Groundwater Flow and Contaminant Migration in the Cohoes Mélange Lithotectonic Unit: Influence of a Thrust Fault

Robert O'Neill, CPG, PG, Brown and Caldwell
James Marolda, CPG, PG, Brown and Caldwell
Steven Stucker, CPG, National Grid

2016 GSA Northeastern Section
Annual Meeting
March 21-23, 2016
Albany, New York

Technical Session:
Integrating Structural Geology and Hydrogeology

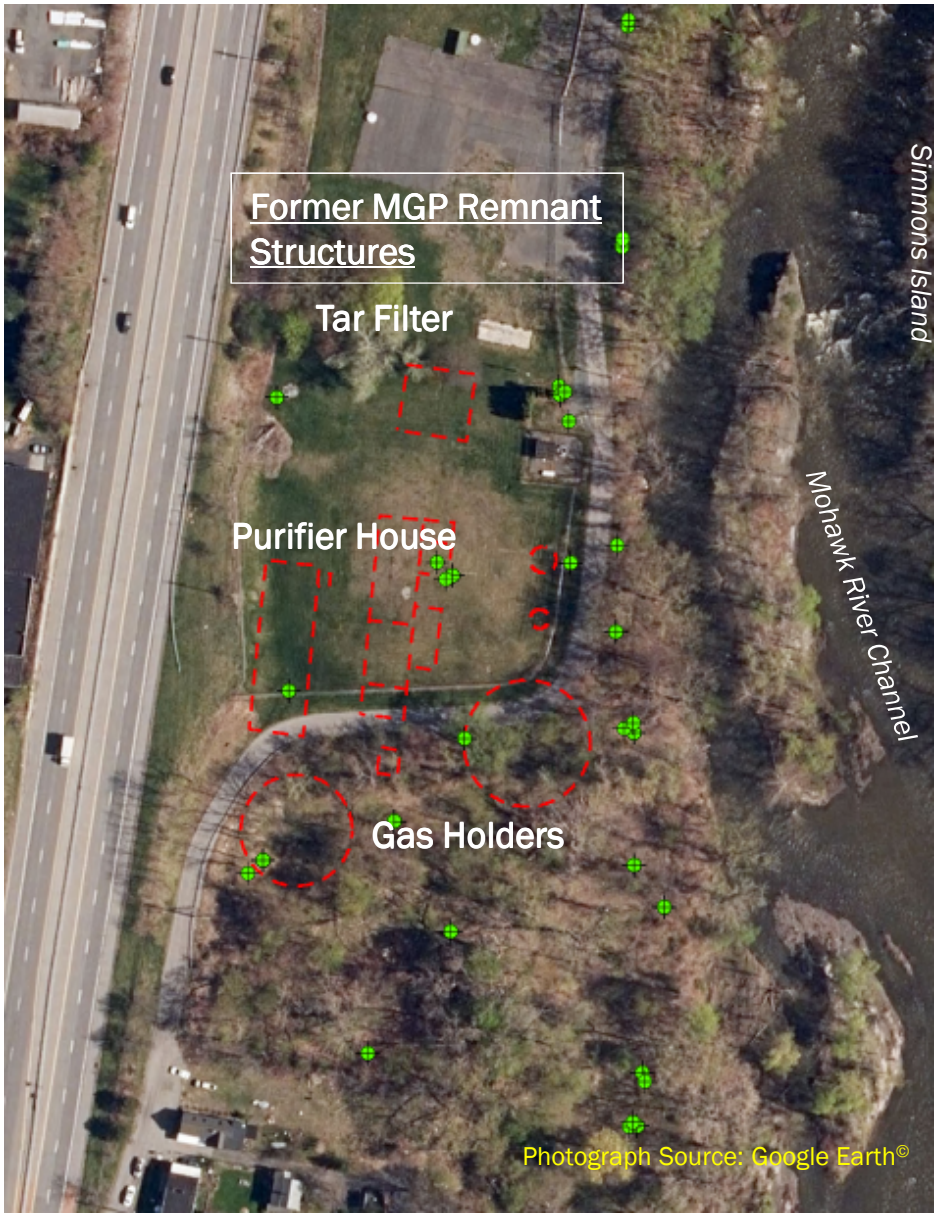
Brown AND Caldwell

nationalgrid

Regional Setting
Former MGP Site, Cohoes, New York

Former MGP Site, Cohoes, New York

- Primary impact associated with Manufactured Gas Plant (MGP) operations was the release of tar, which typically behaves as a DNAPL.
- Tar is source of dissolved-phase constituents to groundwater such as benzene, toluene, ethylbenzene, xylenes, and naphthalene.

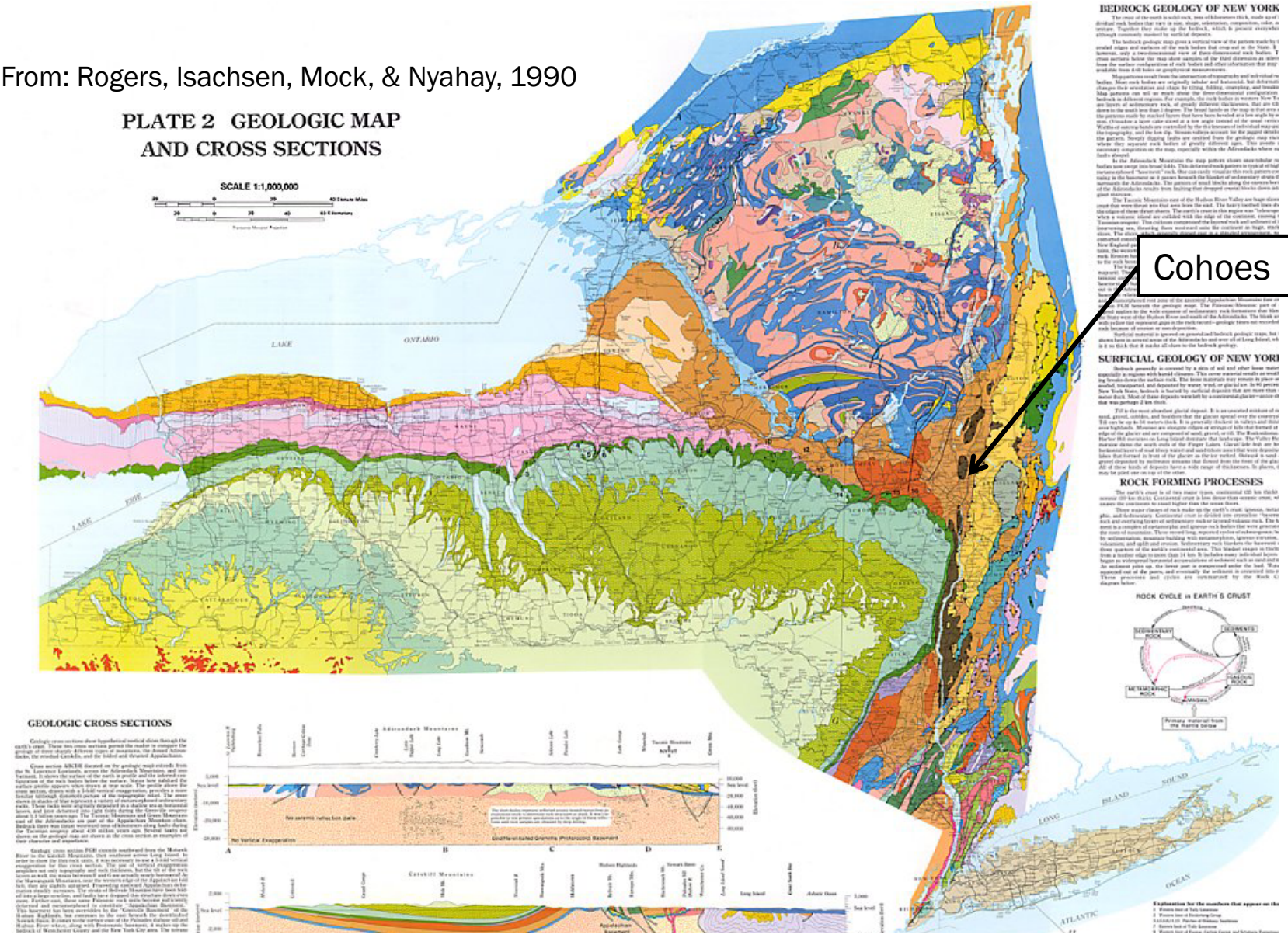


Purpose of Presentation

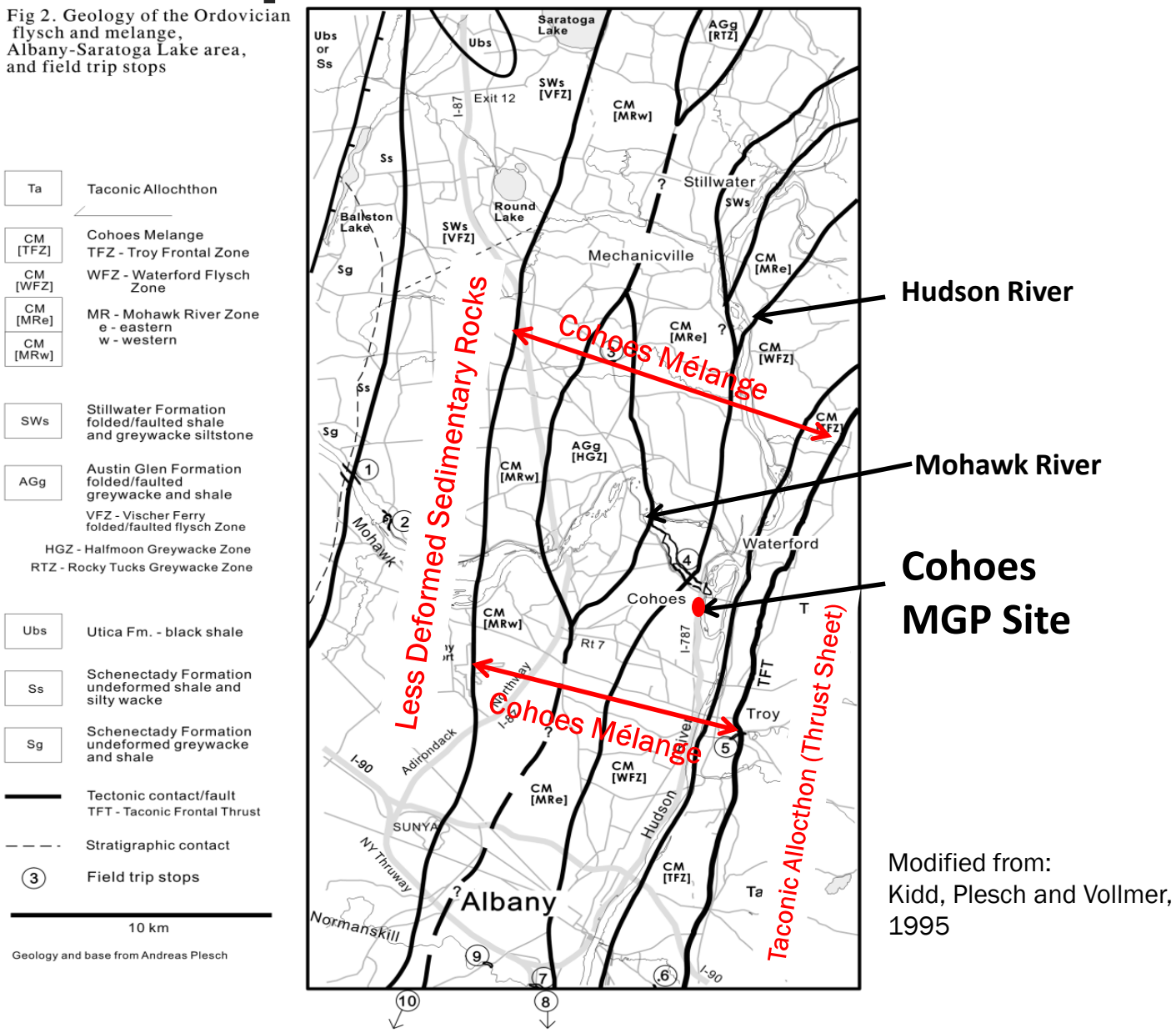
- To describe development of a conceptual model of groundwater flow, DNAPL (tar) migration and dissolved-phase constituent migration in highly-deformed sedimentary rock sequence at a former Manufactured Gas Plant (MGP), including discussion of:
    - Investigation approach;
    - How understanding the regional structural characteristics of the rock facilitated development of the conceptual model and guided the investigation; and
    - The influence of a thrust fault on groundwater flow and contaminant migration.

Bedrock-New York

From: Rogers, Isachsen, Mock, & Nyahay, 1990



Lithotectonic Map

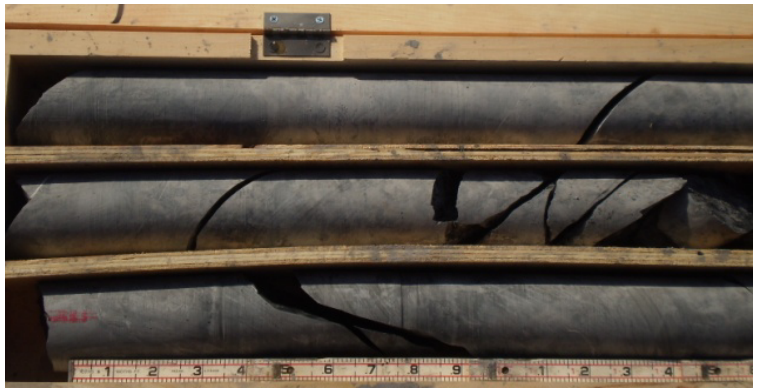


Modified from:
Kidd, Plesch and Vollmer, 1995

Bedrock Conditions at Cohoes MGP Site: Deformed Sedimentary Rock

- "Cohoes Mélange" Lithotectonic Unit.
- Originally bedded shale and mudstone unit with some sandstone and siltstone beds.
- Deformed in shear zone during Taconic mountain building event (Ordovician Period).
- Ductile and brittle deformation: Faults, folds, disrupted bedding, closely-spaced cleavage
- No continuous marker beds remain for stratigraphic correlation. Nearly uniform lithology.

Outcrop of Cohoes Mélange in river channel adjacent to site



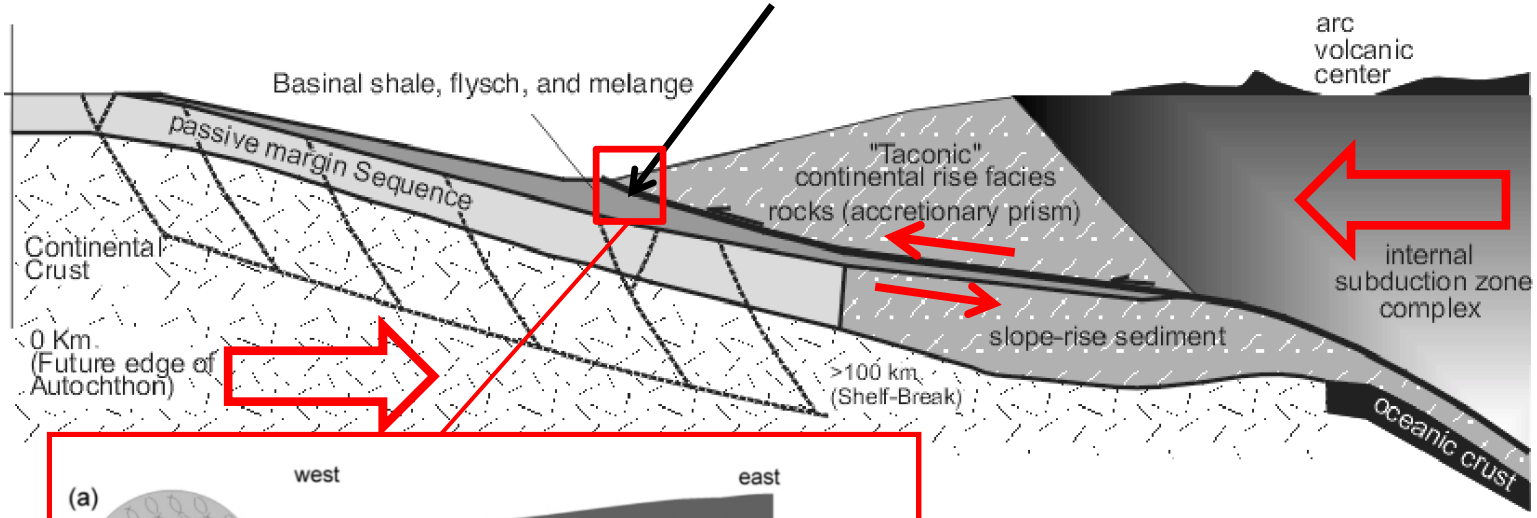
Rock core from Cohoes Mélange: shale w/no visible beds. Breaks are along cleavage.

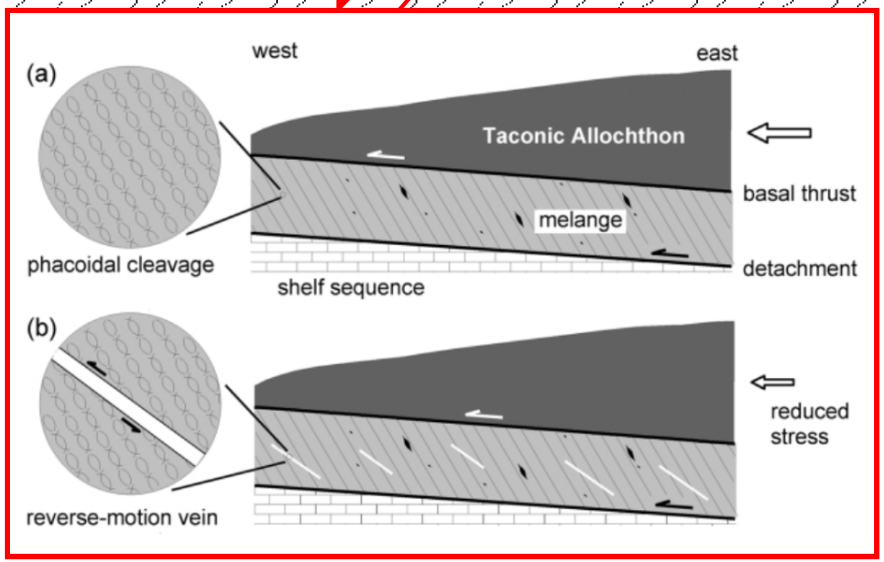
Taconic Mountain Building Event
Schematic Cross-Section

West

Cohoes Bedrock

East





(Modified from Hayman and Kidd, 2002)

(From Lim, et al, 2005)

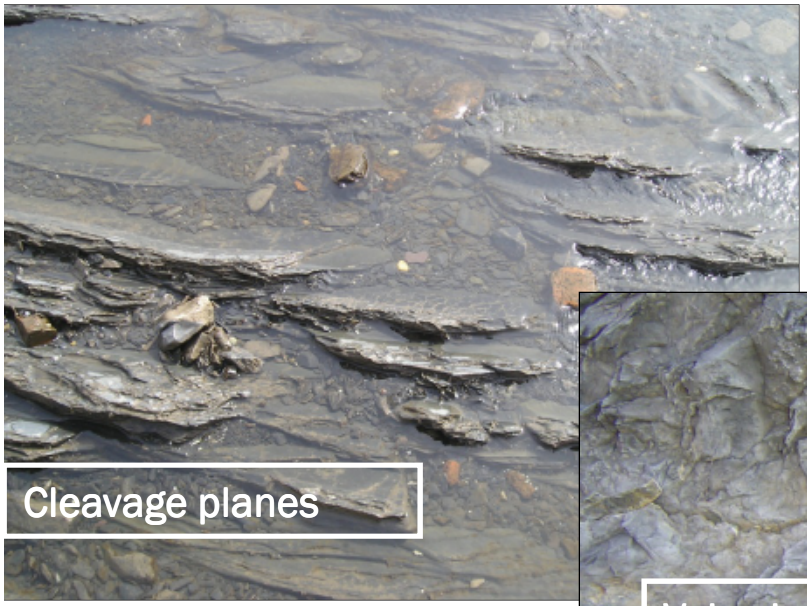
Deformation of Sedimentary Bedrock at Cohoes MGP Site

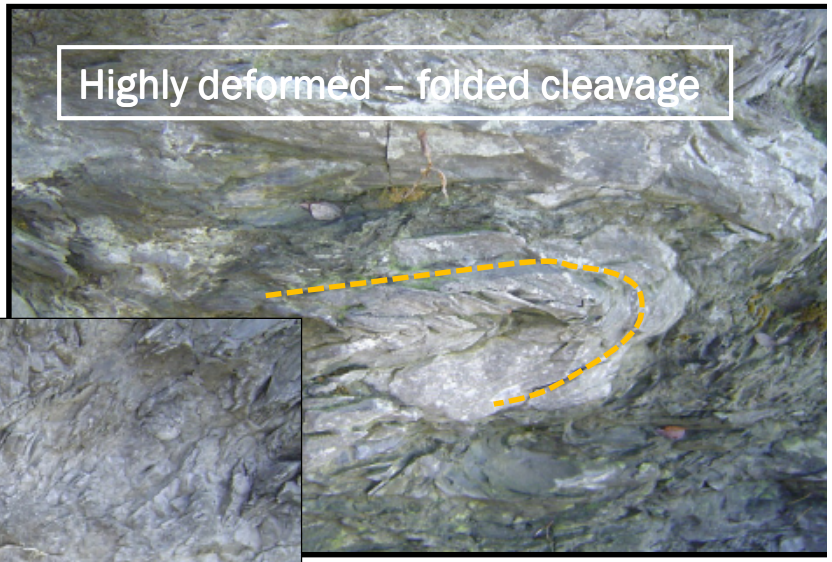
<u>Pre-deformation</u>:
Original rock type was shale with thin sandstone beds.

<u>Post-deformation (Cohoes Mélange):</u> Sandstone block (disrupted bed) surrounded by shale matrix (original bedding in shale not visible).

Cohoes Mélange – Outcrop Near Site

Cohoes Mélange – Outcrops


Cleavage planes


Highly deformed – folded cleavage

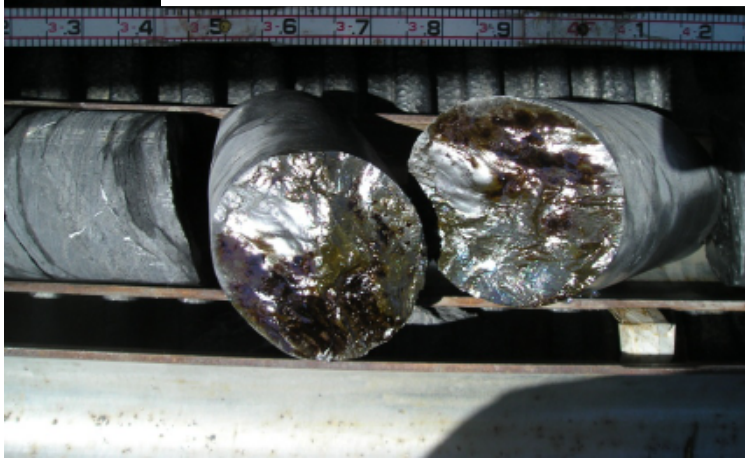

Veins indicating reverse displacement


Disrupted bedding

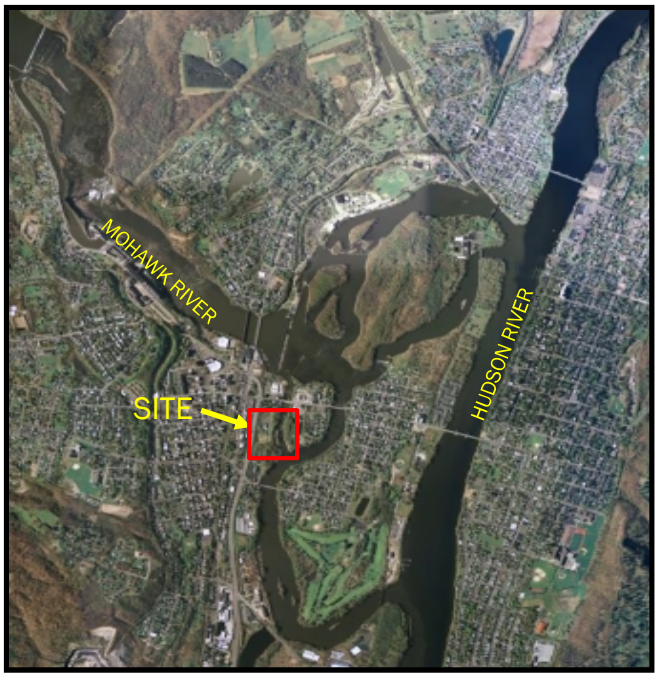

Outcrops in river

Cohoes Mélange – Core from Site

NAPL observations in core



Locations for Bedrock Evaluation/Wells: Initial Phase of Investigation

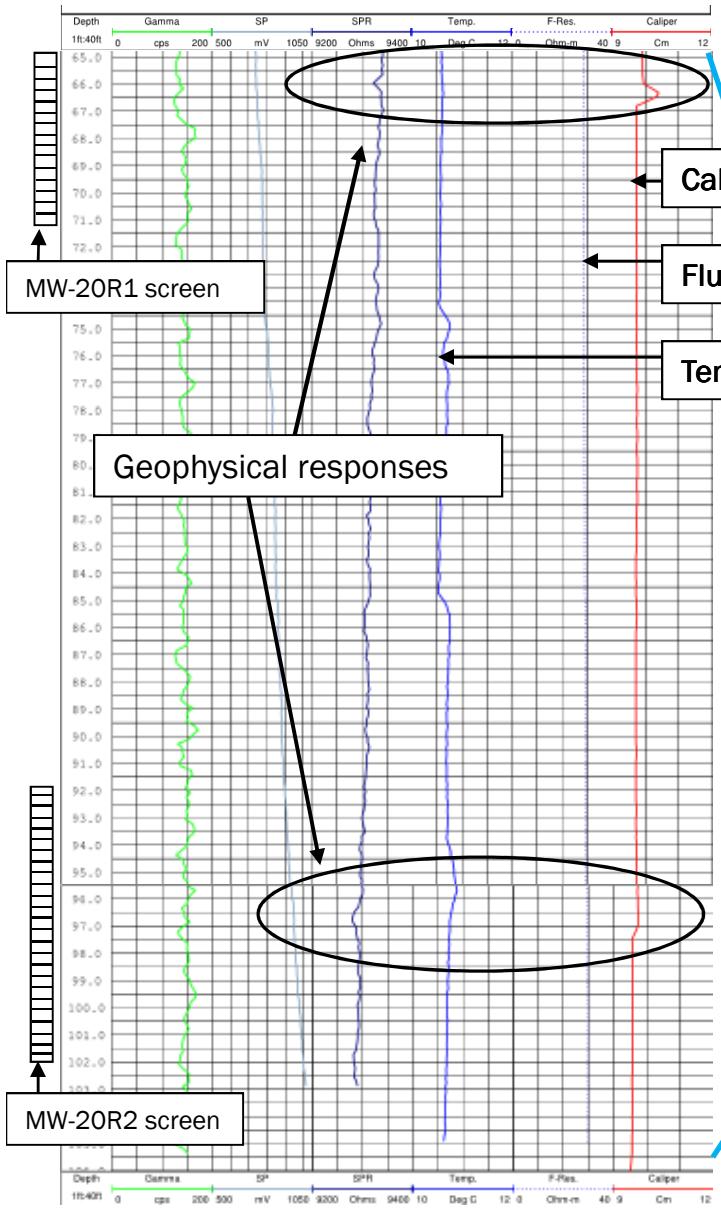


Bedrock evaluation and well location, initial phase

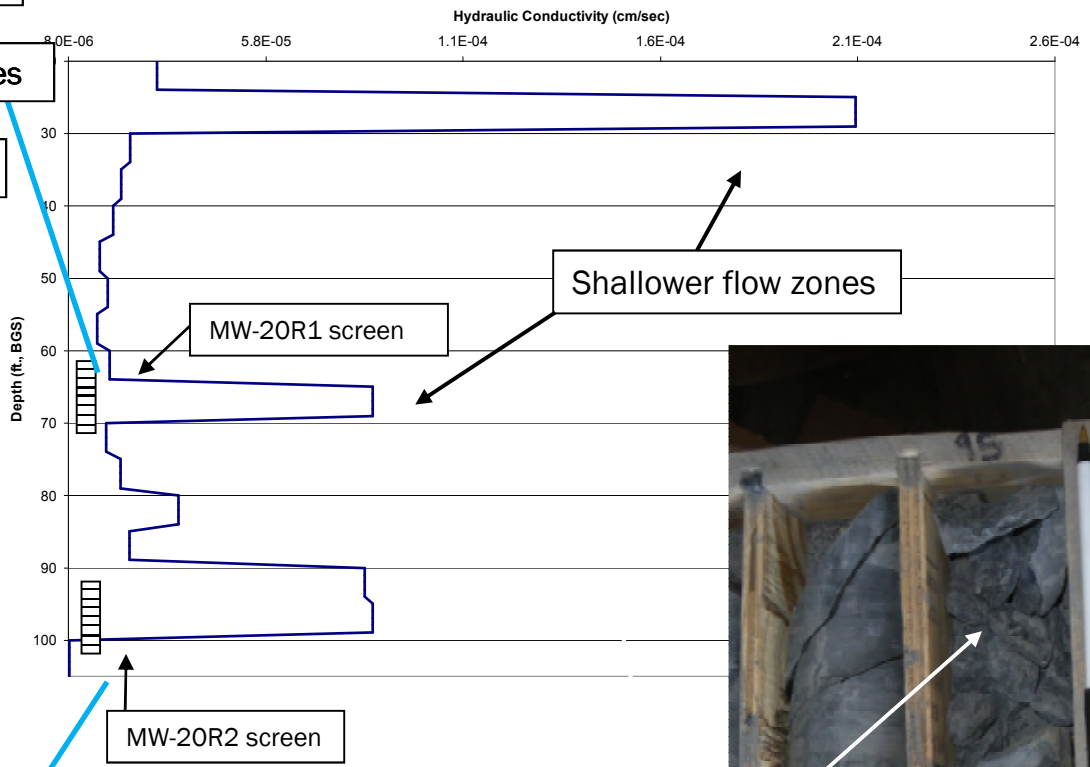
B B' Line of cross-section

Bedrock Evaluation Approach at Individual Locations: *Field Data*

Geophysical Logs (Field Output)

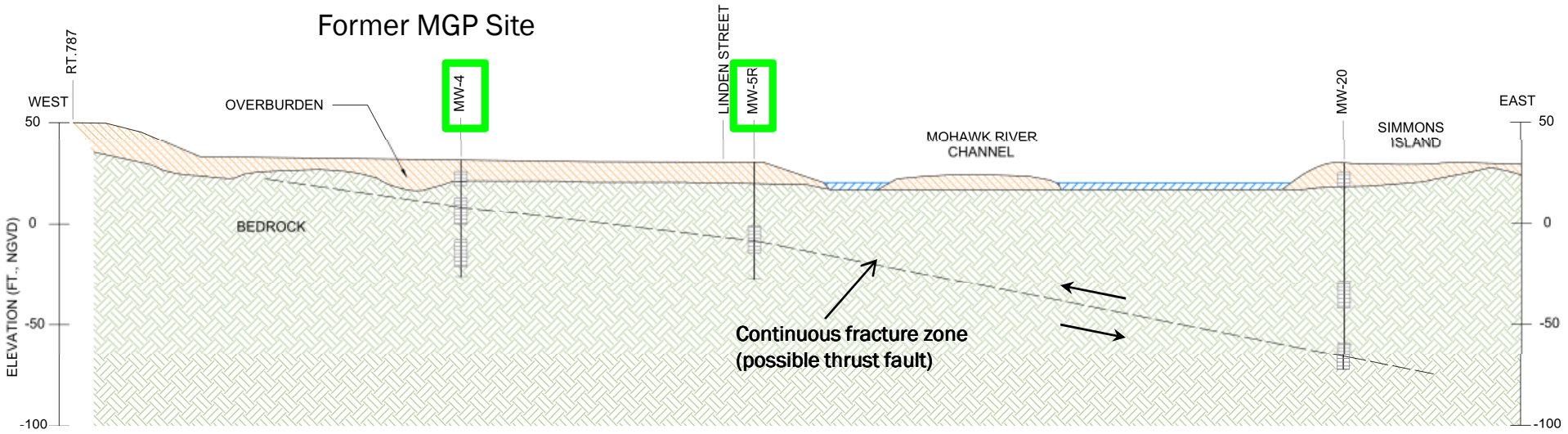


Packer Pressure Test K (cm/s)



Bedrock core from approximate depth of geophysical indicators and transmissive zones identified during packer pressure testing

Field/Working Cross-Section: Continuous Fracture Zone



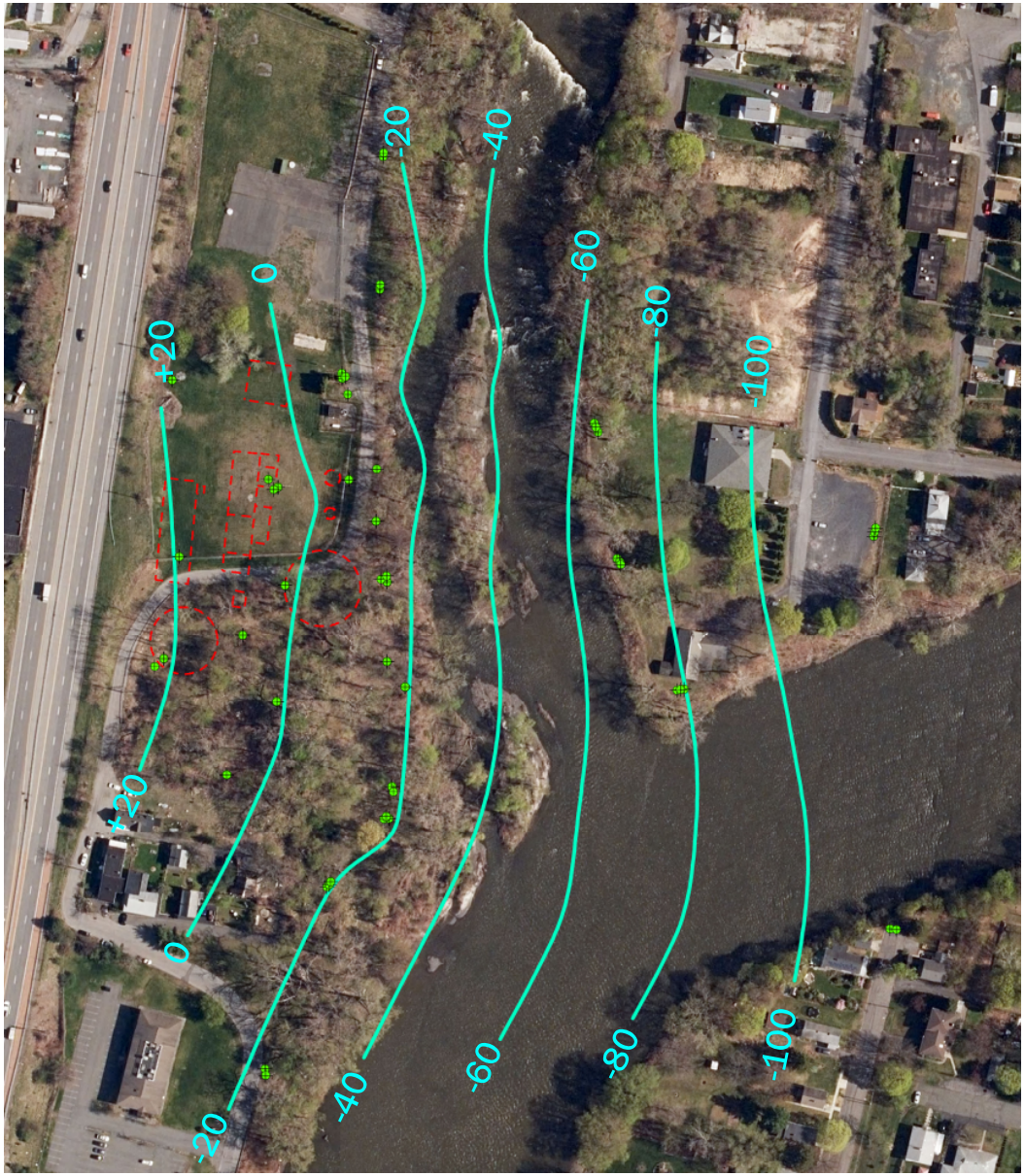
Bedrock evaluation and well location, initial phase of investigation

0 50 100
SCALE IN FEET
HORIZONTAL & VERTICAL

No vertical exaggeration

- During initial phase: at wells w/ greatest dissolved-phase concentrations, the water-bearing fractures intersecting the screen plotted on an east-dipping plane.
- Geometry of plane is similar to thrust faults in region.
- Projected plane down-dip and along strike to plan subsequent drilling to evaluate this potentially continuous fracture zone.

Thrust Fault Elevation Contours



0 100 ft

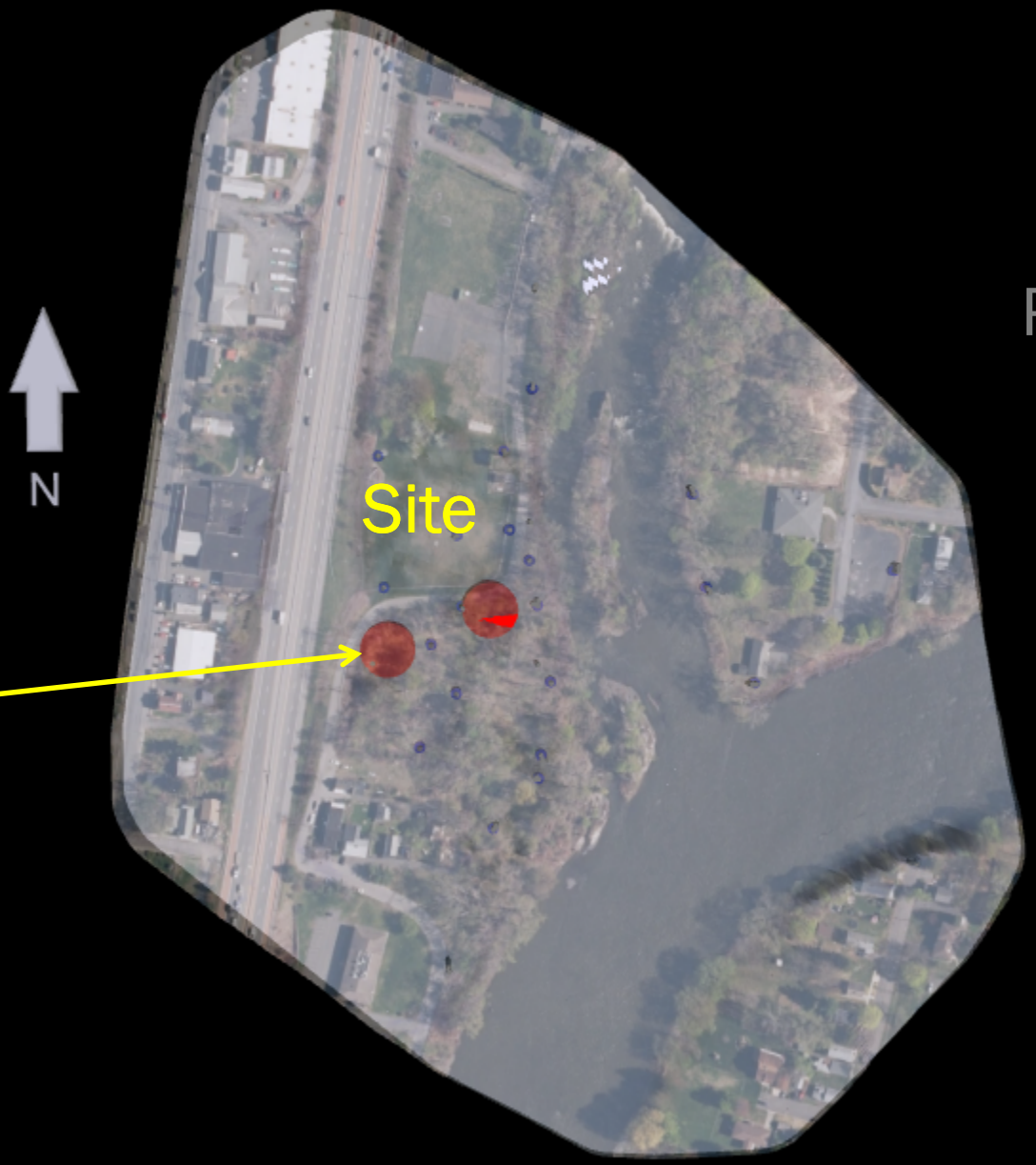
Scale
(approximate)

Contour units:
feet, NGVD

Cohoes Mélange Outcrops: Thrust Fault

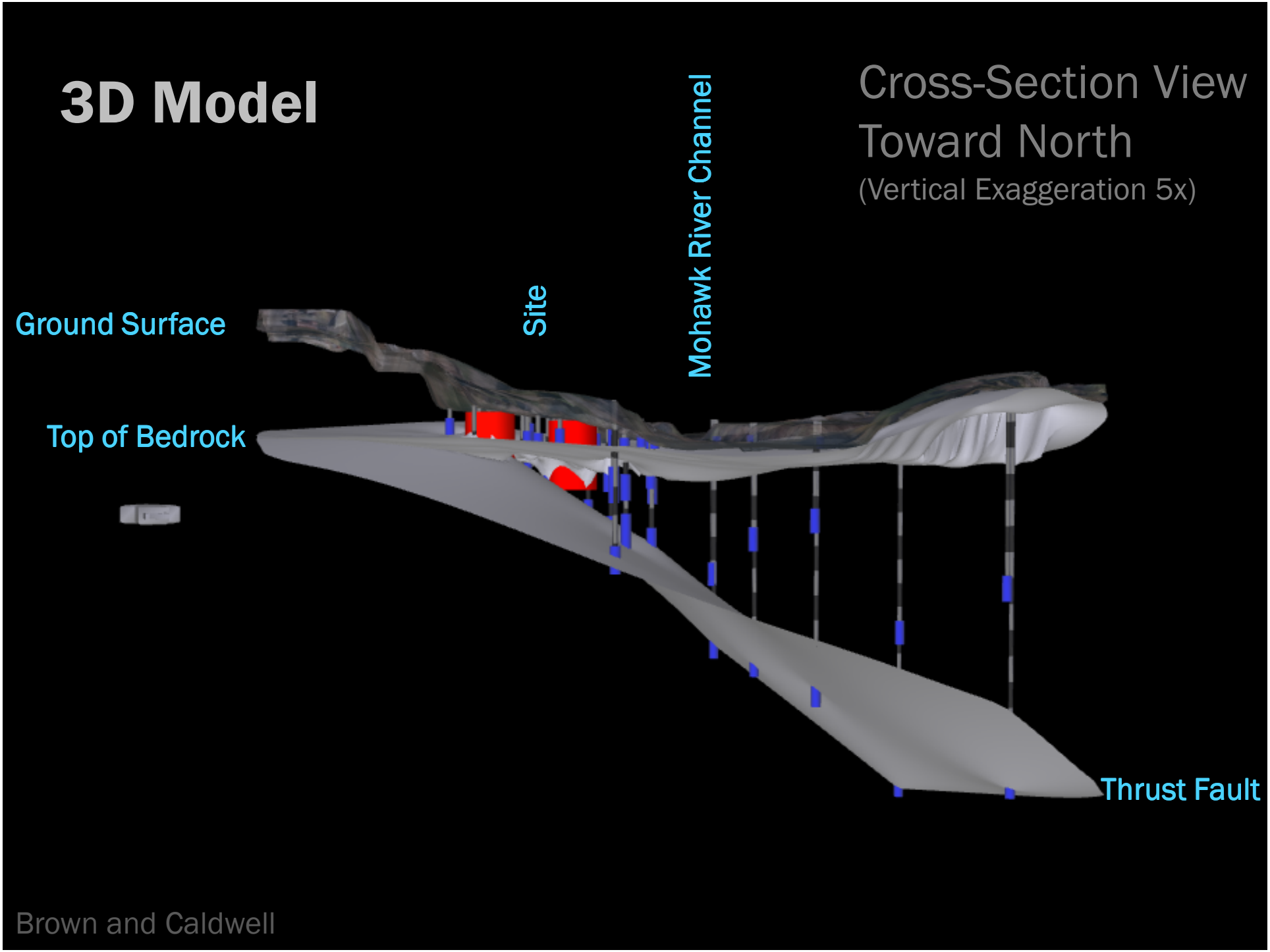
Cohoes Mélange Outcrops: Thrust Fault

3D Model



3D Model

Cross-Section View
Toward North
(Vertical Exaggeration 5x)

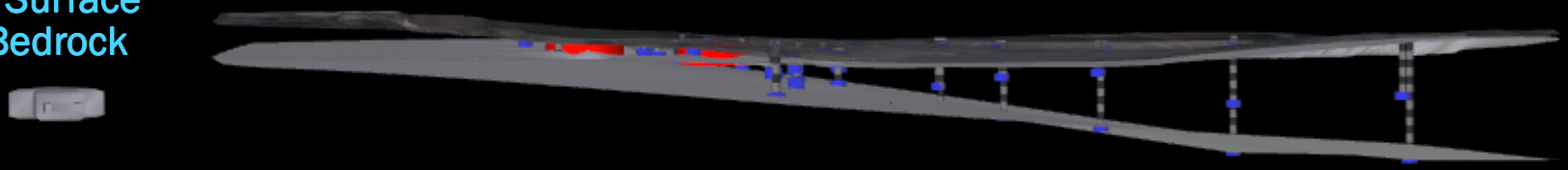


Brown and Caldwell

3D Model

Cross-Section View
Toward North
(No Vertical Exaggeration)

Ground Surface
Top of Bedrock

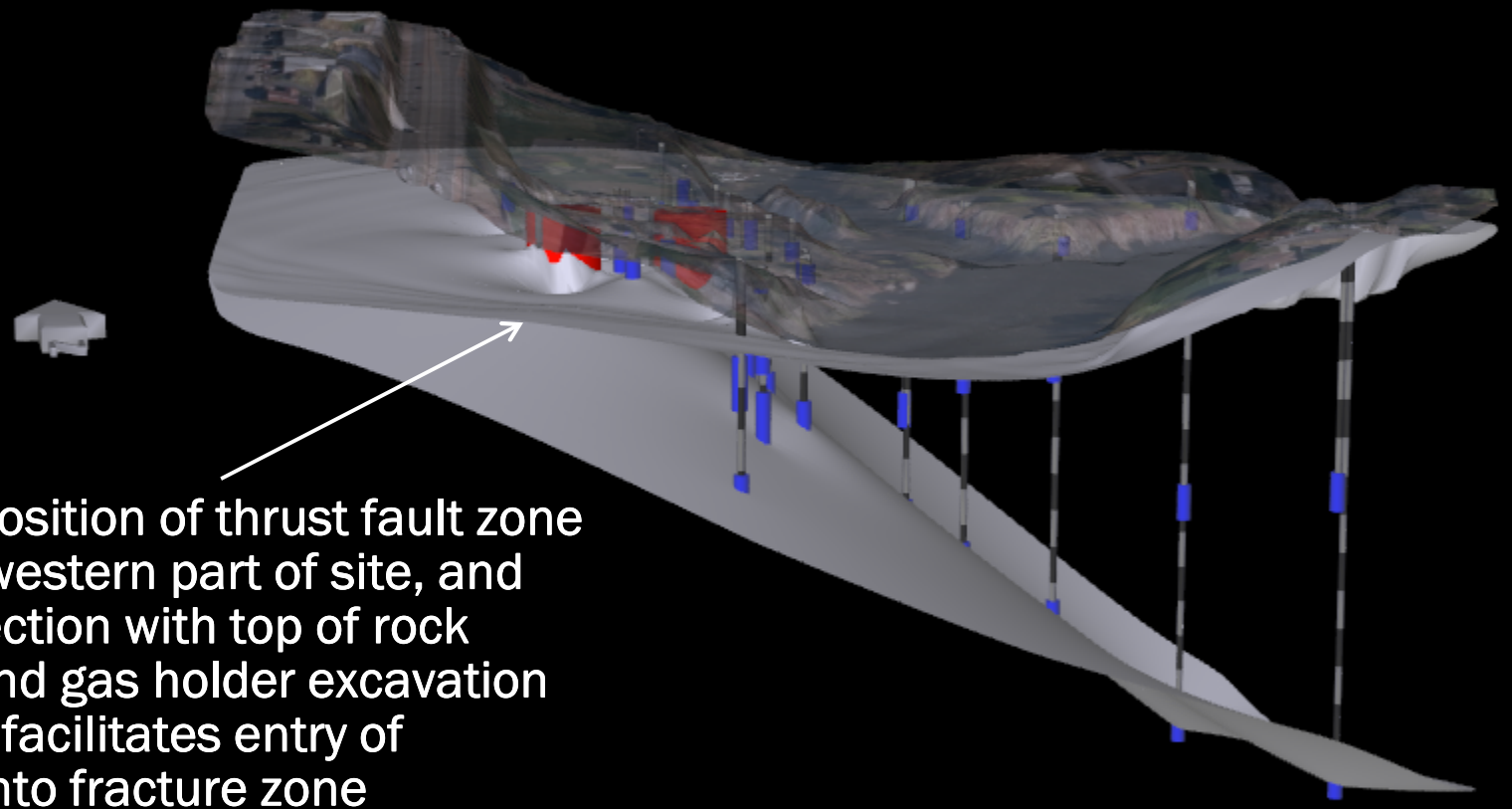


Thrust Fault

Brown and Caldwell

3D Model

Cross-Section View
Toward North (Rotated)
(Vertical Exaggeration 5x)



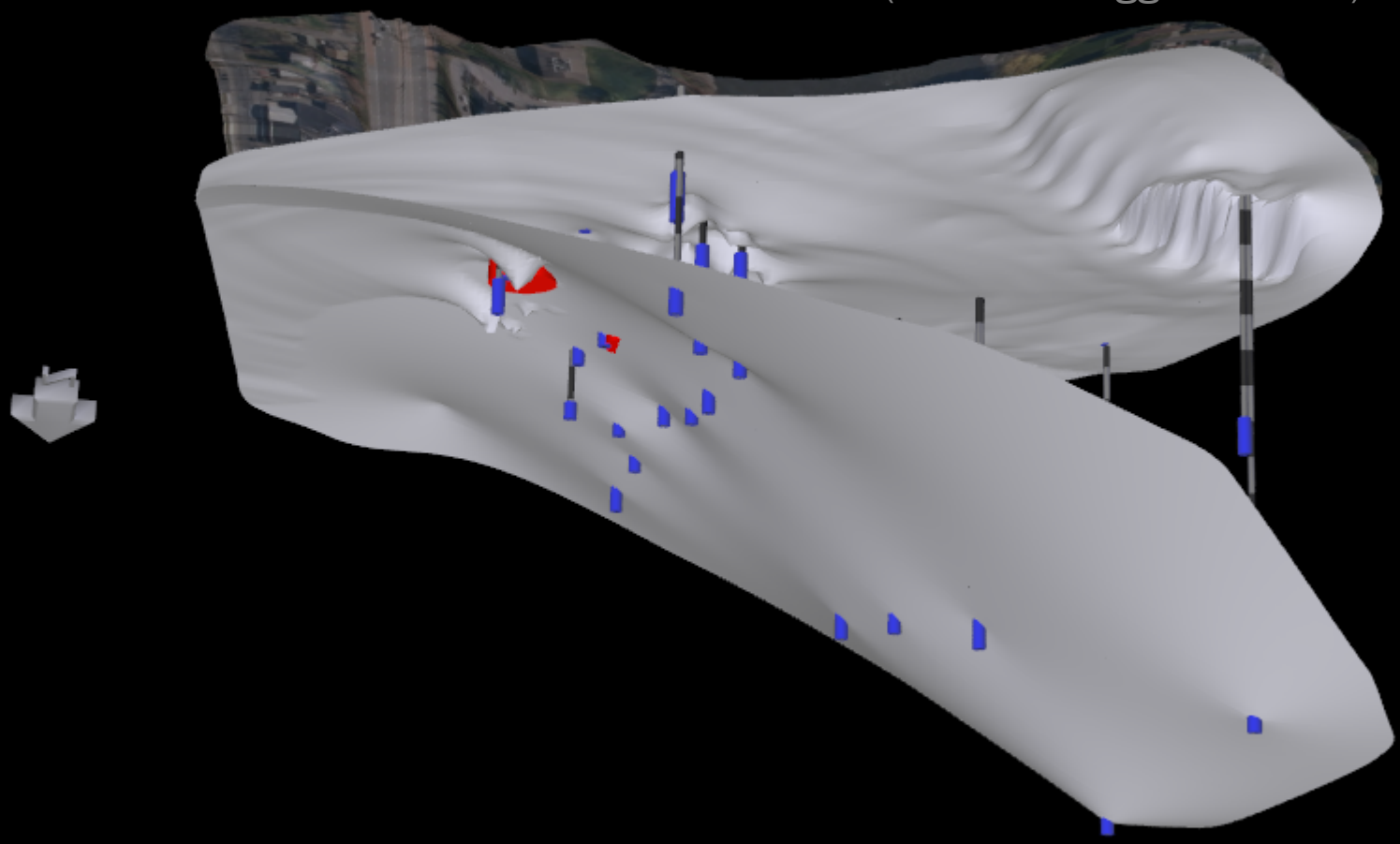
Shallow position of thrust fault zone beneath western part of site, and its intersection with top of rock surface and gas holder excavation into rock, facilitates entry of impacts into fracture zone

Thrust Fault

Brown and Caldwell

3D Model

Cross-Section View
Toward North (Rotated)
(Vertical Exaggeration 5x)

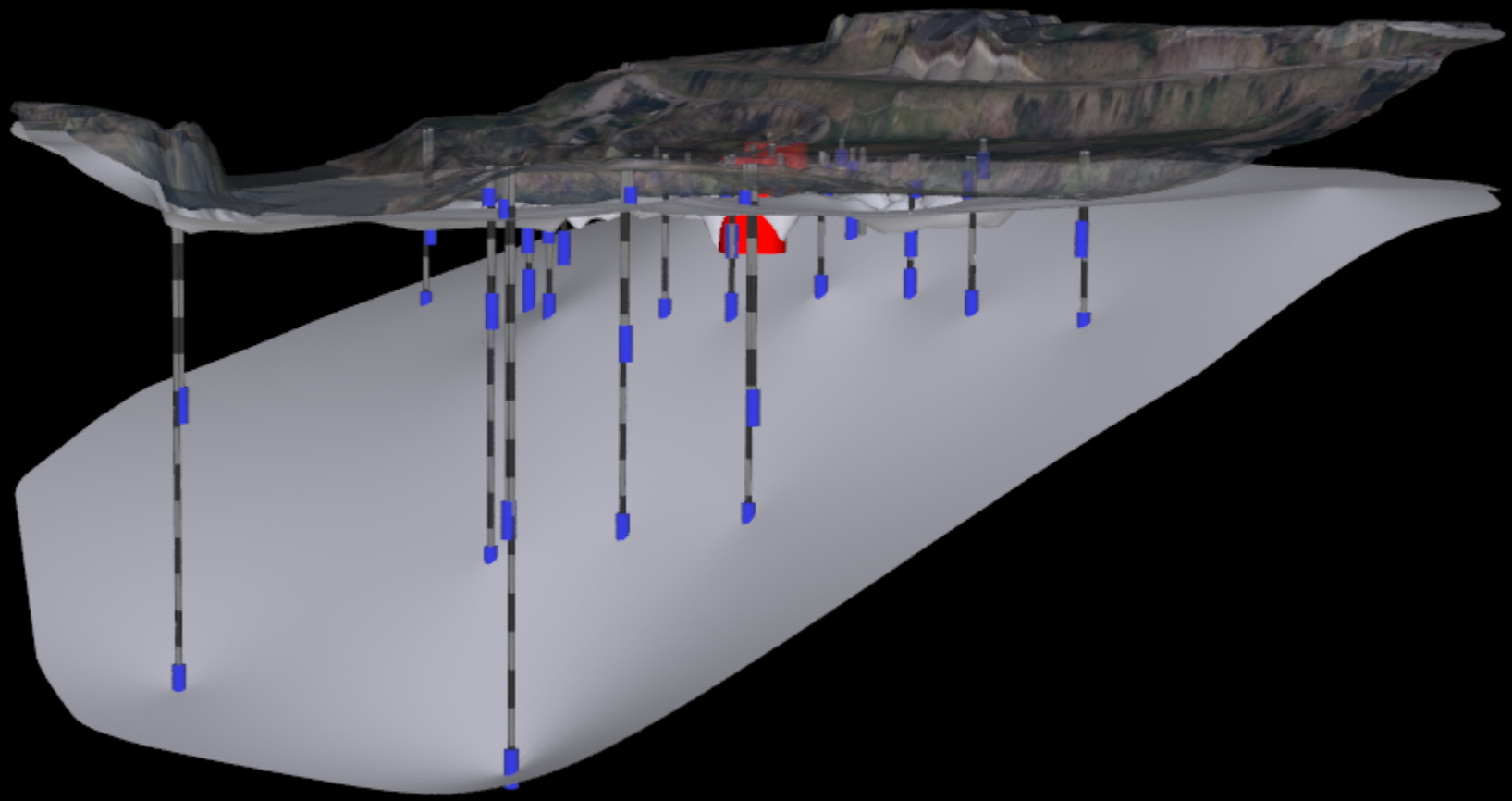


Thrust Fault
(view from below)

Brown and Caldwell

3D Model

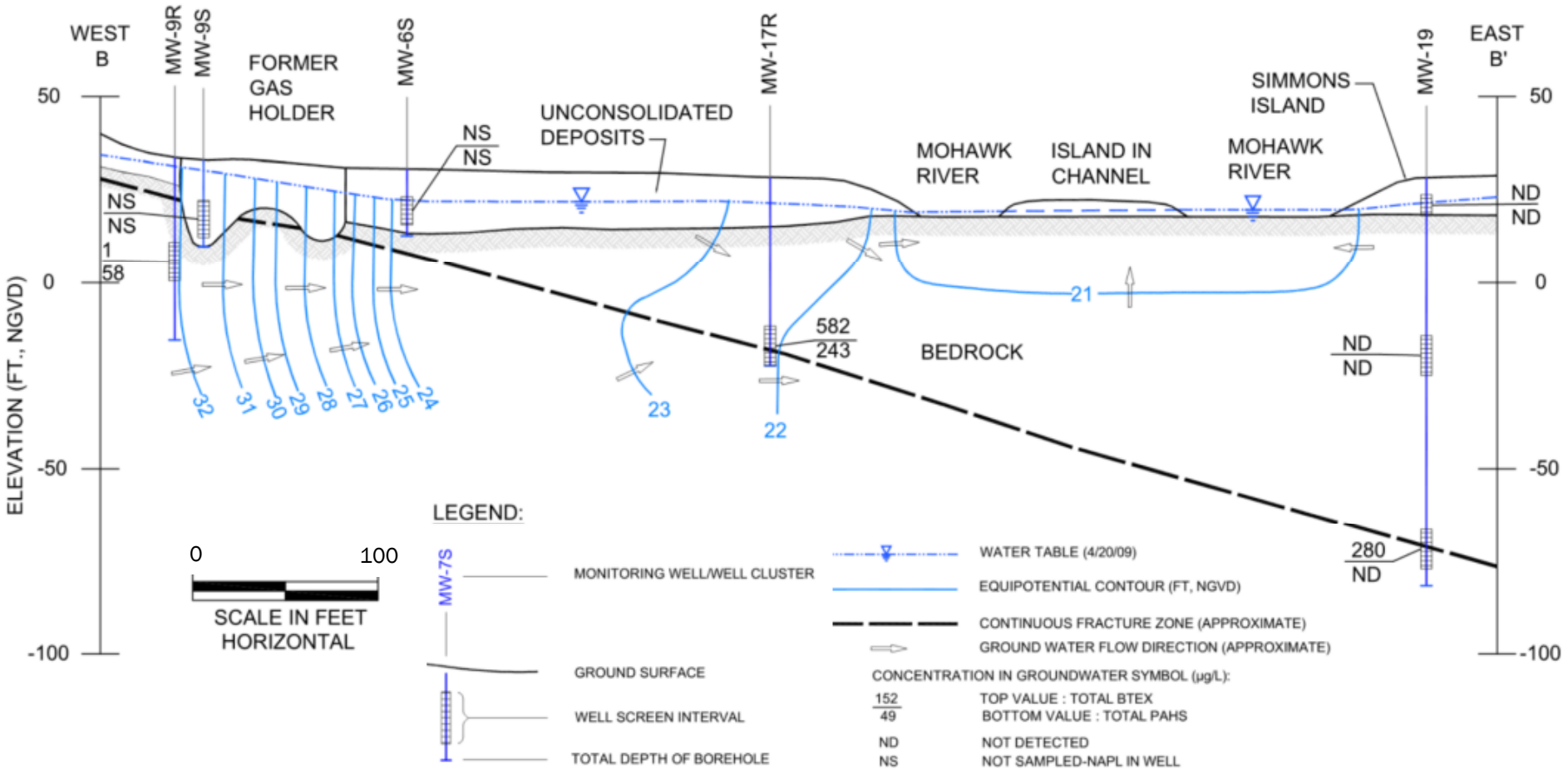
Cross-Section View
Toward Southwest
(Vertical Exaggeration 5x)



Thrust Fault

Brown and Caldwell

Cross-Section B-B’ (West to East)

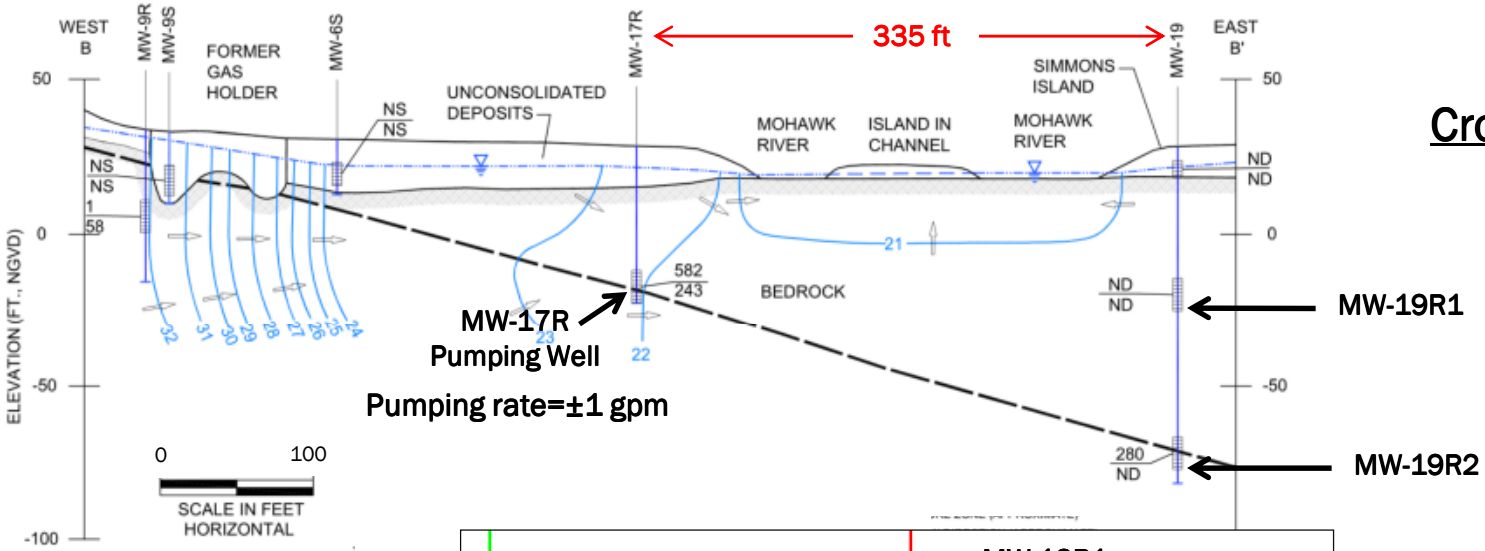


- Beneath Site, hydraulic head is lowest in thrust fault zone
- To east, under river, vertical hydraulic gradient is upward from thrust fault zone toward river

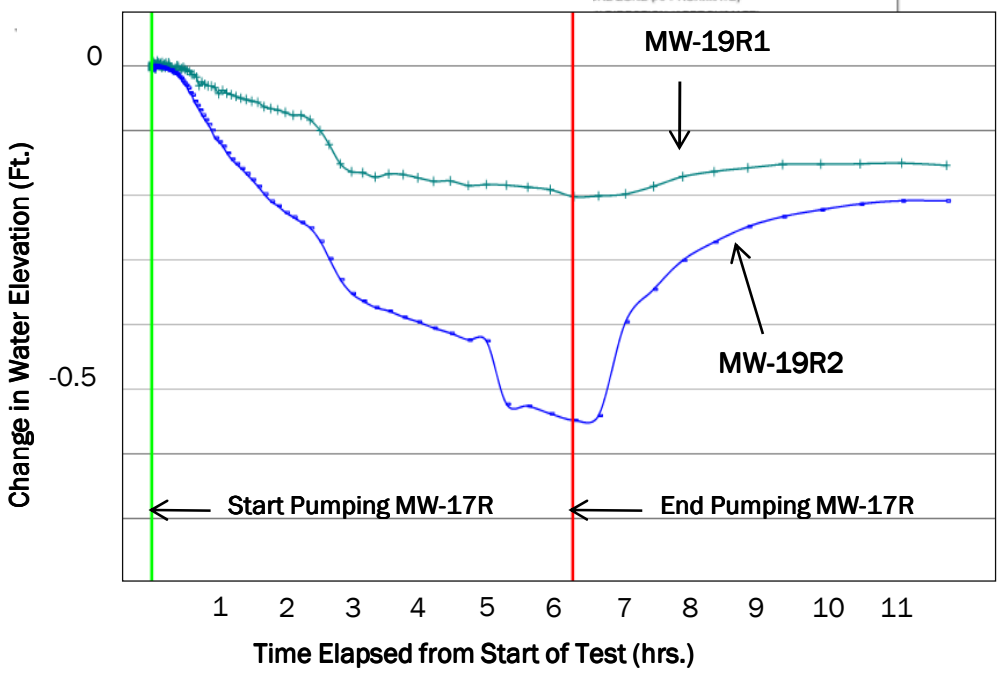
Pumping Tests-Short Term

- Four short-term pumping/recovery tests (±6-hr pumping) were conducted over course of investigation.
- Purpose-Qualitatively assess degree of hydraulic connectivity between:
  - Potential bedrock water-bearing zones screened at individual wells at different locations (lateral connectivity)
  - Potential water-bearing zones identified at an individual location (vertical connectivity)

Short-Term Pumping Tests to Evaluate Hydraulic Connectivity



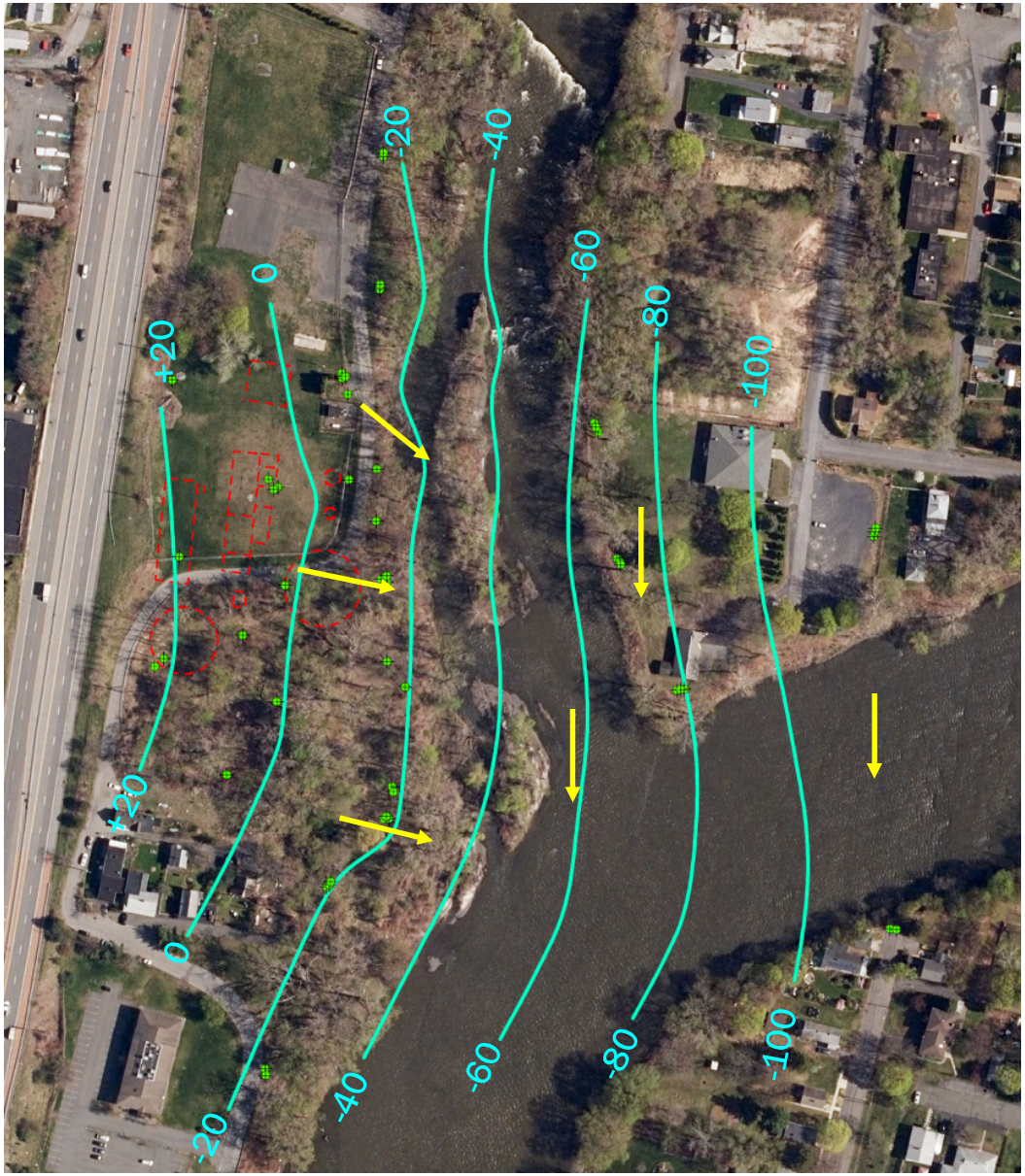
Cross-section



Drawdown vs. Time

- Greater degree of hydraulic connection between wells screened in east-dipping fracture zone

Lateral Groundwater Flow along Fault



0 100 ft

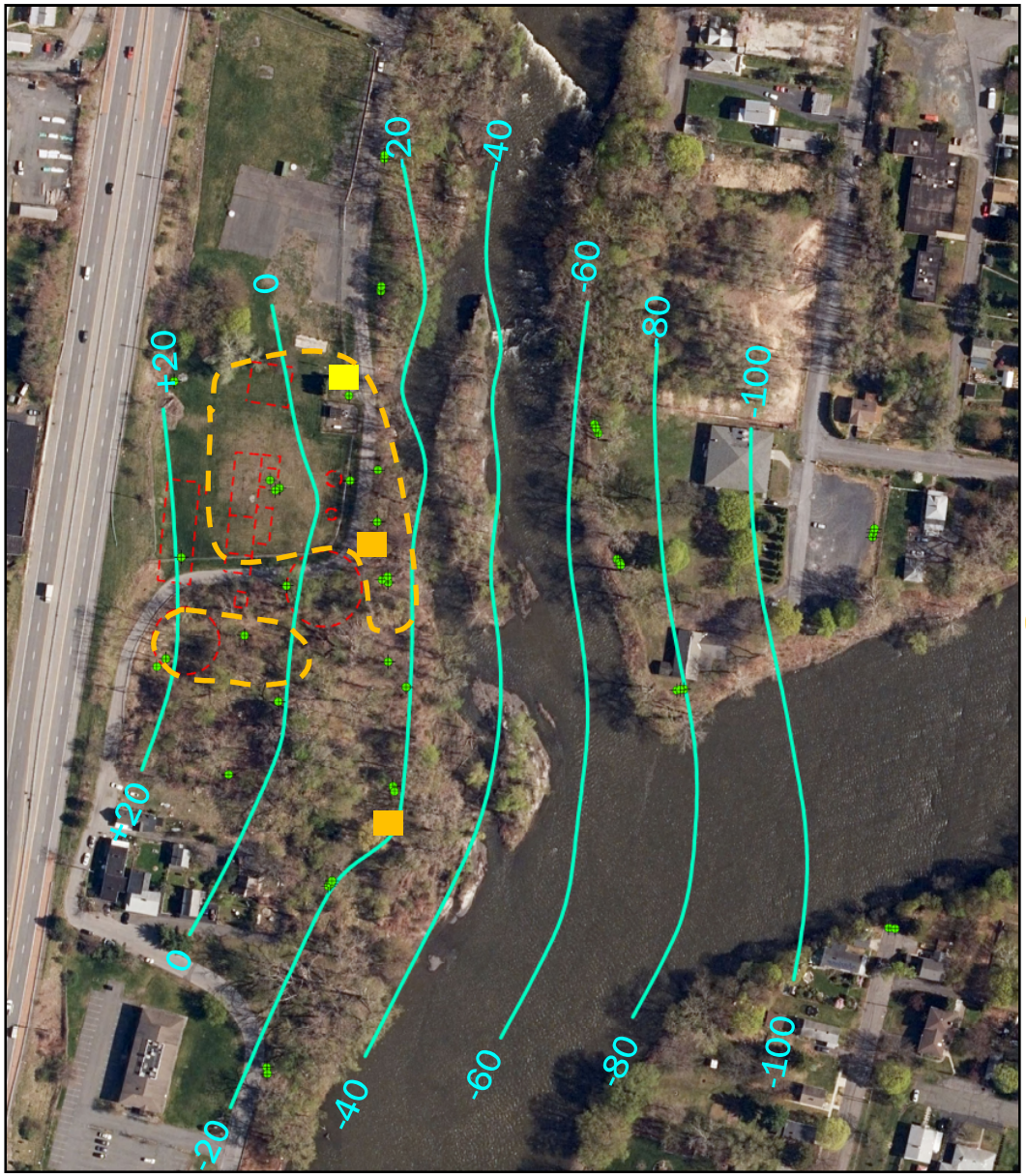
Scale
(approximate)

Generalized direction of groundwater flow in thrust fault zone.

-100

Fault elevation contour (ft. NGVD)

NAPL or Potential NAPL in Bedrock above Fault



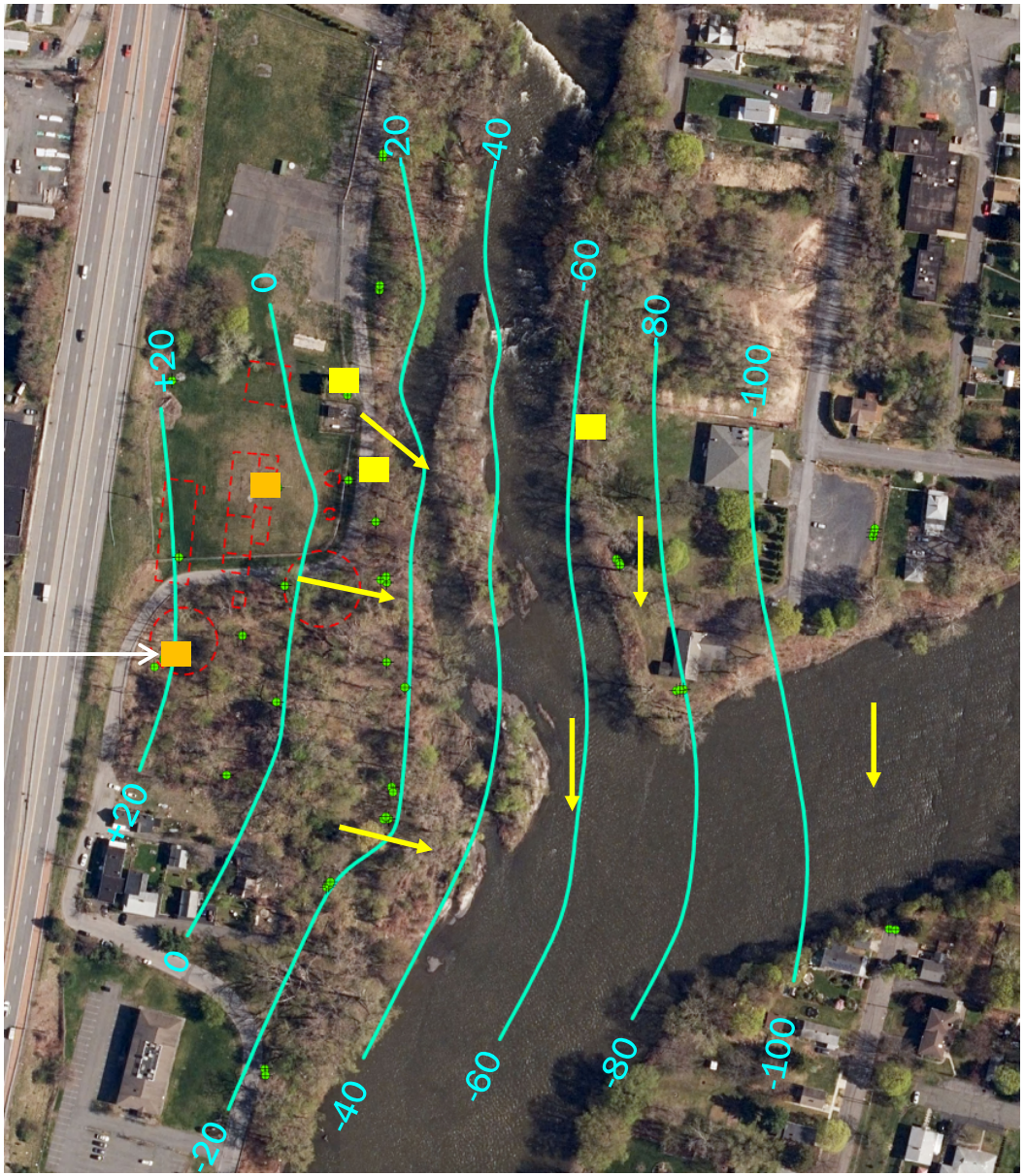
- NAPL observed in bedrock well or in rock core
- NAPL potentially in vicinity of bedrock well screen based on dissolved-phase concentrations
- Approximate area of DNAPL in overburden on top of bedrock (primarily residual, locally saturated)

-100 — Fault elevation contour (ft. NGVD)

0 100 ft

Scale (approximate)

NAPL or Potential NAPL in Fault



NAPL in gas holder foundation intersected by thrust fault

0 100 ft

Scale (approximate)

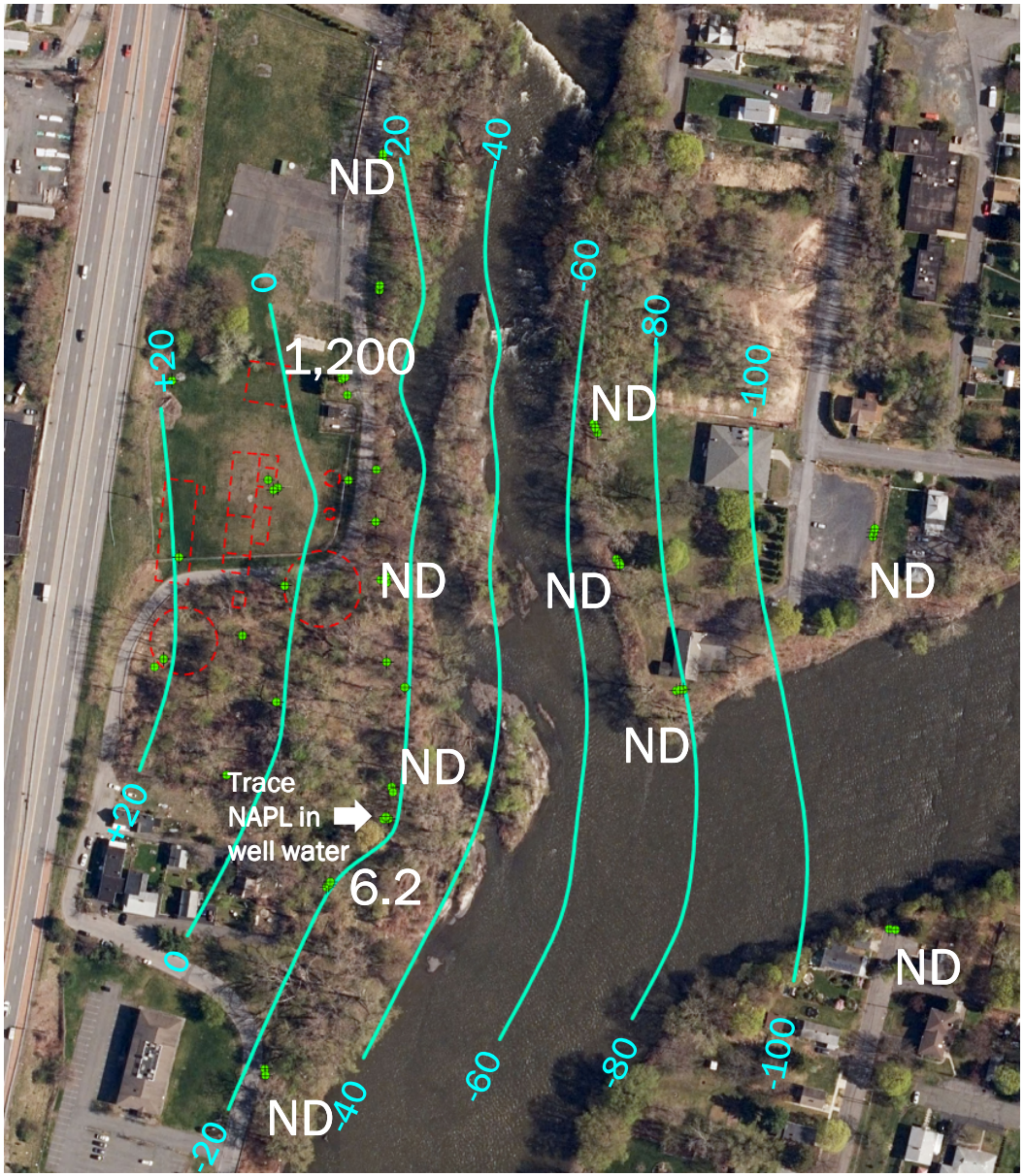
- NAPL observed in bedrock well or in rock core
- NAPL potentially in vicinity of bedrock well screen based on dissolved-phase concentrations

Generalized direction of groundwater flow in thrust fault zone.

-100

Fault elevation contour (ft. NGVD)

Naphthalene in Bedrock Groundwater above Fault



Naphthalene Concentrations in µg/L

ND- Not detected

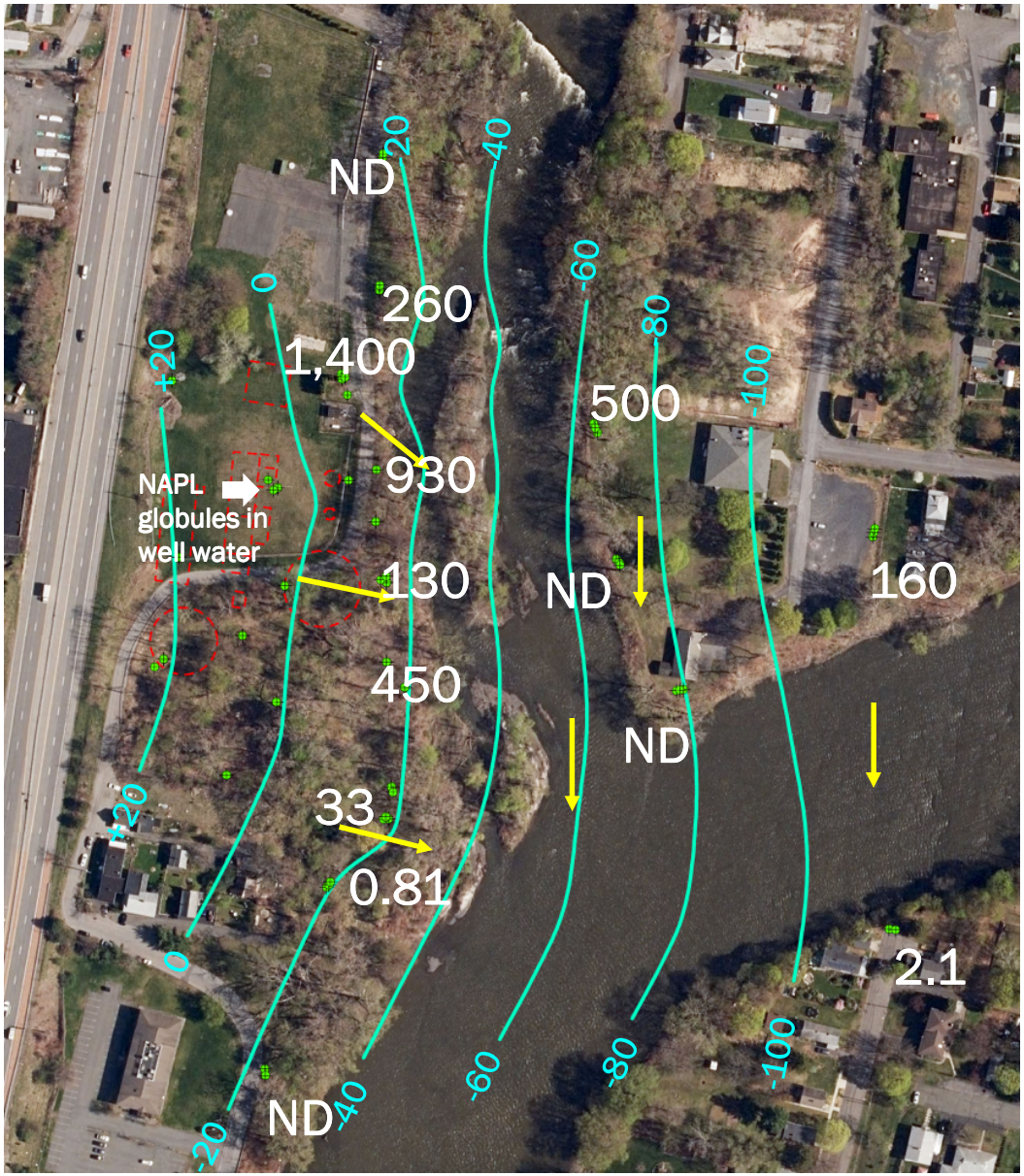
0 100 ft

Scale (approximate)

-100

Fault elevation contour (ft. NGVD)

Naphthalene in Groundwater in Fault



Naphthalene Concentrations in µg/L

ND- Not detected

Generalized direction of groundwater flow in thrust fault zone.

-100 Fault elevation contour (ft. NGVD)

0 100 ft

Scale (approximate)

Summary:
Extent of Impacts in Bedrock Groundwater

- East of the Site, potential DNAPL and high dissolved-phase constituent concentrations are at depth within east-dipping thrust fault zone.
- No detections of MGP-related constituents in groundwater above the thrust fault east of site.
- Dissolved-phase constituent concentrations decrease within thrust fault zone downgradient of the potentially DNAPL impacted areas.
- Bedrock groundwater eventually discharges to the river.
- Biased-high mass flux evaluation indicates no impact to surface water in river. Surface water sampling supports this conclusion.

Conclusions

- Identified a shallowly eastward-dipping, continuous fracture zone that serves as a water-bearing zone in bedrock.
- The geometry of this zone is similar to low-angle thrust faults identified elsewhere in the Cohoes Mélange.
- The thrust fault zone is the primary control on lateral groundwater flow and dissolved-phase constituent migration from the site in rock, and also influences DNAPL (tar) distribution.
- Other water-bearing fractures were identified above & below that are as not as continuous. These are typically, to varying degrees, hydraulically connected to the more continuous thrust fault-related zone.
- Beneath the site, the thrust fault approaches/intersects the top of bedrock surface, facilitating entry of site constituents into this zone.

References

- *Hayman, N.W. and Kidd, W.S.F, 2002*. The Champlain Thrust System in the Whitehall-Shoreham area: influence of pre- and post-thrust normal faults on the present thrust geometry and lithofacies distribution. Field trip A7, pages 7-1 to 7-24 *in* McLelland, J.M., and Karabinos, P. (eds), Guidebook for Field Trips in New York and Vermont. New England Intercollegiate Geological Conference 94th Annual Meeting, and New York State Geological Association 74th Annual Meeting, Lake George, NY, September 27th – 29th, 2002.
- *Kidd, W.S.F., Plesch, A., and Vollmer, F.W., 1995*. Field Trip A4: October 14th. Lithofacies of the Taconic Flysch, Mélange, & Allochthon in the New York Capital District. Field Trip Guidebook for the 67th Annual Meeting of the New York State Geological Association, edited by; John I. Garver and Jacqueline Smith.
- *Lim, C., Kidd, W.S.F., and Howe, S.S., 2005*. Late Shortening and Extensional Structures and Veins in Western Margin of the Taconic Orogen (New York and Vermont). Journal of Geology, v. 113, p. 419-438.
- *Rogers, W.B., Isachsen, Y.W, Mock, T.D., and Nyahay, RE., 1990*. New York State Geologic Highway Map. New York State Museum Educational Leaflet 33.

Questions?

Brown AND Caldwell

nationalgrid