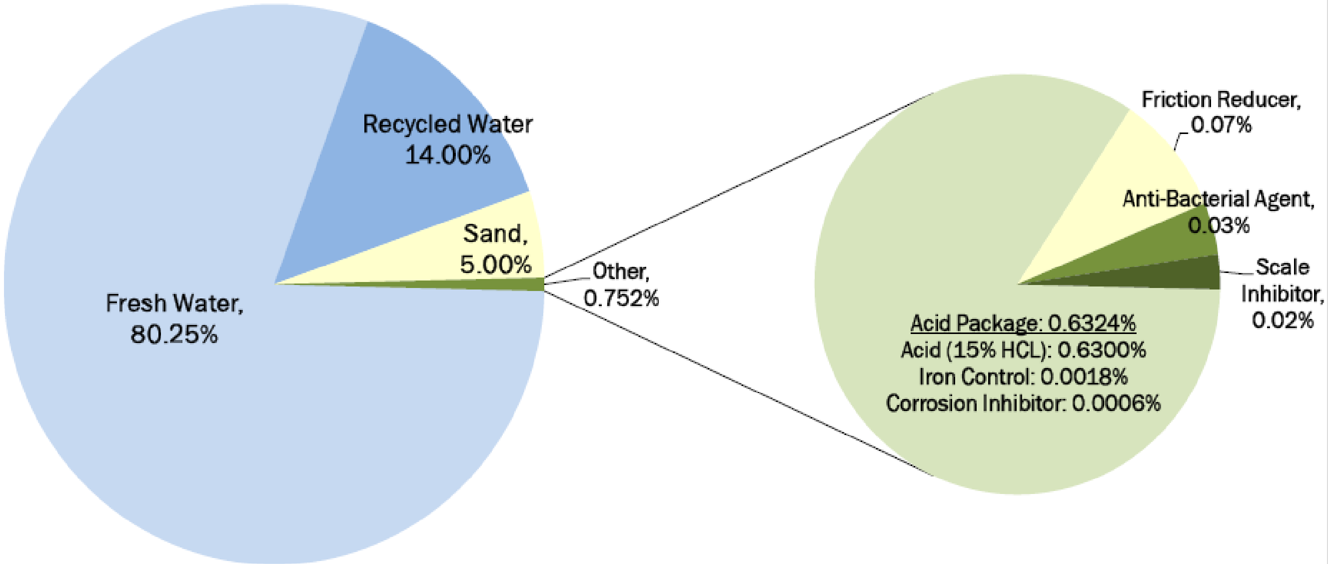
Water Resource Management for Shale Energy Development

Presented by Dave Yoxtheimer, P.G.

PENNSTATE Marcellus Center *for* Outreach and Research

Shale Gas Development Water Use



Source: Chesapeake Energy

- **~400,000 L of water used during drilling**
- **12-20 million L of water used during hydraulic fracturing**
- **Approximately 8-10% of injected fluids return as flowback water**

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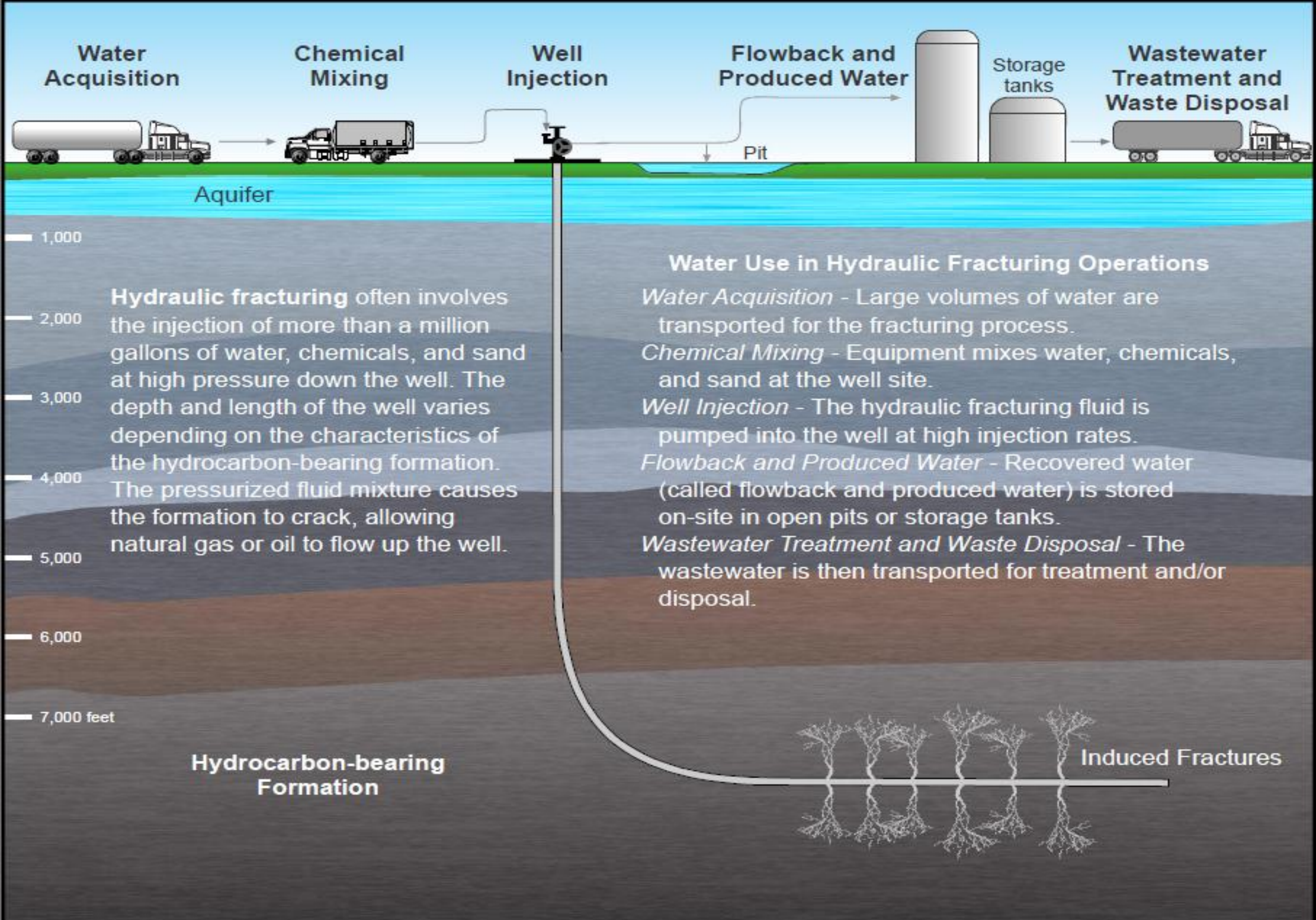


Source: Draft EPA Hydraulic Fracturing Study Workplan

Water Supply Considerations

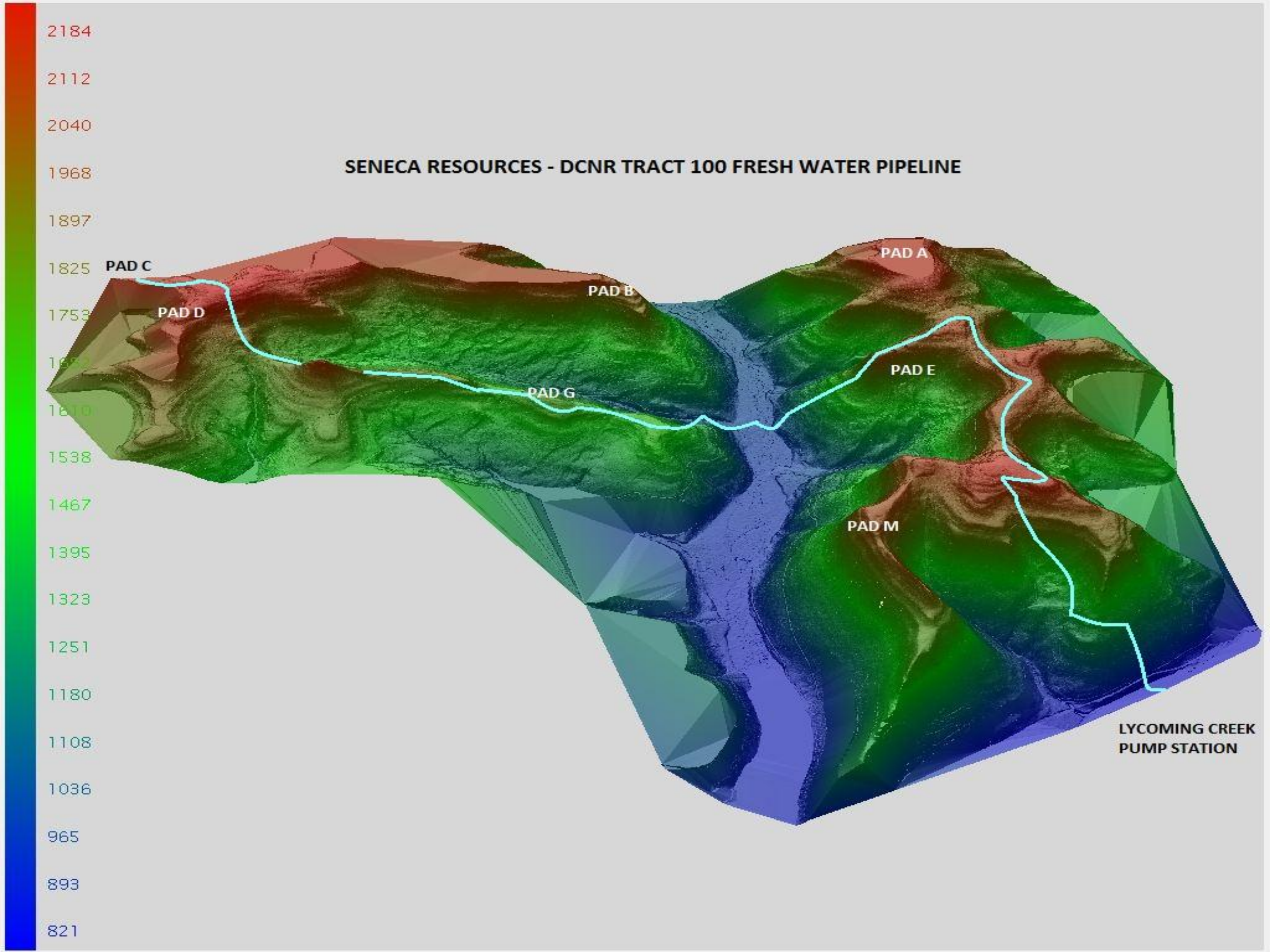
Number of factors to consider:

- Access to water near the drilling project area
- Proximity to well site: piping vs. trucking
- Availability-seasonal or perennial
- Will pass-by flows be required?
- Water quality
- Drilling schedule vs. permitting schedule
- Permitting complexity
- Budget

Pass-by Flow Requirements

- Need to allow sufficient downstream flow
- A reference gauge may be used to determine if there is sufficient flow
- On site gauge may be installed
- Many surface withdrawal points taken off-line during summer

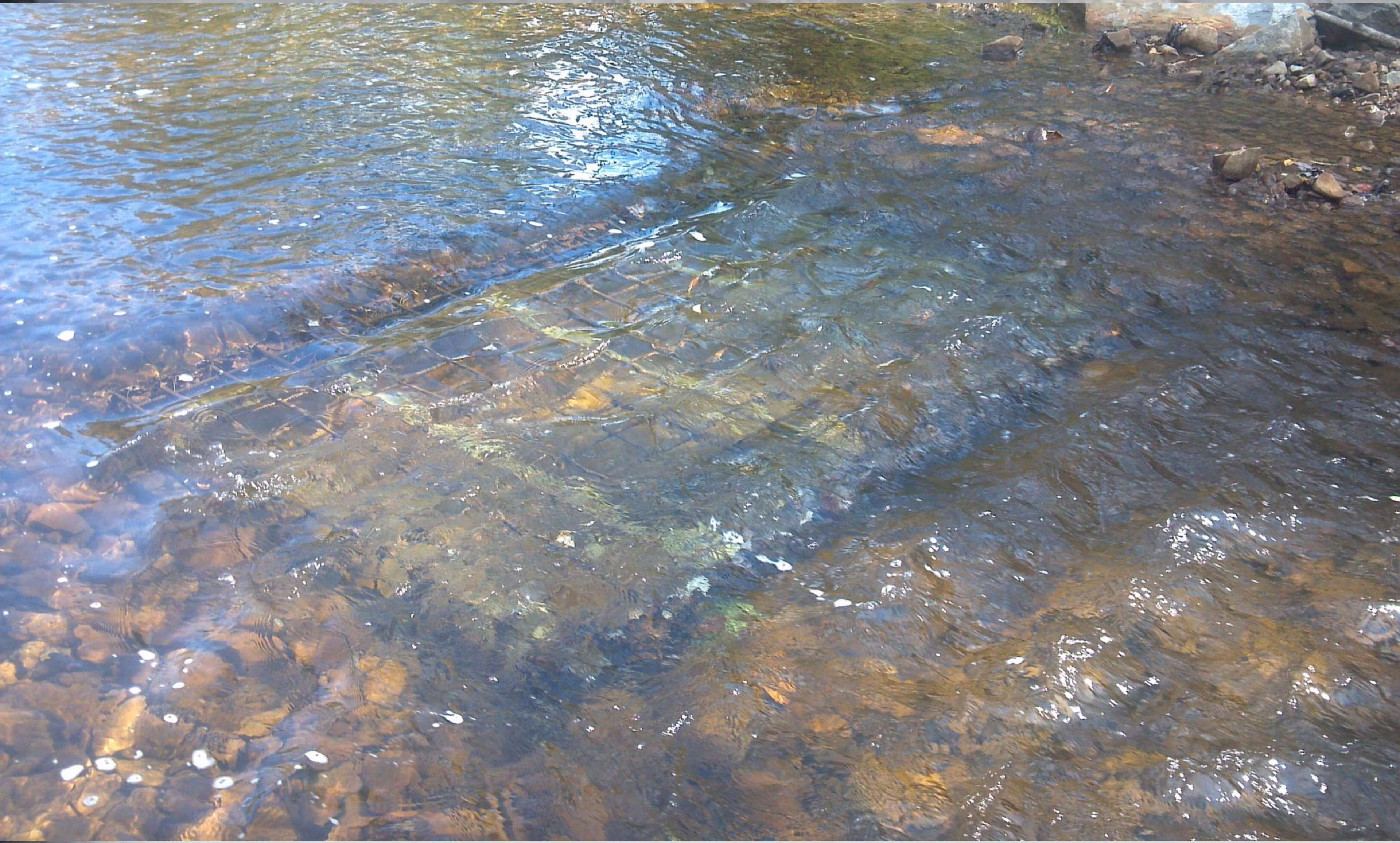
Water Transport



2184
2112
2040
1968
1897
1825
1753
1538
1467
1395
1323
1251
1180
1108
1036
965
893
821
SENECA RESOURCES - DCNR TRACT 100 FRESH WATER PIPELINE
PAD C
PAD D
PAD B
PAD A
PAD E
PAD G
PAD M
LYCOMING CREEK
PUMP STATION

Pumping Station

Intake Structure



Fresh Water Storage

Example impoundment design specifications (PaDEP):

- Store < 50 ac-ft
- <15’ deep w/minimum 2’ freeboard at all times
- Stay out of water course
- 3:1 side slope w/minimum 12’ berm width
- 30-mil poly liner required

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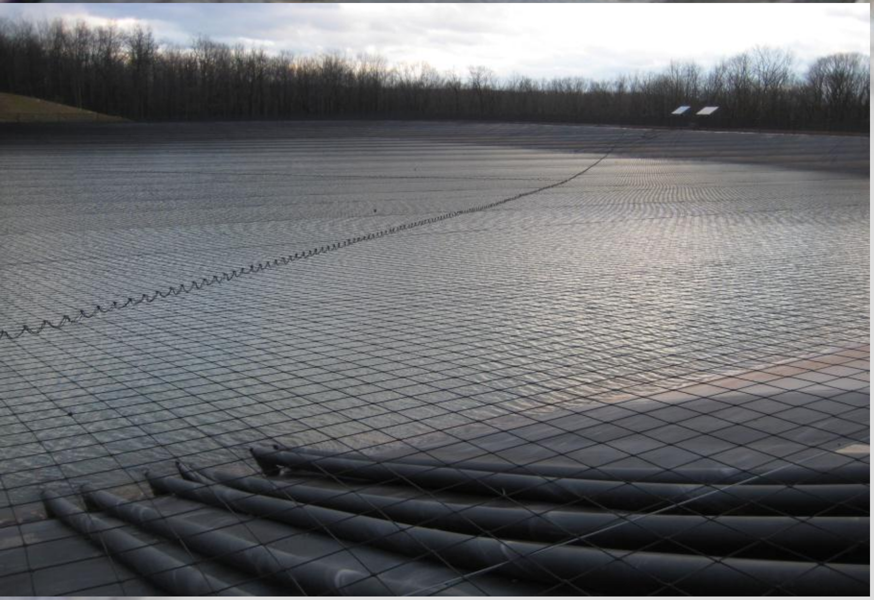
Above Ground Storage

Vertical Storage Tanks

Centralized Impoundment Dam Permit for Flowback Water

- 3:1 side slope w/suitable material
- Minimum 12’ berm width
- Two 40-mil poly liners required
- Leak detection and monitoring system required (wells and sumps)
- Setbacks distances from floodplains, wetland, water supplies, occupied dwellings

Produced Fluids Storage



Flowback may be stored in lined impoundments for reuse

- Groundwater monitoring wells and leak detection
- Bird netting

Steel tanks are often used to store flowback and produced fluids

- Minimizes potential for spill

Closed Loop Drilling System

Flowback Water Management Options

- Direct reuse (blending)
- On-site treatment w/reuse
- Off-site treatment w/reuse
- Off-site treatment and disposal (UIC wells)

~90% flowback and produced water reuse in Pennsylvania as of June 2012

Treatment standards for new or expanding treatment facilities that will discharge

- TDS-500 mg/L
- Chlorides-250 mg/L
- Strontium-10 mg/L
- Barium-10 mg/L

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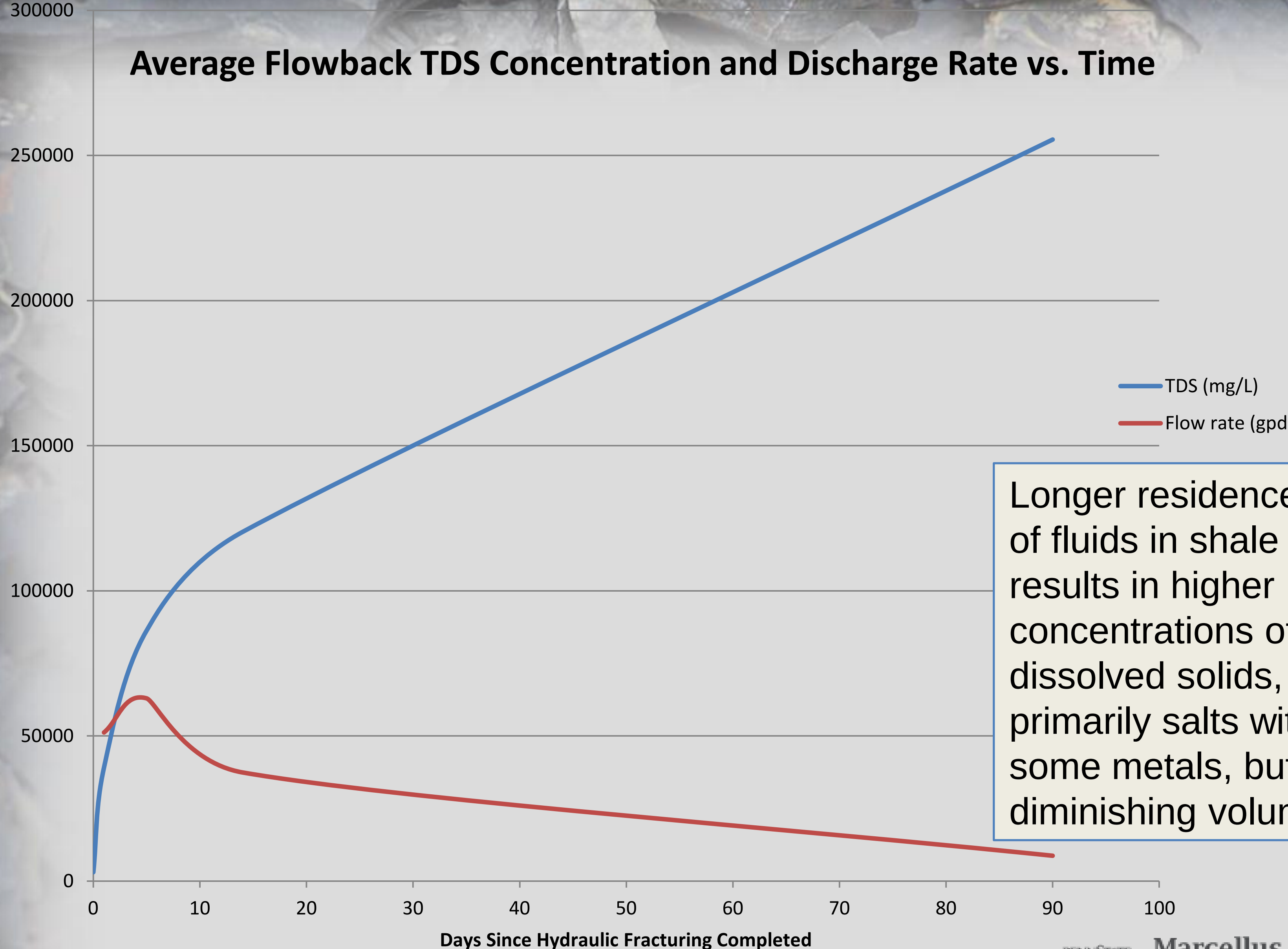
Flowback Water Quality Trends



Longer residence time of fluids in shale results in higher concentrations of total dissolved solids, primarily salts with some metals, but with diminishing volumes.

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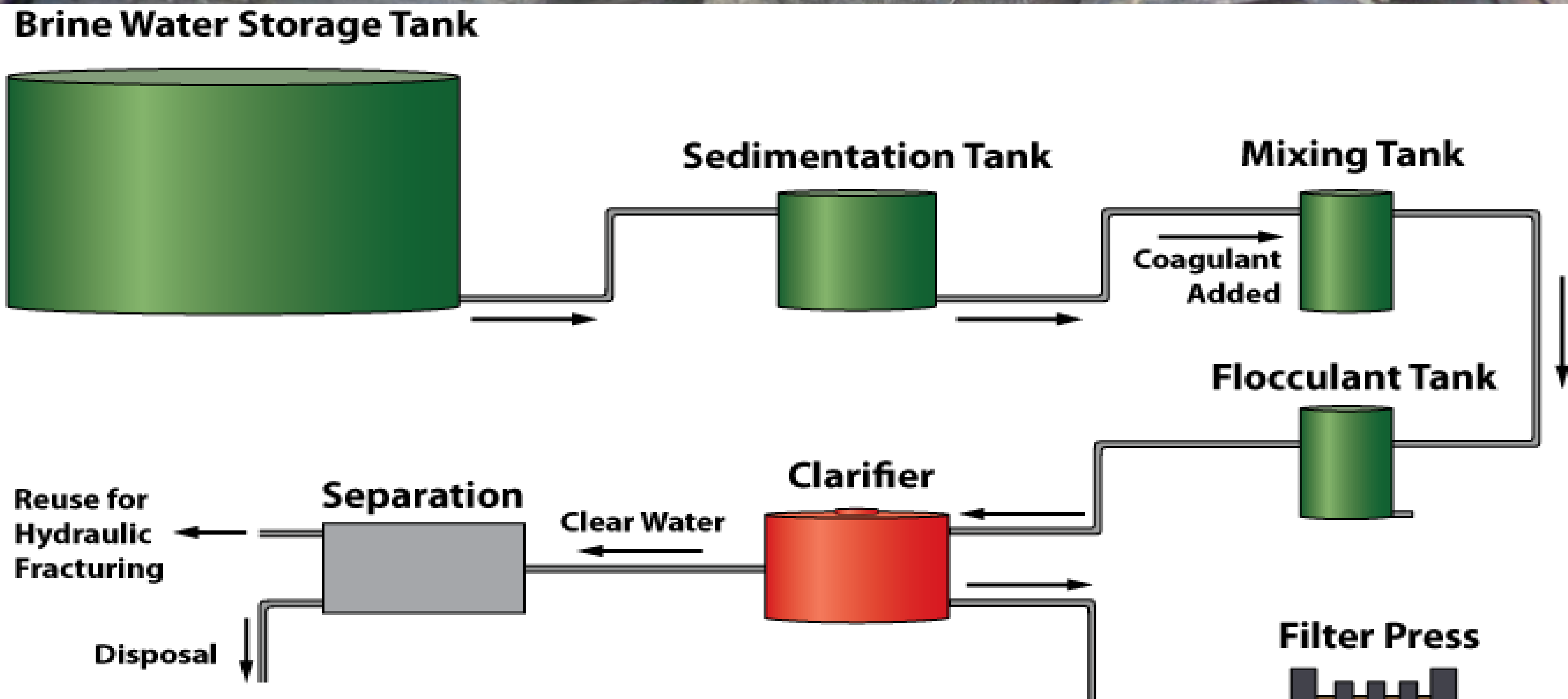
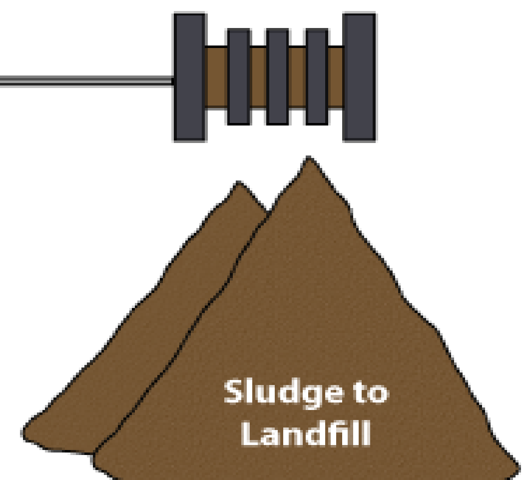
Typical Flowback Water Quality for Parameters of Concern

Parameter	Concentration Range
Total dissolved solids:	10,000 - >300,000 mg/L
Chloride:	5,000 - >150,000 mg/L
Sodium:	2,500 - >75,000
VOCs (primarily BTEX):	ND – 2 mg/L
Radium 226:	100 pCi/L – 16,000 pCi/L

Typical Treatment Scheme for Reuse



-Chemical precipitation can have >99% removal efficiency for potential scaling agents,
-Not generally designed to remove salts,
-Can generate several tons of sludge per 100,000 gallons treated, requiring landfill disposal.



High TDS Treatment Options

Technology	Maximum TDS (mg/L)
Reverse osmosis	45,000
Evaporation	100,000
Membrane distillation	250,000
Crystallizer	300,000

Mobile Treatment Technology

Mobile treatment use increasing due to reduction in:

-Costs

-Trucking transport

-Fresh water use

-Environmental impact

Flowback Treatment Specifications

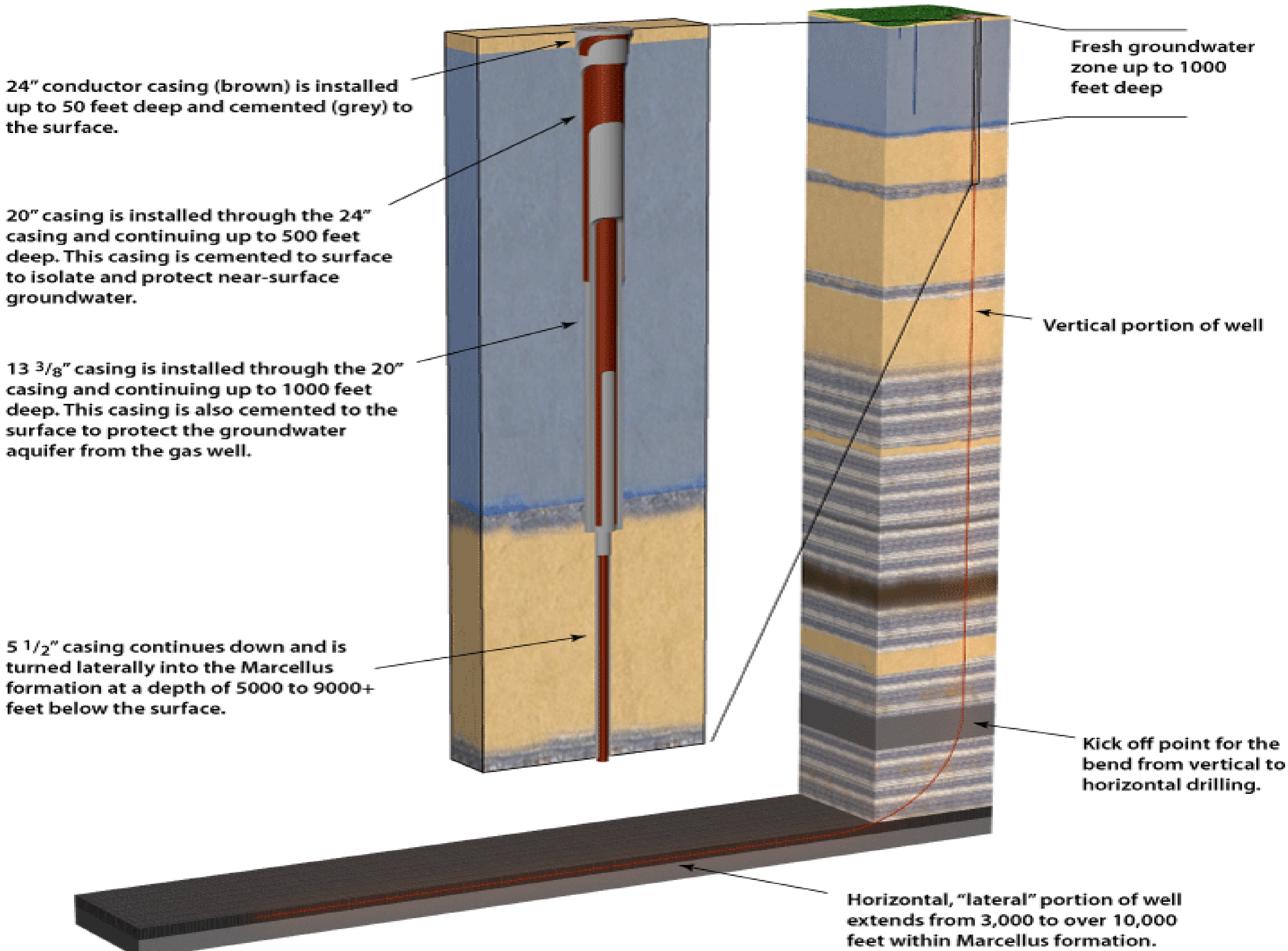
Example flowback treatment levels for recycling purposes per industry standards:

- Total cations 10 - 2,000 ppm range
  - Acceptable levels range from company to company
  - Primary focus on Ba and Sr, but Ca also a concern
  - Ba, Sr , Fe, Mn, Mg < 10 ppm
  - Ca <1,000 ppm
- Processed water sulfates levels <30 ppm
- TSS <30 ppm
- TDS is variable, >50,000 ppm can be acceptable

Potential Water Resource Impact Pathways

- Faulty well construction
  - Allow methane or other hydrocarbons to migrate upwards into an aquifer
  - Possible fracturing fluid migration pathway

- Surface spills
  - Well blowouts
  - Tear in flowback storage impoundment liner
  - Leaking valve in tanks
  - Spill of fracturing fluids
  - Fuel spills



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Methane Migration

- Methane detected in shallow groundwater often occurs naturally prior to any natural gas drilling
  - ~25% to >50% of private wells have detectable methane prior to drilling in Pennsylvania and New York,
  - Up to 80% of private wells in some areas of northeastern Pennsylvania have pre-existing methane
- Increased levels of methane have been detected in water wells after gas well drilling primarily in NE PA
  - Inadequate gas well construction (ie bad cement seal) allowed methane to migrate upward into aquifers
  - Approximately 12-15 cases of methane migration attributable to Marcellus drilling operations
- Need to distinguish between pre-existing methane and its source (thermogenic vs. biogenic)

Recommended* Analytes for Water Supply Testing

Analyte (Inorganic)
Alkalinity
Chloride
Conductivity
Hardness
Oil and Grease
pH*
Sulfate
Total Dissolved Solids*
Residue - Filterable
Total Suspended Solids
Residue – Non Filterable

Analyte (Trace Metal)
Barium
Calcium
Iron*
Magnesium
Manganese*
Potassium
Sodium*
Strontium

Analyte (Organic)
Ethane*
Methane*

Analyte (Microbiology)
Total Coliform/E.coli

Considerations for pre-drilling testing:

-Have an independent third party collect and analyze samples

-Need to have proper chain-of-custody for samples

-Need to use state-certified lab for analysis

-If change in water quality within 12 months and 2,500 feet of shale well then operator assumed liable and must remedy

*From PaDEP recommendations

Conclusions

- Pre-drilling water quality is essential to establish back ground conditions,
- Understanding the geology is a key element proper gas well design,
- Gas well construction with sufficiently deep casing and high-integrity cement seals are critical to minimize methane or fluid migration,
- Fluids management at surface requires use of best management practices such as lined pads and secondary containment,
- Hydraulic fracturing itself does not pose a significant threat to groundwater in deep shale formations.

The End

Questions??

Thank you!!

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