Standard Operating Procedure—Great Salt Lake Water Density Measurement and Salinity Calculation

by

Great Salt Lake Salinity Advisory Committee

Suggested citation:

Great Salt Lake Salinity Advisory Committee, 2020, Standard operating procedure—Great Salt Lake water density measurement and salinity calculation: Utah Geological Survey Open-File Report 728, 6 p., https://doi.org/10.34191/OFR-728.

Disclaimer

OPEN-FILE REPORT 728
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
2020

Blank pages are intentional for printing purposes.

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 Ryan Rowland, Andrew Rupke, Jake VanderLaan, and Elliot Jagniecki provided substantial contributions to the effort and document. This standard operating procedure (SOP) was largely built upon the U.S. Geological Survey's methods for measuring Great Salt Lake density and, to a lesser extent, the Utah Geological Survey's methods.

The 2020 members of the Great Salt Lake Salinity Advisory Committee are:

Cory Angeroth, U.S. Geological Survey

Jamie Barnes, Utah Division of Forestry, Fire and State Lands

Bonnie Baxter, Westminster College

Thomas Bosteels, Great Salt Lake Brine Shrimp Cooperative

Jaimi Butler, Westminster College (alternate)

Jim Harris, Utah Division of Water Quality

Joe Havasi, Compass Minerals

Tim Hawkes, Great Salt Lake Brine Shrimp Cooperative (alternate)

Ben Holcomb, Utah Division of Water Quality (alternate)

Elliot Jagniecki, Utah Geological Survey (alternate)

Paul Jewell, University of Utah (alternate)

Bill Johnson, University of Utah

Bill Kerner, Compass Minerals (alternate)

Krishna Khatri, Utah Division of Water Resources (alternate)

John Luft, Utah Division of Wildlife Resources

Craig Miller, Utah Division of Water Resources

Ryan Rowland, U.S. Geological Survey (alternate)

Andrew Rupke, Utah Geological Survey

Kyle Stone, Utah Division of Wildlife Resources (alternate)

Tom Tripp, US Magnesium

Jake VanderLaan, Utah Division of Water Quality*

Laura Vernon, Utah Division of Forestry, Fire and State Lands (alternate)

*No longer a member, but was a member at the time of document preparation.

Standard Operating Procedure

Great Salt Lake Salinity Advisory Committee, June 2020

Great Salt Lake Water Density Measurement and Salinity Calculation

Introduction

Characterization of the salinity of Great Salt Lake (GSL) water is essential to understanding the complex dynamics of GSL and has been a common measurement made by lake users, managers and researchers alike. Although there has been coordination of data, different organizations have used different field and laboratory analytical methods to develop and report the salinity of GSL. The Great Salt Lake Salinity Advisory Committee (SAC) completed a round robin in early 2020 to examine the different methods and develop a standard protocol for measuring and reporting the density and salinity of GSL waters (Jacobs 2020). This Standard Operating Procedure (SOP) is an adaptation of the US Geological Survey (USGS) SOP (2019) and the Utah Geological Survey (UGS) SOP (2019) for GSL water density measurement and salinity calculations and has been recommended for use with GSL waters by the SAC.

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).

Purpose

This SOP establishes a standardized method for measuring and reporting GSL water density and calculating and reporting its salinity in weight per volume units. It sets a consistent protocol to ensure the quality of data collected and reported for GSL — resulting in improved uniformity, reproducibility, verifiability, and defensibility of the data.

Applicability

This SOP is available for use by all organizations measuring and reporting GSL water density and salinity data. Individual organizations may measure GSL density and salinity using an alternative method; however, data intended for use in comparison with long term

datasets should include a description of the method used to enable interpretation and comparison of results.

> ***Note:*** *Density measurements are not necessarily a reliable proxy for salinity at or near saturation.*

Parameters

1. Water density, in grams per cubic centimeter (g/cm^3). Density shall be rounded to the nearest thousandth; e.g. 1.018 g/cm^3.
2. Water temperature at time and location of density measurement (i.e., not the temperature in field), in degrees Celsius (°C)
3. Salinity, in grams per liter (g/L)

Personnel Qualifications

Personnel should be familiar with laboratory safety practices and steps necessary to avoid contaminating samples. Personnel preparing samples for the first time should be supervised by someone familiar with these procedures.

Density Instrument

Instrument- The density of water samples shall be determined with a density meter that uses the oscillating U tube method (e.g., Anton Paar DMA 35 or equivalent).

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

Density Acceptance criteria and response if not acceptable- The maximum permissible error is ±0.001 g/cm^3. If a calibration check reading is outside the maximum permissible error, the density meter should be returned to the manufacturer for maintenance/repair.

Calibration frequency and location- Calibration checks should be completed per the manufacturer's recommendations. Laboratory calibration checks are performed prior to each use.

Density Measurement Procedure

> ***Important:*** *Measurements shall be done near room temperature (preferably at 20°C).*

1. Attach the filling tube to the bottom of the 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 ultra-pure deionized water that is near room temperature. The measured density should be within ±0.001 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 °C. The density of pure water is based on Spieweck and Bettin (1992).

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 ultra-pure deionized water is not within ± 0.001 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 sample (bring the sample to 20 ± 0.5 °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 density measurements until two consecutive density values are equal, or within ±0.0001 g/cm^3. 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 ultra-pure deionized water before proceeding to the next sample.

   ***Important**: Depress pump slowly several times on last rinse to get water out before taking the next measurement.*

9. When finished with sample measurements recheck the calibration of the unit with ultra-pure deionized water (rinse the meter three times with ultra-pure deionized water before checking the calibration). Pump out the deionized water after the calibration check.

10. To begin cleaning the instrument, flush with several mL (50 or more) of water (deionized or tap) using the pump.

11. 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.

12. Power down the unit, remove the filling tube, and store the meter in its designated area.

    ***Note:** * Grain alcohol that is at least 95 percent alcohol (e.g., Everclear™) may be used as a substitute cleaning and drying agent. Alconox may also be used to flush through the instrument as recommended by the manufacturer. Applying the Alconox step would come before flushing water through the instrument after measurements have been taken.*

Salinity Calculation

Measured densities of water samples collected from GSL are used to compute the salinity of each sample (in grams per liter (g/L)).

Salinity is calculated with an equation of state specific to GSL waters with salinities ranging from 23 to 182 g/L (Equation 1; Naftz et al., 2011). The GSL SAC is working with its partners to develop a new equation of state for GSL waters with salinities ranging from 10 to about 360 g/L. Until the new equation is developed, results for GSL waters outside of the range of 23 to 182 g/L shall be noted as "outside the salinity range used to develop the GSL equation of state". 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 (Equation 2). Note that water temperature refers to the temperature of the water when the density measurement is made (should be 20 ± 0.5 °C), not the temperature measured in the field, when the sample was collected.

Equation 1 (Naftz et al, 2011).

$$\rho - \rho^0 = \left(184.01062 * (1.04708 * S) - (1.21061 * T) + \left(3.14721^{-4} * S^2\right) + \left(0.00199 * T^2\right) - (0.00112 * S * T)\right) * 1000$$

Equation 2 (transposed from Equation 1).

$$S=\frac{\left(\left(\sqrt{\left(\left(1.04708-(0.00112*T)\right)^{2}\right)-\left(4*0.000314721*\left(-(\rho*1000)+(\rho^{0}*1000)+(0.00199*T^{2})-(1.21061*T)+184.01602\right)\right)}\right)-\left(1.104708-(0.00112*T)\right)+}{(2*0.000314721)}$$

ρ = density of GSL water (g/cm^3)
ρ^0 = density of pure water (g/cm^3)
S = salinity (g/L)
T = water temperature (°K)

Reporting

Water density (in g/cm^3) and the temperature of the water when the density was measured (in °C) shall be reported for each water sample. 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 the water temperature of the sample when collected from Great Salt Lake.

> ***Important:*** *The density and temperature of a water sample shall always be measured and reported together; the density of a water sample will vary with temperature.*

> ***Note:*** *The GSL SAC recognizes that the density of GSL water has been historically measured and reported at different temperatures. Users of density data must be aware of the corresponding temperature at which the water density was measured as the density of a water sample will be different at different temperatures. A means to facilitate accurate comparison and evaluation of these GSL water density data that is independent of water temperature would be useful. The SAC is evaluating the feasibility of developing an equation to normalize water densities measured at various water temperatures to a water density at 20°C.*

References

Anton Paar DMA 35N Portable Density Meter Instruction Manual

Jacobs Engineering Group Inc (Jacobs). 2020. Round Robin of Methods to Estimate the Salinity of Great Salt Lake Waters. Technical memorandum prepared with the Great Salt Lake Salinity Advisory Council.

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

US Geological Survey (USGS). 2019. Great Salt Lake Water Density Measurement and Salinity Calculation. 4pp.

Utah Geological Survey (UGS). 2019. Density Meter Procedures. 1p.