GROUNDWATER PROTECTION COUNCIL

HYDRAULIC FRACTURING & SAFE DRINKING WATER

Hydraulic Fracturing Workshop
March 30, 2011

DEP

GROUNDWATER PROTECTION COUNCIL

Joseph J. Lee, Jr., P.G.
President

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Environmental Protection
Bureau of Watershed Management
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KEY MESSAGES

1. **State Oil & Gas (O&G) regulations are adequate to protect water resources**
2. **Well construction regulations are adequate for Hydraulic Fracturing (HF); However, development of adaptable BMPs would assist operators and states**
3. **There are environmental challenges for water and drinking water programs posed by gas shale development**
4. **We know surface water & ground water stressed by past mineral extraction in area of Marcellus Shale**
5. **We have holes in our understanding of ground water going forward**

MAP 7

GEOLOGIC MAP OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
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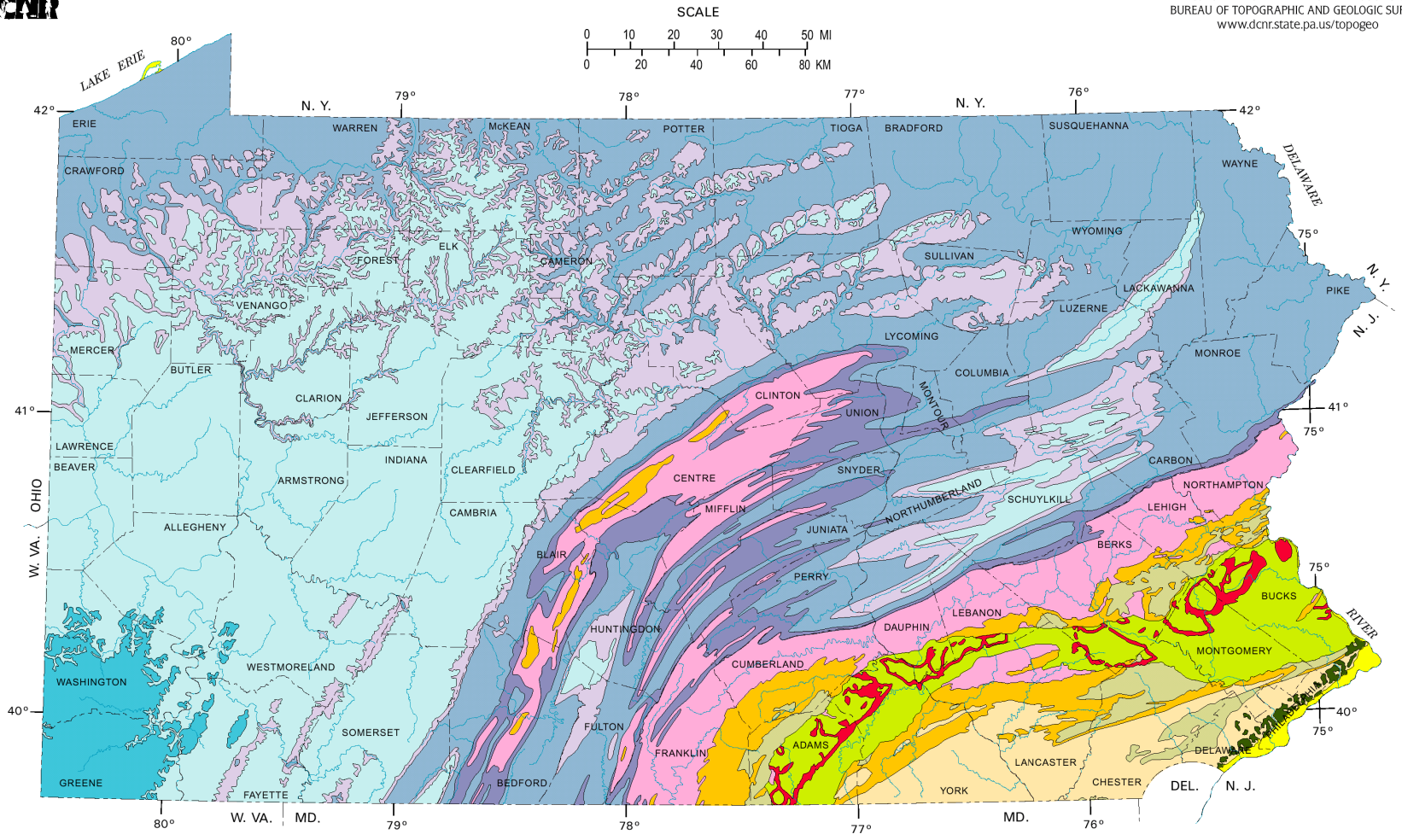

EXPLANATION

QUATERNARY	TERTIARY	JURASSIC AND TRIASSIC	PERMIAN	PENNSYLVANIAN	MISSISSIPPIAN	DEVONIAN	SILURIAN	ORDOVICIAN	CAMBRIAN	LOWER PALEOZOIC	PRECAMBRIAN
(0–2 mil. yrs.)	(2–67 mil. yrs.)	(140–250 mil. yrs.)	(250–290 mil. yrs.)	(290–330 mil. yrs.)	(330–365 mil. yrs.)	(365–405 mil. yrs.)	(405–430 mil. yrs.)	(430–500 mil. yrs.)	(500–570 mil. yrs.)	(430–570 mil. yrs.)	(older than 570 mil. yrs.)
Sand, gravel, and silt. *Sand and gravel.*	Sand, gravel, silt, and clay. *Sand and gravel.*	Red sandstone, shale, and conglomerate (green), intruded by diabase (red). *Building stone, iron.*	Cyclic sequences of shale, sandstone, limestone, and coal. *Lime, clay.*	Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, coal, and limestone. *Coal, clay, lime, building stone.*	Red and gray sandstone, shale, and limestone. *Flagstone, limestone, clay.*	Red sandstone, gray shale, black shale, limestone, and chert. *Flagstone, silica sand, clay, lime.*	Red and gray sandstone, conglomerate, shale, and limestone. *Lime, building stone.*	Shale, limestone, dolomite, and sandstone. *Slate, limestone, zinc, clay.*	Limestone, dolomite, sandstone, shale, quartzite, and phyllite. *Lime, building stone.*	Metamorphic rocks (metasedimentary and meta-igneous); schist, gneiss, quartzite, serpentine, slate, and marble. *Building stone, talc.*	Gneiss, granite, anorthosite, metadiabase, metabasalt, metarhyolite, and marble. *Building stone, graphite, sericite.*

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Third Edition, 1990; Third Printing, Revised, 2000.

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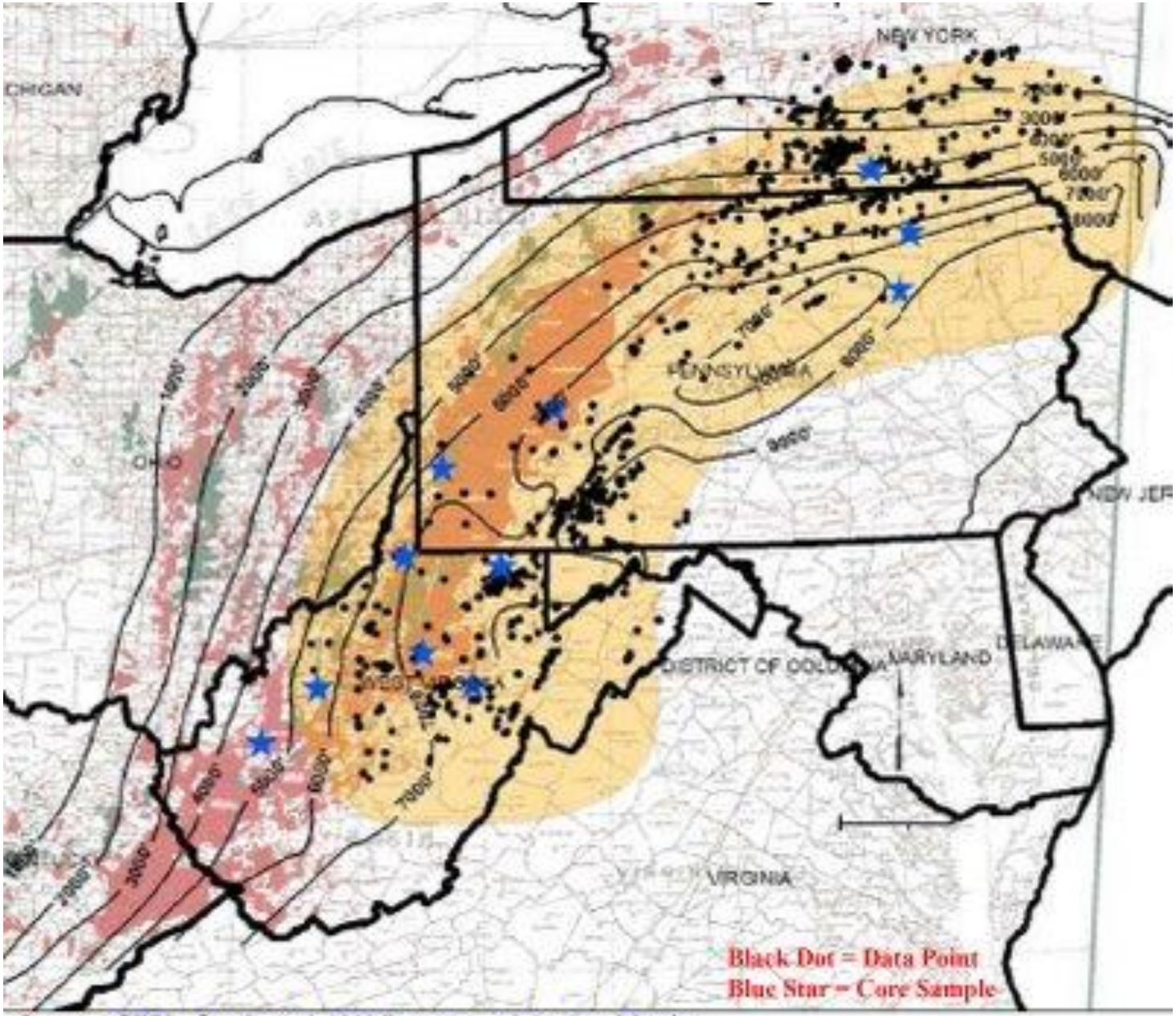
Depth to Marcellus Shale in feet



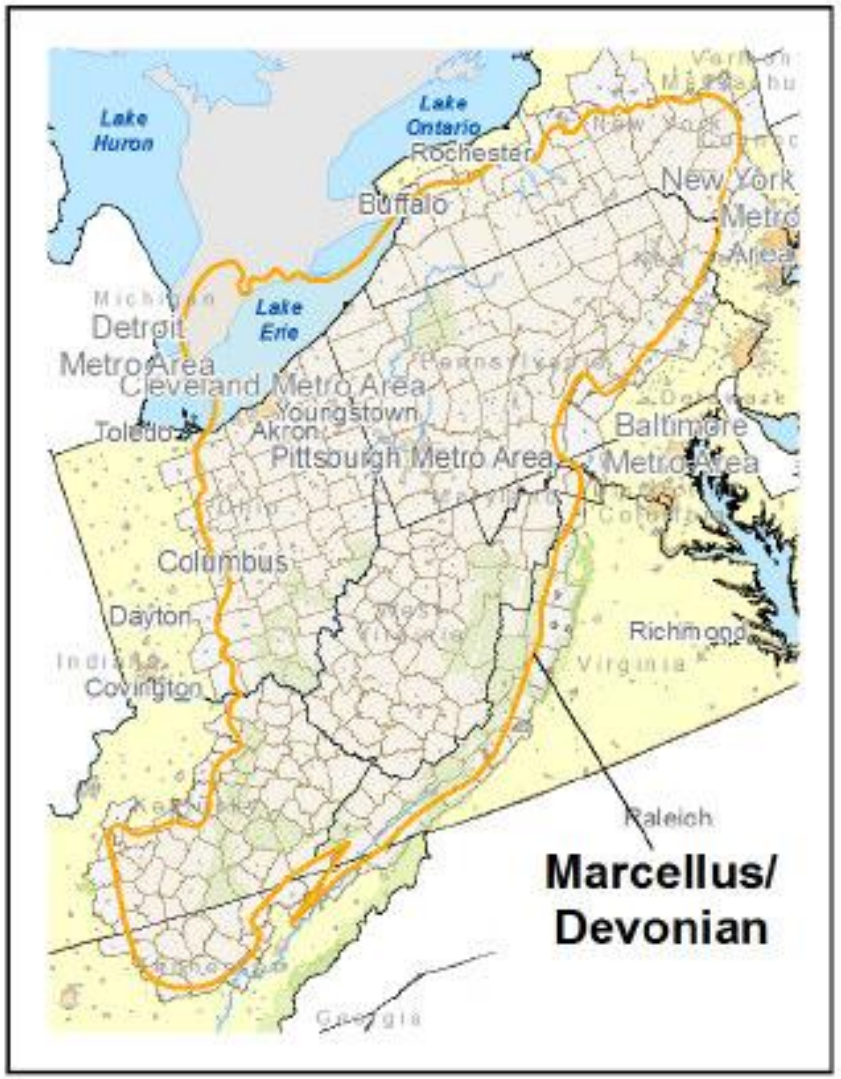
Source: CHK - October 16, 2008 Investor and Analyst Meeting

EXHIBIT 18: STRATIGRAPHY OF THE MARCELLUS SHALE

Period		Group/Unit	
Penn		Pottsville	
Miss		Pocono	
Devonian	Upper	Conewango	
		Conneaut	
		Canadaway	
		West Falls	
		Sonyea	
		Genesee	
	Middle	Tully	
		Hamilton Group	Moscow
			Ludlowville
			Skaneateles
			Marcellus
		Onandaga	
	Lower	Tristates	
		Helderberg	

Source: Arthur et al, 2008[148]

EXHIBIT 19: MARCELLUS SHALE IN THE APPALACHIAN BASIN



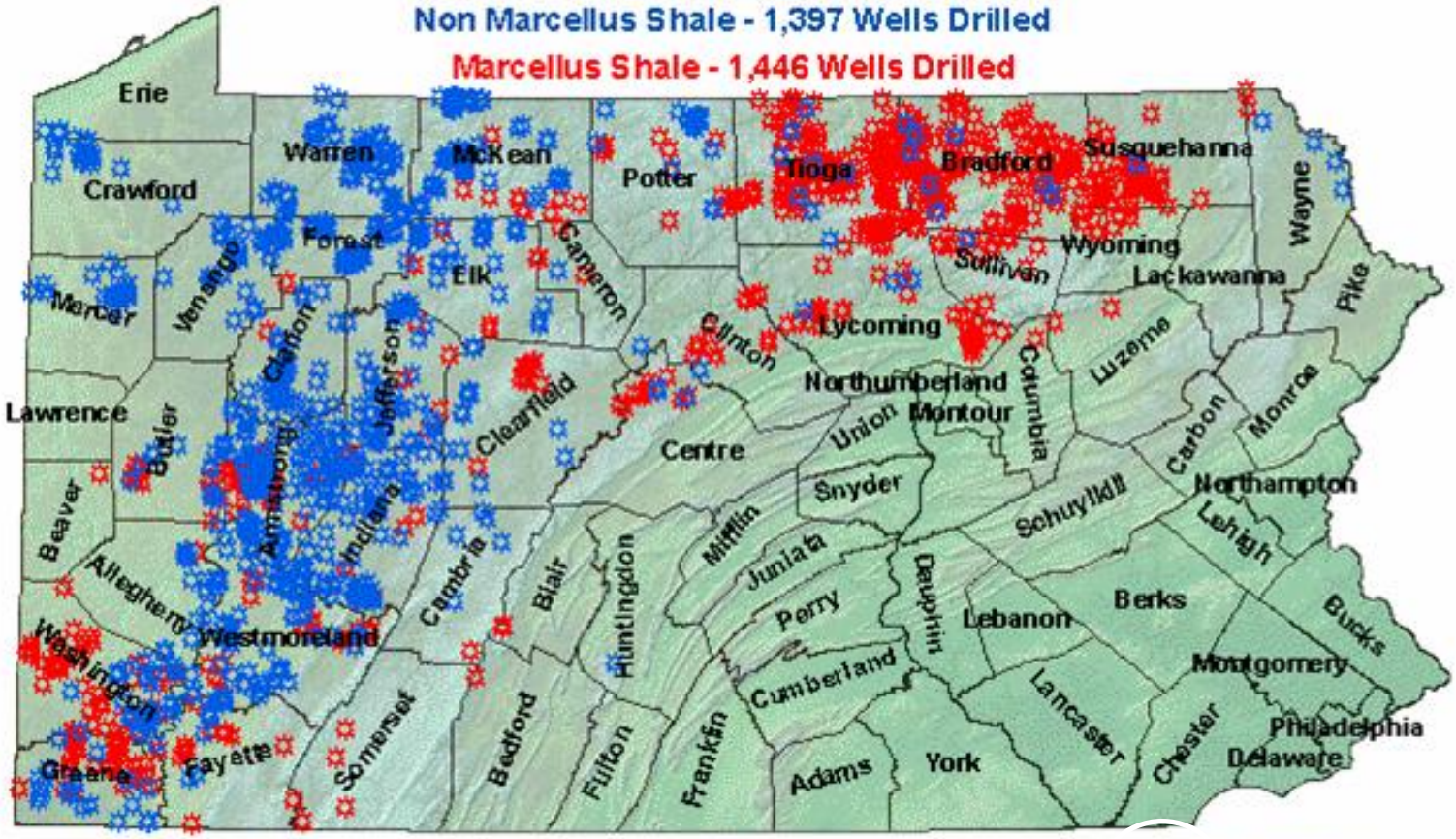
Source: ALL Consulting, 2009

Department of Environmental Protection
Bureau of Oil and Gas Management
Wells Drilled

2010 January-December Wells Drilled - 2,843

Non Marcellus Shale - 1,397 Wells Drilled

Marcellus Shale - 1,446 Wells Drilled



As Reported by Operators

Updated 01/25/2011

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What We Know

Impacts on Water Resources

- **Water withdraws for HF solutions: streams, CWS**
- **Produced water containment, transport, treatment, discharge or disposal.**
- **Earth disturbance / construction, access & pipelines**
- **Site waste – equipment maintenance repair & other operations.**

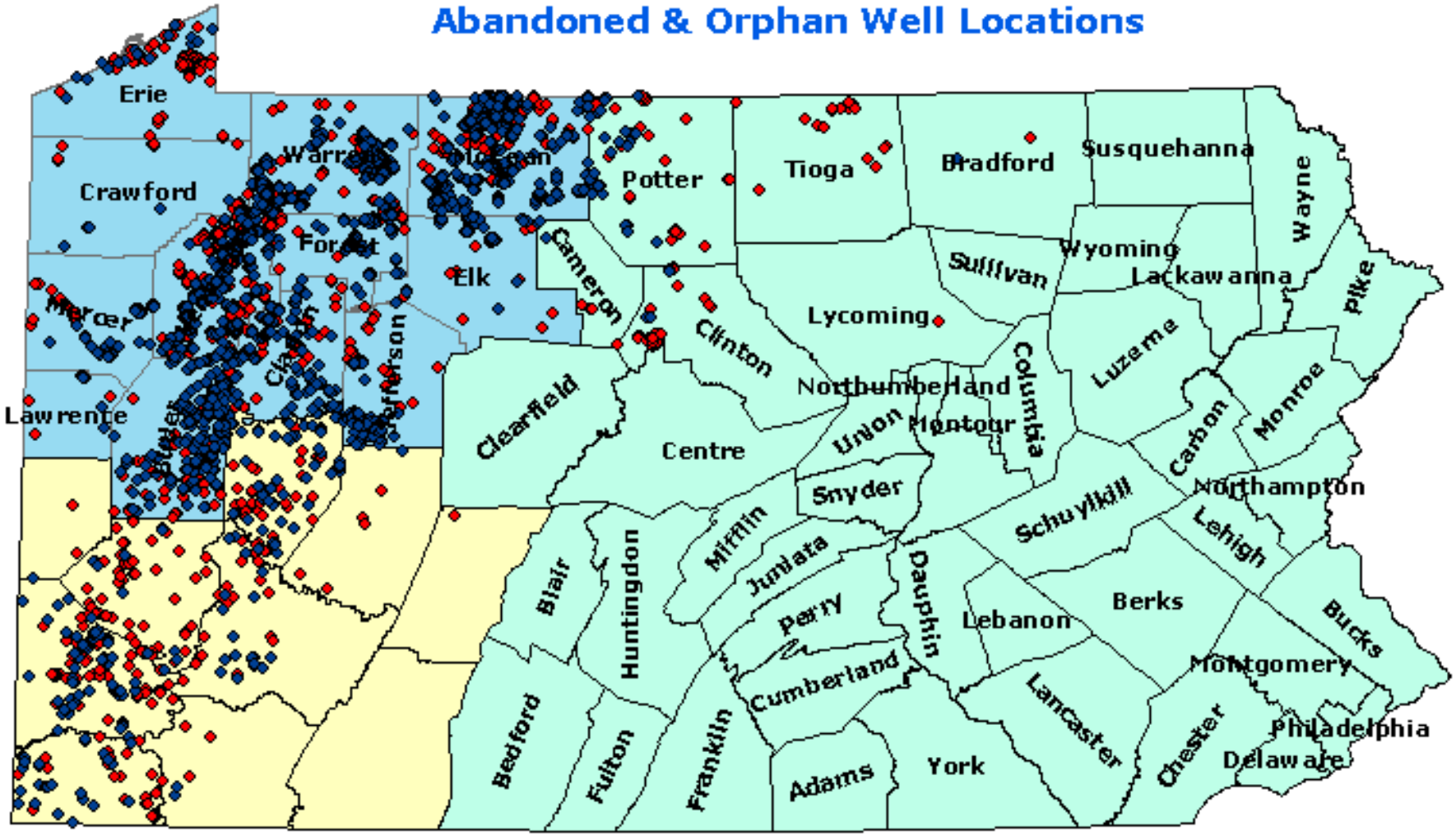
- Marcellus and Other Shale Issues

What We Know

Water Pollution Causes:

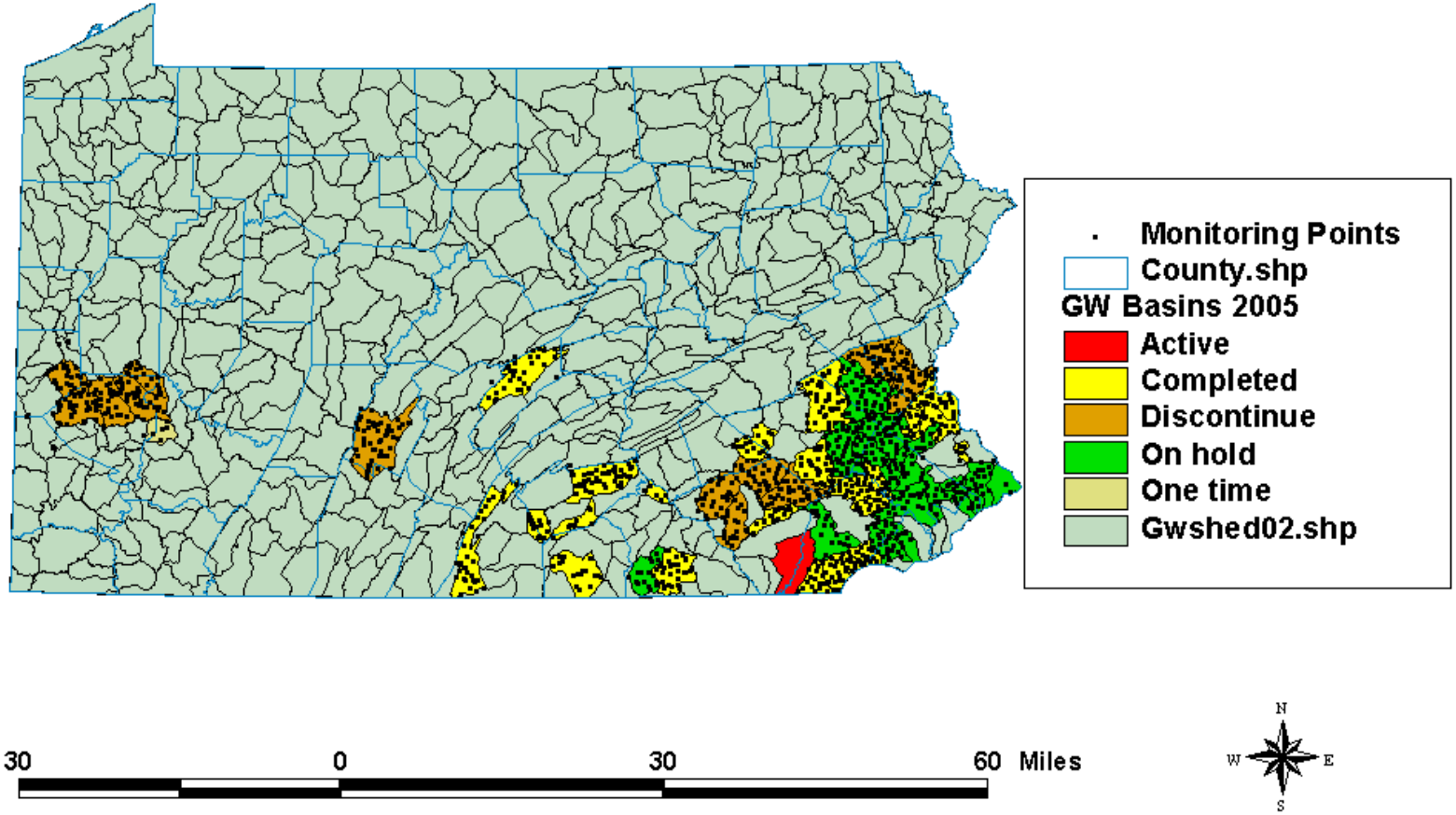
- Loss of produced water or wastes at the surface
- Improper well casing design or construction
- Aquifer disturbance during drilling
- Improper treatment
- No evidence or concern in Pennsylvania that HF has caused direct migration of fluids to underground sources of drinking water

Commonwealth of Pennsylvania
Department of Environmental Protection
Bureau of Oil & Gas Management
Abandoned & Orphan Well Locations



Abandoned Wells **Orphan Wells**

Ground Water Monitoring Status



State Ground Water Quality Monitoring

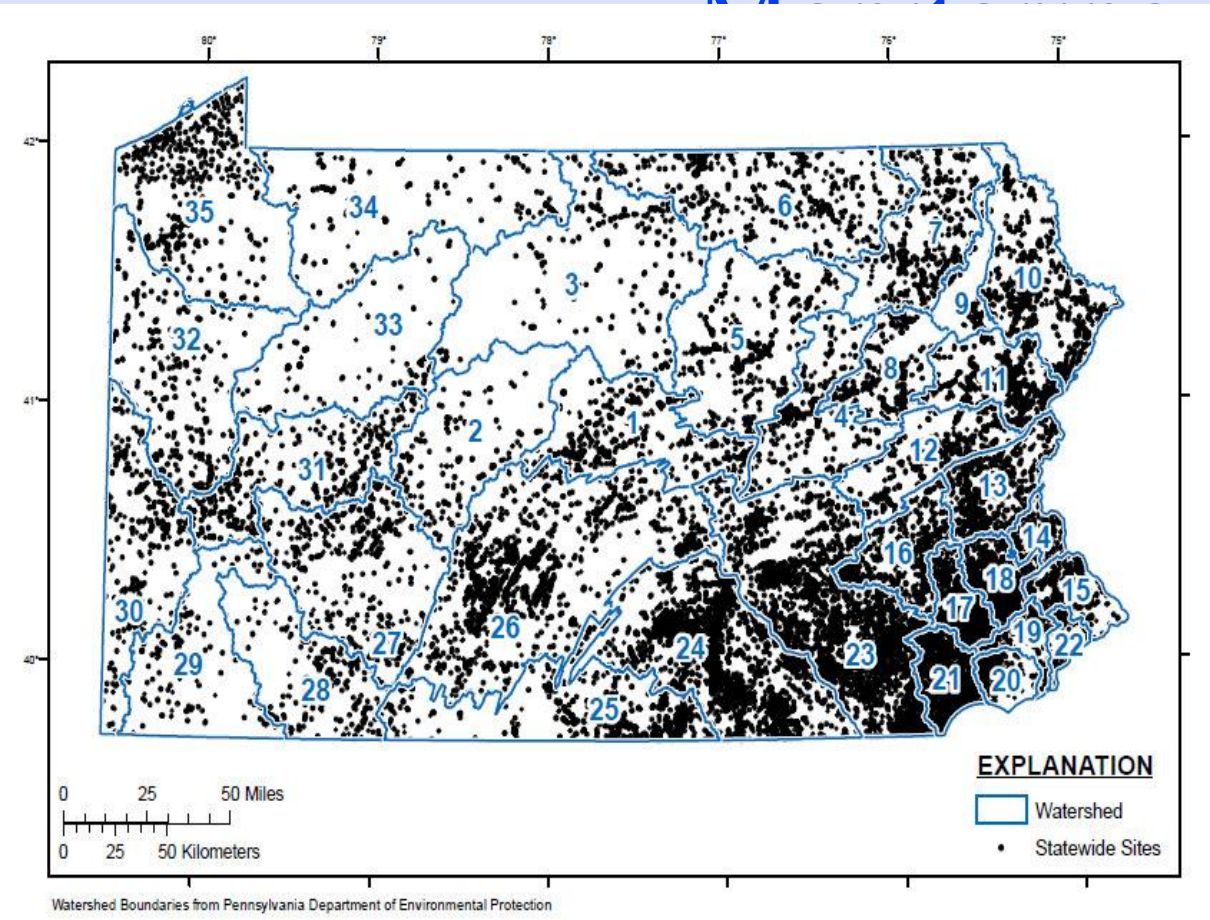
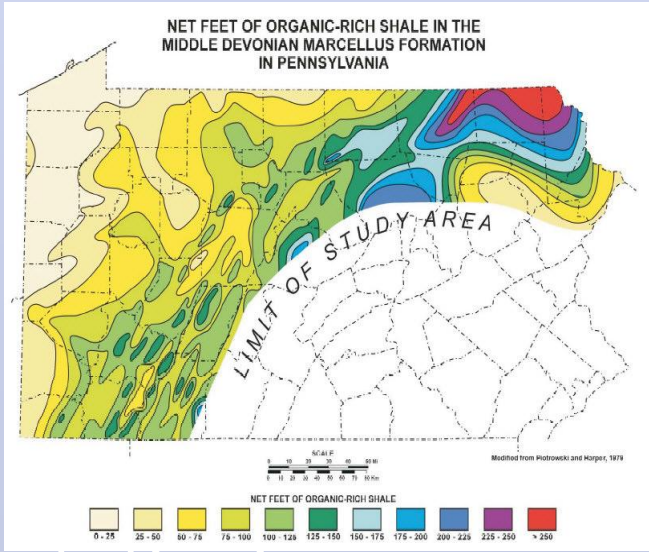


Figure 4. Well and spring locations with ground-water data compiled from 14 source agencies or programs representing the period 1979-2006 for Pennsylvania.

USGS Data Series Report 314 (2009):



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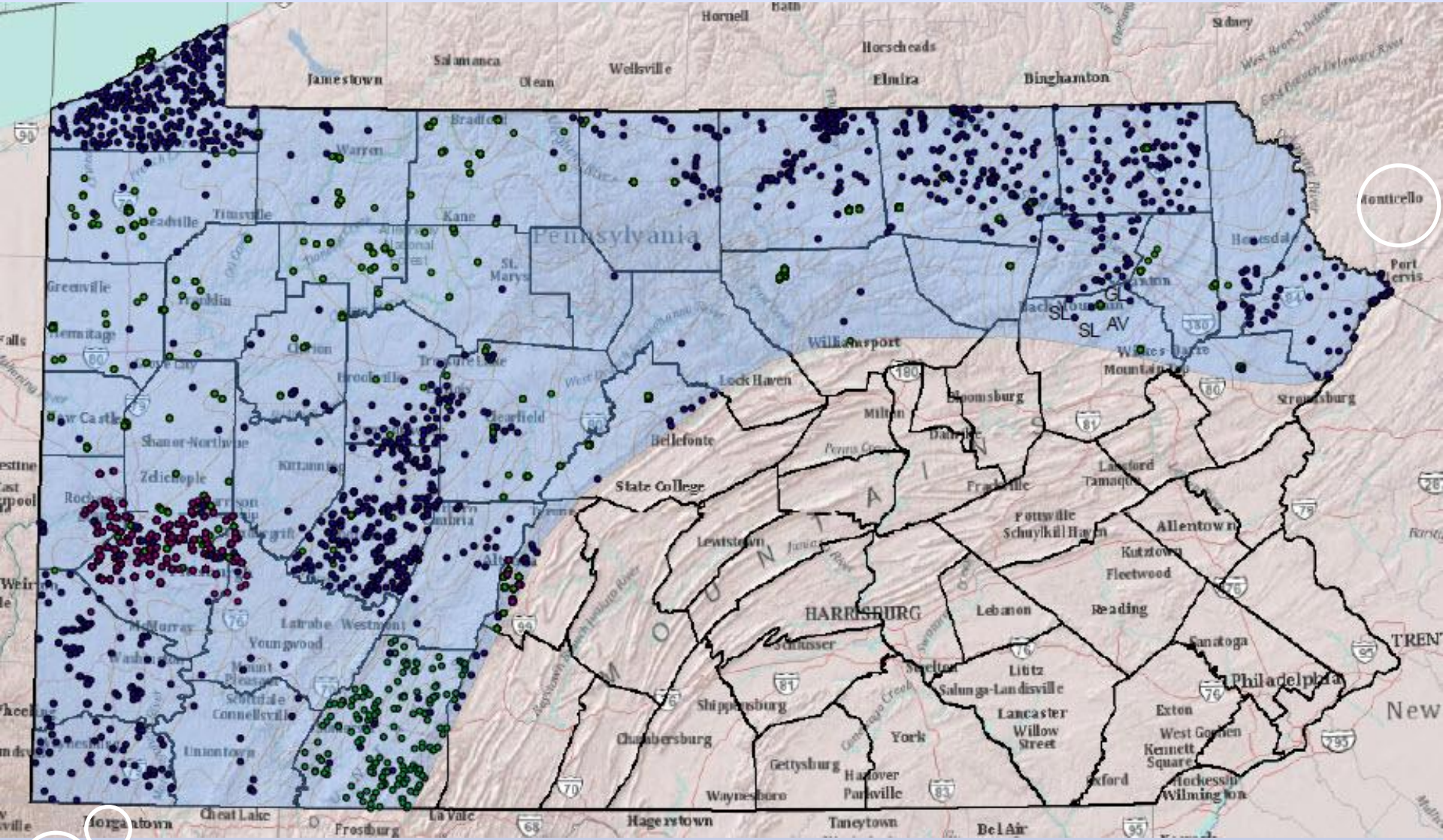
water


Hornell
Bath
Sidney
Horseheads
Jamestown
Salamanca
Olean
Wellsville
Elmira
Binghamton
Bradford
Warren
Titusville
Kane
Pennsylvania
Monticello
Greenville
St. Marys
Port Jervis
Hermitage
Clarion
Lock Haven
Bloomsburg
Milton
Strousburg
Shanor-Northvue
Bellefonte
Zelienople
State College
Lansford
Tamaqua
Pottsville
Schuylkill Haven
Allentown
Lewistown
Kutztown
Fleetwood
HARRISBURG
Lebanon
Reading
Latrobe
Youngwood
Saratoga
Philadelphia
Shippensburg
Lititz
Salunga-Landisville
Lancaster
Willow Street
Exton
West Goshen
Kennett Square
Chambersburg
York
Gettysburg
Hanover
Parkville
Oxford
Hockessin
Wilmington
Waynesboro
Morgantown
Cheat Lake
LaVale
Frostburg
Hagerstown
Taneytown
Bel Air

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- Abandoned Mine Drainage

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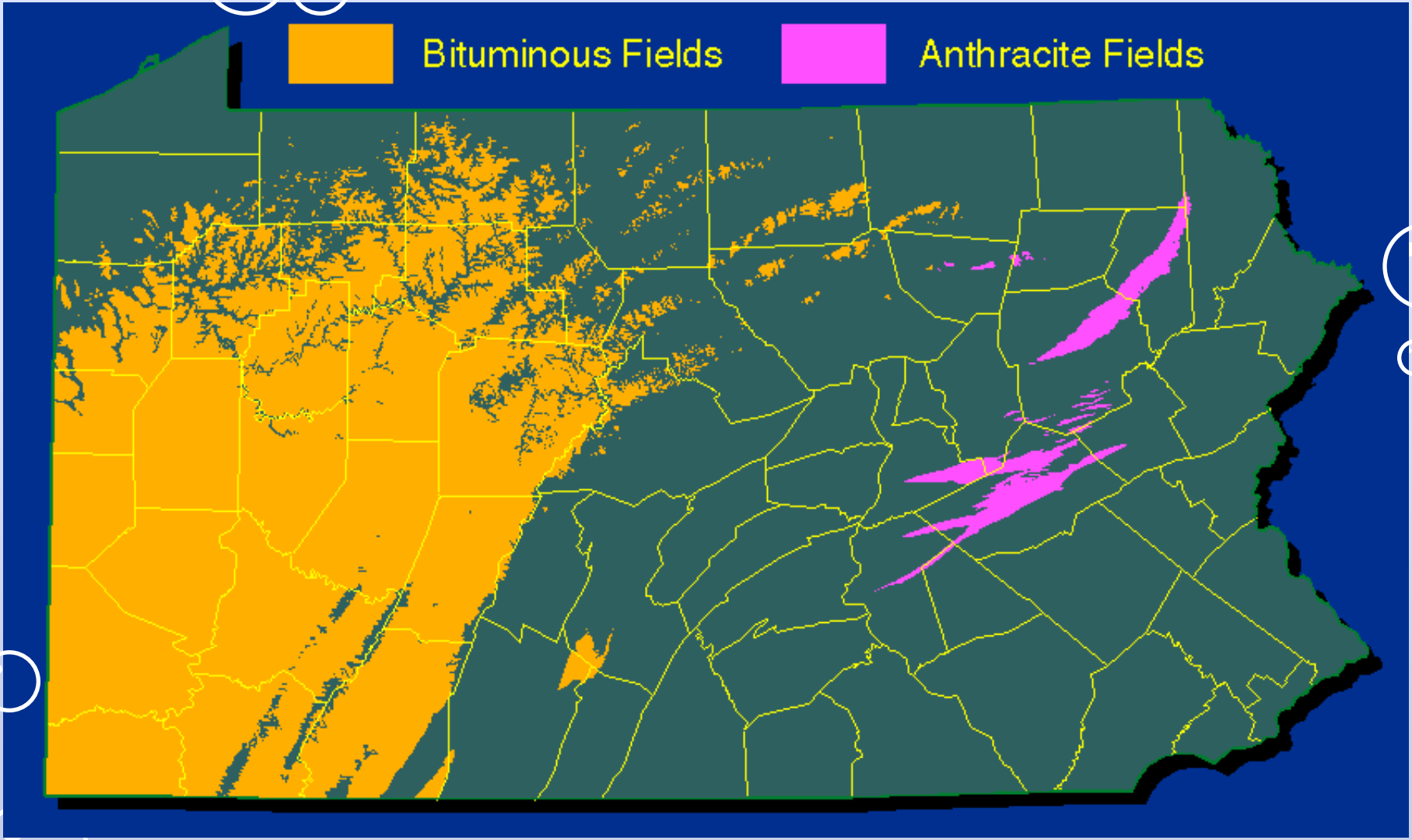

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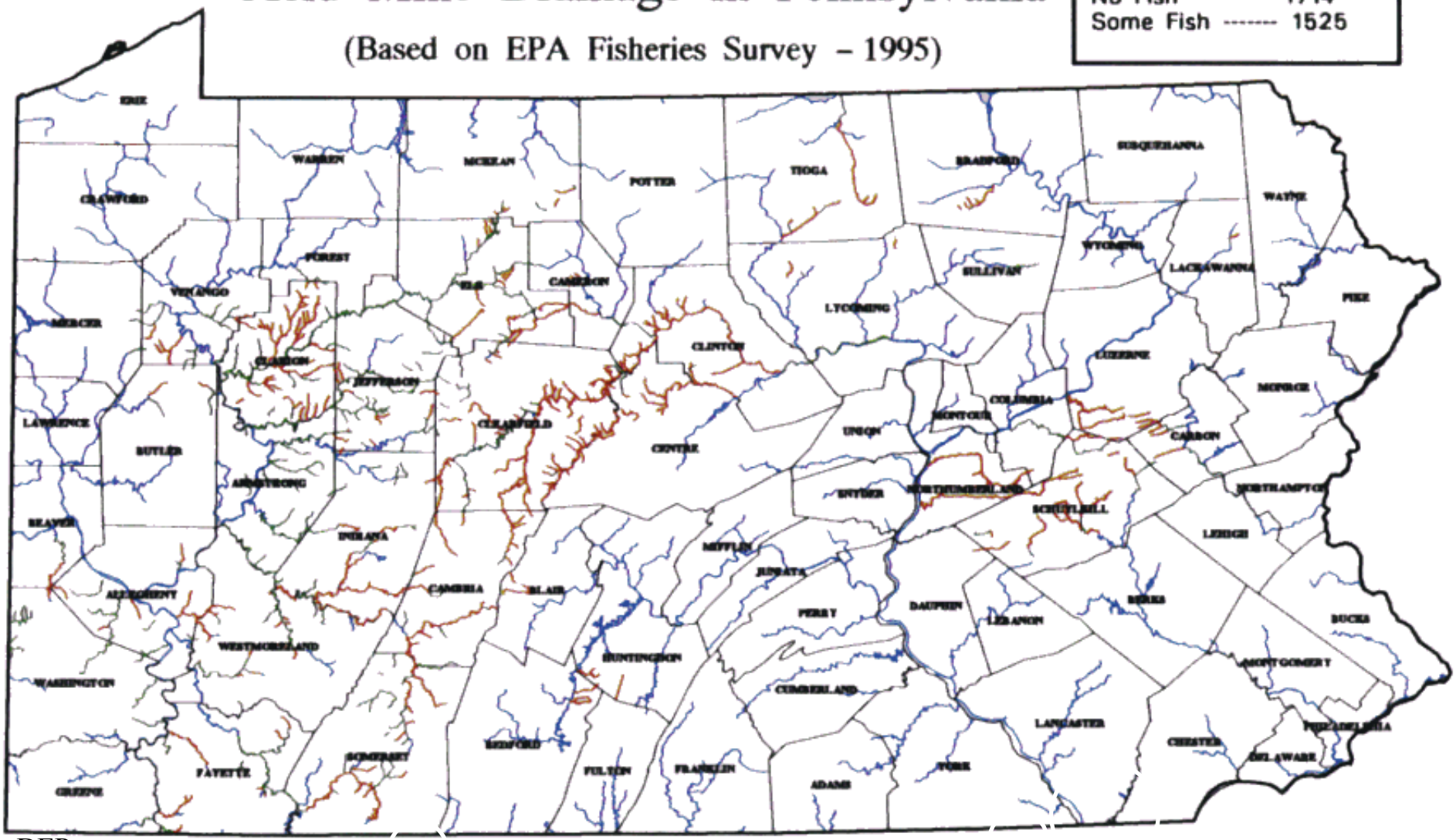
Streams and Fisheries Impacted by Acid Mine Drainage in Pennsylvania

(Based on EPA Fisheries Survey – 1995)



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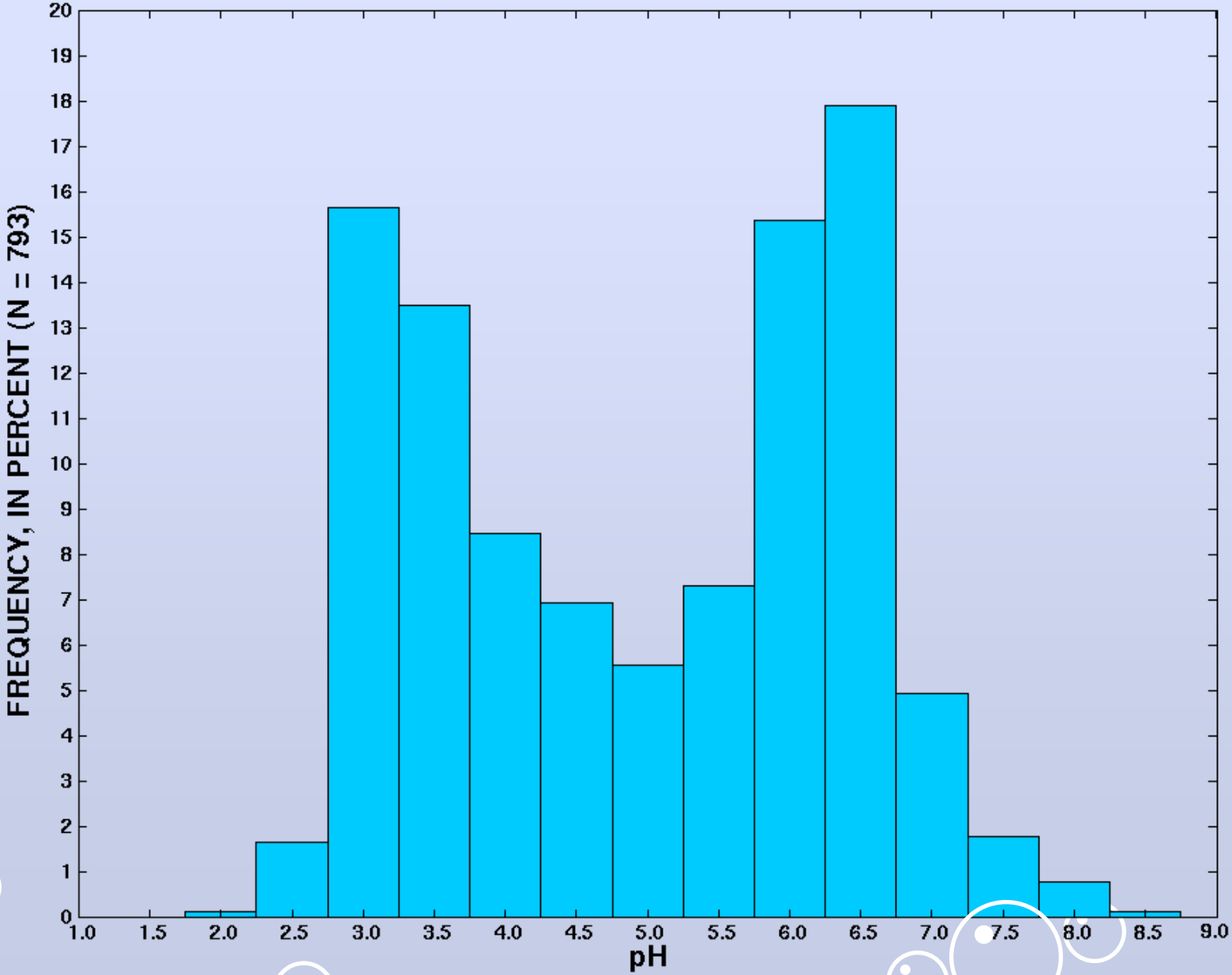
BITUMINOUS COAL-MINE DISCHARGES IN PENNSYLVANIA



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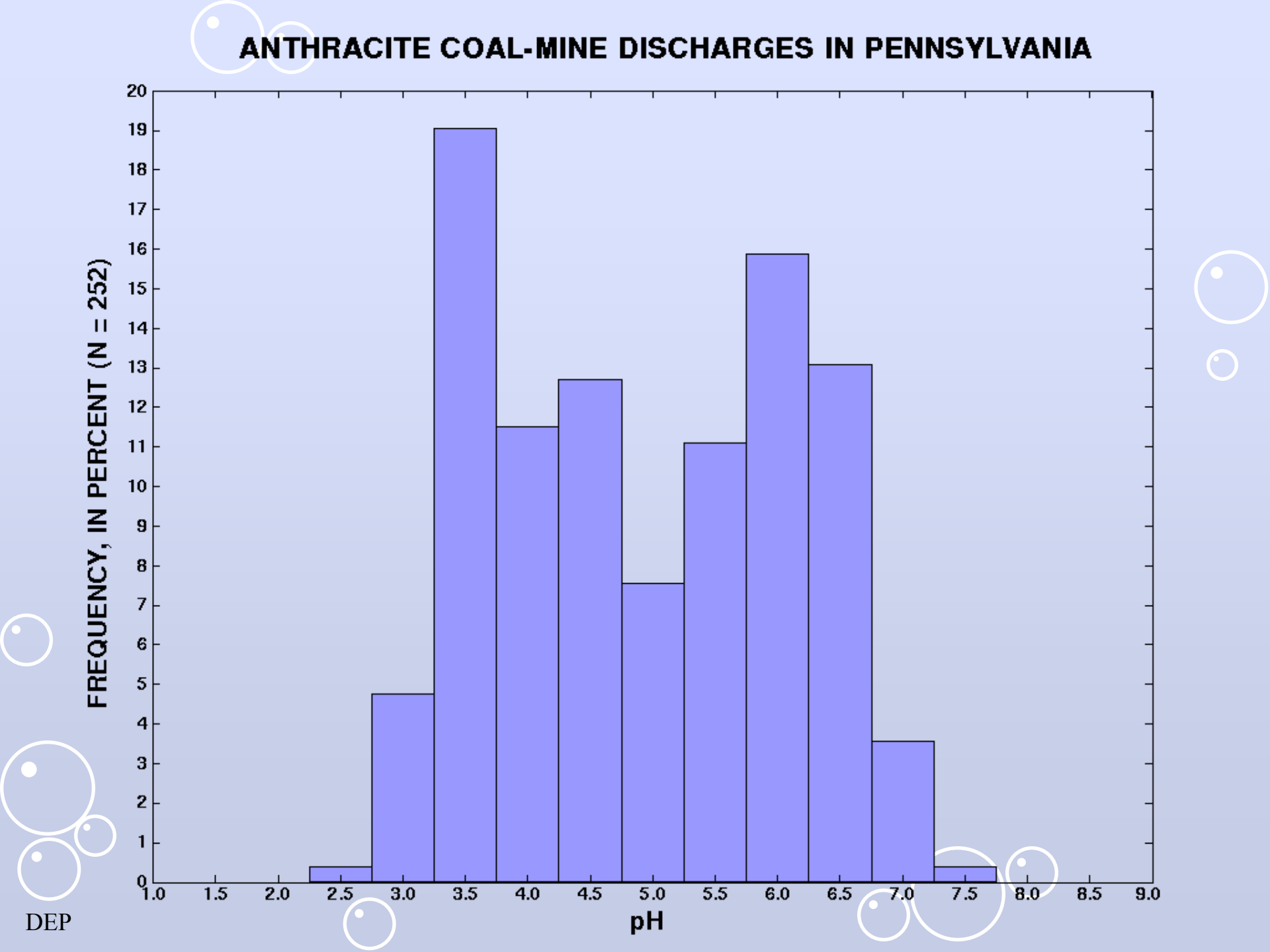
ANTHRACITE COAL-MINE DISCHARGES IN PENNSYLVANIA
FREQUENCY, IN PERCENT (N = 252)
pH
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0

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Monogahela River - Elevated TDS 2008

- 10/2008 - Elevated total dissolved solids (TDS) > than SDWA standard (500 mg/l)
- Potential sources of TDS in watershed include abandoned & active surface and deep coal mines, waste water and industrial discharges (receiving HF flow-back)
- PA DEP reduced HF % flow at wastewater treatment plants
- River under historic low flow conditions
- TDS concentrations returned to normal in December 2008 after recovery of river flow

Source: Chesapeake Energy Corporation, 2008

Hydraulic Fracturing of a Marcellus Shale Well, West Virginia

- Marcellus and Other Shale Issues

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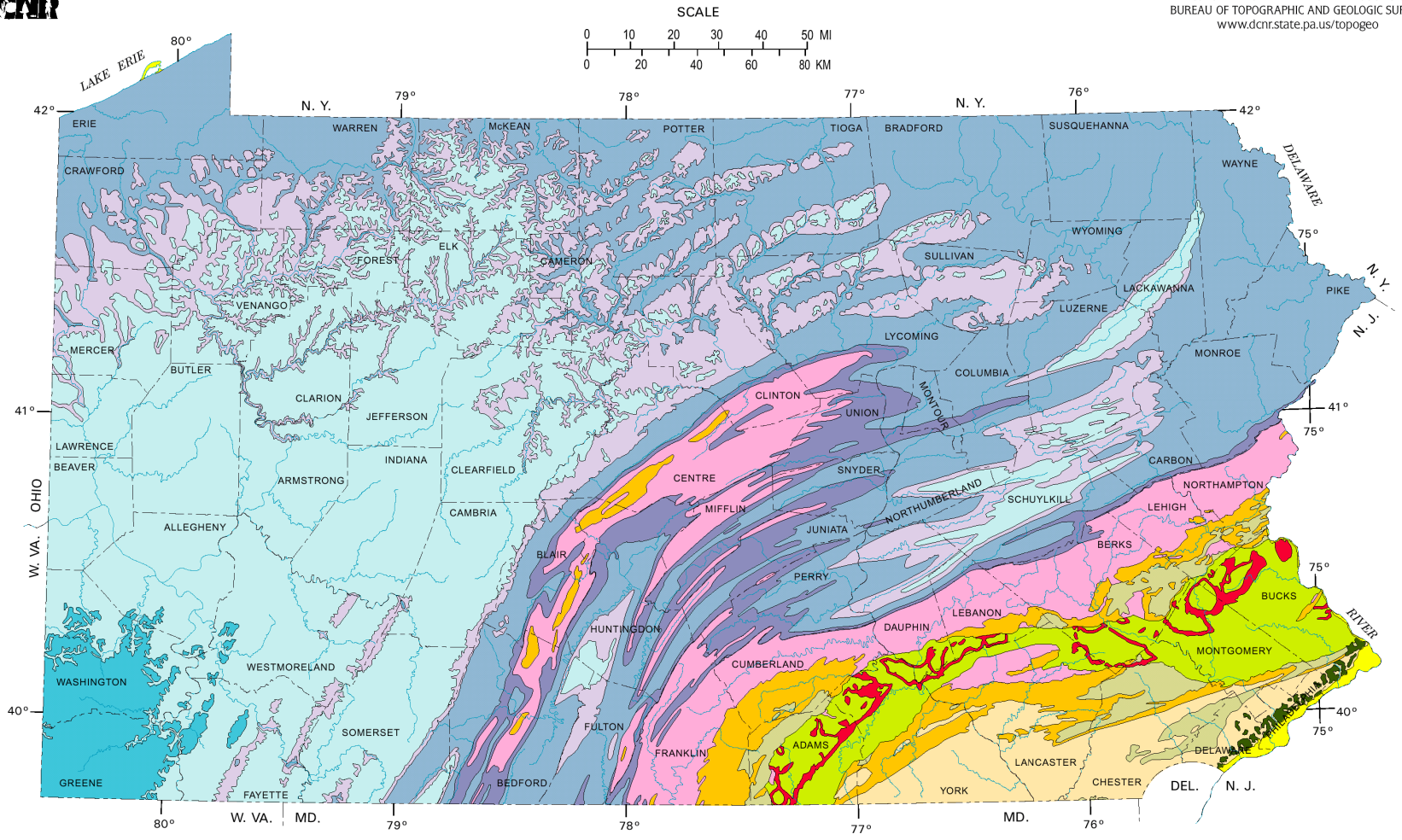

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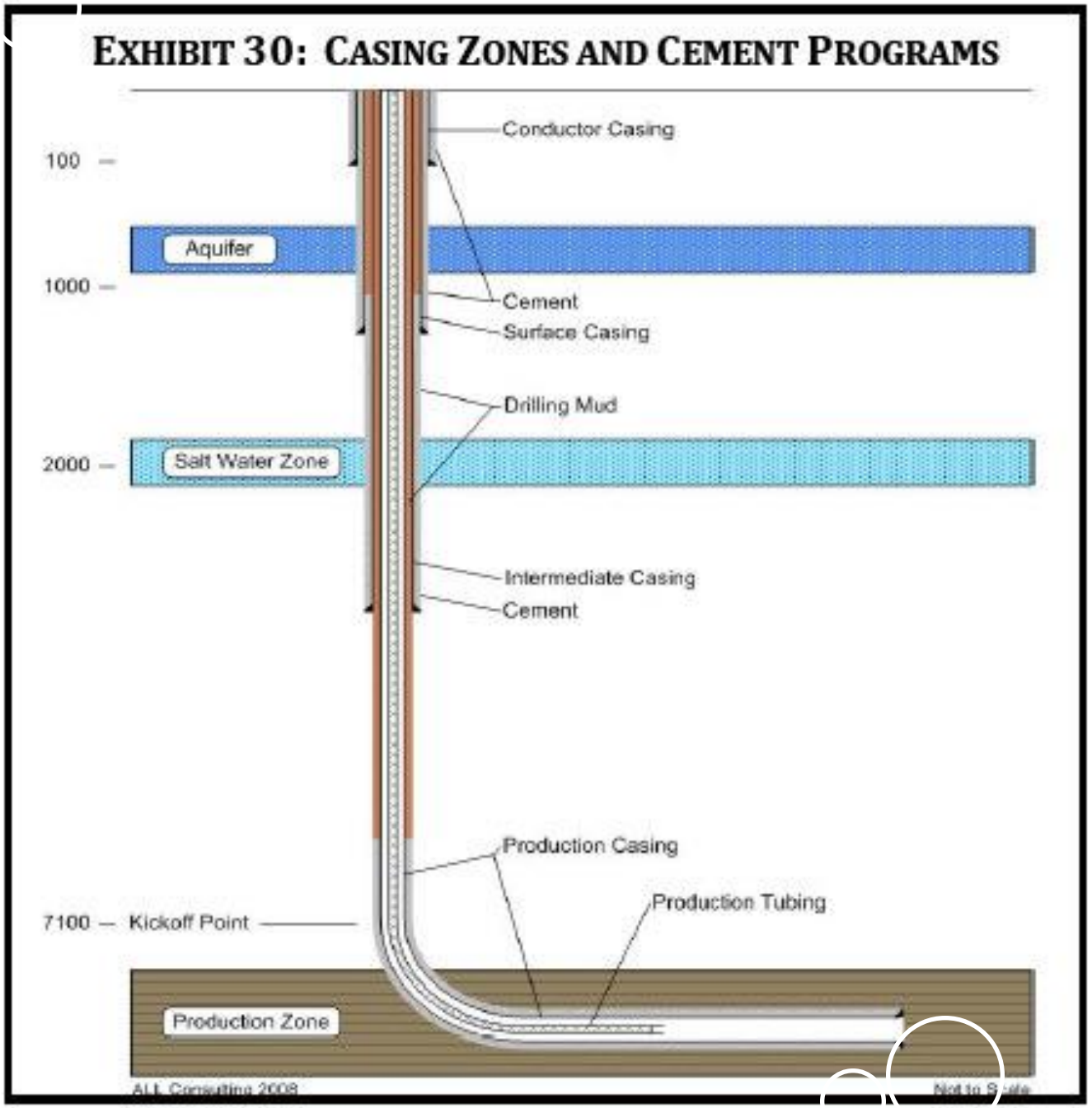
EXHIBIT 30: CASING ZONES AND CEMENT PROGRAMS
Conductor Casing
100
Aquifer
1000
Cement
Surface Casing
Drilling Mud
2000
Salt Water Zone
Intermediate Casing
Cement
Production Casing
Production Tubing
7100
Kickoff Point
Production Zone
ALL Consulting 2008
Not to Scale

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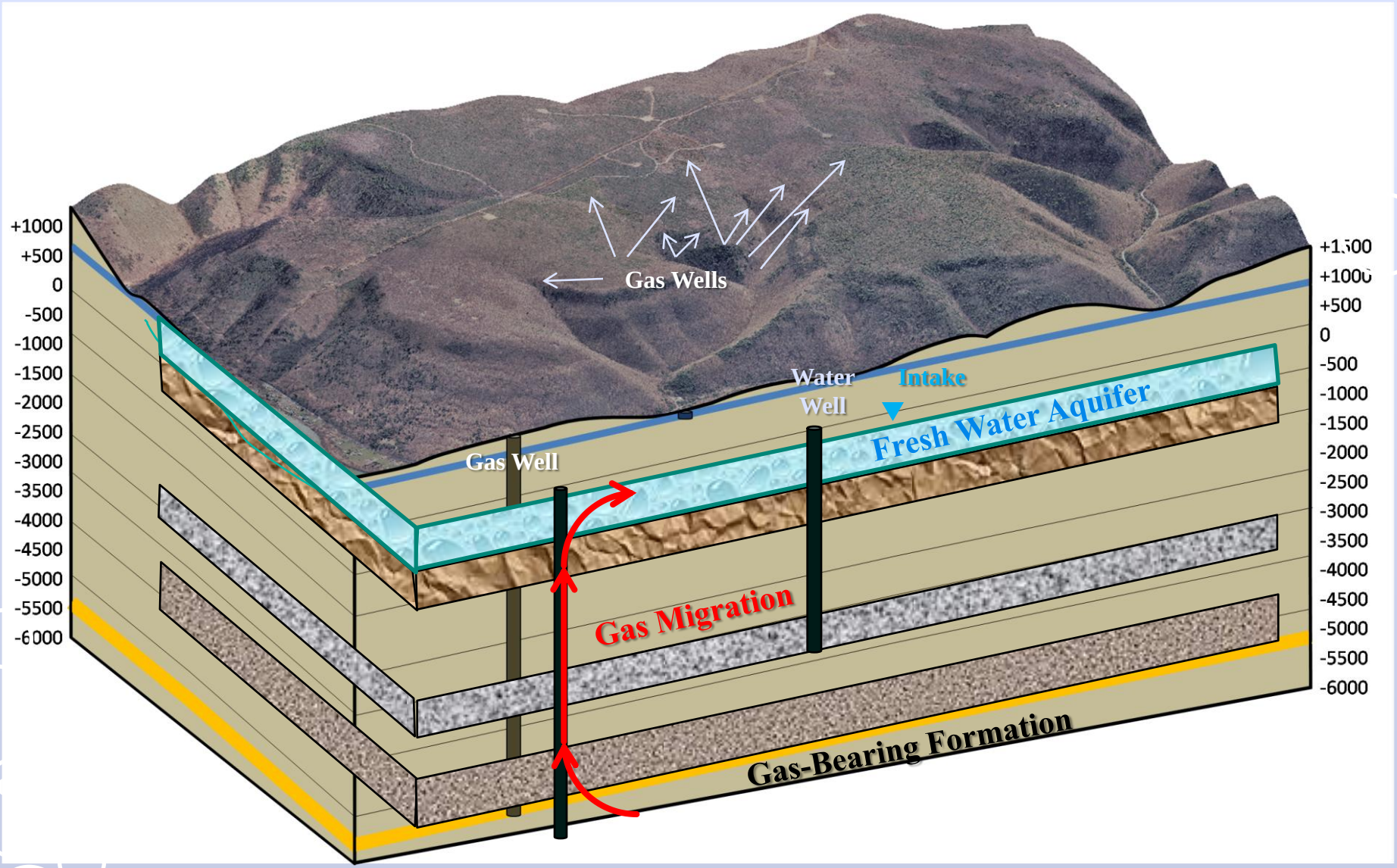
Gas Wells
Water Well
Intake
Fresh Water Aquifer
Gas Well
Gas Migration
Gas-Bearing Formation
+1000
+500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000

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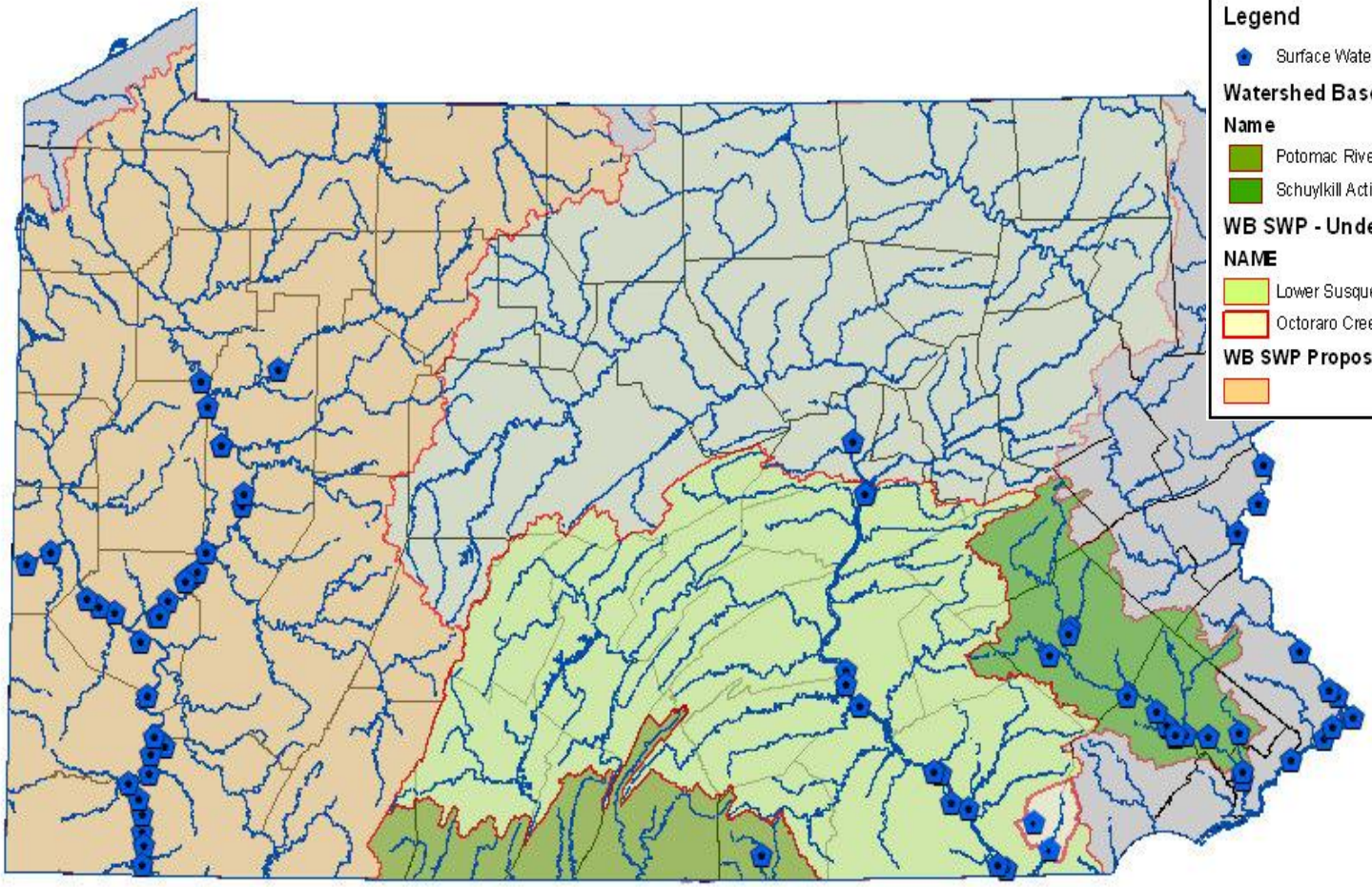
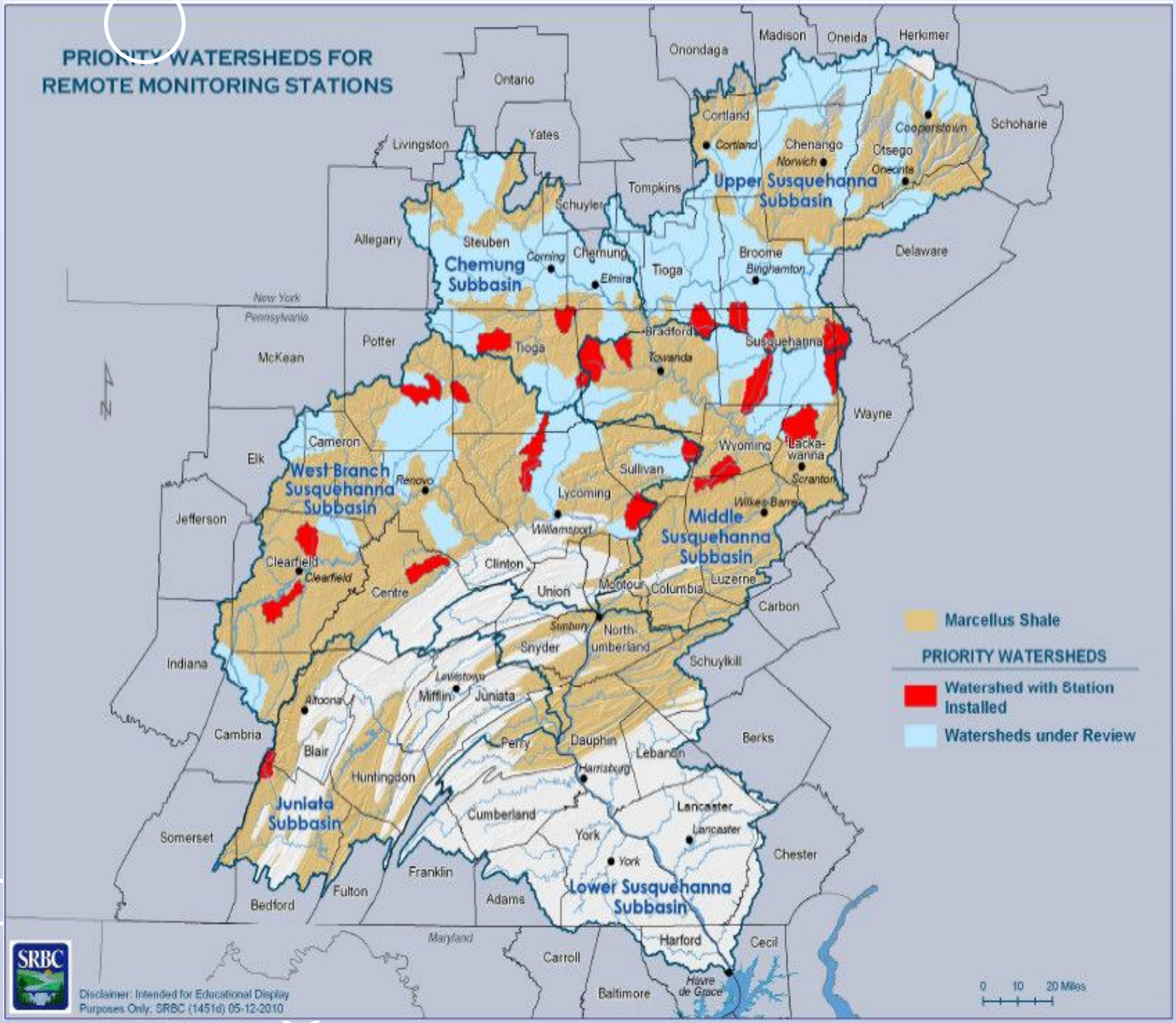
PA Watershed Based Source Water Protection Program



pennsylvania

Bureau of Watershed Management

JJL - 09/23/2010


PRIORITY WATERSHEDS FOR
REMOTE MONITORING STATIONS
Upper Susquehanna Subbasin
Chemung Subbasin
West Branch Susquehanna Subbasin
Middle Susquehanna Subbasin
Juniata Subbasin
Lower Susquehanna Subbasin
Marcellus Shale
PRIORITY WATERSHEDS
Watershed with Station Installed
Watersheds under Review
Disclaimer: Intended for Educational Display Purposes Only. SRBC (1451d) 05-12-2010
0 10 20 Miles

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