



CLASS I HAZARDOUS WASTE DEEP WELL INJECTION: A SAFE AND PROVEN DISPOSAL TECHNOLOGY FOR MANAGING PFAS AND AFFF

Executive Summary

Federal, state, and local environmental agencies face significant challenges as they confront the emerging need to manage waste containing PFAS, such as AFFF from takeback programs. Although new destruction technologies are being developed and merit continued investment, none have demonstrated large-scale operational capacity. EPA identified three disposal options in their 2024 interim destruction and disposal guidance for PFAS: landfilling, incineration, and deep well injection.¹ Landfilling and incineration both present potential concerns with secondary contamination due to leachate management and air emissions. Class 1 Hazardous Waste Deep Well Injection is an EPA-recommended disposal method that is proven as a permanent solution for handling waste containing PFAS and AFFF.

This guide provides federal, state, and local environmental officials with essential information about deep well injection technology, including its regulatory framework, safety record, and practical applications, so that agencies and departments can make informed decisions to address their PFAS and AFFF disposal needs.

Key Takeaways about Class 1 Hazardous Waste Deep Well Injection:

- Heavily regulated, EPA-approved permanent disposal method with more than 50 years of safe operation.
- Strict design and permitting requirements under RCRA and UIC, including having an EPA 10,000-year no-migration petition.
- Offer immediate processing capacity for PFAS, AFFF, and other hazardous liquid waste.
- Require specific geological conditions, making most places unsuitable for siting, but accessible nationwide through rail and road networks.
- Safest of any class of injection well.
- Least risk of air emissions or drinking water impacts.

Understanding Deep Well Injection Technology

What is Class I Hazardous Waste Deep Well Injection?

Class I Hazardous Waste Deep Well Injection is a permanent disposal method that injects liquid hazardous waste deep underground into isolated geological formations, typically 5,000 to 7,000 feet below Earth's surface. This technology is endorsed by the EPA and has been regulated under the EPA's Underground Injection Control (UIC) program for over four decades.² In the 2024 Interim Guidance on PFAS Destruction and Disposal, the EPA determined that the use of Class I Hazardous Waste wells "has a lower potential for environmental release when compared to other PFAS destruction and disposal options, and there is relatively low uncertainty in this determination".

How It Works

The injection process involves several carefully controlled steps:

- 1. Testing:** All waste is tested and formally approved by the facility prior to acceptance.
- 2. Transportation:** Waste is transported via truck or rail to the injection facility under DOT hazardous materials regulations.
- 3. Storage:** Upon arrival, waste is stored in ASTs until injection.
- 4. Pre-treatment and characterization:** Waste is analyzed and, if necessary, treated to meet injection specifications.
- 5. Injection:** Liquid waste is pressure-injected through the injecting tubing into a deep, porous rock formation (the injection zone).
- 6. Confinement:** The waste is permanently confined by impermeable rock layers (confining zones) above and below preventing migration outside the injection zone.

The geological formation acts as a natural containment system. The porous injection zone absorbs the liquid waste, while dense confinement zones above and below while mitigate movement.

¹ 2024 EPA Interim Destruction and Disposal Guidance

² EPA's UIC Program (generic)

Why Geology Matters

Not all locations are suitable for Class I Hazardous Waste wells. The technology requires very specific geological conditions:

- **Porous injection zone:** A deep geologic formation with sufficient porosity and permeability to accept liquid waste.
- **Confining layers:** Thick, impermeable rock layers (typically shale) above and below the injection zone.
- **Geologically stable area:** No fractured bedrock or unaccounted artificial penetrations, minimal seismic activity, and stable geology over geological timescales.
- **Depth:** Injection zones must be far below any underground sources of drinking water (USDWs).

In the United States, the most suitable formations for hazardous waste deep well injection are found in specific regions, such as in parts of Texas where the Frio sand formation provides ideal geological conditions. The Frio formation features highly porous sand layers confined by thick shale deposits, creating a natural containment system that has remained stable for millions of years.

These strict geological requirements act as a natural safety feature. The technology cannot be deployed anywhere – it can only exist where geology provides permanent containment.

Regulatory Framework and Safety Oversight

Distinguishing Among Well Classes

Not all injection wells are created equal. The UIC program classifies wells into six categories based on the fluids injected and the geology involved:

Class I:	Hazardous No Migration Petition (the focus of this document).
Class I:	Non-hazardous industrial waste injection.
Class II:	Oil and gas production waste.
Class III:	Mining-related solution mining.
Class IV:	Hazardous or radioactive waste into or above underground sources of drinking water (banned since 1984).
Class V:	All other injection wells (typically shallow and low-risk materials).
Class VI:	Carbon dioxide sequestration.

Class I Hazardous Waste wells face the most stringent regulatory requirements of any well class. Historical concerns about groundwater contamination or induced seismicity from other well classes (particularly Class II wastewater disposal wells in some regions) do not apply to properly sited and operated Class I Hazardous Waste wells. According to a study by the EPA Office of Solid Waste and Emergency Response (OSWER), which evaluated the relative risks posed by many waste management practices, Class I hazardous wells are “*safer than virtually any other waste disposal practice*.”¹

Federal Regulation: The Underground Injection Control (UIC) Program

Class I Hazardous Waste wells are regulated under the EPA’s Underground Injection Control (UIC) program², established by the Safe Drinking Water Act (SDWA)³. These wells also fall under the Resource Conservation and Recovery Act (RCRA)⁴ and are required to have a hazardous waste permit.

Key Takeaways about Class 1 Hazardous Waste Deep Wells

Stringent Permitting Process:

- Detailed geological and hydrological characterization.
- Engineering design review and approval.
- Public notice and comment period.
- State and federal review, approval, and oversight.

Continuous Monitoring:

- Real-time injection pressure and flow rate monitoring.
- Regular monitoring and well testing above and below the injection zone.
- Mechanical integrity testing of well construction.
- Annual reporting to regulatory agencies.

No-Migration Petition:

- Operators must demonstrate to EPA’s satisfaction that hazardous constituents will not migrate from the injection zone for 10,000 years.
- Wells must be located below the lowest underground source of drinking water.

Operational Requirements:

- Waste compatibility testing before acceptance.
- Operating pressure limits to prevent fracturing.
- Emergency response plans.
- Financial assurance for closure and post-closure care.

In states with primacy over the UIC program (like Texas), state environmental agencies provide. For example, the **Texas Commission on Environmental Quality (TCEQ)**⁵ conducts regular inspections, reviews operational data, and enforces strict compliance requirements.

¹ EPA Study on Class I Injection Wells

² EPA’s UIC Program (Class I Wells)

³ Safe Drinking Water Act (SDWA)

⁴ Resource Conservation and Recovery Act (RCRA)

⁵ TCEQ Class I Injection Well Regulations

Environmental Benefits

Deep well injection offers several environmental advantages over alternative disposal methods:

Permanent Containment – No Soil or Groundwater Risk: The waste is confined in stable geological formations that have remained isolated for millions of years and are demonstrated to remain so for at least 10,000 years into the future. Unlike landfills, which can risk liner failure and generate contaminated leachate that has the potential to affect soil, groundwater, and surface waters, deep well injection permanently isolates waste thousands of feet below any drinking water sources.

Little Air Emissions: Unlike incineration, deep well injection produces very minor vapors which are captured, little greenhouse gases, and no combustion byproducts. This is particularly significant for PFAS, as incomplete combustion generates toxic air emissions that can impact communities and the environment. The DOD currently has a moratorium on incinerating waste containing PFAS for this reason.

Unparalleled Risk Mitigation: Because the waste is permanently sequestered, there is no risk of future CERCLA or RCRA liability.

No Waiting Period: Deep well injection is an established technology available today with demonstrated scale and capacity. Many PFAS destruction technologies are unproven at commercial scale.

Economic Considerations

The total cost of hazardous waste disposal includes multiple components beyond just the disposal fee:

- 1. Transportation:** Distance to facility, mode of transport, waste volume.
- 2. Packaging and handling:** Container sizes, quantities, loading/unloading, other requirements.
- 3. Pre-treatment:** Any required waste stabilization or blending.
- 4. Disposal method:** The actual treatment or disposal fee.
- 5. Documentation and compliance:** Manifests, reporting, certificates of disposal.
- 6. Timeline:** How quickly the waste can be accepted and processed.

Deep well injection is often most cost-effective for:

- **Long-term Risk Mitigation:** Permanent disposal without ancillary environmental risks.
- **Large volumes of liquid waste:** Transfer stations are accessible to consolidate waste streams for bulk transportation to achieve a more economical solution.
- **Projects requiring rapid mobilization:** Established Class 1 deep wells have immediate capacity to manage large volumes of waste.

Maximizing Options for Managing Hazardous Waste

Every state has different requirements and needs. When evaluating management options, agencies should compare total project costs and long-term risk mitigation across all EPA-approved methods, including incineration, landfilling, emerging destruction technologies, and deep well injection. Each method has different cost structures, timelines, and capacity constraints. Deep well injection should be included as an option in disposal evaluations to ensure states receive the most competitive and complete set of bids.

1. Provide clear specifications (when possible) to allow vendors to submit accurate pricing and competitive bids:

- Estimated waste volumes (or volume ranges).
- Container types and quantities.
- Number and general location of pickup sites.
- Waste characteristics (concentration, contamination levels).
- Project timeline and any milestone requirements.

2. Avoid limiting possible solutions based on geographic proximity.

While Class I Hazardous Waste wells are located in specific geological regions, the waste doesn't need to be generated nearby.

Facilities with truck and rail capabilities can accept waste from across the United States. The key question is not "Does my state have a deep well?" but rather "What are the total project costs, including transportation and other factors?"

3. Specify needs without limiting solutions. When evaluating disposal options, consider:

- What is the total project cost (disposal + transportation + handling)?
- How quickly can the vendor mobilize?
- What is the vendor's safety and compliance record?
- What disposal capacity does the vendor have available?
- What environmental monitoring and reporting will be provided?
- What are the long-term risk implications (ongoing monitoring, potential future liability)?

Understanding all available disposal technologies—including their costs, benefits, limitations, safety records, and potential future regulations—enables agencies to make informed decisions that protect public health and the environment while managing taxpayer resources responsibly.

By including deep well injection as an eligible option in procurement processes, federal, state, and local agencies can ensure they receive competitive bids and select the disposal method that best meets their needs.

FAQs

What are examples of situations where deep well injection should be considered?

- PFAS-Contaminated Materials, such as AFFF from fire departments and military installations, contaminated groundwater from remediation sites, and contaminated wastewater from industrial processes.
- Other Hazardous and Non-Hazardous Liquid Wastes, such as mercury-contaminated liquids, industrial chemical wastes, and contaminated water from environmental cleanups.
- Emergency Response Situations, such as chemical spills requiring rapid disposal capacity, industrial accidents producing liquid hazardous waste, and natural disasters that cause liquid hazardous waste releases.
- Residuals and byproducts from water treatment methods such as Reverse Osmosis or Ion Exchange that may generate a new waste stream containing PFAS.

Is deep well injection available in my state?

Geography is not a limiting factor for using deep well injection. Just like other disposal options, waste can be transported safely to deep well injection sites by truck or rail. Agencies can determine whether the total cost (including transportation) is competitive with other disposal options.

Is there a risk of injection wells causing earthquakes or contaminating groundwater?

These concerns typically relate to Class II injection wells used for oil and gas wastewater disposal. Class I Hazardous Waste injection wells have stricter regulatory requirements, including the 10,000-year no-migration petition, continuous monitoring, and siting in

geologically stable formations far below drinking water sources. The safety concerns about other well classes do not apply to properly permitted and operated Class I Hazardous Waste wells.

Is there any opposition from Texas or the local community to taking waste from other states?

The Texas Molecular facility in Deer Park, Texas, has operated for more than 40 years with community and state support. The facility is heavily regulated, continuously monitored, and has a proven safety record. During the East Palestine, Ohio train derailment response — a high-profile, sensitive situation — there was no community opposition to accepting the waste. Responsible hazardous waste management is preferable to leaving waste stockpiled or inadequately managed.

Aren't there new PFAS destruction technologies we should wait for?

Several emerging technologies show promise for PFAS destruction, including electrochemical oxidation, supercritical water oxidation, and plasma-based systems. However, many are still being proven at commercial scale, have limited current capacity, or face their own technical and economic challenges. While continued research is valuable, agencies with immediate disposal needs — such as AFFF takeback programs or contaminated site cleanups — should not delay action waiting for technologies that may take years to scale up. Deep well injection is available now with demonstrated capacity and a 50+ year track record.

Additional Resources: www.vlses.com

About VLS Environmental Solutions

VLS Environmental Solutions has safely disposed of liquid waste using Class I Hazardous Waste deep well injection technology for more than 40 years with:

- Zero accidents affecting public health or the environment.
- Zero spills during injection operations.
- Zero impacts to groundwater or drinking water sources.
- TCEQ-calculated compliance score of 0.0, which is the best score obtainable, and classifies the VLS Texas Molecular Deer Park facility as a “high performer.”

VLS has significant experience managing hazardous wastes and materials for federal, industrial, and commercial clients for over 40 years. When properly sited, constructed, and operated under EPA and state regulations, Class I Hazardous Waste deep wells have an exemplary safety record. Of the six commercially available wells in this category, VLS owns and operates four. The VLS Texas Molecular Deer Park facility location disposes of more hazardous waste by volume per year than any other facility in the country.

