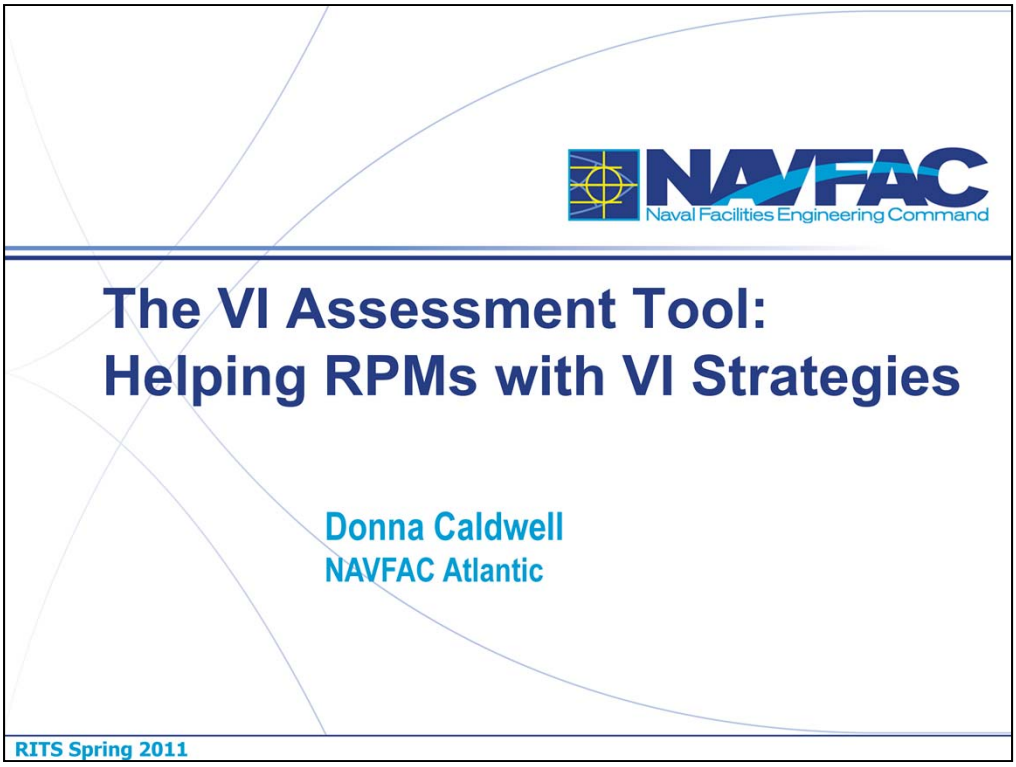
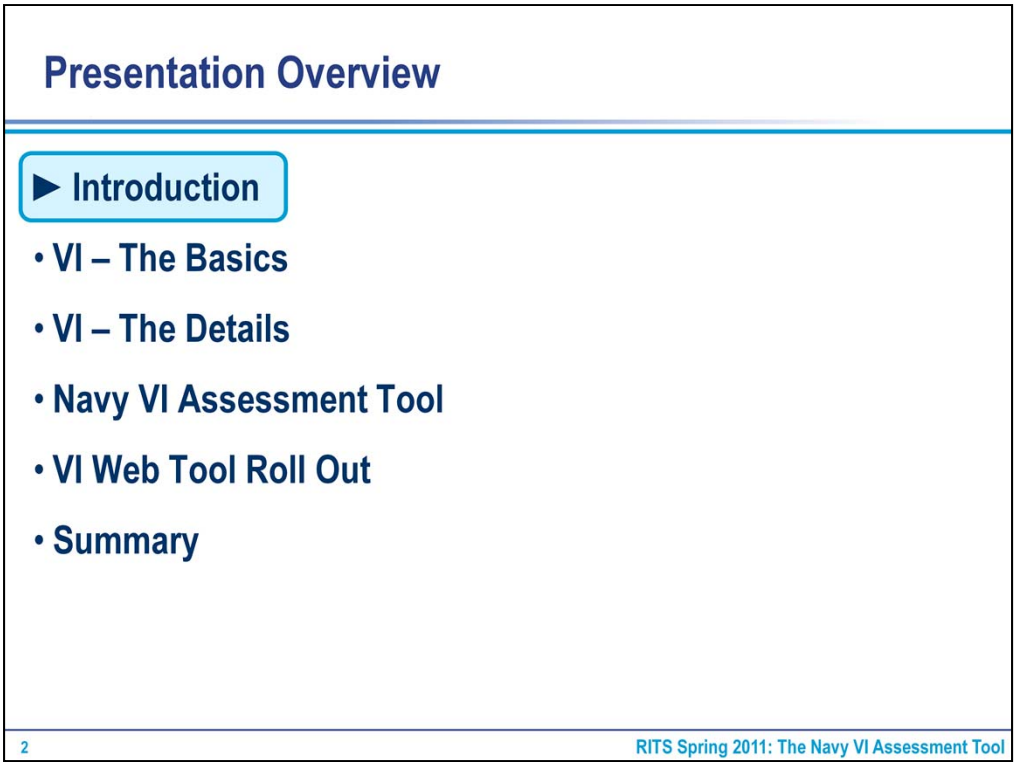


I am Donna Caldwell with NAVFAC Atlantic. I've been working on the Navy's restoration program since 1999. But for the past three years, I've only been with NAVFAC Atlantic. This has also been a collaborative effort with the engineering services center to bring the expertise of Battelle for computer web design and programming, we coordinated to ensure that this tool is compatible with NIRIS and we also solicited review during design of this tool from industry experts and we have a lot of scientific power behind this tool.



Today we're going to start off with a brief introduction and then walk you through the science of vapor intrusion, both the basics and the details. Then we'll go live to the website and I'll walk you through the tool. We'll talk about how we're going to roll this out so you can use it as a resource. And then our take home messages. I want to talk about the results of our vapor intrusion data call this past summer.

2010 VI Data Call – 116 VI Sites

- Vapor intrusion is all about indoor air (IA) – the medium of concern
- Chemicals of Concern
  - ~85% chlorinated groundwater plumes
  - ~10% petroleum plumes
  - ~5% both chlorinated and petroleum mixed
  - NAPL present at 33 sites (28%)

FEC	BRAC NE	
RPM	Ted Baker	
Installation	NAS Burton	
Sites	Eastern Plume	Site 29
Type of Contamination (select from dropdown)	Chlorinated	Chlorinated
DNAPL or LNAPL Present (select from dropdown)	No	No
Source Zone (select from dropdown)	Groundwater (Beneath Bldg.)	Groundwater (Near Bldg.)

- Samples Collected
  - 21 sites indoor air samples – generally fewer than 10 samples per site
  - 16 sites concurrent indoor air and subslab samples
- Samples planned
  - 49 sites indoor air sampling FY11-FY12
  - 15 of 49 sites with concurrent indoor air and subslab samples FY11
  - 8 of these represent first time indoor air sampling
- ~50 % of sites are pre-ROD and 50% are post-ROD
- ~ 75% of the sites for current buildings

3 Introduction RITS Spring 2011: The Navy VI Assessment Tool

We have 116 sites identified. If you remember, in 2008 we had seventy five sites that we were looking at this pathway on. But one thing that hasn't changed is that we're still looking at about 85% of our sites associated with chlorinated solvent plumes we have not collected a great deal of indoor air data, only 21 sites so far but that's going to change based on the recent data call. We're looking at about 49 sites where indoor air sampling is planned. I think it's interesting that we're about 50/50 pre run and post run for assessing this pathway so that shows the influence of the 5 year review process in assessing vapor intrusion. We have about 25% of our RPMs trying to manage this pathway in the absence of any buildings—mostly in our BRAC sites looking at relinquishing properties.

What you should get from this presentation?

- **Basic science of vapor intrusion**
  - Source/migration/receptors
- **Fundamental truths**
  - Multiple lines of evidence are typical for VI evaluations
  - Not all lines of evidence are created equal
  - Strength of the evidence depends on the conceptual site model (CSM)
- **How to use tool to meet challenges in VI evaluations**
  - Spatial/temporal variability of data
  - Background sources (indoor and outdoor)
  - Determining the significance of the evidence
  - Evolving science of VI/regulatory variability

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF SOLID WASTE AND EMEGENCY RESPONSE

REVIEW OF THE DRAFT 2002 SUBSURFACE VAPOR INTRUSION GUIDANCE

BACKGROUND

Vapor intrusion is a potential pathway for human exposure to subsurface contamination. Vapor intrusion occurs when volatile compounds migrate from contaminated groundwater or soil into the indoor air of an overlying or nearby building. Vapor intrusion can result in human exposure to vapor-forming chemicals, such as volatile organic compounds (VOCs) and some other organic and inorganic compounds, which may pose a potential health risk.

In November 2002, the U.S. Environmental Protection Agency (EPA) released the *Draft OSWER Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soil (Subsurface Vapor Intrusion Guidance)* (EPA 530-D-02-004, henceforth referred to as 2002 Draft Vapor Intrusion Guidance).1 Since the November 2002 Draft Vapor Intrusion Guidance was released, EPA's knowledge and experience with vapor intrusion has increased considerably. In the past 8 years, federal and state cleanup agencies have been investigating contaminated sites across the country for possible exposure via the vapor intrusion pathway, and when warranted, have taken action to significantly reduce vapor intrusion exposure. These experiences have led to an improved understanding and approaches for assessing and managing vapor intrusion.

In 2009, EPA's Office of the Inspector General (OIG) released the evaluation report *Lack of Final Guidance on Vapor Intrusion Impedes Efforts to Address Indoor Air Risks* (Report No. 10-P-042; U.S. EPA, 2009a) and made a number of recommendations regarding vapor intrusion guidance efforts. Among other things, the OIG recommended that EPA identify and publicly report the portions of Office of Solid Waste and Emergency Response's (OSWER's) November

1 The 2002 Draft Vapor Intrusion Guidance was designed for investigations of vapor intrusion conducted under authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA), and other relevant authorities and programs, such as Brownfields. However, it was not recommended for use at Subtitle I Underground Storage Tank sites. Available at: http://www.epa.gov/epawaste/hazard/correctiveaction/eis/vapor/complete.pdf

1

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So let's talk about what you should get from this presentation. There are three fundamental truths associated with vapor intrusion. The first is that multiple lines of evidence are typical for VI and required when you're talking about VI. Secondly, not all lines of evidence are created equal and then thirdly and very importantly the line of evidence and the strength associated with that evidence depends on the conceptual site model. This tool will help you as RPMs overcome some of these challenges here such as spatial and temporal variability, you may have heard the phrase that's been coined: "variability is the norm". We do have significant variability. Dealing with background sources, anytime you're sampling indoor air you do have to deal with the background sources. And then ultimately, how do you determine what is significant and what is not significant. And then as many of you know, the science of VI is continuing to evolve.

Navy VI Guidance and Resources*

- Navy VI Policy (2008)
- DoD Vapor Intrusion Handbook (DoD, 2009)
- Vapor Intrusion Assessment Tool (password protected during beta testing, Beta Tester POC for each FEC will be identified)
- Guidance for Environmental Background Analysis, Volume IV: VI Pathway
- Vapor Intrusion Web Site
- Review of Best Practices, Knowledge and Data Gaps, and Research Opportunities of the U.S. Department of Navy Vapor Intrusion Focus Areas. (DON, 2009)

*See reference list at the end of this presentation

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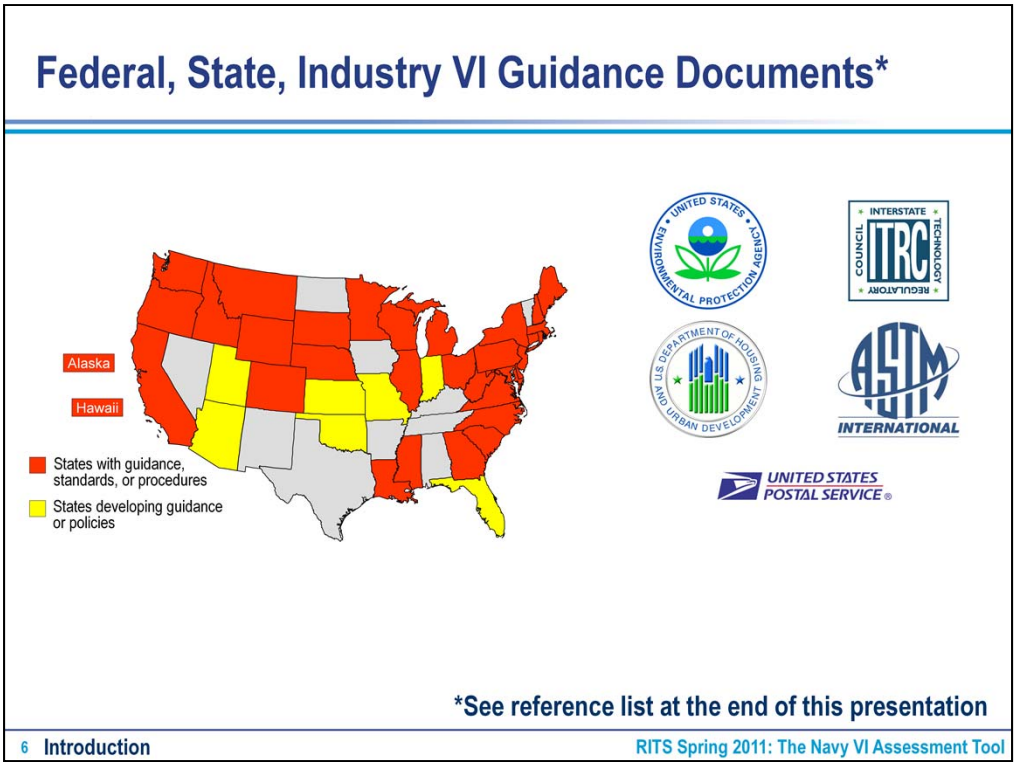
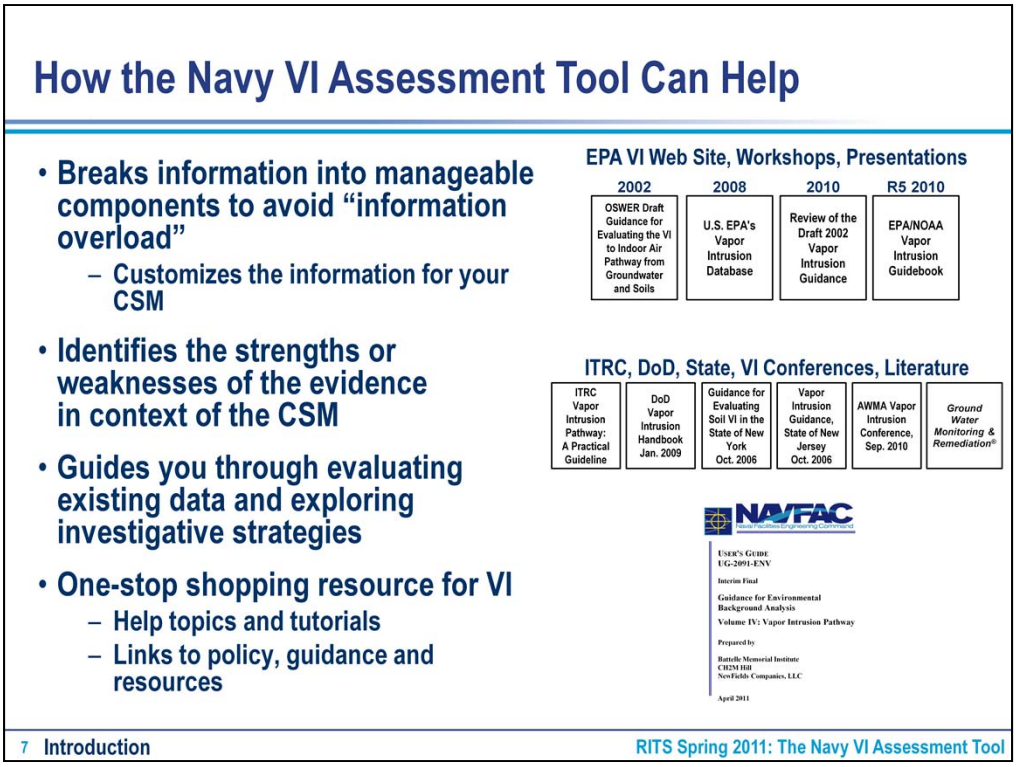
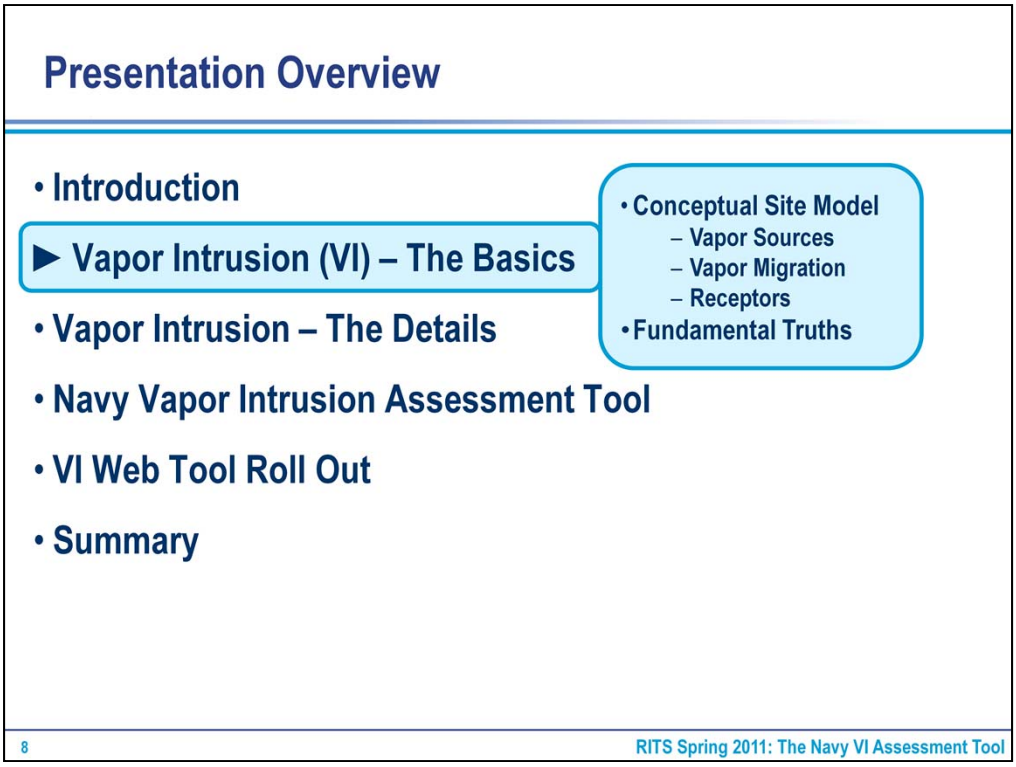
This is just a resource, you'll find it in your notebook. So you can see the Navy has been very active in the developing VI policy and guidance.



This is a slide that shows you how many different states across the country have developed guidance, or have standards or policies for dealing with VI. In addition to that, you can see there are quite a few federal agencies. How many of you knew that when you went to the post office that you could ask them for their recent guidance document? So there is a lot of interest and if I were to stack those documents on the desk right here we'd probably be talking a pile that's a good 3 ft high. So how, as RPMs, are you supposed to deal with that? I know you enjoy weekend reading and if you have trouble sleeping at night, grab a couple of these documents and put them on your night stand and it will definitely solve the problem.



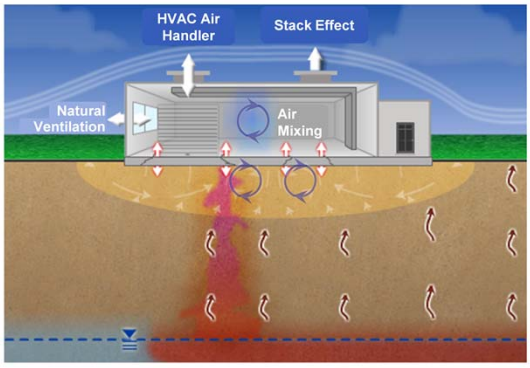
But how can this tool help you? Ultimately, it breaks the information into manageable chunks in an effort to help you avoid "information overload". It's very easy in VI to become overloaded. The power behind this tool is that it helps you identify the strengths and weakness associated with your evidence in the context of your conceptual site model. Not only does it help you evaluate your data, but it will help you explore investigative strategies—pick the best one for your site. It is designed to be a one stop shopping resource we've incorporated help topics, tutorials and links to policy, guidance and resource documents in the tool.



So let's talk about the basics and then we'll get into the details.

What is Vapor Intrusion?

- Migration of sufficiently volatile chemicals from subsurface (groundwater, soil, soil gas) into indoor air
- Vapor migration in vadose zone
  - Diffusion
  - Advection/convection
- Transport to indoor



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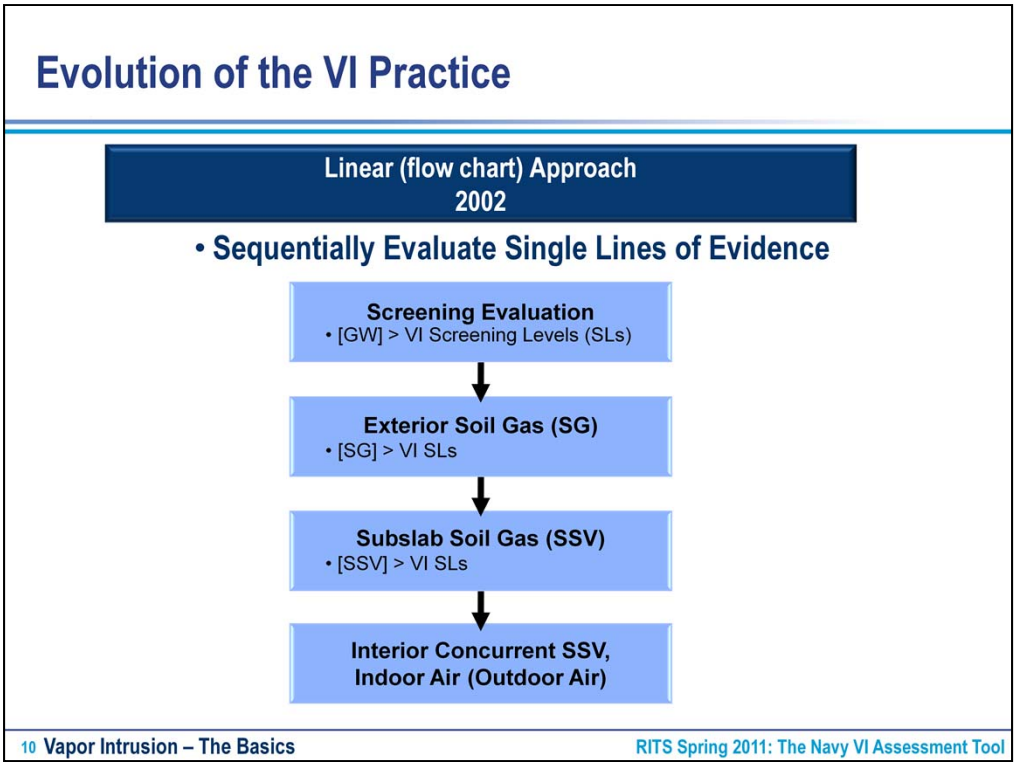
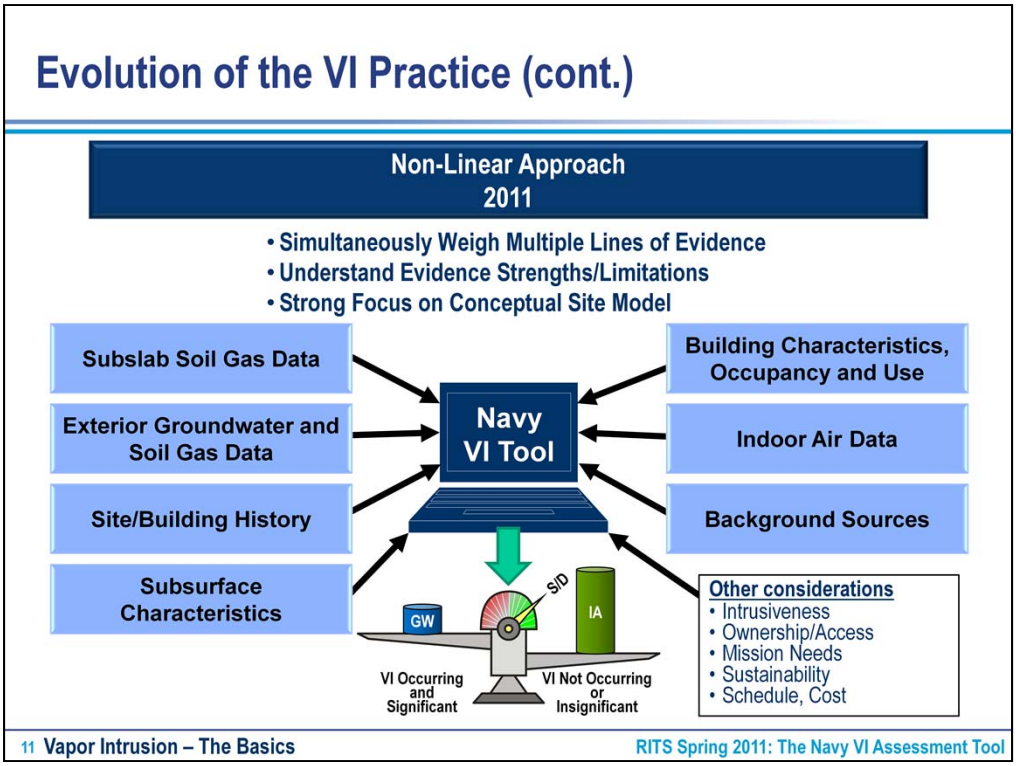
EPA defines it as the migration of sufficiently volatile chemicals from the subsurface into indoor air. We'll talk about those processes in a bit more detail on the next few slides. The vapor migration in the subsurface offgassing from groundwater--the migration in subsurfaces is mainly predominated by diffusion and only diffusion. Once those vapors reach the zone of influence below the building—and that is the envelope associated with the building where, as a result of air movement within the building and pressure differentials, the air actually reaches down into the subsurface and advection and convection, (remember advection is just the mechanical movement of air, it is not diffusion it is forced air) and then transporting to the indoor air and mixing.



The evolution of the VI process. Here we are at about 10 years after EPA released their guidance document. They're planning on updating their guidance next year, and back in 2002 we generally took a linear or flowchart type of approach. When you look at the 2002 document, you'll see these flowcharts and some of them have 50 or so boxes associated with those flowcharts. We really stopped linear flow charting back in 2002 and that's really changed. Here we are in 2011 and there are three fundamental truths associated with vapor intrusion.



We're no longer thinking linearly, you can see here are the multiple lines of evidence that we can feed into this tool and sift through. Considering them simultaneously and ultimately then our goal is to weigh those lines of evidence and draw a conclusion from them to identify a particular pathway. Notice that these lines of evidence are not all analytical; there are a number of non analytical lines of evidence. Don't forget you have clear considerations that are risk management types of considerations.

What is sufficiently volatile?

- Henry's Law Constant > 10^{-5} atm m^3/mol
- DoD Vapor Intrusion Handbook Appendix A (June 2009)
  - Volatile organic compounds
  - Select semi-volatile organic compounds
  - Some inorganic
    - Elemental mercury
    - Hydrogen sulfide
- Most current volatility/toxicity information is available in EPA regional screening level (RSL) tables

DoD Vapor Intrusion Handbook Appendix A:
Chemicals that are Sufficiently Volatile and Toxic

Analyte	CAS No.	Sufficiently Volatile?	Suffuciently Toxic?
Acetaldehyde	75-07-0	YES	YES
Acetone	67-64-1	YES	YES
Acetonitrile	75-05-8	YES	YES
Acetophenone	98-86-2	YES	NA
Acrolein	107-02-8	YES	YES
Acrylonitrile	107-13-1	YES	YES
Aldrin	309-00-2	YES	YES
Ammonium Perchlorate	7790-98-9	NA	NA
Aniline	62-53-3	YES	YES
Benzaldehyde	100-52-7	YES	NA
Benzene	71-43-2	YES	YES
Benzoic Acid	65-85-0	NO	NA
Benzyl Alchohol	100-51-6	YES	NA
Benzyl Chloride	100-44-7	YES	YES
Biphenyl, 1,1'-	92-52-4	YES	NA
Bis(2-chloroethyl)ether	111-44-4	YES	YES
Bis(2-chloro-1-methylethyl)ether	108-60-1	YES	YES
Bis(2-ethylhexyl)phthalate	117-81-7	YES	NA
Bis(chloromethyl)ether	542-88-1	YES	YES
Bromodichloromethane	75-27-4	YES	NA
Bromoform	75-25-2	YES	YES
Bromomethane	74-83-9	YES	YES
Butadiene, 1,3-	106-99-0	YES	YES
Butanol, N-	71-36-3	YES	NA
Butyl Benzyl Phthalate	85-68-7	YES	NA
Carbon Disulfide	75-15-0	YES	YES
Carbon Tetrachloride	56-23-5	YES	YES
Chlordane	12789-03-6	YES	YES
Chloro-1,3-butadiene, 2-	126-99-8	YES	YES

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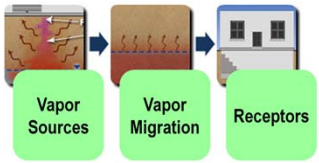
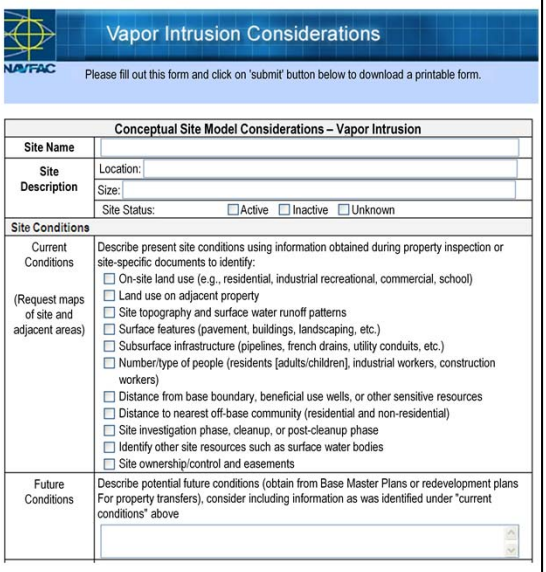
Now what do I mean when I say a chemical is sufficiently volatile. In the 2002 document they defined it as a chemical with a Henry's Law constant greater than this value here. The DOD VI document, in an appendix, lists chemicals that are sufficiently volatile and toxic. So you have to have sufficient volatility and toxicity to be concerned about a chemical. This table was based on the EPA 2002 guidance therefore it is really important that you go to the EPA regional screening level and make sure that you have the most current definition of volatile and toxicity always changes and the EPA is trying to capture that in their tables.

Conceptual Site Model (CSM)

- **CSM Resource – ERT2 Multimedia Training Tools**
- **Develop CSM**



- **Multiple lines of evidence**
  - **Analytical**
  - **Non-analytical**



NAVFAC

Vapor Intrusion Considerations

Please fill out this form and click on 'submit' button below to download a printable form.

Conceptual Site Model Considerations – Vapor Intrusion	
Site Name	
Site Description	Location:
	Size:
	Site Status: ☐ Active ☐ Inactive ☐ Unknown
Site Conditions	
Current Conditions (Request maps of site and adjacent areas)	Describe present site conditions using information obtained during property inspection or site-specific documents to identify: ☐ On-site land use (e.g., residential, industrial recreational, commercial, school) ☐ Land use on adjacent property ☐ Site topography and surface water runoff patterns ☐ Surface features (pavement, buildings, landscaping, etc.) ☐ Subsurface infrastructure (pipelines, french drains, utility conduits, etc.) ☐ Number/type of people (residents [adults/children], industrial workers, construction workers) ☐ Distance from base boundary, beneficial use wells, or other sensitive resources ☐ Distance to nearest off-base community (residential and non-residential) ☐ Site investigation phase, cleanup, or post-cleanup phase ☐ Identify other site resources such as surface water bodies ☐ Site ownership/control and easements
Future Conditions	Describe potential future conditions (obtain from Base Master Plans or redevelopment plans For property transfers), consider including information as was identified under "current conditions" above

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The Navy has developed a resource to develop conceptual site models. There's actually a module within that tool specific to VI, and so there's a screenshot of a CSM checklist to help guide you through that for vapor intrusion. With respect to the CSM you really need three things for the VI pathway to really even be a concern.

#1 you need a source of vapors

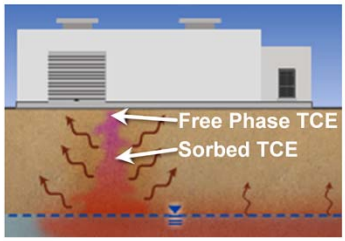
#2 you need those vapors to be able to migrate through the vadose zone into the building and

#3 you need receptors for the pathway to be complete.

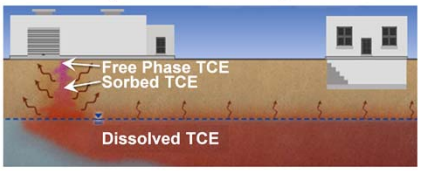
CSM – Vapor Sources

- Primary (CERCLA) release of volatile chemicals
- Presence/absence of non-aqueous-phase liquid (NAPL)
- Composition, concentration, and distribution of volatiles in soil, groundwater, soil gas
- Vertical and horizontal distances between vapor sources and buildings

Primary Source



Primary Source-to-Building Distance

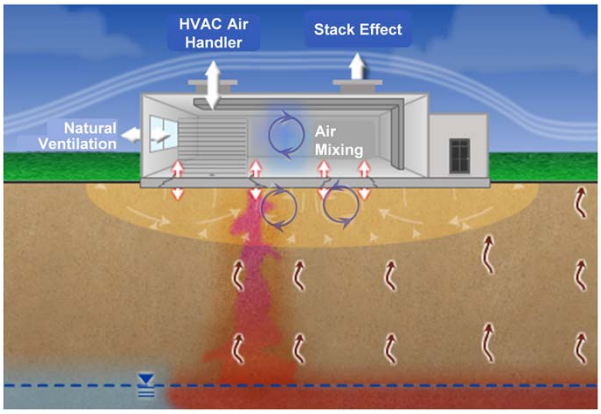


So let's talk about sources then. In the environmental restoration program, you're primarily interested in your CERCLA release sources. Those sources can exist as NAPL—chemicals sorbed to the soil or get dissolved in the groundwater. The concentration and distribution of those chemicals are extremely important and the vertical and horizontal distance is also a very important factor when you begin to evaluate the VI factor.

CSM – Vapor Migration

What is it?

- **Subsurface transport (diffusion, advection, attenuation)**
- **Migration across the building slab**
- **Mixing with indoor air**



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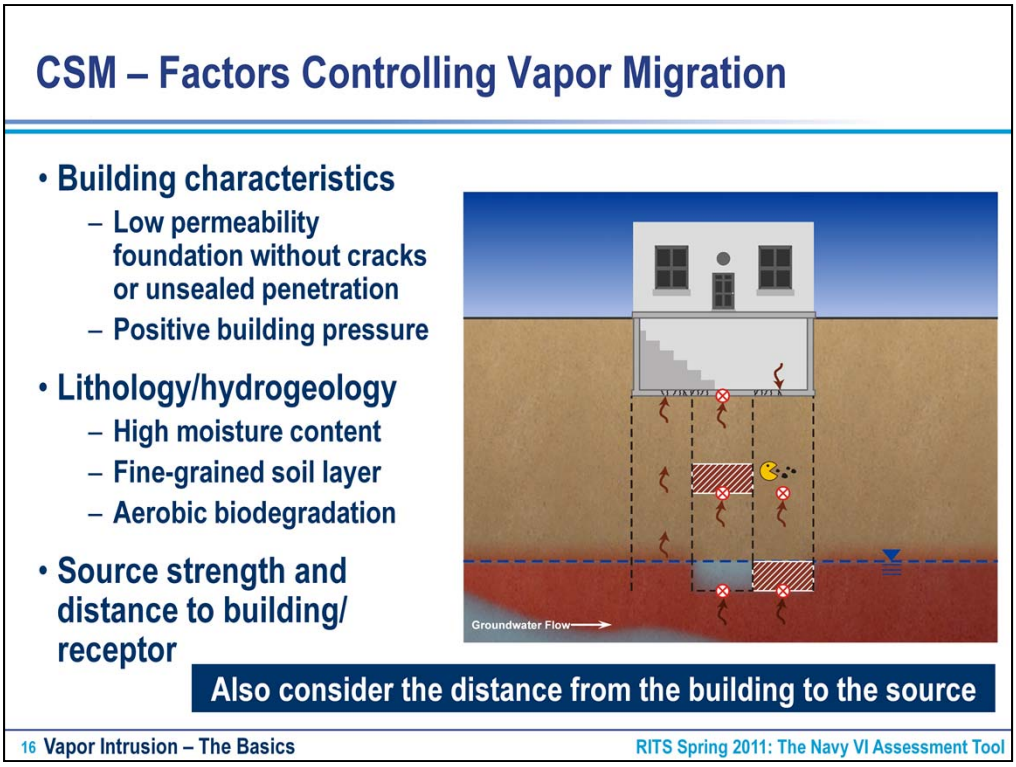
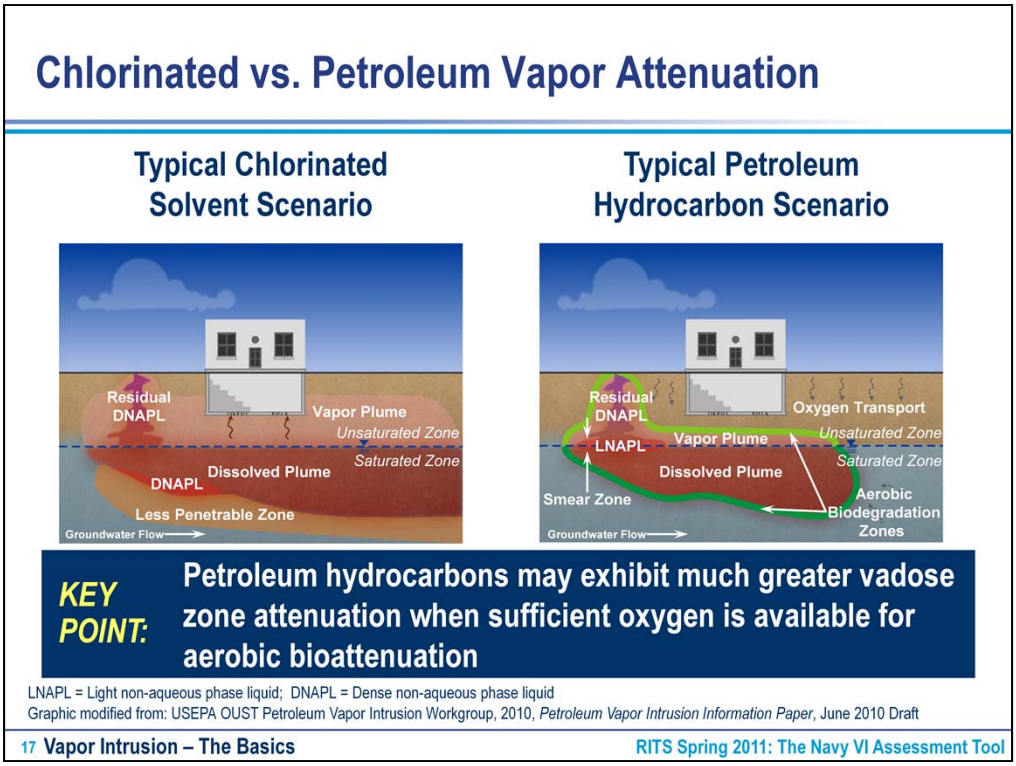
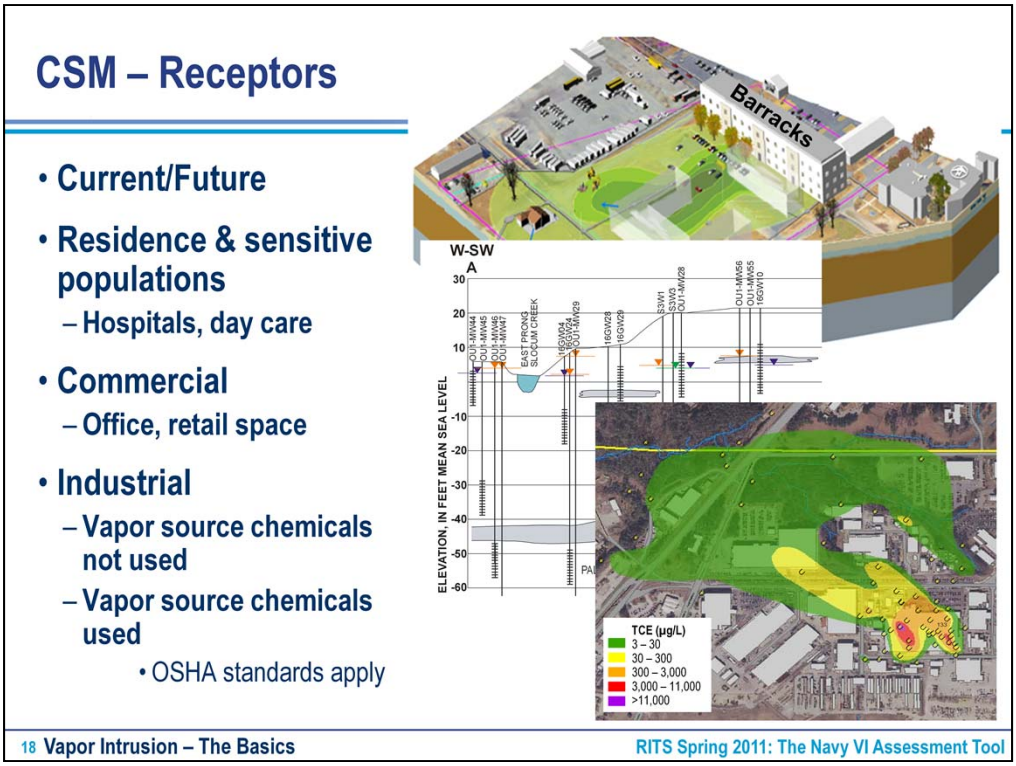
So let's talk about that migration process. I've already talked a bit about advection but what I didn't mention was this attenuation. As the vapors are moving in the subsurface and migrating into the building mixing with the air, you will have some level of attenuation. Determining that level of attenuation is the main check column of vapor intrusion. We'll notice here with respect to the amount of migration across the slab that I show arrows in both directions. If you're looking at the 2002 guidance or even the ITRC guidance, they only show vapors coming into the building, but it's really important to remember that a building actually breathes. I'm standing right next to one of those big vents and they're noisy in commercial/industrial type of buildings that airflow in that building can be quite significant.



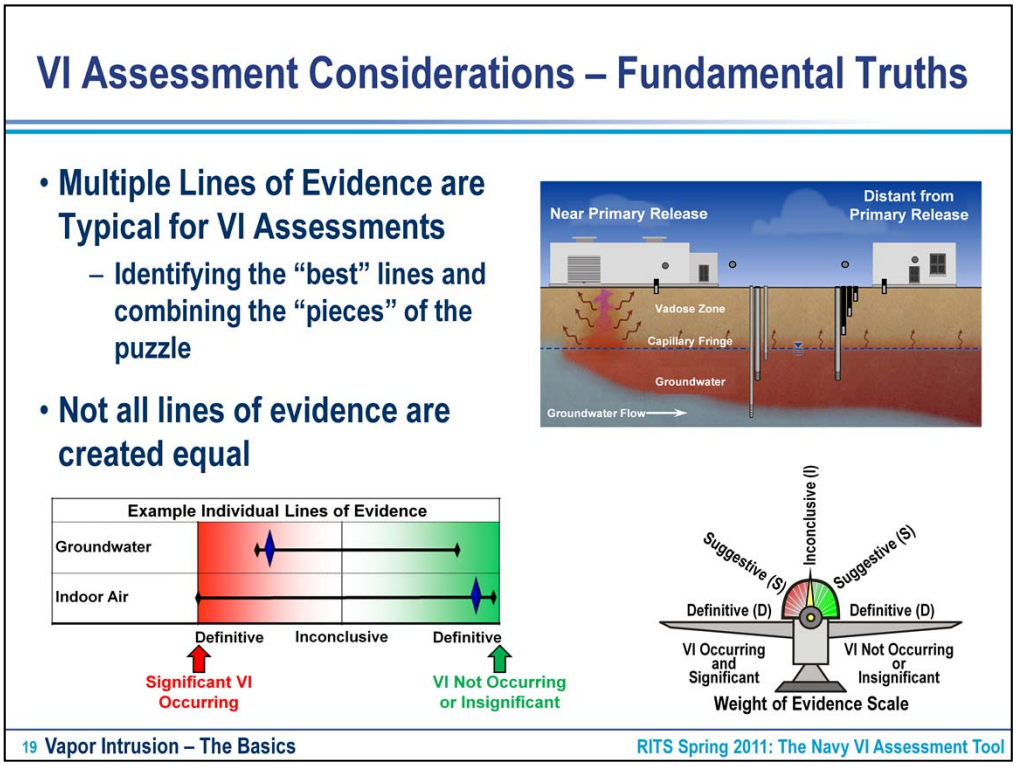
So what are the factors controlling vapor migration? There's building characteristics, lithology/hydrogeology, and then the source strength and distance. Characteristics associated with the building, we list low permeability slabs: with many of your sites those buildings have very very competent slabs. We're going to be going to a base and drilling through 30" of slab to install a subslab probe, so you'll find that your buildings do have very competent slabs so that can play a role in controlling the movement of volatiles into the building. Not only that, I mentioned pressure, this is a pressure relative to the subslab so indoor:subslab. If your building is positively pressurized—if you walk into a Lowes building or open a door and get pulled in or do you get slammed in the face with air, if you get slammed in the face with air—that building is positively pressurized, if you get pulled into the building that is most likely negatively pressurized with respect to the subslab. Lithology: we show three different soils that have high moisture content, they're typically the fine grained soils. Here's a high moisture soil here in the middle and those type of layers can be vapor barriers. Moisture has a tendency to inhibit vapor transport since that occurs in the air phase within the vadose cell—soil air pore spaces. This third one here represents aerobic biodegradation—the little pacman chewing up the particles as they're moving upwards and as you can see on this next slide.



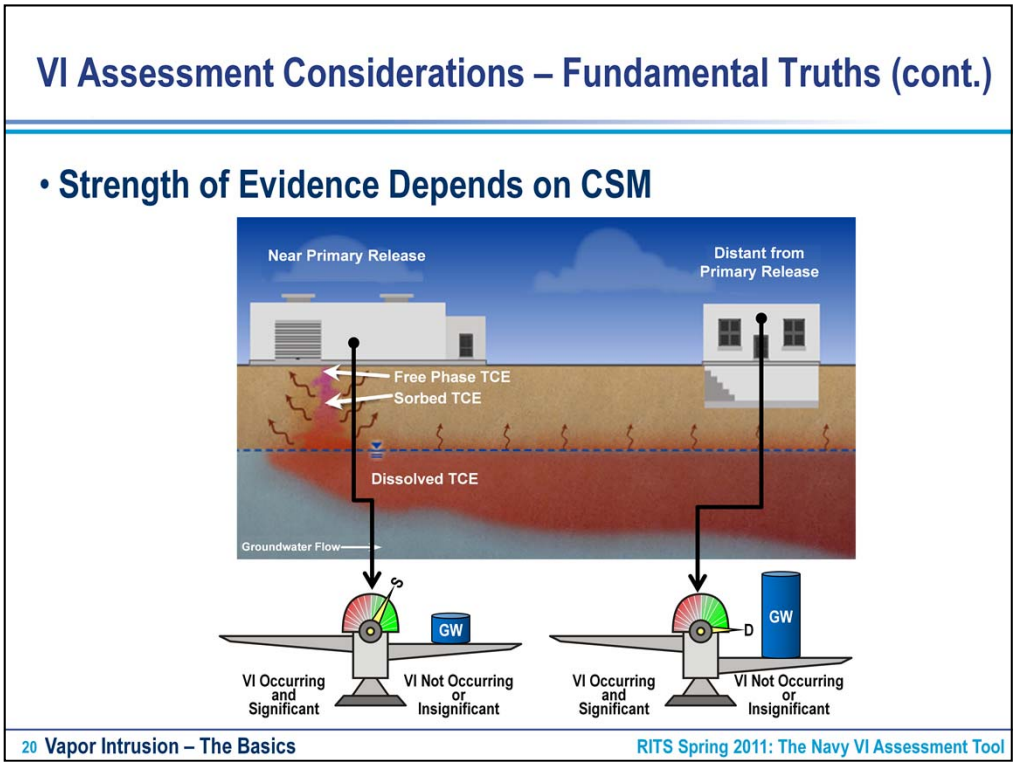
Significant aerobic biodegradation is typically more significant when you're talking about petroleum hydrocarbons. This was a slide that was presented at an EPA VI work group to depict that there's a big difference between chlorinated solvents that don't generally attenuate or biodegrade as quickly as petroleum hydrocarbons.



Receptors you need to consider current vs. future. 25% of the sites right now are sites that don't have existing buildings so you need to look at the potential for future receptors. You need to also look at the types of receptors, are they sensitive types of receptors? Are they hospitals, day cares, residential areas or are they commercial or industrial? Remember, when you're dealing with industrial sites, an important question is whether or not the chemicals that you're evaluating underneath your building are also used inside the structure. That is very common with petroleum hydrocarbons but not so common with chlorinated solvents. If that's the case you may find that OSHA standards may apply during the duration of use of those chemicals.



Let's talk a bit about those fundamental truths I mentioned. The first one, multiple lines of evidence are typically required. Not only are they typically required but it's really important that you think about which are the best and then to start putting them together as you would a puzzle. What do I mean by not all lines of evidence are created equal. That's depicted here by this scale. So, on this scale you see VI not occurring or insignificant on the right side and you can have vapor intrusion occur, but if it's not significant then we're going to be on the right side. But on the left side you have VI occurring but it needs to be significant. And then this scale is to represent for each individual line of evidence and then for the cumulative lines of evidence, the definitive evidence suggestive or inconclusive in both directions. As you begin to use this tool we represent these with slider bars, each line of evidence is a row and then, as you can see, the green side indicates VI not occurring or insignificant and the red side indicates significant VI occurring and then we have definitive, suggestive and inconclusive and we use these diamonds to indicate where you're going to ultimately decide where the line of evidence lies on this slider scale. The black bars represent the range of possibilities for that particular line of evidence for your particular conceptual site model.



The third fundamental truth: the strength of the evidence relies on the conceptual site model. What do we mean by that? Lets take this scenario here where you have a release very close to this building, it impacts the groundwater and it migrates downgradient and you have a building there. You decided to collect some top-of-the-groundwater water quality data. You've done a really good job and you have spatial and temporal variability and your groundwater concentrations at the top of the water table, beneath or very close to the top of the water table are below your screening levels so what should we designate in terms of the strength of that particular line of evidence? You'll see here we use a large weigh to depict that in that case that vapor intrusion is not a significant path of concern assuming you use conservative screening measures. Now lets do this again the same thing over here by this building, we've addressed spatial concerns and temporal concerns all of our concentrations are below screening levels. How many of you would draw the same conclusion for this building on the left side, would you say this intrusion is the same and all of your concentrations were below screening levels. Notice that the size of the weight is smaller and the needle is only barely into suggestive. If you have a release associate with the building, we call that a primary release in this tool—a release in this zone, that release will and can be a potential vapor release source. Even if your groundwater concentrations are below levels, that only provides suggestive evidence because you still have some sources below that building. Therefore, not all sources of evidence are created equal, in fact the same

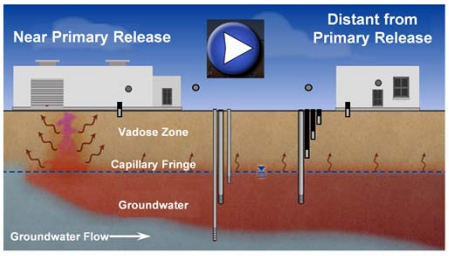
line of evidence, depending upon your CSM , can be definitive or only suggestive.

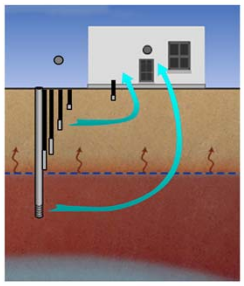
Presentation Overview

- Introduction
- Vapor Intrusion (VI) – The Basics
- ► Vapor Intrusion – The Details
  - VI Assessment Considerations
    - Groundwater & Soil Gas
    - Indoor Air
- Navy Vapor Intrusion Assessment Tool
- VI Web Tool Roll Out
- Summary

VI Assessment Considerations – Groundwater & Soil Gas

- Indoor air concentrations can only be predicted from subsurface data
- Transport mechanisms and uncertainties
  - Volatilization from groundwater and transport across capillary fringe
  - Soil gas migration in unsaturated zone
  - Transport of vapors across building slab
  - Mixing with indoor air





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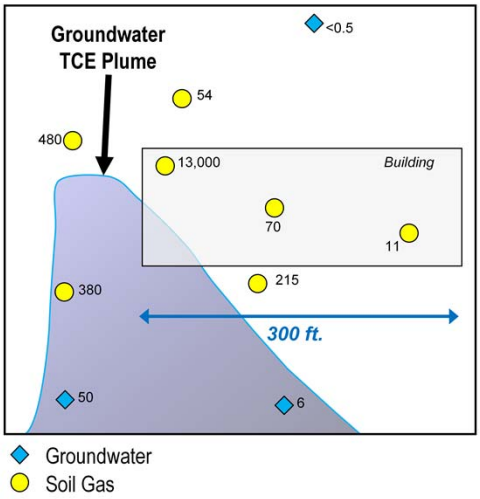
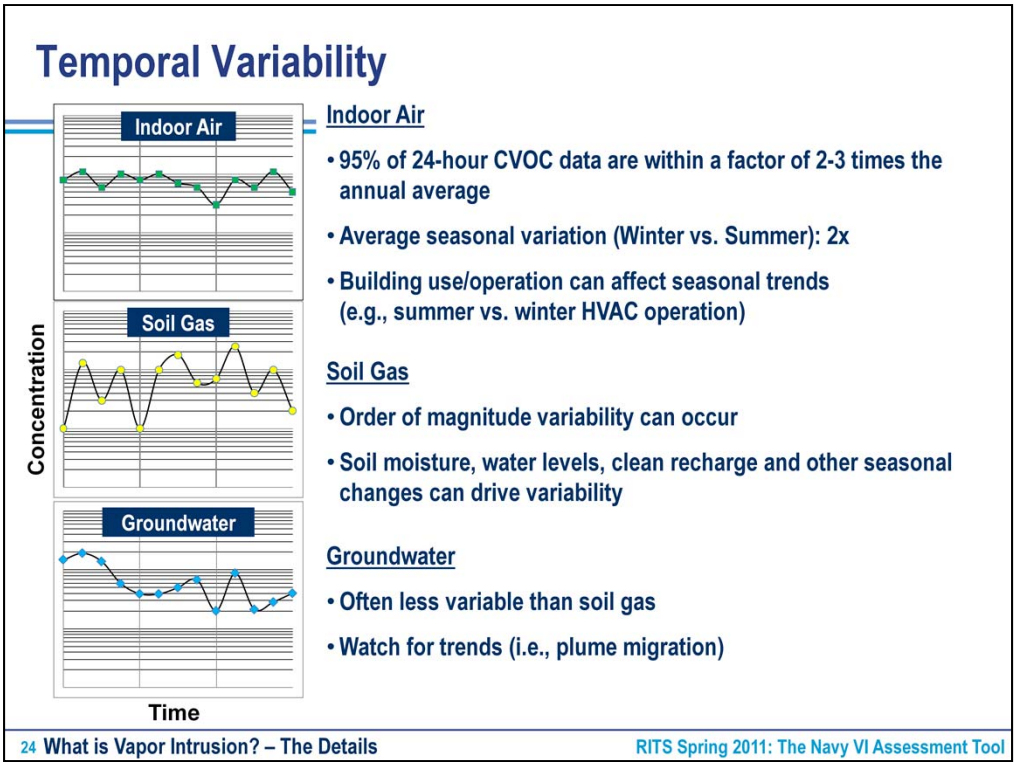
Let's talk a little bit more about the line of evidence, remember indoor air can only be predicted from subsurface data. So that's one of the reasons why you're going to see that needle, or that line of evidence be suggestive when you're looking at groundwater or soil gas data. We're talking about those soil transport mechanisms.

Subsurface Spatial Variability

- Can vary by orders of magnitude, requiring more samples
- Important to understand CSM (releases, attenuation)
- May be difficult to correlate groundwater/exterior soil gas/subslab



Here's the importance of subsurface data when considering special variability. Spatial variability in the subsurface can be orders of magnitude. Here's an example. We've a groundwater plume associated with an upgradient contaminant release, the groundwater plume is within a critical distance of the building, so we collect some exterior soil gas data and some subslab soil gas data. Notice what happened. Here's the highest concentration in that northwest corner near the groundwater source. What is the source of that? Is it just inherent variability or do you think there's some reason for that concentration? There was actually an oil water separator in that corner of the building. If you're not looking at all the potential sources, even if you're looking at all the sources, that oil-water separator has widespread groundwater plume. We are finding more and more often that you can have releases, and because of all of the pavement and the lack of infiltration, those releases just hang out right below the slab.



•Temporal variability. So three different media we typically sample, indoor air, soil gas and groundwater. When you're in the indoor air the temporal variability is not as great as when you move into the subsurface or even the groundwater. There are a couple of legacy sites INDICOT and then a Department of Transportation site in Denver, where they looked at upwards of 10 years of data they've determined that a majority of the data associated with the 24-hr samples are within 2-3 times the annual average so they were sampling monthly in some cases and then there was a seasonal variation with 24-hr summa canisters of about two-fold. We are better understanding that building use and operation can affect these seasonal trends so you may see larger variability than I'm showing here, but once you move to the soil gas there's a considerably greater amount of variability and that's due to the soil moisture, water levels, the ability to recharge, and other seasonal effects and once you're in groundwater it's less variable but be sure to watch for trends.

VI Assessment Considerations – Groundwater & Soil Gas

- **Predicting indoor air concentrations from groundwater or soil gas**
  - **Use an Attenuation Factor (AF) to predict indoor air concentrations**

Predicted IA_{GW} = Vapor concentration at water table * AF_{GW-IA}

Predicted IA_{SG} = Soil gas concentration * AF_{SG-IA}

  - **Methods to estimate AFs**
    - Numerical modeling (e.g., Johnson & Ettinger)
    - Empirically developed
      - EPA 2008 database (primarily residential)
      - Site-specific data
        - » Tracer compounds (radon)
        - » Paired subslab and indoor air

GW = groundwater
IA = indoor air
SG = soil gas

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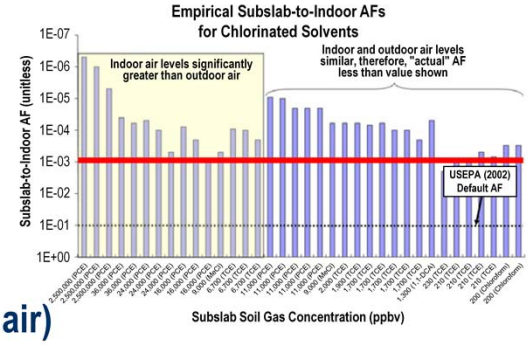
We predict indoor air concentrations when you're measuring subsurface concentrations. We do that using an attenuation factor: simply a ratio of indoor air to subsurface. You have to be careful in how you come up with your sub surface factors because you can bias by orders of magnitude, but assuming you have a good attenuation factor, you take the concentration in the subsurface, for groundwater we move it out of the groundwater with Henry's law then we apply the attenuation factor. For soil gas, you just apply it directly. And that's how you ultimately predict your indoor air concentration. How do we come up with those attenuation factors? Two different ways. We either model the AF with, for example, the Johnson and Ettinger model, or you can empirically derive those comparing the indoor air to the subslab after applying the filtering criteria. EPA has taken this approach to come up with empirical AF using paired subslab and indoor air data. You can even do a better job if you use a tracer compound like radon.

VI Assessment Considerations – Groundwater & Soil Gas

Empirical AFs

- **EPA 2008 Database of Empirical AFs**
  - **Based on ~85% residential**
    - 1E-06 to 1E-03 for groundwater
    - 1E-06 to 1E-01 for soil gas
  - **Industrial building AFs not available**
- **Example empirical AFs for Navy industrial buildings (subslab soil gas to indoor air)**
  - **Range from 1E-06 to 1E-03**



Here is that EPA database. They first released the database in 2002 and then they updated it in 2008. Unfortunately its about 85% residential and, for most of your Navy buildings, it's not terribly helpful. Those attenuation factors range from 1E-6 to 1E-3 for groundwater and 1in a million attenuation to one in a thousand attenuation. For soil gas its one in a million all the way up to one in ten. Kind of a worst case scenario, EPA assumes attenuating by a factor of ten. Remember, industrial building attenuation is not available in the EPA database. So we're just showing an example here of a Navy base where we collected data from several buildings and filtered the data and ultimately calculated attenuation factors and, as you can see for those industrial buildings, for subslab to indoor air, the attenuation factors range from 1E-06 to 1E-03. That's shown here with this red line and focus on the yellow area here and those are the buildings where vapor intrusion was likely really occurring and we're not biasing our attenuation factors. But compare 1/1000 to the EPA default of 1 in 10. The buildings, we are seeing significant differences in attenuation vs. EPA default of 1 in ten. Keep that in mind.

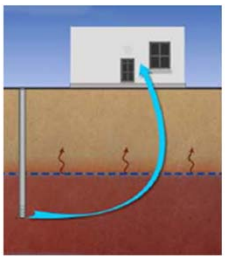
VI Assessment Considerations – Groundwater & Soil Gas

Screening Levels (SLs)

- **Comparing groundwater and soil gas data with screening levels**
  - **Screening levels are concentrations that yield acceptable indoor air concentrations**
  - **Calculating screening levels**
    - Start with acceptable indoor air concentration (EPA or state) and apply an AF

$$SL_{GW} = \frac{\text{Acceptable Indoor Air Concentration}}{AF_{GW\text{-}IA} * H}$$

$$SL_{SG} = \frac{\text{Acceptable Indoor Air Concentration}}{AF_{SG\text{-}IA}}$$



Okay so I talked about how to predict indoor air, what if you just want to get a number to compare your groundwater concentration or soil gas concentration with and we call those screening levels. It's not rocket science here, all we're doing is a little bit of algebra and rearranging equations—the more important factor is that attenuation factor so all we do is rearrange the equations, start with an indoor air concentration and then back it up into the subsurface. So for groundwater take that indoor air, divide by attenuation factor and apply Henry's law. For soil gas, take that indoor air, divide it by the attenuation factor and you have your groundwater and soil gas screening levels. Remember they're only predictive at best.

VI Assessment Considerations – Groundwater & Soil Gas

Screening Levels: EPA vs. State

- **EPA and state screening levels vary by orders of magnitude**
  - **Assumptions in attenuation factors**
    - Uncertainty in predicting volatilization and subsurface migration and transport
  - **Target risk**
  - **Toxicity**

Agency	Tetrachloroethene (PCE)		
	Groundwater (µg/L)	Soil Gas (µg/m^3)	Indoor Air (µg/m^3)
U.S. EPA	5[(a)]	4.1	0.41
California	NA	180	0.41
New Jersey	1[(a)]	34	3
Michigan	25,000	2,100	42
Pennsylvania	42,000	NA	36

State screening values taken from Eklund (2006)
(a) Maximum contaminant level or drinking water quality standard

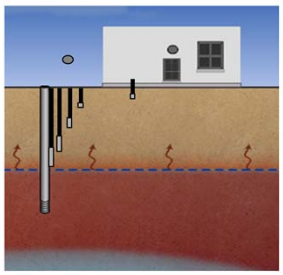
Look at the screening levels here, they can vary by orders of magnitude and that's because of the assumptions that go into those attenuation factors, assumptions made in determining acceptable target risk, and then ultimately the toxicity values a particular state or region may require you to use. So here's an example showing how variable those screening levels can be, soil gas: orders of magnitude, groundwater: orders of magnitude. So use caution. The tool does not tell you which screening level to use, that is based on your professional judgment and your site specific information.

VI Assessment Considerations – Groundwater & Soil Gas

Lines of Evidence

- Determining the strength of groundwater or soil gas data as a line of evidence
- Concentrations > SL only suggestive that VI is occurring because it is predictive

- Can be definitive that VI is not occurring when:
  - Groundwater is the only vapor source
  - Levels at or near water table are below SL
  - Site is well characterized at the water table



How do you determine the strength of evidence? Lets use groundwater or soil gas, lets say your concentrations are greater than your screening levels, what does that mean? Well, it only provides a suggestive line of evidence that vapor intrusion is occurring so notice we put the diamond right here. And notice the black bar does not extend beyond suggestive since it is suggestive at best because it's predictive. Here's the example I already gave you where groundwater can be definitive but its only definitive that groundwater vapor data is not occurring and you have to determine that groundwater is the only source and that the levels at or near the water table are below the screening level and the site is well characterized. So notice the groundwater is suggestive at this side here but its definitive that there is no significant vapor intrusion under these conditions.

VI Assessment Considerations – Indoor Air

- Vapor intrusion is all about indoor air – the medium of concern
- Factors that affect mixing of subsurface vapors with indoor air
  - Building volume
  - Ventilation (mechanical & natural)
  - Indoor-to-outdoor air exchange
- Air Exchange Rates
  - EPA default is 0.25 exchanges/hr (residential)
  - Industrial exchange rates are generally higher
    - 1 to 20 exchanges/hr

Default (residential) assumptions may not be applicable to Navy industrial buildings.

Photos courtesy of U.S. Navy

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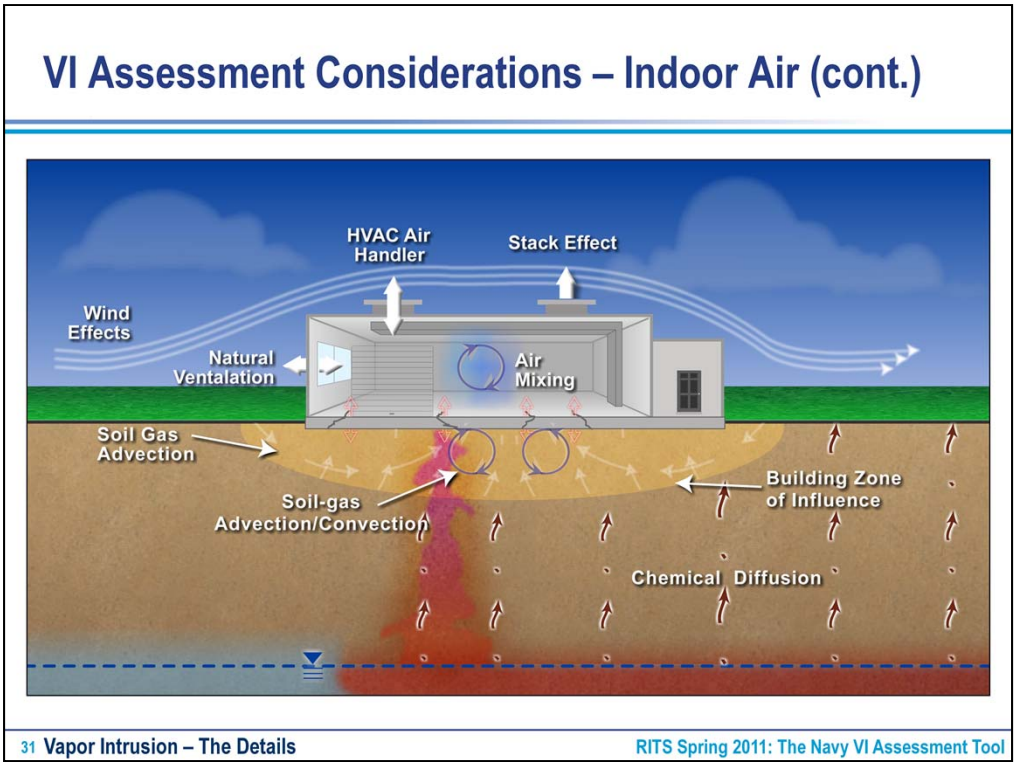
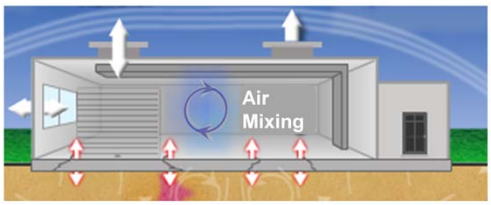
What about indoor air? We talked about groundwater and soil gas, but vapor intrusion is all about indoor air. That is the medium of concern and that is becoming more and more of an issue, don't be afraid of sampling indoor air. Factors that affect the indoor air concentration include volume, ventilation inside the building, and the indoor-to-outdoor air exchange rate. I've listed some of those indoor-to-outdoor exchange rate, the default for residential scenarios is about a quarter of the volume inside a home gets exchanged every hour, but in buildings like what we're sitting in now, those exchange rates are significantly higher, one to twenty exchanges/hour.

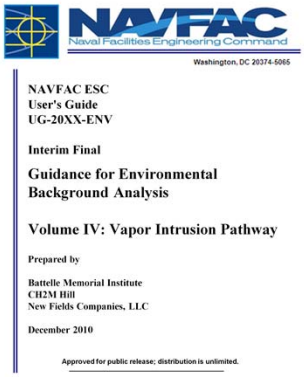


So as you can imagine that provides an environment for those vapors to get mixed and the concentrations to be lower. The only reason I'm showing this slide is to emphasize the two directional nature of ventilation in and out, the HVAC system is also an in and out scenario and the stack effect is also, when you have air flowing across openings in the building, that can create a negative pressure condition.

VI Assessment Considerations – Indoor Air
Background Evaluation

- If IA > SL_{IA} conduct background evaluation
  - Compare with site or published background outdoor/indoor air data
  - Compare constituent ratios
    - Single and/or multiple constituents
  - Background source identification
    - Building surveys
    - Real-time analyses
  - Differential pressure monitoring




NAVFAC
Naval Facilities Engineering Command
Washington, DC 20374-5065

NAVFAC ESC
User's Guide
UG-20XX-ENV

Interim Final

Guidance for Environmental Background Analysis

Volume IV: Vapor Intrusion Pathway

Prepared by

Battelle Memorial Institute
CH2M Hill
New Fields Companies, LLC

December 2010

Approved for public release; distribution is unlimited.

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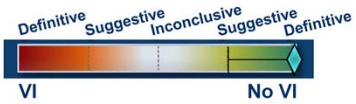
So we have background evaluation. If your indoor air concentrations are greater than your screening levels, it is absolutely critical that you conduct a background evaluation and I'm listing a number of methods that we've incorporated into the tool. We helped the navy write this guidance here on background evaluations. Conduct a background evaluation, why is that important? If your indoor air concentrations are within your screening levels, this provides a definitive line of evidence that vapor intrusion is not a significant line of concern.

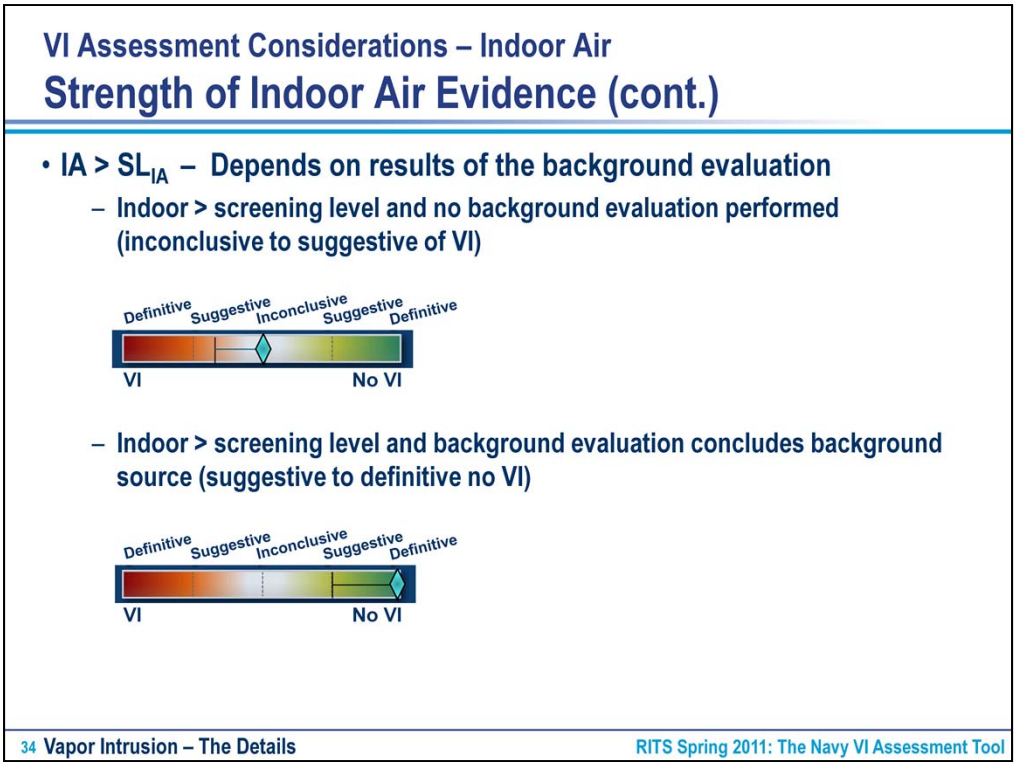
VI Assessment Considerations – Indoor Air

Strength of Indoor Air Evidence

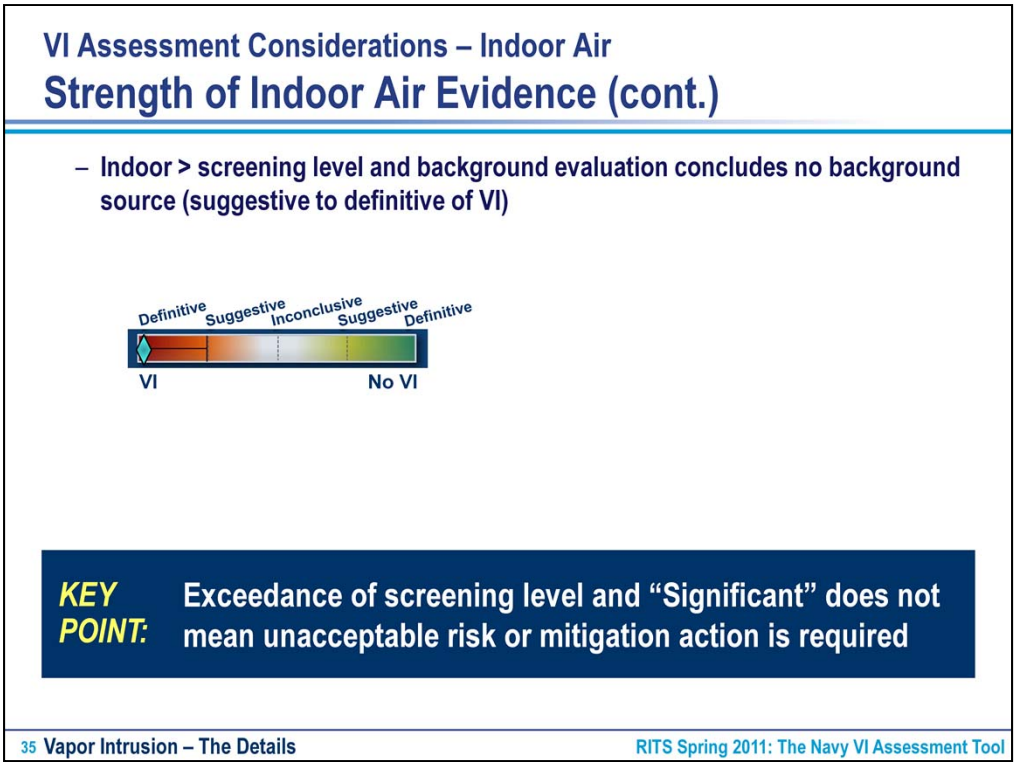
- IA < SL_{IA} – Suggestive to definitive VI not occurring or insignificant
  - Suggestive with limited spatial/temporal coverage
  - Definitive with adequate CSM and spatial/temporal indoor air data



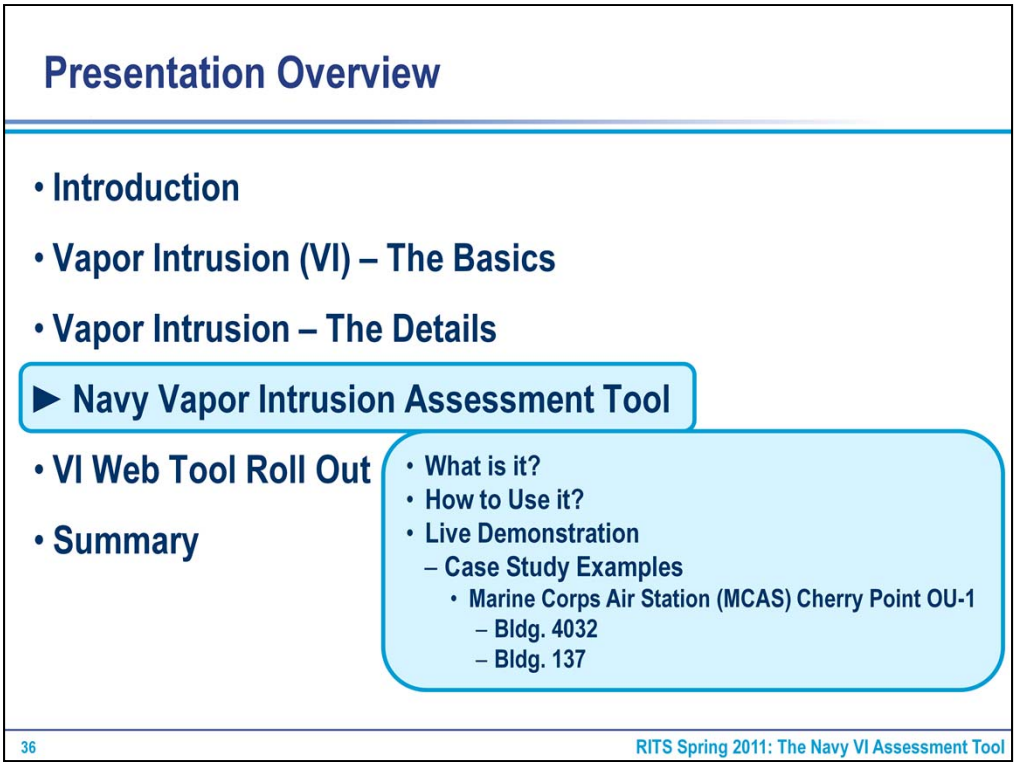
It's only suggestive if you don't adequately cover spatial and temporal variations we don't care if there's a background source as long as your concentrations are below.



But if they're above, if you do not conduct a background evaluation, your diamond sits on inconclusive. Some might argue that a concentration above a screening level is suggestive of vapor intrusion but it we'll never know if we don't do the background evaluation. So let's do the background evaluation and our background evaluation concludes that we actually have a background source. So, all of your measured indoor air concentrations are due to background. What happens to our slider? It moves clear over here to our strongly suggestive to definitive. If it's all due to background it's not a significant VI source.



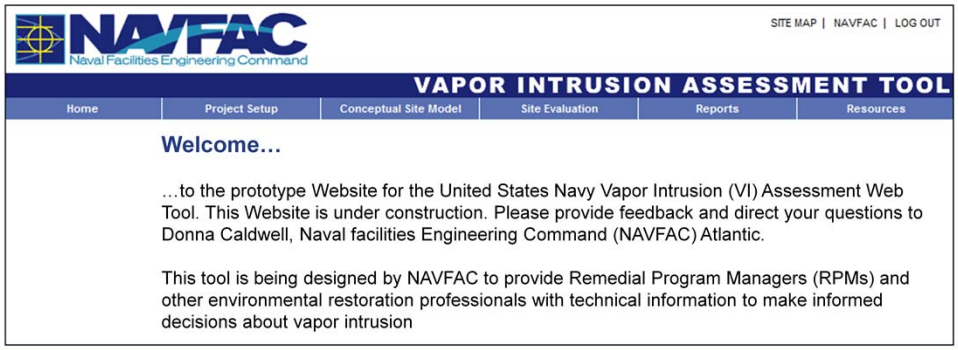
If your background evaluation concludes there are no significant background sources, our slider moves all the way over to the other end of the scale, and that provides suggestive to definitive evidence that you have vapor intrusion occurring. An exceedance of screening level and "significant" does not mean you have unacceptable risk and that mitigation action is required.



Well Loren said we'd go straight to the demo but that's not true. First I want to talk about what this tool is and how you can use it and then we'll use a case study from Marine Corps Air Station (MCAS) Cherry Point OU-1 to demonstrate how you can use this tool.

Navy VI Assessment Tool: What is it?

- A one-stop shopping resource to help Navy RPMs meet VI investigation challenges
  - Avoid information overload
  - Weighing the evidence
- Can be used to track VI sites, lessons learned, regulatory variability, and magnitude of Navy VI impacts and costs



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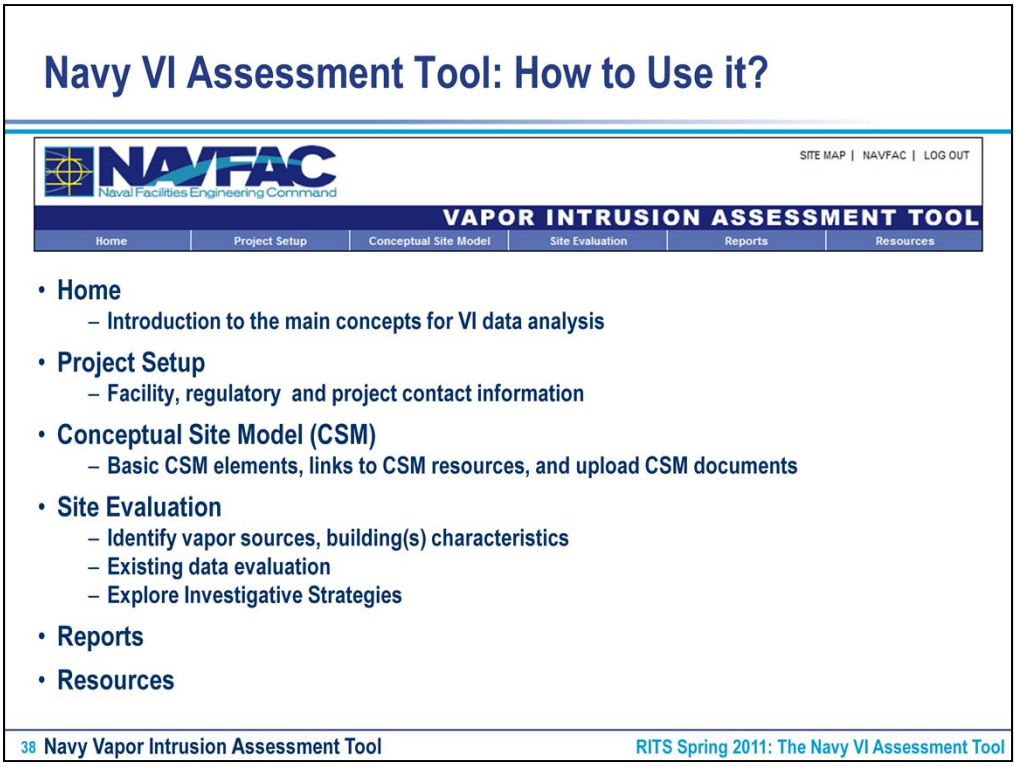
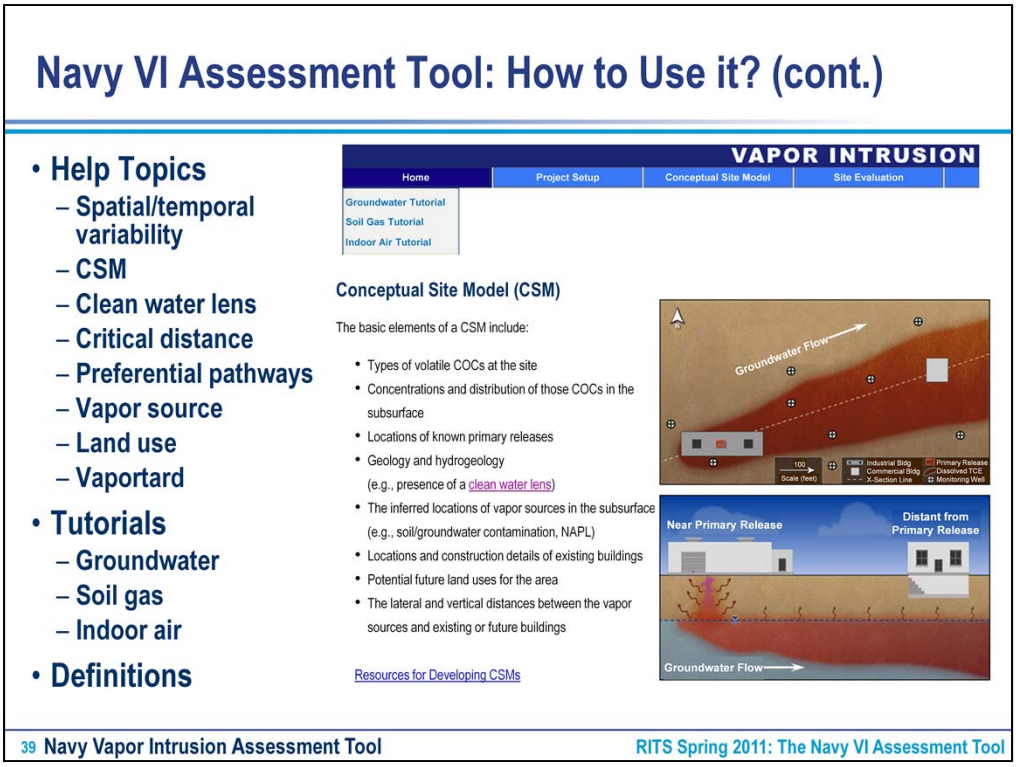
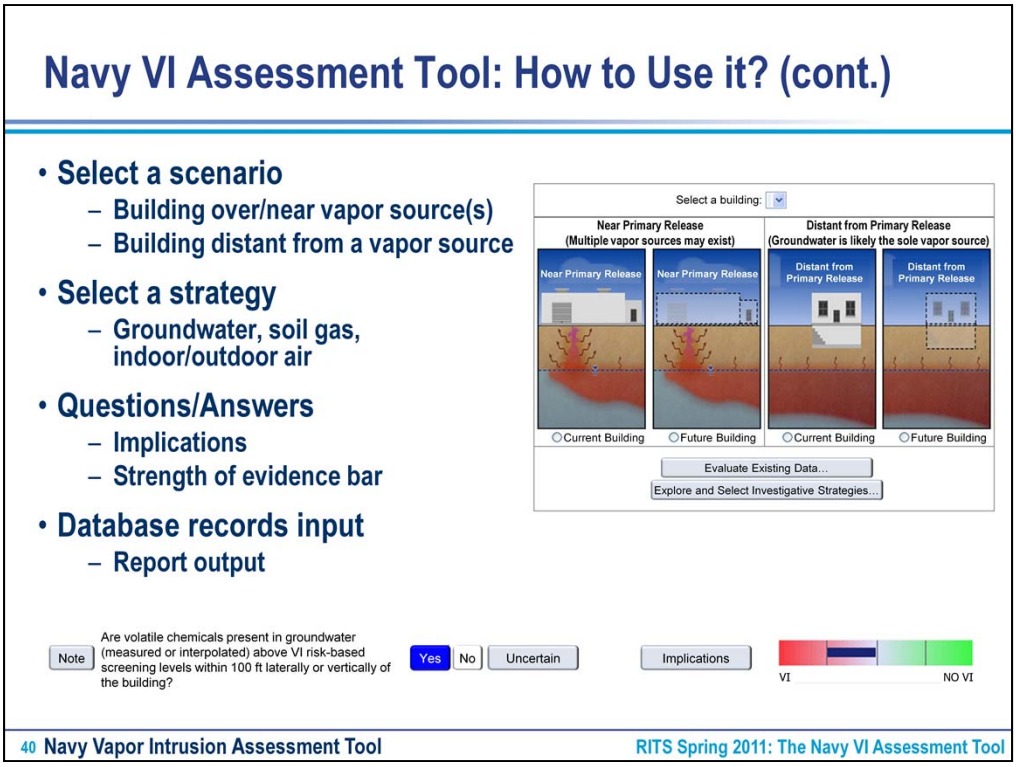
This is going to be a one stop shop on how to deal with vapor intrusion and it should help you avoid that overloaded information by breaking up all that mountain of data into manageable data consistent with your CSM and its going to help you understand the strength of the lines of evidence that you're looking at. It's also a tool for the managers to check our vapor intrusion sites so they can get a sense of the variability across the space so they can get a sense of the variability and an understanding of vapor intrusion impacts and the cost associated with our restoration program.



When we go to the tool you'll see a number of tabs across the top: home, project setup, site evaluation, reports tab, and a resources tab. And we'll go into those later in a lot of detail.

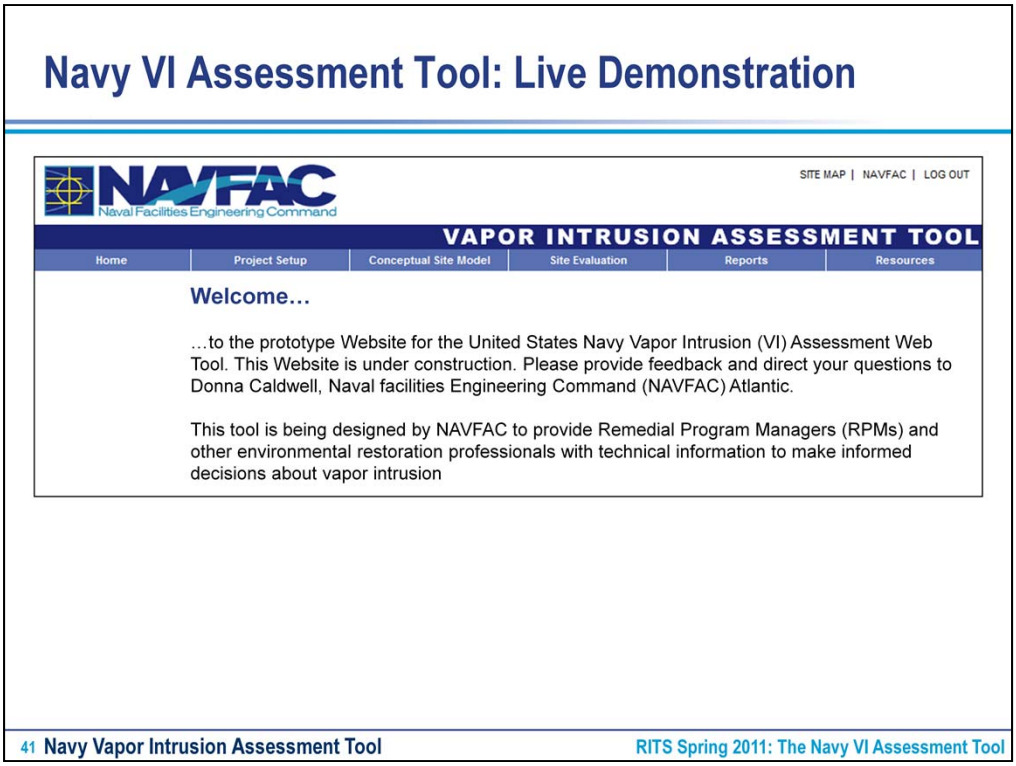


Now integrated into this tool is a lot of help topics which are pop up boxes that provide a little more detailed information on those key topics of vapor intrusion and I’ve listed those here. There are tutorials where we go even more into the topic to understand the science of vapor intrusion through these media and then we have definitions that appear as blue text that, when you select it, it gives you additional information to make sure you understand the information you’re presented with if you’re not familiar with the terminology.



Now the way you're going to use this tool is identify which scenario your site most represents. Here we have a scenario where your building is near a primary release where you might have multiple sources of vapor in the vadose zone, or is your site scenario where your building is distant from a vapor source and you only have one source of vapors, typically the leading edge of a groundwater plume. Then select the strategy you're going to look at analytical groundwater soil gas, air, or even non analytical strategies. And then in the tool we have these questions/answers/implication. You'll be presented with a question to help you assess whether or not vapor intrusion is going to be a problem at the site. How you answer that question: yes, no or uncertain, will be an implication and that strength of evidence bar and where you are in that yes or no continuum.

This is also a database, so every time you put an input into this tool, it is saved under your specific project database that you set up and then we can later retrieve that information in a report and take it to stakeholder meeting discussions.



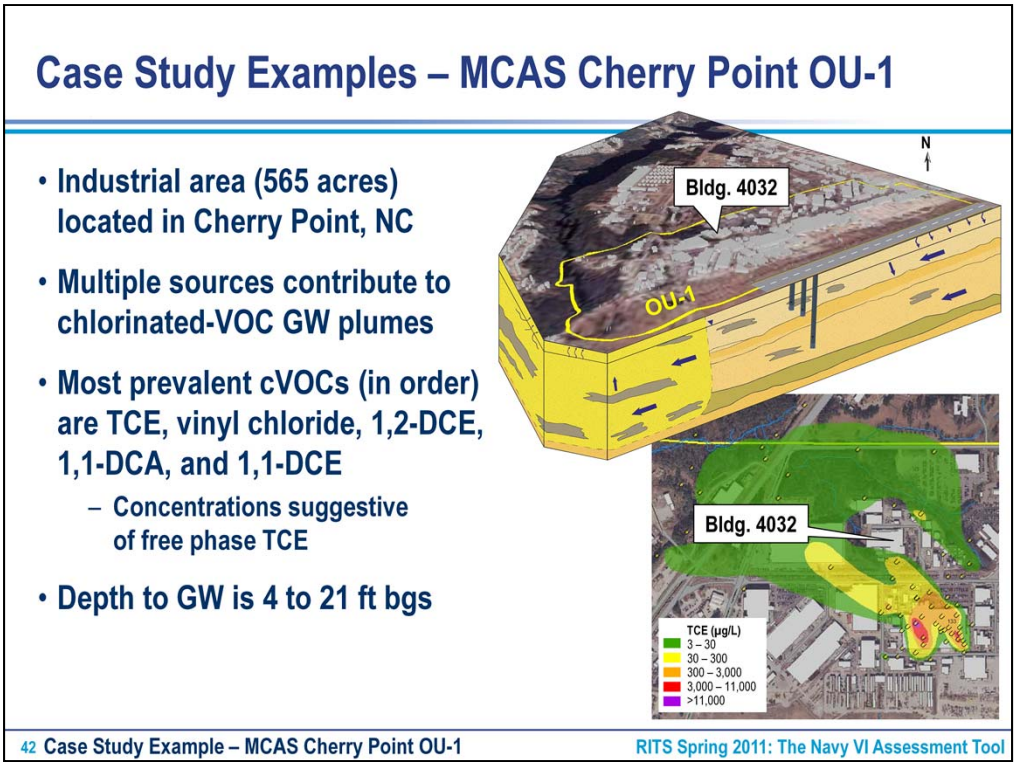
When you go to the site, you'll log in and then it takes you to the homepage where we welcome you to the vapor intrusion assessment tool. There's some basic introductory information on the science of vapor intrusion that Loren introduced you to—those fundamental truths, we introduce the concept of the weight of evidence scale and how we graphically represent that. And then at the top on the homepage tab we have pull down menus on those topics.

And just to give you a sense of the level of detail that's in these tutorials we'll just open up the groundwater one. We introduce you to the concept that groundwater can only be predictive of what's happening in the indoor air, we have a fancy little graphic that explains the transport mechanisms, where you're volatilizing off the groundwater, migrating through the vadose zone, and each time you have these steps taking place, you're attenuating even more. And transport across the slab, mixing with indoor and outdoor air, and all of these factors play into this attenuation. The tutorial also defines the attenuation factor, shows you how to calculate it, we also introduce you to screening levels and how you can calculate those. We introduce you to the uncertainties, spatial and temporal variability so you understand the uncertainties that go into the idea of the strength of evidence depending on your CSM. We show you the sliding bar, the two basic scenarios, and then the range in the strength of that evidence depending on which scenario you're looking at, in this case it's groundwater. So the indoor air and the soil gas tutorials have a similar level of information available to you.

Now the next tab is the project set up tab. This is where you're going to actually set up your project and there is where you're going to input all of your project information and project contact information so we're going to select Cherry Point because I'm going to walk you through the tool that we've already completed so you'll have these pull down menus containing fields consistent with the fields in NIRIS, and regulatory information so you can identify your regulatory stakeholders and points of contact, your Navy regulatory contacts and even your Navy contractors contact information. And then we have a notes field down here where you can annotate any information about the project, perhaps the building you're looking at is a mission critical building and logistical access to that building has been restricted and you want to show that up front.

So you set your project up, and all of that is saved in your project database and the next tab is our conceptual site model tab. This tool does not develop your conceptual site model for you but it gives you information to help you understand how to develop your conceptual site model for this pathway. So we provide the types of content it should have, now this is one of the modules for a clean water lens as you're developing a conceptual site model—if you're not familiar with what we mean by that, you get additional information to recognize that it's going to be the top of the water table that's going to be the most relevant if groundwater is your source of concern. So you can incorporate that knowledge into your conceptual site model. We also have a link to the checklist to developing the conceptual site model. This takes you to the ERT2 site for vapor intrusion and then on the second site there's a checklist itself that you can download. So, as you develop your CSM these resources are here to help you develop it for this pathway.

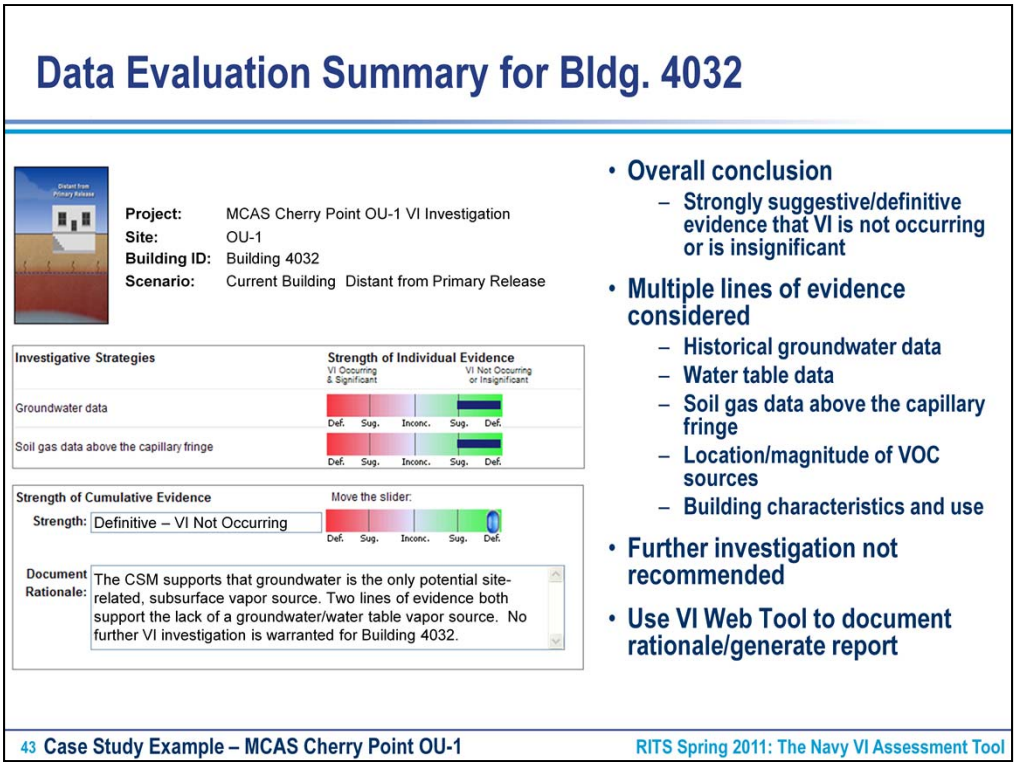
Now what this tool can do for you, is allow you to upload those conceptual site model documents so that when you're using the tool, you can have frequent access to that information. While it's not going to develop them for you, we've uploaded three here for our case study in the form of a cross section, a plume map, and a site map. And it's a simple upload, browse to the file, and upload. Now the next tab is your site evaluation tab and we have three things happening here. We have a threshold evaluation where you're going to ask yourself "do I have a building that is close enough to a primary release?". You can evaluate existing data for that building or you could explore investigative strategies if you haven't collected any data yet. So the first step is the threshold evaluation, asking that 'is my building close enough to a critical source' question, then to answer that question you need to identify vapor sources. So we want you to understand what we mean by a vapor source, we have a help topic for that, and then we want you to input those vapor sources into this database.



Now, our case study, we have loaded a lot. It just so happens that this site is a very large industrial area, so we have a lot of buildings that are either known or potential sources to volatiles to subsurface media and we identify which media might be associated with that particular source where you upload information on your sources, a very simple form where you upload and those vapor sources are saved in your project database. We can also have these linked back to your CSM files so, at any point, you have frequent and easy access to pull those documents down as you try to answer these questions to help you understand what your vapor sources are. Then next to this is your buildings, identifying which buildings are within a critical distance. We have a help topic for the critical distance. Currently EPA considers 100 ft for chlorinated solvents, and 30 ft for petroleum hydrocarbons. And again you have a form you can fill out, you can populate information on the buildings you're interested in, not just the name, but what the building is used for, what the occupancy is like, what the relationship is (distance wise) to that release, and what are the construction topics that may be relevant to you and so you populate all of the buildings that you're going to be looking at, and the next piece of this is selecting which to evaluate. And to actually walk through this, we're going to first look at building 4032.

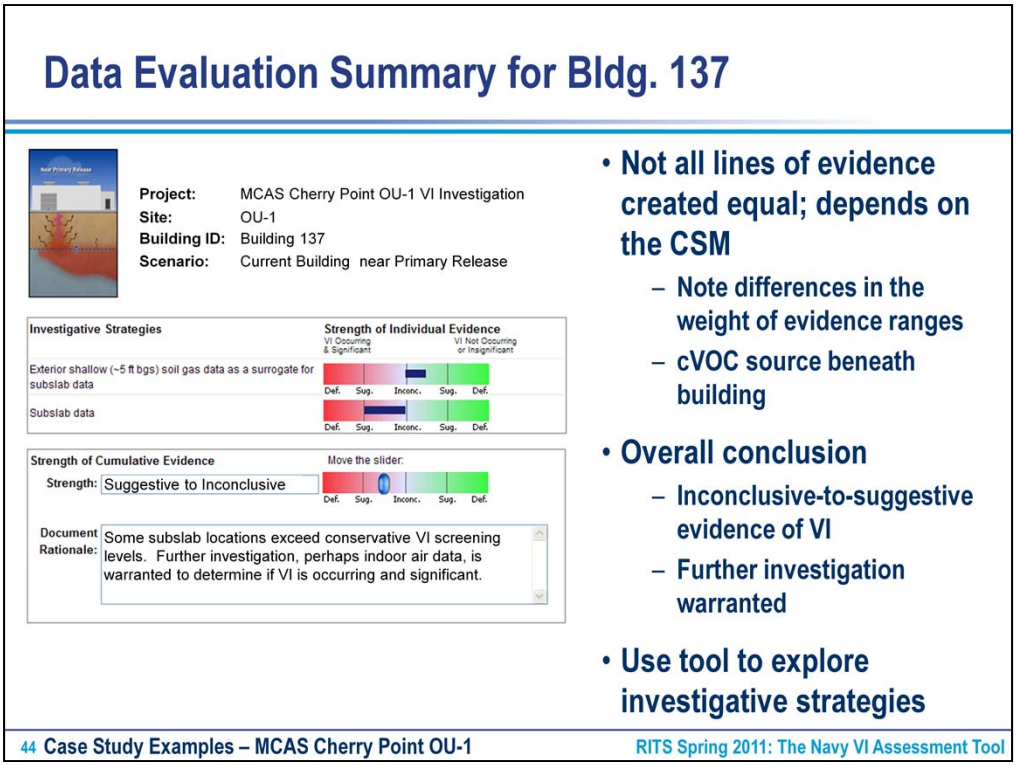
This quite distant from our primary release so before we go and evaluate existing data or explore strategies, I'm going to take you to conceptual site model documents so you understand the site as we go through using this tool. So this is that large industrial area. These orange squares represent these VI sites, some of the sources are known sources of VOCs. The next CSM is our plume map and we're going to focus on buildings 137 and 4032. Here is our initial primary release, reflected by these high concentrations over here and then we have this large plume and this building within 100 ft of these VOCs so we want to assess it. We also have building 137 that appears to have a source below the building based on historical groundwater data. So given this information, we can go use the tool and say "how can I assess this pathway based on this historical groundwater data" and we'll evaluate existing data. Now that's going to take you to a page that's going to present all the information you've noted, it shows you your site, your building, what scenario you've characterized it as, we have links back to the tutorials just so you can understand the science of movement of vapors in that media and then we have these strategies for the background evaluation: whether you have constituent comparisons, comparing indoor to outdoor air, and then we have our subsurface strategies to compare our soil gas, our subslab, the whole soil gas profile. For this here, let's evaluate for the groundwater data. Now this takes us to a page, our questions/answers/implications page. Our information is carried forward and you're presented with a question: are volatile chemicals present in groundwater above groundwater vapor levels of concern within one hundred feet of your building? We are going to answer yes to that question. And you see, when we do that we get posed with another question. We also have an implications tab that's activated and we also have our strength of evidence tab that's activated. We're inconclusive to suggestive that VI could be a concern because we have elevated concentrations higher than the screening levels. So the next question: do groundwater data adequately characterize the groundwater table? Let's go to our CSM documents and we have wells screened at a variety of depths and very few are screened across the top of the water table, so we're going to answer 'no' to that question. When we do that, we see that our implications tab is highlighted and our strength of evidence tab has moved back towards inconclusive. So we can click our implications tab and get an understanding of why that is and where the water lens is and that the top of the water table is important, it just tells you that you need to recognize that there's going to be uncertainty if you're going to characterize the top of the water table. Now for each section, we have a notes tab. So that you can click on this, and add any reason as to why you answered the way you did, it gets saved because at the end of the day you can print out a report that says how you answered the questions and why you answered them the way you did. So we'll save that survey and this one and it's going to ask us if we want to evaluate another line of evidence, which we do—but before we do that, I want to take you back to the CSM documents because what our team did was they recognized they had uncertainty based on the historical groundwater data and they went back out and collected additional groundwater and soil gas data, and a shaded cell indicates the exceedence of a screening level. We don't have any shaded cells so the groundwater at the top had no exceedences of screening levels and neither did the soil gas.

So we'll take this information and go back to our tool to evaluate groundwater again, and this time not the historical data will be used, but the new data. All the information carries forward and so, do we have volatiles now? The answer is no we don't.



The bar is then going to move to the other side being suggestive that vapor intrusion is not occurring. But now we have to answer 'did we adequately characterize the water table' well yes, we deliberately went out to do that. Then we're posed with another question, do we feel confident that we have good coverage? We're going to say that we do have good groundwater data and that we are strongly suggestive to definitive that VI is not a concern. Now we also collected soil gas data, so lets save this survey and take a look at our soil gas data. We collected data above the capillary fringe, evaluated it and did not have any exceedences. So we're going to answer 'no, VOCs have not been detected', 'no vapor intrusion is not a concern', and we do feel like we have sufficient data. And when we do, our strength of evidence bar slides over towards definitive. So now we've looked at three lines of evidence and can look at a summary for all of our information that has been carried forward.

From building our scenario, and then the individual lines of evidence that you've evaluated and you can see that, based on this, VI is not a concern based on the groundwater and soil gas data. But as a project manager, you have to make the decision so you move this slider to decide whether or not, based on your cumulative understanding of the individual lines of evidence whether or not VI is a concern. And then you can document your rationale as to why you made that conclusion about VI for this building and then you can save that. When you do, you can go to a reports tab and print all that data out. We're just going to jump ahead and show you that we're going to print out a report and look at that detailed data evaluation and all of that decision-making is there even the first consideration of historical groundwater data. The report functionality is a report built into the tool.



So lets go back and consider our building 137. They went out and collected three subsoilslab samples because they knew they had a source and they collected exterior shallow—above the capillary fringe—soil gas samples. You see a lot of exceedences, but note that we don't have any on the exterior samples. So it goes to show that the soil gas is going to depend on the conceptual site model—if we would've just looked at the exterior samples we may have declared that VI is not a concern and overlook that fact. The team did decide that they weren't comfortable making decisions with this data and they wanted to explore investigative strategies and they wanted to collect indoor data. In this case, we're going to explore investigative strategies.

Now this takes us to a page with our existing site data, what if the team decided they only wanted to collect indoor data. We've got links here that show scopes of work which are generic language if you want to solicit contractor's support to develop an IFP and it's for soil gas, indoor air, subslab, building characteristics, generic language that you might want to throw into a scope of work if you want to solicit subcontractor support. We also have links to analytical methods, the range and strength of evidence, and the questions/answers/implications so you can start to play 'what if' games. What if I collect some indoor air and the data comes back this way, I could click that implications tab and say 'what does that mean, what's that strength of evidence going to give me'. So we can sit here and play 'yes no' so before you spend any time and money to collect the data you'll have a better understanding on how you're going to use the data and what the strength of evidence it's going to give you to help you make a decision based on that data. We also include these other considerations—its not always about collecting the data, you may have logistical concerns or community involvement to dictate your decision. We have links to screening levels and SOPs.

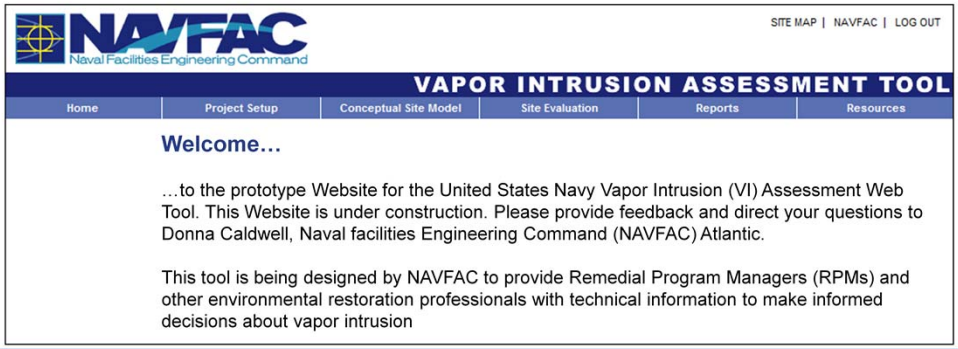
You can select what reports you want to print out to take to a stakeholder meeting, the project setup, the building information, etc. You can select what you want to print out to take to a partnering meeting and then what to take to your stakeholders. The last tab is the help location if you need help on any of this.

Presentation Overview

- Introduction
- Vapor Intrusion (VI) – The Basics
- Vapor Intrusion – The Details
- Navy Vapor Intrusion Assessment Tool
- Case Study Examples
- ► VI Web Tool Roll Out
- Summary

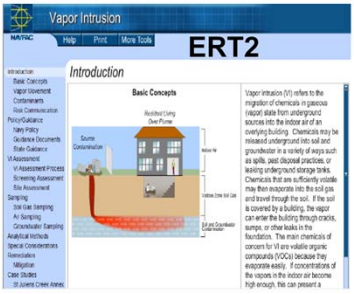
VI Web Tool Roll Out

- Interested in being a VI Web Tool beta tester?
  - RPMs: Web Tool is for you and **your input is important**



VI Web Tool Roll Out (cont.)

- ERT2 Portal
  - Development and initial availability
- Transfer to NIRIS
  - Transfer timeframe TBD
- Available for use by contractors and stakeholders
  - NIRIS access required once transferred
- Intended to be "living" resource with current state of the science



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Take-Home Points

- VI pathway can be complex and dynamic
  - Multiple lines of evidence
  - Lines of evidence are not created equal
  - Strength of evidence depends on the CSM
- VI Tool is one-stop shopping resource
  - Manage complexity
  - Guide informed decisions
- NAVFAC Atlantic and NAVFAC EXWC are here to help you!

49 Summary RITS Spring 2011: The Navy VI Assessment Tool

These fundamental truths are very important! This is your one-stop shopping resource.

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