difference was there between the footprints of the precise excavation and one defined solely on characterization data ?**
- **What additional cost or scheduling burdens did this approach place on the remediation process?**

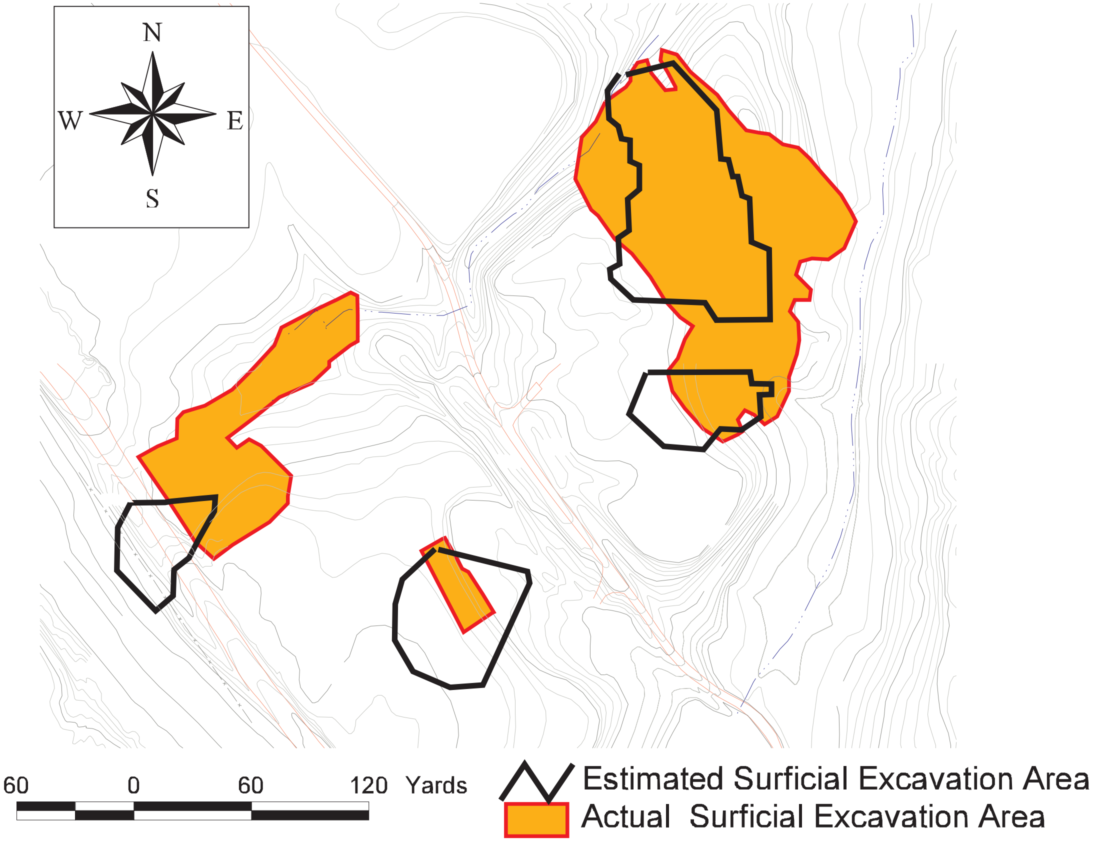
How “Precise” was the Excavation?

- Of 146 composite samples collected to characterize material for shipment 97% exceeded the clean-up criteria. Of the 4 composite samples below the clean-up criteria, 2 were collected during the first two weeks of excavation.

- Of the more than 400 final status survey samples collected post-remediation, only a few exceeded the Th-230 cleanup criteria. No follow-up remediation work required.

Was the Difference Between Footprints of Precise Excavation and Characterization Data Significant?

For the surficial lift, 4,000 cubic yards would have been excavated unnecessarily and 8,000 cubic yards would have been missed if excavation had been based on RI data.



What Additional Cost or Scheduling Burdens did this Approach Place on the Remediation Process?

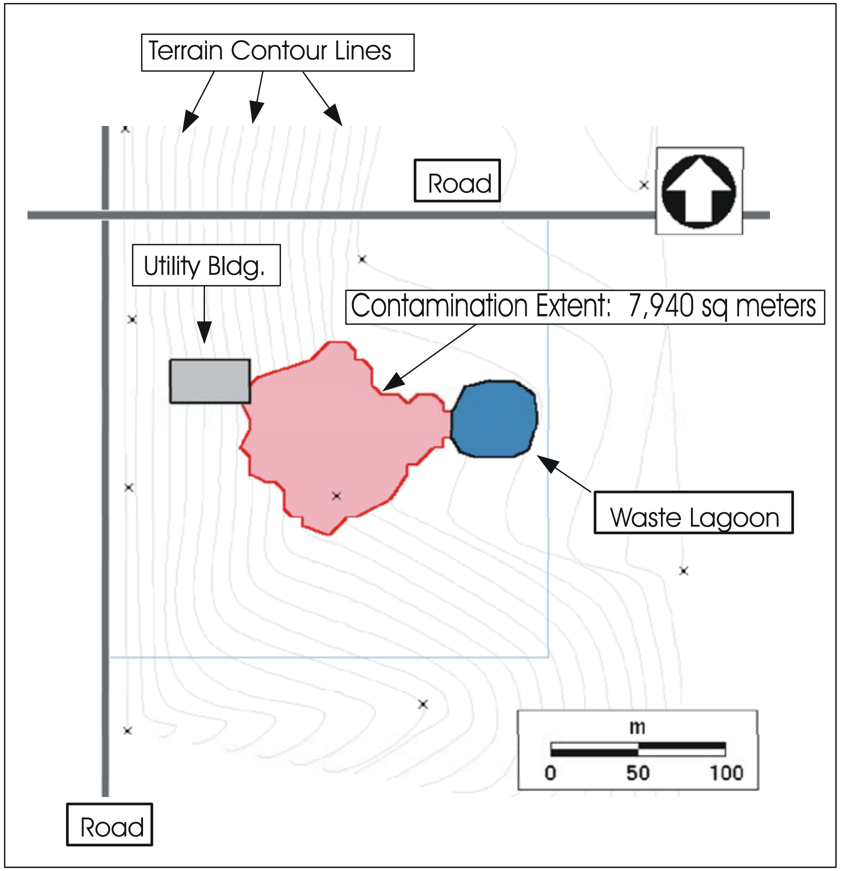
- Excavation cannot proceed until after screening, possibility of down-time for excavation crews. This was not the case at Ashland 2.
- Preliminary estimates indicate costs of $200,000 for gamma walkover data and data analysis.
- Considering the surficial lift alone, over $1.5 million in cost savings were achieved by avoiding unnecessary disposal costs.
- Corps estimated total cost savings of >$10M from waste stream minimization.

Other Benefits of the Precise Excavation Approach at Ashland 2

- Money was spent on remediation and not more studies.
- Data collection techniques provided assurance that contaminated soil had been removed when demobilization took place. No final status survey surprises.
- Allowed for the rapid identification and correction of operational problems as they arose.
- Provided documentation and justification for quantities of soil removed. 45,000 cubic yards of soil excavated in all.
- Web page was an excellent way to share data among project team members, including the State of New York.

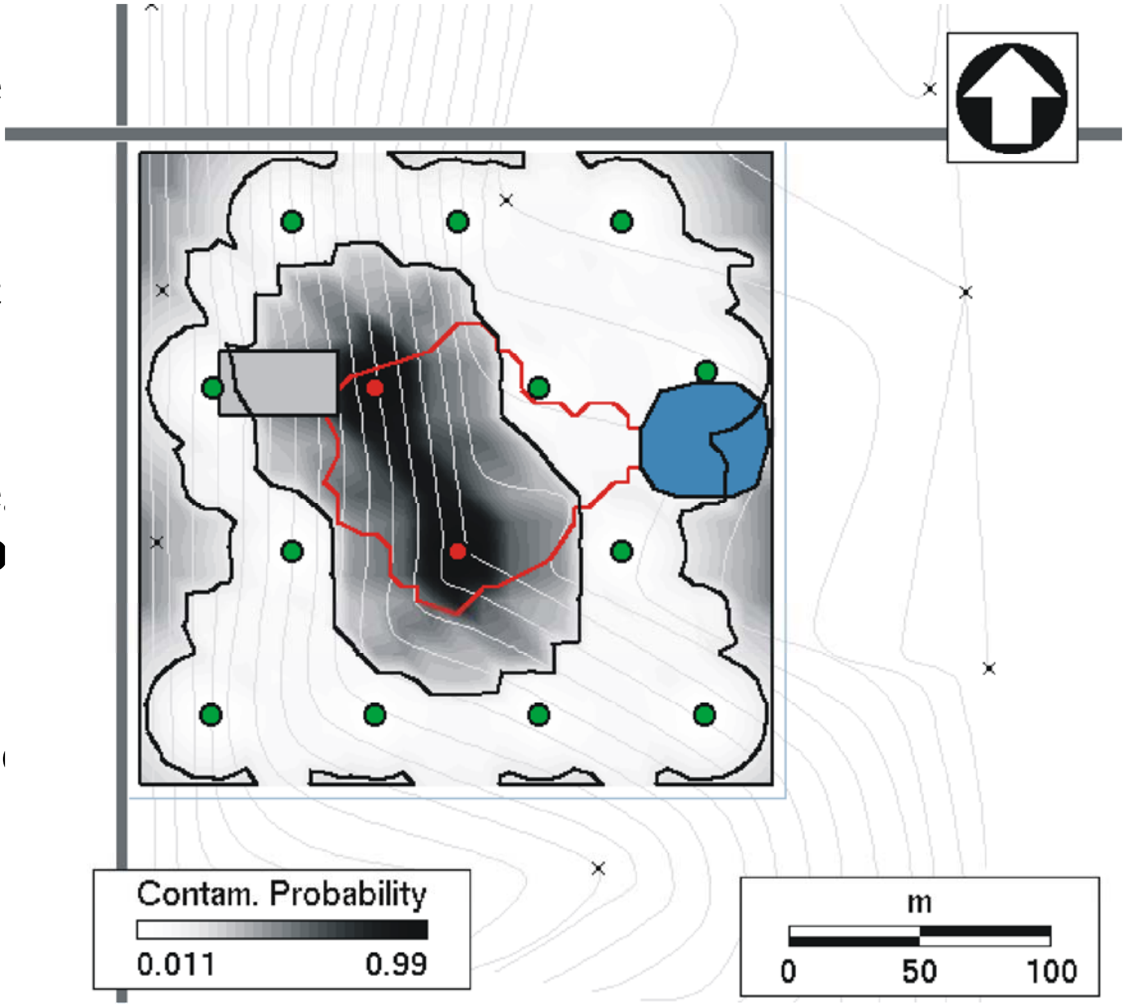
Example: Surface Soil Contamination

- Surface soil contamination problem.
- Resulted from spillage from the lagoon.
- 7,940 sq m actually contaminated, an area unknown to the responsible party.
- Soft information available for the site includes:
  - Slope of land;
  - Location of barriers to flow;
  - Location of source.
- Owner will remediate anything with greater than 20% chance of being contaminated.

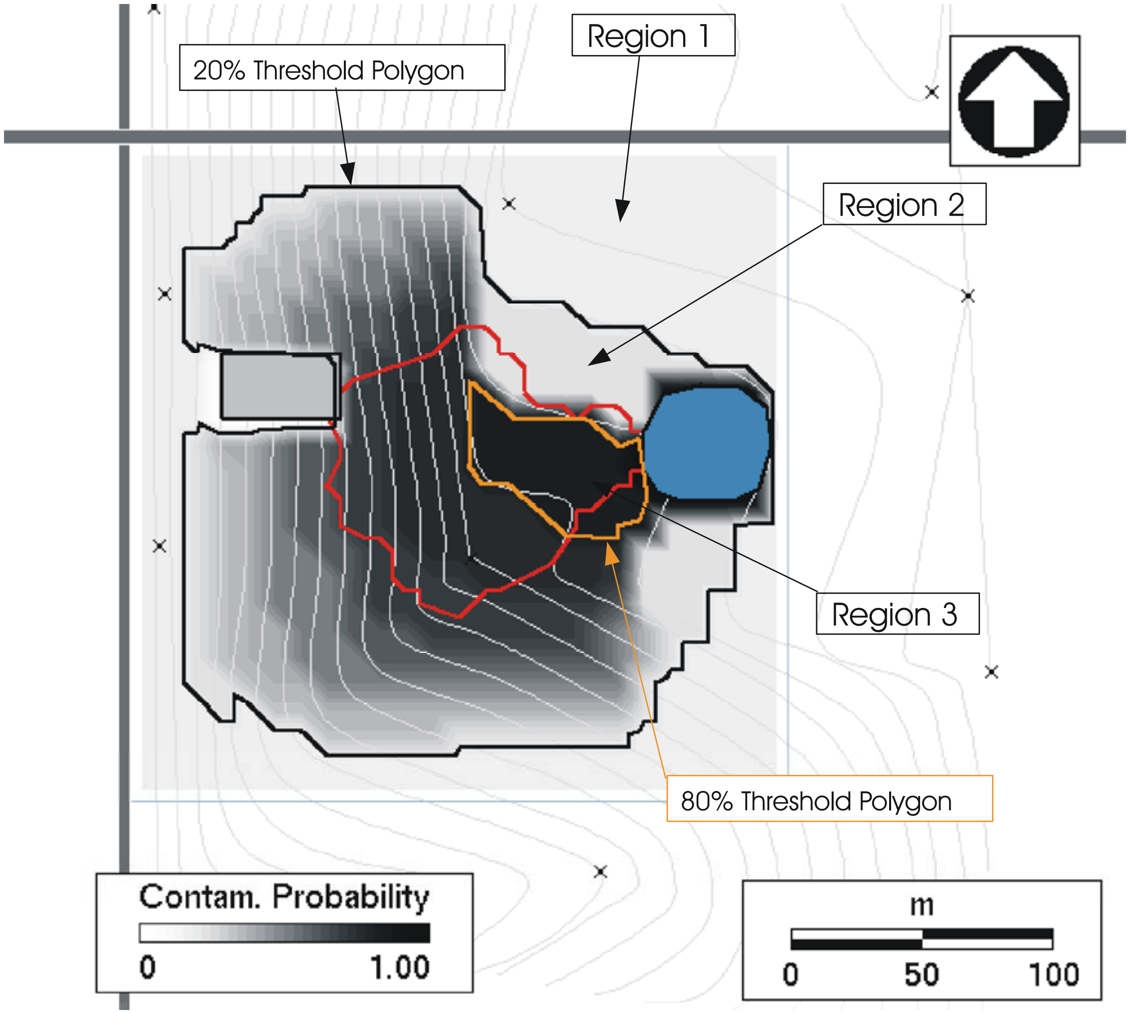


Standard Gridded Sampling Program

- Determine sample numbers.
- Layout systematic grid.
- Sample all at once send off to a lab fo analysis.
- Interpolate based results.

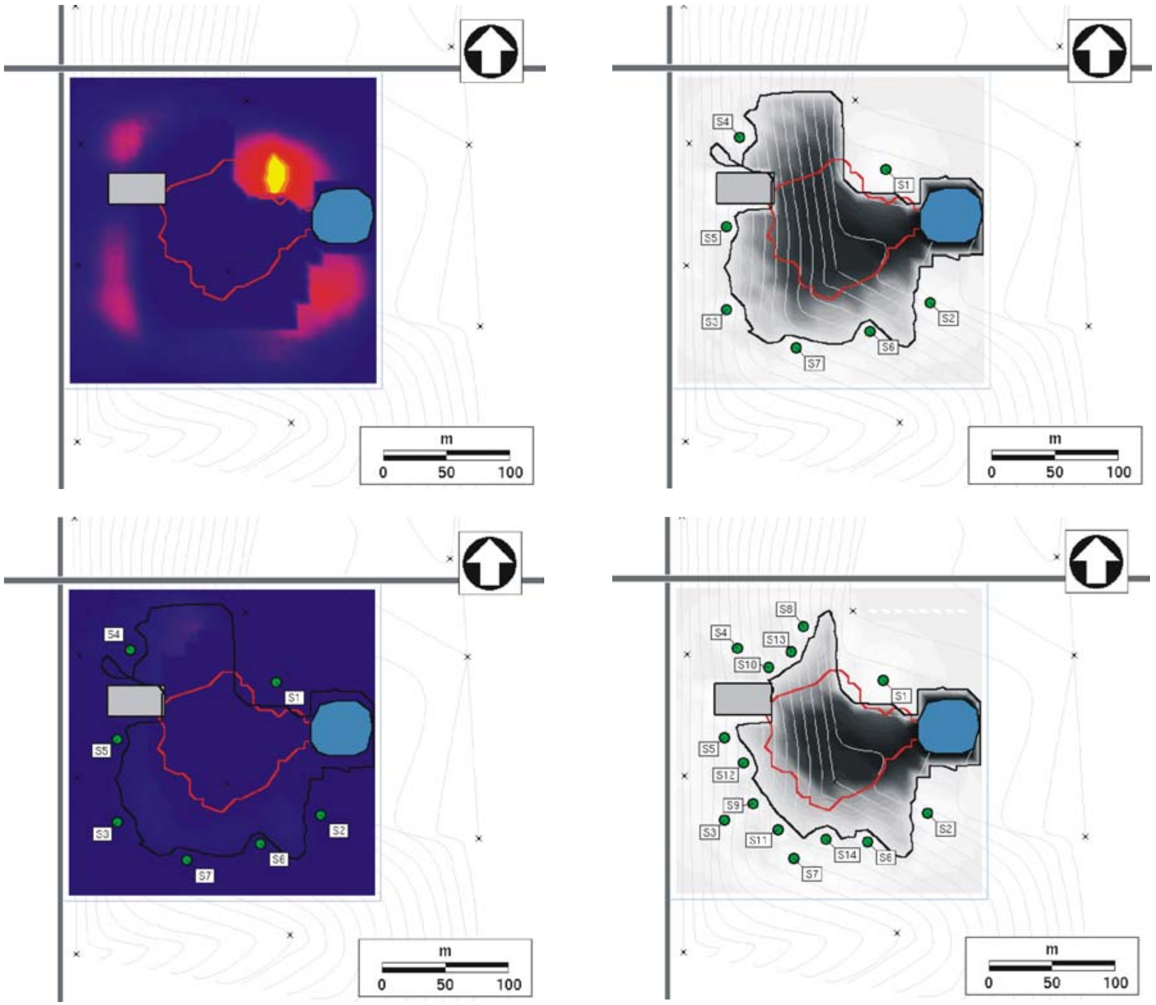


Adaptive Approach: Conceptual Site Model

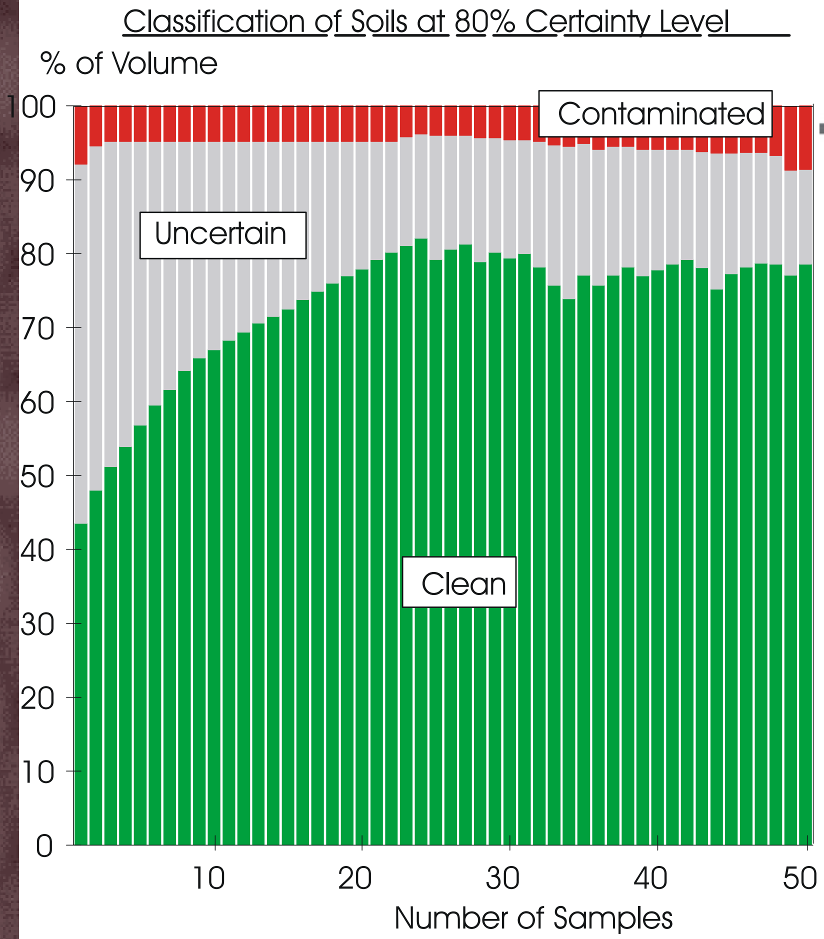


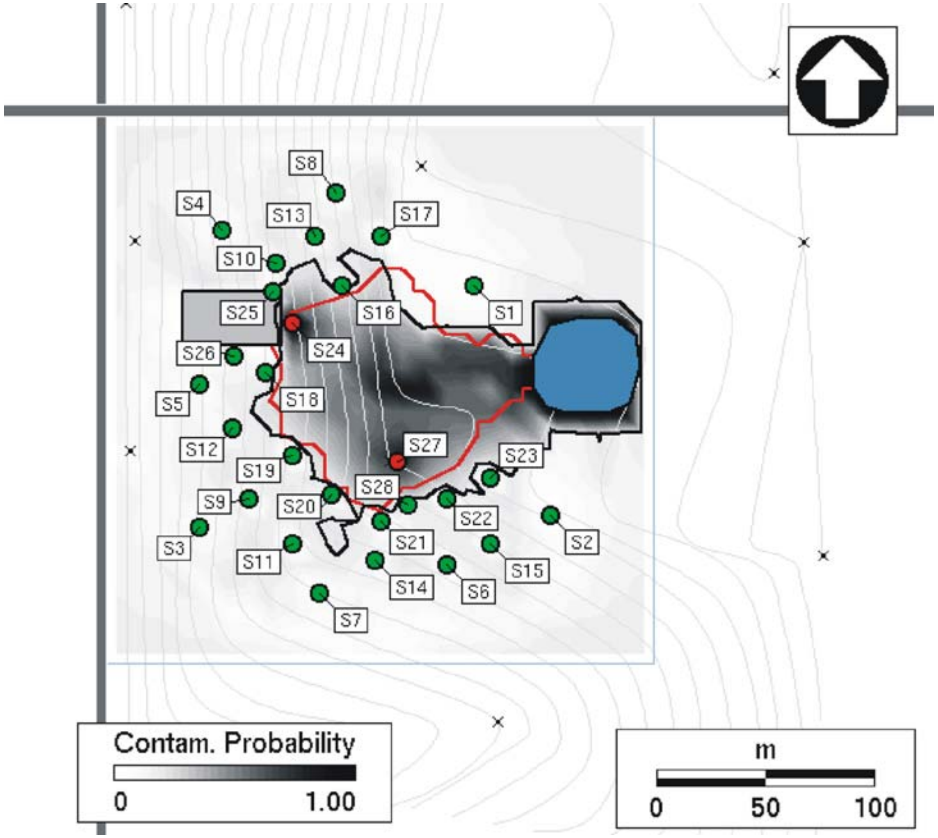
Sampling Progression with Adaptive Alternative

- Samples are collected sequentially with an appropriate FAM providing “real-time” data.
- New sample locations selected based on initial conceptual model updated with current sampling results.
- In this example, locations are selected to maximize the area with less than 0.2 probability of contamination.

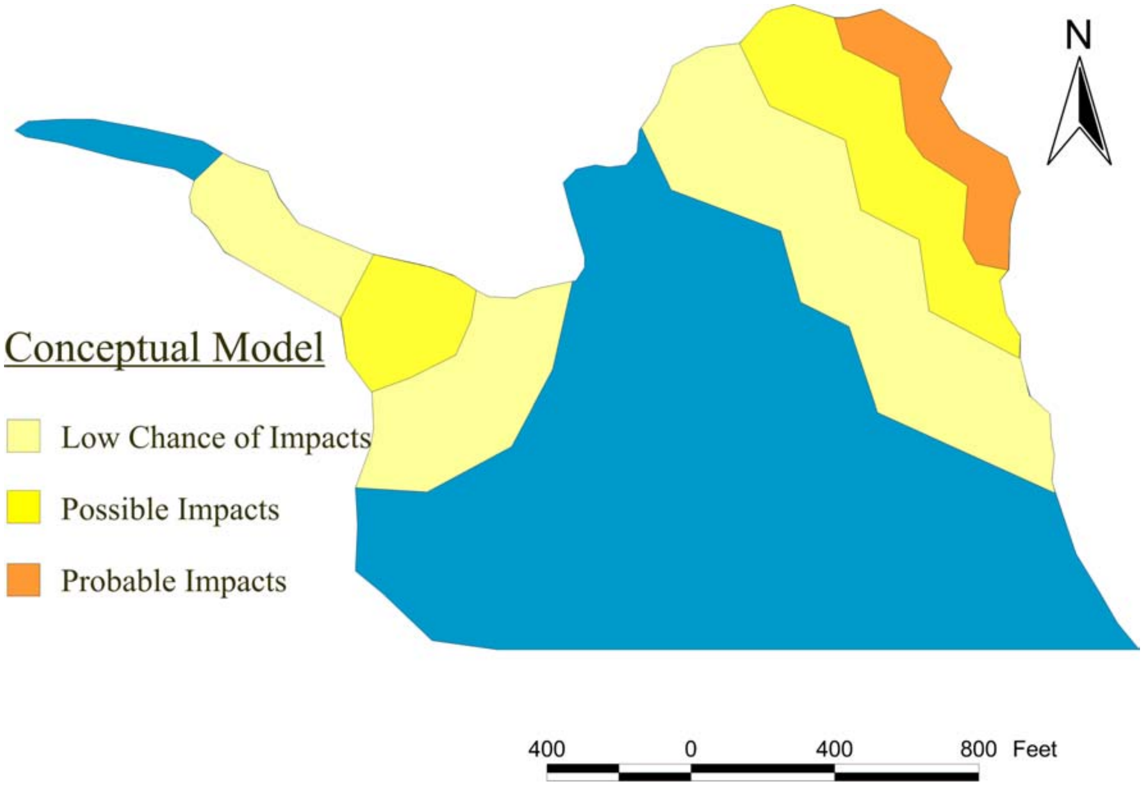


Sampling Can Continue Until Goals are Achieved



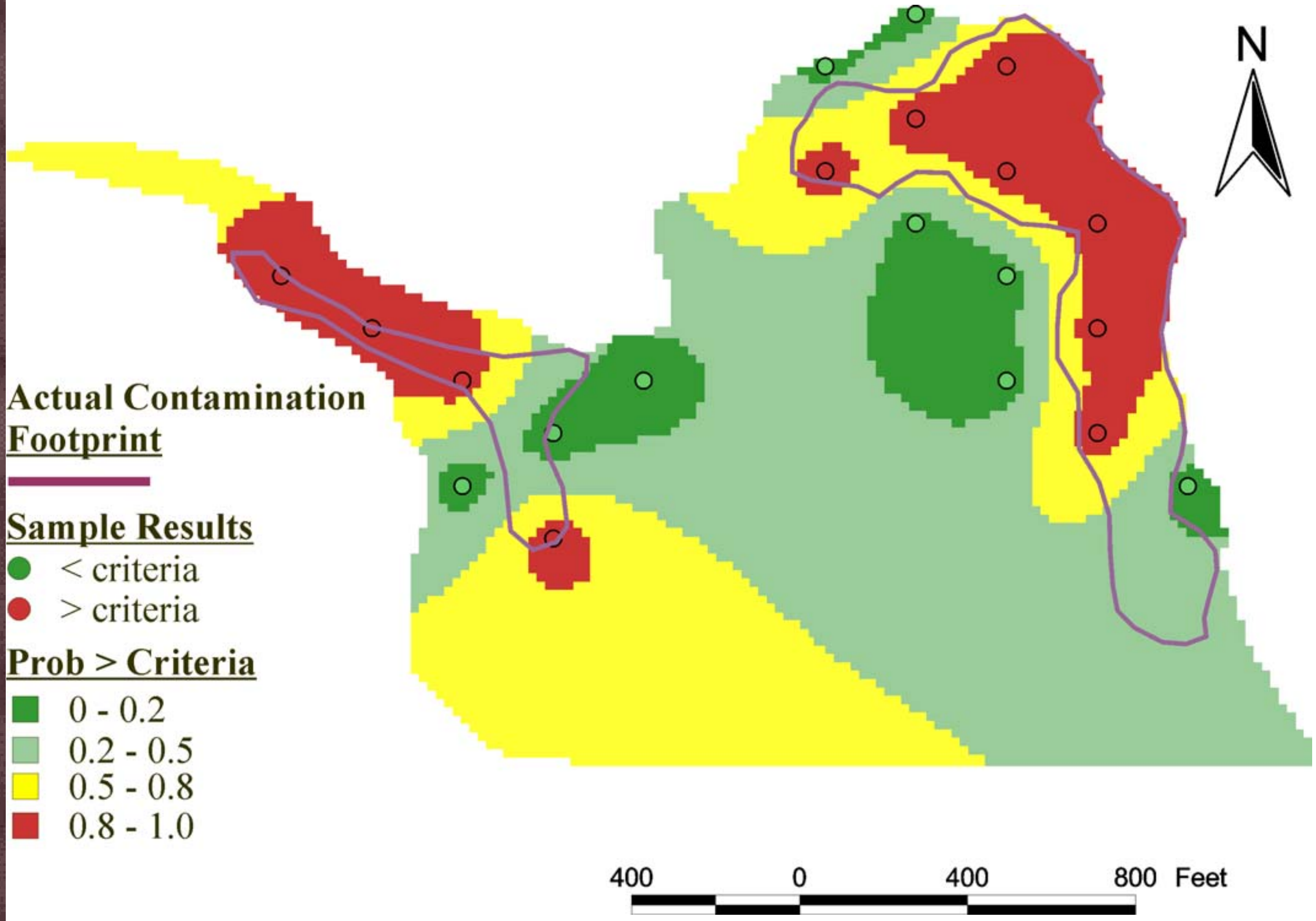


Example: Characterization of Sediment Contamination in Hypothetical Bay



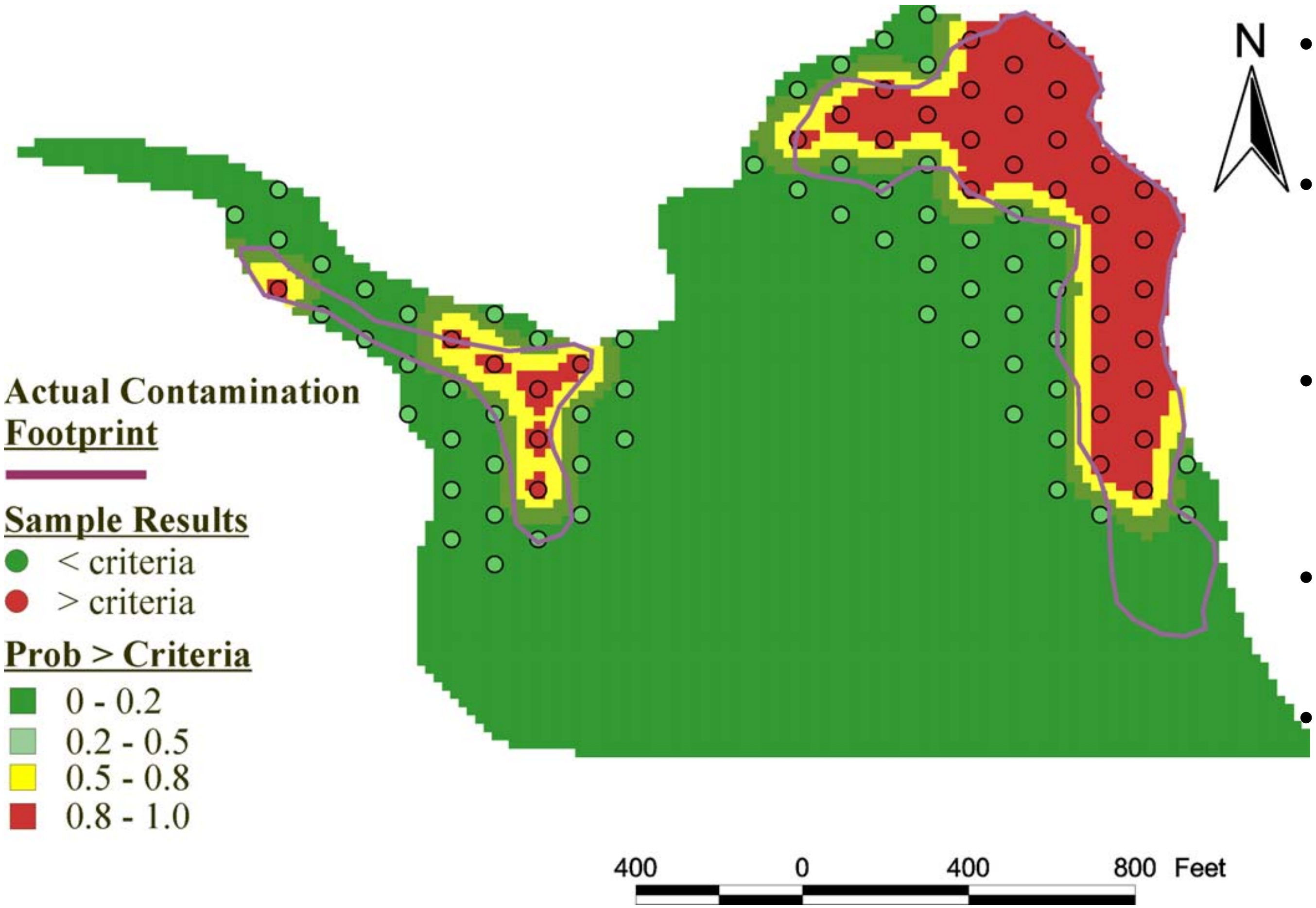
- 63 acre bay;
- Likely PCB contamination;
- Simple conceptual site model (26.4 acres of concern);
- Goal is to delineate contamination footprint.

Standard Approach: One-Time, Gridded Sampling with Off-Site Sample Analysis



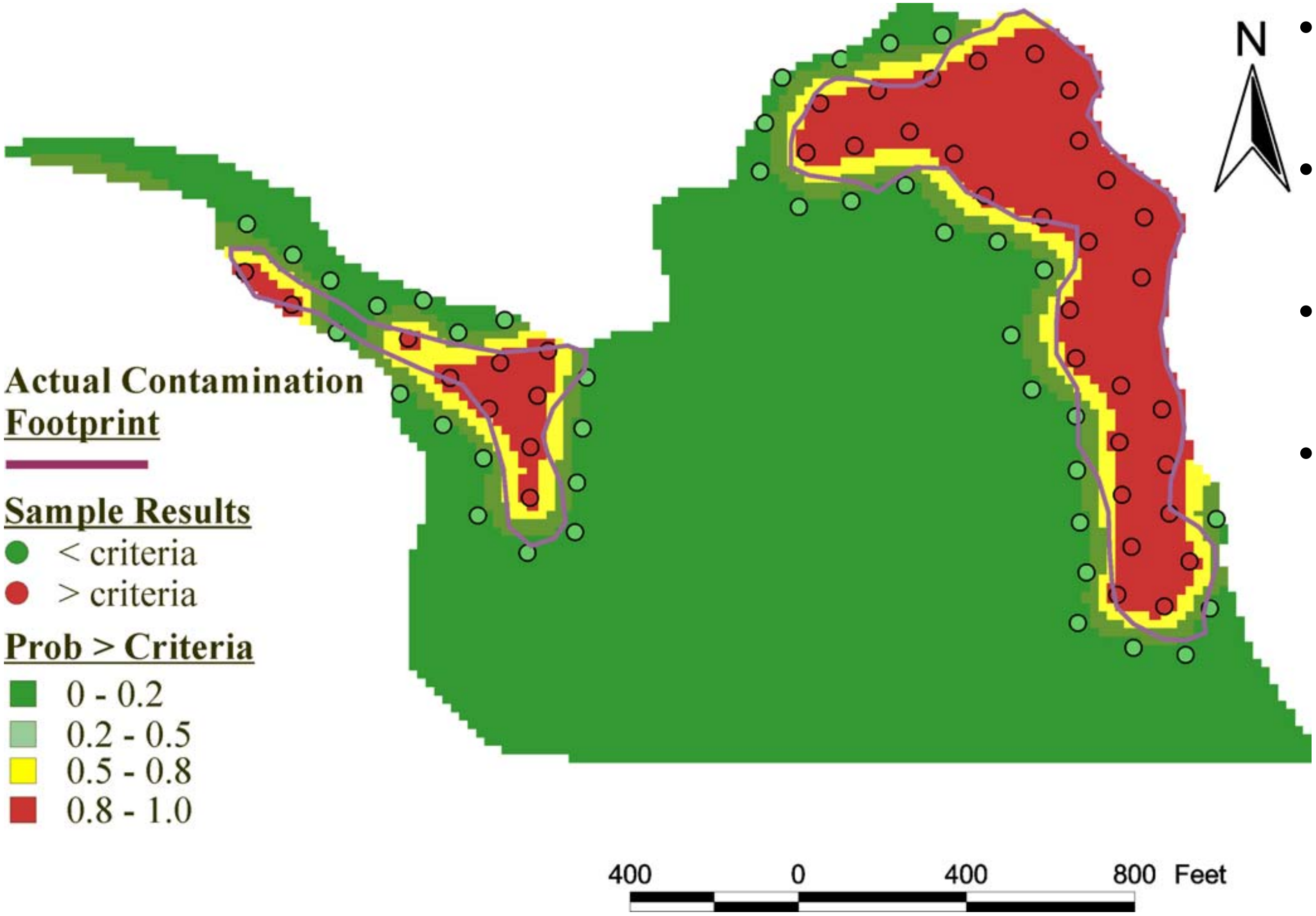
- triangular, preplanned grid;
- off-site lab analysis ($400 per sample);
- sample numbers limited by budget;
- 20 samples collected;
- 250 feet between samples.

One-Time, Gridded Sampling with Analyses Done with “Real-Time” Field Technique



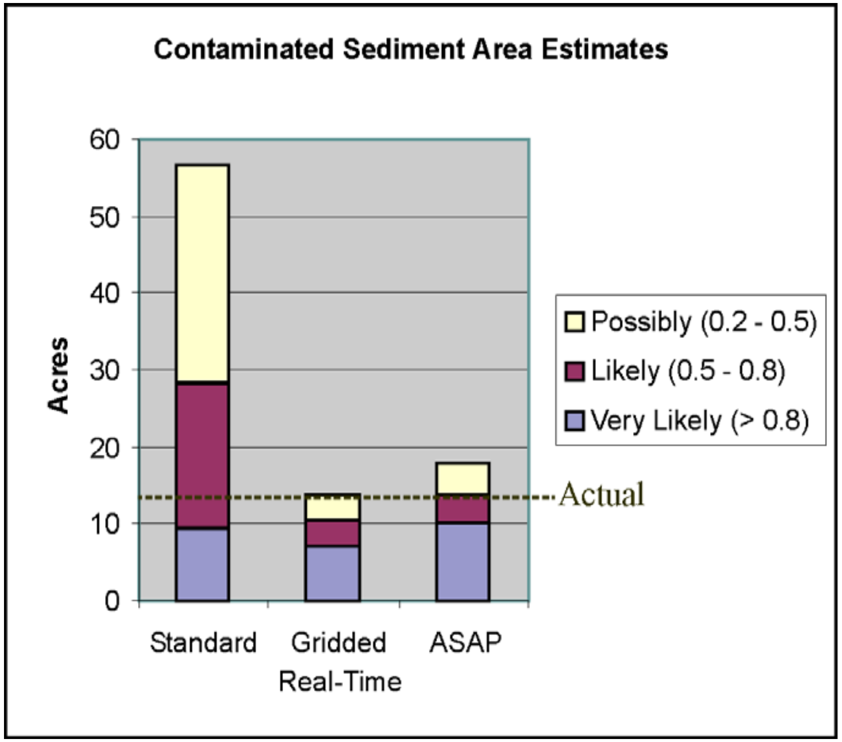
- triangular, preplanned grid;
- real-time analysis ($80 per sample);
- sample numbers limited by budget;
- 96 samples collected;
- 120 feet between samples.

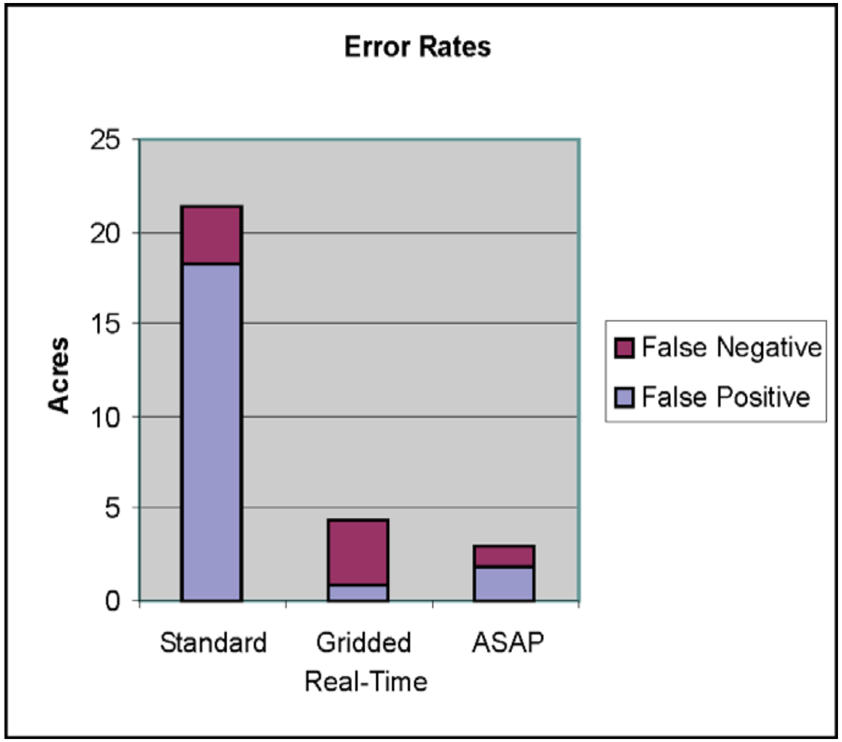
ASAP Approach: Iterative Sampling with Field Technique Focused on Defining Boundaries



- dynamic adaptive sampling strategy;
- real-time analysis ($80 per sample);
- 79 samples collected;
- 120 feet between samples.

Performance Comparisons Show Reduced Uncertainty (in addition to reduced characterization costs)





- **Much more accurate estimate of actual contaminated area.**
- **Significantly improved false positive/negative error rates.**
- **Ability to resolve "surprises" as they arise (in this case, contamination that extended beyond what was originally expected).**

ASAP/Triad Approach Can Add Value at Several Points in the Cleanup Process

Process Point	*Problems with Traditional Approaches*	*Triad/ASAP Advantages*
Remedial Investigation	■ Expensive analytics limit sample numbers. ■ No mechanism for responding to surprise results.	■ Reductions in analytical costs. ■ Improved understanding of nature and extent. ■ Ability to address surprises while RI data collection is in progress.
Feasibility Study & Remedial Design	■ Data inadequate for accurate alternative evaluation. ■ Data inadequate for good design.	■ Selectively address data gaps and issues unresolved by RI datasets. ■ Provide improved estimates of contaminant volumes and footprints.
Remediation	■ Fixed, inaccurate excavation or dredging footprints. ■ Missed contamination and subsequent closure problems. ■ Inadvertent removal of “clean” material.	■ Allows dynamic work plans that can be adjusted based on data. ■ Waste stream minimization. ■ Ability to balance investments in data with expected cost reductions.
Long Term Monitoring & Closure	■ Either too much or not enough sampling. ■ Expensive analytics. ■ Limited flexibility to address unexpected outcomes.	■ Adjust data collection to meet the specific needs of individual areas. ■ Reductions in analytical costs. ■ Flexibility to modify monitoring on-the-fly in response to surprises.