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You Get What You Measure:" Emerging Concepts and Philosophies for the Application and Interpretation of LNAPL Transmissivity

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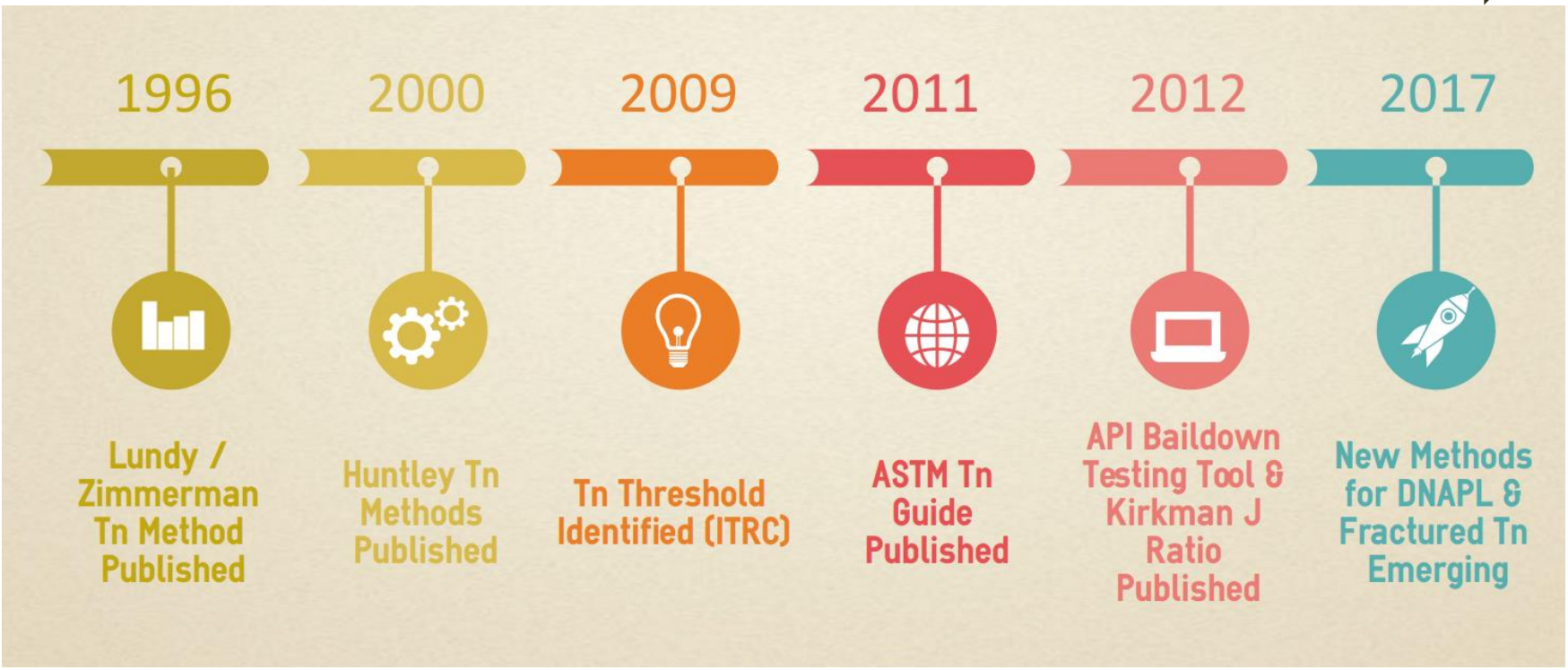
The Evolution of LNAPL Transmissivity (Tn)

Sophistication / Experience / Knowledge



Common Sense Says a Well that Recharges Slowly isn't Recoverable, so:

Quantify Common Sense to Define Levels of Effort for Desired Tn Purposes

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You Get What You Measure

- Systems are optimized to the metrics measured even if they are ineffective
- Examples of Ineffective Metrics
  - Regulatory requirements focused on ANT
  - O&M staff focused on maximizing total liquid extraction assuming more water = more NAPL
- Thus, it is imperative to:
  - Define optimal metrics
  - **Match methods/procedures to required precision**

SET vs MEP

- MEP: no basis in SET
  - Example: confined LNAPL slowly recharging to large thickness
- Use SET metrics for common sense MEP
  - Site-specific or standard Tn threshold for early achievement agencies
  - Glide path for medium achievement agencies
  - Csat via NSZD for late achievement agencies

SET – Science Engineering & Technology
MEP – Recovery to the Maximum Extent Practicable

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Tn Measurement Precision by Use

Application	Sensitivity	Comment
Threshold Metric	Low	Quantify sufficiently to demonstrate Tn is below the threshold
Progress Metric	Low	Target typically lower than threshold to account for rebound so sensitivity is normally low
Model Calibration Metric	High	Model calibrated to Tn for technology selection and remedy design purposes requires high precision Tn measurement(s)

Match procedures to required level of precision:

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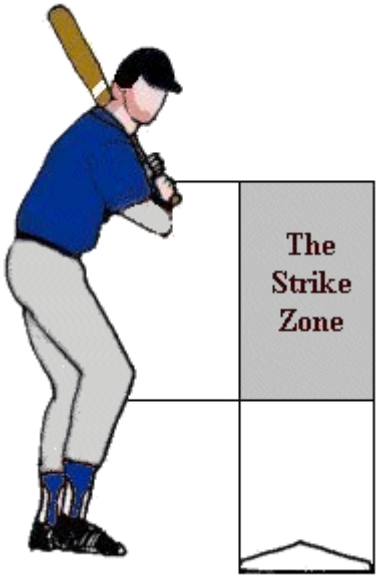
Match Relative Precision to Desired Use

Required precision for the MOAB/FOAB to hit a target is on the order of hundreds of feet

Required precision for a baseball pitcher to hit the strike zone is on the order of inches



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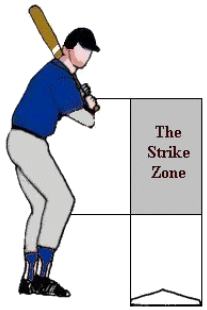
Detection Limit vs ASTM Approaches

Detection Limit Approach	ASTM Approach
Low Precision "Rapid" Upper Boundary Estimation Methods	High Precision "Slow" Estimation Methods
DvD Lower Bound Approach (Hawthorne et al, 2016)	Complete Recharge for recharge based methods (ASTM, 2011)
BR Type Curve Approach (Kirkman)	Factor of 2 reproducibility
MS Type Curve Approach (Hawthorne / Kirkman)	
OWR Detection Limit Approach (Hawthorne / Kirkman)	



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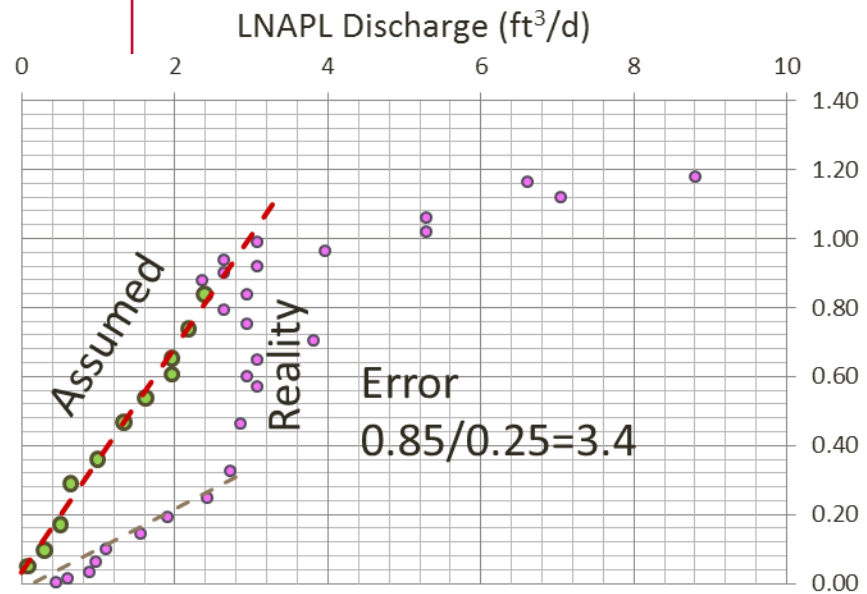
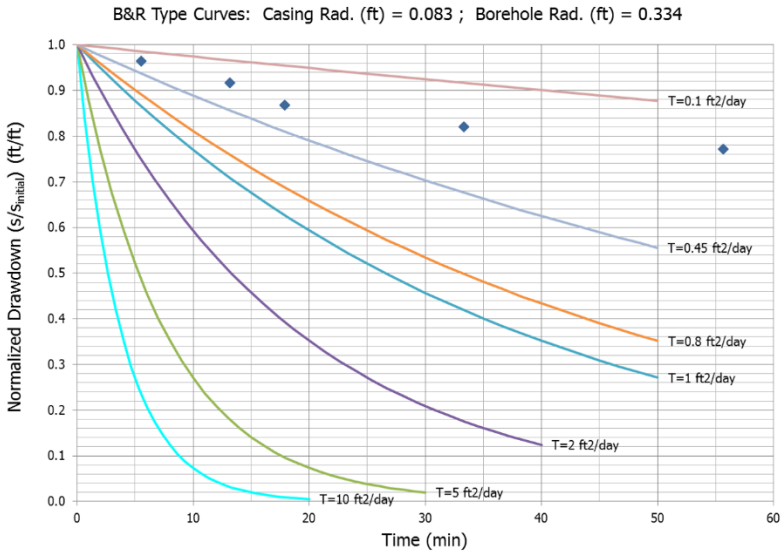
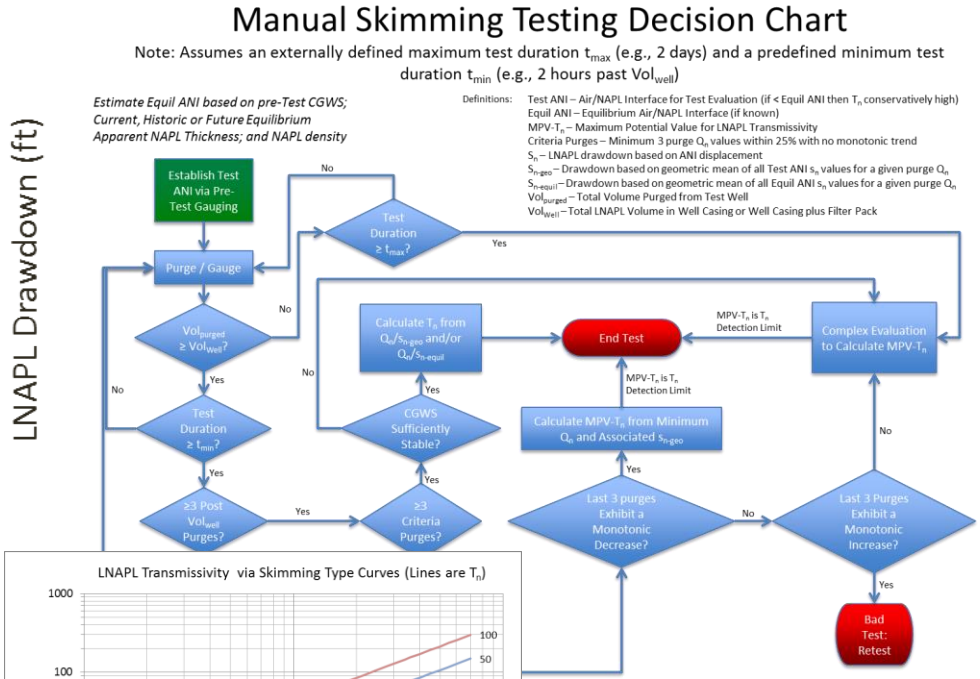
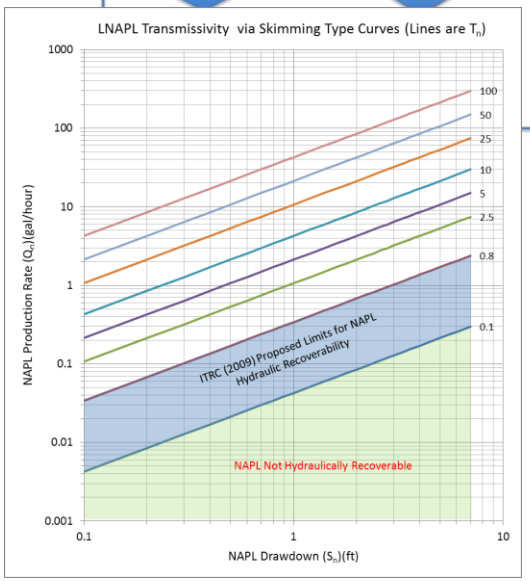
Detection Limit Tool Examples









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Tn Testing Sources of Error

Error Type	Baildown	Manual Skimming	Oil/Water Ratio
Drawdown	√	√	
Qn		√	
Qn/Qw Ratio			√
K			√

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NAPL is not Groundwater!

- Tn Violates Classic Groundwater Assumptions:
  - Infinite aquifer
    - Not typically
    - Heterogeneity of NAPL saturation distribution
  - Instantaneous removal
    - Even groundwater doesn't meet this assumption
    - BR translation deals with non-instantaneous tests (Butler, 1998)
    - BR demonstrated to be equivalent to CJ (Palmier et al, 2016; Kolhatkar et al, 1999)
    - Therefore "instantaneous" is not a major issue
  - Tn changes with water-table fluctuations
    - Drawdown error – discuss shortly
    - Forthcoming article in prep

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How Does this Apply to Tn?

- Maintain Perspective:
  - Tn is used for OOM estimates up to factor of 2 estimates (when modeling)(ASTM, 2013)
  - Quantify how much can be removed relatively to
    - Compare technologies
    - Can the source be reduced? (longevity, mass, migration potential)
    - Tn gives us the power to quantify recovery that previously required pilot testing data
  - It has been demonstrated in literature to be a good predictor of initial expected recovery rates (Palmier, 2016; and Kolhatkar et al, 1999)

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Drawdown Sensitivity Analysis Basis

- Given that the most significant errors associated with baildown testing are drawdown errors
- Assume a given magnitude of drawdown error (e.g., 0.05 foot for an ANT of 0.25 foot – 20% error)
  - That error is constant for every recharge reading obtained
  - The percent error is lowest when the drawdown is highest
  - The percent error is highest when the drawdown is lowest
- Drawdown is highest during early time data, so the data least affected by errors is the early data and the data most affected by errors is late data

$$s_{ERR} = s_t \pm (20\% \times s_o)$$

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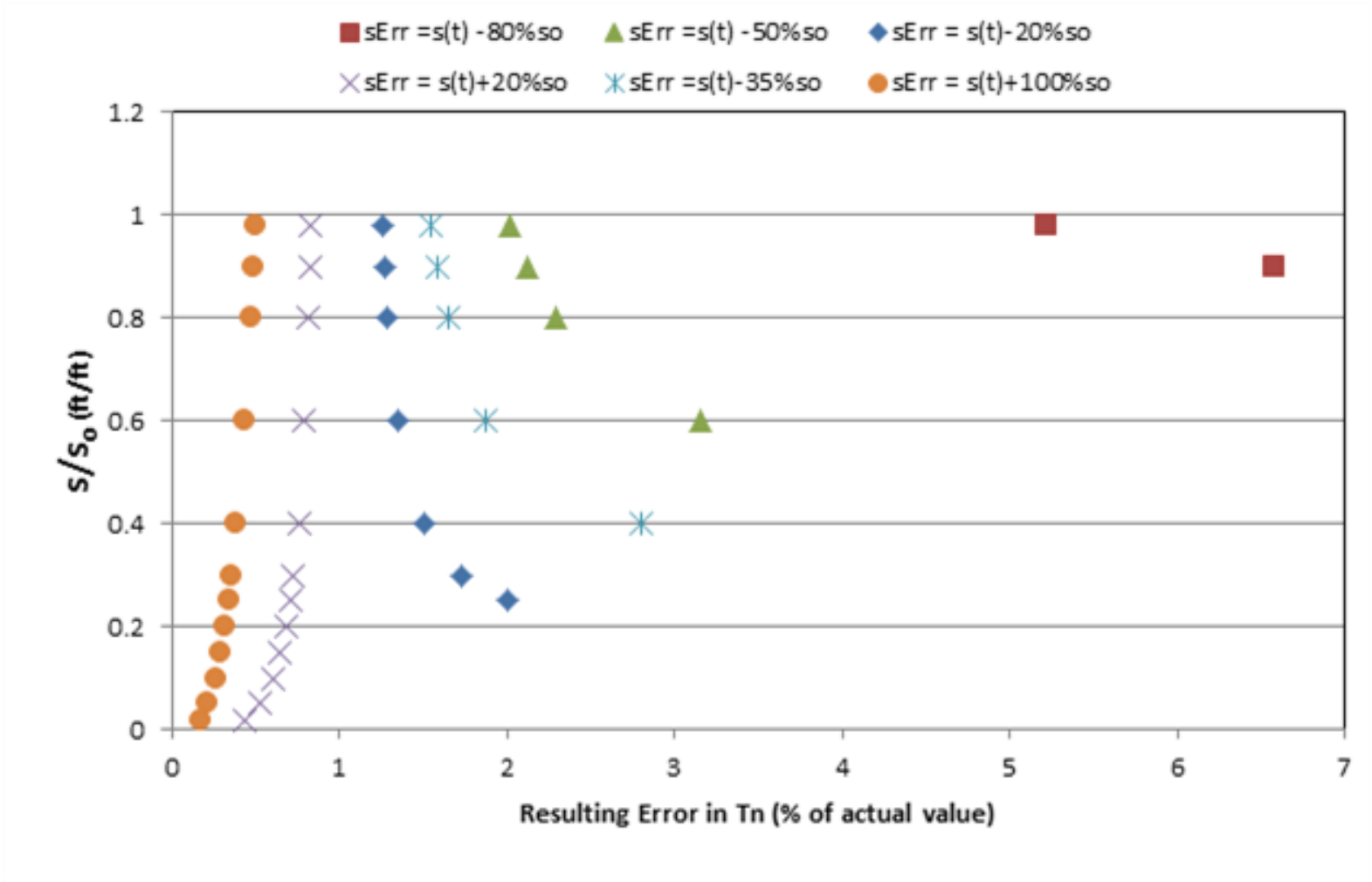
Drawdown error impact on Tn variability



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Practical Applications

- Match test precision to the LNAPL transmissivity application
  - Threshold / Progress Metric: Low Precision
  - Model Calibration Metric: High Precision
- Detection Limit (type curve) vs. ASTM Approach
- One Day Baildown Test Method
  - “Instantaneous” error is not significant
  - Primary errors in drawdown and filter pack recharge
  - Eliminate/reduce filter pack by removing total volume
  - Filter pack volume removal allows use of early data
  - Early data affected least by drawdown error
  - Use Type Curve approach to screen <0.8 ft^2/d wells

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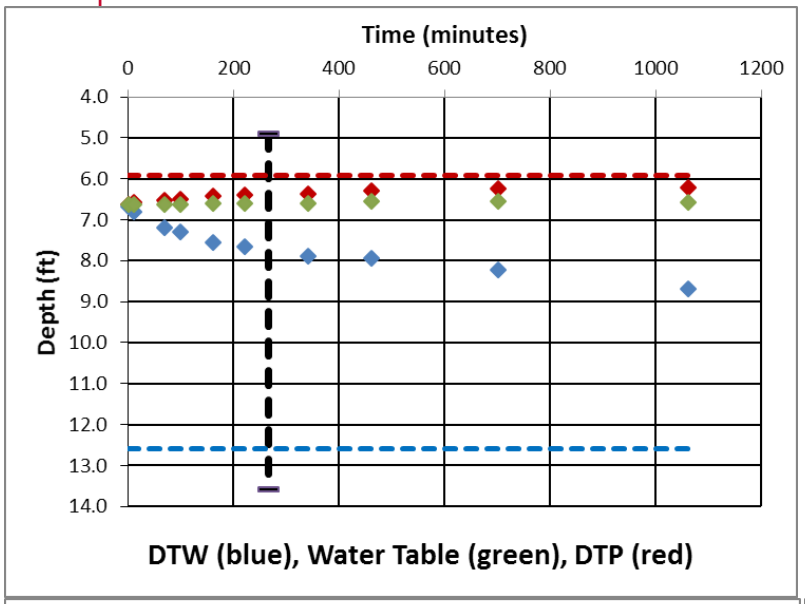
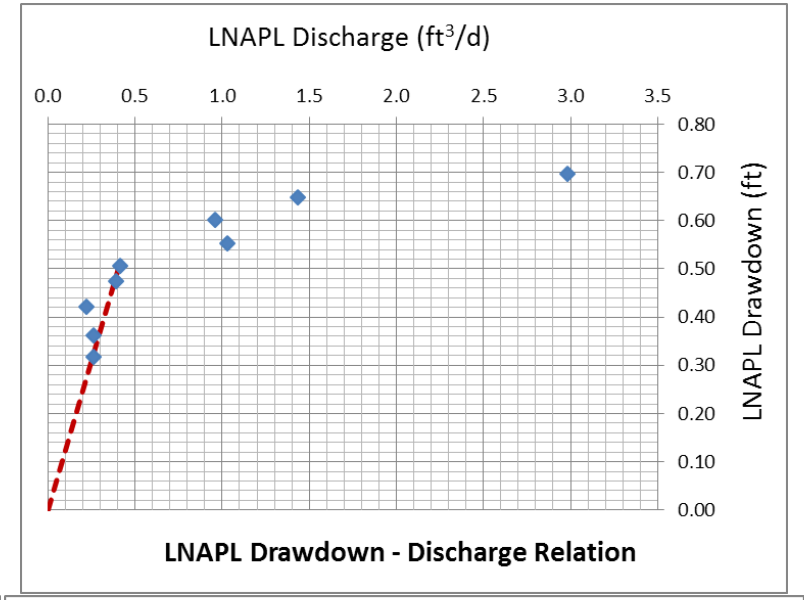
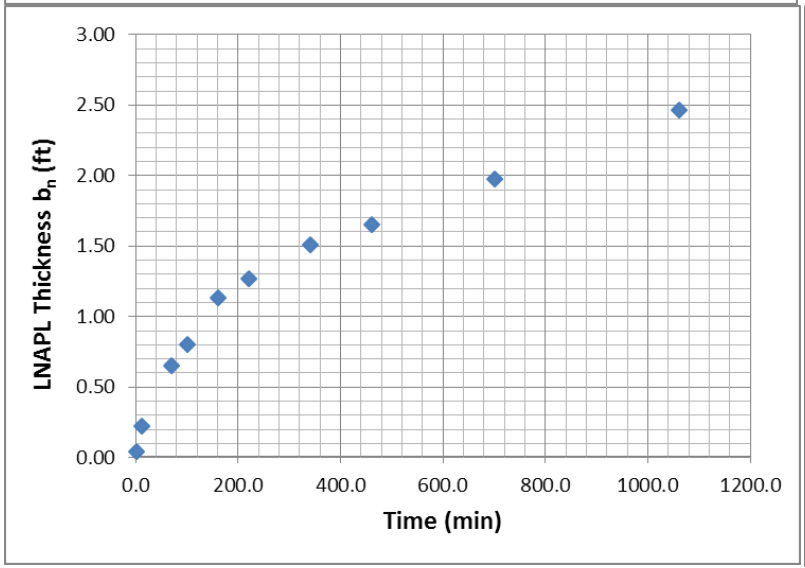
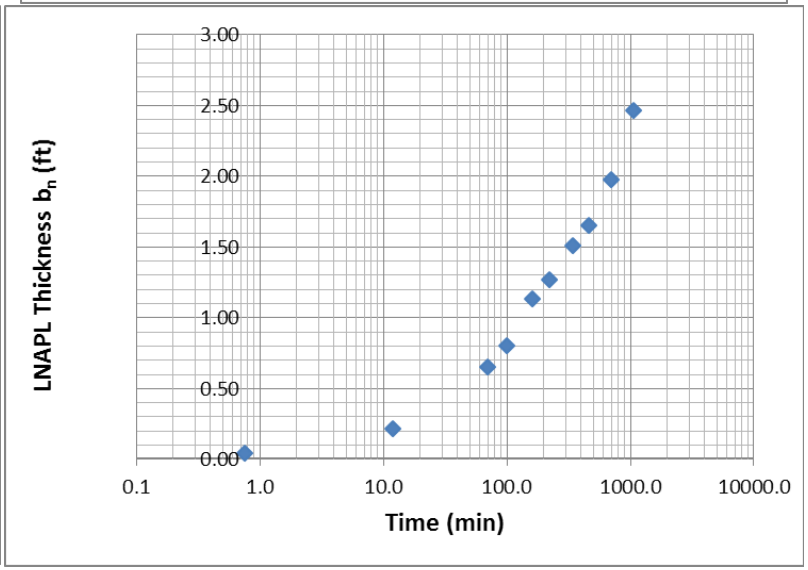
Unconfined vs Perched/Confined?









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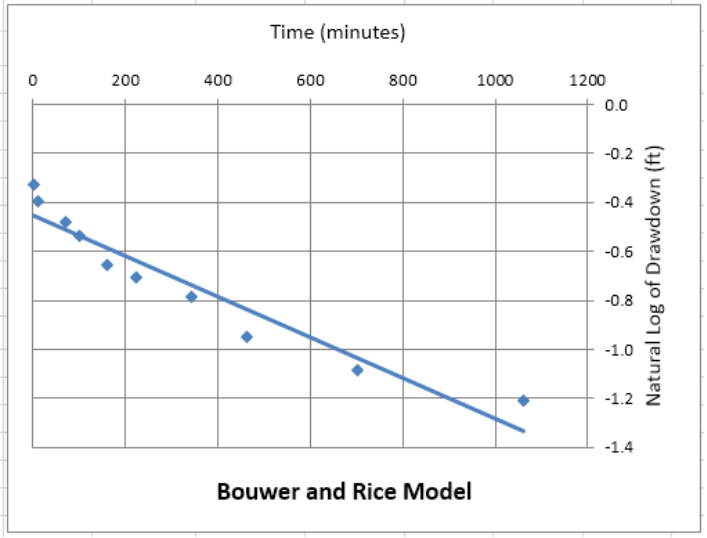
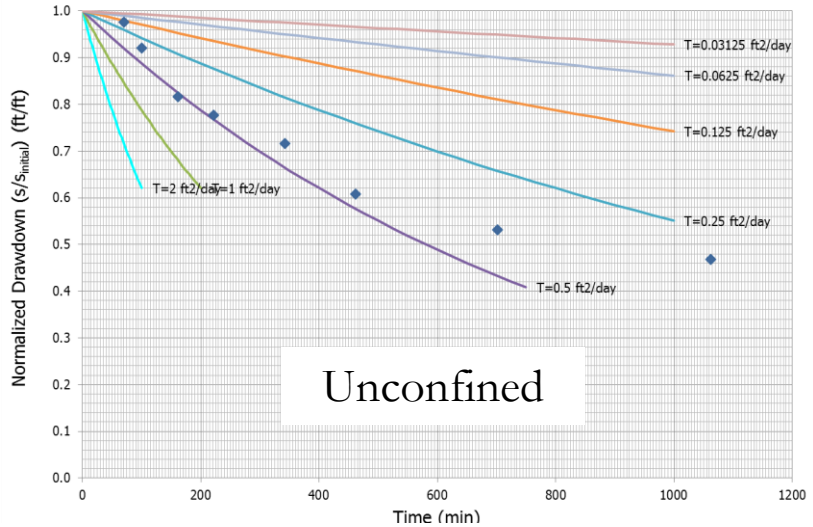
Unconfined vs Perched Tn

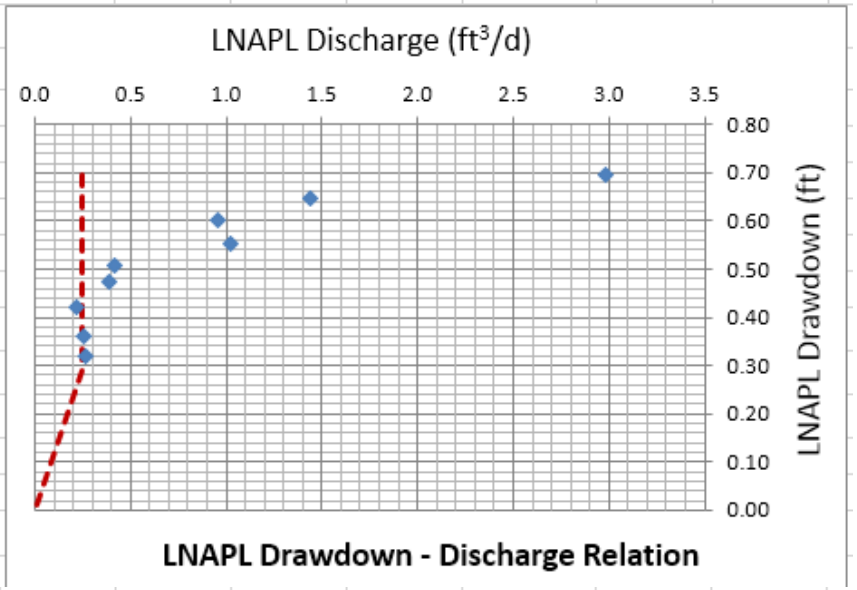
Model Results: T_n (ft^2/d) : 0.35 +/- 0.04 ft^2/d



B&R Type Curves: Casing Rad. (ft) = 0.166666666666667 ; Borehole Rad. (ft) = 0.333333333333333



6.2
0.25
4.0
6.9
0.3
5.9
13.8
0.36



6
0.25
4.0
6.9
0.1
5.9
13.8
1.16