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Technical Analysis of Freshwater Use as Part of a Responsibly Sourced Gas ESG Strategy

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Abstract

The Unconventional Oil and Gas industry has seen growth over the last ten years that has drastically transformed the domestic energy outlook while bringing up increased concerns over climate and environmental issues. The rise of ESG and RSG can be seen as direct answers to these growing issues as communities and operators have both begun to demand better practices to limit the overall effects of UOG production. Few quantifiable metrics exist that holistically try to determine the overall effect UOG production has on local water resources. The FR2 metric/framework developed in this paper attempts to use commonly kept data such as water withdrawn and flowback volumes in conjunction with a new water stress index to quantify the effects operators are having on local water supplies. Testing this framework on a handful of operators from the Marcellus basin using open-source data revealed the value added by these methods as well as their use in a general RSG program.

Keywords

Responsible Sourced Gas, UOG, Water Stewardship, Water Stress, Water Sustainability

1. Introduction

The development of the US Unconventional Oil and Gas (UOG) industry has had transformative impacts on the energy outlook both nationally [1] and internationally [2]. At the same time, the growing threat of climate change [3] and its relationship to fossil fuel use is receiving increased amounts of attention [4] casting doubt on the sustainability of current levels of natural gas extraction and use [5]. Another issue related to the environmental sustainability of the UOG industry is the impact on water resources, particularly in semi-arid regions of the US where several major UOG basins are located [6].

Compounding the perceived unsustainability of the UOG industry [7] with respect to water is the severe drought that is impacting much of the US [8]. As of August 17, 2021, greater than 47% of the area of the lower 48 states in the US was affected by some level of drought [9]. Drought conditions were impacting almost 75 million people, including populations that are in many of the most productive UOG basins [9].

The dual environmental issues of methane emissions from the natural gas supply chain and freshwater use in drought prone oil and gas basins have prompted the establishment of a new category of natural gas, Responsibly Sourced Gas [10]. Responsibly Sourced Gas (RSG) is gas that has been certified by a third party to have been procured through environmentally and socially responsible practices (**Figure 1**). At this point, certification programs only exist for upstream UOG assets and standards have not yet been established. The framework proposed in this paper is a first attempt to establish RSG metrics and standards for water resource management in UOG upstream operations.

RSG programs will require quantitative methods to evaluate these factors such that certification standards can be developed. Considering the central role of water in oil and gas production [11], developing freshwater acquisition, and produced water disposal methods with minimal environmental and social impacts are an important part of any RSG program [12]. In general, the companies that will be considered the best stewards of water in the UOG industry will be those that minimize or eliminate freshwater usage and wastewater generation, thus providing no competition with other societal uses in a basin [13]. In addition,

Figure 1. RSG framework [10].

companies that treat wastewater as a resource that can be reused or recycled internally or externally to UOG operations will be considered more responsive and efficient to Environmental Social Governance (ESG) objectives [14].

The role of ESG can no longer be ignored by those in the UOG industry [15]. At every level, from production to distribution, investors have begun to evaluate the impact that fossil fuel companies have on the environment and in particular, climate change. While ESG has existed for some time, many have questioned its effectiveness [16] due to insufficient metrics that do little to accurately inform investors about the risks associated with a company's operations. Developing metrics that accurately assess freshwater usage is a key niche in the ESG framework that has not seen significant activity. The metrics proposed in this paper, the freshwater replacement ratio and the water stress index will provide more understanding of water resource management for the public, stakeholders, and the industry.

While other research has been undertaken to better understand water usage and its effects on those outside the UOG industry [17], none have coupled quantitative methods with measures of drought and water stress. By accounting for water scarcity at the county level, the research presented here has both increased the accuracy of these measures for evaluation of water usage while also allowing for higher resolution that allows for water usage to be understood at a local level. The framework presented here also lends itself well to the eventual categorization of water usage such that operators can be ranked in hopes of incentivizing better water stewardship. The data needed to evaluate individual operators is either publicly available or already measured and recorded by producers due to state regulations. This means that future attempts at this ranking can be done with minimal additional effort, as no new data will need to be gathered.

2. The Fresh Water Replacement Ratio

The Fresh Water Replacement Ratio (FR2) is a holistic metric that accounts for oil and gas operators use of water both in the initial drilling/fracturing phase as well as flowback and produced water in the production phase. The goal is to develop methods to evaluate the responsible water stewardship of oil and gas operators in a world that is prioritizing sustainable practices while continuing to supply essential energy resources. The method and resultant metrics described here can be important components in future ESG certification.

The key part of this process is defining the Fresh Water Replacement Ratio as a comprehensive measure of sustainable water usage. The metric (shown in the equation below) in its simplest terms aims to sum all positive or sustainable uses of water utilized by operators divided by the amount of fresh water withdrawn.

$$\text{Fresh Water Replacment Ratio}\left(\text{FR}2\right)=\frac{\text{WW NC}+\text{PW R}+\text{PW D}+\text{CC}}{\text{WW C}}$$

**CC (Conservation Credits) are credits that are awarded for work that restores freshwater resources.*

**PW D (Produced Water Discharged) is produced water that is treated and then discharged to surface bodies.*

**PW R (Produced Water Recycled) is produced water that is recycled.*

**WW C (Water Withdrawn Competitive) is water withdrawn from competitive freshwater sources.*

**WW NC (Water Withdrawn Non-Competitive) is water withdrawn from non-competitive sources.*

The specific parameters used to calculate the FR2 as shown above will possibly change depending on the basin as strategies for managing water vary widely across the country, but the general concept will remain the same. Oil and gas production is very much a cycle that fluctuates between extensive drilling requiring lots of freshwater and times of managing the flowback leading to large amounts of produced water [18]. For this reason, FR2 will be calculated using quarterly data as kept by operators but it will be quantified as a rolling average of the last four quarters. This is done to try and manage the cyclic nature of oil and gas production as measuring single quarters can lead to deceptively high variability. Water used for hydraulic fracturing and drilling could come from competitive freshwater sources and non-competitive water sources (non-freshwater sources such as brackish groundwater). Wastewater generated (commonly known as produced water) will be treated to reuse or sent to saltwater disposal (SWD) disposal wells without treatment. Either acquiring water from non-competitive sources or using treated wastewater would contribute to the water sustainability in UOG operations. Therefore, we use the ratio between the amount of "sustainable" water used and competitive freshwater withdrawn to represent the operator's contribution to water sustainability.

3. Water Stress Indicator

Water stress is often used to assess the scarcity, or the deficit of water and it represents the relationship between water use and water availability. Methods used to calculate the water stress index vary because different indices use different inputs and therefore have different optimal applications. Falkenmark [19] uses water supply per capita per year to measure water scarcity. The limitation of traditionally established water stress indices is that they represent the water stress at a larger spatial scale, such as basin and country, and these indices are not robust enough to measure the water stress in shorter timeframes. In the UOG industry, standard practice and water regulations can vary from county to county. The water stress index with large spatial and temporal scales might not be a good representation of impacts on a local scale.

Water availability usually changes significantly throughout the year with some seasonal trends or regular patterns and therefore to estimate the local water stress and its impacts on oil and gas activities requires an index with temporal flexibility. The U.S. Drought Monitor (USDM) is a unified drought indicator used by federal agencies to trigger drought responses, produced by NDMC (the National

Drought Mitigation Center at the University of Nebraska-Lincoln), NOAA (the National Oceanic and Atmospheric Administration), and USDA (the U.S. Department of Agriculture). This bi-weekly (updated every other Tuesday) data indicates drought conditions throughout the country based on several numeric and climatological models.

We have incorporated USDM data and population estimation data to assess a county-level drought-based water stress indicator applicable to UOG operations (Equation (4)). There are three major components in our OG-related WSI (Water Stress Index): Equation (1): DSCI (USDM) Drought Severity and Coverage Index), Equation (2): drought severity (duration of D3 plus D4), and Equation (3): drought weighted population.

$$\mathrm{DSCI} = 1 \times \mathrm{D}_0 + 2 \times \mathrm{D}_1 + 3 \times \mathrm{D}_2 + 4 \times \mathrm{D}_3 + 5 \times \mathrm{D}_4 \tag{1}$$

$$\text{Severity Drought} = \text{Duration of } \mathrm{D}_3 + \text{Duration of } \mathrm{D}_4 \left(\text{in weeks}\right) \tag{2}$$

$$\begin{aligned} &\text{Drought weighted population}\left(\mathrm{DWP}\right) \\ &= \left(\mathrm{None}_{\mathrm{pop}} * 1 + \mathrm{D0}_{\mathrm{pop}} * 1.2 + \mathrm{D1}_{\mathrm{pop}} * 1.4 + \mathrm{D2}_{\mathrm{pop}} * 1.6 \right. \\ &\quad \left. + \mathrm{D3}_{\mathrm{pop}} * 1.8 + \mathrm{D4}_{\mathrm{pop}} * 2\right) * \text{population} \end{aligned} \tag{3}$$

$$\mathrm{WSI} = \left(\mathrm{Score}_{\mathrm{DSCI}} + \mathrm{Score}_{\text{Severity Duration}} + \mathrm{Score}_{\mathrm{DWP}}\right)/3 \tag{4}$$

Five classifications including four levels of drought (D1 - D4) and abnormally dry (D0) are used in the U.S. Drought Monitor dataset [20]. The USDM dataset has two different types of data, one is based on area and the other is based on population. Values of D0 - D4, $\mathrm{D0}_{\mathrm{pop}}$ - $\mathrm{D4}_{\mathrm{pop}}$ represent the normalized area and population percentages (to the total area) of the corresponding categories, respectively.

Figure 2 is an example of USDM data for Weld County, CO during the week of 02-23-2021 and 03-09-2021 (two weeks). The numbers shown in **Figure 2** are the categorical area percentage. "28.31" in "D1" means 28.31% of the total area of Weld County is in D1 drought. None means no drought conditions. During this period, more than 99% of the area of Weld County was either D1 or D2 drought conditions (D1 + D2) with DSCI of 272.

Each of the three components, DSCI, severity drought and drought weighted population (DWP) will be transformed to a score from 1 - 5 by quintile. A scale of 5 equals values ranking in the range of 80% - 100% of the total data (quintile 80% - 100%), 4 equals quintile of 60% to 80% and so on. The final UOG-related WSI ranges from 0 - 5 and could be aggregated in different timescales (e.g. monthly, quarterly or annually).

Figure 3 shows the temporal changes of OG-WSI for Weld County in Colorado. On the left of the first three rows are the scores of the three WSI

Week	None	D0	D1	D2	D3	D4	DSCI
2021-02-23	0.00	0.00	28.31	70.93	0.77	0.00	272

Figure 2. Example of USDM dataset (Weld County).

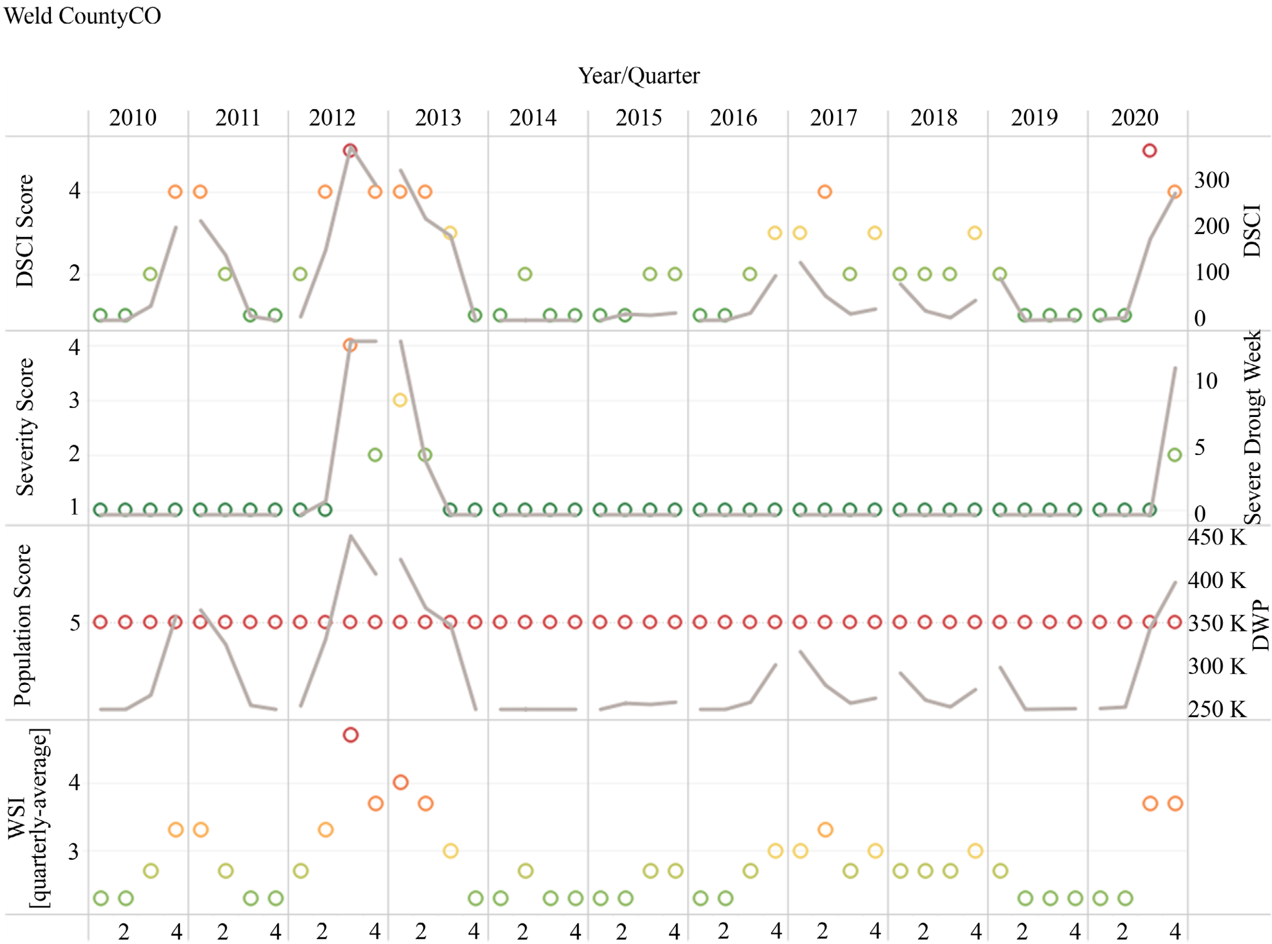

Figure 3. Time series WSI for weld county, CO.

components, the score of DSCI, the score of severity and the score of DWP (drought weighted population). The right axis of the top three rows are the actual numbers of DSCI, duration of the severe drought in week and the drought weighted population.

Figure 4 shows how the quarterly averaged WSI varied nationwide in 2020, at a county level resolution for data analysis. There is an increasing WSI in the western US from Q1 to Q4 in 2020.

4. WSI-FR2

Accounting for the levels of water stress at a basin level is a key goal of this process. To do this the already introduced Fresh Water Replacement Ratio will be weighted using the WSI to give an even more accurate representation of an operator's impact on the water usage and stress in a particular basin or county.

$$\text{WSI Weighted Fresh Water Replacment Ratio} = \frac{\text{WW NC} + \text{PW R} + \text{PW D} + \text{CC}}{\text{WW C} * \text{WSI}}$$

** WSI will be adapted to a scale of 1 - 2 with interval of 0.2.*

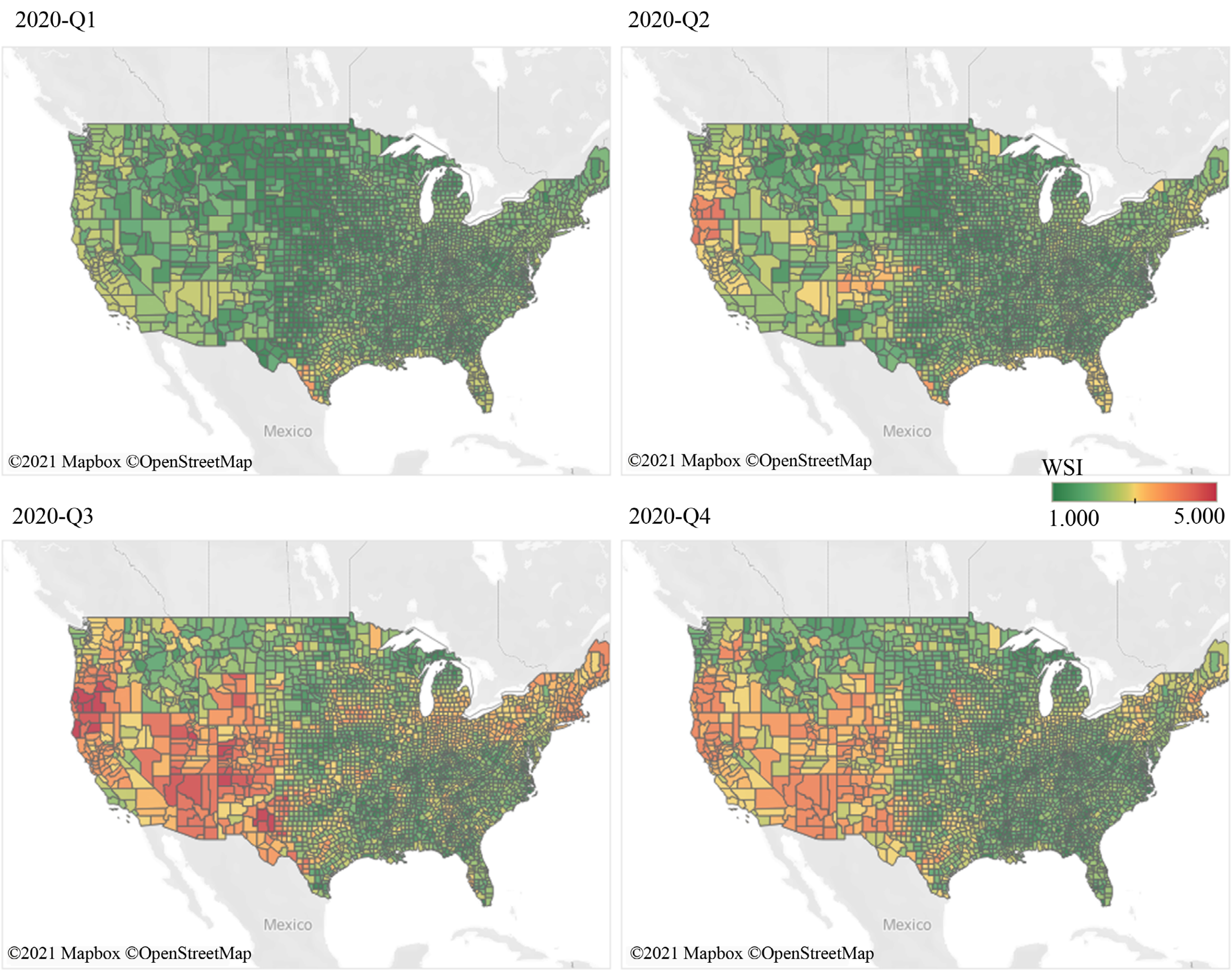

Figure 4. Map of quarterly averaged 2020 OG-related WSI at a county level analysis resolution.

For those operating in regions of elevated water stress it is important to be cognizant of current conditions. To this end, as water stress increases operators need to do more to mitigate their impact on freshwater availability in the region, whether this means drawing less freshwater or being more resourceful with their produced water. This metric will also be calculated on a 4-quarter rolling average with the WSI for the given area being incorporated into the rolling average for the desired period.

5. Case Study

To test the methods outlined in this paper, a case study was developed using data from the Pennsylvania Department of Environmental Protection (PA DEP).

To conduct this study, state-wide waste reports and water management plans were downloaded for ten operators for the years 2019 and 2020. The operators were primarily selected due to their status as large producers of natural gas in the state of Pennsylvania. The data available was then rolled into quarterly totals and used in conjunction with the FR2 and the WSI to determine the water stress weighted FR2. For the purposes of this study, only produced fluid was considered as waste and other types of waste such as drill casings were omitted. This was done as the scope of both metrics and this study primarily focused on water and while some water may be found in other types of waste, it is not a significant source when compared to produced water. The WSI while originally done at a county level could be aggregated to reflect the corresponding spatial coverage according to the scope.

The framework presented was purposely developed to be adaptable for the different techniques used in water management. While the open-source nature of the data used in this case study led to some uncertainty, when deployed as part of an RSG program, discussion with participating operators would allow for any adaptations that would need to be made. Current research is also actively being undertaken to try and identify other accurate data sources to be used within this framework. The operators reviewed for this case study have been anonymized. The analyses presented in this case study are a first of their kind and demonstrate the value of quantitative approaches to water usage for future RSG certification programs as part of an overall ESG strategy. Shown in **Figure 5** is the calculated WSI for the State of Pennsylvania for 2019 and 2020. The accompanying **Table 1** gives the calculated Rolling Average to be used with the WSI FR2.

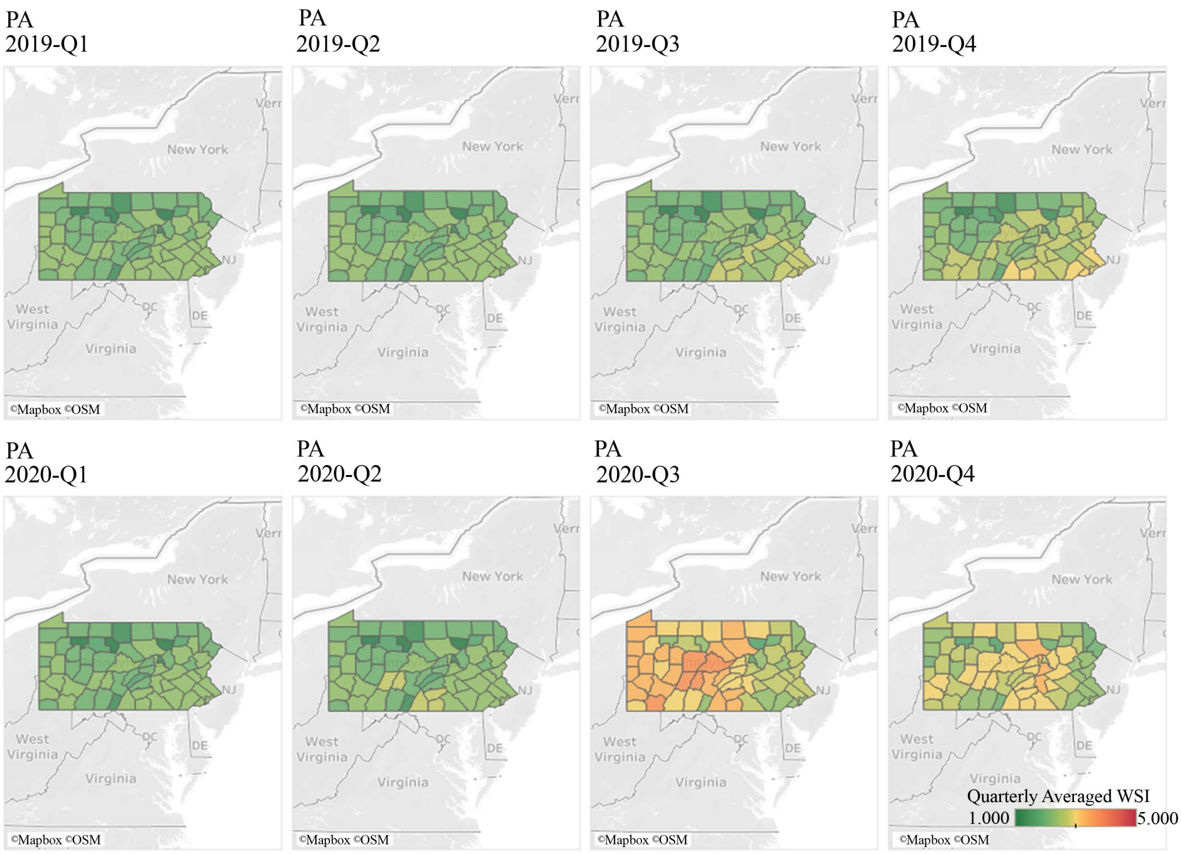

Figure 5. WSI for the state of Pennsylvania over selected time span.

It should be noted that over this period, Pennsylvania had consistent water stress with a slight increase coming at the end of 2020 (**Table 1**). Having analyzed other states over similar periods, a greater variability is expected for other major UOG basins reflecting a need to adjust water usage throughout the year as water stress changes.

Table 2 and **Figure 6** show the calculated WSI-weighted FR2 values for the ten operators studied.

This data shows that significant variability exists between operator practices leading to very different values for the freshwater replacement variable. Some operators have already begun to limit their freshwater use by recycling either their own water or using non-fresh sources for drilling operations. Others still rely heavily on freshwater and could do more to recycle or reuse the water they receive as flow back. The goal of highlighting these differences is to allow operators, investors, and the public to understand where producers stand in terms of their individual freshwater footprint such that changes can be made to be more responsible stewards of this valuable resource.

To better understand the differences in water stewardship as well as to potentially begin to address certifications, summary statistics were calculated and are shown in **Table 3**.

Table 1. WSI rolling average for state of Pennsylvania, 2019-2020.

	Rolling Average 1 (19Q1-19Q4)	Rolling Average 2 (19Q2-20Q1)	Rolling Average 3 (19Q3-20Q2)	Rolling Average 4 (19Q4-20Q3)	Rolling Average 5 (20Q1-20Q4)
WSI Rolling Average	2.10	2.10	2.20	2.30	2.40

Table 2. WSI weighted fresh water replacement ratio for state of Pennsylvania.

Operator	Rolling Average 1 (19Q1-19Q4)	Rolling Average 2 (19Q2-20Q1)	Rolling Average 3 (19Q3-20Q2)	Rolling Average 4 (19Q4-20Q3)	Rolling Average 5 (20Q1-20Q4)
1	1.49	2.73	3.00	15.07	1.85
2	0.41	0.64	0.89	2.00	1.53
3	0.29	0.31	0.27	0.29	0.24
4	0.20	0.22	0.21	0.23	0.22
5	0.31	0.35	0.33	0.37	0.30
6	1.21	1.28	1.26	1.21	1.86
7	0.18	0.18	0.72	0.94	0.13
8	0.19	0.17	0.15	0.12	0.10
9	0.06	0.06	0.04	0.03	0.03
10	0.07	0.07	0.07	0.07	0.07

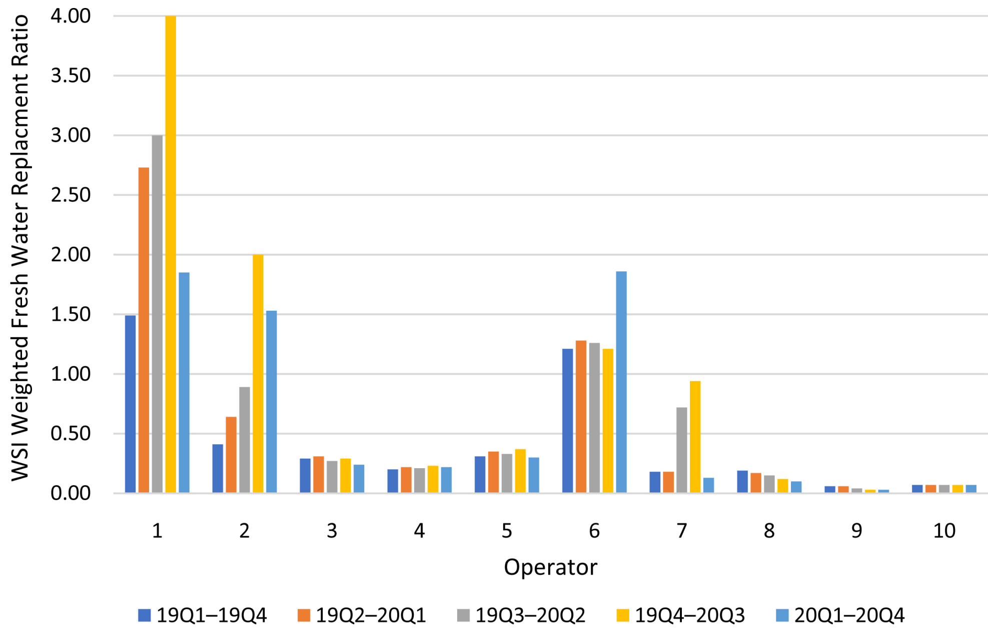

Figure 6. Time series data of WSI FR2 for selected operators and period.

Table 3. Summary statistics for wsi weighted fresh water replacement ratio.

	Rolling Average 1 (19Q1-19Q4)	Rolling Average 2 (19Q2-20Q1)	Rolling Average 3 (19Q3-20Q2)	Rolling Average 4 (19Q4-20Q3)	Rolling Average 5 (20Q1-20Q4)
10^{th} Percentile	0.07	0.07	0.07	0.07	0.07
1^{st} quartile	0.18	0.17	0.16	0.15	0.10
Median	0.25	0.26	0.30	0.33	0.23
3^{rd} quartile	0.38	0.57	0.85	1.14	1.22
90^{th} Percentile	1.24	1.42	1.44	3.31	1.85
Average	0.44	0.60	0.69	2.03	0.63

From this table, it is clear that while those on the bottom of the spectrum (<median) have seen little change over the past 2 years, those who have committed to water stewardship (3^{rd} quartile and 90^{th} percentile) have seen consistent positive change over this same period. This is a good sign and shows that some operators have already prioritized water stewardship even without strict guidelines and ranking systems. It does however also show that much work is still needed to bring the underachievers closer to sustainable use. For those who have still not accepted their role as stewards of sustainable water use, very little has been implemented to reduce water usage. While some of these underachievers even claim to follow ESG guidelines, it is clear they are still not doing enough. It is through research like this that these operators can get a holistic view of their operations with quantifiable metrics such that they can develop goals and practices to increase their positive water usage.

6. Conclusion

The methods detailed in this paper give light to new ways to quantify the relationship between sustainable water usage and UOG. By tying publicly available water usage data to the unique drought conditions that exist for localized regions, the metrics presented above give high resolution accuracy that can be used by operators in evaluating their impacts to make adjustments that reflect the wave of ESG expectations facing the industry. While much has been made about the lack of transparency of many ESG goals, the methods presented here provide actual ways to quantifiably track the effective impact on water supplies. In many ways, this is a first-of-its-kind approach as it relies primarily on publicly available data while also tying water usage to drought conditions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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