DRAFT FOR PUBLIC REVIEW

New Jersey Assessment of Water Losses for Public Community Water Systems

A report for the New Jersey Department of Environmental Protection

Daniel J. Van Abs, PhD, FAICP/PP with Jillian Drabik, PhD on the statistical analysis

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An analysis of water loss information collected by the NJDEP and DRBC concludes that PCWS in Coastal Plain areas have consistently and significantly lower water losses than PCWS in Bedrock Provinces. Large, Medium and Small PCWS have somewhat different water loss rates, but this distinction is less (and less consistent) than that of the geophysical comparison.

- Daniel J. Van Abs, PhD, FAICP/PP with Jillian Drabik, PhD on the statistical analysis

Overview

A major factor in future water demand projections is the amount of water withdrawn from the raw water resources (e.g., reservoirs, rivers, aquifers) that is not delivered to metered customers (billed water) or other valid uses (e.g., unmetered, authorized demands such as firefighting, line cleaning). Measuring this "lost" water is complicated by several factors, including potential meter error, record-keeping errors, water theft, and the difficulty of measuring authorized but non-metered flows.

The water allocation regulations of NJDEP have long required analysis of "unaccounted for water" (UFW) at certain periods in a permit cycle. UFW is a simple measure comparing gallons of water billed (which can include unbilled metered water and unbilled authorized consumption such as firefighting) to the total water placed into water mains, resulting %UFW. NJDEP provided data for more than 200 PCWS for the years 2016-2019, though not all PCWS provided UFW values for all four years.

The Delaware River Basin Commission requires use of the AWWA methodology for PCWS under their jurisdiction, providing a more detailed analysis of water volumes as billed, unbilled, apparent loss and real loss. DRBC provided data for 2018 through 2020 for almost 90 PCWS. The 2018 and 2019 audits used Version 5 of the AWWA methodology; these were used in this analysis for consistency with the NJDEP data years. The 2020 audits used a combination of Versions 5 and 6; they were not used. Again, not all PCWS provided water audits for all three years. It should be noted that the DRBC and NJDEP do not require that PCWS have their results independently verified or certified, raising possibilities for reporting error.

Many PCWS in the DRBC dataset were also in the NJDEP data set. DRBC data were used wherever there is an overlap <u>and</u> the data were sufficient.[1] In both cases, detailed quality control reviews have not occurred, resulting in some anomalies within the data sets. For example, some PCWS reported negative results, which would indicate that more water was metered to customers than was placed into the distribution system, an obvious impossibility. In such cases, the results were excluded, along with results showing zero losses, which likewise is not feasible (all systems have some leakage). Second, some PCWS reported extraordinarily high levels of water losses, from 90% to 100%, which would indicate that nearly all or all water placed into the distribution system was lost; such results indicate poor use of the

[1] The Water Quality Accountability Act is expected to lead to a more detailed accounting using the Water Loss Audit methodology of the American Water Works Association (Manual 36), but that requirement is not in place. Even when implemented, many PCWS will require significant training on the AWWA methodology. a more detailed analysis of "non-revenue water" (NRW), which parses out the unmetered flows into authorized flows, apparent losses (e.g., meter and record-keeping errors), and real losses (e.g., theft and leakages from within the transmission system and service lines prior to the customer meter).

methodology, poor records, or other problems, and were also excluded. In both cases, the excluded results were so few that the resulting statistical analyses were not materially affected.

Given that the project seeks to understand how recent water demands are divided into residential, commercial and industrial sectors and "water losses", average 2018/2019 results were used from both the NJDEP and DRBC data sets, unless no results were available for those years, at which point the average 2016/2017 results from NJDEP were used as a proxy. For both datasets separately, and then for the combined datasets, each PCWS was categorized by its service area's primary geophysical location, either Bedrock Provinces (Valley & Ridge, Highlands and Piedmont) or Coastal Plain Provinces (Inner and Outer Coastal Plains), to test whether UFW/NRW results differed between the two areas. To further examine the results, the PCWS were also categorized by PCWS size based on the total water limits reported in NJDEP's Deficit/Surplus Analysis from June 2022. Large PCWS were those with limits exceeding 300 MGM, Medium as greater than 30 MGM, and Small as greater than or equal to 5 MGM. Smaller systems than 5 MGM (less than 165,000 gallons per day) rarely provided information on UFW or NRW to the agencies; they were not included in the analysis. Statistical test results using t-tests and Mann-Whitney U Tests are provided in the Appendix.[2]

Results from the NJDEP UFW Information

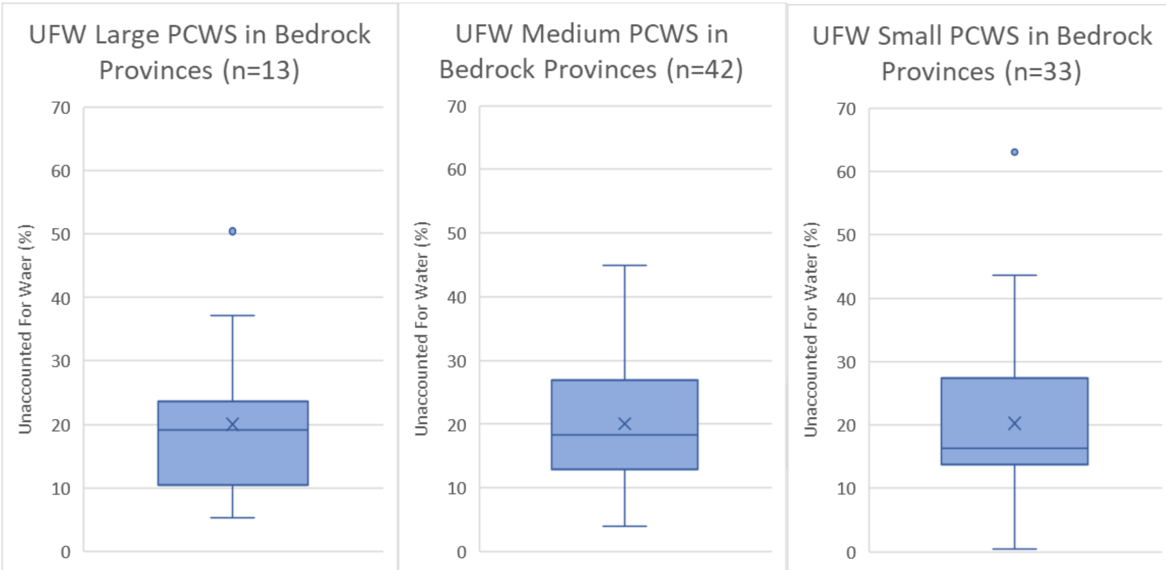
For all 234 PCWS in NJDEP dataset with usable data, basic statistics show the following results. Aside from the very large ranges between minimum and maximum values, the most useful point is that the medians and averages are not greatly different.

	UFW 2018 Calc %	UFW 2019 Calc %	Average 2016-2019 %UFW	Average 2018-2019 %UFW	% UFW Used
MAXIMUM	52.9	86.7	63.0	63.0	63.0
MINIMUM	0.2	0.1	0.1	0.1	0.1
MEDIAN	13.1	14.1	13.3	13.4	13.5
AVERAGE	15.1	16.2	15.8	15.4	15.5

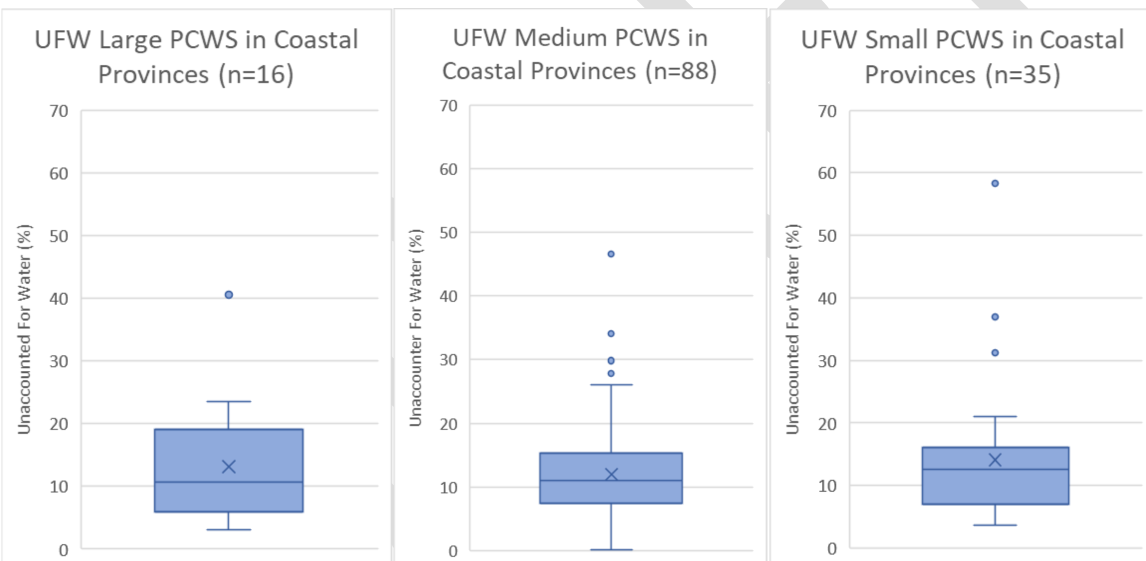
The results by PCWS category provide a different picture of UFW results. The PCWS in Bedrock Provinces have the following results by PCWS size. The blue box represents the PCWS from the 25th to 75th percentiles, the line within the box represents the median (the 50th percentile), the X represents the mean (average), the whiskers represent results within the top and bottom quartiles, with any points above or below the whiskers being outliers.[3] The number of PCWS is indicated by the "n".

[2] In the t-test the main (or null) hypothesis is considering if the mean of sample 1 is equal to the mean of sample 2. A non-significance finding indicates a failure to reject the hypothesis and the data provides support to conclude that there is no difference between the means. However, the t-test assumes normal distribution, which is not correct for the data sets. Therefore, the statistical analysis also includes Mann-Whitney U Tests, a statistical test that does not assume samples have a normal distribution. This is a nonparametric test of the null hypothesis that, for randomly selected values X and Y from two populations, the probability of X being greater than Y is equal to the probability of Y being greater than X.

[3] These plots were developed in Microsoft Excel, which "uses the Tukey industry standard, which states that values are considered outliers only if they lie 1.5 times the length of the box (known as the interquartile range) from either end of the box." (Microsoft Excel Team Blog)



The PCWS in Coastal Plain Provinces have the following results by PCWS size.



Within these results, the following table shows the median and 25th percentile results for the three PCWS size categories in two geophysical settings. Two interesting patterns are shown. First, Large PCWS in the Bedrock grouping have a higher median than the Medium PCWS, which in turn have a higher median than the Small PCWS. In the Coastal group, the relationship is reversed, with the Small PCWS having the highest median. However, as discussed in the Appendix, none of the differences between the three PCWS sizes within each geophysical setting is statistically significant. Second, the Coastal grouping has much lower values for both median and 25th percentile. The ratio of median and 25th percentile values for Bedrock/Coastal PCWS is show for each PCWS size category, and ranges from two-thirds higher to nearly double for Bedrock, except for Small PCWS, where a roughly 30% higher result is seen for Bedrock. As discussed further in the Appendix, this finding is statistically significant; the Coastal PCWS water loss results are different from those for the Bedrock PCWS. This finding is consistent with prior work from Van Abs, et al. (2018), showing a consistent finding that Coastal PCWS in general have lower total water losses as measured by UFW. As shown by the box and whisker plots, this also is true for the 75th percentile values for each PCWS size.

PCWS Size	Median Bedrock %UFW	Median Coastal %UFW	Ratio Bedrock to Coastal	25th Percentile Bedrock %UFW	25th Percentile Coastal %UFW	Ratio Bedrock to Coastal
Large	19.1	10.6	1.80	10.4	5.8	1.79
Medium	18.3	11.0	1.66	12.9	7.4	1.74
Small	16.3	12.6	1.29	13.8	7.0	1.97

Results from the DRBC NRW Information

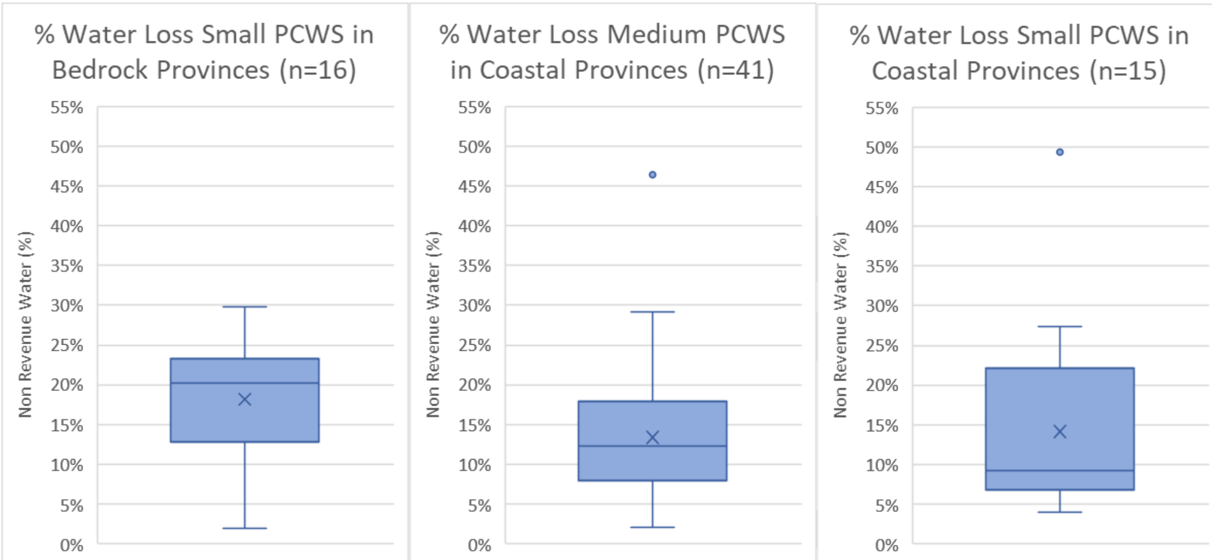
As discussed above, PCWS provide more detailed information about real, apparent and total water losses to the DRBC, using the AWWA methodology. The closest comparable value to NJDEP's UFW is the metric "Water Losses as % by Volume of Water Supplied" (shown here as % Water Loss or %WL), which is used in this analysis. The alternative approach would be to use Non-Revenue Water, but this metric includes metered and unmetered unbilled water, neither of which is a water loss. The following table provides information on the results from 2018 and 2019. As with the NJDEP UFW data set, the range from maximum to minimum are very large, especially in 2019, but the medians and averages are fairly close.

	2018 Calc % WL	2019 Calc % WL	Average 2018-2019 % WL
MAXIMUM	46.4%	86.7%	49.4%
MINIMUM	0.1%	0.7%	1.9%
MEDIAN	12.4%	10.8%	12.3%
AVERAGE	13.8%	14.5%	14.6%

As with the NJDEP UFW information, the DRBC data set was analyzed by PCWS size and geophysical province location. The data set is considerably smaller, with only 84 PCWS represented, instead of the more than 200 PCWS from the NJDEP data set. The portions of New Jersey within the Delaware River Basin are in general less densely populated than northern New Jersey, resulting in low representation among large systems (e.g., only one PCWS within the Large PCWS-Bedrock category), and the following table indicates categories for which less than 10 PCWS are represented. The ratios highlighted in yellow are based on a small number of reported values for one or both of the compared categories; they should not be used as definitive results.

PCWS Size	Median Bedrock %WL	Median Coastal %WL	Ratio Bedrock to Coastal	25th Percentile Bedrock %WL	25th Percentile Coastal %WL	Ratio Bedrock to Coastal
Large	21.1 (n=1)	10.6 (n=6)	1.99	NA	NA	NA
Medium	16.6 (n=4)	12.5 (n=41)	1.28	NA	10.0	NA
Small	20.5 (n=16)	9.6 (n=15)	2.14	15.1	8.1	1.86

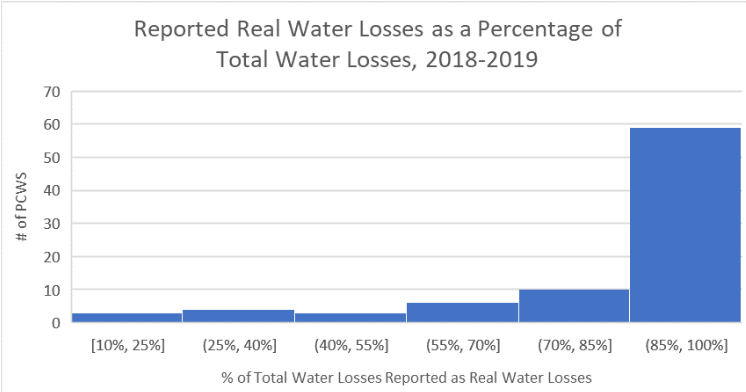
Only three box and whisker plots were developed for this analysis, as the other three categories lacked sufficient data for analysis. As with the NJDEP data set, the 25th percentile values for Medium and Small Coastal Plain PCWS are markedly lower than for the Small Bedrock PCWS.

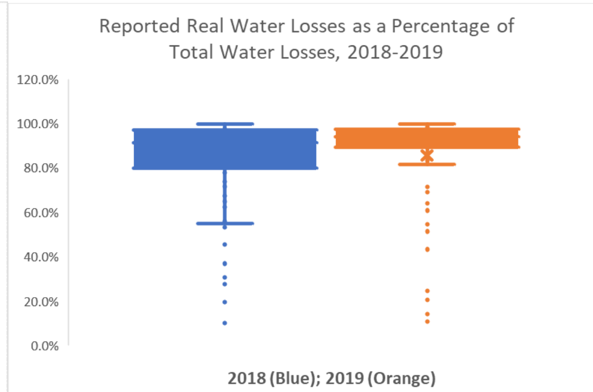


Insights from DRBC Data Set

Information from the data set can be useful for understanding the value and limitations of this metric. First, the AWWA methodology provides opportunities for comparing real water losses to apparent water losses. An evaluation of these values across all reporting PCWS shows that in the 2018 reports, real losses comprised an average of 83% of total water losses, with a median of 91%. No results higher than the median were outliers, but there are seven low outliers below the lower whisker (i.e., less than 54.8%). For 2019 reports, the average was 85.5% and the median is 94%. For this year, again there were low outliers above the median, and the lower whisker is at 81.5%, a much tighter range of results. For 2019, 11 results were low outliers.

Therefore, real losses represent most of the total water losses, though some utilities indicated their real losses as low as 10%, a highly unlikely value. The results are shown in the following histogram for both years, and the box and whisker plots for each year. In many cases, the low values are from 2018, with the same PCWS showing much higher values in 2019 (e.g., a jump from 10.1% to 96.9%). The reverse is true for only a few PCWS (e.g., a drop from 67.3% to 24.5%). However, in some cases, very low values are reported for both 2018 and 2019, indicating either a major problem with apparent losses or poor use of the AWWA methodology. It is likely that major year-to-year changes are a result of accounting differences in use of the methodology, rather than fundamental changes in real water losses. However, further inquiries with the specific water systems would be required to assess the reasons behind either consistently low results or highly variable results; such inquiries were beyond the scope of this project.





For the purposes of this report, where a utility reported values below the lower whisker for 2018 (54.8%), they were removed from the analysis if the water losses for that year were greatly different from the other year. Otherwise, a data entry error was assumed for apparent water losses. For example, one utility reported the following values:

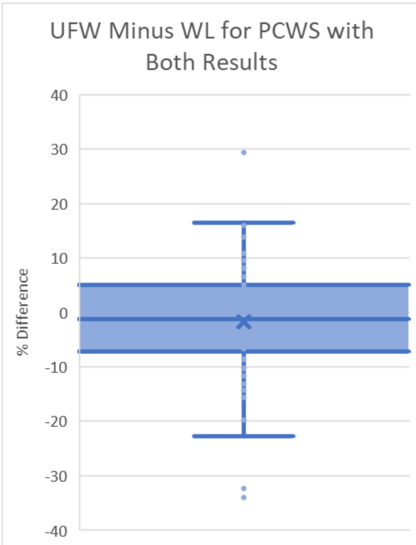
Example Utility	2018	2019
Real Losses	6.704	41.252
Apparent Losses	53.744	1.286
Real as % of Total	11.1%	97.0%

The probable error is in 2018, where the values were inverted. As both real and apparent losses are included within total water losses, this error does not change the values used in the water loss analysis above. Using this approach, either 2018 or 2019 results were removed from the analysis for 11 utilities, resulting in water loss values based on a single year.

Another AWWA water loss metric is the “real losses per service connection per day”, which for both years had an average value of just over 30 gallons per service connection per day; for both years, the median value was lower, at 27 gallons for 2018 and 22 gallons for 2019. For both years, the reported values ranged widely, from close to zero (an unlikely value that in every case was correlated with very low reported values for “real losses as a percentage of total water losses”) to highs of 213 gallons in 2018 and 144 gallons in 2019.

Analysis of Combined NJDEP and DRBC Data Sets

As noted above, the data sets were combined and compared, with DRBC Water Loss (WL) results being used instead of the NJDEP UFW results wherever a PCWS provided usable results to both agencies. As discussed in the Appendix, there is no statistically significant difference between the two data sets for all PCWS that reported results to both NJDEP and DRBC, allowing for combination of the data sets for this purpose. Of the 84 PCWS that reported usable result to DRBC, 77 are also contained within the NJDEP data set. Of these, in 41 PCWS, the reported WL results exceeded the reported UFW results, while for 36 PCWS the UFW results exceeded the WL results. The distribution of WL/UFW results for all 234 records is shown in the following box and whisker plot, with the utility size and province breakdown in the table.

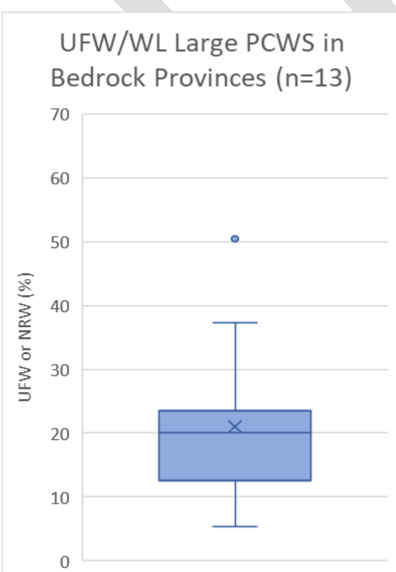


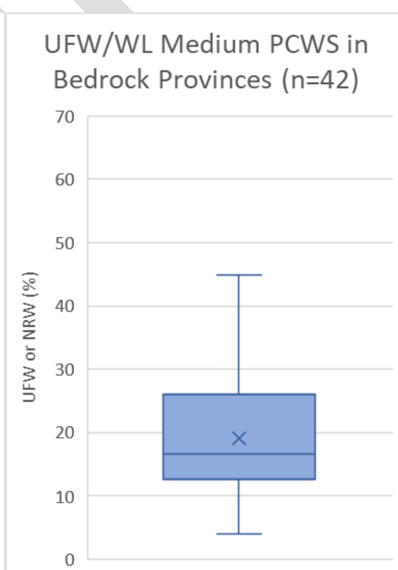
PCWS Size	Bedrock n=	Coastal n=	Total
Large	13	16	**29**
Medium	42	90	**132**
Small	35	38	**73**
Total	**90**	**144**	**234**

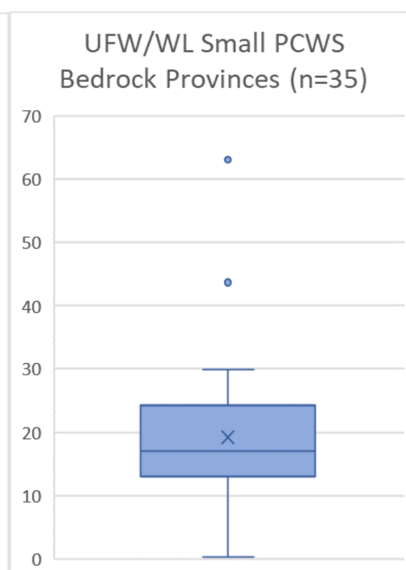
The overall results for 234 PCWS provide a median of 14.1% and an average of 15.9%. The breakdown results by category are shown in the following table. The results are somewhat different from the NJDEP UFW analysis due to the inclusion of DRBC WL values. Most importantly, the differences between Bedrock and Coastal Plain median and 25th percentile values are lower but still statistically significant.

PCWS Size	Median Bedrock %WL/UFW	Median Coastal %WL/UFW	Ratio Bedrock to Coastal	25th Percentile Bedrock %WL/UFW	25th Percentile Coastal %WL/UFW	Ratio Bedrock to Coastal
Large	20.1	11.8	1.71	12.6	7.3	1.73
Medium	16.5	11.2	1.47	12.7	7.8	1.63
Small	17.1	13.7	1.25	13.0	9.2	1.41

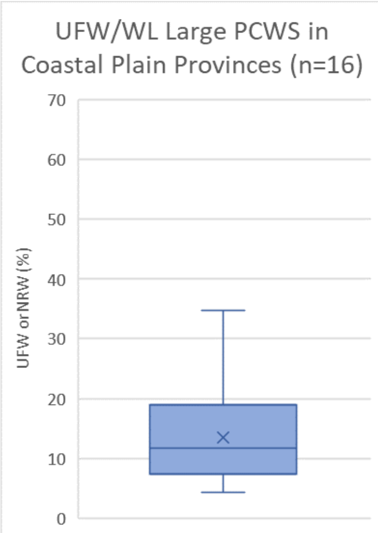
The box and whisker plots below provide additional information regarding the distribution of results for PCWS in the Bedrock Provinces.

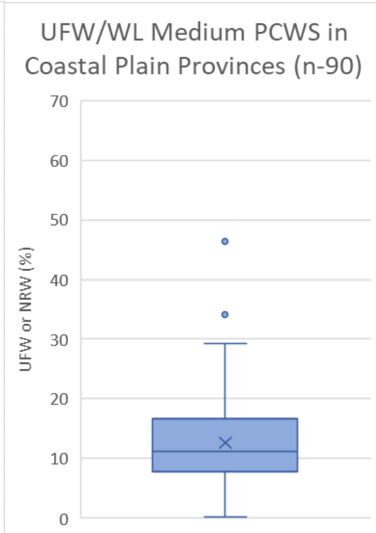


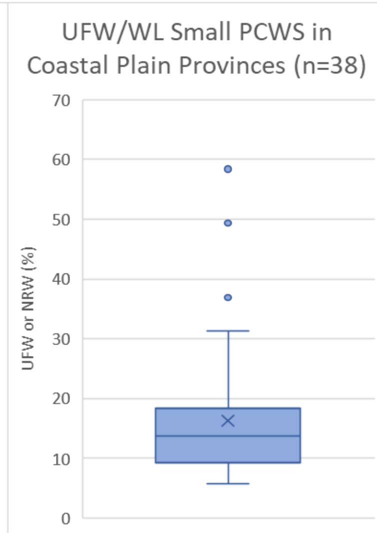




Similarly, the following box and whisker plots provide additional information regarding the distribution of results for PCWS in the Coastal Plain Provinces.

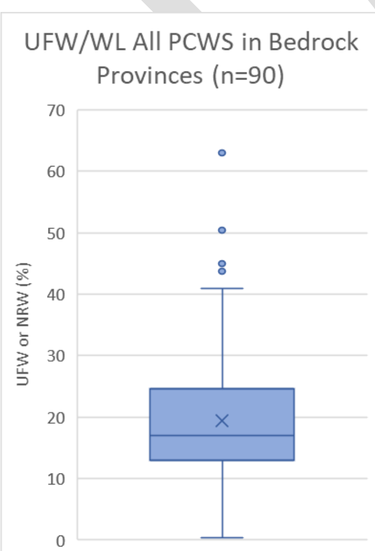


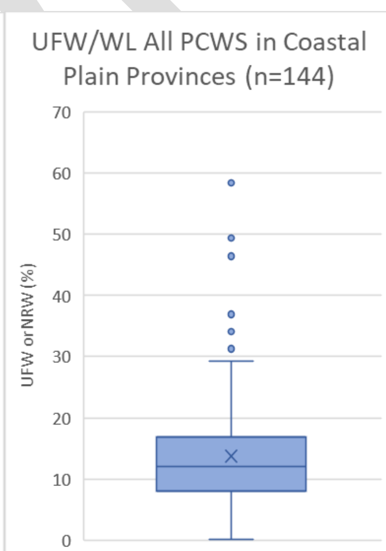




The Coastal Plain results are both lower and tighter (i.e., with a smaller range from 25th to 75th percentile) than the Bedrock results for large and especially medium PCWS sizes, but for small PCWS, the median, average and 25th percentile results do not differ greatly. The statistical analysis in the Appendix indicates that the results by utility size within each geological region are not statistically different. Therefore, a final analysis of all utilities in the Coastal Plain and Bedrock regions are in the next table, along with the box and whisker plots.

PCWS Size	Median Bedrock %WL/UFW	Median Coastal %WL/UFW	Ratio Bedrock to Coastal	25th Percentile Bedrock %WL/UFW	25th Percentile Coastal %WL/UFW	Ratio Bedrock to Coastal
All	16.1	11.4	1.4	12.3	7.7	1.6





Conclusion

The most significant finding is that PCWS in the Bedrock Provinces exhibit higher results than those in the Coastal Plain Provinces across all PCWS size categories, for both median and 25th percentile results. The differences are statistically significant. This difference is most pronounced for the Large PCWS, and least pronounced for the Small PCWS.

Median results for water losses (WL) or unaccounted for water (UFW) among Medium and Small PCWS in the Bedrock Provinces are similar, with the Large PCWS having higher results, while the 25th percentile results are very close. Median results among Large, Medium and Small PCWS in the Coastal Plain Provinces are close, though the Small PCWS have somewhat higher results, while the 25th percentile results are very similar. However, statistical analyses indicate that the differences among PCWS size categories for each region are not statistically significant, and therefore the use of a single planning target by region is justified for the median (Nominal) and 25th percentile (Optimum) Water Loss.

The statistically significant differences between the Bedrock and Coastal Plain water losses provide a basis for having different planning targets in the two regions. In all cases, the real water losses will be somewhat lower. As shown with the DRBC data set, real water losses are estimated to comprise the vast majority of total water losses (average of 85.5% and median of 94%). The following table shows the results for WL/UFW and a Real Losses result that assumes real water losses are 90% of all water losses.

PCWS Size	Median Bedrock %NRW/UFW	Median Coastal %NRW/UFW	25th Percentile Bedrock %NRW/UFW	25th Percentile Coastal %NRW/UFW
All	17.0	12.0	13.0	8.1
Real Losses	15.3	10.8	11.7	7.3

The median results are used as an indicator of what the median utility currently achieves regarding water losses. The 25th percentile results are used as an indicator of what PCWS with robust asset management programs can achieve regarding real water losses. The consistent differences between PCWS in the two geophysical areas indicate that PCWS in the Bedrock Provinces may have a long-standing potential for higher real water losses, which will be a factor in 2050 water withdrawals from reservoirs, rivers and aquifers.

This research did not address causes for large differences in NRW and UFW between the regions. The consistent differences may be related to operational needs, such as multiple and higher pressure zones to overcome elevation differences within their services areas that Coastal Plain PCWS may not experience. Another possibility would be differences in distribution system ages, for which data are just becoming available through the Water Quality Accountability Act reporting process. Finally, some of the PCWS reported rates may be inaccurate. Further research would be needed to evaluate such issues. In addition, the AWWA water audit version 5 was used for the DRBC data set in 2018 and 2019. Version 6 is now being used; it may provide more accurate information for those PCWS using the method. However, because the method has only been in use for the 2020 data set from DRBC, this research relies on the most recent two years that use a consistent method. The year 2020 was also the onset of the Covid19 pandemic, which may cause significant differences in water losses from prior years, due to a possible shift in water demands between sectors, difficulties in PCWS O&M functions, and difficulties in the implementation of aggressive field monitoring and line repair/replacement for water leaks.

Appendix: Statistical Analyses

The table below provides the findings of statistical tests that were conducted to detect significant differences in PCWS water loss across geological setting and PCWS size. Both water loss variables (%WL and % UFW) did not have a normal distribution, an assumption for t-tests that is especially important for conducting tests with smaller sample sizes (less than 20). For this reason, the table displays findings from the conducted t-tests along with the findings from the conducted Mann-Whitney U Tests, a statistical test that does not assume samples have a normal distribution. For comparative purposes, the table displays the t-test findings for each water loss test and its corresponding Mann-Whitney U test directly below it in italic. Greater confidence was placed in significant findings detected across both statistical tests. However, significant findings from only one test can warrant future analysis and may be the result of factors such as small sample size.

First, statistical tests were conducted using the 77 PCWS that reported to both the NJDEP and DRBC, to examine if reported water loss significantly differed between the two data sources used for this white paper's analysis (DRBC's %WL and NJDEP's %UFW). DRBC's average PCWS water loss (14.07) was slightly smaller than NJDEP's (14.44), and this difference was not found to be significant. Therefore, the two data sets can reasonably be combined for statewide analysis.

A series of statistical tests relying on both water loss metrics (%WL and %UFW) were conducted to examine significant differences in PCWS water loss across Bedrock and Coastal Plain geological regions. Overall, the difference in average water loss among all Bedrock and Coastal Plain systems was found to be significant in both conducted tests (t=4.21, p=0.00; U=8944, p=0.00). This finding was robust across both DRBC and NJDEP data sources. When considered separately, the difference in average %WL and %UFW water loss among Bedrock and Coastal Plain PCWSs was found to be significant in both sets of tests (DRBC: t=2.22, p=0.03; U=925, p=0.00: NJDEP: t=3.68, p=0.00; U=3851, p=0.00, respectively) (*See the first four statistical tests in table section: Water Loss-Source Specific (DRBC or NJDEP) for more information*).

Closer examination of the difference in average water loss (%WL and %UFW) among medium Bedrock and Coastal Plain systems was found to be significant (t=3.84, p=0.00; U=2680, p=0.00). Evidence was also detected of a significant difference in average water loss among large Bedrock and Coastal Plain systems (t=2.06, p=0.05 (marginal significance); U=153, p=0.03).

Several statistical tests were also conducted to determine significant differences in reported water loss among different sized PCWSs within a specific geological setting. However, none of these tests yielded significant findings.

In summary, the tests consistently found that water losses for PCWS were statistically different <u>between</u> the two geological regions, while the water losses for PCWS by utility size categories <u>within</u> each geologic region were not. The results indicate a profound effect of geological region on utility water loss results, but that planning targets for water losses within each geological region can be the same across utility sizes.

A final series of statistical tests was conducted to examine PCWS water loss with data provided by either DRBC (%WL) or NJDEP (%UFW). Similar to the significant differences in average water loss among medium and large Bedrock and Coastal Plain systems found in tests that relied on both water loss metrics, the difference in average water loss among medium Bedrock and Coastal Plain systems using only NJDEP's %UFW data was also found to be significant (t=4.18, p=0.00; U=1378, p=0.00). The difference in average %UFW water loss among large Bedrock and Coastal Plain systems was found to be marginally significant in the conducted t-test (t=1.88; p=0.08) and not significant in the Mann-Whitney U Test (U=84; p=0.12). Although the sample sizes of some of the statistical tests were small (particularly, the tests examining large PCWSs), the results are consistent with the findings from the other methods of analysis presented in this white paper.

Table: Statistical Tests Conducted to Examine PCWS Water Loss

Water Loss Variable	Testing Populations	Sample Size	Mean	Variance (t-test)/ Standard Deviation (Mann-Whitney U Test)	t-Score (t-tests) / U Statistic (Mann-Whitney U Test)	P-Value
Water Loss by Data Source (PCWS Reporting to Both Agencies)						
%WL & %UFW (t-test)	DRBC	77	14.07	69.37	-0.26	0.80
	NJDEP	77	14.44	95.50		
(Mann-Whitney U Test)	*DRBC*	*77*	*14.07*	*8.33*	*3011*	*0.87*
	NJDEP	*77*	*14.44*	*9.77*		
Water Loss Across Topography (Bedrock & Coastal Plain)						
%WL & %UFW (t-test)	Bedrock	90	19.05	114.31	4.21	0.00**
	Coastal Plain	144	13.38	78.17		
(Mann-Whitney U Test)	*Bedrock*	*90*	*19.05*	*10.69*	*8944*	*0.00***
	Coastal Plain	*144*	*13.38*	*8.84*		
%WL & %UFW (t-test)	Bedrock (small)	35	18.49	133.21	0.97	0.33
	Coastal Plain (small)	38	15.84	137.98		
(Mann-Whitney U Test)	*Bedrock (small)*	*35*	*18.49*	*11.54*	*815*	*0.10**
	Coastal Plain (small)	*38*	*15.84*	*11.75*		
%WL & %UFW (t-test)	Bedrock (medium)	42	18.90	95.05	3.84	0.00**
	Coastal Plain (medium)	90	12.40	53.66		
(Mann-Whitney U Test)	*Bedrock (medium)*	*42*	*18.90*	*9.75*	*2680*	*0.00***
	Coastal Plain (medium)	*90*	*12.40*	*7.33*		
%WL & %UFW (t-test)	Bedrock (large)	13	21.01	140.47	2.06	0.05*
	Coastal Plain (large)	16	13.08	65.32		
(Mann-Whitney U Test)	*Bedrock (large)*	*13*	*21.01*	*11.85*	*153*	*0.03***
	Coastal Plain (large)	*16*	*13.08*	*8.08*		

Table: Statistical Tests Conducted to Examine PCWS Water Loss						
Water Loss Variable	Testing Populations	Sample Size	Mean	Variance (t-test)/ Standard Deviation (Mann-Whitney U Test)	t-Score (t-tests) / U Statistic (Mann-Whitney U Test)	P-Value
Water Loss by PCWS Size - within Topography Comparison (Bedrock or Coastal Plain)						
%WL & %UFW (t-test)	Bedrock (small)	35	18.49	133.21	-0.16	0.87
%WL & %UFW (t-test)	Bedrock (medium)	42	18.90	95.05	-0.16	0.87
(Mann-Whitney U Test)	*Bedrock (small)*	*35*	*18.49*	*11.54*	*716*	*0.85*
(Mann-Whitney U Test)	*Bedrock (medium)*	*42*	*18.90*	*9.75*	*716*	*0.85*
%WL & %UFW (t-test)	Bedrock (medium)	42	18.90	95.05	-0.58	0.57
%WL & %UFW (t-test)	Bedrock (large)	13	21.01	140.47	-0.58	0.57
(Mann-Whitney U Test)	*Bedrock (medium)*	*42*	*18.90*	*9.75*	*243*	*0.56*
(Mann-Whitney U Test)	*Bedrock (large)*	*13*	*21.01*	*11.85*	*243*	*0.56*
%WL & %UFW (t-test)	Bedrock (small)	35	18.49	133.21	-0.66	0.52
%WL & %UFW (t-test)	Bedrock (large)	13	21.01	140.47	-0.66	0.52
(Mann-Whitney U Test)	*Bedrock (small)*	*35*	*18.49*	*11.54*	*197*	*0.49*
(Mann-Whitney U Test)	*Bedrock (large)*	*13*	*21.01*	*11.85*	*197*	*0.49*
%WL & %UFW (t-test)	Coastal Plain (small)	38	15.84	137.98	1.67	0.10
%WL & %UFW (t-test)	Coastal Plain (medium)	90	12.40	53.66	1.67	0.10
(Mann-Whitney U Test)	*Coastal Plain (small)*	*38*	*15.84*	*11.75*	*1951*	*0.21*
(Mann-Whitney U Test)	*Coastal Plain (medium)*	*90*	*12.40*	*7.33*	*1951*	*0.21*
%WL & %UFW (t-test)	Coastal Plain (medium)	90	12.40	53.66	-0.31	0.76
%WL & %UFW (t-test)	Coastal Plain (large)	16	13.08	65.32	-0.31	0.76
(Mann-Whitney U Test)	*Coastal Plain (medium)*	*90*	*12.40*	*7.33*	*718*	*0.99*
(Mann-Whitney U Test)	*Coastal Plain (large)*	*16*	*13.08*	*8.08*	*718*	*0.99*
%WL & %UFW (t-test)	Coastal Plain (small)	38	15.84	137.98	0.99	0.33
%WL & %UFW (t-test)	Coastal Plain (large)	16	13.08	65.32	0.99	0.33
(Mann-Whitney U Test)	*Coastal Plain (small)*	*38*	*15.84*	*11.75*	*345*	*0.45*
(Mann-Whitney U Test)	*Coastal Plain (large)*	*16*	*13.08*	*8.08*	*345*	*0.45*

Table: Statistical Tests Conducted to Examine PCWS Water Loss

Water Loss Variable	Testing Populations	Sample Size	Mean	Variance (t-test)/ Standard Deviation (Mann-Whitney U Test)	t-Score (t-tests) / U Statistic (Mann-Whitney U Test)	P-Value
Water Loss-Source Specific (DRBC or NJDEP)						
%WL (DRBC) (t-test)	Bedrock	21	17.62	40.77	2.22	0.03**
	Coastal Plain	62	13.51	90.53		
(Mann-Whitney U Test)	*Bedrock*	*21*	*17.62*	*6.39*	*925*	*0.00***
	Coastal Plain	*62*	*13.52*	*9.52*		
%UFW (NJDEP) (t-test)	Bedrock	69	19.48	136.80	3.68	0.00**
	Coastal Plain	82	13.29	69.78		
(Mann-Whitney U Test)	*Bedrock*	*69*	*19.48*	*11.70*	*3851*	*0.00***
	Coastal Plain	*82*	*13.29*	*8.35*		
% WL (DRBC) (t-test)	Bedrock (small)	16	18.15	46.41	1.13	0.27
	Coastal Plain (small)	15	14.12	148.53		
(Mann-Whitney U Test)	*Bedrock (small)*	*16*	*18.15*	*6.81*	*170*	*0.05***
	Coastal Plain (small)	*15*	*14.12*	*12.19*		
%UFW (NJDEP) (t-test)	Bedrock (small)	19	18.78	212.75	0.44	0.66
	Coastal Plain (small)	23	16.96	134.22		
(Mann-Whitney U Test)	*Bedrock (small)*	19	18.78	14.59	227	0.84
	Coastal Plain (small)	23	16.96	11.59		
%UFW (NJDEP) (t-test)	Bedrock (medium)	38	19.35	101.33	4.18	0.00**
	Coastal Plain (medium)	49	11.57	38.83		
(Mann-Whitney U Test)	*Bedrock (medium)*	*38*	*19.35*	*10.07*	*1378*	*0.00***
	Coastal Plain (medium)	*49*	*11.57*	*6.23*		
%UFW (NJDEP) (t-test)	Bedrock (large)	12	21.01	153.24	1.88	0.08*
	Coastal Plain (large)	10	13.25	42.31		
(Mann-Whitney U Test)	*Bedrock (large)*	*12*	*21.01*	*12.38*	*84*	*0.12*
	Coastal Plain (large)	*10*	*13.25*	*6.51*		
*implies significance at alpha=0.10						
**implies significance at alpha=0.05						