Innovative Use of Petrophysics in Field Rehabilitation, with Examples from the Heather Field

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Brovig RDS

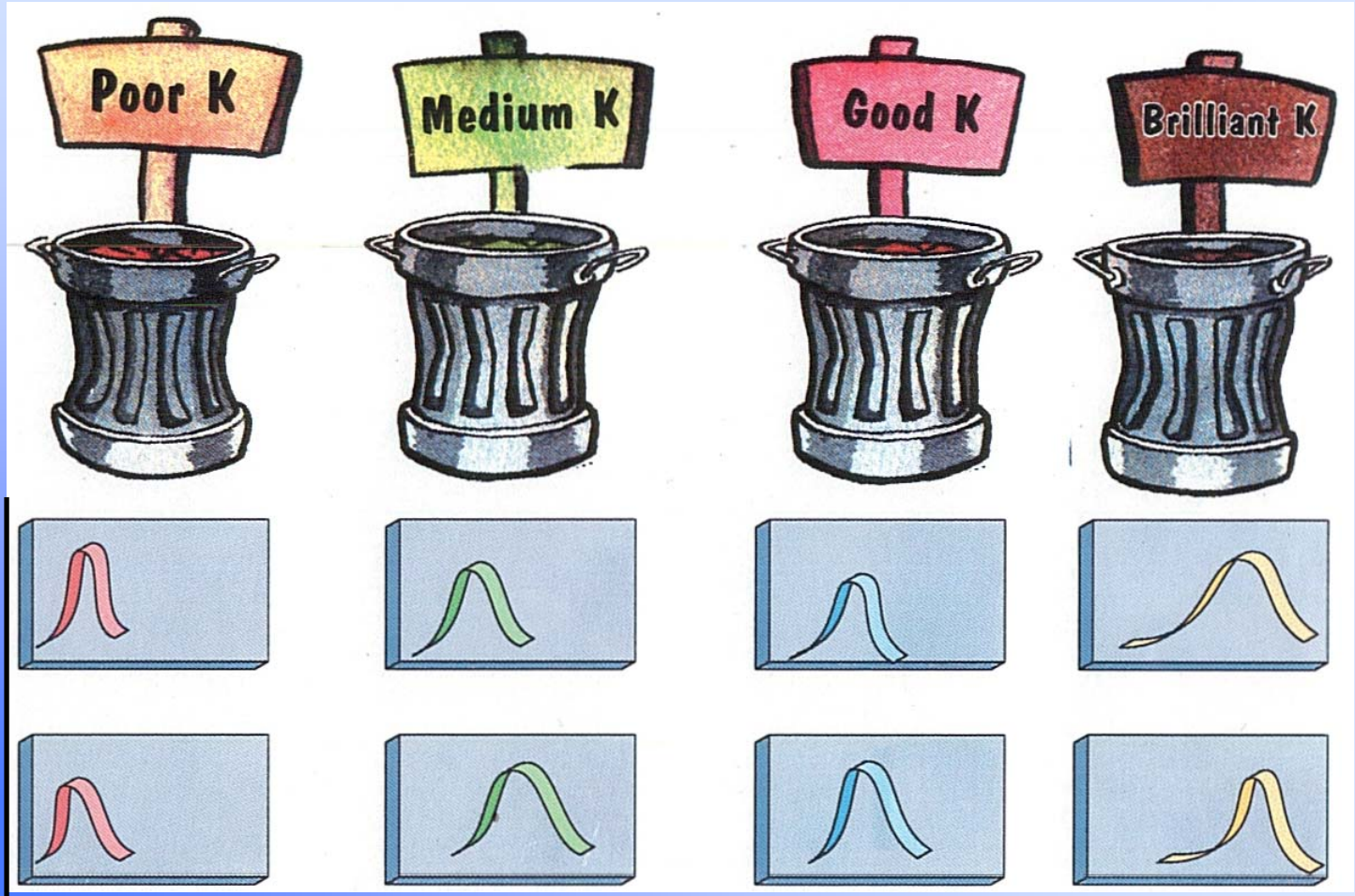
Innovative Petrophysical Methods

- Dynamic log curve repair
- Permeability prediction
- Saturation modeling
- Geosteering using saturation modeling

Genetic Algorithm and Fuzzy Logic (GAFL)

- GAFL - statistical methods that find relationships within datasets and use these to make predictions.
- A family of log curves from the same geological formation will have many physical characteristics in common, and relationships exist between, for example, core permeabilities and GR, RHOB, RT, DT.
- Proprietary software developed by Brovig-RDS and Aberdeen University to run GAFL within Paradigm Geophysical's ***Geolog*** log analysis software.
- The processes are automatic and fast.

Fuzzy Logic Prediction Method



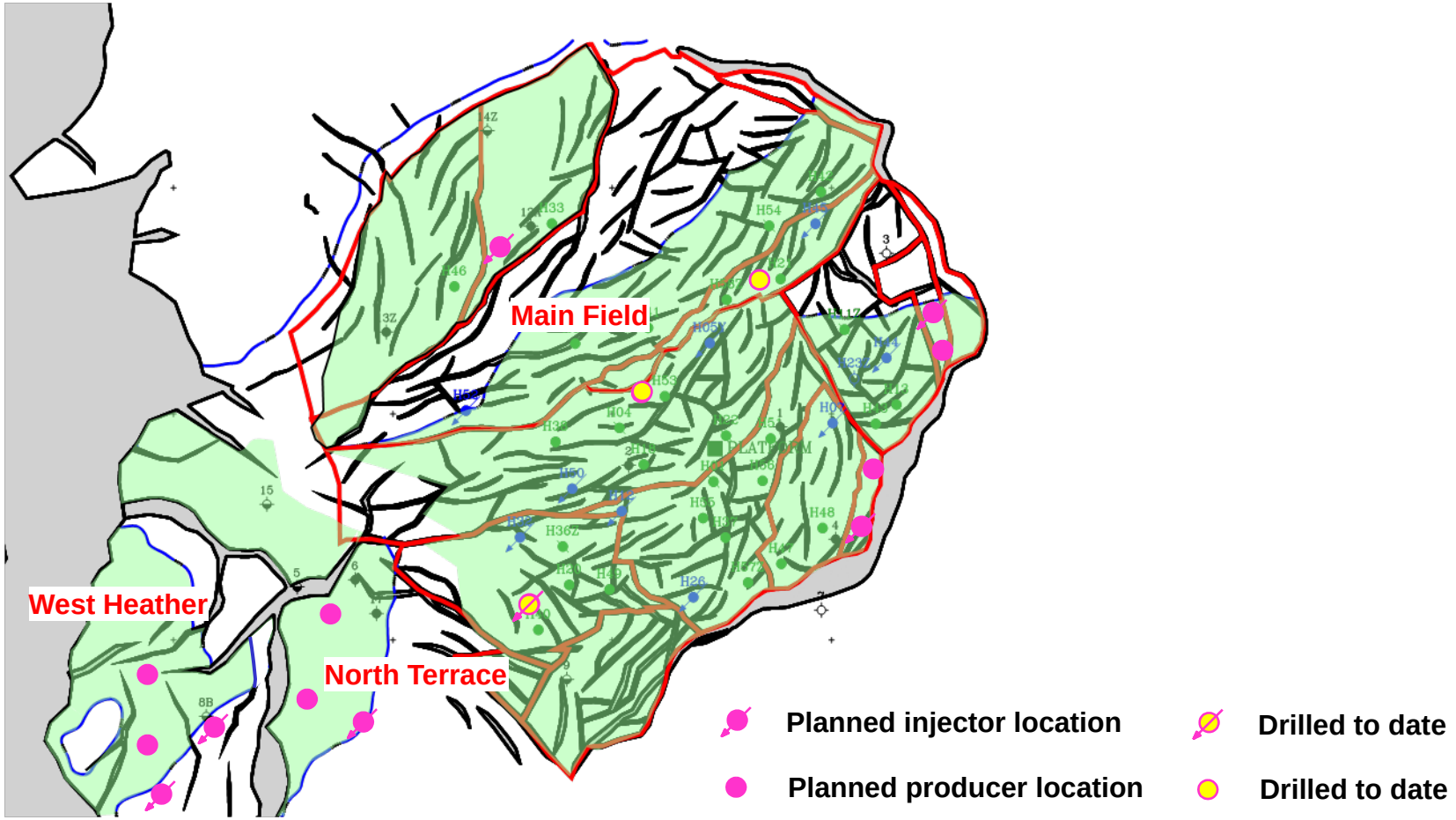
Sonic log

Gamma-ray

NMR

Other logs

Heather Field Examples of Curve Repair and Permeability Prediction



Light green areas denote extent of oil accumulation.

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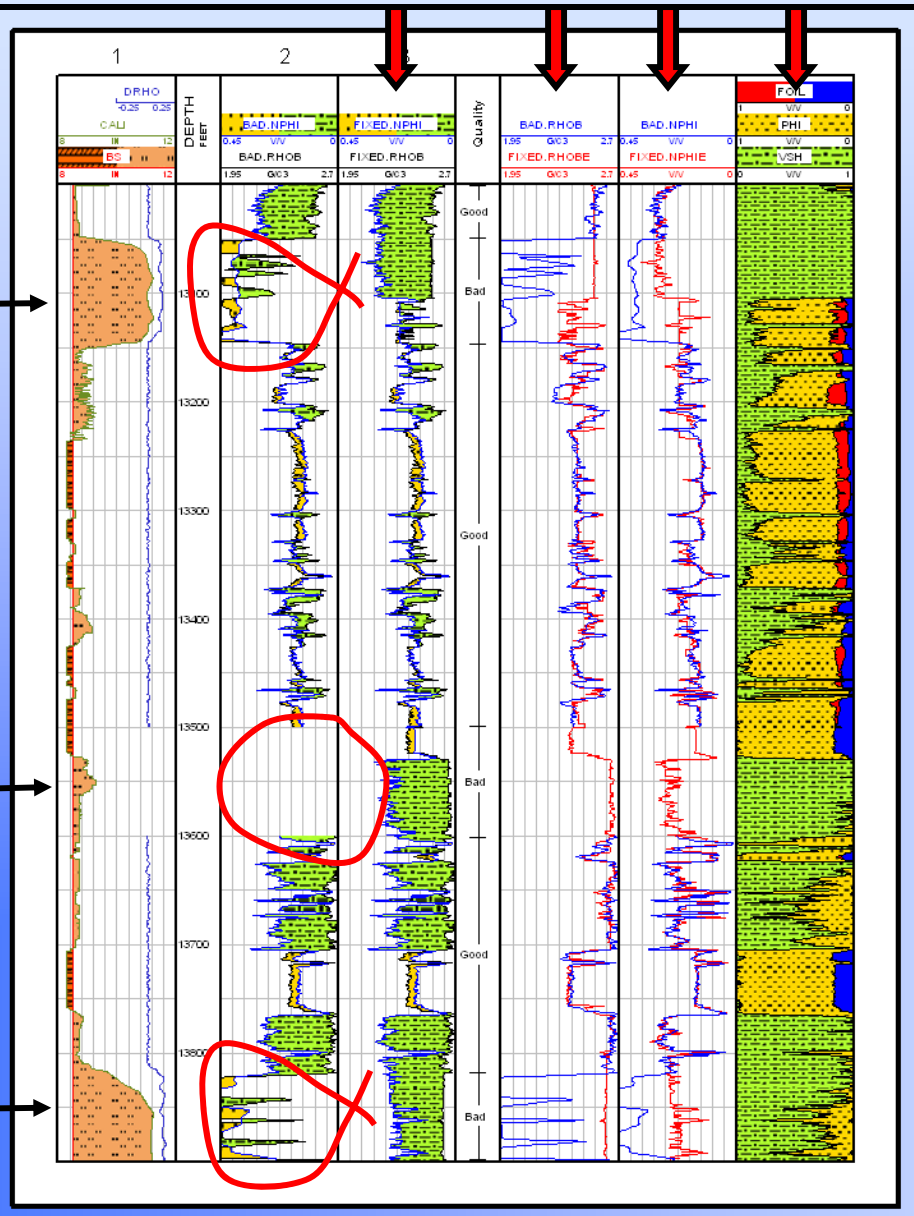
Dynamic Curve Repair



Hole washout

Tool failure

Hole washout

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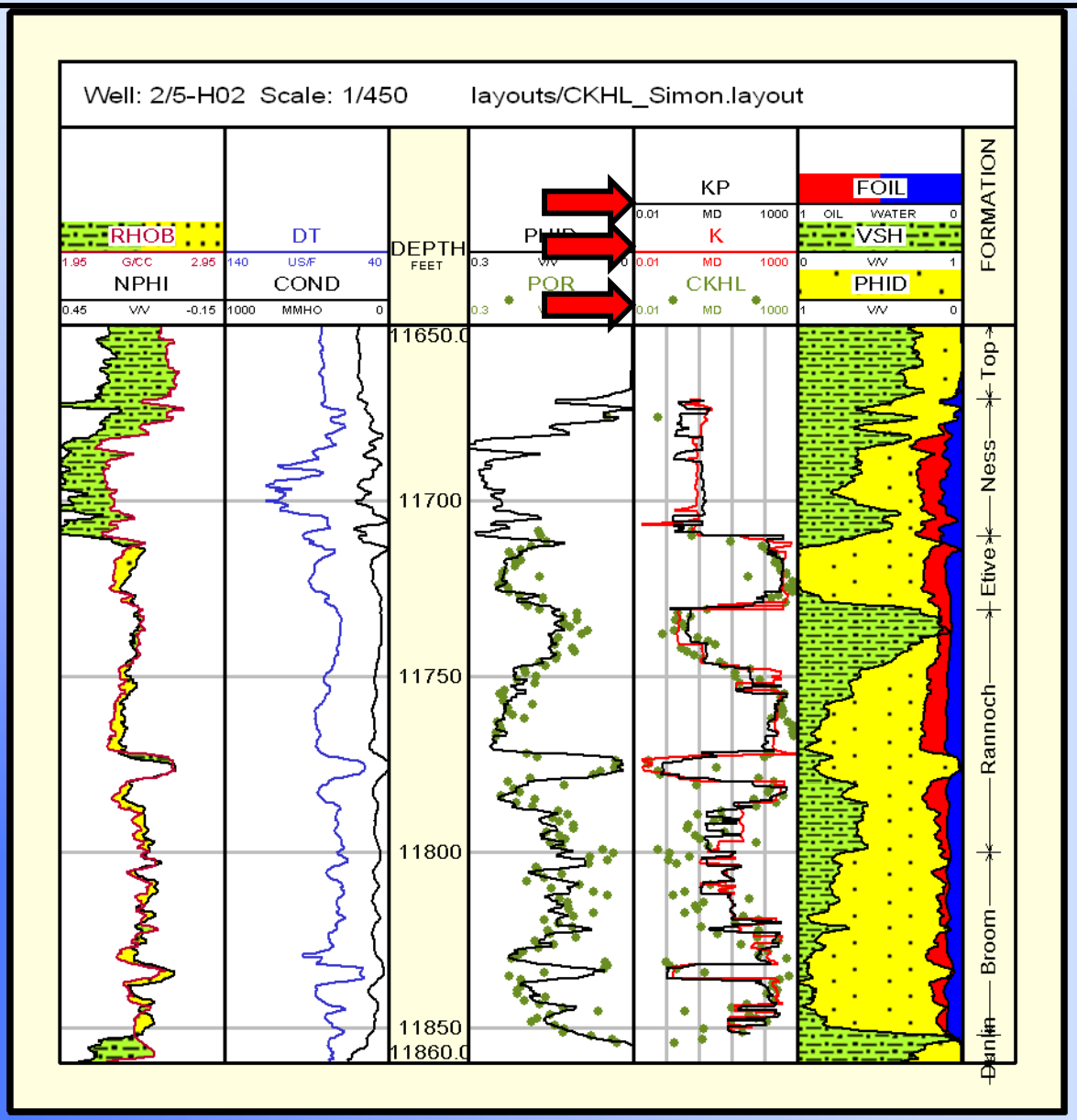
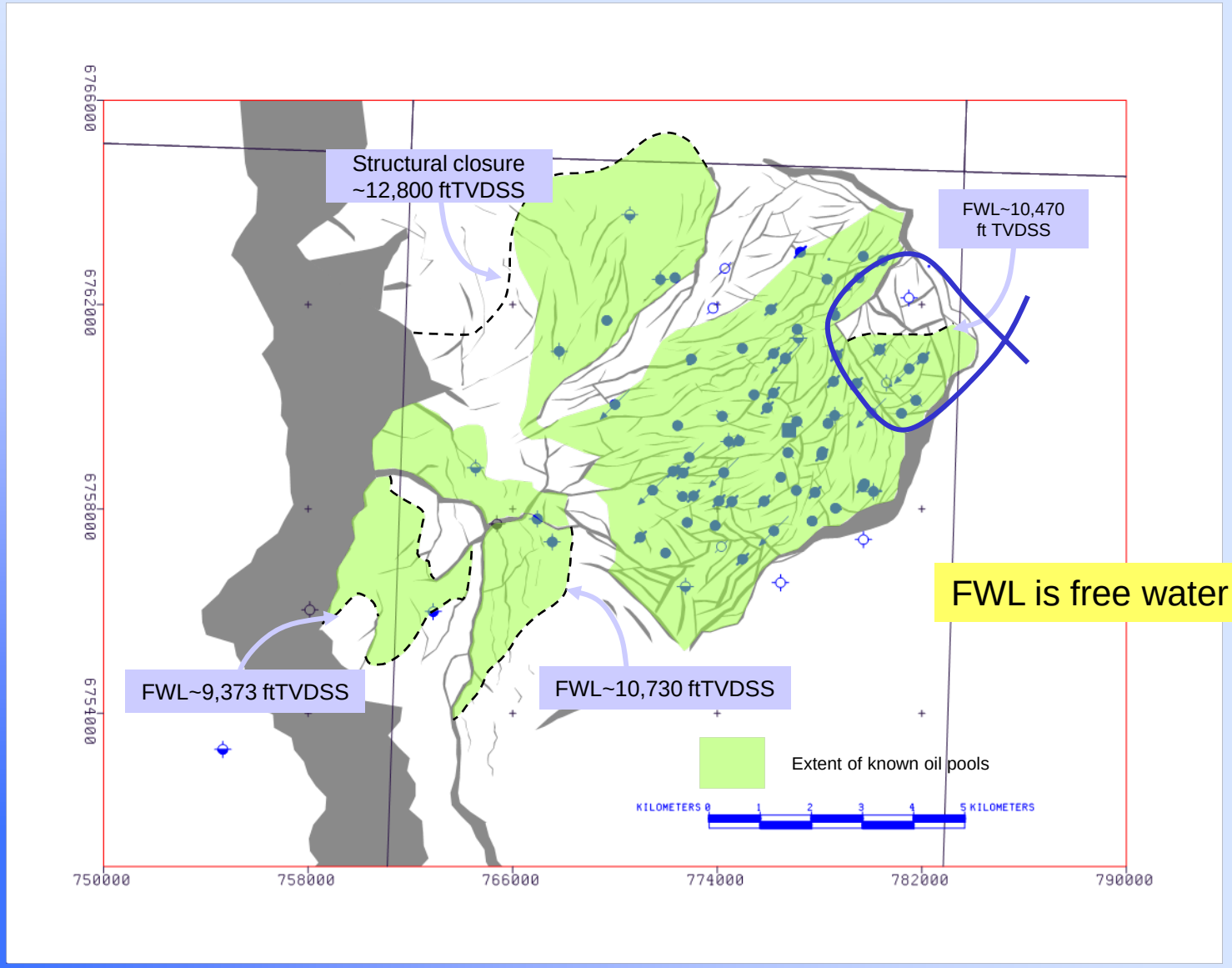
Permeability Prediction



Heather Field Saturation Modeling



FWL is free water level

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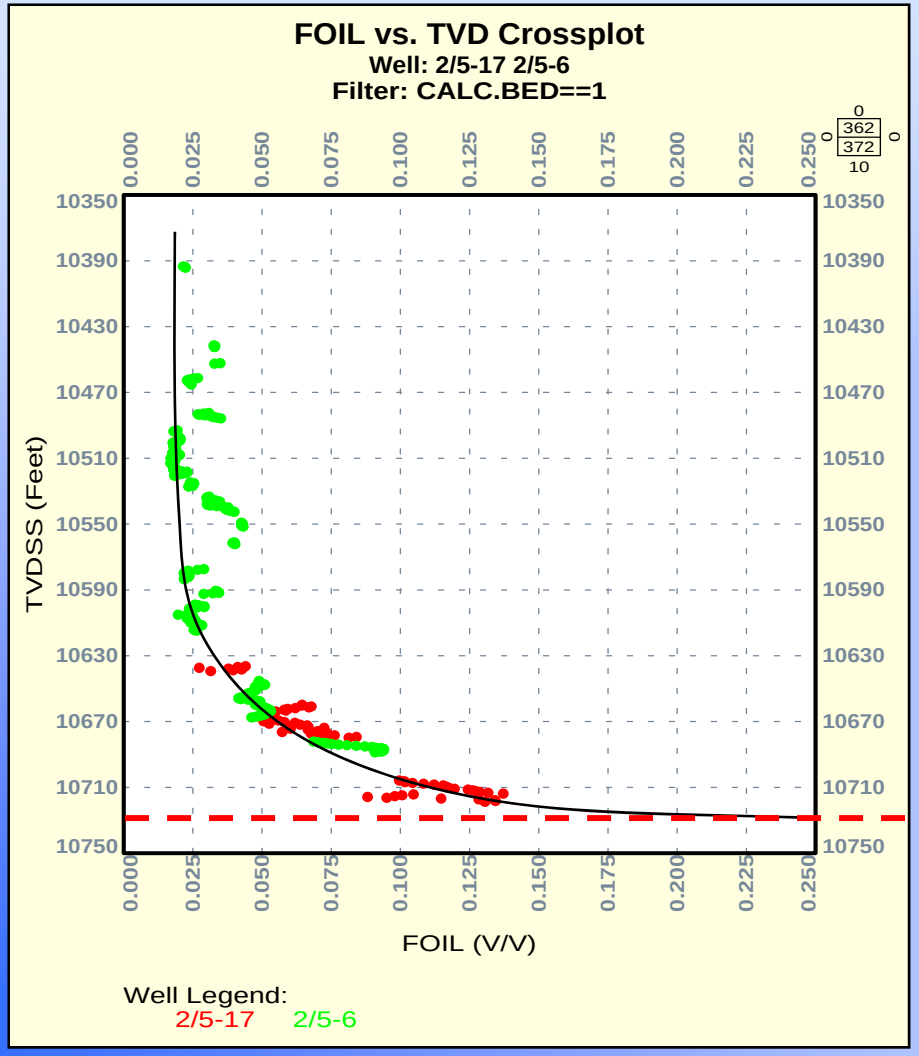
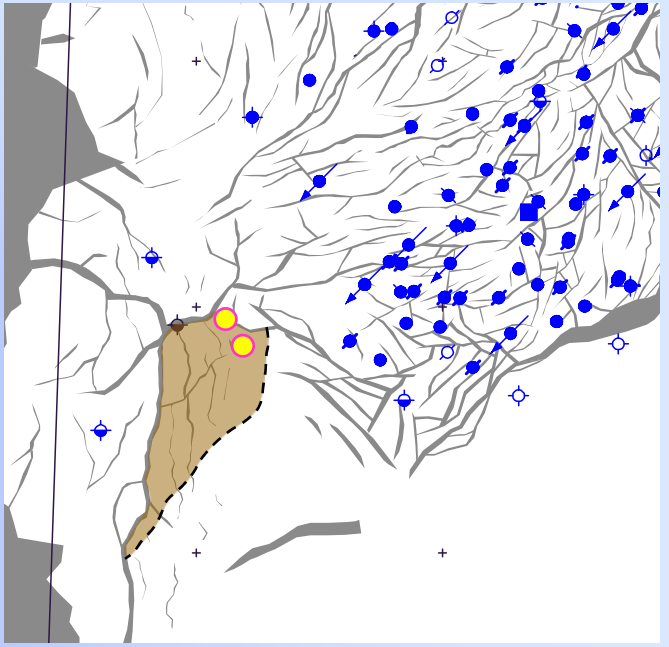
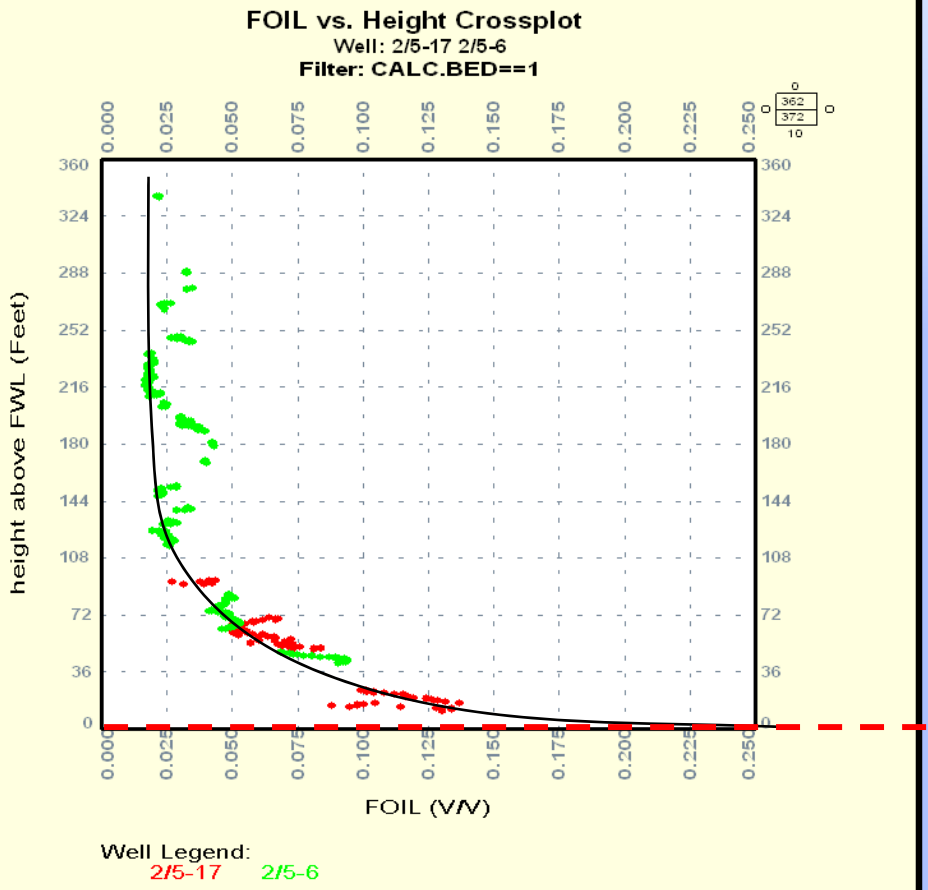
Saturation Modeling - Foil Plot for North Terrace Wells 2/5-6 and 2/5-17 (1)





Free water level approx. 10,730ft TVDSS

Saturation Modeling - Foil Plot for North Terrace Wells 2/5-6 and 2/5-17 (2)



FWL

Note plot is in height above free water level

The fluid distribution can be completely described by only one variable!

FOIL function = a H^{b}
where a=0.7873, b= -0.6513,
H is height above free water level

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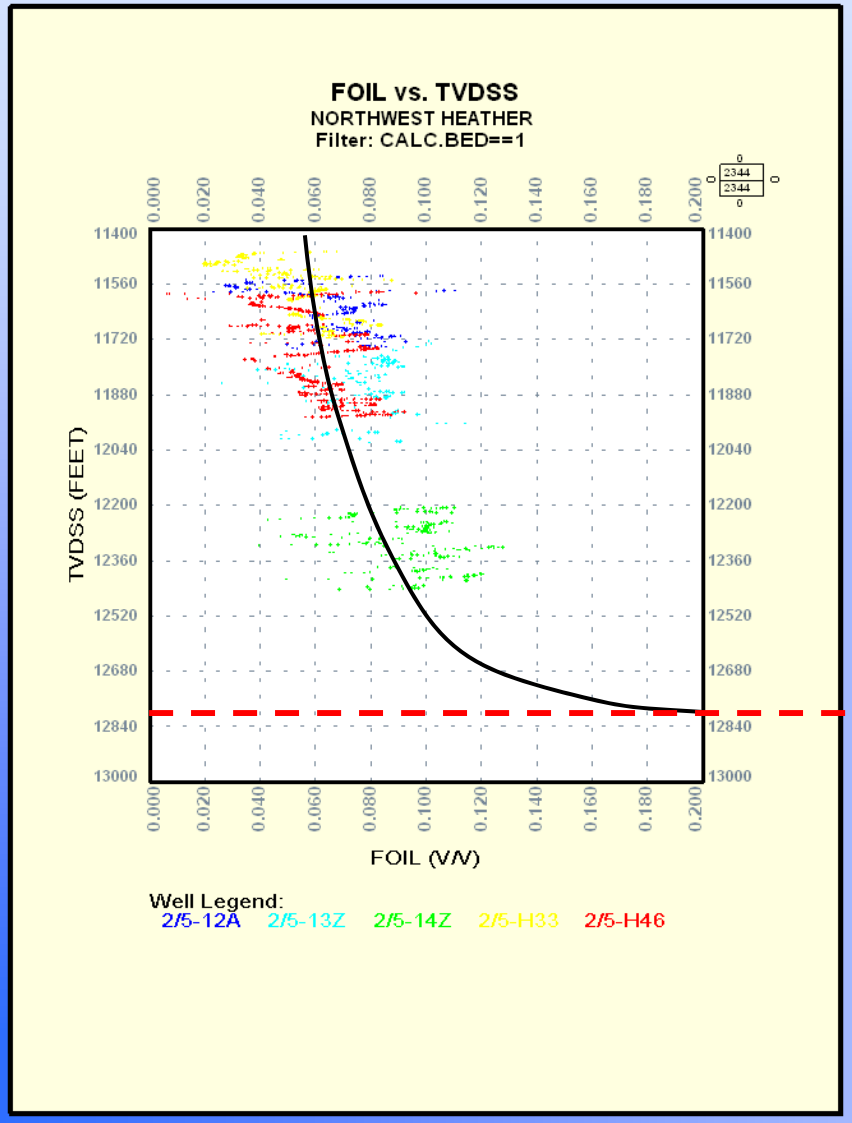
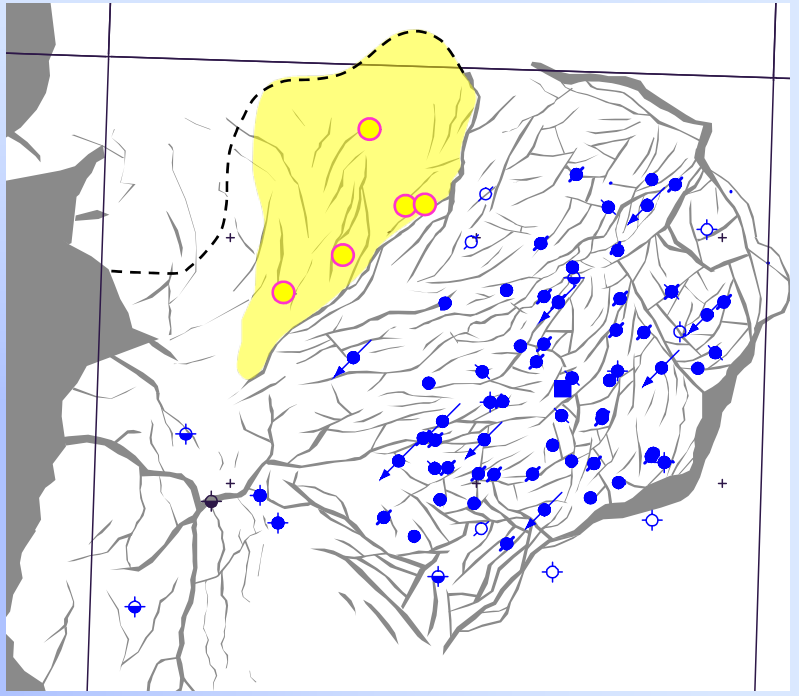
Saturation Modeling - FOIL Plot for NW Heather

DNO





FWL approx. 12,800ft TVDSS?

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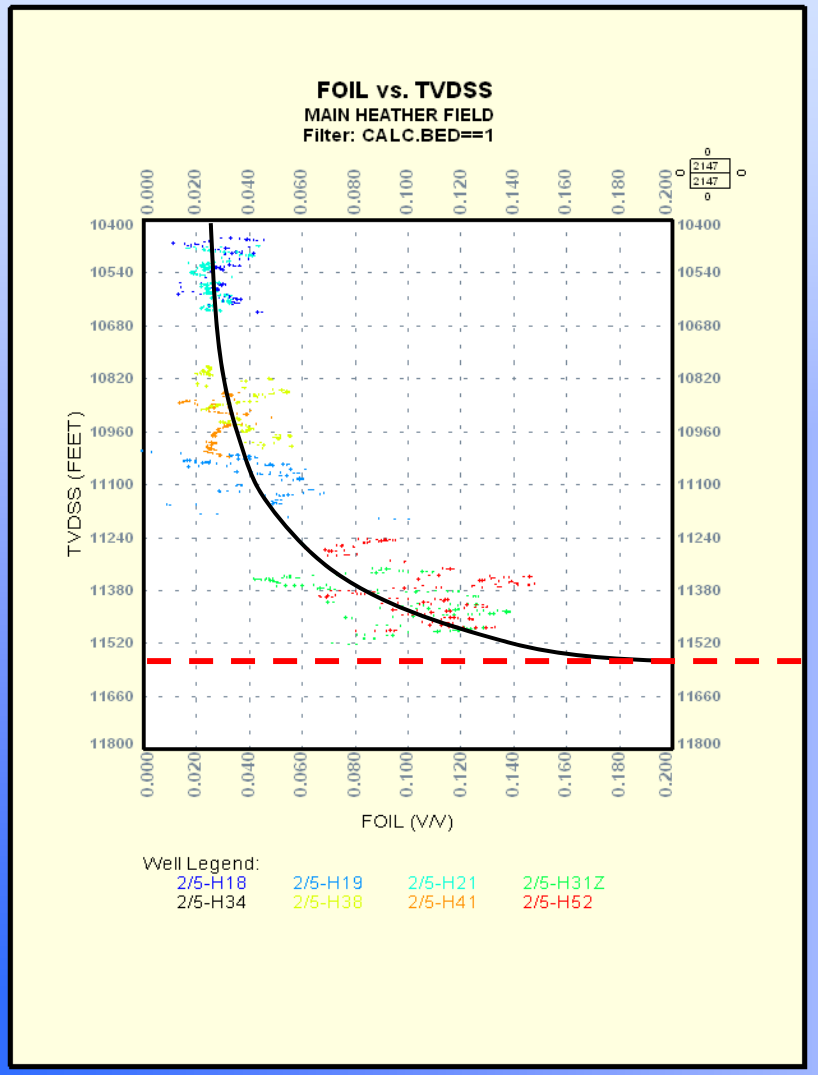
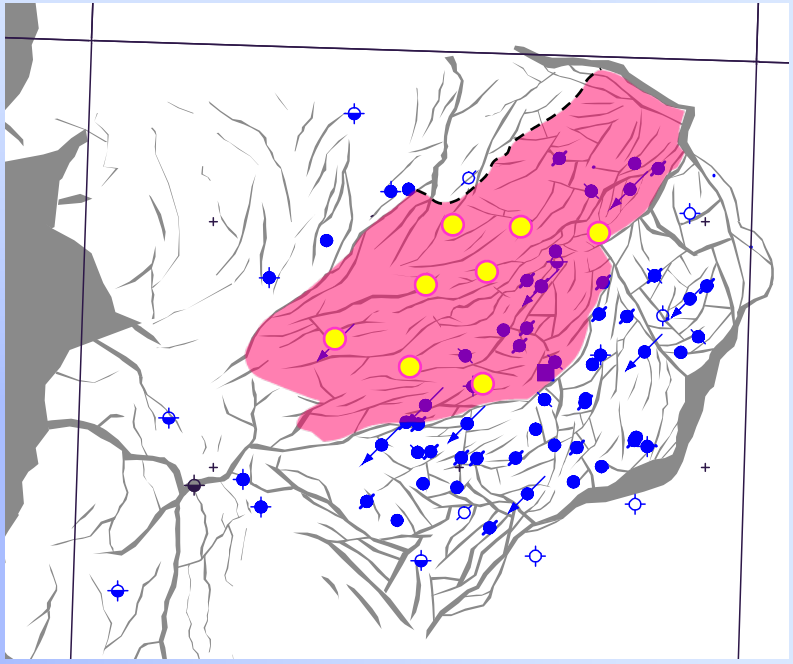
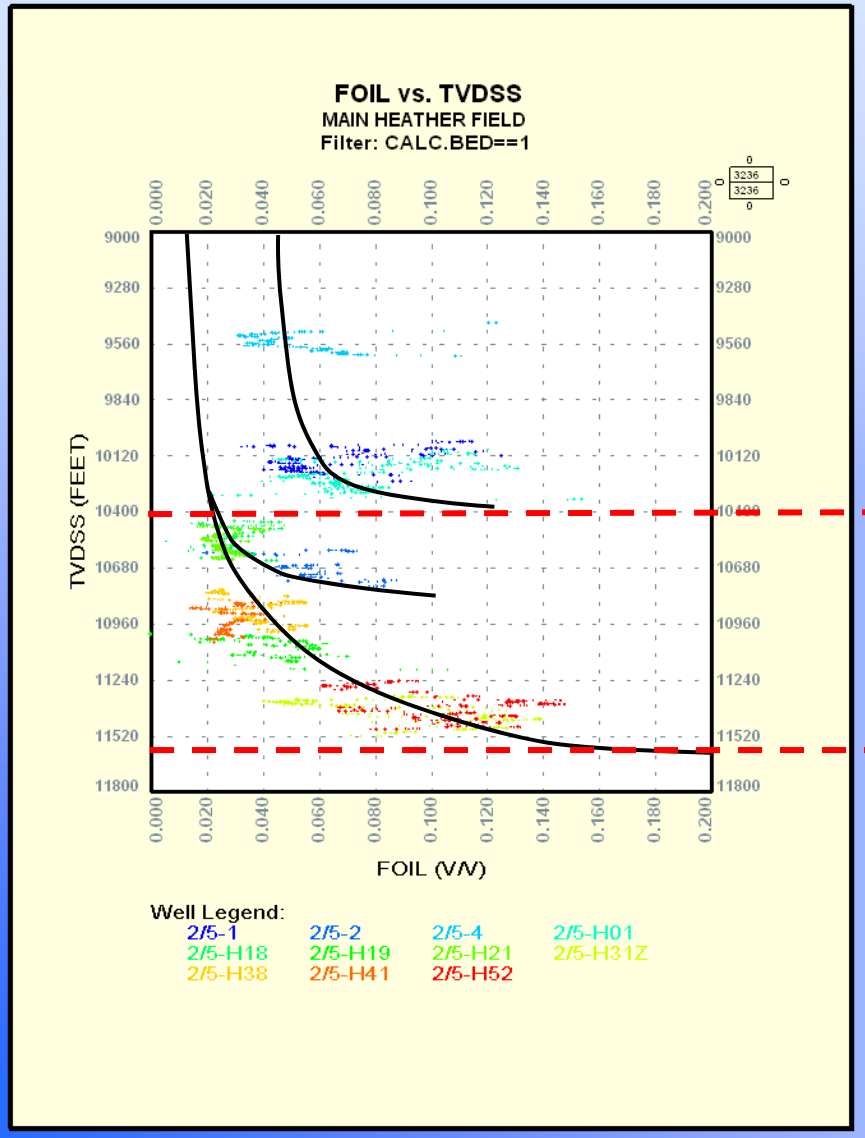
Saturation Modeling - FOIL Plot from Main Field Blocks A, H & C

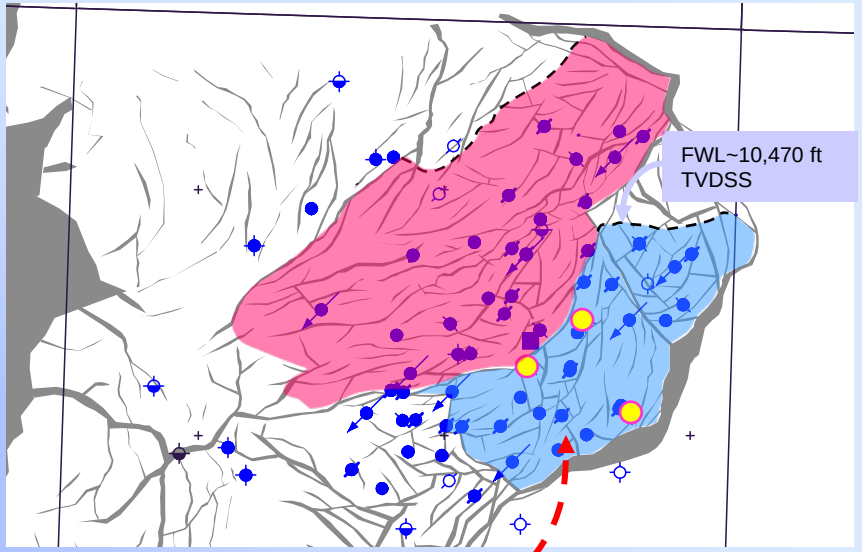




FWL approx. 11,550ft TVDSS

Saturation Modeling - FOIL Plots from Main Field including Crestal Wells





FWL higher in crestal D & E Blocks

A, H & C Block FWL approx. 11,550ft TVDSS (previous slide)

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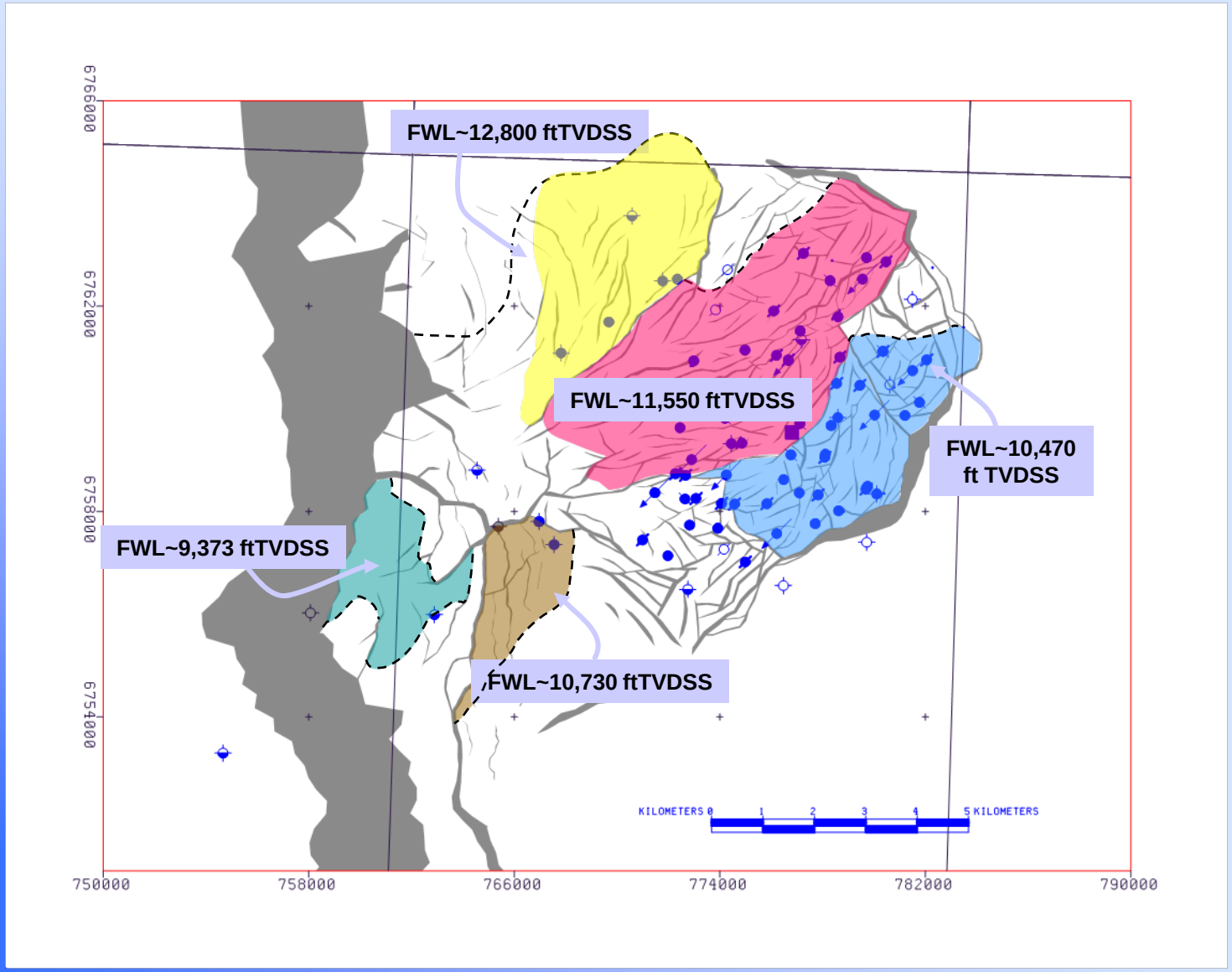
Heather Field: Possible FWLs

DNO



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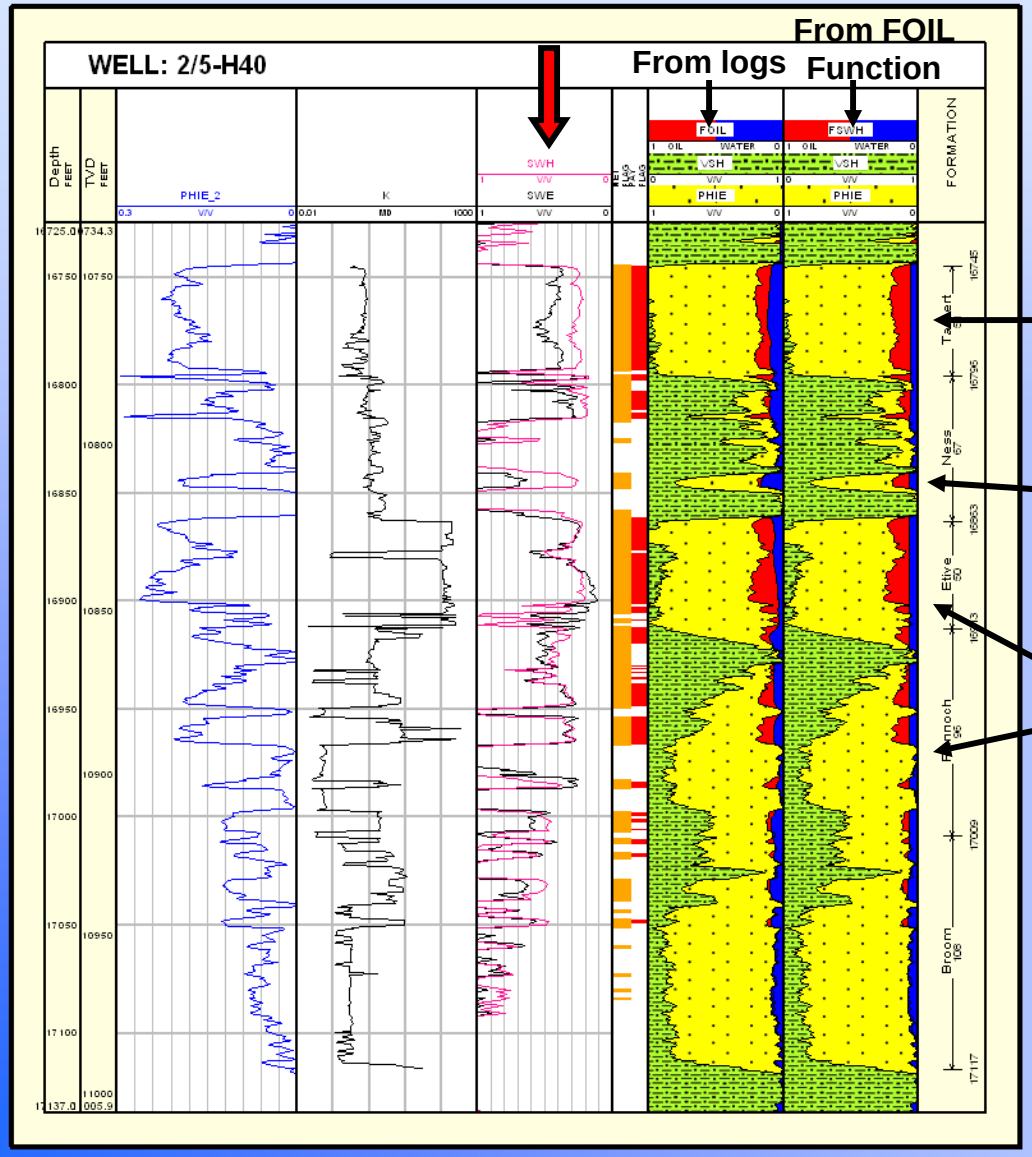
Example Well CPI Comparing SW Calculated from Resistivity and Directly from FOIL Function



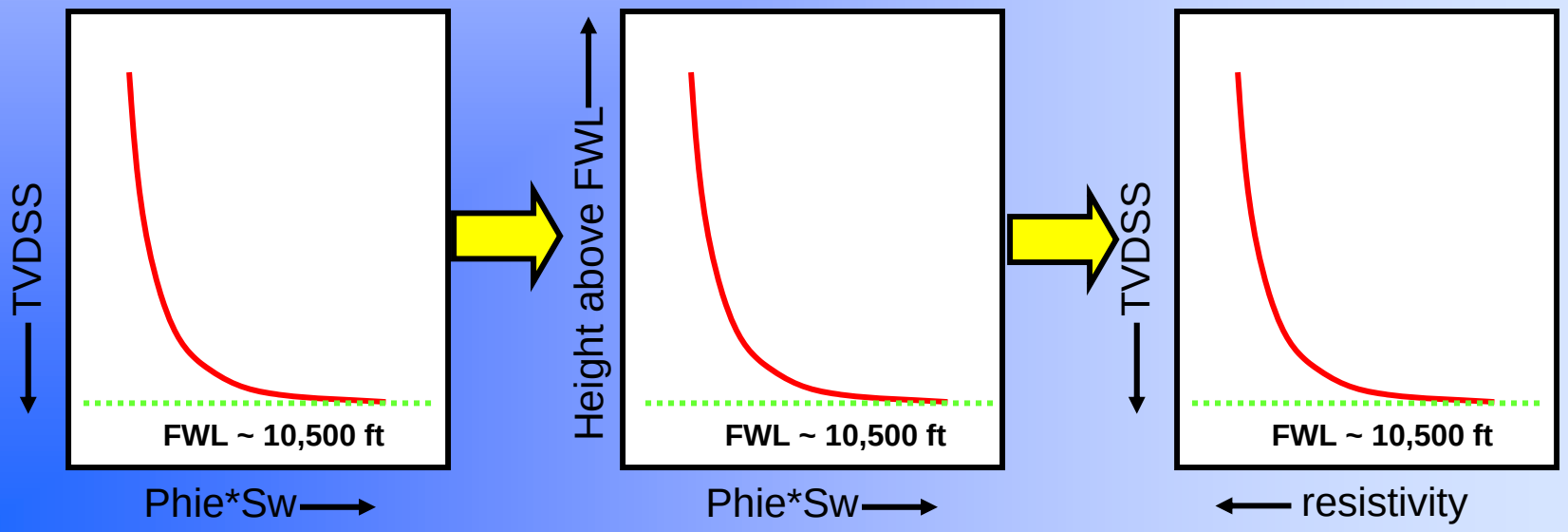
Swept zone - FOIL function computes initial saturations

Thin beds - FOIL function is probably a better measure of saturations than the resistivity tool

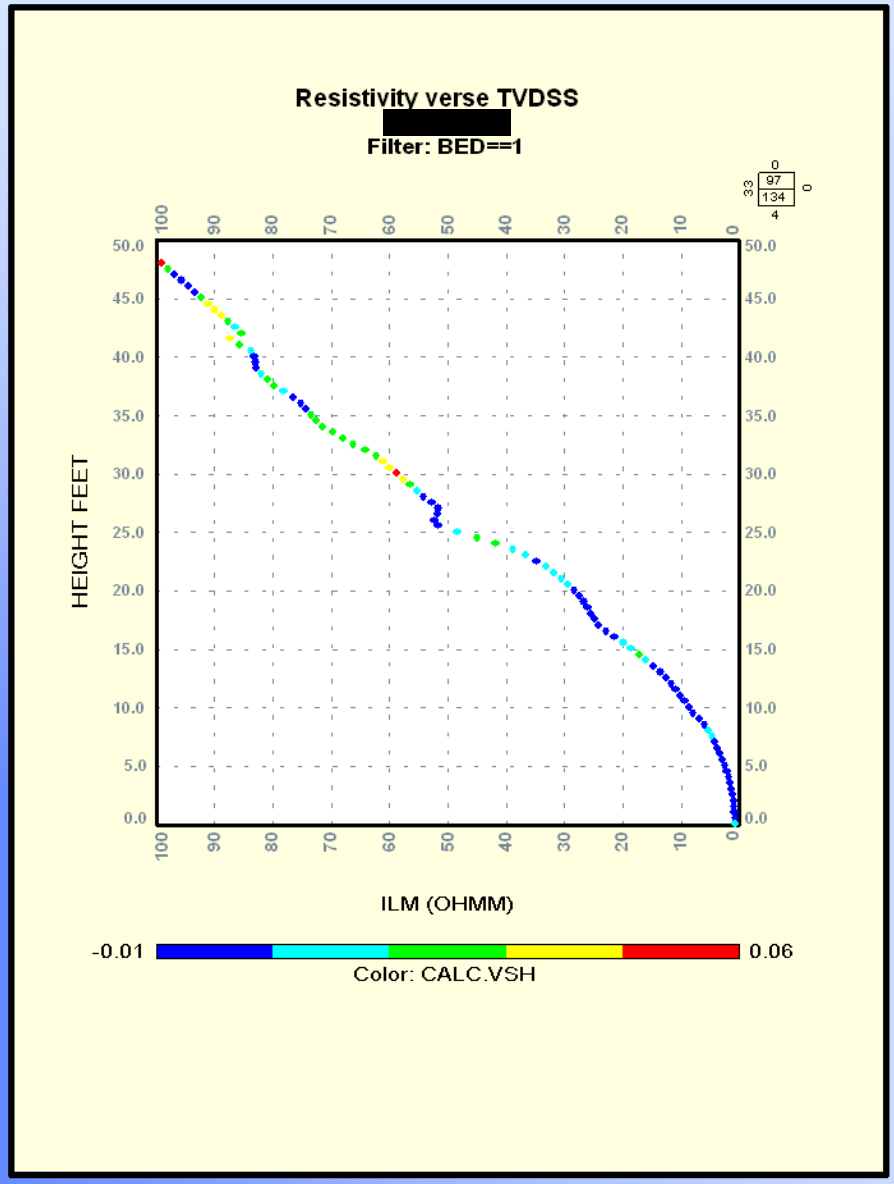
FOIL function accurately describes saturation in thick beds

Geosteering using Modeled Curve Data

- Determine free water level (FWL) in offset wells
- Build 3D model and extract curve data (GR, resistivity, density)
- Model for tool response and hole angle
- Back out resistivity/height profile

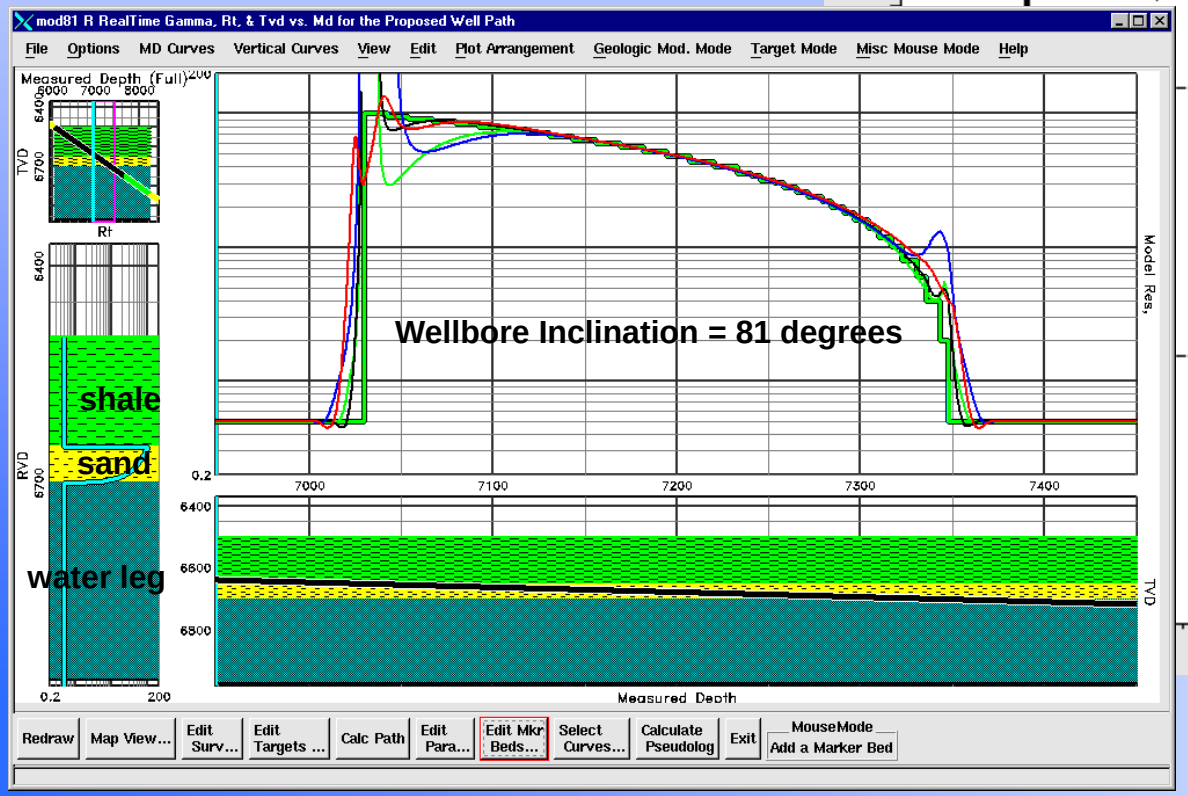


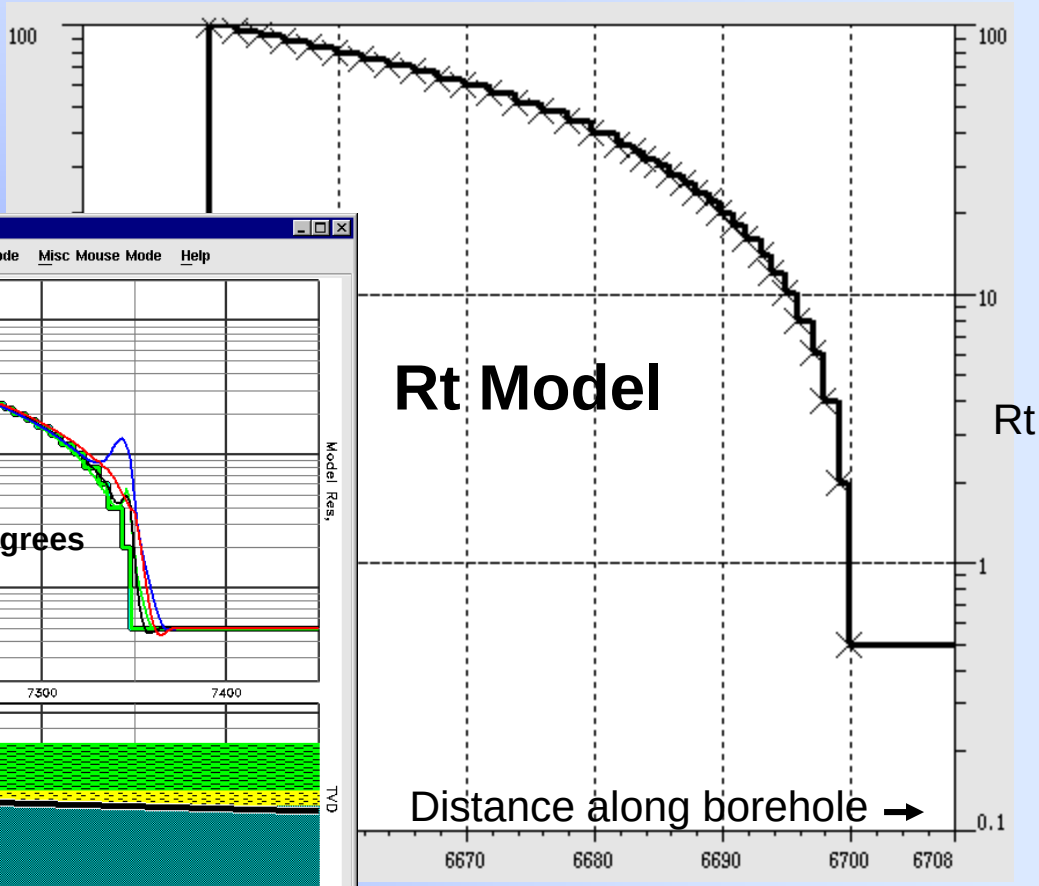
Resistivity vs Height Example



Resistivity Model Example for a High Angle Well

- **Compensated Waveform Resistivity**
  - R55A - Blue
  - R25A - Green
  - R55P - Red
  - R25P – Black
- **Anisotropy = 1**
- **Dielectric Constant = 10**





Conclusions

- Fuzzy Logic is a powerful predictive tool with many rock property prediction applications
- Dynamic Curve Repair - LWD data are often lower quality than wireline data
  - Dynamic curve repair can bridge the quality gap
- Permeability prediction by Fuzzy Logic allows better choice of perforating intervals
  - It is still reliant on a good core permeability database
- The FOIL function is a simple and effective way of describing fluid saturations
  - It can help in thin beds and in wells where the resistivity tool was not run
- Saturation modeling with the FOIL function has many uses
  - Locate free water levels
  - Aid understanding of structural complexity
  - Identify swept zones
  - Can be used in geosteering to maintain a required distance from fluid boundaries
  - 3D reservoir modeling