Beneficial Use of Produced Water for Roadspreading:

Perspectives for Colorado Policymakers

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Abstract

The multifaceted and controversial practice of applying produced water to roads for dust and ice control has now gained the attention of Colorado policymakers. The state is deciding whether to permit the beneficial use of produced water on roads, including that from hydraulic fracturing operations, but a number of uncertainties hamper the decision-making process. Among these uncertainties are the precise practices and policies surrounding roadspreading in other American states, particularly in regards to how decisions are justified and framed to the general public. Academic studies on both policy and technical aspects of roadspreading are scant, necessitating further research. This paper provides a Colorado-tailored comparative study of state-level roadspreading policies, including the context under which current policy has been developed. Interview results from relevant administrators in government agencies across a sample of both roadspreading and non-roadspreading states are presented. Select interviews with relevant experts and key players are also featured. Finally, insights from these conversations, state-specific experiences surrounding roadspreading, and recommendations to policymakers in Colorado are provided. A lack of knowledge on the chemical constituents found in produced water, as well as the effects they may have on public health and the environment when released via road applications, cautions against state approval of off-site, wide-scale roadspreading.

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Introduction/Background

As shale gas development expands and its costs continue to drop, management of waste byproducts from hydraulic fracturing is as complex as ever. When this expansion is combined with water shortages in the Western United States, efficient re-use of produced water from oil and gas operations becomes increasingly prudent. Therefore, treatment and recycling toward beneficial use has gained attention recently as Western states cope with stressed water resources.

The opportunity to utilize conventional and fracking-based produced water for dust suppression and de-icing on roads, which is one example of beneficial use, has garnered both positive and negative feedback in Colorado. The Colorado Department of Public Health and Environment (CDPHE) is at a crossroads on the issue of whether to permit and promote the application of produced water from hydraulic fracturing operations on roads for dust suppression and de-icing, also known as roadspreading. Compounds such as magnesium chloride along with other commercially available products are currently used for these purposes and feature a measurable track record regarding impacts on public health and the environment. However, one industrial facility on the state's Western Slope is petitioning CDPHE to allow usage of produced water containing hydraulic fracturing flowback for roadspreading. Said facility intends to accept payments from oil and gas producers in exchange for receiving and treating produced water, including that which contains flowback. It then desires to sell this brine to other entities partly for application toward dust suppression. This facility had previously been allowed to sell brine to Montezuma County, among other jurisdictions, but it fell out of compliance with CDPHE in May 2017 due to reporting and labelling violations and its permit was revoked (Mimiaga, 2017).

In the meantime, the agency has deliberated over whether allowing roadspreading of produced water (also known as oilfield brine) is consistent with safeguarding public health and

the environment. CDPHE must now determine the best course of action, as its decision may set a precedent in a state where several other facilities desire to apply such on-site or purchased produced water toward beneficial use and roadspreading.

The purpose of this project is to provide CDPHE with added knowledge and perspective on how produced water, including that which originates from fracking operations, is dealt with elsewhere vis-à-vis beneficial use and roadspreading. This paper tackles two primary research questions: What dust suppression-related policies and practices govern beneficial use of produced water in other states? And under what conditions should produced water be approved for beneficial use on Colorado roads? In gathering data on policies and practices seen in other states and applying this information to Colorado, the paper develops recommendations to CDPHE on whether to allow produced water for these purposes. Further recommendations are offered on how CDPHE can best proceed in the areas of implementation, consideration of alternatives, solicitation of stakeholder input, framing, and justifying its decision.

Organizational Profile

The Colorado Department of Public Health and Environment (CDPHE) is a cabinet-level state agency of Colorado whose primary responsibility is protection of public health and the environment, as its title suggests. CDPHE's mission is "to protect and improve the health of Colorado's people and the quality of its environment", while its official vision is that "Colorado will be the healthiest state with the highest quality environment." CDPHE uses evidence-based practices and responds to emerging issues with the goal of creating a healthy state populated by healthy people. The Department head functions as the state's chief medical officer, and the agency's budget is approximately $563 million. Originally founded in 1876 as a nine-person health board, CDPHE now employs 1,311 people, most of whom are based at the agency's

Glendale campus as well as its central laboratory in Denver.

Literature Review

As a relatively young policy issue, beneficial use of produced water does not feature an enormous amount of extant literature, especially when narrowed down further to dust suppression and de-icing practices, specifically. While comprehensive, reliable studies focusing on the use of produced water for dust suppression and de-icing are practically nonexistent, a body of research on the beneficial use of produced water in general is available and, taken together with literature on water management at oil and gas sites, the environmental and public health impacts of hydraulic fracturing and other energy extraction, energy production in Colorado, and public engagement, it is possible to build a foundation for the research at hand.

Basics of produced water in the West: Arid Western areas of the United States, such as Colorado, lie at the forefront of the water-energy nexus. This nexus pits the health and volume of water systems that citizens depend on for drinking water, agriculture, recreation, and other functions against the needs of oil and gas interests, which depend equally on an ample, accessible water supply for everyday operations (Sullivan Graham, Jakle, & David Martin, 2015). As droughts continue to afflict the West, one major implication of the water-energy nexus is that wastewater from Western oil and gas operations is slowly coming to be regarded as an asset, rather than a liability (Dallbauman & Sirivedhin, 2005).

In Colorado, the number of active unconventional gas wells more than doubled between 2000 and 2015 from 22,228 to 53,228, with much of this growth occurring in the Wattenberg Field of the Denver-Julesburg Basin (Rosenblum et al., 2017). Over 41,000 acre-feet of produced water was generated in the state in 2012, with about half of this total originating from the Western Slope (Colorado Energy Office & Colorado Mesa University Water Center, 2014).

Broadly speaking, Colorado water law regards industrial re-use of produced water as a valid use of water. If withdrawn and used within the same geological basin, Colorado regulators may allow well operators to re-use this produced water for dust suppression on operators' lease roads without a permit, as long as it is non-tributary, as per CRS § 37-90-137(7) (Colorado Energy Office et al., 2014). If an underground body of produced water is classified as tributary, a permit must be sought from the State Engineer prior to extraction so as to safeguard vested water rights (Vance v. Wolfe, 2009).

Management, treatment, and composition of produced water: Fracking fluids are used to puncture, widen, and otherwise create passageways within rock through which hydrocarbons can be extracted. Fracking fluids normally re-emerge at the surface on the first day and in the first two to three weeks after initial fracturing of shale-containing rock, when approximately 10-40% of fracking fluid returns out through the wellbore (Gregory, Vidic, & Dzombak, 2011), but remnants of fracking fluid may persist below ground for years. On the other hand, produced water (also known as formation water or oilfield brine) is water that naturally exists in geological formations underground and which flows up to the surface gradually via the wellbore upon drilling. Produced water typically features high salinity, with varying salt levels depending on site-specific geology, but aside from the addition of some maintenance chemicals over the life of a well, produced water contains fewer, only trace amounts, or sometimes none of the industrial chemicals that are a signature of fracking fluids (Konkel, 2016; Silva et al., 2017). In other words, fracking fluids are distinct from produced water, but at times produced water may contain lingering constituents from fracking fluids and flowback.

Water management in the field of unconventional gas drilling entails a water life cycle

consisting of five primary stages: water acquisition, chemical mixing, well injection, flowback and produced water generation, and treatment and disposal (Torres, Yadav, & Khan, 2016, 480-483). As Schaffer et al. (2013) indicate, management of produced water from oil and gas operations is highly dependent on underlying economic factors which are shaped by the volume and quality of produced water at hand, the nature of state and federal regulations, infrastructure available for treatment and handling, geography, and geology. In the oil and gas industry, a full 5-15% of all drilling and related management expenditures are spent on water management, transport, storage, disposal, and treatment (Silva et al., 2017). By some estimates, over 98% of produced water in the United States is currently reinjected underground (Schaffer et al., 2013; Farag & Harper, 2014). A total of 20 billion barrels of produced water are created each year in the United States from all conventional and unconventional oil and gas operations, of which an estimated 3.5 billion barrels can be attributed to unconventional gas drilling such as fracking (Silva et al., 2017).

As many researchers note (Schaffer et al., 2013; Pichtel, 2015; Silva et al. 2017; Torres et al., 2016), produced water can contain a variety of constituents known to deleteriously impact environmental and human health, including total dissolved solids (TDS), suspended solids, dissolved and suspended organic compounds (including volatile organic compounds [VOC's]), high concentrations of salt (brine), industrial chemicals introduced during fracturing, heavy metals, bacteria, scaly (hard or course) substances that can corrode storage or treatment infrastructure that they come into contact with, hydrocarbons, and radioactive isotopes. Plenty of these compounds and substances are toxic to humans even at exceedingly miniscule concentrations (Silva et al., 2017). This is especially true of VOC's, including benzene, toluene, ethylbenzene, and xylenes (Silva et al., 2017; Schaffer et al., 2013). According to Farag &

Harper (2014), both acute and chronic exposure to sodium chloride and bicarbonate adversely affect the health of aquatic species, possibly through ionoregulatory upset, which alters enzyme levels in aquatic populations. These constituents are common in produced water, and if applied to roads for dust suppression and de-icing, may migrate into water bodies and harm aquatic life. It follows that drier ecologies like Colorado are less well-equipped to flush out salinity and sodicity, since there is less precipitation to help dilute values (Dallbauman & Sirivedhin, 2005).

Treatment and desalination prior to re-use most often aims to reduce TDS levels through thermal or reverse osmosis membrane technologies, but other target constituents and treatment technologies are frequently combined and included as well (Schaffer et al., 2013; Pichtel, 2015). As illustrated by Pennsylvania's recent experience, produced water should not be sent directly to municipal water treatment plants after extraction. The state found that concentrations of radionuclides, heavy metals, and chlorides were actually higher in water bodies downstream than upstream from municipal treatment plants that were receiving produced water. Upon this discovery, Pennsylvania compelled pre-treatment of virtually all produced water at central industrial sites in 2011, and by 2015 the Environmental Protection Agency (EPA) had promulgated national rules and guidelines on pre-treatment prior to processing at municipal facilities (Silva et al., 2017). Proppants, gellants, foamers, cross-linkers, breakers, acids, pH control, biocides, corrosion inhibitors, scale inhibitors, iron control, clay stabilizers, defoamers, friction reducers, and surfactants are among the multitude of chemical classes found in injected fracking fluids and, taken together with traditional constituents found in formation water, create immense challenges in unpacking possible threats to public health and the environment (Pichtel, 2015; Silva et al., 2017).

The specific geological characteristics of each hydrocarbon basin dictate TDS levels and

other produced water characteristics that inform treatment and management. In the case of hydraulic fracturing flowback, it is common to find industrial chemicals, unlike in produced water, but salinity levels and TDS are typically lower than that of produced water (Hume, 2015; Colorado Energy Office et al., 2014). This allows for easier and more cost-effective treatment, as high salinity presents an impediment to treatment processes. On the other hand, saltier samples of produced water also tend to possess heightened concentrations of radionuclides (Rosenblum et al., 2017; Brown, 2014; Silva et al., 2017). Some researchers have found that diluting radioactive oilfield water with acid mine drainage, another common pollutant in the West, can reduce these heightened radioactivity levels and double beneficial use (Brown, 2014).

By some accounts, and contrary to estimated reinjection rates noted above, up to 5% of all wastewater from oil and gas operations in the United States is released to the environment illegally or accidentally (Konkel, 2016). This reality, along with the fact that each horizontal fracturing well uses between 2 million and 5 million gallons of water in its lifetime (Konkel, 2016; Pichtel, 2015), has created an added impetus to re-use water in the West. Re-use and recycling of produced water, however, requires infrastructure overhauls and capital expenditures such as enhancement of treatment systems, tank and pit storage, pipelines, and pump stations (Sullivan Graham et al., 2015).

Implications for ecological and human health: Konkel (2016) uncovers several other items of note relating to produced water. Most importantly, very little is known about how various carcinogens and other toxicants found in produced water affect human health and the environment, as studies on specific compounds are rare and establishing correlation-causation is difficult. Although the EPA has gathered and released to the public a list of toxicity values for over 1,600 chemicals found in fracking operations, the effort suffers from enormous gaps in

toxicological data that could ideally be used to form risk assessments and gauge what levels of daily exposure present a threat to public and environmental health (Konkel, 2016). As it stands, a sizeable and growing body of epidemiological research demonstrates an association between close proximity to drilling operations, including fracking, and incidence of birth defects, miscarriage, decreased semen quality, and other endocrine disruptions. One experiment on mice found that exposure to both high and low levels of fracking-related chemicals increased hormonal and estrogenic abnormalities, and a separate study of water samples in spill-prone drilling areas of Garfield County, Colorado found well-above-average levels of endocrine disruptors that affect humans (Konkel, 2016).

Moreover, Colborn, Kwiatkowski, Schultz, and Bachran (2011) identified 353 chemicals found in ingredients used for natural gas drilling and discovered that a large percentage may damage human health in both the short- and long-term, even if symptoms are not expressed right away. Specifically, over 75% of these chemicals can affect the respiratory system, the gastrointestinal system, the liver, and sensory organs such as eyes and skin, while over half exhibit effects on the nervous system and brain. Highlighting organs susceptible to long-term, chronic damage, 52% of these 353 chemicals affect the nervous system, 40% affect the immune system and kidneys, 46% affect the cardiovascular system, 37% affect the endocrine system, and over 25% can cause cancer. More than 40% have also been demonstrated to harm ecological systems. Further, according to Colborn et. al, the little-studied chemical makeup of evaporation ponds and pits feature the most extreme toxicity of the natural gas process, and all but one out of the 40 evaporation infrastructure-related chemicals researched appear on the EPA's Superfund registry. But without expanded data and testing that accounts for baseline health outcomes measured against human health near drilling sites, there is no way to accurately associate specific

chemicals found in produced water and flowback with adverse health effects (Konkel, 2016).

Salinity and geological chemicals in fracking fluid-laced flowback water are generally more diluted than in produced water (Silva et al., 2017), but said water does contain a range of contaminants that do not naturally occur in liberated underground water formations. New figures indicate that about 18.9% of chemicals in fracking fluids (one to two percent by volume) are withheld from public disclosure (Konschnik & Dayalu, 2016). The exact makeup of these varying proprietary mixes is likely to be unknown to authorities, but such mixtures are now widely recognized to contain endocrine disruptors and other constituents toxic to human health (Konkel, 2016; Pichtel, 2015). Nevertheless, in some cases, produced water can be more hazardous than fracking fluid used at the same well, owing to millennia-long geological seepage into the ancient seabeds from whence produced water is drawn. Additionally, depending on underground geology, a drilling site may generate more flowback water than produced water (usually in the case of dry formations), or vice versa (Silva et al., 2017). When not re-used on-site toward further drilling, these wastewaters are most often disposed of via off-site injection wells, evaporation ponds, transport to treatment plants, controlled release to natural water bodies (when deemed safe), and agricultural application (Pichtel, 2015; Torres et al., 2016). Gregory et al. (2011) articulate the benefits of on-site re-use, including a lessening of water volumes that need treatment, lower costs as transport and hauling are obviated, and a geographical reduction in environmental risk and footprint, but technical drawbacks such as potential declines in gas production may also occur when the same produced water is repetitively used in gas wells.

Roadspreading of Produced Water: Currently, the utilization of produced water for dust suppression only accounts for a miniscule portion of produced water re-use, but momentum is gaining to divert increased amounts of wastewater toward roadspreading, rather than to deep-

well injection. In 2009-2010, only 0.007% of all produced water generated in the Marcellus Shale region was directed toward dust suppression on roads, although a separate figure indicates that 3% of Pennsylvania's produced water is roadspread (Torres et al., 2016; Skalak et al., 2014). One study found that beneficial use of produced water for de-icing elevates radium, strontium, sodium, and calcium levels in roadside soils (Skalak et al., 2014). Another study examined the effectiveness of dust suppression using produced water on three unpaved North Dakota roads, concluding that the produced water at hand failed to decrease dust loading (Graber, Hargiss, Norland, and DeSutter, 2017). Yet another study found that inadequate administrative oversight and an absence of site-specific pre-assessment of environmental impacts led to harmful spreading of oilfield brines in an aquifer recharge zone in Ohio (Eckstein, 2011). Data on existing roadspreading is otherwise scarce.

Public attitudes and involvement: As for public perceptions of energy development, hydraulic fracturing, and related regulatory oversight of public health, Hagstrom, Lyles, Pattanayek, DeShields, and Berkman (2016) explain that skepticism and alarm are coursing through many citizens and advocacy organizations. Recent well-publicized incidents, such as the lead crisis in Flint, Michigan, and the questionable application of Chevron's produced water on California agriculture, have brought increased negative attention to industry practices and governmental failures to safeguard public health. Therefore, it is important that policy decisions surrounding produced water account for sensitivities and misgivings expressed by members of the public and interest groups who are wary of contamination. To better understand public perceptions on fracking flowback re-use and management, Theodori et al. (2014) surveyed residents of the Marcellus Shale region of Pennsylvania, the setting of a major ongoing shale gas play. This study is summarized in Appendix A. Both Hagstrom et al. (2016) and Theodori et al. (2014)

agree that increased collaboration, transparency, and trust-building with the public on the part of government and industry will be necessary to assuage citizen concerns.

When setting policy and practice on hydraulic fracturing, Perry (2012) recommends a distinct framework for gauging nonmonetary and non-quantitative impacts of natural gas and other drilling. Since purely scientific and technical appraisals often fail to account for the full effects of an action or policy on a social, community, cultural, environmental justice, or psychobehavioral level, a more holistic approach to risk assessment is appropriate. With ecological, regulatory, and industry variables as inputs, Perry develops a community-based method of calculating risk that supplements scientific and technical considerations. This same framework can be applied to policymaking on beneficial use of produced water so that a more wholesome picture of risk may emerge and the under-measured long-term and cumulative impacts on ordinary people may be better understood by policymakers from the outset. To Perry, consultation with the public is an integral first step in crafting policy rather than a last step that precedes a final decision and follows the heavy lifting of technical and practical analysis.

A 2014 Grand Junction stakeholder summit on produced water, hosted by the Colorado Energy Office and Colorado Mesa University, revealed a willingness among myriad actors across Colorado to enhance re-use and recycling. A summary of this summit can be found in Appendix B. All in all, participants broadly agreed that clarification of the state's regulatory structure relating to dust suppression is overdue (Colorado Energy Office & Colorado Mesa University Water Center, 2014).

As a whole, a review of the literature suggests that increased unconventional oil and gas development in the West has created a bevy of water management challenges that interact with the West's need to conserve clean water. As production brine has been displaced from

geological formations and put to beneficial use, many negative ecological and human health impacts have been recorded, raising the suspicions of the public, academia, government, and others. To this day, though, very little research has been carried out on roadspreading of produced water, and where it has, generalizable findings are few and far between.

Methods

This research project is of a qualitative, descriptive nature, and aims to answer the following research questions:

- What dust suppression-related policies and practices govern beneficial use of produced water, including that which contains constituents from hydraulic fracturing flowback, in other states?
    - When deciding to approve or disallow produced water for beneficial use on roads, how have other states framed and justified their decisions? What experiences influenced these decisions?
- How do Colorado's particular circumstances affect the decision to approve or deny produced water for beneficial use on roads, and what helps or hinders the effort in Colorado to implement this decision? In other words, under what conditions should produced water be approved for beneficial use on Colorado roads?
    - What regulatory approach should Colorado decide to take?

Interviews via phone were conducted with relevant agencies in a total of 11 states. Of these, all six states that allow off-site roadspreading of produced water (Michigan, New York, North Dakota, Ohio, Pennsylvania, and West Virginia) were sampled, as well as five that do not permit off-site roadspreading (Arizona, California [Central Valley Region], Oklahoma, South Dakota, and Texas). In-depth interviews were used for the former states, while the latter were asked a less-expansive series of questions due to their restrictive policies. Prior to interviews, familiarity with the basics of pertinent state policies was attained so as to help guide interviews.

This research also entailed a supplementary stage-setting element that helps answer the second research question relating to underlying circumstances that would be necessary for approval in Colorado. To provide added insights, a small series of interviews were conducted

with in-state and out-of-state experts and relevant actors. Industry representatives, environmental protection specialists, university researchers, and others that boast high levels of relevant knowledge and expertise on produced water and dust suppression were consulted and their perspectives and experiences on the matter chronicled. This element helped develop recommendations and translate state-to-state findings to the Colorado context.

During the process of gathering data, various components of the issue were grouped together into four categories according to general theme:

Regulatory/Legal:

- Legal and regulatory status of roadspreading using produced water;
- Types of beneficial use allowed, such as dust suppression and de-icing;
- Agency jurisdiction over regulation/management: on-site, off-site, types of waste, delineation of regulatory tasks, etc.;
- Who, exactly, may physically apply the water (operator, intermediary, etc.);
- Whether beneficial use rules are codified in law/official policy, or through guidance;
- Whether there is a uniform policy or a case-by-case basis for permitting roadspreading;
- Any proposed changes, including rejected proposals (and reasons for rejection);

Practical Considerations:

- States' positions on application and measurement of fracking flowback water (distinct from normal produced water);
- Runoff controls for road applications, such as rules on frequency, duration, and volume;
- Tracking and monitoring;
- Facilitators for implementing beneficial use of produced water on roads;
- Impediments to implementing beneficial use of produced water on roads;
- Level of concern over increased salinity and related harmful effects on ecology;
- Costs of transporting produced water, and other economic aspects;

Technical/Scientific:

- Specific chemicals/substances required to be tested in order to grant beneficial use;
- Overall testing criteria, including if brine is tested for accurately;
- Whether current testing and sampling is considered adequate;
- Extent of knowledge on the makeup of produced water and flowback;
- Alternative commercial products used, compared, or tested;
- Treatment options and present realities;
- Geological considerations;

Stakeholder/Public Input, and Framing/Justification of Current Policy:

- Stakeholder process(es) surrounding promulgation of rules/guidelines on produced water;

- Whether states' decisions on the matter are political, economic, or technical/scientific;
- Justifications for current policies to the public, industry, and government;
- Conditions necessary for permission of roadspreading using produced water;
- State-specific experiences that influenced decision-making

Trends, patterns, and phenomena useful to CDPHE's decision-making process contained within these four categories are unpacked and presented in the *Results* section.

In selecting the most appropriate sample of states for the research at hand, it was decided that an attempt would be made to gather data from every roadspreading state, which was successful. The remainder of the sample comprises states whose geographies, geologies, political and regulatory traditions, and industrial bases substantially resemble those of Colorado. Other such states were contacted, but only the five included here were available for interviews.

Internal validity is achieved, as the data gathered from representatives of state agencies is truthful and relatively complete. Reliability is achieved, as a subsequent researcher can use the same framework and interview questions to piece together similar results on beneficial use of produced water as presented in this paper. It was crucial to construct clear questions, ensure confidentiality, and meticulously record responses so that validity and reliability are upheld.

Results

Findings from interviews shed light on roadspreading practices and experiences throughout the country. Detailed results from roadspreading states can be found in Appendix C, from non-roadspreading states in Appendix D, and from experts/relevant actors in Appendix E.

Roadspreading States:

Regulatory/Legal: Six states in total currently allow the use of produced water for roadspreading on a wide scale beyond lease roads, with all banning fracking fluids. West Virginia only allows oilfield brine for winter management such as pre-wetting, anti-icing, and de-icing on roads, and Pennsylvania limits roadspreading to dust suppression and road stabilization, but Michigan, New

York, Ohio, and North Dakota allow roadspreading during any season for both dust and ice management. These states regulate roadspreading through their respective environmental, health, and natural resources agencies, with some shared duties at times. Additionally, Ohio's Department of Natural Resources and New York's Department of Environmental Conservation leave the decision of whether or not to allow roadspreading of produced water up to local and county governments, only choosing to set and enforce standards for those jurisdictions that do elect to roadspread. Many counties in the Western, energy-producing region of New York permit the spreading of oilfield brines, while other Downstate/Eastern counties expressly prohibit the practice, partially for political reasons and fear of public outcry. In Ohio, local governments must pass an authorizing resolution before roadspreading can be initiated within their jurisdiction. Formal Beneficial Use Determinations (BUDs) are only required in New York, but the other states often feature approval processes that function similarly.

Table 1: Brief Summary of Roadspreading States

State	Regulatory/Legal	Practical	Technical/Scientific	Rationale/Framing
Michigan	Allowed for dust/ice control, codified	Historical use	7 constituents tested	Legal, public safety on roads, no contamination seen
New York	Allowed for dust/ice control, codified	Historical use	15 constituents tested	Economic/scientific, environmentally sound
North Dakota	Allowed for dust/ice control, guidance	Historical use	20 constituents tested	Scientific, comparison to market alternatives
Ohio	Allowed for dust/ice control, codified	No major historical use	0 constituents tested	Political/economic at first, scientific after, no contamination seen
Pennsylvania	Allowed for ice control/road stabilization, guidance	Historical use	5 constituents tested	Political/scientific/ economic, no widespread impacts
West Virginia	Allowed for ice control, guidance	No major historical use	13 constituents tested	Economic/scientific, comparison to market alternatives

Typically, these states require brine storage plans and roadspreading plans detailing application rates, volumes, durations, runoff control, and locations prior to approval. Parameters on runoff controls and rules on application are set by all states, which are in place to prevent oversaturation and migration to water bodies. West Virginia, for instance, sets a maximum application rate of 10 gallons per ton during pre-wetting, 50 gallons per lane mile during anti-icing, and 100 gallons per lane mile during de-icing. However, in some cases such as Pennsylvania's and North Dakota's, application specifications are simply guidelines and not stringent rules. Moreover, New York delegates rules on application rate, frequency, duration, and volume to local governments. In all permitting states, logs must be kept by spreader trucks detailing time, location, volumes, rates, and geological sources of produced water applied, but in practice tracking and monitoring is nearly nonexistent in most states, and it is difficult for state agencies to access roadspreading records, some of which are not well-maintained, from busy county supervisors. Some states also require hauling and waste transporter permits.

Three states have codified their roadspreading regulations, while the other three regulate through guidance. Criteria during initial permitting are more stringent than afterward, and annual re-approval is found in Pennsylvania. High-volume fracking well water is ineligible for roadspreading in all states, while only low-volume fracking operations may provide brine in Michigan and New York (where fracking flowback and fluids are banned), and only very few cases of horizontal wells in specific formations supply brine in Ohio. Unconventional wells are banned from providing brine in Pennsylvania and West Virginia, while shale formations only very rarely supply brine in North Dakota, where flowback and fracking fluids are also banned. Despite approval, roadspreading does not occur in West Virginia due to the economics of testing.

Practical Considerations: Similar to the runoff-related rules above that specify application rates, volume, and frequency, several other rules on practical elements of roadspreading exist. Agencies realize that bodies of surface water and ground water near roads are susceptible to migrating constituents found in produced water, so roadspreading cannot simply occur anytime at any place. As an example, in New York roadspreading cannot take place within 50 feet of any water body, before or during rainfall, or on roadways with a grade higher than 10 percent. Most states do not allow roadspreading outside of daylight hours in case of spill or visibility issues.

At least four of the states (Michigan, New York, North Dakota, and Pennsylvania) feature specific regions with a long tradition of oil and gas development and, hence, roadspreading of produced water. For instance, New York's Western region, long the state's primary setting for oil and gas infrastructure and an area less-advantaged economically than others, has seen historical roadspreading since at least the 1940's. Interestingly, horse-drawn carts may have even spread produced water in Pennsylvania as early as the 1890's, and the state's northern region is known to historically roadspread. Townships and counties in these particular regions consider the abundance and cheap cost of nearby produced water to be economically advantageous compared to commercial products. These communities enjoy the self-reliance this brings, and residents are favorable to oil and gas activities in general. Additionally, said rural areas in sampled states often contain a plethora of gravel roads, all of which need adequate ice prevention and control during brutal winters as well as dust abatement at other junctures.

On the other hand, these states elect to continue roadspreading in spite of the unknown long-term effects on human and environmental health it may cause, and in some cases even in spite of known contamination near some brine-receiving roadways. Citizen wariness, liability concerns, and regulatory limitations have also at times been an impediment to implementation.

Technical/Scientific: All but one roadspreading state (Ohio) test for varying sets of chemicals when allowing applicants to spread produced water. Some states require chemical analyses for only a handful of constituents, such as Pennsylvania's requirement to find only chloride, calcium, magnesium, sodium, and TDS values. In other states, samples must undergo testing for a wide spectrum of constituents, such as in North Dakota where 20 constituents are targeted. Salt ions such as sodium and chloride as well as TDS are ubiquitous among targeted constituents across states, but pH levels, hydrocarbon content, heavy metals, and VOC's also appear in some testing regimens. Notably, no roadspreading states test for naturally occurring radioactive materials (NORM) such as radium. Although VOC's are included in New York's, West Virginia's, and Michigan's testing requirements, these compounds are absent from tests in Pennsylvania and North Dakota. Arsenic and hydrogen sulfide, another constituent of emerging concern common in oilfield waste, are only tested for in North Dakota. All roadspreading states prohibit the use of flowback and fracking fluids, but without testing for these fluids' chemical markers, there is no guarantee that sources of produced water selected for roadspreading will not contain trace amounts of constituents found during the completion stage of a well. Although agencies consider testing adequate, they admit that enhanced testing regimens would improve their regulatory ability to protect the environment and reassure citizens that the practice is safe.

Agencies have determined that no significant deleterious effects on environmental and human health occur due to roadspreading, at least compared to commercial alternatives. This observation often springs from state-sanctioned studies of a limited scope that evaluate constituent values in roadside sediments as well as comparability to magnesium chloride and other products on the market. However, no roadspreading state was able to cite peer-reviewed, independent, scientific research that demonstrably shows the practice to be safe, and some noted

that such research could result in revisions to current policy if elevated risk is proved.

Other dust suppression and de-icing compounds used in roadspreading states include mixtures of magnesium chloride, calcium chloride, or salt brine (water with 23% dissolved salt). States that have chosen to add produced water brine to this mix have concluded that such brine is safe, effective, and cost-efficient. A state-sanctioned study in North Dakota indicates as much, finding that magnesium chloride is the most favorable substance for dust suppression on roads, closely followed by produced water. Given the high price of magnesium chloride ($7,000 per road mile spread), inexpensive oilfield brine earned positive attention for its comparability to other chlorides, effectiveness at suppressing dust, abundance, and cost-efficiency.

Varying geology plays a large role in the acceptability of specific sources of produced water for road application, as some formations deliver brine with high calcium and magnesium content while others lack these elements or contain high levels of contaminants and are therefore ill-suited for roadspreading. Furthermore, the only treatment process required by roadspreading states is oil-water separation to prevent hydrocarbon product from appearing on roads. Other treatment technologies are deemed economically infeasible at the time of writing.

Stakeholder/Public Input, and Framing/Justification of Current Policy: Various stakeholder processes were used when promulgating policy in these states, including public hearings, comment periods, stakeholder meetings, and informal presentations. Public backlash was a key feature in New York, and pockets of resistance were present in the other states, but significant enough segments supported oil and gas development and related ice and dust control that efforts to legalize roadspreading were not derailed. All agencies point to the fact that many residents will oppose anything related to the oil and gas industry no matter what, so complete buy-in is unrealistic, but affected roadside residents' concerns are usually listened to carefully.

Most states' decisions were politically, economically, and scientifically based all at once, although the economic rationale for roadspreading oilfield brine was always prominent. For fear that doing so would be onerous, agencies hesitate to outlaw a practice that socioeconomically disadvantaged citizens rely on. The acute need for ice and dust suppression is a legitimate public safety issue and is framed as such by permitting agencies. North Dakota uses comparability with alternatives as a starting point for their determination, and comparability also plays into other states' rationales. Framing of roadspreading's permissibility to the public includes promotion of the steps taken to reduce environmental impacts, reminders that the practice has not been demonstrated to result in widespread contamination, citation of economic benefits, wisdom of recycling and re-use, and retelling of the relatively small quantity of water actually roadspread.

Interviewees commented on myriad underlying conditions and recommendations for successful roadspreading policy should it be approved. Respondents noted the importance of adherence to regulatory specifications on oilfield brine sources, application rates, runoff controls, testing, and tracking as key to implementation. Also, the product needs to be truly effective at dust and ice control and compare favorably to alternatives. Maintaining the public's trust, keeping a robust field presence including compliance specialists, maximizing administrative capacity and necessary resources, engaging third parties and stakeholders, and consideration of geography, climate, and environmentally sensitive areas were all mentioned as wise management ideas. Other steps include possibly charging a fee to help with compliance, better tracking and monitoring than seen in the six states, ensuring that it does not become a mass disposal method, foregoing all fracking flowback and drilling fluids, notifying members of the public in advance of spreading, and instituting heavily punitive enforcement capabilities for violators.

Non-Roadspreading States

Of the five non-roadspreading states selected, two mentioned their states' relative lack of oil and gas activity when explaining their rationale for not roadspreading, which in turn means they feel less pressure to manage and re-use vast quantities of produced water. California's Central Valley allows roadspreading on lease roads, but this rarely or never happens in Arizona, Texas, Oklahoma, and South Dakota. Concerns over contamination were not as prominent as one might expect, although Arizona named contamination as one reason not to roadspread. Texas would be amenable to the practice, but its regulatory framework for doing so is not currently robust. Oklahoma's Water for 2060 initiative to re-use and recycle oil and gas wastewater does not mention roadspreading of produced water, while South Dakota's experience with certain cases of haphazard roadspreading in the 1980's led their regulators to restrict virtually all roadspreading.

Discussion and Recommendations

The findings described above provide a cross-section of perspectives on the beneficial use of produced water for dust and ice management. Results indicate that permitting states often allow roadspreading for largely economic reasons, owing to the cheap cost and plentiful supply of produced water. Oilfield brine's effectiveness at controlling dust and ice relative to other solutions also factors in. For these states, potential toxicological effects on human health and the environment are outweighed by the aforementioned benefits. However, only limited evidence cited or provided by these states suggests that they have a solid understanding of the full impacts that roadspreading may carry for public and environmental health. Most experts also legitimated concerns over exposing the public and clean water sources to little-understood produced water and fracking constituents.

The state policies, procedures, and regulations outlined above, along with their attached justifications, serve to answer the first research question (What policies and practices are in place

in roadspreading states?). The second research question (Under what conditions and using which procedures would it be wise to allow roadspreading of produced water in Colorado?) is a more difficult one to thoroughly answer based on the results, but a number of both general and specific insights and recommendations can still be drawn to that end. A small sample of experts and relevant actors were interviewed for this project, with nearly all expressing reservations about the unknown environmental effects of roadspreading, especially as it relates to receiving water bodies. These experts' insights were helpful in developing the recommendations below.

Constituents: First off, Colorado should optimally acquire a much deeper level of knowledge on the complex constituents found not just in produced water but also fracking fluids. Even when focusing only on Colorado, the state's dramatically variable geology from which produced water originates complicates any standard approach. These geological variations are amplified when observing wastewater management elsewhere across the country, so lessons drawn on specific constituents may be incongruent to Colorado's circumstances. Due to conflicting geology, satisfactorily testing all oilfield brine sources in the state is not only a logistical and technical nightmare but also an extremely costly proposition. It appears that many of the sampled states' exceedingly narrow testing regimens can be attributed to these logistical, technical, and economic hurdles, as is the absence of vigorous treatment. The multitudinous toxicological possibilities and often proprietary nature of fracking fluid chemicals have also led roadspreading states to ban fracking fluids from beneficial use on roads, a striking and significant trend in states which are seemingly eager to utilize and re-use oil and gas wastewater. These steps would be consistent with literature on policy learning, whereby conceptual and practical lessons from other polities could inform Colorado's policy process on roadspreading (Heikkila & Gerlak, 2013).

Migration of contaminants: Second, every effort must be made to both prevent and study the

migration of contaminants from roads after oilfield brine is applied. Colorado may choose to finance a pilot study of migration pathways and runoff incidence, a step that can strengthen the state's comprehension of the effects of roadspreading on ecology and public health. Designers of the pilot study may elect to focus on the incidence and movement of specific constituents of concern such as VOC's, NORM, heavy metals, and salt ions. According to this pilot study and other information, restrictions on duration, frequency, and volume may need to exceed those found in other states, as Colorado's lack of precipitation and inability to quickly dilute contamination means that valuable water bodies could need extensive, miles-long setbacks.

Stakeholders: Third, stakeholders in other roadspreading states may have not always been given an opportunity to record their approval or dissent toward the practice. When a contested issue with as many implications and nuances as roadspreading of produced water presents itself, failure to include the public, scientists, academia, advocacy coalitions, industry, or other underrepresented sectors in proceedings can be fatal to maintaining public trust, responsiveness, and transparency. By including these sectors throughout the decision-making process, fewer unpleasant surprises and greater buy-in can be expected. Colorado can avoid backlash by implementing a wholesome stakeholder process replete with town halls, public commenting, inter-sectoral commissions or working groups, a roadspreading task force, and governmental openness generally. In doing so, Colorado could achieve a degree of consensus and openness mentioned in advocacy coalition framework literature, under which external events, internal events, learning, and negotiated agreement converge upon a political subsystem to bring about a policy appropriate to its broader political environment (Weible, Sabatier, & McQueen, 2009).

History: Fourth, many roadspreading states cite historical use of roadspreading as a rationale, pointing to onerous effects on local communities if the practice is banned. Since Colorado does

not feature regions historically dependent on roadspreading, onerous effects should not be feared.

Taken together, the insights above are items of caution for decision-makers weighing whether to permit roadspreading of oilfield wastewater products. As such, it is hereby recommended that *if* Colorado does choose to allow roadspreading, it should:

- Limit roadspreading to produced water from conventional drilling sources;
- Insist on a strict and thorough battery of tests on brine samples, especially for substances neglected by other roadspreading states such as NORM, hydrogen sulfide, and VOC's;
- To enhance trust, responsiveness, and transparency, a robust stakeholder process must take place comprising members of the public, scientists, academia, nonprofit groups, industry, and government, with proceedings scheduled *before* and *during* initial decision-making and deliberation, rather than afterward as part of comment periods;
- Monitor and track all roadspreading more closely than in other states, such as by establishing a publicly accessible database that pinpoints all in-state roadspreading;
- Impose tight runoff controls that go above and beyond those found elsewhere, especially as it relates to surface water and ground water bodies;
- Invest in treatment technologies that will allow for the removal of constituents of highest concern, thereby minimizing human and ecological exposure;
- Devote adequate administrative capacity and resources to proper regulation, including by hiring compliance specialists and ensuring proper enforcement of violations;
- Study site-specific climactic, geographical, and environmental sensitivity parameters prior to application, including migratory pathways that lead to water bodies;
- Design a pilot study that focuses on short- and long-term health and ecological impacts;
- Gain a greater understanding of the chemical make-up of produced water;
- Use alternative substances for dust and ice management whenever economically feasible.

The above elements and safeguards recommended for any roadspreading regulatory proposal are imperative in the case of approval. At this time, however, it is not recommended that Colorado adopt roadspreading of produced water, at least until the state can confidently infer that the practice will not substantially, negatively impact public health and the environment. Without clearer and substantiated scientific evidence that produced water is comparatively safe when held up against other dust and ice control substances, it would not be prudent to forge ahead on roadspreading, especially in a state with such sensitive ecologies and water systems. The precautionary principle applies, as the costs of roadspreading gone awry would far outpace

any costs from choosing to forego roadspreading for the time being.

There are several limitations to this research. As this paper is policy-oriented and its scope mostly confined to public administration, a large array of technical considerations were either given little attention or excluded altogether in the interest of keeping the paper focused. Time constraints also restricted the number of contacts and interviews conducted, so there is a possibility that, given more time, differing agencies or representatives in each state could have provided added or conflicting information that may have changed some overall insights.

Conclusion

The prospect of roadspreading using produced water in the West carries rewards but also great risks. The amount of produced water in the state along with attendant water management challenges are increasing, and a legitimate need to re-use and recycle water means Colorado must become increasingly creative with its water management techniques. Industry, municipal governments, and county taxpayers would also enjoy the economic savings that could come with easily re-using abundant supplies of oil and gas produced water on roads for dust and ice control. On the other hand, roadspreading of produced water may open up new exposure pathways for the state's residents as well as its ecological systems. The extreme paucity of reliable and conclusive data on the impact of spreading oilfield brines, which may sometimes even contain fracking fluids, across wide swaths of territory should give policymakers and regulators pause. State-by-state comparisons where roadspreading is currently practiced provide several lessons for Colorado, and recommendations for the state developed here include the necessity of robust stakeholder processes, stringent testing and monitoring, strict runoff controls, and further scientific data on the toxicological effects of constituents found in produced water and fracking flowback. Until these conditions are met, it is not in Colorado's best interest to move ahead with

roadspreading of produced water.

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Appendix A: Theodori, et al. (2014) survey of Marcellus Shale residents' attitudes toward hydraulic fracturing

To better understand public perceptions on fracking flowback reuse and management, Theodori et al. (2014) surveyed residents of the Marcellus Shale region of Pennsylvania, the setting of a major ongoing shale gas play. Respondents indicated that contributions to their knowledge of fracking originated most from newspapers, the natural gas industry, and conservation/environmental groups, while documentary films, university professors, and regulatory agencies rated lowest in this regard. Moreover, respondents trusted information and considered it unbiased when it came from university professors, conservation/environmental groups, newspapers, and landowner groups, while trust was lowest toward documentary films, the natural gas industry, and regulatory agencies.

Beyond the espousing of a sub-optimal level of faith in regulatory authorities, this discrepancy can tell us that, although the public may be most exposed to certain sources of information on fracking, their trust may often be placed in separate sources of information which are not as prominent. Additionally, 33.2% of subjects self-scored themselves as extremely unfamiliar with fracking flowback management in Pennsylvania, and 38.5% were extremely unfamiliar with flowback treatment technologies, whereas only single-digit percentages considered themselves extremely familiar with either knowledge area. In all, general unfamiliarity with flowback management eclipsed general familiarity.

Seventy-seven percent also believed that treated wastewater from fracking can safely be put toward industrial use, although this item did not specify whether it included roadspreading. Only 31% believed this wastewater can be safely applied in agricultural irrigation settings. Overall, respondents who were males, resided in high-density drilling areas, and possessed higher levels of education were more likely to believe that fracking wastewater could be reused safely by industry than those who did not belong to any of these descriptors. Both Hagstrom et al. (2016) and Theodori et al. (2014) agree that increased collaboration, transparency, and trust-building with the public on the part of government and industry will be necessary to assuage citizen concerns.

Appendix B: Grand Junction stakeholder summit on produced water

A 2014 Grand Junction stakeholder summit on produced water, hosted by the Colorado Energy Office and Colorado Mesa University, revealed a willingness among myriad actors across Colorado to enhance reuse and recycling. The summit brought oil and gas firms, state and local government agencies, agricultural entities, community organizations, environmental groups, treatment companies, researchers, and attorneys together to form a dialogue on produced water reuse.

Participants recognized several realities, including that high treatment costs and logistical difficulties present a barrier to non-industrial reuse, increased reuse can be spurred on by a streamlining of regulations and permitting, heightened public engagement and transparency on the issue is prudent, and opportunity for re-use is heavily site-specific and geology-specific. Also, the participants reached agreement on the need to minimize the negative environmental and health effects of trucking produced water on the state's roads, as well as lowering ozone-causing air pollution emissions from evaporation ponds housing VOC's. Smaller energy firms with unfavorable economies of scale expressed a desire for centralized and shared treatment facilities in order to provide entities that lack capital and infrastructure a pathway toward re-use. Of course, many at the summit also voiced unease over the toxicity of produced water and flowback, particularly at the risks of said water leaving behind a larger footprint across the state as it is trucked, handled, and treated for reuse at ever-expanding sites and locales.

On the specific topic of beneficial use of produced water for dust suppression, members of industry shared their frustration with what they viewed as cumbersome regulations, permitting, and other impediments thwarting further roadspreading on lands used for energy extraction. Industry representatives and others recognized that salinity values found in produced water may compare to or resemble those in commercially available magnesium chloride solutions meant for suppressing dust on roads, which would fulfill part of the EPA's beneficial use criteria. Conversely, many attendants noted the paucity of reliable data and peer-reviewed studies on the environmental impacts and treatment possibilities surrounding the use of produced water for dust suppression. All in all, participants broadly agreed that clarification of the state's regulatory structure relating to dust suppression is overdue (Colorado Energy Office & Colorado Mesa University Water Center, 2014).

Appendix C: Findings from Roadspreading States

Regulatory/Legal Aspects

Regulatory/Legal Status

Michigan
Roadspreading of brine from produced water is allowed under specific conditions. DEQ attempted to ban roadspreading of oilfield brines in the 1980's, but was rebuffed when county road commissioners across the state filed lawsuits claiming the costs of alternatives were prohibitive. A court order eventually led to a consent agreement signed by DEQ.

New York
Allowed at the county level. All such counties are in the state's Western oil- and gas-producing region. A Waste Transmitter Permit and BUD must be obtained from DEC. About 100 BUDs are currently issued. Production water from fracking operations (low-volume only) may be applied.

North Dakota
Formally allowed since 2012 on a case-by-case basis. Prior to 2007 the practice was allowed, widely used (including by the state's Department of Transportation), and unregulated.

Ohio
Roadspreading of produced water is allowed off-site. Local governments must endorse roadspreading of brine through a local authorizing resolution. A municipal board or legislative entity must hold a minimum of one well-promoted public hearing on any plan to allow brine on roads. Such a resolution is then submitted to ODNR for approval.

Pennsylvania
Dust suppression and road stabilization using production brine is allowed, including from natural gas operations, but not from unconventional drilling sources.

West Virginia
Allowed for ice management only. A 2011 memorandum stipulated conditions under which roadspreading may occur, but at this time no entities actually roadspread produced water in WV due largely to the cost of meeting specifications, particularly the chemical analyses required. Only CBM and conventional wells may supply brine.

Type of Roadspreading Allowed

Michigan
Dust and ice management.

New York
Dust and ice management.

North Dakota
Dust and ice management.

Ohio
Dust and ice management.

Pennsylvania
Dust management and road stabilization only (not ice control).

West Virginia
Ice control only (not dust control).

Jurisdiction over Regulation/Management

Michigan
Michigan Department of Environmental Quality (DEQ)

New York
New York Department of Environmental Conservation (DEC)

North Dakota
North Dakota Department of Health (DoH)

Ohio
Ohio Department of Natural Resources (ODNR)

Pennsylvania
Pennsylvania Department of Environmental Protection (DEP)

West Virginia
West Virginia Department of Environmental Protection (DEP) and Department of Transportation (DOT)

Entities that may Apply Brine

Michigan
Those who receive a Groundwater Discharge General Permit: waste haulers with a dedicated truck, counties, etc.

New York
Anyone that receives necessary permits: hauling companies, contractors, well operators, firms, counties, towns.

North Dakota
County government and private road owners. Both have the option of contracting out application of the brine.

Ohio
Counties, with contracting out possible. Private entities/third parties must receive county commissioner approval before use on lease roads. A brine hauler permit is needed for any entity or vehicle that physically roadspreads.

Pennsylvania
Municipalities or other similar entities, along with third parties, but not oil/gas companies themselves.

West Virginia
Governments (state, counties, towns and cities). Entities need not receive a permit, but must meet state specifications when roadspreading.

Codified in Law/Official Policy, or Through Guidance

Michigan
Codified in Law: Part 615 (Supervisor of Wells) of Michigan's Natural Resources and Environmental Protection Act (NREPA, 1994) tasks DEQ with administration of wastes from oil and gas activities. Rule 324.705 (Disposition of Brine) sets conditions for approval of roadspreading of brine. A Groundwater Discharge General Permit is needed as per Rule 323.2215. A court order led to a consent agreement with DEQ originally. Some procedures are also through guidance, such as a memo to staff directing them not to approve brine sources from high-volume fracking operations.

New York
Codified in Law. 2009 Notice to Haulers (see below) was guidance, but now everything is codified. Additional guidance-based measures are in place, too, including numerical limits on constituents.

North Dakota
Guidance. Permission to roadspread is not formalized in the form of BUDs, but the approval process functions similarly.

Ohio
Codified in law. Applications, local authorizing resolutions, and required annual reports are reviewed by ODNR for accuracy and to make sure all statutory parameters are met.

Pennsylvania
Permits and policies governing roadspreading are carried out through guidance. DEP spent 5 years working on rules to codify, but these were rejected by the General Assembly, so until the

legislature enacts roadspreading policies into law, guidance will remain. DEP does not use formalized BUDs, but its approval process is basically the same.

West Virginia
Guidance. A 2011 memorandum of understanding between WV's DEP and DOT outlines permissible roadspreading practices, which does not have the full force of law.

Uniform Policy, or Case-by-Case Basis

Michigan
Mostly Uniform.

New York
DEC approves on a case-by-case basis.

North Dakota
Case-by-case.

Ohio
Case-by-case.

Pennsylvania
Case-by-case.

West Virginia
Uniform.

Recently Adopted Changes

Michigan
None.

New York
New DEC rules (11/2017) expressly prohibit roadspreading of fracking flowback and drilling fluids, while Marcellus Shale water is now also outlawed on roads.

North Dakota
None.

Ohio
None.

Pennsylvania
None.

West Virginia
None.

Proposed Changes and Recently Rejected Proposals

Michigan
After DEQ noticed that some spreaders were applying brine that contained substantial amounts of hydrocarbons, whereby free product was detected on roads, the Water Resources Division and Oil, Gas, and Minerals Division conducted a review process. However, after weighing changes to testing procedures, no revisions were made.

New York
A new rule will require annual chemical analyses of constituents. Industry protests over the financial costs of this new requirement are expected, including litigation. Also, DEC is working on expanded guidance/interpretation documents for their regulations. These may make it difficult for some entities to renew their BUDs due to additional costs.

North Dakota
DoH is evaluating and reviewing general recycling rules including those related to beneficial use products after a recent fire at a ND recycling facility. This may result in fresh rule-making procedures, although so far it is unclear. Roadspreading may come under review as a part of said rule-making.

Ohio
A proposed bill, Senate Bill 165, is in front of the Legislature. This would create a framework for treating/defining brine as a commodity. SB 165 would allow entities to comply with less stringent regulations if they meet certain standards. If met, a product can be considered a commodity (for ice/dust control), and circumvent current regulations. There would be an annual report, but no hauling registration requirements. It is unclear whether SB165 will eventually even come to a vote, let alone pass.

Pennsylvania
A framework that would have codified roadspreading regulations with the full force of law was struck down in 2016 by the General Assembly. DEP policies are still only guidance-based as a result. Further attempts at codification rule-making may be coming.

West Virginia
There has been no legislative pressure to move forward further with roadspreading.

Elements Necessary for Approval

Michigan
Brine sources must undergo chemical analyses and meet a calcium chloride threshold. Spreaders

must develop Standard Operating Procedures detailing application and monitoring methods. Disposers shall keep records on source of brine, volume, location, and brine makeup (going back a minimum of 3 years), along with application logs (kept in vehicles for at least 2 weeks).

New York
BUD must contain a Roadspreading Plan (duration, frequency, location, runoff, etc.), Brine Storage Plan (runoff control, secondary containment, contingency plan), and chemical analysis of a representative sample of brine (verified at a state-approved laboratory). Counties themselves may apply for BUDs. Written approval from local-level highway superintendent or town supervisor required before application. Private entities (farms, etc.) must obtain a signed letter from property owner allowing a town or hauler to spray. Waste Transporter Permit costs $500 per vehicle, and less for each additional vehicle.

North Dakota
A Waste Transmitter Permit from DoH is needed. Even when only hauling/handling brine rather than spreading it, entities must receive this permit. Roadspreading and storage plans detailing locations, rate, frequency, geological origin, and chemical analysis of brines are required. Impact studies in case a facility is abandoned or excavated are also required. A permit to transport and spread brine costs $75 in the initial year and $25 annually afterward. "BRINE" signs must be displayed on roadspreading vehicles.

Ohio
All statute requirements must be met after county governments give initial approval.

Pennsylvania
Permits must be renewed each year. Municipalities or other road owners must agree in writing to roadspreading of brine. Towns that roadspread must develop annual dust suppression plans containing information on specific roads, volumes, frequencies, and equipment involved in application, along with identifying geological formation(s) where the brine originates. Monthly reports are also to be submitted to DEP on locations and amounts of roadspreading. Spreader bars featuring shut-off controls are required.

West Virginia
Roadspreaders must simply meet defined parameters, procedures, and specifications set by DEP and DOT. No approval process is involved, and no actual permits are issued by either agency.

<u>Other Regulatory/Legal Realities</u>

Michigan
Only produced water from low-volume fracking operations can be roadspread (of which there are roughly 4,000 wells). In 2012, DEQ approved permits for operators to sell oilfield wastewater from over 100 wells for roadspreading efforts. In the 1980's, DEQ attempted to ban roadspreading because it was becoming an unregulated, widespread disposal practice for oil/gas wastewater.

New York
If the current ban on high-volume fracking is ever lifted, the state's proposed regulatory framework would prohibit all roadspreading of produced water. Low-volume fracking is still allowed, and most of NY's road brine originates from low-volume production. About 30% of NY's re-used produced water is spread on roads. Municipalities are not considered transporters and may or may not have a Waste Transporter Permit. Therefore, municipalities only need a BUD. Large operations and storing entities need a Waste Transport Permit. Water from shale formations is not allowed.

North Dakota
Roadspreading of produced water from shale formations is technically allowed, but only very rarely occurs.

Ohio
ODNR can ask for additional compliance measures: One company wanted to take in brine, filter it, and promote/sell it as a suppressant. This was approved, but it required annual testing of constituents. ODNR regulates handling and spreading of brine and reviews approvals, while local entities decide whether or not to roadspread at all. No specific BUD is needed, but ODNR standards must be adhered to.

Pennsylvania
DEP believes that compliance is going well overall. PA has a robust non-commercial residual waste program, and oil and gas regulations sit in a "fallback category" of residual waste. A recent appeal before the DEP hearing board challenged roadspreading in a certain part of the state, but was dismissed. Once a municipality gains approval, they are held liable in case of accident. If contracted out, contractors are liable if an accident occurs under their watch. Well operators can be held responsible, too, but this is unlikely.

West Virginia
Only conventional natural gas wells may produce brine for roadspreading, and all fracking fluids and flowback are banned. The 2011 memo describes DEP's and DOT's shared duties in overseeing successful regulation of roadspreading. Roadspreading is technically allowed, but "the economics aren't there to make it worthwhile." As long as roadspreading and brine source specifications are met, entities do not need a permit from DEP or DOT.

Practical Considerations

Required/Recommended Runoff Controls

Michigan
Application may occur only 3 or 4 times per year, depending on county. Spreader bars that spray over a width of at least 8 feet are required. Maximum application rates of 1,500 gallons per lane mile on roads and 1,250 per acre on land lots have been set for dust control purposes. For ice control, maximums of 500 gallons per lane mile on roads and 400 gallons per acre on land lots

are in place, and brine cannot be spread when temperatures are below 20 degrees Fahrenheit. Brine also cannot be spread at environmental remediation sites with existing chloride contamination.

New York
In the case of dust suppression, brine may not be spread "within 50 feet of a stream, creek, lake or other body of water; on sections of road having a grade exceeding 10 percent; or on wet roads, during rain, or when rain is imminent." Brine shall not be applied within 12 feet of structures that cross drainage ditches or bodies of water. In the case of de-icing, brine must be applied "in a manner that prevents brine from flowing or running off into streams, creeks, lakes and other bodies of water." Application allowed only between sunrise and sunset, and roadspreading vehicles must move at least 5 miles per hour. Local government are largely responsible for setting appropriate application rates, while DEC requires use of a "spreader bar" or other similar technology so as to prevent runoff.

North Dakota
Guidelines impel roadspreaders to minimize impacts on water bodies and ecology, while recommending a maximum of one half gallon per square yard during initial spreading and one-third of a gallon per month thereafter. One gallon per square yard is allowed specifically for race tracks and mining haul roads. However, these are only guidelines for use, not rules. Spreader bars with shut-off controls are required.

Ohio
Statutorily required: Brine cannot be applied to an already-saturated surface, to nearby vegetation, during darkness, or within 12 feet of any structure that crosses a drainage ditch or body of water. Vehicles must use spreader bars with a maximum nozzle opening of three-quarters of an inch in diameter and move a minimum of 5 miles per hour during application. The maximum uniform application rate of brine is 3,000 gallons per mile on a 12-foot-wide road or 3 gallons per 60 square feet on unpaved lots. Spreader bars must spray at a maximum 60 degree angle of discharge, and at least the first 75% of a spreader's contents must be discharged via atmospheric pressure.

Pennsylvania
Brine cannot be applied within 150 feet of a stream, creek, lake or other body of water, and it cannot be spread while it is raining or when rain is imminent. If the slope of a road is at an angle steeper than 10 percent, brine cannot be used. After a state-commissioned study in 1996 found a potential for contamination of water bodies, Pennsylvania reduced its maximum recommended application rate from 1 gallon of brine per square yard of road to half a gallon per square yard during initial spreading. One-third of a gallon is recommended only once per month after initial application. However, these are guidelines for use, not rules. Plans are denied if the above runoff controls are not generally adhered to.

West Virginia
Application rates must be a maximum of 10 gallons per ton during pre-wetting, 50 gallons per lane mile during anti-icing, and 100 gallons per lane mile during de-icing. These are standard operating procedures that both agencies agreed should not be exceeded.

Facilitators of Roadspreading Produced Water

Michigan
Historical use of and reliance on roadspreading; abundance of produced water; expensive cost of alternatives; the acute need for ice and dust control in several counties; county self-reliance.

New York
Western NY's preponderance of produced water; the high cost of other de-icing solutions; Western NY's historical usage of produced water on roads during its rough winters.

North Dakota
ND's long-standing, historical use of roadspreading, especially in rural counties that must perform ice and dust control to maintain public safety; the cheap cost of produced water compared to commercial products.

Ohio
The economics and road maintenance needs found in rural towns and counties; public backlash against the practice is minimal in OH.

Pennsylvania
The expansive, historical usage of produced water for roadspreading; towns' ability to procure a cheap supply of produced water; PA's many gravel roads.

West Virginia
Cheap cost of produced water; many source wells compare favorably to commercial alternatives; the need for successful ice control in WV.

Impediments to Roadspreading Produced Water

Michigan
Nonzero levels of contamination from historical, long-term roadspreading exist, which may require remediation and restrictions in already-affected areas.

New York
A relatively large proportion of NY's population is highly skeptical of all oil and gas activities; Downstate/Eastern residents and municipalities are sensitive about their Upstate sources of drinking water.

North Dakota
Unknown effects on human health and the environment; liability concerns on the part of counties.

Ohio

ODNR is hamstrung by regulatory limitations on enforcement actions.

Pennsylvania
A lack of authoritative studies on environmental impacts; DEP's duty to protect water bodies (encompassed in its mission statement) could conflict with roadspreading if safeguards are not in place; negative public perceptions at times.

West Virginia
The cost of testing needed to make regulators certain that the practice is wise; opposition from some segments of the public.

Level of Concern over Increased Salinity, NORM, VOC's, Heavy Metals, and other Contaminants that may Harmfully Effect Ecology and Human Health

Michigan
Some roadside areas that saw heavy, historical, cumulative roadspreading have experienced chloride and hydrocarbon contamination, but roadspreading now takes place at a "practical level" at rates that are not anticipated to lead to contamination. Additionally, Radium-226 and -228 have been tested on roads consistently since the mid-1980's, and values have held stable during this time.

New York
A 1999 study (An Investigation of Naturally Occurring Radioactive Materials [NORM] in Oil and Gas Wells in New York State) found that use of produced water for de-icing posed no radiological threat to public health. The study did not evaluate the effects of dust suppression. DEC deems NORM too difficult and costly to test for in current required chemical analyses.

North Dakota
One drawback of roadspreading cited by DoH is the unknown effects of releasing the product into the environment, such as on human and ecological health. In 2007, the agency undertook two evaluations. First, DoH identified areas where roadspreading of oilfield brines had occurred, sampling surface water bodies, road crossings, etc. DoH could not make a determination of any difference between these areas and locations where commercial products had been applied. Next, DoH analyzed constituent values in soils, and did not observe high levels of any constituent of concern, concluding there was “not much difference” with commercial products. There can be some variability, but "nothing significant" from an environmental standpoint.

Ohio
ODNR collects brine samples from Class II facilities regularly. Four regional UIC inspectors sample from a variety of different sources every 1-2 weeks and look at constituent values to make sure negative impacts are not occurring. Annual reports and historical studies are evaluated to see if levels remain the same. A radiation division observes NORM incidence and may adjust rules/request changes as needed.

Pennsylvania

A state-commissioned study in 2016 found no negative environmental impacts or unhealthy water bodies due to roadspreading, so DEP feels pretty comfortable with results. A study found NORM values to be below action levels, but DEP could not claim there was "no increase" in NORM levels, as there was a flaw in the experiment whereby a selected control road was discovered to have actually been roadspread in the past. Salinity contamination of streams and drinking water will be a major concern if roadspreading for ice control is ever approved.

West Virginia
The practice does not seem to meet Clean Water Act stipulations, but this did not prevent approval from being granted, even after regulators "struggled with" the decision. WV has more precipitation and dilution than CO, so "usually" there will not be contamination. Regulators have not observed high chloride content in groundwater. The public's fear of radioactivity led Marcellus waters to be banned. WV's groundwater regulations require that not only present use of water, but also future use of water in WV must be protected. A pilot study in the late 1980's on salt brinefrom conventional wells found mixed results from an environmental standpoint.

Economic Considerations

Michigan
Many counties rely on produced brine for cheap ice and dust control. This fact led county road commissioners to sue when DEQ wanted to ban roadspreading in the 1980's.

New York
Costs of sampling for constituents are evaluated in the 1992 GEIS. Economic and jobs impacts of these regulations are also covered in the 1992 GEIS. Several counties are economically dependent on local supplies of produced brine for ice control.

North Dakota
The low costs of roadspreading brine from produced water are appealing to the state government. Other brines and salts must often be imported from Utah, adding to transportation costs. Controlling dust confers aggregate cost savings for ND when taking into account vehicle accidents. Counties have an economic incentive not to waste produced water, and appreciate its low cost.

Ohio
Townships in OH are going to choose cheaper road management substances such as produced water instead of commercial alternatives due to budgetary constraints and economic factors.

Pennsylvania
Pricing: how do operators dispose of produced water when every penny they spend adds up? Waste disposal for firms and municipalities is very expensive, and when hauling and injection are bypassed, cost savings accrue. The state is currently evaluating the economic feasibility and wisdom of certain treatment technologies.

West Virginia

The state weighed the cost of currently-used rock salt with that of produced water, especially in terms of hauling and transport. It found that produced water would carry considerable cost savings due to less distances traveled. Ironically, though, the economics of testing have rendered the usage of produced water nonviable for governments and firms. Chemical analyses have proved too costly, so roadspreading, in effect, is nonexistent.

Distinction Between Produced Water and Fracking Flowback/Fluids

Michigan
Up until 2012, no distinction was made between produced water from conventional drilling and hydraulic fracturing. But in June 2012 a moratorium on roadspreading of high-volume fracking-based produced water went into effect.

New York
Yes: fracking fluids may not be applied, but produced water can.

North Dakota
Yes: fracking flowback and drilling fluids cannot be roadspread, but produced water can. It is "tough to determine" exactly when flowback becomes produced water. It is dependent on specific source wells, well history, fracturing timeline, etc. DoH wants to see about one year pass from when a well was initially fractured/drilled.

Ohio
Flowback is banned. Horizontal wells are defined in statute as formation-based (not only dependent on direction of wellbore; S.B. 315, 1509.01GG). Utica, Point Pleasant, and Marcellus Shales are off-limits. Horizontally-produced water from high-quality sources are permissible. Devonian Black Shale and Clinton formations feature organic sources of produced water from horizontal wells, but these sources are very rarely used for road brine (only a couple of operators).

Pennsylvania
Fracking fluids and flowback are not allowed, as all unconventional sources of oilfield brines are prohibited, but conventional sources are permissible.

West Virginia
Fracking fluids and flowback may not be roadspread. Conventional wells may supply brine, while unconventional sources such as fracking wells may not.

Tracking and Monitoring

Michigan
Aside from spreader logs and brine records kept by permittees, tracking is not undertaken. Limited long-term monitoring of Radium-226 and -228 has been done, with results indicating stable and safe levels.

New York
NY does not geographically or otherwise track roadspreading of brine or require annual reporting from roadspreaders. NY government is not obligated to do so because of produced water's classification as industrial waste (not subject to the same "manifesting" as hazardous waste). Brine imported from PA is not tested or tracked. NY's only tracking takes place through what is recorded in Waste Transporter Permits. PA "is better" at tracking than NY. DEC is usually aware of locations where brine is spread, but unaware of volumes.

North Dakota
Counties track roadspreading and keep records. They were originally deemed better at doing so, although when the state wants to access records, sometimes it is hard to procure these records in a timely manner from busy county supervisors. Occasionally, DoH will sample soils from roads to ensure no contamination is occurring.

Ohio
Spreader logs are not required. Without said job logs, tracking and monitoring is a tough task. ODNR does have authority to request that brine haulers who employ county workers keep daily logs of brine sources and drop-off locations, but proper documentation is not always maintained. Ensuring compliance is difficult, as verifying that entities are following regs and quantities is hard, as is regulating the practice across the entire state and on every road where it occurs. ODNR is unable to enforce its mandate fully, as it cannot levy significant fines due to regulatory structure. People who live in roadspreading areas file complaints over impropriety, and there are "bad apples" at times (some of which are caught), but enforcement is a challenge even with the low volumes compared to injection wells.

Pennsylvania
Towns file plans detailing their roadspreading specifications when seeking approval. DEP also receives monthly reports on volumes and locations of roadspreading. Aside from this, little tracking and monitoring takes place on the part of state government. Entities must notify DEP if contamination or spillage occurs. 5 gallons of brine at a well site is considered a spill.

West Virginia
None. There is no roadspreading to track or monitor currently, and provisions are not made for this in the 2011 memo.

<u>Other Practical Considerations</u>

Michigan
Counties that roadspread often have 2-3 different oil/gas wells in-county, leading to a level of self-reliance. Calcium chloride levels in these in-county brine sources, when high, carry effectiveness and preclude the need for alternatives.

New York
NY imports substantial quantities of production brine from Pennsylvania, some of which is

spread on roads, but this imported brine is not tested or tracked. Haulers in both NY and PA spread brine, and a very small amount of cross-border application takes place right near the state lines.

North Dakota
Many counties are now less willing to adopt roadspreading of produced water due to liability concerns. Management standards exist for the processing and handling of production brines. DoH believes produced water can be effective based on conditions, but that many commercial products can also be more effective.

Ohio
Only rural areas roadspread. Violations can result in enforcement, but ODNR is unable to enforce its mandate fully, e.g. their power to fine violators has regulatory restrictions. Inspectors are tasked with ensuring the practice takes place only at authorized, listed/designated roads and locations. Upon complaints/calls from the public, roadspreading sites/spreaders are reviewed, and at times adherence to application rules are verified in the field (based on saturation and other measures).

Pennsylvania
Roadspreading of brine is common in the northern tier of the state, including 188 municipalities in 22 counties. Currently, DEP cannot be certain that improper roadspreading doesn't occur, partially due to these regulations lacking codification. Current application rates are not concerning, but cumulative, long-term impacts could be an issue. Not aware of any streams that are out of compliance, but there have been problems downstream from some treatment plants.

West Virginia
Initially, WV focused on trying to keep impurities down. But no matter how roadspreading would occur, it seemed to violate the Clean Water Act with respect to streams. On the other hand, road ice was deemed a public safety issue, so it was chosen that roadspreading would be allowed. The practice is really not being used, as a lot of its cost is attributed lab tests. Anytime a new source is added or deleted, a new test was required, so it became expensive, as firms did not want to deal with testing/procedures.

Scientific/Technical Aspects

<u>Overall Testing Criteria</u>

Michigan
Michigan's annual testing regimen targets 4 common VOC's, which must fall under 1,000 µg/l. Brine must also test at or higher than 20,000 mg/l of calcium chloride, leading some prospective brine sources to be rejected.

New York
15 constituents are tested, and depending on results, DEC may ask for tests of additional

constituents. Chemical analysis is currently done only upon initial permitting, but a new rule will require annual testing. Radium and barium feature very low upper limits in NY.

North Dakota
Virgin materials are tested for, with chemical analysis of 20 total constituents required. Some permit applications have been denied due to excess salinity, hydrocarbons, or other long-term health risks.

Ohio
No testing requirements prior to application. ODNR has the ability to brine, and can ask entities for chemical analyses based on circumstances, but there are no requirements for townships/businesses, and sampling is seldom sought.

Pennsylvania
Applicants must test their brine sources once per year for 5 constituents. Proposed 2016 regulatory framework that was voted down in the General Assembly would have required tests for 14 constituents, including VOC's.

West Virginia
Roadspreaders must provide a chemical analysis to DOT's Division of Highways measuring 13 different constituents. This testing regimen has proven too expensive for would-be roadspreaders.

Specific Constituents Tested For

Michigan
Annual testing for 4 constituents: benzene, ethylbenzene, toluene, and xylene. Initial, one-time tests on brine must also target hydrogen sulfide, chloride, and calcium. Brine from wells that contain over 20 ppm of hydrogen sulfide in the gas stream cannot be used for roadspreading unless these brines feature hydrogen sulfide concentrations of less than 500 ppm.

New York
15 constituents: calcium, sodium, chloride, magnesium, TDS, pH, iron, barium, lead, sulfate, oil & grease, benzene, ethylbenzene, toluene, and xylene.

North Dakota
20 constituents: calcium plus magnesium, chloride, hydrogen sulfide, pH, specific conductivity, major ions, TDS, alkalinity, oil and grease, aluminum, ammonia, arsenic, barium, boron, copper, chromium, lead, nickel, selenium, and zinc.

Ohio
None.

Pennsylvania
5 constituents: chloride, calcium, magnesium, sodium, and TDS.

West Virginia
13 constituents: TDS, chloride, sodium, calcium, pH, iron, barium, leads, oil & grease, benzene, ethylbenzene, toluene, and xylene.

Whether Current Testing is Considered Adequate

Michigan
Constituent ratios and values tend to stay the same over time, so MI's one-time testing is thought to be satisfactory.

New York
Yes, although DEC is pushing for annual rather than one-time testing.

North Dakota
Yes, because field testing has found no determination of significant environmental difference compared to commercial products.

Ohio
Yes: the legislature did not feel the need to mandate a battery of chemical analyses for specific constituents.

Pennsylvania
Somewhat: DEP wanted to expand testing to 14 constituents, but for now the current testing regimen will remain in place.

West Virginia
Yes: in fact, due to the cost of stringent testing requirements, no entities currently roadspread.

Treatment Options, Costs, and Realities

Michigan
No treatment is required, but an oil-water separation is considered the norm.

New York
Only oil-water separation treatment is mandatory. Much of NY's produced water is sent to PA and OH for treatment and injection.

North Dakota
Only oil-water separation is normally undertaken in order to remove VOC's.

Ohio
Technically no treatment requirements exist, but it is in companies' best interest to remove oil product. Entities are statutorily barred from spreading hydrocarbons/oil, and only brine can be

applied (also defined in S.B. 315, 1509.01U), so in effect oil-water separation is mandated. Separation occurs either at well tank battery or Class II facilities.

Pennsylvania
The state is investigating the economic feasibility of a number of treatment methods. The economics of more complex treatments are currently infeasible. Economics are more of an issue than technical feasibility.

West Virginia
None.

Alternative Commercial Products Compared, Used, or Tested

Michigan
Solid salt mixed with sand is common. MI boasts salt caverns and mineral wells that produce salt, but distances between these sources and many of the state's most problematic roads are great, and purchasing these supplies is often more expensive than choosing oil and gas produced water. When local wells produce brine high in calcium, there is no need to seek alternatives from elsewhere.

New York
Conventional de-icers are costly in the oil- and gas-producing Western region, but produced water is not. Central NY features mining of salt caverns, but these salts are weaker and less effective on roads than the denser brine from oil and gas wells. NY DOT's pre-wetting blend is usually just salt and water, sometimes combined with mag chloride. Roughly a dozen de-icing BUDs have been issued for roadspreading of beet juice, distillery products, de-sugared molasses, and other organic enhancers. However, these compounds feature high phosphorus levels which can severely degrade surface water bodies, so it is like "trading one problem for another."

North Dakota
Comparisons with commercial products are the basis for ND's policies. A recent state-sanctioned study conducted by McKenzie County, Dunn County, and the state Petroleum Research Fund found magnesium chloride to be the most favorable substance for dust suppression on roads. But with the high price of mag chloride ($6,000-$7,000 per road mile spread) and calcium chloride (over $8,000), oilfield brine earned positive attention as well for its comparability to other chlorides, effectiveness at suppressing dust, abundance, and cost-effectiveness (about $700 per road mile spread).

Ohio
Produced water is sometimes mixed with sand or small aggregates for enhanced traction. A number of different products have been evaluated by ODNR, including one from Northeast Indiana that is used in some districts: formation water from a non-oil/gas producing formation mixed with beet juice and sugars. Chlorides in this brine help melt ice. Filtered brine has also been utilized, but must be tested annually.

Pennsylvania
Fresh water alone is not effective enough for road stabilization, so produced water is added sometimes. Significantly high levels of constituents of concern in these mixes have been flagged occasionally, but usually no hard and steadfast values are set. Otherwise, alternatives have not been closely studied. Sometimes, companies will request permission to apply a novel mixture, but when DEP asks for more detailed chemical analyses and plans, said companies do not follow up with this information.

West Virginia
Oilfield brines were compared with traditional rock salt and found to be cheaper, just as (if not more) effective, and at least as safe. This was the basis for WV's original decision. The logistics of moving traditional brine across the state also became expensive, and produced water was found to decrease bounce and scatter, plus allow cost savings.

Geological Considerations

Michigan
Michigan produced water can range in salinity from nearly freshwater quality to over 180,000 ppm. Deeper parts of the Michigan Basin feature lower chloride values.

New York
Marcellus Shale features higher-than-usual radioactivity levels, and Marcellus waters are of poor quality for road applications regardless. Pennsylvania's aversion to Marcellus waters are noted by DEC and are also a factor in this restriction.

North Dakota
ND's best wells for ice control are not in the Bakken formation. Older wells from formations that have higher magnesium content are better.

Ohio
Marcellus, Utica, and Point Pleasant Shales are ineligible, while Clinton and Devonian Shales are eligible. Usually, non-shales are a preferred source of brine.

Pennsylvania
PA's produced water is particularly salty compared to other states.

West Virginia
No Marcelllus Shale water may be used for roadspreading. Not all conventional wells produce high quality brines and are dependent on sodium content, freezing points, etc.

Stakeholder/Public Input, and Framing/Justification of Current Policy

Stakeholder Process(es) Surrounding Development of Rules/Guidelines on Roadspreading

Michigan
Stakeholders were given opportunities to present their stances during the court proceedings and consent order surrounding DEQ's attempted ban and related litigation in the 1980's. Since that time, there have not been similar stakeholder processes because no significant changes to policy have occurred. In 1994, rules were added, and there was public engagement during the rulemaking process, including public hearings. In the last 5-6 years, relevant DEQ staff have conducted 350-400 public presentations and meetings dealing with hydrofracking, along with a few that focused specifically on roadspreading.

New York
During drafting of the 2011 Supplemental GEIS, there were many public meetings and hearings. Members of the public expressed major concerns at these meetings. It was "easy" for Downstate/Eastern citizens to criticize the practice, as they have not traditionally relied on oilfield brines for road maintenance. In many cases, these were citizens who simply express reservations about anything at all involving the oil and gas industry. During hearings on beneficial reuse of coal ash on roads a few years earlier, similar complaints were voiced.

North Dakota
There was no formal public input process, but many informal stakeholder processes were held. DoH met with concerned groups as well as counties who were interested and gathered input, as it was a guidance process, not rule-making.

Ohio
At least one well-promoted public hearing must be held prior to a local authorizing resolution. When new rules are passed, input of affected parties and public meetings are required, which seemingly occurred with roadspreading regulations. Public notification of the rules and upcoming public hearing (e.g. a notice placed in local newspaper) is required. “Real animosity” has not been observed at these meetings, other than rare exceptions (e.g. a private company was caught performing unrelated illegal practices by another agency, which levied fines and shut down one of their facilities, so when the same company wanted to roadspread, the public was opposed). Rural populations typically support roadspreading, but some segments of the population will always be opposed to all oil/gas activity.

Pennsylvania
2016 rule-making resulted in about 28,000 comments, much of which was focused on conventional drilling sources. At one rural public hearing, 54 people spoke up for roadspreading, but no one spoke out against it. The Oil and Gas Technical Advisory Board weighs in on technical aspects, and Act 52 rejecting 2016's proposed regulations created the Crude Development Advisory Council, which provides an opportunity to review and comment on proposed oil/gas regs. Any proposed guidance or policy is put in front of the Independent Regulatory Review Commission, which publishes proposed regs in the state bulletin with an opportunity for public comment. A normal 30 days of public comment was stretched out to 120 days in 2016 due to immense public interest, and 12 public hearings were held. (Stakeholder Processes continued in "Other Relevant Information" below.)

West Virginia
No stakeholder process was undertaken during promulgation of the 2011 memo. Stakeholder were met with after the rules were developed, and a considerable outcry happened. The agencies "took some heat" from the public over the fear that roadspreading would create an easy disposal method for the oil and gas industry, so it was repeatedly pointed out that the 2011 memo prevented such behavior.

Whether States' Decisions were Political, Economic, or Scientific

Michigan
Legal, but also all of the above: a Michigan court ultimately decided the fate of roadspreading via the 1980's court order. Court proceedings included an evidentiary hearing in which the Court was convinced of the merits based on benefits vs. risk. The Court found that preventing rural counties (whose budgets are typically fixed) from roadspreading produced water would be financially onerous. Additionally, the Court found that DEQ would have to demonstrate cases of contamination if the practice were to be banned, which proved difficult.

New York
All of the above. Economic and job impacts were taken into account in the regulatory documents (such as the 1992 GEIS). Scientific determinations are also "balanced against" said economic concerns. Multiple considerations were at play.

North Dakota
Scientific as deemed by DoH due to the agency's process of comparing produced water with commercial products based on technical parameters.

Ohio
Initially, it was a decision based on political considerations and cost-effectiveness. Eventually, after a number of scientific studies (e.g. rock salt vs. produced water), scientific rationales/decisions were made “after the fact”.

Pennsylvania
A mix of all of the above. The science behind the decision is considered solid, as DEP is "not seeing widespread impacts." On the other hand, prohibiting unconventional drilling sources of brine is purely a political decision, as permitting these would be unacceptable to the public.

West Virginia
Scientific, as well as economic originally. WV assessed produced water's comparability with commercial alternatives, and moved forward with roadspreading at first due to the economics of trucking.

Overall Rationale for Current Policy

Michigan

The policy brings benefits for public health and safety: ensuring visibility on gravel and dirt roads prevents accidents (dust), and ice-related crashes are a legitimate concern.

New York
1992 GEIS (see below) lays out the rationale. The Western region has an acute need for de-icing materials, as winters are brutal. It is onerous to ban roadspreading of produced water completely, but DEC has taken many steps to fully regulate the practice, including caps on non-conventional constituents.

North Dakota
DoH focuses primarily on produced water's comparability to commercial products, including in terms of environmental impacts. As current beneficial use rules began to be developed in 2007, DoH asked itself, is it "comparable to a commercial product?" Comparisons were undertaken, and the policy took shape from there. The state-sanctioned study conducted by McKenzie and Dunn Counties (see below) has been interpreted as further evidence for allowing roadspreading.

Ohio
Roadpreading has been permitted since 1985 when the legislature granted approval. Townships and counties pushed for approval of this practice, as their budgets are too small to acquire large quantities of rock salt. These locales benefit economically from roadspreading of oilfield brine, which is available at low or no cost. The public knows when “something different is going on” and improper use occurs, such as spreading a day before expected rainfall, so the public's watch helps ensure appropriate spreading.

Pennsylvania
Roadspreading of produced water has occurred for a century in Northwest PA so it is "grandfathered in". Rural locales depend on cheap oilfield brines for dust suppression. PA features large amounts of gravel roads that need dust abatement and proper maintenance. Also, PA does not have as much capacity for underground injections as Oklahoma does. DEP has not seen anything yet that gives them “significant pause” impact-wise.

West Virginia
Even though WV had concerns over how roadspreading could comport with the Clean Water Act, the public safety hazard of not de-icing outweighed these concerns. Regulators determined that if it met certain criteria, it would be equal to or better than currently used rock salt in terms of both effectiveness and contamination, as rock salt carries environmental contaminants, too, such as heavy metals. Also, transportation inefficiencies for rock salt in WV meant there would be cost savings if oilfield brines were adopted instead.

<u>Justifications For and Framing of Current Policy</u>

Michigan
"Keeping ice off the road is a safety concern." But steps are also taken to reduce the risk of negatively impacting the environment. State residents living on gravel roads need serious ice control and favor roadspreading of produced water. Anti-fracking MI residents expectedly

oppose the practice and are frightened “when they see a brine truck go down the road”. When complaints are lodged, DEQ goes out to robustly investigate. Companies, not taxpayers, are forced to clean up any contamination. DEQ has not seen any significant contamination problems. “There's probably fairly wide public acceptance”, so “if it’s done properly,” there should be no major problems.

New York
It is argued that current regulations have strengthened environmental protections while promoting economic development in NY's lesser-advantaged Western region. The policy also makes it easier to recycle materials, in this case produced water, and cuts down on costly rock salt and mag chloride purchases. Roadspreading is done in a "restrained" manner, and no more is applied than needed. Constituent values are kept at non-dangerous levels. Framing: pose questions to recalcitrant towns and members of the public such as: "Do you want icy, dangerous roads? Do you want super-high taxes so that your municipality buys salt?" Remind people that "no one will die from this."

North Dakota
Since the practice was already widely used in 2007, DoH did not want to upend this traditional use. The agency argued that efforts were/are made to properly evaluate current practices, rather than just prohibiting an existing practice. Ice control should be regarded as a public safety question, as well as a cost question for road owners, municipalities, counties, etc. Dust control is a public safety issue, too. If done properly, roadspreading of oilfield brines turns out the same as using commercial alternatives. In the right amount, place, and time, the practice is a benefit to ND. Illegal dumping has brought vigorous enforcement.

Ohio
Historical and contemporary studies in OH indicate that roadspreading is not resulting in degradation of the environment or public health. If additional data show ill effects, the policy can change. But only a small volume of brine is roadspread, the lowest volume of any oil/gas disposal method in OH. Ultimately, local jurisdictions are the ones who approve of roadspreading, not the state, and local governments make their decisions according to their specific needs. Unlike Michigan's state-wide regulations, OH's regulatory structure is locally oriented. At any time, approval can be revoked, and if elected officials want, they can alter the policy. Many townships spread little to no brine, but may keep their ability to do so on the books in case they ever want to. Volumes are dwindling in OH (more options on alternatives, more funding than in the 1980's, and plugging of local wells).

Pennsylvania
Roadspreading is a longstanding practice in PA that has essentially been "grandfathered in," making any prospective ban all the more difficult. Rural townships insist they need this resource in order to "keep a good road a good road". Any ban would be a burden on these towns, especially cost-wise. It is "practical" to provide this type of assistance to municipalities to help them build and maintain roads correctly. It is wise to “find a proper use for materials that would otherwise be turned into waste” according to a hierarchy of uses. Reuse enhances the possibility of keeping fresh water where it is cleanly. Moreover, DEP finds that it is quite difficult to have a rational conversation with the public on seismic activity and radiation, specifically.

West Virginia
It was argued that the substance compares favorably to other road maintenance products. Regulators showed data that was convincing enough of the fact that, if specifications are met, oilfield brine would be superior to rock salt. Commercial products are not as clean as produced water much of the time. However, the public doesn't question commercial products, so its effectiveness, cost-efficiency, and safety were emphasized. There had been a fair amount of testing done that produced water would contain less impurities than current alternatives. WV also had to reiterate to the public the 2011 memo's stipulation that this would not be a waste disposal method for fracking entities.

Conditions Necessary for Permission of Roadspreading using Produced Water

Michigan
Companies, counties, and other entities that roadspread should closely adhere to state-promulgated criteria that prevent run-off, contamination, and public backlash.

New York
Roadspreading practices need to actually be effective at controlling ice and dust so that DEC can "say with a straight face" that it is an appropriate practice. Also, PA's buffer zone requirement of 150 feet from surface water bodies is "not enough". A relative lack of information on the practice in NY a few years ago created major anxiety among the public, so adequate information and transparency are needed in order to reduce this anxiety if roadspreading is approved.

North Dakota
Brine must test comparably to commercial products. The question to start with: is produced water better, the same, or worse than alternatives on the market? If it is worse (either in terms of effectiveness or environmental impact), find ways to treat, dilute, or otherwise alter it so that negative impacts are minimized and ample dust and ice control is achieved.

Ohio
Robust evaluation of the product is needed, including constituent values, formation characteristics, and comparisons to other products. In rural areas, the economic ramifications of either re-paving pot-hole filled roads or buying extra salt is a major factor for townships, so if they can somehow acquire a lower-cost product, they will. Larger counties have approved some roadspreading, but others also denied applications. This may be attributed to anticipated negative public reaction. Overall, there is "not a huge outcry against brine spreading" in OH, aiding approval. The need to keep roads in a passable condition is also a factor. Winters in the last two years have not been severe, so ice control has not been much of an issue.

Pennsylvania
DEP must maintain the public's trust, as inevitable complaints and concerned citizens will need to be dealt with. Proper restrictions, runoff controls, and a robust regulatory program should be in place, while equipment and conditions of approval must reflect ensuring safety. A tangible field presence that includes inspectors and compliance specialists can better monitor and enforce

policy, as well as verify any problems that may turn up. Oil and gas industry buy-in is not necessary, but helps a lot, so working with industry to figure out economic and technical aspects is productive. Having an open, rational conversation about industry concerns can go a long way, and pushing back too hard against the industry is risky. Engaging third parties is extremely helpful to all parties.

West Virginia
Produced water must be of equal or better quality compared to commercial products, which is an easy selling point to the public. The effectiveness of chloride/sodium/ calcium/magnesium revolves around freezing points, so source wells must provide brine with characteristics appropriate for roads. After all, regulators would not want the brine to be creating a problem rather than correcting a problem. Freezing point matters, and not all salts are created equal. Specifications must be set and met, and if a brine source is changed, it will be necessary to re-run chemical analyses. Doing so prevents a "witches' brew" of brine sources from being used.

State-Specific Experiences that Influenced the Decision

Michigan
Environmentalists and members of the public across the state who reported the spreading of fracking fluids and other allegedly unsafe roadspreading practices may have contributed to the impetus and momentum behind the 2012 moratorium on spreading produced water from fracking activities. During the 1980's, plaintiffs who sued DEQ were the only counties that roadspread.

New York
For decades (since the 1940's), roadspreading of oilfield brines was an accepted practice, so municipalities became accustomed to it, especially in oil-producing regions. Up until 2009, NY allowed roadspreading of flowback fluids, but after a public outcry, this was banned. Through 2009 NY had only required issuance of Waste Transporter Permits in order to roadspread produced water, but staff became concerned that the law was being "stretched beyond reasonable bounds". Therefore, DEC started requiring BUDs. BUDs were streamlined at first (no chemical analysis requirement) due to DEC's fear of an initially overwhelming quantity of paperwork, and were attached to Waste Transporter Permits.

North Dakota
Roadspreading of oilfield brine was allowed and unregulated until 2007, when the Department of Health began limiting it to a case-by-case basis due to a lack of data on environmental and human health impacts. Before this, the Department did not fully understand the wide extent of brine roadspreading in the state that had existed for 40+ years.

Ohio
A state document (Spreading Oil-Field Brine for Dust and Ice Control in Ohio: A Guidance For Local Authorities, 2004; see below) discusses the history of how OH came to their decision. Roadspreading of oilfield brines was allowed in Ohio prior to 1965, when ODNR was established. In 1985, ODNR's stance was to prohibit the practice, but the Legislature determined that the agency did not have enough information to do so. For this reason, a fee was briefly

charged to spreaders that funded various brine-spreading research (nearly $110,000 was raised; see below for examples). Based on the outcome of these studies, the Legislature and ODNR decided to proceed with roadspreading, and the fee was removed.

Pennsylvania
Horse-drawn carts may have been spreading produced water in PA as early as the 1890's. PA's original regulatory program did not make a distinction between conventional and unconventional sources until 2016, when DEP explicitly banned produced water from unconventional and shale wells. This upset the oil and gas industry, so lawsuits may be inevitable. In prior years there was a Residual Waste Permit for ice control, but not anymore. Ice control may be approved again in coming years, but PA's Department of Transportation has only lukewarm interest in ice control using produced water, since specifications could be difficult to meet. PA contains a preponderance of gravel roads.

West Virginia
Around the time of the 2011 memo, one firm wanted to use conventional oil/gas brine of a relatively high quality for roadspreading. They were planning to mix it with rock salt. This coincided with the boom in horizontal fracturing, and the public was pushing back against fracking generally and fracking fluids specifically, so WV had to make clear that no frack fluids would be allowed. Oilfield brine was determined to be more efficient and a unique source with qualities that were good for roadspreading, and a pilot project was initiated. Previously, salt brine produced in one corner of the state had to be transported to other parts, leading to cost inefficiencies. However, this raised much negative public perception.

Advice For Colorado Decision-Makers

Michigan
Set rules on constituent concentrations, frequency of application, and other criteria for safe use. DEQ believes MI's criteria to be adequate and that a "pretty good framework" is in place in the state.

New York
Make clear from the outset that no drilling fluids will be allowed. Also keep in mind that shale formations usually provide poor-quality brine. Such brine should not be "foisted" upon townships when it does more harm than good. Find the right type of brine for the specific road management method and location selected. Moreover, implement robust tracking, as well as application rules. Separate the petroleum product from the water as best as possible. Those who find themselves in an "ivory tower" should take the time to learn why rural towns and municipalities would support and greatly benefit from roadspreading of produced water.

North Dakota
Keep detailed records, including on brine sources, and centralize all tracking of roadspreading at the state level instead of delegating tracking and record-keeping to counties. Efforts must be made to distribute brines evenly across roads so as to prevent spottiness and chunkiness that may lead to runoff. Set stringent maximum application rates. Compare with commercial products as

a basis for approval. Require "BRINE" signs on vehicles.

Ohio
All in all, an “ongoing evaluation of what is occurring” is needed from regulatory agencies. Enhanced notification and data provision on the part of roadspreading entities would help effective tracking/response when incidents happen. Involve a more frequent reporting/sampling period rather than only annual reporting. Representative well sources should be used for analyses. Don't simply burden regulatory agencies with sampling, but also get producers/operators to sample regularly, although this could increase costs. Better communication/notification on when spreading is occurring would alleviate instances of public complaints over spreading when it is not actually taking place. CO could need stricter standards than OH due to terrain and climate, and slope degree restrictions should be contemplated.

Pennsylvania
Implementation of specific parameters is key to preventing runoff and harmful constituents. Municipal involvement in the approval process and in implementation/ safety measures can decrease the likelihood of mishaps. Government must also earn the "social license" to operate as it regards allowing roadspreading, since negative public perceptions and a lack of transparency can erode trust in regulators. States must closely investigate the composition of specific produced water sources, effectiveness on roads, costs, sensitivity of watersheds, and legitimacy of end-uses related to roadspreading before moving ahead. Tailor the program to match a deep level of analysis. Ensure adequate staffing levels, administrative capacity, and resources so that safeguards are properly deployed and "match the task". "Be willing to bring the hammer down" when enforcement is necessary.

West Virginia
It is imperative that regulators know exactly how roadspreading is being done. Public perceptions cannot be ignored, so it must be demonstrated that roadspreading is not a "get out of jail free card" for disposers. There has to be a tangible benefit to the state, not just companies. Some people will automatically oppose anything to do with the oil and gas industry no matter what, so governments need material proof to show and support that the oilfield brine works. A demonstrable advantage to the state and "factual" beneficial use will help lessen opposition, of which there was "a lot" in WV due to the issue's emergence at the same time as increased fracking development. Also, the practice can be sold to the public as a legitimate recycling method and as a possibly better alternative to underground injection wells.

<u>Other Relevant Information</u>

Michigan
Officials at DEQ consistently receive complaints from members of the public over potential roadspreading contamination. The main complaints center on odor. Hydrogen sulfide levels of 500 ppm or less can be smelled, and odors can be significant at times, which many residents resent. Residents also "hate" seeing free product on roads, and are made unhappy at the sight of brine trucks spraying during a rainstorm, too.

New York
Many counties/localities have banned the practice on their roads, largely due to the public image they want to create. Very few of these counties host any oil and gas drilling. Also, DEC has not been sued yet due to these regulations, but lawsuits are likely inevitable.

North Dakota
Counties, not firms, are held legally liable for any miscues that occur during/after handling and application. In general, use of produced water on roads has slowed down in recent years. Firms and other entities that roadspread must follow rules and guidelines, and only measured quantities may be applied at a time. DoH keeps watch to ensure roadspreading does not become a mass disposal method for produced water.

Ohio
Without requiring job logs/daily logs, tracking is difficult. ODNR does have authority to require brine haulers to make a daily log of every source and drop off location. If a county is spreading using county employees, ODNR can request this information, but actual documentation may be lacking. Not aware of any enforcement actions against governments, but a number of actions against private entities have occurred, in which restoration/remediation is required. Some well operators don't even charge counties for their produced water. Over time, OH has funded studies and projects (some through OSU) evaluating roadspreading of produced water, including on application rates, groundwater effects, and chemical makeup of different formations (see below).

Pennsylvania
PA does not charge fees to roadspreading permittees, but should in order to help hire more inspectors. There are an average of 120 approvals each year. In 2016, 285,000 barrels were roadspread. Some brine from PA is exported for application on roads in New York State. DEP is not aware of any recent enforcement actions. DEP receives reports/complaints of roadspreading gone wrong, such as roadside plants dying, so maintaining trust is key.
(Continued from "Stakeholder Processes" above:) DEP's Environmental Quality Board approves Department rule-making, which involved lots of different informal work-group meetings in different cities. Overall, it takes about 2 years to get an idea through the rule-making process.

West Virginia
Regulators are particularly concerned with meeting state and federal groundwater quality standards.

<u>Relevant Documents and Links</u>

Michigan
-Groundwater Discharge General Permit: http://www.michigan.gov/documents/deq/wrd-groundwater-GW1550000_490624_7.pdf ;
-Act 451 of 1994 (Natural Resources and Environmental Protection Act):
http://www.legislature.mi.gov/documents/mcl/pdf/mcl-act-451-of-1994.pdf ;
-Rule 324.705 (Disposition of Brine, pp. 46-48):
http://dmbinternet.state.mi.us/DMB/ORRDocs/AdminCode/1298_2013-101EQ_AdminCode.pdf

;
-Brine Flowchart: https://www.michigan.gov/documents/deq/whm-hwp-Brine-flowchart-4-07_193374_7.pdf ;
-The Use of Oil Field Brine on Michigan Roadways (1983): http://www.michigan.gov/documents/deq/Oil_Field_Brine_opt_306999_7.pdf

New York
-1992 Generic Environmental Impact Statement: http://www.dec.ny.gov/energy/45912.html ;
-2011 Supplemental Generic Environmental Impact Statement (proposed regulatory framework governing oilfield wastes if fracking ban is lifted): http://www.dec.ny.gov/energy/75370.html ;
-2009 Notice to Haulers of Oil & Gas Well and LPG Storage Brine (BUD requirement and ban on roadspreading flowback): http://catskillcitizens.org/learnmore/DECBRINE.pdf ;
-An Investigation of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Wells in New York State (1999): http://www.dec.ny.gov/docs/materials_minerals_pdf/normrpt.pdf ;
-New solid waste regulations: http://www.dec.ny.gov/regulations/81768.html ;
-Press release for new solid waste regulations: http://www.dec.ny.gov/press/111459.html ;
-Guide on BUDS in NY: http://www.dec.ny.gov/chemical/8821.html ;
-University Transportation Research Center - Final Report on Environmental Impacts of Oil and Gas Brine Applications for Dust and Ice Control in New York (2015): http://www.utrc2.org/sites/default/files/Final-Report-Environmental-Impacts-of-Oil-and-Brine.pdf

North Dakota
-Guidelines for the Use of Oilfield Salt Brines for Dust and Ice Control: https://www.ndhealth.gov/WQ/gw/pubs/IceDustControlUsingOilfieldBrine_20130321.pdf ;
-Analysis of Dust Control Measures Applied in Dunn and McKenzie Counties (2012): http://studylib.net/doc/7207774/executive-summary-analysis-of-dust-control ;
-Powerpoint on same study: http://www.ndltap.org/events/conference/downloads/12_2012_Dust_Control.pdf

Ohio
-Spreading Oil-Field Brine for Dust and Ice Control in Ohio: A Guidance For Local Authorities (2004): https://oilandgas.ohiodnr.gov/portals/oilgas/pdf/Brine.pdf ;
-Senate Bill 315: http://oilandgas.ohiodnr.gov/laws-regulations/senate-bill-315 ;
-Chemical and Isotopic Characteristics of Brines from Three Oil- and Gas-Producing Sandstones in Eastern Ohio (2013): https://pubs.usgs.gov/wri/1984/4314/report.pdf ;
-Effects of Highway Deicing Chemicals on Shallow Unconsolidated Aquifers in Ohio (2004): https://pubs.usgs.gov/sir/2004/5150/pdf/SIR2004_5150.pdf ;
-Subsurface Transport of Inorganic and Organic Solutes from Experimental Road Spreading of Oil-Field Brine (1990): https://ohiogasdrilling.files.wordpress.com/2012/10/road-use-study1.pdf ;
-The Isotopic Composition of Strontium in Brines from Petroleum Fields of Southeastern Ohio (1979): http://www.sciencedirect.com/science/article/pii/0009254179901220

Pennsylvania
-Act 52 – Grade Crude Development Act (rejection of 2016 proposed regulations):

http://www.legis.state.pa.us/CFDOCS/Legis/PN/Public/btCheck.cfm?txtType=PDF&sessYr=2015&sessInd=0&billBody=S&billTyp=B&billNbr=0279&pn=1903 ;
-General Permit WMGR123 – Processing and Beneficial Use of Oil and Gas Liquid Waste (2012):
http://files.dep.state.pa.us/Waste/Bureau%20of%20Waste%20Management/WasteMgtPortalFiles/SolidWaste/Residual_Waste/GP/WMGR123.pdf ;
-Approval of Brine Roadspreading Plans:
http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-48261/550-2100-007.pdf

West Virginia
-2011 Memorandum of Agreement - WVDOH/WVDEP Salt Brine from Gas Wells Agreement:
http://dep.wv.gov/WWE/Documents/WVDOHWVDEP%20Salt%20Brine%20Agreement.pdf

Appendix D: Findings from Non-Roadspreading States

Regulatory/Legal Status

Arizona
Not allowed.

California (Central Valley Region)
Onsite re-use on lease roads is allowed, but not off-site use. Brines must be used within the same geological field as their origin. Fracking fluids and flowback are prohibited.

Oklahoma
Not allowed. Briefly in the 1980's, OK allowed roadspreading for icy roads, but then determined that "it was not a good use of a bad product" as it was not effective.

South Dakota
Not allowed, except under very specific circumstances, so roadspreading effectively does not occur. Current policy is in draft form, and changes are not expected anytime soon.

Texas
Permits are not issued for beneficial use of produced water on roads, including lease roads, even though a process for permitting land disposal is in place.

Rationale for Restricting Roadspreading of Produced Water

Arizona
Air quality concerns necessitate dust control. Roadspreading regulations have passed the muster of public and industry input, and opposition to current regulations is not deemed widespread. The practice went through considerable stakeholder engagement and public processes when the rules were being formulated, including public meetings and a comment period. The Board meets with stakeholders every other month, where the permits are discussed, along with regular meetings with industry. A Board meeting in December is scheduled featuring oilfield updates and a public component.

California (Central Valley Region)
Air quality concerns necessitate dust control. Roadspreading regulations have passed the muster of public and industry input, and opposition to current regulations is not deemed widespread. The practice went through considerable stakeholder engagement and public processes when the rules were being formulated, including public meetings and a comment period. The Board meets with stakeholders every other month, where the permits are discussed, along with regular meetings with industry. A Board meeting in December is scheduled featuring oilfield updates and a public component.

Oklahoma
Roadspreading of produced water has never taken place on a large scale in OK. Normally, water

is simply re-used on-site for further exploration and drilling. This is the preferred method of re-use. Industry has not pressured OK government to permit the practice. Public backlash and the attitude of citizens are something regulators and lawmakers try to avoid.

South Dakota
SD looked at other states when deciding and found that North Dakota's policies were best for SD. It must be shown that roadspreading works and is not being used simply for disposal, as per beneficial use rules. When SD observed brine being dumped haphazardly on roads in previous years, restrictions were developed that barred it except under certain circumstances. In the 1980's a landowner wanted permission, but the Department declined to grant it because this would be "bad policy."

Texas
Companies can make money off of it, and ranchers would welcome it, but it would all have to meet criteria, which have not yet been established. It's all "do-able", and could create savings for oil companies and a window of opportunity for subcontractors, but regulatorily speaking it would be difficult and move at a "snail's pace". Flowback is also heavy in particulates and TDS, which would worry regulators. Every company's flowback recipe is different, and robust sampling would be needed.

Justifications for and Framing of Current Policy

Arizona
Too many environmental risks, including effects on soils, plus it is unnecessary given the relatively small quantity of produced water in AZ.

California (Central Valley Region)
Adequate dust control is needed in the region due to air quality issues. Re-use on-site saves fresh water from being utilized for this activity. Current policy takes into account protection of water bodies. Public/stakeholder input allows various actors to weigh in.

Oklahoma
Other re-use opportunities are easier and benefit oil and gas infrastructure/productivity.

South Dakota
Only a relative pittance of produced water must be managed in SD, so there is no need to create policies that allow roadspreading when there is not much water to begin with. SD water is less saline than in ND, and is high in sodium, not magnesium or calcium. Also, SD would like to avoid any public backlash.

Texas
A set of technical criteria for roadspreading do not exist, and regulatory processes are not in place, so TX is not ready to allow roadspreading.

Other Types of Beneficial Use Allowed

Arizona
N/A

California (Central Valley Region)
Much attention has been paid to beneficially re-using produced water for agricultural purposes in CA.

Oklahoma
Re-use for drilling and fracturing is encouraged. Oil-based mud can be applied on county roads, but must be mixed with other materials so that there are no free-flowing liquids and nothing is mobile (see below).

South Dakota
None in any significant quantity, aside from most produced water being sent for reinjection.

Texas
99.9% of permits issued are for down-hole re-use. A permit process for roadspreading of greywater exists. Re-use of grey- or black-water is limited to 5,000 gallons per day.

Alternative Commercial Products Compared, Used, or Tested

Arizona
Sand-salt is used in higher elevations where ice control is needed. Some other products are organic- and mineral-based.

California (Central Valley Region)
CA produced water is on the saltier side, lacking magnesium but high in sodium chloride. It ranges from extremely good quality on the East side of the valley to bad/salty quality on the West side.

Oklahoma
N/A

South Dakota
N/A

Texas
Greywater can be applied on roads for dust suppression.

Conditions under which Roadspreading could be Allowed or the Current Policy could Change

Arizona
Samples for chemical analysis would have to be truly representative. Safety Data Sheets needed prior to wide-scale application. Petroleum-based hydrocarbons, heavy metals, and runoff must be prevented.

California (Central Valley Region)
CA's Central Valley does not have some of the issues CO has, as all of their public roads are paved and there are no icy conditions, so salty water is not needed for ice control. For changes to occur, it would have to be demonstrated that roadspreading will not create water quality problems.

Oklahoma
It would be "surprising" if the policy changes anytime soon, and state agencies would likely not support it. The legislature would need to request these changes, but is locked in a battle over the state budget currently, and all else is on hold. The Oklahoma Corporation Commission can technically also request changes, but will not forseeably do so.

South Dakota
Since policy is through guidance, everything would have to fit the parameters of SD's beneficial use rules, which are very close to those found in ND. Roads in Harding County (SD's oil/gas producing region) have been asphalted, so there is now little need for it there.

Texas
A standard set of regulatory criteria would need to be developed before any roadspreading could occur.

Advice for Colorado Decision-Makers

Arizona
Evaluate how brine would "potentially migrate."

California (Central Valley Region)
N/A

Oklahoma
N/A

South Dakota
Policy vs. rules: policy is better because it can be changed easily. Regardless of which is chosen, enforcement is key. In place of a virgin product, the water must perform like a virgin product, i.e. it must be effective, and can be proved as favorably comparable to commercial products. The road has to be well maintained and constructed, otherwise roadspreading will accomplish nothing.

Texas
Closely evaluate the chemistry of the source water and soil chemistry of receiving bodies, and determine if any damage would be caused. If not within an environmentally sensitive area, spreaders can be more liberal about application. The more re-use of produced water, the better.

Other Relevant Information

Arizona
Contaminated soil: AZ has a standard definition for "contaminated soil" at the state level, found below in the Petroleum Contaminated Soil Fact Sheet. This document contains regulatory parameters on how/when soil is considered contaminated, and provides some of the rationale for why Arizona decides to forego roadspreading of produced water.

California (Central Valley Region)
This data is only for the Central Valley Region, CA's premier hydrocarbon-producing region. Other Regional Water Quality Control Boards operate differently. Samples are needed for permits of discharge of waste to land. Dust-related applications need a roadspreading plan on how spreading will take place, prevention of migration offsite into surface and groundwater, volumes, etc. Approval was on a case-by-case guidance basis until April 2016, when a "general order" for meeting certain conditions was adopted. Annual reporting on volume, quality, safety measures, application methods, etc. required. Electrical conductivity, chloride, boron, and sodium are tested for. Arsenic in nearby groundwater cannot be above 10 μg/l after roadspreading. Groundwater monitoring is less stringent for small- and medium-sized firms in terms of time schedules. Other testing may be needed or recommended (see Order R5-2017-0036 below). There are instances of intricate filtering systems for oil-water separation in use.

Oklahoma
The Water for 2060 initiative to re-use and recycle oil and gas wastewater in Oklahoma does not mention roadspreading of produced water. Some OK formations produce very little water. Beneficial use of oilfield mud: when spread on land, it contains solids which are relatively benign. At least a 50-foot barrier (100 feet in some instances) from spread area to property boundaries is required, as fluids/solids can mobilize and need space. However, oilfield muds do not work themselves into roads well, except when combined with clay, in which case it gets too mushy and hence lacks effectiveness, so this practice is only mildly practical.

South Dakota
Produced water must be treated as if it is not waste. If not, it would be solid waste disposal without a permit. Several entities have requested permission to roadspread, to which letters were sent out detailing steps and measures needed for approval, but said entities never followed up nor completed necessary steps. In prior years, produced water was being used for spreading, but after entities again failed to comply with state letters outlining rules and parameters, the practice was deemed disposal and thereby disallowed. Harding County is very pro-drilling and represents the only county in SD with any significant oil/gas extraction. The County has pushed for roadspreading and is frustrated by regulators, but is "like a desert" with a very deep water table, lacking populated areas or crops, so environmental contamination is not a concern there.

Texas
Dust suppression is constricted by a tighter approval process than for other beneficial uses. Landowners must give written approval, which can cost a prospective roadspreader money, and a 10-day notice is required, which can open oil/gas companies up to liability. Trucking costs are prohibitive. East of the 98th Meridian, produced water falls into a dual permit situation between TX and EPA Region 6. EPA evaluates toxicity/chemical analyses, then the Texas Railroad Commission reviews and approves permits (along with the EPA).

Relevant Documents and Links

Arizona
Petroleum Contaminated Soil (PCS) Fact Sheet (July 2008):
http://legacy.azdeq.gov/environ/waste/solid/download/pcs_july08fact.pdf

California (Central Valley Region)
General Order - Order R5-2017-0036 - Waste Discharge Requirements for Oil Field Discharges to Land:
https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2017-0036.pdf

Oklahoma
None.

South Dakota
Reuse of Aqueous Waste Streams For Transportation-Related Applications (2016; see Chapter 5): https://openprairie.sdstate.edu/cgi/viewcontent.cgi?article=2107&context=etd

Texas
Texas Administrative Code Title 16, Part 1, Chapter 3 (disposal and beneficial use rules for oil/gas wastes): http://txrules.elaws.us/rule/title16_chapter3_sec.3.8

Appendix E: Highlights of Expert/Relevant Actor Insights

(Representative[s] from the following underlined entities were confidentially interviewed.)

National-Level Environmental Nonprofit

Benefits/Facilitators of Roadspreading: Re-use/recycling opportunities.

Drawbacks/Barriers of Roadspreading: Roadspreading will create more "exposure to risk". Long-term effects on human and environmental health are not understood. Toxicity levels for many constituents are unknown. The sheer number of complex chemicals plus a lack of knowledge on proprietary constituents is worrying. It is difficult to know exactly what to test for. Robust treatment is needed, but this could also remove too much salt, rendering dust suppression less effective, unless salt is added back in. There is "no bright dividing line" between produced water and fracking flowback.

Advice/Recommendations For Colorado Decision-Makers: It would be better to look for re-use opportunities that do not create increased exposure pathways, such as on-site recycling. Before any roadspreading occurs, strict specifications on constituent values should be set and met. At this time, it is not in Colorado's best interest to "experiment with" use of road salt derived from oil and gas wastewater outside of carefully controlled and monitored environments. The question of whether to allow or reject roadspreading of produced water should not center on regulatory measures, but rather on what scientific research needs to be conducted in order to assure decision-makers that the practice will be safe. Communicate attendant risks to all sectors of society that may become affected. It would be "troubling" if it were true that independent academic studies are not being used by states to inform their roadspreading policies. The ultimate question should be whether leaders have the information they need in order to make a reason-based decision. If they do not have this information, roadspreading is discouraged.

Federal Agency #1

Benefits/Facilitators of Roadspreading: An alternative, additional supply of water. Facilitator: third parties can be brought in for treatment/management. In such cases, there are market opportunities on both sides. In CO, many prior water rights issues have been resolved recently.

Drawbacks/Barriers of Roadspreading: Water quality (regulatory), liability and cost (industry), environmental health outcomes (society), "chemical cocktails", making a point-source of pollution a non-point source, runoff into drainage. There is no national standard for produced water re-use. Also, high-salinity testing is unreliable, and the unknowns here are noteworthy (damage to water bodies, aquatic life, soil, etc.).

Advice/Recommendations For Colorado Decision-Makers: "If it can be proved treated, it's OK." Physically the practice is OK, but water quality is a major concern. Proscriptive treatment

methods as part of regulations could be wise. Set a specific timeframe for wells that prevents fracking fluids from making their way onto roads, as it relates to determining eligibility and safety of produced water. E.g., brine from wells must not be used if less than 14 days from initial fracturing. Public education and industry education of the practice should be promoted prior to it being permitted. People must feel comfortable with the practice and buy in, otherwise trust will be damaged. Set clear standards and requirements for roadspreading. State should be flexible toward new technologies and ideas surrounding roadspreading. Safety measures governing constituents must be robust, and every effort should be made to prevent fracking fluid constituents from being applied on roads. Include opposing voices in the stakeholder process. Use aeration techniques on roads to prevent runoff. Salinity, organic compounds, NORM, dissolved gas, hydrogen sulfide, boron, trace metals, and proppants (silica) are all unsafe constituents that must be monitored. Similar ground applications such as to agriculture may be better re-use opportunities.

Technical/Scientific: Treatment: Wellington has a treatment system that treats to a quality equal or better than groundwater. Pinedale, WY treatment facility works on re-use/discharge. No best practices, industry gets creative with treatment at times. Walnut shell filters are a new treatment technology that could make a difference. It can pre-treat, is simple, and works well on organic compounds. It targets ions and is gaining popularity, but is also relatively expensive. Electrode coagulation also an option. It uses an aluminum or iron plate and a running current, and doesn't carry as many scaling issues as other technologies. Reverse osmosis, traditional membrane technologies are most common for this. However, membrane-based methods for treating all produced water are not durable, as maintenance and chemical cleaning is expensive and iron can foul up membrane treatment. The best treatment method will meet end-use goals and be specific to such goals. Staged treatment should be kept in mind.

Other: Brackish water is one potential alternate product for roadspreading. Studies on expanded brackish water application may be informative. Around 12 days in, flowback turns into produced water, although even 12 months in, there's still a chance of fracking fluids turning up.

Private Industry #1

Benefits/Facilitators of Roadspreading: Icy conditions in Northern states require robust road management. Purchasing/storage of salt and other commercial products store is costly. If produced water is in the same area, it makes sense to use it. "Taking a byproduct that would otherwise be disposed" and putting it to beneficial use is good, as long as it is environmentally OK.

Drawbacks/Barriers of Roadspreading: Roads, plants, streams could get contaminated potentially. Commercial road salt itself impacts streams and plants, if done incorrectly. Normal salt runoff into trout streams can have environmental impacts as well. To mitigate, institute runoff controls. Until 10 years ago, produced water was coming from conventional wells and was relatively uniform. With fracking and flowback, though, people were assuming it was different from before and toxic/harmful. Public perception of flowback "blows the risk out of

proportion".

Advice/Recommendations For Colorado Decision-Makers: Interviewee would be OK with roadspreading. Recommendations: permitting process, annual or quarterly reports, setbacks, and a ban on spreading of flowback.

Stakeholder/Public Engagement: Science-wise, salts (chlorides) are the greatest risk. Not toxic to humans, though. Policy-wise, there will always be people who are "scared of oil and gas" and "are going to assume" a "stew of toxic chemicals", so it will be hard to placate these members of the public.

State Agency

Benefits/Facilitators of Roadspreading: Much of produced water has similar charcteristics to current magnesium chloride solutions. If there's a way to re-use it for this type of activity and verify that no bad impacts occur, it might be a great use of produced water.

Drawbacks/Barriers of Roadspreading: Variability of formations across the state: some are fresh with low TDS, others are extremely high in TDS. Different water characteristics, including in terms of chlorides and hydrocarbons, are a challenge. Consider the source. It's "possible" that ecologies and human health may be harmed. Confirm the true water chemistry. Raw water is more of a concern. Treatment requirements are probably needed.

Advice/Recommendations For Colorado Decision-Makers: There needs to be "more profiling and testing to rule out contaminants of concern." "Having control" of what the chemical profile of the water is when it's produced is important. Raw produced water may need treatment standards. Make sure no sensitive areas with surface waters are roadspread at/near. Overall: opinion is that produced water can be used in many beneficial ways, and if done correctly, this may be one of them.

Technical/Scientific: Worrying consitutents: Salts, trace metals (agricultural areas need to prevent trace metals from entering lands), magnesium, sulfate, chloride (bad for waterways). Organics: volatiles and semi-volatiles. Source characteristics are important. Wild card: there are lot of down-hole chemicals over the life of a well. Fluids can end up in there. Once production starts (different from completion), and it starts being sold, they consider it no longer flowback. Could still have completion chemicals in it, but it's being separated.

Stakeholder/Public Engagement: PR component: a faction of people will always exist who are automatically against any oil/gas practice such as this. They think that it's all toxic, no matter what.

University Research Group

Benefits/Facilitators of Roadspreading: Re-using a wastewater stream that would otherwise

be removed from the cycle, economic benefits, and possibly creation of some jobs.

Drawbacks/Barriers of Roadspreading: The long-term environmental impacts of using improperly treated waters are a major drawback.

Advice/Recommendations For Colorado Decision-Makers: Unless treated to water discharge levels, roadspreading of produced water is not recommended. The 2,500 TDS limit means it is impossible to treat down to a safe level cost-effectively. Roadspreading of flowback strongly discouraged. Advanced indicators are needed for testing. Diluting out salts should be one treatment objective. The best use of produced water would be re-use for fracturing and oil/gas development. Deep-well injection is another safer option than roadspreading. Water usage for oil/gas is just going to increase exponentially as long as fracking continues. Long-term loading of heavy metals is a key difference with commercial products. Even bio-treatment will not remove everything, and that unremovable remainder is unknown constituent-wise. Treatment will always come down to cost. CO formations have a lot of dissolved organic carbon, which cannot be removed via a normal oil-water separation. Biological processes will be needed. Preferred safe management practice: disposal underground.

Practical: Harm to ecological and human health is possible, but if treated to an adequate level, these waters would be similar to current roadspreading compounds. By introducing heavy metals to the environment for 10-20 years, there could be some extremely negative impacts.

Technical/Scientific: Membrane technology is the most expensive treatment. “Non-traditional” constituents in the water are most worrisome, because traditional water/wastewater indicators do not apply or work well with these. Produced waters are "a new animal." CDPHE should approach produced water as they would regular wastewater, and set standards accordingly. In order to create a viscous solution to travel into cracks, a lot of sugar is added to the water, but sugar interferes with testing mechanisms. 10 milligrams per liter of benzene has been found in the waters at times, but .05 micrograms is the standard normally. Consider all aspects of the water. Classic indicators alone like chemical oxidation levels and TSS are inadequate, as polyaromatics, 78 different VOC's, semi-volatiles, and TENORM all need to be accounted for. On-site testing still only targets classic indicators, but "non-traditional" constituents are still missing, and NORM requires a 30-day analysis. Some flowback chemicals might show up for a short period, but will partition into the oil/hydrocarbon after a certain point in time. There is no hard and steadfast line between produced water and flowback. Flowback chemicals can be seen for years.

Stakeholder/Public Engagement: Get everyone in the room together, and make use of figures whose technical knowledge of the topic surpasses that of regulators. Meet with the experts on produced water at universities, have a conversation, and include the entities that want to roadspread as well. A seminar-type of process could go a long way. Bring in the experts, especially since there are not that many. Get everyone in the room together, including other stakeholders.

Other: Very few (20-30) comprehensive studies on produced water exist, and only half a dozen labs have access to produced waters. There are not that many academic experts on produced

water, and they're all splintered into different sub-fields.

Private Industry #2

Benefits/Facilitators of Roadspreading: It costs a lot to buy magnesium chloride every year, and transportation/hauling is also expensive. Locally produced brine is much cheaper, "makes a lot of sense", and rural counties can instead spend funds on health care and other functions. Cost savings can be "enormous," and the product is shown to be effective. Re-use and saving of fresh water is also enhanced. The hazards of magnesium chloride are "greater" than for produced water.

Drawbacks/Barriers of Roadspreading: "Unknown unknowns". Plus, the public has an incomplete understanding of oil and gas byproducts, and so may overreact or cry foul over inconsequential developments. Another problem is that the oil/gas industry pretends their produced water contains no radium or other contaminants. Oil/gas companies are concerned about liability when it comes to roadspreading produced water, so clearer liability parameters should be determined by states. The "lack of an established time tested regulatory network" is a drawback.

Advice/Recommendations For Colorado Decision-Makers: A best practices framework should be developed by the EPA that outlines how best to roadspread produced water. Regulatory approval should be given for safe roadspreading operations.

Policy/Regulatory: Industry should make every effort to keep traditional produced water separate from that which is tainted by fracking fluids. On the industry side, this can cost a lot and "requires a change in mindset" on the part of oil and gas companies, because they usually simply mix everything together. Trucks that transport oilfield wastes are also not cleaned out enough before roadspreading, as prior nasty chemicals may remain and taint the product, so this needs to occur more often.

Practical: Current dust suppressants are not regulated and don't have to abide by stringent standards. Plants alongside roads have died due to these common products. Larimer County suspended two commercial products due to contamination, but reinstated them a year later after accidents went up due to lack of mag chloride.

Technical/Scientific: Most produced water in CO is not strong enough for dust suppression. CO does feature a number of formations with a high calcium content, which is perfect for roadspreading. "Treatment would upset the economics of roadspreading". Treatments are problematic many times anyhow because removing concerning constituents would also remove valuable salinity needed for actual dust suppression.

Stakeholder/Public Engagement: There is definitely a market for this. However, the state does not have the resources or expertise to deal with this issue alone. One option would be to assign these functions to a major university (test, monitor, verify) for beneficial use analysis.

Other: "There ought to be a third party" on the national level that recognizes, qualifies, and monitors dust suppression products. Currently there is none. Counties do not carry out any kind of performance test when approving/disapproving roadspreading techniques, such as for specific constituents, but instead are swayed by commercial representatives selling the water. These counties do not know what constituents are contained in the product, but they enjoy its effectiveness.

Federal Agency #2

Benefits/Facilitators of Roadspreading: It's cheap, local road departments love it, and it can work under certain conditions at a fraction of the cost of commercial alternatives, especially for underfunded users. Re-use and savings of fresh water are also a benefit.

Drawbacks/Barriers of Roadspreading: All of the unknowns. Until it can be discovered what constituents make up produced water and where the water will end up, it is impossible to craft regulations that ensure the practice is done safely. Impacts to surface water, ground water, air, etc. must be better understood.

Advice/Recommendations For Colorado Decision-Makers: From an environmental standpoint, it's still a "black box" with limitless uncertainty. Forging ahead without environmental impact considerations would be very risky. Regulatory bodies should try to compare environmental impacts with the economic impacts of not allowing it, as well as find out whether there are better alternatives that meet the same economic goals. The primary consideration needs to be necessary safeguards that account for the unknowns. Mobility needs to be investigated. How does one know where the water will end up without knowledge of what's in it? And how does one design safeguards without the knowledge of where the water will end up? These questions remain unanswered. Operators say, "tell us how to treat it and we'll do it". Regulators don't know what treatment to require, though, so this proposition is unrealistic. The more that regulators learn about roadspreading, "the more [they] understand that they don't understand." The mentality that "it's mostly just water" should be countered.

Technical/Scientific: The constituents of most concern depend on composition. Radium in particular, as well as fracking fluids, but even salt can ruin crops and water bodies. Dependent on activity and types of exposure. Composition can vary so widely, so the unknowns are most troubling.

Other: Most Western states have a least a slight amount of on-site/lease road roadspreading. Flowback vs. produced water: There should not be an arbitrary marker for when water is no longer additives/frack fluids and not simply formation water. There are still maintenance chemicals even when only formation water is coming up to the surface. Without knowing what chemical inputs are being applied, it is impossible to know whether this is an appropriate use. It will always be a tough sell as long as there are so many unknowns.

Appendix F: Interview Structure and Questions Template
[Brackets indicate the wording of questions for states that do not currently roadspread.]

(…)
It appears that your state has Y POLICY. Is this correct? Is there anything else I should know about X STATE'S current policy? Ok then, so let's start with a couple of general open-ended questions that I have for X STATE.

-How did X STATE decide to adopt [or not adopt] its roadspreading policy, and what was the rationale?

-What are some of the general opportunities, as well as concerns, that you see in X STATE as it relates to allowing [possibly allowing] the beneficial use of produced water from hydraulic fracturing for roadspreading?

So:

-Who specifically can apply the brine on roads for dust suppression and de-icing? Well operators, an intermediary entity, county government, etc. And are there rules in place governing frequency and duration of application, as well as runoff control?

-Are all of these beneficial use rules codified in law and official policy, or through guidance? And is there a uniform policy or a case-by-case basis for allowing roadspreading of produced water?

-Are there any proposed changes to these rules, and have any recently been rejected? Why?

-Does X STATE distinguish between fracking flowback water and produced water from geological formations when regulating roadspreading? And are the chemicals present in conventional drilling that are similar to those used in fracking accounted for? Is produced water from shale gas formations allowed on roads?

I have some more technical items I'd like to ask about, too. Namely:

-How does X STATE view the potential that increased levels of salinity, TDS, volatile organic compounds, radioactive materials, and other contaminants found in fracking operations may harm ecological and human health?

-What constituents in the water are currently tested for and targeted that the state worries may negatively impact public health in general? Is testing considered adequate? Are there any unique or varying geological characteristics that may change the calculus or are worrisome? Are there any doubts raised over the absence of NORM or VOC testing?

-What kinds of treatment are currently utilized? And how do the costs and effort involved in transporting and treating produced water for beneficial use inform regulation?

-Are there any alternative commercially available substances that are used, tested, or compared for roadspreading in place of oilfield brine, such as magnesium chloride?

Switching gears now, we also want to know about stakeholder input and public engagement:

-Was there a stakeholder process involved when these roadspreading policies [restrictions] were being considered? If so, what was it like?

-Was the ultimate decision more of a political, economic, or scientific judgement?

-How was the policy justified and framed to members of the public, industry, and government?

-What conditions are [would be] necessary for roadspreading of produced water to be allowed? Were there any specific experiences or developments in your state that influenced the decision?

And finally, to wrap it all up:

-What should Colorado decision-makers and regulators keep in mind as we weigh whether to give the green light to roadspreading of produced water?

Appendix G: MPA Reflection Piece

In piecing together my Capstone project, I have drawn upon numerous areas of knowledge instilled in me by the MPA program. Since this Capstone represents the culmination of my studies as an aspiring public administrator, it required me to utilize what I have learned in my core courses.

To begin, Research and Analytic Methods was most instrumental in preparing me for the actual heavy lifting of conducting research. This course was extremely helpful in setting the stage for students as they begin to ponder how to tackle their Capstones, and the research techniques taught in Methods were highly applicable to any style or topic of public administration-oriented graduate research.

In terms of my own Capstone, the extensive, in-depth interviews that the research necessitated were made easier by concepts taught in the course. Allotting enough time and flexibility to procure the interviews, often with busy upper-management figures in state government agencies, was a key task over the course of my research. Ethical considerations as far as confidentiality, anonymity, and an offer to share my research with participants upon its completion also came into play. These aspects of research were covered well in Methods, and gave me an idea of what to expect if I were to elect a qualitative approach, which I did.

The mechanics and minute details of both designing and presenting academic research in the arena of public affairs were also covered in-depth, including through the construction of a research proposal containing many of the elements seen in a full Capstone. This process also sharpened my writing skills and improved my ability to create a well-focused literature review. All in all, Research and Analytic Methods equipped me with the mindset and tools to carry out a

largely independent piece of research in a professional and well-rounded manner.

Next, Organizational Management and Behavior was instrumental in allowing me to better understand how organizations work, especially as someone who had very little experience in the public and nonprofit sector prior to the Capstone, and certainly no relevant experience in massive organizations or bureaucracies. This course furthered my knowledge of the organizational setting, and many aspects of the course proved pertinent as I worked through the Colorado Department of Public Health to develop my paper. CDPHE is a sizeable organization with 1,300 employees, bound by the constraints and challenges one might expect from a relatively large government agency.

Course coverage of proper communication, ethics, and the organizational steps required to adequately deliver public services informed my research, especially as it relates to the context found within CDPHE. It was illuminating to apply what I learned in the classroom through Organizational Management and Behavior to a real-world bureaucracy of which I was a part.

Third, the Policy Process and Democracy course was particularly relevant to my attempt to wrap my head around and develop recommendations on a specific policy choice, in this case the decision on whether or not to roadspread produced water on public Colorado roads. Understanding all of a policy's consequences, facilitators, and barriers is not easy, but the course made this endeavor simpler through its presentation of theories and applicable case studies that show how policies can be developed wholesomely, rather than in a harried or one-dimensional way.

For one, stakeholder engagement and consideration of citizen attitudes was a major element to crafting my research. Partially owing to concepts found in Policy Process, I made a point of asking interviewees about the public-facing and "people" side of the equation. As the

course mentions repeatedly, successful policy is often dependent on policymakers' success or failure at having their finger on the pulse of public reaction. It is imperative that regulators and decision-makers anticipate how a policy will both directly and indirectly affect stakeholders, especially the public at large. When a controversial policy choice such as roadspreading of produced water arrives at the desk of public administrators, scientific/technical, economic, and practical aspects of the issue must all play a role, but too often there is a disconnect with citizens and affected parties on the ground. Policy Process considers this by addressing policy windows, implementation, citizen engagement, and other concepts that were central to my research.

Oil and gas industry practices, clean drinking water, and the economics of road management products are all explosive issues that, if handled improperly, could lead to severe public backlash. The topic at hand deals in all three, so it was decided that the ability of states to "sit everyone down at the table" to discuss and collaborate would be explored. At first glance, it might appear that stakeholder engagement would not be as important an aspect of my research as the science behind the effects this policy could have on the environment and public health, but in the end it is apparent that no picture of roadspreading would be complete without reflecting on the role of everyday citizens and other potentially interested or affected parties.

The Policy Process and Democracy course prepared me for these eventualities by showing that public buy-in is invaluable to successful implementation, and that policies themselves can be bettered by involving public and stakeholder input at every turn, and not just after the key details have been ironed out. Similarly, the Leadership and Professional Ethics course expounded the value of transparency, collaboration, and holistic leadership, all of which were on full display as I collected my data.

Without the core competencies taught in the MPA program, my Capstone would have

suffered from an array of limitations, including inadequate attention paid to public and stakeholder input, my own lack of experience in public organizations, a lesser ability to synthesize complex and expansive data, and less of a detail-oriented focus than the project required. It follows that, as it portends to beginning my career in public administration, the intricacies of the Capstone have given me an indication of what is in store in the field. As a result, the aforementioned core competencies introduced to me in the MPA program will continue to positively affect my thought processes, decision-making, and overall professional practices as a public administrator.