# A High Resolution Vertical Gradient Approach for Delineation of Hydrogeologic Units at a Contaminated Sedimentary Rock Field Site

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*High Resolution, Depth-Discrete Groundwater Monitoring - Benefits & Importance*

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UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

360

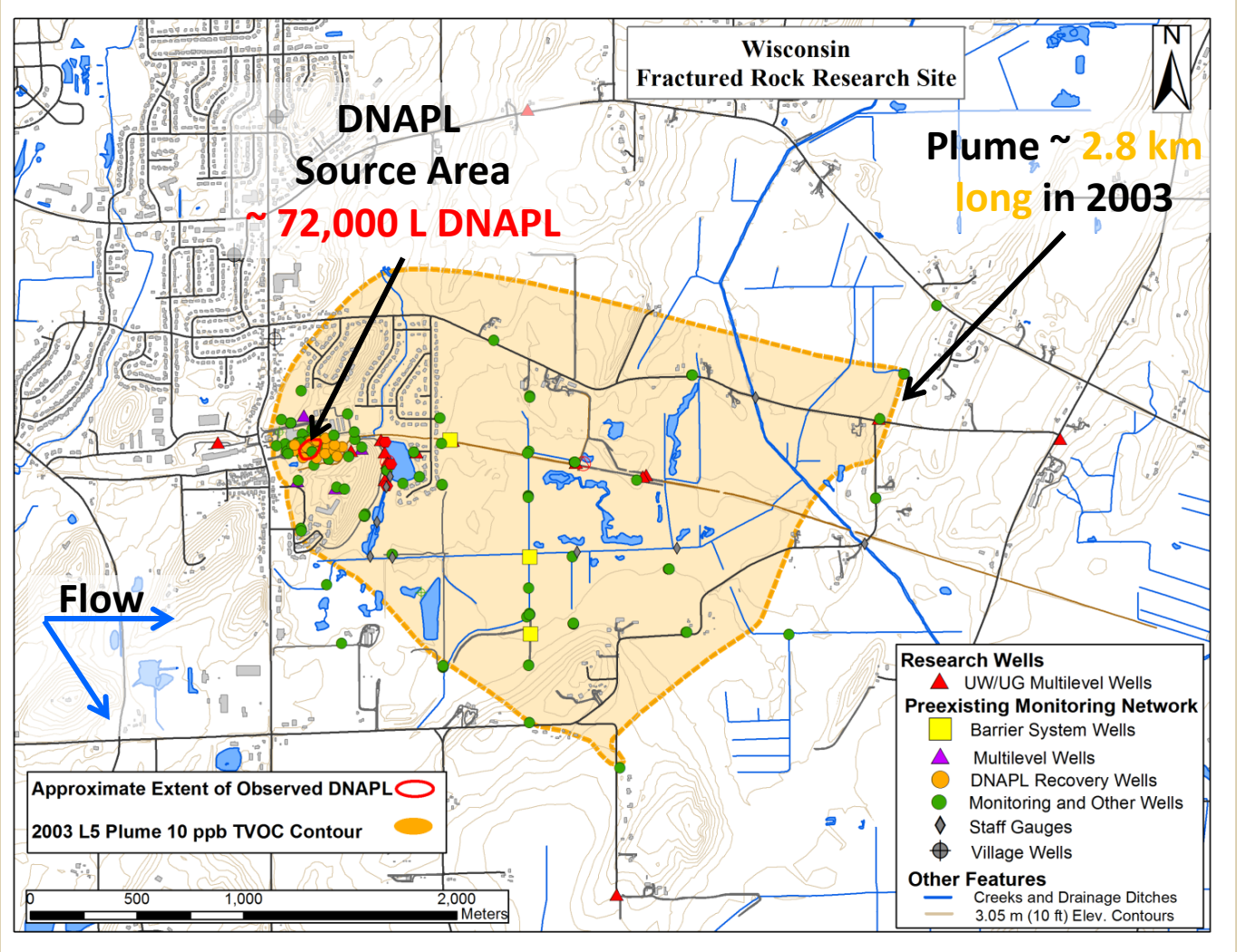
# DNAPL Fractured Rock Site in Southern Wisconsin

Contamination in a fractured sandstone

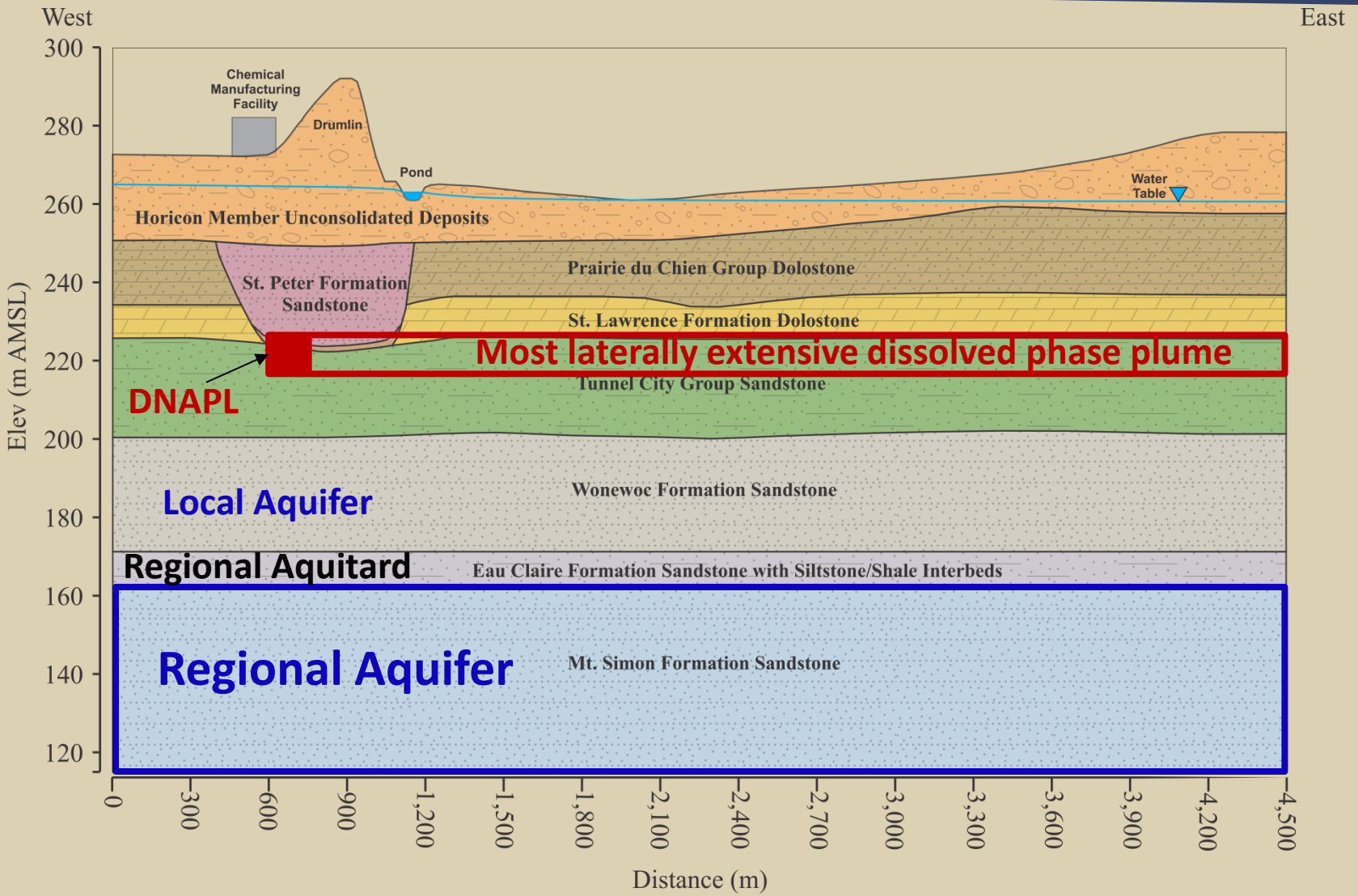
- Multicomponent ***DNAPL*** source zone
- ***Dissolved phase*** plume ~ 3 km long

# Mixed Organic Contaminants Plume in Fractured Sandstone

- 154 monitoring locations
- 20 multilevel systems
- Total of 558 monitoring points
- Flow generally toward east to southeast



# Pleistocene Unconsolidated Sediments
# Cambrian/Ordovician Sedimentary Bedrock



# Objectives

- High resolution hydraulic basis for delineation of hydrogeologic units

- High resolution characterization of the mass distribution

# Hydrogeologic Units (HGUs)

Represent partitions of the groundwater flow domain with contrasting hydraulic conductivities

# Why are HGUs Important

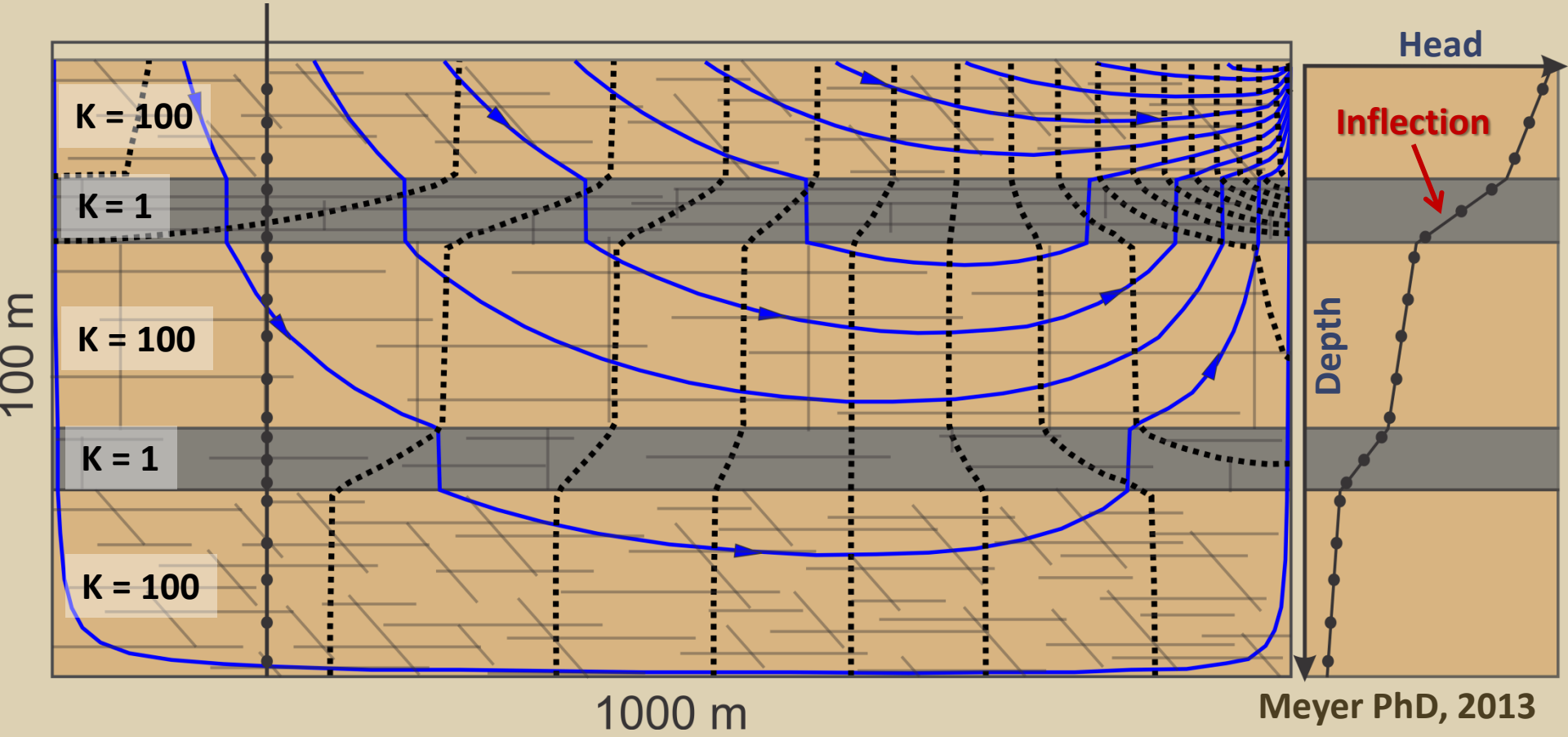
Used as a framework for ***ALL*** conceptual and numerical models of groundwater flow and contaminant transport

# All Groundwater Studies Require Delineation of HGUs

- Position
- Thickness
- Lateral Extent/geometry

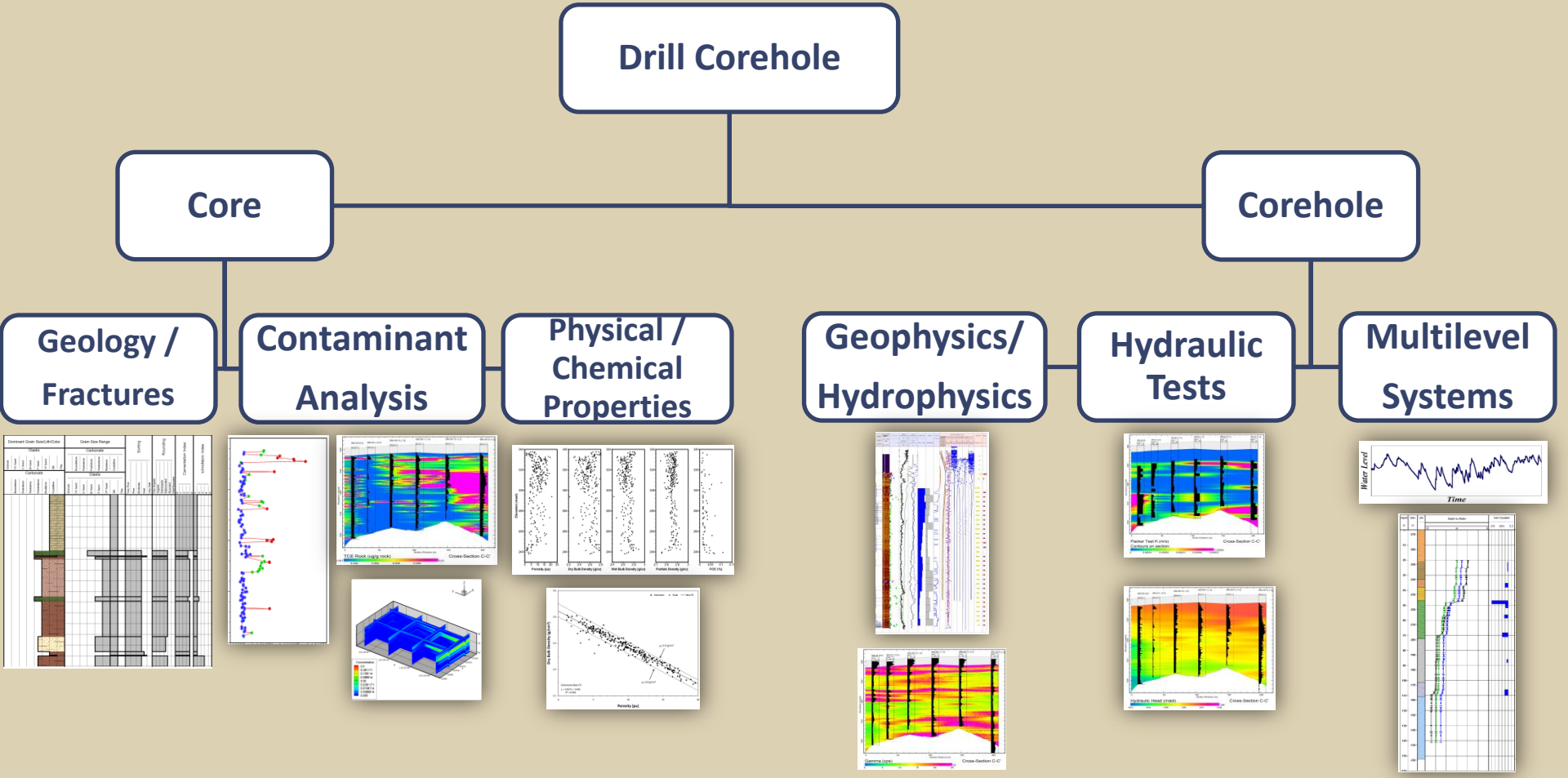
# Hypothesis

High resolution head profiles identify the position / thickness of $K_v$ contrasts that can be used to delineate HGUs




Meyer PhD, 2013

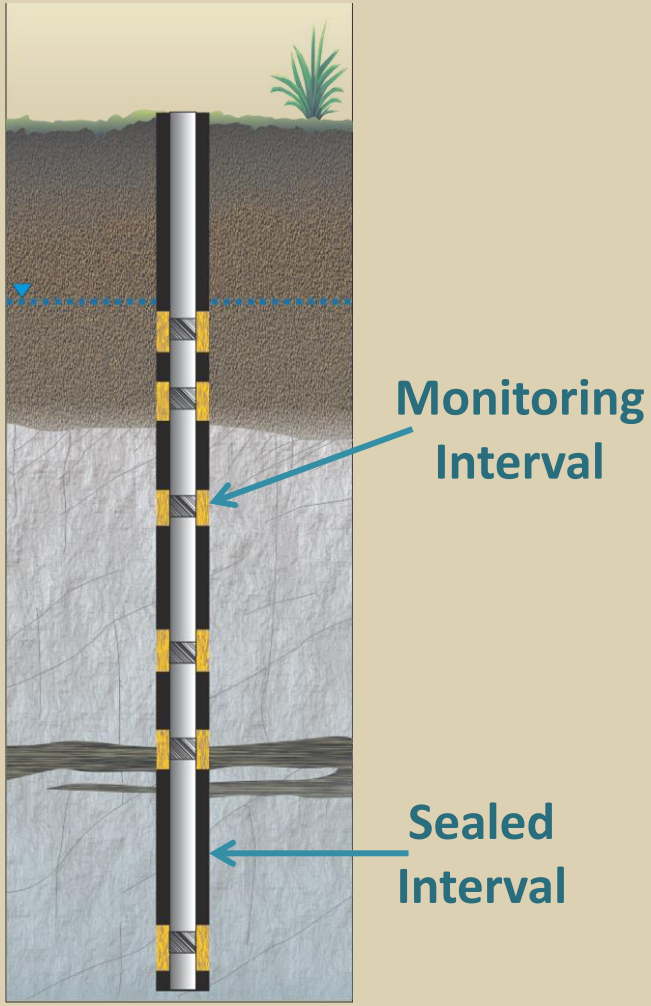
# Discrete Fracture Network (DFN) Approach to Site Characterization




Parker et al., 2012, AQUA mundi

# Multilevel System (MLS)

Generic Multilevel System



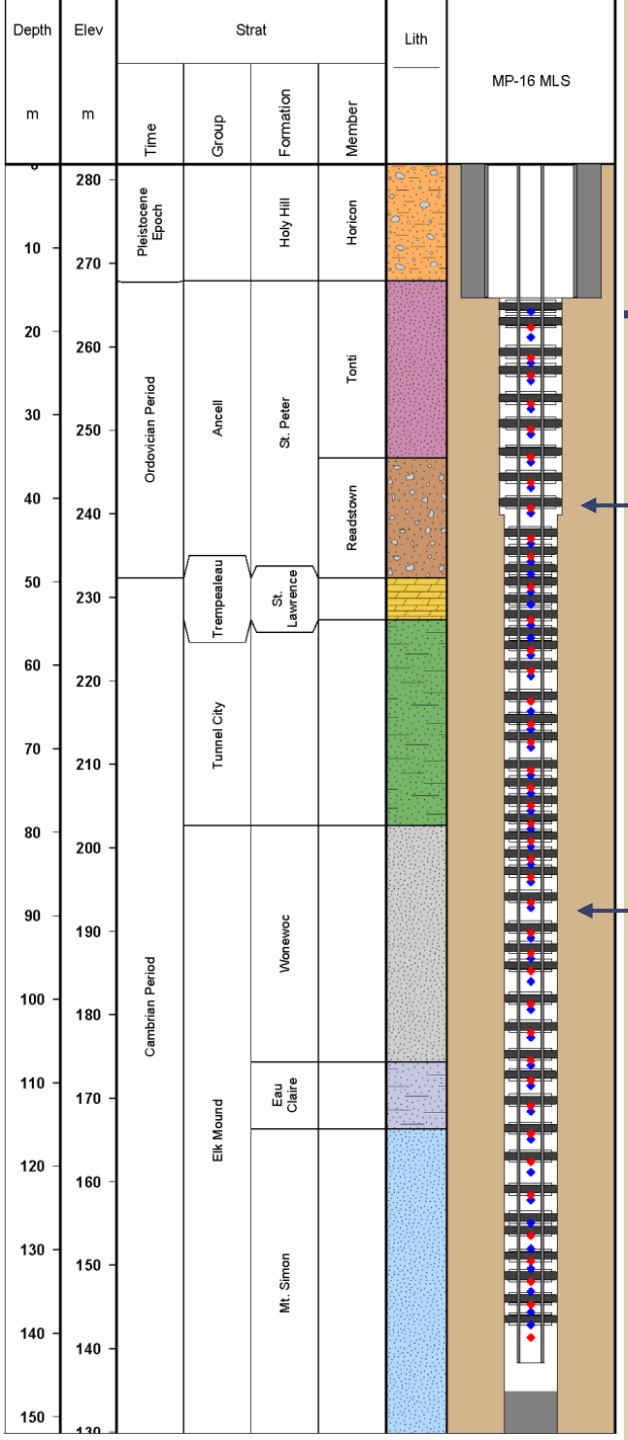

## Definition:

A single device assembled on surface and then installed in a borehole or a multi-screened casing to divide the hole into many separated intervals for data acquisition from many depth-discrete segments of the hole

# High Resolution MLS Design Objectives

- Avoid blending HGUs
  - Position monitoring zones and seals based on complimentary data sets
  - Use short monitoring zones
  - Seal un-monitored sections of the borehole
- Maximize the number of monitoring zones

# High Resolution Design



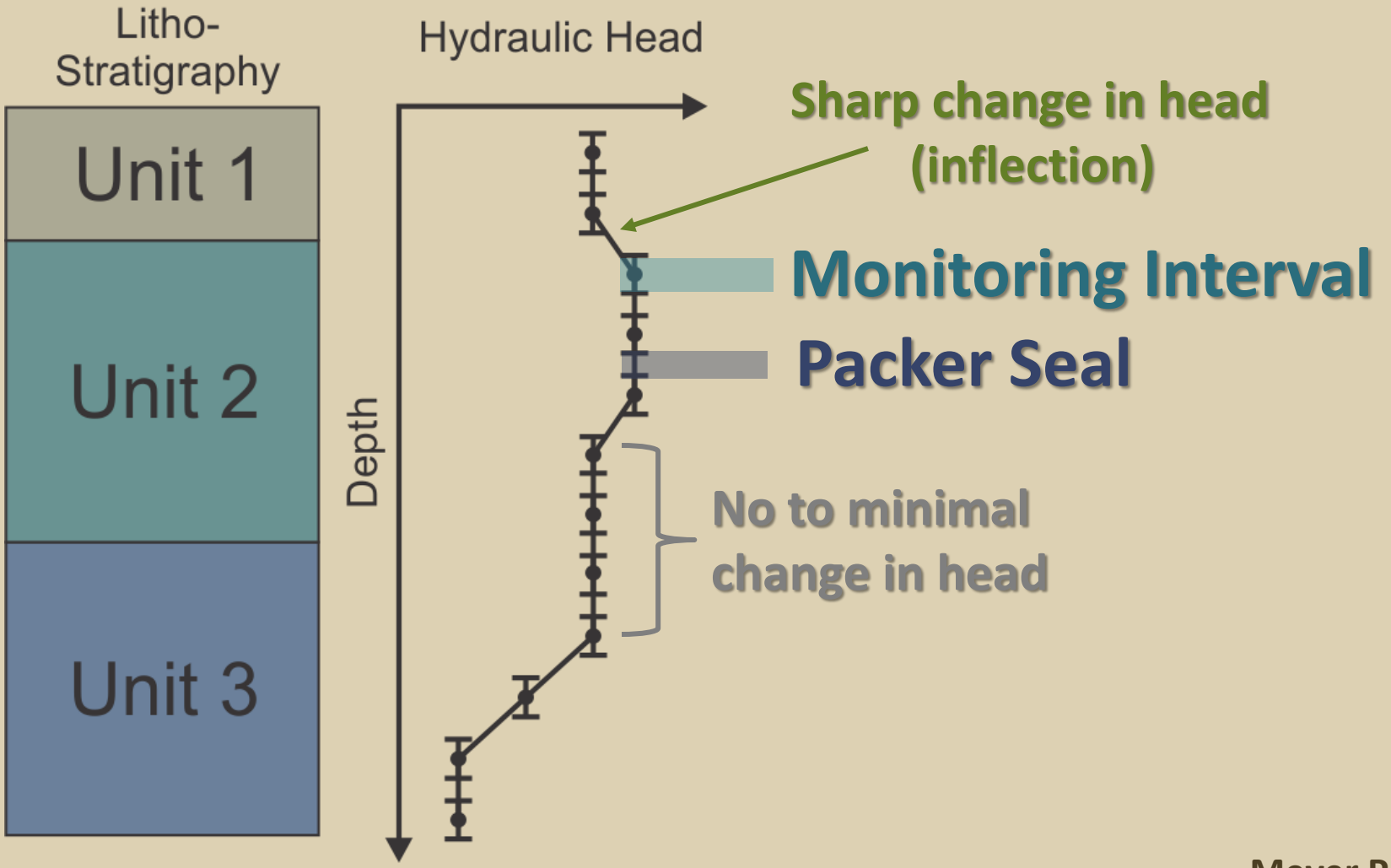

Packer

Monitoring Interval

## Multilevel System

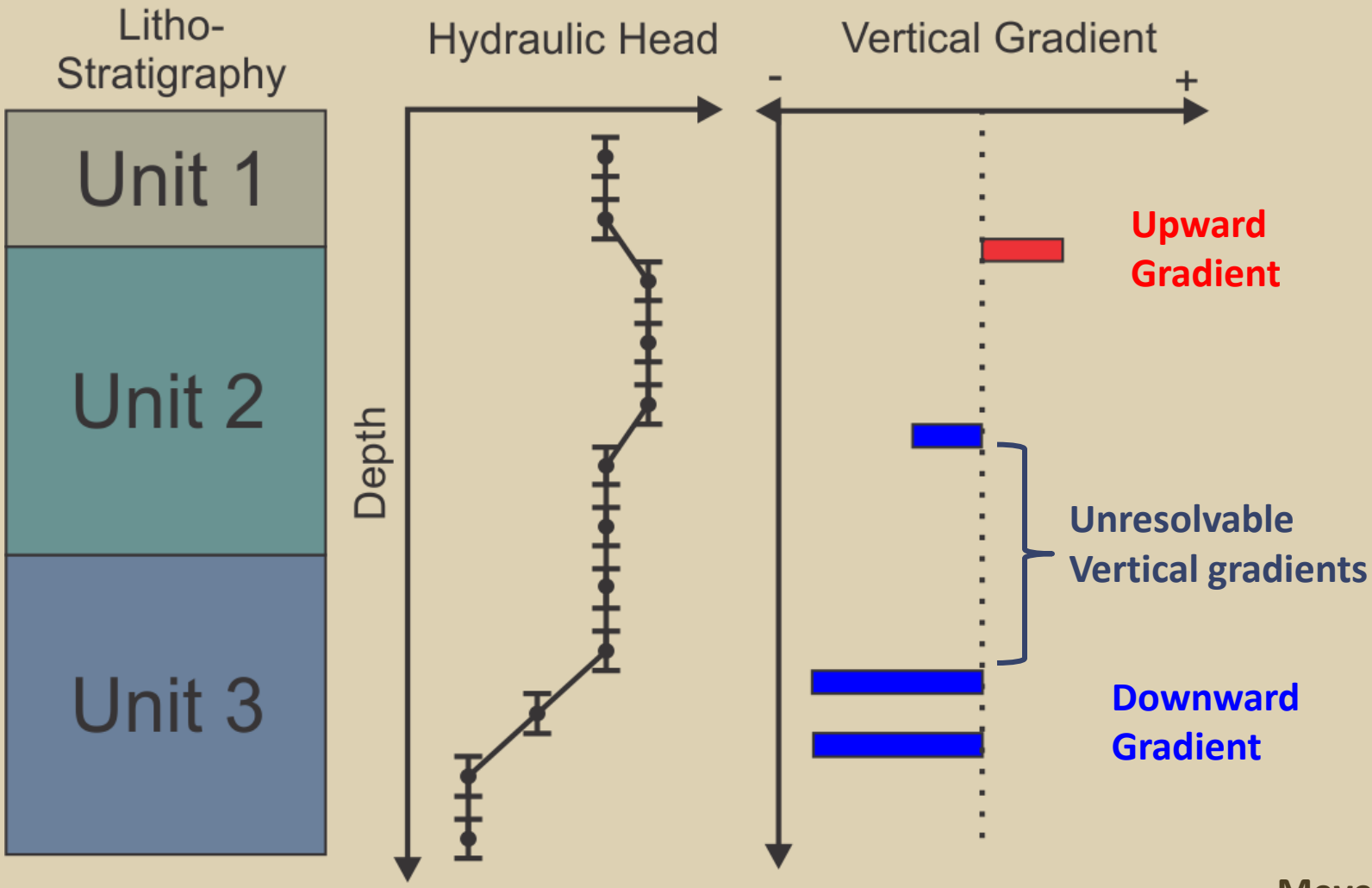
- ✓monitors 129.5 m of bedrock
- ✓46 monitoring zones
- ✓3.6 zones per 10 m
- ✓32% sealed

# Schematic Head Profile

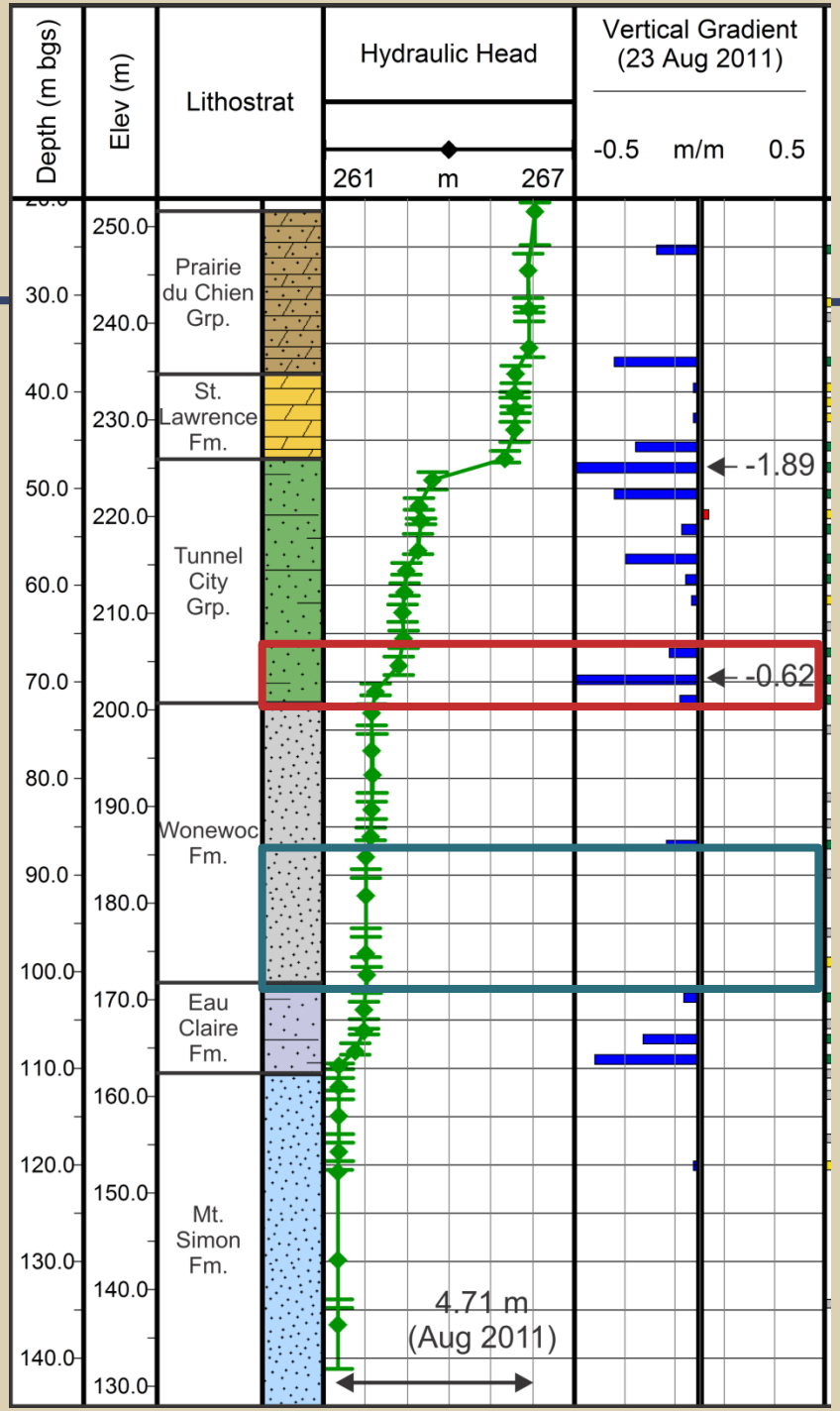



Meyer PhD, 2013

# Schematic Vertical Gradient Profile




Meyer PhD, 2013




# Head Profiles are Geometric

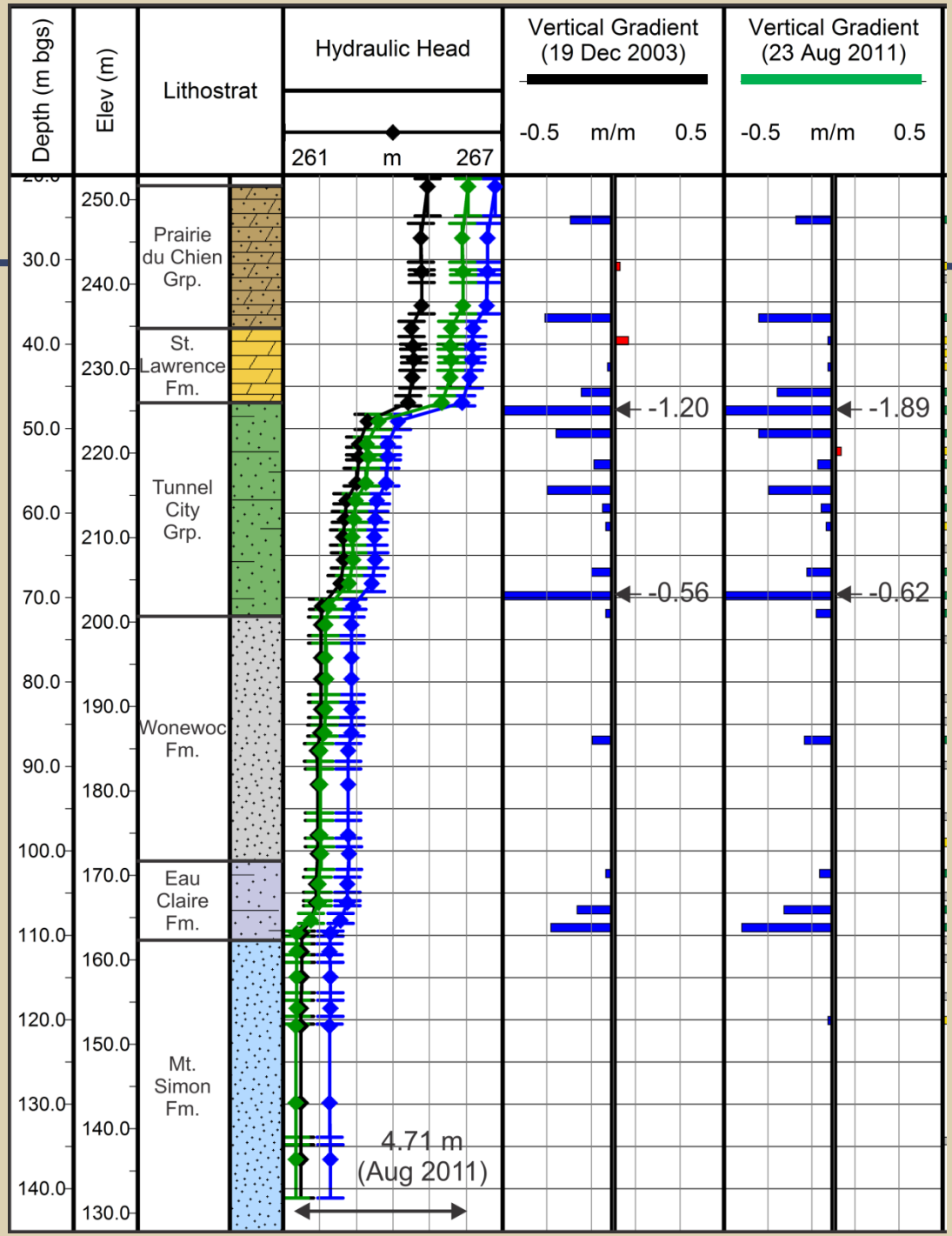
Thin sections of large vertical gradient (inflections)

– Relatively low $K_v$

Thick sections of unresolvable vertical gradient

– Relatively high $K_v$

Meyer et al. 2008, Meyer PhD 2013



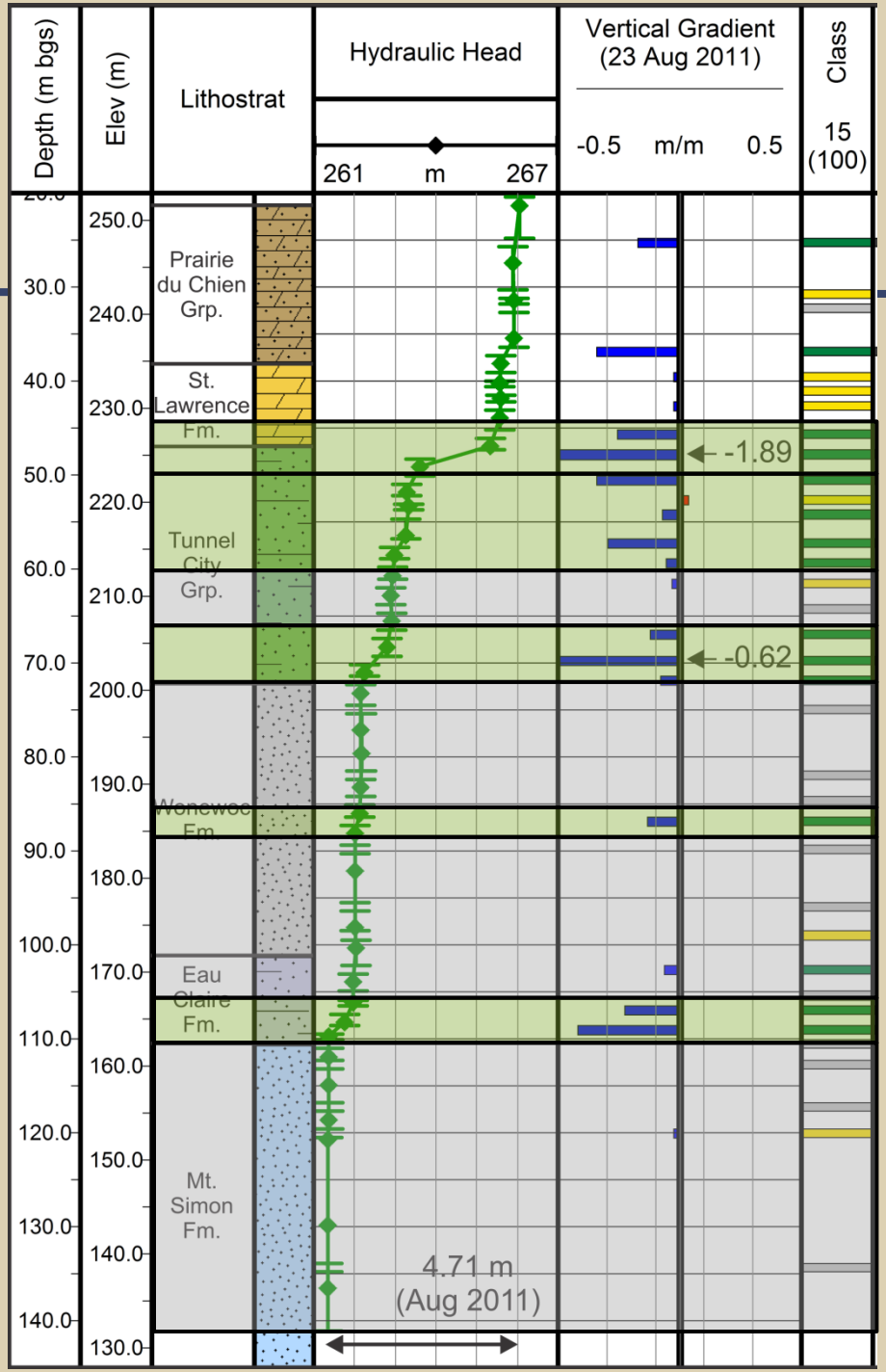

# Head Profiles are Repeatable

— Dec 2003

— Jun 2009

— Aug 2011

Meyer et al. 2008, Meyer PhD 2013




# Comparison to Lithostratigraphy

**Relatively low $K_v$**

**Relatively high $K_v$**

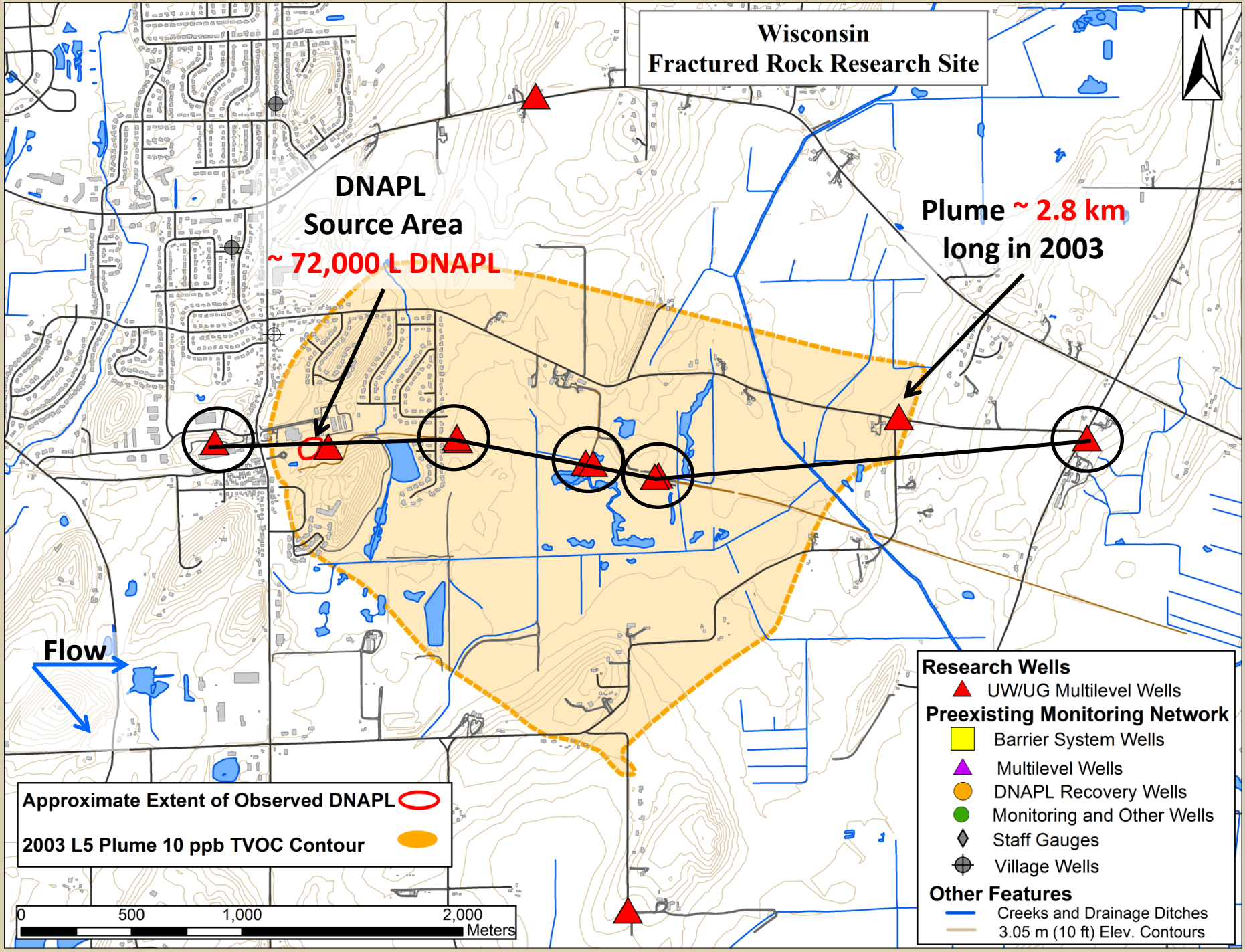
Lithostratigraphy is not predictive of the position/thickness of $K_v$ contrasts

**Meyer et al. 2008, Meyer PhD 2013**

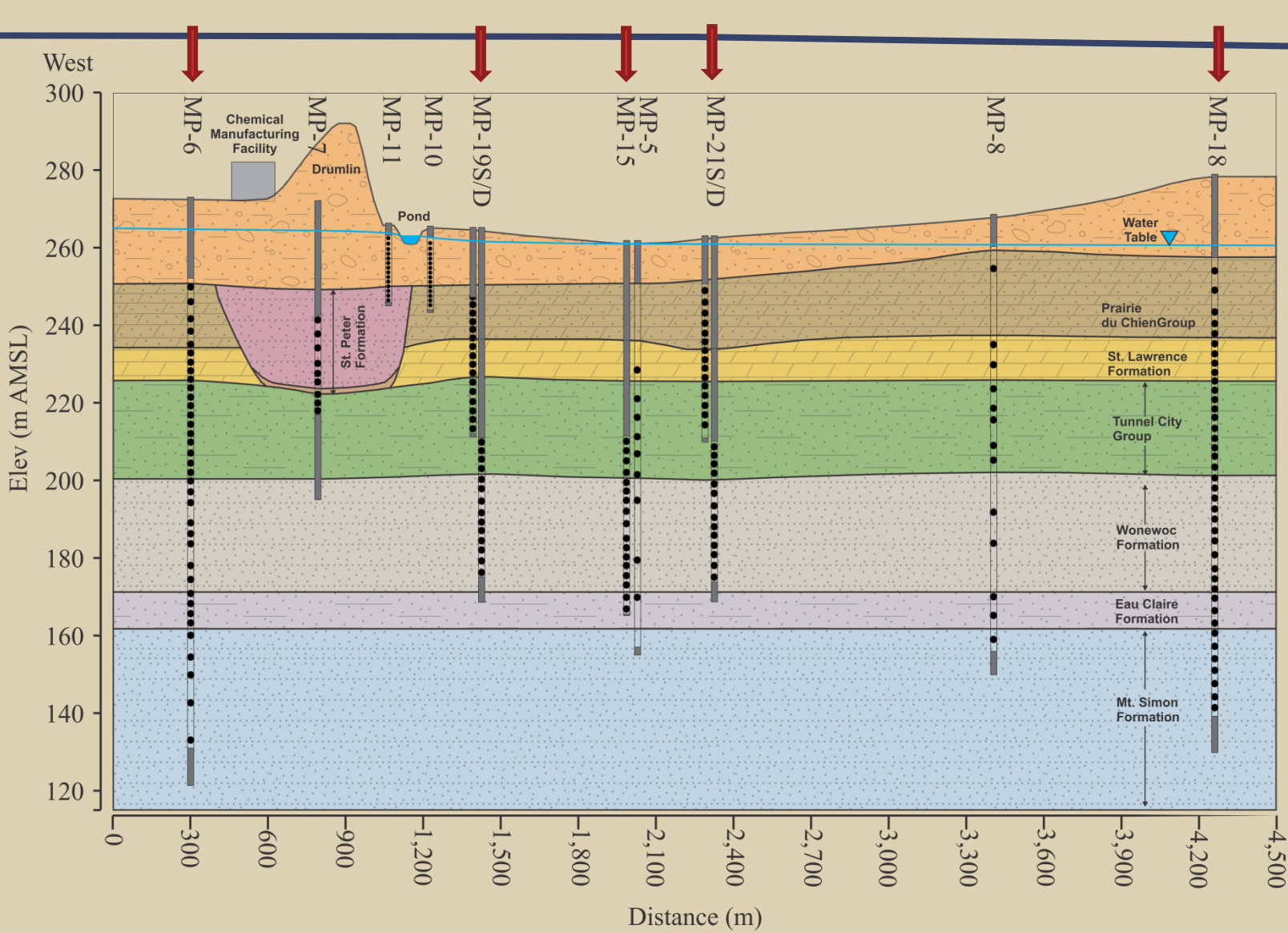
# Research Questions

- Do the vertical gradients correlate between locations

- What is the geologic basis for the shape of the head/vertical gradient profiles?


Wisconsin
Fractured Rock Research Site
N
DNAPL
Source Area
~ 72,000 L DNAPL
Plume ~ 2.8 km
long in 2003
Flow
Approximate Extent of Observed DNAPL
2003 L5 Plume 10 ppb TVOC Contour
0
500
1,000
2,000
Meters
Research Wells
UW/UG Multilevel Wells
Preexisting Monitoring Network
Barrier System Wells
Multilevel Wells
DNAPL Recovery Wells
Monitoring and Other Wells
Staff Gauges
Village Wells
Other Features
Creeks and Drainage Ditches
3.05 m (10 ft) Elev. Contours

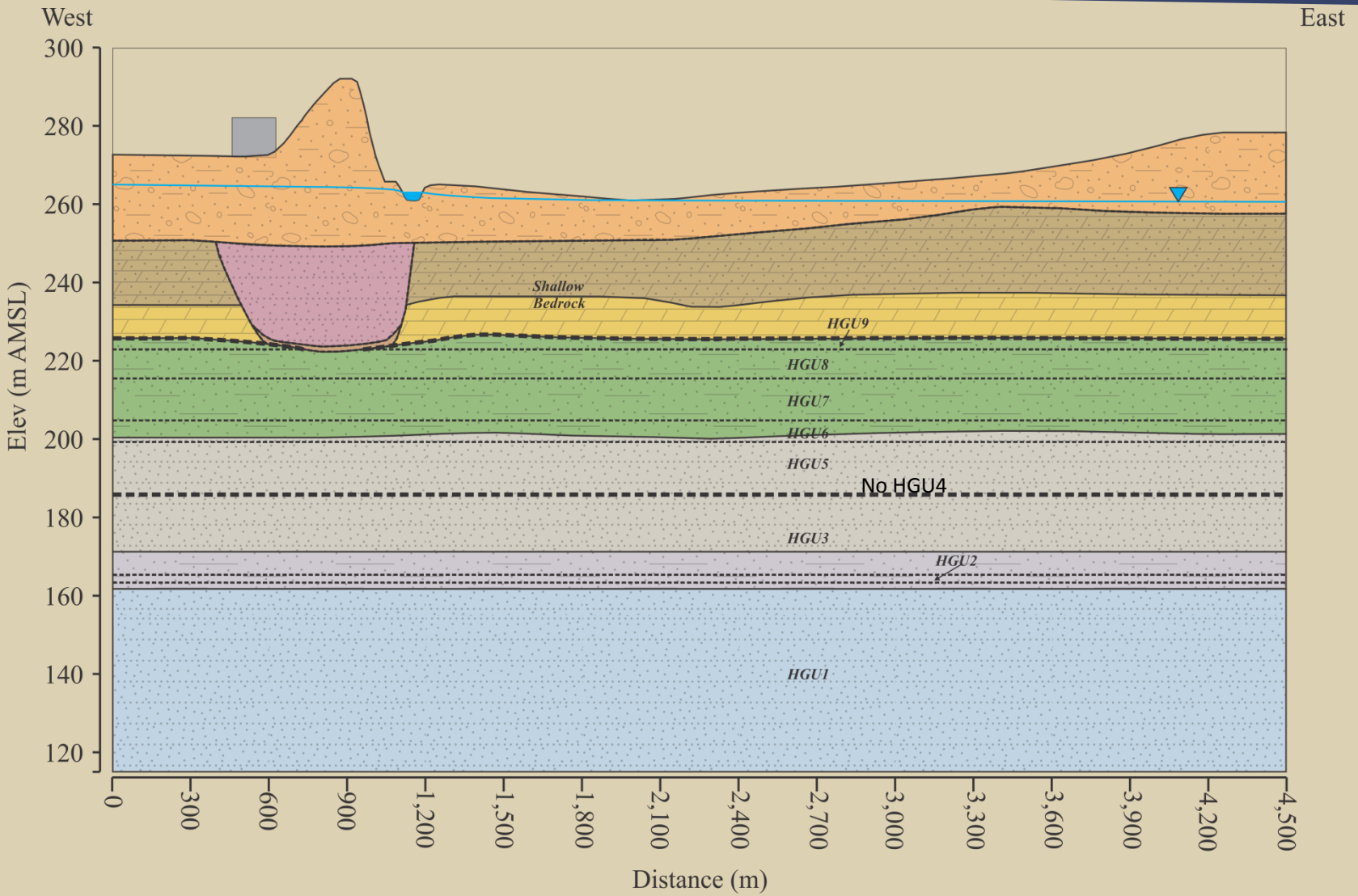
# High Resolution MLS Transect



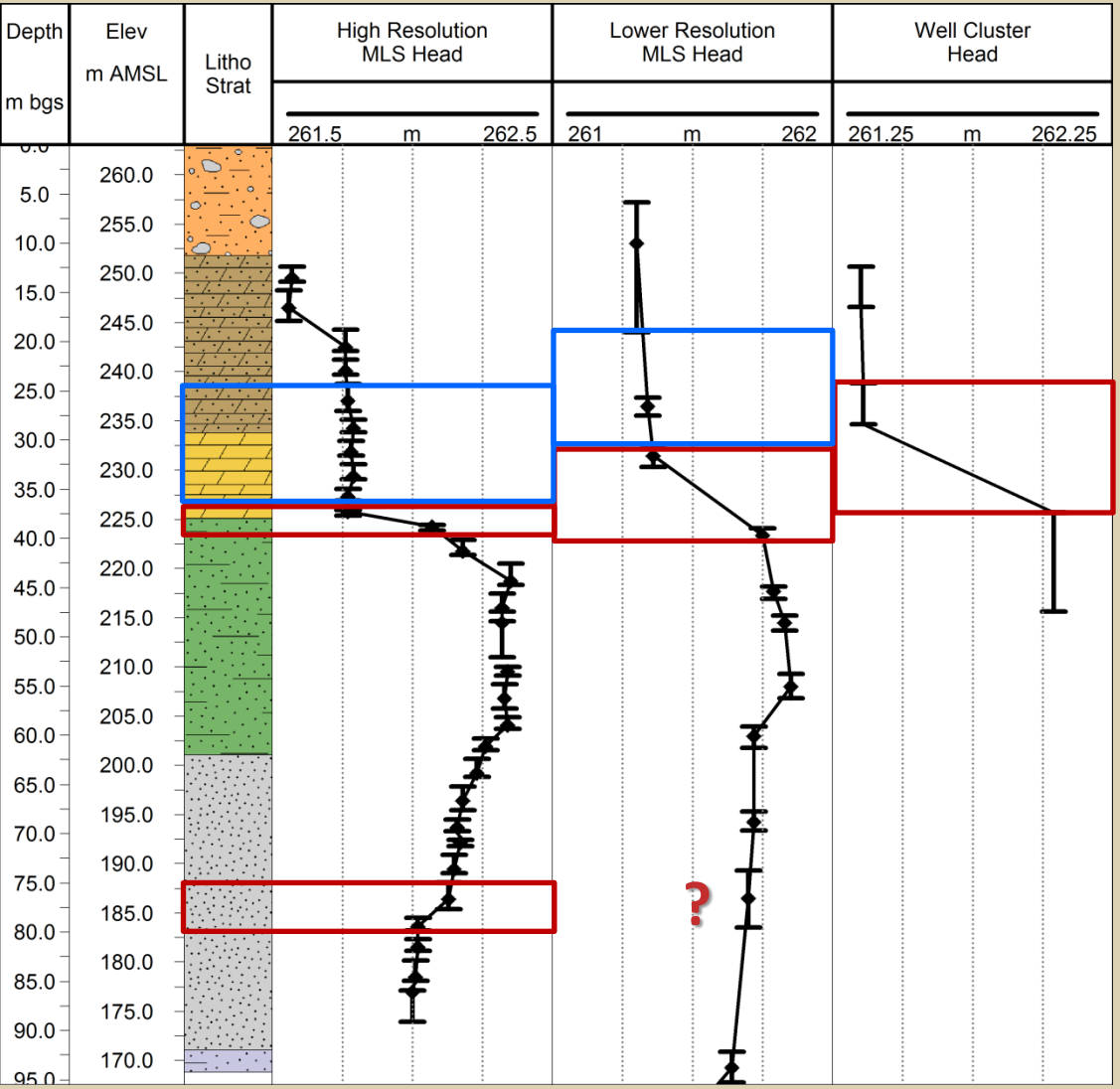
# Key Points

- Vertical gradients occur at similar stratigraphic positions across the site (they correlate!)
- Indicate laterally extensive contrasts in K
- K contrasts are not coincident with lithostratigraphy

# New Basis for Numerical Models
# Vertical Gradient Based Bedrock HGUs



# How Much Resolution is Enough?




## Lower resolution profiles

- do not accurately identify the position and thickness of K contrasts
- do not identify thin but important contrasts in K
- provide inaccurate (blended) heads and gradients

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