

**Case Study for the Use of a Decision Support Tool:
Using SADA to Guide Contaminated Soil Removal at the
Barker Chemical Company Site, Inglis, Florida**

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Prepared by:



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Comments or questions about this report may be directed to Stephen Dymant, EPA, OSRTI (5203P), 1200 Pennsylvania Avenue NW, Washington, D.C. 20460; telephone: (703) 603-9903; e-mail: dymant.stephen@epa.gov.

Foreword

This case study is one in a series designed to provide information on use of decision support tools that support the use of data, models, and structured decision processes in decision-making. These case studies include reports on selected tools that have been used to support activities such as site assessment and remediation, data management and visualization, and optimization. They are prepared to offer operational experience and to further disseminate information to project managers, site owners, environmental consultants, and others who wish to screen decision support tools and benefit from their previous use at sites.

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1.0 SITE BACKGROUND

The Barker Chemical Company (BCC) Superfund site is a former fertilizer manufacturing facility and shipping terminal located near the Gulf Coast of Florida, 80 miles north of Tampa. The U.S. Environmental Protection Agency (EPA) used the Spatial Analyst and Decision Assistance (SADA) software to guide the removal of soil contamination attributed to the BCC site from 42 residential parcels.

The fertilizer manufacturing facility, which operated from 1904 until 1931, treated low-grade “hard rock” phosphate ore (commonly called phosphate rock) with sulfuric acid to produce ordinary superphosphate, a solid fertilizer product. The sulfuric acid process produced solid waste that consisted of pyrite cinders that likely contained significant quantities of arsenic and lead from the ore roaster. The waste pyrite cinders were reportedly stockpiled in an area east of the plant, used as fill material in roadbeds, or used to control vegetation on the plant property (Tetra Tech 2005).

The BCC Site is relatively flat with elevations ranging from sea level to 15 feet above mean sea level (AMSL). The BCC Site is bounded to the north, east, and west by mixed residential, light industrial, agricultural, and undeveloped property. The Withlacoochee River, which flows into the Gulf of Mexico 7 miles to the southwest, borders the site to the south. The site is composed of two distinct areas: Garden Mall Court (GMC), and the Former Inglis Road (FIR). GMC is a residential development of 96 acres located at the former phosphate plant, and FIR is an abandoned roadbed that can be traced for several miles northeast of GMC. The roadbed was constructed using waste material from the phosphate plant.

The EPA conducted remedial investigations at the site from 1995 to 2005. Removal actions were conducted in 1996 and 2005 at areas of the BCC Site where the primary constituents of concern (COC) — arsenic and lead — were identified at concentrations above EPA time-critical removal levels. Some soil with arsenic and lead at concentrations above the EPA time-critical removal levels may have remained at locations where the soil removal actions occurred, usually where physical conditions prevented further excavation. A final removal action was conducted in 2006 to address these gaps and additional residential parcels where EPA had only recently been granted access by the property owners.

Pre-removal samples were collected at FIR in October 2005 and at GMC in December 2005 to provide the baseline data for this final removal action. The FIR alignment was identified from maps and from ground surface features, particularly a reddish coloration that is associated with the cinder material. The FIR was divided into 100-foot by 75-foot wide segments. Each segment was divided into 3 sub areas or “grids”: a central 25-foot wide grid representing the roadbed flanked by two 25-foot wide easements. The GMC area is divided into private parcels that range from 0.1 acre to more than 1 acre. Parcels were

subdivided into 1 to 8 grids, depending on the size and shape of the parcel. Discrete sample locations were developed based on a five-spot pattern in each grid.

Samples were analyzed in the field using an X-ray fluorescence (XRF) field instrument, and a portion of the samples were sent to an off-site laboratory to develop a confirmation data set. The five aliquots were measured with the XRF and then composited in most grids. The composite sample was also measured with the XRF and then sent off to a laboratory for analysis. All five samples at one of every eight grids were sent to an off-site laboratory for analysis after field measurement with an XRF.

In 2006, EPA evaluated analytical results for soil samples collected in 2005 at the GMC (Tetra Tech 2006a) and FIR (Tetra Tech 2006b) to support removal of all soil that still contained contaminants at concentrations that exceeded time-critical removal levels of 40 milligrams per kilogram (mg/kg) for arsenic and 400 mg/kg for lead. Furthermore, EPA agreed to evaluate whether concentrations of arsenic and lead could be delineated in soil to a level that would satisfy the Florida Department of Environmental Protection (FDEP) criterion for soil considered elevated in arsenic (8 mg/kg) and, if technically feasible, to excavate and remove this soil.

Lab-analyzed composite samples were used as the primary decision data for determining whether a removal action was warranted at a particular parcel. However, the extents of the areas to be excavated were estimated by interpolating (contouring) discrete samples.

2.0 USE OF DECISION SUPPORT TOOLS

Real-time measurement technologies, such as XRF, are ideal tools to guide time-critical removal actions. Similarly, decision support tools (DST) provide their greatest support to a removal action when their output can be integrated with real-time measurement tools in the field. For instance, DSTs may be used to direct sampling with the XRF to delineate the boundaries of soil with elevated levels of COCs. The SADA software was selected as a DST for the BCC removal project because of its versatility for managing and interpolating data to delineate areas of concern (AOC) to be removed.

SADA was first used in October 2005 to prepare visualizations of the historical data and to identify data gaps before the October and December 2005 sampling events were conducted. A new SADA file was created after the sampling event, keeping the new data separate from the historical data. SADA was subsequently applied to develop contour maps of arsenic and lead concentrations and AOC maps of arsenic and lead using various regulatory thresholds. AOC maps were used to delineate the portion of the site where concentrations exceed the EPA and FDEP regulatory thresholds and estimate the volume of soil within these areas. The AOC data were exported from SADA, post-processed in ArcGIS, and loaded

to portable global positioning system (GPS) units as polygons that bounded the soil that was above regulatory thresholds. The polygons enabled field personnel to navigate to the planned excavation extents in the field and guide the excavation.

2.1 PRE-PROCESSING AND LOADING THE DATA

Widespread concentrations of arsenic that were above the FDEP removal level, yet below the XRF instrument's detection limits, provided a significant challenge to AOC delineation. Table 1 illustrates this challenge by showing the low rate of arsenic detections using the XRF compared with the arsenic detections from laboratory analysis. Note the number of detections of lead using the XRF is much higher.

Table 1
Percentage of Detections for XRF and Laboratory Data

Site	Analyte	XRF				Laboratory				
		Detect	Nondetect	Total	% Detect	Detect	J-qualified	Nondetect	Total	% Detect
GMC	As	25	1178	1213	2.1%	194	35	182	411	55.7%
GMC	Pb	768	435	1213	63.3%	317	91	6	414	98.6%

Notes:

% Percentage
 As Arsenic
 J-qualified Estimated value below detection limit
 Pb Lead
 XRF X-ray fluorescence

The low action level for arsenic required the use of regression equations to correlate the concentration of arsenic (generally below detection limits) to the concentration of lead, which was generally detected above the instrument's detection limits. A regression equation that related concentrations of lead measured with the XRF to concentrations of arsenic measured in the laboratory yielded a good correlation (coefficient of 0.92). The equation was embedded in a spreadsheet to transform results for lead to estimated concentrations of arsenic wherever the XRF yielded a lead concentration but not an arsenic concentration. Although the regression analysis was conducted outside of SADA, the data set was loaded to SADA as a comma-delimited file.

SADA includes a data-loading module that is easy to use and that contains automatic routines for matching columns in the input data file to SADA data requirements, error checking, and duplicate data resolution. The column matching routine requires that the user identify five columns of data needed to run SADA, including easting, northing, and depth (to give SADA the location of each data point in three-dimensional space), the name of the analyte, and the result of each individual analysis. All other data attributes may be loaded to SADA in additional columns; these attributes may be posted on SADA visualizations, but contour maps cannot be created of these other data attributes.

An unconventional data identification and column matching protocol was used because of the different sample types involved in the sampling program. Instead of using the “analyte” column to identify different chemical species, it was used to distinguish between different sample types (aliquot, composite, and grab), allowing each group of samples to be plotted and mapped, independently or collectively. As a result of the structure of this input data file, the analytical results for other chemicals (such as lead) were available only as information that could be posted. Therefore, a second data file had to be created where the “result” column was populated with results for lead to contour lead data.

Finally, it may be useful to note the other modifications that were made to the input data file, which must be a “flat” file exported as a comma-delimited file from Microsoft Access, Excel, or similar database or spreadsheet programs. SADA does not allow “null” values; thus, the file must be checked for blank cells and these cells must be populated, or the row deleted from the input file. The following modifications are therefore commonly required before data can be imported to SADA:

- Make certain that the Z coordinate (depth or elevation) is in the same units as the easting and northing. This step usually requires the conversion of location data from a latitude/longitude system to a state plane system.
- Create a “sample midpoint” column if depths are given as an interval (the depth must be a point value).
- Create a “data qualifier” column populated with binary data (detections assigned a value of “1” while nondetects are assigned a value of “0”).
- Code sample media using the two-character alphabetic code that is specified by SADA (for instance, soil is “SO,” groundwater is “GW”).

2.2 DATA INTERPOLATION (MAPPING)

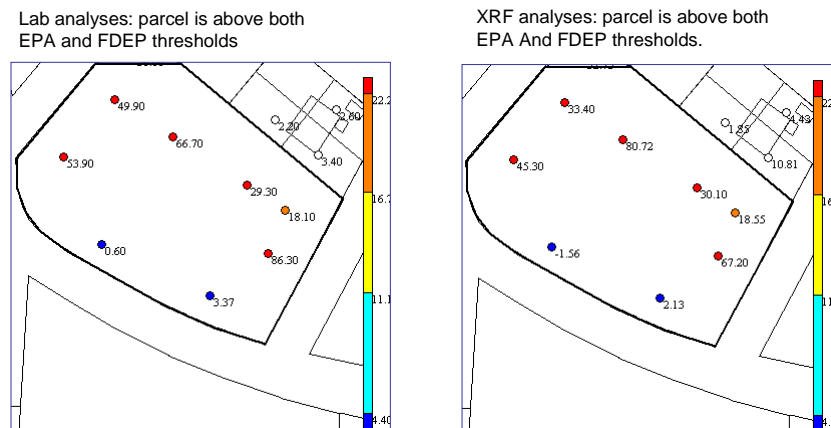
The data set that was loaded to SADA contained all the results from the October and December 2005 sampling events. The maps created in SADA were output from SADA and pasted into PowerPoint slides. One PowerPoint file was developed for each parcel. The PowerPoint file included posted data maps to show the results of each sample type and contour maps that used all of the “point” data as the input data for interpolation. (Composite sample data could not be contoured because there are too few data points to support the contouring process.)

Posted data maps show the values of each composite result beside a color-coded marker that indicates the sample location. The default option for plotting data maps uses a legend with a continuous color ramp. However, SADA also allows the user to define a custom “categorical” legend with colors that correspond to user-specified “less-than” intervals. This option is generally better to use with environmental data

because a single result that is many orders of magnitude higher than the remaining data will skew the color ramp such that the majority of the data appear to have the same low value. The categorical legend was used in the example below, which shows the results of composite samples that were collected at parcel BCC-103 and analyzed in the field with an XRF (on the right) and later in a laboratory (on the left).

Some data manipulation was required to use composite sample results for decision purposes. Evaluation of the discrete data sets indicated a near constant relative standard deviation for all data sets. Using this information, the project team calculated a modified action level of 22 mg/kg for arsenic to use with the composite samples, based on the 95 percent upper confidence limit (UCL) relating the composite sample results to an average of five discrete sample results from the same grid. (A composite sample below the modified action level of 22 mg/kg has a 95 percent probability that it correctly indicates the parcel is “clean”, as indicated by an average of five discrete samples collected from the same grid.) For this reason, the scales (color ramps) shown below on Figure 1 were adjusted by reducing the arsenic action level from 40 mg/kg to 22 mg/kg.

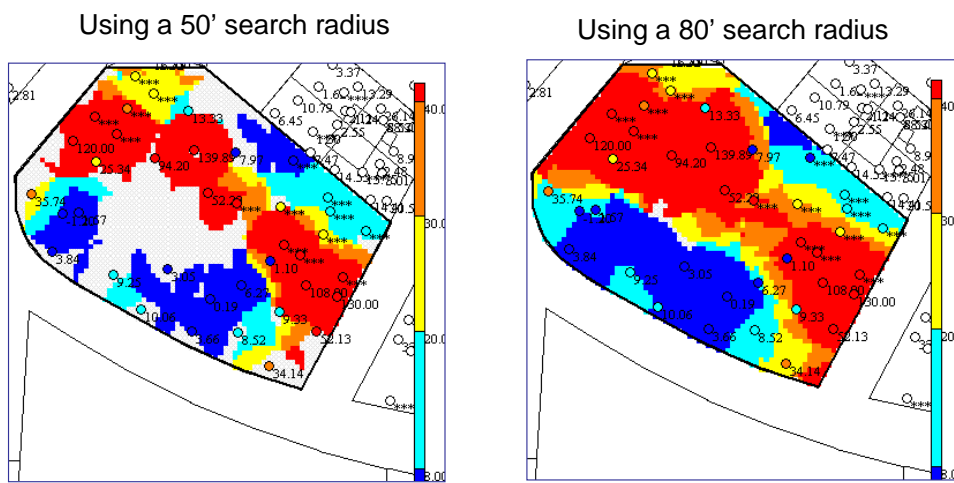
FIGURE 1
DATA POST MAP OF COMPOSITE SAMPLE RESULTS
PARCEL BCC-103, BARKER CHEMICAL COMPANY SUPERFUND SITE



Contour maps were also prepared for this parcel. As discussed above, all point data were included in the data set that was used as the basis for the contours. Contouring data requires the user to define a grid that will be used to estimate the values at the grid nodes. In this case, a 5-foot by 5-foot grid was used. The contour maps were prepared using the inverse distance weighting (IDW) interpolation scheme. The IDW scheme is one of the easier interpolation schemes to implement in SADA. The IDW scheme does not require the user to conduct a geostatistical analysis or make assumptions on the spatial correlation of the data; rather, the IDW algorithm weights nearby data points by the square (or cube, depending on user

input) of the distance from the node to the data point. The user must also define neighborhood search parameters. Neighborhood search parameters dictate which data are used to estimate a value at each node of the estimation grid by specifying the radial distance of the search neighborhood. This procedure is essentially like throwing a circular “net” around each grid node to capture the data that will contribute to the estimate; the search radius defines the size of the “net.” The search neighborhood is also defined by the data minimum and data maximum the user selects. If the number of data points within the search radius is less than the data minimum, the algorithm will not calculate an estimate and will leave the cell blank. If there are more data points than the data maximum within the search radius, the algorithm will ignore the additional points (whichever are the farthest from the node). The effects of two different search radii are shown in Figure 2, below.

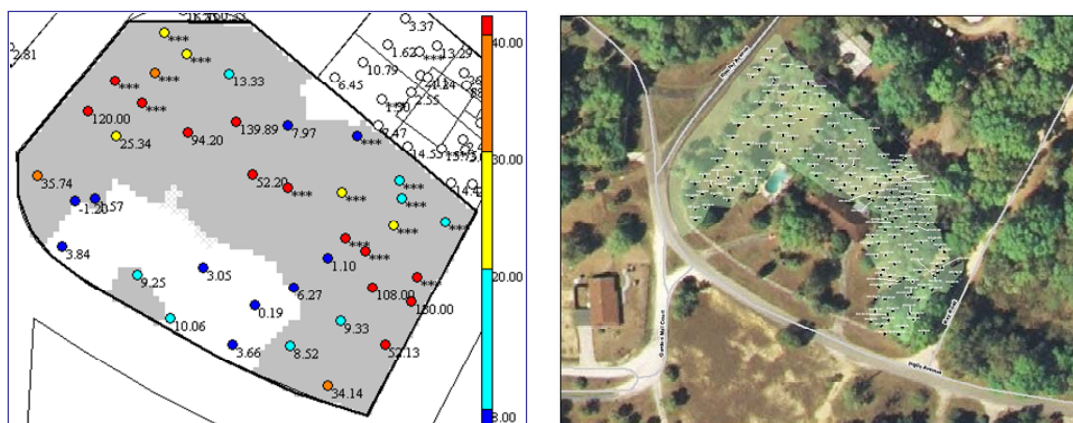
FIGURE 2
CONTOUR MAPS OF SAMPLE RESULTS (POINT DATA)
PARCEL BCC-103, BARKER CHEMICAL COMPANY SUPERFUND SITE



Note: asterisks denote co-located samples. Current version of SADA does not post multiple labels from a single set of coordinates.

After contour maps were prepared, SADA was used to estimate the extent of the AOC where contaminant concentrations were above an action level. The AOC module was selected after the data were contoured. The “user defined decision goal” was set equal to the action level of interest to estimate the volume of soil with an average contaminant concentration above the action level. SADA maps the area that is above the level and provides the estimated volume at the bottom of the screen. The AOC estimated for arsenic (based on the FDEP action level of 8 mg/kg) at parcel BCC-103 is shown in Figure 3. Lead was estimated to be at concentrations below the FDEP and EPA thresholds everywhere in the parcel. The area above the FDEP action level for arsenic at the parcel equaled 1.48 acres, corresponding to a volume of 63,725 cubic feet that would have to be removed to comply with this action level.

FIGURE 3
AOC MAP FOR ARSENIC IN THE 0.0 TO 1.0-FOOT INTERVAL
PARCEL BCC-103, BARKER CHEMICAL COMPANY SUPERFUND SITE



SADA AOC Map: Shading indicates interpolated arsenic concentrations are ≥ 8 mg/kg.

Excavation Map: Shading indicates area that was excavated.

Digital AOC maps were exported from SADA as Excel files. While in the AOC mode, the user clicks the “get information” button, which generates a table of integers, ordered by row, column, and layer of the estimation grid with additional columns that specify the state plane coordinates of the cell. The final column gives the “value” of the cell, which provides a binary indicator (1 = “dirty” and 0 = “clean”) of the estimated value versus the user-specified action level. A text value “not estimated” is output for the cell if an estimate was not generated because there were too few data within the search radius. The table was exported to an Excel file by clicking the Excel icon at the top-right corner of the information window. Post-processing of the file was conducted in ArcGIS to convert the integer data to a polygon that outlined the area above the action level. The polygon shape files created in ArcGIS were loaded to a GPS backpack unit that allowed personnel in the field to direct the excavation crew in the field. The excavation boundaries interpolated by SADA were demarcated on each property. Prior to excavation, the excavation boundaries were screened with an XRF to verify areas of contamination interpolated by SADA and refine the excavation boundaries, as needed. Field verification of the SADA-interpolated excavation boundaries indicated that SADA adequately represented the areas that required excavation.

3.0 LESSONS LEARNED

SADA provided visualizations and analyses that allowed both agencies (EPA and FDEP) to develop and execute plans to achieve their goals: EPA identified parcels where soil removal was required based on lab-analyzed composite samples exceeding the EPA removal criterion of 40 mg/kg. Once parcels where concentrations of COCs exceeded the 40 mg/kg criterion were identified, the excavation was extended to remove the entire area that was estimated to exceed the FDEP criterion of 8 mg/kg, based on AOC maps of discrete sample results that were interpolated (contoured) in SADA. As a final step, SADA contour maps were created for the parcels where the contaminant concentration in soil was estimated to exceed FDEP, but not EPA, criteria. These maps were provided to FDEP to guide excavation that may be pursued under a state program.

Historical data, spanning 10 years of investigation, were loaded to SADA and contoured while the sampling plan was being developed. These maps were used to identify data gaps and shortcomings of previous sampling efforts. After the sampling effort, a new SADA file was created that included only these new results. SADA maps were created to illustrate different approaches for evaluating the XRF data for arsenic that were below detection limits and their effects on data density and the size of the estimated AOC. These maps also were used to support the decision to use a regression equation to estimate arsenic values for results that were below field instrument detection limits.

Using the regression equation, the density of data from the 2005 sampling effort was adequate to create interpolation maps of both lead and arsenic concentrations. The new data were interpolated in SADA to create maps indicating the volume of soil that exceeded the 40 mg/kg and 8 mg/kg action levels. SADA enabled the EPA to conduct removal activities on 42 parcels throughout the FIR and GMC areas of the Barker Chemical Company site in approximately 6 months.


Confirmation samples were collected from the floors of the excavations at a rate of one every 250 square feet following excavation. These were compared to the EPA action level of 40 mg/kg. Of the 75 samples collected, only two were above the action level. In both cases, further excavation was constrained by shallow limestone bedrock.

The SADA maps provided an updated characterization that was more accurate than pre-existing maps and information. For instance, at parcel 103, a pre-existing map of the extents of the 1996 removal actions

was available. The pre-existing map indicated that the excavation encompassed most of the southern two-thirds of the parcel. SADA maps developed from the new data, however, showed that several samples within the supposed extent of 1996 excavation appeared to have elevated arsenic concentrations and as a result, this area was removed. Thus, it is likely that contaminated soil may have been left in place at parcel 103 by the recent removal action if it had been based on the 1996 excavation map rather than the 2005 sampling results and subsequent SADA analysis.

The one significant limitation of SADA that was encountered during the project was the need to post-process the AOC maps externally from SADA (in ArcGIS) to create polygons that could be used for field navigation. Such a utility would be helpful if it could be incorporated into future versions of SADA. SADA is not as robust as ArcGIS in manipulation and presentation of spatial data, some of its limitations are apparent on the figures presented above. For instance, the user is limited to posting a single attribute at each location identified by a coordinate pair. SADA, however, provides a variety and level of sophistication in spatial interpolation and analysis that is matched by few proprietary programs and it can be obtained free of charge from the SADA website: <http://www.tiem.utk.edu/~sada/index.shtml>

4.0 POINTS OF CONTACT

Randy B. Nattis
Federal On Scene Coordinator
U.S. EPA Region IV
61 Forsyth Street, 11th Floor
Atlanta, GA 30303
nattis.randy@epa.gov
 404.562-8757

Sandra Harrigan
Project Manager
Tetra Tech EM Inc.
1955 Evergreen Boulevard
Building 200, Suite 300
Duluth, GA 30096
sandra.harrigan@ttemi.com
 678.775.3088

Jim Wulff
SADA Analyst
Tetra Tech EM Inc.
950 17th Street, 22nd Floor
Denver, CO 80202
jim.wulff@ttemi.com
 303.312.8834

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