ALLIANCE FOR INNOVATION AND INFRASTRUCTURE

ESG in the Oilfield

Understanding the Impact of Nationwide Incidents and Improving Reporting Practices

DECEMBER 2021

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EXECUTIVE SUMMARY

Running ahead of public policy, the corporate world is adopting new and innovative ways to ensure responsible operations and stewardship of their environments. The approach of environmental, social, and corporate governance (ESG) has given companies a framework to prioritize projects, minimize their footprint, engage their communities, and measure their performance for shareholders, as well as consumers and the public.

Within the energy industry, approaches to ESG differ from the broader corporate world. For the oil and gas sector, ESG means practical and grounded actions aimed at responsibly developing natural resources, minimizing releases of hazardous material, and safeguarding surrounding farm and ranchland. Assessing current activity and charting the path forward requires performance and incident data from the exploration and production (E&P) sector of the industry.

While performance is traditionally measured through oil and gas volumes extracted and safely transported, an ESG framework calls for higher standards and nuanced impact evaluation. For this reason, we must assess oil and gas, as well as wastewater byproducts, handled at and near the well pad and carried across sensitive agricultural land.

To evaluate and understand ESG in the oilfield, we must understand the relative rate of incidents, the volumes released, and the underlying root causes. This must be data-driven and analyzed independently of regulatory or industry interests. Available data shows that produced water is generated in volumes vastly surpassing valuable product, possesses higher potency and risk of environmental damage, and spills at higher rates and volumes than marketable hydrocarbons. Evaluating the treatment and focus on produced water relative to oil and gas reveals that ESG within the industry is missing an important element. Grounded ESG must incorporate produced water and waste management while continuing its strong existing focus on oil and gas.

A survey of oil and gas producing states reveals two sets of challenges and solutions to bring about improved ESG. These both implicate data availability and material investments.

Challenges

- Data: Only seven states require spills of produced water to be reported, and often treat it less stringently than valuable hydrocarbons. Limited access to public data on incident rates and volumes hinders needed insights for improvement and targeted investment.
- Materials: From limited available data, produced water incident rates and spill volumes regularly surpass the volumes of marketable oil and gas. The identifiable root causes across all products are equipment failure, material issues (e.g. corrosion), and human error.

Solutions

- Data: As the industry seeks to improve its ESG and better self-regulate, access to more and better-quality data is essential. Forming or contributing to a voluntary reporting database on incident rates and volumes that details root causes will provide individual companies and the industry the insights it needs to further drive down incidents and improve operations.
- Materials: With available incident data and internal analysis, companies can begin to invest in better products and equipment with more resilient materials that are less susceptible to corrosion and other common issues in production lines, tanks, and other facilities.

INTRODUCTION

The energy industry has been almost solely responsible for providing the power that built and now maintains modern life. Over the course of the last century, abundant energy has facilitated medical innovation, poverty alleviation, and discovery from the depths of the ocean to the reaches of the solar system. Access to abundant energy is critical to human progress and societal growth. Yet as time has passed, the need to steward our resources for the health and security of our posterity – and the environment itself – has come into sharper focus.

Acknowledging the criticality of stewardship, many industries have embraced a framework for committing to improved environmental, social, and corporate governance (ESG). This in large part emphasizes the need to conserve resources and invest in innovative ways to reduce our impact on the planet. The views and implementation of ESG vary across industries, especially those that center on developing natural resources and providing energy to society. Typical examples include switching to compostable or sustainable products, committing to mitigate the corporation's environmental footprint through emissions reductions programs or carbon offset purchases, and even investing in community and educational efforts. While some of these can be undertaken in the oil and gas sector, the primary approach to ESG that differs from the rest of the corporate world is the focus on incident reduction – as this sector handles environmentally dangerous goods; meaning when accidents or mismanagement happens, its errors can create direct harms.

In order to calibrate and optimize ESG efforts, each company must assess itself and its industry. Only when equipped with a thorough and contextual understanding of current impacts and trends can companies take meaningful steps forward.

This paper surveys not only what it means to focus on environmental, social, and corporate governance within the fossil fuel industry, but the availability and role of data in improving operations for the sake of stakeholders, the environment, and future generations. Once the current state of incident rates, spill volumes, and reporting practices is understood, companies can set in place new goals and commitments while investing most efficiently in assets, materials, and personnel.

MEASURING ESG IN THE OILFIELD

While many sectors measure environmental, social, and corporate governance through their ability to reduce reliance on fossil fuels, oil and gas producers instead work to improve safety and efficiency, while stewarding the environment in which they work. For those who dutifully and responsibly cultivate these natural resources, achieving and improving upon ESG means providing more efficient access to resources with less disruption and a smaller surface footprint, protecting surrounding land – including ranch and farmland – from contamination, significantly reducing incident rates, limiting waste, recycling when possible, and ensuring that disposal is completed responsibly.

To do this, the energy industry must also rely on partnering sectors and industries like transportation. This primarily implicates pipelines and trucks. Pipelines are the most popular and efficient means of transporting energy resources and have by far the most effective safety record. Upstream, the decision between pipelines and trucks is a fine economic line, often settled based on geography and topography, as well as cost. Through an ESG lens, however, costs are calculated on a lifecycle basis and include a robust assessment of all externalities; lost product, damage, and environmental harm are only part of that total. Longer-term considerations like recycling wastewater also contribute to the cost of building or maintaining pipelines or utilizing trucking. Still, other factors like traffic, dust, and accidents, as well as the threat to agriculture of truck or pipeline spills raise the risk of contract and lease issues, lawsuits, and regulation.

Operators already understand the need for continuous improvement. While all segments of the transportation industry ultimately demonstrate the favorability of pipelines on a safety and effectiveness record, newer and more specialized designs remain important to pursue and implement. In fact, the standard steel pipeline design has not changed significantly over the course of the last century – remaining susceptible to corrosion and other failures. That is why better pipelines, more resilient materials, and diligent maintenance are essential. As the data reveals, flow lines and pipes are the best middle- and long-distance transport options for high-risk waste, but also represent the most potential for ESG improvement.

To date, the safety and effectiveness of pipelines has been measured largely by the transmission and distribution infrastructure – the midstream and downstream segments of the oil and gas industry. Upstream, however often utilizes different pipe, handle different materials, and have different needs.

At the E&P stage of the energy sector, the considerations are even more demanding than other industry segments; not only are oil and gas running through production lines, separators, and tanks, but also high volumes of flowback and produced water. These materials are all highly corrosive and present significant challenges for existing equipment.

For this reason, ESG focus is about more than reliable movement of crude oil and natural gas. Well-balanced ESG in the oilfield means vigilance over energy resources, water, and waste, which can devastate farm and ranch land near E&P operations when safety is not at the forefront. Ensuring smaller diameter flowlines near the well head are free from corrosion, fitting incidents, and other failures as well as durable against line strikes, weather, and pressure is at the heart of ESG in the oil field. Reliance on flow lines and gathering lines wherever possible to displace trucks and the need for material to change custody and transport mediums helps reduce incidents. This means ensuring that produced water is handled with the highest level of care, transported safely and effectively, and stored securely. With the volume of corrosive wastewater far outpacing oil and gas extracted from a well over its lifetime, a committed ESG approach should make water a part of its focus.

There are three states to view the ESG path, take proactive steps to improve, and track that progress. These are an assessment of the current state and its considerations, the ideal state for stakeholders and the environment, and the challenges and roadmap to arrive.

The current state exhibits unnecessary numbers and volumes of incidents, but also lack of clear and accessible data. From limited available data, equipment and material failures may reflect a lack of investment in high quality material and labor, which may also suggest a shorter-term cost/profit approach. Viewing costs in this short-term way could open entities up to losses, negative publicity, regulation, or fines. As seen through media and studies on land-based incidents, high incident rates are devastating to operators and invite regulatory oversight.

The ideal state is to be not only a thriving company, but have longevity based on goodwill and stakeholder support. This is not only about protecting the environment and the rights of surrounding landowners, but also protecting shareholders and investors from future criminal or civil legal liability and the negative outcomes that sour their relationships with the public generally and the investment community specifically. With high-quality materials and experienced labor alongside robust self-regulation, the industry can improve its performance, harmonize relationships with landowners, and avoid cumbersome, costly, or unnecessary regulation.

The challenges are partly a feature of the status quo. At this point, it is difficult to ascertain at scale how to measure whether activities in the oil patch are consistent with ESG pledges and obligations, as there is a dearth of data on where, how, and why incidents are occurring, what specific practices and materials are involved in failures or incidents, and how companies can adopt sounder ESG-compliant practices moving forward. In many cases, limited data does exist but is not standardized or made publicly available. Elsewhere, industry self-regulation responsibly manages incidents and spills, but does not necessarily provide transparency or publish data for the industry or interested public to assess incident causes, volumes, or impacts.

The approach to these stages may be varied. In some instances, new practices may be needed. Elsewhere, investment in stronger or more resilient materials will be key. Knowing that one of the primary concerns is lost product or waste, great attention should be paid to pipelines, storage facilities, and other transportation components. That said, it is critical to let data inform the areas in need of improvement and create a roadmap after understanding the full state of the industry.

This leads to the need to survey the existing reporting rules for the oil and gas industry, where such data may be found, with special emphasis on produced water and other production waste. If requirements do not exist, voluntary databases and trackers are consulted.

REPORTING REQUIREMENTS

The primary limitation to implementing reforms in the E&P sector is access to data. From mines to oilfields, without knowing the nature and rate of incidents across the industry, it is impossible to know how to improve. Knowing that data in context is essential for knowing one's impact on the environment and society. This means not only knowing and committing to improving one's own safety record but understanding their place in the industry against the background of existing trends.

It is important to caution that better reporting alone may not necessarily reduce incident rates. It does, however, shed light on existing trends and help lay out a roadmap for operators to improve their own efforts and stand out among their industry.

Currently, few reporting requirements exist for the upstream segment of the industry. Within the energy transportation sector, there are robust rules for interstate crude oil and natural gas infrastructure, and midstream and downstream industry participants provide clear and copious reporting to the federal government's Pipeline and Hazardous Materials Safety Administration (PHMSA). That data includes information on the location and date of incidents, the product volume lost, nature of the incident or root cause, and a dollar amount in direct property damage.[1] This data has served the transportation sector by providing invaluable insights into product defects, material failures, personnel issues, and areas where industry action or public policy can take a more effective lead.

Without access to similar data in the E&P sector, whether through an agency or private entity, the same insights cannot easily be drawn. This limits both the ability to improve the performance and extent that stakeholders and future generations can measure commitment to ESG. Moreover, as already discussed, the E&P sector handles far more than hydrocarbons, so the existing data on oil and gas discharges only paints half of the picture. Knowing and measuring the impact from all releases – especially flowback and produced water – is vital. With production wastewater being subject to state jurisdiction, there are dozens of approaches to the matter.

Where state-level reporting requirements do exist, they are limited. An independent survey of the 34 oil and gas producing states in the union revealed that only 23 states specifically regulate produced water, while only seven states have a rule in place through law or regulation requiring that leaks and spills of produced water, brine, and other E&P wastewater from the oil and gas development process be reported to the state or other designated authority. Even this subset demonstrates different levels of transparency with the data.

For instance, the state governments of Arkansas and Illinois collect and maintain data on failures in production lines and produced water spills, but do not make the information publicly available except upon request. Colorado, North Dakota, and Wyoming make information available but fail to normalize their data, and the information must be meticulously sorted to be meaningful. New Mexico maintains possibly the most comprehensive dataset, available to the public in a searchable, exportable database.

The specific reporting information also varies, with spill reporting thresholds low enough to capture any spill and as high as only requiring reports of 10 barrels or more. This means that even in some states that do require reporting, spills up to 420 gallons can still go unreported. Elsewhere far higher volumes would technically go unreported because no law or regulation is in place. This is troubling given that independent analysis and a review of the literature indicates that the majority of produced water incidents are small spills.[2] Other reporting requirements depend on the nature and location of the spill, whether it escaped the berm or occurred on the well pad, in transit, at a storage facility, or by reference to its effect to soil or water.

Summary of State Reporting Requirements

State	Oil Volume Threshold	Produced Water Threshold	Reporting Timeframe	Report type	Mandatory	Location Requiring Reporting
Arkansas	1 barrel	5 barrels	24 Hours	Telephone and form	Yes	Anywhere
Colorado	1 barrel	1 barrel	24 Hours	Telephone or writing	Yes, with qualification	Only if outside of berms
	5 barrels	5 barrels	24 Hours	Telephone	Yes	Anywhere
Illinois[3]	Any spill	5 barrels	24 Hours	Written report within 90 days	Yes	Anywhere
New Mexico	5 barrels	5 barrels	24 Hours	Written report within 15 days	Yes	Anywhere
North Dakota	10 barrels over 15-day period	10 barrels over 15-day period	10 days after cleanup	Written report	Yes, with qualification	Anywhere
	Any spill	Any spill	10 days after cleanup	Written report	Yes	Outside of well site
Montana	50 barrels	50 barrels	Immediate notice by telephone	Written report within five days	Yes	Anywhere
	Any spill	Any spill	Immediate notice by telephone	Written report within five days	Yes	Entering or degrading surface or groundwater
Wyoming	10+ barrels	10+ barrels	Immediate notice	Telephone or writing	Yes	Only if uncontained

See Appendix B

While these seven have clear reporting requirements, other states encourage proactive spill responses, mandating that operators contain, clean, and remedy spills of any size but not necessarily requiring any reporting to the state that a spill occurred.

Still, some states have ambiguous rules, which either lack clarity or are subject to competing interpretation by regulators and industry, making them nearly unenforceable, and consequently, often unenforced. Indiana requires all spills to be reported, even encouraging notice of nonreportable spills and allowing the state agency to advise that the incident in question did not need to be reported. Louisiana, which regulates produced water through discharge permitting, only requires reporting by permit holders of "unauthorized discharge" rather than spills.[4]

In Texas, there is mandatory reporting for spills, leaks, and breaks for all oil, gas, well liquids, and associated product lost.[5] This can include, but does not require, produced water. Further, while there is a five-barrel threshold for oil, the only guidance for produced water is a draft field guide stating that "the responsible operator is **encouraged** to notify the Railroad Commission" of produced water spills exceeding 25 barrels.[6]

All states direct operators to report to the National Response Center (NRC) operated by the United States Coast Guard, either as an alternative or in addition to state reporting.[7] This database fields public reports from anyone witnessing an oil spill, chemical release, or maritime security incident. While vast in scope, it does not deliver narrow or quality information on produced water sufficient to define ESG metrics for the industry going forward.[8,9] The NRC does forward information to state authorities, even where volumes reported are below statutory thresholds for that state to trigger mandatory reporting.

While state reporting requirements and regulations are not necessary to acquire this critical data, they do establish definitive guidelines and a central collection point for data. High quality voluntary reports, or industry self-regulation can also achieve this, but has thus far not been the case in this sector. As an ESG matter, avoiding incidents is already the priority, while responsibly mitigating and remediating spills is the standard follow-through. The stride forward to record and report the data on incidents, however, can help vastly improve an individual company's ESG while helping lift the entire industry by providing access to information that may reduce incidents for other companies.

Throughout this survey, we have separated out reporting requirements for product of value (oil and gas), which all states regulate, and byproduct waste (flowback, brine, produced water, etc.). Highlighting the different treatment between spilling the oil and gas product itself and the frac fluid used to produce it as well as waste that comes up alongside the product is important because it underpins the current mindset in the industry and sheds light on how trending toward ESG will also require a change in mindset.

The product itself has monetary value and is heavily regulated. The frac water is in not subject to federal regulations, which makes information more difficult to come by. Further, incidents are tracked less strenuously because produced water is not a commodity with a market value.[10] Still, the information is important for state regulators, investors, and most importantly, local landowners and residents.

In the next section, we survey databases of upstream incidents recorded by state authorities and published in previous studies. We report volumes of both valuable product as well as waste to demonstrate the scale of ESG concerns and highlight the existing emphasis placed on these incidents by industry, regulators, and the public.

CURRENTLY AVAILABLE DATA

In 2017, approximately 24.4 billion barrels of produced water were generated from over 900,000 wells across the United States.[11] In contrast, the U.S. averaged just over 6.7 billion barrels of petroleum production in the past year.[12] Globally, average production ratio is five barrels of produced water to each single barrel of oil, with certain regions ranging as low as 3:1 and as high as 22:1 over the lifetime of the wells.[13] Some domestic wells, like those in the Mississippi Lime Play have water cuts as high as 90 percent with nearly 100 barrels of water to each barrel of oil. With this greatly disproportionate ratio of wastewater to commodity, along with the potency of the produced water, one may reasonably expect robust data on produced water spills.

A review of previous studies and available databases on the diverse products, waste, and materials handled by the E&P sector reveals surprisingly little but still contain valuable insights. Many hundred-page reports on produced water fail to even include the words “leak” or “spill,” despite describing the caustic nature of the substance and outcomes when produced water reaches farmland or groundwater.[14] Among the sources reviewed are several states agencies, the Environmental Protection Agency, the National Response Center, and studies conducted by academia, private firms, and nonprofits.

By surveying available databases and studies, several findings emerge: operators and transporters in the upstream sector handle vast quantities of product and waste, and despite current efforts, large volumes are spilled every year. While ESG is a lens through which to view existing information and future plans, the first step is to identify trends such as volumes of waste spilled and root causes. The following data display only gross spill volumes for oil and produced water. While spills can be contained and volumes recovered, this report only identifies spilled volumes not net loss. That is because this paper seeks to understand the root causes leading to the releases in the first place, where recovery or net loss is not relevant, and secondly because even when recovered, produced water can salt the earth and leave a long-lasting impact on agricultural land.

Summary of Select State Findings

We start by reviewing the most transparent databases and findings from select top-producing states. These include New Mexico, North Dakota, Wyoming, Colorado, and Texas. We summarize the latest available data by reporting incident numbers and volumes for 2020. Across the board, incident rates and volumes were lower in 2020 than in previous years, likely due to COVID-19, market forces, and other factors, but the nature of incidents are consistent across years. Those seeking to improve their ESG should take a keen interest in root causes.

In New Mexico, where produced water can exceed 10 barrels for every one barrel of oil, produced water is regulated and spills are required to be reported. The state's Oil Conservation Division maintains a searchable database revealing that millions of gallons of produced water leak each year.[15] While the number of incidents and spill volumes vary from year to year, the underlying causes remain relatively consistent. In 2018, 727 spills caused the release of 97,638 barrels of produced water, while 517 crude oil spills released 17,832 barrels. In 2019, 853 incidents led to 105,572 barrels of produced water being spilled, whereas only 482 incidents spilled 16,413 barrels of crude oil. In 2020, 745 incidents caused 65,239 barrels to be released in total, with 403 incidents spilling 13,423 barrels of crude oil.

The data clearly show that incident numbers and spill volumes of produced water consistently outpace crude oil. With produced water being the more environmentally detrimental substance, and many years demonstrating high-volume losses, there also appears to be a low ESG focus on this type of incident in the field. To understand how to address it, we turn to root causes.

Inspecting produced water spill data by cause, we can see that across all sources (e.g. flow lines, pumps, separators, tanks, etc.) the leading issue is equipment failure, responsible for over 30,000 barrels (over 1.4 million gallons) of briny produced water spilling in 2020. Due to the caustic nature of the substance, corrosion is a close second, leading to 275 incidents and spilling over 13,000 barrels. The third individual cause is human error, likely due to a confluence of inadequate training, poor judgment, and miscommunication.

New Mexico Produced Water Spills Jan. 1, 2020 – Dec. 31, 2020

Causes, All Sources	Number of Spills	Average Spill Volume (BBL)	Median Spill Volume (BBL)	Total Spilled
Equipment Failure	312	111.39	25	34,754
Corrosion	275	48.76	19	13,410
Human Error	50	101.62	23	5,081
Overflow	11	38.73	35	426
Vehicle Incident	6	841.67	15	5,050
Blow Out	3	23.67	13	71
Normal Operation	3	13.33	5	40
All Others	85	75.388	14	6,407
Total, All Causes	**745**	**87.57**	**20**	**65,239**

Exploring production flow lines provides further insight, as both valuable product and wastewater run through these lines. In 2020, over 9,000 barrels of the produced water that spilled came from production flow lines alone. In contrast, only 1,083 barrels of crude oil spilled from production flow lines that year. The leading cause is corrosion, while equipment failure comes in second, with human error again ranking third.

New Mexico Produced Water Spills Jan. 1, 2020 – Dec. 31, 2020

Production Flow Line	Number of Spills (BBL)	Average Spill Volume (BBL)	Median Spill Volume (BBL)	Total Spilled (BBL)
Corrosion	59	74.14	16	4,374
Equipment Failure	27	112.94	23	1,360
Human Error	8	324.13	100	2,593
All Others	13	67.23	21	874
Total	**107**	**85.99**	**20**	**9,201**

Additionally, 91 produced water incidents in New Mexico in 2020 occurred at valves, attributable to the causes of equipment failure, corrosion, and human error respectively. The valve incidents released 6,540 barrels. Pipelines broadly (though excluding production flow lines) were the sources of 11,563 barrels spilled, again following the cause failure of equipment failure, corrosion, and human error. These glimpses at incident numbers and volumes establish a clear pattern that material failures lead to the most incidents, followed by human error, with weather, accidents, and other causes rounding out the remainder.

I**n North Dakota**, data is also made publicly available. Prior to January 1, 2021, data was reported to separate agencies and not unified in a single database. To a large extent, transparency is a function of both availability and manageability. The decision to unify the databases has made the produced water and oil data far more accessible.

Many studies have focused on North Dakota because of its high production of both oil and produced water, alongside a traditionally agricultural community that is particularly vulnerable to incidents. These have identified large numbers of spills in the state, with the largest produced water spill reported occurring in 2015, when approximately 70,000 barrels (2.9 million gallons) were released.[16,17]

One study conducted in North Dakota identified many root causes, suggesting that spills of produced water largely implicate design (including material and equipment quality), installation, operation, and monitoring.[18] This is further borne out by the summary data presented below.

ND Spill Volume, January 1, 2020 through December 31, 2020

Annual Spill Volumes	Crude Oil (BBL)	Produced Water (BBL)
Average Release	18.52	83.16
Median Release	2	83.16
Total Release	**5,166**	**27,608**

ND Count of Incidents by Type, January 1, 2020 through December 31, 2020

Leading Incident Types	Number of Crude Oil Spills	Number of Produced Water Spills	Combined Total[19]
Equipment Failure	53	66	103
Valve/Piping Connection Leak	39	75	85
Tank Leak/Overflow	35	47	69
Pipeline Leaks	18	58	62
Vehicle Incident	5	22	20
All Others	129	64	199
Total	**279**	**332**	**538**

ND Spill Volumes by Incident Type, January 1, 2020 through December 31, 2020

Volumes by Incident Type	Crude Oil (BBL)	Produced Water (BBL)
Equipment Failure	1,352.30	3,979.68
Valve/Piping Connection Leak	1,474.80	5,824.73
Tank Leak/Overflow	969.94	3,267.47
Pipeline Leaks	518.32	9,636.94
Vehicle Incident	24.43	1,195.13
All Others	826.37	3,704.41
Total	**5,166.16**	**27,608.36**

In line with data from New Mexico and other states, equipment failure is the top cause of breakdowns in North Dakota leading to the most individual incidents. The next cause is valve or piping connection issues, which accounted for a greater volume of loss than equipment failure, despite fewer incidents. Of note, pipeline leaks (a combination of production flow lines and other pipe) actually led the state in volume lost, while only ranking fourth in the number of incidents. Individual incident descriptions routinely point to internal and external corrosion as a key factor leading to pipeline incidents, which is a root cause common across both equipment failure and pipeline leaks.

Due partially to differences in reporting terminology, and somewhat subjective spill reporting by operators, the exact comparisons or specific type of equipment and material failures are difficult to discern relative to New Mexico and other states. But what is clear is that produced water does spill at high volumes predominantly due to equipment failures, flow and pipelines, and occurring at valve and connection points. Similar root causes affect oil and gas, but at lower rates.

In Wyoming, there were 823 oil and gas spills in 2019, of which 513 involved produced water. This led to a total volume of 39,653 barrels of produced water being spilled that year.[20] In Wyoming, only spills of 10 barrels or more are required to be reported. The following table is derived from the Wyoming Department of Environmental Quality's Spill and Complaint website, which does not capture every spill in the state, but nevertheless demonstrates consistency with other states on the root cause of produced water incidents.

Wyoming Produced Water Spills, Janruary 1, 2020 - December 31, 2020[21]

Causes, All Sources	Number of Spills	Average Spill Volume (BBL)	Median Spill Volume (BBL)	Total Spilled (BBL)
Equipment Failure	61	334.84	50	20,425.53
Pipeline Incident	12	255.27	50	2,908
Human Error	4	135.5	34	534
Others/Unknown	5	16.21	2	81.05
Total	**83**	**288.54**	**45**	**23,948.4**

In Colorado, over 28,000 barrels of produced water spilled from 639 incidents in 2019.[22] For 2020, 476 total oil and gas spills led to 12,582 barrels of produced water being released. In the Centennial State, produced water volumes surpass oil production and the number of incidents follows consistently, with a 2.84 times greater volume of produced water spilling than oil.[23]

Of the total oil and gas spills in 2020, at least 238 spills involved produced water, while another 102 incidents list the produced water volume as unknown. Of the verified produced water incidents, 16 were reported as spilling less than one barrel of produced water, 106 were reported to spill between one and five barrels, and 98 spilled between five and 100 barrels, while 18 reported spills of produced water in excess of 100 barrels. The median spill value in Colorado is approximately eight barrels. This is consistent with other studies finding that most spills are small to medium, with the largest spills being outliers.[24] This is also an important finding to consider, as many states draw spill reporting thresholds above the level of small spills. This means that even where reporting is mandatory, many states do not capture spills volumes below five barrels or even up to 10 barrels. In addition to missing this environmental data, smaller spills may have different root causes than larger spills. Without this data, ESG-focused boardrooms cannot identify the proper investments to avoid incidents and losses.

While root causes are not listed for every spill event in Colorado, and a consistent categorization is not used, a survey of individually written summaries in the state reveals that the top factors were material and equipment failures. With 40 percent of produced water incidents occurring in flow or pipelines and another 40 percent occurring at the tank battery, the notable root causes included corrosion of carbon steel pipelines (internal or external), stress on fiberglass pipelines, corrosion of other facilities, freezing conditions, overflows, and human error, among others.

In Texas, where oil and gas production considerably outpace the rest of the country, over 1.7 billion barrels of crude oil is produced annually. The state also has an estimated produced water to oil ratio of 6.5 to one, meaning approximately 11 billion barrels of produced water was generated in 2020. Texas manages produced water through a three-step permitting process, but perhaps surprisingly does not require reporting of spills, nor does the state maintain a public database to record them. Based on sheer volume in Texas, along with data from other states, it is highly likely that hundreds of thousands of barrels of produced water are spilled or unintentionally discharged in the state annually.

Examining reporting forms that capture "more than five (5) barrels of crude oil, gas well liquids, or associated products," Texas reports a total of 529 reported incidents in 2020. Of those, 316 occurred at the tank battery, 48 were flowline failures, 21 were pipeline breakdowns, 12 were valve issues, and the remainder were other facilities or uncategorized. The causes of these failures include 251 incidents of equipment failure, 120 counts of corrosion, and 44 human errors, with theft, vandalism, and other causes accounting for the remainder. While these are predominantly oil and gas reports, several do make reference to produced water, although it is not an independent category. The findings remain relevant, as they validate the trend of material, corrosion, and human error causes being the top three root reasons for incidents.

Implications of Current Data for ESG

Viewing the root causes from these select states through the lens of percentage, we can see that around 45 percent of failures and breakdowns are attributable to equipment failure, while corrosion and pipeline incidents account for around 24 percent, with value, joint, and fittings accounting for a further 10 percent. This makes equipment or material factors equal to nearly 80 percent of incidents, while human error follows around six percent on average.[25] A mixture of other and uncategorized causes sum up the remainder. This percentage breakout of root causes is generally consistent in explaining both incident numbers and the associated volumes spilled.

This glimpse into the incident causes consistently focuses on material or equipment failures, which may be due to a lack of investment or maintenance of high-quality material. However, the volume of produced water generated also creates a challenge for transport. The information above centers largely at the wellhead or between the well and central tank battery.[26] A broader view also accounts for how and where the wastewater is moved to its ultimate destination – whether that is reinjection, treatment, long-term storage, or safe environmental discharge. This highlights the importance of transportation, specifically between trucks and pipelines. Moving into a more comprehensive ESG mindset, such comparisons are important.

Cross-industry and well-established data indicates that pipelines are the most effective method of transport for liquid products, while trucks tend to lead to a greater number of incidents but a smaller volume of loss per incident.[27,28] Where trucks are concerned, new considerations emerge, including different impacts to landowners beyond spills and ways that vehicle traffic impacts communities, crops, and more.[29]

Due to certain limitations in state reporting, a literature review of several studies explores the challenge of pipe and trucking considerations. As a matter of incident rates and volumes, each method has positive and negative aspects. An ESG focus must consider these as well as the context of lifecycle costs to include property rights issues and externalities beyond wastewater spills, such as land use, traffic, maintenance, and even dust.

> With produced water being the more environmentally detrimental substance, and many years demonstrating high-volume losses, there also appears to be a low ESG focus on this type of incident in the field.

The *Produced Water Report*, a comprehensive study on production, handling, disposal, and recycling potential of produced water, explores some of the considerations at play. From this report, cost is presented in several ways, and regulation is the primary lens for minimizing impacts.

Beginning with safety record, the report concludes that "Transferring produced water via pipeline is safer with less risk of spills than trucking, yet the regulations often make it difficult to transfer water via pipeline."[30] This is largely due to fewer changes in custody (the product switching mediums at valves and hookups), but also because trucks entering roadways introduce the additional and unpredictable variable of other drivers and wear-and-tear road conditions. Citing a pipe buildout by Shell, the report explains that the newly piped water had the additional benefit of "reduc[ing] road safety exposure" by removing produced water tanker trucks from the road.[31] Considering the volume moved as well, many more trucks are needed to move the same volume that can be run through a single pipeline.[32]

Perhaps most telling is the trend of companies switching and preferring to use pipe. "Companies estimate that 30 to 85% of the produced water is conveyed via water pipelines to disposal wells with the remaining balance being transported by trucked [sic]. Piped water generally has a lower spill risk and reduces the road traffic. The percentage of piped produced water is expected to continue growing."[33] With the rate of piping expected to grow, this signals both an improvement in ESG, but also an implicit confirmation that trucks are less desirable for moving produced water – although trucks remain essential in certain regions and markets.

Considering costs, there are two issues: accounting cost and economic cost, with the former being the expense or price to transport water and the latter including the externalities and impacts on local communities and landowners. In both considerations, data suggests pipelines are generally preferrable, but only when design and material quality are sufficient to avoid common incidents:

> Moving water can be expensive. Trucking costs for a typical trip from a tank battery to a saltwater disposal (SWD) well can range from $1 to $3 per barrel. The cost of constructing permanent pipelines currently averages about $1.45 million per mile depending on pipe size, terrain, right of way costs, and other factors. The use of temporary pipe, sometimes referred to as "lay flat pipe", is less expensive than permanent pipe but comes with its own set of problems, including increased maintenance needs and higher leakage rates.[34]

Elsewhere, the costs differ slightly, but remain consistent in magnitude. According to one Texas study, "Hauling water away from well pads via truck can cost anywhere from $1 to $5 per barrel depending on travel distance and terrain, which can be prohibitively expensive when compared to the $.30 it reportedly costs to pipe water from a production well to a disposal well."[35] These cost considerations are primarily the accounting cost and make financial sense to companies even before considering broader costs and externalities.

These studies have already pointed to safety, which is one primary consideration in evaluating externalities. By referencing spill likelihood and road safety considerations, pipelines emerge as the preferred and less expensive option. Other considerations are unique to each transportation method. Pipelines generally traverse private land and require installation and maintenance easements, while trucks utilize roads. These roads, however, tend to be gravel or dirt roads and often also infringe and cross private land. High traffic to manage vast produced water volumes also means degrading roads and churning up dust, which impacts local communities in ways as diverse as harming respiratory health to coverage of crops. To the extent that spills do occur, leaks in pipe may be located in farming or grazing land, while trucks tend to spill on or near roadways, but the relative incident rates and volumes released tend to equalize such considerations.

Importantly, trucks remain critical for transport in many areas, and not all pipelines are ideal due to either geography or design. Because produced water contains high salinity, hydrocarbons, and even radioactive material and is generated in volumes upwards of five times higher than petroleum, this enormous amount of waste must be handled with the utmost care. Overall, pipelines represent lower lifecycle costs when factoring in incident rates, transport costs, and externalities.

What remains vital is that these pipelines be designed and rated for the temperatures, pressures, and corrosive attributes of the produced water running through them, and that they are not susceptible to the types of equipment and material failures that are most often observed. This requires high material quality, but also adequate personnel training on installation, operation, maintenance, and monitoring.

Finally, more information is still needed. The survey of the top producing states and transparent databases reveals that still little quality information is known and publicly available about produced water, incident rates and volumes, and the root causes behind them. For individual companies to improve, and for the industry to take strides forward, more is needed. How that data is best generated, reported, and disseminated remains unsettled.

ACQUIRING BETTER DATA

In general, the data available to the public is only a fraction of the total information on production volumes and spill data, while oil and gas information is generally well reported. Within the subset of available data, differing levels of transparency exist. In some states, despite a state agency collecting the data, it is only available upon request. Elsewhere, the collection is done and made available publicly, but a lack of standardized reporting and normalized data makes its transparency very limited. As a better model is considered, attention should be paid not only to collecting and reporting more data, but better data that is standardized and accessible.

The need for better data is clear. Whether it is collected voluntarily or prescribed through regulation due to industry inaction, reporting thresholds must be evaluated. Only a few states currently require reporting of spills and incidents involving produced water, and those that do have different reporting thresholds. With most spills around the country happening in small volumes, the vast majority of incidents likely go unreported altogether. Some states only require reporting when spills occur outside the berm or off the well pad. This is intuitive from a regulatory standpoint, but with an ESG focus, this is inadequate. The rationale that spills on the well pad are contained or do not threaten landowners misses a bigger picture. The oil and produced water spilled even inside the berm of a well pad still impacts remediation of the land over time. Enough single-barrel spills – going reported – will permanently salt the land hosting the tank battery, making it impossible to remediate and return to environmental balance when the well is closed, and the E&P companies move on.

Not only is this a stewardship and ESG concern, but it represents incredible missed opportunity for analyzing and understanding the issues on the ground. Minimal and narrow reporting practices preclude companies from being able to identify and invest in resolving underlying root causes to meet ESG goals, but also inhibits shareholders interested in tracking progress. Collecting more data allows companies to demonstrate transparency, which in turn allows investors and the market to reward companies excelling in managing their ESG risks.

Ideally, there should be public access to robust data with broad and granular information present.[36] Within the energy sector, the state of New Mexico has a database that achieves a version of this standard. Not only can users search incidents by data, cause, facility, or other metric, but they can export and sort this data as well. This picture of a functional database is merely an end point; it does not explain how best to arrive there.

With produced water and other E&P waste being subject to state jurisdiction, there is clearly no room for overarching federal rules to compel reporting. With companies focusing on environmental, social, and governance pledges, a consistent reform would be voluntary transparency and self-reporting. If this failed to improve data, state cooperation, either in aligning rulemaking or sharing data they already collect, is the next logical step.

There are a few models of voluntary reporting across industries. The most directly applicable is the National Response Center, which fields public notifications on spills and leaks of virtually every kind. NRC is valuable in that it contains copious voluntary reports, but it is somewhat like the wild west in terms of data presentation. There is no consistency in terminology, volumes, material, or other reporting fields, containing whatever individuals reported, seemingly without any collating or refining of the data by personnel or algorithms at the NRC. Not unlike a document dump, too much data can obfuscate transparency and accessibility.

Another model is the American Petroleum Institute's (API) Pipeline Strategic Data Tracking System (PSDTS).[37] There, members and participants report any incident involving five gallons or more of oil along with smaller volumes released into water from the midstream segment. Importantly, this undertaking is explained as a strategic effort within the industry to understand and improve industry performance, elaborating: "The availability of more detailed data is crucial to that objective. Although many individual operators had developed stringent internal reporting criteria, there were no industry-wide aggregations to enable industry to identify lead indicators and learn from them to prevent spills." Broadening this effort into the upstream sector, or E&P companies recreating this effort, would be a great stride forward.

Outside of the energy or transportation sectors directly is a model from the excavation damage prevention group, the Common Ground Alliance (CGA). A member organization of utility owners and operators, locators, excavators, and One-Call center personnel, CGA collects voluntary reports of near miss and excavation damage incidents nationwide. Available through a searchable dashboard and annual reports,[38] this information has guided stakeholders and policymakers in the damage prevention space for years. More than simply being a repository of voluntary reports, CGA also examines the data and has built a statistical model to account for redundant reports and unreported incidents. This is one major limitation of state E&P incident databases and the NRC, which often go unmanaged for things like multiple reports of the same incident and estimating below-threshold omissions.

The conceptual infrastructure of the needed model is already in place. Every state already requires that spills of oil and other substances be reported, and in most states, producers submit data on production volumes including produced water. But companies must rise to a new standard to bring about a more meaningful system.

Taking the best of API, the NRC's breadth, and the CGA's data analysis, and reporting it in a form similar to New Mexico, would give companies, shareholders, regulators, and the public access to valuable information. Doing this through voluntary reporting is the best for company buy-in but may miss out on small incidents that operators in the field fail to report.

Consultation with experts, like the CGA model, could help account for this. Absent an industry-led movement for better data, states could choose to increase the regulatory pressure and require more reporting, either to their own agency or to an outside organization, but this could have an inverse effect if not done in consultation with the industry.

With this mindset at the forefront, some trends to acquire better data and reduce incidents have moved toward punitive measures. New Mexico is even considering laws that would make it illegal to spill.[39] This imprudent approach of criminalizing accidents may discourage private companies from volunteering spill data to public databases if they fear liability. It also further emphasizes the need for ESG to lead the way in reducing incidents proactively and not the government setting new rules reactively.

> "...achieving and improving upon ESG means providing more efficient access to resources with less disruption and a smaller surface footprint, protecting surrounding land – including ranch and farmland – from contamination, significantly reducing incident rates, limiting waste, recycling when possible, and ensuring that disposal is completed responsibly."

More and better data is needed, and it must also be accessible and transparent. This is most aptly done through voluntary reporting. Of course, the more ESG-focused a company is, the less it would have to report, because the efficient investment in high-quality material and training would reduce incidents. But to make those investments, cross-industry data is still needed.

PATH TO IMPROVEMENT

The energy industry and transportation sector have made incredible strides to reduce incident rates, mitigate emissions, and improve their relationship to the environment. This is especially evident in recent ESG commitments. Despite this, produced water has emerged as a real problem that must be addressed through both understanding of data and targeted investment where the data reveals pitfalls. To capitalize on ESG pledges and further reduce incidents, there are two needed actions, one by individual companies and one by industry itself.

For individual companies, investment in design and material is essential to ESG.[40] This means identifying internal data and issues and striving to replace and upgrade material and operating procedures that allow failures to continue. Making these decisions also requires lifecycle cost analysis and a review of the externalities imposed on landowners and communities where they do business. Companies can leverage their internal analysis and review of contracts and locations to make great change, but the industry can only improve with a collaborative effort to produce information and make it available and accessible.

Better data is essential. This will guide companies in their investment in better materials, equipment, and training by informing them about the relative frequency of incidents, nature and causes, and standing against the backdrop of the entire industry. What is more, it will either ensure the industry remains free of burdensome regulation by demonstrating progress or could invite public scrutiny by continuing to withhold transparency.

Presently, few public databases exist to make information on upstream incidents available to the public. Among the public datasets, a wide variety of terminology and reporting practices exist. This makes findings difficult to determine and obfuscates the critical factors at play. The path to improvement requires that individual companies and the industry broadly buy in and make voluntary reports whenever incidents occur.

A single database is ideal, but that should also include a standardized form with set terminology and uniform volume units (or a software that includes auto conversions between ounces, liters, gallons, barrels, etc). Whether maintained by an individual company, nonprofit organization, or even regulatory agency, a single point is critical. Working groups, former industry personnel, or consultants may help this process.

In the end, the more that is reported, the more engineers and executives have to work with to refine their designs, make more efficient investments, conduct better trainings, and achieve ESG goals. This in turns reduces the amount of reporting necessary, as the industry rises with the tide of lower incident numbers. This will also improve relationships with the community, landowners, and regulators.

CONCLUSION

A basic look at the world around us makes clear that the energy sector, as well as its transportation partners, make modern life possible and empower other sectors by providing energy resources, raw materials, and economic value. As much good as the upstream oil and gas sector does for the nation and the world, it nevertheless faces untapped potential to streamline its operations, safeguard the environment, lower costs, and ultimately renew its commitment to partners such as landowners and local communities. The ESG actions taken to achieve these ends must nevertheless be based on data and dependent on a clear roadmap that lays out next steps to enable industry participants and outside observers to evaluate success and measure its impacts.

The longstanding – and still current – model is to produce high volumes, mitigate losses, and clean up spills if and when they routinely occur. It is clear, however, that this model is not adequate for keeping up with shareholder priorities of profits and environmental stewardship. That is because incidents cost more than just the value of lost product and cleanup dollars. Every incident risks externalities costing reputation, threats to future leases and contracts, invitations to litigation, and potentially provoking greater regulatory oversight and bureaucratic involvement.

In line with the longstanding model, oil and gas are the primary metrics used to measure the industry. This is rightly due to these commodities being the economic product extracted, transported, processed, refined, and sold. Yet the immense volume of waste from the E&P sector, exceeding the volume of valuable product in most instances, is the most direct threat to landowners and the environment today, and that makes it a threat to operators as well. Data on waste like produced water is not transparent, and thus makes it difficult to assess current actions or evaluate future commitments. From the limited data available today, we see that failure to invest in and maintain quality equipment is a key issue.

Equipment and material failures, corrosion, and human error at the well site, in transit, and at the central tank battery combine to leak millions of gallons of produced water annually across the country.

The ESG action that most easily addresses this is investment in the types of material less likely to fail, or less susceptible to the types of failure, corrosion, and human error. This includes reliance on flowlines made of high-quality materials and other pipe in place of trucking where possible to mitigate losses and reduce dust and other land disruptions. This also minimizes valve connections and exchange of fluids between modes, where spills are statistically more likely.

To establish the best ESG roadmap for any individual operator or corporation, and to step forward as an industry, better data must be a priority. While investment in materials and training are a necessary individual action, only by coming together to form a uniform reporting database will cross-industry transparency be effective. This will not only afford operators a chance to improve their own operations, but will provide metrics to measure their commitments and allow the public, shareholders, partners, and policymakers to ensure progress. An ESG commitment on this level may be necessary to avoid further costs, litigation, and regulatory oversight.

Recommended Citation for this report

B. Dierker. (December, 2021). *ESG in the Oilfield: Understanding the Impact of Nationwide Incidents and Improving Reporting Practices.* Alliance for Innovation and Infrastructure.

About Aii

The Alliance for Innovation and Infrastructure (Aii) is an independent, national research and educational organization that explores the intersection of economics, law, and public policy in the areas of climate, damage prevention, energy, infrastructure, innovation, technology, and transportation.

The Alliance is a think tank consisting of two non-profits: the National Infrastructure Safety Foundation (NISF), a 501(c)(4) social welfare organization, and the Public Institute for Facility Safety (PIFS), a 501(c)(3) educational organization. Both non-profits are legally governed by volunteer boards of directors. These work in conjunction with the Alliance's own volunteer Advisory Council.

Board of Directors

The Alliance for Innovation and Infrastructure (Aii) is an independent, national research and educational organization. An innovative think tank, Aii explores the intersection of economics, law, and public policy in the areas of climate, damage prevention, energy, infrastructure, innovation, technology, and transportation.

METHODOLOGY

Data is pulled from state departments of Environmental Quality and Oil and Gas Commission databases. Each state collects and reports data differently, and many operators or incident reporters use different terminology. When reports are normalized, we report those directly from state databases.

Where data is not normalized and individual incidents are not categorized, we grouped the following under the label "produced water": produced water, brine, saltwater, production water, saline water, oily water, connate water, formation water, flowback water, and additional synonymous terms like the above including "fluid". Additionally, all data was normalized to barrels, meaning initial reports in ounces, gallons, or other metric were rounded to the hundredth's decimal for barrels. These factors may lead to different totals than a given state may report. Efforts were made to eliminate redundant reports of the same incident.

Due to rounding, estimations, and grouping of categories, some numbers may not be exact.

APPENDIX A: NATIONAL RESPONSE CENTER (NRC)

There are only 412 incidents reported to the NRC in 2020 that unambiguously identified produced water or one of its synonyms (e.g. brine, saltwater, oily water, etc) as the Material Involved. These are reported in units as diverse as barrels, cubic meters, gallons, quarts, liters, cups, ounces, and teaspoons. The total amounts to approximately 25,000 barrels, which is well under the national level of produced water reported by state agencies.

The entries also reflect typos and redundancy, with alternate spellings of the same material field, variants of the same material with different punctuation, and more. Because the NRC fields public reports, it also includes many unknown substances that individuals believed were a concern. Finally, reports to the NRC span geographic areas from waterways to inland agricultural areas, urban settings to rural neighborhoods, and include sewage, natural runoff, and environmental flows like mud. This leads to reports for dropped groceries, spills in garages and auto shops, and manufacturing locations in addition to barge, pipeline, rail, truck incidents. Accordingly, materials range in type and specificity as widely as "almond milk" to "SPECTRA GRAFX ENVELOPE METHYL VIOLET / 4681".

APPENDIX B: STATE REPORTING REQUIREMENTS

Arkansas, *Arkansas Oil and Gas Commission General Rule B-26 and B-34*:

"Requires reporting immediately or within 24 hours of all fires, blow-outs, spills, leaks or discharges in excess of one (1) barrel of crude oil or five (5) barrels of produced water, which occur at these facilities."

Colorado, *Colorado Oil and Gas Conservation Commission Rule 906:*

"An operator must report to the Director of the COGCC, verbally or in writing (within 24 hours of discovery), a spill or release in which one (1) barrel of more of E&P waste or produced fluids is spilled or released outside of berms or other secondary containment or a spill." Does not specify regulations for produced water or the method of its transportation in rules regulating spilling rules.

A. A spills/release of any size that impacts or threatens to impact any waters of the state, a residence or occupied structure, livestock, or public by way;

B. A spill/release in which one (1) barrel or more of E&P Waste or produced fluids is spilled or released outside of berms or other secondary containment;

C. A spill/release of five (5) barrels or more regardless of whether the spill/release is completely contained within berms or other secondary containment."

Illinois, *Illinois Compiled Statutes 225 ILCS 732 Sec 1-75(c)(12)*

"…any release of produced water in excess of 5 barrels shall be cleaned up, remediated, and reported pursuant to Department requirements."

New Mexico, *N.M. Code R. § 19.15.29.9*

"**A.** The responsible party must notify the division on form C-141 of a major or minor release occurring during the drilling, producing, storing, disposing, injecting, transporting, servicing or processing of oil, gases, produced water, condensate or oil field waste including regulated NORM, or other oil field related chemicals, contaminants or mixture of the chemicals or contaminants, in accordance with the requirements of 19.15.29 NMAC.

B. If state, federal or tribal lands are involved, the responsible party must send a copy of the form C-141 to the appropriate land managing agency including the state land office, the BLM or tribal authority, as applicable."

North Dakota, *N.D. Century Code 38-08-04 Rule 2*

"A person controlling or operating a well, pipeline, receiving tank, storage tank, treating plant, or other receptacle or production facility associated with oil and gas, or with water production, injection, processing, or well servicing, shall report to the commission any leak, spill, or release of fluid. A report to the commission is not required if the leak, spill, or release is crude oil. produced water, or natural gas liquids in a quantity of less than ten barrels cumulative over a fifteen-day time period, remains on the site or facility, and is on a well site where the well was spud after September 1, 2000, or on a facility, other than a well site, constructed after September 1, 2000."

Montana, *Administrative Rules of Montana 36.22.1103*

"(1) The owner or operator of a facility must give immediate notice by telephone to an authorized representative of the board and a written report to the board administrator within five working days of any of the following emergencies:

(a) the spill, leak, or release of more than 50 barrels of oil or water containing more than 15,000 parts per million (ppm) total dissolved solids (TDS) ;

(b) the spill, leak, or release of any amount of oil or of water containing more than 15,000 ppm TDS that enters surface water or groundwater;

(c) the spill, leak, or release of any amount of produced water that degrades surface water or groundwater;"

Wyoming, *Oil and Gas Conservation Commission Chapter 4 Sec. 3*

" (a) The Owner or Operator shall take all reasonable precautions to prevent accidents and fires, shall notify the Supervisor within twenty-four (24) hours of all accidents (other than personal injuries and deaths) or fires of major consequence, and shall submit a full report thereon within fifteen (15) days.

(b) Uncontained spills or unauthorized releases of produced fluids, drilling muds, produced water, hydrocarbons, or chemicals which enter, or threaten to enter, waters of the state must be verbally reported to the Commission no later than the next business day following discovery of the incident. The Owner or Operator shall file a written report within fifteen (15) working days.

(c) Regardless of the type of surface containing the fluids, contained spills of crude oil, condensate, produced water, or a combination thereof, which occur on a lease, unit, or communitized area, except on state lands, and do not physically enter waters of the state and are immediately contained, removed, and disposed of properly,

(i) Contained spills of less than one (1) barrel (42 gallons) are not required to be verbally reported. The Owner or Operator shall maintain a record of such spills, the volume and actions taken to contain, remove and properly dispose and have the records available for review by the Commission upon request.

(ii) Contained spills of greater than one (1) barrel (42 gallons) and less than ten (10) barrels (420 gallons) are not required to be verbally reported. The Owner or Operator shall file a written report within fifteen (15) working days of the spill.

(iii) Contained spills equal to or greater than ten (10) barrels (420 gallons) shall be verbally reported to the Commission no later than the next business day following discovery of the incident. The Owner or Operator shall file a written report within fifteen (15) working days of the spill.

(iv) An example of the information normally required by the Commission for reporting spills is included in the Incident Report (Form 21; Appendix E). The Commission accepts copies of reports prepared to satisfy the requirements of the Department of Environmental Quality or the Bureau of Land Management."

CITATIONS AND NOTES

[1] Pipeline and Hazardous Materials Administration (2021). *Pipeline Incidents 20 Year Trends*. Retrieved from https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends.

[2] Groundwater Protection Council (2019). *Produced Water Report: Regulations, Current Practices, and Research Needs*. p. 59.

[3] Additionally, any release of one or more barrels of hydraulic fracturing fluid or flowback must be reported.

[4] *Louisiana Administrative Code Title 33 Sec 708 (C)(1)(iv)* "In the event of an unauthorized discharge of oil, produced water, or any other product or waste material, a remedial response must be immediately initiated and the Office of Environmental Compliance shall be notified in accordance with LAC 33:I.3901 et seq."

[5] *Texas Administrative Code Title 16 Part 1 Chapter 3 (a) (1)* "Operators shall give immediate notice of a fire, leak, spill, or break to the appropriate commission district office by telephone or telegraph. Such notice shall be followed by a letter giving the full description of the event, and it shall include the volume of crude oil, gas, geothermal resources, other well liquids, or associated products lost."

[6] Quiroga, C., Holik, W., Li, J., Tsapakis, I., Bierling D. (2019). *Temporary Saltwater Pipelines: Current Practice and Recommendations*. Texas A&M Transportation Institute. P. 82. (emphasis added)

[7] United States Coast Guard National Response Center (2021). *Initial Incident Data*. Retrieved from https://nrc.uscg.mil/.

[8] The National Response Center compiles reports from laypeople, industry, and others. It does not appear to be curated for redundancy, standardized with set categories, or normalized in metrics.

[9] Summary findings of NRC in Appendix A

[10] Although it can be used for enhanced oil recovery and other injection purposes, as well as thoroughly treated and recycled for irrigation or other purposes.

[11] Balboa, B. (2020, March 1). *GWPC report shows us produced water up alongside oil and Gas*. Journal of Petroleum Technology. Retrieved from https://jpt.spe.org/gwpc-report-2017-shows-us-produced-water-alongside-oil-and-gas.

[12] U.S. Energy Information Administration (2021). *Frequently Asked Questions (FAQ)*. Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=268&t=6.

[13] Coffee, S., (2018). *Texas Produced Water Management*. Retrieved from https://www.texasdesal.com/wp-content/uploads/2017/12/Steve-Coffee.pdf

[14] Although the synonym "discharge" is often used, primarily in reference to disposing of or appropriately releasing the water rather than accidental releases.

[15] New Mexico Oil Conservation Commission (2021). *Oil Conservation Division Spill Database*. Retrieved from https://wwwapps.emnrd.state.nm.us/ocd/ocdpermitting/Data/Spills/Spills.aspx.

[16] Lauer, N. E., Larkness, J. S., and Vengosh A. (2015). *Brine spills associated with unconventional oil development in North Dakota*. Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University.

[17] U.S. EPA (U.S. Environmental Protection Agency). 2016. *Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States*. Executive Summary. Office of Research and Development, Washington, DC. EPA/600/R-16/236ES.

[18] Energy and Environmental Research Center, University of North Dakota (2015). *Liquids Gathering Pipelines: A Comprehensive Analysis*. Retrieved from https://undeerc.org/Bakken/pdfs/EERC%20Gathering%20Pipeline%20Study%20Final%20Dec15.pdf.

[19] Combined total is not a sum of crude plus produced water, because some incidents spilled both substances.

[20] Center for Western Priorities (2019). *2019 Wyoming Oil and Gas Spill Tracker*. Retrieved from https://westernpriorities.org/2020/02/27/2019-wyoming-oil-and-gas-spills-tracker/.

[21] Wyoming Department of Environmental Quality (2021). *Spills and Complaints*. Retrieved from https://deqspills.wyo.gov/home.

[22] Colorado Oil and Gas Commission (2021). *Spill Analysis by Year 1999-2nd Quarter 2021*. Retrieved from https://cogcc.state.co.us/documents/data/downloads/environmental/SpillAnalysisByYear.pdf.

[23] Id.

[24] U.S. Environmental Protection Agency (2015). Review of State and Industry Spill Data: Characterization of Hydraulic Fracturing-Related Spills. Retrieved from https://www.epa.gov/sites/default/files/2015-05/documents/hf_spills_report_final_5-12-15_508_km_sb.pdf.

[25] Human error here is the result of self-reporting by the operator on site. This finding is in sharp contrast with an EPA study published in 2015, which found that for a select group of hydraulic fracturing-related spills, human error was the majority cause of incidents and spills. The EPA investigation likely went beyond reports to identify additional human errors or pulled out human error as a separate category when an incident had a dual cause such as equipment failure and human error. Finally, the study dates included years during the fracking boom, when demand for labor was high and new workers entered the E&P sector. Data for 2020 likely differs for a number of reasons.

[26] Although many states do include gathering systems in their reporting. Further, due to categorization, "transportation" can sometimes conflate all modes of movement, while "vehicle" can also identify instances where a vehicle struck a pipeline or tank, rather than a spill happening from a vehicle rollover accident or wastewater being leaked or spilled during change of custody.

[27] Alliance for Innovation and Infrastructure (July 2021). *How the U.S. Moves Hazardous Materials*. Retrieved from https://www.aii.org/wp-content/uploads/2021/07/How-the-U.S.-Moves-Hazardous-Materials.pdf.

[28] Dierker, B. (May 14, 2021). *"Pipe Is The Best Way to Go," Says Biden Energy Secretary*. Retrieved from https://www.aii.org/pipe-is-the-best-way-to-go-says-biden-energy-secretary/.

[29] "Most of well development-related traffic in Texas occurs on rural roads. These rural roads, such as farm-to-market (FM) roads, ranch-to-market (RM) roads, and county roads, were never designed to carry the huge amount of truck traffic associated with energy developments. Most of those roads were built decades ago to serve mostly local low-volume traffic needs, not repetitive heavy truckloads. The result has been accelerated degradation of pavements and roadside infrastructure, as well as increases in congestion and crash and fatality rates." Supra note 6 at p. 1.

[30] Groundwater Protection Council (2019). *Produced Water Report: Regulations, Current Practices, and Research Needs*. p. 234.

[31] Id. at p. 222.

[32] "Hydraulic fracturing operations at a well site may require approximately 50,000 barrels of water per day. Trucks typically have a capacity of 120 barrels. Thus, if a truck is making a 20-mile round trip to deliver 120 barrels of water and all of the water is delivered by truck, the trucks would drive about 8,300 miles per day. If the loading, unloading, and roundtrip driving took two hours, the ongoing operations would require 35 trucks 24 hours per day. For these reasons, sourced water for operations is largely provided by a series of permanent and/or temporary water pipelines" Id. at p. 51.

[33] Id. at p. 242.

[34] Id. at p.11-12.

[35] Lyons, B., Tintera, J., & Wright K., (2019). *Sustainable Produced Water Policy, Regulatory Framework, and Management in the Texas Oil and Gas Industry: 2019 and Beyond*. Texas Alliance of Energy Producers, p.6.

[36] Although industry protection of sensitive information or liability may be considered through a dual-accessible database that includes basic information publicly and private information behind an industry log-in portal.

[37] American Petroleum Institute (2021). *Pipeline Strategic Data Tracking System (PSDTS)*. Retrieved from https://www.api.org/oil-and-natural-gas/wells-to-consumer/transporting-oil-natural-gas/pipeline-performance-tracking-system/ppts-overview.

[38] Common Ground Alliance (2021). *2020 Analysis and Recommendations*. Retrieved from https://commongroundalliance.com/Publications-Media/DIRT-Report.

[39] Wyland, S. (2021, June). New Mexico commission weighs rule to prevent oil, gas drillers from making spills. Santa Fe New Mexican, https://www.santafenewmexican.com/news/local_news/new-mexico-commission-weighs-rule-to-prevent-oil-gas-drillers-from-making-spills/article_ce02b924-c931-11eb-921c-27dfdd1af43f.html.

[40] "Permanent pipelines require appropriate design, considering physical and operating conditions including normal operating pressures and flows, pipeline material, pump station spacing, and control and isolation valves." Produced Water Report, p. 58.

[Image 1] Gira, Lindsey. "Williston North Dakota Oil Field Tank Batteries." Https://Commons.wikimedia.org/Wiki/File:Williston_North_Dakota_Oil_Field_Tank_Batteries_(5894584980).Jpg.

[Image 2] Gira, Lindsey. "Williston North Dakota Oil Field Oil Rig." https://commons.wikimedia.org/wiki/File:Williston_North_Dakota_Oil_Field_Oil_Rig_(5894614162).jpg.

[Image 3] Photo by Chris Landsberger, The Oklahoman. Presented for educational purposes.

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