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INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Investigation of Manmade Preferential Pathways

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Background

The purpose of this guidance document is to provide additional tools to enhance conceptual site model (CSM) development. This document does not endorse any technologies mentioned in the text. This technical guidance document does not alter any existing IDEM guidance, rule, etc.

Introduction

The following facts, observations, and examples are based on multiple scenarios where manmade conduits (sewer pipe) or utility corridors (backfill around underground utilities) greatly influence groundwater hydraulics and/or the distribution and extent of subsurface contamination. This listing does not cover every potential scenario or investigative technique as the evaluation of vapor intrusion resulting from manmade conduits is discussed in a separate document.

> Preferential Pathway: A route of least resistance for fluid flow, or a more permeable feature than the surrounding materials. A pathway may extend vertically or horizontally and be derived naturally (i.e. Karst, bedding planes) or by human activities. Feature orientation may be such that fluid flow could go in an unexpected direction. Generally, pathways are limited in width but extensive in length. Examples include but are not limited to: improperly sealed wells, field tiles, buried utility lines, and building foundations.

Most remediation sites are in developed areas where humans have altered the original subsurface environment. Human activity also changes areas that are not urbanized. The shallow subsurface in both urban and rural environments may be disturbed by drainage improvements, subsurface utilities, and cut and fill for construction. Often these features are unknown prior to the investigation.

Why are Manmade Preferential Pathways Important?

Disturbed sediments are more porous and permeable than naturally deposited ones regardless of their composition and grain size. For example, sand fill is more permeable because it is placed without sorting or compaction to fill a void. Textbook porosity and permeability values assume that materials are uniform and compacted, but these values are not representative of human altered materials.

Manmade preferential pathways can transmit all phases of contaminants tens to hundreds of feet away from the release point regardless of groundwater depth. This movement is often in directions up-gradient or cross-gradient of a release. In areas where groundwater is deeper than a conduit or utility corridor contaminants may leak out of the conduit and act as a secondary source for soil or groundwater contamination. Where shallow groundwater is present, product and dissolved phase plumes can travel quickly and without attenuation beyond the property boundary. Preferential pathways can also provide a vertical migration route to deeper aquifer horizons by intersecting and breaching fine-grained layers.

Preferential Pathways and the CSM

Preferential pathway assessment begins before or during the initial investigation phase. A comprehensive CSM considers the operational history and probable contaminant release mechanisms. Often, investigation proceeds forward with delineation from a '"source" without evaluation of how the contaminant reached its distribution in the subsurface. This can lead to wasted effort by misinterpreting the contaminant distribution.

For example, nearly all pre-1980s dry cleaning machines were plumbed to the sewer. Also, petroleum service stations are usually on busy corners near large diameter sewers and utility corridors. These are features to examine early in the investigation.

The CSM should account for both the presence and characteristics of the preferential pathways with respect to the release area if manmade features are suspected contaminant transport routes. Additional investigation should also seek to understand how preferential pathways may affect the subsurface hydraulic properties. This preferential pathway survey should involve a more comprehensive view of the site layout, the site's surroundings, the local and regional geology and topography, and the degree and age of urbanization in the area.

Preferential Pathway Identification

This section lists the common, subsurface elements which influence NAPL migration, soil source geometry, and contaminated groundwater flow (a separate document provides guidance for evaluating vapor risks to receptors). One or more of these elements are present at nearly every site:

- **Storm/Sanitary Sewers** are the most common preferential pathways associated with subsurface contaminant releases. Contamination from subsurface releases enters the more transmissive backfill around the sewer lines. At many dry cleaners and some industrial facilities, the lines are a source area, because wastes discharged into drains or the storm sewer received run-off from surface spills. Storm sewers and many older sanitary lines are leaky and allow contaminated wastewater to enter the subsurface or can allow contaminated groundwater in. Sewers should always be assessed, as they are present at nearly all sites. Both main lines and laterals need to be located. Also, floor drains within buildings need to be diagrammed and added to the CSM.

  The backfill (utility corridor) around the sewer line may still influence contaminant distribution even if the groundwater table is below the sewer lines. Additionally, localized perched aquifers may be associated with the lines, and in some areas sewer main lines can be as much as 30 feet deep. The location and depth of storm and sanitary sewer lines and lateral connections need to be included on site maps. Approximate depths can be obtained by gauging nearby manholes. The sewer should be shown, to scale, on cross sections. The direction the sewer flows and if it flows constantly or intermittently (i.e. near a lift station) is important information as the conduit can move contaminants in directions different from the groundwater gradient.

Although sewers are the most common feature associated with manmade preferential pathway flow, there are other kinds of subsurface features which may affect contaminant distribution:

- **Energized subsurface utility lines (Gas, Water, Electric, Fiber Optic, etc.)** are usually not primary pathways because they are not as large, not buried as deep, and not designed to carry water like sewers. However, they are still surrounded by porous backfill which can intercept contaminants. Sometimes they are in the same trench as the sewer lines, which can complicate an investigation. Depending on the size, depth, and location of the lines, they may explain contaminant distribution. The investigator should determine the locations of energized or pressurized lines in order to safely drill at a location (or use a hand auger, air knife or HydroVac, see below).

- **Septic Systems and other localized wastewater management systems** have many names including “concrete vaults”, “dry wells”, “oil/water separators” or “water distribution pits.” These are common pathways in rural or semi-rural areas similar to sewer lines in urban areas. At these sites, the investigator can assume that they are at least a partial source of contamination. Recently urbanized or suburban areas may still have these structures in place even if they are not currently used for wastewater management. They were often used as dry wells to dispose of waste oil and spent solvents.

- **Field Tiles and French Drains** are a system of clay pipes (tiles) or gravel- filled trenches (drains) that are intended to lower an area’s water table for development or farming. Often, these intercept or directly connect to existing storm sewer lines or nearby streams. Tank vaults and other structures may also intersect these features. In older buildings, floor drains may be connected into these instead of a sewer or septic system. They are usually not a factor at small sites or in heavily urbanized areas but historical drainage improvements can cause problems remediating large urban, suburban, or rural facilities when the site history is not researched.

  Almost all glacially derived soils in Indiana have been extensively tiled or ditched to allow drainage for building. In rural and suburban areas, the county surveyor’s office might be able to provide some information on the type and density of tiles. County soil surveys will also list the natural depth to saturation, and thus the probability of drainage lines.

- **Large Filled Areas** are present at many sites. All disturbed areas tend to transmit water, vapors, and contamination more readily than natural soils. Large fill areas can be a source of contamination or control groundwater hydraulics. Estimating the distribution and nature of fill around a site takes a more wide-ranging investigation.

Consider the area around the site. Boring logs are sometimes not enough. A thorough Phase I investigation can be invaluable. Reviewing the topographic maps for the area can be a great help, as can current and historical aerial photographs. When available, Sanborn maps provide an excellent description of historical structures and property usage. Sometimes intermittent drainage ways have been filled in. Sometimes, perennial streams have been channelized under urban development and there is no surface expression. Slopes along creek valleys might have been filled to grade.

The fill material's effects on the contaminant plume depend on the following:

- **The contrast between the fill and the native materials.** If sand fill is adjacent to coarse-grained or poorly sorted sand, the pathway is less pronounced. However, well-sorted, fine-grained sands (i.e. dunes) are much more resistant to flow than poured-in backfill. The interface between sandy fill and clayey soils is often an obvious, primary pathway. A large amount of source material may be in the gravel sub-base of parking lots, storage areas, and buildings.
- **The sources of contamination with respect to the fill**. Contamination released into the fill tends to stay in the fill. Surface releases are more susceptible to this. Contamination released into natural soil may also collect in fill down-gradient of the source.
- **The distribution and thickness of fill across the site**. If the whole site is covered with fill, the investigation is simpler than if only portions of the site are filled. Typically, if only portions of the site are covered, it is to fill in low spots or to make high spots. These areas create pools and drainage pathways for contaminants.

- **Existing Foundations** including footers and foundation drains are typically affected by contamination in the fill material surrounding the walls and floor. Most commonly, the sub-base is contaminated by seepage through concrete floors in process and storage areas. Thorough site investigation can characterize their effect on contaminant distribution.

- **Abandoned Foundations, Basements, and Cisterns** act as barriers or pathways to migration.
    - As a barrier: Outside the source area, abandoned basements and subsurface structures can be islands of cleaner soil/groundwater. Borings placed within or directly down-gradient of these areas may lead to misidentifying the extent of contamination.
    - As a pathway: These can be pools of continuing source from a process or disposal area that has been long abandoned.

- **Improperly abandoned or installed wells (water, oil, or gas)** are usually discovered when contamination unexpectedly shows up in a deeper zone. If an investigator is diligent, historical research and a thorough site walk through may turn up such information as an abandoned pump house, neighbors with wells, or pipes present at the surface. The Department of Natural Resources should be notified when abandoned wells are found (312 IAC 13-10-2).

Qualitative Lines of Evidence

- **The location of the source with respect to known sewer main lines and laterals**:

Active sewer lines and laterals are usually obvious, but their hydrologic effects are often overlooked. When the contaminant source is adjacent to the sewer or directly discharges to the sewer, an investigation of the lines and backfill for source material (regardless of the groundwater depth) is needed. If heavily contaminated groundwater flows toward a sewer line that is below the water table, the backfill above the sewer trench should be investigated to determine if it is directing dissolved contaminants off-site.

- **Irregular distribution of contamination**: Contaminant transport through a porous media creates a plume of generally predictable size, shape, and concentration gradient based on the hydraulic conductivity and groundwater gradient. It is possible that a preferential pathway is influencing contaminant travel if contamination is much more widespread than the known geology would tend to allow; contamination suddenly "disappears", the magnitude of contamination is disproportionate to known source, or heavily contaminated soil, groundwater, or vapors are detected in unexpected places.

- **The development and operational history of the site**: Original subsurface alterations and drainage may still be in place even if the property has changed usage, relocated process areas and added or removed structures. For example, sites which were originally residential may still have sewer laterals, cisterns, water wells, and below ground structures (i.e. old MGPs). There may have been pre-development dumping at the site. The site may lie in an area of previous sand and gravel mining where pits were filled with waste. The sewer or other on-site wastewater management areas need to be fully investigated if the site operations used contaminants in solution or had to store and dispose of chemicals once they were "spent."

Historical research: Determining the site history is key to finding abandoned subsurface structures. Sometimes there is no obvious surface expression. The original site features may be altered beyond recognition, but fill areas are found by chance during investigation or a pre-development clay tile is penetrated during boring. Careful review of aerial photographs and historical property maps can be very helpful. An assessment of the building construction may find built-on areas and added parcels. These features are common at industrial facilities where processes have changed or moved and in areas which were previously residential prior to commercial development. A telephone call to the department of public works may provide both previous and current utility locations. If those desktop methods are not sufficient, or they cannot satisfactorily explain what is happening, then a non-invasive investigation of the subsurface may help determine whether there are manmade disturbances influencing contaminant travel.

- **Geophysical surveys:** These are generally the most reliable way to find disturbed areas and subsurface pathways without excavating the entire site. Two types of surveys are commonly used to find and map non-metallic subsurface features.

    - **Ground Penetrating Radar (GPR)**: This technique is better for finding subsurface structures such as tanks, wells, and foundations but can find most features. It is also more suited to smaller areas and locations with surface obstructions.
    - **Resistivity/Conductivity**: This technique is better for finding changes in soil structure and composition such as trenches and filled areas but can find most features. This method is better suited to large open areas.

If large areas are covered by reinforced concrete, most geophysical methods are unlikely to be successful.

<u>Direct investigation of pipes</u>: If unexpected pipes or tiles are found during the investigation, there are several methods available to determine if these features need further evaluation as secondary sources.

- **<u>Smoke Tests</u>**: Smoke testing will show where air flows through a pipe. It is especially useful for finding open drain traps and near-surface breaks.
  Usually the fire department and nearby neighbors need to be informed before completing a smoke test.
- **<u>Vacuum Tests</u>**: Vacuum tests are useful if there are multiple pipes that may or may not be connected to a nearby source or receptor.
- **<u>Dye Traces</u>**: Dyes can determine if water entering a drain connects to sanitary or storm sewers. The local authorities need to be contacted if dye will outfall to a stream.
- **<u>Sewer cameras</u>**: These are useful if the line is completely filled with water, a break in the line is a suspected source, or if trying to precisely locate a line.

<u>Quantitative Lines of Evidence</u>

Standard site investigation and the qualitative measures listed above can show that preferential pathways influence contaminants. However, if there are potential receptors the subsurface soils, and groundwater adjacent to utility lines need to be sampled to determine risks. Whether this is necessary depends on the nature of the release, the contaminant toxicity, and the closure strategy. Common reasons to collect data adjacent to a conduit (i.e. within the corridor) include:

- Source area concentrations for site characterization and risk assessment.
- Soil and groundwater quality to complete a pathway elimination assessment.
- Soil gas concentrations moving through conductive materials.

<u>Sampling of preferential pathway</u>

Sampling the preferential pathways for the characterization of soil and groundwater is not the same as for vapor. The investigation of vapor intrusion from preferential pathways is found in a separate guidance document.

Typically, a well-researched site conceptual model, combined with thoughtfully placed soil borings and monitoring wells, can indirectly explain how a manmade preferential pathway effects contaminant distribution in the soil and groundwater. However, it is sometimes necessary to physically sample the subsurface soils, and groundwater, if present, in the utility corridor. Collecting soil samples from the utility corridor is appropriate when the sewer lines are a known or probable source. The locations for soil samples within the utility corridor will depend on piping layout. Samples should be collected near entry points (drains) and junctions. As-built drawings from the city or town, surveys of the pipes with a camera, vacuum, or smoke can help determine these locations if they are not obvious. When determining the source area concentrations for site characterization and risk assessment it may be necessary to directly sample the sediment and liquids within the conduit.

Investigating around sewer lines is complicated by the slight risk of encountering an active line. Often, multiple utilities are located in the same trench. If there are known active water, sewer, or gas line trenches that need to be investigated, the municipality will need to be informed. City utility workers can be an excellent source of information about location and construction of active utilities. Private utility locators will show only the location of subsurface lines, but tell nothing about depth, construction, or quality of either the conduits or utility corridors.

Options which pose little risk to the lines themselves are readily available. The methods listed below are not typically part of a standard drilling program. Common tools include:

- Hand auguring: This drilling tool is turned into the ground by muscle power. They have a maximum depth of about 20 feet, depending on soil type. They may not be effective if the utility backfill is very coarse or heterogeneous.

The other two methods require a mobilization with a separate drilling machine. This nearly guarantees that the lines will not be damaged. If there are multiple areas that need to be investigated, this is often the fastest way to investigate and requires the least physical effort.

- Water knife: This machine is similar to a power washer and uses high pressure water to remove unconsolidated material. However, the addition of water can leach adsorbed contamination into the groundwater. For this reason, these tools are not very commonly used at contaminated sites.
- Air knife: This machine works almost exactly like a water knife, but uses high pressure air to remove soil. The loose sediment is collected with a vacuum on the back of the truck. However, they might not be as effective in tightly compacted or heterogeneous backfill. Also, they may not be effective in cold weather when shallow sediments or fill material may be frozen. There is a large amount of waste soil generated by an air knife, and this may be a consideration if the corridor is suspected to be highly contaminated. The investigator also needs to account for potential VOC loss due to the high pressure air.

Occasionally, it is simply not possible to directly sample due to factors such as fragile water lines, high pressure gas lines, high voltage lines, or interstate pipelines. It may be difficult or impossible to acquire a right of way access permit from a municipality or individual. Situations like this are handled on a case by case basis.

Examples of the Influence of Preferential Pathways on Contaminant Transport

Contamination source in sewer pipe or utility trench backfill: This scenario occurs at sites where wastes were poured down the drain either as pure product disposal or as a result of poor housekeeping. Sewer disposal often leads to disconnected, high concentration contaminant source areas with very small source footprints. Once on-site investigation has shown there is source material in and around drains, the evaluation needs to continue in the flow direction of the pipe. Pure product can travel some distance through competent pipes, so common disconnected source locations are at T and L junctions, nearby lift stations, and any low points in the line or the trench.

Dissolved contamination intercepted by utility trench: This scenario occurs when a release into the subsurface travels down-gradient with groundwater flow until it intercepts the disturbed soils within the utility corridor. This situation leads to plumes which apparently "end" on-site despite having high concentrations near the property line. In order to confirm the extent of contamination, the investigator may need to drill directly adjacent to the trench in the down-gradient direction of flow *within the preferential pathway* (this is not necessarily the same direction as groundwater flow). If investigation shows that contamination is traveling along the trench, there is the potential for discharge of contaminated groundwater or vapor intrusion at nearby receptors.

Utilities that control groundwater hydraulics: This scenario is probable in urban areas with shallow groundwater, low groundwater gradient and large diameter sewer lines. It is particularly notable in areas with fine-grained subsurface materials. Common indicators of utility-influenced hydrology include unexplained low or high water levels in wells next to the utility trench, and wells off-site and outside the utility corridor that dramatically change on-site groundwater flow direction.

Fill creates ephemeral water table for contaminant movement: Although the perennial water table may be well below filled areas, the contrast in materials permeability tends to allow for horizontal fluid transport until there is sufficient head pressure to drive it downwards. If there is an above ground release, this mechanism spreads the source material outward and increases the footprint of the contamination. This is a probable cause when there is a very small contaminant source (i.e. sink sized degreaser) but a horizontally extensive shallow soil source. In this scenario, depending on the contrast between native and manmade materials, groundwater contaminant concentrations may be low to moderate, while vapor contamination is extremely high. This is a primary concern in buildings with large areas of interconnected, coarse grained sub-base.

Contamination source or transport in drain tiles: Unlike other pathways, drainage tiles usually discharge to nearby perennial or ephemeral surface water features. Once contaminated drainage tiles are found on a site, there needs to be an evaluation of surface drainage areas for contaminated sediments or contamination discharging into surface waters.

Cross-contamination due to wells: This scenario usually occurs at large industrial facilities with multiple production wells. Typical cross-contamination problems come from wells installed prior to current DNR grouting and abandonment requirements outlined in 312 IAC 13. Properly installed wells will not allow cross-contamination.

Contaminated preferential pathways can affect cleanup and closure strategies

This guide is not intended to be a comprehensive discussion of remedial or closure methods. Not every site will require a specific remedy to remove the risk from contamination. However, if preferential pathways are significantly affecting the groundwater hydraulics or vapor flow, they can also affect both active and passive closure strategies. A good investigation using the principles noted above should determine if and how pathways might be affecting the contaminants. Sometimes, the pathways can make remediation easier, because contamination has been contained within a structure or is being funneled to a single discharge point. Some of the more common difficulties with remediation affected by preferential pathways are listed below:

- Overestimation of radius of influence. Things to monitor during pilot testing to help characterize the site and the influences of the preferential pathway are:
  - One or more distant observation points show a much greater effect than points nearby.
  - All extraction influence is concentrated in one direction.
  - Testing is performed only in areas of disturbed soil or backfill rather than native materials.
- Short circuiting.
- Underestimation of source area.
- Plume stability. Continued flow of water through a utility corridor can destabilize contamination. The presence of utility corridors can also influence the accuracy of perimeter of compliance wells.
- Fate and transport models. The assumptions for uniform, homogenous subsurface conditions rapidly break down in the presence of preferential flow. If they are not taken into account, the risk can be underestimated.

Further Information

If you have any additional information regarding this technology or any questions about the evaluation, please contact the Office of Land Quality, Science Services Branch at (317) 232-3215. IDEM will update this technical guidance document periodically or on receipt of new information.

Resources

IDNR Well Rule 312 IAC 13 http://www.in.gov/legislative/iac/T03120/A00130.PDF?

State Coalition for the Remediation of Dry Cleaners, 2010: Conducting Contamination Assessment at Dry cleaning Sites; http://astswmo.org/files/Resources/SCRD/Conducting-Contamination-Assessment-Work-at-Drycleaning-Sites.pdf

Sewer Smoke Testing:
https://www.city.waltham.ma.us/sites/g/files/vyhlif6861/f/file/file/smoketestfaq.pdf

Video Sewer Inspections: https://www.plymouthin.com/egov/documents/1635279460_67025.pdf

Wisconsin Department of Natural Resources, 2000: Guidance for Documenting the Investigation of Utility Corridors; PUBL-RR-649, 9 pages.

USEPA, 1997: Expedited Site Assessment Tools For Underground Storage Tank Sites: A Guide For Regulators: Chapter 3 Surface Geophysical Methods, (EPA 510-B-97-001).
https://www.epa.gov/sites/default/files/2014-03/documents/esa-ch3.pdf

Citizens Energy Group Sanitary Standards Manual 2019:
https://www.citizensenergygroup.com/Documents/Standards/SanitaryStandardsManual