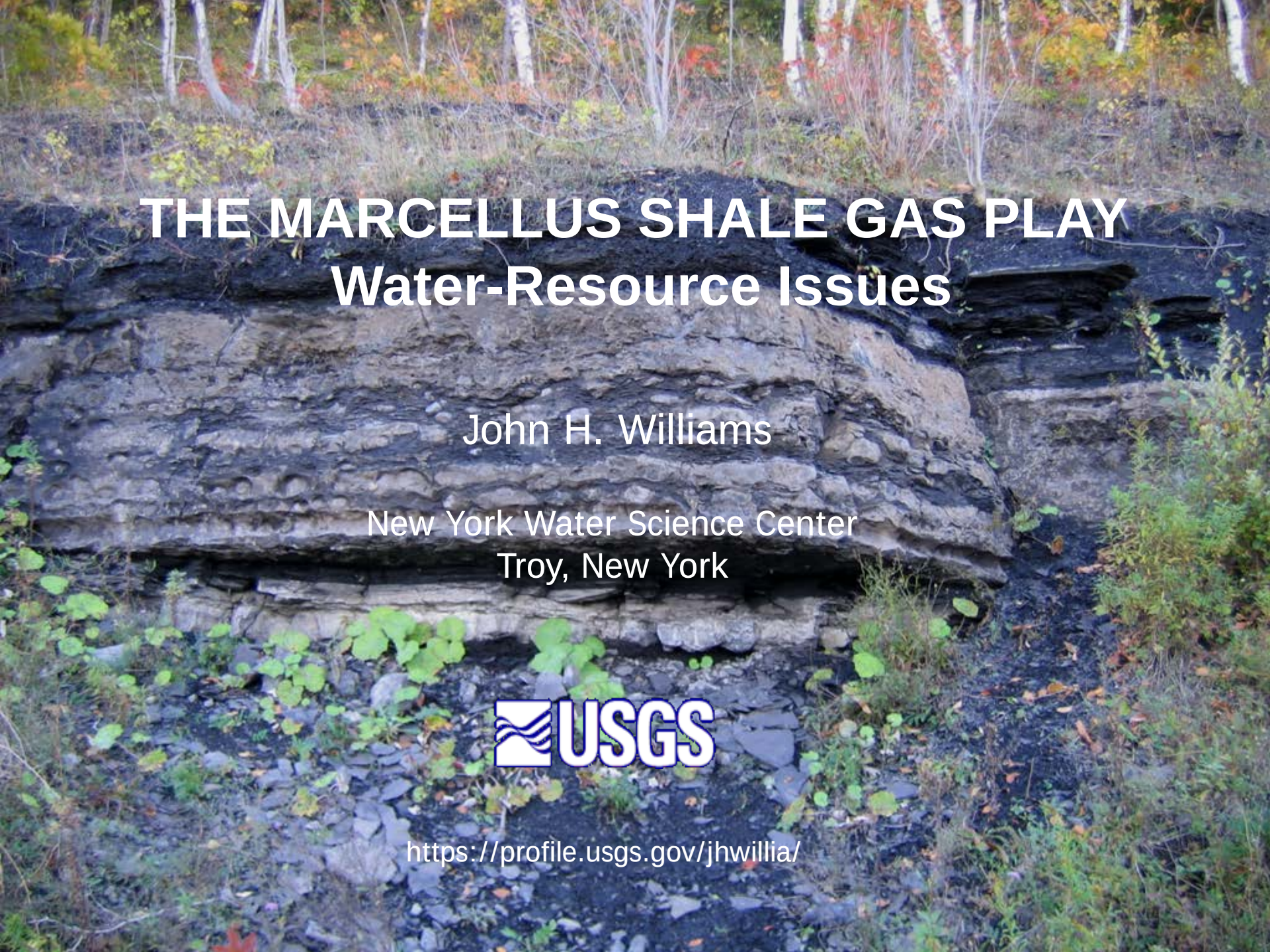


THE MARCELLUS SHALE GAS PLAY
Water-Resource Issues

John H. Williams

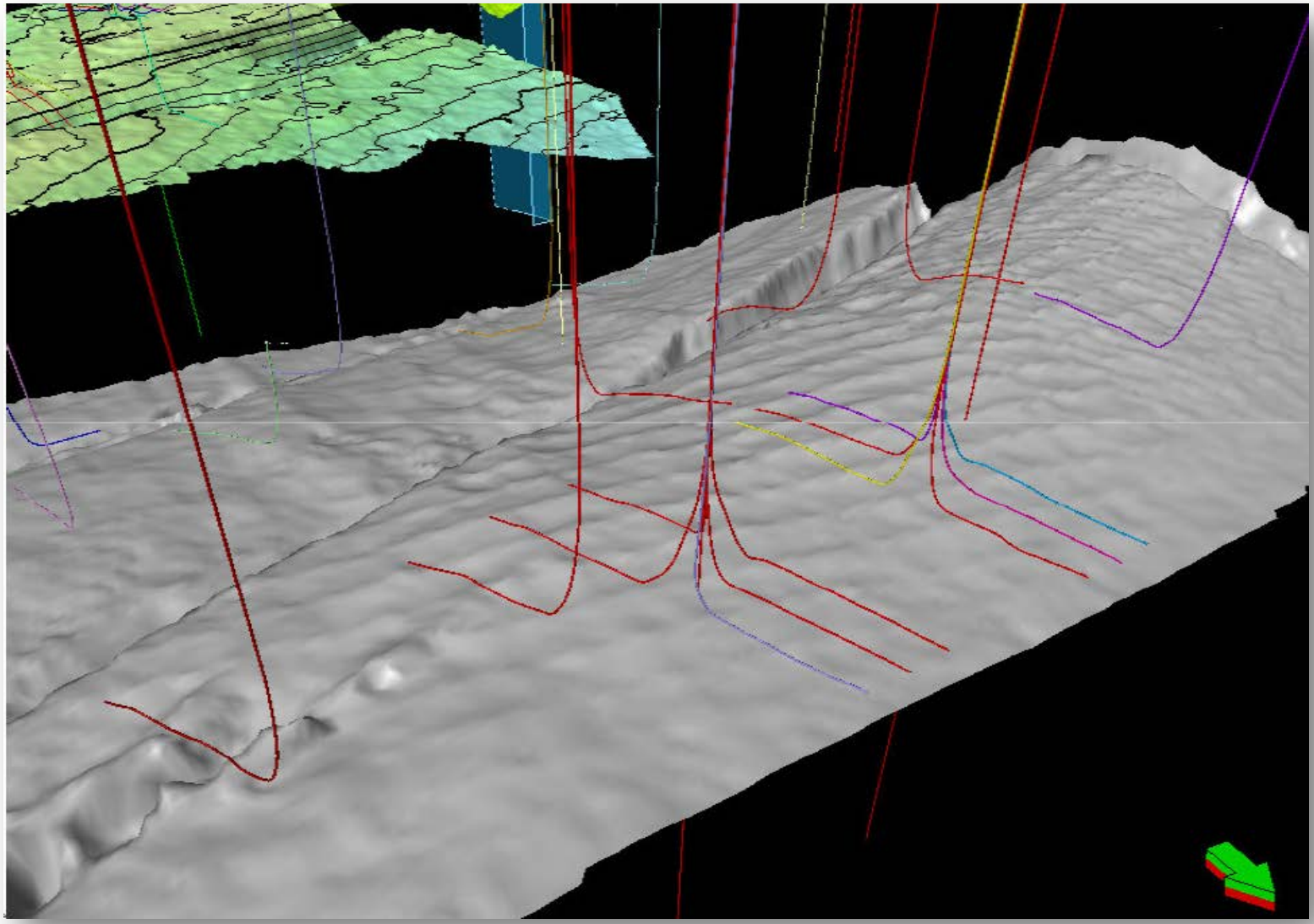
New York Water Science Center
Troy, New York

https://profile.usgs.gov/jhwillia/

Water Resource Issues

- Drill cuttings
- Frac flowback
- Faults and fractures
- Methane migration

Horizontal wells target basal Marcellus Shale

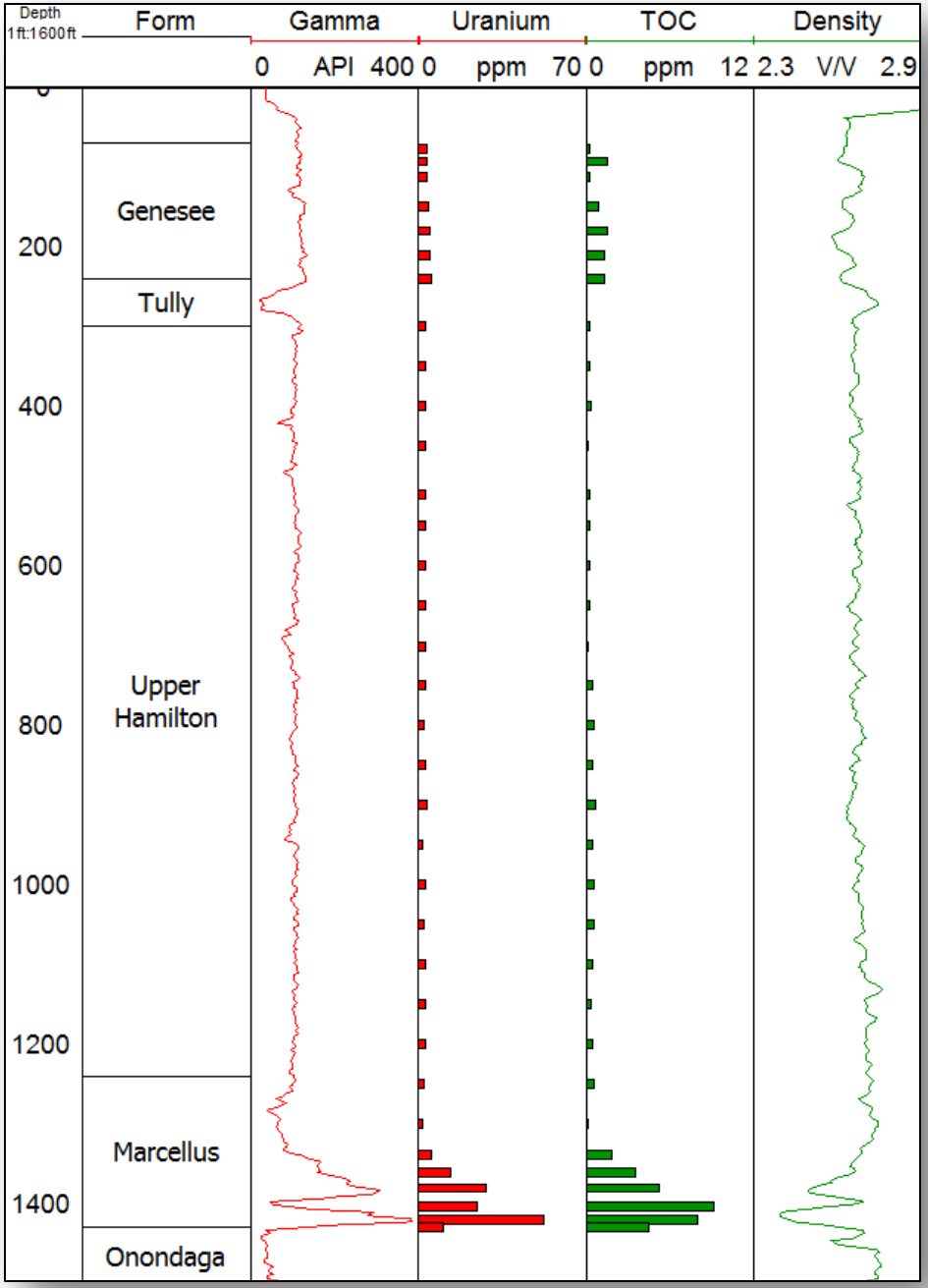


Teff (2011)

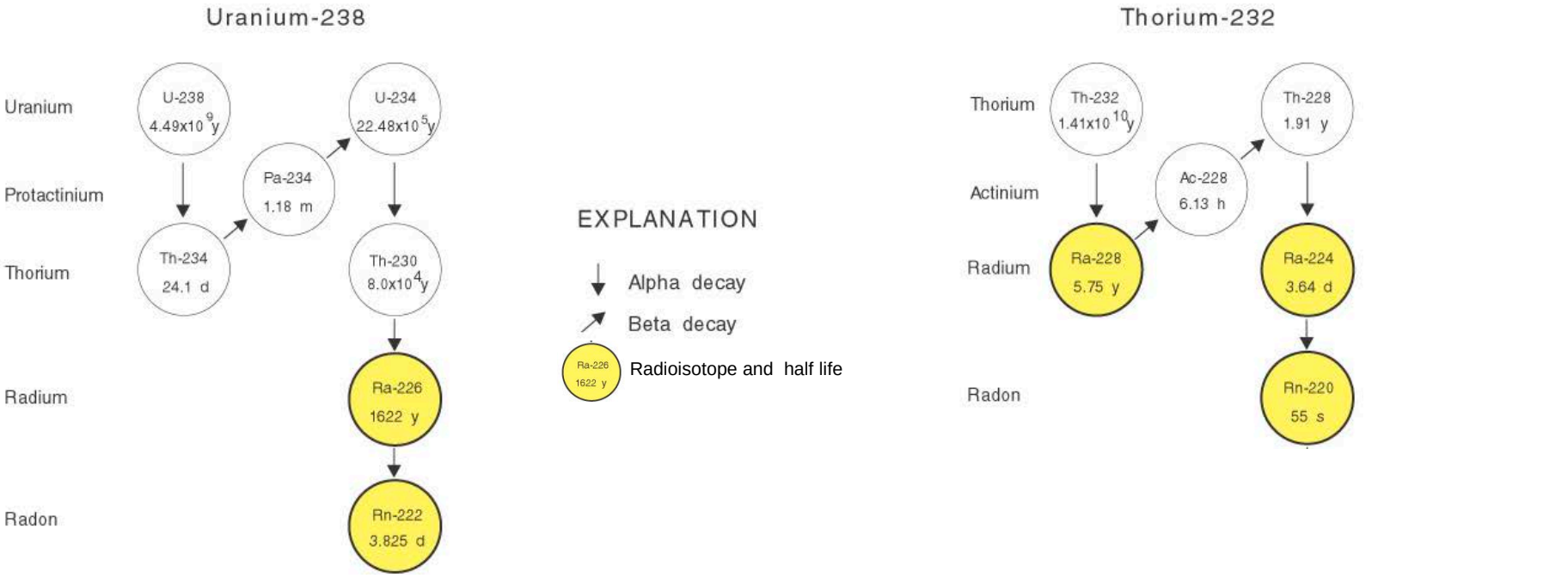
High TOC and elevated radioactivity in basal Marcellus Shale

Location of the Core	Uranium Content (ppm)
Allegheny, NY	8.9 – 67.7
Tompkins County, NY	25 – 53
Livingston County, NY	16.6 – 83.7

Levanthal and others (1981)

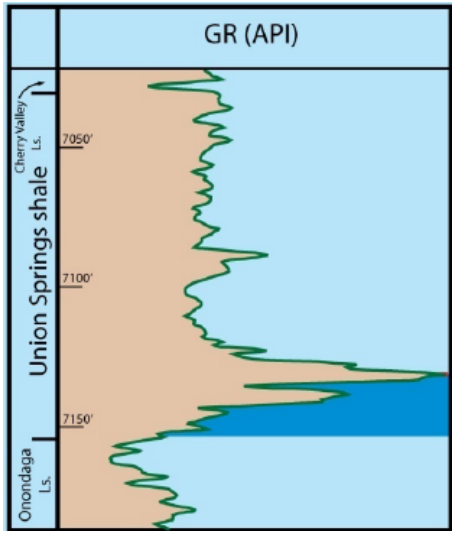


Uranium & Thorium to Radium & Radon Radioactive Decay Series

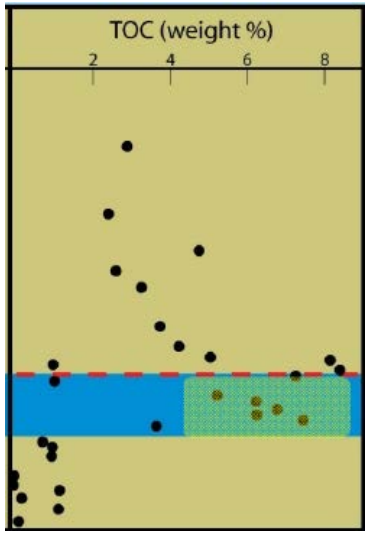


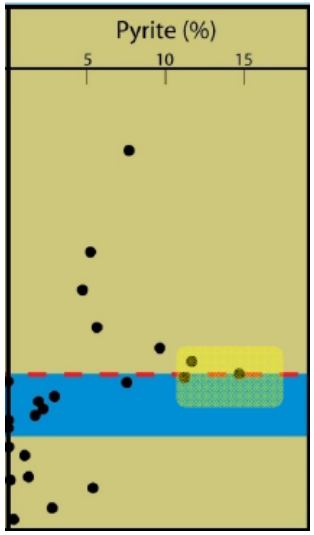
High TOC and abundant pyrite in basal Marcellus Shale

Gamma Log



Drill Core Sample Analysis





Lash and Engelder (2009)

Drill Cuttings

- **Elevated uranium and abundant pyrite in high-TOC black shale**
- **Multi-horizontal well site will generate more than 500 times the volume of shale cuttings than single-vertical well site**

Core of target interval

Drill cuttings

Drilling Fluids and Cuttings

Lined pit

Closed-loop system

Mixed with sawdust

Offsite disposal in landfill

Flowback

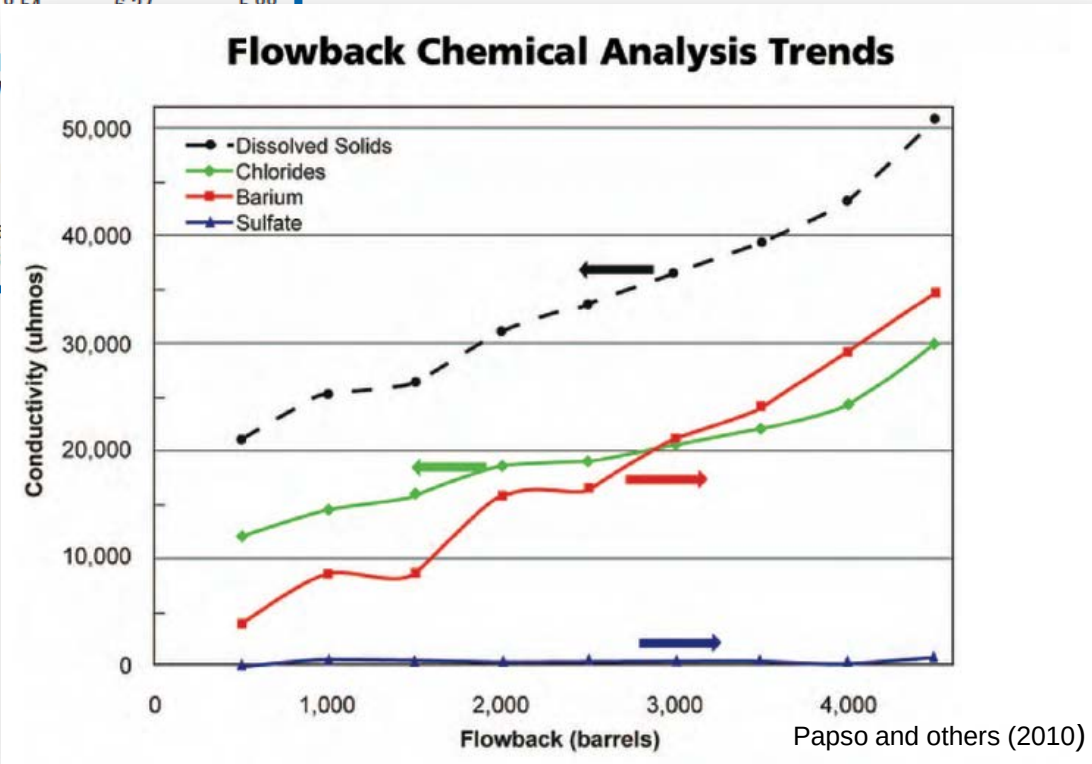
Contains elevated TDS, chlorides, barium, and radioisotopes whose concentrations increase during the flowback period approaching formation brine

TABLE 1. Flowback water analysis (Case 1)

Flowback, bbl	500	2,500	6,000	11,000	15,000
Anions					
P alkalinity, mg/L as $CaCO_3$	0	0	0	0	0
M alkalinity, mg/L as $CaCO_3$	580	560	360	260	160
Chloride, mg/L as Cl^-	2,000	5,800	16,400	53,000	104,000
Sulfate, mg/L as $SO4^{2-}$	1,115	910	588	57	24
Cations					
Sodium, mg/L as Na^{1+}	714	1,470	2,671	9,062	12,830
Potassium, mg/L as K^{1+}	27	40	105	381	544
Calcium, mg/L as Ca^{2+}	240	536	1,960	6,840	9,720
Magnesium, mg/L as Mg^{2+}	44	73	171	341	805
Total hardness, mg/L as $CaCO_3$	780	1,640	5,600	18,500	27,600
Barium, mg/L as Ba^{2+}	0.4	0.5	2.1	7.3	70.2
Strontium, mg/L as Sr^{2+}	16.5	48.4	211	995	1,837
Ferrous iron, mg/L as Fe	1.8	0.8	0.4	0.6	3.3
Total iron, mg/L as Fe	42	27	38	157	78
Miscellaneous					
pH	7.25	8.31			
Total suspended solids, mg/L	90	20			
Specific gravity, g/ml	1.001	1.016	1		
Conductivity, µΩ	7,160	16,800	37		
Δ ATP (microbiological content), relative light units	5	6			
Microbiological content	Low	Low			
Langelier saturation index (LSI)	1.02	2.37			
Langelier potential scaling	Scaling	Scaling	Sca		
Calcium sulfate scaling potential	Positive	Positive	Pos		

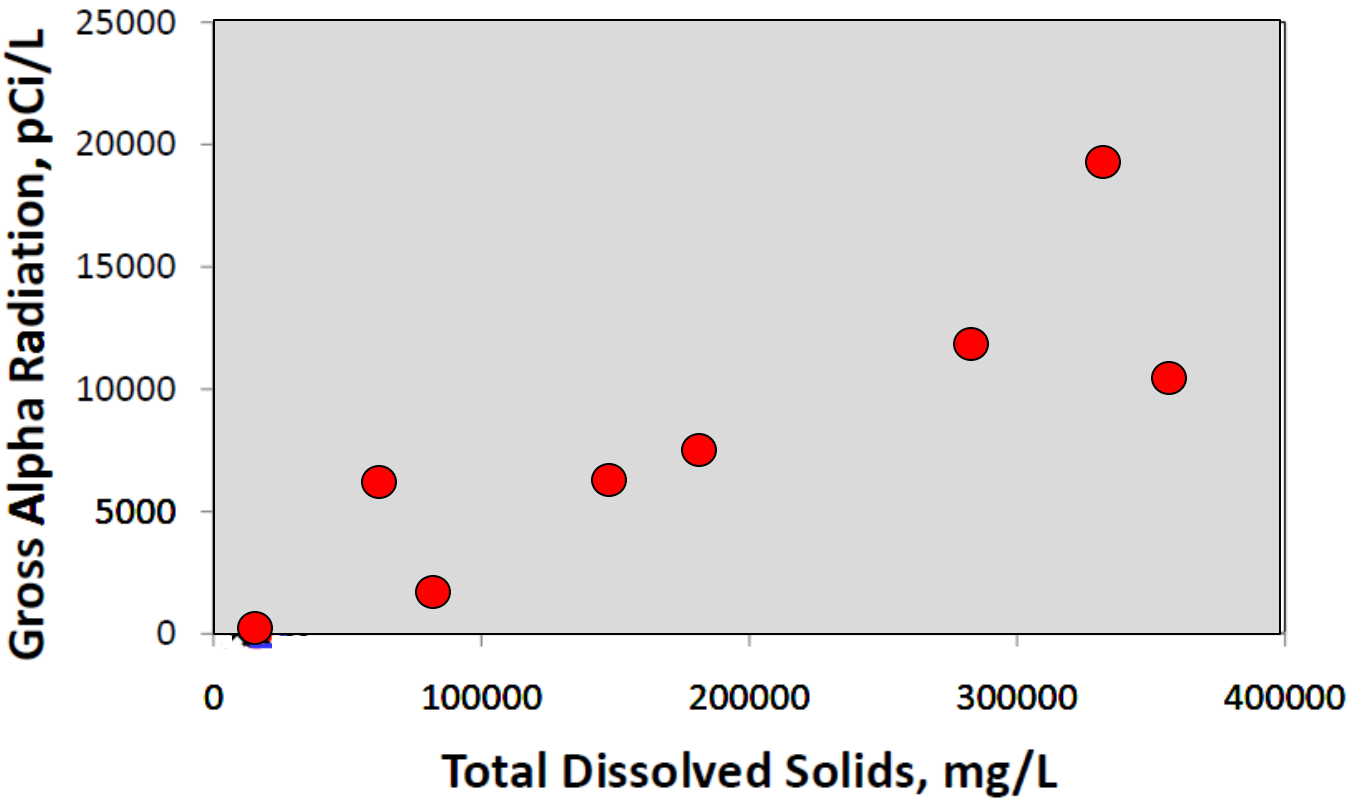
WORLD OIL **JULY 2010**

Blauch (2010)



Papso and others (2010)

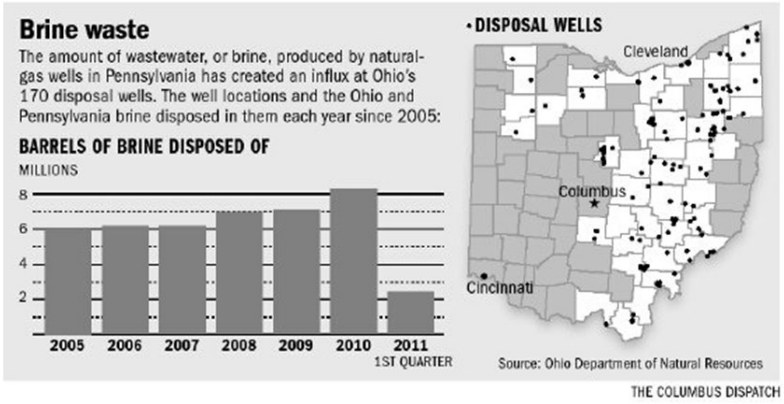
TDS and Radioactivity of Flowback Water



Kirby (2011)

Ra-226 increases relative to Ra-228 in the later higher TDS flowback consistent with a U-rich source for the water such as the Marcellus shale (Engle and others, 2011)

Municipal wastewater treatment plants not designed to handle flowback chemistry

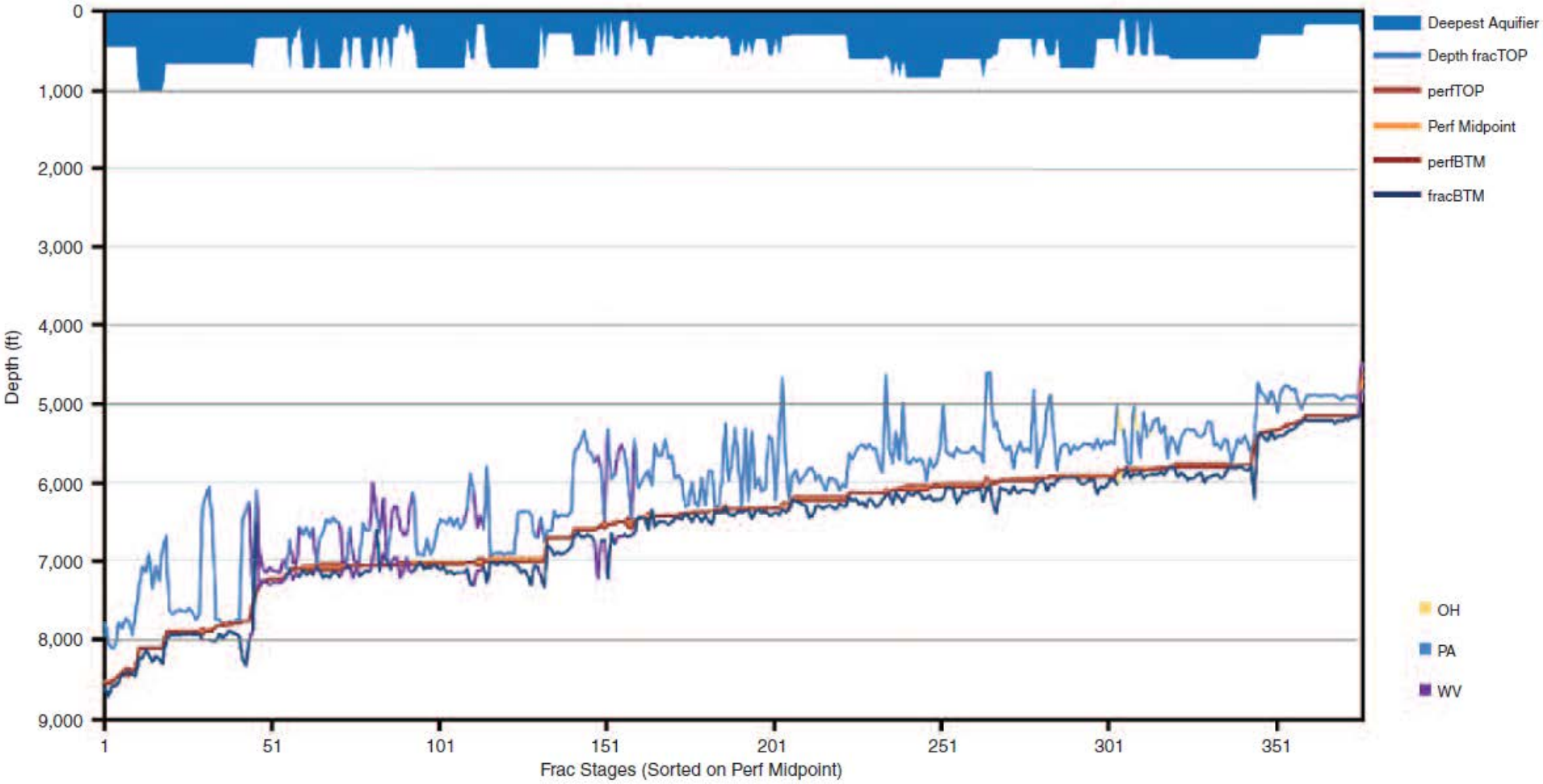


Limited number of disposal wells in Ohio

Reuse flowback, onsite treatment for solids / blend with 70 % freshwater

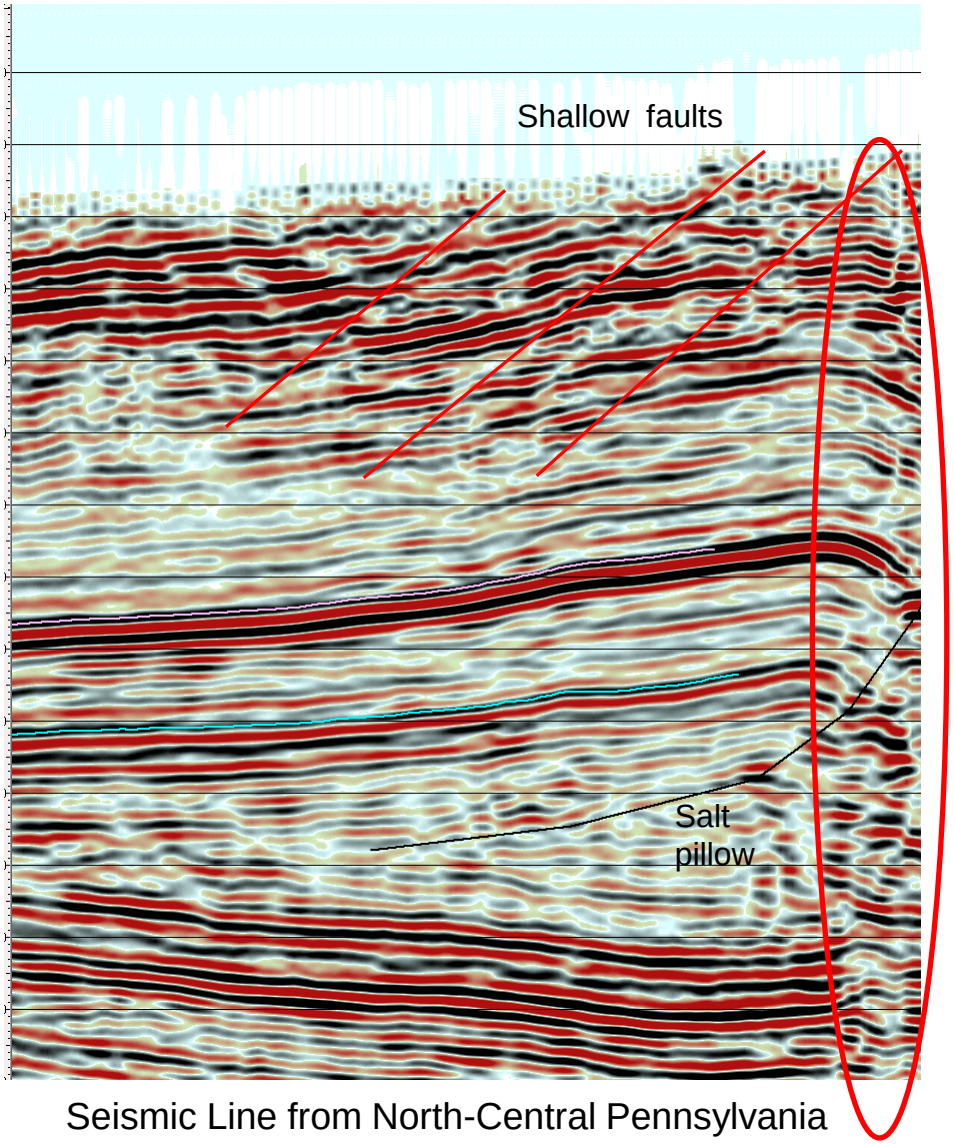
Microseismic Mapped Frac Tops and Bottoms

Marcellus Shale



Fisher (2010)

Faults and Fractures



Upper Devonian bedrock containing freshwater aquifers above sandstone gas reservoirs.

Burkett Shale

Tully Limestone

Marcellus Shale

Onondaga Limestone

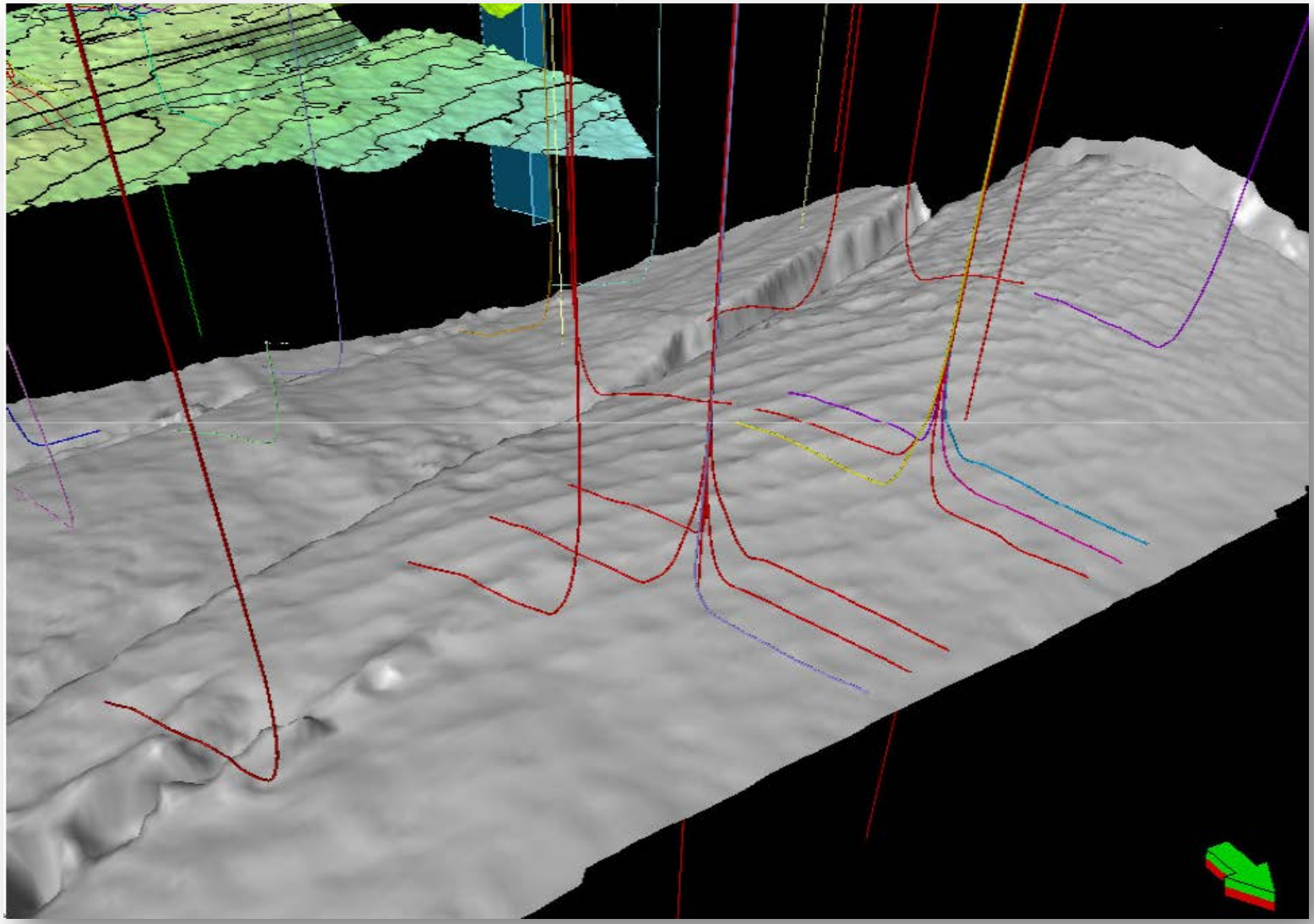
Salt

Deep-seated fracture zone

Seismic Line from North-Central Pennsylvania

Seismic data courtesy of Shell Appalachia

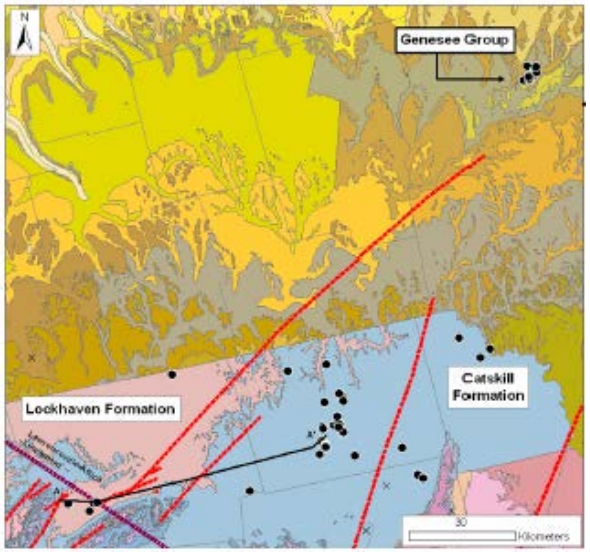
Avoid Hydraulic Fracturing across Structures



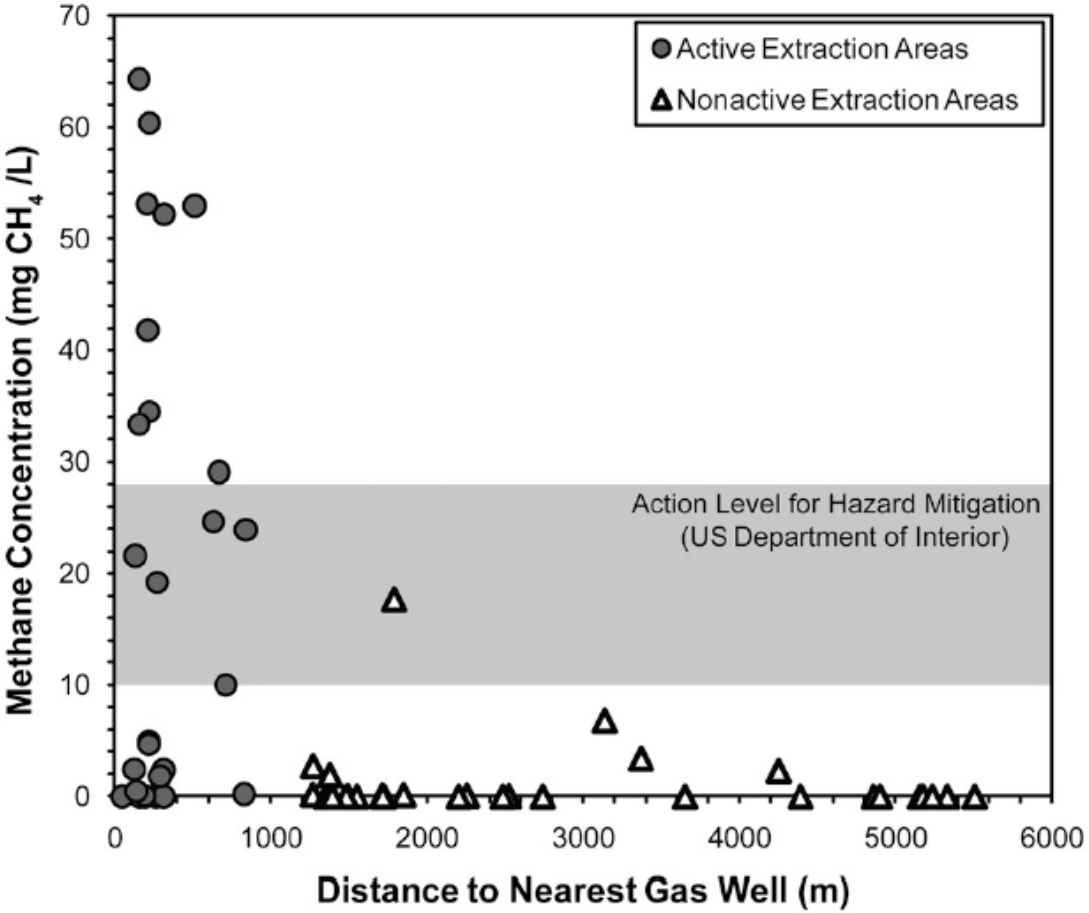
Teff (2011)

Methane in Water Wells

Marcellus/Utica Gas-Play Area

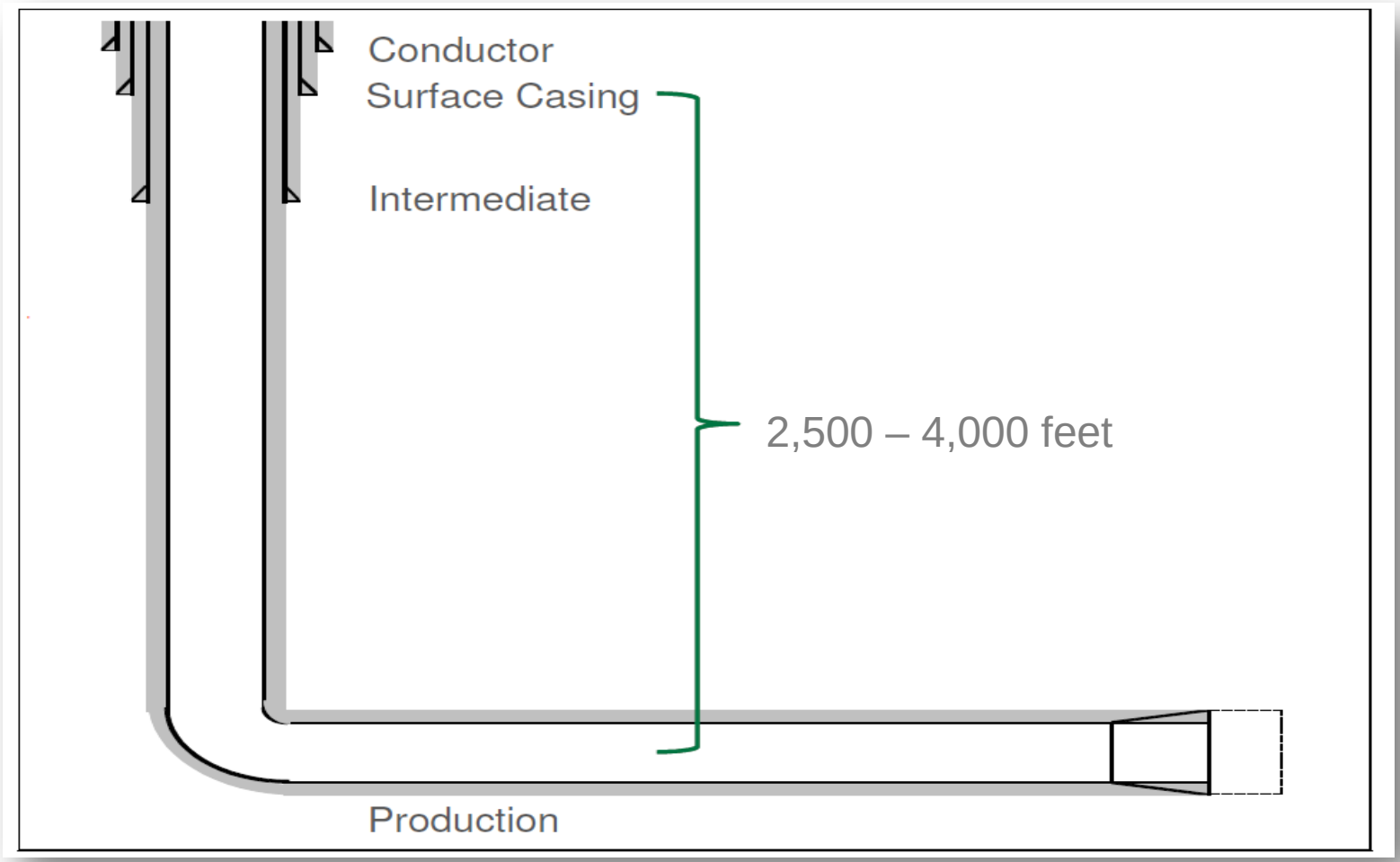


Sampling sites



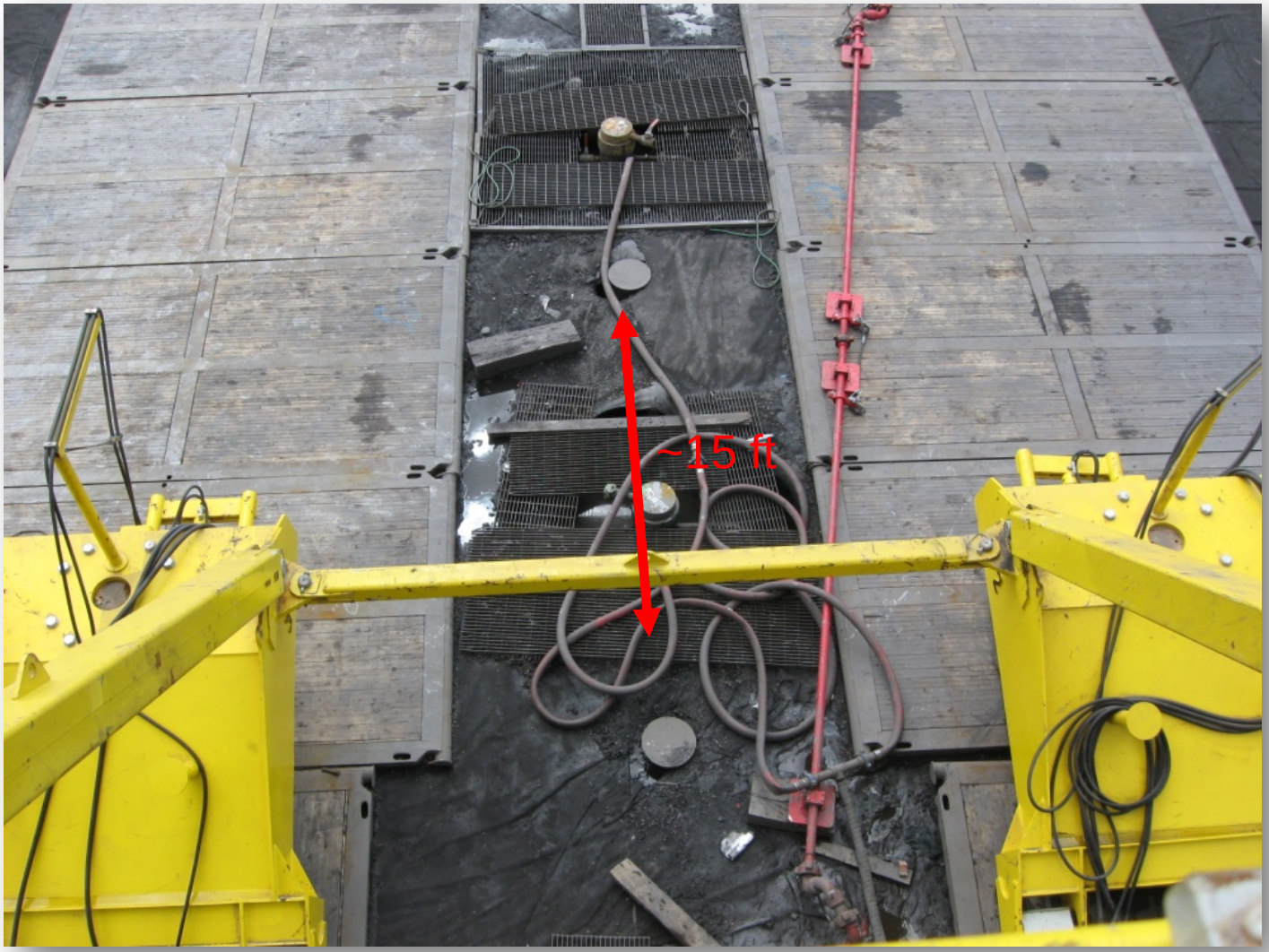
Osborn and others (2011)

Marcellus Gas-Well Construction

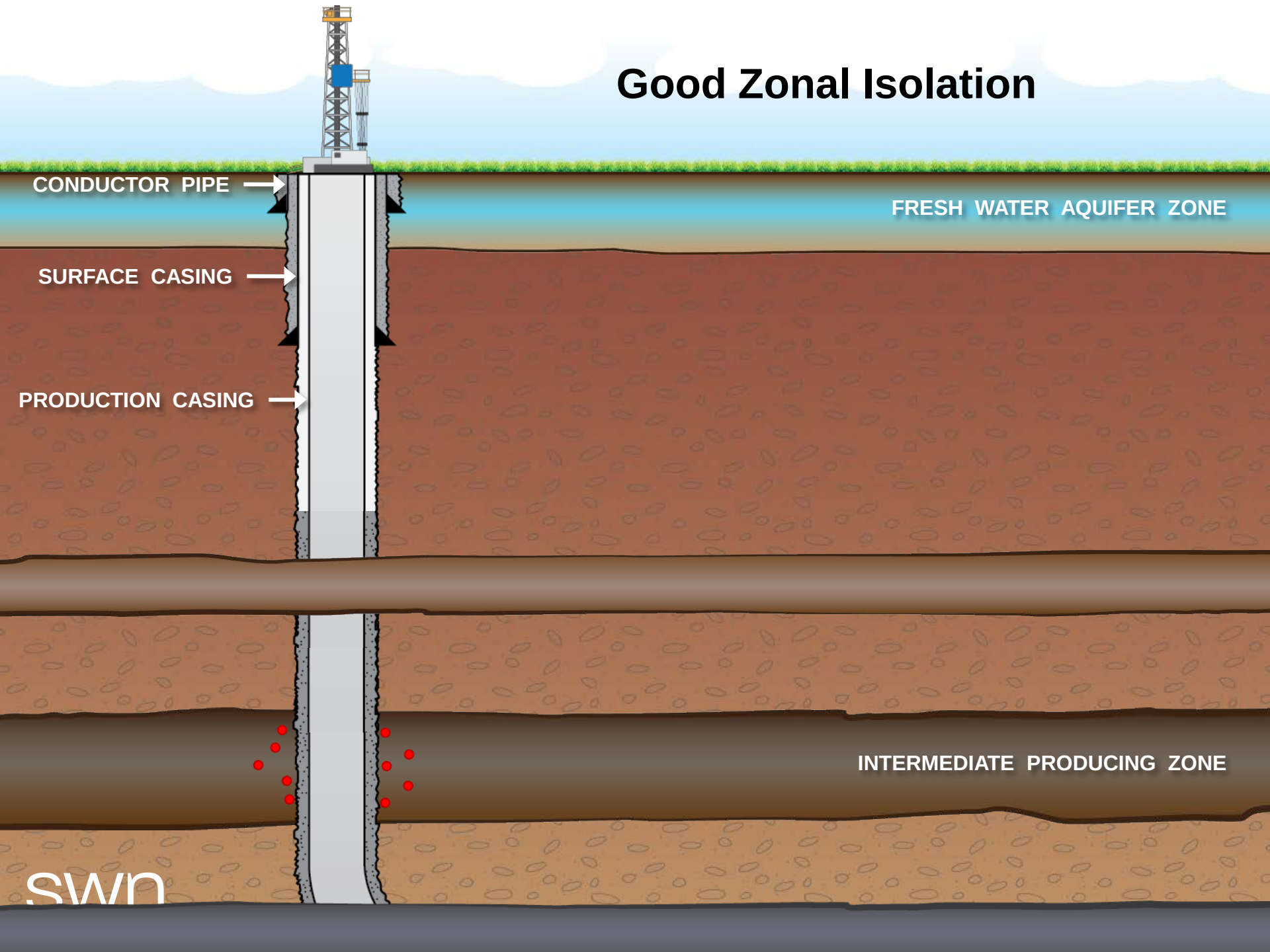


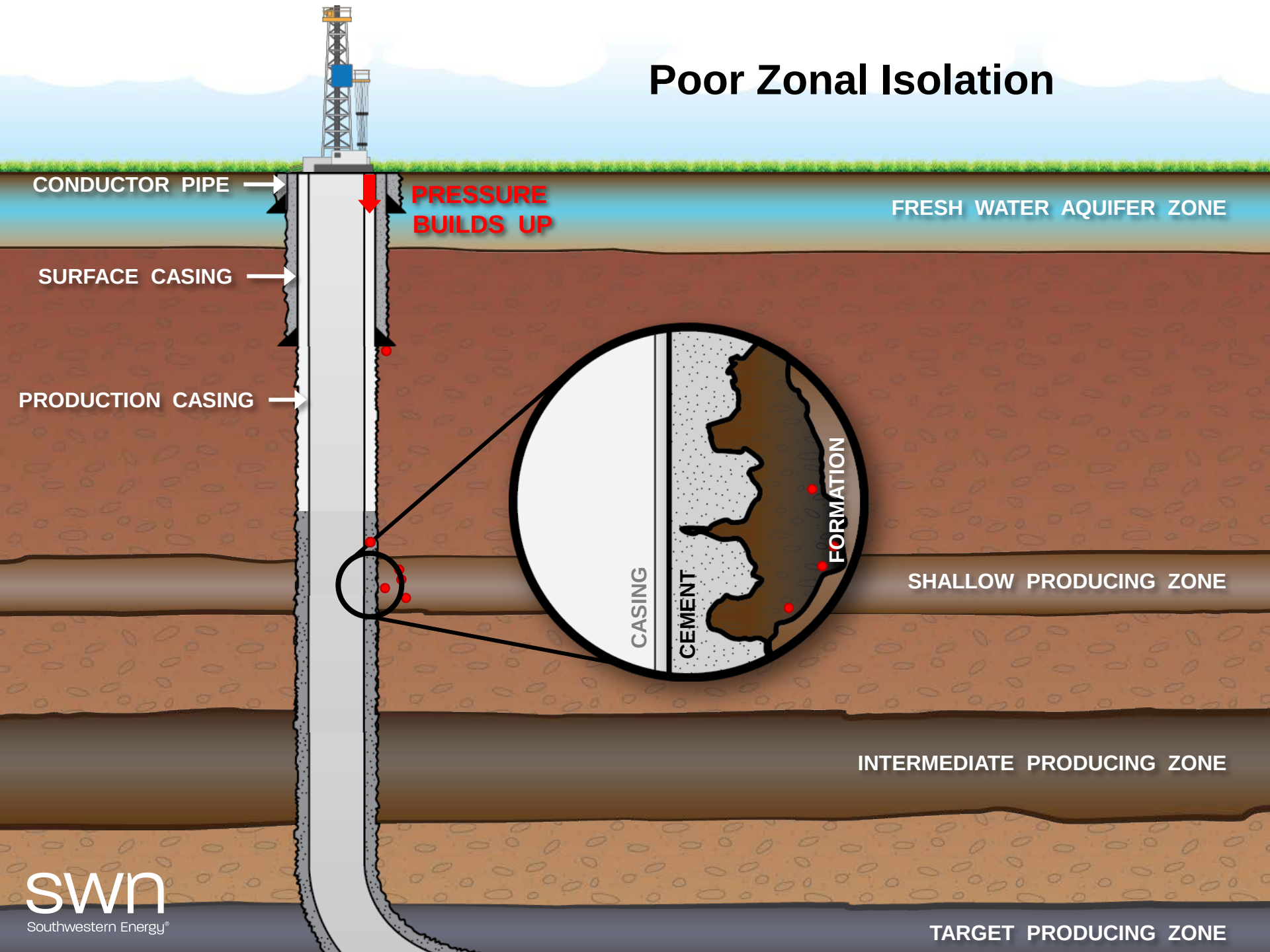
Top-set rig for drilling vertical surface- and intermediate-cased interval

Directional rig for drilling horizontal leg

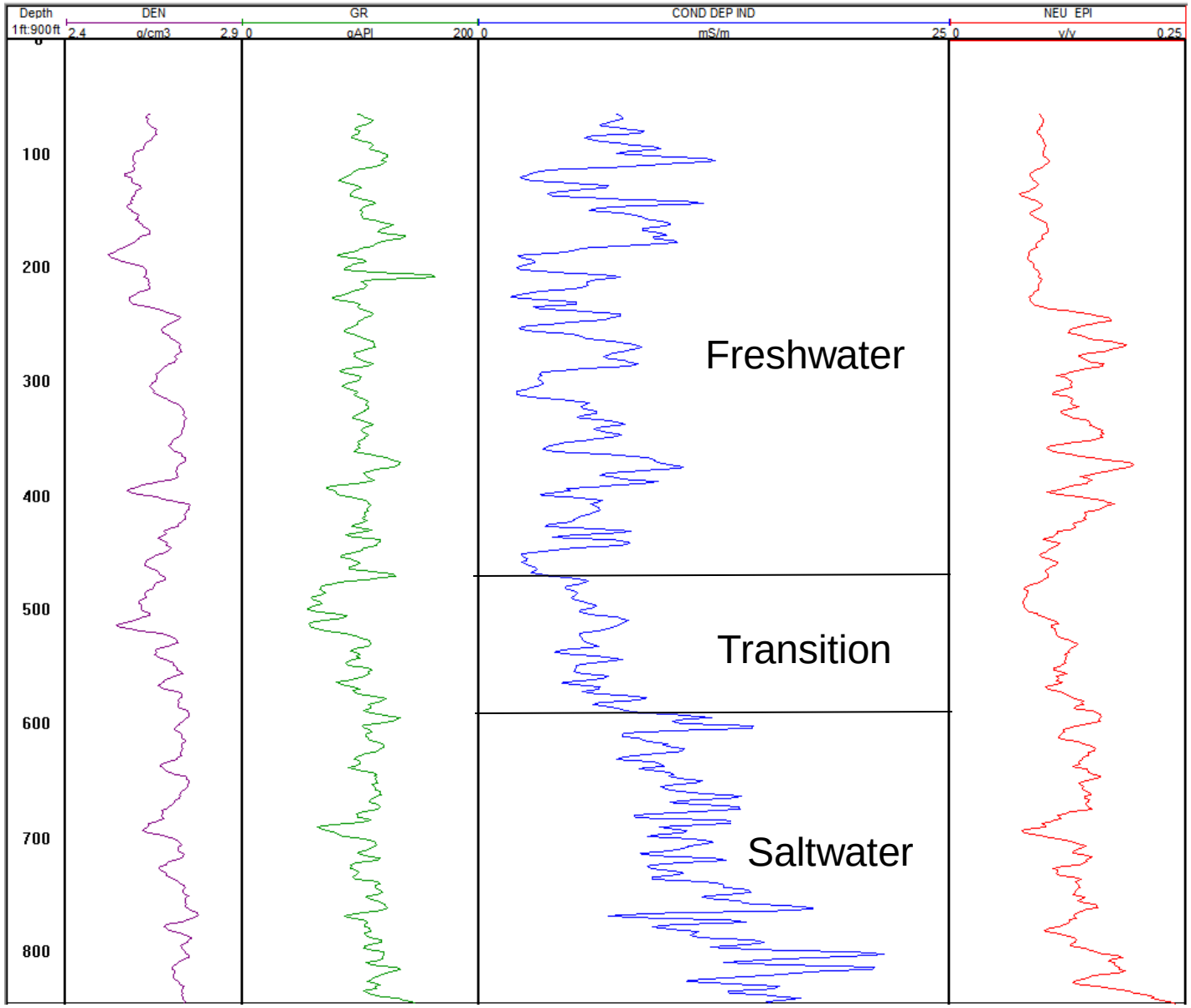


Wellheads of first two of six horizontal wells


Good Zonal Isolation
CONDUCTOR PIPE
SURFACE CASING
PRODUCTION CASING
FRESH WATER AQUIFER ZONE
INTERMEDIATE PRODUCING ZONE
swn


Poor Zonal Isolation
CONDUCTOR PIPE
PRESSURE BUILDS UP
FRESH WATER AQUIFER ZONE
SURFACE CASING
PRODUCTION CASING
CASING
CEMENT
FORMATION
SHALLOW PRODUCING ZONE
INTERMEDIATE PRODUCING ZONE
TARGET PRODUCING ZONE
swn
Southwestern Energy®

Geophysical Logs and Base of Freshwater Aquifer



Log data courtesy
of Shell Appalachia

Shale Gas Development

Best practices based on state-of-the-art technology and science

- Geophysical logging to delineate base of freshwater aquifers
- Surface casing/cement deep enough to protect freshwater aquifers
- Intermediate and production casing/cement/packers to prevent upward migration of gas
- Cement-bond logging and pressure testing to ensure good seals
- Drilling and frac fluid storage in tanks and offsite burial of drill cuttings
- Avoid hydraulic fracturing near structures
- Microseismic monitoring of hydraulic fracs
- Reuse of frac fluid reduces freshwater resource impacts and disposal issue
- Water-well sampling before and after drilling/hydraulic fracturing operation

"Zealous for the Marcellus"