DNR REMEDIATION & REDEVELOPMENT PROGRAM GUIDANCE FOR PUBLIC COMMENT

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DOCUMENT TRACKING NUMBER

RR-649

DOCUMENT TITLE

Guidance: Investigation of Human-made Preferential Pathways Including Utility Corridors

BACKGROUND/SUMMARY

This guidance focuses on vapor migration in utility corridors and explains how other human-made preferential pathways can influence contaminant migration of vapor and groundwater, soil or surface water. The guidance describes methods and options to assess and sample the pathways to meet the requirements of Wis. Admin. Code § NR 716.11(5)(a).

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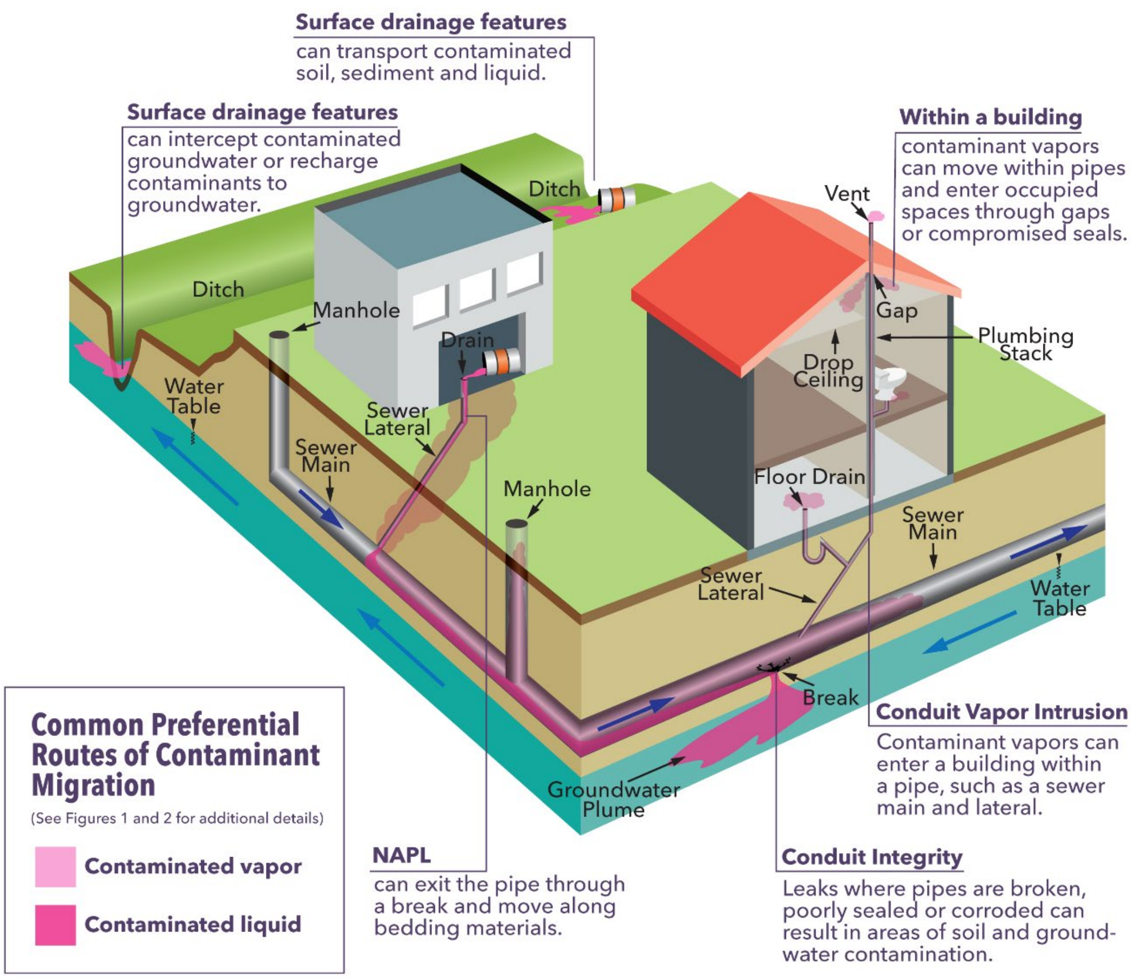
Please use subject line: “RR-649 Comments”

Guidance: Investigation of Human-made Preferential Pathways Including Utility Corridors (RR-649)

Wis. Admin. Code § NR 716.11(5)(a)



Purpose
The guidance focuses on vapor migration in utility corridors and explains how other human-made preferential pathways can influence contaminant migration of vapor and groundwater, soil or surface water. The guidance describes methods and options to assess and sample the pathways to meet the requirements of Wis. Admin. Code § NR 716.11(5)(a).

Related Guidance
Wisconsin Department of Natural Resources (DNR) publications and forms referenced in this document include a number beginning with "RR-" or "4400-." Locate these publications and forms by visiting dnr.wi.gov and searching "RR documents."

- *Vapor Intrusion Guidance* (RR-800)
- *When Contamination Crosses a Property Line* (RR-589)

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1 Introduction

1.1 Applicability

Contaminants migrate preferentially through zones of higher permeability, which include natural features such as fractures in bedrock and sand layers in finer-grained clay till. Human-made features may provide additional pathways of preferential flow both inside and outside buildings. Site investigations are required to evaluate all potential pathways for the migration of contamination (Wis. Admin. Code § NR 716.11(5)(a)). When starting an evaluation, the DNR recommends incorporating the known and potential preferential pathways into the conceptual site model (CSM) and documenting the pathways in a site investigation work plan or report. When preferential pathways indicate a potential route for contaminant migration at a site, sampling is required to determine if contaminants are moving through them.

1.2 Acronyms and Abbreviations

Acronym or Abbreviation	Meaning
CSM	conceptual site model
CVOCs	chlorinated volatile organic compounds
DNR	Wisconsin Department of Natural Resources
FLIR	forward looking infrared radar
GC/MS	gas chromatography / mass spectrometer
HVAC	heating, ventilation, and air conditioning
LOE	line of evidence
NAPL	non-aqueous phase liquid
PID	photoionization detector
PM	project manager (DNR)
ROW	right of way
RP	responsible party
RR	Remediation and Redevelopment Program
SSGSL	sanitary sewer gas screening level
TCE	trichloroethylene
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VAL	vapor action level
VRSL	vapor risk screening level
Wis. Admin. Code	Wisconsin Administrative Code
Wis. Stat.	Wisconsin Statutes

1.3 Definitions

Attenuation factor means the ratio of the indoor air concentration arising from vapor intrusion to the subsurface vapor concentration at a point or depth of interest in the vapor intrusion pathway (Wis. Admin. Code § NR 700.03(1s)).

Conduit is a subset of preferential pathways that allow fluid or vapor to flow easily with little or no resistance.

Drainage improvements or features are features that move surface water or groundwater away from an area and may include surface features such as ditches and subsurface features such as drain tiles.

Non-residential setting is a setting other than residential, such as for commercial or industrial purposes (Wis. Admin. Code § NR 700.03(39m)).

Preferential pathway means high-capacity transport pathways for vapors in the vadose zone or for groundwater flow[1] that are either natural or human-made. In this document, "preferential pathway" refers to human-made preferential pathways utility corridors and features within a building such as sumps, floor drains, plumbing vent pipes and plenums that may allow contaminant vapors to move from source areas into buildings and to migrate beyond plume boundaries and historically recommended screening distances.

Residential setting is any dwelling designed or used for human habitation including single or multiple family housing, and educational, childcare, and elder care (Wis. Admin. Code § NR 700.03(49g)).

Sanitary sewer gas screening level (SSGSL) is the recommended concentration of vapors in a sanitary sewer main calculated by dividing the applicable indoor air vapor action level (VAL) by an attenuation factor. The SSGSL is one type of vapor risk screening level (VRSL).

Spatial variability occurs when the value of a measured quantity (such as contaminant concentration) varies across locations where measurements are collected.

Temporal variability occurs when the value of measured quantity (such as contaminant concentration) varies over time at a constant location where measurements are collected.

Utility corridor means an underground or buried utility line or pipe (conduit), including any bedding or excavated and subsequently backfilled trench where the utility line or pipe is located. Utility corridors include but are not limited to sanitary and storm sewers, utility tunnels, water lines, gas lines, sewer force mains, buried electric power distribution lines and buried telephone, cable television or telecommunication lines. Utility corridors are present in public rights of way (ROWs), including streets or roads, as well as on the properties being served by the utilities.

Utility lateral means the piping systems that run from a property to the primary systems, normally located within the street. For example, the "sewer lateral" is the wastewater connection between a building's wastewater drain facilities and a public sewer.

Vapor action level (VAL) means the concentration of vapors from volatile compounds is at or above the 1−in−100,000 (1x10E-05) excess lifetime cancer risk or is at or above a hazard index of 1 for non−carcinogens (Wis. Admin. Code § NR 700.03(66p)).

Vapor risk screening level (or VRSL) means the concentration of vapors in samples collected outside a building to estimate indoor vapor concentrations. The VRSL is equal to the VAL divided by

[1] USEPA 2015.

an appropriate attenuation factor (Wis. Admin. Code § NR 700.03(66w)).

Winter Assessment Period is the period between November 1 and March 31 when frost conditions, with closed doors and windows and active heating, are more likely to create maximum indoor air contaminant concentrations.

Women who are or may become pregnant are between the ages of 15 to 44 (the Centers for Disease Control references women of child-bearing age as females between 15 to 44 years old).

2 Acute Risk Concerns

When there is a threat to public health, responsible parties must evaluate the need for an interim action (Wis. Admin. Code § NR 708.11). The action must be taken immediately if there is an imminent threat (e.g., acute risk) to public health (Wis. Admin. Code § NR 708.05(2)).

Trichloroethylene (TCE) – Special Concern
TCE may pose a health risk to women who are or may become pregnant if contaminant concentrations exceed the VAL in air even during brief periods of time.[2] If TCE is present, the responsible party should act quickly to determine whether women who are or may become pregnant are at risk.

Because migration of contaminants through utility conduits can result in rapid swings in indoor air concentrations, it is particularly important to identify preferential pathways at sites with TCE contamination. Assessing temporal variability is more important if TCE is present.

TCE and other contaminants may pose an acute health risk to all persons if present at high enough concentrations in indoor air. Visit dnr.wi.gov, search "vapor" for additional information on the acute health risks from TCE and other contaminants. See Vapor Intrusion Guidance (RR-800), for detailed information about vapor intrusion, screening, investigation, immediate and interim actions and mitigation.

3 Access

Contaminants migrating through preferential pathways commonly cross property lines. Responsible parties are required to investigate the extent of contamination regardless of whether it crosses a property line (Wis. Admin. Code § NR 716.11(5)). Responsible parties need permission to enter properties from all property owners prior to conducting an investigation, including right of way (ROW) holders. See RR-589, When Contamination Crosses a Property Line, for more information.

Excavators, except those performing utility work, must maintain minimum clearance distances from utility lines and associated underground and above ground facilities (Wis. Stat. § 182.0175). The DNR recommends that investigators consult the Diggers Hotline (diggershotline.com) and work closely with utility owners when performing work near or within underground utility pipes and lines.

4 Notification of Sample Results and Activities

Responsible parties are required to evaluate the need for public participation and notification

[2] DHS 2017, DHS 2021.

appropriate for the site and the situation (Wis. Admin. Code § NR 714.07).

Utility corridor investigations may reveal the presence of contamination on off-site properties. Sample results for vapor and other media collected from the site and any off-site properties, including within ROWs, must be shared with the DNR, property owners and occupants, as appropriate, within 10 business days of receiving the results unless otherwise approved by the DNR (Wis. Admin. Code § NR 716.14).

5 Investigation Overview

The route of contaminant migration can be complicated and may involve more than one preferential pathway (Figures 1 and 2). For example, a contaminant may have been disposed into a sewer as a liquid, migrated within the sewer in vapor form into a nearby building and leaked out of the sewer in liquid form elsewhere, causing additional soil and groundwater contamination.

Evaluating contaminant migration in utilities and other human-made preferential pathways differs from an iterative soil and groundwater investigation to define the degree and extent of contamination. See Appendix A, Investigating Utility Corridors and Other Human-Made Preferential Pathways, for a visual representation of a typical preferential pathway investigation.

DNR Assistance when Vapor Intrusion is a Concern
Site investigations involving vapor are often complicated, iterative, time-consuming and resource intensive. The DNR recommends working with the DNR project manager assigned to an individual site for response to general questions. To request technical assistance, submit Form 4400-237, *Technical Assistance, Environmental Liability Clarification or Post-Closure Modification Request* and the associated fee (Wis. Admin. Code ch. NR 749).

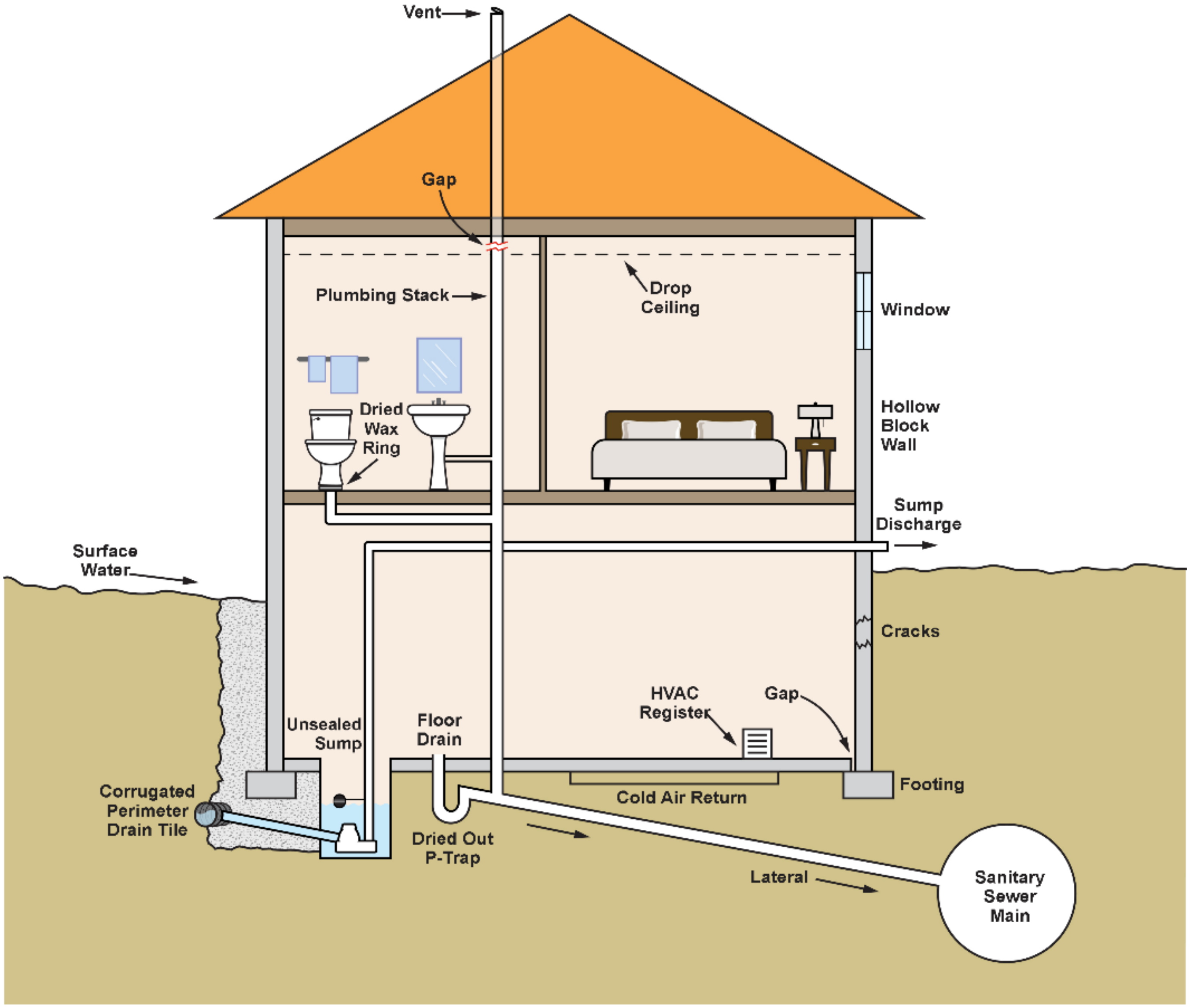
Resources for communicating with affected off-site property owners on vapor intrusion is available on by visiting dnr.wi.gov and searching “vapor intrusion for environmental professionals.”

General questions on vapor intrusion can be directed to state or regional DNR vapor intrusion specialists. Visit dnr.wi.gov and search “RR Contacts.”

5.1 Preferential Pathways – Buildings

Certain features associated with buildings can provide discrete points of entry for contaminants into the building (e.g., sumps, floor drains). Some examples are shown on Figure 1 and an additional list of examples is under “Building Features” in Section 6.

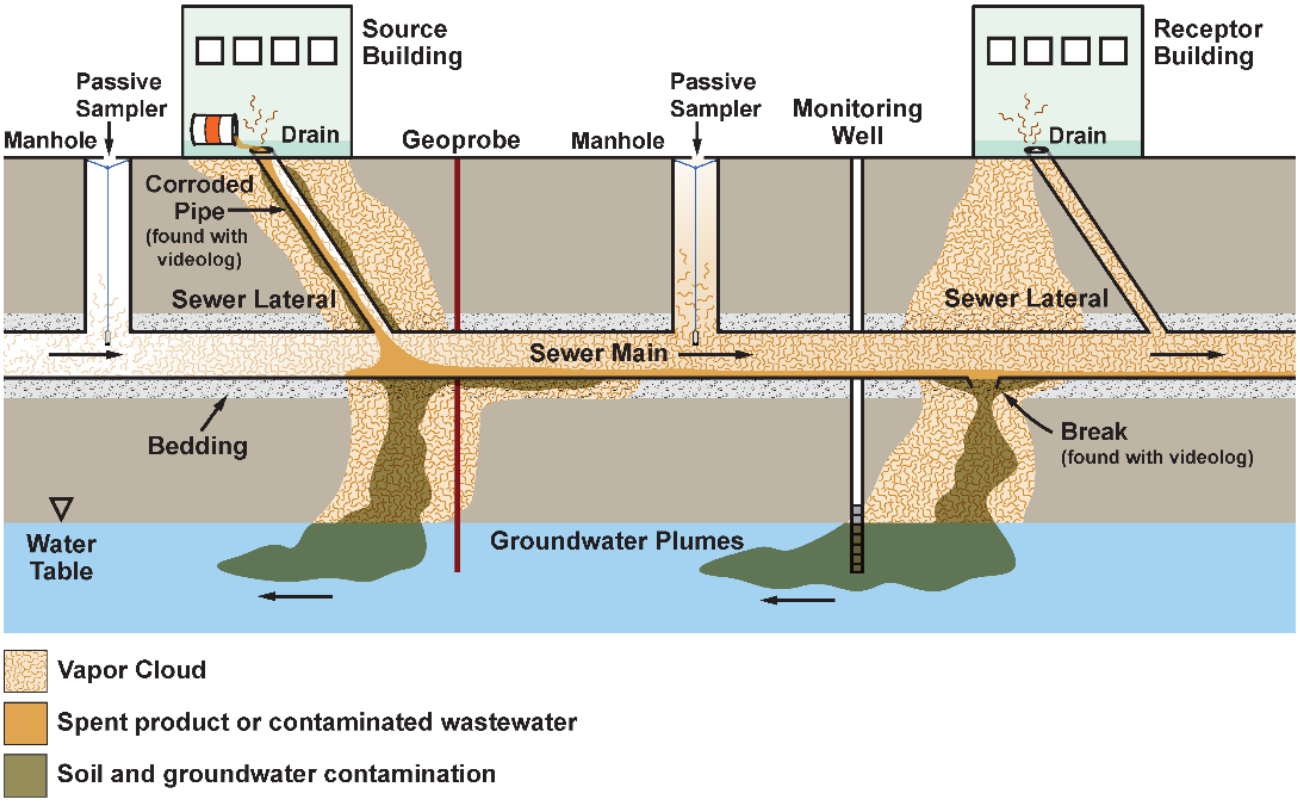
Figure 1: Examples of Preferential Pathways for Investigation - Buildings



5.2 Preferential Pathways – Utility Corridors

Utility corridors can allow contaminants to migrate and impact buildings, soil, groundwater and surface water long distances from the source or at locations that differ from the direction of groundwater flow (Figure 2). Assessment of contaminant migration within utility conduits, through utility conduit leaks, within bedding materials and into potable water mains may be necessary.

Figure 2: Examples of Preferential Pathways for Investigation - Utility Corridors



5.2.1 Contaminant Migration Within Utility Conduits

Contaminants may have been disposed of directly into a utility conduit (e.g., sanitary or storm sewer) or enter the utility conduit from contaminated soil or groundwater sources through compromises in the pipe that are a result of corrosion, poor fittings or breaks. The risk for migration through a utility conduit depends on the concentration, volume and type of contaminants. Liquid and volatile contaminants are the most likely to migrate.

If contaminants are found within a utility conduit that is designed to convey fluids, the utility can carry the contaminant far from the source with the help of gravity and pumping within a force main; contaminated vapor from that liquid can migrate several hundred feet farther.

If the contaminated utility conduit is connected to a building, the utility conduit can provide a direct route of entry for contaminated liquids or vapor into a building. A common example is vapor intrusion into buildings through a sanitary sewer pipe where solvents were historically disposed.

At sites where disposal took place many years ago and contaminated liquid or sludge no longer remains within the pipe, the contaminated pipe and surrounding bedding (material placed in the bottom of the trench on which the pipe is laid) can still pose a risk. Vapors from these contaminated materials can migrate through the pipe into occupied buildings.

5.2.2 Contaminant Migration Through Utility Conduit Leaks

Contaminants within a utility conduit can leak into the surrounding bedding and soils along the flow path if the conduit is compromised. Leaks from a compromised sewer pipe can result in soil, groundwater and vapor contamination at a down-flow location. At some sites in Wisconsin, contamination leaked from sewer pipes and caused significant soil and groundwater contamination which resulted in a vapor intrusion risk more than a quarter mile from the source property. Many sewer pipes, particularly older ones, have insufficient integrity to prevent leaks. Leaks can occur at poorly sealed connections or cracks. Some contaminants can permeate through pipes (particularly clay tile or concrete) or corrosive contaminants can enhance pipe degradation. This may occur especially where pipes have settled.

5.2.3 Contaminant Migration Within Bedding Materials

Bedding and backfill materials for utility corridors often have properties that allow migration of contaminants more readily than the native materials that surround them. Preferential movement of vapor can occur in bedding materials in some situations (e.g., short distances along sewer laterals, strong pressure gradients); however, few investigations have documented vapor movement at significant distances in unsaturated bedding materials.[3] Migration within the utility pipe rather than the surrounding bedding is a prevailing concern for contaminant vapor migration.[4]

5.2.4 Potable Water Mains

It is possible for contaminants to be drawn into a pipe through faulty joint seals if contaminated soil or groundwater comes into contact with a potable water main. Although water mains are normally pressurized, pressure transients from service outages, pumping by fire departments and pressure transients from changes in demand can induce inward flow. These are likely atypical situations. However, if high levels of contamination are found surrounding a water main or lateral, assessment of impact to potable water may be warranted.

5.3 Preferential Pathways – Surface Drainage Features

Surface water drainage features such as stormwater ditches and culverts, which intersect contaminated soil or groundwater, can carry contaminants far from the source. A detailed understanding of site hydrology (i.e., surface water drainage, groundwater-surface water interaction) may be necessary to determine where and how contamination is migrating.

6 Scoping and the Conceptual Site Model (CSM)

The DNR recommends assessing whether preferential pathways are present early in the investigation process; preferential pathways near contaminant sources must be evaluated under Wis. Admin. Code § NR 716.11(5). Preliminary information on preferential pathways is used to develop a CSM, which informs where to conduct field work. See Section 5.2 and Appendix A of the *Vapor Intrusion Guidance* (RR-800) for additional information on development of a CSM.

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[3] McHugh 2018, Hamilton 2017.

[4] McHugh 2018.

Not all human-made preferential pathways will be routes of concern for contaminant migration at a site. If the evaluation during scoping concludes that a particular pathway is not of concern, collecting information for that pathway and sampling may not be necessary and should be documented in the site investigation work plan or report (Wis. Admin. Code §§ 716.09(1), (2) (d) – (f), 716.11 (5)(a), 716.15(2)(d)4.). For example, if low levels of petroleum contamination are detected in the soil of the ROW, further assessment of a nearby sanitary sewer may not be warranted without additional evidence of a concern (such as a non-aqueous phase liquid (NAPL) intersecting sewer bedding).

The DNR recommends updating the CSM and adjusting the site investigation as it proceeds. For example, the focus of a vapor investigation may initially be performing sub-slab, indoor air and utility conduit sampling on the source property. However, if during the initial investigation it appears that the utility conduits are contaminated, those conduits must be investigated beyond the property boundary (Wis. Admin. Code § NR 716.11(5)(a)). The evaluation must determine whether the contaminated conduit contributes to impacts to connected buildings or soil and groundwater beyond the source property.

Examples of Human-made Preferential Pathways

Exterior Features

- Ditching
- Drain tile systems
- Dry wells
- Excavations
- On-site waste(septic) system tanks, pipes, drain fields
- Permeable trenches
- Sanitary sewers
- Storm sewers Tunnels
- Utility corridor bedding for gas, potable water, electricity, telecommunication, etc.

Building Features

- Cisterns (beneath basements)
- Crawl spaces
- Earthen floors
- Floor drains
- Foundation seams, joint, cracks
- Elevator shafts
- Heating, ventilation and air conditions (HVAC ducts, plenums)
- Pipes
- Sumps and drainage pits
- Utility penetrations
- Wall voids (such as hollow cinder block)
- Waste lines

6.1 Building Information

The DNR recommends identifying all utility conduit routes within and near the building with a focus on sewers and drainage and include the location and depth, where applicable, of:

- Floor drains

- Plumbing features connected to the sewer system (e.g., sinks, toilets)
- Construction and functioning of plumbing traps
- Sewer vent pipes
- Clean-outs
- Sumps
- Drain tile system external to the building
- Sump discharge pathways and points
- Sewer laterals on the property leading to the municipal sanitary sewer main
- Abandoned laterals on the property
- On-site waste disposal (septic) systems
- Locations of penetrations of the building foundation by sanitary sewer lines and other utilities

Building information may be readily available from building plans or observation. Supplemental investigations using video logging, ground-penetrating radar, metal detectors or other methods may be needed to document the location of pipes and other features, particularly in older buildings where this information may not be available.

The DNR recommends using the *Vapor Intrusion Building Evaluation (VIBE)* Form 4400-011 for collecting and reporting building information relevant to vapor intrusion investigations. Visit dnr.wi.gov and search “4400-011.”

6.2 Utility Corridor Information

6.2.1 Vapor Within Conduits

The area of evaluation for preferential pathways for vapor migration within utility corridors depends on site-specific conditions. Contaminated vapors typically decrease by 80% or more at 500 feet from the source area within sewer conduits.[5] Therefore, if vapor migration along or within a utility corridor is a concern, the DNR recommends collecting the information itemized in the list under “Bedding” in Section 6.2.3 at least 500 feet in both an up-flow and down-flow direction from where contamination intersects a utility corridor (e.g., a groundwater plume), or from where a utility corridor is joined by any utility lateral carrying contamination.

6.2.2 Liquid Within Conduits

Liquid contaminants can travel long distances within conduits. Contamination from leaking sewers has resulted in significant soil, groundwater and vapor contamination more than a quarter mile from where the contaminant entered the sewer system. The area of evaluation should be based on site-specific knowledge of disposal practices, contaminant type and utility characteristics (such as age and construction of pipe materials). For liquid contaminants that do not present a vapor risk, collection of only down-flow information is recommended.

6.2.3 Bedding

If contamination in the gas or liquid phase intersects utility corridor bedding, the area of evaluation should be based on 1) site-specific knowledge of disposal practices, 2) contaminant type, and 3) utility characteristics (slope, characteristics of the bedding material,

[5] McHugh, 2018

differential transport characteristics between the bedding and native material). For each of these situations, the DNR recommends the following information be obtained for the area where there is potential for a utility migration pathway:

- Plan view with respect to source area
- Depth of utilities
- Date(s) of construction
- Pipe materials
- Bedding materials (grain size, thickness)
- Flow directions
- Locations of laterals
- Locations of manholes
- History of cleaning, repair or video-logging since construction
- Planned upgrades or maintenance
- Abandoned laterals or other features
- Relationship of utilities including bedding to groundwater

The local municipality (e.g., city engineer or public works) is a source for utility corridor information. Other possible sources of information include utility maps, soil maps, results from other nearby investigations and historical use maps, including fire insurance maps and United States Geological Survey (USGS) topographic maps. Field investigation may be needed to fill in data gaps when this information is not available.

6.3 Contaminant Information

The DNR recommends that the CSM address the following questions regarding the nature of the contaminants:

- Are vapor-forming contaminants present?
- Is TCE present?
- Is it likely that contaminants were disposed into utility conduits?
- Is free product migration likely?
- Are explosive conditions likely?
- What receptors could be impacted?
- Do the contaminants present a corrosive risk to conduit integrity?
- Are the liquid or vapor transmitting characteristics of the bedding materials substantially different from the surrounding native soils?
- Does indoor air data suggest a preferential pathway is allowing contaminants into occupied spaces?

See Appendix C of the *Vapor Intrusion Guidance* (RR-800) for additional information on common commercial and industrial sources of vapor intrusion, including dry cleaning operations and other operations with chlorinated solvents.

When Indoor Air Data Indicate a Preferential Pathway
Indicators that conduit vapor intrusion may be occurring include situations where indoor air concentrations in a building are higher in rooms serviced by utilities, higher in upper levels of a building or are high compared to data from sub-slab vapor ports. In these situations, the DNR

recommends a more in-depth inventory of potential indoor air sources and further evaluation of the potential for conduit vapor intrusion.

6.4 CSM for Vapor Intrusion

CSMs for vapor intrusion have historically focused on migration of contaminant vapors through the soil and entry into buildings through cracks in the foundation. Investigations typically assessed buildings by collecting sub-slab samples and indoor air samples in the lowest level of the structure based on this CSM. However, recent studies have shown that preferential flow of vapors into buildings within utility conduits, primarily sanitary sewer pipes, is common and appropriate to be included in the CSM for vapor intrusion.[6] Typical sub-slab to indoor air sampling strategies, although still important, may miss other routes of exposure to contamination with equal or more severe health risk. For example, higher levels of contamination within indoor air than within sub-slab vapor may be incorrectly attributed to indoor sources if the potential entry of contaminant vapors through utility conduits is not evaluated.

Vapor intrusion through preferential pathways can occur within buildings on the source property, as well as affecting off-site properties. The recommended strategy for assessing preferential pathways is:

1. Assess preferential routes into buildings close to the source (from contaminated soil or groundwater)
2. Determine whether utility corridors are taking contaminants farther away from the source, particularly beyond the limits or direction of the groundwater plume
3. Assess buildings served by those utilities

Once a volatile contaminant enters a utility conduit, vapors can move by diffusion or differential pressure into the buildings served by those conduits. Plumbing traps are designed to prevent intrusion of sewer gases into buildings. However, dry plumbing traps at infrequently used plumbing fixtures, loose connections and cracks in vent pipes can allow contaminant vapor intrusion into indoor air. Concentrations of contaminants above VALs can be present even when a sewer gas smell is below the odor threshold.[7] Deviations from plumbing codes and other types of conduits (such as large utility vaults) can act as pathways for vapor intrusion. Cracks in sub-slab pipes can also result in vapors accumulating beneath the foundation, allowing for more typical through-the-foundation vapor intrusion. Although all buildings have preferential pathways (e.g., some degree of foundation cracking, utility penetrations), these may not always be pathways for significant movement of vapors into occupied spaces. Larger and more complicated building layouts are more likely to have spaces differentially affected by preferential pathways. Vapor intrusion through these pathways is a greater concern when advective (pressure) gradients have little resistance to flow from the source, such as from a highly contaminated sewer lateral into a home through a leaky plumbing vent stack. When diffusion controls vapor movement and the contaminant source is a distance away, such as within a deep groundwater plume, a preferential pathway may not provide a significant source of vapor intrusion, and typical assessment strategies (sub-slab and indoor air sampling) may be sufficient. However, as the distance to the source decreases and source strength increases, so does the concern for exposure to contaminant vapors through preferential pathways.

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[6] Riis 2010, Nielsen 2017, McHugh 2018.

[7] Nielsen, 2017.

High concentrations of contaminants behind plumbing traps present an additional concern. There may not be a current indoor air quality problem if the plumbing traps are functioning at the time of initial assessment, however, exposure to contaminant vapors may occur without notice or detection if the integrity of pipes or traps is compromised. A recent study indicated that typical indoor plumbing joints may lead vapors into indoor air even when properly installed.[8] The DNR recommends performing an indoor air investigation when vapor concentrations within conduits in the building are high, even if plumbing is intact.

7 Investigating Preferential Pathways for Contaminant Migration

7.1 General Investigation Principles

A field investigation should evaluate likely routes of migration identified during preparation of the CSM and use appropriate sampling methods. These methods may include surface water and surficial soil sampling, soil borings, groundwater monitoring wells, gas probes, geophysical assessment, collection of sub-slab vapor or indoor air or other methods that apply depending on site-specific conditions.

Contaminant movement via preferential pathways can occur in very discrete zones. Sampling near a utility line may not be sufficient to assess the pathway. For example, a soil boring or gas probe located a few feet from a utility line may not be representative of contaminant concentrations in the utility bedding. Accomplishing representative sampling often has to be balanced against potential damage to the utility line.

See Section 7.3.3 of the *Vapor Intrusion Guidance* (RR-800) for additional recommendations related to investigating preferential pathways.

7.2 Investigating Conduit Integrity

The integrity of a conduit should be assessed if contaminants were disposed of into a utility conduit. The assessment can help determine the likelihood and location of leaks into the subsurface through the conduit wall. Without this information, sampling outside the conduit can miss significant zones of impact. Video logging of utility conduits is a common method to identify zones of breaks, sags, corrosion or other discontinuities where leaks outside the conduit are likely. Leaks often occur where pipes join (e.g., lateral to sanitary sewer main or at elbows). Other useful techniques include pressure testing, smoke testing and tracer testing. When laterals are short, the investigation often proceeds directly to sampling soils and groundwater or bedding surrounding the pipe (see Section 7.4).

The extent of the investigation should depend on the known or suspected discharge(s), any historical disposal and history of utility repair or replacement. If larger quantities of contaminants or longer periods of discharge or disposal are suspected, the likelihood of migration beyond the property boundary increases. In most cases, the initial focus of investigation should be on pipes beneath the source building leading from drains and the sanitary sewer lateral from the source building to the sewer main. Although direct disposal of contaminants into a compromised utility conduit is a common scenario, contaminants from a groundwater or a NAPL plume may also enter a

[8] Tay, 2025.

conduit, making assessment of conduit integrity and exterior sampling down-flow necessary.[9]

7.3 Investigating Utility Conduits

Situations where utility conduits may play a role in contaminant migration beyond the source property include the following:

- Disposal of contaminants directly into sewer lines is known or suspected
- Conduits intersect contaminated groundwater
- Conduits intersect contaminated soil in the vadose zone

If contamination is identified within a utility conduit on the source property, or disposal of contaminants into a conduit system is known or suspected, the conduit must be assessed beyond the property boundary (Wis. Admin. Code § NR 716.11(5)(a)). Sampling within the conduit in the ROW or adjoining property is commonly needed. Sampling of liquids and solids within the conduit may be useful for certain contaminants; however, when vapors from volatile contaminants are a concern, sampling vapor directly yields the best data for assessing vapor migration. Contaminated liquid entering a sewer pipe can act as a source of vapor contamination over longer sections of sewers. Therefore, sampling liquid is recommended when entry of contaminated liquid is likely, such as due to disposal or infiltration of contaminated groundwater. See Section 7.6.2 "ROW Assessments" under Investigating Preferential Pathways for Vapor Intrusion for details on scoping a vapor investigation in the utility conduits.

7.4 Investigating Utility Bedding

Once an area of possible utility conduit compromise has been identified or the utility bedding has been identified as a potential preferential migration pathway, sampling should be performed in the conduit bedding and surrounding soil and groundwater. Sampling of soil, liquid and/or vapor in bedding materials can provide useful information about the presence of contaminants in backfill materials. Passive gas samplers may be an option when other investigation techniques (e.g., borings close to a utility line) are difficult.

Vapor samples collected from utility bedding can provide qualitative information, however, given the variable nature of vapor concentrations in such an environment this data should not be used to make risk decisions for nearby structures without additional lines of evidence (LOEs).

If contamination is found surrounding utility conduits that extend to the property boundary, the extent of impact along the utility main must be determined (Wis. Admin. Code § NR 716.11(5)(a)).

7.5 Investigating Surface Drainage Features

Investigating surface drainage features can be straightforward. Access is typically less difficult than with subsurface media and contamination may be visible. Standard soil and water sampling techniques can be used in these situations.

Investigating surface draining features may be more complex when features intersect soil or groundwater contamination. These features may transport and discharge contamination to groundwater downstream or to other surface water features. In these situations, understanding

[9] McHugh, 2018.

surface-groundwater interactions within the drainage feature may be required. Sampling techniques such as active and passive sampling methods for surface water, pore water (transition zone) and groundwater are available. Water quality parameters including temperature, specific conductance, dissolved oxygen, pH, turbidity and redox potential may also provide valuable information when evaluating contaminant migration pathways.

7.6 Investigating Preferential Pathways for Vapor Intrusion

It is highly likely that disposal to the sewer occurred for some types of operations such as dry cleaners.[10] **Utility corridors, including source property drains and laterals, must be evaluated at dry cleaner sites in accordance with Wis. Admin. Code § NR 716.11(5).** See Appendix C of the *Vapor Intrusion Guidance* (RR-800) for more information on common historical practices by dry cleaning operations and other industries that used chlorinated solvents.

7.6.1 Source Building Assessment

Buildings near the source of contamination are at the highest risk of vapor intrusion through preferential pathways. Sub-surface pipes may intersect contaminated soil or groundwater and disposal of contaminants into drains may cause contamination of the pipes and/or discharge to the surrounding bedding materials. The pipe or bedding can allow vapor movement back into the source building.

Conduits within the source building should be evaluated based on:

1. Knowledge of operational history
2. Evidence of disposal (such as staining around drains)
3. Known distribution of contaminants (e.g., soil, groundwater or vapor contamination that appears to correlate with sewer pipes)

Investigations conducted in Wisconsin revealed that 29 out of 50 (59%) of buildings located on the source property had a vapor sample exceeding the non-residential VAL for either PCE or TCE collected from within a conduit such as a cleanout, floor drain or sump. This percentage may be higher as only a single short-term duration conduit sampling event took place at some of these buildings. **The DNR recommends sampling building conduits using the strategies described below if chlorinated solvents were used or detected at the source property.**

Collect Conduit Vapor Samples (sewer/plumbing systems)

Vapor sampling within utility conduits can assess whether vapors are entering or have the potential to enter occupied spaces via conduits through leaky plumbing joints or compromised plumbing traps or pipes. In most cases air within the conduit can be sampled through clean-outs, however a site-specific device may need to be configured to collect a representative sample.

Clean-outs: Clean-outs are normally found in the interior of the building but may also be present externally. Samples may be collected by placing an appropriate active or passive sampler at a clean-out. The clean-out cover should be removed and a temporary cover installed that allows insertion of a tube (active samples) or a passive sampler to collect the

[10] International Fabricare 1988, Cal WQB 1992, Missoula City-County 1999.

vapor sample. It is important that the pipe is adequately sealed so that the sample is isolated from indoor air. After the temporary cover is installed, the conduit should be allowed to equilibrate for at least an hour if a sample is collected by active means (pumped tube, syringe, evacuated glass cylinder, canister, etc.). For canister sampling, a valve should be installed above the temporary cover to allow pressure testing of fittings. At least three volumes of air should be purged from the tubing prior to sample collection.

Other collection points: If needed, other sampling locations include sampling below the wax ring once a toilet is removed, running tubing from the sampling canister past the water in the p-trap or sampling down the plumbing vent pipe. Sealing and sampling floor or other drains and sumps are also options.

If a sample is collected from a drain with a functioning p-trap, the liquid in the trap should be removed prior to sampling for the sample to be representative of gas in the plumbing system. Any time a trap is removed, the sample must be obtained from a location that is sealed to prevent indoor air from diluting the sample. After the sampling location is sealed, it should equilibrate for an hour before the sample is collected. Traps should always be returned to a functioning state after sampling. It may be useful to have a licensed plumber assist with assessments of plumbing systems.

See Section 7.5.2 of the *Vapor Intrusion Guidance* (RR-800) for more information on sampling sump pits. Collecting liquid samples from sumps also provides useful data and may indicate the need to investigate soil, groundwater and/or surface water farther along the piping transfer and/or at the outfall for the sump discharge. If sump water is contaminated, the outfall to a storm sewer or surface discharge may no longer be appropriate.

Other assessment methods: Using real-time samplers, tracers, smoke testing, borescopes and manipulating building or sewer pressure to differentiate sources are other methods to assess preferential pathways. In addition to sampling air for contaminants of concern, adding certain indicator compounds to the analyte list may help differentiate the source. For example, certain compounds such as chloroform are common in sewer gas.

Number of sampling events: Contaminant concentrations in plumbing systems can vary over time. Performing multiple sampling events are recommended since one event may be insufficient to identify the presence of a contaminant pathway. When contaminant concentrations are low, other LOEs should be used to determine the number of sampling events needed to rule out the pathway. Investigators in Denmark report a 3 to 4 order of magnitude variation in contaminant concentrations over time.[11]

Non-sewer System Pathways

Preferential pathways other than the sewer/plumbing system may require evaluation. These types of pathways may include but are not limited to hollow foundation walls (e.g., cinder block), large gaps where foundation elements meet, elevator shafts, heating, ventilating and cooling (HVAC) ducts beneath the slab, historic chimneys and false ceilings. Real-time assessment can help evaluate these potential pathways using a photoionization detector (PID) or techniques such as a portable gas chromatography-mass spectrometer (GC/MS), hot

[11] Loll, P., 2024.

wire anemometers, and forward-looking infrared radar (FLIR).[12]

Focused Indoor Air Sampling

Indoor air samples should be collected in rooms served by conduits, which may include rooms with plumbing features, floor drains, utility penetrations through the foundation, or with walls adjacent to plumbing vents. The indoor air data, when paired with conduit vapor data, can help distinguish indoor air sources from conduit sources and evaluate for acute risk to determine whether immediate action is necessary to protect public health.

7.6.2 ROW Assessment

Vapor Sampling Methods

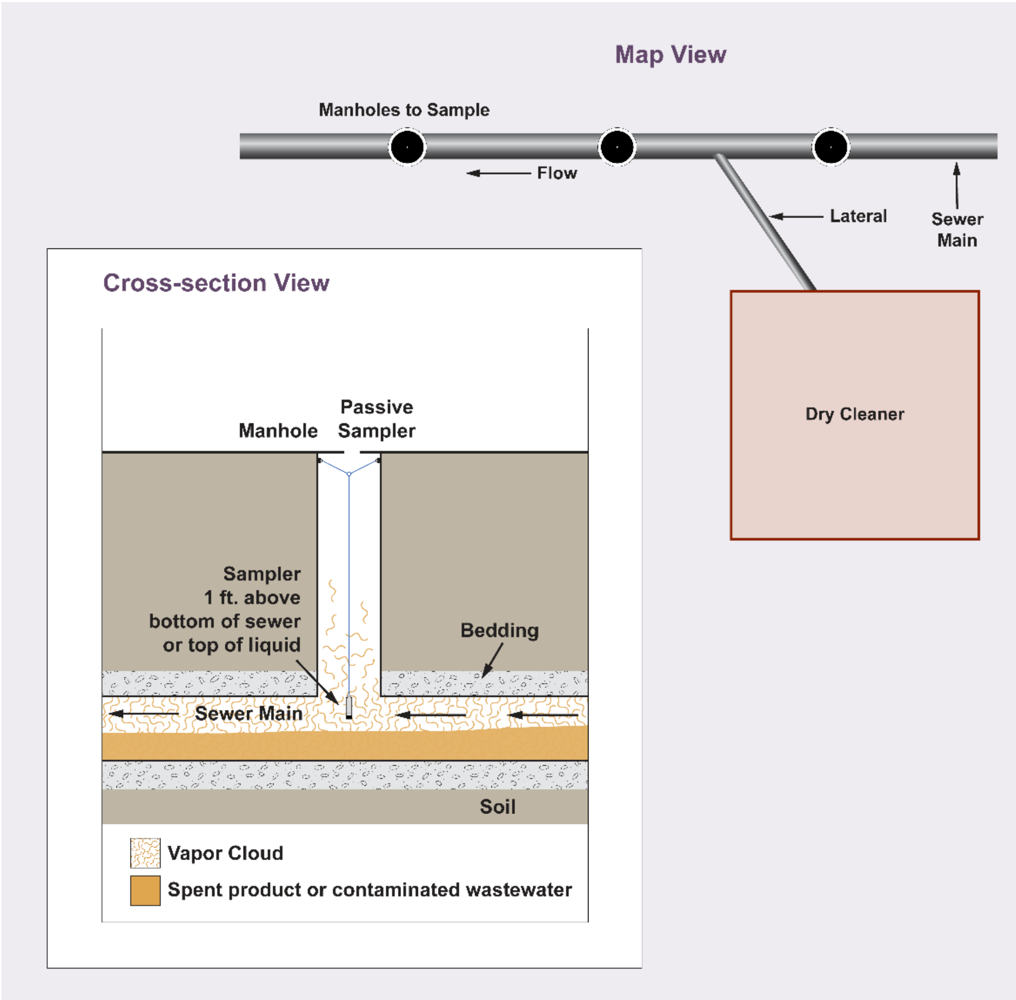
The current recommended method to assess the potential for vapor impacts beyond the source property through a utility corridor conduit is to obtain a sample from manholes beyond the source property. Most manholes have a vent through which vapor samples can be collected or a cover that can be removed for sampling.

Short duration sampling within conduits at a site are unlikely to be representative of typical concentrations in the conduit. The DNR recommends using passive sorbent samplers where possible to collect additional samples to investigate vapor concentrations in sewer mains.

See *Vapor Intrusion Guidance* (RR-800), Section 7.3.3., for specific sampling recommendations.

[12] Lee, 2020.

Figure 3. Typical Initial Sewer Manhole Vapor Sampling



Scope of Initial Sampling

Initially, the DNR recommends samples be collected from at least one location up-flow from where the utility corridor intersects the contamination or discharge (such as the lateral from the source property) and several down-flow locations. The number of samples collected is site-specific and based on the spacing of the manholes or access points, accessibility, nature of the contamination, knowledge of the conduit system and presence of receptors. If a contaminant plume intersects a longer stretch of the corridor, more significant volumes of contaminants were discharged or discontinuities in the conduit within the corridor are known, additional samples may be needed. A minimum of three sampling points (one up-flow, two down-flow) within the sewer main is the initial recommendation (see Figure 3).

Assessing Sample Results Using Sanitary Sewer Gas Screening Levels (SSGSLs)

In cases where sanitary sewers may allow vapor phase contaminants into occupied buildings, DNR recommends that a SSGSL be calculated for each of the contaminants of concern. The SSGSL provides a concentration to use in assessing the need to collect additional samples within the sanitary sewer pipe over time or spatially, and whether the conduit vapor pathway should be further assessed in occupied buildings served by those sewers.

The SSGSL is calculated by dividing the applicable indoor air VAL by the attenuation factor of 0.03.[13] The 0.03 attenuation factor is used for all types of buildings, regardless of type of use, because the sewer lateral construction and gas traps designed to prevent intrusion of sewer gases are similar for all types of buildings. If any residential use takes place within a building or the area is zoned for residential use, the lower residential VAL should be used in the calculation of the SSGSL.

The use of SSGSLs is a screening tool that is only appropriate for samples collected from within sewer mains, not samples collected within sewer laterals, other locations closer to the occupied spaces, or in conduits not adequately protected by plumbing traps where comparison to the VAL may be more appropriate. Data collected from sewer laterals should be assessed on a case-by-case basis.

When TCE is a contaminant of concern…
A study conducted prior to 2021 recommended using an attenuation factor of 0.03 to estimate the degree that contaminant vapor concentrations attenuate between sanitary sewer mains and the indoor air of connected buildings.[14] However, investigations conducted in Wisconsin since 2021 show the exceedance of a VAL for TCE in buildings due to vapor intrusion from a sanitary sewer conduit even when the concentration in the sewer was well below the SSGSL calculated with an attenuation factor of 0.03. Investigations found TCE above the VAL in connected buildings with deteriorated plumbing fixtures, compromised traps, plumbing out of compliance with code or episodic sewer cleaning events that emptied plumbing traps. Since TCE may pose an acute risk to sensitive populations over shorter durations and the compromised plumbing is widespread, DNR recommends an evaluation of impact to air in buildings connected to a sewer when the concentration of TCE exceeds 10% of the SSGSL.

Follow-up ROW Sampling

Temporal: Studies and investigations show greater long-term (i.e., seasonal) variability of vapor concentrations in sanitary sewer systems than short-term (i.e., over the period of a few days).[15] Based on this, the DNR recommends the following:

1. If results from the initial sampling exceed the SSGSL, the DNR recommends assessing adjacent buildings and collecting samples from different manholes (see *Spatial Delineation*). However, sampling from impacted manholes in subsequent events may provide data that aids in interpretation of data from other manholes.
2. If the results from the initial sampling are greater than 10% of the SSGSL but below the SSGSL, additional rounds of sampling at the same manholes (at least one additional round of sampling in a different season) is recommended. **If the samples show TCE greater than 10% of the SSGSL, evaluation of the occupied buildings connected to the sewer main is also recommended**. Consider the following when making sampling decisions:
    - Higher concentrations of contaminants may be drawn into the sewer system during periods of greatest temperature differential between sewer air and outdoor air. Therefore, the DNR recommends at least one of the sampling events occur

[13] McHugh, 2018.
[14] McHugh, 2018.
[15] McHugh, 2018, Guo, 2020.

during the winter assessment period.
- The DNR also recommends sampling when the water table rises to the elevation of the sewers to evaluate the potential for contaminated groundwater entering the sewer main and off-gassing within the sewer if that was different during the initial sampling event. Investigations in Wisconsin have shown that even low concentrations of chlorinated volatile organic compounds (CVOCs), such as TCE of 1 to 5 micrograms per liter (μg/L), can cause high concentrations in the vapor phase well above the SSGSL.

3. If the results from the initial sampling are less than 10% of the SSGSL, no further sampling may be needed after considering all LOEs.

Because of the evolving science and recommendations on preferential pathways, the DNR recommends requesting a technical review (with fee) (Wis. Admin. Code ch. NR 749) to discuss initial sample results prior to scheduling additional sampling.

Spatial Delineation: Sewer gas concentrations exhibit a high degree of spatial variability. The DNR recommends the following:

- Sample additional manholes to define the extent of the risk if the SSGSL is exceeded in any of the initial manhole samples.
- Sample manholes or other locations along the utility corridor laterally until there are two consecutive locations with concentrations of contaminants less than the SSGSL.
- Sample additional upflow manholes if the upflow manhole was impacted during the initial sampling event to determine if the impact is from the site or another source. Contaminant vapors may travel several hundred feet opposite sewer liquid flow.
- Develop an alternative strategy to determine the spatial extent of impact if other sources of the contaminant of concern are suspected.

Assessing Sample Results from a Storm Sewer or Other Exterior Conduit

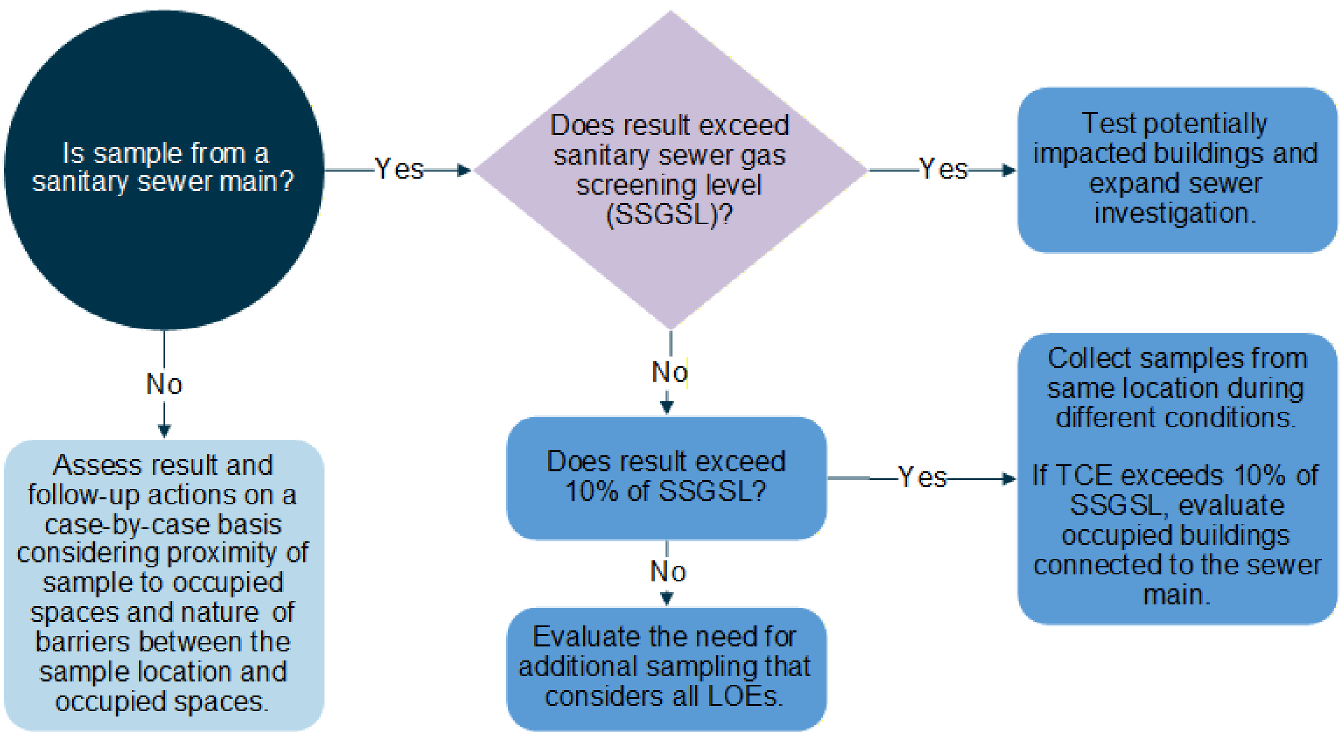
Vapor concentrations in conduit systems not connected to the interior of occupied spaces may be evidence of contaminant migration . Contaminant migration may not necessarily mean intrusion of vapors into an occupied space. If vapor concentrations are measured in such conduits, the results should be assessed based on site-specific circumstances (Wis. Admin. Code § 716.11(5)(a)). It may be appropriate to consider the data as a LOE in development of a CSM. See Appendix A of the *Vapor Intrusion Guidance* (RR-800) for additional discussion on LOEs and development of a CSM.

7.6.3 Off Site Building Assessment

The DNR recommends assessment of occupied buildings connected by laterals and if the concentration of a contaminant of concern exceeds the SSGSL in a sanitary sewer main, sampling is often recommended. However, when TCE is the contaminant of concern and concentrations within the sewer main exceed 10% of the SSGSL, the DNR recommends sampling withing occupied buildings connected by laterals . Sampling should focus on routes into the building and not discharges from the building. Contaminant concentrations in plumbing conduits at off-site buildings may be similar to concentrations in the sanitary sewer main. Since contaminant concentration in these conduit systems may be variable, a few off-site building conduit samples may not be sufficient to rule out a risk to indoor air via this pathway. Instead, an alternative to collecting building conduit sampling is to evaluate the integrity of the building's plumbing to mitigate the pathway into the building and evaluate other remedial action options.

The DNR recommends sampling of indoor air to determine if an acute risk is occurring. However, because conduit vapor concentrations can be episodic, indoor air concentrations less than a VAL do not preclude a future impact. Sample data collected within a building, such as clean-outs and plumbing vent pipes, should be assessed on a case-by-case basis. See RR-800. For conduit systems that are not connected to the interior of occupied spaces, such as a storm sewer manhole connected to an exterior drain, the vapor concentrations may be evidence of contaminant migration but not necessarily vapor intrusion through the conduit and use of the SSGSL may not be appropriate. If vapor concentrations are measured in such conduits, the results should be assessed based on site-specific circumstances.

Figure 4: Conduit Vapor Data Assessment and Decision Recommendations



Note: The use of the 0.03 attenuation factor is only appropriate for samples from a sewer main manhole, generally where the sample is not close to the occupied space and the entry of vapors into buildings is inhibited by traps.

7.6.4 Assessment of Data Collected Behind Plumbing Traps and Mitigation Decisions

No established standards or screening levels currently exist for contaminants within conduits that enter occupied buildings; however, if vapor concentrations are high behind plumbing traps (e.g., p-traps, wax rings, stack vent pipes) and those safeguards are compromised, indoor air quality can quickly deteriorate, even if indoor air concentrations are currently found below VALs. This is analogous to a structure with indoor air concentrations less than the VAL, but sub-slab concentrations greater than the VRSL. The high sub-slab concentrations represent the potential for vapor intrusion in the future.

In addition, vapor intrusion through preferential pathways can be very episodic in response to changing pressures in indoor air that are the result of meteorological factors and changes to the building structure or use. It can be difficult to determine whether preferential pathways are compromising indoor air quality with the collection of only a few indoor air samples. For these reasons, mitigation decisions should be made on a case-by-case basis with the information available.

Consider mitigating a conduit pathway as close to the point that contaminants enter the conduit as possible. For example, where contaminated groundwater is entering a sanitary sewer and the vapors are migrating through the sewer lateral into an apartment building, consider the following:

- Implementing measures to prevent contaminated groundwater from entering the sanitary sewer (such as lining the sewer pipe)
- Ventilating the sewer main or lateral outside the building
- Installing gas trap siphons or one-way valves to prevent vapors from entering the building

While checking and repairing deteriorated plumbing pipes, fixtures and traps inside a building can be an effective initial measure, maintenance of such features can be difficult and unlikely to be protective in the long term. See *Vapor Intrusion Guidance* (RR-800), Section 9.3, for additional recommendations.

8 Applicable Action or Screening Levels and Suggested Sample Nomenclature

Investigating contaminant migration through preferential pathways includes collecting air/vapor samples from a variety of locations with variable applicable VALs or VRSLs. Sample locations may include indoor air, outdoor air, sub-slab vapor (beneath the foundation), soil gas, headspace from temporarily sealed sumps, floor drains (behind the p-trap), lateral/plumbing cleanouts (behind the p-trap), within the sanitary sewer gas main, etc. The DNR recommends working with the assigned DNR project manager to discuss site-specific concerns. See Tables 12 and 13 in *Vapor Intrusion Guidance* (RR-800) for sample locations, applicable VALs, VRSLs, default attenuation factors and suggested sample nomenclature.

9 Remediation of Preferential Pathways

Remedial measures for contaminant vapors in conduits
Contaminant vapors within conduits connected to buildings pose a risk to indoor air quality and the building occupants. Plumbing systems in buildings are intended to include features such as traps to prevent intrusion of gases within the sewer from entering the occupied space of the building. However, plumbing integrity is unreliable:

- Plumbing in older buildings may deteriorate
- Pipe joints and elbows are known to leak vapors even when properly installed (Tay 2025)
- Water in traps may evaporate
- Plumbing modifications by owners/occupants that are not licensed plumbers are common,

especially in residences
- Temporary conditions may empty water in plumbing traps or draw vapors from the sewer main toward the building during routine sewer main cleaning or weather events, such as high wind or low pressure atmospheric events

Therefore, the DNR recommends remedial measures be implemented that eliminate or reduce the concentration of vapor contaminants within conduits, particularly when TCE is a contaminant.

If VRSLs are exceeded in soil gas or groundwater, remedial actions must be evaluated and selected to reduce the mass and concentration of the source, to the extent practicable (Wis. Admin. Code §§ NR 722.07, 722.09 and 726.05(8)). Mitigation does not meet the criteria since it does not reduce contaminant mass and concentration. Natural attenuation is also not an acceptable remedy for chlorinated solvents since they persist in the environment.

See *Vapor Intrusion Guidance* (RR-800) for detailed information about vapor intrusion, screening, investigation, immediate and interim actions and mitigation. Additional resources on mitigation and remedial action of vapor is available (visit dnr.wi.gov, search "vapor").

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Appendix A: Investigating Utility Corridors and Other Human-made Preferential Pathways