# Lifecycle Water Management Considerations & Challenges for Marcellus Shale Gas Development

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# Shale Gas History

- First Commercial Gas well – Fredonia, NY (1821)
  - Production from "Dunkirk Shale" at a depth of less than 30 feet
- Ohio Shale – Big Sandy Field (1880)
- Hydraulic fracturing used in the oil & gas industry (1950-60s)
- Barnett Shale – Ft. Worth Basin development (1982)
- Horizontal wells in Ohio Shales (1980s)
- Successful horizontal drilling in Barnett Shale (2003)
- Horizontal drilling technology applied in Appalachian Basin, Devonian and Marcellus Shales (2006)

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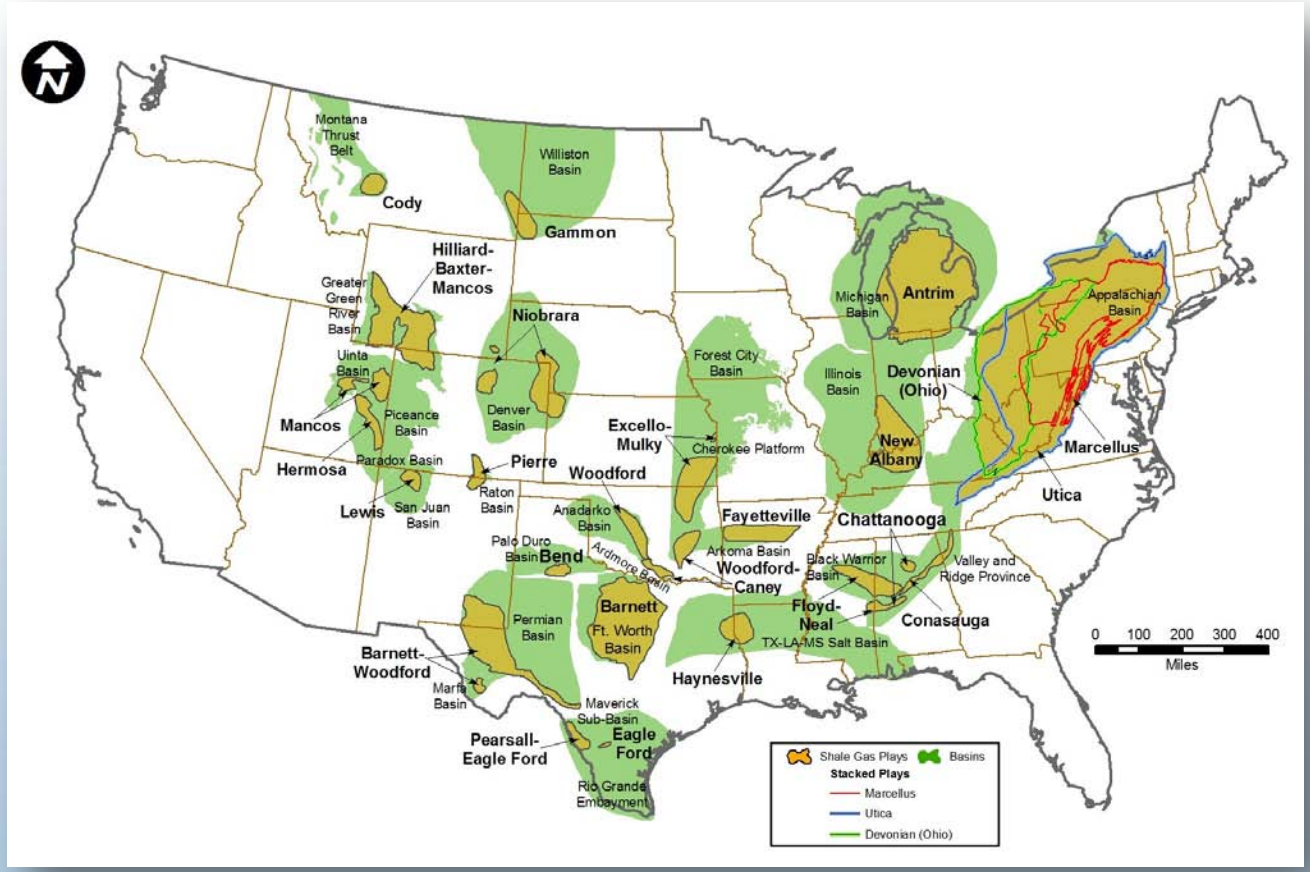
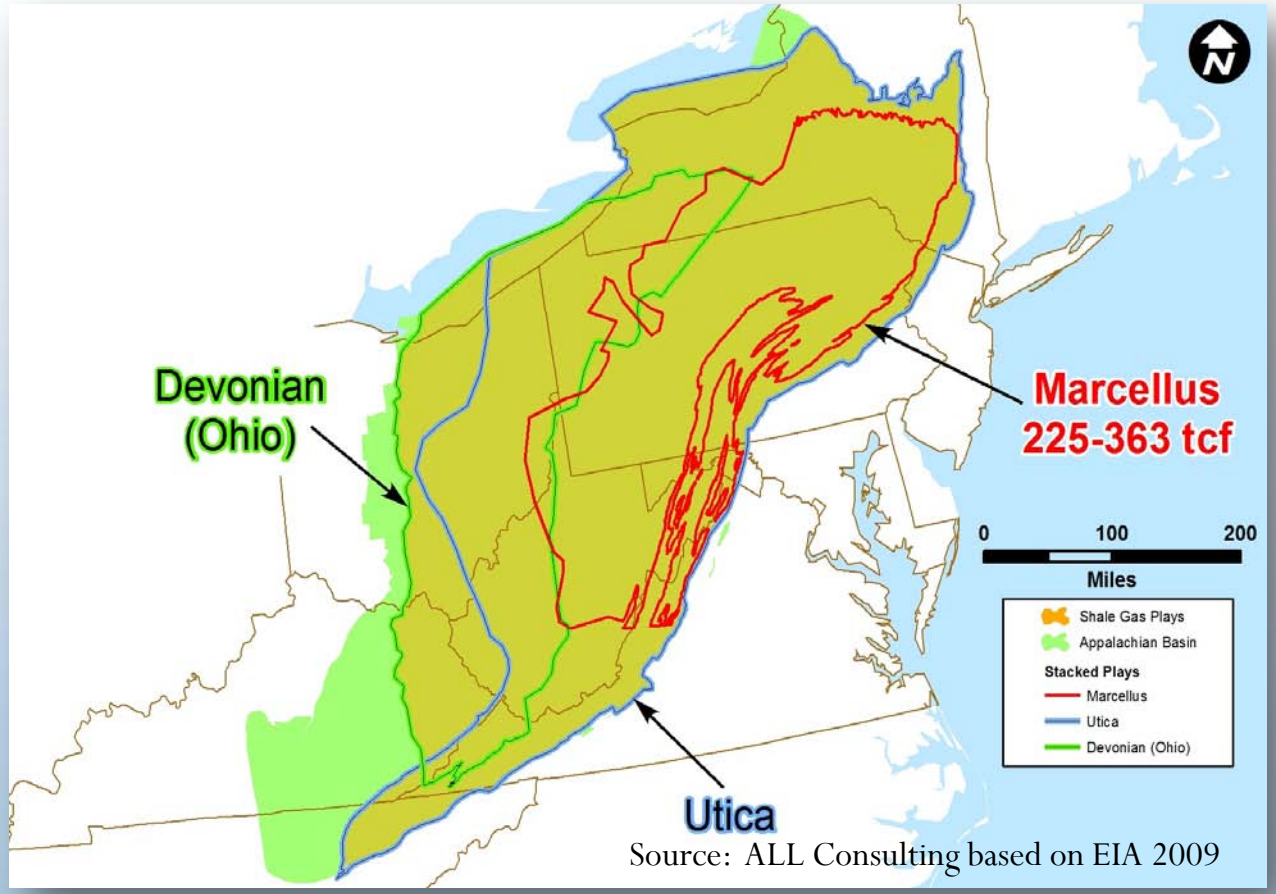
# Shale Gas Basins of the U.S.




Source: ALL Consulting based on EIA 2009

# MARCELLUS/UTICA/DEVONIAN SHALE PLAY




Source: ALL Consulting based on EIA 2009

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# Water Management Lifecycle

- Phases of water management for shale gas development:
  - Withdrawal
  - Transport
  - Storage
  - Use (drilling and fracturing)
  - Treatment and reuse/recycle
  - Treatment and disposal
- Each involves challenges

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# Water Management Challenges

- **Withdrawal**: Access to supply sources, timing, permitting
- **Transport**: Cost, impact on roads and traffic
- **Storage**: Cost, surface disturbance, permitting
- **Drilling and Fracturing**: Surface handling, fluid left underground
- **Treatment**: Cost, volume of resulting concentrate
- **Reuse/Recycle**: Reuse for HF, other markets for recycled water, demand characteristics (quantity, quality, timing)
- **Disposal**: Availability/permitting of injection zones, capacity at commercial/municipal plants, discharge permits

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# Water Withdrawal

- Primary water needs are for drilling fluids and hydraulic fracturing.
- Other water needs can include dust suppression and cleaning/flushing of the rig and equipment.
- Sources of water and water volumes are needed at sufficient volume and timing.

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# Water Withdrawal: Challenges

- Even in the relatively wet Marcellus Shale region, water supply is a concern.
- The public may perceive shale gas water use as a threat to local supplies and competing uses.
- Governments and regulatory bodies are worried about cumulative impacts resulting from withdrawal. Ultimate disposal is also a concern.
- Timing and location of withdrawals may be sensitive, especially in draught years.
- Multiple watershed-related jurisdictions complicate the issues.

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# Shale Gas Water Use - 4 Major Shale Plays

- **Barnett Shale**
  10,000 BBLS used for Drilling
  70,000 BBLS used for Fracturing
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  80,000 Total BBLS Used
  **Assumed** Wells per Year: 600
  Projected Total Water Use per Year:
  **48 Million BBLS**

- **Haynesville Shale**
  25,000 BBLS used for Drilling
  65,000 BBLS used for Fracturing
  ---
  90,000 Total BBLS Used
  **Assumed** Wells per Year: 200
  Projected Total Water Use per Year:
  **18 Million BBLS**

- **Fayetteville Shale**
  1,500 BBLS used for Drilling
  70,000 BBLS used for Fracturing
  ---
  71,500 Total BBLS Used
  **Assumed** Wells per Year: 250
  Projected Water Use per Year:
  **18 Million BBLS**

- **Marcellus Shale**
  2,000 BBLS used for Drilling
  90,000 BBLS used for Fracturing
  ---
  92,000 Total BBLS Used
  **Assumed** Wells per Year: 600
  Projected Total Water Use per Year:
  **55 Million BBLS**

Basin-wide activity based on one operator's peak year projections.

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# Total Water Use – 4 Major Shale Plays

| Shale Play | Public Supply | Industrial and Mining | Power Generation | Irrigation | Livestock | Shale Gas Wells | Total Water Use (Billion Bbl/yr) |
|---|---|---|---|---|---|---|---|
| Barnett | 82.70% | 4.50% | 3.70% | 6.30% | 2.30% | 0.40% | 11.15 |
| Fayetteville | 2.30% | 1.10% | 33.30% | 62.90% | 0.30% | 0.10% | 31.9 |
| Haynesville | 45.90% | 27.20% | 13.50% | 8.50% | 4.00% | 0.80% | 2.15 |
| Marcellus | 11.97% | 16.13% | 71.70% | 0.12% | 0.01% | 0.06% | 85 |

Shale Gas water use based on one operator's peak year projections for basin-wide activity.

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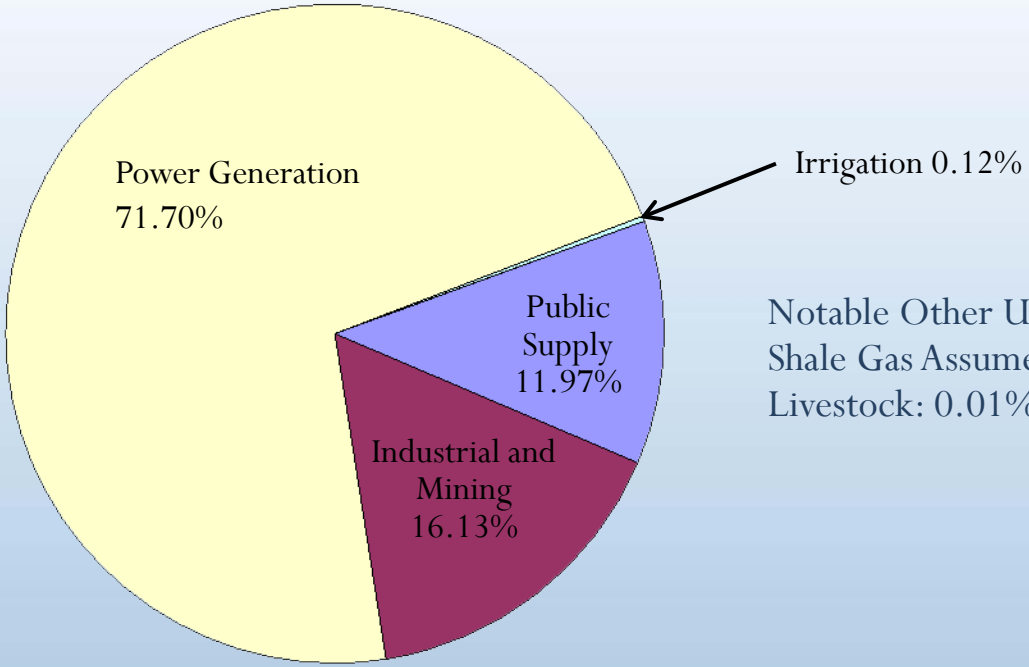
# Water use in Marcellus Shale Area

**Total Water Use (Surface Water and Ground Water) in Central PA (32 County Area), Southern NY (10 County Area), Northern WV (29 County Area), Western VA and MD (5 County Area), and Eastern OH (3 County Area) by Sector**

Total Water Use in Marcellus Area: 85 Billion Barrels per Year




Notable Other Uses:
Shale Gas Assumed Use: 0.06%
Livestock: 0.01%

Source: 1) USGS Estimated Use of Water in US, County Level Data for 2000; 2) Shale Gas water use based on one operator's peak year projections for basin-wide activity.

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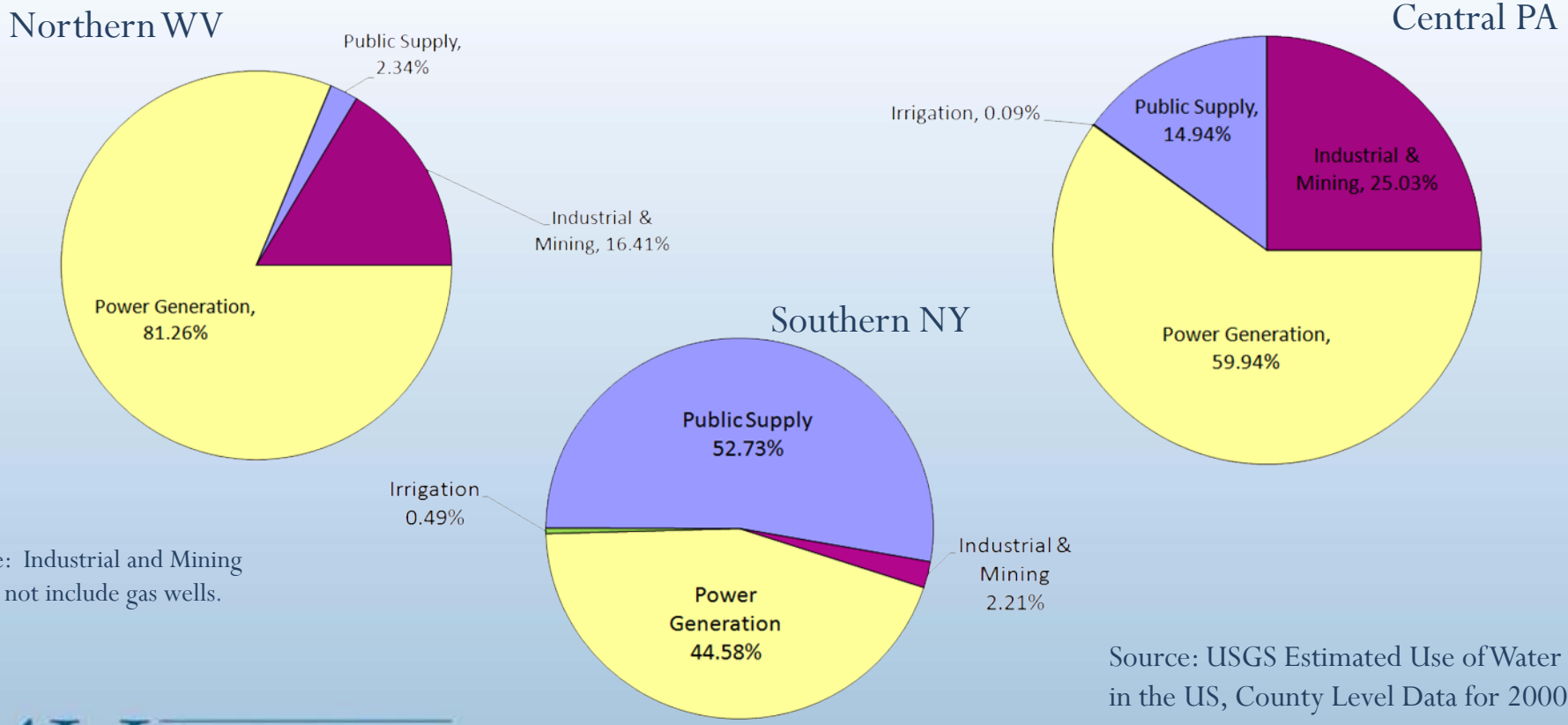
# Total Water Use by Sector

(surface and groundwater)




Note: Industrial and Mining does not include gas wells.

Source: USGS Estimated Use of Water in the US, County Level Data for 2000

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# Water Withdrawal - Sources

- **Surface water** is a primary source of water for drilling and hydraulic fracturing fluids. In the Marcellus Shale play area, the Delaware, Susquehanna, and Ohio River Basins are principal sources. Private stock ponds are also a possible source.
- **Groundwater** is a potential source if surface water is not available. Groundwater availability is limited in the Marcellus where it typically consists of shallow alluvial aquifers less than 200 feet below ground.
- **Municipal water** suppliers can also be a source where available.
- **Waste water** from municipal and industrial treatment facilities can be used depending on quality of the effluent and availability.
- **Produced water** can be treated and reused depending on the quality of the water; primarily the TDS, chloride, and sulfide concentrations. Typically, the water must be treated to about 20,000 ppm TDS, but service companies are evaluating the use of higher concentration water.

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# Water Transport

- Trucking costs can be the biggest part of the water management expense.
- Impacts on roads and traffic can negatively affect local communities.
- Producers are increasingly turning to temporary surface pipelines to transport fresh water to impoundments and to pads.
- Some producers are using rail tank cars to transport produced water to UIC wells in Ohio.

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# Water Storage

- Needed for both fresh water and flowback water.
- The decision on central vs. distributed impoundments for fresh water must consider:
  - Cost, transport, surface disturbance/availability.
- Industry is considering centralized impoundments to manage flowback water.
  - Frac tanks are expensive.
  - Transportation is expensive.

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# Drilling and Fracturing

- Hydraulic fracturing uses more water than drilling.
- Fracturing fluid is >98% water and sand.
- Experience in the Marcellus:
  - Only about 10% to 30% of the fracture fluid is recovered.
  - TDS is generally in the 40,000 to >100,000 ppm range.
- Vertical distance between the shallow fresh water zone and the deep natural gas zone is 3000' to 7000'.
  - Analysis shows extremely low probability of fracture fluid migration from the shale up to fresh water zones.

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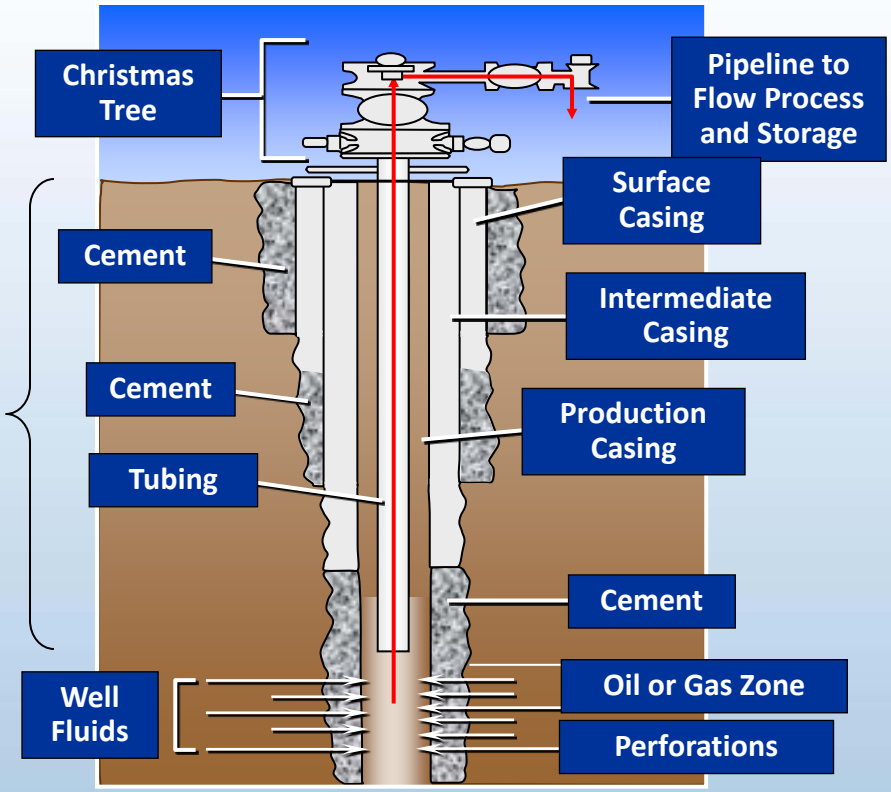
# Groundwater Contamination Risk




Vertical Producing Well

- A 1988 API study rated Appalachian Basin as low risk for corrosion.
- In a 1989 API & DOE Study of basins with "reasonable" likelihood of corrosion, the probability (risk) of injectate reaching a USDW ranged from one in 200,000 to one in 200 million for disposal wells injecting on a continuous basis.
- Hydraulic fracturing events in the Marcellus occur inside of nested casing strings over a short duration, and with considerable vertical separation (thousands of feet of confining strata) between the shale and shallow USDWs.

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# Produced Water Treatment Options

- At present, economically viable options for the treatment of produced water consist primarily of Distillation/Evaporation or Reverse Osmosis systems.
- Both processes have limitations as to the quality and quantity of water that can be treated.
- Both produce a high concentration solute that requires disposal.
- Typically, as the TDS of the produced water increases, the quantity of useable treated water decreases. If the TDS of the produced water is >150,000 ppm, then often only about 50% of the water treated would be useable and the remaining 50% would require disposal.

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# Produced Water Disposal Options

- Currently in the Marcellus Shale Play area, the primary means for management of flowback and produced water is treatment and disposal at commercial wastewater treatment facilities.
- Since Shale Gas development is occurring in areas that have not had oil and gas development in the past, there are few existing Class II UIC wells available.
  - The Marcellus Shale development area is geologically challenged with regard to available injection zones.
  - Currently there are only 6 disposal wells in NY and 8 in PA.
  - Permitting a Class II well in NY may take a year or more.
- Marcellus shale operators are exploring reuse/recycling of flowback and produced water as alternatives to injection.

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# Reuse/Recycling

- In the Marcellus, there is a movement by producers toward recycling of flowback/produced water.
  - Addresses uncertainties specific to UIC wells and commercial/municipal treatment plants.
  - Reduces transport costs.
  - Driven by current and future regulatory limits.
- Research is needed on reuse of flowback water.
- Research is needed on potential water markets.

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# Sustainable Development

- Sustainable shale gas development will require a toolbox approach to both water supply and wastewater management issues.
- Producers will have to track and manage lifecycle water issues (volumes, costs, and impacts): source, transport, storage, use, treatment, and disposal, along with permitting and compliance.
- Overall, the quantity of water needed for shale gas development is small and temporary compared to long term uses such as electrical power generation.
- Management of the shale gas water lifecycle may dictate the pace of development in some areas.

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