LTMO Tools and Approaches Methodology and Data Requirements

LTMO Tool/Approach	*Overview*	*Frequency Optimization Methodology*	*Spatial Distribution Methodology*	*Data Requirements*	*Appropriate Site Size*
Cost Effective Sampling (CES)	CES is a methodology for reviewing and assessing the lowest-frequency sampling schedule for a given groundwater monitoring location.	Rule-based decision algorithm based on trend, variability, and magnitude statistics recommends optimal frequency at each well.	Not included	− At least 6 quarterly monitoring results per well − Clean down-gradient "guard wells"	Unlimited (well-by well analysis) within same operable unit
Geostatistical Temporal/Spatial Optimization Algorithm (GTS)	GTS is a spatial and temporal algorithm developed by AFCEE that utilizes geostatistical methods to optimize sampling frequency and to define the network of essential sampling locations. The GTS algorithm incorporates a decision pathway analysis that incorporates both spatial and temporal components and is used to identify spatial and temporal redundancies in existing monitoring networks.	1) Iterative thinning approach reconstructs baseline trends with fewer samples to determine optimal frequency on a well-by-well basis. 2) Temporal variogram is applied to determine composite autocorrelation and optimal site-wide frequency.	Weighting scheme utilizing locally weighted quadratic regression examines multiple "time slices" to identify redundant wells based on cost-accuracy trade-off curves.	− More than 8 events per well (temporal) − Greater than 30 wells (spatial)	30 to thousands of wells

Monitoring and Remediation Optimization System (MAROS)	The MAROS public domain software was developed in accordance with the AFCEE Long-Term Monitoring Optimization guide. MAROS is a decision support tool based on statistical methods applied to site-specific data that accounts for relevant current and historical site data as well as hydrogeologic factors. The software recommends optimal future sampling frequency, location and density, as well as providing information on the plume state over time.	Modified cost-effective sampling method (rule-based decision algorithm based on trend, variability, and magnitude statistics) recommends optimal frequency for each well.	Weighting scheme utilizing Delaunay triangulation identifies redundant wells. Can evaluate multiple chemicals at one time.	− More than 4 events per well (temporal) − Greater than 6 wells per zone (spatial)	40 to 80 wells recommended (per aquifer zone)

Parsons 3-Tiered LTMO	The 3-Tiered LTMO consists of a qualitative evaluation, an evaluation of temporal trends in contaminant concentrations, and a statistical spatial analysis. The results of the three evaluations are combined to assess the degree to which the monitoring network addresses the primary objectives of monitoring. A decision algorithm is applied to assess the optimal frequency of monitoring and the spatial distribution of the components of the monitoring network, and to develop recommendations for monitoring program optimization.	Qualitative evaluation, temporal statistical evaluation (Mann-Kendall), and spatial statistical evaluation are combined to identify wells for exclusion or retention and make final sampling frequency recommendations.	Qualitative evaluation, a weighting scheme using kriging, and temporal evaluation are combined to identify the relative spatial value of each well And make final network distribution recommendations.	− More than 4 events per well (temporal) − Greater than 10 wells per zone (spatial)	10 to 100s of wells (per aquifer zone)