Nothing Compares
NORTH CAROLINA

Risk-Based Remediation Training

May 24, 2017

Risk Assessment Training Topics of Discussion

I. **Regulatory Framework**

II. Risk Assessment 101

III. NC-Specific Risk Assessment Procedures

IV. Groundwater Only Site Closure Examples

V. Introduction to Risk Calculator

VI. Risk Calculator Site Closure Example

VII. Wrap-up & Questions

Introduction

A risk-based remedy is one remedial option which allows residual contamination to remain in place if…

- There are no current unacceptable risks to human health or ecological receptors from exposure to the contamination
- All future risks of exposures are controlled through remediation, engineering controls, and/or institutional controls

"a paradigm shift"

Regulatory Framework

October 2015 – Governor signed Session Law 2015-286 (via House Bill 765)

- Amends the 2011 "Risk-Based Environmental Remediation of Sites" Law proposed in HB 45: **N.C.G.S. 130A-310.65 through 310.77**
- Extends risk-based remediation as an option to virtually all cleanup programs
- Allows off-site groundwater impacts to be addressed using a risk-based approach – under certain conditions

Eligibility

- Hazardous Waste/RCRA Sites
- Above-Ground Petroleum Releases
- Inactive Hazardous Sites
- Division of Water Resources Sites
- Permitted Solid Waste Sites

…but not:

- Sites Regulated under the Coal Ash Management Act
- Permitted Animal Waste Management Systems
- Sites with existing risk-based cleanup legislation (UST, DSCA, PRLF)

Applicability

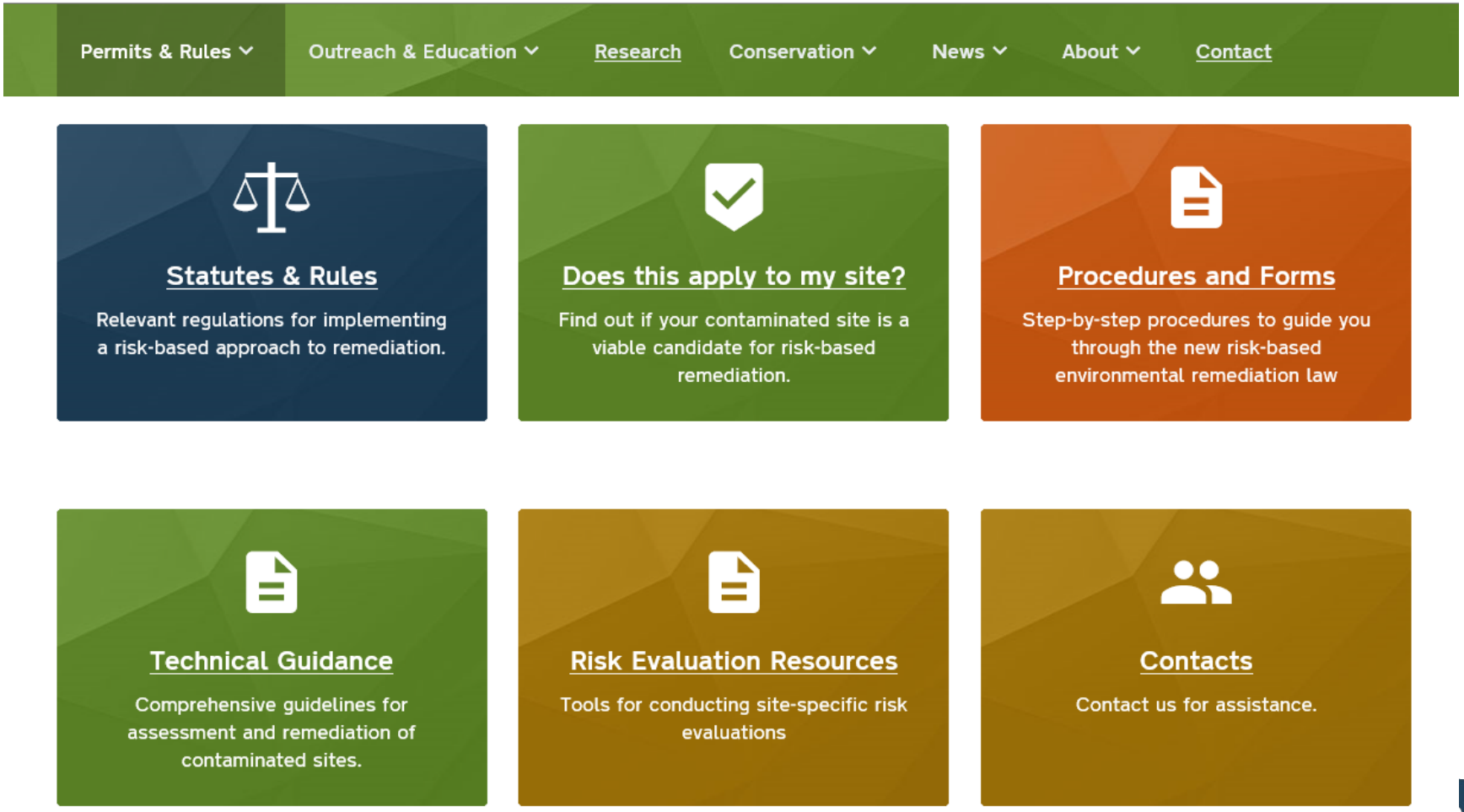
The best candidates for risk-based remediation will be sites with sufficient data to show that:

- Site conditions are stable, *and* plume is stable or decreasing in size and/or concentration
- Contaminant behavior, concentration, and extent *(in all affected media)* are well understood and predictable

General Statutes Require Specific Actions

- Complete investigation/assessment and submit report
- Obtain property owner consent
  - NCGS 130A-310.65-310.77
  - *Contaminated Property: Issues & Liabilities*
  - Property Owner Consent Form
- Issue a Notice of Intent to Remediate
  - Notice to affected and adjacent property owners
- Estimate fees
  - Application fee = $5,000/acre (max. $100,000)
  - Oversight fee = $500/acre (max $25,000)
- Obtain DEQ approval on the above items
- Prepare/submit risk-based remediation plan and fee

http://deq.nc.gov/permits-regulations/risk-based-remediation



Department of Environmental Quality

Administrative Process

Other Considerations

Remedies involving Rights of Way

- address contaminated off-site property including DOT and municipal rights of way for public streets, roads, and sidewalks
- any necessary land-use restrictions need to be negotiated with the ROW holder(s)

Surface Water

- the NC 2B standards continue to be the remediation standards for surface water. There is no risk-based alternative for surface waters.

Financial Assurance

- requires remediating parties provide financial assurance to implement and maintain active remediation and controls used to prevent exposures

Getting Started

- Review the online resources
- Screen project sites as possible risk-based remedy candidates and consider data needs, such as:
  - Survey of all likely receptors
  - Current and anticipated future land uses
  - Data verifying plume stability
  - Permissions from affected property owners
- Meet with the agency early in the process

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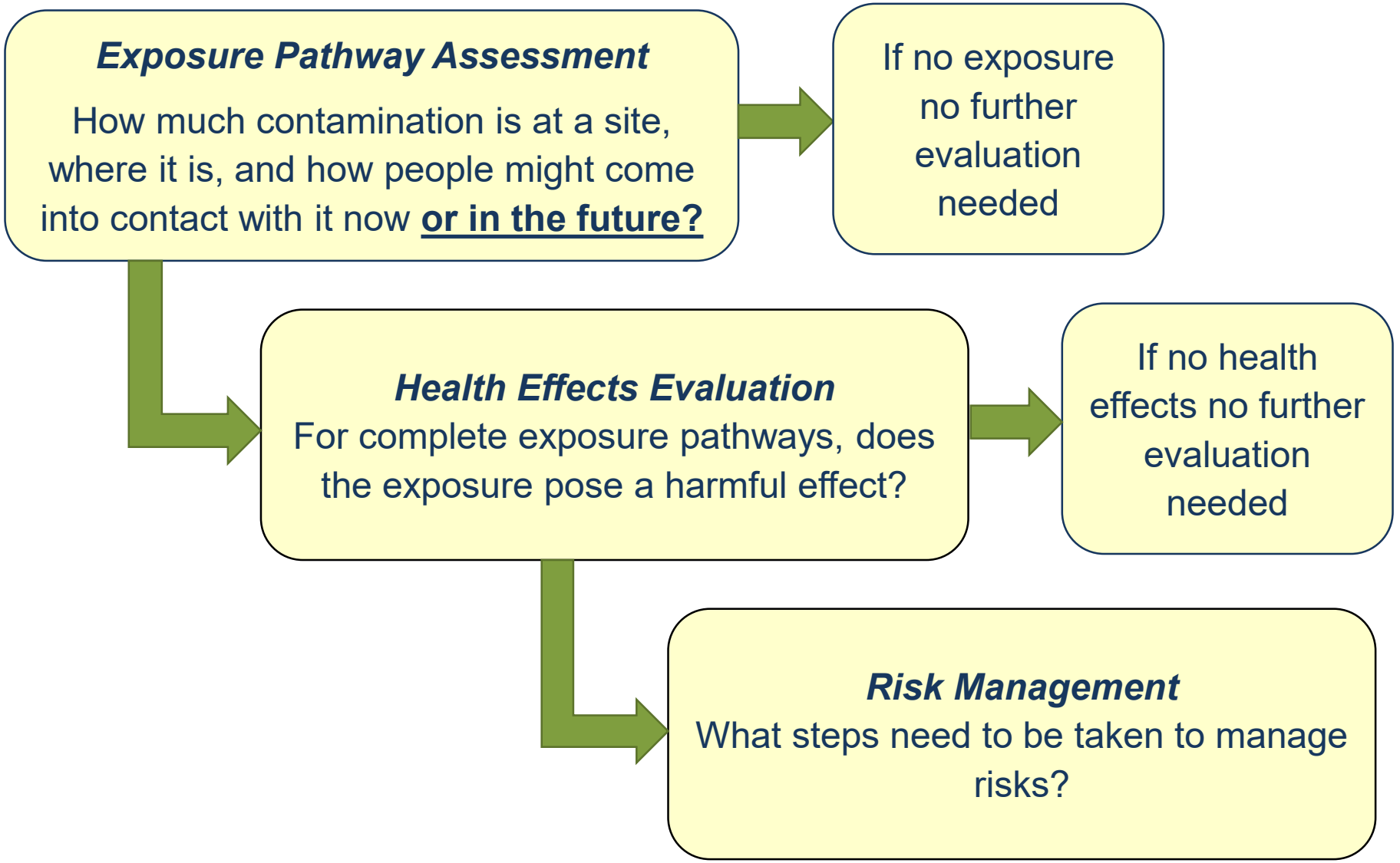
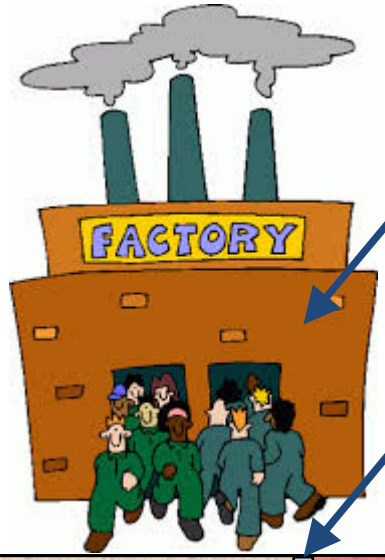
Human Health Risk Assessment



Example of Exposure Pathways – Non-Residential Worker

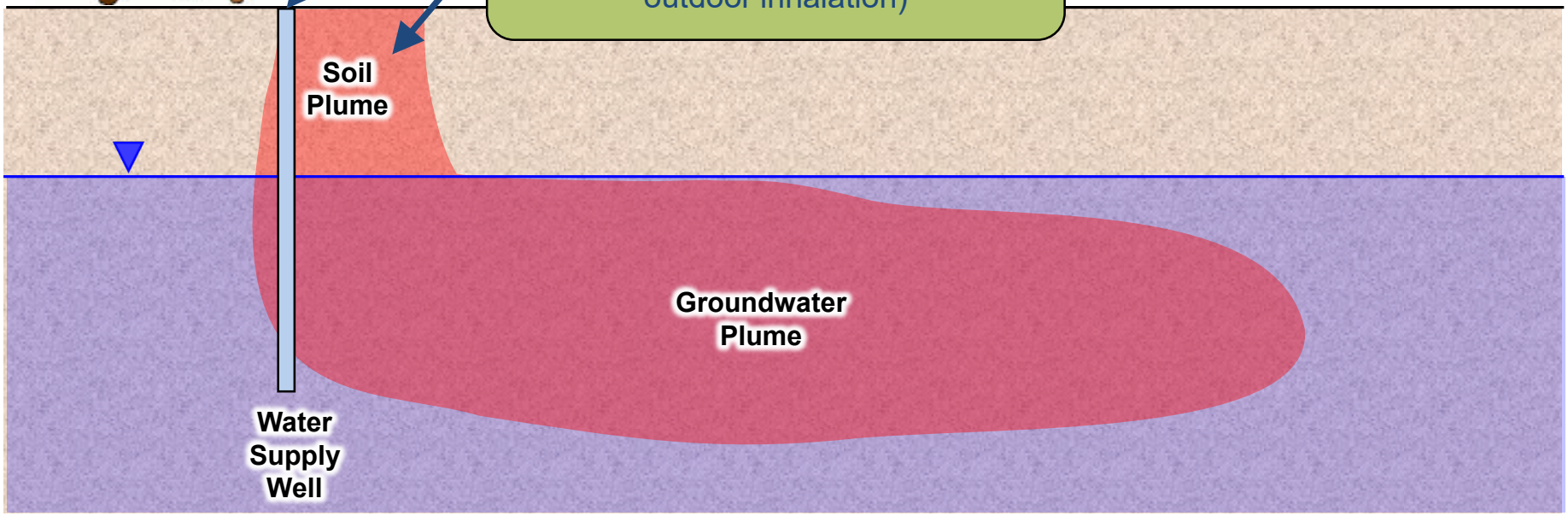


Vapor Intrusion Pathway
(indoor inhalation of vapor emissions from soil & groundwater

Groundwater Combined Pathways
(groundwater ingestion, dermal contact, & tapwater inhalation

Soil Combined Pathways
(soil ingestion, dermal contact, & outdoor inhalation)

What are some of the ways one of these non-residential workers could be exposed to contamination under this scenario?



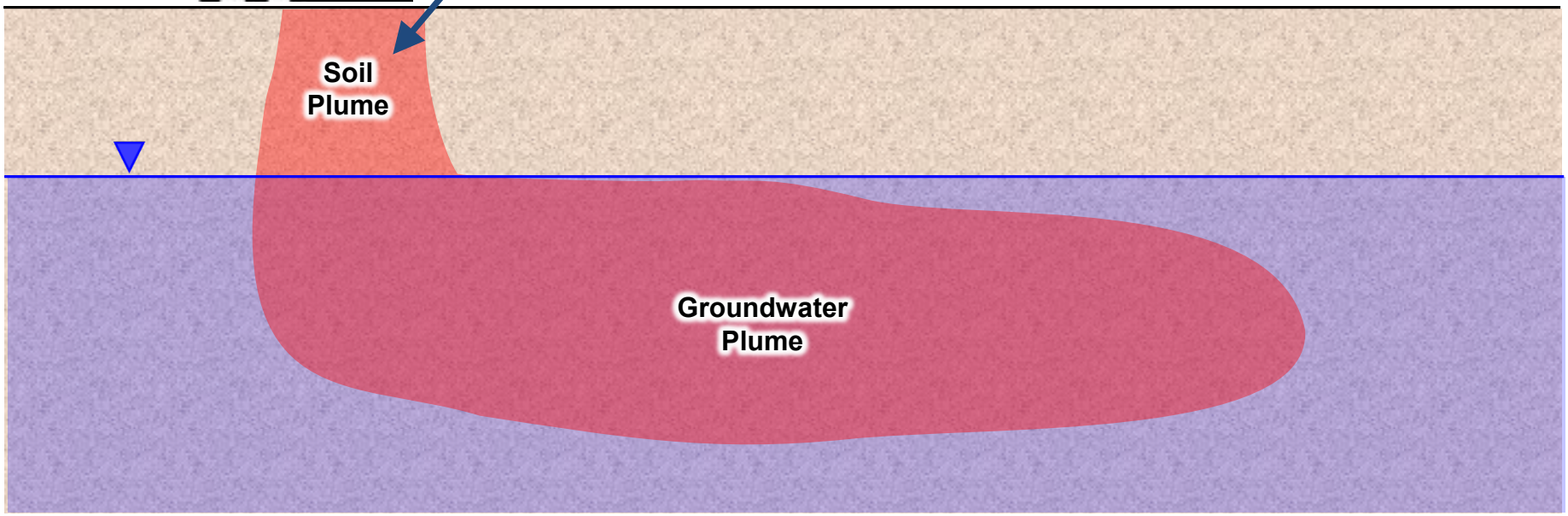
Example of Exposure Pathways – Construction Worker

Vapor Intrusion Pathway — X — Not Complete

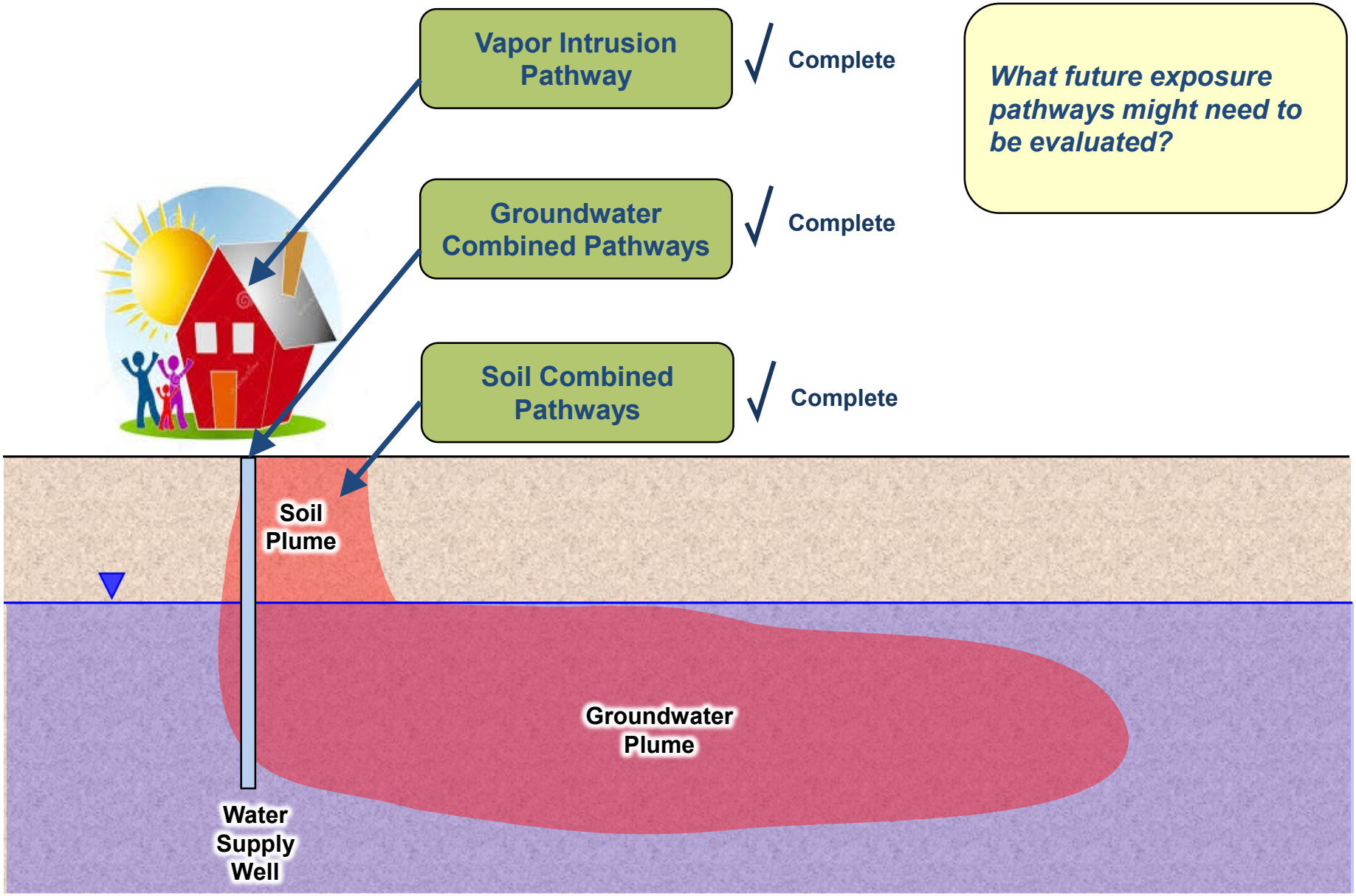
Groundwater Combined Pathways — X — Not Complete

Soil Combined Pathways — √ — Complete

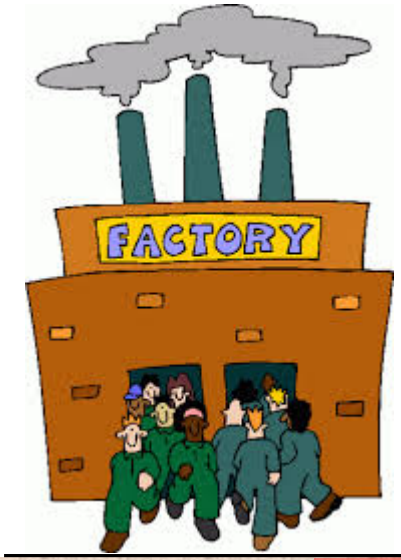
What future exposure pathways might need to be evaluated?



Example of Exposure Pathways - Resident



Example of Exposure Pathways – Off-Site

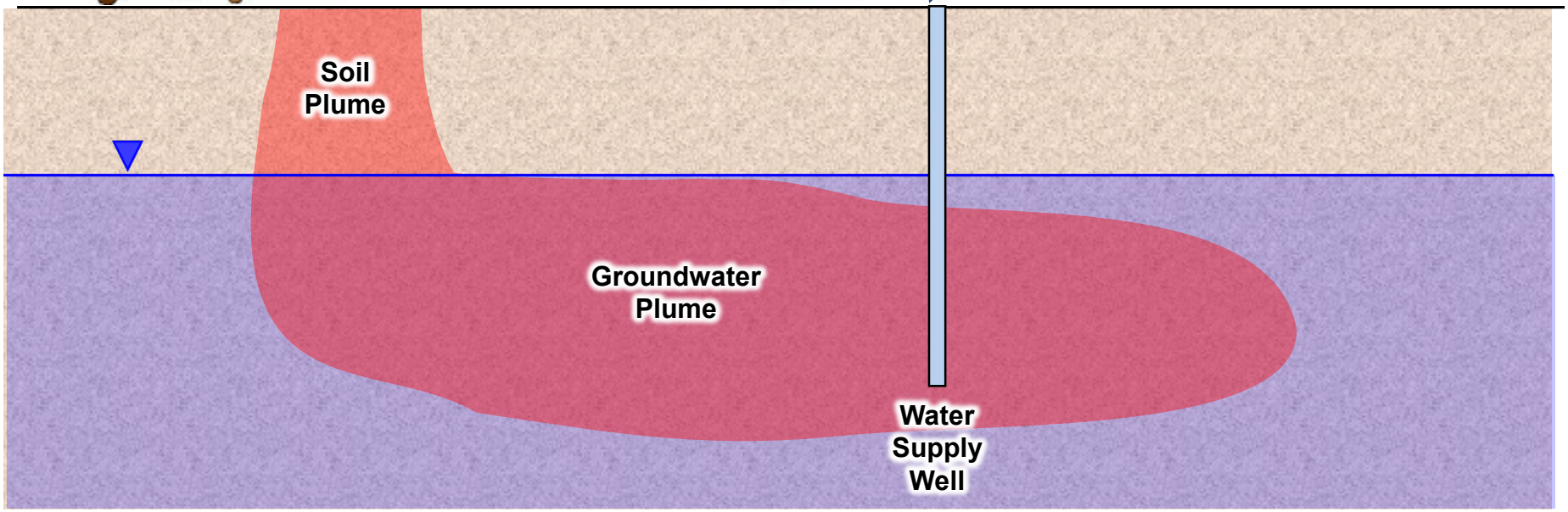


Are exposure pathways going to be different in different areas of the plume?

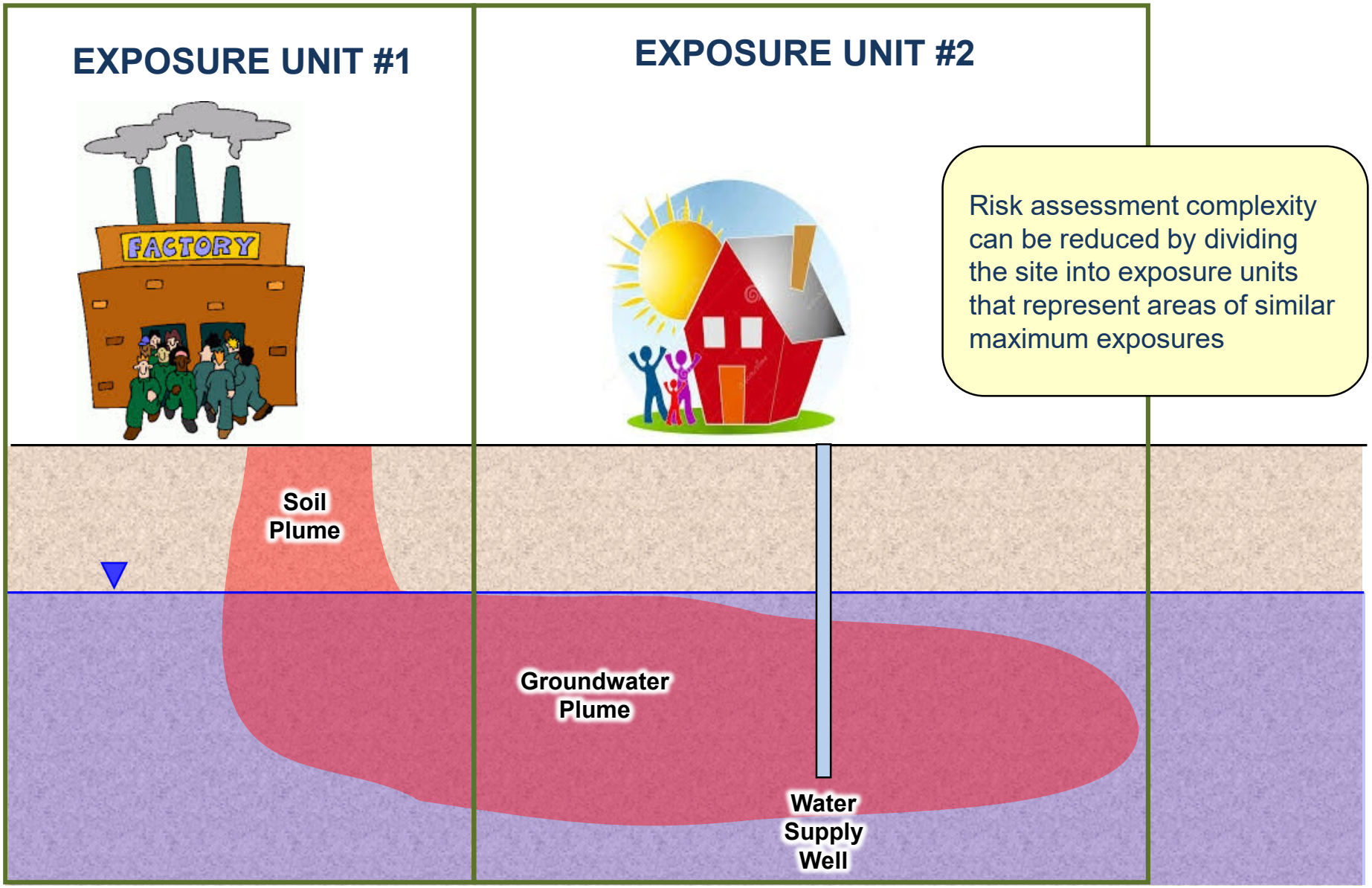
Vapor Intrusion Pathway (groundwater source only) √ **Complete**

Groundwater Combined Pathways √ **Complete**

Soil Combined Pathways X **Not Complete**



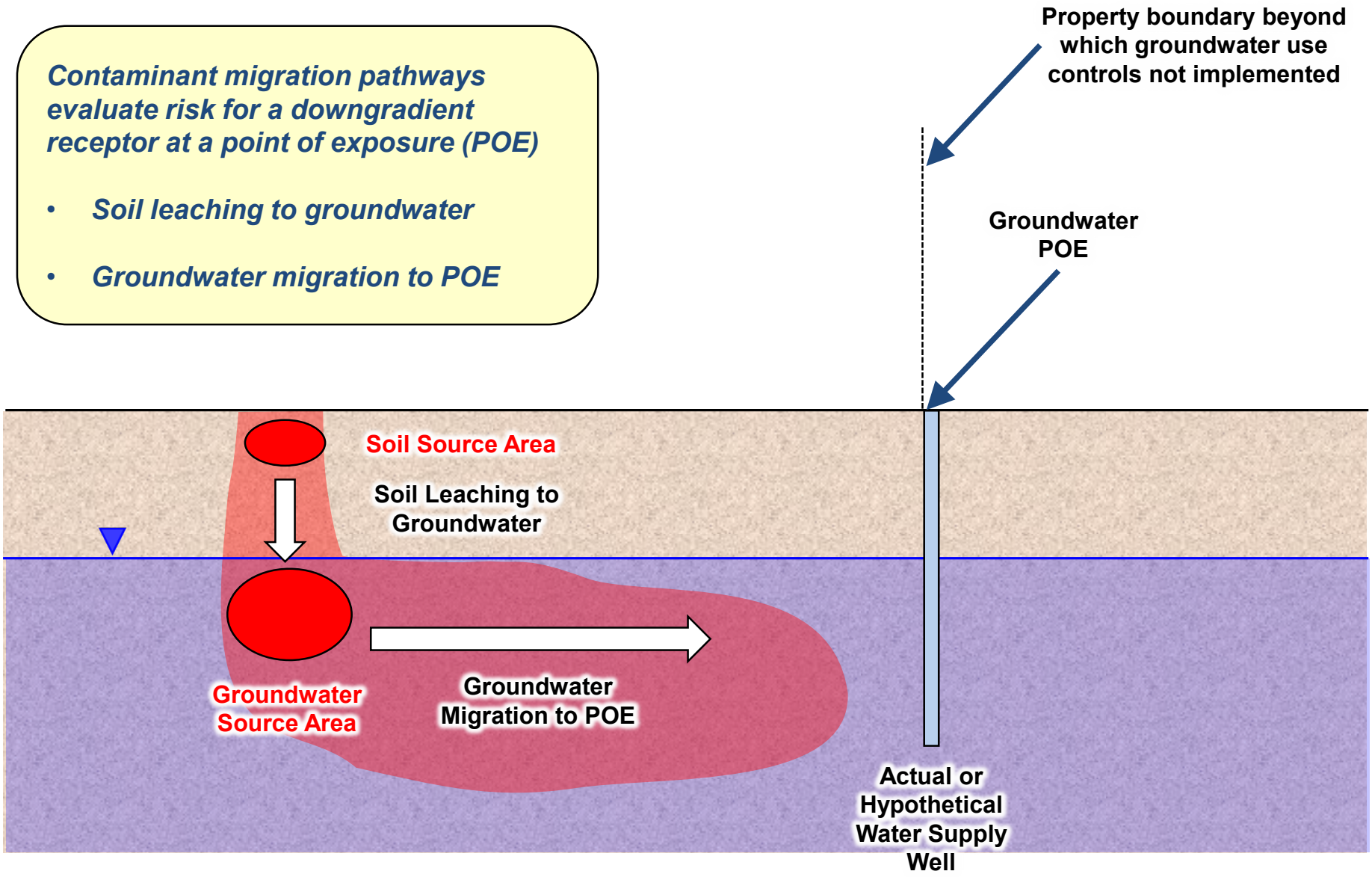
Exposure Pathways - Exposure Units



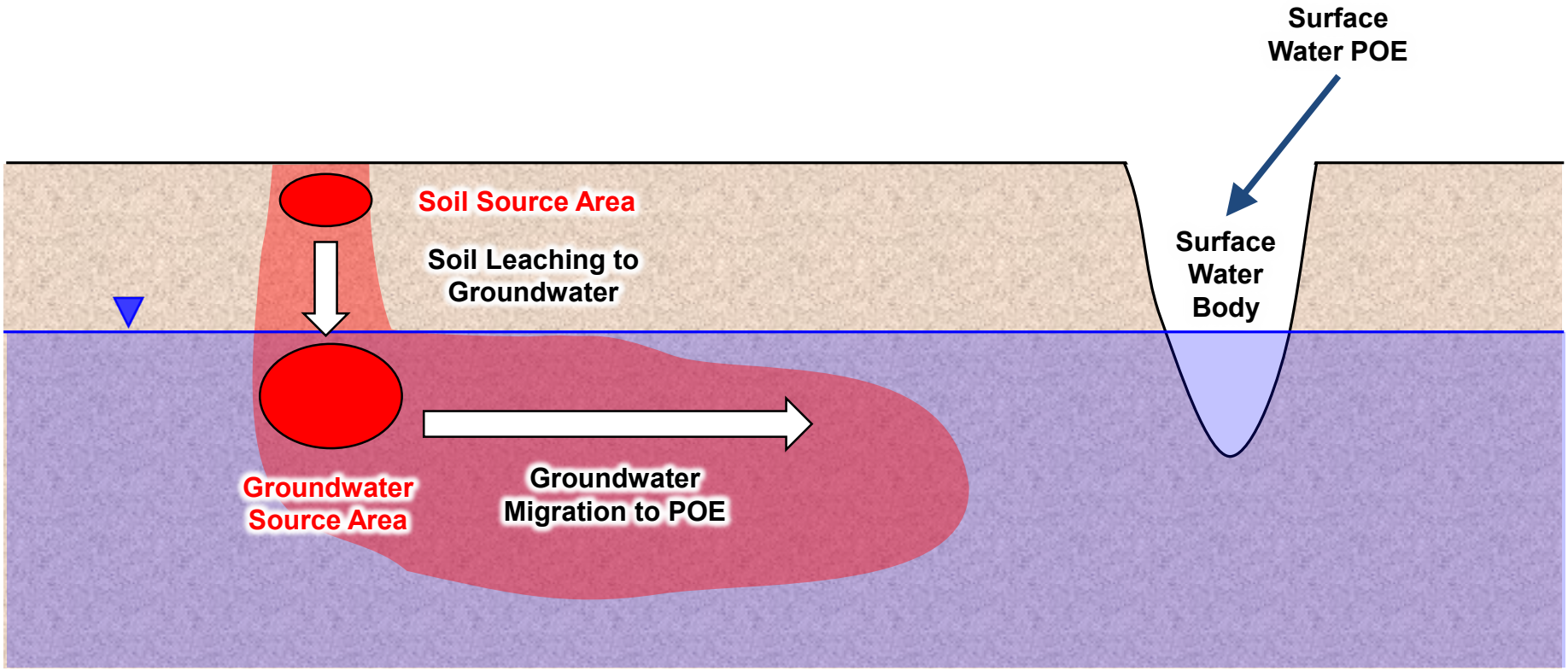
Contaminant Migration to Groundwater POE

Contaminant migration pathways evaluate risk for a downgradient receptor at a point of exposure (POE)

- *Soil leaching to groundwater*
- *Groundwater migration to POE*



Contaminant Migration to Surface Water POE



Health Effects Risk Evaluation

Non-Carcinogenic Risks

Hazard Quotient (HQ) = Ratio of level of exposure to a chemical of concern over a specified time period to a reference dose for that chemical of concern derived for a similar exposure period. Termed Hazard Index (HI) if all chemicals and pathways included.

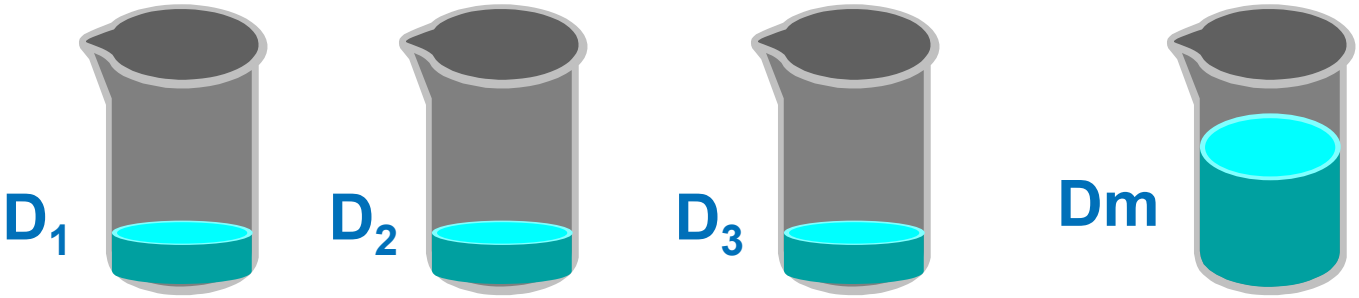
HI > 1 = Adverse health effects possible
HI < 1 = Adverse health effects not possible

Carcinogenic Risks

Individual Excess Lifetime Cancer Risk (CR) = Increase over background in an individual's probability of getting cancer over a lifetime due to exposure to a chemical.

CR = 10^{-6} = 1/1,000,000 increased risk of cancer
CR = 10^{-5} = 1/100,000 increased risk of cancer
CR = 10^{-4} = 1/10,000 increased risk of cancer

Chemical Risk Additivity



- Risk commonly based on additive dose for exposures from all constituents and exposure pathways
- Conservatively assumes same mode of action and toxicological similarity

Chemical Risk Additivity

- Screening levels for individual constituents and pathways typically set at lower target risks levels to account for additivity
- Higher risk levels typically applicable for a cumulative risk evaluation that calculates actual risks for all constituents and exposure pathways

Non-Carcinogenic Risks

HI > 1 = Adverse health effects possible
HI < 1 = Adverse health effects not possible

Carcinogenic Risks

CR = 10^{-6} = 1/1,000,000 increased risk of cancer
CR = 10^{-5} = 1/100,000 increased risk of cancer
CR = 10^{-4} = 1/10,000 increased risk of cancer

Risk Calculation

EXAMPLE EQUATION
Indoor Air Screening Levels
Residential Non-Carcinogenic Equation

Indoor Air Screening Level

OR

Concentration

Target Hazard Quotient

OR

Calculated Risk

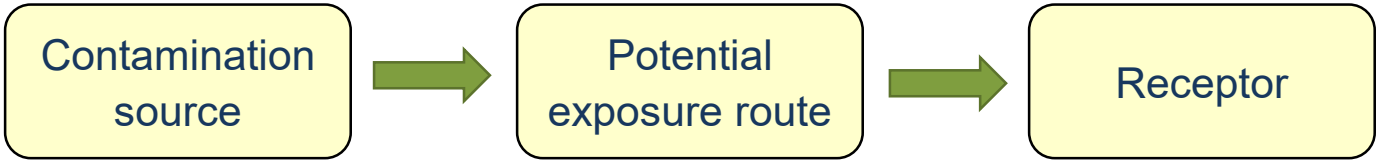
$$IASLnc = \frac{THQ \times ED}{EF \times ED \times ET \times \frac{1}{RfC}}$$

ET = Exposure Time = 26 yrs
ED = Exposure Duration = 350 days/yr
EF = Exposure Frequency = 24 hrs/day

RfC = Reference Concentration = Chemical specific toxicity value

Risk Management

Elimination of one of these elements will make pathway incomplete:



- Consider both current and future conditions
- Evaluate both complete and potentially complete pathways
- Land use controls are used to manage future risks

Risk assessment and management decisions are often iterative and dynamic and may lead to a variety of products or outcomes

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Risk Assessment Process

- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- Cumulative risk calculation
- Further risk evaluation
- Risk management

Risk Screening

Compare maximum concentrations to conservative screening levels:

Soil:

- Health Based:
  - Unrestricted Use Health-Based PSRGs
  - Industrial/Commercial Health-Based PSRGs
- Protection of Groundwater:
  - Protection of Groundwater PSRGs
  - Note other options for evaluation of soil leaching to groundwater

Groundwater: 15A NCAC 02L Standards

Surface Water: 15A NCAC 02B Standards

Vapor Intrusion: DWM Vapor Intrusion Screening Levels for groundwater, soil gas, and indoor air

Risk Screening

Soil PSRGs and vapor intrusion screening levels set at:

- **Target hazard quotient (HQ) of 0.2**
- **Target carcinogenic risk (CR) of 10^{-6}**

If there are more than 5 non-carcinogens, cumulative risk evaluation using the Risk Calculator is required.

Chemical	Hazard Quotient
Chemical #1	0.2
Chemical #2	0.2
Chemical #3	0.2
Chemical #4	0.2
Chemical #5	0.2
TOTAL FOR ALL CHEMICALS	**1**

Risk Assessment Process

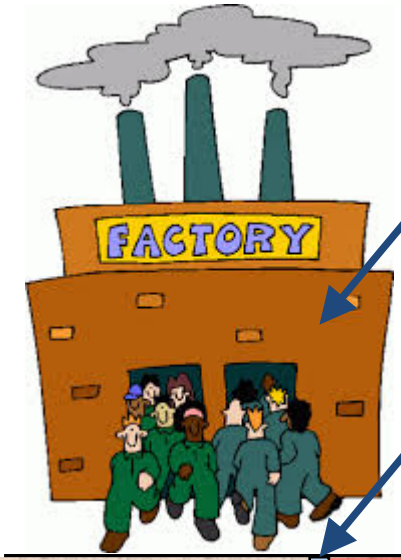
- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- **Cumulative risk calculation**
- Further risk evaluation
- Risk management

Cumulative Risk Calculation

- Evaluates cumulative risk of multiple contaminants and exposure pathways
- Risk levels calculated for each receptor then compared to maximum acceptable risk levels
- Incorporates site-specific or conservative default values for contaminant migration parameters

Max Acceptable Risk Levels		
Risk Type	**Individual Contaminants**	**Sum of all Contaminants (Cumulative Risk)**
Non-Carcinogenic Hazard Quotient (HQ)/ Hazard Index (HI)	0.2	1
Carcinogenic Risk (CR)	10^{-6}	10^{-4}

Cumulative Risk Calculation

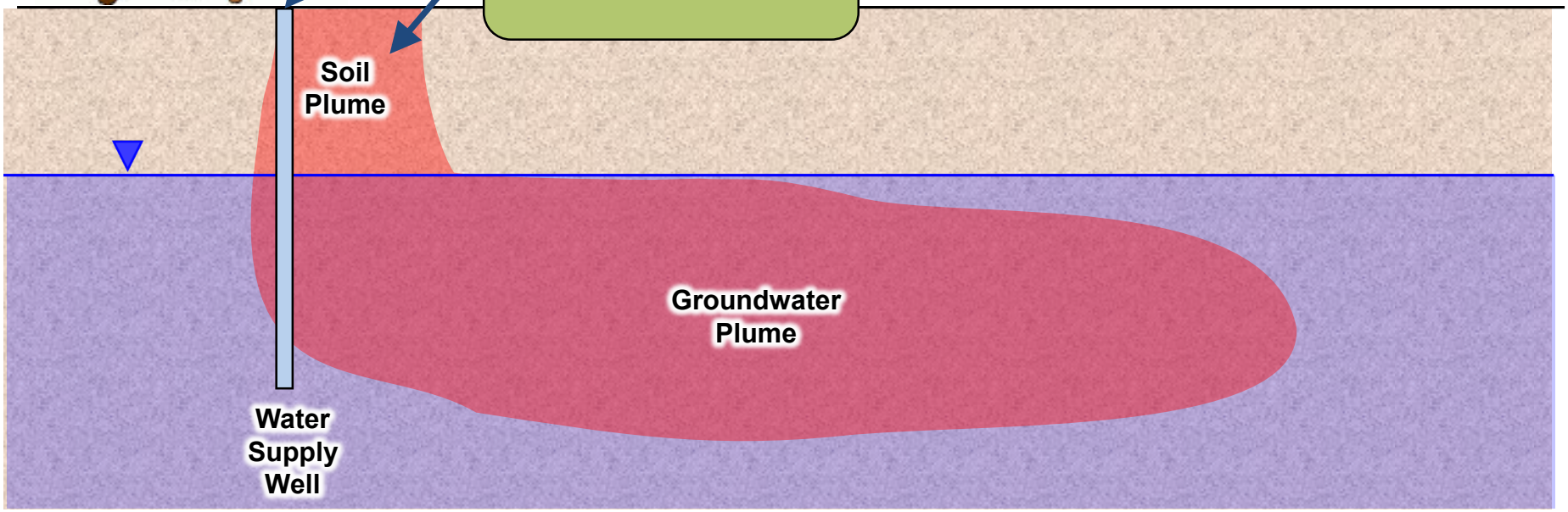


Vapor Intrusion Pathway

Groundwater Combined Pathways

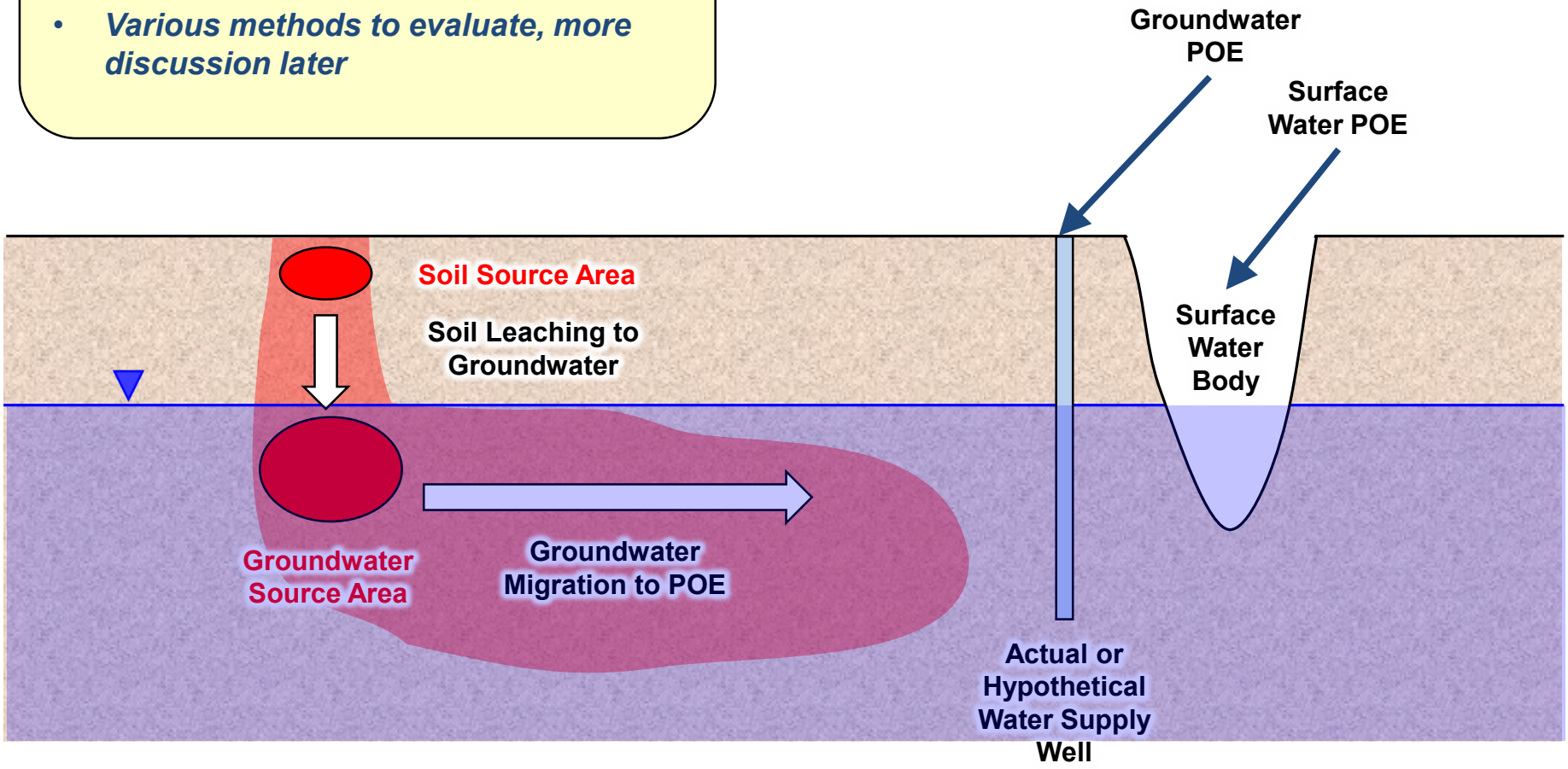
Soil Combined Pathways

- ***Calculate risks for combined chemicals of concern and combined exposure pathways and compare to cumulative risk criteria (HI < 1, CR < 1E-04)***
- ***Perform for each current or future receptor in each exposure unit***

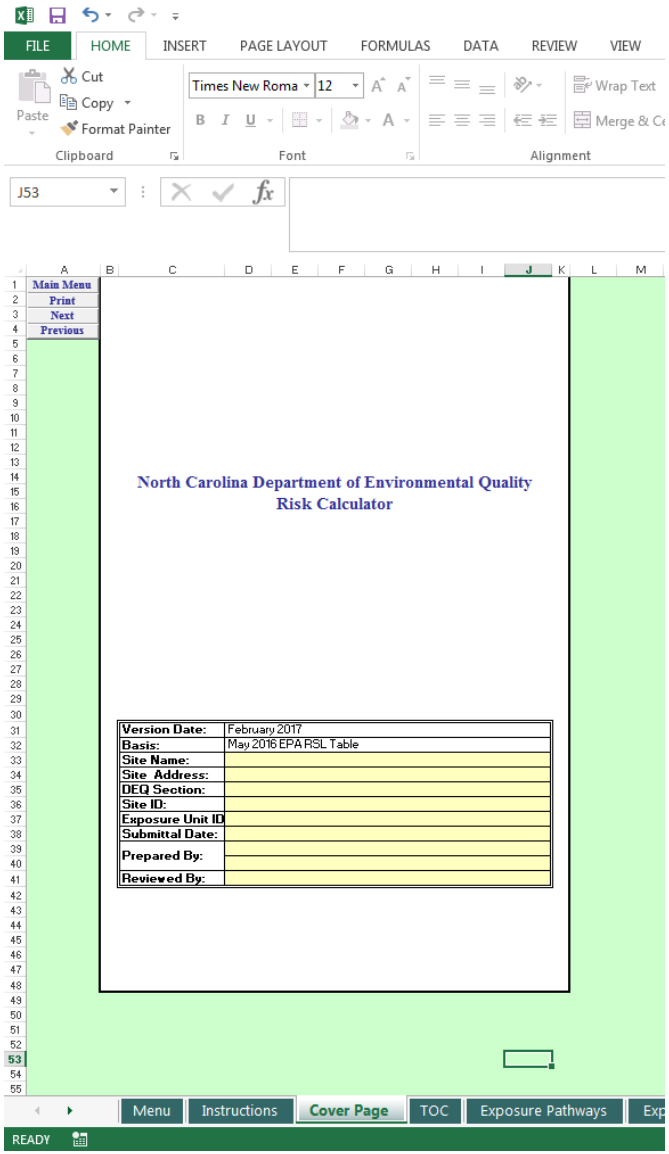


Evaluation of Contaminant Migration to POEs

- *Evaluates risk to a downgradient POE*
- *Evaluated separately from cumulative risk pathways*
- *Various methods to evaluate, more discussion later*



Cumulative Risk Calculation

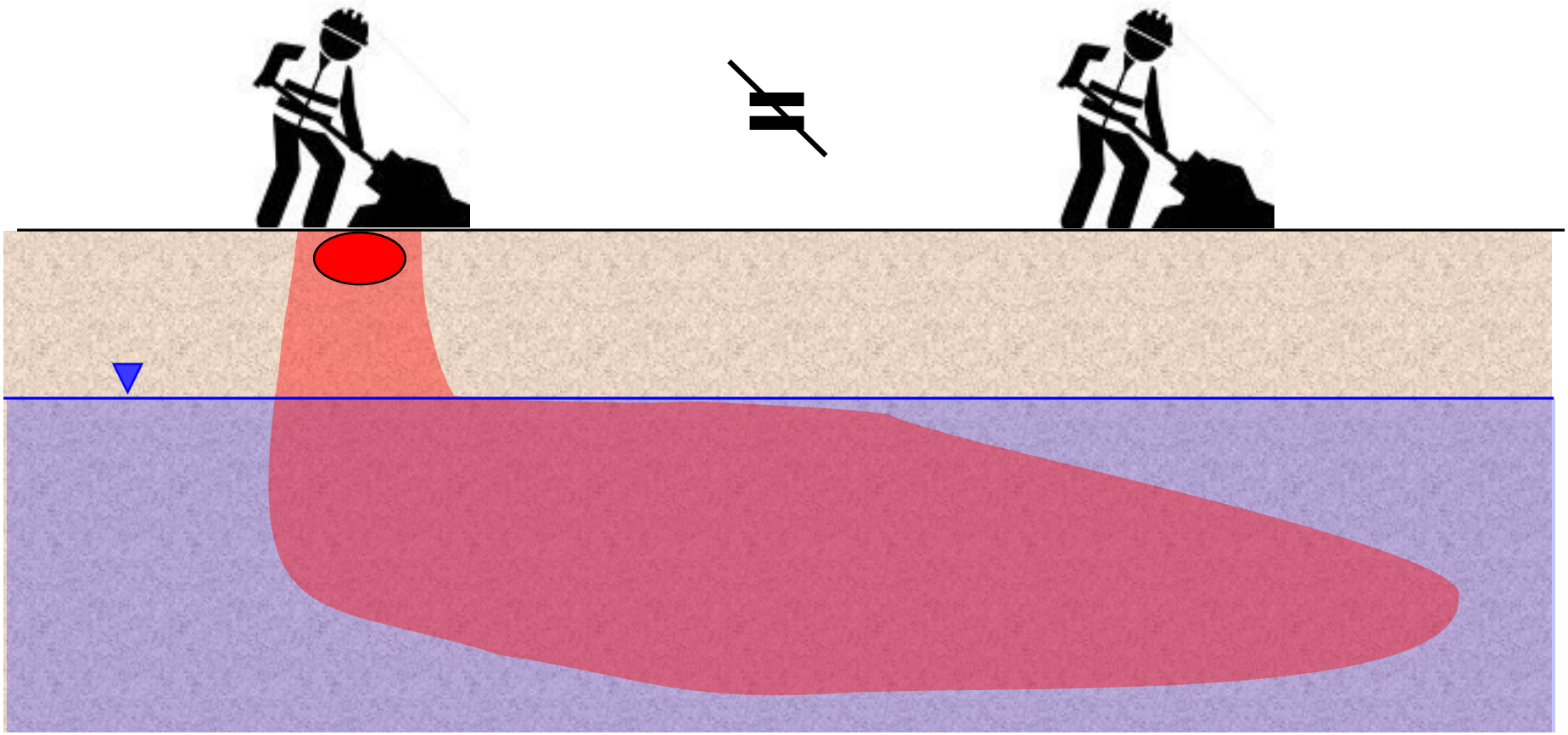


NCDEQ risk calculator developed to assist with cumulative risk calculation considering all contaminants in all media at a site

Risk Assessment Process

- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- Cumulative risk calculation
  - **Define exposure units**
  - Define POEs
  - Define exposure pathways
  - Define exposure point concentrations
  - Run calculator to characterize risks
- Further risk evaluation
- Risk management

Defining Exposure Units

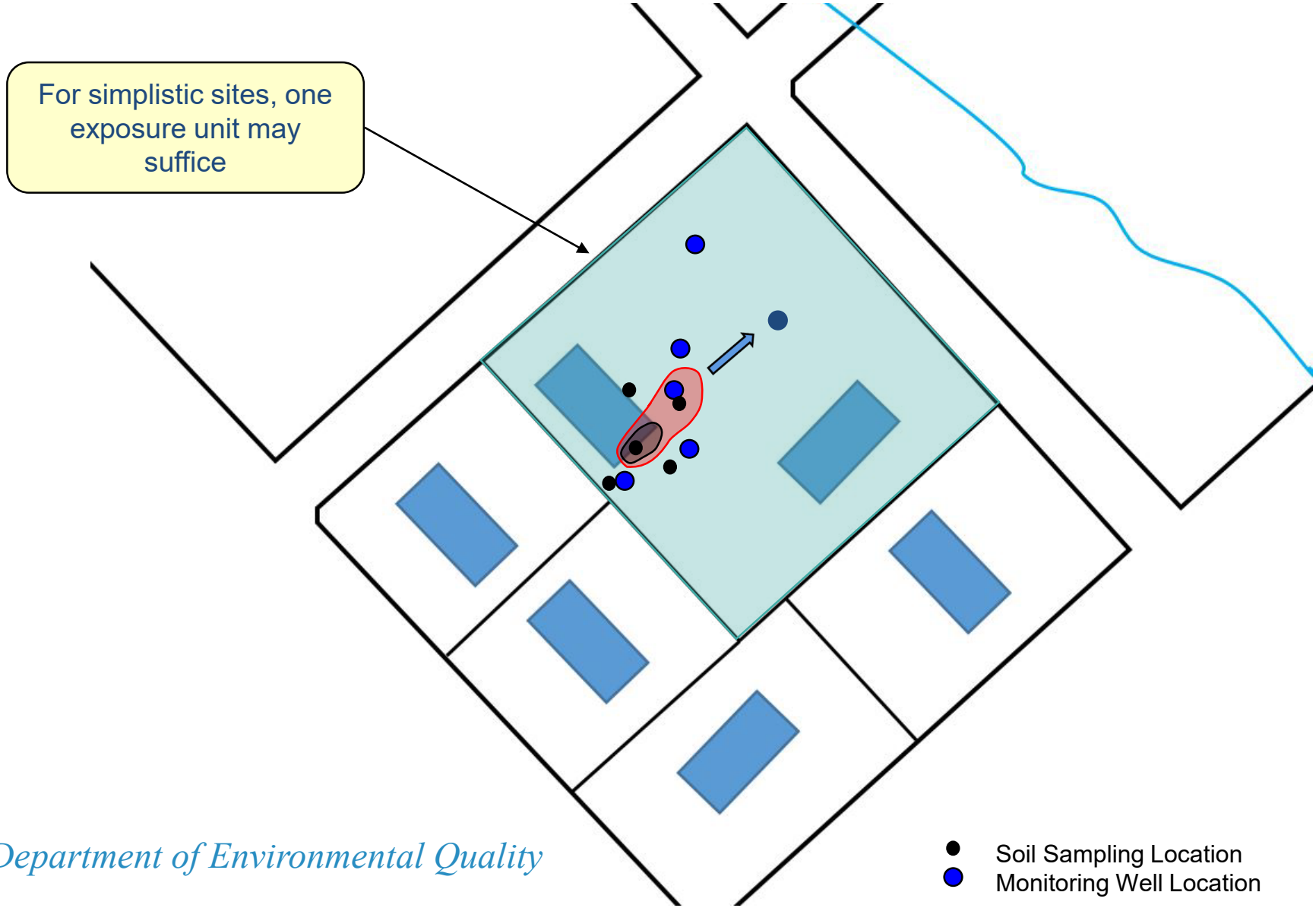


Current and future exposure pathways at a contaminated site may vary widely depending on contaminant distribution, land uses, and types of receptors

Defining Exposure Units

- Risk assessment complexity can be reduced by dividing the site into Exposure Units (EUs) that represent areas of similar maximum exposures.
- Current and future risks calculated for each receptor in each EU.
- EU boundaries are often used to define land-use control areas. Ideally should be physical, surveyable boundaries, such as a property boundary, building footprint, fenced area, etc.

Defining Exposure Units



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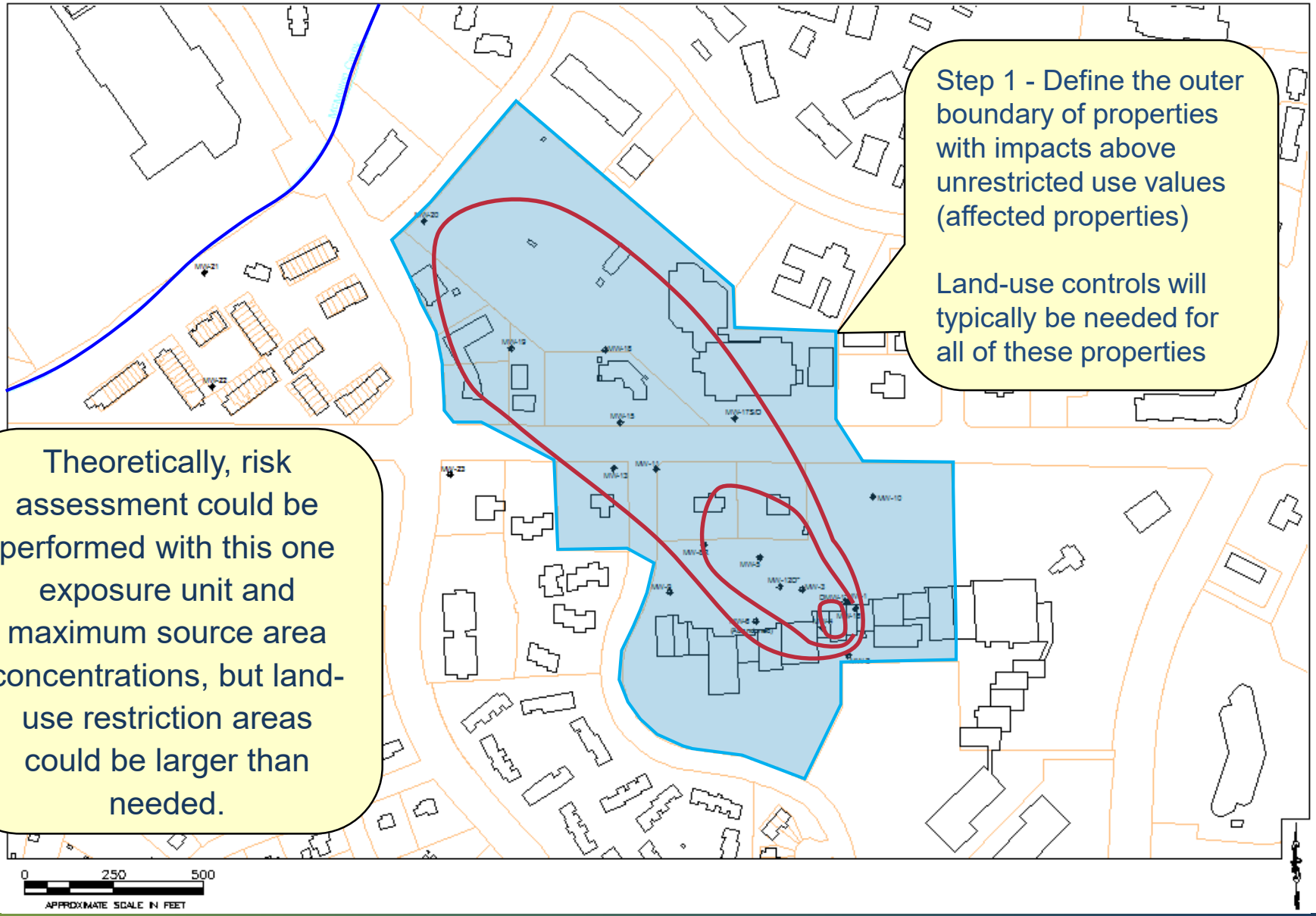
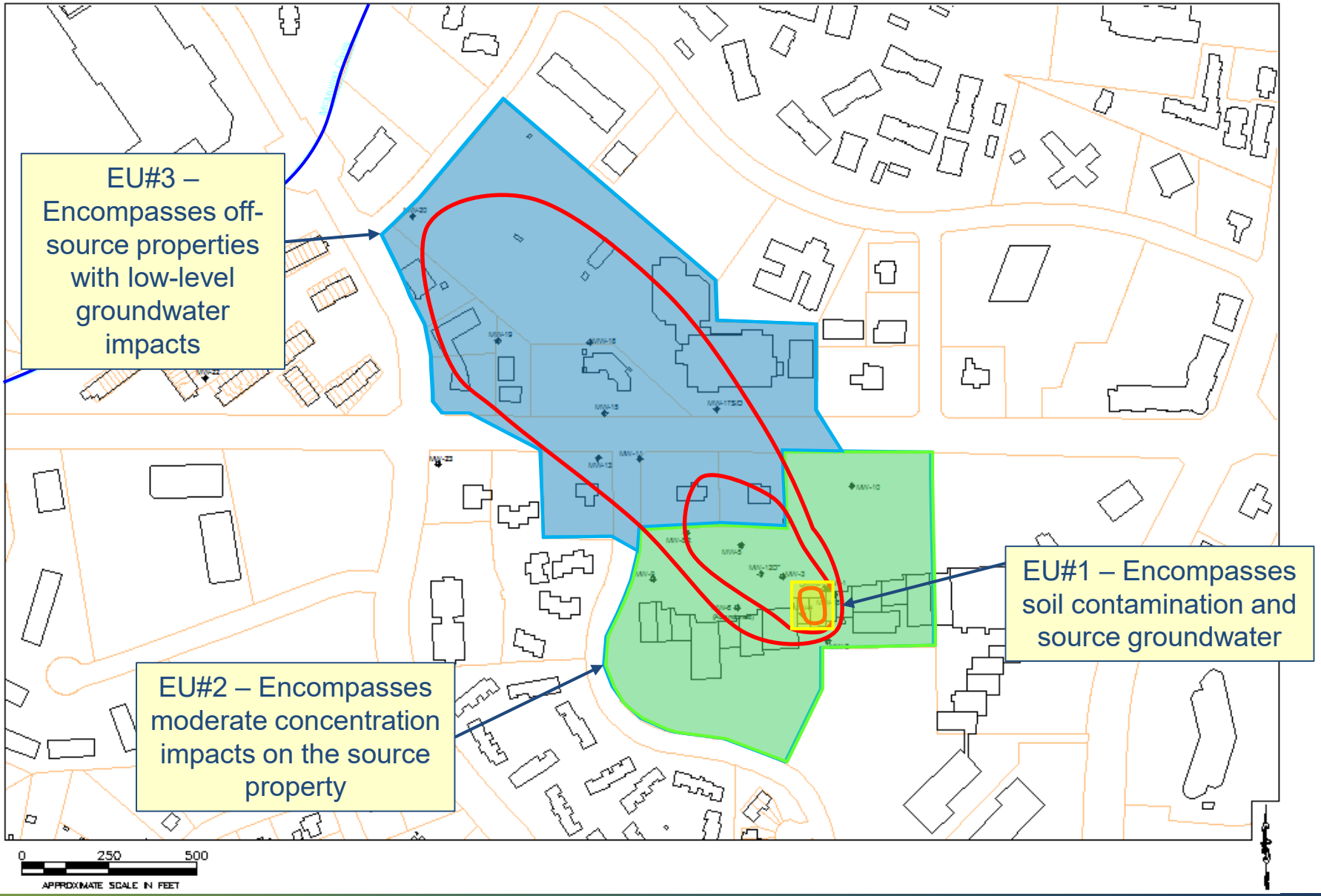


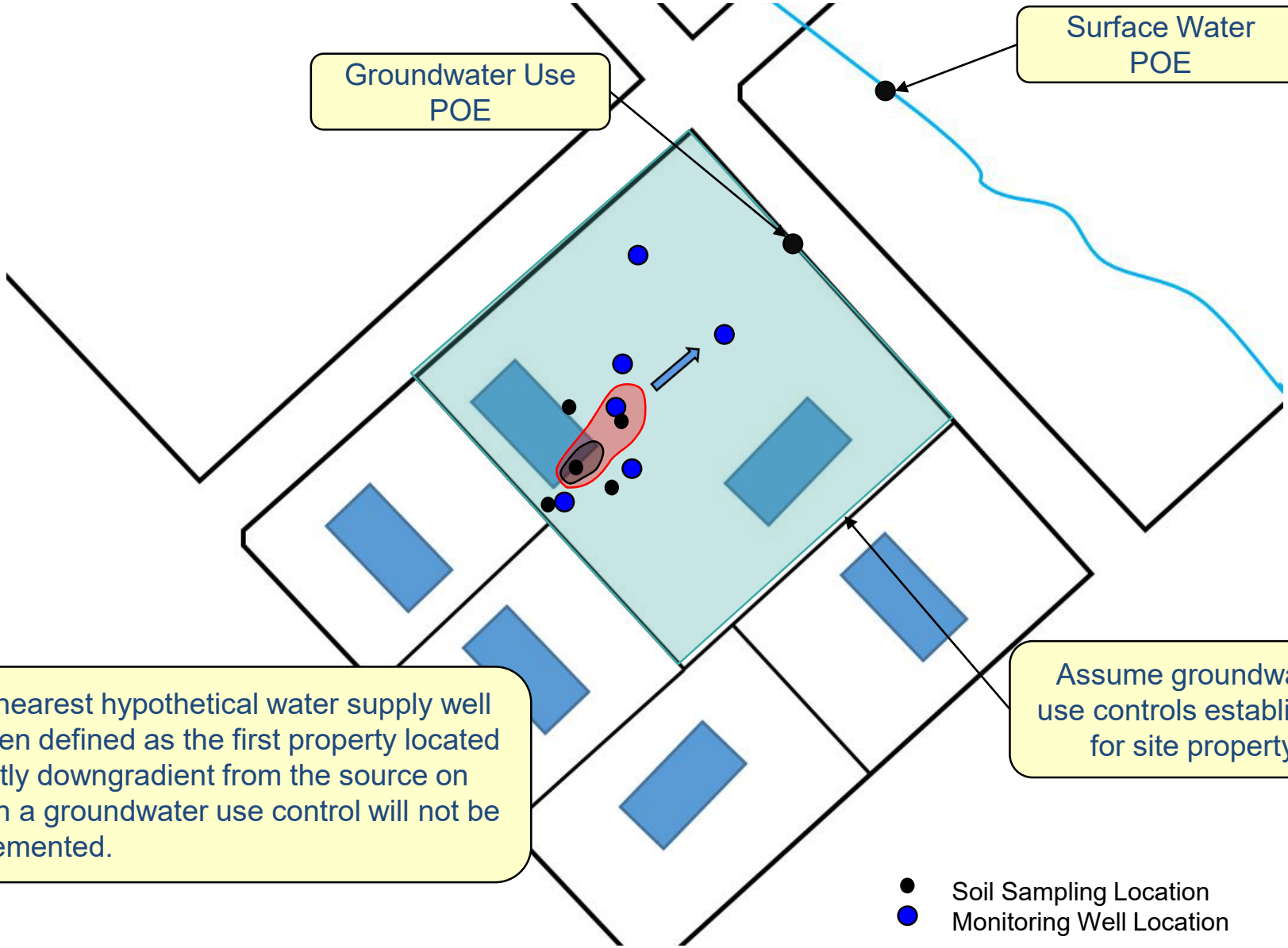
Defining Exposure Units



Risk Assessment Process

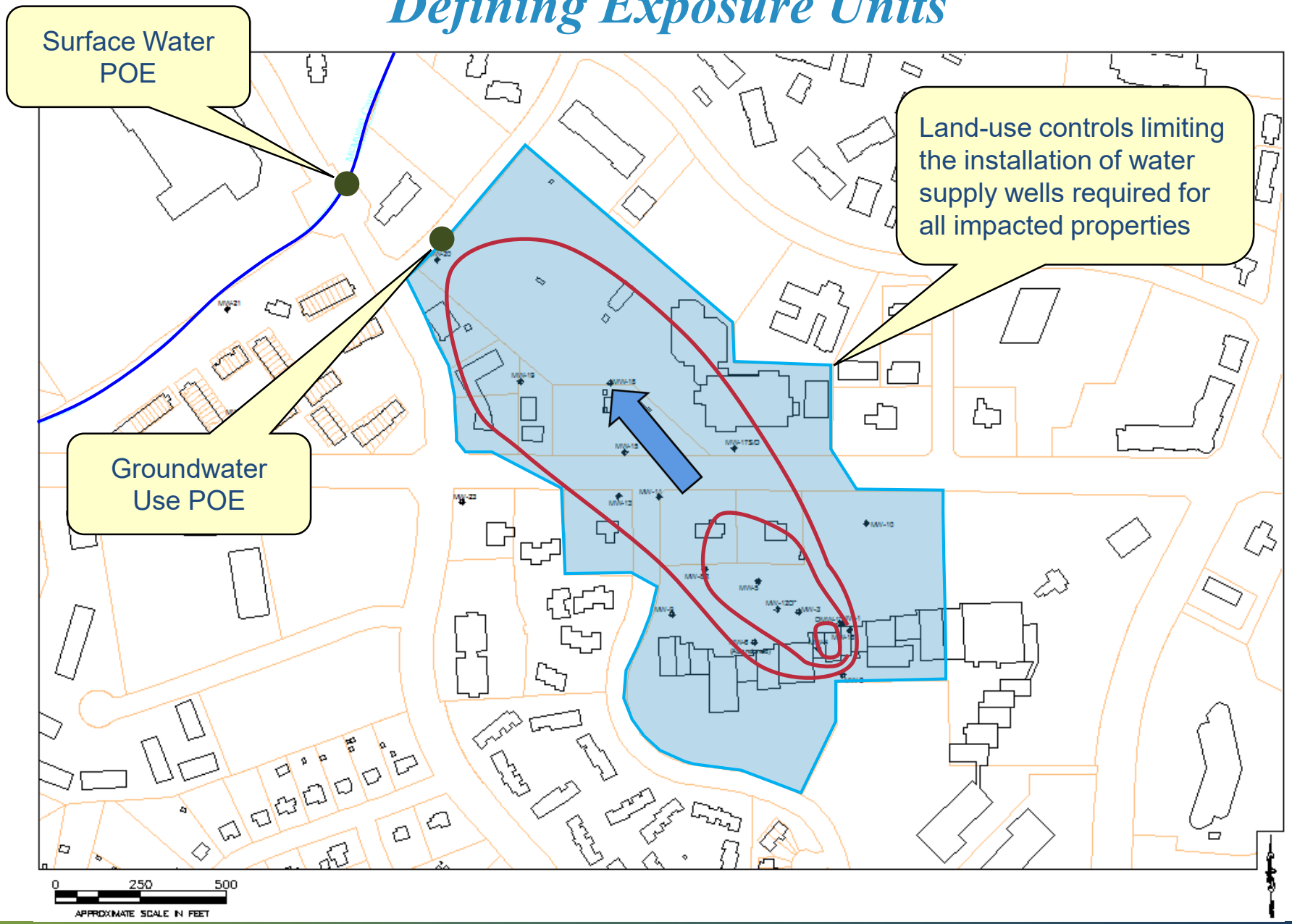
- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- Cumulative risk calculation
  - Define exposure units
  - **Define Points of Exposure (POEs)**
  - Define exposure pathways
  - Define exposure point concentrations
  - Run calculator to characterize risks
- Further risk evaluation
- Risk management

Defining POEs



The nearest hypothetical water supply well is often defined as the first property located directly downgradient from the source on which a groundwater use control will not be implemented.

Defining Exposure Units



Risk Assessment Process

- Delineate contamination in all media
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  - Define exposure units
  - Define POEs
  - **Define exposure pathways**
  - Define exposure point concentrations
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Exposure Pathways

PRIMARY PATHWAYS	
Resident	Soil Combined Pathways
	Groundwater Combined Pathways
Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
Construction Worker	Soil Combined Pathways
User Defined	Soil Combined Pathways
	Surface Water Combined Pathways
VAPOR INTRUSION PATHWAYS	
Resident	Groundwater to Indoor Air
	Soil Gas to Indoor Air
	Indoor Air
Non-Residential Worker	Groundwater to Indoor Air
	Soil Gas to Indoor Air
	Indoor Air
CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Types of Receptors

Resident	Single-family homes, townhouses, apartment, dormitories, child/daycare facilities, schools through high school, and hospitals.
Non-Residential Worker	Office buildings, commercial/industrial facilities, colleges and universities (excluding dormitories).
Construction Worker	Workers exposed during construction activities. Assumes shorter exposure time but higher contamination exposure as compared to non-residential worker.
User-Defined: Trespasser Recreator Other	Typical trespasser is adolescent at inactive sites. Recreator is assumed to spend a limited amount of time at the site for recreation. Other site specific scenarios (church, for example). Evaluation typically not needed unless non-residential restriction being implemented (not common).

Exposure Pathways

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Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
Construction Worker	Soil Combined Pathways
User Defined	Soil Combined Pathways
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Protection of Surface Water	Source Soil
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CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Soil Combined Pathways

Soil Combined Pathways

Soil Combined Pathways

- Includes ingestion, dermal contact, and outdoor inhalation of volatiles and particulates
- Calculator uses EPA soil equations which are similar to health-based PSRG equations
- Note sediment is not included as a media, but equations are same as for soil

Exposure Pathways

PRIMARY PATHWAYS	
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	Groundwater Combined Pathways
Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
Construction Worker	Soil Combined Pathways
User Defined	Soil Combined Pathways
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	Indoor Air
CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Groundwater Combined Pathways (for tap water)

NOTE: This pathway calculates risk from drinking, cooking and bathing.

Groundwater Combined Pathways

Groundwater Combined Pathways

- Calculator uses EPA tapwater equations
- Includes ingestion, dermal contact, and inhalation (inhalation associated showering, dishwasher, etc., not vapor intrusion)
- Applicable for resident and non-residential worker

- ***Sites with exceedences of 2L Standards in groundwater need groundwater use control***
- ***In most cases, risk assessor can simply reference that a groundwater use control will be implemented and eliminate the need to evaluate this pathway in the Risk Calculator***

Exposure Pathways

PRIMARY PATHWAYS	
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	Groundwater Combined Pathways
Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
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CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Surface Water Combined Pathways

Surface Water Combined Pathways

Surface Water Combined Pathways

- Calculator uses EPA recreator equations
- Includes ingestion and dermal contact
- Applicable for user-defined receptor (could include trespasser, recreator, or other)

- ***Sites with exceedences of 2B Standards in surface water generally cannot be closed out***
- ***In many cases, risk assessor can simply reference that impacts have not been detected in surface water at concentrations above 2B Standards and eliminate the need to evaluate this pathway in the Risk Calculator***

Exposure Pathways

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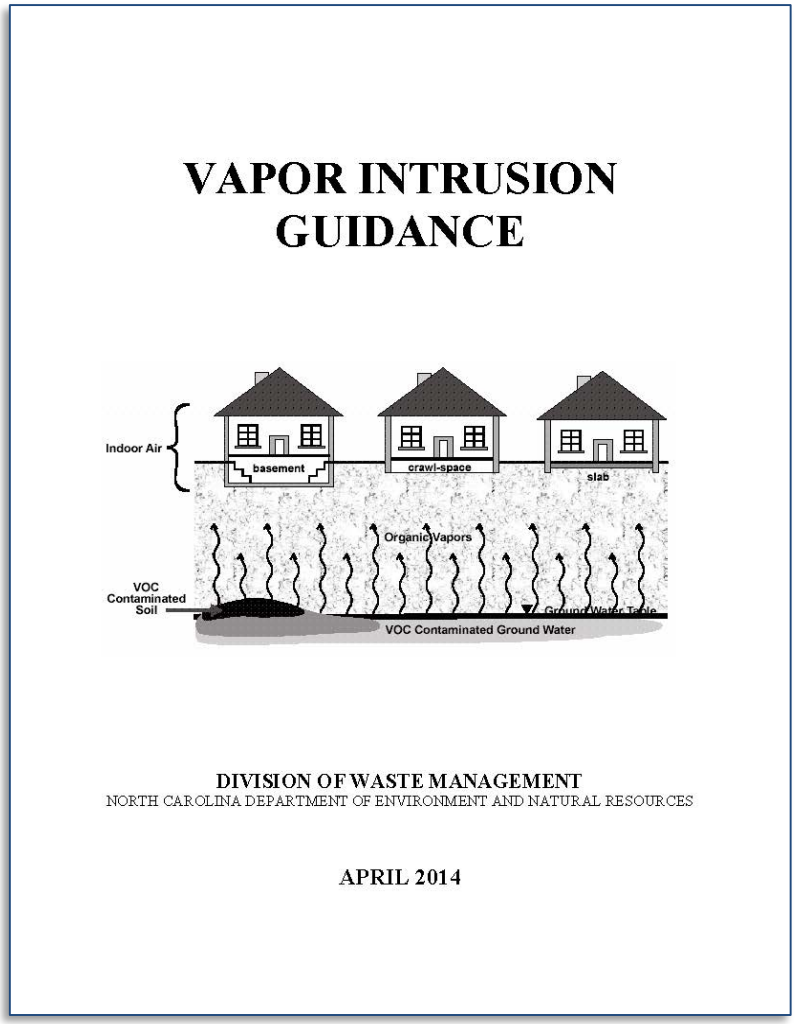
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Vapor Intrusion Pathways

- Calculators available for groundwater to indoor air, soil gas to indoor air, and indoor air

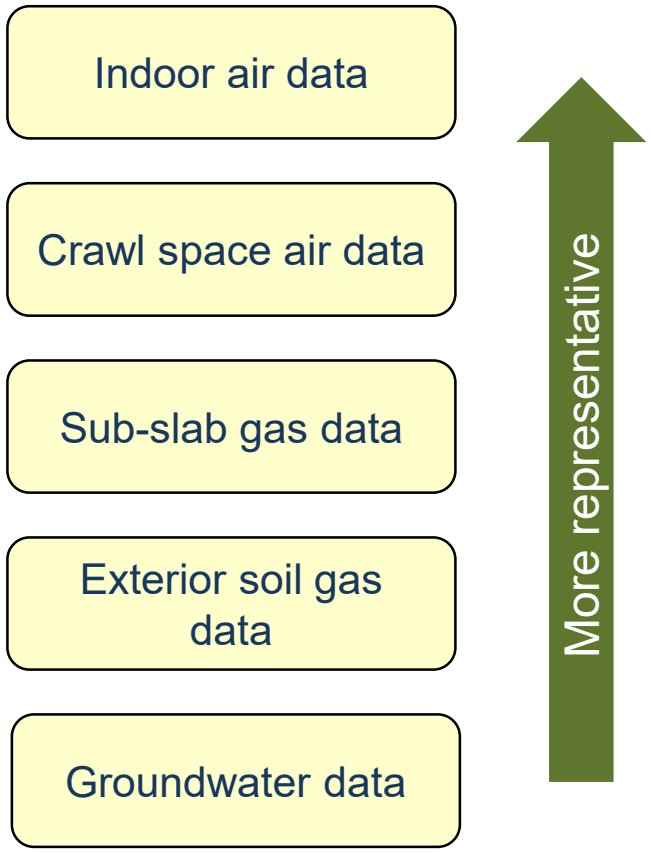
Vapor Intrusion Pathways



- Refer to DWM Vapor Intrusion Guidance
- Same equations as EPA VISL calculator, but with NC attenuation factor for non-residential soil gas
- Applicable for a resident or non-residential worker
- Risk can be evaluated using indoor air data, soil gas data, or groundwater data
- Don't include risk for more than one media in cumulative risk calculation as this would double-count risk

Vapor Intrusion Pathway – Existing Structures

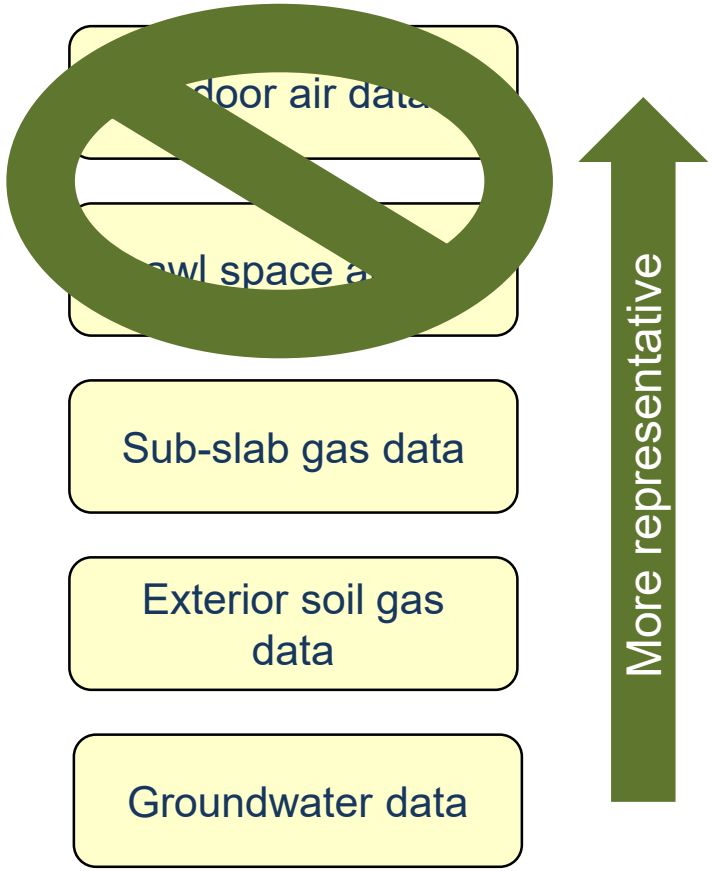
Evaluate indoor inhalation pathway using available data that is most representative of actual exposures:



Note: No risk procedures established for soil to indoor air. Collection of sub-slab or soil gas data needed to evaluate vapor intrusion in areas of impacted soil.

Vapor Intrusion Pathway – Future Structures

Cannot evaluate based on indoor air or crawl space air data because concentrations may vary based on building construction.



Exposure Pathways

PRIMARY PATHWAYS	
Resident	Soil Combined Pathways
	Groundwater Combined Pathways
Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
Construction Worker	Soil Combined Pathways
User Defined	Soil Combined Pathways
	Surface Water Combined Pathways
VAPOR INTRUSION PATHWAYS	
Resident	Groundwater to Indoor Air
	Soil Gas to Indoor Air
	Indoor Air
Non-Residential Worker	Groundwater to Indoor Air
	Soil Gas to Indoor Air
	Indoor Air
CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Risk directly calculated for these pathways and used in cumulative risk evaluation. Cumulative CR cannot exceed 10^{-4} and cumulative HI cannot exceed 1.

Exposure Pathways

PRIMARY PATHWAYS	
Resident	Soil Combined Pathways
	Groundwater Combined Pathways
Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
Construction Worker	Soil Combined Pathways
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	Indoor Air
CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

For cumulative risk evaluation distance to POE is essentially “0”.

POE is actual or hypothetical water supply well or surface water body located some distance downgradient of source

Exposure Pathways

PRIMARY PATHWAYS	
Resident	Soil Combined Pathways
	Groundwater Combined Pathways
Non-Residential Worker	Soil Combined Pathways
	Groundwater Combined Pathways
Construction Worker	Soil Combined Pathways
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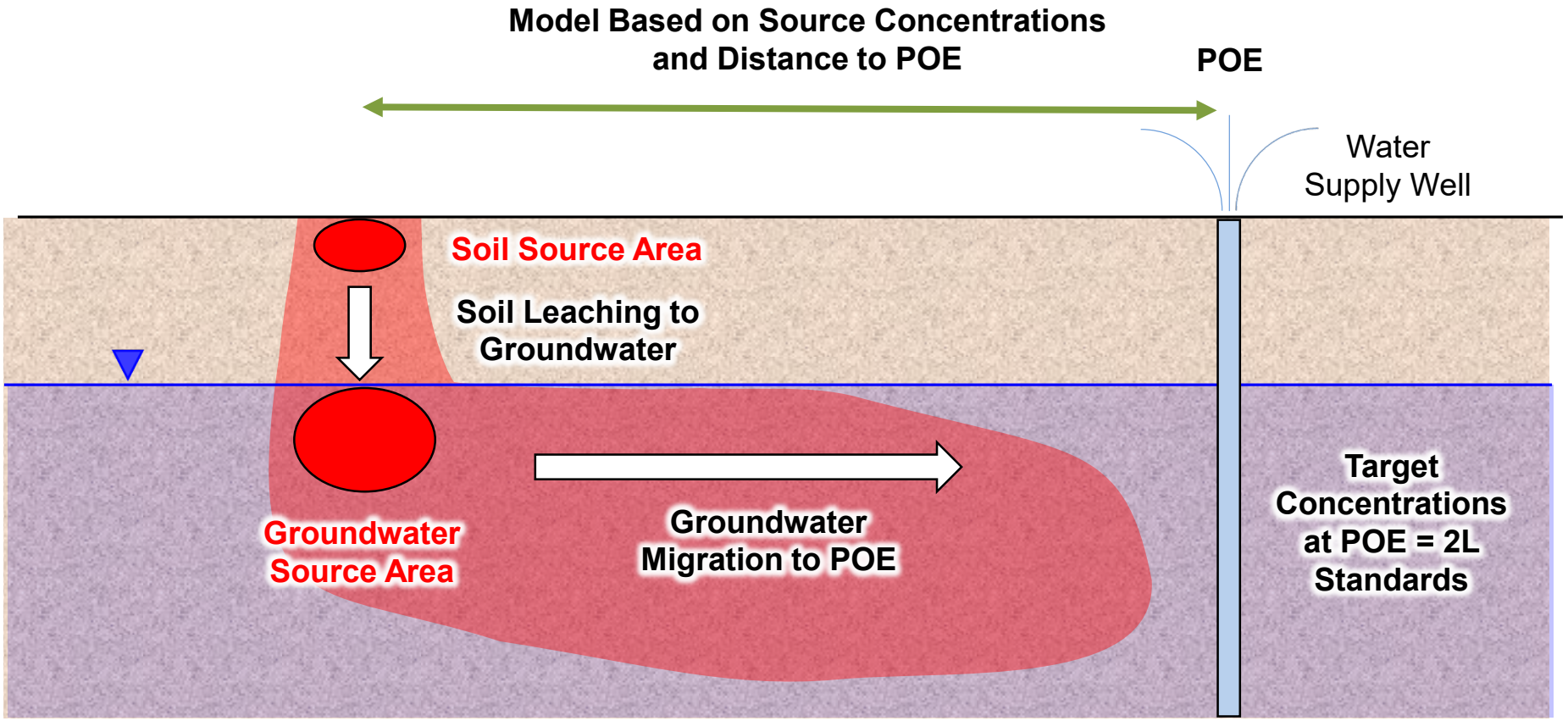
	Indoor Air
CONTAMINANT MIGRATION PATHWAYS	
Protection of Groundwater Use	Source Soil
	Source Groundwater
Protection of Surface Water	Source Soil
	Source Groundwater

Contaminant Migration Pathways

- Soil leaching to groundwater and groundwater migration to a point of exposure (POE)
- POE for Protection of Groundwater Use is nearest actual or hypothetical water supply well
- POE for Protection of Surface Water is nearest surface water body

Protection of Groundwater Pathway



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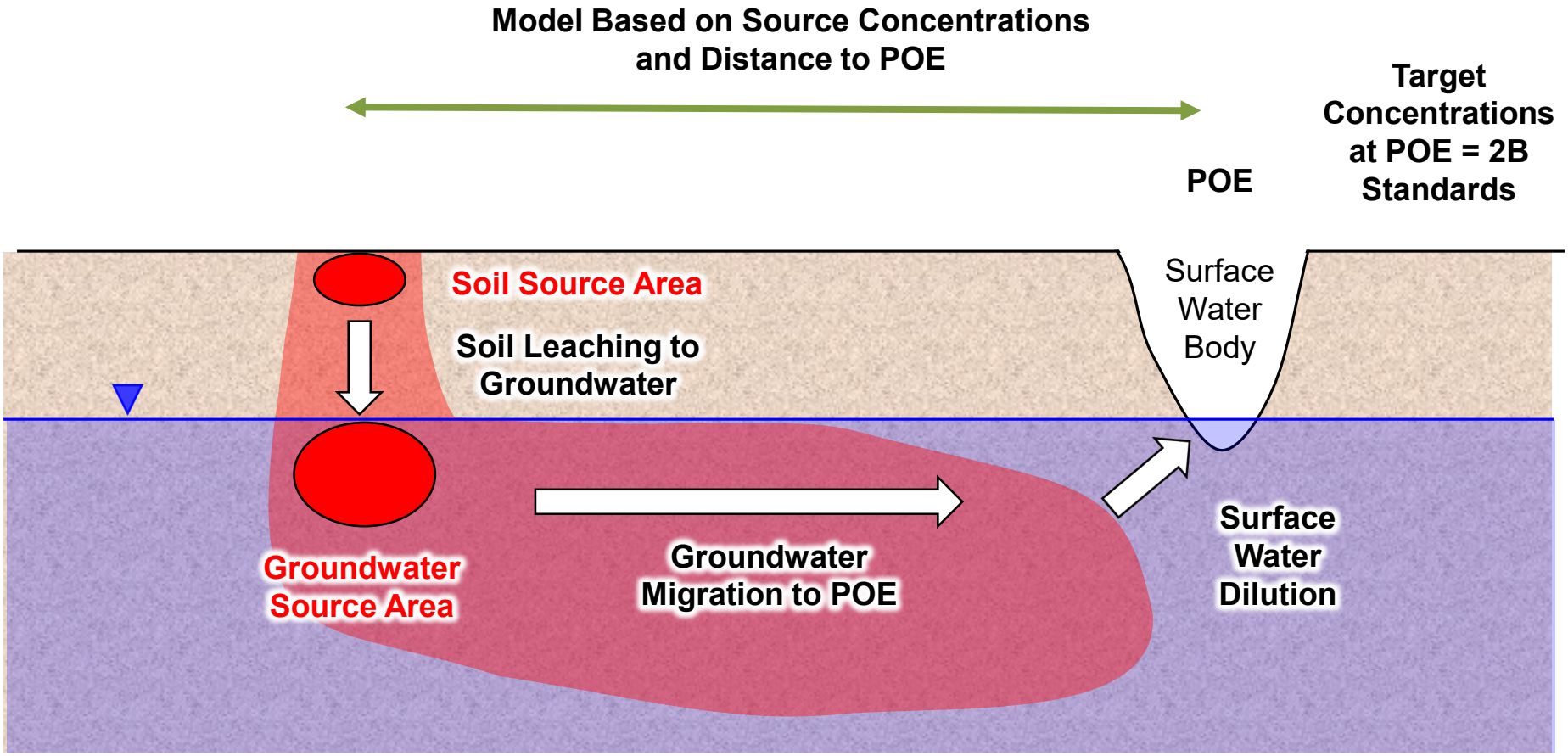
Protection of Surface Water Pathway



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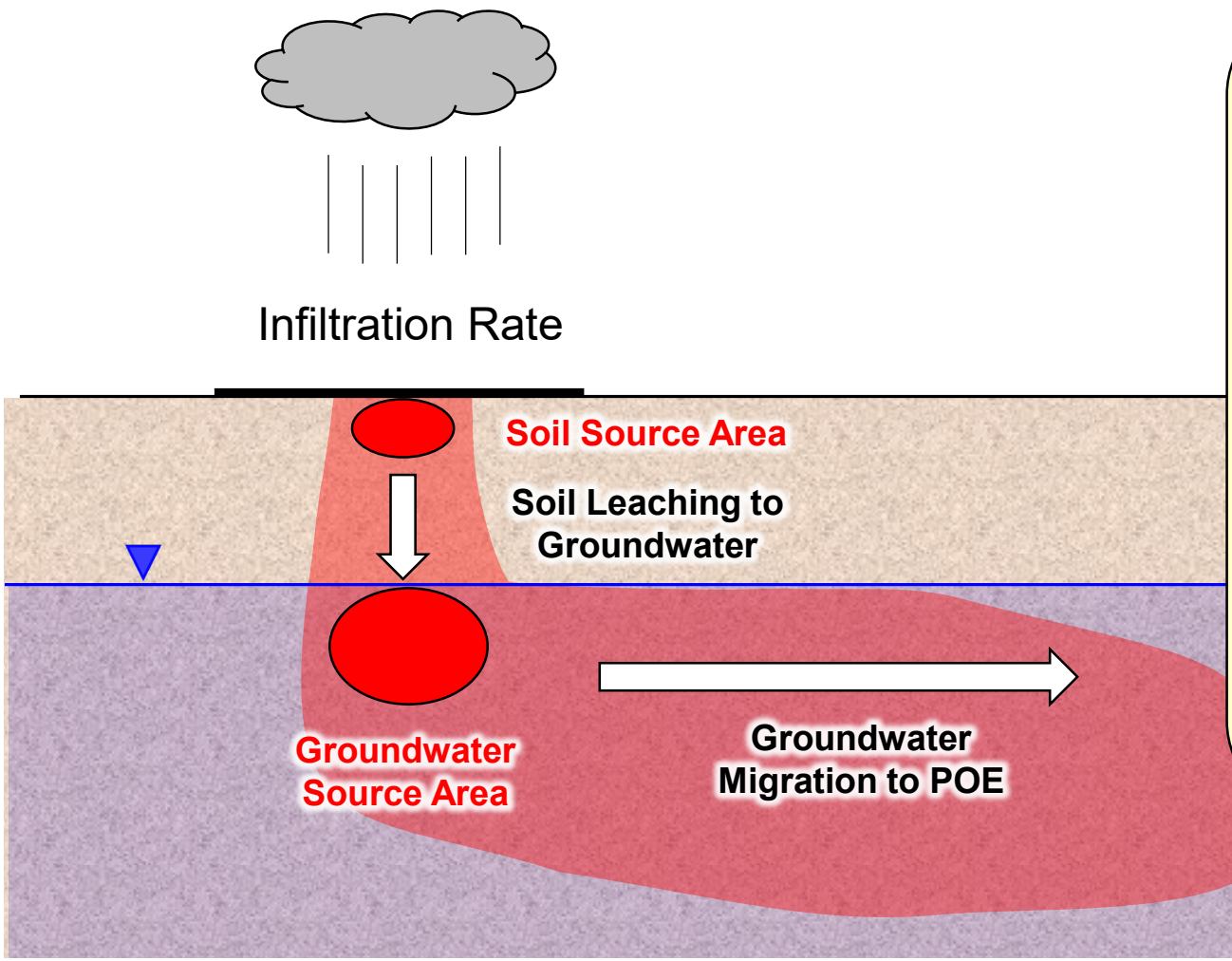
Options for Contaminant Migration Pathways

- Use Risk Calculator
  - Soil leaching to groundwater modeled using standard EPA leaching equations
  - Incorporates both mass limit and unlimited source equations
  - Groundwater migration modeled using simplistic Domenico equation incorporating dispersion only (no degradation)
  - Migration from groundwater into surface water modeled using simplistic dilution equation
- Other models may be used, but complex modeling often not warranted

Actual monitoring data documenting plume extent and stability over time is considered more reliable than modeling results

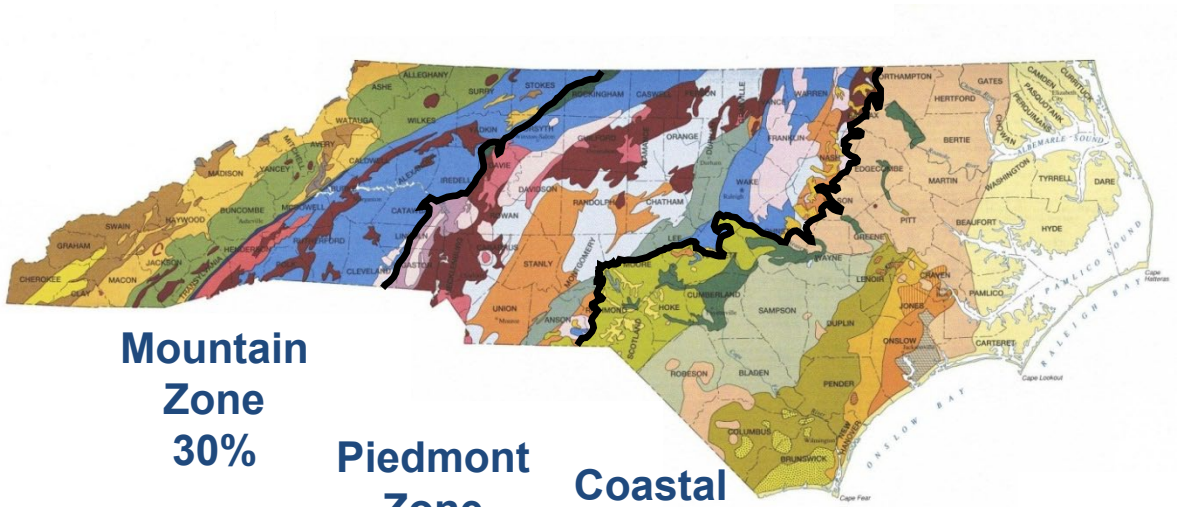
Interpretation of Contaminant Migration Results



- Infiltration rate is a sensitive parameter for soil leaching to groundwater
- If soil source area is currently covered to minimize infiltration, removal of that cover could increase infiltration and render the plume unstable
- Land-use restriction to maintain a cover over the soil source area may be required

Default Infiltration Rates

- Default infiltration rates in the absence of surface cover determined based on modeling of 20 sites across State of NC
- Modeling performed using EPA HELP model



Mountain Zone 30%

Piedmont Zone 25%

Coastal Plain Zone 45%

Default Infiltration Rate = Published precipitation multiplied by specified geographic percent

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Risk Assessment Process

- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- Cumulative risk calculation
  - Define exposure units
  - Define POEs
  - Define exposure pathways
  - **Define exposure point concentrations**
  - Run calculator to characterize risks
- Further risk evaluation
- Risk management

Exposure Point Concentrations

- Exposure point concentrations will be different for different exposure units and/or pathways

- Initial risk evaluation should be based on maximum concentrations of each contaminant in each medium of concern in the exposure unit being evaluated

If initial risk evaluation indicates risks above acceptable levels, further evaluation may be performed using more appropriate exposure point concentrations, exposure assumptions, or gathering additional data

Risk Assessment Process

- Delineate contamination in all media
- Confirm plume is stable or predictable
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- Cumulative risk calculation
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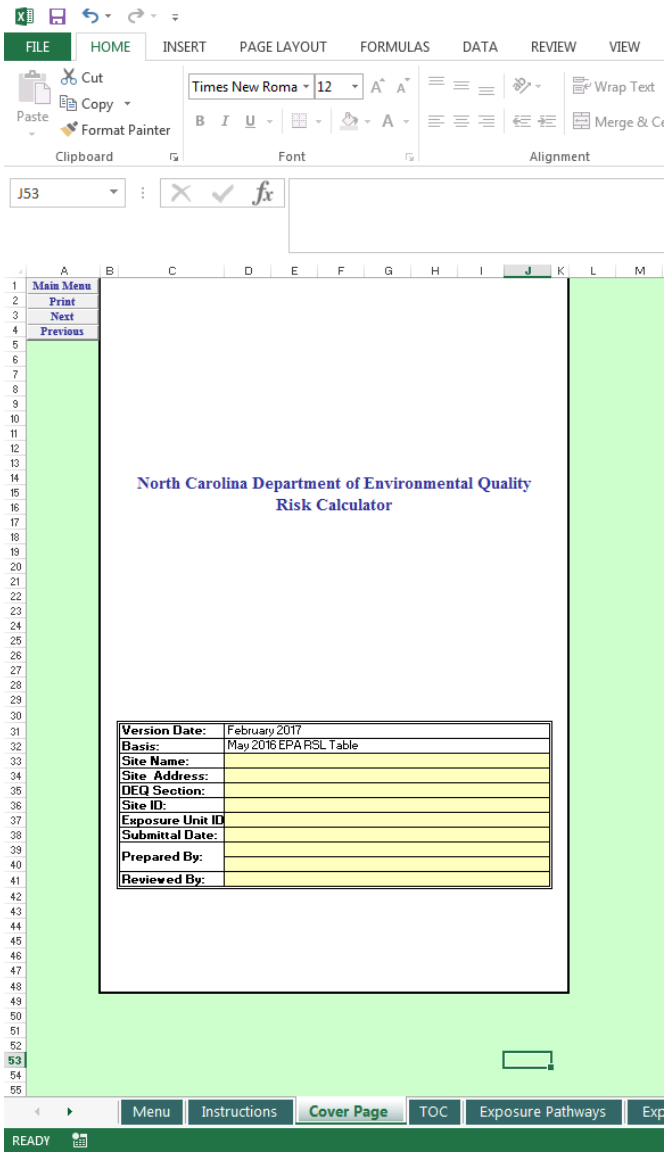
Risk Calculator



Risk calculator will be reviewed during next portion of presentation.

Risk Assessment Process

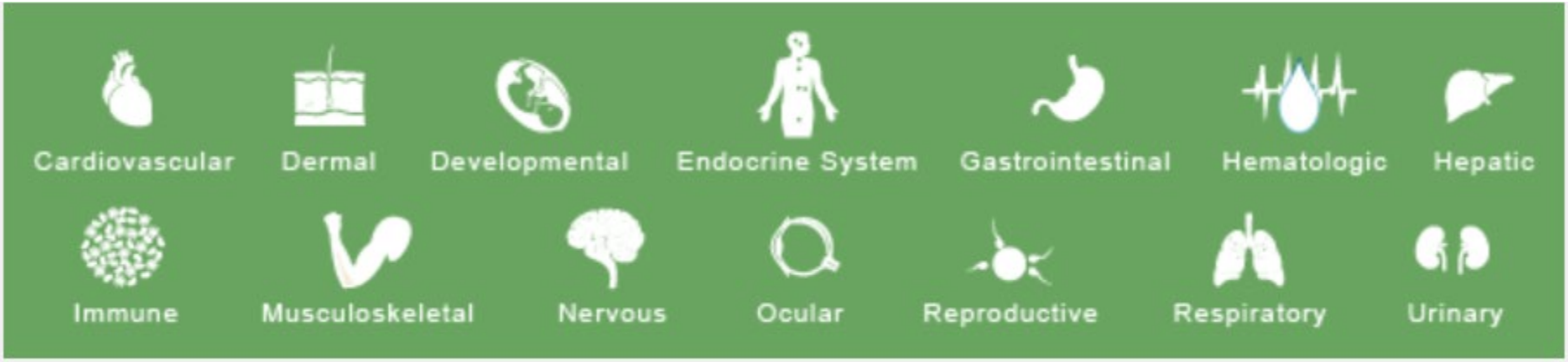
- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- Cumulative risk calculation
  - Define exposure units
  - Define POEs
  - Define exposure pathways
  - Define exposure point concentrations
  - Run calculator to characterize risks
- **Further risk evaluation**
- Risk management

Complex Risk Assessment

A complex site-specific risk assessment beyond the Risk Calculator will require professional risk assessor oversight. Examples would include:

- Bioaccumulative chemical exposures
- Target organ/critical effect specific modes of action
- More specific mathematical modeling of contaminant fate and transport

Refer to EPA Risk Assessment Guidance for Superfund and consult with DEQ risk assessors regarding scope before initiating.



Risk Assessment Process

- Delineate contamination in all media
- Confirm plume is stable or predictable
- Risk screening
- Cumulative risk calculation
  - Define exposure units
  - Define POEs
  - Define exposure pathways
  - Define exposure point concentrations
  - Run calculator to characterize risks
- Further risk evaluation
- **Risk management**

Risk Management

Primary risk management options:

- Eliminate contamination (i.e., remediate)
- Eliminate exposure pathways via engineering controls or land-use controls (current and future)
- Combination of both options

There are often multiple options for managing risks. Risk management decisions often involve balancing costs, property use objectives, acceptance of land-use controls, community acceptance, and feasibility of meeting cleanup goals.

Risk Assessment Training Topics of Discussion

I. Regulatory Framework

II. Risk Assessment 101

III. NC-Specific Risk Assessment Procedures

IV. Groundwater Only Site Closure Examples

V. Introduction to the Risk Calculator

VI. Risk Calculator Site Closure Example

VII. Wrap-up & Questions

Progress of Risk-Based Remediation

- Example Sites – (non-calculator)
  - Site Conceptual Model (CSM)
  - Plume stability
  - Acceptable risks from contamination in all media
  - Protectiveness of remedy
  - Comments and considerations
  - Controls needed to mitigate risks

Conceptual Site Model

A strong conceptual site model answers:

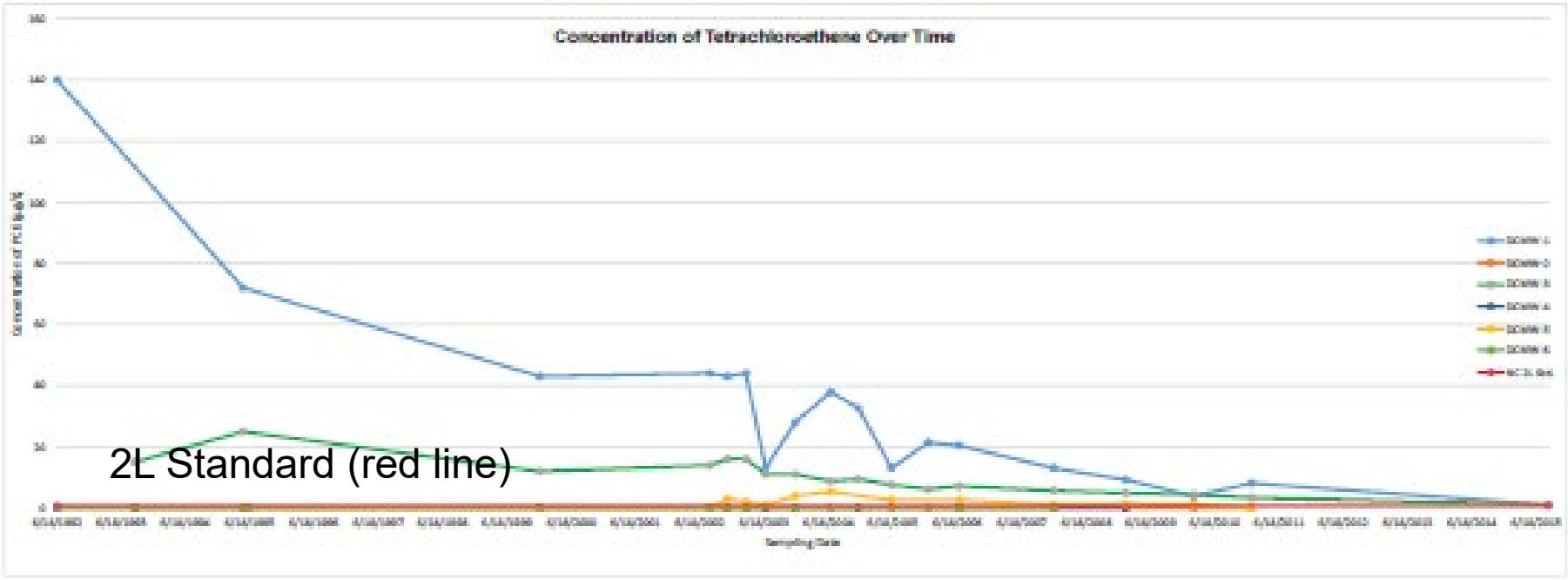
- What Is The Contamination?
- Where Did It Come From?
- Where Is It Now?
- Where Is It Going?
- How Is It Getting There And When?
- Who/What Could Be At Risk?

Example Site #1
Groundwater Only

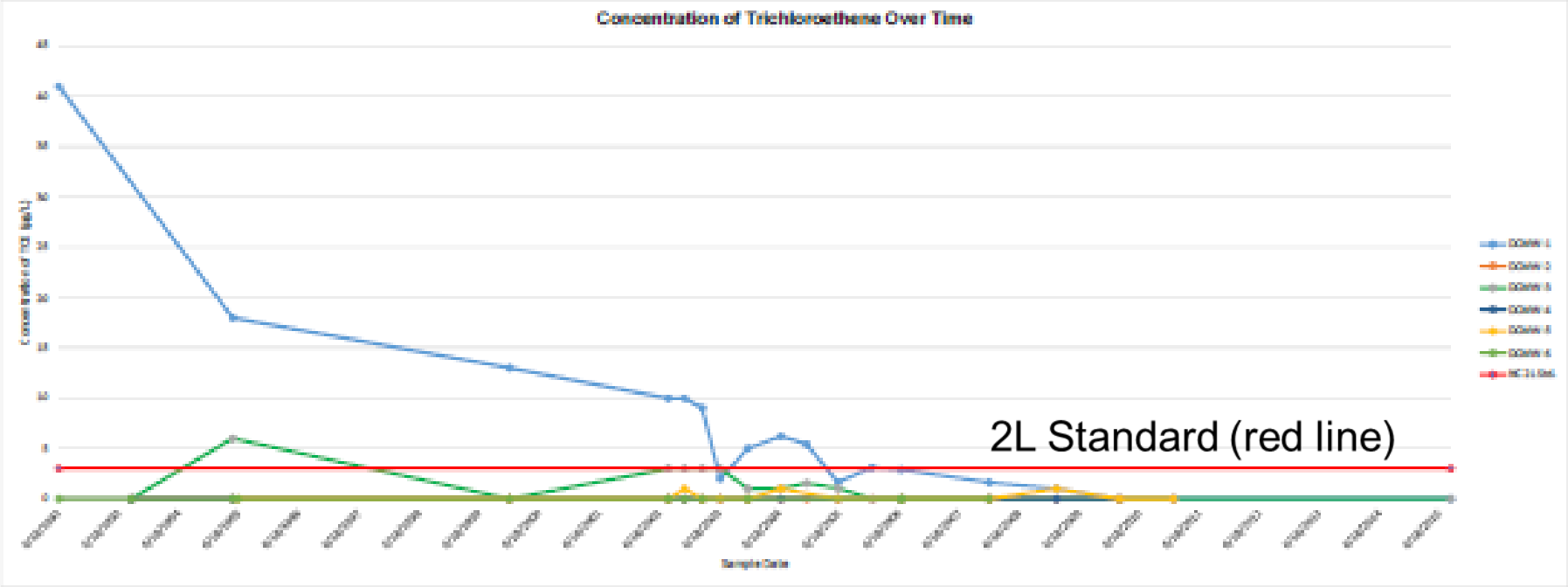
Former Textile Mill near River - Mixed-use area

Residual PCE remain in GW
No soil or vapor issues

PCE Concentrations in Groundwater (20 years of monitoring data)



TCE Concentrations in Groundwater (20 years of monitoring data)



Risk Management

Identified or potential risks:

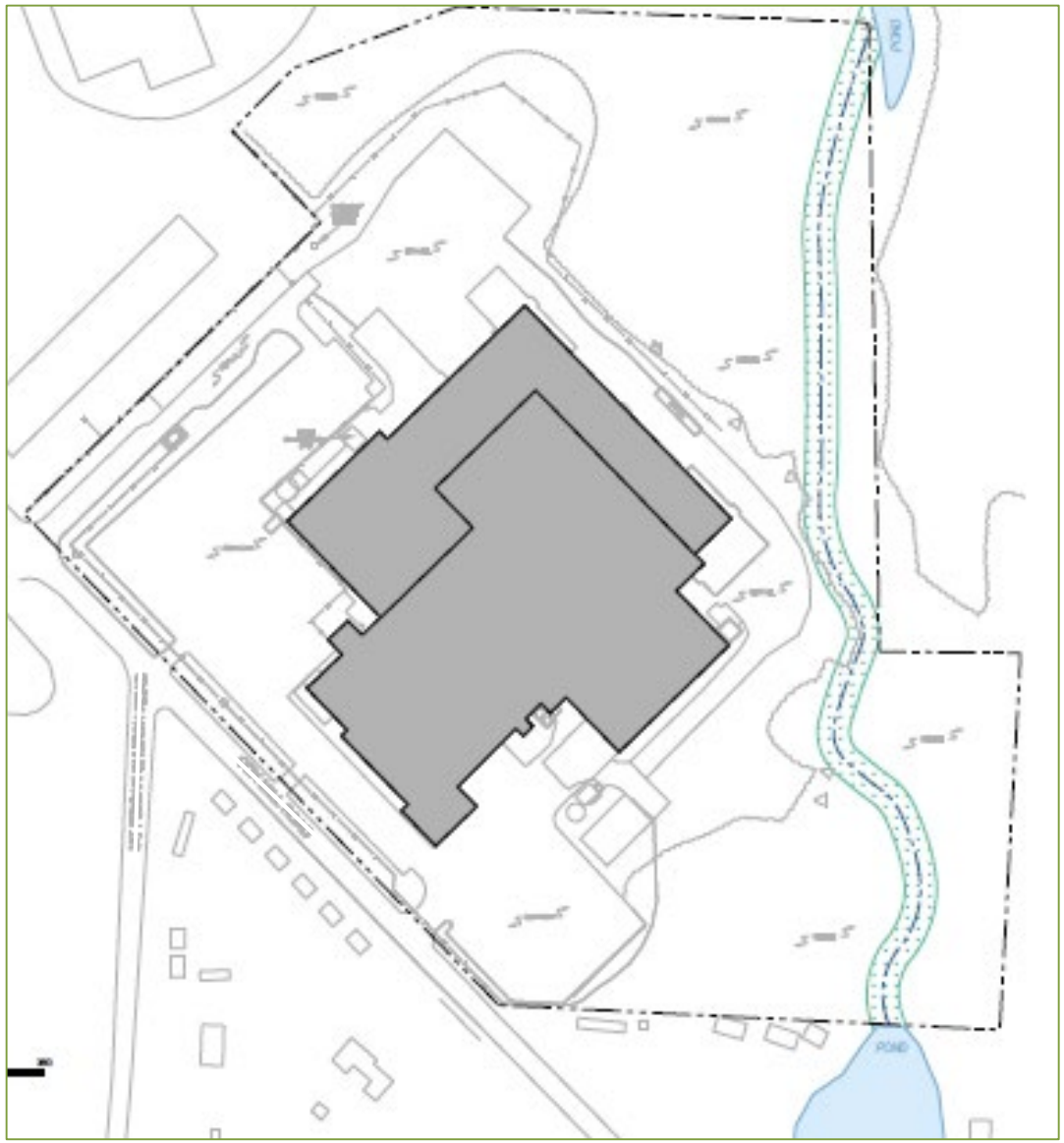
- Groundwater use on source property only
- No other contaminated media

Risk management:

- Institutional controls recorded on property deed
  - Declaration of Perpetual Land-Use Restriction (DPLUR) specifying groundwater- use restriction
  - Notice of Residual Contamination (survey plat)

Example Site #2
A More Complex Site

Active Manufacturing Facility in a Mixed-Use Area




POND
UPSTREAM
419.72
411.75
409.6
410.16
414.06
414.4
413.5
413.69
413.74
413.43
413.16
416.52
415.63
413.03
411.77
411.95
408.92
406.75
403.94
407.3
403.07
399.21
412.9
411.54
407.42
403.06
400.92
406.08
406.09
402.5
402.49
DOWNSTREAM
POND
427.13
424
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418
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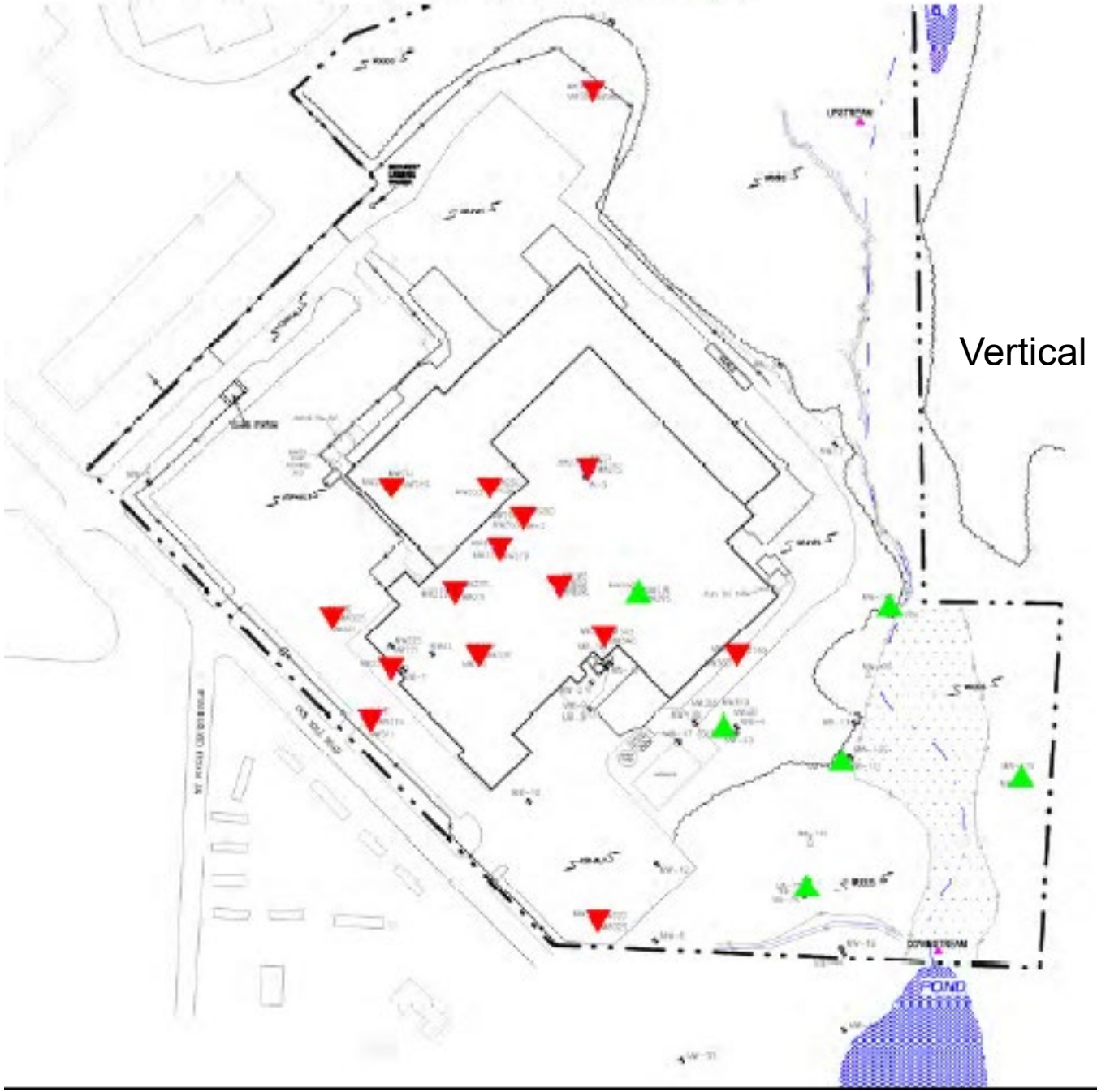
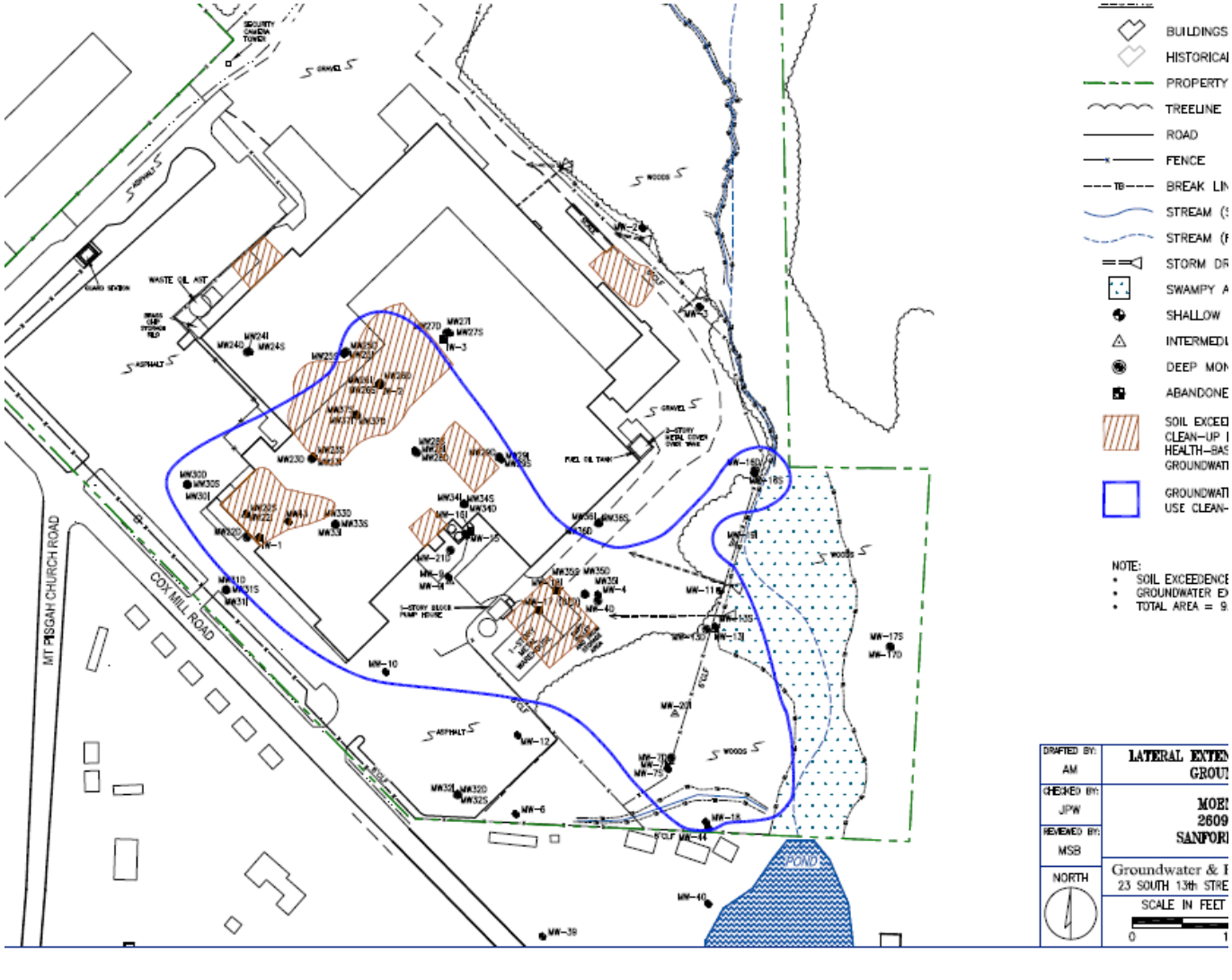
404
402

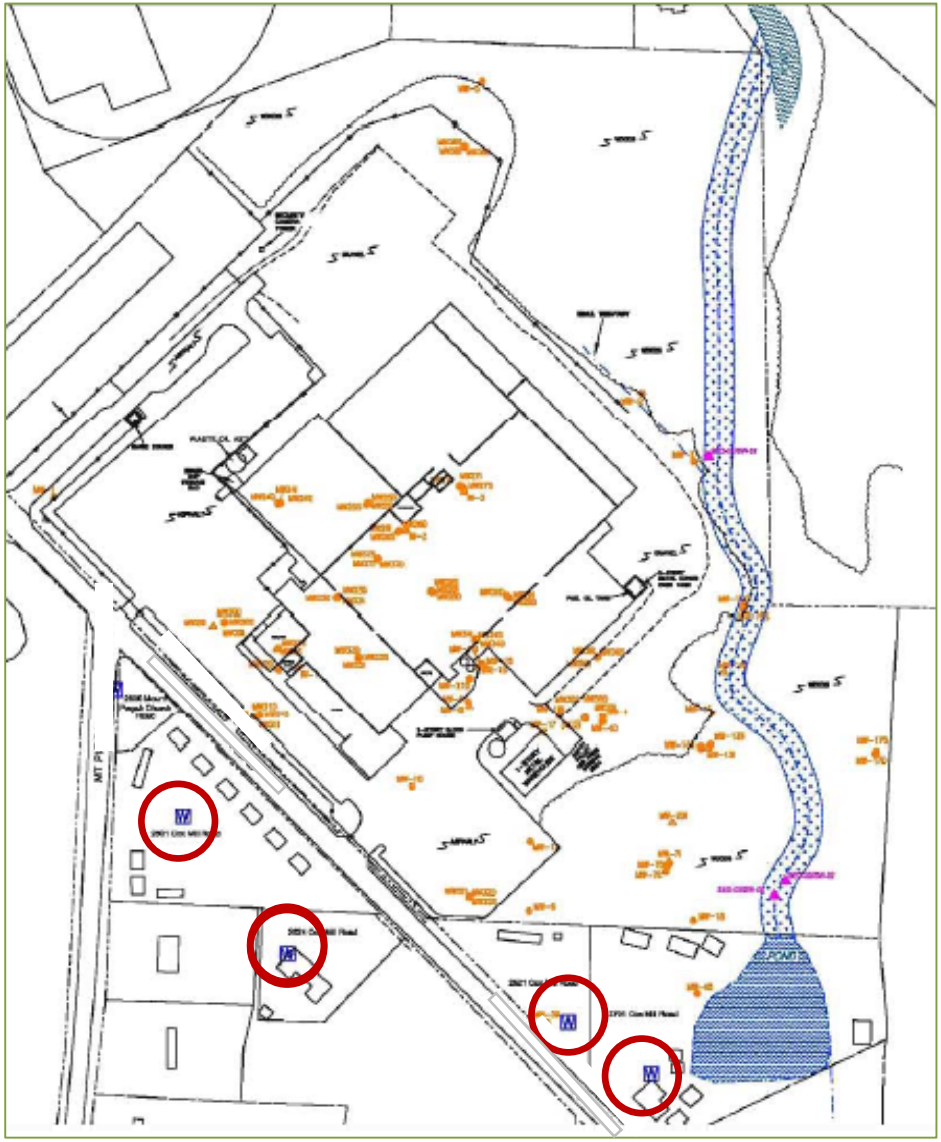


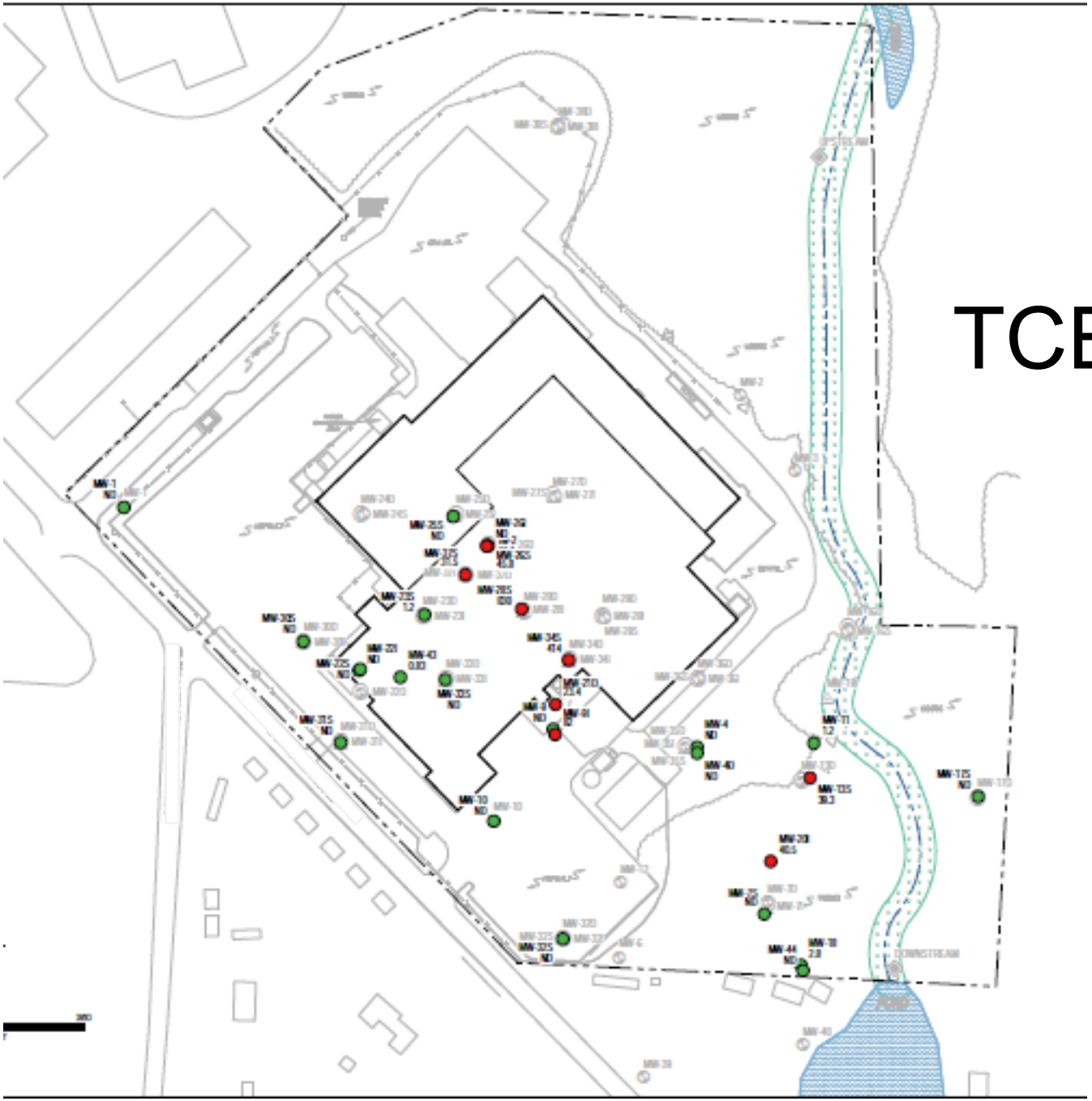
Vertical Gradients

TCE and 1,4-Dioxane in Groundwater (2013 Extent)



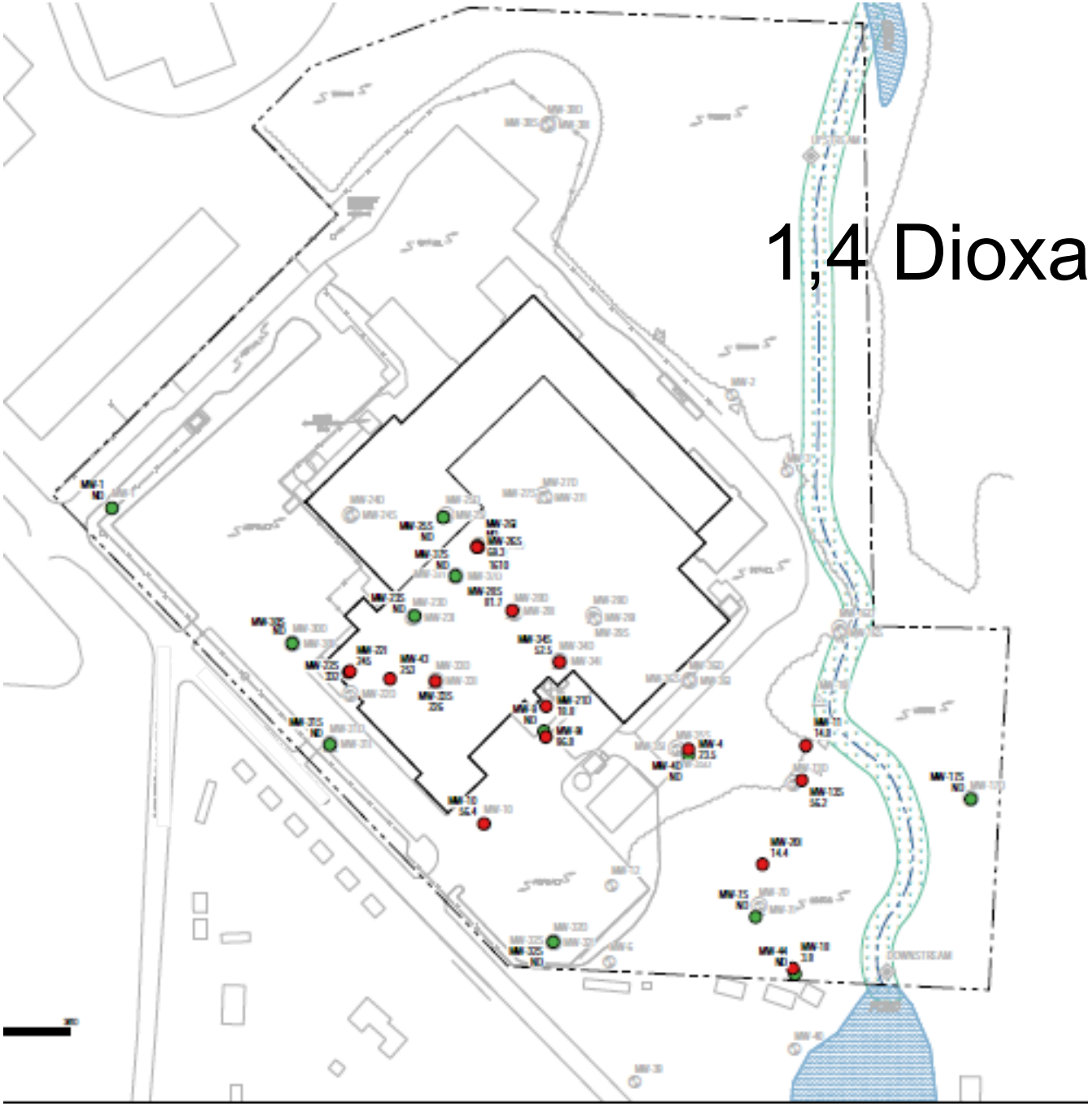
Potable Water Supply Wells Abandoned in 2010





TCE

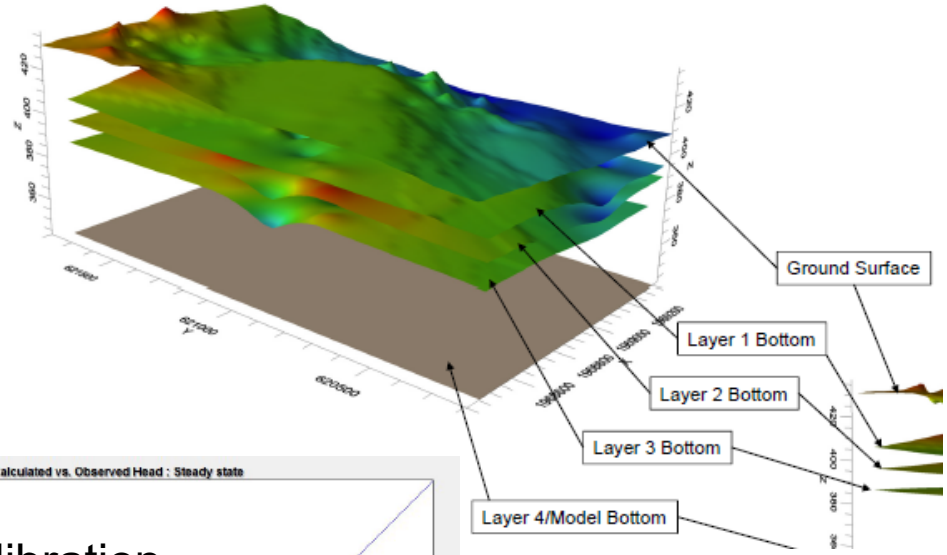
1,4 Dioxane

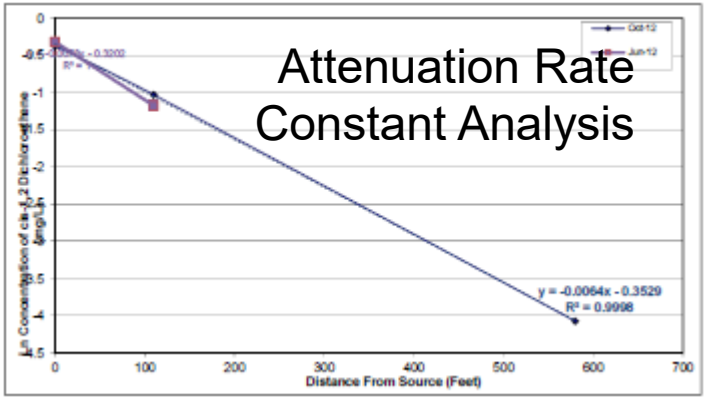


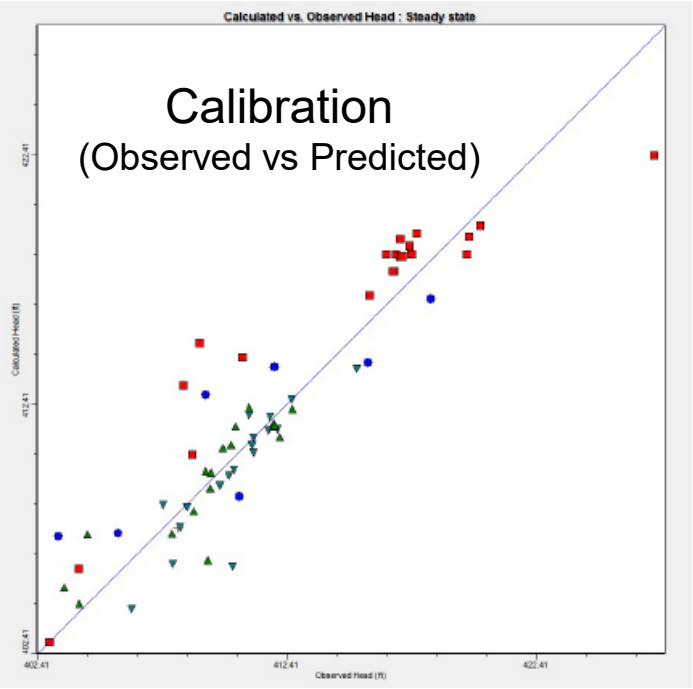
Demonstrating Plume Stability

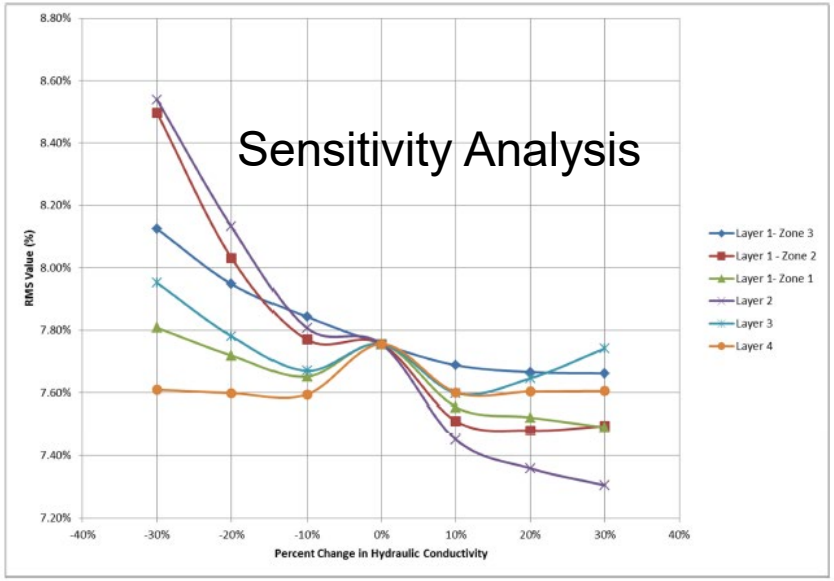
- Provided one set of groundwater plume stability isoconcentration maps for each contaminant
- Provided sets of tabulated data from various reports

Presented a complex multi-layer fate and transport model in support of site data







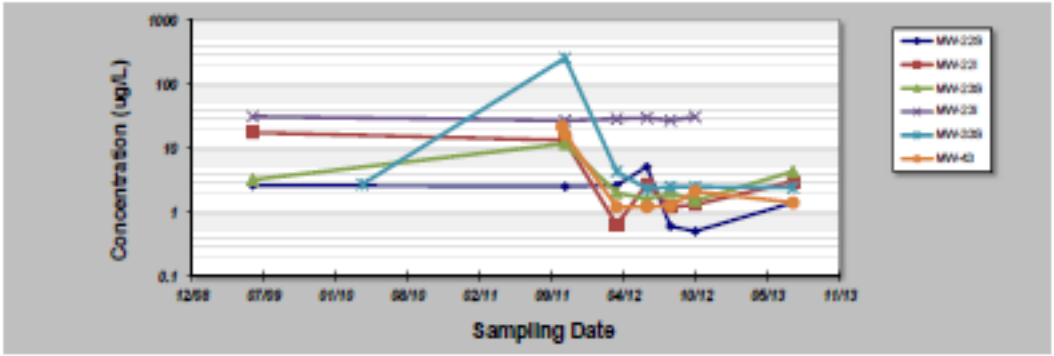


GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 25-Jul-13
Facility Name: Moen Incorporated
Conducted By: JPW

Job ID: 1201856
Constituent: TCE
Concentration Units: ug/L

Sampling Point ID:	MW-22S	MW-22I	MW-23S	MW-23I	MW-33S	MW-43	
Sampling Event	Sampling Date	TCE CONCENTRATION (ug/L)						
1	5-Jun-09	2.6	17.4	3.2	31			
2	6-Apr-10					2.72		
3	12-Oct-11						21.6	
4	21-Oct-11	2.5	13.2	11.7	26.9	254	16.2	
5	12-Mar-12	2.6	0.63	2	28.4	4.3	1.2	
6	4-Jun-12	5.1	2.7	1.6	29.6	2.3	1.2	
7	8-Aug-12	0.6	1.2	2	27	2.5	1.35	
8	16-Oct-12	0.5	1.3	1.5	30.7	2.5	2.1	
9	15-Jul-13	1.4	3	4.3		2.4	1.4	
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.72	1.20	0.97	0.06	2.46	1.35	
Mann-Kendall Statistic (S):		-6	-5	-6	1	-10	-4	
Confidence Factor:		84.5%	71.9%	76.4%	50.0%	90.7%	66.7%	
Concentration Trend:		Stable	No Trend	Stable	No Trend	Prob. Decreasing	No Trend	



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≥0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

Evaluated Other Media

Soil
Surface Water
Sediment
Vapor

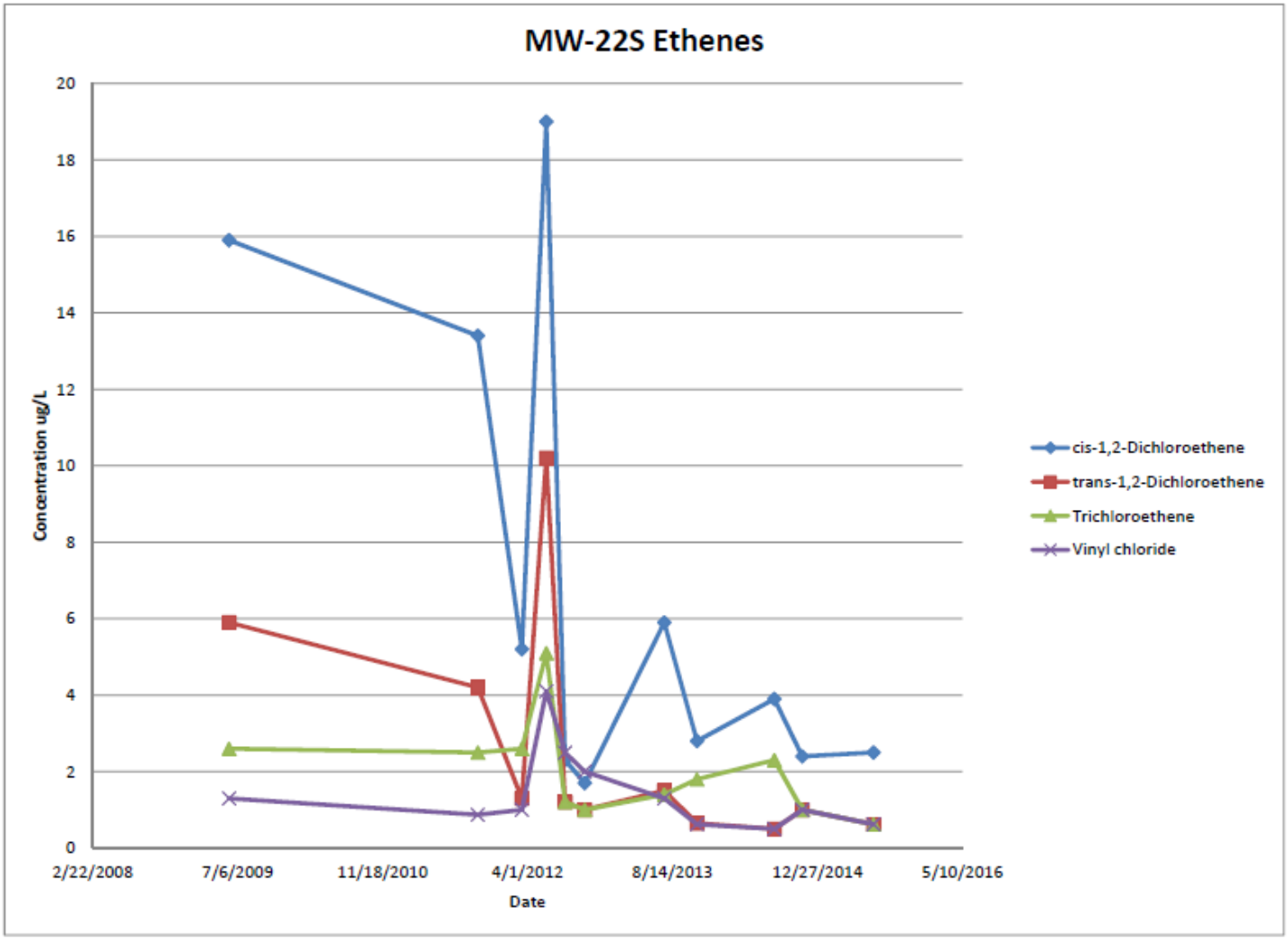
- Summarized potential exposure pathways for both current and future land use
- Provided earlier risk assessment of vapor data

Comments on Technical Demonstration

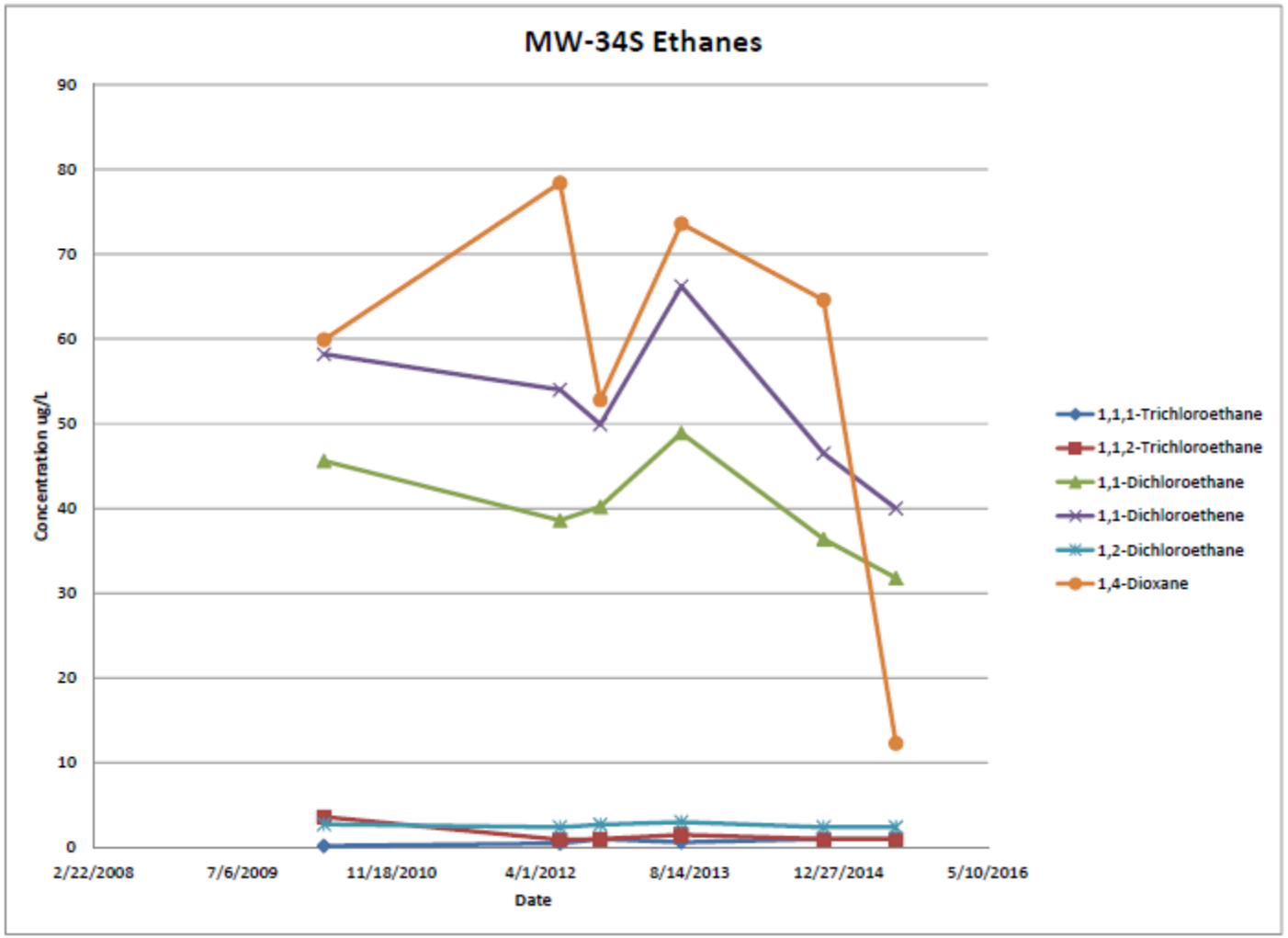
State requested additional use of site data

- Trend plots for select key wells located along the length of the plume
- Cross sections with recent groundwater and analytical data superimposed
- Identify soil exceedances to determine needed controls

Source Area Monitoring Well



Downgradient Monitoring Well



More Comments on Technical Demonstration

"the current and probable future use of GW shall be identified and protected"

Current conditions were understood

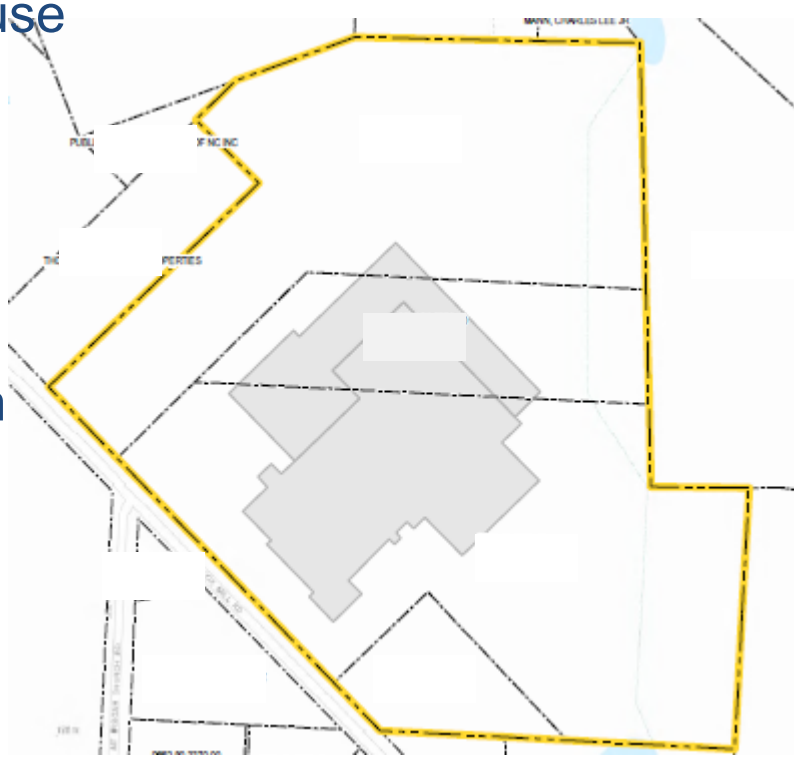
What about the future use of groundwater on the adjacent residential properties?

- Minimal buffer between plume and property boundary
- One WSW had previously detected a site contaminant

- Demonstrate through modeling that future wells will not draw the plume off-property, or
- Request permission to restrict groundwater use on adjacent properties

Source Property Institutional Controls

- DPLUR
  - PROPERTY: industrial or commercial use
  - GROUNDWATER: use prohibited
  - SOIL: no removal from the property
  - SOIL & VAPOR: Area A (building footprint) restriction – no digging or structural modification
  - VAPOR: no building construction within 100 ft of soil or groundwater contamination unless vapor mitigation measures are installed
  - Annual inspection report
- Notice of Residual Contamination survey plat



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Non-Source Property Institutional Controls

Notice of Residual Contamination survey plat only

- Prior permission obtained from each property owner
- 2C Rule prohibiting well installation in contaminated aquifers is referenced on the Notice in lieu of a recorded LUR document
- No annual inspection and reporting requirement for Notices

Take-Aways

- Use site data to demonstrate understanding of where contamination is and where it could be going in the future
- Include soil contamination and potential vapor issues in the risk evaluation
- Consider future risks to adjacent uncontaminated properties
- Cleanup levels do not need to be calculated if remaining contaminant concentrations at the site pose no unacceptable risk

Risk Assessment Training Topics of Discussion

I. Regulatory Framework

II. Risk Assessment 101

III. NC-Specific Risk Assessment Procedures

IV. Groundwater Only Site Closure Examples

V. Introduction to the Risk Calculator

VI. Risk Calculator Site Closure Example

VII. Wrap-up & Questions

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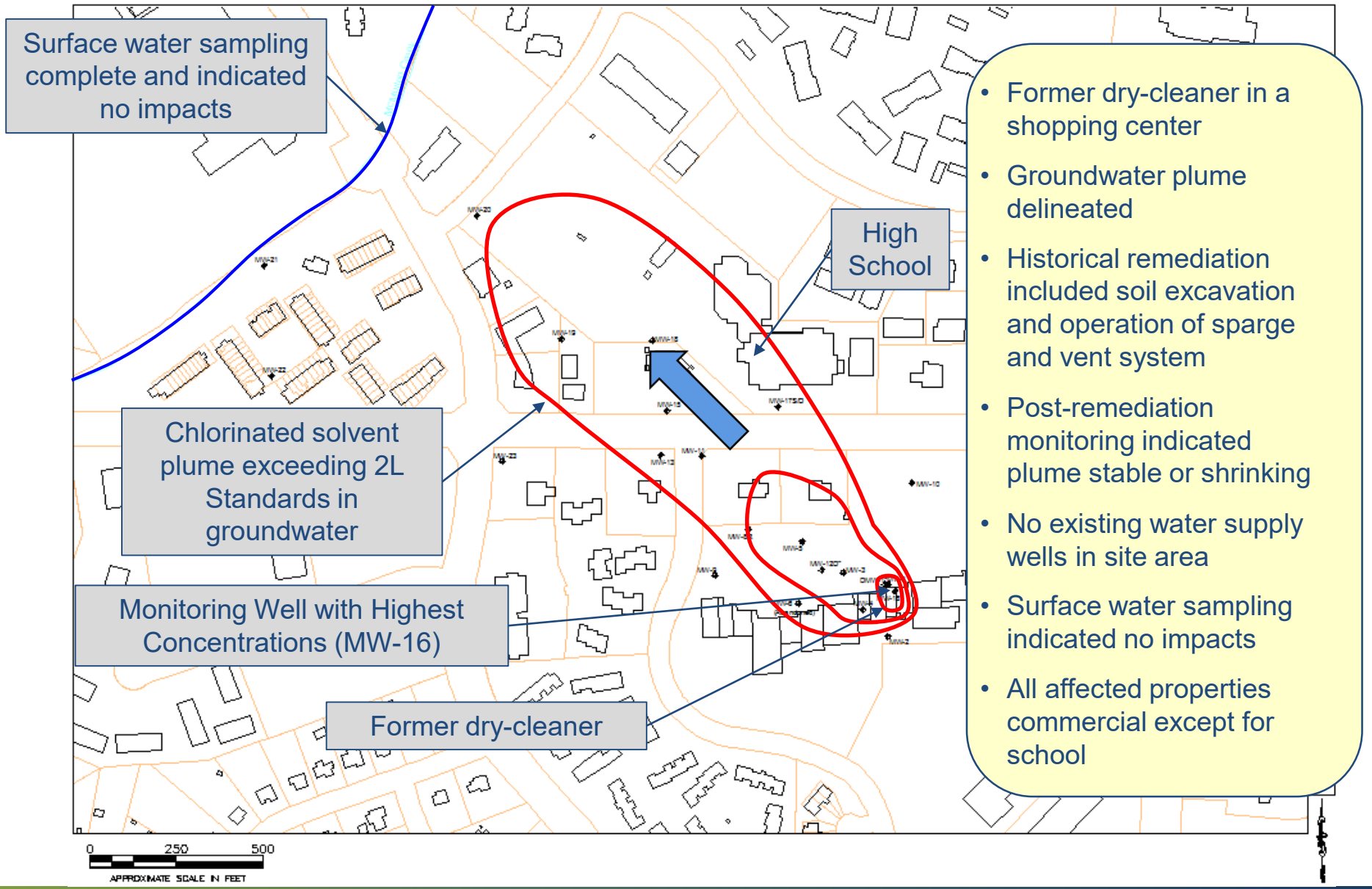
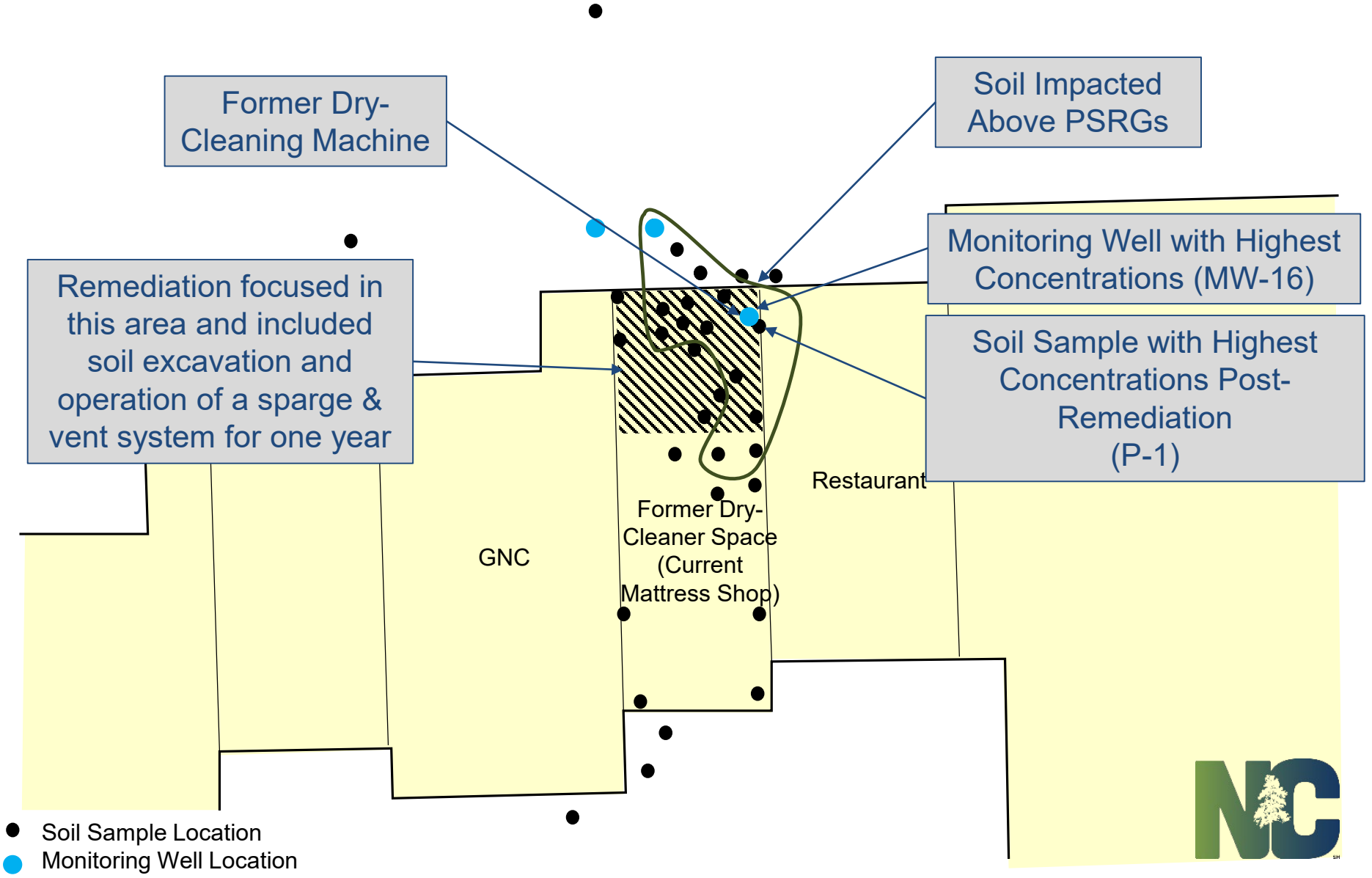
Site Closure Example –Background & Groundwater Data



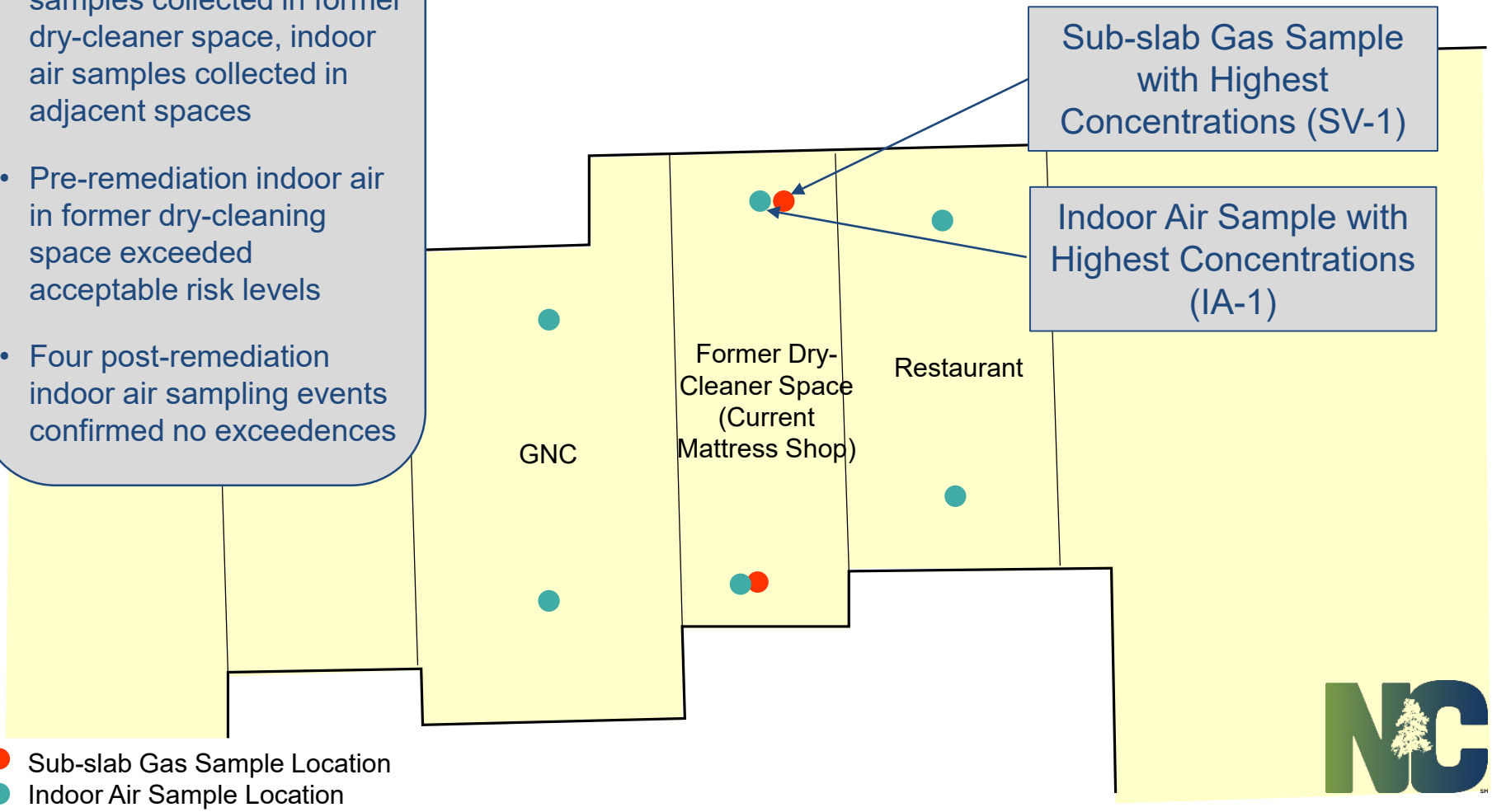
- Former dry-cleaner in a shopping center
- Groundwater plume delineated
- Historical remediation included soil excavation and operation of sparge and vent system
- Post-remediation monitoring indicated plume stable or shrinking
- No existing water supply wells in site area
- Surface water sampling indicated no impacts
- All affected properties commercial except for school

Risk Calculator Site Closure Example – Soil Data

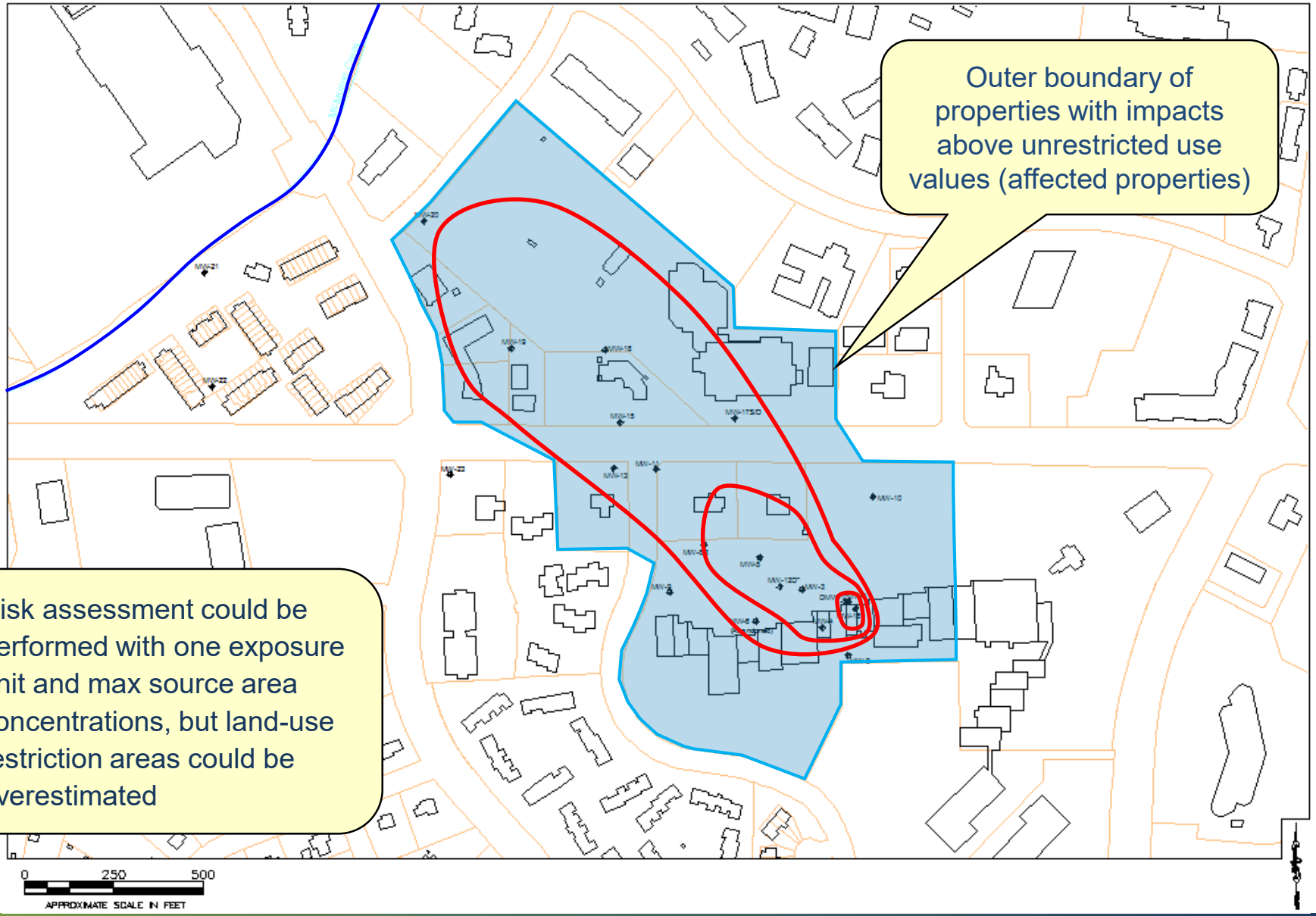


Risk Calculator Site Closure Example – Vapor Intrusion Data

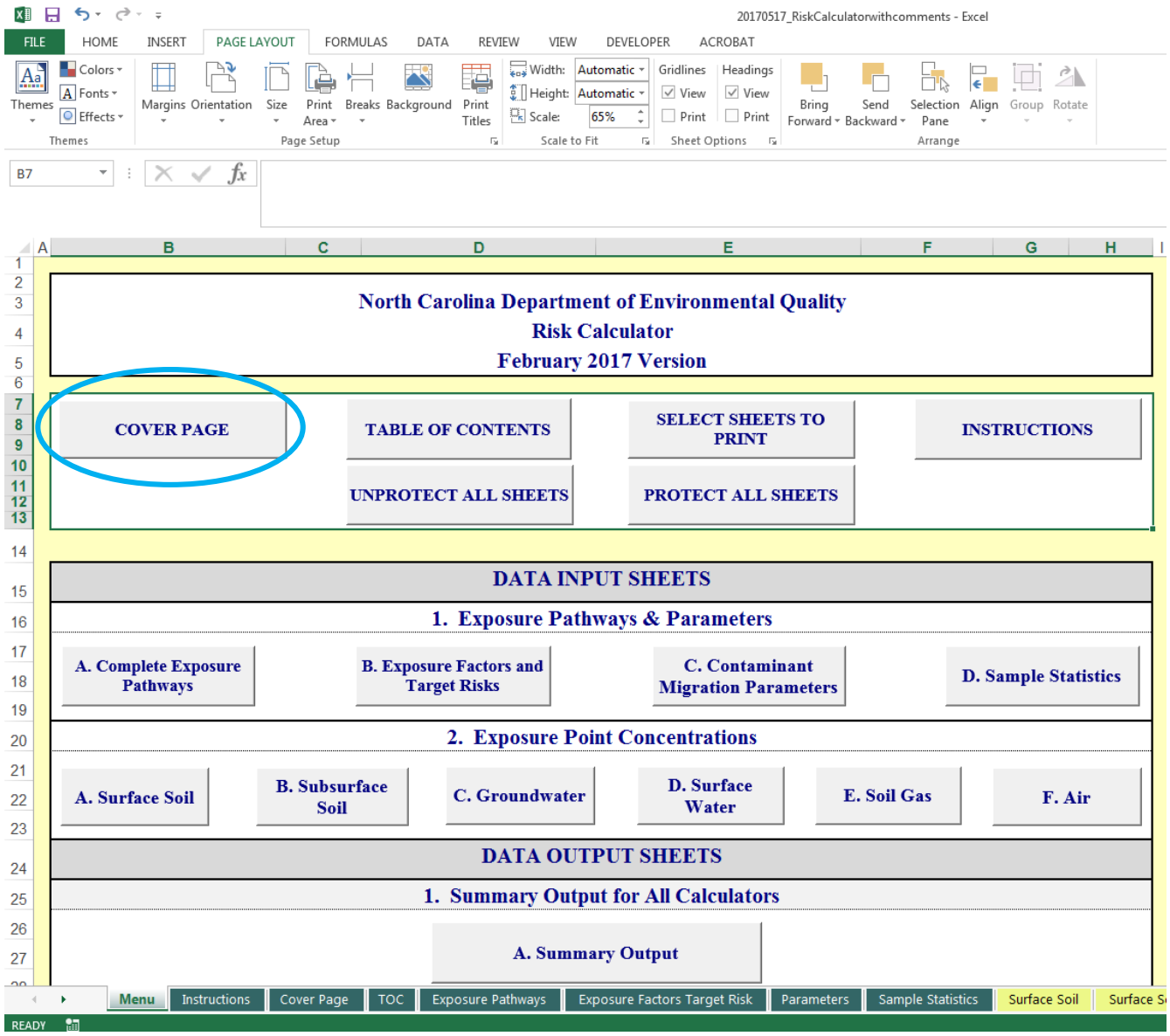
- Sub-slab gas and indoor air samples collected in former dry-cleaner space, indoor air samples collected in adjacent spaces
- Pre-remediation indoor air in former dry-cleaning space exceeded acceptable risk levels
- Four post-remediation indoor air sampling events confirmed no exceedences



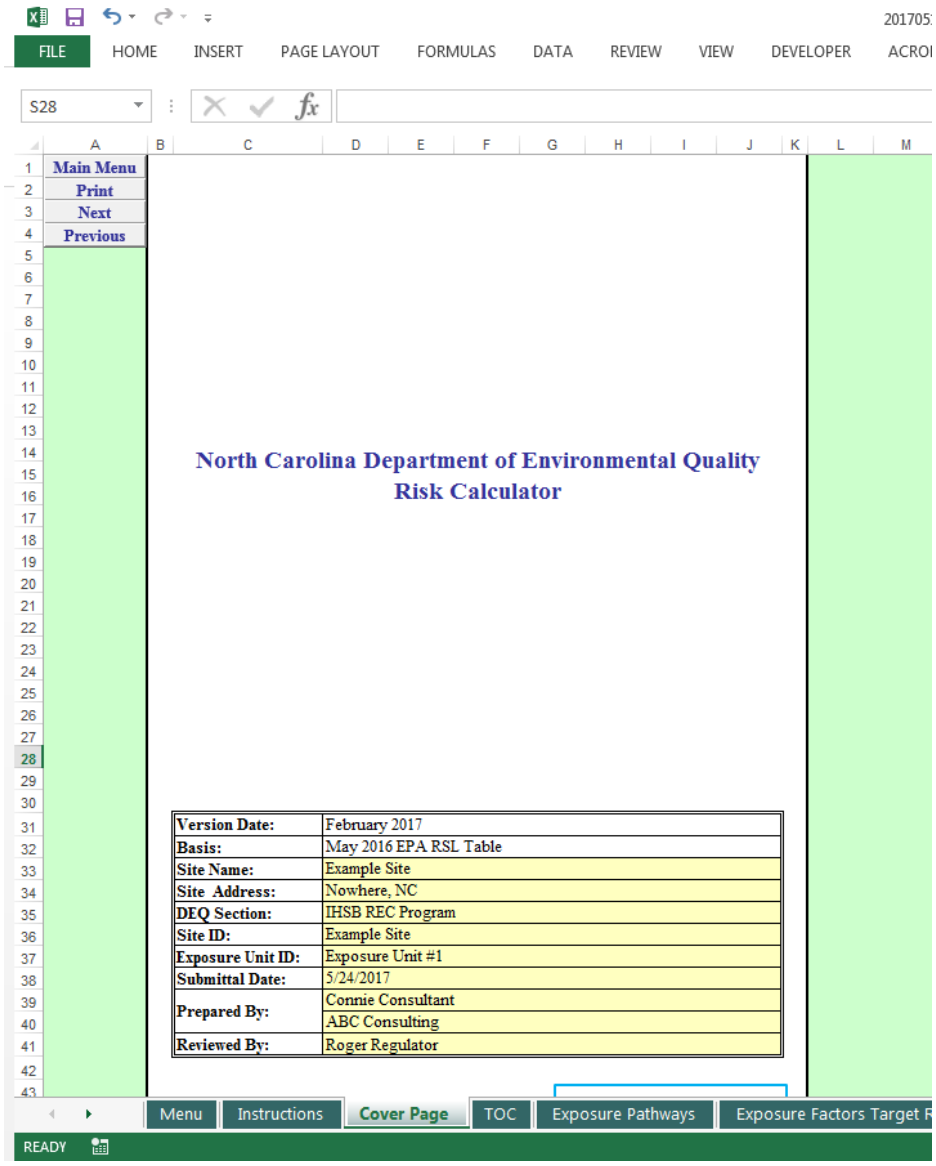
Defining Exposure Units (EUs)



EU#1 Calculator Inputs

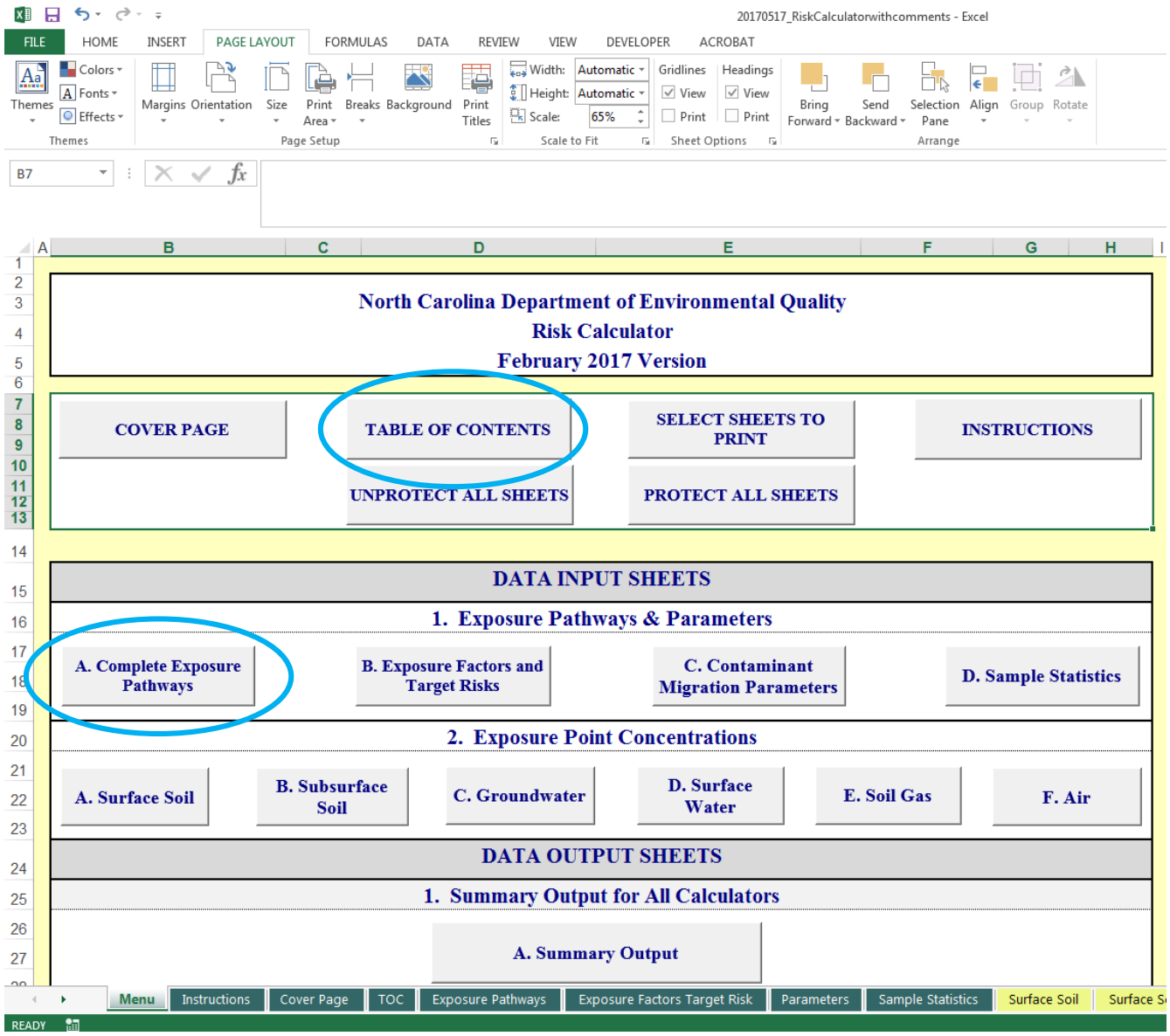


EU#1 Cover Page



- Enter site information and "Exposure Unit #1"

EU#1 Calculator Inputs



- Table of contents can be completed but is not required or linked to other calculator inputs

EU#1 – Soil Combined Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	✓
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
Non-Residential Worker	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

- Soil combined pathways complete since impacted soil is present
- Current receptor is non-residential worker
- Future receptors are resident and construction worker
- User-defined receptor evaluation not typically required

EU#1 – Groundwater Combined Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	✓
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
Non-Residential Worker	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

- A groundwater use control will be implemented for all impacted properties, so evaluation of groundwater combined pathways using calculator not required
- See “Contaminant Migration Pathways” section for evaluation of future impacts downgradient of current plume extent

EU#1 – Surface Water Combined Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	✓
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
Non-Residential Worker	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

- Surface water sampling completed and indicate no impacts, so evaluation of surface water combined pathways using calculator not required
- See “Contaminant Migration Pathways” section for evaluation of future impacts downgradient of current plume extent

EU#1 – Vapor Intrusion Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	✓
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	✓
	Indoor Air	✓
Non-Residential Worker	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	✓
	Indoor Air	✓
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

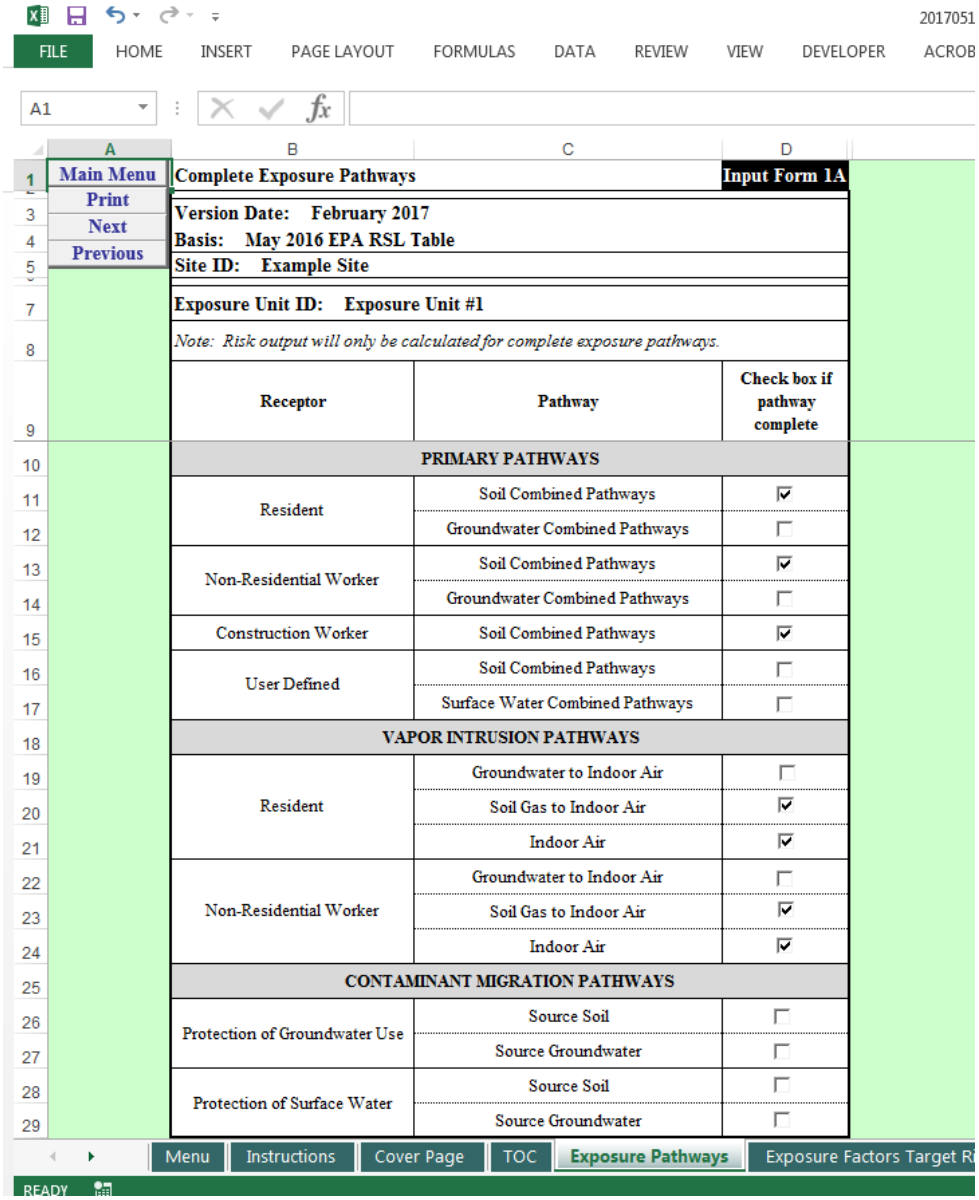
- Indoor air data is “most representative” of current conditions and therefore used for current risk evaluation
- Indoor air data cannot be used for future risk evaluation due to potential for changes in building construction, so sub-slab gas data used

EU#1 – Contaminant Migration Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	✓
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	✓
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	✓
	Indoor Air	✓
Non-Residential Worker	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	✓
	Indoor Air	✓
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

Contaminant migration pathways to be reviewed after cumulative risk pathways

EU#1 Complete Exposure Pathways



Main Menu	Complete Exposure Pathways	Input Form 1A
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Version Date: February 2017
Basis: May 2016 EPA RSL Table
Site ID: Example Site

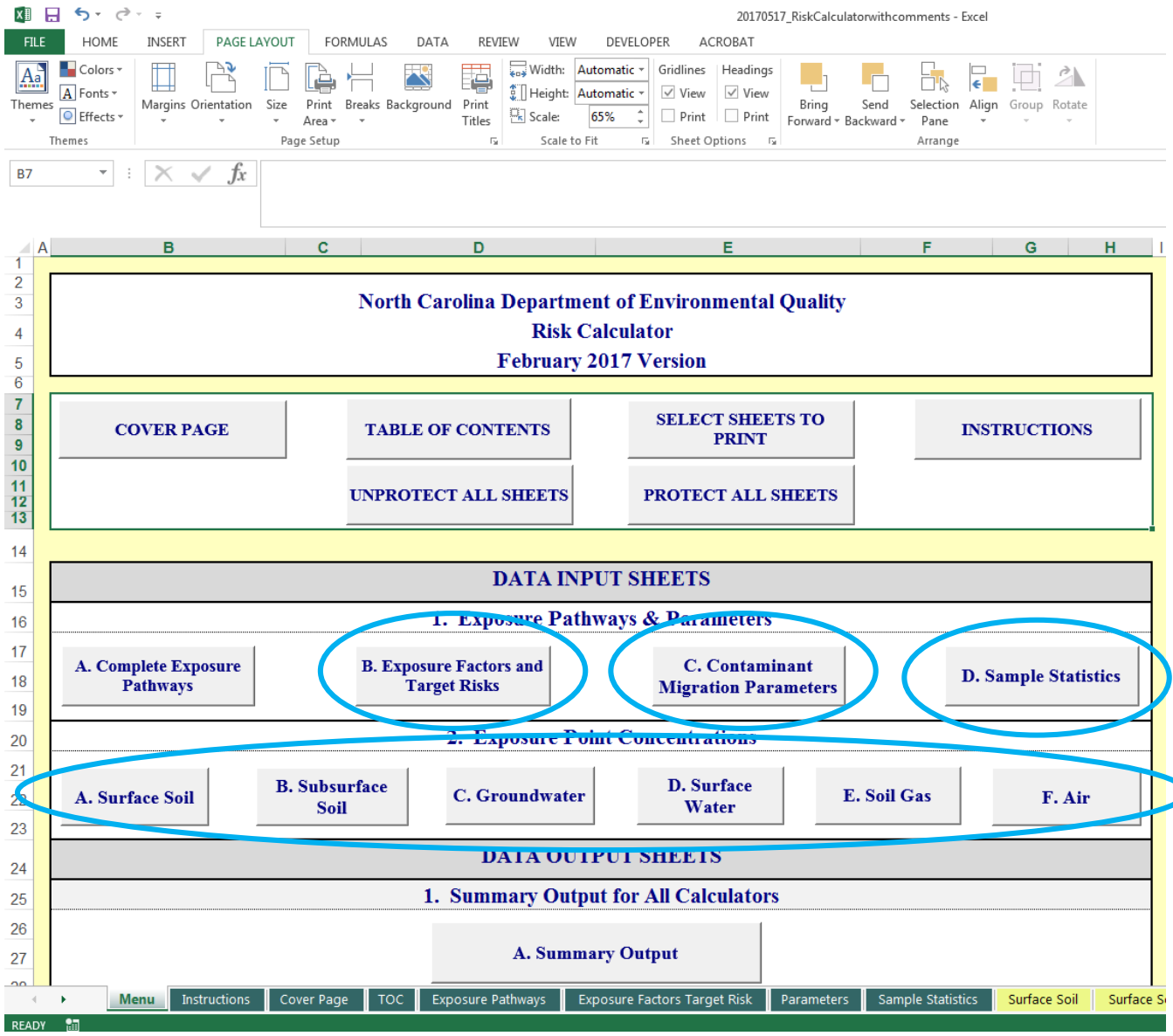
Exposure Unit ID: Exposure Unit #1

Note: Risk output will only be calculated for complete exposure pathways.

Receptor	Pathway	Check box if pathway complete
PRIMARY PATHWAYS		
Resident	Soil Combined Pathways	☑
	Groundwater Combined Pathways	☐
Non-Residential Worker	Soil Combined Pathways	☑
	Groundwater Combined Pathways	☐
Construction Worker	Soil Combined Pathways	☑
User Defined	Soil Combined Pathways	☐
	Surface Water Combined Pathways	☐
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	☐
	Soil Gas to Indoor Air	☑
	Indoor Air	☑
Non-Residential Worker	Groundwater to Indoor Air	☐
	Soil Gas to Indoor Air	☑
	Indoor Air	☑
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	☐
	Source Groundwater	☐
Protection of Surface Water	Source Soil	☐
	Source Groundwater	☐

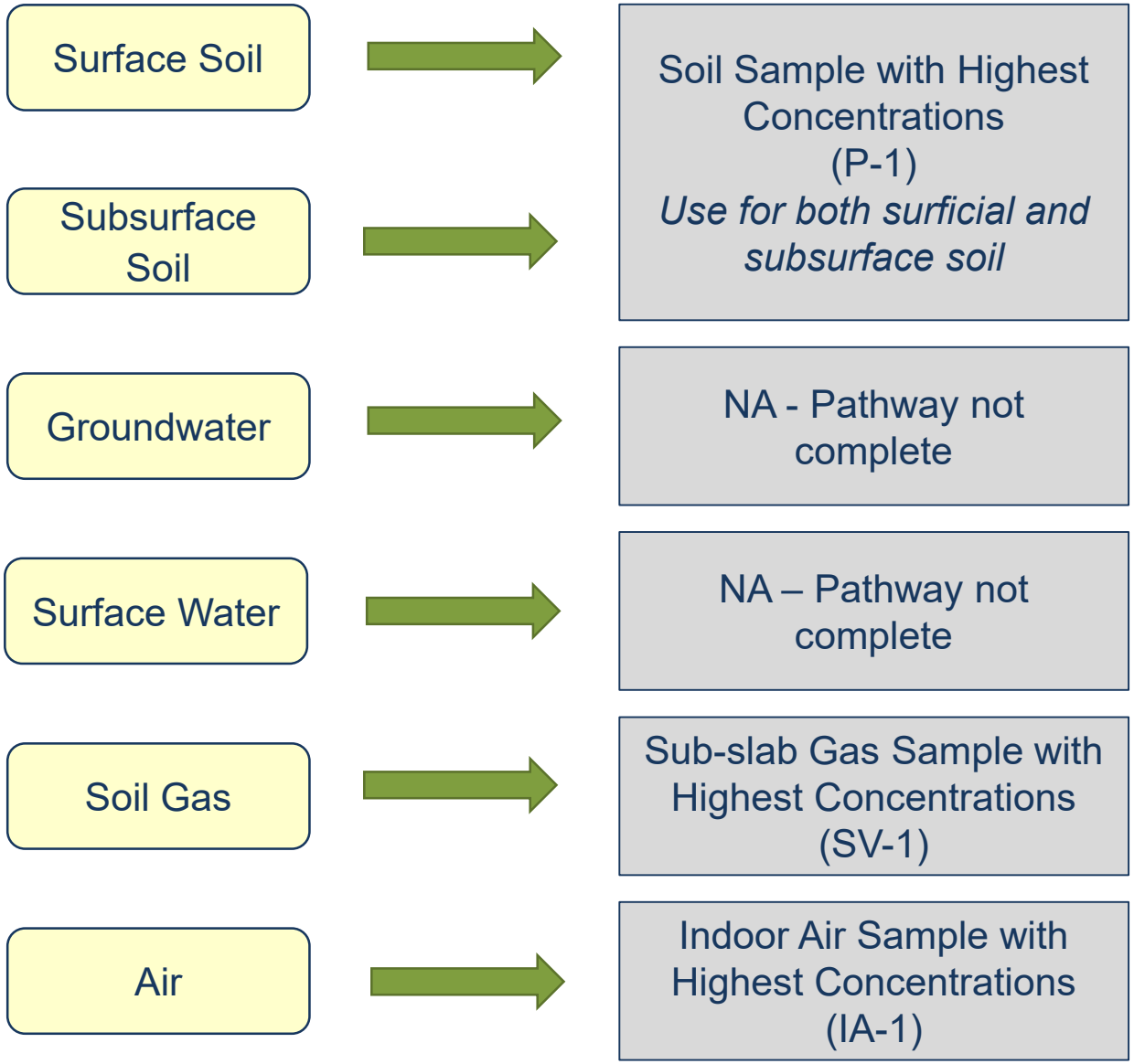
- Check boxes in the calculator for the pathways to be evaluated

EU#1 Calculator Inputs

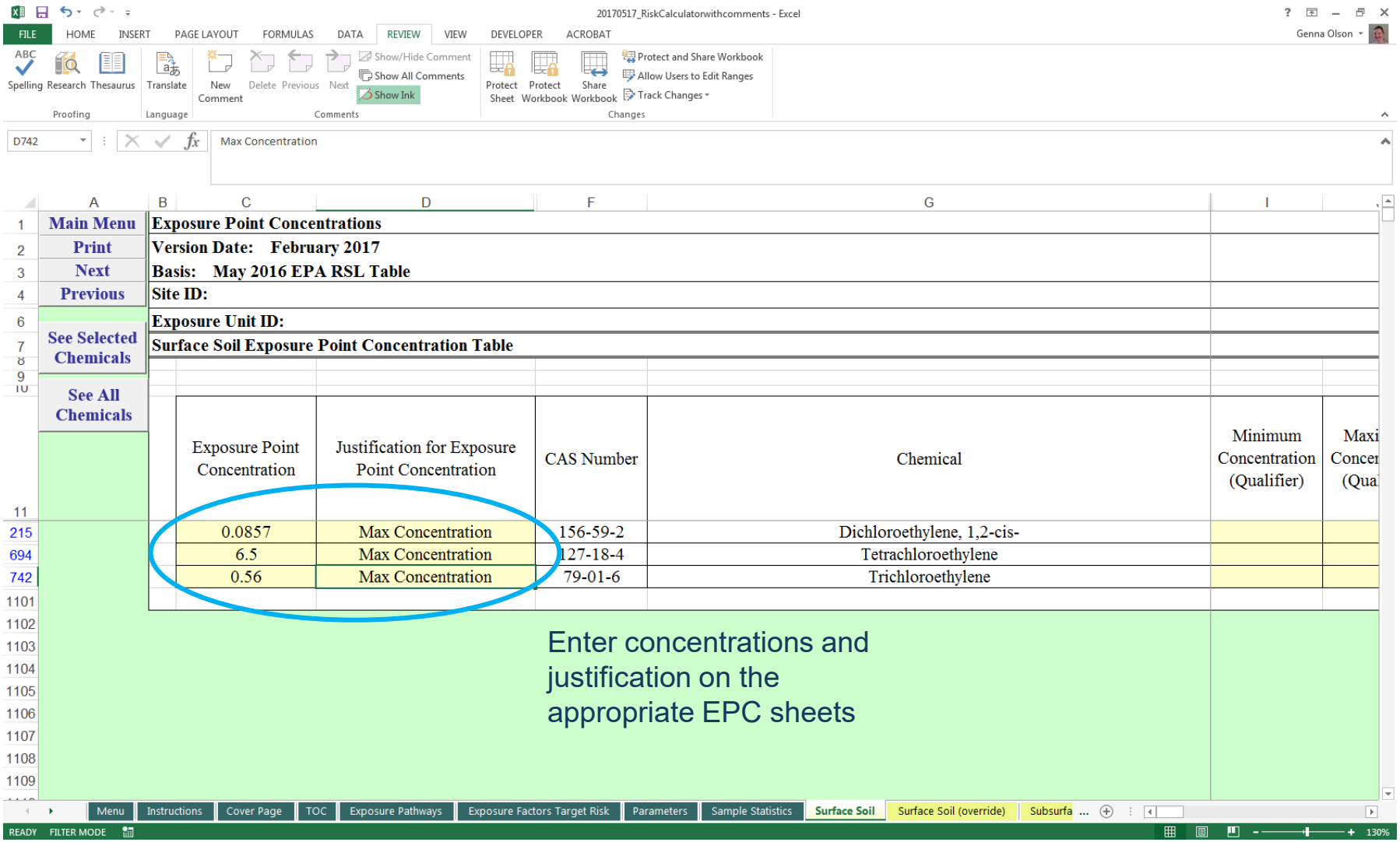


- No data entry needed on Exposure Factors and Target Risks tab
- Enter site-specific info where available under Contaminant Migration Parameters tab
- No data entry needed on Sample Statistics tab

EU#1 Exposure Point Concentrations



Example Exposure Point Concentration Table



20170517_RiskCalculatorwithcomments - Excel

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Exposure Point Concentrations

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID:

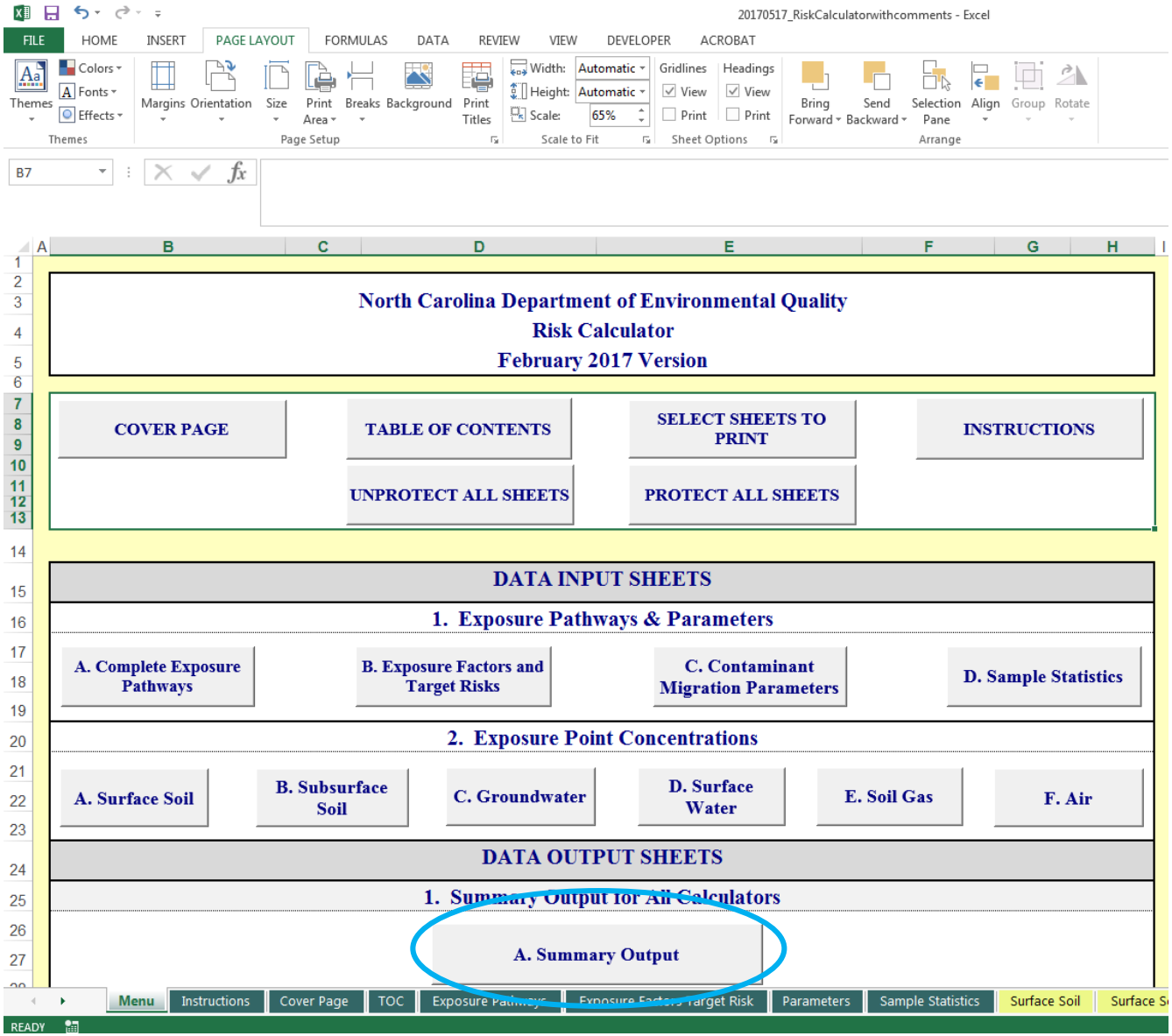
Exposure Unit ID:

Surface Soil Exposure Point Concentration Table

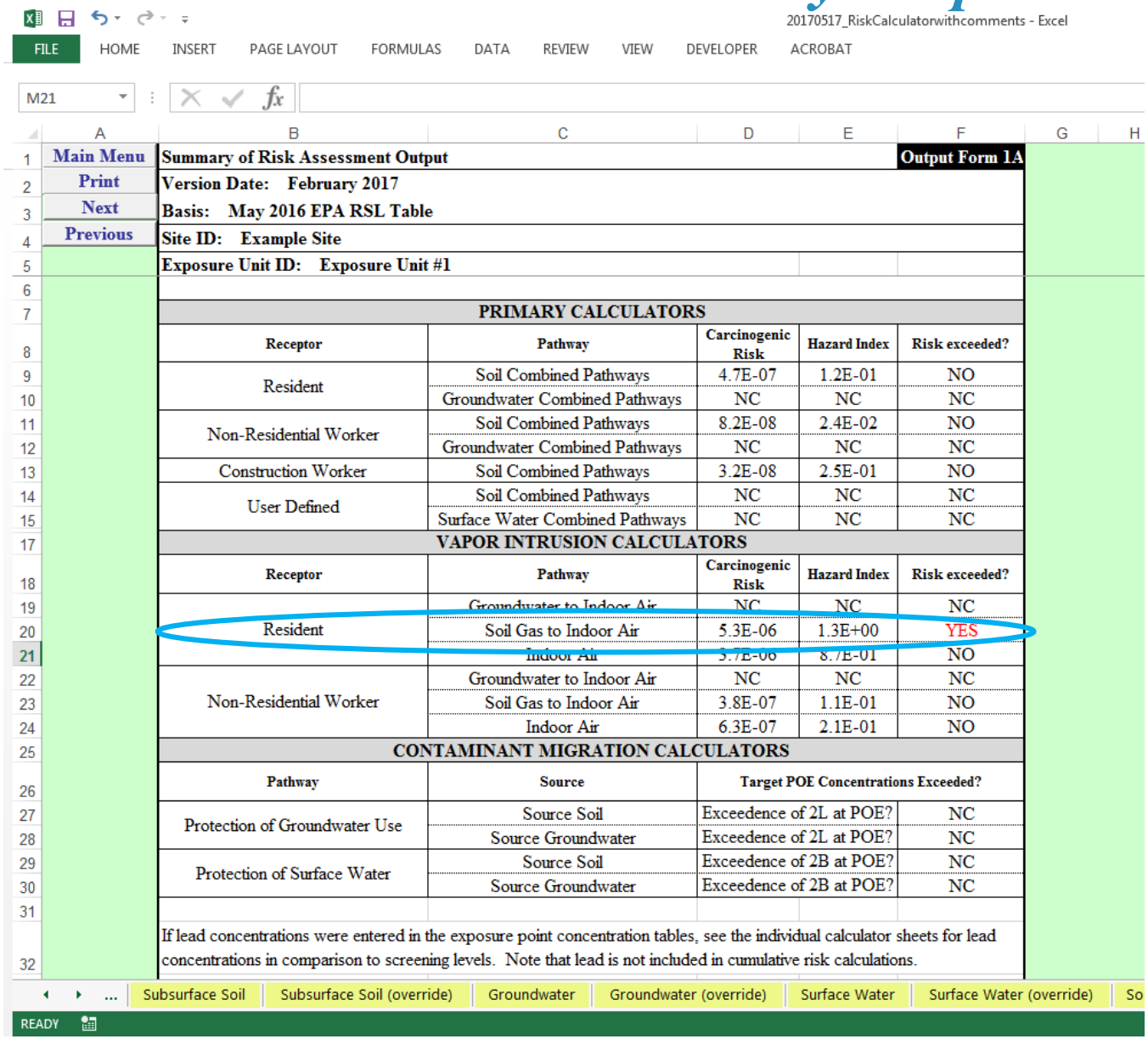
Exposure Point Concentration	Justification for Exposure Point Concentration	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maxi Concer (Qua
0.0857	Max Concentration	156-59-2	Dichloroethylene, 1,2-cis-		
6.5	Max Concentration	127-18-4	Tetrachloroethylene		
0.56	Max Concentration	79-01-6	Trichloroethylene		

Enter concentrations and justification on the appropriate EPC sheets

EU#1 Calculator Outputs



EU#1 Summary Output Sheet



20170517_RiskCalculatorwithcomments - Excel

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Summary of Risk Assessment Output — **Output Form 1A**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Exposure Unit ID: Exposure Unit #1

PRIMARY CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Soil Combined Pathways	4.7E-07	1.2E-01	NO
	Groundwater Combined Pathways	NC	NC	NC
Non-Residential Worker	Soil Combined Pathways	8.2E-08	2.4E-02	NO
	Groundwater Combined Pathways	NC	NC	NC
Construction Worker	Soil Combined Pathways	3.2E-08	2.5E-01	NO
User Defined	Soil Combined Pathways	NC	NC	NC
	Surface Water Combined Pathways	NC	NC	NC

VAPOR INTRUSION CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
	Groundwater to Indoor Air	NC	NC	NC
Resident	Soil Gas to Indoor Air	5.3E-06	1.3E+00	YES
	Indoor Air	3.7E-06	8.7E-01	NO
Non-Residential Worker	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	3.8E-07	1.1E-01	NO
	Indoor Air	6.3E-07	2.1E-01	NO

CONTAMINANT MIGRATION CALCULATORS

Pathway	Source	Target POE Concentrations Exceeded?	
Protection of Groundwater Use	Source Soil	Exceedence of 2L at POE?	NC
	Source Groundwater	Exceedence of 2L at POE?	NC
Protection of Surface Water	Source Soil	Exceedence of 2B at POE?	NC
	Source Groundwater	Exceedence of 2B at POE?	NC

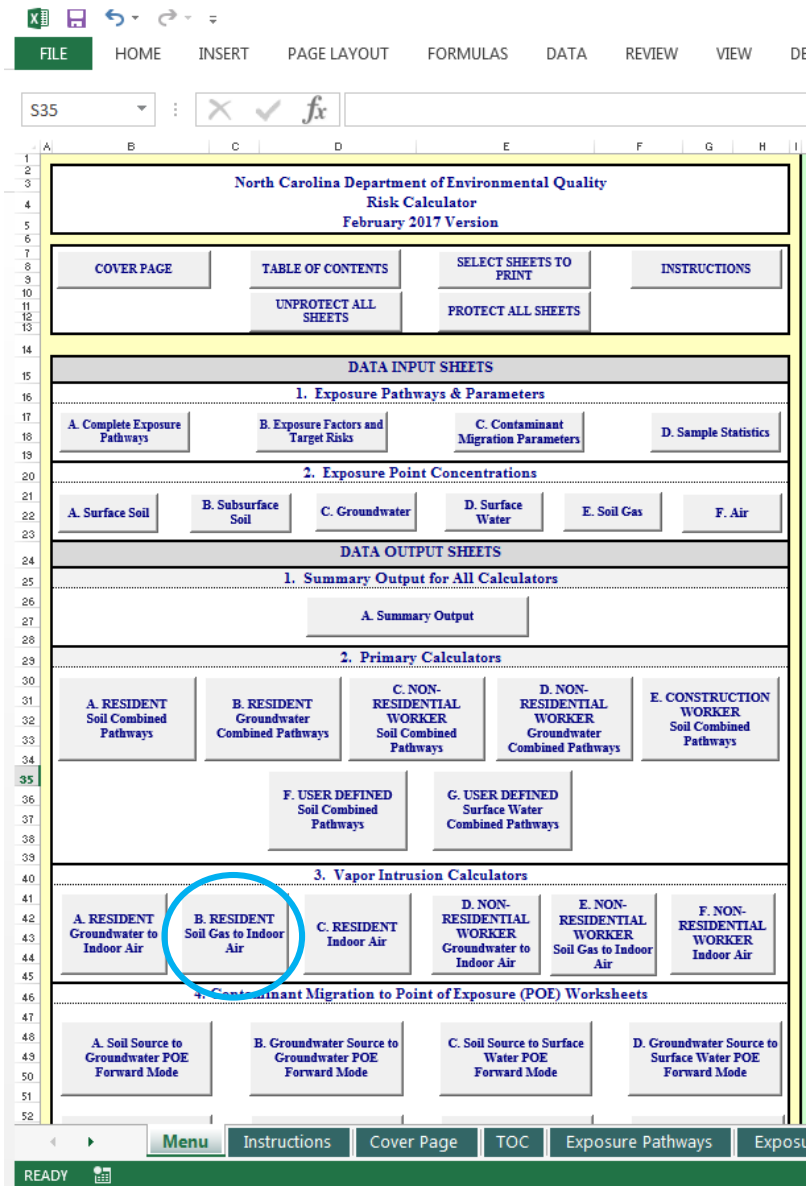
If lead concentrations were entered in the exposure point concentration tables, see the individual calculator sheets for lead concentrations in comparison to screening levels. Note that lead is not included in cumulative risk calculations.

Subsurface Soil | Subsurface Soil (override) | Groundwater | Groundwater (override) | Surface Water | Surface Water (override) | So

READY

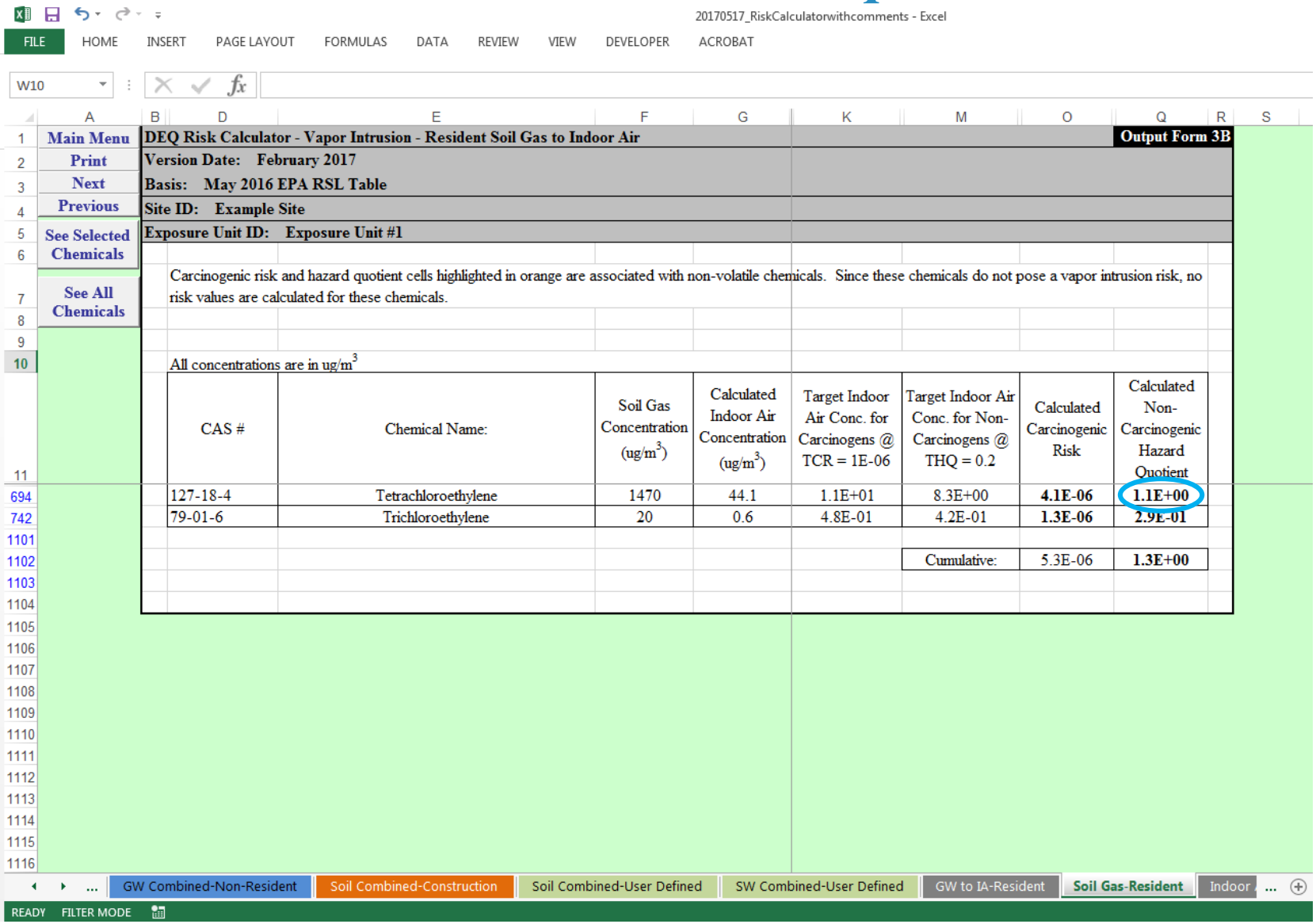
- "NC" indicates pathway not complete
- "YES" and "NO" indicates whether risk is exceeded for individual pathways

EU#1 Calculator Outputs



- Results for individual constituents can be viewed on detailed calculator outputs

EU#1 Calculator Outputs



20170517_RiskCalculatorwithcomments - Excel

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DEQ Risk Calculator - Vapor Intrusion - Resident Soil Gas to Indoor Air — **Output Form 3B**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Exposure Unit ID: Exposure Unit #1

Carcinogenic risk and hazard quotient cells highlighted in orange are associated with non-volatile chemicals. Since these chemicals do not pose a vapor intrusion risk, no risk values are calculated for these chemicals.

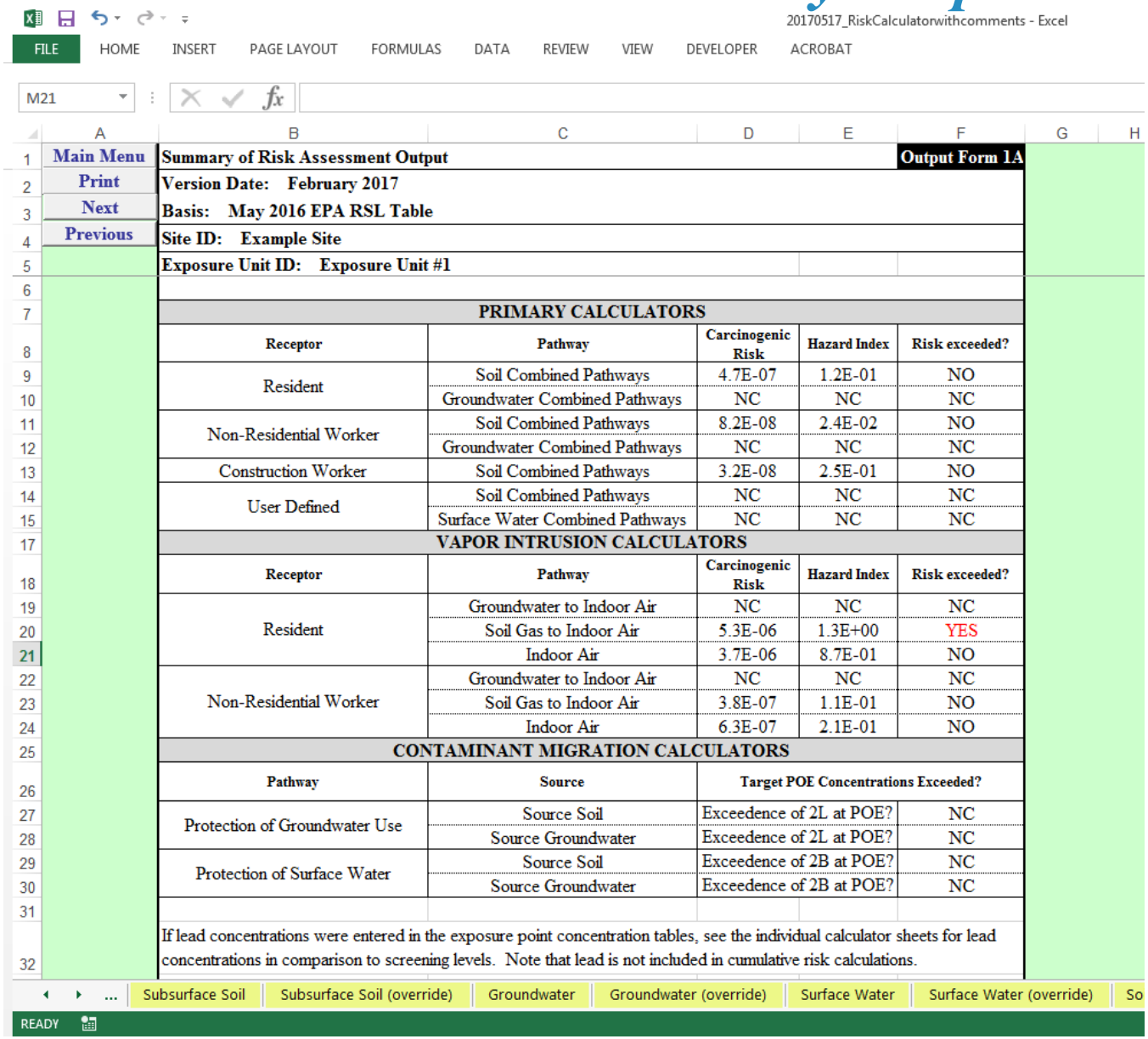
All concentrations are in ug/m^3

	CAS #	Chemical Name:	Soil Gas Concentration (ug/m^3)	Calculated Indoor Air Concentration (ug/m^3)	Target Indoor Air Conc. for Carcinogens @ TCR = 1E-06	Target Indoor Air Conc. for Non-Carcinogens @ THQ = 0.2	Calculated Carcinogenic Risk	Calculated Non-Carcinogenic Hazard Quotient
694	127-18-4	Tetrachloroethylene	1470	44.1	1.1E+01	8.3E+00	**4.1E-06**	**1.1E+00**
742	79-01-6	Trichloroethylene	20	0.6	4.8E-01	4.2E-01	**1.3E-06**	**2.9E-01**
1101								
1102						Cumulative:	5.3E-06	**1.3E+00**

GW Combined-Non-Resident | Soil Combined-Construction | Soil Combined-User Defined | SW Combined-User Defined | GW to IA-Resident | Soil Gas-Resident | Indoor ...

READY FILTER MODE

EU#1 Summary Output Sheet



20170517_RiskCalculatorwithcomments - Excel

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Summary of Risk Assessment Output — **Output Form 1A**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Exposure Unit ID: Exposure Unit #1

PRIMARY CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Soil Combined Pathways	4.7E-07	1.2E-01	NO
	Groundwater Combined Pathways	NC	NC	NC
Non-Residential Worker	Soil Combined Pathways	8.2E-08	2.4E-02	NO
	Groundwater Combined Pathways	NC	NC	NC
Construction Worker	Soil Combined Pathways	3.2E-08	2.5E-01	NO
User Defined	Soil Combined Pathways	NC	NC	NC
	Surface Water Combined Pathways	NC	NC	NC

VAPOR INTRUSION CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	5.3E-06	1.3E+00	YES
	Indoor Air	3.7E-06	8.7E-01	NO
Non-Residential Worker	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	3.8E-07	1.1E-01	NO
	Indoor Air	6.3E-07	2.1E-01	NO

CONTAMINANT MIGRATION CALCULATORS

Pathway	Source	Target POE Concentrations Exceeded?	
Protection of Groundwater Use	Source Soil	Exceedence of 2L at POE?	NC
	Source Groundwater	Exceedence of 2L at POE?	NC
Protection of Surface Water	Source Soil	Exceedence of 2B at POE?	NC
	Source Groundwater	Exceedence of 2B at POE?	NC

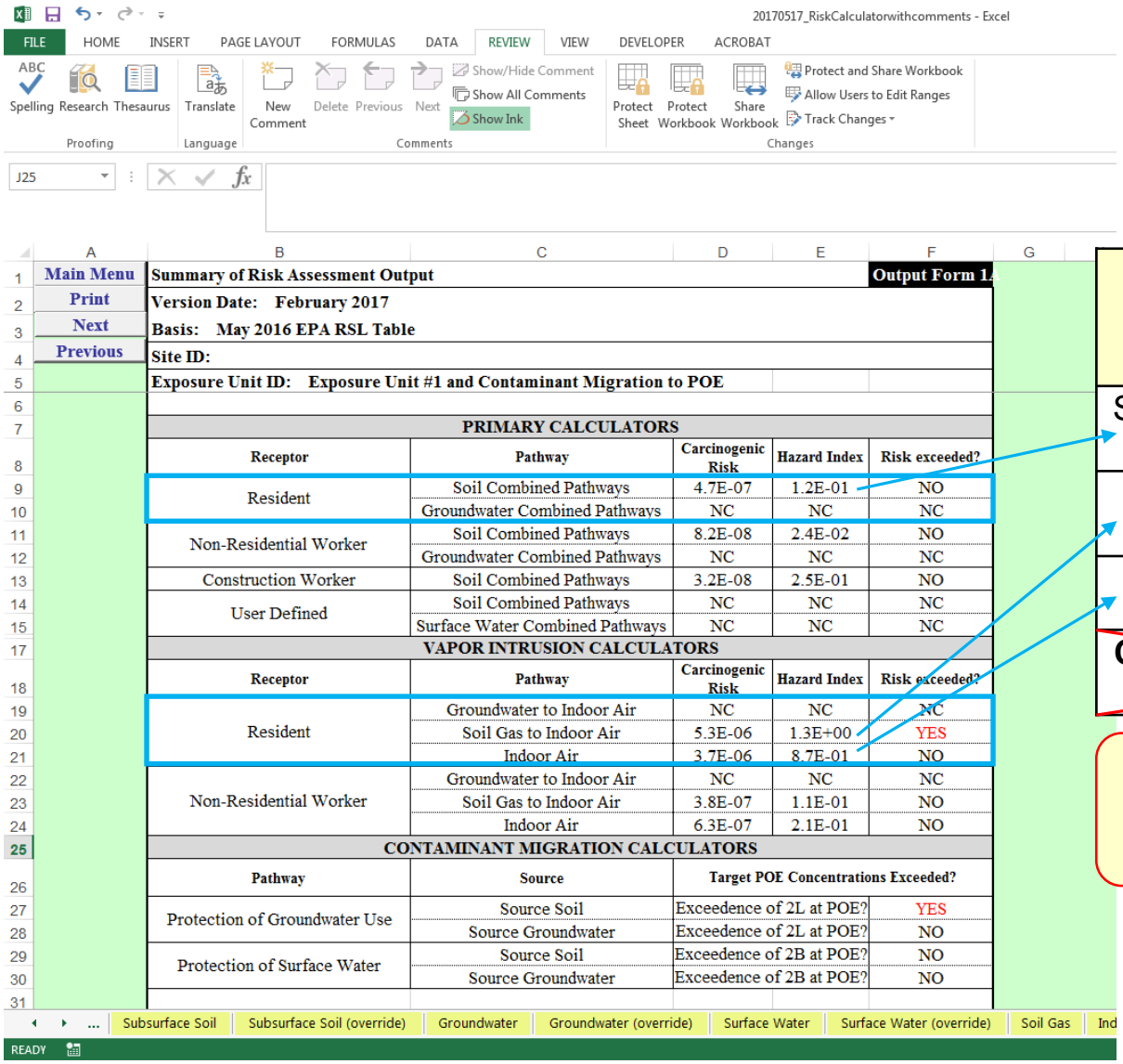
If lead concentrations were entered in the exposure point concentration tables, see the individual calculator sheets for lead concentrations in comparison to screening levels. Note that lead is not included in cumulative risk calculations.

Subsurface Soil | Subsurface Soil (override) | Groundwater | Groundwater (override) | Surface Water | Surface Water (override) | So

READY

- "NC" indicates pathway not complete
- "YES" and "NO" indicates whether risk is exceeded for individual pathways
- Risk calculator does not add up cumulative risk values if more than one pathway is complete
- Risk assessor must do those calculations separately

EU#1 Summary Output Sheet



Pathway	Carcino-genic Risk	Hazard Index
Soil Combined Pathways	4.7E-07	1.2E-01
Soil Gas to Indoor Air	5.3E-06	1.3E+00
Indoor Air	3.7E-06	8.7E-01
~~**CUMULATIVE RISK**~~	~~**9.5E-06**~~	~~**2.3E+00**~~

Wrong – adding all together would double count vapor intrusion risk.

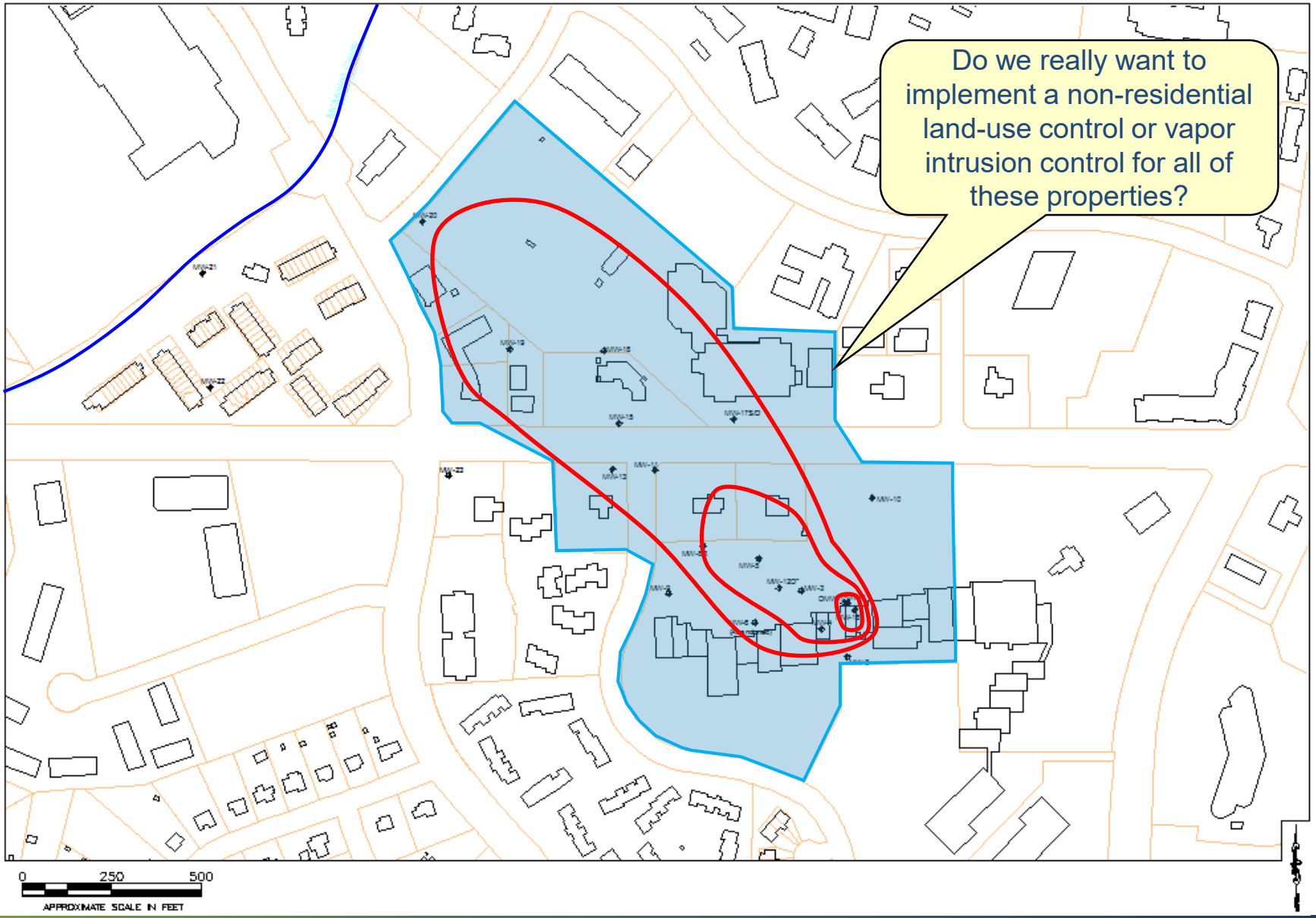
EU#1 Cumulative Risk Addition

Current Scenario		
Pathway	Carcino-genic Risk	Hazard Index
Soil Combined Pathways	4.7E-07	1.2E-01
Soil Gas to Indoor Air		
Indoor Air	3.7E-06	8.7E-01
CUMULATIVE RISK	**4.2E-06**	**9.9E-01**
ACCEPTABLE LIMITS	**1.0E-04**	**1.0E00**
RISK EXCEEDED	**NO**	**NO**

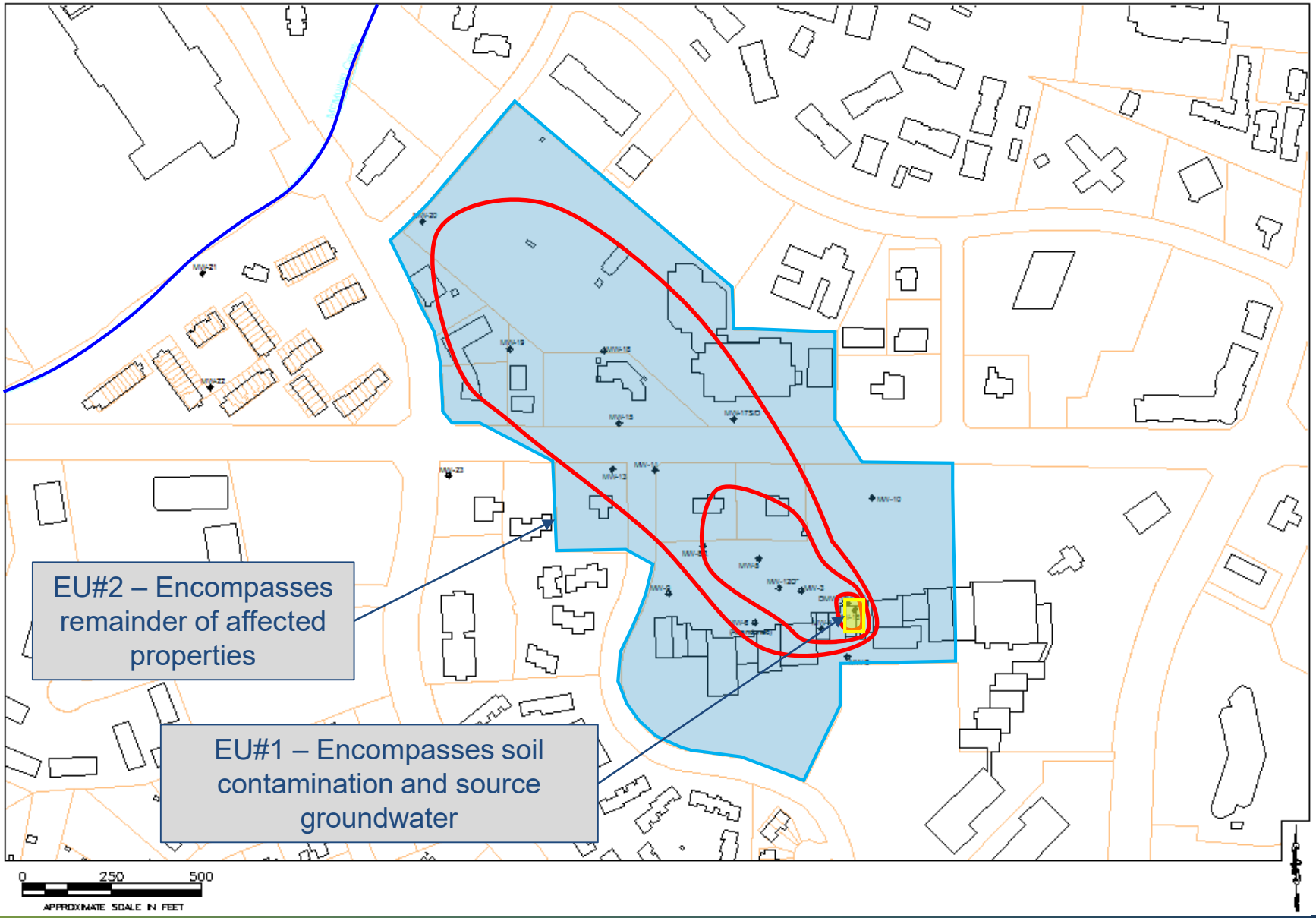
Future Scenario		
Pathway	Carcino-genic Risk	Hazard Index
Soil Combined Pathways	4.7E-07	1.2E-01
Soil Gas to Indoor Air	5.3E-06	1.3E+00
Indoor Air		
CUMULATIVE RISK	**5.8E-06**	**1.4E+00**
ACCEPTABLE LIMITS	**1.0E-04**	**1.0E00**
RISK EXCEEDED	**NO**	**YES**

Soil gas emissions to indoor air if the building construction changes in the future or the land-use changes is the risk driver. This could be addressed with a non-residential land-use control or a vapor intrusion control.

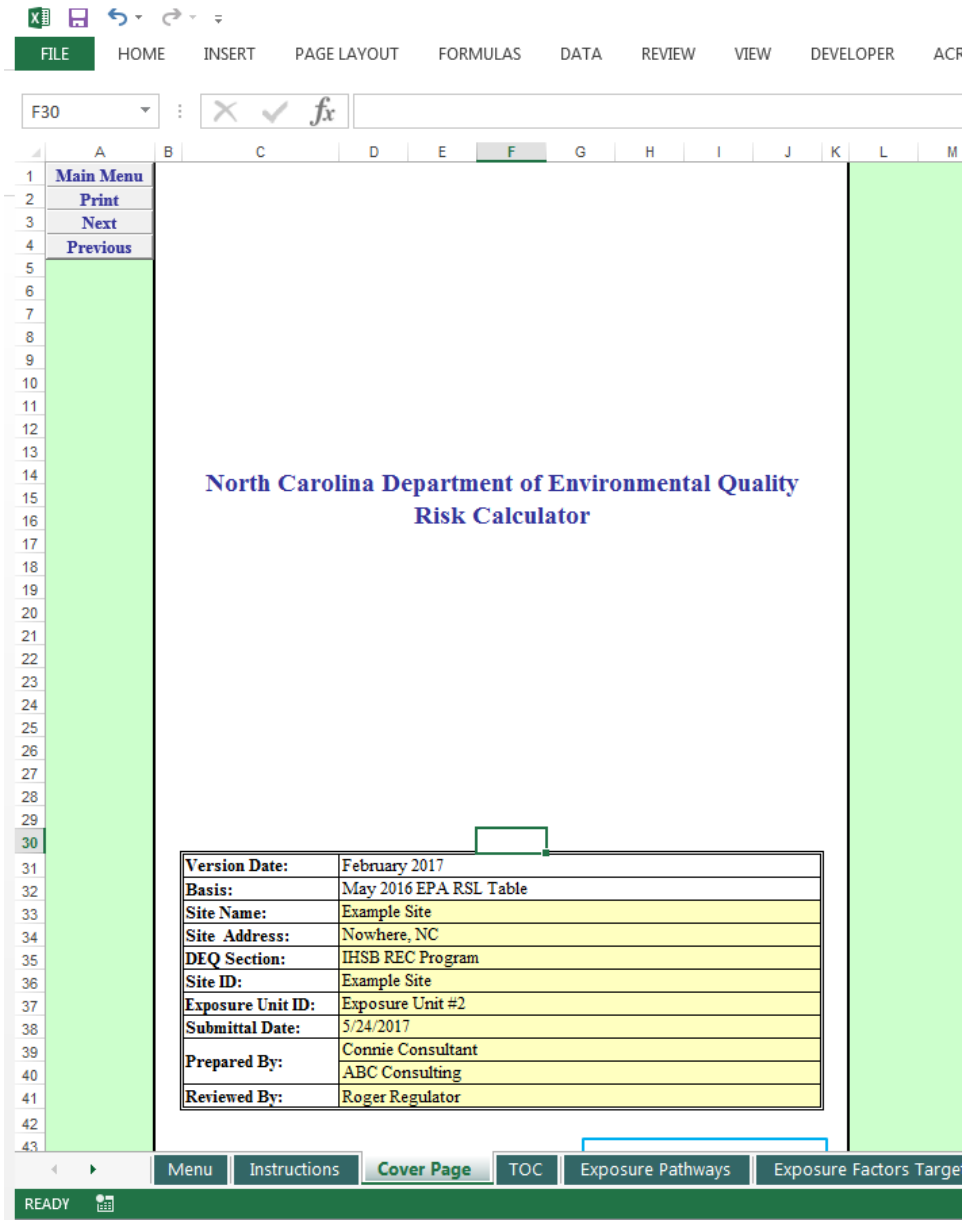
EU#1 Risk Management



Revisions to Exposure Units



EU#2 Cover Page



- Resave calculator file and change exposure unit id to “Exposure Unit #2”

EU#2 Exposure Pathways

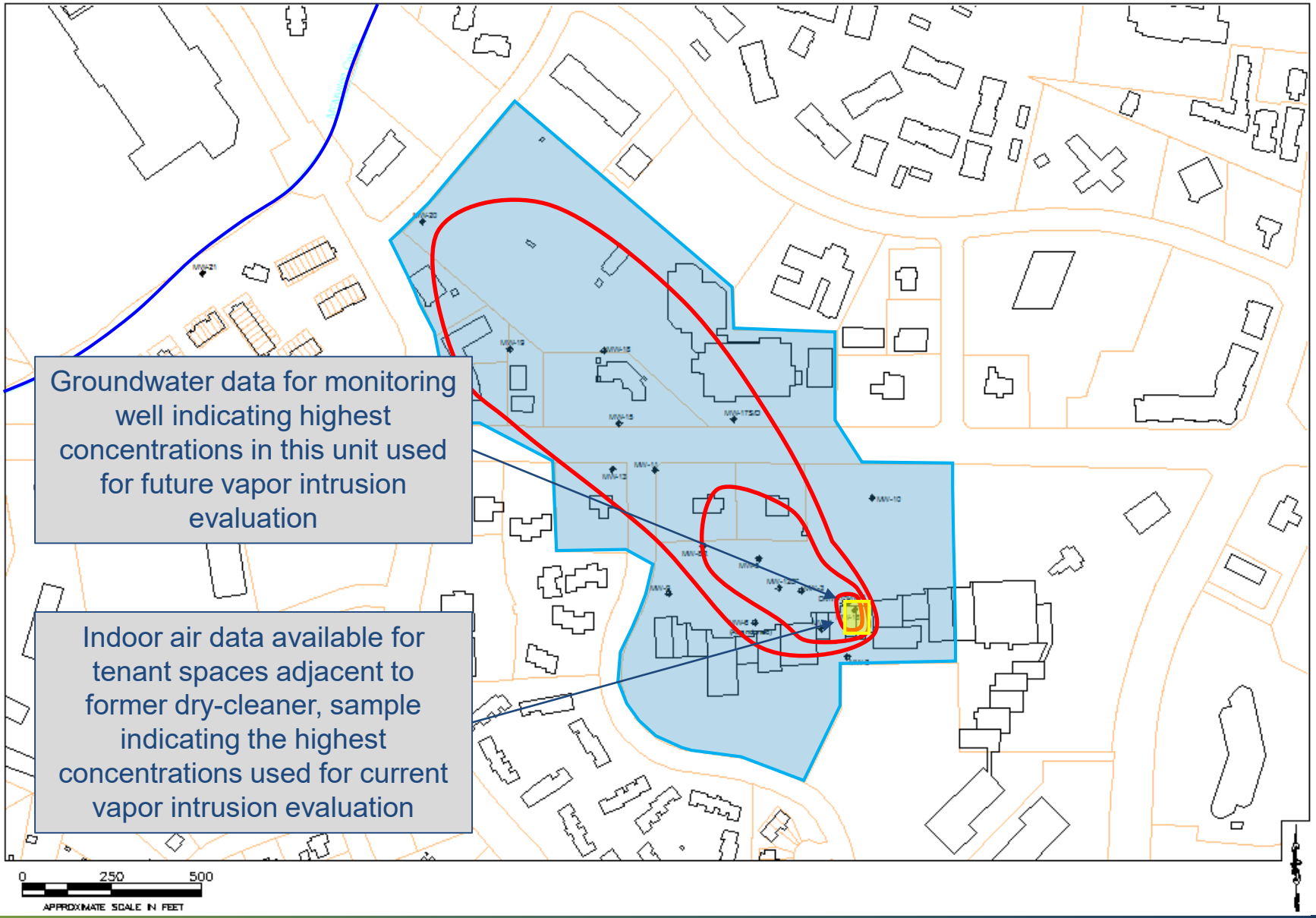
PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
Non-Residential Worker	Groundwater to Indoor Air	
	Soil Gas to Indoor Air	
	Indoor Air	
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

- No impacted soil in this unit so soil combined pathways incomplete
- Groundwater use control will be implemented to groundwater combined pathways incomplete
- No surface water impacts detected so surface water combined pathways incomplete

Only complete pathways are associated with vapor intrusion

Contaminant migration pathways to be reviewed after cumulative risk pathways

EU#2 Exposure Point Concentrations

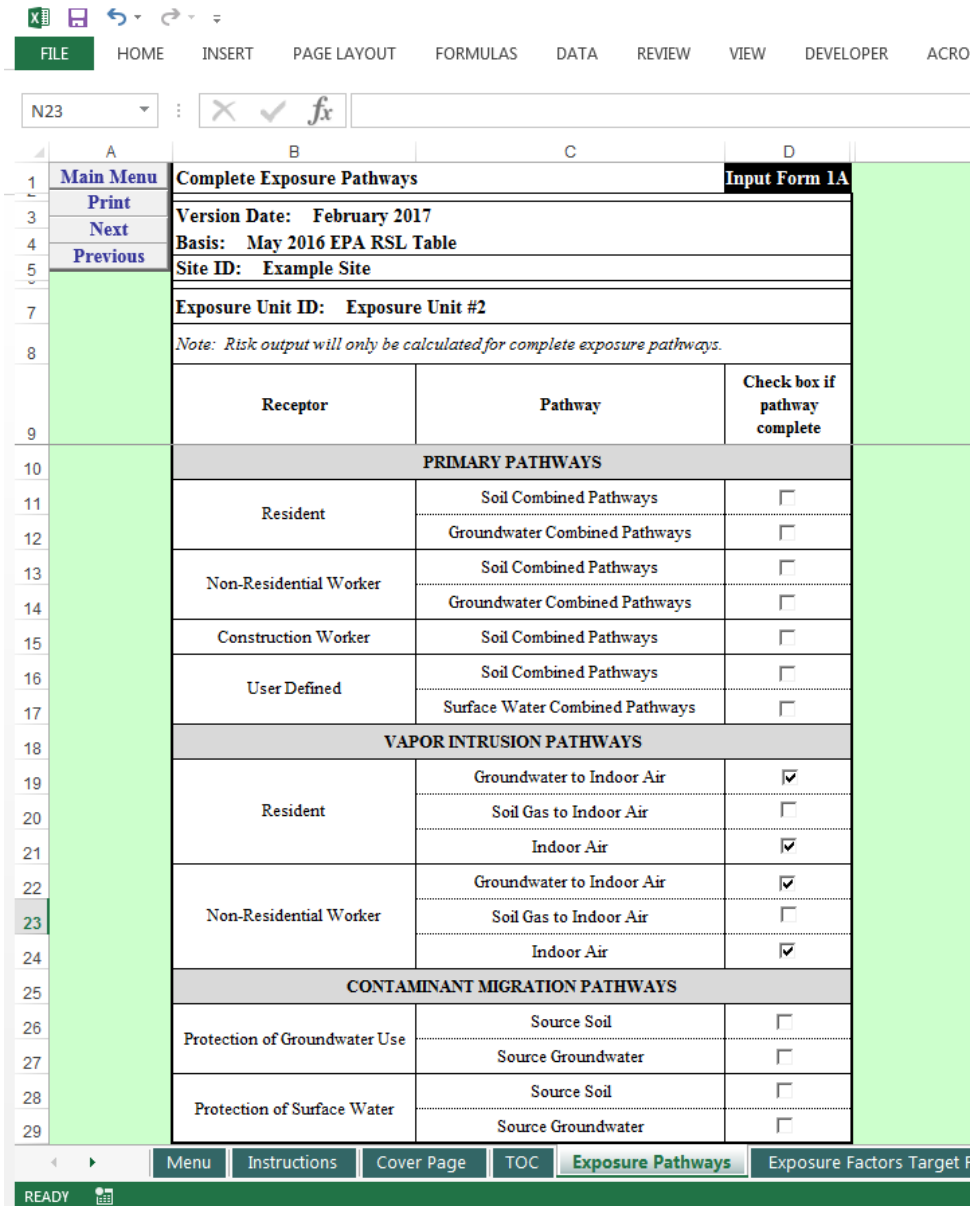


EU#2 Exposure Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	✓
	Soil Gas to Indoor Air	
	Indoor Air	✓
Non-Residential Worker	Groundwater to Indoor Air	✓
	Soil Gas to Indoor Air	
	Indoor Air	✓
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

- Indoor air data used for current vapor intrusion evaluation
- Groundwater data used for future vapor intrusion evaluation

EU#2 Exposure Pathways



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Complete Exposure Pathways — **Input Form 1A**

Version Date: February 2017
Basis: May 2016 EPA RSL Table
Site ID: Example Site

Exposure Unit ID: Exposure Unit #2

Note: Risk output will only be calculated for complete exposure pathways.

Receptor	Pathway	Check box if pathway complete
PRIMARY PATHWAYS		
Resident	Soil Combined Pathways	☐
	Groundwater Combined Pathways	☐
Non-Residential Worker	Soil Combined Pathways	☐
	Groundwater Combined Pathways	☐
Construction Worker	Soil Combined Pathways	☐
User Defined	Soil Combined Pathways	☐
	Surface Water Combined Pathways	☐
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	☑
	Soil Gas to Indoor Air	☐
	Indoor Air	☑
Non-Residential Worker	Groundwater to Indoor Air	☑
	Soil Gas to Indoor Air	☐
	Indoor Air	☑
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	☐
	Source Groundwater	☐
Protection of Surface Water	Source Soil	☐
	Source Groundwater	☐

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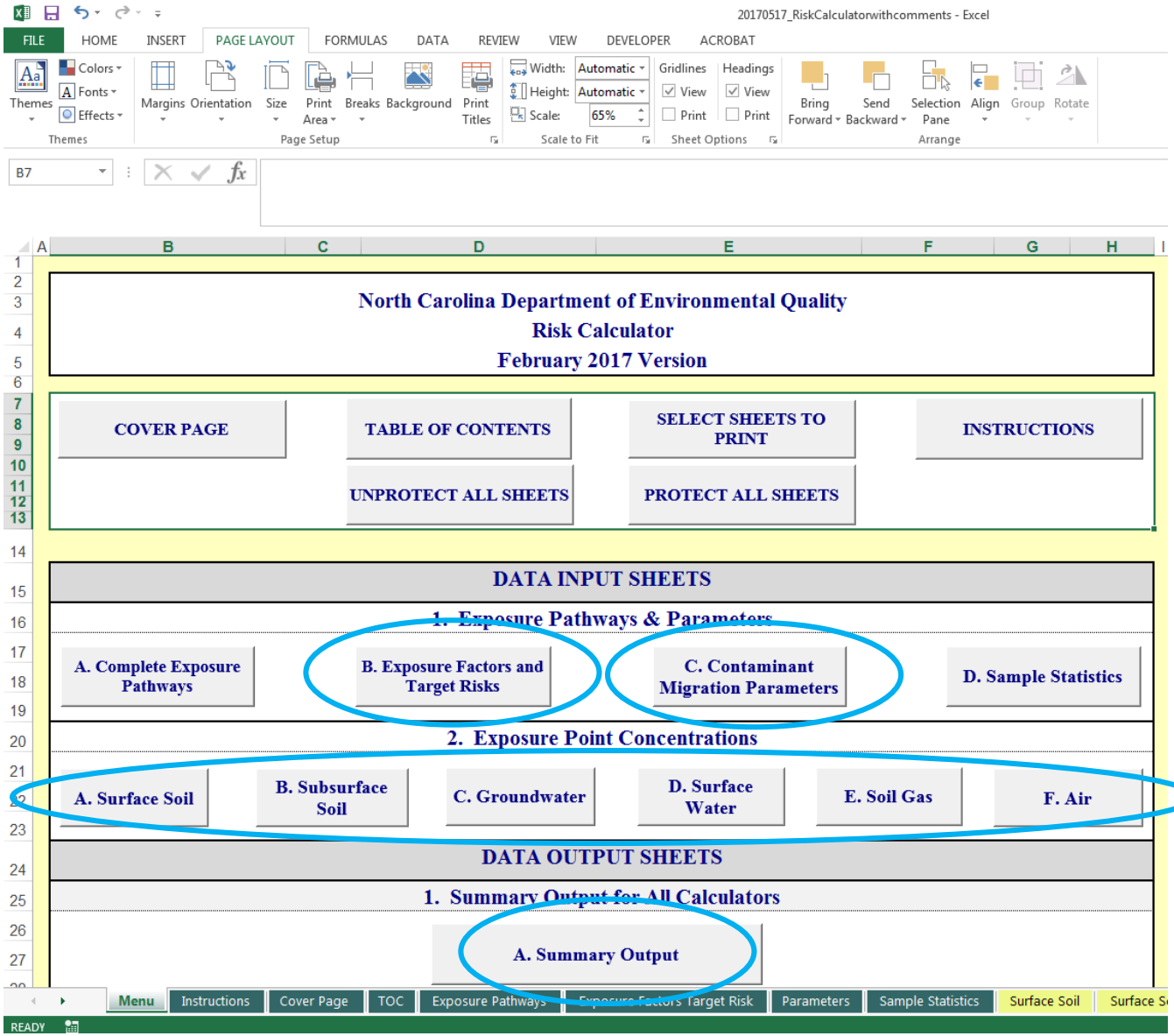
READY

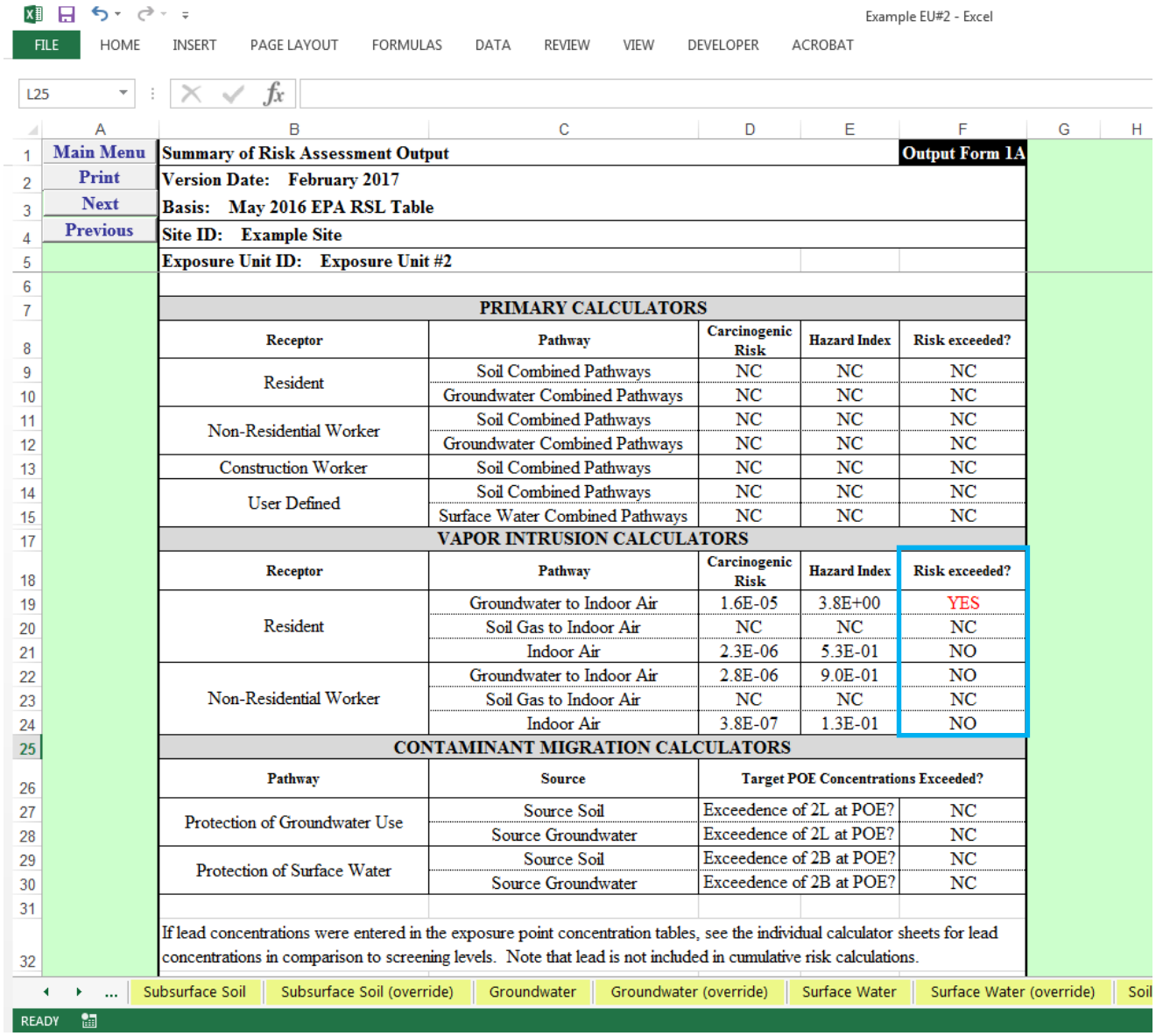
- Check boxes in the calculator for the pathways to be evaluated

EU#2 Calculator Inputs



- No changes to Exposure Factors and Target Risks or Contaminant Migration Parameters
- Delete Exposure Point Concentrations from EU#1 model run and enter groundwater and indoor air concentrations for EU#2 model run

EU#2 Summary Output Sheet



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Next	**Basis: May 2016 EPA RSL Table**					
Previous	**Site ID: Example Site**					
	Exposure Unit ID: Exposure Unit #2					

PRIMARY CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Soil Combined Pathways	NC	NC	NC
	Groundwater Combined Pathways	NC	NC	NC
Non-Residential Worker	Soil Combined Pathways	NC	NC	NC
	Groundwater Combined Pathways	NC	NC	NC
Construction Worker	Soil Combined Pathways	NC	NC	NC
User Defined	Soil Combined Pathways	NC	NC	NC
	Surface Water Combined Pathways	NC	NC	NC

VAPOR INTRUSION CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Groundwater to Indoor Air	1.6E-05	3.8E+00	YES
	Soil Gas to Indoor Air	NC	NC	NC
	Indoor Air	2.3E-06	5.3E-01	NO
Non-Residential Worker	Groundwater to Indoor Air	2.8E-06	9.0E-01	NO
	Soil Gas to Indoor Air	NC	NC	NC
	Indoor Air	3.8E-07	1.3E-01	NO

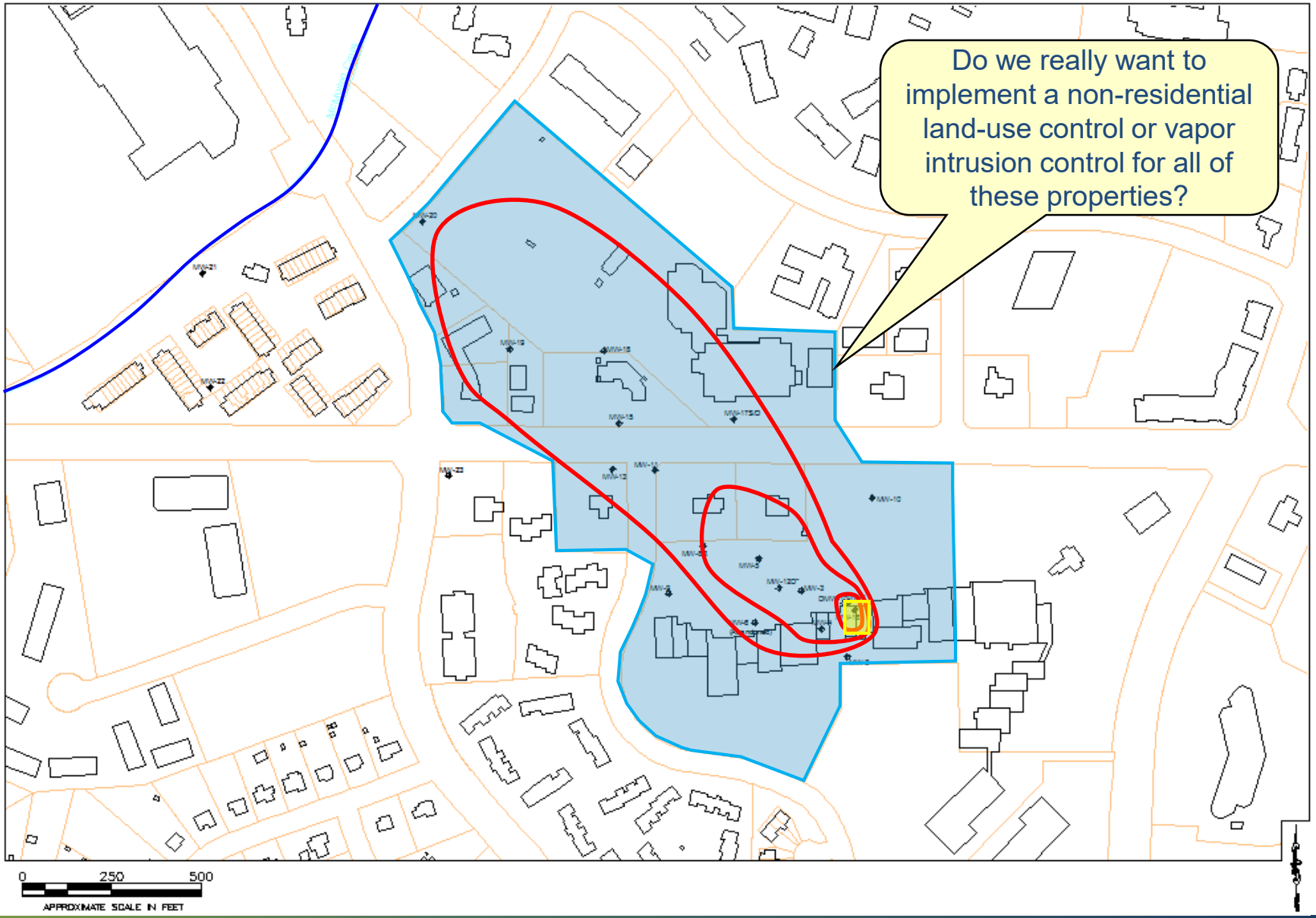
CONTAMINANT MIGRATION CALCULATORS

Pathway	Source	Target POE Concentrations Exceeded?	
Protection of Groundwater Use	Source Soil	Exceedence of 2L at POE?	NC
	Source Groundwater	Exceedence of 2L at POE?	NC
Protection of Surface Water	Source Soil	Exceedence of 2B at POE?	NC
	Source Groundwater	Exceedence of 2B at POE?	NC

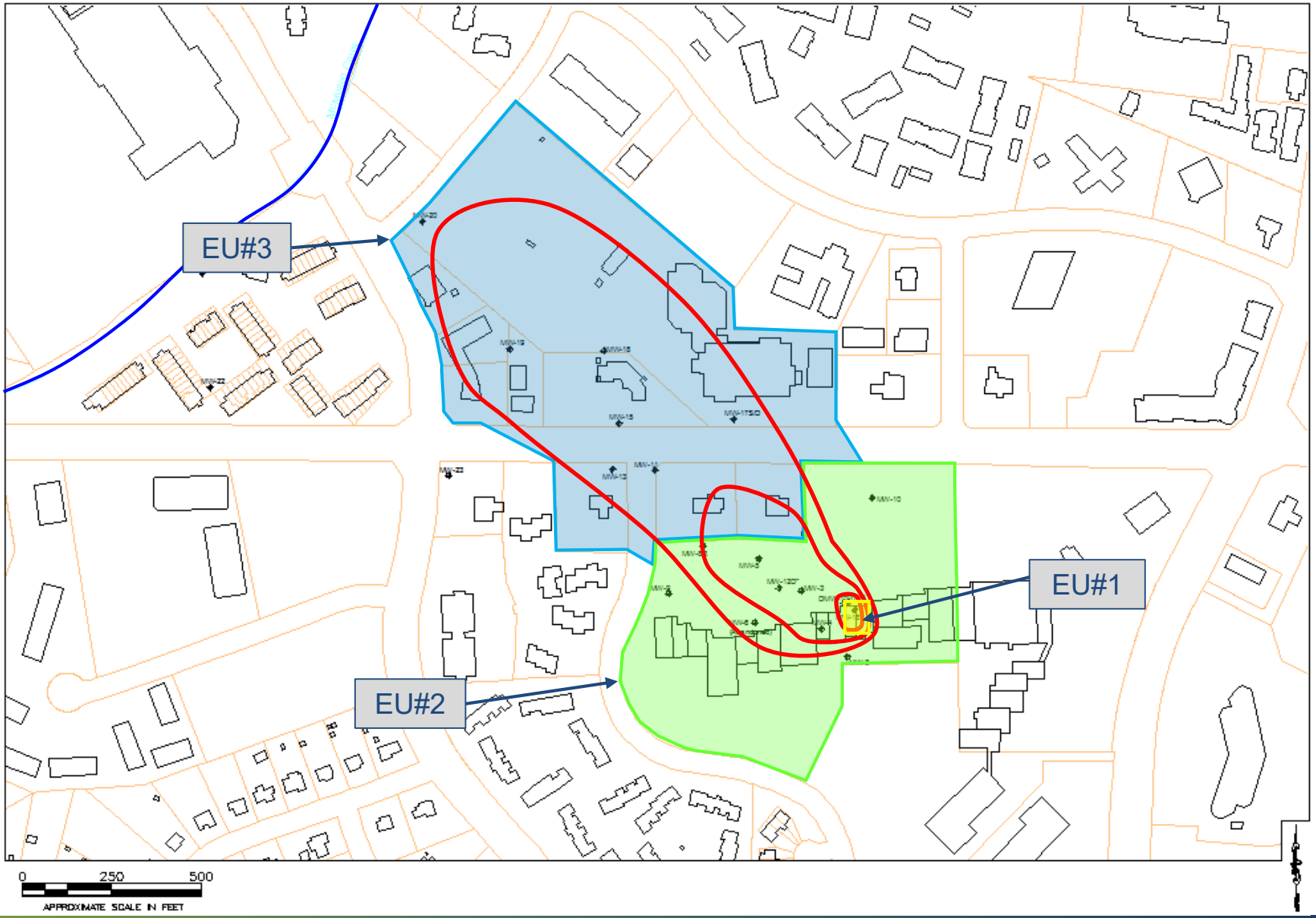
If lead concentrations were entered in the exposure point concentration tables, see the individual calculator sheets for lead concentrations in comparison to screening levels. Note that lead is not included in cumulative risk calculations.

- Only pathway is vapor intrusion so no separate addition needed
- Only exceedance is for future residential vapor intrusion
- Could address with non-residential land-use restriction of vapor intrusion restriction

EU#2 Risk Management



Revisions to Exposure Units



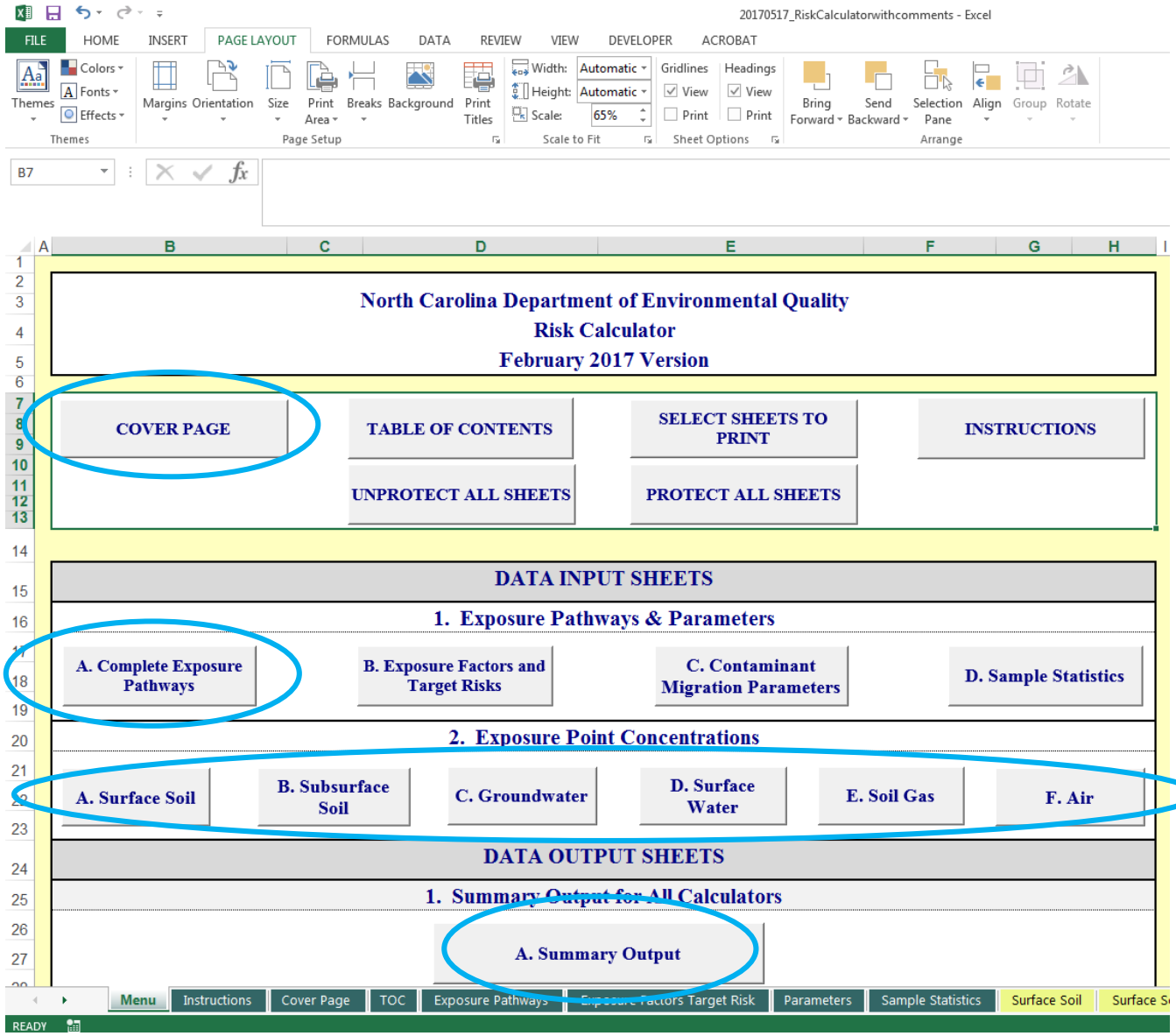
EU#3 Exposure Pathways

PRIMARY PATHWAYS		Complete?
Resident	Soil Combined Pathways	
	Groundwater Combined Pathways	
Non-Residential Worker	Soil Combined Pathways	
	Groundwater Combined Pathways	
Construction Worker	Soil Combined Pathways	
User Defined	Soil Combined Pathways	
	Surface Water Combined Pathways	
VAPOR INTRUSION PATHWAYS		
Resident	Groundwater to Indoor Air	✓
	Soil Gas to Indoor Air	
	Indoor Air	
Non-Residential Worker	Groundwater to Indoor Air	✓
	Soil Gas to Indoor Air	
	Indoor Air	
CONTAMINANT MIGRATION PATHWAYS		
Protection of Groundwater Use	Source Soil	
	Source Groundwater	
Protection of Surface Water	Source Soil	
	Source Groundwater	

- No impacted soil in this unit so soil combined pathways incomplete
- Groundwater use control will be implemented to groundwater combined pathways incomplete
- No surface water impacts detected so surface water combined pathways incomplete
- Only complete pathways associated with vapor intrusion
- No indoor air or soil gas data available for this unit to groundwater data used for current and future vapor intrusion evaluation

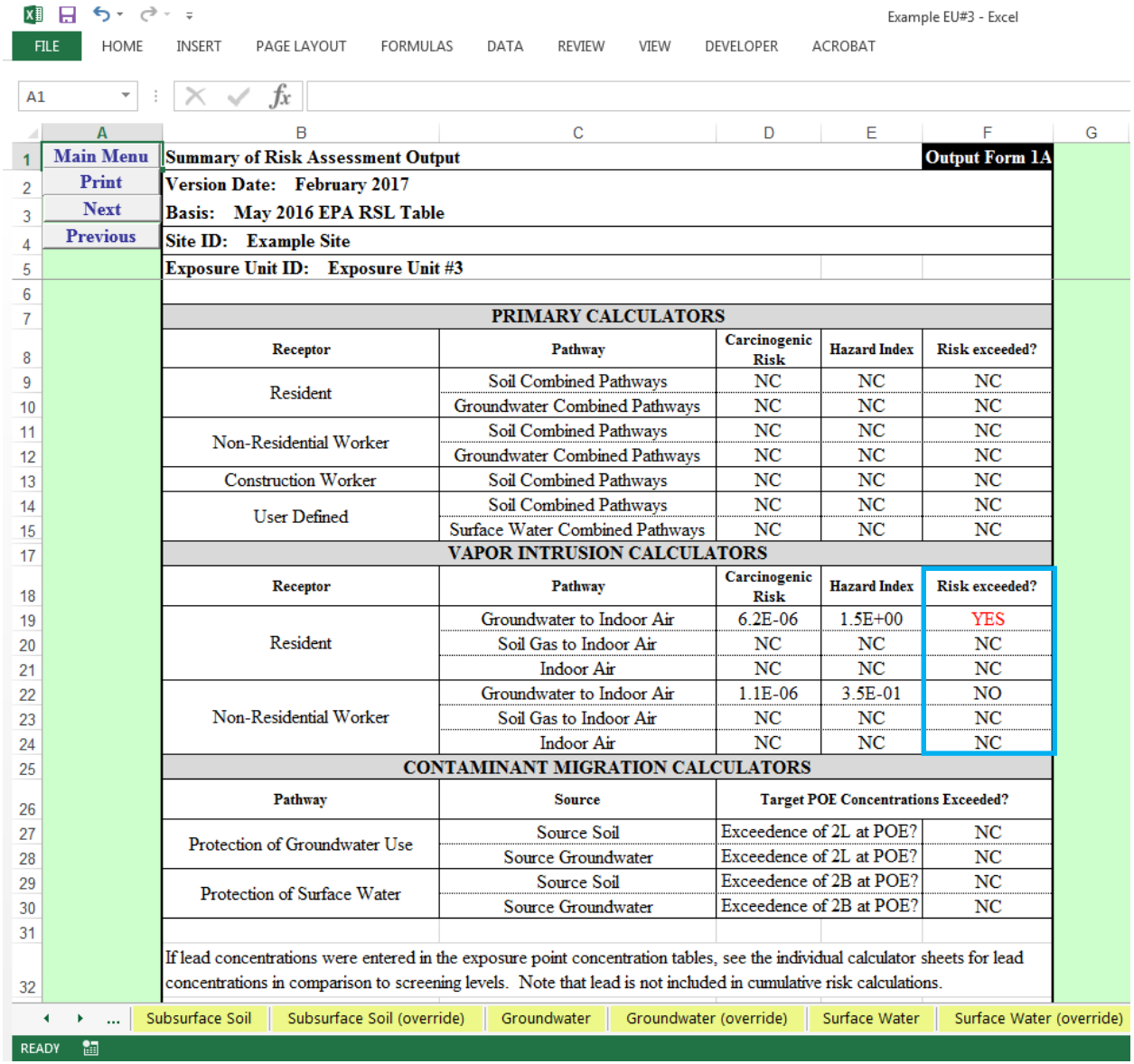
Contaminant migration pathways to be reviewed after cumulative risk pathways

EU#3 Calculator Inputs



- Resave the calculator and edit the exposure unit id to “Exposure Unit #3”
- Edit complete exposure pathways to check residential and non-residential groundwater to indoor air
- Delete Exposure Point Concentrations from EU#2 model run and enter groundwater concentrations for EU#3 model run

EU#3 Calculator Output



Example EU#3 - Excel

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Summary of Risk Assessment Output — **Output Form 1A**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Exposure Unit ID: Exposure Unit #3

PRIMARY CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Soil Combined Pathways	NC	NC	NC
	Groundwater Combined Pathways	NC	NC	NC
Non-Residential Worker	Soil Combined Pathways	NC	NC	NC
	Groundwater Combined Pathways	NC	NC	NC
Construction Worker	Soil Combined Pathways	NC	NC	NC
User Defined	Soil Combined Pathways	NC	NC	NC
	Surface Water Combined Pathways	NC	NC	NC

VAPOR INTRUSION CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Groundwater to Indoor Air	6.2E-06	1.5E+00	YES
	Soil Gas to Indoor Air	NC	NC	NC
	Indoor Air	NC	NC	NC
Non-Residential Worker	Groundwater to Indoor Air	1.1E-06	3.5E-01	NO
	Soil Gas to Indoor Air	NC	NC	NC
	Indoor Air	NC	NC	NC

CONTAMINANT MIGRATION CALCULATORS

Pathway	Source	Target POE Concentrations Exceeded?	
Protection of Groundwater Use	Source Soil	Exceedence of 2L at POE?	NC
	Source Groundwater	Exceedence of 2L at POE?	NC
Protection of Surface Water	Source Soil	Exceedence of 2B at POE?	NC
	Source Groundwater	Exceedence of 2B at POE?	NC

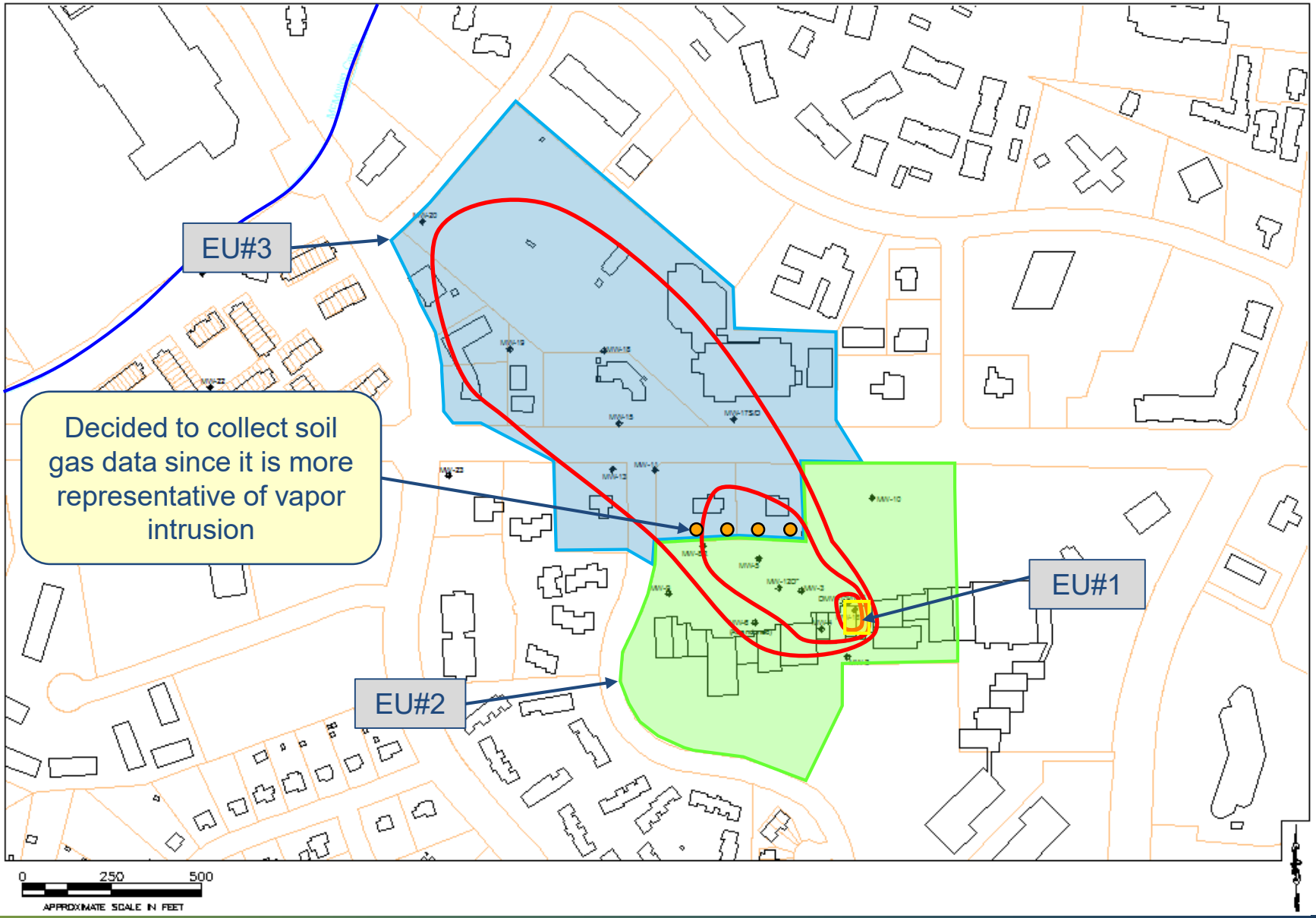
If lead concentrations were entered in the exposure point concentration tables, see the individual calculator sheets for lead concentrations in comparison to screening levels. Note that lead is not included in cumulative risk calculations.

Subsurface Soil | Subsurface Soil (override) | Groundwater | Groundwater (override) | Surface Water | Surface Water (override)

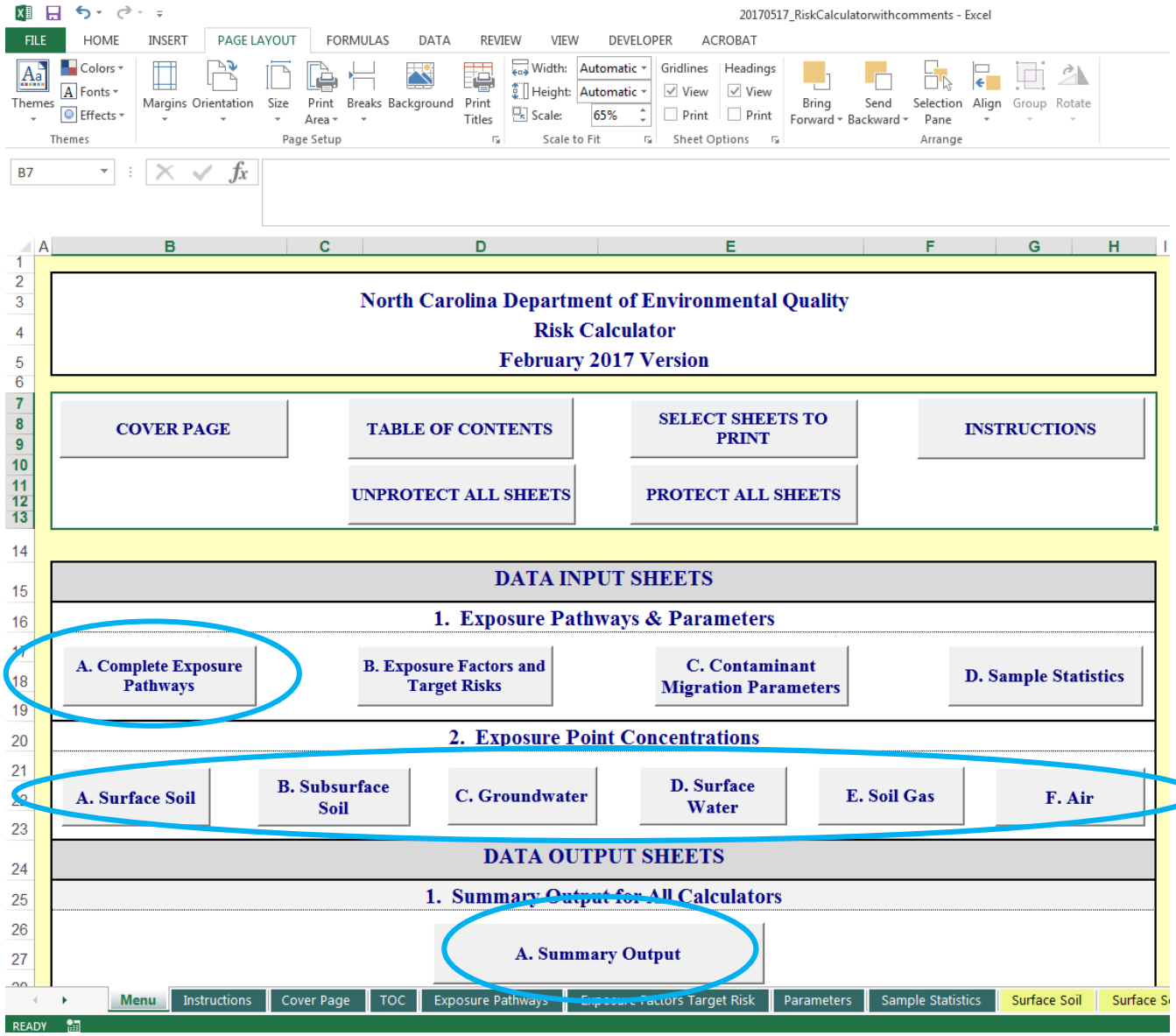
READY

- Only exceedance is for future residential vapor intrusion
- Could address with non-residential land-use restriction or vapor intrusion restriction
- OR…

EU#3 Additional Data Collection

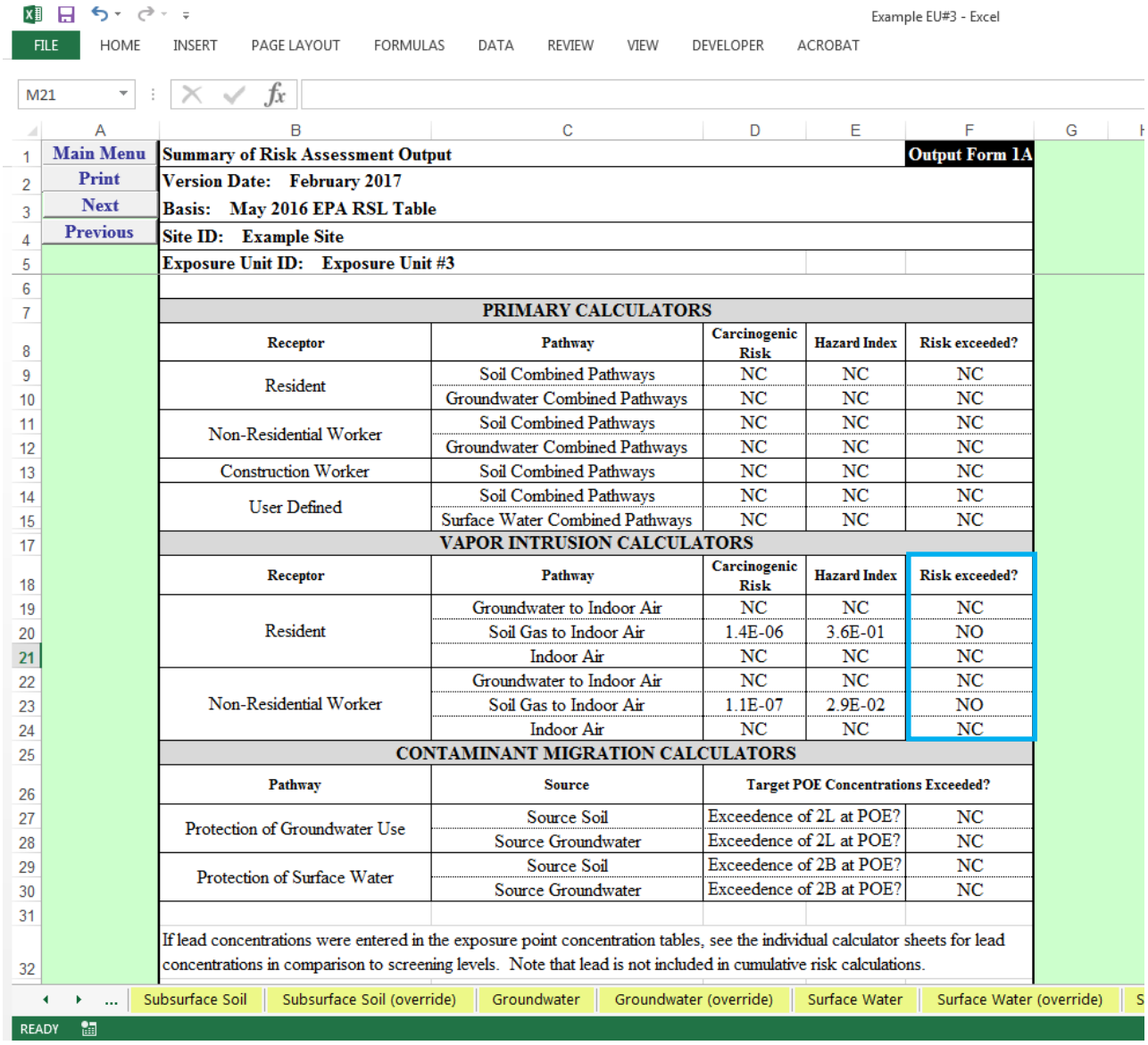


EU#3 Revised Calculator Inputs



- Edit complete exposure pathways to check residential and non-residential soil gas to indoor air instead of groundwater to indoor air
- Delete groundwater concentrations and enter soil gas concentration

EU#3 Revised Calculator Output



Example EU#3 - Excel

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Summary of Risk Assessment Output — **Output Form 1A**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Exposure Unit ID: Exposure Unit #3

PRIMARY CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Soil Combined Pathways	NC	NC	NC
	Groundwater Combined Pathways	NC	NC	NC
Non-Residential Worker	Soil Combined Pathways	NC	NC	NC
	Groundwater Combined Pathways	NC	NC	NC
Construction Worker	Soil Combined Pathways	NC	NC	NC
User Defined	Soil Combined Pathways	NC	NC	NC
	Surface Water Combined Pathways	NC	NC	NC

VAPOR INTRUSION CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	1.4E-06	3.6E-01	NO
	Indoor Air	NC	NC	NC
Non-Residential Worker	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	1.1E-07	2.9E-02	NO
	Indoor Air	NC	NC	NC

CONTAMINANT MIGRATION CALCULATORS

Pathway	Source	Target POE Concentrations Exceeded?	
Protection of Groundwater Use	Source Soil	Exceedence of 2L at POE?	NC
	Source Groundwater	Exceedence of 2L at POE?	NC
Protection of Surface Water	Source Soil	Exceedence of 2B at POE?	NC
	Source Groundwater	Exceedence of 2B at POE?	NC

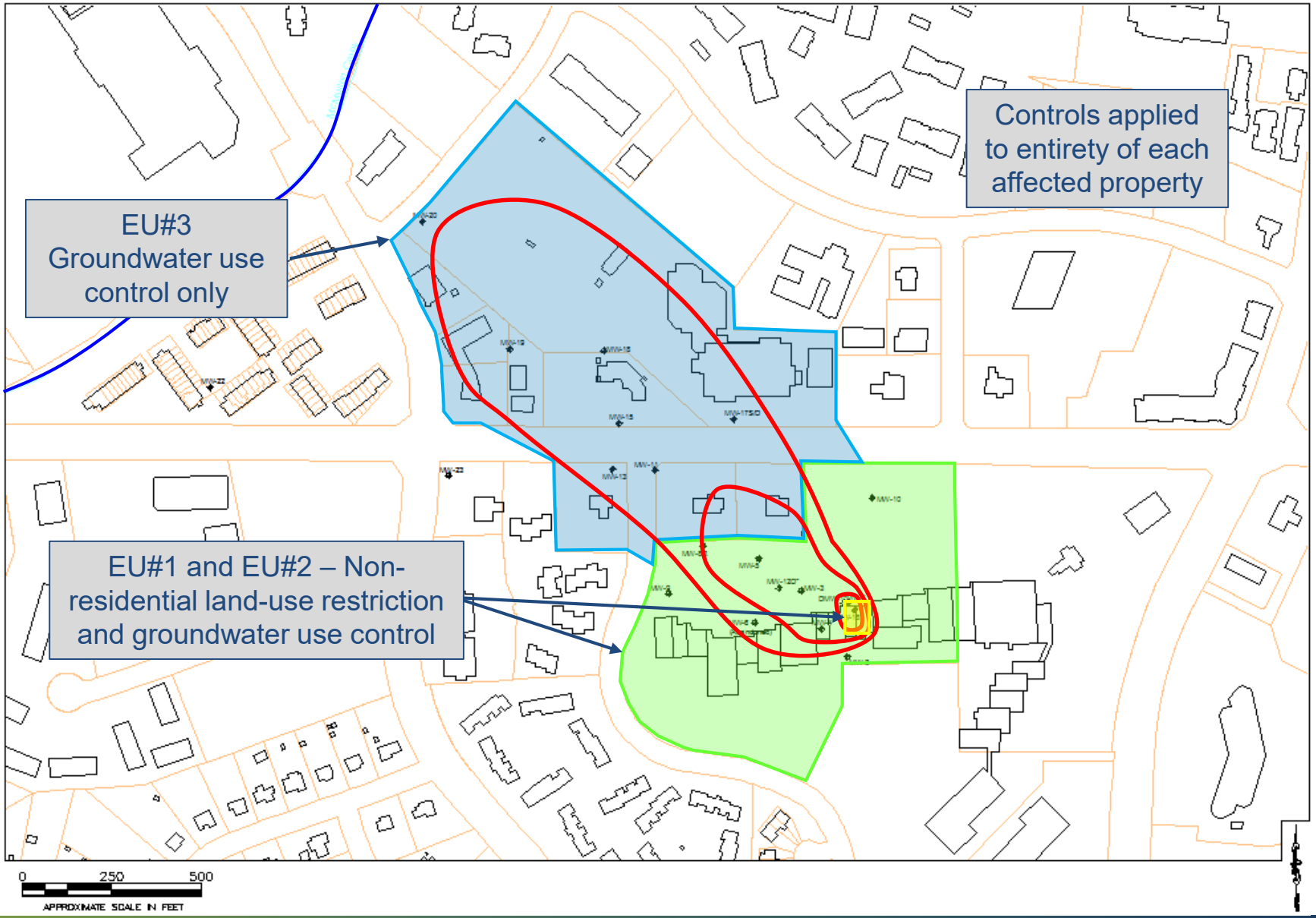
If lead concentrations were entered in the exposure point concentration tables, see the individual calculator sheets for lead concentrations in comparison to screening levels. Note that lead is not included in cumulative risk calculations.

Subsurface Soil | Subsurface Soil (override) | Groundwater | Groundwater (override) | Surface Water | Surface Water (override)

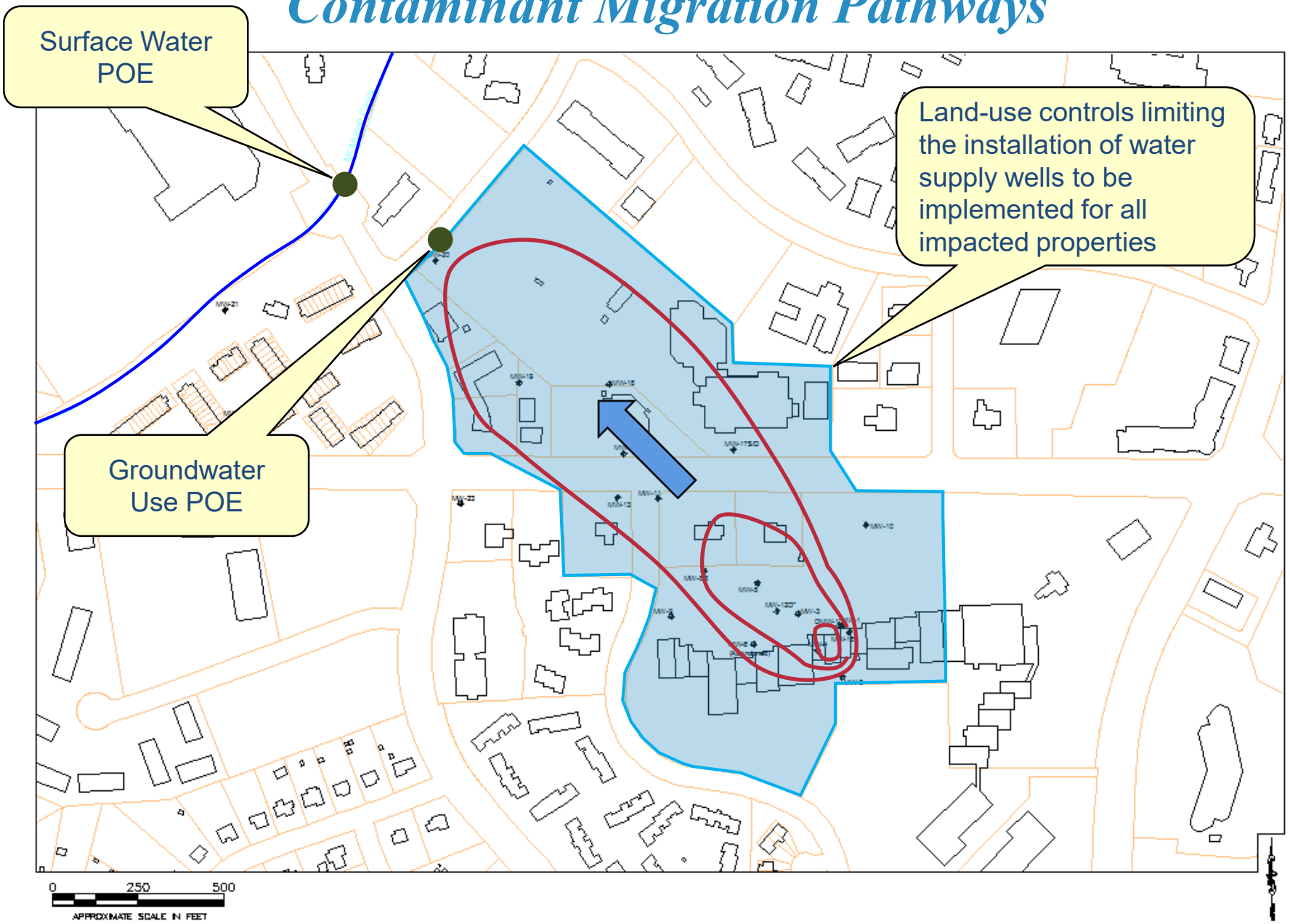
READY

- No exceedences for EU#3 using soil gas data
- Only land-use control needed for EU#3 is a groundwater use control

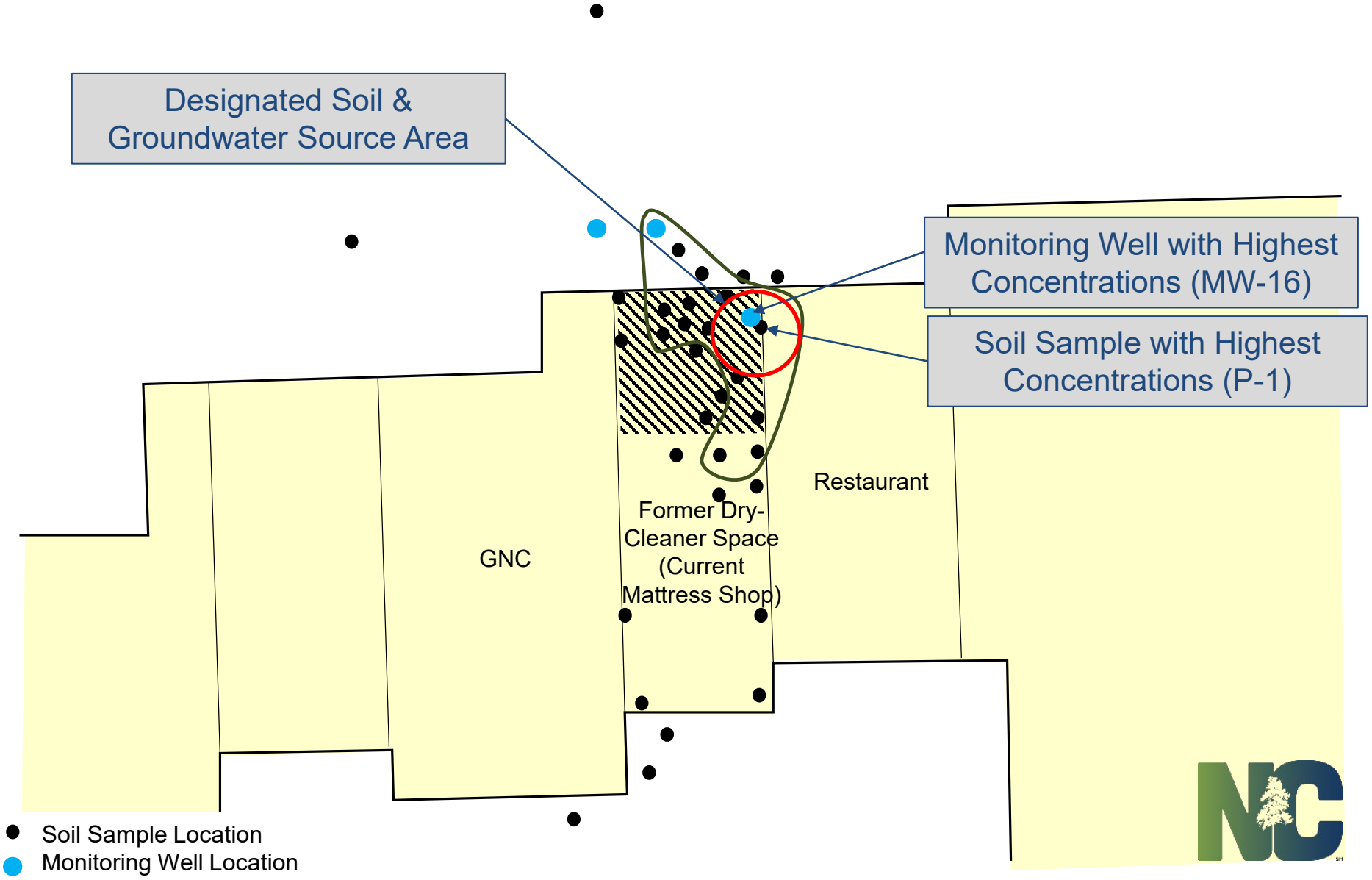
Risk Management Based on Cumulative Risk Evaluation



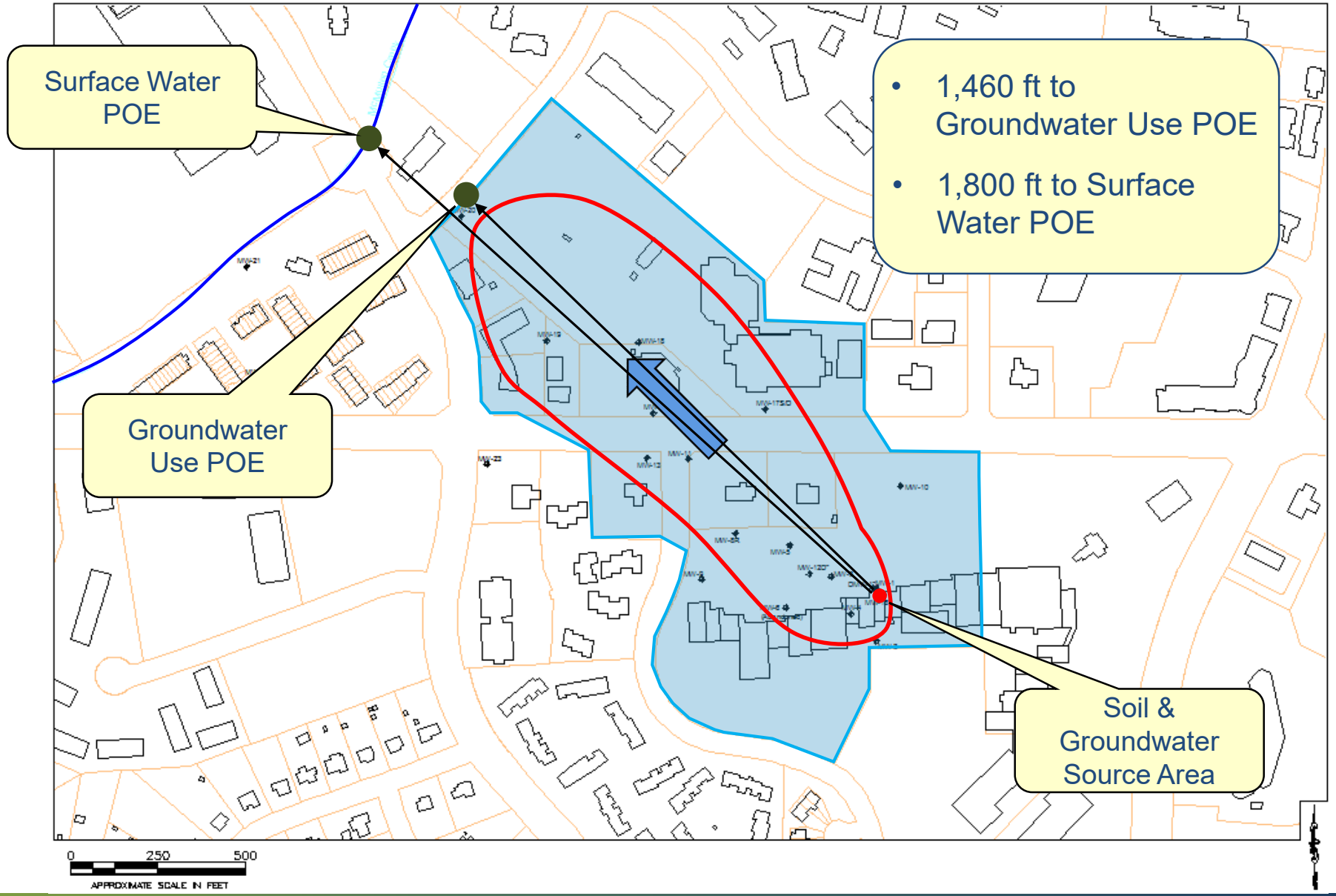
Contaminant Migration Pathways



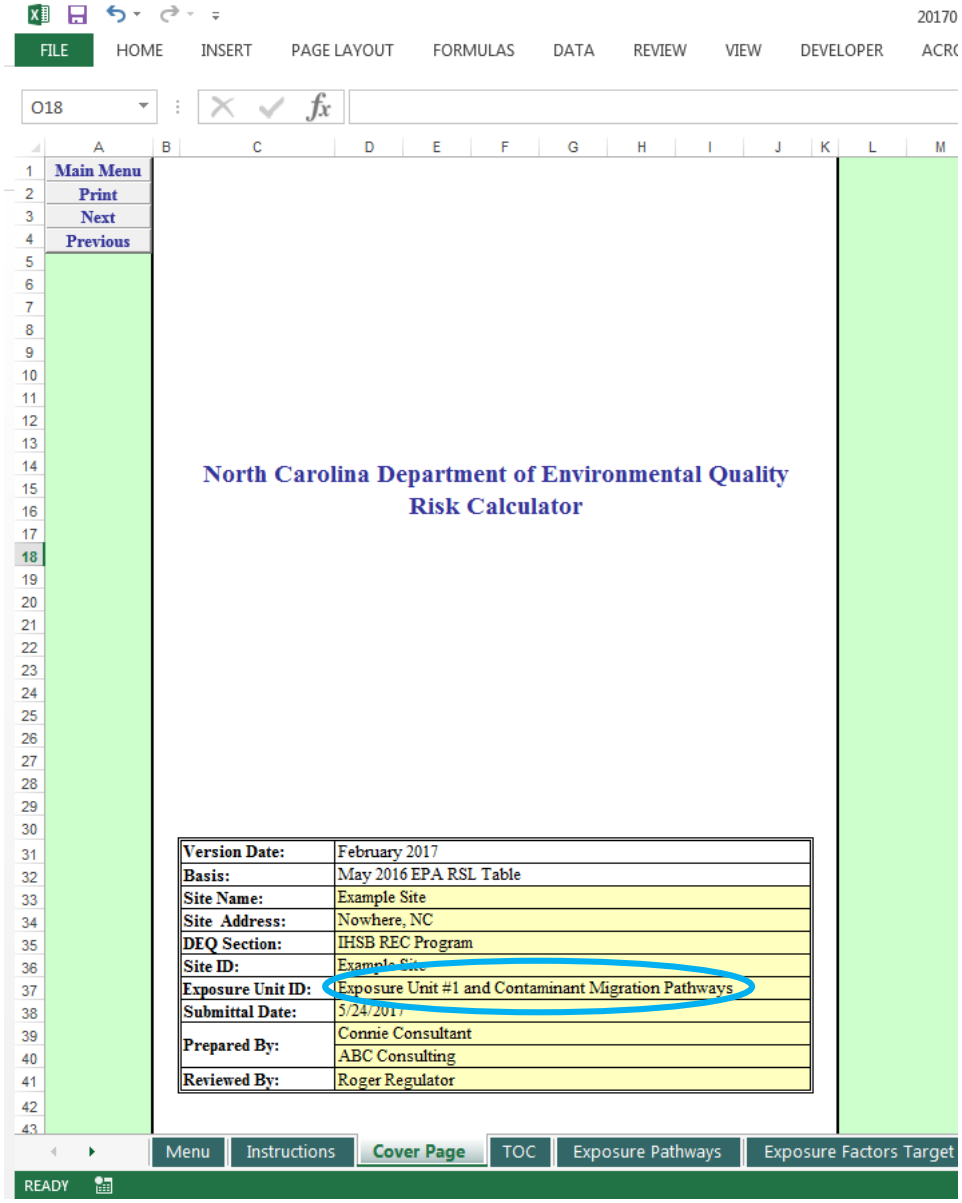
Soil and Groundwater Source Area



Contaminant Migration Pathways

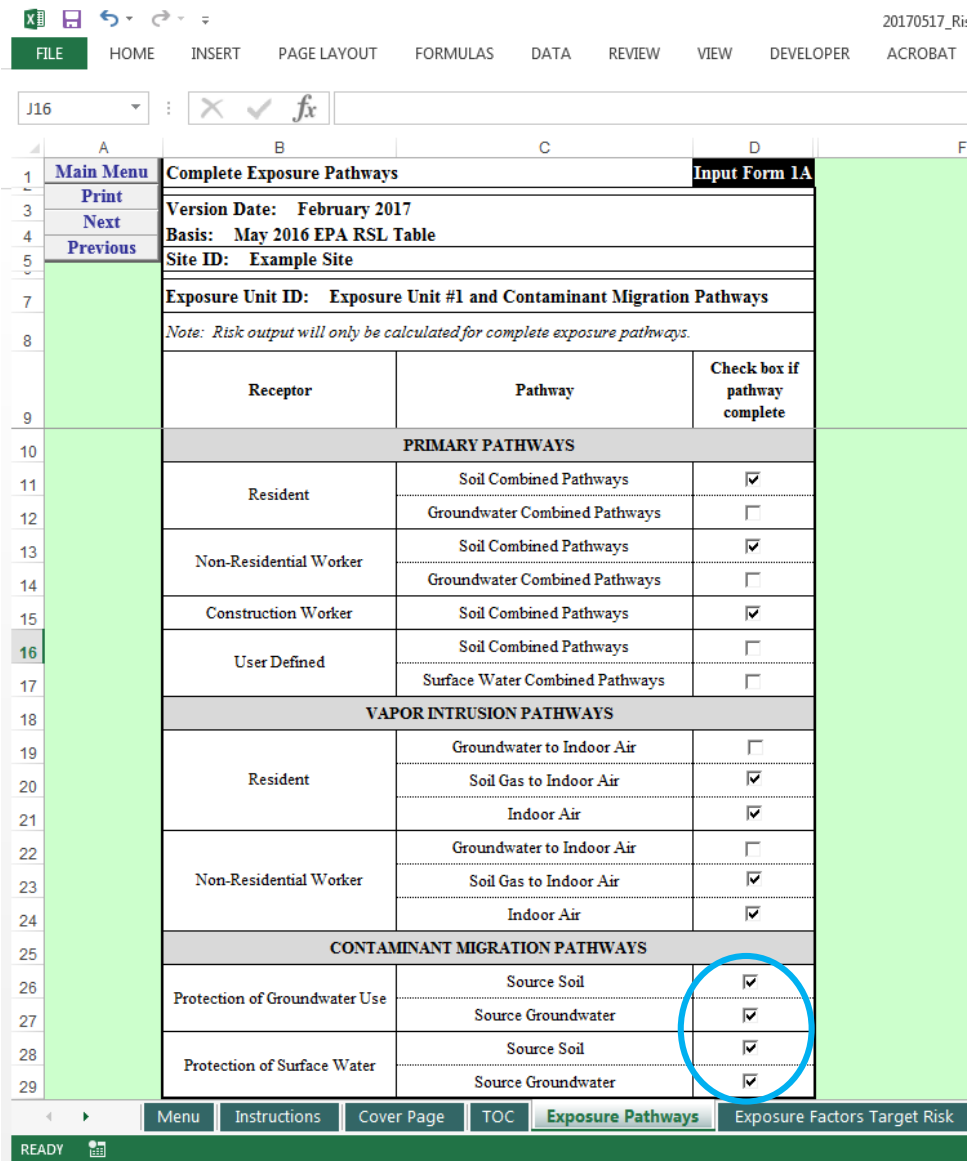


Contaminant Migration Pathway Calculator Inputs



- Source area soil and groundwater concentrations also commonly used for EU#1 model run
- Edit exposure unit ID to reference "Exposure Unit #1 and Contaminant Migration Pathways"

Contaminant Migration Pathway Calculator Inputs



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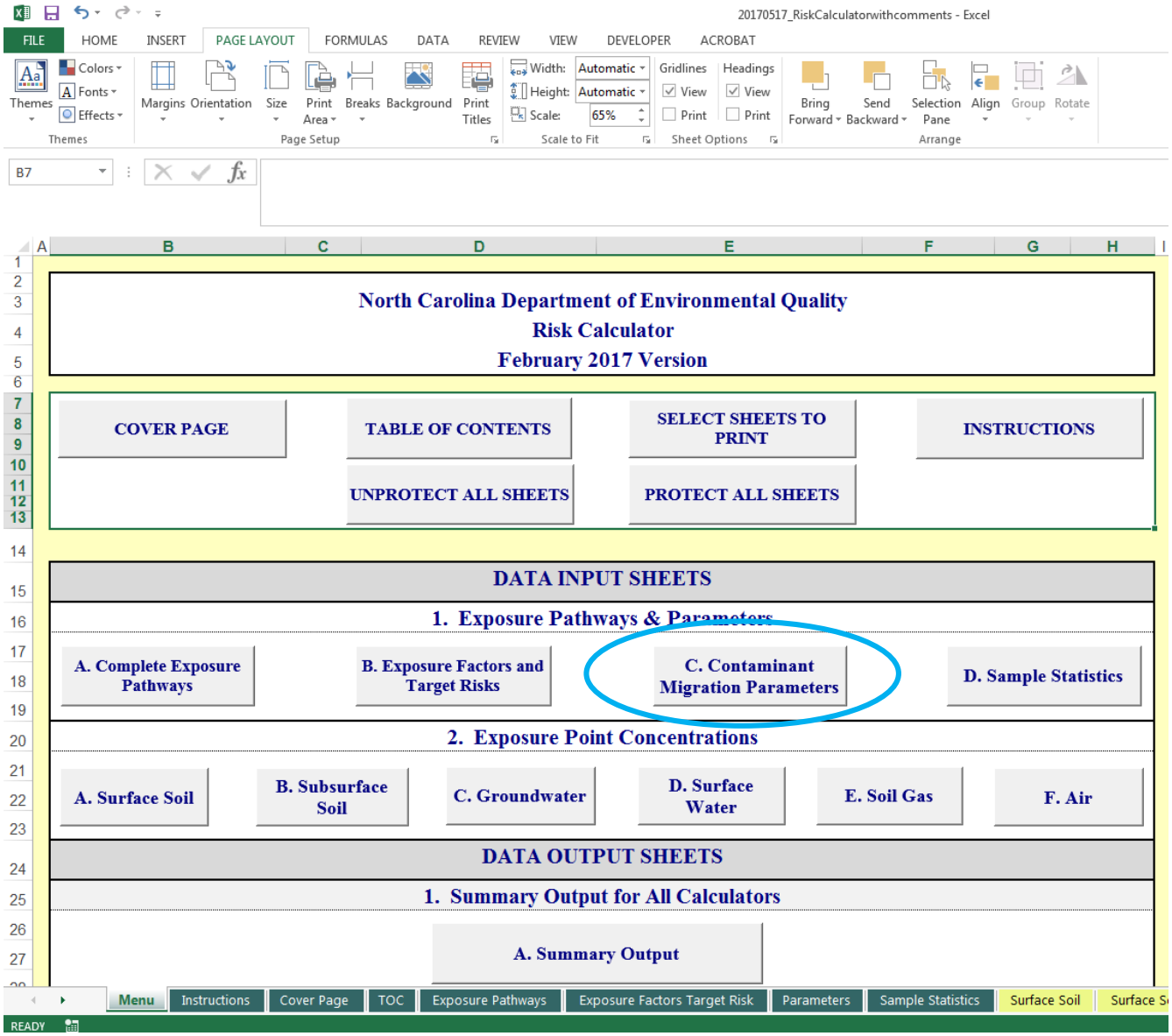
	A	B	C	D
1	Main Menu	**Complete Exposure Pathways**		**Input Form 1A**
3	Print	**Version Date: February 2017**		
4	Next	**Basis: May 2016 EPA RSL Table**		
5	Previous	**Site ID: Example Site**		
7		**Exposure Unit ID: Exposure Unit #1 and Contaminant Migration Pathways**		
8		*Note: Risk output will only be calculated for complete exposure pathways.*		
9		**Receptor**	**Pathway**	**Check box if pathway complete**
10		**PRIMARY PATHWAYS**		
11		Resident	Soil Combined Pathways	☑
12			Groundwater Combined Pathways	☐
13		Non-Residential Worker	Soil Combined Pathways	☑
14			Groundwater Combined Pathways	☐
15		Construction Worker	Soil Combined Pathways	☑
16		User Defined	Soil Combined Pathways	☐
17			Surface Water Combined Pathways	☐
18		**VAPOR INTRUSION PATHWAYS**		
19		Resident	Groundwater to Indoor Air	☐
20			Soil Gas to Indoor Air	☑
21			Indoor Air	☑
22		Non-Residential Worker	Groundwater to Indoor Air	☐
23			Soil Gas to Indoor Air	☑
24			Indoor Air	☑
25		**CONTAMINANT MIGRATION PATHWAYS**		
26		Protection of Groundwater Use	Source Soil	☑
27			Source Groundwater	☑
28		Protection of Surface Water	Source Soil	☑
29			Source Groundwater	☑

Menu | Instructions | Cover Page | TOC | Exposure Pathways | Exposure Factors Target Risk

READY

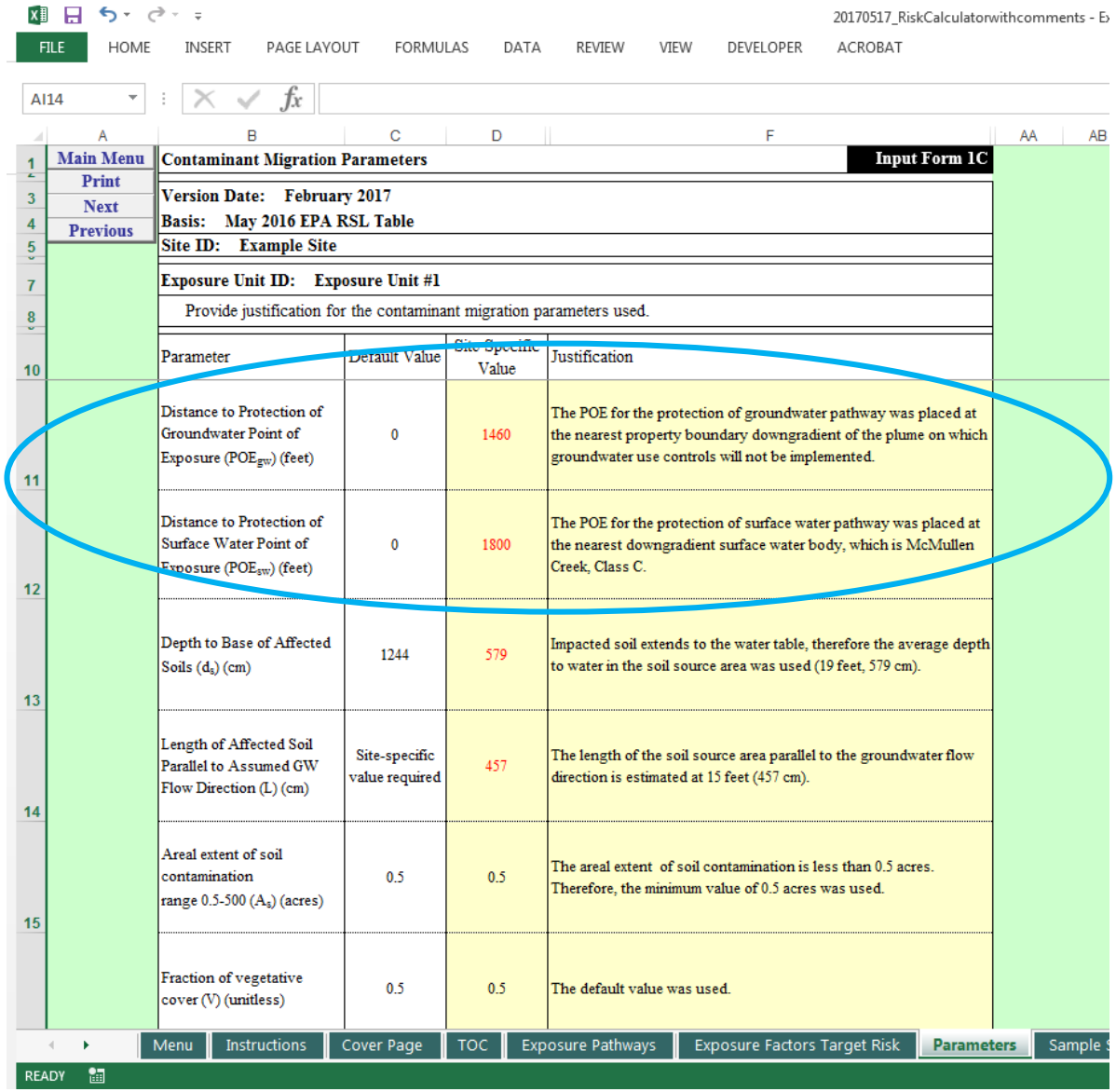
- Check boxes for contaminant migration pathways

Contaminant Migration Pathways Calculator Inputs



- Distances to POEs are entered in Contaminant Migration Parameters sheet

Contaminant Migration Pathways Calculator Inputs



20170517_RiskCalculatorwithcomments - E

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Contaminant Migration Parameters — **Input Form 1C**

Version Date: February 2017
Basis: May 2016 EPA RSL Table
Site ID: Example Site

Exposure Unit ID: Exposure Unit #1

Provide justification for the contaminant migration parameters used.

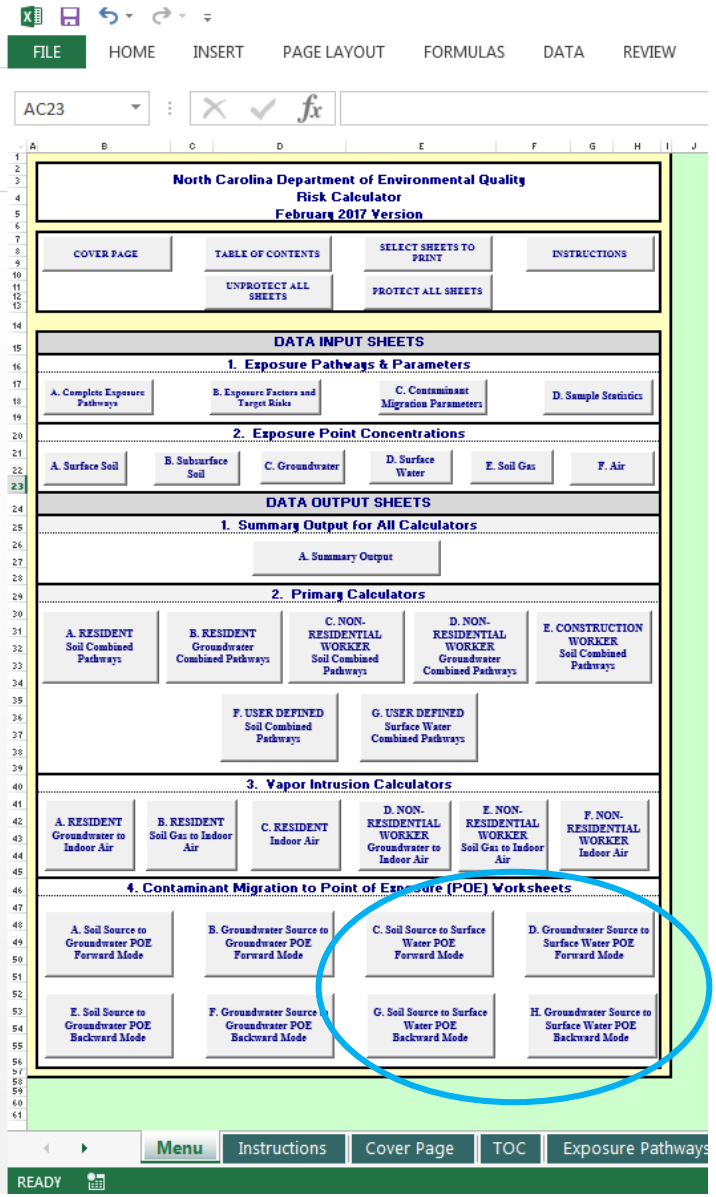
Parameter	Default Value	Site-Specific Value	Justification
Distance to Protection of Groundwater Point of Exposure (POE_{gw}) (feet)	0	1460	The POE for the protection of groundwater pathway was placed at the nearest property boundary downgradient of the plume on which groundwater use controls will not be implemented.
Distance to Protection of Surface Water Point of Exposure (POE_{sw}) (feet)	0	1800	The POE for the protection of surface water pathway was placed at the nearest downgradient surface water body, which is McMullen Creek, Class C.
Depth to Base of Affected Soils (d_s) (cm)	1244	579	Impacted soil extends to the water table, therefore the average depth to water in the soil source area was used (19 feet, 579 cm).
Length of Affected Soil Parallel to Assumed GW Flow Direction (L) (cm)	Site-specific value required	457	The length of the soil source area parallel to the groundwater flow direction is estimated at 15 feet (457 cm).
Areal extent of soil contamination range 0.5-500 (A_s) (acres)	0.5	0.5	The areal extent of soil contamination is less than 0.5 acres. Therefore, the minimum value of 0.5 acres was used.
Fraction of vegetative cover (V) (unitless)	0.5	0.5	The default value was used.

Menu | Instructions | Cover Page | TOC | Exposure Pathways | Exposure Factors Target Risk | Parameters | Sample

READY

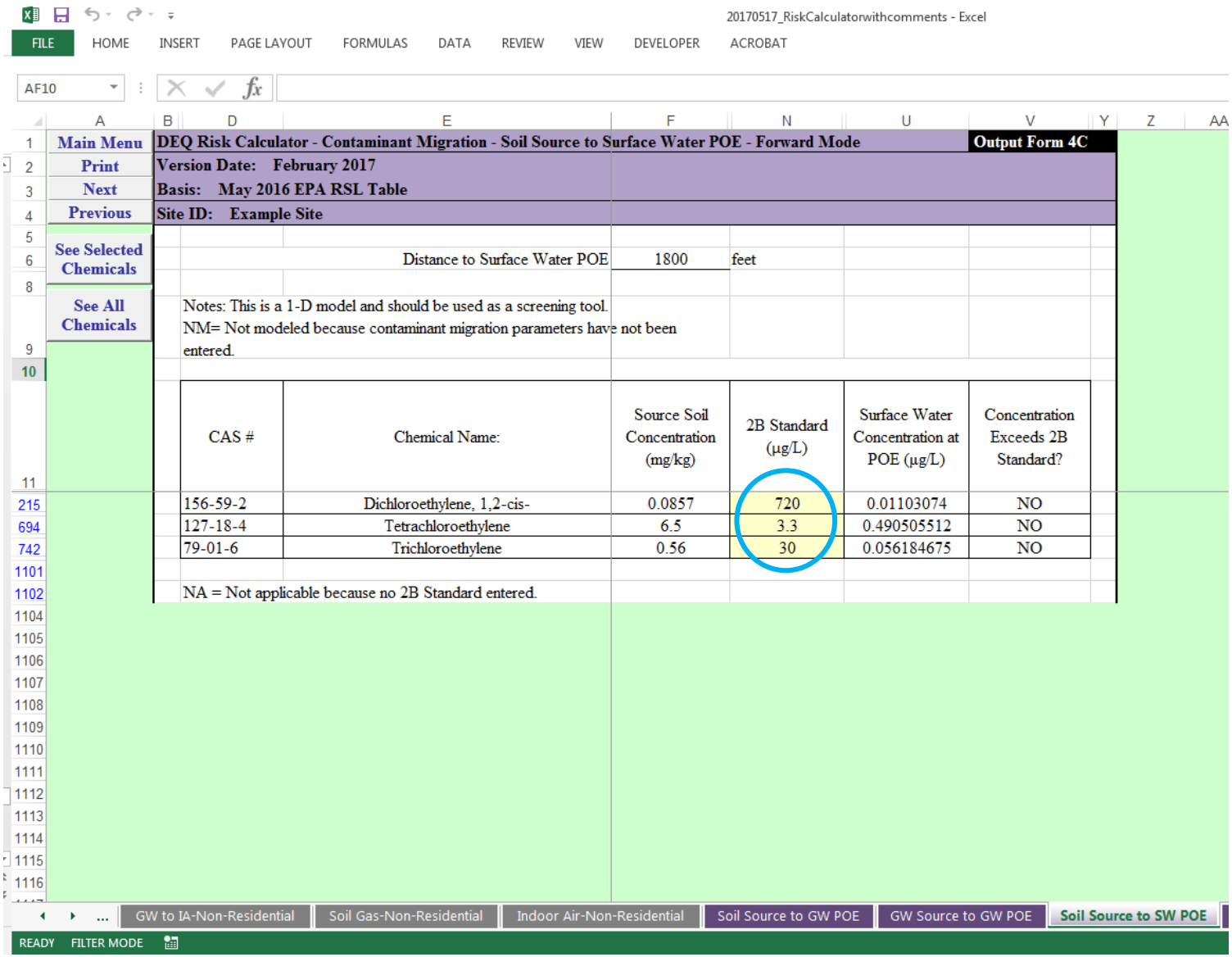
- Distances to POEs are entered in Contaminant Migration Parameters sheet

Contaminant Migration Pathways Calculator Output



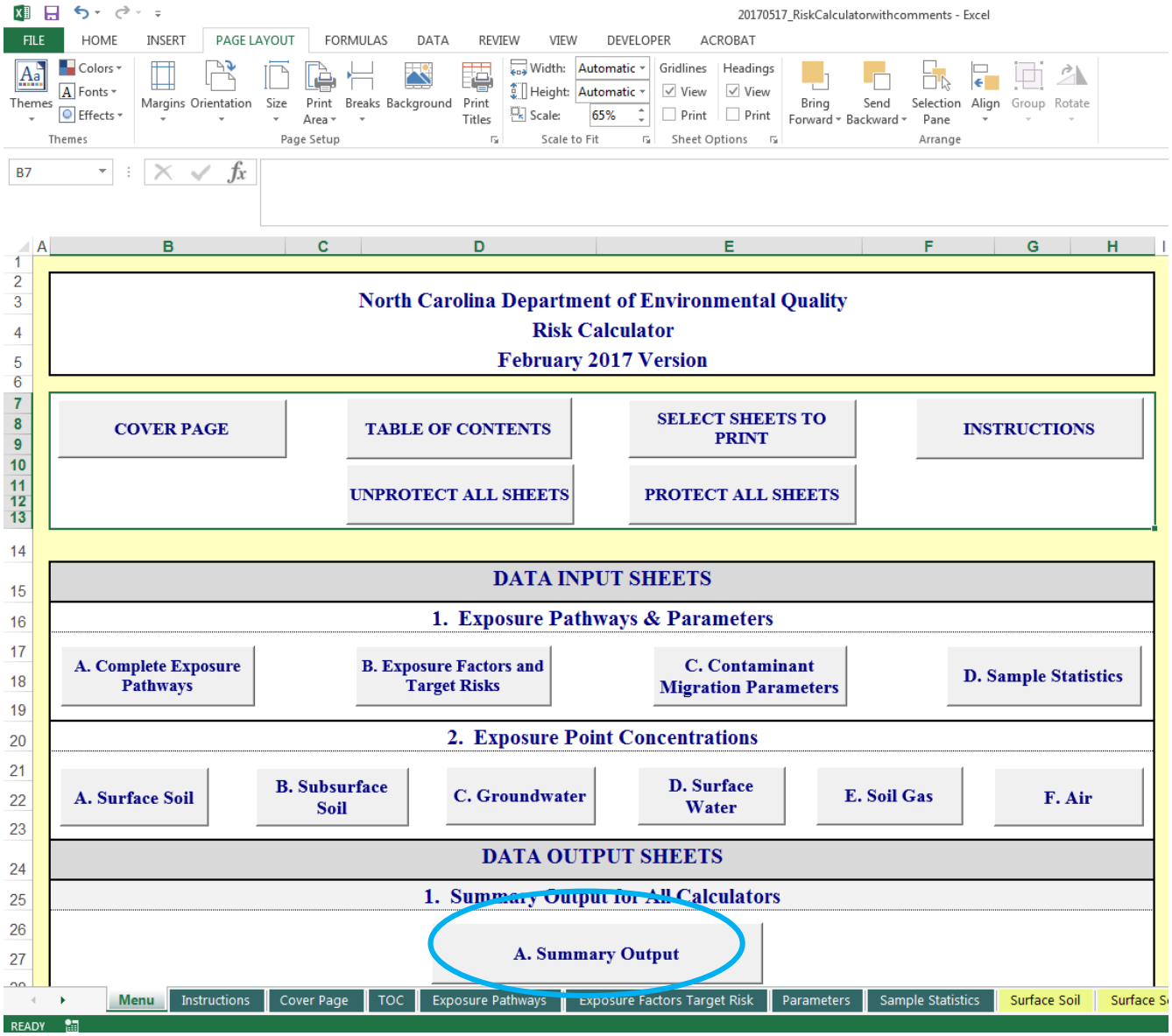
- Don't forget to enter surface water standards

Contaminant Migration Pathways Calculator Output

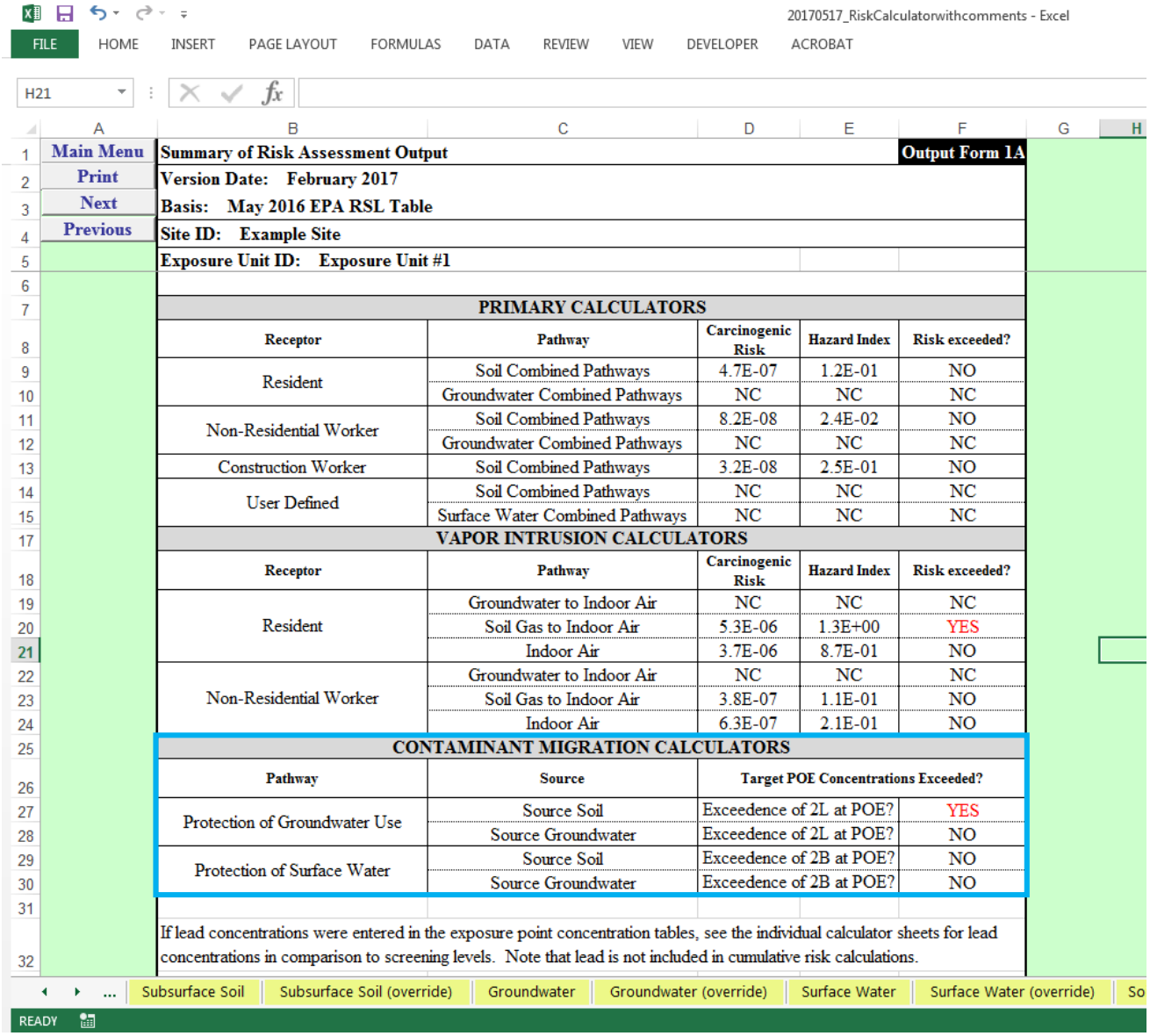


Don't forget to enter surface water standards

Contaminant Migration Pathways Calculator Output



Contaminant Migration Pathways Calculator Output



20170517_RiskCalculatorwithcomments - Excel

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Summary of Risk Assessment Output — **Output Form 1A**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Exposure Unit ID: Exposure Unit #1

PRIMARY CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Soil Combined Pathways	4.7E-07	1.2E-01	NO
	Groundwater Combined Pathways	NC	NC	NC
Non-Residential Worker	Soil Combined Pathways	8.2E-08	2.4E-02	NO
	Groundwater Combined Pathways	NC	NC	NC
Construction Worker	Soil Combined Pathways	3.2E-08	2.5E-01	NO
User Defined	Soil Combined Pathways	NC	NC	NC
	Surface Water Combined Pathways	NC	NC	NC

VAPOR INTRUSION CALCULATORS

Receptor	Pathway	Carcinogenic Risk	Hazard Index	Risk exceeded?
Resident	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	5.3E-06	1.3E+00	YES
	Indoor Air	3.7E-06	8.7E-01	NO
Non-Residential Worker	Groundwater to Indoor Air	NC	NC	NC
	Soil Gas to Indoor Air	3.8E-07	1.1E-01	NO
	Indoor Air	6.3E-07	2.1E-01	NO

CONTAMINANT MIGRATION CALCULATORS

Pathway	Source	Target POE Concentrations Exceeded?	
Protection of Groundwater Use	Source Soil	Exceedence of 2L at POE?	YES
	Source Groundwater	Exceedence of 2L at POE?	NO
Protection of Surface Water	Source Soil	Exceedence of 2B at POE?	NO
	Source Groundwater	Exceedence of 2B at POE?	NO

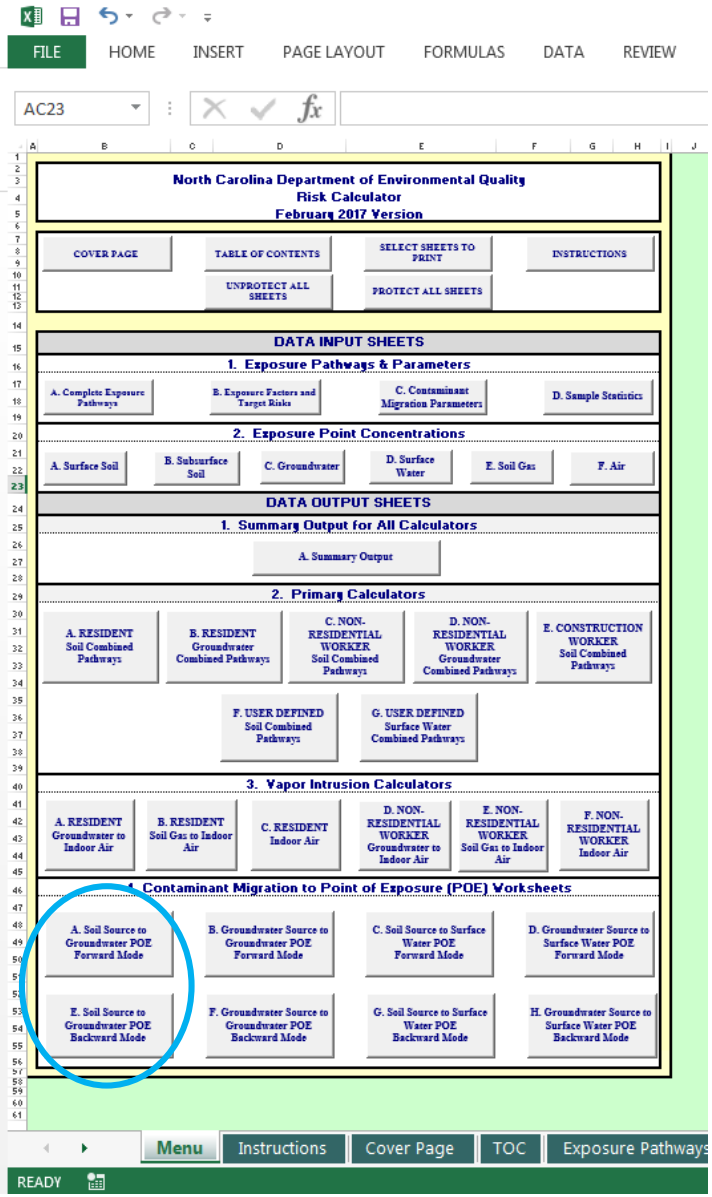
If lead concentrations were entered in the exposure point concentration tables, see the individual calculator sheets for lead concentrations in comparison to screening levels. Note that lead is not included in cumulative risk calculations.

Subsurface Soil | Subsurface Soil (override) | Groundwater | Groundwater (override) | Surface Water | Surface Water (override) | So

READY

- Source soil exceeds for Protection of Groundwater Use
- No exceedences for source groundwater for Protection of Groundwater Use
- No exceedences for source soil or groundwater for Protection of Surface Water

Contaminant Migration Pathways Calculator Output

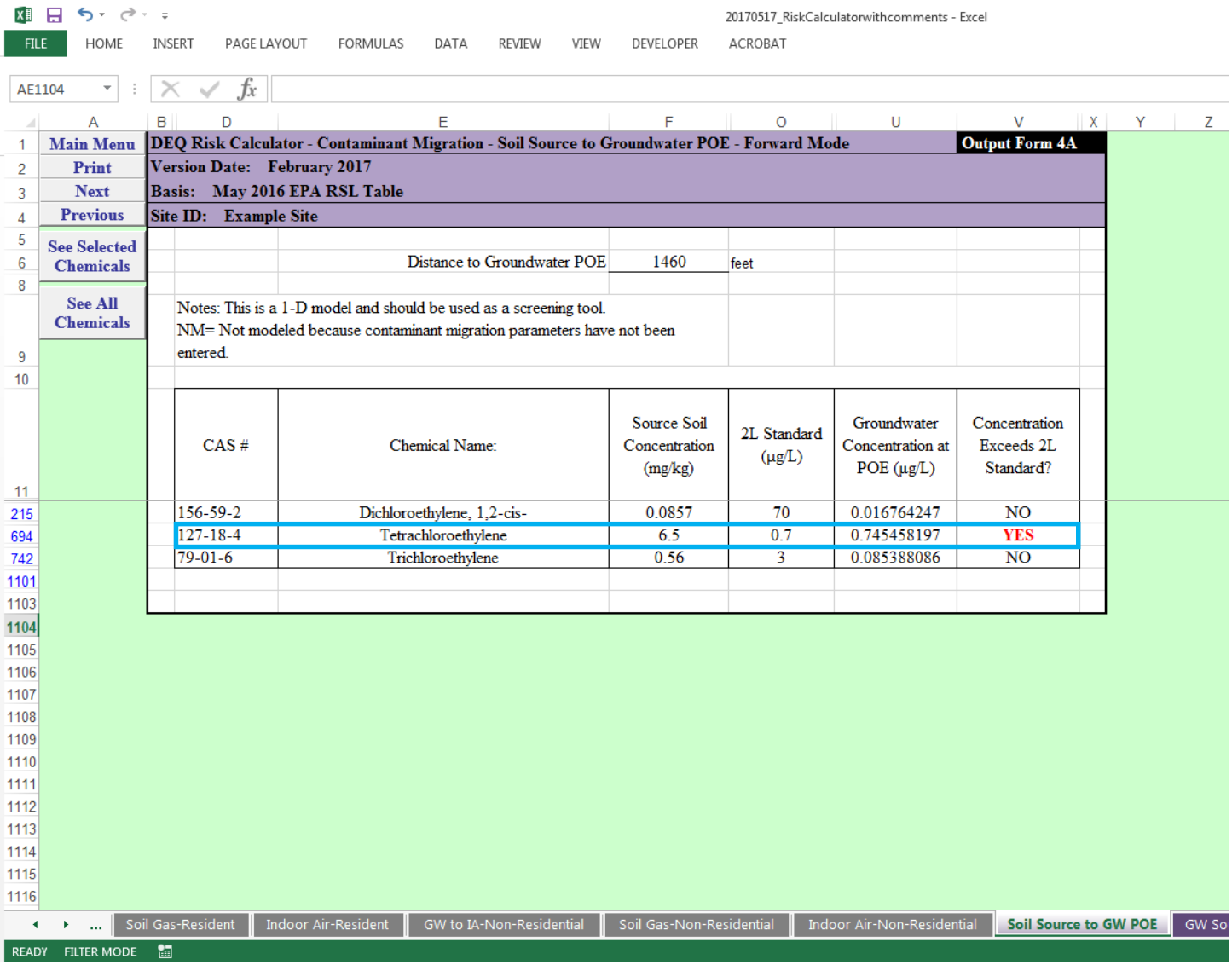


Restriction to maintain surface cover needed because:

- Model indicates exceedences for soil source area
- Soil source area currently covered
- Removal of surface cover could cause increased infiltration and plume expansion

- To evaluate area of surface cover restriction go to Soil Source to Groundwater POE Forward and Backward Calculators

Soil Source to Groundwater POE Forward Calculator Output



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DEQ Risk Calculator - Contaminant Migration - Soil Source to Groundwater POE - Forward Mode — **Output Form 4A**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Distance to Groundwater POE: 1460 feet

Notes: This is a 1-D model and should be used as a screening tool.
NM= Not modeled because contaminant migration parameters have not been entered.

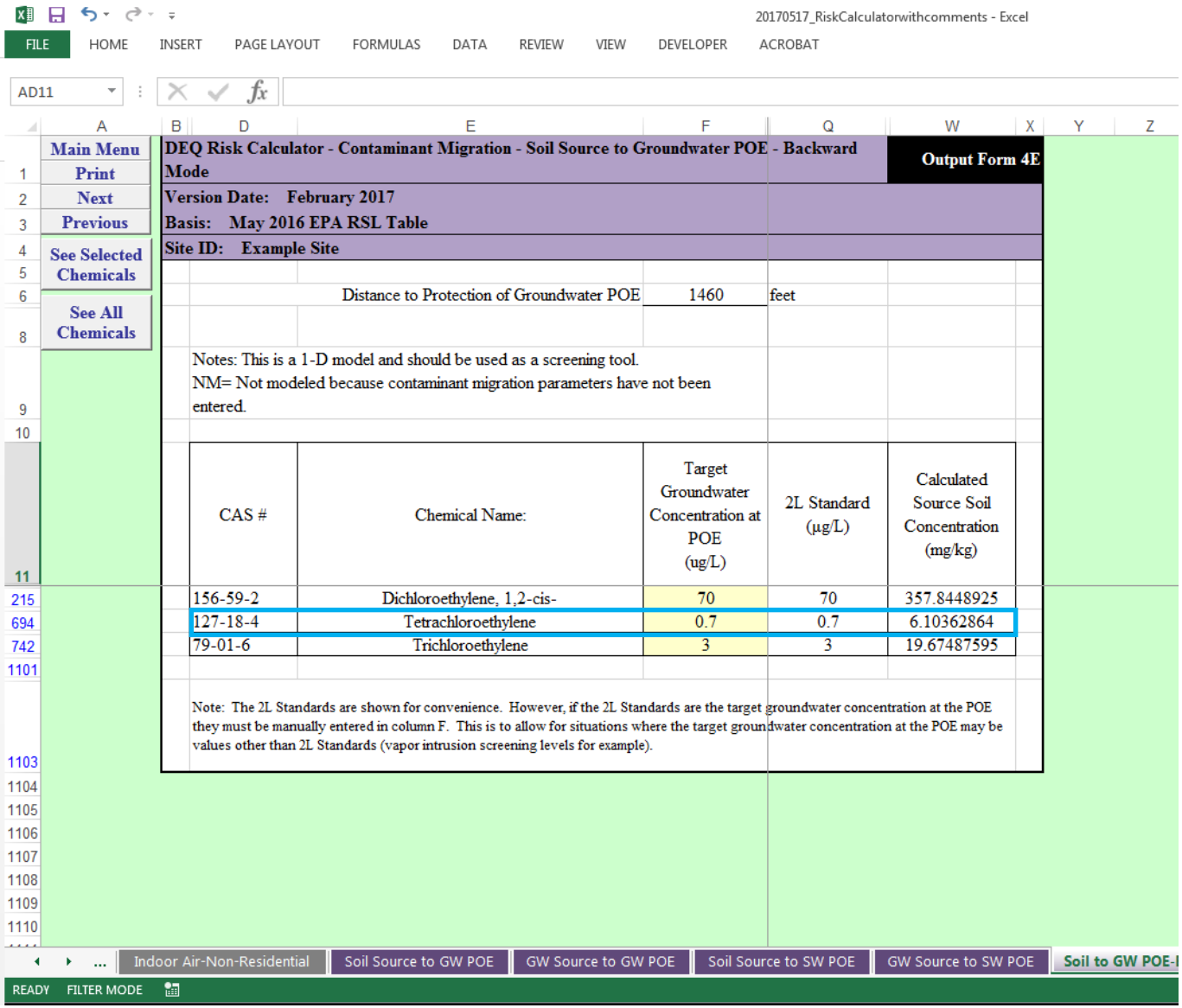
CAS #	Chemical Name:	Source Soil Concentration (mg/kg)	2L Standard (µg/L)	Groundwater Concentration at POE (µg/L)	Concentration Exceeds 2L Standard?
156-59-2	Dichloroethylene, 1,2-cis-	0.0857	70	0.016764247	NO
127-18-4	Tetrachloroethylene	6.5	0.7	0.745458197	YES
79-01-6	Trichloroethylene	0.56	3	0.085388086	NO

Soil Gas-Resident | Indoor Air-Resident | GW to IA-Non-Residential | Soil Gas-Non-Residential | Indoor Air-Non-Residential | Soil Source to GW POE | GW So

READY FILTER MODE

Model predicts a groundwater concentration of 0.75 ug/L at the Groundwater Use POE, which exceeds 2L Standard of 0.7 ug/L

Soil Source to Groundwater POE Backward Calculator Output



20170517_RiskCalculatorwithcomments - Excel

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DEQ Risk Calculator - Contaminant Migration - Soil Source to Groundwater POE - Backward Mode — **Output Form 4E**

Version Date: February 2017

Basis: May 2016 EPA RSL Table

Site ID: Example Site

Distance to Protection of Groundwater POE: 1460 feet

Notes: This is a 1-D model and should be used as a screening tool.
NM= Not modeled because contaminant migration parameters have not been entered.

CAS #	Chemical Name:	Target Groundwater Concentration at POE (ug/L)	2L Standard (µg/L)	Calculated Source Soil Concentration (mg/kg)
156-59-2	Dichloroethylene, 1,2-cis-	70	70	357.8448925
127-18-4	Tetrachloroethylene	0.7	0.7	6.10362864
79-01-6	Trichloroethylene	3	3	19.67487595

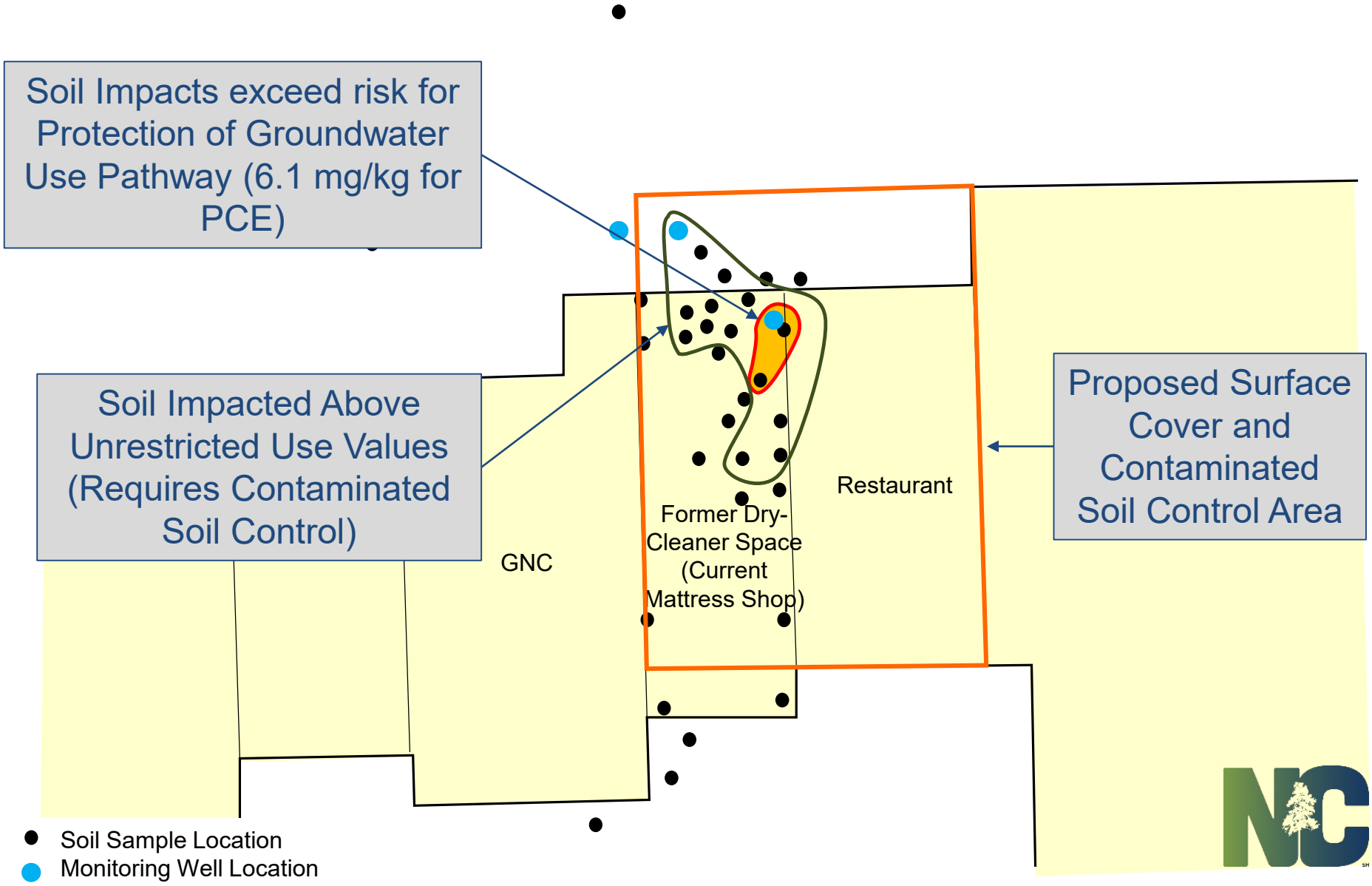
Note: The 2L Standards are shown for convenience. However, if the 2L Standards are the target groundwater concentration at the POE they must be manually entered in column F. This is to allow for situations where the target groundwater concentration at the POE may be values other than 2L Standards (vapor intrusion screening levels for example).

Indoor Air-Non-Residential | Soil Source to GW POE | GW Source to GW POE | Soil Source to SW POE | GW Source to SW POE | Soil to GW POE-I

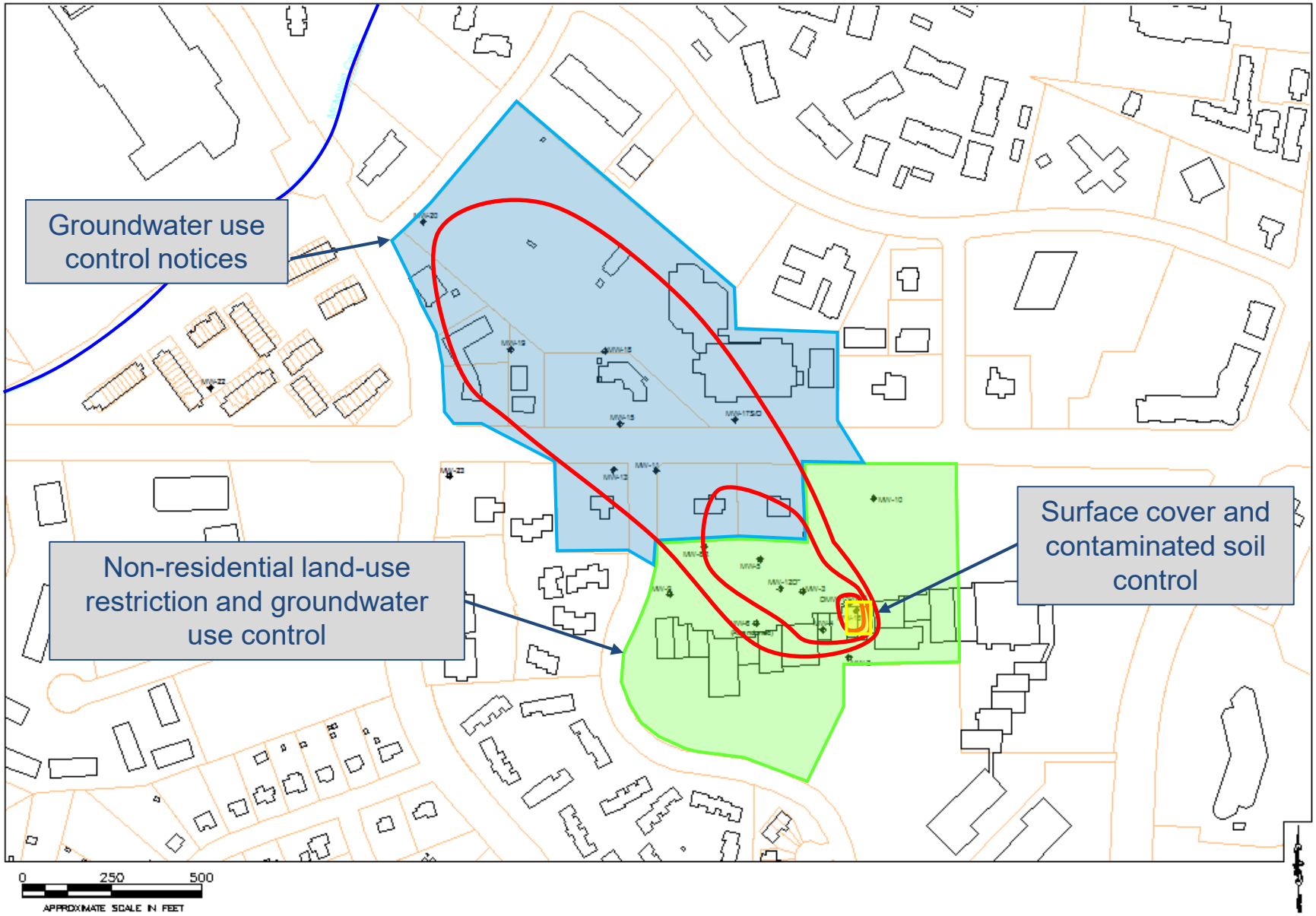
READY FILTER MODE

To achieve 2L Standard of 0.7 ug/L at POE, model calculates a target screening level of 6.1 mg/kg for PCE in soil source area

Surface Cover Restriction Area



Final Risk Management Decisions



Risk Assessment Training Topics of Discussion

I. Regulatory Framework

II. Risk Assessment 101

III. NC-Specific Risk Assessment Procedures

IV. Groundwater Only Site Closure Examples

V. Introduction to the Risk Calculator

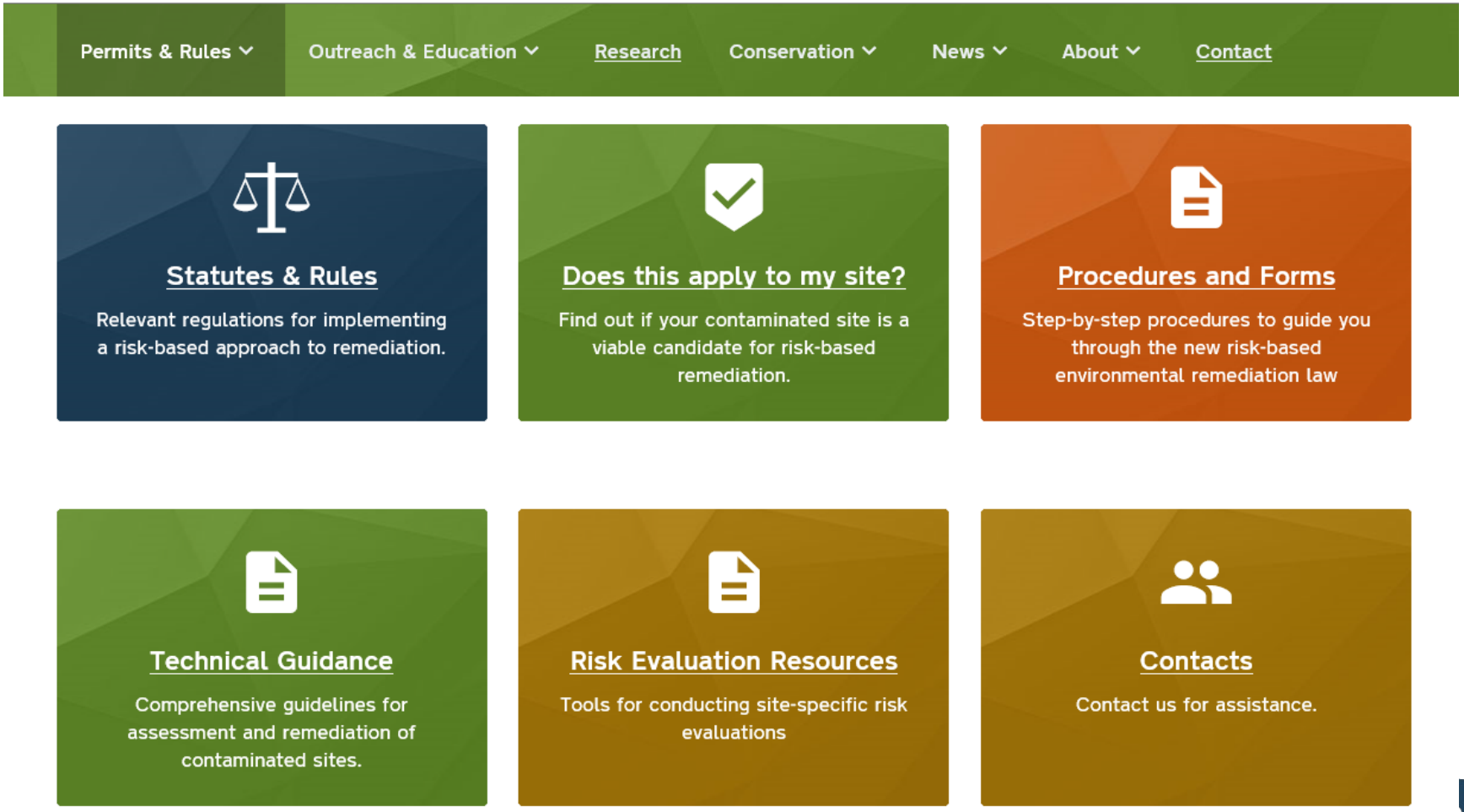
VI. Risk Calculator Site Closure Example

VII. Wrap-up & Questions

Department of Environmental Quality

Where do I find more information?

http://deq.nc.gov/permits-regulations/risk-based-remediation



Department of Environmental Quality

Technical Guidance

Permits & Rules | Outreach & Education | Research | Conservation | News | About | Contact

Technical Guidance

The Technical Guidance for Risk-Based Environmental Remediation of Sites provides to the extent practicable, a common set of methods and standards for assessment and cleanup of contaminated sites. Its purpose is to outline key elements and procedures specified in North Carolina General Statutes (G.S.) 130A 310.68 through 310.77 for implementing consistent and successful contaminant assessment and risk-based remediation strategies across applicable DEQ programs.

Technical Guidance for Risk-Based Environmental Remediation of Sites (March 2017)

- Executive Summary
- List of Links By Chapter

Risk Evaluation Resources

Vapor Intrusion Guidance

Risk-Based Remediation

- Statutes and Rules
- Does this apply to my site?
- Procedures and Forms
- **Technical Guidance**
- Risk Evaluation Resources
- Contacts

Risk Evaluation Resources

Risk Evaluation Resources

DEQ's procedures for evaluating human health risks are outlined in the Tier 1/Tier2 flowchart. Contact the appropriate oversight program with any questions.

Screening

Initial screening (Tier 1) using the tables and lin ntaminant concentrations meet unrestricted use standards

- Preliminary Soil Remediation Goals (PSRG) Table 2016)
- Groundwater Standards and IMACs (15A NCAC
- Surface Water Standards (15A NCAC 02B)
- Vapor Intrusion Screening Levels *(October 2*

Calculating Risk

A risk calculator (Tier 2) is provided to q ntify human health risks when multiple contaminants are present and when conditions justify using site-specific input parameters.

- DEQ Risk Calculator *(August 2016)*
- Risk Assessment Report Forms
- Risk Assessment Equations and Calculations

Be sure to use the most recent version of the DEQ Risk Calculator

Risk-Based Remediation

- Statutes and Rules
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- Contacts

Questions?

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