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ENVIRONMENTAL AND WATER RESOURCE CONSULTANTS

Success Factors for Pumping Test Designers and Interpreters

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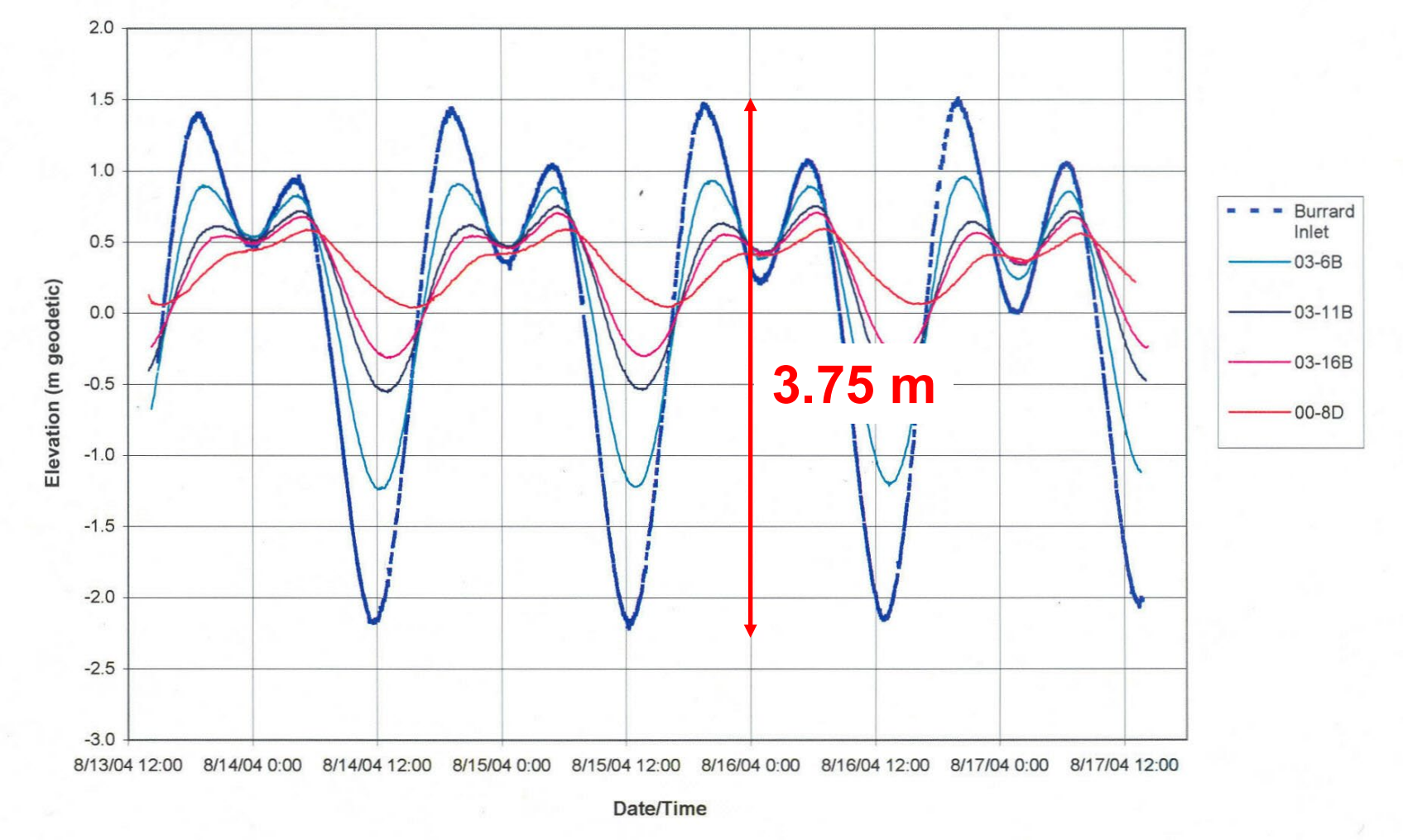
Success factors for pumping tests

1. Test design
2. Data quality assurance
3. Data processing
4. Interpretation
5. Assessment of the interpretation
6. Perspective

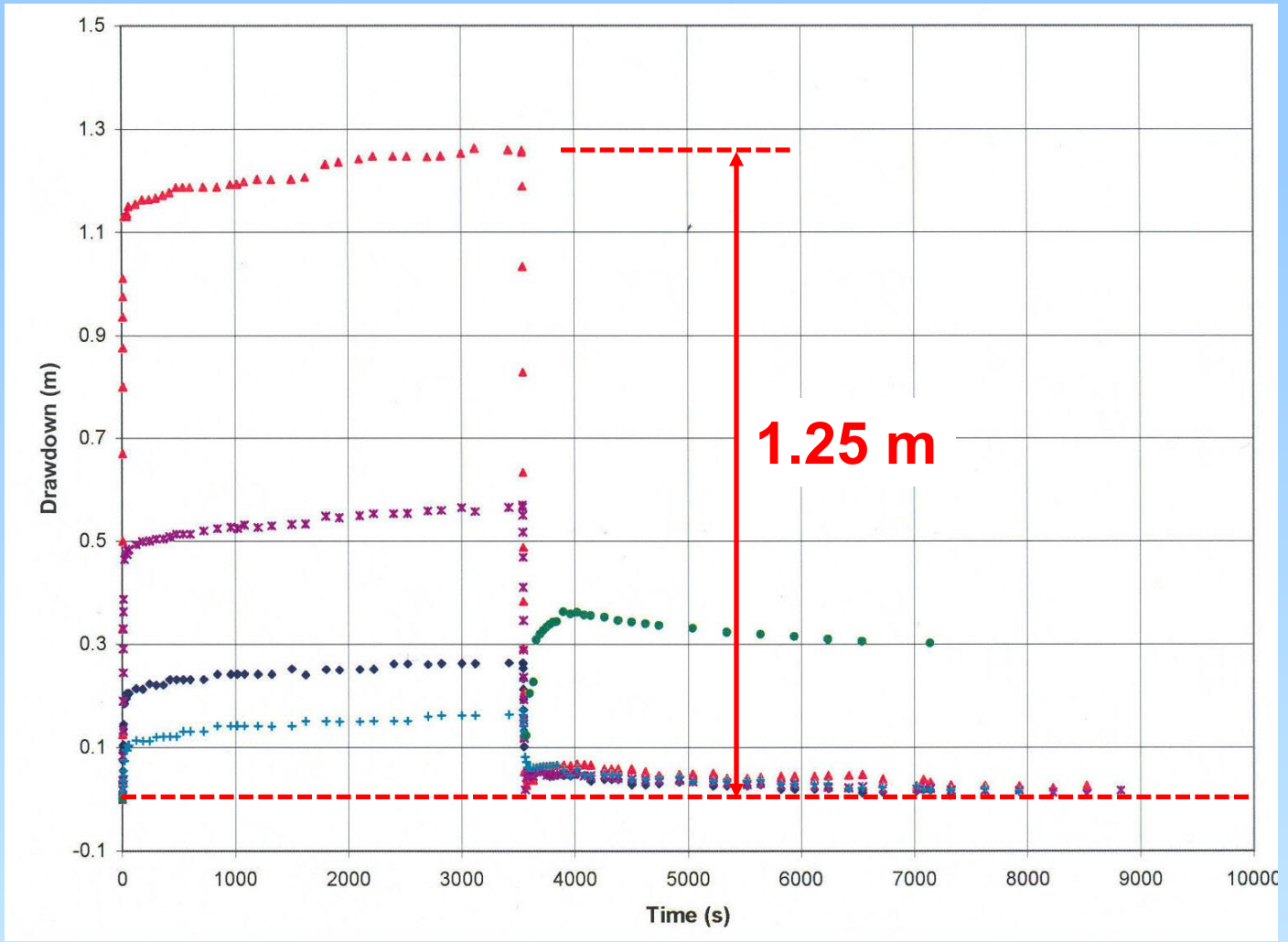
1. Pumping test design

- Pumping tests should always be designed.
- The work plan for a pumping test should include a clear statement of the objectives of testing.
- Never design a pumping test that you may not be able to interpret.

Pumping test in a coastal setting: Background water levels

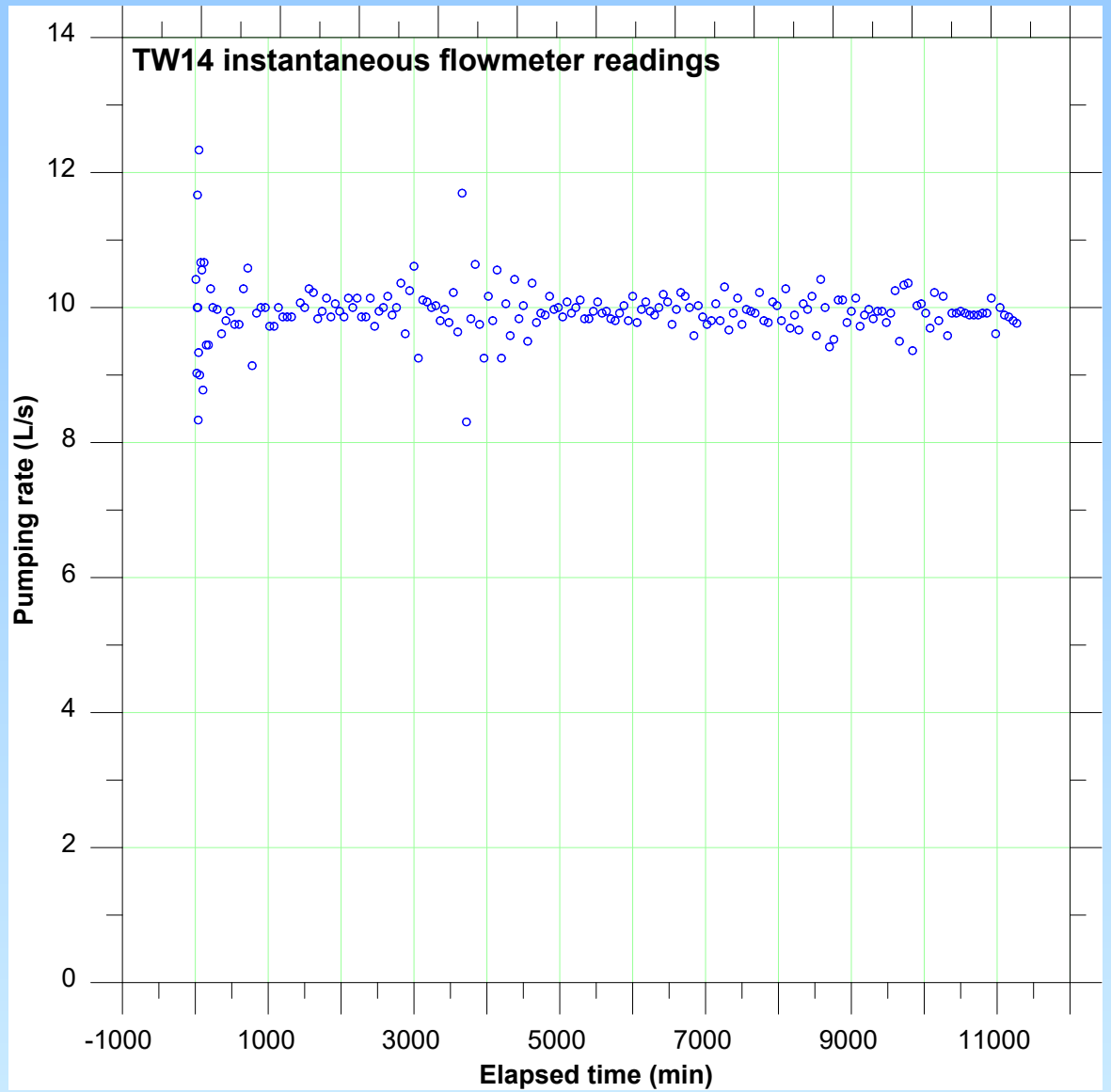


Pumping test in a coastal setting: Drawdowns

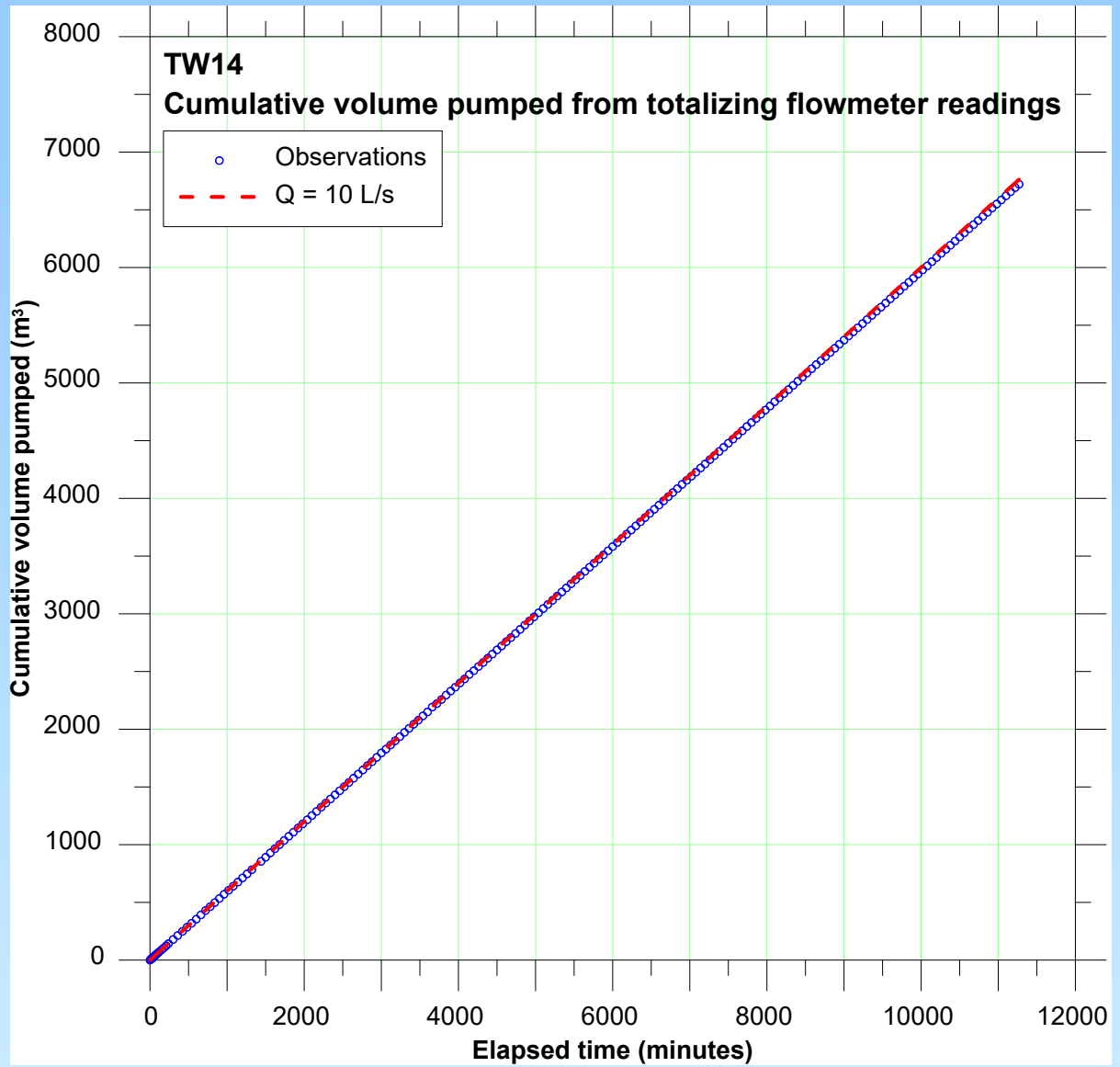


Avoid designing tests in which the “noise” (background fluctuations) may overwhelm the signal (drawdowns caused by pumping).

2. Data Quality Assurance (1)

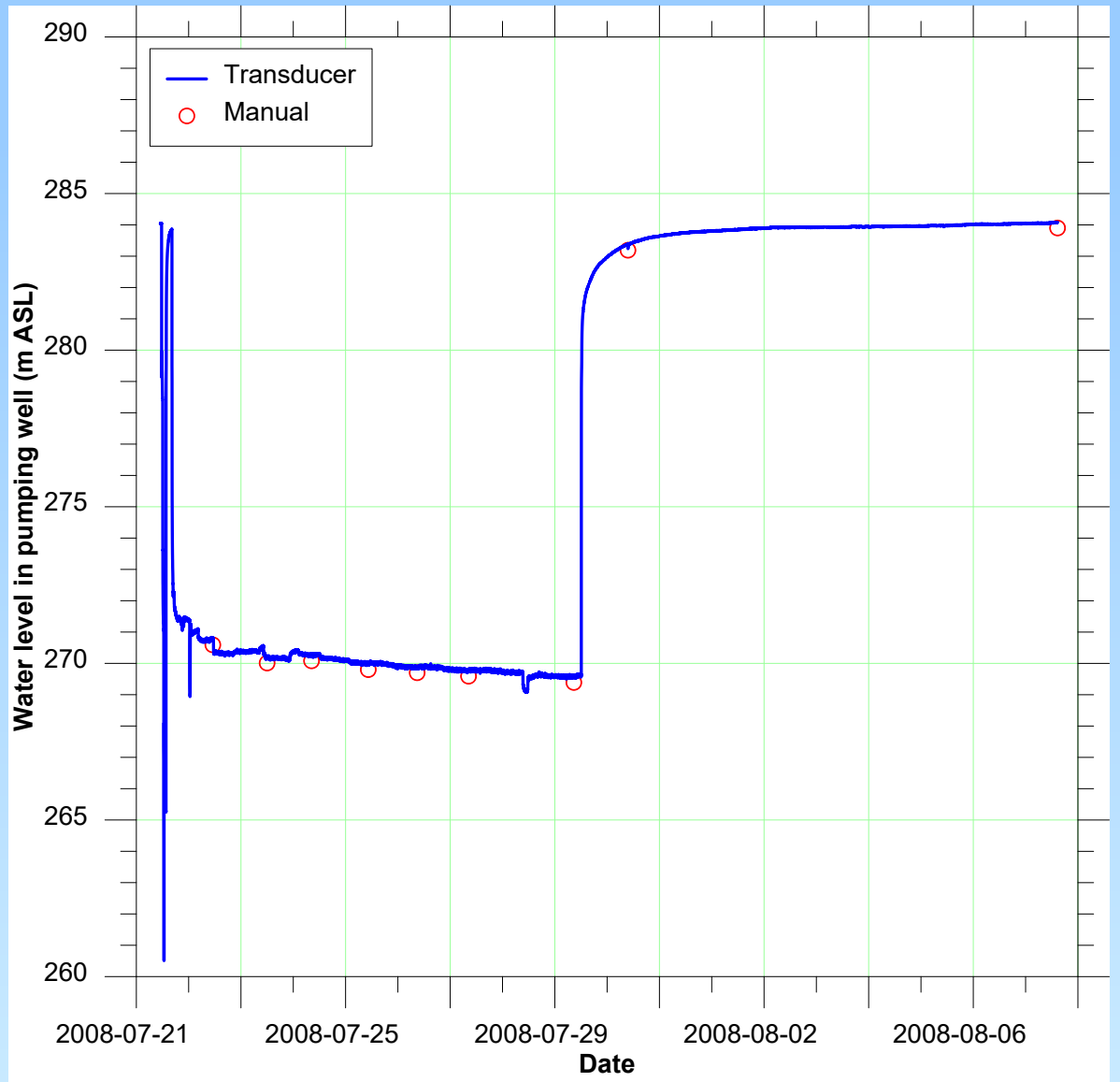


Frequent readings of the instantaneous pumping rate are good.



Frequent readings of the instantaneous pumping rate and a totalizing flowmeter are even better.

Data QA (2)



Transducers are great, but they have been known to fail.

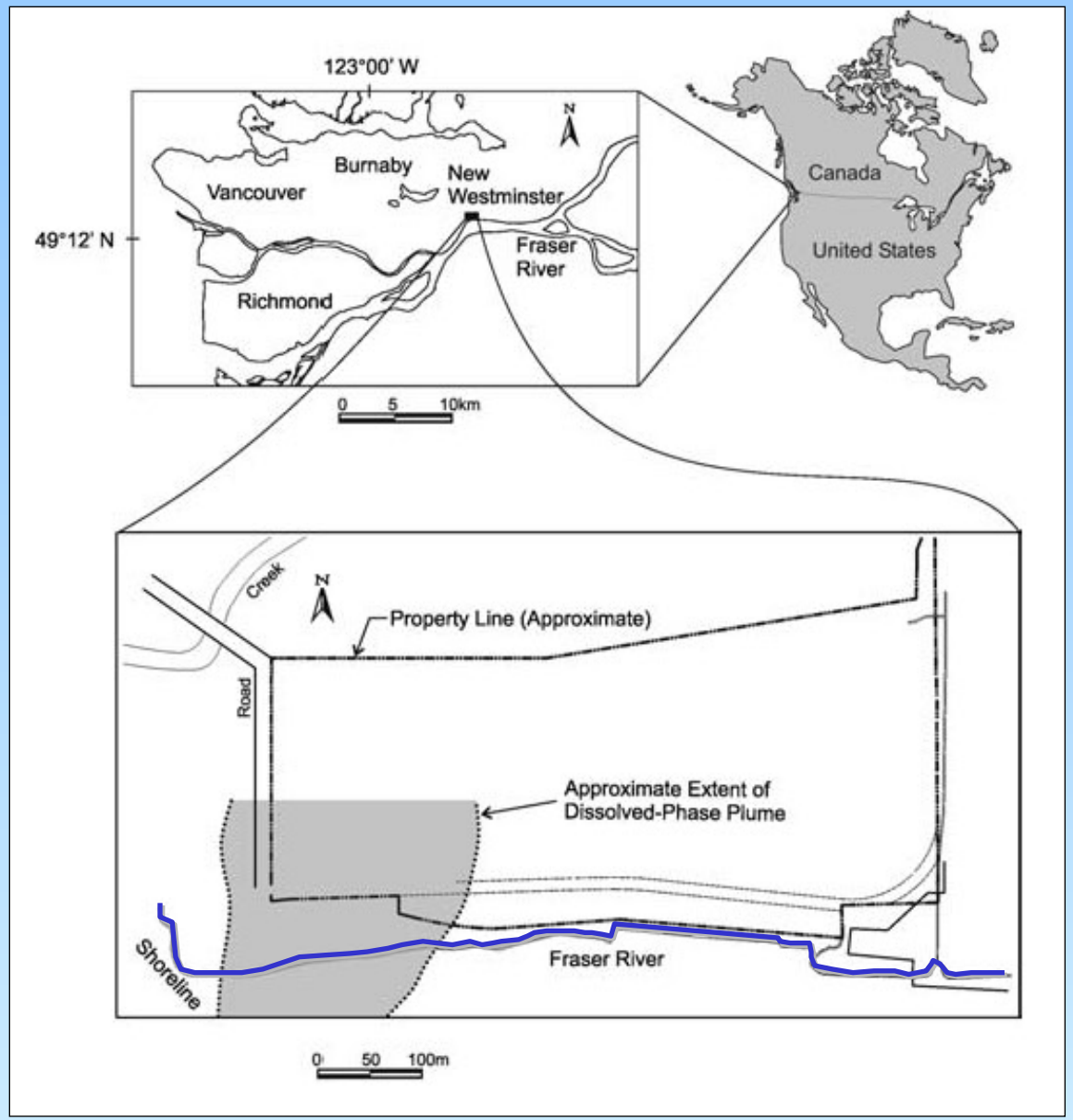
Check the transducer readings frequently with manual measurements.

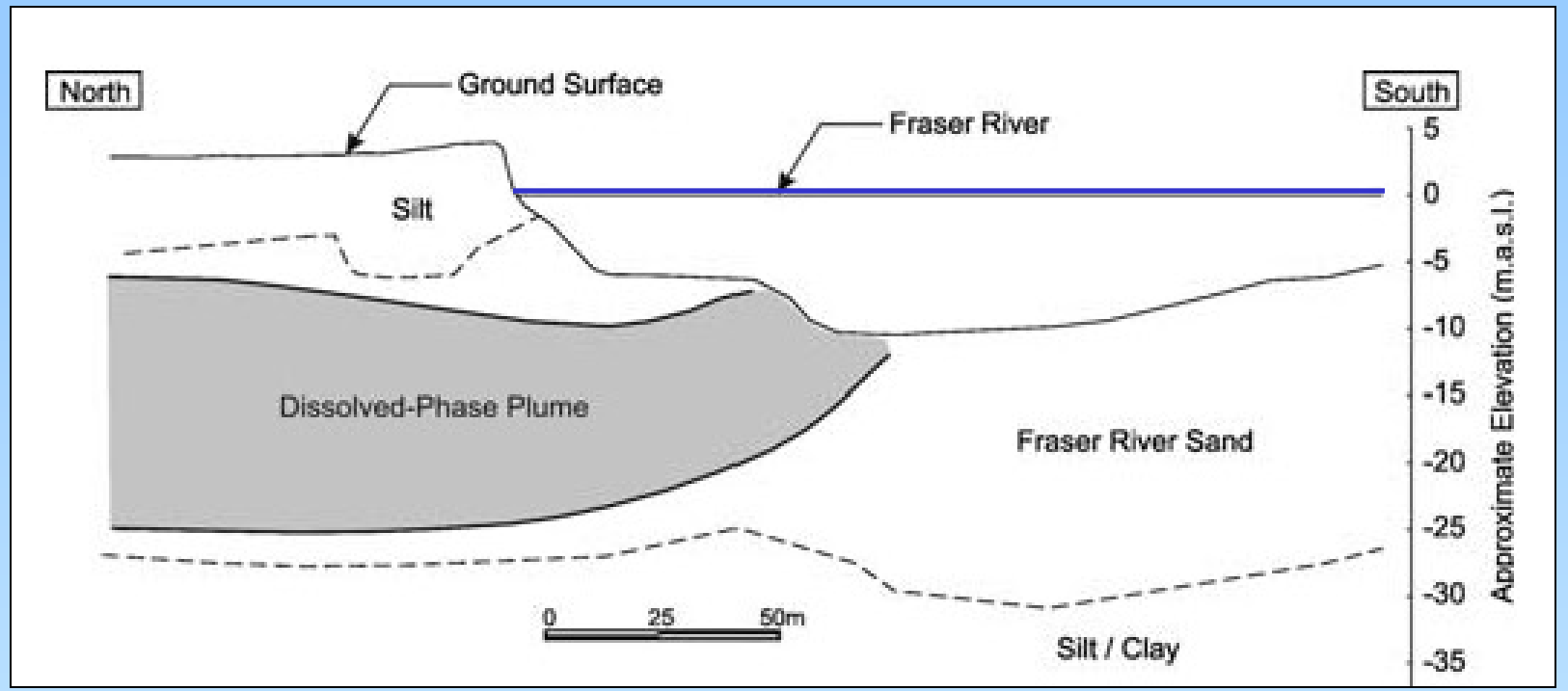
3. Data processing

The interpretation of a pumping test begins with identifying the water levels changes that are caused only by our pumping.

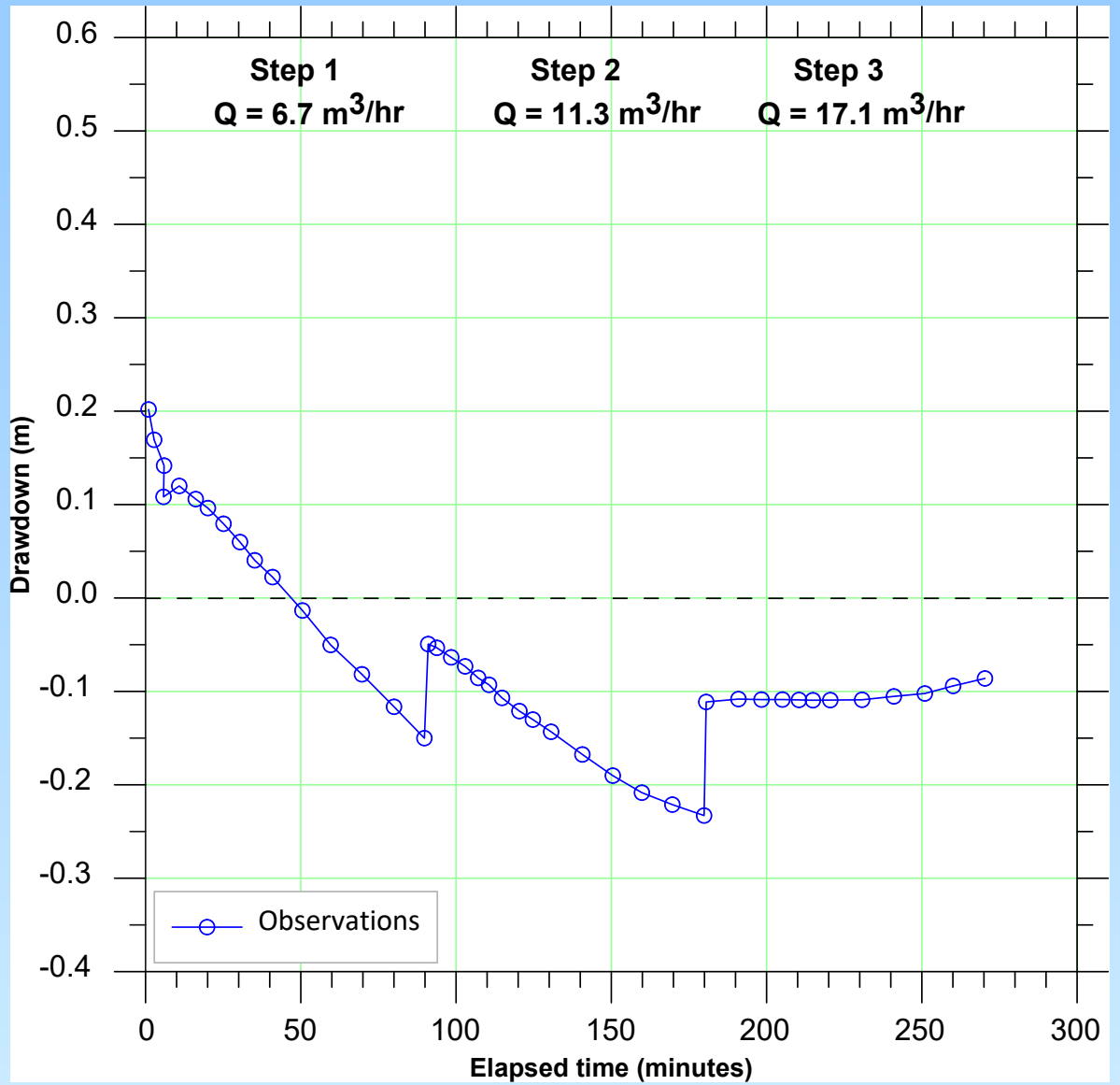
Water levels usually must be filtered for external influences. The filtering must usually be accomplished outside of any interpretation software.

Case study

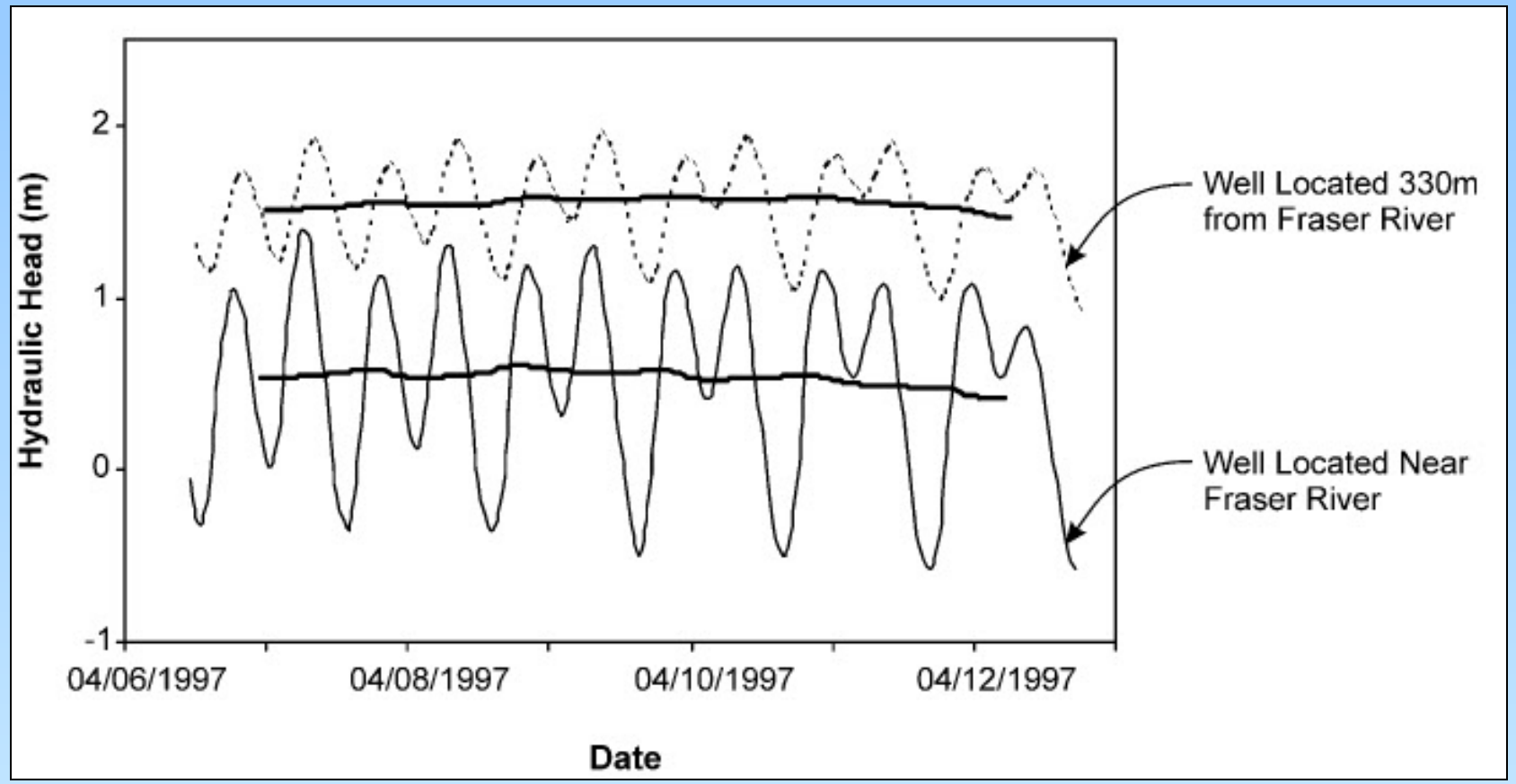

123°00' W
49°12' N
Burnaby
New Westminster
Vancouver
Fraser River
Richmond
0 5 10km
Canada
United States
Creek
Road
Property Line (Approximate)
Approximate Extent of Dissolved-Phase Plume
Fraser River
Shoreline
0 50 100m


North
Ground Surface
Fraser River
South
Silt
Dissolved-Phase Plume
Fraser River Sand
Silt / Clay
0
25
50m
5
0
-5
-10
-15
-20
-25
-30
-35
Approximate Elevation (m.a.s.l.)

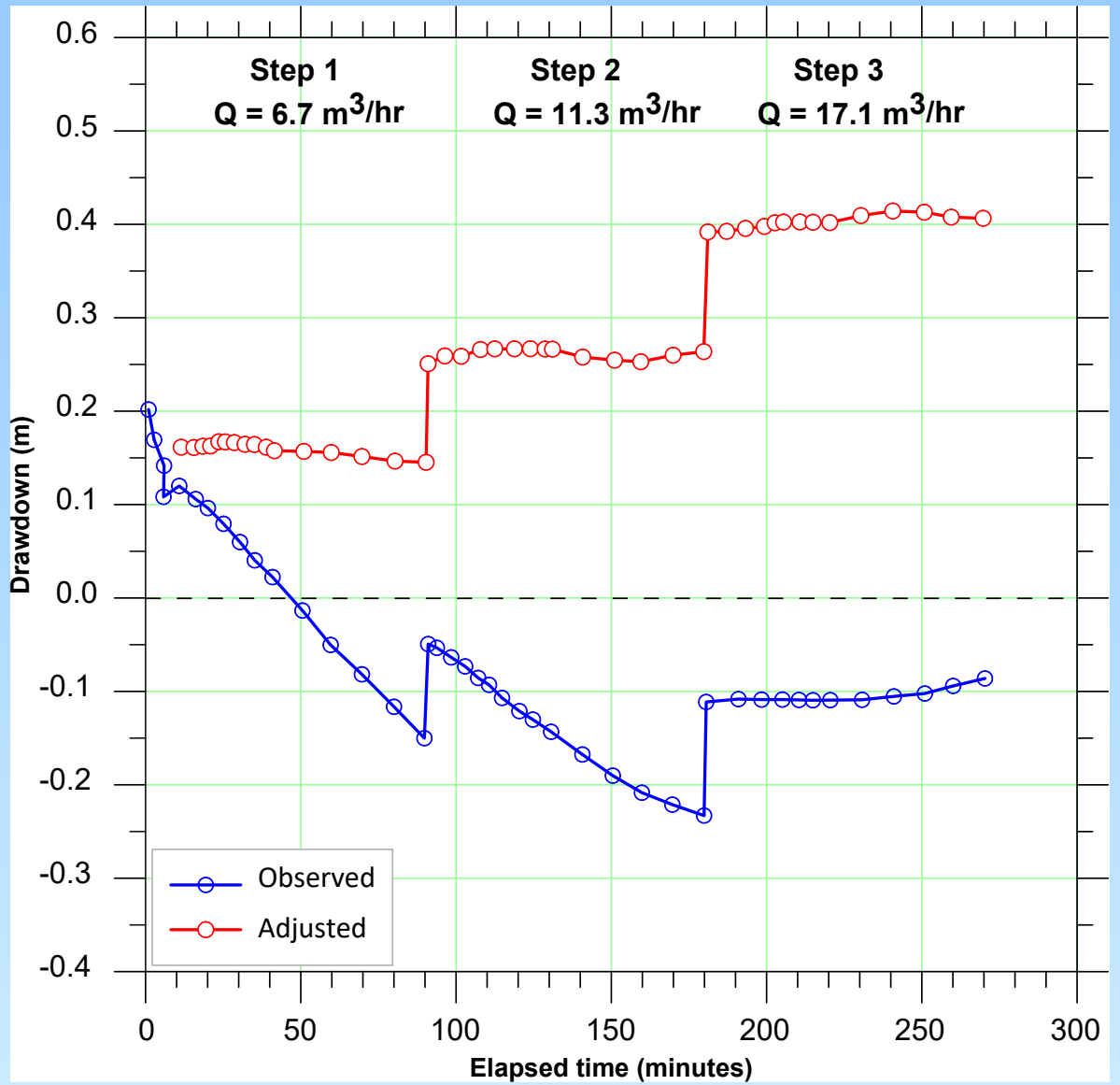
Step test (raw)



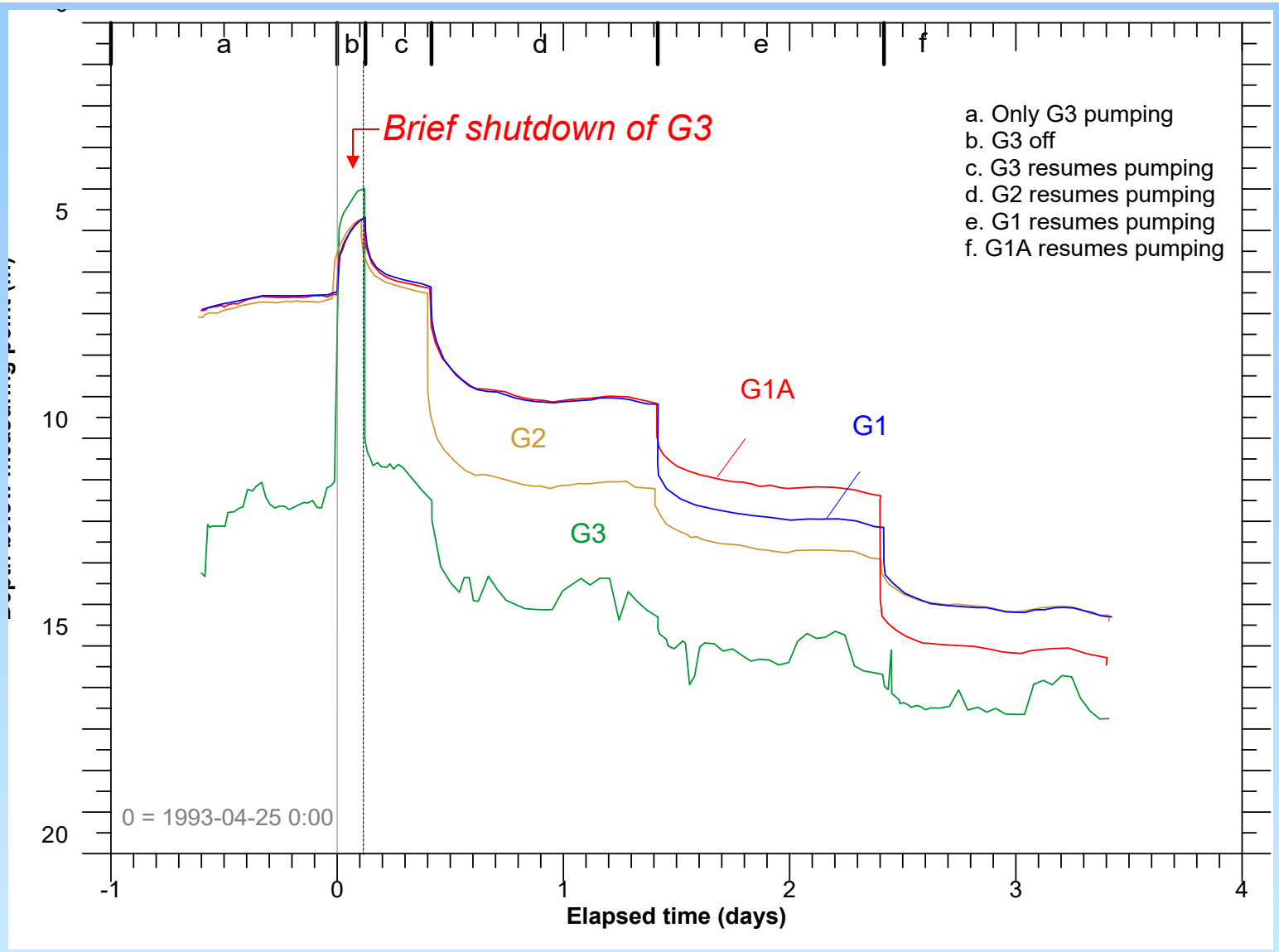
Natural fluctuations



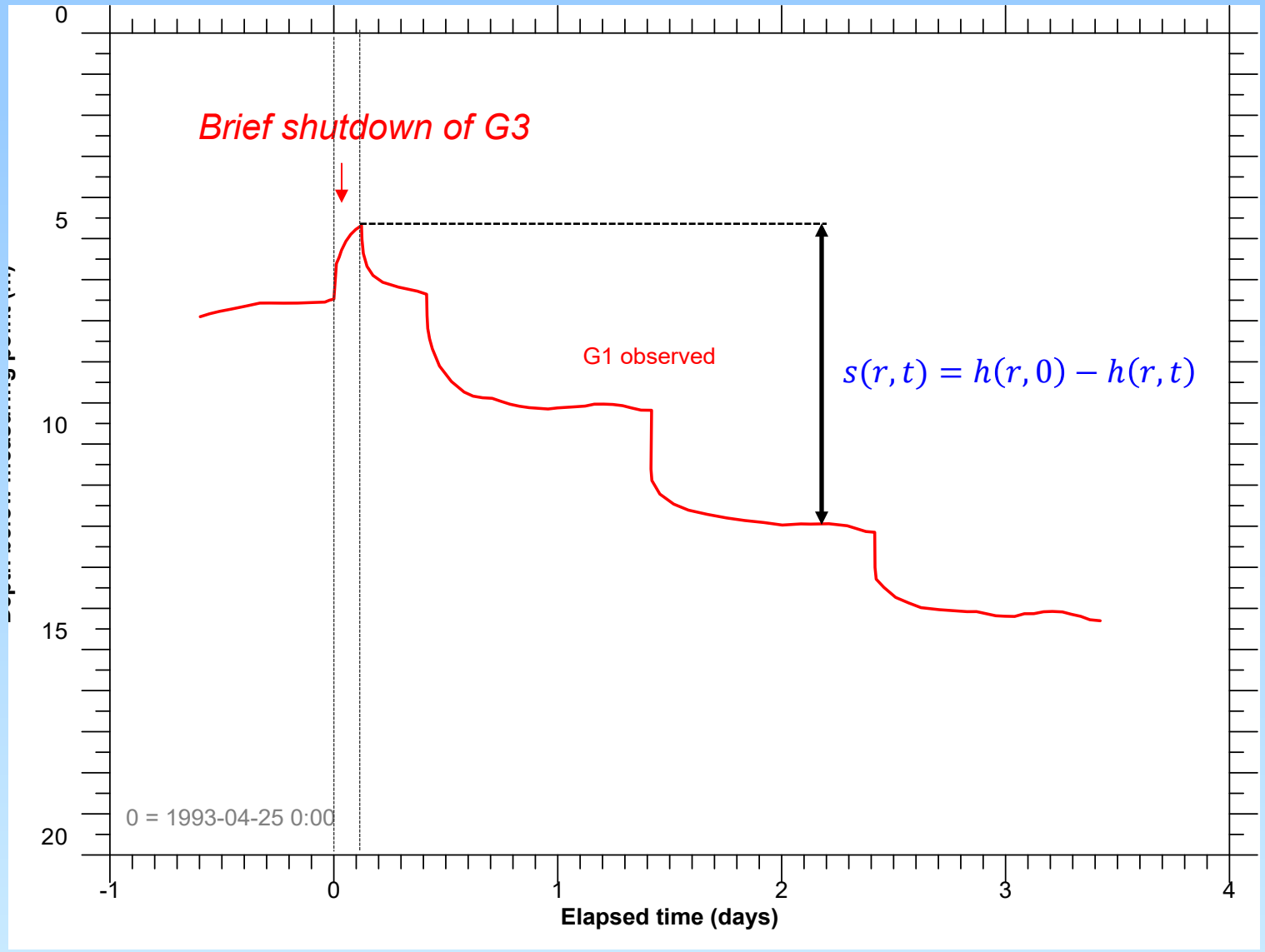
Step test (adjusted)



Case Study:
Middleton Street Well Field, Cambridge, Ontario



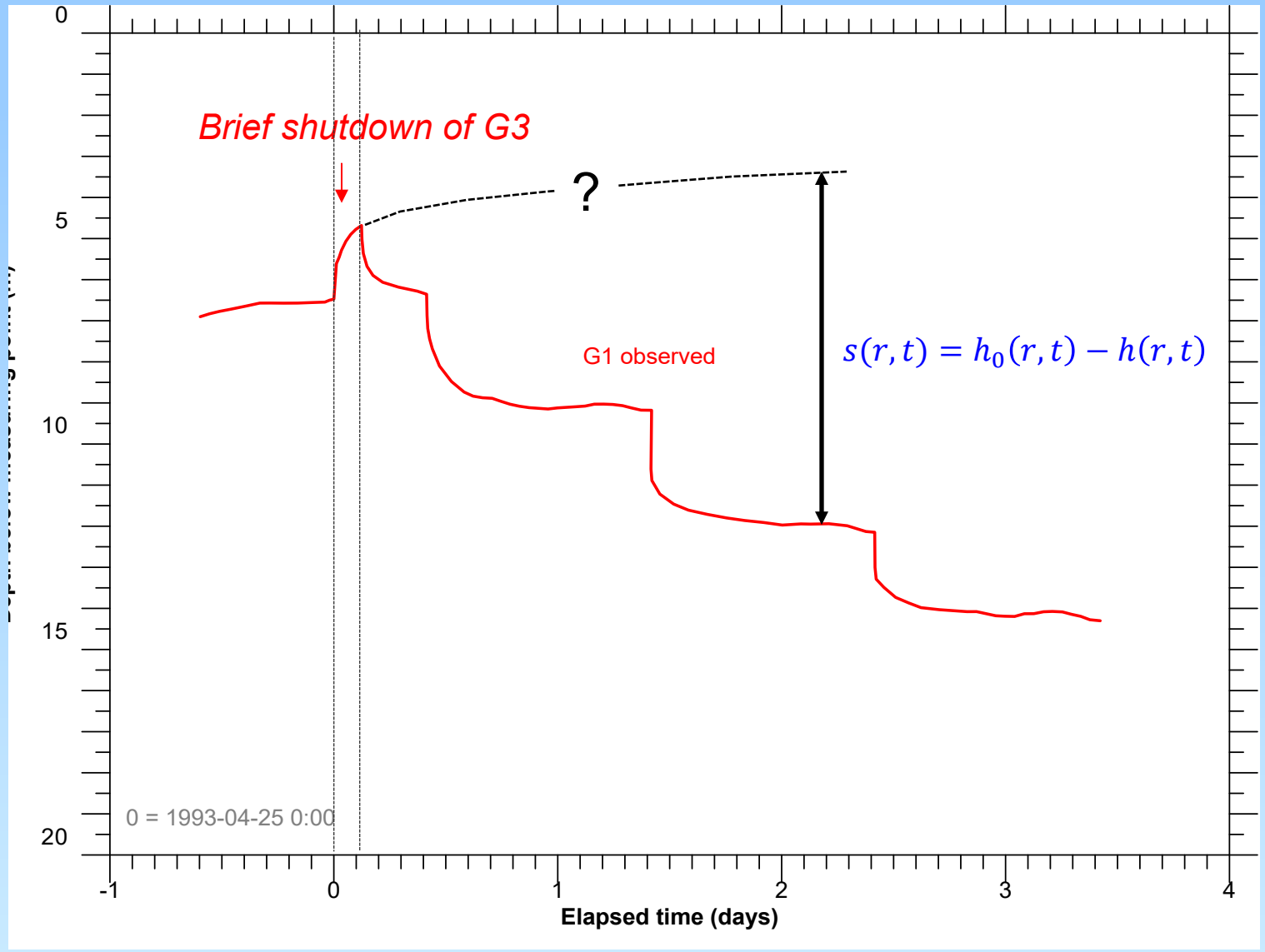
Estimation of drawdowns: Incorrect approach



Why is this approach incorrect?

The effects of the brief shutdown of G3 were persisting after G3 resumed pumping.

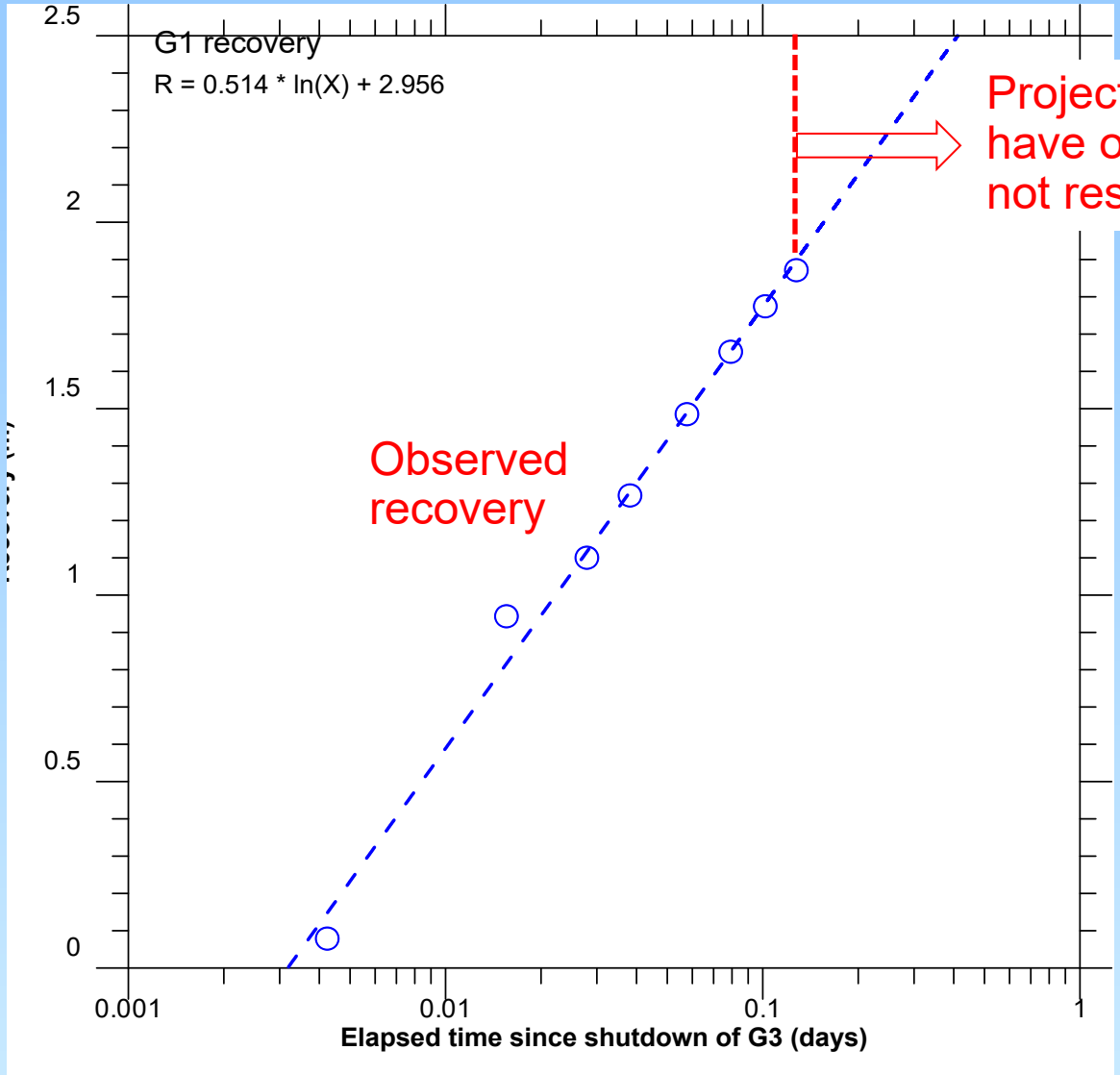
Estimation of drawdowns: Correct approach

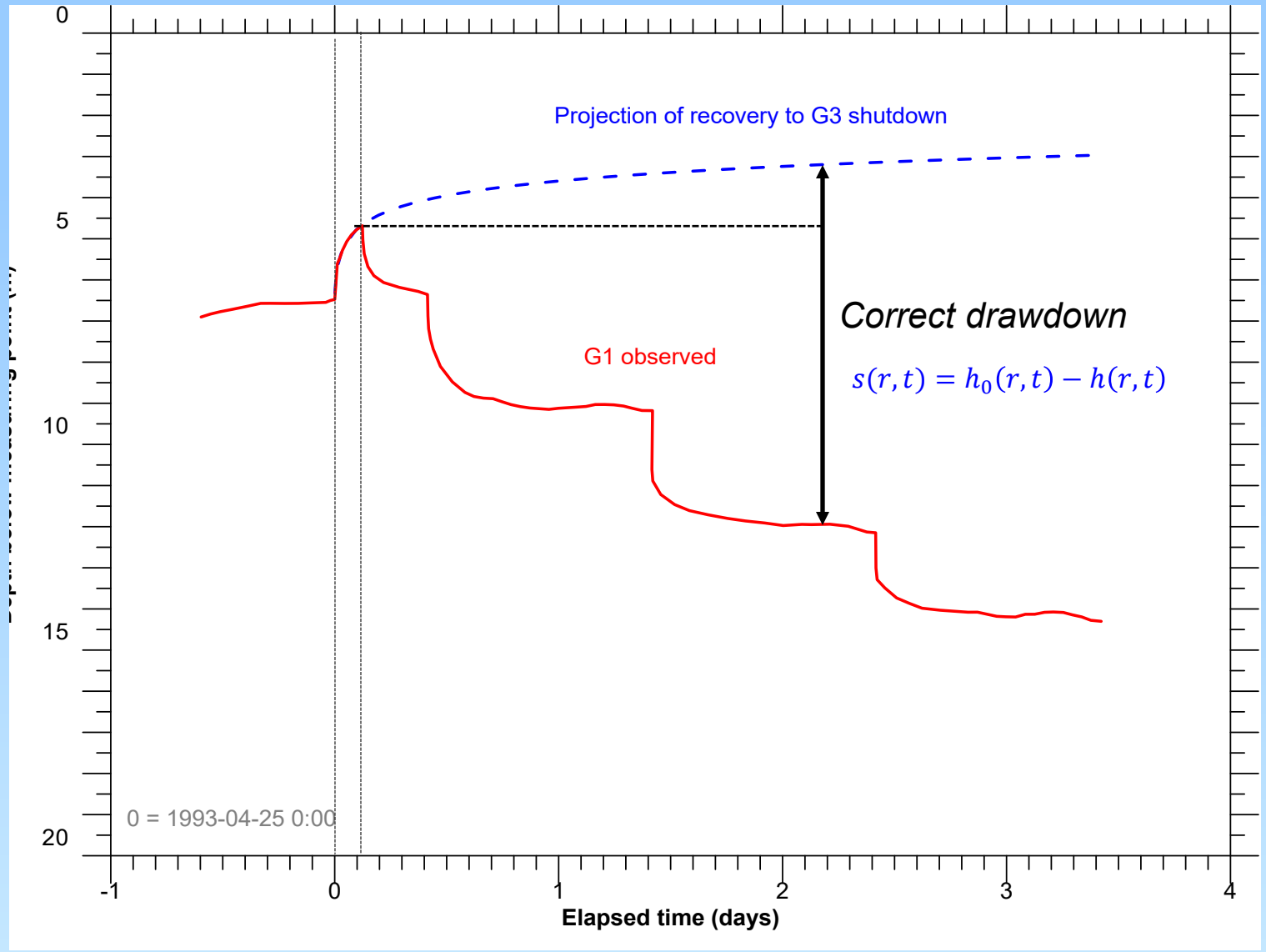


$h_0(r,t)$ is the water level that would have been observed in the absence of pumping.

In this case, that means the water level that would have been observed if G3 had not resumed pumping.

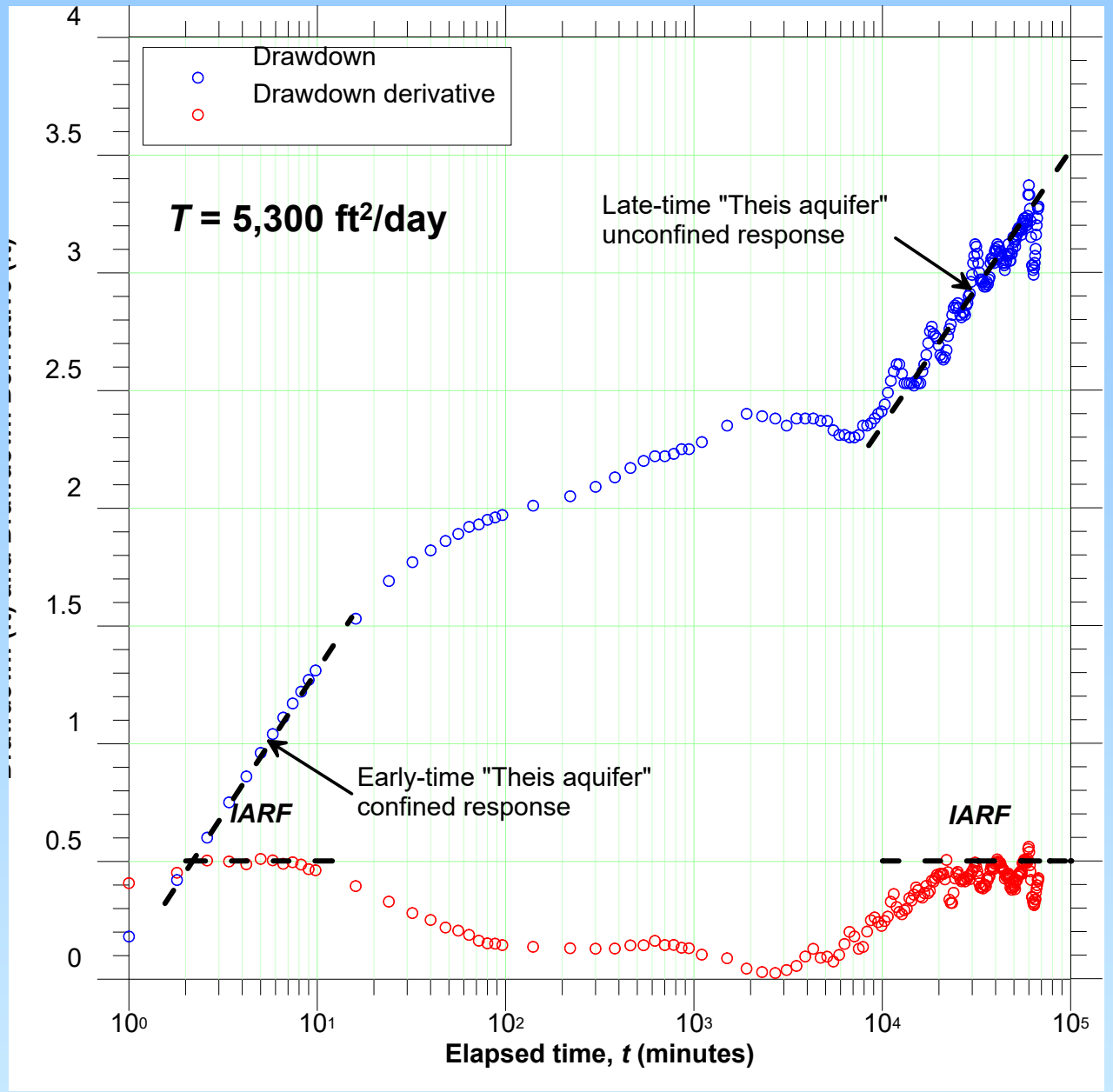
Estimation of background trend during the resumption of pumping

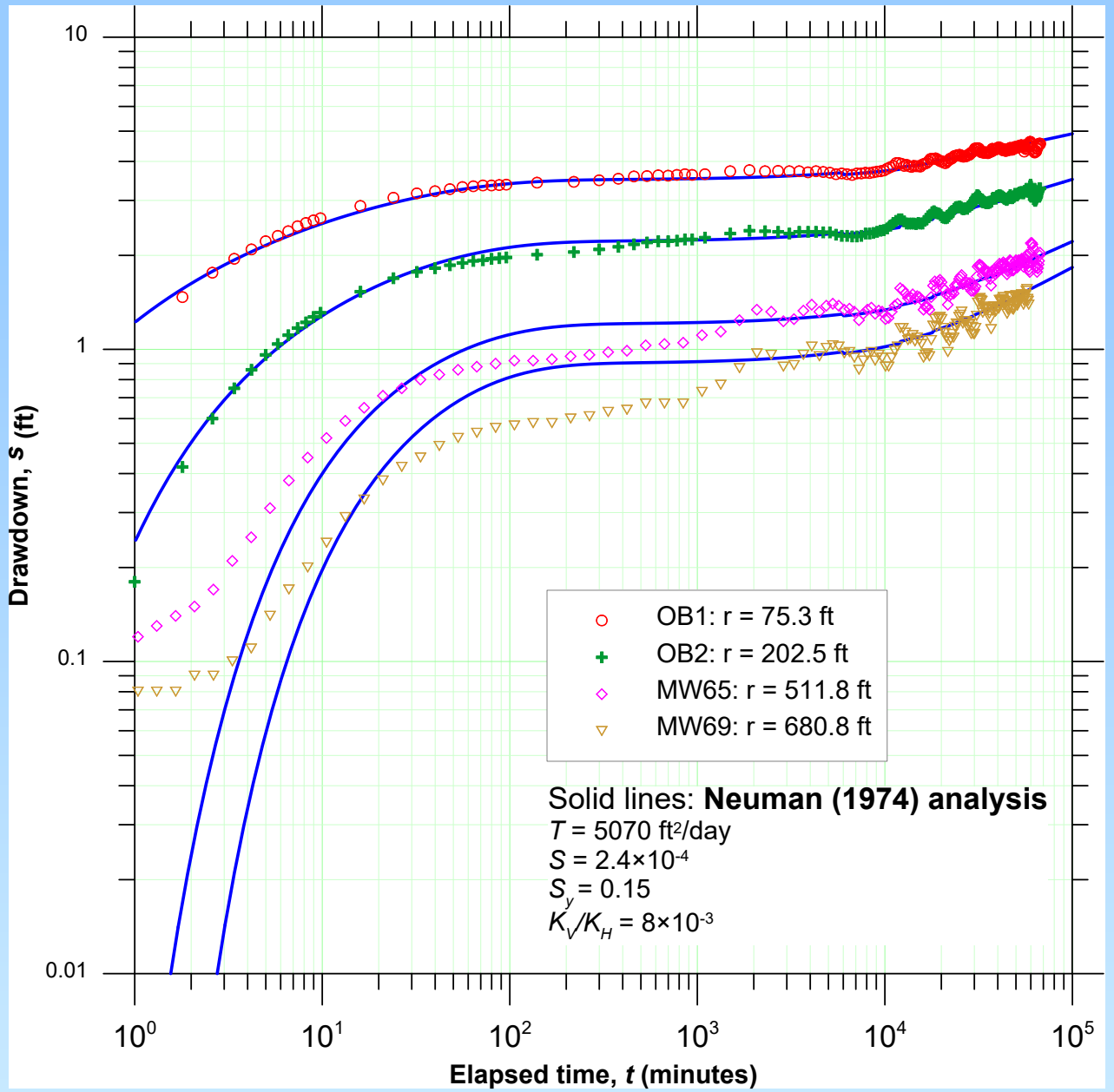



Projection of recovery to G3 shutdown
Correct drawdown
$s(r,t) = h_0(r,t) - h(r,t)$
G1 observed
0 = 1993-04-25 0:00
0
5
10
15
20
-1
0
1
2
3
4
Elapsed time (days)

4. Interpretation

- Estimate aquifer properties from the appropriate portion of the response
- Infer the Site Conceptual Model from the matches to the full responses


Drawdown
Drawdown derivative
T = 5,300 ft²/day
Late-time "Theis aquifer"
unconfined response
Early-time "Theis aquifer"
confined response
IARF
IARF
4
3.5
3
2.5
2
1.5
1
0.5
0
10⁰
10¹
10²
10³
10⁴
10⁵
Elapsed time, t (minutes)


10
1
0.1
0.01
Drawdown, s (ft)
10^0
10^1
10^2
10^3
10^4
10^5
Elapsed time, t (minutes)
OB1: r = 75.3 ft
OB2: r = 202.5 ft
MW65: r = 511.8 ft
MW69: r = 680.8 ft
Solid lines: **Neuman (1974) analysis**
T = 5070 ft²/day
S = 2.4×10⁻⁴
S_y = 0.15
K_V/K_H = 8×10⁻³

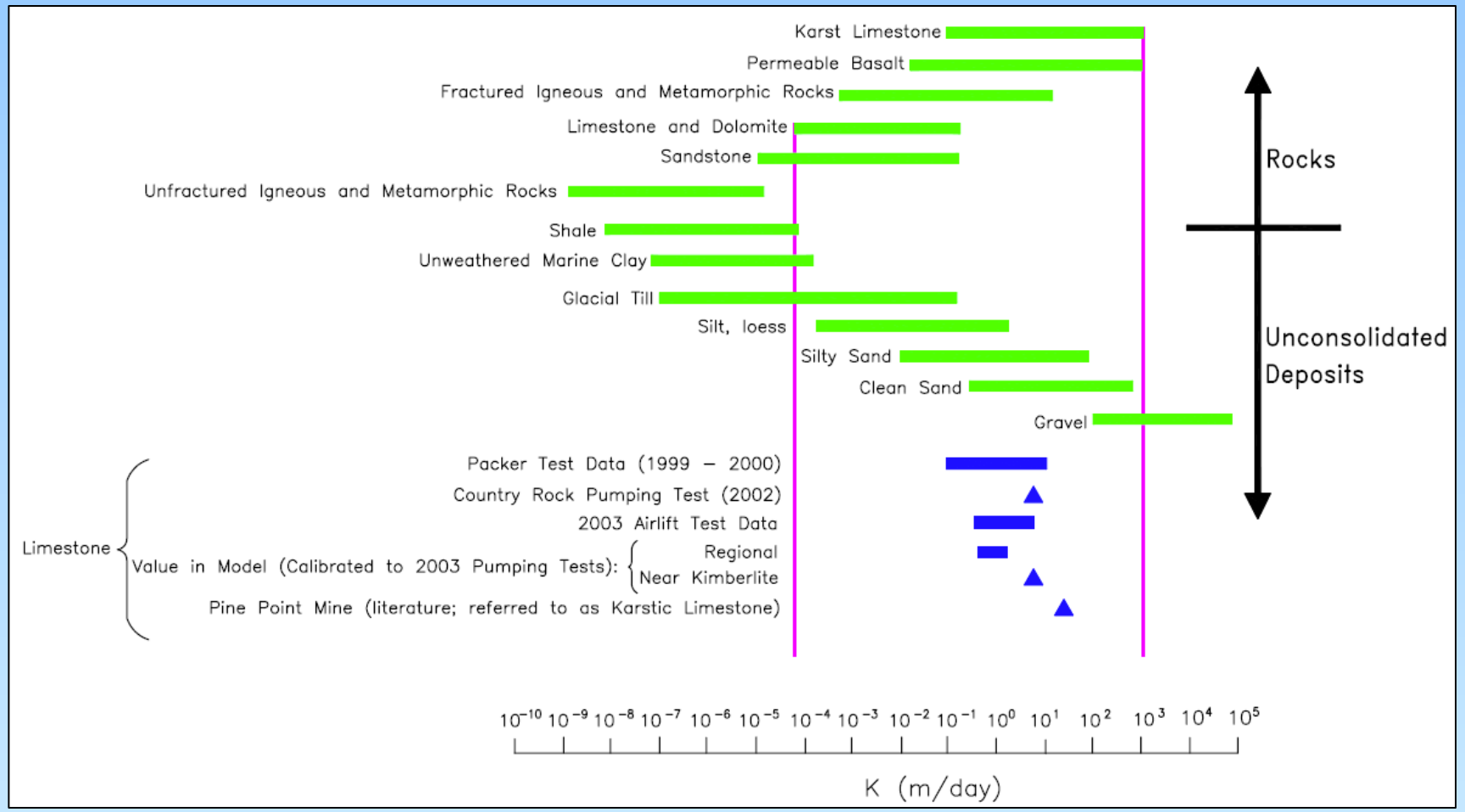
5. Assessment of the interpretation

1. Are our interpretations consistent with our Conceptual Site Model (i.e., everything else we know about the site)?

2. Are our parameter estimates meaningful?

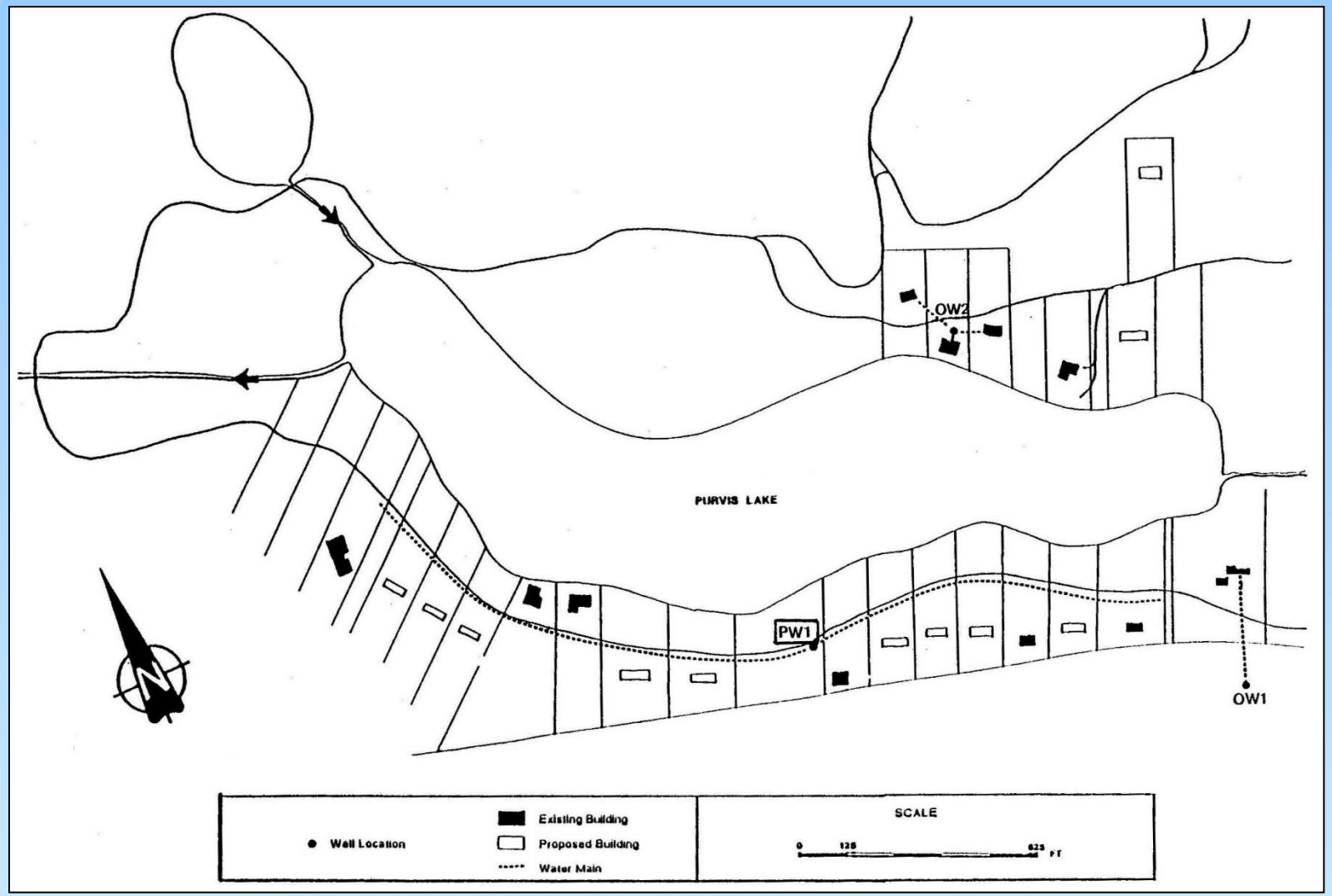
3. Are our parameter estimates representative?

Consistency with the geologic characterization?

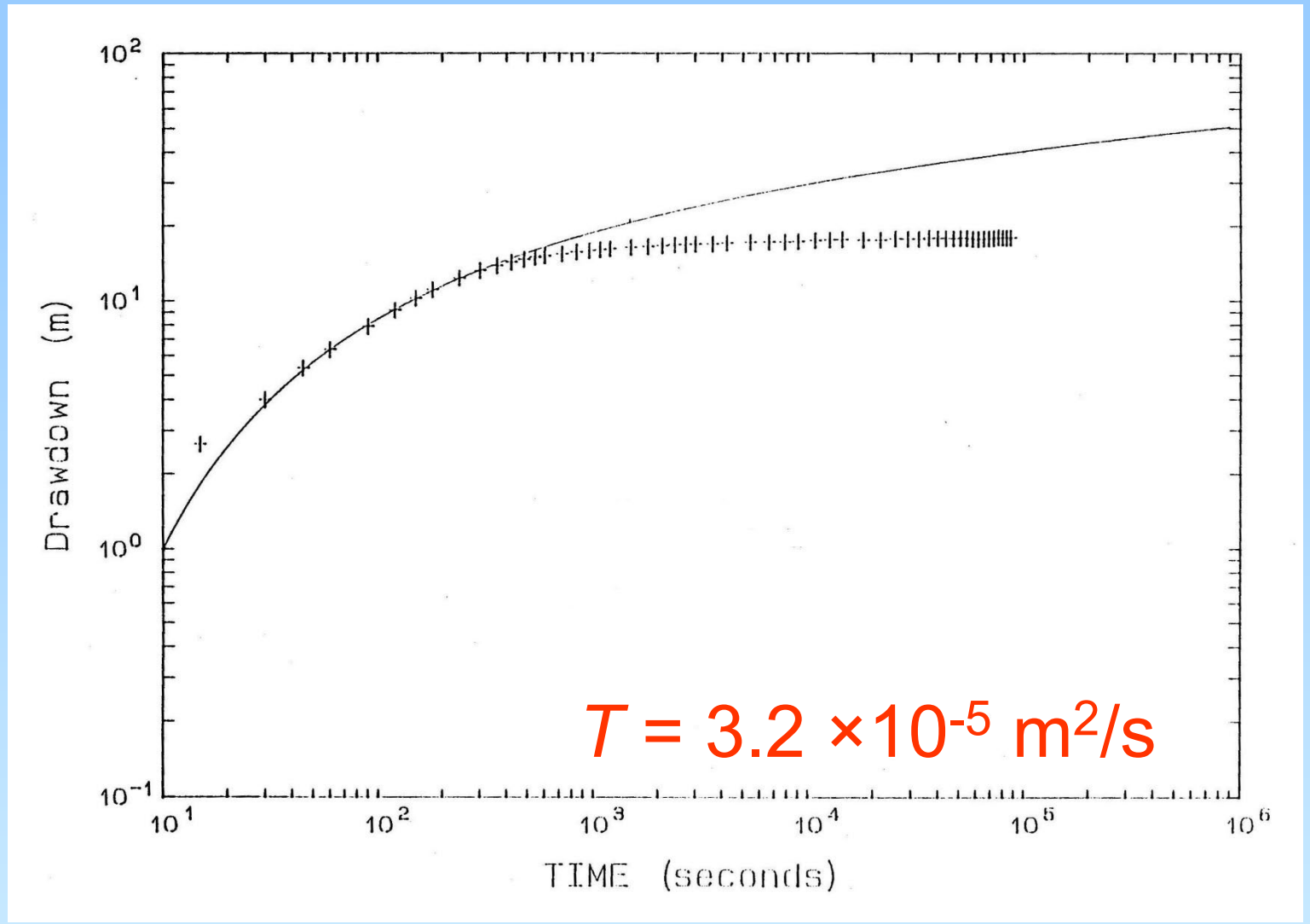


HCItasca Company, 2004: Feasibility Study for Victor Diamond Project

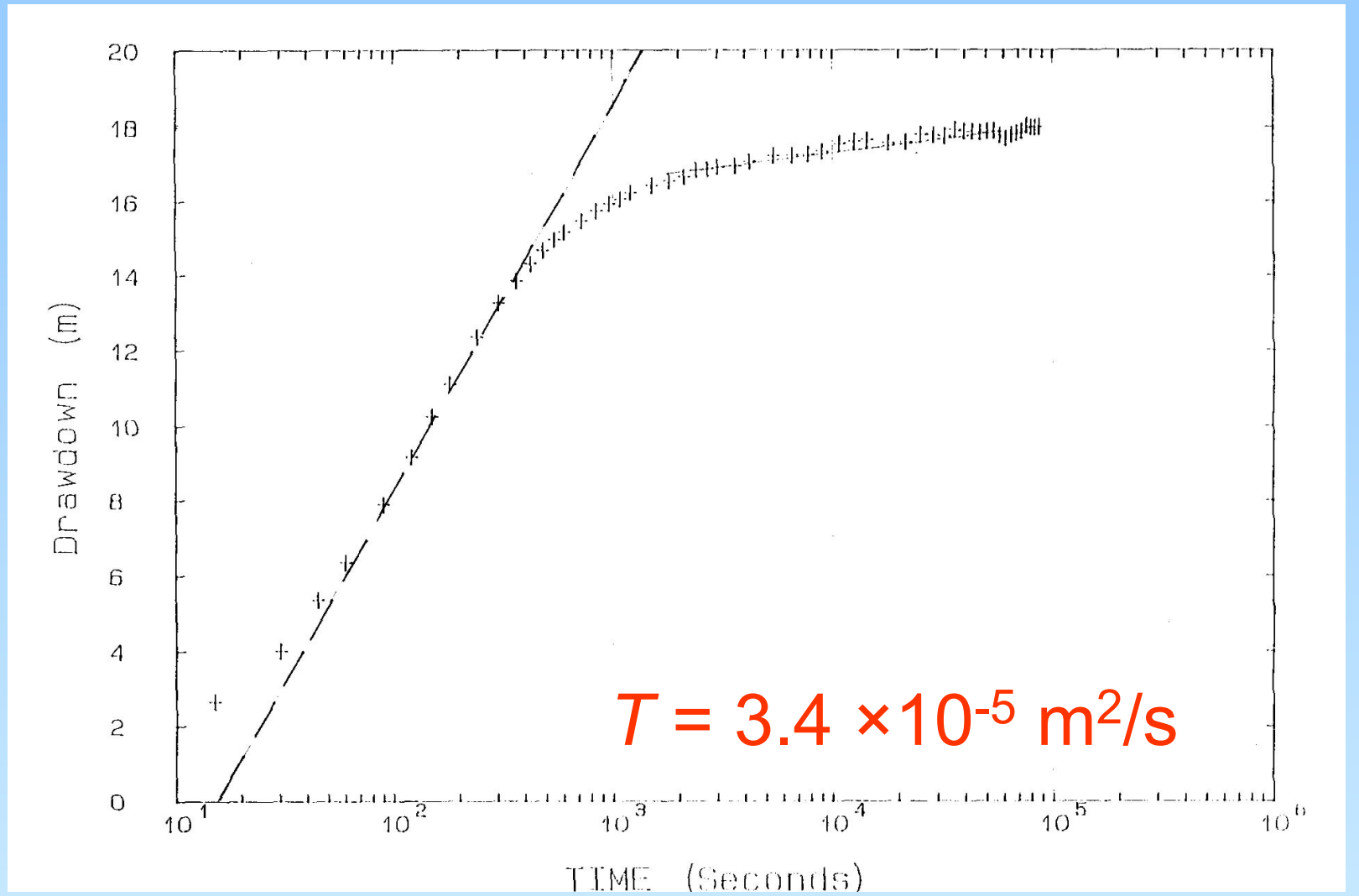
Sensibility Analysis: Case Study



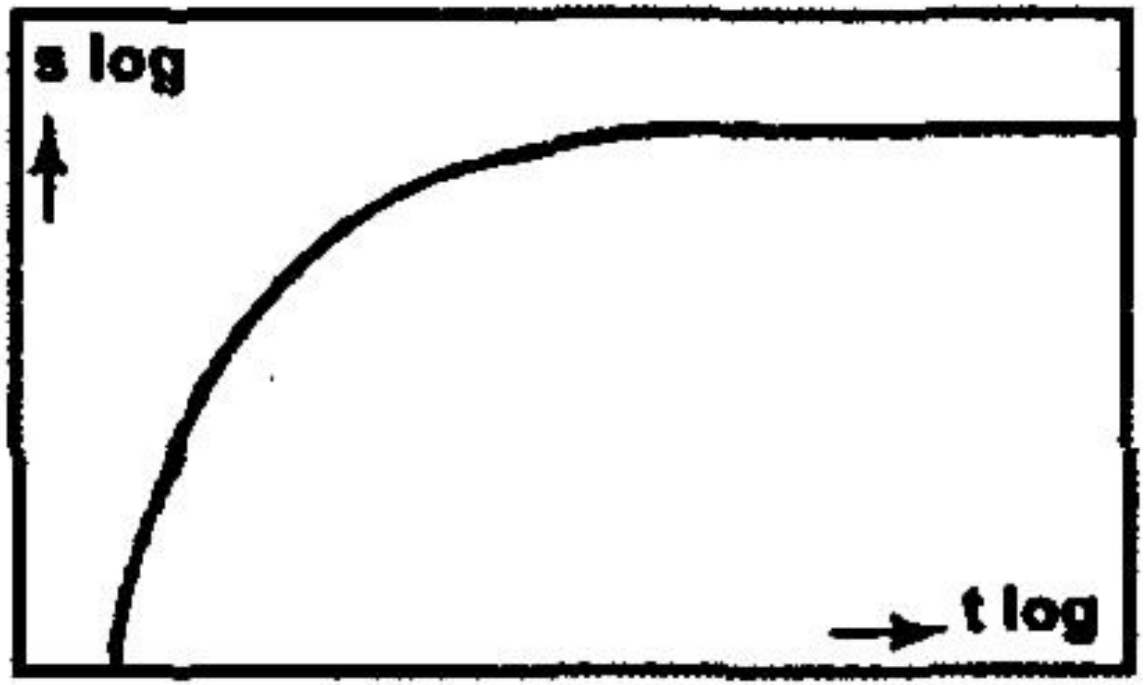
Theis analysis



Cooper-Jacob analysis

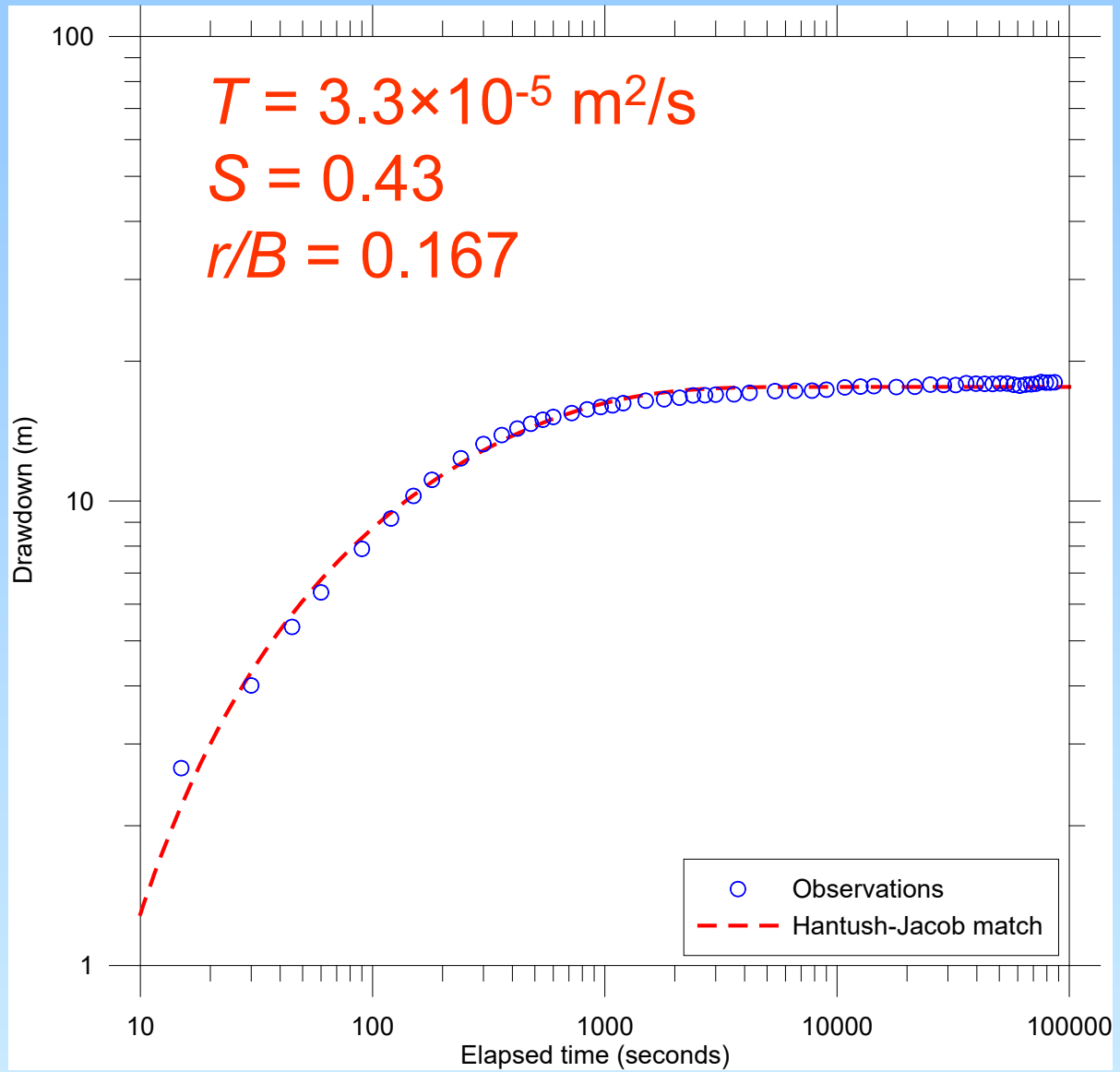


The drawdowns look like a typical leaky aquifer response



Let’s try to match the drawdowns with a leaky aquifer model (Hantush-Jacob).

Match with Hantush-Jacob solution



Evaluation of the Hantush-Jacob match

1. Nice fit!

2. What about the parameters?

$T = 3.3 \times 10^{-5}$ m^2/s √

$S = 0.43$ X

$r/B = 0.167$?

Check on the value of *r/B*

$$\frac{r}{B} = \frac{r}{\sqrt{\frac{Tb'}{K'}}} = 0.167$$

r = 0.0508 m

T = 3.3×10^{-5} m^2/s

b'= 10 m

→ **K' = 3.6×10^{-3} m/s**

For b = 10 m, $K = 3.3 \times 10^{-6}$ m/s

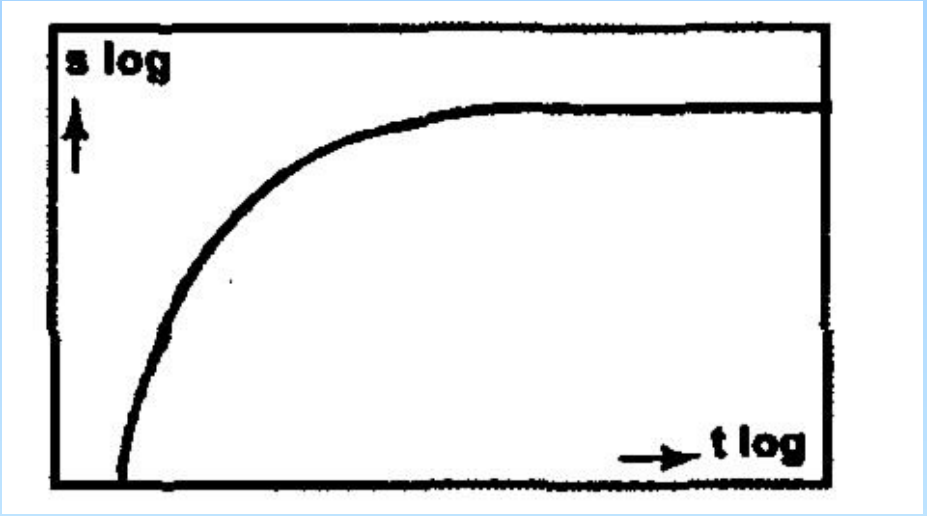
$K' = 3.6 \times 10^{-3}$ m/s

$K' = 1000\ K$

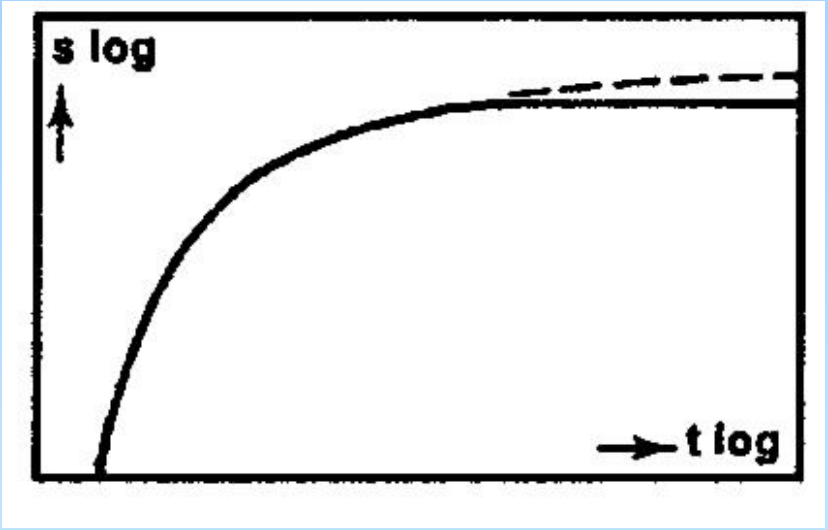
Can we use the Hantush-Jacob model?

Other conceptual models yield drawdowns that look like a typical leaky aquifer response

Leaky aquifer



Recharge boundary

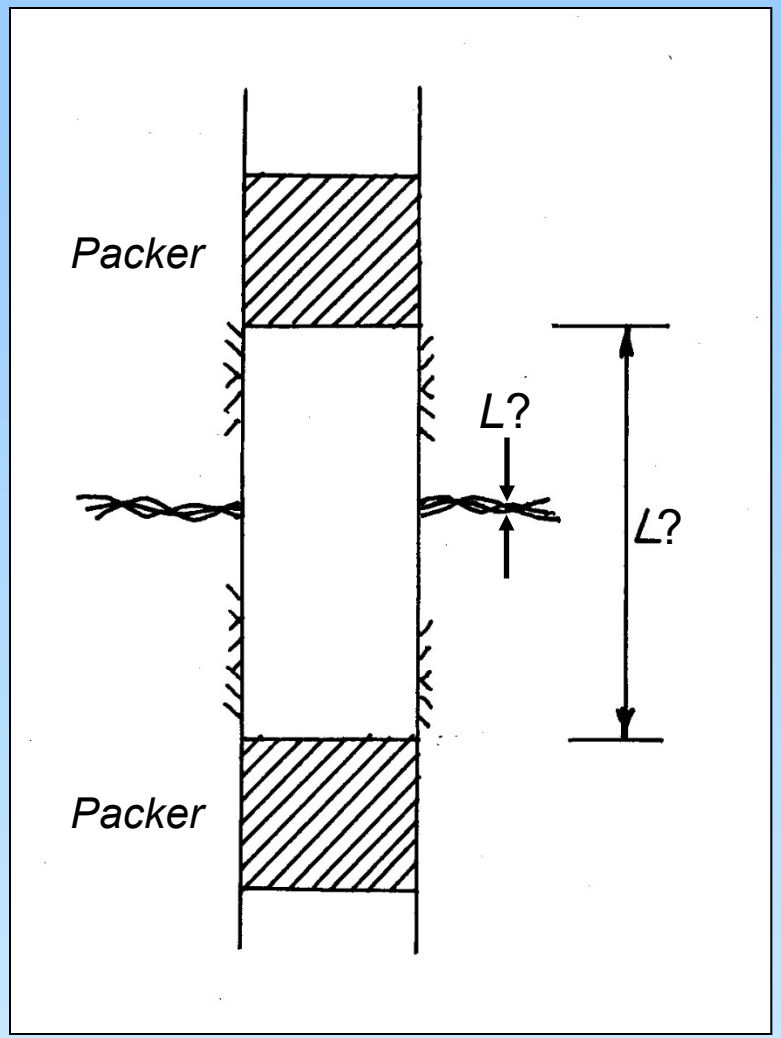


Representative parameter estimates?

There are several reasons our estimates may not be representative.

1. Our interpretation may introduce artifacts.
2. Our interpretations may depend on the scale of the investigation.

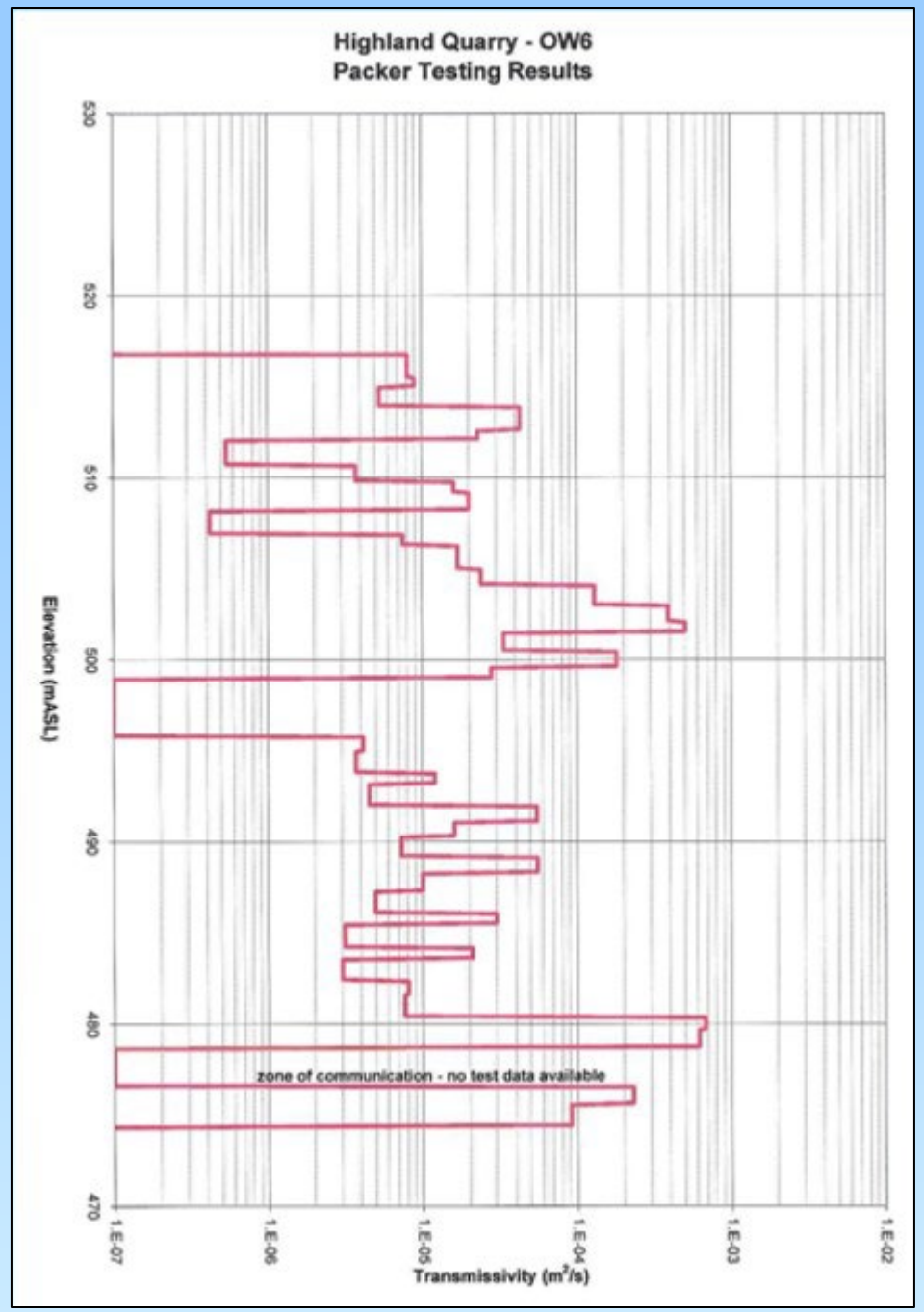
1. Artifacts



T is estimated, but for solute transport we require ***K***

$$K = \frac{T}{\text{Length}}$$

What length?



Averaging?

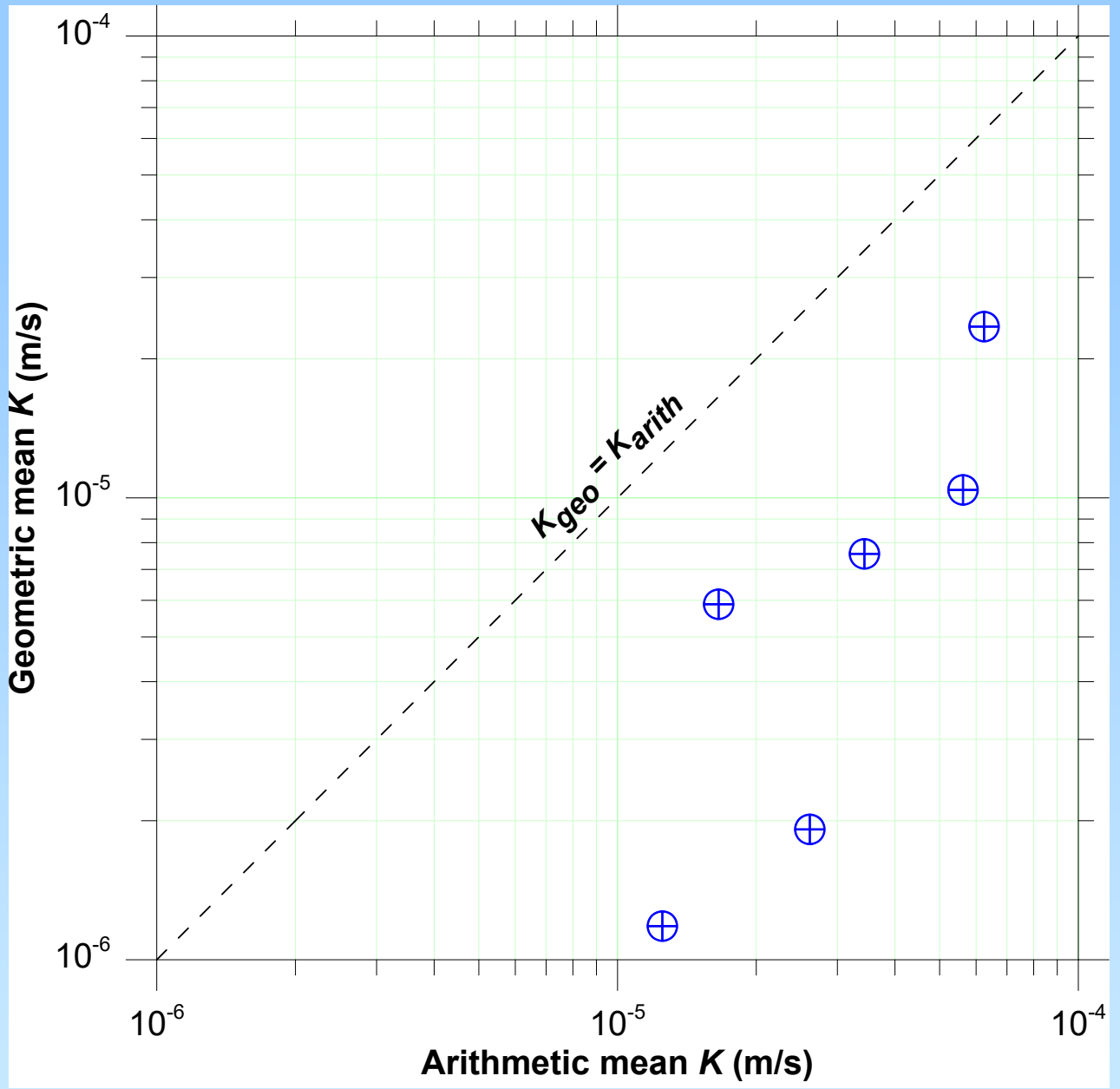
For radial flow:

$$K_{\mathrm{H-eff}} = \frac{\sum T_i}{\sum L_i}$$

For uniform packer spacing, *L*:

$$K_{\mathrm{H-eff}} = \frac{T}{B} = \frac{L \sum K_{Hi}}{nL} = K_{\mathrm{arith}}$$

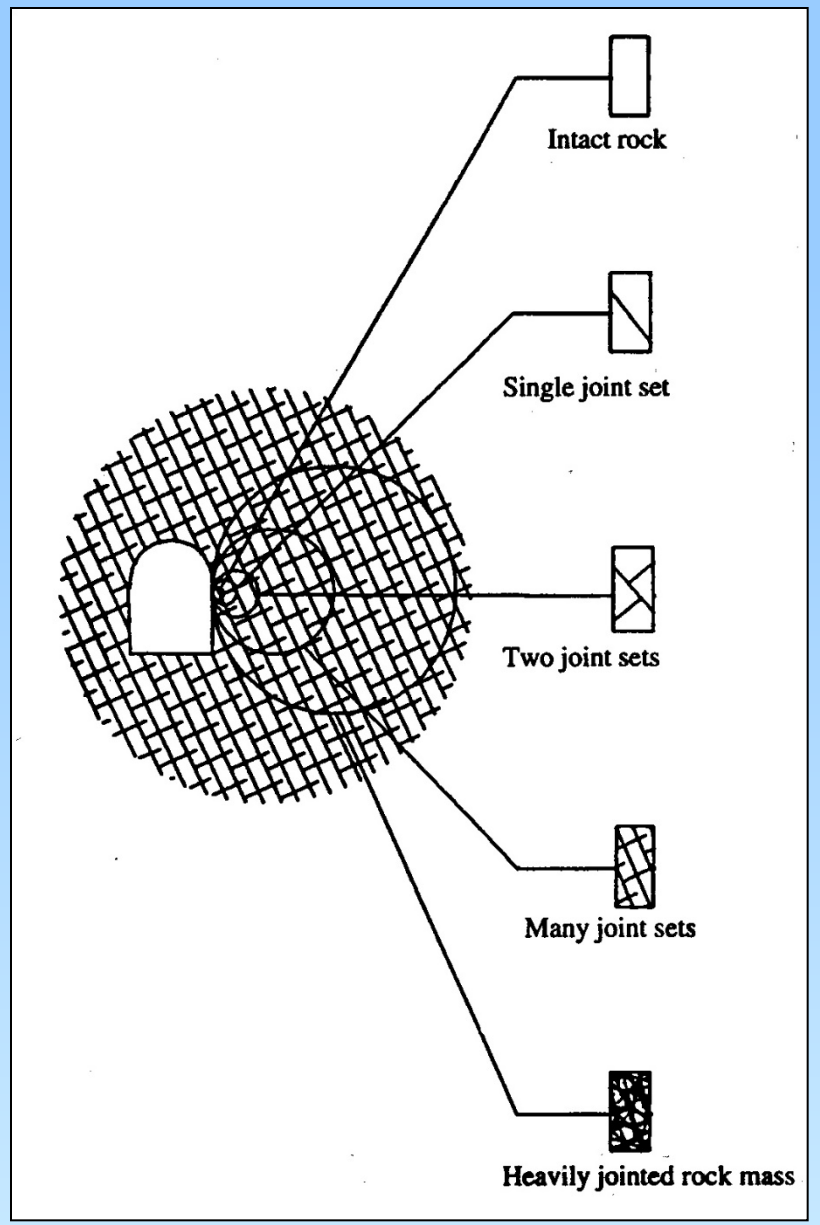
$$\neq K_{\mathrm{geo}}$$



$$K_{\text{arith}} > K_{\text{geo}}$$

2. Scale effects

Our impression of the magnitude of hydraulic conductivity may vary depending upon the scale of investigation and the support scale of our tests.



Hoek and Bray (1981)

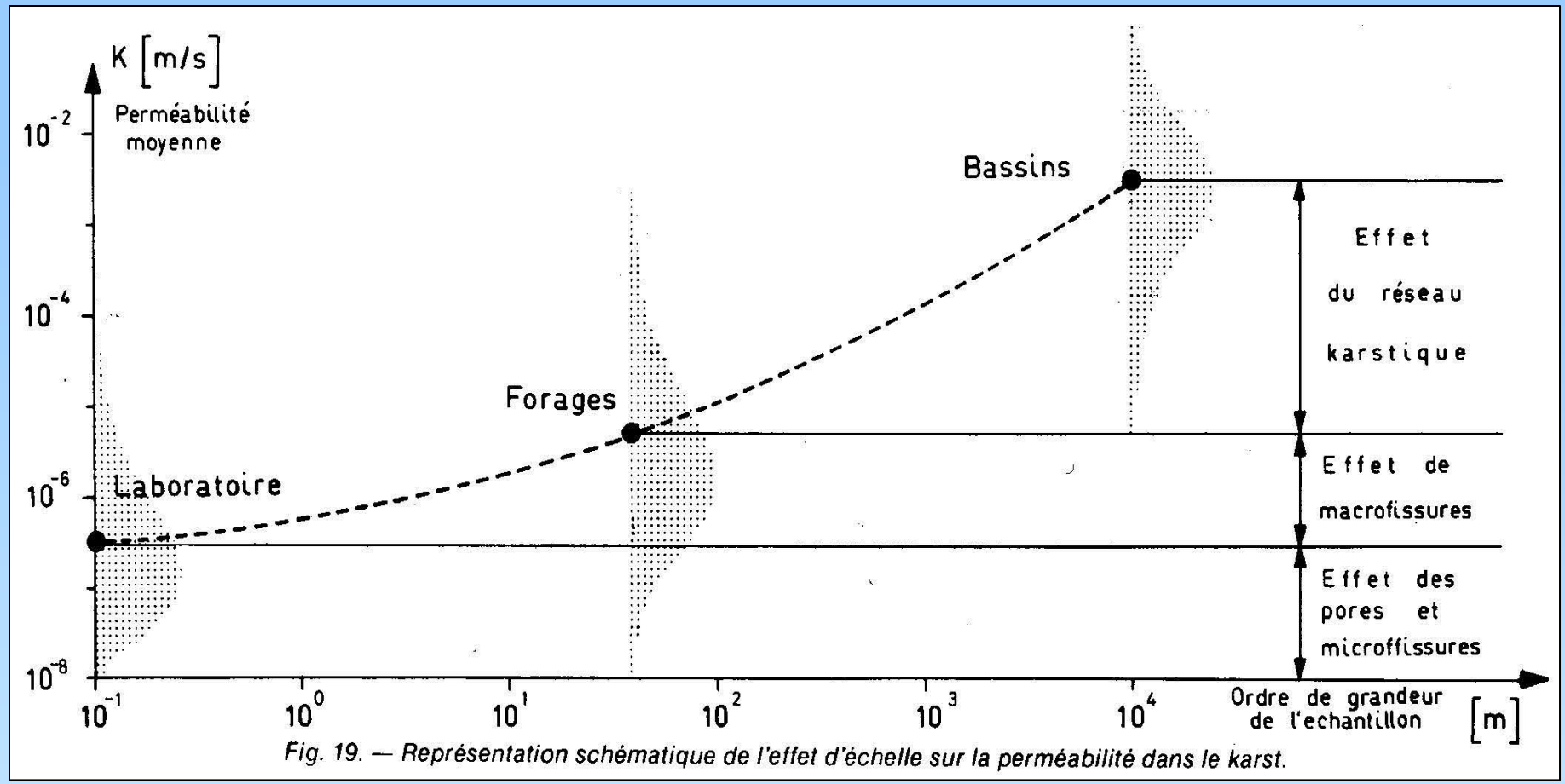


Fig. 19. — Représentation schématique de l'effet d'échelle sur la perméabilité dans le karst.

Kiraly (1975)

6. Perspective

- Hydrogeology is an *interpretative* discipline rather than an *exact* science.
- All of our parameter estimates are provisional.
- Our reporting should never be too precise.
- We should always ask ourselves whether our interpretations make sense (and whether we are willing to bet our salaries on them).

Parting thoughts

- Thank you very much for your attention.
- I am always working on my notes, and welcome corrections, suggestions for improvement, and requests for clarification.
- I love to discuss hydraulic testing data.
  My door is always open.

I can be contacted at:

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