2014 Annual Interim Monitoring Report

Union Pacific Railroad Great Salt Lake Causeway Culvert Closure and Bridge Construction Project

SPK-2011-00755

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Acronyms

AWAL	American West Analytical Laboratories
EPA	U.S. Environmental Protection Agency
IMP	Interim Monitoring Plan
MDL	method detection limit
MRL	method reporting limit
NELAP	National Environmental Laboratory Accreditation Program
NGVD	National Geodetic Vertical Datum
NWP	Nationwide Permit
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
TDS	total dissolved solids
UDWQ	Utah Division of Water Quality
UGS	Utah Geological Survey
UPRR	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSE	water surface elevation

1.0 Introduction

In 2014, Union Pacific Railroad (UPRR) monitored the ambient water quality in the Great Salt Lake in accordance with UPRR's Interim Monitoring Plan (IMP) for Temporary Closure of the East Culvert, Great Salt Lake Causeway (UPRR 2014a). The IMP was developed pursuant to the requirements of Special Conditions 2a and 2b of the U.S. Army Corps of Engineers' (USACE) Nationwide Permit 14 verification (USACE NWP 14) issued December 6, 2013 (SPK-2011-0075) and Condition 3 of the Utah Division of Water Quality's (UDWQ) 401 Water Quality Certification (No. SPK 2011-00755) issued December 16, 2013 (USACE 2013, 2014; UDEQ 2013).

The IMP described the scope and frequency of the both the water quality monitoring and its reporting. After USACE and UDWQ approved the IMP in May 2014, UPRR conducted three monitoring events during May, July, and September 2014. As required in the USACE NWP 14, UPRR submitted interim monitoring event reports after each monitoring event in 2014. These reports were submitted on August 22, 2014; October 13, 2014; and December 17, 2014 (UPRR 2014b, 2014c, 2014d).

This report reviews and summarizes the ambient lake monitoring results for the monitoring events conducted in 2014. With the submittal of this report, UPRR is fulfilling the Utah 401 Water Quality Certification requirement to submit an annual interim monitoring report by January 1 of the year following data collection.

2.0 Interim Monitoring Goals and Objectives

Interim monitoring goals and objectives are provided in Table 1 below. The monitoring focused on characterizing the open waters of Gilbert Bay and Gunnison Bay near the project site. The monitoring consisted of four elements: (1) compiling water surface elevation (WSE) data for each monitoring event, (2) collecting in-situ water profiles, (3) collecting grab sample water quality samples for analyses at an off-site laboratory, and (4) collecting brine shrimp samples for analyses and counts by off-site laboratories. The activities of compiling WSE data (element 1) and collecting salinity gradient data (part of element 2) meet the USACE NWP 14 interim monitoring requirements (USACE 2013). Elements 2, 3, and 4 meet the UDWQ 401 Water Quality Certification interim monitoring requirements (UDWQ 2013).

Table 1. Interim Monitoring Goals and Objectives

Element	Goals	Objectives
1. Water surface elevations	Capture temporary hydrologic impacts resulting from closure of the east culvert.	Obtain WSEs for the North Arm and South Arm of the Great Salt Lake from USGS reporting stations located at Saline and Saltair.
2. Surface water profiles and conventional water quality	Collect Great Salt Lake total depth, depth to deep brine layer[a] (if present), ambient Secchi depth, pH, temperature, and salinity data set.	Collect salinity data consistent with UDWQ and USGS methods and reporting limits.
3. Surface and bottom water metals, sulfate sampling and dissolved oxygen	Collect Great Salt Lake ambient metals, sulfate, hardness, and dissolved oxygen data set in surface water.	Collect metals, sulfate, and dissolved oxygen water samples at specified locations consistent with UDWQ reporting limits.
4. Brine shrimp counts and tissue sampling	Collect Great Salt Lake ambient brine shrimp population data and tissue metals and percent moisture data set at co-located South Arm water quality stations.	Collect brine shrimp for taxonomic identification, counts, and tissue analysis at specified locations in accordance with UDWQ-approved reporting limits.

UDWQ = Utah Division of Water Quality; USGS = U.S. Geological Survey

[a] *Deep brine layer depth* refers to the vertical zone in a water column in which salinity changes rapidly with depth. For the purpose of this annual interim monitoring report, *deep brine layer depth*, *halocline*, and *chemocline* are synonymous.

3.0 Methods

The methods used for the monitoring events are described in the IMP and in each interim monitoring event report and so are only summarized below. UPRR conducted ambient lake monitoring at three locations in Gilbert Bay and two locations in Gunnison Bay, including locations to the south and north of the UPRR Great Salt Lake causeway in the vicinity of the east and west culverts and a location in Gilbert Bay in the basin between the causeway and the rest of Gilbert Bay (see Figure 1 and Table 2 below). These sampling sites were located in the open waters of Gunnison and Gilbert Bays at locations specified in the Utah 401 Water Quality Certification and in the USACE NWP 14. In-situ measurements and water quality samples were collected at each site (see Table 3 on page 6). Brine shrimp parameters were collected at the Gilbert Bay sites only.

Figure 1. Interim Monitoring Sampling Sites and USGS Gage Locations

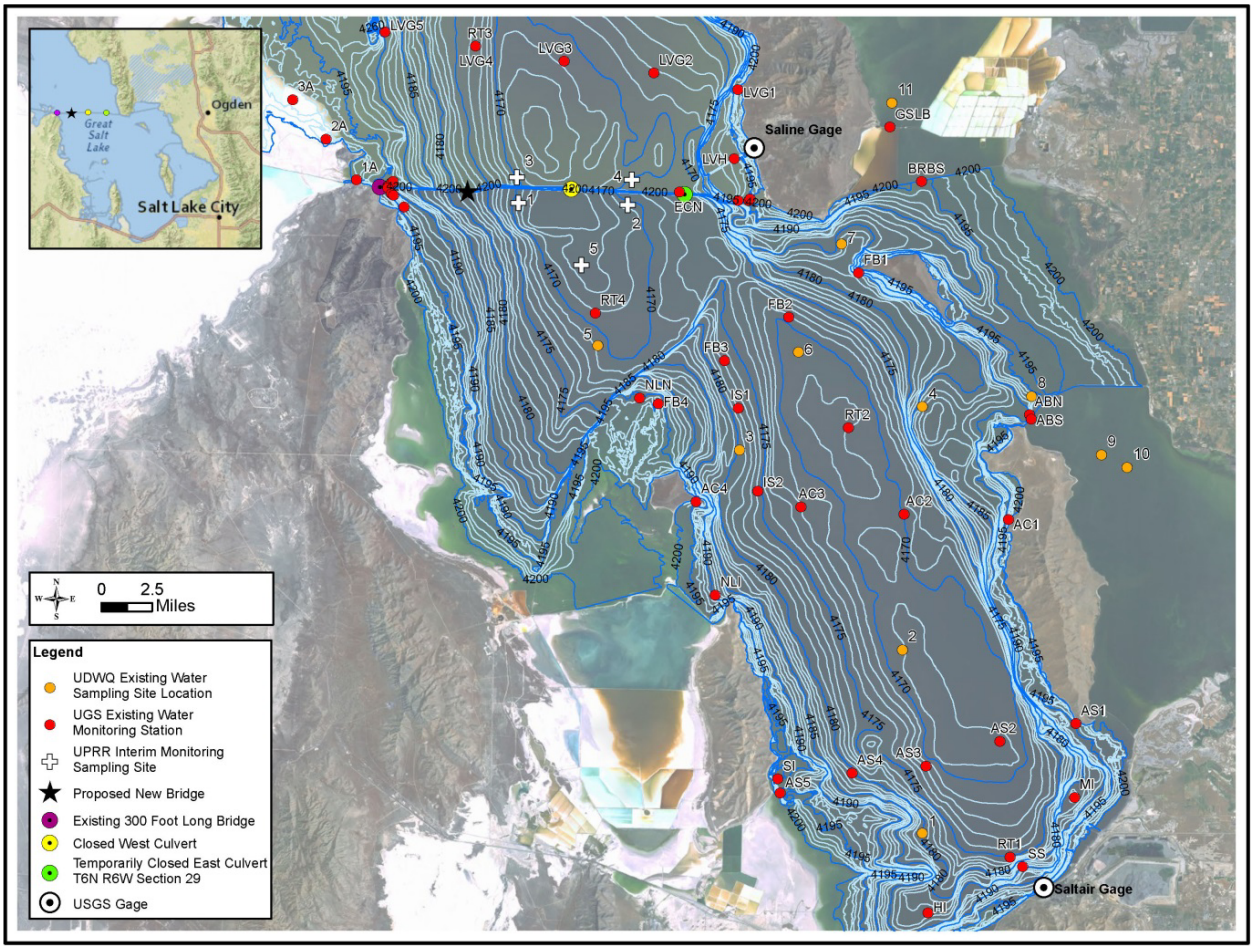


Table 2. Sampling Site Coordinates and Descriptions

Site Name	Latitude	Longitude	Description
Gilbert Bay			
Sampling site 1	41° 12' 49.65" N	112° 43' 4.82" W	Halfway between the proposed bridge and the west culvert; 1 km south of the UPRR causeway
Sampling site 2	41° 12' 47.86" N	112° 36' 52.62" W	Halfway between the west and east culverts; 1 km south of the UPRR causeway
Sampling site 5	41° 10' 9.65" N	112° 39' 25.81" W	6 km south of the west culvert
Gunnison Bay			
Sampling site 3	41° 13' 54.62" N	112° 43' 11.77" W	Halfway between the proposed bridge and the west culvert; 1 km north of the UPRR causeway
Sampling site 4	41° 13' 34.84" N	112° 36' 40.64" W	Halfway between the west and east culverts; 0.5 km north of the UPRR causeway

km = kilometers; UPRR = Union Pacific Railroad

Table 3. Interim Monitoring Locations and Frequency

Parameter	Number and Sample Depth	Frequency	Field Duplicate[a]	Field Blank[a]	Equipment Rinsate[a]	Sampling Site				
						1	2	3	4	5
Total water depth	One measurement taken from water surface to bottom of lake.	Four times per year	NA	NA	NA	X	X	X	X	X
Depth to deep brine layer	One location inferred from conductivity profile.	Four times per year	NA	NA	NA	X	X	X	X	X
Secchi depth	Measurements taken from water surface and averaged.	Four times per year	NA	NA	NA	X	X	X	X	X
Temperature, pH, conductivity	Vertical profile; measurements taken *in situ* every 0.5 m. The field conductivity measurements will establish whether there is a deep brine layer present.	Four times per year	NA	NA	NA	X	X	X	X	X
Total dissolved solids, density	Vertical profile; grab samples taken every 1.5 m in upper brine layer; samples taken every 0.5 m in the deep brine layer.	Four times per year	10% of samples	10% of samples	10% of samples	X	X	X	X	X
Total metals (As, Cu, Pb, Se, Hg, Zn), SO_4, hardness, and DO	Grab samples taken 0.2 m from the water surface and 0.5 m from the bottom.	Four times per year	10% of samples	10% of samples	10% of samples	X	X	X	X	X
Brine shrimp count	One sample from one vertical tow.	Tri-annually (May, July, and September)	1 per quarter	NA	NA	X	X	NA	NA	X
Brine shrimp tissue, percent moisture	Composite sample from up to three vertical tows.	Tri-annually (May, July, and September)	1 per quarter	NA	NA	X	X	NA	NA	X

m = meters
NA = not applicable
X = parameter measured at this site
As = arsenic
Cu = copper
DO = dissolved oxygen
Hg = mercury
Pb = lead
Se = selenium
SO_4 = sulfate
Zn = zinc

[a] Field duplicate, field blank, and equipment rinsate samples were collected as part of the field quality assurance program, the results of which are described in the three individual interim monitoring event reports.

3.1 In-situ Measurements

In-situ water quality measurements included total depth, depth to deep brine layer, Secchi depth, and vertical profiles of water temperature, conductivity, and pH. Secchi depth was measured first. Then, water temperature, conductivity, dissolved oxygen, and pH were measured every 0.5 meters with a multiprobe water quality meter. The water quality meter was calibrated using the manufacturer's recommended calibration methods. These water quality measurements were used to determine the depth, if present, of the deep brine layer. The depth of the deep brine layer was used to determine the frequency of the grab samples for dissolved oxygen, total dissolved solids, and density according to the following rules:

- If a deep brine layer is present:
  - Collect samples above the deep brine layer every 1.5 meters
  - Collect samples below the deep brine layer every 0.5 meter
- If a deep brine layer is not present:
  - Collect samples every 1.5 meters

In addition to the density samples being sent off site to the laboratory, specific gravity was determined via hydrometer for the July and September monitoring events. The two Fisher brand hydrometers used were calibrated for 60 degrees Fahrenheit, one for specific gravities of 1.100–1.220 and one for specific gravities of 1.200–1.420.

3.2 Surface Water Samples

Surface water samples were sent to Brooks Rand Laboratories in Seattle, Washington, for metals analyses. Surface water samples were sent to American West Analytical Laboratories (AWAL) in Salt Lake City, Utah (May) and to ChemTech Ford in Salt Lake City, Utah (July and September) for dissolved oxygen, hardness, sulfate, and total dissolved solids (TDS) analyses. It was necessary to change general chemistry laboratories from AWAL to ChemTech Ford because AWAL experienced a fire at its facility in July 2014 and suspended all operations. All three laboratories are certified under the National Environmental Laboratory Accreditation Program (NELAP).

Each laboratory sample was collected into laboratory-supplied clean containers. Water samples were collected at depth with a Kemmerer sampler. Water samples to be analyzed for metals were collected using "clean hands" methods consistent with the U.S. Environmental Protection Agency's (EPA) Method 1669 (EPA 1996) and the UDWQ standard operating procedure for "Trace Metals Sample Collection (Clean Hands/ Dirty Hands), Decontamination, and Multiprobe In-situ Monitoring Procedures." The samples were preserved (as appropriate), stored, and delivered to the laboratory for analyzing the laboratory parameters listed in the IMP (see Table 4 below; UPRR 2014a). A chain-of-custody record was maintained with the samples at all times. Shared sampling equipment used to collect the deep-water quality samples was decontaminated between sampling sites.

Table 4. Water Quality Parameters and Constituents To Be Measured and Methods, with Detection Limits, Reporting Limits, and Laboratory Hold Time

Parameter		Method [a]	Method Detection Limit	Method Reporting Limit	Hold Time
Field Measurements – Surface Water					
Lake elevation [b]	—	USGS automated gage	—	—	—
Total water depth	—	Troll 9500 field measurement	—	0.1 m	Field
Depth to deep brine layer [c]	—	Troll 9500 field measurement	—	0.1 m	Field
Secchi depth	—	—	—	0.1 m	Field
pH	—	SM 4500-H	0.1 su	0.1 su	Field profile
Specific conductivity	—	SM 2510A	0.001 µmhos	0.001 µmhos	Field profile
Temperature	—	SM 2520	0.1 ºC	0.1 ºC	Field profile
Laboratory Analyses – Surface Water [d,e]					
Density	—	SM 2710F	—	0.001 g/mL	7 days
Dissolved oxygen	DO	SM 4500-OC	—	0.1 mg/L	8 hours
Hardness	—	SM 2340 C	—	1 mg/L as $CaCO_3$	14 days
Sulfate (total)	SO_4^{2-}	EPA 300.0	—	1 mg/L	28 days
Total dissolved solids	Salinity	SM 2540C	—	5 mg/L	7 days
Arsenic (total)	As	EPA 1640	0.05 µg/L	0.15 µg/L	180 days
Copper (total)	Cu	EPA 1640	0.04 µg/L	0.12 µg/L	180 days
Lead (total)	Pb	EPA 1640	0.003 µg/L	0.013 µg/L	180 days
Mercury (total)	Hg	EPA 1631E	0.15 ng/L	0.40 ng/L	28 days
Selenium (total)	Se	EPA 1640	0.070 µg/L	0.210 µg/L	180 days
Zinc (total)	Zn	EPA 1640	0.26 µg/L	0.75 µg/L	180 days
Laboratory Analyses – Gilbert Bay Brine Shrimp [e]					
Percent moisture	—	SM 2540G	—	1.0%	—
Arsenic (total)	As	EPA 1638	0.014 mg/kg	0.040 mg/kg	180 days
Copper (total)	Cu	EPA 1638	0.03 mg/kg	0.16 mg/kg	180 days
Lead (total)	Pb	EPA 1638	0.004 mg/kg	0.040 mg/kg	180 days
Mercury (total)	Hg	EPA 1631	0.12 ng/g	0.4 ng/g	28 days
Selenium (total)	Se	EPA 1638	0.06 mg/kg	0.15 mg/kg	180 days
Zinc (total)	Zn	EPA 1638	0.20 mg/kg	1.00 mg/kg	180 days

Table 4. Water Quality Parameters and Constituents To Be Measured and Methods, with Detection Limits, Reporting Limits, and Laboratory Hold Time

Parameter	Method [a]	Method Detection Limit	Method Reporting Limit	Hold Time
Laboratory Counts – Gilbert Bay Brine Shrimp				
Brine shrimp (*Artemia franciscana*)	Dissection microscope	Not applicable	Not applicable	Not applicable

°C = degrees Celsius
$CaCO_3$ = calcium carbonate
EPA = sampling method from EPA
USGS = U.S. Geological Survey
µmhos = micromhos
SM = Standard Methods for the Examination of Water and Wastewater
m = meters
g/mL = grams per milliliter
mg/L = milligrams per liter
µg/L = micrograms per liter
ng/L = nanograms per liter
mg/kg = milligrams per kilogram
ng/g = nanograms per gram
su = standard units

[a] Laboratory analytical method or field equipment.
[b] See Section 4.1, Water Surface Elevation, of this report.
[c] *Deep brine layer depth* refers to the vertical zone in a water column in which salinity changes rapidly with depth. The location of the deep brine layer is determined from abrupt changes in conductivity, temperature, and dissolved oxygen.
[d] Estimated by American West Analytical Laboratories and Brooks Rand Laboratories (metals). Due to the nature of Great Salt Lake water, reporting limits might be elevated for some analyses.
[e] Estimated by Brooks Rand Laboratories. Due to the nature of brine shrimp tissue, reporting limits might be elevated for some analyses.

3.3 Brine Shrimp Samples

One vertical plankton tow was performed at sites 1, 2, and 5 to obtain brine shrimp for analytical laboratory analysis. Brine shrimp samples were sent to Brooks Rand Laboratories for metals analysis (see Table 4 above). One additional plankton tow was performed at these sites to collect brine shrimp samples which were sent EcoAnalysts, Inc., for taxonomic life stage identification and counts.

Each tow was from the bottom of the water column to the water surface, using a 165-micrometer net with a 50-centimeter-diameter opening and a screened sample bucket attached at the bottom of the net. The net was lowered to the desired depth and raised at an approximate rate of 0.5 meter per second to collect brine shrimp from the water column. The analytical sample was concentrated into the sample bucket and transferred to a labeled and laboratory-supplied sample jar. The procedure was repeated to collect a sample for brine shrimp taxonomic analysis. The samples were stored and recorded on separate chain-of-custody forms (one for the analytical laboratory and one for the taxonomic laboratory).

3.4 Quality Assurance

All data were collected in accordance with the IMP's Quality Assurance Project Plan (QAPP) (UPRR 2014a). After each monitoring event, UPRR subjected all data to quality assurance/quality control (QA/QC) procedures including but not limited to spot checks of transcription, review of electronic data submissions for completeness, comparison of geographic information systems (GIS) maps with field notes on locations, and identification of any inconsistent data. As a result of this process, UPRR observed the following:

- The multi-probe water quality meter sonde and the boat's depth sounder sometimes contradicted each other. The sonde's depth was recorded as the depth at each sampling site.
- Laboratory measurements of density in May were inconsistent with respect to depth and were not consistent with cation and anion concentrations. Consequently, UPRR determined that the laboratory's May density data were not usable and qualified these data as "R" (rejected).
- Laboratory measurements of dissolved oxygen, via the Winkler method, in May were suspected to be inaccurate due to an unknown interference during sample collection and preparation. Consequently, UPRR determined that the laboratory's May dissolved oxygen data were not usable and qualified these data as "R" (rejected).

UPRR also evaluated the analytical data for their consistency with the data quality objectives in the QAPP. The QAPP specifies representativeness, accuracy, precision, comparability, and completeness objectives for data acquisition (UPRR 2014a, Table 7-1).

- **Representativeness.** Representativeness was ensured via the location of sample sites as well as the monitoring event intervals. Representative locations and measurement intervals were prescribed by USACE and UDWQ and are listed in Table 2, Sampling Site Coordinates and Descriptions, of this report.
- **Accuracy.** Accuracy for field and laboratory measurements is defined as the degree of conformity of a measured or calculated quantity to its actual (true) value. The accuracy objective provided in the QAPP for the monitoring events (UPRR 2014a) was met by using standard methods and calibrated instruments. Field instrument calibration records and laboratory Level 2 data packages are provided in Appendix F, Data Quality Assurance Documentation, and Appendix G, Field and Analytical Laboratory Data Reports, of each interim monitoring event report. QA samples (method blanks, laboratory control samples, method spikes, and others) were analyzed as appropriate for each method. In the few instances when laboratory QC analyses were outside acceptable limits, the laboratory qualified the data as biased high or low and flagged the data accordingly.
- **Comparability.** The comparability objective provided in the QAPP for the monitoring events (UPRR 2014a) was ensured by meeting the target reporting limits provided in Table 4, Water Quality Parameters and Constituents To Be Measured and Methods, with Detection Limits, Reporting Limits, and Laboratory Hold Time, of this report. Though the brine matrix did require dilutions, method reporting limits (MRL) and method detection limits (MDL) were met. Per the IMP, selenium and zinc observed at concentrations between the MDL and MRL are provided "as is" in Appendix C, Surface Water Analytical Results, and Appendix G, Field and Analytical Laboratory Data Reports, of each interim monitoring event report but were reported as non-detect at the MRL in the main text of each report.

- **Precision.** Precision is an assessment of reproducibility under a particular set of conditions. The precision objective provided in the QAPP for the monitoring events consisted of the laboratory meeting all of its QA requirements and field duplicate results within 10% (UPRR 2014a). Equipment rinsates and field blanks also provide insight into the sampling results' precision.
    - Level 2 data packages are provided in Appendix G, Field and Analytical Laboratory Data Reports, of each interim monitoring event report. QA samples (method blanks, laboratory control samples, method spikes, and others) were analyzed as appropriate for each method. In the few instances when laboratory QC analyses were outside acceptable limits, the laboratory qualified the data as biased high or low and flagged the data accordingly.
    - In July, brine shrimp metals analyses were all qualified as estimated (H) because they arrived warmer than 4 degrees Celsius, which is outside the laboratory's acceptable limits.
    - Duplicate agreement for detected arsenic, copper, lead, and zinc exceeded 10% in some surface water and brine shrimp analysis, and the results were qualified as estimated (V) during the verification review.
    - Equipment rinsate results in May, July, and September 2014 had elevated mercury levels, and mercury results for the lower-water-column samples were qualified as estimated (V) during the verification review.
    - All field blank results were trace or non-detect.
- **Completeness.** The completeness objective provided in the QAPP for the monitoring events was 90% (UPRR 2014a) and is defined as the number of valid measurements divided by the number of measurements collected. For each monitoring event, 41 analytes were measured for each of the 5 water samples, and 14 analytes were measured for each of the 3 brine shrimp samples. Though some project variances and non-conformances resulted in data loss or qualification (see Section 5.0, Summary of Variances from the Interim Monitoring Plan, of this report and Section 2.6, Study Variances and Corrective Action, of each monitoring report), the completeness objective of 90% was met for each monitoring event for both surface water and brine shrimp.

Documentation of this process is provided in Appendix F, Data Quality Assurance Documentation, of each interim monitoring event report.

4.0 Summary of Results

The results of each 2014 monitoring event as well as the QA/QC review are presented in the three 2014 interim monitoring event reports, which were published on August 22, 2014; October 13, 2014; and December 17, 2014 (UPRR 2014b, 2014c, 2014d). Data packages (Level 2) and other supporting documentation are also provided in these three reports. A summary of the results is provided below.

4.1 Water Surface Elevation

This section summarizes the WSE data and in-situ measurements collected during 2014.

Water Surface Elevation Data. UPRR acquired WSE data in 15-minute increments for Gunnison and Gilbert Bay from the U.S. Geological Survey's (USGS) website (USGS 2014; see Appendix A, Surface Water Elevation Data, of each interim monitoring event report). South Arm WSEs were obtained for

USGS station 10010000 (Saltair gage), and North Arm WSEs were obtained for USGS station 10010100 (Saline gage; see Figure 1, Interim Monitoring Sampling Sites and USGS Gage Locations, of this report). The difference between the North and South Arm is referred to as the head difference; it is obtained by subtracting the North Arm WSE from the South Arm WSE (see Table 5). The USGS data presented in this report are reported by USGS as preliminary and will be updated when available.

Table 5. Water Surface Elevation and Computed Head Difference

Sampling Date	Water Surface Elevation (feet NGVD 29)		Head Difference (feet)
	South Arm	North Arm	
South Arm Sampling Date			
May 23, 2014	4,195.0	4,194.3	0.7
July 15, 2014	4,194.2	4,193.7	0.5
September 23, 2014	4,193.4	4,192.8	0.6
North Arm Sampling Date			
May 22, 2014	4,195.1	4,194.4	0.7
July 17, 2014	4,194.2	4,193.7	0.5
September 10, 2014	4,193.6	4,192.9	0.7

4.2 Vertical Profiles

UPRR used synoptic in-situ methods, which are listed in Table 4, Water Quality Parameters and Constituents To Be Measured and Methods, with Detection Limits, Reporting Limits, and Laboratory Hold Time, of this report. Synoptic in-situ dissolved oxygen measurements were also collected. The range of WSEs, total water depth, and depth to brine layer for all monitoring events are summarized in Table 6 below. Temperature, pH, dissolved oxygen, TDS, and salinity profiles are provided below as Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6, respectively.

Depth to Brine Layer. Total water depth, Secchi depth, and Gilbert Bay brine layer depth ranges observed in 2014 are summarized in Table 6 below. The following general observations are made:

- The range in lake bottom elevations at sampling sites (see Figure 2 through Figure 6 below) can be attributed to varying field conditions; that is, sampling when there was significant wave action.
- For each monitoring event, a weak brine layer or no brine layer was observed at Gilbert Bay site 2. Water quality measurements in the lower water column at site 2 were often more similar to the upper water column than to the more distinctive lower water column layers observed at sites 1 and 5.
- A deep brine layer was observed at Gilbert Bay sites 1 and 5 for all monitoring events.
- A deep brine layer was not observed in Gunnison Bay.
- Secchi depths for Gilbert Bay were greater than for Gunnison Bay for all monitoring events.

Table 6. Water Level, Total Depth, Secchi Depth, and Brine Layer Depth Ranges – 2014

Parameter	Units	Gilbert Bay (Sites 1, 2, and 5)		Gunnison Bay (Sites 3 and 4)	
		Minimum	Maximum	Minimum	Maximum
Average WSE of sampling day	feet NGVD 29	4193.4	4,195.0	4,192.8	4,194.3
Secchi depth	meters (feet)	1.8 (5.9)	3.1 (10.2)	0.7 (2.3)	0.8 (2.6)
Total water depth	meters (feet)	7.2 (23.6)	9.1 (29.9)	5.9 (19.4)	7.7 (25.3)
Depth from water surface to deep brine layer	meters (feet)	5.5 (18.0)	7.5 (24.6)	Not found	Not found
Deep brine layer thickness	meters (feet)	0.25 (0.82)	2 (6.5)	Not found	Not found

NGVD 29 = National Geodetic Vertical Datum of 1929

Temperature. Temperature profiles for each monitoring event and each sampling site are shown in Figure 2 on page 15. The following observations are made:

- As the year progressed, temperatures became more consistent between Gilbert and Gunnison Bays. During the May monitoring event, Gunnison Bay was warmer than Gilbert Bay.
- Reduced temperatures were observed in the Gilbert Bay deep brine layer at sites 1 and 5.

pH. pH profile data for each monitoring event and each sampling site are shown in Figure 3 on page 16. The following general observations are made:

- Gilbert Bay sites had pH levels higher than Gunnison Bay sites for all sampling events.
- Reduced levels of pH were observed in the Gilbert Bay deep brine layer at sites 1 and 5.

Dissolved Oxygen. Dissolved oxygen profile data are shown for each monitoring event and each sampling site in Figure 4 on page 17. The following general observations are made:

- In May, Gilbert Bay (sites 1, 2, and 5) had lower dissolved oxygen concentrations than Gunnison Bay (sites 3 and 4). However, in July and September, dissolved oxygen became more consistent between Gilbert and Gunnison Bays.
- Lower dissolved oxygen conditions were observed in the Gilbert Bay deep brine layer at sites 1 and 5 than in the upper water column.
- Very low dissolved oxygen concentrations were observed at the Gilbert Bay sites in May. The existing data record is not sufficient to determine whether these values are anomalous.

Total Dissolved Solids (TDS). TDS profile data are shown for each monitoring event and each sampling site in Figure 5 on page 18. The following general observations are made:

- TDS concentrations indicated that a deep brine layer was present at sites 1 and 5, since the lower-water-column TDS concentration values were elevated relative to the upper-water-column TDS concentration values. The May event deep brine layer thickness was observed to be about 2 meters (6.5 feet) thick, based on laboratory TDS data.
- TDS concentrations in Gunnison Bay (sites 3 and 4) were similar, both spatially and vertically.

Salinity. Salinity profile data are shown in Figure 6 on page 19. Two methods were used to calculate salinity for each water sample collected at depth. In May, density was estimated from TDS concentrations per the USGS-defined relationships of USGS 1973, and the estimated density was used to calculate salinity (UPRR 2014c), due to unacceptable laboratory density analytical results. In July and September, hydrometer-measured specific gravities were used to determine sample densities, which in turn were used in combination with laboratory-reported TDS values to calculate salinity. Density and salinity results are provided in Appendix C, Surface Water Analytical Results, of each interim monitoring event report. Figure 6 on page 19 compares the July and September results as they were determined using the hydrometer readings. The following general observations are made:

- Salinity in Gunnison Bay was greater than in Gilbert Bay.
- Higher salinities were observed in the Gilbert Bay deep brine layer at sites 1 and 5 than in its upper water column.

UPRR calculated average salinities for each sampling site and for the July and September monitoring events for the Gunnison Bay and Gilbert Bay sites to be used in further analysis, as discussed in Section 6.0, Determination of No Adverse Effects, of this report. UPRR calculated average salinities using a slightly different methodology for this analysis than what was previously used and documented in the interim monitoring event reports. UPRR changed the calculation methodology to allow a common comparison to recently collected Utah Geological Survey (UGS) data.

At each UPRR sampling site, samples were collected at various depths, and hydrometer-specific gravity readings were measured in a controlled setting after returning from the field. Observed specific-gravity measurements were corrected for temperature and then used to estimate densities and calculate salinities, following the USGS-defined density-salinity relationships (USGS 1973). These discrete salinities were averaged in the water column weighted by the depth of each sample. The average salinity for each of the Gilbert Bay sites (1, 2, and 5) was then equally averaged, producing a single average salinity result for the North Arm and South Arm (see Table 7). Similarly, the average salinity for the Gunnison Bay sites (3 and 4) was calculated and is reported in Table 7.

Table 7. North and South Arm Average Salinities Based on Hydrometer Measurements

Location	Monitoring Event Average Calculated Salinity (%)	
	July 2014	September 2014
North Arm	29.10	29.26
South Arm	16.17	16.48

Figure 2. Temperature Profiles – 2014

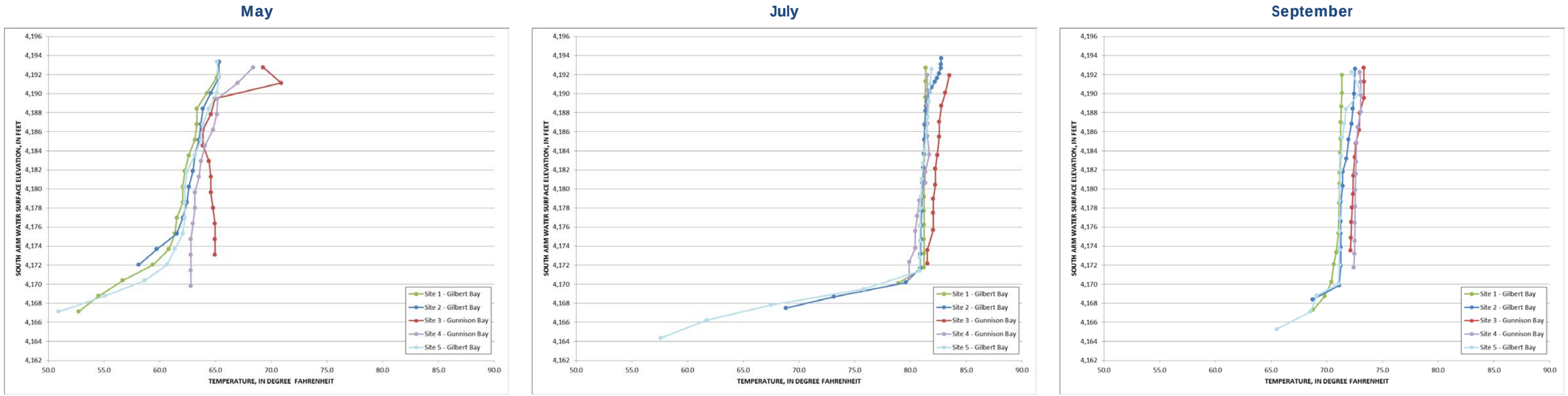


Figure 3. pH Profiles – 2014

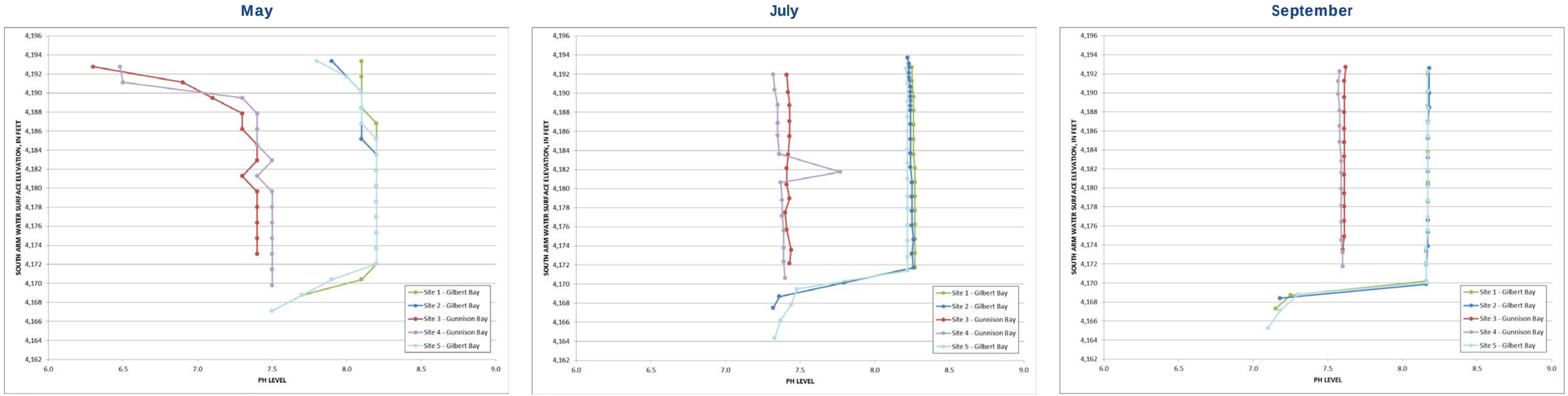
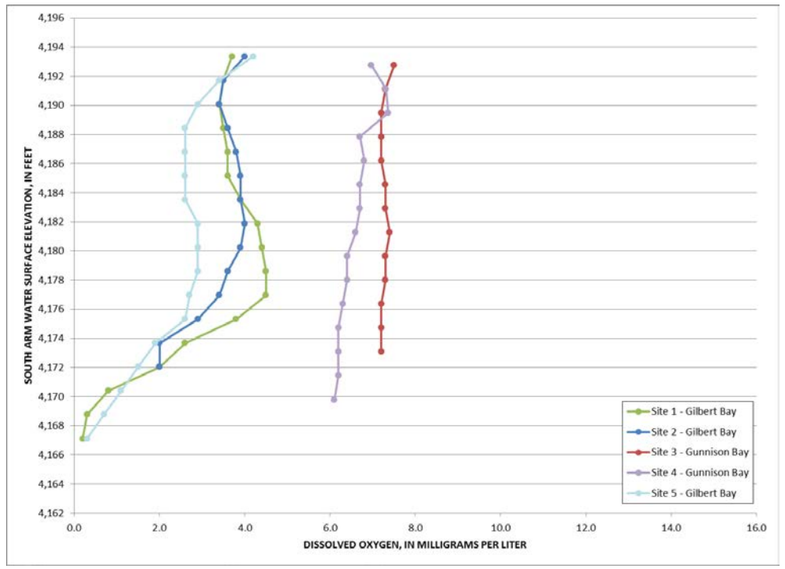
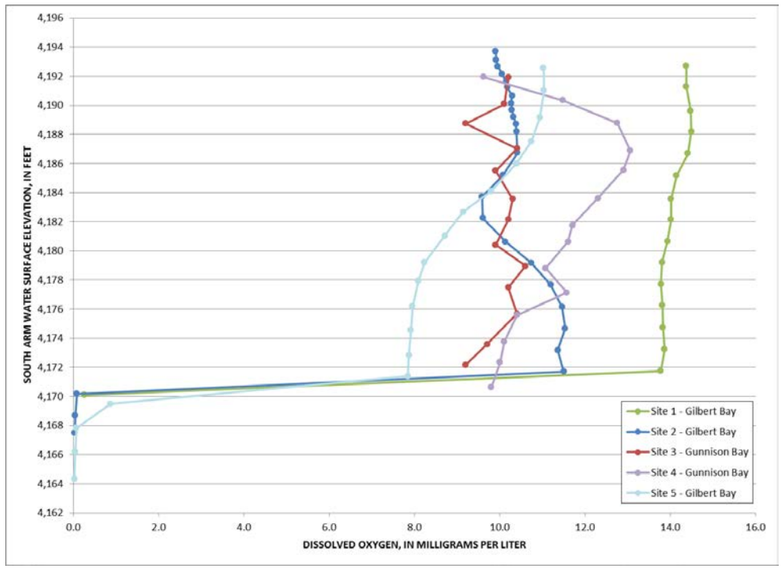


Figure 4. Dissolved Oxygen – 2014

May



July



September

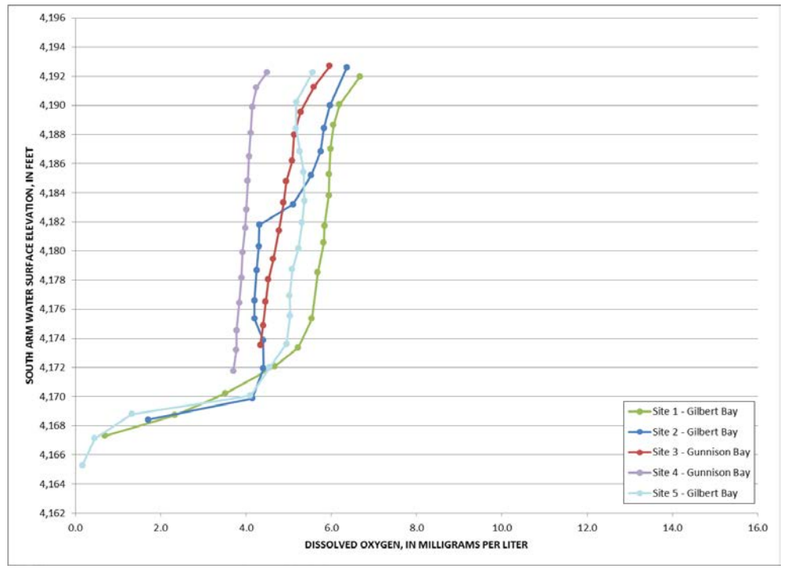
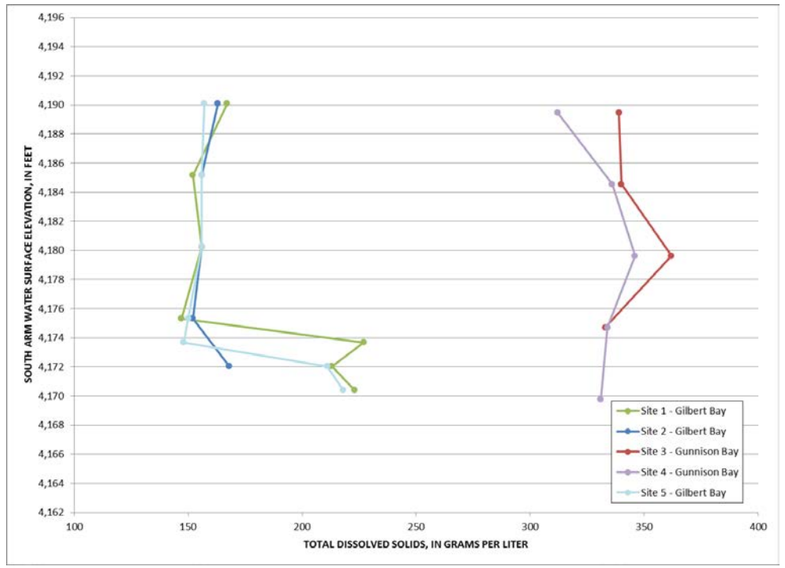


Figure 5. TDS Profiles – 2014

May



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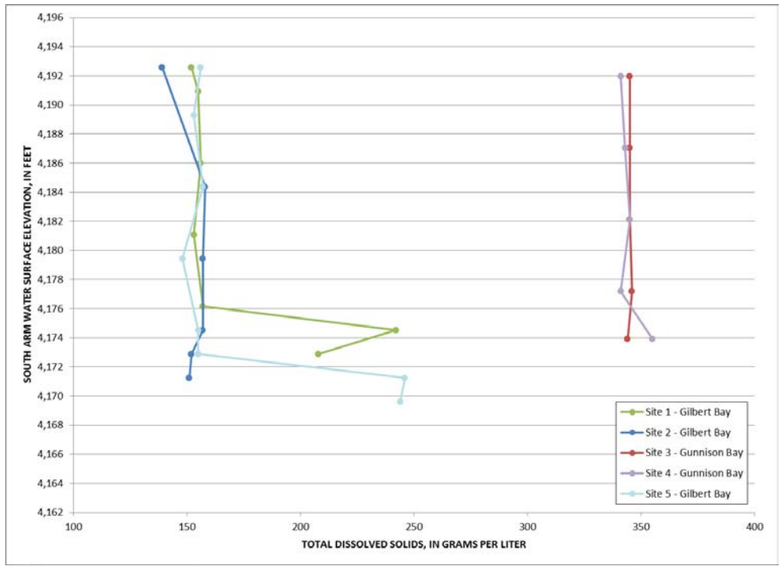

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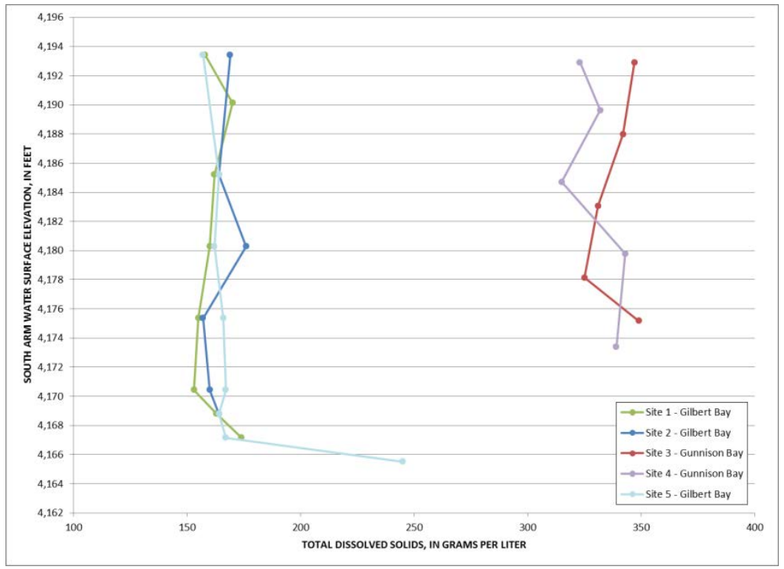
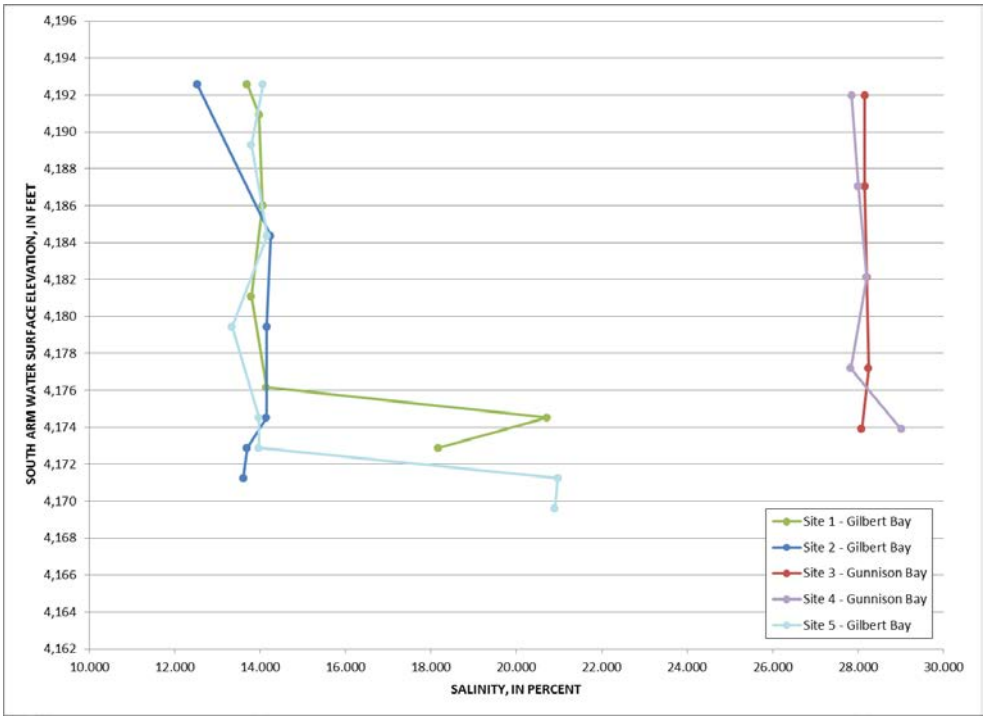


Figure 6. Salinity Profiles – 2014

July



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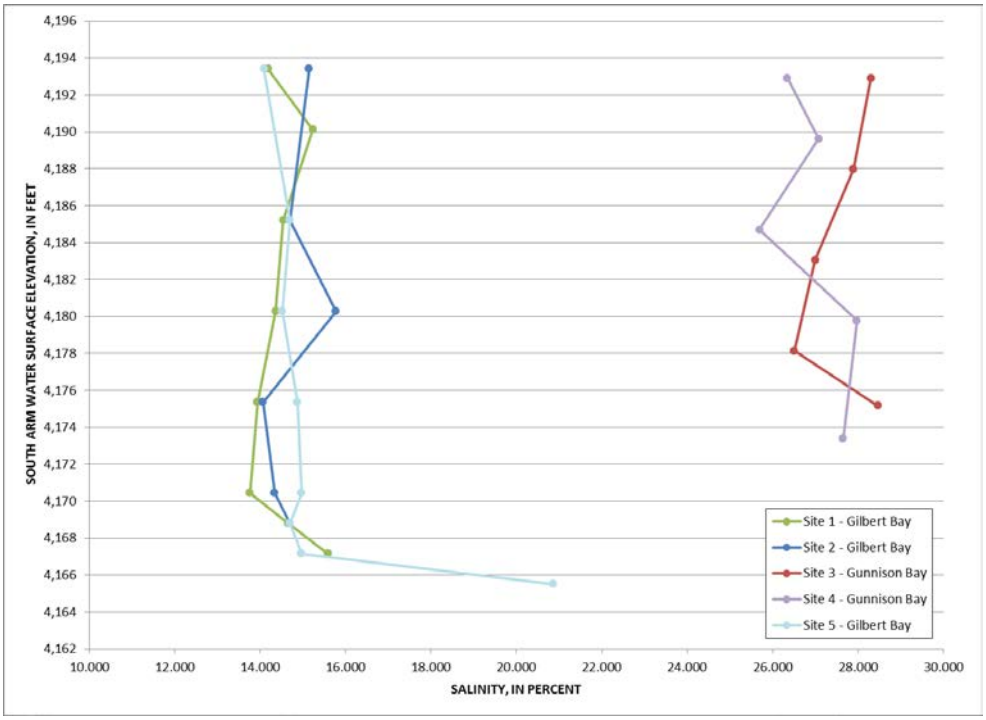


4.3 Surface Water Summarized Results

Analytical data collected from the three 2014 monitoring events are summarized in Table 8 below. These data were provided in their entirety in each of the 2014 interim monitoring event reports, which were published on August 22, 2014; October 13, 2014; and December 17, 2014 (UPRR 2014b, 2014c, 2014d). The complete data set is also available in Microsoft Excel format on request.

4.4 Brine Shrimp Summarized Results

Brine shrimp metals data and sample life stage composition are summarized in Table 9 on page 23. These data were provided in their entirety in each of the 2014 monitoring event reports, which were published on August 22, 2014; October 13, 2014; and December 17, 2014 (Appendices D and E, Brine Shrimp Analytical and Taxonomic Results, of UPRR 2014b, 2014c, and 2014d).

Life stages that contributed more than 1% to the overall sample population are included in Table 9 on page 23. Of note is the fact that less than 1% of each sample population was adult. However, there was still a noticeable increase in the percentage of eggs[1] between the May and September monitoring events. To summarize:

- The total brine shrimp count varied significantly among all sites for each monitoring event.
- In May 2014, total brine shrimp counts were observed with densities between 14,679 and 42,213 individuals per cubic meter. Most of the individuals were in the egg and early metanauplius life stages.
- In July 2014, total shrimp counts were observed with densities between 34,290 and 70,290 individuals per cubic meter. Nearly all individuals were in the egg stage.
- In September 2014, total shrimp counts were observed with densities between 64,601 and 127,187 individuals per cubic meter. Nearly all individuals were in the egg stage.
- The September data indicate that, while total counts varied, almost all individuals were classified as eggs.

4.5 Data Quality Assurance Summary

All data were collected in accordance with the IMP's Quality Assurance Project Plan (QAPP) (UPRR 2014a). After each monitoring event, UPRR subjected all data to QA/QC procedures including but not limited to spot checks of transcription, review of electronic data submissions for completeness, comparison of geographic information systems (GIS) maps with field notes on locations, and identification of any inconsistent data.

In addition, UPRR evaluated the resulting data for their consistency with the data quality objectives. Data quality objectives were met for the majority of analytes and samples; in the instances where data were found to be outside of QAPP specifications, the data were qualified. Additional details can be found in Appendix F of the associated 2014 interim monitoring event reports.

[1] For the purpose of this report, the terms *cyst* and *egg* are synonymous. The laboratory includes *cyst* in the category *egg*.

Table 8. Results of Chemical Analyses for All Monitoring Events – 2014

Parameter	Units	Gilbert Bay				Gunnison Bay	
		Surface Water		Brine Shrimp (wet-weight)		Surface Water	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Upper Water Column							
Hardness, total	mg/L	20,100	25,300	—	—	5,290	51,200
Sulfate [a]	mg/L	9,560	11,100	—	—	20,700	26,800
Arsenic	µg/L or mg/kg	86.4 **V**	113	2.65	7.79 **H**	129	180
Copper	µg/L or mg/kg	1.45	2.73	2.28	7.45 **H**	0.71	9.12
Mercury	ng/L or ng/g	3.77	10.1	19.5 **H**	61.3	2.89	27.2
Lead	µg/L or mg/kg	1.21	1.56	0.163	1.07 **H**	0.169	0.64
Selenium	µg/L or mg/kg	< 1.05	< 1.05	0.34	1.05 **H**	< 1.05	1.35
Zinc	µg/L or mg/kg	< 3.75	< 3.75	12.5	30.2 **H**	< 3.75	14.4
Lower Water Column							
Hardness, total	mg/L	20,300	38,000	—	—	5,200	52,200
Sulfate [a]	mg/L	10,600	16,900	—	—	20,400	26,400
Arsenic	µg/L	83.2	177	—	—	134 **V**	188
Copper	µg/L	2.04	22.5	—	—	0.98	5.36
Mercury	ng/L	6.69 **V**	85.0 **V**	—	—	2.26 **V**	38 **V**
Lead	µg/L	1.17	10.3	—	—	< 0.065	0.492
Selenium	µg/L	< 1.05	1.42	—	—	< 1.05	1.23
Zinc	µg/L	< 3.75	20.4	—	—	< 3.75	4.88

Table 8. Results of Chemical Analyses for All Monitoring Events – 2014

Parameter	Units	Gilbert Bay				Gunnison Bay	
		Surface Water		Brine Shrimp (wet-weight)		Surface Water	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum

H = Estimated. Samples warmed above 4 degrees Celsius during shipping.

N = Laboratory reports that quantity reported is estimated.

V = Upon data review and verification, determined to be estimated.

< = Not detected at the method reporting limit.

mg/L = milligrams per liter

µg/L = micrograms per liter

ng/L = nanograms per liter

[a] Data quality objectives for sulfate met quality assurance objectives (UPRR 2014a); UPRR notes that historical Utah Geological Society data were analyzed to a greater level of resolution.

Table 9. Brine Shrimp Metals Results by Monitoring Event and Life Stage Composition – 2014

Parameter		Site 1			Site 2			Site 5		
		May	July	Sept.	May	July	Sept.	May	July	Sept.
Life Stage Sample Composition (≥ 1% of at least one sample)										
Egg/cyst	Count per cubic meter	6,846 (46%)	33,858 (98.7%)	73,761 (97.4%)	22,176 (53%)	69,583 (99.0%)	64,601 (95.2%)	16,394 (58%)	46,740 (97.2%)	127,187 (98.0%)
Nauplius		402 (3%)	118 (0.3%)	363 (0.5%)	783 (2%)	123 (0.2%)	544 (0.8%)	1,423 (5%)	325 (0.7%)	325 (0.3%)
Early metanauplius		5,449 (36%)	283 (0.8%)	1424 (1.9%)	15,578 (37%)	245 (0.3%)	2558 (3.8%)	8,816 (31%)	813 (1.7%)	2013 (1.6%)
Mid metanauplius		1,292 (9%)	0 (0.0%)	0 (0.0%)	3,465 (8%)	92 (0.1%)	0 (0.0%)	1,114 (4%)	33 (0.1%)	65 (0.1%)
Total		**14,949**	**34,290**	**82,984**	**42,213**	**70,290**	**64,689**	**28,488**	**48,073**	**174,627**
Percent Solids										
Total solids	%	20.84	39.22	29.16	16.75	27.97	20.58	21.73	27.46	27.70
Metals, Wet-Weight										
Arsenic	mg/kg	2.73	7.79 **H**	5.76	2.65	3.85 **H**	5.15	3.07	5.42 **H**	6.05
Copper	mg/kg	2.31	7.45 **H**	2.89	2.28	4.82 **H**	3.90	2.86	5.79 **H**	3.35
Mercury	ng/g	29.1	34.9 **H**	57.0	32.5	19.5 **H**	48.3	40.3	45.0 **H**	61.3
Lead	mg/kg	0.163	0.889 **H**	0.270	0.353 **M**	1.07 **H**	0.670	0.214	0.955 **H**	0.245
Selenium	mg/kg	0.41	1.05 **H**	0.79	0.34	0.56 **H**	0.76	0.47	1.01 **H**	0.99
Zinc	mg/kg	12.5	30.2 **H**	18.7	15.1	14.9 **H**	17.8	16.8	24.8 **H**	20.4

Table 9. Brine Shrimp Metals Results by Monitoring Event and Life Stage Composition – 2014

Parameter		Site 1			Site 2			Site 5		
		May	July	Sept.	May	July	Sept.	May	July	Sept.
Metals, Dry-Weight										
Arsenic	mg/kg	13.1	19.9 **H**	19.7	15.8	13.8 **H**	25.0	14.1	19.7 **H**	21.8
Copper	mg/kg	11.1	19.0 **H**	9.93	13.6	17.2 **H**	18.9	13.2	21.1 **H**	12.1
Mercury	ng/g	140	89.0 **H**	195	194	69.6 **H**	235	182	164 **H**	221
Lead	mg/kg	0.781	2.27 **H**	0.927	2.11 **M**	3.84 **H**	3.26	0.983	3.48 **H**	0.885
Selenium	mg/kg	1.98	2.68 **H**	2.69	2.04	2.00 **H**	3.70	2.15	3.67 **H**	3.59
Zinc	mg/kg	59.8	77.0 **H**	64.0	90.3	53.3 **H**	86.6	77.4	90.2 **H**	73.5

H = Estimated. Samples warmed above 4 degrees Celsius during shipping.

M = Duplicate precision was outside of acceptance criteria. Result might be biased low and is estimated.

mg/kg = milligrams per kilogram

ng/g = nanograms per gram

5.0 Summary of Variances from the Interim Monitoring Plan

The 2014 monitoring was conducted in conformance with the IMP. Variances from the IMP were described in each monitoring event report. The following five variances are summarized below.

1. In May, July, and September, brine shrimp sample collection for metals analysis was limited to one vertical plankton tow per site instead of three tows as specified in the IMP. This was a result of an abundance of brine shrimp biomass, in that one vertical tow yielded the required sample amount. Data quality was not reduced due to this variance.
2. The IMP stated that the depth to the deep brine layer in Gilbert Bay would be determined via conductivity readings. However, in May, in-situ conductivity measurements could not be collected. The incorrect (low-range) probe was deployed on the Troll 9500 sensor packet. The correct probe was used for the July and September monitoring events.
3. In May, UPRR rejected the density measurements from the laboratory during the data-verification process (see Section 3.4, Quality Assurance, of this report). UPRR's stated corrective action was to adopt the hydrometer-specific gravity data measured from the same samples (UPRR 2014b). Specific gravity (dimensionless) was converted to density (grams per milliliter) before salinities were calculated to support the salinity calculation methodology. Data collected via hydrometer were found to be more consistent and predictable than laboratory measurements and were more consistent with UGS's analysis methodology. Hydrometer-derived data combined with laboratory TDS values are reflected in the calculated salinity profiles in all reports.
4. Dissolved oxygen sonde measurements, not laboratory measurements, were used to characterize dissolved oxygen conditions.
5. The IMP requires the monitoring team to collect density and TDS samples "every 1.5 meters" above the deep brine layer and "every 0.5 meter" within the deep brine layer, if present. In September, one of the density and TDS samples near the surface was not collected at Gilbert Bay site 2. However, sample depths above and below the missing sample depth had similar results.

Additional details can be found in Appendix F, Data Quality Assurance Documentation, of each interim monitoring event report.

6.0 Determination of No Adverse Effects

UPRR evaluated interim monitoring data collected and reported for South Arm salinity and WSEs for determination of no adverse effects to the Great Salt Lake due to the temporary closure of the east culvert. This evaluation is provided to support the data interpretation approach as described in Section 8.1, Data Interpretation Approach, of the IMP (UPRR 2014a) and Special Condition 2(c) of the USACE NWP 14 for the temporary closure of the east culvert (USACE 2013).

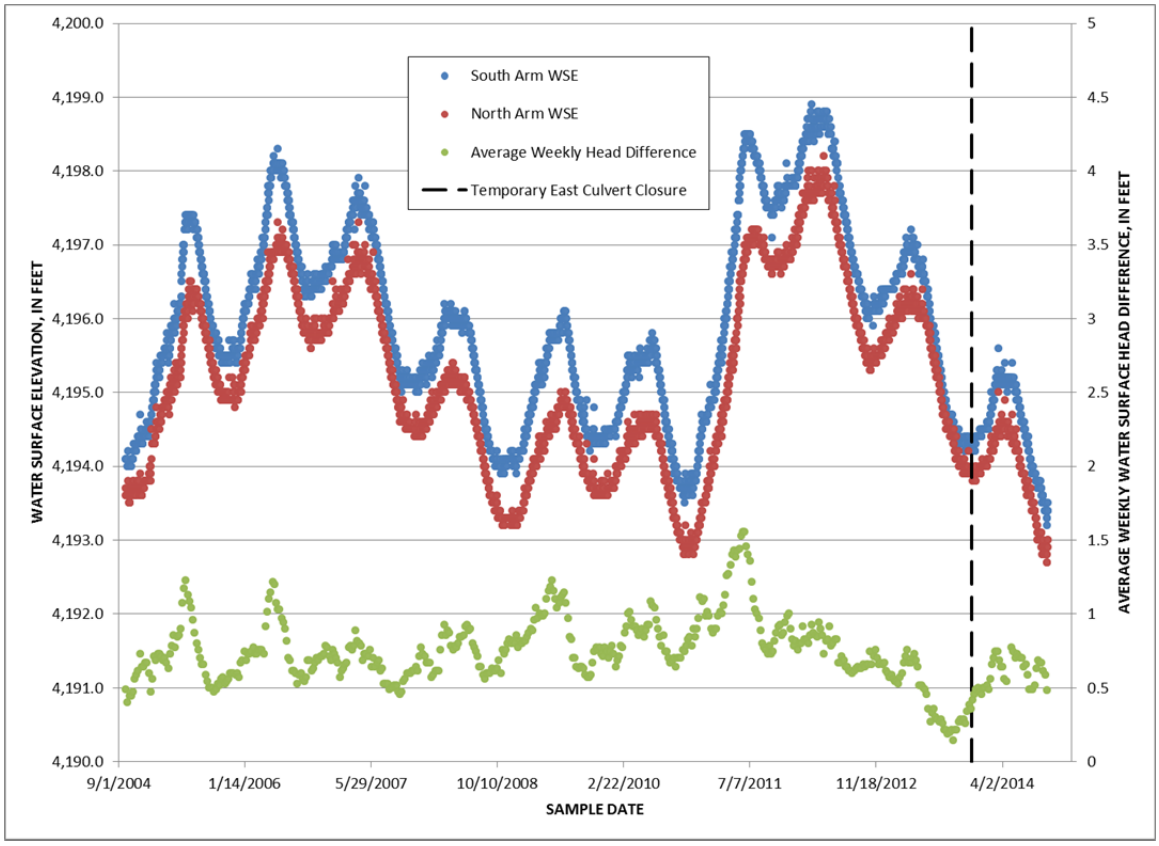
The following sections compare the observed WSE and measured South Arm salinity data to the historic water surface elevation and UGS salinity data to support this determination.

6.1 Water Surface Elevation

UPRR acquired real-time WSE data as recorded by the USGS gages located on the Great Salt Lake (see Figure 1, Interim Monitoring Sampling Sites and USGS Gage Locations, and Section 4.1, Water Surface Elevation, of this report). The North Arm's WSE is monitored at the Saline gage at the southeast corner of the North Arm at USGS site 10010100. The South Arm's WSE is monitored at the Saltair gage at the south end of the South Arm at USGS site 10010000. These data are available at ut.water.usgs.gov/greatsaltlake/elevations. UPRR has collected the historical real-time data for the WSEs over the last 10 years (USGS 2014). UPRR (1) computed weekly averages and the difference between the South Arm WSE and the North Arm WSE (head difference; see Table 5, Water Surface Elevation and Computed Head Difference, and Section 4.1, Water Surface Elevation, of this report) and (2) graphed the resulting data in Figure 7 below.

The data collected and provided below indicate that, since the temporary closure of the east culvert, the head differences are consistent with the head differences of the past 10 years through October 2014. Based on this analysis, UPRR determined that the temporary closure of the east culvert has not resulted in any adverse head difference effects on the Great Salt Lake.

Figure 7. North and South Arm WSE and Head Difference



6.2 South Arm Salinity

UPRR compared average salinities computed from interim monitoring event measurements for July and September to average historic UGS salinities and more recently collected measurements to conduct the evaluation.

UPRR used the UGS Great Salt Lake Brine Chemistry Database to define the historic South Arm salinity range (UGS 2012). By analyzing the reported density, TDS by percent weight (% wt TDS), and WSE data for the three South Arm locations of AC3, AS2, and FB2, UPRR developed a graph of average South Arm salinities compared to reported South Arm WSEs taken on the day that UGS conducted the sampling. A qualitative analysis of the uncertainty and error associated with the collection and analysis of the UGS data was conducted, and UPRR, with UDWQ's concurrence, applied a 5% error to the averaged data to develop the historic South Arm salinity range.

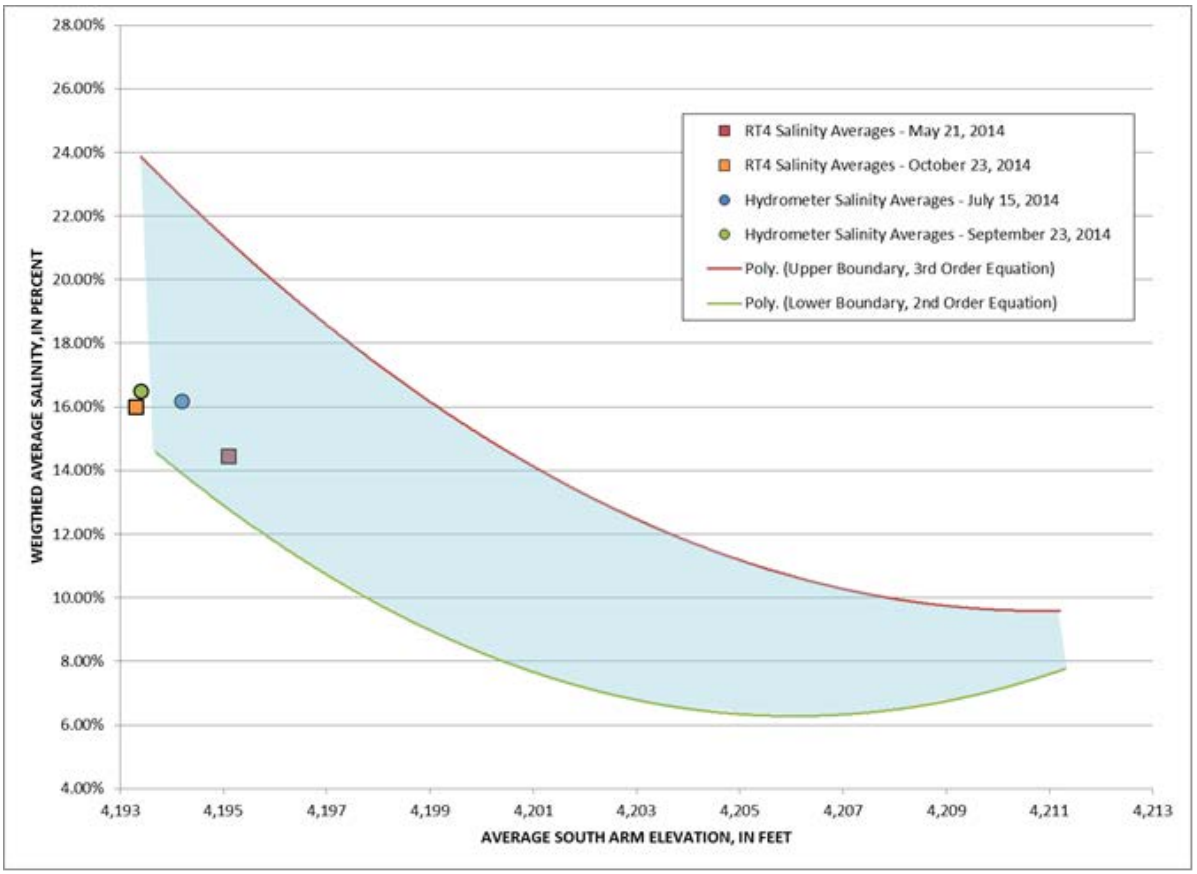
These three UGS sampling locations were chosen because of the amount of data collected consistently over the period of record (1966–2011) and because these sampling locations were used by USGS and UPRR in the calibration process for the water and salt balance model that was used to conduct the impacts re-evaluation.

UPRR has plotted and compared the interim monitoring average South Arm salinity data for the July and September monitoring events to the average historic South Arm salinity (Figure 8 below).

The historic collection of lake samples and analysis for salinity occurred over a South Arm WSE range of about 4,194 feet to about 4,212 feet. Due to current low lake WSEs, the salinity data collected by UPRR in September 2014 and by UGS in October 2014 correspond to WSEs that are slightly lower than the historic data represents in Figure 8. To better understand this, UPRR requested 2014 sampling data from UGS. Shown in Figure 8 for reference purposes only is the average salinity for UGS site RT4 which was collected on May 21 and October 23, 2014 (UGS 2014). UGS provided density data collected at site RT4 at various depths. Using the same methodology as described in Section 4.2, Vertical Profiles, of this report, UPRR calculated average salinities for each monitoring event. The UGS site RT4 is located in Gilbert Bay south of the UPRR causeway and sampling sites, as shown in Figure 1, Interim Monitoring Sampling Sites and USGS Gage Locations, of this report.

The South Arm interim monitoring salinity data and the comparative analysis indicate that South Arm salinities are consistent with the reported historic South Arm salinities. These salinities are also consistent with recent UGS data for nearby site RT4. Based on this analysis, UPRR determined that the temporary closure of the east culvert has not resulted in any adverse salinity effects on the South Arm of the Great Salt Lake.

Figure 8. Interim Monitoring, Recent UGS and Historic South Arm Salinity Comparison



7.0 References

[EPA] U.S. Environmental Protection Agency

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2014c Interim Monitoring Report – July 2014 Monitoring Results. October 13.

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