Human Health and Ecological Risk Assessment with Spatial Analysis and Decision Assistance (SADA) Freeware

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Human and Ecological Risk Functions

- SADA implements EPA methods for conducting ecological and human health risk assessments
- Calculation of site-specific preliminary remediation goals
- Benchmark database for contaminant effects on ecological receptors
- Exposure modeling for humans and over 20 other terrestrial species
- Contains IRIS/HEAST toxicity databases for calculating risk from exposure
- Contains EPA default exposure parameters for the risk models
- Tabular screening and risk results
- Point screens
- Risk and dose mapping

Sample Laboratory Data

PROJECT NAME	PROJECT #	SAMPLEI	SAMPLE ID	DATE COLL	DATE RECD	ANALYZED	TAI LAB #	ANALYTE	RESULT	PQL	UNITS	METHOD
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Aldrin	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	a-BHC	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	b-BHC	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	d-BHC	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	g-BHC, Lindane	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	4,4'-DDD	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	4,4'-DDE	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	4,4'DDT	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Dieldrin	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endosulfan I	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endosulfan II	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endosulfan Sulfate	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endrin	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endrin Aldehyde	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endrin Ketone	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Heptachlor	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Heptachlor Epoxide	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Methoxychlor	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Toxaphene	< 0.00500	0.005	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	alpha-Chlordane	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	gamma-Chlordane	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1016	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1221	< 0.00100	0.001	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1232	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1242	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1248	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1254	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1260	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/5/2002	02-A162603	Arsenic	< 0.0050	0.005	mg/l	6010B
I-40/I-640 SINKHOLE	4969.013	BWJJO	HSSW1	10/1/2002	10/3/2002	10/5/2002	02-A162603	Barium	0.08	0.01	mg/l	6010B

Or transport model output files

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Data Formats

SADA can accept data in two formats: comma delimited files (csv) and Microsoft Access.

Requires the presence of certain fields in the data set.

- Easting
- Northing
- Depth
- Value
- Name

Can use other forms of information as well

- Media
- Detection
- Date
- CAS Number

Any other form of meta data can be imported as well. User can plot and retrieve this meta data during an analysis.

SADA recognizes soil, sediment, surfacewater, groundwater, air, biota, and background, and the “basic” media type. Basic is assigned to data that have no media type.

Data!

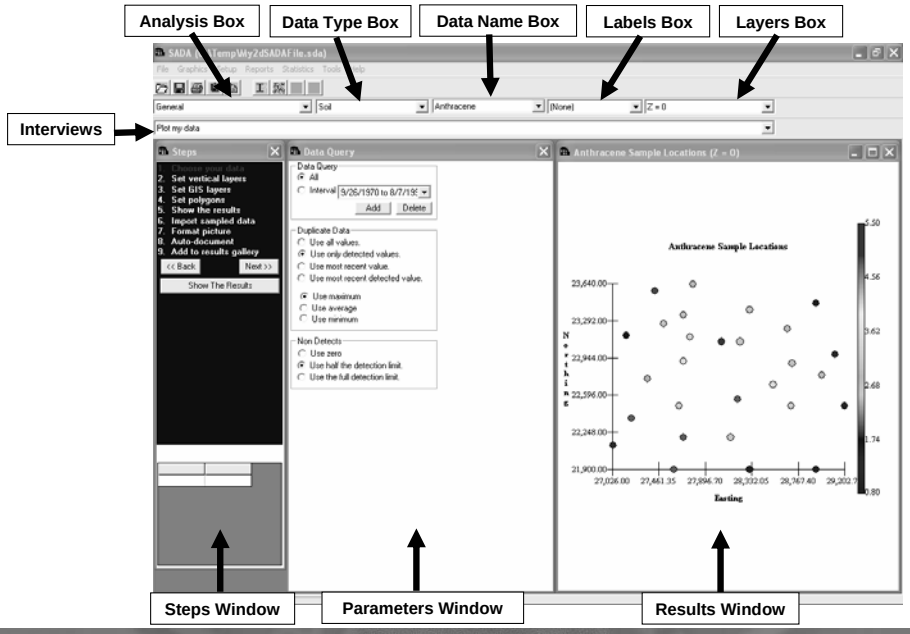
Risk Assessments are data driven:

as quality and confidence in data increases, then

so does the quality and confidence in risk estimates.

SADA offers reliable and effective data storage, visual analysis, and synthesis that can enhance risk assessments. But ultimately, the quality of the risk assessment is dependent upon the quality and quantity of the data.

Scaleable interface



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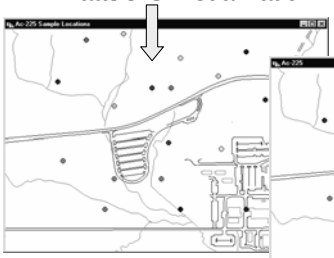
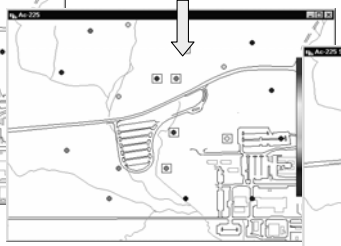
Basic Data Exploration

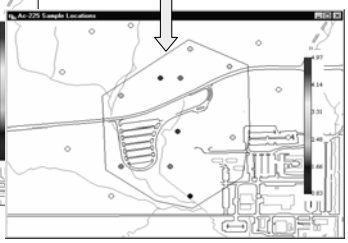
Data/GIS Visualization



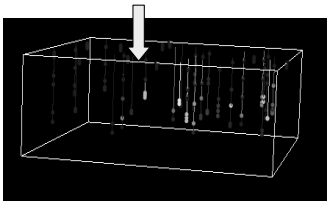
Data Screening



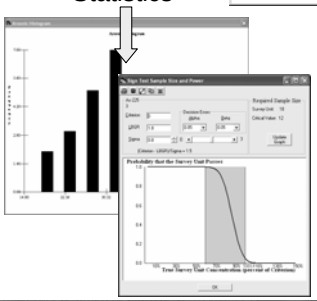
Spatial Aggregation



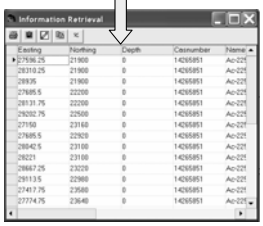
3D visualization



Statistics



Spatial Data Query



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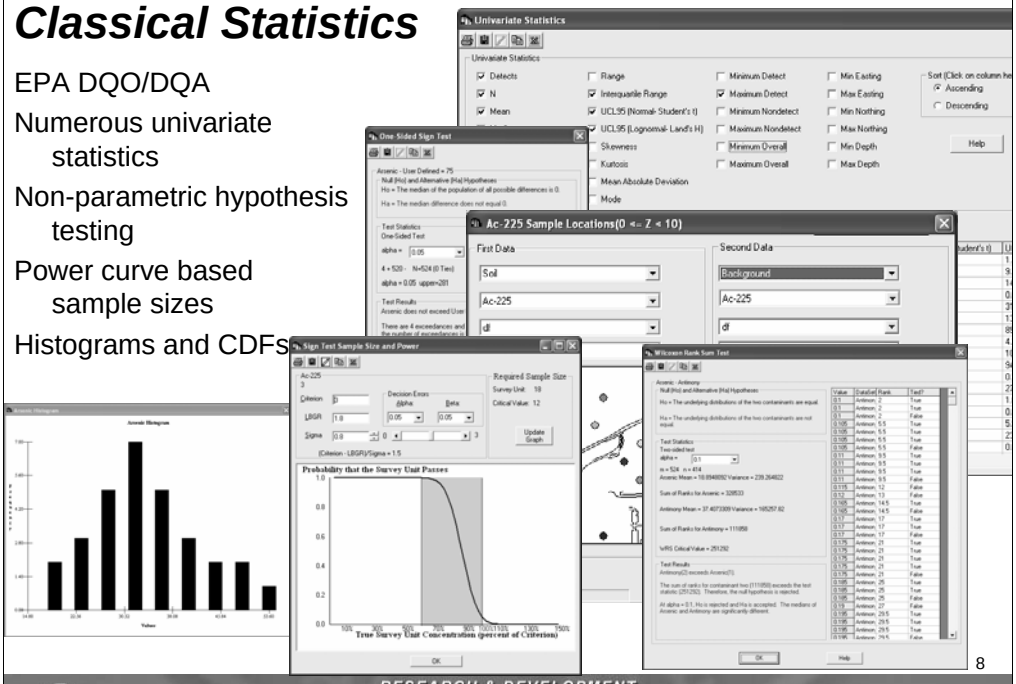
Classical Statistics

- EPA DQO/DQA
- Numerous univariate statistics
- Non-parametric hypothesis testing
- Power curve based sample sizes
- Histograms and CDFs



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RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

Human Health Risk

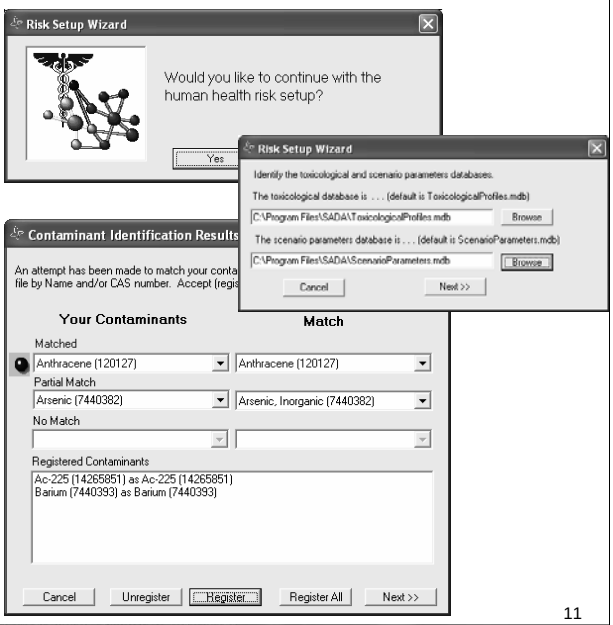
- SADA implements EPA methods for conducting human health risk assessments
- Calculation of site-specific preliminary remediation goals
- Exposure modeling for humans for five different land use scenarios
- Contains IRIS/HEAST toxicity databases for calculating risk from exposure
- Contains EPA default exposure parameters for the risk models
- Tabular screening and risk results
- Point screens
- Risk and dose mapping

SADA Human Health Functionality

Setting Up Human Health
Viewing Scenario Parameters
Viewing Toxicological Parameters
Changing Target Risk/Hazard Index
Setting Screening and Exposure Statistics
PRG Tables
PRG Screen Tables
Risk Tables
Spatial PRG Screens
Point Risk Maps
Rematching a Single Contaminant

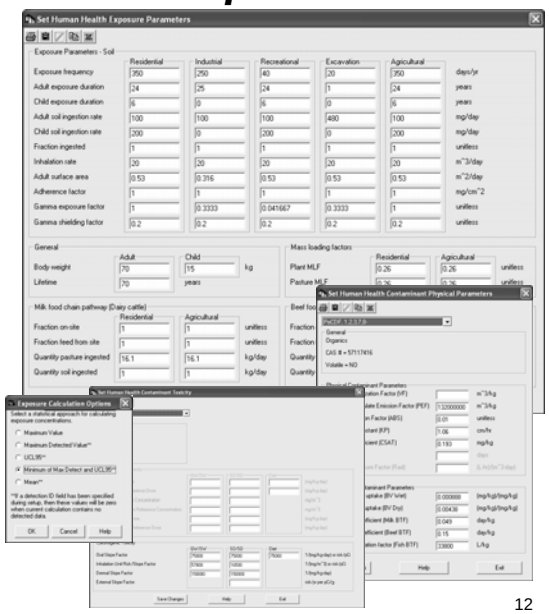
Setup Human Health

- After a SADA file is created
- Imports toxicity and exposure data to the SADA file
- Link contaminants in toxicity file to those in SADA file

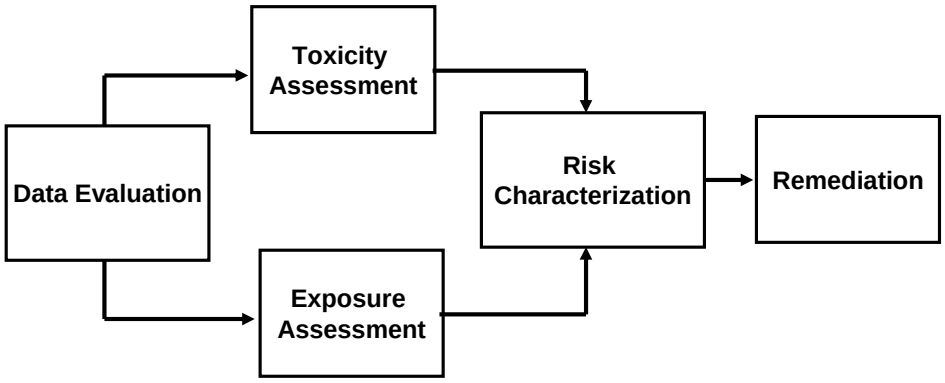


Human Health Risk Inputs

- Media Data: Soil, Sediment, Surface Water, Groundwater
- Exposure Scenarios: Residential, Industrial, Recreational, Agricultural, Excavation
- Exposure Pathways: Ingestion, Inhalation, Dermal Contact, Food Chain (Beef, Milk, and Vegetable Ingestion)
- IRIS and HEAST Toxicity Databases for Carcinogenic and Noncarcinogenic Effects
- Physical Parameters for Modeling: Bioaccumulation Factors, Volatilization, Particulate Emission Factors, Permeability Constants, Absorption Factors, Saturation Coefficients, etc.



Standard Steps of a Risk Assessment



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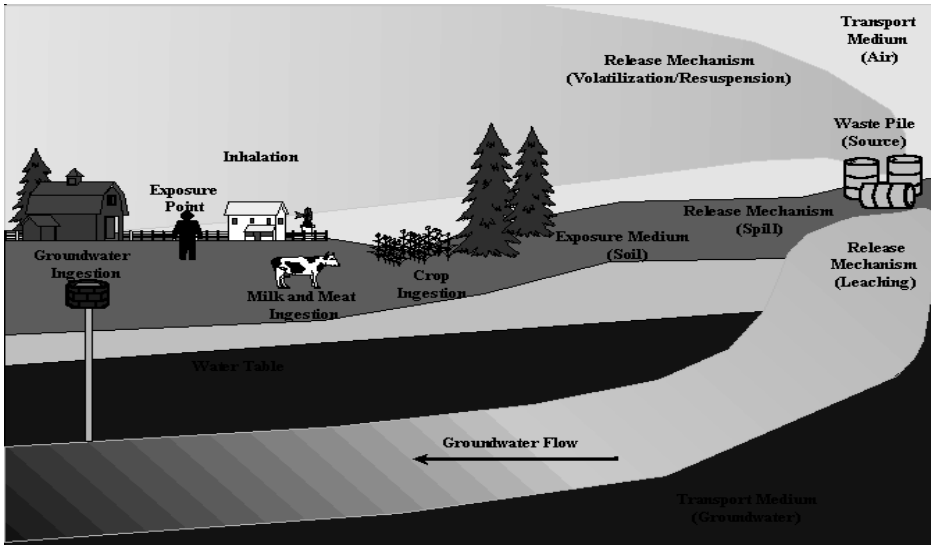
Risk Assessment- Exposure



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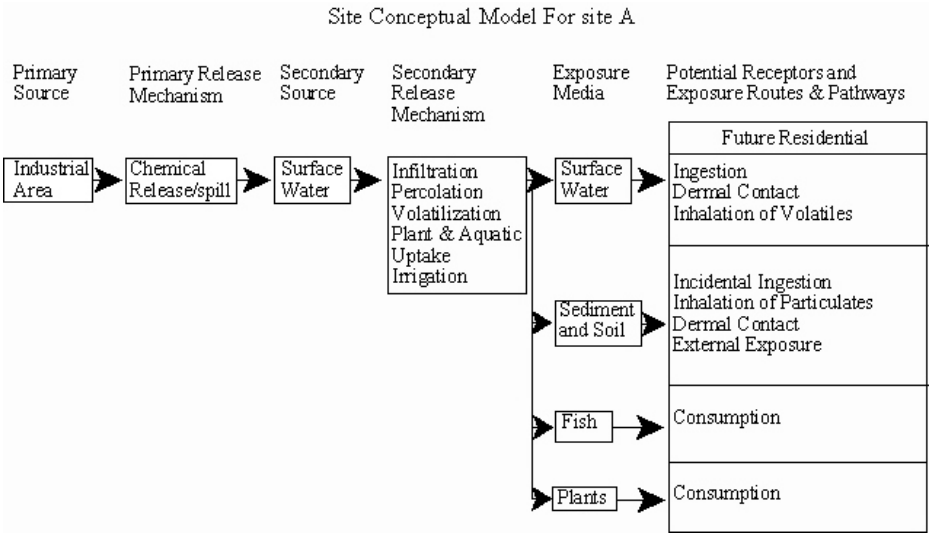
Exposure- Conceptual Site Model



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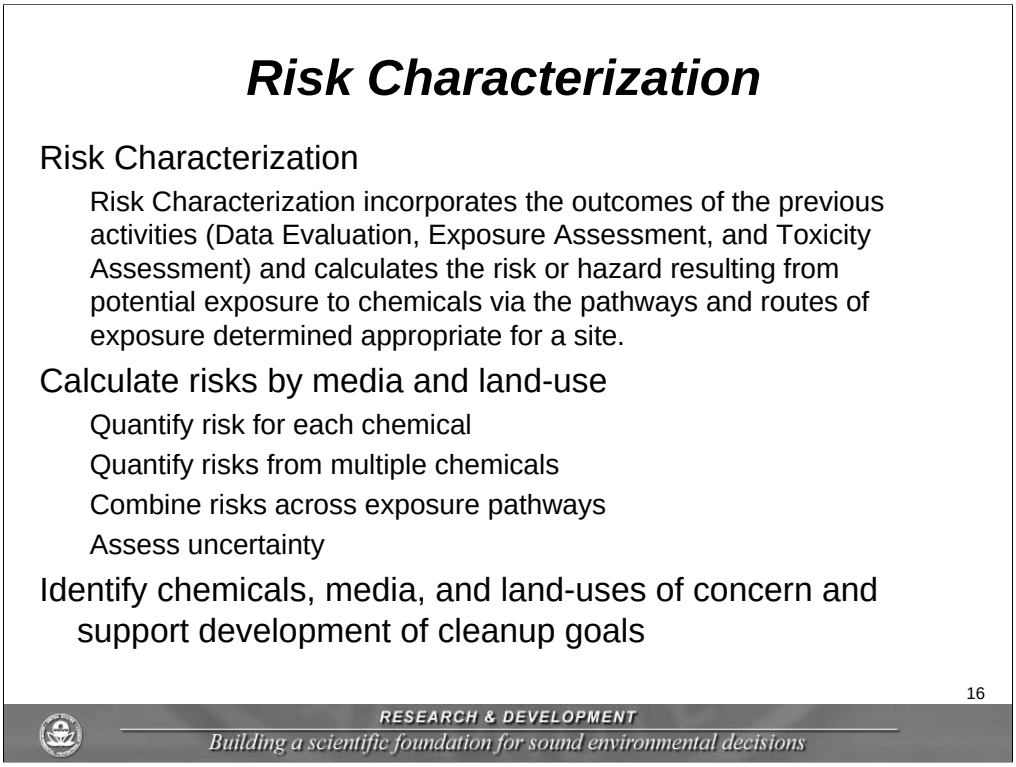


We have now selected the data to be used in the risk assessment (through screening); we have selected the exposure routes and pathways (in the exposure assessment); and we have selected the appropriate toxicity values.

All of this previous information will now be used in the risk characterization step.

We are now ready to perform the forward calculations of the risk and hazard equations. Please note that the PRG determinations have been backwards (extrapolating from a set risk or hazard levels BACK to a “safe” or “acceptable” residual concentration level for a specific medium [groundwater or soil]).

In the forward calculations, we will determine the risk from each of the chemicals within each pathway. The RAIS does not calculate the total risk or hazard values in the forward direction (needed in the backward direction, though).

As appropriate, you can then sum the risks from the different chemicals within each pathway and across the pathways to determine pathway and scenario total risk and hazard values.

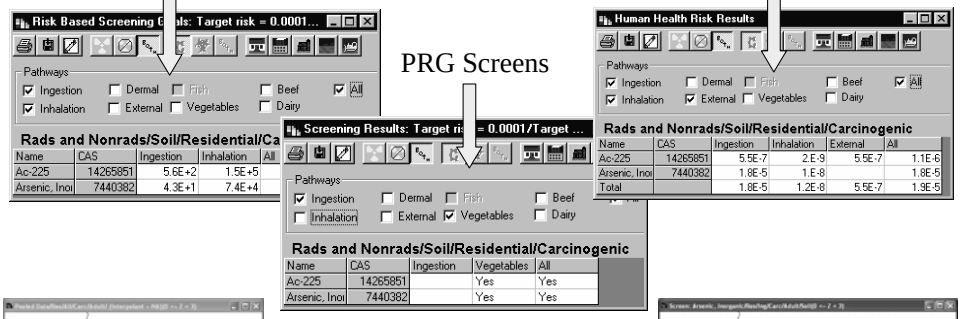
Note: EPA’s default assumption is one of additivity for risk and hazard values. However, there are chemicals that act together in non-additive manners, I.e. synergistic or antagonistic (PICK SOME GOOD EXAMPLES FOR EACH).

For more help, you can look at the online tutorial.

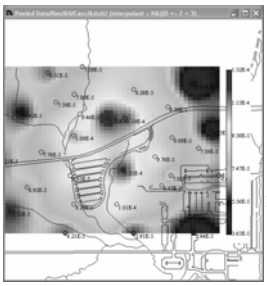
Human Health Risk Outputs

PRG Calculation

Forward Risk

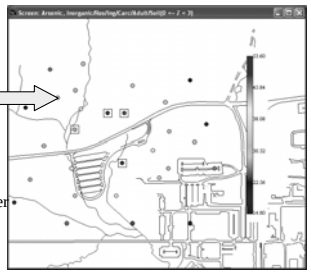


PRG Screens



Risk Based Spatial Screens

Risk Mapping



Residential, Industrial, Agricultural, Recreational, Worker
Ingestion, Inhalation, Dermal, External, Food Chain
Soil, Sediment, Surfacewater, Groundwater
Packaged with Editable Scenario Parameters
Packaged with IRIS and HEAST Database

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RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

Exposure Statistics

Default values are maximum detected value for screening calculations and lesser of the maximum detected value and the UCL95 for exposure calculations.

User can change the approach:

- Maximum Value: the maximum concentration, detected or nondetected, for normal or lognormal distribution
- Maximum Detected Value: the maximum detected concentration for normal or lognormal distribution
- UCL95: the 95% upper confidence limit on the mean for normal or lognormal distribution
- Mean: the average concentration over all values for normal or lognormal distribution

Help File and Users' Manual

Extensive documentation of human health methods and parameters in SADA help file

320 page user guide available from:

http://www.tiem.utk.edu/~sada/SADA_4_1_Usersguide.pdf

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Current limitations for Human Health Risk

- ProUCL95 (confidence limits, automatic distribution testing)
- Additional tox info, target organs
- RAGS Part D reporting format
- Screening PRGs as benchmarks
- Air, dermal modifications
- Uncertainty analysis

Ecological Capabilities in SADA

SADA implements EPA methods for conducting ecological risk assessments

Benchmark database for contaminant effects on ecological receptors

Exposure modeling for over 20 other terrestrial species

Contains EPA default exposure parameters for the risk models where available

Tabular screening and risk results

Point screens

Risk and dose mapping

Ecological Functionality

Setting Up Ecological Risk
Ecological Risk Assessment Procedure
Setting Physical Parameters
Description of Ecological Benchmark Database
Histograms of Benchmark Values
Tables of Benchmark Values
Setting Screening and Exposure Statistics
Area Result Tables (Screens, Ratios)
Map Result Values (Screens, Ratios)
Rematching a Single Contaminant
Checking Ecological Version
Terrestrial Dose Modeling

Setup Ecological Risk

- Identify source benchmarks database
- Match contaminants in data to benchmark contaminants
- Adds ecological information to SADA file

Hazard v. Risk Assessment

Ecological Hazard Assessment- a comparison of an environmental concentration to an estimated toxic threshold for a particular contaminant

- -most common method for examining effects of chemicals in environment
- -comparison of environmental exposure concentration to a toxic threshold (benchmark)
- -iterative (or tiered) implementation
- -number of toxicity data sets for soil, sediment, and surface water available for screening

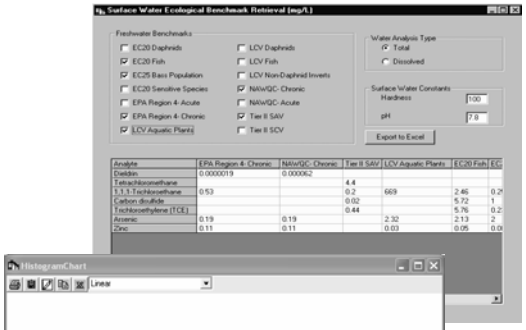
Ecological Risk Assessment- explicitly attempts to estimate the probability and magnitude of the effects of exposure to contamination

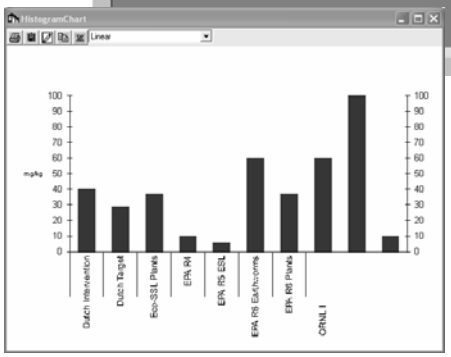
Benchmark Screening

- Media-specific concentration benchmarks
- Choice of statistics (max, percentile, UCL95, etc.)
- Hierarchy of media-specific benchmarks for screening
- Spatial and tabular display of ratios
- Derivation of Benchmarks:
  - Toxicity testing (acute or chronic)
    - -regression of concentration-response data
    - -hypothesis testing
  - Extrapolation from another benchmark
  - Simulation of an assessment endpoint

Ecological Benchmark Screening

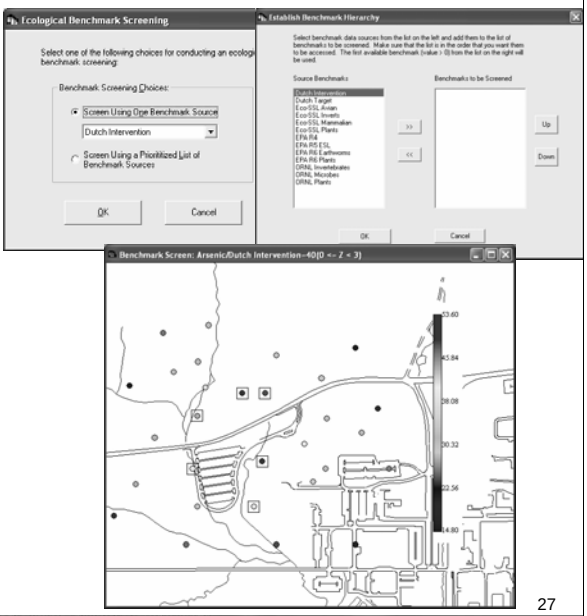
- Suitable for screening ERAs
- Compilation of ecological benchmarks for surface water (14), soil (11), sediment (17), and biota (8)
- Benchmarks a function of environmental variables where appropriate
- Choice of statistics (max, percentile, UCL95, etc.)
- Hierarchy of media-specific benchmarks for screening
- Spatial and tabular display of ratios





Map Result Screens and Ratios

- Screens concentration against benchmarks at each sample location
- Places a box around locations that exceed benchmark
- Can use one benchmark source or establish a site-specific hierarchy



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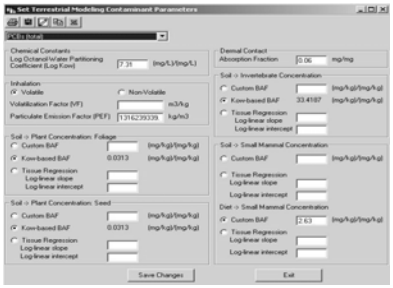
SADA Terrestrial Dose Modeling

- SADA calculates dose (mg/kg BW d) from food ingestion, soil ingestion, dermal contact, and inhalation for terrestrial exposures as well as total dose summed over all pathways selected.
- SSL, Female, Male, or Juvenile
- Number of different species
- Use a polygon to identify home range
- Select species/sex
- Click exposure pathways
- Returns dose in mg/kg/day for each exposure pathway

Ecological Exposures Inputs and Outputs

a)



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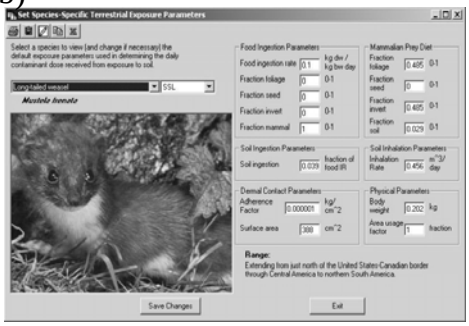

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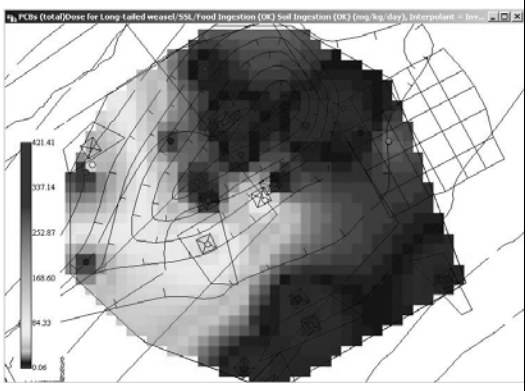

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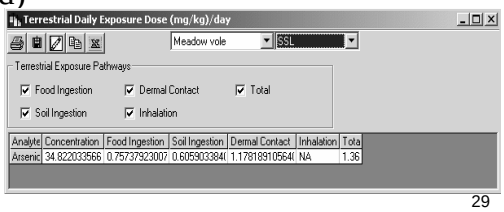

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RESEARCH & DEVELOPMENT

Building a scientific foundation for sound environmental decisions

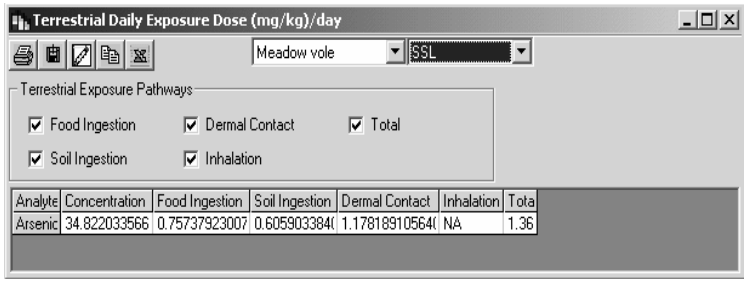
Calculate Exposure for Home Range

Use a polygon to identify home range

Select species/sex

Click exposure pathways

Returns dose in mg/kg/day for each exposure pathway



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SADA Ecological Risk Needs

- Additional benchmarks
- Radionuclide benchmarks and dose assessment methods
- Terrestrial movement and habitat models
- Eco PRG tables/calculations
- Aquatic dose models
- Uncertainty for dose assessment

Spatially Explicit Ecological RA

Use spatial distribution of contamination with dynamic movement models that also incorporate:

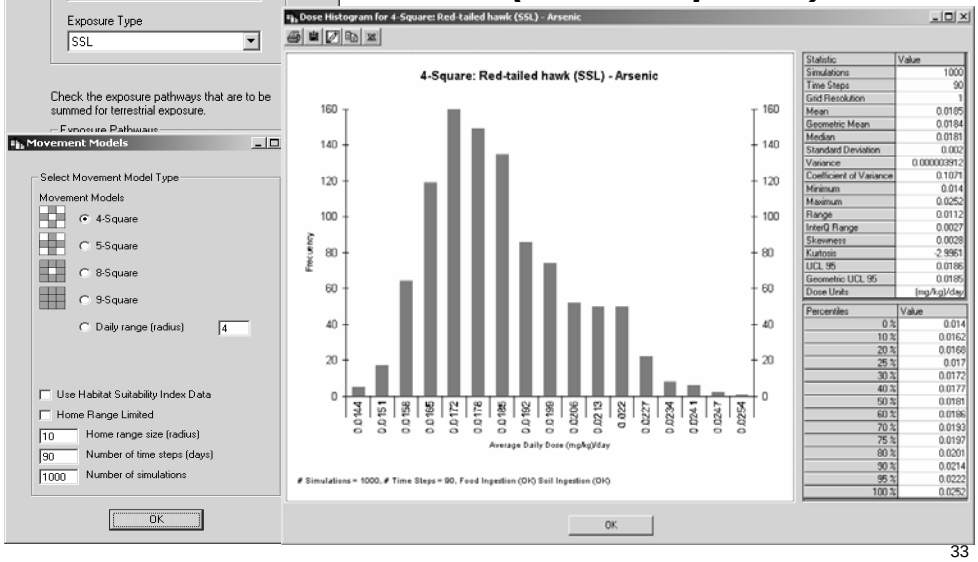
-Habitat quality

-Foraging behavior

-Ecological interactions

Number of movement models available in the literature

Terrestrial Movement Models (in development)



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Spatial Risk Assessment

Conventional Risk Assessment Limitations

- Typically regulatory exposure assessment guidance recommends a summary statistic for the exposure concentration
- Spatial information is lost when a summary statistic is used in the RA- exposure is assumed to be continuous in space and time
- Often this lost info not recovered in the rest of the assessment/remediation process

Spatial Risk Assessment

Reasons for incorporating spatial statistics into risk assessment

- Maximize the use of limited resources
  - Efficiently collect data
  - Retain collected spatial info in the risk assessment
  - Use all types of available data, including expert judgment
- To more adequately characterize the exposure distribution
  - Extrapolate from known data to cover data gaps
  - Account for spatial processes related to exposure
  - Better understand uncertainties in the exposure assessment
- Efficient (selective) determination of areas in need of remediation

Selective Remediation

Process that achieves a local- and/or site-specific concentration level while minimizing cleanup volume.

Implementation requires:

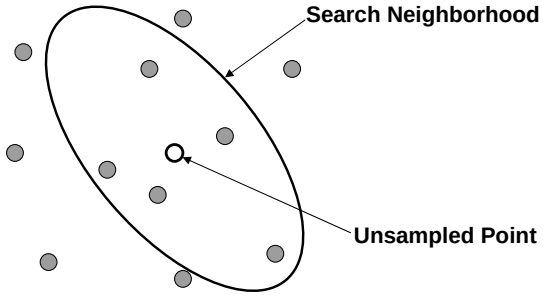
- data
- spatial interpolation model
- decision-maker cleanup criteria
- spatial scale inputs

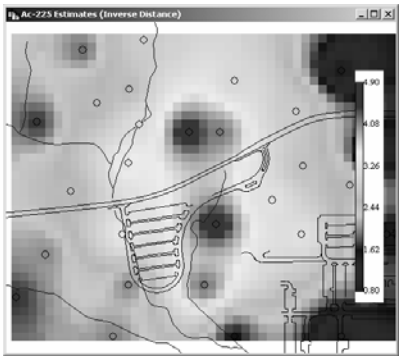
Results in a spatially explicit remedial design

Spatial Estimation

The estimated value V_o at all unsampled grid locations is estimated as a weighted average of nearby values.

$$V_0 = \sum_{i=1}^{N} w_i V_i$$





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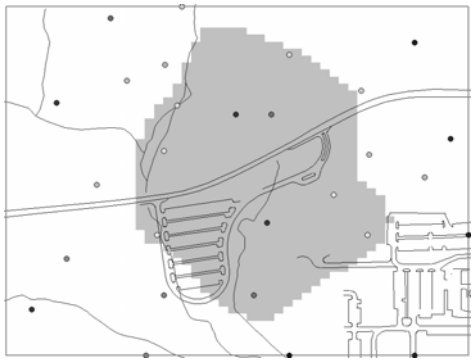
Determining Areas of Concern

- Map of interpolated concentration values can be compared to ecological or human health risk criteria to develop areas of concern
- SADA reports area or volume of exceedance and coordinates or areal extent



SADA web site

http://www.tiem.utk.edu/~sada/

Or just google “SADA” to freely download program and documentation.

Questions?

Comments?

This presentation has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Case Studies and Additional Slides

Marino Brothers Scrap Yard, Rochester Borough, Pennsylvania

- **http://www.frtr.gov/decisionsupport/PDF/FIELDS_SADACaseStudy_8-22-05.pdf**
- **http://www.kvvm.hu/szakmai/karmentes/egyeb/us_epa/22_Marino Brothers CS.pdf**

Navy TCE Plume, Lemoore Naval Air Station, Lemoore, California

- **http://www.kvvm.hu/szakmai/karmentes/egyeb/us_epa/14_Navy TCE Plume Case Study.pdf**

Small Arms Range, Tacoma, Washington

- **http://www.kvvm.hu/szakmai/karmentes/egyeb/us_epa/18_Rifle Range Case Study.pdf**

Barker Chemical Company, Inglis, Florida

- **http://www.frtr.gov/decisionsupport/PDF/SADA Case Study_053907Barker.pdf**
- **manuscript in review- Environmental Modeling and Assessment**

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Use of SADA Software at David Witherspoon Inc. 901 Site

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Use of SADA Software at David Witherspoon Inc. 901 Site

- Spatial Analysis and Decision Assistance (SADA) software was used as the primary risk assessment/spatial assessment tool
- Operations at the site resulted in widespread radionuclide and other hazardous substances
- Shut down in 1993
- Contaminated Soil, Sediment, Groundwater and Surface Water
- 10.5 acre site

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Brief site description

Use of SADA Software at David Witherspoon Inc. 901 Site

- Visualization
- Geospatial Analysis
- Statistical Analysis
- Human Health Risk
- Ecological Risk
- Cost/Benefit Analysis
- Sample Design
- Decision Analysis

- Site Characterization
- Data Aggregation
- Risk Assessment
- 3-D Risk Modeling
- Removal Volumes
- Decision Analysis
- Sample Design
- Data Screening

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On left things SADA can do. On right Things we used SADA for.

Use of SADA Software at David Witherspoon Inc. 901 Site

0-1 ft layer

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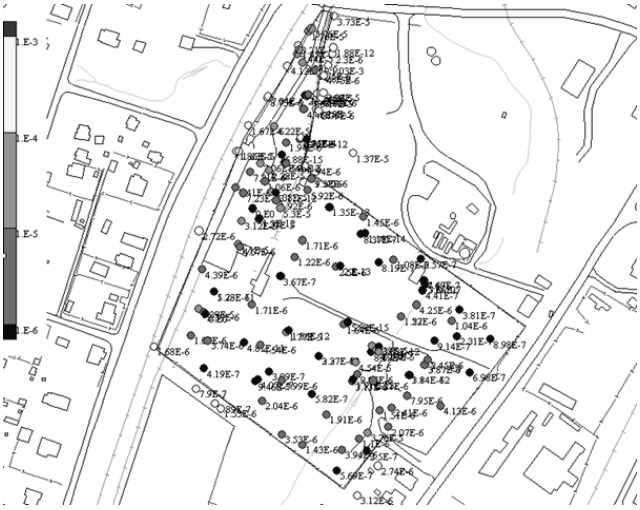
A picture of all soil borings.

Use of SADA Software at David Witherspoon Inc. 901 Site



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Point risk map of surface soil

Use of SADA Software at David Witherspoon Inc. 901 Site

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Contoured risk. (each contaminant modeled separately).

Use of SADA Software at David Witherspoon Inc. 901 Site

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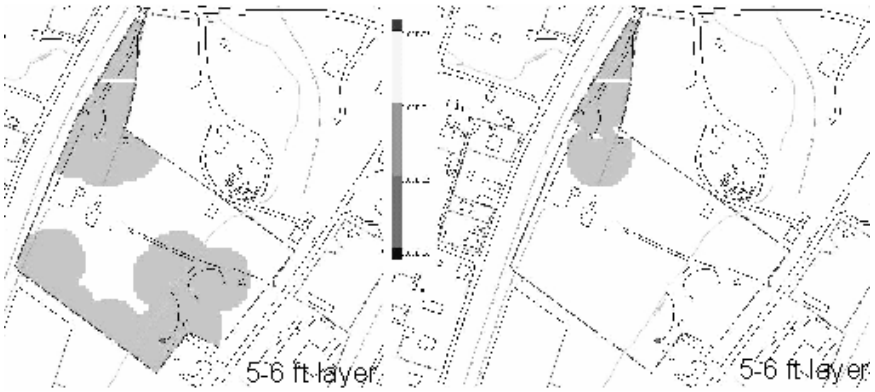
Where to dig to meet risk goal. Remove 1 ft on whole site and then determine various depths

Use of SADA Software at David Witherspoon Inc. 901 Site



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Block scale on left. Site scale on right. Notice no actual data points.

Use of SADA Software at David Witherspoon Inc. 901 Site

- Tools in SADA that were useful
  - Overburden
  - Benching Angles
  - Selection of Interpolation Models
  - Volume Calculations
  - Reproducibility for changes at meetings
  - Auto documentation
  - Dynamics of Risk Library
  - Site Scale versus Block Scale

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Use of SADA Software at David Witherspoon Inc. 901 Site

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Predicted excavation depth was right on. Notice the color change. Foundry sand

Use of SADA Software at David Witherspoon Inc. 901 Site

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Note the slag. Not predicted well at all. 15 ft deep trench.

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Candora rd.

Use of SADA Software at David Witherspoon Inc. 901 Site

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Back to Candora rd

Use of SADA Software at David Witherspoon Inc. 901 Site

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Top to bottom

Questions?

Comments?

Thank You

After viewing the links to additional resources, please complete our online feedback form.

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