M-Scale: Uncertainty-Based Risk Classification and Scaling for Remedial Decision-Making

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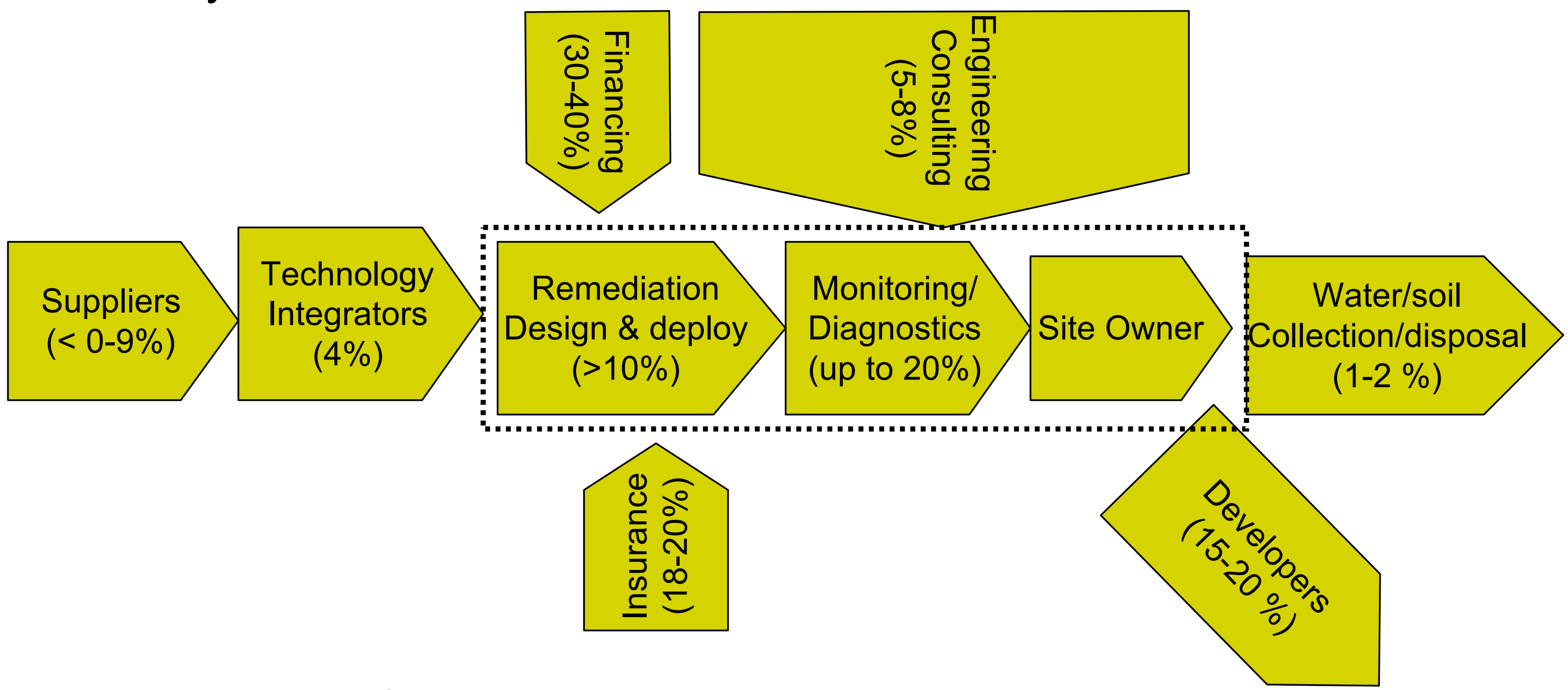
Remediation

- Market size (est. 2008): $28 bn.
- Cumulative VC investment: $ 30 m.
- Cumulative IPO: $ 12 M.

“Many technologies (biological, physical, thermal) have decreased the cost and increased efficiency of cleanup, and are less impacting on ecosystems. Hampered by limited standardization and regulatory acceptance of innovation.”

Remediation Value Chain

- Opportunity space: Remediation includes technology developers to remediation industries and the financial and liability insurance industry.



Highest margins in financial sector because these industries assume risk and liability for site remediation.

Strategic Drivers

- Environmental regulations: increasing stringency favors remediation contractors and developers
- Developing economies: economic growth and increasing standards of living promote demand for remediation
- Public awareness: long term impacts of contamination drives legislation
- Tax incentives: e.g. Brownfield Tax Incentive programs renders cleanup costs deductible in first year (est. to leverage $ 3.4 bn. in private investment)
- Quest for real estate: land valuations in coastal locations will drive developers to seek cleanup and reuse of abandoned sites
- Superfund: U.S. Government largest purchaser of remediation services ($ 1 bn/yr)

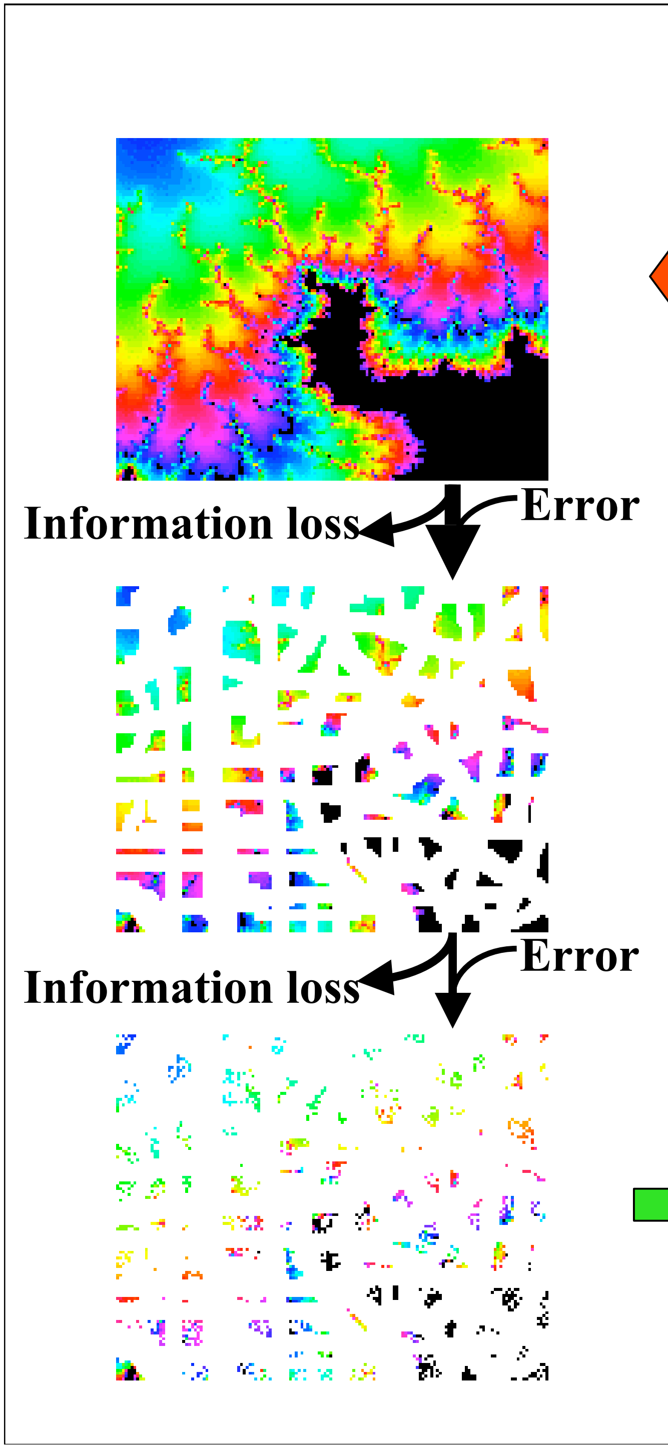
Risk Based Remediation

- In the past, the public and governing agencies demanded total site remediation to “pristine” conditions.
- More recently, agencies have adopted risk-based approaches to remediation.
- Responsible parties now have the opportunity to develop risk-based, site-specific remediation goals.
- This approach conserves client and agency resources by balancing the clean up costs with the risks associated with the intended use of the property.

Challenges

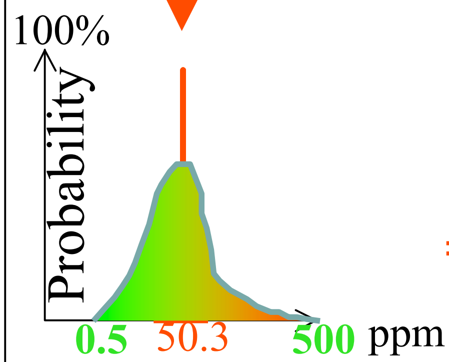
- Complexity of sites: drives containment rather than cleanup
- Unproven technologies: few industry standards (e.g. dredging, pump and treat, etc…)
- Budget cuts and changing priorities: political winds drive climate change over remediation; tax incentives uncertain
- Complexity of regulations: differences instate vs. federal codes impedes decisions
- Cost: high up front investment; cost-benefit

Pain: Data Uncertainty



Reality

- During sampling and analysis:
  - information is lost,
  - error is introduced



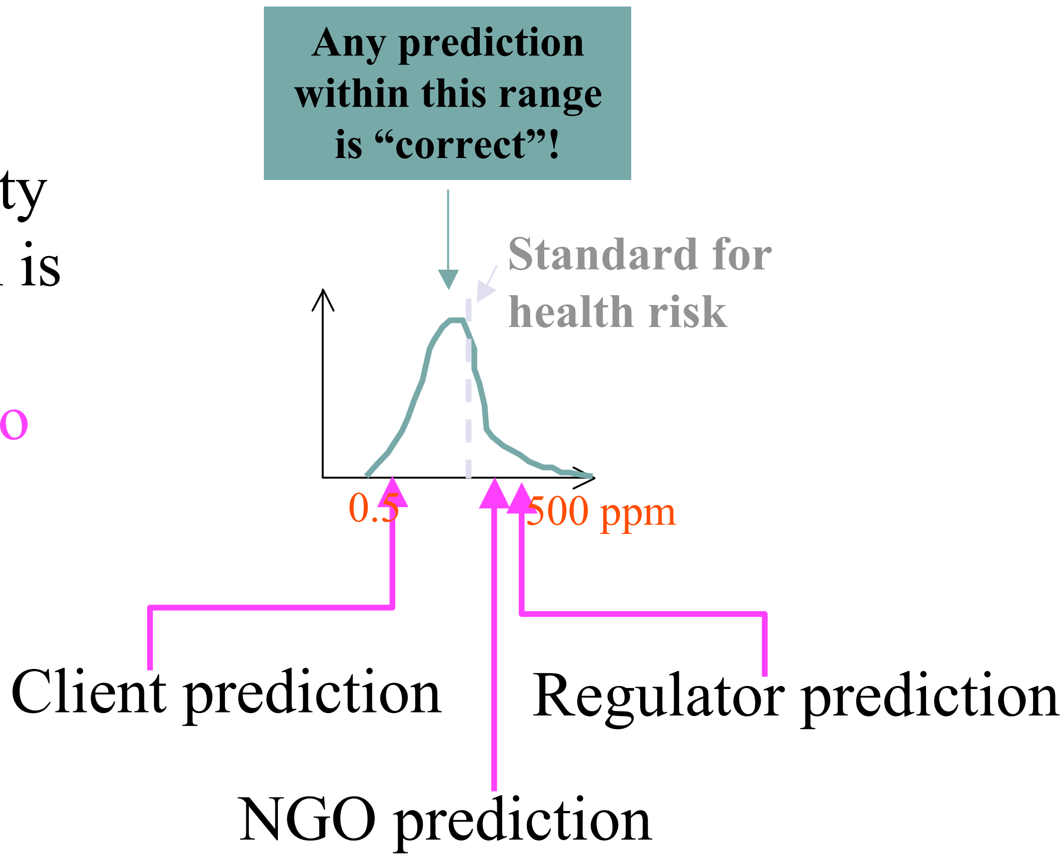
=> reality is only known within a range with a certain probability

Prediction

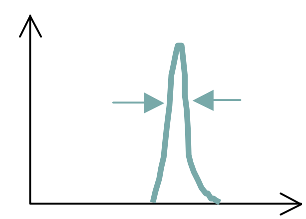
Any prediction within this range is "correct"! → Roadblock to decisionmaking

Impact of Information Uncertainty

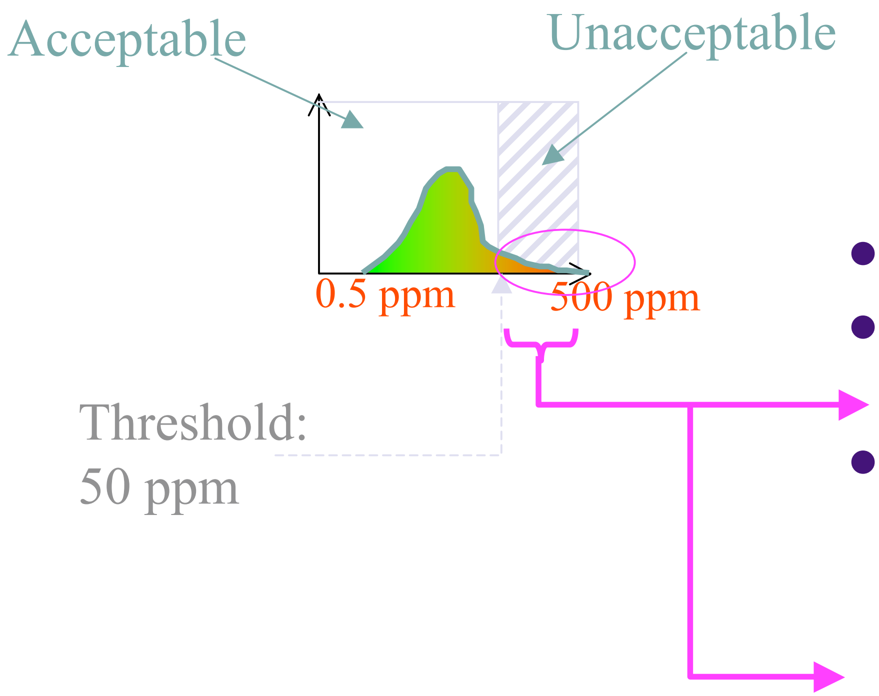
If probability distribution is unknown: roadblock to remedial negotiation



If probability distribution is known: need to collect more data to reduce uncertainty



Impact of Uncertainty



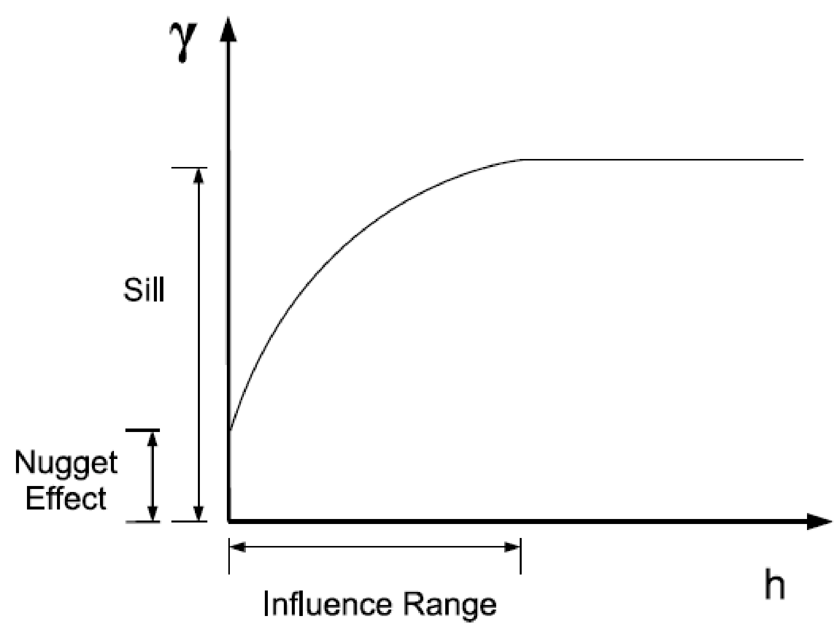
- Remedial decision threshold
- False positive/false negative designations
- Cost, timeframe and volume of media to be remediated

Negotiations need to determine
what threshold is acceptable
what level of probability is acceptable.

Solution: Geostatistical prediction tools to quantify uncertainty for remedial decision-making.

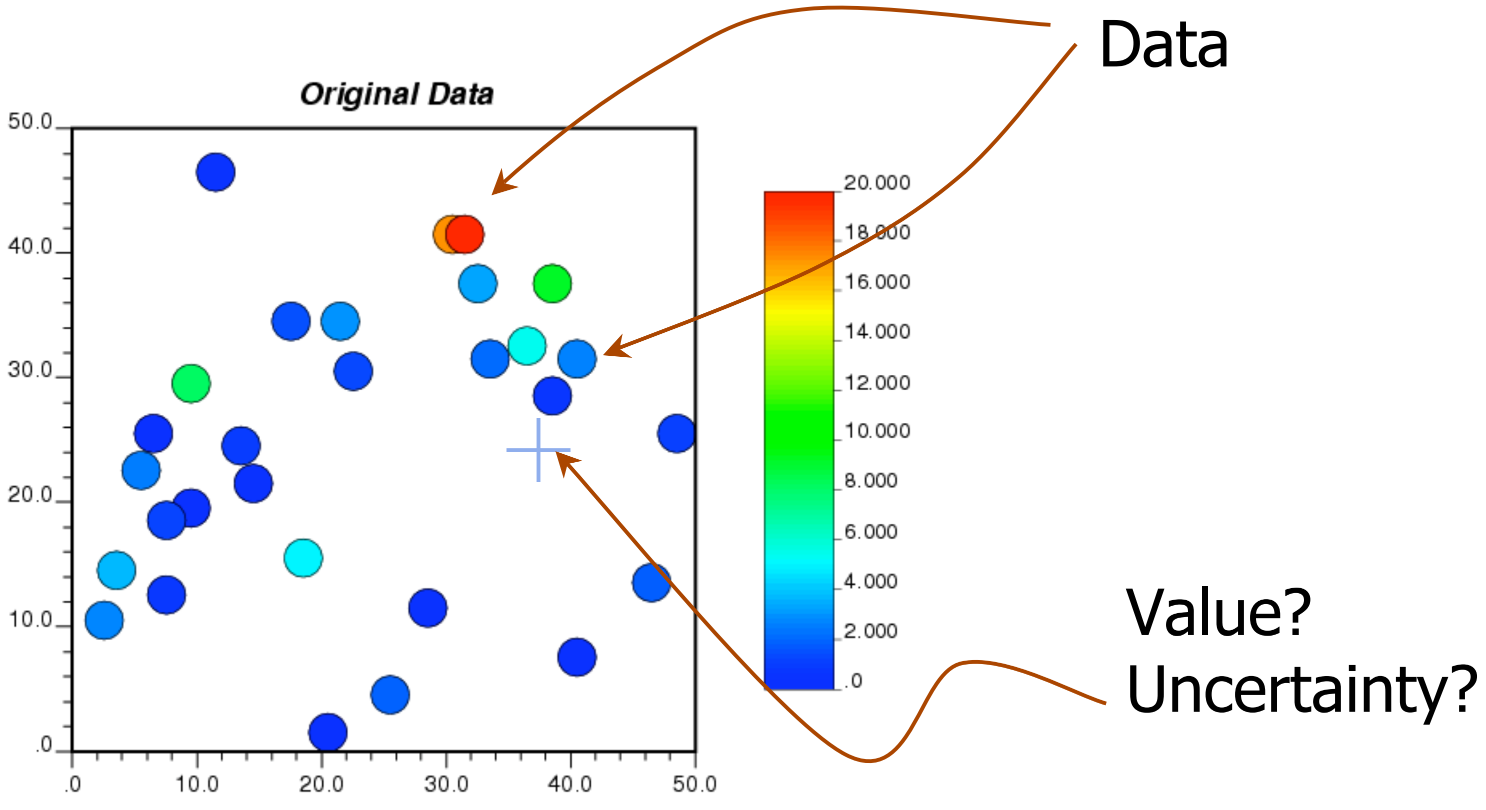
Geostatistics

- Uncertainty in the estimates is a derivative from both:
  - the uncertainty in the statistical model, and
  - the uncertainty in the data input.
- The uncertainty in the data (from different sources) is usually expressed as the nugget effect in a semivariogram.
- Nugget effect:
  - Microscale variability
  - Random error



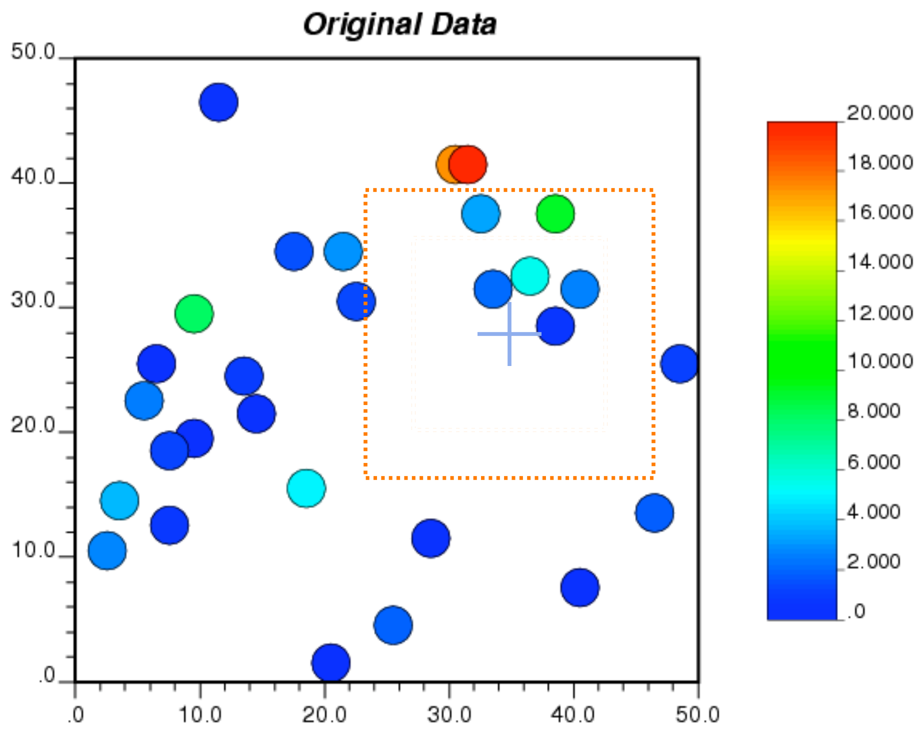
Principle of Spatial Estimation

- Spatial estimation uses available data to estimate values at unsampled locations



Local Spatial Estimation

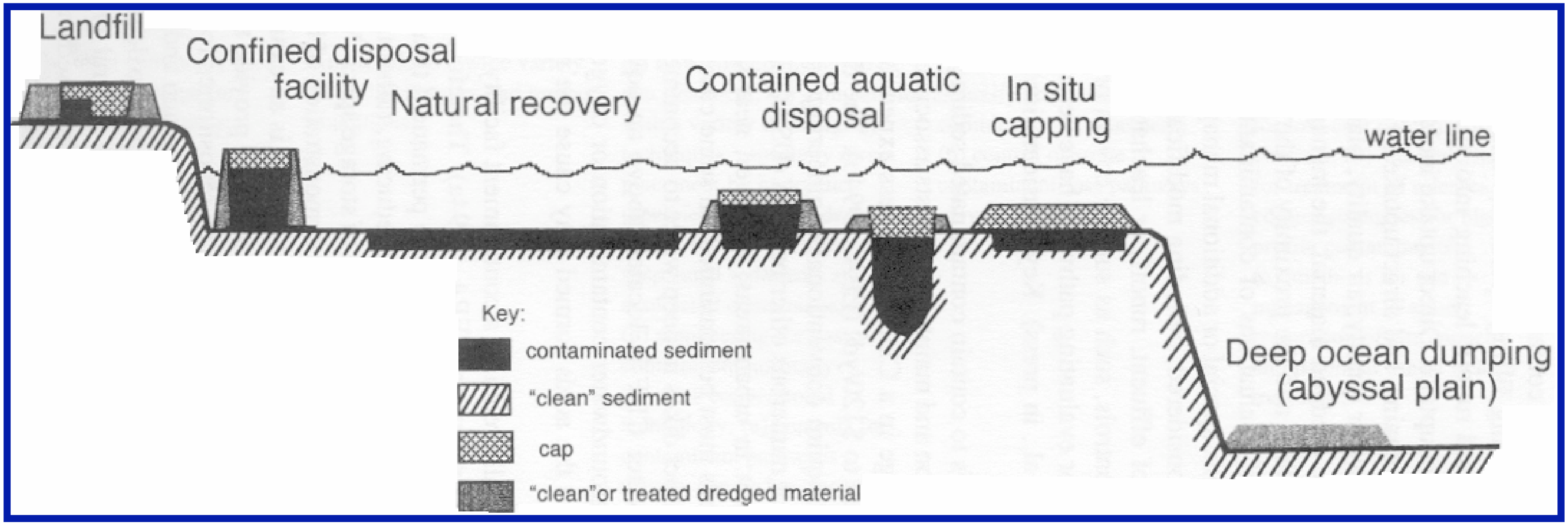
- …uses local averages to estimate attribute values at locations without measurements



The size of the neighborhood, or "scale," affects the estimate.

Example: Sediment Remedial Options

<u>Non-removal technologies</u>: in situ capping, containment or treatment
<u>Disposal technologies</u>: confined disposal facilities (CDF), landfills



200 180 20 < 100 50-150 <50 $/ton

-> Cost driven by volume and technology selection

Dredging and Disposal of Contaminated Sediments at a Confined Disposal Facility (CDF)

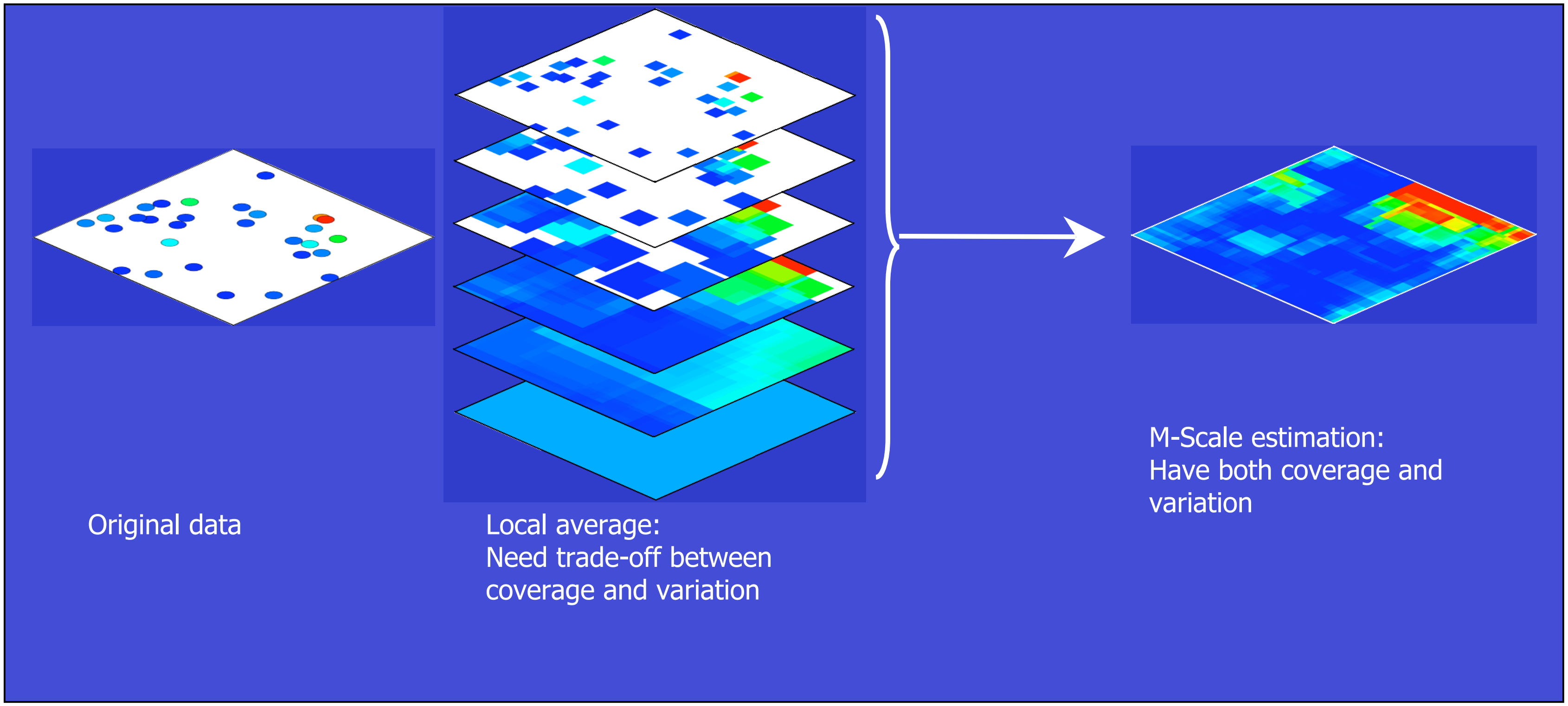
Value Proposition: Uncertainty-Based Decision Tools

- For remediation design: cost and time
- For liability insurance: reduced risk
- For financial industry: reduced risk
- For property owner: flexibility

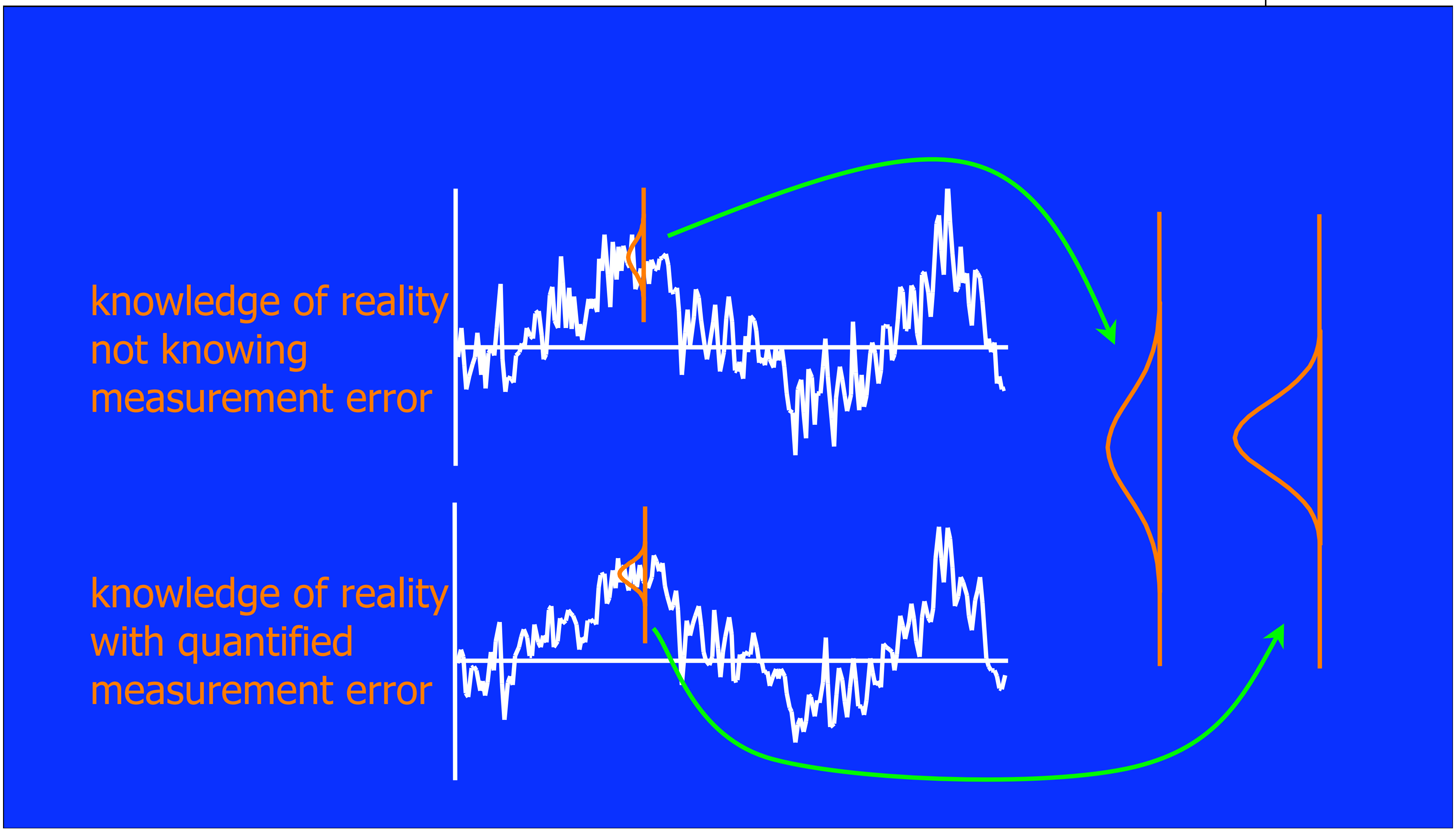
"Many geospatial uncertainty models exist, but few explicitly address scale beyond point-to-point interpolation"

M-Scale Model Attributes

- An algorithm that explicitly estimates events at variable scales
- Uses local averages to estimate attribute values at locations without measurements
- Integrates data averages gathered at small and large scales in a single estimator.
- **Separates microscale variability from random error, resulting in a reduction of nugget effect and decreased estimation uncertainty**

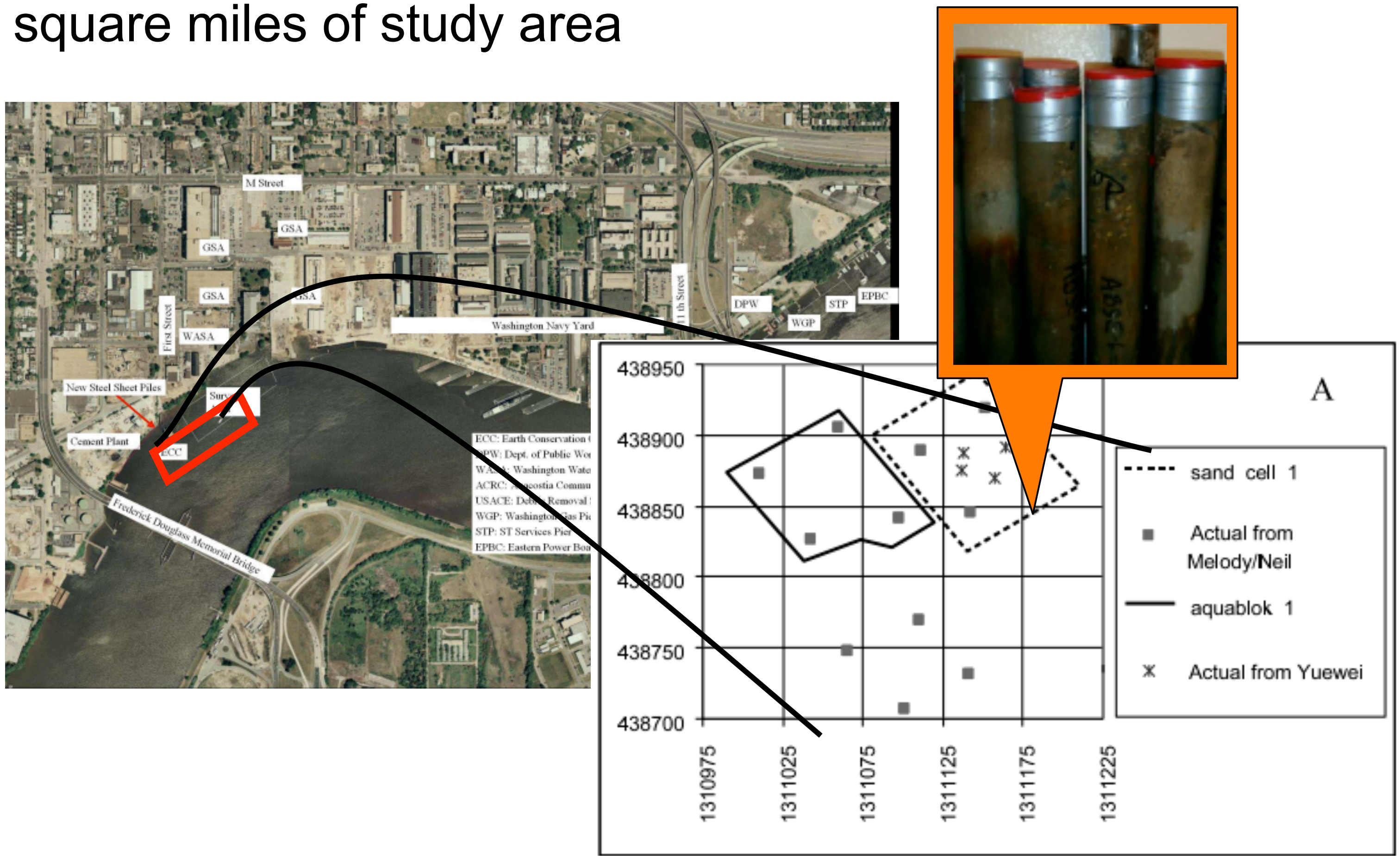


How Reduce Uncertainty? Nugget Effect

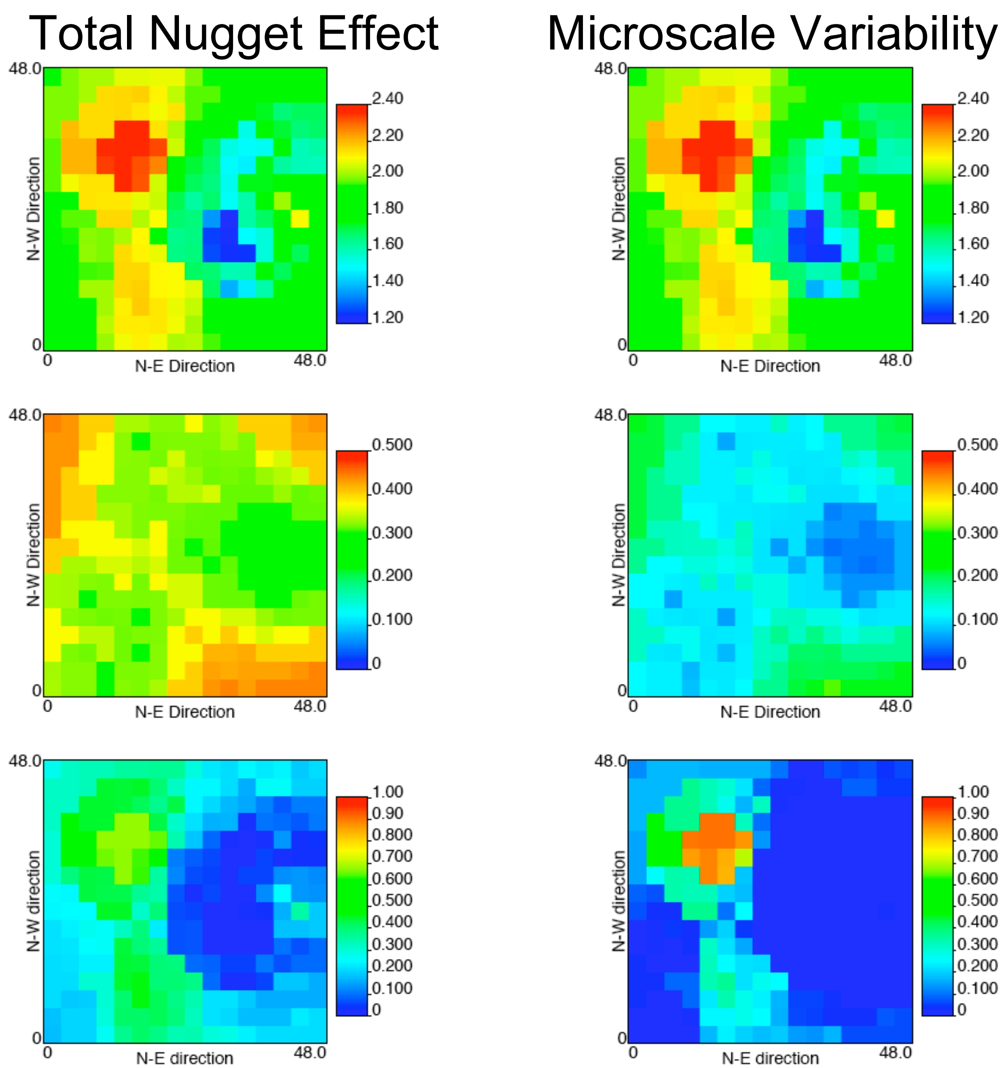


Case Study: Anacostia River (Washington, DC)

- 16 sample locations with paired cores in Aquablok™, Sand cap and uncapped sediments
- 176 square miles of study area



Impact of Micro-Scale Variability on Spatial Estimation of Values



estimation map,

estimation variance,

likelihood of the estimate to exceed 2.2×10^7 organisms (for bioremediation under cap)

M-Scale Comparison to Other Geospatial Models

- for a remedial design with a low likelihood thresholds (low willingness to accept an incorrect decision):
  - A reduced area (in %) of exceedance is delineated using the M-Scale model
  - Resulting in savings for unnecessary remediation

	M-Scale		OK		CK	
Likelihood Threshold	Nugget Effect Retained	Nugget Effect Adjusted	Nugget Effect Retained	Nugget Effect Adjusted	Nugget Effect Retained	Nugget Effect Adjusted
0.2	60.55	14.84	59.77	39.45	59.77	48.05
0.4	10.94	8.20	19.92	13.28	41.41	36.33
0.6	4.69	6.64	3.12	3.52	25.00	23.83
0.8	0.00	3.52	0.00	0.39	7.81	10.16

Conclusions

- Risk-based remedial decisions are impacted by data uncertainty, resulting in escalating cost and time
- Geospatial tools quantify uncertainty (e.g. likelihood of exceeding a threshold value), and its impact on the scale of the remedial design
- M-scale offers high precision estimates that reduces the estimation uncertainty, and thus cost of remediation (e.g. precision dredging, etc…)

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