Decision Support Tools – Development of a Screening Matrix for 20 Specific Software Tools

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Prepared by:

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FOREWORD

This report is designed to provide information on decision support tools that support the use of data, models, and structured decision processes in decision-making. This includes an evaluation of selected tools that have been used to support activities such as site assessment and remediation, data management and visualization, and optimization. The evaluations led to the development of a matrix of information to be disseminated to project managers, site owners, environmental consultants, and others who wish to screen decision support tools and benefit from their use at environmental sites.

ACKNOWLEDGMENTS

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LIST OF ACRONYMS

1D	One-dimensional
2D	Two-dimensional
AMD	Acid mine drainage
AOC	Area of Concern
ARAMS	Army Risk Assessment Modeling System
COC	Chemical of concern
CSM	Conceptual site model
DoD	Department of Defense
DOE	Department of Energy
DPGD	Decision Performance Goal Diagram
DQO	Data quality objective
DST	Decision support tool
EDD	Electronic data deliverable
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERT	Environmental Response Team
ETV	Environmental Technology Verification
FIELDS	FIeld EnvironmentaL Decision Support
FRAMES	Framework for Risk Analysis in Multimedia Environmental Systems
FRTR	Federal Remediation Technologies Roundtable
GIS	Geographic information system
GMS	Ground Water Modeling System
GPS	Global positioning system
GUI	Graphical user interface
HSSM	Hydrocarbon Spill Screening Model
IDW	Inverse distance weighting
LNAPLs	Light non-aqueous phase liquids
MAROS	Monitoring and Remediation Optimization System
NA	Natural attenuation
NAC	Natural attenuation capacity
NAS	Natural Attenuation Software
NN	Natural neighbor
NRC	Nuclear Regulatory Commission
OSC	On-scene coordinator
PDA	Portable data assistant
RAGS	Risk Assessment Guidance for Superfund
RPM	Remedial project manager
SADA	Spatial Analysis and Decision Assistance
VSP	Visual Sample Plan
XRF	X-ray fluorescence

1.0   INTRODUCTION

A decision support tool (DST – see box below) facilitates the use of data, models, and structured decision processes in decision-making. Project managers, site owners, environmental consultants, and others use DSTs in a variety of ways to support activities such as site assessment and remediation, data management and visualization, and optimization. The U.S. Environmental Protection Agency (EPA) has briefly evaluated selected DSTs, developed a matrix of information obtained from the evaluation, and is making the matrix available to users who wish to screen DSTs based on project-specific needs.

What is a Decision Support Tool?

DSTs are interactive software tools used by decision-makers to help answer questions, solve problems, and support or refute conclusions. They can be incorporated into a structured decision-making process for environmental site cleanup.

Many of the DSTs included in this matrix relate to use of the Triad approach. The Triad approach is an innovative approach to decision-making for hazardous waste site characterization and remediation. Additional information about the Triad approach is provided below under background.

1.1   BACKGROUND

Interest in DSTs that can be used for environmental decision-making has been building within EPA, as well as the other government agencies that constitute the Federal Remediation Technologies Roundtable (FRTR – *www.frtr.gov*). In 1997, and again in 2002, the Department of Energy's (DOE) Brookhaven National Laboratory conducted a preliminary evaluation of selected environmental DSTs related to site characterization and remediation. That evaluation (Sullivan 2002), referred to hereafter as the Brookhaven report, described the capabilities of the various tools and discussed issues related to their use; but a final version of the document was not issued. The Brookhaven report looked at 17 DSTs, including both commercial and non-commercial tools. The EPA, through its Environmental Technology Verification (ETV) program, performed evaluations of six selected environmental decision support software tools. For example, in February 2000, EPA published a report on the use of the Spatial Analysis and Decision Assistance (SADA) software program (*http://www.epa.gov/etv/verifications/vcenter1-1.html*).

Since that time, members of the FRTR have examined several DSTs, especially in the context of the Triad approach. The Triad approach (see box below) is particularly well suited to the use of DSTs, because of its emphasis on dynamic work strategies and real-time measurement technologies. Several FRTR member agencies have provided information about specific DSTs, including tools that have been used at sites following the Triad approach. Highlights of recent FRTR meetings about DSTs include:

- During a June 2003 presentation, members of the FRTR solicited agency interest in sponsoring development and maintenance of a DST page on the FRTR Web site. Several case studies about sites that have used DSTs were presented.

- During a December 2003 meeting, participants discussed the availability and applicability of DSTs. At that time, the FRTR "product" was envisioned, and participation was requested.

- In June 2004, EPA briefed the FRTR on its plan for development of a DST screening matrix. A list of DSTs was compiled based on information from EPA laboratories and regions, in addition to other federal agencies, such as DOE and the Department of Defense (DoD).

The Triad Approach

The Triad approach is an integrated method to manage decision uncertainty at hazardous waste sites. The Triad approach draws on advancing science, technology and practitioner experience to perfect strategies for making site work more defensible, resource-effective, and more responsive to stakeholder concerns (Crumbling and others, 2004).

The three elements of the Triad approach are systematic planning, dynamic work strategies, and real-time analytical results. The *systematic planning* process provides the overarching framework for project planning, contracting, and stakeholder communication. The systematic planning process compels the stakeholder group to reach consensus on critical issues — schedule, milestones, data management, communication and, most importantly, exit strategy — as early as possible in the project's life cycle.

The systematic planning framework is designed to focus all parties on the objectives of the project by developing and refining a conceptual site model (CSM). The CSM unifies existing data into a concise description of the physical setting, contaminant release and transport mechanisms, and exposure points that describe the problem. The CSM is treated as a working hypothesis of site conditions that will be refined and improved over the course of the project.

Dynamic work strategies are embodied in dynamic (flexible) planning documents. The key aspect of a dynamic work strategy is a defined decision logic that members of the field team can follow as they collect and evaluate data. Also essential is a strategy for data management and communication that allows the team and stakeholders to efficiently work together during the project. By focusing on decisions and communication instead of on instructions, the dynamic work strategy produces a flexible, efficient investigation that achieves a concrete result acceptable to all parties.

The Triad approach also focuses on using *real-time analytical tools* for site characterization and data analysis to increase the amount of data available to support decision-making. Decision-making for many projects can occur in real time while the samples are being collected rather than after months of data review, report preparation, and approval. Further information about the Triad approach is available at *www.triadcentral.org*.

1.2   PURPOSE

This report provides an overview of the process used to identify DSTs included in the screening matrix, evaluate each of the DSTs, and prepare the matrix. In addition, the report discusses the screening matrix and its various components.

1.3   TECHNICAL APPROACH

In Fall 2004, EPA began development of a DST screening matrix. To prepare the matrix, EPA selected 20 specific software tools (see Section 2.0) and conducted an evaluation of each tool. The purpose of the evaluation was as follows:

- Identify the types of functions that can be performed with the DST
- Assess the relative ease for performing basic tasks, such as loading data and graphics
- Assess the types of expertise needed to use the DST

To perform the evaluations, EPA identified "standard data sets" and had a team of environmental professionals test the DSTs using one of these data sets. The environmental professionals were technically proficient field workers but had no expertise in the specific DSTs they evaluated. A limited amount of time was allotted for each evaluator to download the DST and use it to enter data, perform relatively simple functions, and output results. Information and observations gleaned from their experience working with the DSTs are captured in the matrix itself.

Table 1 shows the type of standard data set that was used to evaluate each of the 20 DSTs. Each DST was evaluated using analytical data from an actual project site that was relevant to the specific DST. Each data set was presented to the evaluator as an Excel spreadsheet and, in some cases, required conversion into other formats.

TABLE 1
DATA SETS USED IN THE DST EVALUATIONS

Software	Type of Site	Type of Data Set	Problem Size (number)		
			Sample Locations	Analytes	Events
AMDTreat	Acid mine drainage	Actual site data	N/A	N/A	N/A
ARAMS	Metals in soil	Actual site data	7	21	1
BIOCHLOR	Chlorinated solvents in ground water	Actual site data	5	5	1
BIOPLUME III	Hydrocarbons in ground water	Actual site data	4	1	1
BIOSCREEN	Petroleum in ground water	Actual site data	2	4	1
CAMEO / ALOHA	Compliance	Demo data	N/A	N/A	N/A
F/S PLUS	Metals in soil	Actual site data	120	17	1
FIELDS	Metals in soil	Actual site data	120	17	1
GeoSEM	Chlorinated solvents in ground water	Demo data	35	5	6
Ground Water Sensitivity Toolkit	Hydrocarbons in ground water	Actual site data	13	7	1
HSSM	Petroleum in soil/ground water	Actual site data	2	4	1

TABLE 1
DATA SETS USED IN THE DST EVALUATIONS (continued)

Software	Type of Site	Type of Data Set	Problem Size (number)		
			Sample Locations	Analytes	Events
Johnson - Ettinger model	Hydrocarbons in soil and ground water	Actual site data	38	5	1
MAROS	Chlorinated solvents in ground water	Actual site data	35	5	6
NAS	Chlorinated solvents in ground water	Actual site data	5	5	1
OnSite	Petroleum in soil/ground water	Actual site data	38	5	1
RESRAD	N/A	N/A	N/A	N/A	N/A
SADA	Metals in soil	Actual site data	120	17	1
Scribe	Chlorinated solvents in ground water	Actual site data	10	3	1
SourceDK	Chlorinated solvents in ground water	Actual site data	4	4	1
VSP	Metals in soil	Actual site data	120	17	1

N/A = Not applicable

The evaluation of the DSTs was not a comparative analysis of one DST against another, nor was it a verification exercise. Rather, the team reviewed each tool independently and sought to provide general information on the DST.

DST developers were provided an opportunity to review the results from the evaluation of their tool before the matrix was posted to the FRTR Web site.

2.0   SELECTION OF DECISION SUPPORT TOOLS FOR THE MATRIX

To identify DSTs for the screening matrix, EPA reviewed the following sources: information in the Brookhaven report, information presented at previous FRTR meetings, Internet searches using "decision support tools" and related key words, and telephone interviews with DST developers and sponsors. EPA determined that 20 DSTs could be evaluated with the resources that were available. Many more than 20 tools were available, however, and the following criteria were used to select specific DSTs to include in the screening matrix:

- The end user was defined as a technically proficient field worker such as an EPA remedial project manager (RPM) or on-scene coordinator (OSC) — one who is able to use a computer but is not an expert in computer modeling.

- The tool had to be a DST. The default output would be predictive in nature and be derived from information that was input to the software.

- The tool must be freely available to the public. (This criterion limited the project to tools that were primarily developed or sponsored by government agencies.)

These criteria were used only to winnow the list of recognized DSTs to a group that became the focus of the current effort. The criteria are not intended to exclude or to define the universe of DSTs.

Based on the criteria, the following 20 DSTs were selected. (Acronyms are defined in the acronym list at the beginning of this report):

- AMDTreat
- ARAMS
- BIOCHLOR
- BIOPLUME III
- BIOSCREEN
- CAMEO
- FIELDS

- F/S PLUS
- GeoSEM
- Ground Water Sensitivity Toolkit
- HSSM
- Johnson-Ettinger Model
- MAROS
- NAS

- On Site
- RESRAD
- SADA
- Scribe
- SourceDK
- VSP

EPA solicited input from a variety of sources, including personnel from EPA program and regional offices, as well as from DOE, Air Force, and consulting companies during development of this list of DSTs.

Why Were Some Commonly Used Software Products not Included in the DST Screening Matrix?

Some software products that are commonly used in environmental projects (such as ArcView and Ground Water Modeling System [GMS]) were not included in the DST screening matrix because the products are not available to the public for free. EPA decided to focus this effort on DSTs that have been developed as freeware and thus are unlikely to have a marketing budget to promote the product.

3.0   DECISION SUPPORT TOOL MATRIX

This section discusses the specific components of the matrix and the types of functions it addresses.

3.1   THE DST MATRIX

The DST matrix is located on the FRTR Web site under Screening Tools at *http://www.frtr.gov/scrntools.htm*. The home page, shown below, is at *http://www.frtr.gov/decisionsupport*.

The matrix is a table that provides general information about each DST, such as the types of files that may be imported to, or exported from, the DST; the types of sites (contaminants and media) it may be applied to; and the functions it performs. The information is provided in columns. The six major column headings, from left to right, include: (1) Decision Support Tool, (2) Functions, (3) File Input/Output, (4) Contaminants, (5) Media, and (6) Potential Technical Team Members. Each of these major columns is described below.

Decision Support Tool: The first column of the matrix presents the name of the DST and a hyperlink to the DST's homepage. The Web site link was included to allow users quick access to download the software or to find online support. The name of the DST is also a hyperlink in the online matrix. It links the user to a summary page for the specific DST. The summary page provides the same detailed information as is described in the remainder of the matrix row, but in a format better suited for printing.

The DST summary page also includes a comments section to discuss the evaluator's observations about working with the DST (see Section 1.3 about Technical Approach). Comments are provided to help the user to work with the DST for the first time. Many of the comments reflect information that was not provided, or that was not easily found, in the DST user manual and other documentation. In many cases, the comments reflect issues that may not be readily apparent to the DST developer or to experienced users. The comments are grouped into the following categories: data loading, graphic loading, logical flow, expert knowledge, functionality, documentation, output, sources, and technical application. Comments represent the evaluator's best professional judgment about the DST based on the limited type of review discussed in Section 1.3.

Functions: The DST functions category defines the tasks the DST performs. This column lists all of the major functions the DST is able to support (as discussed in the documentation). The boxes next to the function indicate whether it was evaluated during the review. (A filled box indicates the function was evaluated; an empty box indicates it was not.) Each functional area is described in Section 3.2.

File Input/Output: The input/output columns indicate how tabular and graphical data are imported to and exported from the DST. "Interactive" input is where the user manually enters information to the DST through pick lists, dialog boxes and spreadsheet macros. "File" input indicates that a data file is the primary mechanism for entering data to the DST. The tabular and graphical input and output columns indicate, by their extensions, the file types that the DST uses.

Contaminants and Media: These columns provide the characteristics of the site that are most appropriate for the specific DST. In most cases, this information was gleaned from the DST itself, such as the types of contaminants or media listed in menus, dialog boxes, or pick lists.

Potential Technical Team Members: The potential technical team member column provides the user with an indication of types of expertise required to most effectively use the DST. This column is based on the documentation associated with the DST and, in some cases, the best professional judgment of the DST evaluator.

3.2   DECISION SUPPORT TOOL FUNCTIONS

Each DST performs unique tasks, commonly referred to as functions. The DSTs in the matrix were categorized into 12 functional areas, as identified by Web site descriptions, software menus, and user manuals. The 12 functional areas are depicted on the Front Page of the Web site and divide the DST matrix into smaller sub-matrices (on separate Web pages) that allow the user to hone in on the type of tools of interest. Individual DSTs may be included under more than one functional area. Each functional area is described in the following sections.

3.2.1   Sampling Plan Development

DSTs are used in sampling plan development to estimate the number of samples required to answer questions about sites as well as identify optimal locations for samples. Questions that can be addressed by DSTs used in sampling plan development include:

- How many samples are required to estimate the mean of a constituent's concentration?

- How many samples are needed to establish whether the concentration of a site constituent is higher than background level?

- What new sample locations should be determined in relation to existing sample locations?

The need for statistically based solutions to these questions increased in response to standardization of the data quality objective (DQO) protocol by government agencies such as EPA and DOE.

DSTs were developed as early as the 1980s in response to this need. The algorithms contained in the early disk operating system (DOS)-based DSTs have been updated and deployed in the Windows environment in tools such as Visual Sample Plan (VSP). VSP was originally developed to address sites where no samples had yet been collected; now, however, its capabilities are expanded to support secondary (adaptive) sampling, although only to a limited degree.

Graphically oriented DSTs, such as SADA and the Fully Integrated Environmental Location Decision Support (FIELDS) system, provide numerous approaches to both initial and adaptive sampling problems. Both of these programs provide algorithms to contour a set of existing data before locations for a new round of samples are estimated. Both programs also allow the user to plot sample locations on an existing base map. FIELDS, in particular, provides sophisticated tools to overlay and manipulate geographic data with its ArcView interface.

3.2.2   Visualization, Geospatial Interpolation, and Geostatistics

A growing acceptance of dynamic field investigation techniques requires that field personnel have the resources to conduct a preliminary analysis of data in the field. This change has led to greater visualization capabilities in DSTs that allow the user to rapidly assimilate new field data and display their distribution and characteristics to support dynamic decision-making in the field. The DSTs presented in the matrix bridge the gap between the sophisticated visualization tools included with expensive, proprietary platforms, and the crude, hand-drawn contours often prepared by field personnel.

At their most simple, these types of DSTs can be used to query the data and post them to a base map, allowing the field team to check the day's progress and make a preliminary evaluation of the evolving data set. Some DSTs, such as SADA and FIELDS, also provide algorithms such as inverse distance weighting (IDW) and natural neighbor (NN) to interpolate the data to produce contour maps that represent the distribution of various constituents. Some even provide tools to develop a geostatistical model of the data, allowing uncertainty to be quantified — a key element of systematic planning under the Triad approach.

3.2.3   Modeling

A predictive model — analytical or numerical — often forms the nucleus of a DST. Models embody the quantitative relationships that enable environmental professionals to make educated predictions about the state of a system and its response to change. Changes, in the context of environmental decision-making, may be removal of contaminated soil or acceleration of natural attenuation processes. The DSTs included in this functional area provide simple models that enable the user to obtain a "first cut" at solving a complex problem.

Analytical models are favored because they are relatively simple to incorporate into a decision analysis platform. For instance, one model — the one-dimensional (1D) Domenico fate and transport model — has been incorporated into many of the DSTs featured on this Web site. Analytical models are built on basic assumptions; they generally assume the media are homogenous and isotropic and thus require only a single value for each parameter of interest. An experienced practitioner recognizes the limitations of this simple analysis but exploits the efficiencies it offers.

The key to effective modeling is to understand and describe the uncertainties inherent in a model through a sensitivity analysis. Even some of the simplest DSTs (OnSite, for example) provide tools to support

this type of analysis. Having framed the possibilities with an analytical model, the practitioner may select a more sophisticated numerical model to represent the problem in greater complexity. BIOPLUME III is a numerical model that allows parameter values to be varied in a two-dimensional (2D) way. A measured, stepwise application of increasingly more sophisticated tools as the problem warrants is a resource effective approach to site characterization; the DSTs in this functional area can be used to support this type of approach.

3.2.4   Remedial Process Selection

Selecting and designing a remedial process may be the central decision a team of environmental professionals may have to make for a site. It is difficult for any software to incorporate the myriad input data and parameters that are required to select and customize a remedial process to a site's unique characteristics. Moreover, new insight and experience are constantly reshaping design and application of a remedial process, even for the most successful and widely used technologies. For this reason, many past attempts at developing DSTs to support remedial process selection have been abandoned or are no longer supported.

The DSTs included in this functional area tend to focus on specific remedial process selection issues; namely, "is remediation by natural attenuation (NA) a viable strategy at my site?" Each of these DSTs approaches the problem differently. For instance, BIOCHLOR is designed to address the application of NA to chlorinated solvent plumes, while BIOSCREEN is designed to handle petroleum plumes. The Hydrocarbon Spill Screening Model (HSSM) simulates the entire petroleum spill, from surface to ground water plume, while SourceDK is targeted at plumes with continuing sources. BIOPLUME III includes a numerical model (see section 3.2.3 about Modeling) that may be used to compare the efficacy of NA versus pump-and-treat remediation.

3.2.5   Data Acquisition

The advent of real-time measurement technologies as an investigation strategy demands greater efficiencies on the front end of the investigation: the data collection process. The DSTs included in this functional area have been developed to capture data almost instantaneously, thus allowing data analysis and decision-making to proceed in "real time."

DSTs such as Scribe and F/S PLUS can be configured to capture data in a pre-established format, known as an electronic data deliverable (EDD). For instance, data captured in a user-specified format on a portable data assistant (PDA) can be loaded to Scribe using its companion software, Scriblets. These tools exemplify the underlying principles of the Triad approach, developing the data management protocol during systematic planning and then implementing it in real time using measurement technologies that can collect data points, in some cases, in a matter of seconds.

DSTs that are currently under development will be capable of capturing data streams generated with radiological detectors, x-ray fluorescence (XRF), and other sampling and analysis tools, merging their data with spatial data acquired with global positioning system (GPS) instruments and transmitting the data to a laptop via wireless technology.

3.2.6   Data Management

New data management tools allow a greater number of project teams on small- to mid-size sites to realize the benefits of maintaining data in a relational database. The ability to sort, query, post, and plot data in the field frees project teams from the need to load data in the office setting. With a modest amount of training or experience, most members of the project team can learn how to carry out basic functions on

Scribe, for example. On Triad projects, this ability means that the field team can conduct an initial evaluation of the data moments after a measurement is made with a real-time tool. Quality control can then be conducted nearly the same time as that data are generated, and errors can be caught and corrected early in the process, before resources are inadvertently used or equipment is demobilized from the field.

Specialized tools tailored to work with certain types of data are also being developed from a Microsoft Access shell. One example, Monitoring and Remediation Optimization System (MAROS), can be used to manage ground water data at smaller sites.

3.2.7   Long-Term Monitoring Optimization

New interest in DSTs that are focused on optimizing long-term ground water monitoring systems reflects the importance to EPA and other governmental agencies of developing better methods for designing monitoring systems that may be in place for 30 years or longer. MAROS is a package of statistical approaches for analyzing trends in ground water concentrations at individual monitoring wells to evaluate where monitoring wells should be added or removed from the overall well network. Other tools may soon be widely available that use water level, rather than concentration, data to conduct a similar analysis.

3.2.8   Statistical Analysis

As the field of environmental problem-solving has matured, statistical approaches have become more fully integrated into a variety of decision types, including sampling, risk assessment, and trend analysis. One area where a statistically based solution may be used is the generation of a sampling plan. SADA and VSP are designed to implement statistically based sample plans. GeoSEM and Army Risk Assessment Modeling System (ARAMS) use statistical methods to estimate exposure point concentrations for risk assessment. MAROS uses statistical methods such as regression analysis to establish whether a statistically significant trend exists among measurements at a well. Although these examples involve disparate types of problems, they exemplify how a DST can support a decision by providing a statistical underpinning to the decision-making process.

3.2.9   Emergency Response/Compliance

An example of a DST used to support an environmental response action is the CAMEO family of DSTs in the areas of emergency response and environmental compliance. CAMEO initially was developed to assist firefighters and first responders with easily accessible and accurate response information. CAMEO has been enhanced to provide emergency planners with a tool to enter local information and to develop incident scenarios to better prepare for chemical emergencies. In addition, CAMEO supports regulatory compliance by helping users meet the chemical inventory reporting requirements of the Emergency Planning and Community Right-to-Know Act (EPCRA). Additional tools have been integrated as the use of CAMEO has grown, including a mapping tool (MARPLOT) and an air dispersion model (ALOHA).

3.2.10   Risk Assessment

The risk of adverse effects to human health or ecological receptors is the primary driver at most environmental sites; thus, it follows that risk assessment and evaluation is a major area for development of new DSTs. These tools range from individual components used in certain types of risk calculations, such as the Johnson-Ettinger model to evaluate one pathway (volatilization of chemicals to indoor air), to DSTs such as GeoSEM, SADA, and FIELDS, that are designed to calculate exposure point concentrations and aerially distributed risk values.

The most comprehensive risk tools, RESRAD and ARAMS, provide a collection of models and databases that the user may link together based on the CSM. ARAMS, which is based on DOE's Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES), provides an object-oriented environment where the user can "build" the CSM interactively. The interactive CSM in ARAMS is an example of how the new environmental investigation tools and techniques focus on development and maturation of the CSM.

3.2.11   Site Screening

A site screening tool uses a "scorecard" to indicate to the user whether certain approaches can or must be considered for site remediation or cleanup. These DSTs are quick to use and provide "ballpark" answers to broad questions. The Ground Water Sensitivity Toolkit, for instance, uses a simple questionnaire as its framework. The user responds to a series of inquiries designed to offer the decision-maker insight into how resources should be allocated based on the sensitivity of a ground water resource to contamination at a site and the value of the ground water resource. Similarly, BIOCHLOR provides a scorecard to indicate the efficacy of NA at the user's site. In both instances, the DST prompts the user for site-specific information, processes the information through a "canned" logical process, and calculates a rank or score that compares the user's site against a knowledge base.

3.2.12   Cost Estimation and Cost-Benefit Analysis

Real-world solutions to environmental problems are largely driven by — or are at least sensitive to — the estimated cost to implement the remedy. Many consider cost estimation to be a discipline unto itself, and several comprehensive software programs are available (generally for a fee) to assist in general cost estimation for construction of any type of system. Several of the DSTs featured on the matrix, however, are specialized tools that may be used to provide crucial support to the components of the cost estimate that are driven by geospatial information. FIELDS, SADA and VSP are designed to use information about the geographic distribution of previous samples and the decision logic inherent in the DQO process to estimate the number and cost of samples required to solve an environmental problem. FIELDS also includes a "remediation tool" that uses interpolated data and user-provided unit costs to estimate the cost of a removal action for soil. AMDTreat, on the other hand, is structured around estimating costs for a specific type of environmental site setting: acid mine drainage (AMD). Geochemical information is the primary input that drives its calculators and spreadsheets, and ultimately the cost and feasibility of remedial options.

4.0   RELEVANCE OF DSTs TO THE TRIAD APPROACH

The Triad approach focuses on the explicit identification and management of decision uncertainty as the organizing principle for conducting environmental projects, both characterization and remediation. It emphasizes collaboration among stakeholders and use of a CSM as a means of identifying and achieving mutual goals. The Triad approach also seeks out and accommodates the latest techniques and technologies to manage uncertainties in decisions and data, to condense the decision-making process through the use of real-time measurement and analysis tools, and to facilitate the rapid dissemination of data and decisions through the stakeholder community to close the feedback loop and shorten the project life-cycle. Use of DSTs is becoming an increasingly important component of the Triad approach because of their ability to help achieve all of these goals.

This section discusses the relevance and use of DSTs in the matrix to various components of a Triad project, including:

- Developing a CSM

- Managing uncertainty

- Undertaking dynamic work planning

- Performing real-time data capture

- Maintaining stakeholder communication and documentation

4.1   DEVELOPING A CSM
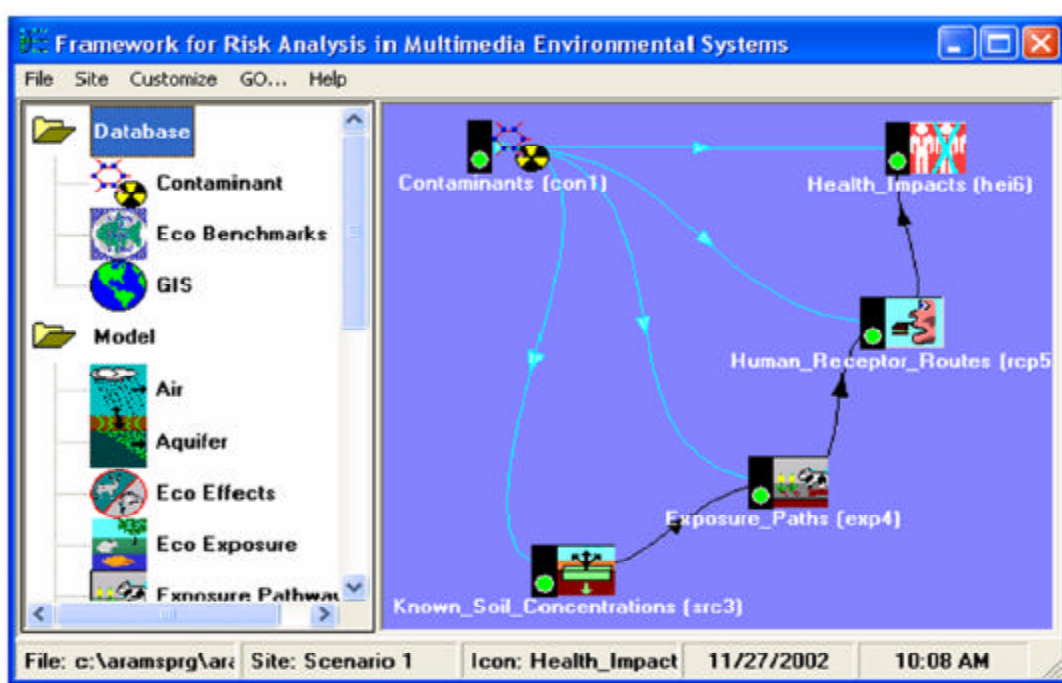##   FEATURED DST: ARAMS

The Triad practitioner uses a CSM to organize and illustrate the understanding of the physical and chemical processes, geologic or hydrogeologic structure, and anthropogenic factors that interacted to create the contaminant distribution at the site. The CSM is fundamentally important to a Triad-based investigation in identifying additional data gaps, adjusting the approach to the investigation, and making project decisions as the field program progresses.

There are two ways to define a CSM. A CSM is sometimes described in the context of a risk assessment as a block diagram that links the contaminant sources, transport pathways, and receptor locations. This type of CSM is also known as a contaminant-pathway-receptor diagram. However, Triad practitioners have a broader definition of a CSM, which is the working hypothesis or multiple working hypotheses that unite and explain the observations about the site.

ARAMS uses the contaminant-pathway-receptor CSM to provide the framework for its graphical user interface (GUI). When the user selects a CSM component (source, pathway, or receptor) from the program's menu, the GUI installs an icon representing the component in its main view and links it to the other components the user has selected. The user can click on the icon at any time to open the various databases, models, and utilities associated with the component (Figure 1). Thus, the simplified contaminant-pathway-receptor CSM serves as the unifying concept for an analysis of risk with ARAMS.

The Triad CSM, however, goes beyond the "box and arrow" structure of the pathway-receptor diagram to explore in greater detail the site characteristics and phenomena that must be understood to make decisions about sampling, remediation, and site reuse. Any one of the DSTs discussed in this report, and particularly the modeling and data visualization DSTs, may enable the practitioner to support or reject the working hypothesis that explains the site.

FIGURE 1
ARAMS – EXAMPLE OF GRAPHICAL USER INTERFACE

4.2   MANAGING UNCERTAINTY
FEATURED DST: VISUAL SAMPLE PLAN, ON SITE

Uncertainty is inherent in all measurements, calculations, and models. The Triad practitioner acknowledges all forms of uncertainty and attempts to address it using a variety of techniques, many of which are incorporated in the DSTs featured in the matrix.

VSP is a DST that was specifically designed to help project teams develop statistically-based sample plan designs that comply with requirements for Step 7 of the DQO process (optimize the design for obtaining data). The Triad practitioner recognizes that classical statistics, which assumes that all measurements are taken from a single, randomly-distributed population, is not always an appropriate approach to developing a sample plan for an environmental investigation. Still, there are instances where it can be applied, provided that the practitioner understands both the underlying assumptions of classical statistical methods and the heterogeneous nature of contaminant distributions. Examples of situations that may warrant use of a classical statistical approach include: (1) sites that are not contaminated, (2) sites that have been cleaned up, (3) sites where contaminants are distributed randomly, or (4) sites where contaminants appear to exist in stratified populations that are internally homogenous provided that the stratified area can be delineated and sampled (Crumbling and others 2004b).

For these situations, VSP can be used to calculate the number of samples needed to test a hypothesis about a sample population, such as, "is the mean of the analyte of interest above or below an action level?" The user provides an estimate of the standard deviation of the parameter of interest and two error rates. (These are the limits specified in Step 6 of the DQO process). The false rejection decision error (also known as a Type I or alpha error) is rejecting the null hypothesis when it is actually true. In cases where the null hypothesis states that the site is "dirty" (that is that the population parameter of interest

exceeds the cleanup standard), this refers to concluding the site is "clean" (below the cleanup standard) when it is actually dirty. The "false acceptance decision error" (also known as a Type II or beta error) is the inverse situation – accepting the null hypothesis when it is actually false (or concluding the site is dirty when it is actually clean).

Together, the two rates define the width of the "grey region," that is, the range of estimated means that are not definitive. VSP provides an interactive tool, the Decision Performance Goal Diagram (DPGD), which shows how the width of the "grey region" of uncertainty changes with a change in an input variable, such as the total number of samples (Figure 2). The DPGD provides an interactive tool allowing the user to adjust the number of samples to achieve a tolerable level of uncertainty, that is, a data set that can be used to make informed decisions about the site.

FIGURE 2
VSP – EXAMPLE OF DECISION PERFORMANCE GOAL DIAGRAM
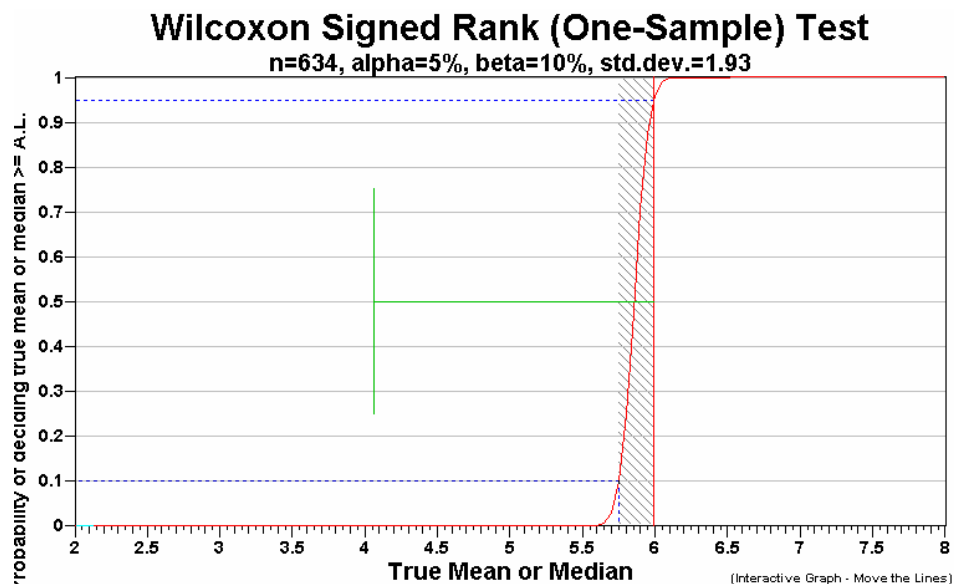
Modeling is another area where experienced practitioners explicitly address uncertainty by conducting a sensitivity analysis to evaluate how uncertainty in each parameter will affect the model's predictions. On Site is a package of calculators and utilities that is available online and includes a version of the 1D Domenico fate and transport model. Output graphs display the effects uncertainty in parameter values have on the model's predictions. The user inputs a range, instead of a value, for nine different input variables, and the model displays a set of breakthrough curves that show the range of possible outcomes as each parameter is varied. Predictions obtained with other models can be tested with On Site. If the curves in the output extend beyond a range of tolerable outcomes, the user should collect more data on the parameter to narrow its range (Figure 3), or consider a different remedial approach.

FIGURE 3
ON SITE – EXAMPLE OF UNCERTAINTY IN MODEL PREDICTIONS
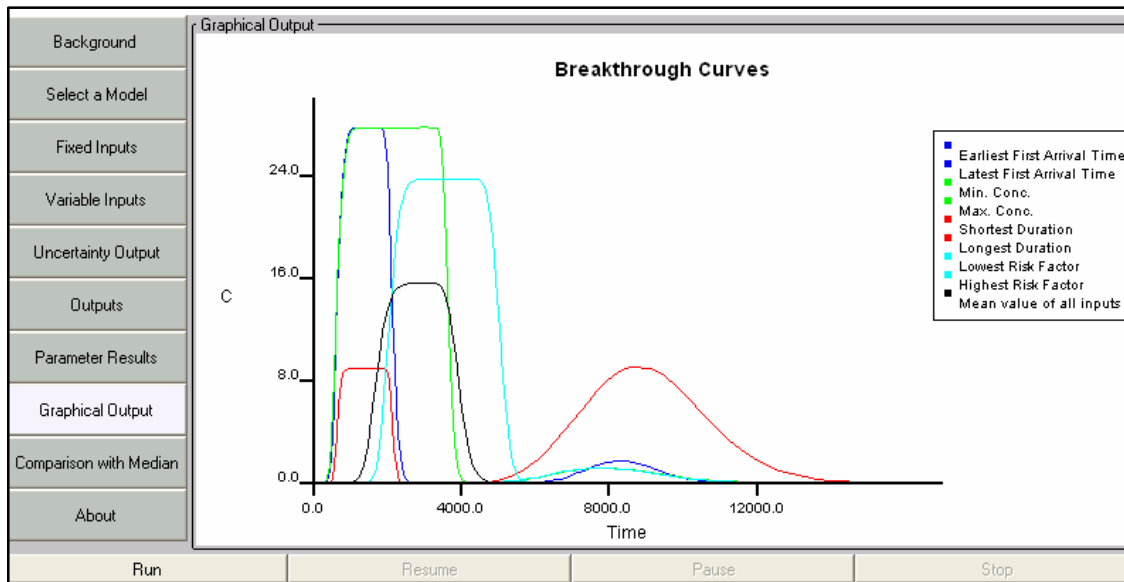
4.3   UNDERTAKING DYNAMIC WORK PLANNING
FEATURED DSTs: SADA, FIELDS

Dynamic work planning, one of the three elements of the Triad approach, can be implemented with the help of many of the DSTs in the matrix. A successful dynamic work plan strategy requires that an initial round of data be loaded into electronic format, then queried, contoured, and displayed in a variety of ways. In most cases, it is crucial that locations for subsequent rounds of sampling are identified rapidly. The emphasis in the Triad approach on establishing a sound scientific basis for any significant expenditure of resources favors tools that provide support for selecting the locations of these samples.
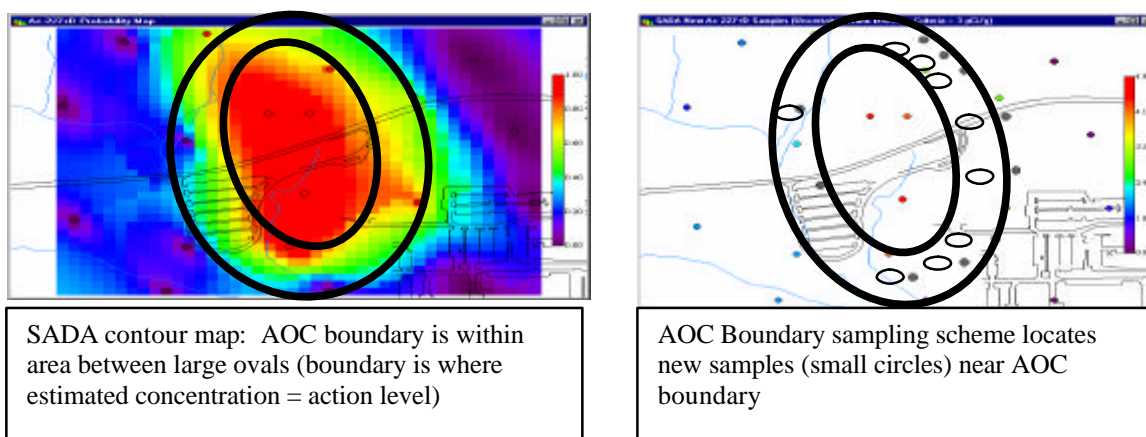
Data visualization and sample plan development are crucial to executing a dynamic work planning strategy. The two DSTs that are included in both of these functional areas are FIELDS and SADA. Both of these tools are comprehensive in scope; they can provide cradle-to-grave support to small- to medium-sized projects and sites.

SADA's greatest strength is its variety of sampling schemes. SADA features 12 initial and 14 secondary (also referred to as "adaptive") sampling schemes. Initial schemes can be generally divided into schemes that place samples on regular spacings (nodes) on a systematic grid, schemes that randomly place samples at nodes of a regular grid, and schemes that place samples at random locations within a random selection of the cells in the grid (often referred to as an "unaligned" grid).

More important to dynamic work planning are the adaptive schemes. Adaptive schemes may be used to target the portions of the site that are expected to exhibit certain characteristics based on the contaminant distribution estimated from the initial round of samples. Adaptive schemes generally require a grid of estimated values developed from pre-existing data (analogous to a set of contours) and a user-defined number of new samples. Given this information, the program chooses an optimal location based on the desired criterion (such as maximum estimated concentration, maximum estimated variance, or closest estimated value to an action level). An example of the latter criterion is provided by SADA's Area of

Concern (AOC) Boundary sampling scheme and is depicted in Figure 4. After the optimal location is identified and a new sample is placed at the node of an empty grid cell (a cell that does not contain existing sample data), the program cycles through the algorithm again to select the most optimal location of the remaining empty cells and continues this process until all of the new sample locations have been established.

FIGURE 4
EXAMPLES OF CONTOUR MAP AND NEW SAMPLE MAP IN SADA

SADA contour map: AOC boundary is within area between large ovals (boundary is where estimated concentration = action level)

AOC Boundary sampling scheme locates new samples (small circles) near AOC boundary

FIELDS also contains sampling schemes such as unaligned grid (initial) and adaptive fill (adaptive), but its strength is its powerful visual display and presentation tools. FIELDS is actually a set of ArcView extensions and most of the ArcView functionality is incorporated into FIELDS.

Both programs also provide a module to calculate areas and volumes that exceed either a numeric action level or an estimated risk value and will recalculate these quantities after each new round of samples. These modules make SADA and FIELDS ideal for updating the CSM in an iterative manner as field work progresses.

4.4 PERFORMING REAL-TIME DATA CAPTURE
FEATURED DST: SCRIBE

A real-time data acquisition, management, and communication strategy enables the project team and stakeholders to work efficiently together during the field program. Data acquisition DSTs are those best suited to obtain data from real-time measurement technologies such as an XRF sensor or a radiation detector. Scribe is a database designed by EPA's Environmental Response Team (ERT) that can be used in conjunction with a companion software called Scriblets to rapidly load real-time data into a database. (Scriblets is designed to log data with a PDA.)

Scribe and Scriblets were recently deployed at a Brownfields site in Milltown, New Jersey. Information from more than 600 soil samples and 130 ground water samples collected from 336 soil, sediment, surface water, and ground water sample locations were loaded to Scribe. The data were loaded daily and were available immediately for sorting and querying. Participants report that Scribe facilitated "in the trailer" review of data and enabled the project team to plan the next day's sample locations before team members left the site for the day.

Scribe also incorporates modules to generate labels and chains-of-custody. Most importantly, Scribe makes available in real time many of the features and advantages of a relational database to smaller projects and sites that, in the past, may not have had the resources or time to load data into a structured, electronic format while the team was still in the field.

4.5   MAINTAINING STAKEHOLDER COMMUNICATION AND DOCUMENTATION FEATURED DST: MAROS

DSTs can foster trust and facilitate communication among stakeholders by making the process more collaborative and transparent. DSTs promote transparency because (1) most DSTs feature a "stored process" that can be approved by all parties during the planning process, and (2) most DSTs provide a reporting utility, allowing the user to export and share formatted reports of DST results. The importance of this capability is acknowledged in the matrix by listing "Print report?" as a separate column in the matrix. MAROS is one example of a DST that has a well-integrated reporting function.

With its emphasis on optimization of existing monitoring systems, MAROS may seem an unlikely example of a Triad-oriented DST; however, the systematic planning process encourages stakeholders to adopt a long-term perspective, one that is focused on reuse and the ultimate disposition of the site. MAROS provides several different statistical methods to evaluate contaminant concentration trends in individual wells and to assess the adequacy of the network as a whole. The various analyses provide multiple "lines of evidence" that are combined in the MAROS Analysis module to provide users the scientific basis to make long-term monitoring decisions.

MAROS can generate reports after any of its four main modules has been completed, or a summary report can be generated through its fifth module, the MAROS output module. The menu system in the output module allows users to document the results of all of the component analyses, or of any single analysis in a summary report format (text file), graphs (Excel) or in a database (Access) file format. An example of an output report is provided in Figure 5.

FIGURE 5
MAROS OUTPUT REPORTS PROVIDING STATISTICAL TREND ANALYSIS (left)
AND MONITORING SYSTEM ANALYSIS (right)
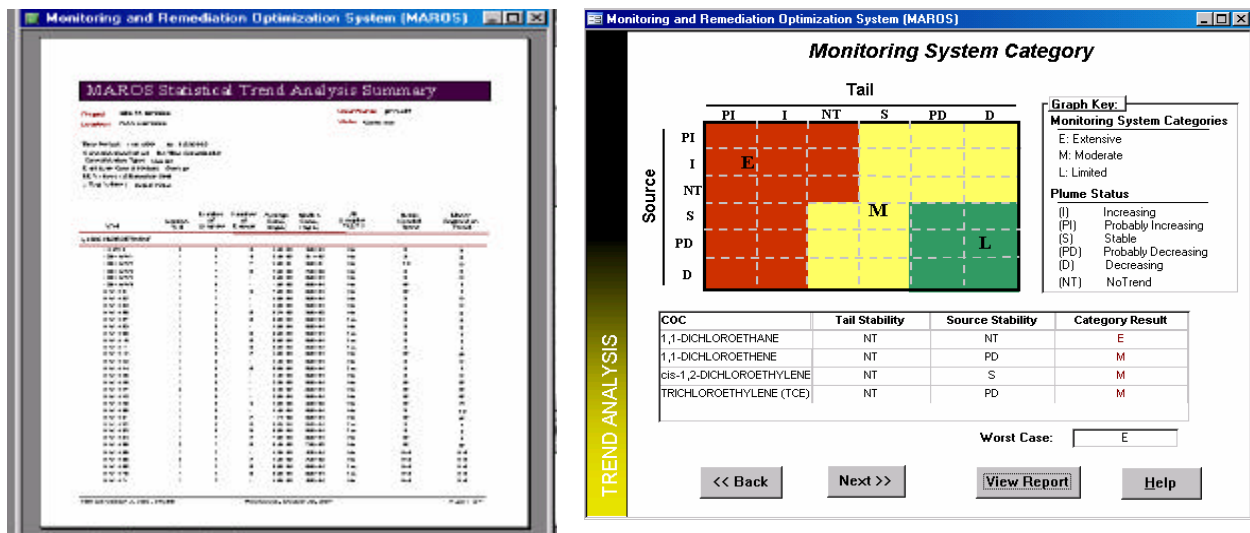
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