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Characterization of the LAWB99-series and ORLEC-series Glasses

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December 2017

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EXECUTIVE SUMMARY

In this report, the Savannah River National Laboratory provides chemical analysis results for a series of simulated low activity waste (LAW) glass compositions. These data will be used in the development of improved sulfur solubility models for LAW glass. A procedure developed at the Pacific Northwest National Laboratory for producing sulfur saturated melts (SSMs) was used to fabricate the glasses characterized in this report. This method includes triplicate melting steps with excess sodium sulfate, followed by grinding and washing to remove unincorporated sulfur salts. The wash solutions were also analyzed as part of this study.

Chemical analyses were performed on a representative sample of each of the sulfur saturated glasses to allow for comparisons with the targeted compositions. Some degree of scatter among the Al_2O_3, B_2O_3, Na_2O, and SiO_2 measurements was noted. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of the data. As expected, most of the measured concentrations of SO_3 were higher than originally targeted due to the use of the sulfur saturation method in fabricating these glasses. Glass EWG-LAW-SSM-S was the exception. Other minor differences between the targeted and measured concentrations of some of the glass components were noted, but in general, the targeted concentrations were successfully met.

Chemical analyses were also performed on a representative sample of each of the wash solutions resulting from the preparation of the sulfur saturated glasses. Minor scatter among the triplicate measurements of some of the analytes of the wash solutions was noted. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of the data. The measured concentrations of SO_4^{2-} in the wash solutions were similar for both of the analytical methods used, and were in the ranges of 1150-1450 mg/L for the LAWB99-series glasses and 1500-1700 mg/L for the ORLEC-series glasses. Glass EWG-LAW-SSM-S, which targeted the composition of the Low-level Reference Material (LRM) glass, had a measured concentration of 0.21 wt % SO_3, which is close to the reference value of 0.3 wt %. In addition, measurements of the wash solution for this glass showed relatively high concentrations of Na and SO_4^{2-}. This may indicate that the reference SO_3 concentration for this glass also corresponds to the saturated value. Further comparisons between the compositions of the glasses and the compositions of the wash solutions may be of interest, although the current sulfur saturation method used does not allow for a complete mass balance to be developed.

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LIST OF ABBREVIATIONS

BDL	Below Detection Limit
DOE	U.S. Department of Energy
HLW	High Level Waste
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
KH	Potassium hydroxide fusion
LAW	Low Activity Waste
LM	Lithium Metaborate fusion
LRM	Low-level Reference Material
ORP	Office of River Protection
PF	Peroxide Fusion
PNNL	Pacific Northwest National Laboratory
SRNL	Savannah River National Laboratory
SSM	Sulfur Saturated Melt
TTQAP	Task Technical and Quality Assurance Plan
wt %	Weight Percent
WTP	Hanford Tank Waste Treatment and Immobilization Plant

1.0 Introduction

The U.S. Department of Energy (DOE) Office of River Protection (ORP) has requested that the Savannah River National Laboratory (SRNL) provide expert evaluation and experimental work in support of the River Protection Project vitrification technology development. DOE is building the Hanford Tank Waste Treatment and Immobilization Plant (WTP) at the Hanford Site in Washington to remediate 55 million gallons of radioactive waste that is temporarily stored in 177 underground tanks. The low-activity waste (LAW) fraction will be partitioned from the high-level waste (HLW). Both the LAW and HLW will then be vitrified into borosilicate glass using Joule-heated ceramic melters.

Efforts are being made to increase the loading of Hanford tank wastes in the glass while conforming to processing requirements and product quality regulations. DOE-ORP has requested that SRNL support the advancement of glass formulations and process control strategies in key technical areas, as defined in the Task Technical and Quality Assurance Plan (TTQAP).[1] Two of these areas are enhancing waste glass property/composition models and broadening the compositional regions over which those models are applicable.

In this report, SRNL provides chemical analysis results for several simulated LAW glass compositions that were fabricated by Pacific Northwest National Laboratory (PNNL) as part of an ongoing development task.[2] Chemical analysis results for the wash solutions generated during the fabrication of these glasses are also provided. These data will be used in the development of improved process control models for LAW glass production at WTP.

2.0 Experimental Procedure

2.1 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in Savannah River Site Manual E7, Procedure 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2. Laboratory data for this study were recorded in the SRNL Electronic Laboratory Notebook system, experiment C3489-00079-15.

2.2 Glasses Selected for Study

The glasses analyzed in this study were selected and fabricated at PNNL. Identifiers for the glasses are listed in Table 2-1. The glasses were provided in two sets, as indicated in Table 2-1 and referred to in this document as the LAWB99-series glasses and the ORLEC-series glasses. Wash solutions resulting from the preparation (sulfur saturation) of these glasses at PNNL were also included in the analyses.

In the sections that follow, the methods used for measuring chemical compositions of the glasses and their wash solutions are described, and reviews of the resulting data are provided. Detailed results from these analyses are included in the appendices.

Table 2-1. Identifiers for the LAWB99-series and ORLEC-series Glasses and Wash Solutions

Glass Identifier	Wash Solution Identifier	Series
LAWB99-SSM-SA	LAWB99-SSM-WA	LAWB99
LAWB99-SSM-SB	LAWB99-SSM-WB	
LAWB99-SSM-SC	LAWB99-SSM-WC	
ORLEC-34-SSM-S	ORLEC-34-SSM-W	ORLEC
ORLEC-44-SSM-S	ORLEC-44-SSM-W	
ORLEC-46-SSM-S	ORLEC-46-SSM-W	
ORLEC-48R-SSM-S	ORLEC-48R-SSM-W	
EWG-LAW-SSM-S	EWG-LAW-SSM-W	

2.3 Glass Composition Analysis

Chemical analyses were performed under the auspices of two analytical plans,[3,4] on a representative sample of each of the glasses listed in Table 2-1, to allow for comparisons with the targeted compositions. Three dissolution techniques, sodium peroxide fusion (PF),[5] lithium metaborate fusion (LM),[6] and potassium hydroxide fusion (KH),[7] were used for preparing each of the glass samples for analysis. The ORLEC-series glasses were prepared in duplicate, while single preparations were performed for the LAWB99-series glasses due to limitations on the amount of glass available for testing.

Each of the (single or duplicate) samples was analyzed twice for each element of interest by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES)[8] or ion chromatography (IC),[9] for a total of two or four measurements per element per glass. Glass standards were also intermittently measured to assess the performance of the ICP-AES and IC instruments over the course of these analyses. Specifically, several samples of the low-level reference material (LRM)[10] were included as part of the analytical plans. The LRM composition reported as the “Consensus Average” is used as the reference composition of this glass for the purposes of this study.[10] The preparation and measurement methods used for each of the reported glass components are listed in Table 2-2.

Table 2-2. Preparation and Measurement Methods Used in Reporting the Concentrations of Each of the Analytes of the Study Glasses

Analyte	Preparation Method	Measurement Method
Al	PF	ICP-AES
B	PF	ICP-AES
Ca	LM	ICP-AES
Cl	KH	IC
Cr	LM	ICP-AES
F	KH	IC
Fe	PF	ICP-AES
K	LM	ICP-AES
Li	PF	ICP-AES
Mg	LM	ICP-AES
Na	LM	ICP-AES
P	LM	ICP-AES
S	LM	ICP-AES
Si	PF	ICP-AES
V	LM	ICP-AES
Zn	LM	ICP-AES
Zr	LM	ICP-AES

2.4 Wash Solution Analysis

Chemical analyses were performed under the auspices of two analytical plans[3,4] on a representative sample of each of the wash solutions from the glasses listed in Table 2-1 that resulted from the preparation of the sulfur saturated melts at PNNL.[11] The samples were diluted based on the expected concentrations of the species in solution in preparation for the analyses.

Each of the samples was analyzed in triplicate for each element of interest by ICP-AES[8] and IC.[9] Solution standards and blanks were also intermittently measured to assess the performance of the ICP-AES and IC instruments over the course of these analyses. The measurement methods used for the reported wash solution components are listed in Table 2-3.

Table 2-3. Measurement Methods Used in Reporting the Concentrations of Each of the Analytes of the Wash Solutions

Analyte	Measurement Method
Al	ICP-AES
B	ICP-AES
Ca	ICP-AES
Cl^-	IC
Cr	ICP-AES
F^-	IC
Fe	ICP-AES
K	ICP-AES
Li	ICP-AES
Mg	ICP-AES
Na	ICP-AES
P	ICP-AES
PO_4^-	IC
S	ICP-AES
SO_4^{2-}	IC
Si	ICP-AES
V	ICP-AES
Zn	ICP-AES
Zr	ICP-AES

3.0 Results and Discussion – LAWB99-Series

3.1 Review and Evaluation of Glass Composition Measurements

Table A-1 in Appendix A provides the elemental concentration measurements in wt % for the LAWB99 glasses by preparation method. Elemental measurements for samples of the LRM standard glass are also included in the tables of Appendix A. These unprocessed data are provided so that the values are readily available should they be of interest for future reviews.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the LRM standard glass are investigated, the measurements for each glass are reviewed, the average chemical composition for each glass is determined, and comparisons are made between the measurements and the targeted compositions of the glasses. JMP™ Pro Version 11.2.1 (SAS Institute, Inc.)[12] was used to support these analyses.

3.1.1 Treatment of Detection Limits

The elemental concentrations in Table A-1 of Appendix A were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During the process of converting to oxide concentrations, an elemental concentration measurement that was reported to be below the detection limit of the analytical process used was set to the detection limit for the purposes of review and calculating a sum of oxides for each glass. Those oxides with one or more concentration measurements that were below the associated detection limit (BDL) will be denoted with a less than symbol (<) as the measured compositions are reported.

3.1.2 Measurements in Analytical Sequence

Exhibit A-1 in Appendix A provides plots of the wt % measurements generated for each sample by oxide and analytical block. The plots are in analytical sequence within each calibration block with different symbols and colors being used to represent each of the study and standard glasses. These plots include all of the measurement data from Table A-1 in Appendix A, with each plotted point identified by its Lab ID. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instruments within and among calibration blocks. A review of these plots did not identify any gross patterns or trends in the analytical process over the course of these measurements. Only minor issues are seen. For example, calibration shifts are visible for the Al_2O_3, Fe_2O_3, and SiO_2 measurements. Taking the average of the measurements for each of these oxides is assumed to negate these minor calibration shifts.

3.1.3 Composition Measurements by Glass Identifier

Exhibit A-2 in Appendix A provides plots of the oxide concentration measurements by the PNNL Glass ID (including the LRM reference glass) grouped by targeted concentration. Different symbols and colors are used to represent the different glasses. These plots show the duplicate measurements for each preparation method representing the two instrument calibrations for each glass. Plotting the data in this format provides an opportunity to review the values for each individual glass as a function of the duplicate measurements. A review of the plots presented in these exhibits reveals the repeatability of the two individual values for each oxide for each glass. Some degree of scatter among the Al_2O_3, B_2O_3, Na_2O, and SiO_2 measurements is visible for the LAWB99 glasses. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of the data. Therefore, the entire set of measurement data was used in determining representative, measured compositions for the study glasses.

3.1.4 Results for the LRM Standard

Exhibit A-3 in Appendix A provides a comparison of the LRM results to their acceptability limits utilized by SRNL.[8] The review is in the form of plots of the measurements arranged by preparation method and element, framed by upper and lower acceptability limits for the concentration of the element in question. The results show that all of the measurements for the elements present in the LRM standard glass were within the acceptability limits utilized by SRNL in conducting instrument and procedure assessments during the execution of these analyses.

3.1.5 Measured versus Targeted Compositions

From the discussion of Section 3.1.3, all of the measurements for each oxide for each glass (i.e., the data presented in Table A-1 in Appendix A) were averaged to determine a representative chemical composition for each LAWB99 glass. A sum of oxides was also computed for each glass based upon the averaged, measured values. Exhibit A-4 in Appendix A provides plots showing the result for each glass for each oxide to allow PNNL to draw comparisons between the measured and targeted values. The following observations are offered from a review of these plots:

- The measured concentrations of Al_2O_3, B_2O_3, Li_2O, and ZrO_2 are somewhat below the targeted values.
- The targeted concentrations of chlorine, Cr_2O_3, and P_2O_5 were below detection limits for all the study glasses.
- The measured concentrations of fluorine were below detection limits for all the study glasses, which is likely due to volatility during the remelting process.
- The measured concentrations of Na_2O are high, potentially due to the addition of excess sodium sulfate in the preparation of these glasses.
- As expected, the measured concentrations of SO_3 are higher than targeted due to the use of the sulfur saturation method in fabricating these glasses.

Table A-2 in Appendix A provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. All of the measured sums of oxides for the study glasses fall within the interval of about 99 to 101 wt %, indicating excellent recovery of the glass components. Entries in Table A-2 show the relative differences between the measured values and the targeted values for the oxides with targeted values above 5 wt %. The relative differences are shaded if they are 10% or more.[a] The highlighted cells are consistent with the observations listed above. Note that no shading was used for the comparison of SO_3 concentrations, since the use of the sulfur saturation method means that there is no targeted SO_3 concentration for comparison.

3.2 Review and Evaluation of Wash Solution Measurements

Table B-1 in Appendix B provide the elemental concentration measurements in mg/L for the wash solutions as measured by ICP-AES. Table B-2 in Appendix B provides the anion concentration measurements in mg/L for the wash solutions as measured by IC. Measurements of the blanks and standard solutions are also included in the tables of Appendix B. These unprocessed data are provided so that the values are readily available should they be of interest for future reviews.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the standard solutions and the wash solutions are reviewed, and the average chemical composition for each wash solution is determined. JMP™ Pro Version 11.2.1 (SAS Institute, Inc.)[12] was used to support these analyses.

3.2.1 Treatment of Detection Limits

The elemental and anion concentrations in Table B-1 and Table B-2 of Appendix B include measurements that were reported to be below the detection limit of the analytical process used. These values were set to the detection limit for the purposes of review and calculating an average composition for each wash solution. Those analytes with one or more concentration measurements that were below the associated detection limit (BDL) will be denoted with a less than symbol (<) as the measured compositions are reported.

3.2.2 Measurements in Analytical Sequence

Exhibit B-1 in Appendix B provides plots of the mg/L measurements generated for each wash solution sample by element or anion and analytical block. The plots are in analytical sequence within each calibration block with different symbols and colors being used to represent each of the wash solutions and standard solutions. These plots include all of the measurement data from Table B-1 and Table B-2 in Appendix B, with each plotted point identified by its Lab ID. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instruments within and among calibration blocks. A review of these plots did not identify any gross patterns or trends in the analytical process over the course of these measurements.

3.2.3 Composition Measurements by Solution Identifier

Exhibit B-2 in Appendix B provides plots of the elemental and anion concentration measurements grouped by the wash solution identifier (including the blanks and standard solutions). Different symbols and colors are used to represent the different solutions. Plotting the data in this format provides an opportunity to review the values for each individual solution as a function of the triplicate measurements. A review of the plots presented in these exhibits reveals the repeatability of the three individual values for each analyte for each solution. All measurements of the blanks were below detection limits. Minor scatter among the triplicate measurements of some of the analytes of the wash solutions was noted. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of

[a] These criteria were selected arbitrarily for the purpose of highlighting differences from targeted concentrations that may be of practical concern.

the data. Therefore, the entire set of measurement data was used in determining representative, measured compositions for the wash solutions.

3.2.4 Results for the Standard Solutions

Table B-3 in Appendix B provides comparisons of the standard solution results to their reference values. Although not a detailed comparison, the results in this table indicate no issues with the performance of the analyses.

3.2.5 Measured Compositions of the Wash Solutions

From the discussion of Section 3.2.3, all of the measurements for each analyte for each wash solution (i.e., the data presented in Table B-1 and Table B-2 of Appendix B) were averaged to determine a representative chemical composition for each solution. Table B-4 in Appendix B provides a summary of the average measured compositions of the wash solutions. Rows in Table B-4 for PO_4^{3-} and SO_4^{2-} include the measured values from both ICP-AES and IC for comparison. The measured P and S concentrations from the ICP-AES analyses were converted to PO_4^{3-} and SO_4^{2-} concentrations by multiplying by the appropriate gravimetric factors to support these comparisons.

The following observations are offered from a review of Table B-4:

- The measured concentrations of Al, Cl, Cr, F, Fe, Mg, P, V, Zn, and Zr in the wash solutions were near or below the detection limits.
- B, K, Li, and Si were present in relatively low concentrations of less than 40 mg/L.
- The measured concentrations of Ca were in the range of about 50-60 mg/L.
- The measured concentrations of Na were in the range of about 400-500 mg/L.
- The measured concentrations of SO_4^{2-} were similar by both the ICP-AES and IC methods (ICP-AES data converted to SO_4^{2-} basis for comparison), and were in the range of about 1150-1450 mg/L.

4.0 Results and Discussion – ORLEC-Series

4.1 Review and Evaluation of Glass Composition Measurements

Table C-1 in Appendix C provides the elemental concentration measurements in wt % for the ORLEC by preparation method. Elemental measurements for samples of the LRM standard glass are also included in the tables of Appendix C. These unprocessed data are provided so that the values are readily available should they be of interest for future reviews.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the LRM standard glass are investigated, the measurements for each glass are reviewed, the average chemical composition for each glass is determined, and comparisons are made between the measurements and the targeted compositions of the glasses. JMP™ Pro Version 11.2.1 (SAS Institute, Inc.)[12] was used to support these analyses.

4.1.1 Treatment of Detection Limits

The elemental concentrations in Table C-1 of Appendix C were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During the process of converting to oxide concentrations, an elemental concentration measurement that was reported to be below the detection limit of the analytical process used was set to the detection limit for the purposes of review and calculating a sum of oxides for each glass. Those oxides with one or more concentration measurements that were below the associated detection limit (BDL) will be denoted with a less than symbol (<) as the measured compositions are reported.

4.1.2 Measurements in Analytical Sequence

Exhibit C-1 in Appendix C provides plots of the wt % measurements generated for each sample by oxide and analytical block. The plots are in analytical sequence within each calibration block with different symbols and colors being used to represent each of the study and standard glasses. These plots include all of the measurement data from Table C-1 in Appendix C, with each plotted point identified by its Lab ID. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instruments within and among calibration blocks. A review of these plots did not identify any gross patterns or trends in the analytical process over the course of these measurements. Taking the average of the measurements for each of these oxides is assumed to negate any minor calibration shifts.

4.1.3 Composition Measurements by Glass Identifier

Exhibit C-2 in Appendix C provides plots of the oxide concentration measurements by the PNNL Glass ID (including the LRM reference glass) by Lab ID grouped by targeted concentration. Different symbols and colors are used to represent the different glasses. These plots show the individual measurements across the duplicates of each preparation method and the two instrument calibrations for each glass. Plotting the data in this format provides an opportunity to review the values for each individual glass as a function of the duplicate preparations and duplicate measurements. A review of the plots presented in these exhibits reveals the repeatability of the four individual values for each oxide for each glass. Some degree of scatter among the individual Al_2O_3, B_2O_3, Na_2O, and SiO_2 measurements was noted for the study glasses. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of the data. Therefore, the entire set of measurement data was used in determining representative, measured compositions for the study glasses.

4.1.4 Results for the LRM Standard

Exhibit C-3 in Appendix C provides a comparison of the LRM results to their acceptability limits utilized by SRNL.[8] The review is in the form of plots of the measurements arranged by preparation method and element, framed by upper and lower acceptability limits for the concentration of the element in question. The results show that all of the measurements for the elements present in the LRM standard glass were within the acceptability limits utilized by SRNL in conducting instrument and procedure assessments during the execution of these analyses.

4.1.5 Measured versus Targeted Compositions

From the discussion of Section 4.1.3, all of the measurements for each oxide for each glass (i.e., the data presented in Table C-1 in Appendix C) were averaged to determine a representative chemical composition for each glass. A sum of oxides was also computed for each glass based upon the averaged, measured values. Exhibit C-4 in Appendix C provides plots showing the result for each glass for each oxide to allow PNNL to draw comparisons between the measured and targeted values. The following observations are offered from a review of these plots:

- The measured concentrations of Al_2O_3, B_2O_3, K_2O, Li_2O, MgO, V_2O_5, and ZrO_2 are somewhat below the targeted values for the ORLEC glasses.
- The measured concentrations of chlorine and fluorine are below the targeted values, potentially due to volatility during the SSM remelting steps.
- The targeted concentrations of Cr_2O_3 and P_2O_5 are below the analytical detection limits for four of the ORLEC glasses.
- The measured Na_2O concentrations are low for three of the ORLEC glasses.
- As expected, most of the measured concentrations of SO_3 are higher than targeted due to the use of the sulfur saturation method in fabricating these glasses. Glass EWG-LAW-SSM-S was the exception, as discussed further in Section 4.2.5.

Table C-2 in Appendix C provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. All of the measured sums of oxides for the study glasses fall within the interval of about 97 to 99 wt %, indicating acceptable recovery of the glass components. Entries in Table C-2 show the relative differences between the measured values and the targeted values for the oxides with targeted values above 5 wt %. The relative differences are shaded if they are 10% or more.[a] The highlighted cells are consistent with the observations listed above. Note that no shading was used for the comparison of SO_3 concentrations, since the use of the sulfur saturation method means that there is no targeted SO_3 concentration for comparison.

4.2 Review and Evaluation of Wash Solution Measurements

Table D-1 in Appendix D provide the elemental concentration measurements in mg/L for the wash solutions as measured by ICP-AES. Table D-2 in Appendix D provides the anion concentration measurements in mg/L for the wash solutions as measured by IC. Elemental measurements of the blanks and standard solutions are also included in the tables of Appendix D. These unprocessed data are provided so that the values are readily available should they be of interest for future reviews.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the standard solutions and the wash solutions are reviewed, and the average chemical composition for each wash solution is determined. JMP™ Pro Version 11.2.1 (SAS Institute, Inc.)[12] was used to support these analyses.

4.2.1 Treatment of Detection Limits

The elemental and anion concentrations in Table D-1 and Table D-2 of Appendix D include measurements that were reported to be below the detection limit of the analytical process used. These values were set to the detection limit for the purposes of review and calculating an average composition for each wash solution. Those analytes with one or more concentration measurements that were below the associated detection limit (BDL) will be denoted with a less than symbol (<) as the measured compositions are reported.

4.2.2 Measurements in Analytical Sequence

Exhibit D-1 in Appendix D provides plots of the mg/L measurements generated for each wash solution sample by element or anion and analytical block. The plots are in analytical sequence within each calibration block with different symbols and colors being used to represent each of the wash solutions and standard solutions. These plots include all of the measurement data from Table D-1 and Table D-2 in Appendix D, with each plotted point identified by its Lab ID. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instruments within and among calibration blocks. A review of these plots did not identify any gross patterns or trends in the analytical process over the course of these measurements.

4.2.3 Composition Measurements by Solution Identifier

Exhibit D-2 in Appendix D provides plots of the elemental and anion concentration measurements grouped by the wash solution identifier (including the blanks and standard solutions). Different symbols and colors are used to represent the different solutions. Plotting the data in this format provides an opportunity to review the values for each individual solution as a function of the triplicate measurements. A review of the plots presented in these exhibits reveals the repeatability of the three individual values for each analyte for each solution. All measurements of the blanks were below detection limits, with the exception of one Na_2O measurement in the second blank. Minor scatter among the triplicate measurements of some of the analytes of the study glasses was noted. These observations were not considered to indicate an error in preparation

[a] These criteria were selected arbitrarily for the purpose of highlighting differences from targeted concentrations that may be of practical concern.

or measurement that had to be addressed in treatment of the data. Therefore, the entire set of measurement data was used in determining representative, measured compositions for the wash solutions.

4.2.4 Results for the Standard Solutions

Table D-3 in Appendix D provides comparisons of the standard solution results to their reference values. Although not a detailed comparison, the results in this table indicate no issues with the performance of the analyses.

4.2.5 Measured Compositions of the Wash Solutions

From the discussion of Section 4.2.3, all of the measurements for each analyte for each wash solution (i.e., the data presented in Table D-1 and Table D-2 of Appendix D) were averaged to determine a representative chemical composition for each solution. Table D-4 in Appendix D provides a summary of the average measured compositions of the wash solutions. Rows in Table D-4 for PO_4^{3-} and SO_4^{2-} include the measured values from both ICP-AES and IC for comparison. The measured P and S concentrations from the ICP-AES analyses were converted to PO_4^{3-} and SO_4^{2-} concentrations by multiplying by the appropriate gravimetric factors to support these comparisons.

The following observations of the ORLEC wash solutions are offered from a review of Table D-4:

- The measured concentrations of Al, F, Fe, Mg, Zn, and Zr were at or below the detection limits.
- The measured concentrations of B, Ca, Cl, Cr, K, Li, Si, and V were generally less than 25 mg/L.
- The measured concentrations of Na were in the range of 600-900 mg/L.
- The measured concentrations of P were less than 5 mg/L by ICP-AES, and below the detection limit (for PO_4^{3-}) of the IC method used.
- The measured concentrations of SO_4^{2-} were similar by both the ICP-AES and IC methods (ICP-AES data converted to SO_4^{2-} basis for comparison), and were in the range of about 1500-1700 mg/L.

Also of note is that glass EWG-LAW-SSM-S, which targeted the composition of the Low-level Reference Material (LRM) glass, had a measured concentration of SO_3 that was close to the reference value. However, measurements of the wash solution for this glass showed relatively high concentrations of Na and SO_4^{2-}. This may indicate that the reference SO_3 concentration for this glass also corresponds to the saturated value.

5.0 Summary

In this report, SRNL provides chemical analysis results for a series of simulated LAW glass compositions. These data will be used in the development of improved sulfur solubility models for LAW glass. A procedure developed at PNNL for producing sulfur saturated melts (SSMs) was used to fabricate the glasses characterized in this report. This method includes triplicate melting steps with excess sodium sulfate, followed by grinding and washing to remove unincorporated sulfur salts. The wash solutions were also analyzed as part of this study.

Chemical analyses were performed on a representative sample of each of the sulfur saturated glasses to allow for comparisons with the targeted compositions. Three dissolution techniques, sodium peroxide fusion, lithium metaborate fusion, and potassium hydroxide fusion, were used for preparing each of the glass samples for analysis. Duplicate preparations were performed for the ORLEC-series glasses, but there was only enough glass for single preparations of the LAWB99-series glasses. Each of the samples was analyzed twice for each element of interest by ICP-AES or IC. Glass standards were intermittently measured to assess the performance of the analytical instruments over the course of these analyses.

A review of the individual glass composition measurements identified some minor shifts between measurement sub-blocks as a result of instrument calibrations. Some degree of scatter among the Al_2O_3, B_2O_3, Na_2O, and SiO_2 measurements was noted. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of the data. There were no issues with measurements of the LRM standard glass. As expected, most of the measured concentrations of SO_3 were higher than originally targeted due to the use of the sulfur saturation method in fabricating these glasses. Other minor differences between the targeted and measured concentrations of some of the glass components were noted, but in general, the targeted concentrations were successfully met.

Chemical analyses were also performed on a representative sample of each of the wash solutions resulting from the preparation of the sulfur saturated glasses. The samples were diluted and then analyzed in triplicate for each element of interest by ICP-AES or IC. No issues were noted for the measurements of the solution standards. Minor scatter among the triplicate measurements of some of the analytes of the wash solutions was noted. These observations were not considered to indicate an error in preparation or measurement that had to be addressed in treatment of the data. The measured concentrations of sulfur in the wash solutions were similar by both the ICP-AES and IC methods (SO_4^{2-} basis), and were in the range of 1150-1450 mg/L for the LAWB99-series glasses and 1500-1700 mg/L for the ORLEC-series glasses. Of note, glass EWG-LAW-SSM-S, which targeted the composition of the LRM reference glass, had a measured concentration of SO_3 that was close to the reference value. However, measurements of the wash solution for this glass showed relatively high concentrations of Na and SO_4^{2-}. This may indicate that the reference SO_3 concentration for this glass also corresponds to the saturated value. Further comparisons between the compositions of the glasses and the compositions of the wash solutions may be of interest, although the current sulfur saturation method used does not allow for a complete mass balance to be developed.

6.0 References

1. Fox, K. M., "Task Technical and Quality Assurance Plan for Hanford Waste Glass Development and Characterization," *U.S. Department of Energy Report SRNL-RP-2013-00692, Revision 1,* Savannah River National Laboratory, Aiken, SC (2016).

2. Peeler, D. K., D. S. Kim, J. D. Vienna, M. J. Schweiger, and G. F. Piepel, "Office of River Protection Advanced Low-Activity Waste Glass Research and Development Plan," *U.S. Department of Energy Report PNNL-24883, EWG-RPT-008,* Pacific Northwest National Laboratory, Richland, WA (2015).

3. Edwards, T. B., "Analytical Plans for Measuring the Chemical Compositions of the LAWB99 Glasses and Their Wash Solutions," *U.S. Department of Energy Memorandum SRNL-L3300-2017-00029, Revision 0,* Savannah River National Laboratory, Aiken, SC (2017).

4. Edwards, T. B., "Analytical Plans for Measuring the Chemical Compositions of the ORLEC-Series Glasses and Their Wash Solutions," *U.S. Department of Energy Memorandum SRNL-L3300-2017-00028, Revision 0,* Savannah River National Laboratory, Aiken, SC (2017).

5. Best, D. R., "Dissolution of Glass, Sludge, and Slurry Samples Using Na_2O_2/NaOH/HCl," *Manual L29, ITS-0040, Revision 2,* Savannah River National Laboratory, Aiken, SC (2013).

6. Best, D. R., "Lithium Metaborate Fusion Preparation," *Manual L29, ITS-0071, Revision 3,* Savannah River National Laboratory, Aiken, SC (2015).

7. "Sample Dissolution Using Potassium Hydroxide Fusion," *Manual L29, ITS-0035, Revision 3,* Savannah River National Laboratory, Aiken, SC (2015).

8. Best, D. R., "Inductively Coupled Plasma-Atomic Emission Spectrometer, Agilent 730 ES," *Manual L29, Procedure ITS-0079, Revision 5,* Savannah River National Laboratory, Aiken, SC (2014).

9. Best, D. R., "Anion Analysis Using the Dionex DX-500 and ICS-5000 Ion Chromatograph," *Manual L29, Procedure ITS-0027, Revision 3,* Savannah River National Laboratory, Aiken, SC (2011).

10. Ebert, W. L. and S. F. Wolfe, "Round-robin Testing of a Reference Glass for Low-Activity Waste Forms," *U.S. Department of Energy Report ANL-99/22,* Argonne National Laboratory, Argonne, IL (1999).

11. Jin, T., "Test Instruction for Sulfate Solubility for LAW Phase 1 Matrix Glasses," *U.S. Department of Energy Report EWG-TI-0026,* Pacific Northwest National Laboratory, Richland, WA (2016).

12. **JMP™ Pro, Ver. 11.2.1,** [Computer Software] SAS Institute Inc., Cary, NC (2014).

Appendix A Tables and Exhibits Supporting the Chemical Analysis of the LAWB99 Glasses

Table A-1. Measurements of the LAWB99 Glasses by Preparation Method

Prep Method	ID	Block	Sequence	Lab ID	Al (wt %)	B (wt %)	Ca (wt %)	Cl (wt %) ar	Cr (wt %)	F (wt %) ar	Fe (wt %)	K (wt %)	Li (wt %)	Mg (wt %)
LM	LRM	1	1	LRMLM11			0.305		0.137			1.19		<0.100
LM	LAWB99-SSM-SC	1	2	D1LM1			7.05		<0.100			0.320		0.667
LM	LAWB99-SSM-SA	1	3	D2LM1			7.21		<0.100			0.319		0.664
LM	LAWB99-SSM-SB	1	4	D3LM1			7.06		<0.100			0.320		0.665
LM	LRM	1	5	LRMLM12			0.305		0.135			1.24		<0.100
LM	LRM	2	1	LRMLM21			0.285		0.137			1.18		<0.100
LM	LAWB99-SSM-SA	2	2	D2LM2			7.28		<0.100			0.314		0.644
LM	LAWB99-SSM-SB	2	3	D3LM2			7.19		<0.100			0.309		0.640
LM	LAWB99-SSM-SC	2	4	D1LM2			7.10		<0.100			0.315		0.644
LM	LRM	2	5	LRMLM22			0.278		0.137			1.19		<0.100
PF	LRM	1	1	LRMPF11	4.89	2.39					0.942		0.113	
PF	LAWB99-SSM-SA	1	2	D2PF1	4.80	3.16					0.734		1.39	
PF	LAWB99-SSM-SC	1	3	D1PF1	4.81	3.19					0.725		1.39	
PF	LAWB99-SSM-SB	1	4	D3PF1	4.71	3.05					0.713		1.36	
PF	LRM	1	5	LRMPF12	4.84	2.33					0.927		0.114	
PF	LRM	2	1	LRMPF21	4.96	2.38					1.01		0.169	
PF	LAWB99-SSM-SB	2	2	D3PF2	5.04	3.19					0.816		1.45	
PF	LAWB99-SSM-SA	2	3	D2PF2	5.12	3.26					0.826		1.48	
PF	LAWB99-SSM-SC	2	4	D1PF2	5.16	3.24					0.834		1.49	
PF	LRM	2	5	LRMPF22	5.11	2.41					1.02		0.169	
KH	LRM	1	1	LRMKH11				<0.050		0.878				
KH	LAWB99-SSM-SB	1	2	D3KH1				<0.050		<0.050				
KH	LAWB99-SSM-SC	1	3	D1KH1				<0.050		<0.050				
KH	LAWB99-SSM-SA	1	4	D2KH1				<0.050		<0.050				
KH	LRM	1	5	LRMKH12				<0.050		0.881				
KH	LRM	2	1	LRMKH21				<0.050		0.886				
KH	LAWB99-SSM-SA	2	2	D2KH2				<0.050		<0.050				
KH	LAWB99-SSM-SB	2	3	D3KH2				<0.050		<0.050				
KH	LAWB99-SSM-SC	2	4	D1KH2				<0.050		<0.050				
KH	LRM	2	5	LRMKH22				<0.050		0.876				

ar – as received

Table A-1. Measurements of the LAWB99 Glasses by Preparation Method (continued)

Prep Method	ID	Block	Sequence	Lab ID	Na (wt%)	P (wt%)	S (wt%)	Si (wt%)	V (wt%)	Zn (wt%)	Zr (wt%)
LM	LRM	1	1	LRMLM11	14.5	0.200	0.087		<0.100	<0.100	0.658
LM	LAWB99-SSM-SC	1	2	D1LM1	8.01	<0.100	0.732		0.695	2.80	2.38
LM	LAWB99-SSM-SA	1	3	D2LM1	7.90	<0.100	0.793		0.690	2.87	2.46
LM	LAWB99-SSM-SB	1	4	D3LM1	7.97	<0.100	0.757		0.677	2.80	2.38
LM	LRM	1	5	LRMLM12	14.4	0.196	0.087		<0.100	<0.100	0.659
LM	LRM	2	1	LRMLM21	14.8	0.202	0.088		<0.100	<0.100	0.645
LM	LAWB99-SSM-SA	2	2	D2LM2	8.27	<0.100	0.787		0.680	2.81	2.40
LM	LAWB99-SSM-SB	2	3	D3LM2	8.36	<0.100	0.721		0.678	2.80	2.38
LM	LAWB99-SSM-SC	2	4	D1LM2	8.34	<0.100	0.689		0.679	2.79	2.41
LM	LRM	2	5	LRMLM22	15.1	0.200	0.096		<0.100	<0.100	0.655
PF	LRM	1	1	LRMPF11				25.9			
PF	LAWB99-SSM-SA	1	2	D2PF1				19.9			
PF	LAWB99-SSM-SC	1	3	D1PF1				19.6			
PF	LAWB99-SSM-SB	1	4	D3PF1				19.3			
PF	LRM	1	5	LRMPF12				25.9			
PF	LRM	2	1	LRMPF21				26.9			
PF	LAWB99-SSM-SB	2	2	D3PF2				20.5			
PF	LAWB99-SSM-SA	2	3	D2PF2				20.7			
PF	LAWB99-SSM-SC	2	4	D1PF2				20.5			
PF	LRM	2	5	LRMPF22				27.1			
KH	LRM	1	1	LRMKH11							
KH	LAWB99-SSM-SB	1	2	D3KH1							
KH	LAWB99-SSM-SC	1	3	D1KH1							
KH	LAWB99-SSM-SA	1	4	D2KH1							
KH	LRM	1	5	LRMKH12							
KH	LRM	2	1	LRMKH21							
KH	LAWB99-SSM-SA	2	2	D2KH2							
KH	LAWB99-SSM-SB	2	3	D3KH2							
KH	LAWB99-SSM-SC	2	4	D1KH2							
KH	LRM	2	5	LRMKH22							

ar – as received

Table A-2. Comparison of Measured and Targeted Compositions for the LAWB99 Glasses

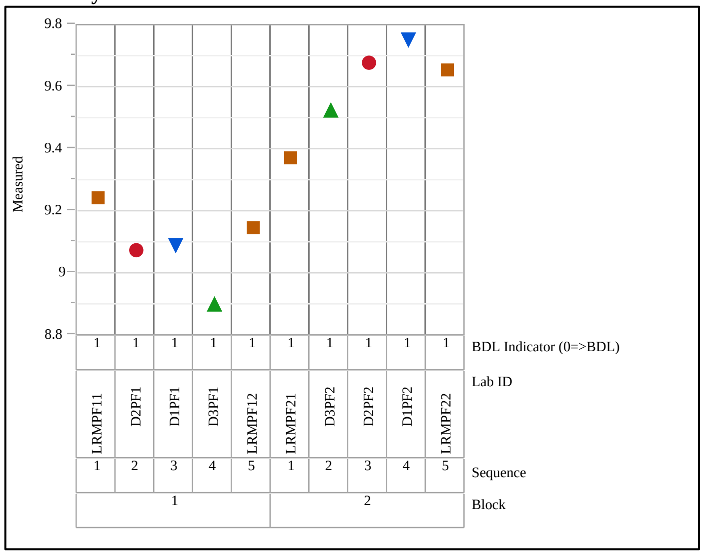
Glass ID	Oxide	BDL (<)	Measured (wt %)	Targeted (wt %)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
LAWB99-SSM-SA	Al_2O_3		9.372	10.150	-0.778	-7.7%
LAWB99-SSM-SA	B_2O_3		10.336	11.010	-0.674	-6.1%
LAWB99-SSM-SA	CaO		10.137	10.210	-0.073	-0.7%
LAWB99-SSM-SA	Cl	<	0.050	0.010	0.040	
LAWB99-SSM-SA	Cr_2O_3	<	0.146	0.110	0.036	
LAWB99-SSM-SA	F	<	0.050	0.070	-0.020	
LAWB99-SSM-SA	Fe_2O_3		1.115	1.150	-0.035	
LAWB99-SSM-SA	K_2O		0.381	0.410	-0.029	
LAWB99-SSM-SA	Li_2O		3.089	3.540	-0.451	
LAWB99-SSM-SA	MgO		1.085	1.150	-0.065	
LAWB99-SSM-SA	MnO_2	<	0.158	0.000	0.158	
LAWB99-SSM-SA	Na_2O		10.899	10.000	0.899	9.0%
LAWB99-SSM-SA	NiO	<	0.064	0.000	0.064	
LAWB99-SSM-SA	P_2O_5	<	0.229	0.030	0.199	
LAWB99-SSM-SA	PbO	<	0.054	0.000	0.054	
LAWB99-SSM-SA	SiO_2		43.428	43.080	0.348	0.8%
LAWB99-SSM-SA	SO_3		1.973	0.750	1.223	
LAWB99-SSM-SA	V_2O_5		1.223	1.240	-0.017	
LAWB99-SSM-SA	ZnO		3.535	3.540	-0.005	
LAWB99-SSM-SA	ZrO_2		3.282	3.540	-0.258	
LAWB99-SSM-SA	Sum		100.733	99.990	0.743	0.7%
LAWB99-SSM-SB	Al_2O_3		9.211	10.150	-0.939	-9.2%
LAWB99-SSM-SB	B_2O_3		10.046	11.010	-0.964	-8.8%
LAWB99-SSM-SB	CaO		9.969	10.210	-0.241	-2.4%
LAWB99-SSM-SB	Cl	<	0.050	0.010	0.040	
LAWB99-SSM-SB	Cr_2O_3	<	0.146	0.110	0.036	
LAWB99-SSM-SB	F	<	0.050	0.070	-0.020	
LAWB99-SSM-SB	Fe_2O_3		1.093	1.150	-0.057	
LAWB99-SSM-SB	K_2O		0.379	0.410	-0.031	
LAWB99-SSM-SB	Li_2O		3.025	3.540	-0.515	
LAWB99-SSM-SB	MgO		1.082	1.150	-0.068	
LAWB99-SSM-SB	MnO_2	<	0.158	0.000	0.158	
LAWB99-SSM-SB	Na_2O		11.006	10.000	1.006	10.1%
LAWB99-SSM-SB	NiO	<	0.064	0.000	0.064	
LAWB99-SSM-SB	P_2O_5	<	0.229	0.030	0.199	
LAWB99-SSM-SB	PbO	<	0.054	0.000	0.054	
LAWB99-SSM-SB	SiO_2		42.572	43.080	-0.508	-1.2%
LAWB99-SSM-SB	SO_3		1.845	0.750	1.095	
LAWB99-SSM-SB	V_2O_5		1.209	1.240	-0.031	
LAWB99-SSM-SB	ZnO		3.485	3.540	-0.055	
LAWB99-SSM-SB	ZrO_2		3.215	3.540	-0.325	
LAWB99-SSM-SB	Sum		99.017	99.990	-0.973	-1.0%
LAWB99-SSM-SC	Al_2O_3		9.419	10.150	-0.731	-7.2%
LAWB99-SSM-SC	B_2O_3		10.352	11.010	-0.658	-6.0%
LAWB99-SSM-SC	CaO		9.899	10.210	-0.311	-3.0%
LAWB99-SSM-SC	Cl	<	0.050	0.010	0.040	
LAWB99-SSM-SC	Cr_2O_3	<	0.146	0.110	0.036	
LAWB99-SSM-SC	F	<	0.050	0.070	-0.020	
LAWB99-SSM-SC	Fe_2O_3		1.114	1.150	-0.036	
LAWB99-SSM-SC	K_2O		0.382	0.410	-0.028	
LAWB99-SSM-SC	Li_2O		3.100	3.540	-0.440	
LAWB99-SSM-SC	MgO		1.087	1.150	-0.063	
LAWB99-SSM-SC	MnO_2	<	0.158	0.000	0.158	
LAWB99-SSM-SC	Na_2O		11.020	10.000	1.020	10.2%
LAWB99-SSM-SC	NiO	<	0.064	0.000	0.064	

Table A-2. Comparison of Measured and Targeted Compositions for the LAWB99 Glasses (continued)

Glass ID	Oxide	BDL (<)	Measured (wt %)	Targeted (wt %)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
LAWB99-SSM-SC	P_2O_5	<	0.229	0.030	0.199	
LAWB99-SSM-SC	PbO	<	0.054	0.000	0.054	
LAWB99-SSM-SC	SiO_2		42.893	43.080	-0.187	-0.4%
LAWB99-SSM-SC	SO_3		1.774	0.750	1.024	
LAWB99-SSM-SC	V_2O_5		1.226	1.240	-0.014	
LAWB99-SSM-SC	ZnO		3.479	3.540	-0.061	
LAWB99-SSM-SC	ZrO_2		3.235	3.540	-0.305	
LAWB99-SSM-SC	Sum		99.860	99.990	-0.130	-0.1%
LRM	Al_2O_3		9.353	9.510	-0.157	-1.7%
LRM	B_2O_3		7.655	7.850	-0.195	-2.5%
LRM	CaO		0.410	0.540	-0.130	
LRM	Cl	<	0.050	0.000	0.050	
LRM	Cr_2O_3		0.200	0.190	0.010	
LRM	F		0.880	0.860	0.020	
LRM	Fe_2O_3		1.394	1.380	0.014	
LRM	K_2O		1.446	1.480	-0.034	
LRM	Li_2O		0.304	0.110	0.194	
LRM	MgO	<	0.166	0.100	0.066	
LRM	MnO_2	<	0.158	0.098	0.060	
LRM	Na_2O		19.816	20.030	-0.214	-1.1%
LRM	NiO		0.191	0.190	0.001	
LRM	P_2O_5		0.457	0.540	-0.083	
LRM	PbO		0.099	0.100	-0.001	
LRM	SiO_2		56.584	54.200	2.384	4.4%
LRM	SO_3		0.223	0.300	-0.077	
LRM	V_2O_5	<	0.179	0.000	0.179	
LRM	ZnO	<	0.124	0.000	0.124	
LRM	ZrO_2		0.884	0.930	-0.046	
LRM	Sum		100.700	98.408	2.292	2.3%

Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence

Variability Gauge Analyte=Al2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=B2O3 (wt%), Prep Method=PF
Variability Chart for Measured

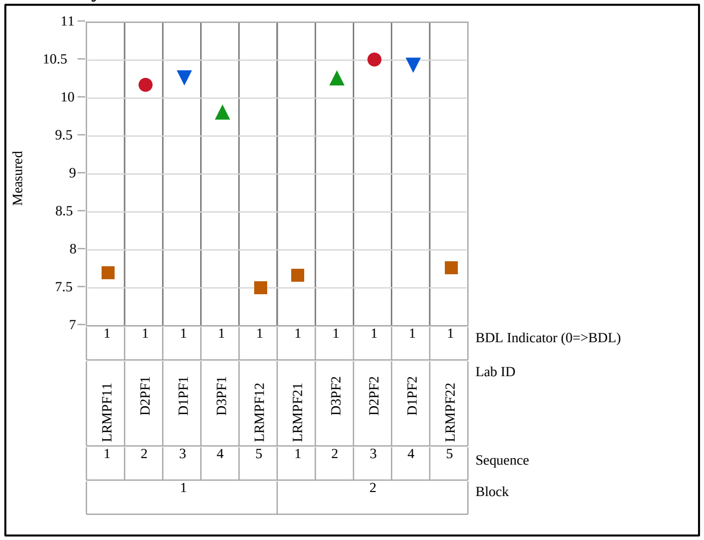
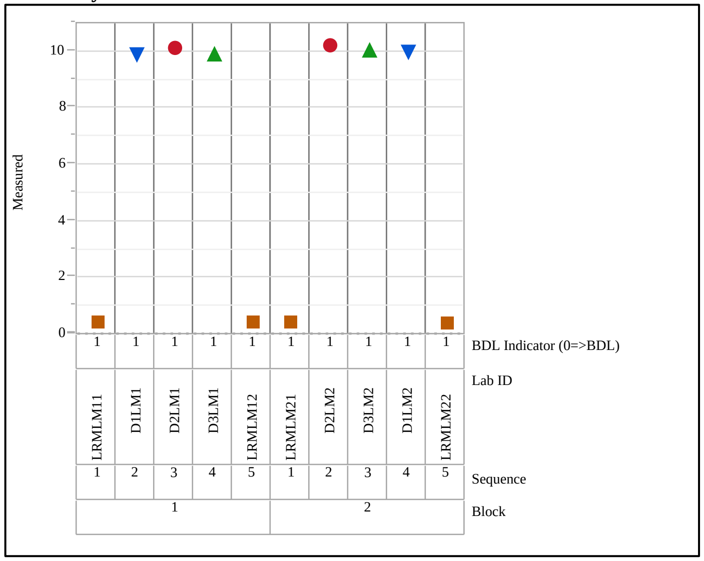


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=CaO (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=Cl (wt%), Prep Method=KH
Variability Chart for Measured

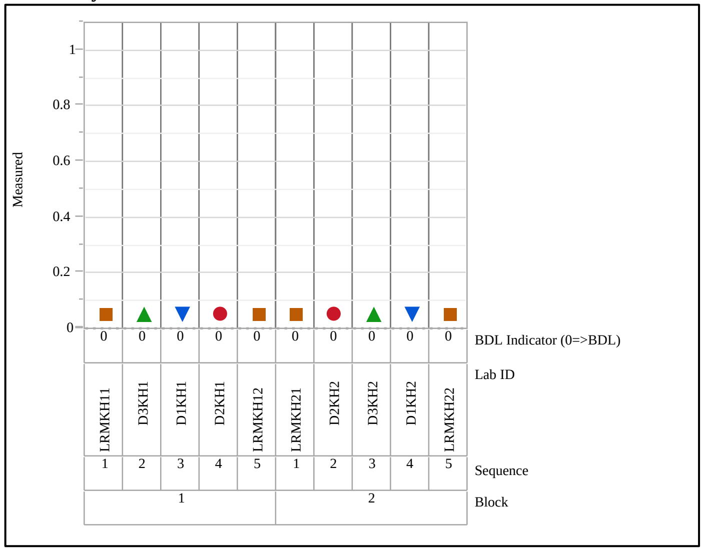
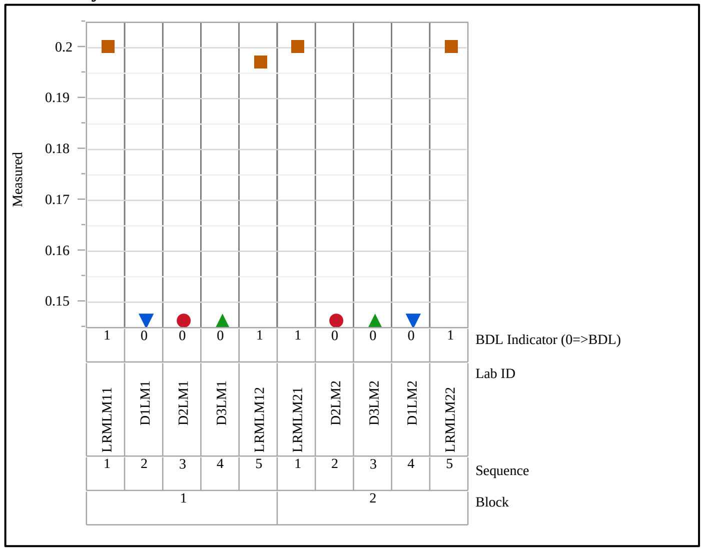


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=Cr2O3 (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=F (wt%), Prep Method=KH
Variability Chart for Measured

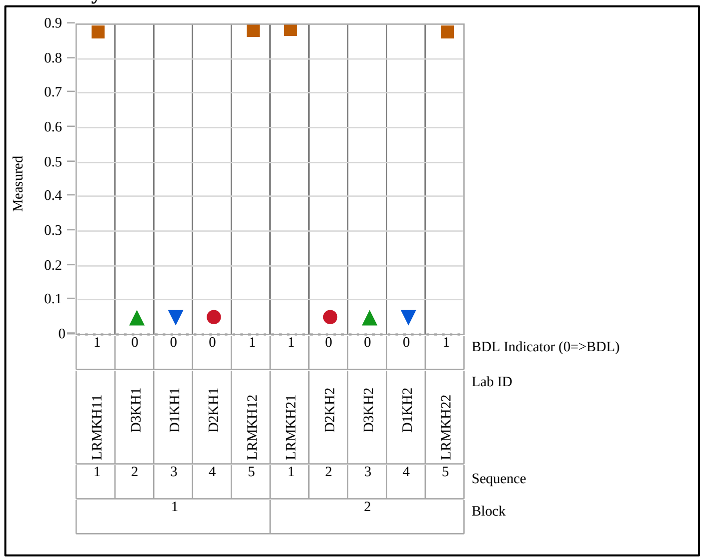
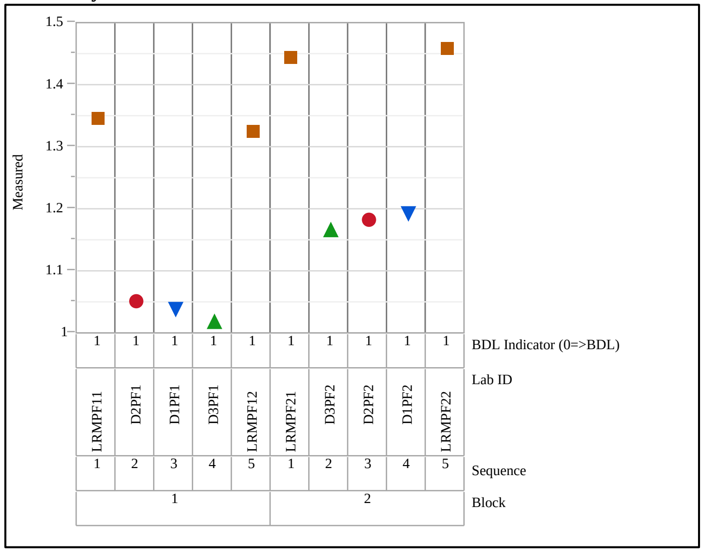


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=Fe2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=K2O (wt%), Prep Method=LM
Variability Chart for Measured

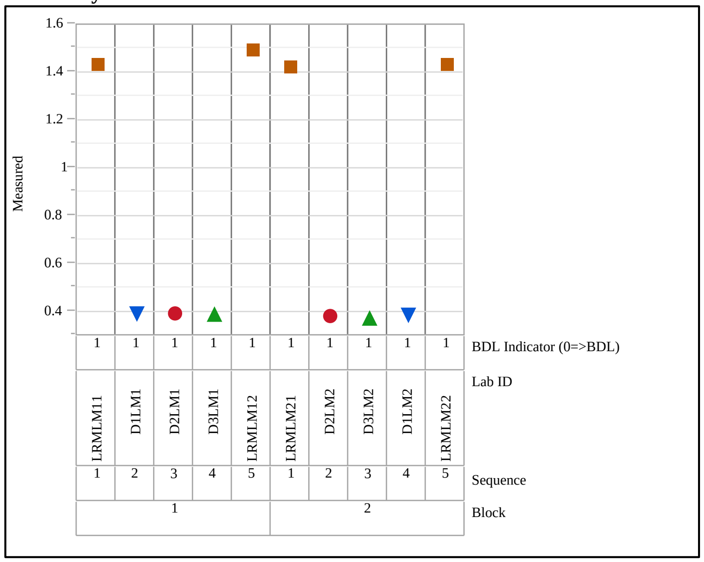
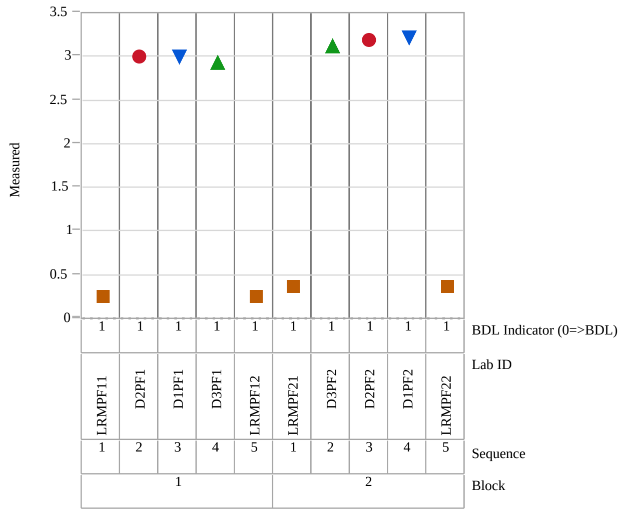


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=Li2O (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=MgO (wt%), Prep Method=LM
Variability Chart for Measured

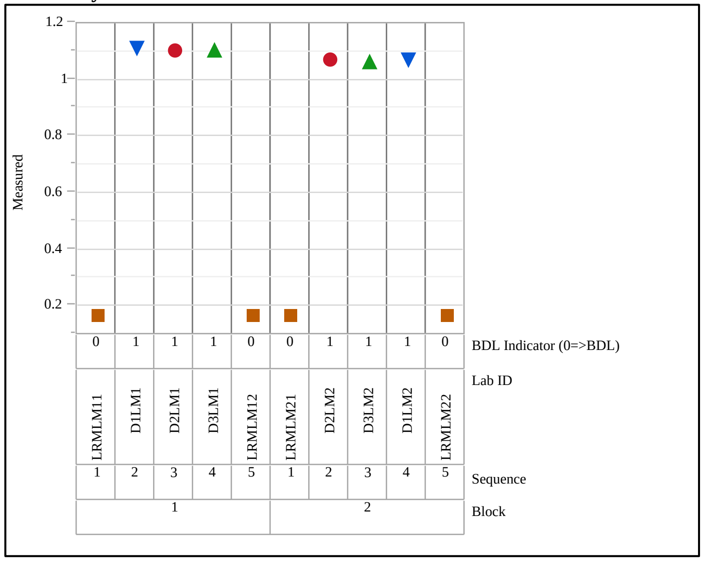
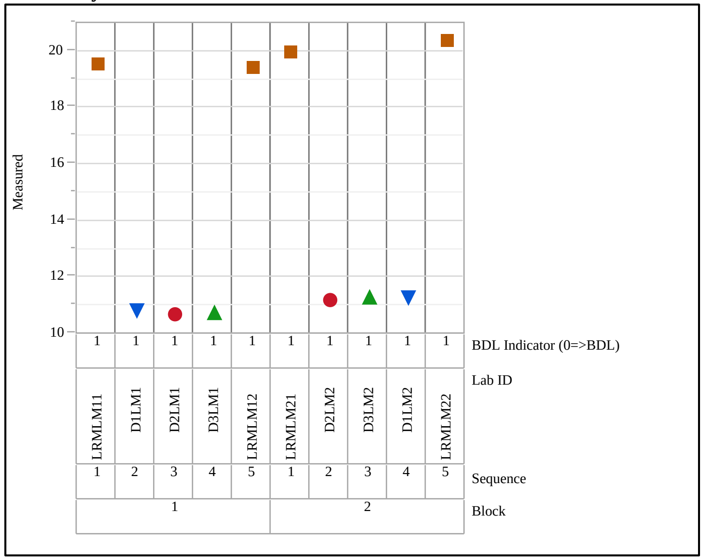


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=Na2O (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=P2O5 (wt%), Prep Method=LM
Variability Chart for Measured

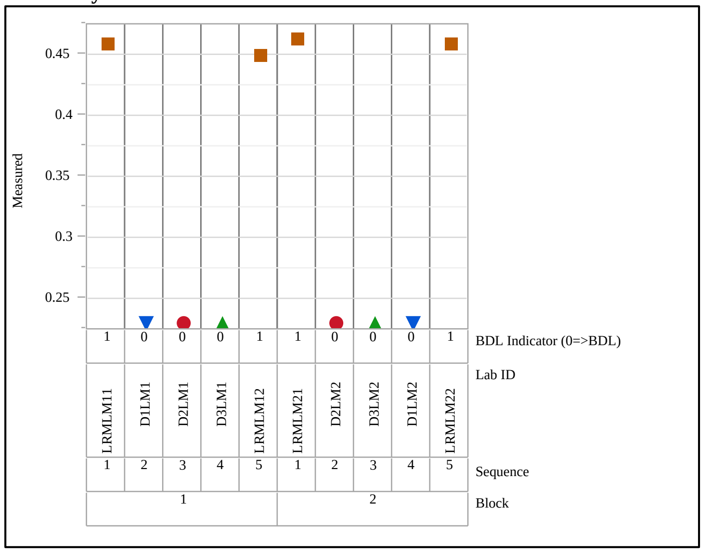
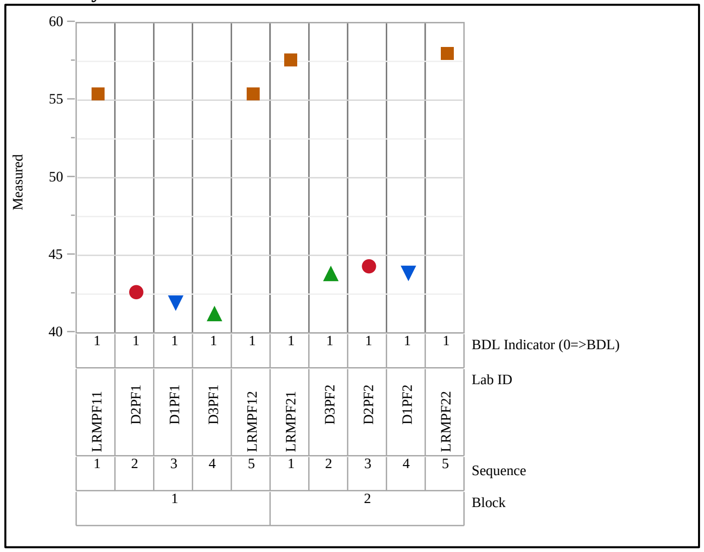


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=SiO2 (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=SO3 (wt%), Prep Method=LM
Variability Chart for Measured

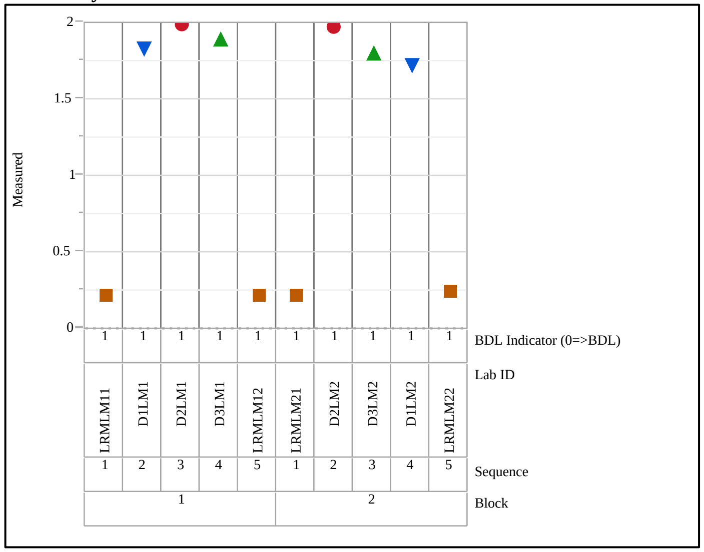
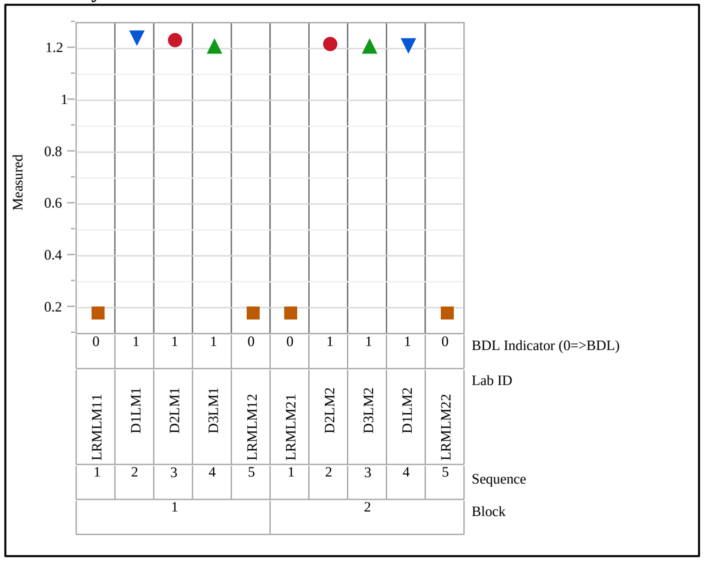


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=V2O5 (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=ZnO (wt%), Prep Method=LM
Variability Chart for Measured

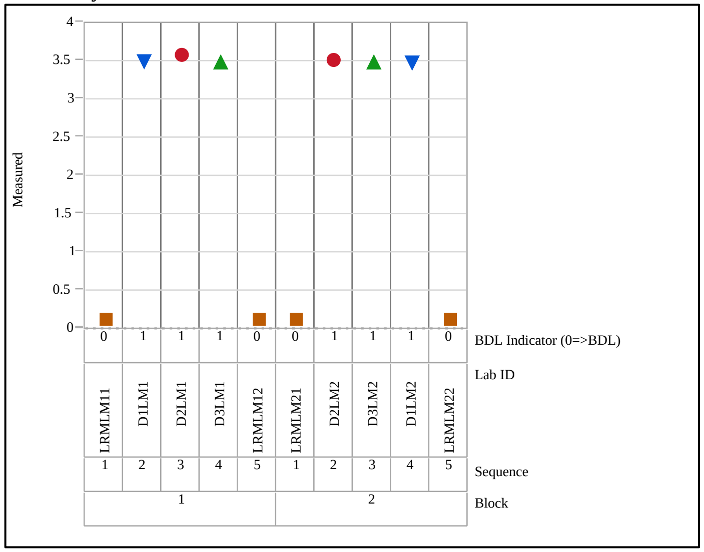


Exhibit A-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Variability Gauge Analyte=ZrO2 (wt%), Prep Method=LM
Variability Chart for Measured

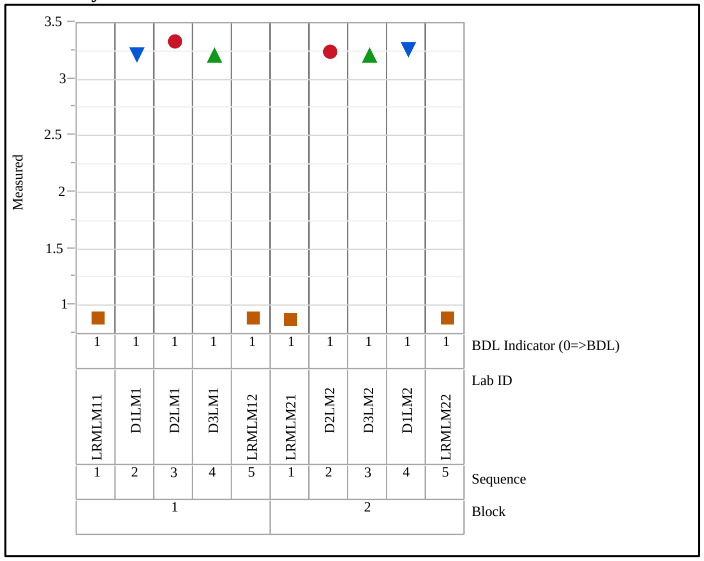
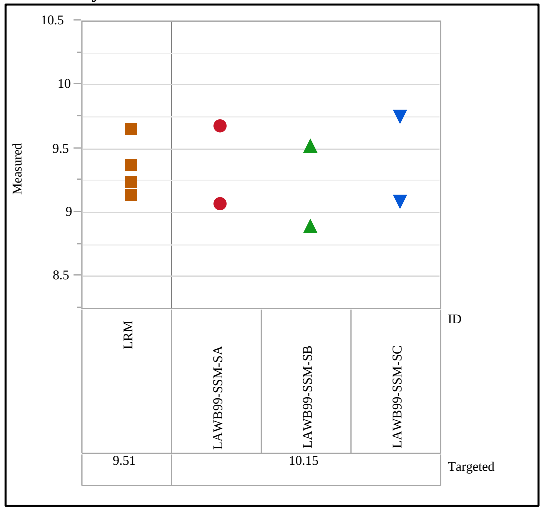
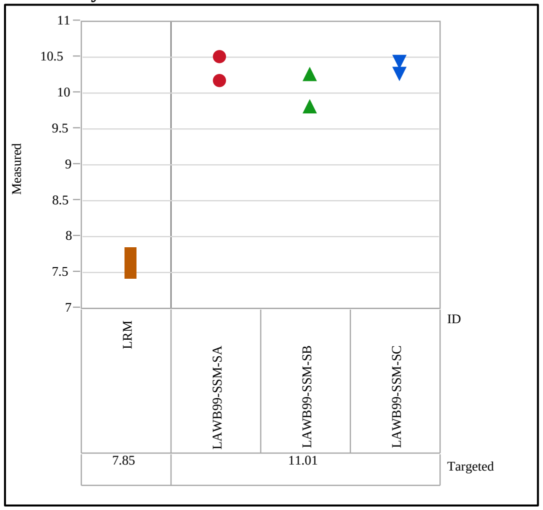


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition

Variability Gauge Analyte=Al2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=B2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=CaO (wt%), Prep Method=LM
Variability Chart for Measured

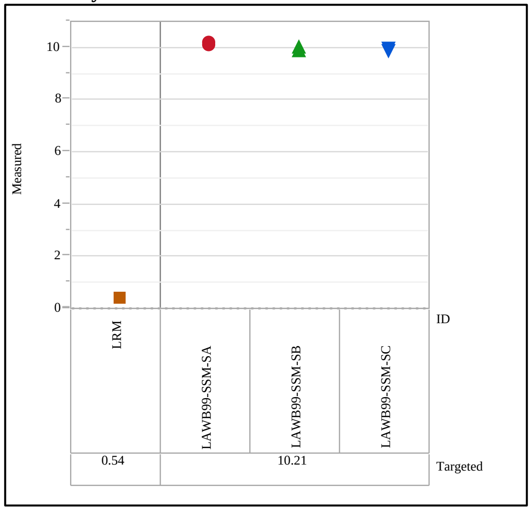
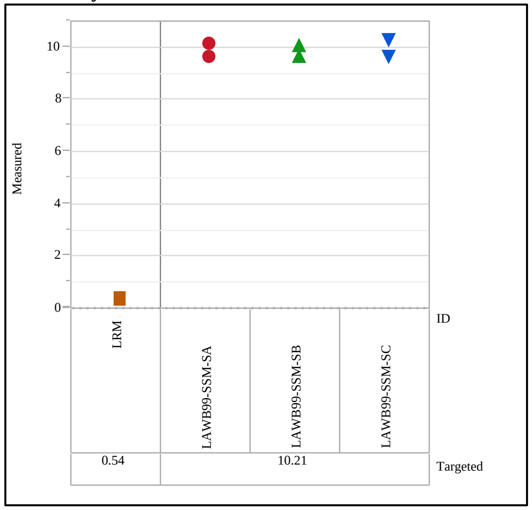
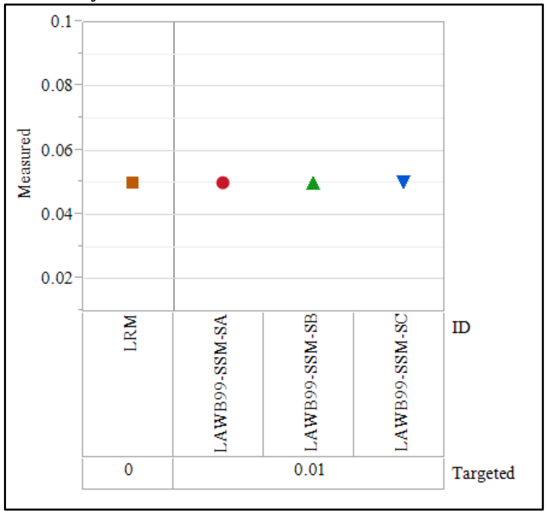


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Variability Gauge Analyte=CaO (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=Cl (wt%), Prep Method=KH
Variability Chart for Measured



Variability Gauge Analyte=Cr2O3 (wt%), Prep Method=LM
Variability Chart for Measured

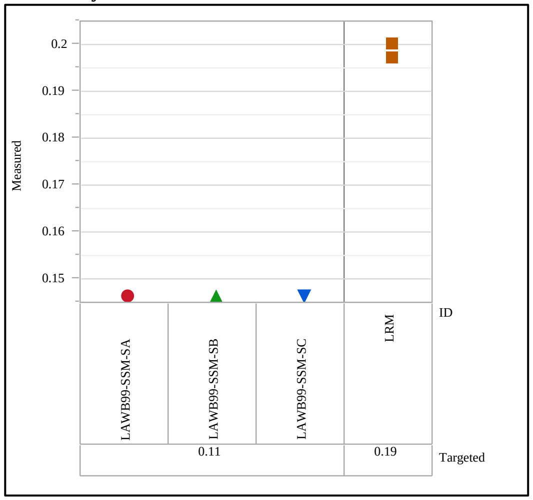
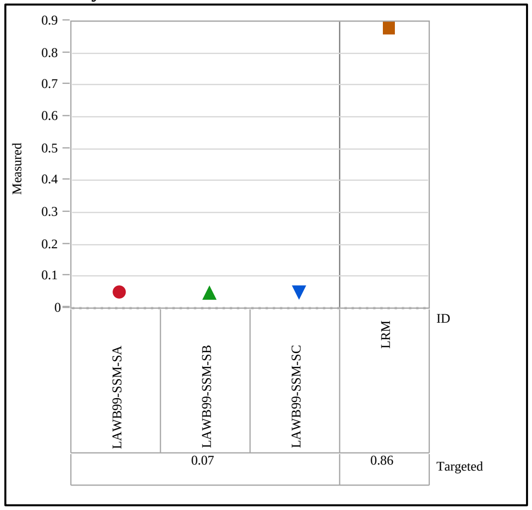
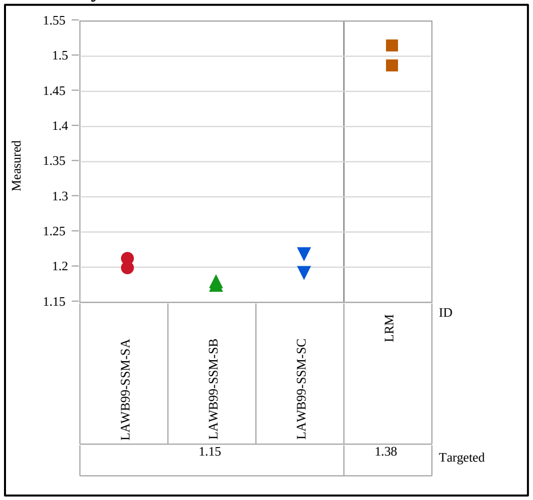


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Variability Gauge Analyte=F (wt%), Prep Method=KH
Variability Chart for Measured



Variability Gauge Analyte=Fe2O3 (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=Fe2O3 (wt%), Prep Method=PF
Variability Chart for Measured

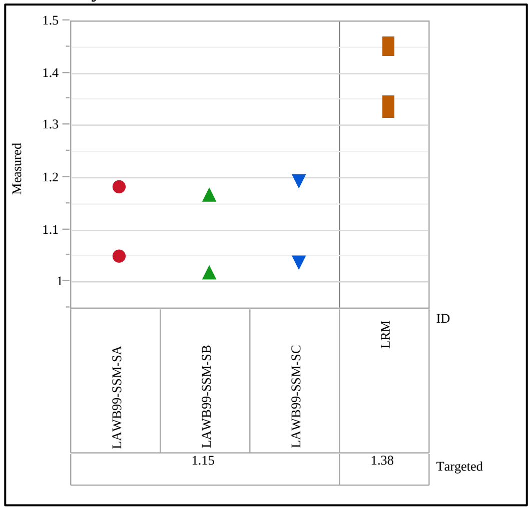
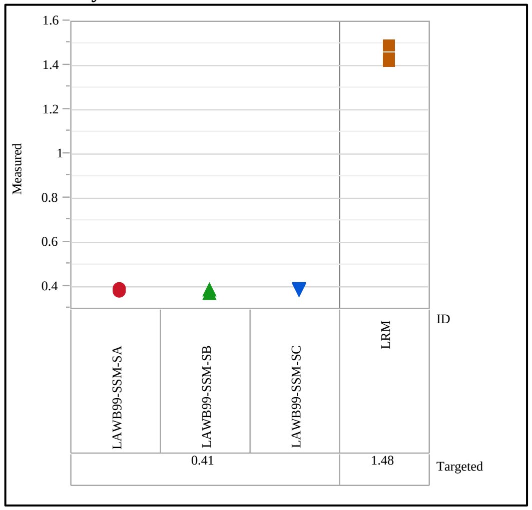
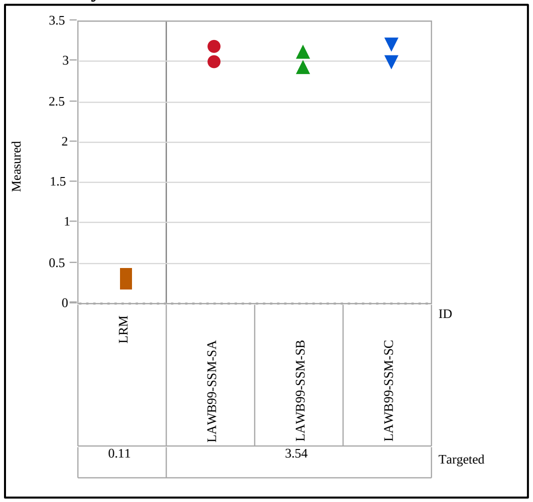


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Variability Gauge Analyte=K2O (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=Li2O (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=MgO (wt%), Prep Method=LM
Variability Chart for Measured

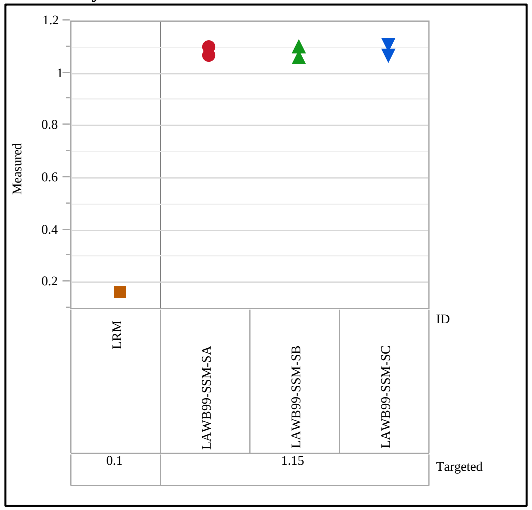
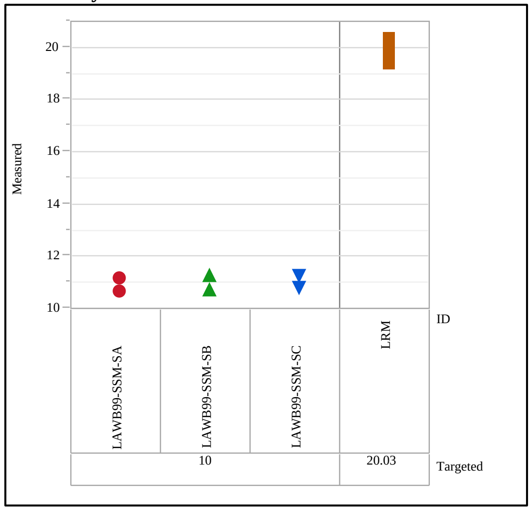
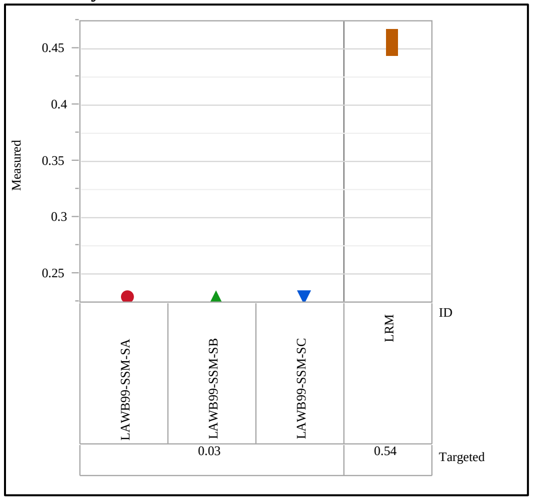


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Variability Gauge Analyte=Na2O (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=P2O5 (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=P2O5 (wt%), Prep Method=PF
Variability Chart for Measured

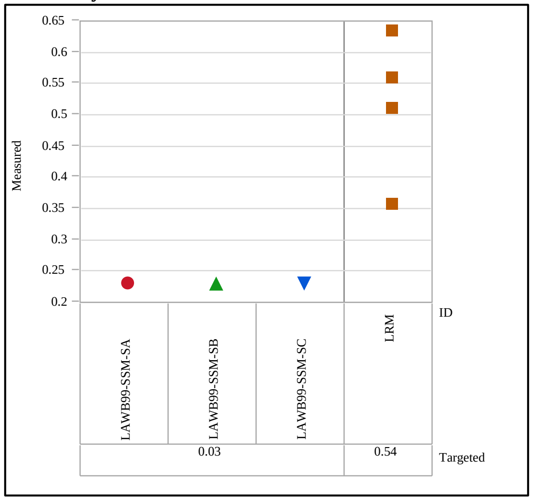
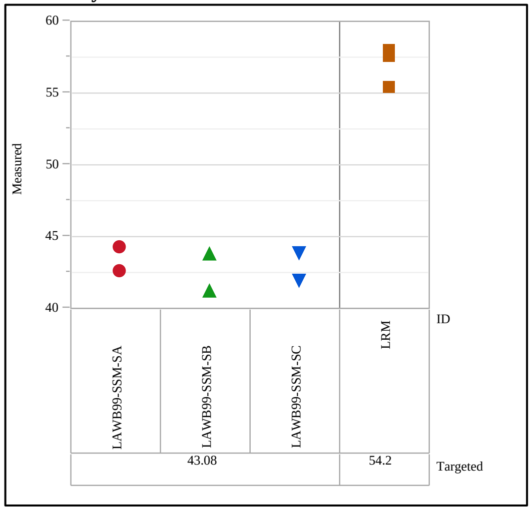
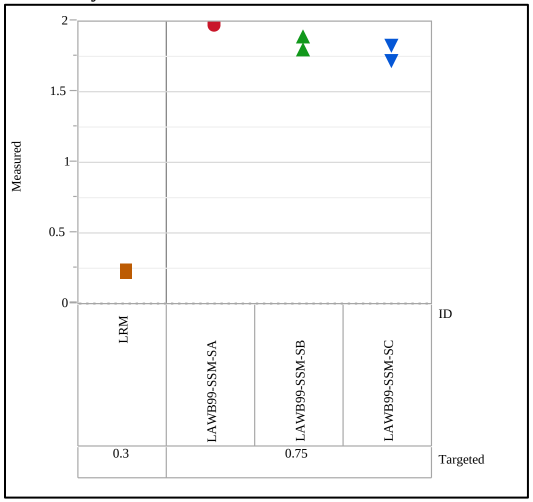


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Variability Gauge Analyte=SiO2 (wt%), Prep Method=PF
Variability Chart for Measured



Variability Gauge Analyte=SO3 (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=V2O5 (wt%), Prep Method=LM
Variability Chart for Measured

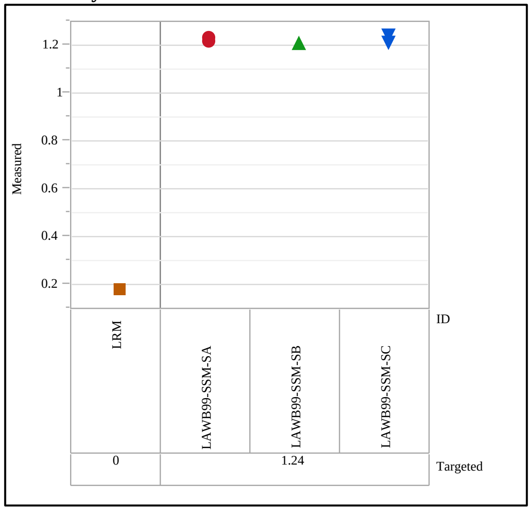
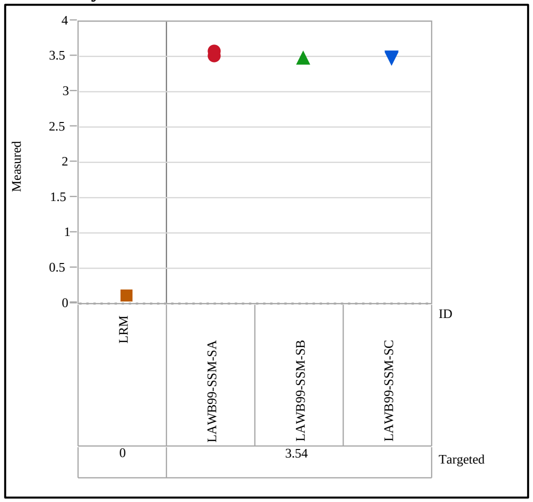


Exhibit A-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Variability Gauge Analyte=ZnO (wt%), Prep Method=LM
Variability Chart for Measured



Variability Gauge Analyte=ZrO2 (wt%), Prep Method=LM
Variability Chart for Measured

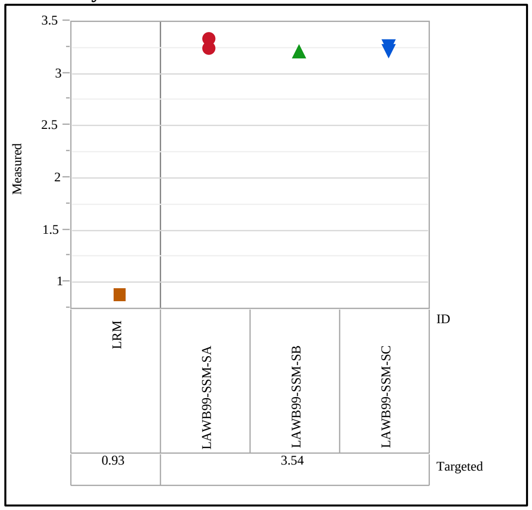
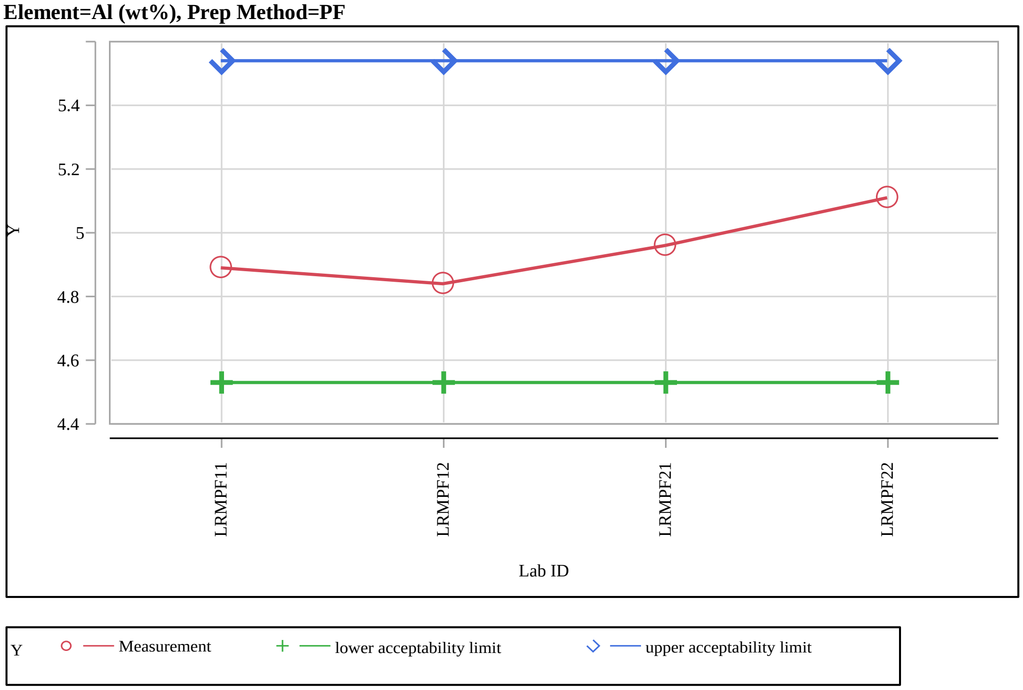


Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass

Element=Al (wt%), Prep Method=PF



Element=B (wt%), Prep Method=PF

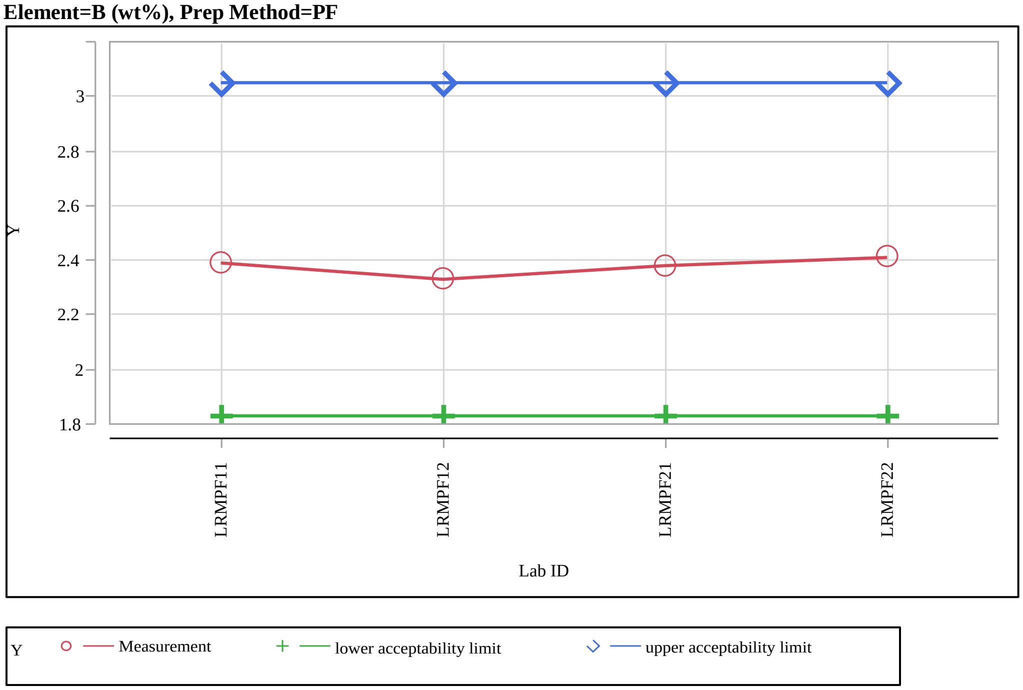
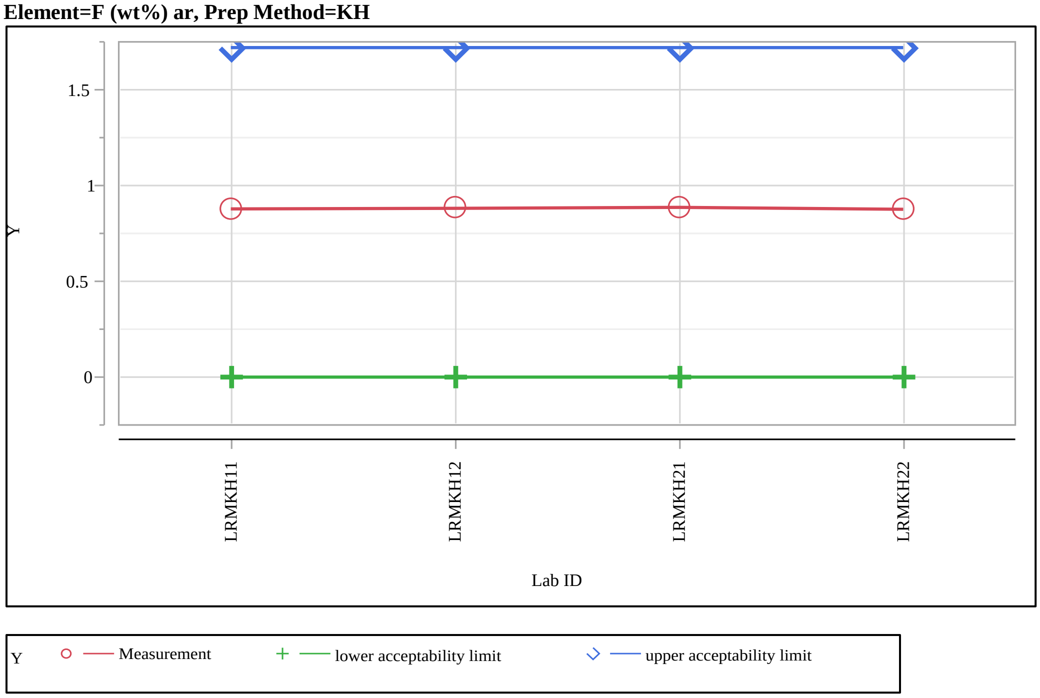


Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)

Element=F (wt%) ar, Prep Method=KH



Element=Fe (wt%), Prep Method=PF

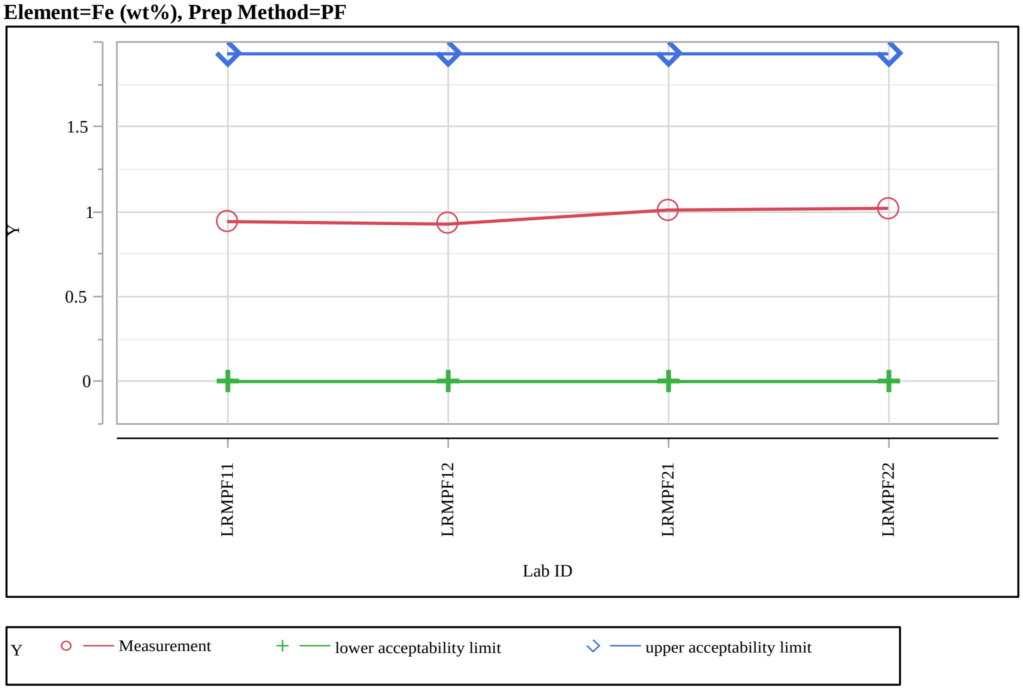
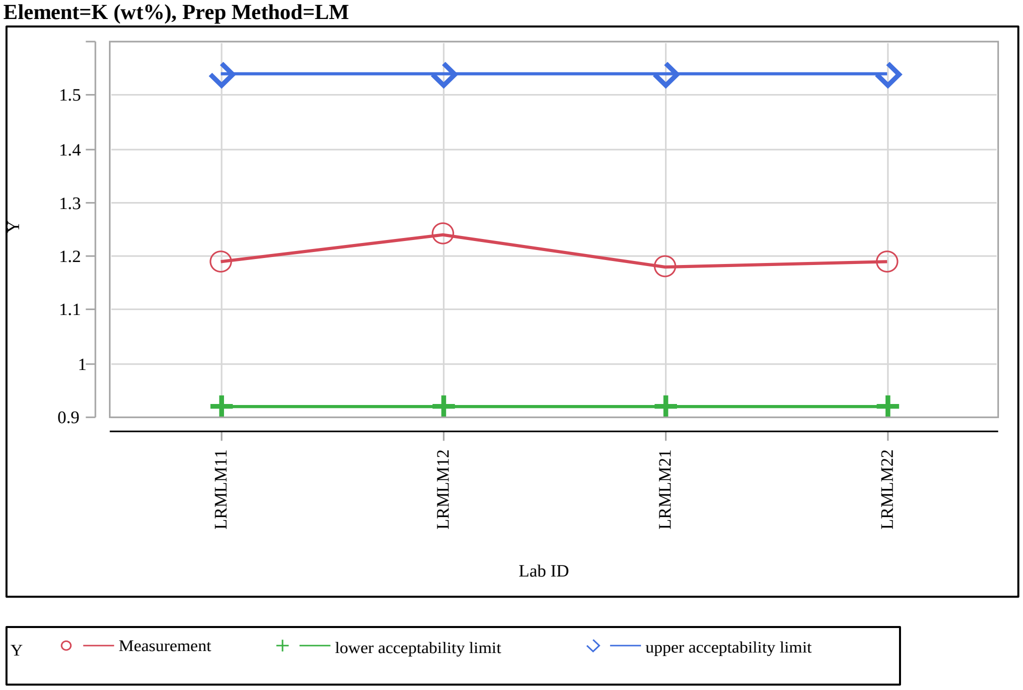


Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)

Element=K (wt%), Prep Method=LM



Element=Na (wt%), Prep Method=LM

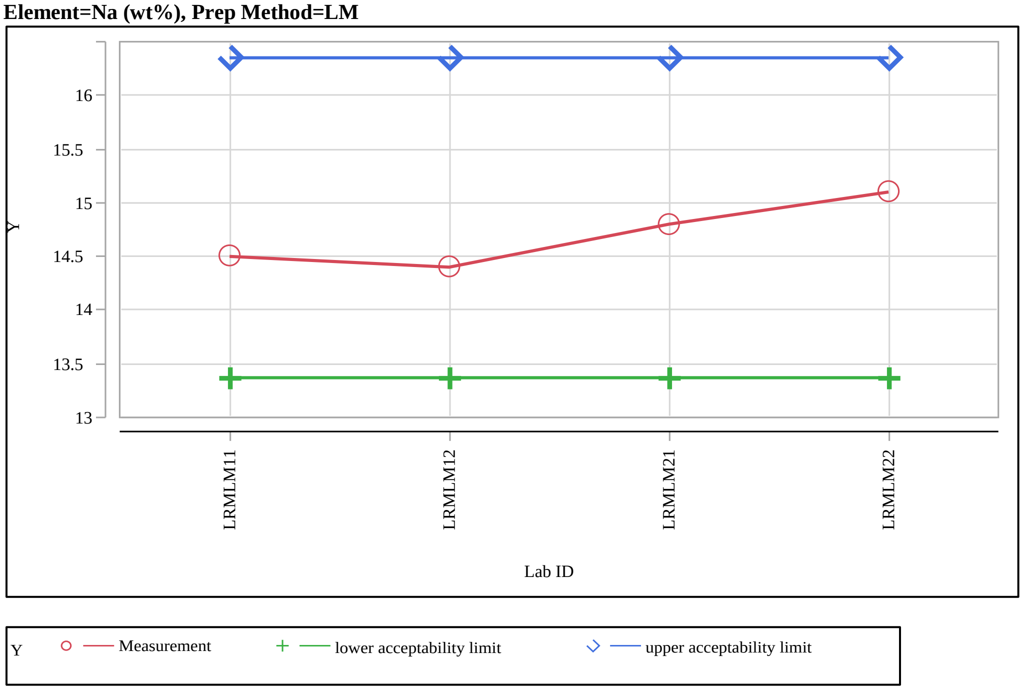
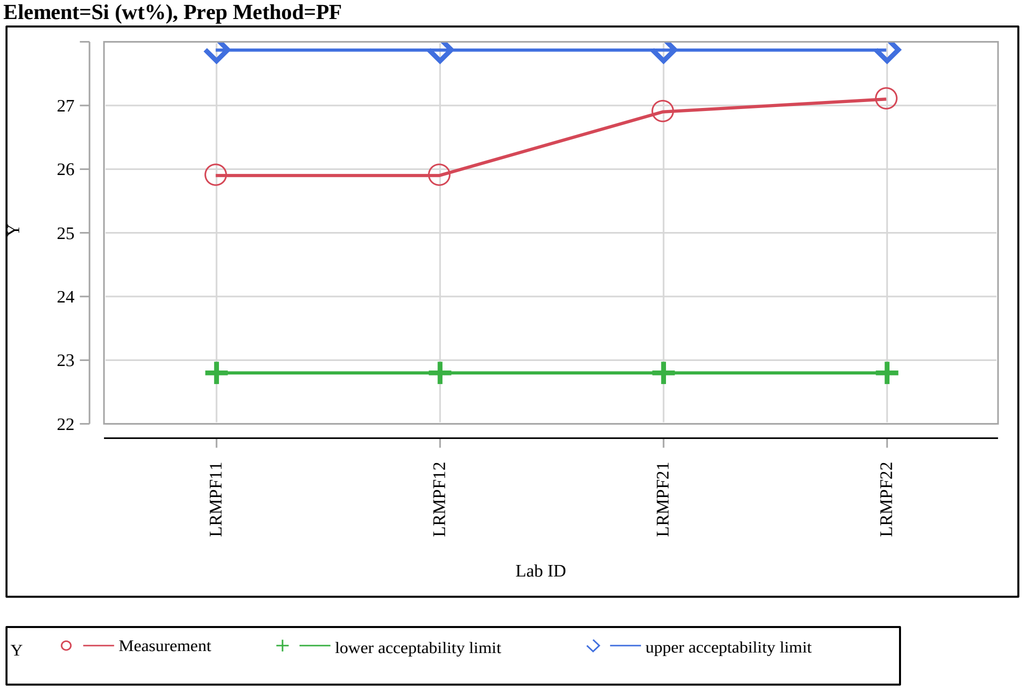


Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)

Element=Si (wt%), Prep Method=PF



Element=Zr (wt%), Prep Method=LM

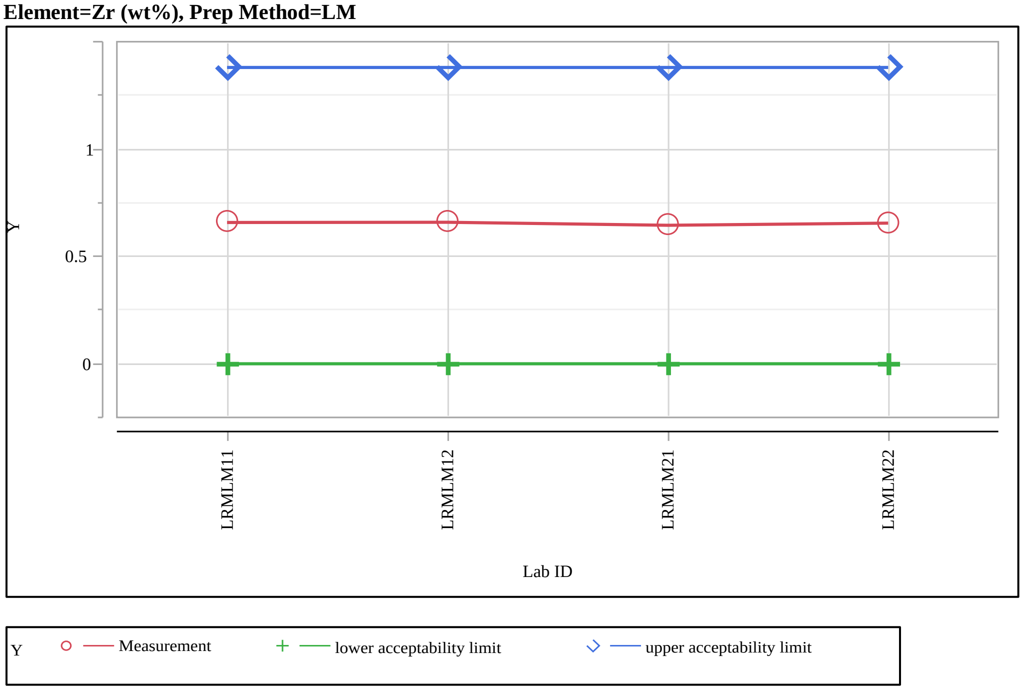
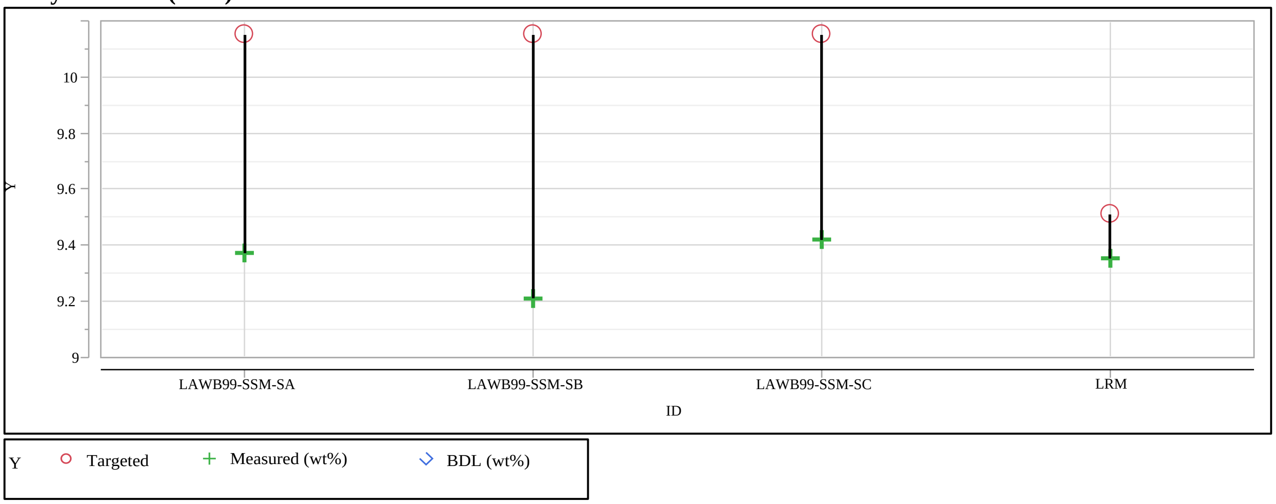
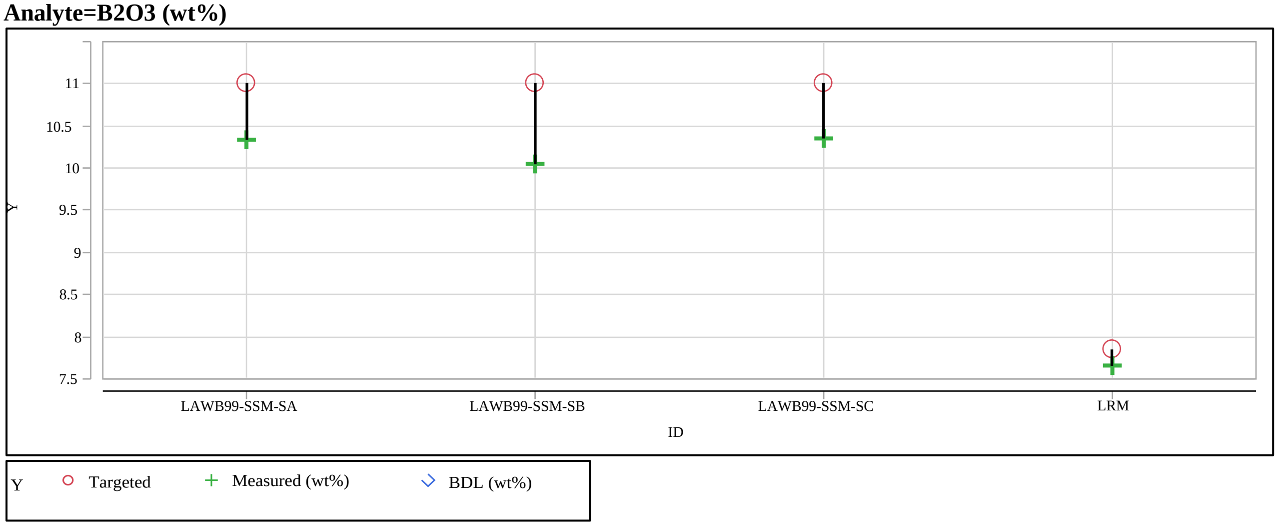


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide

Analyte=Al2O3 (wt%)



Analyte=B2O3 (wt%)



Analyte=CaO (wt%)

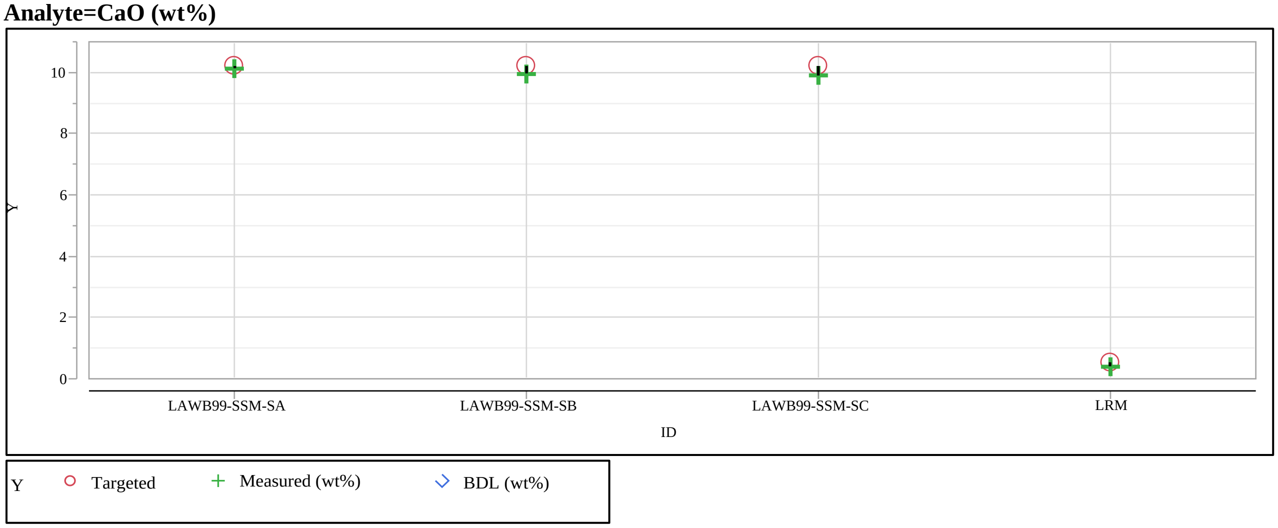
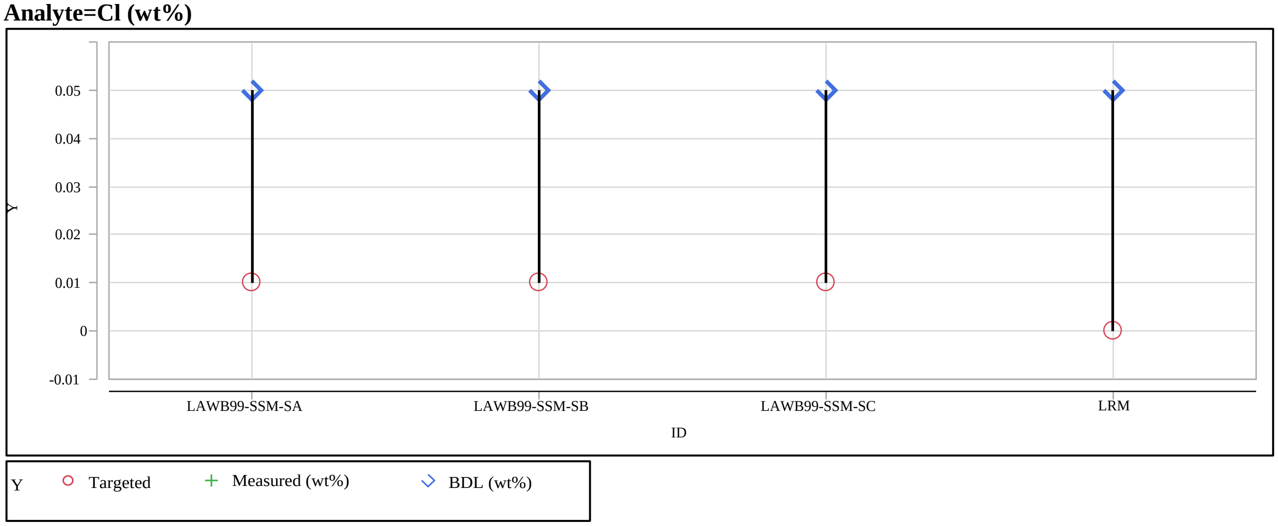
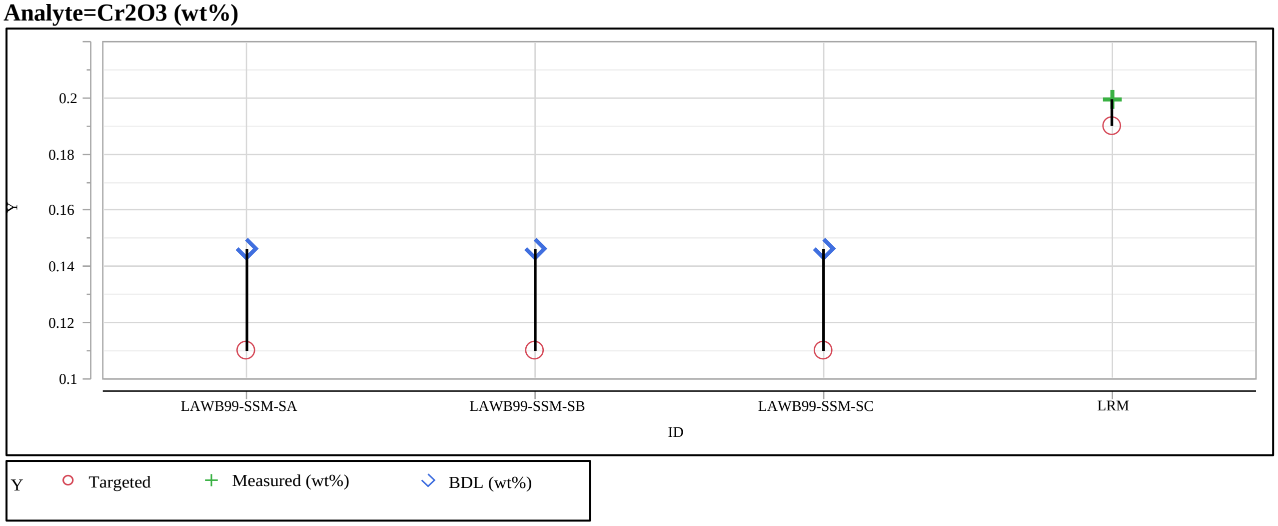


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=Cl (wt%)



Analyte=Cr2O3 (wt%)



Analyte=F (wt%)

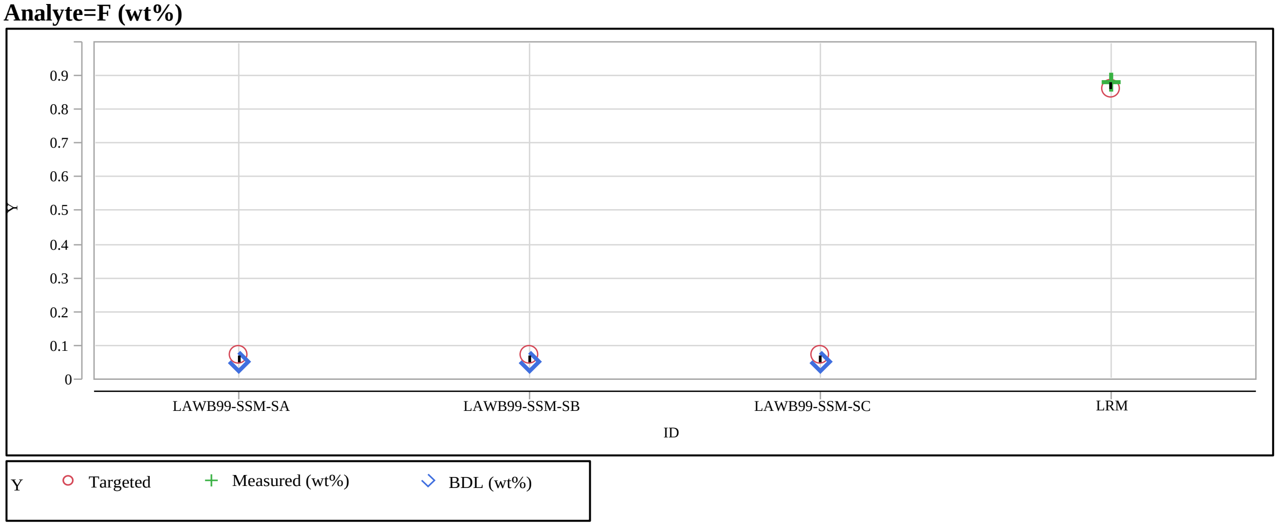
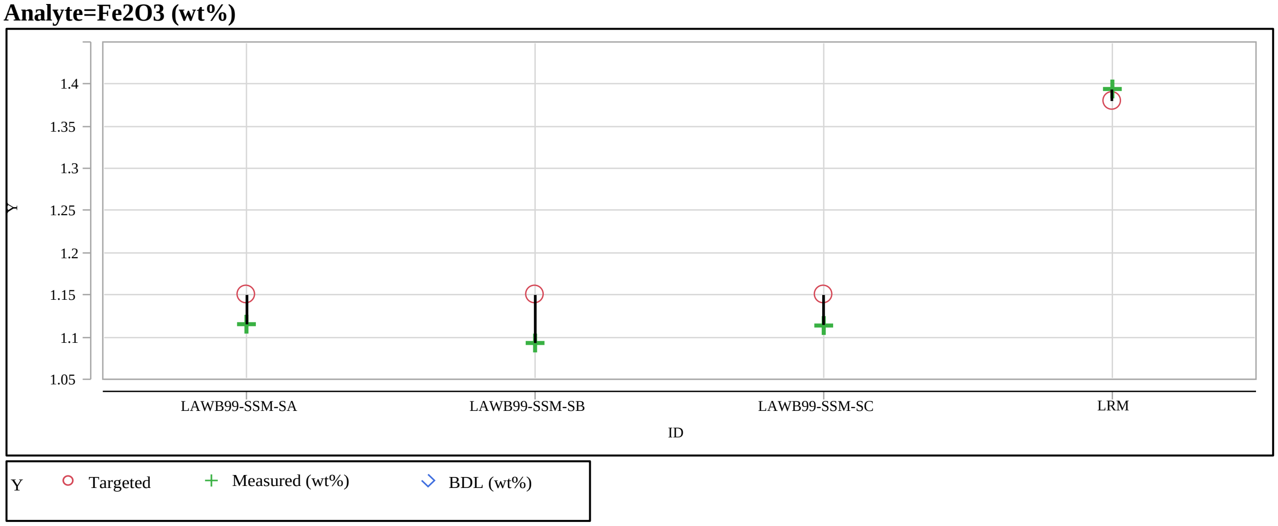
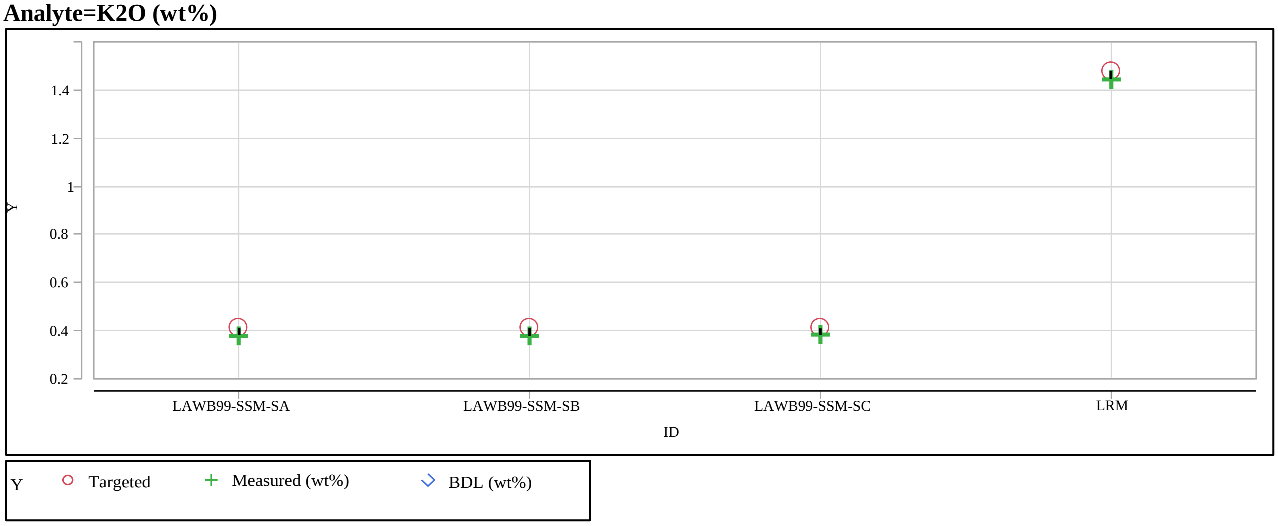


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=Fe2O3 (wt%)



Analyte=K2O (wt%)



Analyte=Li2O (wt%)

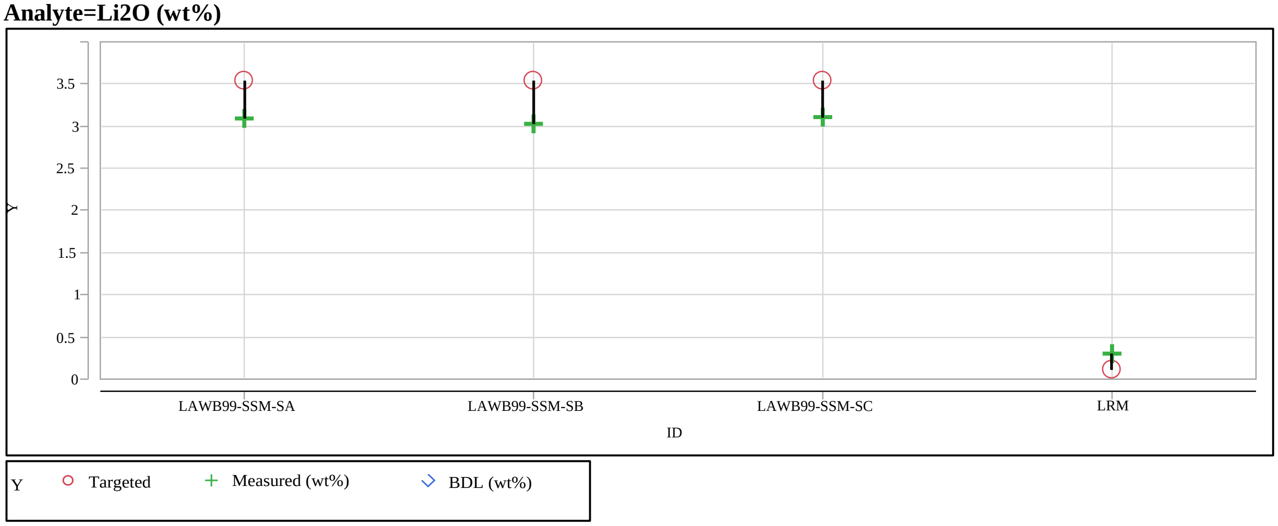
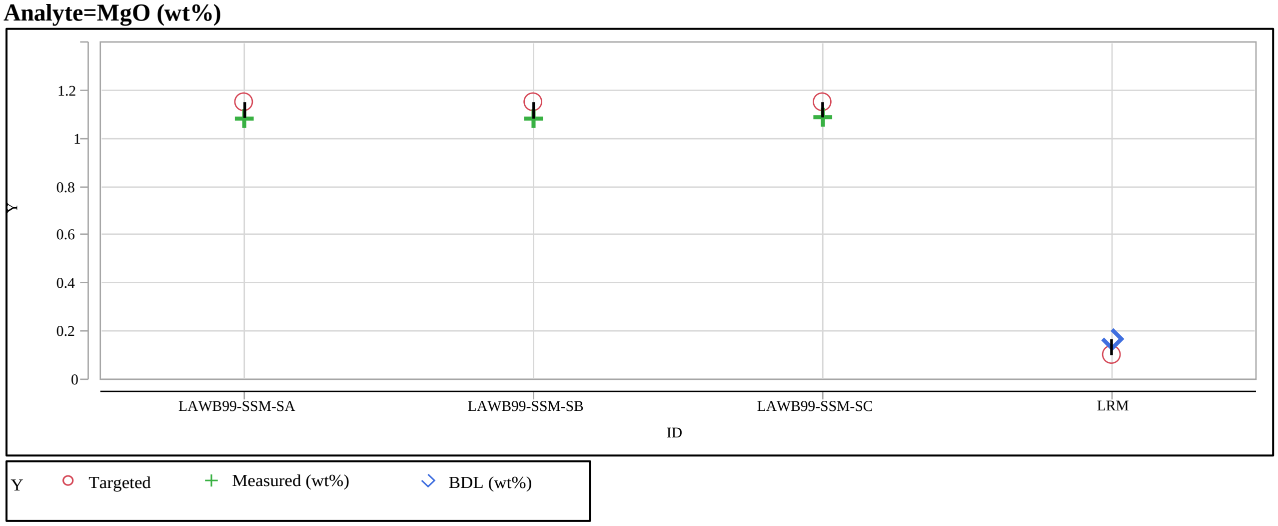
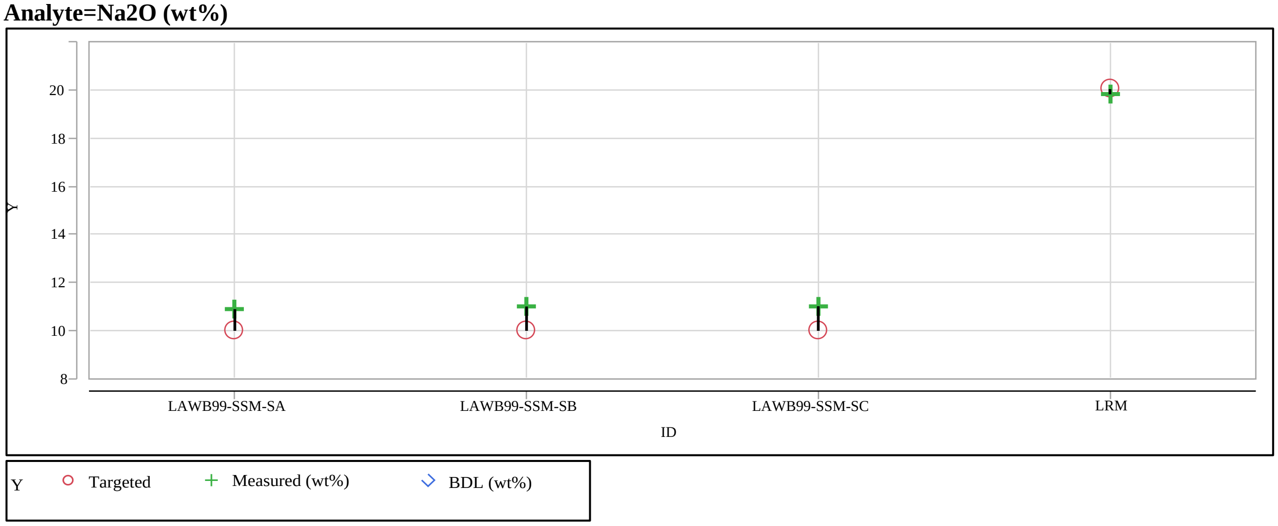


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=MgO (wt%)



Analyte=Na2O (wt%)



Analyte=P2O5 (wt%)

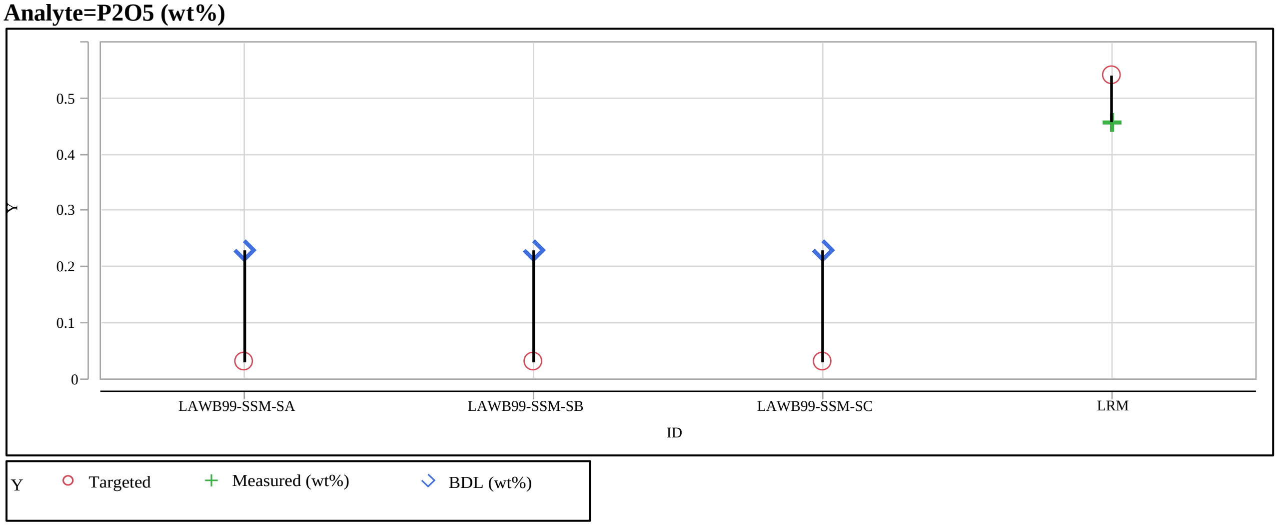
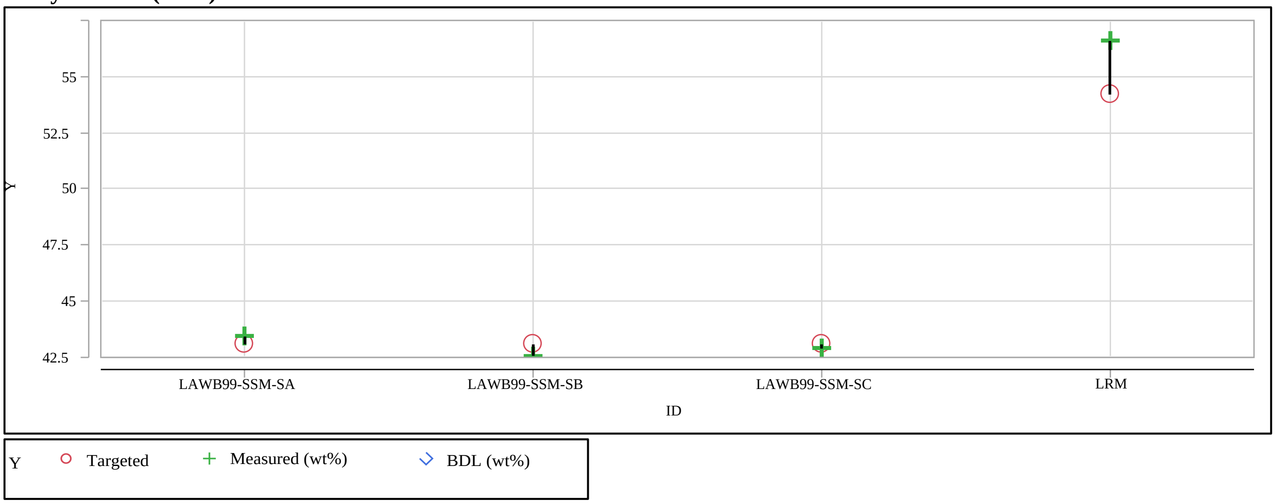
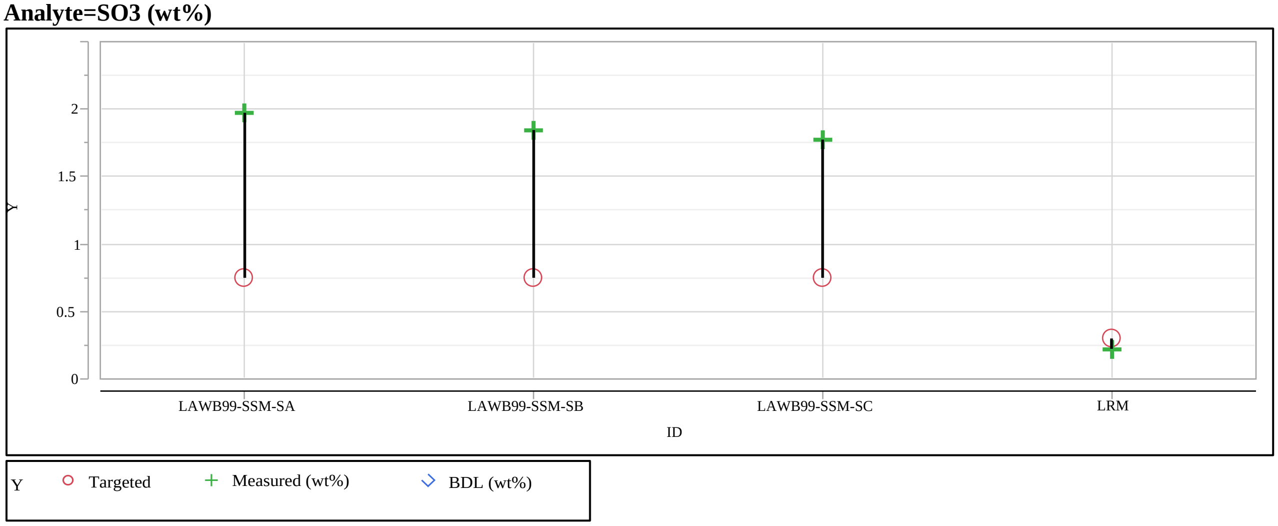


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=SiO2 (wt%)



Analyte=SO3 (wt%)



Analyte=V2O5 (wt%)

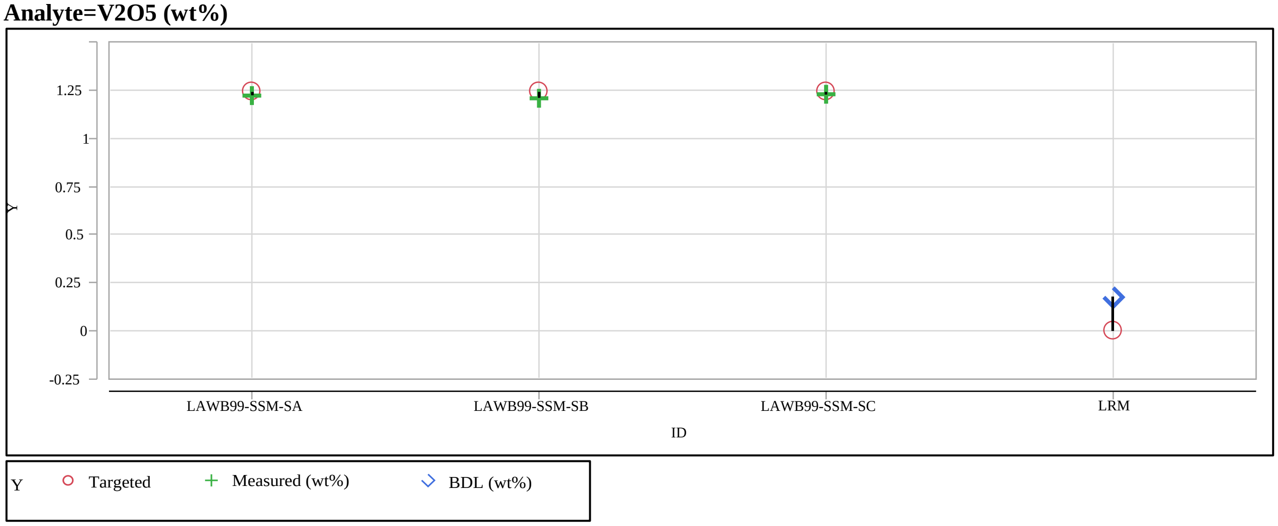
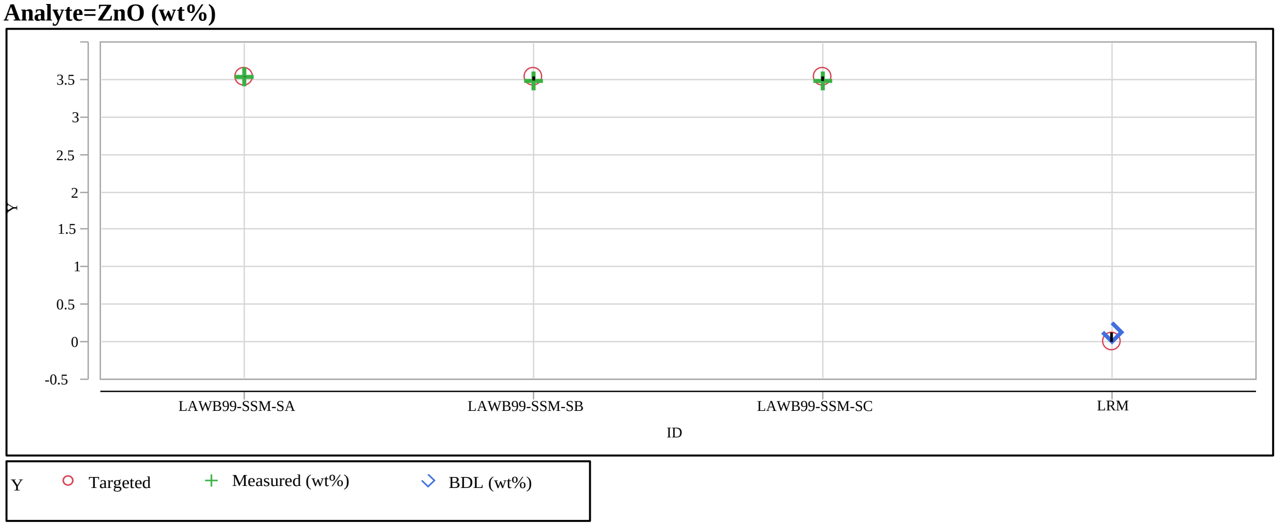
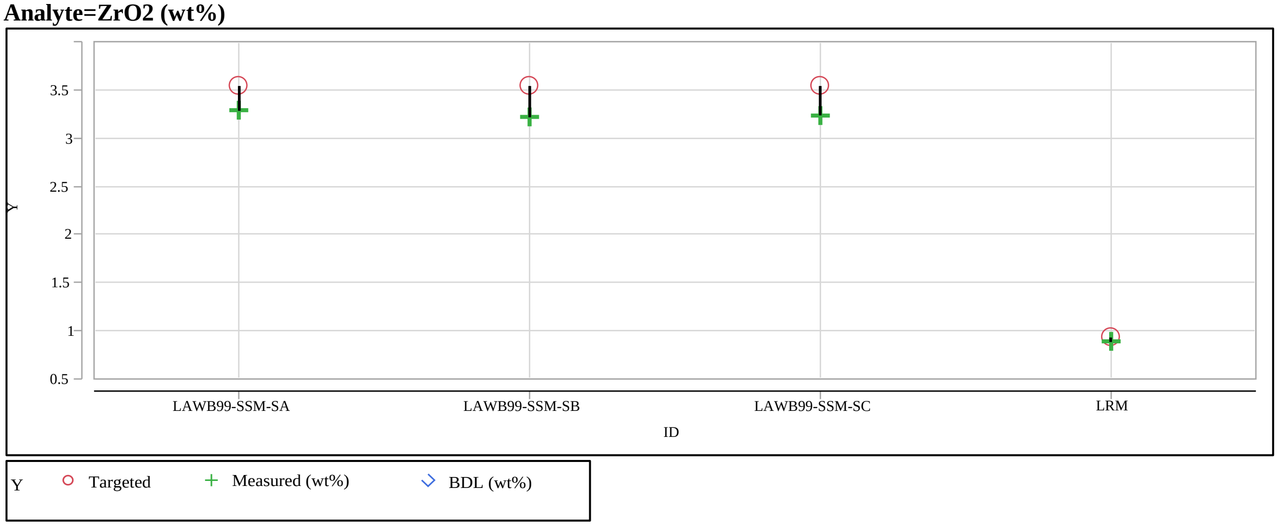


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

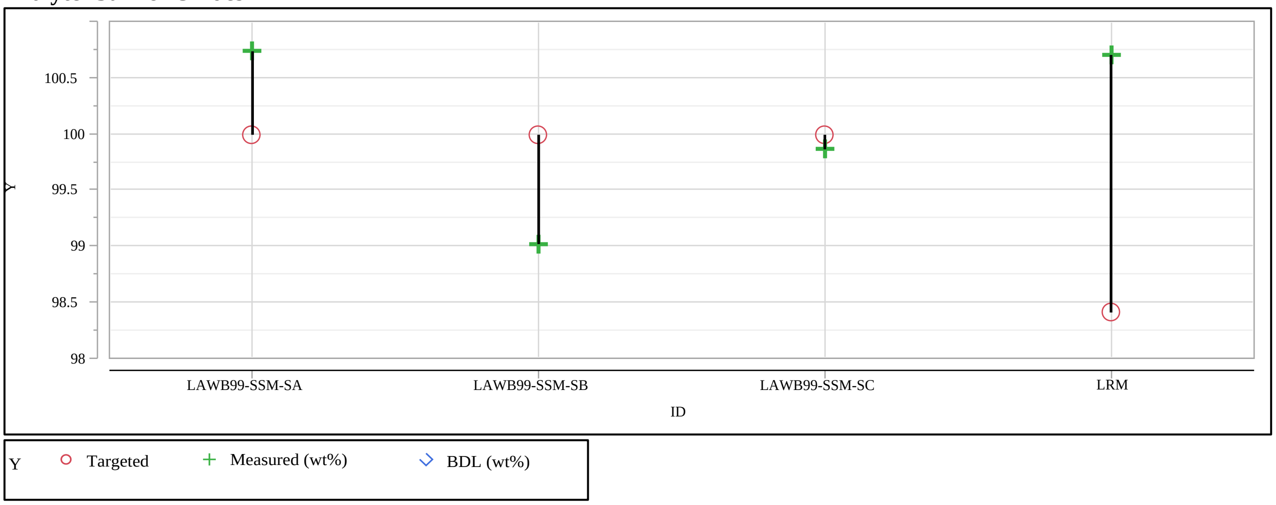
Analyte=ZnO (wt%)



Analyte=ZrO2 (wt%)



Analyte=Sum of Oxides



Appendix B Table and Exhibits Supporting the LAWB99 Wash Solution Chemical Analysis

Table B-1. ICP-AES Measurements (mg/L) of Wash Solutions

Soln ID	Blk	Seq	Lab ID	Al	B	Ca	Cr	Fe	K	Li	Mg	Na	P	S	Si	V	Zn	Zr
solnstd	1	1	solnstd1-1	3.78	21.4	<1.00	<1.00	3.97	9.69	9.61	<1.00	75.0	<1.00	<1.00	54.0	<1.00	<0.100	<1.00
LAWB99-SSM-WB	1	2	T1-1	2.75	8.92	49.9	3.10	<1.00	16.0	30.5	<1.00	416	<1.00	401	13.0	4.20	1.04	<1.00
High-Purity Standards SM-744-063	1	3	hpstd-11	51.6	<1.00	<1.00	<1.00	49.9	<1.00	<1.00	<1.00	142	<1.00	11.0	<1.00	<1.00	<0.100	<1.00
LAWB99-SSM-WA	1	4	T3-1	<1.00	8.04	49.2	3.33	<1.00	17.9	32.7	<1.00	445	<1.00	430	4.01	4.30	<0.100	<1.00
blank	1	5	blank-1	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<0.100	<1.00
High-Purity Standards SM-744-063	1	6	hpstd-12	52.2	<1.00	<1.00	<1.00	50.3	<1.00	<1.00	<1.00	141	<1.00	11.0	<1.00	<1.00	<0.100	<1.00
LAWB99-SSM-WC	1	7	T2-1	1.51	9.07	60.9	3.87	<1.00	19.9	37.6	<1.00	513	<1.00	502	7.65	4.92	0.405	<1.00
solnstd	1	8	soln std 1-2	3.91	19.6	<1.00	<1.00	3.94	9.48	9.67	<1.00	77.5	<1.00	<1.00	54.9	<1.00	<0.100	<1.00
solnstd	2	1	soln std 2-1	3.64	19.6	<1.00	<1.00	3.84	9.91	9.72	<1.00	81.0	<1.00	<1.00	52.5	<1.00	<0.100	<1.00
LAWB99-SSM-WA	2	2	T3-2	<1.00	7.32	48.5	3.25	<1.00	18.4	33.1	<1.00	450	<1.00	421	4.00	4.15	<0.100	<1.00
High-Purity Standards SM-744-063	2	3	hpstd-21	51.9	<1.00	<1.00	<1.00	49.4	<1.00	<1.00	<1.00	141	<1.00	9.98	<1.00	<1.00	<0.100	<1.00
LAWB99-SSM-WC	2	4	T2-2	1.44	8.42	60.2	3.79	<1.00	22.4	37.6	<1.00	499	<1.00	475	7.69	4.84	0.465	<1.00
blank	2	5	blank-2	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<0.100	<1.00
High-Purity Standards SM-744-063	2	6	hpstd-22	52.2	<1.00	<1.00	<1.00	49.6	<1.00	<1.00	<1.00	145	<1.00	9.70	<1.00	<1.00	<0.100	<1.00
LAWB99-SSM-WB	2	7	T1-2	2.62	7.88	49.1	2.95	<1.00	17.2	30.8	<1.00	392	<1.00	379	12.8	4.07	1.08	<1.00
solnstd	2	8	soln std 2-2	3.72	19.5	<1.00	<1.00	3.82	10.2	9.75	<1.00	75.5	<1.00	<1.00	52.8	<1.00	<0.100	<1.00
solnstd	3	1	soln std 3-1	3.73	20.9	<1.00	<1.00	3.89	9.29	9.85	<1.00	82.4	<1.00	<1.00	53.8	<1.00	<0.100	<1.00
LAWB99-SSM-WC	3	2	T2-3	1.31	9.65	61.4	3.83	<1.00	20.8	37.3	<1.00	522	<1.00	484	7.25	4.82	0.323	<1.00
High-Purity Standards SM-744-063	3	3	hpstd-31	52.8	<1.00	<1.00	<1.00	49.5	<1.00	<1.00	<1.00	146	<1.00	10.2	<1.00	<1.00	<0.100	<1.00
LAWB99-SSM-WB	3	4	T1-3	2.62	8.52	48.6	2.89	<1.00	16.0	29.8	<1.00	448	<1.00	379	12.4	3.96	0.926	<1.00
blank	3	5	blank-3	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<0.100	<1.00
High-Purity Standards SM-744-063	3	6	hpstd-32	51.6	<1.00	<1.00	<1.00	49.8	<1.00	<1.00	<1.00	137	<1.00	10.3	<1.00	<1.00	<0.100	<1.00
LAWB99-SSM-WA	3	7	T3-3	<1.00	7.79	48.7	3.21	<1.00	17.3	32.9	<1.00	442	<1.00	401	3.88	4.16	<0.100	<1.00
solnstd	3	8	soln std 3-2	3.67	19.9	<1.00	<1.00	3.79	9.11	9.71	<1.00	78.1	<1.00	<1.00	53.3	<1.00	<0.100	<1.00

Table B-2. IC Measurements (mg/L) of Wash Solutions

Soln ID	Blk	Seq	Lab ID	Cl	F	PO4	SO4
10 ppm ckstd	1	1	10 ppm ckstd	9.97	9.92	9.79	9.94
solnstd	1	2	Soln Std 1-1	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WA	1	3	T3-1	<10.0	<10.0	<10.0	1250
High-Purity Standards SM-744-063	1	4	hpstd-11	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WC	1	5	T2-1	<10.0	<10.0	<10.0	1440
blank	1	6	Blank-1	<10.0	<10.0	<10.0	<100
High-Purity Standards SM-744-063	1	7	hpstd-12	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WB	1	8	T1-1	<10.0	<10.0	<10.0	1140
solnstd	1	9	Soln Std 1-2	<10.0	<10.0	<10.0	<100
10 ppm ckstd	1	10	10 ppm ckstd	9.91	9.90	9.71	9.96
10 ppm ckstd	2	1	10 ppm ckstd	9.97	9.95	10.0	9.96
solnstd	2	2	Soln Std 2-1	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WC	2	3	T2-2	<10.0	<10.0	<10.0	1450
High-Purity Standards SM-744-063	2	4	hpstd-21	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WA	2	5	T3-2	<10.0	<10.0	<10.0	1240
blank	2	6	Blank-2	<10.0	<10.0	<10.0	<100
High-Purity Standards SM-744-063	2	7	hpstd-22	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WB	2	8	T1-2	<10.0	<10.0	<10.0	1130
solnstd	2	9	Soln Std 2-2	<10.0	<10.0	<10.0	<100
10 ppm ckstd	2	10	10 ppm ckstd	9.94	9.90	9.57	9.97
10 ppm ckstd	3	1	10 ppm ckstd	10.0	10.0	9.92	10.0
solnstd	3	2	Soln Std 3-1	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WC	3	3	T2-3	<10.0	<10.0	<10.0	1460
High-Purity Standards SM-744-063	3	4	hpstd-31	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WA	3	5	T3-3	<10.0	<10.0	<10.0	1260
blank	3	6	Blank-3	<10.0	<10.0	<10.0	<100
High-Purity Standards SM-744-063	3	7	hpstd-32	<10.0	<10.0	<10.0	<100
LAWB99-SSM-WB	3	8	T1-3	<10.0	<10.0	<10.0	1140
solnstd	3	9	Soln Std 3-2	<10.0	<10.0	<10.0	<100
10 ppm ckstd	3	10	10 ppm ckstd	9.93	9.92	9.48	10.0

Table B-3. Results for Standards Utilized During the Measurement of the Wash Solutions

Soln ID	Analyte	Instrument	Reference Value (mg/L)	Mean (mg/L)	Number of Measurements
High-Purity Standards SM-744-063	Al	ICP-AES	50	52.05	6
High-Purity Standards SM-744-063	Fe	ICP-AES	50	49.75	6
High-Purity Standards SM-744-063	Na	ICP-AES	150	142	6
High-Purity Standards SM-744-063	S	ICP-AES	10	10.363	6
solnstd	Al	ICP-AES	4	3.742	6
solnstd	B	ICP-AES	20	20.15	6
solnstd	Fe	ICP-AES	4	3.875	6
solnstd	K	ICP-AES	10	9.613	6
solnstd	Li	ICP-AES	10	9.718	6
solnstd	Na	ICP-AES	81	78.25	6
solnstd	Si	ICP-AES	50	53.55	6

Table B-4. Average Measurements of Wash Solutions

Soln ID	Analyte	Instrument	Mean (mg/L)	BDL Indicator (0=>BDL)
LAWB99-SSM-WA	Al	ICP-AES	1.00	0
LAWB99-SSM-WA	B	ICP-AES	7.72	1
LAWB99-SSM-WA	Ca	ICP-AES	48.80	1
LAWB99-SSM-WA	Cl	IC	10.00	0
LAWB99-SSM-WA	Cr	ICP-AES	3.26	1
LAWB99-SSM-WA	F	IC	10.00	0
LAWB99-SSM-WA	Fe	ICP-AES	1.00	0
LAWB99-SSM-WA	K	ICP-AES	17.87	1
LAWB99-SSM-WA	Li	ICP-AES	32.90	1
LAWB99-SSM-WA	Mg	ICP-AES	1.00	0
LAWB99-SSM-WA	Na	ICP-AES	445.67	1
LAWB99-SSM-WA	P	ICP-AES	1.00	0
LAWB99-SSM-WA	PO4	IC	10.00	0
LAWB99-SSM-WA	PO4	ICP-AES	3.07	0
LAWB99-SSM-WA	S	ICP-AES	417.33	1
LAWB99-SSM-WA	Si	ICP-AES	3.96	1
LAWB99-SSM-WA	SO4	IC	1250.00	1
LAWB99-SSM-WA	SO4	ICP-AES	1250.29	1
LAWB99-SSM-WA	V	ICP-AES	4.20	1
LAWB99-SSM-WA	Zn	ICP-AES	0.10	0
LAWB99-SSM-WA	Zr	ICP-AES	1.00	0
LAWB99-SSM-WB	Al	ICP-AES	2.66	1
LAWB99-SSM-WB	B	ICP-AES	8.44	1
LAWB99-SSM-WB	Ca	ICP-AES	49.20	1
LAWB99-SSM-WB	Cl	IC	10.00	0
LAWB99-SSM-WB	Cr	ICP-AES	2.98	1
LAWB99-SSM-WB	F	IC	10.00	0
LAWB99-SSM-WB	Fe	ICP-AES	1.00	0
LAWB99-SSM-WB	K	ICP-AES	16.40	1
LAWB99-SSM-WB	Li	ICP-AES	30.37	1
LAWB99-SSM-WB	Mg	ICP-AES	1.00	0
LAWB99-SSM-WB	Na	ICP-AES	418.67	1
LAWB99-SSM-WB	P	ICP-AES	1.00	0
LAWB99-SSM-WB	PO4	IC	10.00	0
LAWB99-SSM-WB	PO4	ICP-AES	3.07	0
LAWB99-SSM-WB	S	ICP-AES	386.33	1
LAWB99-SSM-WB	Si	ICP-AES	12.73	1
LAWB99-SSM-WB	SO4	IC	1136.67	1

Table B-4. Average Measurements of Wash Solutions (continued)

Soln ID	Analyte	Instrument	Mean (mg/L)	BDL Indicator (0=>BDL)
LAWB99-SSM-WB	SO4	ICP-AES	1157.42	1
LAWB99-SSM-WB	V	ICP-AES	4.08	1
LAWB99-SSM-WB	Zn	ICP-AES	1.02	1
LAWB99-SSM-WB	Zr	ICP-AES	1.00	0
LAWB99-SSM-WC	Al	ICP-AES	1.42	1
LAWB99-SSM-WC	B	ICP-AES	9.05	1
LAWB99-SSM-WC	Ca	ICP-AES	60.83	1
LAWB99-SSM-WC	Cl	IC	10.00	0
LAWB99-SSM-WC	Cr	ICP-AES	3.83	1
LAWB99-SSM-WC	F	IC	10.00	0
LAWB99-SSM-WC	Fe	ICP-AES	1.00	0
LAWB99-SSM-WC	K	ICP-AES	21.03	1
LAWB99-SSM-WC	Li	ICP-AES	37.50	1
LAWB99-SSM-WC	Mg	ICP-AES	1.00	0
LAWB99-SSM-WC	Na	ICP-AES	511.33	1
LAWB99-SSM-WC	P	ICP-AES	1.00	0
LAWB99-SSM-WC	PO4	IC	10.00	0
LAWB99-SSM-WC	PO4	ICP-AES	3.07	0
LAWB99-SSM-WC	S	ICP-AES	487.00	1
LAWB99-SSM-WC	Si	ICP-AES	7.53	1
LAWB99-SSM-WC	SO4	IC	1450.00	1
LAWB99-SSM-WC	SO4	ICP-AES	1459.00	1
LAWB99-SSM-WC	V	ICP-AES	4.86	1
LAWB99-SSM-WC	Zn	ICP-AES	0.40	1
LAWB99-SSM-WC	Zr	ICP-AES	1.00	0

Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence

Analyte=Al (mg/L)
Variability Chart for Measurement (mg/L)

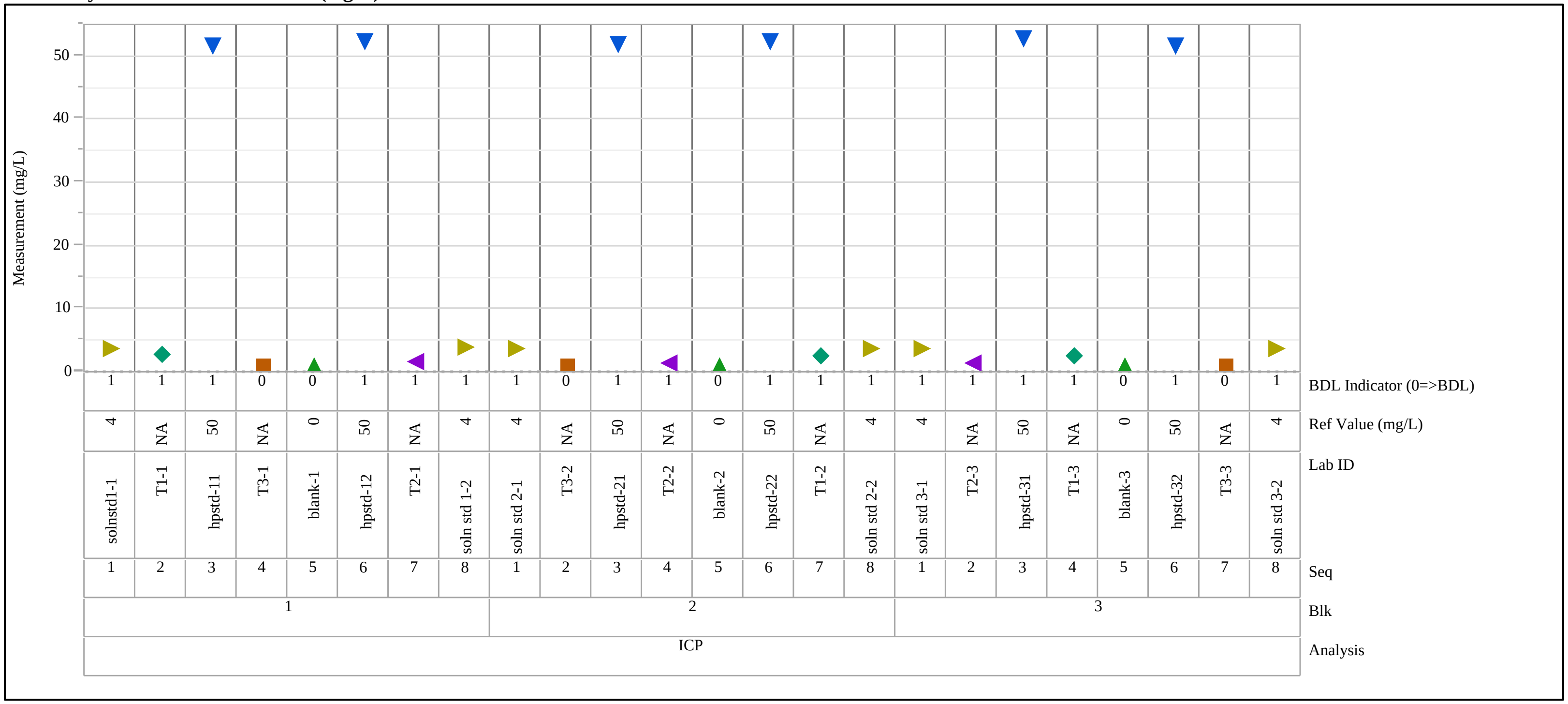


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=B (mg/L)
Variability Chart for Measurement (mg/L)

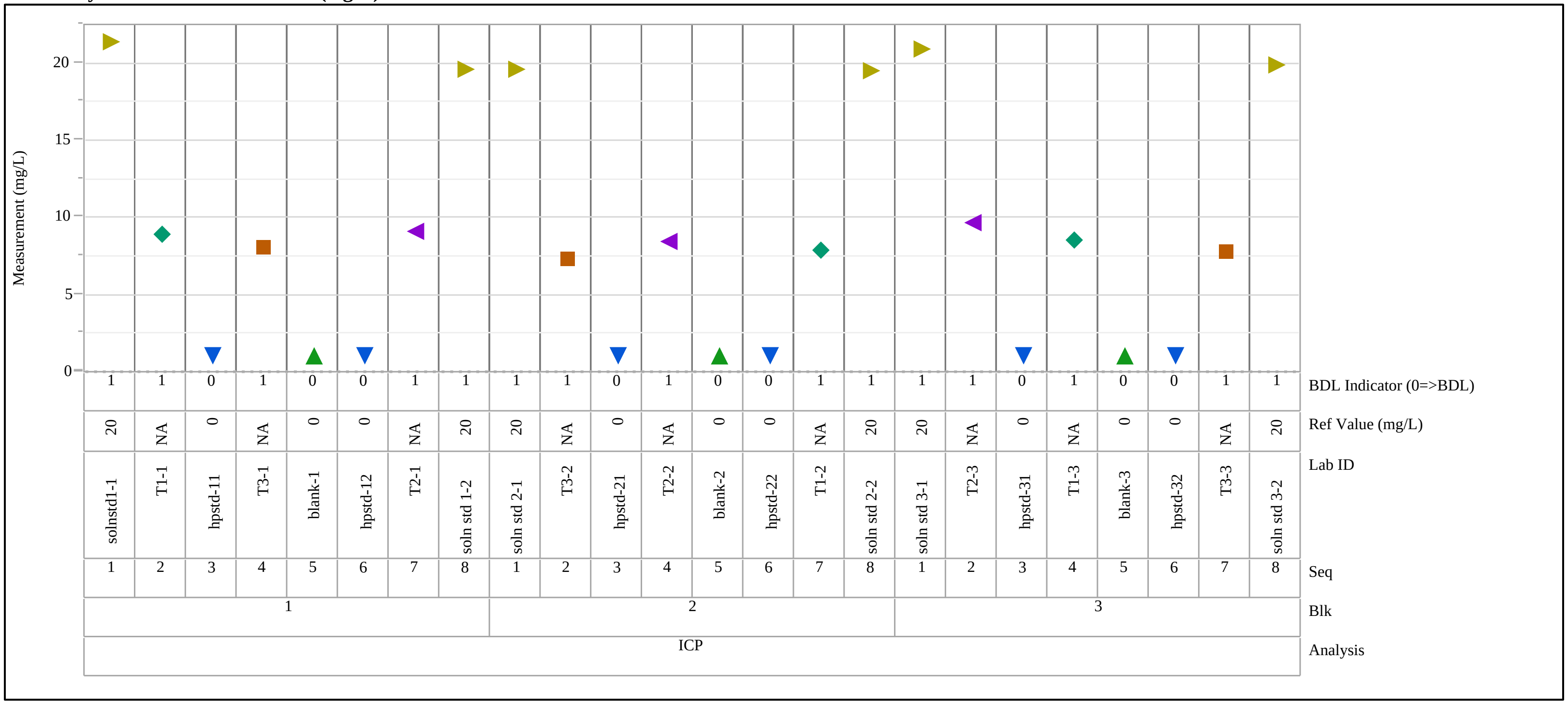


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Ca (mg/L)
Variability Chart for Measurement (mg/L)

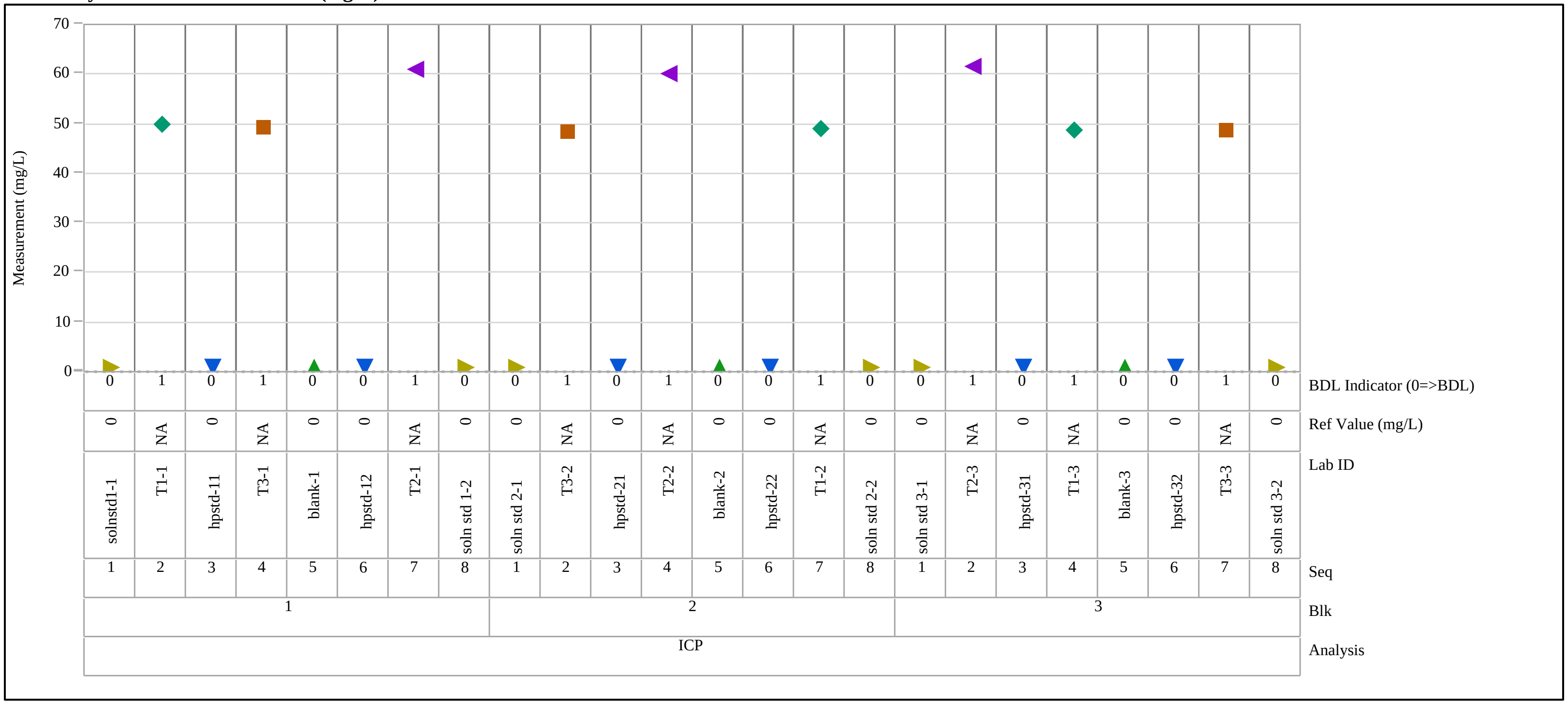


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Cl (mg/L)
Variability Chart for Measurement (mg/L)

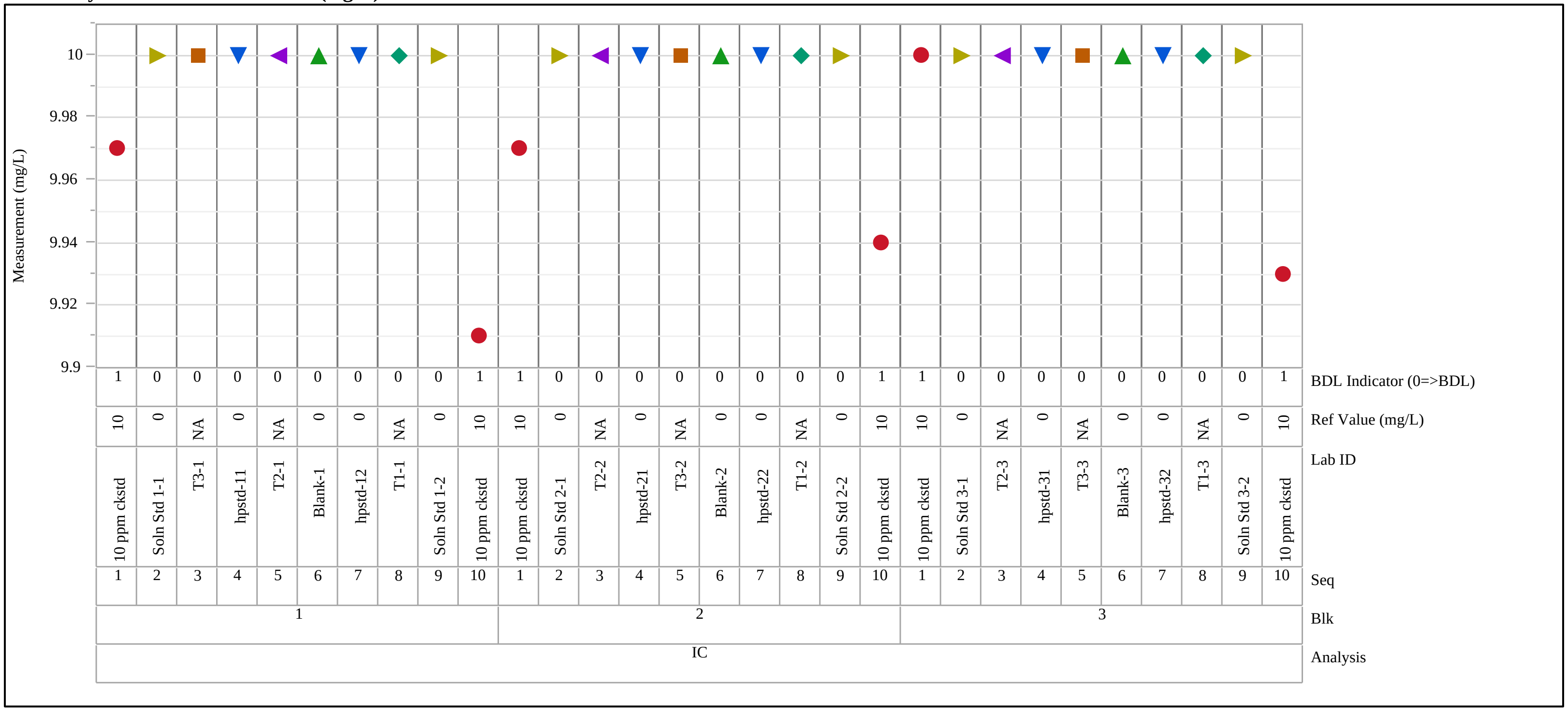
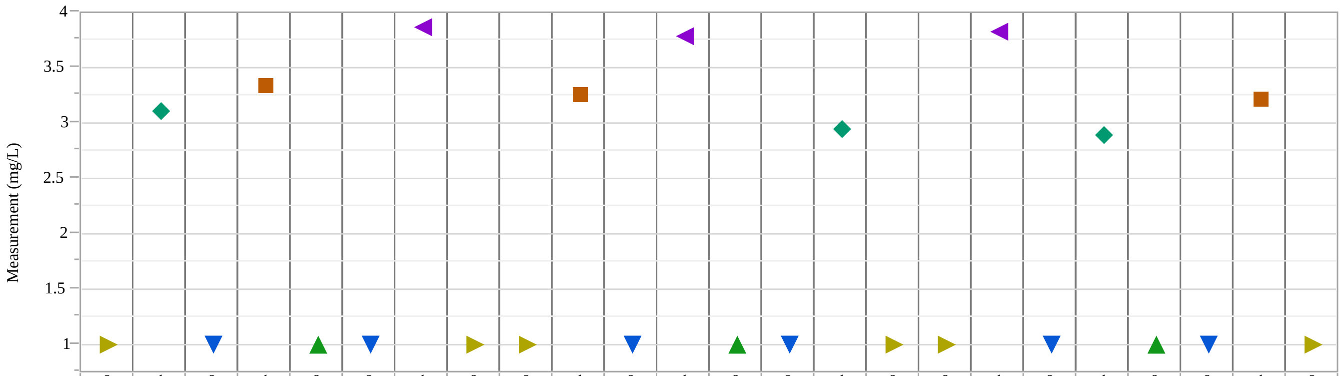


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Cr (mg/L)
Variability Chart for Measurement (mg/L)



BDL Indicator (0=>BDL)	0	1	0	1	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1	0	0	1	0
Ref Value (mg/L)	0	NA	0	NA	0	0	NA	0	0	NA	0	NA	0	0	NA	0	0	NA	0	NA	0	0	NA	0
Lab ID	solnstd1-1	T1-1	hpstd-11	T3-1	blank-1	hpstd-12	T2-1	soln std 1-2	soln std 2-1	T3-2	hpstd-21	T2-2	blank-2	hpstd-22	T1-2	soln std 2-2	soln std 3-1	T2-3	hpstd-31	T1-3	blank-3	hpstd-32	T3-3	soln std 3-2
Seq	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Blk	1								2								3							
Analysis	ICP																							

Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=F (mg/L)
Variability Chart for Measurement (mg/L)

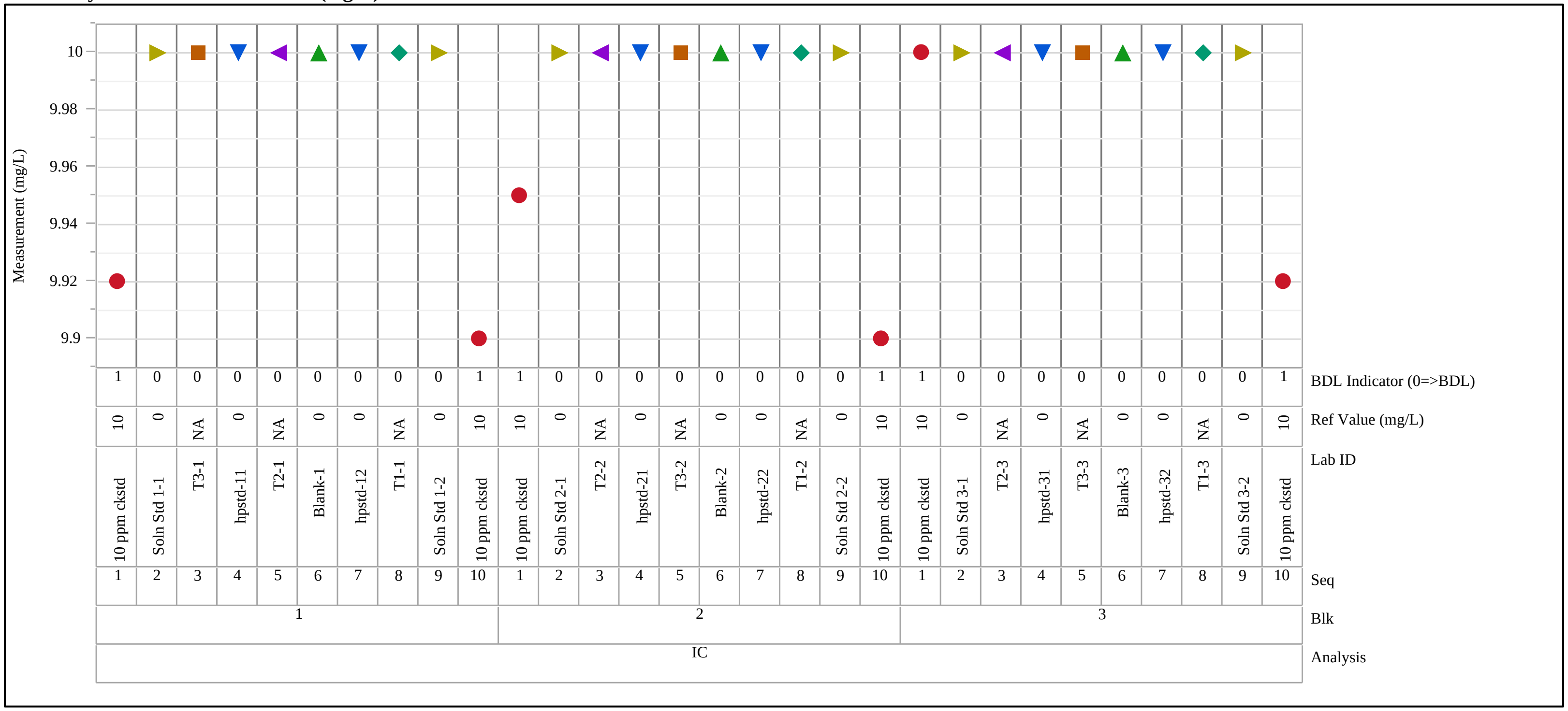


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Fe (mg/L)
Variability Chart for Measurement (mg/L)

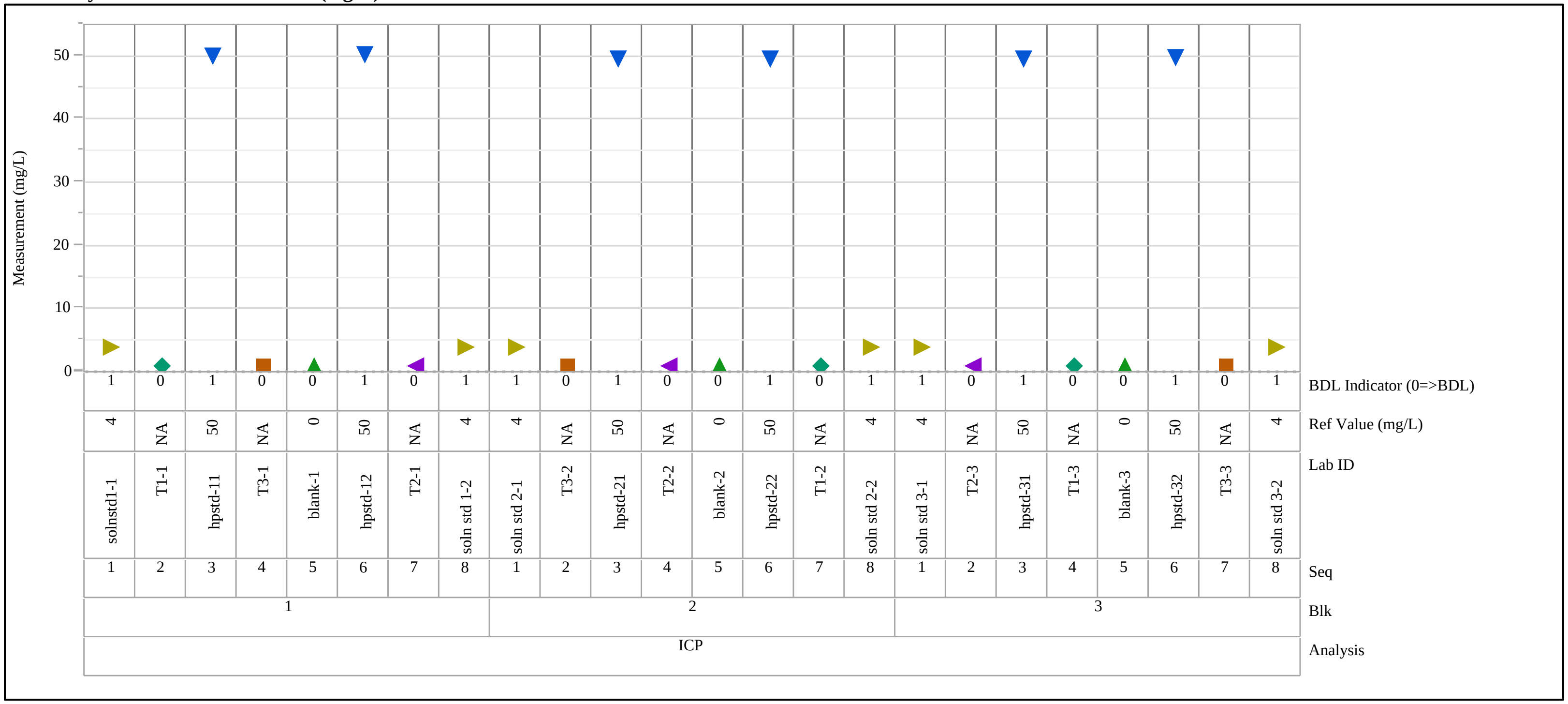


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=K (mg/L)
Variability Chart for Measurement (mg/L)

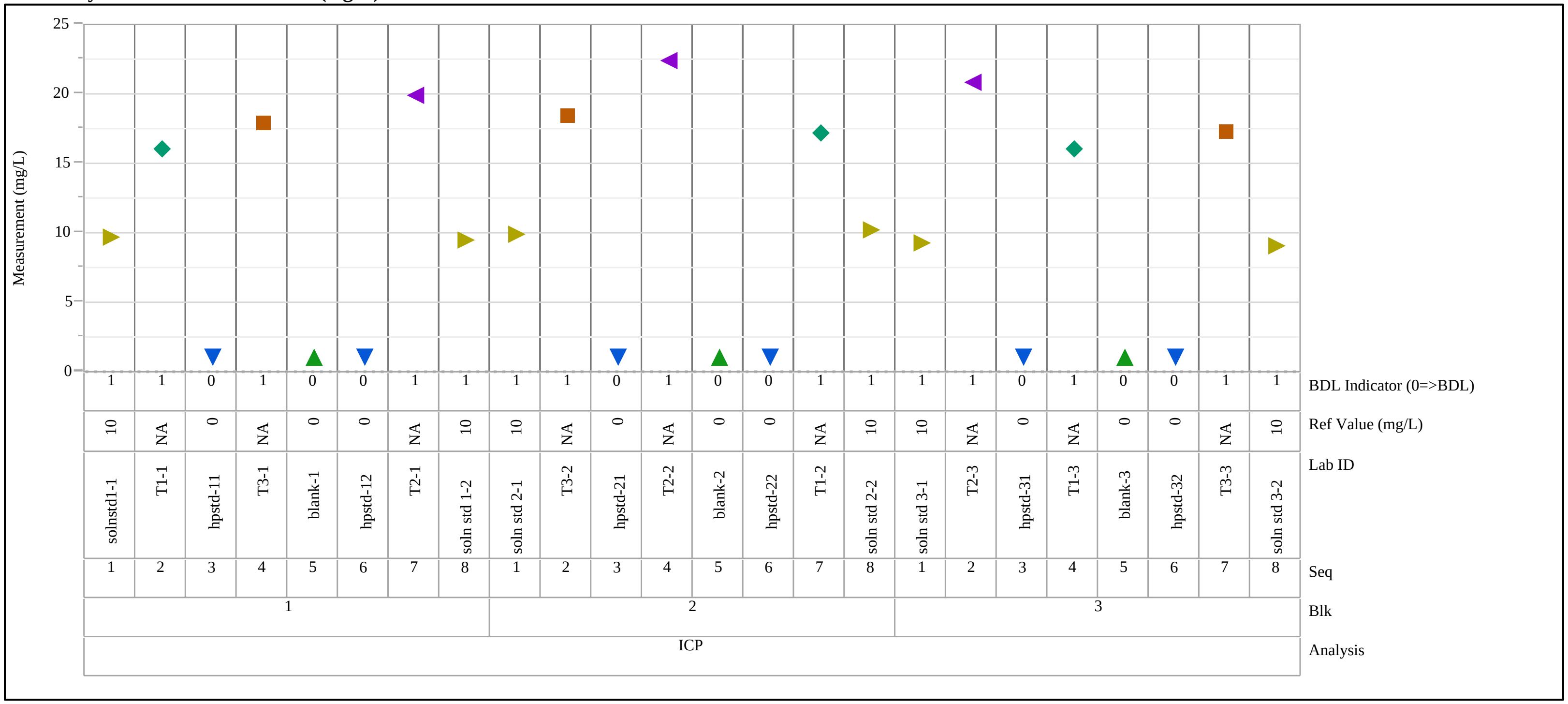


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

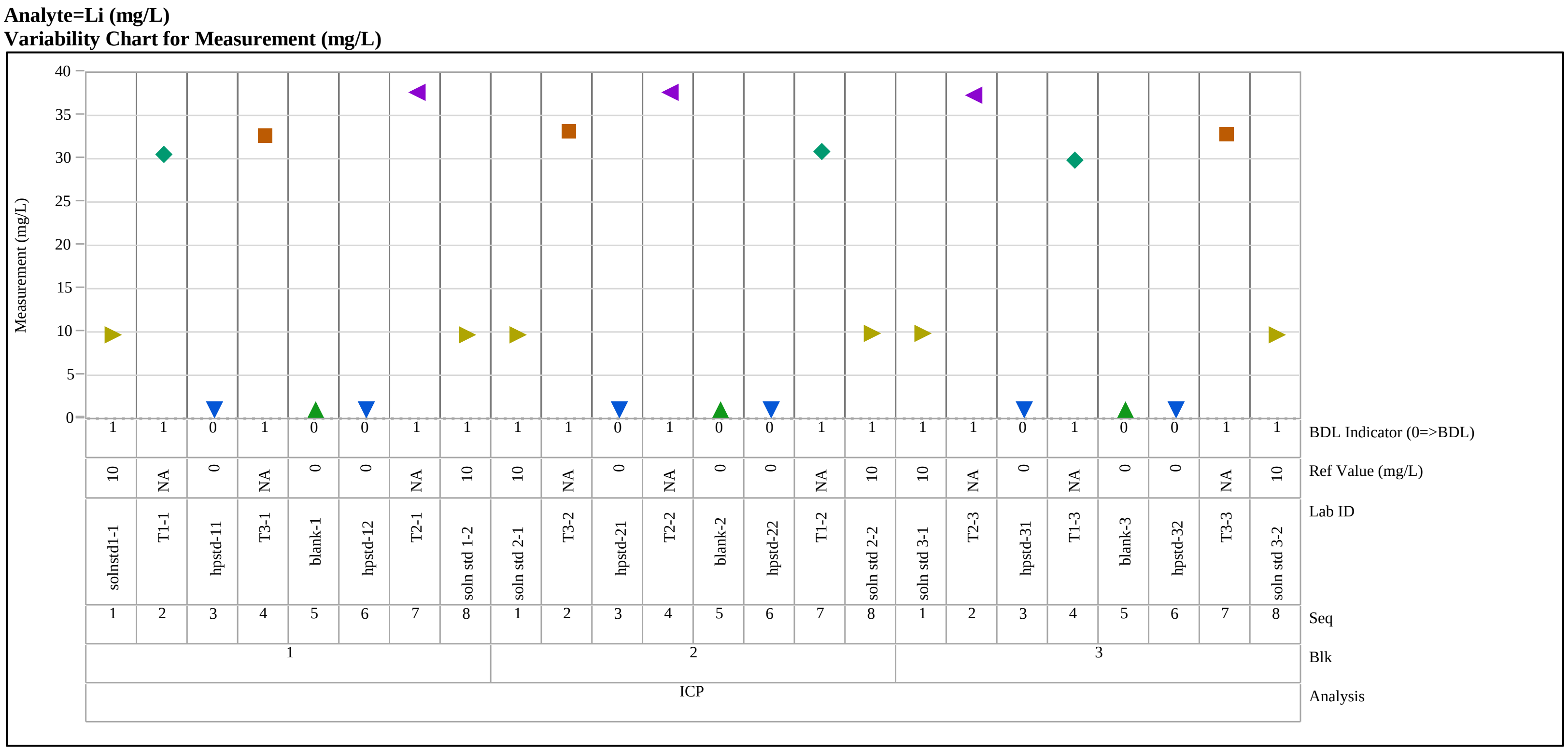


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Mg (mg/L)
Variability Chart for Measurement (mg/L)

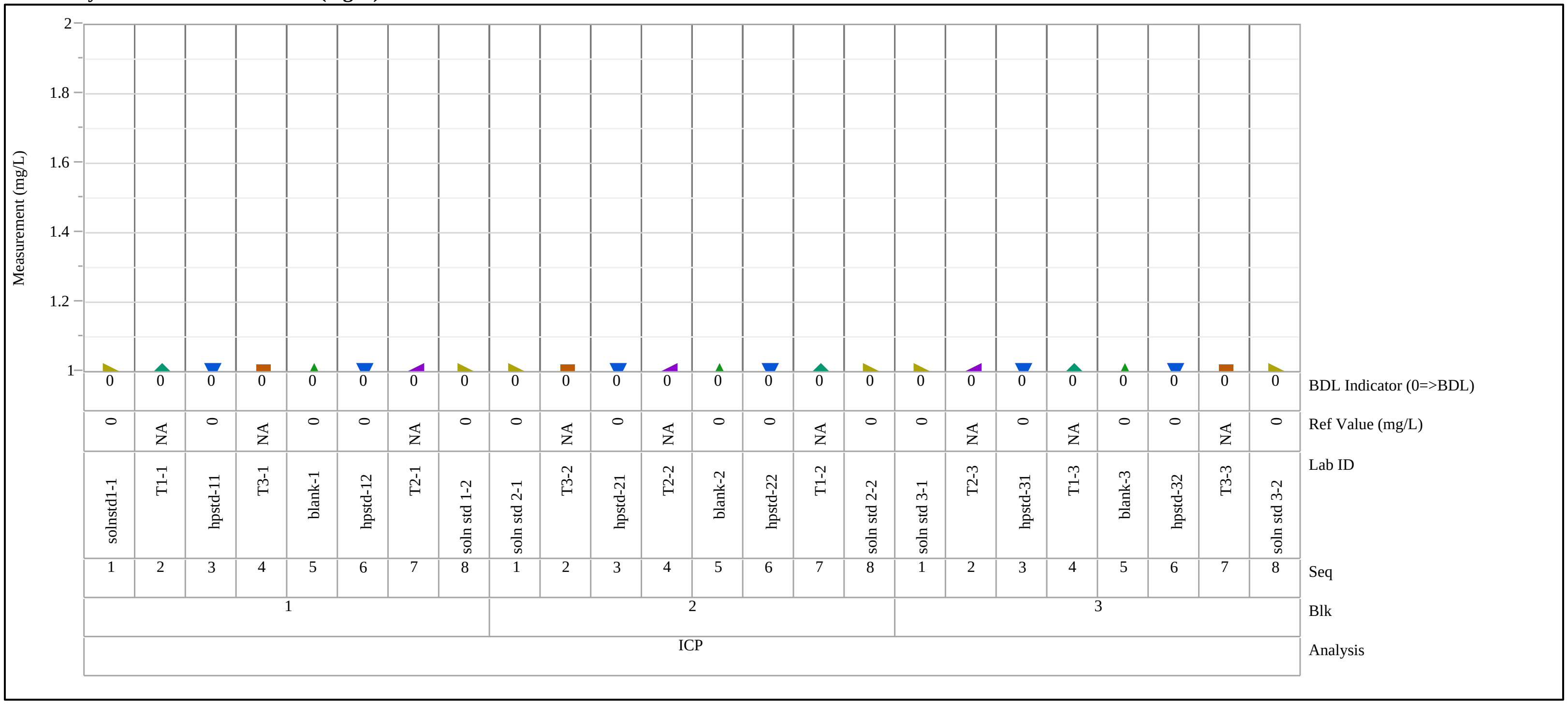


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

nalyte=Na (mg/L)
Variability Chart for Measurement (mg/L)

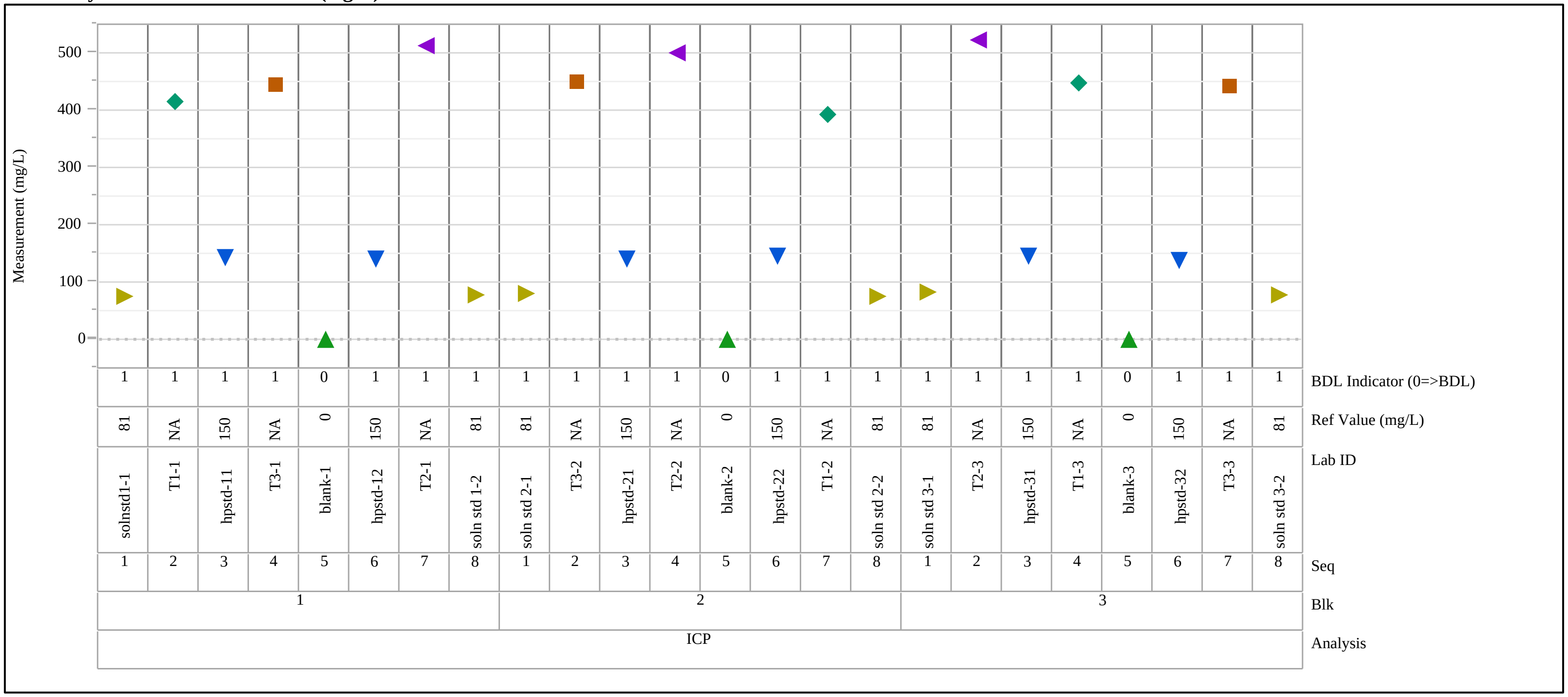


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=P (mg/L)
Variability Chart for Measurement (mg/L)

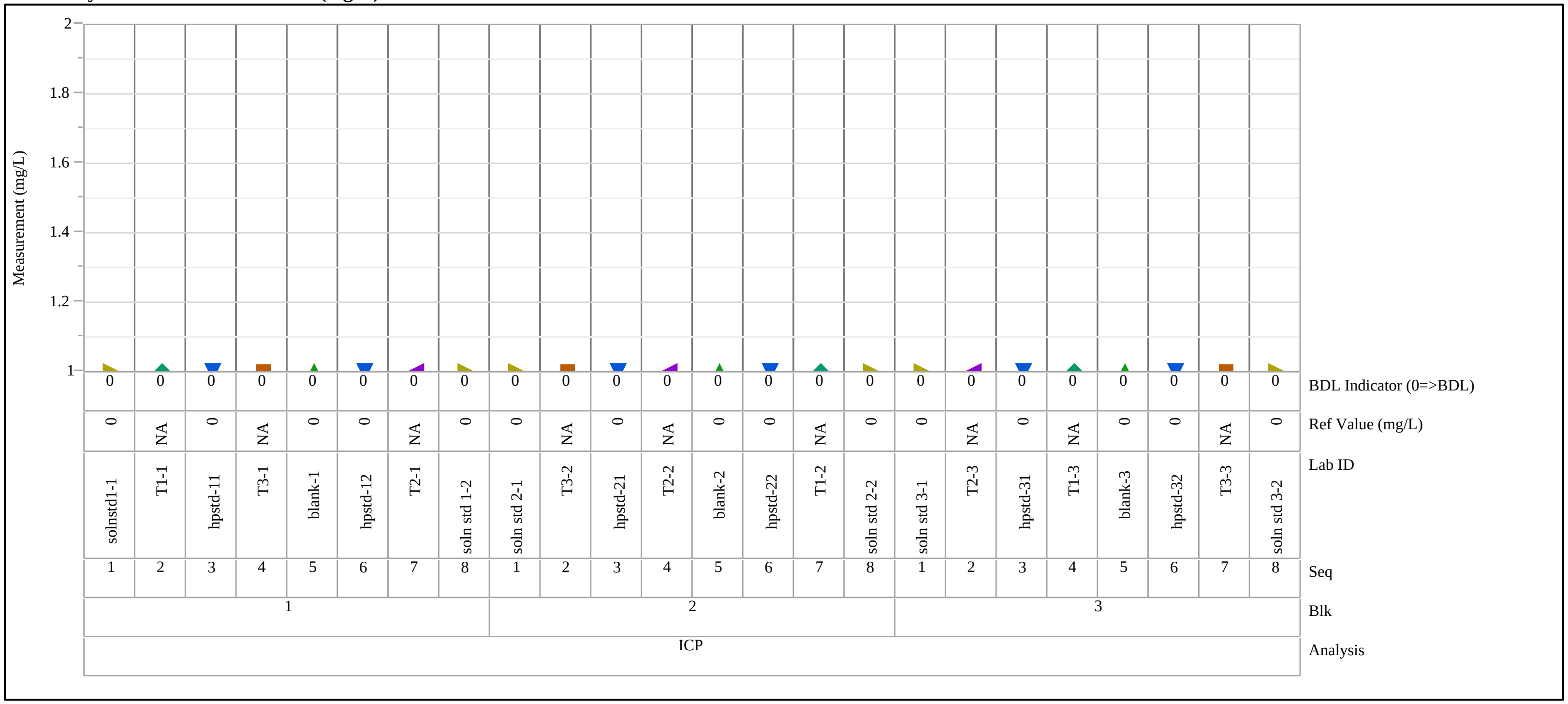


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=PO4 (mg/L)
Variability Chart for Measurement (mg/L)

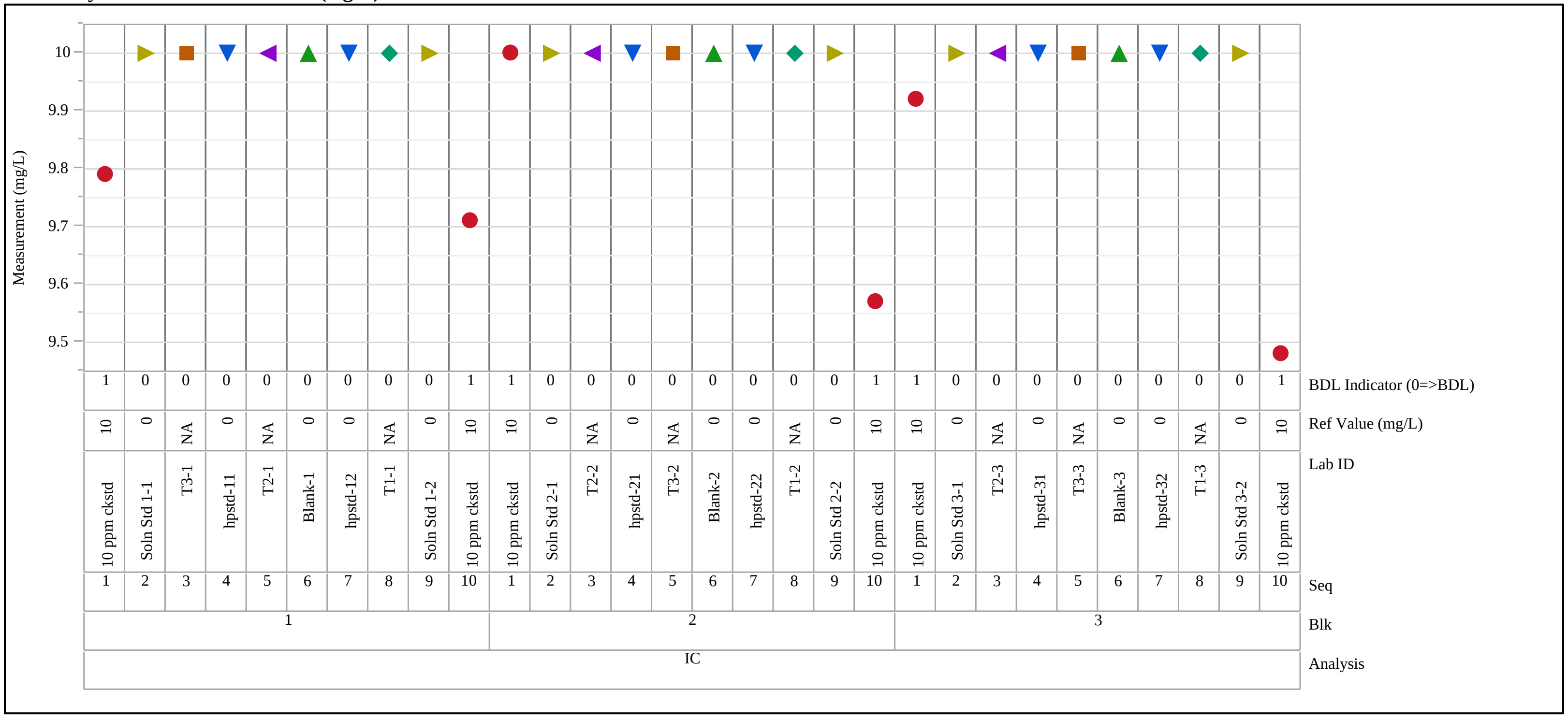


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=S (mg/L)
Variability Chart for Measurement (mg/L)

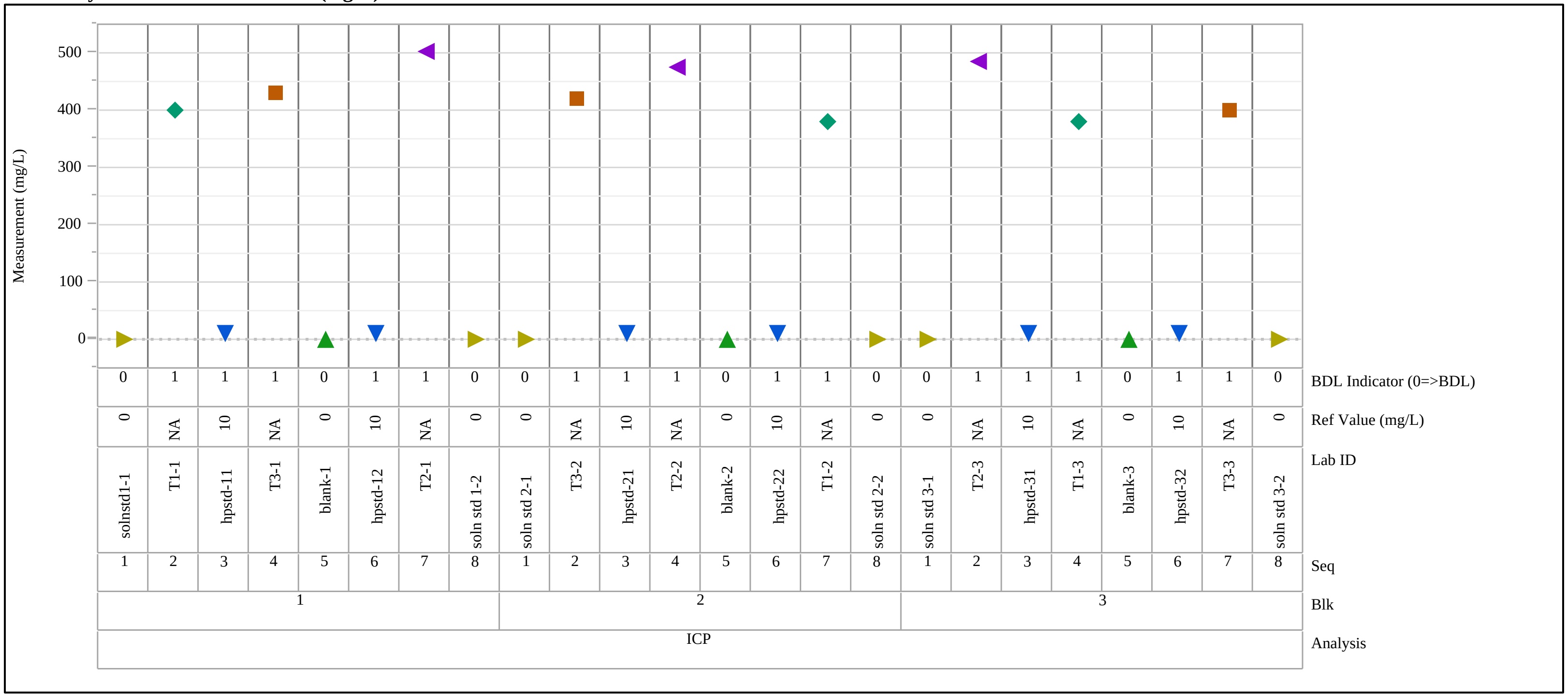


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Si (mg/L)
Variability Chart for Measurement (mg/L)

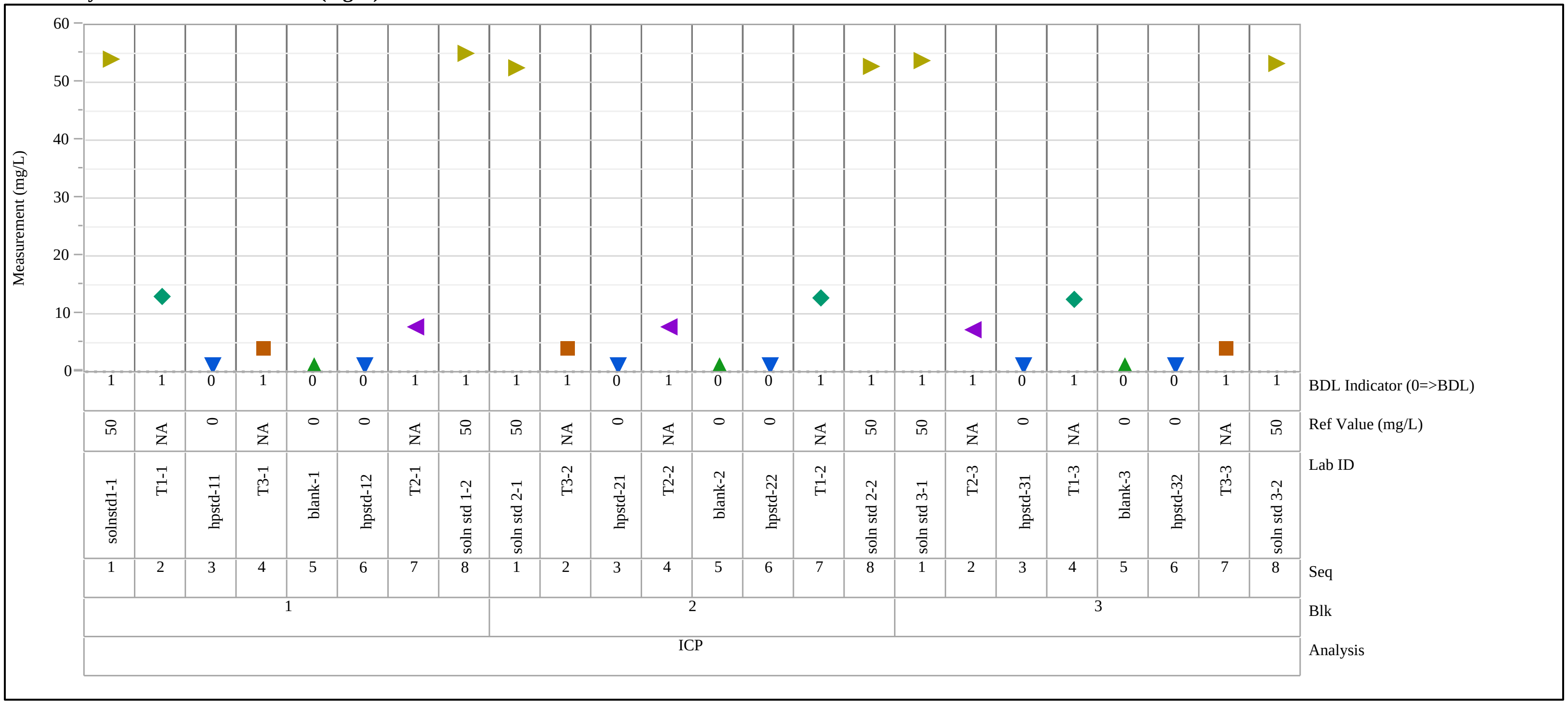


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=SO4 (mg/L)
Variability Chart for Measurement (mg/L)

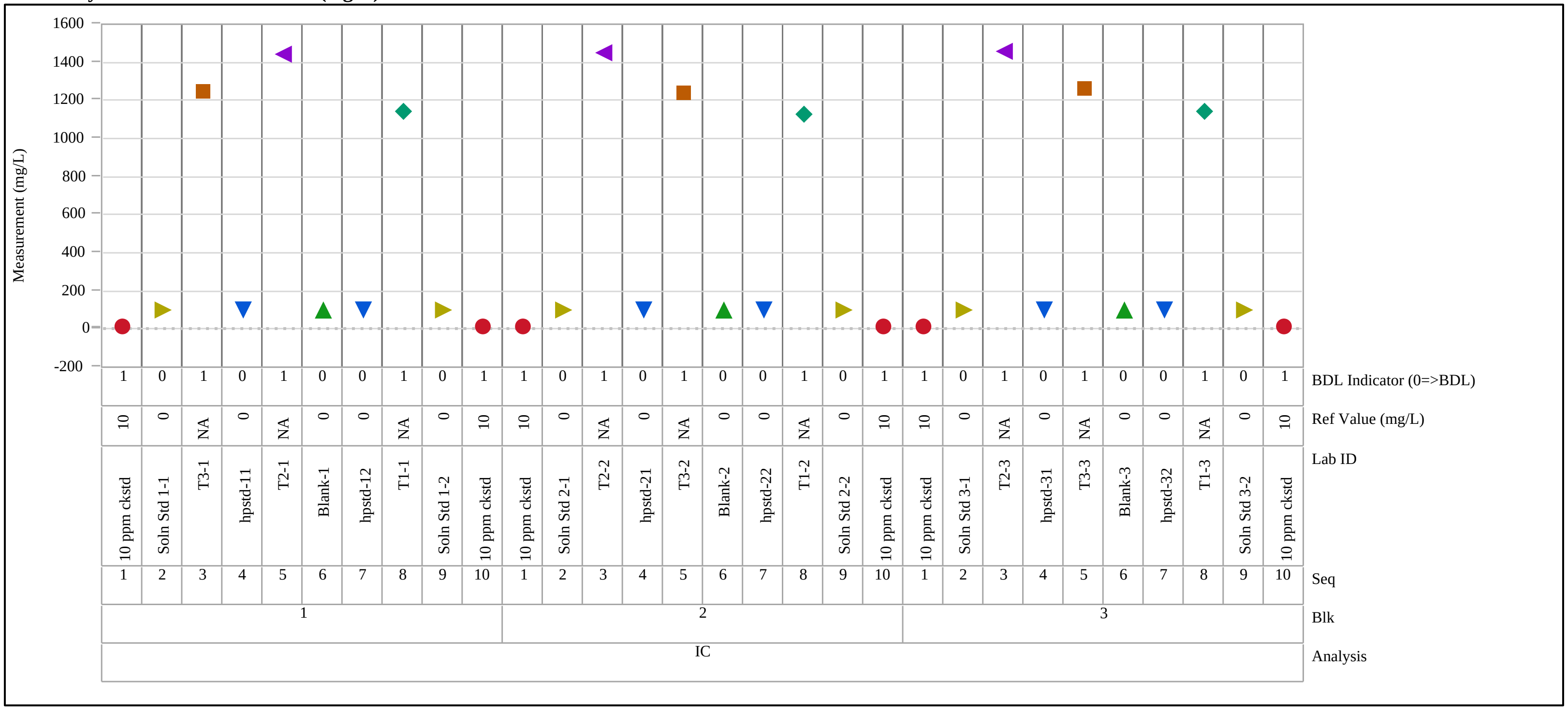


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=V (mg/L)
Variability Chart for Measurement (mg/L)

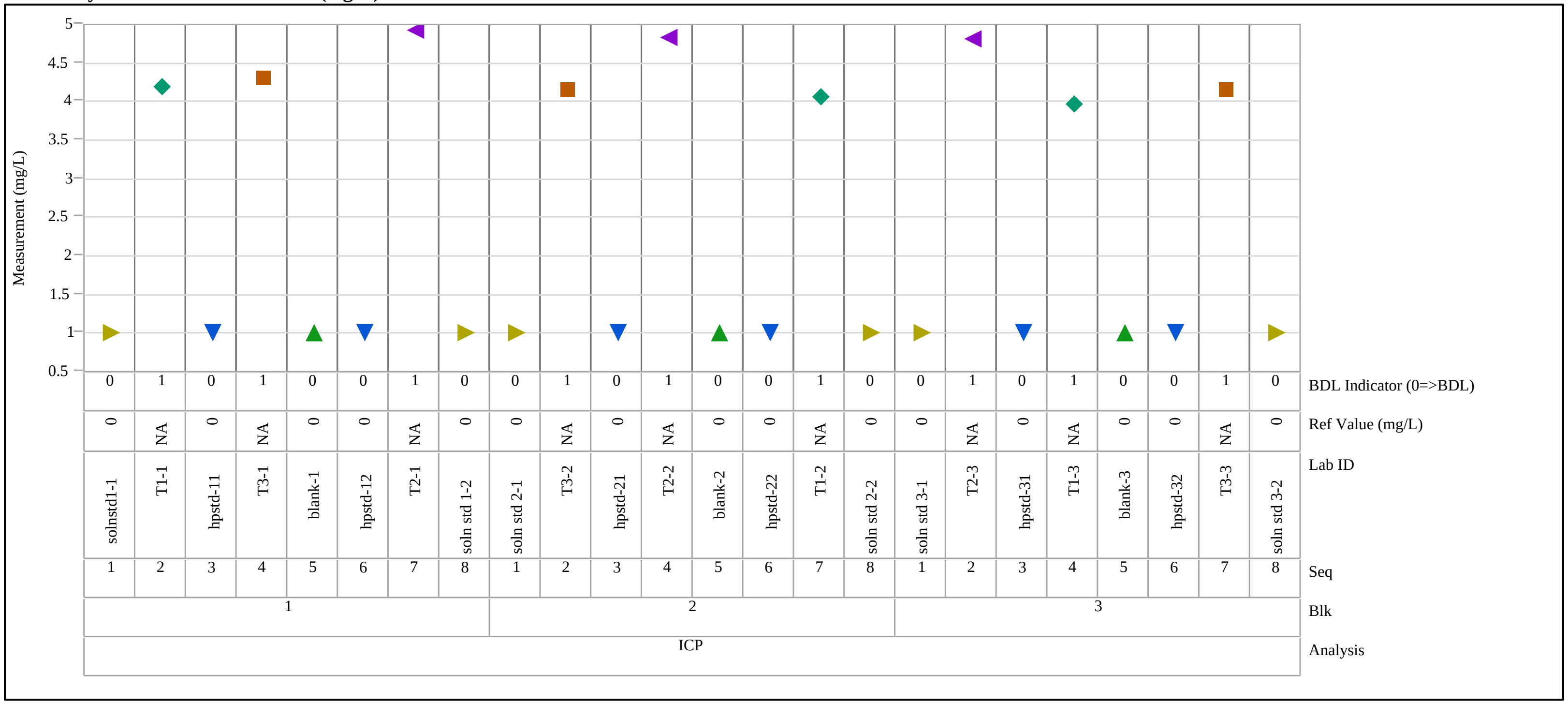


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Zn (mg/L)
Variability Chart for Measurement (mg/L)

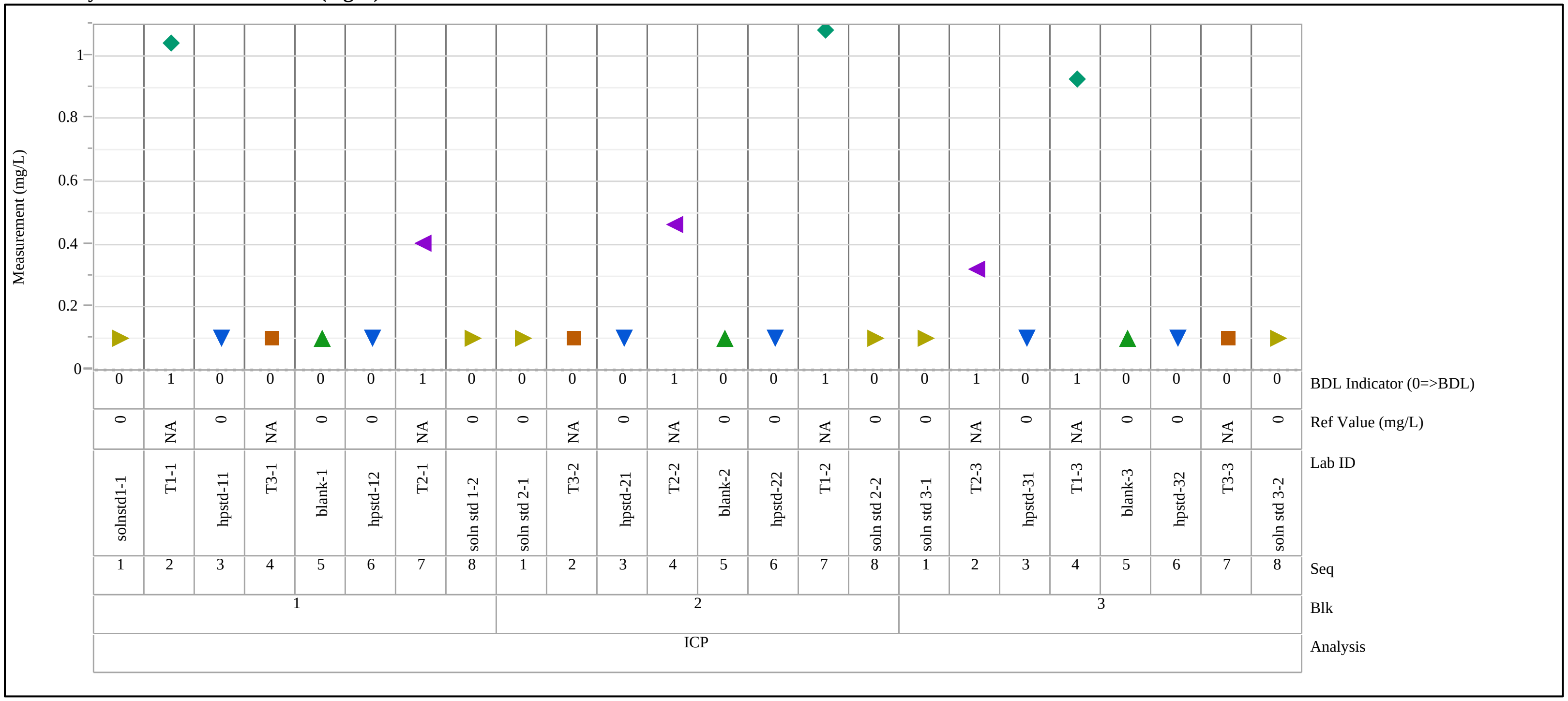


Exhibit B-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Zr (mg/L)
Variability Chart for Measurement (mg/L)

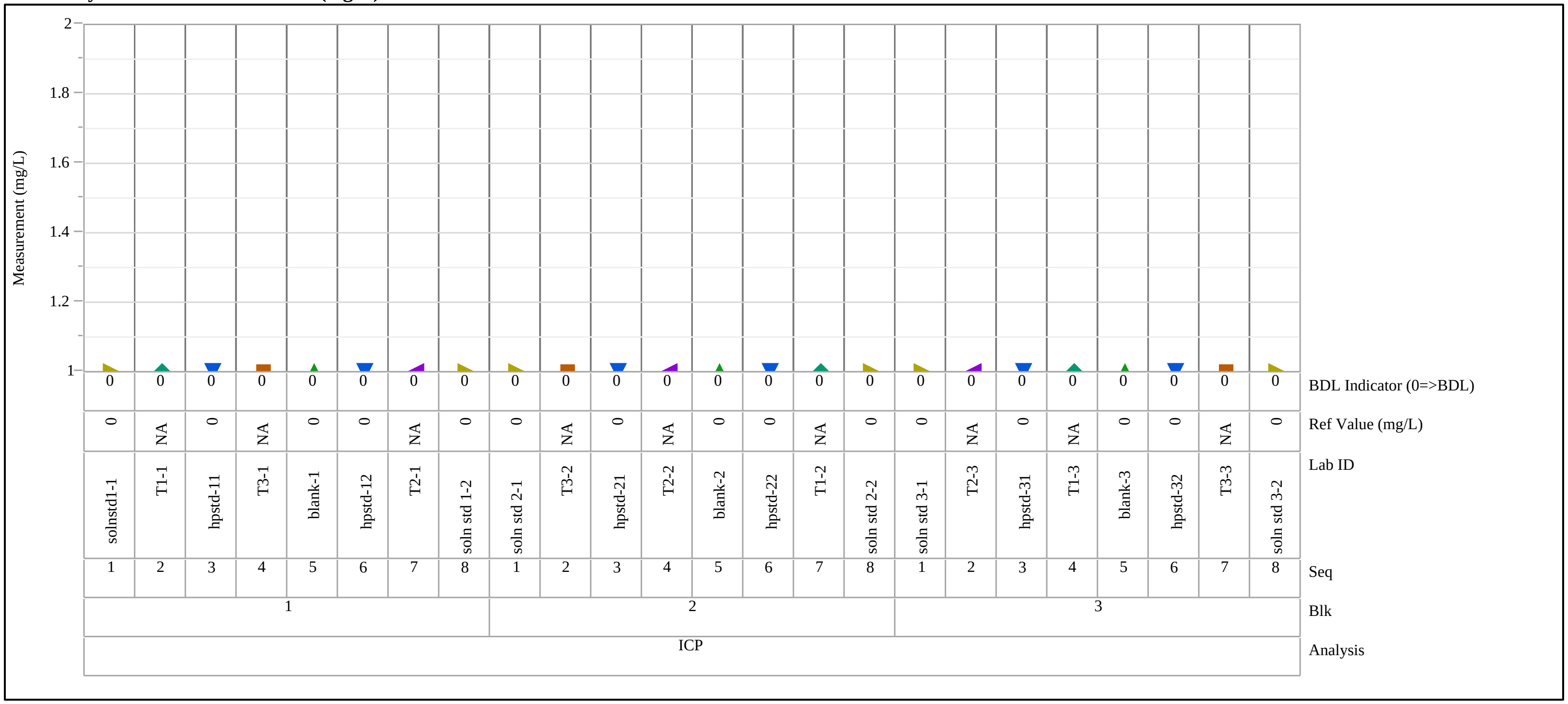
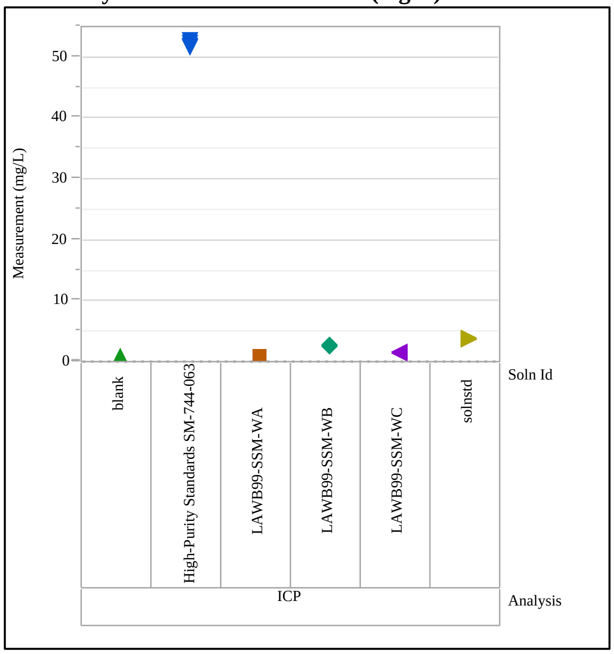
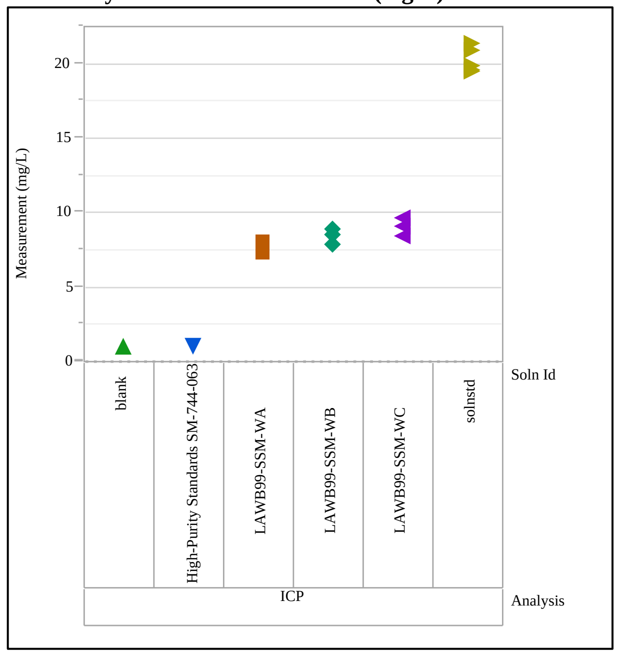


Exhibit B-2. Analysis of Wash Solutions by Solution Identifier

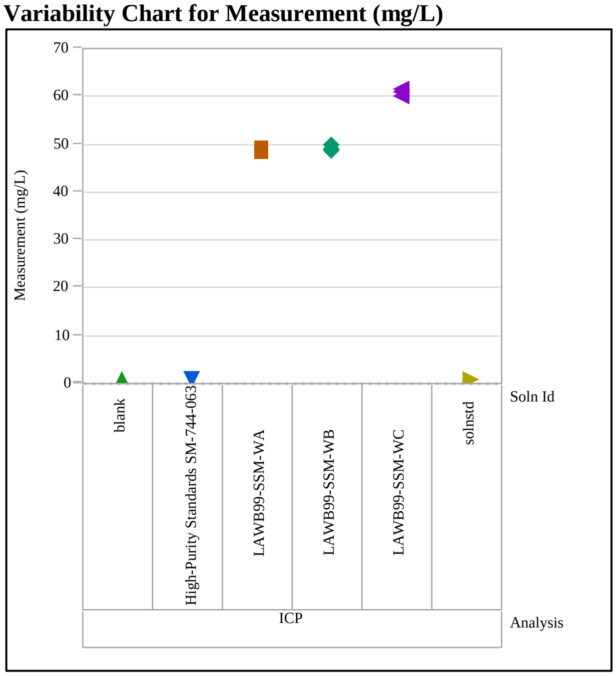
Analyte=Al (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=B (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Ca (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Cl (mg/L)
Variability Chart for Measurement (mg/L)

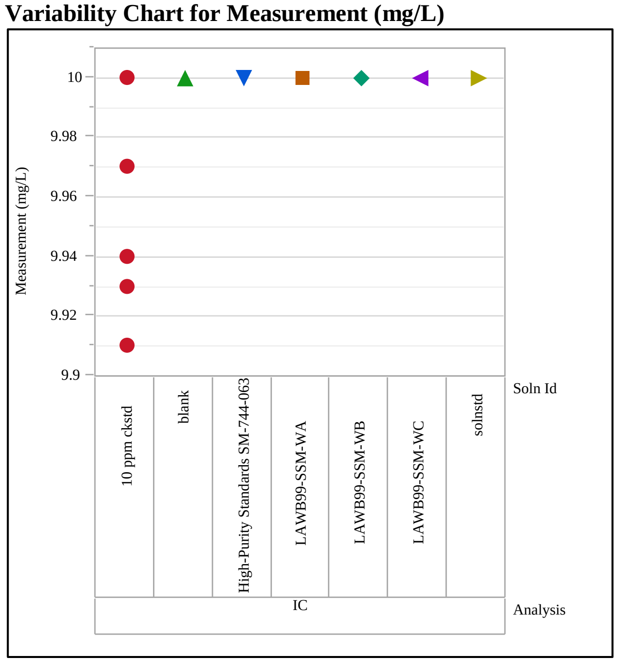
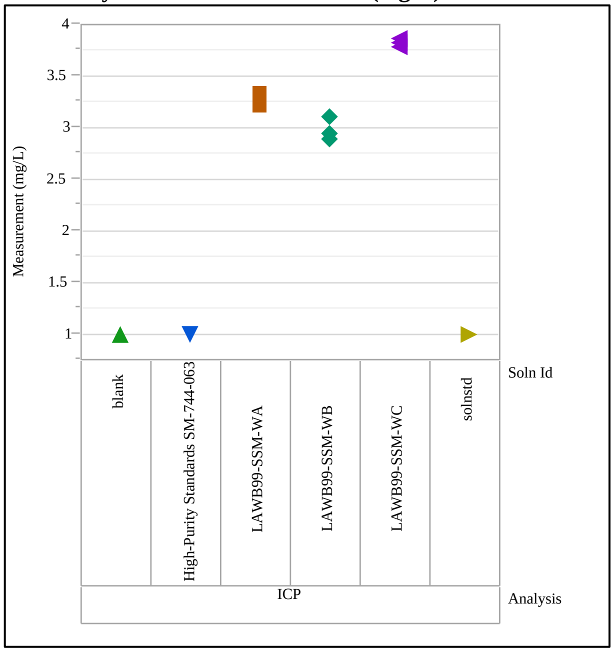
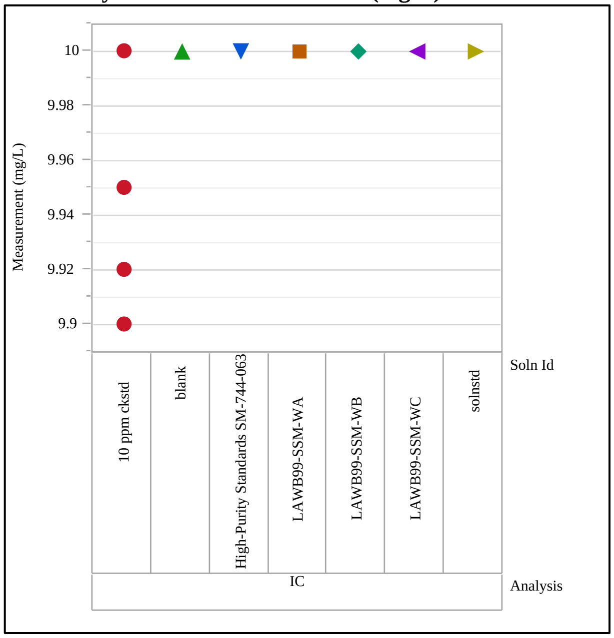


Exhibit B-2. Analysis of Wash Solutions by Solution Identifier (continued)

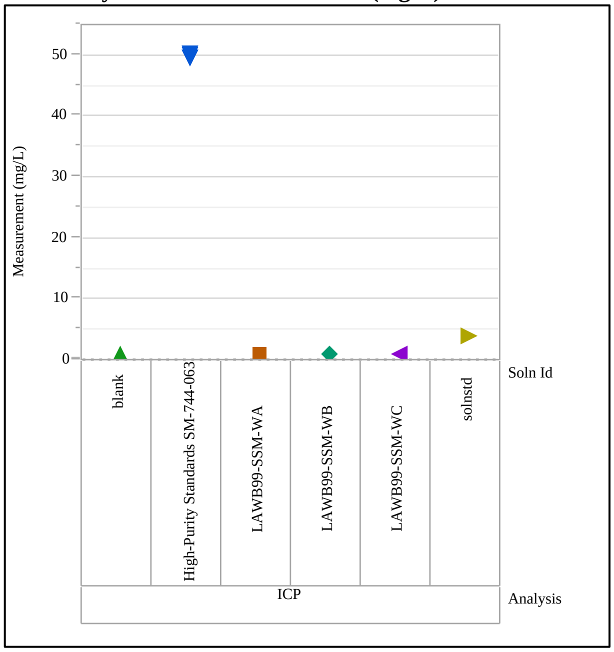
Analyte=Cr (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=F (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Fe (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=K (mg/L)
Variability Chart for Measurement (mg/L)

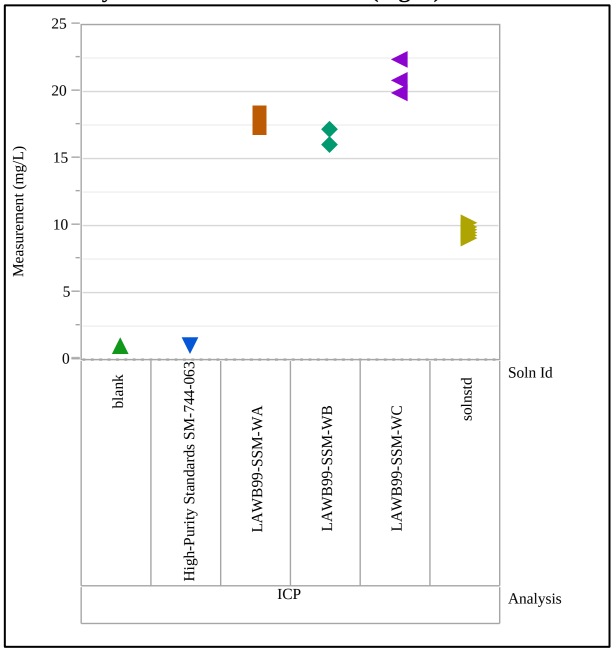
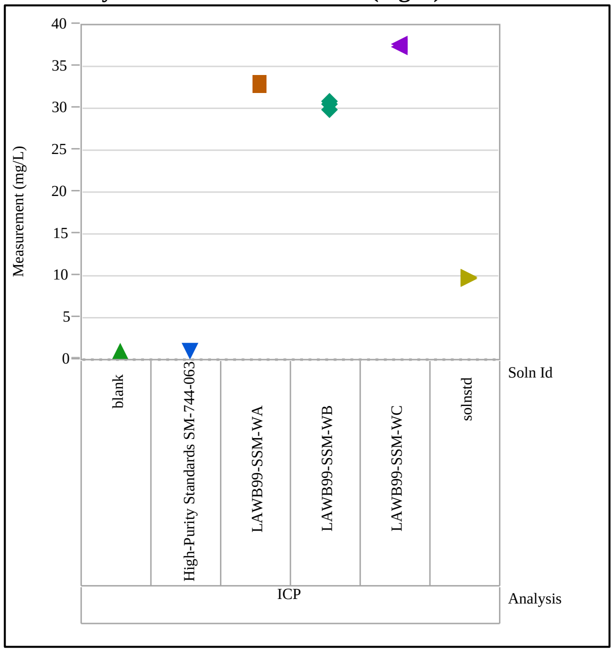
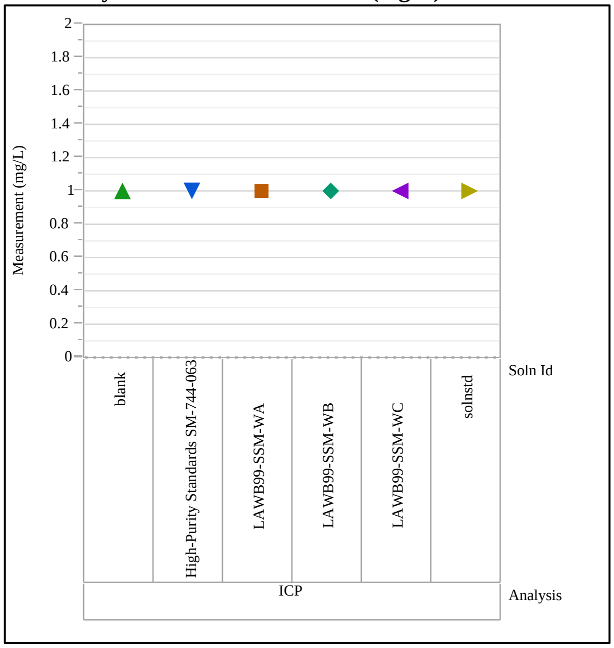


Exhibit B-2. Analysis of Wash Solutions by Solution Identifier (continued)

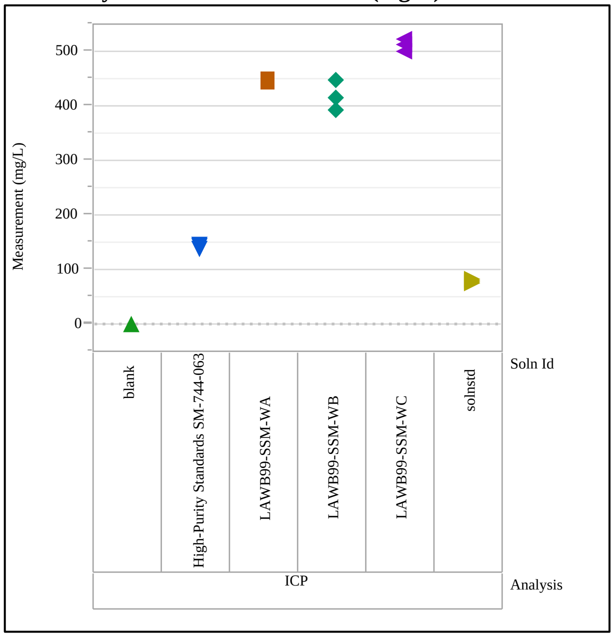
Analyte=Li (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Mg (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Na (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=P (mg/L)
Variability Chart for Measurement (mg/L)

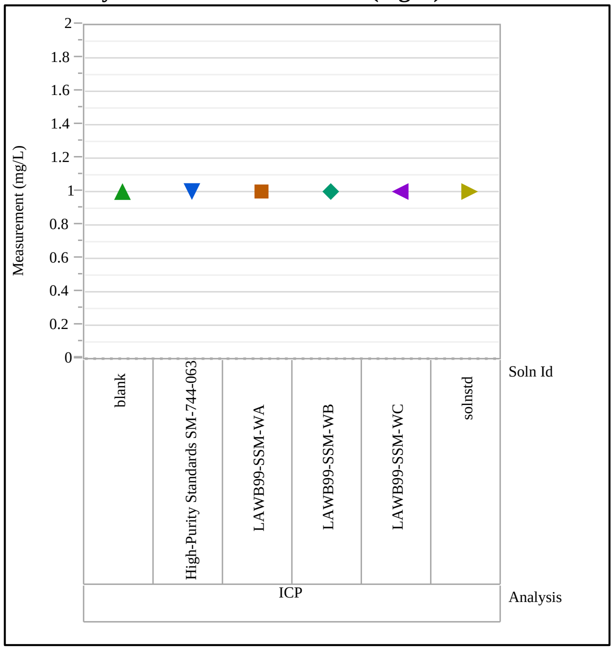
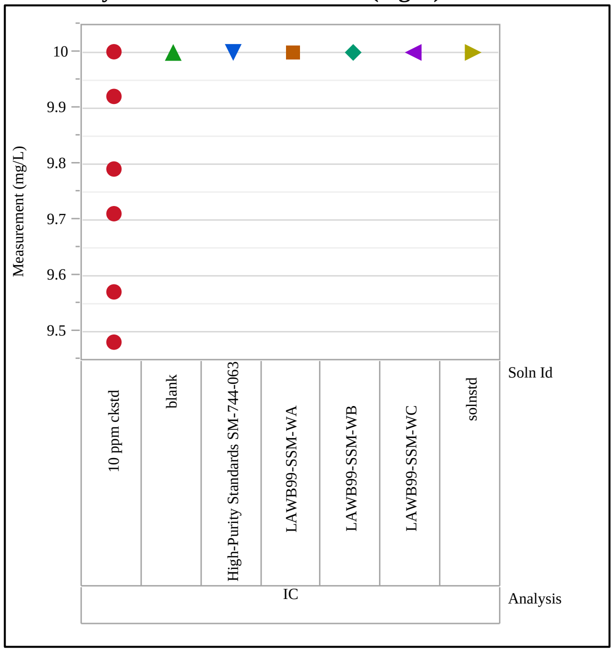
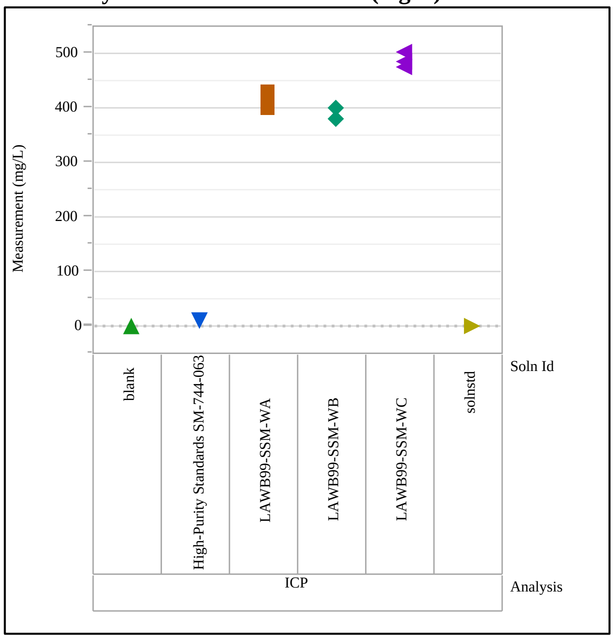


Exhibit B-2. Analysis of Wash Solutions by Solution Identifier (continued)

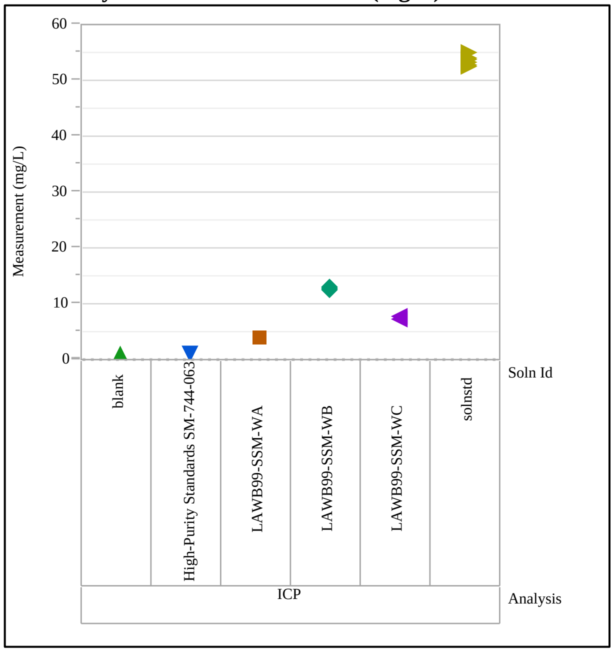
Analyte=PO4 (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=S (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Si (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=SO4 (mg/L)
Variability Chart for Measurement (mg/L)

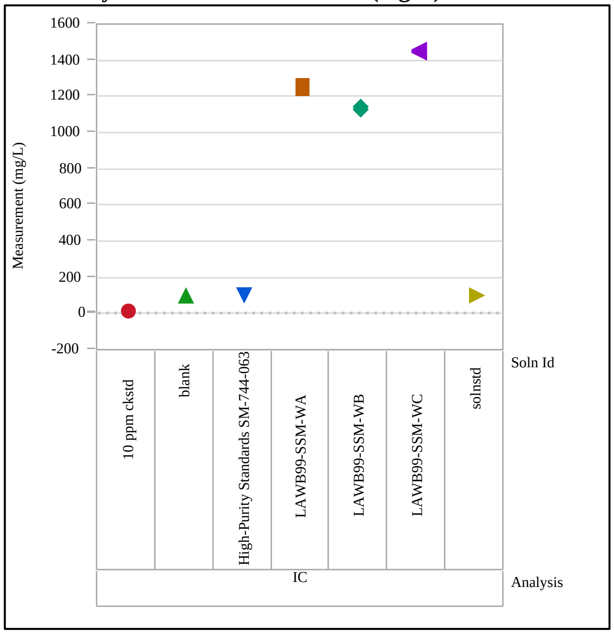
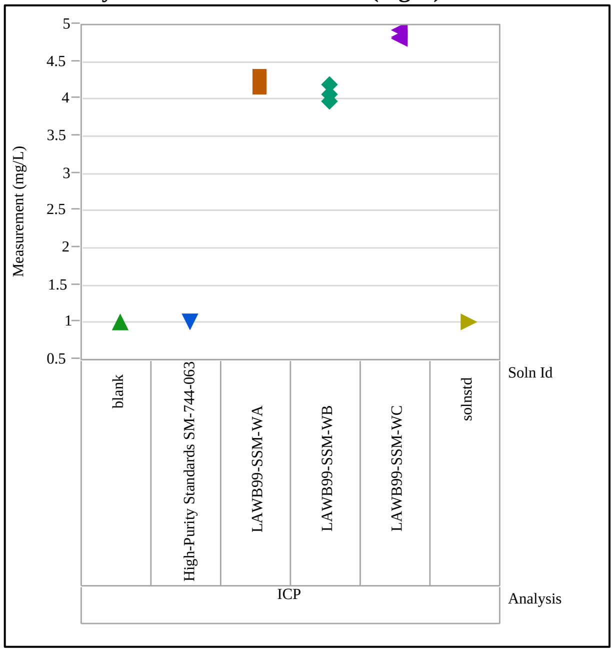
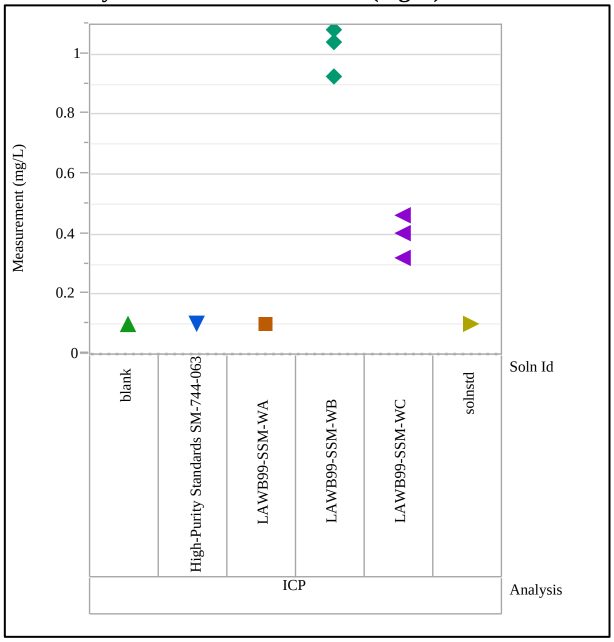


Exhibit B-2. Analysis of Wash Solutions by Solution Identifier (continued)

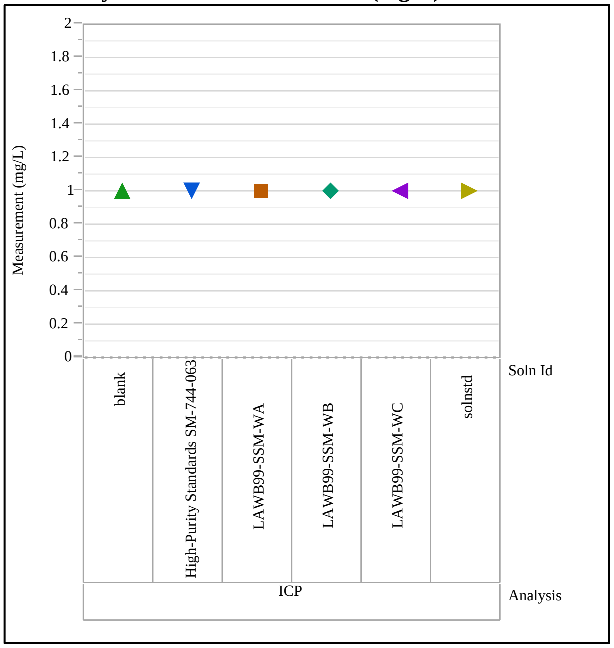
Analyte=V (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Zn (mg/L)
Variability Chart for Measurement (mg/L)



Analyte=Zr (mg/L)
Variability Chart for Measurement (mg/L)



Appendix C Tables and Exhibits Supporting the Chemical Analysis of the ORLEC Glasses

Table C-1. Elemental Measurements (wt%) of the Study Glasses by Preparation Method

Prep	ID	Block	Seq	Lab ID	Al	B	Ca	Cl	Cr	F	Fe	K	Li	Mg	Na	P	S	Si	V	Zn	Zr
LM	LRM	1	1	LRMLM11			0.364		0.124			1.15		<0.100	15.0	0.193	0.081		<0.100	<0.100	0.661
LM	ORLEC-46-SSM-S	1	2	R4LM21			4.89		<0.100			0.363		0.548	12.7	<0.100	0.677		1.24	2.25	2.16
LM	EWG-LAW-SSM-S	1	3	R1LM11			0.369		0.125			1.12		<0.100	13.8	0.191	0.087		<0.100	<0.100	0.666
LM	ORLEC-44-SSM-S	1	4	R5LM11			4.01		<0.100			0.361		0.562	13.2	<0.100	0.660		1.19	2.23	2.18
LM	EWG-LAW-SSM-S	1	5	R1LM21			0.367		0.126			1.11		<0.100	15.2	0.193	0.080		<0.100	<0.100	0.657
LM	ORLEC-44-SSM-S	1	6	R5LM21			4.32		<0.100			0.352		0.556	14.3	<0.100	0.653		1.27	2.38	2.32
LM	LRM	1	7	LRMLM12			0.369		0.124			1.21		<0.100	14.9	0.200	0.080		<0.100	<0.100	0.669
LM	ORLEC-34-SSM-S	1	8	R2LM21			2.89		<0.100			0.361		0.555	15.2	<0.100	0.537		1.16	2.38	2.64
LM	ORLEC-48R-SSM-S	1	9	R3LM21			5.83		<0.100			0.346		0.548	11.1	<0.100	0.739		1.29	2.33	2.27
LM	ORLEC-34-SSM-S	1	10	R2LM11			2.89		<0.100			0.352		0.543	14.4	<0.100	0.514		1.14	2.38	2.46
LM	ORLEC-46-SSM-S	1	11	R4LM11			5.02		<0.100			0.369		0.565	13.4	<0.100	0.727		1.28	2.33	2.27
LM	ORLEC-48R-SSM-S	1	12	R3LM11			5.94		<0.100			0.375		0.554	11.8	<0.100	0.779		1.31	2.38	2.30
LM	LRM	1	13	LRMLM13			0.382		0.130			1.20		<0.100	14.7	0.204	0.090		<0.100	<0.100	0.703
LM	LRM	2	1	LRMLM21			0.378		0.129			1.13		<0.100	15.2	0.205	0.087		<0.100	<0.100	0.674
LM	ORLEC-44-SSM-S	2	2	R5LM12			4.02		<0.100			0.368		0.567	15.0	<0.100	0.659		1.20	2.18	2.19
LM	ORLEC-48R-SSM-S	2	3	R3LM12			5.67		<0.100			0.367		0.557	12.0	<0.100	0.778		1.25	2.22	2.21
LM	ORLEC-34-SSM-S	2	4	R2LM12			2.79		<0.100			0.381		0.555	15.5	<0.100	0.533		1.10	2.23	2.36
LM	ORLEC-44-SSM-S	2	5	R5LM22			4.10		<0.100			0.368		0.561	14.0	<0.100	0.661		1.21	2.20	2.23
LM	ORLEC-48R-SSM-S	2	6	R3LM22			5.62		<0.100			0.362		0.555	13.0	<0.100	0.764		1.24	2.18	2.22
LM	LRM	2	7	LRMLM22			0.375		0.128			1.14		<0.100	15.6	0.206	0.082		<0.100	<0.100	0.681
LM	ORLEC-34-SSM-S	2	8	R2LM22			2.77		<0.100			0.368		0.547	16.1	<0.100	0.535		1.12	2.23	2.58
LM	ORLEC-46-SSM-S	2	9	R4LM22			4.79		<0.100			0.372		0.548	13.4	<0.100	0.696		1.23	2.19	2.17
LM	EWG-LAW-SSM-S	2	10	R1LM22			0.373		0.131			1.16		<0.100	14.7	0.204	0.087		<0.100	<0.100	0.673
LM	EWG-LAW-SSM-S	2	11	R1LM12			0.391		0.135			1.15		<0.100	14.6	0.213	0.087		<0.100	<0.100	0.703
LM	ORLEC-46-SSM-S	2	12	R4LM12			4.97		<0.100			0.377		0.571	14.0	<0.100	0.736		1.27	2.25	2.28
LM	LRM	2	13	LRMLM23			0.390		0.136			1.15		<0.100	15.7	0.216	0.085		<0.100	<0.100	0.714
PF	LRM	1	1	LRMPF11	4.81	2.37					0.931		<0.100					24.9			
PF	ORLEC-34-SSM-S	1	2	R2PF11	4.41	3.41					0.150		<0.100					19.1			
PF	EWG-LAW-SSM-S	1	3	R1PF21	5.22	2.52					1.01		<0.100					24.5			
PF	ORLEC-46-SSM-S	1	4	R4PF21	3.82	3.49					0.118		0.757					18.1			
PF	ORLEC-34-SSM-S	1	5	R2PF21	4.29	3.40					0.125		<0.100					18.4			
PF	ORLEC-44-SSM-S	1	6	R5PF11	3.86	3.37					0.117		0.419					18.7			
PF	LRM	1	7	LRMPF12	5.09	2.39					0.978		<0.100					24.3			
PF	ORLEC-48R-SSM-S	1	8	R3PF11	3.79	3.15					0.122		1.05					19.5			
PF	ORLEC-48R-SSM-S	1	9	R3PF21	3.71	3.07					0.130		1.02					19.3			
PF	ORLEC-44-SSM-S	1	10	R5PF21	3.72	3.01					0.109		0.404					19.8			
PF	ORLEC-46-SSM-S	1	11	R4PF11	3.69	3.11					0.118		0.740					20.1			
PF	EWG-LAW-SSM-S	1	12	R1PF11	4.79	2.02					0.926		<0.100					25.1			

Table C-1. Elemental Measurements (wt%) of the Study Glasses by Preparation Method (continued)

Prep	ID	Block	Seq	Lab ID	Al	B	Ca	Cl	Cr	F	Fe	K	Li	Mg	Na	P	S	Si	V	Zn	Zr
PF	LRM	1	13	LRMPF13	4.73	2.39					0.904		<0.100					25.8			
PF	LRM	2	1	LRMPF21	5.01	2.42					1.00		0.138					23.8			
PF	ORLEC-46-SSM-S	2	2	R4PF12	3.73	3.16					0.168		0.788					19.0			
PF	ORLEC-34-SSM-S	2	3	R2PF22	4.05	3.03					0.164		0.128					19.9			
PF	EWG-LAW-SSM-S	2	4	R1PF12	4.80	2.20					0.962		0.136					24.6			
PF	ORLEC-44-SSM-S	2	5	R5PF12	3.57	2.95					0.157		0.443					21.8			
PF	ORLEC-44-SSM-S	2	6	R5PF22	3.56	2.85					0.149		0.429					20.9			
PF	LRM	2	7	LRMPF22	4.67	2.07					0.923		0.135					27.7			
PF	ORLEC-48R-SSM-S	2	8	R3PF22	3.89	3.35					0.186		1.08					20.7			
PF	ORLEC-34-SSM-S	2	9	R2PF12	4.35	3.27					0.189		0.127					20.8			
PF	EWG-LAW-SSM-S	2	10	R1PF22	5.17	2.43					1.03		0.134					26.3			
PF	ORLEC-46-SSM-S	2	11	R4PF22	3.94	3.36					0.170		0.812					20.8			
PF	ORLEC-48R-SSM-S	2	12	R3PF12	3.97	3.46					0.175		1.11					19.7			
PF	LRM	2	13	LRMPF23	5.06	2.34					1.00		0.137					25.6			
KH	LRM	1	1	LRMKH11				<0.050		0.825											
KH	ORLEC-48R-SSM-S	1	2	R3KH21				0.056		0.066											
KH	ORLEC-34-SSM-S	1	3	R2KH21				0.058		0.066											
KH	ORLEC-44-SSM-S	1	4	R5KH21				<0.050		0.073											
KH	EWG-LAW-SSM-S	1	5	R1KH11				<0.050		0.854											
KH	ORLEC-44-SSM-S	1	6	R5KH11				<0.050		0.084											
KH	LRM	1	7	LRMKH12				<0.050		0.843											
KH	ORLEC-34-SSM-S	1	8	R2KH11				0.052		0.086											
KH	EWG-LAW-SSM-S	1	9	R1KH21				<0.050		0.853											
KH	ORLEC-46-SSM-S	1	10	R4KH11				0.059		0.067											
KH	ORLEC-48R-SSM-S	1	11	R3KH11				0.052		0.078											
KH	ORLEC-46-SSM-S	1	12	R4KH21				0.058		0.070											
KH	LRM	1	13	LRMKH13				<0.050		0.840											
KH	LRM	2	1	LRMKH21				<0.050		0.838											
KH	ORLEC-34-SSM-S	2	2	R2KH12				0.054		0.084											
KH	ORLEC-48R-SSM-S	2	3	R3KH22				0.053		0.081											
KH	ORLEC-46-SSM-S	2	4	R4KH22				0.058		0.071											
KH	ORLEC-34-SSM-S	2	5	R2KH22				0.056		0.079											
KH	ORLEC-48R-SSM-S	2	6	R3KH12				0.051		0.082											
KH	LRM	2	7	LRMKH22				<0.050		0.829											
KH	EWG-LAW-SSM-S	2	8	R1KH12				<0.050		0.849											
KH	ORLEC-44-SSM-S	2	9	R5KH22				<0.050		0.084											
KH	ORLEC-44-SSM-S	2	10	R5KH12				<0.050		0.083											
KH	EWG-LAW-SSM-S	2	11	R1KH22				<0.050		0.833											
KH	ORLEC-46-SSM-S	2	12	R4KH12				0.055		0.076											
KH	LRM	2	13	LRMKH23				<0.050		0.835											

Table C-2. Comparison of Measured versus Targeted Compositions for the ORLEC Glasses

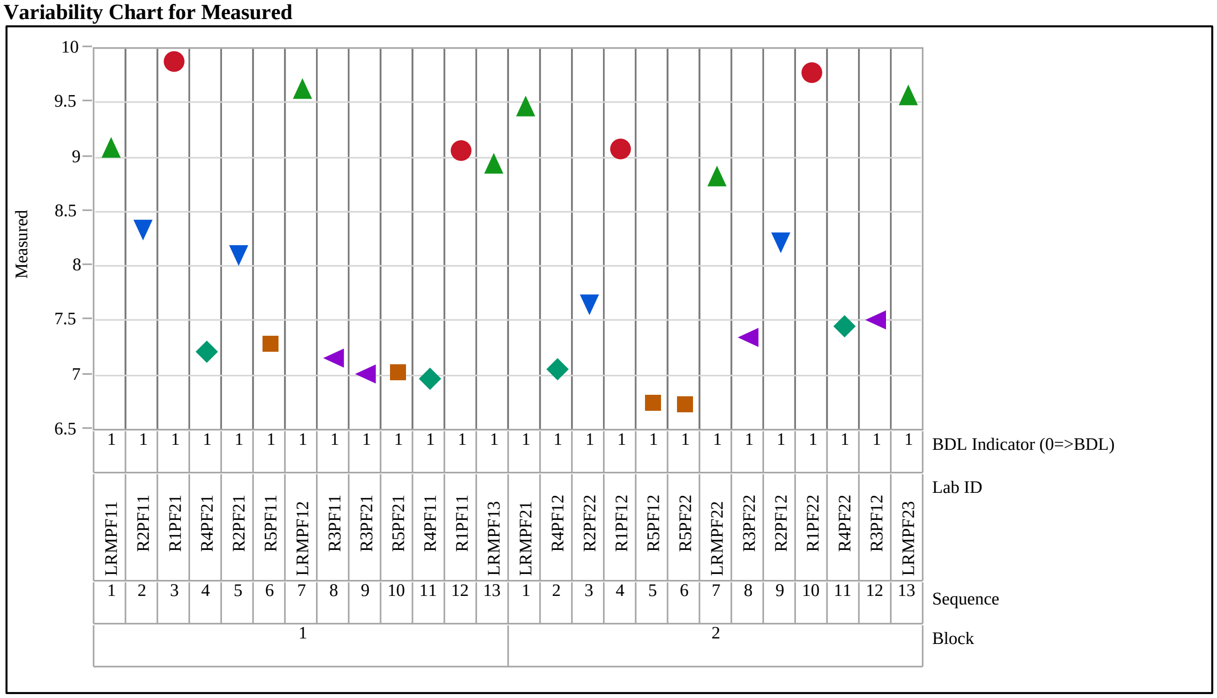
Glass ID	Oxide	BDL (<)	Measured (wt %)	Targeted (wt %)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
EWG-LAW-SSM-S	Al_2O_3		9.438	9.510	-0.072	-0.8%
EWG-LAW-SSM-S	B_2O_3		7.382	7.850	-0.468	-6.0%
EWG-LAW-SSM-S	CaO		0.525	0.540	-0.015	
EWG-LAW-SSM-S	Cl	<	0.050	0.000	0.050	
EWG-LAW-SSM-S	Cr_2O_3		0.189	0.190	-0.001	
EWG-LAW-SSM-S	F		0.847	0.860	-0.013	
EWG-LAW-SSM-S	Fe_2O_3		1.404	1.380	0.024	
EWG-LAW-SSM-S	K_2O		1.367	1.480	-0.113	
EWG-LAW-SSM-S	Li_2O	<	0.253	0.110	0.143	
EWG-LAW-SSM-S	MgO	<	0.166	0.100	0.066	
EWG-LAW-SSM-S	Na_2O		19.647	20.030	-0.383	-1.9%
EWG-LAW-SSM-S	P_2O_5		0.459	0.540	-0.081	
EWG-LAW-SSM-S	SiO_2		53.750	54.200	-0.450	-0.8%
EWG-LAW-SSM-S	SO_3		0.213	0.300	-0.087	
EWG-LAW-SSM-S	V_2O_5	<	0.179	0.000	0.179	
EWG-LAW-SSM-S	ZnO	<	0.124	0.000	0.124	
EWG-LAW-SSM-S	ZrO_2		0.911	0.930	-0.019	
EWG-LAW-SSM-S	Sum		97.031	98.020	-0.989	-1.0%
LRM	Al_2O_3		9.249	9.510	-0.261	-2.7%
LRM	B_2O_3		7.502	7.850	-0.348	-4.4%
LRM	CaO		0.527	0.540	-0.013	
LRM	Cl	<	0.050	0.000	0.050	
LRM	Cr_2O_3		0.188	0.190	-0.002	
LRM	F		0.835	0.860	-0.025	
LRM	Fe_2O_3		1.367	1.380	-0.013	
LRM	K_2O		1.401	1.480	-0.079	
LRM	Li_2O	<	0.255	0.110	0.145	
LRM	MgO	<	0.166	0.100	0.066	
LRM	Na_2O		20.467	20.030	0.437	2.2%
LRM	P_2O_5		0.467	0.540	-0.073	
LRM	SiO_2		54.231	54.200	0.031	0.1%
LRM	SO_3		0.210	0.300	-0.090	
LRM	V_2O_5	<	0.179	0.000	0.179	
LRM	ZnO	<	0.124	0.000	0.124	
LRM	ZrO_2		0.923	0.930	-0.007	
LRM	Sum		98.269	98.020	0.249	0.3%
ORLEC-34-SSM-S	Al_2O_3		8.078	8.360	-0.282	-3.4%
ORLEC-34-SSM-S	B_2O_3		10.553	11.000	-0.447	-4.1%
ORLEC-34-SSM-S	CaO		3.967	3.640	0.327	
ORLEC-34-SSM-S	Cl		0.055	0.200	-0.145	
ORLEC-34-SSM-S	Cr_2O_3	<	0.146	0.080	0.066	
ORLEC-34-SSM-S	F		0.079	0.000	0.079	
ORLEC-34-SSM-S	Fe_2O_3		0.224	0.200	0.024	
ORLEC-34-SSM-S	K_2O		0.440	0.500	-0.060	
ORLEC-34-SSM-S	Li_2O	<	0.245	0.000	0.245	
ORLEC-34-SSM-S	MgO		0.912	1.000	-0.088	
ORLEC-34-SSM-S	Na_2O		20.624	22.000	-1.376	-6.3%
ORLEC-34-SSM-S	P_2O_5	<	0.229	0.124	0.105	
ORLEC-34-SSM-S	SiO_2		41.823	42.407	-0.584	-1.4%
ORLEC-34-SSM-S	SO_3		1.323	1.095	0.228	
ORLEC-34-SSM-S	V_2O_5		2.017	2.267	-0.250	
ORLEC-34-SSM-S	ZnO		2.869	3.000	-0.131	
ORLEC-34-SSM-S	ZrO_2		3.391	4.030	-0.639	
ORLEC-34-SSM-S	Sum		97.103	99.903	-2.800	-2.8%

Table C-2. Comparison of Measured versus Targeted Compositions for the ORLEC Glasses (continued)

Glass ID	Oxide	BDL (<)	Measured (wt %)	Targeted (wt %)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
ORLEC-44-SSM-S	Al_2O_3		6.949	7.600	-0.651	-8.6%
ORLEC-44-SSM-S	B_2O_3		9.805	11.000	-1.195	-10.9%
ORLEC-44-SSM-S	CaO		5.754	5.488	0.266	4.9%
ORLEC-44-SSM-S	Cl	<	0.050	0.200	-0.150	
ORLEC-44-SSM-S	Cr_2O_3	<	0.146	0.080	0.066	
ORLEC-44-SSM-S	F		0.081	0.000	0.081	
ORLEC-44-SSM-S	Fe_2O_3		0.190	0.200	-0.010	
ORLEC-44-SSM-S	K_2O		0.436	0.500	-0.064	
ORLEC-44-SSM-S	Li_2O		0.912	0.993	-0.081	
ORLEC-44-SSM-S	MgO		0.931	1.000	-0.069	
ORLEC-44-SSM-S	Na_2O		19.041	20.000	-0.959	-4.8%
ORLEC-44-SSM-S	P_2O_5	<	0.229	0.124	0.105	
ORLEC-44-SSM-S	SiO_2		43.428	42.527	0.901	2.1%
ORLEC-44-SSM-S	SO_3		1.644	1.249	0.395	
ORLEC-44-SSM-S	V_2O_5		2.173	2.443	-0.270	
ORLEC-44-SSM-S	ZnO		2.798	3.000	-0.202	
ORLEC-44-SSM-S	ZrO_2		3.012	3.500	-0.488	
ORLEC-44-SSM-S	Sum		97.706	99.904	-2.198	-2.2%
ORLEC-46-SSM-S	Al_2O_3		7.171	7.600	-0.429	-5.6%
ORLEC-46-SSM-S	B_2O_3		10.561	11.000	-0.439	-4.0%
ORLEC-46-SSM-S	CaO		6.881	6.940	-0.059	-0.9%
ORLEC-46-SSM-S	Cl		0.058	0.200	-0.143	
ORLEC-46-SSM-S	Cr_2O_3	<	0.146	0.080	0.066	
ORLEC-46-SSM-S	F		0.071	0.000	0.071	
ORLEC-46-SSM-S	Fe_2O_3		0.205	0.200	0.005	
ORLEC-46-SSM-S	K_2O		0.446	0.500	-0.054	
ORLEC-46-SSM-S	Li_2O		1.667	1.864	-0.197	
ORLEC-46-SSM-S	MgO		0.925	1.000	-0.075	
ORLEC-46-SSM-S	Na_2O		18.030	18.000	0.029	0.2%
ORLEC-46-SSM-S	P_2O_5	<	0.229	0.124	0.105	
ORLEC-46-SSM-S	SiO_2		41.716	42.028	-0.312	-0.7%
ORLEC-46-SSM-S	SO_3		1.770	1.370	0.400	
ORLEC-46-SSM-S	V_2O_5		2.240	2.498	-0.258	
ORLEC-46-SSM-S	ZnO		2.807	3.000	-0.193	
ORLEC-46-SSM-S	ZrO_2		2.999	3.500	-0.501	
ORLEC-46-SSM-S	Sum		98.049	99.904	-1.855	-1.9%
ORLEC-48R-SSM-S	Al_2O_3		7.256	7.600	-0.344	-4.5%
ORLEC-48R-SSM-S	B_2O_3		10.489	11.000	-0.511	-4.6%
ORLEC-48R-SSM-S	CaO		8.066	8.140	-0.074	-0.9%
ORLEC-48R-SSM-S	Cl		0.053	0.200	-0.147	
ORLEC-48R-SSM-S	Cr_2O_3	<	0.146	0.080	0.066	
ORLEC-48R-SSM-S	F		0.077	0.000	0.077	
ORLEC-48R-SSM-S	Fe_2O_3		0.219	0.200	0.019	
ORLEC-48R-SSM-S	K_2O		0.437	0.500	-0.063	
ORLEC-48R-SSM-S	Li_2O		2.293	2.584	-0.291	
ORLEC-48R-SSM-S	MgO		0.918	1.000	-0.082	
ORLEC-48R-SSM-S	Na_2O		16.142	16.000	0.142	0.9%
ORLEC-48R-SSM-S	P_2O_5	<	0.229	0.124	0.105	
ORLEC-48R-SSM-S	SiO_2		42.358	42.006	0.352	0.8%
ORLEC-48R-SSM-S	SO_3		1.910	1.470	0.440	
ORLEC-48R-SSM-S	V_2O_5		2.272	2.500	-0.228	
ORLEC-48R-SSM-S	ZnO		2.835	3.000	-0.165	
ORLEC-48R-SSM-S	ZrO_2		3.039	3.500	-0.461	
ORLEC-48R-SSM-S	Sum		98.866	99.904	-1.038	-1.0%

Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence

Analyte=Al2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=B2O3 (wt%), Prep Method=PF
Variability Chart for Measured

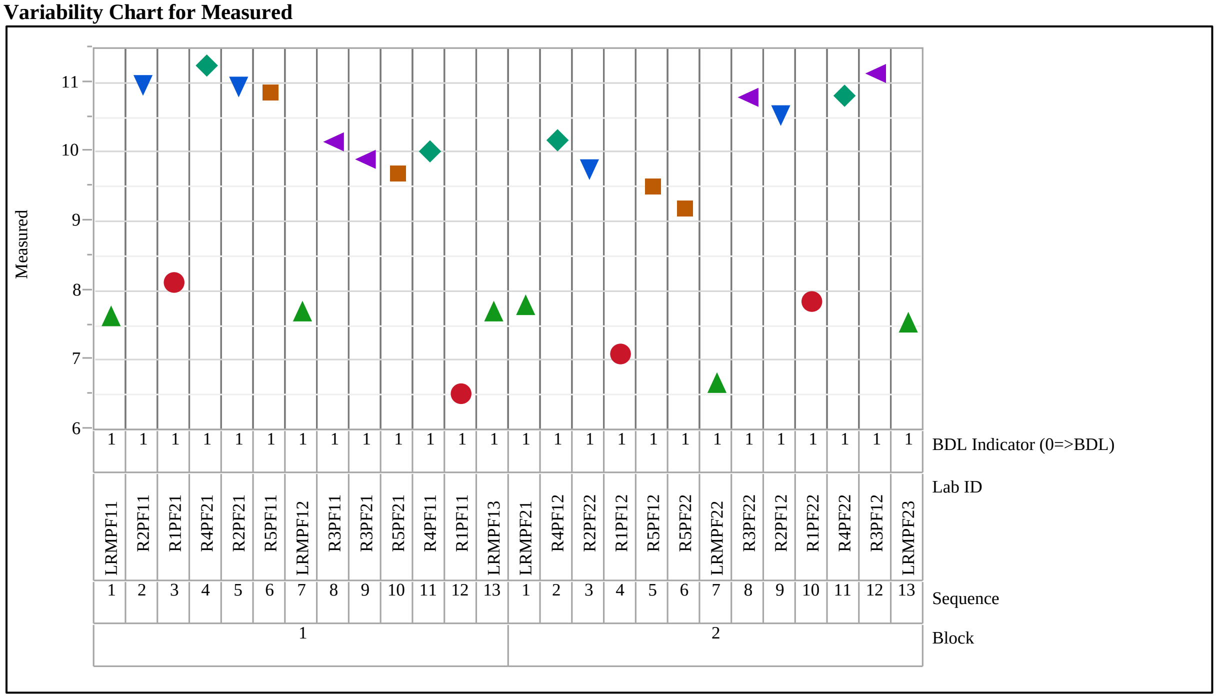
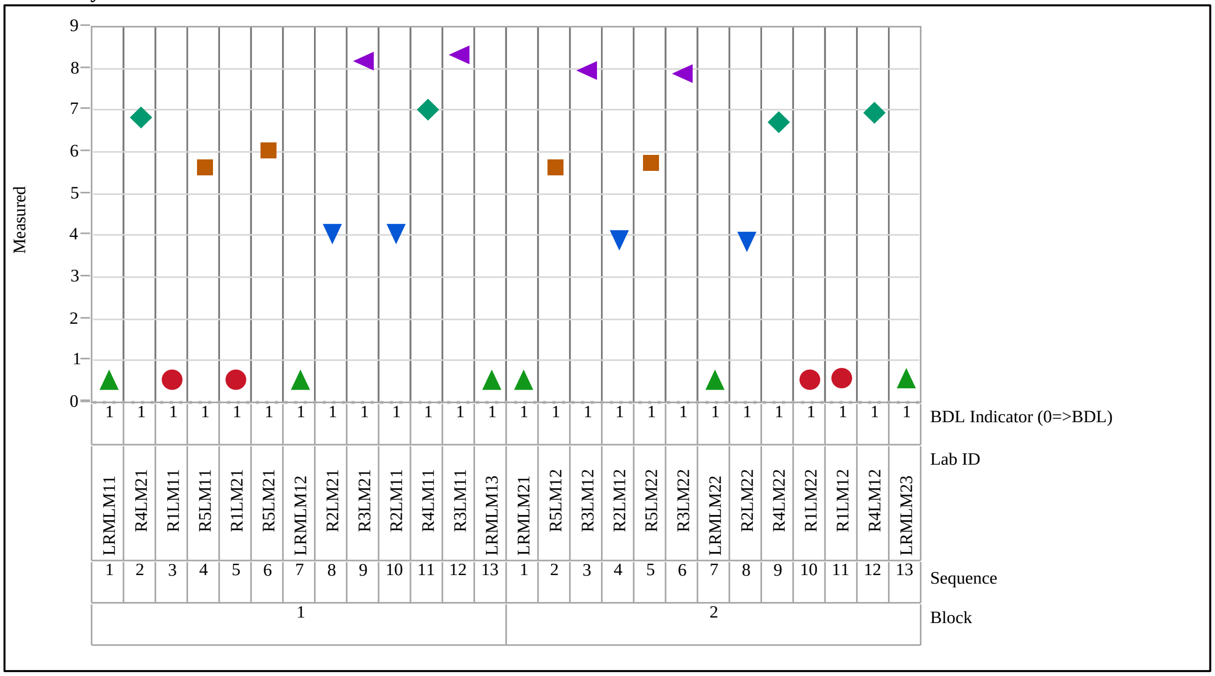


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=CaO (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=Cl (wt%), Prep Method=KH
Variability Chart for Measured

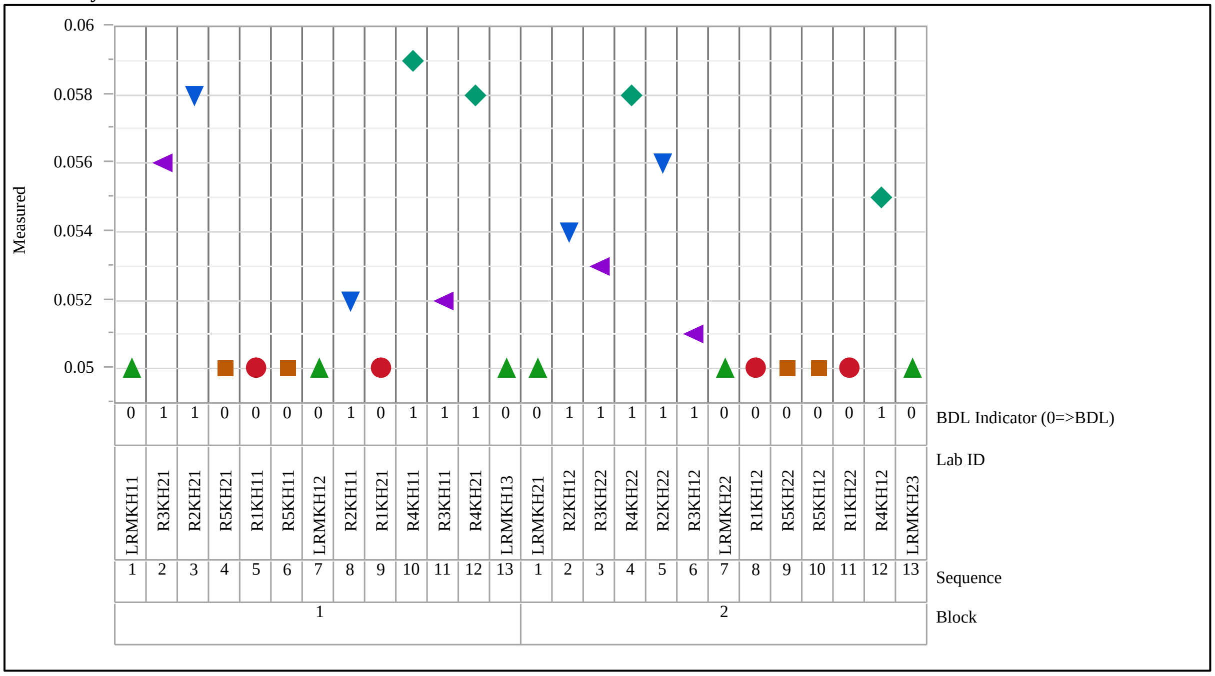
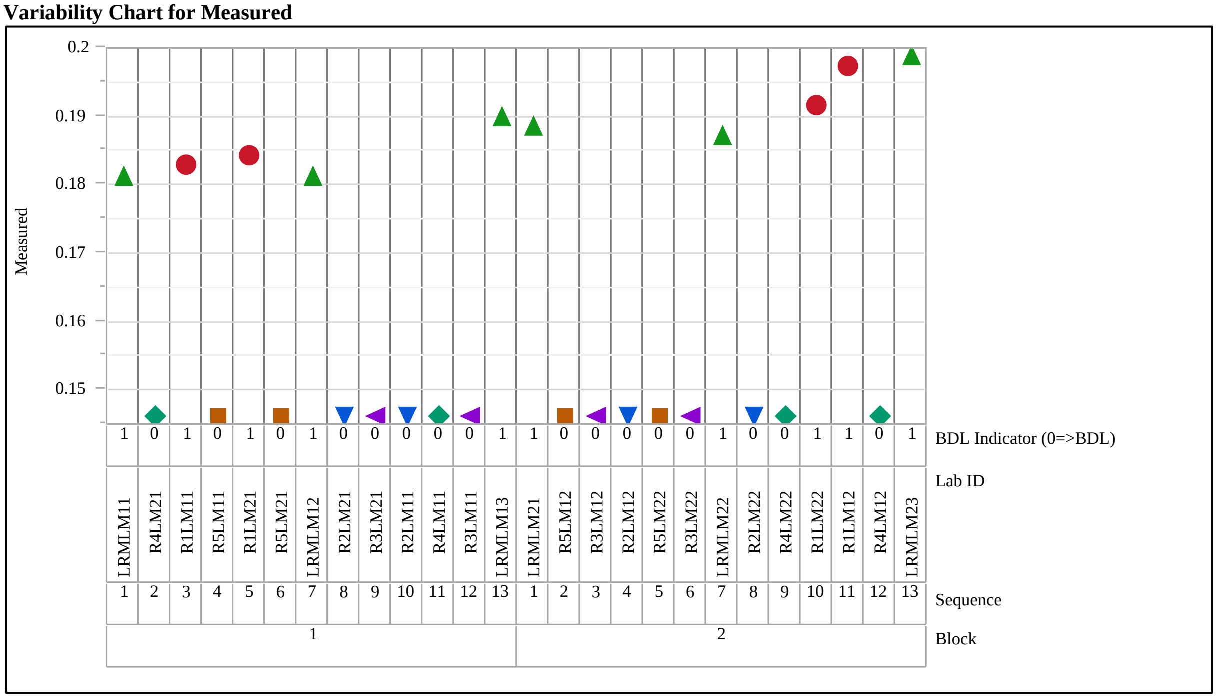


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=Cr2O3 (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=F (wt%), Prep Method=KH
Variability Chart for Measured

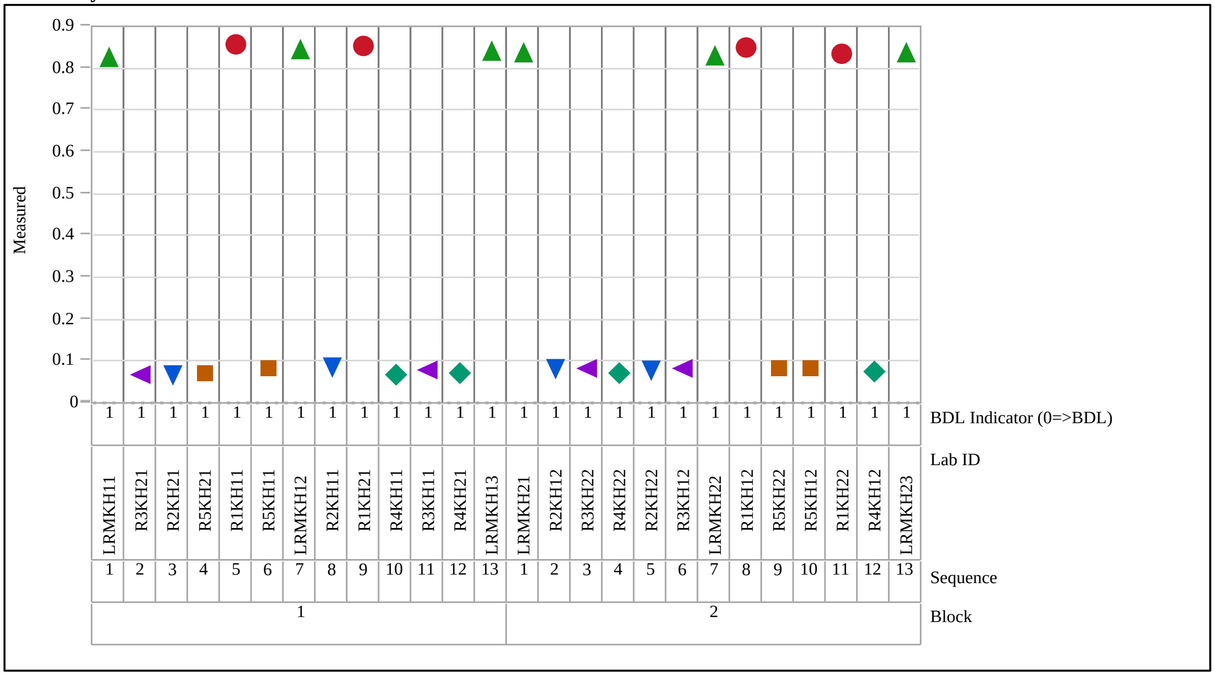
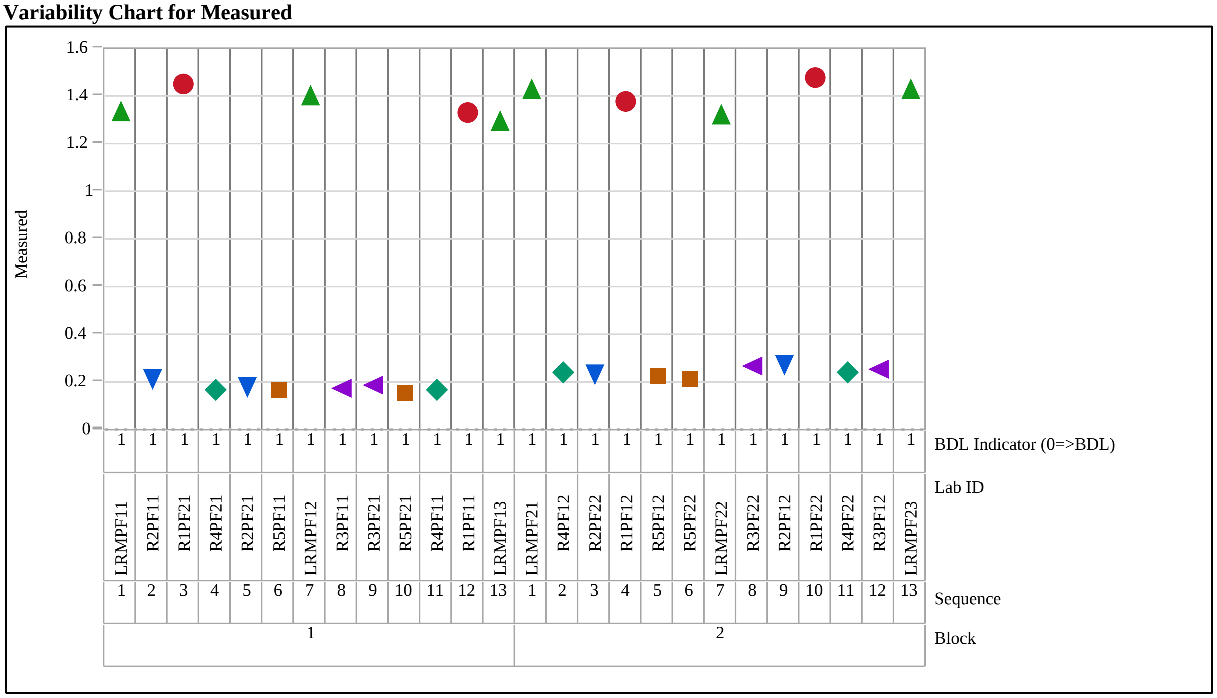


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=Fe2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=K2O (wt%), Prep Method=LM
Variability Chart for Measured

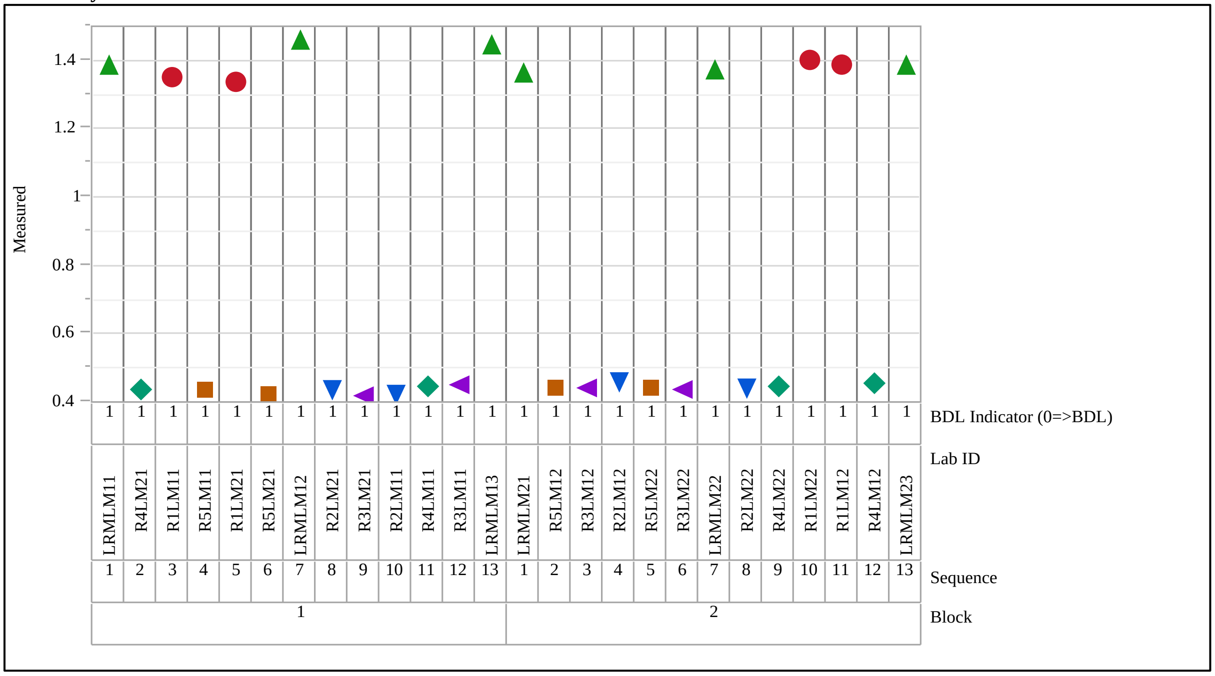
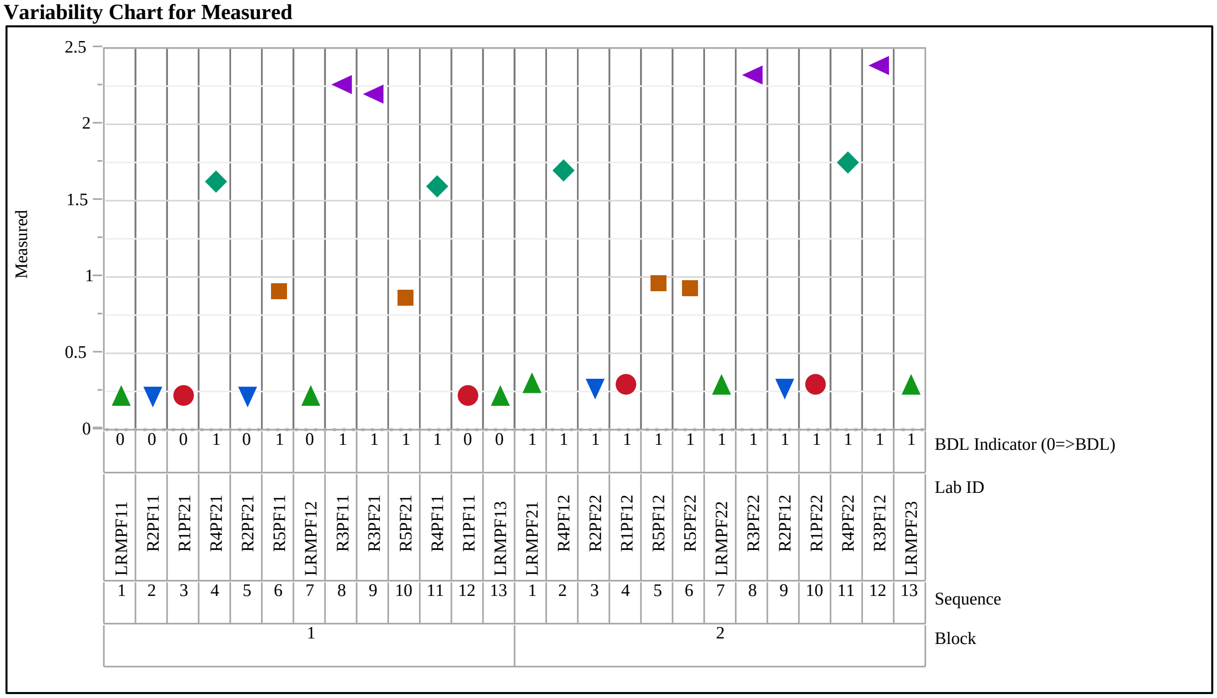


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=Li2O (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=MgO (wt%), Prep Method=LM
Variability Chart for Measured

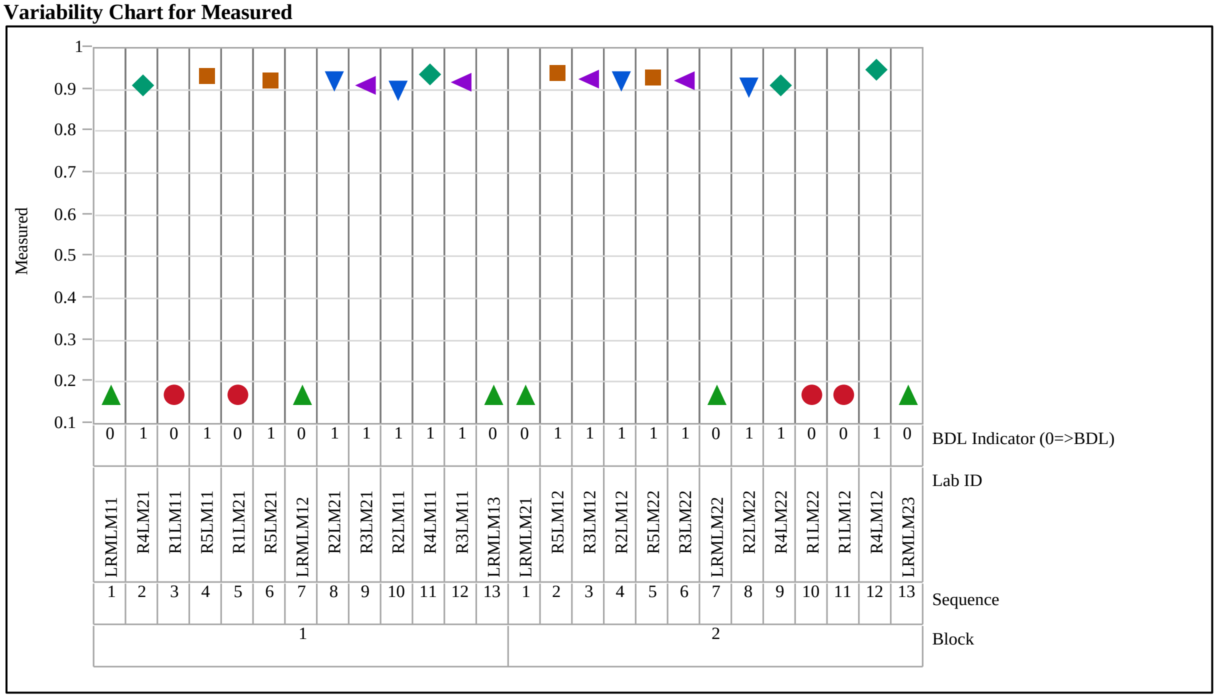
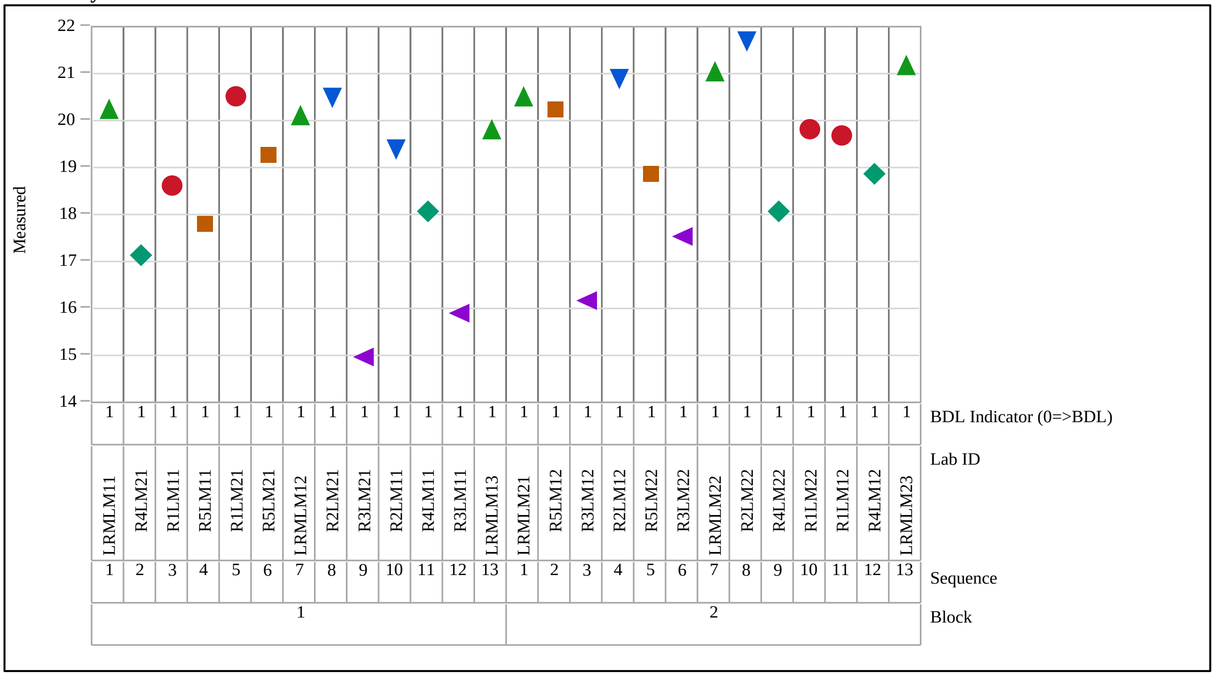


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=Na2O (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=P2O5 (wt%), Prep Method=LM
Variability Chart for Measured

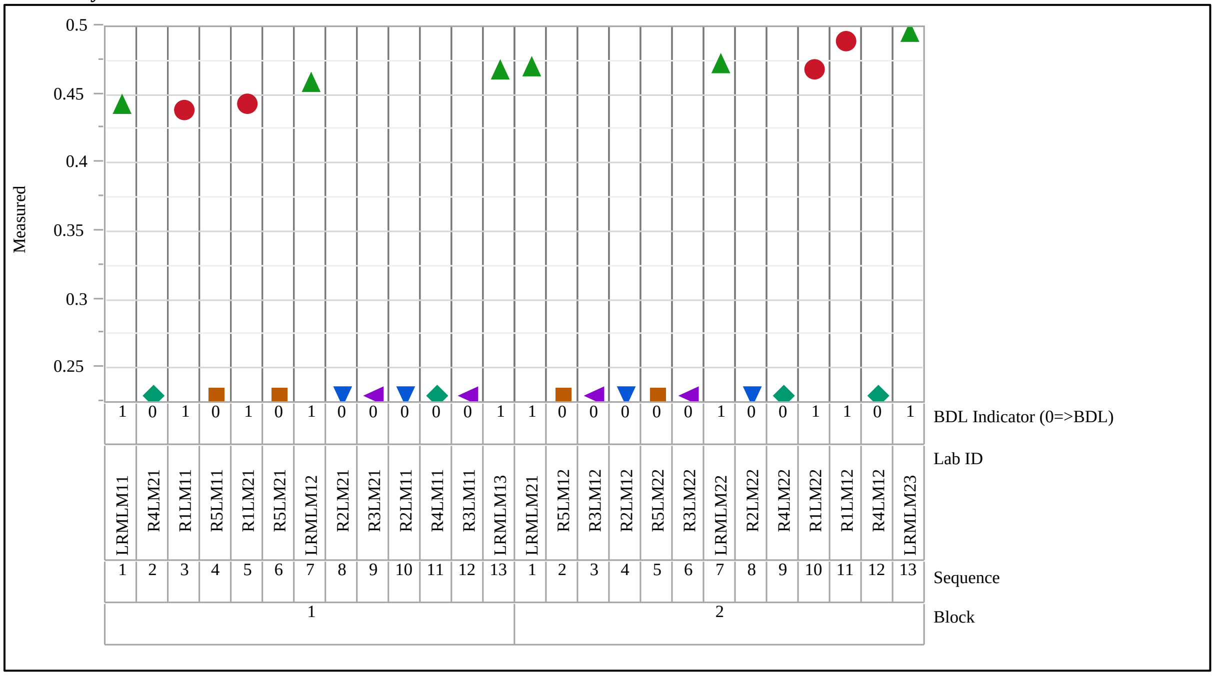
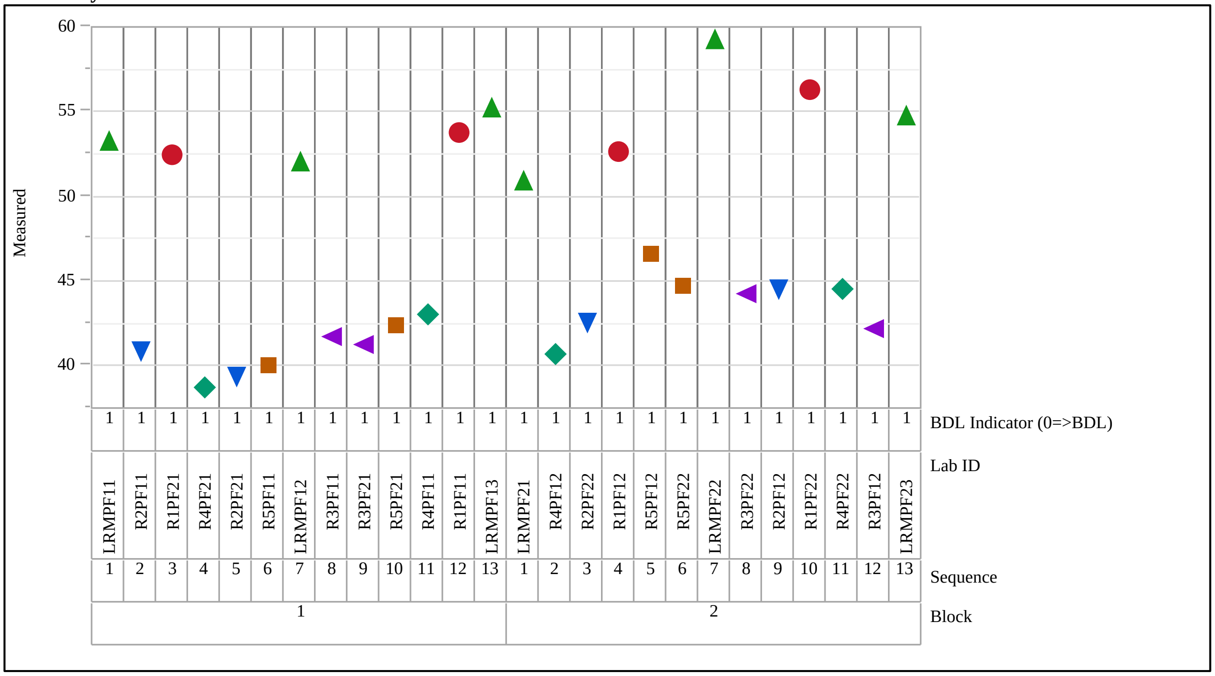


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=SiO2 (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=SO3 (wt%), Prep Method=LM
Variability Chart for Measured

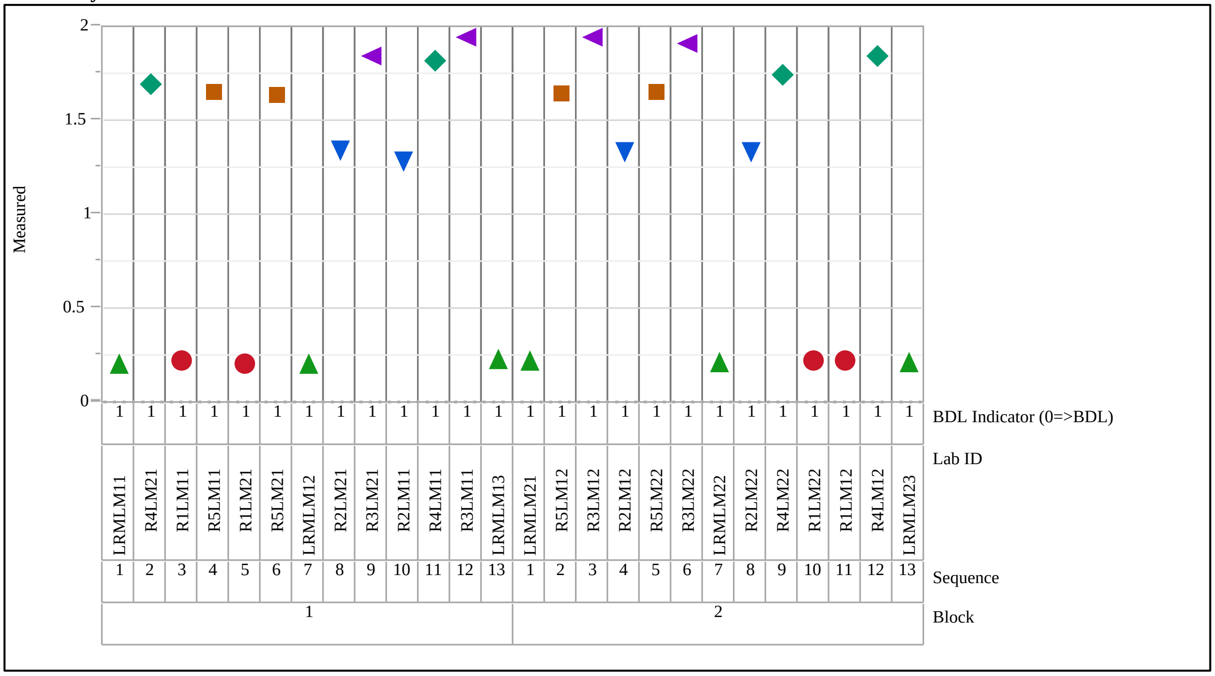
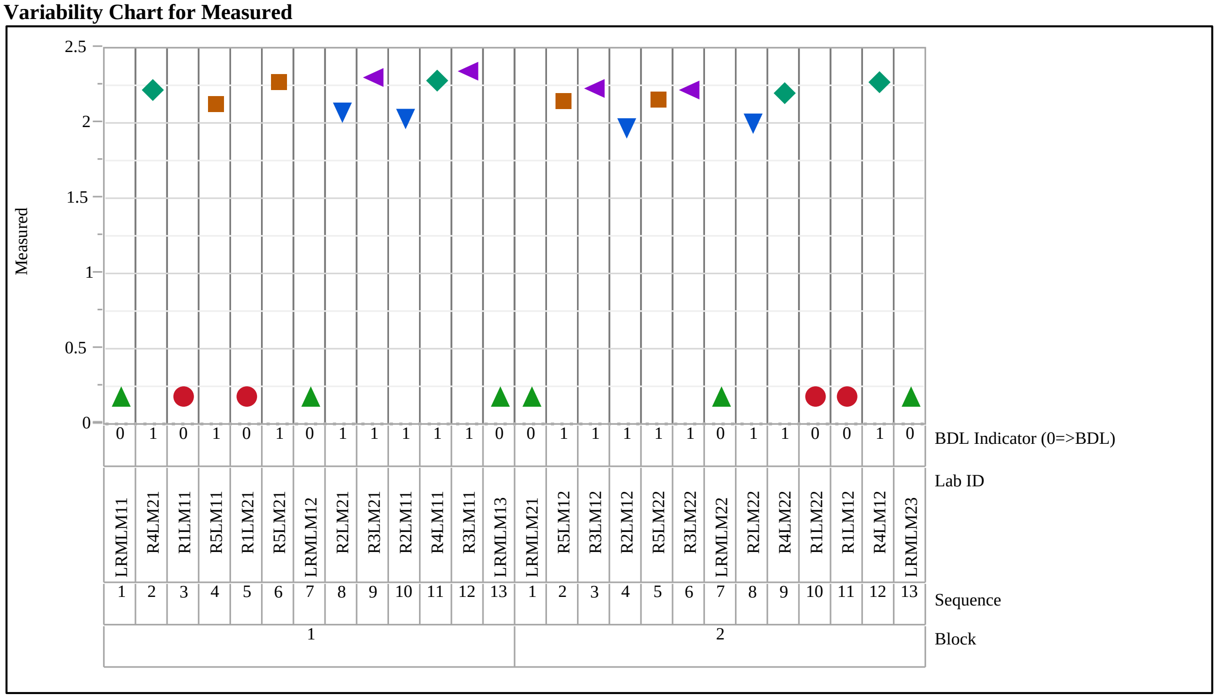


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=V2O5 (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=ZnO (wt%), Prep Method=LM
Variability Chart for Measured

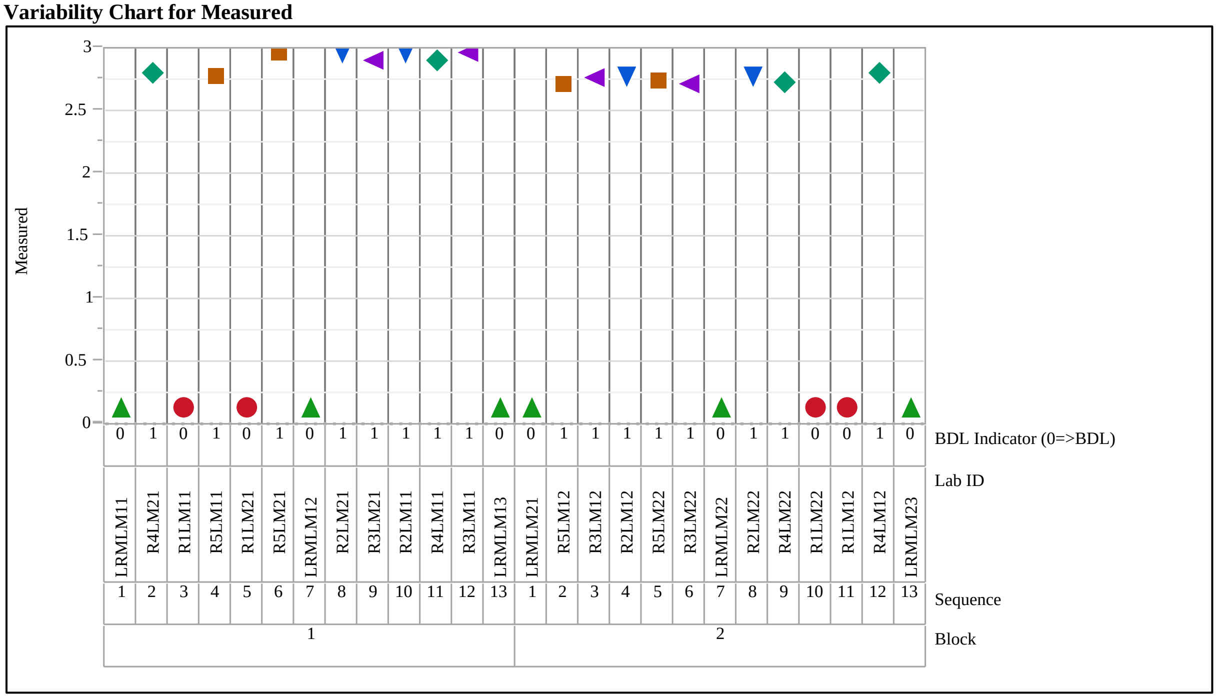


Exhibit C-1. Measurements by Analyte by Preparation Method in Analytical Sequence (continued)

Analyte=ZrO2 (wt%), Prep Method=LM
Variability Chart for Measured

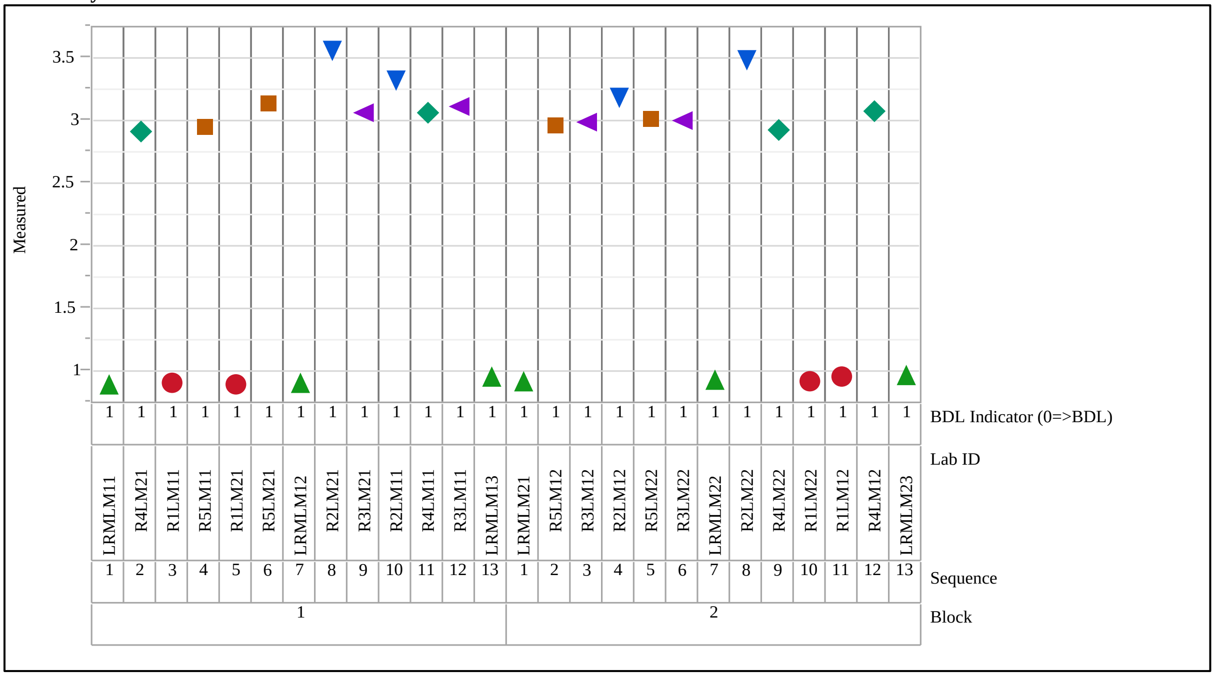
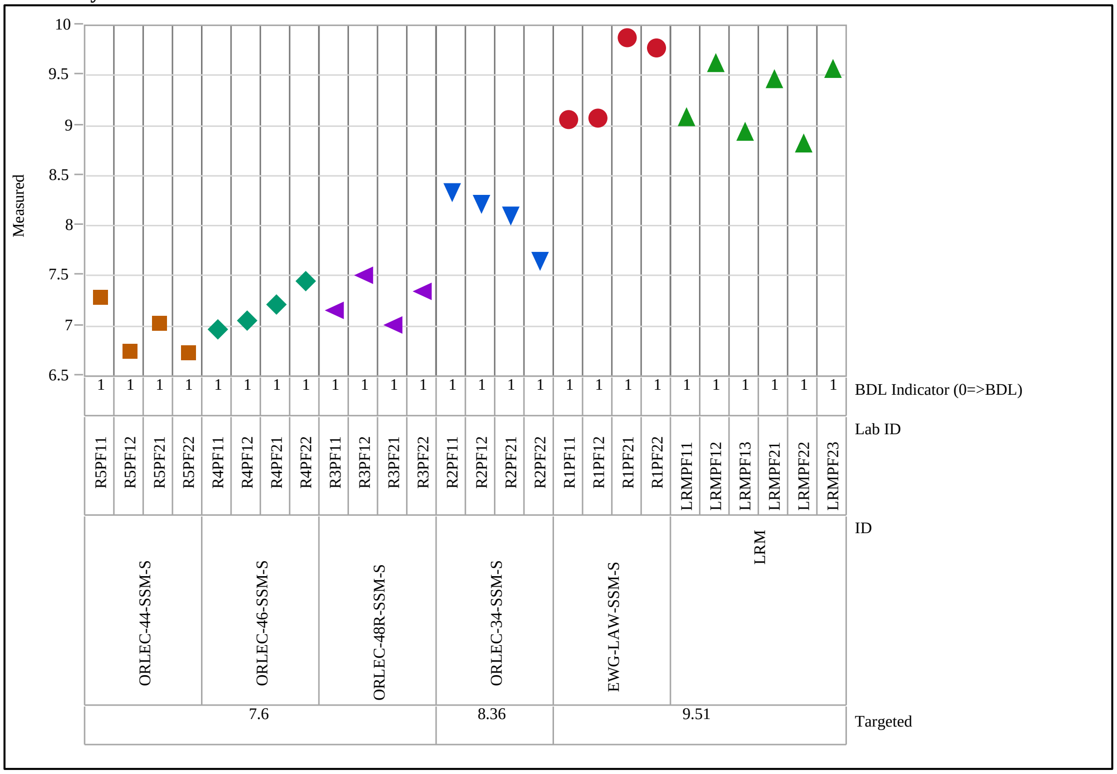


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition

Analyte=Al2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=B2O3 (wt%), Prep Method=PF
Variability Chart for Measured

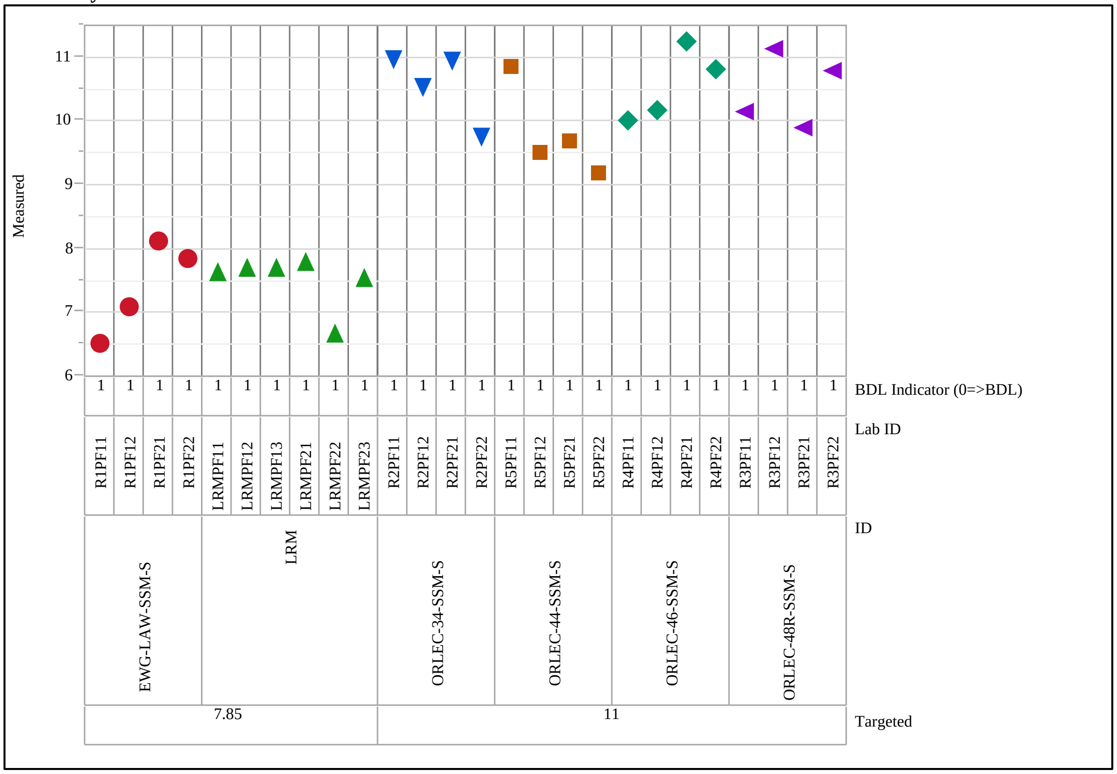
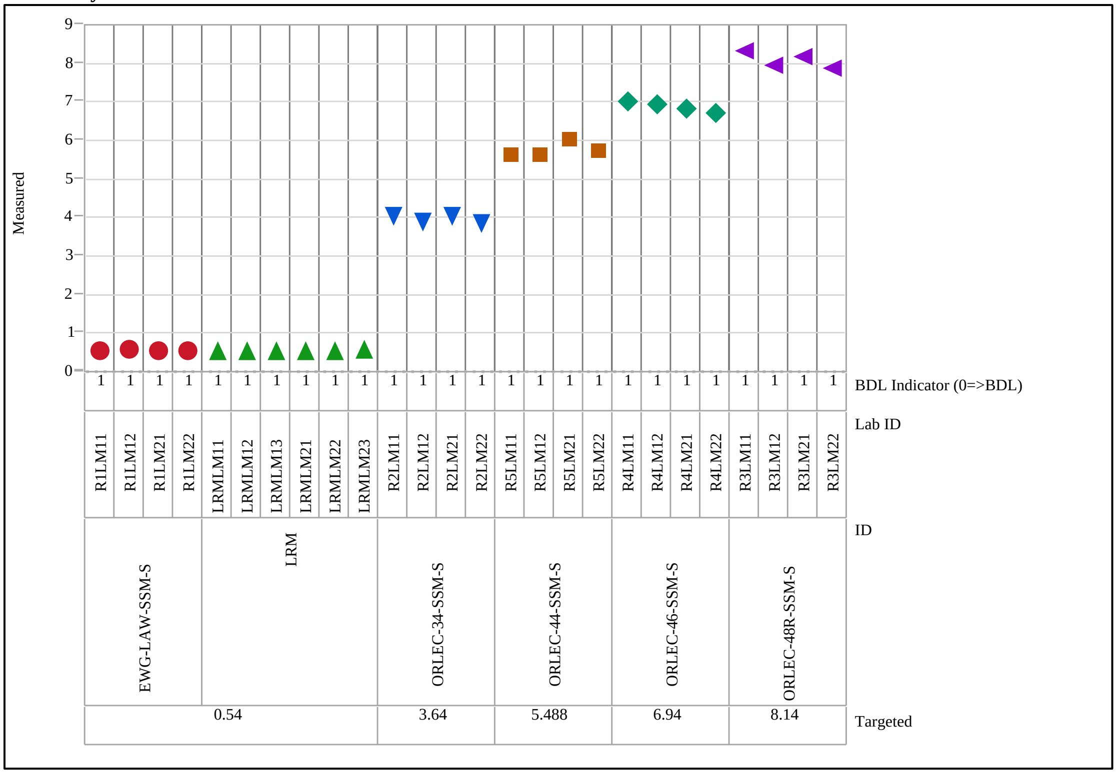


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=CaO (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=Cl (wt%), Prep Method=KH
Variability Chart for Measured

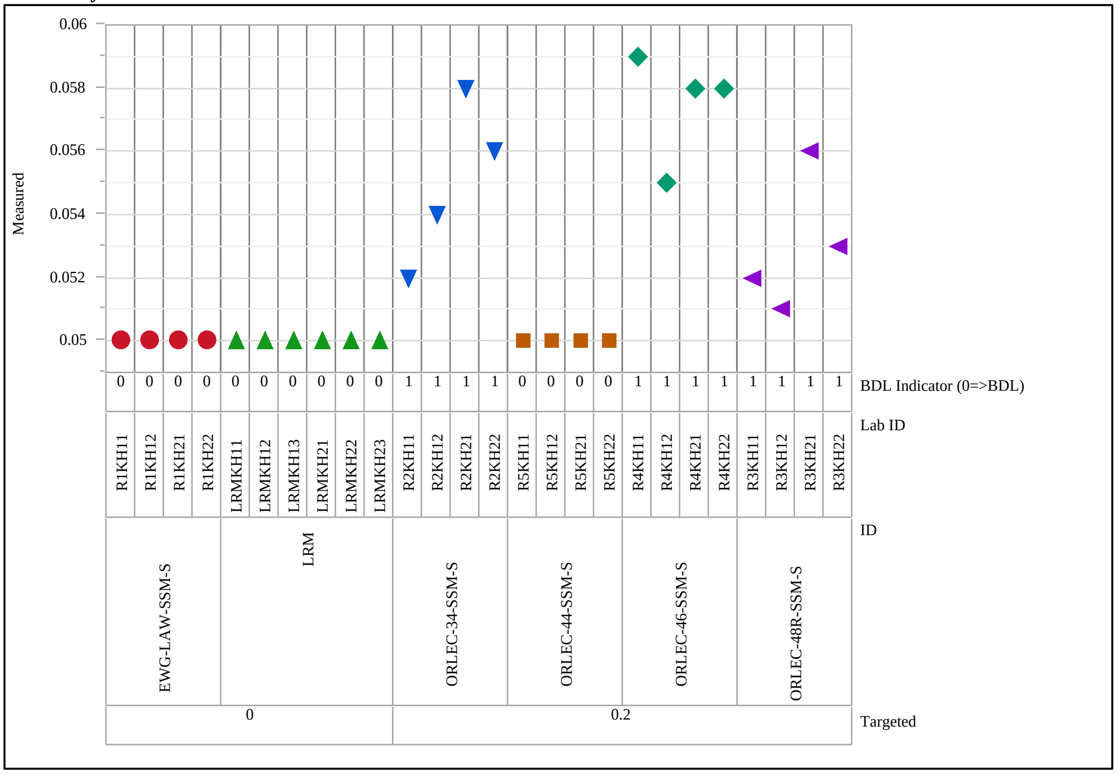
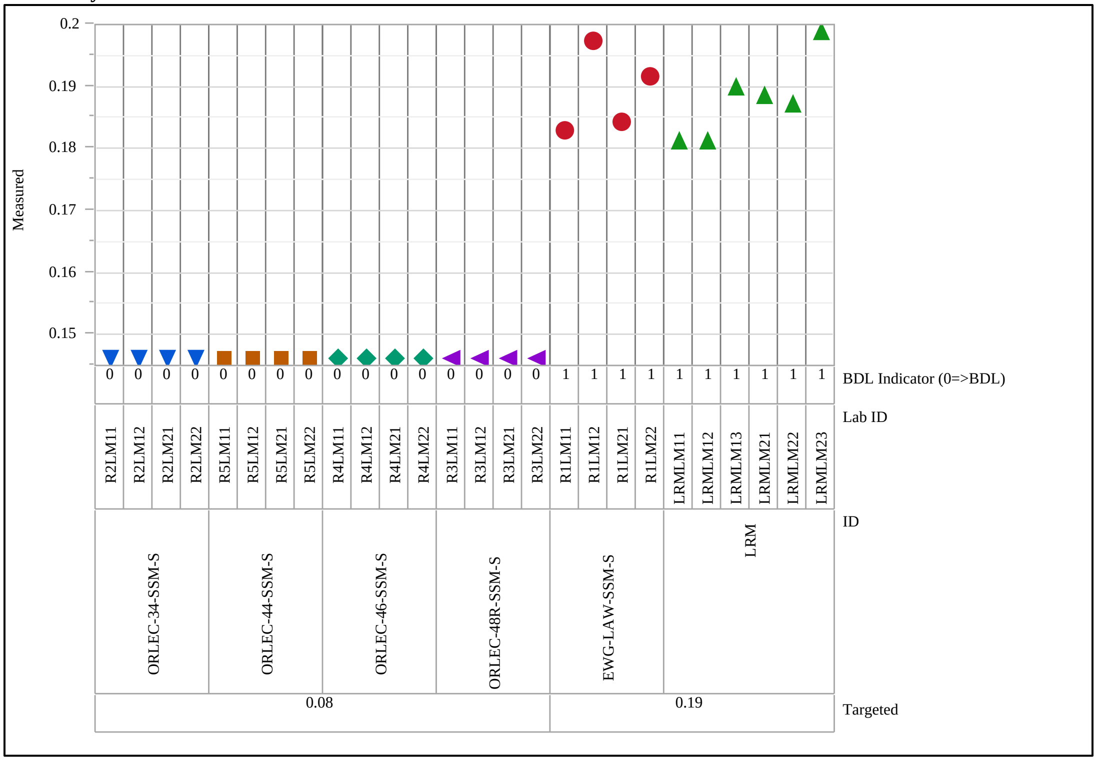


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=Cr2O3 (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=F (wt%), Prep Method=KH
Variability Chart for Measured

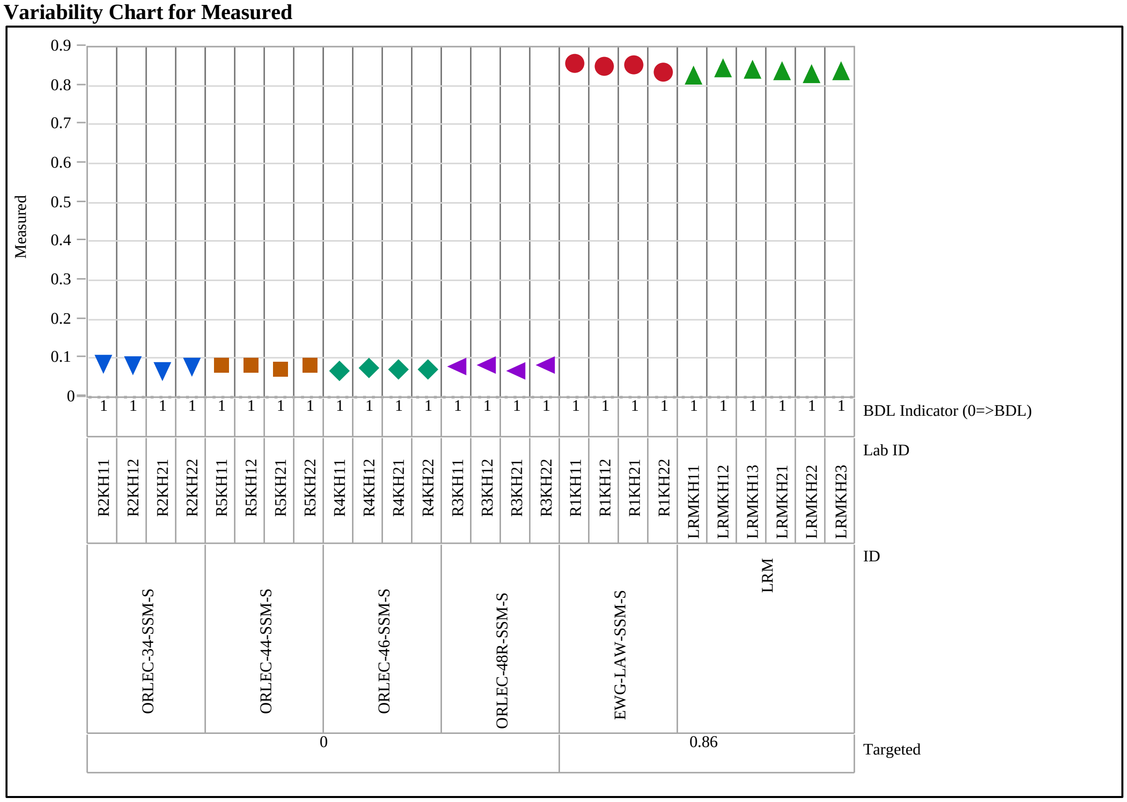
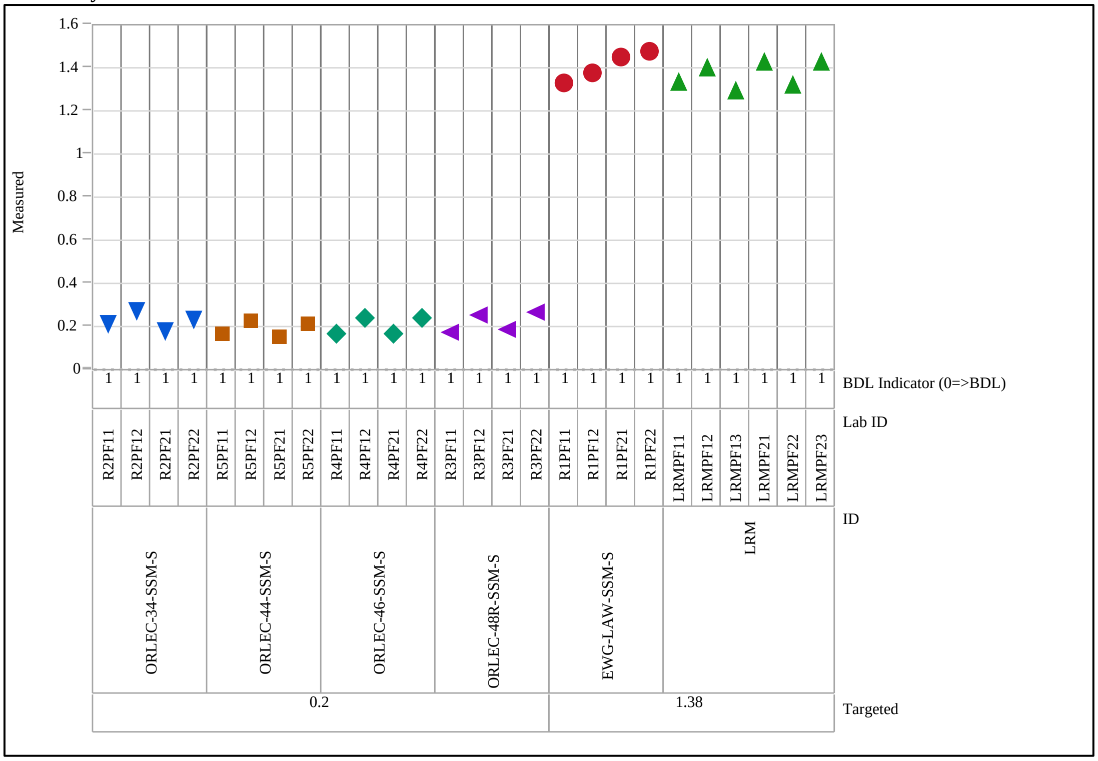


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=Fe2O3 (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=K2O (wt%), Prep Method=LM
Variability Chart for Measured

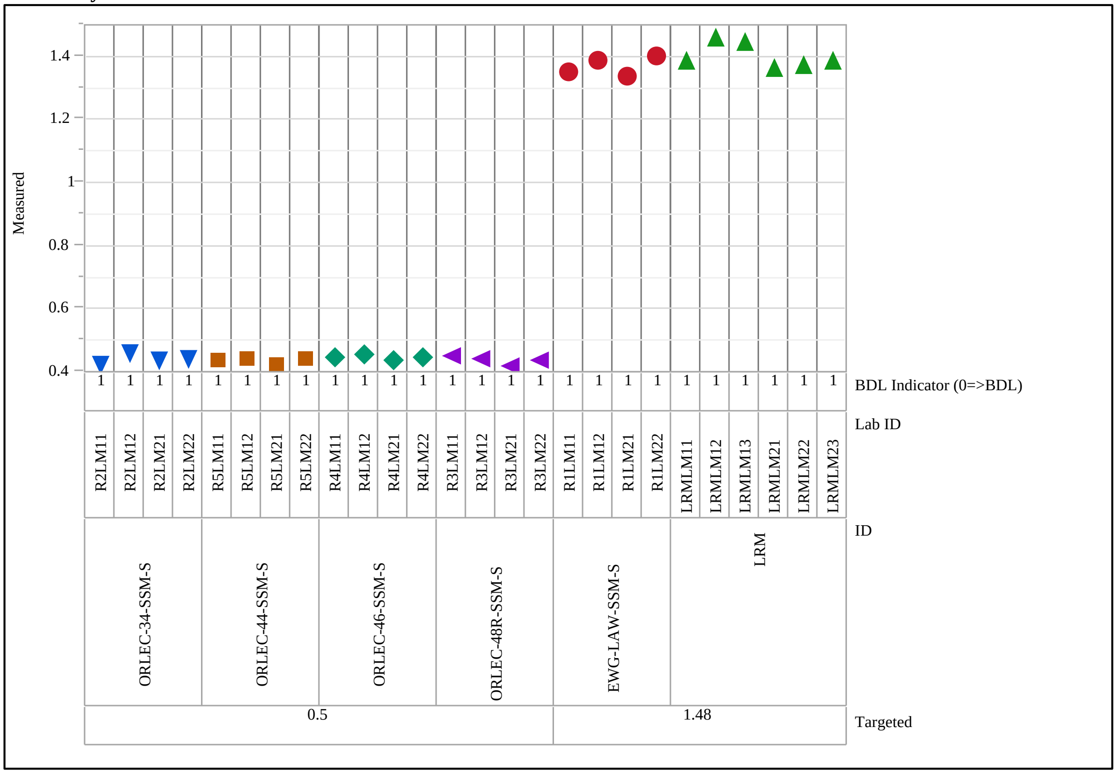
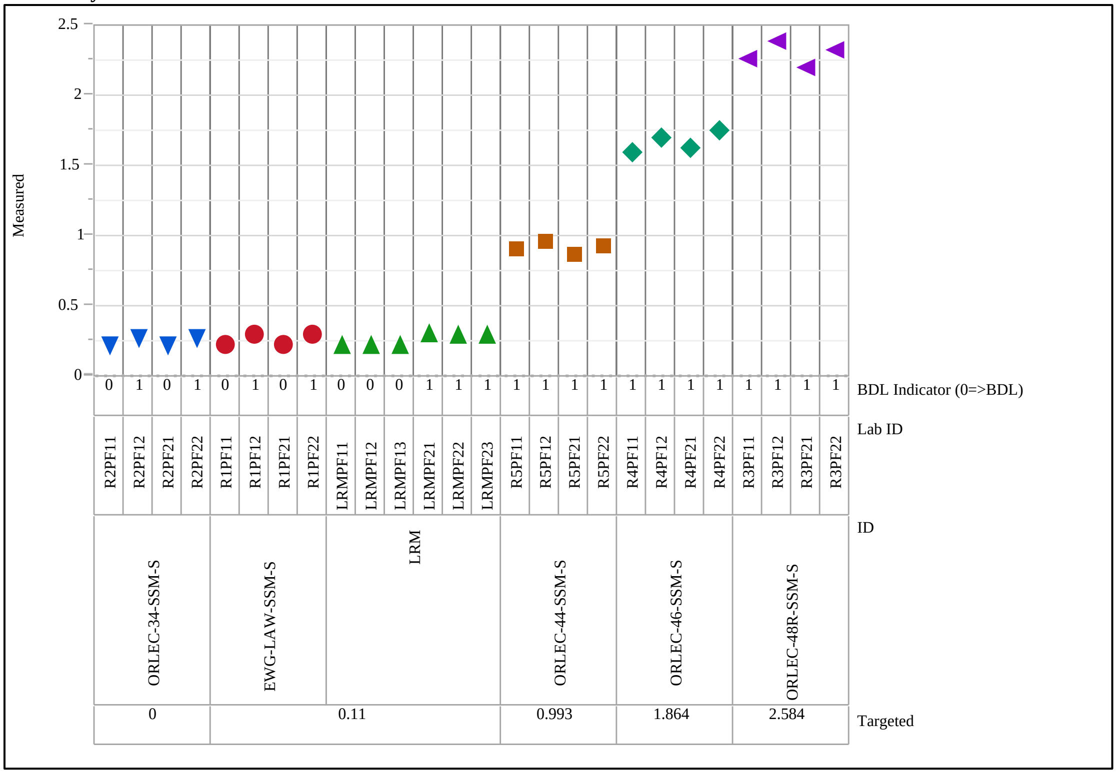


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=Li2O (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=MgO (wt%), Prep Method=LM
Variability Chart for Measured

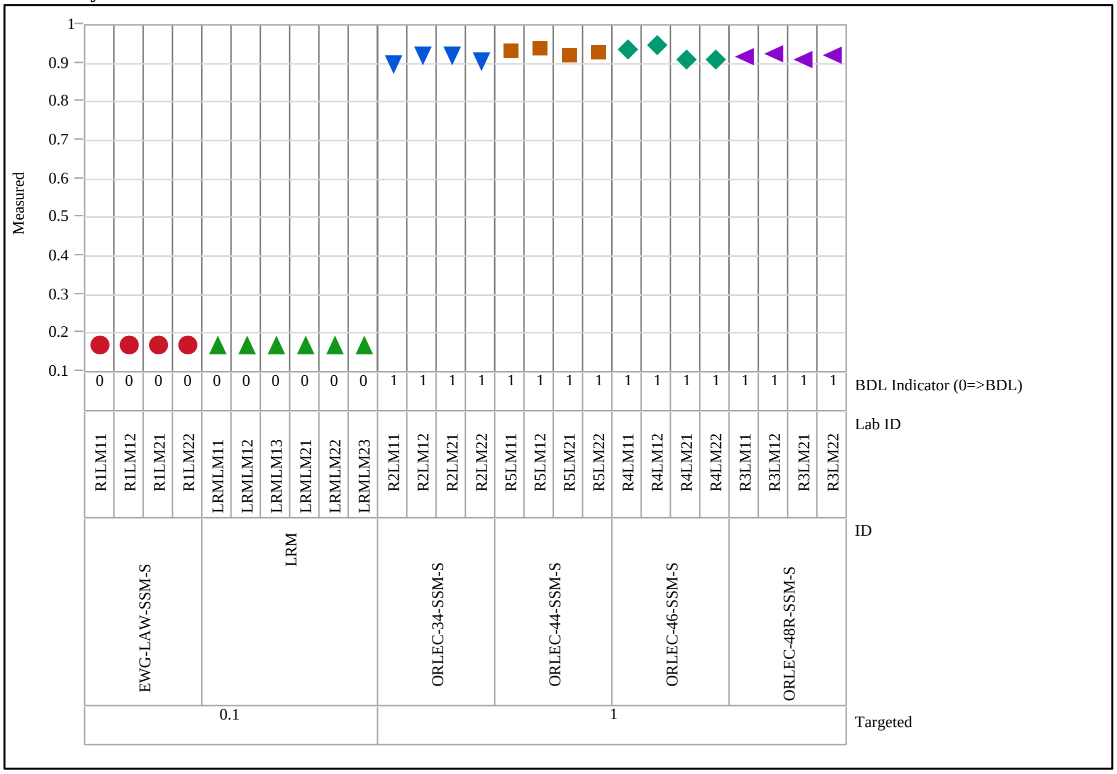
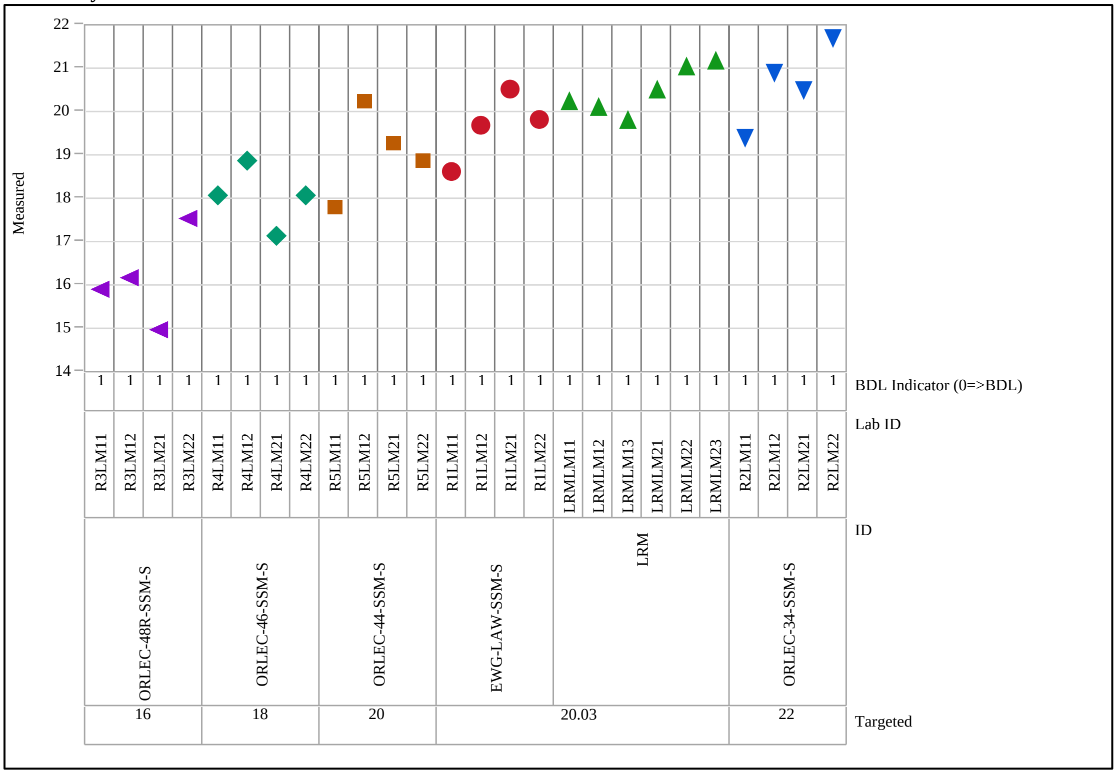


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=Na2O (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=P2O5 (wt%), Prep Method=LM
Variability Chart for Measured

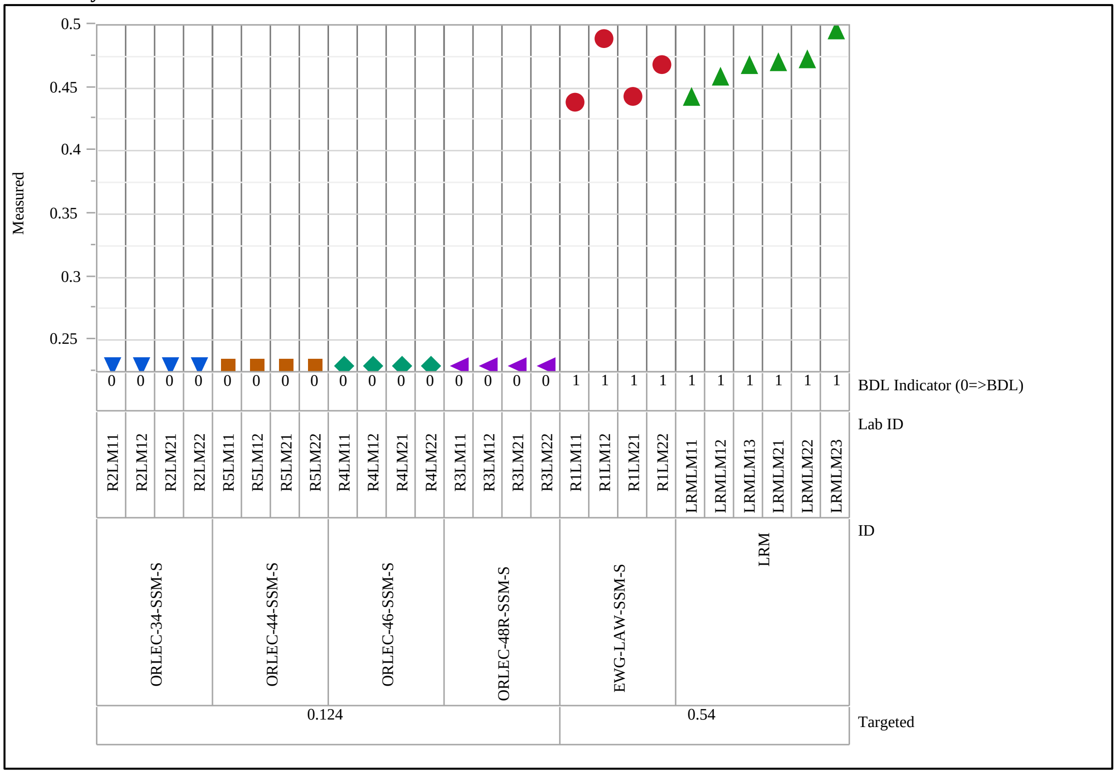
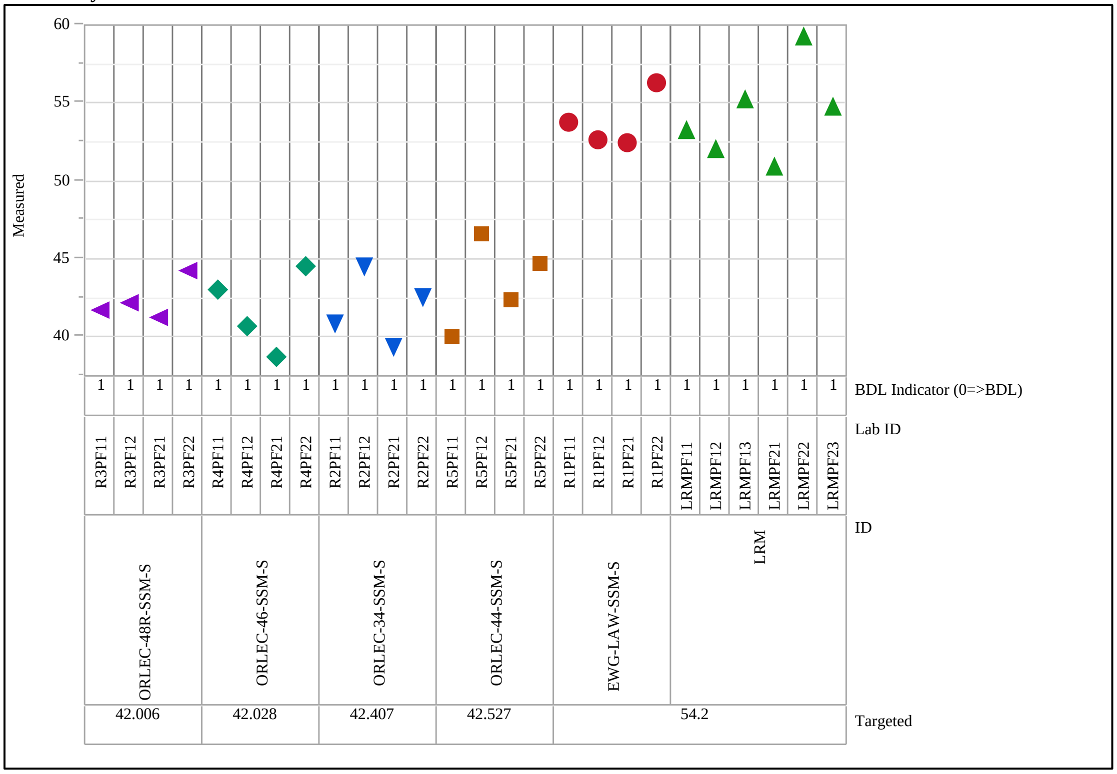


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=SiO2 (wt%), Prep Method=PF
Variability Chart for Measured



Analyte=SO3 (wt%), Prep Method=LM
Variability Chart for Measured

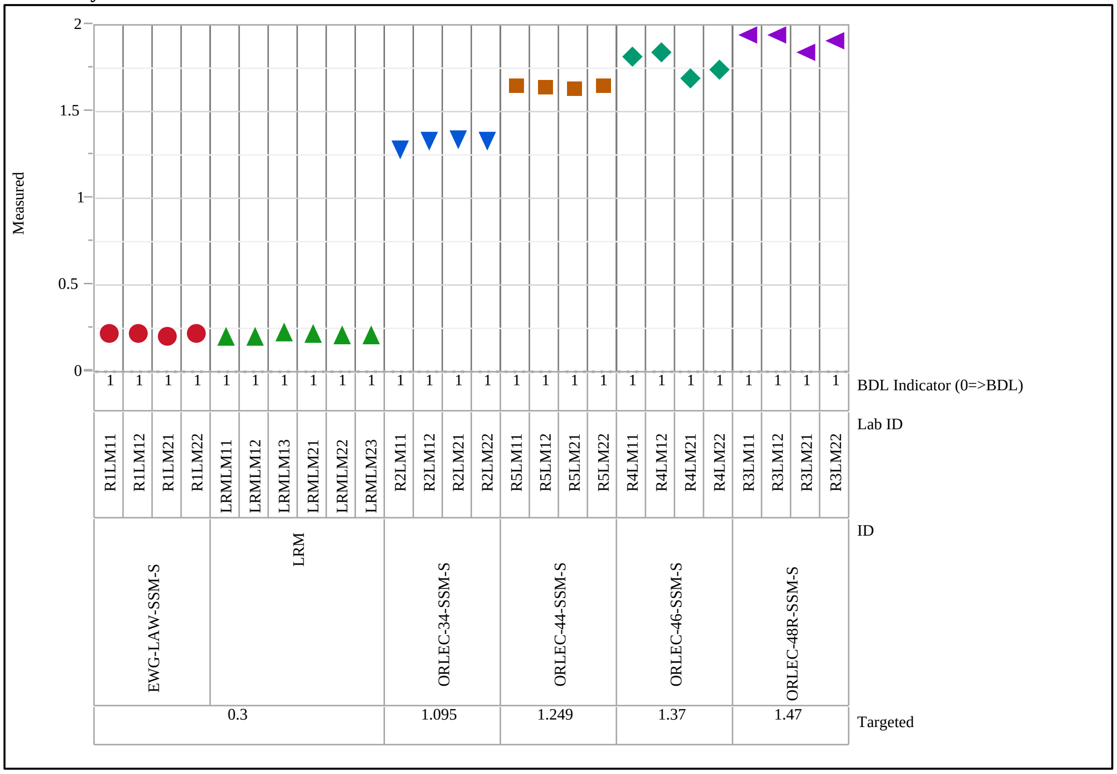
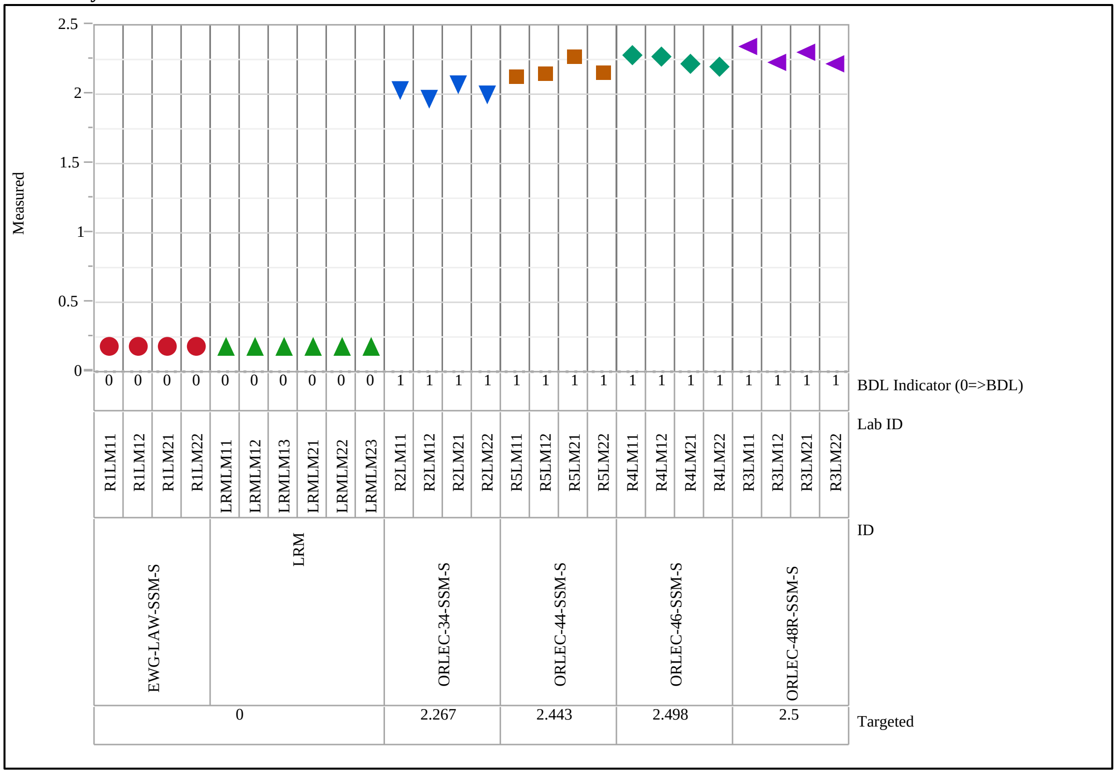


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=V2O5 (wt%), Prep Method=LM
Variability Chart for Measured



Analyte=ZnO (wt%), Prep Method=LM
Variability Chart for Measured

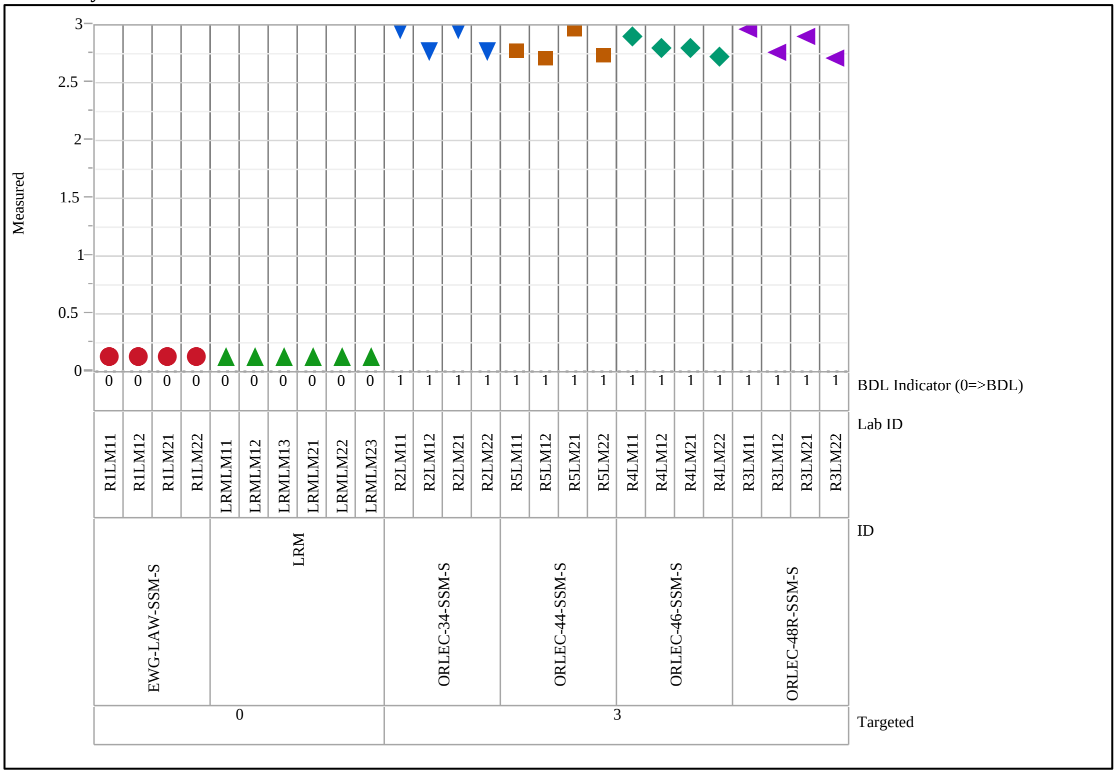


Exhibit C-2. Measurements by Analyte by Preparation Method Grouped by Targeted Composition (continued)

Analyte=ZrO2 (wt%), Prep Method=LM
Variability Chart for Measured

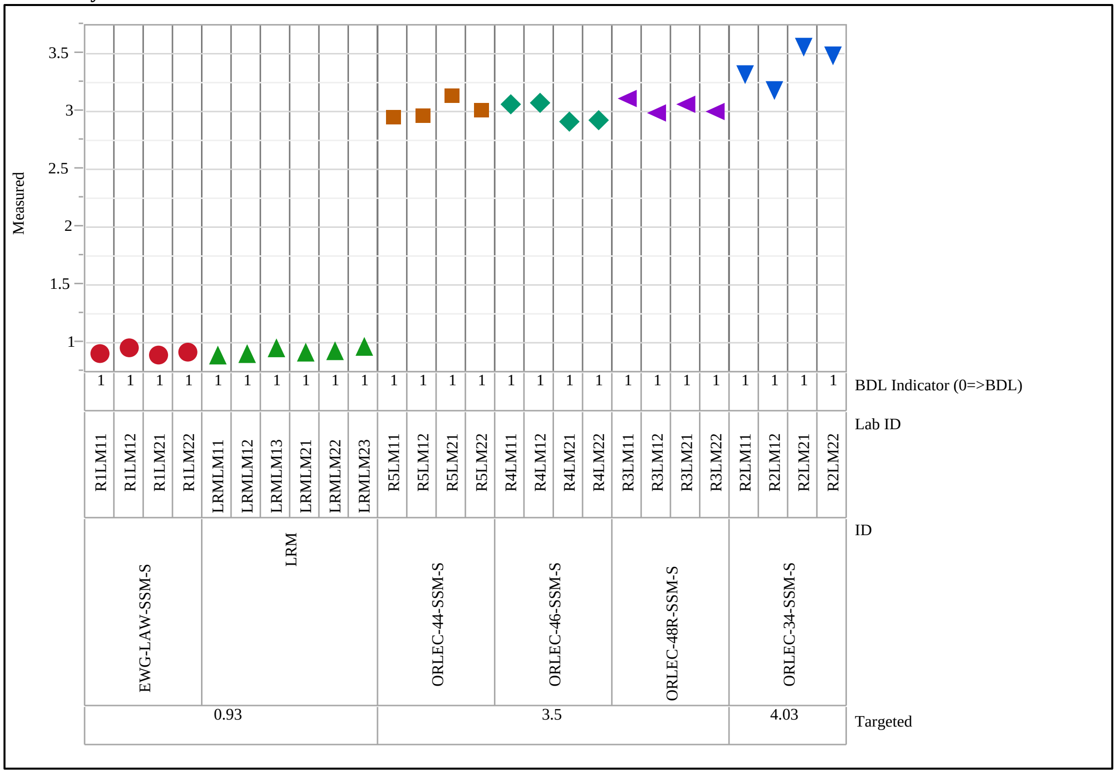
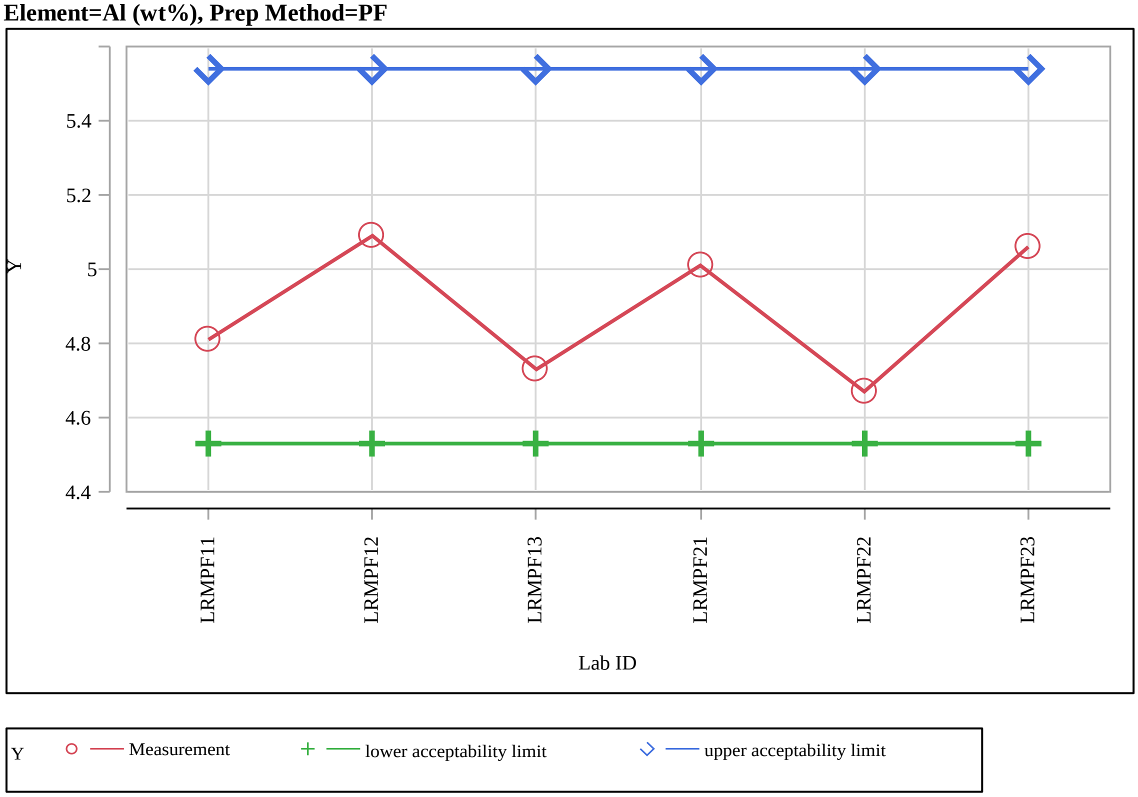


Exhibit C-3. Acceptability Evaluation for Measurements of the LRM Standard Glass

Element=Al (wt%), Prep Method=PF



Element=B (wt%), Prep Method=PF

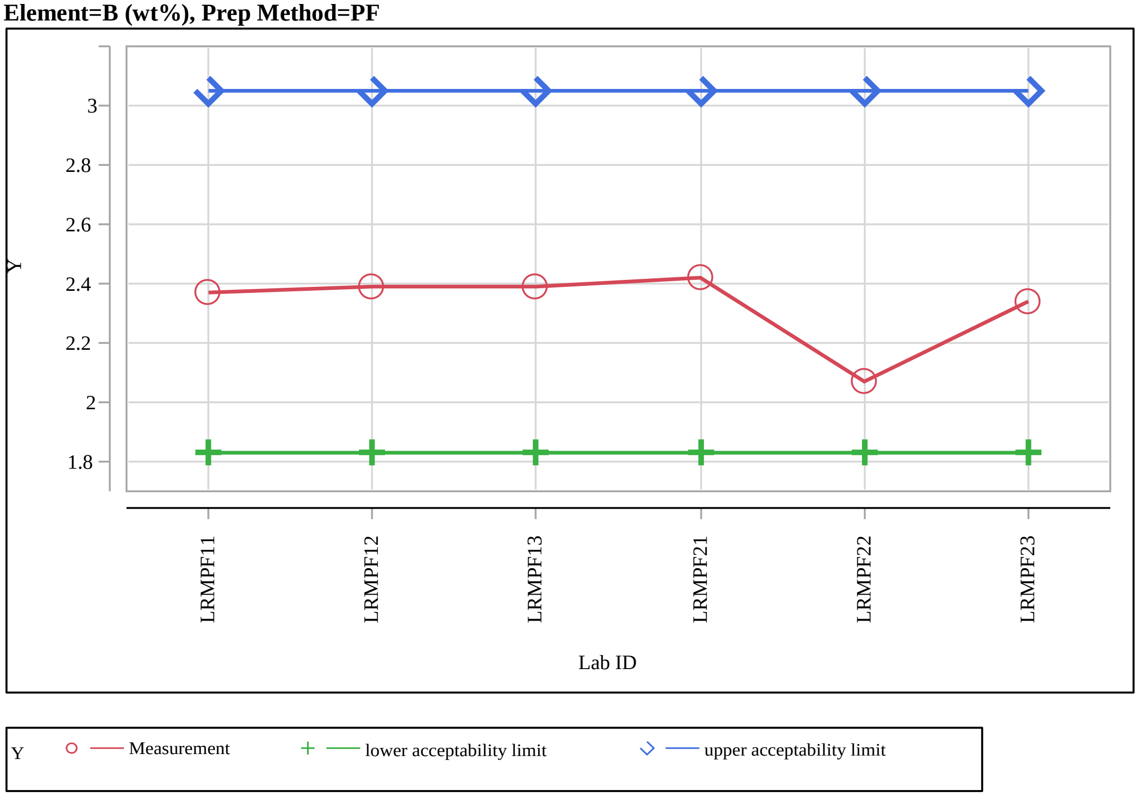
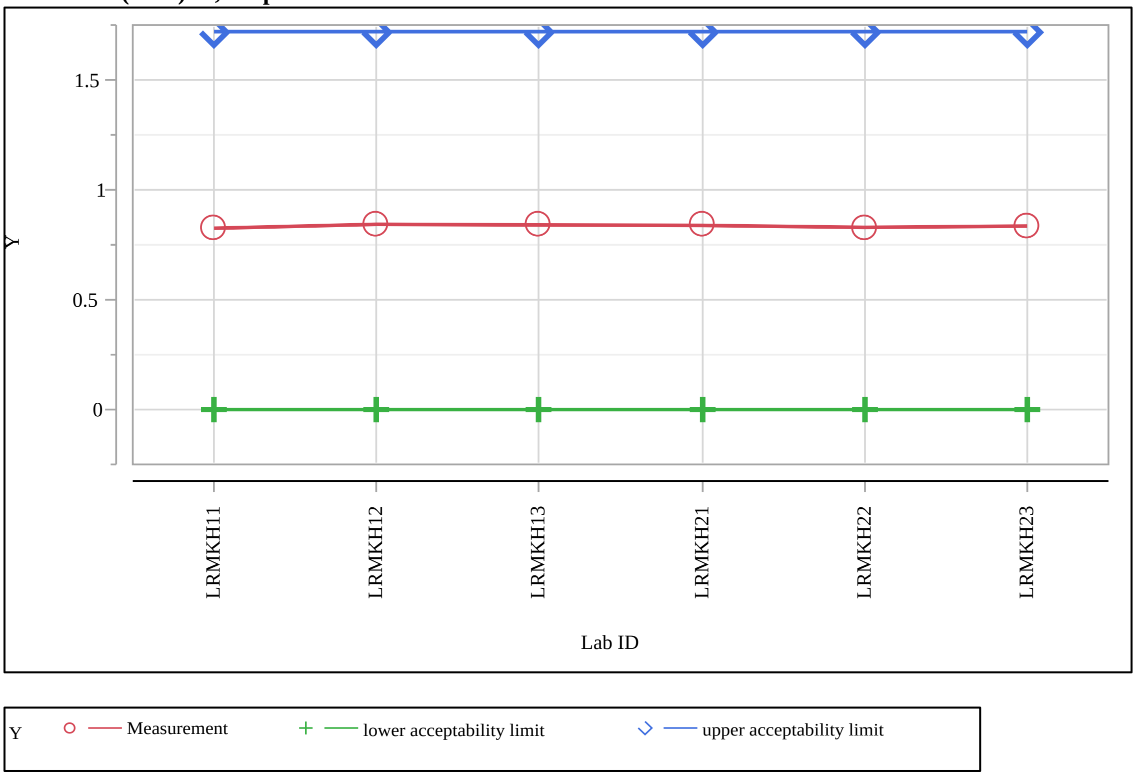


Exhibit C-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)

Element=F (wt%) ar, Prep Method=KH



Element=Fe (wt%), Prep Method=PF

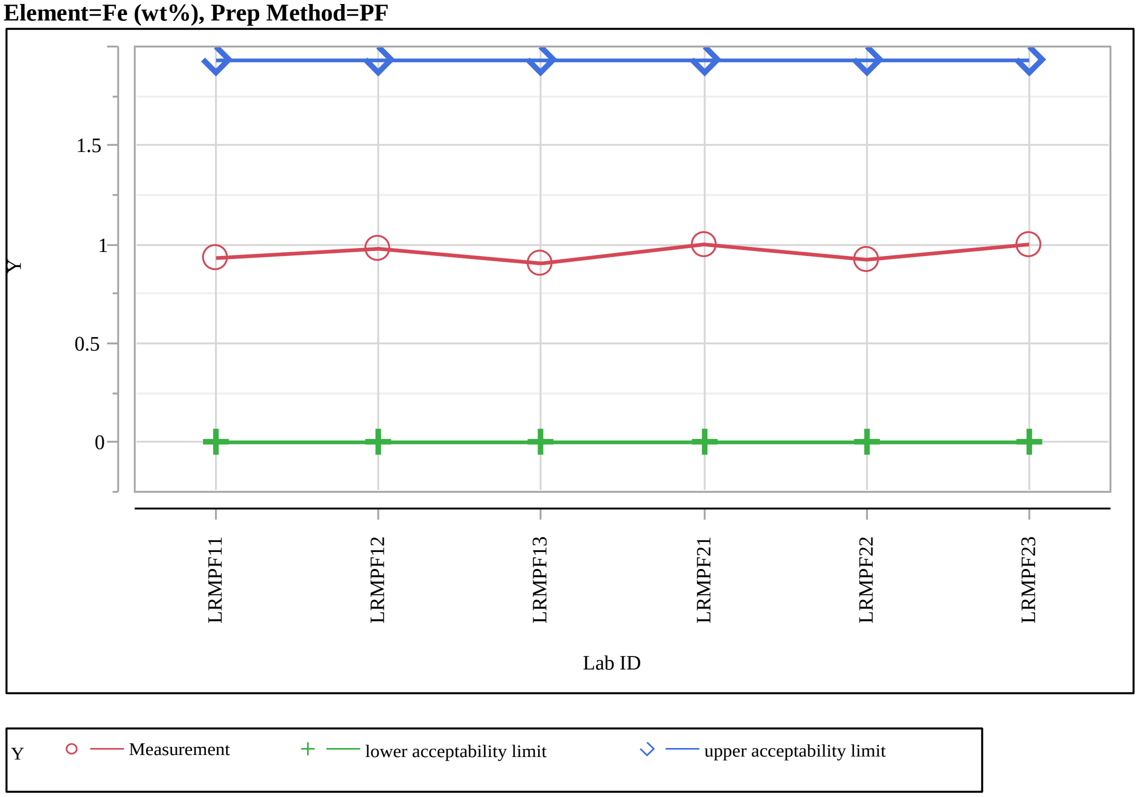
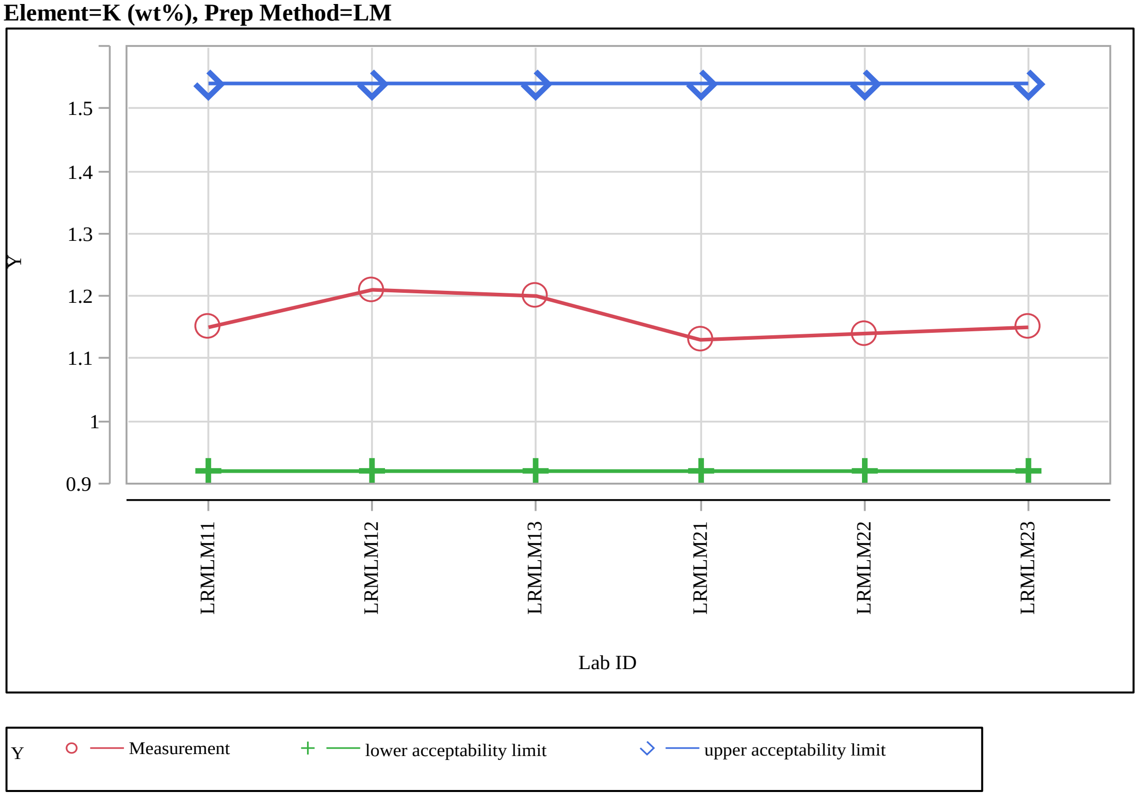


Exhibit C-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)

Element=K (wt%), Prep Method=LM



Element=Na (wt%), Prep Method=LM

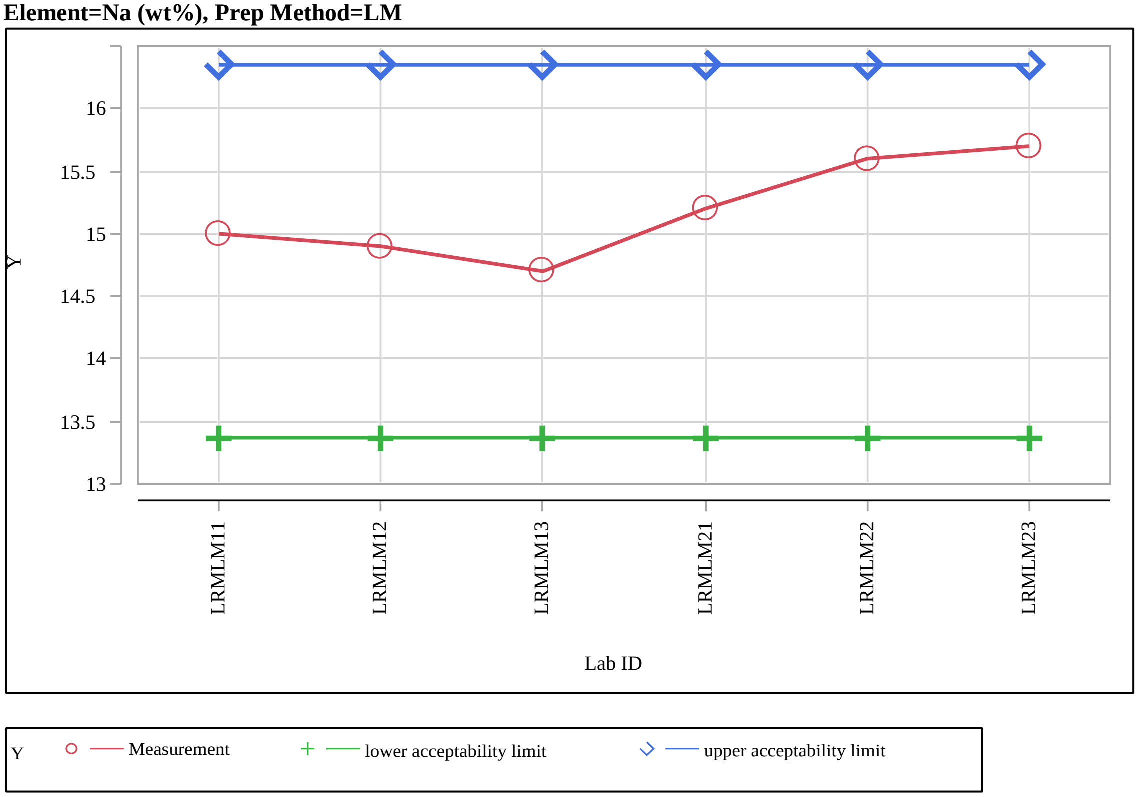
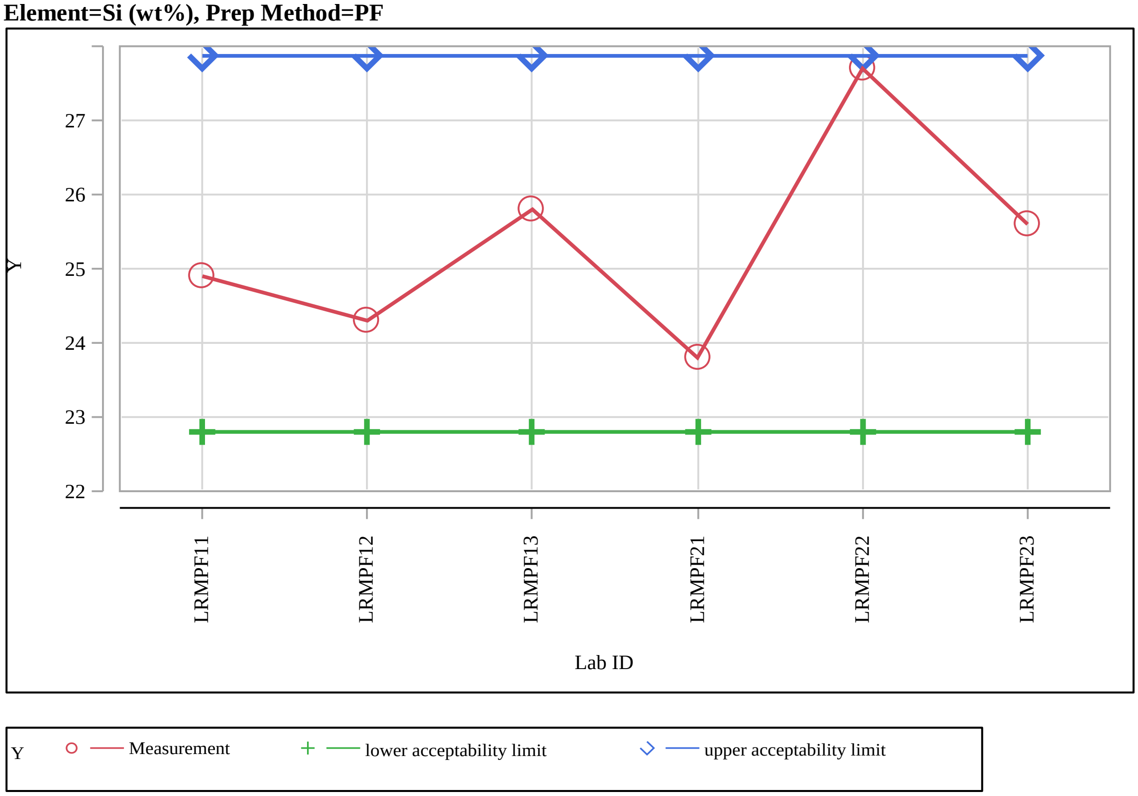


Exhibit C-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)

Element=Si (wt%), Prep Method=PF



Element=Zr (wt%), Prep Method=LM

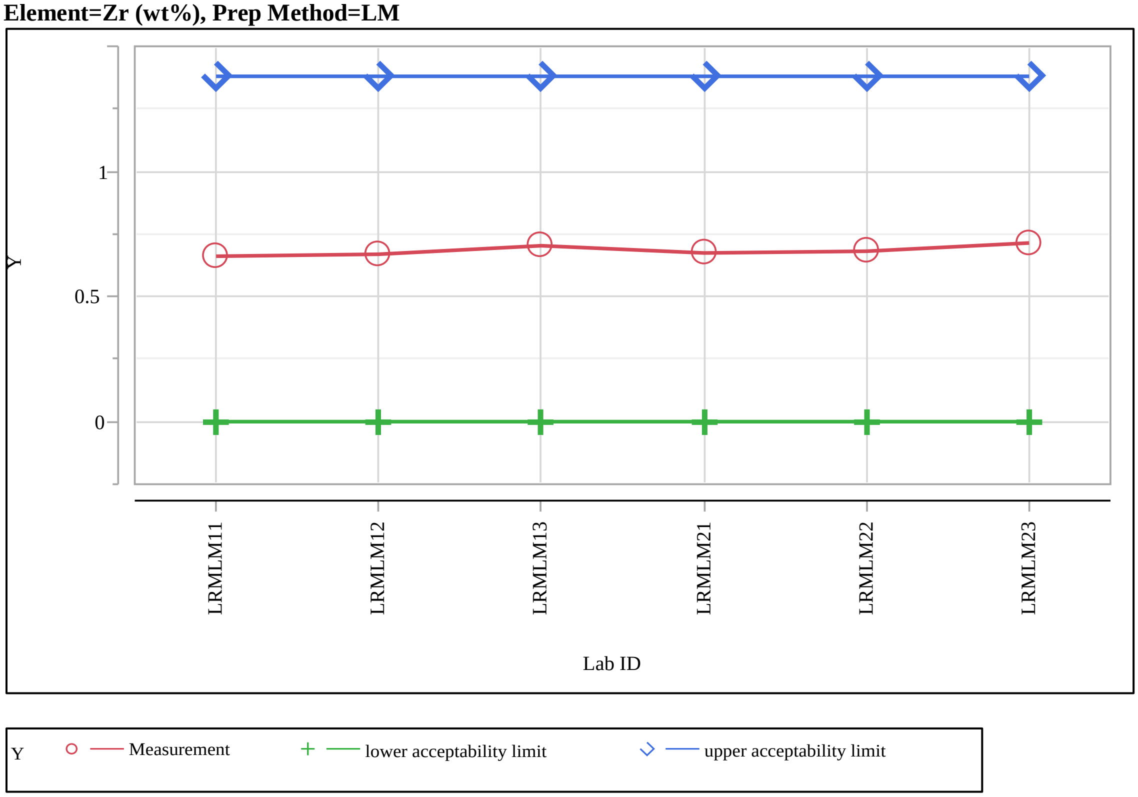
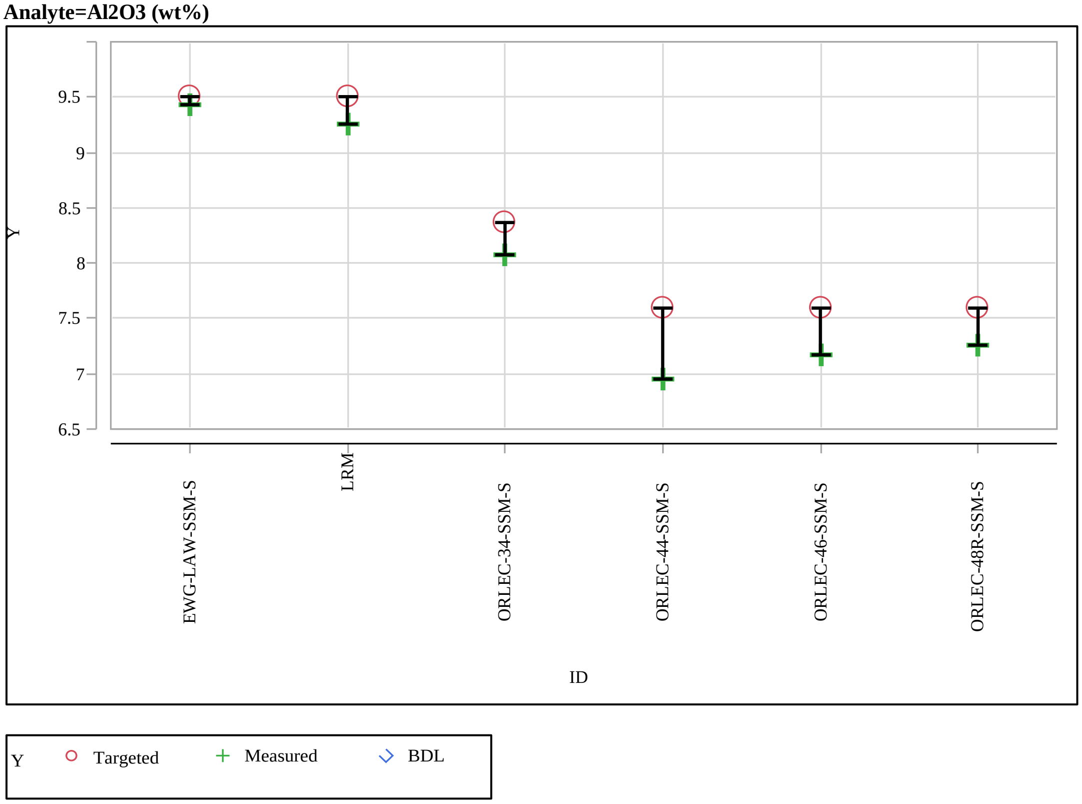


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide

Analyte=Al2O3 (wt%)



Analyte=B2O3 (wt%)

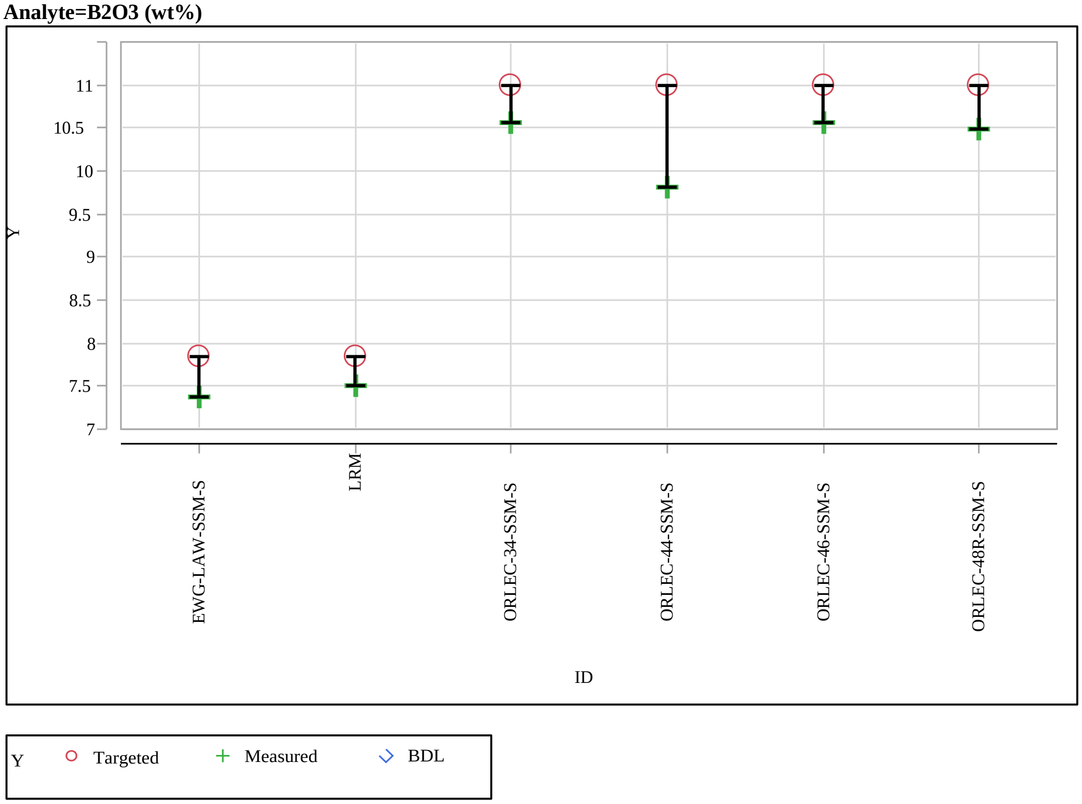
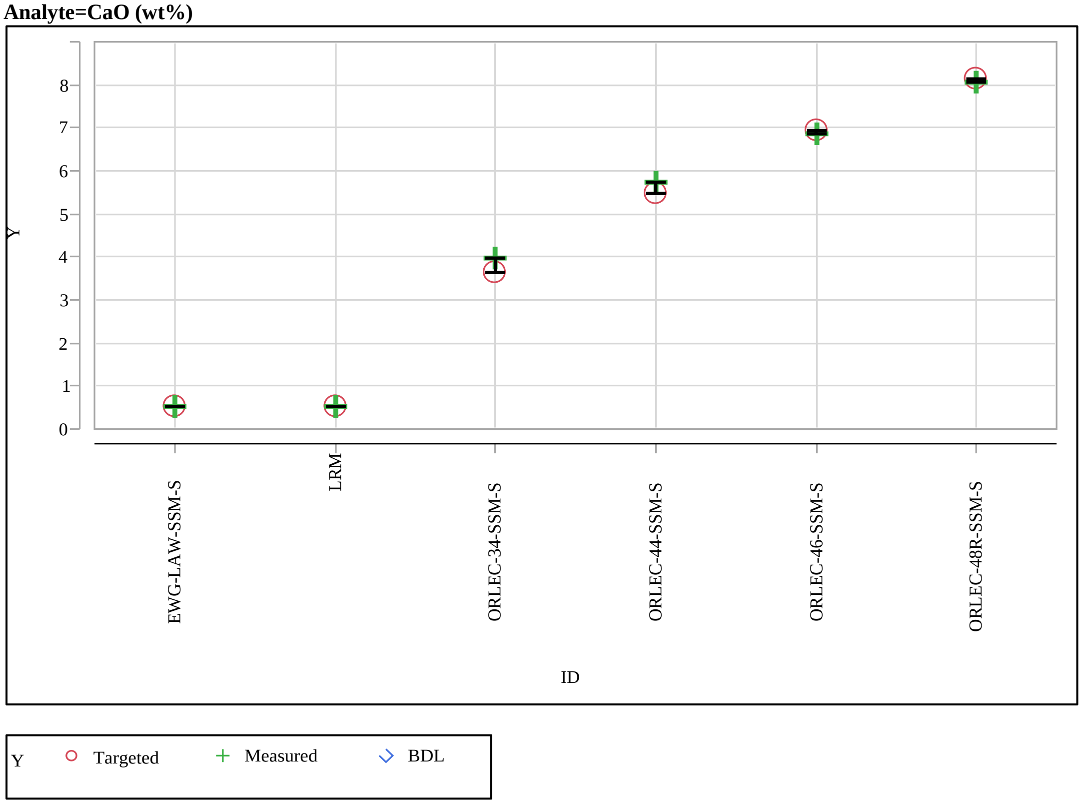


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=CaO (wt%)



Analyte=Cl (wt%)

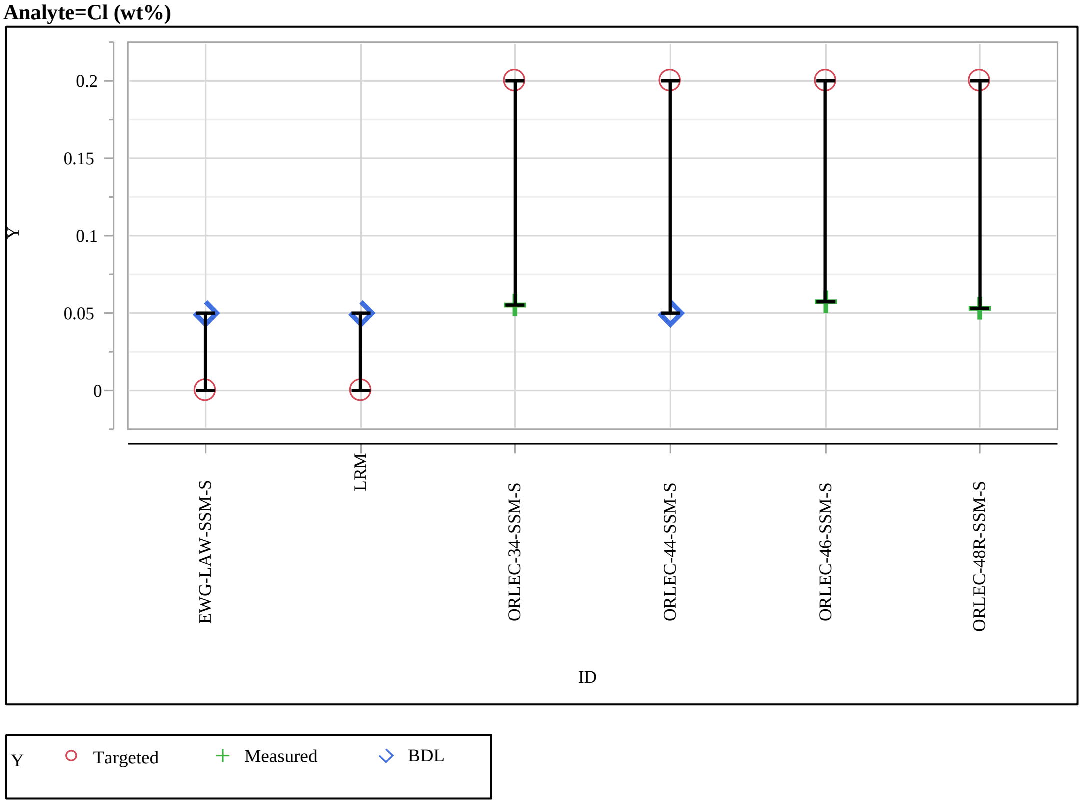
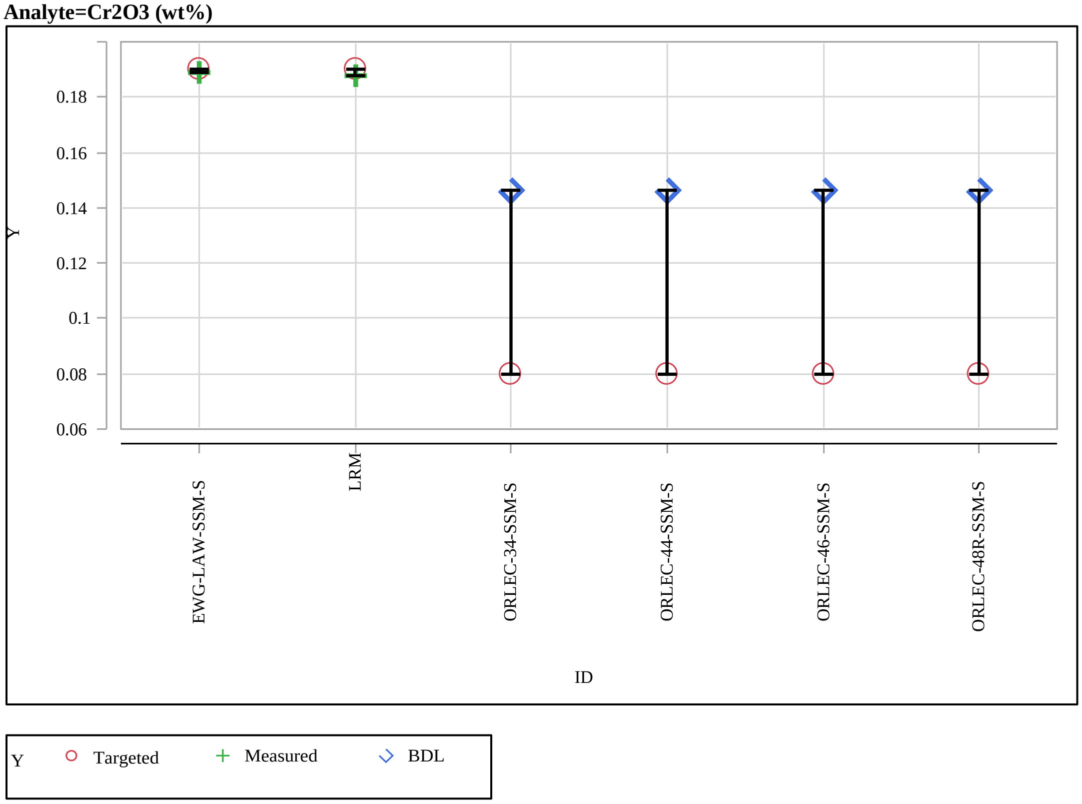


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=Cr2O3 (wt%)



Analyte=F (wt%)

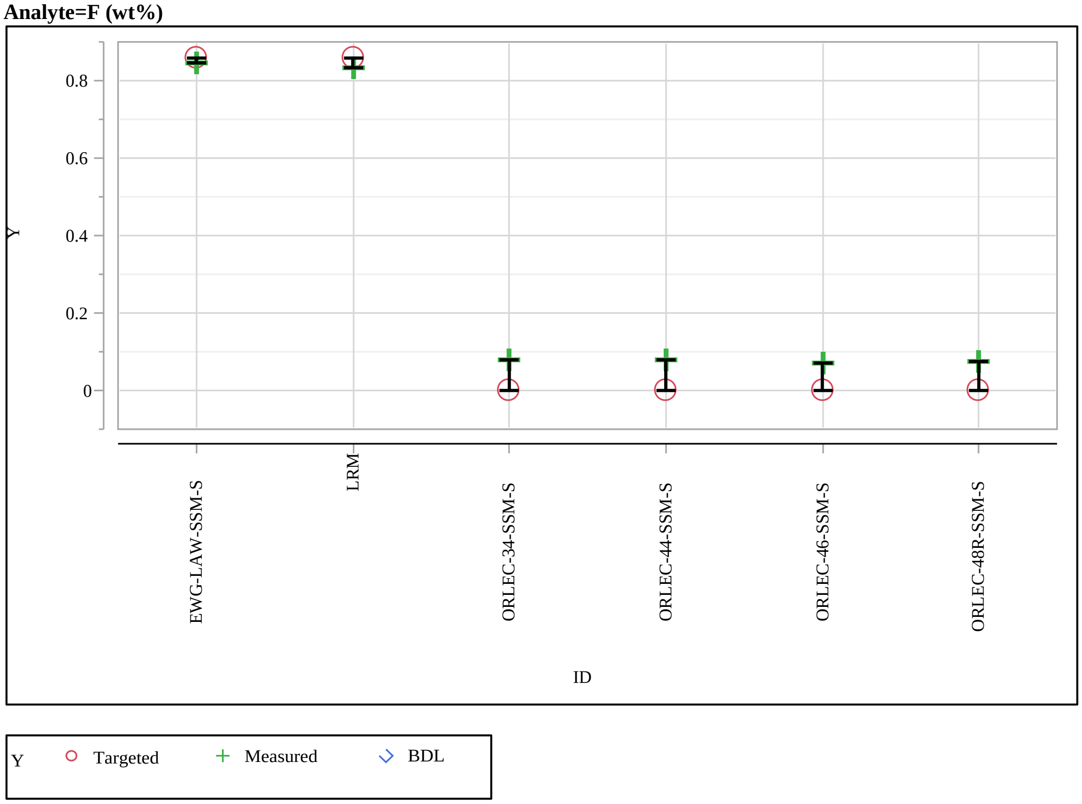
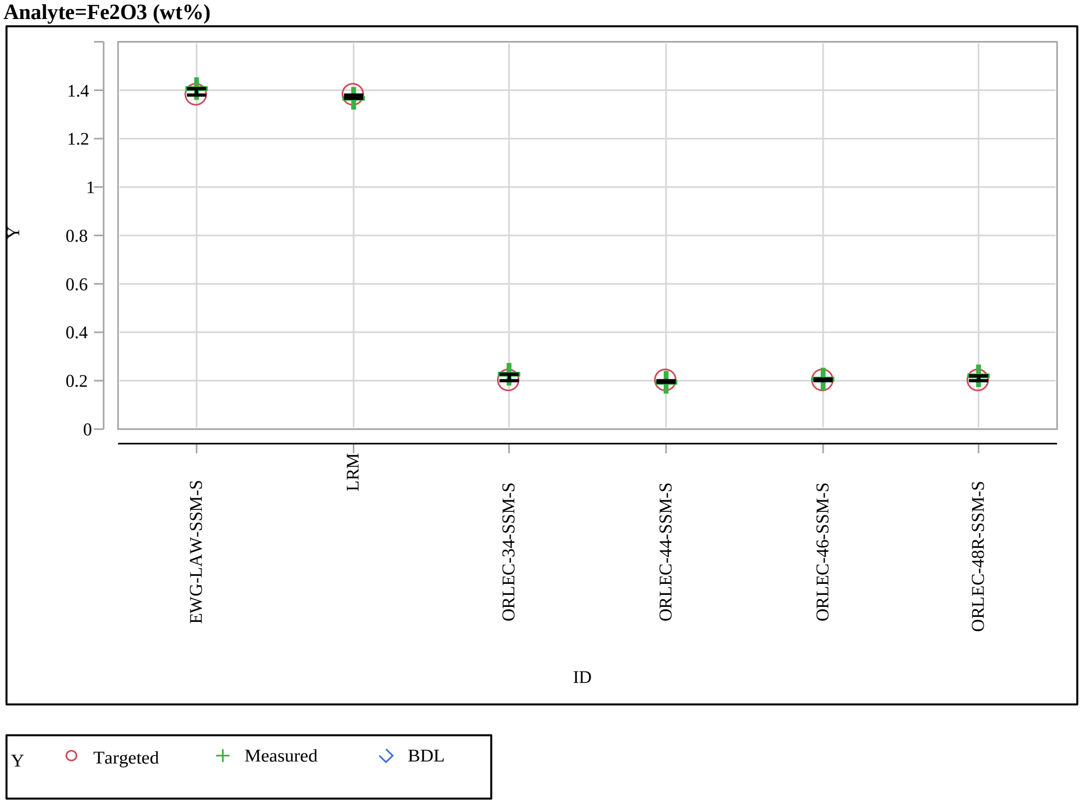


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=Fe2O3 (wt%)



Analyte=K2O (wt%)

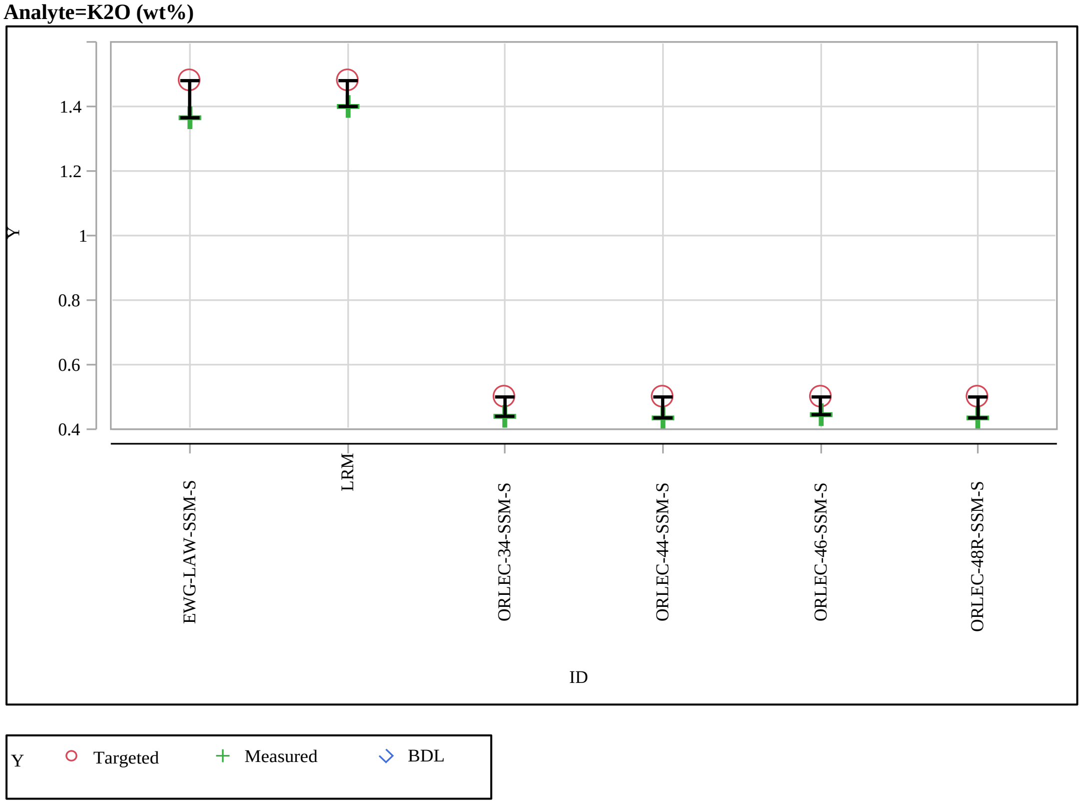
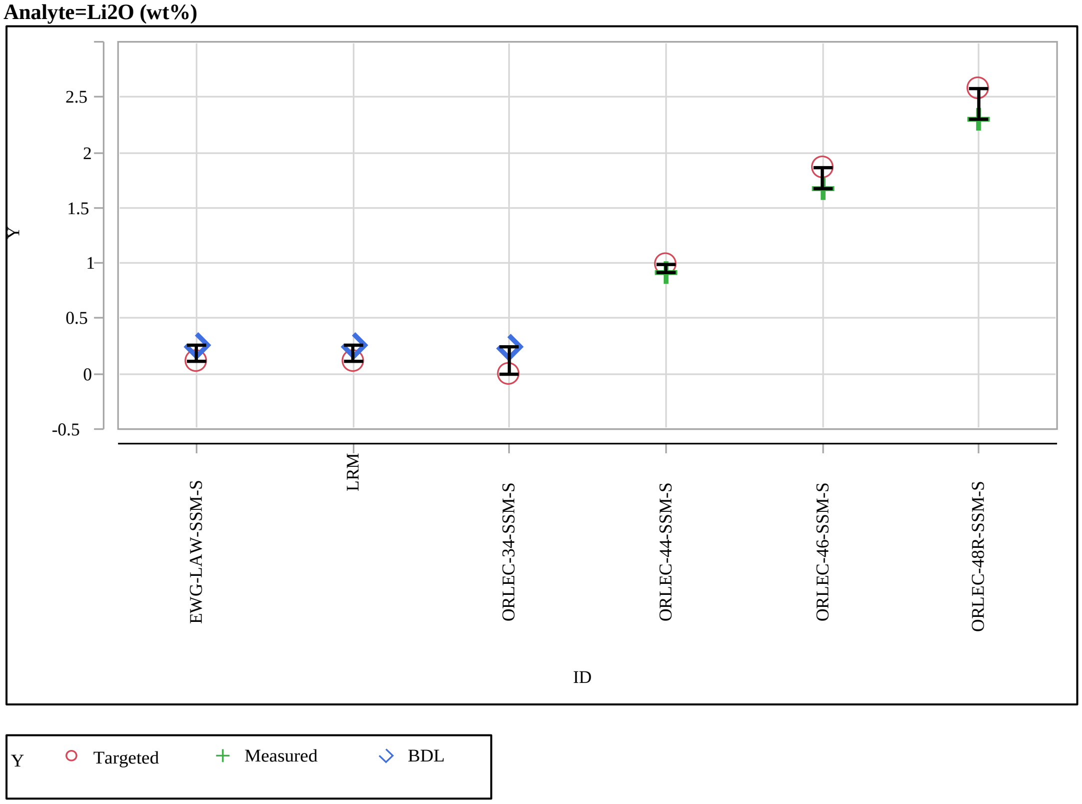


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=Li2O (wt%)



Analyte=MgO (wt%)

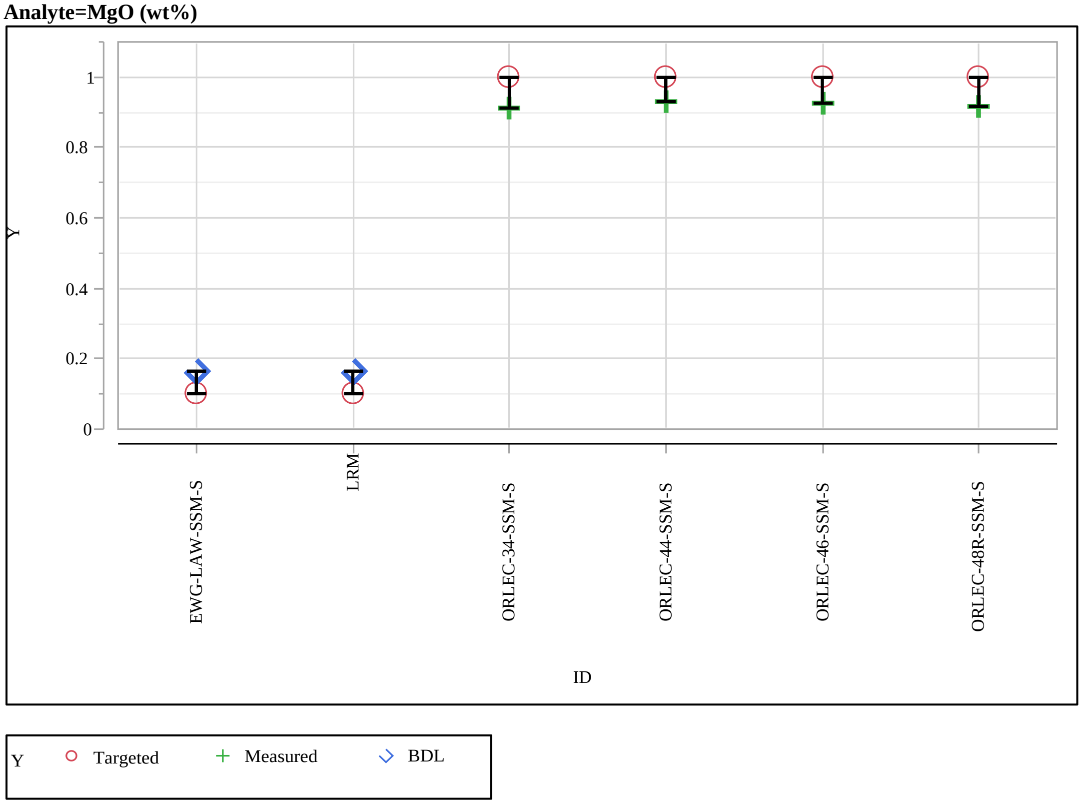
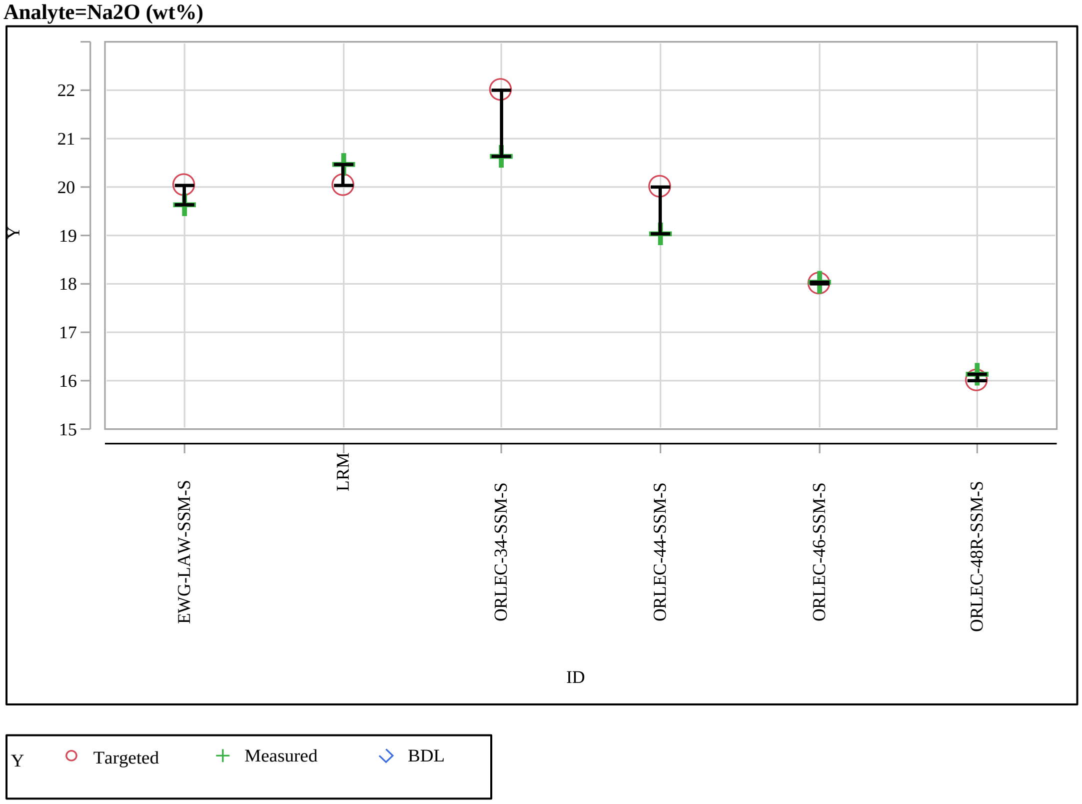


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=Na2O (wt%)



Analyte=P2O5 (wt%)

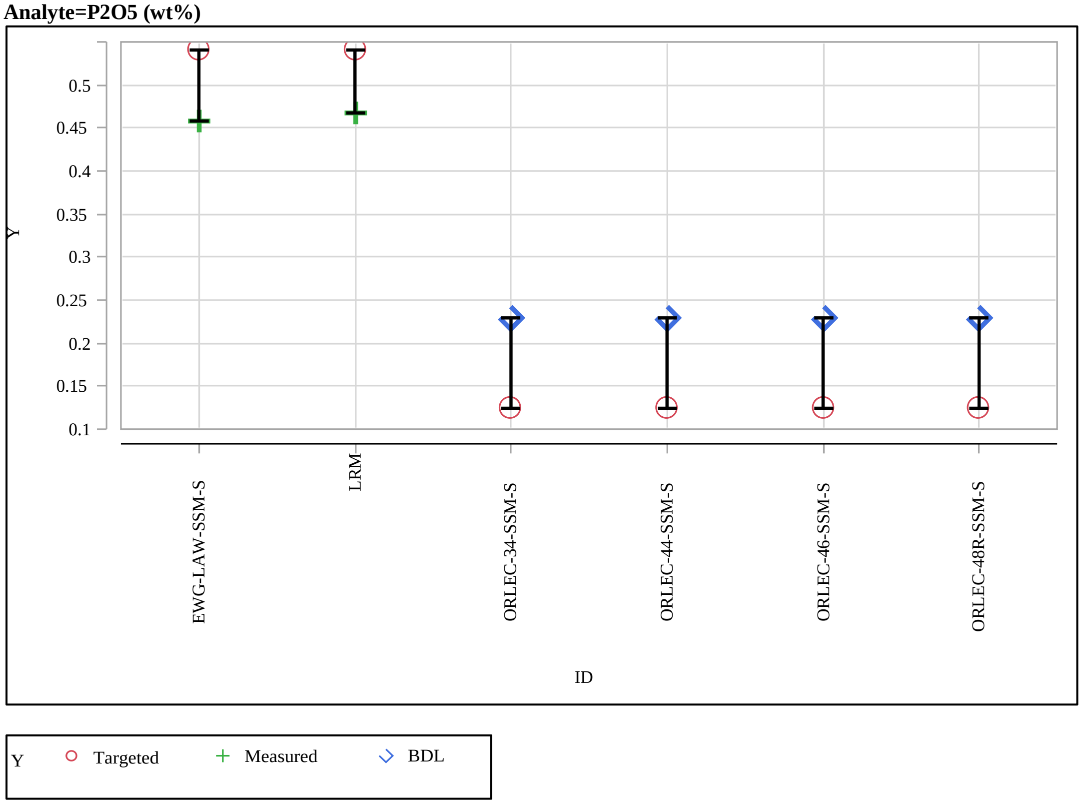
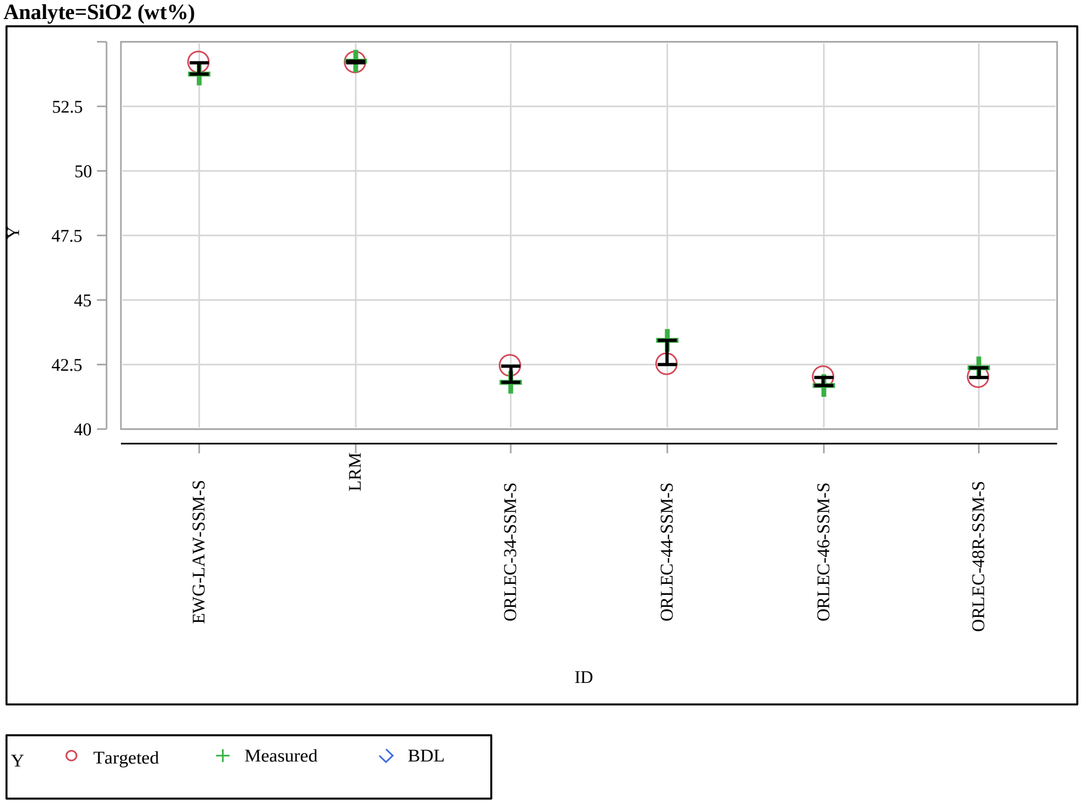


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=SiO2 (wt%)



Analyte=SO3 (wt%)

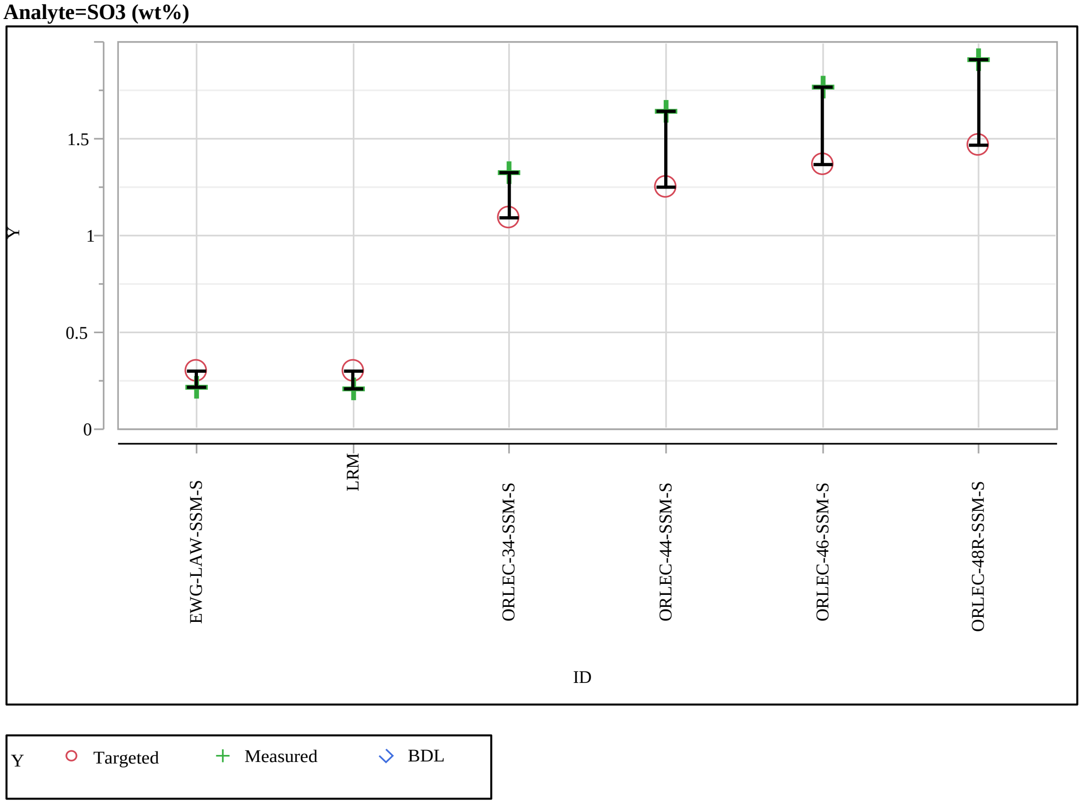
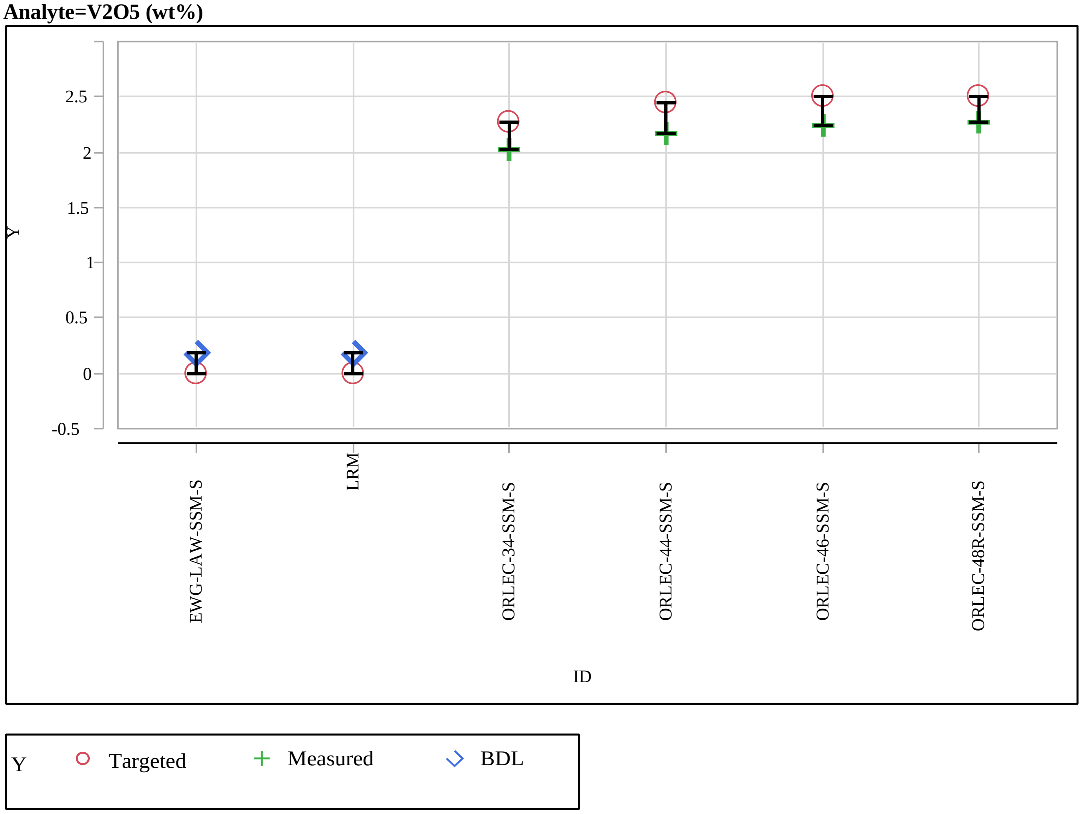


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=V2O5 (wt%)



Analyte=ZnO (wt%)

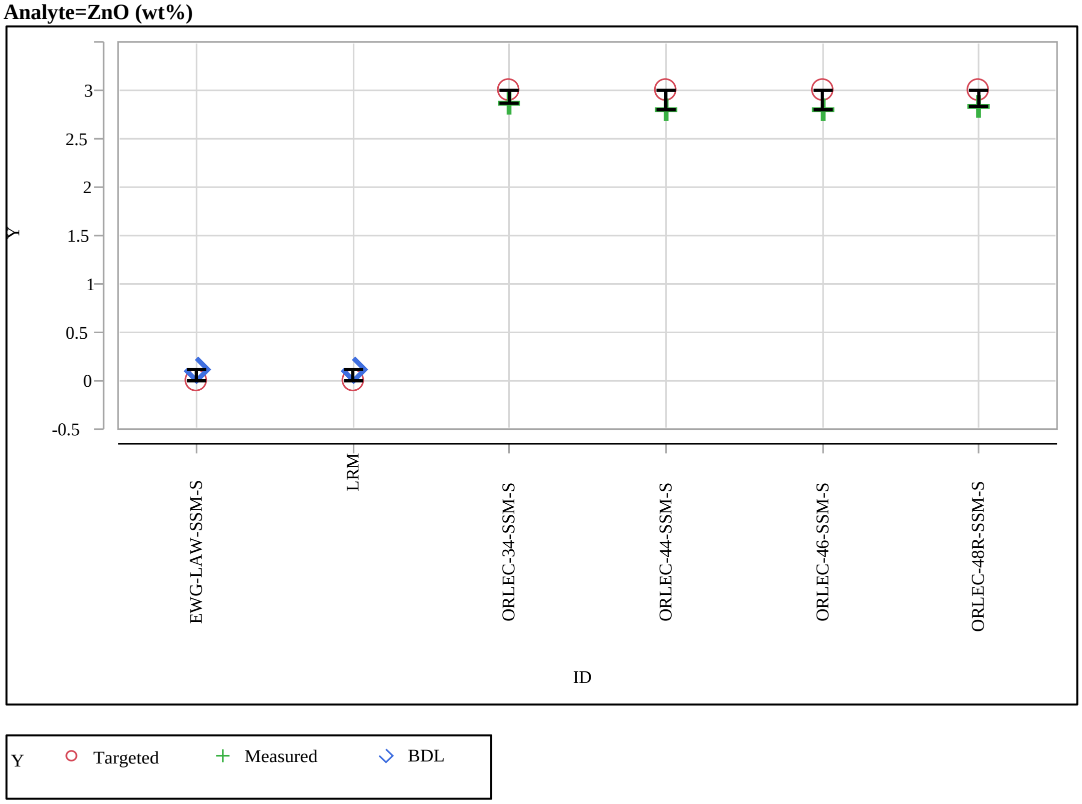
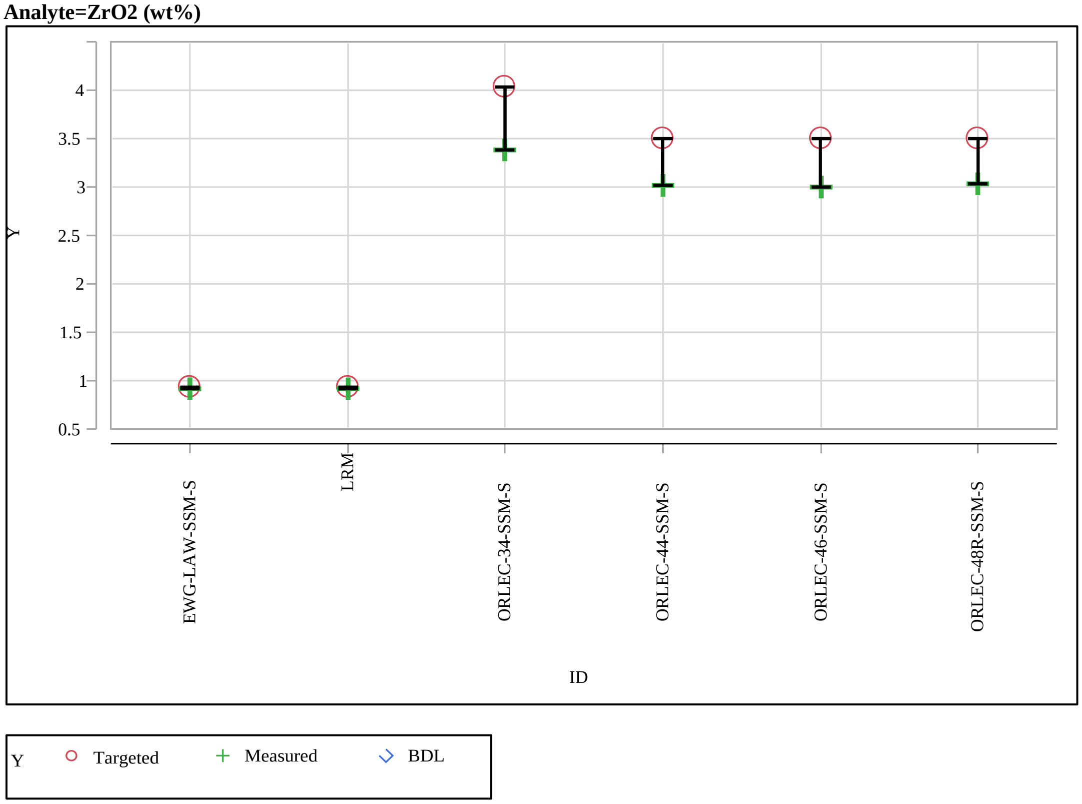
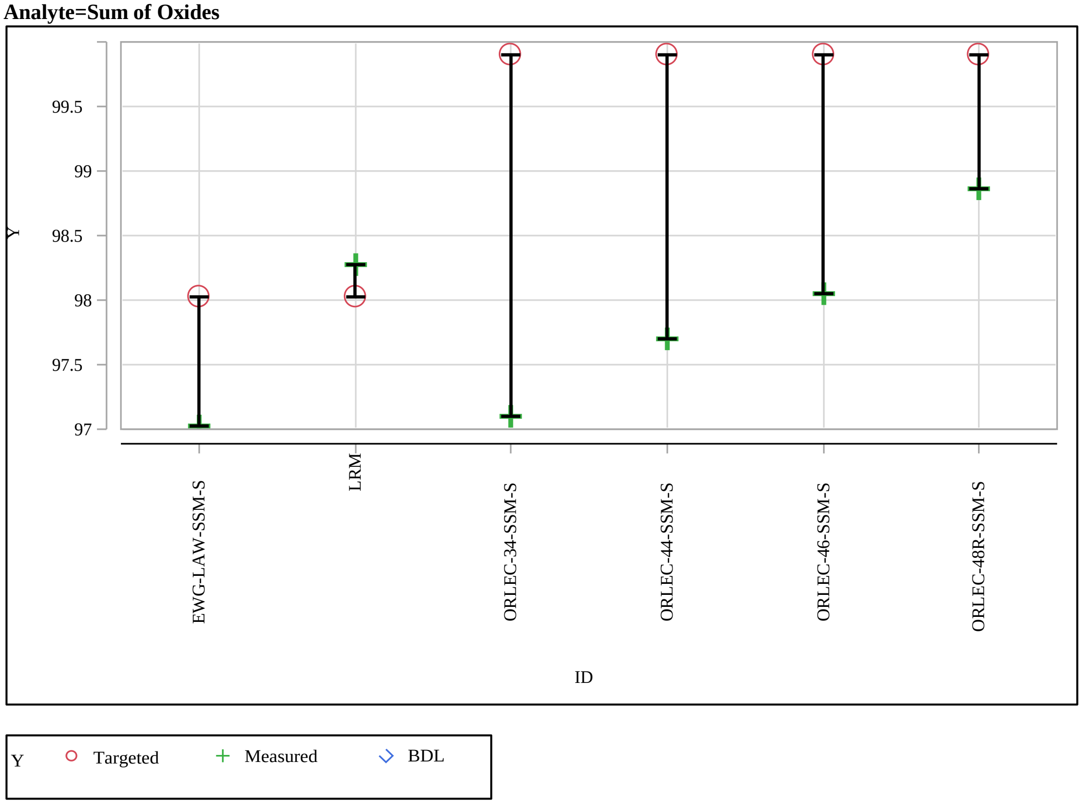


Exhibit C-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Analyte=ZrO2 (wt%)



Analyte=Sum of Oxides



Appendix D Tables and Exhibits Supporting the ORLEC Wash Solution Chemical Analysis

Table D-1. ICP-AES Measurements (mg/L) of Wash Solutions

Soln ID	Block	Seq	Lab ID	Al	B	Ca	Cr	Fe	K	Li	Mg	Na	P	S	Si	V	Zn	Zr
Soln Std	1	1	solnstd1-1	3.84	19.2	<1.00	<1.00	3.86	9.39	9.32	<1.00	82.7	<1.00	<1.00	54.8	<1.00	<1.00	<1.00
ORLEC-46-SSM-W	1	2	U4-1	<1.00	16.8	21.6	2.84	<1.00	22.5	15.1	<1.00	844	1.33	526	11.8	15.4	<1.00	<1.00
High-Purity Standards SM-744-063	1	3	hpstd-11	49.9	<1.00	<1.00	<1.00	49.3	<1.00	<1.00	<1.00	154	<1.00	10.9	<1.00	<1.00	<1.00	<1.00
ORLEC-34-SSM-W	1	4	U3-1	<1.00	21.4	9.39	2.69	<1.00	23.8	<1.00	<1.00	940	2.28	572	10.7	18.5	<1.00	<1.00
First blank	1	5	blank-1	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
ORLEC-44-SSM-W	1	6	U1-1	<1.00	18.9	15.6	2.85	<1.00	21.6	7.99	<1.00	731	1.53	510	10.8	15.9	<1.00	<1.00
Second blank	1	7	blank2-1	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
ORLEC-48R-SSM-W	1	8	U5-1	<1.00	14.8	29.1	2.75	<1.00	24.6	23.7	<1.00	714	<1.00	532	15.2	14.3	<1.00	<1.00
High-Purity Standards SM-744-063	1	9	hpstd-12	49.6	<1.00	<1.00	<1.00	49.3	<1.00	<1.00	<1.00	152	<1.00	10.7	<1.00	<1.00	<1.00	<1.00
EWG-LAW-SSM-W	1	10	U2-1	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	703	<1.00	435	<1.00	<1.00	<1.00	<1.00
Soln Std	1	11	solnstd1-2	3.85	19.2	<1.00	<1.00	3.86	9.06	9.39	<1.00	85.9	<1.00	<1.00	53.2	<1.00	<1.00	<1.00
Soln Std	2	1	solnstd2-1	3.86	19.9	<1.00	<1.00	4.08	9.70	9.55	<1.00	79.1	<1.00	<1.00	54.7	<1.00	<1.00	<1.00
ORLEC-48R-SSM-W	2	2	U5-2	<1.00	15.8	30.1	2.92	<1.00	25.4	24.2	<1.00	730	<1.00	511	15.2	15.1	<1.00	<1.00
High-Purity Standards SM-744-063	2	3	hpstd-21	50.2	1.20	<1.00	<1.00	50.8	<1.00	<1.00	<1.00	144	<1.00	10.0	<1.00	<1.00	<1.00	<1.00
EWG-LAW-SSM-W	2	4	U2-2	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	626	<1.00	431	<1.00	<1.00	<1.00	<1.00
First blank	2	5	blank1-2	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
ORLEC-34-SSM-W	2	6	U3-2	<1.00	22.1	9.78	2.82	<1.00	23.2	<1.00	<1.00	859	2.17	567	10.9	19.7	<1.00	<1.00
Second blank	2	7	blank2-2	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
ORLEC-46-SSM-W	2	8	U4-2	<1.00	17.4	22.2	2.98	<1.00	23.2	15.0	<1.00	785	1.58	519	12.2	16.5	<1.00	<1.00
High-Purity Standards SM-744-063	2	9	hpstd-22	50.8	1.05	<1.00	<1.00	51.1	<1.00	<1.00	<1.00	154	<1.00	9.81	<1.00	<1.00	<1.00	<1.00
ORLEC-44-SSM-W	2	10	U1-2	<1.00	19.9	16.0	3.00	<1.00	21.8	7.88	<1.00	804	1.69	503	10.5	16.9	<1.00	<1.00
Soln Std	2	11	solnstd2-2	3.94	20.2	<1.00	<1.00	4.15	9.14	9.64	<1.00	86.2	<1.00	<1.00	53.5	<1.00	<1.00	<1.00
Soln Std	3	1	solnstd3-1	3.66	20.2	<1.00	<1.00	4.16	9.63	9.54	<1.00	76.2	<1.00	<1.00	54.7	<1.00	<1.00	<1.00
EWG-LAW-SSM-W	3	2	U2-3	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	570	<1.00	447	<1.00	<1.00	<1.00	<1.00
High-Purity Standards SM-744-063	3	3	hpstd-31	50.4	<1.00	<1.00	<1.00	51.1	<1.00	<1.00	<1.00	138	<1.00	9.61	<1.00	<1.00	<1.00	<1.00
ORLEC-44-SSM-W	3	4	U1-3	<1.00	19.6	16.2	3.04	<1.00	22.0	7.85	<1.00	734	1.78	559	10.3	16.9	<1.00	<1.00
First blank	3	5	blank1-3	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
ORLEC-46-SSM-W	3	6	U4-3	<1.00	16.5	22.0	2.98	<1.00	21.9	14.9	<1.00	663	1.83	542	11.6	16.4	<1.00	<1.00
Second blank	3	7	blank2-3	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.04	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
ORLEC-34-SSM-W	3	8	U3-3	<1.00	22.0	9.93	2.85	<1.00	20.8	<1.00	<1.00	797	2.68	586	10.6	19.7	<1.00	<1.00
High-Purity Standards SM-744-063	3	9	hpstd-32	51.6	<1.00	<1.00	<1.00	51.0	<1.00	<1.00	<1.00	149	<1.00	9.90	<1.00	<1.00	<1.00	<1.00
ORLEC-48R-SSM-W	3	10	U5-3	<1.00	15.4	30.6	2.94	<1.00	21.2	23.7	<1.00	688	1.10	557	14.9	15.2	<1.00	<1.00
Soln Std	3	11	solnstd3-2	3.68	19.9	<1.00	<1.00	4.14	9.31	9.60	<1.00	76.4	<1.00	<1.00	54.5	<1.00	<1.00	<1.00

Table D-2. IC Measurements (mg/L) of Wash Solutions

Soln ID	Block	Seq	Lab ID	Cl	F	PO4	SO4
Chk Std	1	1	1 ppm ckstd	1.02	1.01	0.966	1.10
Soln Std	1	2	Soln Std 1-1	<10.0	<10.0	<10.0	<100
EWG-LAW-SSM-W	1	3	U2-1	<10.0	<10.0	<10.0	1330
High-Purity Standards SM-744-063	1	4	HPSTD-11	<10.0	<10.0	<10.0	<100
ORLEC-34-SSM-W	1	5	U3-1	15.8	<10.0	<10.0	1700
First blank	1	6	BLANK1-1	<10.0	<10.0	<10.0	<100
ORLEC-46-SSM-W	1	7	U4-1	11.6	<10.0	<10.0	1550
Second blank	1	8	Blank2-1	<10.0	<10.0	<10.0	<100
ORLEC-48R-SSM-W	1	9	U5-1	11.0	<10.0	<10.0	1580
High-Purity Standards SM-744-063	1	10	hpstd-12	<10.0	<10.0	<10.0	<100
ORLEC-44-SSM-W	1	11	U1-1	12.0	<10.0	<10.0	1530
Soln Std	1	12	Soln Std 1-2	<10.0	<10.0	<10.0	<100
Chk Std	1	13	1 ppm ckstd	0.910	0.974	0.936	1.07
Chk Std	2	1	1 ppm ckstd	1.04	1.02	1.00	1.08
Soln Std	2	2	Soln Std 2-1	<10.0	<10.0	<10.0	<100
ORLEC-46-SSM-W	2	3	U4-2	12.0	<10.0	<10.0	1560
High-Purity Standards SM-744-063	2	4	HPSTD-21	<10.0	<10.0	<10.0	<100
ORLEC-34-SSM-W	2	5	U3-2	15.5	<10.0	<10.0	1700
First blank	2	6	BLANK1-2	<10.0	<10.0	<10.0	<100
ORLEC-48R-SSM-W	2	7	U5-2	10.8	<10.0	<10.0	1590
Second blank	2	8	Blank2-2	<10.0	<10.0	<10.0	<100
EWG-LAW-SSM-W	2	9	U2-2	<10.0	<10.0	<10.0	1310
High-Purity Standards SM-744-063	2	10	hpstd-22	<10.0	<10.0	<10.0	<100
ORLEC-44-SSM-W	2	11	U1-2	11.7	<10.0	<10.0	1540
Soln Std	2	12	Soln Std 2-2	<10.0	<10.0	<10.0	<100
Chk Std	2	13	1 ppm ckstd	0.908	0.974	0.918	1.09
Chk Std	3	1	1 ppm ckstd	1.03	1.02	0.977	1.07
Soln Std	3	2	Soln Std 3-1	<10.0	<10.0	<10.0	<100
EWG-LAW-SSM-W	3	3	U2-3	<10.0	<10.0	<10.0	1300
High-Purity Standards SM-744-063	3	4	HPSTD-31	<10.0	<10.0	<10.0	<100
ORLEC-46-SSM-W	3	5	U4-3	11.8	<10.0	<10.0	1570
First blank	3	6	BLANK1-3	<10.0	<10.0	<10.0	<100
ORLEC-44-SSM-W	3	7	U1-3	11.8	<10.0	<10.0	1540
Second blank	3	8	Blank2-3	<10.0	<10.0	<10.0	<100
ORLEC-34-SSM-W	3	9	U3-3	15.6	<10.0	<10.0	1720
High-Purity Standards SM-744-063	3	10	hpstd-32	<10.0	<10.0	<10.0	<100
ORLEC-48R-SSM-W	3	11	U5-3	11.1	<10.0	<10.0	1590
Soln Std	3	12	Soln Std 3-3	<10.0	<10.0	<10.0	<100
Chk Std	3	13	1 ppm ckstd	0.916	0.979	0.953	1.09

Table D-3. Results for Standards Utilized During the Measurement of the Wash Solutions

Soln ID	Analyte	Instrument	Reference Value (mg/L)	Mean (mg.L)	Number of Measurements
Chk Std	Cl	IC	1	0.971	6
Chk Std	F	IC	1	0.996	6
Chk Std	PO4	IC	1	0.958	6
Chk Std	SO4	IC	1	1.083	6
High-Purity Standards SM-744-063	Al	ICP-AES	50	50.417	6
High-Purity Standards SM-744-063	Fe	ICP-AES	50	50.433	6
High-Purity Standards SM-744-063	Na	ICP-AES	150	148.500	6
High-Purity Standards SM-744-063	S	ICP-AES	10	10.153	6
Soln Std	Al	ICP-AES	4	3.805	6
Soln Std	B	ICP-AES	20	19.767	6
Soln Std	Fe	ICP-AES	4	4.042	6
Soln Std	K	ICP-AES	10	9.372	6
Soln Std	Li	ICP-AES	10	9.507	6
Soln Std	Na	ICP-AES	81	81.083	6
Soln Std	Si	ICP-AES	50	54.233	6

Table D-4. Average Measurements of Wash Solutions

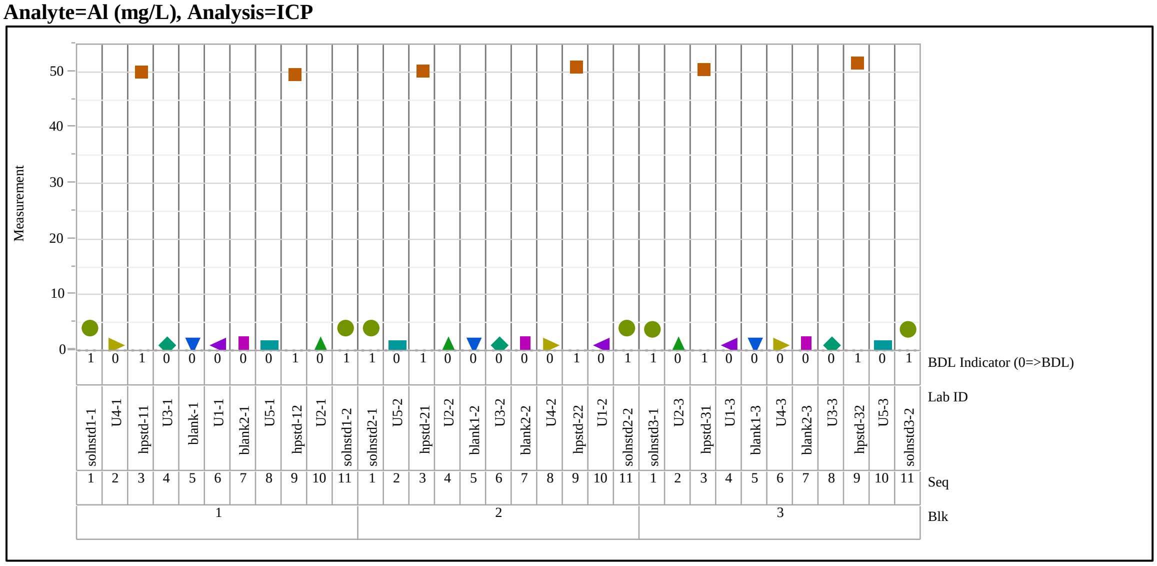
Soln ID	Analyte	Instrument	Mean (mg/L)	BDL Indicator (0=>BDL)
EWG-LAW-SSM-W	Al	ICP-AES	1.0	0
EWG-LAW-SSM-W	B	ICP-AES	1.0	0
EWG-LAW-SSM-W	Ca	ICP-AES	1.0	0
EWG-LAW-SSM-W	Cl	IC	10.0	0
EWG-LAW-SSM-W	Cr	ICP-AES	1.0	0
EWG-LAW-SSM-W	F	IC	10.0	0
EWG-LAW-SSM-W	Fe	ICP-AES	1.0	0
EWG-LAW-SSM-W	K	ICP-AES	1.0	0
EWG-LAW-SSM-W	Li	ICP-AES	1.0	0
EWG-LAW-SSM-W	Mg	ICP-AES	1.0	0
EWG-LAW-SSM-W	Na	ICP-AES	633.0	1
EWG-LAW-SSM-W	P	ICP-AES	1.0	0
EWG-LAW-SSM-W	PO4	IC	10.0	0
EWG-LAW-SSM-W	PO4	ICP-AES	3.1	0
EWG-LAW-SSM-W	S	ICP-AES	437.7	1
EWG-LAW-SSM-W	Si	ICP-AES	1.0	0
EWG-LAW-SSM-W	SO4	IC	1313.3	1
EWG-LAW-SSM-W	SO4	ICP-AES	1311.2	1
EWG-LAW-SSM-W	V	ICP-AES	1.0	0
EWG-LAW-SSM-W	Zn	ICP-AES	1.0	0
EWG-LAW-SSM-W	Zr	ICP-AES	1.0	0
ORLEC-34-SSM-W	Al	ICP-AES	1.0	0
ORLEC-34-SSM-W	B	ICP-AES	21.8	1
ORLEC-34-SSM-W	Ca	ICP-AES	9.7	1
ORLEC-34-SSM-W	Cl	IC	15.6	1
ORLEC-34-SSM-W	Cr	ICP-AES	2.8	1
ORLEC-34-SSM-W	F	IC	10.0	0
ORLEC-34-SSM-W	Fe	ICP-AES	1.0	0
ORLEC-34-SSM-W	K	ICP-AES	22.6	1
ORLEC-34-SSM-W	Li	ICP-AES	1.0	0
ORLEC-34-SSM-W	Mg	ICP-AES	1.0	0
ORLEC-34-SSM-W	Na	ICP-AES	865.3	1
ORLEC-34-SSM-W	P	ICP-AES	2.4	1
ORLEC-34-SSM-W	PO4	IC	10.0	0
ORLEC-34-SSM-W	PO4	ICP-AES	7.3	1
ORLEC-34-SSM-W	S	ICP-AES	575.0	1
ORLEC-34-SSM-W	Si	ICP-AES	10.7	1
ORLEC-34-SSM-W	SO4	IC	1706.7	1
ORLEC-34-SSM-W	SO4	ICP-AES	1722.6	1
ORLEC-34-SSM-W	V	ICP-AES	19.3	1
ORLEC-34-SSM-W	Zn	ICP-AES	1.0	0
ORLEC-34-SSM-W	Zr	ICP-AES	1.0	0
ORLEC-44-SSM-W	Al	ICP-AES	1.0	0
ORLEC-44-SSM-W	B	ICP-AES	19.5	1
ORLEC-44-SSM-W	Ca	ICP-AES	15.9	1
ORLEC-44-SSM-W	Cl	IC	11.8	1
ORLEC-44-SSM-W	Cr	ICP-AES	3.0	1
ORLEC-44-SSM-W	F	IC	10.0	0
ORLEC-44-SSM-W	Fe	ICP-AES	1.0	0
ORLEC-44-SSM-W	K	ICP-AES	21.8	1
ORLEC-44-SSM-W	Li	ICP-AES	7.9	1
ORLEC-44-SSM-W	Mg	ICP-AES	1.0	0
ORLEC-44-SSM-W	Na	ICP-AES	756.3	1
ORLEC-44-SSM-W	P	ICP-AES	1.7	1
ORLEC-44-SSM-W	PO4	IC	10.0	0
ORLEC-44-SSM-W	PO4	ICP-AES	5.1	1

Table D-4. Average Measurements of Wash Solutions (continued)

Soln ID	Analyte	Instrument	Mean (mg/L)	BDL Indicator (0=>BDL)
ORLEC-44-SSM-W	S	ICP-AES	524.0	1
ORLEC-44-SSM-W	Si	ICP-AES	10.5	1
ORLEC-44-SSM-W	SO4	IC	1536.7	1
ORLEC-44-SSM-W	SO4	ICP-AES	1569.9	1
ORLEC-44-SSM-W	V	ICP-AES	16.6	1
ORLEC-44-SSM-W	Zn	ICP-AES	1.0	0
ORLEC-44-SSM-W	Zr	ICP-AES	1.0	0
ORLEC-46-SSM-W	Al	ICP-AES	1.0	0
ORLEC-46-SSM-W	B	ICP-AES	16.9	1
ORLEC-46-SSM-W	Ca	ICP-AES	21.9	1
ORLEC-46-SSM-W	Cl	IC	11.8	1
ORLEC-46-SSM-W	Cr	ICP-AES	2.9	1
ORLEC-46-SSM-W	F	IC	10.0	0
ORLEC-46-SSM-W	Fe	ICP-AES	1.0	0
ORLEC-46-SSM-W	K	ICP-AES	22.5	1
ORLEC-46-SSM-W	Li	ICP-AES	15.0	1
ORLEC-46-SSM-W	Mg	ICP-AES	1.0	0
ORLEC-46-SSM-W	Na	ICP-AES	764.0	1
ORLEC-46-SSM-W	P	ICP-AES	1.6	1
ORLEC-46-SSM-W	PO4	IC	10.0	0
ORLEC-46-SSM-W	PO4	ICP-AES	4.8	1
ORLEC-46-SSM-W	S	ICP-AES	529.0	1
ORLEC-46-SSM-W	Si	ICP-AES	11.9	1
ORLEC-46-SSM-W	SO4	IC	1560.0	1
ORLEC-46-SSM-W	SO4	ICP-AES	1584.8	1
ORLEC-46-SSM-W	V	ICP-AES	16.1	1
ORLEC-46-SSM-W	Zn	ICP-AES	1.0	0
ORLEC-46-SSM-W	Zr	ICP-AES	1.0	0
ORLEC-48R-SSM-W	Al	ICP-AES	1.0	0
ORLEC-48R-SSM-W	B	ICP-AES	15.3	1
ORLEC-48R-SSM-W	Ca	ICP-AES	29.9	1
ORLEC-48R-SSM-W	Cl	IC	11.0	1
ORLEC-48R-SSM-W	Cr	ICP-AES	2.9	1
ORLEC-48R-SSM-W	F	IC	10.0	0
ORLEC-48R-SSM-W	Fe	ICP-AES	1.0	0
ORLEC-48R-SSM-W	K	ICP-AES	23.7	1
ORLEC-48R-SSM-W	Li	ICP-AES	23.9	1
ORLEC-48R-SSM-W	Mg	ICP-AES	1.0	0
ORLEC-48R-SSM-W	Na	ICP-AES	710.7	1
ORLEC-48R-SSM-W	P	ICP-AES	1.0	0
ORLEC-48R-SSM-W	PO4	IC	10.0	0
ORLEC-48R-SSM-W	PO4	ICP-AES	3.2	0
ORLEC-48R-SSM-W	S	ICP-AES	533.3	1
ORLEC-48R-SSM-W	Si	ICP-AES	15.1	1
ORLEC-48R-SSM-W	SO4	IC	1586.7	1
ORLEC-48R-SSM-W	SO4	ICP-AES	1597.8	1
ORLEC-48R-SSM-W	V	ICP-AES	14.9	1
ORLEC-48R-SSM-W	Zn	ICP-AES	1.0	0
ORLEC-48R-SSM-W	Zr	ICP-AES	1.0	0

Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence

Analyte=Al (mg/L), Analysis=ICP



Analyte=B (mg/L), Analysis=ICP

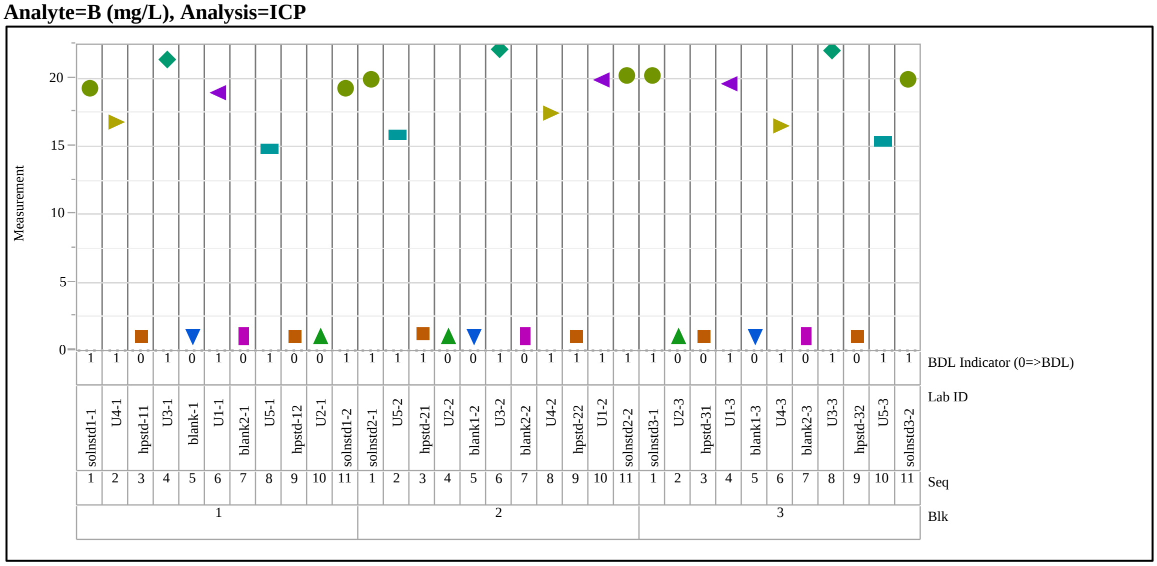
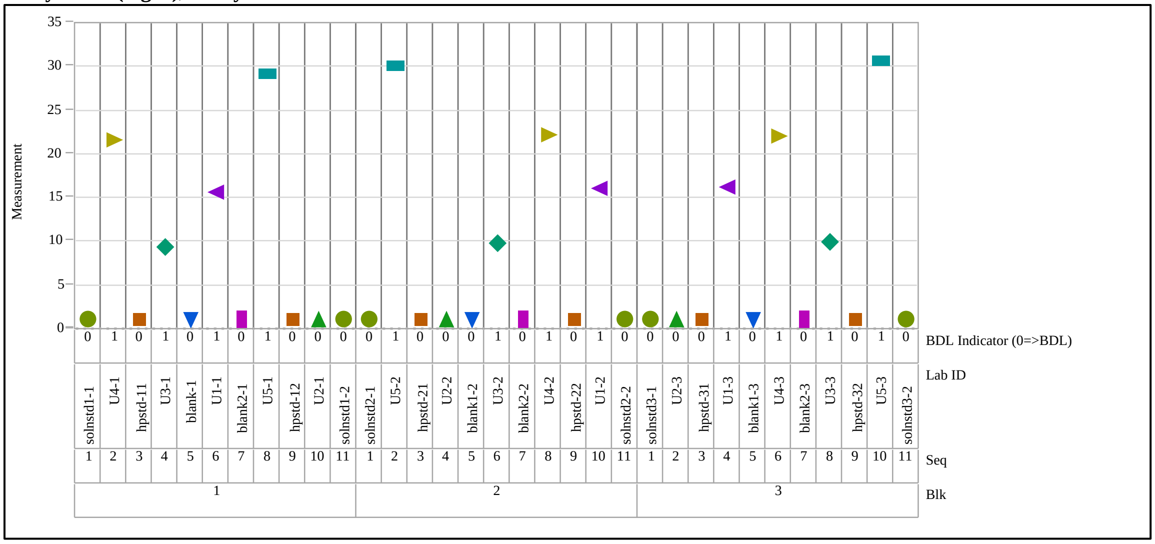


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Ca (mg/L), Analysis=ICP



Analyte=Cl (mg/L), Analysis=IC

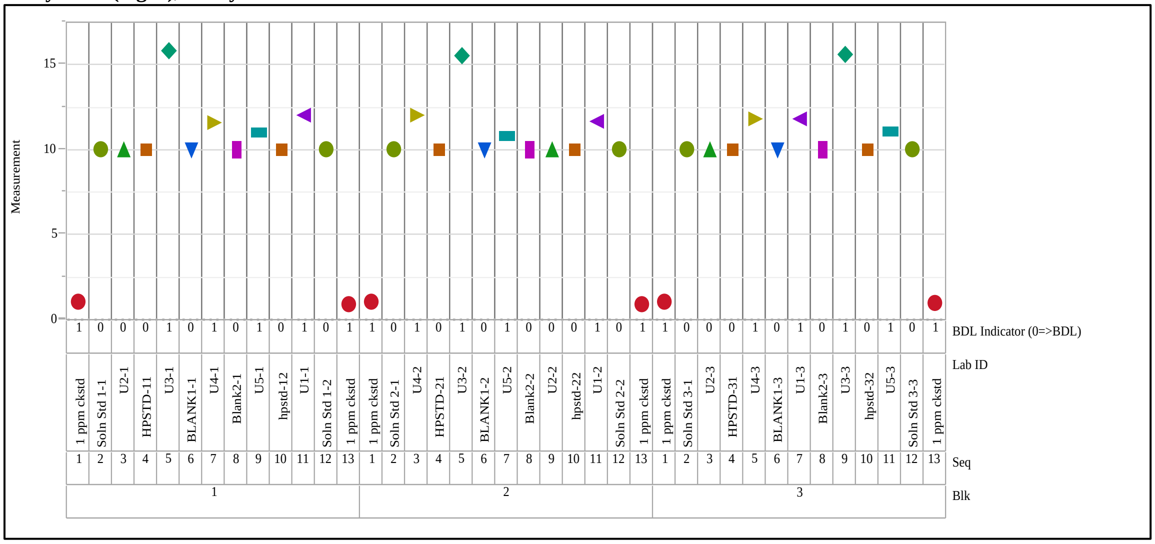
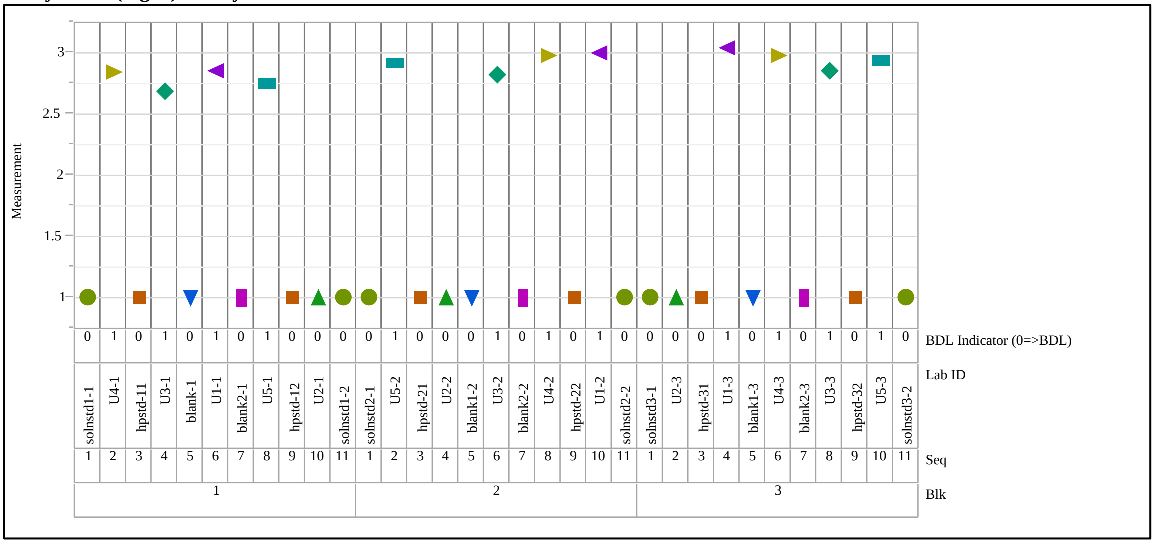


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Cr (mg/L), Analysis=ICP



Analyte=F (mg/L), Analysis=IC

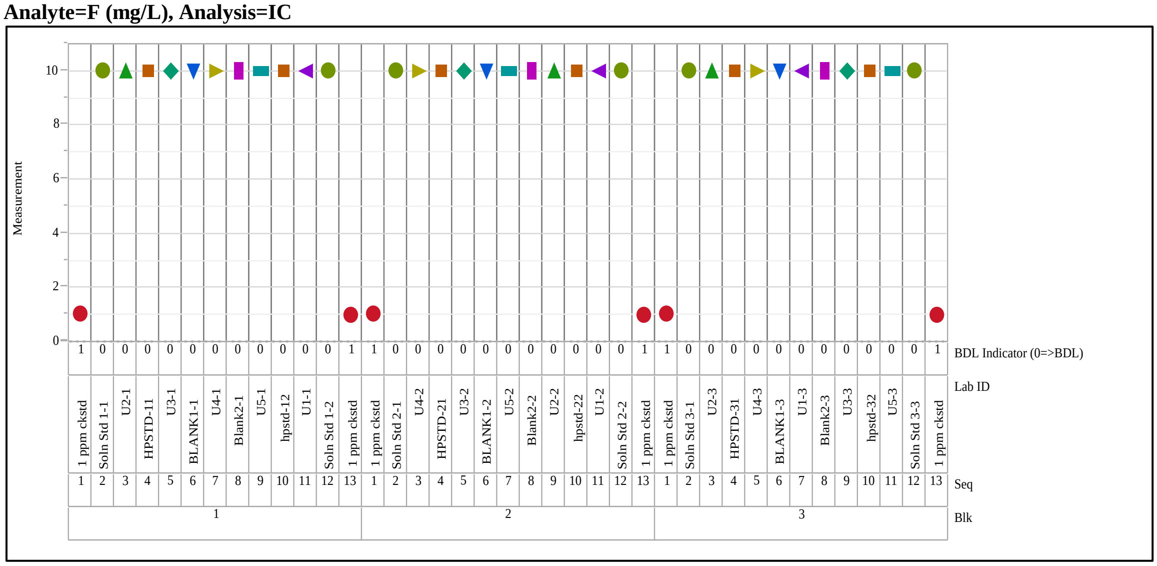
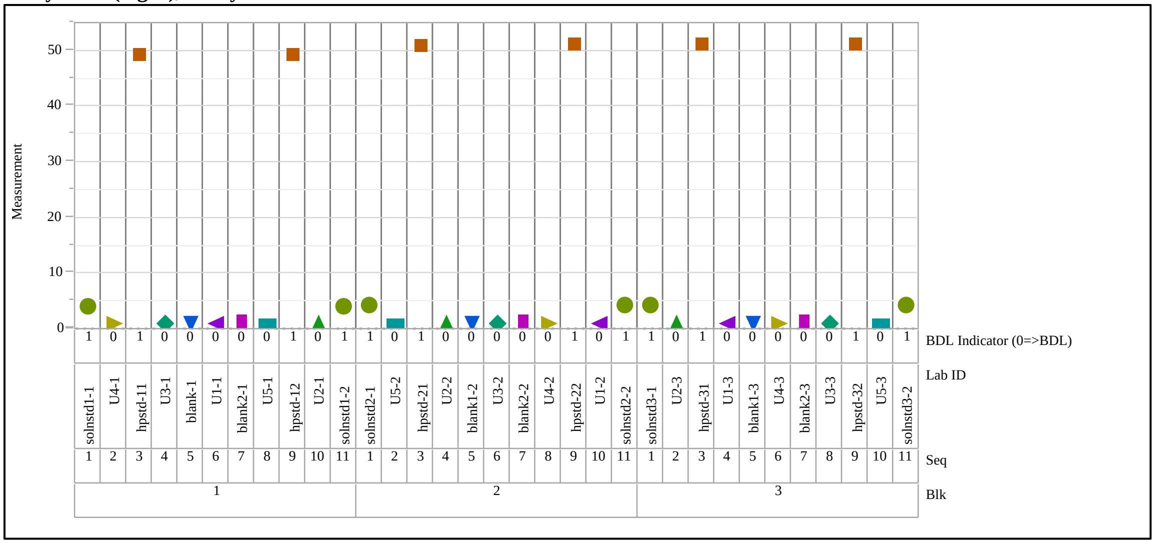


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Fe (mg/L), Analysis=ICP



Analyte=K (mg/L), Analysis=ICP

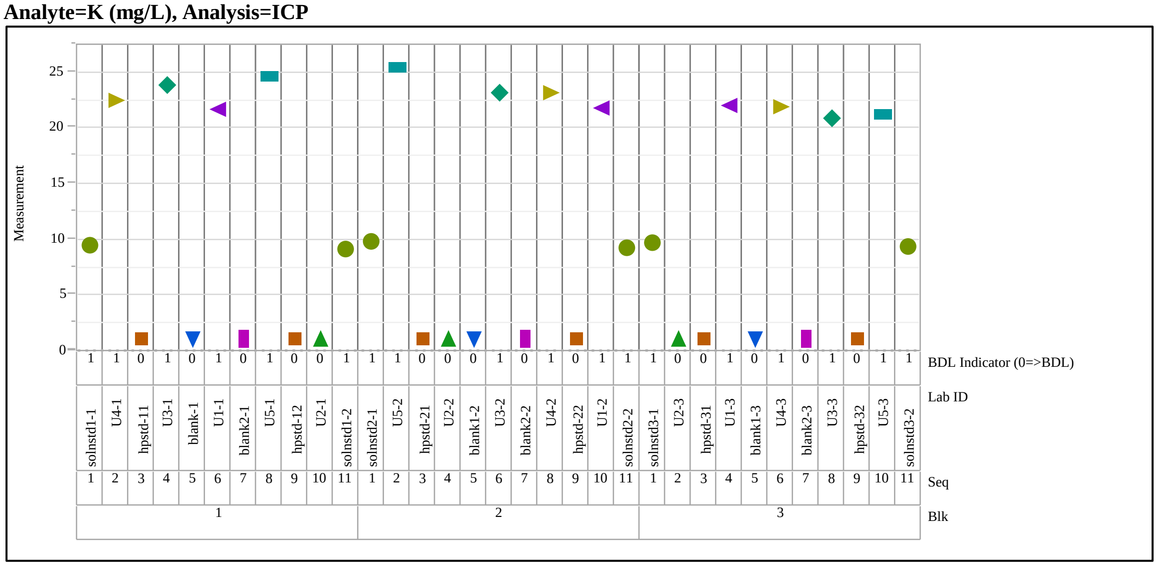
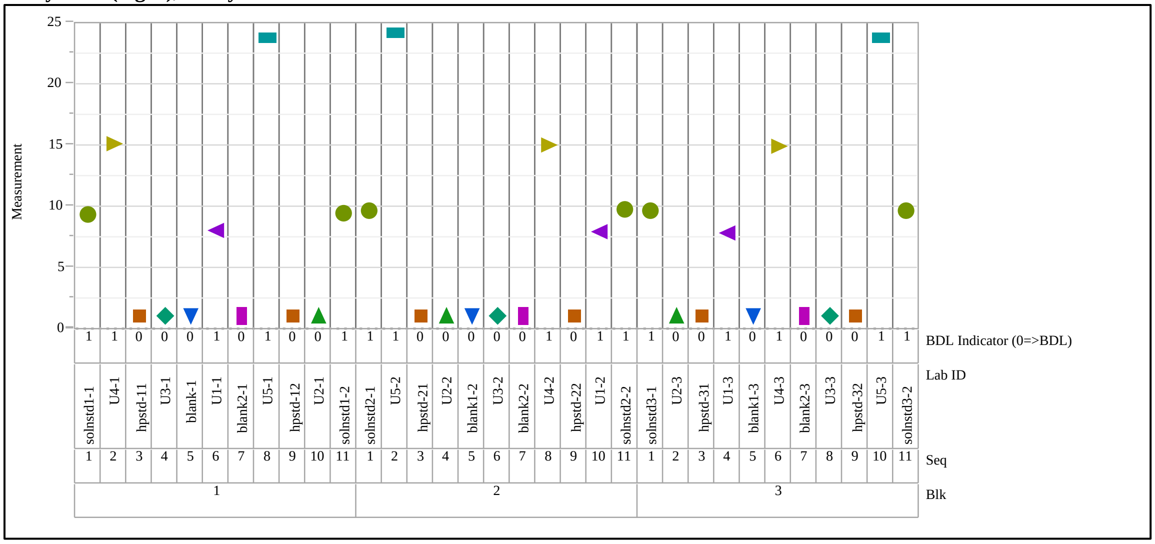


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Li (mg/L), Analysis=ICP



Analyte=Mg (mg/L), Analysis=ICP

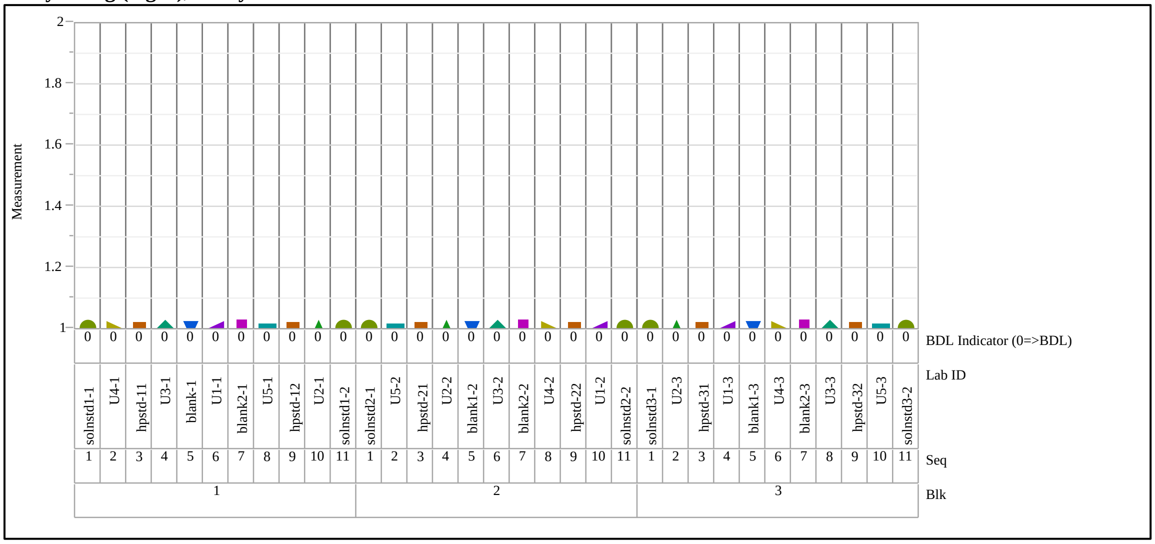
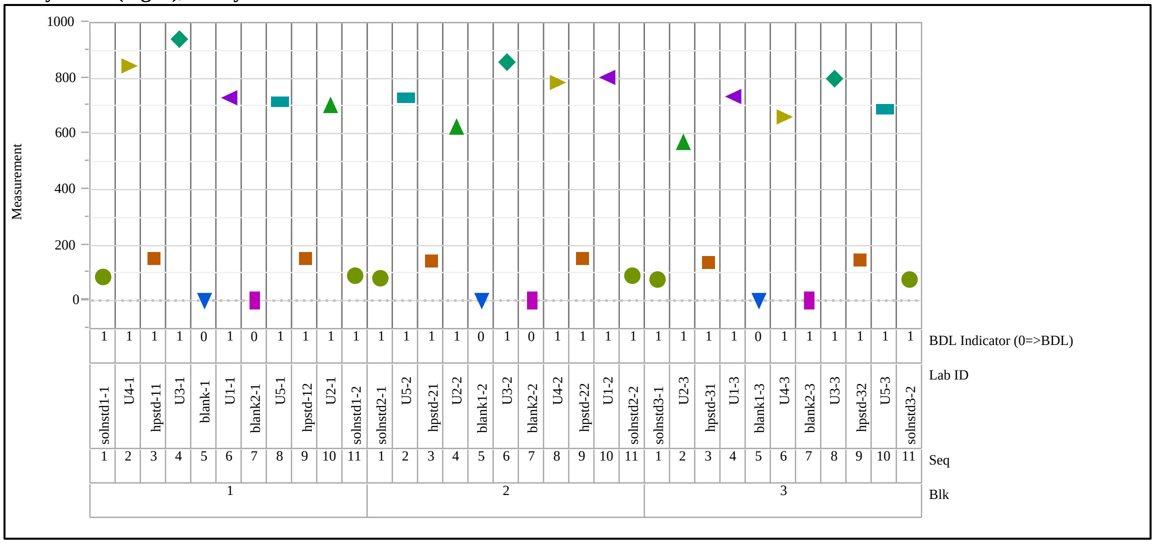


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Na (mg/L), Analysis=ICP



Analyte=P (mg/L), Analysis=ICP

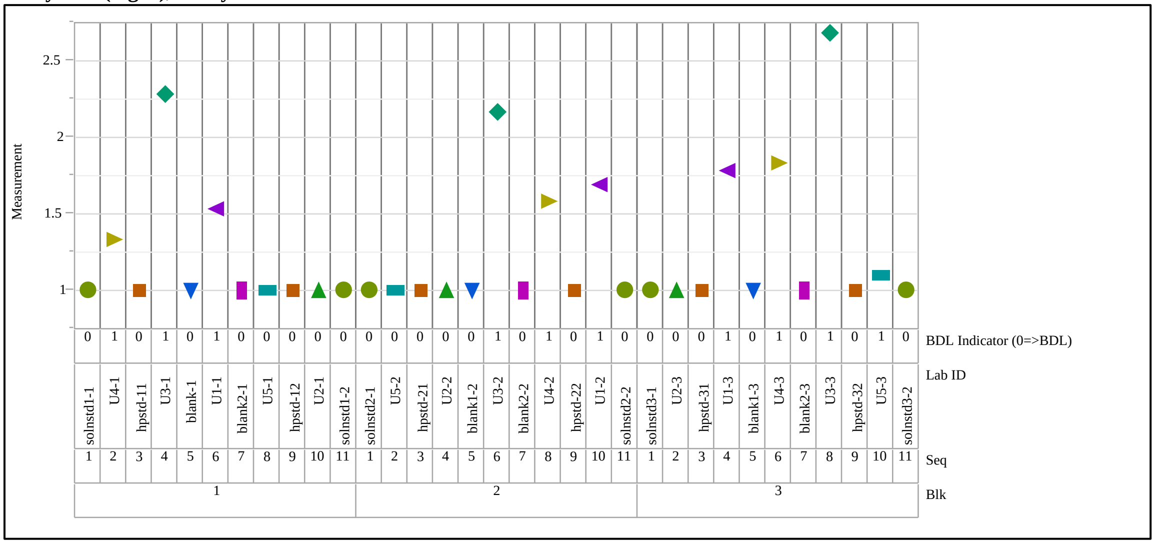
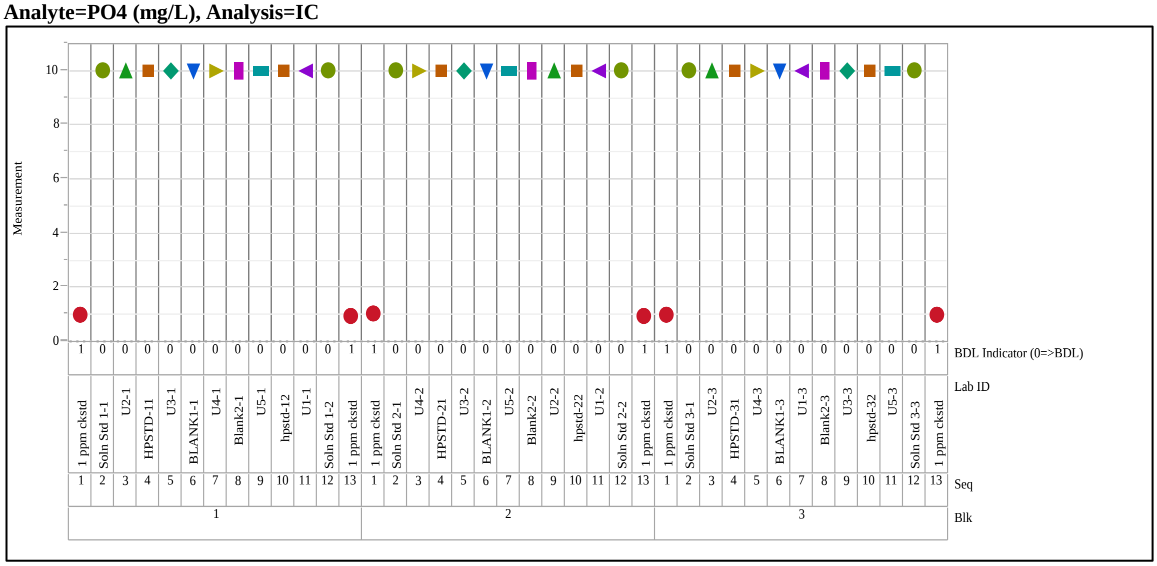


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=PO4 (mg/L), Analysis=IC



Analyte=S (mg/L), Analysis=ICP

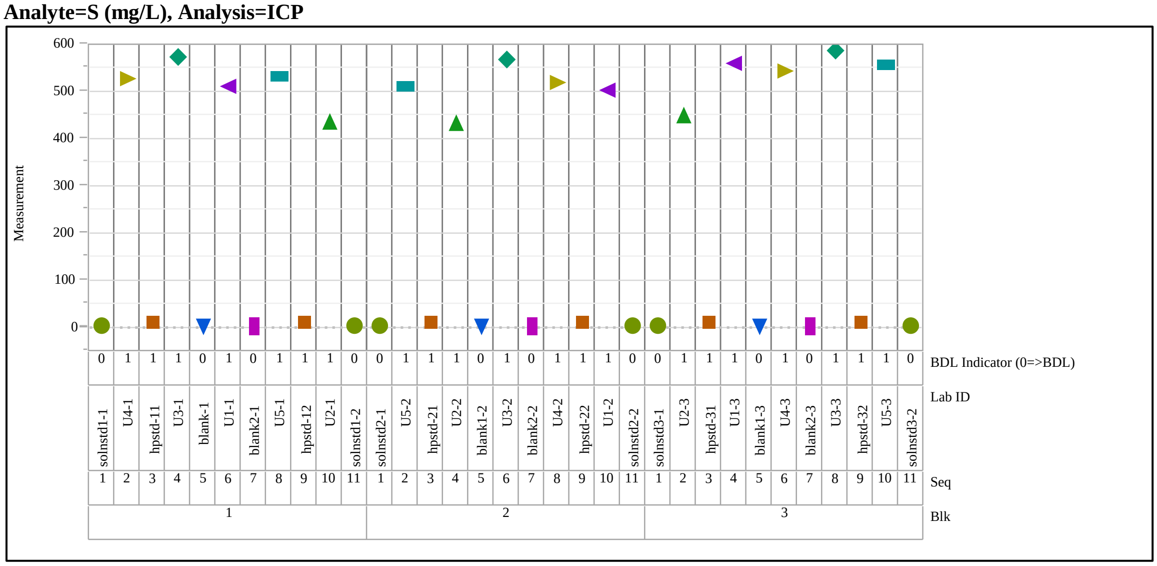
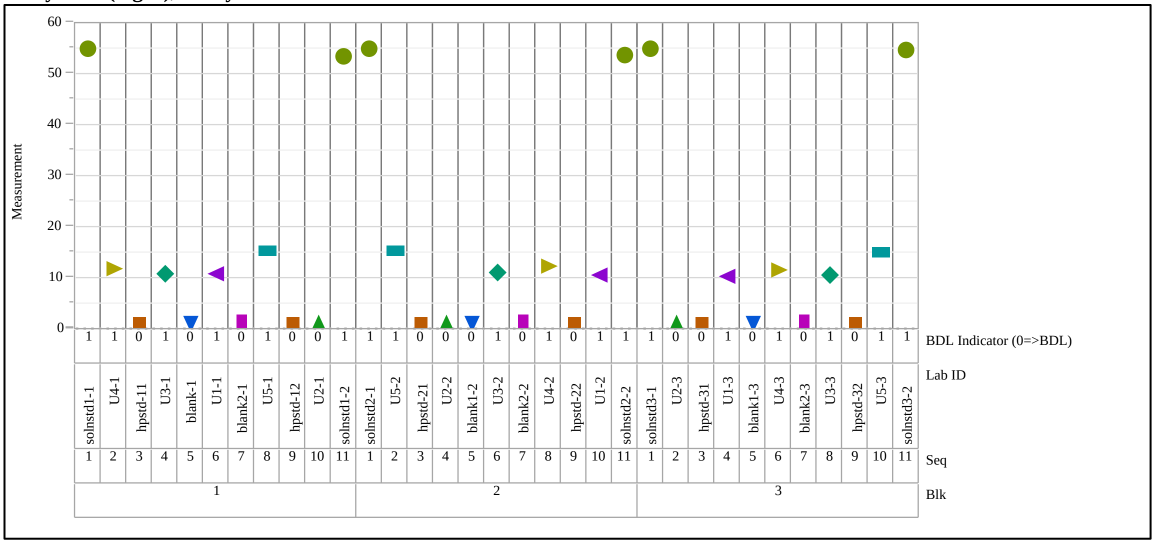


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Si (mg/L), Analysis=ICP



Analyte=SO4 (mg/L), Analysis=IC

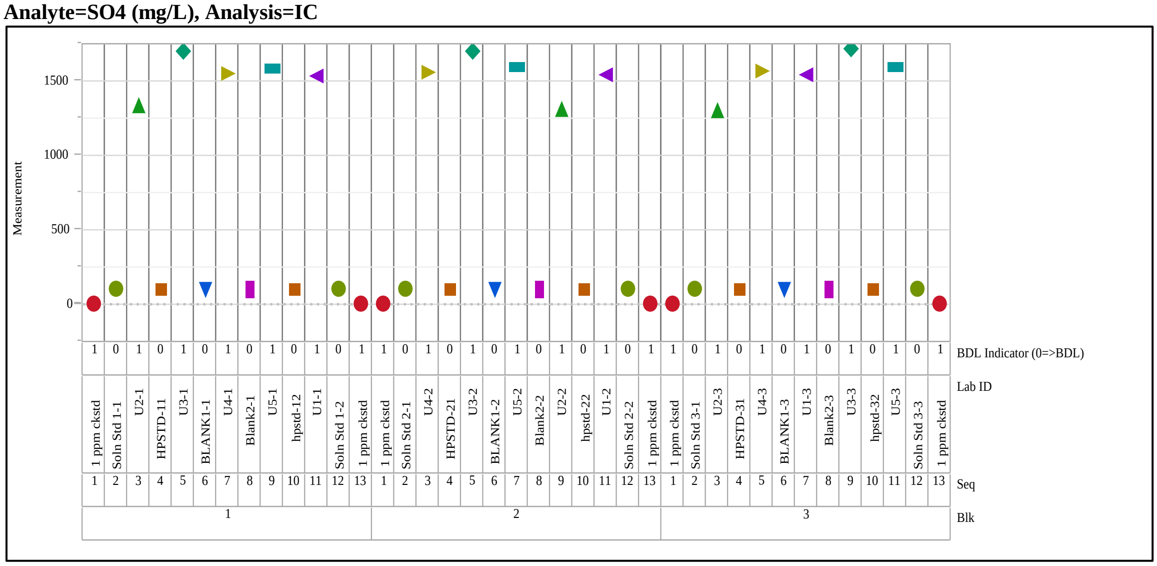
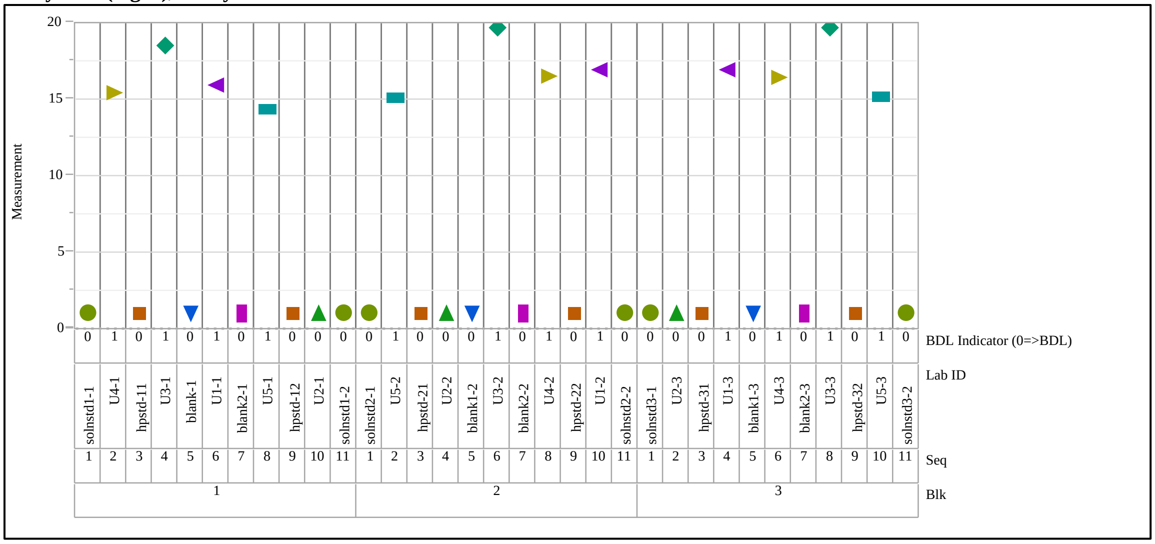


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=V (mg/L), Analysis=ICP



Analyte=Zn (mg/L), Analysis=ICP

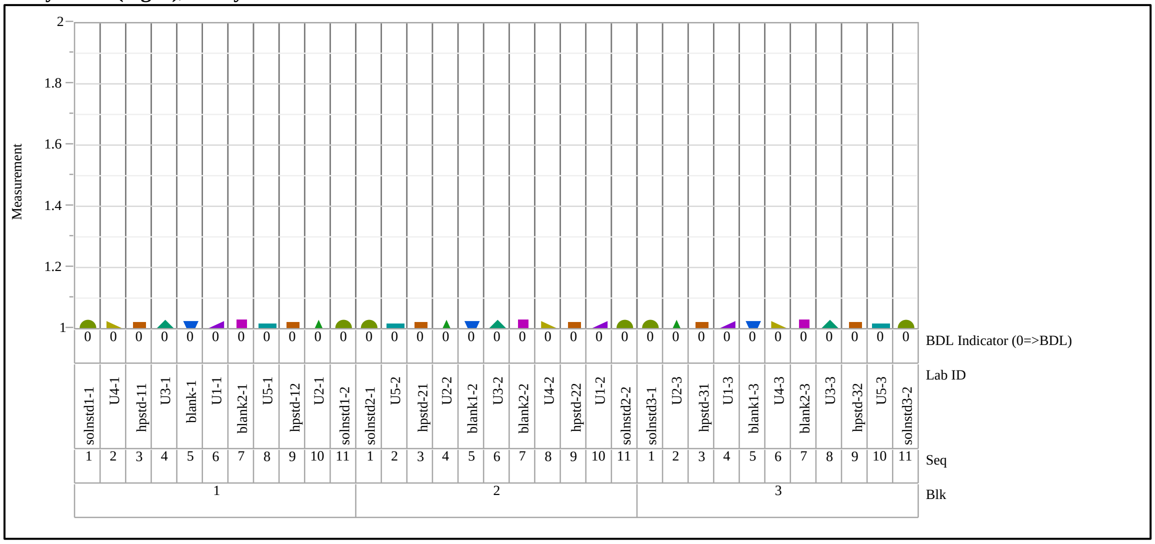


Exhibit D-1. Measurements of Wash Solutions by Analyte Grouped by Block in Analytical Sequence (continued)

Analyte=Zr (mg/L), Analysis=ICP

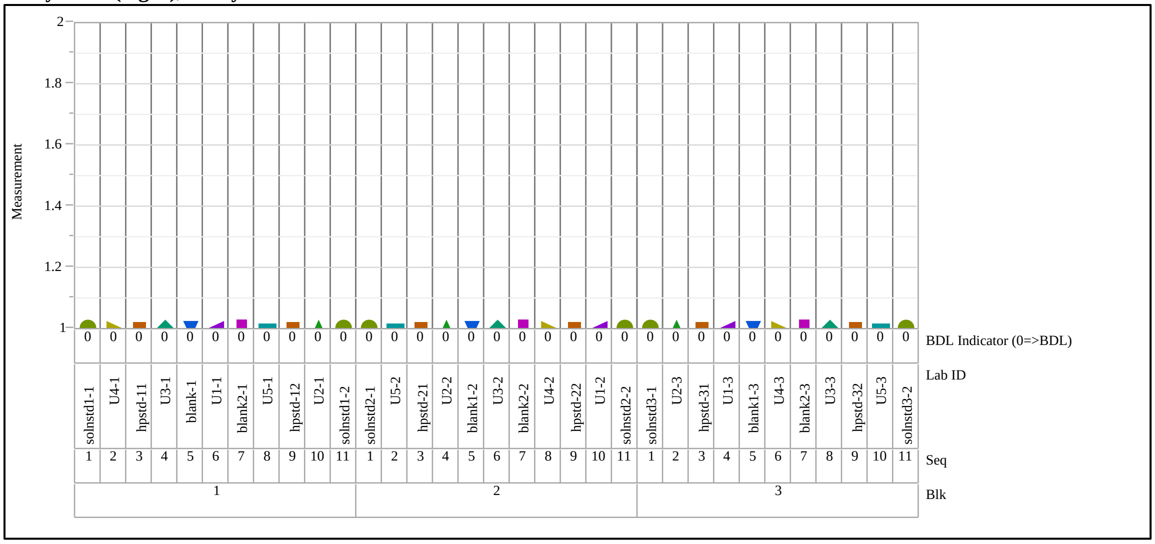


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier

Variability Gauge Analyte=Al (mg/L), Analysis=ICP
Variability Chart for Measurement

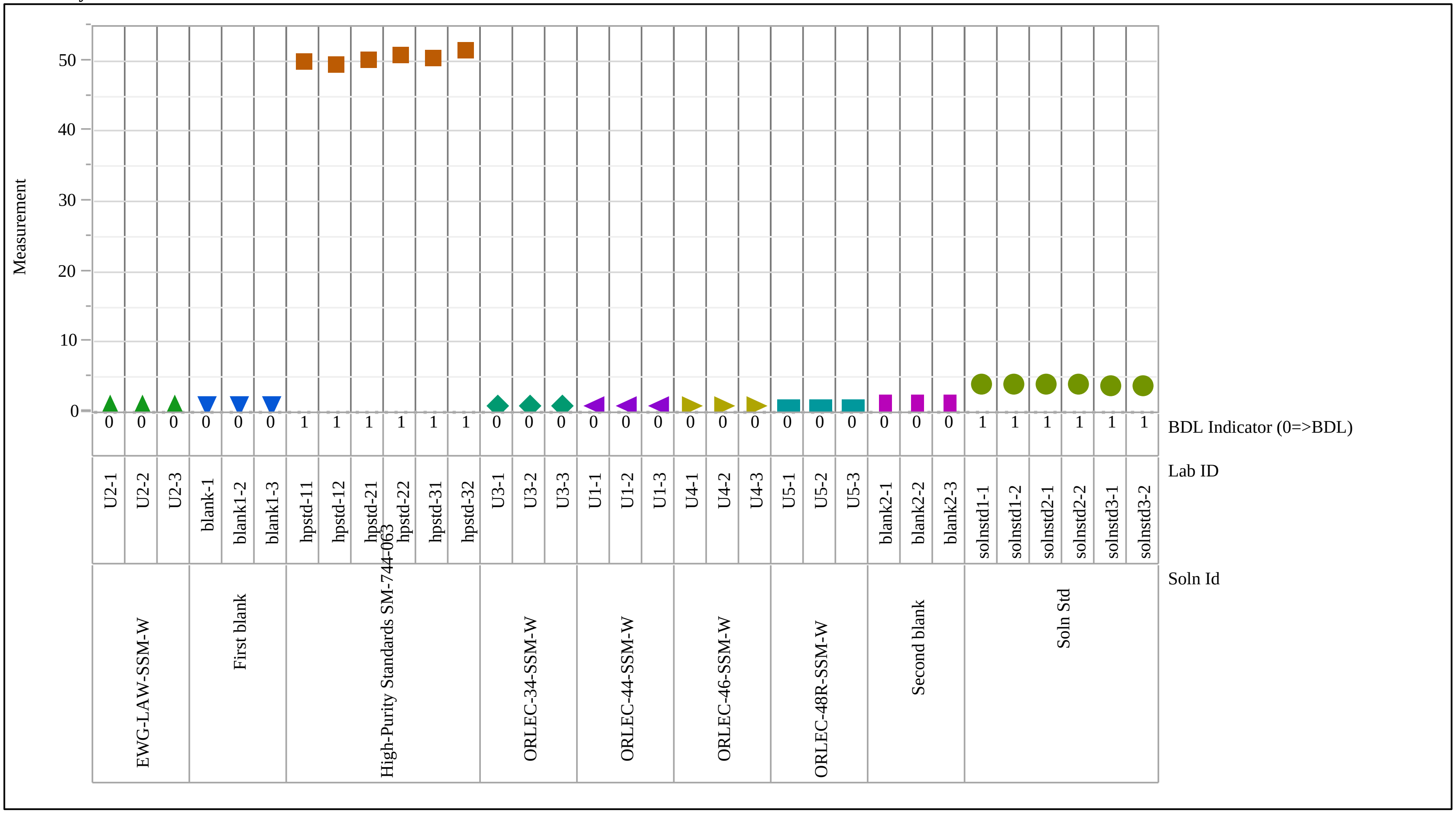


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=B (mg/L), Analysis=ICP
Variability Chart for Measurement

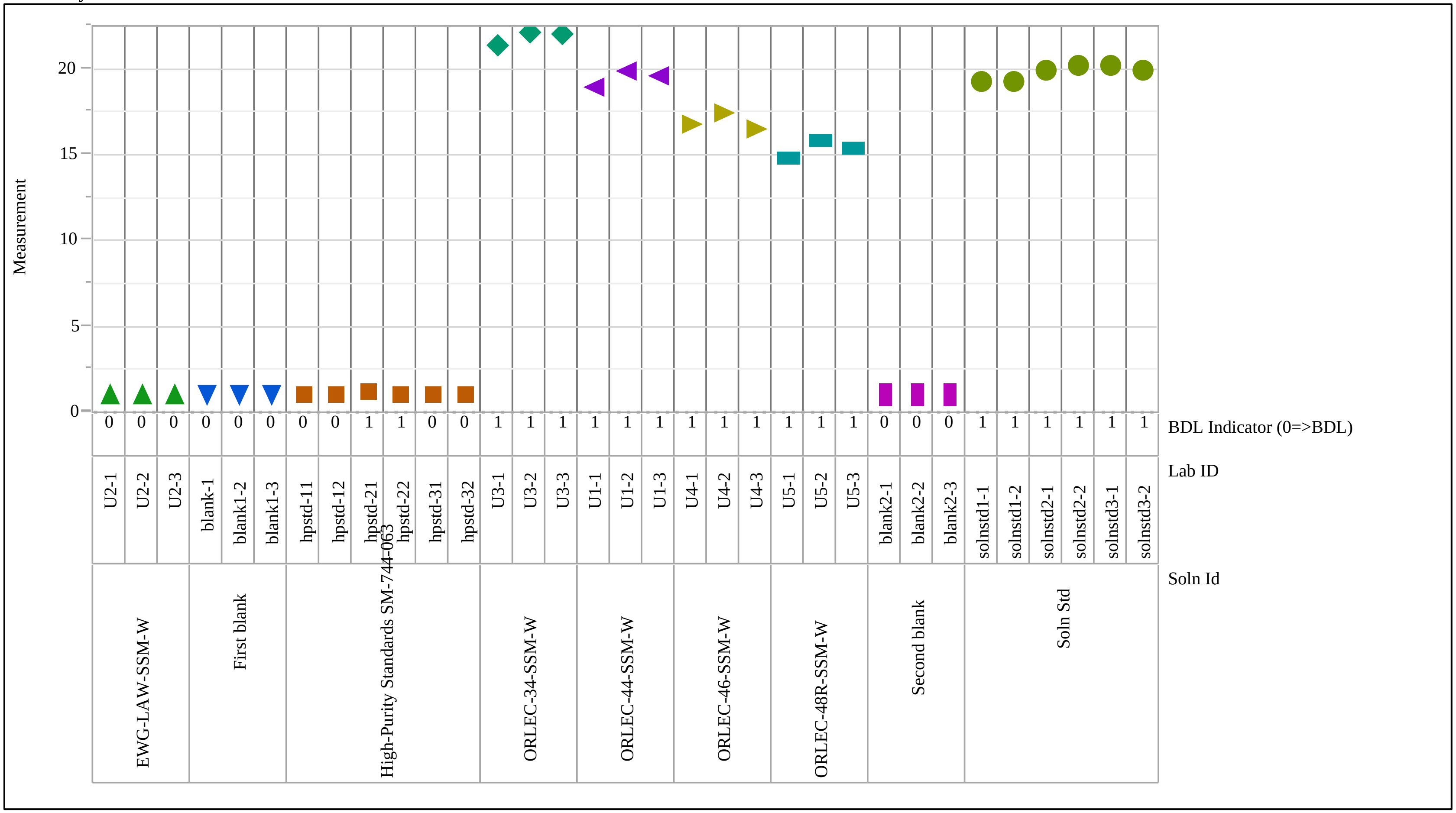


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Ca (mg/L), Analysis=ICP
Variability Chart for Measurement

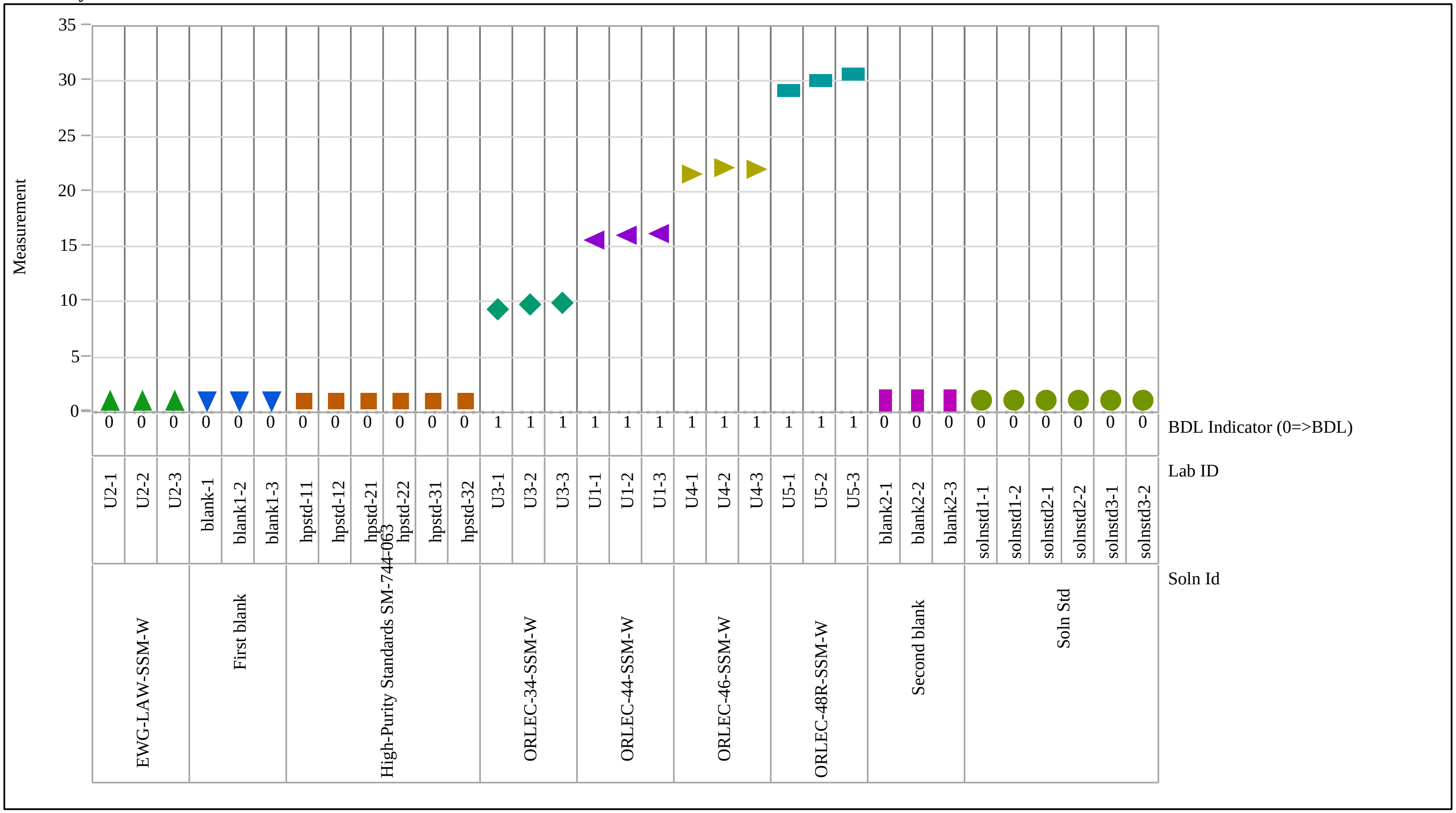


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Cl (mg/L), Analysis=IC
Variability Chart for Measurement

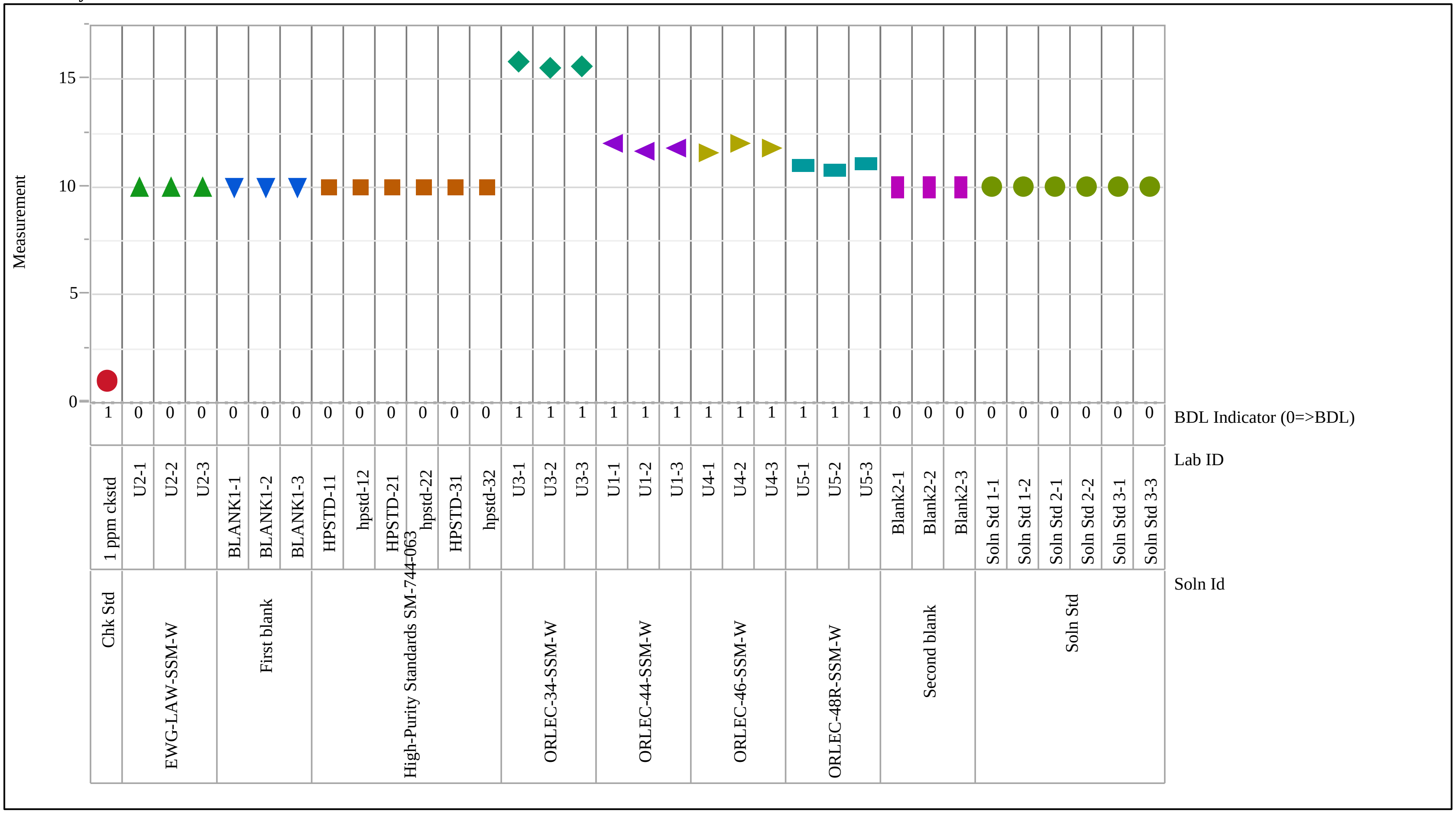


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Cr (mg/L), Analysis=ICP
Variability Chart for Measurement

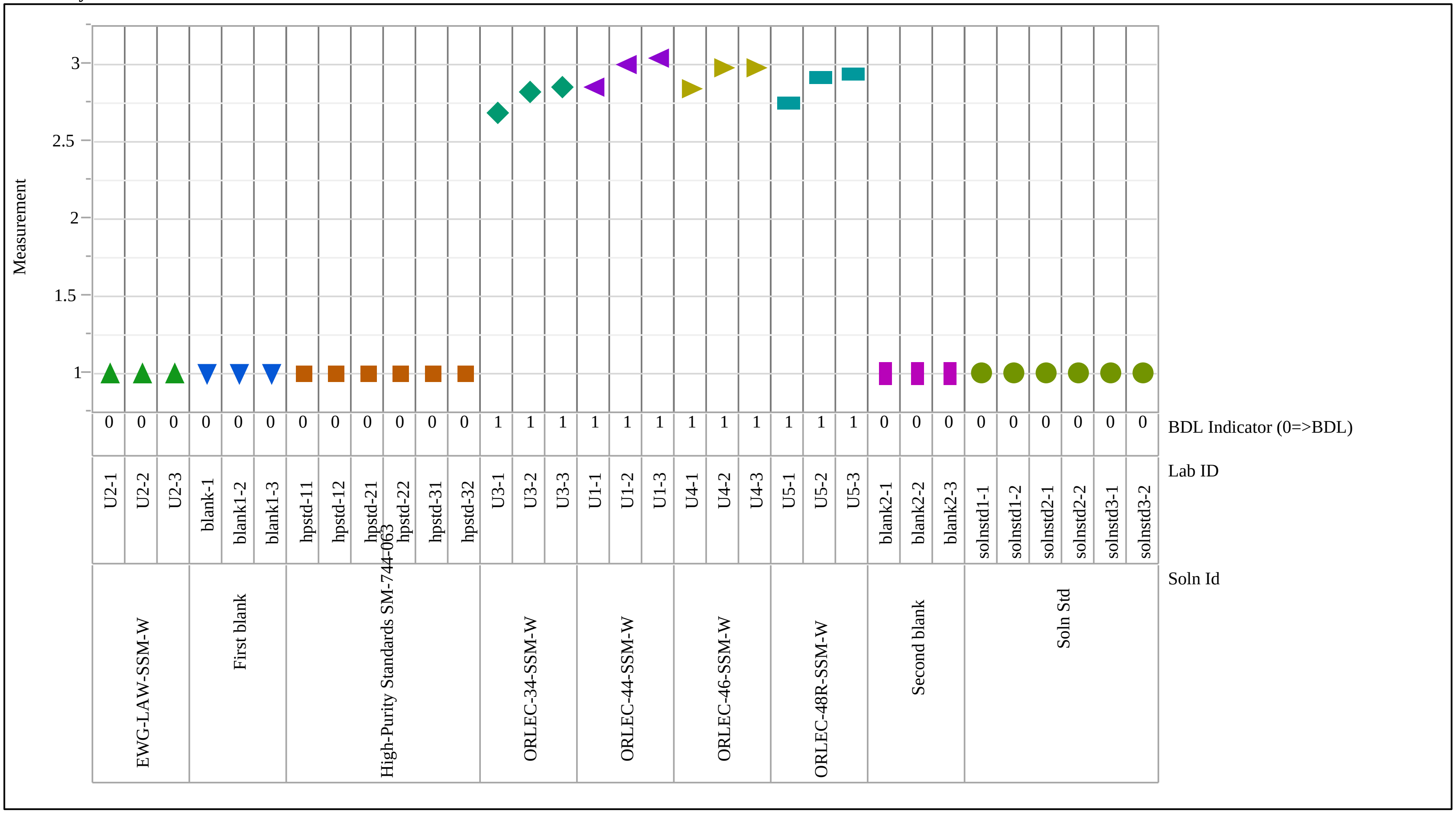


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=F (mg/L), Analysis=IC
Variability Chart for Measurement

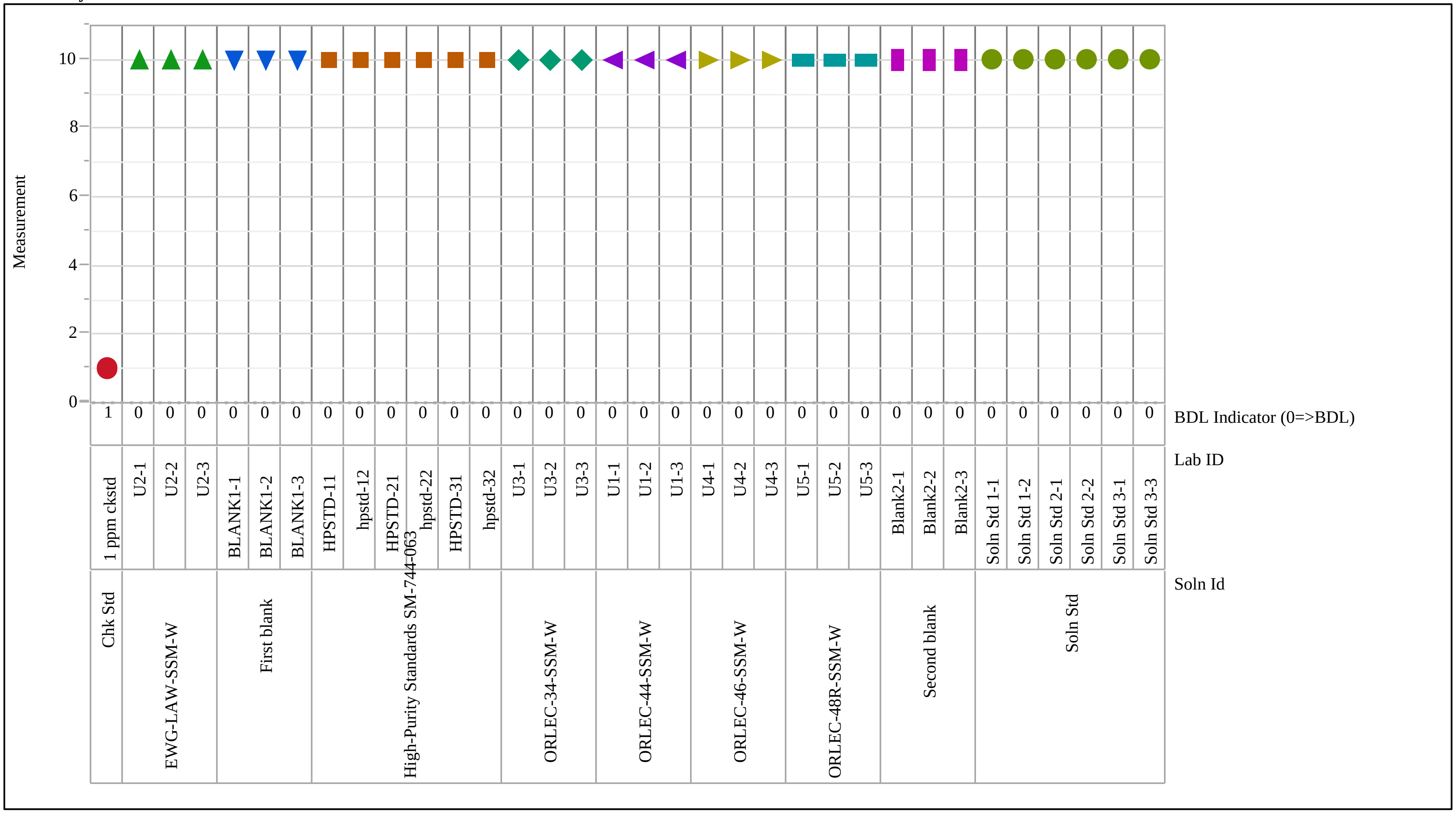


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Fe (mg/L), Analysis=ICP
Variability Chart for Measurement

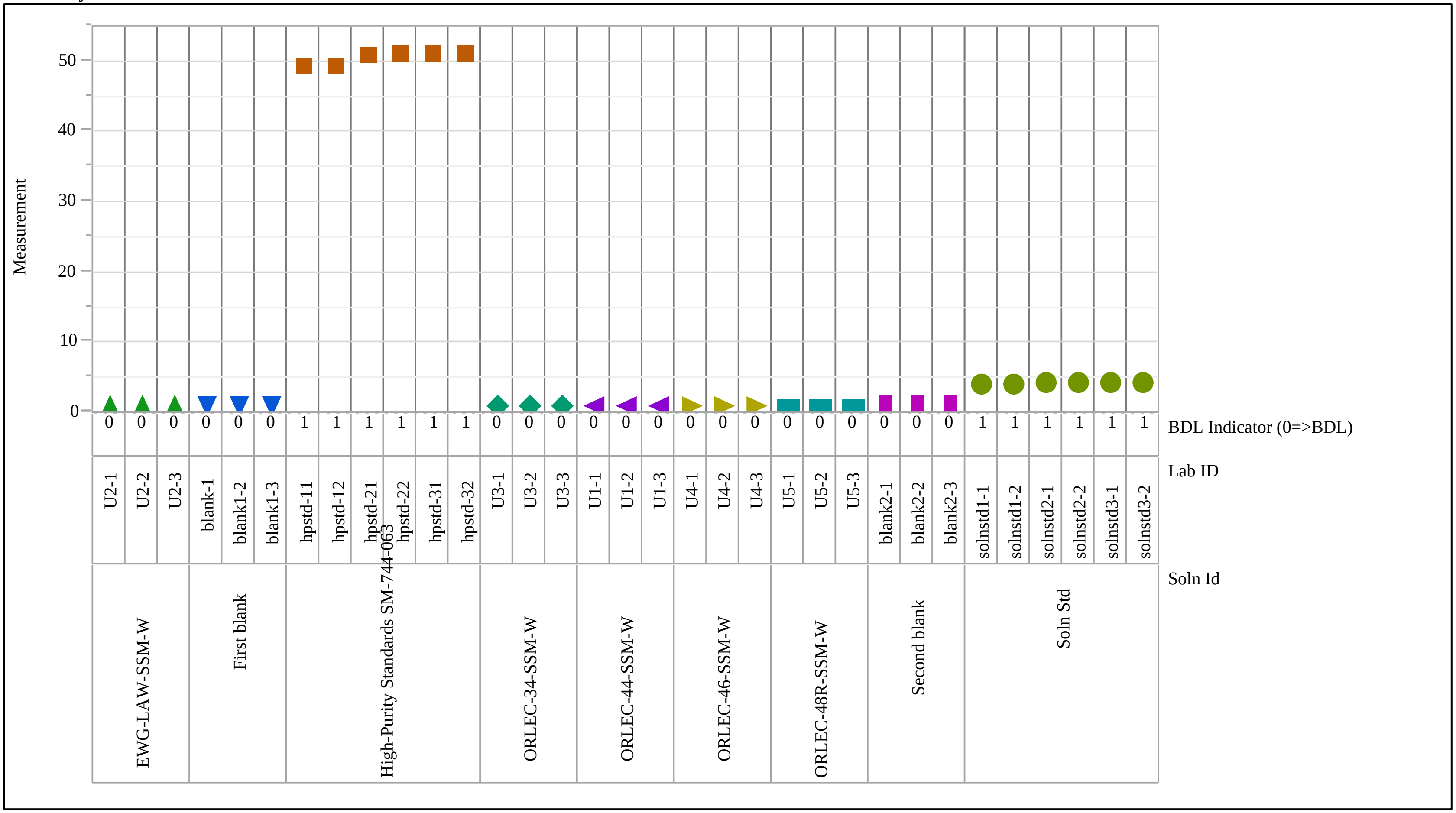


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=K (mg/L), Analysis=ICP
Variability Chart for Measurement

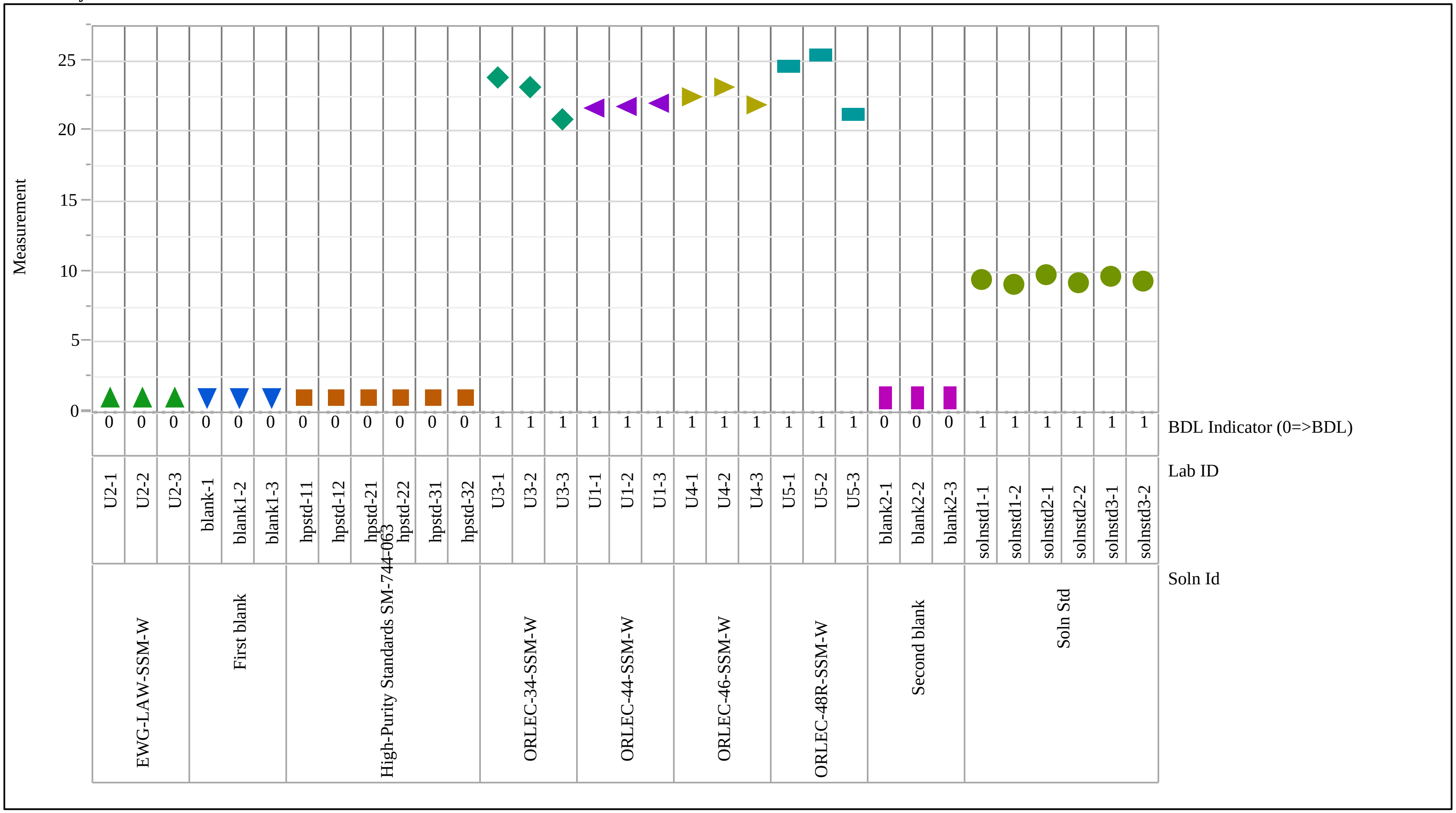


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

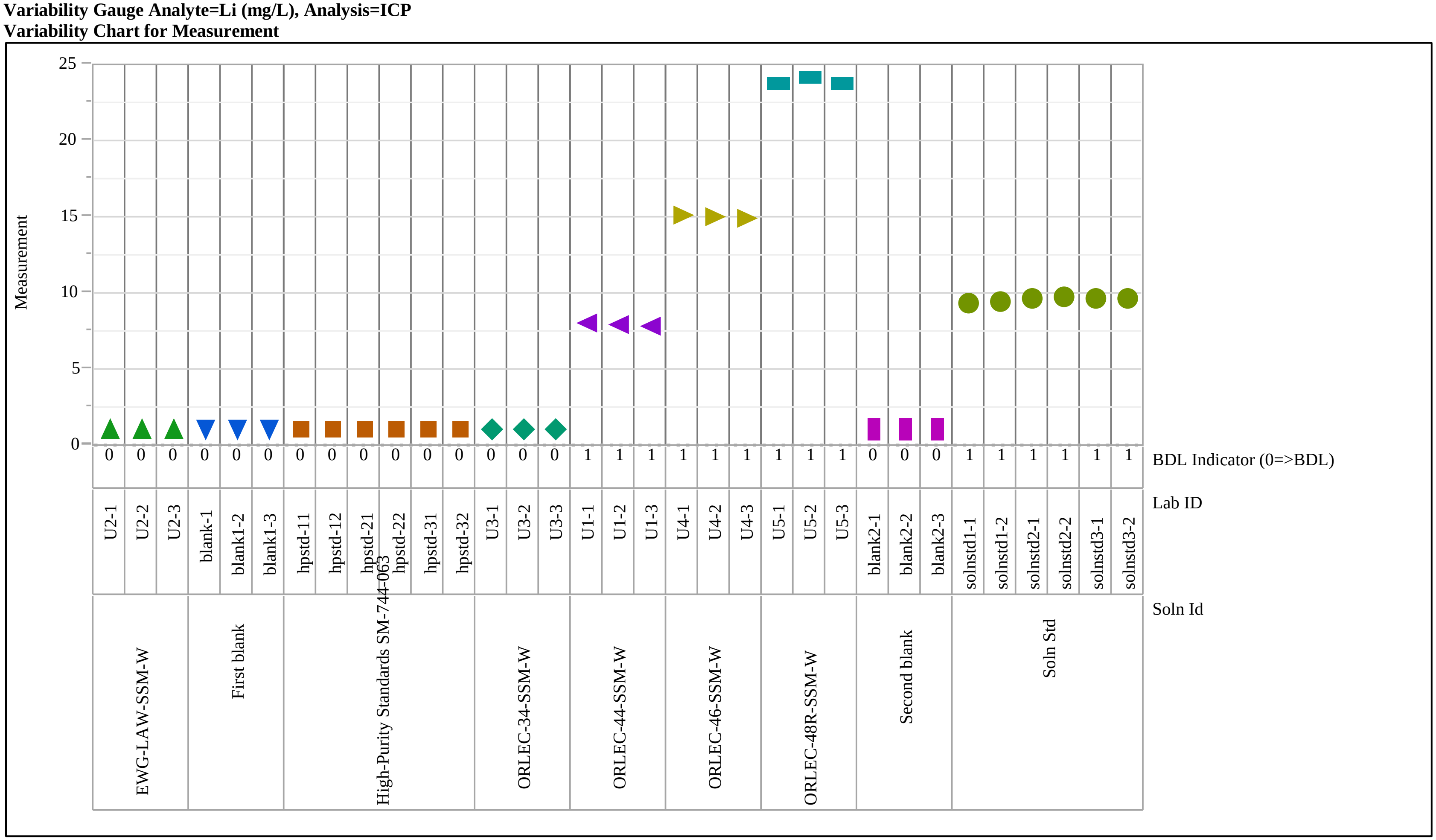


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Mg (mg/L), Analysis=ICP
Variability Chart for Measurement

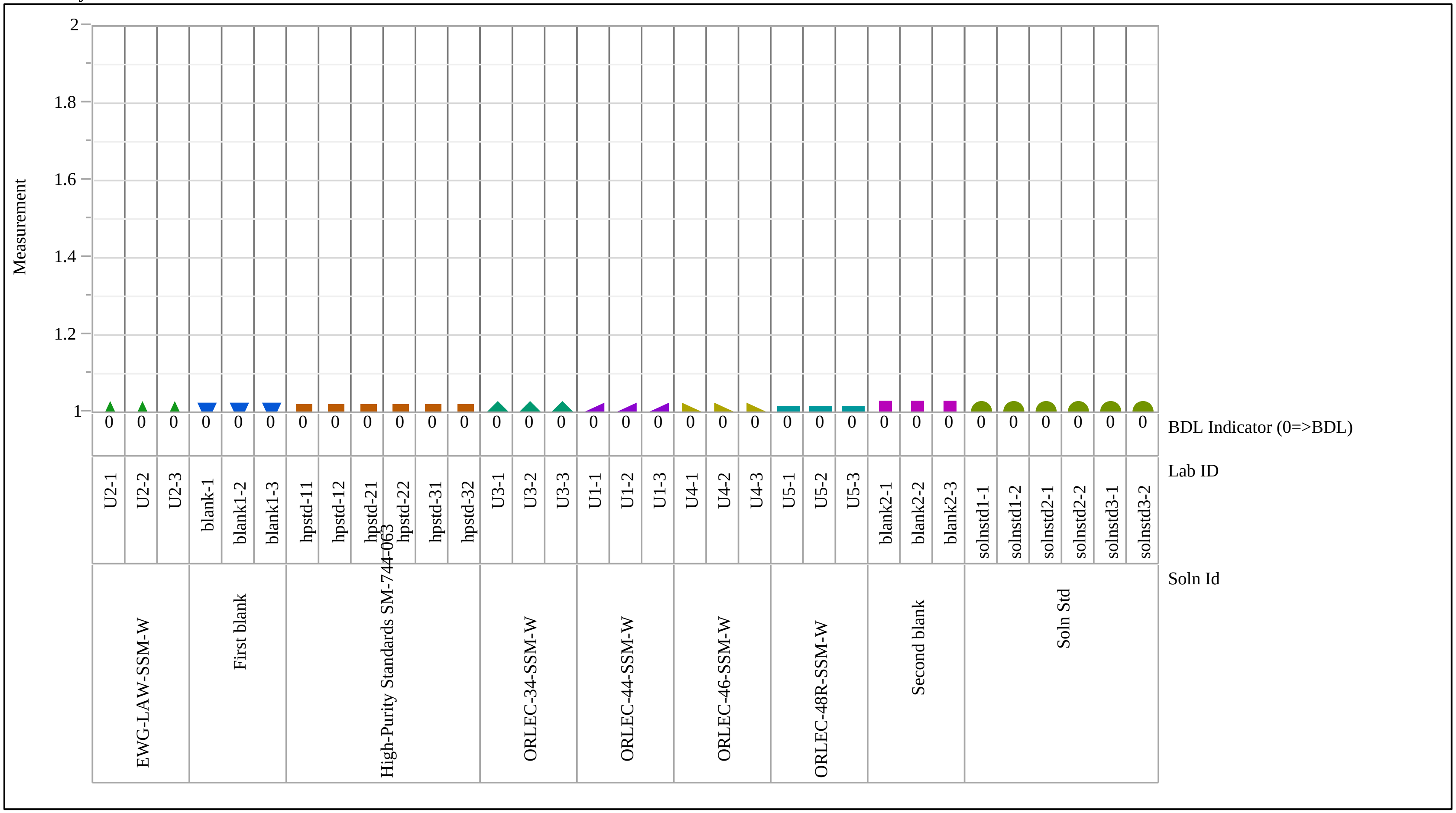


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Na (mg/L), Analysis=ICP
Variability Chart for Measurement

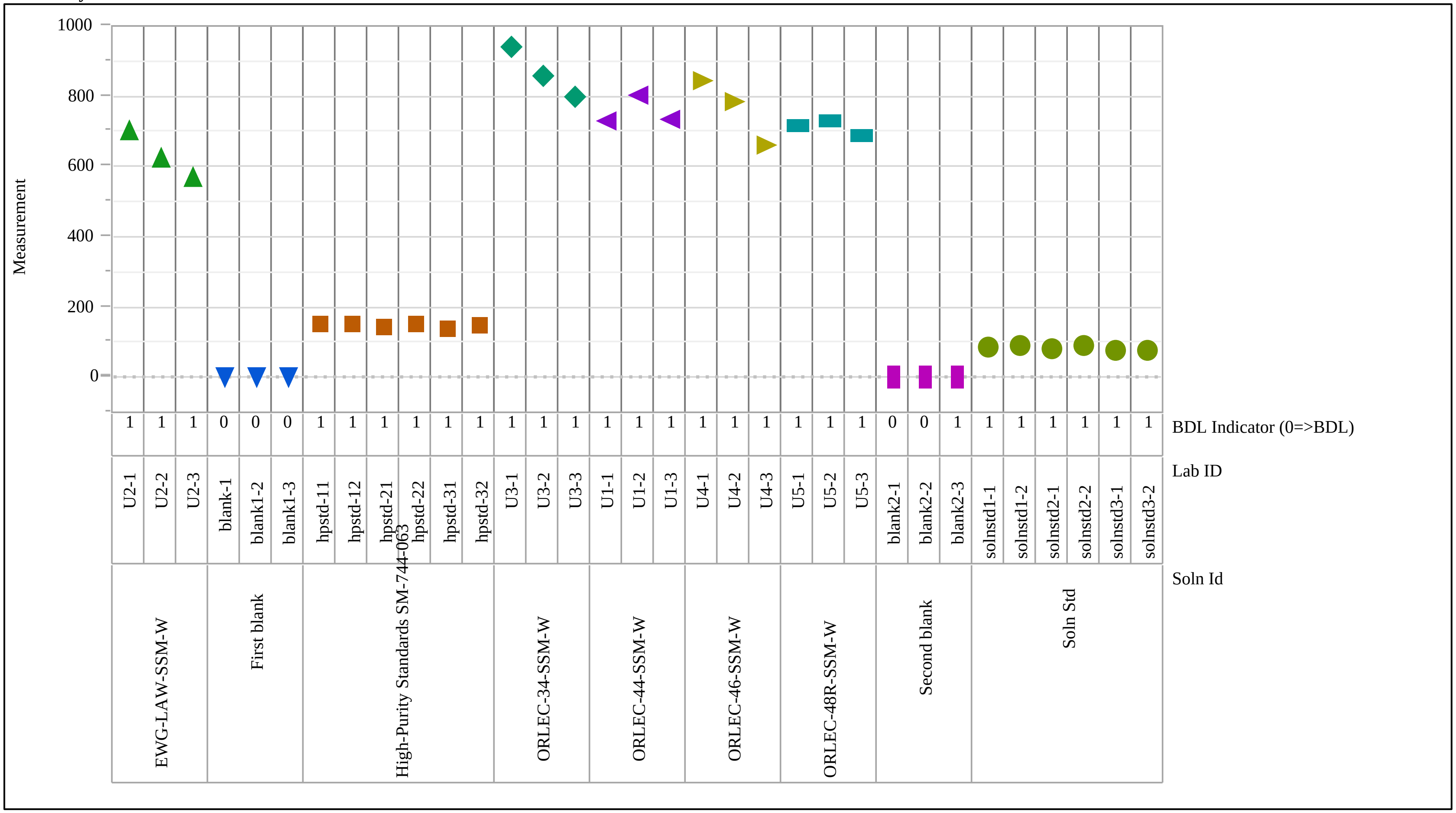


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=P (mg/L), Analysis=ICP
Variability Chart for Measurement

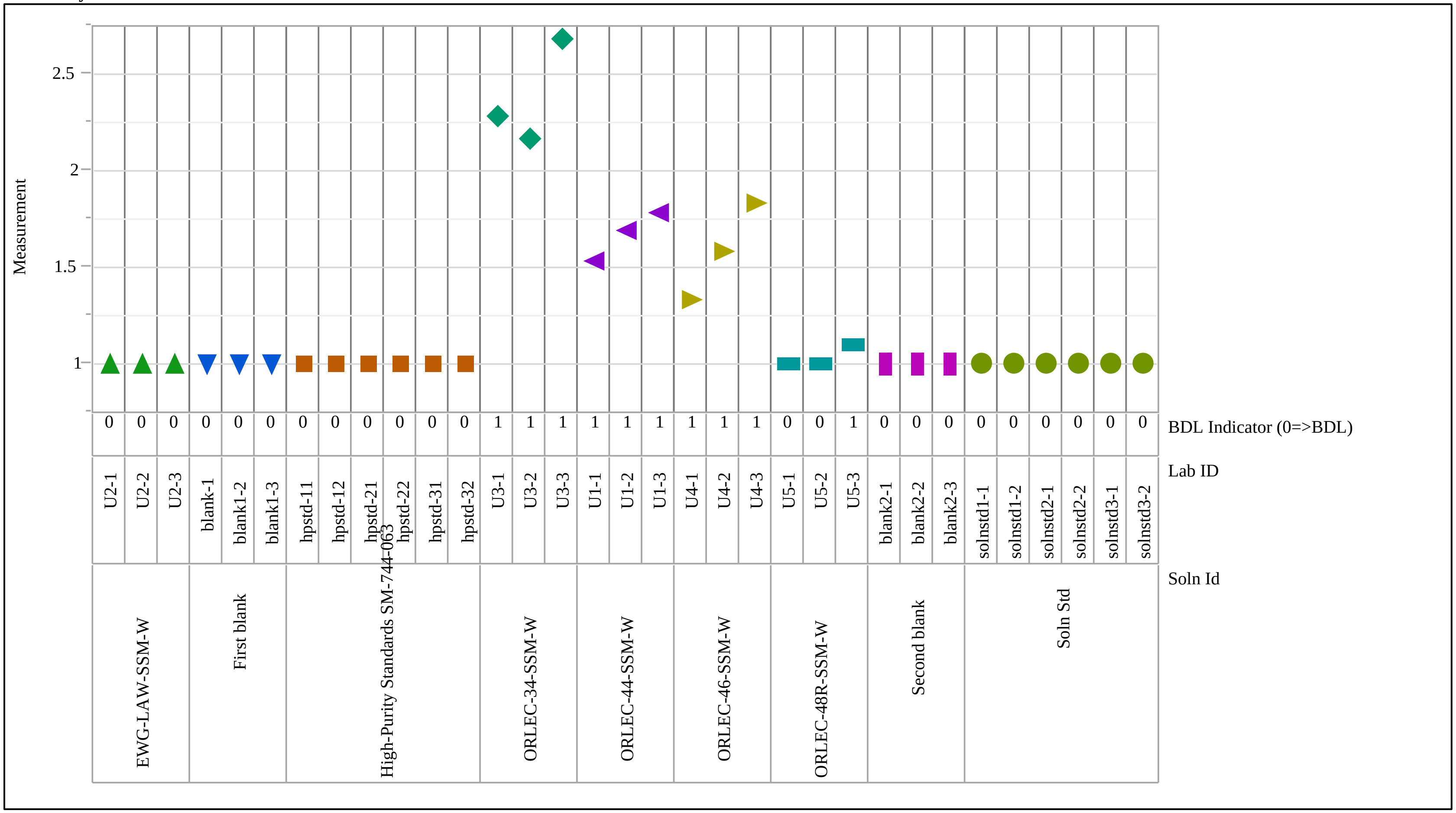


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=PO4 (mg/L), Analysis=IC
Variability Chart for Measurement

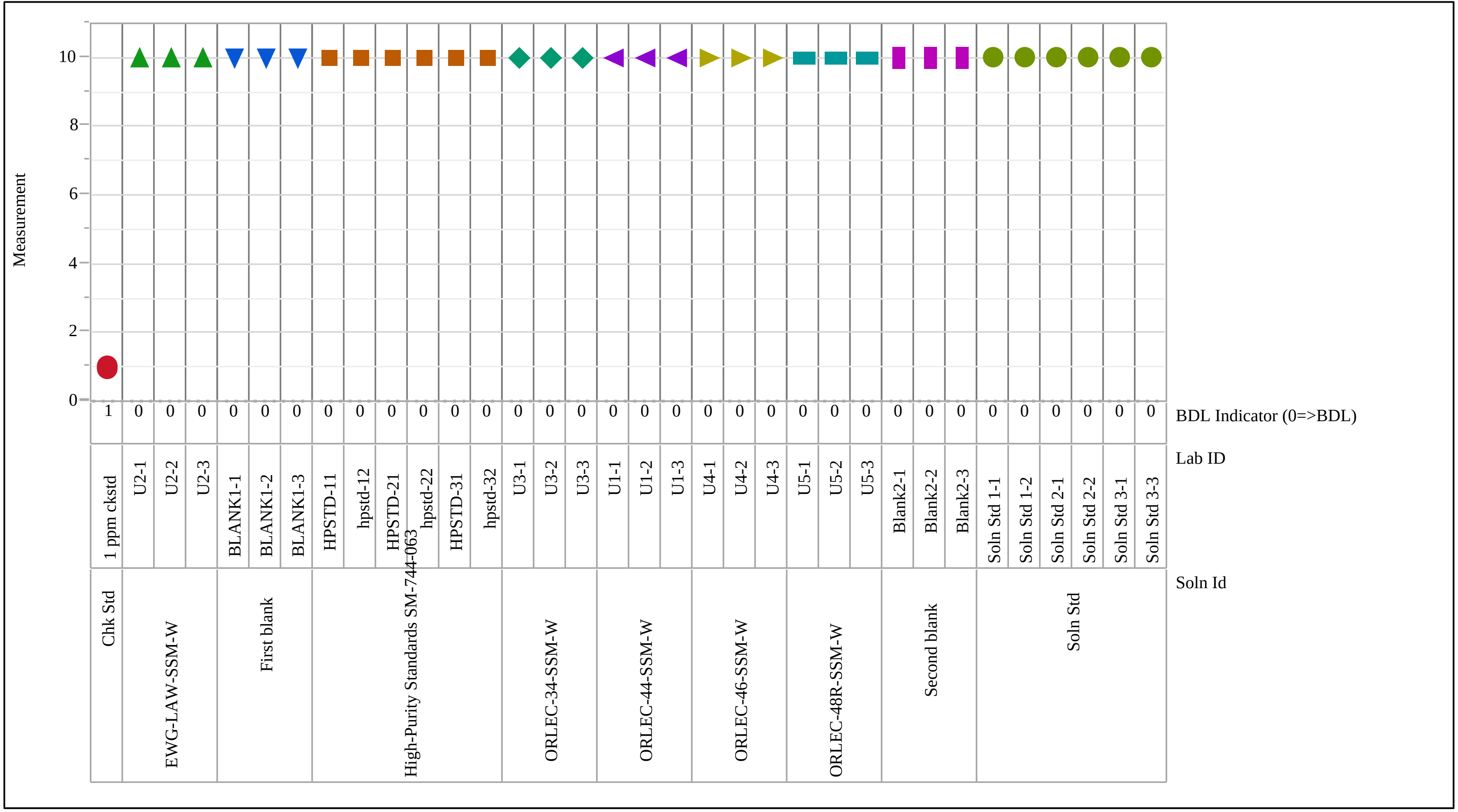


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=S (mg/L), Analysis=ICP
Variability Chart for Measurement

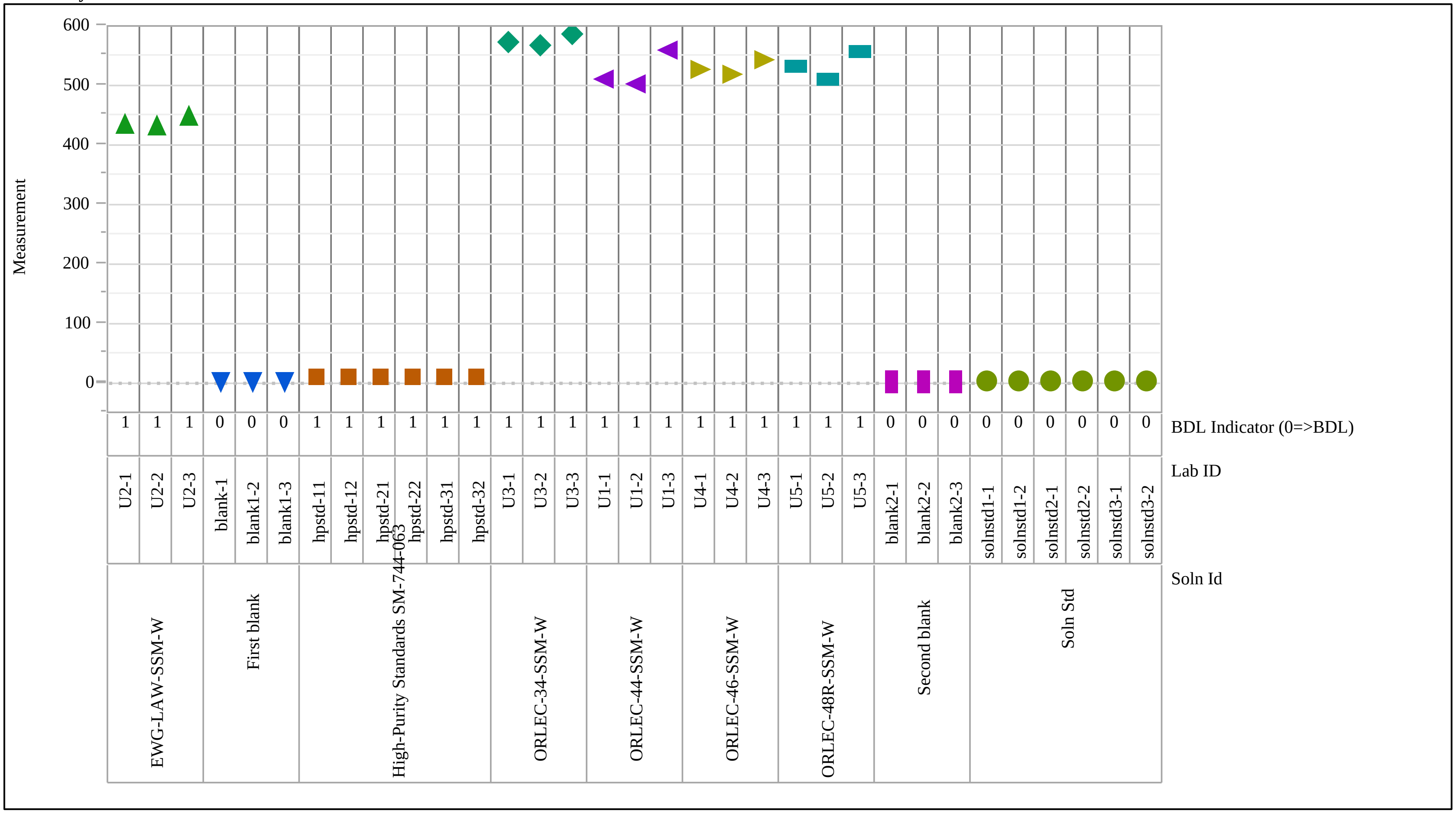


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

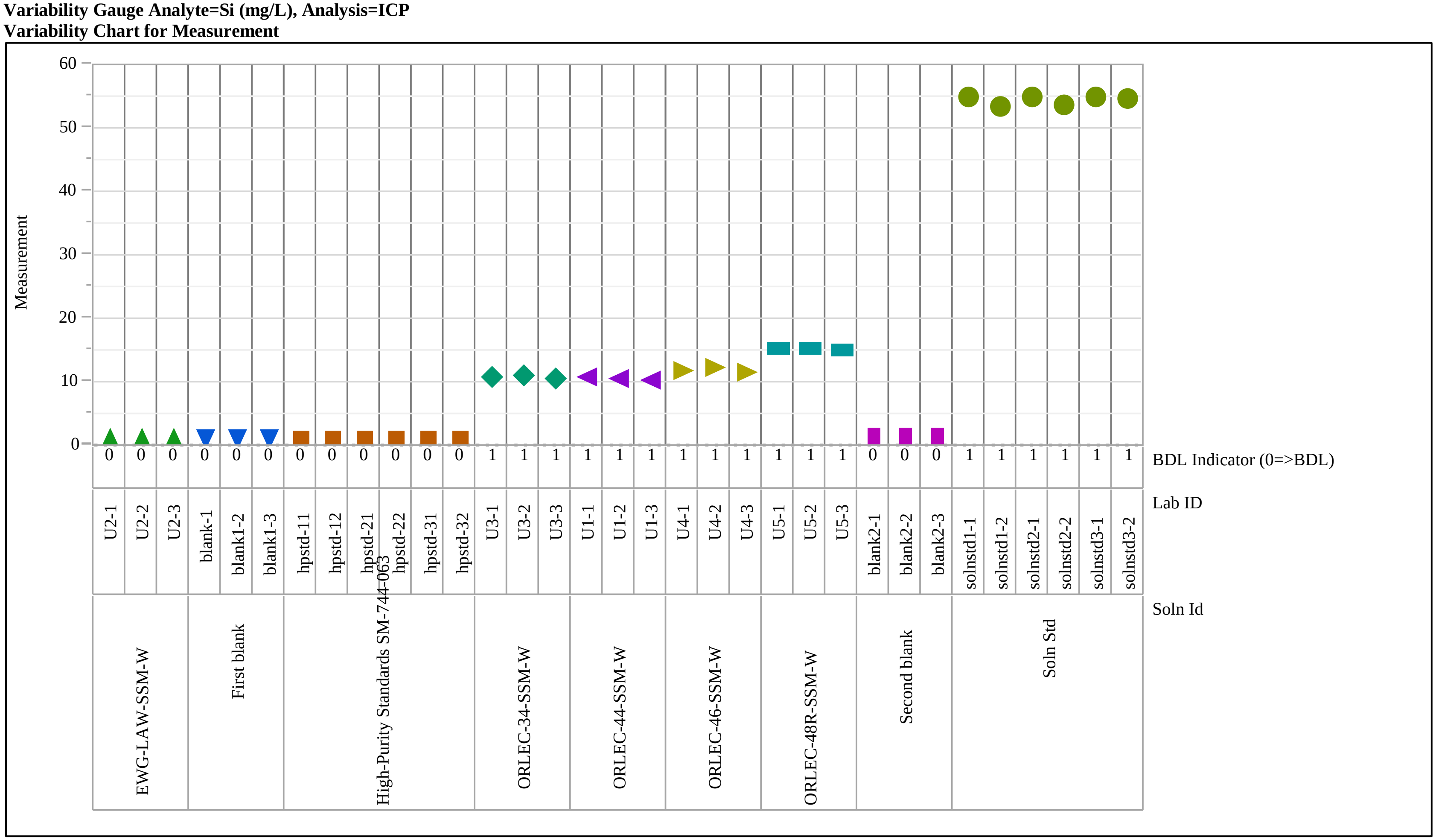


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=SO4 (mg/L), Analysis=IC
Variability Chart for Measurement

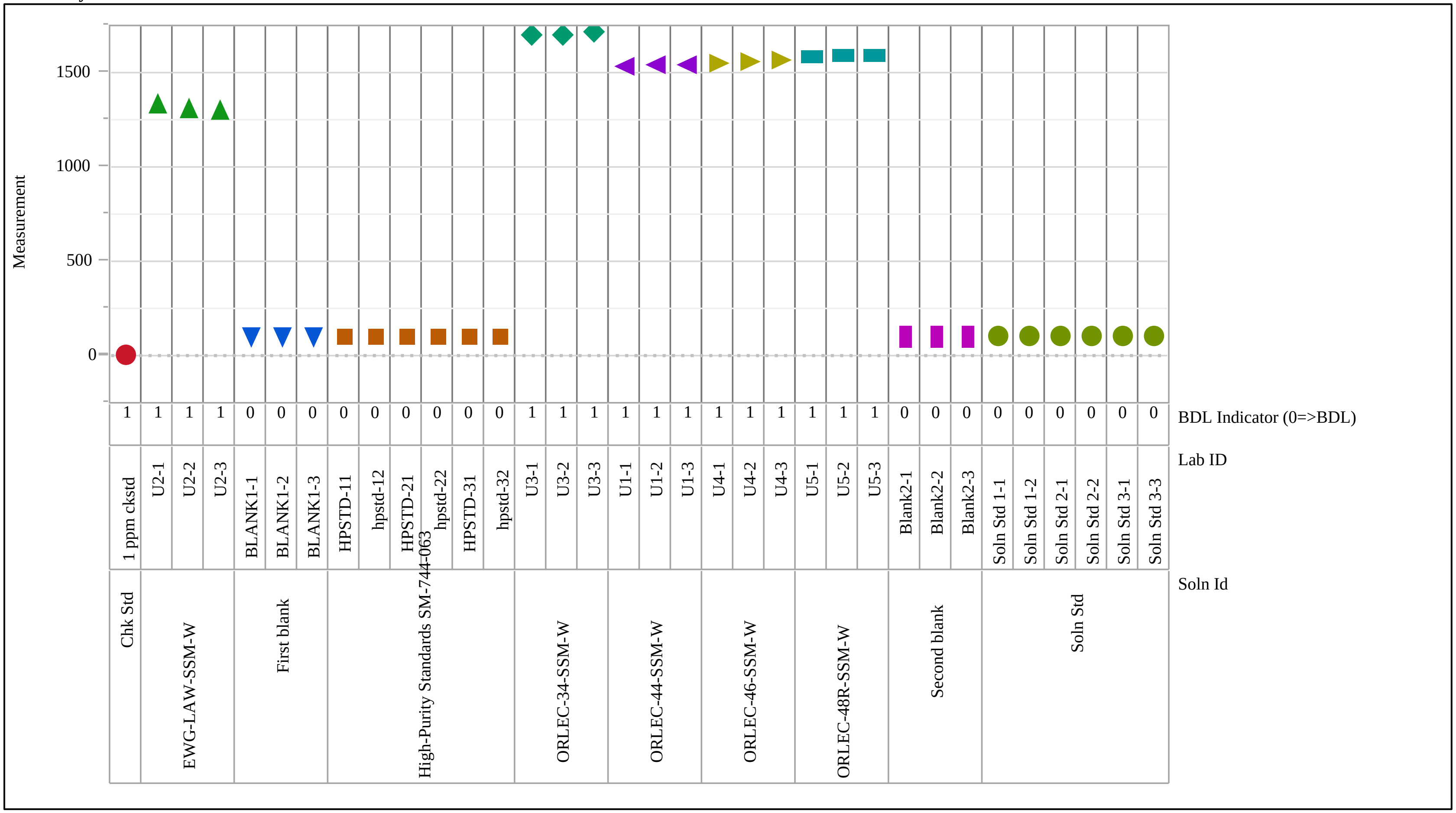


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=V (mg/L), Analysis=ICP
Variability Chart for Measurement

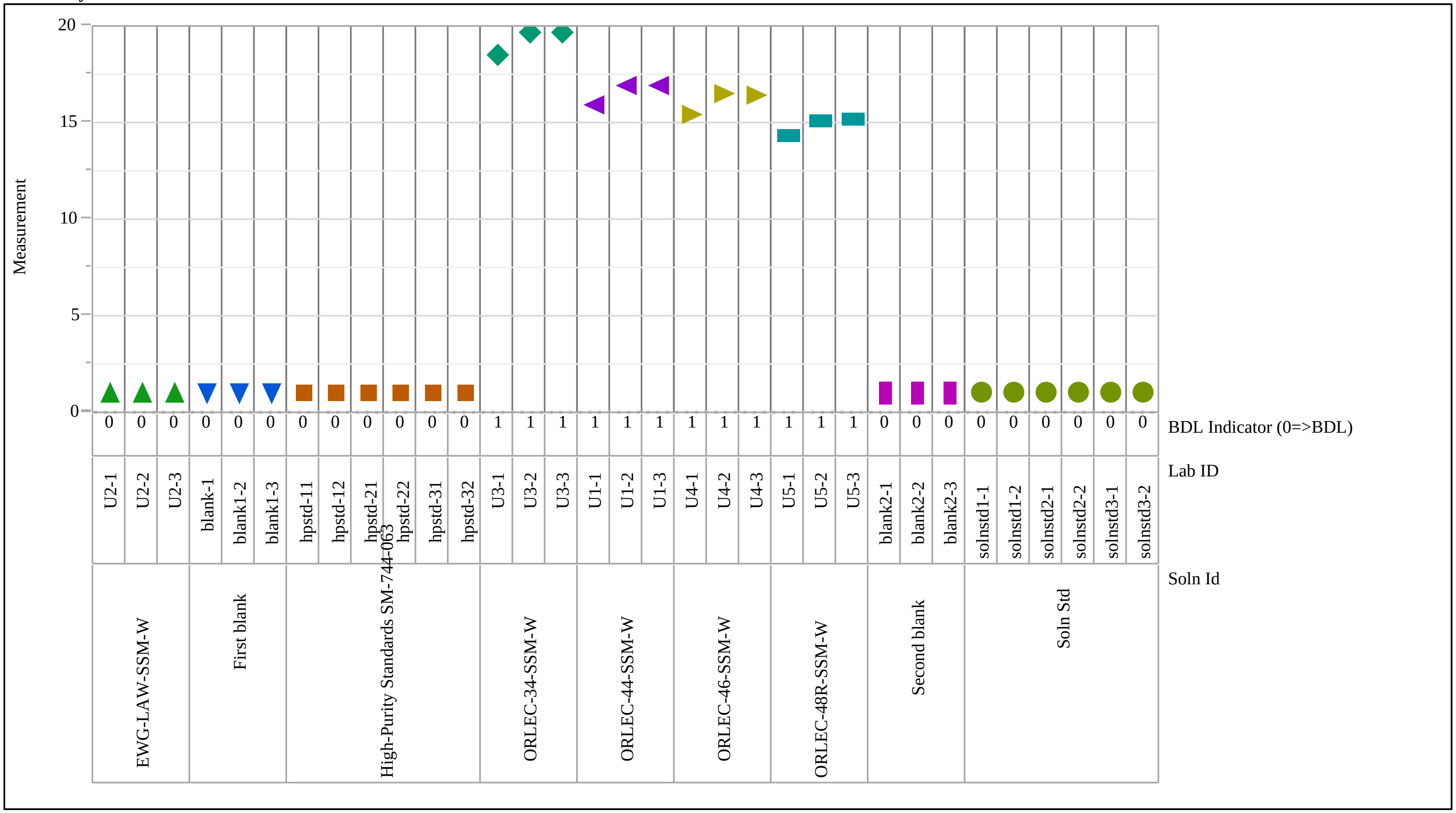


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Zn (mg/L), Analysis=ICP
Variability Chart for Measurement

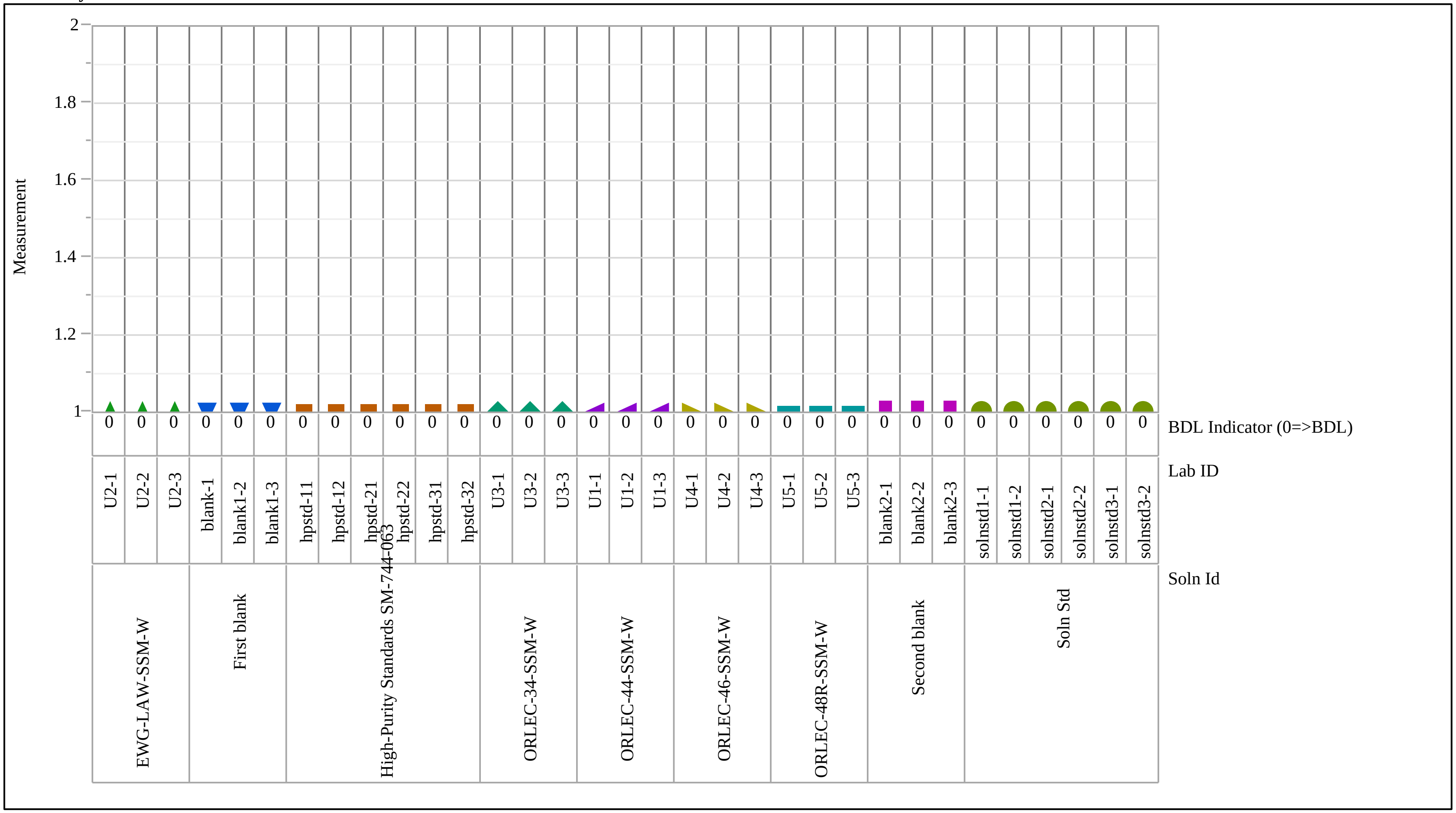
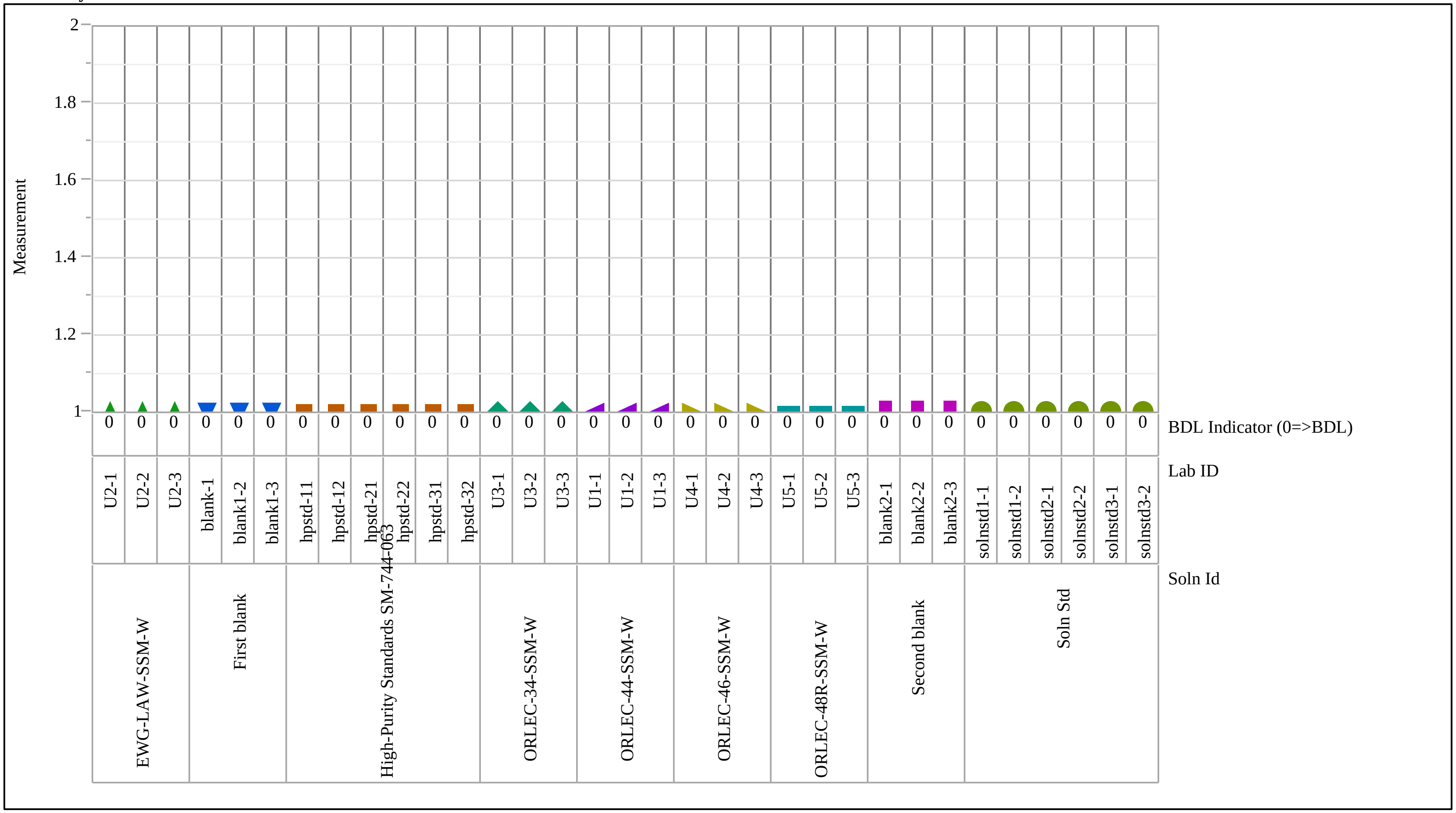


Exhibit D-2. Analysis of Wash Solutions by Solution Identifier (continued)

Variability Gauge Analyte=Zr (mg/L), Analysis=ICP
Variability Chart for Measurement



Distribution:

J. W. Amoroso, 999-W
T. B. Brown, 773-A
M. E. Caldwell, 999-W
A. D. Cozzi, 999-W
C. L. Crawford, 773-42A
W. C. Eaton, PNNL
T. B. Edwards, 999-W
S. D. Fink, 773-A
K. M. Fox, 999-W
C. C. Herman, 773-A
A. M. Howe, 999-W
C. M. Jantzen, 773-A
T. Jin, PNNL
F. C. Johnson, 999-W
D. S. Kim, PNNL
A. A. Kruger, DOE-ORP
J. Matyáš, PNNL
D. J. McCabe, 773-42A
D. L. McClane, 999-W
F. M. Pennebaker, 773-42A
A. A. Ramsey, 999-W
W. G. Ramsey, 999-W
W. T. Riley, 999-1W
R. L. Russell, PNNL
M. J. Schweiger, PNNL
G. N. Smoland, 999-1W
C. L. Trivelpiece, 999-W
J. D. Vienna, PNNL
B. J. Wiedenman, 773-42A
W. R. Wilmarth, 773-A
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