

Conceptual Site Model (CSM) Development: Plume Behavior

4.1 Introduction

The saturated subsurface is a dynamic environment, in which contaminant migration can occur through a variety of pathways and processes. Understanding ground water contaminant plume behavior allows evaluation of potential *future* risk to receptors.

This section describes a variety of contaminant, site, and plume characteristics useful in understanding the nature and extent of a contaminant release. Each characteristic offers insight into contaminant plume behavior. While no single characteristic is enough to understand the overall behavior of a contaminant plume, agreement among multiple lines of evidence (LOEs) provides greater confidence in assessing plume behavior. It is not necessary to develop any particular LOE discussed in this section – only those needed to provide adequate confidence in the understanding of plume behavior.

Active remediation can be conducted at any time. However, because active remediation alters plume dynamics, the potential future risk associated with contaminated ground water cannot be evaluated during active remediation. An equilibration period is necessary between the end of active remediation and the beginning of a trend analysis monitoring program.

4.2 Applicability

Ground water contaminant plume behavior is a necessary component of the CSM. Plume behavior should be evaluated prior to closure for all sites with ground water that exceeds residential remediation objectives. However, it may be appropriate to postpone or forgo the complete assessment of plume behavior when:

- The nature and extent of contamination is still under investigation.
- Active remediation is occurring.
- The ground water remediation objective is an unconditional residential closure.
- The ground water remediation objective is closure via a background or off-site source demonstration.
- Other LOEs demonstrate that the evaluation is unnecessary.

A high level of confidence in plume behavior may not be necessary under the above conditions. Even so, it may prove worthwhile to consider plume behavior LOEs prior to investigative and remedial activities, either to meet specific program requirements, or in case a plume behavior evaluation becomes necessary in the future.

4.3 Plume Behavior

The concentration of a ground water contaminant will generally decrease as it migrates. Causes of this decrease may include dilution, adsorption to matrix materials, or physical/chemical degradation. The distance over which contaminant concentrations decrease to acceptable levels will depend on the chemical properties of the contaminant, the physical properties of the saturated zone, and the magnitude of the contamination.

Ground water plumes resulting from petroleum-related releases have been extensively documented and shown to generally migrate and degrade within reasonably predictable parameters. For instance, data indicate that 95% of benzene, toluene, ethylbenzene, and xylene (BTEX) ground water plumes will terminate within 750 feet of their origin, regardless of the physical properties of the subsurface or the nature of the release (Mace *et al.*, 1997; Newell *et al.*, 1990; Rice *et al.*, 1995; Wiedemeier *et al.*, 1999). Conversely, ground water plumes of persistent chemicals (e.g., tetrachloroethene) can extend for long distances – sometimes more than a mile.

4.3.1 Investigating Plume Behavior

Well locations are important when characterizing plume behavior. Data on contaminant levels and aquifer characteristics should come from wells and boreholes capable of providing a clear three-dimensional picture of the hydrogeologic and geochemical characteristics of the site. If the wells do not meet appropriate criteria, or if site conditions change, previously installed wells may no longer produce samples that adequately represent the plume. In such cases, new wells *may* be necessary.

CSM development may require further characterization of ground water contaminant plumes through additional ground water monitoring and assessment of data trends (e.g., plume area, contaminant concentrations, contaminant mass, and the center of mass over time). Assessment of these trends helps understand plume behavior, and the potential for contamination to migrate beyond the exposure control area.

If hydraulic conductivity, saturated thickness, flow gradients, or other important characteristics vary significantly over the evaluation area, it may prove difficult or impossible to confidently predict plume behavior. Similarly, preferential pathways (e.g., karst conditions, fracture flow, utility backfill, etc.) that control ground water flow and contaminant migration complicate assessment of plume behavior. Where this is the case, understanding plume behavior may require assessment of LOEs that do not appear in this document.

4.4 Lines of Evidence (LOEs)

As noted above, numerous factors affect the behavior of a ground water contaminant plume. While any single factor provides some insight into the behavior of the plume, examination of multiple LOEs provides the most comprehensive assessment of plume behavior. LOEs can be grouped into three categories:

- Contaminant characteristics (Section 4.5)
- Site characteristics (Section 4.6)
- Plume characteristics (Section 4.7)

The following subsections present and describe LOEs that IDEM will use to evaluate ground water contaminant plume behavior. Other LOEs may be submitted, and IDEM will evaluate them on a site-specific basis.

4.5 Lines of Evidence: Contaminant Characteristics

Some contaminants behave in reasonably predictable ways. For example, benzene readily degrades in well oxygenated subsurface conditions, while tetrachloroethene does not (Howard, 1990, 1991). Certain contaminant properties help predict how a contaminant plume is likely to behave. Appropriate LOEs based on contaminant characteristics include:

- Toxicity
- Solubility
- Persistence

4.5.1 Toxicity

Contaminant toxicity is important when evaluating the relative threat the contaminant poses to a receptor. Highly toxic contaminants require a greater level of confidence in plume behavior than do less toxic contaminants. In the context of evaluating plume behavior, IDEM bases the relative toxicity of a contaminant on its human health effect (e.g. carcinogenic, mutagenic, etc.).

4.5.2 Solubility

Contaminant solubility directly relates to mobility, which affects the level of confidence needed in plume behavior. Greater solubility implies a greater need for confidence in plume behavior. IDEM may also consider effective solubilities. See Wiedemeier *et al.* (1999) and U.S. EPA's [Effective Solubility Calculator](http://www.epa.gov/athens/learn2model/part-two/onsite/es.html)³⁶ for more information on evaluating site-specific effective solubilities.

4.5.3 Persistence

Contaminant persistence determines the relative timeframe over which confidence in the plume behavior is needed. Highly persistent contaminants require a greater degree of confidence in the plume behavior, while short-lived contaminants require less.

³⁶ <http://www.epa.gov/athens/learn2model/part-two/onsite/es.html>

4.6 Lines of Evidence: Site Characteristics

Nature and extent investigations typically generate data applicable to evaluation of plume behavior. Several site characteristics are easy to document and reproducibly measure by established methods. Appropriate site characteristic LOEs for evaluating the behavior of ground water contaminant plumes include:

- Age of the release
- Presence of non-aqueous phase liquid (NAPL)
- Maximum concentration
- Plume core size
- Hydraulic conductivity
- Ground water time of travel to exposure control area boundary
- Ground water time of travel to nearest receptor
- Variation in ground water flow direction
- Variation in ground water elevation

Exercise due diligence in identifying any receptors with a high probability of human exposure. Give special consideration to municipal well fields, wellhead protection areas, public reservoirs, rivers, or other potential receptors near contaminant plumes. IDEM recommends contacting public water utilities or other significant local water users to determine if there are any planned changes in well locations, pumping rates, or other activities that could influence ground water elevation or flow direction.

4.6.1 Age of the Release

This LOE applies only to BTEX contamination. Given the well documented behavior of petroleum releases, the age of the release is an appropriate indicator of the plume lifecycle. Regardless of the size of the release or subsurface conditions, the extent of *most* petroleum related releases will stabilize within approximately five years (Rice *et al.*, 1995). Given this relationship, IDEM will have greater confidence in the behavior of petroleum plumes that have documented historic release dates. Conversely, the behavior of recent petroleum releases merits less confidence.

4.6.2 Presence of Non-aqueous Phase Liquid

NAPL may be an ongoing source of ground water contamination. While the presence of NAPL does not preclude understanding the behavior of a ground water contaminant plume, it does complicate that understanding. In such cases, additional LOEs may bolster IDEM's confidence in the understanding of plume behavior

Examples include the NAPL, maximum concentration, and plume core size LOEs. While interdependent, each of these LOEs provides additional information about the magnitude of the ground water contamination. In some instances, however, some of these LOEs may prove redundant and unnecessary for the evaluation of plume behavior.

In general, IDEM will consider NAPL to be present if measurable light NAPL (LNAPL) thickness exceeds 0.1 feet, or if one or more dense non-aqueous phase liquid (DNAPL) forming contaminants are present at concentrations exceeding ten percent of their solubility. IDEM will consider NAPL as *potentially* present if measurable LNAPL thickness lies between 0.01 and 0.1

feet, or if one or more DNAPL-forming contaminants are present at concentrations between one and ten percent of their solubility.

4.6.3 Maximum Concentration

The maximum ground water contaminant concentration is an appropriate measure of the relative magnitude of the contamination and the confidence level needed to assess plume behavior. Ground water plumes with maximum concentrations at or near the remediation objective require less confidence in plume behavior, while higher concentrations require more confidence.

4.6.4 Plume Core Size

Plume core size is a measure of the area of the plume with the highest contaminant concentrations. It is the area where the maximum extent of the contamination exceeds a contaminant specific threshold concentration, which is often less than the absolute solubility limit. Threshold concentrations allow use of a large, more easily measured, region of the contaminant plume to represent the source of the contamination. Plume core size may be completely measured using sampling points, or partially inferred using sampling data and the nature of the release. IDEM will give more weight to plume core size measurements obtained with more sampling.

The initial threshold concentration for BTEX constituents is defined by the effective solubility of the fuel blend:

$$\text{Effective Solubility } C_w = X_0 S$$

$$C_w = \text{Effective solubility}$$

$$X_0 = \text{mole fraction (of chemical in fuel)}$$

$$S = \text{solubility}$$

$$\text{Mole Fraction } X_0 = MF_x MW_0 / MW_x$$

$$MF_x = \text{mass fraction of selected chemical in fuel}$$

$$MW_0 = \text{average molecular weight of fuel}$$

$$\text{Est. 105 g/mole for gasoline}$$

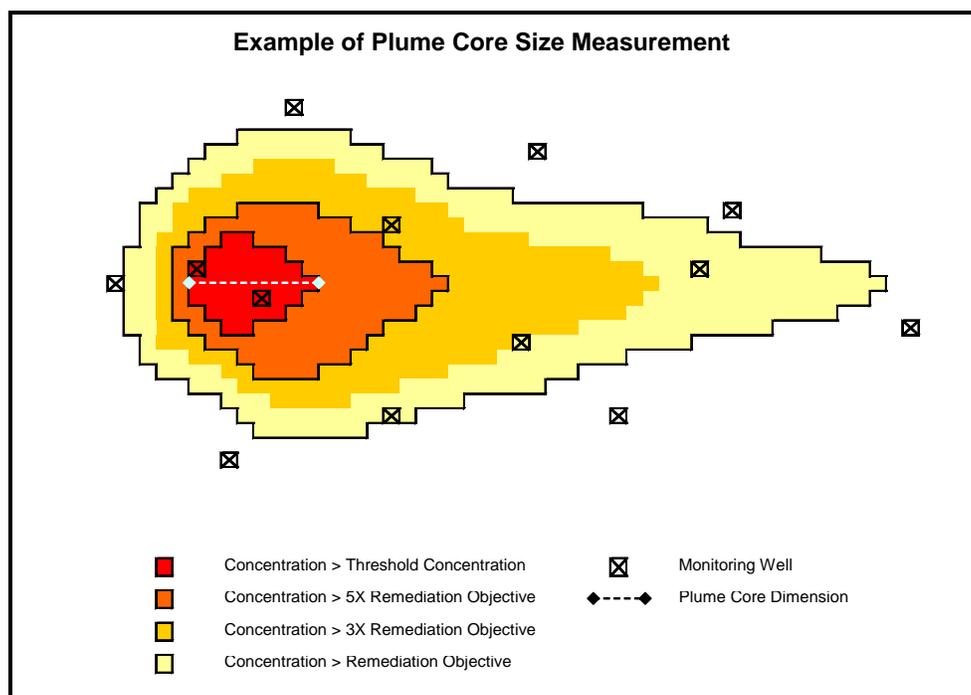
$$\text{Est. 165 g/mole for jet fuel}$$

$$\text{Est. 230 g/mole for diesel fuel}$$

$$MW_x = \text{molecular weight of selected chemical}$$

For unknown fuel blends, standard mass fractions for BTEX constituents are as follows: benzene – 0.4%; toluene – 8.6%; ethylbenzene – 1%; total xylenes – 5.3%. These mass fractions correspond to effective solubilities of 9,570 µg/l; 51,500 µg/l; 1,480 µg/l; and 8,160 µg/l, respectively. For DNAPLs, the threshold concentration is one percent of the constituent's absolute solubility. Consult IDEM technical staff for threshold concentrations of other contaminant classifications.

To measure plume core size, develop an adequate isopleth representing the contaminant specific threshold concentration. The plume core size is the longest transect across the area within the isopleth. If the threshold concentration isopleth includes more than one contiguous area, combine the lengths of the longest transect for each area. If the maximum concentration (Section 4.6.3) exceeds the threshold concentration, the plume core size will likely be large. Figure 4-A depicts an example of determining the plume core size.

Figure 4-A: Plume Core Size Measurement

Developing this LOE may require a monitoring well network of greater density than that necessary to characterize the extent of contamination. Special care should be taken when designing monitoring well networks in the presence of potential DNAPLs.

Ground water contaminant concentrations at or near their solubility limit suggest direct transmission of contamination to the ground water. The larger the area of the ground water plume approaching the solubility limit, the greater the potential for a large contaminant plume with variable behavior. Conversely, a plume with a limited extent of contamination approaching solubility is more likely to result in a limited plume with more readily assessed behavior.

4.6.5 Hydraulic Conductivity

Hydraulic conductivity affects the ability of contaminants to migrate within the subsurface. All other hydraulic factors being equal, hydraulic conductivity, and the potential for migration of contaminants dissolved in a clay-rich aquifer, will be orders of magnitude lower than in a coarse sand and gravel aquifer. Hydraulic conductivity depends in part on the density and scale of aquifer features such as grain-size distribution, fracturing, gravel lenses, or other types of bedding. Hydraulic conductivity estimates must be site-specific, documented, reproducible, and representative of conditions at a scale relevant to contaminant transport. Given the potential for greater mobility, high hydraulic conductivities require more robust demonstrations of plume behavior.

4.6.6 Ground Water Time of Travel (Exposure Control Area)

This LOE estimates the time it will take for ground water to travel from the furthest extent of concentrations exceeding the remediation objectives to the edge of the exposure control area. This LOE provides perspective on the size of the plume relative to the exposure control area. Sometimes, the exposure control area will coincide with the property boundary. In other cases, environmental restrictive covenants (ERCs) or environmental restrictive ordinances (EROs) may extend the exposure control area beyond the property boundary. Ground water chemistry and contaminant interactions with matrix materials complicate estimation of migration rates and may require site-specific data. *IDEM will not consider time of travel estimates that are contradicted by the known extent of contamination as representative.*

4.6.7 Ground Water Time of Travel (Nearest Receptor)

This LOE estimates the time it will take for ground water to travel from the furthest extent of concentrations exceeding the remediation objective to the nearest receptor. This LOE provides perspective on the size of the plume relative to the location of the receptors. In the context of this section, the receptor pathway is in direct contact with contaminated ground water. However, a thorough understanding of plume behavior is important when evaluating potential receptors via the vapor inhalation pathway. *IDEM will not consider time of travel estimates that are contradicted by the known extent of contamination as representative.*

4.6.8 Variation in Ground Water Flow Direction

Ground water flow is usually the primary driver of ground water contaminant plume migration. A thorough understanding of ground water flow is fundamental to evaluating the behavior of the plume. A consistent ground water flow direction lends confidence to the understanding of plume behavior, while highly variable or erratic ground water flow direction yields less confidence. Highly variable ground water flow also makes it difficult to determine proper locations for monitoring wells that consistently represent plume conditions. Evaluate this LOE based on changes in the calculated ground water flow direction measured using a minimum of three representative monitoring wells determined to be appropriate by the facility representative and IDEM. While this approach cannot capture all the complexities of ground water flow, it does provide a consistent measurement.

4.6.9 Variation in Ground Water Elevation

High variability in depth to ground water reduces confidence in understanding plume behavior. Significant contaminant mass can often remobilize when ground water elevations undergo large fluctuations, which introduces uncertainty in understanding contaminant plume behavior. This LOE applies only to unconfined aquifers, and should be evaluated in the area of the highest contaminant concentrations.

4.7 Lines of Evidence: Plume Characteristics

The previously listed contaminant and site characteristic LOEs are appropriate for evaluating how a plume is *likely* to behave. However, actual plume behavior is a more robust LOE. Appropriate LOEs for evaluating the actual behavior of a plume are as follows:

- Plume length
- Commingled plume
- Qualitative analysis
- Natural attenuation
- Modeled behavior
- Trend analysis

4.7.1 Plume Length

A significant body of research shows that regardless of the size of a petroleum (BTEX) release or hydrogeological conditions, benzene will stabilize to 10 parts per billion (ppb) within 750 feet of the release point (Newell and Connor, 1998). Evaluating the length of a plume of benzene against the statistical distribution of benzene plume lengths provides a reasonable indication of the plume's behavior. Longer plume lengths provide greater confidence that the petroleum related contaminant plume is nearing its maximum extent, while short plume lengths warrant additional information on the plume behavior. This LOE applies only to petroleum contamination; it does not apply to petroleum additives or special blends (e.g., E85).

4.7.2 Commingled Plumes

It is not uncommon to encounter ground water contaminant plumes that commingle with additional ground water contaminant plumes originating from the same or adjacent facilities. In these instances, it can be difficult to differentiate the behavior of one plume from the other. Thus, commingling of ground water contaminant plumes reduces confidence in plume behavior. While the presence of commingled plumes does not preclude a thorough understanding of plume behavior, it does require additional information to obtain a greater degree of confidence in the plume behavior.

4.7.3 Qualitative Analysis

Qualitative analysis of plume behavior relies on specific knowledge of site conditions rather than analytical data. While quantitative examinations of contaminant trends are powerful tools for evaluating the behavior of a contaminant plume, meaningful statistical tests require substantial monitoring timeframes to acquire sufficient data. In some situations, trends in contaminant concentrations are qualitatively discernible in shorter timeframes. IDEM will evaluate such interpretations on their merits. If sufficient data (eight or more consecutive quarters) are available for quantitative trend analysis, then it is likely that the quantitative and qualitative analyses will be redundant demonstrations. Therefore sites with eight or more consecutive quarters of data should only utilize qualitative demonstrations as contrary evidence to quantitative analytical methods. For example, statistical analysis may show no discernible trend, but a qualitative examination of the most recent sampling events may suggest decreasing concentrations.

4.7.4 Natural Attenuation

Natural attenuation of a plume involves processes such as dilution, matrix adsorption, and contaminant degradation (IDEM 2004; U.S. EPA 1999c, 2004a; API 2007). Demonstrating the occurrence of these processes can provide powerful evidence of the plume's behavior. Changes in the distribution of contaminants and geochemical parameters in and around the ground water contaminant plume over time and space can provide confirmation of natural attenuation activity. Some considerations for making this demonstration appear below.

It is possible to make general statements about the effects of various geochemical parameters on natural attenuation (e.g. high dissolved oxygen (DO) is generally good for degrading benzene). However, specific levels are relative to the contamination at the site (e.g. 1 ppm dissolved oxygen is adequate for Site A, but Site B needs 4 ppm dissolved oxygen to have the same effect on the contamination). Therefore, it is more appropriate to show that conditions are having an effect in the area of contamination. This typically involves demonstrating contrasting geochemical parameters between the areas where contamination is and is not present (e.g. high DO levels decrease in the areas of contamination, and biodegradation byproducts increase).

Degradation by-products or daughter products are also acceptable as criteria. However, degradation products may present a greater risk than the parent contaminant. Natural attenuation demonstrations should consider the following:

Contrasting conditions. As noted earlier, natural attenuation is a highly site-specific phenomenon, and IDEM has not established specific geochemical criteria. An effective demonstration will show contrasting geochemical parameters between contaminated and uncontaminated areas (e.g., decreased DO levels and high biodegradation product levels in contaminated areas). Graphical means (isoconcentration maps, box plots, etc.) are acceptable for this purpose.

Parameters. Geochemical parameters of interest should be consistent with API (2007), IDEM (2004), and U.S. EPA (1999c, 2004a) and/or other scientific literature. Parameters of interest include, but are not limited to, dissolved oxygen, nitrate, sulfate, soluble ferrous iron, oxidation-reduction potential, hydrogen sulfide, and degradation byproducts.

Timeframe. This demonstration is not necessarily of a time-dependent, statistical nature, and thus does not require at least eight quarters of data. However, demonstrations may require professional judgment to interpret seasonal fluctuations in ground water conditions, where that occurs.

Biological. IDEM will review biological assay results, but has determined that they are not the most significant metric in evaluating natural attenuation.

4.7.5 Modeled Plume Behavior

Models are useful for describing the behavior of a contaminant in ground water, as long as they adequately reproduce observations of the ground water system. It is important to choose models that are appropriate for the contaminant and conditions at the site. Most importantly, input parameters for the model should fall within realistic ranges for the hydrogeologic system defined during CSM development (ASTM, 2008). Use of literature-based parameters or undocumented site-specific parameters may invalidate model results. Some modeling demonstrations may require site-specific calibration and/or field verification to be suitable for demonstrating confidence in contaminant plume behavior.

Possible modeling approaches for demonstrating plume behavior include plume length versus time, centerline concentration versus distance, or well contaminant concentration versus time. IDEM will consider other approaches on a site-specific basis.

4.7.6 Plume Trend Analysis

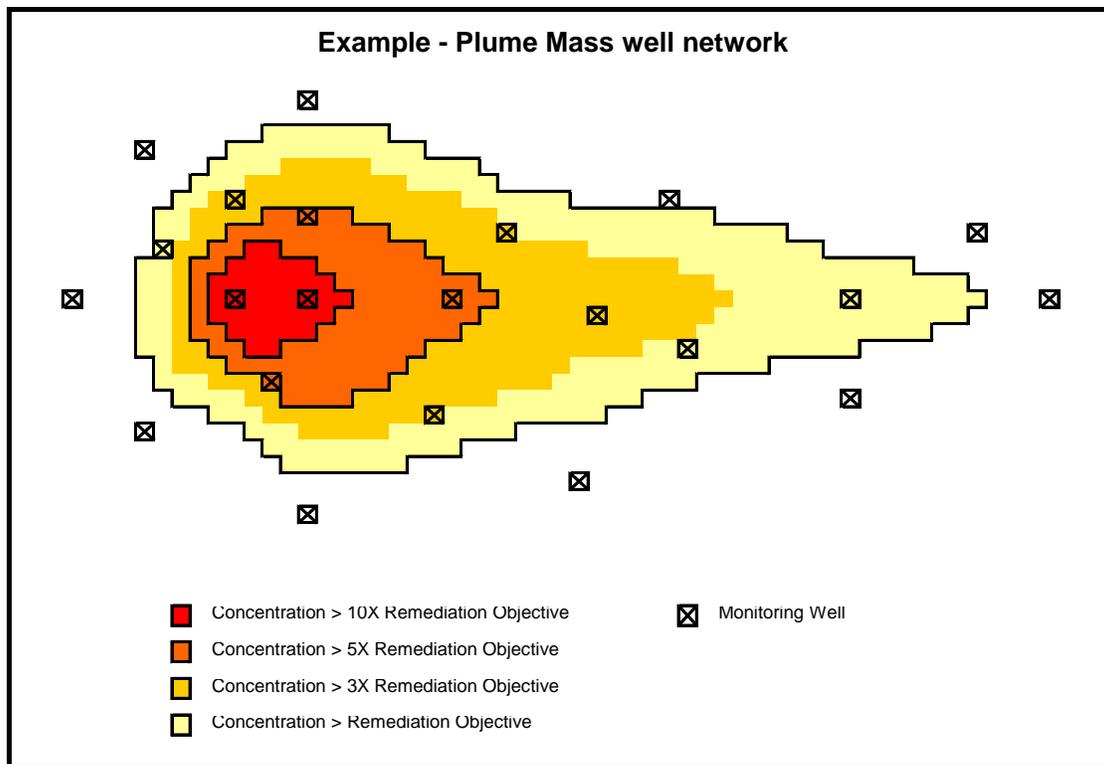
Plume trend analysis provides a statistically-based demonstration that a ground water contaminant plume is behaving in a consistent manner, both temporally and spatially. However, the usefulness of the demonstration depends heavily on the quantity of data available. Statistical trend analysis of time-series data requires a minimum of eight quarters of data. Further, it is inappropriate to assess trends in the ground water data for the purpose of defining plume behavior while active remediation measures are underway. Several possible trend analysis LOEs appear below. IDEM will evaluate other methods on a case by case basis.

4.7.6.1 Plume Trend Analysis: Plume Mass

Plume mass is defined by a three-dimensional understanding of dissolved contaminant concentrations. The quantitative vertical extent of contamination is vital to this analysis. A statistical evaluation that shows a decreasing plume mass provides a high level of confidence in the expected behavior of the plume. Fundamental to this LOE is the characterization of the plume mass with sufficient resolution to accurately represent changes in the overall plume mass. This demonstration may require an extensive ground water monitoring network that includes multiple sampling depths to accurately characterize the plume in three dimensions. The mass may be completely measured using sampling points, or partially inferred using sampling data and the nature of the subsurface. Plume mass measurements using more sampling data will increase the value of the LOE.

The extent of the necessary monitoring well network will vary on a site-by-site basis. Consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration. IDEM recommends beginning with a regression analysis and concluding with a Mann-Kendall analysis of the change in mass over time. However, IDEM will evaluate alternative statistical demonstrations on a site-specific basis.

Figure 4-B: Illustration of Plume Mass Well Network

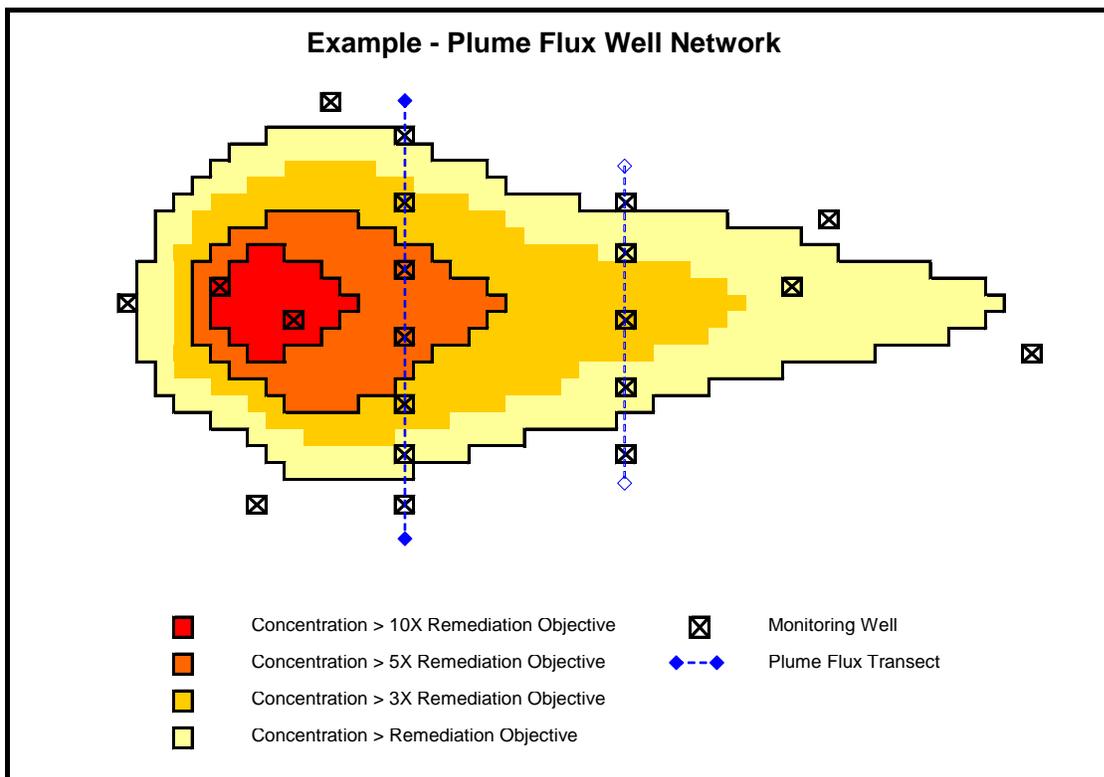


4.7.6.2 Plume Trend Analysis: Plume Flux

Plume flux is a measurement of change in contaminant concentration across a plane. Examining the trend in plume flux across one or more projected planes is a useful way to evaluate contaminant migration (Figure 4-C). However, as with plume mass, complete and accurate characterization of flux may require a substantial monitoring well network that includes multiple transects across the plume at multiple sampling depths. Plume flux may be completely measured using sampling points, or partially inferred using sampling data and the nature of the subsurface. Plume flux measurements using more sampling data will increase the weight of this LOE.

Consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration. Plume flux analysis supplements the plume mass LOE with additional statistical evaluations. IDEM recommends beginning with regression analysis for each transect, and concluding with Mann-Kendall analysis for each transect. However, IDEM will evaluate alternative statistical demonstrations on a site-specific basis.

Figure 4-C: Plume Flux Well Network

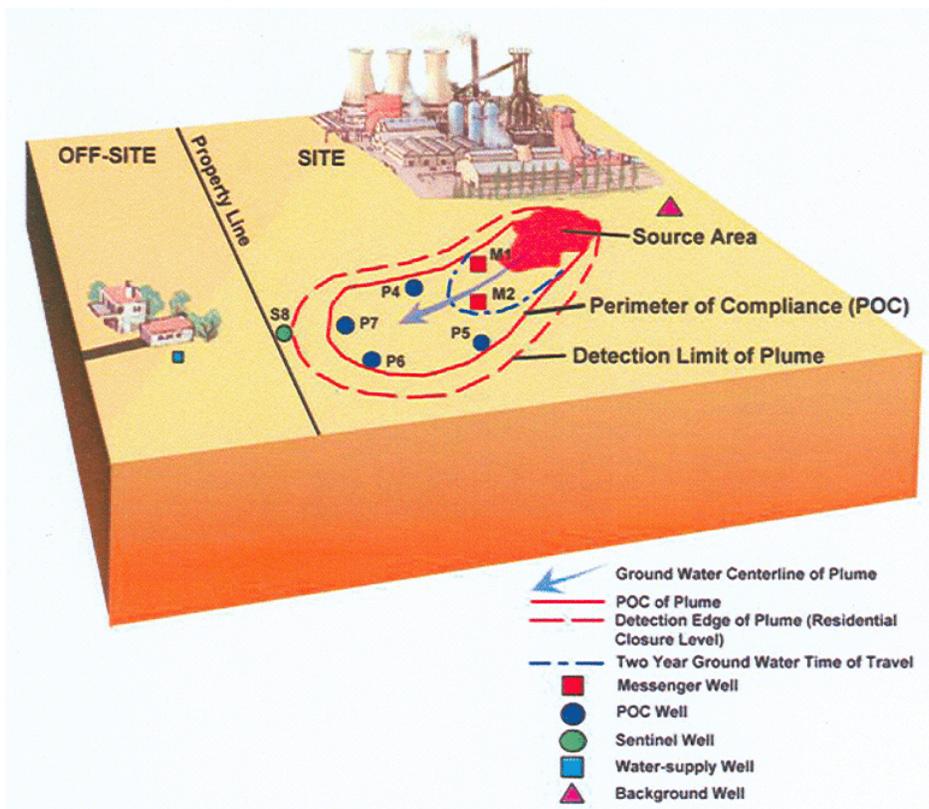


4.7.6.3 Plume Trend Analysis: Statistical Analysis

This powerful LOE combines monitoring data with regression analysis, trend analysis, and other statistical tests from a representative ground water monitoring well network to demonstrate an increasing, decreasing, or constant plume. A demonstration via this method that a plume is decreasing provides a high level of confidence that risks are decreasing. Conversely, an increasing plume warrants additional investigation and/or monitoring. Consistent characteristics across the extent of the plume provide a higher level of confidence that the potential future behavior of the plume is understood (U.S. EPA, 2006d). This involves evaluating the trend of multiple sampling locations with multiple observations; all else equal more data will increase the weight of this LOE. Confidence is lower when at least two of the plume monitoring wells exhibit different trends, or when characteristics are not consistent across relevant monitoring wells.

All monitoring methods require properly designed, located, and installed ground water monitoring wells. Figure 4-D depicts typical plume behavior demonstration well locations.

Figure 4-D: Plume Monitoring Network



Messenger wells are in the internal area of the plume, downgradient from the source, within the two-year ground water time-of-travel distance. At least one messenger well must be adjacent to the source, and a second messenger well must be between the first messenger well and the two-year ground water time-of-travel distance of the plume. Most ground water closure demonstrations use two to four messenger wells. Some large or multi-lobed plumes may require more messenger wells. Messenger wells should be (1) as near to the center flow line or flow path as possible and (2) in an area where the contaminant concentrations are likely to be highest and significantly exceed closure levels.

The network should include at least three **perimeter of compliance** (POC) wells located hydraulically downgradient from the messenger wells, where:

- Dissolved contaminant concentrations will likely exceed estimated quantitation limits (EQLs) for at least 75 percent of the monitoring events.
- Contaminant concentrations approximate remediation objectives.
- It is possible to monitor the contaminant plume after it has passed through the source and messenger well areas.

Install **sentinel wells** if there is potential risk to downgradient receptors. Locate sentinel wells hydraulically downgradient from POC wells and along a line between the source and any potential receptors. Though sentinel wells are highly useful for signaling an expanding plume, they may be unnecessary if there is no downgradient receptor.

Place **background wells** upgradient of the area of concern and out of the zone of influence of the source. Background wells are essential to understanding upgradient ground water conditions. If both upgradient and downgradient concerns exist at a site, at least one background well is necessary. However, additional background wells may be necessary, depending on conditions discussed below.

Characterization of hydrogeologic conditions may require additional wells. If the wells do not meet appropriate criteria, or if site conditions change, previously installed wells may no longer produce samples that adequately represent the plume. In such cases, new wells may be necessary, or existing wells may be redesignated to serve a different monitoring function than originally intended.

Some wells must be located within specific ground water time-of-travel distances from the source. Before installing wells, estimate the advective flow velocity of ground water at the site to ensure that the new wells will meet ground water time-of-travel requirements. This approach will allow sufficient time during monitoring to ensure that ground water from the closure area reaches key monitoring wells.

One process for evaluating plume behavior is as follows:

- Step 1: Regression analysis of data from each well
- Step 2: Mann-Kendall trend analysis of data from each well
- Step 3: Graphical demonstration that data from each well exhibit similar trends and slopes
- Step 4: Homogeneity of variance analysis
- Step 5: Monotonic trend analysis

Figure 4-E illustrates the steps in the above approach. IDEM will evaluate other plume trend analysis methods on their merits. U.S. EPA (2006d) describes various methods for evaluating trends of different combinations of spatial and temporal data.

Figure 4-E: An Example of Plume Trend Analysis

