U.S. EPA "State of VI Science" Workshop

Workshop 05, Part I: Vapor Intrusion Protection Cost-Effectiveness Simulation Tool (2.0)

Vapor Intrusion Site Investigation, Mitigation and/or Remediation Simulation

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Presentation archived at https://iavi.rti.org/

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PRAXIS ENVIRONMENTAL TECH. INC

Simulation Objectives and Rules

Purpose

- Examine the economic and environmental protection tradeoffs between various approaches to managing vapor intrusion sites
- Simulate 20 years of decision making and data collection in 3 hours.
- Reflect, learn, and grow as VI professionals by exercising our project management experience.

Why do a simulation?

- “Simulations allow individuals to experience errors and failures and learn about their consequences in a safe environment.”
  https://www.upstate.edu/psych/research/sms.php

- "Tell me and I forget. Teach me and I remember. Involve me, and I learn" — Benjamin Franklin
- Learning these skills on one site can take an entire career

https://collider.com/matrix-5-in-development/

The Challenge of VI Site Assessment

- Multiple lines of evidence are crucial for accurate vapor intrusion (VI) site investigations.
- Minimizing false negatives and confirming source attribution requires substantial sampling.
- Traditional VI investigations can be complex, time-consuming, and expensive.

VI Site Assessment Simulation

Instructions

Simulation Instructions

Important Disclaimer

The Vapor Intrusion Site Investigation, Mitigation, and Remediation Simulation: This prototype was designed to addresses the elements:

- Support of verifiable confidence in VI protection
- Prioritizing (re-) Evaluation of VI Exposure Decisions/Management
- Metrics for Verifiable Confidence in VI Protection
- Documenting the verifiable VI protection provided

The preliminary version of this simulation was tested with EPA at the March 2025 workshop at AEHS West in San Diego, CA. This simulation and proof of concept is being shared for internal review by EPA and should not be considered a final product, released externally, or used for operational decision-making at this stage.

Simulation Instructions

This simulation is designed to simulate the various decisions and trade-offs typical in vapor intrusion site investigation, mitigation, and/or remediation. The simulation progresses over 1 year increments and user has the ability to select sample media, sample prioritization metrics, mitigation type and number, and remediation options for any given year. Once a remediation option is selected, it should remain selected in subsequent years to capture system O&M costs. Once a household mitigation option is selected, it should be set back to 0 in subsequent years. Click below to see more detailed simulation documentation:

Download Simulation Handout

Simulation Setup – Target levels

Enter the target or action levels for DCE and TCE you would like us in this simulation

1,2-Dichloroethane (DCE)

Indoor Air Target Concentration (µg/m³):

4.1

Soil Gas Target Concentration (µg/m³):

138

Groundwater Target Concentration (µg/L):

3.9

Trichloroethylene (TCE)

Indoor Air Target Concentration (µg/m³):

2.1

Soil Gas Target Concentration (µg/m³):

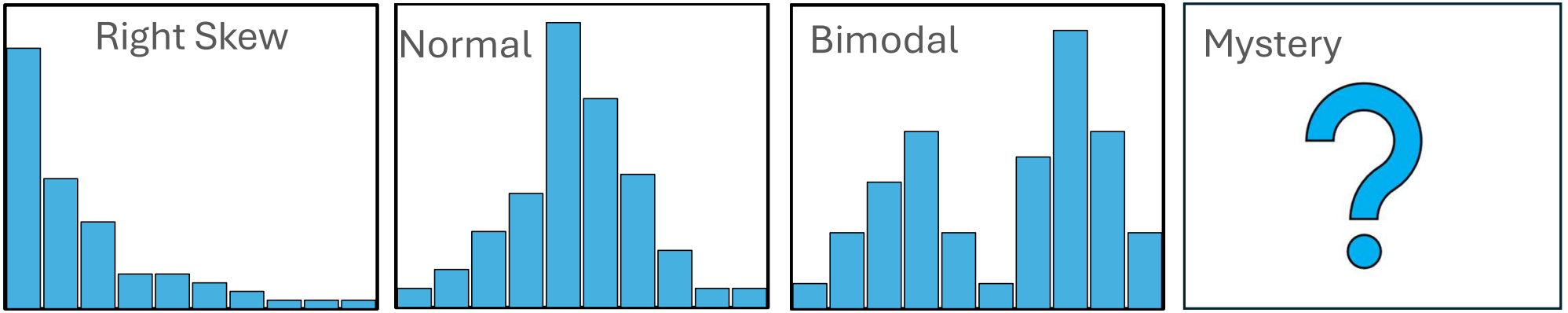
70

Groundwater Target Concentration (µg/L):

5.2

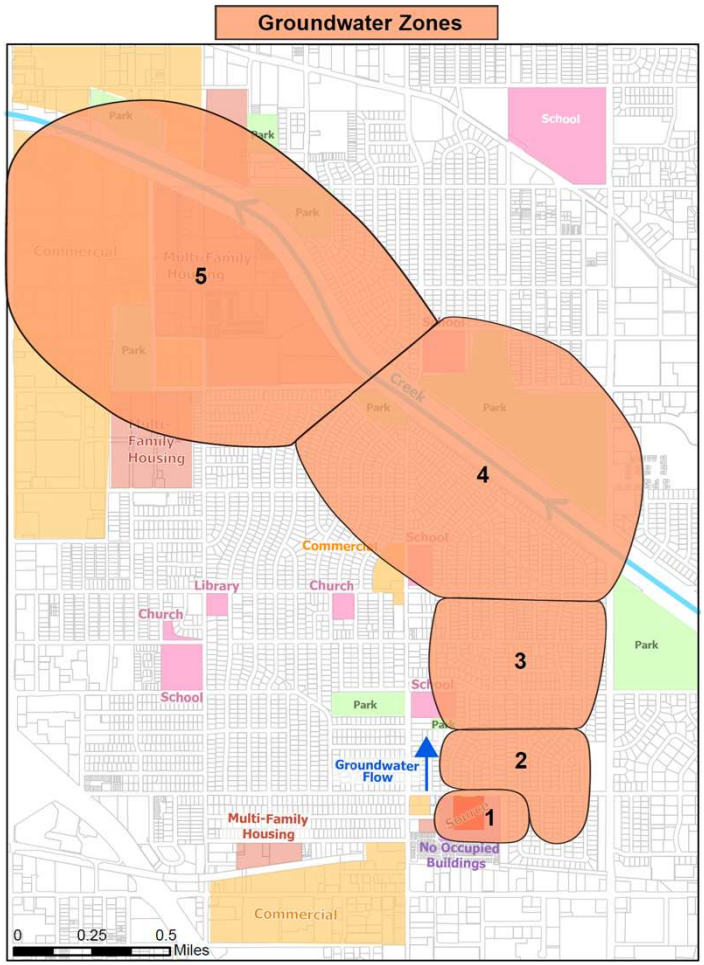
Simulation Setup – Underlying distribution

You can customize your distribution to match an existing site or get a mystery distribution



Groundwater and Soil Gas Sampling by Grouped Zone

- Each zone represents a group of 25 wells or monitoring points
- Simulation rounds ask you to choose a zone for groundwater and soil gas sampling
- You do not have to select a zone
- Each round you can turn off or on sampling for each zone
- The first time a zone is selected, you'll pay installation costs, subsequent years, you'll only pay sampling costs



Groundwater – Cost Breakdown and What You Get

The first year of Groundwater sampling includes:

1. the creation of a QAPP,
2. access agreements,
3. well installation for 25 wells, and
4. the collection of an initial sample at 25 wells per zone.

These cost $182,050 per zone and are added only to the first year an area is monitored.

Additionally, the user can choose to simultaneously install nested soil gas vapor monitoring points in the drilled wells for an added cost of $41,000 per zone in the first year a zone is monitored.

Sampling groundwater for VOCs and field parameters costs $43,250 per year for each zone sampled starting in year 2. Sampling groundwater from wells with nested soil gas vapor monitoring points installed is $52,601 per year for each zone sampled starting in year 2.

Soil Gas – Cost Breakdown and What You Get

All soil gas sampling includes the creation of a QAPP and access agreements ($15,800) in the first year a zone is monitored.

The user can select between 3 different monitoring and installation strategies:

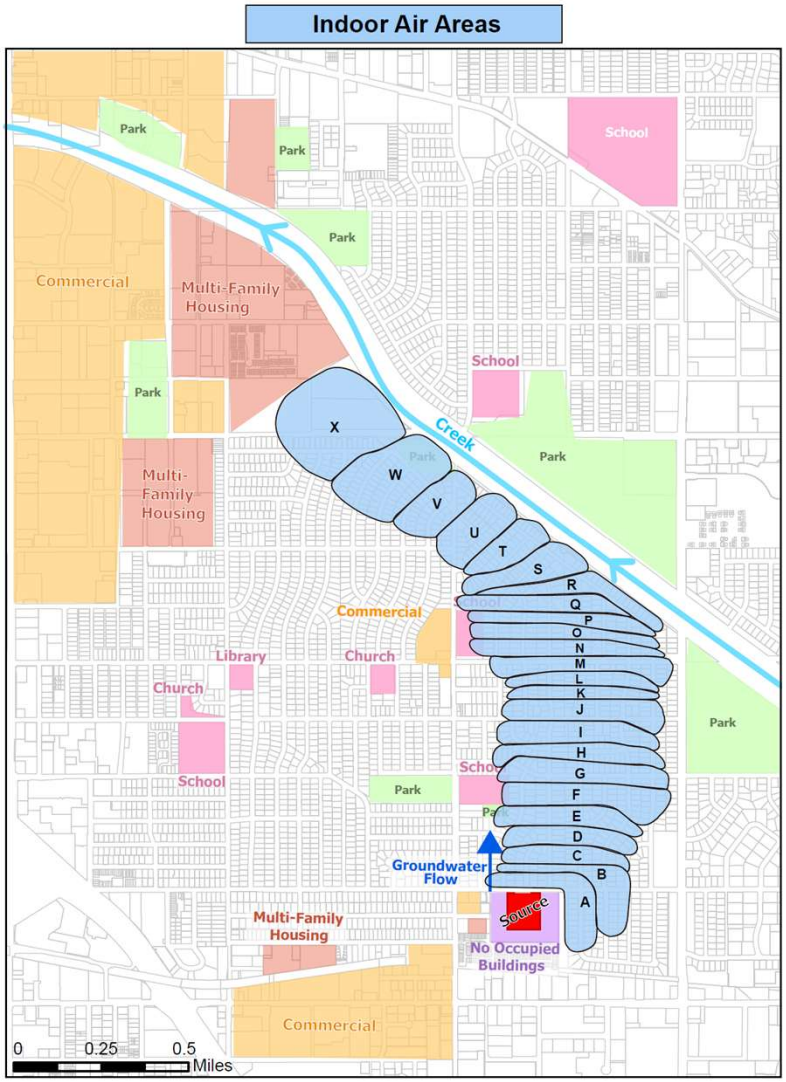
1. installing semi-permanent soil gas probes,
2. Installing soil gas vapor monitoring points (not in groundwater wells),
3. Installing temporary soil gas probes to collect data for a year.

If the user selects to install nested soil gas vapor monitoring points concurrently with groundwater wells, the soil gas monitoring strategy will be automatically selected.

Description	Installation Cost	Annual Sampling Cost
In year 1, install, sample for the first time and report 25, semipermanent external soil gas probes at 10' bls with direct push. In years 2 and beyond, Twice per year external soil gas probe sampling, at 25 semipermanent probe locations.	$ 98,000	$ 32,190
Install and sample 25 temporary passive external soil gas samplers at 2' bls with man portable tools. This cost is applied each year in each zone.	$ 21,000	
Install 25 multidepth soil gas monitoring points with the 25 groundwater wells. Twice per year VMP sampling for VOCs at 25 GW wells (3 VMPs/well)	$ 41,000	$ 26,340
Install 25 independent multidepth soil gas monitoring points. Twice per year VMP sampling for VOCs at 25 GW wells (3 VMPs/well)	$ 83,862	$ 26,340

Indoor Air Sampling by Housing Block

- Each housing block (Area; A-X) represents 30 houses
- Simulation rounds ask you to choose an Area for indoor air and subslab sampling
- You do not have to select an area
- You need to select how many of the 30 houses in an area you approach allow sampling
- Each round you can turn off or on sampling for each area
- The first time an area is selected, you'll pay installation costs, subsequent years, you'll only pay sampling costs unless you add additional houses



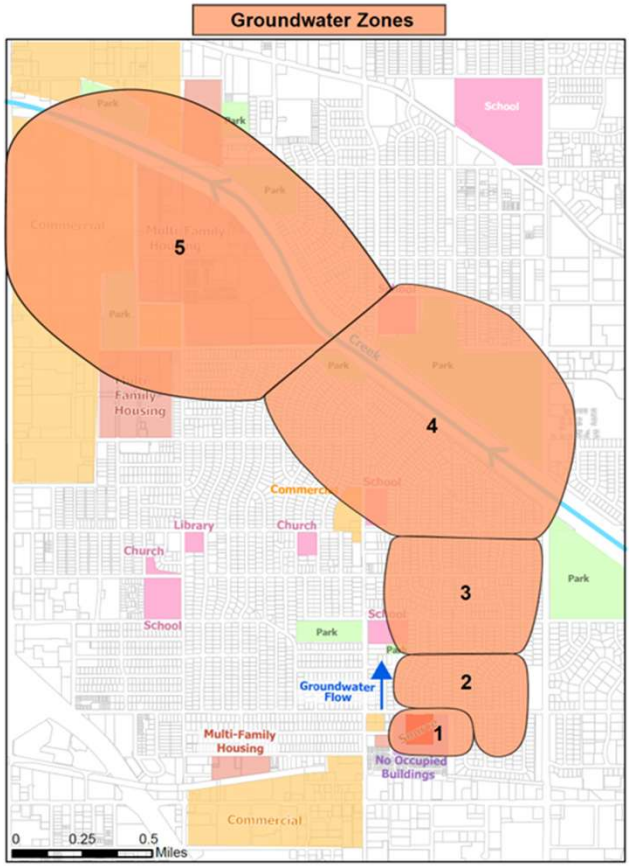
Indoor Air – Cost breakdown and What You Get

Indoor air sampling includes creation of a sampling plan, access agreements with houses, an initial indoor air survey and installation of on average 2 subslab ports per house. Installation costs are added the first time an area is studied.

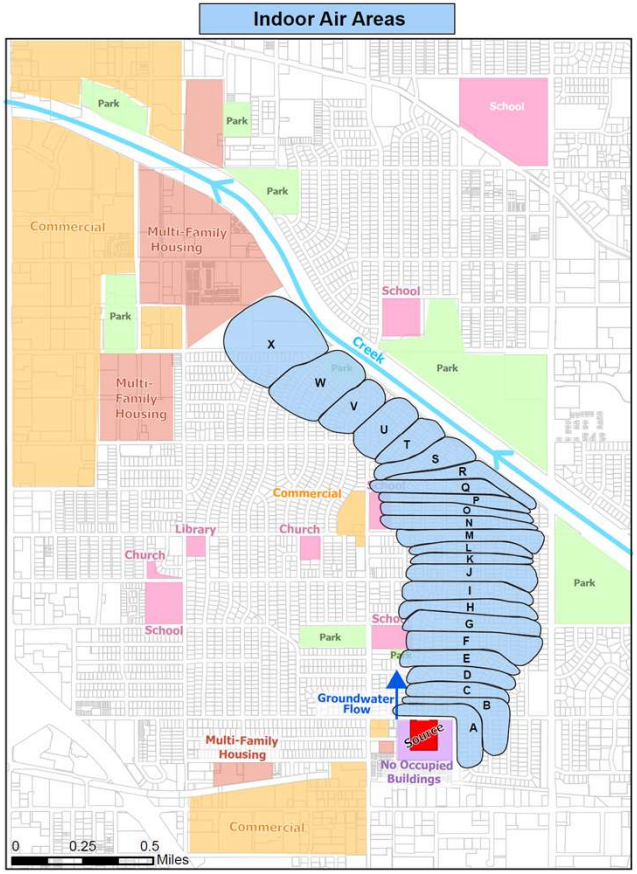
Sampling can be scheduled with the following options:

Sampling Type	Cost per House per Year	Description
Seasonal	$11,200	Set of 4 Rounds of Indoor Air Sampling and Subslab Sampling, TO-15, Seasonal Timed, 2 indoor and 2 subslab locations. Per house costs plus QC and reporting
ITS	$10,900	Set of 4 Rounds of Indoor Air Sampling, TO-15 and 2 Rounds Subslab Sampling, Indicator Tracer and Surrogate Timed Indoors (one year of two Airthings units per structure), 2 indoor and 2 subslab locations per structure plus QC and reporting. Per house costs
Convenience	$11,600	Set of 4 Rounds of Indoor Air Sampling and Subslab Sampling, Convenience Timed, 2 indoor and 2 subslab locations per structure plus QC and reporting. Per house costs

Zone – Area Overlap



GW	IA
1	A
2	B-D
3	E-L
4	M-W
5	X



Mitigation Description

- The user can choose the number of new mitigation systems to install at the household level.
- Mitigation system installation includes consent forms, regulatory plans, permits, design, install, and testing in year 1 and costs $13,964 per house.
- Operation, maintenance, and monitoring (1 sampling round every year) in years 2-5 costs $1,360 per house per year.
- Operation, maintenance, fan replacement and monitoring (1 sampling round every 5 years) in years 6+ costs $816 per house per year.
- Once a mitigation system is installed O&M costs will continue to accumulate for that house indefinitely and the “Select number of new households to mitigate:” option will be set back to 0.

Description	Cost per house per year
Mitigation Design, consent forms, regulatory plans and permits, install, and testing for first year, modification as needed, reporting and homeowner communication.	$ 13,964
Mitigation years 2-5, Monitoring and Maintenance (inspection plus one round sampling; small number of system revisions each year).	$ 1,360
Mitigation years 6 to 15, Monitor and Maintenance for 30 structures (inspection plus one round of sampling every 5 years, inspection with differential pressure only in other years), Fan replacements of 70% of installed fans, reporting	$ 816

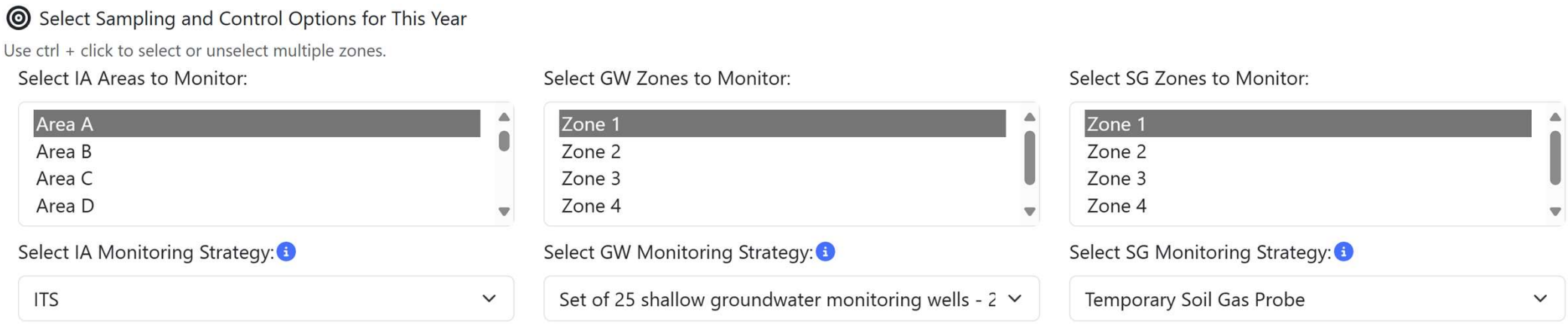
Remediation (SGM) Description

- Choosing a soil gas management plan involves Developing a design basis for soil gas management (SGM) under 30 homes, install and operate a single well pilot, and then install the 2 sgm systems under 30 homes with an effective radius of 85 feet. This costs $369,000 in the first year.

- You'll need to select SGM in batches of 30 houses and leave it selected to continue O&M Costs:

Description	Cost per year
Operate & monitor the 1st Year (ROEM = 85 ft)	$ 108,000
Operate & monitor Years 2 & 3 cost (ROEM = 85 ft)	$ 72,500
Operate & monitor 5-year increments (ROEM = 85 ft)	$ 34,800

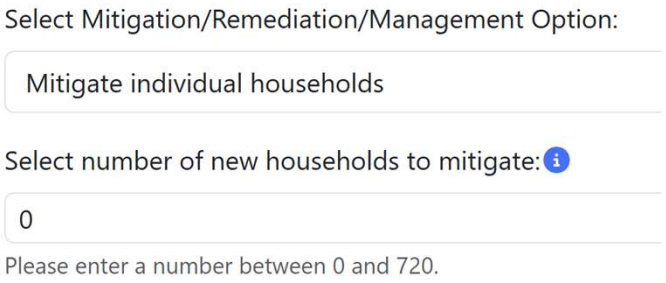
Selecting your actions for a year



- You can select any or no sampling actions
- You can select or unselect (with ctrl + select) any action
- When you select a monitoring area or zone, you will be prompted to also select a monitoring strategy. The (i) has more information on the cost and what goes into each strategy
- You can advance without selecting any sampling actions

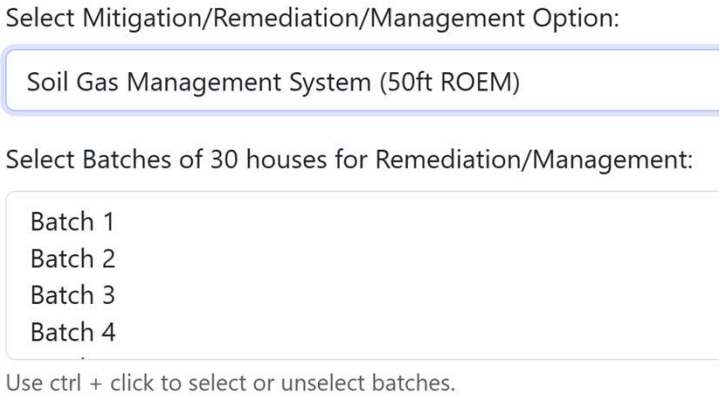
Selecting your mitigation or remediation options

- You can select by individual household:



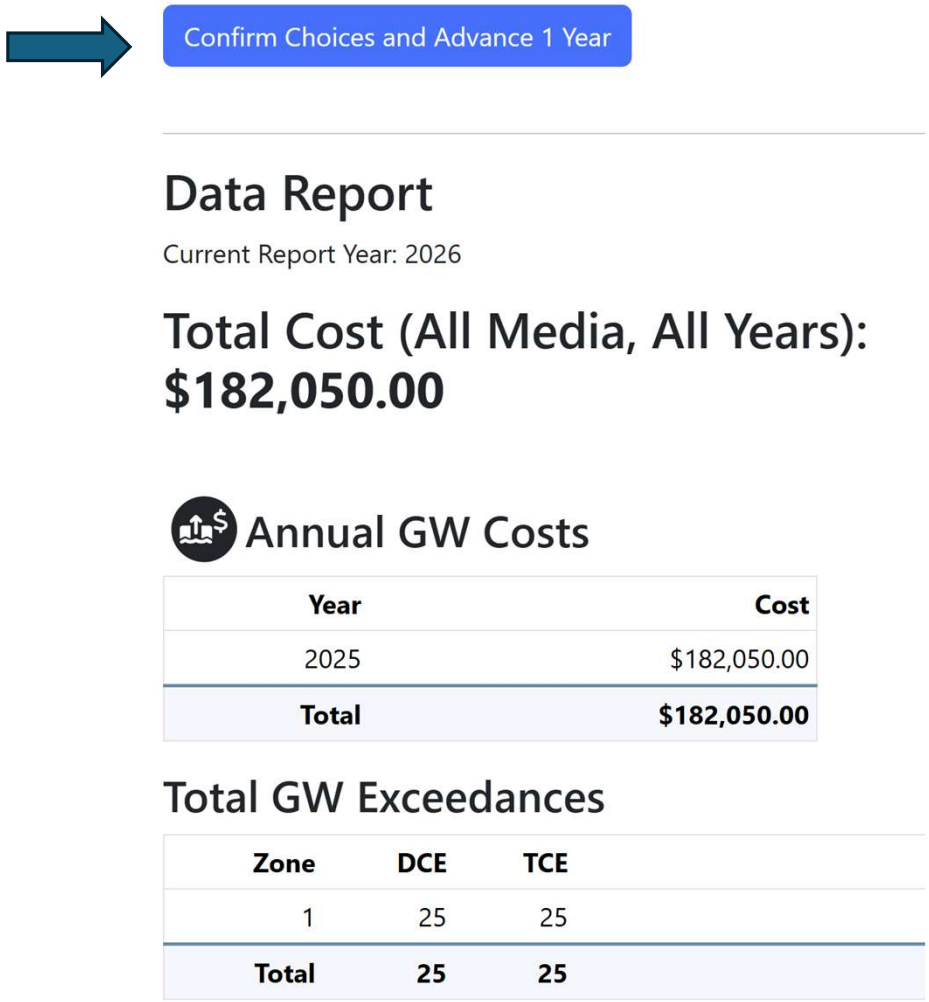
OR

- You can select block level remediation:



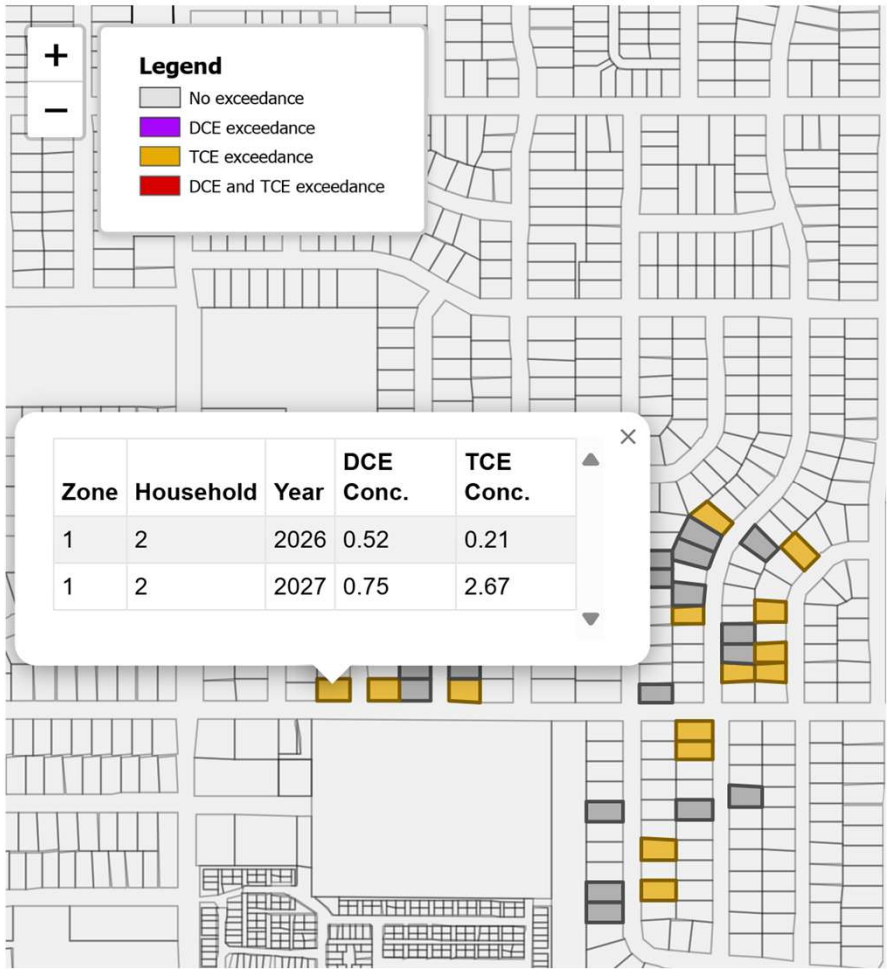
Advancing the simulation

- You push “Confirm Choices and Advance 1 Year”
- A data report will show up with cost and exceedance data
- The cost will update each year starting with 2025



Visualizing Results:

- The built in mapper will display groundwater, soil gas, and indoor air data.
- Groundwater and soil gas data is presented as a heat map.
- Indoor air data is presented at the household level.
- Historical indoor air data can be seen by clicking on a specific hous



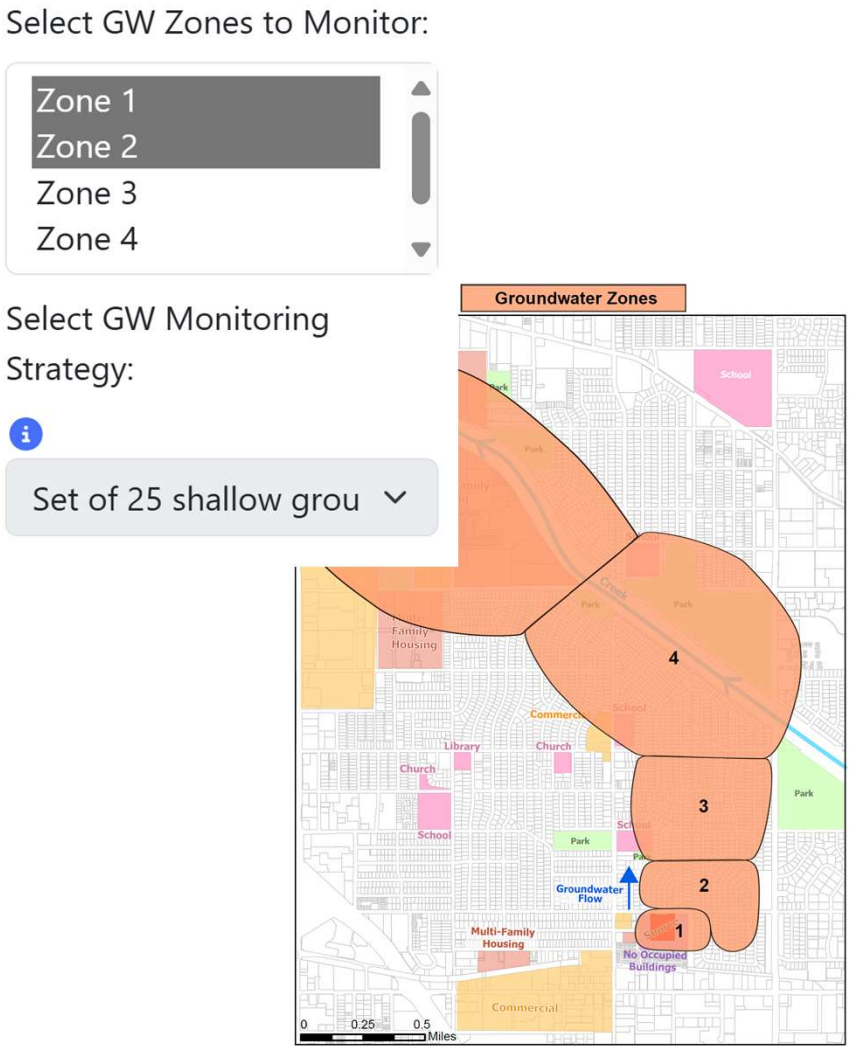
Trialing it out!

Conventional Strategy

- Initial Sampling Strategy: Groundwater focus
- Use Groundwater sampling to Identify areas impacted.
- Once areas are identified, move to External Soil Gas
- Monitor SG until we identify several zones with issues
- Assess need for mitigation with Indoor Air Sampling
- Mitigation in households in response to indoor air sampling

Initial Selections

- Let's write a QAPP to do groundwater sampling
- Get permits for installing the wells
- Drill the wells
- Conduct our first round of sampling
- ~1 year of effort (all at the push of a button)
- Zone 1 is the source so we're selecting both zone 1 and 2 initiall)



Results from Round 1

- We see all the GW wells at the source with an exceedance

- Many wells downstream of the source also high in TCE and DCE

Total GW Exceedances

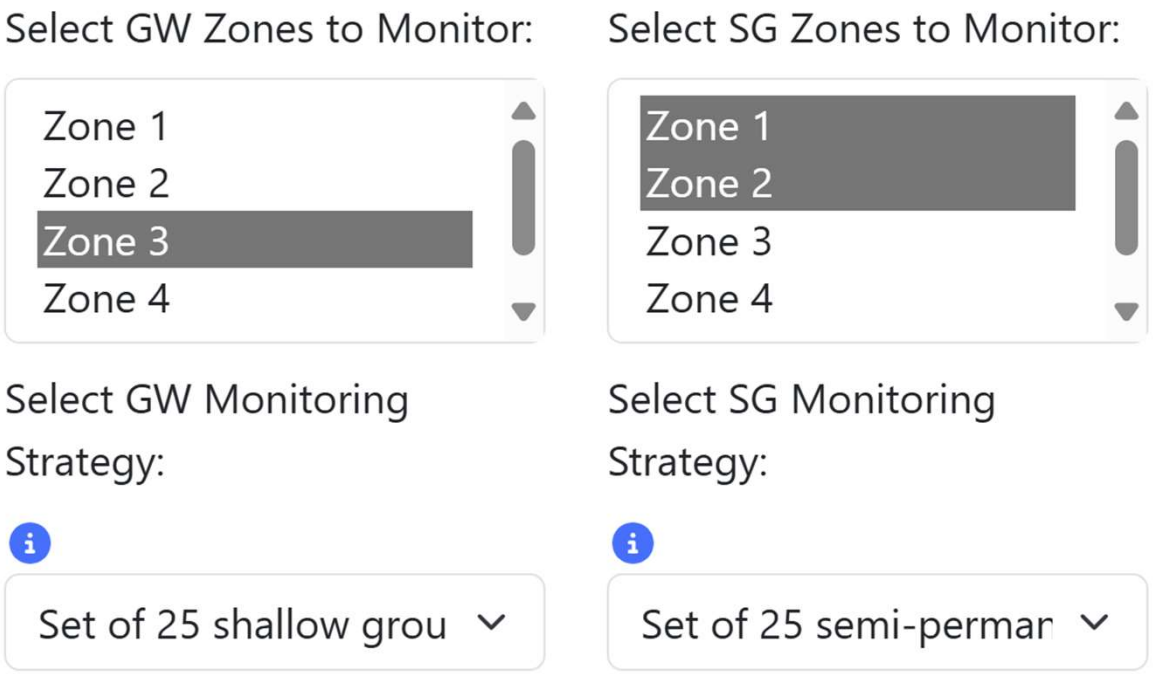
Zone	DCE	TCE
1	25	25
2	14	12
Total	**39**	**37**

Annual GW Costs

Year	Cost
2025	$354,300.00
Total	**$354,300.00**

Next Steps

- Expand our GW plume identification to zone 3
- Install and start sampling Soil Gas (SG) wells in zones 1 and 2
- SG zones are the same as GW zones



Results from round 2

- Our groundwater plume is growing
- We've now tested water from 75 wells with 50 exceeding DCE guideline values and 48 exceeding TCE guidelines
- Soil gas testing reveals a similar trend
- We should start testing indoor air in houses

Total GW Exceedances

Zone	DCE	TCE
1	25	25
2	14	12
3	11	11
Total	**50**	**48**

Total SG Exceedances

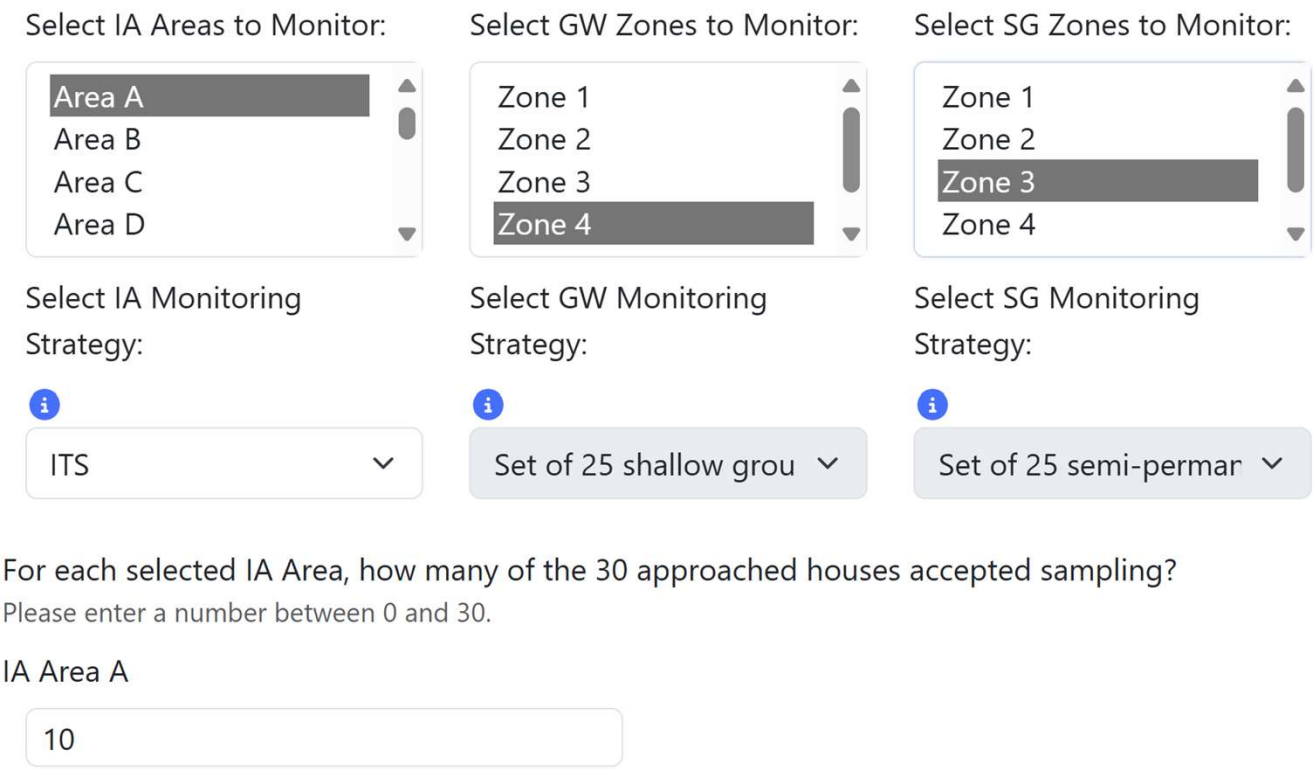
Zone	DCE	TCE
1	25	24
2	12	10
Total	**37**	**34**

Total Costs

Year	IA Cost	GW Cost	SG Cost	Control Cost	Total Cost
2025	$0	$354,300.00	$0	$0	**$354,300.00**
2026	$0	$172,250.00	$217,800.00	$0	**$390,050.00**
Total	**$0.00**	**$526,550.00**	**$217,800.00**	**$0.00**	**$744,350.00**

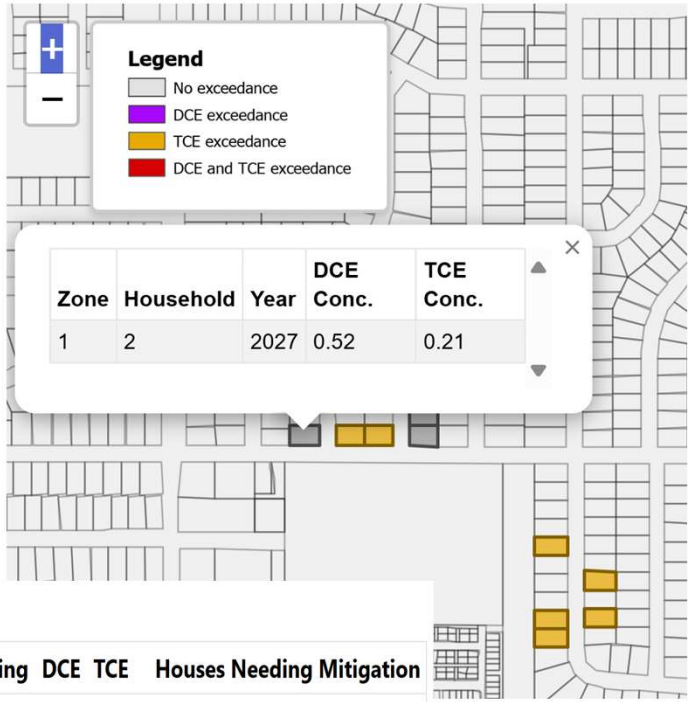
Next Round

- Expand GW and SG sampling
- Approach 30 houses to sample
- Conduct initial evaluation and sampling in 10 houses



Results from round 3

- We have data from our first 10 houses
- 7 of them exceed TCE guidelines
- Our GW plume is expanding
- As we expand our GW and SG exceedance rates go down



Total IA Exceedances

Area	Houses Approached	Houses Participating	DCE	TCE	Houses Needing Mitigation
A	30	10	0	7	7
Total	**30**	**10**	**0**	**7**	**7**

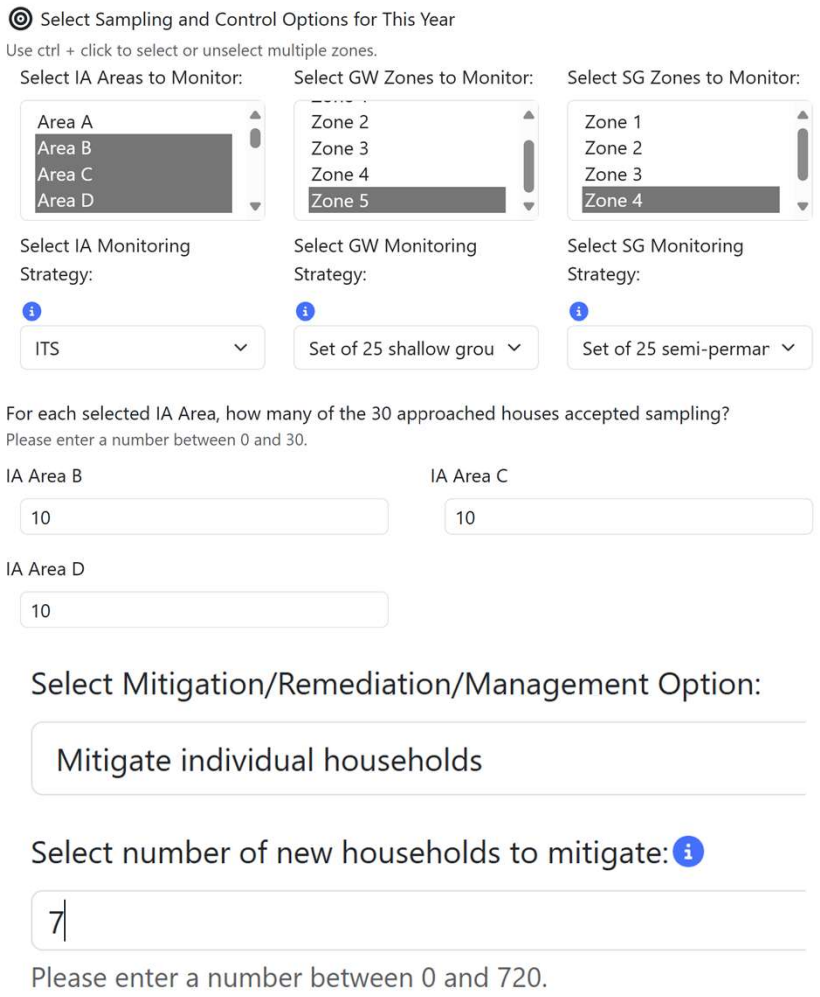
Total Costs

Year	IA Cost	GW Cost	SG Cost	Control Cost	Total Cost
2025	$0	$354,300.00	$0	$0	**$354,300.00**
2026	$0	$172,250.00	$217,800.00	$0	**$390,050.00**
2027	$140,110.00	$172,250.00	$104,000.00	$0	**$416,360.00**
Total	**$140,110.00**	**$698,800.00**	**$321,800.00**	**$0.00**	**$1,160,710.00**

Next Round

- Start Mitigation
- Expand IA sampling reach
- Expand GW and SG reach
- And so on…

- Pausing here so we don’t ruin the endgame for everyone. We’ll share the final results once we run our live session.



Results: Traditional 20 years later

- Total Cost: $13 million
- Houses sampled: 240
- Houses in study area: 720
- Houses with IA Exceedances: 167
- Houses protected by mitigation systems: 167
- People Protected: 390
- $ per person protected: $ 33,573 / person

Type	Cost
Indoor Air	$7,093,320
Groundwater	$871,050
Soil Gas	$529,800
Control	$4,599,299
Total	$13,093,469

Indoor Air Early Strategy

- Starting with both Indoor/Subslab Air and External Soil Gas sampling
- Expand rapidly including multiple zone expansions per year
- Goal is to move to mitigation as quickly as possible
- Piecemeal mitigation – household level mitigation
- Working to build movement momentum

Results: IA Early 20 years later

- Total Cost: $12.5 Million
- Houses sampled: 240
- Houses in study area: 720
- Houses with IA Exceedances: 174
- Houses protected by mitigation systems: 174
- People Protected: 399
- $ per person protected: $ 31,247 / person

Type	Cost
Indoor Air	$6,804,320
Groundwater	$0
Soil Gas	$529,800
Control	$5,133,740
Total	$12,467,860

Indoor air early with block level mitigation decisions

Starting with both Indoor/Subslab Air and External Soil Gas sampling

Expand rapidly including multiple zone expansions per year

Goal is to move to mitigation as quickly as possible

Block level mitigation

If 20-30% of a block exceeds, you'd move to a neighborhood wide mitigation approach vs household

Results: IA Early – Block Mitigation 20 years later

- Total Cost: $ 34.5 Million
- Houses sampled: 240
- Houses in study area: 720
- Houses with IA Exceedances:
- Houses protected by SGM systems: 720
- People Protected: 1,800
- $ per person protected: $ 19,150 / person

Type	Cost
Indoor Air	$ 6,804,320
Groundwater	$ 0
Soil Gas	$ 529,800
Control	$ 27,137,040
Total	$ 34,471,160

An innovative approach

- Installed in Groundwater wells with multi-depth soil monitoring probes to monitor both Groundwater and External Soil Gas
- Where necessary:
  - Pilot, Design, and implement a Soil Vapor Extraction system to provide large scale remediation
  - Continue O&M for 20-30 years

Results: Innovative approach 20 years later

- Total Cost: $26.6 Million
- Houses sampled: 0
- Houses in study area: 720
- Houses with IA Exceedances: Unknown
- Houses protected by mitigation systems: 720
- People Protected: 1,800
- $ per person protected: $ 14,786 / person

Type	Cost
Indoor Air	$ 0
Groundwater	$ 871,050
Soil Gas	$ 205,000
Control	$ 25,538,816
Total	$ 26,614,866

Let’s do a case together

www.iavisim.org

Username: viuser

Password: vipassw0rd!

After Action Review

- Which strategy in this case seemed to be the most effective combination of steps to investigate, mitigate and remediate this site?
- What site/project specific factors controlled which lines of evidence you wanted to collect first in this simulation?
- What site/project specific factors controlled when you chose to start mitigation or remediation in this simulation?
- How would your decisions change if:
  - The structures were more spread apart or some of the land was undeveloped?
  - The groundwater was much deeper (say 60’ to groundwater)
  - The groundwater was much shallower (say 5’ to groundwater)
  - The source (on site) was much stronger?
  - The housing stock was more diverse in age?
- What lessons/learnings can you apply to your real-life project management practice?

Additional potential after action review questions

- What were your initial reactions to the scenario/situation as it was first presented – did they turn out to be true in the end?
- What were the key decision points for you?
- What would have the public's perception been of how you managed this VI site investigation/mitigation/remediation?
- How did you adapt to unexpected data?
- Were you satisfied that the actions you took appropriately balanced cost and human health protection from unacceptable exposures?
- Are there policy or process constraints that prevent you from efficiently investigating/mitigating/remediating real sites?