West Texas Earthquake Observations

Implications for the Oil and Gas Industry

February 2022

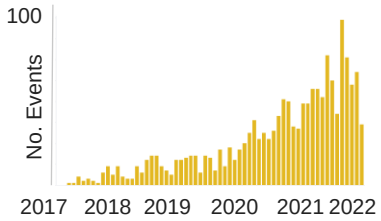
ankura

West Texas Earthquake Situation Overview

Intensive earthquakes have recently been observed across the Midland and Delaware Basins

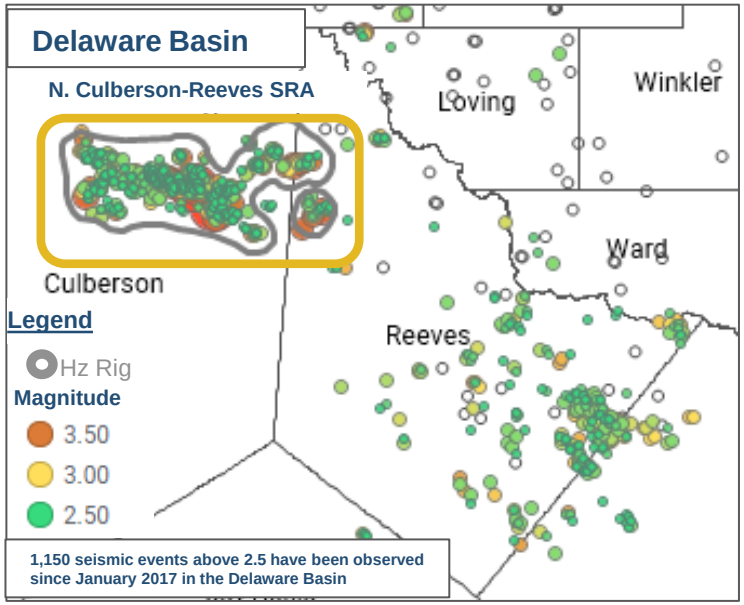
Situation Overview

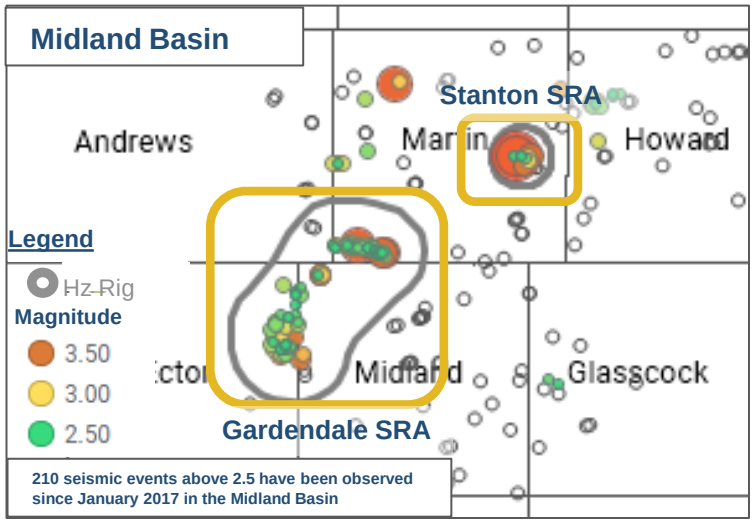
- Beginning in January 2017, Texas Bureau of Economic Geology was tasked by the Texas Legislature to monitor earthquakes in Texas. This led to the Bureau creating the TexNet Seismic Monitoring Program (TexNet)
  - Over 1,500 seismic events have been recorded in areas of oil and gas production (~1,300 in the Permian) that are above 2.5 in magnitude (M)
  - Seismic activity significantly increased during 2021 in unique count and intensity



- The Texas Railroad Commission (RRC) have identified three Seismic Response Areas (SRAs) in the Permian Basin and have determined that saltwater disposal (SWD) injections contribute to the seismic activity
  - The North Culberson-Reeves SRA was established in October 2021 after 15 4.0 M or greater earthquakes were recorded since January 2020
  - The Gardendale SRA was established in September 2021 after six earthquakes of 3.5 M or greater occurred between February 2020 and September 2021
  - The Stanton SRA was established in January 2022 after nine earthquakes of 3.0 M or greater occurred since January 2020, including a 4.6 M on December 28, 2021

Permian Basin Seismic Events





Source: Enverus, Texas Railroad Commission, TexNet. Earthquakes as of January 15, 2022

Some Initial Questions to the Evolving Situation…

Are the seismic events substantially isolated to the defined SRA areas?

- There are several seismic events outside these areas, though the existing SRAs contain the majority of the concerning activity. Seismic activity has continued in 2022 within and outside of the SRAs

Are the seismic events reduced and /or stop once SWD injection is halted?

- It's too early to tell but limiting and then stopping injection altogether has not eliminated the seismic events in the Gardendale SRA
- Seismic events have continued to occur in all SRAs and other areas
  - Roughly an earthquake per day above 2.0 M has been recorded in the North Culberson-Reeves SRA over the last two weeks, with the largest registering 4.2 M on February 13

The SRAs account for ~11%(1) of total Permian SWD injection volumes. Can volumes be re-directed to shallower zones or outside the SRAs areas or different disposal techniques utilized?

- TexNet's current monitoring of daily injection pressures and volumes are showing varying response levels to changes in disposal patterns and is potentially too early to tell the long-term impacts
- Though deep well injection, into the "basement" formations and near major fault lines, may be the primary concern, shallower injection remains of concern as well
  - The majority of injection volumes currently in the North Culberson-Reeves SRA and Stanton SRA are from shallow injection wells, 78% and 58% respectively
- Multiple water disposal companies and operators are actively utilizing or developing alternative wastewater management solutions, including recycling and evaporation ponds, but such alternatives are a small fraction of the wastewater volumes being produced
- We expect to see operators truck wastewater volumes out of the affected areas, with an increase in disposal costs

What is currently being done to address the issue?

- The RRC is working with the operators and the approach to each SRA has been different
- Gardendale (first SRA): initially limited injection volumes and stopped deep water injections for a subset of wells, but more recently stopped all deep water injections, as the seismic activity did not stop. The RRC has ceased issuing permits in the Gardendale SRA
- North Culberson-Reeves SRA: operators originally given 90 days to come up with proposal of next steps, which with progress was extended to 120 days, with February 22 as next decision date
- Stanton SRA: Industry is being given 90 days to come up with a response plan and the RRC will implement it's own plan if they are not happy with the industry response

Source: Enverus

(1) Last month injection volume in the SRAs (largest radius provided) and last month injection volume in the Delaware and Midland Basin as of January 2022.

Some Initial Questions to the Evolving Situation…(cont.)

Will the response in Texas be similar to what happened in Oklahoma?

- The RRC has not communicated any "forever plans" but have stated the goal is no seismic events over 3.5 M after 18 months from the date of response implementation
- The Oklahoma Corporation Commission (OCC) established areas of interest (AOIs) based on concentration and severity of seismic activity (similar to Texas SRAs) and targeted the deep or "basement" Arbuckle formation
- Detailed Regional and Local Directives were established to manage the problem, including:
  - Monitoring and reporting requirements
  - Regional water disposal volume limits in affected areas and with specific wells
  - Agreements to eliminate injection into the Arbuckle in local areas, including shutting in certain SWD wells or reducing depth ("plugging back")
  - Hydraulic fracturing was also cited as a lesser influence contributing to seismic activity but certain protocols and reporting were required for fracking in the affected areas
- Earthquakes declined from 2017 forward, though it coincided partially with a reduction in activity in the Midcontinent

How is New Mexico responding to the same issue, where seismic activity has also increased?

- New Mexico has experienced an increase in seismic activity, with a specific area of concern on the Lea and Eddy County line, just north of the border with Texas, where there has been substantial oil & gas development
- New Mexico's Oil Conservation Division (OCD) released revised seismicity response protocol on December 20, 2021, that will increase reporting and monitoring measures while also reducing the volume of water injected based on further observed seismic activity
- The response is differentiated by two categories
  - Category 1 is within a 10-mile radius when two 2.5 M earthquakes occur within 30 days. No reduction in injection is required in Category 1 except for daily monitoring and reporting
  - Category 2 is one event of 3.0+ or 3.5+ M that requires injection rate reductions or well shut in

Other obvious questions:

- What will the long-term response and plan look like for Texas operators and water disposal companies?
- Will the limitation or prohibition of deep well injection into the "basement" formations be the long-term solution, as was the solution in Oklahoma?
- Will other SRAs be established or a broader basin-wide plan be considered?
- What additional costs will be realized by and reporting and monitoring be required of operators?
- Can water recycling and other forms of wastewater treatment and rehabilitation be used and increased in capacity to reduced SWD injection volumes?
- Which operators and water midstream companies impacted the most?
- Will the continued earthquakes create issues for underground pipelines and other infrastructure?

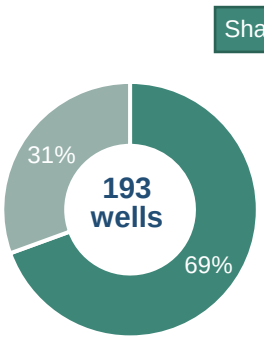
Source: Enverus

(1) Last month injection volume in the SRAs (largest radius provided) and last month injection volume in the Delaware and Midland Basin as of January 2022.

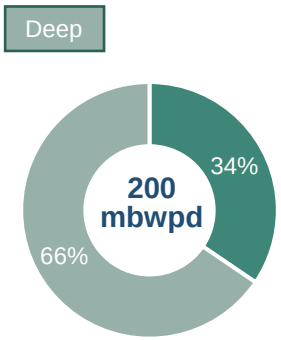
Potentially Affected Disposal Well Operators

W. Texas and New Mexico upstream operators and midstream water companies will be affected by any near and long-term response

Gardendale SRA

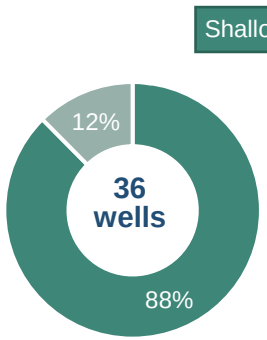


By Well Count(1)



By Volume (bbl)(2)

Stanton SRA



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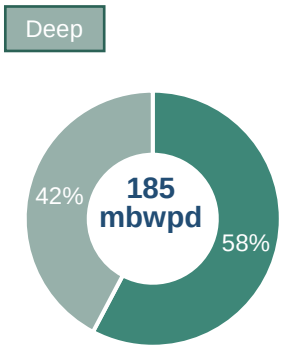
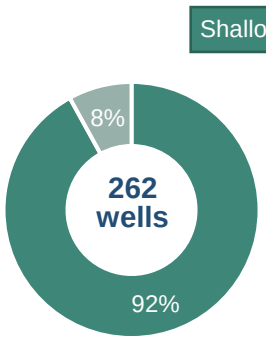
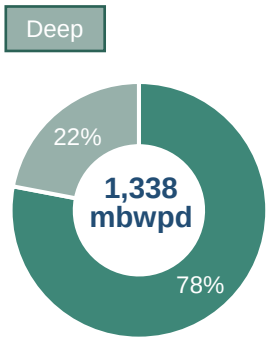


By Volume (bbl)(2)

N. Culberson-Reeves SRA



By Well Count(1)



By Volume (bbl)(2)

SWD ownership is split ~57% - 43% upstream operator vs. midstream water companies

Source: Enverus, Texas Railroad Commission
(1) Assumed 7,000' upper perforation as demarcation of deep vs. shallow
(2) Last publicly reported monthly volume injected as of January 2022

Additional Information

Reference Sources locations to continue tracking as the situation evolves

Key Reference Sources

- Texas Railroad Commission Seismic Response:
  - https://www.rrc.texas.gov/oil-and-gas/applications-and-permits/injection-storage-permits/oil-and-gas-waste-disposal/injection-disposal-permit-procedures/seismicity-review/seismicity-response/#StantonResponse
- TexNet Seismic Monitoring Program:
  - https://www.beg.utexas.edu/texnet-cisr/texnet/earthquake-catalog
- USGS Earthquake Hazard Catalog:
  - https://www.usgs.gov/programs/earthquake-hazards/earthquakes
- TexNet Injection Volume Reporting Tool(daily injection volumes and pressures submitted by operators):
  - https://injection.texnet.beg.utexas.edu/
- Industry Coverage on the Events:
  - https://www.hartenergy.com/exclusives/top-texas-shale-producers-hit-quake-driven-well-disposal-closures-report-198173
  - https://www.reuters.com/world/us/magnitude-45-earthquake-strikes-permian-basin-usgs-2021-12-28/
  - https://www.eenews.net/articles/earthquakes-linked-to-drilling-are-messing-with-texas/
  - https://seekingalpha.com/news/3783639-earthquake-hits-west-texas-oil-patch-as-seismic-activity-accelerates
- Texas Railroad Commission Notices to Oil and Gas Operators:
  - https://www.rrc.texas.gov/oil-and-gas/publications-and-notices/notices-to-operators/

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