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Total Dissolved Solids: Environmental Express StableWeigh™ Analytical Testing Vessels Method Equivalency

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Abstract

This report summarizes the evaluation of the StableWeigh™ vessel and system. Data from multiple Total Dissolved Solids (TDS) concentrations were collected. The results for the StableWeigh vessels Quality Control (QC) met the requirements of Standard Methods for the Examination of Water and Wastewater (SM) 2540 C TDS and were more precise and accurate than the traditional porcelain evaporation dish. Evaluation of the thermal stability and cooling time results shows that the StableWeigh system reduces the overall time and labor to complete a TDS test. Review of the labor costs for just maintaining the traditional porcelain evaporation dish indicates significant labor and cost recovery utilizing the StableWeigh disposable vessel.

Introduction

This report summarizes the evaluation of the StableWeigh™ vessel and system. It has produced results that show it reduces the amount of time spent preparing, weighing, cooling, and cleaning the laboratory Total Solids (TS) equipment. The StableWeigh vessels Quality Control (QC) results met the requirements of Standard Methods for the Examination of Water and Wastewater 2540 B TS and were more precise and accurate than the traditional porcelain evaporation dish.[1, 2] Review of the labor costs for just maintaining the traditional porcelain evaporation dish shows significant labor and cost recovery of utilizing the StableWeigh disposable vessel.

Historical Review of Total Dissolved Solids (Residue) Methods

Historically TS have been recognized as a water use (quality) measurement over the last 3 centuries, though the analytical chemistry that defines what is a dissolved solid is constantly changing.[3] TS can be either defined as the residue left after filtration and drying at a constant temperature [4, 5] or as the electrochemical conductance that originates from disassociated ions in solution. [6, 7].

The TDS residue method is defined by the United States Environmental Protection Agency (USEPA) as a Method Defined Analyte (MDA). The MDA relies on descriptive results, *mass of residue*, for the analyte measured. The TDS determined by this method is only the mass of analyte that passes through a filter and is stable after a set period of drying at an elevated temperature.

Electrochemical conductance is also a MDA, but is specific to only the disassociated ions in solution and does not measure dissolved organic material. Electrochemical conductance is performed at room temperature and can measure thermally labile ions.

The current USEPA approved method for TDS can be found in Standard Methods for the Examination of Water and Wastewater (SM). [1, 2] SM has been a consensus method organization for over 3 centuries (1895-Present) and has focused on developing analytical methods that are *Standard* to the profession. A Standard method is defined by the SM editorial board as *"the best current practice of American water analysts"*. As these current practices have changed over time, a summary of these changes is provided in Table 1 below.

Table 1: Summary of Total Dissolved Solids Methods in Standard Methods for the Examination of Water and Wastewater				
SM Edition	**Water Standard Methods Section and Filter Media**	**Water Drying Temperature**	**Sewage Standard Methods Section and Filter Media**	**Sewage Drying Temperature**
1st 1905	Determination of Residue on Evaporation, Berkefeld, paper or asbestos.	103 ºC	Determination of Residue on Evaporation, Berkefeld, paper or asbestos.	103 ºC
3rd 1917	Residue on Evaporation, Asbestos	103 ºC or 180 ºC	None Identified in Edition	
6th 1925	XIII Residue on Evaporation, Asbestos	180 ºC		
7th 1933	XIII Residue on Evaporation, Asbestos	103 ºC		
8th 1936	Dissolved Residue, Asbestos	103 ºC	XV Suspended Solids, Asbestos	103 ºC
9th 1946	Residue, Total Dissolved Residue, Asbestos	103 ºC	Residue C, Asbestos	103 ºC
10th 1955	Residue, Gravimetric Methods, Dissolved Residue, Asbestos	103-105 ºC	Residue C, Asbestos	103 ºC

Table 1: Summary of Total Dissolved Solids Methods in Standard Methods for the Examination of Water and Wastewater				
SM Edition	**Water Standard Methods Section and Filter Media**	**Water Drying Temperature**	**Sewage Standard Methods Section and Filter Media**	**Sewage Drying Temperature**
11th 1960	Residue B, Asbestos, Glass Fiber, Membrane, Paper, Diatomaceous Filter Candles	103-105 ºC or 179-181 ºC	Residue E, Asbestos	103 ºC
12th 1965	Residue B, Asbestos, Glass Fiber, Membrane, Paper, Diatomaceous Filter Candles	103-105 ºC or 179-181 ºC	Residue E, Asbestos	103 ºC
13th 1971	148 B, Glass Fiber, Membrane, Paper, Diatomaceous Filter Candles	103-105 ºC or 179-181 ºC	224E, Glass Fiber	103 ºC
14th 1976	208 B, Glass Fiber, 180 ± 2 ºC 208 C, Glass Fiber, 103-105 ºC			
17th 1989	2540 C, Glass Fiber, 180 ± 2 ºC 2540 D, Glass Fiber, 103-105 ºC			
18th 1992	2540 C, Glass Fiber, Initial Drying at 103-105 ºC with Final Drying at 180 ± 2 ºC			

TDS Method Changes in Standard Methods for the Examination of Water and Wastewater

The main analytical differences that can be seen in Table 1 are:

1. 1st edition TDS is defined with filtration by a Berkefeld (Diatomaceous Filter Candles), paper or asbestos filter and drying to 103 °C
2. 2nd – 10th editions TDS is defined with filtration by an asbestos filter and drying to 103 °C, 103 °C - 105 °C or 180 °C. No explanation is given for the change in filter or variations of temperature. It can be assumed that the standards committee utilized the current standard experimental methods being used by the laboratories.
3. 11th – 13th editions TDS has the introduction of the glass fiber filter. Other filter media included are Asbestos, Membrane, Paper, and Diatomaceous Filter Candles. The temperature used for drying residue was water type specific. Drinking water gave two different temperatures 103-105 ºC or 179-181 ºC and wastewater had only one 103 ºC. No explanation is given for the change in filter or variations of temperature. It can be assumed that the standards committee utilized the current standard experimental methods being used by the laboratories.
4. The 14th – 17th editions unified the drinking water and wastewater TDS into one method, use only the glass fiber filter , but have two different temperatures 103-105 ºC and 180 ± 2 ºC.
5. The 18th edition contains the current USEPA approved TDS method. This method has been carried forward into the current 22nd edition and online. The filter is still glass fiber, but the temperature has been combined to:
    a. Evaporate water 103-105 ºC
    b. Dry solid 180 ± 2 ºC
6. Additionally in the online and 22nd edition TDS, Quality Control (QC) parameters have been added.

Environmental Express StableWeigh System: Meeting USEPA TDS Testing Requirements

The traditional TDS method requires that

1. A well-mixed sample of known volume is filtered into a filter flask.
2. The filter is then washed with deionized water (DI water).
3. The washing is then transferred with the filtrate to a tared porcelain evaporation dish.
4. The porcelain evaporation dish is then transferred to a steam bath or oven and the water sample is evaporated to dryness at 103-105 ºC.
5. The porcelain evaporation dish is then transferred to an oven and heated to 180 ± 2 ºC for at least 1 hour.
6. The porcelain evaporation dish is then transferred to a desiccator and allowed to cool to room temperature.
7. The porcelain evaporation dish is then weighed to the nearest 0.1 mg.
8. The porcelain evaporation dish is then returned to an oven and heated to 180 ± 2 ºC for at least 1 hour.
9. The porcelain evaporation dish is then transferred to a desiccator and allowed to cool to room temperature.
10. The porcelain evaporation dish is then weighed to the nearest 0.1 mg.
11. Steps 8-9 are repeated until two consecutive weight differences are less than 4% of previous weight or 0.5 mg, whichever is less.
12. Then the porcelain evaporation dish must then be
    a. cleaned,
    b. dried at 180 ± 2 ºC,
    c. cooled in a desiccator
    d. tared and stored in a desiccator

The StableWeigh system provides the following improvements/changes to the traditional TDS analyses;

1. Tared polymer disposable weighing vessels to take the place of porcelain evaporation dishes.
2. Filling Stations to hold vessels and replace filter flasks.
3. Modular racks to hold vessels both in the oven, in the desiccator and at the balance.
4. Weighing bracket to position the vessel on the balance.

Environmental Express StableWeigh Vessels and Support Supplies

Environmental Express StableWeigh TDS vessels are fabricated from a thermally inert polymer that can sustain an extended period in the drying oven at 180 °C. The StableWeigh vessel comes pre-weighed to 0.1 mg and this weight does not change during the TDS test.

Figure 1: StableWeigh Total Solids Disposable Vessel

The StableWeigh system also includes analytical support equipment to allow the laboratory to maximize labor savings. The Filling Stations positions the StableWeigh vessel so as to receive the TDS sample efficiently.

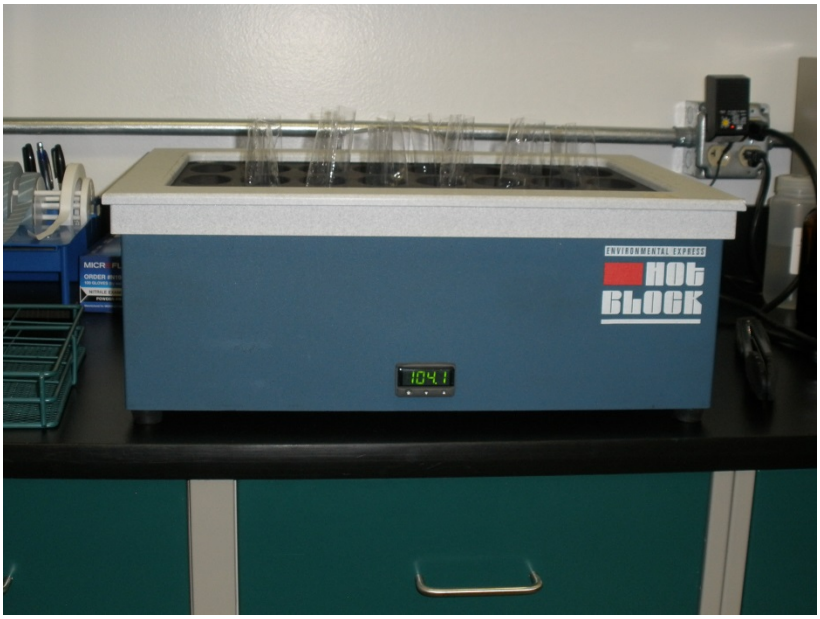

Figure 2: StableWeigh Hot Block

Figure 3: StableWeigh Modular Rack, 5-Place

Once the TDS sample has been transferred to the StableWeigh vessel in the Filling Station, the vacuum is released and the vessel is removed from the Filling Station and transferred to the Modular Rack. The Modular Rack comes with 5 rows that can be assembled together to fit the depth of your oven or desiccator. The rack helps to easily transport the vessels from the filtration area, to the oven, to the desiccator, and finally to the balance.

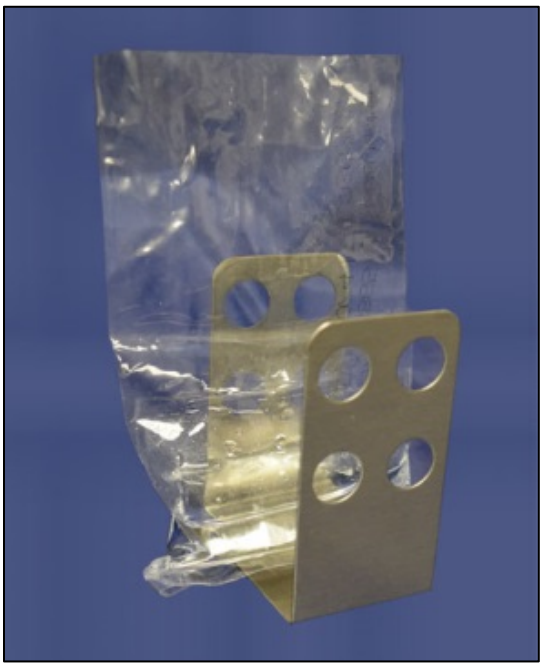

Figure 4: StableWeigh Weighing Bracket

At the balance, the Weighing Bracket will stabilize the StableWeigh vessel and allow the efficient weighing of the TDS sample.

Comparison and Review of Traditional TDS Analyses Compared to StableWeigh TDS

The data obtained from the study is provided in detain in the appendixes (Appendix 1). Formulas to determine all precision and duplicate analyses can be found in the current edition of Standard Methods for the Examination of Water and Wastewater Parts 1010 and 2020. [1, 2]

Precision of Analyses

Standard Methods QC Requirements

The Quality Control (QC) determination of the Part 2540 C TDS analytical results are detailed in Standard Methods for the Examination of Water and Wastewater Parts 1010 and 2020. The requirements are divided into the Initial Quality Control that must be performed to show laboratory and analysts capabilities to determine TDS and Ongoing QC.

The Initial Quality Control for most Part 2000 methods in Standard Methods for the Examination of Water and Wastewater require:

1. Initial Demonstration of Capability (IDC) is performed with known Laboratory Fortified Blank (LFB) in which a known amount of analyte is dissolved in water. Sodium chloride with diatomaceous earth was used for the TDS LFB. It was dissolved/suspended in DI water and a known aliquot after filtration was transferred to a StableWeigh vessel and the TDS was determined. This data was then used to set control limits for acceptable data ranges.[8]
2. Method Detection Level (MDL) and Operational Range (OR) are set by the Mettler Toledo balance as 1 mg with a reproducibility of 0.1 mg. As additional aliquots of TDS samples can be added to the vessel, the OR will be dependent on the total sample size evaporated.

The Quality Control Table in Part 2020 specifically lists the following Ongoing QC parameter must be determined for the Total Dissolved Solids 2540 C:

1. Method Blank (MB) is performed with DI water. A known aliquot was transferred to a StableWeigh vessel and the TDS was determined. This data was then used compared to set OR limits for acceptable data ranges. For this study TDS balance MDL of 1 mg was used.
2. Laboratory Fortified Blank (LFB) is a known amount of analyte dissolved in water. Sodium chloride was used for the TDS LFB. Sodium chloride with diatomaceous earth was used for the TDS LFB. It was dissolved/suspended in DI water and a known aliquot after filtration was transferred to a StableWeigh vessel and the TDS was determined. This data was then compared to IDC control limits for acceptable data ranges.

3. Duplicates are run per each analysis sample set or batch. For this study as the LFBs were analyzed twenty five (25) times, the minimum and maximum value was used to calculate the Relative Percent Difference (RPD)

Analytical QC Results

1. Figures 5-6 chart the IDC for each batch of StableWeigh vessels at different TDS weights and for porcelain evaporation dishes. All data points fall within the IDC limits. Theses LFBs show Initial and Ongoing QC at acceptable levels.
2. Table 2 contains the % RSD and the RPD for each analysis set. The % RSD increases with the smaller mass sample, which is expected due to small variations in a result's value impacts lower mass values more that higher mass numbers. The larger %RSD value seen for the porcelain evaporation dishes for 20 mg of TDS vs. the StableWeigh vessel indicates that the greater variance seen with the porcelain evaporation dishes. All StableWeigh results produced % RSD < 10% while the porcelain evaporation dishes % RSD was > 15%. 15% RSD has been set as the acceptable variance limit.
3. Figure 7 charts the values of both the StableWeigh and porcelain evaporation dish 20 mg TDS values. The average TDS value for the StableWeigh vessel varied a + 0.1 mg from the known value and the porcelain evaporation dish average varied + 0.4 mg above the known value (Appendix 1). The greater variation of the mean compared to the known value for the porcelain evaporation dish indicates less accurate precision.
4. Table 3 contains the weigh variance for the MB for a sample set. No StableWeigh vessel had a weight difference outside of the ± 0.5 mg of a zero (0) mg MB.
5. Table 4 contains the Matrix Spike and Matrix Spike Duplicate data. The % RSD was significantly lower than 15 % and the RPD was significantly below 20 %. Refer to the Environmental Express TDS method for detailed QC procedures.

Table 2: StableWeigh and Porcelain Evaporation Dish Precision					
TDS Mass	**Vessel**	**Average**	**Standard Deviation**	**% RSD**	**Duplicate Relative Percent Difference**
200 mg	StableWeigh	200.4	0.57	0.29%	1.00%
100 mg	StableWeigh	100.0	0.52	0.52%	2.50%
20 mg	StableWeigh	20.2	0.35	1.71%	9.05%
20 mg	Porcelain Evaporation Dish	20.6	0.60	2.94%	15.31%

Table 3: StableWeigh Method Blank																									
Sample #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Blank Weight Difference (mg)	-0.1	0	-0.1	0.2	-0.2	0	-0.1	0	0	-0.3	0.4	0	-0.1	0	0	0	0	0.1	-0.2	0	0	0.5	0.1	0.2	-0.4

Table 4: StableWeigh Matrix Spike and MSD Dish Precision					
TDS Samples	**Vessel**	**Average**	**Standard Deviation**	**% RSD**	**Duplicate Relative Percent Difference**
Ground Water	StableWeigh	272.8	1.1	0.40%	
Matrix Spike	StableWeigh	472.0	5.7	1.20%	
Matrix Spike Duplicate	StableWeigh	474.4	11.7	2.47%	4.74%

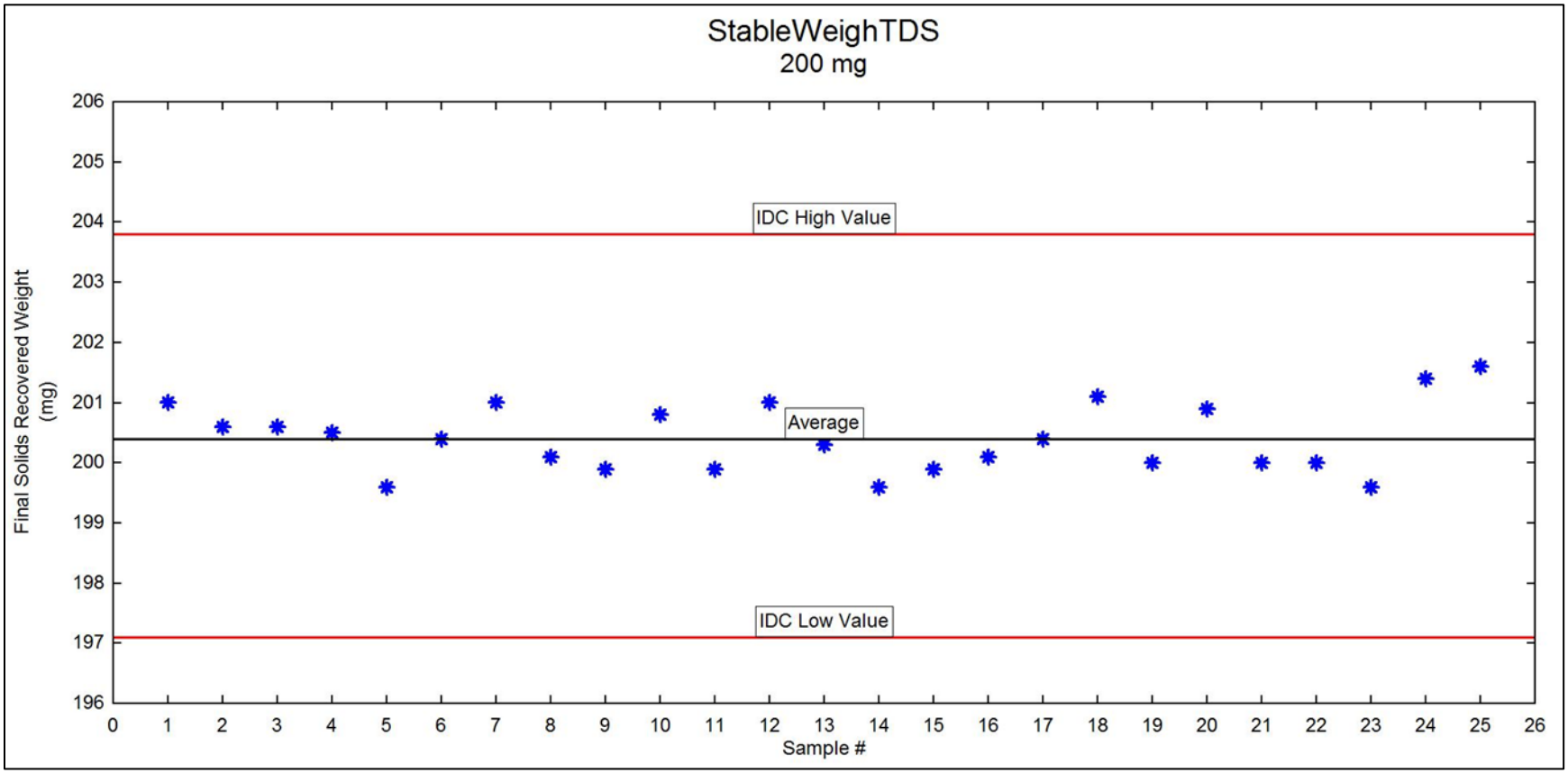

Figure 5: StableWeigh 200 mg Initial Demonstration of Capability

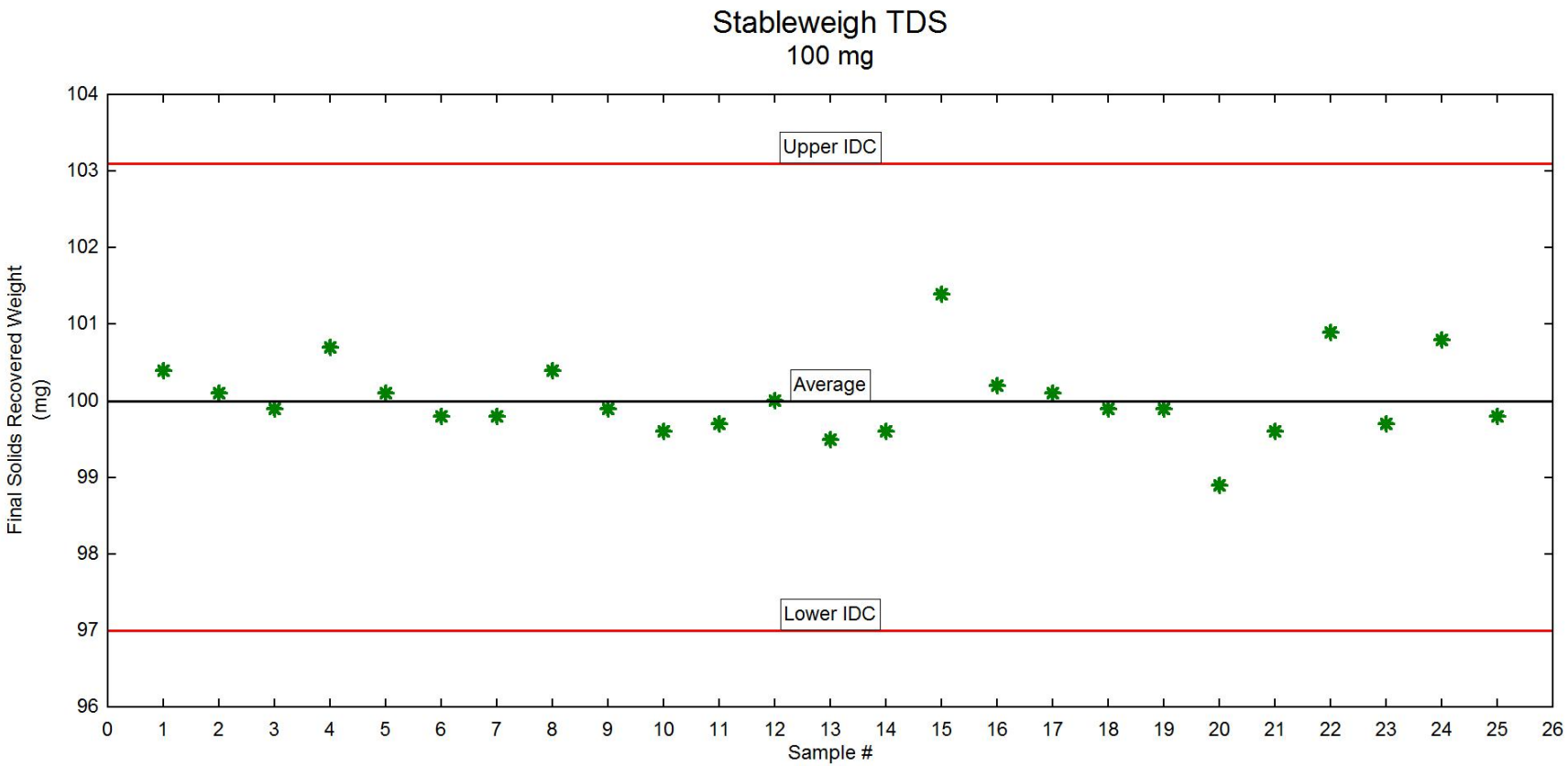

Figure 6: StableWeigh 100 mg Initial Demonstration of Capability

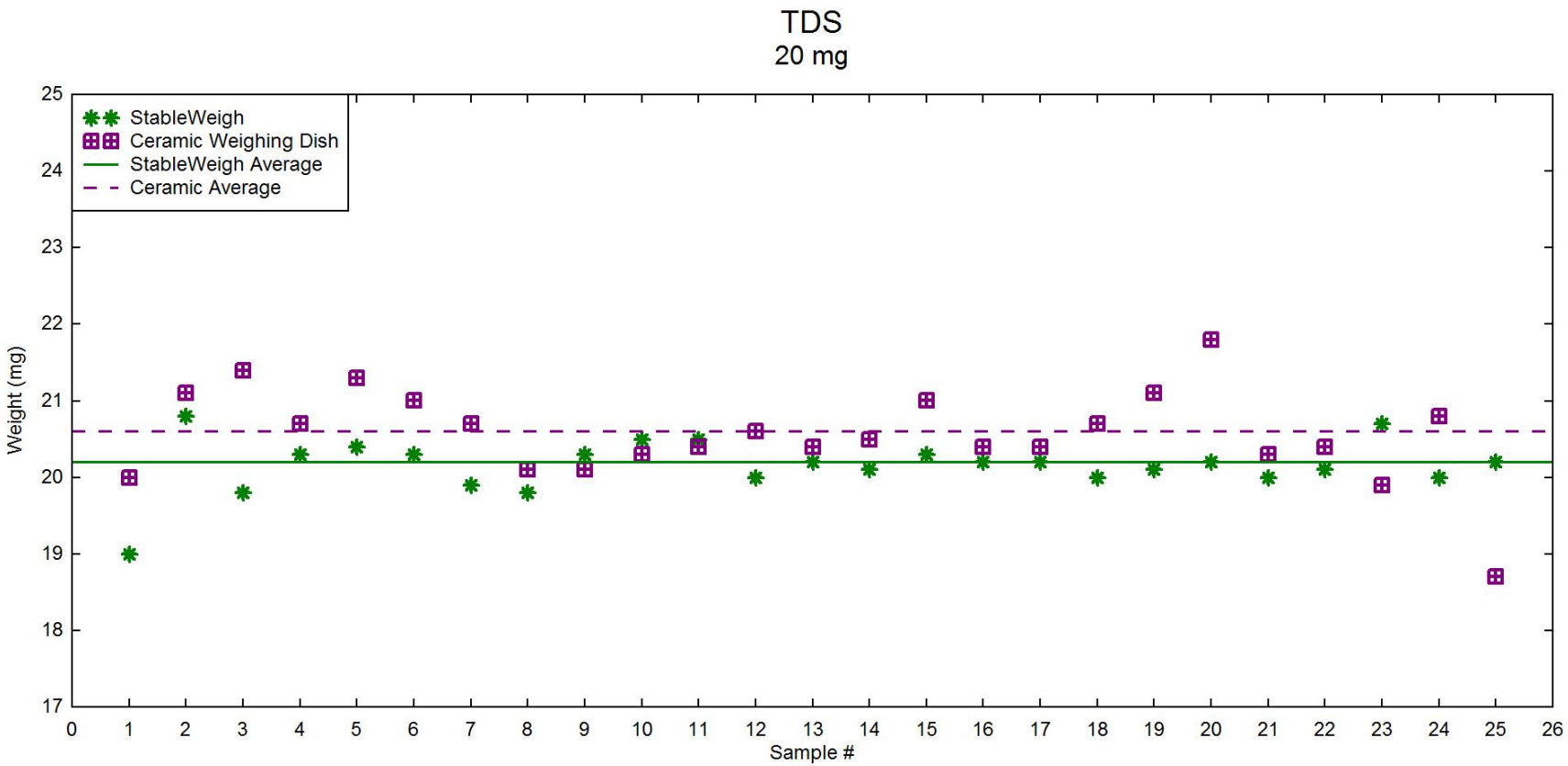

Figure 7: StableWeigh vs. Porcelain Evaporation Dish Averages

Traditional vs. StableWeigh Vessel Volumes

The ASTM D5907-03 does not specifically specify evaporation dish or vessel material just that it is of an acceptable volume and heat stable at the required temperatures. Therefore, the size of the oven and desiccator has defined what size of evaporation dish or vessel is commonly used. For a typical traditional TDS analyses, a 120 mL porcelain evaporation dish is used with an effective usable volume of 100 mL. The StableWeigh vessel has a volume on ~ 300 mL, an effective volume of 250 mL and is thermally stable which is considered an equivalent vessel ASTM D5907-03.

As such, the StableWeigh vessel has the flexibility to take over twice the initial volume of a porcelain evaporation dish. This allows the laboratory to achieve lower detection limits without having to transfer additional TDS aliquots to sample to the vessel during the evaporation.

StableWeigh Vessel Thermal Stability

The StableWeigh vessel is thermally inert at 180 ± 2 ºC over extended periods of time (24 hrs.). This thermal stability allows the laboratory flexibility in performing the TDS determination over the course of a typical laboratory work day.

Vessel Moisture Absorption

Porcelain evaporation dishes do absorb moisture both during the TDS analyses and when cleaned, tared, stored in a desiccator. Weight gain after taring the porcelain evaporation dish can occur.

As the StableWeigh vessel is an inert polymer, there is no moisture abortion either during the TDS analysis or when unused vessels are stored in the desiccator. This means that the tared weight printed on the vessel is accurate and precise.

Time to Thermal Equilibrium

Due to the thermal mass of a porcelain evaporation dish, cool down time in a desiccator is significantly longer than the StableWeigh vessel (1 hr. or more). This cool-down time adds to the laboratory completion time for traditional TDS analyses.

The time required to cool a heated porcelain evaporation dish TDS sample in a desiccator must be monitored as storing a TDS sample too long in a desiccator during cool-down can cause the difference weight to vary outside of the less than 4% of previous weight or 0.5 mg range.

The StableWeigh vessel mass is an order of magnitude lower than a traditional porcelain evaporation dish and does not hold as much heat energy and will cool to balance temperature much faster. Having the mass of the vessel closer to the mass of the weighed residue also gives greater precision and accuracy. This will help to reduce the number of drying and weighing cycles needed to obtain a constant weight

Labor and Material Costs for TDS Analysis

The costs associate with porcelain evaporation dishes are not only the initial purchase cost, but also the costs to clean, dry, tare and store the vessel before the next TDS analysis. Tables 4 summarize just the porcelain evaporation dish cleaning costs for TDS analysis.

The porcelain evaporation dish costs summarized do not include:

1. The value of extra analyst time available for performing tasks other than washing.
    a. Taring the porcelain evaporation dish.
    b. Checking the tared value after a set desiccator storing time.
2. The elimination of quality issues associated with detergent or sample-residue contamination in the crucibles
3. Glass/ceramic safety

The StableWeigh vessel cost savings:

1. Comes tared with the weight to the nearest 0.1 mg printed on the vessel.
2. The StableWeigh vessel is a disposable vessel and requires no labor to clean and store.
3. Additional labor savings can be realized if a Filling Station is used. The Filling Station replaces the traditional filter flask and removes the labor requirements for cleaning

Table 4: Porcelain Evaporation Dish Lifetime Costs for Total Solids					
Hand Wash Cost			**Dishwasher Cost**		
Crucible Amortization			**Crucible Amortization**		
Initial Porcelain Crucible Cost	$13.25		Initial Porcelain Crucible Cost	$13.25	
Avg. # of Uses (life of crucible)	100	uses	Avg. # of Uses (life of crucible)	100	uses
Labor Costs			**Labor Costs**		
Hourly Labor Rate	$15.00		Hourly Labor Rate	$15.00	
Actual Hourly Cost (= Rate X 1.4)	$21.00		Actual Hourly Cost (= Rate X 1.4)	$21.00	
Wash/Handling Minutes Per Crucible	1.00	minutes	Handling Minutes Per Crucible	0.50	minutes
Cleaning Reagent Costs			**Cleaning Reagent Costs**		
Crucibles Cleaned Per Reagent-Batch	1,000		Crucibles Cleaned Per Reagent-Batch	1,000	-
Cleaning Reagent Cost-Per-Batch	$35		Reagent Cost-Per-Batch	$35	-
Water Costs			**Water Costs**		
Potable H2O Cost-per-Gallon	$0.0007		Potable H2O Cost-per-Gallon	$0.0007	
DI/Lab Water Cost-per-Liter	$0.0500		DI Water Cost-per-Liter	$0.0500	
Sewage Cost-per-Gallon	$0.0005		Sewage Cost-per-Gallon	$0.0005	
Wash & Rinse Water Per Crucible	0.50	liters	Wash & Rinse Water Per Crucible	5.00	liters
Extra Time Costs vs. StableWeigh			**Extra Time Costs vs. StableWeigh**		
Batch (24) Preconditioning	5	minutes	Batch (24) Preconditioning	5	minutes
Batch (24) Cooling Wait Time	60	minutes	Batch (24) Cooling Wait Time	60	minutes
Batch (24) Crucible Weighing Time	30	minutes	Batch (24) Crucible Weighing Time	30	minutes
Totals			**Totals**		
Crucible Amortization	$0.13		Crucible Amortization	$0.13	
Labor Costs	$0.25		Labor Costs	$0.13	
Water and Reagent Costs	$0.06		Water and Reagent Costs	$0.29	
Time Costs - Crucibles	$0.99		Time Costs - Crucibles	$0.99	
Total Cost-Per-Crucible to use	**$1.4322**	*	**Total Cost-Per-Crucible to use**	**$1.5337**	*
** Three categories that the cost-calculation form **does not** take into account are **(1)** the value of extra analyst time available for performing tasks other than washing, (2) the elimination of quality issues associated with detergent or sample-residue contamination in the crucibles, and (3) glass/ceramic safety*					

Summary and Conclusion

Summarization of the analyses of the StableWeigh tests results, the QC and the overall vessel performance in the SM 2540C TDS method:

1. The StableWeigh vessels consistently met the IDC requirements.
2. The StableWeigh vessels had more acceptable precision and duplicate recovery than the traditional porcelain evaporation dish.
3. The StableWeigh vessels had MB acceptable results.
4. The StableWeigh vessels Matrix Spike/Matrix Spike Duplicate had precise and acceptable results.
5. The StableWeigh vessels reach thermal stability sooner than the traditional porcelain evaporation dish and allow the TDS measurement to meet the TDS difference requirements.
6. The StableWeigh vessels reduce or eliminate the additional time and labor needed to clean and tare traditional porcelain evaporation dishes and filter flasks.

In conclusion, the StableWeigh system can meet and exceed the requirements for the USEPA approved SM 2540C TDS method with time and cost savings when compared to the traditional porcelain evaporation dishes and filter flasks.

EPA Method Equivalency Check-Off Table from Richard Redding Memo, Flexibility to Modify CWA Methods, 2007	
Equivalency Requirement	**Section in Report**
Concentrations of calibration standards. Document the range of the concentrations of material used to establish the relationship between response of the measurement system and analyte concentration.	Yes, Table 2, Figures 5-12
% RSD or correlation coefficient of calibration regression.	Yes, Table 2
Performance range tested with units.	Yes, Yes, Table 2, Figures 5-12
Sample(s) used in initial demonstration have the recommended preservative, where applicable.	Yes, see Environmental Express StableWeigh TDS Method
Sample(s) used in initial demonstration met recommended holding times, where applicable.	Yes
Interferences.	None for StableWeigh, See Appendix 1 Tables.
Document the qualitative identification criteria used.	LFB percent recovery. Table 2. LRB Table 3. % RSD from QC samples. Table 2. IDC Figures 5-12
Performance evaluation studies performed for analytes of interest, where available.	LFB percent recovery. Table 2. LRB Table 3. % RSD from QC samples. Table 2. IDC Figures 5-12
Latest study sponsor or title	NA
Latest study number.	NA
Analysis of external reference material	NA.
Results of analyses on reference material from a source different from that used to prepare the calibration standards, if applicable.	See Appendix 1 Tables
Sources of external reference material, if applicable.	NA
Surrogates used, if applicable.	Not Required

EPA Method Equivalency Check-Off Table from Richard Redding Memo, Flexibility to Modify CWA Methods, 2007	
Equivalency Requirement	**Section in Report**
Concentrations of surrogates, if applicable.	Not Required
Recoveries of surrogates appropriate to the proposed use, if applicable.	Not Required
Sample preparation.	As per Standard Methods 2540 (C)
Clean-up procedures.	As per Standard Methods 2540 (C)
Method blank result.	Table 3
Matrix (reagent water, drinking water, effluent)	Reagent water and Ground water
Matrix spikes.	See table 4 and Appendix
Spiking system, appropriate to the method and application.	See Environmental express TDS Method, Table 4 and Appendix
Spike concentrations (with units corresponding to the final sample concentration) and recoveries.	See Environmental express TDS Method, Table 4 and Appendix
Source of spiking material.	Raw Ground Water Source for Drinking Water
Number of replicate spikes	See Appendix
Initial demonstration of capability.	See Figures 5-12
Precision (analyte by analyte) Duplicates.	See Table 2, Figures 5-12, Appendix 1 Tables
Bias (analyte by analyte).	See Table 2, Figures 5-12, Appendix 1 Tables
Detection limit (with units; analyte by analyte).	NA
Confirmation of detection limit, if applicable.	NA
Quantitation limit (with units; analyte by analyte) Minimum level (ML), practical quantitation level (PQL) or limit of quantitation (LOQ).	NA.
Qualitative confirmation.	Not Required

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Appendixes

Appendix 1: StableWeigh and Porcelain Evaporation Dish Study Data

Table 1A: Environmental Express TDS Stable-Weigh Tests Blank									
Analyst	**Edward F. Askew**								
Date	**4/14/2016**								
Blank									
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Percent Change**
1	**144**	100	3.7783	3.7785	3.7782		-0.3	3.7782	0.00265%
2	**145**	100	3.7329	3.7330	3.7329		-0.1	3.7329	0.00000%
3	**147**	100	3.8709	3.8709	3.8708		-0.1	3.8708	0.00258%
4	**148**	100	3.7953	3.7958	3.7955		-0.3	3.7955	-0.00527%
5	**150**	100	3.8747	3.8748	3.8745		-0.3	3.8745	0.00516%
6	**75**	100	3.7540	3.7543	3.7540		-0.3	3.7540	0.00000%
7	**58**	100	3.7246	3.7249	3.7245		-0.4	3.7245	0.00268%
8	**81**	100	3.7105	3.7107	3.7105		-0.2	3.7105	0.00000%
9	**82**	100	3.7503	3.7503	3.7503		0.0	3.7503	0.00000%
10	**83**	100	3.7500	3.7495	3.7497		0.2	3.7497	0.00800%
11	**94**	100	3.7312	3.7313	3.7316		0.3	3.7316	-0.01072%
12	**86**	100	3.7855	3.7854	3.7855		0.1	3.7855	0.00000%
13	**77**	100	3.9155	3.9153	3.9154		0.1	3.9154	0.00255%
14	**85**	100	3.7716	3.7716	3.7716		0.0	3.7716	0.00000%
15	**79**	100	3.8572	3.8574	3.8572		-0.2	3.8572	0.00000%
16	**111**	100	3.6931	3.6929	3.6931		0.2	3.6931	0.00000%
17	**53**	100	3.8009	3.8009	3.8009		0.0	3.8009	0.00000%
18	**74**	100	3.8078	3.8079	3.8079		0.0	3.8079	-0.00263%
19	**52**	100	3.7902	3.7896	3.7900		0.4	3.7900	0.00528%

Table 1A: Environmental Express TDS Stable-Weigh Tests Blank									
Analyst	**Edward F. Askew**								
Date	**4/14/2016**								
Blank									
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Percent Change**
20	**80**	100	3.7825	3.7826	3.7825		-0.1	3.7825	0.00000%
21	**143**	100	3.7904	3.7907	3.7904		-0.3	3.7904	0.00000%
22	**42**	100	3.7561	3.7566	3.7566		0.0	3.7566	-0.01331%
23	**141**	100	3.8124	3.8124	3.8125		0.1	3.8125	-0.00262%
24	**140**	100	3.7322	3.7327	3.7324		-0.3	3.7324	-0.00536%
25	**139**	100	3.7765	3.7763	3.7761		-0.2	3.7761	0.01059%
								Average	-0.00002%
								Standard Deviation	0.00508%

Table 2A: Environmental Express TDS Stable-Weigh Tests 200 mg										
Analyst	**Edward F. Askew**									
Date	**4/18/2016**									
200.03 mg per 50 mL										
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
1	**188**	50	3.7495	3.9508	3.9505		-0.3	3.9505	201.0	100.50%
2	**187**	50	3.7712	3.9721	3.9718		-0.3	3.9718	200.6	100.30%
3	**186**	50	3.8070	4.0078	4.0076		-0.2	4.0076	200.6	100.30%
4	**185**	50	3.7333	3.9339	3.9338		-0.1	3.9338	200.5	100.25%
5	**184**	50	3.8077	4.0074	4.0073		-0.1	4.0073	199.6	99.80%
6	**182**	50	3.7256	3.9263	3.9260		-0.3	3.9260	200.4	100.20%
7	**183**	50	3.7304	3.9318	3.9314		-0.4	3.9314	201.0	100.50%
8	**181**	50	3.6925	3.8962	3.8926		-3.6	3.8926	200.1	100.05%
9	**180**	50	3.7520	3.9522	3.9519		-0.3	3.9519	199.9	99.95%
10	**179**	50	3.7577	3.9580	3.9585		0.5	3.9585	200.8	100.40%
11	**178**	50	3.7507	3.9509	3.9506		-0.3	3.9506	199.9	99.95%
12	**177**	50	3.7350	3.9356	3.9360		0.4	3.9360	201.0	100.50%
13	**153**	50	3.7772	3.9776	3.9775		-0.1	3.9775	200.3	100.15%
14	**165**	50	3.8030	4.0027	4.0026		-0.1	4.0026	199.6	99.80%
15	**176**	50	3.7986	3.9986	3.9985		-0.1	3.9985	199.9	99.95%
16	**167**	50	3.7678	3.9679	3.9679		0.0	3.9679	200.1	100.05%
17	**168**	50	3.8320	4.0326	4.0324		-0.2	4.0324	200.4	100.20%
18	**166**	50	3.7805	3.9820	3.9816		-0.4	3.9816	201.1	100.55%
19	**169**	50	3.7557	3.9559	3.9557		-0.2	3.9557	200.0	100.00%

Table 2A: Environmental Express TDS Stable-Weigh Tests 200 mg										
Analyst	**Edward F. Askew**									
Date	**4/18/2016**									
200.03 mg per 50 mL										
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
20	**171**	50	3.7430	3.9435	3.9439		0.4	3.9439	200.9	100.45%
21	**170**	50	3.8467	4.0469	4.0467		-0.2	4.0467	200.0	100.00%
22	**172**	50	3.7228	3.9229	3.9228		-0.1	3.9228	200.0	100.00%
23	**174**	50	3.7589	3.9589	3.9585		-0.4	3.9585	199.6	99.80%
24	**138**	50	3.8743	4.0761	4.0757		-0.4	4.0757	201.4	100.70%
25	**163**	50	3.7442	3.9456	3.9458		0.2	3.9458	201.6	100.80%
								Average	200.4	100.21%
								Standard Deviation	0.6	0.29%

Table 3A: Environmental Express TDS Stable-Weigh Tests 100 mg										
Analyst	**Edward F. Askew**									
Date	**4/20/2016**									
100.0 mg per 50 mL										
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
1	**160**	50	3.8295	3.9296	3.9299		0.3	3.9299	100.4	100.40%
2	**159**	50	3.8089	3.9089	3.9090		0.1	3.9090	100.1	100.10%
3	**157**	50	3.8275	3.9276	3.9274		-0.2	3.9274	99.9	99.90%
4	**155**	50	3.7905	3.8908	3.8912		0.4	3.8912	100.7	100.70%
5	**132**	50	3.6963	3.7967	3.7964		-0.3	3.7964	100.1	100.10%
6	**126**	50	3.7543	3.8542	3.8541		-0.1	3.8541	99.8	99.80%
7	**121**	50	3.8094	3.9093	3.9092		-0.1	3.9092	99.8	99.80%
8	**154**	50	3.7894	3.8895	3.8898		0.3	3.8898	100.4	100.40%
9	**135**	50	3.7178	3.8179	3.8177		-0.2	3.8177	99.9	99.90%
10	**137**	50	3.7489	3.8488	3.8485		-0.3	3.8485	99.6	99.60%
11	**136**	50	3.7907	3.8907	3.8904		-0.3	3.8904	99.7	99.70%
12	**61**	50	3.8120	3.9121	3.9120		-0.1	3.9120	100.0	100.00%
13	**56**	50	3.7894	3.8890	3.8889		-0.1	3.8889	99.5	99.50%
14	**NA**	50	3.7348	3.8346	3.8344		-0.2	3.8344	99.6	99.60%
15	**69**	50	3.7634	3.8644	3.8648		0.4	3.8648	101.4	101.40%
16	**92**	50	3.8360	3.9362	3.9362		0.0	3.9362	100.2	100.20%
17	**96**	50	3.7731	3.8732	3.8732		0.0	3.8732	100.1	100.10%
18	**60**	50	3.7506	3.8504	3.8505		0.1	3.8505	99.9	99.90%
19	**93**	50	3.7791	3.8791	3.8790		-0.1	3.8790	99.9	99.90%

Table 3A: Environmental Express TDS Stable-Weigh Tests 100 mg										
Analyst	**Edward F. Askew**									
Date	**4/20/2016**									
100.0 mg per 50 mL										
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
20	**103**	50	3.7646	3.8638	3.8635		-0.3	3.8635	98.9	98.90%
21	**84**	50	3.7944	3.8945	3.8940		-0.5	3.8940	99.6	99.60%
22	**78**	50	3.8620	3.9630	3.9629		-0.1	3.9629	100.9	100.90%
23	**86**	50	3.7344	3.8343	3.8341		-0.2	3.8341	99.7	99.70%
24	**87**	50	3.7374	3.8379	3.8382		0.3	3.8382	100.8	100.80%
25	**161**	50	3.7346	3.8346	3.8344		-0.2	3.8344	99.8	99.80%
								Average	100.0	100.03%
								Standard Deviation	0.5	0.52%

Table 4A: Environmental Express TDS Stable-Weigh Tests 20 mg										
Analyst	**Edward F. Askew**									
Date	**4/24/2016**									
20.1 mg per 50 mL										
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
1	**195**	50	3.8442	3.8635	3.8632		-0.3	3.8632	19.0	94.53%
2	**194**	50	4.1223	4.1430	4.1431		0.1	4.1431	20.8	103.48%
3	**193**	50	3.9300	3.9498	3.9498		0.0	3.9498	19.8	98.51%
4	**191**	50	3.8884	3.9087	3.9087		0.0	3.9087	20.3	101.00%
5	**189**	50	3.9631	3.9836	3.9835		-0.1	3.9835	20.4	101.49%
6	**190**	50	3.7477	3.7681	3.7680		-0.1	3.7680	20.3	101.00%
7	**184**	50	3.8975	3.9170	3.9174		0.4	3.9174	19.9	99.00%
8	**188**	50	3.9284	3.9479	3.9482		0.3	3.9482	19.8	98.51%
9	**187**	50	3.8906	3.9112	3.9109		-0.3	3.9109	20.3	101.00%
10	**186**	50	3.9480	3.9680	3.9685		0.5	3.9685	20.5	101.99%
11	**209**	50	3.8724	3.8925	3.8929		0.4	3.8929	20.5	101.99%
12	**185**	50	3.9345	3.9543	3.9545		0.2	3.9545	20.0	99.50%
13	**210**	50	3.9015	3.9221	3.9217		-0.4	3.9217	20.2	100.50%
14	**219**	50	3.7434	3.7632	3.7635		0.3	3.7635	20.1	100.00%
15	**213**	50	3.7270	3.7472	3.7473		0.1	3.7473	20.3	101.00%
16	**212**	50	3.9431	3.9632	3.9633		0.1	3.9633	20.2	100.50%
17	**218**	50	3.7349	3.7549	3.7551		0.2	3.7551	20.2	100.50%
18	**217**	50	3.8864	3.9062	3.9064		0.2	3.9064	20.0	99.50%
19	**216**	50	3.9130	3.9329	3.9331		0.2	3.9331	20.1	100.00%

Table 4A: Environmental Express TDS Stable-Weigh Tests 20 mg										
Analyst	**Edward F. Askew**									
Date	**4/24/2016**									
20.1 mg per 50 mL										
Sample #	**Bag #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
20	**215**	50	3.7322	3.7522	3.7524		0.2	3.7524	20.2	100.50%
21	**214**	50	3.7237	3.7437	3.7437		0.0	3.7437	20.0	99.50%
22	**211**	50	3.7281	3.7486	3.7482		-0.4	3.7482	20.1	100.00%
23	**220**	50	3.7186	3.7394	3.7393		-0.1	3.7393	20.7	102.99%
24	**221**	50	3.7429	3.7629	3.7629		0.0	3.7629	20.0	99.50%
25	**196**	50	3.6729	3.6929	3.6931		0.2	3.6931	20.2	100.50%
								Average	20.2	100.28%
								Standard Deviation	0.3	1.72%

Table 5A: Environmental Express TDS Stable-Weigh Tests 20 mg-Evaporation Dish										
Analyst	**Edward F. Askew**									
Date	**4/22/2016**									
20.2 mg per 50 mL (Evaporation Dish)										
Sample #	**Evaporation Dish #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
1	**1**	50	80.0804	80.1007	80.1004		-0.3	80.1004	20.0	99.01%
2	**2**	50	88.0705	88.0913	88.0916		0.3	88.0916	21.1	104.46%
3	**3**	50	80.7484	80.7695	80.7698		0.3	80.7698	21.4	105.94%
4	**4**	50	80.6551	80.6759	80.6758		-0.1	80.6758	20.7	102.48%
5	**5**	50	80.1832	80.2041	80.2045		0.4	80.2045	21.3	105.45%
6	**6**	50	71.8200	71.8405	71.8410		0.5	71.8410	21.0	103.96%
7	**7**	50	77.3487	77.3690	77.3694		0.4	77.3694	20.7	102.48%
8	**8**	50	71.2989	71.3192	71.3190		-0.2	71.3190	20.1	99.50%
9	**9**	50	71.0469	71.0674	71.0670		-0.4	71.0670	20.1	99.50%
10	**10**	50	70.3869	70.4077	70.4072		-0.5	70.4072	20.3	100.50%
11	**11**	50	71.0414	71.0622	71.0618		-0.4	71.0618	20.4	100.99%
12	**12**	50	71.3383	71.3591	71.3589		-0.2	71.3589	20.6	101.98%
13	**13**	50	71.7408	71.7612	71.7612		0.0	71.7612	20.4	100.99%
14	**14**	50	70.1571	70.1774	70.1776		0.2	70.1776	20.5	101.49%
15	**15**	50	82.6046	82.6254	82.6256		0.2	82.6256	21.0	103.96%
16	**16**	50	70.3772	70.3975	70.3976		0.1	70.3976	20.4	100.99%
17	**17**	50	71.1090	71.1291	71.1294		0.3	71.1294	20.4	100.99%
18	**18**	50	69.7257	69.7460	69.7464		0.4	69.7464	20.7	102.48%
19	**19**	50	88.4661	88.4867	88.4872		0.5	88.4872	21.1	104.46%

Table 5A: Environmental Express TDS Stable-Weigh Tests 20 mg-Evaporation Dish										
Analyst	**Edward F. Askew**									
Date	**4/22/2016**									
20.2 mg per 50 mL (Evaporation Dish)										
Sample #	**Evaporation Dish #**	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Solids Recovered Weight (mg)**	**Percent Recovery**
20	**20**	50	91.8973	91.9196	91.9191		-0.5	91.9191	21.8	107.92%
21	**21**	50	92.1109	92.1311	92.1312		0.1	92.1312	20.3	100.50%
22	**22**	50	93.7274	93.7480	93.7478		-0.2	93.7478	20.4	100.99%
23	**23**	50	92.0551	92.0755	92.0750		-0.5	92.0750	19.9	98.51%
24	**24**	50	94.5897	94.6106	94.6105		-0.1	94.6105	20.8	102.97%
25	**A**	50	83.3947	83.4134	83.4134		0.0	83.4134	18.7	92.57%
								Average	20.6	101.80%
								Standard Deviation	0.6	2.99%

Table 6A: Matrix Raw Drinking Water/Ground Water								
Sample #	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Total Dissolved Solids (mg/L)**
1	50	3.6582	3.6722	3.6718		-0.4	3.6718	272.0
2	50	3.7170	3.7312	3.7307		-0.5	3.7307	274.0
3	50	3.6640	3.6785	3.6774	3.6776	0.2	3.6776	272.0
4	50	3.6406	3.6545	3.6543		-0.2	3.6543	274.0
5	50	3.6689	3.6826	3.6825		-0.1	3.6825	272.0
							Average	272.8
							Standard Deviation	1.1

Table 7A: Matrix Spike									
Sample #	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Total Dissolved Solids (mg/L)**	**Matrix Spike Recovery**
1	50	3.6227	3.6464	3.6461		-0.3	3.6461	468.0	97.98%
2	50	3.6657	3.6891	3.6892		0.1	3.6892	470.0	97.98%
3	50	3.6573	3.6811	3.6808		-0.3	3.6808	470.0	98.98%
4	50	3.6754	3.6994	3.6995		0.1	3.6995	482.0	103.98%
5	50	3.6856	3.7091	3.7091		0.0	3.7091	470.0	98.98%
							Average	472.0	99.58%
							Standard Deviation	5.7	2.51%

Table 8A: Matrix Spike Duplicate										
Sample #	**Volume (ml)**	**Initial weight (g)**	**Final weight 1 (g)**	**Final weight 2 (g)**	**Final weight 3 (g)**	**Two Consecutive Weights Difference (mg)**	**Final weight used (mg)**	**Final Total Dissolved Solids (mg/L)**	**Matrix Spike Recovery**	**Relative Percent Difference**
1	50	3.6839	3.7078	3.7082		0.4	3.7082	486.0	106.98%	8.78%
2	50	3.6388	3.6619	3.6618		-0.1	3.6618	460.0	92.98%	5.24%
3	50	3.6686	3.6927	3.6923		-0.4	3.6923	474.0	100.98%	2.00%
4	50	3.7493	3.7728	3.7726		-0.2	3.7726	466.0	95.98%	8.00%
5	50	3.6896	3.7142	3.7139		-0.3	3.7139	486.0	106.98%	7.77%
							Average	474.4	474.40%	4.74%
							Standard Deviation	11.7	6.34%	2.77%