

308

---

Q200210040002

Scientific Notebook # 510

21  
150

R

CAMERA

510

Walter Illman

### The Boorum & Pease® Quality Guarantee

The materials and craftsmanship that went into this product are of the finest quality. The pages are thread sewn, meaning they're bound to stay bound. The inks are moisture resistant and will not smear. And the uniform quality of the paper assures consistent rulings, excellent writing surface and erasability. If, at any time during normal use, this product does not perform to your expectations, we will replace it free of charge. Simply write to us:

Boorum & Pease Company

71 Clinton Road, Garden City, NY 11530

Attn: Marketing Services

Any correspondence should include the code number printed at the bottom of this page as well as the book title stamped at the bottom of the spine.

### One Good Book Deserves Many Others.

Look for the complete line of Boorum & Pease® Columnar, Journal, and Record books. Custom-designed books also available by special order. For more information about our Customized Book Program, contact your office products dealer. See back cover for other books in this series.

Made in U.S.A.

# Geostatistical Analysis of Pneumatic, Hydraulic<sup>1</sup> and Thermal Properties of Unsaturated Fractured Rocks at the ALRS (Apache Leap Research Site)

## Objectives of this Study:

- To investigate <sup>the</sup> variation in pneumatic, hydraulic, and thermal properties of unsaturated fractured tuffs at the Apache Leap Research Site, near Superior, AZ.
- To summarize the statistical data on <sup>2</sup> properties hydrological properties including its model structure, covariance type, mean, variance, and skewness
- To establish which parameters vary the most in a statistical sense so that subsequent numerical modeling can incorporate this information.

Computers used: PC in my ENWRA office  
(San Antonio, TX)

Code used: ISATIS geostatistical package  
Excel 97 SR-2 spreadsheet  
Version 3.1.3 RWF 9/30/02

Collaborators: Debra Hughes  
Randal Fedars - RWF  
Cynthia Dithwiddie



2. 3/31/2002

11/19/2001 (TEF)

①

To do for TEF report geometric means

Add a section on:

Comparison of ALRS &amp; YM data

→ Ins. In testing of Processes AMR

→ Gaugelin's W&amp;I reports

Surface BH data

→ Comparison of matrix values.

→ Fracture densities → I am not so sure how one would apply the correction factor.

orientation bias

orientation of fractures

corrected

yes, corrected

Check if quoted means are arithmetic/geom. mean.

$$K_{sat} = 21.31 \times 10^{-9} \text{ m/s}$$

$$K = \frac{k}{\mu} \rho \gamma$$

$$k = \frac{K \mu}{\rho \gamma} = \frac{(21.31 \times 10^{-9} \text{ m/s})(1.00 \times 10^{-3} \text{ N/s})}{(1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)} = 2.17 \times 10^{-15} \text{ m}^2$$

3/31/2002

3/31/2002

3

11/19/2001

(TEF)

②

①

Calculation of geometric means

	Geo. mean	Arith. mean
Field <del>ha</del> low	$7.25 \times 10^{-16} \text{ m}^2$ $7.89 \times 10^{-16} \text{ m}^2$	$2.71 \times 10^{-14} \text{ m}$ $2.77 \times 10^{-14} \text{ m}$
Lab. <del>ha</del> low	$1.27 \times 10^{-15} \text{ m}^2$ $5.66 \times 10^{-16} \text{ m}^2$	$5.71 \times 10^{-15} \text{ m}$ $2.18 \times 10^{-15} \text{ m}$

WI  
3/31/02

Table 4-2 to calculate the  
Look at geometric mean values → Take  $10^{\wedge \text{value}}$   
to get geo mean of variables.  
Go to p. 20-22 for  
spreadsheet used to calculate geometric/arithmetic means

②

Fracture density values → corrections done  
→ Type in material from Rasmussen et al (1990)  
Report

③

Check Report

stochastic continuum vs. dual  
continuum  
approach

Think about this and properly state  
the reasons why we can use statistics  
from ALRS at Yucca Mtn.

WI 3/31/02

Information potentially subject to copyright protection was redacted from this location. The redacted material is from the following reference:

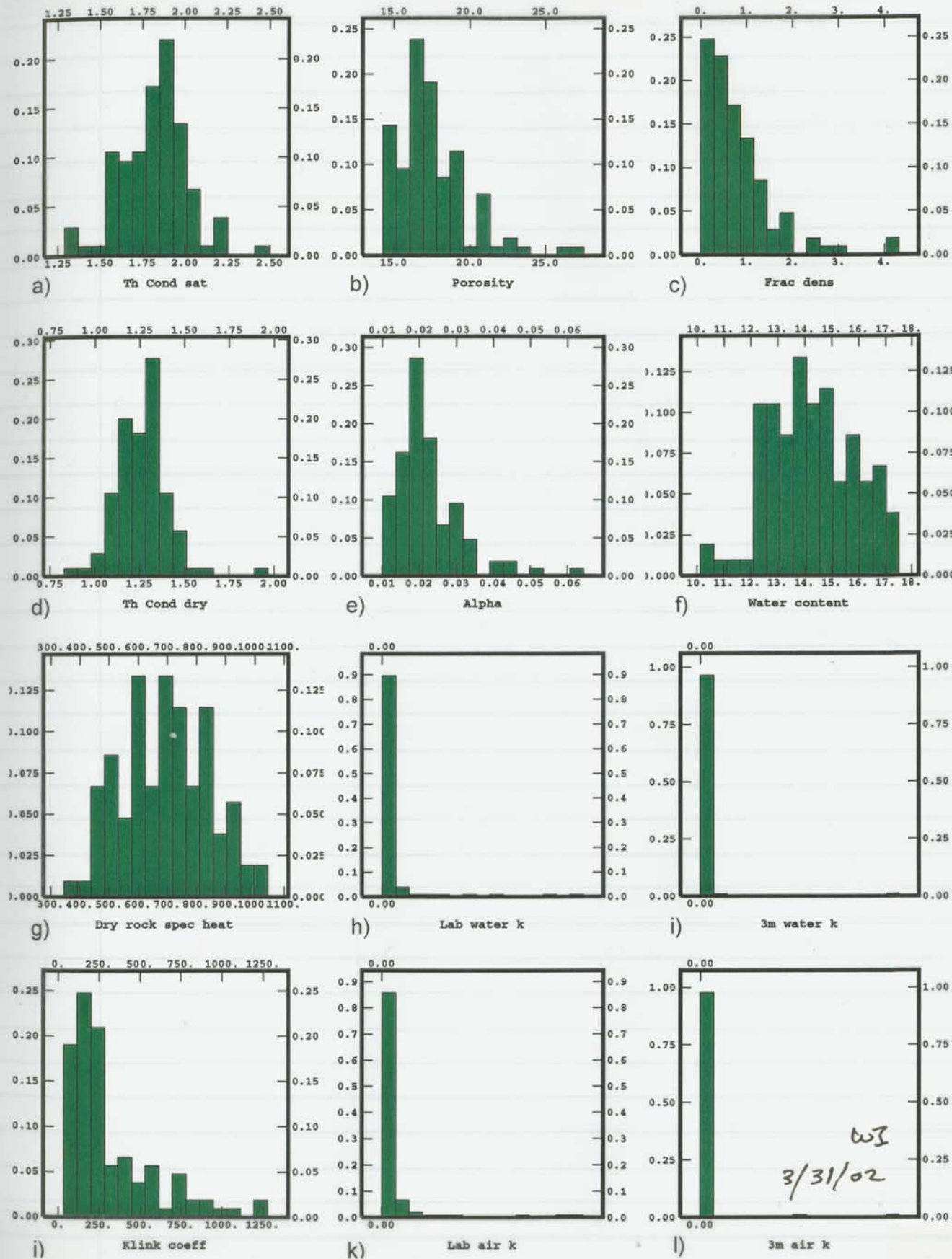
Illman, W.A. and S.P. Neuman. "Type-Curve Interpretation of a Cross-Hole Pneumatic Test in Unsaturated Fractured Tuff." Figure 1. Water Resources Research. Vol. 37, No. 3. pp. 583-604. 2001.

Data originates from the Apache Leap Research Site (ALRS) located near Superior, AZ.

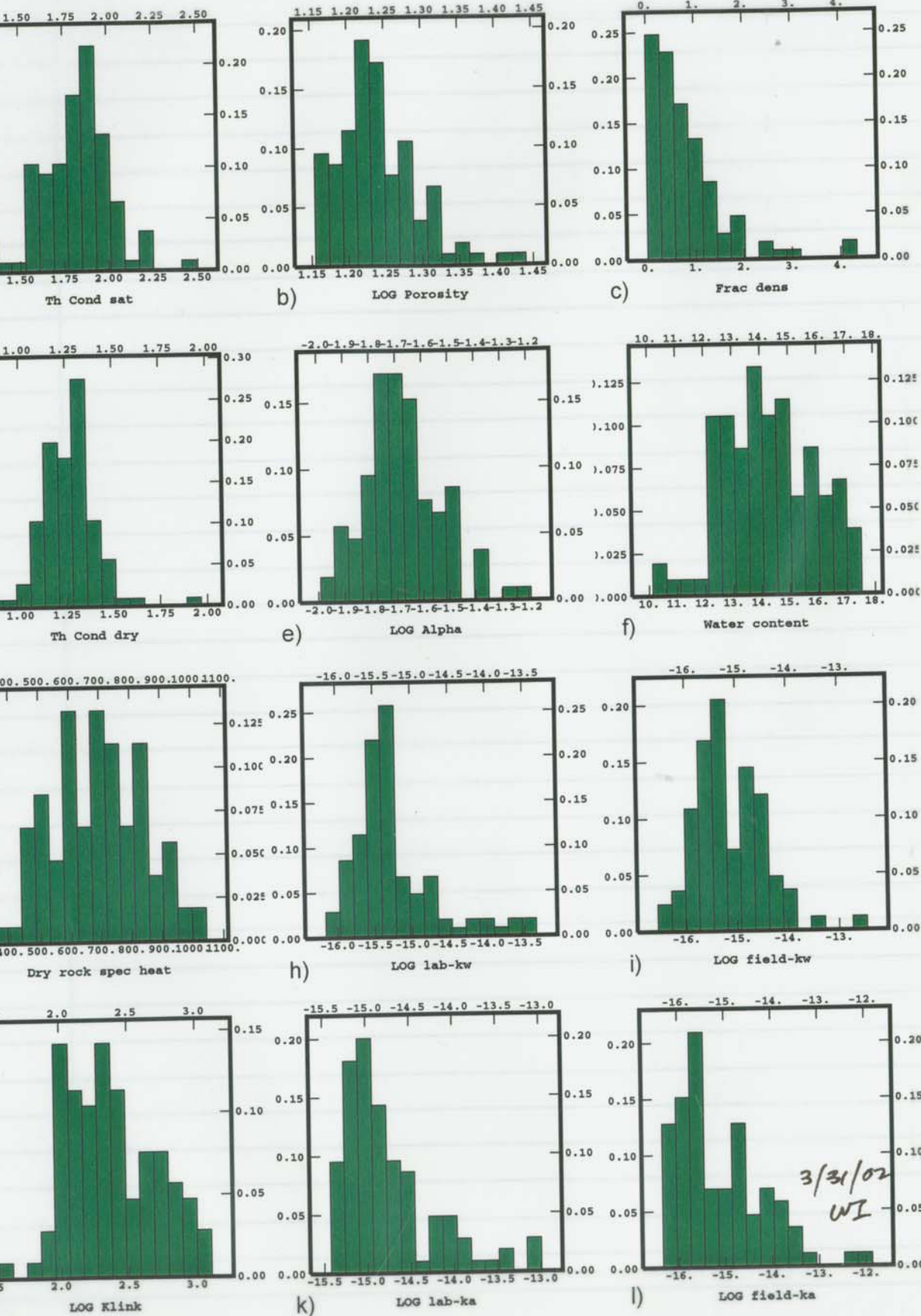
The site is approximately 100 miles north of Tucson, AZ.

Details to the site can be found in various NUREGs completed for the NRC.

3/31/02 WJ







3/31/02

Information potentially subject to copyright protection was redacted from this location. The redacted material is from the following reference:

Illman, W.A. and S.P. Neuman. "Type-Curve Interpretation of a Cross-Hole Pneumatic Test in Unsaturated Fractured Tuff." Figure 6. Water Resources Research. Vol. 37, No. 3. pp. 583-604. 2001.

*This figure suggests that fracture density is not a good measure of air permeability at the site.*

3/31/02  
WI

3/31/02 WI

Information potentially subject to copyright protection was redacted from page 8. The redacted material is from the following reference:

Vesselinov. Figure 3: A three-dimensional perspective of boreholes.... 2000. Further information on this reference is unknown.

Information potentially subject to copyright protection was redacted from page 9. The redacted material is from the following reference:

Illman, W.A. and S.P. Neuman. "Type-Curve Interpretation of a Cross-Hole Pneumatic Test in Unsaturated Fractured Tuff." Figure 2. Water Resources Research. Vol. 37, No. 3. pp. 583-604. 2001.

Location of data sets used for the  
geostatistical analysis conducted in  
this report

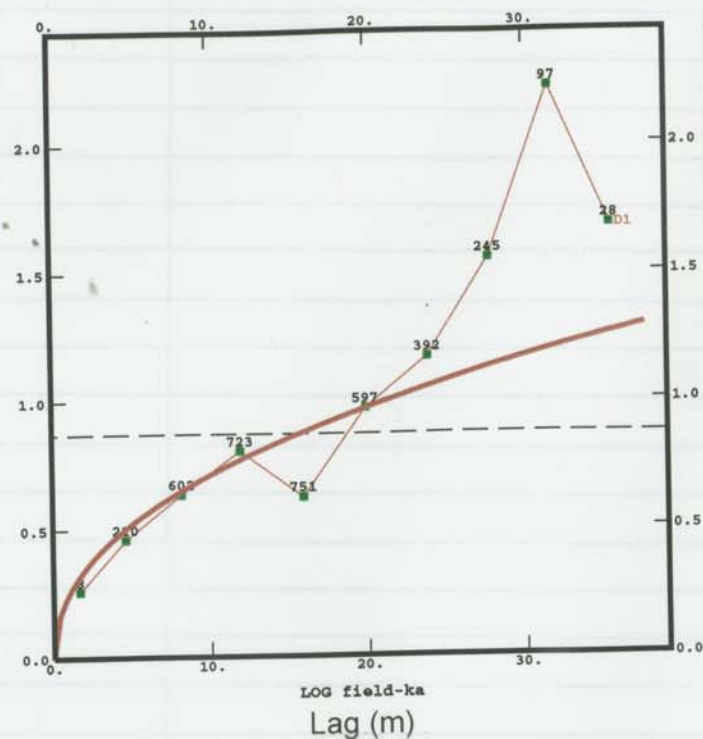
The W-series, G-series, and V-series  
boreholes were drilled after the  
completion of X, Y-, Z & series  
boreholes

3/31/02 WI

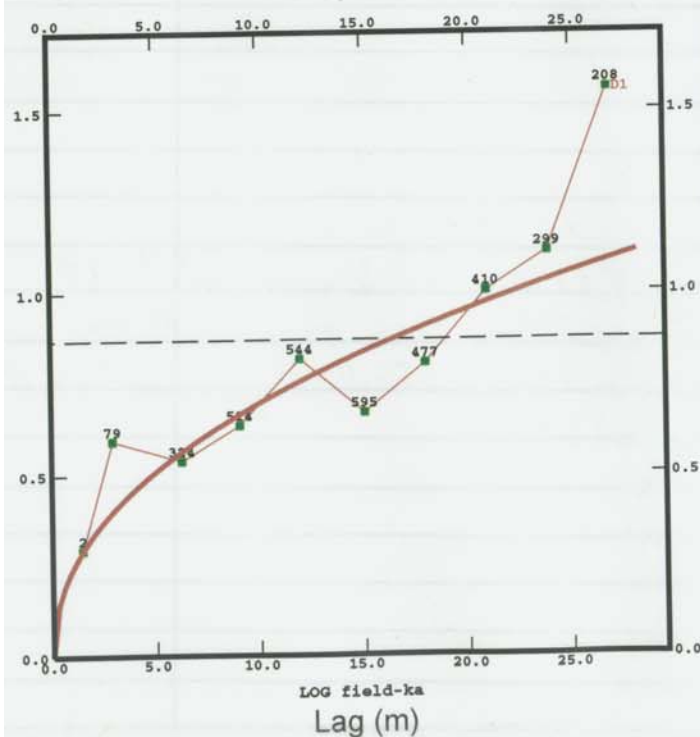
There should be additional boreholes at  
the site - drilled after the completion  
of pneumatic tests conducted by Illman (1988)  
and Illman et al. (1998)

3/31/02 WI

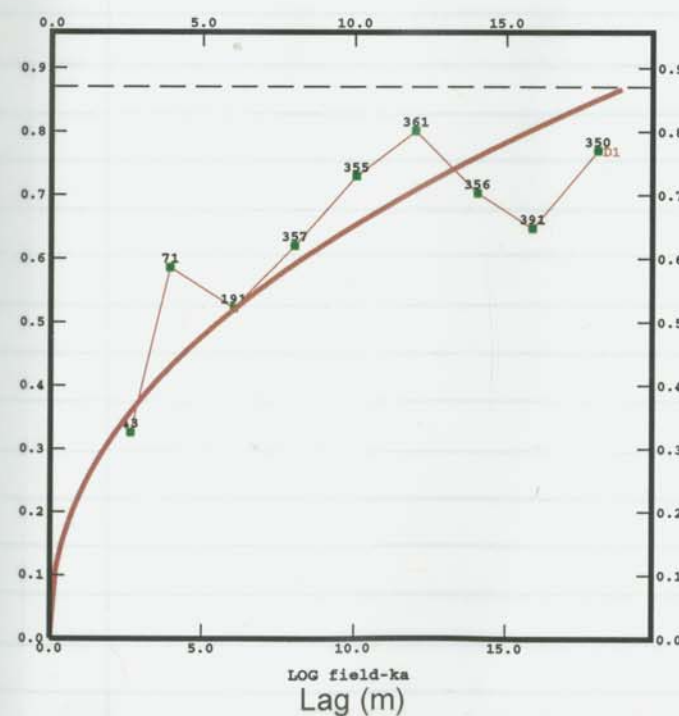
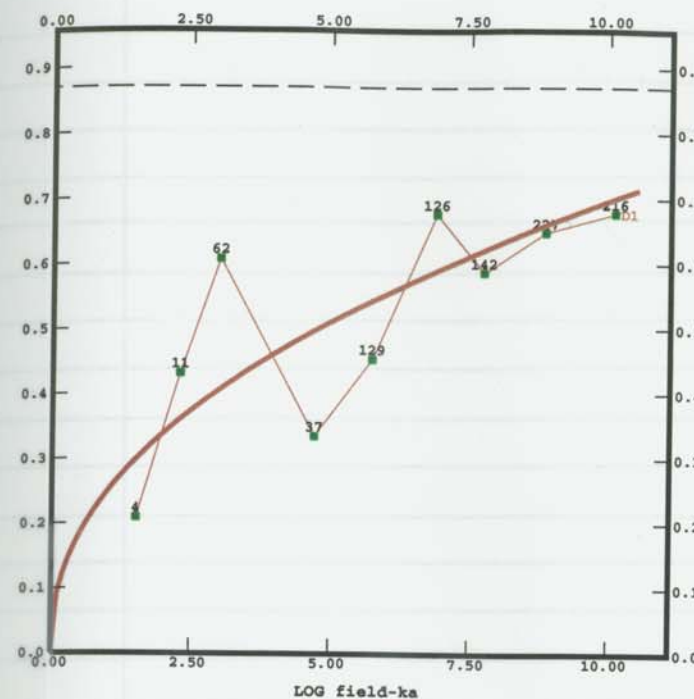




parameters should  
be defined in the  
ISATIS manual.

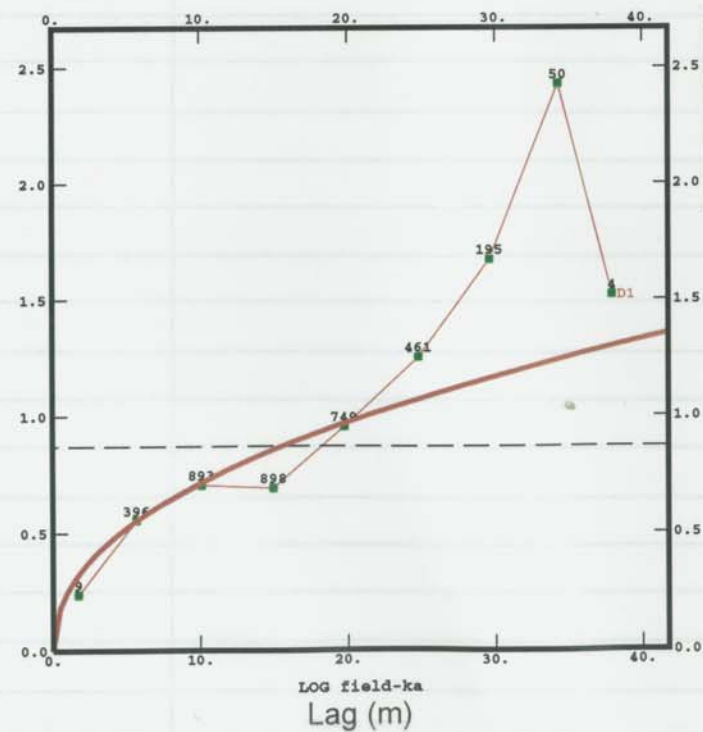
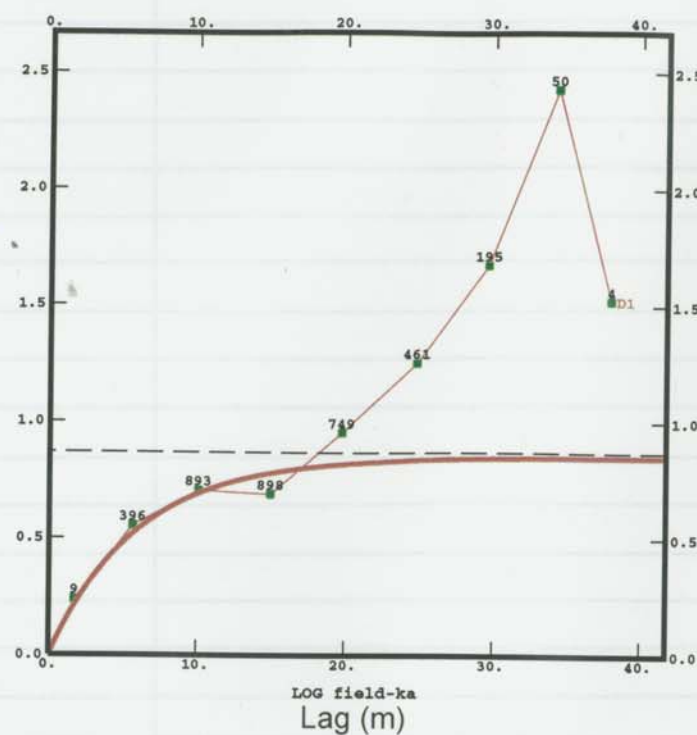


3/31/02 WI

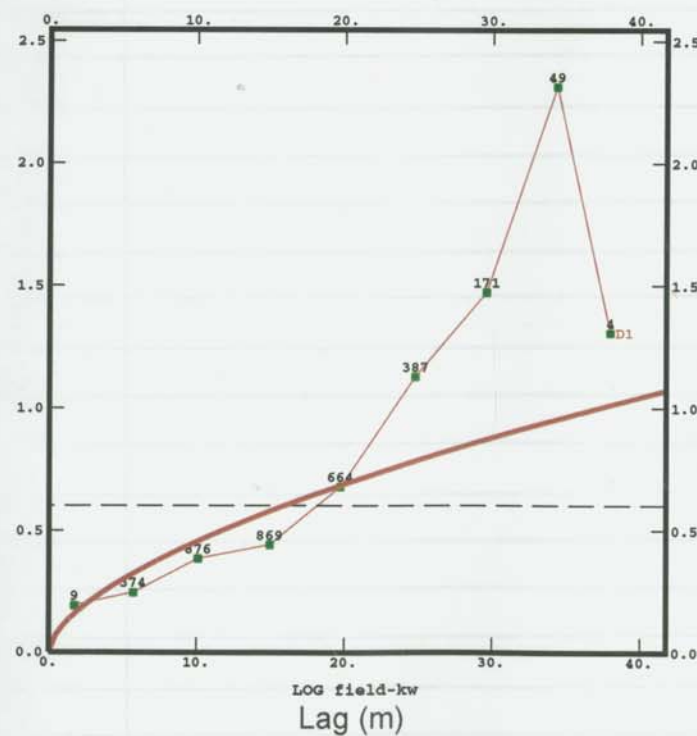
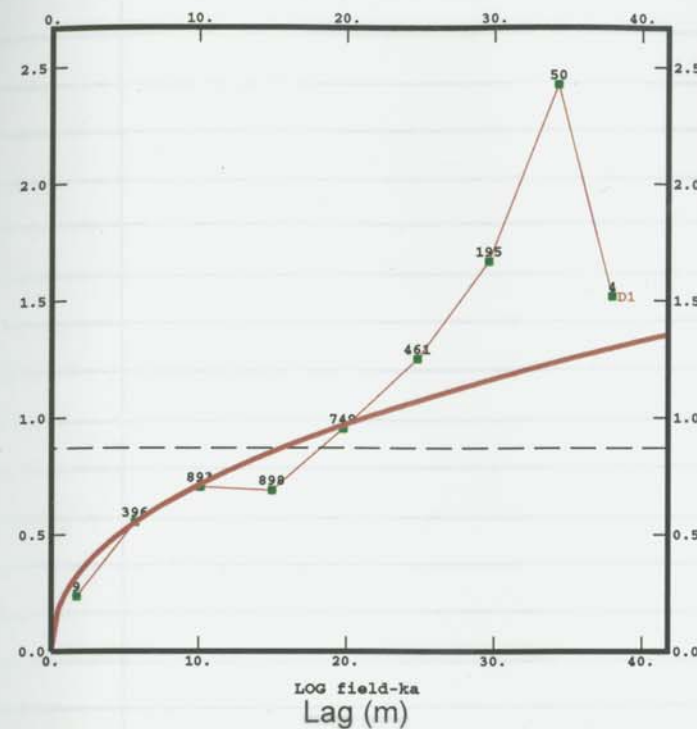


3/31/02 WI

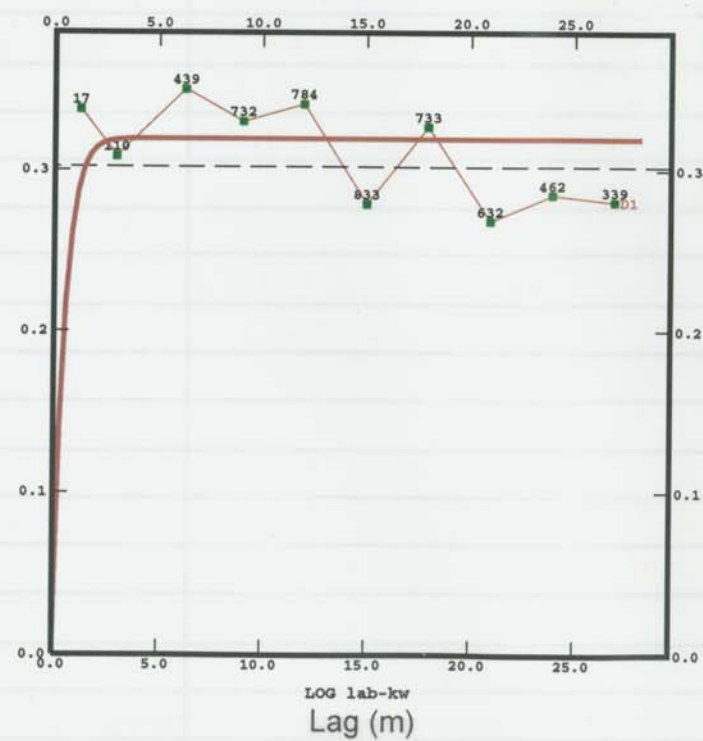
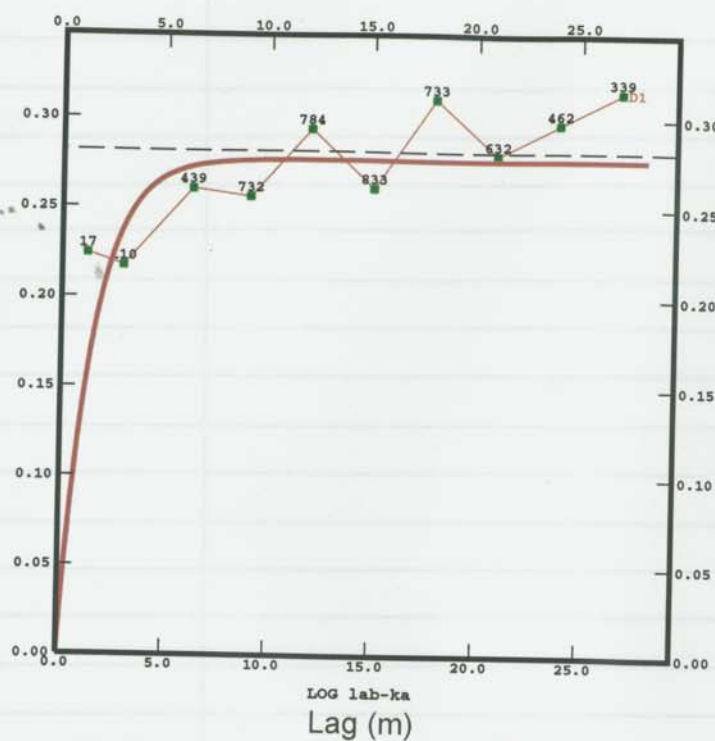




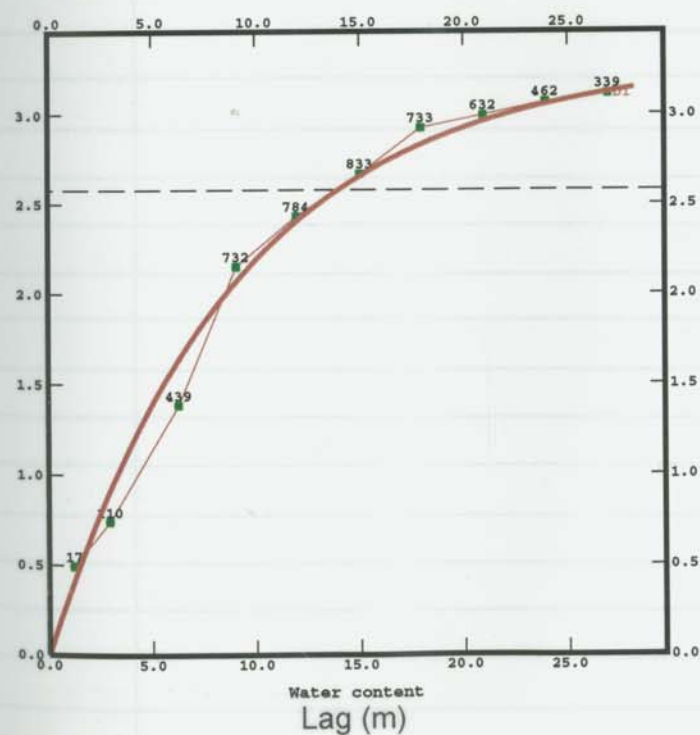
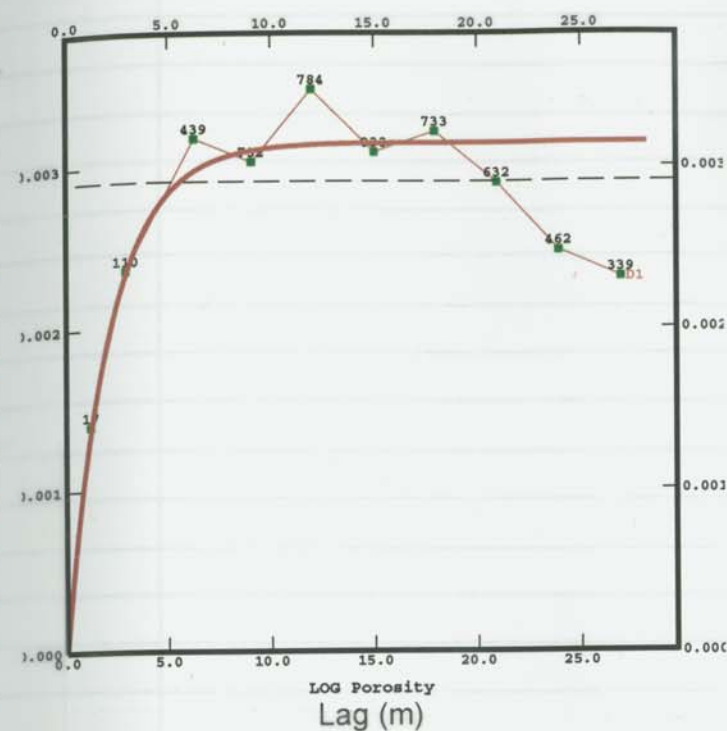
3/31/02 WI



3/31/02 WI

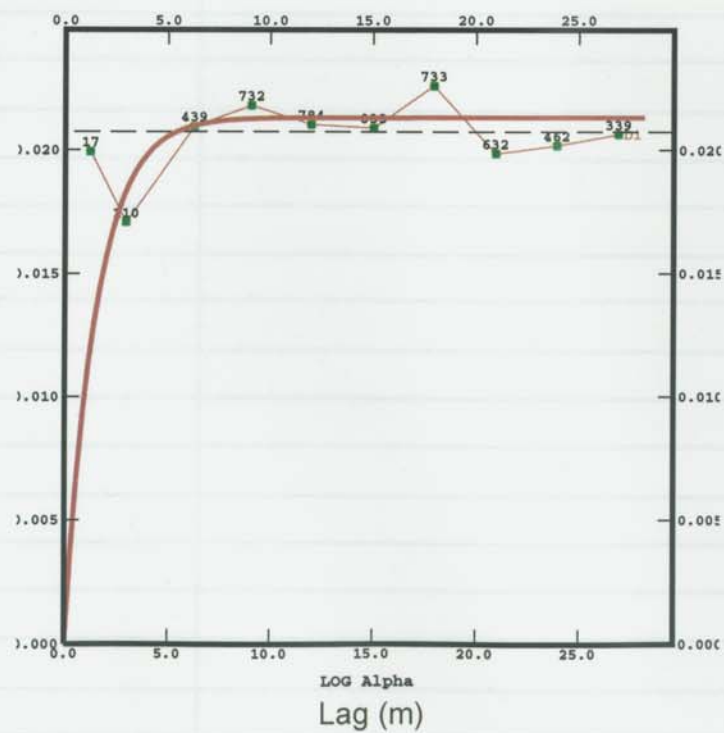
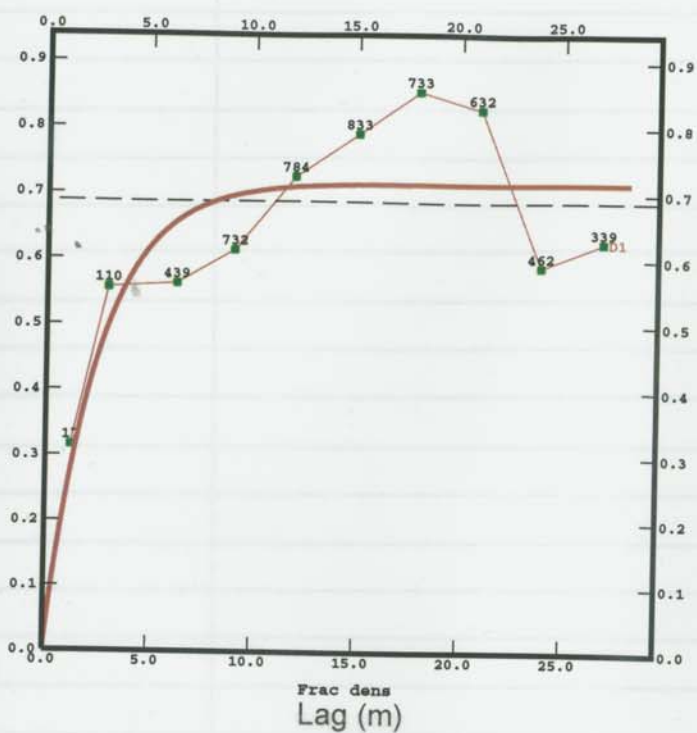


3/31/02 WZ

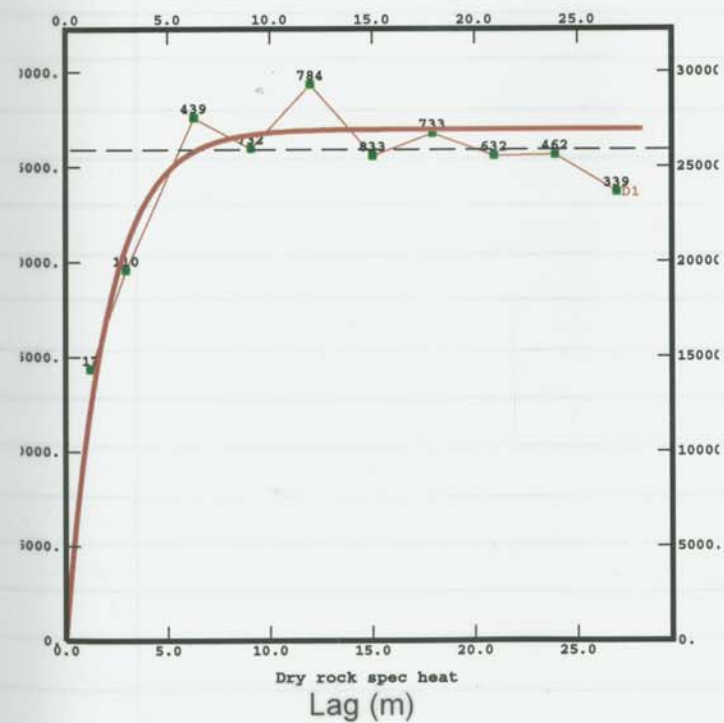
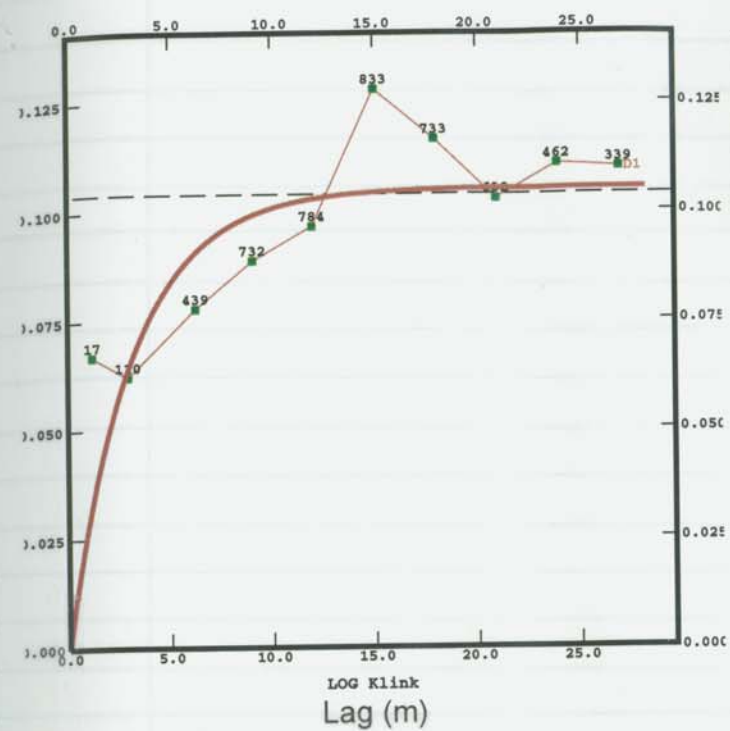


3/31/02 WZ



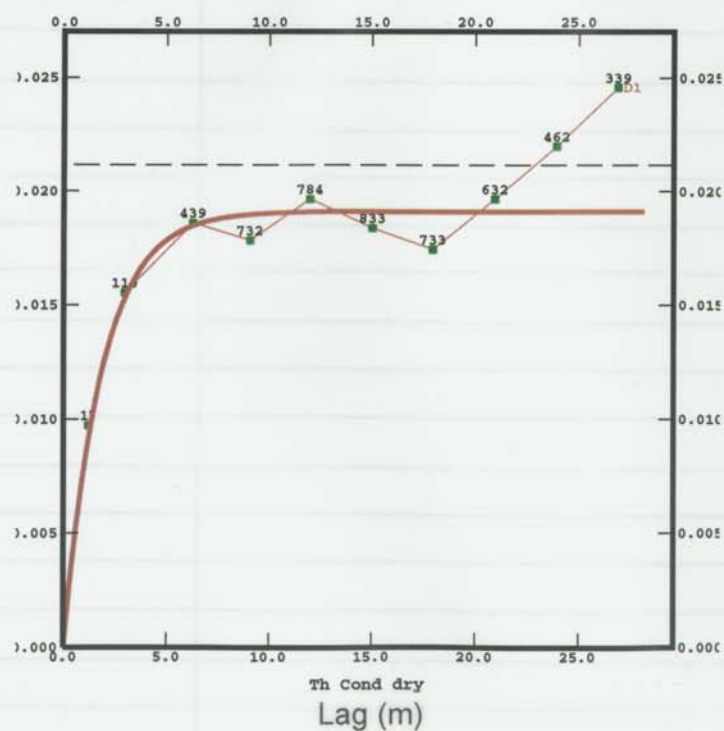
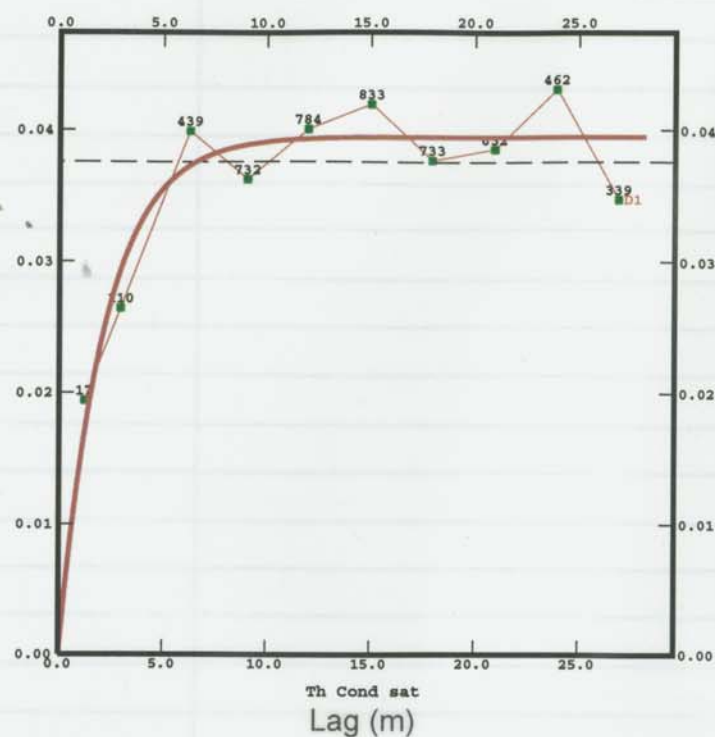


3/31/02 wI



3/31/02 wI





3/31/02 WI

## Geostatistical Analysis

- ① Results and draft report were submitted to Debra Hughes on late November. All tasks were completed on time and within budget.
- ② As the submitted deliverable was a draft, figures have not been modified at that time so that it would conform with ENR&A deliverable standards:
  - numbers on axes are too small
  - values are given on all 4 <sup>WI 3/31/02</sup> ~~axes~~ sides
- ③ Much of the effort was expended on writing the draft deliverable and refining the texts.
 

RVF for WI 10/1/02
- ④ Recent work included a incorporation of additional material by Randy Fedors and Cynthia Pinnodde of the ENR&A. Those authors have made a significant contribution in associating the ARS data with Yucca Mtn.

3/31/02 WI



13/1/02  
20

Spreadsheet employed to calculate the geom/cr<sub>1/2</sub> mean

of LOG<sub>10</sub> k<sub>a</sub>, b<sub>0</sub> values from the laboratory and the field 21

Field k <sub>a</sub>	LOG10 k <sub>a</sub>	Field k <sub>w</sub>	LOG10 k <sub>w</sub>	Lab k <sub>a</sub>	LOG10 k <sub>a</sub>	Lab k <sub>w</sub>	LOG10 k <sub>w</sub>
4.73E-16	-1.53E+01	3.00E-16	-1.55E+01	8.43E-15	-1.41E+01	1.46E-15	-1.48E+01
2.13E-16	-1.57E+01	3.68E-17	-1.64E+01	1.51E-15	-1.48E+01	4.80E-16	-1.53E+01
6.63E-15	-1.42E+01	2.97E-16	-1.55E+01	1.36E-15	-1.49E+01	2.24E-16	-1.56E+01
1.00E-16	-1.60E+01	1.06E-16	-1.60E+01	5.35E-16	-1.53E+01	1.23E-16	-1.59E+01
5.44E-17	-1.63E+01	1.16E-16	-1.59E+01	4.40E-16	-1.54E+01	1.02E-16	-1.60E+01
2.54E-15	-1.46E+01	5.92E-15	-1.42E+01	4.17E-16	-1.54E+01	1.41E-16	-1.59E+01
7.92E-17	-1.61E+01	5.74E-16	-1.52E+01	3.98E-16	-1.54E+01	1.50E-16	-1.58E+01
1.59E-15	-1.48E+01	4.42E-16	-1.54E+01	2.55E-14	-1.36E+01	1.49E-14	-1.38E+01
6.61E-14	-1.32E+01	2.62E-15	-1.46E+01	1.71E-15	-1.48E+01	3.43E-16	-1.55E+01
1.37E-15	-1.49E+01	1.94E-15	-1.47E+01	1.35E-15	-1.49E+01	4.57E-16	-1.53E+01
9.83E-16	-1.50E+01	8.75E-16	-1.51E+01	8.19E-16	-1.51E+01	7.05E-17	-1.62E+01
2.06E-15	-1.47E+01	1.27E-15	-1.49E+01	6.03E-16	-1.52E+01	2.51E-16	-1.56E+01
1.59E-16	-1.58E+01	1.96E-16	-1.57E+01	2.50E-15	-1.46E+01	1.61E-15	-1.48E+01
1.98E-16	-1.57E+01	4.87E-16	-1.53E+01	2.04E-15	-1.47E+01	1.14E-15	-1.49E+01
9.87E-17	-1.60E+01	9.81E-17	-1.60E+01	6.63E-15	-1.42E+01	3.84E-15	-1.44E+01
3.97E-15	-1.44E+01	2.07E-15	-1.47E+01	9.94E-16	-1.50E+01	4.94E-16	-1.53E+01
9.18E-15	-1.40E+01	2.54E-15	-1.46E+01	1.35E-15	-1.49E+01	6.75E-16	-1.52E+01
1.44E-15	-1.48E+01	1.32E-15	-1.49E+01	1.52E-15	-1.48E+01	8.31E-16	-1.51E+01
1.79E-16	-1.57E+01	4.10E-16	-1.54E+01	6.51E-16	-1.52E+01	2.79E-16	-1.56E+01
9.90E-17	-1.60E+01	7.05E-17	-1.62E+01	3.07E-15	-1.45E+01	7.04E-16	-1.52E+01
2.21E-16	-1.57E+01	3.46E-16	-1.55E+01	1.27E-15	-1.49E+01	4.70E-16	-1.53E+01
8.30E-17	-1.61E+01	2.09E-16	-1.57E+01	2.76E-15	-1.46E+01	3.75E-16	-1.54E+01
8.32E-17	-1.61E+01	4.98E-16	-1.53E+01	1.63E-15	-1.48E+01	2.81E-16	-1.56E+01
6.75E-17	-1.62E+01	1.14E-16	-1.59E+01	2.17E-15	-1.47E+01	2.74E-16	-1.56E+01
1.33E-15	-1.49E+01	2.92E-16	-1.55E+01	1.48E-15	-1.48E+01	3.17E-16	-1.55E+01
2.87E-16	-1.55E+01	1.98E-16	-1.57E+01	9.92E-16	-1.50E+01	4.75E-16	-1.53E+01
1.66E-15	-1.48E+01	2.76E-17	-1.66E+01	9.51E-16	-1.50E+01	5.71E-16	-1.52E+01
1.60E-16	-1.58E+01	4.40E-16	-1.54E+01	6.30E-16	-1.52E+01	2.98E-16	-1.55E+01
5.18E-17	-1.63E+01	1.51E-16	-1.58E+01	6.00E-16	-1.52E+01	3.32E-16	-1.55E+01
3.40E-16	-1.55E+01	1.37E-16	-1.59E+01	5.27E-16	-1.53E+01	2.56E-16	-1.56E+01
3.43E-16	-1.55E+01	1.29E-16	-1.59E+01	6.01E-16	-1.52E+01	2.09E-16	-1.57E+01
2.09E-16	-1.57E+01	1.08E-16	-1.60E+01	9.04E-16	-1.50E+01	5.16E-16	-1.53E+01
1.92E-16	-1.57E+01	5.25E-15	-1.43E+01	7.20E-16	-1.51E+01	3.82E-16	-1.54E+01
9.69E-17	-1.60E+01	5.96E-16	-1.52E+01	8.50E-16	-1.51E+01	4.43E-16	-1.54E+01
5.10E-15	-1.43E+01	5.11E-16	-1.53E+01	5.20E-16	-1.53E+01	2.17E-16	-1.57E+01
4.21E-16	-1.54E+01	1.28E-15	-1.49E+01	6.59E-16	-1.52E+01	1.77E-16	-1.58E+01
1.10E-15	-1.50E+01	4.27E-15	-1.44E+01	3.52E-15	-1.45E+01	4.71E-16	-1.53E+01
1.65E-15	-1.48E+01	1.48E-15	-1.48E+01	1.78E-15	-1.47E+01	3.66E-16	-1.54E+01
1.68E-14	-1.38E+01	9.15E-16	-1.50E+01	6.02E-16	-1.52E+01	1.13E-16	-1.59E+01
1.57E-15	-1.48E+01	3.63E-16	-1.54E+01	6.56E-16	-1.52E+01	1.04E-16	-1.60E+01
3.45E-16	-1.55E+01	2.20E-16	-1.57E+01	4.99E-16	-1.53E+01	1.47E-16	-1.58E+01
4.46E-16	-1.54E+01	2.20E-16	-1.57E+01	6.18E-16	-1.52E+01	2.45E-16	-1.56E+01
6.55E-17	-1.62E+01	3.48E-15	-1.45E+01	6.01E-15	-1.42E+01	1.65E-15	-1.48E+01
9.70E-17	-1.60E+01	1.34E-15	-1.49E+01	1.42E-14	-1.38E+01	1.83E-15	-1.47E+01
7.82E-15	-1.41E+01	2.98E-15	-1.45E+01	1.56E-15	-1.48E+01	2.27E-16	-1.56E+01
1.54E-15	-1.48E+01	3.12E-15	-1.45E+01	2.51E-15	-1.46E+01	2.94E-16	-1.55E+01
1.91E-15	-1.47E+01	2.23E-15	-1.47E+01	5.88E-16	-1.52E+01	2.04E-16	-1.57E+01
1.86E-15	-1.47E+01	3.98E-16	-1.54E+01	2.10E-15	-1.47E+01	1.12E-15	-1.50E+01
5.41E-16	-1.53E+01	3.33E-16	-1.55E+01	9.74E-16	-1.50E+01	3.71E-16	-1.54E+01
1.09E-16	-1.60E+01	4.93E-16	-1.53E+01	1.25E-14	-1.39E+01	8.44E-15	-1.41E+01

3/31/02  
W2

3/31/02

Arith mean  
Geo mean

1.85E-16	-1.57E+01	3.26E-16	-1.55E+01	8.39E-16	-1.51E+01	4.29E-16	-1.54E+01
2.71E-16	-1.56E+01	5.80E-16	-1.52E+01	7.81E-16	-1.51E+01	4.34E-16	-1.54E+01
1.35E-16	-1.59E+01	1.91E-16	-1.57E+01	7.26E-16	-1.51E+01	3.62E-16	-1.54E+01
3.01E-16	-1.55E+01	1.68E-16	-1.58E+01	9.85E-16	-1.50E+01	4.76E-16	-1.53E+01
1.45E-16	-1.58E+01	9.60E-17	-1.60E+01	2.72E-15	-1.46E+01	5.88E-16	-1.52E+01
1.04E-16	-1.60E+01	5.41E-17	-1.63E+01	8.84E-15	-1.41E+01	1.08E-15	-1.50E+01
7.09E-17	-1.61E+01	9.80E-15	-1.40E+01	1.74E-14	-1.38E+01	3.19E-15	-1.45E+01
4.58E-17	-1.63E+01	2.63E-15	-1.46E+01	7.40E-14	-1.31E+01	2.45E-14	-1.36E+01
1.65E-14	-1.38E+01	4.43E-14	-1.34E+01	1.05E-15	-1.50E+01	1.43E-16	-1.58E+01
1.79E-14	-1.37E+01	4.24E-15	-1.44E+01	1.01E-13	-1.30E+01	4.48E-14	-1.33E+01
6.62E-13	-1.22E+01	1.95E-12	-1.17E+01	4.20E-15	-1.44E+01	1.36E-15	-1.49E+01
1.20E-14	-1.39E+01	2.82E-16	-1.55E+01	6.91E-16	-1.52E+01	3.77E-16	-1.54E+01
4.73E-17	-1.63E+01	2.00E-16	-1.57E+01	5.25E-16	-1.53E+01	4.33E-16	-1.54E+01
8.29E-17	-1.61E+01	2.74E-15	-1.46E+01	6.30E-16	-1.52E+01	2.69E-16	-1.56E+01
8.71E-15	-1.41E+01	1.00E-14	-1.40E+01	7.92E-16	-1.51E+01	4.31E-16	-1.54E+01
2.45E-14	-1.36E+01	3.12E-15	-1.45E+01	8.49E-16	-1.51E+01	3.72E-16	-1.54E+01
1.94E-15	-1.47E+01	8.68E-15	-1.41E+01	5.49E-16	-1.53E+01	2.10E-16	-1.57E+01
3.77E-14	-1.34E+01	5.26E-15	-1.43E+01	9.95E-16	-1.50E+01	4.02E-16	-1.54E+01
2.37E-14	-1.36E+01	1.75E-15	-1.48E+01	8.21E-16	-1.51E+01	4.10E-16	-1.54E+01
2.34E-16	-1.56E+01	6.72E-16	-1.52E+01	3.81E-16	-1.54E+01	1.47E-16	-1.58E+01
6.17E-15	-1.42E+01	4.28E-16	-1.54E+01	2.86E-15	-1.45E+01	5.61E-16	-1.53E+01
4.95E-15	-1.43E+01	6.89E-16	-1.52E+01	1.95E-15	-1.47E+01	3.56E-16	-1.54E+01
2.03E-16	-1.57E+01	5.76E-16	-1.52E+01	3.55E-14	-1.34E+01	1.06E-14	-1.40E+01
2.95E-16	-1.55E+01	1.08E-15	-1.50E+01	5.31E-15	-1.43E+01	4.60E-16	-1.53E+01
3.89E-16	-1.54E+01	1.26E-15	-1.49E+01	1.01E-15	-1.50E+01	2.44E-16	-1.56E+01
4.40E-16	-1.54E+01	2.09E-15	-1.47E+01	1.20E-14	-1.39E+01	2.63E-15	-1.46E+01
5.95E-15	-1.42E+01	7.26E-16	-1.51E+01	2.60E-15	-1.46E+01	2.67E-16	-1.56E+01
3.48E-16	-1.55E+01	3.28E-16	-1.55E+01	8.56E-16	-1.51E+01	1.47E-16	-1.58E+01
1.34E-16	-1.59E+01	1.40E-15	-1.49E+01	1.19E-15	-1.49E+01	3.05E-16	-1.55E+01
3.42E-15	-1.45E+01	3.62E-15	-1.44E+01	5.16E-15	-1.43E+01	1.68E-15	-1.48E+01
1.23E-14	-1.39E+01	5.79E-16	-1.52E+01	1.03E-15	-1.50E+01	4.88E-16	-1.53E+01
1.40E-15	-1.49E+01	3.51E-13	-1.25E+01	1.02E-14	-1.40E+01	5.57E-15	-1.43E+01
7.90E-16	-1.51E+01	4.56E-16	-1.53E+01	9.16E-14	-1.30E+01	3.84E-14	-1.34E+01
1.92E-16	-1.57E+01	<b>2.97E-14</b>	<b>-1.51E+01</b>	8.97E-15	-1.40E+01	9.88E-16	-1.50E+01
1.34E-12	-1.19E+01	<b>7.89E-16</b>		1.29E-15	-1.49E+01	4.36E-16	-1.54E+01
9.60E-17	-1.60E+01			1.18E-15	-1.49E+01	3.58E-16	-1.54E+01
<b>2.71E-14</b>	<b>-1.51E+01</b>			6.14E-16	-1.52E+01	2.13E-16	-1.57E+01
	<b>7.75E-16</b>			1.23E-15	-1.49E+01	4.57E-16	-1.53E+01
				2.41E-15	-1.46E+01	8.31E-16	-1.51E+01
				1.02E-15	-1.50E+01	1.37E-16	-1.59E+01
				2.09E-15	-1.47E+01	6.69E-16	-1.52E+01
				3.38E-14	-1.35E+01	1.94E-14	-1.37E+01
				9.23E-15	-1.40E+01	5.31E-15	-1.43E+01
				7.92E-16	-1.51E+01	2.41E-16	-1.56E+01
				2.82E-15	-1.45E+01	1.60E-15	-1.48E+01
				5.50E-15	-1.43E+01	2.03E-15	-1.47E+01
				1.08E-15	-1.50E+01	4.16E-16	-1.54E+01
				7.66E-16	-1.51E+01	3.38E-16	-1.55E+01
				8.24E-16	-1.51E+01	4.93E-16	-1.53E+01
				1.02E-15	-1.50E+01	4.92E-16	-1.53E+01
				9.14E-16	-1.50E+01	3.80E-16	-1.54E+01
				2.37E-15	-1.46E+01	6.35E-16	-1.52E+01

3/31/02 WI



3/31/02

1.35E-15	-1.49E+01	5.81E-16	-1.52E+01
1.83E-15	-1.47E+01	6.27E-16	-1.52E+01
1.21E-15	-1.49E+01	4.40E-16	-1.54E+01
5.71E-15	-1.48E+01	2.18E-15	-1.52E+01
	1.77E-15		5.66E-16

3/31/02 W3

LAST ENTRY  
RWF 9/30/02

I have reviewed this scientific notebook and find it in agreement with QAP-001. There is sufficient information regarding methods used for conducting tests, acquiring and analyzing data so that another qualified individual could repeat the activity.

E. C. P  
10/1/02