Insights from 100 Baildown Tests

Pace of Progress toward LNAPL Transmissivity Metrics

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Progress:

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Problem:

It's not always clear how LNAPL transmissivity changes in response to LNAPL removal and NSZD.

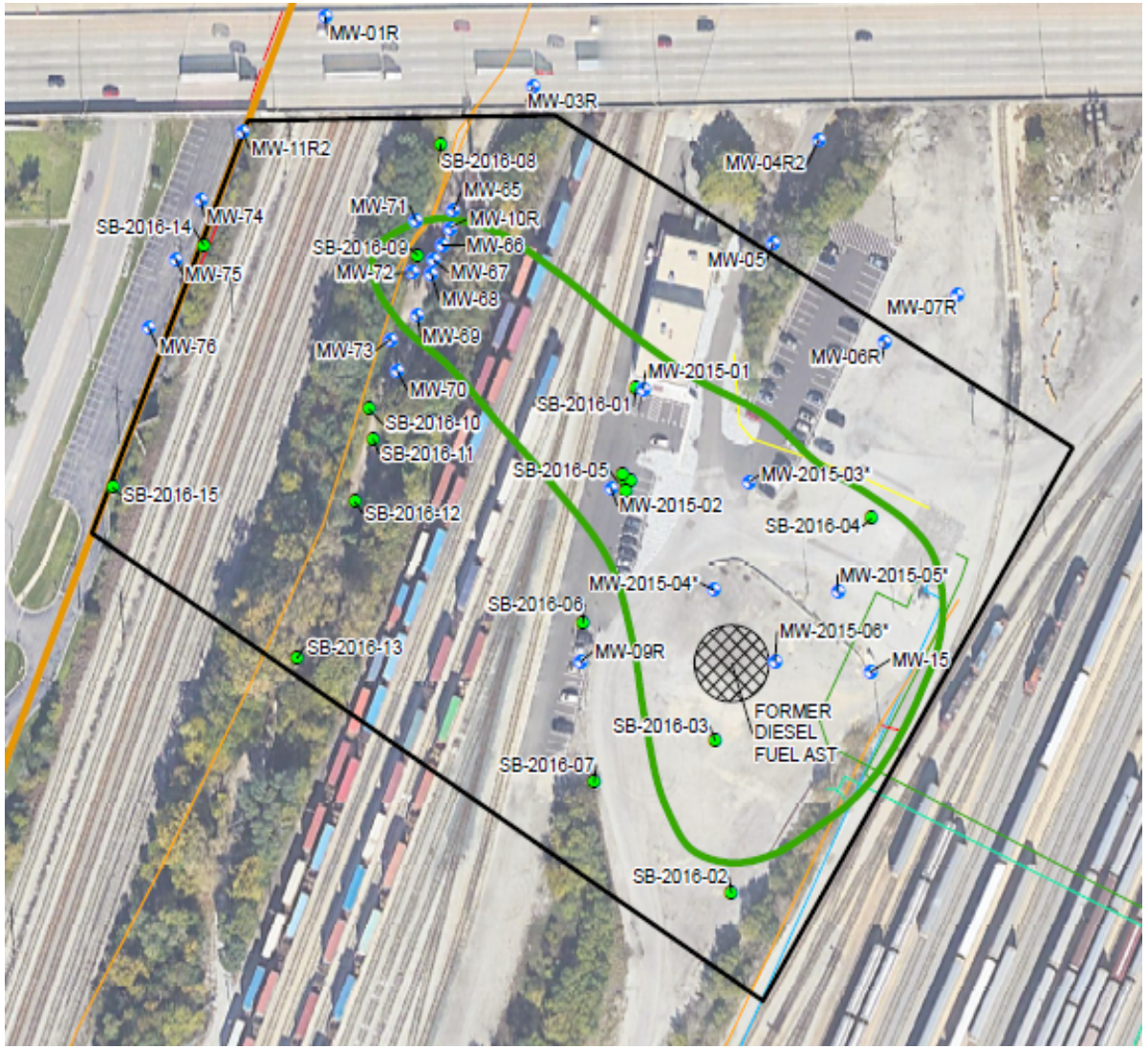
How quickly will I get from 5 ft^2/d to 0.8 ft^2/d?

How much LNAPL will I need to remove?

Do these concepts even correlate?

Project Background

- Former **railroad fueling facility** in Chicago area
- Diesel **LNAPL body stable** and delineated within yard
- Initial site assessment in 2014-2016 showed **high LNAPL transmissivity** at some locations, and LNAPL recovery would be necessary to reach closure
- No extensive history of LNAPL recovery (past systems, unknown



LNAPL Recovery Efforts

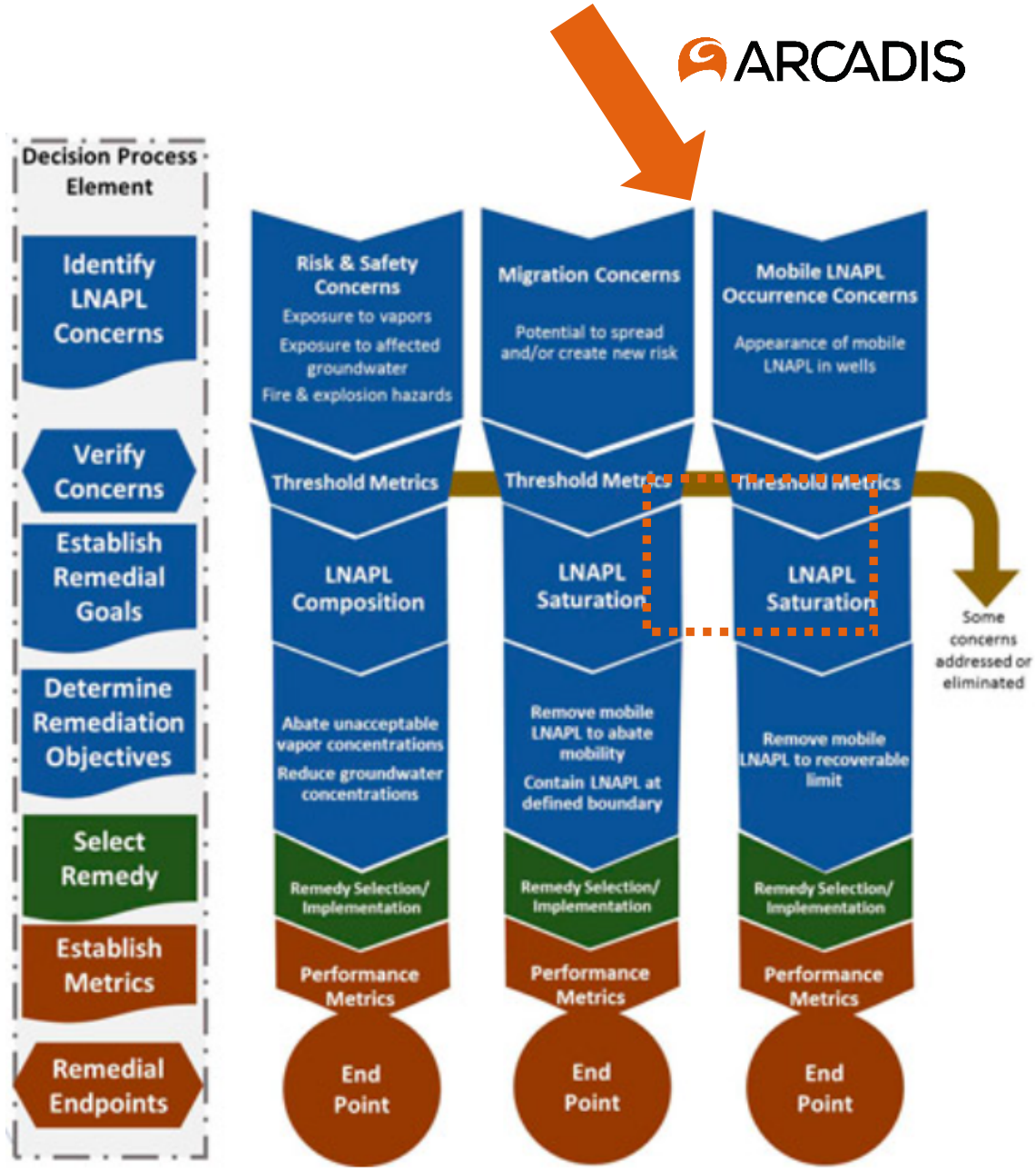
- **Two skimming systems** operated seasonally (spring through fall)
- Rotated among wells with **highest recoverability/transmissivity**
- Systems operated for **six years**, 2016-2021
- Approx. **2700 gallons of LNAPL** removed
- LNAPL **transmissivity calculated** two ways:
  - Directly from **skimming** data
  - Recurring **baildown testing** events for performance monitoring (all suitable site wells 2-4 times annually) -- results are independent of skimmer operation

Year	LNAPL Recovered (gallons)
2016	377
2017	359
2018	577
2019	627
2020	564
2021	193
2022	0
Total	**2,697**

LNAPL Transmissivity Testing

- Because **achieving a specific LNAPL transmissivity goal** was the focus of our remedial action, periodic monitoring looked different than the typical site
- LNAPL transmissivity tests (**baildown tests/manual skimming tests**) were completed on a regular basis, 2-4 times per year
- Periodic LNAPL **transmissivity testing replaced** periodic groundwater monitoring – tracking overall remedial performance, trends, and progress

What can we learn from this larger-than-usual data set?



From ITRC 2018

What can the data give us?

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Pace of progress for LNAPL saturation reduction

- How quickly will we reach our transmissivity objectives?

Degree of variability in LNAPL transmissivity measurements

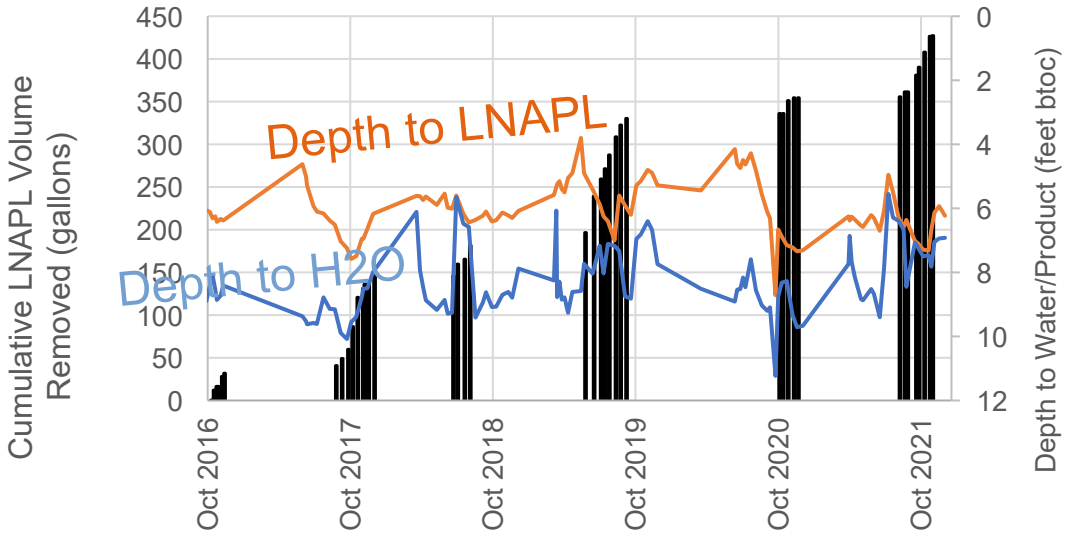
- How much do transmissivity measurements change seasonally?
- Will LNAPL transmissivity rebound after recovery stops?

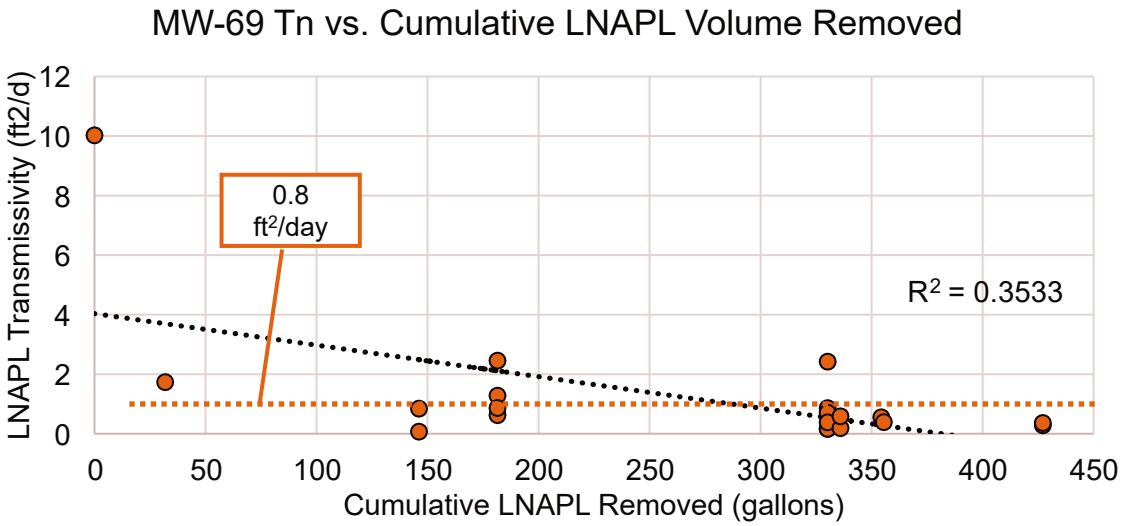
Reinforcement that in-well LNAPL thickness and LNAPL recoverability are not correlated

Perhaps most importantly:

A starting point for an apples-to-apples comparison of hydraulic recovery and NSZD, supporting confident and sustainable remedial decisions.

MW-69 LNAPL Recovery

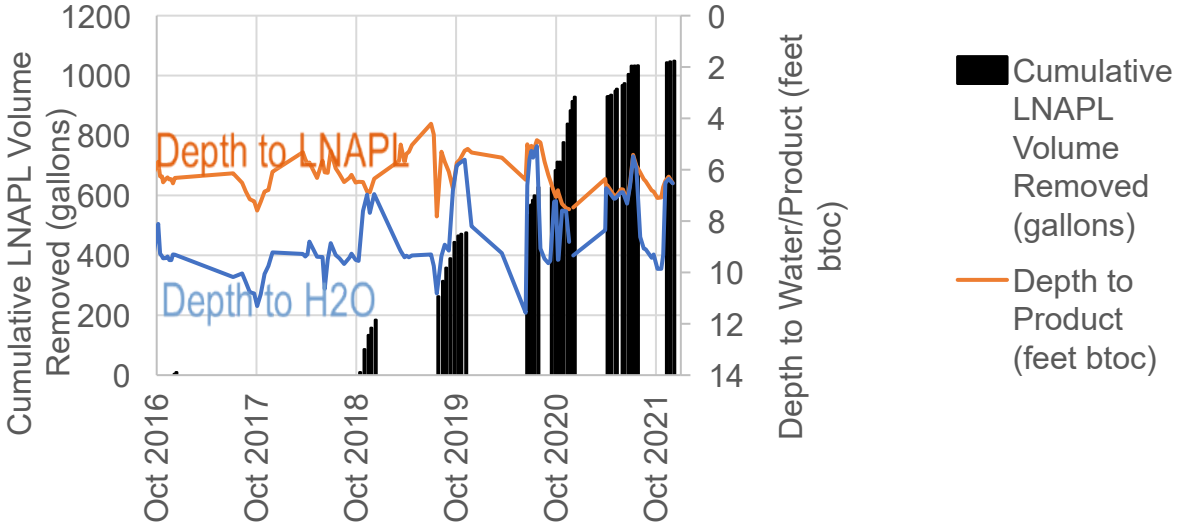


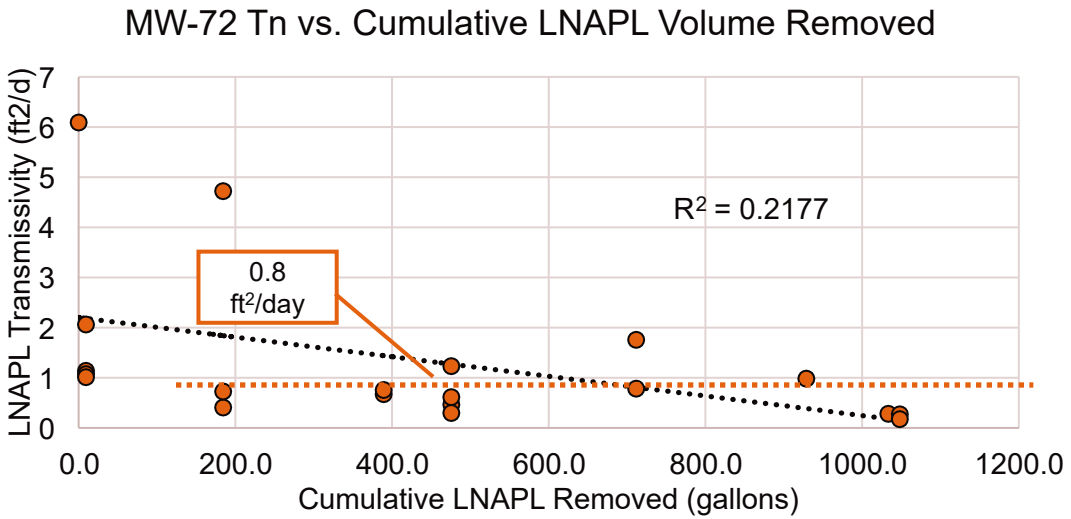


Year	LNAPL Recovered (gallons)
2016	32
2017	114
2018	35
2019	149
2020	24
2021	73
2022	0
Total	427

Test Date		LNAPL Transmissivity (ft^2/d)
11/18/2015	Test 1	10.03
6/1/2017	Test 1	1.74
12/4/2017	Test 1	0.07
3/12/2018	Test 1	0.85
12/6/2018	Test 1	0.63
12/7/2018	Test 2	2.46
3/6/2019	Test 1	1.29
3/7/2019	Test 2	0.87
9/4/2019	Test 1	0.17
9/5/2019	Test 2	2.43
12/2/2019	Test 1	0.17
12/3/2019	Test 2	0.86
3/16/2020	Test 1	0.71
3/17/2020	Test 2	0.39
10/7/2020	Test 1	0.19
10/8/2020	Test 2	0.59
3/29/2021	Test 1	0.56
8/24/2021	Test 1	0.39
12/8/2021	Test 1	0.29
3/15/2022	Test 1	0.37

MW-72 LNAPL Recovery



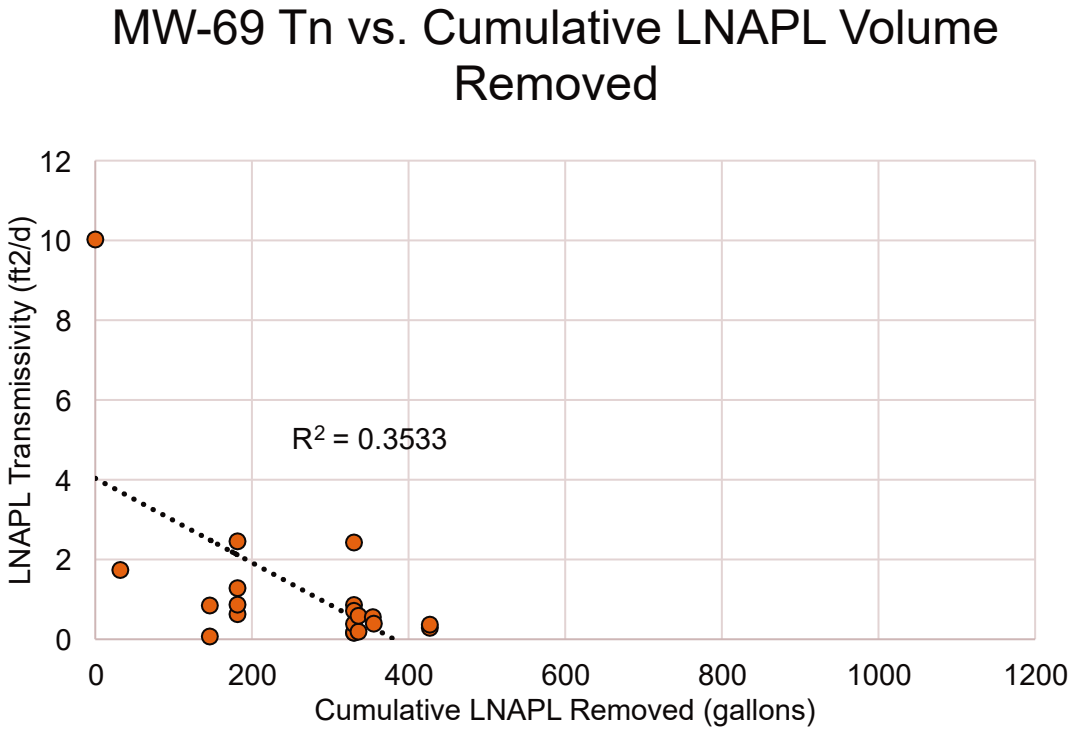


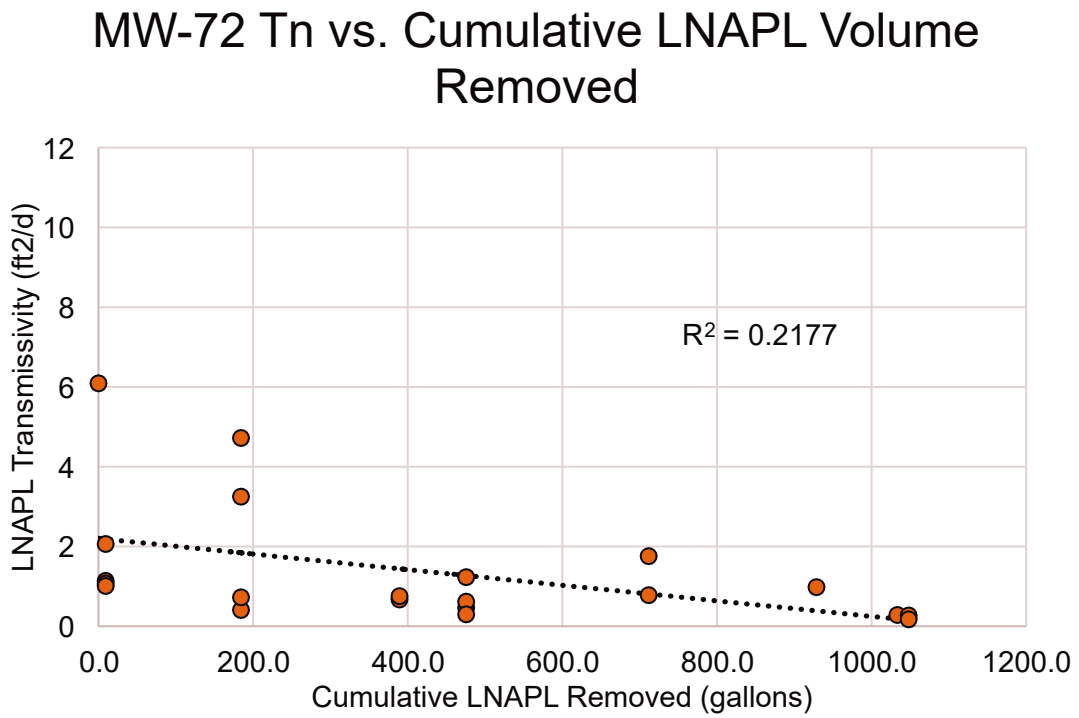
Year	LNAPL Recovered (gallons)
2016	9.3
2017	0
2018	175
2019	291
2020	453
2021	120
2022	0
Total	1048.3

Test Date		LNAPL Transmissivity (ft^2/day)
11/19/2015	Test 1	6.1
12/4/2017	Test 1	2.1
12/5/2017	Test 2	1.1
3/12/2018	Test 1	1.1
3/13/2018	Test 2	1.0
12/6/2018	Test 1	0.41
12/7/2018	Test 2	0.73
3/6/2019	Test 1	3.3
3/7/2019	Test 2	4.7
9/4/2019	Test 1	0.67
9/5/2019	Test 2	0.76
12/2/2019	Test 1	0.47
12/3/2019	Test 2	0.62
3/16/2020	Test 1	1.2
3/17/2020	Test 2	0.30
10/7/2020	Test 1	0.78
10/8/2020	Test 2	1.8
3/29/2021	Test 1	0.98
8/24/2021	Test 1	0.28
12/8/2021	Test 1	0.27
3/15/2022	Test 1	0.18

LNAPL Recovery and T_n Reductions

- Slope for a linear correlation of T_n (ft^2/d) to volume removed (gal) ranges roughly from -0.002 to -0.01 at this site
- Depending on well conditions, that suggests **100 gallons of LNAPL removal** may lead to a reduction in T_n of **0.2 to 1 ft^2/d**
- **Important to also consider effects of ongoing NSZD**
- LDRM modeling and other lines of evidence may help to improve estimates and refine projections





LNAPL Saturation Reduction

How do recovered volumes track with our understanding of LNAPL distribution?

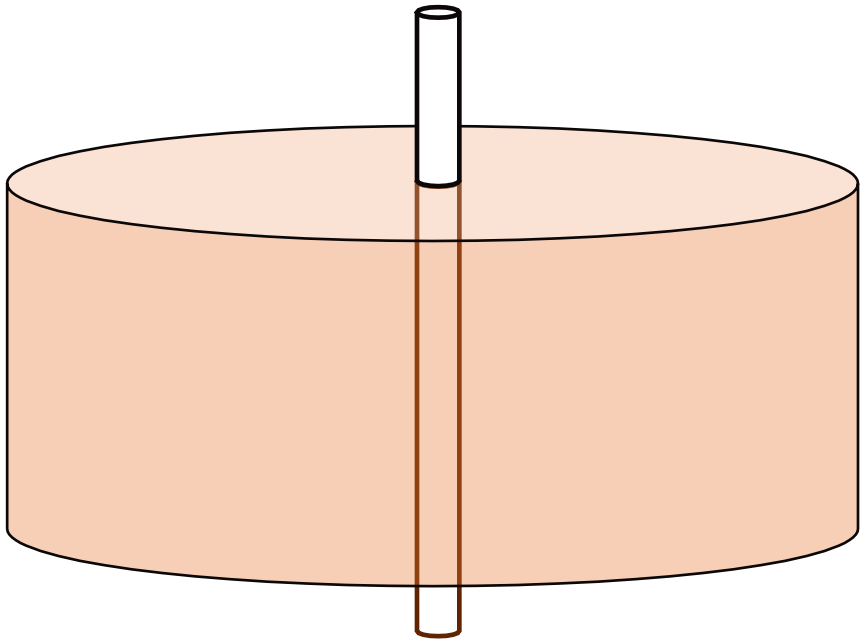
Can we estimate the area that an LNAPL recovery effort is influencing?

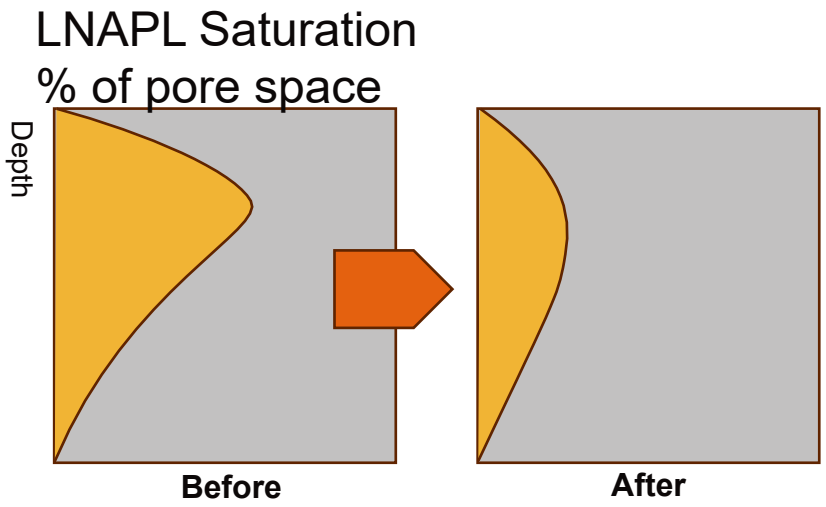
Hypothetical Scenario:

- 4 – foot smear zone
- 15 - foot radius around well
- 35% soil porosity
- 20% average initial LNAPL saturation

Total LNAPL volume (including residual): 1480 gal

If 700 gallons are removed, average LNAPL saturation drops from 20% to 10.5%





Comparing NSZD and Active Recovery

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Typical question: **what does that large NSZD rate (2,000 gal/ac/yr)** mean at an individual well?

Example scenario - Skimming

- LNAPL skimming will likely yield an average of 100 gal/yr from MW-1, and affect roughly a 15-foot radius
- Remedial goal is to reduce T_n to below 0.8 ft^2/d; estimated that removing 500 gallons of LNAPL will achieve this
- Approx. 4 years to achieve objective (considering ongoing NSZD)

Example scenario – NSZD

- Measured NSZD rate of 2,000 gal/ac/yr
- For the same 15-foot radius around the well (0.016 acres), NSZD loss of approx. 32 gal/yr
- Remedial goal is to reduce T_n to below 0.8 ft^2/d; estimated that removing 500 gallons of LNAPL will achieve this
- Approx. 15 years to achieve objective (possibly faster due to ongoing residualization)

•Comparing timeframes in this way puts technologies on equal footing, with similar goals

•Is achieving a recoverability metric in 4 years vs. 15 years a good use of resources?

Similar Comparison in API LNAPL FAQ (2nd Ed., 2018)

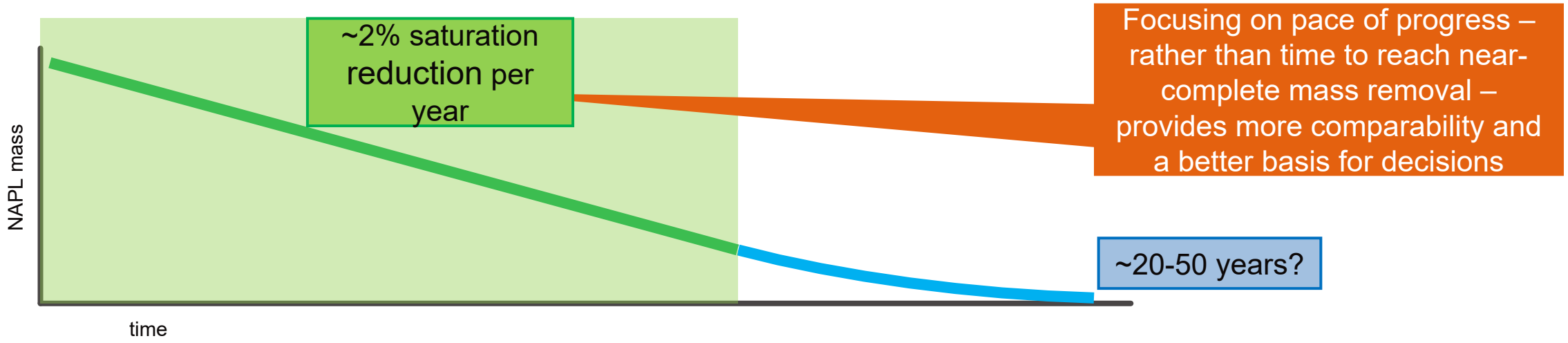
This concept and approach – considering pace toward endpoints, and comparing different approaches using similar metrics - is referenced in other documents and based on straightforward math and assumptions

Comparison of LNAPL Recovery to NSZD and Enhanced NSZD

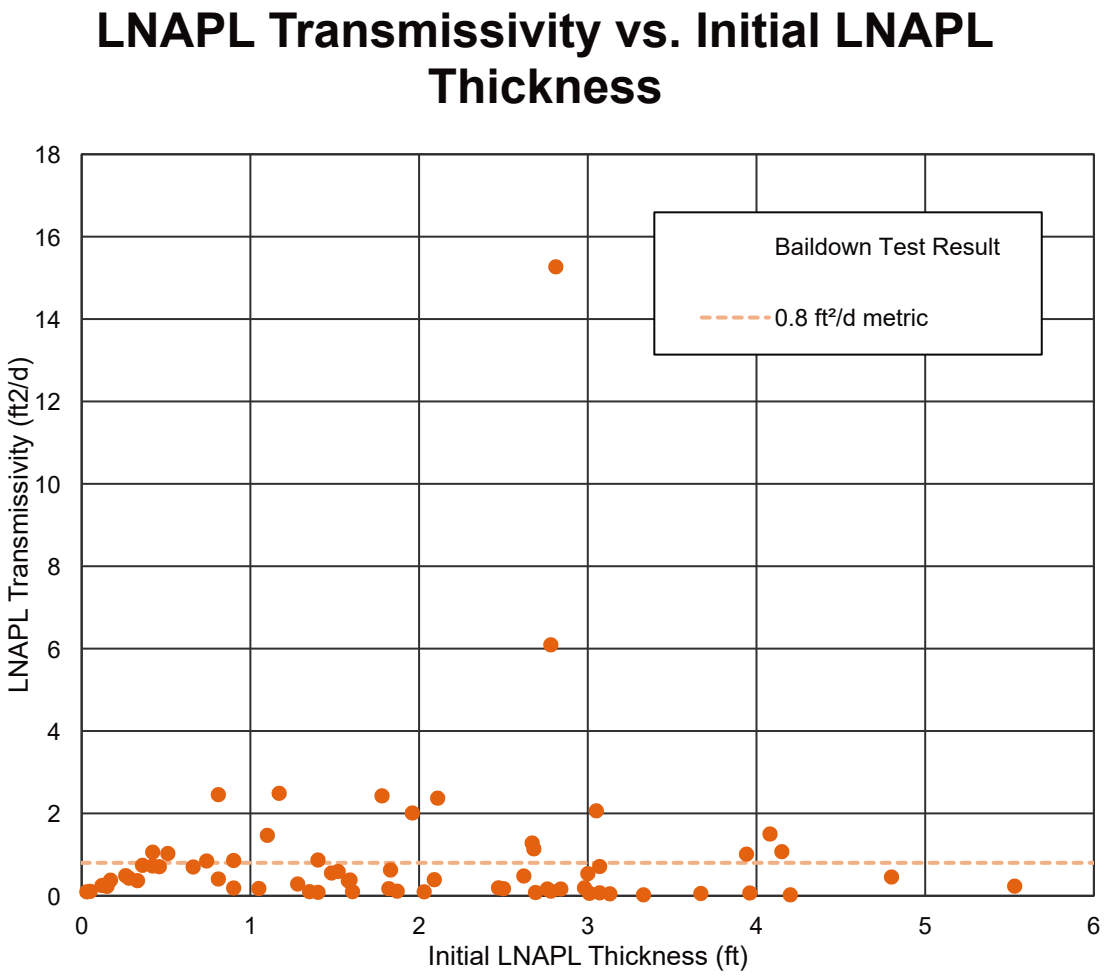
Wells/acre	16	1	16	1	16	1
Effective ROC (ft)	29	118	29	118	29	118
LNAPL Transmissivity (ft2/day)	0.1	0.1	0.8	0.8	5	5
Drawdown (ft)	0.1	2	0.1	2	0.1	2
Source Reduction Rate via LNAPL Recovery (gal/acre/yr)	599	575	4,791	4,599	29,944	28,742
1 foot Mobile Interval Saturation Reduction (%PV/yr)	0.53%	0.50%	4.20%	4.03%	26.26%	25.20%
NSZD Rate (gal/acre/year)	2,000	2,000	2,000	2,000	2,000	2,000
Average Saturation Reduction Across 10 ft Smear Zone						
Without LNAPL Recovery [NSZD Alone] (%PV/yr)	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%
With LNAPL Recovery (%PV/yr)	0.23%	0.23%	0.60%	0.58%	2.8%	2.7%
Enhanced NSZD						
Bioventing (gal/acre/year)	11,000	11,000	11,000	11,000	11,000	11,000
Average Saturation Reduction Across 10 ft Smear Zone						
Without LNAPL Recovery [NSZD Alone] (%PV/yr)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
With LNAPL Recovery (%PV/yr)	1.0%	1.0%	1.4%	1.4%	3.6%	3.5%

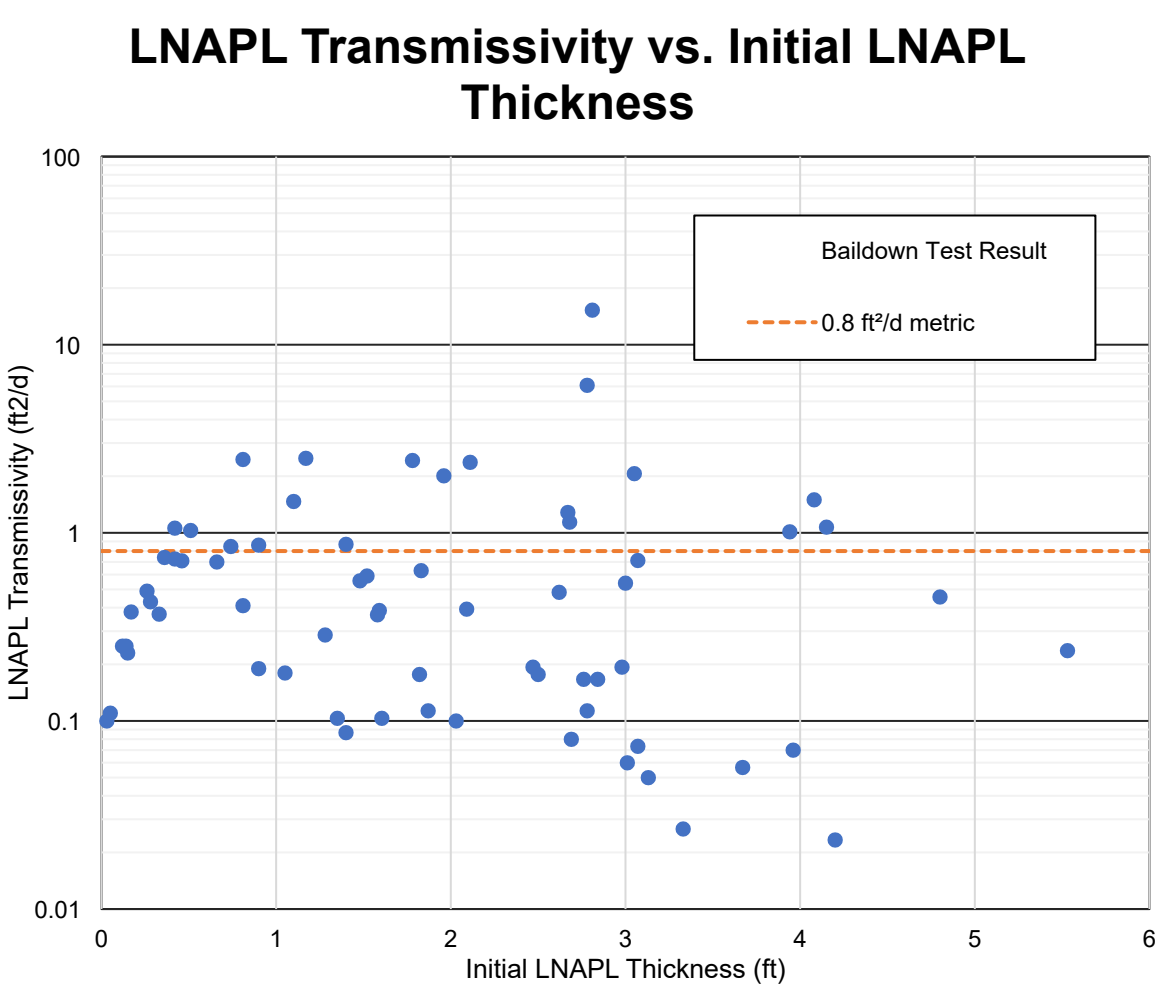
Changing our Conceptualization of NSZD Effectiveness

- NSZD rates are often initially extrapolated to a “time to remove all NAPL”
- Familiar challenges with this approach:
  - **How much LNAPL** is actually there?
  - Does NSZD change from a roughly **zero-order** process to something else, and when?
  - Is the **last 5% or 10%** of NAPL mass actually a concern?
- Other technologies (skimming, enhanced bio, etc.) are not judged based on this endpoint – why NSZD?



A final point: In-well Thickness …*still* not a good metric!





Results reinforce that there is no correlation between in-well thickness and LNAPL recoverability

Problem:

It’s not always clear how LNAPL transmissivity changes in response to LNAPL removal and NSZD.

How quickly will I get from 5 ft^2/d to 0.8 ft^2/d?

How much LNAPL will I need to remove?

Do these concepts even correlate?

Real-world LNAPL recovery data and a strong LCSM can help answer these questions, support realistic projections, and support sound, sustainable remedial decisions.

Thank you for your attention

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