Where's the LNAPL?

How about Using LIF to Find It?

by Paul Stock

The Minnesota Pollution Control Agency (MPCA) Petroleum Remediation Program (PRP) routinely uses data from laser-induced fluorescence (LIF) probes to target petroleum light non-aqueous phase liquids (LNAPLs) when remediation is necessary. Given our experience in using LIF, PRP staff had gained a great deal of insight on LNAPL behavior and found themselves nodding their heads in agreement during the Interstate Technology Regulatory Council's (ITRC) internet-based training on LNAPL behavior when it first became available in March 2009.

A couple of months ago, several PRP technical staff were invited to attend a dry run of the ITRC's LNAPL Classroom Training in order to provide the ITRC's LNAPL Team with feedback. The LNAPL Team has developed a set of excellent classroom training modules that lay out the latest understanding of LNAPL behavior using a multiple lines of evidence approach—LNAPL science. if you will. This science is consistent with and provides a much deeper understanding of what PRP staff have observed about LNAPL behavior using LIF. The LNAPL Classroom Training also includes a process for selecting the appropriate remedial technology to address specific LNAPL concerns using an LNAPL science-based site conceptual model (SCM). You may have guessed by now that one of the first things one needs know is: where's the LNAPL?

The PRP has found that LIF data can reliably answer the question: where's the LNAPL? Moreover, LIF data can also help lead to answers for many other important questions about site-specific LNAPL behavior and its remediation. After more than a decade using LIF, we have concluded that its strategic application results in cost-effective use of limited resources. The word must be getting out. More frequently over the past couple of years, we have been contacted by regulators, consultants, contractors, and even some responsible parties from other states inquiring about the PRP's use of LIF. Recently, a regulator from another state invited PRP staff to train their staff on how to interpret LIF data. The following discussion has been designed to address some of these questions.

NOTE: I should explain that, as we became more aware of what LIF was telling us about the behavior of petroleum products released in the subsurface, we began to abandon the term "free product" in favor of LNAPL. We believe that LNAPL is more scientifically accurate and descriptive, and less prone to past and existing misconceptions about free product. However, I will occasionally use the term "free product" in the following discussion when historically appropriate.

What Is LIF?

Folks working the oil patch have long used ultraviolet light to induce fluorescence when examining drill cuttings for the presence of petroleum hydrocarbons. That basic principle can be applied to the down-hole environment. As a probing tool is advanced to depth, ultraviolet light is directed through a transparent window on to the immediately adjacent soil and whatever fluid occupies the soil pores. A sensor detects and records any florescent light returning through the window.

Essentially, the more petroleum present in the pores adjacent to the window, the stronger the recorded fluorescent response. Because different chemical compounds predictably fluoresce at varying wavelengths and decay times, even more information can be gleaned from further analyses of the light returning to the sensor. In addition, filters can be used to eliminate or reduce unwanted responses.

I am aware of two companies that design and produce commercially available field sensors using ultraviolet light to induce fluorescence of aromatic hydrocarbons for detecting petroleum LNAPLs in the subsurface: Vertek, a division of Applied Research Associates, Inc., out of Randolph, Vermont; and Dakota Technologies, Inc. (DTI), out of Fargo, North Dakota. Information on Vertek's and DTI's respective sensors can be found at *www.vertekcpt.com* and *www.dakotatechnologies.com.*

These sensors are designed to detect lighter and heavier petroleum-based fuels, oils (including crude and lubricants), and/or creosote and tar. The main output is in the form of a graph, typically called a log, of fluorescent response versus depth for each probing location. When a laser is used to generate the ultraviolet light, the technology is generically referred to as laser-induced fluorescence, or LIF for short. Figure 1 shows a sample LIF log.

The Ins and Outs of LIF

It is important to note that induced fluorescence data must be integrated with all available standard site data, including site history, present land use, geology, and soil and groundwater contamination, to develop an SCM using multiple lines of evidence. Moreover, considering typical geological heterogeneity and consequential LNAPL behavior, the benefits of viewing side-by-side LIF and geology data can hardly be overstated.

The induced fluorescent tools are typically deployed with Cone Penetrometer Testing (CPT) or Electrical Conductivity (EC) sensors. These sensors allow collection of side-by-side, high resolution, geologic data. CPT and EC often provide a more objective and complete data set than obtained from typically limited geologic descriptions of physical soil samples collected during routine site investigations.

LIF detects polycyclic aromatic hydrocarbon (PAH) molecules (e.g., naphthalene, perylene, anthracene) that fluoresce efficiently when present in an aliphatic solution like typical petroleum LNAPLs composed of gasoline, diesel, heating oil, kerosene, jet fuel, and so on. We have also used LIF to delineate heavier

■ continued on page 14

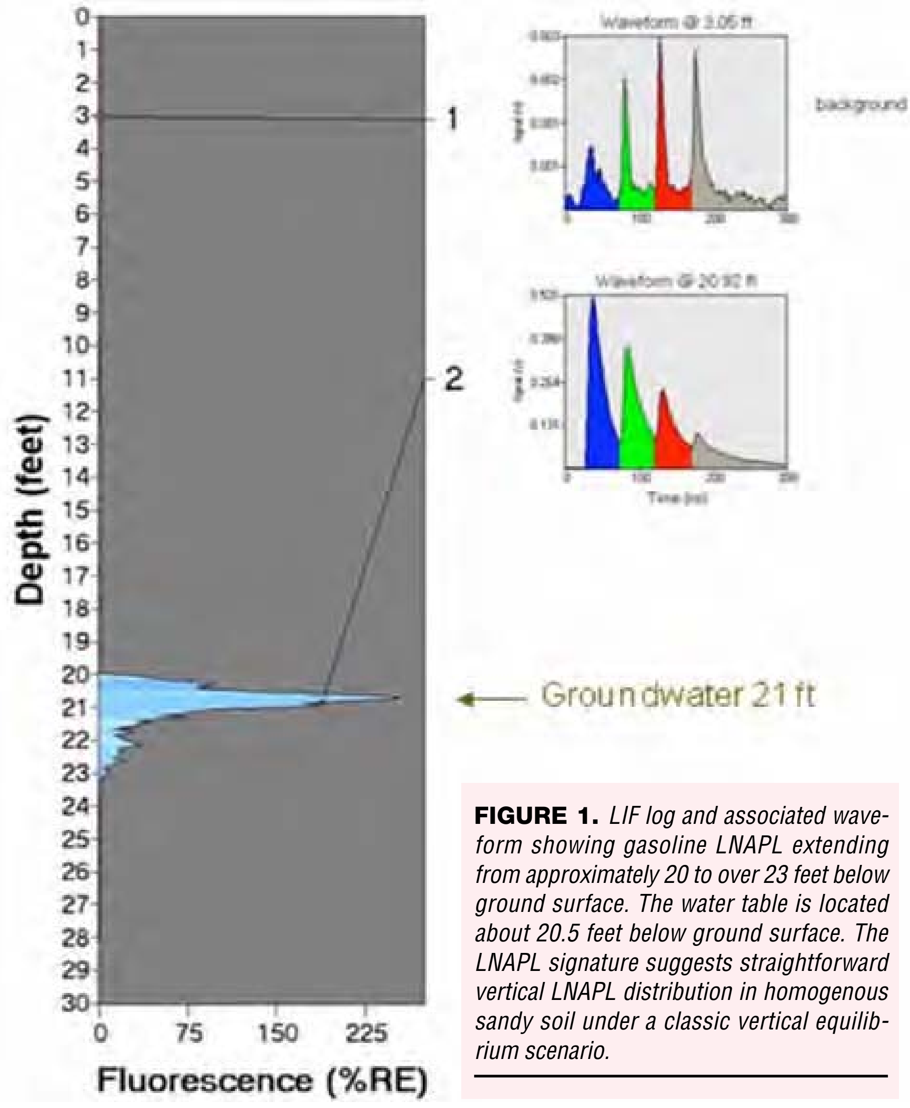

FIGURE 1. *LIF log and associated waveform showing gasoline LNAPL extending from approximately 20 to over 23 feet below ground surface. The water table is located about 20.5 feet below ground surface. The LNAPL signature suggests straightforward vertical LNAPL distribution in homogenous sandy soil under a classic vertical equilibrium scenario.*

■ **Using LIF** *from page 13*

petroleum products such as no. 6 fuel oil, motor oil, and hydraulic oil.

Monoaromatic compounds do not fluoresce efficiently, so LIF will not reliably detect LNAPLs composed of, for example, pure benzene or xylene. In addition, LIF does not detect individual contaminant molecules occurring in the other three physical phases of subsurface petroleum contamination commonly associated with an LNAPL—the aqueous, vapor, and adsorbed phases. In other words, LIF does not detect PAHs, BTEX, or other petroleum-related molecules dissolved in water, dissolved in soil gas, or adsorbed to soil solids because they do not fluoresce efficiently.

Although not responding to PAHs, we have also used LIF to successfully investigate a release of 100 percent soy biodiesel—that's when we found out that even banana skins will fluoresce. There are some other nonpetroleum compounds that fluoresce when stimulated by ultraviolet light (e.g., mineral calcite and many natural organic molecules, such as those found in peat and other carbonaceous sediments).

To discriminate between interfering fluorescence and fluorescence caused by LNAPL, LIF can display waveforms (Figure 1) from selected depths (e.g., call-outs) which, along with a multiple lines of evidence approach, are useful for eliminating these false positives. Moreover, the waveforms vary systematically among different petroleum products; thus they can be used forensically to differentiate situations such as side-by-side or overlapping gasoline and diesel LNAPL bodies. However, differential weathering and other phenomena can also result in differing waveforms from borings completed across a single LNAPL body. For this reason, forensic use of LIF should be done very cautiously with corroboration by multiple lines of evidence and logical consistency.

LIF has given us pause when considering a definition for the sometimes-confounding term "soil contamination." Conceptually, we have found it more straightforward and useful to determine in which of the four physical phases a detected organic contaminant molecule exists in the subsurface, rather than classifying it generically as soil contamination.

Because many organic contamination detection methods, such as headspace screening and laboratory analysis, are nonspecific with regard to contaminant phase, we have found that misconceptions about soil contamination can lead to confusion when developing an SCM and designing corrective action. LIF's ability to detect only the LNAPL is perhaps the single most important concept to understand when using LIF data.

A Real Free-Product Eye-Opener!

Although some fundamental principles of LNAPL science, such as vertical equilibration and multiphase flow, were already understood, it is fair to say that, back in the 1980s and 1990s, free product behavior was somewhat of a mystery to many regulators, including the PRP. It is also fair to say that some misconceptions persist to this day. The PRP began experimenting with LIF in 1998 and, by 2000, began to recognize its usefulness for understanding LNAPL behavior and mapping its actual distribution in the subsurface. This simple mapping approach caused us to abandon long-held preconceptions about free product that were simply not supported by an objective evaluation of the new evidence supplied by LIF.

With tongue in cheek, a colleague from a southern clime once asked me if we have ever found any frozen LNAPL in Minnesota using LIF. No we have not, but one of the first things we learned from LIF is that LNAPL is ubiquitous. Its presence should be suspected at all petroleum release sites, even if direct evidence of LNAPL, such as measurable thicknesses in monitoring wells, is not present.

Perhaps the most profound misconception held by many of us was that petroleum releases organized themselves into a layer of free product floating on top of the water table in the formation. Admittedly, this concept seemed self-evident in light of how free-product floats on top of the water in monitoring wells. Indeed, monitoring wells were designed to straddle the water table with this misconception in mind.

LIF evidence made it immediately obvious that LNAPL does not float on the top of the water table. In fact, it was clear that the majority mass of LNAPL was almost always situated in the pores below the water table. We realized this had profound implications for development of successful remediation strategies. By 2003, the PRP started requiring LIF data at many high-risk leak sites where aggressive remediation was necessary.

LIF data allowed us to confidently target remediation efforts on the LNAPL with almost surgical precision. At the same time, we groaned upon realizing that earlier soil excavations had often stopped at the water table while soil-vapor extraction would not have significantly affected submerged LNAPL. On the other hand, we realized why air sparging had, perhaps inadvertently to a degree, resulted in some notable successes.

Until we learned that LNAPL does not float on the water table, we assumed that free product would simply follow the water table gradient as it migrated away from the release point. LIF data showed us that this is rarely the case; rather, migrating LNAPL follows the path of least resistance above and below the water table. Upon encountering the water table, the LNAPL continues to penetrate downward some distance and then spreads laterally in all directions within the saturated zone, including opposite the hydraulic gradient. That is not to say that the LNAPL continues to expand forever.

Strategic Regrouping

Under the misconception that free product was floating on the water table and migrating down gradient, almost like water flowing down a hill, we had conceptualized that there was nothing much stopping it from continuing to migrate, albeit slowly in most cases. There was no way we wanted to close sites if there was any chance of free product migration, while the risks posed by free-product migration seemed ever present.

However, after mapping LNAPL bodies with LIF data, and integrating standard investigation and long-term monitoring data, the LNAPL bodies from legacy releases appeared remarkably stable under prevailing, natural, hydraulic conditions. Obviously, there were, albeit poorly understood by us at the time, natural forces counteracting the forces behind LNAPL migration.

LIF allowed us to strategically locate monitoring and remedial wells inside and outside an LNAPL body. At first we were surprised when no LNAPL showed up in some wells purposefully screened across the LNAPL body. We also noticed how rarely actively migrating LNAPL was observed in the sentinel wells purposefully located just outside an LNAPL body from a legacy release. It became apparent that, after a relatively short-duration, active-migration period immediately following a release, an LNAPL body becomes stable. However, the LNAPL within the stable LNAPL body manifested itself in one of two basic fractions within the subsurface: mobile and immobile.

Clearly, the mobile fraction was locally mobile but, more importantly, not necessarily migrating en mass from the locales where it was found. We also noticed that mapping an LNAPL body often provided clues as to where the mobile fraction could be found within the LNAPL body footprint. On the other hand, we realized that both mobile and immobile LNAPL act collectively as a source of the chemicals of concern (COC) for the more extensive aqueous and vapor phases.

LIF quickly taught us that the migration and, ultimately, the distribution of LNAPL in the subsurface is often complex, with abrupt changes occurring over short lateral (and vertical) distances, due in large part to geologic heterogeneity. Infrequently, heterogeneity manifested itself with LNAPL-less borings inside the footprint of an LNAPL body.

We have found that geologic heterogeneity must be accounted for not only when completing a LIF investigation and corrective action design, but also when evaluating standard site investigation data, such as laboratory analysis of discrete soil samples. In other words, samples collected using standard methods may not be as representative as often assumed, especially if not evaluating the standard data with an SCM accounting for the four phases of subsurface petroleum contamination.

LNAPL Loves Sand and Hates Clay

A somewhat crude rule of thumb developed from our LIF experience is that LNAPL loves sand and hates clay. However, that's only part of the story, especially when it comes to clay. Pore size, structure, and geometry, rather than grain size per se, seemed to control LNAPL migration and distribution. LIF showed us that LNAPL readily occupies a clay's secondary porosity features, such as cracks and fractures (i.e., relatively large pores), while not being present within the primary porosity (i.e., very small pores).

I personally confirmed what the LIF data was telling us when I observed this behavior in fractured clay till while attending an excavation of an LNAPL body. Moreover, the LNAPL can penetrate far into the saturated zone along these fractures. A better description of LNAPL's seemingly curious behavior in fine-grained soil is presented in a paper by Mark Adamski and others in the Winter 2005 edition of the National Ground Water Association's publication *Ground Water Monitoring and Remediation*. This subject is also covered in the ITRC LNAPL Classroom Training, including a couple of very clever but straightforward demonstrations that you can even try at home.

Keeping in mind that LNAPL does not like clay, LIF data showed us that LNAPL can be found under several general geologic scenarios when coarser-grained lithologies are present. When homogenous, sandy geologic conditions are present, the

■ continued on page 16

■ **Using LIF** *from page 15*

LNAPL will usually be found floating *in* the water like an ice cube in a glass of water (not *on* the water like a solid sheet of ice on a Minnesota lake in the depth of winter; see Figure 1). Unfortunately, this ideal, simple scenario appears to be rare in Minnesota.

Things get much more complicated when both finer- and coarser-grained soils are present in discrete layers. In the unsaturated zone, LNAPL can be found perched on top of a clay layer, and the attitude of the clay's upper surface can control LNAPL accumulation and migration direction. Within the saturated zone, LNAPL can be found in discrete layers reflective of inter-layered finer- and coarser-grained soils, including finer- versus coarser-grained sand layers.

Most surprisingly, under appropriate geologic conditions, an LNAPL layer can be found along the top of a hydraulically confined sand unit (an aquifer!), several to a dozen or so feet *below* the water table present in the overlying, confining clay unit. It shouldn't be a surprise that LIF data has shown that more than one of the above-described LNAPL distribution scenarios are present at a single geologically complex site.

Watch Out for Those LNAPL Arms

Now I don't mean to say that hydraulic gradients have nothing to do with LNAPL migration. Mapping of LNAPL bodies with LIF data has shown us that even apparently minor, induced (i.e., not natural) hydraulic gradients can have a significant effect on LNAPL migration, even when the induced gradients are applied some time after the initial migration period when an LNAPL body has stabilized under prevailing natural conditions.

Most LNAPL bodies will be more or less circular, or roughly oblong, and centered under the release source in map view. However, some will have lobes and some of these lobes may take the form of relatively narrow and sometimes surprisingly long arms. Only because of a dense LIF grid pattern (discussed below), and probably some luck, have we been able to identify some of these LNAPL arms.

If there is an LNAPL arm, I know where I am going to go looking for actively migrating LNAPL. But, my main point is that we have observed LNAPL arms that apparently developed due to human-induced hydraulic gradients caused by pumping water wells screened within the hydro-stratigraphic unit where the LNAPL occurs. LIF data have shown us LNAPL arms reaching out from an LNAPL body toward: a) a relatively deep, high production municipal well located several hundred feet away; b) a relatively shallow, low-production domestic well located less than 200 feet away, or c) a perennially pumping but low-volume basement sump less than 100 feet away. (The sump pump example was a big surprise, especially since it was located up gradient.) Moreover, when very strong induced vertical gradients are present, the LNAPL arms have been observed "diving" deeper as they migrate laterally.

Added Value of LIF Logs

LIF data led us to another unanticipated but very important benefit. We found the LIF logs to be very useful when negotiating cleanup plans with responsible parties. It must be the visual thing. The LIF logs allowed the responsible parties to "see" the LNAPL at their sites and better understand the nature of the problem. This clearer understanding often led these important stakeholders to take more ownership of the problem and its resolution. Moreover, it often elicited additional important site history information that, in turn, yielded a more informed SCM. Indeed, some parties wanted to use LIF on their other problem sites as quickly as possible due to LIF's problem resolution capabilities.

LIF Investigation Strategy

It should be understood that the PRP's requirements for LIF investigation and data analysis are typically designed to yield a well-defined remediation target while also developing an updated, evidence-based SCM including the role of LNAPL. Thus, a LIF investigation is typically completed after a standard site investigation; so there is often standard data to guide LIF planning. Nonetheless, we require prior submission of a site-specific LIF investigation work plan for our review before approving LIF investigations.

If available, we often recommend that LNAPL samples be collected from monitoring wells before conducting a LIF investigation. This can be done well before mobilizing the LIF equipment to the site. The samples can be held to the probe window to see how the LNAPL responds to LIF. One can also obtain LNAPL waveforms from the samples to confirm how well the LNAPL from the wells matches the LNAPL in the formation.

For targeting purposes, and subsurface heterogeneity being the rule rather than the exception when faced with Minnesota's complex glacial terrane, the PRP generally requires that borings be completed across a grid with 25 to 35 feet node spacing. However, it is important to slightly adjust, or add, some nodes within the grid so as to be directly adjacent to known or suspected LNAPL occurrences such as at standard borings or monitoring wells with evidence of LNAPL, as well as potential or known release locations (e.g., tanks, dispensers, product lines, spills).

LNAPL is laterally delineated by LIF borings completed at grid nodes in all directions around a confirmed detection until the LNAPL body is completely circumscribed by LIF pushes with no evidence of LNAPL. To be sure, some delineation node locations may need to be adjusted slightly to accommodate small footprint obstructions.

Large footprint obstructions such as buildings or other major infrastructure should be accommodated with delineation probes completed on all sides. This is due to the often unexpected, complex nature of LNAPL migration in the subsurface that could render convenient assumptions about limited LNAPL distribution unwise. The requirement for complete lateral delineation during a single LIF equipment mobilization event belies our advice to obtain site access permission beforehand for all properties where LIF data may be needed.

Vertically, we generally require that all LIF probes be advanced to depths at least 10 feet below the deepest detectable LNAPL at a given site (one of the reasons to start probing in the source area) or below the water table. But it is often wise to go deeper, depending on site geology or other evidence suggesting that deeper LNAPL may be present. Regardless, we generally require at least one boring to 20 feet below a site's deepest detectable LNAPL or the water table to confirm that there is no deep LNAPL. We have sometimes been surprised. The surface elevation of all LIF borings must be surveyed relative to the same on-site datum used for groundwater elevations and other site features.

It is important to note that LIF data is displayed in real time as the probes are advanced, and entire logs can be generated on-site immediately after completing a boring. With an ever-evolving SCM in mind, this capability allows a seasoned investigator to rapidly adapt and make informed decisions in the field as to how deep to advance the probe or where to go to conduct the next boring.

LIF Data Analysis Strategy

The evaluation of any LNAPL body via LIF log interpretation usually begins with the logs from the release location, if known; otherwise, from where the obvious shallowest and/or thickest LNAPL is observed, as these often provide clues about the release location. After the release area logs are interpreted, we move on to interpret the logs in order of distance from and in all directions around the release point. In other words, we follow LNAPL migration pathways away from the release point. This will usually result in immediate insights as to LNAPL migration behavior over time, including why the LNAPL is distributed as it is now and where it may migrate in the future.

If side-by-side geology data from CPT or EC are available, those are also interpreted when evaluating respective LIF data; otherwise, geology from nearby standard borings is used cautiously. In addition, LNAPL thicknesses and corrected water level elevations—including fluctuation history—from nearby monitoring wells are noted. "Snapshot" boring water levels are considered less useful than long-term monitoring well data but can be useful for identifying perched conditions in the unsaturated zone.

Each LIF log is first evaluated for the presence of LNAPL using a "machine-language" approach—is LNAPL present or not? False positives, if any, are also identified and discounted. If LNAPL is present, the top and bottom depths of the LNAPL interval are noted, as well as the maximum fluorescence response and its depth within the LNAPL interval.

With hydrogeology of the LNAPL interval in mind, we also note the shape, or signature, of the fluorescent response as it varies vertically across the LNAPL interval. We have found that this signature is evidence of varying pore structure and geometry (i.e., geology) and/or relative LNAPL pore saturations within a homogeneous geologic unit.

Under homogenous hydrogeologic conditions, the LIF signature can reflect a pore saturation profile reflective of the vertical equilibrium model for LNAPL behavior under multiphase flow conditions in porous media (Figure 1). More often than not, complex geology results in complex LNAPL distribution, and the LNAPL may be present in relatively thick and/or thin, discrete sand layers.

When clay geology is predominant, keep in mind that intermittent, very thin, solitary LNAPL signatures may indicate the LNAPL is in secondary porosity features, especially if they don't correlate between adjacent borings. As one interprets each LIF log, adjacent LIF logs are kept in view and progressively correlated with each other, often illuminating an overall pattern of LNAPL body geometry and behavior across the site as it relates to release and migration history, and geology and hydrogeology.

LNAPL Structural Mapping

Once the LIF logs are systematically interpreted, LNAPL elevations are calculated and all the LIF data interpretations and calculations are tabulated. The data are then used to map the structure of the LNAPL body from two perspectives: map (plan) view and cross section. Usually, at least four types of LNAPL body structure maps are constructed by contouring four LIF data sets: 1) maximum fluorescence response; 2) elevation of the top of the LNAPL body; 3) elevation of the bottom of the LNAPL body; and 4) LNAPL body thickness (i.e., isopach).

Sometimes a depth, rather than elevation, datum is used to map the structure of the LNAPL body when more appropriate for the proposed remediation strategy (e.g., an LNAPL body excavation). At this point, I should admit to being a former coal geologist; thus I like to treat the LNAPL body as a coal seam or an ore body, if you will. I also happen to be partial to LNAPL body excavations since I can be confident in the quick risk reduction that occurs when one removes nearly 100 percent of the LNAPL mass.

The maximum fluorescence response map is completed first. Preparation of the maximum fluorescence-response map is initiated by first mapping the horizontal extent of LNAPL. This is easy to do if the LNAPL has been delineated using the grid approach; simply draw a line weaving along halfway between LNAPL-present and LNAPL–not present data points. All of the LNAPL structure maps are then constructed by contouring the data inside this common LNAPL body footprint.

Cross-sections are constructed showing the LNAPL body as it relates to site geology, hydrogeology (e.g., fluctuating water levels), and the other dependent contamination phases. The cross sections should also show other relevant site features such as buildings, basements, buried utility lines, water wells, and other preferential migration pathways, barriers, obstructions, and receptors. The vertical and horizontal variation of fluorescence response within the LNAPL body can be contoured on cross sectional views to illuminate patterns of internal LNAPL body structure, providing additional insights about LNAPL migration and behavior.

The various LNAPL structure maps and cross-sections are used to accurately target the LNAPL body with the remediation strategy in mind. For example, the LNAPL structure maps can be used to strategically plan an LNAPL body excavation so as to remove only LNAPL-impacted soil for expensive treatment while using the segregated overburden as backfill (remember, I am a formal coal miner).

The LNAPL body isopach map allows for accurate estimation of

■ continued on page 18

■ **Using LIF** *from page 17*

the in-place volume of the LNAPL-impacted soil to be selectively removed. Alternatively, if a multiphase extraction system will be used under a dewater and aerate remediation strategy, the elevation of the bottom of the LNAPL body map can be superimposed with flow maps constructed with pilot-test or full-scale system hydraulic data for evaluating the degree and extent of LNAPL body dewatering around and between extraction wells. The structure maps and cross sections can also be used to explain the remediation strategy (e.g., by superimposing various proposed remedial structures, such as extraction or injection wells, on them).

If geology is a key factor in controlling LNAPL behavior and employment of a given remediation strategy, structural geology elements, such as the elevation of a clay/sand contact are also contoured. Facies changes, as well as sand bodies or buried sand channels embedded within finer-grained soil, should also be mapped, if relevant.

As an example of geologic mapping's usefulness when combined with LIF data, we have seen evidence of perched LNAPL stranded in syncline- or basin-like geologic structures. We have also seen evidence of perched LNAPL migrating "down dip" and cascading off the edge of the confining unit like a slow motion subsurface waterfall. We have observed the migration of submerged LNAPL, apparently controlled by anticline- or dome-like geologic structures at the top of a hydraulically confined sand unit.

From a remediation strategy perspective, geologic mapping allows one to be aware of the limitations imposed, but also the opportunities presented, by site-specific geologic structures. Of considerable importance, we have found that integrating LNAPL distribution with geology results in the need to consider more than one remediation strategy to address different areas of a complexly distributed LNAPL body.

We also like to point out that one can sometimes take advantage of LNAPL's propensity to distribute the bulk of its mass in more highly permeable layers. Understanding the location of the LNAPL relative to geologic structure is particularly useful for designing remediation wells to precisely focus remediation efforts and/or avoid short-circuiting.

Proximal, standard soil, groundwater, and soil-gas analytical data are also reviewed and evaluated to see what they are telling us about LNAPL chemistry, the COCs in particular, and the evolution and behavior of the aqueous and soil-gas plumes originating from the LNAPL. For example, soil-gas data can sometimes appear confounding, with the need to sort out false positives.

Soil and groundwater samples collected from within the LNAPL body often contain entrained LNAPL. Even if they don't, the samples are likely representative of the COCs present in the LNAPL. So, if no benzene is detected (and the benzene detection limit is not elevated) in soil and groundwater samples directly associated with a given LNAPL body, it would be logically consistent to use that line of evidence for questioning any positive detection of benzene in a soil-gas sample when evaluating the vapor-intrusion pathway.

Moving Forward

In August 2010 we implemented a new policy for managing LNAPL risks, including a risk-based definition of free-product recovery to the maximum extent practicable when only LNAPL migration risks are present. The development of this new policy is the direct result of integrating what we learned from LIF and the ITRC.

The PRP is in the business of reducing risks posed by LNAPL in the formation pores, not cleaning up individual wells, so we no longer use an in-well minimum free-product thickness criterion for determining the need for and completion of LNAPL recovery efforts. We believe our approach is consistent with the requirements listed in 40 CFR 280.64, including to "use abatement of free-product migration as a minimum objective." The policy is outlined in MPCA Guidance Document 2-02 "LNAPL Management Strategy" which can be downloaded from *www.pca.state.mn.us/bkzq810.*

More recently, we implemented new policies for oversight of corrective action, in particular, the design and implementation of aggressive remediation systems targeting LNAPL. The development of new corrective action policies was substantially informed by what we learned about remediation using LIF to target LNAPL bodies. In most cases, the entire LNAPL body must be targeted when risks are posed by COCs that originate from the LNAPL. This includes the immobile, sometimes called residual, fraction of the LNAPL that cannot migrate but is still a potent, long-term, source of COCs. These new policies are outlined in MPCA Guidance Document 7-01, *Corrective Action Design and Implementation*, which also contains LIF guidance in Appendix B. That document can also be downloaded from *www.pca.state.mn.us/bkzq810.*

I am very excited about ITRC's plan to take their LNAPL Classroom Training on the road. The training is designed for regulators, consultants, and others LNAPL remediation stakeholders.

Although a finalized schedule has not been publicized, I have been told the first two-day course will be offered during fall 2011. A total of up to twelve training events across the country are envisioned, so most everyone should have an opportunity to attend a relatively nearby offering. In the meantime, the ITRC's internet-based training is still being conducted and past sessions can be downloaded for review at your convenience. For more information on the internet-based training schedule or downloads, check the ITRC's website, *www.itrcweb.org.* The classroom training schedule will be posted there when it becomes available. Two ITRC LNAPL-related publications can also be downloaded, as well as other useful documents and links to other relevant websites.

In conclusion, I hope Minnesota's story will give you some reasons to consider induced fluorescence methods the next time you find yourself trying to answer the question: where's the LNAPL? ■

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