Initial Research on Computing Estimated Measures of Sampling Variability for the *Weekly Natural Gas Storage Report*

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Abstract[1]
The U.S. Energy Information Administration releases the *Weekly Natural Gas Storage Report*, designated as a Principal Federal Economic Indicator, to provide weekly estimates of both working gas levels held in underground storage facilities and the net changes in these levels, using survey data collected from a sample of natural gas storage operators in the Lower 48 states. Because the estimator used to compute these estimates is nonlinear, initial research was conducted to compute estimated measures of sampling variability using the bootstrap method. The research focused on the weekly estimates from April to November of 2015 that were based on the most recent sample that was selected and the new five-region breakout. Based on this initial research, it appeared that accurate measures of sampling variability could be estimated using a repeatable process, which could be implemented in production to enhance the content of future releases. This paper will discuss the nonlinear estimator, implementation of the bootstrap method, and the results of the research to date on computing estimated measures of sampling variability for both level and change estimates produced from the survey.

Key Words: establishment surveys, complex surveys, bootstrap, variance estimation, nonlinear estimator

1. Introduction

The U.S. Energy Information Administration (EIA) releases the *Weekly Natural Gas Storage Report* (WNGSR)[2], designated as a Principal Federal Economic Indicator in January 2008, to provide weekly estimates of both working gas levels held in underground storage facilities and the net changes in these levels, using survey data collected from a sample of natural gas storage operators in the Lower 48 states. EIA collects the survey data using Form EIA-912, "Weekly Natural Gas Storage Report"[3]. For a given week, Form EIA-912 collects an operator's working gas volumes by region. Starting with the November 19, 2015 report, EIA published WNGSR using the new five-region breakout, which EIA believed would provide more accurate estimates than those based on the prior three-region breakout, because the new groupings better align with actual operating conditions and practices unique to each region.

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[1] The analysis and conclusions contained in this paper are those of the authors and do not represent the official position of the U.S. Energy Information Administration or the U.S. Department of Energy.
[2] The latest WNGSR release may be found at http://ir.eia.gov/ngs/ngs.html.
[3] Form EIA-912 may be found at http://www.eia.gov/survey/form/eia_912/form.pdf.

EIA does not currently publish measures of sampling variability for the level and net change estimates that are included in the WNGSR releases, and this information was of particular interest given the new five-region breakout. Because the estimator used to compute these estimates is nonlinear, as will be shown in Section 2, initial research was conducted to compute estimated measures of sampling variability using the bootstrap method, which is described in Section 3. The research focused on the weekly estimates from April to November of 2015 that were based on the most recent sample that was selected and the new five-region breakout. Based on the results of this initial research, it appeared that accurate measures of sampling variability could be estimated using a repeatable process that could be implemented in production to enhance the content of future WNGSR releases. EIA plans to implement this process in production for WNGSR starting in the fall of 2016. Section 4 discusses EIA's plan for future production processing and research, including making enhancements for production processing, computing estimated measures of sampling variability when a revised sample is introduced, and looking into possible alternative estimation methodologies.

2. Sample Design and Estimation Methodology for WNGSR

Before describing the sample design and estimation methodology for the WNGSR sample that was selected in 2015, we will briefly discuss the types of fields that are most common for underground natural gas storage. We will also discuss the compositions of the three-region and five-region breakouts of the Lower 48 states used for WNGSR.

2.1 Common Field Types Used for Underground Natural Gas Storage and Regional Breakouts of the Lower 48 States Used for WNGSR

Natural gas is most commonly stored in inventory underground under pressure in three types of fields – depleted reservoirs in oil and/or natural gas fields, aquifers, and salt caverns. Depleted oil and natural gas reservoirs are the most common because of their wide availability, and converting a field from production to storage takes advantage of existing wells, gathering systems, and pipeline connections. Natural aquifers have been converted to natural gas storage reservoirs in some parts of the U.S., particularly the Midwest. Though the geology is similar to that of depleted oil and natural gas reservoirs, aquifers usually require more base gas, which is the volume of natural gas intended as permanent inventory to maintain adequate pressure and deliverability rates, and allow less flexibility in injecting and withdrawing. Most salt cavern storage facilities have been developed in salt dome formations in the Gulf Coast states, but salt caverns have also been developed, using a process called leaching, in bedded salt formations in states located in the Northeast, Midwest, and Southwest. Though construction of salt caverns is more costly than depleted oil and natural gas reservoirs, salt caverns have lower annual costs due to their ability to perform several withdrawal and injection cycles each year.

The target population for WNGSR includes operators with fields located in the Lower 48 states, which includes the District of Columbia and excludes Alaska and Hawaii. Table 1 in the Appendix shows the states included in the prior three-region and current five-region breakouts, where "X" indicates that a given state is classified in the particular region. EIA believes that the new regions provide more accurate estimates because the new groupings better align with actual operating conditions and practices unique to each region. For 2015, EIA compared the stock estimates from WNGSR to those published in the *Natural Gas Monthly*[4], and it suggested that the five-region estimates from WNGSR were closer to the monthly values than the three-region estimates.

2.2 Design of the 2015 WNGSR Sample

WNGSR data are collected from a stratified probability-proportional-to-size (PPS) sample of natural gas storage operators in the United States. The most recent sample for WNGSR was selected in 2015. The sampling frame was based on a census of 131 operators that reported monthly field-level data using Form EIA-191, "Monthly Underground Natural Gas Storage Report"[5]. The sampling frame was partitioned into six primary strata based on the new five-region breakout – East, Midwest, Mountain, Pacific, South Central (Salt Fields), and South Central (Nonsalt Fields). Each primary stratum was split into certainty and noncertainty substrata, using a size cutoff that was determined so that at least 90% of the stratum's measure of size was covered by the sample. The measure of size was based on the average of the most recent March and October working gas volumes for a given operator from the EIA-191. An operator with a measure of size greater than or equal to the cutoff for its stratum was selected in the sample with probability 1, while an operator with a measure of size below the cutoff for its stratum was subjected to PPS sampling in its stratum.

For a given stratum, a systematic PPS sample of noncertainty operators below the size cutoff was selected without replacement as follows:

1. The operators were sorted by the measure of size, which guaranteed that the sample would be comprised of operators with varying magnitude in terms of the measure of size.

2. For each operator, an interval was assigned based on the cumulative measure of size, where the width of the interval for a given operator is its measure of size.

3. A random start from 0 to $\frac{X_h}{n_h}$ was determined, where X_h is the total measure of size for stratum h, and n_h is the noncertainty sample size for stratum h, which ranged from 3 to 6 operators. Denote this random start by a_h.

4. The operators whose intervals contained $a_h + \left(\frac{X_h}{n_h}\right) k_h$ were selected for the sample, where $k_h = 0, \ldots, n_h - 1$.

2.3 Methodology for Computing Weekly Level and Net Change Estimates

This section describes the methodology for computing weekly level and net change estimates for WNGSR. For more information on the methodology used to compute estimates for WNGSR, see EIA's web site[6]. To produce the published WNGSR level estimates, stratum-level estimates are aggregated to form estimates for the Lower 48 states and by region. The corresponding stratum-level variance estimates may be similarly aggregated because the samples by stratum were selected independently. For week t and stratum h, the estimator for the volume of working gas stored, $Y_{t,h}$, is:

[4] The latest *Natural Gas Monthly* release may be found at http://www.eia.gov/naturalgas/monthly.
[5] Form EIA-191 may be found at http://www.eia.gov/survey/form/eia_191/form.pdf.
[6] A more detailed description of the WNGSR estimation methodology may be found at http://ir.eia.gov/ngs/methodology.html.

$$\hat{Y}_{t,h} = \sum_{i \in R} y_{t,h,i} + \sum_{i \in NR} \hat{y}_{t,h,i}$$

where *i* denotes a given operator, *y* denotes working gas volume, *R* denotes reporters to the survey, and *NR* denotes nonreporters that are comprised of operators that either were not selected for the sample or were selected but did not respond to the survey. Note that, instead of producing weighted estimates based only on the sample, the estimator includes all operators on the sampling frame. Estimated volumes, denoted by $\hat{y}$, are imputed for all nonreporters. Imputation of missing or unusable data for a reporter typically occurs by treating the reporter as a nonreporter or by applying a ratio of current-to-prior-week data for other reporters in the region to the prior-week data for the reporter. However, response to Form EIA-912 is mandatory under the Federal Energy Administration Act of 1974 (Public Law 93-275), so unit nonresponse to the survey is infrequent.

The formula for imputing the weekly working gas volume for a given nonreporter *i* is:

$$\hat{y}_{t,h,i} = \bar{m}_{M,h,i} * R_{t,h}^{f_{M,h,i}}$$

where:

1. $\bar{m}_{M,h,i} = \frac{1}{12}\sum_{k=M-11}^{M} m_{k,h,i}$, which is the average of the monthly working gas volume, $m_{k,h,i}$, for the 12 months ending with the most recent data month *M*.

2. $R_{t,h}$ is the median of $\frac{y_{t,h,j}}{\bar{m}_{M,h,j}}$ for the reporters *j* in stratum *h*, including both certainty and noncertainty operators.

3. $f_{M,h,i} = \frac{c_{M,h,i}}{C_{M,h}}$, where $c_{M,h,i} = \frac{\sqrt{\frac{1}{12}\sum_{k=M-11}^{M}\left(m_{k,h,i} - \bar{m}_{M,h,i}\right)^2}}{\bar{m}_{M,h,i}}$ is a coefficient of monthly seasonal variation and $C_{M,h}$ is the median of $c_{M,h,j}$ for the reporters *j* in stratum *h*, including both certainty and noncertainty operators.

The imputation formula is similar in general form to the U.S. Census Bureau's "ratio of identicals" imputation method, which is described by Kott (1987) and uses a ratio of two weighted totals from respondents in the imputation cell to adjust the value of an auxiliary variable for the unit requiring imputation for a survey item. The numerator of the ratio is based on the survey item being imputed, and the denominator is based on the auxiliary variable. However, here, $f_{M,h,i}$ corrects the ratio, based on data for the reporters in stratum *h*, for monthly seasonal variation of operator *i* relative to the reporters. For operator *i*, if there is no monthly variation, then $f_{M,h,i} = 0$ and the imputed value is $\bar{m}_{M,h,i}$. If the monthly variation for operator *i* relative to $\bar{m}_{M,h,i}$ is the same as the median for the reporters in the stratum, then $f_{M,h,i} = 1$, and the imputed value for operator *i* is $\bar{m}_{M,h,i} * R_{t,h}$.

For week *t* and stratum *h*, the estimator for the net change, or difference, in volume of working gas stored, $D_{t,h}$, is:

$$\widehat{D}_{t,h} = \widehat{Y}_{t,h} - \widehat{Y}_{t-1,h}$$

3. Initial Research on Variance Estimation for WNGSR

In this section, we will start by discussing the prior research on variance estimation for WNGSR that was conducted based on the three-region breakout. Then, we will discuss the current research for the 2015 WNGSR sample based on the five-region breakout.

3.1 Prior Research on Variance Estimation Based on Three Regions

Vartivarian and Kasprzyk (2006) documented the research that was completed in 2006 by Mathematica Policy Research, Inc. with Abacus Technology on the general form of the variance estimator for WNGSR based on the prior three-region breakout. For two reasons that limited the options, they decided on the bootstrap method over linearization, balanced repeated replication, and jackknife. First, the stratum-level estimator used as the basis for producing WNGSR level estimates, which was described in Section 2.3, is nonlinear and not a smooth function of the Horvitz-Thompson estimator of total. Second, the nonzero noncertainty sample sizes by stratum were small, ranging from 3 to 10 operators based on three regions. Note, as discussed in Section 2.2, the noncertainty sample sizes are even smaller for the 2015 sample, ranging from 3 to 6 operators.

Mathematica made two additional recommendations. First, to incorporate imputation variance, as well as sampling variability, Mathematica suggested that both reporters and nonreporters with activity in the last 12 months be subjected to selection in the replicate samples, instead of just reporters. Second, Mathematica suggested that finite population correction (FPC) be incorporated as a future enhancement due to the large sampling fractions by stratum.

Mathematica proposed the following bootstrap methodology based on Rao, Wu, and Yue (1992), with the choice of replicate sample size based on Rust and Rao (1996). The bootstrap formula for estimating the variance of the estimated volume of working gas stored for week *t* and stratum *h* is:

$$v\left(\widehat{Y}_{t,h}\right) = \frac{1}{A}\sum_{\alpha=1}^{A}\left(\widehat{Y}^{*}_{t,h,\alpha} - \widehat{\widehat{Y}}^{*}_{t,h}\right)^{2}$$

where:

1. For each stratum, separate replicate samples are selected from the noncertainty reporters and from the noncertainty nonreporters. Replicate samples of size $n_h - 1$ are selected at random with replacement from the reporters, and replicate samples of size $n'_h - 1$ are selected at random with replacement from the nonreporters, where $n'_h = N_h - n_h$ and N_h is the number of noncertainies on the sampling frame in stratum *h*.

2. $\widehat{Y}^{*}_{t,h,\alpha} = \sum_{i \in C} y_{t,h,i} + \sum_{i \in NC \cap R} w_{t,h,i,\alpha} y_{t,h,i} + \sum_{i \epsilon NC \cap NR} w_{t,h,i,\alpha}\, \hat{y}_{t,h,i}$ is the estimator of $Y_{t,h}$ based on replicate α, where *C* denotes the certainty operators

that are included in each replicate estimate, *NC* denotes the noncertainty operators, *R* denotes the reporters, and *NR* denotes the nonreporters (operators that either were not selected for the sample or were selected but did not respond to the survey).

3. $w_{t,h,i,\alpha} = \left(\frac{n_h}{n_h - 1}\right) d_{t,h,i,\alpha} b_{h,i}$ is the weight for a noncertainty reporter, where $d_{t,h,i,\alpha}$ is the number of times *i* was selected in replicate α and $b_{h,i} = 1$ is the base weight, which is not the inverse of the probability of selection for reporters. Similarly, $w_{t,h,i,\alpha} = \left(\frac{n'_h}{n'_h - 1}\right) d_{t,h,i,\alpha} b_{h,i}$ is the weight for a noncertainty nonreporter.

4. $\hat{\bar{Y}}^*_{t,h}$ is the mean of the estimators of $Y_{t,h}$ over the *A* = 1,000 replicates.

Though Rao, Wu, and Yue (1992) state that the sum of squared deviations may be taken about either the full-sample estimator or the mean of the estimators over the *A* replicates, the multiplier of $\frac{1}{A}$ is typically used when the sum of squared deviations is about the full-sample estimator, while $\frac{1}{A-1}$ is typically used when the sum of squared deviations is about the mean of the estimators over the *A* replicates (see Efron and Tibshirani (1986)). But, using $\frac{1}{A}$ instead of $\frac{1}{A-1}$ results in only a slight downward bias when *A* is large.

In 2011, EIA conducted research on variance estimates associated with estimates of weekly net change produced from WNGSR for the three-region breakout. Given that the estimator for weekly net change is a linear combination of the estimators of level for two consecutive weeks, the bootstrap method was also researched for this estimator. Using the weeks from May 2010 through January 2011, EIA used an updated bootstrap formula for estimating the variance of the estimated net change in volume of working gas stored for week *t* and stratum *h*:

$$v(\hat{D}_{t,h}) = (1 - \bar{f}_h) \frac{1}{A-1} \sum_{\alpha=1}^{A} \left(\hat{D}^*_{t,h,\alpha} - \hat{\bar{D}}^*_{t,h}\right)^2$$

where:

1. $\hat{D}^*_{t,h,\alpha} = \hat{Y}^*_{t,h,\alpha} - \hat{Y}^*_{t-1,h,\alpha}$ is the estimator of $D_{t,h}$ based on replicate α.

2. $\hat{\bar{D}}^*_{t,h}$ is the mean of the estimators of $D_{t,h}$ over the *A* = 1,000 replicates.

3. From Wolter (2007), $(1 - \bar{f}_h)$ is an approximate FPC for PPS sample designs, where $\bar{f}_h$ is the average selection probability for stratum *h*:

$$\bar{f}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} \pi_{h,i}$$

Here, $\pi_{h,i}$ is the probability that operator *i* was selected in the sample for stratum *h* and is proportional to the measure of size used in the sample design, $m_{h,i}$, which was the average of the most recent monthly volumes for October and March from the EIA-191 survey:

$$\pi_{h,i} = n_h \left(\frac{m_{h,i}}{\sum_{i=1}^{N_h} m_{h,i}} \right)$$

where N_h is the number of noncertainty operators for stratum *h* on the sampling frame.

Substituting the above expression for $\pi_{h,i}$ in the expression for $\bar{f}_h$ results in something analogous to the sampling fraction, $\frac{n_h}{N_h}$, for stratified simple random sampling:

$$\bar{f}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} \left[n_h \left(\frac{m_{h,i}}{\sum_{i=1}^{N_h} m_{h,i}} \right) \right] = \frac{\sum_{i=1}^{n_h} m_{h,i}}{\sum_{i=1}^{N_h} m_{h,i}}$$

For this research, EIA used aggregated 2010 monthly data from the EIA-191 survey as a proxy for the measure of size used in the sample design, which was updated when the sample was revised in October 2010. Also, note that the multiplier of $\frac{1}{A-1}$ is the one typically used when the sum of squared deviations is about the mean of the estimators over the *A* replicates.

For a given variance estimate, the standard error is estimated as the square root of the variance estimate. Using the above bootstrap methodology for estimating the variance of estimates of net change for May 2010 through January 2011, the mean standard error of the estimate of weekly net change for the Lower 48 states was 2.25 Bcf. Only once was an estimate of weekly net change for the Lower 48 states not significantly different from 0 at the 5% level. However, one challenge was that there was insufficient memory to run the SAS programs after EIA's switch to virtual PCs, so the programs were modified to process replicates simultaneously, instead of sequentially.

3.2 Current Research on Variance Estimation Based on Five Regions

Given the switch from the prior three-region breakout to the current five-region breakout for the Lower 48 states, EIA wanted to estimate measures of sampling variability for estimates published using the five-region breakout, with particular emphasis on the estimates of weekly net change. Because the basis for the strata used for WNGSR changed as a result of switching from three to five regions, this resulted in changes to the application of the imputation methodology for the nonreporters, which changed the imputed values for the nonreporters. EIA's test of these methodological changes included producing estimates using the prior and current region breakouts in parallel for each week of 2015. Differences in estimated levels for the Lower 48 states during this period ranged from -8 Bcf to +10 Bcf, with the absolute difference averaging about 3 Bcf, or 0.14%. Several of the absolute differences exceeded 4 Bcf, which is the newly adopted publication revision threshold for WNGSR.

EIA modified the programs used to implement the bootstrap methodology for the three-region breakout, which was described in Section 3.1, to estimate measures of sampling variability for published estimates of weekly volume of working gas stored and net change in weekly working gas storage, based on the new five-region breakout. For the variance estimator for estimates of working gas storage, EIA incorporated the FPC used in the variance estimator for estimates of net change. For input, EIA used weekly data from April 2015 to November 2015 that were based on the 2015 WNGSR sample. EIA initially tried to use WNGSR data back to January 2010, but there were many strata that had missing standard errors because earlier samples based on the prior three-region breakout had fewer than 2 noncertainties for some of these strata. There were also two additional requirements. First, due to the different patterns of weekly change exhibited by these technologies, EIA wanted to produce separate standard errors for estimates of salt/nonsalt fields, instead of just using this information to impute data for nonreporters in the South Central region. Second, EIA wanted to produce 95% confidence intervals about published estimates, which were sometimes noticeably different from the average of the replicate estimates.

Initially, the standard errors for the estimates of weekly net change averaged over 30 Bcf for the Lower 48 states and were unstable by region. These results were not acceptable, given the design of the 2015 WNGSR sample. So, EIA modified the implementation of the variance estimation procedure as follows. The most important reason for the initial results was that, for a given replicate, a different random seed was used for each week, so EIA used the same seed across weeks to better reflect the covariance between the weekly level estimates. EIA made corrections to the WNGSR micro data to better reflect the input to published estimates, and EIA made corrections to sampling information for a large Pacific operator that should have been selected with certainty and 6 Midwest operators that were selected in the 2015 WNGSR sample but were not included in the initial data collection. Also, the finite population correction based on monthly data was unstable, so EIA used the measure of size from sample selection, which stabilized the correction by stratum to an acceptable range of approximately 32% to 52%.

On March 1, 2016, EIA released "Types of Possible Survey Errors in Estimates Published in the *Weekly Natural Gas Storage Report*"[7]. This report included the results of research that EIA conduced on variance estimation for WNGSR based on the five-region breakout. For a given estimate of weekly volume of working gas stored, EIA published the coefficient of variation, which was the standard error of the estimate divided by the estimate. For a given estimate of net change in weekly working gas volume, EIA published the standard error. Information in the tables from this report is reproduced in Tables 2, 3a, 3b, and 4 of the Appendix.

For the Lower 48 states, Table 2 in the Appendix gives coefficients of variation for the published estimates of weekly working gas storage and standard errors for the published estimates of net change in weekly working gas storage. The coefficients of variation for estimates of working gas storage averaged about 0.9%, which is well below the threshold of 5% used for the sample design. The average standard error for estimates of net change was approximately 1.8 Bcf, which was comparable to the 2.25 Bcf average from the research based on three regions that EIA conduced in 2011. The largest standard error was approximately 2.5 Bcf, so each of these changes (15 Bcf is the smallest in magnitude) was significantly different from 0 when tested individually at the 5% level.

For each of the five regions, Tables 3a and 3b in the Appendix give coefficients of variation for the published estimates of weekly working gas storage and standard errors

[7] This report may be found at http://ir.eia.gov/ngs/possiblesurveyerrors.html.

for the published estimates of net change in weekly working gas storage, respectively. The coefficients of variation ranged from 1.4% to 4.1%, with the Pacific region posting the highest coefficients of variation. The average standard error for the estimates of net change by region was approximately 0.5 billion cubic feet (Bcf) for the East region, 0.6 Bcf for the Midwest region, 0.3 Bcf for the Mountain region, 0.8 Bcf for the Pacific region, and 1.2 Bcf for the South Central region. For the salt/nonsalt breakout of the South Central region, Table 4 in the Appendix gives coefficients of variation for the published estimates of weekly working gas storage and standard errors for the published estimates of net change in weekly working gas storage. The coefficients of variation ranged from 1.6% to 4.0% and were higher for the salt estimates, which were smaller than the corresponding nonsalt estimates. For both salt and nonsalt fields, the average standard error for the estimates of net change was approximately 0.8 Bcf.

4. Plan for Future Production Processing and Research

Based on EIA's research on variance estimation for WNGSR based on five regions, EIA believes that accurate measures of sampling variability can be calculated using a repeatable process, which can be implemented in production with some minor changes in the fall of 2016, to enhance the content of future WNGSR releases. The initial research was based on input spreadsheets that were read by the variance estimation program in SAS, which were manually created by extracting data from the production WNGSR database. As discussed in Section 3.2, some of the information that was input needed to be corrected. EIA plans to update the information on the 2015 WNGSR sample in the production database, automate the creation of the input files from the production database each week, and create historical input files for the weeks that follow the end of the initial research period and precede the start of implementation in production so that measures of sampling variability can be published since the introduction of the 2015 WNGSR sample. EIA also plans to make the constant factor in the bootstrap formula for levels consistent with the one for net changes, create separate input files of parameters and FPCs, and improve the documentation of the code to make it easier to maintain.

Though new operators and inactive operators identified in the EIA-191 are rare, EIA is developing a plan for handling these operators in weekly production, with the idea to maintain consistency between the noncertainty operators included in the selection of the bootstrap replicate samples for both the current week, when an operator is added to the sample or removed from the sample, and the prior week. By maintaining this consistency, the bootstrap variances for estimates of net change should appropriately reflect the covariance between the level estimates for the consecutive weeks. If a newly identified operator is relatively small and treated as a noncertainty nonreporter, then EIA plans to include the operator in selection of the bootstrap replicate samples for current and prior weeks, and EIA plans to impute positive data for the current week and to impute zero data for the prior week. EIA plans to exclude an inactive operator, defined as being inactive for the most recent 12 months in EIA-191, from selection in the bootstrap replicate samples for both current and prior weeks. If the inactive operator is a noncertainty that was not selected in the noncertainty sample, then imputing zero data each week does not contribute to the variance of the weekly estimates because the imputed value is a fixed constant and is not based on the noncertainty sample that was selected. If the operator is a noncertainty that was selected in the noncertainty sample, which is extremely rare, then its moving average based on the last 12 months is 0, so it cannot be used to impute data for nonreporters for either the full sample or the bootstrap replicate samples.

EIA plans to research how to calculate measures of sampling variability when the next WNGSR sample is introduced, which will probably be sometime in the spring of 2017. EIA conducts a sample overlap for WNGSR in which estimates from the current and new samples are compared before the new sample is introduced. The planned methodology for producing estimates for WNGSR during this overlap is as follows. Let $\hat{Y}_{t,h}^{C}$ denote the WNGSR estimate for week *t* and stratum *h* from the current sample, and let $\hat{Y}_{t,h}^{N}$ denote the WNGSR estimate for week *t* and stratum *h* from the new sample. If EIA gradually introduces the new sample over *w* weeks (e.g., *w* = 4 for a 4-week period) using a composite estimator, then we have as follows for the level estimates:

Last week using current sample entirely (*t* = 0): $\hat{Y}_{0,h}^{C}$
First week using current and new samples (*t* = 1): $\left(1-\frac{1}{w}\right)\hat{Y}_{1,h}^{C}+\left(\frac{1}{w}\right)\hat{Y}_{1,h}^{N}$
Second week using current and new samples (*t* = 2): $\left(1-\frac{2}{w}\right)\hat{Y}_{2,h}^{C}+\left(\frac{2}{w}\right)\hat{Y}_{2,h}^{N}$
…
Last week using current and new samples (*t* = *w*-1): $\left(1-\frac{w-1}{w}\right)\hat{Y}_{w-1,h}^{C}+\left(\frac{w-1}{w}\right)\hat{Y}_{w-1,h}^{N}$
First week using the new sample entirely (*t* = *w*): $\hat{Y}_{w,h}^{N}$

The corresponding estimates of net change would then be:

For *t* = 1: $\left[\left(1-\frac{1}{w}\right)\hat{Y}_{1,h}^{C}-\hat{Y}_{0,h}^{C}\right]+\left(\frac{1}{w}\right)\hat{Y}_{1,h}^{N}$

For *t* = 2: $\left[\left(1-\frac{2}{w}\right)\hat{Y}_{2,h}^{C}-\left(1-\frac{1}{w}\right)\hat{Y}_{1,h}^{C}\right]+\left[\left(\frac{2}{w}\right)\hat{Y}_{2,h}^{N}-\left(\frac{1}{w}\right)\hat{Y}_{1,h}^{N}\right]$
…
For *t* = *w*-1: $\left[\left(1-\frac{w-1}{w}\right)\hat{Y}_{w-1,h}^{C}-\left(1-\frac{w-2}{w}\right)\hat{Y}_{w-2,h}^{C}\right]+\left[\left(\frac{w-1}{w}\right)\hat{Y}_{w-1,h}^{N}-\left(\frac{w-2}{w}\right)\hat{Y}_{w-2,h}^{N}\right]$

For *t* = *w*: $\left[\hat{Y}_{w,h}^{N}-\left(\frac{w-1}{w}\right)\hat{Y}_{w-1,h}^{N}\right]-\left(1-\frac{w-1}{w}\right)\hat{Y}_{w-1,h}^{C}$

Because the current and new samples are independent, producing estimated variances for the level and net change estimates is similar to the methodology previously discussed, except the composite weights need to be incorporated.

In April 2016, EIA presented the methodology described in Section 3 at EIA's meeting with the American Statistical Association Committee on Energy Statistics. Though the bootstrap methodology seemed reasonable to the committee, the committee was concerned about the limitations of the bootstrap method in terms of the types of errors (i.e., sampling variance and imputation variance) that it can measure. The committee recommended that EIA research possible improvements to the estimation methodology, with a particular focus on the accuracy of the imputation procedure for nonreporters. Though EIA's priority is to first implement the bootstrap methodology in production, EIA plans to look into possible improvements to the estimation methodology as time permits.

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Appendix

Table 1: Prior and Current Breakouts by Region for the *Weekly Natural Gas Storage Report*

State	Five-Region Breakout					Three-Region Breakout		
	East	Midwest	South Central	Mountain	Pacific	East	West	Producing Region
AL			X					X
AR			X					X
AZ				X			X	
CA					X		X	
CO				X			X	
CT	X					X		
DE	X					X		
DC	X					X		
FL	X					X		
GA	X					X		
IA		X				X		
ID				X			X	
IL		X				X		
IN		X				X		
KS			X					X
KY		X				X		
LA			X					X
MA	X					X		
MD	X					X		
ME	X					X		
MI		X				X		
MN		X					X	
MO		X				X		
MS			X					X
MT				X			X	
ND				X			X	
NE				X		X		
NH	X					X		
NC	X					X		
NJ	X					X		
NM				X				X
NV				X			X	
NY	X					X		
OH	X					X		
OK			X					X
OR					X		X	
PA	X					X		
RI	X					X		
SC	X					X		
SD				X			X	
TN		X				X		
TX			X					X
UT				X			X	
VA	X					X		
VT	X					X		
WA					X		X	
WI		X				X		
WV	X					X		
WY				X			X	

Table 2: Published estimates of weekly working gas storage and net change in weekly working gas storage (in billion cubic feet) for the Lower 48 States for April to November 2015

Week Ending	Lower 48 States			
	Stocks (Bcf)	**CV (%)**	**Change (Bcf)**	**SE (Bcf)**
4/10/15	1,539	1.2		
4/17/15	1,628	1.1	89	1.4
4/24/15	1,711	1.1	83	1.9
5/1/15	1,785	1.0	74	1.3
5/8/15	1,897	1.0	112	1.9
5/15/15	1,989	1.0	92	1.7
5/22/15	2,101	1.0	112	2.0
5/29/15	2,233	1.0	132	2.4
6/5/15	2,344	1.0	111	1.7
6/12/15	2,433	1.0	89	1.6
6/19/15	2,506	0.9	73	1.3
6/26/15	2,579	0.9	73	1.5
7/3/15	2,666	0.9	87	1.7
7/10/15	2,764	0.9	98	1.9
7/17/15	2,823	0.9	59	1.2
7/24/15	2,872	0.9	49	1.2
7/31/15	2,910	0.9	38	1.9
8/7/15	2,975	0.9	65	1.8
8/14/15	3,027	0.9	52	1.6
8/21/15	3,094	0.9	67	2.0
8/28/15	3,190	0.9	96	2.0
9/4/15	3,262	0.9	72	2.1
9/11/15	3,336	0.9	74	1.8
9/18/15	3,441	0.9	105	1.7
9/25/15	3,537	0.9	96	1.6
10/2/15	3,634	0.9	97	2.5
10/9/15	3,731	0.9	97	1.7
10/16/15	3,813	0.8	82	1.9
10/23/15	3,875	0.8	62	1.2
10/30/15	3,931	0.8	56	2.3
11/6/15	3,985	0.8	54	2.3
11/13/15	4,000	0.8	15	2.0

Source: "Types of Possible Survey Errors in Estimates Published in the *Weekly Natural Gas Storage Report***"**

Table 3a: Published estimates of weekly working gas storage (in billion cubic feet) and Coefficients of Variation (in percents) by Region for April to November 2015

Week Ending	East		Midwest		Mountain		Pacific		South Central	
	Stocks	CV	Stocks	CV	Stocks	CV	Stocks	CV	Stocks	CV
4/10/15	250	2.2	263	1.7	117	3.2	273	4.1	637	1.8
4/17/15	271	2.1	282	1.7	118	3.1	276	4.0	681	1.7
4/24/15	294	2.1	296	1.7	118	3.1	281	3.6	721	1.7
5/1/15	310	2.1	311	1.6	119	2.9	287	3.6	758	1.6
5/8/15	341	1.9	339	1.6	123	2.8	292	3.4	802	1.6
5/15/15	371	1.9	364	1.6	125	2.7	298	3.4	832	1.6
5/22/15	404	1.9	396	1.5	129	2.6	307	3.3	866	1.6
5/29/15	440	1.9	431	1.5	136	2.4	316	3.2	910	1.7
6/5/15	470	2.0	464	1.5	142	2.3	322	3.2	946	1.7
6/12/15	499	2.0	493	1.5	147	2.2	327	3.3	968	1.7
6/19/15	524	1.9	517	1.5	150	2.2	333	3.2	982	1.6
6/26/15	552	1.9	546	1.5	155	2.1	333	3.2	993	1.6
7/3/15	584	1.9	582	1.5	158	2.0	329	3.2	1,013	1.6
7/10/15	609	1.9	612	1.5	164	1.9	334	3.3	1,045	1.7
7/17/15	627	1.8	636	1.5	167	1.8	337	3.3	1,056	1.6
7/24/15	643	1.7	659	1.6	171	1.8	340	3.2	1,059	1.6
7/31/15	658	1.7	683	1.6	174	1.8	341	3.2	1,054	1.6
8/7/15	681	1.6	713	1.6	176	1.8	344	3.0	1,061	1.7
8/14/15	704	1.6	740	1.6	179	1.9	345	2.9	1,059	1.7
8/21/15	725	1.5	770	1.7	183	2.1	345	2.8	1,071	1.7
8/28/15	751	1.4	815	1.7	188	2.2	345	2.7	1,091	1.7
9/4/15	769	1.4	848	1.8	191	2.3	349	2.6	1,105	1.7
9/11/15	787	1.4	883	1.8	194	2.3	347	2.7	1,125	1.7
9/18/15	812	1.4	918	1.8	197	2.3	352	2.6	1,162	1.6
9/25/15	837	1.4	952	1.8	201	2.3	355	2.7	1,192	1.6
10/2/15	863	1.4	984	1.8	206	2.2	359	2.9	1,222	1.6
10/9/15	880	1.4	1,016	1.8	210	2.1	367	2.8	1,258	1.6
10/16/15	899	1.4	1,046	1.8	213	2.0	367	2.9	1,288	1.5
10/23/15	905	1.4	1,072	1.8	216	1.9	373	2.9	1,309	1.5
10/30/15	916	1.4	1,097	1.9	216	1.9	377	2.8	1,325	1.5
11/6/15	929	1.4	1,117	1.9	217	1.9	382	2.8	1,340	1.5
11/13/15	934	1.4	1,124	1.9	214	1.6	381	2.7	1,347	1.5

Source: "Types of Possible Survey Errors in Estimates Published in the *Weekly Natural Gas Storage Report*"

Table 3b: Published estimates of net change in weekly working gas storage (in billion cubic feet) and Standard Errors (in billion cubic feet) by Region for April to November 2015

Week Ending	East		Midwest		Mountain		Pacific		South Central	
	Change	**SE**	**Change**	**SE**	**Change**	**SE**	**Change**	**SE**	**Change**	**SE**
4/17/15	21	0.2	19	0.4	1	0.1	3	0.6	44	1.2
4/24/15	23	0.6	14	0.4	0	0.1	5	1.2	40	1.3
5/1/15	16	0.4	15	0.4	1	0.3	6	0.3	37	1.1
5/8/15	31	0.4	28	0.5	4	0.2	5	0.4	44	1.8
5/15/15	30	0.3	25	0.4	2	0.3	6	0.4	30	1.6
5/22/15	33	0.7	32	0.2	4	0.2	9	0.9	34	1.6
5/29/15	36	1.3	35	0.5	7	0.2	9	1.0	44	1.6
6/5/15	30	1.0	33	0.5	6	0.1	6	0.5	36	1.2
6/12/15	29	0.8	29	0.6	5	0.1	5	0.6	22	1.1
6/19/15	25	0.3	24	0.5	3	0.1	6	0.2	14	1.2
6/26/15	28	0.4	29	0.5	5	0.1	0	0.6	11	1.1
7/3/15	32	0.7	36	0.8	3	0.2	-4	0.5	20	1.2
7/10/15	25	0.3	30	0.4	6	0.3	5	0.6	32	1.6
7/17/15	18	0.3	24	0.4	3	0.4	3	0.5	11	0.9
7/24/15	16	0.4	23	0.5	4	0.2	3	0.3	3	1.0
7/31/15	15	0.5	24	0.7	3	0.4	1	1.2	-5	1.2
8/7/15	23	0.5	30	0.7	2	0.5	3	1.3	7	0.9
8/14/15	23	0.3	27	0.7	3	0.5	1	1.1	-2	0.8
8/21/15	21	0.5	30	0.7	4	0.8	0	1.5	12	0.8
8/28/15	26	0.6	45	1.1	5	0.5	0	1.2	20	0.7
9/4/15	18	0.4	33	1.1	3	0.4	4	1.6	14	0.7
9/11/15	18	0.4	35	1.1	3	0.1	-2	1.2	20	0.8
9/18/15	25	0.6	35	0.8	3	0.2	5	0.9	37	1.0
9/25/15	25	0.6	34	0.8	4	0.2	3	0.5	30	1.1
10/2/15	26	0.7	32	0.6	5	0.3	4	1.3	30	1.9
10/9/15	17	0.4	32	0.5	4	0.3	8	0.7	36	1.4
10/16/15	19	0.4	30	0.6	3	0.5	0	0.9	30	1.5
10/23/15	6	0.4	26	0.7	3	0.4	6	0.3	21	0.9
10/30/15	11	0.6	25	1.2	0	0.1	4	0.8	16	1.7
11/6/15	13	0.2	20	0.5	1	0.3	5	1.5	15	1.7
11/13/15	5	0.3	7	0.2	-3	1.8	-1	0.3	7	0.7

Source: "Types of Possible Survey Errors in Estimates Published in the *Weekly Natural Gas Storage Report*"

Table 4: Published estimates of weekly working gas storage and net change in weekly working gas storage (in billion cubic feet) for Salt and Nonsalt Fields in the South Central Region for April to November 2015

Week Ending	South Central							
	Salt Fields				Nonsalt Fields			
	Stocks (Bcf)	CV (%)	Change (Bcf)	SE (Bcf)	Stocks (Bcf)	CV (%)	Change (Bcf)	SE (Bcf)
4/10/15	171	3.3			466	2.1		
4/17/15	191	3.0	20	0.9	490	2.1	24	0.8
4/24/15	209	2.9	18	0.9	512	2.0	22	1.0
5/1/15	223	2.7	14	0.7	535	2.0	23	0.9
5/8/15	243	2.8	20	1.4	559	2.0	24	1.2
5/15/15	251	2.7	8	0.5	581	2.0	22	1.5
5/22/15	261	2.6	10	0.4	605	2.0	24	1.5
5/29/15	277	2.6	16	0.5	633	2.1	28	1.5
6/5/15	291	2.7	14	1.0	655	2.1	22	0.7
6/12/15	295	2.9	4	0.8	673	2.1	18	0.7
6/19/15	295	2.8	0	0.7	686	2.0	13	0.9
6/26/15	292	2.8	-3	0.9	700	2.0	14	0.7
7/3/15	297	2.9	5	1.1	716	2.0	16	0.5
7/10/15	305	3.2	8	1.5	739	1.9	23	0.6
7/17/15	304	3.2	-1	0.2	752	1.9	13	0.9
7/24/15	300	3.3	-4	0.2	759	1.9	7	0.9
7/31/15	292	3.4	-8	0.6	762	1.9	3	1.0
8/7/15	291	3.5	-1	0.6	769	1.9	7	0.7
8/14/15	286	3.7	-5	0.5	773	1.9	4	0.6
8/21/15	287	3.8	1	0.4	784	1.8	11	0.7
8/28/15	290	3.9	3	0.5	801	1.8	17	0.6
9/4/15	293	4.0	3	0.5	811	1.8	10	0.4
9/11/15	298	4.0	5	0.5	828	1.7	17	0.6
9/18/15	312	3.9	14	0.9	850	1.7	22	0.4
9/25/15	321	3.9	9	0.9	870	1.7	20	0.6
10/2/15	331	3.9	10	1.8	891	1.7	21	0.6
10/9/15	346	3.8	15	1.2	912	1.6	21	0.8
10/16/15	357	3.5	11	1.3	930	1.6	18	0.8
10/23/15	366	3.5	9	0.5	944	1.6	14	0.7
10/30/15	371	3.3	5	1.5	955	1.6	11	0.8
11/6/15	373	3.3	2	1.6	967	1.6	12	0.4
11/13/15	377	3.4	4	0.6	970	1.6	3	0.4

Source: “Types of Possible Survey Errors in Estimates Published in the *Weekly Natural Gas Storage Report***”**