Department of Toxic Substances Control

CalEPA California Environmental Protection Agency

What's New About Vapor Intrusion?

MARCH 2025

Agenda

- Vapor Intrusion Background
- RWQCB/DTSC's Approach to VI
  - Multiple lines of evidence
  - Interpreting indoor air data
  - Mitigation Construction Quality Assurance
  - Radon and vent riser sampling
  - Types of regulatory closure
- Case studies
- Discussion

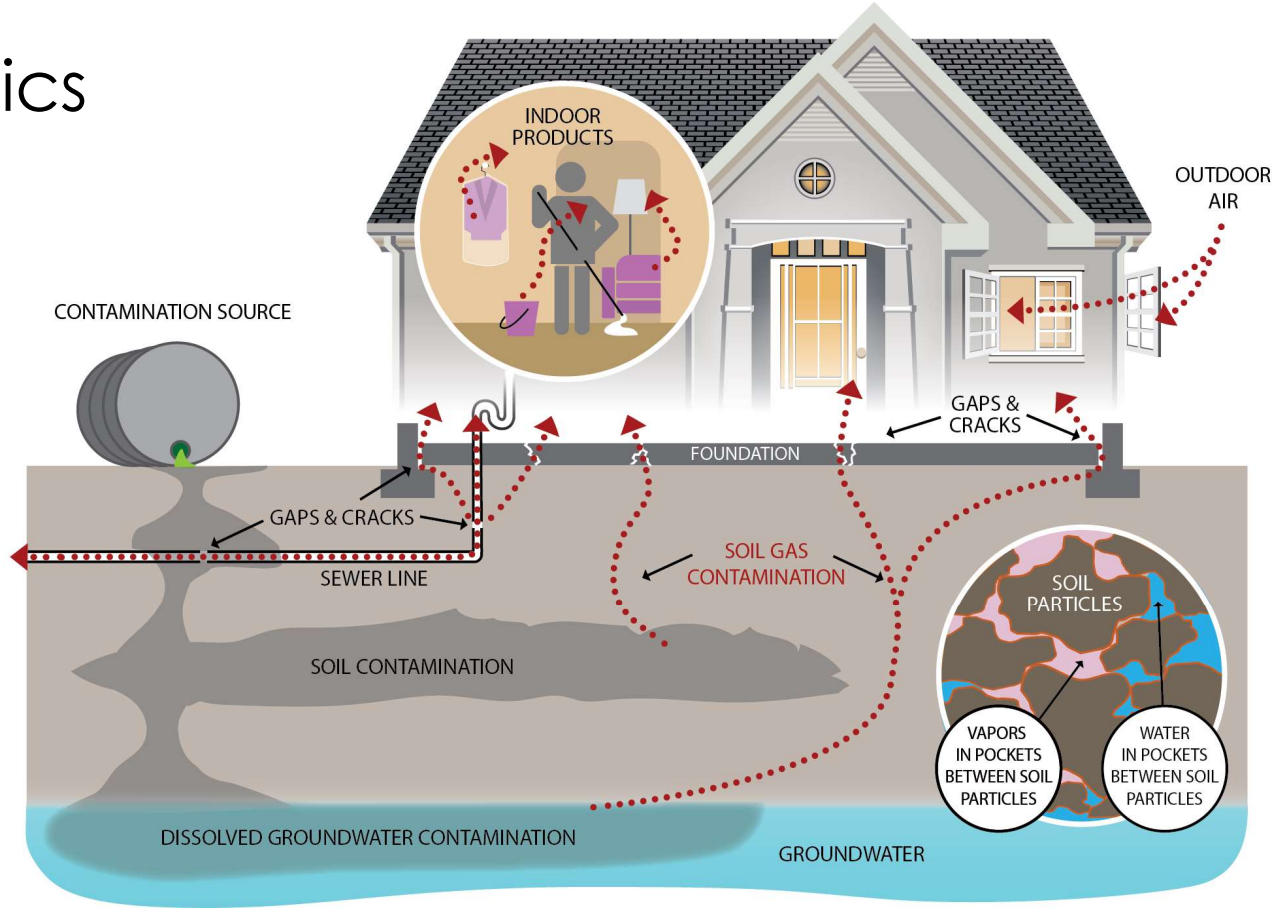
Vapor Intrusion Basics

Vapor Intrusion = migration of chemicals in vapor phase into buildings

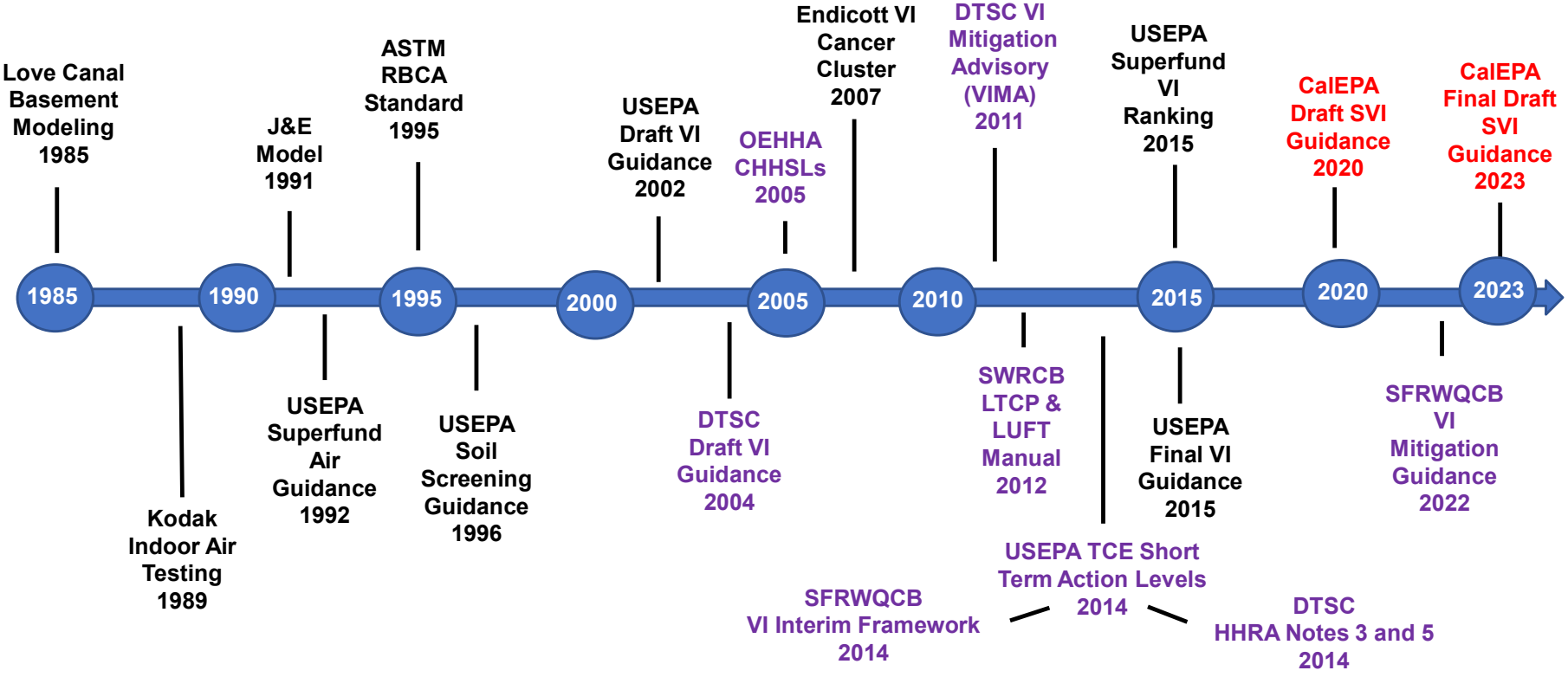
Sub-Slab Soil Vapor = vapors immediately below building's sub-slab foundation

Soil Vapor = vapors within the vadose zone

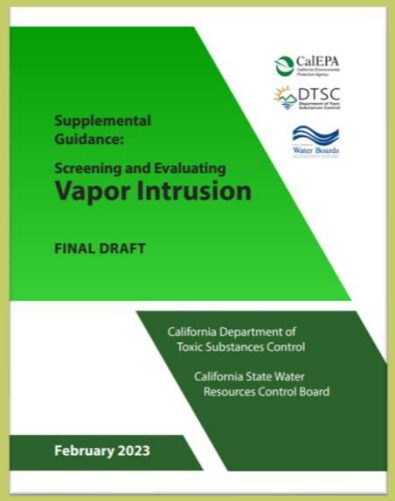
Attenuation Factor - Ratio between sub-slab and indoor air concentrations.



Vapor Intrusion Timeline



2023 Supplemental VI Guidance



- Uses 0.03 attenuation factor (AF) for screening only
- 0.03 AF is intentionally conservative to make sure we collect data to identify problems
- Allows for alternative approaches using multiple lines of evidence (LOEs)
- Not intended to provide specific guidance for:
  - Mitigation measures
  - Developing Alternative AFs
  - Full site characterization & cleanup methods
  - Risk management decisions and cleanup goals
  - Closure and No Further Action

Other Guidance

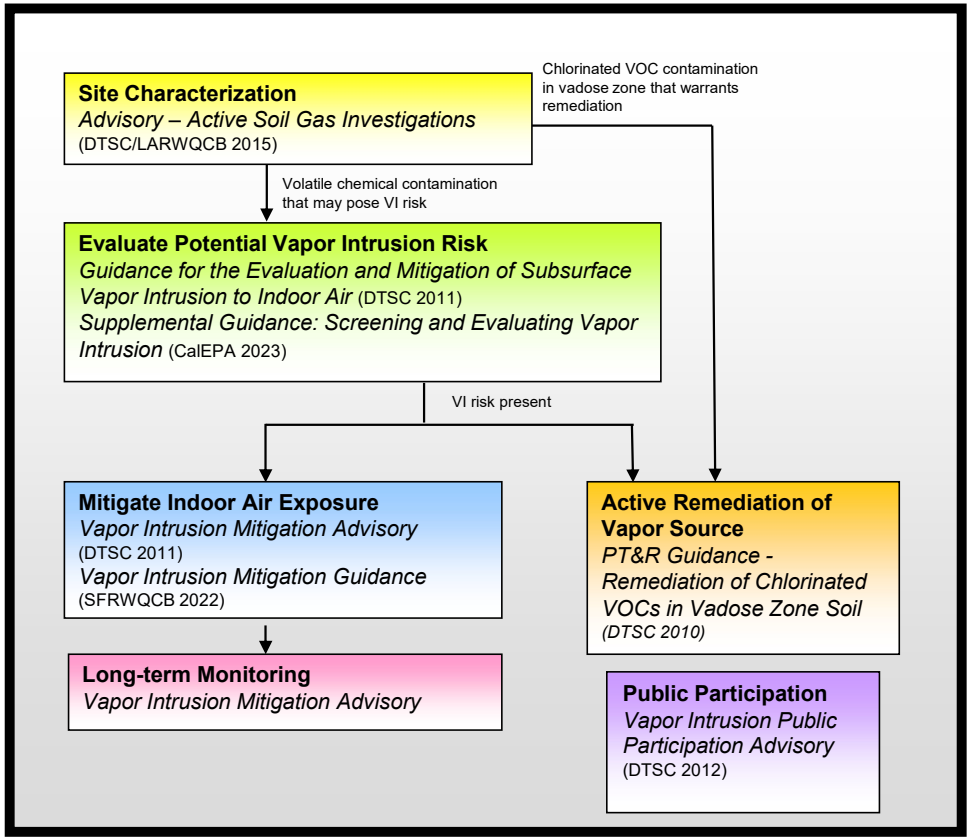
Slide 6

BS0 Tina’s slides from the internal training

Stanphill, Benjamin@DTSC, 2025-02-14T21:52:40.418

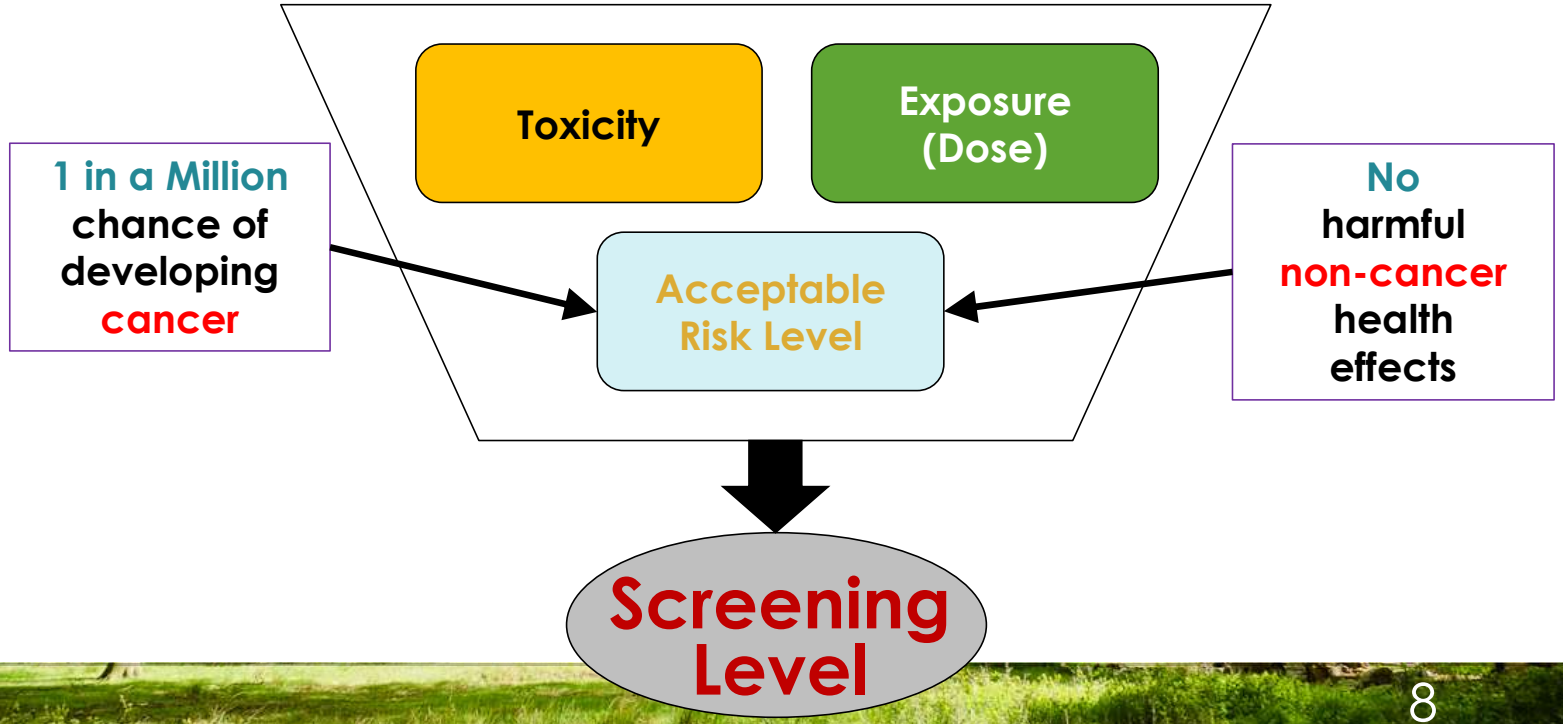
Guidance Documents

- https://dtsc.ca.gov/vapor-intrusion/



Screening Levels

- Environmental contaminant concentrations that pose an acceptable risk to receptors



Sources of Screening Levels

Regulation
- DTSC Toxicity Rule: https://dtsc.ca.gov/regs/toxicity-criteria-for-human-health-risk-assessment/

Guidance
- DTSC Human Health Risk Notes: https://dtsc.ca.gov/human-health-risk-hero/

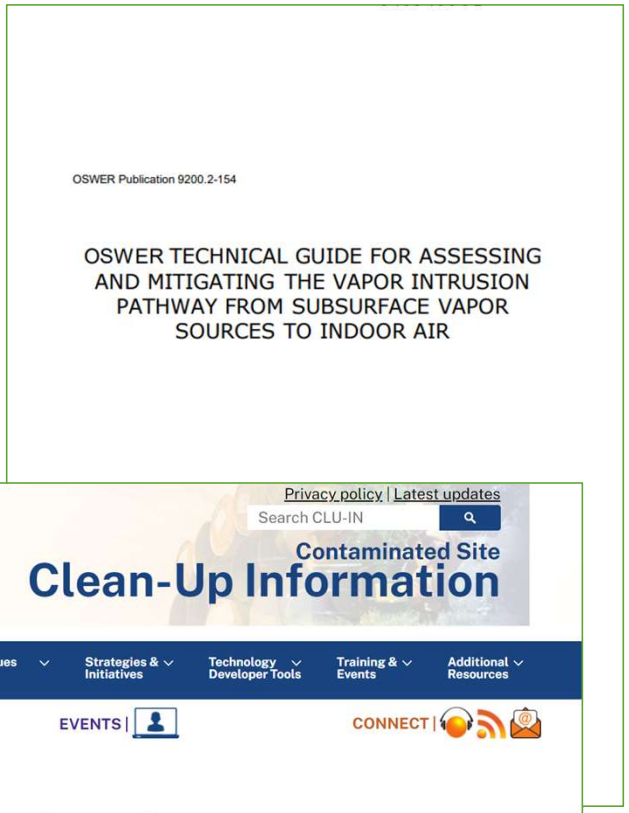
Guidance
- USEPA Regional Screening Levels: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

Guidance
- San Francisco Bay Regional Board ESLs: https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/esl.html

Outdated
- California Human Health Screening Levels: **OUTDATED DO NOT USE** https://oehha.ca.gov/risk-assessment/california-human-health-screening-levels-chhsls

USEPA

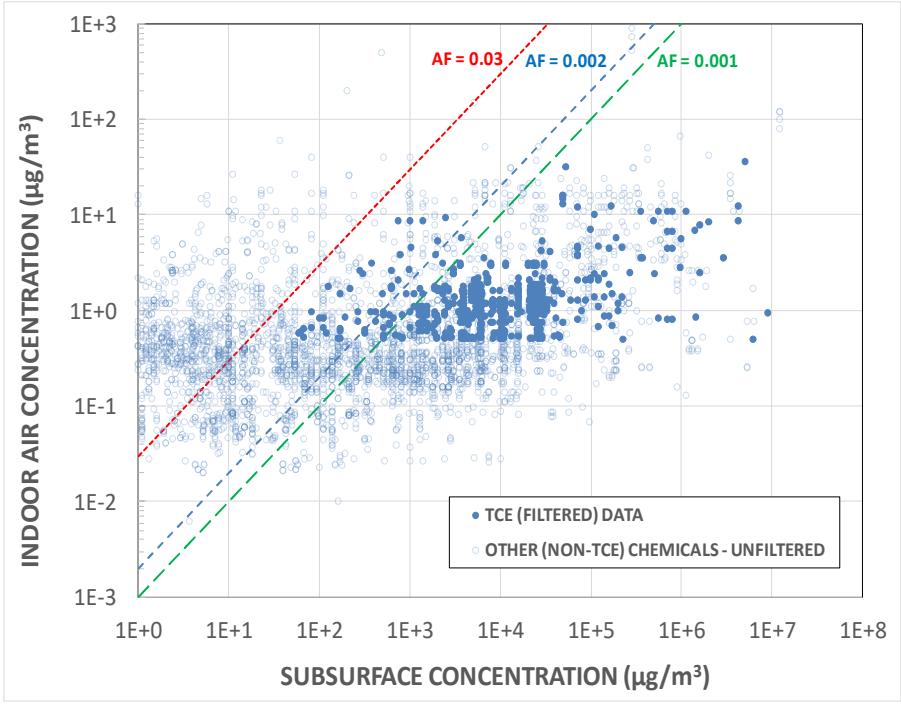
- OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway, 2015
- Vapor Intrusion Database, 2012
- EPA Website & Conceptual Site Model: https://www.epa.gov/vaporintrusion
- Clu-In https://clu-in.org/issues/default2.focus/sec/Vapor_Intrusion/cat/Overview/


OSWER Publication 9200.2-154

OSWER TECHNICAL GUIDE FOR ASSESSING AND MITIGATING THE VAPOR INTRUSION PATHWAY FROM SUBSURFACE VAPOR SOURCES TO INDOOR AIR

Databases

- USEPA: 2012 (draft 2008)
- DOD: Non-residential AFs 2021 https://pubmed.ncbi.nlm.nih.gov/33989123/
- Industry: Ettinger and Lahvis 2021 https://ngwa.onlinelibrary.wiley.com/doi/full/10.1111/gwmr.12450
- Abbasi et. al. 2022 https://ngwa.onlinelibrary.wiley.com/doi/abs/10.1111/gwmr.12559
- Common themes:
  - J&E model not protective for many sites
  - Attenuation factor can be conservative bound, poor predictor



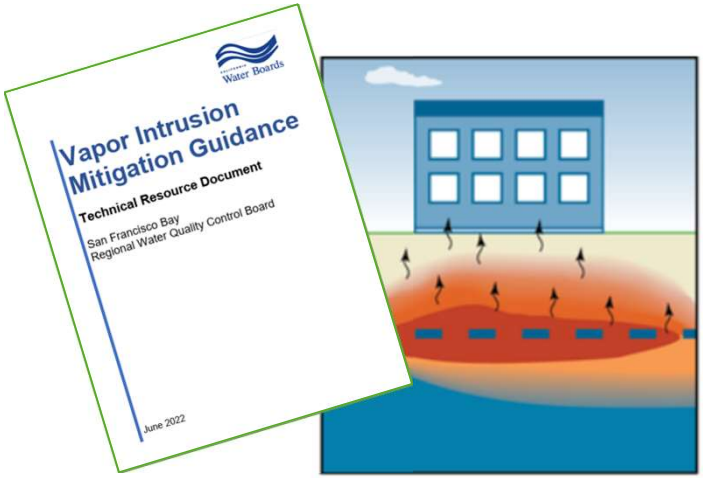
Mitigation Guidance

- American Association of Radon Scientists and Technologists (AARST) https://aarst.org/

- ITRC Vapor Intrusion Mitigation Training https://itrcweb.org/teams/training/vapor-intrusion-mitigation-training

- San Francisco Bay Regional Board: VI Mitigation Guidance https://www.waterboards.ca.gov/rwqcb2/water_issues/programs/sitecleanup/2022_VIM_Guidance.pdf

National Consensus Standards for Every Building Type



Common Themes

- Good assessment and evaluation of soil, soil vapor, and groundwater is important
- Sample data is more reliable than modeling
- Samples closer to receptors are more representative of exposure
- Buildings can be screened with soil gas
- Vapor behavior is complicated, manage the uncertainty
- Use conservative assumptions to protect human health

How do we use all this?

BS0

DTSC's Approach

- Efficient, Sufficient Characterization
- Source Removal
- Protect People Faster
- Confirmation IA Sampling
- Consistent, not identical, screening, cleanup, and OMM decisions

Slide 15

BS0 This is one of Ben’s slides that no one has reviewed, someone should review.
Stanphill, Benjamin@DTSC, 2025-01-25T00:32:39.383

DTSC's Approach

Identification
What are the contaminants of concern and what media are affected?

Delineation
How deep and widespread is the contamination?

Source
What are the on and off-site sources of contamination?

Risk
How are people on the site being exposed and are they safe?

Risk
What ecological receptors are being exposed and are they safe?

Off-site Impacts
Has contamination migrated and is it impacting neighbors?

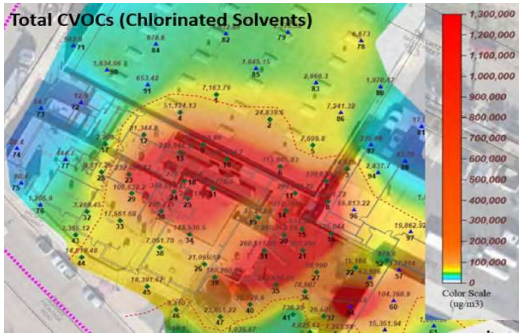
Community Engagement
How will you help people understand what you are doing in their community?

Collaboration
How can we work together to achieve health, safety, and reuse?

Long-term Protection
How will the site continue to remain safe and protective in perpetuity?

Solutions
What needs to be done to address the contamination source and make sure that exposure is eliminated or mitigated?

Typical Site Cleanup Process



Site Investigation

- Indoor Air Sampling
- High Resolution Site Characterization
- Well Installations and sampling
- Vapor Mitigation

Interim Remedial Measures - Source Removal

- Excavation
- Soil Vapor Extraction
- Injections
- Thermal
- Vapor Mitigation

Full-Scale Remediation

- Source Polishing
- Distal Plume
- Vapor Mitigation
- Operation, Maintenance, and Monitoring

Project Close Out

- Closure
- Long-Term Monitoring

Slide 17

BS0 This is Craig's framework, consider whether it fits with this forum

Stanphill, Benjamin@DTSC, 2025-01-25T00:15:45.759

Milestones toward No Further Action

- **Suitable to Occupy** – While DTSC and the Water Board are not land use agencies, both can write letters stating cleanup and mitigation are functioning such that proposed occupants of the property will not be exposed to unacceptable risks. May be used if active cleanup is ongoing.
- **Remedy Construction Complete** – DTSC can certify that the remedy is constructed and operating as designed. There may be long term operation and maintenance requirement to verify that the remedy remains protective over time.
- **Certified Remedy with Land Use Control** – For sites with long term operation and maintenance requirements. DTSC will require annual inspections and Five-Year Reviews. Analogous site status in GeoTracker.
- **Low Threat Closure** – Water Board may close the case if contaminants are naturally attenuating and unlikely to pose an unacceptable threat.
- **No Further Action** – The site has been cleaned up or remediated to levels that will allow unrestricted land use.

Indoor Air Sample Challenges Chloroform and Benzene

- Chloroform is associated with disinfection of tap water
- Benzene is in vehicle exhaust and many consumer products
- **These may be at your site, but are they associated with the release?**

- Understand the releases at your site – Were these chemicals used?
- Compare indoor air concentrations to outdoor air and subsurface – Is it an indoor source? Outdoor source?
- Look at sitewide distribution – Is chloroform uniformly present in soil vapor in irrigated areas?

BS1

Using Multiple Lines of Evidence to Close Cases

BS0

Site specific AF? – Rarely used

- On-site Sources are remediated
- Lateral and vertical delineation of the soil vapor plume
- Sufficient spatial/temporal vapor data to show stability
- Indoor air data shows that VI is not occurring
- Groundwater is characterized and relatively clean

Slide 20

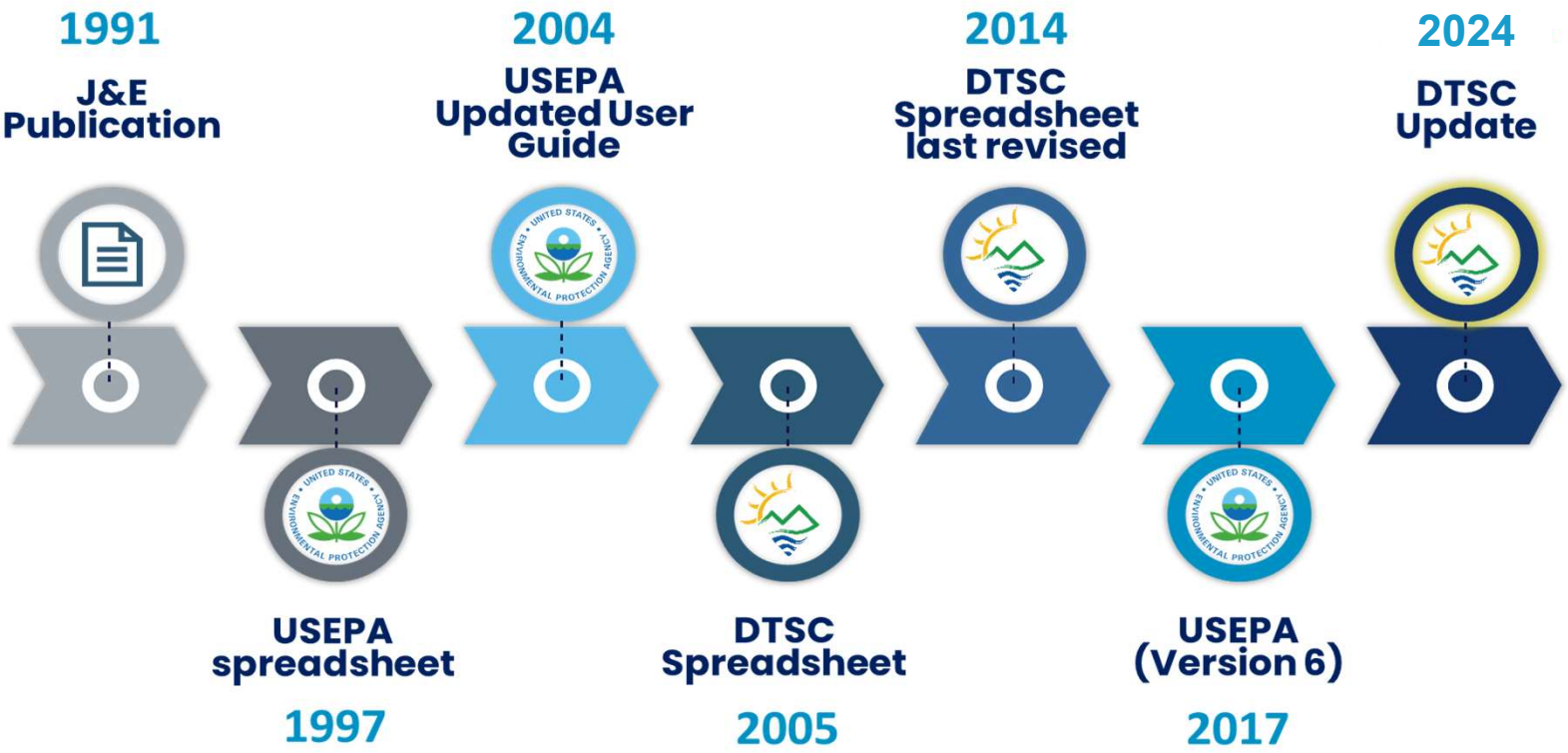
BS0 Check with Path to Closure Group, our team
Stanphill, Benjamin@DTSC, 2025-01-25T00:30:45.490

BS1 This is Ben’s content that no one has reviewed, someone should review
Stanphill, Benjamin@DTSC, 2025-01-25T00:33:01.773

New DTSC Update J&E Model

HTTPS://DTSC.CA.GOV/VAPOR-INTRUSION/

Chronology of J&E Model



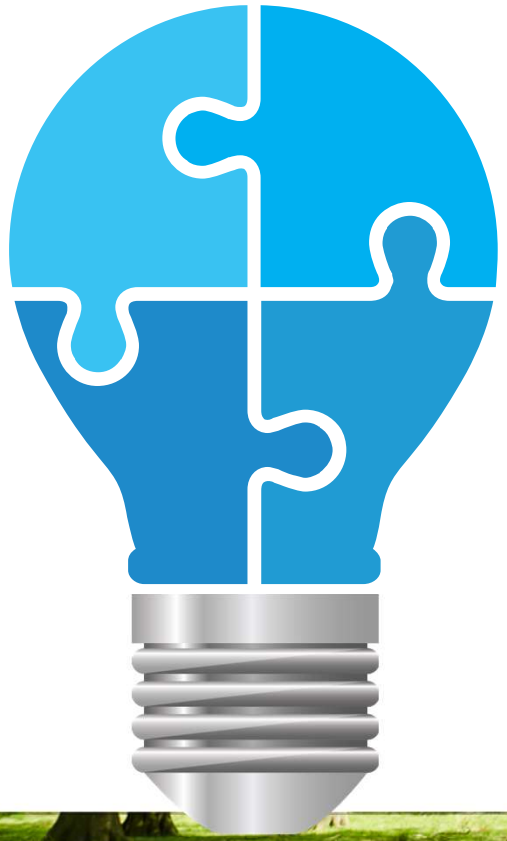
Scope of DTSC Update

Same Template/Equations as U.S. EPA J&E Model Spreadsheet Version 6.0 (2017)

Identify and fix known programming bugs

Include California-specific toxicity values and building parameters as model inputs

Key Changes in the DTSC Update



- **Known programming bugs fixed**
  - Trichloroethylene (TCE) risk calculation for commercial workers
  - Crawl space building parameters
  - Plotting routine for modeled soil vapor profile (groundwater source)
- **Options for capillary fringe modeling (van Genuchten moisture retention profile)**
- **Include California-specific toxicity values and building parameters**

Key Assumptions in the J&E Model

- One-dimensional transport
- Single contaminants source in soil or groundwater
- Steady-state conditions
- No degradation of contaminants
- Vapors entering a building through cracks
- Uniform pressure difference across the foundation (convective flow)
- Uniform air mixing in the building

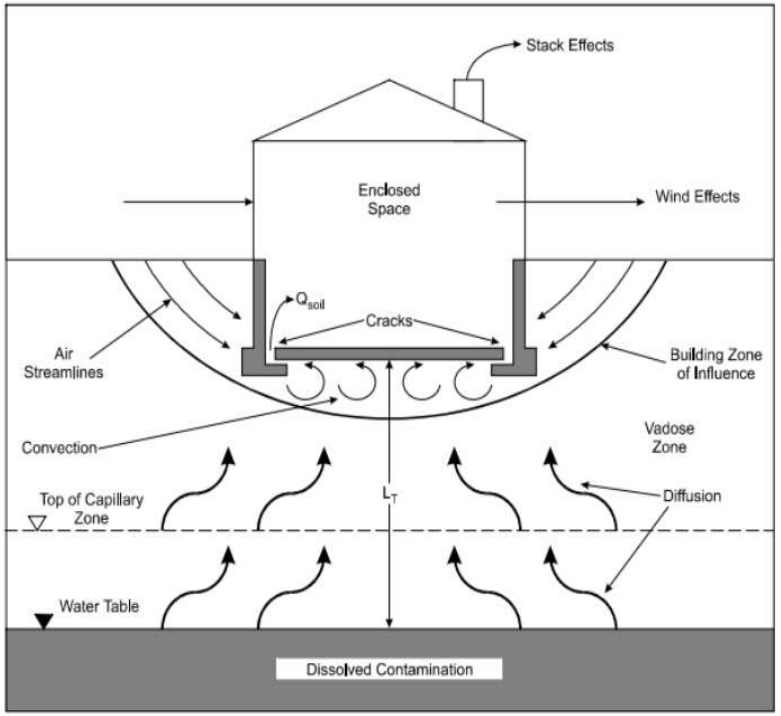


Figure 2. Conceptual Diagram of Groundwater Contamination

Guidance Framework for Model Use

DTSC Vapor Intrusion Guidance (2011)

"…When used in combination with site-specific information, the results of modeling will add to the overall weight of evidence used to evaluate the exposure pathway."

USEPA OSWER VI Guidance (2015)

"When suitably constructed, documented, and verified, mathematical models can provide an acceptable line of evidence supporting risk management decisions pertaining to vapor intrusion."

*"In certain situations (e.g., for future construction on vacant properties), it is particularly useful to employ mathematical modeling to predict **reasonable maximum indoor air concentrations**, because indoor air testing is not possible."*

CalEPA Supplemental VI Guidance (Final Draft, 2023)

"Use of the Johnson and Ettinger model or other appropriate models may be appropriate where the use is consistent with Attachment 1 and used in consultation with the regulatory oversight agency." (Page 44)

"The use of models as an LOE to support risk management decisions requires more advanced characterization of subsurface conditions and contamination than is needed for screening." (Attachment 1)

Key Considerations for the J&E Model

- Supported by robust Conceptual Site Model (CSM) + site data
- Conservative approach
- Possible ranges of model inputs / outputs
- Changes in building conditions
- Indoor air sampling as a key LoE, when possible

J&E Model as a LoE

- **Not recommended for initial screening** [Steps 1 through 3 in SVIG (CalEPA, 2023)]
- Adequate investigation data and sufficient site-specific information are needed to support model use [Step 4 in SVIG]
- **Possible use as a Line of Evidence in VI evaluation:**
  - Estimating future risks at redevelopment sites
  - Properties where indoor air sampling cannot be completed
  - Development of site-specific AFs and cleanup goals

BSO

Department of Toxic Substances Control

Mitigation and Construction Quality Assurance

Slide 29

BS0 Add a plug for 2022 VI Mitigation Guidance

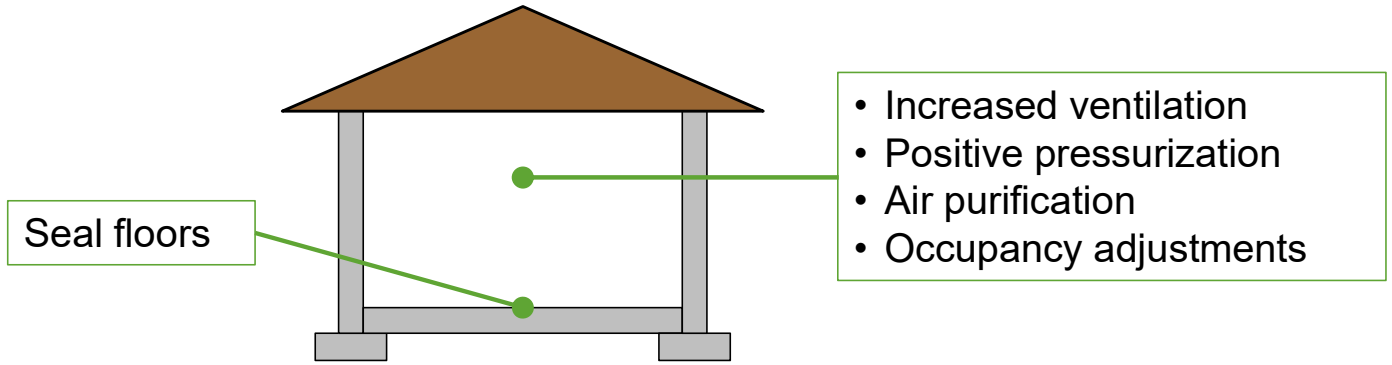
Stanphill, Benjamin@DTSC, 2025-03-07T21:06:02.570

Mitigation vs Remediation

- Mitigation is not a substitute for remediation
- Preferred use of mitigation is as an interim measure
- Mitigation is often necessary where achieving cleanup standards may take years
- May require considerations for sea level rise
- In some cases, mitigation may be the only viable long-term response action
  - Source is off-property, regional, or inaccessible
  - Remediation is infeasible or performed to extent practicable

Short-Term Mitigation Measures

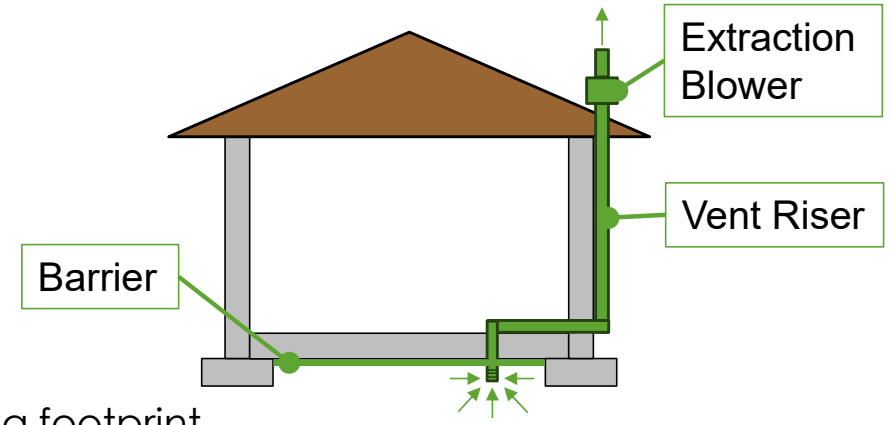
- **Purpose** – Address current VI exposure



- **Timing** – Before engineered VI mitigation system (VIMS) and/or remediation
- **Reliability** – Low, typically requires frequent monitoring to demonstrate continuing effectiveness

Engineered VI Mitigation Systems (VIMS)

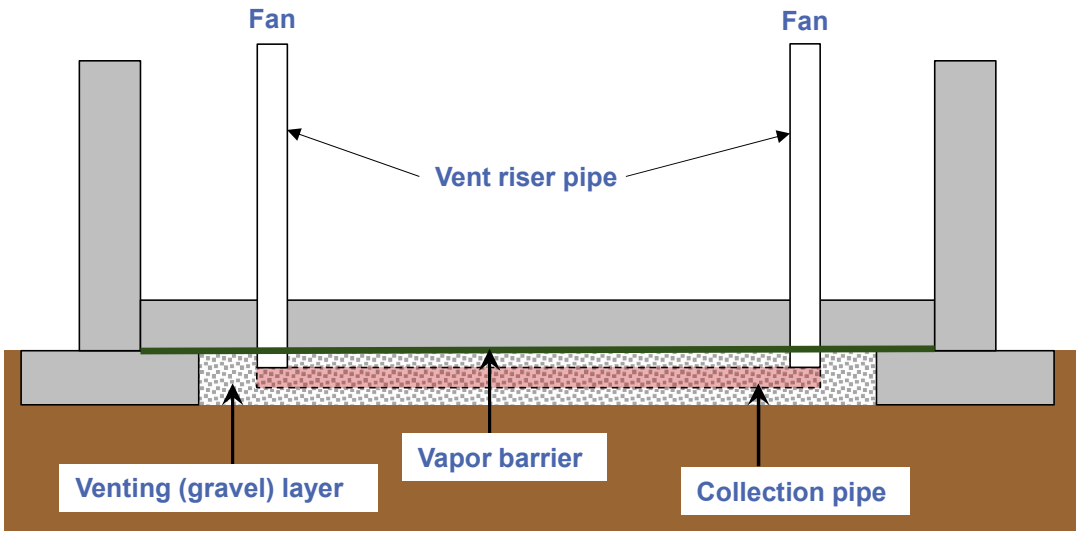
- **Purpose** – Address current and future VI exposure
- **Types/Examples**
  - Sub-slab depressurization
  - Passive ventilation and barrier
  - Soil vapor extraction (for multiple buildings)



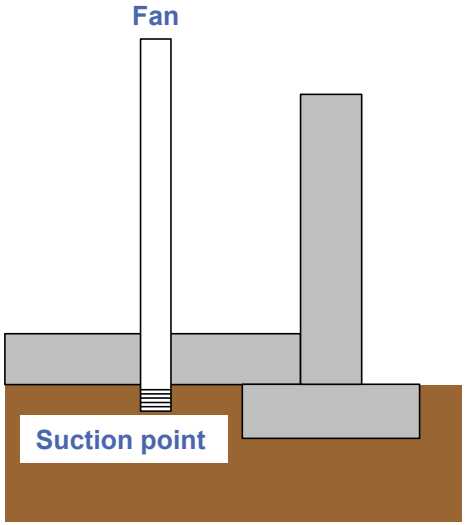
- **Considerations**
  - VIMS should generally cover the entire building footprint
  - Type of VIMS determines the monitoring needs and affects the design
- **Timing** – Not rapid. Permitting likely required
- **Reliability** – Can be high but requires management and oversight

VIMS Examples

New Construction



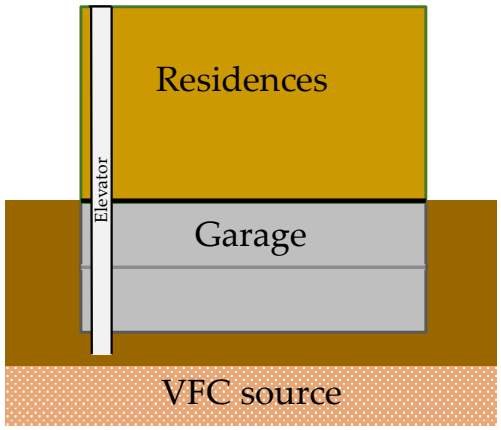
Existing Building (retrofit)



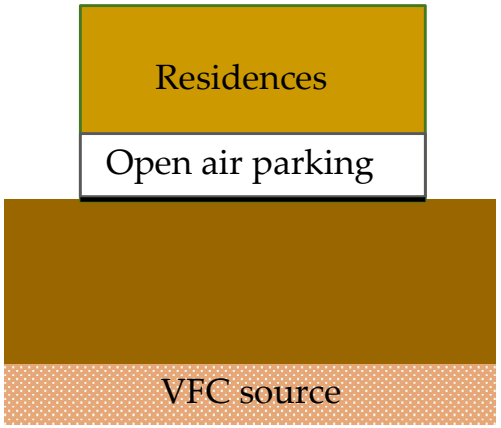
Mitigation by Building Design

- Buildings with ventilated, unoccupied floor(s) between subsurface vapor source and receptor. Still requires monitoring!

Example 1: Subterranean ventilated garage

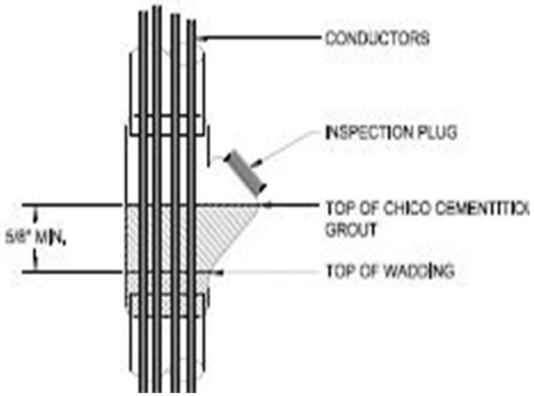


Example 2: Open air garage



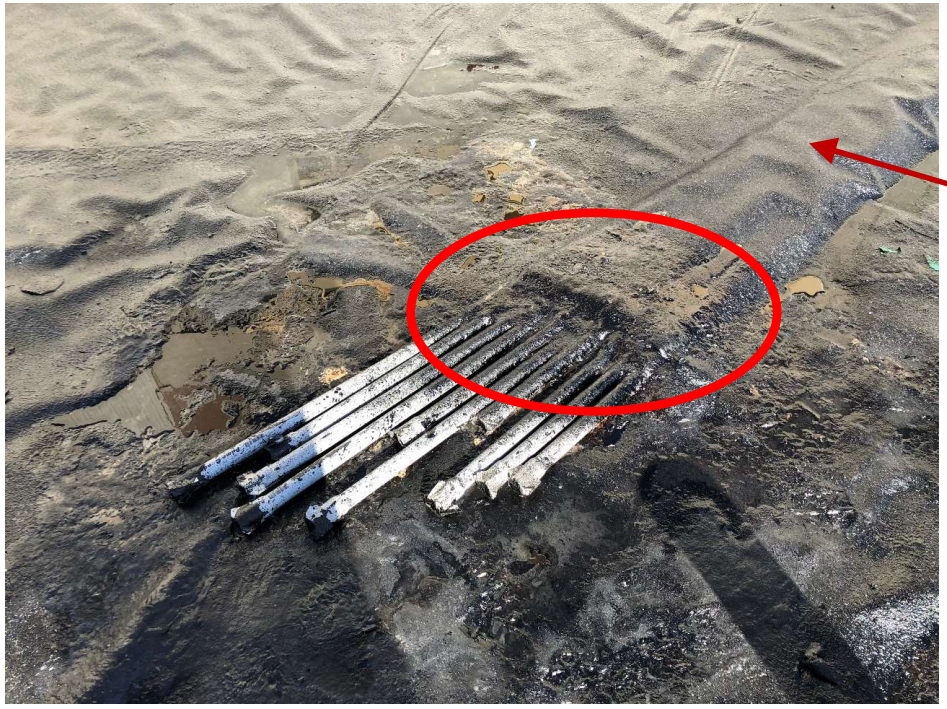
Common Issues During Construction

- Construction crews do not understand the significance of the VIMS
- Poor documentation
- Not following the design
- Design is not constructable
- Field changes to the approved design without consulting/informing the regulatory agency
- Excessive moisture on membrane during installation
- Excessive temperature (hot or cold) during membrane installation
- Follow-on trades damage VIMS components
- Inadequate sealing of electrical conduits (use eys fittings)



Construction Issues

Conduits so close they must be sealed as a unit



Spray on layer over base membrane

Construction Issues

Constructability

- Dirt on Membrane
- Complicated Seams

Loading dock at large warehouse

Construction Issues

Utility Penetrations are Potential Vapor Entry Points

- Pipe wrap on penetrations can create a gap between pipes and cured slab
- Pipe wrap typically is not vapor tight
- Membrane "boot" subject to damage during rebar install and pour
- Shower drains require later penetrations

Slide 38

BS0 Make sure barrier goes under black box.
Stanphill, Benjamin@DTSC, 2025-02-14T22:50:25.184

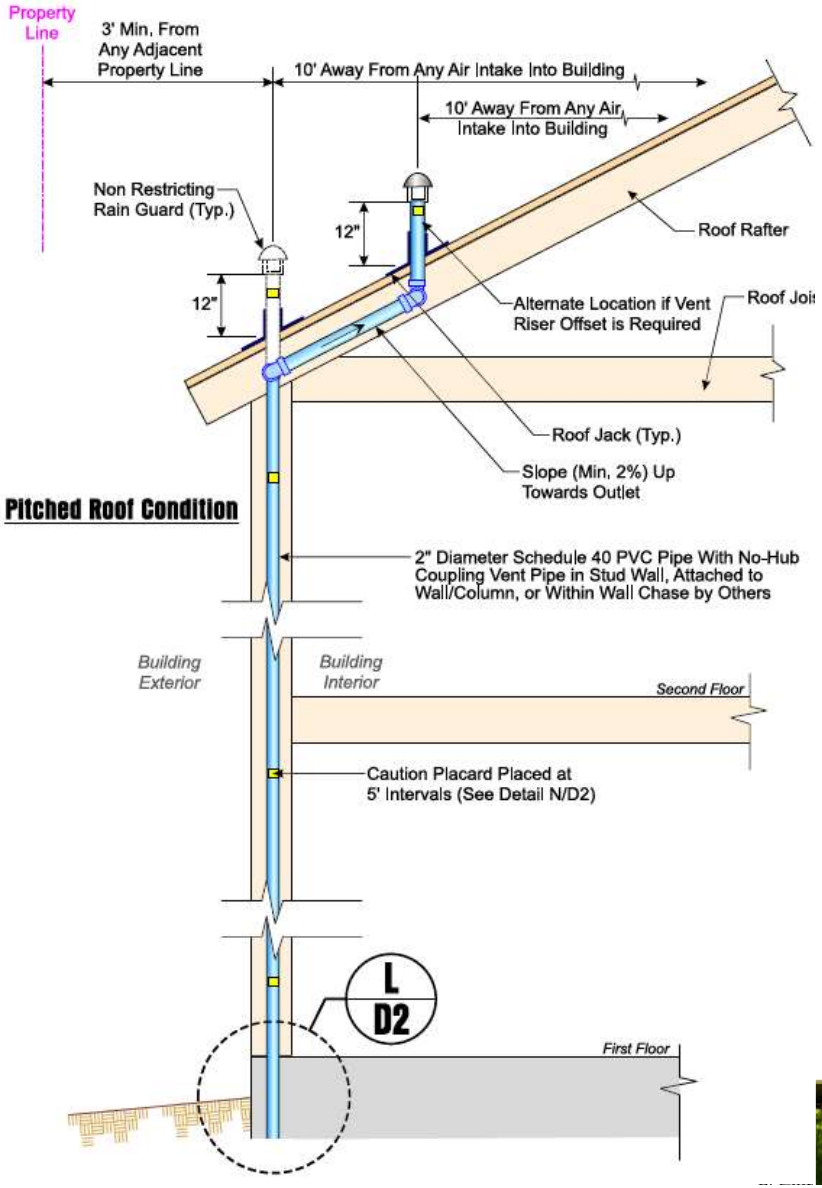
Construction Issues

Smoke testing and closeup of repair area identified during testing

Post-Construction Issues

Cracks in post-tension slabs, ~5 yr old townhomes (2 different). Required repairs

Vent Riser Construction



Vent Riser Sampling

- Vent risers are straight lines on paper, not when constructed
- Need to manage condensate
- Prefer sampling above and below-membrane sub-slab probes
- If vent risers are sampled:
  - Need a well-thought-out sampling procedure
  - Ground-level access points preferred, roof sampling discouraged
  - An isolation valve is helpful

Monitoring Objectives

1. Demonstrate that the VIMS is operating properly and successfully controlling exposure

   [post-construction/installation, pre-occupancy]

2. Continue to demonstrate that VIMS is operating properly and successfully controlling exposure

   [post-occupancy]

Performance Monitoring

Measurements + Inspections

Measurements

- **Vapor forming chemical (VFC) concentration**
  - Indoor Air (IA)
  - Subslab Soil Gas (SS)
  - Outdoor Air
  - Vent Riser Air
  - Crawl Space Air
  - Exterior Near-Source Soil Gas
  - Groundwater
- **SS to IA pressure differential ($\triangle P_{SS-IA}$)**

Inspections

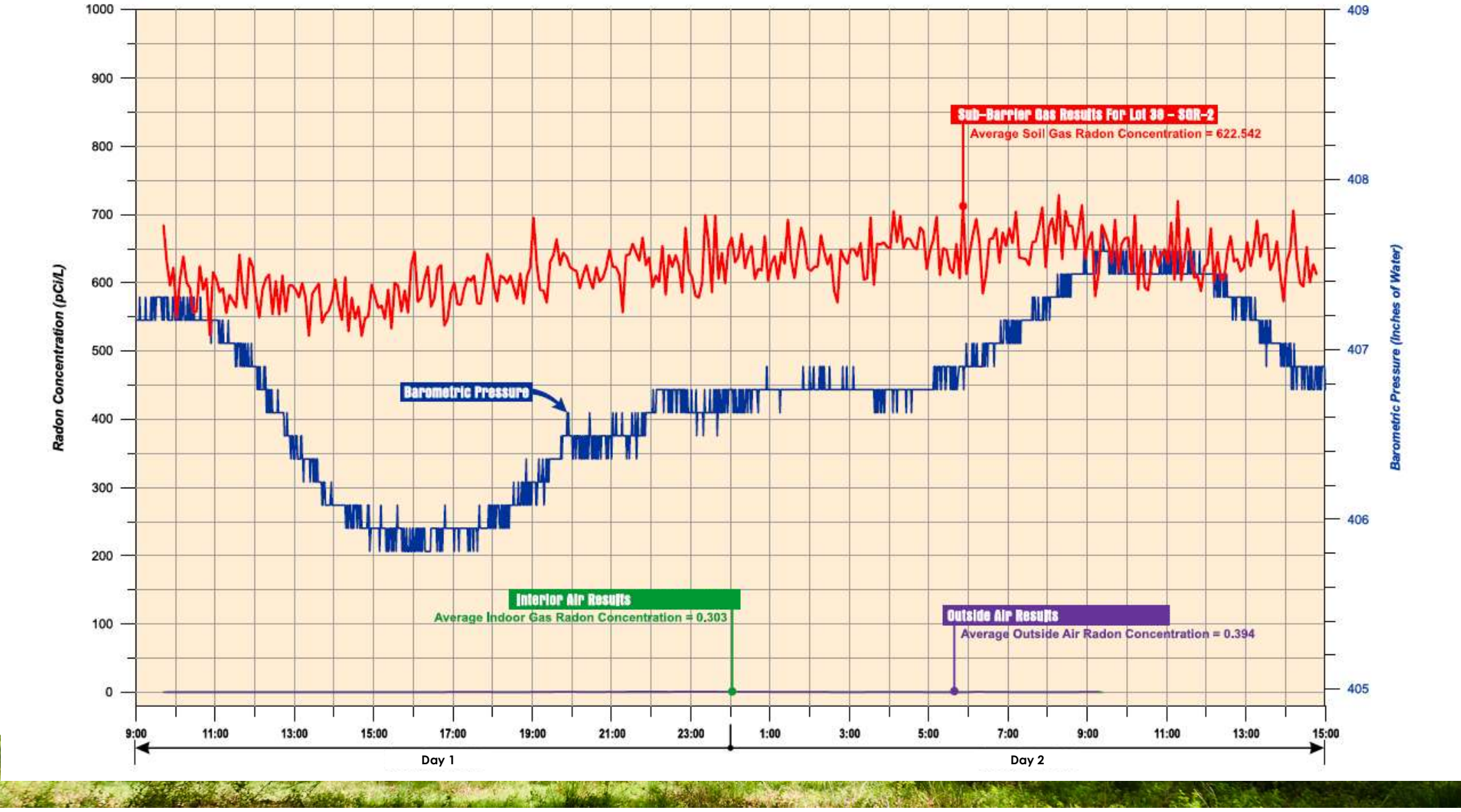
- **Building Inspections**
- **Enclosed Garage Inspections**
- **VIMS Inspections**

Radon Sampling

- Idea: Use naturally occurring radon as a tracer to evaluate VIMS performance
- Challenges
  - Distribution is different than vapor forming chemicals
  - VIMS permeance is different than vapor forming chemicals
- Increasing acceptance as **A** line of evidence, but cannot be **THE** line of evidence

Radon Sampling

- Possible use cases
  - Pair subslab and indoor air radon and VOC sample, support AF calculation when VOCs are non-detect or affected by background
  - Monitor radon during long-term O&M, change in radon concentrations may trigger additional investigation/monitoring
  - Identify periods when VI is more or less likely to be occurring


Radon Concentration (pCi/L)
Barometric Pressure (Inches of Water)
1000
900
800
700
600
500
400
300
200
100
0
409
408
407
406
405
Sub-Barrier Gas Results For Lot 30 - SGR-2
Average Soil Gas Radon Concentration = 622.542
Barometric Pressure
Interior Air Results
Average Indoor Gas Radon Concentration = 0.303
Outside Air Results
Average Outside Air Radon Concentration = 0.394
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
3:00
5:00
7:00
9:00
11:00
13:00
15:00
Day 1
Day 2

Department of Toxic Substances Control

What's New About VI? Case Study

CASE STUDY – ASSESSING THE POTENTIAL PATHWAY OF VI TO INDOOR AIR

GERARD (JERRY) AARONS, PG, CHG – SR. ENGINEERING GEOLOGIST

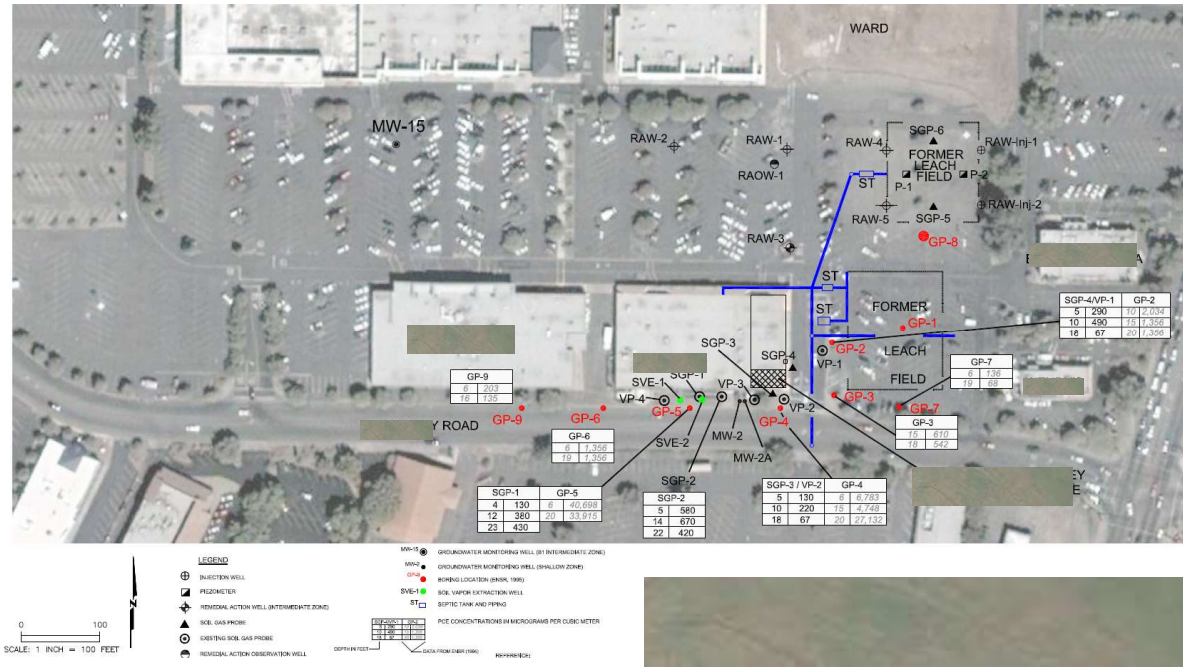
Case Study - Former Retail Dry Cleaner Site (Operated 1964-1997)

- 0.5-acre dry cleaner – next to retail bank and store
- Soil & groundwater contaminated with PCE and breakdown products
- Septic system discharged to leach fields east of building

Former Retail Dry Cleaner Site (Operated 1964-1997)

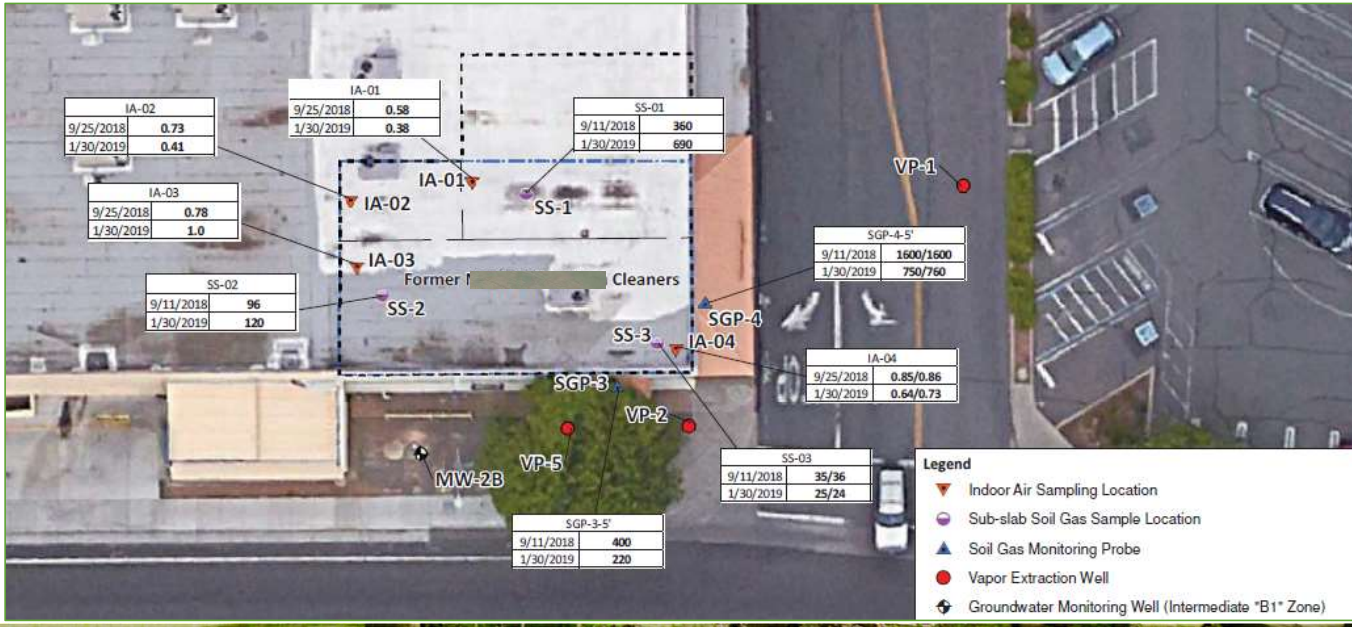
- Initial PCE Conc. in subsurface soil gas up to 40,968 µg/m^3 (GP-5)
- SVE operated from 1997 to 1999 modified and restarted in 2004 - ran until 2012

Post-SVE: PCE concentrations in soil gas (µg/m^3) March 2013



Post-SVE Soil Vapor Data (Sept. 2018 & Jan. 2019)

- Maximum PCE
  - 1.0 µg/m^3 in indoor air
  - 690 µg/m^3 in sub-slab
  - 1,600 µg/m^3 @ 5 ft bgs



Criteria used for calculating potential VI to indoor-air

Screen sub-slab PCE concentrations using U.S EPA default attenuation factor (AF) = 0.03

Calculate site-specific AF – using paired sub-slab to indoor-air PCE concentrations alone.

Calculate site-specific AF using 5ft bgs soil gas to indoor-air PCE concentrations alone.

Cal/EPA Dept. Toxic Substances Control's Human Health Risk Assessment Office (HERO) = U.S. EPA Region 9's

Compound	DTSC Commercial/Industrial Indoor Air Screening Level ($\mu g/m^3$)	Sub-Slab Screening Level ($\mu g/m^3$)
PCE	2*	67
TCE	8+	267
Cis-1,2-DCE	35*	1167
Trans-1,2-DCE	350*	11,670
Vinyl Chloride	0.16*	5.3

* = DTSC HERO HHRA Note 3

+= DTSC HERO HHRA Note 5, Accelerated Response Action

Sub-slab screening levels calculated using the indoor air screening level divided by default attenuation factor of 0.03

Calculated AFs using Site-Specific Data

- Calculated AF: indoor-air/sub-slab – range: 0.0006 to 0.02
  - Note: sub-slab SS-03 - PCE Conc. of 25 μg/M^3 did not meet source screen strength >50 times background (indoor-air)
    - EPA's Vapor Intrusion Database EPA 530-R-10-002 March 16, 2012
- Calculated AF: soil gas at 5 ft bgs/sub-slab – range: 0.0005 to 0.003
- For indoor-air/sub-slab sample pairs only, the average attenuation factor is 0.017
- Based on site-specific data, there is no excess risk to Human Health for commercial building occupants, based on measured indoor-air concentrations.

Final Site Remedy

- Removed the following from the Removal Action Workplan (RAW):
  - (1) on-property (source area) hydraulic containment and
  - (2) soil vapor extraction to address PCE near the former dry cleaner
- Parts of the original RAW were kept, including:
  - proposed final Site remedy is MNA for groundwater on- and off-Site, in conjunction with the operation of municipal well downgradient

Groundwater Monitoring Well Network

Depth to first water originally 20-45' bgs, lately ~45'-60' bgs

A Zone (to ~45 ft bgs)
PCE: 8.29 – 22.8 µg/L

Eight (8) A Zone wells mostly dry from 2011 to 2013.

Groundwater Monitoring Network in B-Zone

Thirteen (13) B Zone wells

Range in depth form 45'-230' bgs

PCE: <0.5 – 8.29 µg/L (MW-02B closest to release site

Groundwater Monitoring & Conceptual Site Model

- Distance from three (3) municipal water supply wells all outside of the Zone B 0.5 µg/L contour line
  - (NW & W ~1,900 ft & NE ~1,200 ft)
  - Screened 200-280 ft bgs & 300-400 ft bgs
  - Pumping at ~650-800 gpm
  - runs ~2 - 7 hrs/day
  - Calculated groundwater gradient in B Zone = 0.003 ft/ft
- Monitored Natural Attenuation (MNA) strategy: to reach Primary Drinking Water Standard's max. contamination levels (MCLs)

Overall Assessment of Conceptual Site Model

- Good site characterization – groundwater, soil gas, sub-slab, and indoor/outdoor air data.
- Source of VOC release area was well understood
- Source removal at buildings through years of soil-vapor extraction
- Demonstrating vapor intrusion to indoor-air is not occurring 6 years after SVE shutdown.
- Case remains open for the groundwater component of the remedy which include monitored natural attenuation (MNA)

Points to Ponder

- Sewer line(s) characterization
- Characterization of other commercial space within the footprint of the large building
- Are individual spaces adequately evaluated (Exposure Units)
- How homogeneous is the subsurface - site Geology, Hydrogeology?
  - Should there be sub-sets of the datasets if heterogeneous?
- SVE System Performance - Operation Optimization
- Decision to stop SVE
- Estimating PCE mass released to subsurface
- Total VOC Mass Removed by SVE operations
- High-Resolution Site Characterization
- Aquifer transmissivity & groundwater gradient
- Is 5' bgs soil vapor probe adequate for characterization (Guidance recommends deeper soil gas points (i.e.,15' bgs)
- Regulatory evaluations from DTSC Technical Services Groups (HERO ESPO GSB)
- Paired data (spatially and temporally)
- Methods for averaging VI AF data

Questions?

- Ben Stanphill, PE,
  Southern California Division Chief
  Benjamin.Stanphill@dtsc.ca.gov
- Gerard (Jerry) Aarons, PG CHG,
  Senior Engineering Geologist
  Jerry.Aarons@dtsc.ca.gov
- Cheryl Prowell, PE
  Assistant Deputy Director
  Cheryl.Prowell@dtsc.ca.gov