Monitoring and Remediation Optimization System Software 3.0

AFCEE MAROS 3.0 New Release

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Monitoring Optimization

Overview: *MAROS 3.0 New Release*

- Goals and Objectives
- Software Structure and New Features

QUESTIONS?

- Detailed Descriptions
- Wrap Up

2

Monitoring Optimization

MAROS – the origin

How can we get more meaning from the data we collect?

3

Monitoring Optimization

MAROS – the origin

What makes a good data collection network?

4

Monitoring Optimization

MAROS – the origin

- *Good Networks*
  - Meets goals
  - Not too much, not too little
  - Reveal what has happened
  - Help 'prepare for' what will happen

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Monitoring Optimization

Method: *Good Networks*

- *What are we looking for?*
  - Variability vs. Consistency
  - Increasing / Decreasing vs. Stable
  - Expected vs. 'Interesting'
  - Moving vs. Stationary
  - Where is most of the mass?

RATE

SCALE

VARIABILITY

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Monitoring Optimization

Goals: *MAROS 1998 -2003*

- Reduce monitoring effort
  - ► Demonstrate Plume Stability
  - ► Reduce Long-Term O&M Costs
  - ► Reduce Number of Wells
  - ► Reduce Sampling Frequency
- ***Make Recommendations for improving network – for long-term O&M***

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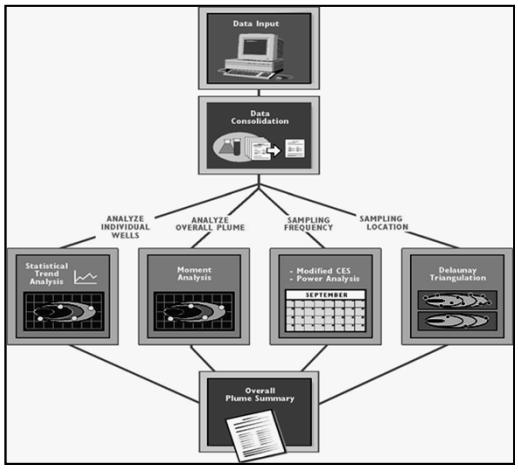
Monitoring Optimization

MAROS – 2.X

- Concentration Trends
- Total mass and distribution
- Spatial uncertainty
- Sampling frequency



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Monitoring Optimization

Goals: *MAROS 2009-2012*

- **Improve analysis of existing data**
  - ► **Demonstrate Remedial Performance**
  - ► **'Best Choice' wells and frequency**
  - ► **Support Cessation of Active Remedies**
  - ► **Support Exit Strategies**
- ***Make Recommendations for improving network – to attain closure***

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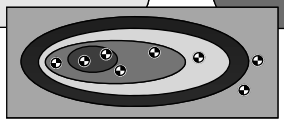
Monitoring Optimization

MAROS 2.2 → MAROS 3.0

- **Limited Individual Well Statistics**
- **Limited spatial analysis options**
- **Limited User choice and interactivity**
- **Usability issues**
- **Limited data export options**

- ***Expanded Individual Well Statistics***
- ***Improved spatial analysis***
- ***More User choice and comparison options for spatial analysis***
- ***Improve Usability***
- ***More export opportunities and options***



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Monitoring Optimization

Overview: *MAROS 3.0 New Release*

- **Goals and Objectives**
- **Software Structure and New Features**

QUESTIONS

- **Detailed Description**
- **Conclusions**

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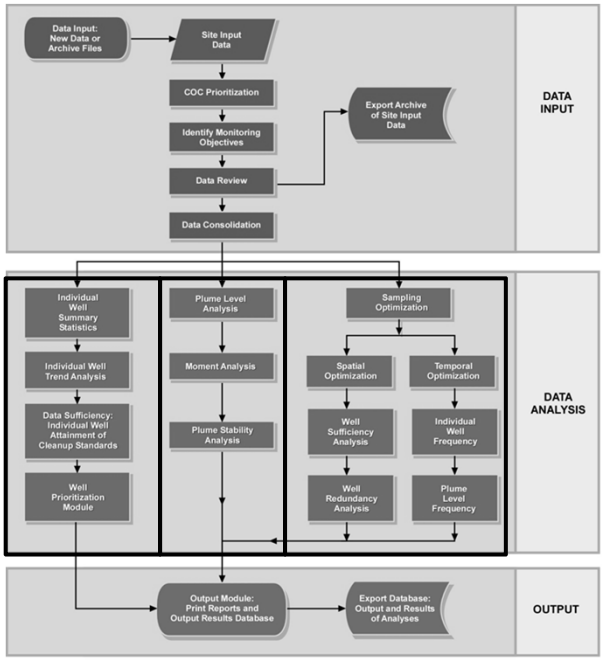
Data Input

Individual Well Analysis

Plume-Level Analysis

Spatial and Temporal Optimization

Data Export



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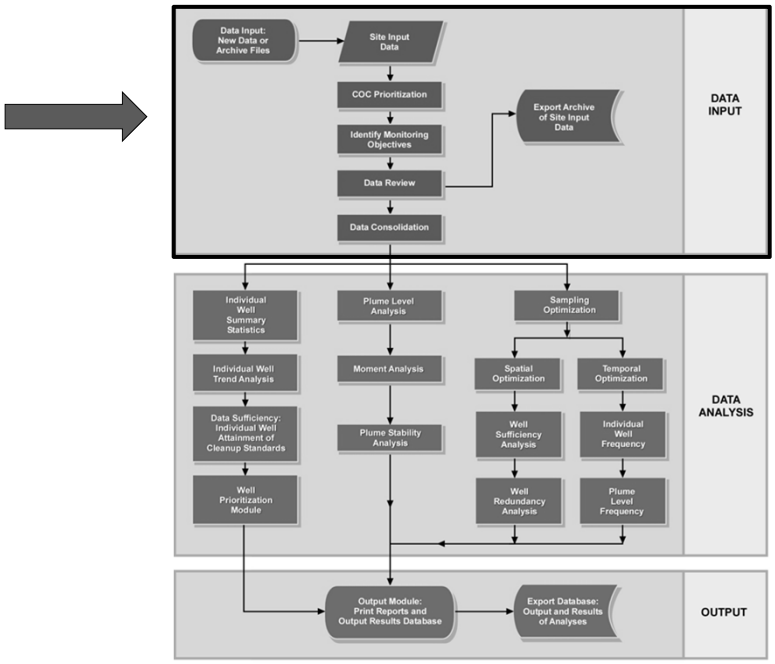

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Column Number	Field Name	Data Type	Description
Initial Input Data			
1	WellName	Text	Name of the groundwater well sampled, all well names should be spelled consistently. *(Required)*
2	XCoord	Number (Double) in Feet	X coordinate or Easting coordinate of the well, although not mandatory for statistical analysis, it is required for spatial analysis purposes. *(Required)*
3	YCoord	Number (Double) in Feet	Y coordinate or Easting coordinate of the well, although not mandatory for statistical analysis, it is required for spatial analysis purposes. *(Required)*
4	Constituent	Text	Constituent of Concern – the User has the option of using the MAROS Constituent Name ***or*** the ERPIMS Code for constituent names. *(Required)*
4	CODE	Text	Constituent of Concern – ERPIMS codes and MAROS Constituent names can be found in the MAROS_ConstituentName_List.xlsx. *(Required)*
5	Sample Date	Short Date	Date Sample was collected: format mm/dd/yyyy. *(Required)* ***NOTE: No Hours: Minute Time Codes.***
6	Result	Number (Double)	Analytical result: enter result as a number, if value is below detection limit (non-detect) then leave the cell blank (null value). *(Required)*
7	Units	Text	Measurement units for result: choices mg/L; ug/L; ng/L; g/L; pg/L. (no Greek symbols) *(Required)*
8	DetLim	Number (Double)	Reporting Limit (detection limit) – units must be the same as the Result field. *(Required)*
9	Flags	Text	Flag "ND" for non-detect (must enter the detection limit in the DetLim field), or "TR" for trace amount (must enter both detection limit and the result). If result is not qualified, the cell should be blank. No other flags should be included in this field. *(Required)*

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Monitoring Optimization

Software: *Data Input*

- **Site Details- Data checker *NEW!***
  - ***MAROS 2.2***
- **Monitoring Objectives- *NEW!***
  - ***Primary – Source, Tail, Delineation***
  - ***Secondary - Sources, Remedy, Delineation***
- **Priority COCs**
  - ***Cleanup Goals***
  - ***Priority by Well – NEW!***

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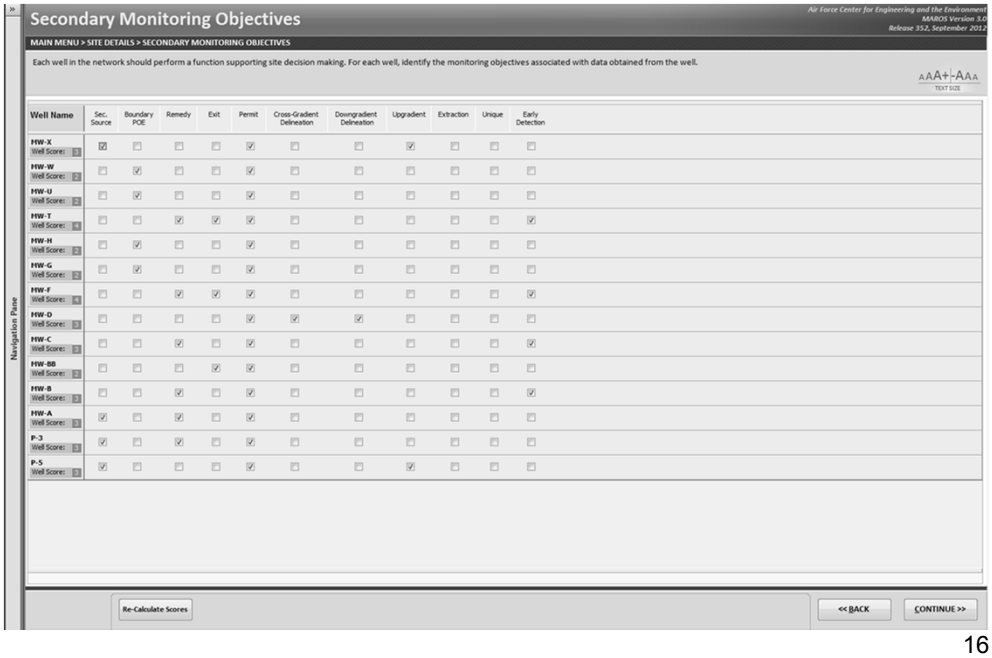

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MAROS COC Assessment

Project: MAROS Tutorial — User Name: John Smith

Location: Bubba's — State: Texas

Toxicity:

Contaminant of Concern	Representative Concentration (mg/L)	PRG (mg/L)	Percent Above PRG
BENZENE	4.2E-01	5.0E-03	8385.0%
PERCHLORATE	1.1E-01	1.7E-02	535.3%
BARIUM	3.2E+00	2.0E+00	58.5%
TOLUENE	1.3E+00	1.0E+00	29.5%
COPPER	1.6E+00	1.3E+00	22.8%

Note: Top COCs by toxicity were determined by examining a representative concentration for each compound over the entire site. The compound representative concentrations are then compared with the chosen PRG for that compound, with the percentage exceedance from the PRG determining the compound's toxicity. All compounds above exceed the PRG.

Prevalence:

Contaminant of Concern	Class	Total Wells	Total Exceedance	Percent Exceedances	Total Detects
BENZENE	ORG	14	10	71.4%	13
BARIUM	MET	14	8	57.1%	14
PERCHLORATE	INO	14	7	50.0%	12
TOLUENE	ORG	14	5	35.7%	14
COPPER	MET	14	5	35.7%	14

Note: Top COCs by prevalence were determined by examining a representative concentration for each well location at the site. The total exceedances (values above the chosen PRGs) are compared to the total number of wells to determine the prevalence of the compound.

Mobility:

Contaminant of Concern	Kd/Koc
PERCHLORATE	
BENZENE	0.0984
TOLUENE	0.347
BARIUM	11
COPPER	40

Note: Top COCs by mobility were determined by examining each detected compound in the dataset and comparing their mobilities (Koc's for organics, assuming foc = 0.001, and Kd's for metals).

Priority Constituents by Well

MAIN MENU > SITE DETAILS > PRIORITY CONSTITUENTS BY WELL

Priority constituents are determined for each well by dividing either the average or the

Well Name	Priority COC Based on Average Concentration	Priority COC Based on Maximum Concentration
MW-1	BENZENE	BENZENE
MW-11	BENZENE	BENZENE
MW-12	BENZENE	BENZENE
MW-13	BENZENE	BENZENE
MW-14	BENZENE	BENZENE
MW-15	COPPER	TOLUENE
MW-16	BENZENE	BENZENE
MW-2	BENZENE	BENZENE
MW-3	BENZENE	BENZENE
MW-4	BENZENE	BENZENE
MW-5	BENZENE	BENZENE
MW-6	TOLUENE	BARIUM
MW-7	BARIUM	BARIUM
MW-8	TOLUENE	TOLUENE

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Monitoring Optimization

Software: *Data Input*

- **Moment Analysis Options**
  - ► ***Moved to Site Details***
- **Export MAROS 3.0 Archive File**
- **Data Consolidation**
  - ► ***First consolidation for Individual Well Analysis***
  - ► ***Second consolidation under Plume Analysis***

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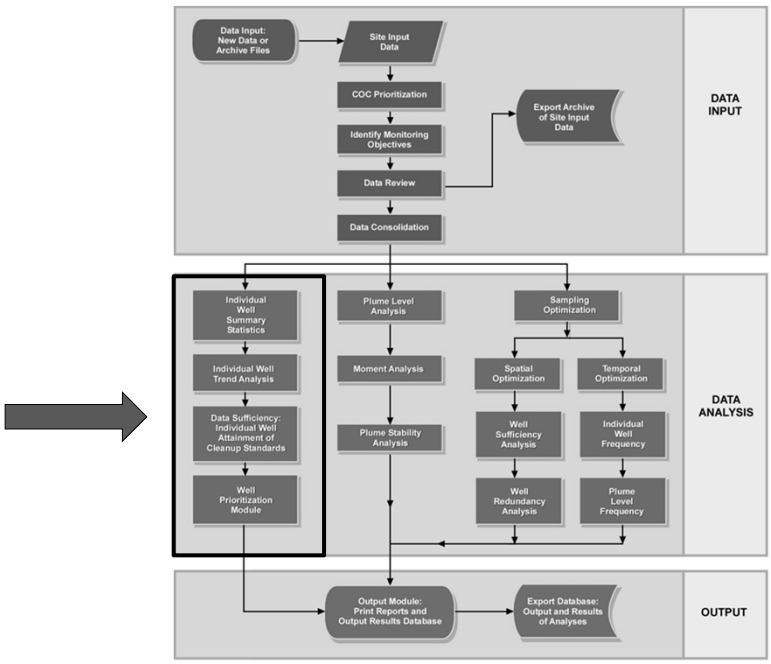

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Monitoring Optimization

Software: *Individual Well Analysis*

- **Summary Statistics – *NEW!***
  - ***Detection Frequencies***
  - ***Kaplan-Meier – Ave., Median, SD.***
  - ***Outliers by Dixon's***
  - ***Shapiro-Wilk Normality***
- **Statistical Trends**
  - ***Mann-Kendall***
  - ***Linear Regression***

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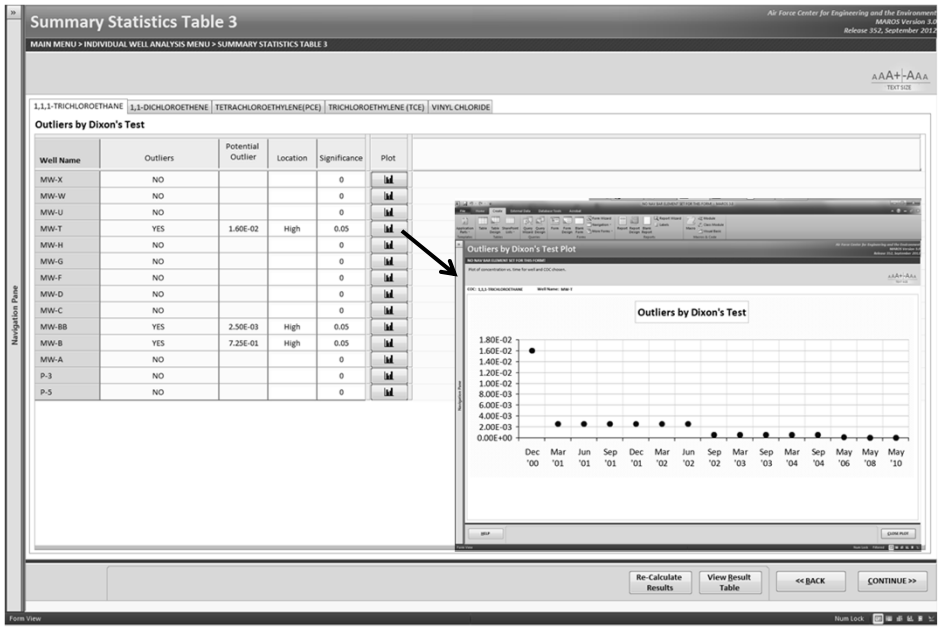

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Monitoring Optimization

Software: *Individual Well Analysis*

- **Data Sufficiency – *NEW Location!***
  - ***Attainment of Cleanup Goals***
  - ***Number of Samples to Attain Goals***
- **Well Scoring – *NEW!***
  - ***Individual Well Summary***
  - ***Well Score – prioritization***

Priority COC	Recent Sample above MCL
Detection frequency	COV
Median above MCL	Distribution
MK Trend	

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Well Priority Decision Logic

Well Name	Source / Tail / Delineation	Monitoring Objective Score	Total Number of Samples	Overall Detection Frequency (%)	Attained Cleanup Goals?	All Samples ND?	Well Score
P-5	S	3	76	91%	NO	NO	52
P-3	S	3	75	100%	NO	NO	66
MW-X	S	3	45	73%	NO	NO	44
MW-W	T	2	54	2%	YES	NO	54
MW-U	T	2	54	4%	YES	NO	56
MW-T	T	4	72	6%	NO	NO	57
MW-H	T	2	34	3%	YES	NO	52
MW-G	T	2	66	0%	YES	YES	45
MW-F	T	4	76	21%	NO	NO	63
MW-D	T	3	70	6%	YES	NO	61
MW-C	T	3	80	27%	NO	NO	58
MW-BB	T	2	45	2%	YES	NO	49
MW-B	T	3	75	79%	NO	NO	70
MW-A	S	3	75	100%	NO	NO	68

Navigation Pane

High score- most important

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Monitoring Optimization

Software: *Individual Well Analysis*

- **Export – *NEW!***
  - ***Screen by Screen - spreadsheet***
  - ***Reports – link on screen***
  - ***Graphs – link on screen***
  - ***Access Database – default export button***

Note: Export Results here- Data consolidation can change under spatial analysis section.

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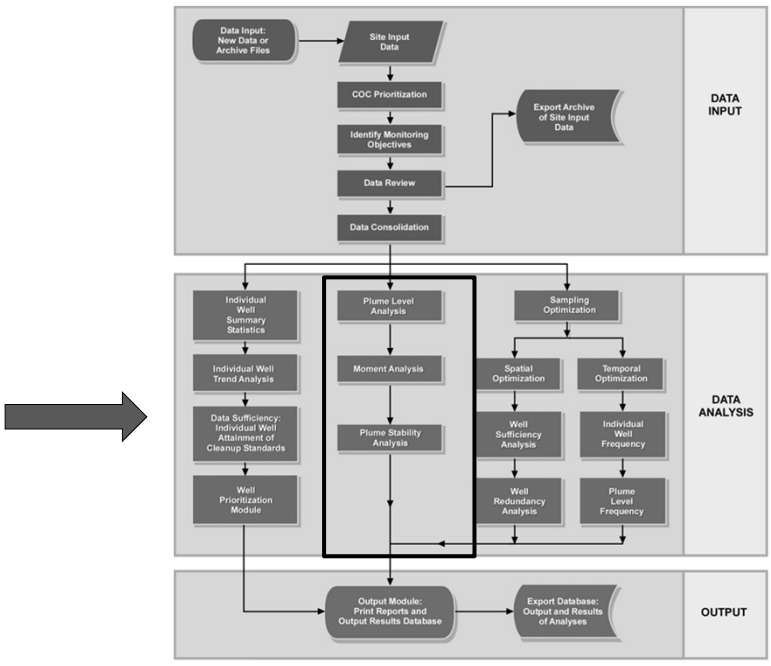
Data Input: New Data or Archive Files
Site Input Data
COC Prioritization
Identify Monitoring Objectives
Data Review
Export Archive of Site Input Data
Data Consolidation
DATA INPUT
Individual Well Summary Statistics
Individual Well Trend Analysis
Data Sufficiency: Individual Well Attainment of Cleanup Standards
Well Prioritization Module
Plume Level Analysis
Moment Analysis
Plume Stability Analysis
Sampling Optimization
Spatial Optimization
Temporal Optimization
Well Sufficiency Analysis
Individual Well Frequency
Well Redundancy Analysis
Plume Level Frequency
DATA ANALYSIS
Output Module: Print Reports and Output Results Database
Export Database: Output and Results of Analyses
OUTPUT

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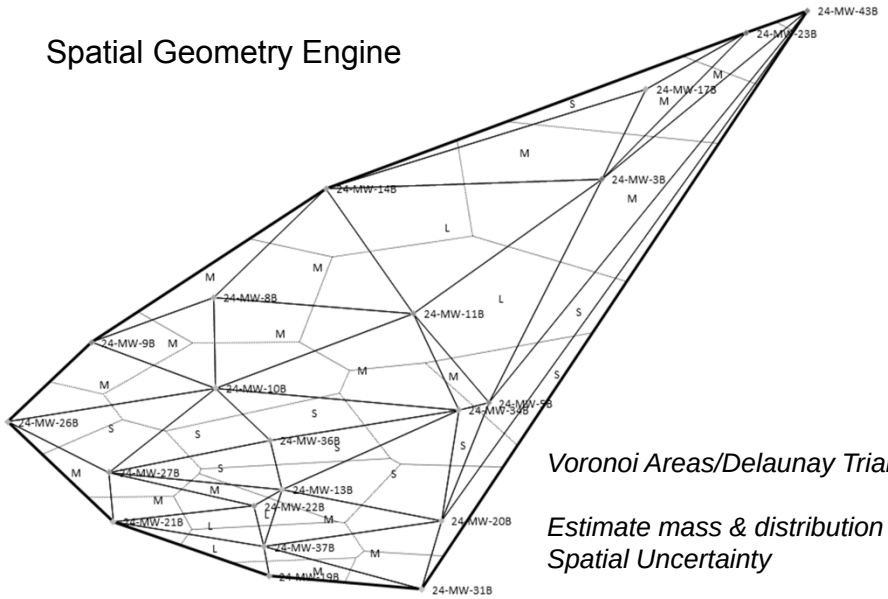
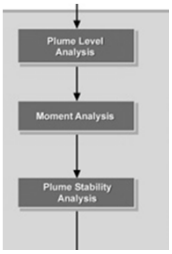

Spatial Geometry Engine
24-MW-43B
24-MW-23B
24-MW-17B
24-MW-14B
24-MW-3B
24-MW-8B
24-MW-11B
24-MW-9B
24-MW-10B
24-MW-26B
24-MW-36B
24-MW-27B
24-MW-13B
24-MW-22B
24-MW-21B
24-MW-20B
24-MW-37B
24-MW-31B
Voronoi Areas/Delaunay Triangles:
Estimate mass & distribution of mass
Spatial Uncertainty

Monitoring Optimization

Software: *Plume-Level Analysis*

- **Moment Analysis**
  - ***Expanded Data Input Choice- NEW!****
    - ***Wells to include***
    - ***Missing Sample Events***
    - ***Data Consolidation***
  - ***Moments***
    - ***As in MAROS 2.2***



* Requires new data consolidation

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Monitoring Optimization

Software: *Plume-Level Analysis*

- **Percent Mass by Well – *NEW!***
  - ***Voronoi Area***
  - ***Estimate mass in well area***
  - ***Percent mass and area each well monitors***

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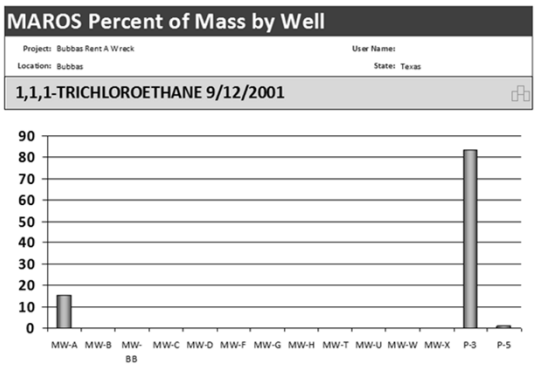

Well	Area (ft2)	Mass (mg)	Percent of Mass	Percent of Area
MW-A	6,096.17	1,265.79	15.50	5.76
MW-B	8,953.17	5.17	0.06	8.46
MW-BB	1,488.18	0.08	0.00	1.41
MW-C	12,352.90	1.62	0.02	11.67
MW-D	4,362.82	0.23	0.00	4.12
MW-F	16,624.12	2.18	0.03	15.71
MW-G	19,702.07	1.03	0.01	18.62
MW-H	3,113.66	0.16	0.00	2.94
MW-T	7,634.34	1.00	0.01	7.21
MW-U	587.28	0.03	0.00	0.55
MW-W	1,396.62	0.07	0.00	1.32
MW-X	10,979.09	0.58	0.01	10.37
P-3	8,819.32	6,806.31	83.34	8.33
P-5	3,726.62	82.56	1.01	3.52

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Monitoring Optimization

Software: *Plume-Level Analysis*

- **MAROS Analysis – Aggregate Trends**
  - ***Source and Tail***
  - ***Two custom groups – NEW!***
  - ***Aggregate MK Trend***
  - ***% Mass for the well group – NEW!***
- **Monitoring System Category**

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Plume Area Trends

MAIN MENU > PLUME ANALYSIS MENU > MAROS ANALYSIS > AGGREGATE TRENDS

The results of the Plume Area Trend assessment are shown. Choose the tab for the COC of interest.

1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

Aggregate Trends

Area	Number Of Wells	Aggregate Trend	Aggregate Mass %
Source	5	PD	96%
Tail	8	PD	4%
Custom Group 1	3	D	10%
Custom Group 2	7	PD	90%

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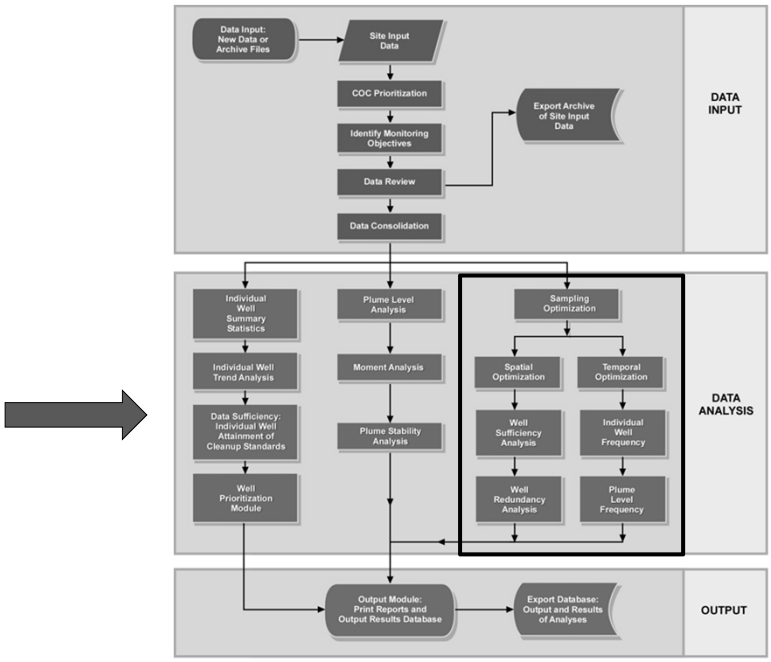

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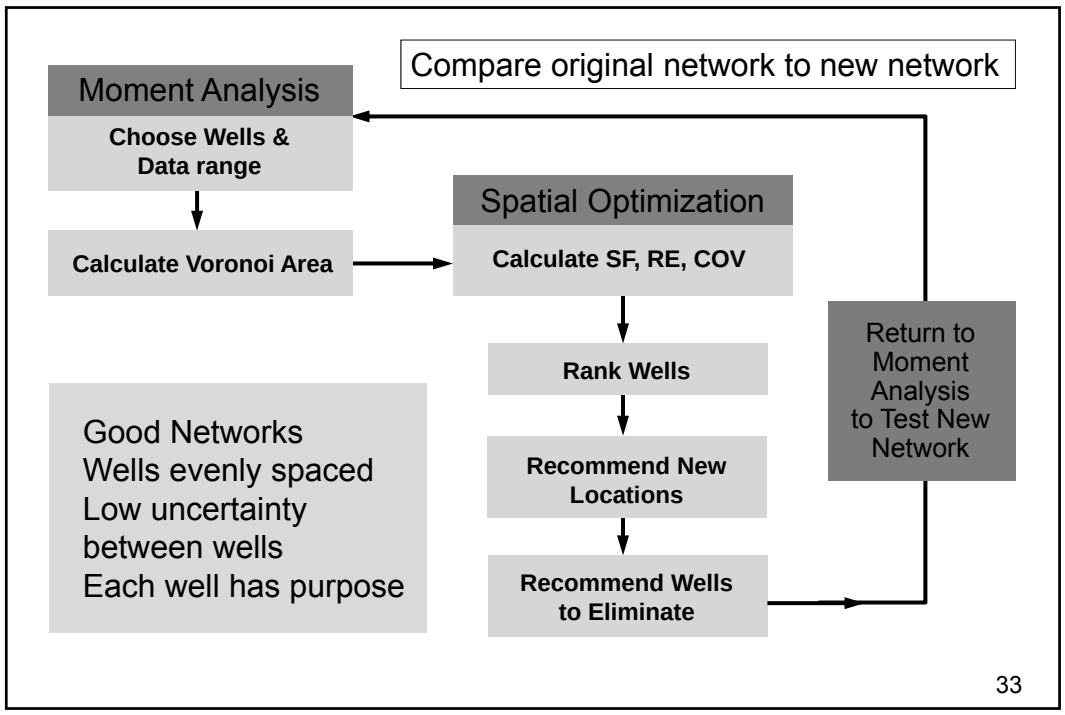
Compare original network to new network
Moment Analysis
Choose Wells & Data range
Calculate Voronoi Area
Spatial Optimization
Calculate SF, RE, COV
Rank Wells
Recommend New Locations
Recommend Wells to Eliminate
Return to Moment Analysis to Test New Network
Good Networks
Wells evenly spaced
Low uncertainty between wells
Each well has purpose
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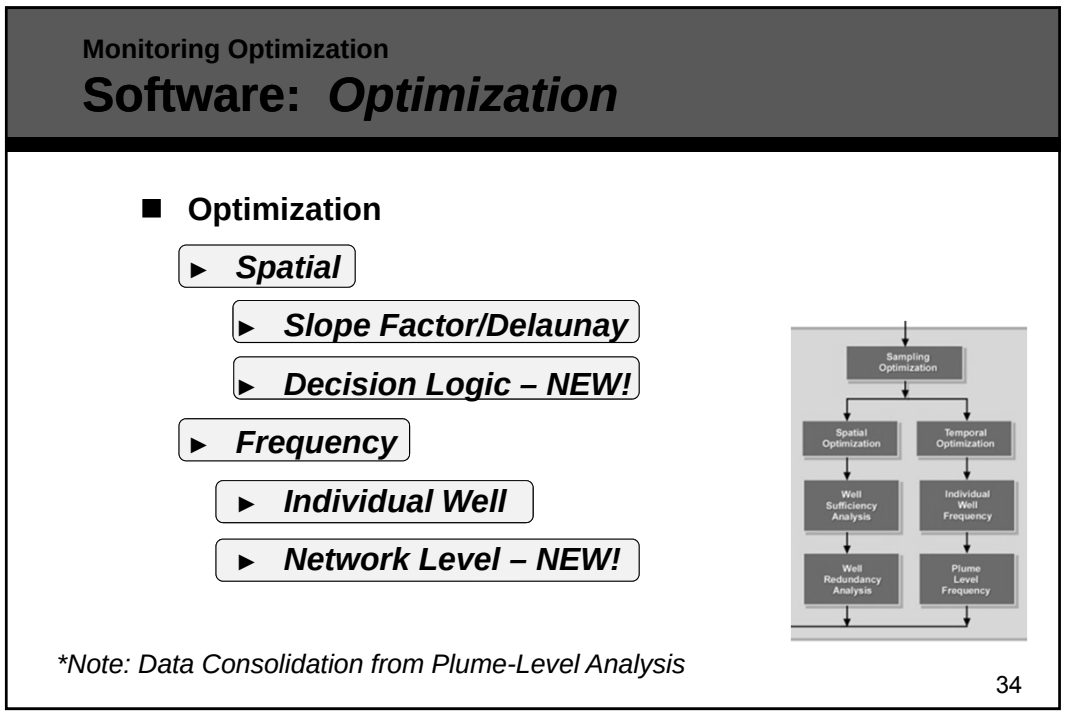
Monitoring Optimization
Software: Optimization
Optimization
Spatial
Slope Factor/Delaunay
Decision Logic – NEW!
Frequency
Individual Well
Network Level – NEW!
Sampling Optimization
Spatial Optimization
Temporal Optimization
Well Sufficiency Analysis
Individual Well Frequency
Well Redundancy Analysis
Plume Level Frequency
*Note: Data Consolidation from Plume-Level Analysis
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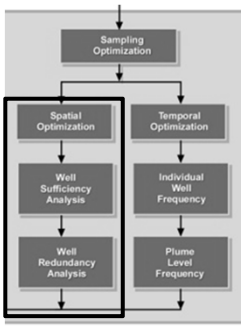
Monitoring Optimization

Software: *Spatial Optimization*

- **Spatial Optimization**
  - ***Slope Factor/Delaunay***
    - ***From MAROS 2.2***
  - ***Decision Logic – NEW!***
    - ***Voronoi Areas***
    - ***Slope Factor and Relative Error***
    - ***Concentration***



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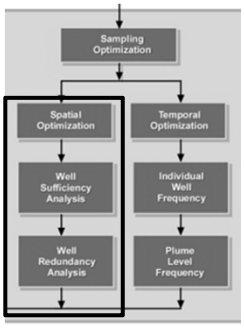
Monitoring Optimization

Software: *Spatial Optimization*

- **Spatial Optimization**
  - ***Decision Logic – NEW!***
    - ***Interactive***
    - ***Multiple Well Configurations***
    - ***Well Sufficiency***
    - ***Well Redundancy***



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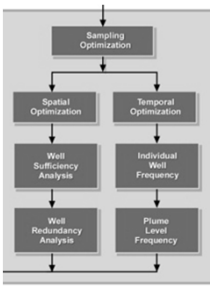
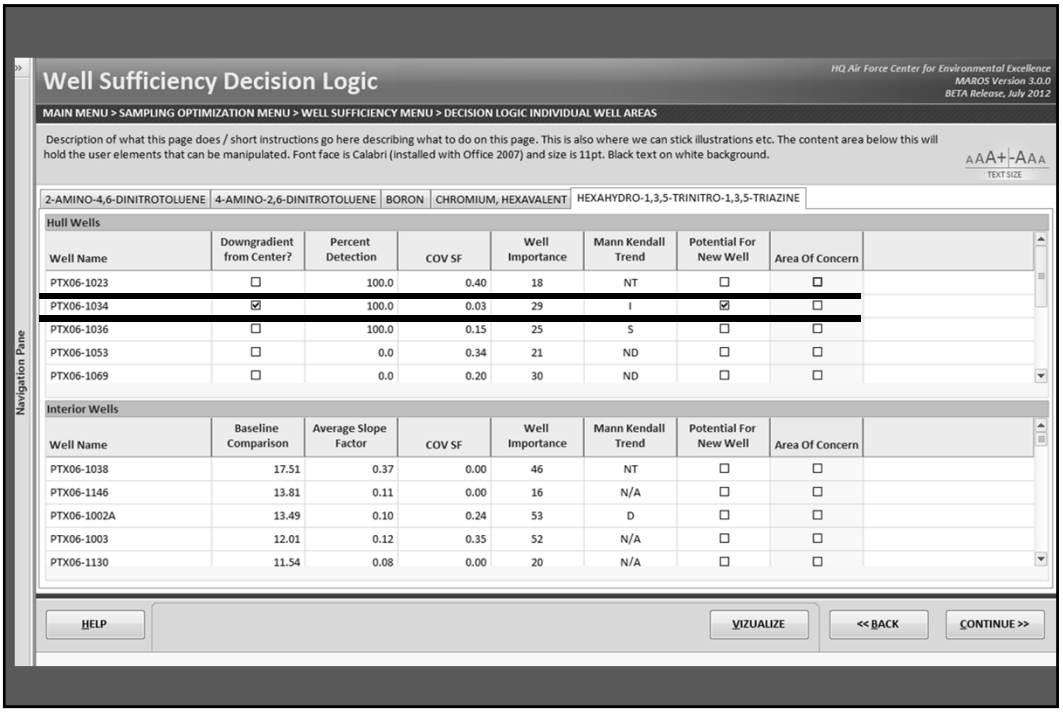
Monitoring Optimization

Software: *Spatial Optimization*

- ***Decision Logic – NEW!***
  - ***Uncertainty –***
    - ***High SF, RE, COV – new well***
    - ***Low SF, RE, COV - redundant***
  - ***Voronoi Area***
    - ***Large – new well***
    - ***Small – redundant***
  - ***Interior vs. Hull wells***
  - ***Trends***



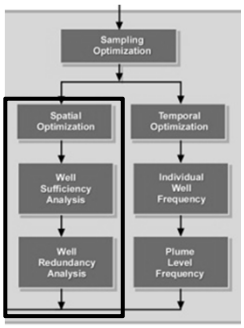
37



Monitoring Optimization

Software: *Spatial Optimization*

- **Spatial Optimization**
  - ***Well Redundancy***
    - ***Lowest 25% Rank***
    - ***User can choose to eliminate***
      - ***Return to Moment Analysis***
      - ***Re-run stats***



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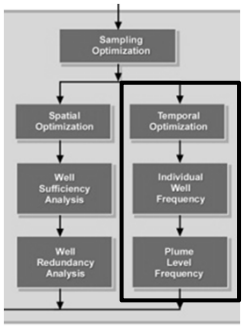
Monitoring Optimization

Software: *Optimization*

- **Optimization**
  - ***Frequency***
    - ***Individual Well***
    - ***Network Level – NEW!***



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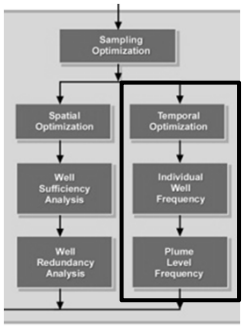
Monitoring Optimization

Software: *Optimization*

- **Individual Well Sampling Frequency**
  - ***Summary info – NEW!***
    - ***Reporting Frequency***
    - ***Travel Time***
    - ***Current Sampling Frequency***
  - ***Modified CES Method***



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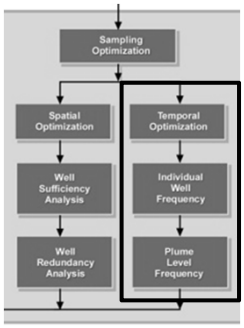
Monitoring Optimization

Software: *Optimization*

- **Network Sampling Frequency – *NEW!***
  - ***Based on Zeroth Moment***
    - ***Rate of change of mass***
    - ***Coefficient of variation***
    - ***Correlation (R2)***
  - ***Recommendation***



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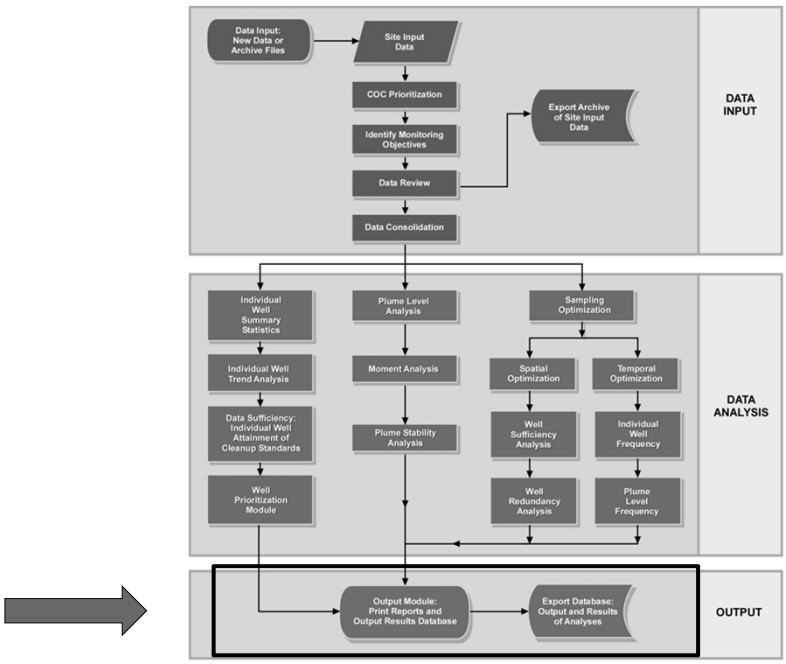

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Monitoring Optimization

Software: *Export Options*

- **MAROS Output**
  - ***Screen by Screen – spreadsheet cut and paste as you go***
  - ***Reports***
    - ***Print as you go***
    - ***Output – view and print reports***
  - ***Graphs***
    - ***View and Print***

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Monitoring Optimization

Software: *Export Options*

- **MAROS Output**
  - ***Excel Tables***
    - ***Multiple tables – default***
    - ***Single Tables***
  - ***Access Database***
    - ***Multiple Tables – default***
    - ***User choses Tables***

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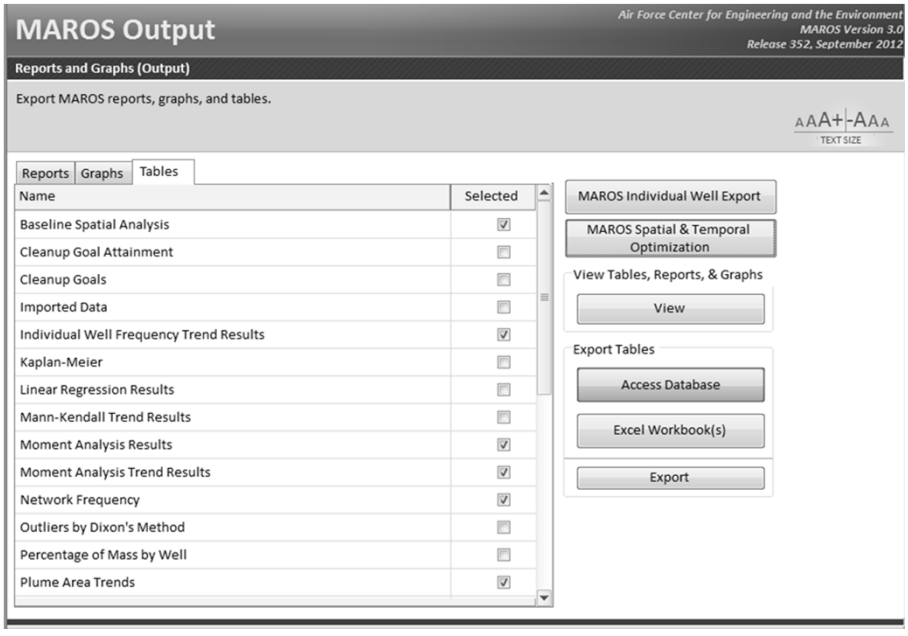

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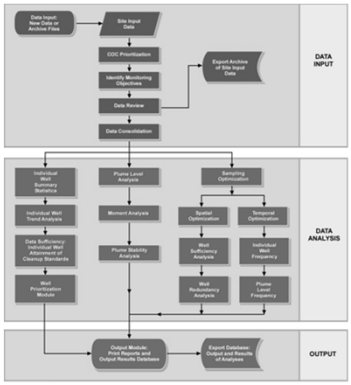
Monitoring Optimization

QUESTIONS?



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Monitoring Optimization

Overview: *MAROS 3.0 New Release*

- Goals and Objectives
- Software Structure and New Features
- Detailed Description
- Conclusions

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Monitoring Optimization

Overview: *MAROS 3.0 New Release*

Detailed Description- *New Features*

- **Individual Well Statistics**
- **Plume-Level Analysis**
- **Optimization**

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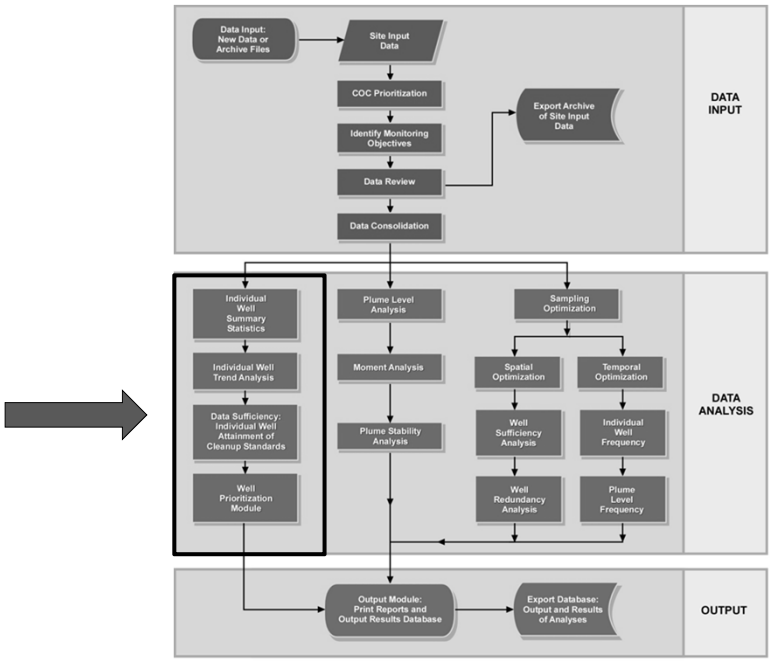

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Monitoring Optimization

Software: *Individual Well Statistics*

Individual Well Concentrations

- **Summary Statistics**
- **Statistical Trends**
- **Attainment of Goals**
- **Well Score**

- ***How much? How often?***
- ***When? Where?***
- ***Lognormal? Normal?***
- ***Outliers?***
- ***Increasing or Decreasing? Variable?***
- ***Clean?***
- ***Important?***

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Monitoring Optimization

Software: *Individual Well Analysis*

- **Summary Statistics – *NEW!***
  - ***Detection Frequencies***
  - ***Kaplan-Meier – Ave., Median, SD.***
  - ***Outliers by Dixon's***
  - ***Shapiro-Wilk Normality***

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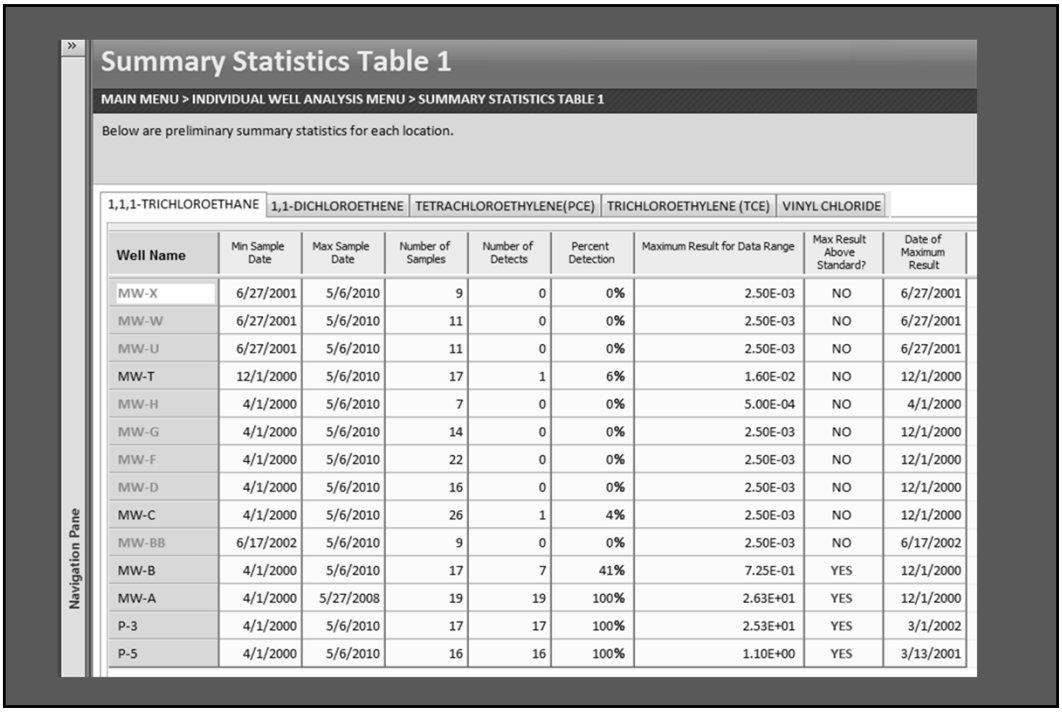


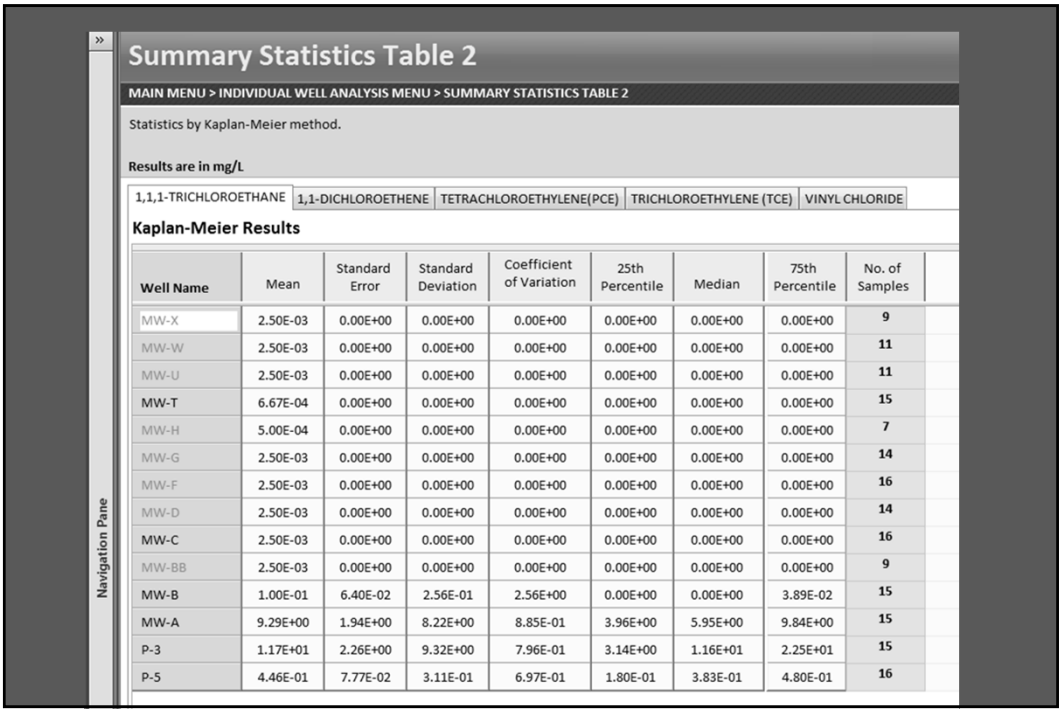
Summary Statistics Table 1

MAIN MENU > INDIVIDUAL WELL ANALYSIS MENU > SUMMARY STATISTICS TABLE 1

Below are preliminary summary statistics for each location.

1,1,1-TRICHLOROETHANE | 1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

Well Name	Min Sample Date	Max Sample Date	Number of Samples	Number of Detects	Percent Detection	Maximum Result for Data Range	Max Result Above Standard?	Date of Maximum Result
MW-X	6/27/2001	5/6/2010	9	0	0%	2.50E-03	NO	6/27/2001
MW-W	6/27/2001	5/6/2010	11	0	0%	2.50E-03	NO	6/27/2001
MW-U	6/27/2001	5/6/2010	11	0	0%	2.50E-03	NO	6/27/2001
MW-T	12/1/2000	5/6/2010	17	1	6%	1.60E-02	NO	12/1/2000
MW-H	4/1/2000	5/6/2010	7	0	0%	5.00E-04	NO	4/1/2000
MW-G	4/1/2000	5/6/2010	14	0	0%	2.50E-03	NO	12/1/2000
MW-F	4/1/2000	5/6/2010	22	0	0%	2.50E-03	NO	12/1/2000
MW-D	4/1/2000	5/6/2010	16	0	0%	2.50E-03	NO	12/1/2000
MW-C	4/1/2000	5/6/2010	26	1	4%	2.50E-03	NO	12/1/2000
MW-BB	6/17/2002	5/6/2010	9	0	0%	2.50E-03	NO	6/17/2002
MW-B	4/1/2000	5/6/2010	17	7	41%	7.25E-01	YES	12/1/2000
MW-A	4/1/2000	5/27/2008	19	19	100%	2.63E+01	YES	12/1/2000
P-3	4/1/2000	5/6/2010	17	17	100%	2.53E+01	YES	3/1/2002
P-5	4/1/2000	5/6/2010	16	16	100%	1.10E+00	YES	3/13/2001



Summary Statistics Table 2

MAIN MENU > INDIVIDUAL WELL ANALYSIS MENU > SUMMARY STATISTICS TABLE 2

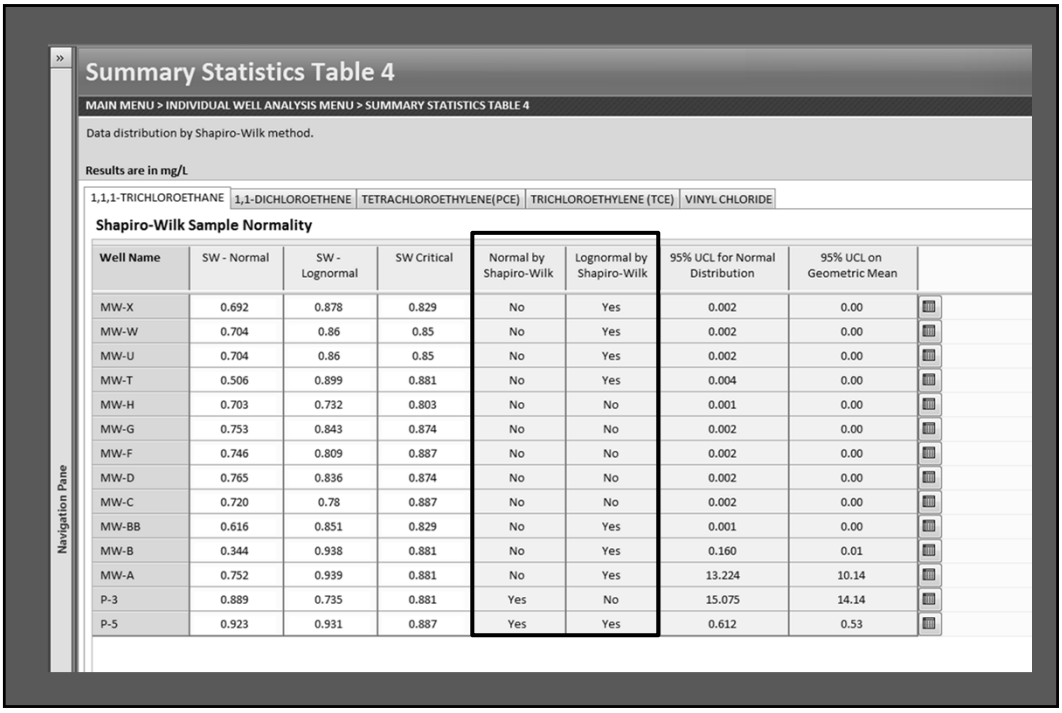
Statistics by Kaplan-Meier method.

Results are in mg/L

1,1,1-TRICHLOROETHANE | 1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

Kaplan-Meier Results

Well Name	Mean	Standard Error	Standard Deviation	Coefficient of Variation	25th Percentile	Median	75th Percentile	No. of Samples
MW-X	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9
MW-W	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	11
MW-U	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	11
MW-T	6.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	15
MW-H	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7
MW-G	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	14
MW-F	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	16
MW-D	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	14
MW-C	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	16
MW-BB	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9
MW-B	1.00E-01	6.40E-02	2.56E-01	2.56E+00	0.00E+00	0.00E+00	3.89E-02	15
MW-A	9.29E+00	1.94E+00	8.22E+00	8.85E-01	3.96E+00	5.95E+00	9.84E+00	15
P-3	1.17E+01	2.26E+00	9.32E+00	7.96E-01	3.14E+00	1.16E+01	2.25E+01	15
P-5	4.46E-01	7.77E-02	3.11E-01	6.97E-01	1.80E-01	3.83E-01	4.80E-01	16



Summary Statistics Table 4

MAIN MENU > INDIVIDUAL WELL ANALYSIS MENU > SUMMARY STATISTICS TABLE 4

Data distribution by Shapiro-Wilk method.

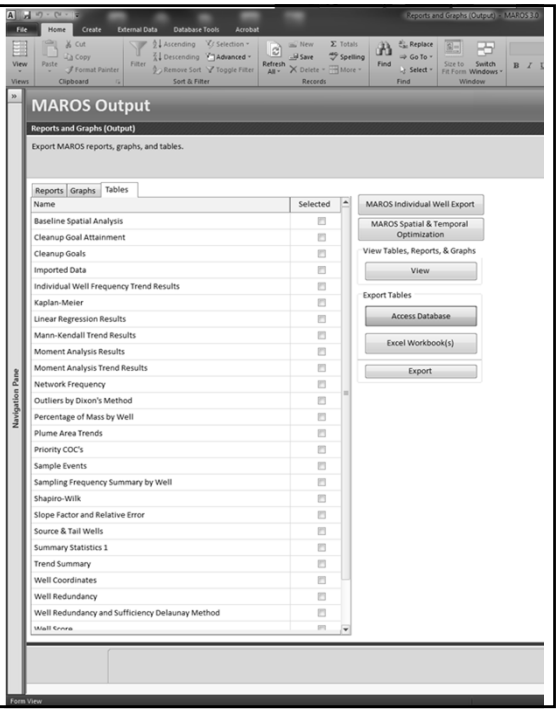
Results are in mg/L

1,1,1-TRICHLOROETHANE | 1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

Shapiro-Wilk Sample Normality

Well Name	SW - Normal	SW - Lognormal	SW Critical	Normal by Shapiro-Wilk	Lognormal by Shapiro-Wilk	95% UCL for Normal Distribution	95% UCL on Geometric Mean
MW-X	0.692	0.878	0.829	No	Yes	0.002	0.00
MW-W	0.704	0.86	0.85	No	Yes	0.002	0.00
MW-U	0.704	0.86	0.85	No	Yes	0.002	0.00
MW-T	0.506	0.899	0.881	No	Yes	0.004	0.00
MW-H	0.703	0.732	0.803	No	No	0.001	0.00
MW-G	0.753	0.843	0.874	No	No	0.002	0.00
MW-F	0.746	0.809	0.887	No	No	0.002	0.00
MW-D	0.765	0.836	0.874	No	No	0.002	0.00
MW-C	0.720	0.78	0.887	No	No	0.002	0.00
MW-BB	0.616	0.851	0.829	No	Yes	0.001	0.00
MW-B	0.344	0.938	0.881	No	Yes	0.160	0.01
MW-A	0.752	0.939	0.881	No	Yes	13.224	10.14
P-3	0.889	0.735	0.881	Yes	No	15.075	14.14
P-5	0.923	0.931	0.887	Yes	Yes	0.612	0.53

- **Summary Statistics –**
  - ***Export Spreadsheet***
  - ***Export Database***
  - ***Export Reports***
  - ***Export Graphs***



MAROS Output

Reports and Graphs (Output)

Export MAROS reports, graphs, and tables.

Reports | Graphs | Tables

Name	Selected
Baseline Spatial Analysis	
Cleanup Goal Attainment	
Cleanup Goals	
Imported Data	
Individual Well Frequency Trend Results	
Kaplan-Meier	
Linear Regression Results	
Mann-Kendall Trend Results	
Moment Analysis Results	
Moment Analysis Trend Results	
Network Frequency	
Outliers by Dixon's Method	
Percentage of Mass by Well	
Plume Area Trends	
Priority COC's	
Sample Events	
Sampling Frequency Summary by Well	
Shapiro-Wilk	
Slope Factor and Relative Error	
Source & Tail Wells	
Summary Statistics 1	
Trend Summary	
Well Coordinates	
Well Redundancy	
Well Redundancy and Sufficiency Delaunay Method	

MAROS Individual Well Export

MAROS Spatial & Temporal Optimization

View Tables, Reports, & Graphs

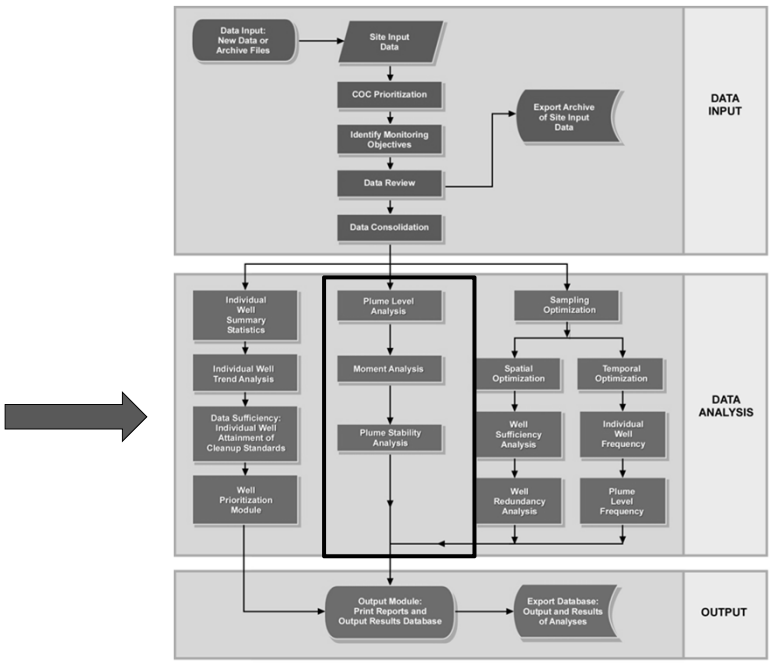
View

Export Tables

Access Database

Excel Workbook(s)

Export



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Monitoring Optimization

Software: *Plume-Level Analysis*

Plume-Level Analysis

- **Moment Analysis**
- **Well % Mass & Area**
- **Trend by Area**
- **Mass by Area**

- ***How much mass? Where?***
- ***How is it changing?***
- ***Which wells monitor the most mass?***
- ***Which wells monitor the most area?***
- ***Increasing or Decreasing? Variable?***

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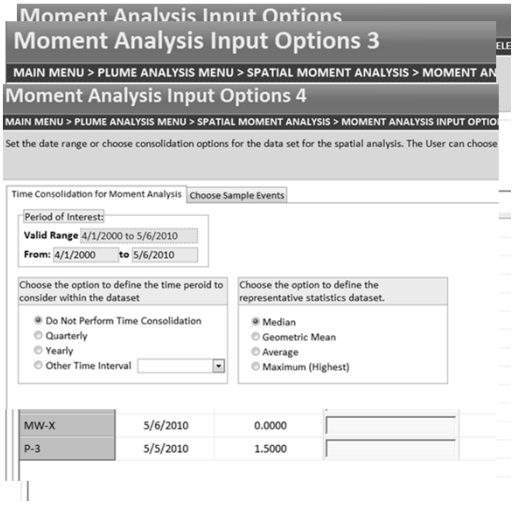
Monitoring Optimization
Software: *Moment Analysis User Choice*



More User Choice

- **Well Choice**
- **Time Frame/Sample Events**
- **Missing Sample Results**

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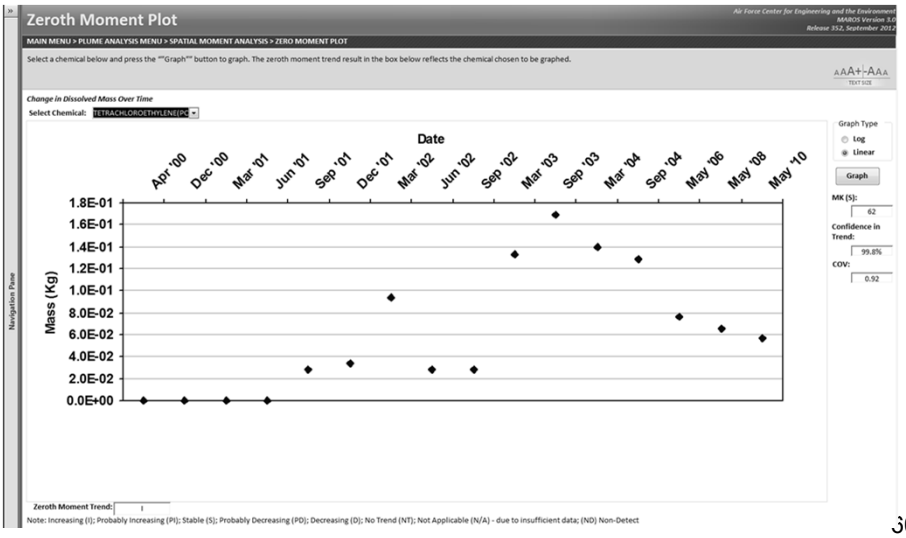
Monitoring Optimization
Software: *Moment Analysis*



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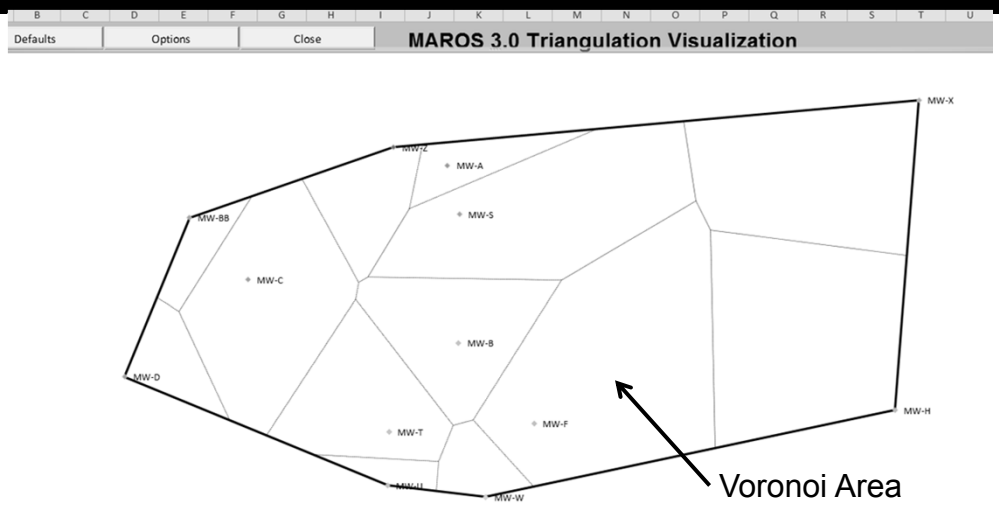
Monitoring Optimization

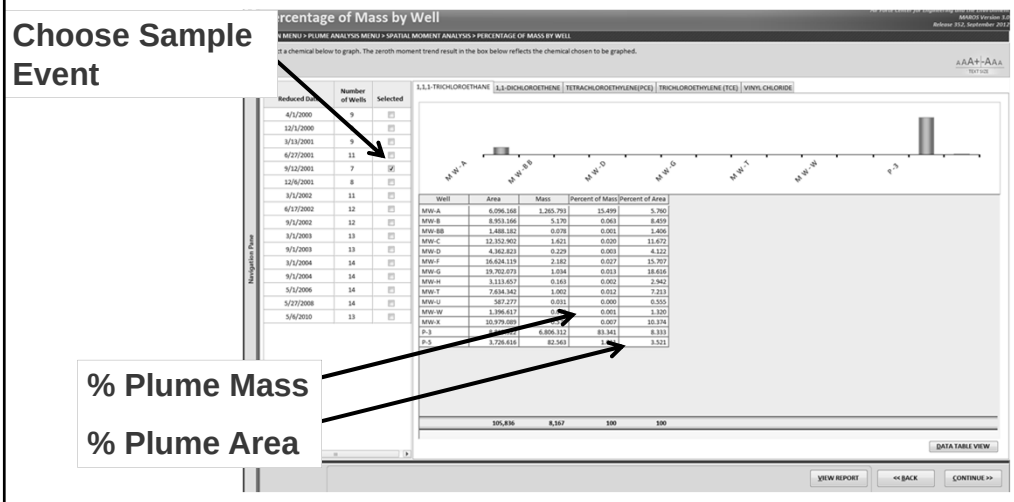
Software: *Plume Mass by Well*



Mass = Area * [C] * Thickness * Porosity

Monitoring Optimization

Software: *Plume Mass by Well*



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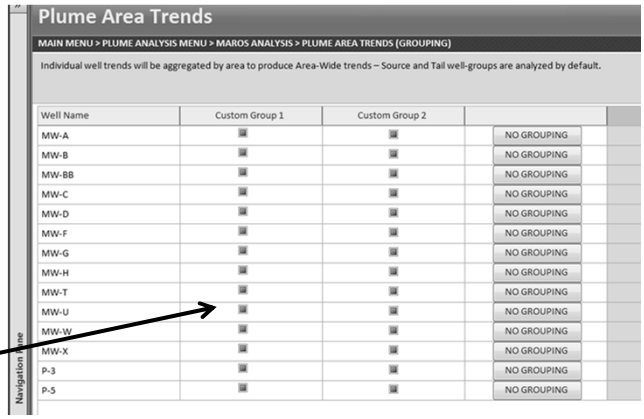
Monitoring Optimization

Software: *Plume Area Trends*

Plume Area Trends

- **Source Wells**
- **Tail Wells**
- **2 Custom Groups**
  - **Choose Wells**



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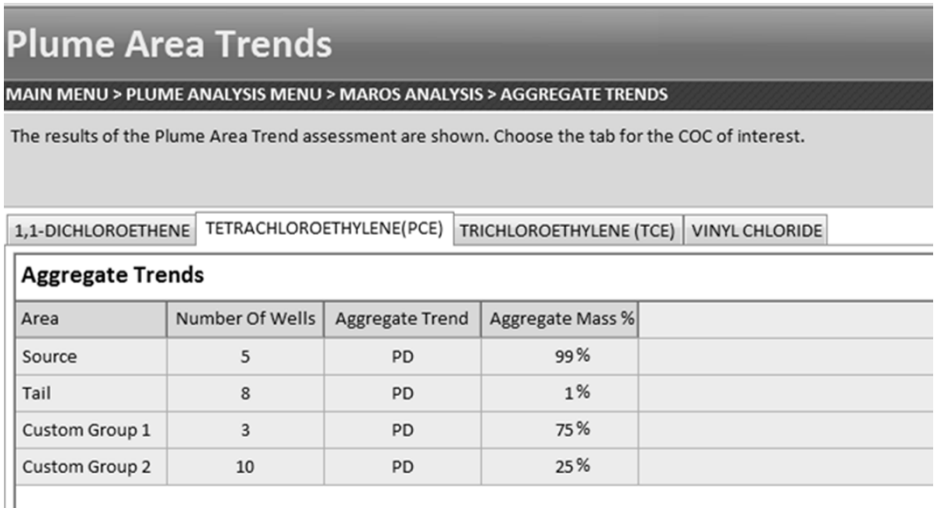
Monitoring Optimization

Software: *Plume Area Trends*



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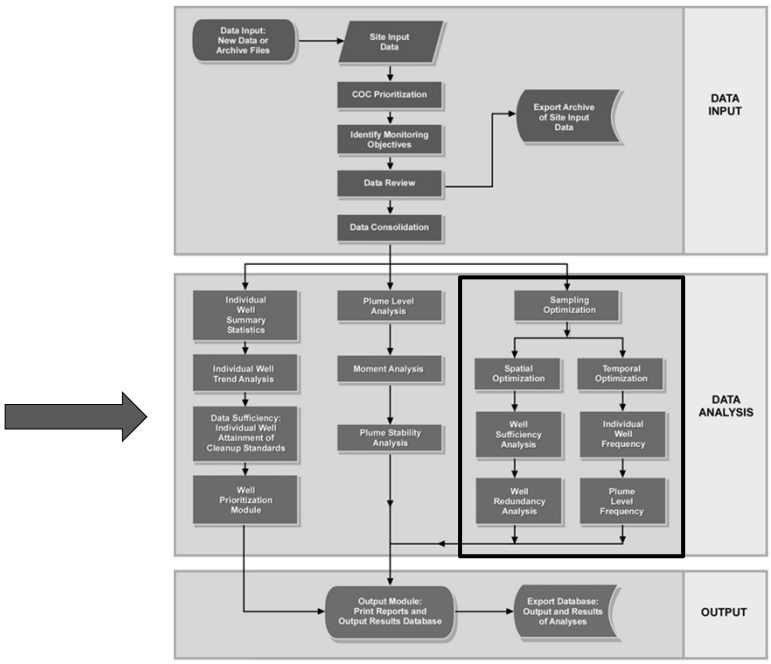

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Monitoring Optimization

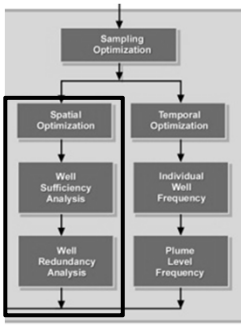
Software: *Spatial Optimization*

- **Spatial Optimization**
  - ***Decision Logic – Theory***

Spatial Optimization is dependent on goals of the program –

It is hard to *automate* diverse goals.

Give the User *useful* information to make their own decisions.



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Monitoring Optimization

Software: *Spatial Optimization*

Spatial Optimization

- **Slope Factor – Delaunay Triangulation**
- **Voronoi Areas**
- **Relative Error and Variability**
- **Trends**
- **Concentration**

- ***Uncertainty between wells?***
- ***Size of monitoring area?***
- ***Variability in uncertainty?***
- ***Increasing or Decreasing? Variable?***
- ***Magnitude of concentration?***

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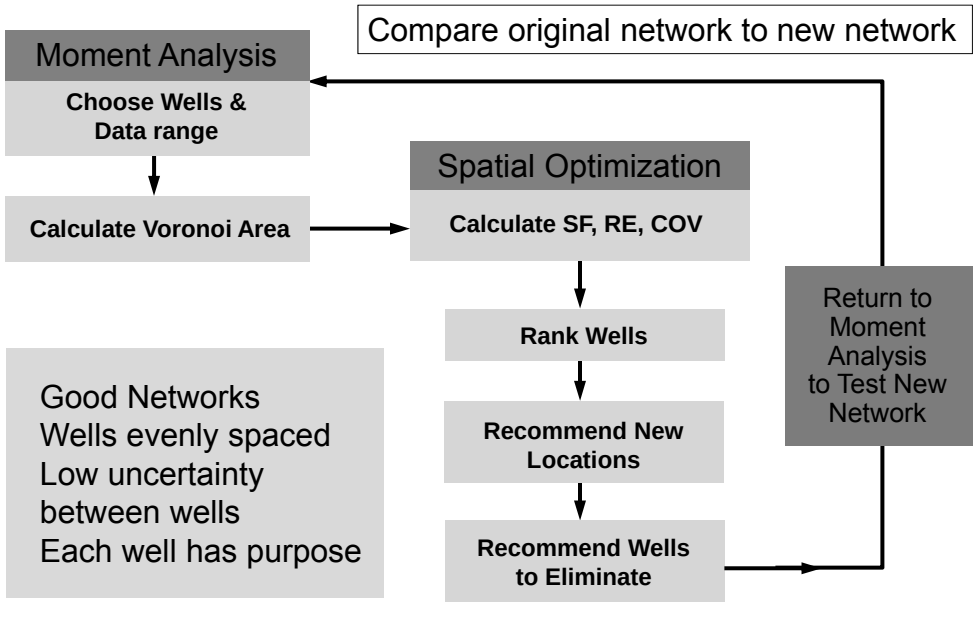

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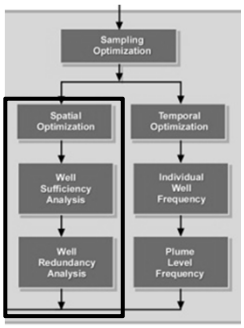
Monitoring Optimization

Software: *Spatial Optimization*

- **Spatial Optimization**
  - ***Decision Logic – NEW!***
    - ***Well Sufficiency***
      - ***Hull vs. Interior Well***
      - ***Downgradient Hull***
      - ***Baseline – VA vs. Ave***
      - ***MK Trend***
      - ***COV SF***



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Monitoring Optimization

Software: *Spatial Optimization*

- **Spatial Optimization – Uncertainty**
  - ***Slope Factor***
    - ***Uncertainty between points normalized by maximum of estimated or known result***
  - ***Relative Error***
    - ***Uncertainty between points normalized by maximum of known result***
  - ***Coefficient of Variation***
    - ***Variability in uncertainty between points over time***

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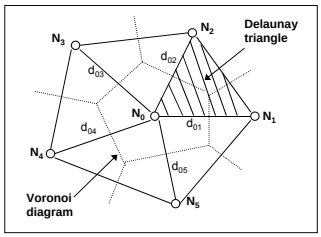
Monitoring Optimization

Software: *Spatial Optimization*

- **Slope Factor and Relative Error**

$$SF_i = \left| \frac{EC_i - NC_i}{Max(EC_i, NC_i)} \right|$$



Estimated concentration of node:

$$EC_i = \left[\sum_{j=1}^{M} NC_j \cdot \frac{1}{d_{ij}} \right] \Big/ \left[\sum_{j=1}^{M} \frac{1}{d_{ij}} \right]$$

where, M = number of triangles surrounding the node

SF → 1, well is important; SF → 0, well is not important

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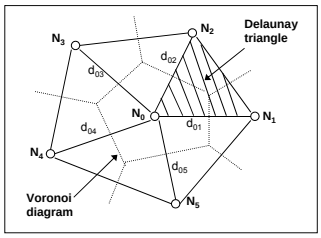
Monitoring Optimization

Software: *Spatial Optimization*

- **Slope Factor and Relative Error**

$$SF_i = \left| \frac{EC_i - NC_i}{Max(EC_i, NC_i)} \right|$$

$$RE_i = \left| \frac{EC_i - NC_i}{NC_i} \right|$$



- Varies over orders of magnitude
- RE → 10000, well is important; RE→ 0, well is not important
- COV – standard deviation/mean for all sample events

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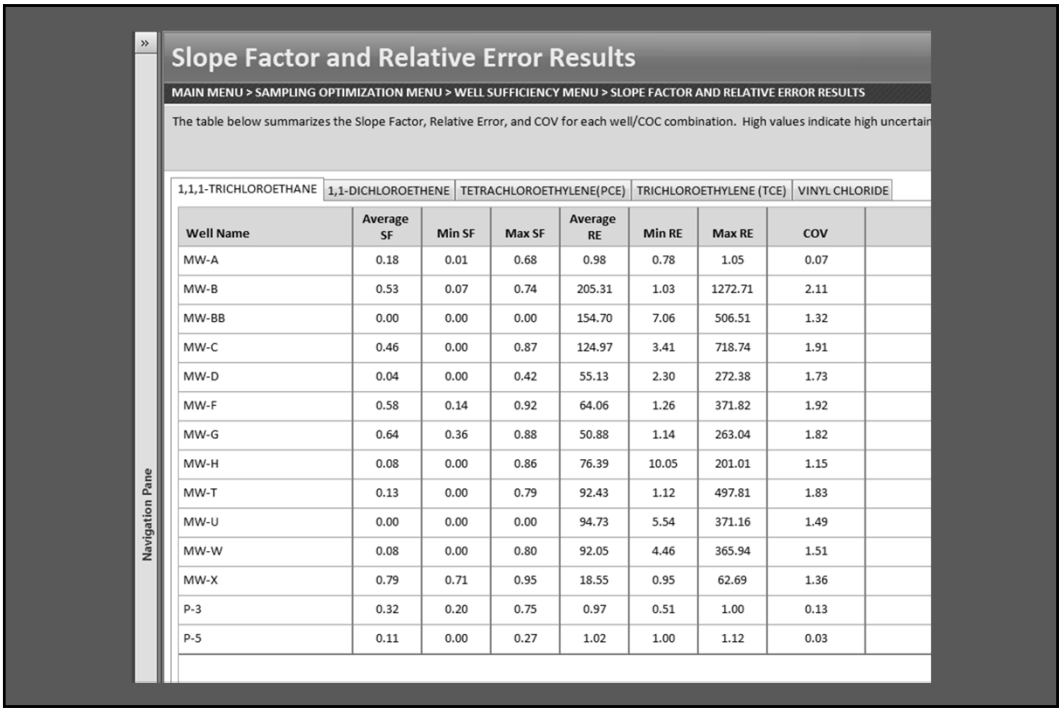


Slope Factor and Relative Error Results

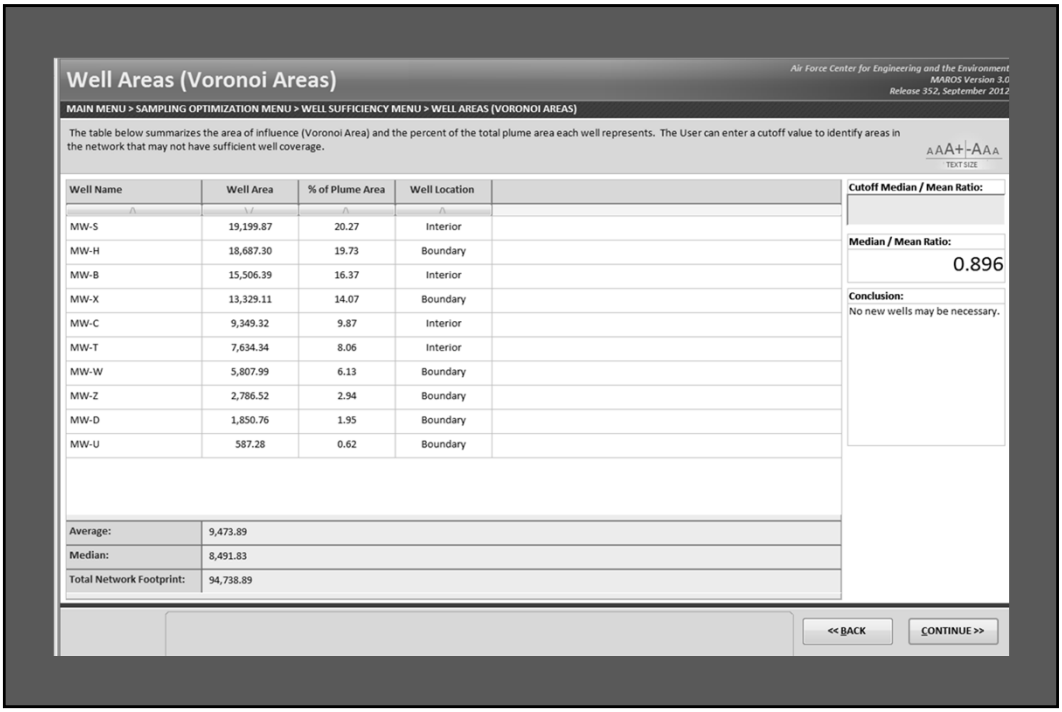
MAIN MENU > SAMPLING OPTIMIZATION MENU > WELL SUFFICIENCY MENU > SLOPE FACTOR AND RELATIVE ERROR RESULTS

The table below summarizes the Slope Factor, Relative Error, and COV for each well/COC combination. High values indicate high uncertain

Navigation Pane

1,1,1-TRICHLOROETHANE | 1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

Well Name	Average SF	Min SF	Max SF	Average RE	Min RE	Max RE	COV
MW-A	0.18	0.01	0.68	0.98	0.78	1.05	0.07
MW-B	0.53	0.07	0.74	205.31	1.03	1272.71	2.11
MW-BB	0.00	0.00	0.00	154.70	7.06	506.51	1.32
MW-C	0.46	0.00	0.87	124.97	3.41	718.74	1.91
MW-D	0.04	0.00	0.42	55.13	2.30	272.38	1.73
MW-F	0.58	0.14	0.92	64.06	1.26	371.82	1.92
MW-G	0.64	0.36	0.88	50.88	1.14	263.04	1.82
MW-H	0.08	0.00	0.86	76.39	10.05	201.01	1.15
MW-T	0.13	0.00	0.79	92.43	1.12	497.81	1.83
MW-U	0.00	0.00	0.00	94.73	5.54	371.16	1.49
MW-W	0.08	0.00	0.80	92.05	4.46	365.94	1.51
MW-X	0.79	0.71	0.95	18.55	0.95	62.69	1.36
P-3	0.32	0.20	0.75	0.97	0.51	1.00	0.13
P-5	0.11	0.00	0.27	1.02	1.00	1.12	0.03



Well Areas (Voronoi Areas)

Air Force Center for Engineering and the Environment
MAROS Version 3.0
Release 352, September 2012

MAIN MENU > SAMPLING OPTIMIZATION MENU > WELL SUFFICIENCY MENU > WELL AREAS (VORONOI AREAS)

The table below summarizes the area of influence (Voronoi Area) and the percent of the total plume area each well represents. The User can enter a cutoff value to identify areas in the network that may not have sufficient well coverage.

AAA+|-AAA TEXT SIZE

Well Name	Well Area	% of Plume Area	Well Location
MW-S	19,199.87	20.27	Interior
MW-H	18,687.30	19.73	Boundary
MW-B	15,506.39	16.37	Interior
MW-X	13,329.11	14.07	Boundary
MW-C	9,349.32	9.87	Interior
MW-T	7,634.34	8.06	Interior
MW-W	5,807.99	6.13	Boundary
MW-Z	2,786.52	2.94	Boundary
MW-D	1,850.76	1.95	Boundary
MW-U	587.28	0.62	Boundary

Average:	9,473.89
Median:	8,491.83
Total Network Footprint:	94,738.89

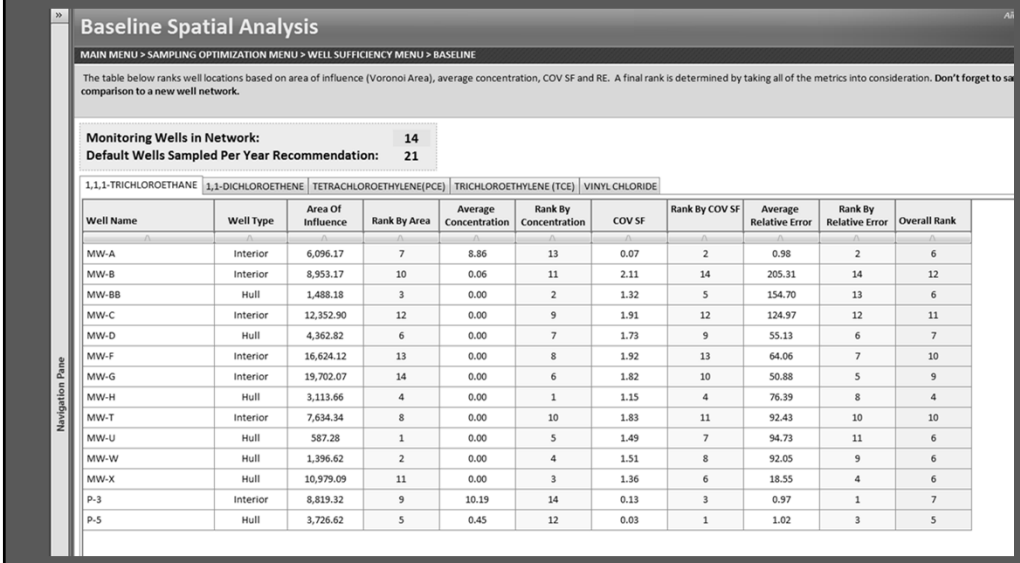
Cutoff Median / Mean Ratio:

Median / Mean Ratio: 0.896

Conclusion: No new wells may be necessary.

<< BACK | CONTINUE >>

Save Table for Later Comparison



Baseline Spatial Analysis

MAIN MENU > SAMPLING OPTIMIZATION MENU > WELL SUFFICIENCY MENU > BASELINE

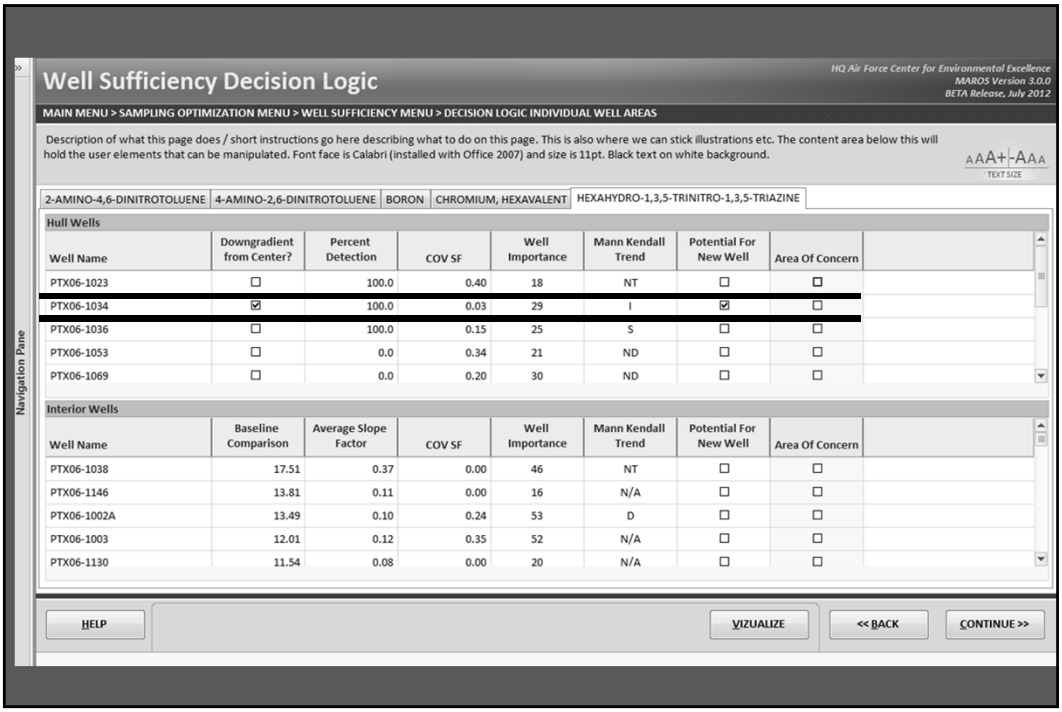
The table below ranks well locations based on area of influence (Voronoi Area), average concentration, COV SF and RE. A final rank is determined by taking all of the metrics into consideration. **Don't forget to sa comparison to a new well network.**

Monitoring Wells in Network: 14
Default Wells Sampled Per Year Recommendation: 21

1,1,1-TRICHLOROETHANE | 1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

Navigation Pane

Well Name	Well Type	Area Of Influence	Rank By Area	Average Concentration	Rank By Concentration	COV SF	Rank By COV SF	Average Relative Error	Rank By Relative Error	Overall Rank
MW-A	Interior	6,096.17	7	8.86	13	0.07	2	0.98	2	6
MW-B	Interior	8,953.17	10	0.06	11	2.11	14	205.31	14	12
MW-BB	Hull	1,488.18	3	0.00	2	1.32	5	154.70	13	6
MW-C	Interior	12,352.90	12	0.00	9	1.91	12	124.97	12	11
MW-D	Hull	4,362.82	6	0.00	7	1.73	9	55.13	6	7
MW-F	Interior	16,624.12	13	0.00	8	1.92	13	64.06	7	10
MW-G	Interior	19,702.07	14	0.00	6	1.82	10	50.88	5	9
MW-H	Hull	3,113.66	4	0.00	1	1.15	4	76.39	8	4
MW-T	Interior	7,634.34	8	0.00	10	1.83	11	92.43	10	10
MW-U	Hull	587.28	1	0.00	5	1.49	7	94.73	11	6
MW-W	Hull	1,396.62	2	0.00	4	1.51	8	92.05	9	6
MW-X	Hull	10,979.09	11	0.00	3	1.36	6	18.55	4	6
P-3	Interior	8,819.32	9	10.19	14	0.13	3	0.97	1	7
P-5	Hull	3,726.62	5	0.45	12	0.03	1	1.02	3	5



Well Sufficiency Decision Logic

HQ Air Force Center for Environmental Excellence
MAROS Version 3.0.0
BETA Release, July 2012

MAIN MENU > SAMPLING OPTIMIZATION MENU > WELL SUFFICIENCY MENU > DECISION LOGIC INDIVIDUAL WELL AREAS

Description of what this page does / short instructions go here describing what to do on this page. This is also where we can stick illustrations etc. The content area below this will hold the user elements that can be manipulated. Font face is Calabri (installed with Office 2007) and size is 11pt. Black text on white background.

AAA+|-AAA TEXT SIZE

2-AMINO-4,6-DINITROTOLUENE | 4-AMINO-2,6-DINITROTOLUENE | BORON | CHROMIUM, HEXAVALENT | HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE

Navigation Pane

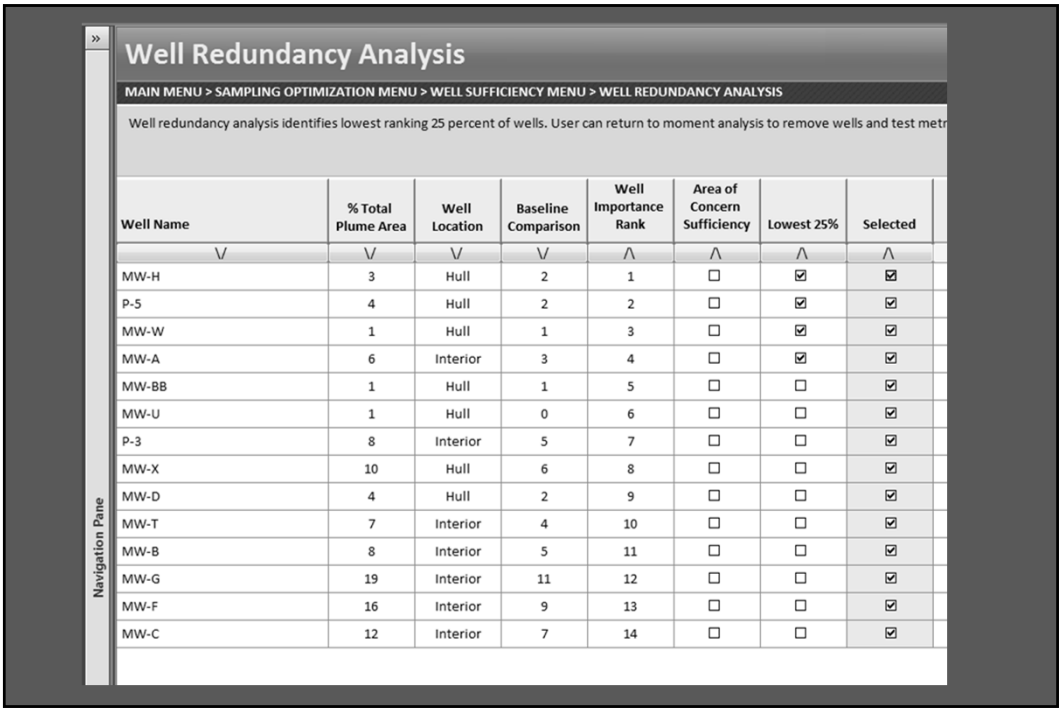
Hull Wells

Well Name	Downgradient from Center?	Percent Detection	COV SF	Well Importance	Mann Kendall Trend	Potential For New Well	Area Of Concern
PTX06-1023	☐	100.0	0.40	18	NT	☐	☐
PTX06-1034	☑	100.0	0.03	29	I	☑	☐
PTX06-1036	☐	100.0	0.15	25	S	☐	☐
PTX06-1053	☐	0.0	0.34	21	ND	☐	☐
PTX06-1069	☐	0.0	0.20	30	ND	☐	☐

Interior Wells

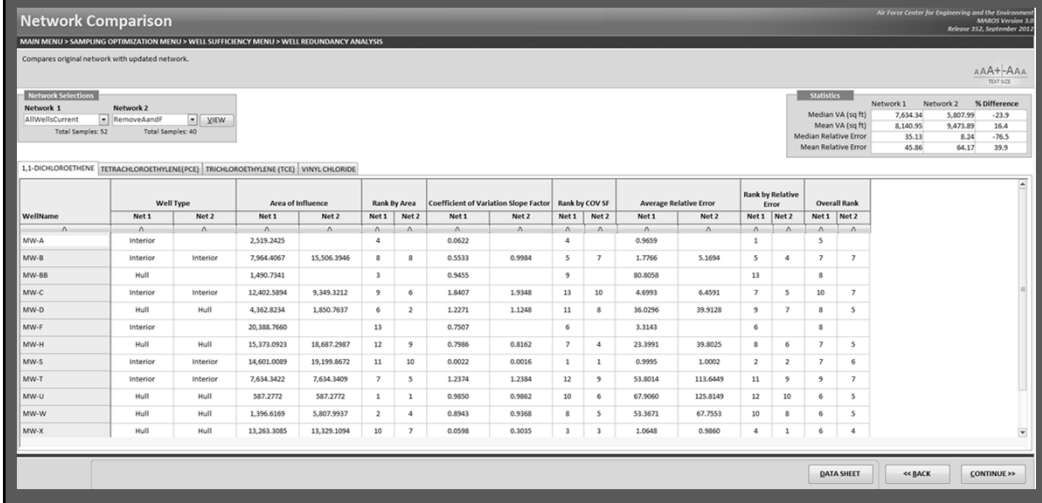
Well Name	Baseline Comparison	Average Slope Factor	COV SF	Well Importance	Mann Kendall Trend	Potential For New Well	Area Of Concern
PTX06-1038	17.51	0.37	0.00	46	NT	☐	☐
PTX06-1146	13.81	0.11	0.00	16	N/A	☐	☐
PTX06-1002A	13.49	0.10	0.24	53	D	☐	☐
PTX06-1003	12.01	0.12	0.35	52	N/A	☐	☐
PTX06-1130	11.54	0.08	0.00	20	N/A	☐	☐

HELP | VIZUALIZE | << BACK | CONTINUE >>



Well Name	% Total Plume Area	Well Location	Baseline Comparison	Well Importance Rank	Area of Concern Sufficiency	Lowest 25%	Selected
MW-H	3	Hull	2	1	☐	☑	☑
P-5	4	Hull	2	2	☐	☑	☑
MW-W	1	Hull	1	3	☐	☑	☑
MW-A	6	Interior	3	4	☐	☑	☑
MW-BB	1	Hull	1	5	☐	☐	☑
MW-U	1	Hull	0	6	☐	☐	☑
P-3	8	Interior	5	7	☐	☐	☑
MW-X	10	Hull	6	8	☐	☐	☑
MW-D	4	Hull	2	9	☐	☐	☑
MW-T	7	Interior	4	10	☐	☐	☑
MW-B	8	Interior	5	11	☐	☐	☑
MW-G	19	Interior	11	12	☐	☐	☑
MW-F	16	Interior	9	13	☐	☐	☑
MW-C	12	Interior	7	14	☐	☐	☑

Compare network stats before and after optimization



WellName	Well Type		Area of Influence		Rank By Area		Coefficient of Variation Slope Factor		Rank by COV SF		Average Relative Error		Rank by Relative Error		Overall Rank	
	Net 1	Net 2	Net 1	Net 2	Net 1	Net 2	Net 1	Net 2	Net 1	Net 2	Net 1	Net 2	Net 1	Net 2	Net 1	Net 2
MW-A	Interior		2,519.2425		4		0.0622		4		0.9659		1		5	
MW-B	Interior	Interior	7,964.4067	15,506.3946	8	8	0.5533	0.9984	5	7	1.7766	5.1694	5	4	7	7
MW-BB	Hull		1,490.7341		3		0.9455		9		80.8058		13		8	
MW-C	Interior	Interior	12,402.5894	9,349.3212	9	6	1.8407	1.9348	13	10	4.6993	6.4591	7	5	10	7
MW-D	Hull	Hull	4,362.8234	1,850.7637	6	2	1.2271	1.1248	11	8	36.0296	39.9128	9	7	8	5
MW-F	Interior		20,388.7660		13		0.7507		6		3.3143		6		8	
MW-H	Hull	Hull	15,373.0923	18,687.2987	12	9	0.7986	0.8162	7	4	23.3991	39.8025	8	6	7	5
MW-S	Interior	Interior	14,601.0089	19,199.8672	11	10	0.0022	0.0016	1	1	0.9995	1.0002	2	2	7	6
MW-T	Interior	Interior	7,634.3422	7,634.3409	7	5	1.2374	1.2384	12	9	53.8014	113.6449	11	9	9	7
MW-U	Hull	Hull	587.2772	587.2772	1	1	0.9850	0.9862	10	6	67.9060	125.8149	12	10	6	5
MW-W	Hull	Hull	1,396.6169	5,807.9937	2	4	0.8943	0.9368	8	5	53.3671	67.7553	10	8	6	5
MW-X	Hull	Hull	13,263.3085	13,329.1094	10	7	0.0598	0.3035	3	3	1.0648	0.9860	4	1	6	4

Monitoring Optimization

Software: *Frequency Optimization*

Frequency Optimization

- **Reporting frequency**
- **Current Frequency**
- **Transport-based Frequency**
- **Decision logic**

- ***How often do I sample now?***
- ***How fast is groundwater moving?***
- ***How fast are concentrations changing?***
- ***Variability?***
- ***Increasing or Decreasing? Variable?***

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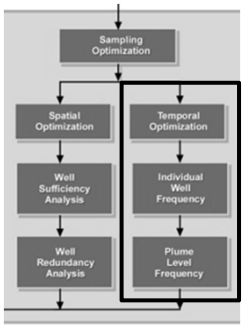
Monitoring Optimization

Software: *Optimization*

- **Optimization**
  - ***Frequency***
    - ***Individual Well***
    - ***Network Level – NEW!***



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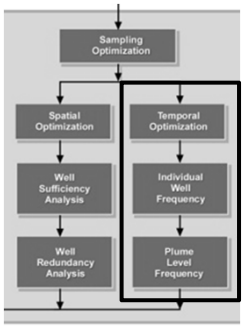
Monitoring Optimization

Software: *Optimization*

- **Individual Well Sampling Frequency**
  - ***Summary info – NEW!***
  - ***Reporting Frequency***
  - ***Travel Time***
  - ***Current Sampling Frequency***
  - ***Modified CES Method***



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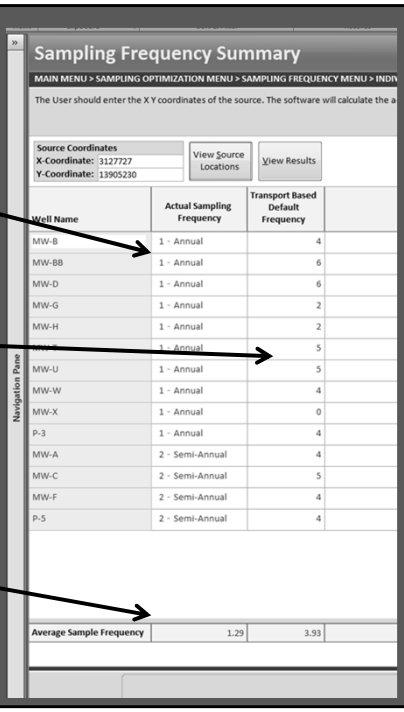
Current Sampling Frequency by well [samples/year]

½ * Distance to source /seepage velocity [years]

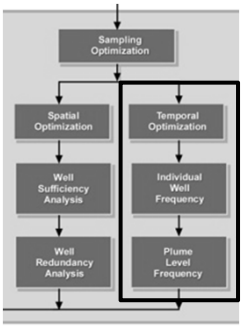
Network Average



Monitoring Optimization

Software: *Optimization*

- **Network Sampling Frequency – *NEW!***
  - ***Based on Zeroth Moment***
  - ***Rate of change of mass***
  - ***Coefficient of variation***
  - ***Correlation (R2)***
  - ***Recommendation***



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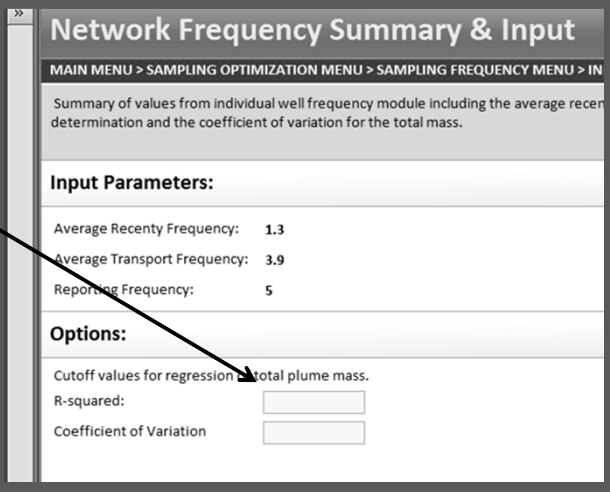
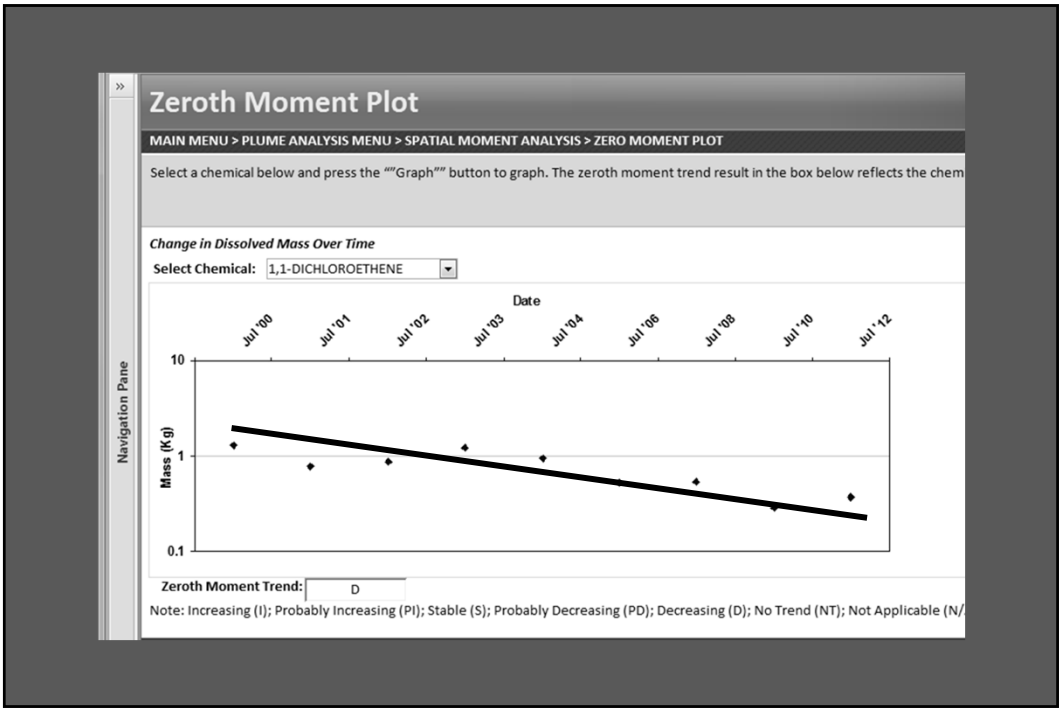
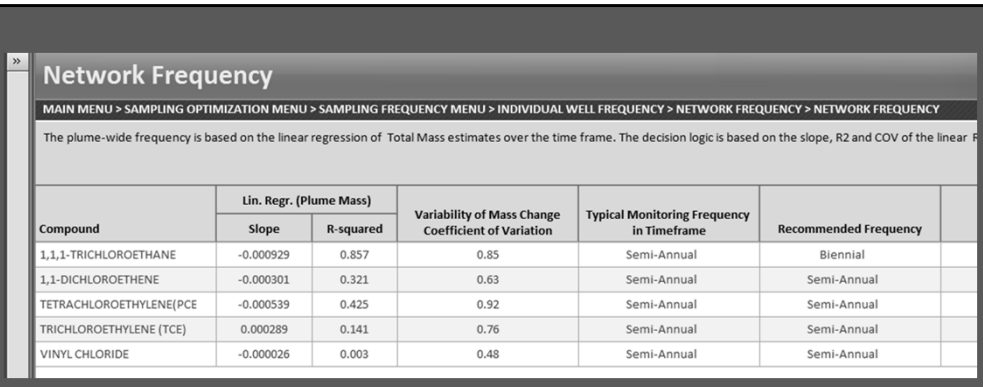
User supplies R^2 and COV cutoff





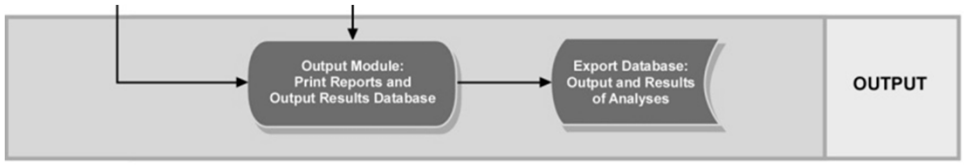


Compound	Lin. Regr. (Plume Mass) Slope	Lin. Regr. (Plume Mass) R-squared	Variability of Mass Change Coefficient of Variation	Typical Monitoring Frequency in Timeframe	Recommended Frequency
1,1,1-TRICHLOROETHANE	-0.000929	0.857	0.85	Semi-Annual	Biennial
1,1-DICHLOROETHENE	-0.000301	0.321	0.63	Semi-Annual	Semi-Annual
TETRACHLOROETHYLENE(PCE	-0.000539	0.425	0.92	Semi-Annual	Semi-Annual
TRICHLOROETHYLENE (TCE)	0.000289	0.141	0.76	Semi-Annual	Semi-Annual
VINYL CHLORIDE	-0.000026	0.003	0.48	Semi-Annual	Semi-Annual

Slope	COV	R2	Result
All	< User cutoff	< User Cutoff	Keep current sample frequency (Average current)
< 0 (negative)	< User cutoff	>= User Cutoff	2 steps less frequent
All	>=User cutoff	< User Cutoff	1 step more frequent
< 0 (negative)	>=User cutoff	>=User cutoff	1 step less frequent
Mass = 0	Do not calculate		Minimum of the reporting frequency or the transport-based frequency

Monitoring Optimization

Software: *Export and Output*



Export and Output

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Monitoring Optimization

Software: *Export Options*

- **MAROS Output**
  - ***Screen by Screen – spreadsheet cut and paste as you go***
  - ***Reports***
    - ***Print as you go***
    - ***Output – view and print reports***
  - ***Graphs***
  - ***Databases***

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Datasheet View by Screen

Summary Statistics Table 1

Air Force Center for Engineering and the Environme
MAROS Version 3
Release 352, September 201

MAIN MENU > INDIVIDUAL WELL ANALYSIS MENU > SUMMARY STATISTICS TABLE 1

Below are preliminary summary statistics for each location.

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TEXT SIZE

1,1-DICHLOROETHENE | TETRACHLOROETHYLENE(PCE) | TRICHLOROETHYLENE (TCE) | VINYL CHLORIDE

WellName	MinSampleDate	MaxSampleDate	NumberOfSamples	NumberOfDetects	PercentDetection	MaximumResultForDataRange	DateOfMaxF	MaxResultAboveSt
MW-A	3/3/2000	6/5/2008	19	19	100	1.90E+01	12/19/2000	YES
MW-B	3/3/2000	6/5/2012	18	18	100	1.50E+01	12/19/2000	YES
MW-BB	6/18/2002	6/5/2012	10	1	10	2.94E-03	6/5/2012	NO
MW-C	3/3/2000	6/5/2012	29	27	93	1.30E-01	6/28/2000	YES
MW-D	3/3/2000	6/5/2012	17	4	24	1.00E-03	3/3/2000	NO
MW-F	3/3/2000	6/5/2012	26	24	92	3.70E-02	12/20/2000	YES
MW-H	3/3/2000	6/5/2012	8	1	12	1.00E-03	3/3/2000	NO
MW-S	3/3/2000	6/5/2012	18	18	100	4.70E+01	6/28/2000	YES
MW-T	12/20/2000	6/5/2012	18	5	28	1.25E-01	12/20/2000	YES
MW-U	12/7/2001	5/6/2010	11	1	9	1.50E-03	3/18/2003	NO
MW-W	12/7/2001	6/5/2012	12	1	8	1.00E-03	12/7/2001	NO
MW-X	12/7/2001	6/5/2012	10	9	90	6.26E-02	3/26/2004	YES
MW-Z	3/3/2000	6/5/2012	17	17	100	1.50E+00	3/14/2001	YES

Reports

MAROS Individual Well Summary Report

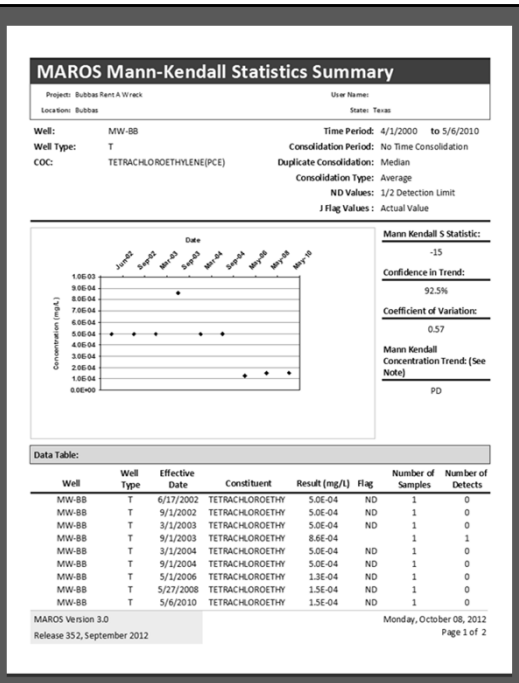
Project: Bubbas Rent A Wreck
User Name:
Location: Bubbas
State: Texas

COC	Priority COC for Well?	Detection Frequency	Recent Sample Above Goal?	MK Trend	COV	95% UCL	Outlier	Distribution Assumption	Attained Cleanup?	
									Normal	Lognormal
MW-A										
TCA111	NO	100 %	YES	D	0.89	13.2238	NO	Lognormal	NO	NO
DCE11	YES	100 %	YES	D	0.49	13.4831	NO	Normal	NO	NO
PCE	NO	100 %	YES	D	0.36	1.9197	NO	Normal	NO	NO
TCE	NO	100 %	YES	S	0.51	0.4332	NO	Lognormal	NO	NO
VC	NO	100 %	YES	D	0.47	2.4329	NO	Normal	NO	NO
MW-B										
TCA111	NO	41 %	NO	D	2.56	0.1599	YES	Lognormal	NO	NO
DCE11	YES	100 %	YES	D	2.09	2.5050	YES	Lognormal	NO	NO
PCE	NO	100 %	NO	D	1.18	0.0681	NO	Lognormal	NO	NO
TCE	NO	56 %	NO	D	2.41	0.0321	YES	No distribution	NO	NO
VC	NO	100 %	YES	D	1.07	0.5644	YES	Lognormal	NO	NO
MW-BB										
TCA111	NO	0 %	NO	ND	0.00	0.0012	YES	Lognormal	YES	NO
DCE11	NO	0 %	NO	ND	0.00	0.0005	NO	No distribution	YES	NO
PCE	YES	11 %	NO	PD	0.00	0.0006	NO	No distribution	YES	NO
TCE	NO	0 %	NO	ND	0.00	0.0005	NO	No distribution	YES	NO
VC	NO	0 %	NO	ND	0.00	0.0005	NO	No distribution	YES	NO
MW-C										
TCA111	NO	4 %	NO	D	0.00	0.0020	NO	No distribution	YES	NO
DCE11	YES	93 %	YES	D	0.94	0.0476	NO	No distribution	NO	NO
PCE	NO	0 %	NO	ND	0.00	0.0005	NO	No distribution	YES	NO
TCE	NO	0 %	NO	ND	0.00	0.0008	NO	No distribution	YES	NO
VC	NO	36 %	NO	NT	2.14	0.0029	NO	No distribution	NO	NO
MW-D										
TCA111	YES	0 %	NO	ND	0.00	0.0018	NO	No distribution	YES	NO
DCE11	YES	25 %	NO	D	1.95	0.0007	NO	No distribution	YES	NO
PCE	NO	6 %	NO	PD	0.00	0.0005	NO	No distribution	YES	NO
TCE	NO	0 %	NO	ND	0.00	0.0008	NO	No distribution	YES	NO

MAROS Version 3.0
Release 352, September 2012

Monday, October 08, 2012
Page 1 of 3

Graphs



MAROS Mann-Kendall Statistics Summary

Project: Bubbas Rent A Wreck — User Name:
Location: Bubbas — State: Texas

Well: MW-BB — Time Period: 4/1/2000 to 5/6/2010
Well Type: T — Consolidation Period: No Time Consolidation
COC: TETRACHLOROETHYLENE(PCE) — Duplicate Consolidation: Median
Consolidation Type: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value

Mann Kendall S Statistic:
-15
Confidence in Trend:
92.5%
Coefficient of Variation:
0.57
Mann Kendall Concentration Trend: (See Note)
PD

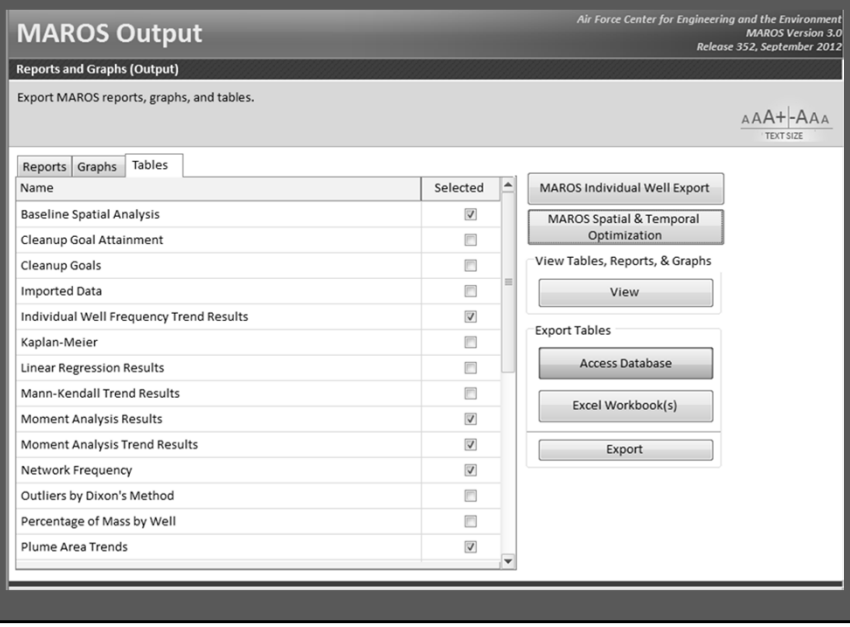
Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
MW-BB	T	6/17/2002	TETRACHLOROETHY	5.0E-04	ND	1	0
MW-BB	T	9/1/2002	TETRACHLOROETHY	5.0E-04	ND	1	0
MW-BB	T	3/1/2003	TETRACHLOROETHY	5.0E-04	ND	1	0
MW-BB	T	9/1/2003	TETRACHLOROETHY	8.6E-04		1	1
MW-BB	T	3/1/2004	TETRACHLOROETHY	5.0E-04	ND	1	0
MW-BB	T	9/1/2004	TETRACHLOROETHY	5.0E-04	ND	1	0
MW-BB	T	5/1/2006	TETRACHLOROETHY	1.3E-04	ND	1	0
MW-BB	T	5/27/2008	TETRACHLOROETHY	1.5E-04	ND	1	0
MW-BB	T	5/6/2010	TETRACHLOROETHY	1.5E-04	ND	1	0

MAROS Version 3.0
Release 352, September 2012

Monday, October 08, 2012
Page 1 of 2

Databases



MAROS Output

Air Force Center for Engineering and the Environment
MAROS Version 3.0
Release 352, September 2012

Reports and Graphs (Output)

Export MAROS reports, graphs, and tables.

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Reports | Graphs | Tables

Name	Selected
Baseline Spatial Analysis	☑
Cleanup Goal Attainment	☐
Cleanup Goals	☐
Imported Data	☐
Individual Well Frequency Trend Results	☑
Kaplan-Meier	☐
Linear Regression Results	☐
Mann-Kendall Trend Results	☐
Moment Analysis Results	☑
Moment Analysis Trend Results	☑
Network Frequency	☑
Outliers by Dixon's Method	☐
Percentage of Mass by Well	☐
Plume Area Trends	☑

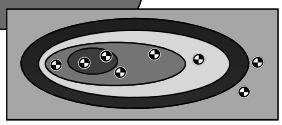
MAROS Individual Well Export
MAROS Spatial & Temporal Optimization
View Tables, Reports, & Graphs
View
Export Tables
Access Database
Excel Workbook(s)
Export

Monitoring Optimization

MAROS 3.0

- ***Expanded Individual Well Statistics***
- ***Improved spatial analysis***
- ***More User choice and comparison options for spatial analysis***
- ***Improve Usability***
- ***More export opportunities and options***

- ***Goals and COC Choice– NEW!***
- ***Individual Statistics– NEW!***
- ***Plume mass by well– NEW!***
- ***Aggregate Trends – NEW!***
- ***Spatial Decision Logic – NEW!***
- ***Travel time data – NEW!***
- ***Frequency Network Level – NEW!***



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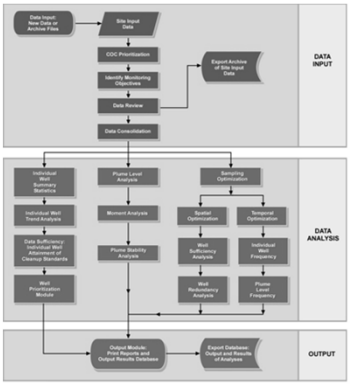
Monitoring Optimization

QUESTIONS?



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