Old LNAPL Conceptual Site Model (Old LCSM)

The Old LCSM had these problematic features:

- There was a large volume of LNAPL in the subsurface as indicated by a calculation where the site-wide average thickness of the LNAPL in the monitoring wells was multiplied by the area of the LNAPL body.
- It was assumed that much of this LNAPL was recoverable by the existing LNAPL skimming system, even though LNAPL recovery was much lower than the initial LNAPL recovery rate.
- It was assumed that LNAPL recovery had to continue until there was no more LNAPL observed in each of the site monitoring well (an apparent LNAPL thickness of zero).
- Although long-term LNAPL monitoring data indicated that LNAPL body was stable and no longer expanding, a U.S. EPA LNAPL model had been used many years ago and indicated that the LNAPL body was likely to continue to expand for the next 30 years without LNAPL recovery. These old modelling results greatly complicated efforts to retire the on-going LNAPL recovery system comprised of 15 LNAPL skimmer wells.
- Based on the scientific knowledge from the mid-1990s, the only process that was removing LNAPL was dissolution of higher solubility constituents in the LNAPL, and it would take hundreds of years to remove these soluble constituents and the lower solubility compounds would likely persist forever.

How to Update the LNAPL Conceptual Site Model (New LCSM)

Step 1. Site consultants used the Tier 1 "How much LNAPL is present?" tab to develop a much more accurate estimate of the **specific volume** of LNAPL based on soil type and LNAPL apparent thickness. When the specific volume was multiplied by the LNAPL body area, an updated estimate of the LNAPL volume in the subsurface was developed. This new estimate was many times lower than the original estimate because the Old LNAPL conceptual site model volume estimation method was deeply flawed.

Step 2. Step 1 indicated more detailed information would be beneficial, and two models were evaluated: the mid-level complexity Tier 2 model in the Concawe Toolbox; and a more complex model called LDRM that is explained in Tier 3 text and videos. Based on this information, the Tier 2 model was selected, site data was compiled and entered into the input data spreadsheet, and the model was run. The Tier 2 "How much LNAPL is present?" model provided a more refined estimate of the total LNAPL present in the subsurface and another piece of information: the amount of LNAPL that is potentially mobile and the amount of LNAPL that is permanently trapped as residual LNAPL.

Step 3. The Tier 2 "How much LNAPL is present?" model (note – this is the same model as in Tier 2 "Will LNAPL recovery be effective?") was used to develop a map of the LNAPL transmissivity that was based on site-specific LNAPL properties, site-specific soil characteristics, and site-specific layering/stratigraphy. With this map, guidance from the U.S. Interstate Technology and Regulatory Council was consulted, which suggested if the LNAPL transmissivity was less than 0.0093 m^2/day then hydraulic recovery of LNAPL was likely not be cost effective or efficient; and if the LNAPL transmissivity was greater than 0.074 m^2/day then hydraulic recovery of LNAPL was likely to be effective. Surprisingly, only one well out of the 15 LNAPL skimming wells exceeded the 0.0093 m^2/day threshold, indicating that 14 of the skimming wells were not providing much environmental benefit. The simple Tier 1 "Will LNAPL recovery be effective?" tab also showed similar results, increasing the confidence that LNAPL recovery should be terminated at 14 of the 15 existing LNAPL skimmer wells.**Step 4.** The Tier 1 "How far will LNAPL migrate?" tab indicated that Natural Source Zone Depletion (NSZD) is a key factor in stopping the continued migration of LNAPL bodies, and the Tier 2 "How far will LNAPL migrate?" tab indicated that the U.S. EPA HSSM model overestimates LNAPL migration because it does not consider NSZD. The site consultants and site owners determined that more NSZD information would be very important to update the LCSM.

Step 5. Based on the discussion of NSZD in the Tier 1 "How far will LNAPL migrate?" tab, the Tier 1 "How can one estimate NSZD?" tab was consulted and quickly showed that almost all LNAPL bodies are naturally attenuating at 10 or 100 times the rate assumed in the Old LSCM. The New LSCM indicated that typically when NSZD is measured at a site, the rates are in the thousands to tens of thousands of litres of LNAPL being biodegraded by NSZD per hectare per year. The Tier 3 "How can one estimate NSZD?" tab provided links and videos on methods to actually measure NSZD at an LNAPL site, and the site consultants began an evaluation to determine if literature NSZD values shown in the Concawe LNAPL Toolbox were sufficient to update the New LCSM or if site-specific measurements were needed.

Step 6. Using mid-range NSZD rates from the Tier 1 NSZD Estimation tab, the Tier 2 "How far will LNAPL migrate?" tab was consulted and the *Kirkman Additional LNAPL Migration Model* built into the Concawe Toolbox was then applied using existing site data. It showed the existing LNAPL body would likely not expand to any significant degree even if the LNAPL skimmer wells were shut down. This provided additional support that most of the LNAPL skimmer wells had done their job and were ready to be retired.

Step 7. The potential longevity of the LNAPL was then evaluated to update the LCSM. After reviewing the Tier 1 "How long will LNAPL persist?" tab, the simple Tier 2 LNAPL lifetime model was applied by entering the volume of LNAPL from Step 2, the area of the LNAPL body, and mid-range NSZD rates from the Tier 1 NSZD Estimation tab. Two different LNAPL volume vs. time graphs were shown. One method assumed a constant NSZD rate into the future and suggested the LNAPL would all be removed by 2030. The second method assumed NSZD rates declined over time and suggested 90% of the LNAPL present now would be gone by the year 2050. Overall, this wide range of LNAPL longevity estimates informed the New LSCM that LNAPL longevity estimates decades in the future have significant uncertainty.

Step 8. Because of the uncertainty in the LNAPL longevity estimates, the site consultants and site owners became interested in estimates of how the hypothetical ingestion risk associated with LNAPL dissolution products might change over time (there is no on-going risk at this site as no exposure pathways were complete). The Tier 2 "How will LNAPL risk change over time?" model was initially run to obtain a forecast of the benzene concentration over time. Later a more sophisticated LNAPL model described in the Tier 3 "How will LNAPL risk change over time?" tab called REMFuel was run, based on the comments included in the Concawe Tier 3 description of REMFuel and the information provided in the video link provided in the Tier 3 tab. This modelling effort showed that the risk associated with the hypothetical ingestion pathway over time was reduced faster than the likely LNAPL removal rate.

Step 9. The Concawe Toolbox helped the site owners and consultants update an old, incorrect LNAPL Conceptual Site Model and greatly strengthen the case for:

- Retiring most of the old, inefficient LNAPL skimming wells at the site because of low LNAPL recoverability and the expectation of little or no LNAPL expansion in the future;

- Better understanding that further significant LNAPL migration was unlikely and that benzene concentrations were expected to go down over time;

- Using NSZD as the LNAPL management technology in the future.