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Challenges and Emerging Practices for the Treatment of Natural Gas Fluids

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Hart Resource Technologies, Inc.

Pennsylvania Brine Treatment, Inc.

HRT Management

Trained and Experienced

- Active members in:
  - West Penn Energy Association
  - Independent Oil and Gas Association
  - Member of Marcellus Shale Coalition
  - Chairman of Environmental Committee (Paul Hart '99-'03)
- Management Team Members each have over 20 years experience in the Oil and Gas Industry
- Three treatment facilities currently in operation; processes millions of gallons of the water disposed of in PA
- Successfully crystallized brine water 1986-1992
- Patent on mobile Frac/Pit water treatment system
- Patent for on-site brine water treatment system
- Owner of Ohio disposal well

HRT CREEKSIDE, PA

PA BRINE JOSEPHINE, PA

PA BRINE FRANKLIN, PA

Company History

- 1984 – Cabot opened Franklin facility
- 1985 – HRT renovated AMD facility in Creekside, PA
- 1986 – Castle Gas opened Josephine facility
- 2003 – PBT purchased Franklin and Josephine facilities
- 2007 – Acquired rail cars to transport water

History of Water Disposal

(Pre 1984 VS Post 1984)

- Pre 1984- Discharge to blow box, surface pit, stream
- Post 1984- Approved Methods
  1. Centralized treatment facility with NPDES stream discharge
  2. Disposal/injection well UIC; seven wells in PA are currently in use (Appalachian brine is more concentrated)
  3. Road spreading for dust control and deicing (Beneficial uses)
  4. Sewage treatment facilities
  5. Reuse
  6. On site treatment/Recycle

Types of Waste Fluids

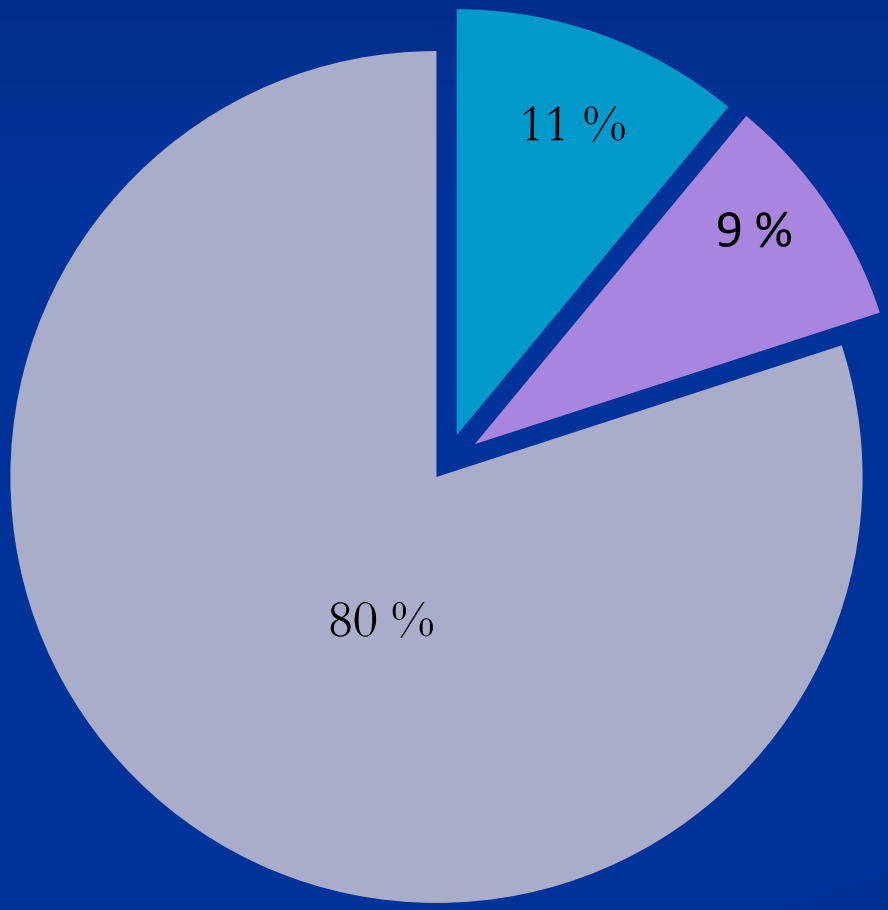
- *Top hole fluid* – freshwater encountered during drilling

- *Drilling fluids*

- *Stimulation "flow back" fluids, Frac water (major source of waste fluids from Marcellus wells)*

- *Production fluids -Brine*

Brine and Drilling/Frac Fluids Disposal 1997



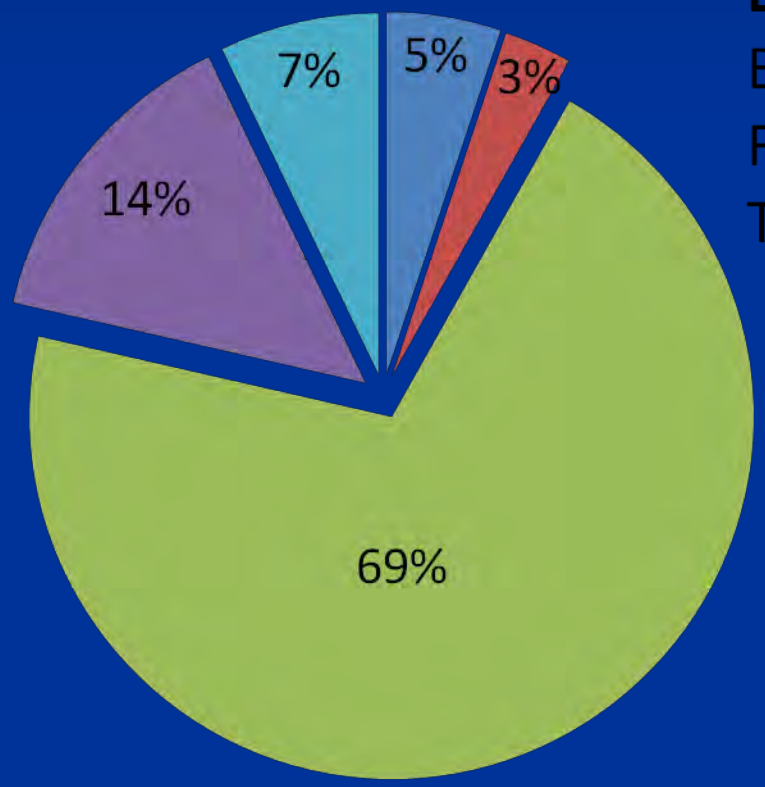
Volumes

Brine 58,594,960 gallons
Fluids 30,862,822 gallons
Total 89,457,782 gallons

- Disposal Wells
- Road Spreading
- Treatment Facilities

Source: Department of Environmental Protection
Bureau of Oil and Gas

Brine and Drilling/Frac Fluids Disposal in PA 2007



Estimated Volumes

Brine 82,000,000 gallons

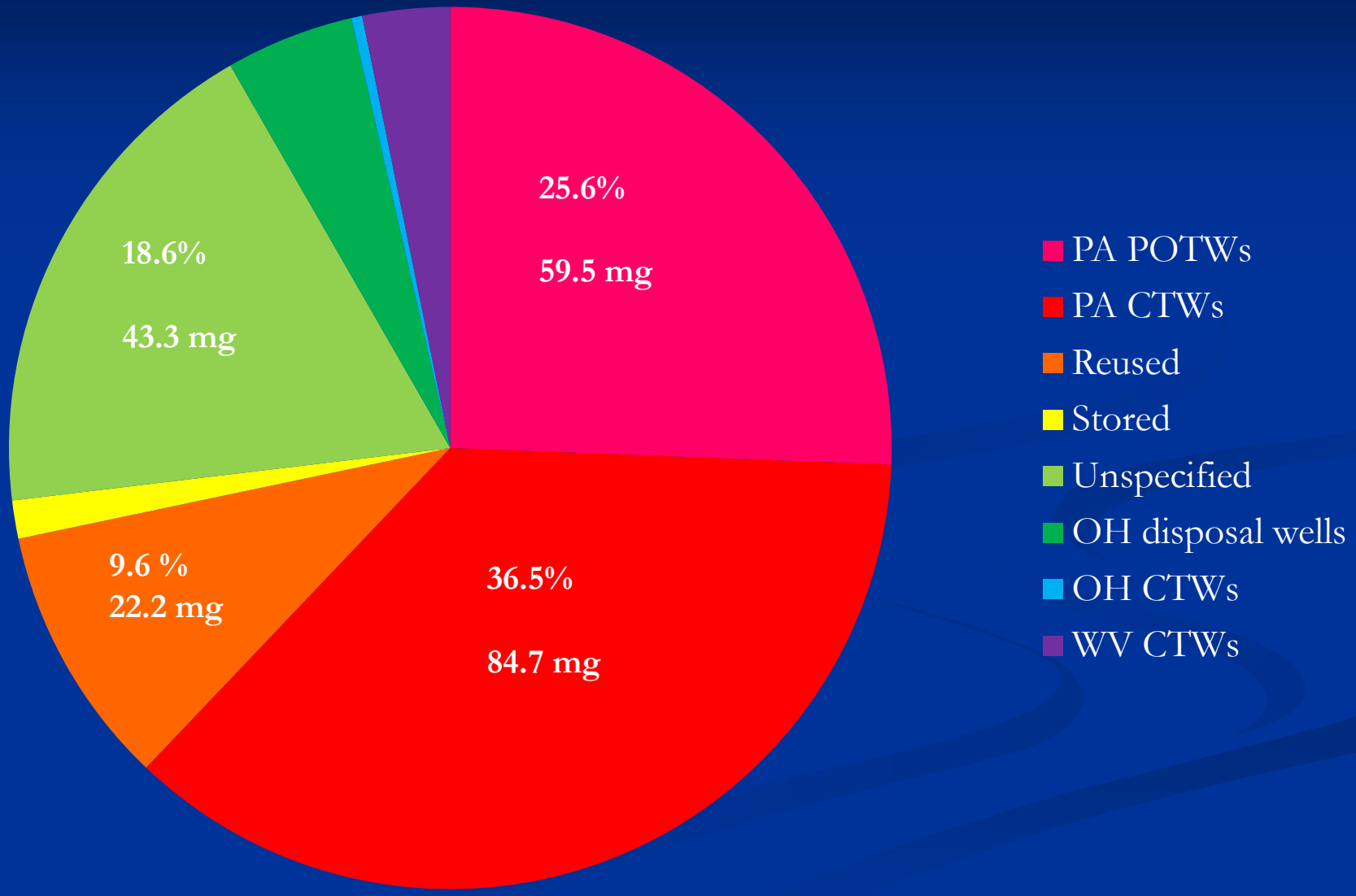
Frac/Pit 100,000,000 gallons

Total 182,000,000 gallons/Day

- Injection Wells
- Beneficial use
- Commercial Treatment Facilities
- Public Sewage Treatment Plants
- Reused/Recycled

Source: Hart Resource Technologies, Inc.

Marcellus operations in PA generated 232.1 million gallons of fluids during July 2009 thru July 2010



Variable Nature of Waste Fluids

(one example)

Pollutant	First 1/3	Second 1/3	Last 1/3
TDS	23,978	142,095	245,987
Chloride	12,098	64,598	134,065
Barium	432	4,786	6,784
Iron	12	27	67
Benzene	BD	BD	18

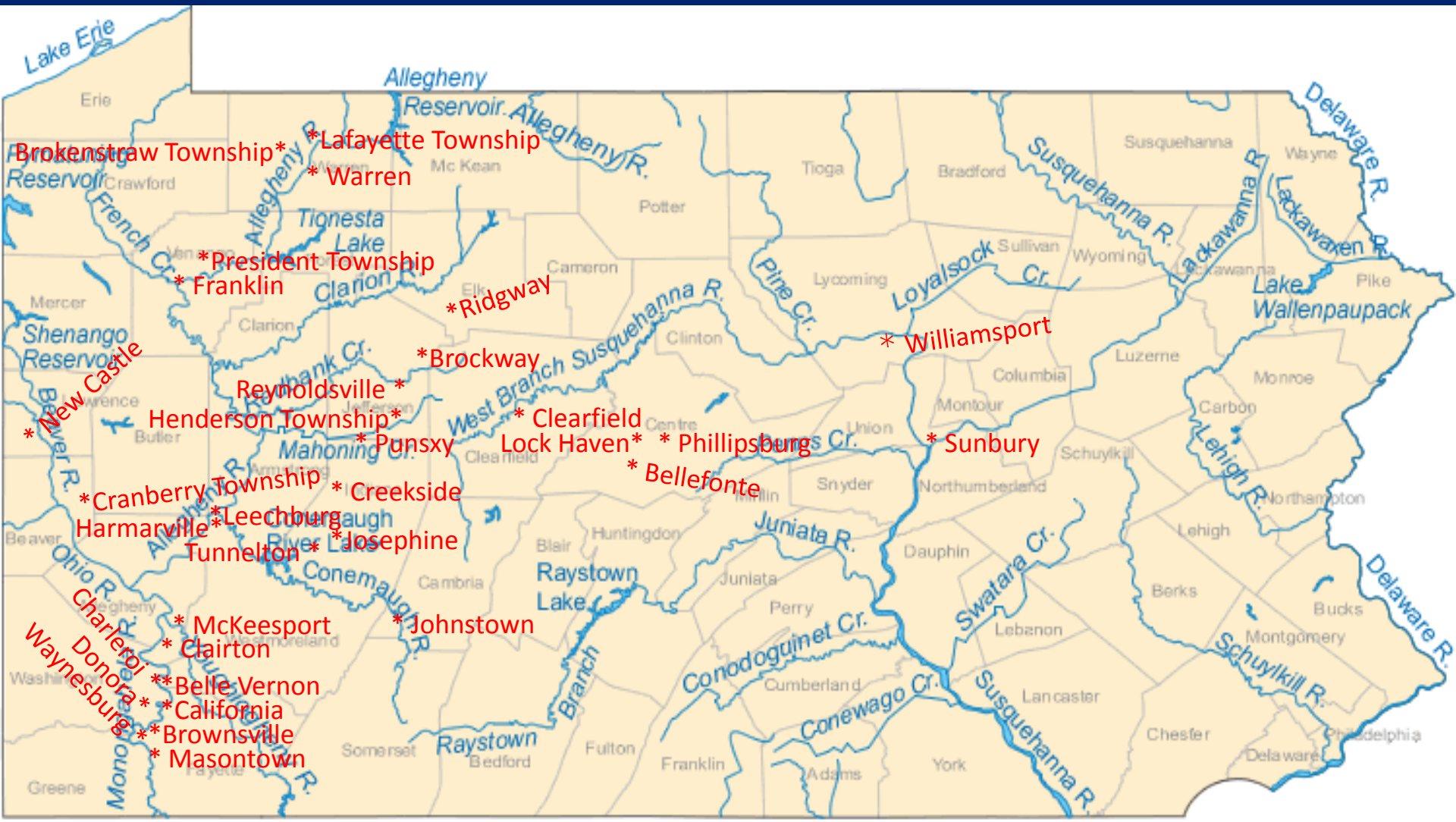
All concentrations in mg/L except benzene (µg/L)
"BD" = below detection

Challenges for Water Disposal

- High Volume
- Changing level of contaminates
- Oil
- Solids
- Salt
- White Brine

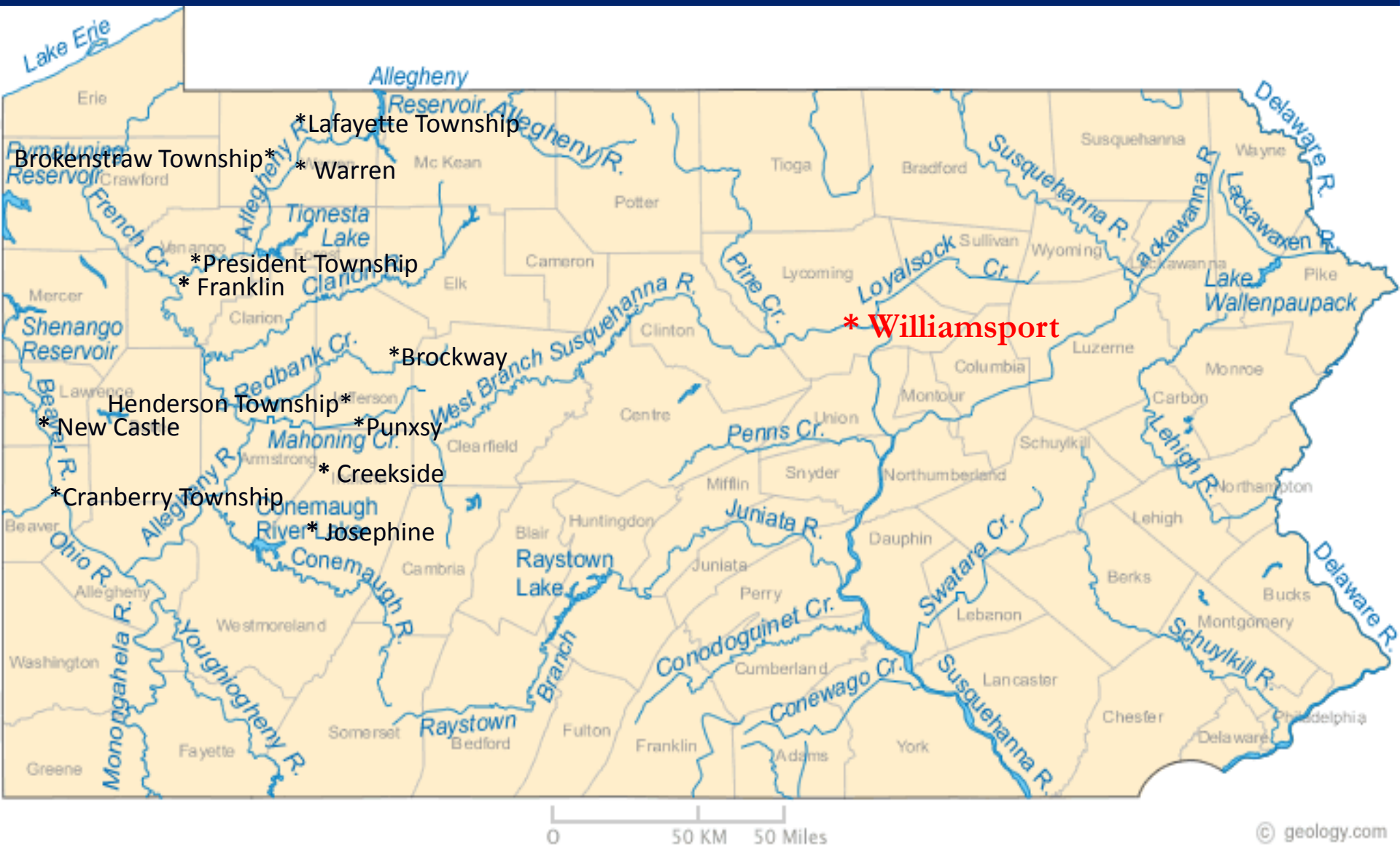
Disposal Facilities Prior to 2010

30 Facilities
(Not Injection Wells)

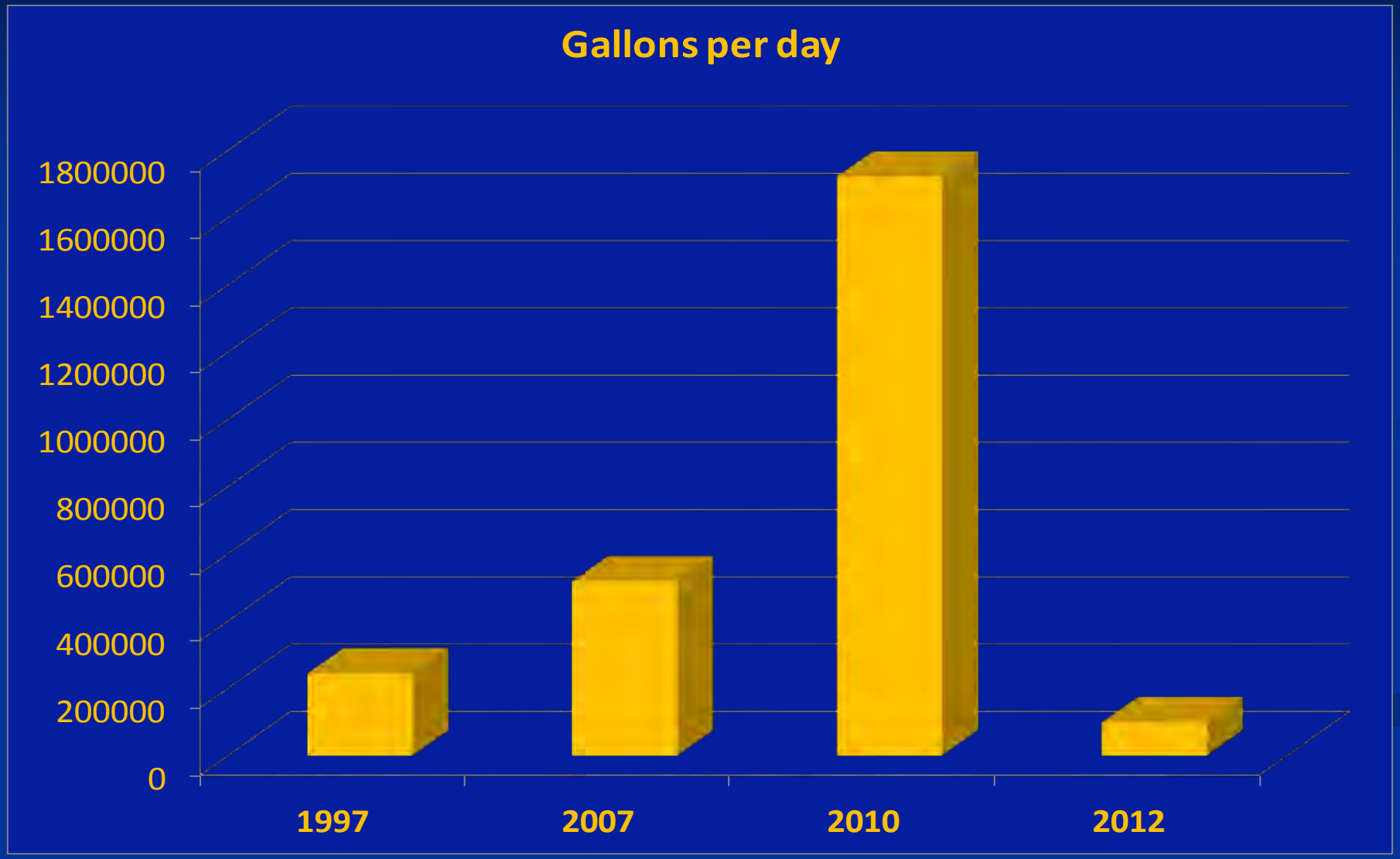


Source: Hart Resource Technologies, Inc

Current Disposal Facilities
(Excluding Disposal Wells)
12



Pennsylvania Disposal Capacity



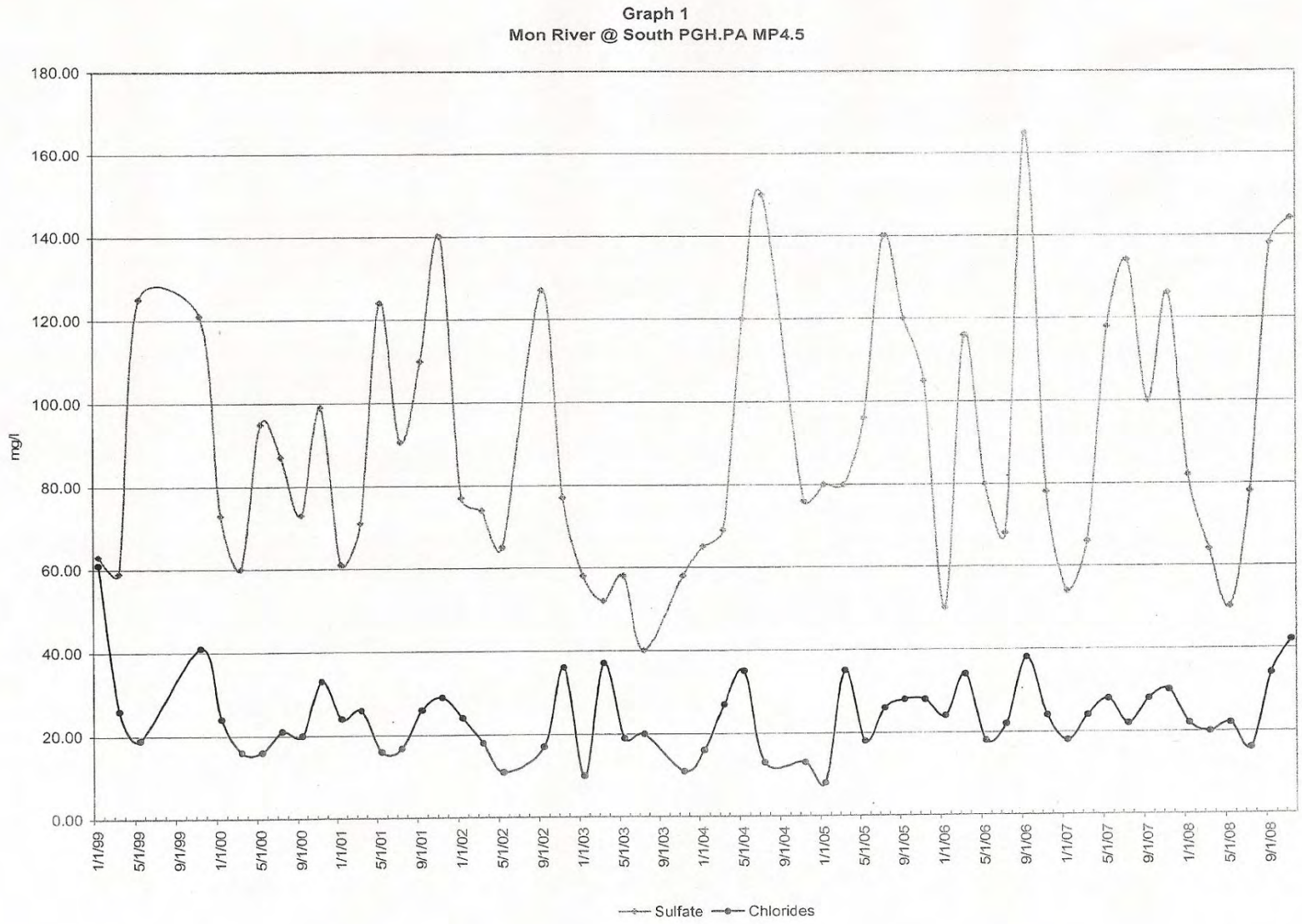
Source: Hart Resource and Technologies, Inc.

Impacts on Water Disposal

- High TDS in Monongahela River, falsely blamed on Natural Gas industry, led to revision of Chap 95 and 500 TDS requirement for discharges
- POTW Restriction – 500 mg/l influent
- Industry was falsely accused of excessive use of fresh water
- Contamination of Dunkard Creek falsely blamed on Natural Gas industry
- Contamination of Dimick water wells falsely blamed on Natural Gas industry
- Notice to producers to cease taking water to 16 identified facilities, due to bromide levels in river

Oil & Gas review of bromides from industry water

- Zero treatment plants in the Allegheny River Basin are discharging treated Marcellus flowback/produced water
- Treatment/discharge of conventional water has been reduced by over 50%
- Effectively reducing the Bromide loadings from Oil & Gas industry below 2005 levels


Graph 1
Mon River @ South PGH.PA MP4.5
mg/l
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1/1/99
5/1/99
9/1/99
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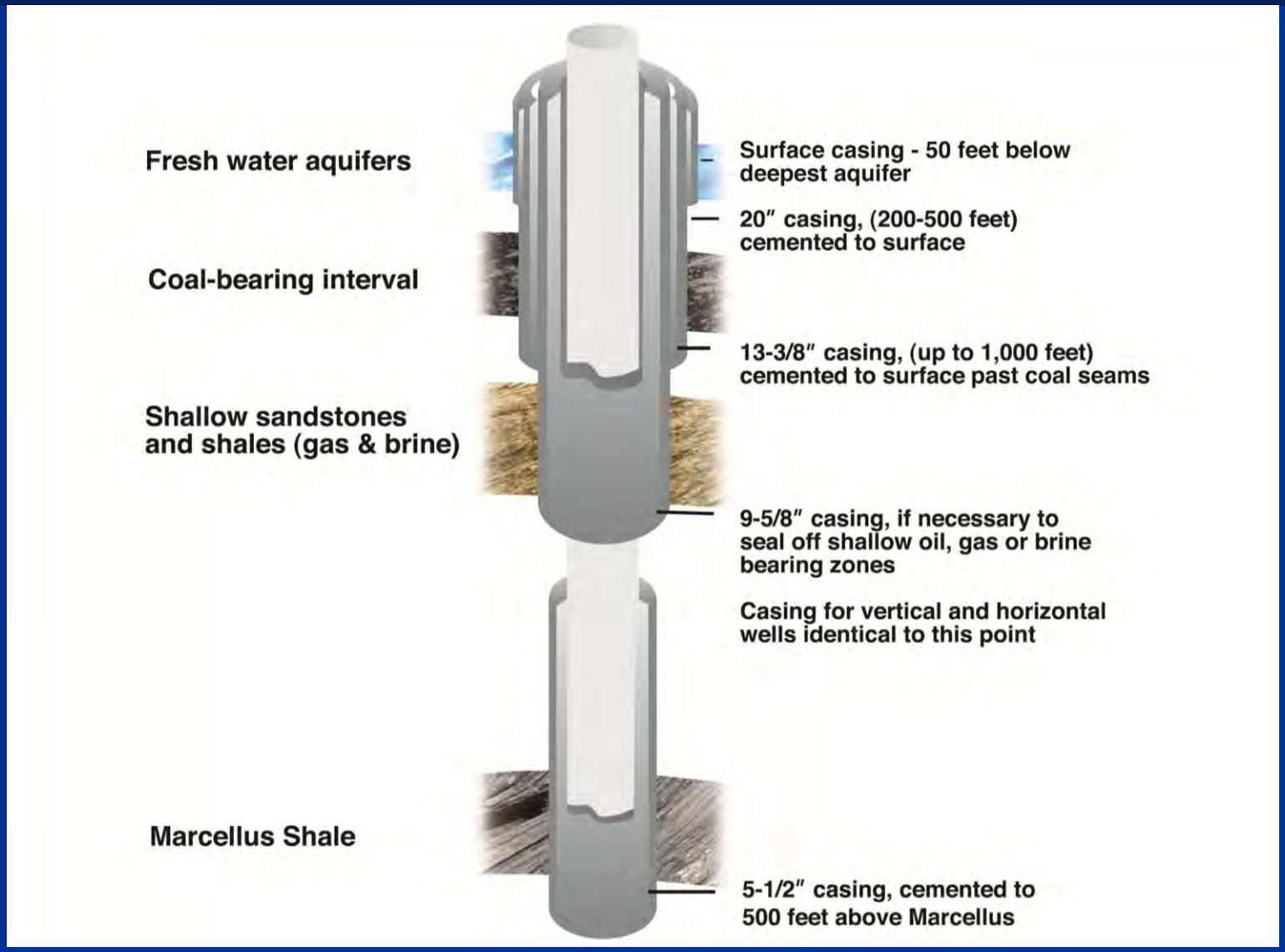
Sulfate
Chlorides

Treatment of NORM: Industrial Treatment Facilities

- Naturally Occurring Radiological Material (NORM) in geological formations such as Marcellus Shale return during flowback process
- Previous inspections showed no threat to environment or public health, continued monitoring in place
- Industrial treatment processes reduce NORM levels in water between 85-95 percent
- Discharges meet state in-stream regulatory criteria
- New and planned facilities coming on line are likely to have stricter requirements. Current discussions focus on radium 226

Casing The Well

Groundwater Protection



Water Supply Complaints

For the fist 6 months of 2009, 148 water supply complaints were filed to DEP related to oil and gas well activities.

- 48% were found not to be related to the oil and gas well activity
- 36% of the complaints are still under investigation
- 16% of the cases were found to have been impacted by activities related to the oil and gas industry

- No impacts were due to hydraulic fracturing

- EPA Study concludes testing of 47 water sources in Dimock, PA. Limited contamination is **not** due to Natural Gas Development

Water Management Options

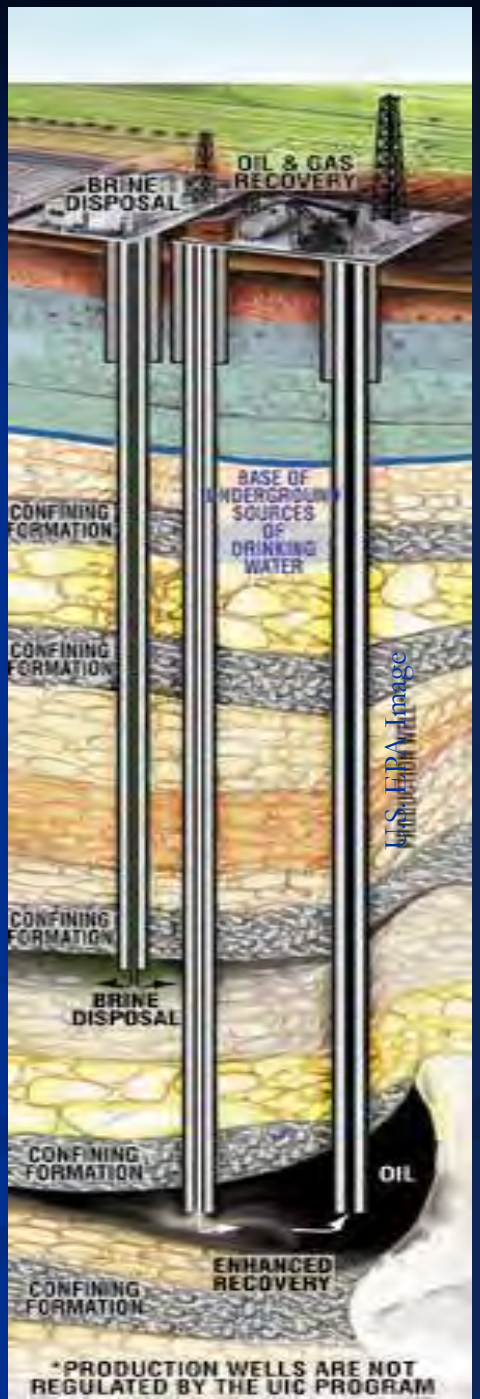
- Recycle/Reuse at the well site
- Recycle at centralized facility
- Evaporate, with or without pretreatment
- Crystallizer
- Injection Well disposal

Dilution and Reuse

- Frac flowback – approx. 1 million gallons per well
  - Immediate re-use of relatively clean initial return fluids
- Remaining fluids <u>may</u> undergo limited treatment to get to a moderate TDS and hardness
- The 1 million gallons of untreated or partially treated fluids are then diluted with 3 million gallons of freshwater for use on the next well
- Advantages
  - Potentially zero discharge
  - Low cost – no need for additional infrastructure
  - Less transportation of waste fluids
- Disadvantages
  - Quality c – changing chemistry
  - Still may need treatment for long-term production fluids

Deep Well Injection

- EPA Underground Injection Control (UIC) program
- Requirements
  - Porous formation to accept fluid (limited in PA)
  - Confining layer free of faults or fractures
  - Plugged or absent orphan gas wells
  - Controlled injection pressure
  - Double containment – casing
- Unlike other states, very few in PA
- Some Marcellus waste fluids go to surrounding state's UIC wells for disposal
- Costly to develop – some expected in PA



U.S. EPA Image

Pennsylvania water to Ohio disposal

- Marcellus Shale foot print

Waste-disposal wells in Ohio

Geologists are studying earthquakes reported in recent years in Arkansas, Texas and West Virginia to determine if they were triggered by the drilling of waste-disposal wells. The map shows the locations of 10 industrial waste-disposal wells and 170 oil and gas waste-disposal wells. Several locations include more than one well.

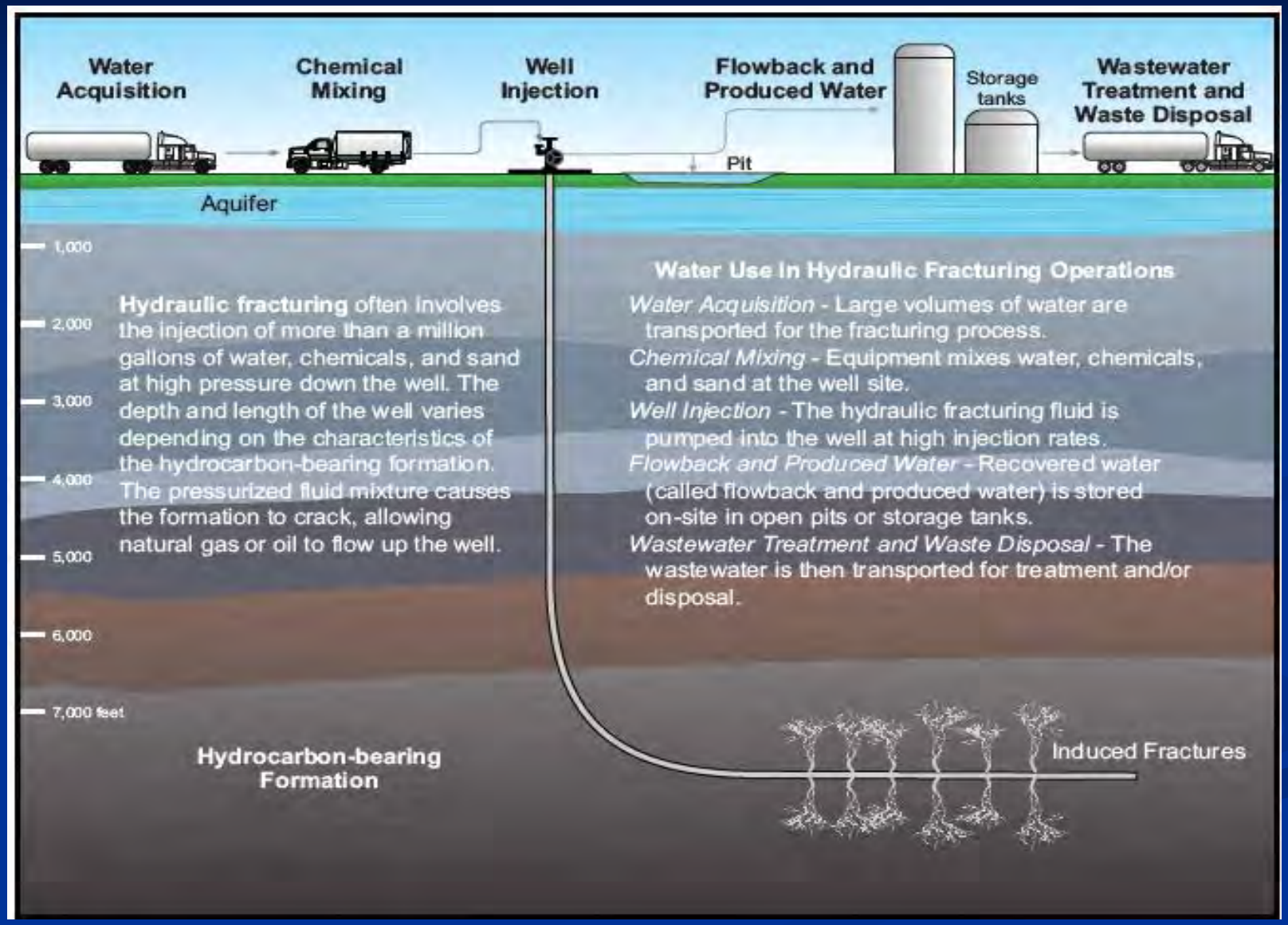
Source: Ohio Geological Survey

THE COLUMBUS DISPATCH

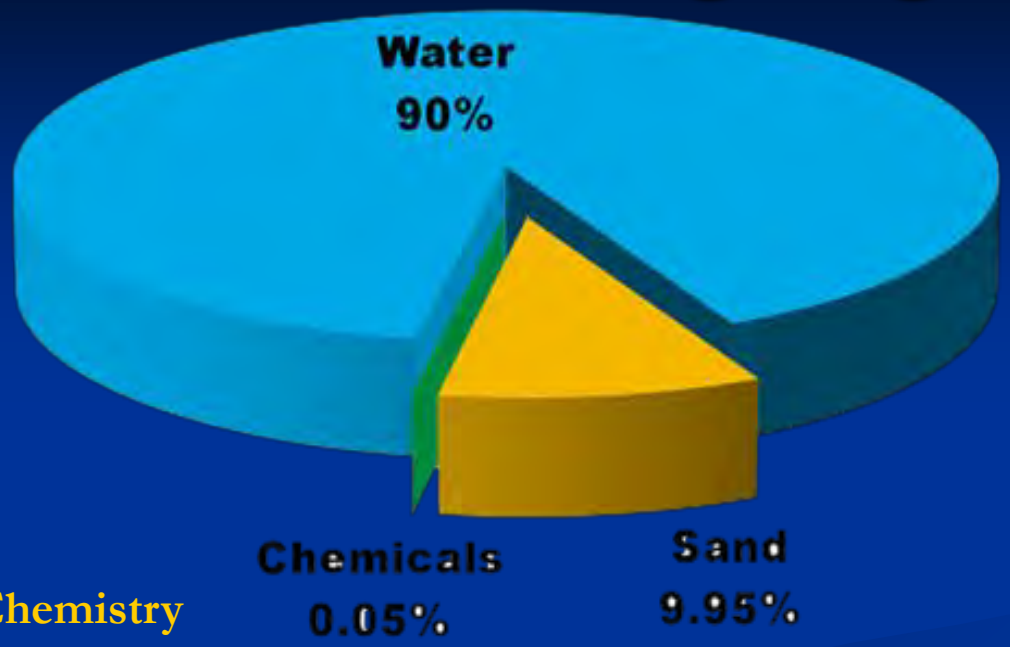
Ohio – 172 disposal wells

PA – 7 disposal wells

Hydraulic Fracturing



Hydraulic Fracturing Ingredients



Frac Water Chemistry (disclosed by FracFocus)

Friction reducer: organic polymer or potassium chloride

Wetting agent: non-ionic surfactant (soap)
Biocide –toxic compound to control micro-organism growth

Scale inhibitor: organic polymer or phosphonate

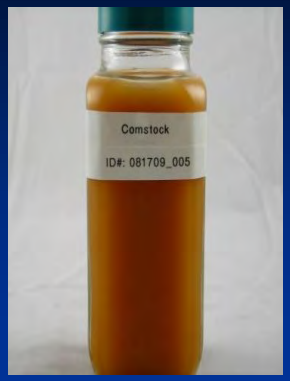
Reducing Contaminates of Concern

Parameter	untreated	treated
barium mg/l	4,300	< 0.1
calcium mg/l	31,300	2.15
iron mg/l	134.1	1.60
magnesium mg/l	1,630	1.10
manganese mg/l	7.0	0.14
strontium mg/l	2,000	1.60
total hardness mg/l (as $CaCO_3$)	90,633	14.9
total dissolved solids mg/l	248,428	150,520

Closed-Loop Reuse Of Flowback Water

2. Frac

3. Store Flowback



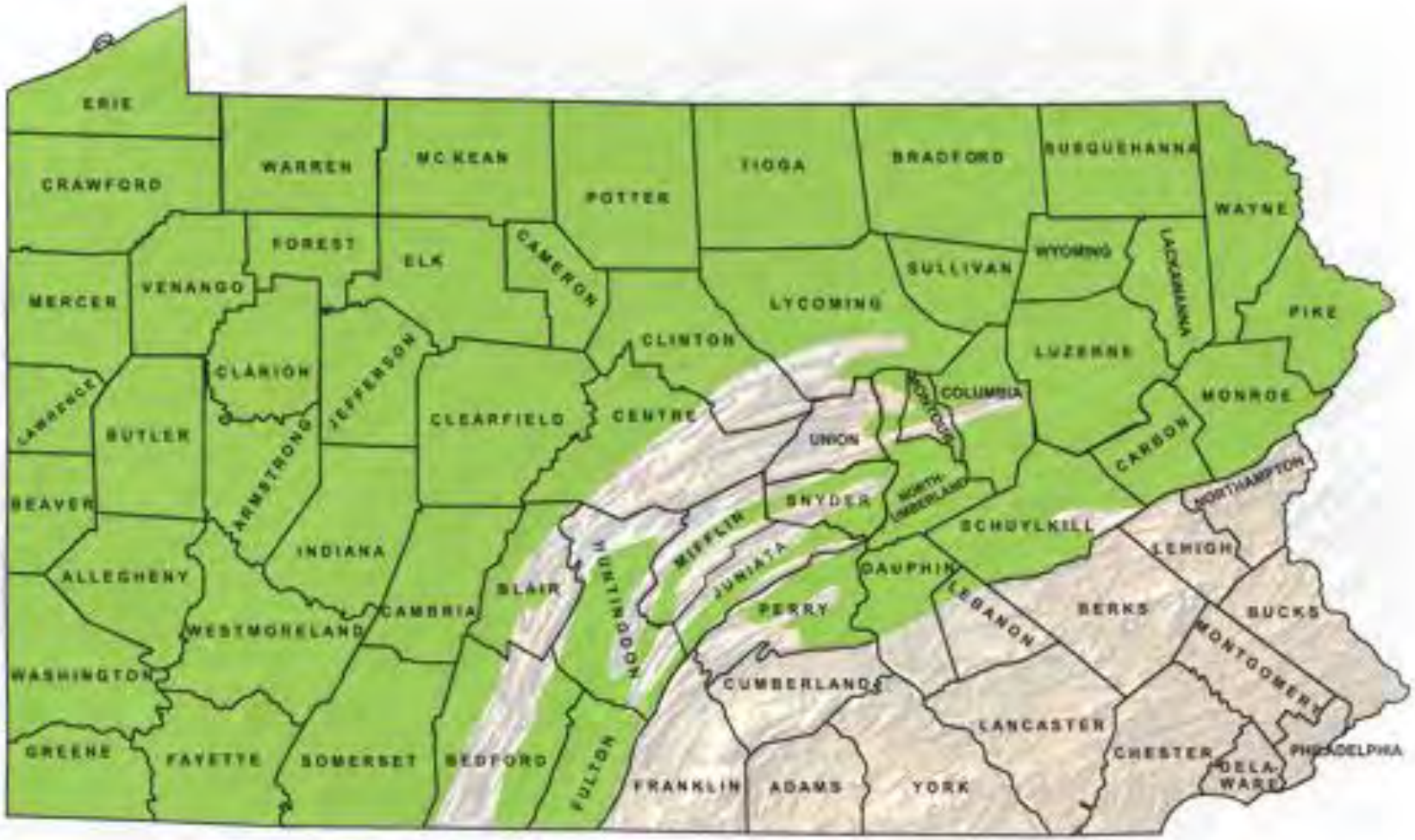
4. Analyze and Treat Flow Back

5.Store Treated Water

6. Determine Chemical Loading for Frac Fluids.

7. Reuse Treated Flow Back Water

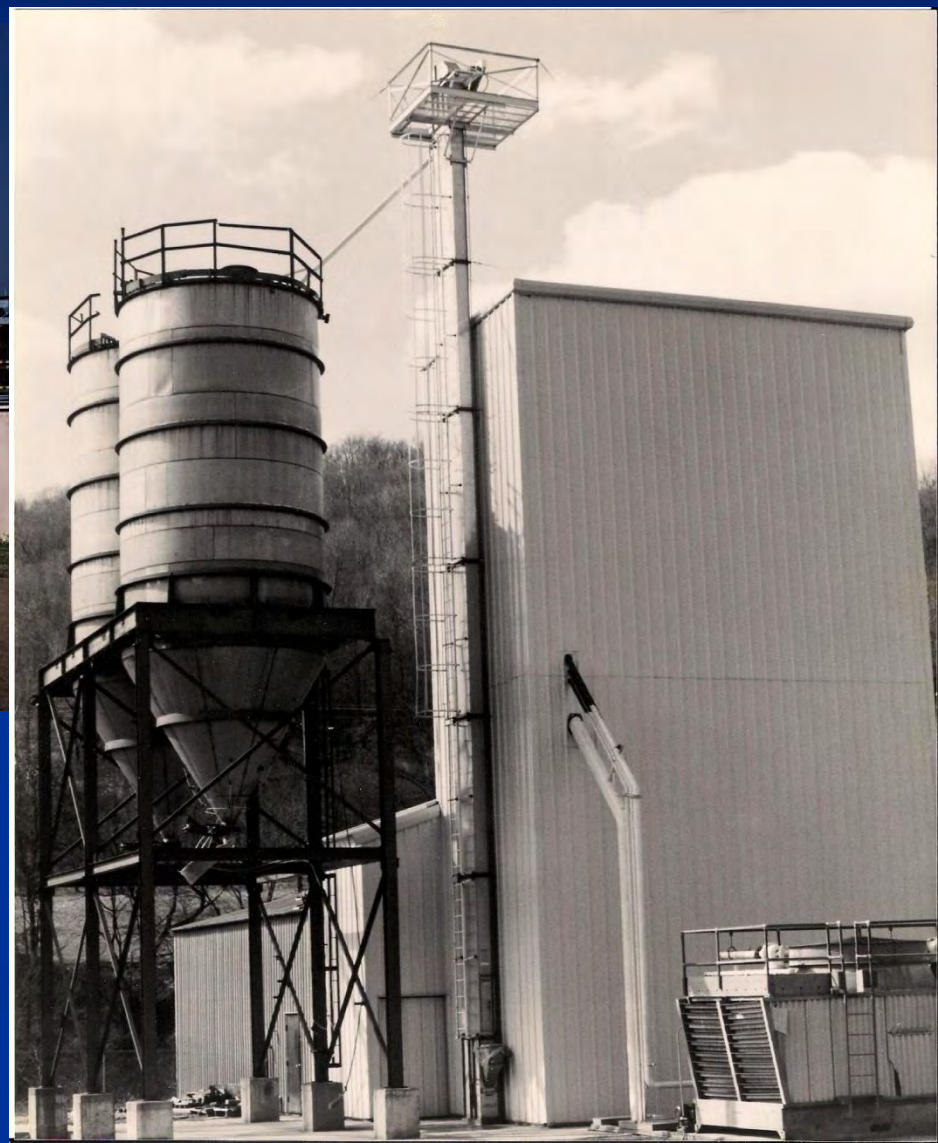
The relation between geography, geology and frac water treatment and disposal in the profile of the well and shale play.



New Treatment Options
Various Advanced Treatment Processes

- Evaporators, crystallization technologies (distillation)
- Membrane technologies (reverse osmosis)
- Advantages
  - Produce effluent that will meet new proposed state regulations on discharges
  - Treated water reusable (zero discharge?)
- Disadvantages
  - Costs greatly increase over traditional treatment ($0.25 or more per gallon)
  - Large solid waste residue – composition and disposal?

Salt manufactured from natural gas well brines.



15 tons per day of 99.4% NaCl crystals.

Crystallization Unit

Changing Treatment and Disposal of Gas Drilling Wastewaters