A Case Study on Well Location Optimization with MAROS Software for Remedial Investigation

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Overview

Background

- Site Condition, Groundwater Sampling during RI

Objective

- Technical objective of groundwater sampling
- Optimization objective

Manual Sampling Location Selection

- Selection Criteria

MAROS Sampling Location Optimization

- Algorithm, application, results comparison

Summary

Background

OU-10 at Redstone Arsenal (Huntsville, AL)

- Spans 1980 acres, encompasses 14 CERCLA sites

Geology and Groundwater (GW) Flow

- Overburden and upper bedrock are highly karstic and intimately interconnected
- Discrete solutionally enlarged bedding-plane partings in deep bedrock
- All intervals are interconnected to some degree, upward hydraulic gradients prevail

COCs

- VOCs (primarily TCE)
- Perchlorate
- Multiple sources

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GW Sampling During Remedial Investigation

	Dates	VOCs	perchlorate
		Wells (Springs)	Wells (Springs)
Phase I	Dec. 1999 – May 2000	153	–
	Jun. – Aug. 2000	56	38
	Dec. 2000 – Mar 2001	–	45
Phase II	May – Jul. 2001	146	146
	Mar. – Jun. 2003	186	186
	"Event 3" Oct. 2003	**TBD**	**TBD**

Event 3 GW Sampling Technical Objectives

Characterize geochemistry, VOCs and perchlorate vertically

- 58 wells in deep bedrock or collocated wells

Collect second data set for VOCs and perchlorate

- 40 new wells

Quarterly sampling for VOC and perchlorate

- 46 treatability study wells

Update delineation of VOC and Perchlorate plumes

- **133 potential sampling locations (shallow)**
  Need: Sampling Location Optimization

Event 3 GW Sampling Optimization

Objectives:

- Minimize number of sampling locations (cost, schedule)
- Maximize info gain on technical objective (plume delineation)

Constraint (soft):

- Budget for GW sampling/analysis
- Number of locations can be increased, if warranted by plume conditions

Approach:

- Manual Sampling Location Selection
- MAROS Sampling Location Optimization

Manual Sampling Location Selection

Criteria

For: (1) Plume edge

(horizontal & vertical extent)

(2) Collocated wells

(vertical extent)

(3) Stand-alone wells

(influence large area)

(4) Preferential flow paths

(concentration change)

(5) Off-site wells (risk assessment)

(6) Concentration (high variability or trend)

(7) Historical data(Insufficient or outdated)

Manual Sampling Location Selection

Criteria

Against: (1) Hot spots (sufficient data, little change)

(2) Upgradient

(sufficient data, little change)

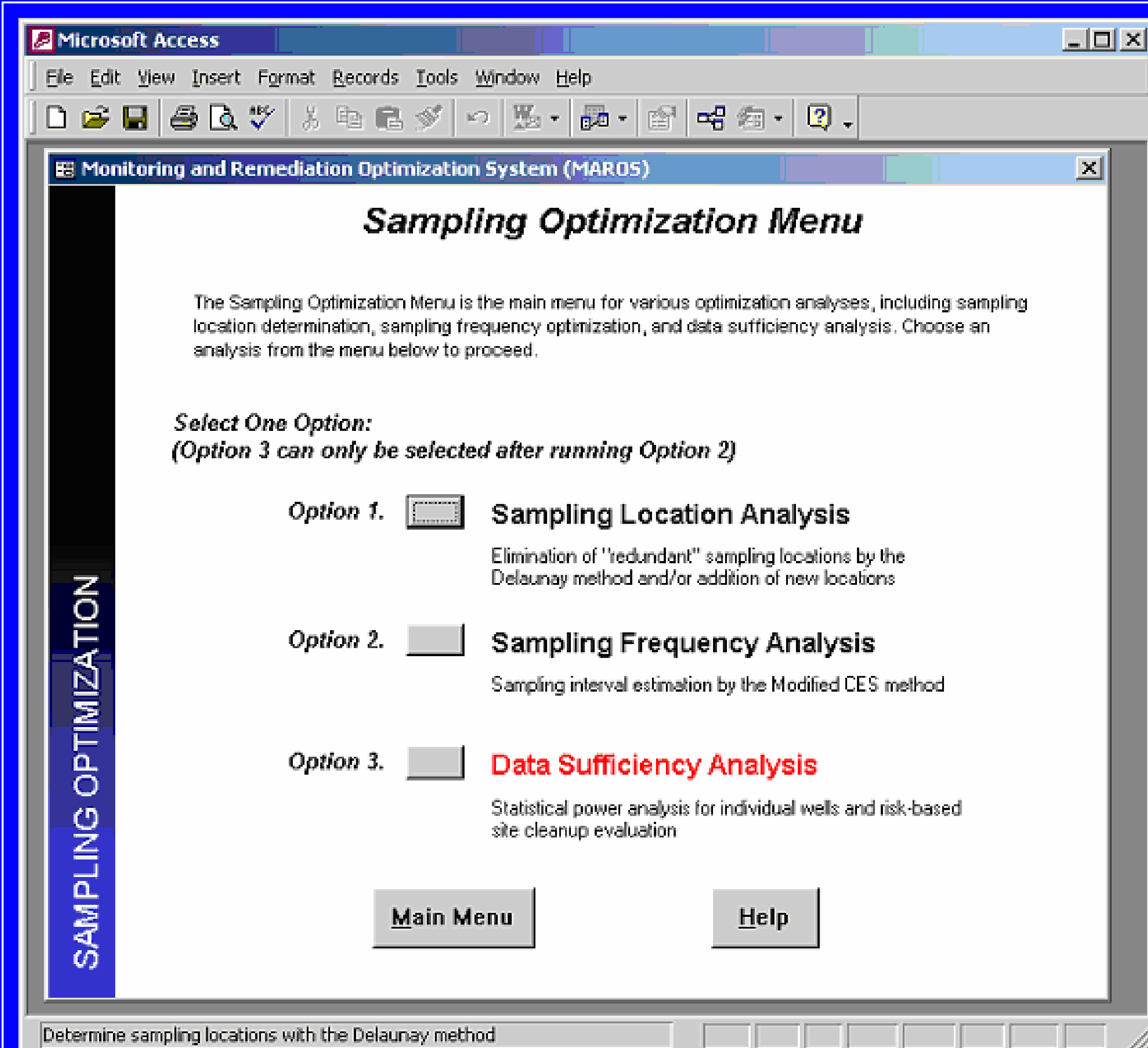
(3) Wells nearby (redundant)

(4) Little concentration variation

Result

70 well eliminated out of 133 potential wells.

MAROS Sampling Location Optimization



MAROS Sampling Location Optimization

Delauney method for eliminating redundant wells

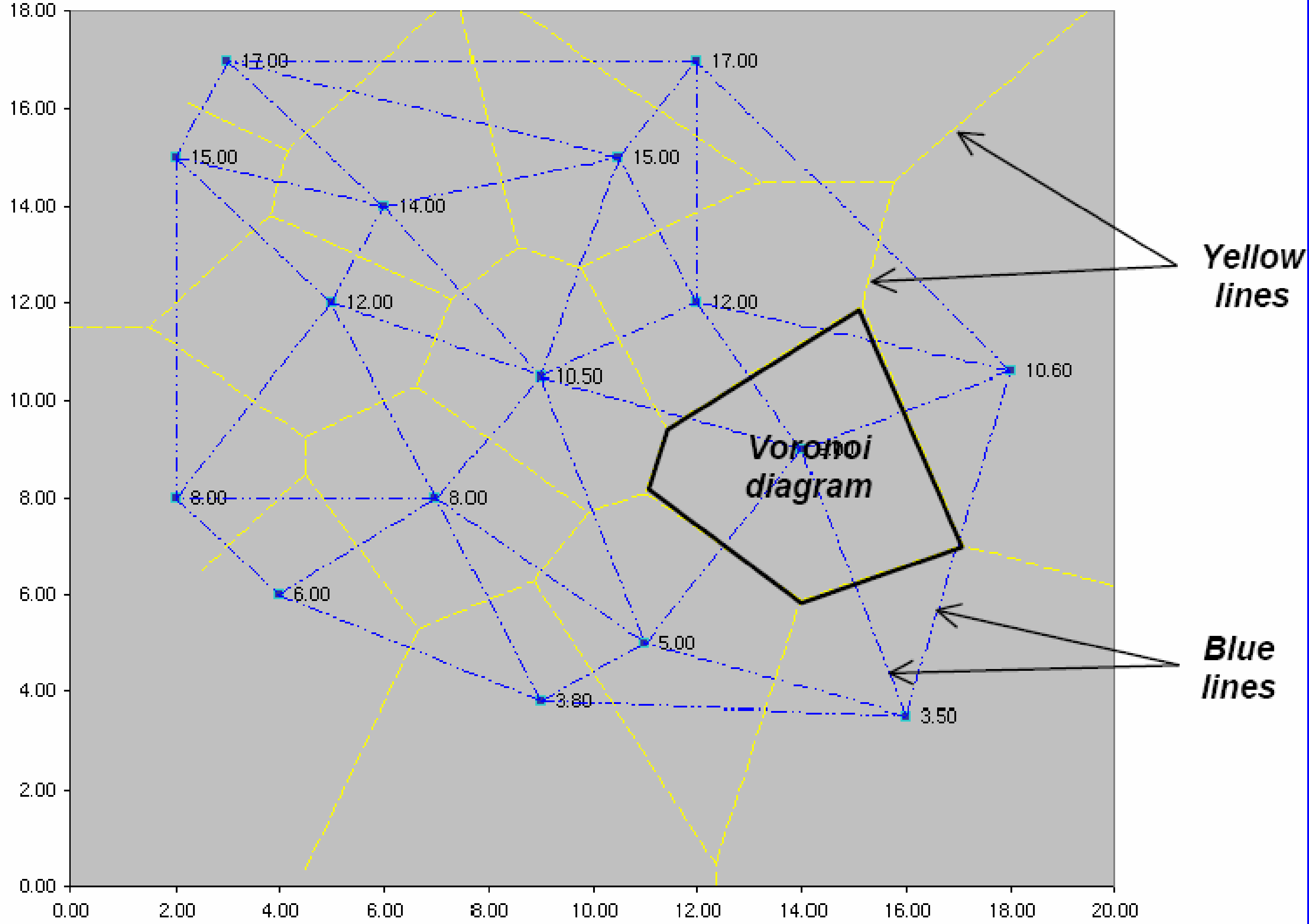


Figure A.2.1 Illustration of the Delaunay Triangulation

MAROS Sampling Location Optimization

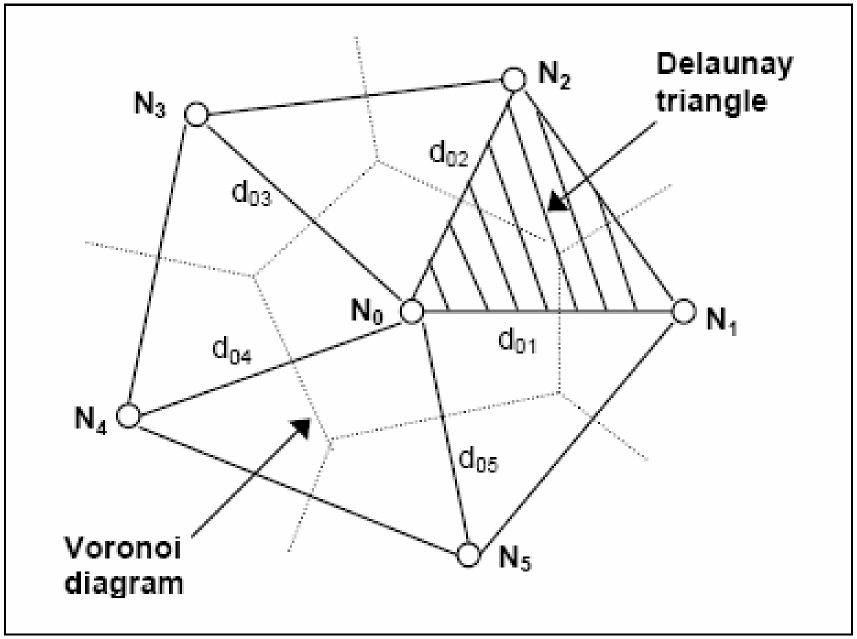


Figure A.2.2 Illustration of Natural Neighbors

Estimated Logarithmic Concentration: Inverse distance weighted average of natural neighbors

Parameters

(1) Selected? / Removable?

(2) Slope Factor (0~1)

$$SF = \left| \frac{\text{Est. Log(C)} - \text{Meas. Log(C)}}{\text{Max(Est. Log(C), Meas. Log(C))}} \right|$$

SF->0, convey little info, candidate for elimination

(3) Area Ratio

$$AR = \frac{\text{Area (after elimination)}}{\text{Area (original)}}$$

AR->1, limited info loss

(4) Concentration Ratio

$$CR = \frac{\text{C(average, current)}}{\text{C(average, original)}}$$

CR->1, limited info Loss

MAROS Sampling Location Optimization

Default parameter thresholds

- Candidates of wells to be eliminated:

  Inside-node SF < 0.1

  Hull-node SF < 0.01
- Termination of optimization when:

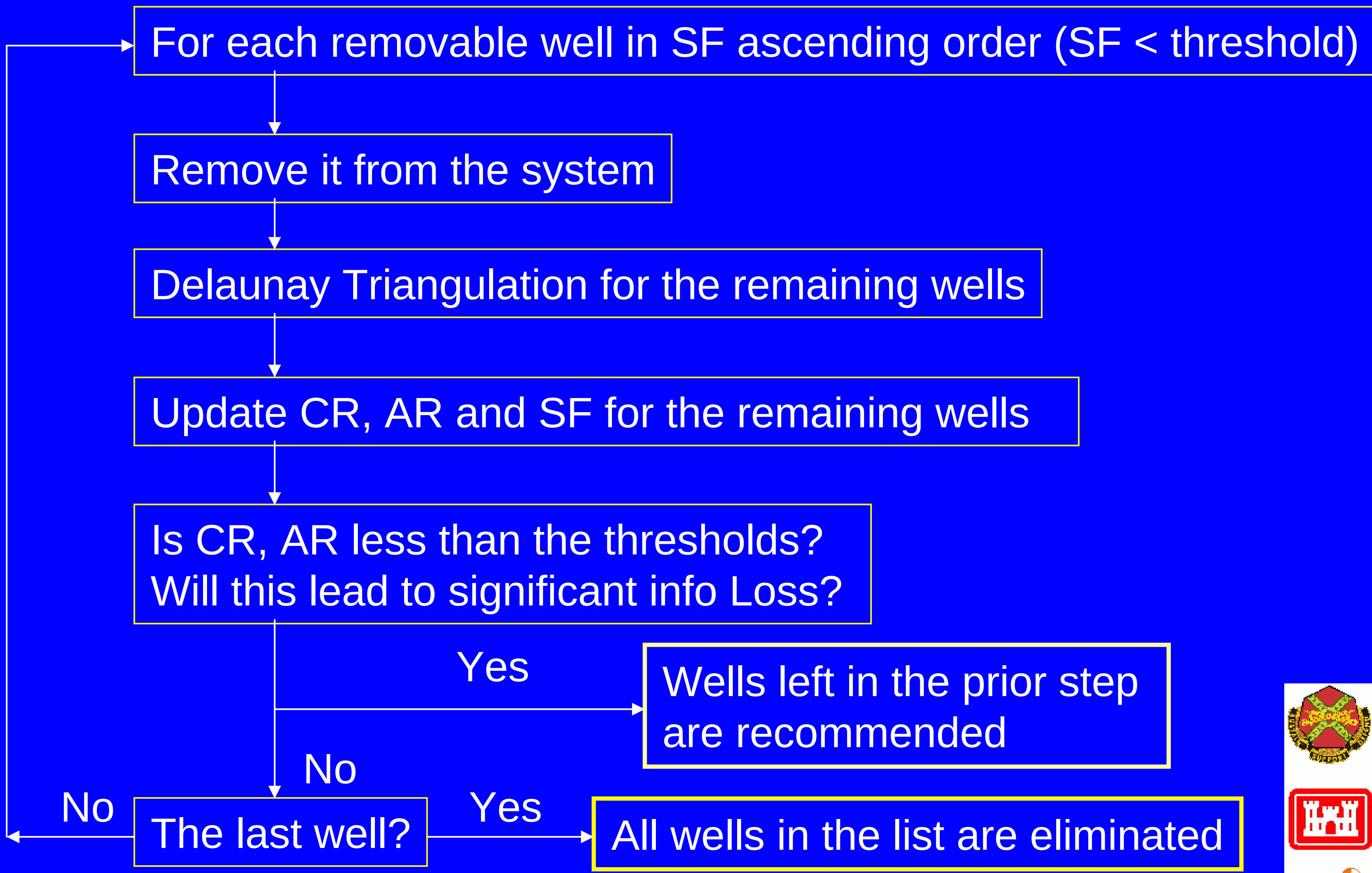
  AR < 0.95

  CR < 0.95

Can deal with multiple COCs and sampling events

- Conduct well elimination for each COC; report eliminated wells for each COC and all COCs.
- Use sampling-event averaged parameters SF, CR, AR in the optimization loop.

MAROS Sampling Location Optimization



MAROS Sampling Location Optimization

Application to OU-10 Event-3 groundwater sampling

- Data from previous two sampling events
- Mix data from different depths of shallow zone
- All shallow zone data “selected” for analysis
- Set predetermined wells (collocated to deep, new, treatability study) to be “irremovable” (left with 133 removable)
- COCs: TCE and perchlorate

Trial-and-error process to achieve a reasonable solution

- Number of wells to eliminate
- Adjust threshold values of SF, AR, and CR
- Make additional elimination-candidates “Irremovable” to avoid termination of program

MAROS Sampling Location Optimization

Reasonable solution:

	TCE	perchlorate
Inside-node SF Threshold	0.3	0.3
Hull-node SF Threshold	0.01	0.01
Area Ratio Threshold	0.95	0.95
Concentration Ratio Threshold	0.9	0.8
RESULT	**59**	**58**
Well Eliminated	**34**	

Five elimination-candidates were designated “irremovable” to avoid termination of optimization.

MAROS Sampling Location Optimization

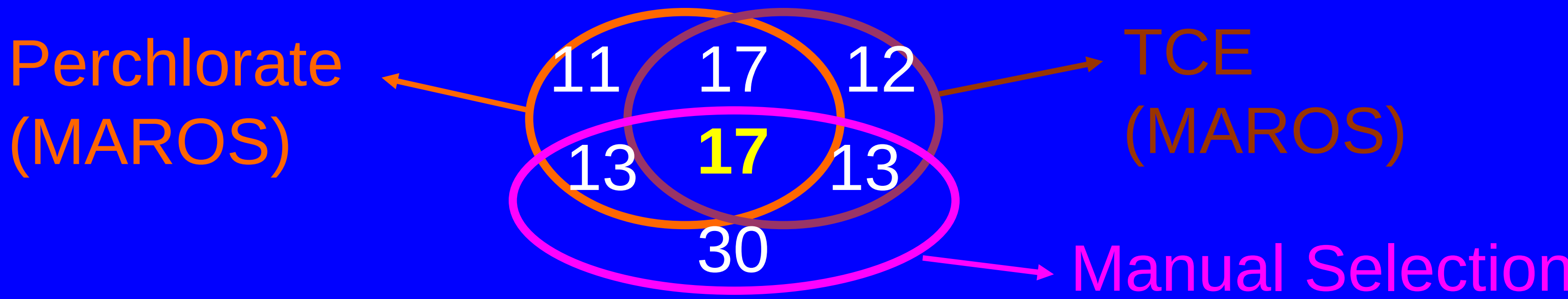
Lessons Learned during Trial-and-Error

- Set hull-node SF threshold low
- Initial SF calculation can indicate whether the ideal number of wells to eliminate can be achieved
- Making certain elimination candidate irremovable can increase the number of wells eliminated

Manual and MAROS Results Comparison

Similarities

- Locations of eliminated wells



17 common locations from 34 MAROS and 70 Manual-selection eliminated locations

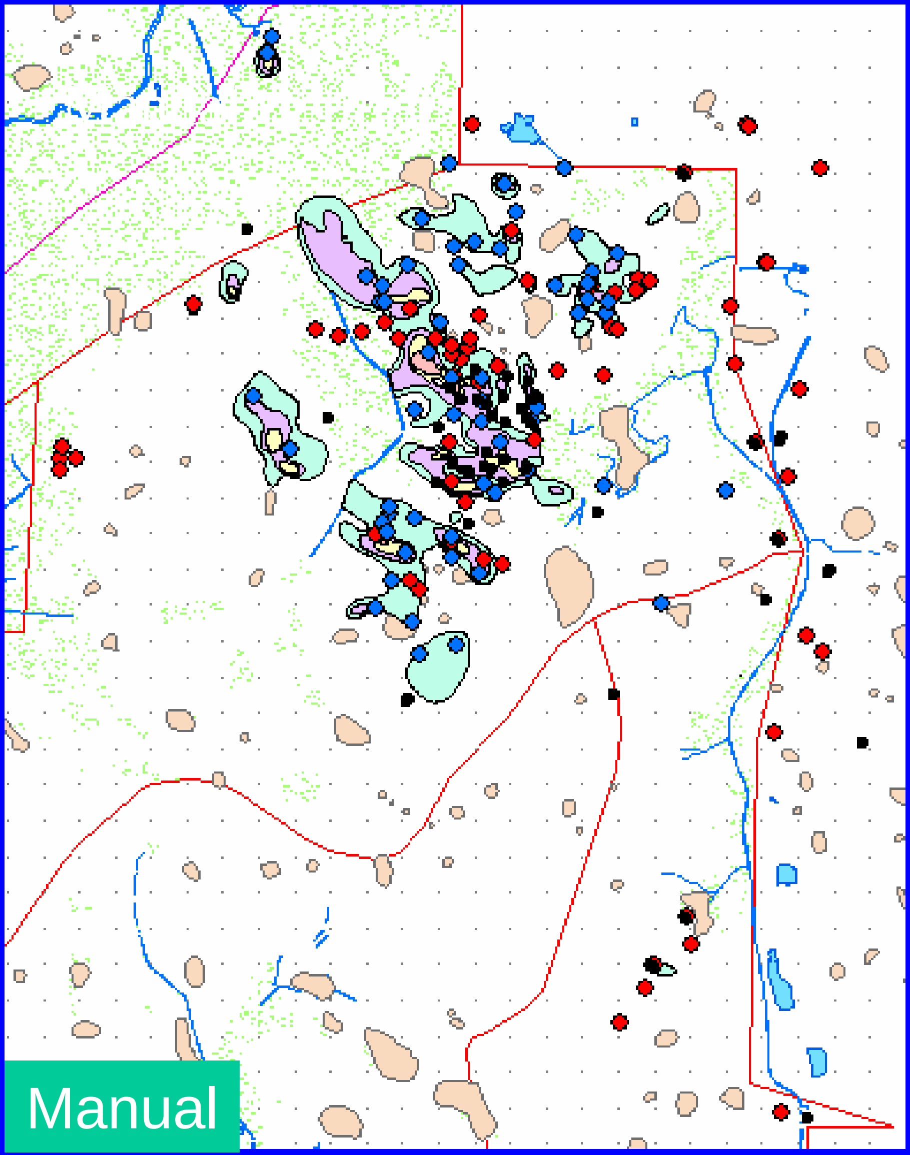
- MAROS facilitates most Manual selection criteria

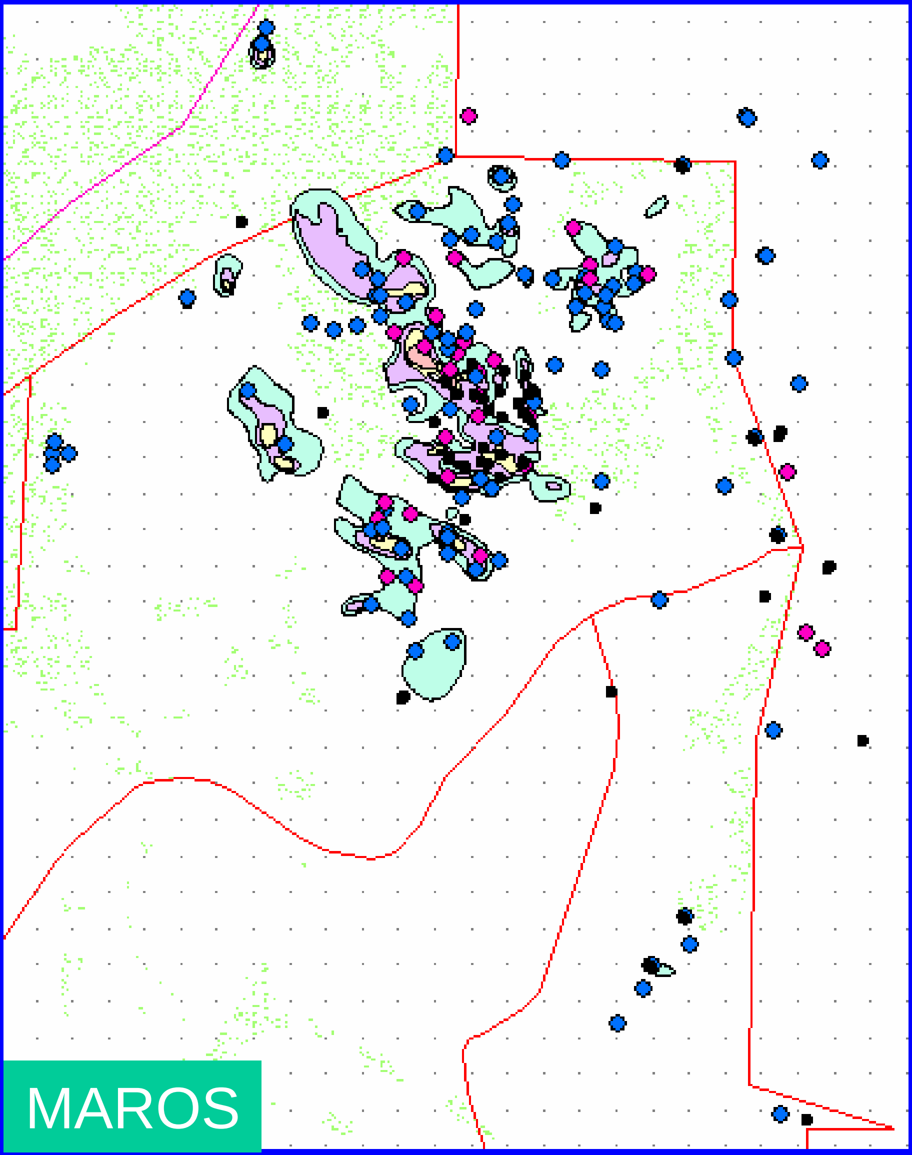
Manual and MAROS Results Comparison

Differences

- Less wells reduced by MAROS (34 versus 70)
- MAROS protects periphery wells
- MAROS reduces slightly less wells near source
- Manual selection gives subjective evaluation of historical data (small scope, nonconcurring)
- Manual selection considers vertical extent of plume

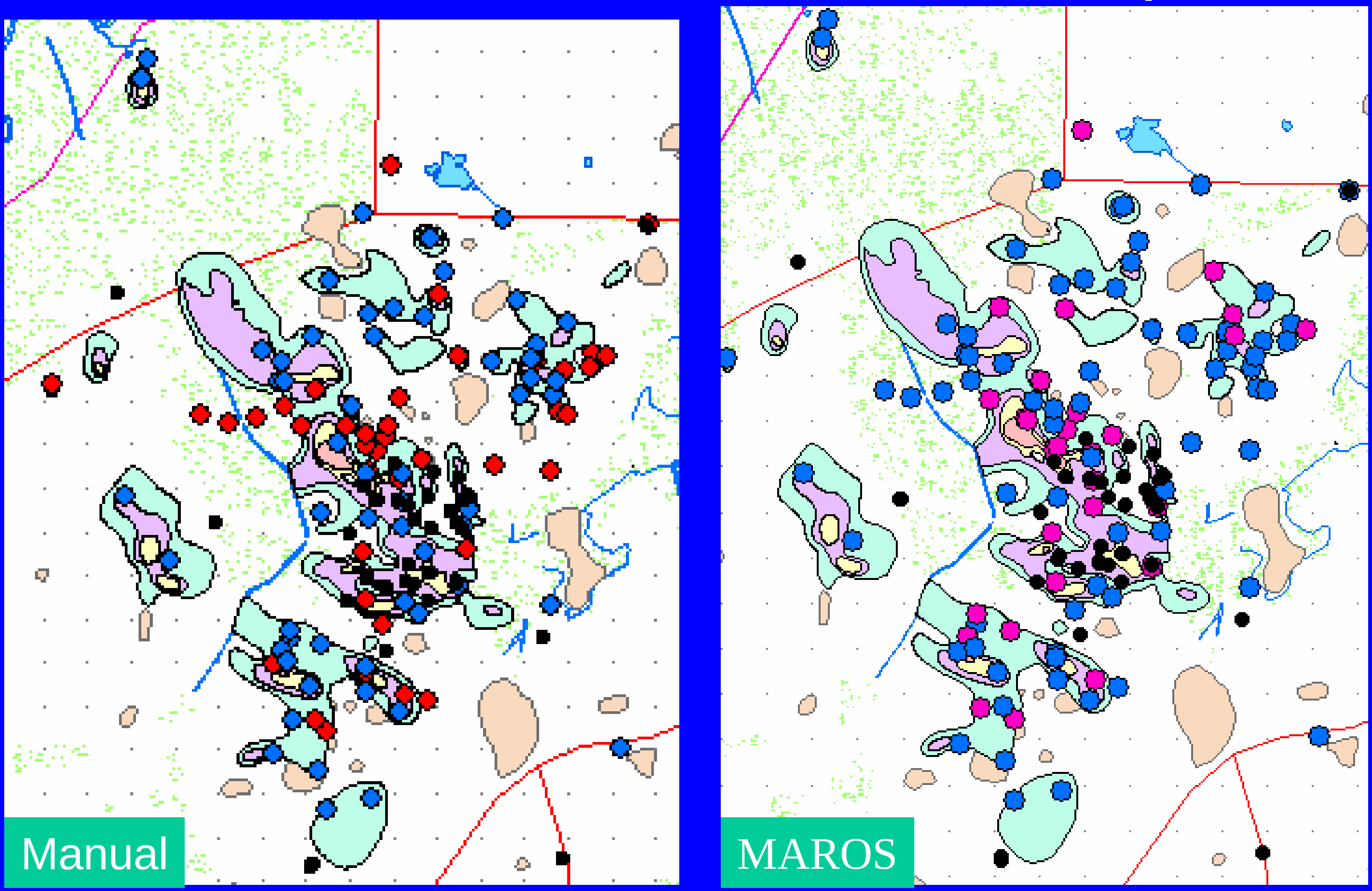
Manual and MAROS Results Comparison





Perchlorate Sampling (Red: wells eliminated; Blue: wells selected)

Manual and MAROS Results Comparison



Perchlorate Sampling (Red: wells eliminated; Blue: wells selected)

Summary

MAROS can be a cost–effective starting point for optimizing a sampling network if sufficient data exist in remedial investigation.

MAROS achieves most of the manual location-selection goals (criteria), but has difficulty:

- incorporating inconsistent/scope-limited data sets
- evaluating vertical extent of plume within a hydraulic unit
- identifying outdated data