

Abstract for presentation to the Geological Society Conference: NAPL in the UK context, does it matter? 6th November 2019 Priory Rooms, Birmingham

Assessing the seriousness of NAPL contamination – Experience from three different sites in the UK.

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NAPL contamination can arise in different forms, at different scales and in different environmental contexts, all of which may require different approaches to investigation, assessment, management and remediation. When faced with the initial discovery of NAPL, many of the more familiar tools for management of land contamination, such as soil screening values, cease to be of much use, so what does it mean for problem holders, what advice can consultants give and how can all parties work together to find an appropriate way forward?

Effective management of NAPL requires not only an appropriate technical approach, but also consideration of many other factors such as associated liability, sustainability and perception. The author's practical experience of assessing three different sites with different real world NAPL problems and characteristics will be used as the basis for discussing different approaches to investigation and assessment, leading to different management strategies.

Case studies include both LNAPL and DNAPL sites and give real examples of challenges faced, lessons learnt, overcoming practical constraints and how important management considerations such as associated liabilities and requirements of the regulatory framework were addressed. Case studies encompass NAPL problems regulated under the different approaches of voluntary remediation, the planning regime and Part 2A of Environmental Protection Act and provide a perspective on how these differing frameworks can influence the management of NAPL contamination.

David is a Technical Associate at the Sirius Group and a Chartered Scientist with almost twenty years' experience, specialising in the quantitative risk assessment of land affected by soil and groundwater contamination. He is involved in the management of a wide range of human health and controlled waters risk assessment projects across the UK ranging from former fuel station sites to large-scale groundwater risk assessment, remediation and monitored natural attenuation schemes. David's work has included investigation, assessment and remediation of a large former tar works site within the context of Part 2A legislation and delivery of training on controlled waters risk assessment for the CIEH. In addition to consultancy, David is also currently undertaking a part time PhD by research into sustainable remediation technologies with the Department of Engineering and Computer Science, at the University of Durham and is an active steering group member of the North East Contaminated Land Forum.

ADVANCES IN IN-SITU AUTOMATOUS LNAPL AND WATER LEVEL MONITORING BY GUIDED WIRE RADAR: DETAILED ANALYSIS OF LNAPL BEHAVIOUR AND IMPROVED SITE UNDERSTANDING.

Recovery of hydrocarbons that are present as Light Non-Aqueous Phase Liquids (LNAPL) in soils is an established remedial process and its success lies on a sound understanding of LNAPL behaviour. LNAPL baildown tests and hydrographs are used to understand the LNAPL mobility and provide important information about soil conditions. While baildown tests themselves are conceptually simple - a stress is applied to the LNAPL body and the response is measured – accurate measurement of fluid levels is not always straightforward. Notably, measuring two dynamic interfaces is difficult in practice and fluid levels may take some time to return to the initial condition, leaving gaps in recorded data as personnel may not be continuously present on site to monitor the test. LNAPL wells can also be in areas that pose significant hazards to site personnel. Furthermore, factors such as groundwater fluctuation and inter-operator variation can cause inconsistencies in the collection of the data.

Understanding of the site is also reliant on longer term monitoring of the LNAPL. Hydrographs are created from periodic monitoring of boreholes but cannot provide a true picture of the groundwater movement-LNAPL relationship within a practical time frame.

Ecologia has developed a safer, more reliable and accurate LNAPL measurement technique for both baildown tests and hydrographs.

The approach uses a guided wire radar sensor. A series of laboratory trials provided robust data and we established that the sensor was able to track movements of LNAPL with a high degree of accuracy and precision. Studies then progressed to field trials where the LNAPL interface data collected could be interrogated and verified, and engineered controls developed to allow the sensor to work on site, allowing recording of the LNAPL and water levels in boreholes to a resolution of 2 mm, with a high degree of repeatability.

The system was also used to carry out baildown tests on several LNAPLs, including a mobile and viscous LNAPL from project start to completion. This allowed LNAPL transmissivity to be used as a leading metric, design parameter and ending metric for LNAPL recovery. Integration of the data with computer modelling provided robust estimates of LNAPL mobility change with recovery, which were subsequently demonstrated to be correct.

The use of the system avoids problems often faced when employing a baildown test. The quality of the data is better than would be obtained by following the current ASTM standard. The set-up can be used to create hydrographs of far greater utility than can be currently made. The accuracy and precision of the set-up are also greater than an interface probe. In addition, the system removes the need for a continuous site operator presence, freeing up site personnel for other work, and more importantly, minimising any health and safety concerns associated with monitoring LNAPL-extraction or monitoring wells.

Felipe Couto

The project's purpose was to perform a site investigation to enable additional characterisation of remaining NAPL to inform a risk assessment and a remedial options appraisal (ROA). Pilot trials were also required to refine the conceptual site model (CSM) and support the remedial options appraisal in identifying and refining the design of the most economically advantageous techniques for remediating the NAPL sources under the site. This ultimately formed part of the strategy to meet the client's overall objective of remediating the site to a standard suitable for sale.

Pilot remediation trials

The pilot remediation trials were designed to assess the options identified in the preliminary ROA to refine the CSM further using the well arrays installed during the site investigation.

RSK mobilised RemedX's multi-technology remediation pilot test trailer to enable the following techniques to be trialled:

- x groundwater and NAPL extraction (total fluids) at ambient temperature
- x DPE at ambient temperature
- x thermally enhanced water flush
- x total fluids extraction
- x steam injection
- x steam-enhanced total fluids extraction
- x steam-enhanced DPE.

Five well arrays were tested over the 12-week trial period during which large amounts of monitoring data were collected for analysis. This trial included arrays installed in the made ground, basalt and sedimentary rock horizons. The work was completed under a mobile plant licence deployment and a temporary consent for discharging to sewers from the relevant regulators.

The results of the trials also enabled the NAPL source areas identified in previous phases to be refined. Estimates could also be made of recoverable NAPL versus the total mass present in the matrix. This ranged from 0.15 to 0.5% under ambient conditions to 4–10% under optimum thermally enhanced conditions. Design considerations were developed for full-scale remediation of the site.

The preliminary ROA was updated on completion of the pilot trials and the associated reporting. This identified the preferred in-situ approach for NAPL removal as thermally enhanced total fluids extraction. A need to address the remaining recoverable NAPL sources in the made ground or associated with structures through use of excavation and ex situ treatment or containment was also identified. Updated cost estimates were developed for full-scale remediation of NAPL sources on the site.

Achievements and added value

- x Significant progress made in developing a detailed remediation strategy for addressing NAPL contamination on a complex site and supporting the client's wider objectives for the site
- x Use of best practice techniques, including field trials and multiple lines of evidence to assess and quantify NAPL extent and behaviour in a complex geological environment at the leading edge of scientific understanding
 - x Maximising the value obtained from drilling rotary boreholes through additional data collection, for example, downhole geophysics testing, and detailed NAPL logging using ultraviolet fluorescence testing
- x Parallel installation of well arrays to minimise mobilisation costs for site investigation work

The project was highly commended in the Best Site Investigation category of the Brownfield Briefing Awards in 2018.

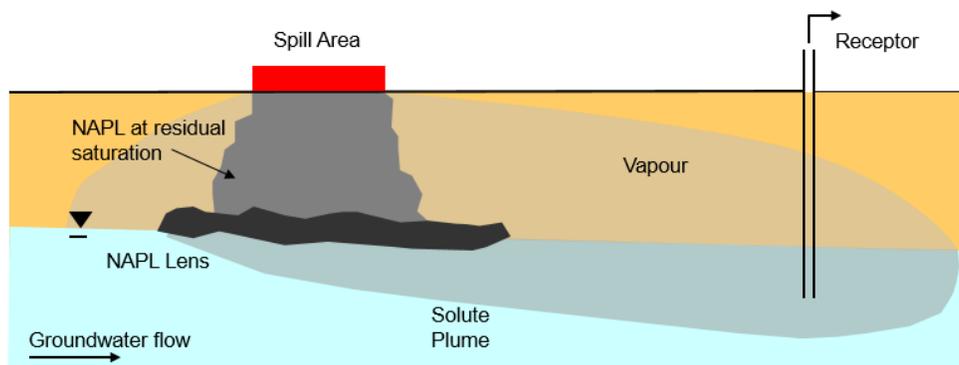
Heather Di Lauro / Anwen Hughes
Golder

Abstract: Tools, methods and models for evaluation of Natural Source Zone Depletion of LNAPL Sources

There is increasing interest in the effective use of natural source zone depletion (NSZD) technology for sustainable management of LNAPL sources at petroleum hydrocarbon sites. Natural Source Zone Depletion (NSZD) and associated unsaturated zone processes (volatilisation, biodegradation and dissolution) is increasingly being recognized as a significant process in the depletion of Light Non-Aqueous Phase Liquid (LNAPL) sources of groundwater dissolved phase plumes. Quantification of these processes in the subsurface supports an improved understanding of the length of time for sources to deplete and how the NSZD processes can be enhanced to aid LNAPL source depletion and support plume attenuation. Based on work completed by Golder in Canada, this presentation will introduce the concept of NSZD and explain its potential importance as part of a remedial solution for LNAPL petroleum hydrocarbons. NSZD guidance and tool kits developed for NSZD implementation will be briefly described. Example methods for measurement and evaluation of source depletion rates will be introduced through example field trial applications at a former refinery site. To close, the role of NSZD within a current UK regulatory context will be considered

Modelling NAPL sources in RAM4

Spills of fuels can present long-term soil and groundwater pollution sources and associated risks to human health and controlled waters receptors. These contaminants typically have low solubility in water and tend to form their own 'non-aqueous phase liquid' (NAPL) in the pore space of the subsurface. Regardless, water quality standards for the dissolved chemical components of fuels or solvents are often very low. If left untreated, spills can migrate through the unsaturated zone and form a floating lens at the water table; this can result in solute plumes and vapour phase migration away from the source area, potentially impacting on groundwater, surface water and human receptors.



Numerical modelling of NAPL spills is complex; it is therefore important to use practical solutions to simplify key processes relating to contaminant behaviour. Such approaches include:

- Characterisation of the lens dimensions and volumetric NAPL content;
- Estimation of subsurface NAPL water characteristic behaviour on the basis of contaminant properties and aquifer particle size distribution curves; and
- Calculation of the mobility of the NAPL lens.

Once the probable location and characteristics of the NAPL within the subsurface have been established a contaminant transport model can be developed to represent key elements of the conceptual understanding.

The updated RAM4 risk assessment software incorporates a NAPL source in the configuration options. This enables the impact from NAPL sources on groundwater receptors to be assessed.

New features within the RAM4 software include:

- Data entry for mass-fraction and molecular weights;
- Guidance on estimating the vaporisation rate from the NAPL lens;
- Calculation of effective solubility of the components of the NAPL lens using Raoult's Law;
- Estimates of dissolution rate from the NAPL lens using theoretical calculations of mixing depth;
- Calculation of the initial inventory of the NAPL source using soil and porewater concentrations;
- Consideration of the residual saturation;
- Ability to combine concentrations from multiple sources at a single receptor.

NAPL contaminant transport models can be very sensitive to key input parameters, such as dissolution rate and lens geometry; RAM4 can be used to refine conceptual models, test hypotheses of NAPL fate and migration, and define appropriate remedial targets.

'Sunshine on the Tyne' - Solar Powered Remediation of DNAPLs within a historic gas holder.

Mark Stacey & Adam Wilson, *Geo² Remediation Ltd*; **Emma King**, *Sweco*; **Neil Whalley**, *Northern Gas Networks*

Geo² Remediation Limited, SWECO and Northern Gas Networks (NGN) present the findings, results and lessons learned from a collaborative DNAPL recovery project, a recipient of the 2019 Ground Engineering Award for Sustainability.

The remediation project comprised design and operation of a robust, field portable entirely solar powered tar pumping system within a historic gas holder tank structure located at NGN's Redheugh site in Gateshead. Previous site investigations (SWECO) characterised thick (c.2m smear zones in places) discontinuous lenses of DNAPL (coal tars and phenols) within a hydraulically closed, deep (c.9m) brick lined gas holder tank base infilled with loose demolition waste. Following drilling, installation and development of remediation wells to target known DNAPL horizons, the remediation system was optimised to meet the specific demands of the site; unmanned & low maintenance, reliable recovery, targetable deployment and operate within a 'live' gas site with no readily accessible energy source.

The modular remedial system constructed of a solar array, NAPL Quarantine Tank, internal battery and compressor powering a series of pneumatic down-hole pumps was designed to give a slow, intermittent pulsed recovery in order to optimise DNAPL recovery. Typical pumping times ranged from 1 min/30-50hrs in order to enable progressive DNAPL recovery and recharge around the remediation wells.

The system has successfully recovered approximately 6,150 litres of NAPL during its operational lifetime over the past two years, utilising only renewable solar energy. Compared with traditional petrol generator powered apparatus, the system has saved approximately 66t of CO₂ and £28,000 in like for like costs, demonstrating a clear sustainable benefit.

The Project has been well received across the Brownfield Industry, winning the Brownfield Briefing Award for Best In Situ Treatment (2018) and most recently the Ground Engineering Award (2019). The remediation project demonstrates that collaborative and creative approaches between site owner, consultant and contractor can result in innovative strategies for the resolution of complex DNAPL site contamination which could not be achieved by conventional dig and dump techniques and deliver net environmental benefits throughout the project life-cycle.

Title: DNAPL Investigation and Remediation for the Thames Tideway Tunnel

Authors: CVB JV (Contact: Emily Riley), Golder Associates (Contact: Matt Wright) and Mott MacDonald (Contact: Dino Giordanelli)

The Thames Tideway Tunnel is a major construction project passing through some of the most developed areas of London. During investigations prior to construction, the legacy of London's industrial past produced some technically challenging contaminated land issues, including DNAPL contamination at the shaft site at Earl Pumping Station (EARPS) in Lewisham. This presentation will describe the approach taken by CVB Joint Venture, the Main Works Contractor for the East Section of Tideway Tunnel, working in close agreement with regulators and the local authority, in characterising, managing and remediating the DNAPL in a sensitive and logistically challenging environment. The work is considered to be a case study of good practice in managing the investigation and remediation of DNAPL, in line with current guidance, in a densely populated residential area with strong engagement between multiple contractors and stakeholders.

The DNAPL product is thought to be a coal tar condensate associated with historical tar, pitch and naphtha works, previously located on and to the south of the current construction site. The DNAPL is contained within the River Terrace Deposits (RTD) and Thanet Formation (TSF) strata overlying the Principal Chalk aquifer, with clay rich deposits at the base of the TSF potentially acting as a barrier to downward migration of DNAPL. Several phases of characterisation have been undertaken informing a comprehensive Conceptual Site Model and Risk Assessment, including robust approaches to drilling through DNAPL, comprehensive analysis of the product's physical and chemical properties, the use of subsurface Leapfrog modelling and ongoing long term groundwater monitoring to assess any effect of the DNAPL on the dissolved phase concentrations. Geotechnical data from drilling works and DNAPL pumping trials have been used to understand DNAPL mobility in the subsurface, with particular attention to the potential clay rich layer at the base of the TSF, and the establishment of sustainable yield for recovery of DNAPL from the TSF during remediation.

The final stage of investigation of DNAPL recovery is currently underway and a remediation method statement is being finalised with a view to installing an automated sustainable DNAPL recovery system in the near future.

The presentation will contain an outline of both characterisation and remediation works completed to date and a summary of the challenges encountered and lessons learned on the project so far.