Application of SADA for 3D Subsurface Characterization and Suggested Approach for Volumetric Compliance with Decommissioning Dose Criteria

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Spatial Analysis & Decision Assistance

Geographic Information Science and Technology

- Freeware desktop application integrating environmental risk analytics, spatial modeling, and decision sciences (EPA, NRC, DOE)
- Embed risk assessment, uncertainty modeling, and downstream decision processes entirely within a spatial context.
- SADA is a collaboration between the University of Tennessee and ORNL
- Footprint within the risk community
  - 20,000+ users going back to 1998
  - 90+ scientific and regulatory communications (e.g. journal articles, reports, web pages, theses, etc.
  - User group, workshops, conferences, international presence etc.

SADA Capabilities

GIS

Spatial Context
Area of Investigation
2D or 3D

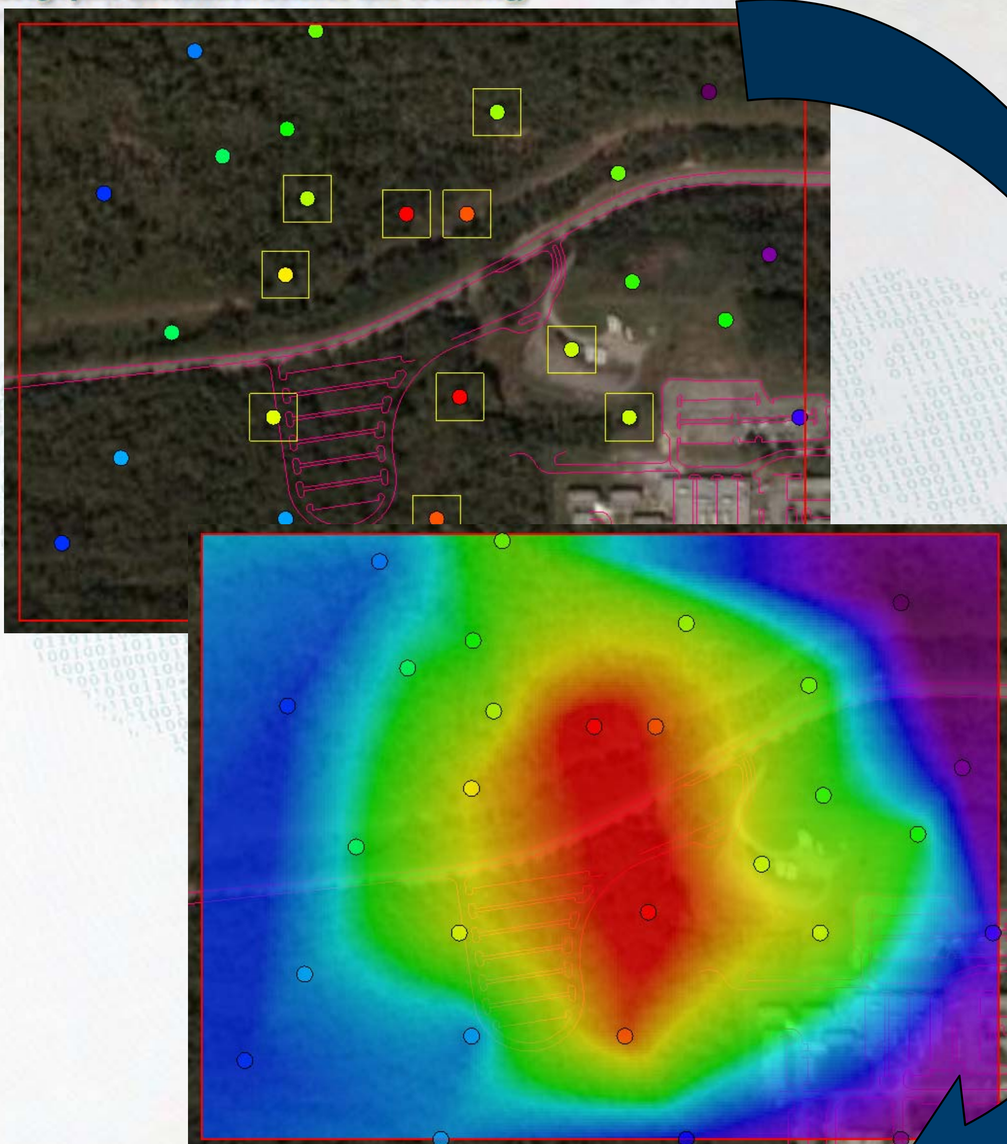
Initial Sample Designs

Judgmental
Random
Simple Grid
Standard Grid
Unaligned Grids
Search Grids
MARSSIM
3D Search

Data Collection

Data Management
Multiple Contaminants
Spatio-Temporal Referenced

SADA Capabilities



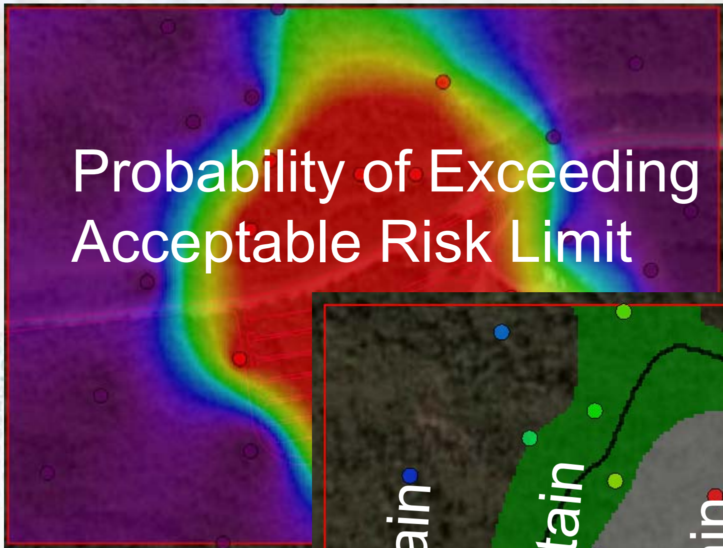
Risk Based Screening

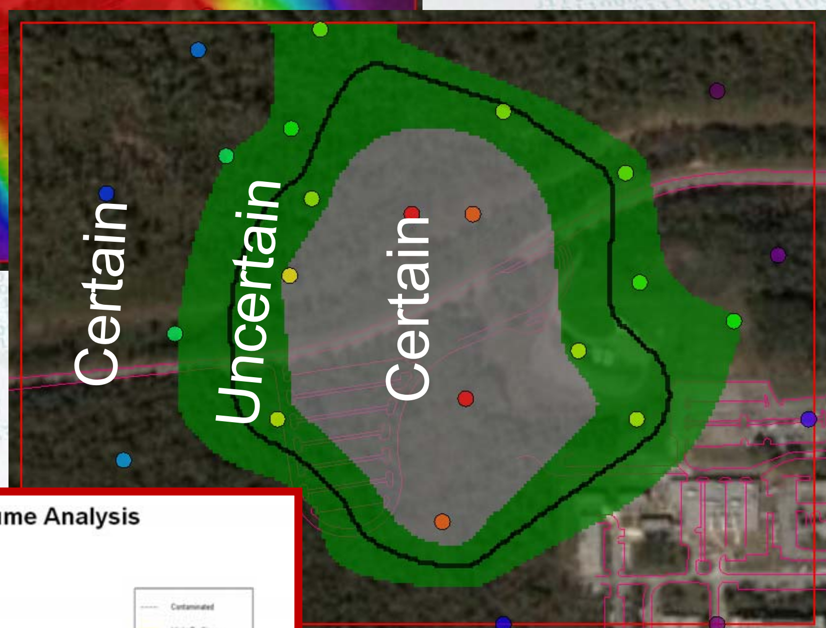
- Radionuclides
- Chemical
- Biological
- Custom
- State
- Federal
- Site Specific
- Landuse, individual behaviors
- Database of 1000s of analytes

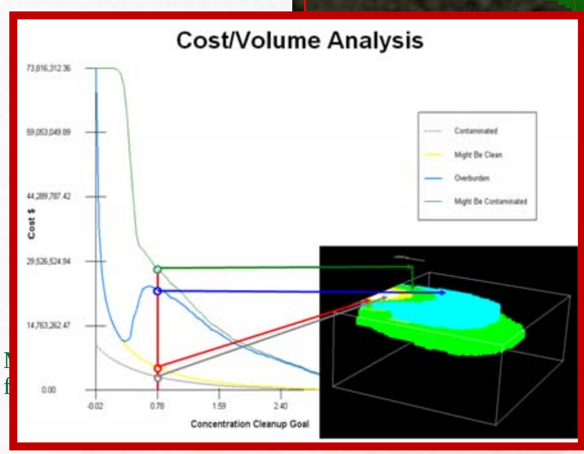
SADA integrates spatial modeling with risk

- Nearest Neighbor
- Natural Neighbor
- Inverse Distance
- Ordinary Kriging
- Indicator Kriging
- Cokriging
- Imported Models

SADA Capabilities







that propagates spatial uncertainty through the risk

Probability Maps

Model Variance Maps

Simulations

And quantifies uncertainty in the final decision

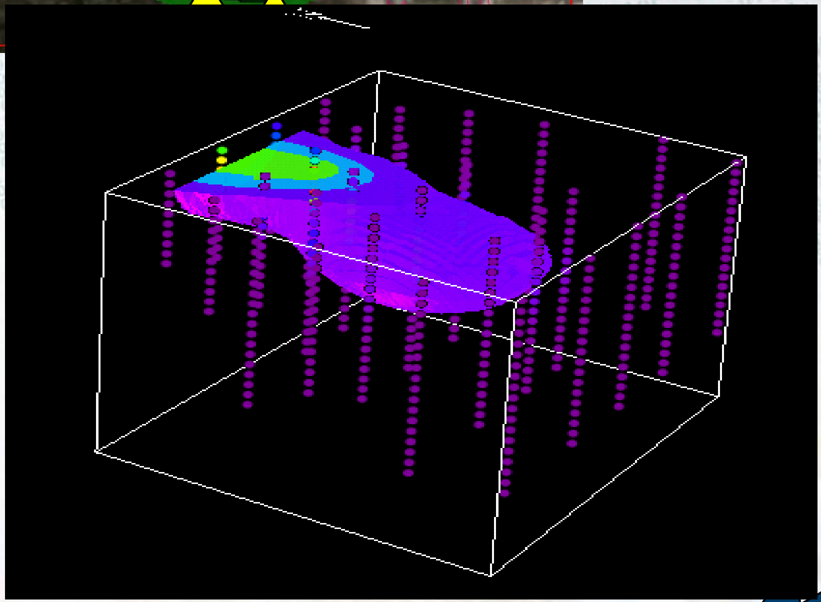
Cost Benefit Analytics

Built on risk-space models

Permit what if's

Quantify cost and *decision* risk reduction

SADA Capabilities



Secondary Sample Designs

Sample where model needs most support....

3D Subsurface Modeling

Subsurface Challenges

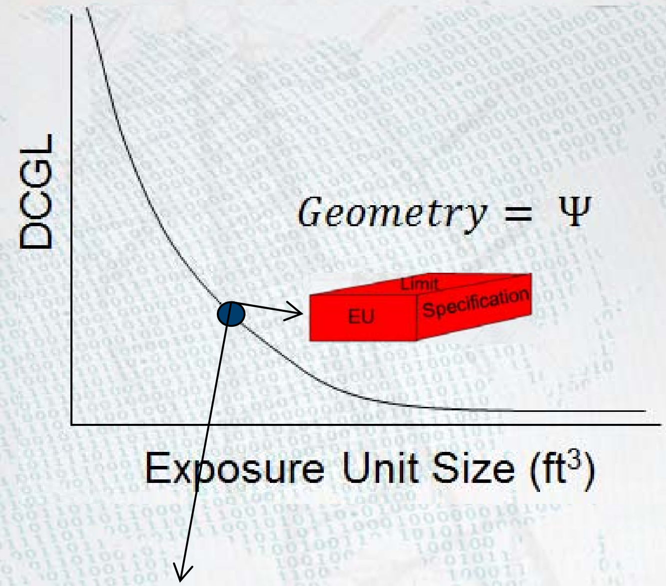
- **Exposure/DCGL values can be unclear**
  - **Groundwater contamination source is common**
  - **Direct exposure (construction, landscaping, removal)**
- **Sampling/Cleanup are more expensive**
  - **Subsurface is less accessible**
  - **Survey units in 3D might be difficult**
- **Complex geological/geophysical considerations**
- **Unable to "scan" the subsurface**
  - **No direct way to fill in the gaps**
- **"Bullet resistant" compliance check is at best difficult**
- **A detailed one-size-fits-all workflow is unlikely**

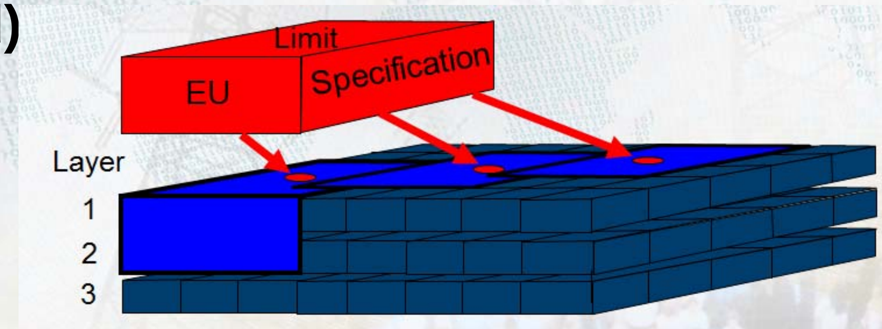
GEM: Geospatial Extension to MARSSIM

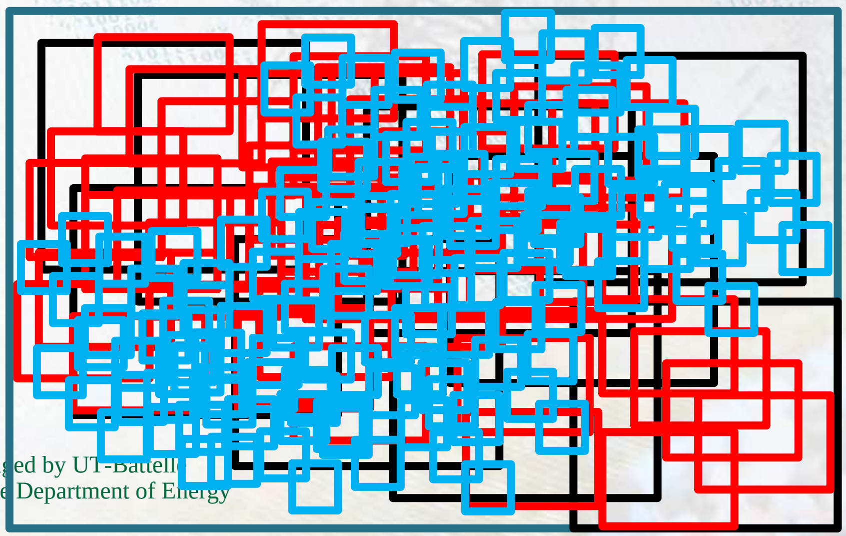
- ***A Geospatial Based Decision Framework for Extending MARSSIM Regulatory Principles Into the Subsurface*** **(Google Trace + Title)**
- **Explores MARSSIM "basic principles" within a subsurface context with direct exposure scenarios in mind, implemented as a prototype in SADA (not publically available yet).**
- **GEM Objectives**
  - **Create a comprehensive, DCGL & scale independent compliance rule/check**
  - **Build on advanced geospatial modeling approaches instead classical statistical approaches that ignore spatial autocorrelation and oversimplify the challenge**
  - **Use field detection data to increase sample space and support modeling.**
  - **Implement geospatially informed sampling and remedial designs that mitigate uncertainty and efficiently lead to compliance.**
  - **Ultimate goal is to propose a starting framework for subsurface that resonates with MARSSIM guidance - much work still remains.**
  - **Increase the presence of advanced methods in regulatory guidance**

GEM Regulatory Limit Rule

- **The RLR is a continuous function specifying the acceptable limit as a function of geometry, volume, and depth.**
- **3D subsurface radiological model scan**
- **Scan evaluates the *probability* that $Mean_{EU} > Limit_{EU}$**
- **Scan at all scales at all positions (ie survey unit delineation not required)**

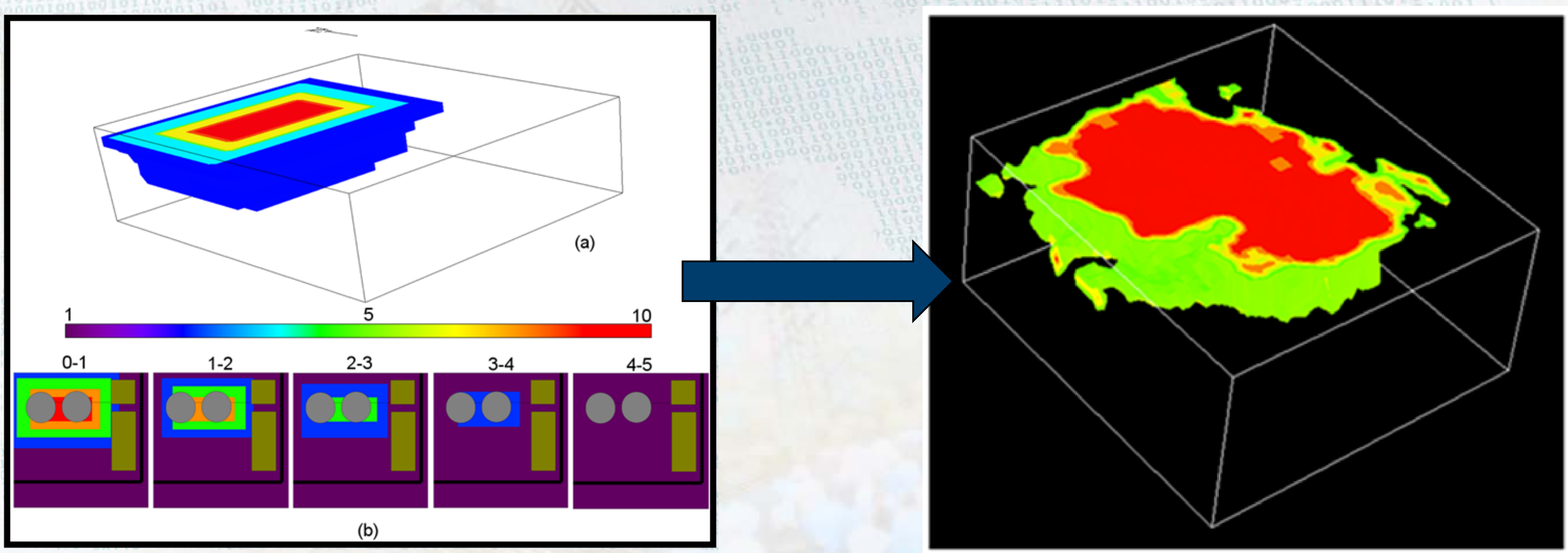






GEM: Geospatial Extension to MARSSIM

- **GEM compliance check is based on an empirically explicit geospatial compliance model that evolves a site conceptual model through the investigation into a high resolution representation.**
- **Built from a rich array of geostatistical methods that embrace correlation and integrate a variety of data types (e.g. field, lab)**
- **Built using “best practices” rather than hard coded steps**



Historical Site Assessment/Scoping

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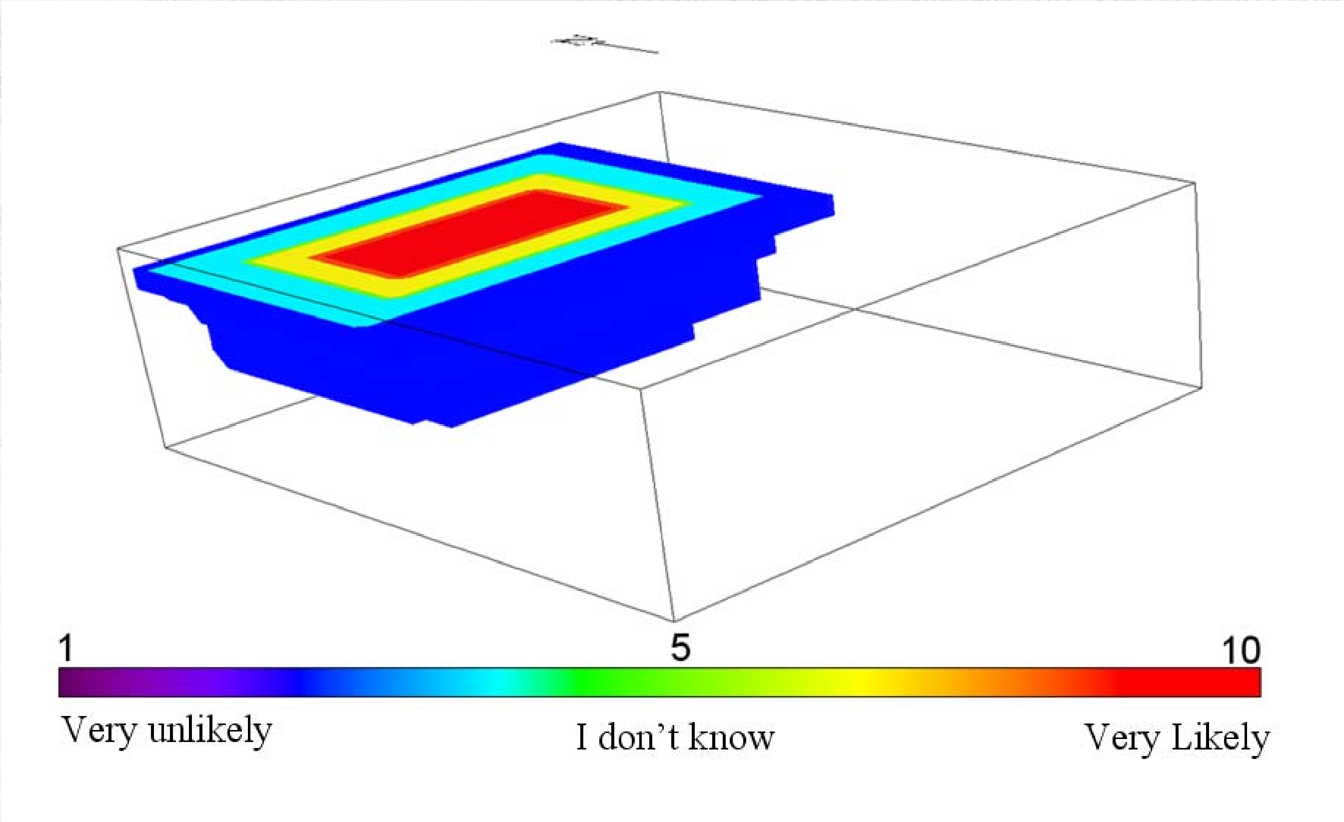
- **A high resolution, numerically explicit, conceptual model is built in the historical site assessment phase.**
- **Expert judgment is expressed as a *level of concern* about contamination.**



Characterization Phase

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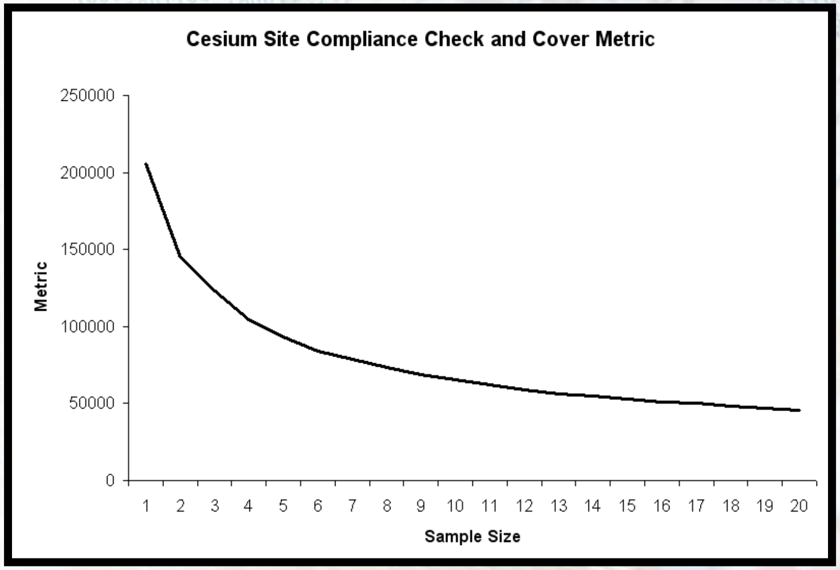
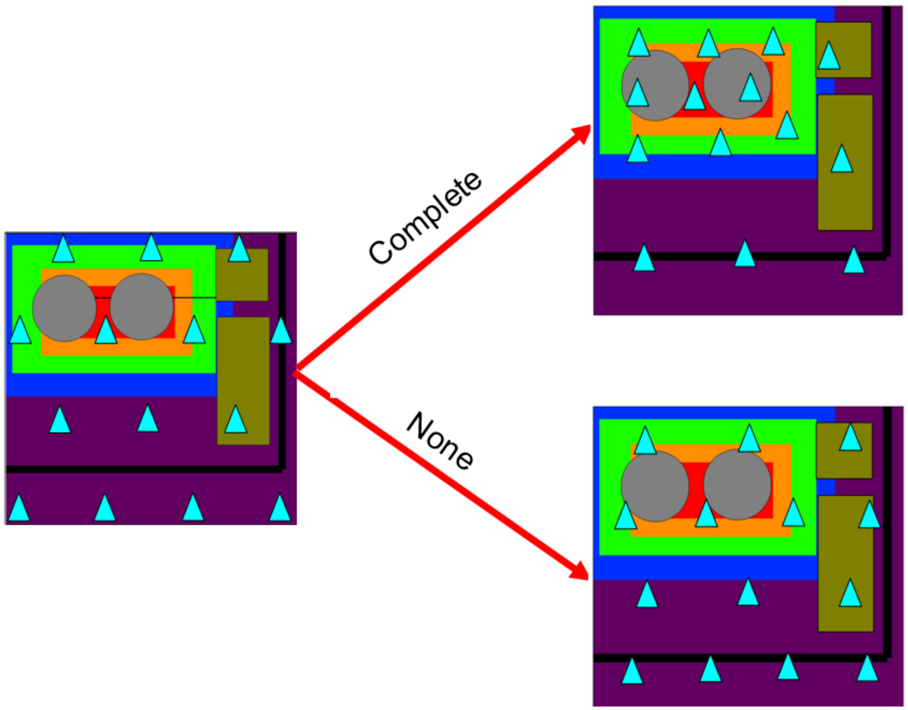
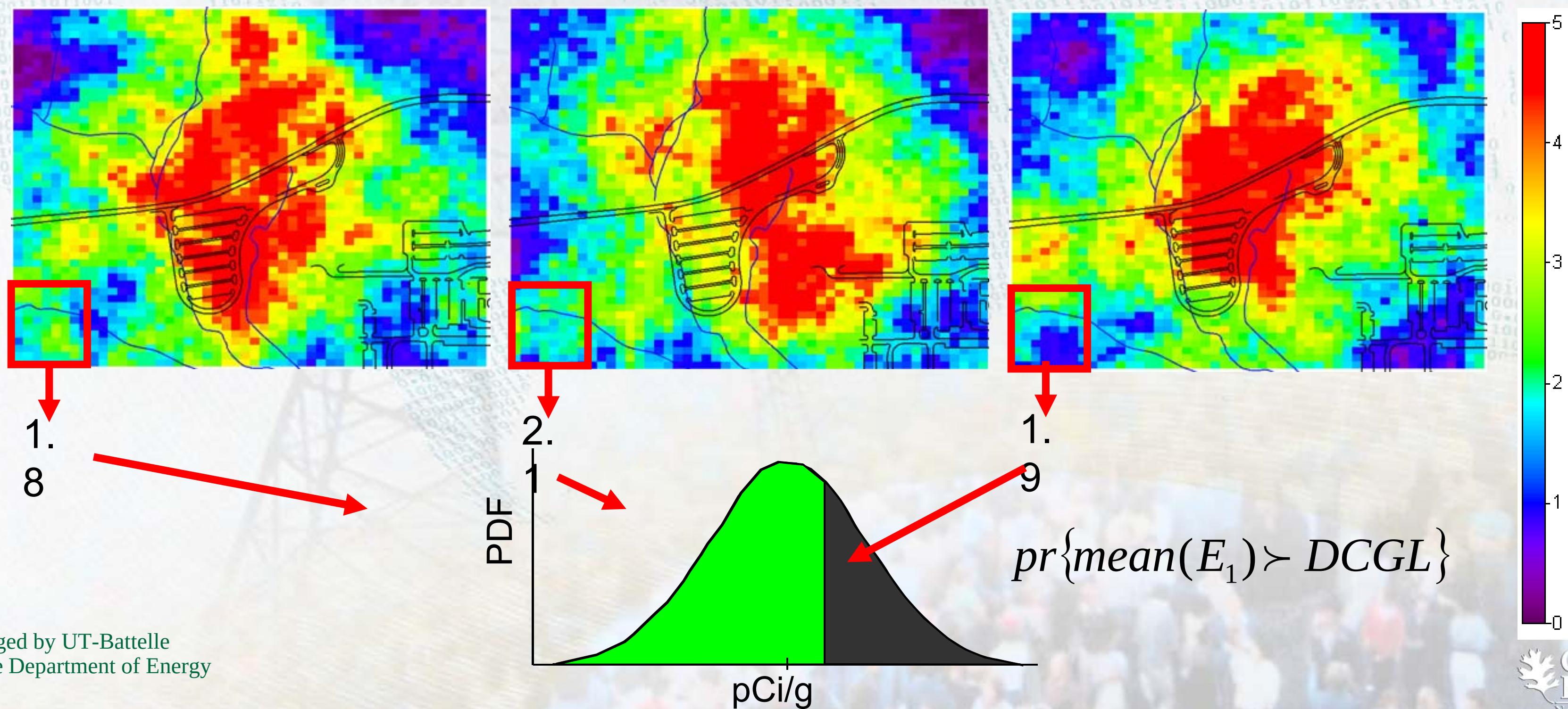
- ***Check and Cover*** **sample design locates initial samples based on the CSM balancing suspect areas with those likely to be clean.**
- **Based on P-Median algorithm for optimal facility location.**
- **Initial sample size can be motivated by external factors but a P-median metric is available for determining the spatial efficiency each additional sample.**
- **Iterative sampling is preferred with tertiary sampling likely driven by situation specific needs.**





Geostatistical Simulation

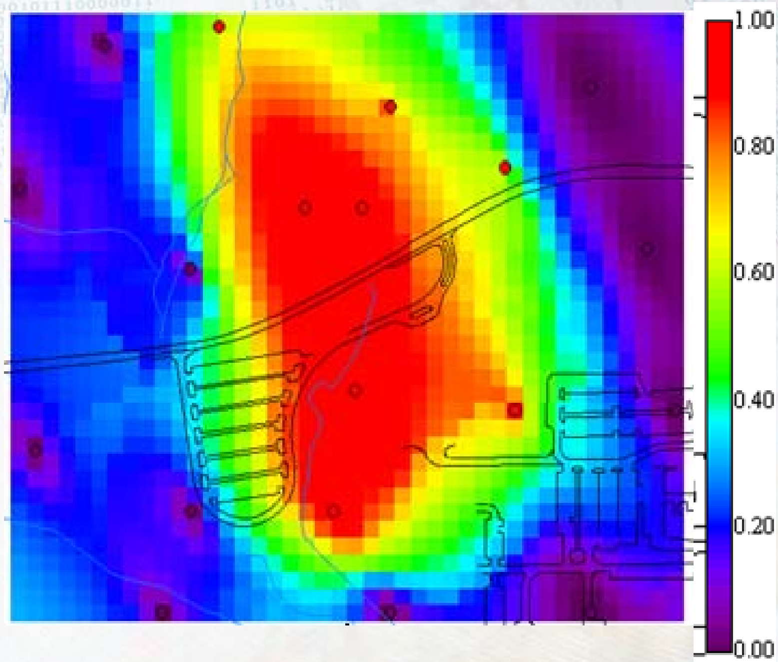
- **Simulation produces multiple realizations of contamination.**
- **Integrates primary (e.g. lab) with secondary (e.g. core hole scan)**
- **Taken together produce a PDF describing concentration uncertainty**
- **PDF can be queried to produce the probability of exceedance.**
- **PDF is available at every scan location for every EU specification**



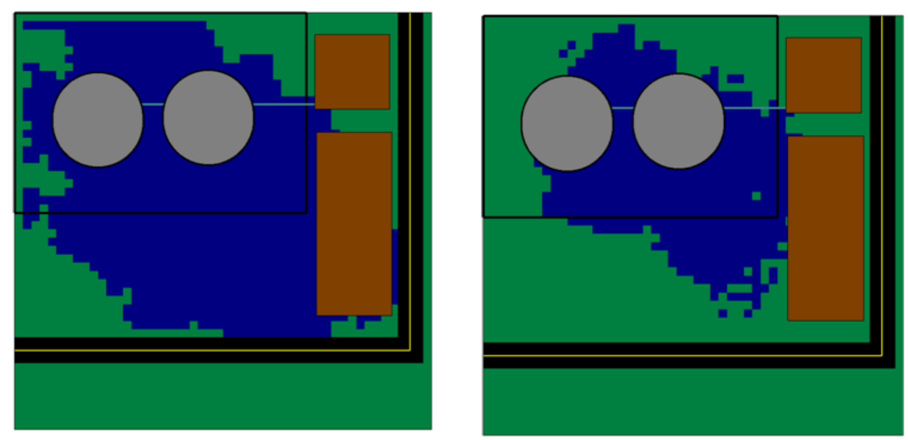
Stochastic Conceptual Site Model

- **Processing realizations in this way produces the *Stochastic Compliance Site Model* (SCSM).**
- **The SCSM is evolved over the investigation life-cycle**

Prob(Mean > Limit)



Location of Failing Units



${}_1\xi^{v,g}_{d,DCGL}$ ${}_2\xi^{v,g}_{d,DCGL}$

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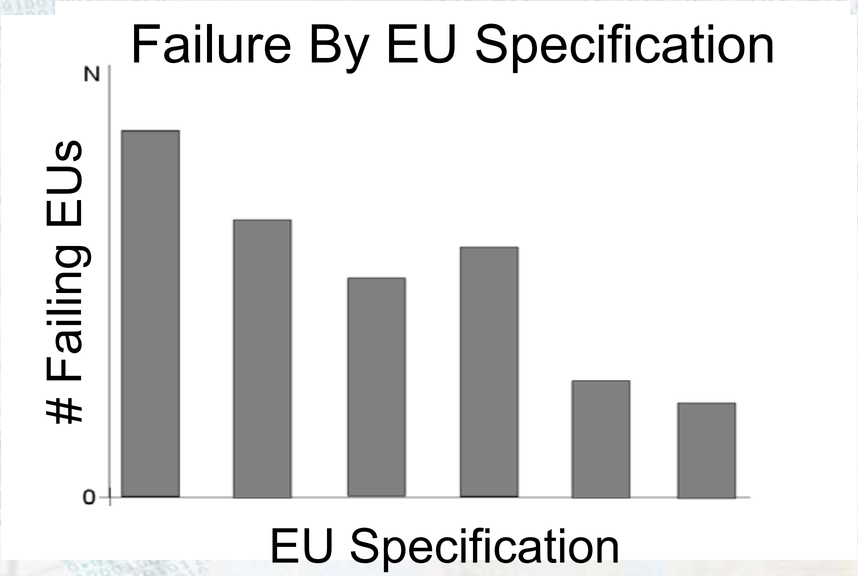
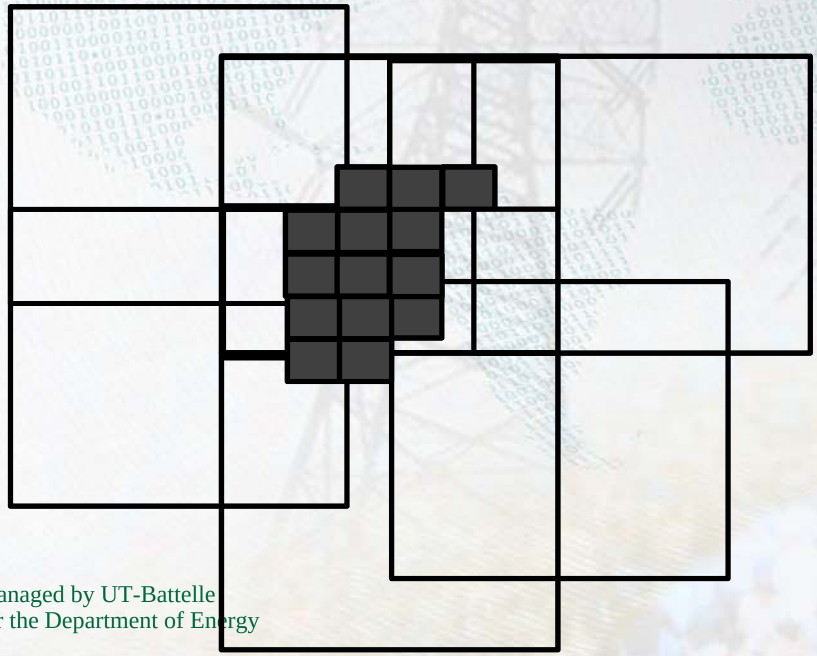
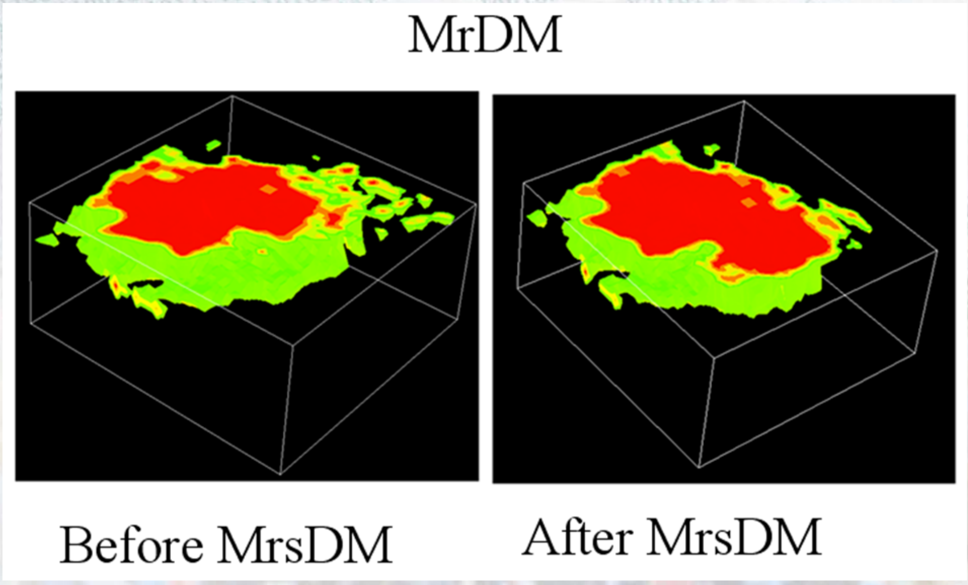


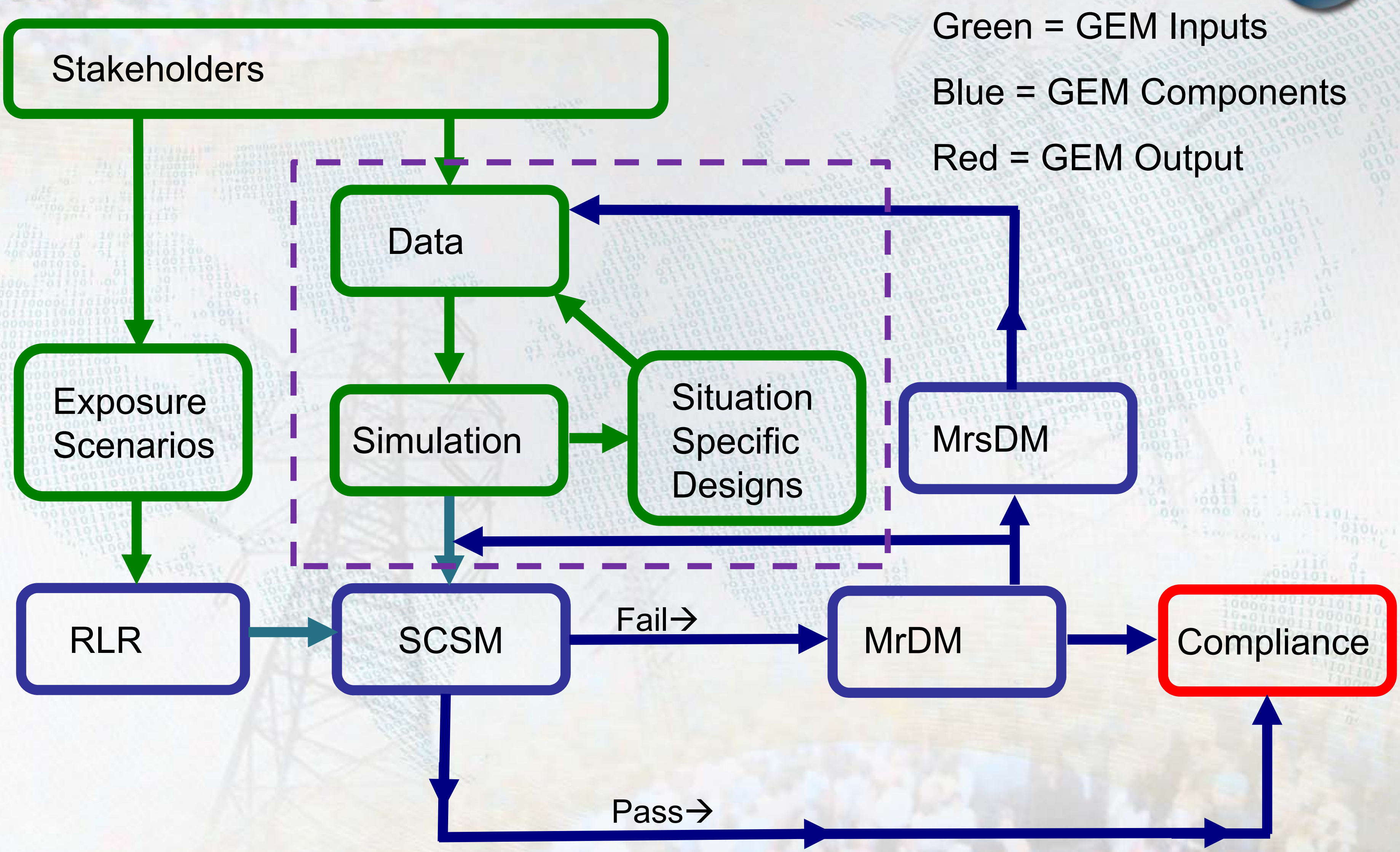
MrDM & MrsDM
Multiscale sampling and remedial designs

- **MrDM identifies the set of remedial units that most efficiently move the site into compliance simultaneously across all spatial scales**
  - **Simulates remediation by replacing model values with post-remedial values in each realization**
  - **Minimizes the total volume by considering overlapping topology and multiple DCGL criteria**
- **MrsDM identifies locations that will likely produce the greatest reduction in MrDM due to a spatial reduction in model uncertainty.**

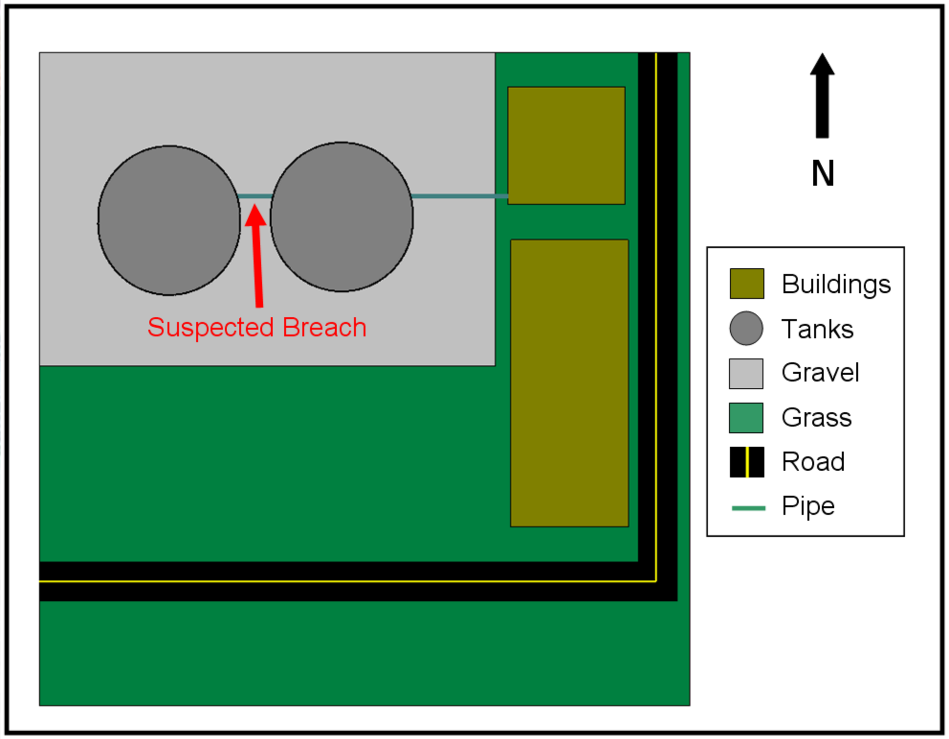


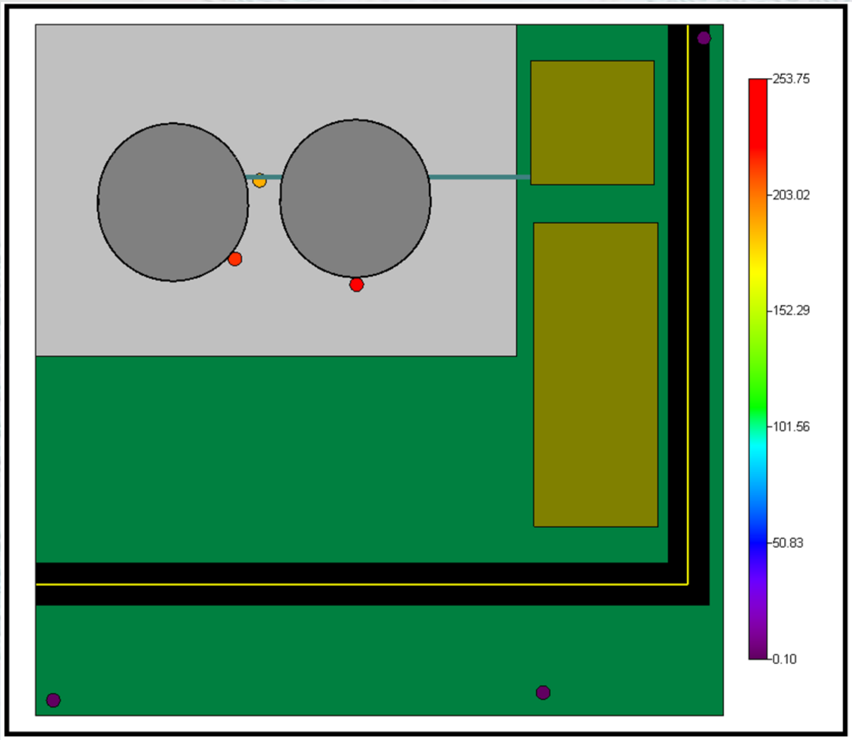


GEM Framework



Cesium Site Example





C&C | RLR | SCSM | MrDM | MrsDM | SCSM

HSA | Scoping | Characterization | Remediation | Compliance

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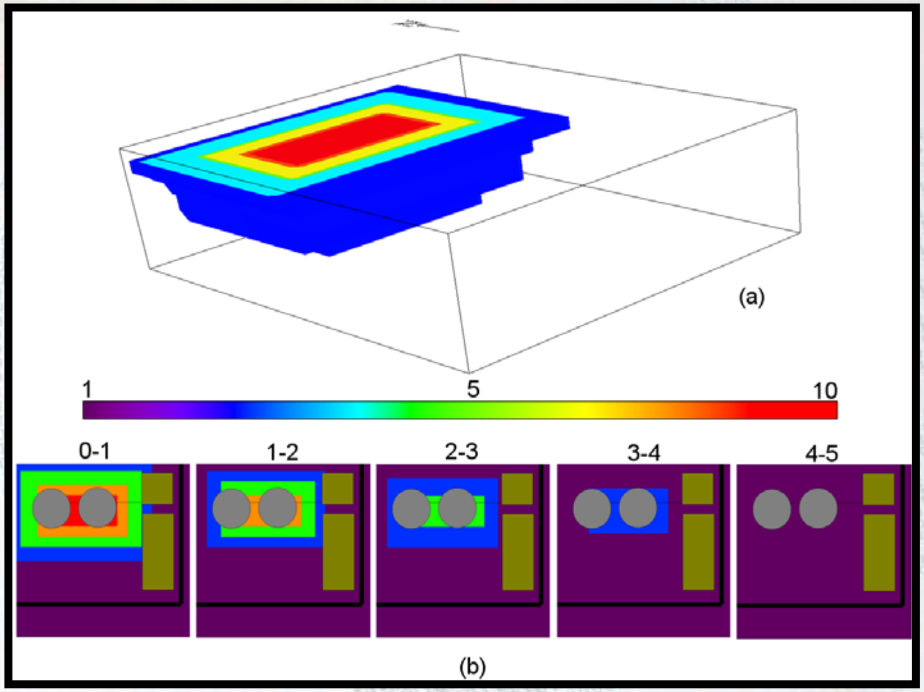

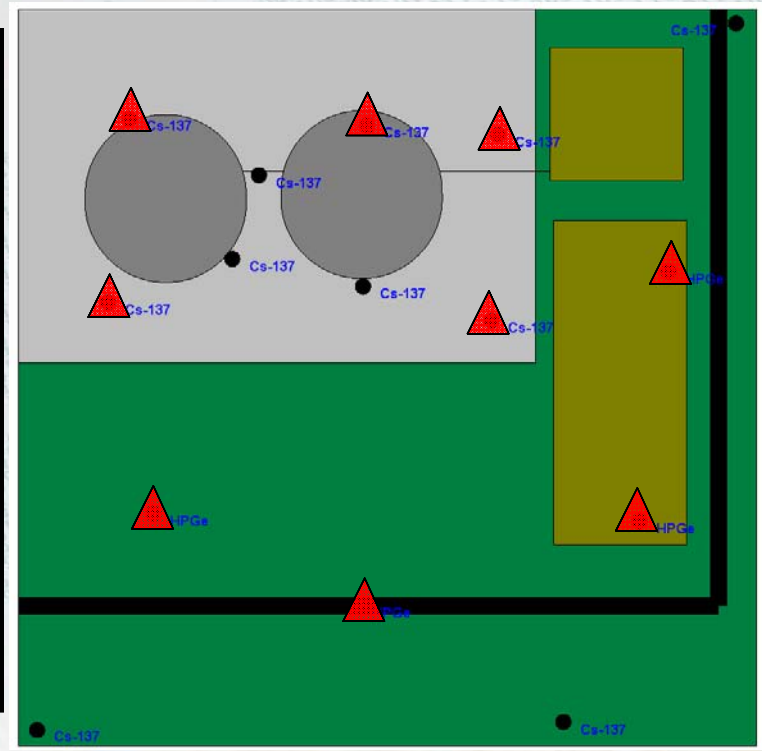

C&C

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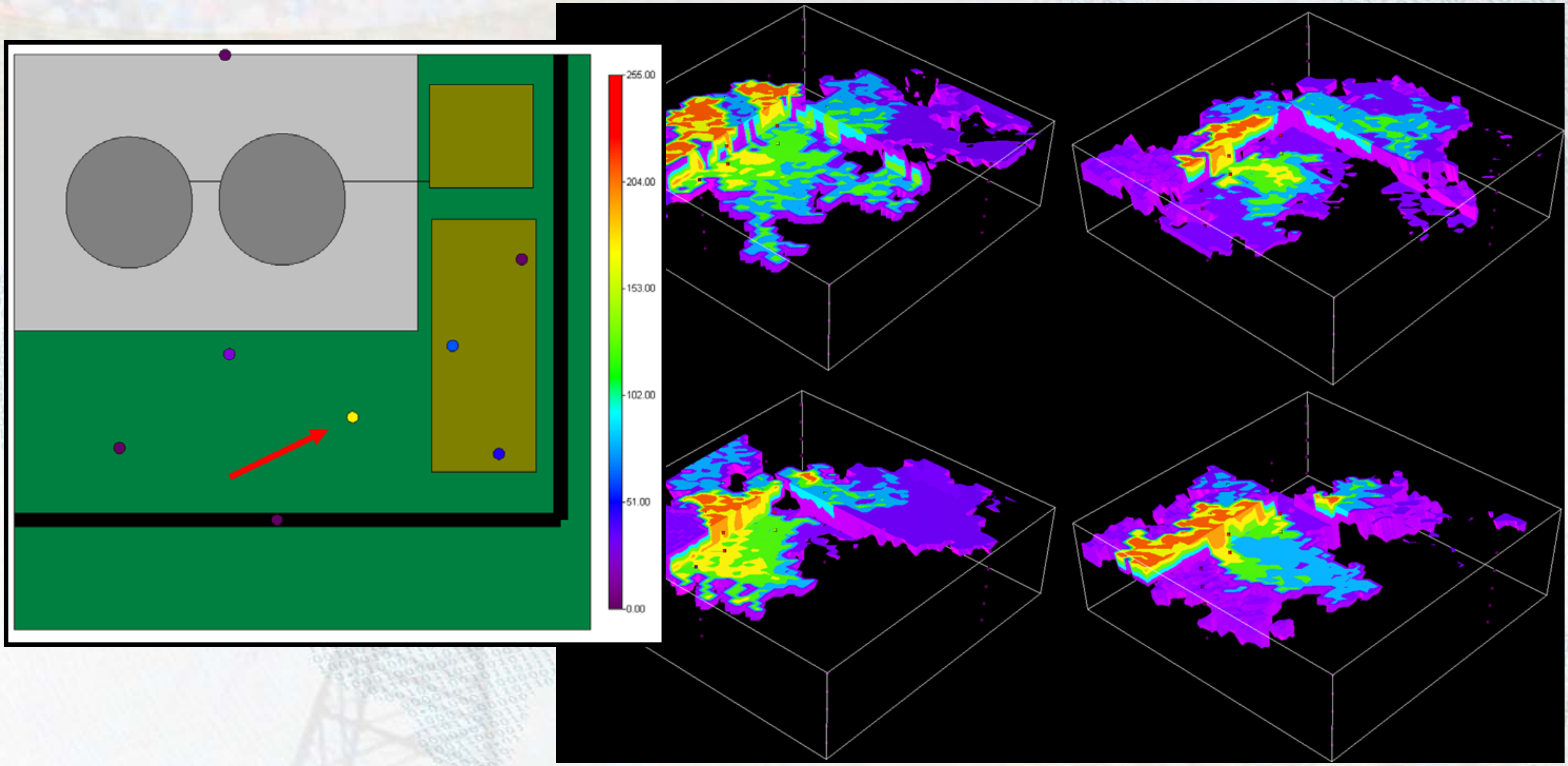

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Cesium Site Example

Geographic Information Science and Technology

```
5, Number of Layers
7, Numberof Geometries - #horizontal neighbors/#neighb
Top,Bottom,0/0,0/1,0/2,1/0,1/1,1/2,2/0
0,1,118.73,112.70,112.54,43.12,41.61,41.58,33.37
1,2,118.73,112.70,112.54,43.12,41.61,41.58,33.37
2,3,118.73,112.70,112.54,43.12,41.61,41.58,33.37
3,4,118.73,112.70,112.54,43.12,41.61,41.58,33.37
4,5,118.73,112.70,112.54,43.12,41.61,41.58,33.37
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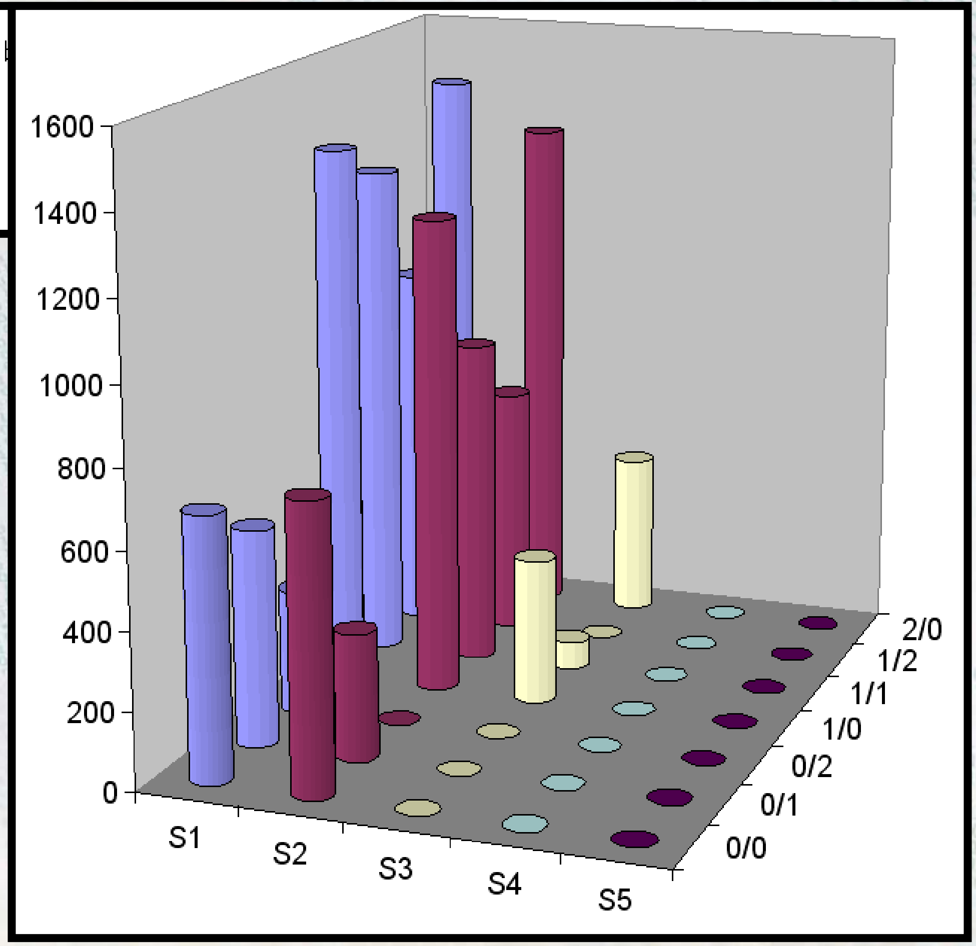

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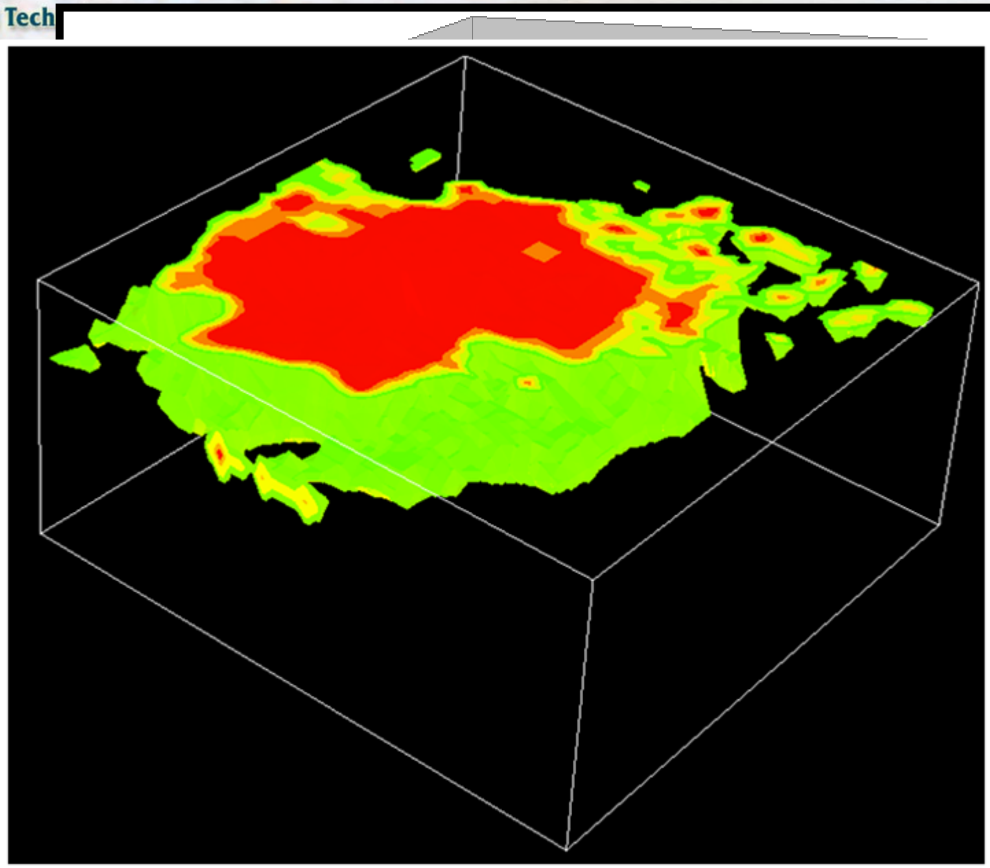
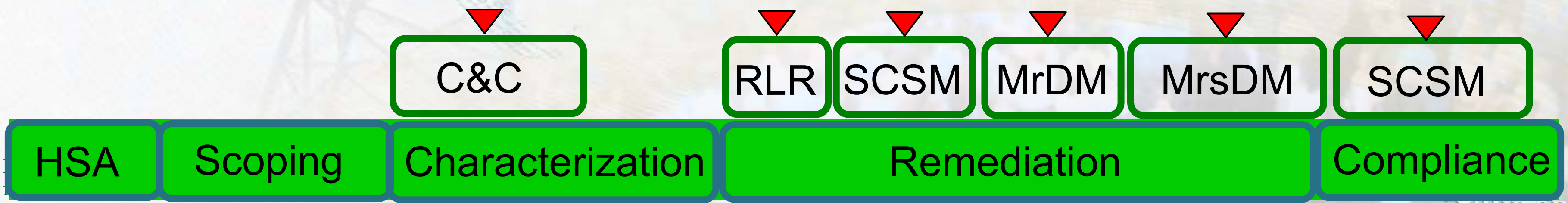
Cesium Site Example

Geographic Information Science and Tech



MrDM Results



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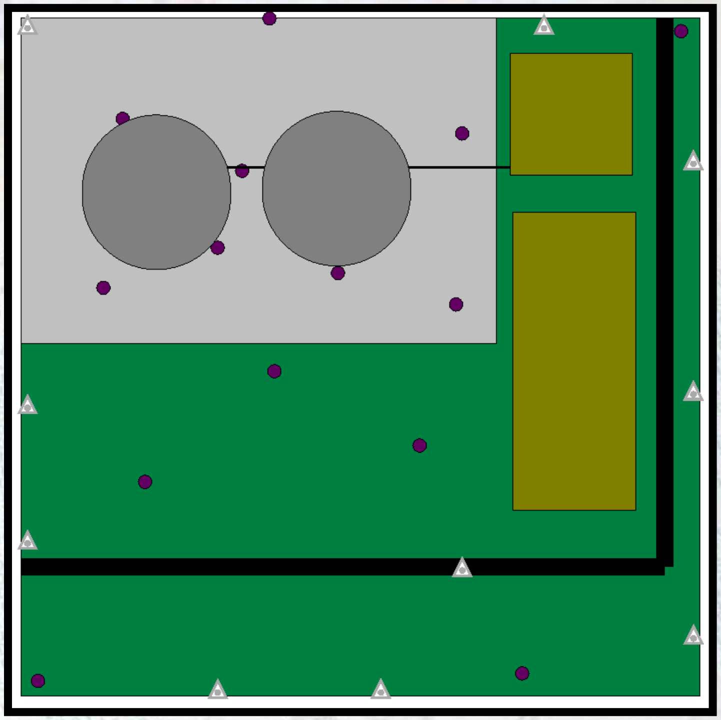

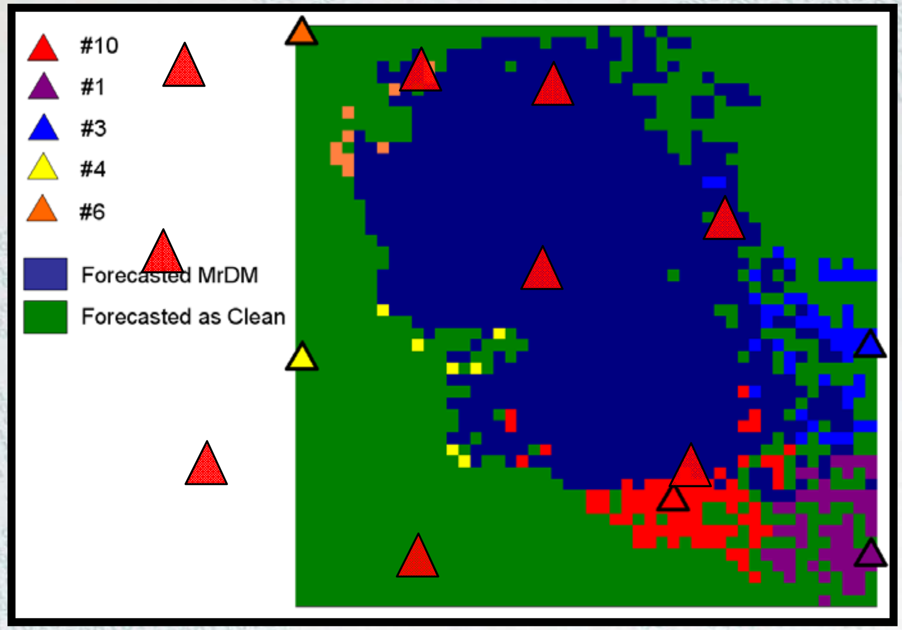

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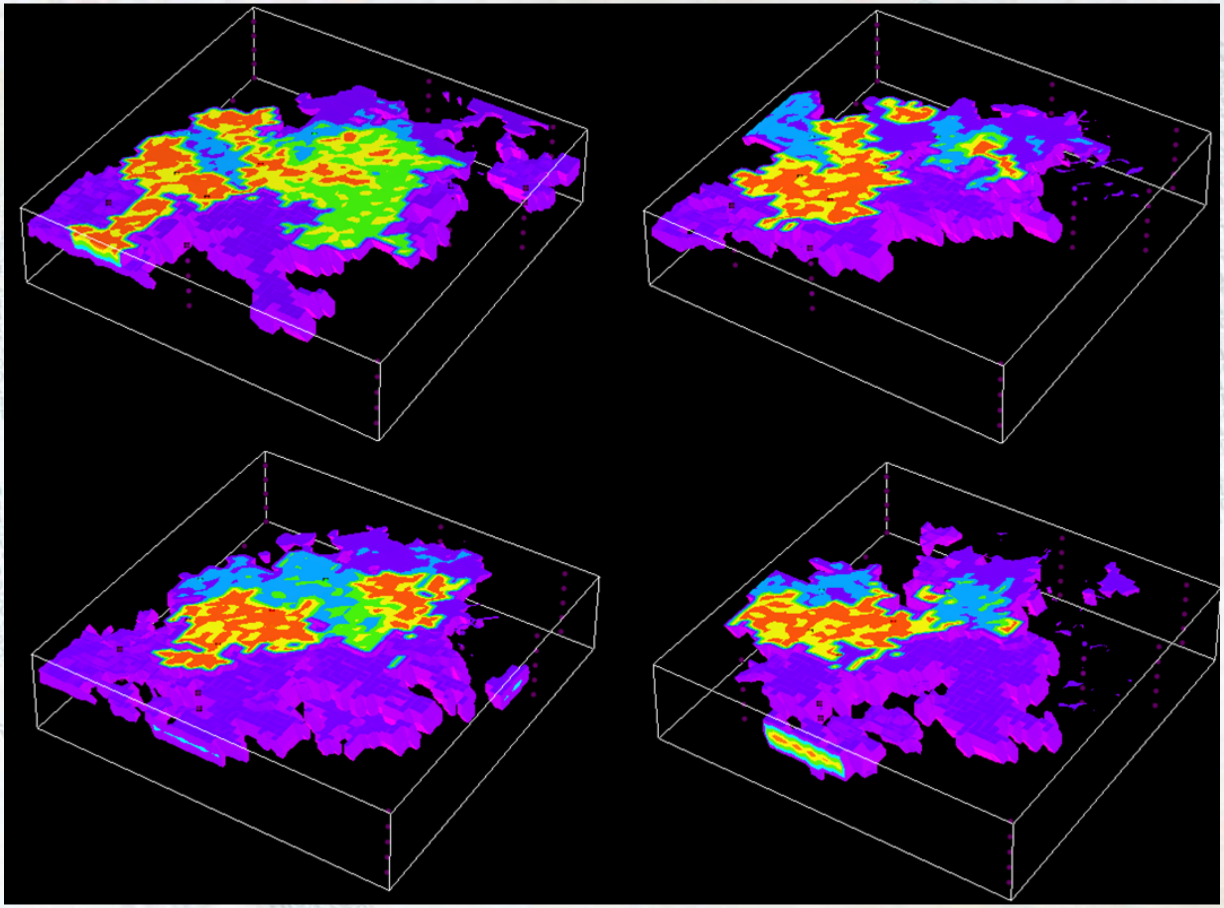

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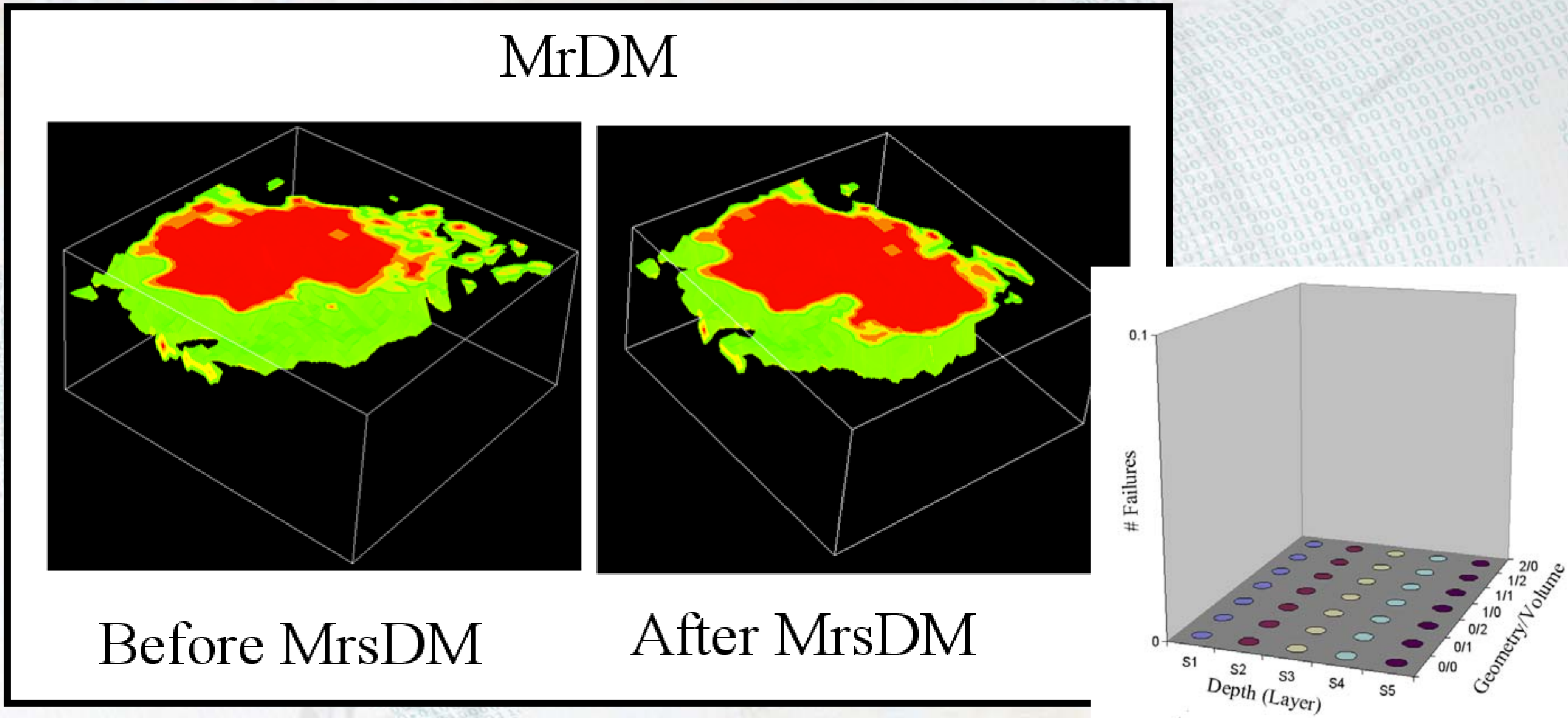

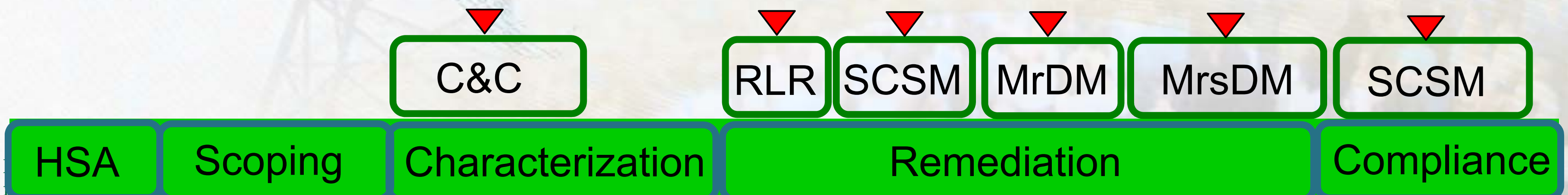

Difficult Challenges Remain

- **What do we mean by "best practices"?**
  - Contributions by multi-disciplinary teams of geostatisticians, geologists, soil scientists, etc
  - Can we frame a sub-process in the simulation block?
  - Can such a process be objectively critiqued?
- **How many samples?**
  - Traditional classical methods assuming independence
  - Geospatial methods that tend to rely on cost-benefit analytics to determine "stopping points"
  - Can we develop stronger methods? Will depend on site specific circumstances.
- **Rolling into regulatory guidance: field demonstrations, training, regulatory language.**