

### ***How long will the LNAPL persist? Tier 3***

A simple box model is provided in Tier 2 and provides a range of time required for the LNAPL to be removed by Natural Source Zone Depletion (NSZD). Users enter the estimated mass/volume of LNAPL present and the estimated NSZD rate.

Two more sophisticated computer tools that can be used to estimate how long the LNAPL might persist at a site are [REMFuel](#) ([Falta et al., 2012](#)) and [LNAST](#) ([Huntley and Beckett, 2002](#)). A short summary of each model is provided below:

#### **Overview of REMFuel**

- REMFuel is a coupled analytical source zone/plume response model distributed by USEPA.
- Based on popular [REMChlor model](#) used at chlorinated solvent sites.
- The source zone model includes a box model where the mass of the dissolution product to be modeled is entered and a relationship “gamma” that describes the mass flux out of the source at any time compared to the remaining mass is specified by the user.
- Solute transport model simulates advection, dispersion, retardation, sorption assuming simple 1-D groundwater flow.
- The user can specify any percent of source removal at any time to model plume response to active remediation.
- The user can model plume remediation at any time in three separate spatial zones by increasing first order decay constants.
- NSZD can also be simulated by entering a value for “Source Decay” although there is no discussion in User’s Guide on how to do this.
- Key output of the model are graphs showing the concentration (or mass discharge) of the constituents in the dissolved plume vs. distance from source.
- Download model from USEPA web page [here](#).

#### **Overview of API’s LNAPL Dissolution and Transport Screening Tool (LNAST; version 2.0.4)**

- LNAST is suite of calculation tools, information about LNAPL, and LNAPL parameter databases. LNAST focuses on LNAPL distribution and fate at the water table. The calculation tool part of LNAST:
  - Predicts LNAPL distribution, dissolution, and volatilization over time.
  - Calculates downgradient dissolved-phase concentration through time.
  - Shows results both with and without hydraulic recovery of LNAPL.
- LNAST simulates the smear zone and the downgradient dissolved plume.
- Combines multi-phase transport, dissolution, and solute transport.
  - Accounts for relative permeability effects caused by LNAPL.
  - Zones of high LNAPL saturation have much less groundwater flow through them, extending the longevity of these zones.
- Good tool for estimating how long an LNAPL-generated plume will persist.
- Powerful tool to see if LNAPL recovery reduces the longevity of the source and plume.
- Key output is concentration of dissolved constituents in the plume vs. time at an observation well.
- Does not account for NSZD.
- Assumes that remediation occurs shortly after the LNAPL release. You cannot release LNAPL many years ago and then start the remediation now a few decades later.
- LNAST can be downloaded [here](#).

## Videos

Two short videos are available to learn more about REMFuel and LNASt:

- [REMFuel](#)
- [LNASt](#)

## Checklist for REMFuel Input Data

Key input data are shown below. One key feature is that the plume produced by the source can be broken up into nine “space-time” domains with three separate time periods and three separate spatial zones. For example, the first third of the plume downgradient from a 40-year-old source can have its own first order decay coefficients for three separate time periods, such as a 20-year natural attenuation period, then a 5-year plume remediation period, then a 15-year post-remediation natural attenuation period.

While much of the input data below is commonly collected during site characterization activities (e.g., Darcy groundwater velocity, source width/height/length, porosity) the source zone gamma term may be unfamiliar to many users. Basically, gamma defines the relationship between mass flux leaving the source and the remaining mass in the source at any time. For example:

- Gamma of zero results in a constant source mass flux until mass is gone, then zero flux (a step function).
- Gamma of 0.5 results in a linear decline in source concentration based on the amount of LNAPL mass originally released and the original source concentrations.
- Gamma of 1.0 results in an exponential decline in source concentration based on the amount of LNAPL mass originally released and the original source concentrations (this is often used as a default value).

REMFuel - [REMFuel Model Parameters]

File Model Help

REMFuel Project

- Project: atouie\_source\_remed\_plum
  - Model Parameters
  - View Model Results
  - View File Output
  - View Graphical Output
  - Output vs. Distance

**Source Zone Parameters**

**Source Parameters**

Gamma: 1

**Source Dimensions**

Source Width (m): 20  
Source Height (m): 2  
Source Length (m): 20

**Flow Parameters**

Darcy Velocity (m/yr): 10  
Porosity: 0.35

**Source Remediation**

Fraction Removed: 0.9  
Source Remediation Time: 15 (Years) 15.5  
Start Time (T1): End Time (T2):

**Transport Parameters**

Velocity: 0.2  
Sigma: 0  
Number of Stream Tubes: 1000  
alpha (m): -0.0002  
alpha (m): -0.0002

Component Name: Benzene

Decay Rate (per year)

	Zone 1	Zone 2	Zone 3
Period 3	(1,3)	(2,3)	(3,3)
Period 2	(1,2)	(2,2)	(3,2)
Period 1	(1,1)	(2,1)	(3,1)

Daughter Name: Benzene\_Daughter

Decay Rate (per year)

	Zone 1	Zone 2	Zone 3
Period 3	(1,3)	(2,3)	(3,3)
Period 2	(1,2)	(2,2)	(3,2)
Period 1	(1,1)	(2,1)	(3,1)

Distance From Source, Meters

X1: 20 X2: 100

**Simulation Parameters**

	Intervals	Min Value	Max Value	Units
X - Direction	101	0.1	600	Meter
Y - Direction	1	-100	100	Meter
Z - Direction	1	0	0	Meter
Time	50	0	50	Year

**Select Component**

Benzene  
Toluene  
Ethyl Benzene  
o-Xylene  
MTBE

Add Component Delete Component

**Component Specific Parameters**

Reaction Type

☐ Zero Order Reaction  
☒ First Order Reaction  
☐ Monod Reaction

Daughter Yield From Parent: 0

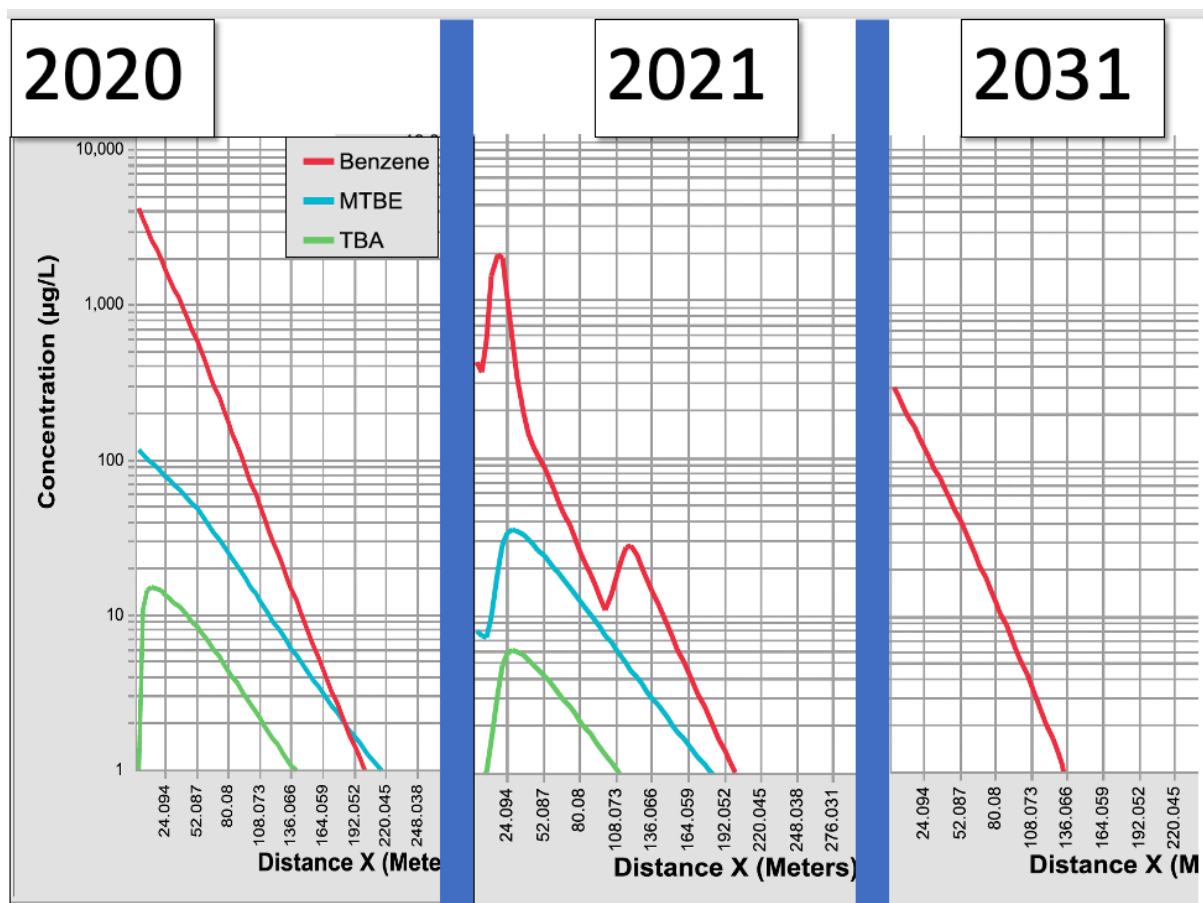
Initial Source

Concentration (g/L): 0.00644 Calculate  
Mass (Kg): 164 Calculate  
Retardation Factor: 1.76 Calculate  
Source Decay (1/yr): 1.1

**REMFuel**

## Example of REMFuel Output Data for Three Separate Time Periods

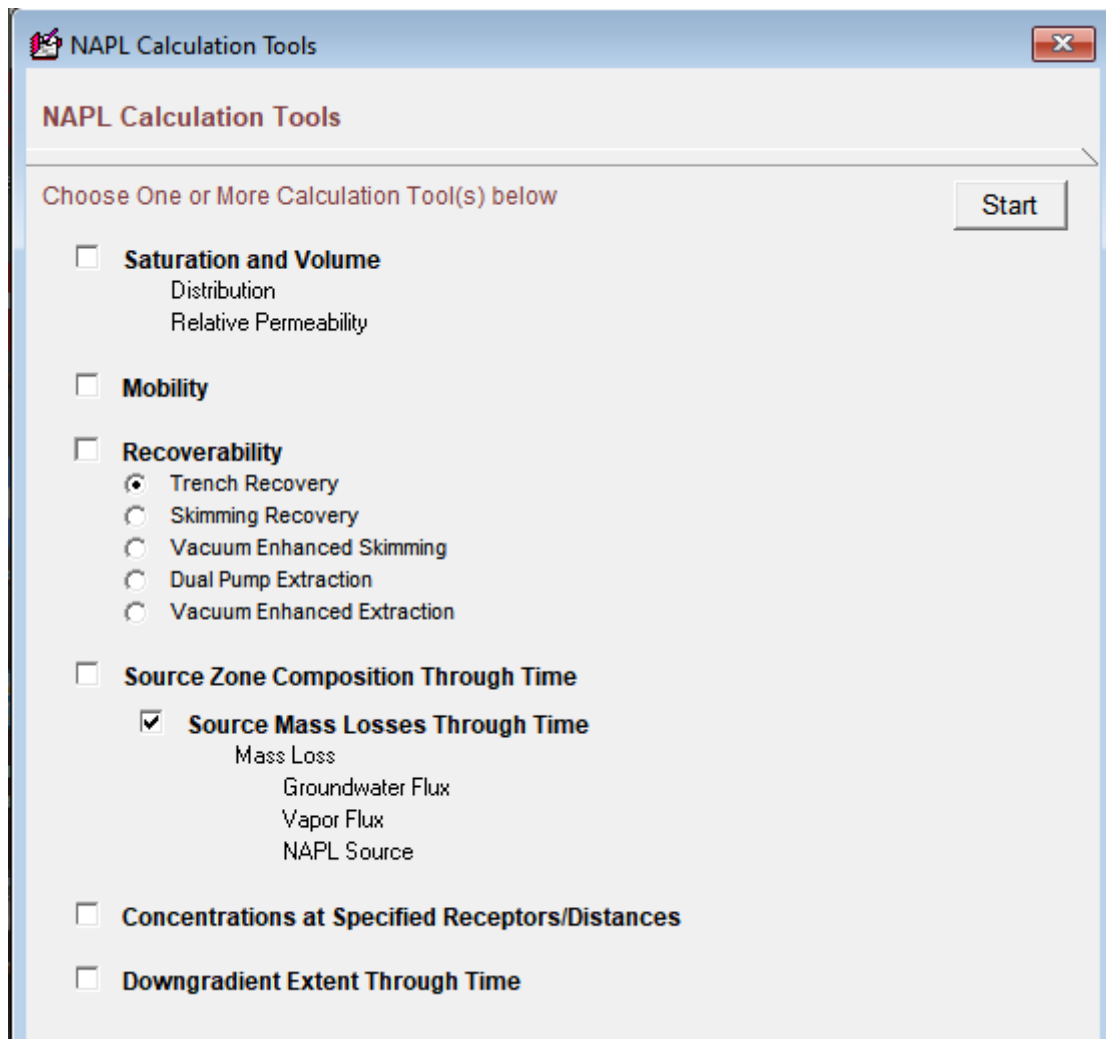
In this example, source remediation and plume remediation were performed, leading to the spikey concentration vs. distance curves in the 2021 panel (see the [REMFuel video](#) for a more detailed explanation). Note that the Y-axis is log-scale.



## Checklist of Input Data for LNAST

Images reproduced courtesy of the American Petroleum Institute from LNAPL Dissolution and Transport Screening Tool, version 2.0.4, February 2006

To use LNAST, the user first indicates the information desired from the tool:



The screenshot shows a window titled "NAPL Calculation Tools" with a standard Windows-style title bar (minimize, maximize, close buttons). The window has a light gray background. At the top, the title "NAPL Calculation Tools" is displayed in a bold, dark font. Below the title, there is a horizontal line. Underneath the line, the text "Choose One or More Calculation Tool(s) below" is displayed in a dark font. To the right of this text is a button labeled "Start". Below the text, there is a list of calculation tools, each preceded by a checkbox. The tools are: "Saturation and Volume" (with sub-items "Distribution" and "Relative Permeability"), "Mobility", "Recoverability" (with sub-items "Trench Recovery", "Skimming Recovery", "Vacuum Enhanced Skimming", "Dual Pump Extraction", and "Vacuum Enhanced Extraction"), "Source Zone Composition Through Time" (with a checked checkbox for "Source Mass Losses Through Time" and sub-items "Mass Loss", "Groundwater Flux", "Vapor Flux", and "NAPL Source"), "Concentrations at Specified Receptors/Distances", and "Downgradient Extent Through Time".

**NAPL Calculation Tools**

Choose One or More Calculation Tool(s) below Start

- ☐ **Saturation and Volume**
  - Distribution
  - Relative Permeability
- ☐ **Mobility**
- ☐ **Recoverability**
  - ☒ Trench Recovery
  - ☐ Skimming Recovery
  - ☐ Vacuum Enhanced Skimming
  - ☐ Dual Pump Extraction
  - ☐ Vacuum Enhanced Extraction
- ☐ **Source Zone Composition Through Time**
  - ☒ **Source Mass Losses Through Time**
    - Mass Loss
    - Groundwater Flux
    - Vapor Flux
    - NAPL Source
- ☐ **Concentrations at Specified Receptors/Distances**
- ☐ **Downgradient Extent Through Time**

The tool then takes the user through a series of eight input screens to define soil properties, groundwater conditions, source area parameters, LNAPL properties, and solute transport.

**Collecting Information**

### Soil Properties - Step 1 of 8

☐ English
 ☒ Metric

Soil Type: Coarse Sand

**Additional Information Required For Multiple Layers:**

Layer Selection: Layer 1 (Lowermost)

Thickness of Layer (m): 0.73

Elevation of Bottom of Layer (m above oil/water): 0

Oscillation Damping:
   
☒ None
 ☐ Moderate
 ☐ Maximum

✓ = Default Value

✓ Van Genuchten Alpha (1/m): 3.87

✓ Van Genuchten n: 1.62

✓ Saturated Hydraulic Conductivity (m/day): 11.6

✓ Residual Saturation of Water: 0.27

✓ Field Residual Saturation of LNAPL: 0.15

✓ Total Porosity: 0.33

**Collecting Information**

### Groundwater Conditions - Step 2 of 8

☐ English
 ☒ Metric

✓ Groundwater Hydraulic Gradient: 0.001

Groundwater Specific Discharge (m/day): 0.0116

Conservative Solute Pore Velocity (m/day): 0.0482

✓ = Default Value

Collecting Information

### Source Area Parameters - Step 3 of 8

☐ English ☒ Metric

- ✓ Initial Thickness of LNAPL (m)
- ✓ Average Depth to top of LNAPL (m)
- ✓ Length of LNAPL Zone (m)
- ✓ Width of LNAPL Zone (m)
- ✓ Criteria for Minimum Mobility (Hydraulic Conductivity) (m/day)

✓ = Default Value

<< Back Next >>

Collecting Information

### Method Used to Calculate LNAPL Saturation Step 4 of 8

- ✓ ☒ Equilibrium LNAPL Distribution
- ☐ Distribution at Minimal Mobility
- ☐ Residual Saturation
- ☐ User Input of Saturation

✓ = Default Value

<< Back Next >>

Collecting Information

### LNAPL Properties - Step 5 of 8

☐ English ☒ Metric

Hydrocarbon Type

- ✓ Density (gm/cc)
- ✓ Oil/Water Interfacial Tension (dynes/cm)
- ✓ Oil/Air Interfacial Tension (dynes/cm)
- ✓ Viscosity (cp)
- ✓ Dissolved Phase Properties

	Pure Phase Solubility (mg/l)	Pure Phase Vapor Conc. (mg/l)	Mass Fraction of LNAPL	Log(Koc)	Biodegradation Half-Life (days)	Target Concentration (ug/l)
MTBE	48000	1204	0.11	1	9000	40
Benzene	1780	324	0.018	2	90	5
Ethyl Benzene	135	57	0.018	3	65	700
Toluene	515	111	0.079	2.06	60	1000
Xylene	175	38	0.075	2.6	150	10000

Add Dissolved Constituent Remove Constituent

✓ = Default Value

<< Back Next >>

**Collecting Information**

**Solute Transport Properties - Step 6 of 8**

☐ English ☒ Metric

✓ Effective Porosity

✓ Longitudinal Dispersivity (m)

✓ Horizontal Transverse Dispersivity (m)

✓ Vertical Transverse Dispersivity (m)

✓ Fractional Carbon Content

Include Volatilization From Source?  
☒ Yes ☐ No

✓ Vapor Diffusion Efficiency Coefficient

✓ = Default Value

<< Back Next >>

**Collecting Information**

**LNAPL Recovery - Step 7 of 8**

✓  Period Of Recovery (yrs) ☐ English ☒ Metric

✓  Width of Trench (m)

✓ = Default Value

<< Back Next >>

**Collecting Information**

**Distances From The Source - Step 8 of 8**

Enter up to 20 distances (meters or ft for metric/english units of measure) downgradient from the source, along the downgradient axis of the resulting plume. Concentrations will be calculated as a function of time at each of these points.

☐ English ☒ Metric

1.	<input type="text" value="0"/>	11.	<input type="text"/>
2.	<input type="text"/>	12.	<input type="text"/>
3.	<input type="text"/>	13.	<input type="text"/>
4.	<input type="text"/>	14.	<input type="text"/>
5.	<input type="text"/>	15.	<input type="text"/>
6.	<input type="text"/>	16.	<input type="text"/>
7.	<input type="text"/>	17.	<input type="text"/>
8.	<input type="text"/>	18.	<input type="text"/>
9.	<input type="text"/>	19.	<input type="text"/>
10.	<input type="text"/>	20.	<input type="text"/>

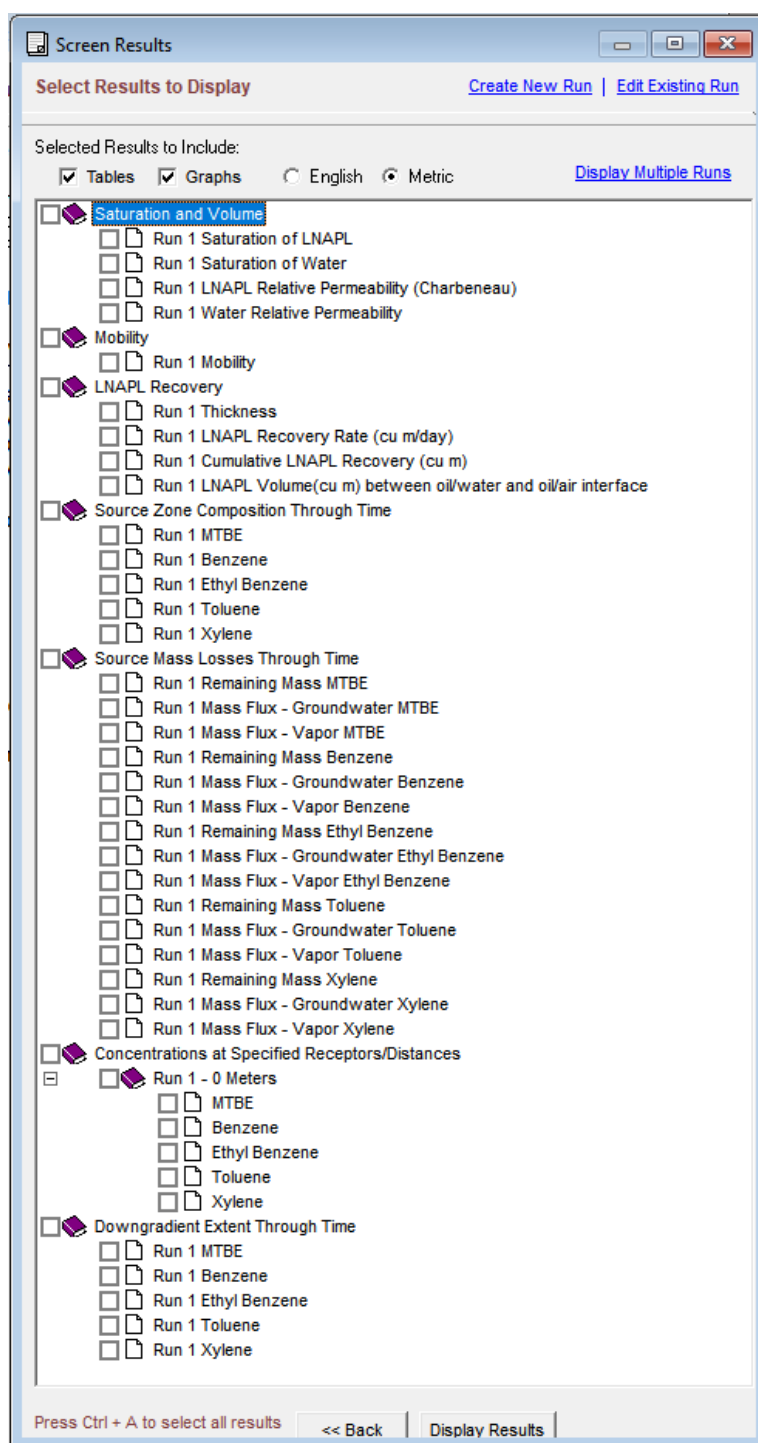
<< Back Calculate



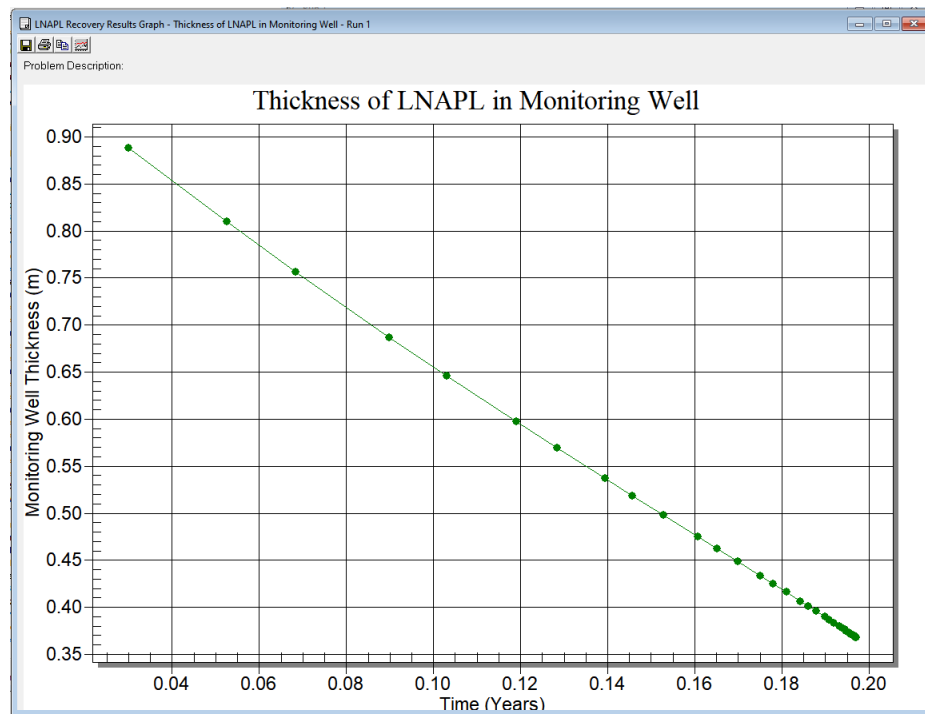
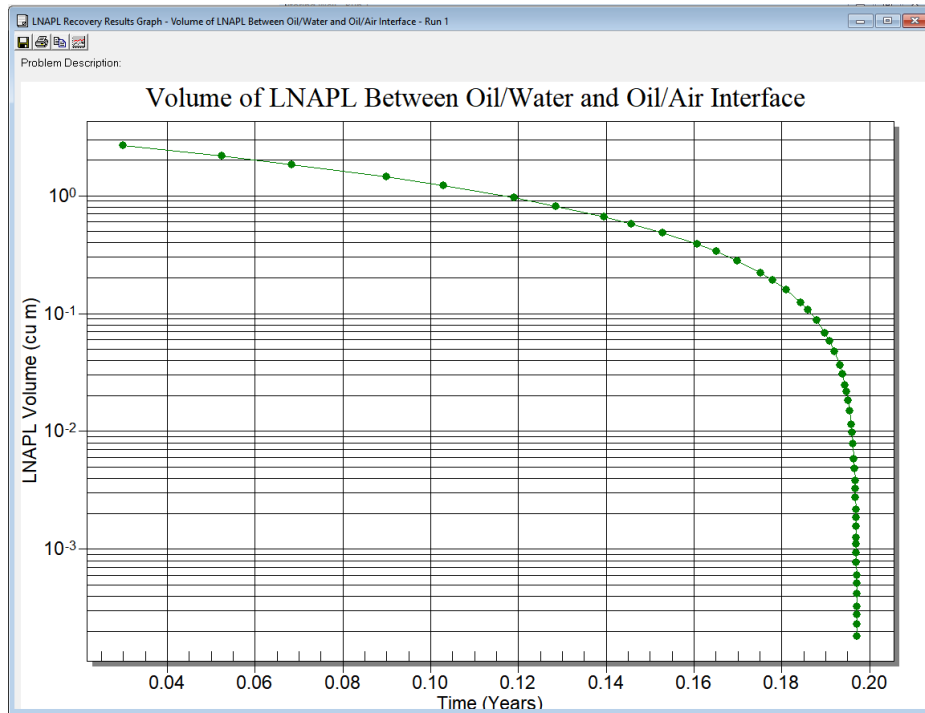
## Example of LNAST Output Data

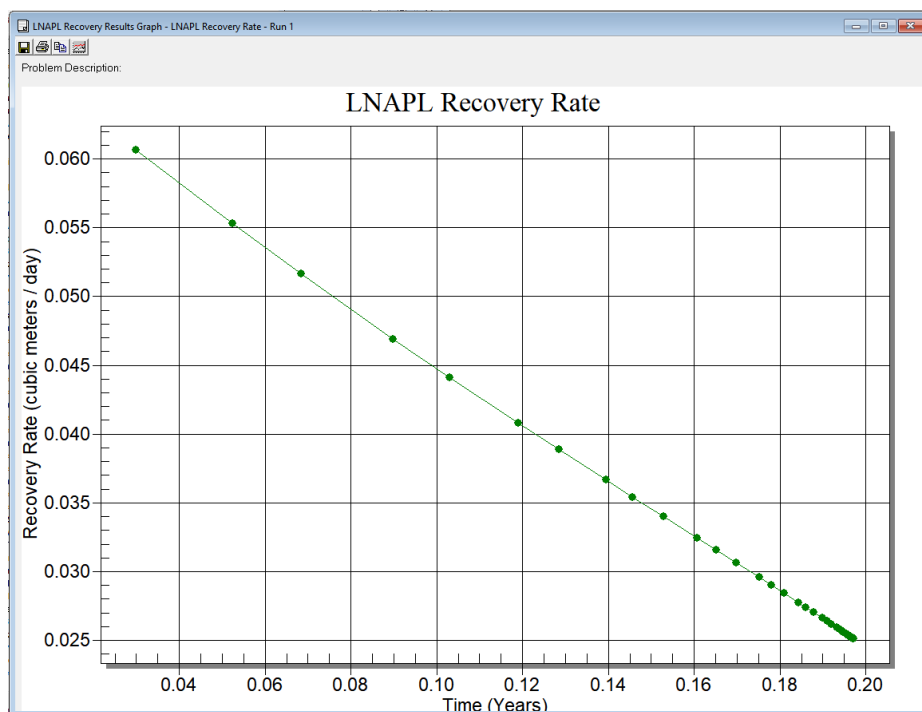
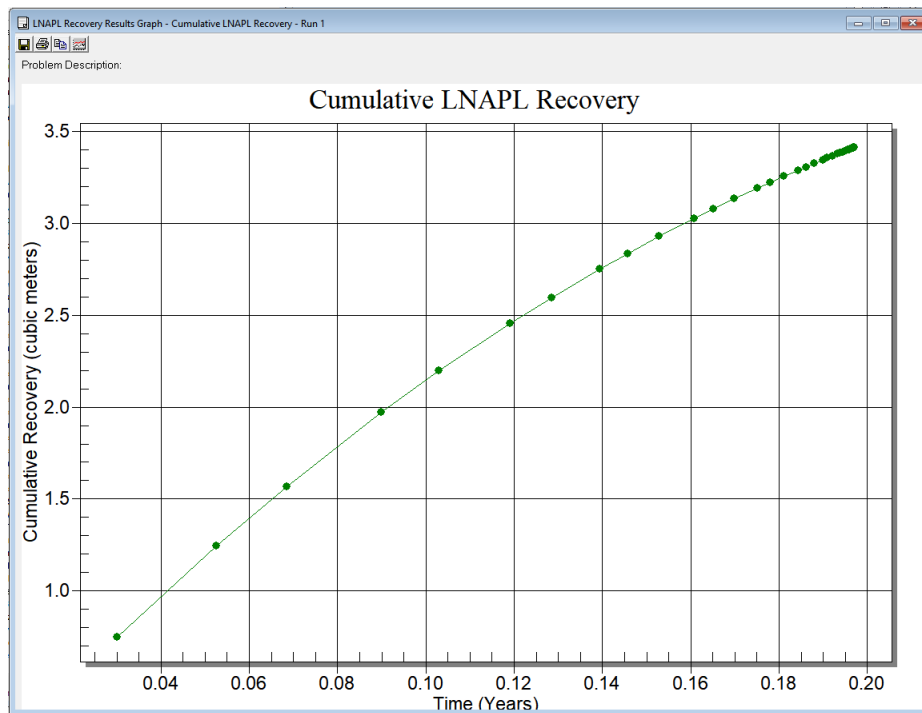
Images reproduced courtesy of the American Petroleum Institute from LNAPL Dissolution and Transport Screening Tool, version 2.0.4, February 2006

After performing the selected calculations, LNAST allows users to display results to the screen, create a report, or export the results.



An example of key output for LNAPL recovery in a trench is shown below:





## References

[Falta, R.W., Ahsanuzzaman, A.N.M., Stacy, M., Earle, R.C., 2012. REMFuel: Remediation Evaluation Model for Fuel Hydrocarbons User's Manual. USEPA.](#)

[Huntley, D., Beckett, G., 2002. Evaluating Hydrocarbon Removal from Source Zones and Its Effect on Dissolved Plume Longevity and Magnitude. American Petroleum Institute.](#)