

Round Robin of Methods to Estimate the Salinity of Great Salt Lake Waters

by

Great Salt Lake Salinity Advisory Committee

Suggested citation:

Great Salt Lake Salinity Advisory Committee, 2020, Round robin of methods to estimate the salinity of Great Salt Lake waters: Utah Geological Survey Open-File Report 727, 94 p., <https://doi.org/10.34191/OFR-727>.

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OPEN-FILE REPORT 727
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
2020

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BACKGROUND

The purpose of this open-file release is to make the attached document prepared by the Great Salt Lake Salinity Advisory Committee available to the public, part of the permanent record, and citable for future reference. The Great Salt Lake Salinity Advisory Committee is a group of scientists and stakeholders convened by the Utah Division of Forestry, Fire and State Lands and the Utah Division of Water Quality. The committee was formed in early 2018. Their goal and purpose, as stated in their charter (version 3), follows:

The goal of the Great Salt Lake (GSL) Salinity Advisory Committee (SAC) is to provide recommendations for long-term management of the salinity of GSL to the Utah Division of Forestry, Fire and State Lands (FFSL) and the Utah Division of Water Quality (UDWQ) that maximize the benefits of GSL in accordance with the public trust doctrine and protect the designated uses of GSL in accordance with the Utah Water Quality Act.

The purpose of the SAC is to review and interpret results from GSL salinity research and monitoring activities and make recommendations to FFSL and UDWQ regarding potential modifications to the UPRR causeway opening, berm or channel and long-term management of the salinity of GSL.

The following document was prepared in large part by Jeff DenBleyker (Jacobs), the facilitator of the committee, with significant input and review by the committee members. In particular, committee members Andrew Rupke, Elliot Jagniecki, Ryan Rowland, and Jake VanderLaan provided substantial contributions to the effort and document.

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Memorandum

Subject Round Robin of Methods to Estimate the Salinity of Great Salt Lake Waters

Completed by Great Salt Lake Advisory Committee

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Date June 17, 2020

A round robin was conducted by members of the Great Salt Lake (GSL) Salinity Advisory Committee (SAC) to compare results from various field and laboratory analytical methods used to estimate the density, salinity, and major ions of GSL waters. This memorandum summarizes the methods and results from the round robin, available density and salinity datasets, and the SAC's recommendations for next steps.

All round robin participants and members of the SAC, particularly Andrew Rupke and Ryan Rowland, are thanked for their participation, discussion, input and review of this document. Their participation and input were critical for completion of this work.

1. Purpose and Need

The GSL SAC determined at its November 12, 2019, meeting that a standard protocol for measuring and reporting the density, salinity, and major ions of GSL waters should be developed to improve the confidence of density and salinity measurements and future management decisions that depend on these data. Although there has been coordination of density and salinity data, different organizations currently use different field and laboratory analytical methods to develop and report the data. It was unknown as to how differences in protocol may affect the precision and accuracy of the data.

The SAC determined that a round robin with different organizations measuring and reporting the estimated density, salinity, and major ions of the same GSL water samples would provide the best means to compare the results and methods.

Water Density

A measure of the mass (grams) per unit volume of water (cubic centimeter) including all solutes (g/cm^3). Water density varies with temperature and total dissolved solids (TDS).

Salinity

A measure of the concentration of all solutes dissolved in water. Solutes in GSL water are unique and difficult to accurately measure; GSL salinity is typically defined as the mass of dissolved solids (or TDS) in grams per liter of water (g/L).

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2. Round Robin Design

The Utah Geological Survey (UGS) collected one bulk water sample each from the North Arm, South Arm, and Farmington Bay on November 19, 2019 (i.e., a total of three bulk water samples). These three water bodies were selected to characterize the broad range of salinities that are typical in GSL. Figure 1 illustrates the approximate location of where the samples were collected.

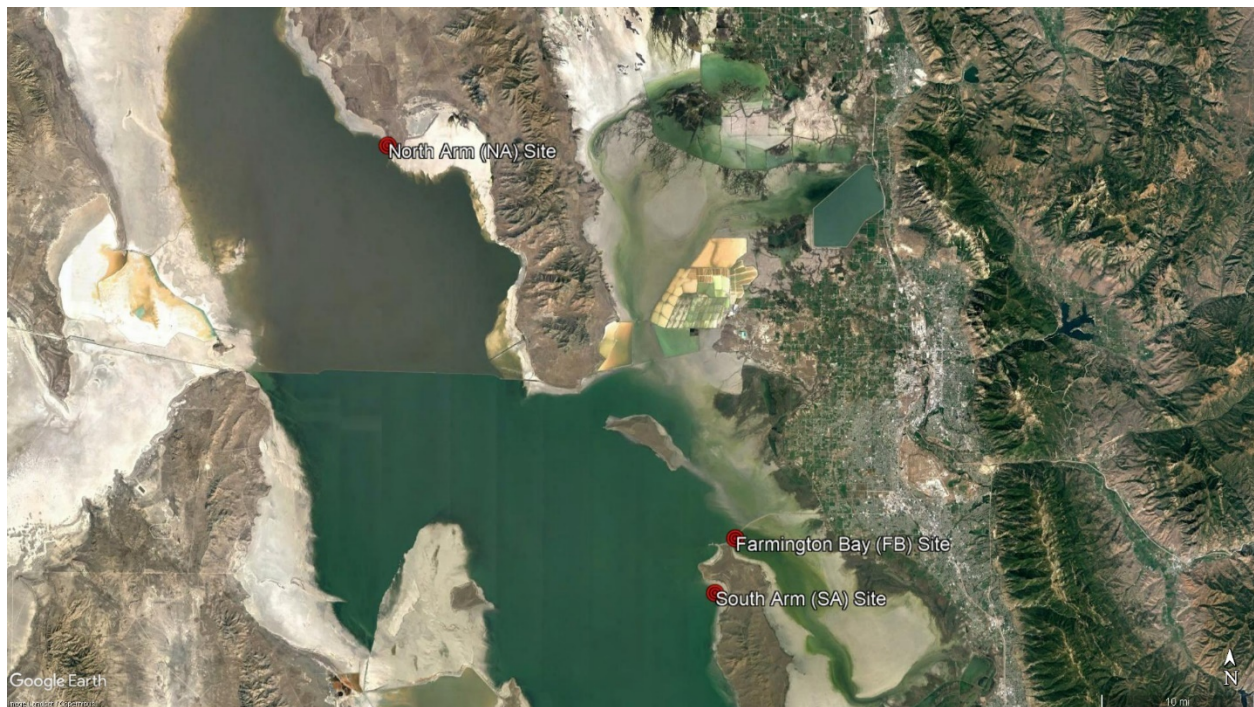


Figure 1. Round Robin Water Sample Collection Sites

The UGS collected five 1-gallon samples of water from just below the water surface at each location and combined them into one 5-gallon high-density polyethylene (HDPE) jug to represent the one bulk water sample for each location. The UGS transported the three 5-gallon jugs to the UGS laboratory where the water in each jug was split into half-gallon HDPE containers. One half-gallon sample of raw, unpreserved water from each of the three locations was provided to the following round robin participants to monitor the density, salinity, and major ions of GSL waters:

- 1) Utah Geological Survey
- 2) North Davis Sewer District (NDSD)
- 3) HDR
- 4) US Magnesium
- 5) U.S. Geological Survey (USGS)
- 6) Jacobs
- 7) Utah Division of Wildlife Resources (DWIR)
- 8) GSL Brine Shrimp Cooperative, Inc.
- 9) Compass Minerals

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Participants were asked to measure and report the density, salinity, and major ions of each water sample using their typical methods. Participants were allowed to further split the samples to evaluate results from alternative methods, laboratories, and technicians. Participants were asked to report their results and summarize their methodology.

3. Analytical Methods

This section summarizes the methods used by each round robin participant. Detailed protocol and reports, when provided, are included as attachments to this memorandum. Results are summarized in Section 4 of this memorandum.

3.1 Utah Geological Survey

The UGS typically collects GSL water samples and transports them to the UGS laboratory where the water samples are allowed at least 12 hours to reach room temperature. The UGS records the temperature and measures the density of the water samples using a density meter (Anton Paar DMA 35) following its protocol (see Attachment A). Water samples are analyzed by a commercial laboratory for chemistry and total dissolved solids (TDS). The typical analytical suite includes the major ions that are found in GSL (sodium, magnesium, potassium, calcium, chloride, and sulfate) as well as TDS. The UGS reports the density, ion concentrations, TDS, and other parameters in their spreadsheet database found at https://geology.utah.gov/docs/xls/GSL_brine_chem_db.xlsx.

For this round robin, the UGS measured the temperature and density of each of the three water samples, split each water sample into two containers, and sent one set of three water samples to American West Analytical Laboratories (AWAL) and one set of three water samples to Chemtech-Ford for analyses. Each commercial laboratory evaluated and reported the concentration and dry weight percent of sodium, magnesium, potassium, calcium, chloride, and sulfate ions in each sample. TDS were reported both as a sum of the concentrations of these ions and determined gravimetrically by Standard Method 2540 C. The analytical methods used by the two laboratories are summarized in Table 1.

Table 1. Analytical Methods used by Commercial Laboratories for UGS

AWAL Methods	Chemtech-Ford Methods
sodium - SW6010D	sodium (dissolved) - EPA 200.7
magnesium - SW6010D	magnesium (dissolved) - EPA 200.7
potassium - SW6010D	potassium (dissolved) - EPA 200.7
calcium - SW6010D	calcium (dissolved) - EPA 200.7
chloride - SW9056A	chloride - EPA 300.0
sulfate - SW9056A	sulfate - EPA 300.0
total dissolved solids - SM 2540 C	total dissolved solids - SM 2540 C

3.2 North Davis Sewer District

The laboratory at NDSD has completed analyses of GSL waters for various researchers over the years. The laboratory typically receives the water samples and allows them to reach room temperature before conducting a full suite of chemical analyses. The NDSD laboratory measures and reports the electrical

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conductivity (EC) of each water sample using analytical method Environmental Protection Agency (EPA) 120.1 [1982] and TDS using analytical method EPA 160.1. Results are typically only reported to the researcher who requested the analyses.

For this round robin, the NDSD laboratory measured and reported the temperature, EC, and TDS of each water sample.

3.3 HDR

HDR typically collects GSL water samples and transports them to its laboratory where the water samples are allowed to reach room temperature. HDR records the water temperature and measures the density of the water samples using a density meter (Anton Paar DMA 35) and hydrometer following the Union Pacific Railroad's Final Sampling and Analysis Plan and Quality Assurance Project Plan (UPRR, 2016a). Measured densities of water samples are used to compute the salinity of the water samples using U.S. Geological Survey (USGS) empirical formulas as documented in Water-Resources Investigations Report 00-4221 (USGS, 2000). Results are reported following UPRR's Updated Final Compensatory Mitigation and Monitoring Plan (UPRR, 2016b).

The salinity, or dissolved solids concentration (TDS), is computed using:

$$C = \frac{(\rho - 1)(1,000)}{0.63}$$

Where C = salinity or TDS (grams per liter [g/L])
 ρ = measured density at 20 degrees Celsius (grams per milliliter [g/mL])

The percent salinity is computed using the measured density and computed TDS using:

$$\text{Salinity, in percent} = \frac{C}{\rho(10)}$$

For this round robin, HDR measured and reported the temperature and density of each water sample using its density meter and hydrometer.

3.4 US Magnesium

For this round robin, the US Magnesium control laboratory had seven technicians analyze each water sample and report the density and percent weight of each ion in each water sample. Analytical methods were not available at the time of writing this memorandum.

3.5 U.S. Geological Survey

The USGS typically collects GSL water samples and transports them to the USGS laboratory where the water samples are allowed to reach room temperature. The USGS records the temperature and measures the density of the water samples using a density meter (Anton Paar DMA 35) following its protocol (see Attachment B). Measured densities of water samples are used to compute the salinity of each sample using a Microsoft Excel spreadsheet that computes the salinity via an equation of state specific to GSL

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waters (Naftz et al., 2011). Both measured density and computed salinity are reported in the National Water Information System (NWIS).

For this round robin, the USGS measured and reported the temperature and density of each water sample and computed and reported the salinity of each sample using the GSL equation of state. The USGS noted that the density of the North Arm water sample was above and the density of the Farmington Bay water sample was below the densities used to develop the GSL equation of state.

3.6 Jacobs

Jacobs typically measures the density of GSL waters in the field using a hydrometer and percent salinity of GSL waters in the field using a refractometer (Atago Master-S28M, 0-28%, units = g/100g sodium chloride) consistent with the State of California's Standard Operating Procedure (SOP) 3.1.3.3 (California State Water Resources Control Board, 2010) (see Attachment C). Distilled water is used to confirm calibration and rinse the instrument and dropper prior to each measurement. The temperature, density, and percent salinity of GSL waters is recorded in project files.

For this round robin, Jacobs measured the percent salinity of each water sample at the UGS laboratory and reported the percent salinity.

3.7 Utah Division of Wildlife Resources

The Utah Division of Wildlife Resources (DWiR) typically measures the percent salinity of GSL waters in the field using a refractometer (Atago Master-S28C, 0-28%, units = g/100g sodium chloride).

For this round robin, DWiR measured and reported the percent salinity of each water sample.

3.8 Great Salt Lake Brine Shrimp Cooperative, Inc.

The Great Salt Lake Brine Shrimp Cooperative, Inc. (GSLBSCI) has an extensive GSL ecological research program that involves routine sampling of GSL water and biota. GSLBSCI provided a summary of its research program and detailed discussion of methods used and results for this round robin (see Attachment D). The GSLBSCI historically measured salinity in the field with a refractometer but found that temperature can materially affect the results. Thus, salinity was measured in the field with a refractometer, but water samples were measured again with a refractometer in the laboratory at room temperature. The GSLBSCI currently only evaluates salinity in the laboratory using a YSI-556 multi-meter probe. North Arm water samples are typically diluted to obtain an acceptable concentration of salinity for the multi-meter.

For this round robin, the GSLBSCI evaluated each water sample in its laboratory using a YSI-556 multi-meter (reporting salinity [g/L], conductivity [uS/cm], and temperature [C]) and a Reed refractometer (reporting percent salinity). GSLBSCI measured and reported salinity as a TDS concentration using a gravimetric method (g/L). The GSLBSCI also evaluated laboratory-prepared standards with the YSI-556 multi-meter and reported those results.

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3.9 Compass Minerals

Compass Minerals routinely collects samples of GSL water from its diversion canal on the west side of the North Arm. GSL water samples are transported to its in-house laboratory and typically analyzed only for the potassium ion. Compass Minerals routinely evaluates the ion composition of the brines within its process stream and occasionally evaluates the density and ion composition of GSL waters. The typical analytical suite includes the major ions in GSL (sodium, magnesium, potassium, chloride, and sulfate) as well as TDS.

Compass Minerals measured the temperature and density of each water sample using a hydrometer. Compass Minerals' laboratory analyzed each sample using two methods: (1) multi-analysis (using atomic emission for sodium and potassium and titrations for magnesium, chloride, and sulfate) and (2) Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES). Results were reported as a percent weight for each ion. TDS was reported as a sum of the concentrations of the ions. Compass Minerals' SOPs for the multi-analysis methods are included in Attachment E.

4. Results

As noted above, each round robin participant reported and computed results for parameters using different methods. A comparison of water density, TDS, and EC as reported by each round robin participant for each water sample is summarized in Attachment F (North Arm water sample), Attachment G (South Arm water sample), and Attachment H (Farmington Bay water sample). Each attachment includes summary tables with summary statistics and graphs illustrating comparisons of the data.

TDS is computed by round robin participants using different methods. Attachments F through H include comparisons of measured and computed TDS using available data. TDS could be computed as a sum of ions or from a measured density via the methods described by USGS (2000), Baseggio (1974), or Naftz et al. (2011). The TDS concentration is often used to compute and report a percent salinity.

Percent salinity is also computed by round robin participants using different methods. Attachments F through H include comparisons of measured and computed percent salinity using available data. Percent salinity could be converted directly from a measured TDS, computed by dividing a measured TDS by measured density, or computed by dividing a computed TDS by a measured density. Participants typically only report GSL salinity as density, TDS, EC, or percent salinity, using the method highlighted in the attachments.

The major ions of each of the three water samples were evaluated by two commercial laboratories for the UGS, by US Magnesium using its standard method, and by Compass Minerals using two methods. Results are included in Attachment I.

5. Available Density and Salinity Datasets

Round robin participants have monitored the density and salinity of GSL with different objectives, methods, and frequencies since the 1960s. Participants collect density and salinity data during discrete sampling events, individual or series of studies, or ongoing monitoring programs, thus creating many disparate datasets. This section summarizes round robin participants' efforts to monitor GSL density and salinity and available datasets.

5.1 Utah Geological Survey

The UGS began a systematic GSL brine sampling program in 1966 to monitor and understand conditions created by changes in lake level, the railroad causeway, and other factors. The UGS collects water samples in partnership with the Utah Division of Forestry, Fire & State Lands at various depths at sites around the lake (see Figure 2), measures the samples for density, and analyzes the samples to determine their ion composition. Sampling locations and data can be found at https://geology.utah.gov/docs/xls/GSL_brine_chem_db.xlsx.

The UGS has sampled GSL brine at 59 sites over the years and is currently monitoring 5 sites in the South Arm (AS2, FB2, RT4, AC3, and AIS) and 3 sites in the North Arm (LVG4, RD2, and SJ-1). Samples are usually collected from the boat at depths of 5 feet from the surface and about 6 inches from the bottom. Near-surface samples are collected 6 inches from the water surface. Samples from the boat are generally collected three times per year: once between April and June, once between July and September, and once between October and November. Near-surface samples are collected more frequently at irregular intervals.

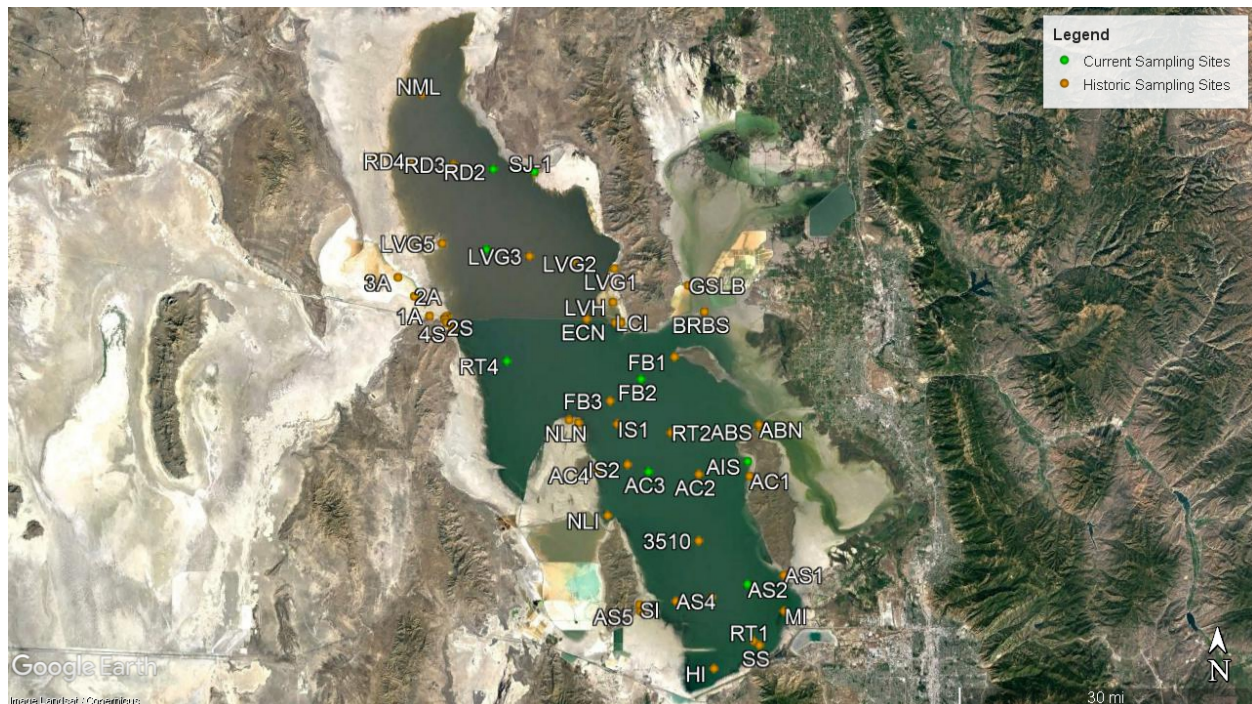


Figure 2. Utah Geological Survey Sampling Sites

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5.2 North Davis Sewer District and Jacobs

The NDSD and Jacobs evaluated conditions in the South Arm east and south of Fremont Island and north of the Antelope Island causeway in 2018 and 2019. This area, called Ogden Spur, has emerged as GSL levels have receded. Water depths were typically less than 18 inches during this period. Water samples were collected at five sampling locations in the open water of Ogden Spur monthly and along the north side of the causeway weekly (see Figure 3). Measurements of GSL water density, TDS, EC and percent salinity are included in their database. Conditions were extremely dynamic; salinities ranged from 1 to 27 percent salinity.

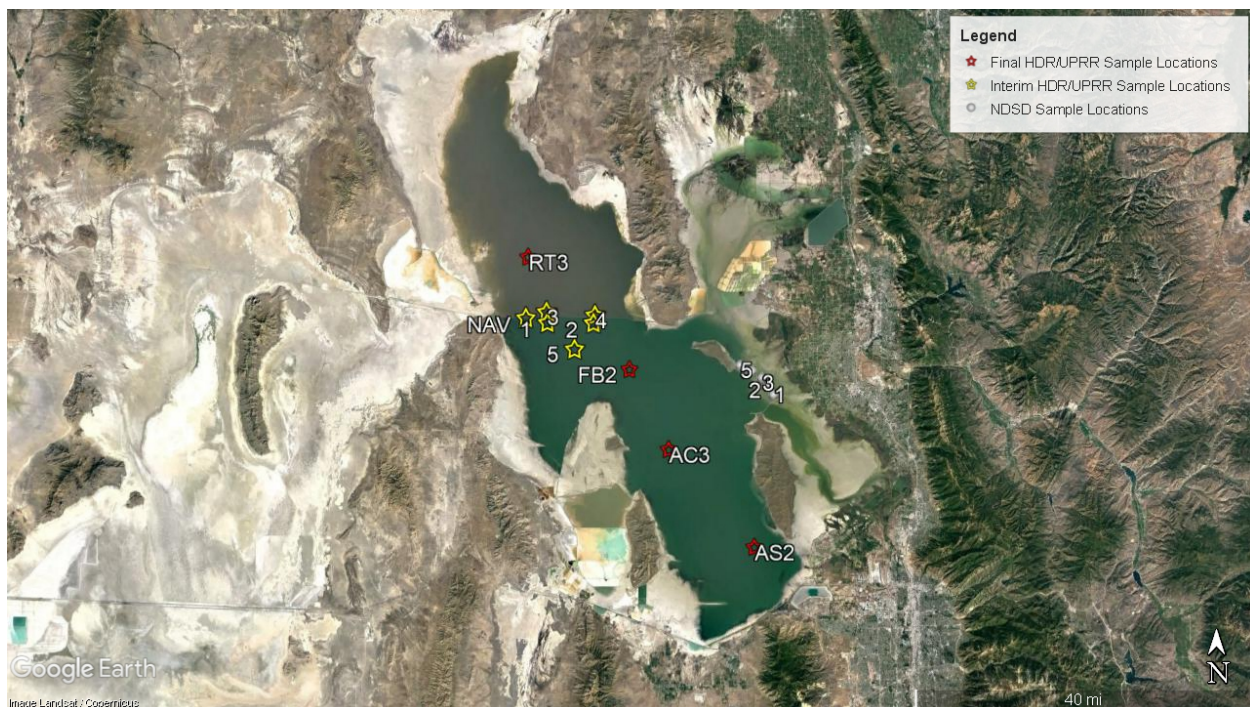


Figure 3. North Davis Sewer District and HDR Sampling Sites

5.3 HDR

HDR monitored GSL density, salinity and temperature on a quarterly basis from 2014 – 2016 at three interim locations in the South Arm and three interim locations in the North Arm (see Figure 3). HDR has monitored GSL density, salinity and temperature (and conductivity in 2018) on a quarterly basis at three final locations in the South Arm and one final location in the North Arm since 2017 (see Figure 3). Sampling has been completed as required in UPRR's Section 401 Water Quality Certification and Section 404 permits for emergency closure of its culverts and construction of the new bridge in the causeway. Grab samples are collected at 1.5-meter intervals in the upper brine layer and at 0.5-meter intervals in the deep brine layer. Annual reports can be found at <https://deg.utah.gov/water-quality/railroad-causeway>.

5.4 U.S. Geological Survey

The USGS monitors the density and salinity of GSL as part of its routine lake level monitoring and water quality monitoring program that is in partnership with the Utah Division of Water Quality and DWiR (see Figure 4). The USGS has measured water temperature, density, conductivity, TDS and determined ion composition (chloride, sulfate, calcium, magnesium, potassium and sodium) at the new breach in the railroad causeway approximately monthly since 2016. This is completed for both south to north and north to south flowing water at the new breach using depth and width integrating protocols to capture average conditions. The USGS has measured water density at six inflow sites every 6 weeks and at four South Arm sites every 4 weeks since 2010. For fresh water inflow sites, density is measured in composite water samples collected using depth and width integrated protocols to capture average conditions within the channel. The USGS has measured water density at eight South Arm sites semi-annually (June and October) since 2011. The USGS has measured specific gravity and/or water density in samples collected just below the surface at its lake level gauges since the 1970s. For open water sites on GSL density is measured in water samples that are typically collected at 0.2-0.5 meters below the water surface and 0.5 meters above lake bottom. All results are posted to the NWIS.



Figure 4. U.S. Geological Survey Sampling Sites

5.5 Utah Division of Wildlife Resources

DWiR has monitored the percent salinity of GSL waters as part of the Great Salt Lake Ecosystem Program since 1996. DWiR monitors the percent salinity of GSL water at the water surface using a refractometer at

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between 17 and 22 sampling locations (depending upon lake level) every 2 weeks (see Figure 5). Data may be made available with a Government Records Access and Management Act request.

5.6 Great Salt Lake Brine Shrimp Cooperative, Inc.

The GSLBSCI has implemented its GSL ecological research program since 1999. Its program includes routine sampling of GSL water and biota as well as abiotic measurements at nine sites in Gilbert Bay weekly or semi-monthly. The GSLBSCI has also periodically sampled five sites in Farmington Bay and occasionally at an additional 21 sites around GSL to evaluate spatial variability. Data may be made available upon request.

5.7 Studies and Research by Others

A number of other researchers have investigated GSL hydrology, water quality, and food web questions and included the measurement of GSL salinity as part of their work. Much of these density and salinity data have not been included in the other long-term databases discussed above. Researchers such Dr. Wayne Wurtsbaugh and at the Utah Division of Water Quality and Wasatch Front Water Quality Council have indicated that the data could be made available if requested.



Figure 5. Utah Division of Wildlife Resources Sampling Sites

6. Observations

Key observations from the round robin and discussion at the January 16 and 29, 2020, SAC meetings include the following:

6.1 Context and Objectives

- 1) Numerous organizations have monitored GSL density and salinity for many years to better understand GSL dynamics, how GSL ecological and mineral resources may respond to density and salinity, and how the resources may be managed. GSL density and salinity has been monitored and studied more than any other parameter except for perhaps water surface level fluctuations.
- 2) GSL density and salinity data have been measured at different locations, depths, and seasons and analyzed, computed, and reported using numerous methods and metrics over the years. This round robin compares these methods.
- 3) Salinity has most often been reported as a TDS concentration, or percent salinity with practitioners most often discussing GSL conditions in terms of TDS concentrations or percent salinity.
- 4) Density and salinity data are typically collected using the best available methods applicable to the researcher's goals and objectives. There has historically not been significant coordination of methods or datasets.
- 5) Goals and objectives for monitoring GSL density and salinity vary depending upon the organization and the ecological or mineral resource being monitored or studied.
- 6) Understanding the ion composition of GSL waters is important to the mineral extraction industry; it is still not understood how ion composition may affect GSL's ecology.
- 7) The UGS has changed laboratories relatively recently for ion composition analyses and has had challenges in getting consistent ion composition results from various laboratories.

6.2 Methods

- 1) Most round robin participants monitor GSL density and salinity by collecting water samples in the field and measure temperature, density, TDS, EC, and/or ion composition in a laboratory. Sample storage temperature before analysis varies among groups.
- 2) Water temperature affects reported density values. The SAC identified a question for further consideration: Can water density values be normalized so that reported values can be compared accurately?
- 3) TDS and EC methods developed for brackish marine salinities have historically been challenging to implement at GSL due to hypersaline conditions. However, researchers have improved these methods in the laboratory with good results (e.g., see Attachment D).
- 4) The UGS and USGS have coordinated methods for measuring water density and consistently use an Anton Paar DMA 35 instrument (see Attachments A and B). Other organizations, such as HDR, have done the same.
- 5) Field salinity has usually been measured using a refractometer (percent salinity) or derived from field measurements of density using a traditional glass hydrometer.

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- 6) Density and salinity measurements (TDS, and EC) have been historically converted to TDS and percent salinity using several methods.
- 7) The USGS has developed a site-specific equation of state for GSL that allows for accurate conversion of density measurements to salinity (TDS) (Naftz et al., 2011). The applicable range of salinities (23 to 182 g/L) does not include salinities typically observed in Bear River Bay, Farmington Bay, or the North Arm.

6.3 Results

- 1) In general, SAC members were encouraged by the consistency of results among researchers, laboratories, methods, and parameters. Results were more consistent than expected.
- 2) Density measurements were the most consistent among the measurements made as part of the round robin, i.e., they had the lowest coefficient of variation.
- 3) Whereas direct measurements of TDS in the North Arm and South Arm water samples were relatively consistent, salinity values computed from density measurements had more consistent results. The USGS (2000) method provided the most consistent conversion of density values to salinity for the North Arm water sample. The USGS GSL equation of state (Naftz et al., 2011) provided the most consistent conversion of density values to salinity for the South Arm water sample. Direct measurement of TDS proved to be the most consistent method to determine the salinity of the Farmington Bay water sample.
- 4) Whereas there are different means to convert salinity values among the parameters, those that were derived from density measurements were most consistent.
- 5) Salinity measurements for the methods were more consistent for hypersaline waters than for the lower salinity observed in the Farmington Bay water sample. Density measurements for the Farmington Bay water sample were the most consistently measured parameter.
- 6) Analyses of ion composition compared well across the laboratories and methods used. Results compared better for North Arm and South Arm water samples than for the Farmington Bay water sample.

7. Conclusions

The SAC agreed that monitoring and tracking the dynamics of GSL density and salinity is critical toward making defensible management decisions for GSL. Much work can and should be done to better understand the characteristics and dynamics of GSL density and salinity.

Upon review of the results from the salinity round robin, the SAC concluded that density measurements (along with temperature measurements) provide the most consistent and accurate means to monitor GSL's salinity. Although density measurements are recommended to be the standard means of measuring and reporting GSL salinity going forward, the SAC recognizes that organizations may still use different methods to measure and monitor GSL density and salinity in accordance with their specific objectives. The SAC also recognizes that density measurements have limitations in a saturated environment, such as in the North Arm.

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The SAC agreed that analyses of ion composition should also be conducted and tracked to understand and monitor how GSL density and salinity changes. Ion composition is important to the mineral extraction industry; it is still not understood how ion composition may affect GSL's ecology.

8. Recommendations

The following recommendations were identified at the January 16 and 29, 2020, SAC meetings:

- 1) A new SOP for measuring the density and calculating the salinity of GSL waters and reporting the data should be developed based upon the methods that the UGS and USGS currently use. The UGS and USGS have agreed to draft an SOP for the SAC's review and approval and eventual release to the public for future use on GSL.
- 2) Density measurements should be made and reported in conjunction with temperature measurements. This enables consistent and accurate interpretation and translation of density measurements to other salinity measures.
- 3) Additional sampling metadata that should be reported are the date, location, and the depth below the water surface at which the sample was collected, and ideally the water temperature of the sample when collected from Great Salt Lake.
- 4) Further work is needed to verify laboratory analytical methods to determine the ion composition of GSL waters. The UGS will coordinate with the mineral extraction industry to identify the most appropriate methods for future use.
- 5) The GSL equation of state (Naftz et al., 2011) should be revisited to account for the full range of salinities observed at GSL and used as the standard means of determining salinity (TDS) for GSL waters.
- 6) Historic GSL density and salinity databases should be reviewed, validated, and possibly integrated into one common GSL database and be made available to the public.
- 7) Water samples collected to monitor GSL density and salinity are often collected at different locations, at different times of the day and year, and at different depths. Any of these factors may affect the reported density and salinity; more work is needed to understand these dynamics. A recommended sampling protocol (e.g., equipment, depth, etc.) should be developed for use on GSL.
- 8) Current GSL density and salinity monitoring programs should be evaluated to determine if there are opportunities for researchers to better collaborate and leverage each other's efforts and data.

9. References

Baseggio, G. 1974. The Composition of Sea Water and Its Concentrates.

California State Water Resources Control Board. 2010. Standard Operating Procedure 3.1.3.3. Measuring Salinity with a Refractometer. Written by Erick Burres in The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment. March 8.

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Memorandum

Round Robin of Methods to Estimate the
Salinity of Great Salt Lake Waters
June 17, 2020

Union Pacific Railroad (UPRR). 2016a. Final Sampling and Analysis Plan and Quality Assurance Project Plan. Union Pacific Railroad Great Salt Lake Causeway Culvert Closure and Bridge Construction Project. October.

Union Pacific Railroad (UPRR). 2016b. Updated Final Compensatory Mitigation and Monitoring Plan, Union Pacific Railroad Great Salt Lake Causeway Culvert Closure and Bridge Construction Project. May 25.

United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987–98. Water-Resources Investigations Report 00-4221.

Attachment A

UGS Methods

Density Meter Procedures

1. Attach filling tube to density meter
2. Flush distilled water through density meter a few times (3 to 4) via pump and filling tube.
3. On last flush, record density of distilled water – should be in a range of about 0.9973 to 0.9967 g/cm³ at room temperature.
4. **Important:** Depress pump slowly multiple times to clear water from density meter before measuring first sample. Repeat until as much water as possible has been removed.
5. Measure sample density (via pump and filling tube). Record both density and temperature.
6. Between measuring samples, use water (tap or distilled) to flush out density meter (via pump and filling tube). Rinse 3 to 5 times. **Important:** Depress pump slowly several times on last rinse to get water out before taking the next measurement.
7. After measuring the last sample, flush the instrument with approximately 100 to 150 mL of water (ideally warm or hot water) using the syringe or pump and filling tube. When using the syringe attachment keep the filling tube attached. To use the syringe, attach the Luer adapter.
8. After flushing instrument with water, flush the instrument with ethanol/ethyl alcohol* 2 to 3 times using the pump. Remove the ethyl alcohol using the pump. Again, depress pump slowly to remove as much of the ethanol as possible.
9. Remove attachments from density meter and return to case.

*Anton Paar service department recommended using Everclear as a cleaning and drying agent. Anton Paar also suggested a solvent known as Alconox to flush through the instrument. Applying the Alconox step would come before flushing water through the instrument after measurements have been taken.

Attachment B

USGS Methods

Great Salt Lake Water Density Measurement and Salinity Calculation

Density Measurement

Instrument- Anton Paar DMA 35N Portable Density Meter (serial number 80112686)

Parameters- Water density, in grams per cubic centimeter (g/cm^3), and water temperature, in degrees Celsius ($^{\circ}\text{C}$).

Calibration method used- Density: factory calibration using pure water and dodecane; Utah Water Science Center calibration checks using ultra pure deionized water. Temperature: factory calibration.

Density Acceptance criteria and response if not acceptable- The manufacturer's published maximum permissible error is $\pm 0.001 \text{ g/cm}^3$. If a calibration check reading is outside the maximum permissible error, the density meter is returned to the manufacturer for maintenance/repair.

Calibration frequency and location- Approximately biannual calibration checks are completed by Anton Paar, 10215 Timber Ridge Drive Ashland, VA, 23005, phone: (800) 722-7556. Beginning February 2015, manufacturer calibration checks will be completed on an annual basis. Office calibration checks are performed prior to each use.

Density Measurement Procedure (measurements should be done near room temperature ($20 \pm 0.5^{\circ}\text{C}$)) -

1. Attach the filling tube to the bottom of the DMA 35N density meter (see instruction manual).
2. Turn on the density meter.
3. Rinse the density meter three times with ultra pure deionized water. Fill the density meter by pushing down on the pump lever, submerging the filling tube in ultra pure deionized water, and slowly releasing the pump lever. Pump out the deionized water by pushing down on the pump lever.
4. After rinsing, check the calibration of the density meter by filling it with ultrapure deionized water that is near room temperature. The measured density should be within $\pm 0.001 \text{ g/cm}^3$ of the density of pure water at the temperature of the sample (the density meter reports water temperature in addition to density). Table 1, below, shows the density of pure water at temperatures ranging from 18-25 $^{\circ}\text{C}$. The density of pure water is based on Spiweck and Bettin (1992). Record the calibration check result in the sensor log book.

Table 1. Density of pure water at 18-25 degrees Celsius.

Temperature, in degrees Celsius	Density, in grams per cubic centimeter
18.0	0.9986
18.5	0.9985
19.0	0.9984
19.5	0.9983
20.0	0.9982
20.5	0.9981
21.0	0.9980
21.5	0.9979
22.0	0.9978
22.5	0.9977
23.0	0.9975
23.5	0.9974
24.0	0.9973
24.5	0.9972
25.0	0.9970

5. If the density of ultrapure deionized water is not within $\pm 0.001 \text{ g/cm}^3$ of the actual value shown in table 1, repeat the measurement. Ensure there are no water bubbles in the measuring cell. If it still fails the calibration check, suspend the density measurements. There is a problem with the deionized water or the density meter needs to be repaired and calibrated by the manufacturer.
6. If the density meter passes the calibration check, proceed to measuring the environmental sample (bring the sample to $20 \pm 0.5 \text{ }^\circ\text{C}$). Rinse the density meter three times with the sample water. Fill the meter a fourth time for the actual measurement. Record the temperature and density value.
7. Pump out the sample and repeat the measurement to verify the initial measurement. Record the check measurement temperature and density value. If the density measurements do not agree, repeat the measurement again. Ensure there are no air bubbles in the measuring cell. Continue repeat density measurements until two consecutive density values are equal. It should only take two or three measurements to verify agreement. There is something wrong with the sensor if it takes more than three measurements to verify the density value.
8. Rinse the meter three times with ultrapure deionized water before proceeding to the next sample.
9. When finished with environmental sample measurements recheck the calibration of the unit with ultrapure deionized water (rinse the meter three times with ultrapure deionized water before checking the calibration) and record the calibration check temperature and density in the sensor log book. Pump out the deionized water after the calibration check.

10. Power down the unit, remove the filling tube, and store the meter in its designated area in the Utah Water Science Center storage room.

Salinity Calculation

Measured densities of water samples collected from the South Arm of Great Salt Lake (GSL) are used to compute the salinity of each sample. Salinity is calculated with an equation of state specific to hypersaline GSL (Naftz and others, 2011). The equation of state can be solved for salinity as a function of water temperature, density of the sample, and the density of pure water at the same temperature as the water sample. Note that water temperature refers to the temperature of the water when the density measurement is made (should be near room temperature), not the temperature measured in the field, when the sample was collected.

An excel spreadsheet was created that computes GSL salinity based on the equation of state. It is archived at the following location on the network:

\\IGSKNJWWAS001\SurfaceWater_Studies\Great Salt Lake\SalinityCalcs\Salinity_Calculator\EqnofState_Salinity_Calculator

The file name is GSL_SalinityCalc.xlsm

The spreadsheet is easy to use. The user simply enters the water temperature (in °C) and density of the GSL sample (in g/cm³) and applies the formulas in adjacent columns to compute the density of pure water (in g/cm³), the salinity of the GSL water sample (in grams per liter (g/L)), and the salinity of the water sample (in percent).

The functions used in GSL_SalinityCalc.xlsm can also be incorporated into excel as add-ins. The file ReadMe_GSL_SalCalc_ADDIN.txt, located in the same directory, provides instructions for making these functions available as add-ins.

Excel files with the salinity calculations should be saved in the GSL electronic archive. Excel files with salinity calculations for samples collected by the State of Utah should be saved at the following location:

\\IGSKNJWWAS001\SurfaceWater_Studies\Great Salt Lake\StateofUT_Monthly\Salinity calcs

Salinity calculations for USGS GSL water samples should be saved in the appropriate monthly file at the following location:

\\IGSKNJWWAS001\SurfaceWater_Studies\Great Salt Lake\SalinityCalcs

NWIS Data Entry

Density

Density values for Great Salt Lake water samples measured with the Anton Paar DMA 35N, in units g/cm³, are entered into NWIS using parameter code 72263, Density of water sample,

unfiltered, in grams per cubic centimeter at 20 degrees Celsius. The method code is UTUBE, water density, oscillating U-tube. Please indicate the analyzing agency as USGSUTWC. Density should be rounded to the nearest thousandth; e.g. 1.018 g/cm³.

Salinity

Salinity values calculated for Great Salt Lake water samples using the Great Salt Lake Equation of State should be entered into NWIS via parameter code is 70305, which is defined as calculated salinity, water, grams per liter. The method code associated with parameter code 70305 is CAL21, which is specific to the Great Salt Lake Equation of State. Calculated salinity values should be rounded to the nearest whole number. Please enter the analyzing agency as USGSUTWC.

References

Anton Paar DMA 35N Portable Density Meter Instruction Manual

Naftz, D.L., Millero, F.J., Jones, B.F., and Green, W.R., 2011, An equation of state for hypersaline water in Great Salt Lake, Utah, USA. *Aquatic Geochemistry* (2011) 17:809-820.

Spieweck F, Bettin H (1992) Review: solid and liquid density determination. *Technisches Messen* 59:285–292

Attachment C

California SOP 3.1.3.3

Standard Operating Procedure (SOP) 3.1.3.3

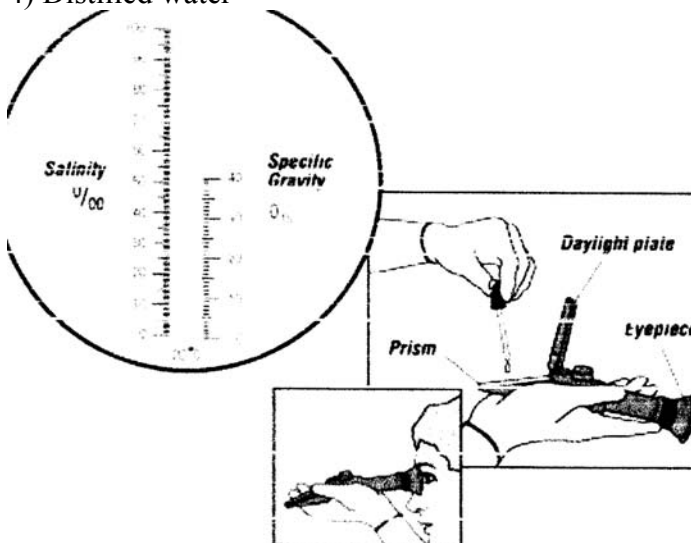
By Erick Burres

Measuring Salinity with a Refractometer

Refractometers are used to measure substances dissolved in water, using the principle of light refraction through liquids, refractivity. The more dissolved solids in water, the slower light travels through it. Refractometers measure the change in the direction of light as it passes from air into water. Salinity and temperature both affect the index. Refractometers use a scale to quantify the effect that dissolved solids in water have on light.

Equipment

- 1) Refractometer
- 2) Dropper
- 3) Lens tissue
- 4) Distilled water



Measuring salinity with a refractometer

- 1) Lift the lid that protects the refractometer's specially angled lens.
- 2) Place a few drops of your sample liquid on the angled lens, and close the lid.
- 3) Peer through the eyepiece.
- 4) Results appear along a scale within the eyepiece. Most refractometers display Specific gravity and parts per thousand (ppt).
- 5) Record the measurement on your data sheet.
- 6) Rinse the lens with a few drops of distilled water, and pat dry, being very careful to not scratch the lens' surface.

Tip: Be very cautious not to get sand on your refractometer.

G.L.O.B.E. 1997 Teachers Manual

Green, L. 1998. "Let Us Go Down to the Sea—How Monitoring Changes from River to Estuary." *The Volunteer Monitor* 10(2): 1-3.

U.S. Environmental Protection Agency (USEPA). 1997. *Volunteer Stream Monitoring: A Methods Manual*. EPA 841-B-97-003. Office of Water, Washington, DC. 211 pp.

Images: <http://www.epa.gov/owow/estuaries/monitor/chptr14.html>

Attachment D

Great Salt Lake Brine Shrimp Cooperative Inc. Report

GREAT SALT LAKE BRINE SHRIMP COOPERATIVE INC.

SALINITY ROUND ROBIN

December 20, 2019

Overview

The Salt Advisory Committee (State of Utah, Utah Division of Forestry, Fire and State Lands & Utah Division of Water Quality) group initiated a round robin process (i.e., interlaboratory test) to assess methods used by GSL stakeholder groups, and scientific teams conducting research on the GSL, for the determination of salinity in water samples. The purpose of the round robin is to record the various methods used for salinity determination and to examine the variability inherent in the methods. The collective results should inform participants on the similarities, or dissimilarities, in salinity measurements thereby providing a means of assessing the comparability of results. There are many methods used for determining salinity, each with their own particular validity and unique limitations or capabilities. Within the broad scope of procedures there is a need to establish some consensus on the term salinity and the means through which it is assessed. By unifying some of the procedures for salinity measurements comparability across labs can be improved and management options for the GSL ecosystem, that by necessity involve salinity goals or objectives, can be more effectively implemented. Additionally, ecosystem functions of GSL biota are decidedly dependent upon salinity. It is therefore critical that there is a means of determining salinity that is comparable across methods and that affords comparisons with historic data on the GSL and that can be compared with studies on saline systems across the globe.

GSLBSCI Ecology Research Program

The GSLBSCI has a GSL ecological research program that involves routinely collecting samples of GSL water and biota as well as abiotic determinations. The basic program elements include the following:

- ✓ 9 sites in Gilbert Bay with testing of discrete intervals within the water column
- ✓ 5 sites in Farmington Bay (periodic program)
- ✓ Additional 14 sites for specific testing of the monimolimnion (periodic program)
- ✓ 21 sites for spatial variability assessments (occasional program)
- ✓ Weekly (present routine) or semi-monthly sampling program from 1999 to 2019
- ✓ *In-situ* abiotic measurements: Dissolved Oxygen, Temperature, Salinity & Conductivity
- ✓ Water samples for nutrient analysis (TN, TKN, NO₂/NO₃, NH₃/NH₄, TP, SRP, SO₄, Mb, Si, TOC, pH)
- ✓ Dual net hauls to collect aquatic invertebrates for population dynamics, dormancy, isotope and contaminant analysis
- ✓ Phytoplankton and periphyton sampling for community structure and abundance determination by microscopic and DNA techniques

Methods and Materials for Round Robin Salinity Test

Instruments used for salinity determination

Historically GSLBSCI has used a variety of automatic temperature compensating refractometers and YSI multi-meters for salinity determination. In recent years (2012 to 2019) salinity has been determined solely using YSI multi-meters. Refractometers have their merits but accuracy is highly dependent upon temperature. Some of the extremes of temperature found in Gilbert Bay water exceeds even the ATC capabilities to provide accurate determination of salinity. To overcome temperature constraints when using refractometers water samples were typically measured in the field and again in collected samples stored at room temperature. Multi-meters have progressively become more reliable and offer a broader range of salinities over which functionality is maintained. Salinity conditions typically experienced in Gilbert Bay (90 – 160 g/L) are within the capability of current YSI multi-meter acceptable range of accuracy, whereas earlier versions were limited to 0-70 g/L. Salinity in the North Arm, which characteristically exceeded 270 g/L, is above the range for accurate determination. Based on these limitations samples from the North Arm need to be diluted in order to obtain an accurate measure of salinity.

For this round-robin we used our YSI 556 multi-meter for the salinity determination. For comparison purposes a refractometer reading was also included, but does not represent current methods used by GSLBSCI for our GSL water samples. A variety of additional comparative tests were done to assess the relationship of our YSI 556 readings to two gravimetric methods for determining TDS, conductivity and laboratory prepared salinity standards. The results of the YSI readings of the round robin samples are shown below in Figures 1a, 1b, 1c and in Table 1. It was necessary to dilute North Arm (NA) water by 50:50 (NA water:Distilled water) in order to achieve an acceptable concentration of salinity for use of the YSI 556 probe.

Samples:

- Three half-gallon (1.89 L) water samples were received in November 2019.
- The samples were labeled as: FB 11-19-19, SA 11-19-19, NA 11-19-19
- Some head space was present in the bottles (~5-10 ml).
- No signs of precipitate were observed.
- Samples were dispensed into three 500 ml HDPE bottles, filled to capacity, tightly sealed and then stored at room temperature until analysis.
- All tests were conducted at room temperature (19-21C).

Sample Testing:

YSI 556 Probe

- Each 500 ml volume (aliquot or original water sample) was tested multiple times separately. The YSI 556 probe was first used to measure dH₂O and then cleaned, dried, and inserted into the next sample. The probe was gently agitated until a stable reading was achieved. Each reading was recorded, the probe was again rinsed, dried and then inserted into the next sample to be tested. Temperature, Salinity, Conductivity were recorded.

Reed Refractometer

- The refractometer was calibrated using room temperature dH₂O and adjusted as necessary to zero. One to two small drops of water were placed on the refractometer and reading observed and recorded. The refractometer was cleaned and dried between each sample.

Results

Figures 1a, 1b, 1c. Results of salinity determination for round robin samples. Results are based on YSI 556 multi-meter readings. North Arm (NA) samples were diluted 50:50 with dH₂O in order to get salinity within an acceptable range for the YSI 556. Non-diluted NA samples were tested and results are shown in Table 1.

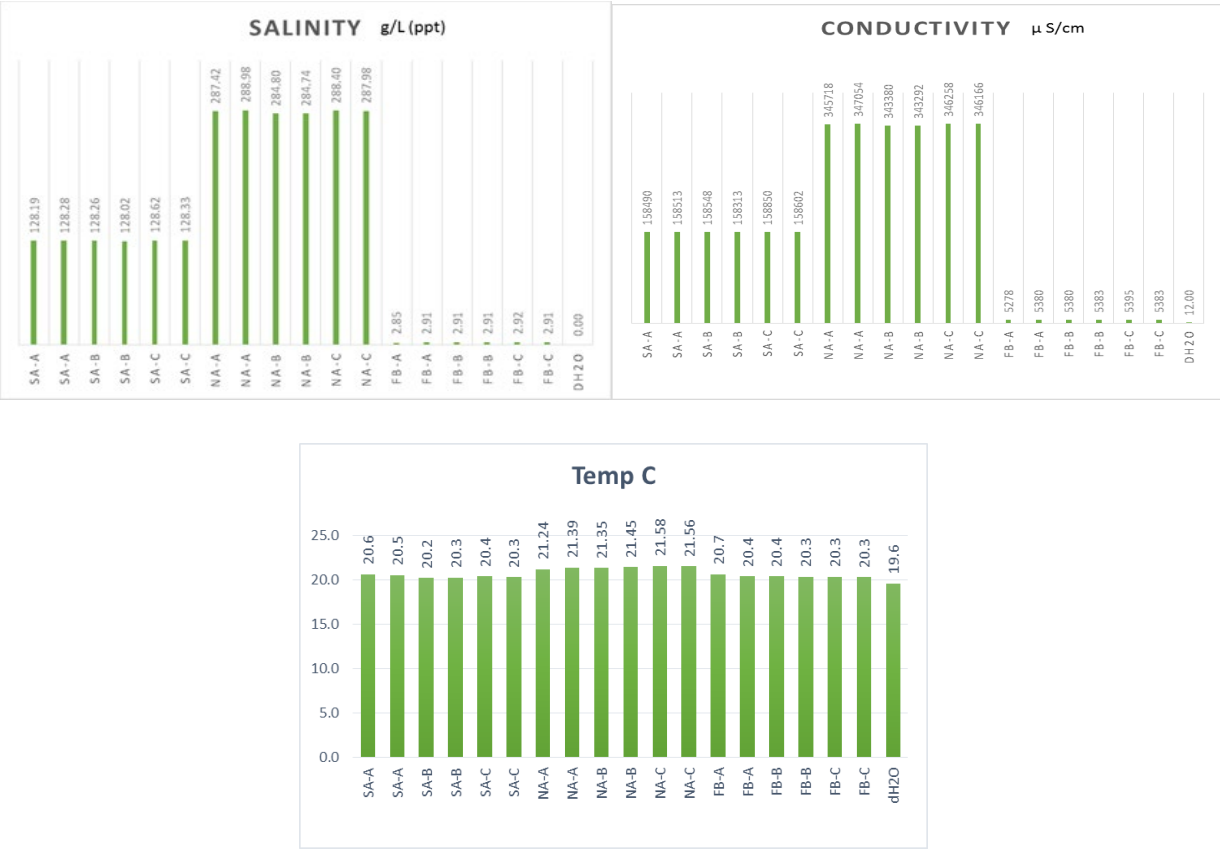


Table 1. The results of sample testing are shown. Results for North Arm (NA) water includes both direct measurement of the sample as provided and for a 50:50 dilution (with 2X conversion) with distilled water. Method 1 TDS test is a relatively simple low volume test (3-10 ml) with drying at 50°C just for comparative purposes, whereas the Method 2 TDS test follows standard gravimetric methods with drying at 180°C.

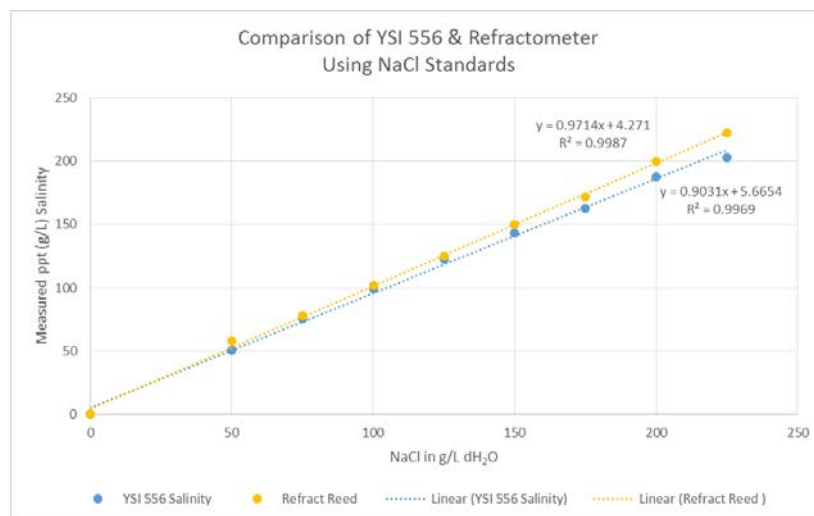
SAMPLE I.D.	YSI 556 Salinity g/L	YSI 556 Conductivity uS/cm	YSI 556 Temperature C	Refractometer % Salinity	Gravimetric Method 1 TDS (50°C) g/L	Gravimetric Method 2 TDS (180°C) g/L
FA-A1	2.85	5278	20.66	0.2	3.34	2.75
FA-A2	2.91	5380	20.42	0.3		
FA-B1	2.92	5380	20.34	0.2	3.34	2.99
FA-B2	2.91	5383	20.40	0.3		
FA-C1	2.91	5395	20.33	0.3	3.23	2.92
FA-C2	2.91	5383	20.30	0.3		
SA-A1	128.19	158490	20.64	13.2	158.93	137.9
SA-A2	128.26	158548	20.21	13.3		
SA-B1	128.62	158850	20.41	13.3	163.73	143.67
SA-B2	128.28	158513	20.52	13.3		
SA-C1	128.02	158313	20.25	13.2	168.17	144.73
SA-C2	128.33	158602	20.31	13.3		
NA-A1	201.58	221669	20.6	27.4	384.07	315.8
NA-A2	201.96	221876	19.9	27.8		
NA-B1	201.40	221508	20.4	27.8	390.74	318.23
NA-B2	202.04	221936	20.0	27.5		
NA-C1	200.38	220698	20.2	27.8	387.70	327.33
NA-C2	200.43	220719	20.2	27.8		
NA 50:50 A1	287.42	345718	21.24	30.4		
NA 50:50 A2	288.98	347054	21.39	30.8		
NA 50:50 B1	284.80	343380	21.35	30.0		
NA 50:50 B2	284.74	343292	21.45	30.0		
NA 50:50 C1	288.40	346258	21.58	30.4		
NA 50:50 C2	287.98	346166	21.56	30.4		
dH2O	0.00	8	19.60	0.0		

Comparison of Methods and Testing of Standards

A variety of comparative tests were done to assess the relationship of instrument salinity readings to gravimetric determination of TDS, conductivity, lab salinity standards and to compare refractometer

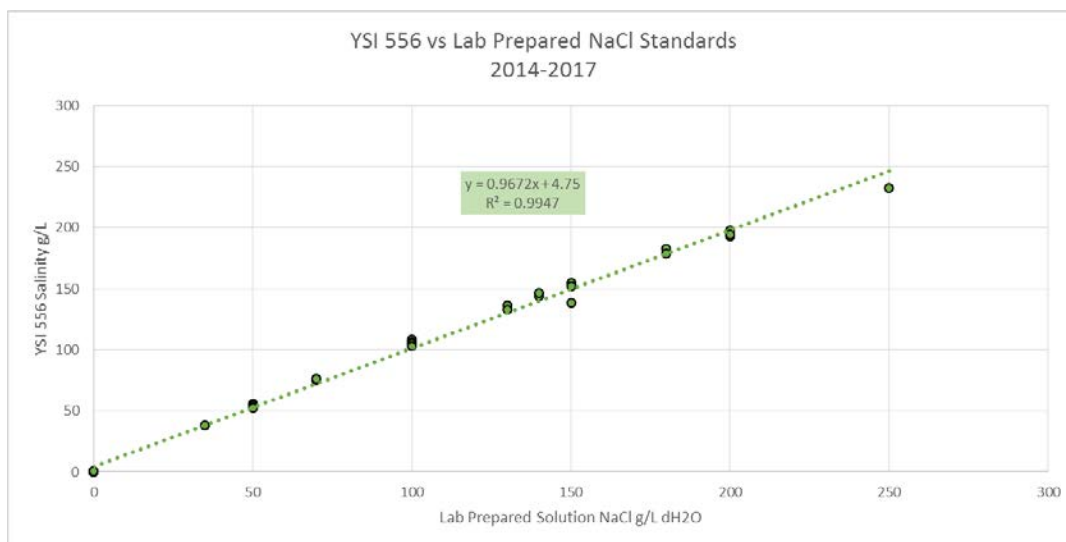
readings with the YSI 556 multi-meter. The results are shown in Figures 2, 3, 4 and 5. Lab salinity standards were prepared by adding desiccated NaCl crystals to measured volumes of dH₂O. The moisture content of dry NaCl was measured prior to use and demonstrated an average moisture content of 0.04%. Water was added by weight with an accuracy to 0.01g. The solution was thoroughly mixed in a 1000 ml Imhoff cone by aeration until all crystals were dissolved. Salt standard solutions were immediately placed in sealed 500 ml HDPE bottles. A comparison of YSI 556 measurements and refractometer showed a linear relationship with the YSI 556 defining a slightly lower estimate of salinity than the refractometer. Within the common range of salinity found in Gilbert Bay the YSI 556 showed results that were an average of 98.3% of the calculated prepared NaCl solutions while the refractometer showed an average of 102% of actual (Figure 2).

Figure 2. Current comparison of YSI 556 to refractometer salinity measurements using lab prepared salinity (NaCl) standards.



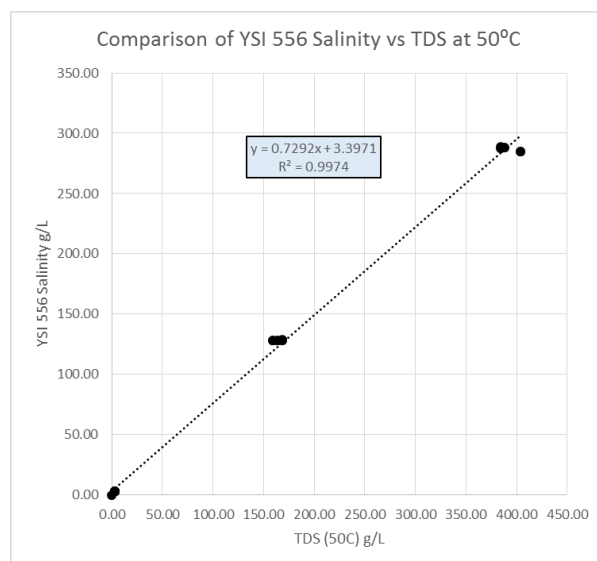
Comparisons of YSI 556 results with lab prepared standards is a routine process in the GSLBSCI lab. A compilation of results involving two YSI 556 meters and multiple probes is shown in Figure 3. As in the current results (Figure 2) there was a definitive linear relationship with a slight underestimate of salinity at higher concentrations.

Figure 3. A multi-year comparison of YSI reading of salinity standards for the time period 2014-2017 is shown. The data include results from multiple YSI meters and multiple probes that were used over a 4-year period.



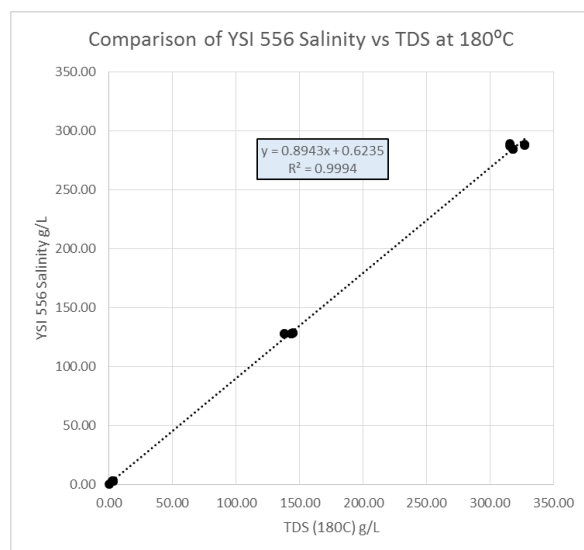
The GSL water samples provided for the round robin were evaluated on the basis of TDS using two different gravimetric methods for determining TDS and then compared to salinity measurements as indicated by the YSI 556 meter. TDS was determined by a gravimetric method in which precise volumes of each GSL solution were dispensed into pre-dried and pre-weighed aluminum weighing boats. In Method 1 the samples were dried for >24 hours at 50°C and then the residual contents were weighed. In Method 2 the samples were initially dried at 60°C for 24 hours and then at 180°C for four hours and then the residual contents were weighed. All water samples were filtered through 0.45 micron capsules prior to dispensing in order to remove all non-dissolved particulate matter. Filtered water samples were dispensed by a calibrated pipette (100.03% v/v precision) into weighing trays and incubated. Weights were recorded to 0.0001 g. Triplicate samples were performed for each of the sample types. The results from Method 1 (Figure 4a) indicate that YSI 556 salinity is an underestimate of TDS, or that Method 1 is an overestimate of TDS, in each of the round robin samples. The percentages of YSI 556 Salinity/TDS_{50°C} (Method 1) for each of the water sources is: FB H₂O = 87.87%; SA H₂O = 78.45%; NA H₂O = 73.29%.

Figure 4a. Comparison of Salinity to Total Dissolved Solids ($TDS_{50^{\circ}C}$) results from Method 1 ($50^{\circ}C$ drying temperature). There was a linear relationship between YSI determined salinity and TDS.



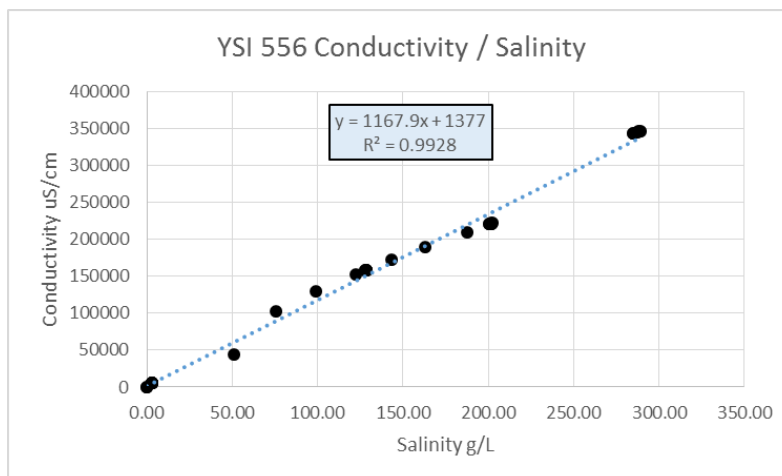
The results from Method 2 (Figure 4b) indicate that Method 1 may have been an overestimate of TDS in the samples and that the YSI 556 salinity measurements differ less than the gravimetric method using a final incubation temperature of $180^{\circ}C$. Method 2 adheres to standardized methods and temperature for TDS methods. The percentages of YSI 556 Salinity/ $TDS_{180^{\circ}C}$ (Method 2) for each of the water sources were: FB H_2O = 100.63%; SA H_2O = 90.32%; NA H_2O = 89.60%.

Figure 4b. Comparison of Salinity to Total Dissolved Solids ($TDS_{180^{\circ}C}$) results from Method 2 ($180^{\circ}C$ drying temperature). There was a linear relationship between YSI determined salinity and TDS.



Salinity and conductivity were plotted to examine linearity across the salinity range. Results are shown in Figure 5 and are linear across the range tested.

Figure 5. Salinity measurements plotted with conductivity. The relationship is linear and reflects only measures within one device and not across devices.



The Purpose of Salinity Measurements from the Perspective of GSLBSCI

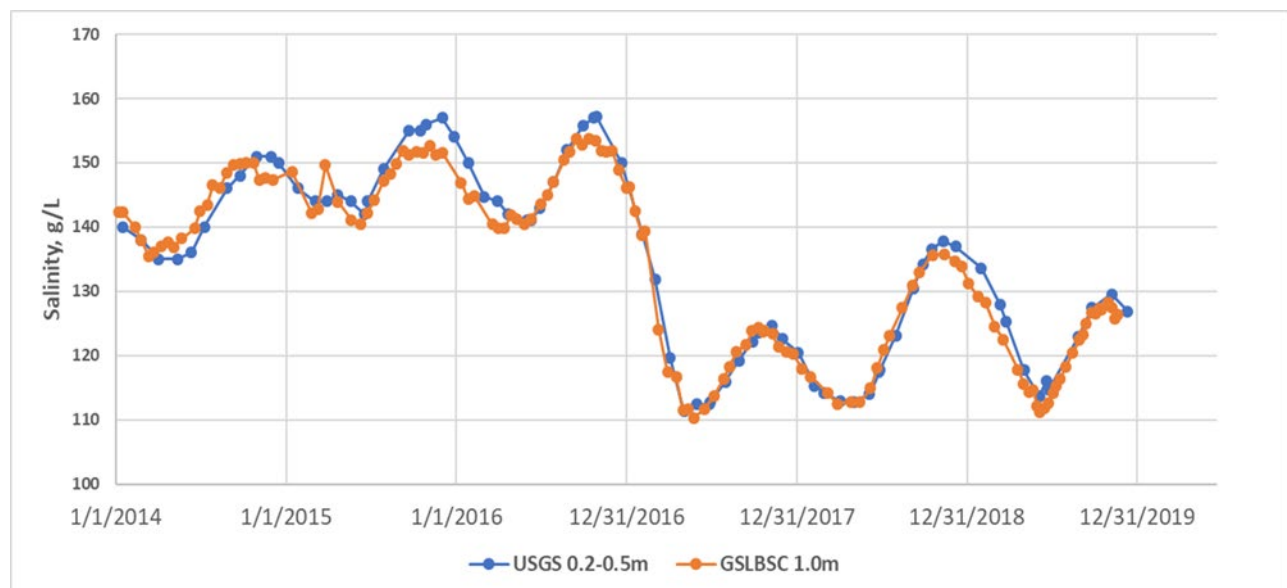
The main objective for GSLBSCI with respect to salinity measurement is to ascertain the relationship of the zooplankton *Artemia* (Brine Shrimp) to its environment. We are concerned with the role that *Artemia* serves in terms of GSL ecosystem functions and services. It is thoroughly established that salinity is an important factor that influences *Artemia* individual fitness, survivability, reproductive capacities and output, stress tolerance, growth and development and interactions with other biota and algal food sources. We desire to be able to compare and contrast conditions on GSL with other saline lakes and to evaluate the characteristics of *Artemia* biotopes that influence *Artemia* population dynamics. GSLBSCI recognizes that many of the *Artemia* and saline lakes studies reported in the scientific literature have used a variety of methods for the determination of salinity, with refractometer readings being common in many of the international investigations. Comparisons of salinity across such studies is challenged by the inconsistency of methods used. Additionally, we recognize that there is a salinity range over which *Artemia* can thrive and are resilient to other stressors and that such salinities should be compared to “optimal” ranges for other biota. This information can be used to inform resource managers with the means to make prudent decisions that serve to enhance the integrity and resiliency of the GSL ecosystem by protecting the biota, such as *Artemia*, that provide critical ecosystem functions and services.

GSLBSCI desires to employ methods that exhibit a reasonable degree of similarity to other research groups that are concurrently working on GSL issues. In particular, GSLBSCI strives to produce salinity data that is comparable to the USGS results. GSLBSCI has relied upon YSI multi-meter readings, with

comparisons to refractometer readings, for our determination of salinity. GSLBSC has not used the gravimetric method for any of our previous reporting. Although our YSI multi-meter values are not always the same as the USGS values they exhibit a high degree of similarity and are typically less than 5 g/L difference. A comparative graph is shown in Figure 6 that includes USGS data for a single site (Site 3510) and average values for all nine routine GSLBSCI sites.

It is important to GSLBSCI to be able to compare our current results with historic results for GSL as well as to compare *Artemia* population dynamics to changes in salinity on GSL and on other saline lakes around the world. This can be a challenge as a broad variety of methods have been used by other investigators to measure salinity and in many articles the exact methods are not sufficiently disclosed. This illustrates the value of comparing methods and contrasting outcomes based on diverse methodological approaches.

Figure 6. GSLBSCI salinity data from 2014 to the present is compared to results obtained by the USGS. Although there are some periods where there is a slight deviation between the methods (<1%) there is general agreement on salinity measurements for Gilbert Bay by the two entities. This is particularly true from 2016 to the present. Deviations could be attributable to the fact that the USGS data is for only one site whereas the GSLBSCI data is an average of 9 sites. Water samples are taken at the 1 meter interval by GSLBSCI and at 0.5 meter interval for USGS.



Conclusion

To be sure salinity is a critical factor in the GSL ecosystem that exerts a profound influence on microbial, algal, invertebrate and vertebrate community structure. Salinity is an osmotic stress that can effect individual fitness and reproductive output. With respect to *Artemia*, salinity serves in a protective capacity by excluding non-halotolerant competitors or predators thereby enhancing population level success of *Artemia*. At salinities below 120 g/L risks to the GSL *Artemia* population begin to increase and


below 100 g/L there is an increased chance of survival of corixid predators (*Trichocorixa verticalis*) that exert a severe predatory pressure on *Artemia*. At very elevated salinities (i.e., >180 g/L) reproductive impacts and reduced survivability can result among *Artemia* due to the energetic demands of osmoregulation. In our best estimate, salinity in the range of 120-160 g/L is the most beneficial for Gilbert Bay *Artemia* given a variety of factors.

Having identified this salinity range that is beneficial for *Artemia* it is clearly important to be able to measure salinity with confidence and to be able to compare and contrast ecological studies of the GSL ecosystem and its resident *Artemia* population with other saline lakes. Within the context of *Artemia* salinity tolerances and population level thresholds, we feel we are comfortable with a 5 g/L error rate, but we are concerned if it exceeds this level, when measuring salinity and comparing with other investigators. Other studies on saline lakes also employ a wide variety of salinity testing methodologies ranging from simple refractometers, to hand-held multi-meters, to sophisticated portable or laboratory installed instrumentation. In the scientific literature on saline lakes there is also a broad range of detail provided on methods used to assess salinity—in some cases very thorough information is provided on sample collection and abiotic measurements, whereas in other publications little to no details are given with regard to measuring salinity.

It is our goal to continuously improve all of our sampling and laboratory methodologies, but also to ensure that if new and improved methods are implemented that there is sufficient overlap with historic methods to afford comparability across long periods of time and between multiple methods. This round robin is an opportunity to examine variability in methods and outcomes and to use such information to define new methods that are both practical and dependable and that allow comparisons across GSL research studies. We appreciate the opportunity to participate and we are open to all positive suggestions for improvement going forward.

Attachment E

Compass Minerals Analytical Methods for Ion Composition

		Determination of Potassium (K) and Sodium (Na) by Atomic Emission Spectroscopy (AE) in the Main Lab	Ogden Site	
Effective Date:	01/18/2016	1510	Review Date:	02/17/2017
Document Owner:	Quality Manager		Next Review Date:	02/17/2019

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1. Applicable Matrix:

- 1.1 In the Main Lab this consists of Pond Samples. Other samples maybe requested for Na and K analysis.
- 1.2 Additional samples requested by engineering may need to be run as well. Changes in procedure need to be discussed with the Quality Manager.

2. Detection Limit:

- 2.1 Na: 40 to 6000 ppm
- 2.2 K: 40 to 4000 ppm

3. Scope and Application:

- 3.1 This method measures the atomic emission of K and Na in the sample. The sample is aspirated into the flame, where the excited ions emit light of a specific wavelength which is measured by the detector.
- 3.2 The procedure for running the AE is a two part procedure. The first part allows for proper dilutions of the variety of samples. The second part allows for the concentration determination in % K or Na of those samples via AE detection.

4. Summary:

- 4.1 Samples are weighed out to proper amounts for dilution.
- 4.2 Samples are diluted and allowed to dissolve completely.
- 4.3 Samples are diluted to volume after stir bar removal and poured into sample cups.
- 4.4 Sample cups are placed onto AE sample tray according to a selected order.
- 4.5 AE is rinsed and turned off.
- 4.6 Sample cups are rinsed.
- 4.7 Analysis is exported to screen display Analysis is exported to screen display.

5. Definitions:

- 5.1 **AE:** Atomic emission spectroscopy (AES) also known as Flame Photometry is a method of chemical analysis that uses the intensity (number of photons) of light emitted from an electron excited by a flame, plasma, arc, or spark. Each atom emits a specific wavelength set. The number of photons emitted of each wavelength is

measured to determine the quantity of an element in a sample. The wavelength of the atomic spectral line gives the identity of the element while the intensity of the emitted light is proportional to the number of atoms of the element. K burns purple, Lithium burns Pink and Na burns yellow.

- 5.2 **Brine:** liquid portion of the evaporation ponds. This liquid can be manipulated by concentration to drop mineral content under certain conditions.
- 5.3 **Diluent Solution:** AKA AE Solution is a solution that contains a small amount of surfactant that is brought in and mixed with a sample at a ratio 33mL / 1.5 mL of sample for optimal flow rate consistency and nebulizer cleaning.
- 5.4 **DI Water:** short term for de-ionized water. Deionized water is a type of purified water with mineral ions (salts) removed. These mineral ions include sodium, calcium, iron, copper, chloride, and bromide. Deionized water is created by taking conventional sediment free water and exposing it to electrically charged resins that attract and bind to the salts, removing them from the water.
- 5.5 **Insoluble:** particles not capable of going into solution. They appear as granules of sand or small rocks in the bottom of flasks.



- 5.6 **Molar (M):** the concentration of a solution expressed in moles of solute per liter of solution. A mole is the amount of any substance that contains as many elementary entities (ions, etc.) as there are atoms in 12 grams of pure carbon -12 (^{12}C).
- 5.7 **3M Lithium Solution (LiCl):** run in the back ground as an internal standard and will account for the variance in flow rate and flame interference.

- 5.8 **mMeq**: the weight of one equivalent can be determined by dividing the gram-atomic weight of the ion by its valence. Also denotes a concentration of 1 millimole per liter. One thousandth of a mole.
- 5.9 **ppm**: the abbreviation for parts per million or 1/1,000,000.
- 5.10 **Quality Control Sample (QC Sample)**: the QC sample is run to verify that the instrument is operating correctly, the sample itself was made correctly, and is a strategic part of the Quality System.
- 5.11 **Tared**: the deduction of the weight of the beaker on the scale so that the true weight of the sample can be determined. Press the “zero / tare” button on most scales.

6. **Interferences:**

- 6.1 Possible interferences include dryer operations, wind directions, radio shielding issues, air pressure fluctuations, electrical surges, flame height and flicker effects; ventilation and clearance; plant vibration, machine warm up temperature, stray light, improper measured amount of sample, build up on the burner and the ignitor; and dust level in the air.

7. **Safety:**

- 7.1 Responsibility for lab safety belongs to every lab employee, and everyone should adhere to the policies and guidelines set forth in policy 1530.xx Chemical Hygiene Plan.
- 7.2 Wear latex or nitrile gloves which should provide adequate protection from minor exposures. Wear safety glasses to protect eyes from splashing chemicals during preparation.

8. **Equipment and Supplies:**

- 8.1 Safety glasses
- 8.2 Nitrile or latex gloves
- 8.3 Volumetric flasks and stoppers
- 8.4 Beakers
- 8.5 Balance with 1/100g accuracy
- 8.6 Stir bars
- 8.7 Stir plates
- 8.8 Funnels

- 8.9 Weigh boats
- 8.10 Transfer pipettes
- 8.11 AE Sample cups
- 8.12 Cole Parmer 2655-10 Dual Channel Flame Photometer
- 8.13 AE Standards
 - 8.13.1 4000 ppm to 250 ppm Standards
 - 8.13.2 200/200 mMeq Standard
- 8.14 3 M LiCl Solution
- 8.15 De-ionized water
- 8.16 M805 Dilutor
- 8.17 Model 860 Auto sampler
- 8.18 Aquet
- 8.19 AE Maintenance Log Book

9. Reagents and Standards:

- 9.1 **Use commercially manufactured reagents first.**
- 9.2 **All reagents and standards are made in large amounts. Only prepare the following when you are close to running out or out.**
- 9.3 **If no one is available in the main lab for making reagents, contact Quality Manager.**
- 9.4 **All reagent chemicals can be located in various chemical storage locations in the main lab.**
- 9.5 **When making standards, use the balance in the main lab that has 1/1000 g accuracy.**
- 9.6 **Dilute to proper volume indicated.**
- 9.7 **All solutions are to be dissolved in de-ionized water unless otherwise stated.**
- 9.8 **Reagents:**
 - 9.8.1 AE Diluent solution
 - a) Dissolve 0.5mL of Aquet into 1 Liter volumetric flask or 9 mL into 18 Liter carboy.
 - 9.8.2 52 % K₂O
 - a) Dissolve 9.62 g of Potassium Sulfate into a 1 Liter flask.
 - 9.8.3 Standard 3M Lithium Solution
 - a) Dissolve 127.18 g of Lithium Chloride into a 1 Liter volumetric flask.

Note: this is an exothermic (extreme heat producing) reaction and should be performed in 25 g increments to avoid a spill.

9.9 Standards:

9.9.1 4000 ppm Standard

- a) Dissolve 7.627 g of KCl and 10.168 g of NaCl into a 1 Liter volumetric flask.

9.9.2 2000 ppm Standard

- a) Dissolve 3.813 g of KCl and 5.084 g of NaCl into a 1 Liter volumetric flask.

9.9.3 1000 ppm Standard

- a) Dissolve 1.907 g of KCl and 2.542 g of NaCl into a 1 Liter volumetric flask.

9.9.4 500 ppm Standard

- a) Dissolve 0.953 g of KCl and 1.271 g of NaCl into a 1 Liter volumetric flask.

9.9.5 250 ppm Standard

- a) Dissolve 0.477 g of KCl and 0.636 g of NaCl into a 1 Liter volumetric flask.

9.9.6 52% K₂O

- a) Dissolve 9.62 g of K₂SO₄ into a 1 Liter volumetric flask.

9.9.7 200/200 mMeq K/Na Standard

- a) Dissolve 14.91 g of KCl, and 11.688 g of NaCl into a 1 liter volumetric flask.

9.9.8 QC Sample

- a) Dissolve 3.051 g of KCl into a 1 Liter volumetric flask.

10. Sample Collection:

- 10.1 Most samples are brought from Ponds and Harvest operators in closed containers and are usually delivered daily.
- 10.2 The Ponds and harvest crew shall deliver samples to the Main Lab according to 5023.xx Ponds Inventory Procedure.

11. Quality Control:

- 11.1 It is the policy of the Ogden Quality Manager and Site management to be concerned with product quality and to ensure that accurate chemical characteristics are determined, identified, and recorded.
- 11.2 It is the responsibility of the lab technicians to perform this procedure properly, to maintain the equipment and instruments used to determine potassium and sodium content, and to record and maintain test results in a common log book and computer database.
- 11.3 It is the responsibility of the lab personnel to apprise the Quality Manager of instrument problems that may require maintenance beyond the replacement parts in the warehouse.
- 11.4 The 2% Potassium solution has been chosen for the QC Sample.

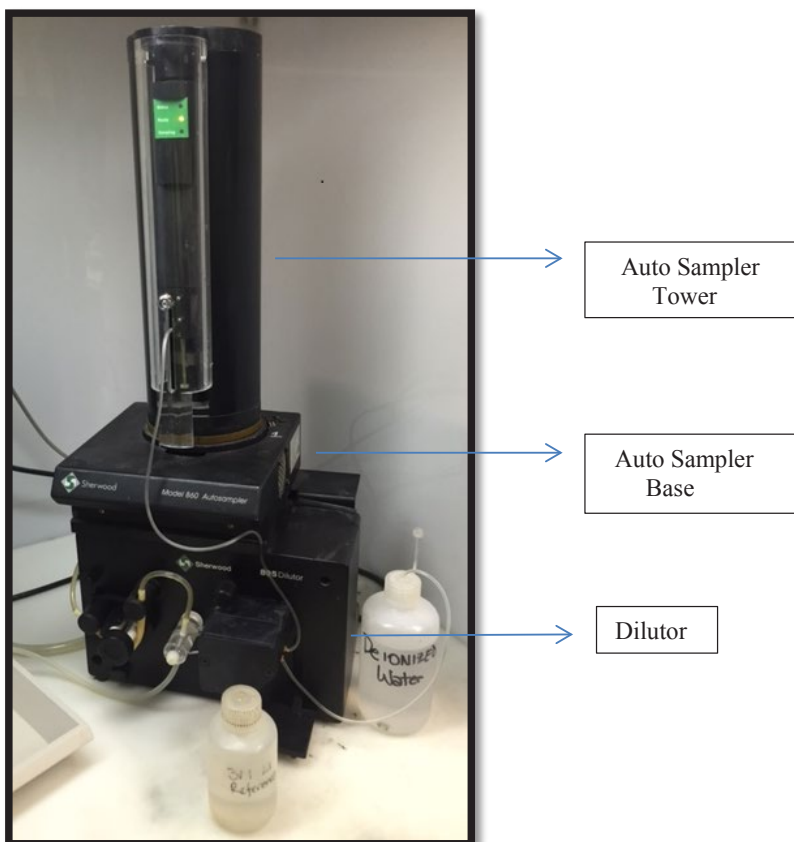
12. Calibration and Standards:

- 12.1 Calibration:
 - 12.1.1 A 2% Potassium solution is used a QC sample to test the calibration set up by the standards.
 - 12.1.2 See Section 13 for Calibration.
- 12.2 Standards:
 - 12.2.1 The 4000 to 250 ppm standards are designed to establish a calibration curve that unknown samples are compared to known values.

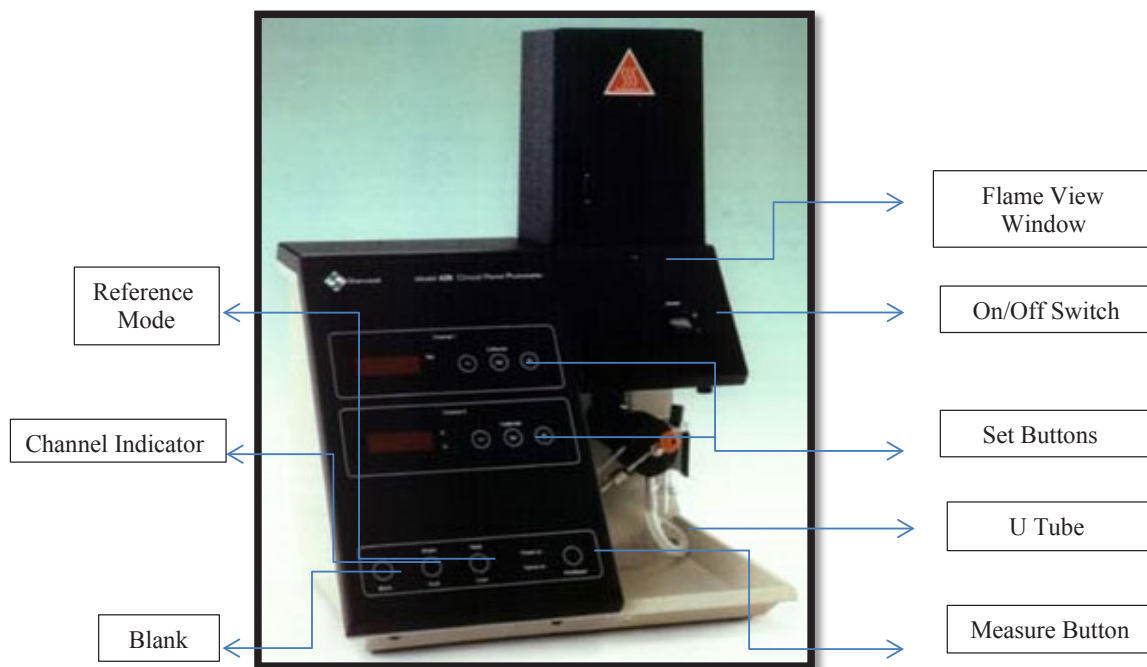
12.2.2 See Section 9 for Standards

13. Procedure:

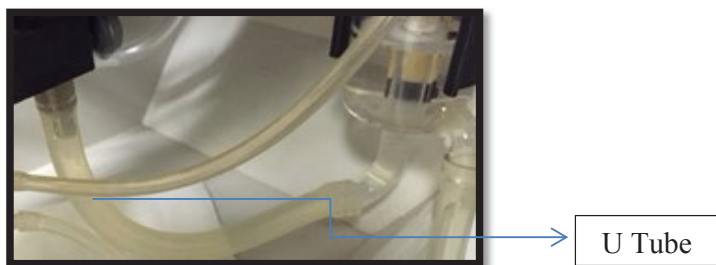
13.1 Warming up the AE.



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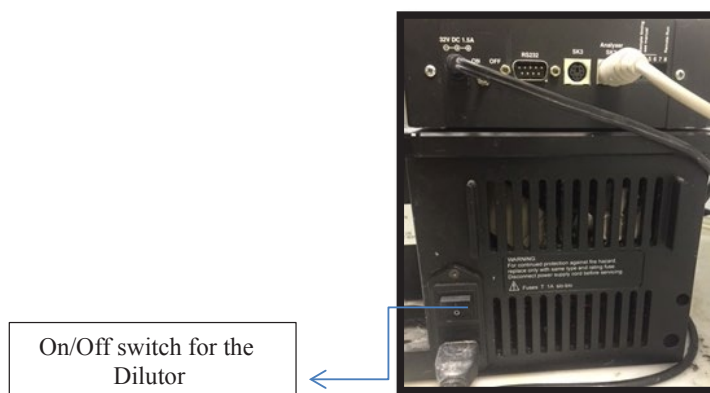
- 13.1.1 Check U tube on the AE for air bubbles. If air bubbles are present, flush the tube with De-ionized water. Try to flush once a shift.



- 13.1.2 Turn on the tower by flipping the switch on the right hand side of the back.



- 13.1.3 Verify that the first two white pegs are down. This limits sample uptake time to 34 seconds.
- 13.1.4 Open diluent solution bottle valve and verify cap is open, but not removed.
- 13.1.5 Turn on the dilutor by flipping the switch on the right hand side of the back.

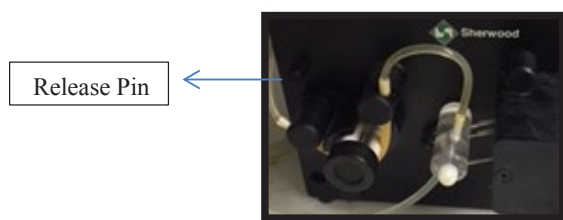


- 13.1.6 Secure the peristaltic pump tubes by sliding the tension arm up to the lock pin and lock the pump plate arm. This will be performed for every run.

Not secured



Secured



- 13.1.7 Turn on AE by flipping the switch on the front of the instrument.
- 13.1.8 Allow for a warm up period of 15 minutes. During the 15 minutes you can pour and load the samples.
- 13.1.9 Run De-ionized Water through tubing as a rinse through the instrument for 13 minutes as part of the warm up.
- 13.1.10 Begin aspirating 3M LiCl Solution into the auto sampler by moving the tube in to the 3M LiCl Solution bottle. This should only last for 2 minutes prior to placing the sample tray on the tower.
- 13.1.11 Open the flame view window to verify that the flame turns pink.
- 13.2 Loading the AE sample Tray:
 - 13.2.1 In the Main Lab, load the sample tray for the AE in the following order:
 - a) Water
 - b) 4000 ppm Standard
 - c) 2000 ppm Standard
 - d) 1000 ppm Standard
 - e) 500 ppm Standard
 - f) 250 ppm Standard
 - g) Water
 - h) Sample 1
 - i) Water
 - j) Sample 2
 - k) Water
 - l) And repeat this pattern until all of the samples including the QC sample are loaded.
 - m) Load sample cups with de-ionized water until it water is the last sample on the outside ring of the sample tray.

- n) Load large sample cup of de-ionized water in the “B” hole closest to the opening in the sample tray.
- o) Load 200/200 meq K/Na standard in a different sample cup and place in the hole the farthest from the sample tray opening “S”.

13.2.2 Secure the peristaltic pump tubes and turn on the auto sampler.

13.3 QC Sample:

13.3.1 This is run every run unless the sample tray is full.

13.4 Running the AE:

Note: When the auto sampler is not working, disconnect the communication and power cable from the tower and then this entire AE Running procedure can be performed by hand with a 10 second delay between each sample cup and 20 seconds for each sample to be drawn in. Move the hose from sample cup to sample cup and press the “Measure” button for each data point you need to acquire.

13.4.1 Place the sample tray over the tower and slide it down to the bottom.

13.4.2 Press “RUN” on top of the tower.



13.4.3 The auto sampler will detect the sample tray alignment by moving slightly back and forth.

13.4.4 The instrument is automatically set to warm up in the “Dual” mode. This will detect both the Na and the K channels.

- 13.4.5 The instrument is automatically set to warm up in the “Peak” and “Ref” mode for running 3M Lithium Solution. If not, press “MODE” button until both “Peak” and “Ref” are lit up.
- 13.4.6 Press the “BLANK” button on the AE. The auto sampler will move to the closest large sample cup and withdraw a sample.
- 13.4.7 When the sample is complete the AE will begin to flash “Cal” in the middle of the display.
- 13.4.8 Press “SET” for each of the channels. The auto sampler will move to the large sample cup filled with the 200/200 mMeq K/Na standard.
- 13.4.9 When the sample is complete, the display will flash “199.0” for both channels and move to the first small sample cup.
- 13.4.10 When the sample is complete the AE will begin to flash “Cal” in the middle of the display.
- 13.4.11 Press “SET” for both channels.
- 13.4.12 Then press “MEASURE/PRINT”. The auto sampler will begin to automatically move from one sample cup to the next taking appropriate samples.
- 13.4.13 The results will automatically be exported to the computer screen.
- 13.5 Shutting the AE down.
 - 13.5.1 When the last sample has been collected, the tower will emit a loud beep.
 - 13.5.2 Press the “STOP CLEAR” button on the top of the tower.



- 13.5.3 When the AE is flashing the last results, move the tube from the 3M Lithium Solution to the De-ionized water.
- 13.5.4 Wait until the flame is blue, then turn off the gas.
- 13.5.5 Release the tension on the 2 peristaltic pumps.
- 13.5.6 Turn of the the power to the AE and the dilutor.
- 13.5.7 Turn off the diluent.

14. Calculations:

- 14.1 If software is not working the following calculation may be used:

$$K20 = \left(\frac{\frac{(\text{Standard 1 Reading} + \text{Standard 2 Reading})}{2}}{\text{Sample Reading}} \right) \times 52$$

$$\text{Curve Samples} = \frac{\left(\left(\frac{Hc - Lc}{Hs - Ls} \right) \times (rdg - Ls) + Lc \right)}{20 \times swt}$$

Where:

- Hs = High Standard Reading
- Ls = Low Standard Reading
- Hc = High Standard Parts per Million
- Lc = Low Standard Parts per Million
- rdg = Sample Reading
- swt = Sample Weight

15. Data Assessment and Acceptance for Out of Control Data:

- 15.1 QC Sample needs to be between 21.70 to 23.60 for the Na and 22.35 to 23.27 for the K.
- 15.2 These acceptance criteria can be changed by Quality Manager ONLY. Make sure there is documentation of the change in procedure such as an email.
- 15.3 Check the AE back ground solution for proper flow through the manifold.
- 15.4 Check all tubing for wear and replace if they are worn.

- 15.5 Check the Nebulizer flow. Replace Nebulizer if necessary.
- 15.6 Using clean sample cups, pour new standard curve, blank and the 200/200 mMeq K/Na standard.
- 15.7 Verify the pump latch is secure.
- 15.8 Re-run the sample tray.

16. Waste Management:

- 16.1 Dump all samples out of the sample cups down the sink drain.
- 16.2 Rinse all glass ware and sample cups three times with de-ionized water.

17. References:

- 17.1 AE Operating Manual
- 17.2 1530.xx Chemical Hygiene Plan
- 17.3 Model 860 Auto Sampler Service Manual
- 17.4 M-805 Dilutor Operations Manual
- 17.5 5023.xx Ponds Inventory Procedure

18. Tables:

- 18.1 **Common AE Errors: these are a list of common errors. For errors that are not listed here, refer to the AE Operations Manual.**

Error	Error meaning	Things to try
E02	The run was “noisy” causing the instrument to malfunction.	Check wear pattern on tubing around the peristaltic pumps, clean the chimney, check for contamination in the flame, flush air from drain
E05	Blank is contaminated.	Change the sample of DI water in the sample cup
E25	Sample exceeds the	Verify that the flow through the nebulizer is

	parameters.	at an acceptable level and check that the 200/200 mMeq Na/K is correctly filled
E35	Lithium is out of range.	Verify the level of the lithium, check that the U tube on the AE is full and does not have an air bubble
Red Flashing Light	The Sample tray has gone off track or the needle has been bent.	Check for water on the bottom of the tray, check the needle and the plastic cover, then restart the run
E61	Instrument is out of gas or not igniting properly	Check level in the propane tank or check for proper air flow

19. Audit:

19.1 The Quality Manager or a designee will audit this procedure as needed for compliance and accuracy.

19.1.1 Compliance:

- a) Are Operators performing the tasks in this procedure to the standard as they are outlined within this document?

19.1.2 Accuracy:

- a) Can the Operators perform the tasks to the standards as outlined within this document?
- b) Have all of the significant changes that have been made to the equipment or procedure that this document covers been updated already?

19.1.3 Revision Requests / Document Updates:


- a) If any of the above questions can be answered as a 'No,' the document needs to be updated by turning in the appropriate revision request.
- Ensure all MOC practices, policies and procedures are followed.

20. Training:

- 20.1 Where available site personnel will go through the relevant Phase 5 Training and Certification Program and will re-certify according to the determined schedule or as needed if the process and/or expectations significantly change.
- 20.2 In Areas and/or Departments where a Phase 5 Training and Certification Program has not yet been implemented, Department Managers, their Supervisors and or their designee will determine the qualifications of their employees in the manor that maintains the current department standard and will ensure necessary training and qualification records are maintained for the personnel under their direction.
- 20.2.1 Refresher training will be done on an as yearly basis or when/if the process and/or expectations of this document significantly change.
- 20.3 Personnel in training will observe a lab technician for at least one full shift then set up and perform the tests while being observed by a lab technician for one full shift or until they demonstrate capability or three weeks. If after three weeks, the personnel in training is not demonstrating capability, they will need to create a meeting with the Quality Assurance Manager and discuss the training and the expectations to determine if they can re-train.

Revision History

Revision Number	Date of Revision	Author	Changed Section(s)
00	1/18/16	Patricia Covington	Original Creation
01	12/15/16	Patricia Covington	Added corrections from Abe Abelman in the shut down process
02	02/17/17	Patricia Covington	Added corrections from Wade Okelberry and added in usage for the Peristaltic Pump arm.

		Determination of Magnesium (Mg^{2+}) Concentration in Brine Materials in the Main Lab	Ogden Site	
Effective Date:	8/21/2015	1511.05	Review Date:	03/01/2019
Document Owner:	Quality management		Next Review Date:	03/01/2021

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1. Applicable Matrix:

- 1.1 This method is to determine the Magnesium (Mg^{2+}) concentration in brine samples throughout the processes in the Main Lab on the Ogden Site.
- 1.2 Additional samples requested by engineering may need to be run as well. Changes in procedure need to be discussed with and approved by quality management.

2. Detection Limit:

- 2.1 $\text{Mg}^{2+} = 0.1\%$ to 12.5% by manual and auto titration.
 - 2.1.1 However, a titrant volume greater than or equal to 2.5 mL as well as a good curve on the graph helps to determine an accurate reading of the Mg^{2+} concentration.

3. Scope and Application:

- 3.1 This method describes the procedure to be followed in determining the concentration of Magnesium ion (Mg^{2+}) with colorimetric and potentiometric indication in Brine materials.
- 3.2 Manual Titration shall be done as back up only.

4. Summary:

- 4.1 Samples are obtained from proper locations.
- 4.2 Samples are weighed out to proper amounts for dilution.
- 4.3 Samples are titrated.
- 4.4 The titration is carried out with auto titration (potentiometric).
- 4.5 Data is recorded on the proper sheet.

5. Definitions:

- 5.1 **Analyte:** in this test method is particularly referred to Magnesium ion (Mg^{2+}) in Brine materials.
- 5.2 **Colorimetric titration:** titration based on color change which is created by the addition of a determined by the color change created by a sensitive dye which is added to the solution.
- 5.3 **DI water:** short term for de-ionized water. Deionized water is a type of purified water with mineral ions (salts) removed. These mineral ions include sodium, calcium, iron, copper, chloride, and bromide. Deionized water is created by taking conventional

sediment free water and exposing it to electrically charged resins that attract and bind to the salts, removing them from the water.

- 5.4 **Molar (M):** the concentration of a solution expressed in moles of solute per liter of solution. A mole is the amount of any substance that contains as many elementary entities (ions, etc.) as there are atoms in 12 grams of pure Carbon -12 (^{12}C).
- 5.5 **Potentiometric titration:** variations in a solution's conductivity are detected (in this case through an ion selective electrode) and the endpoint is determined through a dramatic shift in electric potential. It is determined in mv/mL (millivolts / milliliter).
- 5.6 **Quality Control Sample (QC Sample):** the QC sample is run to verify that the instrument is operating correctly, the sample itself was made correctly, and is a strategic part of the Quality System.
- 5.7 **Tared:** the deduction of the weight of the beaker on the scale so that the true weight of the sample can be determined. Press the "zero / tare" button on most scales.
- 5.8 **Titrant:** is defined as a reagent which is prepared as a standard solution and reacts with an analyte to determine the concentration of the reagent.

6. **Interferences:**

- 6.1 Contamination with other compounds.
- 6.2 Build up on the probe.
- 6.3 Un-trained operators to what the correct endpoint is.
- 6.4 Improper sample collection and/or processing.

7. **Safety:**

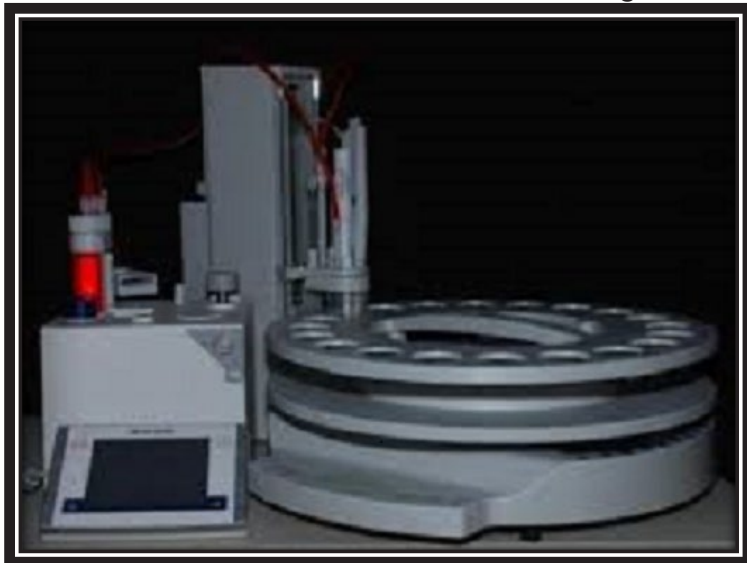
- 7.1 Responsibility for lab safety belongs to every lab employee, and everyone should adhere to the policies and guidelines set forth in policy 1530.xx, Chemical Hygiene Plan.
- 7.2 Overall, when handling acids, bases and chemical indicators, wear latex or nitrile gloves which should provide adequate protection from minor exposures. Wear safety glasses to protect eyes from splashing chemicals during preparation and titration as well as flying debris from shattering glassware.
- 7.3 Read SDS on pH10 buffer as an inhalation and contact hazard.

8. **Equipment and Supplies:**

- 8.1 Safety glasses
- 8.2 Latex or Nitrile gloves

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- 8.3 De-ionized water
- 8.4 Mettler Toledo model T50 Auto-titrator: Auto – titrator operating system and sample changer system should be installed and run correctly. The electrode used for Magnesium titration should be stored and maintained according to the Guidebook.



- 8.5 Volumetric Flasks with stoppers
- 8.6 Calmagite solution
- 8.7 Ethylenediaminetetraacetic acid (E.D.T.A.)
- 8.8 Magnesium Chloride Hexahydrate
- 8.9 Eppendorf Pipette
- 8.10 Waste containers
- 8.11 150 mL Beakers
- 8.12 Magnesium phototrode



- 8.13 Balance: Balance should keep accurate and readable to 0.01 g. All weighing shall be recorded to the nearest reading.

- 8.14 For Manual Titration only:
 - 8.14.1 250 mL Beakers
 - 8.14.2 Stir Plate
 - 8.14.3 Stir Bars
 - 8.14.4 Burette: Burette should be kept clean and readable to the 0.1 mL.

9. Reagents and Standards:

- 9.1 **Use commercially manufactured reagents first.**
- 9.2 **All reagents and standards are made in large amounts. Only prepare the following when you are close to running out or out.**
- 9.3 **All reagent chemicals can be located in various chemical storage locations in the main lab.**
- 9.4 **Make reagents in fume hoods.**
- 9.5 **Dilute to proper volume indicated.**
- 9.6 **All solutions are to be dissolved in de-ionized water unless otherwise stated.**
- 9.7 **Reagents:**
 - 9.7.1 De-ionized water (DI)
 - 9.7.2 0.05% Calmagite Solution
 - a) Dissolve 0.50 g of Calmagite crystalline in a 1 liter volumetric flask.
 - 9.7.3 pH 10 Buffer
 - a) Add 1350 g ammonium chloride to dissolve in about 6 liters of DI water in a 20 liter container. Then 11.4 Liters of ammonium hydroxide is added slowly to the container while stirring constantly. Fill the container to 18 liters with DI water.
 - 9.7.4 Calmagite Indicator Solution
 - a) Mix 50 mL 0.05 Calmagite and 450 mL pH 10 buffer.
 - 9.7.5 EDTA Titrant Solution
 - a) Add 288 g Ethylenediamine Tetraacetic acid disodium salt to dissolve in 18 liters of DI water in a 20 liter container.
 - 9.7.6 QC Sample
 - a) Add 49.98 g of Magnesium Chloride Hexahydrate ($\text{MgCl}_2(\text{H}_2\text{O})_6$) to a one liter volumetric flask.

9.8 Standards:

9.8.1 1,000 ppm Standard Magnesium Solution is purchased from a commercial provider.

a) Limits on the 1,000 ppm control samples are to be $1,000 \pm 10$ ppm.

9.8.2 6% Magnesium Standard QC sample

a) Add 49.98 g of Magnesium Chloride Hexahydrate ($\text{MgCl}_2(\text{H}_2\text{O})_6$) to a one liter volumetric flask.

10. Sample Collection, Preservation and Storage:

10.1 Most samples are brought from Mag Plant and harvest operators in closed containers.

10.2 The Ponds and harvest crew shall deliver samples to the Main Lab according to 5023.xx Ponds Inventory Procedure.

10.3 The Mag Plant Operators shall deliver the samples to the Main Lab according to 4111.xx MAG Plant Sampling Requirements Procedure.

11. Quality Control:

11.1 It is the policy of the quality and site management to be concerned with product quality and to ensure that accurate chemical characteristics are determined, identified, and recorded.

11.2 It is the responsibility of the lab technicians to perform this procedure properly, to maintain the equipment and instruments used to determine magnesium content, and to record and maintain test results in a common log book and computer database.

11.3 It is the responsibility of the lab personnel to apprise quality management of instrument problems that may require maintenance beyond the replacement parts in the warehouse.

11.4 A pre-determined quality control sample is analyzed to verify the instrument and the detection is functioning properly. In this procedure it is the 1,000 ppm Magnesium Standard solution and the 6% solution.

11.4.1 Limits on the 1000 ppm control samples are to be 1000 ± 10 ppm.

11.4.2 25.0 mL Aliquot of the 1000 ppm Standard and 5 mL of the 6% Magnesium Solution shall be used as a monitoring system to detect any deviations in the testing process.

11.5 The titration volume of the runs shall be recorded on *1535.xx Sample Sheet*.

12. Calibration and Standards:

12.1 Calibration:

12.1.1 The Instrument is calibrated every run by running a sample of the 1000 ppm Mag standard. The factor on the EDTA and the Mag standard is verified each run.

12.1.2 EDTA Titrant Solution Standardization

- a) Pipette 25.0 mL aliquot of the 1,000 ppm Standard Magnesium Solution into a 150 mL Erlenmeyer flask.
- b) Follow the same titration process as in Section 13.9.
- c) Record the consuming titrant volume as “ V_{MgSTD} ” with milliliter (mL) as the unit.
- d) EDTA Standard Factor shall be used to describe “milligrams of Magnesium per mL of EDTA”. The EDTA standard factor is calculated according to the following equation:
- e) $\text{EDTA Standard Factor} = 25 / V_{\text{MgSTD}}$

12.1.3 1,000 ppm standard is commercially made.

12.2 Standard:

12.2.1 25mL of the 1000 ppm mag standard is run as a standard.

12.2.2 The second sample of the first run every shift.

12.2.3 5 mL of the 6% Mag Standard is run at the end as a standard.

12.2.4 The first sample of the first run of every shift.

13. **Procedure:**

13.1 Sample Preparation:

- 13.1.1 Tare a dry and clean 8 ounce cup on the balance.
- 13.1.2 Pour between 35.00 g to 40.00 g of the Brine sample into the cup or 10 g of a solid and weigh to the nearest 0.01 g.
- 13.1.3 Record the weight of Brine sample on ***1535.xx Sample Sheet*** form.
- 13.1.4 Place a funnel into a clean dry 500 mL volumetric flask.
- 13.1.5 Rinse the same cup into funnel several times so it falls into the flask.
- 13.1.6 Fill the volume with DI water.
- 13.1.7 Place a stopper on the bottle.
- 13.1.8 Mix the solution thoroughly by shaking the volumetric flask.
- 13.1.9 5.0 mL Aliquot of this created solution will be used for determination of Magnesium weight percent ($\text{Mg}\%$). This is the sample used for the auto-titrator.

Note:

A 50.0 mL aliquot of this diluted solution will be used for determination of Sulfate (SO_4) weight percent.

Make sure that the burette does not contain air bubbles and is operating properly the first thing every shift.

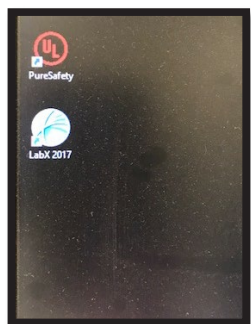
13.2 Running the Auto-Titrator:

- 13.2.1 Verify that all auto-titrator solutions are full.
 - Fill the bottles with the appropriate solution.
 - Run a 150 mL beaker full of 50 mL water in the first position on the rondo to purge the lines.
- 13.2.2 *For the first run of the shift:* Pipette 5.0 mL aliquot of 1,000 ppm standard magnesium solution into a 150 mL glass beaker; load the beaker into Position 1 on the auto-sampler tray of auto-titrator.
 - a) *For the first run of the shift:* Pipette 5.0 mL aliquot of 6% ppm standard magnesium solution into a 150 mL glass beaker; load this beaker as the last sample of the run.
 - b) Place the samples on the rondo.

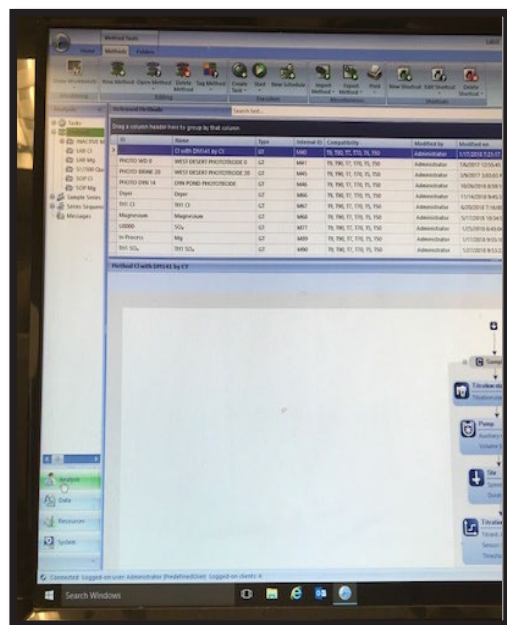
1511.05 Determination of Magnesium (Mg^{2+}) Concentration in Brine Materials in the Main Lab

13.3 Preparing the auto- titrator:

13.3.1 Turn on Lab X:

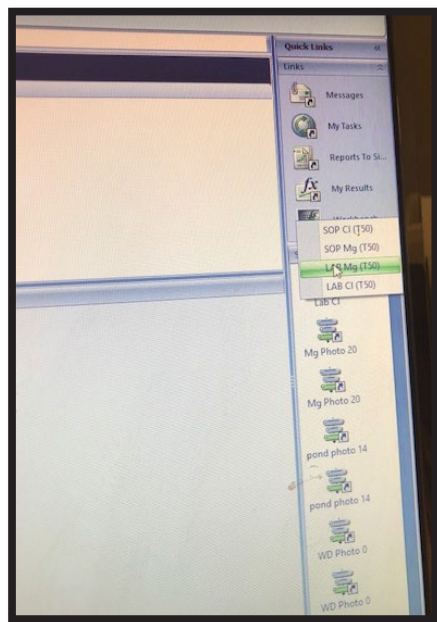


13.3.2 Open the software:

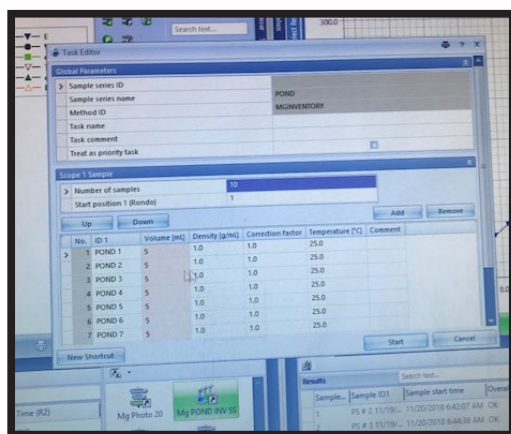


13.3.3 Select the correct program:

1511.05 Determination of Magnesium (Mg^{2+}) Concentration in Brine Materials in the Main Lab



13.3.4 Select the proper number of samples for your run:



13.3.5 Take the Mg ISE electrode out from the storage tube, rinse with DI water and insert to the titration head.

- If you need to change the conditioning beaker with fresh DI water, soak the Mg electrode in the conditioning beaker for 20 minutes prior to use.
- Verify that the solutions are being pumped in and the stirrer is moving and the curve is starting out well.

13.4 Manual Titration (For Back up Only)

- For the second sample:* Pipette 5.0 mL aliquot of 1,000 ppm standard magnesium solution into a 250 mL glass beaker.
- For the first sample:* Pipette 25.0 mL aliquot of QC standard magnesium solution into a 250 mL glass beaker.
- Dilute each sample to 100mL with de-ionized water.
- Add 10mL of Calmagite and pH10 buffer solution mix to each sample.
- Add stir bar to each sample.
- Allow each sample to mix for at least a minute.
- Titrate each sample with EDTA to the end point. The endpoint will be the first appearance of blue. See Figure 1.

13.4.2 Record each volume on the “**Mg Brine Shipments**” Log.

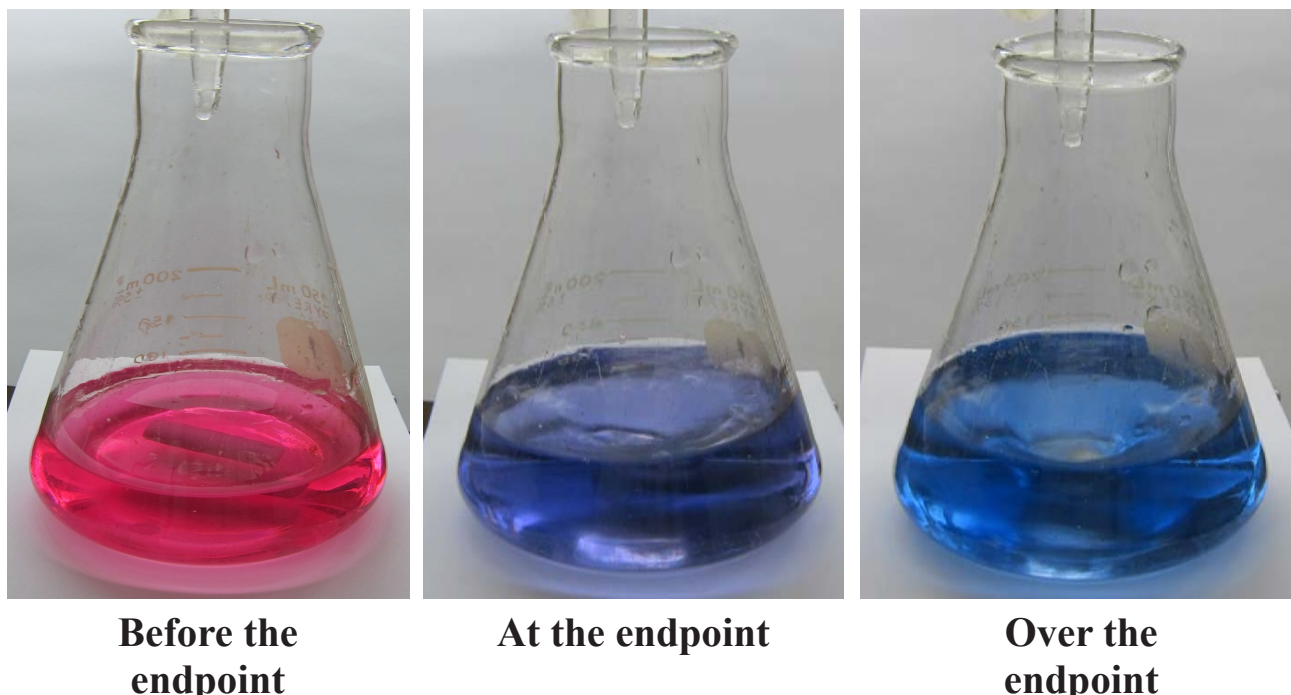


Figure 1. Left flask: A red color before the titration endpoint; **Center flask:** A dark purple color at the endpoint; **Right flask:** A deep blue color past the endpoint.

14. Calculations:

14.1 The EDTA standard factor is calculated according to the following equation:

$$14.1.1 \text{ EDTA Standard Factor} = 25 / V_{\text{MgSTD}}$$

**Printed policies and procedures are only valid at the time of printing.
Please refer to the electronic version for current policies and procedures.**

- 14.2 The Magnesium content of the Quality sample and Magnesium Standard is calculated according to the following equations:

14.2.1 $5 \frac{ml \text{ for Mag QC}}{ml \text{ for Mg Standard}} = 6.00$ 6.00 +/- 0.08 is within range.

14.2.2 1,000 ppm standard

a) $Mg \text{ (ppm)} = (\text{Titration Volume} \times \text{EDTA Standard Factor} \times 1000) / 3.0$

15. Data Assessment and Acceptance for Out of Control Data:

- 15.1 Once the initial run is complete, the results are accurately entered in to the proper data base and data tabs.
- 15.2 Upon data entry, the results are analyzed and the data base will indicate if the sample passes or fails the accepted criteria.
- 15.3 If the sample passes, report the results to the appropriate departments via email.
- 15.4 If the sample fails, verify that the data entered was entered properly and correctly, then repeat the testing from the diluted sample.
- 15.4.1 If this passes, record these results in the data base.
- a) Report the results to the appropriate departments via email.
- 15.4.2 If the second test sample fails, re-prepare from the original sample and repeat the test one more time.
- a) If this sample passes or fails, report the results to the appropriate departments via email and quality management.
- b) Call the Mag Plant immediately and request another sample upon the failure of the third retest.
- c) Test new sample as soon as possible.
- 15.4.3 Report all data to quality management regardless of pass or failure status.

16. Waste Management:

- 16.1 All samples are to be disposed of down the drain.

- 16.2 All samples that have been used to identify chlorides as well as magnesium need to be disposed of in the titration waste barrels.

17. References:

- 17.1 *1530.xx Chemical Hygiene Plan*
 17.2 *5023.xx Ponds Inventory Procedure*
 17.3 *4111.xx MAG Plant Sampling Requirements*
 17.4 Auto Titrator Operations manual

18. Tables:

- 18.1 There are currently no tables necessary for this procedure.

19. Audit:


- 19.1 Quality Management or a designee will audit this policy as needed for compliance and accuracy.
 19.2 Operators are able to perform the tasks in this policy as they are outlined within this document.
 19.2.1 This policy is in compliance with other approved site policies.
 19.3 When revisions are necessary, ensure all MOC practices, policies, and procedures are followed.

20. Training:

- 20.1 All Lab employees will be required to review this policy as part of their training.
 20.1.1 Refresher training will be made available as needed.

Revision History

Revision Number	Date of Revision	Author	Changed Section(s)
01	08/21/2015	Patricia Covington	Original Creation
02	07/14/2016	Patricia Covington	Changed the incorrect layout for the rondo, Manual titration and added QC Sample data.
03	09/21/2016	Patricia Covington	Changed number from 1530 to 1511. Mistake in numbering
04	12/21/2018	Patricia Covington	Updated LAB X usage
05	03/01/2019	Patricia Covington	Removed Quality Manager

		Chloride Determination in the Main Lab	Ogden Site	
Revision Date:	8/6/19	1506	Expiration Date:	8/22
Document Owner:		Quality Department		

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1. **Applicable Matrix:**

- 1.1 This procedure is for all samples collected at process steps where chloride determination will aid production.

2. **Detection Limit:**

Detection limit is >0.02% Cl⁻.

3. **Scope and Application:**

This procedure details the necessary sample prep and procedures for both potentiometric and colorimetric titration analysis of chloride levels for both samples in the process matrix as well as final and pure products.

4. Summary:

- 4.1 Liquid and solid samples are collected from several process stages.
- 4.2 Samples are weighed and dissolved (as necessary).
- 4.3 The titration is carried out either manually (colorimetric) or by auto titration (potentiometric).
- 4.4 Data is recorded in the appropriate log.

5. Definitions:

- 5.1 Potentiometric titration: A titration one where variations in a solution's conductivity are detected (in this case through an ion selective electrode) and the endpoint is determined through a dramatic shift in electric potential.
- 5.2 Colorimetric titration: A titration determined by the color change of a matrix sensitive dye which is added to the solution
- 5.3 Aliquot: An amount drawn out in a pipette
- 5.4 Titrant: The solution used to analyze the sample.

6. Interferences:

- 6.1 There are no common interferences for this procedure.

7. Safety:

- 7.1 Silver is an irritant. Protective clothing should be worn and care should be taken to avoid skin exposure or ingestion.
- 7.2 Chromium (used in the colorimetric titration) is a carcinogen, genetic mutagen, and a strong oxidizer as well as a heavy metal toxin. Protective clothing including chemical resistant gloves should be worn and care should be taken to avoid exposure.
- 7.3 Nitric acid (used in the colorimetric titration) is a strong oxidizer, very corrosive, and can cause immediate severe damage to skin and internal organs. Protective clothing including chemical resistant gloves should be worn and care should be taken to avoid exposure to spills and or vapors.

8. Equipment and Supplies:

- 8.1 Protective Gloves
- 8.2 Safety Glasses
- 8.3 Mettler Toledo model T50 Autotitrator
- 8.4 50 ml Burette
- 8.5 100-250 ml beakers
- 8.6 Stir bars and stir plate
- 8.7 Scale with accuracy to nearest 0.01 g
- 8.8 Weigh boats

9. Reagents and Standards:

- 9.1 5% Potassium Chromate solution (5g/100mL de-ionized water)
- 9.2 1:4 Nitric Acid solution (1 part acid to 4 parts de-ionized water)
- 9.3 0.1% Methyl Red indicator solution (0.1g/100mL de-ionized water)
- 9.4 Saturated Sodium Bicarbonate solution (excess sodium bicarbonate in de-ionized water)
- 9.5 0.1M Silver Nitrate solution (17g/L in de-ionized water)
- 9.6 0.1M Sodium Chloride standard solution (5.845g/L in de-ionized water)
- 9.7 0.05M Sodium Chloride standard solution (2.423g/L in de-ionized water) – may be prepared by 50/50 dilution of 0.1M Sodium Chloride standard.

10. Sample Collection:

- 10.1 Collection will be done by Operations personnel.

11. Quality Control:

- 11.1 It is the policy of the Ogden Quality Manager and Site management to be concerned with product quality and to ensure that accurate chemical characteristics are determined, identified, and recorded.
- 11.2 It is the responsibility of the lab technicians to perform this procedure properly, to maintain the equipment and instruments used to determine potassium and sodium content, and to record and maintain test results in a common log book and computer database.
- 11.3 It is the responsibility of the lab personnel to notify the Quality Manager of instrument problems that may require maintenance beyond the replacement parts in the warehouse. If a work order or purchase order is required to maintain the instrument, it would be the responsibility of the Quality Manager to approve such orders.
- 11.4 The 0.05M Sodium Chloride standard solution will be used for quality control.
- 11.5 A 25mL aliquot of the standard solution should be analyzed according to the procedure in section 14 once per shift.

12. Calibration and Standards:

- 12.1 The 0.1M Sodium Chloride standard is used for calibration of the Silver Chloride titrant.
- 12.2 A 25mL aliquot of the standard solution should be analyzed according to the procedure in section 13 every time a new titrant solution is made.

13. Procedure:

- 13.1 Samples should be measured out into a beaker or Erlenmeyer flask the appropriate range for the sample type as follows:
 - 13.1.1 For Liquid samples in the main lab: 5.0mL
 - 13.1.2 For Solid samples in the main lab: 10.00g

- 13.1.3 For in-process dryer and compaction samples: 8.00-9.00g
- 13.1.4 For in-process feed and thickener samples: 0.15-0.30g
- 13.1.5 For process water samples: 15.00-20.00g
- 13.2 A stir bar and about 75mL of de-ionized water should then be added.
- 13.3 Place the beaker on the stir plate under the titrant buret and begin stirring the solution.
- 13.4 If using the Autotitrator initialize the instrument and continue with 14.9.
- 13.5 Add 3 drops of the Methyl Red indicator solution.
- 13.6 Add 3 drops of the Nitric Acid solution.
- 13.7 Add one squirt of saturated Sodium Bicarbonate.
- 13.8 Add one squirt of the Potassium Chromate solution.
- 13.9 Titrate with the Silver Nitrate solution until the first permanent (longer than 30 sec) appearance of a red-orange color. Avoid over titration if continuing with magnesium titration using the same solution.
- 13.10 The titration value should be read at the bottom of the meniscus and recorded in the appropriate log.

14. Calculations:

- 14.1 In-process sample calculations are performed by software on the control computers.
- 14.2 The calibration factor is determined by the equation: $\text{factor} \equiv 25 \div \text{ml of titrant}$
- 14.3 The factor should be recorded in the appropriate log book and data system as well as fixed to the container of titrant.
- 14.4 If software is not working the following calculation may be used:
- 14.5 $(\text{Titrant vol} \times \text{factor} \times \text{dilution volume}) \div (10 \times \text{weight or aliquot volume})$

15. Data Assessment and Acceptance for Out of Control Data:

- 15.1 Data should be accepted if any of the following conditions are met:
- 15.2 The data is near the then normal range for the sample type.
- 15.3 The Operations crew is aware of or creating conditions which would cause significant variation from the then normal range for the sample type.
- 15.4 The Quality Control sample was also run and it came out normal.

16. Waste Management:

- 16.1 Waste from this determination must be disposed of in the titration waste barrel.

17. References:

- 17.1 There are currently no references.

18. Tables:

- 18.1 There are currently no applicable tables or charts.

19. Audit:


- 19.1 The Quality manager or a designee will audit this procedure as needed for compliance and accuracy.
- 19.1.1 Operators are able to perform the tasks in this procedure as they are outlined within this document.
- 19.1.2 This procedure is in compliance with other approved site policies.
- 19.2 When revisions are necessary, ensure all MOC practices, policies, and procedures are followed.

20. Training:

- 20.1 The lab tech training and certification program requires recertification annually or as needed if the process and/or expectations change.
- 20.1.1 Refresher training will be made available as needed.

Revision History

Revision #	Revision Date	Author	Change(s) Made
1506.00	7/16/2014	Nathan Averill	Original Creation
1506.01	11/6/2015	Wade Okelberry	
1506.02	8/6/2019	Nick Coffin	Updated to current format

		Determination of Sulfate SO ₄ ²⁻ in the Main Lab	Ogden Site	
Effective Date:	12/22/2016	1518.06	Review Date:	03/21/2019
Document Owner:	Quality Manager		Next Review Date:	03/21/2021

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1. Applicable Matrix:

- 1.1 This procedure applies to samples in the Main Lab.
 - 1.1.1 Ponds and Harvest samples.
 - 1.1.2 Mag Chloride Plant samples.
 - 1.1.3 Shipment Samples
 - 1.1.4 Salt Samples
- 1.2 Additional samples requested by engineering may need to be run as well. Changes in procedure need to be discussed with the Quality Management, Shift Supervisor and Board Operator.

2. Detection Limits:

- 2.1 $\text{SO}_4^{2-} = 0.2$ to 100.0 %
 - 2.1.1 However, a titrant volume greater than or equal to 2.5 mL as well as a good curve on the graph helps to determine an accurate reading of the SO_4^{2-} concentration.

3. Scope and Application:

- 3.1 This procedure will involve test methods for Sulfate determination by colorimetric titration.

4. Summary:

- 4.1 By titration
 - 4.1.1 Samples are weighed out.
 - 4.1.2 Sample is dissolved in water.
 - 4.1.3 Solutions are added.
 - 4.1.4 Mixture is allowed to blend.
 - 4.1.5 Mixture is to be titrated.

5. Definitions:

Brine: Liquid portion of the evaporation ponds. This liquid can be manipulated by concentration to drop mineral content under certain conditions.

6. Interferences:

- 6.1 Contamination with other compounds.
- 6.2 Un-trained operators to what the endpoint is.
- 6.3 Dirty glassware.
- 6.4 Other suspended particles.
- 6.5 Ion strength increases solubility of sulfate.

7. Safety:

- 7.1 Responsibility for lab safety belongs to every lab employee, and everyone should adhere to the policies and guidelines set forth in policy *1530.xx, Chemical Hygiene Plan*.

- 7.2 Overall, when handling acids, bases and chemical indicators, wear latex or nitrile gloves which should provide adequate protection from minor exposures. Wear safety glasses to protect eyes from splashing chemicals during preparation and titration.
- 7.3 No Food or Drink is allowed in the titration areas.
- 7.4 Read the safety data sheets for Perchloric Acid and Barium Chloride.

8. Equipment and Supplies:

- 8.1 Safety glasses
- 8.2 Latex or nitrile Gloves
- 8.3 Sulfa ver packets
- 8.4 Balance: Balance should be kept accurate and readable to 0.01 g. All weighing shall be recorded to the nearest reading.
- 8.5 Burette: Burette should be kept clean and readable to 0.10 mL.
- 8.6 Stir Plate: Device should be capable of stirring water and Brine solution in a mixing vessel.
- 8.7 Beakers
- 8.8 Barium Chloride
- 8.9 Volumetric Flasks
- 8.10 Stir bars
- 8.11 Methanol
- 8.12 Perchloric acid
- 8.13 Alizarin red
- 8.14 Pipette
- 8.15 Waste container
- 8.16 ISE Probe



9. Reagents and Standards:

- 9.1 Use commercially manufactured reagents first.
- 9.2 All reagent chemicals can be located in various chemical storage locations in the main lab.
- 9.3 All reagents and standards are made in large amounts. Only prepare the following when you are close to running out or out.
- 9.4 Make reagents in fume hoods.
- 9.5 Dilute to proper volume indicated.
- 9.6 All solutions are to be dissolved in de-ionized water unless otherwise stated.
- 9.7 Reagents:

**Printed policies and procedures are only valid at the time of printing.
Please refer to the electronic version for current policies and procedures.**

- 9.7.1 De-ionized Water
- 9.7.2 0.2% Alizarin Red S Solution
 - a) Dissolve 2.00 grams of Alazarin Red S in a 1 Liter volumetric flask.
- 9.7.3 0.1 M Perchloric Acid Solution
 - a) Mix 11 mL of 60% Perchloric acid into a 1 Liter volumetric flask.
- 9.7.4 Methanol
 - a) Use the ACS grade methanol.
- 9.7.5 0.1 M Barium Chloride (BaCl_2) Titrant Solution
 - a) Place 432 grams Barium Chloride Crystalline form in a 20 L container then adding 18 L de-ionized water while stirring until all of the solids have dissolved into all of the liquid. Then add 1.0 mL of 60% Perchloric acid solution to the container.
- 9.7.6 10 mg/mL Ammonium Sulfate Standard
 - a) Dissolve 27.51 grams of Ammonium Sulfate into a 2 Liter volumetric flask.
 - b) This is a reagent as well as a standard.

9.8 Standards:

- 9.8.1 10 mg/mL Ammonium Sulfate Standard
 - a) Dissolve 27.51 grams of Ammonium Sulfate into a 2 Liter volumetric flask.

10. Sample Collection, Preservation and Storage:

- 10.1 The samples shall be obtained for testing in accordance with the appropriate sampling procedure in effect. For SOP reference 3609.xx Control Board Sample Procedure, for Mag Plant, reference 4111.xx MAG Plant Sampling Requirements Procedure; and for Salt, reference 2182.xx Salt Process Operator Normal Rounds Procedure.
- 10.2 Most samples are collected in closed containers, or they have been recently collected.

11. Quality Control:

- 11.1 It is the policy of the quality and site management to be concerned with product quality and to ensure that accurate chemical characteristics are determined, identified, and recorded.

- 11.2 It is the responsibility of the lab technicians to perform this procedure properly, to maintain the equipment and instruments used to determine sulfate content, and to record and maintain test results in a common paperwork and computer database.
- 11.3 It is the responsibility of the lab personnel to notify the quality management of instrument problems that may require maintenance beyond the replacement parts in the warehouse.
- 11.4 A pre-determined quality control sample is analyzed to verify the lab analyst can detect the end point properly. In this procedure it is the 10 mg/mL sulfate standard solution.

12. Calibration and Standards:

12.1 Standards:

12.1.1 Barium Chloride Titrant Solution Standardization

- a) Replace the empty titrant source and fill the lines with the new titrant to be standardized.
- b) Pipette 25.0 mL aliquot of 10 mg/mL Ammonium Sulfate Standard into a 250 mL glass beaker containing a magnetic stirring bar.
- c) Follow the titration procedure listed below.
- d) Record the consuming titrant volume as V SO₄ STD with “mL” as the unit.
- e) BaCl₂ Standard Factor shall be used to describe “milligrams of sulfate per mL of BaCl₂”.
- f) The BaCl₂ standard factor is calculated according to the following equation:
 - 1. BaCl₂ Standard Factor = 250 / V SO₄ STD
 - 2. Label container with the calculated factor.
 - 3. Never mix standardized lots.

12.1.2 Standard Sulfate Solution

- a) Commercially made at 10 mg/mL.

13. Procedure:

13.1 There are four options for testing:

- 13.1.1 *Ponds and Harvest*
- 13.1.2 *Mag Brine*
- 13.1.3 *Salt*

- a) Uses a turbidimeter

13.1.4 *Shipments*

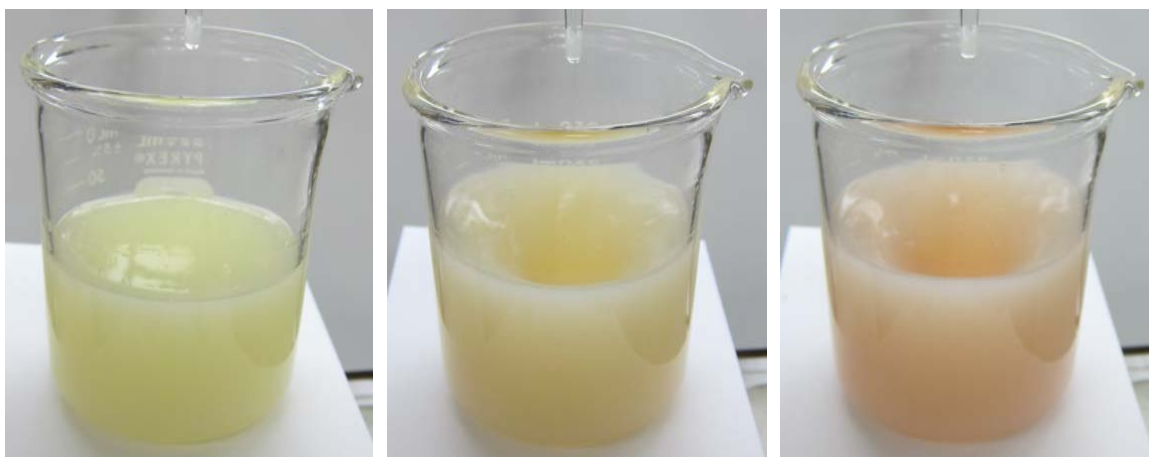
13.2 Sample Preparation for ***Ponds and Harvest***:

- 13.2.1 Place clean, dry funnels into clean, dry labeled 500 mL volumetric flasks.
- 13.2.2 Record weight of the tared jar on the Mg brine shipment form.
- 13.2.3 Rinse the jar and the funnel several times being careful to not over fill the volumetric flask.
- 13.2.4 Fill the volumetric flask to the marker.
- 13.2.5 Stopper the volumetric and invert it several times to mix the sample.
- 13.2.6 Pipette 20.0 mL aliquot of brine sample solution into a 250 mL beaker containing a magnetic stirring bar.
- 13.2.7 Add 20 mL of methanol to the beaker.
- 13.2.8 Add 5 drops of 0.1 M Perchloric Acid.
- 13.2.9 Add 5 drops Alizarin Red S.
- 13.2.10 Add 10.0 mL of 10 mg/mL Ammonium Sulfate Standard to each sample solution.
- 13.2.11 Allow the solution to mix.
- 13.2.12 Titrate the resulted solution with 0.1 M Barium Chloride titrant solution to the endpoint. The endpoint will be the first appearance of permanent pink which must persist for 60 seconds. (See Figure 1)
- 13.2.13 Record the Titrant Volume as T/RSO₄ with mL as the unit on the “Mg Brine Shipments” Form.

13.3 Sample Preparation for ***Mag Brine***:

- 13.3.1 Tare a dry and clean 8 ounce cup on the balance.
- 13.3.2 Pour between 35.00 g to 40.00 g of the Brine sample into the cup or 10 g of a solid and weigh to the nearest 0.01 g.
- 13.3.3 Record the weight of Brine sample as “**Weight**” in grams on “**Mg Brine Shipments**” form.
- 13.3.4 Place a funnel into a clean dry 500 mL volumetric flask.
- 13.3.5 Rinse the same cup into funnel several times so it falls into the flask.
- 13.3.6 Fill the volume with DI water.
- 13.3.7 Pipette a 20 mL sample.

- 13.3.8 Add stir bar.
- 13.3.9 Add 20 mL of Methanol.
- 13.3.10 Add a squirt of 0.2 % Alizarin Red S.
- 13.3.11 Enough to see the color change, but not too much to alter the color.
- 13.3.12 Add 10 drops of 0.1 M Perchloric Acid Solution.
- 13.3.13 Allow to mix.
- 13.3.14 Titrate with BaCl₂ to endpoint. (See Figure 1)
- 13.3.15 Record volume of titrant used on the form.



**Before the
endpoint**

**At the
endpoint**

**Past the
endpoint**

Figure 1. Left: A pale-yellow color before the titration endpoint. Center: A pink color at the endpoint. Right: A dark-pink color past the endpoint.

- 13.4 Sample Preparation for Turbidimeter: Turn on the turbidimeter prior to running any analysis.
 - 13.4.1 Sulfate Standard Curve
 - a) Obtain Sulfate Solution Standards. These Standards will contain 5.0% NaCl.
 - b) Place 25 mL of each Standard solution in their own beaker with a stir bar in it.
 - c) Add one pillow of Sulfa Ver 4 Powder Pillows in to each solution.
 - d) Gently stir each solution until dissolved.

- e) Rinse a clean dry cuvette for each solution with a small portion of each standard solution. Repeat again for each solution.
 - f) Pour each sample into its cuvette.
 - g) Rinse and dry the outside of the cuvette.
 - h) Place the cuvette into the turbidimeter.
 - i) Read the turbidity value and record it for each standard.
 - j) Run a linear regression on the concentrations (ppm) and the readings from the standards.
 - The reading is the X axis.
 - The concentration (ppm) is the Y axis.
 - k) Calculate the slope and the Y-intercept of the regression.
 - l) Use the slope, the Y-intercept and the NTU reading from a sample to determine the % sulfate in the sample.
- 13.4.2 Brine SO₄ Concentration
- a) Obtain 100 grams of a properly blended sample.
 - b) Place 25 to 50 grams in a clean dry 500 mL volumetric flask. Record the weight.
 - c) Add de-ionized water to the mark.
 - d) Mix the solution with a stir bar.
 - e) Place 25 mL of the solution in a beaker.
 - f) Add one pillow of Sulfa Ver 4 Powder Pillows in to the solution.
 - g) Gently stir solution until the powder is dissolved.
 - h) Rinse a clean dry cuvette for each solution with a small portion of each standard solution. Repeat again for each solution.
 - i) Pour each sample into its cuvette.
 - j) Rinse and dry the outside of the cuvette.
 - k) Place the cuvette into the turbidimeter.
 - l) Record the NTU value and record the reading.

Note: If the sample is suspected to be a high level then decrease the sample weight to 5 grams of a properly blended sample. And repeat the steps accordingly.

13.4.3 Salt SO_4 Concentration

- a) Obtain about 50 grams of a properly blended representative sample.
- b) Tare a clean dry 500 mL volumetric flask.
- c) Add 25 mg of the sample to the flask.
- d) Add De-ionized water to the mark.
- e) Mix the solution with a stir bar.
- f) Place 25 mL of the solution in a beaker.
- g) Add one pillow of Sulfa Ver 4 Powder Pillows in to the solution.
- h) Gently stir solution until the powder is dissolved.
- i) Rinse a clean dry cuvette for each solution with a small portion of each standard solution. Repeat again for each solution.
- j) Pour each sample into its cuvette.
- k) Rinse and dry the outside of the cuvette.
- l) Place the cuvette into the turbidimeter.
- m) Record the NTU value and record the reading.

13.4.4 Water SO_4 Concentration

- a) Obtain 100 g of a representative sample.
- b) Place 25 mL of the water into a beaker.
- c) Add one pillow of Sulfa Ver 4 Powder Pillows in to the solution.
- d) Gently stir solution until the powder is dissolved.
- e) Rinse a clean dry cuvette for each solution with a small portion of each standard solution. Repeat again for each solution.
- f) Pour each sample into its cuvette.
- g) Rinse and dry the outside of the cuvette.
- h) Place the cuvette into the turbidimeter.
- i) Record the NTU value and record the reading.

13.5 For Shipment Samples:

- 13.5.1 The concentration is calculated from the results of the XRF analysis and exported.

14. Calculations:

14.1 Titration Method

$$\% \text{SO}_4^{2-} = \frac{A * B}{C * 10}$$

Where

A= Titration Volume

B = Factor mL SO_4^{2-} / mL BaCl_2

C = Sample weight in grams

15. Data Assessment and Acceptance for Quality Control:

- 15.1 Alert the quality management of the failed result.
- 15.2 Sample data that does not come into the acceptance criteria should be repeated.
- 15.3 If the sample has been repeated and the results are similar then the standards will need to be tested. If there is a problem with the standards replace with new ones and repeat both standards and sample.

16. Waste Management and Disposal:

- 16.1 All SOP samples are to be disposed of in the toxic drains that collect into titration waste barrels.

17. References:

- 17.1 Auto Titrator Operations manual
- 17.2 *3609.xx Control Board Sample Procedure.*
- 17.3 *1530.xx Chemical Hygiene Policy*

18. Tables:

- 18.1 There are no Tables necessary for this procedure.

19. Audit:

- 19.1 Quality management or a designee will audit this procedure as needed for compliance and accuracy.
- 19.1.1 Operators are able to perform the tasks in this procedure as they are outlined within this document.
- 19.1.2 This procedure is in compliance with other approved site policies.
- 19.2 When revisions are necessary, ensure all MOC practices, policies, and procedures are followed.

**Printed policies and procedures are only valid at the time of printing.
Please refer to the electronic version for current policies and procedures.**

20. Training:

20.1 The lab technician training and certification program requires recertification annually or as needed if the process and/or expectations change.

20.1.1 Refresher training will be made available as needed.

Revision History

Revision Number	Date of Revision	Author	Changed Section(s)
01	07/2014	Dr. Yuan Chu/ Patricia Covington	Added turbidimeter sections
02	12/21/15	Patricia Covington	Eliminated correction and turbidimeter sections
03	1/14/16	Patricia Covington	Added audit and training sections added quality control sample as well
04	12/23/16	Patricia Covington	Added methanol manipulation to 1:1 on most samples
05	12/14/2018	Patricia Covington	Removed auto titrator and five ion references due to MOC 1875
06	03/21/2019	Patricia Covington	Removed quality manager

Attachment F

**Results and Comparisons for Water Sample
from North Arm, Great Salt Lake**

Summary for North Arm (Gunnison Bay), Great Salt Lake

Great Salt Lake Salinity Methods Round Robin, 2020

Great Salt Lake Salinity Advisory Committee

Lab No.	Laboratory	Method	Reported Laboratory Results				Calculated TDS ¹ (g/L)	% Salinity	
			Density (g/cm ³)	TDS (g/L)	EC (umhos/cm)	Temperature (°C)		Measured	Converted from Lab TDS [TDS/10] Calculated from Lab TDS/ Lab density
1a	UGS: AWAL	Density: Anton Paar DMA 35 TDS: SM2540c	1.211	286		22.2		28.6	23.6
1b	UGS: AWAL	Density: Anton Paar DMA 35 TDS: Sum of Ions	1.211	321		22.2		32.1	26.5
1c	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: SM2540c	1.211	329		22.2		32.9	27.2
1d	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: Sum of Ions	1.211	312		22.2		31.2	25.8
2	North Davis Sewer District	TDS: EPA 160.1 EC: EPA 102.1 [1982]		258	200000	23.5		25.8	
3a	HDR	Density: Hydrometer	1.215			21.5			
3b	HDR	Density: Anton Paar DMA 35	1.2117			21.5			
4	US Magnesium: Control Lab	Density: Reported TDS: Calc from Sum of Ions	1.212				324	32.4	26.7
5	US Geological Survey	Density: Anton Paar DMA 35	1.213	268		20.0		26.8	22.1
6	Jacobs	% Salinity: Refractometer						26.5	
7	Division of Wildlife Resources	% Salinity: Refractometer						27.6	
8a	GSL Brine Shrimp Cooperative	% Salinity: Refractometer						27.7	
8b	GSL Brine Shrimp Cooperative	TDS: 50° C		388					38.8
8c	GSL Brine Shrimp Cooperative	TDS: 180° C		320					32.0
8d	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556		201	221401	20.2			20.1
8e	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556 (50:50 dilution w/ distilled water)		287	345311	21.4			28.7
9	Compass Minerals	Density: Hydrometer TDS: Calc from Sum of Ions	1.21			20.2	306	30.6	25.3
Average			1.212	297				27.3	30.0
Standard Deviation			0.001	47.189				0.539	4.374
Coefficient of Variation			0.0012	0.1588				0.0198	0.1458

Lab No.	Laboratory	Method	USGS 2000		Baseggio 1974		Naftz et al., 2011 ²		
			Calculated TDS from Lab Density (g/L)	% Salinity (from Calc TDS/ Lab Density)	Calculated TDS from Density (g/L)	% Salinity (from Calc TDS/ Lab Density)	Laboratory Temperature (K)	Calculated Density pure H ₂ O (ρ ₀), in g/cm ³	% Salinity (converted from Calc TDS [TDS /10])
1a	UGS: AWAL	Density: Anton Paar DMA 35 TDS: SM2540c	334.9	27.7	318.3	26.3	295.35	0.998	26.6
1b	UGS: AWAL	Density: Anton Paar DMA 35 TDS: Sum of Ions	334.9	27.7	318.3	26.3	295.35	0.998	26.6
1c	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: SM2540c	334.9	27.7	318.3	26.3	295.35	0.998	26.6
1d	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: Sum of Ions	334.9	27.7	318.3	26.3	295.35	0.998	26.6
2	North Davis Sewer District	TDS: EPA 160.1							
3a	HDR	Density: Hydrometer	341.3	28.1	323.7	26.6	294.65	0.998	27.1
3b	HDR	Density: Anton Paar DMA 35	336.0	27.7	319.3	26.3	294.65	0.998	26.7
4	US Magnesium: Control Lab	Density: Reported TDS: Calc from Sum of Ions	336.5	27.8	319.7	26.4	273.15	1.000	25.6
5	US Geological Survey	Density: Anton Paar DMA 35	338.1	27.9	321.0	26.5	293.15	0.998	26.7
6	Jacobs	% Salinity: Refractometer							
7	Division of Wildlife Resources	% Salinity: Refractometer							
8a	GSL Brine Shrimp Cooperative	% Salinity: Refractometer							
8b	GSL Brine Shrimp Cooperative	TDS: 50° C							
8c	GSL Brine Shrimp Cooperative	TDS: 180° C							
8d	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556 (direct measurement)							
8e	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556 (50:50 dilution w/ distilled water)							
9	Compass Minerals	Density: Hydrometer TDS: Calc from Sum of Ions	333.3	27.5	316.9	26.2	293.35	0.998	26.4
Average			336.1	27.7	319.3	26.4			26.6
Standard Deviation			2.2	0.2	1.9	0.1			0.4
Coefficient of Variation			0.0066	0.0054	0.0059	0.0047			0.0141

Notes:

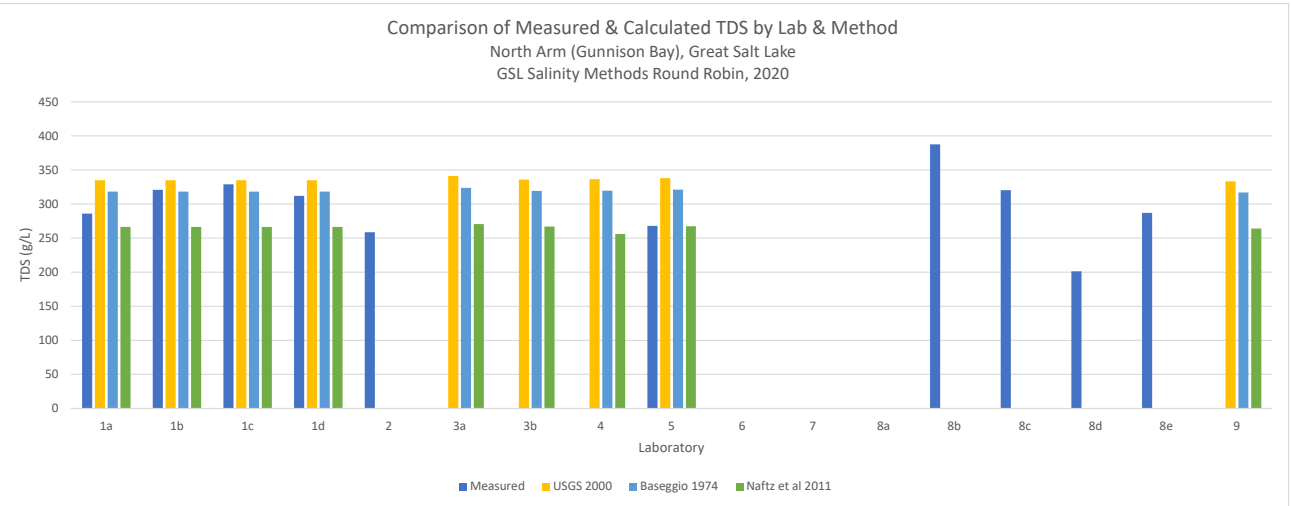
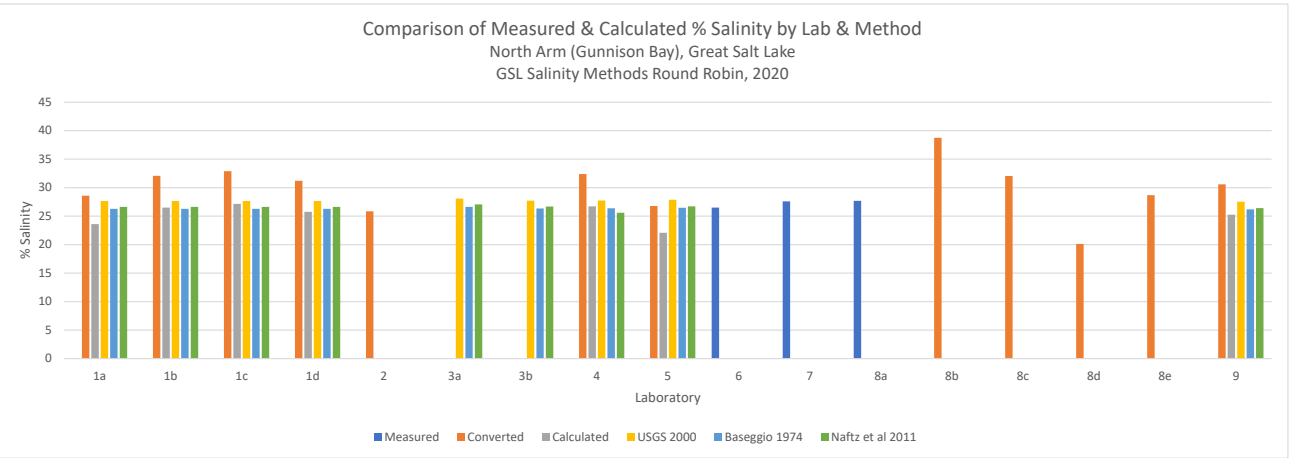
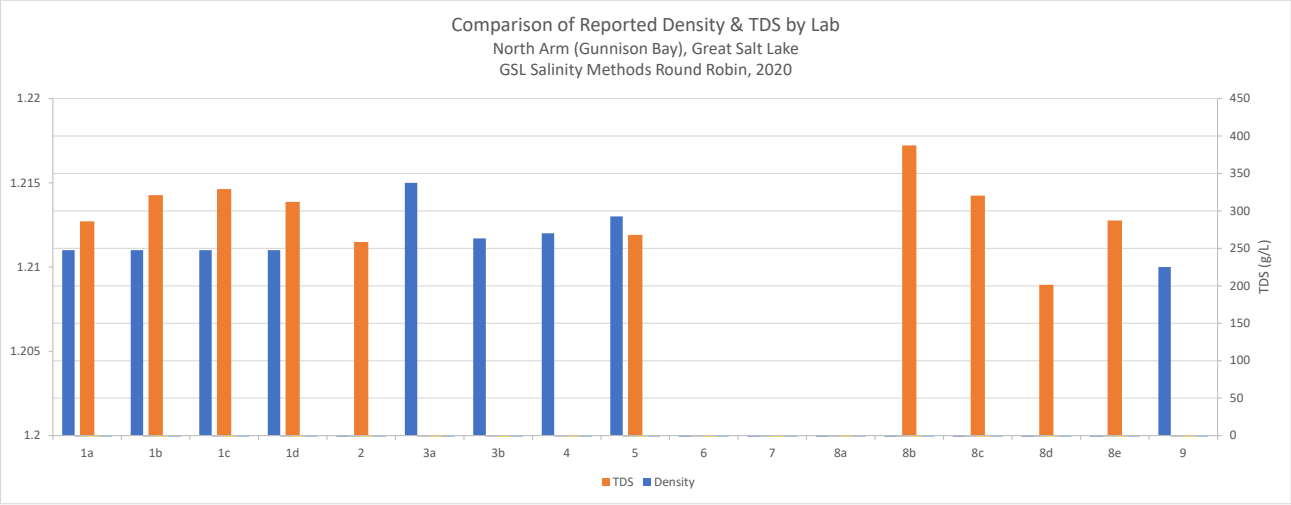
¹ TDS was calculated as a sum of the ions.

² Great Salt Lake Equation of State was developed for conductivity salinities of 23 - 182 g/L. Gunnison Bay and Farmington Bay are typically outside that range.

Designates calculation typically used by the laboratory/agency in reports.

References:

Baseggio, G. 1974. The Composition of Sea Water and Its Concentrates.
Naftz, D., Millero, F., Jones, B., Green, W.. (2011). An Equation of State for Hypersaline Water in Great Salt Lake, Utah, USA. Aquatic Geochemistry. 17. 809-820. 10.1007/s10498-011-9138-z.
United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987-98. Water-Resources Investigation Report 00-4221
United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987-98. Water-Resources Investigations Report 00-4221.



Attachment G

**Results and Comparisons for Water Sample
from South Arm, Great Salt Lake**

Summary for South Arm (Gilbert Bay), Great Salt Lake

Great Salt Lake Salinity Methods Round Robin, 2020

Great Salt Lake Salinity Advisory Committee

Lab No.	Laboratory	Method	Reported Laboratory Results				Calculated TDS ¹ (g/L)	% Salinity	
			Density (g/cm ³)	TDS (g/L)	EC (umhos/cm)	Temperature (°C)		Measured	Converted from Lab TDS [TDS/10] Calculated from Lab TDS/ Lab density
1a	UGS: AWAL	Density: Anton Paar DMA 35 TDS: SM2540c	1.096	153		22.2		15.3	14.0
1b	UGS: AWAL	Density: Anton Paar DMA 35 TDS: Sum of Ions	1.096	147		22.2		14.7	13.4
1c	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: SM2540c	1.096	135		22.2		13.5	12.3
1d	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: Sum of Ions	1.096	137		22.2		13.7	12.5
2	North Davis Sewer District	TDS: EPA 160.1 EC: EPA 102.1 [1982]		126	147600	23.5		12.6	
3a	HDR	Density: Hydrometer	1.100			21.7			
3b	HDR	Density: Anton Paar DMA 35	1.0963			21.7			
4	US Magnesium: Control Lab	Density: Reported	1.100				144	14.4	13.1
5	US Geological Survey	Density: Anton Paar DMA 35	1.097	130		20.0		13	11.9
6	Jacobs	% Salinity: Refractometer						13.2	
7	Division of Wildlife Resources	% Salinity: Refractometer						13.4	
8a	GSL Brine Shrimp Cooperative	% Salinity: Refractometer						13.3	
8b	GSL Brine Shrimp Cooperative	TDS: 50° C		164					16.4
8c	GSL Brine Shrimp Cooperative	TDS: 180° C		142					14.2
8d	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556		128	158553	20.4			12.8
9	Compass Minerals	Density: Hydrometer	1.11			20.2	135	13.5	12.2
		TDS: Calc from Sum of Ions							
Average			1.100	140.261				13.289	14.019
Standard Deviation			0.005	11.718				0.083	1.077
Coefficient of Variation			0.0044	0.0835				0.0063	0.0768

Lab No.	Laboratory	Method	USGS 2000		Baseggio 1974		Naftz et al., 2011 ²		
			Calculated TDS from Lab Density (g/L)	% Salinity (from Calc TDS/ Lab Density)	Calculated TDS from Density (g/L)	% Salinity (from Calc TDS/ Lab Density)	Laboratory Temperature (K)	Calculated Density pure H ₂ O (ρ ₀), in g/cm ³	Calculated TDS from Density (g/L)
1a	UGS: AWAL	Density: Anton Paar DMA 35 TDS: SM2540c	152.4	13.9	137.7	12.6	295.35	0.998	129.7
1b	UGS: AWAL	Density: Anton Paar DMA 35 TDS: Sum of Ions	152.4	13.9	137.7	12.6	295.35	0.998	129.7
1c	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: SM2540c	152.4	13.9	137.7	12.6	295.35	0.998	129.7
1d	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: Sum of Ions	152.4	13.9	137.7	12.6	295.35	0.998	129.7
2	North Davis Sewer District	TDS: EPA 160.1							
3a	HDR	Density: Hydrometer	158.7	14.4	143.8	13.1	294.85	0.998	134.5
3b	HDR	Density: Anton Paar DMA 35	152.9	13.9	138.2	12.6	294.85	0.998	129.9
4	US Magnesium: Control Lab	Density: Reported	158.7	14.4	143.8	13.1	273.15	1.000	126.0
		TDS: Calc from Sum of Ions							
5	US Geological Survey	Density: Anton Paar DMA 35	154.0	14.0	139.2	12.7	293.15	0.998	129.9
6	Jacobs	% Salinity: Refractometer							
7	Division of Wildlife Resources	% Salinity: Refractometer							
8a	GSL Brine Shrimp Cooperative	% Salinity: Refractometer							
8b	GSL Brine Shrimp Cooperative	TDS: 50° C							
8c	GSL Brine Shrimp Cooperative	TDS: 180° C							
8d	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556							
9	Compass Minerals	Density: Hydrometer	174.6	15.7	159.1	14.3	293.35	0.998	146.1
		TDS: Calc from Sum of Ions							
Average			156.5	14.2	141.6	12.9			131.7
Standard Deviation			6.9	0.6	6.6	0.5			5.5
Coefficient of Variation			0.0439	0.0397	0.0467	0.0424			0.0416

Notes:

¹ TDS was calculated as a sum of the ions.

² Great Salt Lake Equation of State was developed for conductivity salinities of 23 - 182 g/L. Gunnison Bay and Farmington Bay are typically outside that range.

Designates calculation typically used by the laboratory/agency in reports.

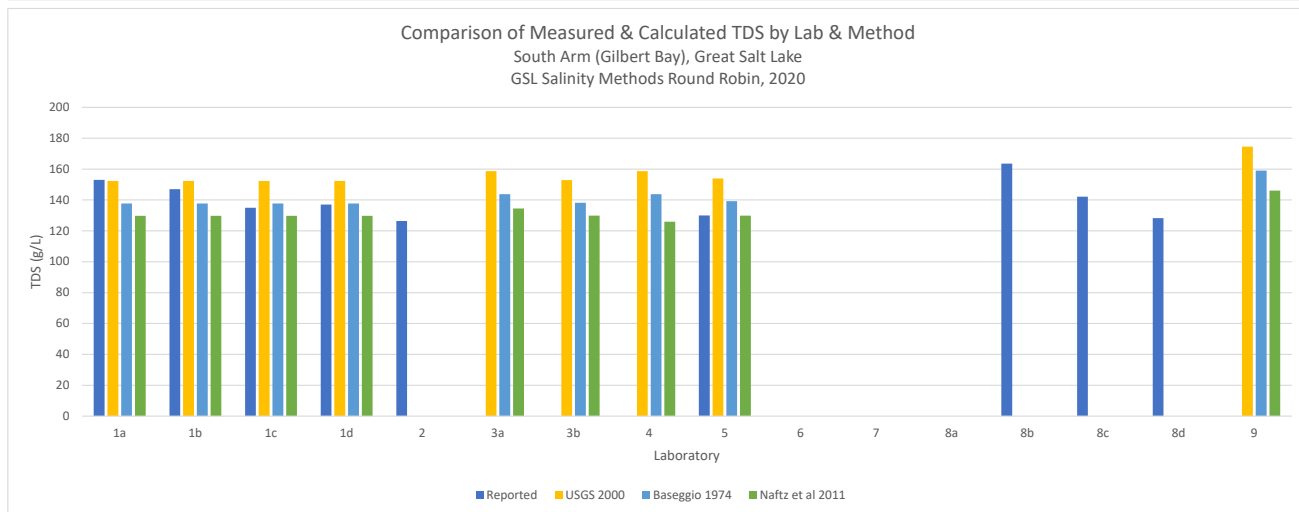
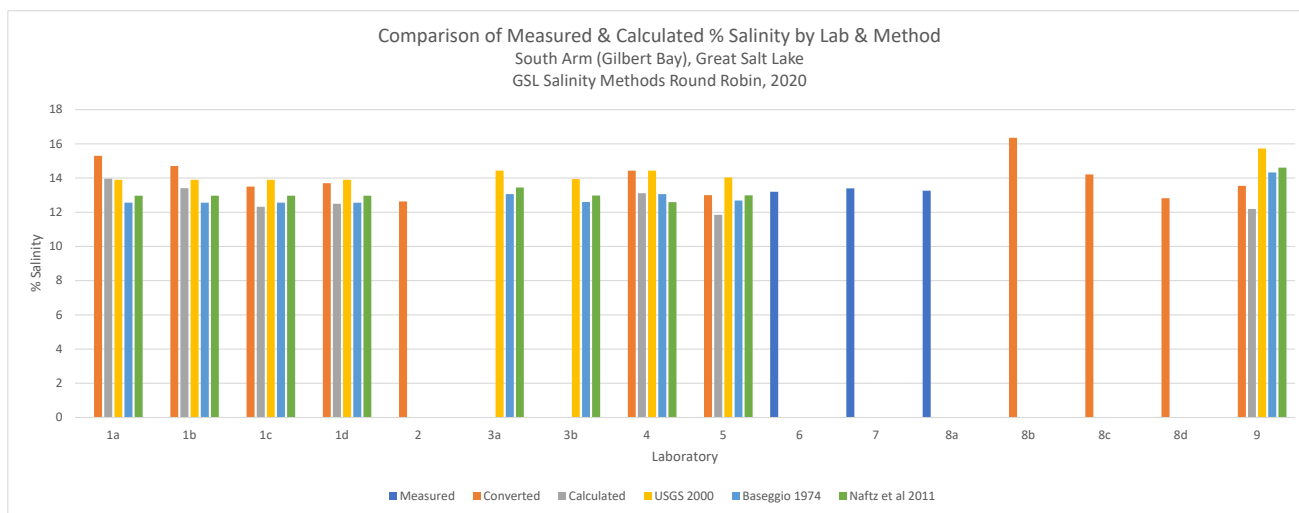
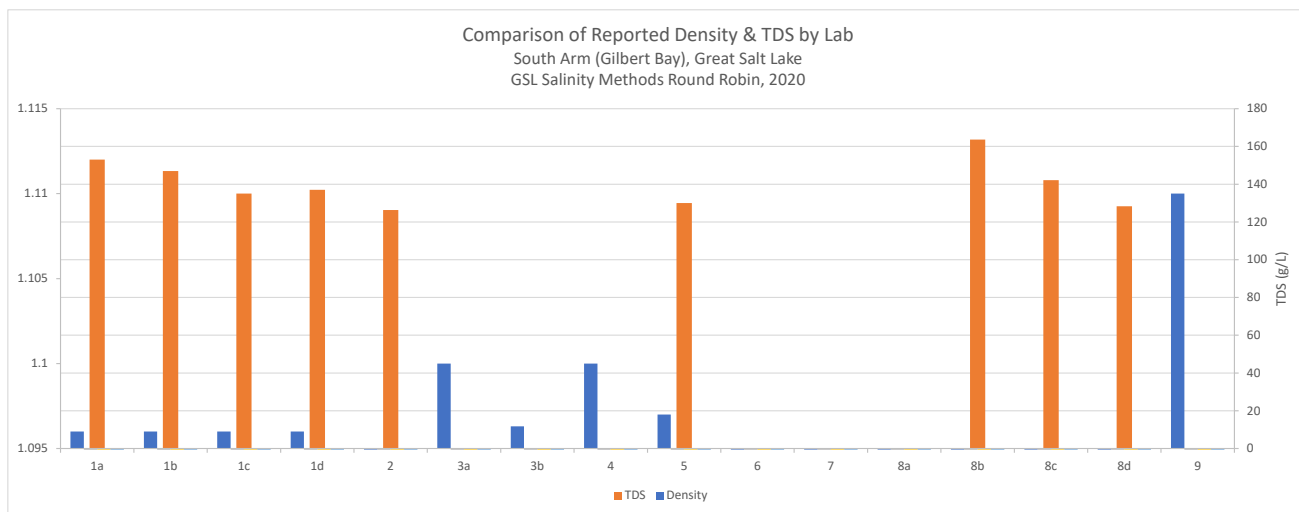
References:

Baseggio, G. 1974. The Composition of Sea Water and Its Concentrates.

Naftz, D., Millero, F., Jones, B., Green, W. (2011). An Equation of State for Hypersaline Water in Great Salt Lake, Utah, USA. Aquatic Geochemistry. 17. 809-820. 10.1007/s10498-011-9138-z.

United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987-98. Water-Resources Investigation Report 00-4221

United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987-98. Water-Resources Investigations Report 00-4221.



Attachment H

**Results and Comparisons for Water Sample
from Farmington Bay, Great Salt Lake**

Summary for Farmington Bay, Great Salt Lake

Great Salt Lake Salinity Methods Round Robin, 2020
Great Salt Lake Salinity Advisory Committee

Lab No. Laboratory Method			Reported Laboratory Results				% Salinity		
			Density (g/cm ³)	TDS (g/L)	EC (umhos/cm)	Temperature (°C)	Calculated TDS ¹ (g/L)	Measured	Converted from Lab TDS [TDS/10] Calculated from Lab TDS/ Lab density
1a	UGS: AWAL	Density: Anton Paar DMA 35 TDS: SM2540c	0.999	2.7		22.2		0.27	0.3
1b	UGS: AWAL	Density: Anton Paar DMA 35 TDS: Sum of Ions	0.999	2.8		22.2		0.28	0.3
1c	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: SM2540c	0.999	2.5		22.2		0.25	0.3
1d	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: Sum of Ions	0.999	2.7		22.2		0.27	0.3
2	North Davis Sewer District	TDS: EPA 160.1 EC: EPA 102.1 [1982]		3.0	5260	23.5		0.3	
3a	HDR	Density: Hydrometer	1.002			21.7			
3b	HDR	Density: Anton Paar DMA 35	1.0004			21.7			
4	US Magnesium: Control Lab	Density: Reported TDS: Calc from Sum of Ions	1.000				4	0.4	0.4
5	US Geological Survey	Density: Anton Paar DMA 35	1.000	2.3		20.0		0.23	0.2
6	Jacobs	% Salinity: Refractometer						0.0	
7	Division of Wildlife Resources	% Salinity: Refractometer						0.4	
8a	GSL Brine Shrimp Cooperative	% Salinity: Refractometer						0.3	
8b	GSL Brine Shrimp Cooperative	TDS: 50° C		3.3				0.33	
8c	GSL Brine Shrimp Cooperative	TDS: 180° C		2.9				0.29	
8d	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556		2.9	5367	20.4		0.29	
9	Compass Minerals	Density: Hydrometer TDS: Calc from Sum of Ions	1.01			20.2	3	0.3	0.3
Average			1.002	2.8				0.2	0.3
Standard Deviation			0.004	0.3				0.2	0.1
Coefficient of Variation			0.0037	0.0976				0.7481	0.2222

Lab No. Laboratory Method			USGS 2000		Baseggio 1974		Naftz et al., 2011 ²		
			Calculated TDS from Lab Density ³ (g/L)	% Salinity (from Calc TDS/ Lab Density) ³	Calculated TDS from Density (g/L) ³	% Salinity (from Calc TDS/ Lab Density) ³	Laboratory Temperature (K)	Calculated Density pure H ₂ O (ρ ₀), in g/cm ³	Calculated TDS from Density (g/L) Calculated from Calc TDS [TDS /10]
1a	UGS: AWAL	Density: Anton Paar DMA 35 TDS: SM2540c	-1.6	-0.2	-1.5	-0.2	295.35	0.998	1.7
1b	UGS: AWAL	Density: Anton Paar DMA 35 TDS: Sum of Ions	-1.6	-0.2	-1.5	-0.2	295.35	0.998	1.7
1c	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: SM2540c	-1.6	-0.2	-1.5	-0.2	295.35	0.998	1.7
1d	UGS: Chemtech-Ford	Density: Anton Paar DMA 35 TDS: Sum of Ions	-1.6	-0.2	-1.5	-0.2	295.35	0.998	1.7
2	North Davis Sewer District	TDS: EPA 160.1							
3a	HDR	Density: Hydrometer	3.2	0.3	3.1	0.3	294.85	0.998	5.7
3b	HDR	Density: Anton Paar DMA 35	0.6	0.1	0.6	0.1	294.85	0.998	3.5
4	US Magnesium: Control Lab	Density: Reported TDS: Calc from Sum of Ions	0.0	0.0	0.0	0.0	273.15	1.000	-2.2
5	US Geological Survey	Density: Anton Paar DMA 35	0.0	0.0	0.0	0.0	293.15	0.998	2.3
6	Jacobs	% Salinity: Refractometer							
7	Division of Wildlife Resources	% Salinity: Refractometer							
8a	GSL Brine Shrimp Cooperative	% Salinity: Refractometer							
8b	GSL Brine Shrimp Cooperative	TDS: 50° C							
8c	GSL Brine Shrimp Cooperative	TDS: 180° C							
8d	GSL Brine Shrimp Cooperative	TDS & Conductivity: YSI 556							
9	Compass Minerals	Density: Hydrometer TDS: Calc from Sum of Ions	15.9	1.6	15.0	1.5	293.35	0.998	16.2
Average			1.5	0.1	1.4	0.1			3.6
Standard Deviation			5.3	0.5	5.0	0.5			4.9
Coefficient of Variation			3.5771	3.5911	3.6090	3.6236			1.3571

Notes:

¹ TDS was calculated as a sum of the ions.

² Great Salt Lake Equation of State was developed for conductivity salinities of 23 - 182 g/L. Gunnison Bay and Farmington Bay are typically outside that range.

³ Negative values for TDS are a result of the density value of < 1.0.

Designates calculation typically used by the laboratory/agency in reports.

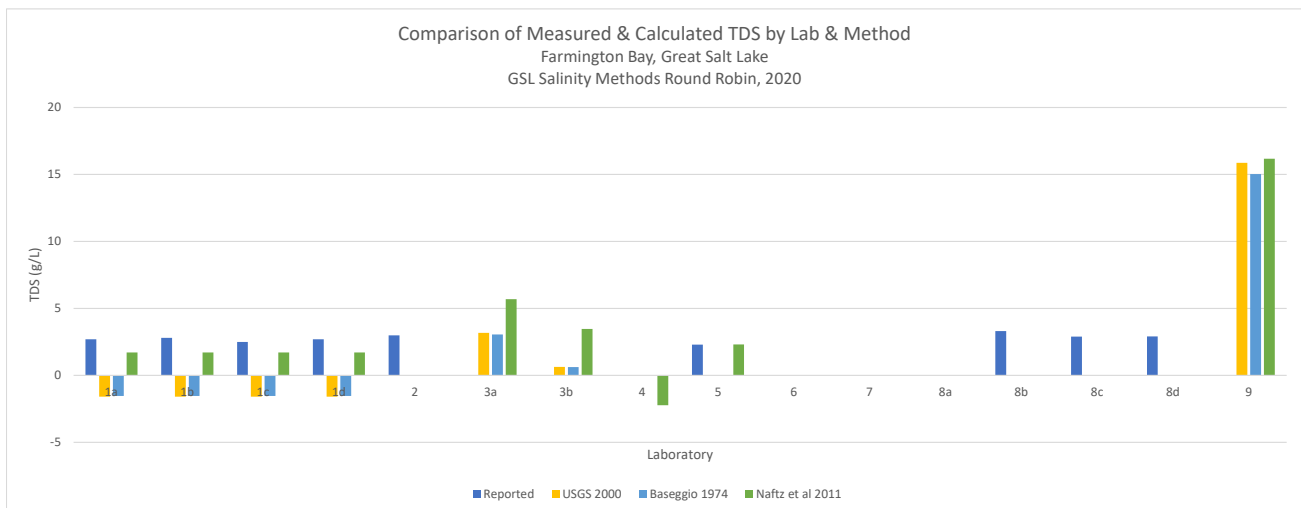
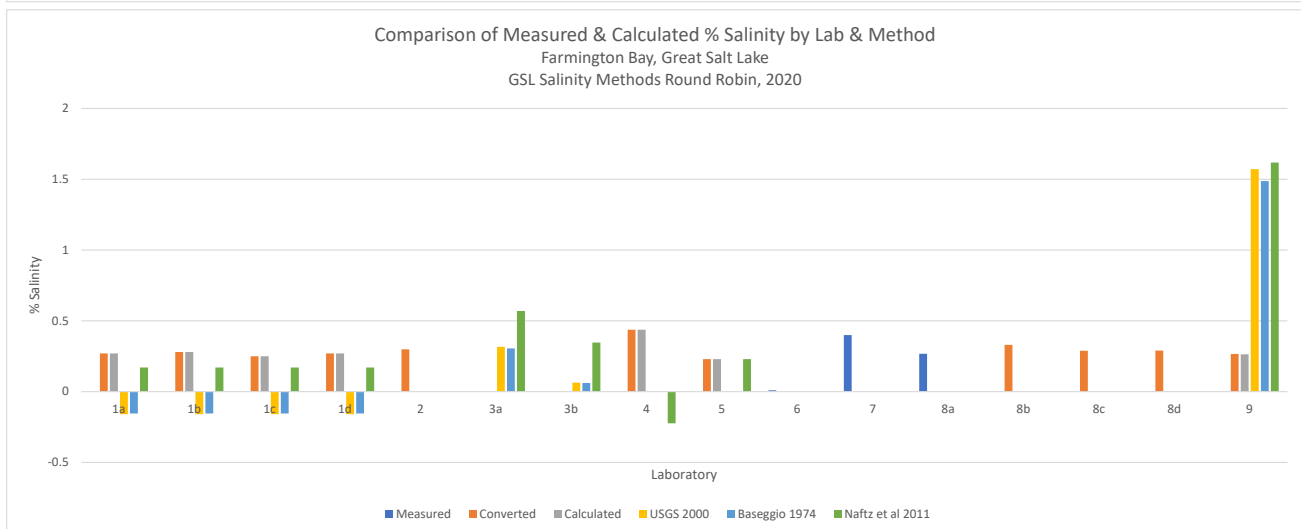
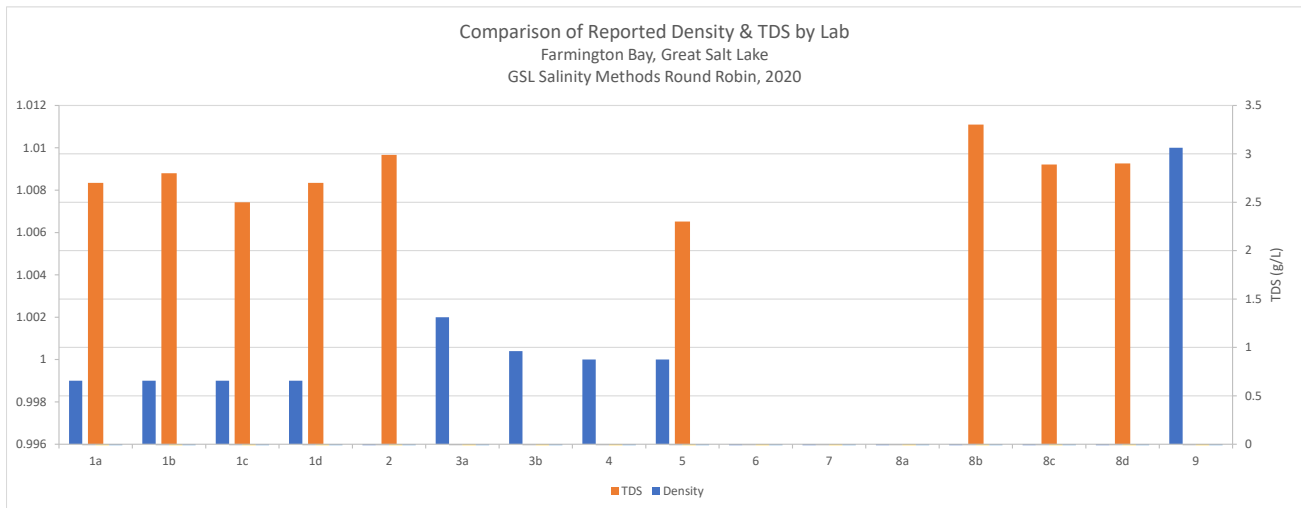
References:

Baseggio, G. 1974. The Composition of Sea Water and Its Concentrates.

Naftz, D., Millero, F., Jones, B., Green, W. (2011). An Equation of State for Hypersaline Water in Great Salt Lake, Utah, USA. Aquatic Geochemistry. 17. 809-820. 10.1007/s10498-011-9138-z.

United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987-98. Water-Resources Investigation Report 00-4221

United States Geological Survey (USGS). 2000. Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987-98. Water-Resources Investigations Report 00-4221.



Attachment I

**Results and Comparisons of the Analysis of
Major Ions in Great Salt Lake Waters**

Summary of Salinity Fractions

Great Salt Lake Salinity Methods Round Robin, 2020

Great Salt Lake Salinity Advisory Committee

Laboratory	Density (g/L)	Na ⁺ (g/L)	Mg ⁺² (g/L)	K ⁺ (g/L)	Li (g/L)	Ca ⁺² (g/L)	Cl ⁻ (g/L)	SO ₄ ⁻² (g/L)	TDS ² (g/L)
North Arm (Gunnison Bay), Great Salt Lake									
UGS: AWAL	1211	93.6	11.8	11.2	N/A	0.3	180.0	23.9	321
UGS: Chemtech-Ford	1211	86.8	12.2	7.4	N/A	0.3	181.0	24.6	312
US Magnesium: Control Lab ¹	1212	100.6	12.1	7.7	0.03	0.4	177.9	25.2	324
Compass Minerals: multi-analysis ¹	1210	98.9	12.3	7.3	N/A	N/A	177.0	23.5	319
Compass Minerals: ICP-OES ¹	1210	89.4	11.6	7.5	N/A	N/A	162.1	22.1	293
<i>Average</i>	<i>1211</i>	<i>93.9</i>	<i>12.0</i>	<i>8.2</i>		<i>0.3</i>	<i>175.6</i>	<i>23.9</i>	<i>314</i>
<i>Standard Deviation</i>	<i>0.707</i>	<i>5.3</i>	<i>0.3</i>	<i>1.5</i>		<i>0.0</i>	<i>6.9</i>	<i>1.1</i>	<i>11.2</i>
<i>Coefficient of Variation</i>	<i>0.0006</i>	<i>0.0566</i>	<i>0.0231</i>	<i>0.1825</i>		<i>0.0598</i>	<i>0.0393</i>	<i>0.0445</i>	<i>0.0357</i>
South Arm (Gilbert Bay), Great Salt Lake									
UGS: AWAL	1096	44.0	4.8	4.1	N/A	0.2	83.3	10.9	147
UGS: Chemtech-Ford	1096	40.1	5.2	3.1	N/A	0.2	77.9	10.5	137
US Magnesium: Control Lab ¹	1097	44.9	5.2	3.5	0.00	0.2	79.7	10.7	144
Compass Minerals: multi-analysis ¹	1110	44.3	5.4	2.6	N/A	N/A	78.9	9.9	141
Compass Minerals: ICP-OES ¹	1110	40.5	4.8	2.9	N/A	N/A	72.3	9.2	130
<i>Average</i>	<i>1100</i>	<i>42.8</i>	<i>5.1</i>	<i>3.2</i>		<i>0.2</i>	<i>78.4</i>	<i>10.2</i>	<i>140</i>
<i>Standard Deviation</i>	<i>5.932</i>	<i>2.0</i>	<i>0.3</i>	<i>0.5</i>		<i>0.0</i>	<i>3.6</i>	<i>0.6</i>	<i>6.1</i>
<i>Coefficient of Variation</i>	<i>0.0054</i>	<i>0.0475</i>	<i>0.0496</i>	<i>0.1655</i>		<i>0.0537</i>	<i>0.0456</i>	<i>0.0590</i>	<i>0.0439</i>
Farmington Bay, Great Salt Lake									
UGS: AWAL	999	0.9	0.1	0.0	N/A	0.0	1.4	0.4	2.8
UGS: Chemtech-Ford	999	0.8	0.1	0.0	N/A	0.1	1.4	0.3	2.7
US Magnesium: Control Lab ¹	1000	0.7	0.2	0.5	0.00	0.0	2.7	0.3	4.4
Compass Minerals: multi-analysis ¹	1010	0.9	0.1	0.1	N/A	N/A	1.4	0.3	2.8
Compass Minerals: ICP-OES ¹	1010	0.8	0.1	0.1	N/A	N/A	1.3	0.3	2.5
<i>Average</i>	<i>1002</i>	<i>0.8</i>	<i>0.1</i>	<i>0.1</i>		<i>0.0</i>	<i>1.6</i>	<i>0.3</i>	<i>3.0</i>
<i>Standard Deviation</i>	<i>4.637</i>	<i>0.1</i>	<i>0.0</i>	<i>0.2</i>		<i>0.0</i>	<i>0.5</i>	<i>0.0</i>	<i>0.7</i>
<i>Coefficient of Variation</i>	<i>0.0046</i>	<i>0.0887</i>	<i>0.2549</i>	<i>1.4233</i>		<i>0.9384</i>	<i>0.3217</i>	<i>0.1131</i>	<i>0.2222</i>

Notes:

¹ Calculated values from reported density and % weight of brine.

² TDS is calculated from the sum of ions.

N/A: Value is not reported.

