Optimizing LTM Networks with GTS: Three New Case Studies

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Basic Goal

- Need adequate & sufficient data to make good decisions
  - But not too much data
  - Want to minimize waste; maximize usefulness of data collected
- Optimization algorithm looks at two areas:
  - Monitoring network locations
  - Sampling frequencies in network

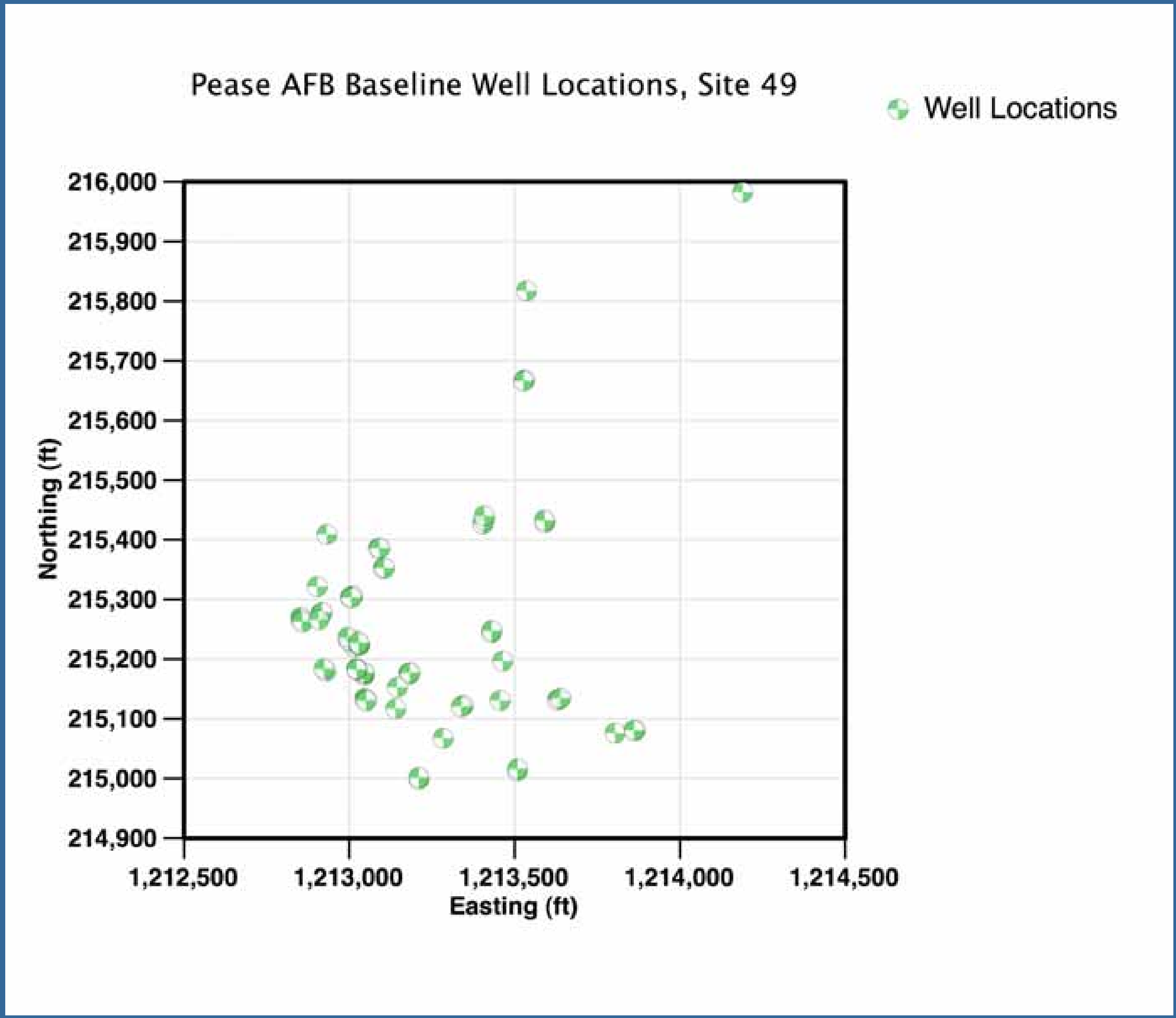
GTS Algorithm

- Designed with decision-logic framework
- Allows for separate identification of temporal & spatial redundancy
- Uses geostatistical and trend optimization methods
  - Variogram = correlation measure
  - Kriging = spatial interpolation = spatial regression
  - Locally-Weighted Quadratic Regression (LWQR)

Case Studies

- 3 AF sites with varied geology
  - Pease AFB, New Hampshire
    - Site 49, TCE plume from underground storage tank
    - Fractured bedrock; varied overlying geology
    - 67 wells used as baseline

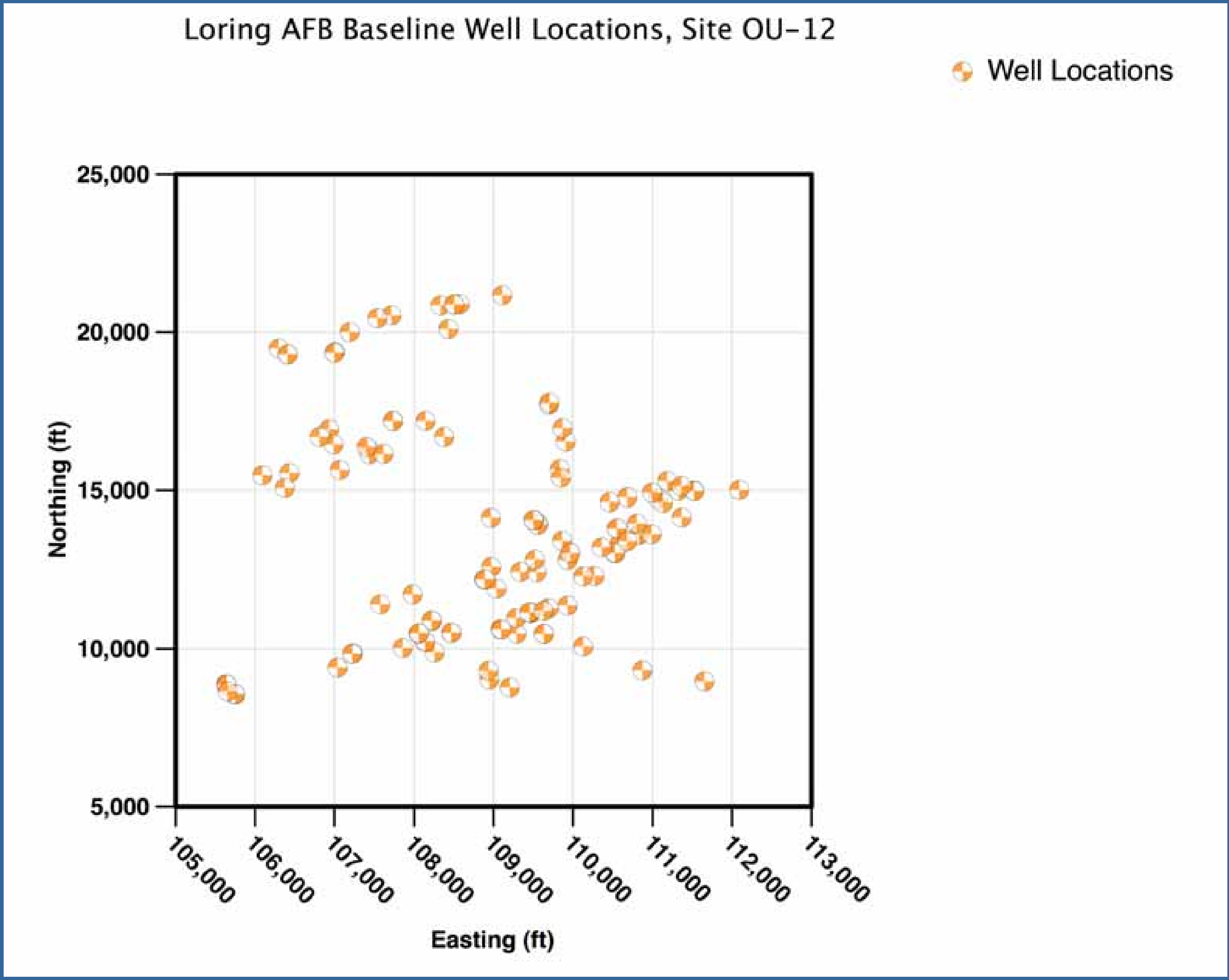
Pease AFB Site 49 Plan View



Case Studies (cont.)

– Loring AFB, Maine
  - Site OU-12, 30 contaminant sources, including BTEX, TCE
  - Lightly to heavily-fractured bedrock; 3 distinct overburden units
  - 115 wells used as baseline

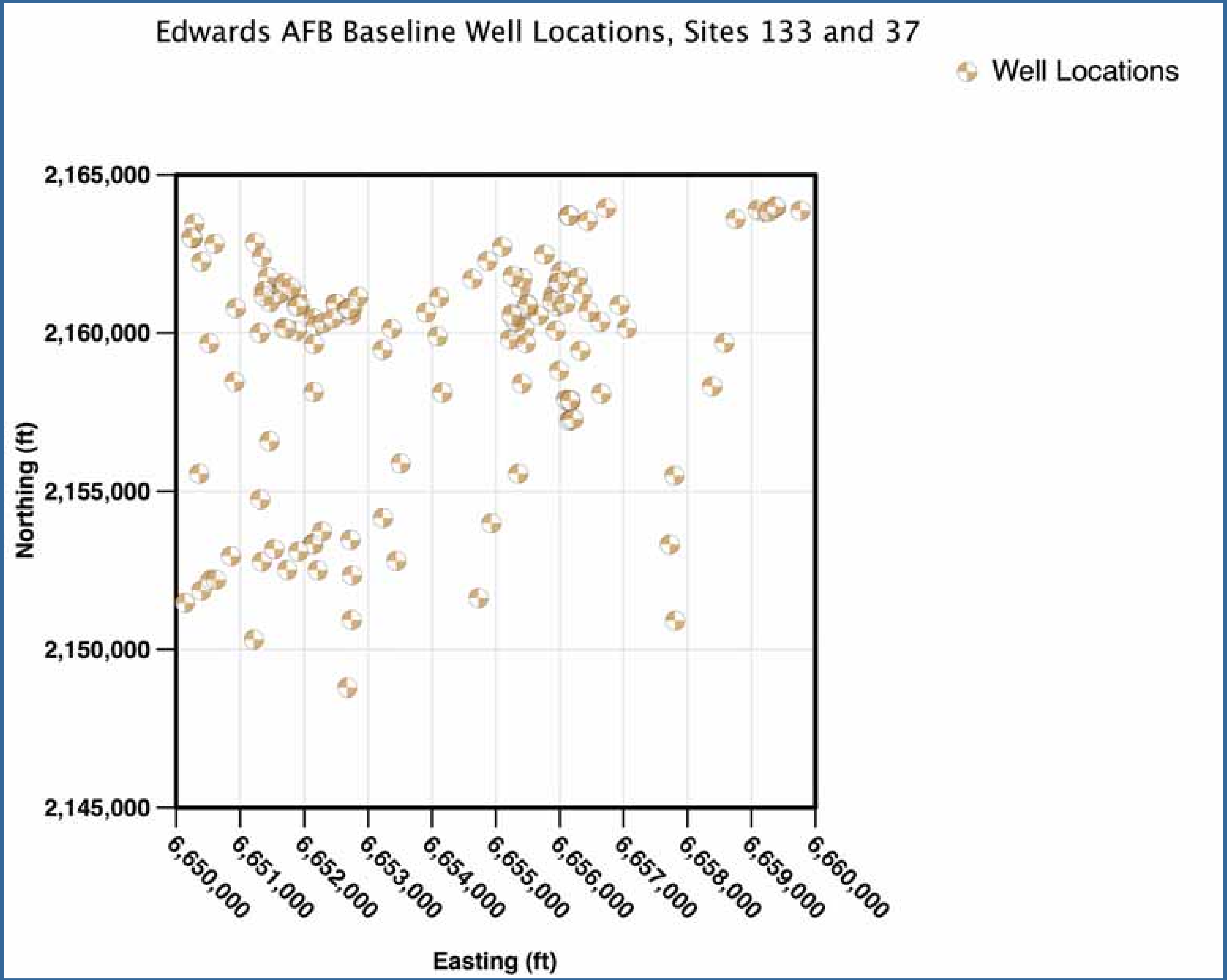
Loring AFB OU-12 Plan View



Case Studies (cont.)

- Edwards AFB, California
  - Sites 133, 37; Contamination due to storage & waste disposal practices
  - Fractured crystalline bedrock; weathered bedrock overlay
  - 140 wells used as baseline
- Question: could GTS be adapted to these situations?

Edwards Site 133 Plan View



Note on Redundancy

- Practical definition: What happens when data removed from current system?
- Temporal
  - Can trends be re-constructed?
  - Do consecutive sampling events become uncorrelated?
- Spatial
  - Can surface map be re-constructed?
    - Plume extent and intensity

Optimality vs. Redundancy

- Redundancy a misnomer
  - All unique data points valuable
  - Always have loss of information if removed
- Must balance tradeoff between cost savings and loss of accuracy
  - Optimal system = minor information loss but large gain in resource savings

Optimality (cont.)

- Common strategy
  - Use existing data to estimate baseline
  - Remove some data (wells, sampling events)
  - Re-estimate baseline with reduced data set
  - Measure relative error incurred
  - Examine cost-accuracy tradeoff

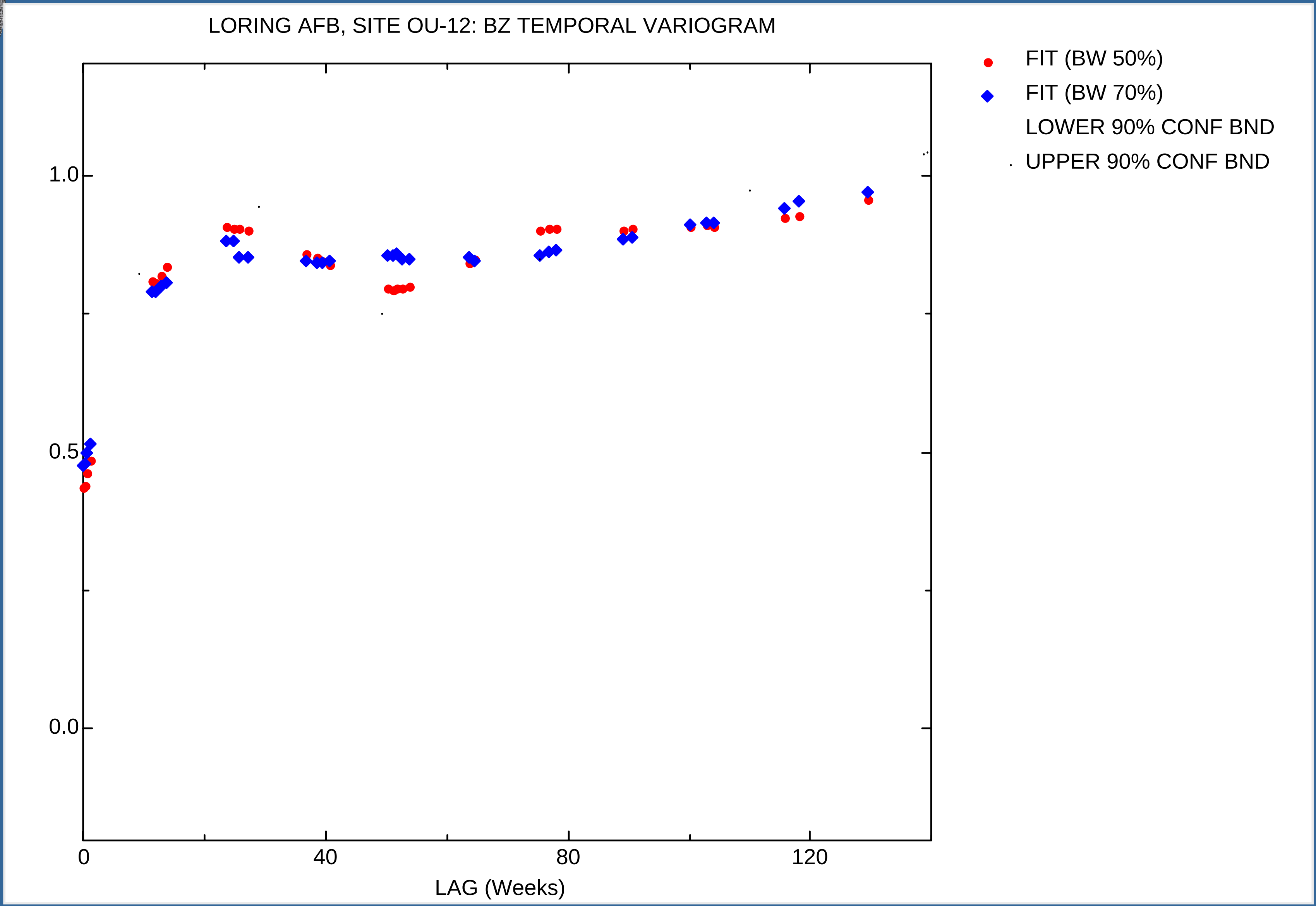
Temporal Optimization

- Examine temporal redundancy
  - Too many sampling events at individual wells?
- Two approaches
  - Temporal variogram to estimate average correlation between sampling events
  - Iterative “thinning” of individual wells to adjust well-specific sampling frequencies

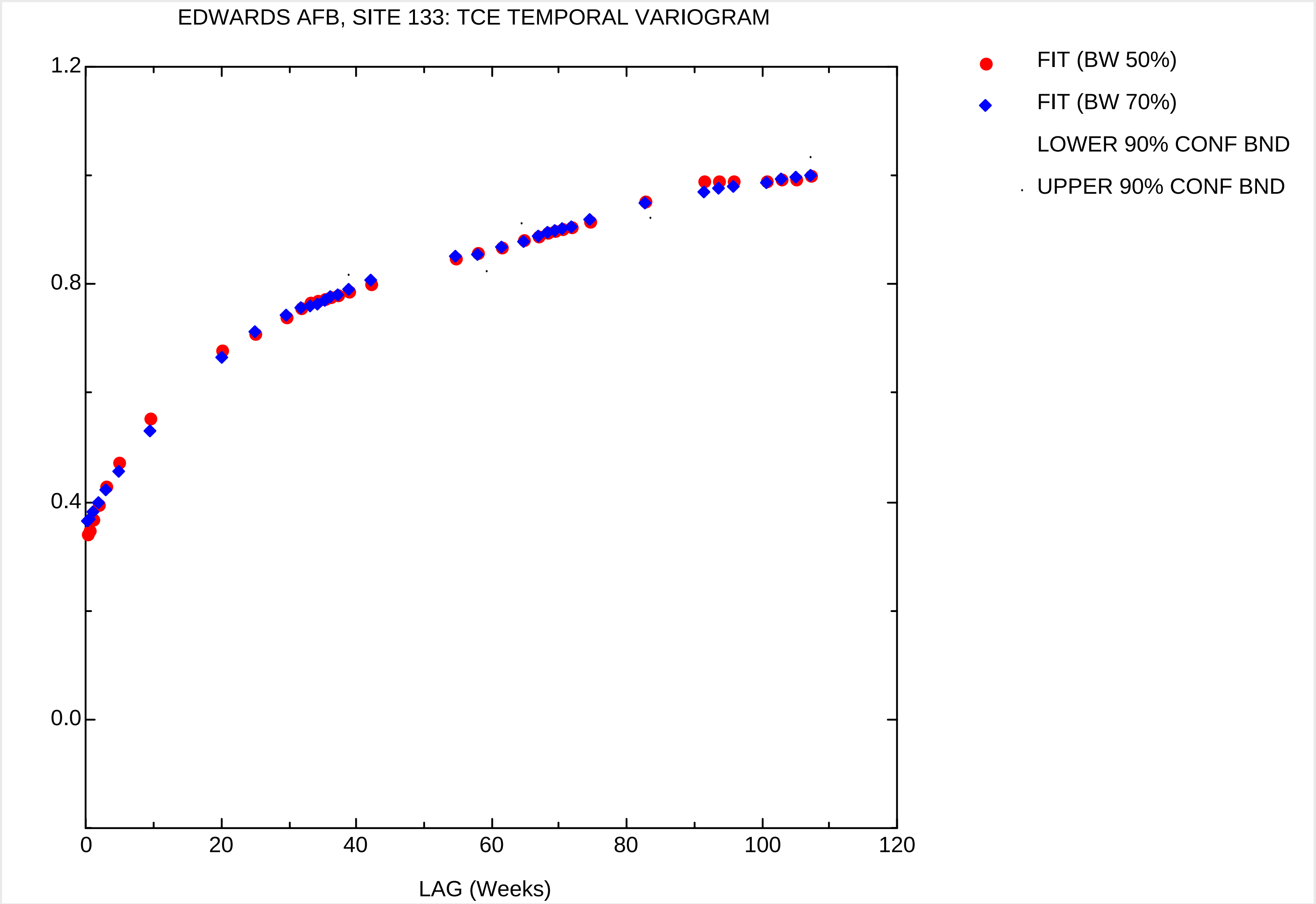
Temporal Variogram

- Advantages
  - Useful with irregularly spaced data
  - Data from multiple wells can be included
  - Single graph shows optimal global sampling interval
- Just need to determine sill and where it begins ("range")
  - Range can be taken as minimum global sampling interval

BZ Temporal Variogram



TCE Temporal Variogram



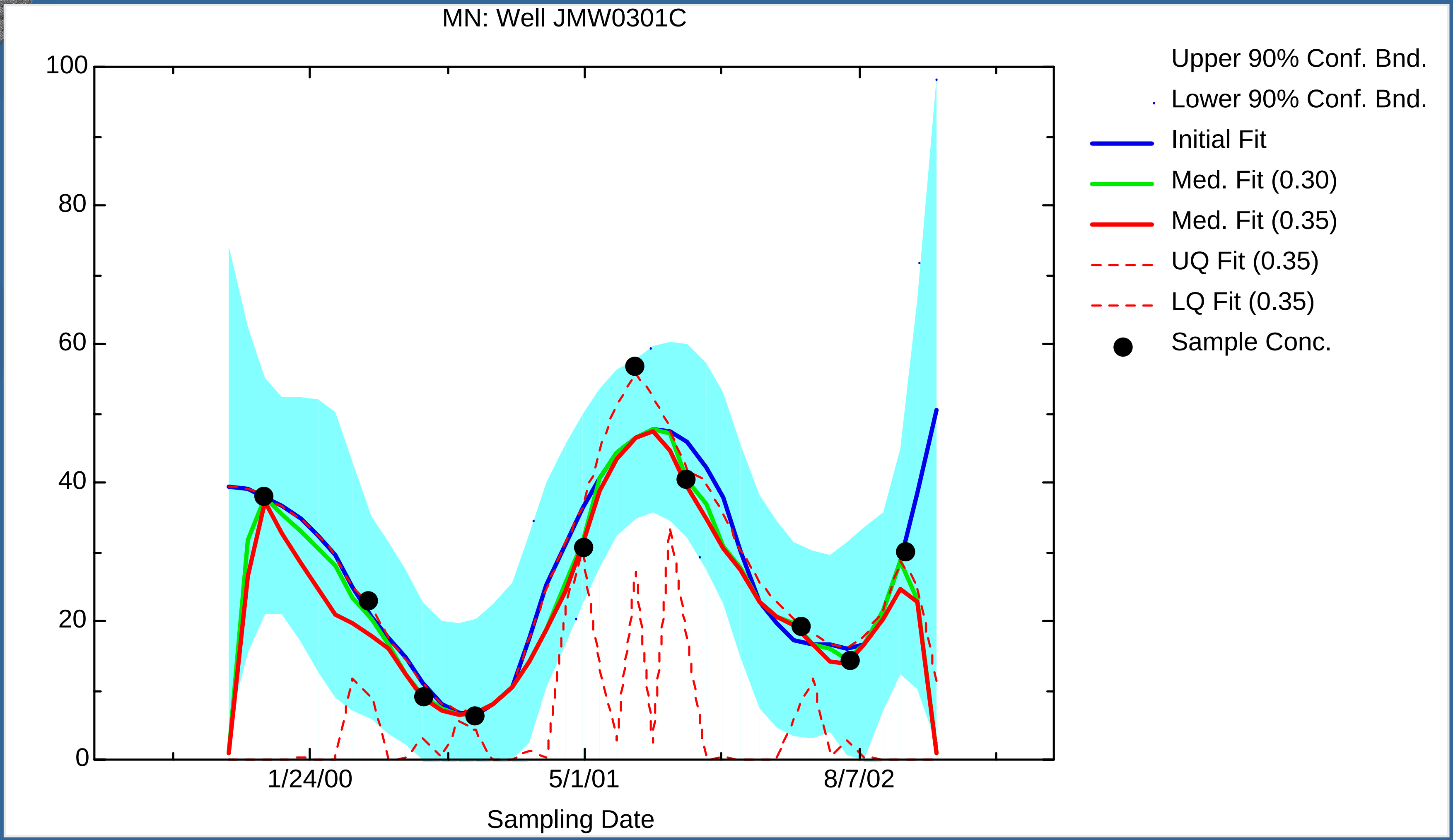
Iterative Thinning

- Adjust individual well sampling frequencies
  - Global sill might not be evident
  - All wells may not behave the same way
  - Operational target interval = median of individual well sampling intervals
- Iterative thinning approach: overview
  - Estimate baseline trend
  - Randomly "weed out" data points
  - Re-estimate trend

Iterative Thinning Advantages

- Complex trends, seasonal patterns OK
  - LWQR fits non-linear trends
- Each well optimized uniquely
  - Not dependent on average correlation like temporal variogram

Iterative Thinning: Loring AFB



Spatial Optimization

- Spatial redundancy
  - Too many wells in network?
- Spatial analysis
  - Use LWQR to estimate typical contribution from each well to plume maps (global regression wgts)
- Wells tagged for removal if their contributions are essentially duplicated by nearby wells
  - Redundant wells have low regression wgts

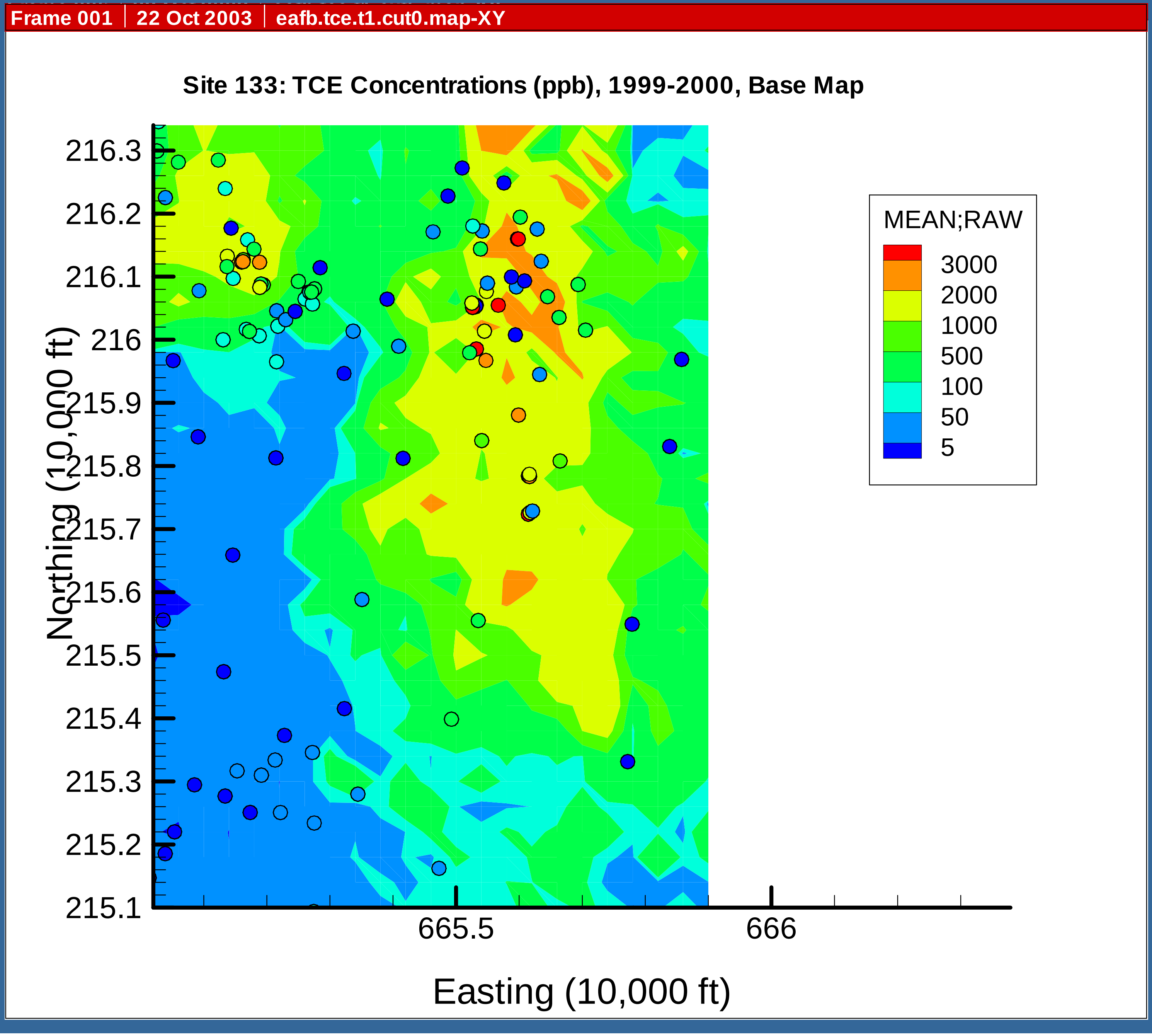
Basic Approach

- Create basemap using all available data
- Iteratively remove lowest contributing wells; re-estimate map
- Measure loss of map quality/accuracy compared to baseline
  - Stop when maps deteriorate too much

Features of Spatial Algorithm

- Advantages to LWQR approach
  - A priori spatial model not required
  - Smoother, not an interpolator
- Can build site maps either in:
  - 3-D space
  - Separately by depth horizon or geologic unit
  - Separately by regulatory or geographic unit
    - As long as enough data available per unit

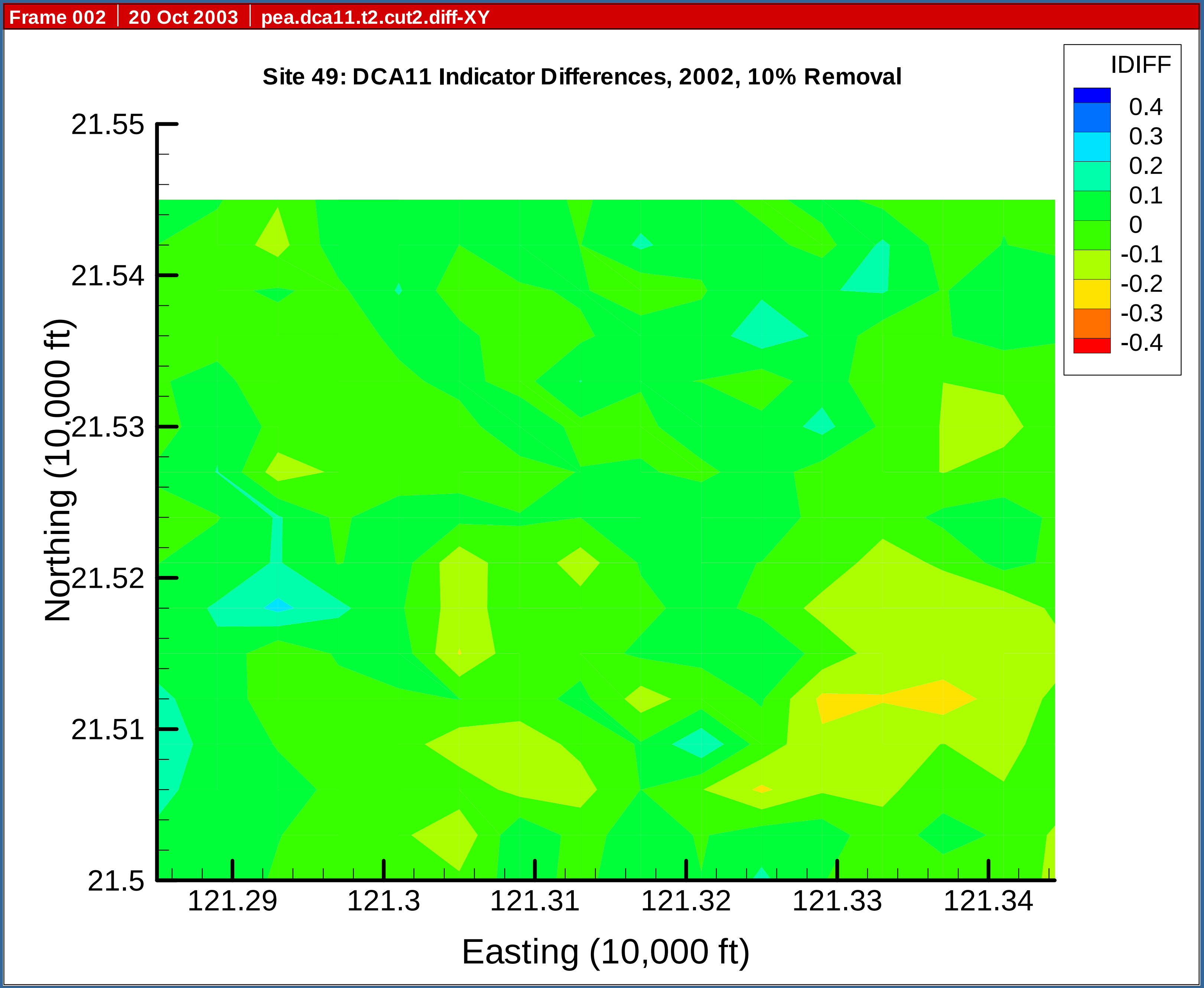
Edwards AFB: Base Map



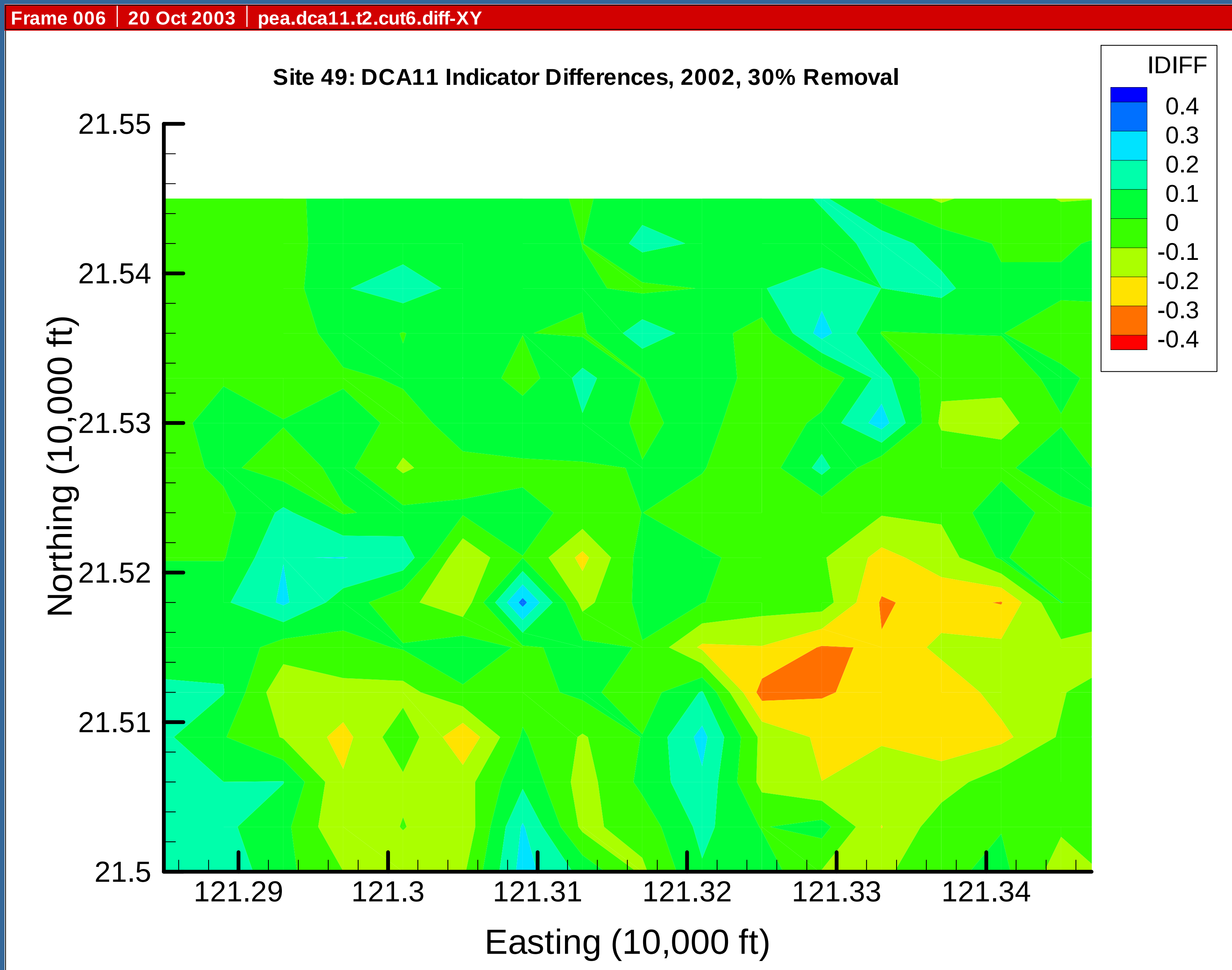
Features (cont.)

- Semi-objective spatial optimization
  - Iterative "removal" of lowest contributing wells/sampling locations
  - At each stage, measure:
    - Differences in site maps from baseline
    - Increases in global uncertainty and average bias
    - Prevalence of areas of high local uncertainty
    - Misclassification bias

Pease AFB: Map Differences



Pease AFB: Map Differences



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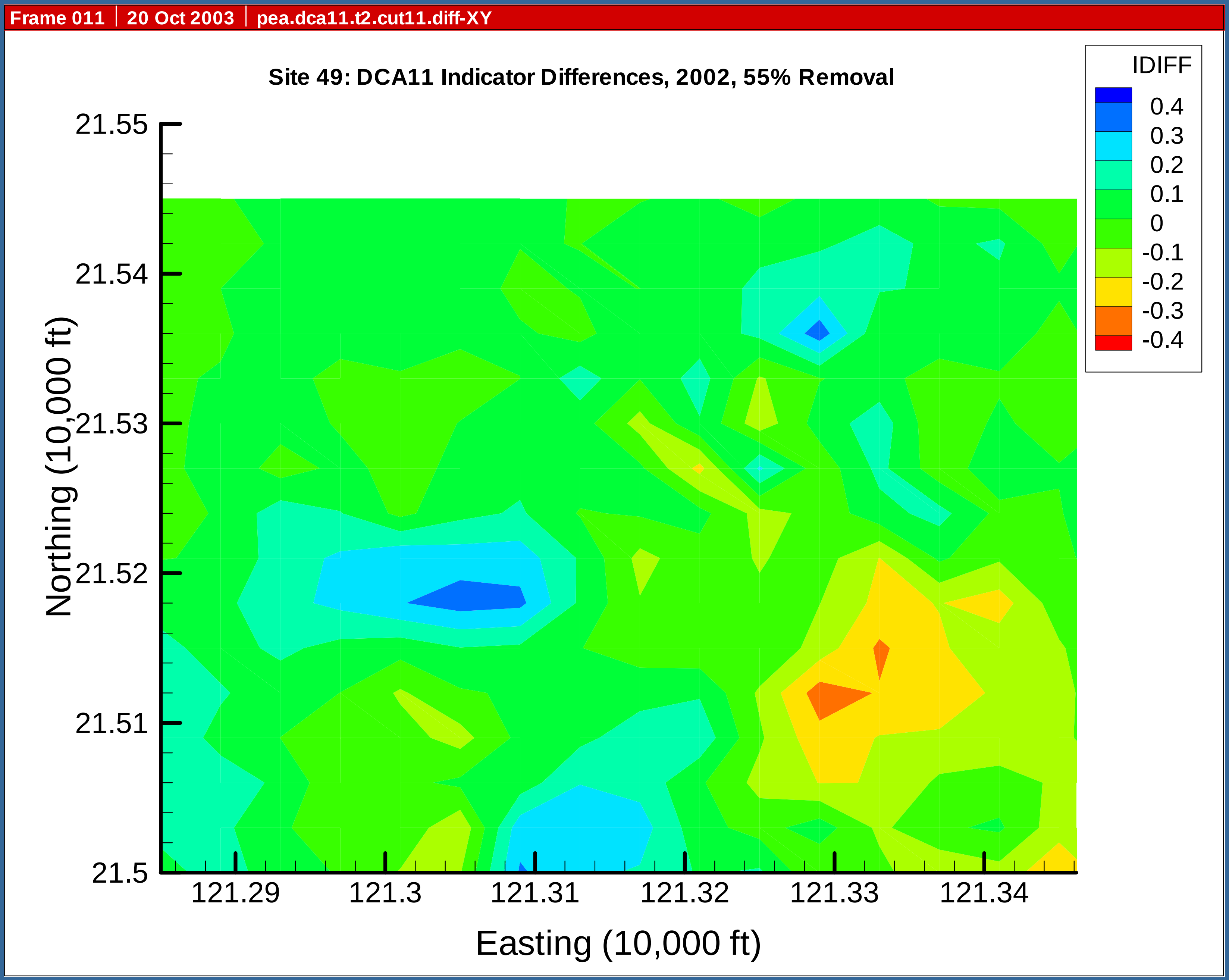
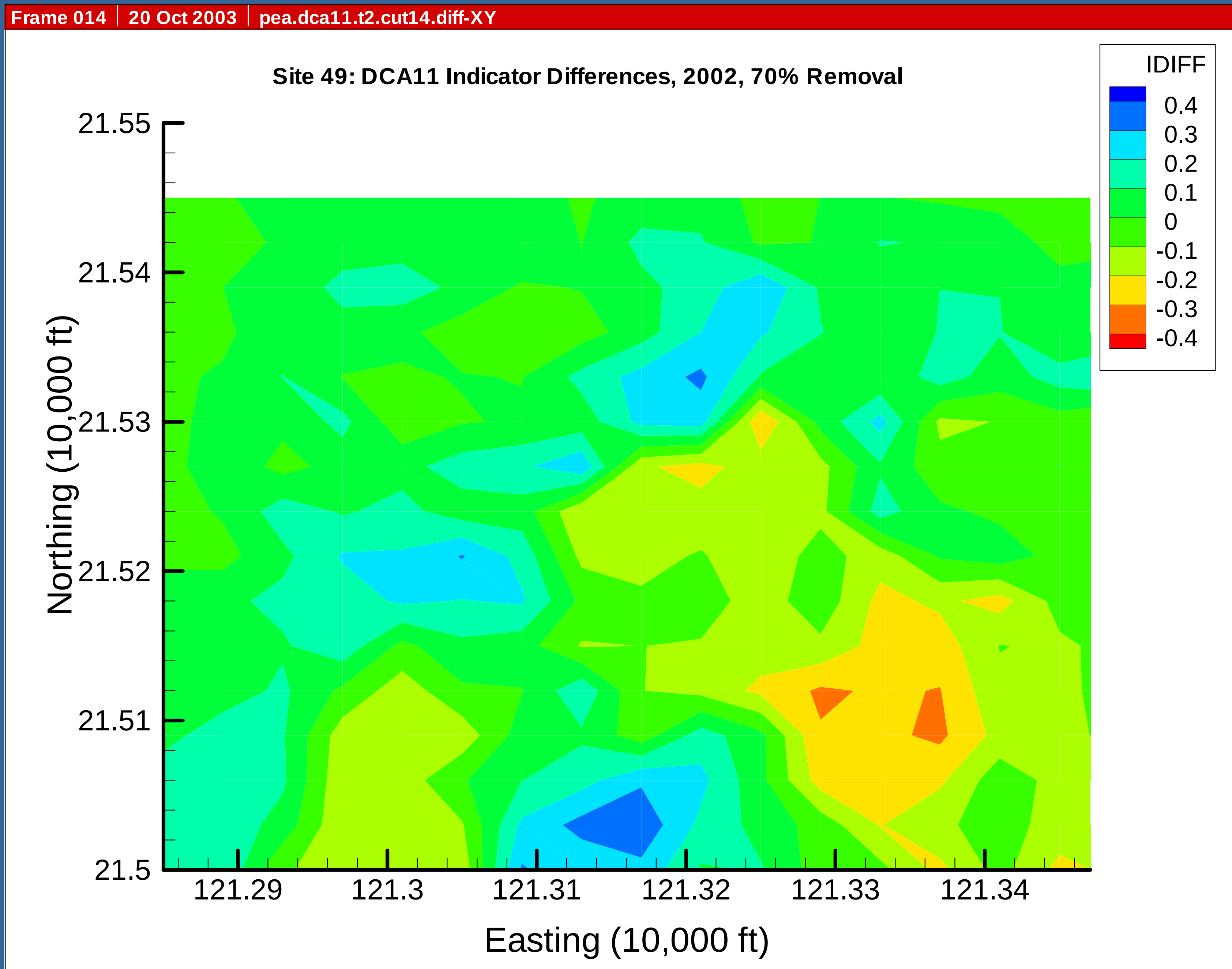


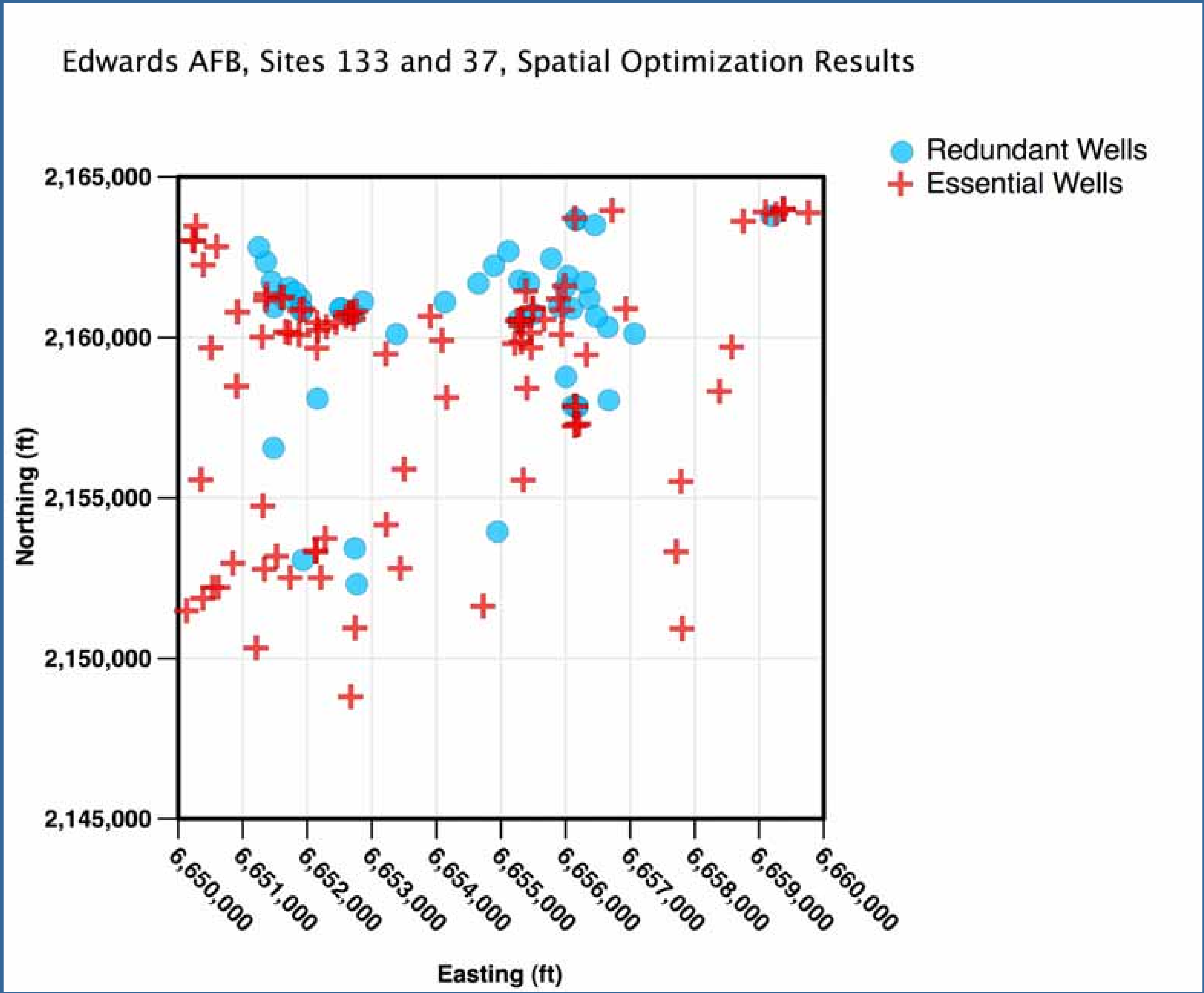
Pease AFB: Map Differences



Case Study Results

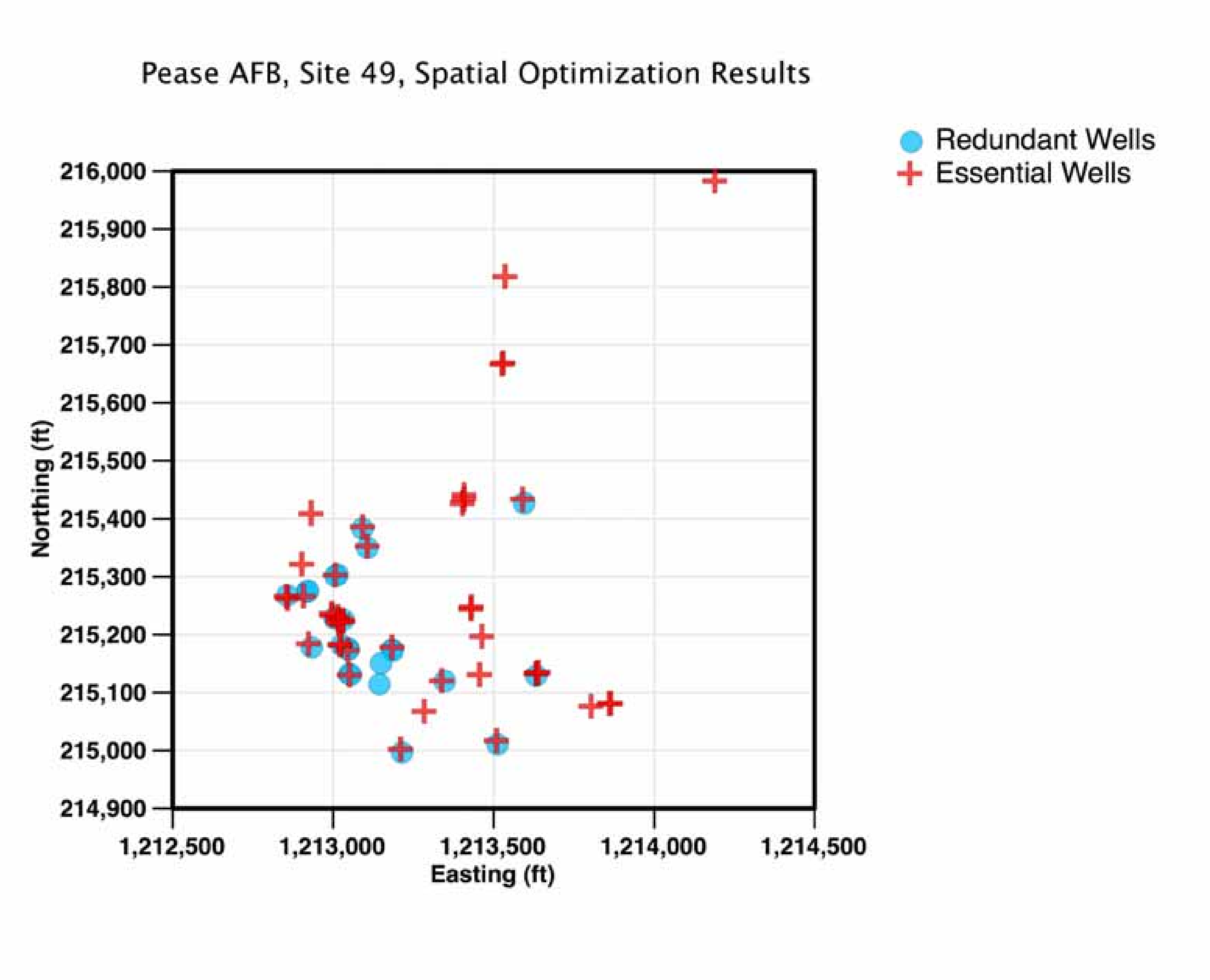
	Edwards	Loring	Pease
Original Interval	Annual	Qtrly	Annual
Optimized Interval	Every 7 Qtrs	Every 2-3 Qtrs	Biennial
Redundant Wells	20-34%	20-30%	10-36%
Cost Reduction	54-62%	33-39%	49-52%
Annual Cost Savings	$230 K-$266 K	$306 K-$358 K	$85 K-$89 K

Edwards: Optimized Wells



Loring: Optimized Wells

Pease: Optimized Wells



Summary

- Novel use of geostatistical & spatial tools
  - Semi-objective optimization process
- "Plug-in" architecture, flexibility
  - Temporal, spatial, or both
- Recommendations can be combined with other optimization, sampling, or monitoring objectives
  - Clarify which wells are vital to monitoring program

Summary (cont.)

- Flexible temporal optimization
  - Iterative thinning for individual wells
  - Temporal variogram for broad selection of sampling locations
  - Edwards AFB
    - Not enough historical data for iterative thinning
    - Temporal variogram reduced sampling from annually to once every 7 quarters
  - Loring AFB
    - Both iterative thinning and temporal variograms suggested once every 2-3 quarters

Summary (cont.)

- Emphasis on visual/graphical output
  - Graphs of temporal variograms
  - Site maps of concentration levels
  - Maps of local uncertainty
  - Plots of redundant and essential sampling locations
- Substantial cost savings