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August 22, 2012

Mr. Nichols von Stackelberg, PE
Utah Division of Water Quality
PO Box 144870
Salt Lake City UT 84114-4870

RE: Union Pacific Railroad Temporary East Culvert Closure, Great Salt Lake
Utah 401 Water Quality Certification No. SPK-2011-00755
Response to Modeling Report Review Comments
Project Impacts Re-evaluation, Water and Salt Balance Model, Supplemental Information

Dear Mr. von Stackelberg:

Union Pacific Railroad (UPRR) is responding to the Utah Division of Water Quality's (UDWQ) May 21, 2014, letter titled "Modeling Report Review Comments" (UDWQ 2014a) that described UDWQ's concurrence with the water and salt balance modeling methods for the Utah 401 Water Quality Certification and with the results and findings presented in the *Great Salt Lake Causeway Final Water and Salt Balance Modeling Report* (Final Modeling Report; UPRR 2014a). UDWQ's letter also requested supplemental information and analyses to further characterize the results and uncertainty of the water and salt balance model.

UPRR has consulted with its modeling team in order to prepare this response. The modeling team includes HDR, Mr. Kidd Waddell (U.S. Geological Survey, retired), and Mr. Wally Gwynn (Utah Geological Survey, retired). This letter responds to the request for supplemental information and analysis.

In addition to the UDWQ review comments, UDWQ transmitted the U.S. Geological Survey (USGS) *Technical Review of the UPRR Great Salt Lake Causeway Bridge Construction Project, Final Modeling Report*, dated May 2, 2014. This letter also includes a response to the USGS request for supplemental information.

Based on the Final Modeling Report, UPRR conducted subsequent modeling to evaluate adjustments to the causeway opening that would meet the mitigation objective, which is to duplicate, as closely as possible, the transfer of water and salt that was occurring through the causeway with the culverts functioning as documented in November 2012 when it was necessary to close the first culvert (the west culvert). UPRR has submitted a Bridge Evaluation Report (UPRR 2014b), which reflects the proposed adjustments to construct a 150-foot opening in the causeway to better meet the mitigation objective. Therefore, the response to both UDWQ's and USGS's modeling review comments includes information in the Bridge Evaluation Report.

RESPONSE TO UDWQ REVIEW COMMENTS

Results Comparison

1. Net Salt Load

UDWQ requested a table that summarizes the salt loads and net salt transfer load calculations for each model, for ease of comparison. UPRR submitted the North and South Arm salt loads to UDWQ in both the Final Modeling Report (UPRR 2014a) and the Bridge Evaluation Report (UPRR 2014b) with time series charts, model outputs, and appendix tables. Nonetheless, Table 1 below shows the salt load tables based on the model outputs for the modeling step simulations. The table identifies beginning and ending salt loads for each arm of the lake for each simulation (culverts, the original 180-foot opening, and the proposed 150-foot opening).

2. Varying Hydrology, Salinity, and Salt Load Difference

UDWQ requested that, for the 2012 UPRR/USGS Varying Hydrology Model for the wet, mild, and dry hydrologic cycles, UPRR report the difference in salt load and the difference in salinity. UPRR provided the salt loads and salinities over the 25-year simulation period for the culvert and the proposed 180-foot causeway opening simulations in Appendix D of the Final Modeling Report (UPRR 2014a, Figure 5 and Figure 6, respectively). UPRR provided the comparison of the culvert and the new 150-foot causeway opening simulations in the Bridge Evaluation Report (UPRR 2014b, Figure 5 and Figure 6, respectively).

To provide the information UDWQ has requested, UPRR has included the same figures below with the additional information requested. Figures 1 and 2 below present the difference in salt load and salinity for the culvert and the 180-foot causeway opening simulations, and Figures 3 and 4 below present the salt load information for the culvert and the 150-foot causeway opening simulations.

Table 1. Salt Load and Net Salt Transfer for UPRR/USGS Water and Salt Balance Model Simulations

in billion tons

Parameter	2012 UPRR/USGS Model			2012 UPRR/USGS Varying Hydrology Model								
				Wet Cycle			Mild Cycle			Dry Cycle		
	Culverts	180-foot Opening	150-foot Opening	Culverts	180-foot Opening	150-foot Opening	Culverts	180-foot Opening	150-foot Opening	Culverts	180-foot Opening	150-foot Opening
North Arm												
Beginning salt load [a]	2.47	2.47	2.47	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
Ending salt load	3.15	2.40	2.91	2.20	2.09	2.14	2.22	2.07	2.20	2.70	2.37	2.87
Change	+0.68	–0.07	+0.44	–0.85	–0.96	–0.91	–0.83	–0.98	–0.86	–0.35	–0.68	–0.18
South Arm												
Beginning salt load [a]	2.08	2.08	2.08	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Ending salt load	1.40	2.16	1.65	2.35	2.46	2.42	2.33	2.48	2.36	1.85	2.18	1.68
Change	–0.68	+0.08	–0.43	+0.85	+0.96	+0.92	+0.83	+0.98	+0.86	+0.35	+0.68	+0.18
Net salt transfer	0.68 to the North Arm	0.08 to the South Arm	0.43 to the North Arm	0.85 to the South Arm	0.96 to the South Arm	0.92 to the South Arm	0.83 to the South Arm	0.98 to the South Arm	0.86 to the South Arm	0.35 to the South Arm	0.68 to the South Arm	0.18 to the South Arm

[a] Measured salt loads for 1987 are used to begin the 1987–2012 simulation for both the North and South Arms. Likewise, the measured salt loads in 2012 were used to begin the varying hydrology model simulations. Note that the total load (north plus south loads) is different for the 2012 UPRR/USGS Model and the 2012 UPRR/USGS Varying Hydrology Model because of the losses to the West Desert Pumping Project that are accounted for during 1987–2012 simulations.

Figure 1. 2012 UPRR/USGS Varying Hydrology Model – Salt Load Comparison, Culverts and 180-foot Causeway Opening

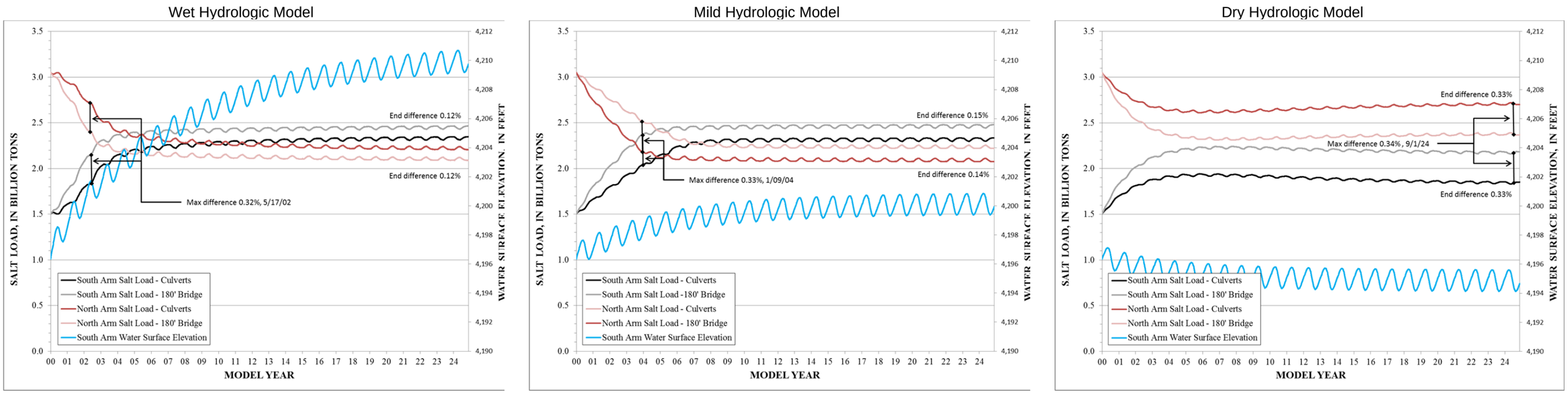


Figure 2. 2012 UPRR/USGS Varying Hydrology Model – Salinity Comparison, Culverts and 180-foot Causeway Opening

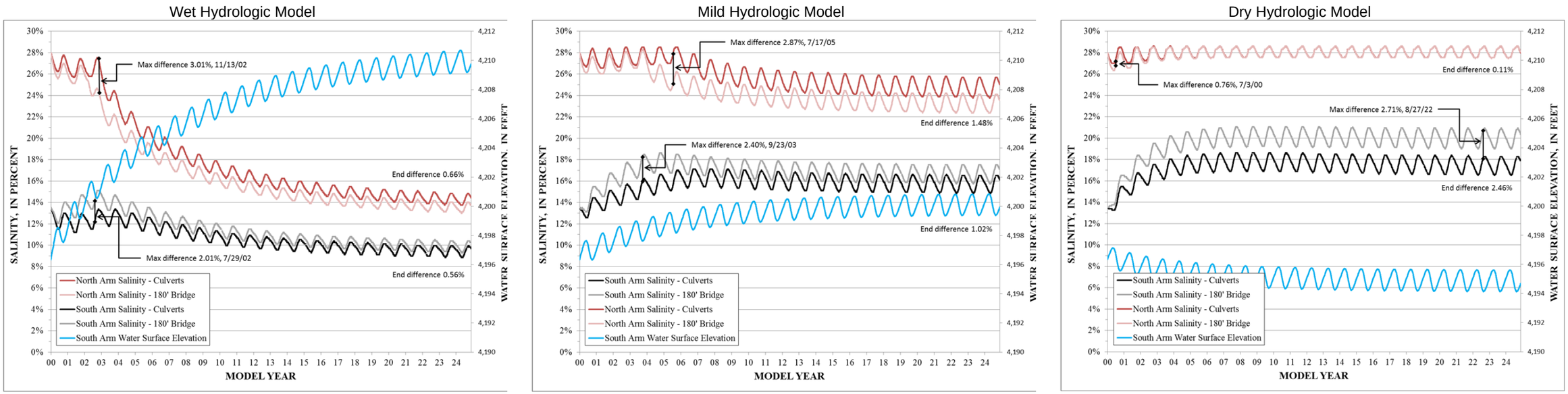


Figure 3. 2012 UPRR/USGS Varying Hydrology Model – Salt Load Comparison, Culverts and 150-foot Causeway Opening

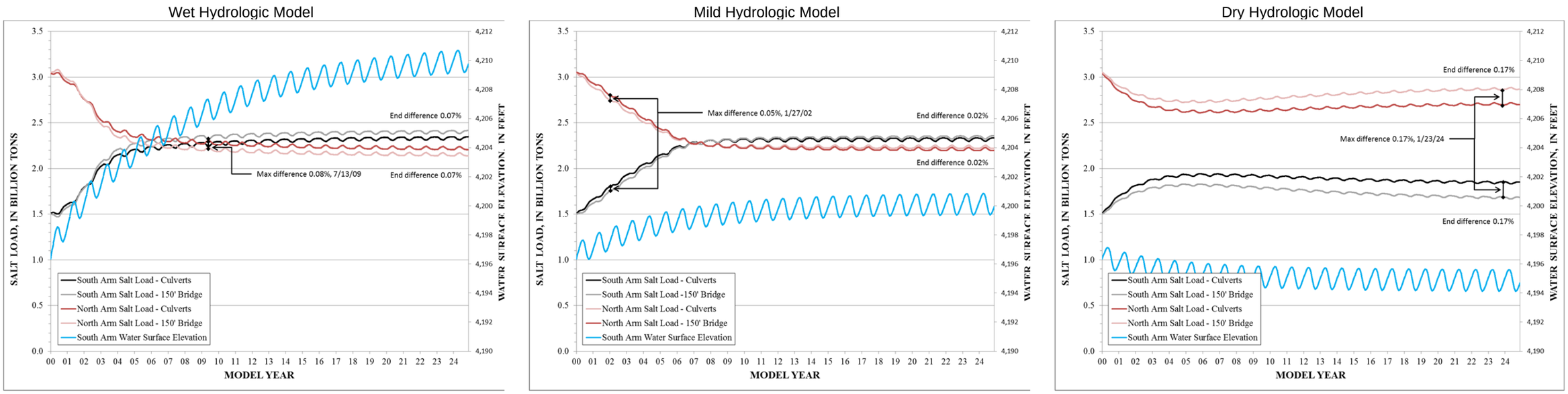
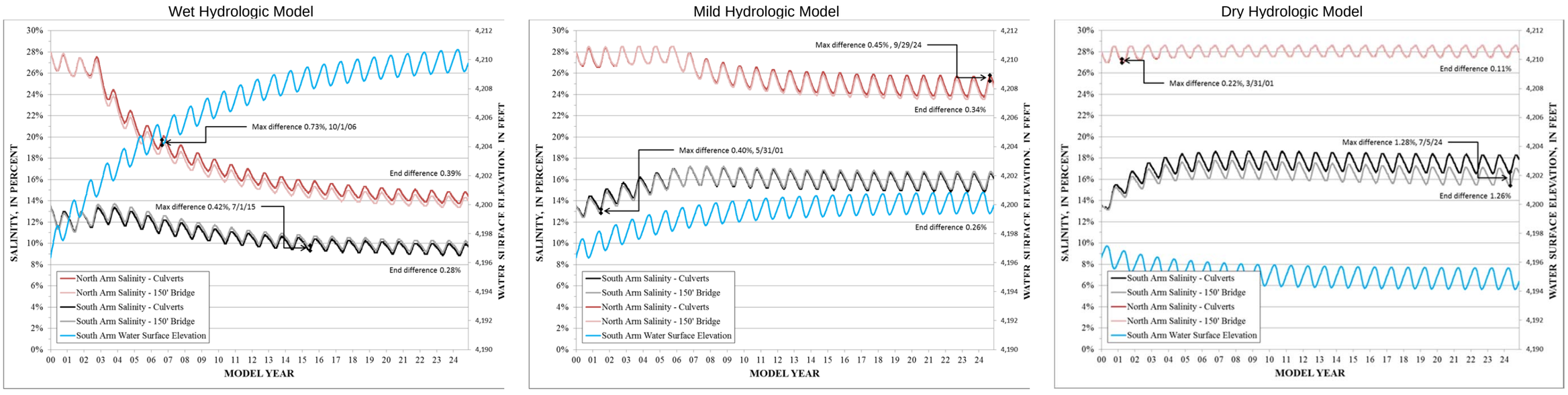


Figure 4. 2012 UPRR/USGS Varying Hydrology Model – Salinity Comparison, Culverts and 150-foot Causeway Opening



Model Limitations

UDWQ requested that additional information about the model capabilities and limitations be provided. UPRR will refer to existing USGS documentation to respond to this request.

USGS initially developed the water and salt balance model in 1973 and has added capabilities and refinements to the model code over the years. The water and salt balance model consists of water budget and salt budget computations to compute salt loads for segmented portions of the Great Salt Lake for actual rising and falling surface water and groundwater inflows and outflows (evaporation). Net water movement and salt load transfer between segmented lake bays are calculated to help planners select engineering options when constructing causeway modifications or new diking alternatives (USGS 1973). The water and salt balance depends on the amount of inflows and outflows and the conveyance properties of the causeway and/or dikes that cross the lake (USGS 2000).

UPRR was required by UDWQ (condition 4 of the Temporary East Culvert Closure Project 401 Certification) and by the U.S. Army Corps of Engineers (USACE) to update, recalibrate, and run the 1998 USGS Water and Salt Balance Model (1998 USGS Model) as described in Water-Resources Investigations Report 00-4221, *Water and Salt Balance of Great Salt Lake, Utah, and Simulation of Water and Salt Movement through the Causeway, 1987–98* (USGS 2000). UPRR undertook the modeling effort with consultation from engineering consultants with HDR and from Mr. Kidd Waddell (USGS, retired) and Mr. Wally Gwynn (Utah Geological Survey, retired).

UPRR conducted the water and salt balance modeling effort, which included three steps to assist in the evaluation of impacts from the proposed culvert closure and bridge construction project. Each step is documented in the Final Modeling Report (UPRR 2014a). UPRR took the greatest of care to respect the 1998 USGS Model's assumptions, limitations, and capabilities in order to simulate the effects of water and salt transfer through the causeway with free-flowing culverts and with the proposed 180-foot and 150-foot openings. In addition to UPRR's consultants, UPRR coordinated with UDWQ and submitted the modeling documentation to USGS for a technical review of the methods, revisions, and outputs. USGS and UDWQ concurred with UPRR's modeling techniques and concurred that the modifications made to the 1998 USGS Model were consistent with past USGS water and salt balance models.

UPRR refers to the USGS water and salt balance model's published documentation to provide detailed information about the capabilities and limitations of the model (and subsequent revisions to the model). Table 2 lists the specific pages in the various USGS models' documentation that provide summary information about the capabilities and limitations for that specific version of the model.

Table 2. Summary of USGS Water and Salt Balance Model Documentation

Model Documentation Report	Reference	Model Capabilities (pages)	Model Limitations (pages)
Water-Resources Bulletin 18	USGS 1973	1	7–8
Water-Resources Bulletin 21	USGS 1977	1, 3, 4	27, 28
Cooperative Investigations Report No. 20	USGS 1980	4–18, 23	21
Water-Supply Paper 2450	USGS 1996	3	12, 14, 19
Water-Resources Investigations Report 00-4221	USGS 2000	Entire document	20, 24, 25

It must be noted that many of the limitations and assumptions listed in the reports issued over the years have changed as the model has been updated and new model documentation has been published. For example, Water-Resources Bulletin 18, page 8, states that the culvert flow equations are not valid for stratified flows in a submerged culvert. This limitation was removed as a result of the inclusion of Holley's equations in Water-Resources Investigation Report 00-4221. In fact, several of the model updates were designed to eliminate some of the limitations identified in previous versions of the model. Some limitations have remained through all revisions. The model limitations described in Water-Resources Investigation Report 00-4221 reflect most recent published changes to the code.

Model Uncertainty

1. Surface Water Inflows

UDWQ requested that UPRR identify the following point-source wastewater inflows and industrial transfers and, if UPRR determines that they are important, include these inflow amounts in future simulations. The requested facility flow data are presented in Table 3 based on the Utah Pollutant Discharge Elimination System (UPDES) permitted design capacity, as published on the State of Utah's online UPDES permit website (UDWQ 2014b). Note that these are maximum facility permit discharge numbers and do not represent actual or current monthly or annual average flows. The 2012 UPRR/USGS Model used measured flows from river/creek gages or estimated monthly flows from correlations for the lake surface water inflows.

Table 3. UPDES Permitted Discharges to the Great Salt Lake

Facility	Design Capacity, MGD	UPDES Permit Number	PDF Page Reference	Discharge Location
Brigham City WWTP	6	UT0022365	51	South Arm
North Davis WWTP	34	UT0021741	54	South Arm
South Davis North WWTP	12	UT0021636	58	South Arm
South Davis South WWTP	4	UT0021628	46	South Arm
Central Davis WWTP	6.3	UT0020974	10	South Arm
Great Salt Lake Minerals	0.09	UT0000647	1	South Arm
Total	**62.39**			

WWTP = wastewater treatment plant; MGD = million gallons per day

The documented total permitted design flows (facility capacity) of these six facilities are about 62 MGD (million gallons per day), which converts to about 70,000 AF/yr (acre-feet per year). For the 2012 UPRR/USGS Model, the average surface water inflow was about 2.02 MAF/yr (million acre-feet per year), so the 70,000 AF/yr represents about 3.5% of the average measured (or estimated) values.

For the varying hydrology simulations, these permitted facility discharge inflows represent about 4.1% of the 1.7 MAF/yr surface water inflow for the varying hydrology, dry simulation surface water inflow; 2.7% of the of 2.6 MAF/yr surface water inflow for the varying hydrology, mild simulation surface water inflow; and about 1.7% of the 4.1 MAF/yr surface water inflow for the varying hydrology, wet simulation surface water inflow. UPRR determined that these maximum facility design flows are not significant, nor are they consistent with the hydrologic inputs into the water and

salt balance model (hydrologic inputs are based on gaged data of actual surface water inflows) and therefore will not include these flows in future simulations.

2. Causeway Fill Flows

UDWQ requested a sensitivity analysis of the hydraulic conductivity of the causeway fill on the predicted salt load in the South Arm to improve its understanding of the importance of this parameter in the 2012 UPRR/USGS Model. The model's sensitivity to hydraulic conductivity values can be best addressed by comparing the effects of past calibration adjustments to the effect on salt load computations.

In Water-Supply Paper 2450 (USGS 1996, Figures 9 and 10), the original causeway hydraulic conductivity values, determined by field investigations (USGS 1973), were reduced by 40% to calibrate the salt balance. The reduction caused the model-computed South Arm salt load to decrease and the North Arm salt load to increase during 1980–1986 to better match measured conditions. The document notes that the standard error estimate for salt loads was 5% for the South Arm and 4% for the North Arm with this calibration effort. UPRR notes that, between 1980 and 1986, the lake was approaching historic high levels, and the causeway fill was being raised and widened to protect railroad operations.

Loving and others (2002) further reduced the hydraulic conductivity values of the fill (below 4,200 feet in elevation) by 90% of those of original values, based on field investigations, for calibration purposes. This adjustment had a similar effect on salt transfer for the time period 1987–1998; that is, the model-computed salt load transfer to the South Arm was reduced, and that of the North Arm was increased, to best match the measured conditions.

In calibrating the model for 1999–2012, UPRR (2014a) compared model-computed and measured salt loads and found that hydraulic conductivity values would have to be decreased in order to achieve a better match between measured and computed salt loads during 1999–2005 but then would need to be increased during 2006–2012 to achieve a comparable agreement between the measured and computed salt loads. Although the comparison of the computed versus measured salt loads for 1999 to 2005 would be improved by a decrease in the hydraulic conductivity values, the comparison for 2006 to 2012 would be degraded by this decrease. If the hydraulic conductivity values were reduced for 1999 to 2005, then the values for 2006 would have to be retained, which would require an increased value or the same as that used by Loving and others. There was no logical reason, based on UPRR causeway maintenance operations, to expect a reversal in the trend in hydraulic conductivity values during 1999–2012. UPRR determined, based on the reasons mentioned above, that the causeway fill conductivity values produced a calibration with good correlation to measured salt loads, so that the hydraulic conductivity values for the 2012 UPRR/USGS Model calibration were not revised from those determined by Loving and others for 1987–1999.

3. Breach and Culvert Flows

UDWQ requested scatter plots of simulated breach and culvert flows versus observed breach and culvert flows to help characterize uncertainty in the calibrated 2012 UPRR/USGS Model.

In the UPRR Modeling Step 2 Report, Section 7.2, model error for the flows through the existing 300-foot bridge were calculated, comparing measured flows to computed flows for the calibrated model. To provide that information in a graphic form, UPRR has included Figures 5 and 6 below for

north-to-south flow and south-to-north flow through the 300-foot bridge, comparing model computed to measured flows.

Note that the 2012 UPRR/USGS Model calibration process used read-in measured values for the breach and the culvert flows. Once the model was calibrated, the code was modified to calculate breach flows while using the read-in measured flows for the culverts. The computed breach flows were then compared to the measured breach flows to provide these charts and calculate the model error. This calibrated model with calculated breach flows was used only to determine the model error for the breach flows, since the culvert and bridge simulations computed all flows. This procedure to compare measured flows for the breach to computed flows followed the documented USGS procedures (USGS 2000, Appendix E).

In response to whether the model tends to “bias” the results due the computed flow rated, UPRR responds that the measurements of flow over the years have been conducted by USGS with various types of equipment and with various water surface elevations (WSE) and weather conditions. Further discussion of USGS flow measurements is given with the next model review response (4. USGS-Measured Breach and Culvert Flows).

To provide additional information, UPRR replicates in Figure 7 below the scatter plots USGS provided in Water-Supply Paper 2450 for the comparison of measured and computed flows through the breach for 1984–1986 (USGS 1996). UPRR understands that, during this period, more-accurate monitoring of the cross-sections and flows was conducted, since the WSE was at the historic high and flows through the breach in both directions covered a larger range of values. As shown in Figure 7, there is good agreement between the measured and computed flows during this time period.

UDWQ requested similar scatter plots of measured flows versus computed flows for the culverts. These data are not available. For the calibrated 2012 UPRR/USGS Model, culvert flows were not computed, since they were frequently obstructed and the computations reflect only free-flowing conditions. UPRR read in the measured flows in accordance with procedures documented by USGS (2000, Appendix F). Comparisons of the computed culvert flows to the measured culvert flows would not be of value, since the computed flows assume free-flowing conditions and a specified invert elevation (as of November 2012), whereas the measured flows were for each culvert individually under varying states of obstruction and at various invert elevations over the years.

Figure 5. Calibrated 2012 UPRR/USGS Model – Computed versus Observed South-to-North Breach Flows

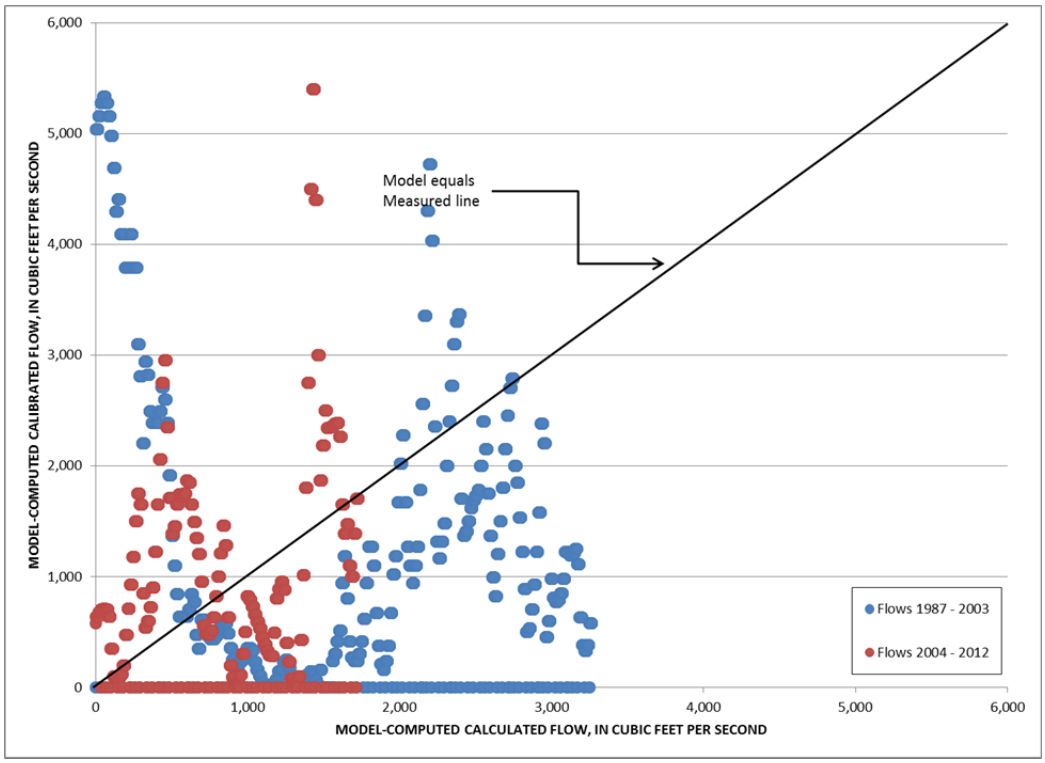


Figure 6. Calibrated 2012 UPRR/USGS Model – Computed versus Observed North-to-South Breach Flows

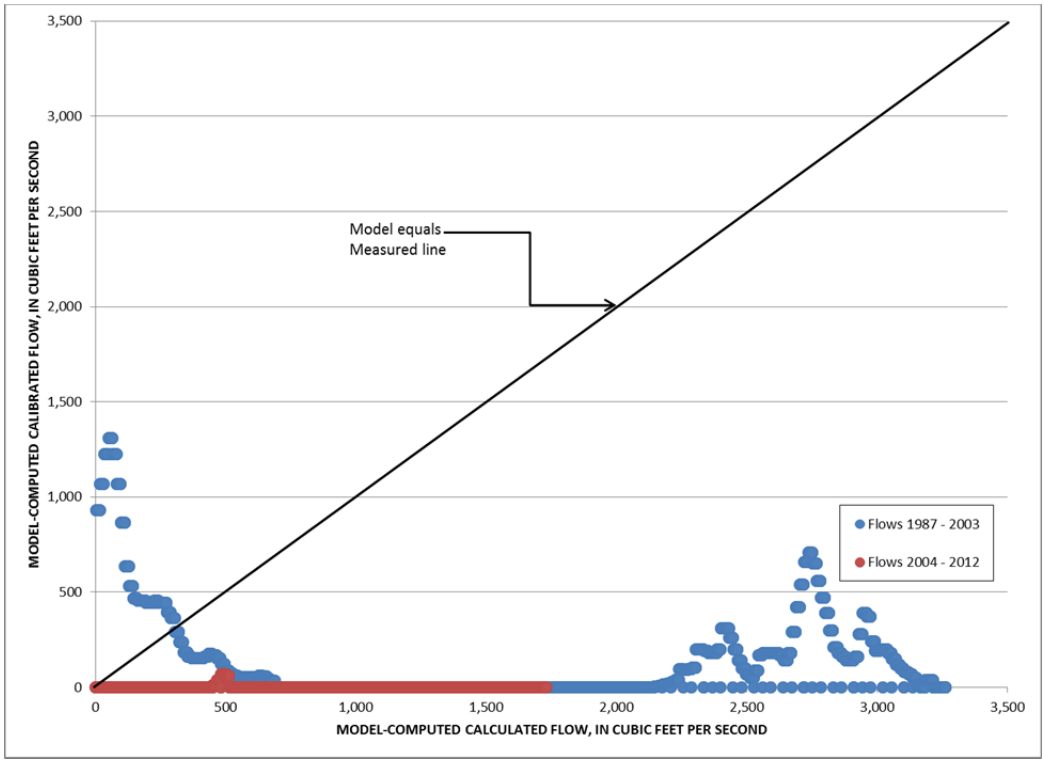


Figure 7. 1984–1987 USGS Water and Salt Balance Model – Computed versus Observed North-to-South Breach Flows

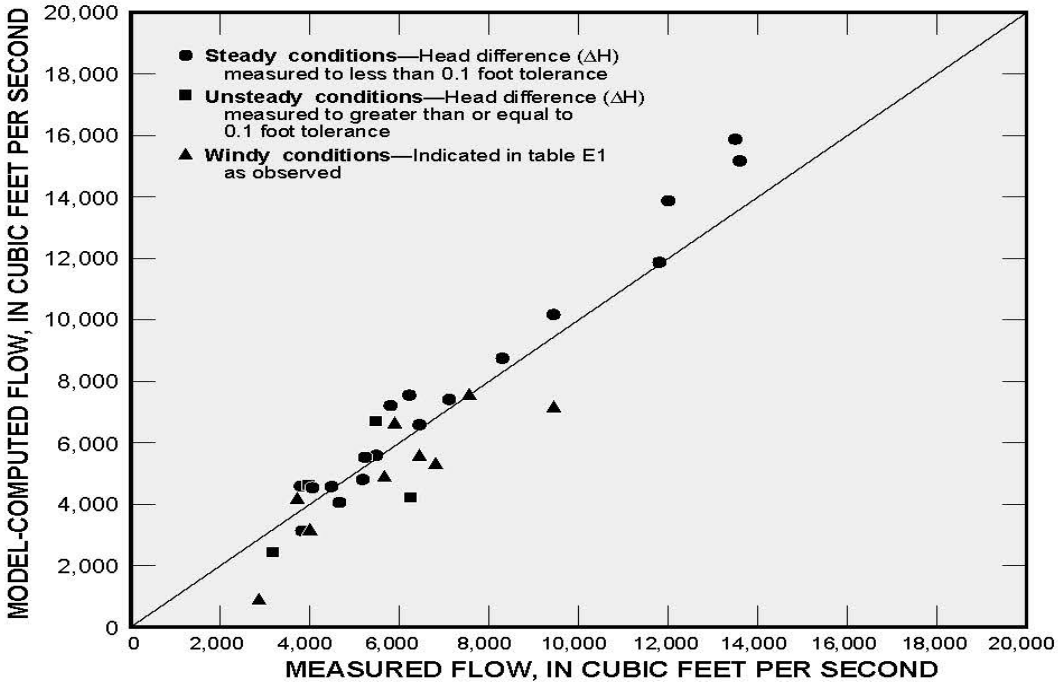


Figure E2. Relation of model-computed to measured south-to-north flow (QSB) through the breach in the causeway across Great Salt Lake, Utah, 1984–86.

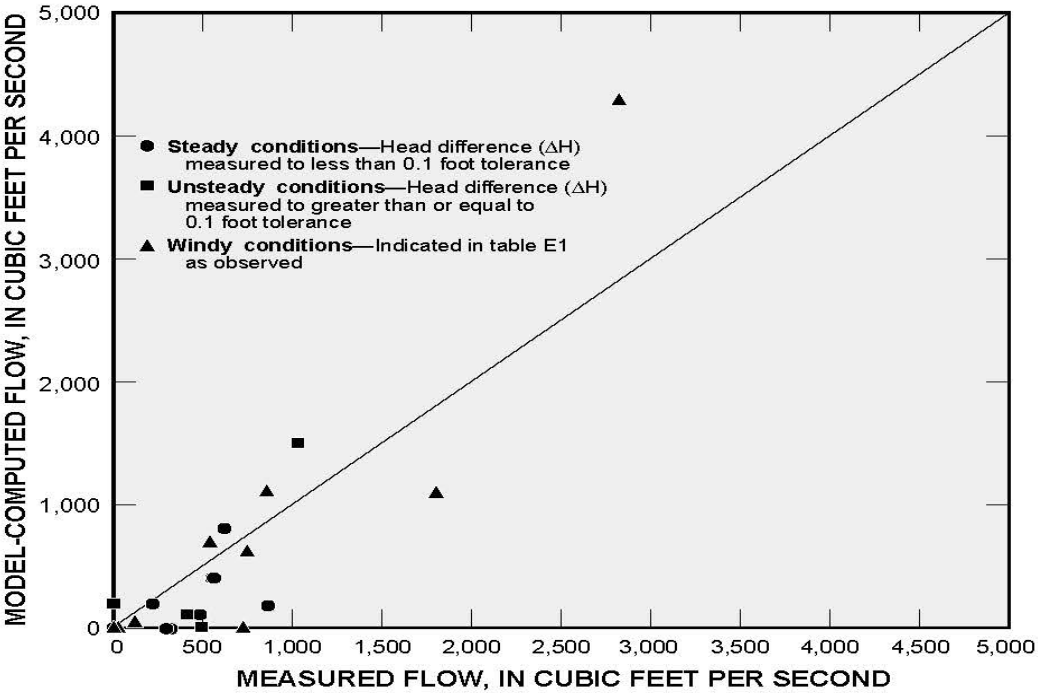


Figure E3. Relation of model-computed to measured north-to-south flow (QNB) through the breac in the causeway across Great Salt Lake, Utah, 1984–86.

4. USGS-Measured Breach and Culvert Flows

UDWQ requested additional information regarding the cause of the apparent USGS measured flow discrepancies between the east and west culverts and their implications on the culvert simulations. We assume that UDWQ believes that the east and west culvert flows should be more similar than what was reported and that such a difference is a discrepancy. This is not necessarily a discrepancy as the two culverts are not exactly physically similar in relation to each other, as discussed below.

UPRR notes that the culvert simulation model runs for the 2012 UPRR/USGS Model and the 2012 UPRR/USGS Varying Hydrology Model do not reflect historic conditions over time, but, for regulatory purposes, reflect the nature (free-flowing) and position (2012 invert) of the culverts before their closure. In the model code, both culverts were represented as a single causeway opening, consistent with prior USGS models.

UPRR's review of the USGS measured flow data and flow collection notes did not reveal an easily described reason why the measured bidirectional flows were not more similar. UPRR did not investigate why the culvert flows varied, but, from UPRR's review of the data gathered during the modeling effort, UPRR theorizes the following:

- UPRR understands that USGS measured breach flows since 1987 and the culvert flows since 1996 under contract with the Utah Department of Natural Resources.
- UPRR's review of the measurement tables and notes indicates that, over time, various types of equipment (a mobile acoustic Doppler current profiler [ADCP], or a current meter and stationery ADCP at the breach) were used to measure the flows.
- UPRR understands that the flows were measured to supplement the modeling efforts on a planning level, not for regulatory purposes.
- Further review by UPRR indicates that not all USGS measurements for the culverts occurred on the same day or under the same weather conditions (wind) and sometimes not at all due to excessive turbidity or other equipment issues.
- The actual data-collection efforts had error, since they were noted as poor to fair readings.
- The two culverts were not identical in elevation, and the levels of obstruction were probably not consistent between the two culverts, possibly due to the different locations of the culverts in the causeway. In 1973, the elevations of the ceilings of the east and west culverts were about 4,203 feet and 4,206 feet, respectively. Since 1973, the culverts have settled, and by 1998 the elevations of the ceilings of the east and west culverts were 4,195 feet and 4,198 feet, respectively (USGS 2000).
- When the culverts were cleaned, and protective berms installed, some channel work was done to transition the inverts to the lake bottom. These modifications were probably similar but not consistent.

These USGS culvert flow measurements cannot be directly compared to the culvert simulations of the UPRR/USGS models due to the nature and position of the culverts assumed in the models. UDWQ may want to discuss these flow measurement results with USGS and, if further accuracy and/or precision in the flow measurements are required for regulatory purposes, discussions on methods and procedures should be re-examined.

5. Head Difference

The 2012 UPRR/USGS Model culvert simulations result in greater head difference between the North and South Arms with the free-flowing culverts than what was measured (UPRR 2014a, modeling step 2, Figure 9). UDWQ requested that the implications of this finding be reviewed. UDWQ expected greater communication between the two arms for the model culvert simulation, and this should have resulted in a lower head difference than what was measured.

There are reasons why the difference in model-computed head difference is larger than the measured head difference, including actual versus model-represented culvert geometry and model calibration. These reasons are discussed below.

- The 1987–2012 culvert simulation (2012 UPRR/USGS Model) represented by the culvert ceilings at an elevation of 4,194 feet, which was the same as measured in 2012. The culvert simulation results, which relied on computation with the three sets of Holley's equations, predicted essentially no south-to-north flows. In reality, however, the ceiling of the east and west culverts during much of 1987–2012 was higher than 4,194 feet, and south-to-north flow was confirmed by USGS measurements (see Appendix A of this letter). In 1998, USGS reported that the east culvert ceiling was about 4,195 feet and the west culvert ceiling was 4,198 feet (USGS 2000). USGS reported on November 19, 2003, that the east culvert ceiling was above the water surface, and the WSE on that date was about 4,195 feet.
- The 2012 UPRR/USGS Model was calibrated to best match computed and measured WSEs for the entire 26-year period. This effort was considered successful; however, the calibrated model WSEs still varied from the measured elevations for some years by more than 1 foot.
- Factors that affect head difference include WSE, WSE relative to the existing breach geometry (invert elevation), culvert geometry, and fill. It is uncertain whether head difference can be correlated solely to the geometry and nature (free-flowing or obstructed) of the culvert.
- A review of Figure 9 (in UPRR 2014a) shows that, while the computed head difference was higher, the trend matched. That is, when the measured head difference was lower, the computed head difference dropped, and when the measured head difference increased, the computed head difference increased.
- The best agreement between the measured and computed head differences occurred when the culverts were submerged, while a variance is more often observed after 2000. UPRR notes that, after 2000, the WSEs were lower than prior to 2000, with the WSE often dropping below the simulated and measured culvert ceilings. The simulations include the lowering of the breach invert in 2000, which also would affect the head difference. It appears that, when the WSE hovers around an elevation of 4,195 feet, the culvert model simulates an increase in head difference (UPRR 2014a, Figure 11).

These considerations make it difficult to accurately determine the significance of the head differences between the observed measurements versus the modeled computed values.

RESPONSE TO USGS MODEL REVIEW COMMENTS

Groundwater Inflow

The 2012 UPRR/USGS Model uses an annual groundwater inflow estimate of 75,000 AF/yr based on 1977 estimates (USGS 1977) as documented in Loving and others (2002). USGS, during modeling coordination meetings and in its review comments, noted that groundwater recharge estimates have been made for the Great Salt Lake in several studies, including an estimate of 58,000 AF/yr by Heilweil and others (USGS 2011). USGS, using the more recent estimate of 58,000 AF/yr, ran the UPRR/USGS simulations and found that the model was “relatively insensitive” to the reduced groundwater inflow (USGS 2014). USGS further recommended that more-recent estimates of groundwater inflow be considered in future model simulations for completeness.

On average, the annual groundwater inflow of 75,000 AF/yr represents 2.7% of the total inflow (precipitation, surface water, and groundwater). The annual groundwater inflow estimate of 58,000 AF/yr represents, on average, 2.1% of the total inflow. The difference of 0.6% is small. As noted in the USGS comment, “very limited deviations” were found based on groundwater sensitivity using these two annual estimates. If future model simulations are conducted, UPRR will consider revising the groundwater inflow to reflect the more-recent estimated value.

Model Period for “Steady-State” Conditions for 2012 UPRR/USGS Varying Hydrology Model Simulations

USGS suggested additional discussion regarding selecting a 25-year modeling period for the varying hydrology scenarios and documenting a criterion for determining steady-state conditions to justify the simulation period. The goal of this modeling effort was to examine the model response to constant hydrology scenarios, not to achieve equilibrium conditions, since it highly improbable that actual lake hydrology would remain constant or even relatively constant for 10 or 20 years.

To determine an appropriate period for the varying hydrology model, the modeling team referenced Water-Resources Bulletin 18 (USGS 1973). This publication documents hypothetical, forward-looking Great Salt Lake modeling efforts that used a period of 10 years. Using this as a reference value, the team initially selected a modeling period of 15 years.

The 15-year varying hydrology model simulations were executed and the results were evaluated to determine whether they met the overall purpose of modeling step 3, which was to respond to agency questions about how the proposed mitigation simulation (at that time, a 180-foot-long bridge) would compare to the culvert simulation for a range of lake levels. The following results were found:

- For the dry hydrologic cycle, it was found that lake levels, salinities, and salt loads were approaching equilibrium but were close enough to identify model response to the simulated causeway openings to meet the objective of the modeling step.
- For the wet and mild hydrology cycles, the simulations were closer to equilibrium than the dry cycle and met the objective of the modeling step.

Therefore, the varying hydrology modeling period was extended to 25 years. UPRR notes that a numerical criterion for measuring “steady-state” conditions was not established and was not deemed necessary by the modeling team to meet the overall purpose of modeling step 3. The results of modeling the 25-year period indicated that, for all hydrologic cycles, the lake levels, salinities, and

salt loads were sufficiently close to equilibrium to meet the overall purpose, which was to determine how the proposed bridge would compare to the free-flowing culverts for a range of lake levels.

Code Modifications

USGS noted in its review comments that, while the model documentation generally described the code modifications, detailed and explicit code modifications were not identified. USGS suggested that specific code modifications be identified so that the comparisons can be made with the USGS 1987–1998 code (USGS 2000).

Appendix B of this letter includes the UPRR-modified code in which the specific Fortran code lines that were modified to accommodate the UPRR/USGS modeling efforts for step 1 and for the step 2 calibration run are highlighted. Key modifications are further described below and generally focus on the technical code changes, not the changes that were made to make the code more user-friendly, (comments or descriptions of channel openings).

- **Modeling step 1 – Run the 1987–1998 USGS Model for the culvert and bridge simulations**
  - Highlights include the following changes to the code:
    - Computational control and channel (ICHN) definition changes to accommodate new bridge
    - ETUL code modifications
    - Use of Holley's equations for channel flows
    - Modification of total causeway flow calculation to include new bridge (as applicable)
    - Extension of Manning's values to accommodate three channels
  - Highlights were not include for the following changes to the code:
    - Minor explanatory comments
    - Modifications associated with formatting the output file
    - Instances where ICHN is used in variables to specify channel selection
- **Modeling step 2 – Create and run simulations on the calibrated 1987–2012 UPRR/USGS model**
  - Highlights include the following changes to the code:
    - Water balance code modifications to extend the time period
    - Water balance code modifications to specify EAI values for the extended time period
    - Salt balance code modifications made for modeling step 1
    - Salt balance code modifications for extended model period
    - Salt balance code modifications to accommodate changing channel geometry including breach deepening
    - Salt balance code modifications to use measured flows for breach and culverts
  - Highlights were not included for the following changes to the code:
    - Minor explanatory comments
    - Modifications associated with formatting the output file
    - Instances where ICHN is used in variables to specify channel selection

Comparison of Independent Simulation Output

USGS ran the models for each modeling step in an attempt to reproduce UPRR's simulation results. USGS found percentage differences for individual time steps for various output parameters. However, over the entire model period, the percentage differences were small; USGS (2014) documented that the differences were less than 0.09% for the entire modeling period.

USGS's basic concern is whether these deviations in simulation output results have a significant effect on the overall model outputs and uncertainty. Further USGS analysis resulted in the following conclusions:

- Differences between the model simulation outputs varied for individual time steps, but these variations are limited to less than 0.01% over the entire simulation period.
- These individual time-step variations might be attributable to Fortran compiler differences, computational precision variation between computers, or numerical dispersion by solution methods.
- The hydraulic bidirectional flow equations (USGS 2000) produce numeric instability at certain time steps that might add to model uncertainty (during the simulation period in which the equations are used). This uncertainty should be considered when reviewing the results for specific time steps.

The UPRR modeling team acknowledges the variation in simulation results which—as noted by USGS reviewers—might be attributed to Fortran compiler differences and other causes. Further, the modeling team agrees that care should be taken when interpreting the model results for a specific time step. USGS has possibly based its analysis too much on percentage differences that can accentuate differences between two values when the difference in the underlying values is actually very small. Potentially, a more valuable analysis would examine absolute differences and then assess whether those absolute differences are relevant to the overall model response.

However, the model efforts and simulation results are not intended to be evaluated and used for mitigation or other purposes *on a time-step basis*. The modeling results are intended to be evaluated and used for the long term (periods of months and years). The documented simulation differences observed by USGS when compared to the overall model period, are small, and interpretation of the simulation results by time step or entire period have to consider the model uncertainty as documented in Water-Resources Investigations Report 00-4221 (USGS 2000) and as summarized in *UPRR Progress Report – Modeling Step 1*, Section 6.0, Model Uncertainty (UPRR 2014a).

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Please contact me if you have any questions about our submittal.

Yours truly,

Mark L. McCune, PE
Director Structures Design

cc: Bill Damery, UDWQ

Appendix A – USGS Breach and Culvert Measured Flows

DISCHARGE THROUGH OPENINGS IN THE UNION PACIFIC
RAILROAD COMPANY CAUSEWAY ON GREAT SALT LAKE, UT
(IN CUBIC FEET PER SECOND)

DATE	WEST CULVERT S => N	WEST CULVERT N => S	EAST CULVERT S => N	EAST CULVERT N => S	BREACH S => N	BREACH N => S	TOTAL S => N	TOTAL N => S	DATE	REMARKS
24-Sep-96	5	0	300	0					24-Sep-96	Initial visit to sites, estimated based on visual observations
09-Dec-96	300	0	300	0					09-Dec-96	Estimates; W. culvert has been partially cleaned since last visit
19-Dec-96					271	0			19-Dec-96	
11-Feb-97					877	0			11-Feb-97	
20-Mar-97	108	0	468	0	1060	0	1640	0	20-Mar-97	W. culvert has been partially cleaned since last visit
14-Apr-97	132	0	442	0	1370	0	1940	0	14-Apr-97	
07-May-97	227	0	733	0	1700	0	2660	0	07-May-97	
29-May-97	167	0	809	0	1980	0	2960	0	29-May-97	E. culvert has been partially cleaned since last visit
19-Jun-97	94	0	574	0	2560	0	3230	0	19-Jun-97	
09-Jul-97			741	0	2180	0			09-Jul-97	
18-Jul-97	137	0		0		0			18-Jul-97	
12-Aug-97					1670	0			12-Aug-97	
04-Sep-97	51	0	496	0					04-Sep-97	
20-Oct-97					1060	0			20-Oct-97	
04-Nov-97	59	0	354	0					04-Nov-97	
03/04-Dec-97	65	0	353	0	1400	0	1818	0	03/04-Dec-97	
21/22-Jan-98			312	0	1840	0			21/22-Jan-98	
11-Mar-98			312	0	2890	0			11-Mar-98	Floating debris (ice) prevented W. Culvert meas.
22/28-Apr-98	25	0	87	0	3780	0	3892	0	22/28-Apr-98	Both culvert disharges are basically estimates
13/14-May-98	55	0			5420	0			13/14-May-98	Floating debris prevented E. Culvert meas.
18/22-Jun-98	2	2	69	3	4360	0	4431	5	18/22-Jun-98	First evidence of bi-directional flow
20-Jul-98	0	0	26	12	3010	0	3036	12	20-Jul-98	West culvert completely buried in gravel- N. side
01-Sep-98	0	0	0	401	1170	61	1170	462	01-Sep-98	West culvert completely buried in gravel- N. side
27-Oct-98	0	0	0	297	1350	152	1350	449	27-Oct-98	West culvert completely buried in gravel- N. side
10-Mar-99	0	0	0	185	2580	194	2580	379	10-Mar-99	West culvert completely buried in gravel- N. side

DATE	WEST CULVERT S => N	WEST CULVERT N => S	EAST CULVERT S => N	EAST CULVERT N => S	BREACH S => N	BREACH N => S	TOTAL S => N	TOTAL N => S	DATE	REMARKS
23-Jun-99	0	0	0	139	3370	180	3370	319	23-Jun-99	West culvert completely buried in gravel- N. side
28-Aug-99	0	105	0	167	1390	317	1390	589	28-Aug-99	The west culvert has been partially cleaned
23-Nov-99	0	144							23-Nov-99	Unable to meas. Breach and E. culv - equip. failure
16-Dec-99			0	177	1670	119			16-Dec-99	
23-Mar-00	0	92			1840	51			23-Mar-00	Unable to measure east culvert due to weather
04-Apr-00	0	67	0	144	2590	173	2590	384	04-Apr-00	
24-May-00	0	83	0	145					24-May-00	
28-Jun-00	0	62	0	156					28-Jun-00	
27-Jul-00	0	20	0	174					27-Jul-00	Unable to measure Breach - equipment
29-Aug-00	0	85	0	167					29-Aug-00	Unable to measure Breach - equipment
12-Sep-00	0	71	0	134	850	176	850	381	12-Sep-00	
21-Nov-00	0	53	0	106	1380	144	1380	303	21-Nov-00	Breach channel has been deepend except for under the bridge
09-Jan-01	0	74	0	104	1400	400	1400	578	09-Jan-01	Breach flow is estimated based on partial measurement (equipment)
18-Jan-01					1940	383	1940	383	18-Jan-01	South wind "pushing flow through breach
17-Apr-01	0	79	0	80	2790	721	2790	880	17-Apr-01	Calm day, used the ADCP at all three sites
09-May-01	0	32	0	76	2060	691	2060	799	09-May-01	Calm day, used the ADCP at all three sites
21-Jun-01	0	50	0	152	1950	598	1950	800	21-Jun-01	Good day with light wind out of North West, used the ADCP at all three sites
05-Sep-01	0	63	0	162	1050	341	1050	566	05-Sep-01	Good Day with light wind out of the South west, used the ADCP at all three sites on a teathered platform instead of boat
11/7/2001	0	13	0	73	484	188	484	274	11/7/2001	ADCP used to measure all three sites; Measurement at the east culvert was made standing on top of the culvert concrete
3/21/2002	0	22	70	30	1370	145	1440	197	3/21/2002	ADCP used to measure all three sites; Measurement at the east culvert was made standing on top of the culvert concrete, but an error occurred in data collection and the East Culvert was estimated
5/9/2002	0	98.6	129	81	2580	353	2709	533	5/9/2002	
6/13/2002	0	119	23	131	945	411	968	661	6/13/2002	

DISCHARGE THROUGH OPENINGS IN THE UNION PACIFIC
RAILROAD COMPANY CAUSEWAY ON GREAT SALT LAKE, UT
(IN CUBIC FEET PER SECOND)

DATE	WEST CULVERT S => N	WEST CULVERT N => S	EAST CULVERT S => N	EAST CULVERT N => S	BREACH S => N	BREACH N => S	TOTAL S => N	TOTAL N => S	DATE	REMARKS
7/8/2002	0	141	0	155	138	1410	138	1706	7/8/2002	
8/14/2002	0	97	0	125	995	190	995	412	8/14/2002	
10/18/2002	0	72	-	-	770	202	770	274	10/18/2002	
1/8/2003	0	59	88	54	888	136	976	249	1/8/2003	
2/26/2003	0	46	82	43	1200	103	1282	192	2/26/2003	West culvert being cleaned during msmt by RR person with heavy equipment on south side.
5/13/2003	0	164	68	50	1190	60	1258	274	5/13/2003	West culvert cleaned since last visit.

DATE	WEST CULVERT S => N	WEST CULVERT N => S	EAST CULVERT S => N	EAST CULVERT N => S	BREACH S => N	BREACH N => S	TOTAL S => N	TOTAL N => S	DATE	REMARKS
7/8/2003	0	170	94	117	1240	0	1334	287	7/8/2003	Msmts observed by Milbor-pita employees. (UPRR consultants)
9/4/2003	0	121	84	123	428	49	512	293	9/4/2003	
11/19/2003	25	38	79	0	326	0	430	38	11/19/2003	Top of east culvert out of water. Steady one directional./ West culvert bi-directional, thin N to S flow observed (estimated).
1/29/2004					621	0	621	0	1/29/2004	Culverts being cleaned by heavy equipment. Breach msmt only.
2/12/2004	13	149							2/12/2004	Met with Milbor-Pita and others to measure fully cleaned West culvert. Bi-directional, interface 4.17 ft blw surface. Wind is calm.
4/8/2004	132	0	307	43	1050	0	1489	43	4/8/2004	Moderate wind from South. Met with F Pita (E culv only). Both culverts cleaned. Hvy work still around culverts. Bi-directional on E culvert only. Interface at 9 ft.
6/2/2004	0	259	54	105	679	0	733	364	6/2/2004	Wind is light from the North. One directional at W culvert and Breach. Bi-directional at E culvert.
8/20/2004	28	174	117	117	141	0	286	291	8/20/2004	Light wind from South. North arm is mostly calm. Bi directional at both culverts. One directional at breach.
9/16/2004	45	132	134	32	79	0	258	164	9/16/2004	Wind from the south ranged from light to moderate. Bi directional both culverts. One directional at breach.
12/3/2004	195	45	362	0	142	0	699	45	12/3/2004	Wind from the south was moderate at the culverts. Calm at the breach. Bi directional W culvert only. One directional . at breach and E culvert.
1/21/2005	83	0	450	122	366	0	899	122	1/21/2005	Foggy cold weather, no wind, very calm on both arms of lake. Bi-directional E culvert only. One directional at breach and W culvert.
4/15/2005	104	73	360	104	1060	0	1524	177	4/15/2005	Clear cool weather, light to moderate wind fro NW, Bi-directional both culverts. One directional at breach.
6/14/2005	210	22	502	22	2910	0	3622	44	6/14/2005	Clear warm weather, Moderate wind from South. Bi-directional both culverts. One directional at breach.
7/19/2005					1760	0			7/19/2005	Breech only. Visit by Sontek Rep., MJF & CA
8/9/2005	0	320	148	178					8/9/2005	Culverts only. Breech msmt was made earlier on 7/19/05. One directional on West Culvert (N to S). Bidirectional on East Culvert.
9/20/2005	23	259	164	194	531	0	718	453	9/20/2005	Clear warm weather, Light wind from SW. Bi-directional both culverts. One directional at breach.
11/10/2005	31	189	158	121	657	0	846	310	11/10/2005	Calm cold day, no wind with light fog. Bi-directional both culverts. One directional at breach.
1/24/2006	50	146	196	70	1070	0	1316	216	1/24/2006	Calm cold day, no wind with light haze. Bi-directional both culverts. One directional at breach. ADCP having difficulties penetrating interfaces at culverts.
4/7/2006	16	100	207	51	2320	0	2543	151	4/7/2006	Warm day with light to moderate wind from the SE.

Measurements at the culverts are rated fair to sometimes poor due to measuring conditions.
Measurements at the breach are rated fair due to measuring conditions.
estimated cfs

DISCHARGES AFTER SEPTEMBER 2005 ARE PROVISIONAL

DISCHARGE THROUGH OPENINGS IN THE UNION PACIFIC RAILROAD COMPANY CAUSEWAY ON GREAT SALT LAKE, UT (IN CUBIC FEET PER SECOND)

NOTE: Measurements at the culverts are rated fair to sometimes poor due to measuring conditions. Measurements at the breach are rated good to fair due to measuring conditions. Times shown are in Mountain Time.

estimated cfs

BREACH MSMT#	DATE	TIME	10010020 Lat. 41º13'21" Long 112º50'57" 01 BREACH S => N	BREACH N => S	TIME	10010030 Lat. 41º13'25" Long 112º40'07" 01 WEST CULVERT S => N	WEST CULVERT N => S	TIME	10010040 Lat. 41º13'18" Long 112º33'40" 01 EAST CULVERT S => N	EAST CULVERT N => S	MEASURED TOTAL S => N	MEASURED TOTAL N => S	REMARKS
103	11/21/00		1,380	144		0	53		0	106	1,380	303	Breach channel has been deepend except for under the bridge
	01/09/01		1,400	400		0	74		0	104	1,400	578	Breach flow is estimated based on partial measurement (equipment)
104	01/18/01		1,940	383							1,940	383	South wind "pushing flow through breach
105	04/17/01		2,790	721		0	79		0	80	2,790	880	Calm day, used the ADCP at all three sites
106	05/09/01		2,060	691		0	32		0	76	2,060	799	Calm day, used the ADCP at all three sites
107	06/21/01		1,950	598		0	50		0	152	1,950	800	Good day with light wind out of North West, used the ADCP at all three sites
108	09/05/01		1,050	341		0	63		0	162	1,050	566	Good Day with light wind out of the South west, used the ADCP at all three sites on a teathered platform instead of boat
109	11/07/01		484	188		0	13		0	73	484	274	ADCP used to measure all three sites; Measurement at the east culvert was made standing on top of the culvert concrete
110	03/21/02		1,370	145		0	22		70	30	1,440	197	ADCP used to measure all three sites; Measurement at the east culvert was made standing on top of the culvert concrete, but an error occurred in data collection and the East Culvert was estimated
111	05/09/02		2,580	353		0	98.6		129	81	2,709	533	
112	06/13/02		945	411		0	119		23	131	968	661	
113	07/08/02		138	1,410		0	141		0	155	138	1,706	
114	08/14/02		995	190		0	97		0	125	995	412	
115	10/18/02		770	202		0	72		-	-	770	274	
116	01/08/03		888	136		0	59		88	54	976	249	
117	02/26/03		1,200	103		0	46		82	43	1,282	192	West culvert being cleaned during msmt by RR person with heavy equipment on south side.
118	05/13/03		1,190	60		0	164		68	50	1,258	274	West culvert cleaned since last visit.
119	07/08/03		1,240	0		0	170		94	117	1,334	287	Msmts observed by Milbor-pita employees. (UPRR consultants)
120	09/04/03		428	49		0	121		84	123	512	293	
121	11/19/03	13:30	326	0	12:40	25	38	10:20	79	0	430	38	Top of east culvert out of water. Steady one directional./ West culvert bi-directional, thin N to S flow observed (estimated).
122	01/29/04	12:00	621	0							621	0	Culverts being cleaned by heavy equipment. Breach msmt only.
	02/12/04				10:20	13	149				13	149	Met with Milbor-Pita and others to measure fully cleaned West culvert. Bi-directional, interface 4.17 ft blw surface. Wind is calm.
123	04/08/04	13:30	1,050	0	10:50	132	0	9:35	307	43	1,489	43	Moderate wind from South. Met with F Pita (E culv only). Both culverts cleaned. Hvy work still around culverts. Bi-directional on E culvert only. Interface at 9 ft.
124	06/02/04	12:45	679	0	10:45	0	259	9:45	54	105	733	364	Wind is light from the North. One directional at W culvert and Breach. Bi-directional at E culvert.
125	08/20/04	12:20	141	0	10:40	28	174	9:40	117	117	286	291	Light wind from South. North arm is mostly calm. Bi directional at both culverts. One directional at breach.
126	09/16/04	13:00	79	0	11:10	45	132	10:05	134	32	258	164	Wind from the south ranged from light to moderate. Bi directional both culverts. One directional at breach.
127	12/03/04	12:45	142	0	11:00	195	45	10:10	362	0	699	45	Wind from the south was moderate at the culverts. Calm at the breach. Bi directional W culvert only. One directional at breach and E culvert..
128	01/21/05	12:45	366	0	11:25	83	0	9:50	450	122	899	122	Foggy cold weather, no wind, very calm on both arms of lake. Bi-directional E culvert only. One directional at breach and W culvert.
129	04/15/05	12:45	1,060	0	11:50	104	73	10:30	360	104	1,524	177	Clear cool weather, light to moderate wind from NW, Bi-directional both culverts. One directional at breach.
130	06/14/05	13:15	2,910	0	12:15	210	22	11:00	502	22	3,622	44	Clear warm weather, Moderate wind from South. Bi-directional both culverts. One directional at breach.
131	07/19/05	11:10	1,760	0							1,760	0	Breech only. Visit by Sontek Rep., MJF & CA
	08/09/05				11:10	0	320	12:00	148	178	148	498	Culverts only. Breech msmt was made earlier on 7/19/05. One directional on West Culvert (N to S). Bidirectional on East Culvert.
132	09/20/05	10:00	531	0	11:10	23	259	12:00	164	194	718	453	Clear warm weather, Light wind from SW. Bi-directional both culverts. One directional at breach.
133	11/10/05	10:00	657	0	11:10	31	189	12:20	158	121	846	310	Calm cold day, no wind with light fog. Bi-directional both culverts. One directional at breach.
134	01/24/06	12:50	1,070	0	11:40	50	146	10:10	196	70	1,316	216	Calm cold day, no wind with light haze. Bi-directional both culverts. One directional at breach. ADCP having difficulties penetrating interfaces at culverts.
135	04/07/06	9:15	2,320	0	10:00	16	100	12:35	207	51	2,543	151	Warm day, Light wind from SE. Bidirectional flow at both culverts. One directional at breach. ADCP having difficulties penetrating interfaces at culverts.
136	05/25/06	12:30	3,120	0	11:20	100	131	10:05	294	98	3,514	229	Warm day, Light wind from NW. Bidirectional flow at both culverts. One directional at breach.
137	08/08/06	11:10	1,410	72	10:05	0	421	9:15	191	241	1,601	734	Clear warm weather, winds were light to moderate from SE. Bidirectional flow at Breach at East culvert, West culvert was N to S only.
	09/26/06				11:50	39	234	10:45	173	151	1,592	385	Clear warm weather, wind light from SE, Bidirectional both culverts. Breach not measured due to modem problems.
138	09/28/06	12:00	1,380	0									Clear warm weather, wind light from SE, Breach measurement only. South to North flow only.
139	11/07/06	13:30	1,730	0	12:00	27	198	10:40	183	119	1,940	317	Warm calm day, Very little wind. Bidirectional flow at both culverts. One directional at breach.
140	01/09/07	12:15	1,720	0	11:15	56	147	9:40	139	92	1,915	239	Cold calm day, No wind. Bidirectional flow at both culverts. One directional at breach. East Culvert flows estimated due to ADCP beams failing to penetrate interface layer.
141	03/19/07	12:10	1,880	0	11:20	55	281	10:00	158	218	2,093	499	Warm day, light wind from North during culvert msmts, Light wind from South during breach msmt. Bidirectional flow at both culverts. One directional at breach. East Culvert flows poor due to ADCP beams failing to penetrate interface layer continuously.
142	05/30/07	11:45	1,560	0	10:40	86	464	9:40	186	264	1,832	728	Warm day, light wind from south. Bidirectional flow at culverts, one direction at breach.
143	08/10/07	11:45	1,090	0	10:40	13	124	9:35	129	116	1,232	240	Warm day, Strong wind from South during Culvert msmts, Bidirectional flow at culverts, one direction at breach.
144	09/18/07	11:30	615	0	10:15	23	198	9:00	162	205	800	403	Warm day, light wind from south. Bidirectional flow at culverts, one direction at breach.
145	11/07/07	12:30	463	0	9:50	63	226	9:00	261	117	787	343	Warm day, light wind from south. Bidirectional flow at culverts, one direction at breach.

DISCHARGE THROUGH OPENINGS IN THE UNION PACIFIC RAILROAD COMPANY CAUSEWAY ON GREAT SALT LAKE, UT (IN CUBIC FEET PER SECOND)

NOTE: Measurements at the culverts are rated fair to sometimes poor due to measuring conditions. Measurements at the breach are rated good to fair due to measuring conditions. Times shown are in Mountain Time.

estimated cfs

			10010020 Lat. 41º13'21" Long 112º50'57" 01		10010030 Lat. 41º13'25" Long 112º40'07" 01			10010040 Lat. 41º13'18" Long 112º33'40" 01					
			BREACH		WEST CULVERT			EAST CULVERT			MEASURED TOTAL		
BREACH MSMT#	DATE	TIME	S => N	N => S	TIME	S => N	N => S	TIME	S => N	N => S	S => N	N => S	REMARKS
146	01/02/08	13:30	560	0	12:15	62	104		N/A	N/A	622	104	Cold day, very light south wind. Bi-directional flow at west culvert. One directional at breach. ADCP unable to penetrate interface layer (thermocline) at east culvert. No measurement was possible at this site.
147	04/17/08	12:45	1,110	0	11:15	74	193	10:15	216	76	1,400	269	Cool day, Light wind from southeast during all three msmts, Bidirectional flow at culverts, one direction at breach.
148	06/09/08	13:30	1,440	0	11:40	90	48	10:40	338	17	1,868	65	Warm day, light wind from south. Bidirectional flow at culverts, one direction at breach.
149	08/12/08	13:15	315	0	12:05	15	202	11:10	227	144	557	346	Warm day, light wind from southeast. Bidirectional flow at culverts, one direction at breach.
	09/29/08				11:20	72	165	12:30	224	83			Warm day, light wind from southeast. Bidirectional flow at culverts.
150	09/30/08	14:00	36	0									GSL breach gage started. Warm day with calm winds.
151	11/18/08	12:41	59	0	11:15	132	41	10:15	449	17	640	58	Warm calm day, Very little wind. Bidirectional flow at both culverts. One directional at breach.
152	12/30/08	12:29	40	0	-----	-----	-----	-----	-----	-----			Cold day, very light wind. ADCP unable to penetrate interface layer (thermocline) at both the west and east culverts. No discharges therefore were obtained at either of the culvert sites.
153	02/20/09	9:26	398	0	-----	-----	-----	-----	-----	-----			Breach msmt only
154	03/27/09	9:47	641	0	-----	-----	-----	-----	-----	-----			Breach msmt only
155	04/29/09	9:06	810	0	10:45	294	0	12:04	801	0	1,905	0	Warm day, Light wind from NW. At all three sites; flow is from South to North only.
156	06/18/09	12:38	1,240	0	11:17	125	273	10:00	474	144	1,839	417	Warm day, Moderate wind from West, Bidirectional flow at culverts, one direction at breach.
157	07/29/09	13:28	828	0	11:45	113	195	10:35	288	103	1,229	298	Warm day, Moderate wind from Northwest, Bidirectional flow at culverts, one direction at breach.
158	10/02/09	9:15	285	0	10:20	148	238	11:15	215	63	648	301	Warm day, Moderate wind from South East, Bidirectional flow at culverts, one direction at breach.
159	11/10/09	11:45	216	0	10:20	160	171	9:05	384	0	760	171	Cool day, Moderate wind from South East, Bidirectional flow at west culvert only, one directional at breach and east culvert.
160	1/15/2010	9:23	274	0	-----	-----	-----	-----	-----	-----			Cloudy cold day, calm. Breach msmt only.
161	3/12/2010	9:27	739	0	-----	-----	-----	-----	-----	-----			Cool day, light wind only. Breach msmt only. Sample collected.
	4/16/2010	-----	-----	-----	9:30	164	51	10:49	439	0			Cool day, Moderate wind from South East, Culverts only. Bidirectional flow at west culvert only, one directional at east culvert.
162	5/3/2010	9:17	724	0	-----	-----	-----	-----	-----	-----			Cool day, Heavy wind from the South.
163	6/17/2010	12:53	943	0	-----	-----	-----	-----	-----	-----			Warm day, Light wind only.
	7/13/2010	-----	-----	-----	9:30	120	226	10:45	416	97			Warm day, Moderate wind from West-Northwest, Bidirectional flow at both culverts.
164	7/29/2010	9:21	509	0	-----	-----	-----	-----	-----	-----			Warm day, Light wind. Breach only.
165	9/1/2010	8:41	134	0	-----	-----	-----	-----	-----	-----			Warm and calm day. Breach only.
166	10/15/2010	9:05	44.7	0	-----	-----	-----	-----	-----	-----			Breach msmt only
167	12/7/2010	10:31	62.7	0	-----	-----	-----	-----	-----	-----			Breach msmt only
168	1/18/2011	10:29	250	0	-----	-----	-----	-----	-----	-----			Breach msmt only
169	2/15/2011	10:31	586	0	-----	-----	-----	-----	-----	-----			Breach msmt only
170	2/22/2011	10:22	864	0	-----	-----	-----	-----	-----	-----			Breach msmt only
171	3/29/2011	12:35	1400	0	-----	-----	-----	-----	-----	-----			Breach msmt only
	4/22/2011	-----	-----	-----	1030	327	0	9:00	1470	0			East and West Culvert only. Very light south wind. Collected Hg samples at Culverts and Breach.
172	5/25/2011	12:19	3400	0	-----	-----	-----	-----	-----	-----			Breach msmt only
173	6/21/2011	12:14	5560	0	-----	-----	-----	-----	-----	-----			Breach msmt only
	7/28/2011	-----	-----	-----	12:20	183	326	13:30	356	220			East and West Culverts only.
174	8/3/2011	13:11	3670	0	-----	-----	-----	-----	-----	-----			Breach msmt only
175	9/15/2011	12:40	1850	0	-----	-----	-----	-----	-----	-----			Breach Measurement only
	9/19/2011	-----	-----	-----	12:30	0	619	13:25	594	544			East and West Culvert only. Calm wind conditions. Hg Samples collected at Breach and culverts.
176	10/12/2011	12:52	1950	0	-----	-----	-----	-----	-----	-----			Breach msmt only
177	11/15/2011	13:00	2500	0	-----	-----	-----	-----	-----	-----			Breach msmt only
	12/7/2011	-----	-----	-----	12:20	10	470	10:25	174	N/A			Could not measure N-S flow at East Culvert due to strong Thermocline. Cool, Calm, Sunny conditions. Both N and S Arms calm. Hg Samples collected.
	12/14/2011	-----	-----	-----	-----	-----	-----	9:45	189	345			Price AA measurement. Light west wind, both north and south arms fairly calm. Light chop on south arm at the end of measurement. Cloudy,
178	12/29/2011	13:50	2350	0	-----	-----	-----	-----	-----	-----			
179	2/15/2012	13:57	2350	0	-----	-----	-----	-----	-----	-----			
	3/29/2012	-----	-----	-----	11:00	0	600	13:30	35	427			East and West culverts only. Had to measure on both north and south side of the causeway to get individual discharge of north and south flov
180	4/12/2012	13:18	377	0	-----	-----	-----	-----	-----	-----			Strong storms passing. Rapidly changing conditions
181	5/31/2012	12:30	2370	0	-----	-----	-----	-----	-----	-----			Breach Only
182	7/10/2012	0:00	1350	0	-----	-----	-----	-----	-----	-----			Breach Only
	7/17/2012	-----	-----	-----	9:30	0	623	11:20	19	495			East and West culverts only. Measured both culverts from north side of causeway due to significant waves south of the causeway due to a south wind. Hg Samples collected. VTG GPS used as reference
183	8/21/2012	9:38	1550	-----	-----	-----	-----	-----	-----	-----			Breach msmt only

DISCHARGE THROUGH OPENINGS IN THE UNION PACIFIC RAILROAD COMPANY CAUSEWAY ON GREAT SALT LAKE, UT (IN CUBIC FEET PER SECOND)

NOTE: Measurements at the culverts are rated fair to sometimes poor due to measuring conditions. Measurements at the breach are rated good to fair due to measuring conditions. Times shown are in Mountain Time.

estimated cfs

			10010020 Lat. 41º13'21" Long 112º50'57" 01			10010030 Lat. 41º13'25" Long 112º40'07" 01			10010040 Lat. 41º13'18" Long 112º33'40" 01				
			BREACH			**WEST CULVERT**			**EAST CULVERT**		**MEASURED TOTAL**		
BREACH MSMT#	**DATE**	**TIME**	**S => N**	**N => S**	**TIME**	**S => N**	**N => S**	**TIME**	**S => N**	**N => S**	**S => N**	**N => S**	**REMARKS**
	9/11/2012	-----	-----	-----	10:15	-----	543	13:50	28	540			East and West culverts only. N. Arm choppy from north wind. Bi-directional flow at East Culvert. East culvert measured with AA meter. Interface at 3.5 ft on north side of culvert. West culvert measured with StreamPro ADCP using Section by Section. All flow in West Culvert N -> S
184	10/9/2012	10:31	962	-----	-----	-----	-----	-----	-----	-----			Breach only
185	11/20/2012	14:48	1180	-----	-----	-----	-----	-----	-----	-----			Breach only
	12/4/2012	-----	-----	-----	-----	-----	-----	10:30	171	418			East culvert only. West culvert plugged. No longer will be making measurements along west culvert. Cloudy, light rain and south wind. Wind increased around 1040. South arm choppy due to increased wind. Measured with Price AA meter. Interface at 3.5 (3ft -4ft). Hg Samples collected
186	1/3/2013	13:10	864	-----	-----	-----	-----	-----	-----	-----			Breach Only
187	3/4/2013	10:25	-----	-278	-----	-----	-----	-----	-----	-----			Reserve flow conditions at the gage. Measurement made with RiverRay
188	4/3/2013	12:37	2120		-----	-----	-----	-----	-----	-----			Breach only
	4/12/2013	-----	-----	-----	-----	-----	-----	10:35	25	387			East culvert only. Clear, cool with moderate NW wind. North arm of lake had large waves due to wind. Measured flow with RiverRay on north side of causeway. Interface was at approx 2.0 ft. Hg sample collected at 0930.
189	5/14/2013	12:02	1010	-----	-----	-----	-----	-----	-----	-----			Breach only
190	6/20/2013	10:11	461	-----	-----	-----	-----	-----	-----	-----			Breach only
191	7/16/2013	9:55	436	-----	-----	-----	-----	-----	-----	-----			Rapidly changing conditions. Breach only
	7/22/2013	-----	-----	-----	-----	-----	-----	10:30	102	315			East culvert only. Clear, hot and calm conditions. Measured with RiverRay ADCP on north side of causeway. Interface was at approx 2.30 ft on north side of causeway. Hg sample collected.
192	8/20/2013	10:23	586	-----	-----	-----	-----	-----	-----	-----			Breach only
193	9/5/2013	12:37	398	-----	-----	-----	-----	-----	-----	-----			Breach only
	9/23/2013	-----	-----	-----	-----	-----	-----	11:00	65	339			East culvert only. Clear, cool and light wind out of the west. Measured with RiverRay ADCP on north side of causeway. Interface was at approx 3.2 ft on north side of causeway. Hg sample collected.

Appendix B – UPRR/USGS Model Code

Modeling Step #1
1998 UPRR/USGS Model Code
(highlighted to show model code changes)

```
      PROGRAM MODEL

C  THIS VERSION MODIFIED BY STEPHEN C. ERTMAN, HDR|HYDROQUAL, FOR USE
C  IN SUPPORT OF UNION PACIFIC RAILROAD.

C    1)  PERIOD OF MODEL RUN IS 1/87 TO 12/98
C    2)  USES EVAPORATION CORRECTION COEFFICIENTS FROM CALIBRATED MODEL
C    3)  EXISTING BREACH AND CULVERT FLOWS ARE CALCULATED
C    4)  INCLUDES NEW BRIDGE AS CHANNEL 3

C ************************  DECLARE VARIABLES  ************************
      INCLUDE 'INCLUDE.TXT'
      LOGICAL*1 LCULV
      REAL*8 CLNPPT,AS,AN,VS,VN,PS,PN,DP,TEMX,PFT,CS
      REAL*8 CN,HAVG,Q1F,Y2F,Q2F,QS,QN,SCFS,SCFN,FCN
C     INTEGER*4 NCHAN,J,IN,JJ,JJJ,K,NPROG,TSCC
      INTEGER*4 NCHAN,J,IN,JJ,JJJ,K,NPROG ! TSCC NOT USED, SCE/20131003

C ************************  OPEN FILES  ******************************

      OPEN (UNIT=15,FILE='inputfile.txt',STATUS='OLD')
      OPEN (UNIT=16,FILE='outputfile.txt',STATUS='UNKNOWN')
      OPEN (UNIT=17,FILE='longoutput.txt',STATUS='UNKNOWN')
      OPEN (UNIT=18,FILE='test.txt',STATUS='UNKNOWN')

C  START READING AND WRITING IN THE OPENED FILES, AT TOP OF EACH FILE
      REWIND (UNIT=15)
      REWIND (UNIT=16)
      REWIND (UNIT=17)
      REWIND (UNIT=18)

C ***********************  SET INITIAL CONDITIONS  *********************

C  WATER AND SALT BALANCE CONSTANTS/INITIAL CONDITIONS
      LS=2.08e9
      LN=3e9
      CLNPPT=0e9
      LNPPT=0.
      RESOLN=0.
      LES=210.97
      LEN=210.37
      HD=LES-LEN
      DAY=1
      AS=995478
      AN=519964
      VS=18852158
      VN=10383004
      PS=1.051
      PN=1.131
      DP=PN-PS
      KLS=39000000
      KLN=51000000
      ClLS=1087000000
      ClLN=1348000000
      MgLS=70000000
      MgLN=70000000
      NaLS=610000000
      NaLN=771000000

C ********************  COMPUTATIONAL CONTROL  *************SCE/20131014
C     NCHAN=1 !HOLLEY'S EQS COMPUTE BREACH FLOWS ONLY;
C     NCHAN=2 !HOLLEY'S EQS COMPUTE BREACH & CULVERT FLOWS
      NCHAN=3 !HOLLEY'S EQS COMPUTE BREACH, NEW BRIDGE, & CULVERT FLOWS

C     *** SEE ALSO LINES JUST AFTER STATEMENT LABEL 140 ***

C ******************  END COMPUTATIONAL CONTROL  ***********SCE/20131014

C  CHANNEL 1 (EXISTING BREACH) DIMENSIONS; SCE/20131029
```

```
      CHANT(1)=214.0
      CHANB(1)=200.0
C     CHANB(1)=213.0   !SET INVERT ELEVATION HIGH TO SHUT OFF FLOW
      CHANB2(1)=198.0  !DEEPENED INVERT ELEVATION AT TSBD (01 AUG 96)
      CHANW(1)=290.0
      BSLOPE(1)=9.0
      EBBR(1)=210.0

C  CHANNEL 2 (COMBINED CULVERTS) DIMENSIONS; SCE/20131029
C     CHANT(2)=203.0  !OLD 87-98 MODEL CROWN ELEVATION
C     CHANB(2)=182.0  !OLD 87-98 MODEL INVERT ELEVATION
      CHANB(2)=213.0  !SET INVERT ELEVATION HIGH TO SHUT OFF FLOW
C     CHANB(2)=173.0  !NEW 2012 BASELINE INVERT ELEVATION
      CHANT(2)=CHANB(2)+(203-182)  !KEEPS CULVERT HEIGHT AT 87-98 VALUE
      CHANW(2)=30.0

C  CHANNEL 3 (NEW BRIDGE) DIMENSIONS; SCE/20131029
      CHANT(3)=214.0  !PROPOSED DESIGN CROWN ELEVATION
      CHANB(3)=178.0  !PROPOSED DESIGN INVERT ELEVATION
C     CHANB(3)=213.0  !SET INVERT ELEVATION HIGH TO SHUT OFF FLOW
      CHANW(3)=180.0
      BSLOPE(3)=3.5
      EBBR(3)=212.0

C  CHANNEL FLOW CONSTANTS/INITIAL CONDITIONS
      SZ=0.0
      TOLX=3.0
      TOLDX=0.01
      TOLQ1=15.0
      TOLHS=0.02
      DELA1=0.2
      ENTRS=0.5
      ENTRN1=0.85
      ENTRN2=0.0
      FCOEF=1.0
      G=32.2

      TSBD=1840 !TIMESTEP FOR FIRST BREACH DEEPENING = 01AUG96

      DO I=1,NCHAN
        NI(I) = NI(I)*SQRT(FCOEF)
        TT(1,I) = (NI(I)/NW1(I))**1.5
        TT(2,I) = (NI(I)/NW2(I))**1.5
        TT(3,I) = (NZ(I)/NW2(I))**1.5
        TT(4,I) = (NZ(I)/NI(I))**1.5
        TT(7,I) = (NT(I)/NI(I))**1.5
        TT(8,I) = (NT(I)/NW1(I))**1.5
        TT(9,I) = (NT(I)/NZ(I))**1.5
      END DO

C  FILL FLOW CONSTANTS/INITIAL CONDITIONS
      FBEI=200.0
      FEEI=200.0
      FBBE=175.0
      FEBE=175.0
      FBNP=1.0
      FENP=1.0
      FBOP=0.1
      FEOP=0.1

C ************************  READ INPUT FILE  ***************************

C  READ IN THE SOUTH AND NORTH PART ELEV/AREA/VOL TABLES
      READ (15,10) ((SOUTHA(I,J),I=1,3),J=1,91)
      READ (15,10) ((SOUTHB(I,J),I=1,3),J=1,91)
      READ (15,10) ((NORTH(I,J),I=1,3),J=1,91)
   10 FORMAT (3F10.0)

C  READ IN THE SOUTH AND NORTH PART EVAP AND INFLOW DATA
```

```
      READ(15,20) (AQES(IN),AQEN(IN),AXES(IN),AXEN(IN),AQIS(IN),
     - AQIN(IN),IN=1,N)
   20 FORMAT (2F11.2,2F11.6,2F11.2)

C  READ IN THE WEST POND PUMPING WATER AND SALT IN/OUTFLOW DATA
      READ(15,30) (AQWP(IN),ALWP(IN),IN=1,N)
   30 FORMAT(f7.0,1x,f7.3)

C  READ IN THE WEST POND PUMPING ION IN/OUTFLOW DATA
      READ(15,35) (ANaLWP(IN),AMgLWP(IN),AKLWP(IN),AClLWP(IN),
     -  IN=1,N)
   35 FORMAT(4f7.3)

C  READ IN THE MEASURED/ESTIMATED BREACH AND CULVERT FLOWS
        READ(15,40) (AMBS(IN),AMBN(IN),AMECS(IN),AMECN(IN),
     -  AMWCS(IN),AMWCN(IN),IN=1,N)
   40 FORMAT(6f8.0)

C  THIS SECTION TAKES VARIABLES WITH ONE VALUE PER MONTH AND GIVES
C    THEM A VALUE FOR EACH TIME STEP
      DO 60 J=1,N
        JJ=J*TSPM-1
        JJJ=JJ+1-TSPM
        IF(J.EQ.N)JJ=JJ+1
        DO 50 K=JJJ,JJ
          QES(K)=AQES(J)*TS
          QEN(K)=AQEN(J)*TS
          XES(K)=AXES(J)*TS
          XEN(K)=AXEN(J)*TS
          QIS(K)=AQIS(J)*TS
          QIN(K)=AQIN(J)*TS
          QWP(K)=AQWP(J)*12./365.*TS
          LWP(K)=ALWP(J)*1e9*12./365.*TS
          ClLWP(K)=AClLWP(J)*1e6*12./365.*TS
          KLWP(K)=AKLWP(J)*1e6*12./365.*TS
          NaLWP(K)=ANaLWP(J)*1e6*12./365.*TS
          MgLWP(K)=AMgLWP(J)*1e6*12./365.*TS
          MBS(K)=AMBS(J)
          MBN(K)=AMBN(J)
          MECS(K)=AMECS(J)
          MECN(K)=AMECN(J)
          MWCS(K)=AMWCS(J)
          MWCN(K)=AMWCN(J)
   50   CONTINUE
   60 CONTINUE

C  READ IN THE FILL FLOW MATRIX
      READ(15,70)MATRIX
   70 FORMAT(F9.3,17F9.2)

C ***********************************************************************
C  WRITE COLUMN LABELS TO OUTPUT FILES
      WRITE(*,77)
      WRITE(16,75)
      WRITE(17,77)
C  FIXED FORMAT 75 & 77 SO LABELS LINE UP WITH COLUMNS      SCE/20131003
C  ADDED FLOW LABELS FOR CHANNEL 3 (NEW BRIDGE)             SCE/20131029
   75 FORMAT(' TSTEP MO/DAY/YR     HD      LES      LEN     '
     & 'DP     PS     PN     LS9     LN9  LNPPT9   '
C    & 'QSC(1)   QNC(1)   QSC(2)   QNC(2)       FS       FN   '     !SCE
     & 'QSC(1)   QNC(1)   QSC(2)   QNC(2)   QSC(3)   QNC(3)       ' !SCE
     & 'FS       FN   QES(I)   QEN(I)     KLS     KLN    '
     & 'ClLS    ClLN    MgLS    MgLN    NaLS    NaLN')
   77 FORMAT(' TSTEP  MO/DAY/YR     HD      LES      LEN     '
     & 'DP     PS     PN     LS9     LN9  LNPPT9   '
C    & 'QSC(1)  QNC(1)  QSC(2)  QNC(2)      FS      FN')            !SCE
     & 'QSC(1)  QNC(1)  QSC(2)  QNC(2)  QSC(3)  QNC(3)      FS      FN')
C ***********************************************************************

```

```
C  WRITE INITIAL CONDITIONS TO OUTPUT FILES
      WRITE(*,80)0,1,DAY,1987,HD,4000.+LES,4000.+LEN,
     -    PN-PS,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9
      WRITE(17,80)0,1,DAY,1987,HD,4000.+LES,4000.+LEN,
     -    PN-PS,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9
   80 FORMAT(I6,1x,2(I2,'/'),I4,F7.2,2F9.2,3F7.3,3F8.4,
C    -  6(1x,F7.0))                                          !SCE
     -  8(1x,F7.0))                                          !SCE
C ***************  BEGIN TIME INTERVAL LOOP (MAIN LOOP)  ***************

      DO 200 I=1,NTS

C  CALCULATE NEW DENSITIES (PS,PN AND DP)
      PS=1.000+0.63*(LS*.0007353)/VS
      PN=1.000+0.63*(LN*.0007353)/VN
      TEMX=12.5+12.0*SIN(.032725*I-1.958)
      PFT= (8*TEMX-(TEMX)**2+132416.)/132432.
      PS=PS*PFT/PF20
      PN=PN*PFT/PF20*.996
      DP=PN-PS
      CS=((PS-1.0)/0.63)*100.
      CN=((PN-1.0)/0.63)*100.
      KCS=KLS/VS
      KCN=KLN/VN
      ClCS=ClLS/VS
      ClCN=ClLN/VN
      MgCS=MgLS/VS
      MgCN=MgLN/VN
      NaCS=NaLS/VS
      NaCN=NaLN/VN

C  FOR FILL FLOW CALIBRATION RUNS, SKIP TO 130
C      GOTO 130

C  BREACH, BRIDGE, AND CULVERT FLOW COMPUTATIONS BEGIN HERE
C    ICHN=1 FOR THE EXISTING BREACH
C    ICHN=2 FOR THE TWO CULVERTS COMBINED
C    ICHN=3 FOR THE NEW BRIDGE

C  DEEPEN THE BREACH BOTTOM TO CHANB2(1) AT THE TIMESTEP IN WHICH
C    THE BREACH WAS DEEPENED (01AUG96)
      IF(I.GT.TSBD)CHANB(1)=CHANB2(1)

C  BEGIN CHANNEL (BREACH/NEW BRIDGE/CULVERT) FLOW CALCULATION LOOP
      DO 130 ICHN=1,NCHAN
      TT1=TT(1,ICHN)
      TT2=TT(2,ICHN)
      TT3=TT(3,ICHN)
      TT4=TT(4,ICHN)
      TT7=TT(7,ICHN)
      TT8=TT(8,ICHN)
      TT9=TT(9,ICHN)

      IF(ICHN.EQ.2)THEN !SKIPS CULVERTS PAST BREACH/BRIDGE CALCULATIONS
         CHNW=CHANW(ICHN)
         GOTO 100
      ENDIF

C  SET THE CHANNEL WIDTHS FOR THE SUBROUTINE CALCULATIONS TO THE ACTUAL
C    BOTTOM WIDTHS OF THE EXISTING BREACH AND NEW BRIDGE, SO THAT BOTTOM
C    FRICTION IS CALCULATED PROPERLY
      IF(CHANB(ICHN).LT.EBBR(ICHN))THEN
         WBB=CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-CHANB(ICHN))
      ELSE
         WBB=CHANW(ICHN)
      ENDIF
      CHNW=WBB

  100 CONTINUE
```

```
C ******************** START MODIFICATION *****************SCE/20131022
C      HS=LES-CHANB(1)     !INCLUDE ALL CHANNELS & MOVE LINE
C      HN=LEN-CHANB(1)     !INCLUDE ALL CHANNELS & MOVE LINE

C  ASSUME CHANNEL FLOW IS ZERO IF LES ABOVE OR BELOW CHANNEL
C      IF((LES.GE.CHANT(ICHN)).OR.
C     -  (LES.LE.CHANB(ICHN)))THEN
C          QSC(ICHN)=0.0
C          QNC(ICHN)=0.0
C          GOTO 130
C      ENDIF

C  TERMINATE MODEL RUN FOR FLOODING OVER CAUSEWAY
       IF(LES.GE.(CHANT(1)-1))THEN  ! 1 FT BELOW BREACH TOP
           WRITE (*,*) 'SOUTH ARM WSEL EXCEEDS FLOODING THRESHOLD OVER
     &                 CAUSEWAY.'
           WRITE (*,*) 'TIME STEP = ', I
           WRITE (*,*) 'EXECUTION STOPPED AT STATEMENT LABEL 105.'
  105      STOP
       ENDIF

C  ASSUME CHANNEL FLOW IS ZERO IF LES BELOW CHANNEL BOTTOM
       IF(LES.LE.CHANB(ICHN))THEN
           QSC(ICHN)=0.0
           QNC(ICHN)=0.0
           GOTO 130
       ENDIF

C  ASSUME WEIR FLOW: LEN <= CHANB AND CHANB < LES < CHANT
       IF((LEN.LE.CHANB(ICHN)).AND.
     -    (LES.LT.CHANT(ICHN)).AND.
     -    (LES.GT.CHANB(ICHN)))THEN
           QSC(ICHN)=3.5*CHNW*(LES-CHANB(ICHN))**1.5
           QNC(ICHN)=0.0
           GOTO 125
       ENDIF

       HS=LES-CHANB(ICHN) !BY MOVING LINE, HS > 0 ALWAYS
       HN=LEN-CHANB(ICHN) !BY MOVING LINE, HN > 0 ALWAYS
C      BUT ADD ERROR TRAP ANYWAY TO PREVENT CODE ERRORS FROM PROPAGATING
       IF ((HS.LE.0.0).OR.(HN.LE.0.0)) THEN
           WRITE (*,*) 'HS = ', HS, 'HN = ', HN
           WRITE (*,*) 'ERROR: HS & HN SHOULD BE GREATER THAN ZERO.'
           WRITE (*,*) 'EXECUTION STOPPED AT STATEMENT LABEL 106.'
  106      STOP
       ENDIF
C ******************** END MODIFICATION ********************SCE/20131022

C  CONVERT DENSITIES TO ENGLISH UNITS & REDUCE DENS. JUST N. OF CHANNEL
       HEIGHT=CHANT(ICHN)-CHANB(ICHN)
       RHO2=1.94*PN*(1.0-3.0E-06*QSC(ICHN))
       RHO1=1.94*PS
       EPS=(RHO2 - RHO1)/RHO2

C  CALCULATE AVERAGE CHANNEL LENGTH BASED ON AVERAGE DEPTH.
C    FL IS BASED ON THE AVERAGE LENGTH FOR A CULVERT WITH A RECTANGULAR
C    LONGITUDINAL CROSS SECTION 136 FT LONG UP TO A DEPTH OF 12 FT AND
C    THEN A TRAPEZOIDAL LONGITUDINAL CROSS SECTION WITH A BASE 88 FT
C    LONG AND END SLOPES OF ONE.
       FL = 136.
       HAVG = 0.5*(HS+HN)
       IF(HAVG .GT. 12.) FL=136.*12./HAVG+(88.-(HAVG-12.))*(HAVG-12.)
     -  /HAVG

C  CALL SUBROUTINE FOR SINGLE LAYER FLOW COMPUTATION. IF NPROG RETURNS
C    EQUAL TO 3, THEN SINGLE LAYER FLOW WAS CORRECT AND PROGRAM IS READY
C    FOR NEXT CONDITION. OTHERWISE, PROCEED TO COMPUTATION FOR ARRESTED
C    WEDGE FLOW.
```

```
346                 LCULV=.TRUE.
347                 CALL CULV3(NPROG)
348                 IF(NPROG .EQ.3) GOTO 120
349     110         CONTINUE
350                 IF(HN*RHO2/RHO1.GT.HS)THEN
351                   CALL CULV2A(NPROG)
352                 ELSE
353                   CALL CULV2B(NPROG)
354                 ENDIF
355
356   C IF NPROG RETURNS EQUAL TO 2, THEN ARRESTED WEDGE WAS THE CORRECT
357   C FLOWTYPE AND PROGRAM IS READY FOR NEW CONDITION. OTHERWISE, PROCEED
358   C TO COMPUTATION FOR TWO LAYER FLOW.
359                 IF(NPROG .EQ. 2.OR..NOT.LCULV) GOTO 120
360                 CALL CULV1(NPROG)
361                 LCULV=.FALSE.
362                 IF(NPROG .EQ. 2) GOTO 110
363
364     120 CONTINUE  !PROGRAM IS READY FOR NEW A CONDITION
365
366         Q1PREV=Q1
367         Q2PREV=Q2
368         IF(Q2.LT.0.0)Q2=-Q2
369         QSC(ICHN)=Q1
370         QNC(ICHN)=Q2
371
372     125 CONTINUE
373
374         IF(ICHN.EQ.2) GOTO 130  !SKIPS CULVERTS PAST BREACH/BRIDGE CALCS
375
376   C  BEGIN EXISTING BREACH & NEW BRIDGE FLOW TRAPEZOIDAL AREA COMPUTATIONS
377   C ---------------------------------------------------------------------
378   C     ETUL=((A1S+A1N)/2.) + CHANB(ICHN)   !ERRONEOUS CODE;  SCE/20131014
379         ETLL = (A2S+A2N)/2. + CHANB(ICHN)
380         ETUL = ETLL + (A1S+A1N)/2.          !CORRRECTED CODE; SCE/20131014
381         IF(CHANB(ICHN).GE.ETLL)ETLL=CHANB(ICHN)
382         SAUL = (ETUL-ETLL)*WBB
383         SALL = (ETLL-CHANB(ICHN))*WBB
384
385   C  COMPUTE AREA OF THE EXISTING BREACH & NEW BRIDGE UPPER FLOW LAYER
386         IF(ETUL.GT.EBBR(ICHN))THEN
387            IF(ETLL.GE.EBBR(ICHN))THEN
388               AUBL=(ETUL-ETLL)*CHANW(ICHN)
389            ELSE
390              AUBL=(ETUL-EBBR(ICHN))*CHANW(ICHN)+(EBBR(ICHN)-ETLL)*
391        -     (CHANW(ICHN)- BSLOPE(ICHN)*(EBBR(ICHN)-(EBBR(ICHN)+ETLL)/2.))
392            ENDIF
393         ELSE
394            AUBL=(ETUL-ETLL)*(CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-
395        -    (ETUL+ETLL)/2.))
396         ENDIF
397
398   C  COMPUTE AREA OF THE EXISTING BREACH & NEW BRIDGE LOWER FLOW LAYER
399         IF(ETLL.GT.EBBR(ICHN))THEN
400            IF(CHANB(ICHN).GE.EBBR(ICHN))THEN
401               ALBL=(ETLL-CHANB(ICHN))*CHANW(ICHN)
402            ELSE
403             ALBL=(ETLL-EBBR(ICHN))*CHANW(ICHN)+(EBBR(ICHN)-CHANB(ICHN))*
404        -    (CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-(EBBR(ICHN)+CHANB(ICHN))
405        -     /2.))
406            ENDIF
407         ELSE
408           ALBL=(ETLL-CHANB(ICHN))*(CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-
409        -   (ETLL+CHANB(ICHN))/2.))
410         ENDIF
411
412   C  COMPUTE THE AREA CORRECTION FACTORS THAT WILL CONVERT THE DISCHARGES
413   C    COMPUTED IN THE SUBS (RECTANGULAR AREAS) TO THE ACTUAL AREAS AT THE
414   C    EXISTING BREACH & NEW BRIDGE (TRAPEZOIDAL AND RECTANGULAR)
```

```
      ULACF=0.
      LLACF=0.
      IF(SAUL.GT.0.0)ULACF=AUBL/SAUL
      IF(SALL.GT.0.0)LLACF=ALBL/SALL

C  ADJUST BREACH & NEW BRIDGE FLOWS FOR CORRECT CROSS-SECTIONAL AREAS
      IF(ICHN.NE.2)QSC(ICHN)=QSC(ICHN)*ULACF
      IF(ICHN.NE.2)QNC(ICHN)=QNC(ICHN)*LLACF
C ---------------------------------------------------------------------
C  END EXISTING BREACH & NEW BRIDGE FLOW TRAPEZOIDAL AREA COMPUTATIONS

  130 CONTINUE

C  SET ALL CHANNEL DISCHARGES TO ZERO IF NCHAN = 0
      IF(NCHAN.EQ.0)THEN
        DO 140 ICHN=1,MCHAN
          QSC(ICHN)=0.0
          QNC(ICHN)=0.0
  140   CONTINUE
      ENDIF

C  USE HOLLEY'S EQUATIONS FOR BREACH/BRIDGE/CULVERT FLOWS; SCE/20131014
C  IF USING COMPUTED BREACH AND/OR CULVERT FLOWS, COMMENT OFF THE
C    LINES BELOW WHICH USE THE MEASURED (READ IN) FLOW VALUES
C     QSC(1)=MBS(I)
C     QNC(1)=MBN(I)
C     QSC(2)=MECS(I)+MWCS(I)
C     QNC(2)=MECN(I)+MWCN(I)
C ********************************************************SCE/20131014

C  USE FILL FLOW MATRIX TO DETERMINE FILL FLOW BASED ON 1973 CONDITIONS
      CALL INTER3(MATRIX,PS,DP,LEN,HD,Q1F)
      FBE=FEBE+I*((FBBE-FEBE)/2304)
      Y2F=LEN-FBE-HD*PS/DP
      IF(Y2F.LE.0.)Y2F=0.0
      Q2F=73.40086*(DP*Y2F**2)
      IF(Q2F.GT.4300.0)Q2F=84.40083*(DP*Y2F**2)-516.5435
      IF(Q1F.LE.0.)Q1F=0.0
      IF(Q2F.LE.0.)Q2F=0.0
      IF(DP.LE..05.AND.HD.GT.0.60)Q2F=0.0

C  FILL FLOW REDUCTION FACTOR EQS
      FEI=FEEI+I*((FBEI-FEEI)/2304)
      FNP=FENP+I*((FBNP-FENP)/2304)
      FOP=FEOP+I*((FBOP-FEOP)/2304)
      FSE=LES
      FNE=Y2F+FBE
      IF(FSE.GE.FEI)THEN
         FCFS=(((FSE-DMAX1(FEI,FNE))*FNP)+
     -    ((FEI-DMAX1(0.00D0,FNE))*FOP))/(FSE-DMAX1(FBE,FNE))
      ELSE
         FCFS=FOP
      ENDIF
      IF(FNE.GE.FEI)THEN
         FCFN=((((FNE-FEI)*FNP)+((FEI-FBE)*FOP))/(FNE-FBE))
      ELSE
         FCFN=FOP
      ENDIF

C  ADJUST FILL FLOWS COMPUTED WITH 1973 CONDITIONS TO REFLECT
C    1987-98 CONDITIONS JUST CALCULATED
      FS=Q1F*FCFS
      FN=Q2F*FCFN

C  COMPUTE TOTAL FLOW THRU THE CAUSEWAY IN EACH DIRECTION IN ACFT
C     QS=(QSC(1)+QSC(2)+FS)*TS*CAC  !SCE/20131028
C     QN=(QNC(1)+QNC(2)+FN)*TS*CAC  !SCE/20131028
      QS=(QSC(1)+QSC(2)+QSC(3)+FS)*TS*CAC  !SCE/20131028
      QN=(QNC(1)+QNC(2)+QNC(3)+FN)*TS*CAC  !SCE/20131028
```

```
C  COMMENT OFF THE FOLLOWING 4 LINES IF YOU WANT TO USE ESTIMATED
C     EVAPORATION COMPUTED IN THE WATER BALANCE PROGRAM
      SCFS=1.0-0.00778*(CS/PS)
      SCFN=1.0-0.00778*(CN/PN)
      QES(I)=XES(I)*AS*SCFS
      QEN(I)=XEN(I)*AN*SCFN

C  COMPUTE NEW VOLUMES, ELEVATIONS AND AREAS
      VS=VS-QS+QN+QIS(I)-QES(I)
      VN=VN+QS-QN+QIN(I)-QEN(I)-QWP(I)
      IF(I.LT.1344)THEN                  ! 1344 = 01JAN94
          CALL RINTER(LES,VS,SOUTHA)
          CALL INTERP(LES,AS,SOUTHA)
      ELSE
          CALL RINTER(LES,VS,SOUTHB)
          CALL INTERP(LES,AS,SOUTHB)
      ENDIF
      CALL RINTER(LEN,VN,NORTH)
      CALL INTERP(LEN,AN,NORTH)

      HD=LES-LEN
      IF(HD.LE.0.08)HD=0.08

C  CALCULATE NEW ION LOAD VALUES
      KLS=KLS-(QS*KCS)+(QN*KCN)
      KLN=KLN+(QS*KCS)-(QN*KCN)-KLWP(I)
      ClLS=ClLS-(QS*ClCS)+(QN*ClCN)
      ClLN=ClLN+(QS*ClCS)-(QN*ClCN)-ClLWP(I)
      MgLS=MgLS-(QS*MgCS)+(QN*MgCN)
      MgLN=MgLN+(QS*MgCS)-(QN*MgCN)-MgLWP(I)
      NaLS=NaLS-(QS*NaCS)+(QN*NaCN)
      NaLN=NaLN+(QS*NaCS)-(QN*NaCN)-NaLWP(I)

C  CALCULATE NEW SALT LOAD VALUES
      LS= LS+(QN*LN/VN-QS*LS/VS)
      LN= LN+(QS*LS/VS-QN*LN/VN)-LWP(I)
      FCN=LN/VN
      LNPPT=0.0
      RESOLN=0.0
      IF (FCN.GT.483.)THEN
         LNPPT=LN-483.*VN
         CLNPPT=LNPPT+CLNPPT
         LN=LN-LNPPT
      ELSE
         RESOLN=.01*(483.*VN-LN)
         IF(RESOLN.GT.CLNPPT)RESOLN=CLNPPT
         CLNPPT=CLNPPT-RESOLN
         LN=LN+RESOLN
      ENDIF
      IF(CLNPPT.LT.0.)CLNPPT=0.

      ClLN=ClLN-(.607*LNPPT)+(.607*RESOLN)
      NaLN=NaLN-(.393*LNPPT)+(.393*RESOLN)

C  INCREASE DATE COUNTERS IN THE LOOP
      YEAR=INT(I*TS/365.+1.)
      MONTH=INT(((I*TS/365.+1.)-YEAR)*12.+1.)
      DAY=DAY+2
      IF(DAY.EQ.33)THEN
        DAY=1
        MONTH=MONTH+1
      ENDIF
      IF(MONTH.EQ.13)THEN
        MONTH=1
        YEAR=YEAR+1
      ENDIF
      YEAR=YEAR+1986
```

```
C*****************  WRITE OUTPUT TO FILES  *************************

C  WRITE TO MAIN OUTPUT FILE FOR AT FIRST OF MONTH
      IF(I.EQ.1)WRITE(16,150)I,MONTH,YEAR,HD,LES+4000.,LEN+4000.,
     -    DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
     -    QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN,
     -    QES(I)/1.9,QEN(I)/1.9,KLS/1E9,KLN/1E9,ClLS/1E9,ClLN/1E9,
     -    MgLS/1E9,MgLN/1E9,NaLS/1E9,NaLN/1E9

      IF(DAY.EQ.1)THEN
        WRITE(16,150)I,MONTH,YEAR,HD,LES+4000.,LEN+4000.,
     -    DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
     -    QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN,
     -    QES(I)/1.9,QEN(I)/1.9,KLS/1E9,KLN/1E9,ClLS/1E9,ClLN/1E9,
     -    MgLS/1E9,MgLN/1E9,NaLS/1E9,NaLN/1E9
      END IF
C 150 FORMAT(I6,1x,I2,'/1/',I4,F7.2,2F9.2,3F7.3,3F8.4,8(1x,F8.0),8F8.4)
  150 FORMAT(I6,1x,I2,'/1/',I4,F7.2,2F9.2,3F7.3,3F8.4,10(1x,F8.0),8F8.4)

C  WRITE TO SCREEN AND OUTPUT FILES FOR TIMESTEP
      WRITE(*,80)I,MONTH,DAY,YEAR,HD,LES+4000.,LEN+4000.,
     -  DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
     -  QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN
      WRITE(17,80)I,MONTH,DAY,YEAR,HD,LES+4000.,LEN+4000.,
     -  DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
     -  QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN
      WRITE(18,190)I,MONTH,DAY,YEAR,FS,FN,PS,PN,CS,CN,VN,
     -  QEN(I),LN,CLNPPT,QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3)
C 190 FORMAT(I6,1x,2(I2,'/'),I4,2F8.2,2F8.4,2F7.0,F12.0,
C    -  F7.0,2F12.0,4F7.0)
  190 FORMAT(I6,1x,2(I2,'/'),I4,2F8.2,2F8.4,2F7.0,F12.0,
     -  F7.0,2F12.0,6F7.0)

C ****************  END MAIN LOOP AND END PROGRAM  ******************

  200 CONTINUE
      ENDFILE (UNIT=15)
      ENDFILE (UNIT=16)
      ENDFILE (UNIT=17)
      ENDFILE (UNIT=18)
      CLOSE (UNIT=15)
      CLOSE (UNIT=16)
      CLOSE (UNIT=17)
      CLOSE (UNIT=18)
      END

      BLOCK DATA BEGIN
      INCLUDE 'INCLUDE.TXT'
C **** EXTEND MANNING'S NUMBERS TO HANDLE 3 CHANNELS; SCE/20131028 ****
C     DATA (NW1(I),NW2(I),NI(I),NZ(I),NT(I),I=1,2)/.015,.015,.01,
C    -    .024,.015, .015,.015,.01,.015,.015/
      DATA (NW1(I),NW2(I),NI(I),NZ(I),NT(I),I=1,3)/.015,.015,.01,
     -    .024,.015, .015,.015,.01,.015,.015, .015,.015,.01,.024,.015/
C ******************************************************************
      END
```

Modeling Step #2
2012 UPRR/USGS Model Code
(highlighted to show water balance model code modifications)

```
      PROGRAM WaterBalance

C     THIS VERSION MODIFIED BY STEPHEN C. ERTMAN, HDR|HYDROQUAL, FOR USE
C     IN SUPPORT OF UNION PACIFIC RAILROAD.

C     This is the calibrated WATER BALANCE PROGRAM
C     The calibration period is 1987-98

      IMPLICIT NONE ! Must declare all variables

C     INITIAL CONDITIONS AND CONSTANTS
      INTEGER, PARAMETER::
C     YEARMAX=12 FOR 1987-1998 RUN; SCE/20131202
C    -  EAVMAX=91,TWELVE=12,YEARFIRST=1987,YEARMAX=12,YRCAL=10
C     YEARMAX=26 FOR 1987-2012 RUN; SCE/20131202
     -  EAVMAX=91,TWELVE=12,YEARFIRST=1987,YEARMAX=26,YRCAL=10
      INTEGER
     -  EAV,EAVNUM,EAVVAL,EAVVALN,EAVVALS,ELEV,EP,MON,VOLNUM,YR
      REAL, PARAMETER::
     -  ENIFIRST=4210.35,
     -  ESIFIRST=4210.97,
     -  EVAPCAL=1.00,
     -  FTFC=1.0/12.0,
     -  INFLOCAL=1.00,
     -  PAAOG=16.43,
     -  PAASLC=14.69,
     -  PAATO=16.05,
     -  PRECIPCAL=1.00
      REAL
     -  AAPEN(3,6),AAPES(3,6),AQENX,AQESX,AQENXC,AQESXC,AQINX,AQISX,
     -  AN,AS,CAUS,CN,CS,DIFFN,DIFFS,DIFVS,EAVN(3,0:EAVMAX),
     -  EAVS(3,0:EAVMAX),EAVS1(3,0:EAVMAX),EAVS2(3,0:EAVMAX),
     -  ENI,ESI,EMI(0:TWELVE),EAI(0:YEARMAX),ENMES(TWELVE,YEARMAX),
     -  ESMES(TWELVE,YEARMAX),EAAN,EAAS,EAN,EAS,EN,ES,EMN,EMS,
     -  HVNC,HVNM,HVSC,HVSM,HVOLN,HVOLS,PAAN,PAAS,PFAC,PMN,PMS,
     -  PMSLC(0:TWELVE,0:YEARMAX),PMOG(0:TWELVE,0:YEARMAX),
     -  PMTO(0:TWELVE,0:YEARMAX),QSNET,QB(0:TWELVE,0:YEARMAX),
     -  QW(0:TWELVE,0:YEARMAX),QJ(0:TWELVE,0:YEARMAX),
     -  QS(0:TWELVE,0:YEARMAX),QTN(0:TWELVE,0:YEARMAX),
     -  QTS(0:TWELVE,0:YEARMAX),RTNC,RTNM,RTSC,RTSM,
     -  SCFN(TWELVE,YEARMAX),SCFS(TWELVE,YEARMAX),SUMPMN,
     -  SUMPMS,SUMQTN,SUMQTS,VNM(0:TWELVE*YEARMAX),
     -  VSM(0:TWELVE*YEARMAX),VNC,VNIC,VSC,VSIC,VNFIRST,
     -  VSFIRST,WESTP(0:TWELVE,0:YEARMAX)

      SUMPMN=0.
      SUMPMS=0.
      SUMQTN=0.
      SUMQTS=0.

C     OPEN FILES
C     OPEN (UNIT=15,FILE='waterin.txt',STATUS='OLD')       !SCE/20131202
      OPEN (UNIT=15,FILE='waterin2012_VER6.txt',STATUS='OLD') !SCE
      OPEN (UNIT=16,FILE='output1.txt',STATUS='UNKNOWN')
      OPEN (UNIT=17,FILE='readcheck.txt',STATUS='UNKNOWN')
      OPEN (UNIT=18,FILE='output2.txt',STATUS='UNKNOWN')
      REWIND (UNIT=15)
      REWIND (UNIT=16)
      REWIND (UNIT=17)
      REWIND (UNIT=18)

C     READ IN MEASURED ELEVATIONS FOR NORTH AND SOUTH PARTS
      READ (15,10) ((ENMES(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      READ (15,10) ((ESMES(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      WRITE(17,10) ((ENMES(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      WRITE(17,10) ((ESMES(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
   10 FORMAT (6(1X,F7.2))
      DO YR=1,YEARMAX
        DO MON=1,TWELVE
```

```
            IF((ENMES(MON,YR).LT.4190.).OR.(ENMES(MON,YR).GT.4215.)) THEN
              PRINT*,"ERROR: ENMES IS OUT OF RANGE: ", ENMES(MON,YR)
              PRINT*,"MON= ",MON,"YR= ",YR
              STOP
            ELSEIF((ESMES(MON,YR).LT.4190.).OR.(ESMES(MON,YR).GT.4215.))
     1      THEN
              PRINT*,"ERROR: ESMES IS OUT OF RANGE: ", ESMES(MON,YR)
              PRINT*,"MON= ",MON,"YR= ",YR
              STOP
            ENDIF
          ENDDO
        ENDDO

C       READ IN AVERAGE ANNUAL PRECIPITATION AND EVAPORATION
C       TABLES FOR NORTH AND SOUTH PARTS
        READ (15,20) ((AAPEN(EP,ELEV),EP=1,3),ELEV=1,6)
        READ (15,20) ((AAPES(EP,ELEV),EP=1,3),ELEV=1,6)
        WRITE(17,20) ((AAPEN(EP,ELEV),EP=1,3),ELEV=1,6)
        WRITE(17,20) ((AAPES(EP,ELEV),EP=1,3),ELEV=1,6)
   20   FORMAT (F10.1,2F10.2)
        EP=1
        DO ELEV=1,6
          IF((AAPEN(EP,ELEV).LT.4190.).OR.(AAPEN(EP,ELEV).GT.4220.)) THEN
            PRINT*,"ERROR: AAPEN IS OUT OF RANGE: ", AAPEN(MON,YR)
            PRINT*,"EP= ",EP,"ELEV= ",ELEV
            STOP
          ELSEIF((AAPES(EP,ELEV).LT.4190.).OR.(AAPES(EP,ELEV).GT.4220.))
     1    THEN
            PRINT*,"ERROR: AAPES IS OUT OF RANGE: ", AAPES(MON,YR)
            PRINT*,"EP= ",EP,"ELEV= ",ELEV
            STOP
          ENDIF
        ENDDO
        DO EP=2,3
          DO ELEV=1,6
            IF((AAPEN(EP,ELEV).LT.0.).OR.(AAPEN(EP,ELEV).GT.99.)) THEN
              PRINT*,"ERROR: AAPEN IS OUT OF RANGE: ", AAPEN(MON,YR)
              PRINT*,"EP= ",EP,"ELEV= ",ELEV
              STOP
            ELSEIF((AAPES(EP,ELEV).LT.0.).OR.(AAPES(EP,ELEV).GT.99.))
     1      THEN
              PRINT*,"ERROR: AAPES IS OUT OF RANGE: ", AAPES(MON,YR)
              PRINT*,"EP= ",EP,"ELEV= ",ELEV
              STOP
            ENDIF
          ENDDO
        ENDDO

C       READ IN ELEVATION-AREA-VOLUME TABLES OF NORTH AND
C       SOUTH PARTS
        READ (15,30) ((EAVN(EAV,EAVVAL),EAV=1,3),EAVVAL=1,EAVMAX)
        READ (15,30) ((EAVS1(EAV,EAVVAL),EAV=1,3),EAVVAL=1,EAVMAX)
        READ (15,30) ((EAVS2(EAV,EAVVAL),EAV=1,3),EAVVAL=1,EAVMAX)
        write(17,30) ((EAVN(EAV,EAVVAL),EAV=1,3),EAVVAL=1,EAVMAX)
        write(17,30) ((EAVS1(EAV,EAVVAL),EAV=1,3),EAVVAL=1,EAVMAX)
        write(17,30) ((EAVS2(EAV,EAVVAL),EAV=1,3),EAVVAL=1,EAVMAX)
   30   FORMAT (F10.1,2F10.0)

C       READ IN INFLOW DATA
        READ (15,40) ((QB(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        write(17,40) ((QB(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        READ (15,40) ((QW(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        write(17,40) ((QW(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        READ (15,40) ((QJ(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        write(17,40) ((QJ(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        READ (15,40) ((QS(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        write(17,40) ((QS(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        READ (15,40) ((QTN(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
        write(17,40) ((QTN(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
```

```
   40 FORMAT (6F10.0)

C    READ IN MONTHLY PRECIPITATION AT SLC AIRPORT, OGDEN SUGAR F, TOOELE
      READ (15,50) ((PMSLC(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      READ (15,50) ((PMOG(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      READ (15,50) ((PMTO(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      write(17,50) ((PMSLC(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      write(17,50) ((PMOG(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      write(17,50) ((PMTO(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
   50 FORMAT (12F6.2)

C     READ IN MONTHLY FRACTIONS FOR ANNUAL EVAPORATION
      READ (15,60) (EMI(MON),MON=1,TWELVE)
      write(17,60) (EMI(MON),MON=1,TWELVE)
   60 FORMAT (12F6.3)
      DO MON=1,TWELVE
        IF((EMI(MON).LT.0).OR.(EMI(MON).GT.1.))THEN
          PRINT*,"ERROR: EMI IS OUT OF RANGE: ",EMI(MON)
          PRINT*,"MON= ",MON
          STOP
        ENDIF
      ENDDO

C     READ IN ANNUAL FRACTIONS OF AVERAGE ANNUAL EVAPORATION
      READ (15,70) (EAI(YR),YR=1,YEARMAX)
      write(17,70) (EAI(YR),YR=1,YEARMAX)
C     FORMAT STATEMENT 70 IS DEPENDENT ON # YEARS IN CALIBRATION PERIOD
C70    FORMAT (100F6.2)
70    FORMAT (13F6.2)  !FORMATTED FOR YEARMAX=26; SCE/20131202
      DO YR=1,YEARMAX
        IF((EAI(YR).LT.0).OR.(EAI(YR).GT.1.))THEN
          PRINT*,"ERROR: EAI IS OUT OF RANGE: ",EAI(YR)
          PRINT*,"YR= ",YR
          STOP
        ENDIF
      ENDDO

C     READ IN SALINITY CORRECTION FACTORS FOR EVAPORATION FOR THE
C     NORTH AND SOUTH PARTS
      READ (15,80) ((SCFN(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      READ (15,80) ((SCFS(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      WRITE(17,80) ((SCFN(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      WRITE(17,80) ((SCFS(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
   80 FORMAT (12F6.3)

C     READ IN WEST POND PUMPING/RETURN FLOWS DURING 1987-92
      READ (15,85) ((WESTP(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
      WRITE(17,85) ((WESTP(MON,YR),MON=1,TWELVE),YR=1,YEARMAX)
   85 FORMAT(12F8.0)

C     SUM INFLOWS TO THE SOUTH PART OF LAKE
      DO YR=1,YEARMAX
        DO MON=1,TWELVE
          QTS(MON,YR)=QB(MON,YR)+QW(MON,YR)+QJ(MON,YR)+QS(MON,YR)
        ENDDO
      ENDDO

C     DEFINE INITIAL VALUES FOR VOLNUM, ENI, AND ESI
      EAVS=EAVS1
      VOLNUM=1
      ENI=ENIFIRST
      ESI=ESIFIRST

C     DETERMINE THE LARGEST ELEVATION IN EAV TABLE LESS THAN ENI AND
C     ITS CORRESPONDING NUMBER EAVVALN
      EAVVAL=1
      DO WHILE((ENI.GE.EAVN(1,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
        EAVVALN=EAVVAL
        EAVVAL=EAVVAL+1
```

```
      ENDDO

C     DETERMINE THE LARGEST ELEVATION IN EAV TABLE LESS THAN ESI AND
C     ITS CORRESPONDING NUMBER EAVVALS
      EAVVAL=1
      DO WHILE((ESI.GE.EAVS(1,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
        EAVVALS=EAVVAL
        EAVVAL=EAVVAL+1
      ENDDO

C     WRITE HEADERS TO OUTPUT FILES
      WRITE (16,90)
   90 FORMAT (32X,'LAKE ELEVATIONS (FEET)',/,22X,'NORTH',26X,'SOUTH',
     - /,'YEAR',3X,'MONTH',2X,'COMPUTED',4X,'MEASURED',2X,'DIFFN',5X,
     - 'COMPUTED',4X,'MEASURED',2X,'DIFFS')
      WRITE (16,140)YEARFIRST-1,12,ENI,ENIFIRST,0.0,ESI,ESIFIRST,0.0
      WRITE (18,95)
   95 FORMAT (5X,'AQESXC',5X,'AQENXC',6X,'AQESX',6X,'AQENX',6X,'AQISX',
     - 6X,'AQINX',9X,'AS',9X,'AN',7X,'SCFS',7X,'SCFN')

C     EAI IS ADJUSTED FOR EACH YEAR TO CALIBRATE THE WATER BALANCE
      EAI(1) =0.76  ! 1987
      EAI(2) =0.86  ! 1988
      EAI(3) =0.89  ! 1989
      EAI(4) =0.86  ! 1990
      EAI(5) =0.86  ! 1991
      EAI(6) =0.86  ! 1992
      EAI(7) =0.86  ! 1993
      EAI(8) =0.86  ! 1994
      EAI(9) =0.86  ! 1995
      EAI(10)=0.86  ! 1996
      EAI(11)=0.94  ! 1997
      EAI(12)=0.86  ! 1998
      EAI(13)=0.84  ! 1999
      EAI(14)=0.95  ! 2000
      EAI(15)=0.94  ! 2001
      EAI(16)=0.89  ! 2002
      EAI(17)=1.02  ! 2003
      EAI(18)=0.94  ! 2004
      EAI(19)=0.72  ! 2005
      EAI(20)=0.92  ! 2006
      EAI(21)=0.96  ! 2007
      EAI(22)=0.98  ! 2008
      EAI(23)=0.87  ! 2009
      EAI(24)=0.99  ! 2010
      EAI(25)=0.77  ! 2011
      EAI(26)=1.13  ! 2012

C     INTERPOLATE NORTH PART VOLUME AT THE BEGINING OF 1ST MONTH
      EAVVAL=EAVVALN-10
      DO WHILE((ENIFIRST.GE.EAVN(1,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
        EAVVAL=EAVVAL+1
      ENDDO
      VNFIRST=(EAVN(3,EAVVAL)-EAVN(3,EAVVAL-1))*
     -  (ENIFIRST-EAVN(1,EAVVAL-1))/(EAVN(1,EAVVAL)-EAVN(1,EAVVAL-1))+
     -  EAVN(3,EAVVAL-1)

C     INTERPOLATE SOUTH PART VOLUME AT THE BEGINING OF 1ST MONTH
      EAVVAL=EAVVALS-10
      DO WHILE((ESIFIRST.GE.EAVS(1,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
        EAVVAL=EAVVAL+1
      ENDDO
      VSFIRST=(EAVS(3,EAVVAL)-EAVS(3,EAVVAL-1))*
     -  (ESIFIRST-EAVS(1,EAVVAL-1))/(EAVS(1,EAVVAL)-EAVS(1,EAVVAL-1))+
     -  EAVS(3,EAVVAL-1)

C ***********************************************************************
C *                          MAIN LOOP                                  *
C ***********************************************************************
```

```
C     COMPUTE INTERPOLATION RATIO FOR EAVN TABLE (RTNM), USING
C     MEASURED ELEVATION OF NORTH PART
      DO YR=1,YEARMAX
        DO MON=1,TWELVE
          EAVVAL=EAVVALN-10
          IF(YR.GE.8) EAVS=EAVS2
          DO WHILE((ENMES(MON,YR).GE.EAVN(1,EAVVAL))
     1     .AND.(EAVVAL.LE.EAVMAX))
            EAVVAL=EAVVAL+1
          ENDDO
          RTNM=(ENMES(MON,YR)-EAVN(1,EAVVAL-1))/
     1     (EAVN(1,EAVVAL)-EAVN(1,EAVVAL-1))
C     COMPUTE AREA (AN) AND VOLUME (VNM) OF NORTH PART, USING
C     MEASURED ELEVATION
          AN=RTNM*(EAVN(2,EAVVAL)-EAVN(2,EAVVAL-1))+EAVN(2,EAVVAL-1)
          VNM(VOLNUM)=RTNM*(EAVN(3,EAVVAL)-EAVN(3,EAVVAL-1))
     1      +EAVN(3,EAVVAL-1)
C     COMPUTE CHANGE IN VOLUME (HVNM) BASED ON MEASURED ELEVATIONS
          IF (YR.EQ.1.AND.MON.EQ.1) VNM(VOLNUM-1)=VNFIRST
          HVNM=VNM(VOLNUM)- VNM(VOLNUM-1)
C     COMPUTE INTERPOLATION RATIO AND INITIAL VOLUME (VNIC) OF NORTH
C     PART USING COMPUTED ELEVATION
C     ASSUME IN EAV TABLE THAT NEW ENI IS LESS THAN +-10 NUMBERS AWAY
C     FROM OLD ENI
          EAVNUM=EAVVALN-10
          EAVVAL=EAVNUM
          DO WHILE((ENI.GE.EAVN(1,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
           EAVVAL=EAVVAL+1
          ENDDO
          RTNC=(ENI-EAVN(1,EAVVAL-1))/(EAVN(1,EAVVAL)- EAVN(1,EAVVAL-1))
          VNIC=RTNC*(EAVN(3,EAVVAL)-EAVN(3,EAVVAL- 1))+EAVN(3,EAVVAL-1)
C     COMPUTE INTERPOLATION RATIO FOR EAVS TABLE (RTSM), USING
C     MEASURED ELEVATION OF SOUTH PART
C     ASSUME IN EAV TABLE THAT NEW ESI IS LESS THAN +-10 NUMBERS AWAY
C     FROM OLD ESI
          EAVNUM=EAVVALS-10
          EAVVAL=EAVNUM
          DO WHILE((ESMES(MON,YR).GE.EAVS(1,EAVVAL))
     1     .AND.(EAVVAL.LE.EAVMAX))
            EAVVAL=EAVVAL+1
          ENDDO
          RTSM=(ESMES(MON,YR)-EAVS(1,EAVVAL-1))/
     1      (EAVS(1,EAVVAL)-EAVS(1,EAVVAL-1))
C     COMPUTE AREA (AS) AND VOLUME (VSM) OF SOUTH PART, USING
C     MEASURED ELEVATION
          AS=RTSM*(EAVS(2,EAVVAL)-EAVS(2,EAVVAL-1))+EAVS(2,EAVVAL-1)
          VSM(VOLNUM)=RTSM*(EAVS(3,EAVVAL)-EAVS(3,EAVVAL-1))
     1      +EAVS(3,EAVVAL-1)
C     COMPUTE CHANGE IN VOLUME (HVSM) BASED ON MEASURED ELEVATIONS
          IF (YR.EQ.1.AND.MON.EQ.1) VSM(VOLNUM-1)=VSFIRST
          HVSM=VSM(VOLNUM)-VSM(VOLNUM-1)
C     COMPUTE INTERPOLATION RATIO AND INITIAL VOLUME (VSIC) OF SOUTH
C     PART USING COMPUTED ELEVATION
          EAVVAL=EAVNUM
          DO WHILE((ESI.GE.EAVS(1,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
            EAVVAL=EAVVAL+1
          ENDDO
          RTSC=(ESI-EAVS(1,EAVVAL-1))/(EAVS(1,EAVVAL)- EAVS(1,EAVVAL-1))
          VSIC=RTSC*(EAVS(3,EAVVAL)-EAVS(3,EAVVAL-1))+EAVS(3,EAVVAL-1)
C     COMPUTE INTERPOLATION RATIO (CS) FOR AVERAGE ANNUAL PRECIPITATION
C     AND AVERAGE ANNUAL EVAPORATION FOR SOUTH PART, USING MEASURED
C     ELEVATIONS
          ELEV=2
          DO WHILE((ESMES(MON,YR).GE.AAPES(1,ELEV)).AND.(ELEV.LE.6))
            ELEV=ELEV+1
          ENDDO
          CS=(ESMES(MON,YR)-AAPES(1,ELEV-1))/
     1          (AAPES(1,ELEV)-AAPES(1,ELEV-1))
          PAAS=CS*(AAPES(2,ELEV)- AAPES(2,ELEV-1))+AAPES(2,ELEV-1)
```

```
      EAAS=CS*(AAPES(3,ELEV)-AAPES(3,ELEV- 1))+AAPES(3,ELEV-1)
C     COMPUTE INTERPOLATION RATIO (CN) FOR AVERAGE ANNUAL PRECIPITATION
C     AND AVERAGE ANNUAL EVAPORATION FOR NORTH PART, USING MEASURED
C     ELEVATIONS
      ELEV=2
      DO WHILE((ENMES(MON,YR).GE.AAPEN(1,ELEV)).AND.(ELEV.LE.6))
        ELEV=ELEV+1
      ENDDO
      CN=(ENMES(MON,YR)-AAPEN(1,ELEV-1))/
     1  (AAPEN(1,ELEV)-AAPEN(1,ELEV-1))
      PAAN=CN*(AAPEN(2,ELEV)- AAPEN(2,ELEV-1))+AAPEN(2,ELEV-1)
      EAAN=CN*(AAPEN(3,ELEV)-AAPEN(3,ELEV- 1))+AAPEN(3,ELEV-1)
C     COMPUTE MONTHLY PRECIPITATION FOR SOUTH PART OF LAKE (PMS),
C     INCLUDES CONVERSION FROM INCHES TO ACRE-FEET
      PFAC=((PMSLC(MON,YR)/PAASLC)+(PMOG(MON,YR)/PAAOG)
     1  +(PMTO(MON,YR)/PAATO))/3
      PMS=PFAC*PAAS*FTFC*AS*PRECIPCAL
C     COMPUTE MONTHLY PRECIPITATION FOR NORTH PART OF LAKE (PMN),
C     INCLUDES CONVERSION FROM INCHES TO ACRE-FEET
      PMN=PFAC*PAAN*FTFC*AN*PRECIPCAL
C     COMPUTE ANNUAL EVAPORATION FOR SOUTH PART OF LAKE
      EAS=EAAS*EAI(YR)
C     COMPUTE ANNUAL EVAPORATION FOR NORTH PART OF LAKE
      EAN=EAAN*EAI(YR)
C     COMPUTE MONTHLY EVAPORATION FOR SOUTH PART OF LAKE,
C     INCLUDES CONVERSION FROM INCHES TO ACRE-FEET AND
C     SALINITY CORRECTION FACTOR, SCFS
      EMS=(EAS*EMI(MON))*(FTFC*AS)*(SCFS(MON,YR))
      IF (YR.EQ.YRCAL) EMS=EMS*EVAPCAL
C     COMPUTE MONTHLY EVAPORATION FOR NORTH PART OF LAKE,
C     INCLUDES CONVERSION FROM INCHES TO ACRE-FEET AND
C     SALINITY CORRECTION FACTOR, SCFN
      EMN=(EAN*EMI(MON))*(FTFC*AN)*(SCFN(MON,YR))
      IF (YR.EQ.YRCAL) EMN=EMN*EVAPCAL

C     INCREASE STREAMFLOW AND GROUND-WATER INFLOW BY FACTOR INFLOCAL
      QTS(MON,YR)=INFLOCAL*QTS(MON,YR)
      QTN(MON,YR)=INFLOCAL*QTN(MON,YR)
C     EVAPORATION (Ac-Ft/Day) FOR CALIBRATION OF THE W&S BALANCE MODEL
      AQESXC=EMS*12.0/(365.0)
      AQENXC=EMN*12.0/(365.0)
C     EVAPORATION (Ft/Day) FOR THE PREDICTIVE W&S BALANCE MODEL
      AQESX=AQESXC/(AS*SCFS(MON,YR))
      AQENX=AQENXC/(AN*SCFN(MON,YR))
C     INFLOW FOR THE WATER AND SALT BALANCE MODEL
      AQISX=(PMS+QTS(MON,YR))*12.0/365.0
      AQINX=(PMN+QTN(MON,YR))*12.0/365.0
      SUMPMS=SUMPMS + PMS
      SUMPMN=SUMPMN + PMN
      SUMQTS=SUMQTS + QTS(MON,YR)
      SUMQTN=SUMQTN + QTN(MON,YR)
C     COMPUTE NET FLOW THROUGH CAUSEWAY FROM SOUTH TO NORTH
      CAUS=HVNM+EMN-PMN-QTN(MON,YR)+WESTP(MON,YR)
C     COMPUTE NET INFLOW TO THE SOUTH PART AS CAUSEWAY FLOW IS
C     SUBTRACTED FROM QTS(MON,YR)
      QSNET=QTS(MON,YR)-CAUS
C     COMPUTE CHANGE IN VOLUME FOR TIME STEP (1 MONTH) FOR SOUTH PART
      HVSC=(PMS+QSNET)-(EMS)
C     COMPUTE CHANGE IN VOLUME FOR TIME STEP (1 MONTH) FOR NORTH PART
      HVNC=(CAUS+PMN+QTN(MON,YR))-(EMN+WESTP(MON,YR))
C     COMPUTE DIFFERENCE BETWEEN MEASURED AND COMPUTED VOLUMES FOR
C     EACH TIME STEP (ONE MONTH)
      HVOLN=HVNM-HVNC
      HVOLS=HVSM-HVSC
C     COMPUTE NEW VOLUMES AT END OF TIME STEP (VNC,VSC)
      VNC=VNIC+HVNC
      VSC=VSIC+HVSC
C     COMPUTE DIFFERENCE BETWEEN COMPUTED AND MEASURED TOTAL VOLUME
      DIFVS=VSM(VOLNUM)-VSC
```

```
C     INTERPOLATE NEW ELEVATION FOR NORTH PART FROM NEW VOLUME (VN)
C     ASSUME IN EAV TABLE THAT NEW ENI IS LESS THAN +-3 NUMBERS AWAY
C     FROM OLD ENI
          EAVNUM=EAVVALN-3
          EAVVAL=EAVNUM
          DO WHILE((VNC.GE.EAVN(3,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
            EAVVAL=EAVVAL+1
          ENDDO
          EN=((VNC-EAVN(3,EAVVAL-1))/(EAVN(3,EAVVAL)-EAVN(3,EAVVAL-1)))*
     1        (EAVN(1,EAVVAL)-EAVN(1,EAVVAL-1))+EAVN(1,EAVVAL-1)
          EAVVALN=EAVVAL
C     INTERPOLATE NEW ELEVATION FOR SOUTH PART FROM NEW VOLUME (VS)
C     ASSUME IN EAV TABLE THAT NEW ESI IS LESS THAN +-10 NUMBERS AWAY
C     FROM OLD ESI
          EAVNUM=EAVVALS-3
          EAVVAL=EAVNUM
          DO WHILE((VSC.GE.EAVS(3,EAVVAL)).AND.(EAVVAL.LE.EAVMAX))
            EAVVAL=EAVVAL+1
          ENDDO
          ES=((VSC-EAVS(3,EAVVAL-1))/(EAVS(3,EAVVAL)-EAVS(3,EAVVAL-1)))*
     1     (EAVS(1,EAVVAL)-EAVS(1,EAVVAL-1))+EAVS(1,EAVVAL-1)
          EAVVALS=EAVVAL
          DIFFS=ESMES(MON,YR)-ES
          DIFFN=ENMES(MON,YR)-EN

C ******************************************************************
C *                      WRITE TO OUTPUT FILES                     *
C ******************************************************************
          WRITE(18,100) AQESXC,AQENXC,AQESX,AQENX,AQISX,AQINX
     -     ,AS,AN,SCFS(MON,YR),SCFN(MON,YR)
  100     FORMAT(2F11.2,2F11.8,2F11.2,2f11.2,2f11.8)

C     WRITE CALIBRATION VARIABLES
          WRITE (*,130)YR,MON,HVSM,HVSC,HVOLS,VSM(VOLNUM),VSC,DIFVS
          IF(VSM(VOLNUM).LT.0)THEN
            PRINT*,"ERROR: NEGATIVE VSM(VOLNUM): ",VSM(VOLNUM)
            STOP
          ENDIF
          IF(VSC.LT.0)THEN
            PRINT*,"ERROR: NEGATIVE VSC: ",VSC
            STOP
          ENDIF
  130     FORMAT (' YR= ',I2,' MO= ',I2,6F10.0)

C     WRITE THE COMPUTED AND MEASURED MONTHLY ELEVATIONS FOR NORTH AND
C     SOUTH PARTS OF THE LAKE BY YEARS (19xx) = YEARFIRST+YR-1
          WRITE (16,140)YEARFIRST+YR-1,MON,EN,ENMES(MON,YR),DIFFN,ES,
     1      ESMES(MON,YR),DIFFS
  140     FORMAT (I4,I6,2F12.2,F7.2,F13.2,F12.2,F7.2)

C     DEFINE INITIAL ELEVATIONS AS FINAL ELEVATIONS FROM LAST TIME STEP
          ENI=EN
          ESI=ES
C     INCREASE COUNTER FOR VOLUMES BY 1
          VOLNUM=VOLNUM+1

        ENDDO
      ENDDO
      STOP
      END
```

Modeling Step #2
2012 UPRR/USGS Model Code
(highlighted to show salt balance code modifications)

```
      PROGRAM MODEL

C  THIS VERSION MODIFIED BY STEPHEN C. ERTMAN, HDR|HYDROQUAL, FOR USE
C  IN SUPPORT OF UNION PACIFIC RAILROAD.

C    1)  PERIOD OF MODEL RUN IS 1/1987 TO 12/2012
C    2)  USES EVAPORATION CORRECTION COEFFICIENTS FROM CALIBRATED MODEL
C    3)  EXISTING BREACH AND CULVERT FLOWS ARE MEASURED
C    4)  INCLUDES NEW BRIDGE AS CHANNEL 3

C ************************  DECLARE VARIABLES  ************************
      INCLUDE 'INCLUDE.TXT'
      LOGICAL*1 LCULV
      REAL*8 CLNPPT,AS,AN,VS,VN,PS,PN,DP,TEMX,PFT,CS
      REAL*8 CN,HAVG,Q1F,Y2F,Q2F,QS,QN,SCFS,SCFN,FCN
C     INTEGER*4 NCHAN,J,IN,JJ,JJJ,K,NPROG,TSCC
      INTEGER*4 NCHAN,J,IN,JJ,JJJ,K,NPROG ! TSCC NOT USED, SCE/20131003

C  VARIABLES FOR CHANGING CHANNEL DIMENSIONS; SCE/20131220
      REAL*8 CHANB2,EBBR3,CHANB3,BSLOPE3
      INTEGER*4 TSBD2,TSBD3

C ************************  OPEN FILES  ******************************

      OPEN (UNIT=15,FILE='SB_inputfile_1987-2012.txt',STATUS='OLD')
      OPEN (UNIT=16,FILE='outputfile.txt',STATUS='UNKNOWN')
      OPEN (UNIT=17,FILE='longoutput.txt',STATUS='UNKNOWN')
      OPEN (UNIT=18,FILE='test.txt',STATUS='UNKNOWN')

C  START READING AND WRITING IN THE OPENED FILES, AT TOP OF EACH FILE
      REWIND (UNIT=15)
      REWIND (UNIT=16)
      REWIND (UNIT=17)
      REWIND (UNIT=18)

C ****************  SET INITIAL & CONTROL CONDITIONS  ****************

C  WATER- AND SALT-BALANCE CONSTANTS/INITIAL CONDITIONS
      LS=2.08e9
      LN=3e9
      CLNPPT=0e9
      LNPPT=0.
      RESOLN=0.
      LES=210.97
      LEN=210.37
      HD=LES-LEN
      DAY=1
      AS=995478
      AN=519964
      VS=18852158
      VN=10383004
      PS=1.051
      PN=1.131
      DP=PN-PS
      KLS=39000000
      KLN=51000000
      ClLS=1087000000
      ClLN=1348000000
      MgLS=70000000
      MgLN=70000000
      NaLS=610000000
      NaLN=771000000

C ******************  COMPUTATIONAL CONTROL  *************SCE/20131014
C     NCHAN=1 !HOLLEY'S EQS COMPUTE BREACH FLOWS ONLY;
C     NCHAN=2 !HOLLEY'S EQS COMPUTE BREACH & CULVERT FLOWS
      NCHAN=3 !HOLLEY'S EQS COMPUTE BREACH, NEW BRIDGE, & CULVERT FLOWS

C     *** SEE ALSO LINES JUST AFTER STATEMENT LABEL 140 ***
```

```
C ******************  END COMPUTATIONAL CONTROL  ***********SCE/20131014

C  TIMESTEPS FOR CHANGES TO CHANNEL DIMENSIONS; SCE/20131220
      TSBD2=1840  ! TIMESTEP FOR FIRST BREACH DEEPENING =  01AUG96
      TSBD3=2608  ! TIMESTEP FOR SECOND BREACH DEEPENING = 01AUG00

C  CHANNEL 1 (EXISTING BREACH) DIMENSIONS; SCE/20131029/20131220
C     CONDITION 1 - INITIAL DESIGN
         CHANT(1)=214.0
         EBBR(1)=210.0
         CHANB(1)=200.0
         CHANW(1)=290.0
         BSLOPE(1)=9.0
C     CONDITION 2 - DEEPENING ON 01 AUG 96 (TSBD2=1840)
         CHANB2=198.0
C     CONDITION 3 - DEEPENING ON 01 AUG 00 (TSBD3=2608)
         EBBR3=208.0
         CHANB3=192.0
         BSLOPE3=6.0
C     *** SHUT OFF CHANNEL 1 FLOW BY RAISING THE INVERT ***
C           CHANB(1)=213.0
C           CHANB2=213.0
C           CHANB3=213.0

C  CHANNEL 2 (COMBINED CULVERTS) DIMENSIONS; SCE/20131029/20131220
C        CHANT(2)=203.0 ! OLD 87-98 MODEL CONDITION
C        CHANB(2)=182.0 ! OLD 87-98 MODEL CONDITION
         CHANW(2)=30.0  ! OLD 87-98 MODEL CONDITION
         CHANB(2)=173.0 ! NEW 2012 CULVERT INVERT ELEVATION
C     *** SHUT OFF CHANNEL 2 FLOW BY RAISING THE INVERT ***
C           CHANB(2)=213.0
         CHANT(2)=CHANB(2)+(203-182) !KEEPS CULVERT HEIGHT AT 87-98 VALUE

C  CHANNEL 3 (NEW BRIDGE) DIMENSIONS; SCE/20131029/20131220
         CHANT(3)=214.0  ! PROPOSED DESIGN CONDITION
         EBBR(3)=212.0   ! PROPOSED DESIGN CONDITION
C        CHANB(3)=178.0  ! PROPOSED DESIGN CONDITION
         CHANW(3)=180.0  ! PROPOSED DESIGN CONDITION
         BSLOPE(3)=3.5   ! PROPOSED DESIGN CONDITION
C     *** SHUT OFF CHANNEL 3 FLOW BY RAISING THE INVERT ***
           CHANB(3)=213.0  ! NEW BRIDGE SHUT OFF FOR FILL CALIBRATION

C  CHANNEL FLOW CONSTANTS/INITIAL CONDITIONS
      SZ=0.0
      TOLX=3.0
      TOLDX=0.01
      TOLQ1=15.0
      TOLHS=0.02
      DELA1=0.2
      ENTRS=0.5
      ENTRN1=0.85
      ENTRN2=0.0
      FCOEF=1.0
      G=32.2

      DO I=1,NCHAN
        NI(I) = NI(I)*SQRT(FCOEF)
        TT(1,I) = (NI(I)/NW1(I))**1.5
        TT(2,I) = (NI(I)/NW2(I))**1.5
        TT(3,I) = (NZ(I)/NW2(I))**1.5
        TT(4,I) = (NZ(I)/NI(I))**1.5
        TT(7,I) = (NT(I)/NI(I))**1.5
        TT(8,I) = (NT(I)/NW1(I))**1.5
        TT(9,I) = (NT(I)/NZ(I))**1.5
      END DO

C  FILL FLOW CONSTANTS/INITIAL CONDITIONS
      FBEI=200.0
      FEEI=200.0
```

```
      FBBE=175.0
      FEBE=175.0
      FBNP=1.0
      FENP=1.0
      FBOP=0.1
      FEOP=0.1

C ************************  READ INPUT FILE  ***************************

C  READ IN THE SOUTH AND NORTH PART ELEV/AREA/VOL TABLES
      READ (15,10) ((SOUTHA(I,J),I=1,3),J=1,91)
      READ (15,10) ((SOUTHB(I,J),I=1,3),J=1,91)
      READ (15,10) ((NORTH(I,J),I=1,3),J=1,91)
   10 FORMAT (3F10.0)

C  READ IN THE SOUTH AND NORTH PART EVAP AND INFLOW DATA
      READ(15,20) (AQES(IN),AQEN(IN),AXES(IN),AXEN(IN),AQIS(IN),
     - AQIN(IN),IN=1,N)
   20 FORMAT (2F11.2,2F11.6,2F11.2)

C  READ IN THE WEST POND PUMPING WATER AND SALT IN/OUTFLOW DATA
      READ(15,30) (AQWP(IN),ALWP(IN),IN=1,N)
   30 FORMAT(f7.0,1x,f7.3)

C  READ IN THE WEST POND PUMPING ION IN/OUTFLOW DATA
      READ(15,35) (ANaLWP(IN),AMgLWP(IN),AKLWP(IN),AClLWP(IN),
     -  IN=1,N)
   35 FORMAT(4f7.3)

C  READ IN THE MEASURED/ESTIMATED BREACH AND CULVERT FLOWS
        READ(15,40) (AMBS(IN),AMBN(IN),AMECS(IN),AMECN(IN),
     -  AMWCS(IN),AMWCN(IN),IN=1,N)
   40 FORMAT(6f8.0)

C  THIS SECTION TAKES VARIABLES WITH ONE VALUE PER MONTH AND GIVES
C    THEM A VALUE FOR EACH TIME STEP
      DO 60 J=1,N
        JJ=J*TSPM-1
        JJJ=JJ+1-TSPM
        IF(J.EQ.N)JJ=JJ+1
        DO 50 K=JJJ,JJ
          QES(K)=AQES(J)*TS
          QEN(K)=AQEN(J)*TS
          XES(K)=AXES(J)*TS
          XEN(K)=AXEN(J)*TS
          QIS(K)=AQIS(J)*TS
          QIN(K)=AQIN(J)*TS
          QWP(K)=AQWP(J)*12./365.*TS
          LWP(K)=ALWP(J)*1e9*12./365.*TS
          ClLWP(K)=AClLWP(J)*1e6*12./365.*TS
          KLWP(K)=AKLWP(J)*1e6*12./365.*TS
          NaLWP(K)=ANaLWP(J)*1e6*12./365.*TS
          MgLWP(K)=AMgLWP(J)*1e6*12./365.*TS
          MBS(K)=AMBS(J)
          MBN(K)=AMBN(J)
          MECS(K)=AMECS(J)
          MECN(K)=AMECN(J)
          MWCS(K)=AMWCS(J)
          MWCN(K)=AMWCN(J)
   50   CONTINUE
   60 CONTINUE

C  READ IN THE FILL FLOW MATRIX
      READ(15,70)MATRIX
   70 FORMAT(F9.3,17F9.2)

C ***********************************************************************
C  WRITE COLUMN LABELS TO OUTPUT FILES
      WRITE(*,77)
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      WRITE(16,75)
      WRITE(17,77)
C  FIXED FORMAT 75 & 77 SO LABELS LINE UP WITH COLUMNS      SCE/20131003
C  ADDED FLOW LABELS FOR CHANNEL 3 (NEW BRIDGE)             SCE/20131029
   75 FORMAT(' TSTEP MO/DAY/YR     HD      LES      LEN     '
     & 'DP     PS     PN     LS9     LN9  LNPPT9   '
C    & 'QSC(1)   QNC(1)   QSC(2)   QNC(2)       FS       FN   '     !SCE
     & 'QSC(1)   QNC(1)   QSC(2)   QNC(2)   QSC(3)   QNC(3)       ' !SCE
     & 'FS       FN   QES(I)   QEN(I)     KLS     KLN    '
     & 'ClLS    ClLN    MgLS    MgLN    NaLS    NaLN')
   77 FORMAT(' TSTEP  MO/DAY/YR     HD      LES      LEN     '
     & 'DP     PS     PN     LS9     LN9  LNPPT9  '
C    & 'QSC(1)  QNC(1)  QSC(2)  QNC(2)      FS      FN')            !SCE
     & 'QSC(1)  QNC(1)  QSC(2)  QNC(2)  QSC(3)  QNC(3)      FS      FN')
C ***********************************************************************

C  WRITE INITIAL CONDITIONS TO OUTPUT FILES
      WRITE(*,80)0,1,DAY,1987,HD,4000.+LES,4000.+LEN,
     -    PN-PS,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9
      WRITE(17,80)0,1,DAY,1987,HD,4000.+LES,4000.+LEN,
     -    PN-PS,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9
   80 FORMAT(I6,1x,2(I2,'/'),I4,F7.2,2F9.2,3F7.3,3F8.4,
C    -  6(1x,F7.0))                                              !SCE
     -  8(1x,F7.0))                                              !SCE
C ***************  BEGIN TIME INTERVAL LOOP (MAIN LOOP)  ***************

      DO 200 I=1,NTS

C  CALCULATE NEW DENSITIES (PS,PN AND DP)
      PS=1.000+0.63*(LS*.0007353)/VS
      PN=1.000+0.63*(LN*.0007353)/VN
      TEMX=12.5+12.0*SIN(.032725*I-1.958)
      PFT= (8*TEMX-(TEMX)**2+132416.)/132432.
      PS=PS*PFT/PF20
      PN=PN*PFT/PF20*.996
      DP=PN-PS
      CS=((PS-1.0)/0.63)*100.
      CN=((PN-1.0)/0.63)*100.
      KCS=KLS/VS
      KCN=KLN/VN
      ClCS=ClLS/VS
      ClCN=ClLN/VN
      MgCS=MgLS/VS
      MgCN=MgLN/VN
      NaCS=NaLS/VS
      NaCN=NaLN/VN

C  FOR FILL FLOW CALIBRATION RUNS, SKIP TO 130
C      GOTO 130

C  BREACH, CULVERT, AND BRIDGE FLOW COMPUTATIONS BEGIN HERE
C    ICHN=1 FOR THE EXISTING BREACH
C    ICHN=2 FOR THE TWO CULVERTS COMBINED
C    ICHN=3 FOR THE NEW BRIDGE

C  DEEPEN THE BREACH BOTTOM (TSBD2=01AUG96, TSBD3=01AUG00); SCE/20131220
      IF (I.GT.TSBD2) THEN
          CHANB(1)=CHANB2
      ELSEIF (I.GT.TSBD3) THEN
          EBBR(1)=EBBR3
          CHANB(1)=CHANB3
          BSLOPE(1)=BSLOPE3
      ENDIF

C  BEGIN CHANNEL (BREACH/CULVERT/NEW BRIDGE) FLOW CALCULATION LOOP
      DO 130 ICHN=1,NCHAN
      TT1=TT(1,ICHN)
      TT2=TT(2,ICHN)
      TT3=TT(3,ICHN)
```

```
      TT4=TT(4,ICHN)
      TT7=TT(7,ICHN)
      TT8=TT(8,ICHN)
      TT9=TT(9,ICHN)

      IF(ICHN.EQ.2)THEN !SKIPS CULVERTS PAST BREACH/BRIDGE CALCULATIONS
         CHNW=CHANW(ICHN)
         GOTO 100
      ENDIF

C  SET THE CHANNEL WIDTHS FOR THE SUBROUTINE CALCULATIONS TO THE ACTUAL
C    BOTTOM WIDTHS OF THE EXISTING BREACH AND NEW BRIDGE, SO THAT BOTTOM
C    FRICTION IS CALCULATED PROPERLY
      IF(CHANB(ICHN).LT.EBBR(ICHN))THEN
         WBB=CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-CHANB(ICHN))
      ELSE
         WBB=CHANW(ICHN)
      ENDIF
      CHNW=WBB

  100 CONTINUE

C ******************* START MODIFICATION *****************SCE/20131022
C     HS=LES-CHANB(1)    !INCLUDE ALL CHANNELS & MOVE LINE
C     HN=LEN-CHANB(1)    !INCLUDE ALL CHANNELS & MOVE LINE

C  ASSUME CHANNEL FLOW IS ZERO IF LES ABOVE OR BELOW CHANNEL
C     IF((LES.GE.CHANT(ICHN)).OR.
C    -  (LES.LE.CHANB(ICHN)))THEN
C         QSC(ICHN)=0.0
C         QNC(ICHN)=0.0
C         GOTO 130
C     ENDIF

C  TERMINATE MODEL RUN FOR FLOODING OVER CAUSEWAY
      IF(LES.GE.(CHANT(1)-1))THEN  ! 1 FT BELOW BREACH TOP
         WRITE (*,*) 'SOUTH ARM WSEL EXCEEDS FLOODING THRESHOLD OVER
     &                CAUSEWAY.'
         WRITE (*,*) 'TIME STEP = ', I
         WRITE (*,*) 'EXECUTION STOPPED AT STATEMENT LABEL 105.'
  105    STOP
      ENDIF

C  ASSUME CHANNEL FLOW IS ZERO IF LES BELOW CHANNEL BOTTOM
      IF(LES.LE.CHANB(ICHN))THEN
         QSC(ICHN)=0.0
         QNC(ICHN)=0.0
         GOTO 130
      ENDIF

C  ASSUME WEIR FLOW: LEN <= CHANB AND CHANB < LES < CHANT
      IF((LEN.LE.CHANB(ICHN)).AND.
     -    (LES.LT.CHANT(ICHN)).AND.
     -    (LES.GT.CHANB(ICHN)))THEN
         QSC(ICHN)=3.5*CHNW*(LES-CHANB(ICHN))**1.5
         QNC(ICHN)=0.0
         GOTO 125
      ENDIF

      HS=LES-CHANB(ICHN) !BY MOVING LINE, HS > 0 ALWAYS
      HN=LEN-CHANB(ICHN) !BY MOVING LINE, HN > 0 ALWAYS
C     BUT ADD ERROR TRAP ANYWAY TO PREVENT CODE ERRORS FROM PROPAGATING
      IF ((HS.LE.0.0).OR.(HN.LE.0.0)) THEN
         WRITE (*,*) 'HS = ', HS, 'HN = ', HN
         WRITE (*,*) 'ERROR: HS & HN SHOULD BE GREATER THAN ZERO.'
         WRITE (*,*) 'EXECUTION STOPPED AT STATEMENT LABEL 106.'
  106    STOP
      ENDIF
C ******************* END MODIFICATION *******************SCE/20131022
```

```
C  CONVERT DENSITIES TO ENGLISH UNITS & REDUCE DENS. JUST N. OF CHANNEL
      HEIGHT=CHANT(ICHN)-CHANB(ICHN)
      RHO2=1.94*PN*(1.0-3.0E-06*QSC(ICHN))
      RHO1=1.94*PS
      EPS=(RHO2 - RHO1)/RHO2

C  CALCULATE AVERAGE CHANNEL LENGTH BASED ON AVERAGE DEPTH.
C    FL IS BASED ON THE AVERAGE LENGTH FOR A CULVERT WITH A RECTANGULAR
C    LONGITUDINAL CROSS SECTION 136 FT LONG UP TO A DEPTH OF 12 FT AND
C    THEN A TRAPEZOIDAL LONGITUDINAL CROSS SECTION WITH A BASE 88 FT
C    LONG AND END SLOPES OF ONE.
      FL = 136.
      HAVG = 0.5*(HS+HN)
      IF(HAVG .GT. 12.) FL=136.*12./HAVG+(88.-(HAVG-12.))*(HAVG-12.)
     -  /HAVG

C  CALL SUBROUTINE FOR SINGLE LAYER FLOW COMPUTATION. IF NPROG RETURNS
C    EQUAL TO 3, THEN SINGLE LAYER FLOW WAS CORRECT AND PROGRAM IS READY
C    FOR NEXT CONDITION. OTHERWISE, PROCEED TO COMPUTATION FOR ARRESTED
C    WEDGE FLOW.
            LCULV=.TRUE.
            CALL CULV3(NPROG)
            IF(NPROG .EQ.3) GOTO 120
  110       CONTINUE
            IF(HN*RHO2/RHO1.GT.HS)THEN
              CALL CULV2A(NPROG)
            ELSE
              CALL CULV2B(NPROG)
            ENDIF

C IF NPROG RETURNS EQUAL TO 2, THEN ARRESTED WEDGE WAS THE CORRECT
C FLOWTYPE AND PROGRAM IS READY FOR NEW CONDITION. OTHERWISE, PROCEED
C TO COMPUTATION FOR TWO LAYER FLOW.
            IF(NPROG .EQ. 2.OR..NOT.LCULV) GOTO 120
            CALL CULV1(NPROG)
            LCULV=.FALSE.
            IF(NPROG .EQ. 2) GOTO 110

  120 CONTINUE  !PROGRAM IS READY FOR NEW A CONDITION

      Q1PREV=Q1
      Q2PREV=Q2
      IF(Q2.LT.0.0)Q2=-Q2
      QSC(ICHN)=Q1
      QNC(ICHN)=Q2

  125 CONTINUE

      IF(ICHN.EQ.2) GOTO 130  !SKIPS CULVERTS PAST BREACH/BRIDGE CALCS

C  BEGIN EXISTING BREACH & NEW BRIDGE FLOW TRAPEZOIDAL AREA COMPUTATIONS
C ---------------------------------------------------------------------
C     ETUL=((A1S+A1N)/2.) + CHANB(ICHN)   !ERRONEOUS CODE;  SCE/20131014
      ETLL = (A2S+A2N)/2. + CHANB(ICHN)
      ETUL = ETLL + (A1S+A1N)/2.          !CORRRECTED CODE; SCE/20131014
      IF(CHANB(ICHN).GE.ETLL)ETLL=CHANB(ICHN)
      SAUL = (ETUL-ETLL)*WBB
      SALL = (ETLL-CHANB(ICHN))*WBB

C  COMPUTE AREA OF THE EXISTING BREACH & NEW BRIDGE UPPER FLOW LAYER
      IF(ETUL.GT.EBBR(ICHN))THEN
         IF(ETLL.GE.EBBR(ICHN))THEN
            AUBL=(ETUL-ETLL)*CHANW(ICHN)
         ELSE
           AUBL=(ETUL-EBBR(ICHN))*CHANW(ICHN)+(EBBR(ICHN)-ETLL)*
     -     (CHANW(ICHN)- BSLOPE(ICHN)*(EBBR(ICHN)-(EBBR(ICHN)+ETLL)/2.))
         ENDIF
      ELSE
```

```
            AUBL=(ETUL-ETLL)*(CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-
     -       (ETUL+ETLL)/2.))
          ENDIF

C  COMPUTE AREA OF THE EXISTING BREACH & NEW BRIDGE LOWER FLOW LAYER
          IF(ETLL.GT.EBBR(ICHN))THEN
            IF(CHANB(ICHN).GE.EBBR(ICHN))THEN
              ALBL=(ETLL-CHANB(ICHN))*CHANW(ICHN)
            ELSE
             ALBL=(ETLL-EBBR(ICHN))*CHANW(ICHN)+(EBBR(ICHN)-CHANB(ICHN))*
     -       (CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-(EBBR(ICHN)+CHANB(ICHN))
     -        /2.))
            ENDIF
          ELSE
            ALBL=(ETLL-CHANB(ICHN))*(CHANW(ICHN)-BSLOPE(ICHN)*(EBBR(ICHN)-
     -       (ETLL+CHANB(ICHN))/2.))
          ENDIF

C  COMPUTE THE AREA CORRECTION FACTORS THAT WILL CONVERT THE DISCHARGES
C    COMPUTED IN THE SUBS (RECTANGULAR AREAS) TO THE ACTUAL AREAS AT THE
C    EXISTING BREACH & NEW BRIDGE (TRAPEZOIDAL AND RECTANGULAR)
          ULACF=0.
          LLACF=0.
          IF(SAUL.GT.0.0)ULACF=AUBL/SAUL
          IF(SALL.GT.0.0)LLACF=ALBL/SALL

C  ADJUST BREACH & NEW BRIDGE FLOWS FOR CORRECT CROSS-SECTIONAL AREAS
          IF(ICHN.NE.2)QSC(ICHN)=QSC(ICHN)*ULACF
          IF(ICHN.NE.2)QNC(ICHN)=QNC(ICHN)*LLACF
C ---------------------------------------------------------------------
C  END EXISTING BREACH & NEW BRIDGE FLOW TRAPEZOIDAL AREA COMPUTATIONS

  130     CONTINUE

C  SET ALL CHANNEL DISCHARGES TO ZERO IF NCHAN = 0
          IF(NCHAN.EQ.0)THEN
            DO 140 ICHN=1,MCHAN
              QSC(ICHN)=0.0
              QNC(ICHN)=0.0
  140       CONTINUE
          ENDIF

C  IF USING COMPUTED BREACH AND/OR CULVERT FLOWS, COMMENT OFF THE
C    LINES BELOW WHICH USE THE MEASURED (I.E., READ-IN) FLOW VALUES
          QSC(1)=MBS(I)            !OVERWRITE HOLLEY'S CALCS FOR BREACH
          QNC(1)=MBN(I)            !OVERWRITE HOLLEY'S CALCS FOR BREACH
          QSC(2)=MECS(I)+MWCS(I)  !OVERWRITE HOLLEY'S CALCS FOR CULVERTS
          QNC(2)=MECN(I)+MWCN(I)  !OVERWRITE HOLLEY'S CALCS FOR CULVERTS
C ***********************************************************SCE/20131014

C  USE FILL FLOW MATRIX TO DETERMINE FILL FLOW BASED ON 1973 CONDITIONS
          CALL INTER3(MATRIX,PS,DP,LEN,HD,Q1F)
C         FBE=FEBE+I*((FBBE-FEBE)/2304) !Make code self-adjusting to
          FBE=FEBE+I*((FBBE-FEBE)/NTS)  !model duration; SCE/20131219
          Y2F=LEN-FBE-HD*PS/DP
          IF(Y2F.LE.0.)Y2F=0.0
          Q2F=73.40086*(DP*Y2F**2)
          IF(Q2F.GT.4300.0)Q2F=84.40083*(DP*Y2F**2)-516.5435
          IF(Q1F.LE.0.)Q1F=0.0
          IF(Q2F.LE.0.)Q2F=0.0
          IF(DP.LE..05.AND.HD.GT.0.60)Q2F=0.0

C  FILL FLOW REDUCTION FACTOR EQS
C         FEI=FEEI+I*((FBEI-FEEI)/2304) !Make code self-adjusting to
C         FNP=FENP+I*((FBNP-FENP)/2304) !model duration; SCE/20131219
C         FOP=FEOP+I*((FBOP-FEOP)/2304) !SCE/20131219
          FEI=FEEI+I*((FBEI-FEEI)/NTS)  !SCE/20131219
          FNP=FENP+I*((FBNP-FENP)/NTS)  !SCE/20131219
          FOP=FEOP+I*((FBOP-FEOP)/NTS)  !SCE/20131219
```

```
      FSE=LES
      FNE=Y2F+FBE
      IF(FSE.GE.FEI)THEN
         FCFS=(((FSE-DMAX1(FEI,FNE))*FNP)+
     -    ((FEI-DMAX1(0.00D0,FNE))*FOP))/(FSE-DMAX1(FBE,FNE))
      ELSE
         FCFS=FOP
      ENDIF
      IF(FNE.GE.FEI)THEN
         FCFN=((((FNE-FEI)*FNP)+((FEI-FBE)*FOP))/(FNE-FBE))
      ELSE
         FCFN=FOP
      ENDIF

C  ADJUST FILL FLOWS COMPUTED WITH 1973 CONDITIONS TO REFLECT
C    1987-98 CONDITIONS JUST CALCULATED
      FS=Q1F*FCFS
      FN=Q2F*FCFN

C  COMPUTE TOTAL FLOW THRU THE CAUSEWAY IN EACH DIRECTION IN ACFT
C     QS=(QSC(1)+QSC(2)+FS)*TS*CAC  !SCE/20131028
C     QN=(QNC(1)+QNC(2)+FN)*TS*CAC  !SCE/20131028
      QS=(QSC(1)+QSC(2)+QSC(3)+FS)*TS*CAC  !SCE/20131028
      QN=(QNC(1)+QNC(2)+QNC(3)+FN)*TS*CAC  !SCE/20131028

C  COMMENT OFF THE FOLLOWING 4 LINES IF YOU WANT TO USE ESTIMATED
C     EVAPORATION COMPUTED IN THE WATER BALANCE PROGRAM
      SCFS=1.0-0.00778*(CS/PS)
      SCFN=1.0-0.00778*(CN/PN)
      QES(I)=XES(I)*AS*SCFS
      QEN(I)=XEN(I)*AN*SCFN

C  COMPUTE NEW VOLUMES, ELEVATIONS AND AREAS
      VS=VS-QS+QN+QIS(I)-QES(I)
      VN=VN+QS-QN+QIN(I)-QEN(I)-QWP(I)
      IF(I.LT.1344)THEN                  ! 1344 = 01JAN94
          CALL RINTER(LES,VS,SOUTHA)
          CALL INTERP(LES,AS,SOUTHA)
      ELSE
          CALL RINTER(LES,VS,SOUTHB)
          CALL INTERP(LES,AS,SOUTHB)
      ENDIF
      CALL RINTER(LEN,VN,NORTH)
      CALL INTERP(LEN,AN,NORTH)

      HD=LES-LEN
      IF(HD.LE.0.08)HD=0.08

C  CALCULATE NEW ION LOAD VALUES
      KLS=KLS-(QS*KCS)+(QN*KCN)
      KLN=KLN+(QS*KCS)-(QN*KCN)-KLWP(I)
      ClLS=ClLS-(QS*ClCS)+(QN*ClCN)
      ClLN=ClLN+(QS*ClCS)-(QN*ClCN)-ClLWP(I)
      MgLS=MgLS-(QS*MgCS)+(QN*MgCN)
      MgLN=MgLN+(QS*MgCS)-(QN*MgCN)-MgLWP(I)
      NaLS=NaLS-(QS*NaCS)+(QN*NaCN)
      NaLN=NaLN+(QS*NaCS)-(QN*NaCN)-NaLWP(I)

C  CALCULATE NEW SALT LOAD VALUES
      LS= LS+(QN*LN/VN-QS*LS/VS)
      LN= LN+(QS*LS/VS-QN*LN/VN)-LWP(I)
      FCN=LN/VN
      LNPPT=0.0
      RESOLN=0.0
      IF (FCN.GT.483.)THEN
         LNPPT=LN-483.*VN
         CLNPPT=LNPPT+CLNPPT
         LN=LN-LNPPT
      ELSE
```

```
            RESOLN=.01*(483.*VN-LN)
            IF(RESOLN.GT.CLNPPT)RESOLN=CLNPPT
            CLNPPT=CLNPPT-RESOLN
            LN=LN+RESOLN
          ENDIF
          IF(CLNPPT.LT.0.)CLNPPT=0.

          ClLN=ClLN-(.607*LNPPT)+(.607*RESOLN)
          NaLN=NaLN-(.393*LNPPT)+(.393*RESOLN)

C  INCREASE DATE COUNTERS IN THE LOOP
          YEAR=INT(I*TS/365.+1.)
          MONTH=INT(((I*TS/365.+1.)-YEAR)*12.+1.)
          DAY=DAY+2
          IF(DAY.EQ.33)THEN
            DAY=1
            MONTH=MONTH+1
          ENDIF
          IF(MONTH.EQ.13)THEN
            MONTH=1
            YEAR=YEAR+1
          ENDIF
          YEAR=YEAR+1986

C*******************  WRITE OUTPUT TO FILES  ************************

C  WRITE TO MAIN OUTPUT FILE FOR AT FIRST OF MONTH
          IF(I.EQ.1)WRITE(16,150)I,MONTH,YEAR,HD,LES+4000.,LEN+4000.,
         -    DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
         -    QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN,
         -    QES(I)/1.9,QEN(I)/1.9,KLS/1E9,KLN/1E9,ClLS/1E9,ClLN/1E9,
         -    MgLS/1E9,MgLN/1E9,NaLS/1E9,NaLN/1E9

          IF(DAY.EQ.1)THEN
            WRITE(16,150)I,MONTH,YEAR,HD,LES+4000.,LEN+4000.,
         -    DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
         -    QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN,
         -    QES(I)/1.9,QEN(I)/1.9,KLS/1E9,KLN/1E9,ClLS/1E9,ClLN/1E9,
         -    MgLS/1E9,MgLN/1E9,NaLS/1E9,NaLN/1E9
          END IF
C 150 FORMAT(I6,1x,I2,'/1/',I4,F7.2,2F9.2,3F7.3,3F8.4,8(1x,F8.0),8F8.4)
  150 FORMAT(I6,1x,I2,'/1/',I4,F7.2,2F9.2,3F7.3,3F8.4,10(1x,F8.0),8F8.4)

C  WRITE TO SCREEN AND OUTPUT FILES FOR TIMESTEP
          WRITE(*,80)I,MONTH,DAY,YEAR,HD,LES+4000.,LEN+4000.,
         -  DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
         -  QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN
          WRITE(17,80)I,MONTH,DAY,YEAR,HD,LES+4000.,LEN+4000.,
         -  DP,PS,PN,LS/1E9,LN/1E9,CLNPPT/1E9,
         -  QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3),FS,FN
          WRITE(18,190)I,MONTH,DAY,YEAR,FS,FN,PS,PN,CS,CN,VN,
         -  QEN(I),LN,CLNPPT,QSC(1),QNC(1),QSC(2),QNC(2),QSC(3),QNC(3)
C 190 FORMAT(I6,1x,2(I2,'/'),I4,2F8.2,2F8.4,2F7.0,F12.0,
C    -  F7.0,2F12.0,4F7.0)
  190 FORMAT(I6,1x,2(I2,'/'),I4,2F8.2,2F8.4,2F7.0,F12.0,
         -  F7.0,2F12.0,6F7.0)

C ****************  END MAIN LOOP AND END PROGRAM  *****************

  200 CONTINUE
          ENDFILE (UNIT=15)
          ENDFILE (UNIT=16)
          ENDFILE (UNIT=17)
          ENDFILE (UNIT=18)
          CLOSE (UNIT=15)
          CLOSE (UNIT=16)
          CLOSE (UNIT=17)
          CLOSE (UNIT=18)
          END
```

```
      BLOCK DATA BEGIN
      INCLUDE 'INCLUDE.TXT'
C **** EXTEND MANNING'S NUMBERS TO HANDLE 3 CHANNELS; SCE/20131028 ****
C     DATA (NW1(I),NW2(I),NI(I),NZ(I),NT(I),I=1,2)/.015,.015,.01,
C    -     .024,.015, .015,.015,.01,.015,.015/
      DATA (NW1(I),NW2(I),NI(I),NZ(I),NT(I),I=1,3)/.015,.015,.01,
     -     .024,.015, .015,.015,.01,.015,.015, .015,.015,.01,.024,.015/
C ******************************************************************
      END
```