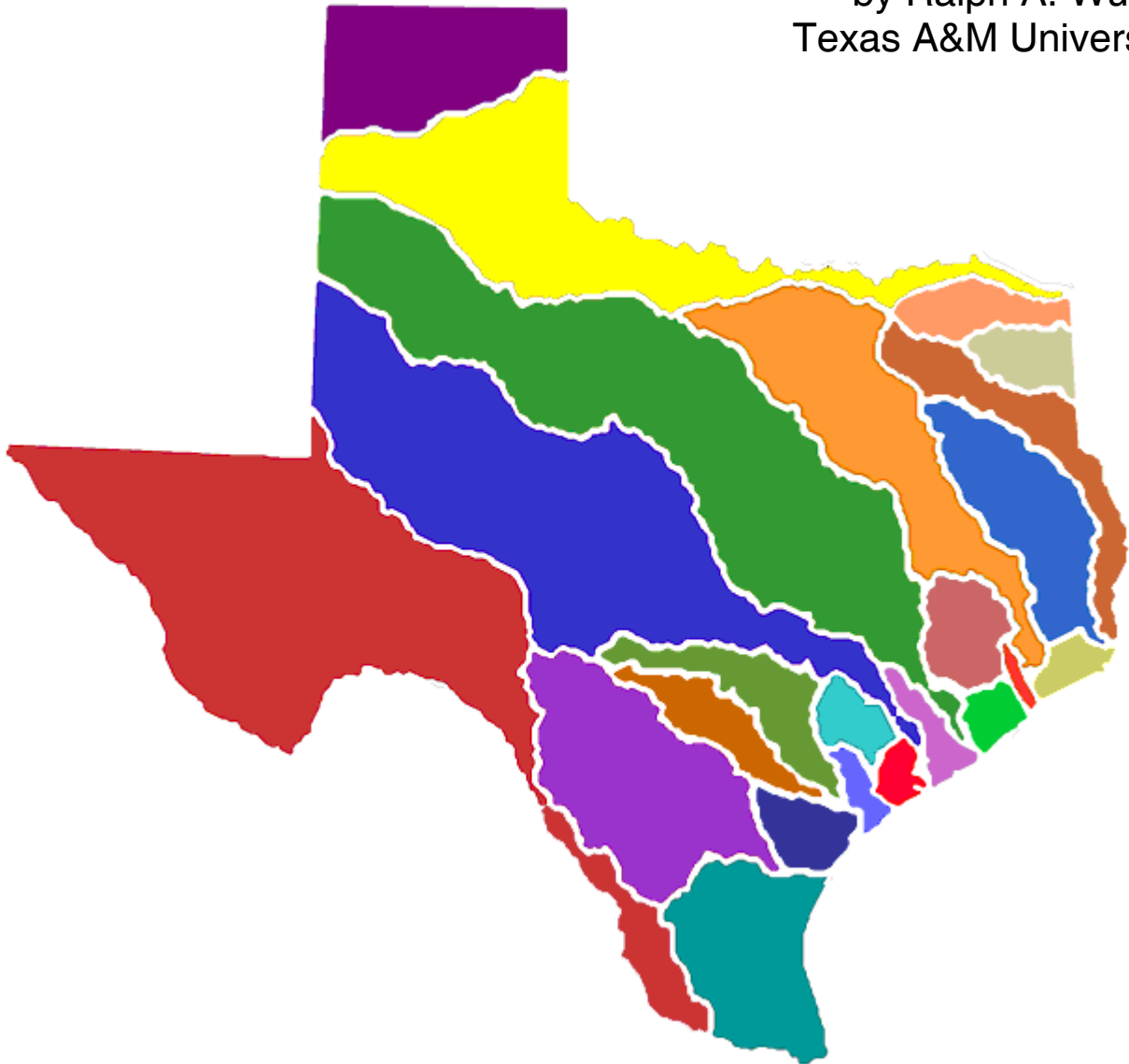


# Salinity Simulation with WRAP

by Ralph A. Wurbs  
Texas A&M University



TR-317  
Texas Water Resources Institute  
College Station, Texas  
July 2009



# **Salinity Simulation with WRAP**

by

Ralph A. Wurbs  
Texas A&M University

for the

Texas Commission on Environmental Quality  
Austin, Texas 78711-3087

Cosponsored with Supplemental Funding Support

from the

Fort Worth District, U.S. Army Corps of Engineers  
and  
Texas Water Resources Institute, Texas A&M University System

Technical Report No. 317  
Texas Water Resources Institute  
The Texas A&M University System  
College Station, Texas 77843-2118

July 2009



## TABLE OF CONTENTS

Introduction.....	1
Salinity Aspects of Water Availability Modeling .....	1
Computer Programs, Data Files, and Input Records .....	2
Spatial Configuration.....	4
Salinity Input Dataset.....	7
Program SALIN.....	8
Volumes, Loads, and Concentrations .....	9
Salinity Simulation with Program <i>SALT</i> .....	12
Reservoir Storage and Outflow Concentrations .....	21
<i>SALT</i> Simulation Results .....	34
<i>TABLES</i> Time Series, Summary, Frequency, and Reliability Tables .....	39
Parameter Calibration Comparison Features .....	40
Constant Salinity Simulation Example .....	41
Salinity Simulation Example .....	43
References.....	59
Appendix A Instructions for Preparing <i>SALT</i> Input Records .....	61
Appendix B Instructions for Preparing <i>SALIN</i> Input Records .....	75
Appendix C Instructions for Preparing <i>TABLES</i> Input Records .....	79

## LIST OF FIGURES

1. Control Point Configuration .....	5
2. Organization of <i>SALT</i> Computations .....	12
3. Outline of the Salinity Simulation Performed by Program <i>SALT</i> .....	13
4. System Schematic for the Example .....	44
5. Outflow Concentrations at Control Points PK and Hemp Plotted with HEC-DSSVue from the DSS File Created with the <i>TABLES</i> 8SAL Record .....	66

## LIST OF TABLES

1. Components of Control Point Inflows and Outflows .....	11
2. Variables from <i>SIM/SIMD</i> Simulation Results .....	14
3. Simulation Results for Example 1 .....	28
4. SIM DAT File for Salinity Example 2 .....	31
5. <i>SALT</i> SIN File for Salinity Example 2 .....	31
6. <i>SALT</i> Output SMS File for Constant Lag of 6 Months .....	32

## LIST OF TABLES (Continued)

7. SALT Output SMS File for Variable Lag .....	33
8. Trace Messages Written to SMS File .....	35
9. Variables in First Line of SMS Data Set .....	35
10. Monthly Volume and Load Budget by Control Point SAL File Dataset .....	36
11. SMS File Table of Total Volume and Load for the Entire River/Reservoir System and Period-of-Analysis .....	37
12. Variables in SAL File.....	39
13. Variables in 8SAL, 8FRE, and 8FRQ Record Tables .....	40
14. SALT SIN File for Salinity Example 3 .....	42
15. Summary Table for Salinity Example 3 .....	43
16. Beginning Reservoir Storage BRS File for the Example .....	47
17. Reservoir Storage BRS File for the Example .....	47
18. SALT Input SIN File for the Example .....	48
19. SALT Message SMS File for the Example .....	51
20. First Portion of SALT Output SAL File for the Example .....	52
21. TABLES Input TIN File for the Example .....	53
22. TABLES Message TMS File for the Example .....	53
23. TABLES Output TOU File for the Example .....	54

## **Introduction**

The Water Rights Analysis Package (WRAP) modeling system is documented by basic reference and users manuals and supplemental manuals covering specific features, including this manual which deals specifically with salinity simulation capabilities. This *Salinity Manual* is an extension of the *Reference* and *Users Manuals* (Wurbs 2009).

Salinity tracking components of WRAP consist of the simulation model *SALT*, auxiliary program *SALIN*, and table building routines in the program *TABLES*. Program *SALT* combines water quantity data read from the *SIM* or *SIMD* simulation results file with concentrations or loads of inflows from a salinity input file. The program *SALIN* provides optional routines designed to assist in developing salinity input data for program *SALT*. Options in *TABLES* organize the *SALT* salinity simulation results and develop frequency statistics. The combined *SIM*, *SALT*, and *TABLES* model is designed for simulating water quality throughout a system of river reaches and reservoirs for alternative scenarios of water use, reservoir system operating policies, and salt control measures. Loads and concentrations of water quality constituents in stream flows, reservoir storage, and diversions throughout the river system are computed.

The salinity simulation features of the WRAP modeling system track loads and concentrations of water quality constituents through a system of river reaches and reservoirs subject to water supply diversions and return flows and reservoir system operations. Salt loads associated with various components of inflow, outflow, and storage are mixed and transported along with the water. Load losses and gains can also be specified as a percentage of stream flow loads and reservoir storage loads. Losses or gains through biological and chemical processes are not otherwise directly modeled. Thus, water quality constituents are assumed to be conservative. The WRAP water quality modeling capabilities are applicable to any essentially conservative constituent though motivated primarily by natural salt pollution.

### **Salinity Aspects of Water Availability Modeling**

Water supply capabilities depend upon water quality as well as quantity. Spatial and temporal variability of salinity represents an aspect of assessing water availability for various uses under alternative water resources development and management scenarios. WRAP salinity modeling features are designed primarily for computing concentration frequency statistics at locations of interest throughout a river system for alternative water management plans.

Salinity refers to dissolved minerals and may be quantified in terms of the concentration of total dissolved solids (TDS) or particular constituents such as chlorides or sulfates. Salinity plays an important role in water resources development and management throughout the world, particularly in relatively arid regions. In the United States, salinity is a particularly important consideration in the states located west of the Rocky Mountains as well as in Texas and neighboring states. In the Southwest, geologic formations underlying the upper watersheds of the Rio Grande, Pecos, Colorado, Brazos, Red, Canadian, and Arkansas Rivers in Texas, New Mexico, Oklahoma, Kansas, and Arkansas contribute large salt loads to the rivers (Wurbs 2002). Primary salt source subwatersheds of these major river basins have streams with TDS concentrations that sometimes exceed that of seawater. The water quality simulation features of WRAP are motivated by the natural salt pollution problems in Texas and neighboring states.

Early research in incorporating salinity considerations into the WRAP modeling system are reported by Wurbs *et al.* (1994), Sanchez-Torres (1994), and Wurbs and Sanchez-Torres (1996). The present salinity simulation features of WRAP were developed during 2004-2009. Krishnamurthy (2005) and Ha (2006) present case study investigations of applying new modeling capabilities during the developmental process. Wurbs and Lee (2009) report more detailed modeling studies of natural salt pollution in the Brazos River Basin based on further improvements in WRAP salinity tracking capabilities.

Salt concentrations are an important consideration in assessing water supply capabilities. The U.S. Environmental Protection Agency secondary drinking water standards suggest limits for TDS, chloride, and sulfate concentrations of 500, 250, and 250 mg/l, respectively, based on health effects and taste preferences and because conventional treatment processes do not remove salinity. Salts also damage pipelines, equipment, household appliances, and industrial facilities. Salinity tolerance for different types of industrial water use varies greatly. Salinity greatly affects irrigated agriculture. Although plants can tolerate and even require minerals for growth, excessive salts within the root zone reduce or prevent plant growth. Tolerable maximum TDS limits for irrigation range from significantly less than 1,000 mg/l to greater than 10,000 mg/l depending on the crop, soil conditions, and proportion of soil moisture supplied by rainfall versus irrigation. Salinity is a major determinant of aquatic habitat. Many aquatic plants and animals are adapted to certain ranges of dissolved solids concentrations. Changes in salinity may significantly impact ecosystems. Dissolved solids affect saturation concentrations of dissolved oxygen and influence the ability of a water body to assimilate wastes. Eutrophication rates depend on TDS. Salts affect the mobility and transformation of other water quality constituents.

WRAP may be applied to assess the impacts of water resources development, management, allocation, and use strategies on salt loads and concentrations throughout a river system. Measures for dealing with salinity may be evaluated. Salinity mitigation measures include blending water from multiple sources such as releases from multiple reservoirs on different tributaries of varying water quality, control of runoff from primary salt source subwatersheds, and desalination facilities. The impacts of interbasin transfers of water of varying salinity or conjunctive use of surface and groundwater resources may be investigated.

### **Computer Programs, Data Files, and Input Records**

A simulation study begins with development of the necessary input datasets. With all input files complete, a salinity simulation is performed in three steps.

1. A *SIM* or *SIMD* simulation is performed to determine water quantities.
2. A *SALT* simulation is performed to combine salinity data with the sequences of monthly time-step simulation results produced by *SIM* or *SIMD*.
3. *TABLES* is used to develop tables that organize and summarize simulation results.

*SALT* has a monthly computational time step, but monthly-aggregated results from a *SIMD* daily time step simulation may be incorporated into the *SALT* simulation. Instructions for preparing input records for *SALT*, *SALIN*, and salinity-related features of *TABLES* are provided in the appendices of this manual. *SALIN* is a pre-simulation utility program that may be used to assist in developing the salt loads or concentrations recorded in the *SALT* salinity input SIN file.

Program *SALT* reads five types of input files and creates three types of output files.

*SALT Input Files*

- DAT – *SIM* or *SIMD* input file (*CP* and *CI* records) (required)
- OUT – *SIM* or *SIMD* output file (required)
- BRS – *SIM* or *SIMD* beginning reservoir storage file (optional)
- BRC – Beginning reservoir concentration file previously created by *SALT* (optional)
- SIN – Salinity input file (required)

*SALT Output Files*

- SAL – Salinity simulation results file read by *TABLES*
- SMS – Message file with error and warning messages and tables of results
- BRC – Beginning-of-simulation reservoir concentrations to be read by *SALT*

Program *SALT* reads DAT, OUT, and BRS files produced by programs *SIM* or *SIMD*. The DAT and OUT files are required. The beginning reservoir storage BRS file is optional.

- The *CP* records are read from the *SIM/SIMD* input file (filename root.DAT) to assign the next downstream control point for each control point which defines the spatial connectivity of the river system. Constant inflow *CI* records are also read.
- The main *SIM/SIMD* simulation results OUT file provides stream flow, diversion, storage, and other pertinent quantities by control point used in the salinity simulation. *SALT* reads the complete set of all control point output records from the OUT file but does not read (skips over) water right and reservoir output records.
- A *SIM/SIMD* BRS file provides beginning-of-simulation reservoir storage contents.

Program *SALT* reads salinity input data from a required SIN file and optional BRC file. The salinity input file with filename extension SIN contains the *SC*, *CO*, *CP*, *CC*, *RC*, and *S* records described in Appendix A. The optional beginning reservoir concentration file (extension BRC) may be used to provide beginning-of-simulation storage concentrations. *SALT* also writes end-of-simulation reservoir concentrations to the BRC file if so specified on the *SC* record.

Program *SALT* produces output files with filename extensions SAL, SMS, and BRC.

1. The final simulation results output file with filename extension SAL is a table with each line containing the year, month, and control point and the following results for the control point: inflow volume, load, and concentration; end-of-month storage volume, load, and concentration; outflow volume, load, and concentration; downstream flow and diversion concentrations; and diversion target and shortage. Program *TABLES* reads the SAL file and reorganizes the salinity simulation results in various formats including time series, frequency, and reliability tables.
2. The message file with filename extension SMS provides a trace of the simulation, error and warning messages, an optional listing of control point information, and three types of optional tables of simulation results.



3. An optional beginning reservoir concentration file with filename extension BRC contains the final storage concentrations at the end of a simulation to be read by a subsequent execution of *SALT* as beginning-of-simulation storage concentrations.

The program *TABLES* reads the program *SALT* output SAL file with the simulation results and the *TABLES* input TIN file with specifications regarding the tables to be created. *TABLES* develops the following tables summarizing the *SALT* simulation results.

*8SAL* records create tables of volumes, loads, and concentrations for control point inflow, storage, and outflow that are identical in format to the *2NAT*, *2STO*, and *2REG*, and other type 2 time series tables.

*8FRE* and *8FRQ* records create frequency tables of volumes, loads, and concentrations for control point inflow, storage, and outflow that are identical in format to the *2FRE* and *2FRQ* records.

*8REL* records create reliability tables that reflect limits on salt concentrations. In addition to the diversion shortages incurred in *SIM/SIMD* due to insufficient water volume, shortages are declared if concentrations exceed specified levels.

*8SUM* records provide control point summaries of volumes, loads, and concentrations.

Other optional types of tables recorded by program *SALT* in the message SMS file do not involve program *TABLES*. The SMS file tables include:

- listing of control points in sequential order of the computations with pertinent information
- lengthy detailed tabulation of intermediate computation results by time step and control point
- tabulation of simulation results by time step and control point showing details of reservoir lag computations
- brief overall water volume and salt load balance summary table

### **Spatial Configuration**

The *SIM* output OUT file read by *SALT* must contain output records for all control points included in the *SIM* input DAT file. The spatial connectivity of a river system is specified by *CP* records in the *SIM* DAT file. *SALT* reads the identifiers of each control point and its next downstream control point from the *CP* records in the DAT file. A salinity simulation involves two other additional considerations related to the spatial configuration of the river system.

1. *SALT* performs its salt load tracking computations by control point in an upstream-to-downstream order. All *SIM* control points must be included in the OUT file.
2. *SALT* obtains information from *CP* records found in both the SIN and DAT files. However, the *CP* records in the SIN file providing salinity data may be fewer in number than the *CP* records in the DAT file establishing the spatial connectivity of the river system. Salinity input may be repeated for any number of control points.

### Upstream-to-Downstream Computational Sequence

The computations performed within *SALT* proceed sequentially by control point in an upstream-to-downstream order. The first control point considered is the most upstream control point on one of the stream branches. The computations are repeated for each individual control point proceeding in an upstream-to-downstream sequence. Computations are performed for a particular control point only after completion of computations for all control points located upstream of that control point. This is necessary because the load of the regulated flows entering the control point from upstream must be included in the salt balance computations.

For example, for the system shown schematically in Figure 1, the computations may begin at either control point CP-1, CP-3, or CP-5. One alternative correct sequencing of control points is as follows: CP-1, CP-2, CP-3, CP-4, CP-5, CP-6. Another of the several alternative acceptable sequences is: CP-5, CP-3, CP-1, CP-2, CP-4, CP-6. If sequencing is performed automatically within *SALT*, the computations will begin at the control point of the first *CP* record found in the *SIM* DAT file for which no other control points are located upstream.

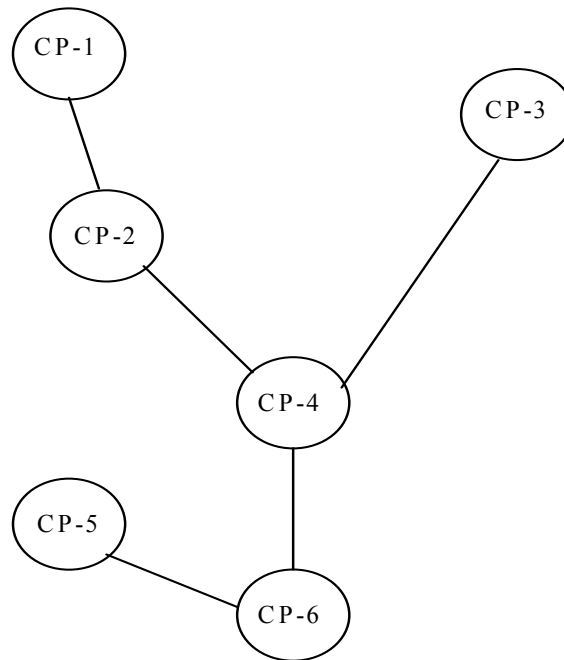


Figure 1 Control Point Configuration

The two control point identifiers on each of the *CP* records read by *SALT* from a *SIM* input DAT file establish the spatial connectivity of the river system. The *CP* records in a *SIM* DAT file may be in any random order. The parameter *UPDOWN* in *SC* record field 7 of a *SALT* input SIN file activates an option that internally within *SALT* properly sequences the control points in an upstream-to-downstream order that satisfies the following rule.

*For each control point, all control points located upstream are listed before that control point.*

*SALT* develops an array of control point identifiers that defines the computational sequence. This *SALT SC* record option is not required if the *SIM* control point *CP* records are properly sequenced in the DAT file in accordance with the above rule.

*CP* records in a *SIM* or *SIMD* DAT file can be easily rearranged manually for small datasets with relatively few control points. For larger datasets, the *TABLES ICPT* record routine is useful for rearranging *CP* records with the proper sequencing required for a *SALT* simulation. With a *ICPT* record, program *TABLES* reads the *SIM* input DAT file and rearranges the *CP* records in an appropriate upstream-to-downstream order. The rearranged *CP* records may then be inserted by the model user into a *SIM* input DAT file to be read by both *SIM* and *SALT*. Alternatively, the *SC* record field 7 option automatically handles the sequencing computationally within the *SALT* simulation.

#### *CP Records in the DAT and SIN Files and Repetition of Salinity Input Data*

Control point *CP* records are included in the *SALT* input SIN file as well as in the *SIM* input DAT file. The SIN file *CP* records may be entered in any order. All control points with *CP* records in the SIN file must also have *CP* records in the *SIM* DAT file. However, all control points with *CP* records in the *SIM* DAT file do not necessarily have *CP* records in the SIN file. Certain pertinent information provided for a *CP* record control point in the SIN file may be repeated for any number of other control points located either upstream or downstream.

Time series of monthly concentrations of local incremental inflows are provided in the *SALT* salinity input SIN file for any number of control points. Alternatively, a constant concentration rather than monthly varying concentrations for a control point may be specified. The concentrations of incremental inflows read from the SIN file for a particular control point may be repeated for any number of other control points. These data may be provided in the SIN file for any or all of the control points. The data must be included for either the most downstream control point or the most upstream control point on each branch for which salinity is modeled.

Options also allow upstream salinity boundary conditions to be defined at control points that are not upstream extremities. Salinity is not modeled by *SALT* at control points located upstream of an upstream boundary condition control point even though water quantities are computed in the *SIM* simulation.

Again using the Figure 1 example, if salinity is to be modeled at all control points, the *SALT* input SIN file must include *CP* records with pertinent salt information for either CP-6 or for CP-1, CP-3, and CP-5. If salinity at CP-1 is not of concern, CP-2 may serve as upstream boundary with CP-1 being omitted from the SIN file. With CP-2 defined as an upstream boundary, salt loads or concentrations for outflows at CP-2 are provided as input in the SIN file. *SIM* water quantities for CP-1 are read but salinity computations begin at CP-2.

Options in *SALT* also allow certain salinity data from the SIN file to be repeated for multiple control points. Assume that the *SIM* DAT file *CP* record sequence for the system of

Figure 1 is CP-1, CP-2, CP-3, CP-4, CP-5, CP-6. Any or all but at least one of these control points must be included in the *SALT* SIN file. Repeat options activated by *SC* record field 11 allow data to be repeated for either upstream (option 1) or downstream (option 2) control points. With option 1, the input data are repeated for all upstream control points not included in the SIN file up to the next control point which is included in the SIN file. For example, with option 1, the concentration of local incremental flows and beginning-of-simulation reservoir storage concentration may be provided as input in the SIN file for CP-6 and automatically repeated within *SALT* for all of the other control points. With option 2, CP-1, CP-3, and CP-5 could be included in the SIN file with repeats occurring as follows. Data input for CP-1 are repeated for CP-2. Input for CP-3 are repeated for CP-4. The data for CP-5 are repeated for CP-6.

### **Salinity Input Dataset**

A *WRAP-SALT* simulation consists of tracking beginning-of-simulation storage loads and the loads entering the river/reservoir system each month. The *SALT* salinity input SIN file includes specification of salinity inflows at all control points in the river/reservoir system being modeled. As discussed in the previous section, the salinity inflow data recorded in the SIN file for a particular control point can be automatically repeated within the *SALT* simulation computations for any number of other control points. The salinity inflows at a particular control point may be provided in the SIN file, as specified by *CP* record field 3, as either:

1. a time series of concentrations or loads entered as a set of *S* records
2. a constant concentration or load entered on a *CC* record
3. zero concentration and load

The salinity inflow data provided on *CC* and *S* records may be of the following alternative forms as specified by *CP* record field 4:

1. concentrations of incremental naturalized flows (The incremental flows are total flows for a control point with no other control points located upstream.)
2. incremental loads (The incremental loads are total loads for a control point with no other control points located upstream.)
3. total loads at an upstream boundary
4. concentrations of total regulated flows at an upstream boundary

Upstream salinity boundary conditions may be defined at control points that are not upstream extremities in the *SIM* dataset. Salinity is not modeled by *SALT* at control points located upstream of a upstream boundary condition control point even though water quantities are computed in the *SIM* simulation. All control points must still be included in the *SIM* output OUT file read by *SALT* to obtain the correct regulated flow volumes at the upstream salinity boundary, even though the salinity computations begin at the boundary and proceed downstream.

Reservoir storage concentrations are specified for the beginning of the simulation period-of-analysis. A beginning concentration may be entered in *CC* record field 4. Alternatively, a beginning reservoir storage (BRC) file option may be activated by *SC* record field 9. The storage concentration at the end of the simulation may be recorded in the BRC file for each control point. The storage concentrations at the beginning of the simulation may be read from the BRC file. Beginning concentrations may be manually set equal to ending concentrations.

## Program SALIN

The availability of salinity data will vary greatly with different river basins and *WRAP-SALT* applications. Program *SALT* provides flexible capabilities for specifying salinity inflows to a river/reservoir system in various formats as outlined in the preceding section. Program *SALIN* is a utility program designed to assist in developing time series of salinity loads or concentrations for inclusion in a *SALT* input SIN file as *S* records. Depending upon data availability and options selected for the *SALT* simulation, the optional *SALIN* pre-simulation program may possibly be useful in developing the SIN file for a particular application. Instructions for preparing *SALIN* input data are provided in Appendix B.

Program *SALIN* provides capabilities for extending the time period covered by the salt concentrations or loads recorded on the SIN file *S* records. For example, Wurbs and Lee (2009) describe a *SALT* simulation performed for a period-of-analysis of January 1940 through December 2007. Naturalized monthly flow volumes are available for the entire 1940-2007 hydrologic period-of-analysis. However, salinity data are available for only the period from October 1963 through September 1986. *SALIN* is applied to synthesize loads or concentrations for January 1940 through September 1963 and for November 1986 through December 2007 based on the salinity data available for October 1963 through September 1986 and the naturalized flow volumes available for the entire 1940-2007 hydrologic period-of-analysis. *SALIN* also computes summary statistics for comparing given and synthesized data sequences.

*SALIN* provides the following alternative approaches for synthesizing either concentrations or loads to extend the period-of-analysis covered by available salinity data.

- conventional least-squares linear or non-linear regression of monthly load or concentration as a function of flow volume
- direct linear interpolation of a flow volume versus load or concentration table

The regression analysis alternative may be advantageous over the direct interpolation alternative from the perspective of providing a better estimate of the expected value of monthly concentration or load for a given monthly volume. However, variations in concentration are lost in the regression approach. The direct interpolation option is advantageous compared to regression from the perspective of better preserving the variability in concentrations.

Standard textbook least-squares regression procedures are applied in *SALIN* to compute the coefficients *a* and *b* in the equation:

$$Y = a X^b \tag{1}$$

*X* is the naturalized monthly flow volume. *Y* denotes either monthly loads or concentrations. The linear regression option sets the exponent *b* at 1.0. The nonlinear regression option allows *b* to deviate from 1.0. In the previously mentioned example, the coefficients *a* and *b* are computed based on the available monthly data for October 1963 through September 1986. Equation 1 is then applied to synthesize loads or concentrations (*Y*) for the remainder of the 1940-2007 period-of-analysis based on the known naturalized flow volumes (*X*). The linear correlation coefficient is also computed as an index of closeness-of-fit.

The volume-load table interpolation option consists of the following steps or variations thereof.

1. Again using the previously noted example for illustration, the pairs of flow volumes and loads for the 276 months from October 1963 through September 1986 are ranked in ascending order of flow volume to develop a volume versus load table (array).
2. Linear interpolation of this table is applied to obtain loads corresponding to known naturalized flow volumes for each month of the remainder of the 1940-2007 period.
3. The 1940-2007 monthly loads and volumes are combined to obtain concentrations.

Tables of statistics for the flow volumes, loads, and concentrations are developed by *SALIN* for pertinent time periods to facilitate comparison of synthesized and given data. The statistics include mean, standard deviation, minimum, maximum, and autocorrelation coefficient.

### **Volumes, Loads, and Concentrations**

The program *SIM* simulation results provide volume/month flow rates and end-of-month storage volumes. The program *SALT* input SIN file provides loads or concentrations for beginning-of-simulation reservoir storage and monthly incremental naturalized stream flows. *SALT* computes loads and concentrations for inflows, outflows, and storage at all control points except those located upstream of optionally defined upstream boundary control points. Program *TABLES* salinity routines build tables for volumes, loads, and concentrations for control point inflows, outflows, and storage. *TABLES* also has a routine for determining water supply diversion reliabilities constrained by maximum allowable salt concentration limits.

#### Units of Measure

Any consistent set of units may be adopted for storage volumes, volume/month flow rates, salt loads, and concentrations. A conversion factor may be entered in *SC* record field 15 to set the unit of measure for concentration for given load and volume units.

Concentration (C), load (L), and storage or flow volume (Q) are related as follows:

$$C = \frac{L}{Q} f_C \quad \text{or} \quad L = \frac{CQ}{f_C} \quad (2)$$

where  $f_C$  is a conversion factor that is entered in *SC* record field 15, with a default of 735.48 that corresponds to units of milligrams per liter (mg/l) for C, tons or tons/month for L, and acre-feet or acre-feet/month for Q. The default factor reflects the following conversions.

$$\frac{\text{mg}}{\text{liter}} = \left( \frac{\text{tons}}{\text{ac-ft}} \right) \left( \frac{2,000 \text{ pounds}}{\text{ton}} \right) \left( \frac{453.59 \text{ g}}{\text{pound}} \right) \left( \frac{1,000 \text{ mg}}{\text{gram}} \right) \left( \frac{\text{ac-ft}}{43,560 \text{ ft}^3} \right) \left( \frac{\text{ft}^3}{28.316 \text{ liters}} \right)$$

$$\frac{\text{milligrams}}{\text{liter}} = \left( \frac{\text{tons}}{\text{acre-feet}} \right) (735.48)$$

For units of mg/l, tons/day, and ft<sup>3</sup>/s, the conversion factor  $f_C = 370.81$  should be entered in SC record field 15.

$$\frac{\text{mg}}{\text{liter}} = \left( \frac{\text{tons/day}}{\text{ft}^3/\text{s}} \right) \left( \frac{2,000 \text{ pounds}}{\text{ton}} \right) \left( \frac{453.59 \text{ g}}{\text{pound}} \right) \left( \frac{1,000 \text{ mg}}{\text{gram}} \right) \left( \frac{\text{day}}{86,400 \text{ s}} \right) \left( \frac{\text{ft}^3}{28.316 \text{ liters}} \right)$$

$$\frac{\text{milligrams}}{\text{liter}} = \left( \frac{\text{tons/day}}{\text{ft}^3/\text{s}} \right) (370.81)$$

Discharge-weighted or volume-weighted mean concentrations  $C_M$  are computed as follows.

$$C_M = \frac{\sum L}{\sum Q} f_C \quad (3)$$

The concentrations of monthly flows entering the confluence of two tributaries are combined to obtain the discharge-weighted mean concentration of flow leaving the confluence. Likewise, monthly loads and flows are summed to obtain a discharge-weighted mean annual concentration.

#### Components of Control Point Inflows and Outflows

The following volume and load balance equations are fundamental to the *WRAP-SALT* simulation computations.

$$\text{change in reservoir storage volume} = \text{inflow volume} - \text{outflow volume} \quad (4)$$

$$\text{change in reservoir storage load} = \text{inflow load} - \text{outflow load} \quad (5)$$

Equations 4 and 5 are applied at each control point for each month of the simulation. For control points with no reservoirs, storage volume and load are zero. For the volume and load balance summary table written to the message SMS file, Equations 4 and 5 are applicable to the total river/reservoir system over the total period-of-analysis. The volume and load balances are actually applicable to any contiguous set of control points over any period of time. From the perspective of volume and load balances at a control point, the inflow and outflow terms in Eqs. 4 and 5 consist of the summation of the inflow and outflow components listed in Table 1.

Monthly volumes of naturalized flow, regulated flow, end-of-month reservoir storage, channel loss credits, channel losses, and return flows are read by *SALT* from the *SIM* output file and are defined in the *Reference* and *Users Manuals*. Monthly diversion targets and shortages are also read from the *SIM* output file, and diversion volumes are computed as their difference. Constant inflows input to *SIM* on *CI* records are not included as separate quantities in the *SIM* output file. Thus, *SALT* reads the *CI* records from the *SIM* input file along with the *CP* records.

The inflow and outflow volumes and loads written to the SAL output file are the totals for the component inflows and outflows listed in Table 1. The inflow and outflow concentrations are the volume-weighted means of the concentrations of each component.

Table 1  
Components of Control Point Inflows and Outflows

---

Control Point Inflows

*incremental naturalized flows* – Cumulative naturalized flow volumes are read from the *SIM* output file. Incremental volumes are computed by *SALT* by subtracting amounts at upstream control points. Either loads or concentrations are read from the SIN file.

*upstream regulated flows* – Monthly volumes are read from the *SIM* output file for all control points. Inflow loads are outflow loads from upstream control points computed earlier in the *SALT* simulation. For stream confluences, outflow volumes and loads at control points located immediately upstream on each tributary are summed.

*channel losses and channel loss credits* – Channel losses/credits associated with upstream control points are used to adjust the total inflows for the control point under consideration. For tributary confluences, volumes and loads at control points located immediately upstream of the site under consideration on each tributary are summed. Channel loss and loss credit volumes are read from the *SIM* output file. Concentrations are computed based on total outflow volumes and loads at each individual upstream control point, but are constrained by the minimum and maximum concentration limits specified on *CC* records in the SIN file.

*return flows* – Monthly volumes are read from the *SIM* output file. Concentrations are assigned based on options specified on SIN file *CC* records.

*constant inflows* – Monthly volumes are read from *CI* records in the *SIM* input file. Concentrations are assigned based on options specified on SIN file *CC* records.

Control Point Outflows

*reservoir evaporation* – Volumes are from *SIM* output file. Loads and concentrations are zero.

*regulated flows* – Monthly volumes are read from the *SIM* output file. Loads are computed by *SALT* through the procedures outlined in Figure 3 based largely on Equation 5.

*diversions* – Diversion volumes are diversion targets less shortages read from the *SIM* output file. Diversion loads are computed by combining concentrations with volumes.

*other reservoir releases* – Monthly volumes for reservoir releases made specifically for hydropower or downstream instream flow requirements are computed by *SALT* based on the volume balance reflected in Eq. 4 with all terms except the *other releases* read from the *SIM* output file. The corresponding loads are computed by the simulation algorithms along with return flow and regulated flow loads.

*load losses or gains* – Losses or gains of constituent load may be specified as a percentage of inflow loads or storage loads which, unlike the other inflow and outflow load components, have no associated volumes or concentrations.

---



## Salinity Simulation with Program SALT

The *WRAP-SALT* model computes salt loads and concentrations for each control point of a river/reservoir system for inflows and outflows during the month and end-of-month reservoir storage for each month of the hydrologic period-of-analysis, for given loads entering the system. Frequency statistics are developed with *TABLES* from the simulation results. The salt tracking algorithms are based on mass balance accounting. Water quality constituents are assumed to be conservative with no chemical or biological transformations. Multiple constituents such as total dissolved solids, chlorides, sulfates, etc., may be included in a single execution of *SALT*. Each constituent is simulated with the same mass balance algorithms, with no differentiation of different characteristics of different water quality constituents.

### Organization of the SALT Simulation

The *SALT* computations are performed within repetitive loops as illustrated in Figure 2. The simulation may be repeated for up to 15 different water quality constituents. For each salt constituent, the simulation steps through each month of the hydrologic period-of-analysis. In a particular month, the computations are repeated for all control points. For each control point in turn, the inflow volumes and loads are first computed. Volumes, loads, and concentrations of outflows and reservoir storage at the control point are then computed. The simulation procedures are outlined in greater detail in Figure 3.

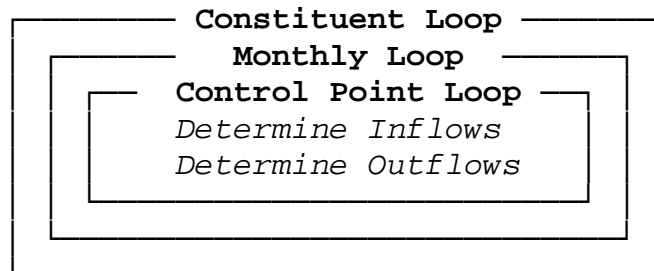


Figure 2 Organization of *SALT* Computations

Inflows and outflows are amounts during the month, and storage amounts are instantaneous values at the end of the month. The volume, load, and concentration of the water stored in reservoirs at the end of a month become the beginning-of-month values for the next month. The reservoir lag options described later in this chapter allow the concentration of reservoir releases to be determined based on storage concentrations in previous months.

A volume and load balance summary table and optional additional detailed results tables are written to the *SALT* message SMS file. The SMS file tables include the component parts of the total control point inflows and outflows as outlined in Table 1. Two other optional data listings may be recorded in the SMS file. Another detailed simulation results table provides information designed for tracking reservoir lag option computations. A control point table showing control point sequencing and other information may also be included in the SMS file.

- 
- Prior to beginning the three computational loops shown in Figure 2
    1. The required *SIM* input (DAT) and output (OUT) and *SALT* input (SIN) and output (SAL, SMS) files are activated.
    2. The optional beginning reservoir storage volume (BRS) and concentration (BRC) files are initiated after reading *SC* record specifications from the SIN file.
    3. The identifier of each control point and its next downstream control point are read from the *CP* records in the *SIM* DAT file to establish spatial connectivity.
    4. All data in the SIN file are read except the *S* records of time series of salt inflows.
  - ***Beginning of Salt Constituent Loop*** \_\_\_\_\_
    1. Salt concentrations or loads are read from the *S* records in the SIN file or constant concentrations from *CC* records are assigned if a SIN file control point has no *S* records.
    2. Beginning-of-simulation reservoir storage concentrations and loads are set.
    3. The initial concentrations are repeated at the other *SIM* control points that are not included in the SIN file.
      - ***Beginning of Monthly Time Step Loop*** \_\_\_\_\_
        1. Beginning-of-month reservoir storage volumes, loads, and concentrations are set at beginning-of-simulation values for the first month and thereafter at end-of-month values from the preceding month.
        2. Water quantities are read from the *SIM* simulation results OUT file.
          - ***Beginning of Control Point Simulation Loop*** \_\_\_\_\_
            1. Lag is set and monthly lag index is updated if the lag options are activated.
            2. Volumes and loads entering the control point are determined.
            3. Concentrations of regulated flows and diversions leaving the control point and the end-of-month storage load and concentration are determined.
            4. Simulation results are written to the SAL and SMS files.
            5. Totals are accumulated for the SMS file total volume and salt balance table.
          - ***Control Point Simulation Loop is Repeated*** \_\_\_\_\_
        - ***Monthly Time Step Loop is Repeated*** \_\_\_\_\_
 

Volume and load totals are written to the summary table in the SMS file.
    - ***Salt Constituent Loop is Repeated*** \_\_\_\_\_
 

End-of-simulation storage concentrations are written to the optional BRC file.
- 

Figure 3 Outline of the Salinity Simulation Performed by Program *SALT*

Simulation results are written to the main *SALT* output file with filename extension SAL at the end of the control point loop for user-selected control points. The SAL file consists of a table for each water quality constituent that contains the following information written for user-selected control points for each month of the simulation.

- year and month and control point identifier
- total volume and load and mean concentration of the inflows to the control point
- total volume and load and mean concentration of the storage at the control point
- total volume and load and mean concentration of the outflows from the control point
- concentration of downstream flows and concentration of diversions
- total water supply diversion targets and shortages for the month at the control point

Inflows and outflows are totals or means during the month, and storage amounts are instantaneous values at the end of the month. The water supply diversion targets and shortages are the volumes read from the *SIM* output file and are included in the SAL file for use by *TABLES* in building a reliability table.

Volume and Load Accounting

Water quantities are provided by the *SIM* simulation results. The control point output records of the *SIM* main output file are read by *SALT* for a given month at the beginning of the monthly time step loop shown in Figure 3. The quantities read for that month for each control point are listed in Table 2. The index cp implies the variable is stored as a control point array. The salt tracking computations include all control points. All control points included in the *SIM* input file must also be included in the *SIM* output file. *SALT* reads only the control point output records from the *SIM* output file. Water right and reservoir output records are skipped. Multiple water rights may be located at the same control point in a *SIM* simulation. *SIM* results used by *SALT* represent summations by control point.

Table 2  
Variables from *SIM/SIMD* Simulation Results

<i>SIM</i> Output Variable	CP Output Record Field	Fortran Variable
diversion shortage	2	DS(cp)
diversion target	3	DT(cp)
net evaporation-evaporation	4	EVAP(cp)
reservoir storage content	5	STO(cp)
return flow returned to cp	8	RET(cp)
naturalized flow	9	NAT(cp)
regulated flow	10	REG(cp)
channel loss credits	11	CLC(cp)
channel losses	12	CL(cp)

The total monthly diversion volume DIV is computed from the corresponding diversion target (DT(cp)) and shortage (DS(cp)) as:

$$\text{DIV} = \text{DT}(\text{cp}) - \text{DS}(\text{cp}) \quad (6)$$

The variable names used in the Fortran code are adopted in the following discussion. Variables with the cp array index are data stored in active memory as the iterative computations progress. Computed variables without indices are repetitively recomputed.

In the *SALT* model, salt loads enter the river/reservoir system in four ways.

1. Beginning-of-simulation reservoir storage loads represent the salt content of reservoirs at the beginning of the first month of the period-of-analysis.
2. Incremental local inflows represent the salt loads entering the river system with the incremental naturalized flows during each month of the simulation. At the most upstream control point on a stream branch, this is the total load associated with the total naturalized streamflow. Progressing downstream, additional local incremental loads at each control are associated with the additional incremental inflows.
3. An option allows a control point to be treated as an upstream boundary. The salinity tracking computations are not performed upstream of this boundary even though volumes are read from the *SIM* output file for all control points including those located above a *SALT* upstream boundary. Salinity loads or concentrations input for an upstream boundary represent outflows from that control point.
4. Salt may also enter the system through return flows from water supply diversions or as *CI* record constant inflows representing flows from outside of the river/river system from sources such as groundwater or interbasin transfers.

A *SALT* simulation consists of tracking or accounting for the movement of these salt loads through the river/reservoir system. Salt loads are tracked by control point in upstream to downstream order. A particular control point may or may not have reservoir storage. The water and salt accounting balances the flow volumes and loads entering and leaving the control point during the month and the change in volume and load in storage at the control point. At each control point, the simulation algorithms perform as the following two tasks.

1. Flows and loads entering the control point as defined in Table 1 are determined.
2. The loads and concentration of outflows leaving the control point, and the loads and concentration of the reservoir storage at the end of the month are determined.

#### Storage Volumes and Concentrations at the Beginning of the Simulation

After the first month, the reservoir storage volume, concentration, and load at each control point at the beginning of a month of the simulation are equal the respective values at the end of the preceding month. Sequential months of the simulation are connected by reservoir storage volume and load. Reservoir storage volume and concentration for each control point must also be established for time zero at the beginning of the first month of the simulation.

The options for setting the beginning-of-simulation storage volumes are controlled by *SC* record field 8. Beginning-of-simulation storage volumes may be specified in the *SIN* file in *CP* record field 9. Another option is for *SALT* to read a beginning-reservoir-storage file with filename extension *BRS* created by *SIM* as specified by *SIM JO* record field 6. A third option is for *SALT* to compute the beginning-of-simulation storage volumes *BSS(cp)* using end-of-month storage (*ST*), streamflow depletion (*DEP*), net evaporation-precipitation (*EP*), and diversion (*DT-DS*) volumes for the first month of the simulation read from the *SIM* main output *OUT* file as follows.

$$BSS(cp) = ST - DEP + EP + DT - DS \quad (7)$$

In some cases the beginning-of-simulation storage may depend upon other reservoir releases not included in the *SIM* output file and Equation 7. Thus, this option may be approximate. The other option of creating a *BRS* file is advantageous in this regard, since the *BRS* file will always contain the exact beginning storages from *SIM*. The first option of entering the beginning-of-simulation storage for particular control points in *SIN* file *CP* record field 9 will over-ride the other options for a particular control point. The other options assign values for all control points including those not included in the *SIN* file.

Options for setting the beginning-of-simulation reservoir storage concentrations are selected by *CP* field 10, *CC* field 4, and/or *SC* record field 9. Beginning storage concentrations from *CC* records are subject to the repeat options of *SC* record field 11 while the concentration on a *CP* record is applied only to that individual control point. Thus, a concentration may be entered for the *CP* record control point on the *CP* record and a different concentration for upstream control points entered on the *CC* record connected to the *CP* record.

If beginning concentrations are not known, the *SALT BRC* file may be applied similarly as the *SIM* beginning-ending-storage (*BES*) file based on the premise of cycling the hydrologic period-of-analysis. *SALT* is executed two or more times as necessary to match ending and beginning conditions. The end-of-simulation concentrations are written to a *BRC* file and can be manually reassigned as beginning-of-simulation concentrations. The concentrations in the *BRC* file are read by subsequent executions of *SALT* as beginning-of-simulation concentrations.

The cycling premise involves setting beginning-of-simulation storage volumes and concentrations equal to end-of-simulation storage volumes and concentrations determined by previous executions of *SIM* and *SALT*. Since, ending values depend upon beginning values, multiple iterative simulations may be performed. The beginning-ending-storage (*BES*) options in *SIM* controlled by *JO* record field 5 facilitate applying this strategy to set the beginning storage volumes. The beginning-of-simulation reservoir concentration file options in *SALT* controlled by *SC* record field 9 facilitate applying the strategy for the concentrations.

### Inflow Volumes and Loads Entering a Control Point

The total monthly inflow volume (*FIN*) and load (*LIN*) that enters a control point is determined based on the following summations.

$$FIN = FNAT + FREG + RET(cp) + CINF(cp,m) + FCLC - FCL \quad (8)$$

$$LIN = LNAT + LREG + LRET + LCIN + LCLC - LCL \quad (9)$$

Using variable names from the Fortran code, the flow volumes (FIN) and salt loads (LIN) entering a control point include the following inflows described in Table 1.

- FNAT, LNAT – monthly volume and load from incremental naturalized inflow
- FREG, LREG – monthly volume and load from upstream regulated flows
- RET(cp), LRET – monthly volume and load from return flows entering cp
- CINF(cp,m), LCIN – monthly volume and load from *CI* record constant inflows

Since inflows include outflows from upstream control points, adjustments are made for:

- FCLC, LCLC – monthly volume and load of channel loss credits
- FCL, CLC – monthly volume and load of channel losses

Incremental naturalized flow volumes (FNAT) and upstream regulated flow volumes (FREG) are determined from NAT(cp) and REG(cp) read from the *SIM* simulation results (Table 2). Channel loss credits (FCLC) and channel losses (FCL) are also computed from CLC(cp) and CL(cp) amounts from the *SIM* output file associated with upstream control points. Return flows (RET(cp)) from the *SIM* output file are used directly without further manipulation.

The incremental naturalized flow (FNAT) entering a control point is computed as the cumulative flow (NAT(cp)) at that control point less the corresponding total flows at any control points located immediately upstream. If no control points are located upstream, the incremental (FNAT) and cumulative (NAT(cp)) naturalized flows are the same. Regulated flow (FREG) entering the control point is computed as the summation of regulated flows (REG(cp)) from upstream control points. Total inflow volumes originating at upstream control points are adjusted for channel loss credits (FCLC) and channel losses (FCL) that are likewise computed as summations of CLC(cp) and CL(cp) at upstream control points read from the *SIM* output file.

Salt loads and concentrations are either provided as input in the SIN file or computed within *SALT* based on combining volumes with concentrations or loads using Eq. 2 or Eq. 3. Loads and concentrations are determined as follows.

- Salinity concentrations of incremental naturalized flows are either read directly from the SIN input file or alternatively computed from loads read from the SIN file.
- If a control point is defined as an upstream boundary, concentrations of the regulated outflows are either read directly from the SIN file or alternatively determined from loads read from the SIN file. Otherwise, loads of entering regulated flows are based on regulated flow loads at upstream control points previously computed in the control point computational loop. The concentration of regulated flows at the control point under consideration in the control point loop is computed as the outflow concentration.
- Two options are provided by *CC* record field 6 for setting the salt concentration of the return flows entering the river system at this control point. A constant return flow concentration may be entered in the *CC* record field 6. Alternatively, the model may

adopt the mean concentration of the outflows from upstream control points constrained by the limits specified in *CC* record fields 8 and 9.

- Two options are provided by *CC* record field 7 for setting the concentration of the *CI* record constant inflows entering the river system at this control point. A constant inflow concentration may be entered in the *CC* record field 7. Alternatively, *SALT* may use the mean concentration of the outflows from upstream control points constrained by the limits specified in *CC* record fields 8 and 9 in the same manner as for return flows.
- Loads of inflows originating from control points located upstream are adjusted for channel losses and loss credits based on concentrations at individual upstream control points determined from previously computed outflow volumes and loads. The limits from *CC* record fields 8 and 9 are applied. Estimating loads associated with channel losses/credits also includes application of an optional multiplier factor (CLF) from *CC* record field 12 that has a default value of 1.0. A CLF of 1.0 means that salt loads and stream flow volumes are lost to channel losses in the same proportion. CLF less than or greater than 1.0 increases or decreases the impact of channel losses on loads.

For a control point with no storage, the total outflow load should equal the total inflow load. However, the *SALT* computations may result in the outflow load not equaling inflow load. The most common such situation is a negative inflow load with the resulting negative outflow load set to zero. This negative inflow and zero outflow would result in a loss of load. *SALT* contains an adjustment to prevent losing load in this manner. The difference in inflow and outflow load (LIX(cp)) occurring in a particular month is added to the inflow load during the next month. The load difference is carried into the next month only for conditions of zero or negative storage load, which include months of zero storage (empty reservoir) for control points with reservoirs as well as control points with no reservoir. With reservoir storage, the inflow-outflow load difference is handled automatically by a change in storage load. However, negative end-of-month storage loads are set to zero with the adjustment carried to the next month.

### Outflow and Storage Volumes, Loads, and Concentrations

The final products of the *SALT* salinity accounting computations are the volume, load, and concentration of outflows leaving each control point during each month and the volume, load, and concentration of the end-of-month storage at each control point. Key variables are listed below with their names from the Fortran code. FOUT(cp) and LOUT(cp) defined below are summations of outflow components which are outlined in the following discussion.

- FOUT(cp) – volume of outflows leaving control point excluding net evaporation
- LOUT(cp) – total load of all the outflows leaving the control point
- COUT, XCOUT, COUTT – average concentration of total of all outflow components computed at different points in the simulation
- STO(cp)– volume of the end-of-month storage at the control point
- STOL(cp)– load of the end-of-month storage at the control point
- STOC(cp)– concentration of the end-of-month storage at the control point
- MC(cp)– mean concentration of the storage during a month

If a control point has no reservoir storage, complete mixing during the month is assumed. With storage, mixing over time may be modeled by activating the optional lag features described later in this chapter. The total monthly flow volume (FOUT(cp)) and load (LOUT(cp)) leaving a control point have the components summed in Equations 10 and 11 and described in Table 1. FOUT(cp) is exclusive of the volume of net reservoir surface evaporation-precipitation (EVAP(cp)). The load and concentration of net evaporation are assumed to be zero.

$$\text{FOUT}(\text{cp}) = \text{REG}(\text{cp}) + \text{DIV} + \text{FOTH} \quad (10)$$

$$\text{LOUT}(\text{cp}) = \text{REGL}(\text{cp}) + \text{LDIV} + \text{LOTH} + \text{LLIL} + \text{LLSL} \quad (11)$$

$$\text{COUTT} = \frac{\text{LOUT}(\text{cp})}{\text{FOUT}(\text{cp})} \text{CF} \quad (12)$$

REG(cp), REGL(cp) – volume and load of regulated flows

DIV, LDIV – volume and load of diversions

FOTH, LOTH – volume and load of any other flows, most typically reservoir releases for hydropower and instream flow requirements

LLIL – load loss as percentage of inflow load not associated with volume loss

LLSL – load loss as percentage of storage load not associated with volume loss

#### Other Reservoir Releases or Other Flows

The other flow volume (FOTH) and load (LOTH) in Equations 10 and 11 are computed as follows.

$$\text{FIN2} = \text{flow in} = \text{flow out} + \text{storage change} \quad (13)$$

$$\text{FIN2} = \text{REG}(\text{cp}) + \text{DIV} + \text{EVAP}(\text{cp}) + \text{STO}(\text{cp}) - \text{BSTO}(\text{cp}) \quad (14)$$

$$\text{FOTH} = \text{FIN2} - \text{FIN} \quad (15)$$

$$\text{LOTH} = \frac{\text{FOTH}(\text{COUT})}{\text{CF}} \quad (16)$$

The other flow volume FOTH is by definition the additional flow component required to make the volume budget at a control point perfectly balance. The corresponding load LOTH is determined by combining FOTH with the downstream regulated flow concentration REGC(cp).

The option switch parameter *OTHER* in SIN file *CP* record field 5 controls the use of the other flow volume (FOTH) and load (LOTH). FOTH and its corresponding LOTH may optionally be either included in the simulation computations or omitted. Either negative values or positive values or both negative and positive values or neither may be zeroed out of the computations. The FOTH and LOTH terms should always be used at control points with reservoirs that release from storage specifically for either downstream instream flow targets or hydropower. Otherwise, the terms may be omitted, or experimentation with the *CP* record field 5 options may be pursued in attempts to improve the volume and load balances.



The FOTH and LOTH terms model releases made specifically for hydroelectric power generation or releases from storage for meeting instream flow requirements. Passing of reservoir inflows for downstream instream flow requirements and water supply releases that incidentally generate hydropower are not included in this category of other releases. The return flows in the *SIM* output file include reservoir releases to meet hydropower and instream flow requirements. Effects of return flows are reflected in the *SIM* regulated flow results. Return flows incorporating these other reservoir releases are included in *SALT* in the control point inflows. To maintain the volume balance, hydropower and instream flow releases must also be included in the computations in the same way as diversions as quantities in the control point outflows.

*SIM* negative incremental naturalized flows, *SALT* negative inflows, and options for dealing with them (*JD* record field 8, *SC* record field 14) may also prevent the control point volume budget from balancing without the FOTH term. Approximations in estimating concentrations and corresponding loads also contribute to unbalanced load budgets. FOTH and LOTH are always positive or zero if solely reflecting reservoir releases for hydropower and instream flow requirements. However, in general, FOTH and LOTH may also be negative.

*Load Losses or Gains Without Accompanying Volume Losses or Gains*

With the exception of the loads LLIL and LLSL discussed here, the inflow and outflow loads summed in Equations 9 and 11 all have corresponding water volumes. The water quality constituent is mixed with and transported with the water. The constituent loads LLIL and LLSL addressed in this section have no corresponding volumes or concentrations. These loads represent losses or gains in addition to those associated with the movement of quantities of water. These load losses or gains may represent the transformation of water quality constituents through biological or chemical processes or may reflect other types of losses or gains. The LLIL and LLSL loads could represent observed but unexplained losses or gains in salt loads.

The parameters LLI(cp) and LLS(cp) are entered in fields 10 and 11 of the *CP* record. LLI(cp) is the fraction of the total inflow loads to a control point that is lost from the river/reservoir system during the month through this type of loss. LLS(cp) is the fraction of the total beginning-of-month reservoir storage load that is lost during the month. The multiplier factors LLI(cp) and LLS(cp) are defined in terms of load losses with positive values for the factors meaning losses from the river/reservoir system and negative values meaning increases (gains) of load into the system. Thus, either load losses or gains may be specified.

The load losses (+ in Eq. 11) or gains (- in Eq. 11) LLL and LLSL are computed within program *SALT* as follows.

$$LLIL = (LIN) (LLI(cp)) \quad (17)$$

$$LLSL = (BSL(cp)) (LLS(cp)) \quad (18)$$

LIN is the total load inflow to the control point as defined by Equation 9. BSL(cp) is the beginning-of-month reservoir storage load, previously computed as the end-of-month reservoir storage load for the preceding month. LLI(cp) and LLS(cp) are the parameters from the *CP* record described in the preceding paragraph.

### Outflow from Control Points with No Reservoir Storage

For a control point with no reservoir or a reservoir that is empty at both the beginning and end of the month, the outflow concentration is determined as follows.

$$COUT = \frac{LIN}{FOUT}(CF) \quad (19)$$

$$REGC(cp) = CDIV = COTH = COUT \quad (20)$$

The total outflow load (LOUT(cp)) includes the regulated flow load (REGL(cp)), diversion load (LDIV), and other load (LOTH). Without storage, their concentrations are all COUT. The load LLIL specified by LLI(cp) from the *CP* record has no associated volume or concentration.

$$REGL(cp) = \left( \frac{REG(cp)COUT}{CF} \right) \quad (21)$$

$$LDIV = \left( \frac{(DIV)(COUT)}{CF} \right) \quad (22)$$

$$LOTH = \left( \frac{(FOTH)(COUT)}{CF} \right) \quad (23)$$

$$LLIL = (LIN)(LLI(cp)) \quad (24)$$

$$LOUT(cp) = REGL(cp) + LDIV + LOTH + LLIL \quad (25)$$

### **Reservoir Storage and Outflow Concentrations**

As discussed above, without reservoir storage, the same concentration COUT is assigned to all three components of outflow. With reservoir storage, the default is to also assign the same concentration COUT to all three outflow components. However, reservoir outflow adjustments may be applied to compute different concentrations for regulated flows in the river below the dam and lakeside water supply diversions withdrawn from the reservoir. With default options activated, Equations 17 through 25 are applied to control points with reservoir storage as well as to those with no storage. The other flow FOTH and other load LOTH in Eqs. 23 and 25 include reservoir releases through hydropower turbines and releases for instream flow requirements.

If a control point has reservoir storage, loads and concentrations are determined for end-of-month storage as well as for outflows. Outflow concentrations and loads for control points with reservoir storage are computed using combinations of Equations 19 through 25 and variations thereof. The algorithms in the model vary depending on user-selected:

- beginning-of-month versus mean storage concentration options selected with the parameter TM in *CP* record field 6
- reservoir outflow concentration lag options set by *CP* record LAG1 and LAG2
- diversion concentration options specified by parameter CDI in *CC* record field 5
- reservoir outflow concentration options activated by the *RC* record

Various options for setting concentrations of reservoir outflows (downstream releases and lakeside diversions) are controlled by *CP* record fields 6, 7, and 8 (lag options), *CC* record field 5 (diversion concentration options), and the *RC* record. An initial reservoir outflow concentration *COUT* is computed as a storage concentration in the current month (*CP* record field 6) or a previous month (as defined by lag options in *CP* record fields 6, 7, 8). Regulated flow concentrations *REGC(cp)* representing downstream releases from the reservoir are set equal to *COUT* unless the adjustments activated by the *RC* record are adopted. Concentrations of diversions *CDIV* representing withdrawals from reservoir storage are also set equal to *COUT* unless otherwise specified by *CC* record field 5 or adjusted by *RC* record features.

At the completion of the simulation for a particular month, the final outflow concentration *COUTT* is computed with Equation 12 combining the total outflow load and volume, which are composed of the sum of diversions, regulated flows, and other outflows. Due to the options for setting outflow concentration noted above, the final *COUTT* may be different than the initially computed *COUT*. Thus, *COUTT* and *COUT* may or may not be equal depending on options selected for assigning concentrations to lakeside water supply diversions and downstream reservoir releases. Without reservoir storage, *COUTT* and *COUT* are equal.

#### Program SALT Computational Procedures

An initial estimate of storage concentration is used in computing outflow loads. The storage concentration is recomputed after finalizing outflow loads. Outflow concentration *COUT* is set equal to either beginning-of-month storage concentration (*BPC(cp)*) or the mean storage concentration (*MC(cp)*) during the month as specified in *CP* record field 6. The total volume leaving the control point includes the reservoir net evaporation (*EVAP(cp)*) as well as *FOUT(cp)*. Volumes are read from the *SIM OUT* file. Loads and concentrations are computed.

The minimum end-of-month storage concentration *MINSC(I)* entered in *CC* record field 10 sets a maximum concentration limit *MAXCON* for the outflow. The outflow concentration (*COUT*) is set equal to either *BPC(cp)* or *MC(cp)* if less than *MAXCON*. Otherwise, *COUT* is set at the *MAXOUT* limit. This limit is determined with Eqs. 26–28 based on the load budget for the actual reservoir rather than the conceptual lag load budget described later.

$$\text{MINSL} = \frac{\text{MINSC(I)} \times \text{STO(cp)}}{\text{CF}} \quad (26)$$

$$\text{MAXOUT} = \text{BSL(cp)} + \text{LIN} - \text{MINSL} \quad (27)$$

$$\text{MAXCON} = \left( \frac{\text{MAXOUT}}{\text{FOUT(cp)}} \right) \text{CF} \quad (28)$$

The option specified by *TM(cp)* in *CP* record field 6 setting outflow concentrations to the mean storage concentration *MC(cp)* during the month is based on the following equations.

$$\text{LOUT} = (\text{FOUT}) (\text{MC}) \quad (29)$$

$$\text{STOL(cp)} = \text{BSL(cp)} + \text{LIN} - \text{LOUT} \quad (30)$$

$$MC = \left( \frac{BSL(cp) + STOL(cp)}{BSTO(cp) + STO(cp)} \right) CF \quad (31)$$

Equations 29, 30, and 31 are algebraically combined to obtain Equation 32.

$$MC = \left( \frac{2.0 \times BSL(cp) + LIN}{BSTO(cp) + STO(cp) + FOUT} \right) CF \quad (32)$$

Depending on the *CP* record field 6 option selected, an initial estimate of the outflow concentration *COUT* is set equal to either the beginning period storage concentration (*BPC(cp)*) or mean concentration (*MC*) or the maximum limit (*MAXCON*). The individual components of *LOUT(cp)* summed in Equation 11 are then computed as outlined in the following sections based on *COUT*. *LOUT(cp)* is then computed with Equation 11. The end-of-month storage load *STOL(cp)* and concentration *STOC(cp)* are computed with Equations 33 and 34.

$$STOL(cp) = BSL(cp) + LIN - LOUT(cp) \quad (33)$$

$$STOC(cp) = \left( \frac{STOL(cp)}{STO(cp)} \right) CF \quad (34)$$

The volume of water leaving a reservoir includes diversions, regulated flow, other releases, and net evaporation from the *SIM* simulation. Net evaporation has no salt load in the *SALT* model. The salt load outflow consists of the loads of the diversions, regulated flow, and other releases, plus optionally other load gains or losses. In both *SIM* and *SALT*, the regulated flow at a control point is the flow leaving the control point and entering the downstream river reach. Diversions typically represent withdrawals for water supply. Hydroelectric power releases and releases from storage for instream flow requirements are treated in *SIM* similarly as diversions and in *SALT* as other flows (*FOTH* and *LOTH*). Storage concentrations computed by *SALT* are end-of-month volume-weighted means for the total reservoir storage.

#### Reservoir Outflow Concentration RC Record Features

The *RC* record activates application of the following equation, where  $OC_M$  denotes mean outflow concentration in month *M*, and  $SC_{M-L}$  is the volume-weighted storage concentration in month *M-L* (lag *L* months before month *M*).

$$OC_M = SC_{M-L} \times F_1 \left[ 1.0 + \left( \frac{V}{V_C} \right) (F_2 - 1.0) \right] \quad (35)$$

The input parameter  $V_C$  in Eq. 35 is a storage volume which is typically the storage capacity of the reservoir. *V* is the average storage contents of the reservoir during the current month computed by *SALT*. The ratio  $V/V_C$  represents storage contents as a fraction of capacity. The factors  $F_1$  and  $F_2$  are input parameters. With  $F_1$  and  $F_2$  defaults of 1.0 and a lag *L* default of zero, Eq. 35 reduces to Eq. 36 where the outflow concentration equals the storage concentration.

$$OC_M = SC_M \quad (36)$$

Equation 35 is rewritten as Equations 37 and 38 using the variable names in the Fortran code.

$$\text{REGC}(\text{cp}) = \text{COUT} \times \text{RCF1} \left[ 1.0 + \left( \frac{\text{V}}{\text{RCVOL}} \right) (\text{RCF2} - 1.0) \right] \quad (37)$$

$$\text{CDIV} = \text{CDIV}_{\text{INITIAL}} \times \text{RCD1} \left[ 1.0 + \left( \frac{\text{VOL}}{\text{RCVOL}} \right) (\text{RCD2} - 1.0) \right] \quad (38)$$

The reservoir outflow concentration *RC* record activates optional features which apply Equations 37 and 38 to compute the regulated flow concentration *REGC*(cp) and diversion concentration *CDIV*. The *RC* record applies only to control points with reservoirs. Without an *RC* record, the regulated flow (downstream release) and lakeside diversion concentrations are *COUT* and *CDIV*<sub>INITIAL</sub>. The parameters *RCF1*, *RCF2*, *RCD1*, and *RCD2*, are entered on the *RC* record and correspond to the parameters *F*<sub>1</sub> and *F*<sub>2</sub> in Equation 35. *RCVOL* is a storage volume entered in *RC* record field 7 which is typically the storage capacity of the reservoir. *VOL* is the average storage contents of the reservoir during the current month computed within *WRAP-SALT*. The ratio *VOL/RCVOL* represents storage contents as a fraction of capacity or other specified volume.

With no *RC* record or the default of 1.0 for the factors *RCF1*, *RCF2*, *RCD1*, and *RCD2* in Equations 37 and 38, the regulated flow and diversion concentrations are as follows.

$$\begin{aligned} \text{REGC}(\text{cp}) &= \text{COUT} \\ \text{CDIV} &= \text{CDIV}_{\text{INITIAL}} \end{aligned}$$

where *COUT* is a defined representation of reservoir storage concentration in the current or an earlier (lagged) month and *CDIV*<sub>INITIAL</sub> is either *CDI* from *CC* field 5, zero, or *COUT*. Initial values of the concentrations of diversions *CDIV* representing either lakeside or downstream withdrawals from reservoir storage may be set by *CC* record field 5 with the default being to set *CDIV* = *COUT*. Thus, *CDIV*<sub>INITIAL</sub> is set at either *COUT*, *CDI*, or zero.

### Reservoir Salinity Lag Options

In the real-world, streams carry salt loads into the upper reaches of a reservoir, and mixing occurs over time. Inflows and their salt loads may require long periods of time to move through the reservoir and reach the outlet. Salt concentrations vary spatially, both horizontally and vertically, throughout a reservoir.

In the *WRAP-SALT* modeling strategy, the concentration of water supply diversions and spills and releases leaving reservoir storage is set equal to the concentration of the water in storage. The end-of-month storage concentration computed by *SALT* is a volume-weighted mean reflecting the total salt load and volume of the reservoir (Eq. 3). The *SALT* simulation procedures are based on the premise of complete mixing at each control point. However, the timing of the inflow loads used to determine outflow concentrations is set by the lag parameters *LAG1*(cp) and *LAG2*(cp) entered in *CP* record fields 7 and 8. The following options are provided.

- If *CP* record fields 7 and 8 are left blank, the lag features are not activated for that control point. The simulation is based on complete mixing within each month.
- The lag options based on the variable LAG are controlled by LAG1(cp) and LAG2(cp) entered in *CP* record fields 7 and 8. A non-zero LAG1(cp) activates use of the lag features. LAG2(cp) selects the manner in which LAG is determined.
  1. With no entry for LAG2(cp) in *CP* field 8, the option is activated in which LAG is set equal to LAG1(cp) from field 7. Thus, the model-user sets a constant LAG that is applied during every month of the simulation.
  2. With an entry for LAG2(cp) in *CP* field 8, a variable LAG is computed in each month based on the concept of retention time. LAG2(cp) is a multiplier factor used in the computation of the retention time parameter.

A non-zero LAG1(cp) entered in *CP* record field 7 is required for either lag option. LAG1(cp) is an integer number of months. For the first lag option, LAG1(cp) is a constant lag adopted in every month. LAG1(cp) serves as the only activation parameter for the first option. A non-zero LAG2(cp) entered in *CP* record field 8 activates the second option. For the second option, LAG1(cp) is the upper limit on lag computed each month based on the concept of retention time. LAG2(cp) is a multiplier factor in the form of a decimal (real) number.

The lag options are based on the premise that salt entering the reservoir in a particular month begins to reach the outlet LAG months later. Complete mixing occurs during the LAG months. Thus, the salt leaves the reservoir over a period of multiple months that begins LAG months after the month in which the quantity of salt entered the reservoir.

Salt load budgets result in end-of-month reservoir load for each month based on an accounting balance of inflow and outflow loads combined with the end-of-month storage load from the preceding month. With the lag features activated, two load budgets are maintained. The regular load budget maintained with or without the lag features reflect the actual total loads in storage with the corresponding volume-weighted mean storage concentrations. The second conceptual computational load budget based on lagged load inflows is maintained solely for the purpose of determining the outflow concentration each month. The timing of the load inflow to this *computational load-budget reservoir* is controlled by the LAG. With the exception of the timing of the salt load inflows, the salinity simulation algorithms are applied in essentially the same manner for maintaining the salt load budgets both with and without the LAG.

The lag options are pertinent only for control points with significant reservoir storage. Without storage, complete mixing during the month without lag is assumed in the model. Selection of the *CP* record reservoir lag parameters LAG1(cp) and LAG2(cp) are necessarily judgmental and may be somewhat arbitrary. They may be treated as calibration parameters in situations where observed data are available for calibration. Lag determined by calibration for reservoirs with observed data may be relevant to other reservoirs as well. Sensitivity analyses with alternative simulations with varying values for the lag parameters may be made to investigate their effects on simulation results.

### Computation of LAG Based on Retention Time

With a non-zero LAG2(cp), the variable LAG in months is computed based on retention time as outlined below. LAG1(cp) is a maximum upper limit on LAG. LAG2(cp) is a multiplier factor that is incorporated in the computation of the retention time parameter.

Retention time is a representation of the time required for a monthly volume of water and its salt load to flow through a reservoir. Retention time is defined as follows.

$$\text{retention time in months} = \frac{\text{reservoir storage volume}}{\text{outflow volume per month}} \quad (39)$$

The computation of LAG is based on computing the parameter ZLAG for each cumulative set of L months from a L of 1 month to a L of MAXL=LAG1(cp) months, where L represents a time period extending backward from the current month.

$$\text{ZLAG} = \left( \frac{(\text{BSTO}(\text{cp}) + \sum \text{BSTO}(\text{cp},L)) / (L+1)}{\sum \text{FOUT}(\text{cp},L) / L} \right) \text{LAG2}(\text{cp}) \quad (40)$$

BSTO(cp) is the beginning-of-month storage for the current month.  $\sum \text{BSTO}(\text{cp},L)$  and  $\sum \text{FOUT}(\text{cp},L)$  are the summations for the preceding L months of the beginning-of-month storage and the outflow during the month. LAG2(cp) is a parameter from CP record field 8 that may be set at 1.0 if calibration or other information is not available to suggest another value.

ZLAG is first computed for the month preceding the current month. Based on the results, either LAG is set or ZLAG is determined for a longer period of time.

$$\begin{aligned} \text{If } \text{ZLAG} < 1.0 \text{ then } \text{LAG} &= 0 \\ \text{If } 1.0 \leq \text{ZLAG} < 2.0 \text{ then } \text{LAG} &= 1 \text{ month} \end{aligned}$$

If ZLAG for one month is 2.0 or more, a second ZLAG is computed for the two month period preceding the current month.

$$\text{If } \text{ZLAG} < 3.0 \text{ then } \text{LAG} = 2 \text{ months}$$

Otherwise, ZLAG is computed for the three month period preceding the current month.

$$\text{If } \text{ZLAG} < 4.0 \text{ then } \text{LAG} = 3 \text{ months}$$

The procedure continues until the length of the preceding period reaches the maximum limit of LAG1(cp) months from the CP record. LAG is set equal to LAG1(cp) if this limit is reached.

### Incorporation of LAG in the Load Budget Simulation

LAG may be treated as a monthly varying variable set based on retention time as outlined above. Alternatively, LAG may be a constant set by the model-user. LAG is applied in a similar manner regardless of the option adopted for its determination.

A separate load budget for a conceptual computational reservoir is maintained for the sole purpose of computing the outflow concentration for the current month. The load inflow (ZLIN) for this load-budget for the current month is the actual load inflow (LIN) for the month that is LAG months earlier plus the inflow loads for any other months prior to LAG months ago that have not yet been activated. If LAG extends back to before the first month of the simulation, the load budget is based on setting the outflow concentrations equal to the reservoir storage concentration at the beginning of the current month and inflow load equal to outflow load.

Salinity Example 1 - Simplified Example of Routing a Slug of Salt through a Reservoir

The lag represents physically the time required for salt entering the reservoir during a month to reach the outlet. The salt is assumed to be completely mixed during the lag time. The load entering a reservoir in a particular month leaves the reservoir over multiple months beginning LAG months after entering.

The following hypothetical example illustrates the computational strategy by focusing on the salt load entering a reservoir in a single month. Several months are required for the *slug* of salt to pass through the reservoir. A constant inflow volume of 10,000 acre-feet/month and outflow of 10,000 acre-feet/month occur in every month of the simulation. The reservoir storage volume remains at a constant 50,000 ac-ft. The net evaporation-precipitation is zero. These quantities are provided by the *SIM* output file and of course typically unlike this example will vary monthly.

In month 1, the inflow has a concentration of 1,000 mg/l and load of:

$$LIN = \frac{FIN (CIN)}{CF} = \frac{(10,000 \text{ ac-ft})(1,000 \text{ mg/l})}{735.48} = 13,597 \text{ tons}$$

The inflow load of 13,597 tons in month 1 is the only salt entering the reservoir. The inflow concentration is zero in all other months of the simulation. The storage concentration is zero at the beginning of the simulation. Thus, this simplified hypothetical example is designed to demonstrate how the salt load in a particular month moves through the reservoir according to the model. Of course, in actual applications, salt inflow loads will be non-zero in every month. The parameters entered on the *CP* record for this example are as follows.

*CP* record field 6: Default results in use of mean concentration based on Eq. 32.

*CP* record field 7: Any integer greater than 5 for LAG1(cp) yields the same results.

*CP* record field 8: LAG2(cp) of 1.0.

The lag (LAG) computed by the repetitive algorithm based on Eq. 40 is 5 months. Beginning with L = 1 month, ZLAG = 5.0 which is greater than 2 months.

$$ZLAG = \left( \frac{(50,000 + 50,000)/(1+1)}{10,000 / 1} \right) (1.0) = 5.0$$



Table 3  
Simulation Results for Example 1

Month	Inflow Load (tons)	Storage Load (tons)	Storage Conc (mg/l)	Computation of Outflow Concentration				Outflow Load (tons)
				Inflow Load (tons)	Storage Load (tons)	Storage Conc (mg/l)	Outflow Conc (mg/l)	
1	2	3	4	5	6	7	8	9
		0	0		0			
1	13,597			0		0	0	0
		13,597	200		0			
2	0			0		0	0	0
		13,597	200		0			
3	0			0		0	0	0
		13,597	200		0			
4	0			0		0	0	0
		13,597	200		0			
5	0			0		0	0	0
		13,597	200		0			
6	0			13,597		90.9	90.9	1,236
		12,361	181.8		12,361			
7	0			0		165.3	165.3	2,247
		10,113	148.8		10,113			
8	0			0		135.2	135.2	1,839
		8,274	121.7		8,274			
9	0			0		110.6	110.6	1,504
		6,770	99.6		6,770			
10	0			0		90.5	90.5	1,231
		5,539	81.5		5,539			
11	0			0		74.1	74.1	1,007
		4,532	66.7		4,532			
12	0			0		60.6	60.6	824
		3,708	54.5		3,708			
13	0			0		49.6	49.6	674
		3,034	44.6		3,034			
14	0			0		40.6	40.6	552
		2,483	36.5		2,483			
15	0			0		33.2	33.2	451
		2,031	29.9		2,031			
16	0			0		27.2	27.2	369
		1,662	24.4		1,662			
17	0			0		22.2	22.2	302
		1,360	20.0		1,360			
18	0			0		18.2	18.2	247
		1,113	16.4		1,113			
-----								
36	0	37.3	0.55	0	37.3	0.49	0.49	6.67
		30.6	0.45		30.6			

After four more repetitions,  $L = 5$  which is less than 6.0 and thus  $LAG = 5$  months.

$$ZLAG = \left( \frac{(50,000 + 200,000)/(5+1)}{50,000 / 5} \right) (1.0) = 5.0$$

With constant inflow volume, outflow volume, and storage volume, the retention time of 5 months and the LAG of 5 months are the same for every month of the simulation.

Simulation results are presented in Table 3. With no salt in the reservoir at the beginning and an inflow of 13,597 tons during month 1, the salt load at the end of month 1 is 13,597 tons, and the storage concentration is:

$$STOC(cp) = \left( \frac{STOL(cp)}{STO(cp)} \right) CF = \left( \frac{13,597 \text{ tons}}{50,000 \text{ ac-ft}} \right) 735.48 = 200 \text{ mg/l}$$

The end-of-month storage load and volume-weighted mean end-of-month storage concentration are tabulated in columns 3 and 4 of Table 3.

The lagged load budget used to determine the outflow concentration is tabulated in columns 5 through 8. The mean storage and outflow concentration ( $COUT = MC$ ) computed with Eq. 32 is tabulated in columns 8 and 9. The outflow load (Eq. 30) is shown in column 9. With a LAG of 5 months, the 13,597 tons of salt entering the reservoir in month 1 begins to affect the outflow concentration in month 6. The actual end-of-month storage load (column 2) decreases from 13,597 tons in month 5 to 1,112 tons in month 18, to 30 tons in month 36, and 2.7 tons in month 48.

### Salinity Example 2 – Effects of Lag Options

Example 2 is designed to further illustrate the reservoir salinity inflow lag options. The input data files are included in the set of electronic input files for all of the WRAP examples and can be used to experiment with *SALT*. The example is comprised of simple unrealistic data designed to allow the simulation computations to be easily tracked. The *SIM* input DAT file and *SALT* input SIN file are reproduced as Tables 4 and 5. The variables in each field of the DAT file are defined in the *Users Manual*. The records in the SIN file are explained in Appendix A.

Example 2 has one control point, one reservoir, and a 3-year hydrologic period-of-analysis. The loads and concentrations could be for total dissolved solids or any other conservative water quality constituent. The DAT and SIN files reproduced as Tables 4 and 5 contain the complete input dataset for this example. *WRAP-SIM* is executed with the DAT file to obtain a *SIM* simulation results output OUT file, which is not shown. *WRAP-SALT* reads the OUT and SIN files and produces the optional SMS file tables shown as Tables 6 and 7. In most actual modeling applications, a SAL file will be produced with *SALT* to be read by program *TABLES* to create a set of tables organizing the salinity simulation results. However, *TABLES* is not applied in this simple hypothetical example. The tables normally produced with *TABLES* are illustrated later by the much larger and more realistic example at the end of this chapter.

Two alternative lag options are compared. Two simulations are presented with the only input data difference being the lag option selected on the *CP* record. Both alternative *CP* records are included in the SIN file shown in Table 5, with one of the *CP* records deactivated with \*\* entered as the first two characters of the record. LAG2(cp) is zero (blank *CP* record field 8) and 1.0 for the two alternative simulations. LAG1(cp) is six months in both simulations. Simulation results tables from the *SALT* output SMS file for the two alternative simulations are reproduced as Tables 6 and 7. The first SMS file table shown in Tables 6 and 7 is a tabulation of monthly simulation results in a format designed for tracking the reservoir lag computations. The second table is a volume and load summary.

The *SALT* message SMS file table at the top of Tables 6 and 7 is designed specifically to facilitate tracking of the lag computations. Model-users can experiment with this simplified example to gain insight to the lag computations. The total volume and load budget summary reproduced at the bottom of Tables 6 and 7 is designed for routine viewing with essentially any *SALT* simulation application. These and other *SALT* output tables found in the SMS and SAL files are discussed later in this chapter.

This dataset is purposely designed for illustrative purposes to have the same load inflow in each of the 36 months of the simulation. The combination of stream flow volumes on the *IN* records in the DAT file (Table 4) and salt concentrations on the *SI* records in the SIN file (Table 5) result in the same load of 10,000 tons/month in each month of the three year 2001-2002 period-of-analysis.

The *SALT* simulation results shown in Table 6 reflect a constant lag of 6 months entered on the *CP* record for control point CP-1. LAG2(cp) is zero (blank *CP* record field 8). The constant lag option serves solely to lag the inflow loads. However, since the load inflows are a constant 10,000 tons/month in every month in this example, the *SALT* simulation results are identical with no lag or a lag of 1 month, 6 months, or any other integer number of months.

The only difference between the input data for the two alternative simulations is the entry for LAG2(cp) on the *CP* record in the SIN file. For the second simulation, the *CP* record is altered to set LAG2(cp) at 1.0 which activates the variable lag option. The LAG1(cp) of 6 months from the *CP* record is now an upper limit on the computed lag. The *SALT* simulation results are shown in Table 7.

The lag computed in each month is tabulated in the fourth column of Table 7. The actual inflow load LIN each month is in the fifth column. The inflow load ZLIN flowing into the computational lag reservoir is shown in the sixth column. The maximum lag limit of 6 months is adopted by the *SALT* simulation computations from January through November 2001 based on iteratively applying Equation 40. The retention time computations result in a lag of 4 months in December 2001. In order to properly maintain a balance load budget, the variable lag option algorithm must ensure that all reservoir inflow loads are included in the computations as the lag changes. ZLIN is 30,000 tons to cover the two preceding months as well as the lag 4 month. Thus, the lag reservoir inflow loads change with changes in the computed lag. Similarly, ZLIN is zero in March 2002 when the lag reduces from four months to three months.

A reservoir outflow concentration *RC* record is included in the SIN file shown in Table 5 for illustrative purposes. The parameters RCF1, RCF2, RCD1, and RCD2 are all set at 1.0. As previously discussed, with the parameters all set at their default of 1.0, the *RC* record has no effect on the simulation results. However, if RCF1, RCF2, RCD1, and RCD2 are set at values other than 1.0, Equations 37 and 38 are incorporated into the computation of regulated flow concentrations and diversion concentrations.

Flow volumes on the *IN* records in the DAT file are in units of acre-feet/month. Concentrations on the *CC* and *SI* records in the SIN file are in tons/acre-foot. With a conversion factor CF of 1.0 entered in *SC* record field 15, loads are in units of tons/month.

Table 4  
SIM DAT File for Salinity Example 2

```
T1 WRAP-SIM Input File SaltExam2.DAT
T2 Salinity Manual Example 2 - Effects of Lag Options
T3 May 2009
**      1          2          3          4          5
**3456789012345678901234567890123456789012345678901234567890123456
JD      3      2001          1      -1
JO      3
CP CP-1      OUT                      0          NONE
WR CP-1
WS ResA      6000.          1.0      1.0
ED
** Naturalized flows in acre-feet
IN CP-1      2001      1000.      1000.      1000.      1000.      1000.      1000.      500.      500.      500.      2000.      2000.      2000.
IN CP-1      2002      1000.      1000.      1000.      1000.      1000.      1000.      500.      500.      500.      2000.      2000.      2000.
IN CP-1      2003      1000.      1000.      1000.      1000.      1000.      1000.      1000.      1000.      1000.      1000.      1000.      1000.
```

Table 5  
SALT SIN File for Salinity Example 2

```
** WRAP-SALT Input File SaltExam2.SIN
** Salinity Manual Example 2 - Effects of Lag Options
** May 2009
**      1          2          3          4          5          6          7          8          9          10          11
**3456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
**      !      !      !      !      !      !      !      !      !      !      !      !      !      !      !      !
SC 2001      3      0      0      0      2      2      0      0      0      2      4      0      1.0
**
** The only difference in the two variations of the CP record is the LAG2 of zero (blank) versus 1.0.
CP CP-1                      6          6000.
**CP CP-1                      6      1.0      6000.
CC                      10.
** The RC record has no effect on simulation results with the four factors all set equal to the default of 1.0.
RC                      1.0      1.0      1.0      1.0      6000.
ED
** Concentrations in tons/acre-foot
S1 CP-1      2001      10.0      10.0      10.0      10.0      10.0      10.0      20.0      20.0      20.0      5.0      5.0      5.0
S1 CP-1      2002      10.0      10.0      10.0      10.0      10.0      10.0      20.0      20.0      20.0      5.0      5.0      5.0
S1 CP-1      2002      10.0      10.0      10.0      10.0      10.0      10.0      10.0      10.0      10.0      10.0      10.0      10.0
```

Table 6  
SALT Output SMS File Tables for Constant Lag of 6 Months

YEAR	M	CPID	LAG	LIN	ZLIN	STOL	STOLLAG	STO	FOUT	LOUT	STOC	STOCLAG	COOT
2001	1	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	2	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	3	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	4	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	5	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	6	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	7	CP-1	6	10000.0	10000.0	64800.0	64800.0	6000.0	500.0	5200.0	10.8	10.8	10.4
2001	8	CP-1	6	10000.0	10000.0	69216.0	69216.0	6000.0	500.0	5584.0	11.5	11.5	11.2
2001	9	CP-1	6	10000.0	10000.0	73278.7	73278.7	6000.0	500.0	5937.3	12.2	12.2	11.9
2001	10	CP-1	6	10000.0	10000.0	60913.4	60913.4	6000.0	2000.0	22365.3	10.2	10.2	11.2
2001	11	CP-1	6	10000.0	10000.0	52081.0	52081.0	6000.0	2000.0	18832.4	8.7	8.7	9.4
2001	12	CP-1	6	10000.0	10000.0	45772.1	45772.1	6000.0	2000.0	16308.9	7.6	7.6	8.2
2002	1	CP-1	6	10000.0	10000.0	47961.0	47961.0	6000.0	1000.0	7811.1	8.0	8.0	7.8
2002	2	CP-1	6	10000.0	10000.0	49813.2	49813.2	6000.0	1000.0	8147.9	8.3	8.3	8.1
2002	3	CP-1	6	10000.0	10000.0	51380.4	51380.4	6000.0	1000.0	8432.8	8.6	8.6	8.4
2002	4	CP-1	6	10000.0	10000.0	52706.5	52706.5	6000.0	1000.0	8673.9	8.8	8.8	8.7
2002	5	CP-1	6	10000.0	10000.0	53828.6	53828.6	6000.0	1000.0	8877.9	9.0	9.0	8.9
2002	6	CP-1	6	10000.0	10000.0	54778.0	54778.0	6000.0	1000.0	9050.5	9.1	9.1	9.1
2002	7	CP-1	6	10000.0	10000.0	59995.8	59995.8	6000.0	500.0	4782.2	10.0	10.0	9.6
2002	8	CP-1	6	10000.0	10000.0	64796.1	64796.1	6000.0	500.0	5199.7	10.8	10.8	10.4
2002	9	CP-1	6	10000.0	10000.0	69212.4	69212.4	6000.0	500.0	5583.7	11.5	11.5	11.2
2002	10	CP-1	6	10000.0	10000.0	58008.9	58008.9	6000.0	2000.0	21203.5	9.7	9.7	10.6
2002	11	CP-1	6	10000.0	10000.0	50006.3	50006.3	6000.0	2000.0	18002.5	8.3	8.3	9.0
2002	12	CP-1	6	10000.0	10000.0	44290.2	44290.2	6000.0	2000.0	15716.1	7.4	7.4	7.9
2003	1	CP-1	6	10000.0	10000.0	46707.1	46707.1	6000.0	1000.0	7583.1	7.8	7.8	7.6
2003	2	CP-1	6	10000.0	10000.0	48752.2	48752.2	6000.0	1000.0	7954.9	8.1	8.1	8.0
2003	3	CP-1	6	10000.0	10000.0	50482.6	50482.6	6000.0	1000.0	8269.6	8.4	8.4	8.3
2003	4	CP-1	6	10000.0	10000.0	51946.8	51946.8	6000.0	1000.0	8535.8	8.7	8.7	8.5
2003	5	CP-1	6	10000.0	10000.0	53185.8	53185.8	6000.0	1000.0	8761.1	8.9	8.9	8.8
2003	6	CP-1	6	10000.0	10000.0	54234.1	54234.1	6000.0	1000.0	8951.7	9.0	9.0	9.0
2003	7	CP-1	6	10000.0	10000.0	55121.2	55121.2	6000.0	1000.0	9112.9	9.2	9.2	9.1
2003	8	CP-1	6	10000.0	10000.0	55871.8	55871.8	6000.0	1000.0	9249.4	9.3	9.3	9.2
2003	9	CP-1	6	10000.0	10000.0	56506.9	56506.9	6000.0	1000.0	9364.9	9.4	9.4	9.4
2003	10	CP-1	6	10000.0	10000.0	57044.3	57044.3	6000.0	1000.0	9462.6	9.5	9.5	9.5
2003	11	CP-1	6	10000.0	10000.0	57499.0	57499.0	6000.0	1000.0	9545.3	9.6	9.6	9.5
2003	12	CP-1	6	10000.0	10000.0	57883.8	57883.8	6000.0	1000.0	9615.2	9.6	9.6	9.6

Total Volume and Load Summary for Constituent 1

	Volume	Load	Concentration
Naturalized flows	39000.	360000.	9.2
Regulated flows at boundary	0.	0.	0.0
Return flows	0.	0.	0.0
CI record constant inflows	0.	0.	0.0
Channel loss credits	0.	0.	0.0
Channel losses	0.	0.	0.0
Regulated flows at outlet	39000.	362116.	9.3
Diversions	0.	0.	0.0
Other flows and loads	0.	0.	0.0
Net evaporation	0.	0.	0.0
-----			
Inflows - Outflows	0.	-2116.	0.0
-----			
Beginning reservoir storage	6000.	60000.	10.0
Ending reservoir storage	6000.	57884.	9.6
-----			
Change in storage	0.	-2116.	0.0
-----			
Volume and load differences	0.	0.	0.0
Naturalized flows at outlet	39000.		

Table 7  
SALT Output SMS File Tables for Variable Lag

YEAR	M	CPID	LAG	LIN	ZLIN	STOL	STOLLAG	STO	FOUT	LOUT	STOC	STOCLAG	COOT
2001	1	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	2	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	3	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	4	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	5	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	6	CP-1	6	10000.0	10000.0	60000.0	60000.0	6000.0	1000.0	10000.0	10.0	10.0	10.0
2001	7	CP-1	6	10000.0	10000.0	64800.0	64800.0	6000.0	500.0	5200.0	10.8	10.8	10.4
2001	8	CP-1	6	10000.0	10000.0	69216.0	69216.0	6000.0	500.0	5584.0	11.5	11.5	11.2
2001	9	CP-1	6	10000.0	10000.0	73278.7	73278.7	6000.0	500.0	5937.3	12.2	12.2	11.9
2001	10	CP-1	6	10000.0	10000.0	60913.4	60913.4	6000.0	2000.0	22365.3	10.2	10.2	11.2
2001	11	CP-1	6	10000.0	10000.0	52081.0	52081.0	6000.0	2000.0	18832.4	8.7	8.7	9.4
2001	12	CP-1	4	10000.0	30000.0	42915.0	62915.0	6000.0	2000.0	19166.0	7.2	10.5	9.6
2002	1	CP-1	3	10000.0	20000.0	41697.3	71697.3	6000.0	1000.0	11217.7	6.9	11.9	11.2
2002	2	CP-1	3	10000.0	10000.0	39897.7	69897.7	6000.0	1000.0	11799.6	6.6	11.6	11.8
2002	3	CP-1	4	10000.0	0.0	39144.2	59144.2	6000.0	1000.0	10753.5	6.5	9.9	10.8
2002	4	CP-1	4	10000.0	10000.0	39275.9	59275.9	6000.0	1000.0	9868.3	6.5	9.9	9.9
2002	5	CP-1	5	10000.0	0.0	40156.5	50156.5	6000.0	1000.0	9119.4	6.7	8.4	9.1
2002	6	CP-1	6	10000.0	0.0	42440.1	42440.1	6000.0	1000.0	7716.4	7.1	7.1	7.7
2002	7	CP-1	6	10000.0	10000.0	48644.9	48644.9	6000.0	500.0	3795.2	8.1	8.1	7.6
2002	8	CP-1	6	10000.0	10000.0	54353.3	54353.3	6000.0	500.0	4291.6	9.1	9.1	8.6
2002	9	CP-1	6	10000.0	10000.0	59605.1	59605.1	6000.0	500.0	4748.3	9.9	9.9	9.5
2002	10	CP-1	6	10000.0	10000.0	51146.5	51146.5	6000.0	2000.0	18458.6	8.5	8.5	9.2
2002	11	CP-1	6	10000.0	10000.0	45104.6	45104.6	6000.0	2000.0	16041.8	7.5	7.5	8.0
2002	12	CP-1	4	10000.0	30000.0	37931.9	57931.9	6000.0	2000.0	17172.7	6.3	9.7	8.6
2003	1	CP-1	3	10000.0	20000.0	37480.8	67480.8	6000.0	1000.0	10451.1	6.2	11.2	10.5
2003	2	CP-1	3	10000.0	10000.0	36329.9	66329.9	6000.0	1000.0	11150.9	6.1	11.1	11.2
2003	3	CP-1	4	10000.0	0.0	36125.3	56125.3	6000.0	1000.0	10204.6	6.0	9.4	10.2
2003	4	CP-1	4	10000.0	10000.0	36721.4	56721.4	6000.0	1000.0	9403.9	6.1	9.5	9.4
2003	5	CP-1	5	10000.0	0.0	37995.0	47995.1	6000.0	1000.0	8726.4	6.3	8.0	8.7
2003	6	CP-1	6	10000.0	0.0	40611.2	40611.2	6000.0	1000.0	7383.9	6.8	6.8	7.4
2003	7	CP-1	6	10000.0	10000.0	43594.1	43594.1	6000.0	1000.0	7017.1	7.3	7.3	7.0
2003	8	CP-1	6	10000.0	10000.0	46118.1	46118.1	6000.0	1000.0	7476.0	7.7	7.7	7.5
2003	9	CP-1	6	10000.0	10000.0	48253.8	48253.8	6000.0	1000.0	7864.3	8.0	8.0	7.9
2003	10	CP-1	6	10000.0	10000.0	50060.9	50060.9	6000.0	1000.0	8192.9	8.3	8.3	8.2
2003	11	CP-1	6	10000.0	10000.0	51590.0	51590.0	6000.0	1000.0	8470.9	8.6	8.6	8.5
2003	12	CP-1	6	10000.0	10000.0	52883.8	52883.8	6000.0	1000.0	8706.1	8.8	8.8	8.7

Total Volume and Load Summary for Constituent 1

	Volume	Load	Concentration
Naturalized flows	39000.	360000.	9.2
Regulated flows at boundary	0.	0.	0.0
Return flows	0.	0.	0.0
CI record constant inflows	0.	0.	0.0
Channel loss credits	0.	0.	0.0
Channel losses	0.	0.	0.0
Regulated flows at outlet	39000.	367116.	9.4
Diversions	0.	0.	0.0
Other flows and loads	0.	0.	0.0
Net evaporation	0.	0.	0.0
Inflows - Outflows	0.	-7116.	0.0
Beginning reservoir storage	6000.	60000.	10.0
Ending reservoir storage	6000.	52884.	8.8
Change in storage	0.	-7116.	0.0
Volume and load differences	0.	0.	0.0
Naturalized flows at outlet	39000.		

## **SALT Simulation Results**

The program *SALT* simulation results are written to two output files. The file with filename extension *SAL* is read by program *TABLES*. Additional information is provided in the message file, which has the filename extension *SMS*. The *SMS* file provides the following information, with options selected by *SC* record field 13 that may be useful in tracking the simulation and performing various analyses.

1. Trace messages track the simulation.
2. Error messages are written if errors or inconsistencies are detected in the input data. An error message is accompanied by termination of model execution.
3. Warning messages are activated by various situations that may occur during the simulation. For example, warning messages are written if the minimum or maximum concentration limits specified in *CC* record fields 8, 9, 10, and 11 are reached. Irregularities in input data may generate a variety of warning messages.
4. A concise overall volume and load balance summary table is provided.
5. The components of detailed monthly control point volume and load balances are recorded as computed in the simulation if specified by *SC* record field 13.
6. Reservoir lag results may be tabulated as illustrated by Tables 6 and 7.
7. An optional listing of control points with pertinent information may be written.

The trace messages printed to the message (*SMS*) file during a successful execution of *SALT* are shown in Table 8. Some messages are printed only if certain options are activated, others are always found in the message file. The program contains routines that check the input data for blunders and inconsistencies. Numerous error and warning messages are possible. Program execution is terminated with an error message but continues with warning messages. The error and warning messages are inserted into the trace of Table 8 as problems are detected during model execution. The trace messages are designed primarily to track the reading of input data. The table discussed below tracks the simulation computations.

An option activated by *SC* record field 13 allows essentially any and all of the quantities computed during the simulation to be recorded in the *SMS* file. In a typical application, *TABLES* is used to organize results written by *SALT* to the *SAL* file without being concerned with this optional message *SMS* file table. However, the *SMS* file dataset with the variables listed in Tables 9 and 10 provides voluminous simulation results that may be useful to model users interested in tracking the computations in detail. The variables listed in Tables 9 and 10 are defined earlier in this chapter. These variables are components of the volume and load balances for a control point for a particular month of the simulation. For each month of the simulation, a set of three lines of data are written for each control point specified by *SC* record field 12 and *CO* records. The variables in the first line are listed in Table 9. The second and third lines of data consist of the volumes and loads listed in Table 10. The lengthy data listing is repeated for each salinity constituent.

Table 8  
Trace Messages Written to SMS File

---

WRAP-SALT Message File

\*\* Starting to read input data.  
 \*\* SC record from the SALT input file was read.  
 \*\* Starting to read CP records from SIM input file.  
 \*\* Read \_\_\_ CP records from SIM input file.  
 \*\* Completed check of sequencing of CP records in SIM input file.  
 \*\* Starting to read CI records from SIM input file.  
 \*\* Read \_\_\_ CI records from SIM input file.  
 \*\* Beginning-of-simulation storage is to be determined.  
 \*\* Beginning storage was computed from data read from SIM output file.  
 \*\* Beginning storage was read from BRS file.  
 \*\* Beginning reservoir concentration was read from BRC file.  
 \*\* Starting to read SIN input file.  
 \*\* CO record from the SIN input file was read.  
 \*\* Read \_\_\_ CP records from SIN input file.  
 \*\* Finished reading SALT input SIN file.  
 \*\* Beginning the simulation for salt constituent 1.  
 \*\* Finished reading S\_ records.  
 (Last two messages are repeated for each salt constituent.)

\*\*\*\*\* Normal Completion of Program WRAP-SALT \*\*\*\*\*

---

Table 9  
Variables in First Line of SMS File Data Set

Description of Variable	Variable Name
1 year	YEAR
2 month (1, 2, 3, ... , 12)	M
3 control point identifier	CPID(cp,1)
4 naturalized flow from <i>SIM</i> output file	NAT(cp)
5 channel loss credits from <i>SIM</i> output file	CLC(cp)
6 channel losses from <i>SIM</i> output file	CL(cp)
7 concentration or load from SIN file	S(cp)
8 total load inflow	LIN
9 total flow inflow	FIN
10 inflow concentration	CIN=(LIN/FIN)CF
11 outflow concentration	COUT
12 beginning storage concentration	BPC(cp)
13 ending storage concentration	STOC(cp)
14 mean storage concentration	MC(cp)
15 lag time in months	LAG

---



Table 10  
Monthly Volume and Load Budget by Control Point in SMS File Data Set

Description of Variable	2 <sup>nd</sup> Line Volume	3 <sup>rd</sup> Line Load
1 incremental naturalized flows	FNAT	LNAT
2 regulated flow entering cp	FREG	LREG
3 return flows	RET(cp)	LRET
4 other inflows	CINF(cp,m)	LCIN
5 channel loss credits	FCLC	LCLC
6 channel losses	FCL	LCL
7 total inflows	FIN	LIN
8 regulated flows leaving cp	REG(cp)	REGL(cp)
9 diversions	DIV	LDIV
10 other flows (hydro and IF releases)	FOTH	LOTH
11 net reservoir evaporation	EVAP(cp)	-0-
12 beginning-of-simulation storage	BSTO(cp)	BSL(cp)
13 end-of-month storage	STO(cp)	STOL(cp)
14 storage change = (13) – (12)	XSTO	XSTOL
15 inflows – outflows = (7) – (8) – (9) – (10) – (11)	XSUM	XSUML

Referring to variables listed at the bottom of Table 10, XSTO and XSUM should have the same values. XSTOL and XSUML should also be the same. These quantities are computed for volume and load balance comparisons as follows.

$$\text{storage change} = \text{ending storage} - \text{beginning storage} \quad (41)$$

$$XSTO = STO(cp) - BSTO(cp) \quad (42)$$

$$XSTOL = STOL(cp) - BPL(cp) \quad (43)$$

$$\text{storage change} = \Sigma \text{ inflows} - \Sigma \text{ outflows} \quad (44)$$

$$\begin{aligned} XSUM &= FNAT + FREG + RET(cp) + CINF(cp,m) \\ &+ FCLC - FCL - REG(cp) - DIV(cp) - FOTH - EVAP(cp) \end{aligned} \quad (45)$$

$$\begin{aligned} XSUML &= LNAT + LREG + LRET + LCIN + LCLC - LCL \\ &- REGL(cp) - LDIV(cp) - LOTH - LLIL - LLSL \end{aligned} \quad (46)$$

Volume and Load Balance Summary Table in SMS File

A volume and load balance summary table providing the totals for the entire river basin system for the entire period-of-analysis is also provided in the *SALT* message file. All control points are reflected in this summary table regardless of the selection of control points for

inclusion in the other *SALT* output. The variables listed in Table 11 are components of the volume and load balances expressed by Equations 47 through 54. The sum for all months of the incremental naturalized flow volumes (FNAT) and loads (LNAT) at all control points represent flows entering the system. Regulated flow volumes (REG(cp)) and loads (REGL(cp)) at the river basin outlet, or multiple outlets as defined by *SIM CP* records, represent river flows leaving the system. The other variables representing inflow and outflow or change in storage are also summed for all control points. The summation of all of the outflows and inflows for each month during the total period-of-analysis equals the change in reservoir storage contents, which is the total storage at the end of the simulation less the total storage at the beginning.

Table 11  
SMS File Table of Total Volume and Load for the  
Entire River/Reservoir System and Period-of-Analysis

Description of Variable	Total Volume	Total Load
Incremental naturalized flows	$\Sigma$ FNAT	$\Sigma$ LNAT
Regulated flows at upstream boundary	$\Sigma$ REG(cp)	$\Sigma$ REGL(cp)
Return flows	$\Sigma$ RET(cp)	$\Sigma$ LRET
CI record constant inflows	$\Sigma$ CINF(cp,m)	$\Sigma$ LCIN
Channel loss credits	$\Sigma$ FCLC	$\Sigma$ LCLC
Channel losses	$\Sigma$ FCL	$\Sigma$ LCL
Regulated flows at outlet(s)	$\Sigma$ REG(cp)	$\Sigma$ REGL(cp)
Water supply diversions	$\Sigma$ DIV	$\Sigma$ LDIV
Other flows and loads	$\Sigma$ FOTH	$\Sigma$ LOTH
Net reservoir evaporation	$\Sigma$ EVAP(cp)	-0-
Parameter CLI load losses (+) or gains (-)		$\Sigma$ LLIL
Parameter CLS load losses (+) or gains (-)		$\Sigma$ LLSL
Summation of inflows minus outflows	Eq. 49	Eq. 50
Beginning-of-simulation storage	$\Sigma$ BSTO(cp)	$\Sigma$ BSL(cp)
End-of-simulation storage	$\Sigma$ STO(cp)	$\Sigma$ STOL(cp)
Change in storage	Eq. 51	Eq. 52
Volume and load balance differences	Eq. 53	Eq. 54
Negative inflows to control point	$\Sigma$ FINNEG	$\Sigma$ LINNEG
Negative incremental naturalized flows	$\Sigma$ FNAT if < 0	-
Naturalized flows at river basin outlet(s)	$\Sigma$ NAT(cp)	-

In general, volume and load balances may be expressed as Equations 47 and 48.

$$\text{change in storage} = \Sigma \text{ inflows} - \Sigma \text{ outflows} \quad (47)$$

$$\text{change in storage} = \text{total ending storage} - \text{total beginning storage} \quad (48)$$

The *SALT* simulation variables included in the SMS file summary table and listed in Table 11 are components of the volume and load balances reflected in the following equations.

$$\begin{aligned} \Sigma \text{ inflow volume} - \Sigma \text{ outflow volume} &= \Sigma \text{FNAT} + \Sigma \text{RET}(\text{cp}) + \Sigma \text{CINF}(\text{cp},\text{m}) \\ &+ \Sigma \text{REGL}(\text{at boundary}) + \Sigma \text{FCLC} - \Sigma \text{FCL} - \Sigma \text{REG}(\text{cp}) - \Sigma \text{DIV}(\text{cp}) - \Sigma \text{FOTH} \\ &- \Sigma \text{EVAP}(\text{cp}) \end{aligned} \quad (49)$$

$$\begin{aligned} \Sigma \text{ inflow load} - \Sigma \text{ outflow load} &= \Sigma \text{LNAT} + \Sigma \text{LRET} + \Sigma \text{LCIN} \\ &+ \Sigma \text{REGL}(\text{at boundary}) + \Sigma \text{LCLC} - \Sigma \text{LCL} + \Sigma \text{REGL}(\text{cp}) - \Sigma \text{LDIV}(\text{cp}) \\ &- \Sigma \text{LOTH} - \Sigma \text{LLIL} - \Sigma \text{LLSL} \end{aligned} \quad (50)$$

$$\text{change in storage volume} = \Sigma \text{STO}(\text{cp}) - \Sigma \text{BPSTO}(\text{cp}) \quad (51)$$

$$\text{change in storage load} = \Sigma \text{STOL}(\text{cp}) - \Sigma \text{BSL}(\text{cp}) \quad (52)$$

The volume and load balance differences in Table 11 represent losses or gains due to modeling approximations or failure to maintain perfect mass balances in the simulation.

$$\begin{aligned} \text{volume balance difference} &= \\ [\Sigma \text{ inflow volume} - \Sigma \text{ outflow volume}] &- [\Sigma \text{STO}(\text{cp}) - \Sigma \text{BPSTO}(\text{cp})] \end{aligned} \quad (53)$$

$$\begin{aligned} \text{load balance difference} &= \\ [\Sigma \text{ inflow load} - \Sigma \text{ outflow load}] &- [\Sigma \text{STOL}(\text{cp}) - \Sigma \text{BSL}(\text{cp})] \end{aligned} \quad (54)$$

Negative volumes and loads complicate the analysis. The physical or computational meaning of negative volumes and loads vary with different situations. The SMS file dataset represented by Table 11 includes the entry *negative inflows to control point*. Inflow volumes (FIN) and loads (LIN) are determined based on Eqs. 8 and 9. Negative values for FIN and LIN are recorded as the variables FINNEG and LINNEG. The summation of FINNEG and LINNEG for all control points and all time periods are included in the summary table. Options for dealing with negative control point total inflows are selected by SC record field 14.

Incremental naturalized flows (FNAT) are negative if the flows at upstream control points exceed the flow at the control point in question. The summation of negative incremental volumes is included in Table 11 for general information. The negative incremental naturalized flows generated in *SALT* may be different than the negative incremental flow adjustments in *SIM*. Whereas *SIM* looks at all control points located optionally either downstream or upstream in computing negative incremental naturalized flow adjustments, *SALT* considers only the upstream control point(s) located immediately adjacent to the control point being considered.

The last variable listed in Table 11 is naturalized flows at the one or more outlets. Outlets are defined by *SIM CP* records. The total naturalized flows  $\Sigma \text{NAT}(\text{cp})$  at outlets should be the same as the sum of the incremental flows  $\Sigma \text{FNAT}$ , which is the first entry in the table.

SALT Output SAL File

SALT writes its main final monthly simulation results to a file with the filename extension SAL, which is read by TABLES. The SIM input and output files should contain exactly the same control points. The SALT computations are performed for all control points in the SIM files except those located above specified upstream boundary control points. However, only user-selected control points are included in the SALT output SAL file. The SAL file contains the data listed in Table 12. The volumes, loads, and concentrations are provided for each month of the hydrologic period-of-analysis for each user-selected control point.

Table 12  
Variables in SAL File

Description of Variable	Variable Name
year and month	YEAR, M
control point identifier	CPID(cp,1)
total inflow volume to control point during month	FIN
total inflow load to control point during month	LIN
mean concentration of total inflow during month	CIN
end-of-month storage volume	STO(cp)
end-of-month storage load	STOL(cp)
end-of-month storage concentration	STOC(cp)
total outflow volume excluding evaporation	FOUT(cp)
total outflow load leaving control point during month	LOUT(cp)
outflow concentration = (LOUT(cp)/FOUT(cp))CF	COUTT
concentration of regulated flow and other flow	REGC(cp)
concentration of diversions	CDIV
total diversion target at control point during month	DT(cp)
total diversion shortage at control point during month	DS(cp)

**TABLES Time Series, Summary, Frequency, and Reliability Tables**

Program TABLES reads the program SALT output file with filename extension SAL that contains the simulation results listed in Table 12. TABLES type 8 salinity routines organize these data and compute reliability indices and frequency relationships. The 8SUM record develops a control point summary. The 8SAL, 8FRE, 8FRQ, and 8REL records described in Appendix C create salinity tables that are essentially identical in format to the corresponding type 2 record tables for water quantities described in the basic Users Manual.

The 8SAL record tabulates the variables listed in Table 13 in the same format as the tables created by 2NAT, 2REG, 2STO and similar type 2 records. The variable identifier shown in the first column of Table 13 is selected in 8SAL record field 5. The data may be organized as tables with annual rows and monthly columns, tabulations to be read by Microsoft Excel, or HEC-DSS records to be read by HEC-DSSVue.

Table 13  
Variables in 8SAL, 8FRE, and 8FRQ Record Tables

Variable ID	Description of Variable	Variable Name
1	total inflow volume to control point during month	FIN
2	total inflow load to control point during month	LIN
3	mean concentration of total inflow during month	CIN
4	end-of-month storage volume	STO(cp)
5	end-of-month storage load	STOL(cp)
6	end-of-month storage concentration	STOC(cp)
7	total outflow volume excluding evaporation	FOUT(cp)
8	total outflow load leaving control point	LOUT(cp)
9	outflow concentration = (LOUT(cp)/FOUT(cp))CF	COUTT
10	concentration of regulated flow and other flow	REGC(cp)
11	concentration of diversions	CDIV

*8FRE* and *8FRQ* records are analogous to *2FRE* and *2FRQ* records. The frequency computations are the same regardless of which variable is represented by the dataset. Frequency analyses may be applied to either of the eleven variables listed in Table 13.

The *8SUM* record develops a summary table of control point inflow, outflow, and storage volumes, loads, and concentrations. Simulation period-of-analysis means of each of the first nine variables listed in Table 13 are tabulated.

The *8REL* record deals with monthly diversion concentrations and the monthly volumes of diversion targets and shortages. These are the last three variables recorded in the SAL file and listed in Table 12. The *8REL* record reliability table extends the *2REL* record table to consider a specified maximum acceptable concentration for each water quality constituent. The model-user specifies an allowable concentration limit for each constituent being considered. The water supply diversion target is considered met only if the concentration of each constituent is at or below its allowable limit. Volume and period reliabilities are shown in the *8REL* table both with and without consideration of the user-specified allowable salinity limits.

### **Parameter Calibration Comparison Features**

Parameter calibration refers to determining optimal values for selected parameters by adjusting the parameter values in iterative executions of a simulation model while attempting to find those parameter values for which simulation results match observed data as closely as possible. *SALT* includes options for comparing simulated and observed salinity concentrations for regulated flow and reservoir storage. The parameter calibration comparison features of *SALT* are motivated by the need to determine values for the reservoir lag parameters TM, LAG1, and LAG2 entered on the control point *CP* record and the parameters RCF1, RCF2, RCD1, and RCD2 entered on the reservoir outflow concentration *RC* record. However, the generic concentration comparison features can be used in various ways to serve a variety of purposes.

The parameter calibration comparison feature consists of developing tables that are recorded in the SMS file comparing statistics for either regulated flow concentrations or storage concentrations. The *SALT* message SMS file tables contain the following information for either regulated flow concentrations or reservoir storage concentrations.

- control point location
- number of months covered by the comparison statistics
- mean of computed flow or storage concentrations
- mean of given *C1* or *C2* record concentrations
- mean of differences (computed – given)
- mean of positive differences (computed – given)
- mean of negative differences (computed – given)
- mean of differences squared (computed – given)
- largest positive difference (computed – given)
- largest negative difference (computed – given)

The parameter calibration comparison feature is activated by the PC switch in *SC* record field 16. The control point at which concentrations are compared is specified in *SC* record field 17. Simulated versus observed (given) concentrations of regulated flows and/or reservoir storage are compared. Observed sequences of regulated flow concentrations are provided on *C1* records. Observed sequences of reservoir storage concentrations are entered on *C2* records.

The observed (given) concentrations entered on *C1* and *C2* records can cover the entire simulation period-of-analysis or any sub-period thereof. One or more months up to all the months in the simulation may be included in the comparison statistics. Each *C1* or *C2* record is for a particular year. *C1* or *C2* records may be provided for any of the years of the simulation period-of-analysis. Individual months within a year having no data and thus not included in comparison statistics are indicated by entries of –1.

The concentration comparison feature described above does nothing other than to simply create tables of statistics (listed above) which provide comparisons of simulated regulated flow and reservoir storage concentrations with given concentrations entered on *C1* and *C2* records. Model-users can use these statistics in whatever manner they find useful. However, the primary motivation for incorporating the comparison feature in *SALT* was to facilitate parameter calibration studies for determining values for reservoir salinity routing parameters.

### **Constant Concentration Salinity Simulation Example**

The next section provides a detailed presentation of a realistic salinity simulation example which extends the example from the *Fundamentals Manual*. A simplified version of this example is explored below to illustrate basic concepts prior to covering the full-scale example in the final section of the chapter. The simplified example is unrealistic but illustrative. The input dataset for the simplified example is included with the electronic files for all of the examples presented in the *Fundamentals*, *Reference*, and *Supplemental Manuals*.

The following Example 3 was developed by modifying the example presented in the next section by assuming that the TDS concentration of all entering stream inflows and beginning-of-

simulation reservoir storage is 1,000 mg/l. Setting all input concentrations at a constant 1,000 mg/l provides an easy-to-track dataset that facilitates experimentation with the salinity model. The *SIM* simulation dataset from the *Fundamentals Manual* is adopted, but the net evaporation-precipitation rates are changed to zero by modifying field 9 of the DAT file *CP* records and *JO* record field 2. The *SALT* salinity input SIN file shown as Table 14 has the *S* records removed from the SIN file of the next section and replaced by a constant concentration of 1,000 mg/l on the *CC* records. Other options are also omitted to develop the following very simple SIN file.

Table 14  
SALT SIN File for Salinity Example 3

```

** SALT Input File SaltExam3.SIN
** Example 3 of Salinity Manual
** All concentrations = 1,000 mg/l
**
**          1          2          3          4
**34567890123456789012345678901234567890
**      !    !    !    !    !    !    !    !    !
SC  1940  58   0   0   0   2
**
CP   PK    2
CC   1000.  1000.   -1   -1
CP  Whit   2
CC   1000.  1000.   -1   -1
CP  Camer  2
CC   1000.  1000.   -1   -1
CP  Hemp   2
CC   1000.  1000.   -1   -1
**
ED

```

The SIN file shown in Table 14 contains all of the salinity data for Example 3. Program *SALT* reads the SIN file along with the *SIM* simulation results OUT file created by program *SIM*. As previously discussed, *SALT* can create several different optional output tables. However, for this example, only the summary table reproduced as Table 15 is shown. Program *TABLES* is not employed. The full-scale example presented in the final section of the chapter illustrates the broad range of formats for presenting and analyzing *SALT* simulation results.

Table 11 defines the variables contained in the *SALT* SMS file summary table. The summary table for Example 3 is reproduced as Table 15. The simulation begins with a fixed concentration of 1,000 mg/l for all naturalized flows and the beginning-of-simulation storage in the six reservoirs as shown in Table 15. With no reservoir net evaporation-precipitation, the storage concentration remains at 1,000 mg/l throughout the simulation. Other concentrations in Table 15 vary slightly from 1,000 mg/l due to computational impreciseness associated primarily with negative inflows.

Reservoir water surface evaporation would increase the storage concentration. If the *SIM* input DAT file is modified to allow evaporation, the storage concentration increases above 1,000 mg/l. Concentrations of diversions, return flows, and regulated flows likewise increase.

**Table 15**  
**Summary Table for Salinity Example 3**

Total Volume and Load Summary for Constituent 1

	Volume	Load	Concentration
Naturalized flows	310818880.	422607328.	1000.0
Regulated flows at boundary	0.	0.	0.0
Return flows	22681966.	30835846.	999.9
CI record constant inflows	0.	0.	0.0
Channel loss credits	6103362.	8296158.	999.7
Channel losses	2556946.	3475992.	999.8
Regulated flows at outlet	211954592.	288182912.	1000.0
Diversions	115129008.	156523888.	999.9
Other flows and loads	10183597.	13855982.	1000.7
Net evaporation	0.	0.	0.0
	-----	-----	-----
Inflows - Outflows	-219934.	-299442.	1001.4
	-----	-----	-----
Beginning reservoir storage	1949640.	2650840.	1000.0
Ending reservoir storage	1729300.	2351254.	1000.0
	-----	-----	-----
Change in storage	-220340.	-299587.	1000.0
	-----	-----	-----
Volume and load differences	406.	145.	263.2
Negative inflows to cpts	61923.	84197.	1000.0
Negative incremental nat flows	4060064.		
Naturalized flows at outlet	310818816.		
Number of control points in SIM DAT and OUT files:		11	
Number of control points included in SALT simulation:		11	

### **Salinity Simulation Example**

The *Fundamentals Manual* presents a hypothetical example that deals only with water volumes. The following example adds salinity. The *SIM* input data and simulation results described in the *Fundamentals Manual* are adopted for the salinity example without change. The water rights and hydrology are covered in the *Fundamentals Manual*. The following discussion focuses on the salinity aspects of the modeling application added with the *SALT* simulation. The system schematic from the *Fundamentals Manual* is reproduced here as Figure 4. The simulation period-of-analysis is 1940-1997.

The river/reservoir system is represented spatially by the 11 control points shown in Figure 4. The *CP* records are entered in the *SIM* input file in the following upstream-to-downstream order: PK, Whit, WacoL, WacoG, High, Belton, George, Grang, Camer, Bryan, Hemp. The *SALT* computational algorithms require that the *SIM* output file include simulation results for all control points and that the results be organized by control point in upstream-to-downstream order. There are six control points with reservoirs and five without reservoirs.



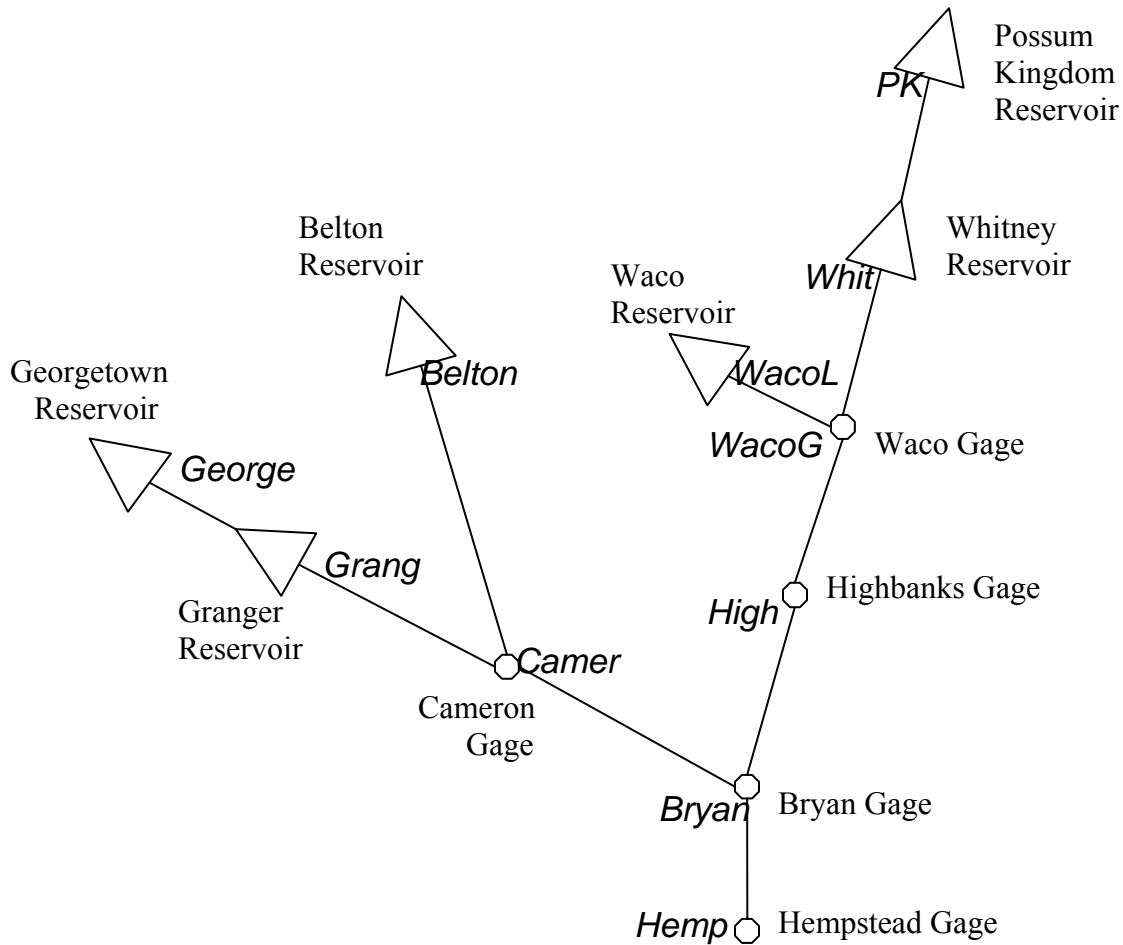


Figure 4 System Schematic for the Example

This example consists of tracking total dissolved solids (TDS) through the river/reservoir system of Figure 4. Salinity constituents such as chlorides and sulfates or other conservative water quality parameters may be modeled in exactly the same manner. Although this example is limited to the single water quality parameter TDS, multiple constituents may be included in a single input dataset and execution of *SALT* with each constituent being considered separately in turn within the model.

With *SC* record field 15 blank, the default conversion factor *CF* of 735.48 is adopted. Volumes are in acre-feet, loads are in tons, and concentrations are in units of mg/l. Other alternative sets of units would require a non-default entry for *CF* in *SC* record field 15.

The *SIM* input dataset and simulation results are described in the *Fundamentals Manual*. *SALT* reads the *CP* records from the *SIM* input DAT file and the quantities listed in Table 2 on page 14 from the main *SIM* output OUT file. The beginning-of-simulation reservoir storage file generated by *SIM* and presented as Table 16 on page 47 is also read by *SALT* to obtain initial storage volumes.

The beginning-of-simulation reservoir storage concentration in each of the six reservoirs for the beginning of January 1940 was set to equal the simulated end-of-simulation reservoir storage concentration for the end of December 1997. The beginning reservoir concentration (BRC) file activated by the BEGCON switch in *SC* record field 9 is reproduced as Table 17. BEGCON options allow beginning-of-simulation storage concentrations to be read from the BRC file and/or end-of-simulation storage concentrations to be recorded in the BRC file. *SALT* was initially executed with an assumed set of beginning concentrations to obtain the ending concentrations. The ending concentrations were then adopted as beginning concentrations. Additional iterative executives of *SALT* are not required for this particular example. The beginning reservoir storage concentrations do not affect ending storage concentrations because the reservoirs are emptied during the extreme drought of the 1950s.

Instructions for developing the SIN file are provided in Appendix A. The salinity input SIN file reproduced as Table 18 includes the following total dissolved solids (TDS) input data.

- TDS loads of naturalized flows are provided on *SI* records for the PK control point. This represents a majority of the salt load entering the river/reservoir system.
- TDS concentrations of incremental naturalized flows at the Whit control point are entered as a constant 350 mg/l on a *CC* record.
- TDS concentrations of incremental naturalized flows at the Camer control point and all other control points located upstream are entered on *SI* records for the Camer control point.
- TDS concentrations of incremental naturalized flows at the Hemp control point and the Bryan, High, WacoG and WacoL control points located upstream are entered on *SI* records for the Hemp control point.

The salinity input data provided by the *CC* and *SI* records for control point *Camer* are repeated internally within *SALT* for control points *Belton*, *George*, and *Grang*. The model also adopts the *CC* and *SI* record data entered for control point *Hemp* for the control points *Bryan*, *High*, *WacoG*, and *WacoL* located upstream. Options for repeating salinity data at multiple control points are selected in *SC* record field 11. The majority of the total dissolved solids (TDS) load at the Hempstead gaging station (control point Hemp) representing the basin outlet originates from primary salt sources in the watershed above Possum Kingdom Reservoir (control point PK).

Reservoir lag options are not activated on the SIN file *CP* records. Without the lag options activated, reservoir inflow loads are assumed to be completely mixed with storage loads during the month. *CC* record field 5 is blank meaning diversion concentrations are determined within *SALT* rather than set as a constant. *RC* records are not included in the SIN file. With no *RC* record and default *CC* record field 5, diversions, downstream regulated flows, and other releases are all assumed to have the same outflow concentration equal to storage concentration.

The *SALT* message SMS file is presented as Table 19. With option 2 specified in *SC* record field 13, the total volume and load summary table described in Table 11 is included in the Table 19 SMS file, but warning messages and the voluminous detailed listing outlined in Tables 9-10 are not included. The beginning of the SAL file created by *SALT* and read by *TABLES* is

reproduced as Table 20. Most of the lengthy SAL file is omitted from Table 20 for brevity. The variables recorded in the SAL output file are defined in Table 12.

The summary table of Table 19 tabulates 1940-1997 total inflow and outflow volumes in acre-feet and loads in tons. The total storage in the six reservoirs at the beginning and end of the 1940-1997 simulation are also included in the summary table. Concentrations in mg/l are total loads divided by total volumes multiplied by the 735.48 conversion factor. The volume and load budgets fail to balance in the amount of 311 acre-feet and 71,010 tons, which are small amounts relative to the total inflows. The volume column in Table 19 is the same as volume budget of Table 5.20 in Chapter 5 of the *Reference Manual* which was created with *TABLES* with a volume budget *2BUD* record. The volume and load summary variables are defined in Table 11.

*TABLES* input TIN, message TMS, and output TOU files are shown as Tables 21, 22, and 23. The TIN file input records for the salinity routines in *TABLES* are documented in Appendix C. Table 23 illustrates the formats into which *TABLES* organizes the *SALT* results. Variables in the tables created with *TABLES* are defined in Tables 12 and 13.

The summary activated by the *8SUM* record is the first table found in the TOU file of Table 23. The inflow and outflow volumes and loads for each control point are the 1940-1997 means of the 696 monthly quantities. The table also includes the 1940-1997 means of the end-of-month storage volumes and loads. The concentrations shown in the table are volume-weighted mean concentrations (Eq. 3) computed from the 1940-1997 total loads and volumes.

The frequency tables created by the *8FRE* and *8FRQ* records are based on the same computations regardless of the particular variable being analyzed. The means of the concentrations are the arithmetic averages of the N monthly mean concentrations, not volume-weighted mean concentrations like the *8SUM* record summary table. Option 2 in *8FRE* or *8FRQ* record field 4 specifies that months with zero volume are not counted in the frequency computations for concentrations. Thus, the total number of months (N) adopted may be less than 696 months for the 1940-1997 period-of-analysis. N is shown in the frequency tables.

A maximum tolerable TDS concentration of 1,000 mg/l is specified on the *8REL* record. The reliability table shows the volume and period reliabilities with and without considering the 1,000 mg/l TDS constraint. For example, monthly water supply diversion targets at the Hemp control point total to 1,119,703 acre-feet/year. Considering both water quality and quantity, diversion targets are fully met in 80.89 percent of the 696 months of the simulation. Considering only the diversion shortages determined in the *SIM* simulation, the period reliability is 83.62 percent. TDS concentrations exceed the 1,000 mg/l limit in 54 of the 696 months, resulting in a period reliability of 92.24 percent considering only water quality.

The *8SAL* record creates tables for any of 11 volume, load, or concentration variables listed in Table 13 for any or all control points. Tables with annual rows and monthly columns are included in the TOU file of Table 23. The means in the last row are arithmetic averages of 696 monthly quantities. Annual means of concentrations in the last column are arithmetic averages of 12 monthly concentration values. In addition to the table format shown in Table 23, *8SAL* record options also allow the data to be organized as columns for transport to spreadsheet programs or as HEC-DSS records for developing plots with HEC-DSSVue.

The last two TOU file tables in Table 23 are tabulations of outflow concentrations at control points PK and Hemp created by the 8SAL record. With ID of 9 selected on the 8SAL record, these are concentrations for the total of all outflows. With no RC record and default CC record field 5 in the SIN file, diversions, downstream regulated flows, and hydropower releases all have the same outflow concentration which is the concentration tabulated in the last two tables.

**Table 16**  
**Beginning Reservoir Storage BRS File for the Example**

Beginning Reservoir Storage (BRS) File

Reservoir	Control Point	Storage Capacity	Beginning Storage
1 PK	1 PK	570240.0	570240.0
2 Whit	2 Whit	627100.0	627100.0
3 WacoL	3 WacoL	192100.0	192100.0
4 Belton	6 Belton	457600.0	457600.0
5 George	7 George	37100.0	37100.0
6 Grang	8 Grang	65500.0	65500.0

**Table 17**  
**Reservoir Storage Concentration BRC File for the Example**

Beginning-of-Simulation Reservoir Storage Concentrations

1 PK	1129.64
2 Whit	545.73
3 WacoL	184.05
4 WacoG	0.00
5 High	0.00
6 Belton	190.55
7 George	214.14
8 Grang	266.18
9 Camer	0.00
10 Bryan	0.00
11 Hemp	0.00

End-of-Simulation Reservoir Storage Concentrations

1 PK	1129.64
2 Whit	545.73
3 WacoL	184.05
4 WacoG	0.00
5 High	0.00
6 Belton	190.55
7 George	214.14
8 Grang	266.18
9 Camer	0.00
10 Bryan	0.00
11 Hemp	0.00



S1	PK	1974	11700	10600	15800	8810	46800	96600	343	23800	157000	137000	109000	63400
S1	PK	1975	63700	90600	46200	37200	140000	74800	134000	64000	110000	45900	67000	36400
S1	PK	1976	39400	22800	22300	83700	65700	11400	53000	41800	73200	108000	91000	50400
S1	PK	1977	55800	43400	28600	154000	222000	73200	18900	43300	16200	751	1170	2280
S1	PK	1978	5600	12300	14400	1000	50700	45900	3770	115000	105000	44400	31300	30400
S1	PK	1979	34500	31400	59200	45100	61300	126000	51100	90100	12600	132	18400	18000
S1	PK	1980	14900	28400	10800	7410	294000	102000	18300	31500	160000	95300	52100	72500
S1	PK	1981	52200	47200	97900	74700	82100	117000	7850	25400	10900	190000	66200	51500
S1	PK	1982	36500	51800	53100	19500	321000	295000	103000	44000	37800	18600	8190	24100
S1	PK	1983	46600	59600	37700	41300	177000	80800	24700	208	1490	299000	219000	114000
S1	PK	1984	84800	48300	50300	24900	19400	7000	747	24800	14300	53300	77900	91800
S1	PK	1985	96200	96200	120000	139000	188000	142000	63100	13100	11100	174000	88500	60200
S1	PK	1986	34700	38300	23700	44100	76400	131000	101000	90800	186000	649272	136590	159496
S1	PK	1987	133060	270576	231108	41784	730030	327723	18685	877	18642	20090	9632	20915
S1	PK	1988	28108	22048	14780	17678	11578	6854	72809	2965	149250	15714	18036	12700
S1	PK	1989	16483	93972	34142	18202	434472	509917	5108	4918	226595	30595	18098	23067
S1	PK	1990	84335	36701	217124	468536	322306	486212	36281	120387	39519	39339	36976	28784
S1	PK	1991	65618	55979	17710	20063	305765	893534	64250	151800	164138	85970	58653	316431
S1	PK	1992	198306	482375	355222	215773	303938	1026303	92713	10927	34226	8470	42374	72476
S1	PK	1993	73328	186155	162334	71136	81908	126835	273	4	7871	12000	5155	9227
S1	PK	1994	5749	10584	6943	2832	404972	30868	2974	3811	46540	20553	63227	31489
S1	PK	1995	29897	17577	39133	13242	337006	297611	25415	157531	94029	26090	32524	29047
S1	PK	1996	25009	15818	12880	12411	7044	18585	10253	67255	270391	42796	29800	38430
S1	PK	1997	14873	150834	47842	140626	274793	149690	13195	71108	17771	11995	9728	72015
S1	Hemp	1940	370	230	374	278	246	206	246	121	238	0	183	155
S1	Hemp	1941	131	183	144	0	75	0	0	4138	125	68	95	133
S1	Hemp	1942	68	221	315	163	72	215	122	164	76	66	191	172
S1	Hemp	1943	212	267	322	395	258	230	91	369	0	510	397	361
S1	Hemp	1944	330	246	107	50	73	40	3217	0	212	287	80	0
S1	Hemp	1945	266	327	0	207	243	205	251	203	169	253	259	174
S1	Hemp	1946	106	183	163	149	66	109	3	556	173	303	196	283
S1	Hemp	1947	168	189	156	244	262	284	54	8	184	2734	245	332
S1	Hemp	1948	310	355	144	126	79	0	0	207	0	0	344	885
S1	Hemp	1949	0	295	192	136	164	109	0	285	0	208	56	314
S1	Hemp	1950	202	130	108	0	501	110	279	324	133	280	368	348
S1	Hemp	1951	341	264	306	316	583	0	0	0	315	318	270	447
S1	Hemp	1952	449	234	626	266	144	255	299	178	575	471	204	250
S1	Hemp	1953	207	307	395	358	124	185	247	4	409	328	171	151
S1	Hemp	1954	411	379	0	386	366	361	162	282	604	505	514	336
S1	Hemp	1955	237	179	250	207	253	20	223	2412	252	0	186	0
S1	Hemp	1956	321	264	294	299	147	414	219	221	354	848	312	216
S1	Hemp	1957	446	175	262	211	114	70	0	0	420	163	84	0
S1	Hemp	1958	99	314	125	0	53	105	278	26	246	0	580	494
S1	Hemp	1959	152	167	196	117	0	106	572	410	446	300	225	155
S1	Hemp	1960	148	179	155	294	136	198	125	259	268	345	184	155
S1	Hemp	1961	208	161	163	64	250	119	29	140	306	154	134	162
S1	Hemp	1962	160	240	136	263	104	126	135	0	91	286	235	188
S1	Hemp	1963	282	222	336	239	405	127	417	239	312	0	307	326
S1	Hemp	1964	232	271	204	0	111	0	0	2734	147	107	120	135
S1	Hemp	1965	55	144	249	197	69	202	148	149	115	72	197	145
S1	Hemp	1966	240	199	270	328	161	228	99	325	0	424	405	416
S1	Hemp	1967	526	443	196	59	124	56	2043	0	267	298	87	0
S1	Hemp	1968	294	347	0	251	199	154	197	261	182	298	228	168
S1	Hemp	1969	138	187	176	123	77	142	3	415	0	369	289	297
S1	Hemp	1970	218	196	147	225	267	296	57	13	186	1658	232	416
S1	Hemp	1971	348	451	208	154	94	0	0	316	0	0	227	483
S1	Hemp	1972	0	293	243	201	152	122	0	266	0	345	55	359
S1	Hemp	1973	190	143	80	0	418	97	353	305	110	168	230	208
S1	Hemp	1974	170	166	231	301	281	0	0	0	168	198	123	239
S1	Hemp	1975	265	138	479	256	108	201	197	245	444	329	164	305
S1	Hemp	1976	281	327	454	224	135	134	141	3	423	167	162	129
S1	Hemp	1977	355	214	0	170	260	288	122	257	448	470	477	295
S1	Hemp	1978	171	176	194	291	238	19	248	1280	340	0	151	0
S1	Hemp	1979	172	189	169	158	95	181	277	107	172	361	243	162
S1	Hemp	1980	183	205	263	211	142	96	0	0	470	173	157	0
S1	Hemp	1981	153	457	175	0	68	70	237	26	263	0	398	453
S1	Hemp	1982	149	237	195	148	0	131	484	432	421	417	267	172
S1	Hemp	1983	177	162	128	253	122	214	155	221	205	330	320	243
S1	Hemp	1984	387	283	190	80	264	180	46	181	507	118	122	146
S1	Hemp	1985	136	202	98	203	103	126	129	0	162	261	140	147
S1	Hemp	1986	290	173	285	250	167	124	352	183	199	0	209	187
S1	Hemp	1987	151	208	156	0	101	0	0	3923	142	116	124	113

S1 Hemp	1988	60	205	249	247	122	300	170	166	121	76	306	224
S1 Hemp	1989	242	215	287	365	195	180	78	301	0	602	411	465
S1 Hemp	1990	481	323	121	55	87	46	3104	0	261	283	96	0
S1 Hemp	1991	250	316	0	236	240	220	279	257	201	420	223	142
S1 Hemp	1992	81	143	152	130	73	104	3	344	0	330	270	254
S1 Hemp	1993	173	161	147	203	222	218	42	12	233	1997	232	373
S1 Hemp	1994	287	303	144	132	66	0	0	348	0	0	232	438
S1 Hemp	1995	0	282	177	129	146	95	0	172	0	239	67	346
S1 Hemp	1996	265	214	142	0	769	221	492	341	91	266	368	230
S1 Hemp	1997	203	152	154	203	255	0	0	0	282	229	195	252
S1 Camer	1940	790	330	464	150	160	118	473	431	324	449	63	99
S1 Camer	1941	76	105	141	242	182	156	288	115	118	341	234	311
S1 Camer	1942	386	337	475	204	170	344	666	717	145	169	241	300
S1 Camer	1943	297	366	299	280	349	490	381	385	319	382	368	367
S1 Camer	1944	203	173	112	326	132	60	273	761	153	282	274	225
S1 Camer	1945	201	271	181	194	208	304	277	184	215	163	230	275
S1 Camer	1946	199	237	195	247	266	324	354	224	184	163	94	209
S1 Camer	1947	206	225	215	423	310	394	236	233	372	380	325	243
S1 Camer	1948	215	178	578	443	208	973	68	241	175	274	521	415
S1 Camer	1949	341	197	172	82	196	199	154	303	363	202	325	284
S1 Camer	1950	416	264	367	214	255	292	234	408	172	488	699	552
S1 Camer	1951	563	432	282	316	257	302	901	327	253	476	647	1025
S1 Camer	1952	1500	624	726	257	211	421	557	717	973	1276	387	268
S1 Camer	1953	250	243	254	223	200	307	420	377	243	156	314	207
S1 Camer	1954	471	498	402	347	523	1582	603	611	446	496	251	504
S1 Camer	1955	430	198	226	168	202	451	1983	322	214	187	341	464
S1 Camer	1956	347	315	444	540	203	655	0	507	0	649	369	309
S1 Camer	1957	425	321	168	84	117	270	480	260	159	97	130	118
S1 Camer	1958	153	106	93	81	56	141	819	405	185	209	294	274
S1 Camer	1959	323	201	213	228	262	120	281	159	268	108	169	110
S1 Camer	1960	124	126	200	203	224	293	274	254	310	95	153	159
S1 Camer	1961	110	93	70	71	2000	188	638	1653	388	89	190	155
S1 Camer	1962	145	142	240	226	391	174	231	332	238	18	180	216
S1 Camer	1963	550	278	337	213	194	199	1044	789	371	396	155	350
S1 Camer	1964	189	223	274	413	396	230	645	162	111	448	200	332
S1 Camer	1965	257	196	336	313	149	459	674	757	252	256	242	304
S1 Camer	1966	321	311	307	223	275	401	355	236	221	346	331	378
S1 Camer	1967	381	393	260	504	271	123	403	1376	204	301	278	344
S1 Camer	1968	187	329	202	283	194	335	254	224	240	303	285	350
S1 Camer	1969	339	340	272	233	309	450	466	213	284	176	167	262
S1 Camer	1970	312	231	195	453	318	359	238	250	247	256	342	290
S1 Camer	1971	239	254	806	590	273	1422	55	171	185	137	265	185
S1 Camer	1972	265	194	249	182	248	259	185	336	389	146	248	269
S1 Camer	1973	249	264	226	190	236	287	228	333	233	198	298	307
S1 Camer	1974	290	298	275	257	220	419	660	98	130	155	174	393
S1 Camer	1975	592	209	376	243	174	311	314	280	348	337	402	394
S1 Camer	1976	350	309	312	166	242	240	234	280	251	222	298	224
S1 Camer	1977	342	247	203	143	377	614	247	323	329	510	375	403
S1 Camer	1978	420	262	237	243	447	821	3063	468	388	331	232	387
S1 Camer	1979	180	196	140	223	181	290	191	280	398	424	478	339
S1 Camer	1980	283	218	191	193	168	542	855	457	205	319	334	223
S1 Camer	1981	296	264	151	122	99	103	766	427	199	165	269	281
S1 Camer	1982	329	250	204	242	197	127	342	239	549	393	384	270
S1 Camer	1983	291	182	218	262	187	252	324	237	378	279	371	507
S1 Camer	1984	327	307	134	150	2000	369	1910	4428	1099	92	252	168
S1 Camer	1985	131	117	178	235	364	202	310	482	569	17	177	186
S1 Camer	1986	506	208	308	234	177	120	920	466	197	187	86	105
S1 Camer	1987	83	128	162	319	230	127	325	119	135	503	228	285
S1 Camer	1988	350	315	430	413	403	439	853	883	387	444	513	575
S1 Camer	1989	377	354	303	331	243	296	290	278	382	451	458	533
S1 Camer	1990	365	349	149	238	159	79	264	709	189	300	322	439
S1 Camer	1991	215	340	278	280	205	335	338	189	193	176	184	143
S1 Camer	1992	138	147	154	217	222	241	228	135	179	167	138	227
S1 Camer	1993	256	180	188	385	259	274	167	211	297	220	240	226
S1 Camer	1994	188	155	495	491	155	671	66	221	156	111	228	160
S1 Camer	1995	210	161	132	82	164	157	119	149	201	143	309	286
S1 Camer	1996	364	367	381	292	377	300	291	208	135	262	294	199
S1 Camer	1997	217	135	127	99	130	165	284	97	210	239	280	286

Table 19  
SALT Message SMS File for the Example

WRAP-SALT Message File

```

** Starting to read input data.
** SC record from the SALT input file was read.
** Starting to read CP records from SIM input file.
** Read 11 CP records from SIM input file.
** Beginning-of-simulation storage is to be determined.
** Beginning storage was read from BRS file.
** Beginning reservoir concentration was read from BRC file.
** Starting to read SIN input file.
** Read 4 CP records from SIN input file.
** Finished reading SALT input SIN file.
** Beginning the simulation for salt constituent 1
** Finished reading S1 records.

```

Total Volume and Load Summary for Constituent 1

	Volume	Load	Concentration
Naturalized flows	310818880.	150458080.	356.0
Regulated flows at boundary	0.	0.	0.0
Return flows	23167034.	17412054.	552.8
CI record constant inflows	0.	0.	0.0
Channel loss credits	6617931.	5887620.	654.3
Channel losses	2631377.	2847115.	795.8
Regulated flows at outlet	207204368.	77699128.	275.8
Diversions	114044272.	81147976.	523.3
Other flows and loads	10817659.	12229774.	831.5
Net evaporation	6154304.	0.	0.0
	-----	-----	-----
Inflows - Outflows	-248135.	-166240.	492.7
	-----	-----	-----
Beginning reservoir storage	1949640.	1542291.	581.8
Ending reservoir storage	1701194.	1305046.	564.2
	-----	-----	-----
Change in storage	-248446.	-237245.	702.3
	-----	-----	-----
Volume and load differences	311.	71006.	167718.1
Negative inflows to cpts	71220.	49073.	506.8
Negative incremental nat flows	4060064.		
Naturalized flows at outlet	310818816.		
Number of control points in SIM DAT and OUT files:		11	
Number of control points included in SALT simulation:		11	

\*\*\*\*\* Normal Completion of Program WRAP-SALT \*\*\*\*\*



**Table 20**  
**First Portion of SAL T Output SAL File for the Example**

First year and number of years, control points and constituents: 1940 58 11 1 735.480

Year	Mon	CP	Flow In	Load In	Conc In	Storage	Sto Load	Sto Conc	Flow Out	Load Out	Conc Out	Flow Conc	Div Conc	Div Target	Shortage
Salinity constituent (IC) = 1															
1940	1	EK	10094.00	928.00	67.62	497885.97	754632.56	1114.75	80013.74	122139.66	1122.70	1122.70	1122.70	13893.51	0.00
1940	1	Whit	64354.62	96500.68	1102.86	625703.62	511924.25	601.74	63955.65	49887.90	573.70	573.70	573.70	1170.00	0.00
1940	1	WaccL	1166.00	586.58	370.00	187144.78	47337.32	186.04	5252.00	1321.28	185.03	185.03	185.03	5252.00	0.00
1940	1	WaccG	62925.27	48918.27	571.76	0.00	0.00	0.00	62925.27	48918.27	571.76	571.76	571.76	161.50	0.00
1940	1	High	63514.24	49035.14	567.82	0.00	0.00	0.00	63514.24	49035.14	567.82	567.82	567.82	224.00	0.00
1940	1	Belton	996.00	1069.83	790.00	440913.44	115319.30	192.36	16545.63	4306.69	191.44	191.44	191.44	10654.95	0.00
1940	1	George	156.00	167.56	790.00	35455.56	10480.70	217.41	1666.32	488.78	215.74	215.74	215.74	1666.32	0.00
1940	1	Grang	1147.08	606.63	388.96	63493.31	23315.80	270.08	2732.74	996.15	268.10	268.10	268.10	2732.73	0.00
1940	1	Carrer	9582.23	4731.26	363.15	0.00	0.00	0.00	9582.23	4731.26	363.15	363.15	363.15	7298.33	460.50
1940	1	Bryan	67096.48	50568.19	554.30	0.00	0.00	0.00	67096.48	50568.19	554.30	554.30	554.30	4087.15	1652.65
1940	1	Hemp	74543.13	53428.72	527.15	0.00	0.00	0.00	74543.13	53428.72	527.15	527.15	527.15	64723.86	372.50
1940	2	EK	10172.00	13016.00	941.11	491928.12	744406.31	1112.96	15346.84	23242.26	1113.86	1113.86	1113.86	15346.86	0.00
1940	2	Whit	-2652.56	-386.31	107.11	599401.69	491951.94	603.64	23902.28	19586.01	602.67	602.67	602.67	1134.00	0.00
1940	2	WaccL	1315.00	411.23	230.00	183313.30	46459.70	186.40	5090.40	1288.85	186.22	186.22	186.22	5090.40	0.00
1940	2	WaccG	3217.75	2015.60	460.71	0.00	0.00	0.00	3217.75	2015.60	460.71	460.71	460.71	258.40	0.00
1940	2	High	6431.24	2133.91	244.03	0.00	0.00	0.00	6431.24	2133.91	244.03	244.03	244.03	358.40	0.00
1940	2	Belton	1663.00	746.17	330.00	432022.03	113166.49	192.66	11075.60	2898.97	192.51	192.51	192.51	11075.60	0.00
1940	2	George	1320.00	592.27	330.00	35274.55	10591.80	220.84	1615.04	481.17	219.12	219.12	219.12	1615.05	0.00
1940	2	Grang	3714.78	1548.31	306.55	65083.16	23891.65	269.99	2648.64	972.46	270.03	270.03	270.03	2648.65	0.00
1940	2	Carrer	20323.59	8349.44	302.15	0.00	0.00	0.00	20323.59	8349.44	302.15	302.15	302.15	7778.15	0.00
1940	2	Bryan	26085.40	9739.11	274.59	0.00	0.00	0.00	26085.40	9739.11	274.59	274.59	274.59	4880.80	0.00
1940	2	Hemp	131563.98	42548.00	237.86	0.00	0.00	0.00	131563.98	42548.00	237.86	237.86	237.86	65110.76	0.00
1940	3	EK	836.00	21.00	18.47	468528.19	717261.19	1125.93	17850.78	27166.15	1119.29	1119.29	1119.29	17850.77	0.00
1940	3	Whit	3858.09	2115.35	403.26	568301.12	471196.88	609.81	27727.64	22870.41	606.64	606.64	606.64	1224.00	0.00
1940	3	WaccL	1182.00	601.06	374.00	176339.44	45653.55	190.41	5494.40	1407.21	188.37	188.37	188.37	5494.40	0.00
1940	3	WaccG	28463.46	20647.92	533.53	0.00	0.00	0.00	28463.46	20647.92	533.53	533.53	533.53	581.40	0.00
1940	3	High	29979.34	21245.87	521.22	0.00	0.00	0.00	29979.34	21245.87	521.22	521.22	521.22	806.40	0.00
1940	3	Belton	989.00	623.94	464.00	417872.03	110509.52	194.50	12466.36	3280.91	193.56	193.56	193.56	12466.36	0.00
1940	3	George	464.00	292.73	464.00	33791.09	10370.99	225.73	1691.96	513.54	223.23	223.23	223.23	1691.95	0.00
1940	3	Grang	1844.85	896.80	357.53	20800.35	7945.29	280.94	45436.23	16843.17	272.64	272.64	272.64	2774.77	0.00
1940	3	Carrer	49476.12	18952.89	281.74	0.00	0.00	0.00	49476.12	18952.89	281.74	281.74	281.74	9258.41	0.00
1940	3	Bryan	75618.37	39340.28	382.63	0.00	0.00	0.00	75618.37	39340.28	382.63	382.63	382.63	5692.08	0.00
1940	3	Hemp	80202.26	41620.01	381.67	0.00	0.00	0.00	80202.26	41620.00	381.67	381.67	381.67	70010.45	0.00
1940	4	EK	16772.00	31940.00	1400.62	461625.97	716701.38	1141.88	21081.34	32499.83	1133.85	1133.85	1133.85	21081.35	0.00
1940	4	Whit	25712.33	13574.92	388.30	567596.00	461811.16	598.41	27953.60	22960.64	604.11	604.11	604.11	1296.00	0.00
1940	4	WaccL	36755.00	13892.82	278.00	192100.00	53746.61	205.78	21497.56	5799.76	198.42	198.42	198.42	5817.60	0.00
1940	4	WaccG	68112.96	30115.60	325.19	0.00	0.00	0.00	68112.96	30115.60	325.19	325.19	325.19	1033.60	0.00
1940	4	High	91500.14	38911.07	312.77	0.00	0.00	0.00	91500.14	38911.07	312.77	312.77	312.77	1433.60	0.00
1940	4	Belton	29935.00	6105.20	150.00	438879.25	112924.51	191.42	14067.44	3690.21	192.93	192.93	192.93	14067.44	0.00
1940	4	George	4019.00	819.67	150.00	36033.70	10657.93	217.54	1768.86	532.72	221.50	221.50	221.50	1768.86	0.00
1940	4	Grang	9793.20	2082.98	156.43	27767.91	9015.24	238.78	2900.89	1013.02	256.84	256.84	256.84	2900.90	0.00
1940	4	Carrer	70101.69	14744.81	154.70	0.00	0.00	0.00	70101.69	14744.81	154.70	154.70	154.70	11152.28	0.00
1940	4	Bryan	154831.39	52475.13	249.27	0.00	0.00	0.00	154831.39	52475.13	249.27	249.27	249.27	6641.35	0.00
1940	4	Hemp	117293.71	38350.30	240.47	0.00	0.00	0.00	117293.71	38350.30	240.47	240.47	240.47	75406.56	0.00
1940	5	EK	114403.00	74062.00	476.13	548220.31	755898.12	1014.10	23909.10	34865.23	1072.51	1072.51	1072.51	23909.15	0.00
1940	5	Whit	24583.54	18796.90	562.36	560585.19	457776.72	600.60	28010.24	22831.33	599.49	599.49	599.49	1530.00	0.00
1940	5	WaccL	0.00	0.00	0.00	182273.41	51810.13	209.06	6868.00	1936.47	207.37	207.37	207.37	6868.00	0.00
1940	5	WaccG	21230.85	18672.71	646.86	0.00	0.00	0.00	21230.85	18672.71	646.86	646.86	646.86	2422.50	0.00
1940	5	High	46696.47	26435.26	416.36	0.00	0.00	0.00	46696.47	26435.26	416.36	416.36	416.36	3360.00	0.00
1940	5	Belton	6951.00	1512.16	160.00	421926.38	110208.19	192.11	16217.96	4228.48	191.76	191.76	191.76	16217.97	0.00
1940	5	George	4673.00	1016.59	160.00	37100.00	10696.37	212.05	3349.94	978.15	214.75	214.75	214.75	2102.12	0.00
1940	5	Grang	12648.23	2921.61	169.89	36617.59	10872.01	218.37	3447.45	1064.84	227.17	227.17	227.17	3447.45	0.00
1940	5	Carrer	102941.33	22716.71	162.30	0.00	0.00	0.00	102941.33	22716.71	162.30	162.30	162.30	16925.62	0.00
1940	5	Bryan	137088.55	46287.34	248.33	0.00	0.00	0.00	137088.55	46287.34	248.33	248.33	248.33	8845.38	0.00
1940	5	Hemp	230992.75	77689.32	247.36	0.00	0.00	0.00	230992.75	77689.32	247.36	247.36	247.36	93410.58	0.00
1940	6	EK	289797.00	81633.00	207.18	570240.00	531312.62	685.27	266073.94	306218.50	846.45	846.45	846.45	26687.95	0.00
1940	6	Whit	307173.62	310035.19	742.33	627100.00	561652.94	658.72	240185.22	206158.95	631.29	631.29	631.29	1674.00	0.00
1940	6	WaccL	61991.00	17363.01	206.00	192100.00	54134.93	207.26	53139.86	15038.21	208.14	208.14	208.14	7514.40	0.00
1940	6	WaccG	350075.47	250728.14	526.76	0.00	0.00	0.00	350075.47	250728.12	526.76	526.76	526.76	6104.70	0.00
1940	6	High	378179.31	256406.39	498.66	0.00	0.00	0.00	378179.31	256406.39	498.66	498.66	498.66	8467.20	0.00
1940	6	Belton	99398.00	15947.36	118.00	457600.00	109801.10	176.48	65379.80	16354.44	183.98	183.98	183.98	17954.70	0.00

**Table 21**  
**TABLES Input TIN File for the Example**

```

** TABLES Input File SaltFundExam.TIN
** Final Main Example in Salinity Manual based on Example from Fundamentals Manual
** May 2009
**      1      2      3      4      5      6      7      8
** 567890123456789012345678901234567890123456789012345678901234
**   !   !   !   !   !   !   !   !   !   !   !   !   !
8SUM
8FRQ  9   0  -1   7   Hemp   100.   200.   400.   600.   800.  1000.  2000.
8FRE  7
8FRE  8
8FRE  9   0  -1
8FRE  6   0  -1
8REL  0   0   0  1000.
8SAL  1   4   0   9   0   2
IDEN  PK   Hemp
**   !   !   !   !   !   !
ENDF

```

**Table 22**  
**TABLES Message TMS File for the Example**

```

TABLES MESSAGE FILE

*** File was opened: SaltFundExam.TIN
*** File was opened: SaltFundExam.TOU
*** Identifiers for the 17 records in the TIN file were checked.
*** File was opened: SaltFundExam.SAL
*** Tables are being developed as specified by a 8SUM record.
*** Tables are being developed as specified by a 8FRE record.
*** Tables are being developed as specified by a 8FRE record.
*** Tables are being developed as specified by a 8FRE record.
*** Tables are being developed as specified by a 8FRE record.
*** Tables are being developed as specified by a 8FRQ record.
*** Tables are being developed as specified by a 8REL record.
*** Tables are being developed as specified by a 8SAL record.
-----DSS---ZOPEN:  New File Opened,  File: SaltFundExam.dss
                    Unit: 25;  DSS Version: 6-KE

Program TABLES output is in file SaltFundExam.TOU

Program TABLES output is in DSS file SaltFundExam.DSS
Date: 05-MAY-09
Time: 12:33:57

***** Normal Completion of Program TABLES *****

```

**Table 23**  
**TABLES Output TOU File for the Example**

**CONTROL POINT SUMMARY**

CONTROL POINT	MEAN MONTHLY VOLUME (AC-FT)			MEAN MONTHLY LOAD (TONS)			MEAN CONCENTRATION (MG/L)		
	Inflow	Outflow	Storage	Inflow	Outflow	Storage	Inflow	Outflow	Storage
PK	66124.	63750.	375511.	109486.	109531.	694359.	1217.7	1263.5	1359.8
Whit	93846.	90536.	533630.	96305.	96446.	626694.	754.7	783.4	863.7
WacoL	29736.	28370.	170134.	7076.	7076.	45321.	175.0	183.4	195.9
WacoG	131399.	131399.	0.	104156.	104151.	0.	582.9	582.9	0.0
High	161580.	161580.	0.	109853.	109852.	0.	500.0	500.0	0.0
Belton	42105.	40994.	273346.	11571.	11566.	81946.	202.1	207.5	220.5
George	4827.	4746.	18584.	1346.	1344.	5638.	205.1	208.3	223.1
Grang	14801.	14556.	36947.	4178.	4191.	11599.	207.6	211.7	230.9
Camer	96559.	96559.	0.	27229.	27229.	0.	207.4	207.4	0.0
Bryan	278380.	278380.	0.	140877.	140879.	0.	372.2	372.2	0.0
Hemp	385983.	385983.	0.	164189.	164199.	0.	312.8	312.8	0.0

**CONCENTRATION FREQUENCY FOR OUTFLOWS FROM CONTROL POINT Hemp**

CONC	FREQ(%)	CONC	FREQ(%)	CONC	FREQ(%)	CONC	FREQ(%)	CONC	FREQ(%)	CONC	FREQ(%)	CONC	FREQ(%)
100.0	98.13	200.0	85.06	400.0	36.78	600.0	20.98	800.0	11.78	1000.0	7.76	2000.0	0.14

**VOLUME FREQUENCY FOR CONTROL POINT OUTFLOWS**

CONTROL POINT	N	STANDARD		PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE										MAXIMUM	
		MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%		10%
EK	696	63750.	120985.	0.0	52.8	1208.6	13893.5	13894.	17851.	21228.	24498.	28897.	71318.	134966.	1806064.
Whit	696	90536.	178212.	-2821.7	-6.7	951.6	14439.1	20764.	28392.	30240.	38109.	52363.	79855.	191222.	2972162.
WacoL	696	28370.	51746.	5090.4	5090.4	5090.4	5252.0	5494.	5818.	7514.	8303.	9534.	22990.	77724.	531638.
WacoG	696	131399.	237720.	-3168.4	2885.0	3719.8	7595.4	14041.	34053.	46156.	63248.	77334.	119422.	306286.	3363994.
High	696	161580.	269477.	-4183.8	3614.1	5148.0	11497.8	20357.	41880.	61390.	77000.	99676.	145070.	394226.	3584505.
Belton	696	40994.	65773.	0.0	0.0	0.0	1614.4	10655.	12466.	15309.	17241.	19790.	35346.	110864.	540670.
George	696	4746.	7867.	0.0	0.0	13.4	72.8	181.	1615.	1769.	2053.	2564.	2846.	12782.	67167.
Grang	696	14556.	23474.	-7.2	17.7	152.7	425.9	2083.	2901.	3742.	4204.	4983.	14593.	45313.	202749.
Camer	696	96559.	151015.	42.0	1153.8	1602.7	6941.4	11153.	19495.	29025.	41359.	59116.	109582.	227017.	1400336.
Bryan	696	278380.	430293.	4451.4	12395.3	20498.8	39287.8	52648.	73203.	107387.	124801.	144201.	282938.	682888.	4530749.
Hemp	696	385983.	537567.	10191.8	19623.2	32691.6	74316.2	78174.	103602.	137507.	154068.	221506.	463683.	982841.	5548849.

**LOAD FREQUENCY FOR CONTROL POINT OUTFLOWS**

CONTROL POINT	N	STANDARD		PERCENTAGE OF MONTHS WITH LOADS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE										MAXIMUM	
		MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%		10%
EK	696	109531.	171471.	0.0	0.0	3402.5	11073.4	20622.	31406.	40758.	49269.	63616.	120332.	275176.	2367888.
Whit	696	96446.	164700.	-6154.8	-12.9	2085.6	13229.8	18334.	28257.	37655.	48308.	60328.	100150.	206206.	1987726.
WacoL	696	7076.	14042.	743.0	818.8	949.4	1142.2	1306.	1646.	2030.	2302.	2722.	5655.	18644.	210339.
WacoG	696	104151.	179266.	0.0	1335.4	2817.3	4747.0	9631.	24083.	35617.	47204.	64105.	119154.	229160.	2069068.
High	696	109852.	182126.	0.0	674.1	1795.6	5203.5	11112.	28384.	41488.	55512.	71104.	122328.	238718.	2102202.
Belton	696	11566.	16564.	0.0	0.0	0.0	689.0	2499.	3647.	4490.	5253.	6472.	11396.	32412.	140206.
George	696	1344.	2092.	0.0	0.0	4.8	38.4	91.	414.	578.	665.	779.	1120.	3443.	16227.
Grang	696	4191.	6118.	0.0	8.7	69.4	281.2	633.	967.	1188.	1518.	2198.	4632.	12454.	39565.
Camer	696	27229.	35223.	0.0	750.5	1264.1	3142.5	4255.	6826.	9952.	14138.	19398.	34943.	66174.	285678.
Bryan	696	140879.	204899.	0.0	5078.7	9516.6	16597.5	27723.	45264.	61600.	77139.	99601.	150172.	309730.	2239331.
Hemp	696	164199.	217340.	0.0	7584.3	14440.1	28153.0	38436.	55534.	77690.	94279.	119490.	181457.	377186.	2396774.

## CONCENTRATION FREQUENCY FOR CONTROL POINT OUTFLOWS

CONTROL POINT	N	STANDARD		PERCENTAGE OF MONTHS WITH CONCENTRATION EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
		MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
PK	689	1712.	5378.	0.0	179.5	308.6	536.3	766.	1029.	1239.	1359.	1502.	1737.	2167.	138417.
Whit	686	871.	338.	230.3	417.5	424.9	453.9	503.	613.	716.	794.	869.	1055.	1395.	1780.
WacoL	696	200.	90.	44.8	94.7	100.1	109.7	125.	163.	178.	189.	201.	221.	263.	942.
WacoG	694	655.	356.	10.6	143.9	186.2	230.5	284.	399.	497.	575.	657.	832.	1218.	2333.
High	694	582.	367.	0.3	97.0	145.6	185.0	232.	323.	406.	474.	563.	731.	1153.	3079.
Belton	674	236.	115.	86.3	112.7	124.1	133.7	150.	189.	214.	231.	243.	270.	302.	2000.
George	686	269.	224.	0.0	83.2	98.6	124.3	145.	193.	224.	244.	259.	290.	350.	4428.
Grang	690	265.	136.	0.0	91.7	103.8	127.2	155.	201.	232.	250.	262.	301.	359.	1910.
Camer	696	280.	230.	0.0	89.3	103.7	125.3	155.	199.	231.	249.	270.	304.	378.	4428.
Bryan	696	491.	331.	0.0	101.7	152.6	176.7	202.	262.	329.	383.	436.	606.	980.	1990.
Hemp	696	434.	316.	0.0	64.0	110.1	151.2	175.	230.	281.	321.	383.	533.	872.	2847.

## CONCENTRATION FREQUENCY FOR RESERVOIR STORAGE

CONTROL POINT	N	STANDARD		PERCENTAGE OF MONTHS WITH CONCENTRATION EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
		MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
PK	648	1411.	547.	50.0	336.2	414.5	598.1	793.	1032.	1240.	1352.	1485.	1716.	2069.	3723.
Whit	696	876.	345.	86.1	412.4	420.5	449.3	498.	613.	715.	794.	884.	1060.	1408.	1781.
WacoL	696	200.	93.	38.1	80.8	96.0	106.4	122.	160.	179.	191.	202.	221.	263.	942.
WacoG		There is no storage at this control point.													
High		There is no storage at this control point.													
Belton	628	224.	54.	84.5	110.4	123.5	131.1	151.	186.	210.	228.	241.	265.	297.	395.
George	517	230.	77.	0.0	83.9	98.4	117.1	142.	187.	218.	233.	249.	276.	307.	1236.
Grang	581	242.	81.	0.0	89.7	97.9	121.5	147.	194.	224.	243.	256.	284.	331.	1001.
Camer		There is no storage at this control point.													
Bryan		There is no storage at this control point.													
Hemp		There is no storage at this control point.													

## RELIABILITIES WITH AND WITHOUT SALINITY CONSTRAINTS

CONTROL POINT	TARGET DIVERSION (AC-FT/YR)	Both Quantity & Quality			----- Quantity Only -----			+++++ Quality Only +++++			Number Months	
		TARGET SHORTAGE (AC-FT/YR)	*RELIABILITY* VOLUME (%)	*RELIABILITY* PERIOD (%)	SHORTAGE (AC-FT/YR)	*RELIABILITY* VOLUME (%)	*RELIABILITY* PERIOD (%)	SHORTAGE (AC-FT/YR)	*RELIABILITY* VOLUME (%)	*RELIABILITY* PERIOD (%)	is Zero	exceeds Limit
PK	254800.0	198312.73	22.17	21.26	10355.69	95.94	94.25	193233.91	24.16	23.85	10	530
Whit	18000.0	5726.66	68.19	68.10	1231.56	93.16	93.39	5184.62	71.20	70.98	0	202
WacoL	80800.1	0.00	100.00	100.00	0.00	100.00	100.00	0.00	100.00	100.00	0	0
WacoG	32300.0	6955.20	78.47	82.33	2679.74	91.70	95.26	6102.47	81.11	84.63	2	107
High	44800.1	9401.16	79.02	84.48	4720.00	89.46	94.83	7527.17	83.20	86.93	2	91
Belton	180260.2	12552.23	93.04	91.09	12552.23	93.04	91.09	638.33	99.65	99.71	22	2
George	25610.0	4712.77	81.60	76.44	4709.84	81.61	76.44	287.30	98.88	98.99	11	7
Grang	42000.1	4053.83	90.35	86.49	4052.37	90.35	86.49	242.10	99.42	99.43	7	4
Camer	209599.8	36042.87	82.80	79.60	34927.34	83.34	79.89	3396.64	98.38	98.71	1	9
Bryan	98899.9	13653.63	86.19	84.05	4858.34	95.09	90.52	10999.29	88.88	90.37	1	67
Hemp	1119703.4	140971.25	87.41	80.89	60401.86	94.61	83.62	95921.19	91.43	92.24	1	54
Total	2106773.5	432382.31	79.48		140488.97	93.33		323533.03	84.64			

OUTFLOW CONCENTRATION (MG/L) AT CONTROL POINT PK

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1940	1123.	1114.	1119.	1134.	1073.	846.	683.	707.	742.	756.	777.	782.	905.
1941	771.	743.	889.	1269.	1373.	1178.	992.	820.	747.	1353.	1846.	1741.	1143.
1942	1737.	1727.	1717.	1327.	883.	755.	731.	785.	886.	944.	986.	1054.	1128.
1943	1118.	1152.	1169.	1229.	1385.	1722.	1959.	2005.	2048.	2070.	2090.	2125.	1673.
1944	2168.	2221.	2135.	1965.	1924.	1864.	1805.	1805.	1772.	1679.	1605.	1633.	1881.
1945	1663.	1655.	1456.	1202.	1091.	1122.	1461.	1722.	1764.	1796.	1795.	1808.	1545.
1946	1789.	1746.	1723.	1717.	1703.	1816.	1948.	1902.	1647.	1526.	1514.	1478.	1709.
1947	1511.	1527.	1526.	1524.	2219.	2824.	2797.	2842.	2864.	2763.	2664.	2577.	2303.
1948	2498.	2517.	2483.	2414.	2341.	2285.	2187.	2068.	2058.	2038.	2274.	2869.	2336.
1949	3017.	3279.	2923.	2272.	1696.	1941.	2128.	2124.	2204.	2106.	1931.	1959.	2298.
1950	2004.	2022.	2030.	1922.	2776.	3212.	2664.	2156.	2043.	2062.	2119.	2169.	2265.
1951	2213.	2262.	2326.	2370.	1990.	1178.	957.	1338.	681.	0.	2974.	0.	1524.
1952	11152.	138417.	6774.	1940.	2794.	988.	1710.	65.	21.	0.	894.	3566.	14027.
1953	0.	26170.	5477.	1296.	541.	577.	520.	816.	1141.	1288.	1358.	1453.	3386.
1954	1501.	1531.	1553.	2141.	1932.	1805.	1797.	1735.	1657.	0.	187.	0.	1320.
1955	2119.	6389.	11060.	246.	2027.	1560.	1368.	1424.	1244.	1820.	2144.	2206.	2801.
1956	2249.	2289.	2349.	2388.	2337.	2257.	2229.	0.	3542.	395.	50.	263.	1696.
1957	0.	548.	578.	416.	301.	589.	984.	1056.	1081.	1046.	1150.	1279.	752.
1958	1294.	1308.	1294.	1245.	1281.	1348.	1163.	991.	975.	951.	973.	1004.	1152.
1959	1017.	1027.	1036.	1088.	1084.	994.	1135.	1371.	1449.	1424.	1428.	1569.	1218.
1960	1673.	1626.	1602.	1587.	1570.	1629.	1870.	2025.	2028.	1867.	1797.	1912.	1765.
1961	1956.	1951.	1993.	2045.	2167.	2338.	2174.	1938.	1818.	1703.	1679.	1662.	1952.
1962	1668.	1683.	1690.	1692.	1710.	1360.	977.	887.	827.	759.	840.	979.	1256.
1963	1063.	1109.	1145.	1097.	1090.	1145.	1159.	1188.	1215.	1239.	1186.	1176.	1151.
1964	1237.	1189.	1148.	1152.	1123.	1126.	1156.	311.	1022.	1240.	379.	287.	948.
1965	373.	440.	470.	850.	926.	977.	1032.	1080.	1118.	1300.	1478.	1504.	962.
1966	1538.	1575.	1625.	1422.	1213.	1200.	1253.	1305.	1287.	1283.	1360.	1416.	1373.
1967	1470.	1508.	1547.	1776.	1979.	1993.	1830.	1683.	1661.	1640.	1684.	1714.	1707.
1968	1187.	967.	966.	959.	991.	1140.	1327.	1426.	1479.	1505.	1528.	1569.	1254.
1969	1601.	1588.	1476.	1321.	1061.	897.	932.	949.	1000.	1107.	1248.	1264.	1204.
1970	1244.	1255.	1294.	1310.	1215.	1174.	1215.	1238.	1255.	1285.	1321.	1339.	1262.
1971	1354.	1360.	1366.	1373.	1837.	2166.	1873.	1116.	897.	1028.	1176.	1307.	1404.
1972	1380.	1429.	1480.	1512.	1465.	1473.	1582.	1913.	2279.	2475.	2042.	1892.	1743.
1973	2028.	2115.	2180.	2124.	2069.	2045.	1971.	1933.	1946.	1900.	1860.	1893.	2005.
1974	1915.	1916.	1932.	1864.	1813.	1868.	1905.	1896.	1271.	883.	745.	727.	1561.
1975	778.	790.	793.	813.	826.	806.	829.	892.	951.	1026.	1096.	1153.	896.
1976	1196.	1232.	1262.	1318.	1359.	1368.	1390.	1415.	1368.	1271.	1230.	1254.	1305.
1977	1299.	1336.	1292.	1266.	1362.	1430.	1448.	1505.	1565.	1590.	1606.	1619.	1443.
1978	1636.	1650.	1648.	1550.	1501.	1608.	1677.	118.	190.	309.	385.	452.	1060.
1979	536.	615.	669.	716.	725.	757.	823.	907.	984.	1004.	1032.	1071.	820.
1980	1099.	1138.	1174.	1191.	1221.	1288.	1364.	1425.	1366.	818.	629.	701.	1118.
1981	776.	872.	986.	996.	1002.	978.	929.	945.	963.	544.	306.	374.	806.
1982	426.	478.	537.	577.	515.	392.	364.	418.	484.	548.	590.	636.	497.
1983	745.	898.	1002.	1089.	1211.	1276.	1316.	1354.	1384.	1642.	2189.	3012.	1427.
1984	3561.	3684.	3991.	3936.	4456.	0.	0.	6235.	8565.	415.	607.	782.	3019.
1985	815.	841.	888.	921.	953.	963.	975.	1013.	1036.	1042.	1111.	1260.	985.
1986	1358.	1419.	1464.	1498.	1545.	1339.	1180.	1231.	1267.	1222.	1208.	1246.	1331.
1987	1310.	1347.	1346.	1317.	1574.	1670.	1447.	1406.	1401.	1414.	1437.	1409.	1423.
1988	1380.	1391.	1404.	1418.	1429.	1408.	1408.	1448.	1503.	1591.	1711.	1826.	1493.
1989	3913.	2961.	2392.	1720.	1550.	1623.	1663.	1594.	1534.	1560.	1608.	1662.	1982.
1990	1820.	1890.	1584.	1058.	715.	737.	911.	969.	944.	886.	910.	937.	1113.
1991	964.	1000.	1025.	1033.	1124.	1247.	1304.	1291.	1263.	1173.	1096.	922.	1120.
1992	776.	767.	769.	889.	1081.	1294.	1371.	1306.	1268.	1274.	1290.	1319.	1117.
1993	1364.	1451.	1520.	1534.	1549.	1571.	1590.	1597.	1587.	1528.	1483.	1476.	1521.
1994	1465.	1457.	1446.	1436.	1303.	1214.	1212.	1207.	1228.	1136.	1045.	1063.	1268.
1995	1095.	1126.	1147.	1152.	1413.	1754.	1819.	1691.	1603.	1621.	1658.	1705.	1482.
1996	1745.	1767.	1774.	1760.	1742.	1728.	1716.	1631.	1225.	1088.	1041.	997.	1518.
1997	993.	913.	823.	834.	964.	1015.	950.	956.	1008.	1032.	1049.	1094.	969.
MEAN	1615.	4351.	1801.	1435.	1485.	1394.	1399.	1400.	1489.	1258.	1334.	1382.	1695.

OUTFLOW CONCENTRATION (MG/L) AT CONTROL POINT Hemp

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1940	527.	238.	382.	240.	247.	431.	315.	686.	572.	175.	233.	174.	352.
1941	141.	228.	178.	259.	588.	536.	238.	1611.	506.	1165.	661.	491.	550.
1942	530.	325.	760.	607.	275.	362.	211.	526.	152.	514.	265.	244.	398.
1943	230.	379.	367.	398.	344.	338.	566.	298.	547.	626.	754.	378.	436.
1944	346.	264.	133.	185.	143.	61.	1078.	348.	329.	391.	147.	67.	291.
1945	260.	293.	166.	230.	245.	242.	355.	203.	237.	266.	326.	210.	253.
1946	145.	216.	195.	202.	127.	158.	138.	578.	816.	421.	313.	496.	317.
1947	217.	249.	219.	334.	654.	452.	1030.	13.	877.	969.	847.	713.	548.
1948	718.	572.	340.	350.	267.	805.	818.	1512.	281.	1067.	1556.	450.	728.
1949	527.	459.	299.	172.	744.	318.	395.	962.	1072.	233.	233.	420.	486.
1950	333.	184.	214.	180.	598.	114.	1415.	774.	815.	695.	1113.	1249.	640.
1951	1281.	1148.	1007.	1030.	1550.	1120.	1367.	1345.	410.	1008.	1032.	1041.	1112.
1952	1082.	773.	823.	367.	291.	303.	305.	912.	640.	420.	265.	273.	538.
1953	255.	302.	398.	392.	145.	290.	910.	819.	734.	225.	262.	164.	408.
1954	407.	797.	930.	1126.	436.	1095.	1343.	1383.	1515.	526.	488.	353.	867.
1955	247.	187.	265.	210.	389.	678.	1051.	1352.	2847.	742.	1005.	1213.	849.
1956	1261.	264.	1083.	1214.	867.	1309.	1185.	788.	1464.	1484.	1131.	1003.	1088.
1957	1459.	1619.	266.	255.	318.	184.	44.	268.	234.	167.	203.	101.	427.
1958	166.	221.	171.	197.	229.	149.	543.	599.	237.	111.	567.	536.	310.
1959	370.	228.	364.	145.	64.	162.	639.	642.	838.	340.	220.	201.	351.
1960	215.	203.	208.	325.	200.	200.	302.	631.	173.	283.	217.	189.	262.
1961	277.	213.	212.	83.	717.	432.	541.	942.	328.	469.	335.	287.	403.
1962	175.	336.	412.	475.	303.	651.	1110.	660.	1014.	606.	398.	261.	533.
1963	319.	276.	545.	314.	751.	918.	780.	313.	931.	924.	794.	330.	600.
1964	535.	506.	346.	480.	384.	358.	824.	0.	285.	383.	193.	329.	385.
1965	171.	161.	270.	240.	163.	228.	293.	404.	411.	321.	238.	197.	258.
1966	257.	227.	276.	278.	274.	350.	253.	428.	683.	518.	711.	353.	384.
1967	718.	439.	790.	251.	259.	546.	901.	1156.	1115.	337.	265.	312.	591.
1968	257.	431.	377.	348.	308.	213.	241.	260.	281.	391.	287.	209.	300.
1969	265.	227.	201.	156.	432.	306.	490.	335.	667.	609.	299.	315.	358.
1970	273.	222.	286.	343.	356.	310.	236.	585.	218.	1314.	387.	472.	417.
1971	464.	496.	428.	362.	313.	767.	248.	759.	1162.	376.	258.	502.	511.
1972	253.	314.	450.	259.	200.	467.	658.	847.	1188.	401.	189.	475.	475.
1973	261.	209.	118.	294.	418.	223.	454.	418.	438.	213.	260.	233.	295.
1974	202.	198.	289.	374.	301.	278.	723.	156.	201.	207.	270.	282.	290.
1975	370.	269.	427.	337.	174.	302.	223.	349.	471.	395.	291.	388.	333.
1976	438.	399.	439.	214.	168.	159.	182.	272.	428.	209.	231.	152.	274.
1977	347.	224.	287.	211.	285.	320.	331.	325.	520.	589.	645.	543.	386.
1978	195.	282.	294.	452.	691.	211.	868.	788.	438.	660.	154.	304.	445.
1979	175.	205.	173.	179.	195.	201.	239.	180.	274.	363.	307.	231.	227.
1980	208.	226.	261.	216.	155.	213.	208.	492.	720.	940.	751.	621.	418.
1981	533.	553.	191.	284.	146.	90.	327.	394.	200.	453.	415.	412.	333.
1982	258.	337.	279.	180.	303.	422.	396.	396.	411.	422.	261.	211.	323.
1983	210.	174.	154.	277.	144.	237.	260.	253.	274.	559.	687.	388.	302.
1984	774.	429.	231.	48.	309.	183.	195.	227.	571.	121.	177.	178.	287.
1985	178.	214.	139.	311.	222.	434.	614.	556.	794.	217.	171.	162.	334.
1986	412.	191.	365.	371.	185.	162.	254.	446.	372.	546.	360.	234.	325.
1987	266.	394.	352.	311.	502.	249.	87.	1243.	520.	622.	201.	242.	416.
1988	290.	396.	327.	420.	558.	275.	761.	306.	968.	980.	321.	841.	537.
1989	264.	332.	306.	374.	431.	355.	135.	333.	419.	605.	615.	746.	410.
1990	445.	421.	157.	566.	364.	291.	1125.	447.	508.	515.	144.	284.	439.
1991	253.	334.	111.	247.	238.	619.	711.	632.	271.	886.	519.	314.	428.
1992	165.	225.	248.	207.	189.	351.	289.	318.	337.	491.	383.	287.	291.
1993	205.	183.	242.	268.	250.	249.	59.	332.	630.	1553.	382.	473.	402.
1994	400.	336.	247.	288.	293.	163.	207.	629.	696.	12.	551.	417.	353.
1995	95.	282.	252.	208.	265.	221.	170.	288.	230.	203.	269.	351.	236.
1996	303.	401.	195.	292.	686.	243.	755.	227.	317.	441.	669.	316.	404.
1997	243.	290.	210.	212.	245.	196.	167.	115.	391.	314.	280.	241.	242.
MEAN	382.	353.	339.	330.	360.	371.	527.	570.	603.	534.	440.	394.	434.

The *TABLES* input TIN file reproduced as Table 21 on page 53 includes an 8SAL record which activates an option to create a HEC-DSS (Hydrologic Engineering Center - Data Storage System) file with the filename SaltFundExam.DSS. Any of the eleven time series variables associated with the 8SAL record can be recorded in a DSS file. HEC-DSSVue (Hydrologic Engineering Center 2005) was used to plot the outflow concentrations at control points PK and Hemp in Figure 5. The PK and Hemp outflow concentrations are tabulated on the preceding two pages and plotted below. Figure 5 was cut and pasted directly from HEC-DSSVue.

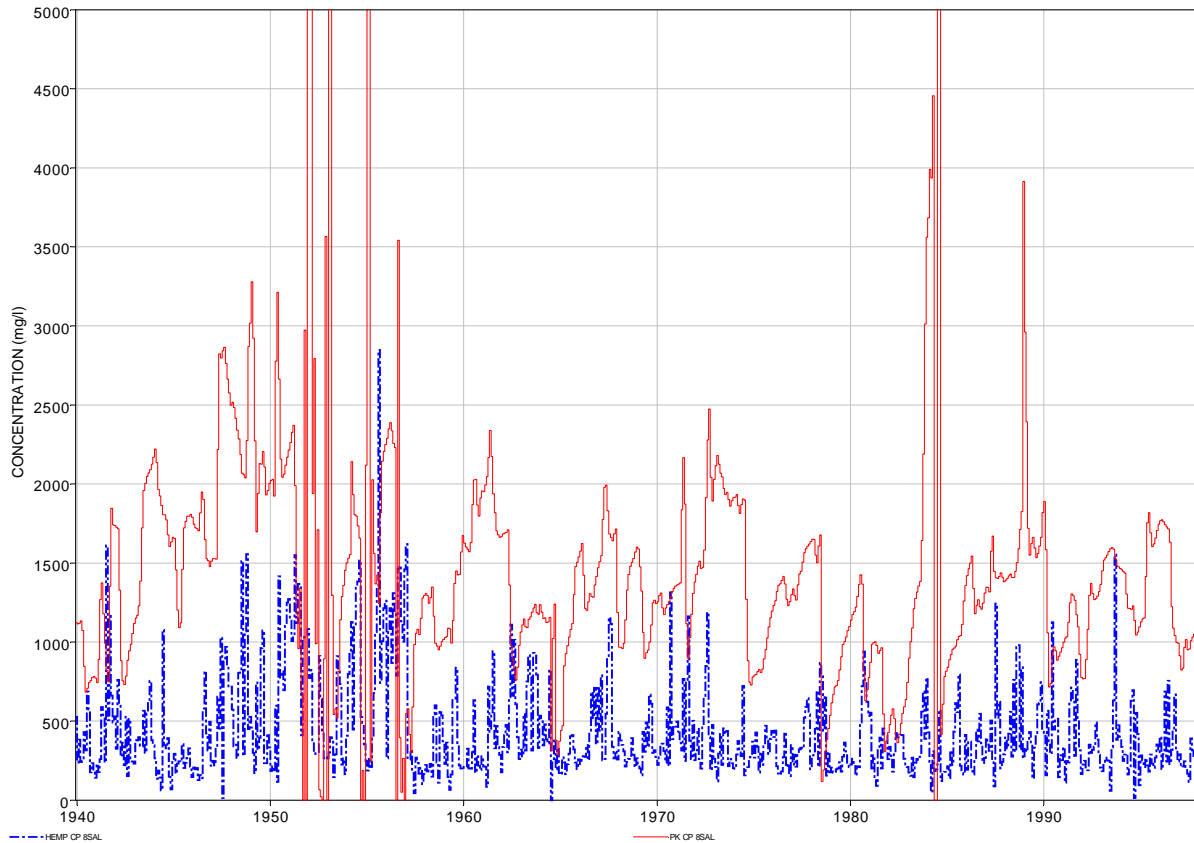


Figure 5 Outflow Concentrations at Control Points PK and Hemp Plotted with HEC-DSSVue from the DSS File Created with the *TABLES* 8SAL Record

The preceding hypothetical *WRAP-SALT* salinity simulation example is based on the *WRAP-SIM* example in the *Fundamentals Manual*. This hypothetical dataset from the *Fundamentals Manual* incorporates certain information from the actual Brazos River Basin but has been significantly altered to create a simple illustrative example. Wurbs and Lee (2009) document an actual detailed *WRAP-SALT* modeling study of the Brazos River Basin.

## References

- Ha, Miae, *Routing Salinity through Reservoirs*, MS Thesis, Texas A&M University, December 2006.
- Hydrologic Engineering Center, *HEC-DSSVue HEC Data Storage System Visual Utility Engine, User's Manual*, Version 1.2, U.S. Army Corps of Engineers, Davis, CA, May 2005.
- Krishnamurthy, Ganesh, *Incorporating Salinity Considerations in Water Availability Modeling*, MS Thesis, Texas A&M University, May 2005.
- Sanchez-Torres, Gerardo, *Reservoir System Reliability Considering Water Rights and Water Quality*, Ph.D. Dissertation, Texas A&M University, December 1994.
- Wurbs, R.A., G. Sanchez-Torres, and D.D. Dunn, *Reservoir/River System Reliability Considering Water Rights and Water Quality*, TR-165, Texas Water Resources Institute, March 1994.
- Wurbs, R.A., and Gerardo Sanchez-Torres, "Simulation of a Surface Water Allocation System," *Water International*, Journal of the International Water Resources Association, 21(2), 1996.
- Wurbs, R.A., "Natural Salt Pollution Control in the Southwest," *Journal of the American Water Works Association*, Vol. 94, No. 12, December 2002.
- Wurbs, R.A., *Water Rights Analysis Package Modeling System Reference Manual*, Technical Report 255, Texas Water Resources Institute, 6th Edition, January 2009.
- Wurbs, R.A., *Water Rights Analysis Package Modeling System Users Manual*, Technical Report 256, Texas Water Resources Institute, 6th Edition, January 2009.
- Wurbs, R.A., *Fundamentals of Water Availability Modeling with WRAP*, Technical Report 283, Texas Water Resources Institute, Fourth Edition, March 2008.
- Wurbs, R.A., and Chihun Lee, *Salinity Budget and WRAP-SALT Simulation Studies of the Brazos River/Reservoir System*, Technical Report 352, Texas Water Resources Institute, July 2009.





**APPENDIX A**  
**INSTRUCTIONS FOR PREPARING SALT INPUT RECORDS**

The *WRAP-SALT* salinity input file has the filename extension SIN. A set of *SC*, *CO*, *CP*, *CC*, *RC*, *C1*, *C2*, and *ED* records begins with a *SC* record and ends with an *ED* record. *S* records (*S1*, *S2*, *S3*, etc.) follow after the *ED* record. Comment records beginning with asterisks \*\* as the first two characters are not read by the program and may be included any place in the data file. The *SC*, *CP*, and *ED* records are required. The others are optional. There is always one *SC* record and one *ED* record and one or more *CP* records. Any number of optional *CO*, *CC*, *RC*, *C1*, *C2*, and *S* (*S1*, *S2*, *S3*, etc.) records may be used.

*SALT* Input Records

Record Identifier	Type of Information	Page Number
SC	Simulation Control	62
CO	Control Points Included in Output File	65
CP	Control Point Salt Data Specifications	66
CC	Water Quality Constituent Concentrations	68
RC	Reservoir Outflow Concentration	70
C1	Flow Concentration Comparison	72
C2	Storage Concentration Comparison	72
ED	End of CO/CP/CC Record Data	74
S	Salt Concentrations or Loads	73

The *SC* record is the first record read. A set of optional *CO* records normally follows immediately behind the *SC* record but actually may be placed anywhere between the *SC* and *ED* records.

A *CP* record is required for each control point for which data are provided in the salinity input file. There must be at least one *CP* record. The *SIM/SIMD* input file may include additional control points that are not included in the salt input file. The input data associated with a salinity input file *CP* record may be repeated for any number of other control points included in the *SIM/SIMD* input file. The optional *CC* and *RC* records must follow immediately behind their associated *CP* record.

The optional *C1* and *C2* records are normally placed after the *CO*, *CP*, *CC*, and *RC* records and just before the *ED* records though they can be inserted at other places between the *SC* and *ED* records as well.

The *S* records are grouped together by constituent after the *ED* record. Each water quality constituent may be assigned a different two-character record identifier such as *S1*, *S2*, *S3*, ... , *S9* or *SA*, *SB*, *SC*. The first character must be *S* but the optional second character is arbitrary.

## ***SALT Input***

### **SC Record – Simulation Control**

field	columns	variable	format	value	Description
1	1-2	CD	A2	SC	Record identifier
2	3-8	YRST	I6	+	First year of simulation
3	9-12	NYRS	I4	+	Number of years in simulation
4	13-16	NC	I4	+ blank,0	Number of water quality constituents Default = 1
<u><i>Control Point Parameters</i></u>					
5	17-20	MCP	I4	+ blank,0	Maximum number of <i>CP</i> records in <i>SALT</i> input file Default = 10
6	21-24	MAXUPCP	I4	+ blank, 0	Maximum number of upstream control points Default = 30
7	25-28	UPDOWN	I4	blank,0,1 2	Upstream-to-downstream reordering is performed. Reordering computations are not performed.
<u><i>Beginning-of-Simulation Storage Volume</i></u>					
8	32	BEGSTO	I4	blank,0,1 2 3	<i>SIM</i> beginning reservoir storage BRS file is read subject to being overridden by <i>CP</i> record field 9. Entered in <i>CP</i> record field 9 or otherwise is zero. Estimated from <i>SIM</i> OUT file variables subject to being overridden by <i>CP</i> record field 9.
<u><i>Beginning Reservoir Concentration (BRC) File</i></u>					
9	36	BEGCON	I4	blank,0,1 2 3 4	BRC file is not created. Ending storage concentration written to BRC file. Beginning storage concentration read from BRC file. BRC file is both written and read.
<u><i>Sequencing of Salt Input Data on S Records</i></u>					
10	40	GROUP	I4	blank,0,1 2	Grouped by control point with sets of annual records. Grouped by year with a set of records for each year.
<u><i>Options for Repeating Salt Data</i></u>					
11	44	REPEAT	I4	blank,0,1 2 3	Data are repeated at control points located upstream. Data are repeated for downstream control points. Data are not repeated.
<u><i>Control Points Included in SALT Output File</i></u>					
12	48	CPOUT	I4	blank,0,1 2 3	Output includes only control points on <i>CO</i> records. Output includes all cpts with <i>CP</i> records in <i>SALT</i> input file plus those cpts listed on <i>CO</i> records. Output includes all control points.

Continued on next page.

## SC Record – Simulation Control (Continued)

---

<i>Information Written to SALT Message File</i>					
13	52	MF	I4	blank,0,1	Warning messages and summary are in message file.
				2	Only summary table is written to the message file.
				3	Detailed results are also written to message file.
				4	Reservoir lagged load-balance results to SMS file.
				5	Control point listing is written to message file.
				6	None of the above are included in message file.
				-1	Only warning messages are written to message file.
<i>Adjustments for Negative Inflow Volume and Load</i>					
14	56	NEGINF	I4	blank,0,1	No adjustments are made to negative inflows.
				2	Adjustments based on beginning-of-period storage.
				3	Negative inflow volumes and loads are set to zero.
<i>Concentration Conversion Factor</i>					
15	57-64	CF	F8.0	blank,0	default = 735.48 for concentration conversion factor
				+	conversion factor: concentration = CF (load/volume)
<i>Zero Flow Criterion</i>					
16	65-72	ZERO	F8.0	blank,0	Default = 0.01 for the flow criterion for setting flow and concentration equal to zero.
<i>Parameter Calibration Comparison</i>					
17	76	PC	I4	Blank,0	Calibration comparison is not activated.
				1	Regulated flow concentrations are compared.
				2	Storage concentrations are compared.
				3	Both flow and storage concentrations are compared.
18	77-84	PCCP	2x,A6	AN	Control point for concentration comparisons.

---

**Explanation of SC Record Fields**

**Fields 2 and 3:** The *SALT* simulation period-of-analysis is defined by a starting year YRST and length NYRS in years. The *SALT* period-of-analysis must be contained within the *SIM* period-of-analysis but may be shorter.

**Field 4:** The simulation may be repeated for up to 15 salt constituents (numbered 1, 2, 3, ... , 15) in a single execution.

**Field 5:** MCP sets the dimension limit for the maximum number of control points to be included in the salt input file. The number of *CP* records in the salt input file can not exceed MCP and also may be less than the number of *CP* records included in the *SIM* input file.

**Field 6:** MAXUPCP is the maximum number of tributaries that flow into any confluence. Each control point may have up to MAXUPCP control points located immediately upstream.

## ***SALT Input***

***Field 7:*** By default, a routine is activated to create an array identifying the upstream-to-downstream order of the control points. The *SALT* simulation computations are sequenced in this upstream-to-downstream order. If the control point *CP* records are already entered in the *SIM* DAT file in the proper upstream-to-downstream order, the reordering algorithm may be deactivated by entering a 2 in field 7. The computations then proceed in the order that the *CP* records are read in the DAT file. An error message is activated if option 2 is specified in field 7 but the *CP* records are not properly sequenced in upstream-to-downstream order.

***Field 8:*** The reservoir storage at each control point at the beginning of the simulation may be read from either a BRS file created by *SIM* or *CP* records. Alternatively, beginning storages may be computed, subject to the computed values being overridden by *CP* record field 8. Option 3 initial storages computed from *SIM* simulation results may be in error because downstream reservoir releases that are not included in the *SIM* output file variables may sometimes be pertinent. Reading a BRS file (option 1) is recommended.

***Field 9:*** Options 2, 3, and 4 result in creation of a beginning reservoir concentration BRC file. Program *SALT* may be executed iteratively until reservoir storage concentrations are the same at the beginning and end of the simulation. End-of-simulation concentrations written to the BRC file are read as beginning concentrations. The concentrations read from the BRC file are replaced for individual reservoirs by CBS from *CC* record field 4 or BC from *CP* record field 10.

***Field 10:*** With option 1 for sequencing the *S* records, all annual records for a particular control point are grouped together. A set of all annual *S* records for a control point follows the complete set for the preceding control point. Option 2 entails placing the *S* records for all control points together as a group for a given year. A set of all *S* records for a given year follows the set of all *S* records for the preceding year.

***Field 11:*** The number of control points in the *SIM* simulation may greatly exceed the number of *SALT CP* records in the salinity input SIN file. Salinity data in the SIN input file for a particular control point may be repeated for any number of other control points located either upstream or downstream. *SALT* repeats all of the salinity data on the *S* and *CC* records and the *CP* record parameters TSC(*CP*), ISALT(*CP*), OTHER(*CP*), and TM(*CP*) for other control points that are not included in the SIN file set of *CP* records in accordance with REPEAT in *SC* record field 11.

***Field 12:*** Options are provided to specify which control points to include in the *SALT* output SAL file and the control point volume/load budgets in the SMS file. The *SIM* output file should include all control points. The *SIM* simulation and *SALT* salinity tracking computations may include many control points that are not included in the *SALT* input SIN file. Any of the control points included in the salinity computations may be included in the *SALT* output file.

***Field 13:*** Options are provided to control whether warning messages, total volume and load summary table, control point volume/load budgets, and reservoir lag results are written to the message file. A listing of control points in upstream-to-downstream order showing spatial connectivity and assignment of salt input data may also be created. These options do not affect the trace and error messages always written to the message file. However, most warning messages are activated only if field 12 is blank, 0, 1, or -1. The volume and load summary table is included with options 1, 2, 3, and 4.

**Field 14:** Negative inflows may result from the computation of the salt loads flowing into a control point. Option 1 carries the negative load forward in the computations without adjustment. Option 2 limits the adjustment of negative inflow loads to not exceed the load in reservoir storage at the beginning of the month. The negative load inflow is changed to zero or as close to zero as the storage load allows, but the load balance is maintained by a corresponding change in end-of-month storage load. Options 1 and 2 are recommended since load balances are maintained. Option 3 is not recommended since it has the effect of creating additional load.

**Field 15:** The conversion factor CF is  $f_c$  in Equation 2 with a default of 735.48.

$$\text{concentration} = \text{CF}(\text{load}/\text{volume})$$

**Field 16:** If a flow or storage volume is smaller than ZERO (default = 0.01) units (such as acre-feet), the flow and concentration are set at zero. Division by zero is not allowed in mathematics. Dividing even a small load by an extremely small volume such as 0.000035 acre-feet may result in an unrealistically high concentration. This may affect computation of loads and concentrations of return flows, *CI* record inflows, channel losses/credits, and regulated stream flows.

**Field 17:** An optional feature designed for reservoir routing parameter calibration studies allows comparisons between computed regulated flow concentrations and the concentrations entered on *CI* records (PC options 1 and 3) and between computed storage concentrations and the concentrations entered on *C2* records (PC options 2 and 3). *CI* and *C2* records are read if and only if PC in *SC* record field 16 is 1, 2, or 3. The feature results in comparison statistics being written to the message SMS file for use in parameter calibration analyses.

**Field 18:** Field 17 is relevant only if PC in *SC* record field 16 is 1, 2, or 3. PCCP entered in field 17 is the identifier of the control point at which regulated flow and/or storage concentrations are compared. The concentration comparison is limited to only one control point, which must be identified in *SC* record field 17.

### **CO** Record – Control Points Included in *SALT* Output File

field	columns	variable	format	value	description
1	1-2	CD	A2	CO	Record identifier
2	3-8	NCPOUT	I6	+	Number of control points listed on this record
3	9-88	CPOID(J) J=1,10	2x,A6	AN	Control point identifiers

A set of one or more optional *CO* records may be inserted anyplace after the *SC* record but before the *ED* record. Any number of control points may be listed on any number of *CO* records with up to ten control points per *CO* record. Data for these control points will be included in the *SALT* output file (filename extension SAL) and in the control point volume/load table in the message file (filename extension SMS). *SC* record field 12 is used along with *CO* records in specifying the selection of which control points to include in the results written to the output files.

## SALT Input

### CP Record – Control Point Salt Data Specifications

field	columns	variable	format	value	description
1	1-2	CD	A2	CP	Record identifier
2	3-8	CPSALT(CP)	A6	AN	Control point identifier
<u>Water Quality Data Options</u>					
3	12	TSC(CP)	I4	blank,0,1 2 3 4 5	Time series are entered on <i>S</i> records. Constant concentrations/loads follow on <i>CC</i> records. Concentrations and loads are zero. Control point is not included in the salt simulation. Salinity data is repeated from the preceding CP.
4	16	ISALT(CP)	I4	blank,0,1 2 3 4	Concentrations of incremental naturalized flows. Data are incremental loads. Data are total loads at an upstream boundary. Concentrations of total regulated flows at boundary.
<u>On/Off Switch for Other Flows (FOTH and LOTH)</u>					
5	20	OTHER (CP)	I4	blank,0,1 2 3 4	Both positive and negative values are adopted. Only positive values are included. Negative zeroed. Only negative values are included. Positive zeroed. Terms omitted. <i>FOTH</i> and <i>LOTH</i> set equal to zero.
<u>Parameters for Concentration of Reservoir Outflows</u>					
6	24	TM(CP)	I4	blank,0,1 2	Adopt mean storage concentration during month. Adopt storage concentration at beginning of month.
7	25-32	LAG1(CP)	I8	blank,0 +	Lag features are not activated. Default is no lag. Lag (blank field 8) or maximum lag in months.
8	33-40	LAG2(CP)	F8.0	blank,0 +	Retention based lag option is not activated Retention multiplier factor used in computing lag.
<u>Beginning-of-Simulation Storage Volume</u>					
9	40-48	VBS(CP)	F8.0	blank,0 +	Beginning storage volume is specified elsewhere. Beginning-of-simulation reservoir storage volume.
10	49-56	BC(CP)	F8.0	blank,0 +	Beginning concentration is specified elsewhere. Beginning-of-simulation storage concentration.
<u>Load Loss Multiplier Factors</u>					
11	57-64	LLI(CP)	F8.0	+	Loss of load as a decimal fraction of inflow load.
12	65-72	LLS(CP)	F8.0	+	Loss of load as a decimal fraction of storage load.
<u>S Record Multiplier Factor</u>					
13	73-80	SX(CP)	F8.0	blank,0 +	Default = 1.0 Factor by which <i>S</i> record amounts are multiplied.

A *CP* record is required for all control points for which salinity data are provided. *SALT* repeats the salinity data on the *S* and *CC* records and *CP* record fields 3, 4, 5, 6 and 13 for other control points that are not included in the *SIN* file set of *CP* records in accordance with *REPEAT* on the *SC* record. *LAG1*, *LAG2*, *BC*, *VBS*, *LLI*, and *LLS* in *CP* record fields 7–12 are not repeated.

### Explanation of CP Record Fields

**Field 2:** An error check routine checks that the control point identifier on the *SALT CP* record matches an identifier on a *SIM CP* record. The control point identifiers on the *S* records are checked against the identifiers on the *SALT CP* records. The *CC* and *RC* record data are assigned to the control point specified on the *CP* record preceding the *CC* and *RC* records.

**Field 3:** Fields 3 and 4 define the meaning and computational role of the salinity input data entered on the *S* and *CC* records. Concentrations or loads of local incremental naturalized flows at a control point may be entered on *S* or *CC* records or set at zero.

**Field 4:** The salt data entered on *S* or *CC* records are defined as being either concentrations or loads for either local incremental naturalized flows or the total stream flow at an upstream boundary. Upstream naturalized flow boundaries occur at the actual most upstream control point on each stream branch. A regulated flow boundary on a stream branch may be set as the most upstream control point that is included in the salt tracking simulation. Control points located upstream of upper boundary control points are omitted from the salinity simulation.

**Field 5:** Field 5 controls use of the other flow volume (FOTH) and load (LOTH) terms in the salinity tracking computations. These terms should always be activated (default option 1 or option 2) for control points at which reservoir releases occur specifically for either hydroelectric power generation or downstream instream flow requirements. This is the only way to properly model in SALT releases made for either hydropower or instream flow requirements. Without reservoir releases for hydropower or instream flow requirements, FOTH and LOTH represent the difference (ideally zero) remaining in the volume and load balance after consideration of all inflows, outflows, and storage changes. A near-zero difference (FOTH  $\approx$  0.0 and LOTH  $\approx$  0.0) is typically desirable. The field 5 options may be used experimentally to investigate or to try to minimize deviations in the volume and load balances.

**Field 6:** Concentrations of outflows leaving a reservoir control point in the current month are set based on the concentration of reservoir storage in the current or a preceding month as defined by fields 6, 7, and 8. The concentration may be the mean storage concentration during the month (field 6 option 1) or the storage concentration at the beginning of the month (field 6 option 2).

**Field 7:** The reservoir outflow concentrations are based on storage concentration for the month set by the lag defined in *CP* record fields 7 and 8. LAG1 is an integer number of months. LAG1 is applied differently in the two alternative lag options. With a blank field 8, the LAG1 in field 7 is a fixed constant lag. With a non-zero LAG2 in field 8, the lag is computed each month based on retention time with LAG1 being a maximum upper limit on the lag.

**Field 8:** A positive LAG2 is required to activate the option of computing lag based on retention time. LAG2 is the multiplier factor in Equation 40 and may be 1.0 or another positive real (decimal) number.

**Field 9:** *SC* record field 8 option 1 specifies that the beginning-of-simulation storage is entered in *CP* record field 9. VBS(CP) in *CP* field 9 also replaces the storage that may have been set by BEGSTO options 2 and 3 activated by *SC* field 8. VBS(CP) applies only to this control point, whereas all other *CP* record entries may be repeated for other control points as specified by REPEAT in *SC* record field 11.

**Field 10:** The beginning-of-simulation storage concentration BBS in *CC* record field 4 is repeated at other control points. The BC in *CP* record field 10 applies only at this control point.

**Fields 11 and 12:** Additional loss of salinity load without a corresponding loss of water volume is computed by multiplying inflow loads by LLI(CP) and beginning-of-month storage load by LLS(CP). Negative values represent load gains. The defaults for LLI(CP) and LLS(CP) are zero, meaning no load losses in addition to those load losses associated with losses of water volume.

**Field 13:** The salinity inflow quantities read from the *S* records are multiplied by this factor.



## SALT Input

### CC Record – Water Quality Constituent Concentrations at Control Point

field	columns	variable	format	value	description
1	1-2	CD	A2	JD	Record identifier
2	3-8		6X		Not read.
3	9-16	CS(CP,IC)	F8.0	+	Constant naturalized flow concentration or load corresponding to TSC(I) = 2 in CP field 3.
4	17-24	CBS(CP,IC)	F8.0	+ blank	Beginning-of-simulation storage concentration. Concentration is zero or provided by BRC file.
5	25-32	CDI(CP,IC)	F8.0	+ -1.0 blank, 0.0	Concentration of diversions. Diversion concentration is determined within SALT. Diversion concentration is set equal to zero.
6	33-40	CRF(CP,IC)	F8.0	+ -1.0 blank, 0.0	Concentration of return flows. Return flow concentration is determined by SALT. Return flow concentration is set equal to zero.
7	41-48	CCI(CP,IC)	F8.0	+ -1.0 blank, 0.0	Concentration of other CI record constant inflows. CI record concentration is determined within SALT. CI record flow concentration is set equal to zero.
8	49-56	MINOC (CP, IC)	F8.0	+	Minimum concentration limit for return flows, CI record inflows, and losses/credits. Default = 0.0
9	57-64	MAXOC (CP,IC)	F8.0	+	Maximum concentration limit for return flows, CI record inflows, losses/credits. Default = 999,000,000
10	65-72	MINSC(,)	F8.0	+	Minimum storage concentration limit. Default = 0.0
11	73-80	MAXROC (CP,IC)	F8.0	+	Maximum limit on reservoir outflow concentration. Default = 999,000,000
12	81-88	ZC(CP,IC)	F8.0	+	Concentration that replaces zero concentration return flows, CI record inflows, and channel losses/credits.
13	89-96	CLF(CP,IC)	F8.0	+	Multiplier factor for loads of channel losses and channel loss credits. Default = 1.0

An optional set of CC records and/or RC records for each salt constituent follow directly behind a CP record. CP record field 2 defines the control point location for the CC and RC record data. The CC record data may be repeated for any number of control points as controlled by parameter REPEAT entered in SC record field 11. The index IC refers to salinity constituent.

#### **Explanation of CC Record Fields**

**Field 3:** Concentrations or loads of incremental naturalized flows or regulated flows may be a constant entered in CC field 3 or a time series provided on S records. CP fields 3 and 4 define the meaning and computational use of the salinity input data entered on the S and CC records.

**Field 4:** Beginning-of-simulation reservoir storage concentrations may be read from a BRC file activated by SC field 8 and/or entered in CC field 4 and/or CP field 10. CBS on the CC record may be repeated at upstream control points while BC on the CP record is applied to only this CP.

**Field 5:** A constant concentration for diversions may be input in *CC* field 5. If a  $-1.0$  is entered in *CC* field 5, the diversion concentration is computed by *SALT* as the average concentration of the total outflow. The default (blank field 5) diversion concentration is zero.

**Field 6:** A constant concentration for return flows returning at this control point may be input in *CC* field 6. If a  $-1.0$  is entered in *CC* field 6, the return flow concentration is computed by *SALT* as the upstream outflow concentration. By default, the return flow concentration is zero. The adopted concentration is adjusted as necessary to not violate the minimum and maximum concentration limits specified in *CC* record fields 8 and 9.

**Field 7:** A concentration for constant inflows from *SIM CI* records is specified in *CC* record field 7 in the same manner as the return flow concentrations in field 6. A  $-1.0$  activates an option by which the concentration of outflows from control points located immediately upstream are adopted for the *CI* record constant inflows. *CC* record fields 8 and 9 limits are applied.

**Fields 8 and 9:** Options in fields 6 and 7 activate application of the limits of fields 8 and 9 to return flows and *SIM CI* record inflows. These limits are also applied to channel losses and loss credits. Return flows and *CI* record inflows are assigned the concentration of the outflows at the one or more (tributaries) control points located immediately upstream. The concentration of each channel loss/credit is the outflow concentration at a single control point. These upstream outflow concentrations are constrained to fall within the limits specified in *CC* fields 8 and 9. If the computed outflow concentration is less than *MINOC(I,IC)* in *CC* field 8 or greater than *MAXOC(I,IC)* in field 9, it is set equal to the limit prior to applying it to assign the concentration to return flows, *CI* record constant inflows, and/or channel losses and loss credits.

**Field 10:** In performing reservoir load balance computations, the storage concentration at the end of a month is not allowed to drop below the minimum limit specified in *CC* record field 10. This has the effect of controlling the maximum concentration of the water released or withdrawn from the reservoir. The field 10 lower limit on storage concentration constrains the maximum load that can be removed from the reservoir that month and thus the outflow concentration.

**Field 11:** A maximum concentration of the outflow from a reservoir may be specified in field 11. If the computed reservoir outflow load results in a concentration exceeding this maximum outflow concentration limit, the outflow load is adjusted accordingly. Thus, to maintain the reservoir load balance, the load remaining in storage increases correspondingly.

**Field 12:** CRF and CCI in fields 6, and 7 include options for computing concentrations within *SALT* for return flows and *CI* record constant inflows, which may result in zero concentrations. The concentration *ZC* entered in field 8 is adopted if these computed concentrations are zero. Concentration *ZC* in field 8 likewise replaces zero concentrations computed for channel losses and channel loss credits. *ZERO* in *SC* field 16 affects whether the concentrations are zero.

**Field 13:** The salt loads of channel losses and channel loss credits are computed by applying the upstream outflow concentration constrained by the limits of *CC* fields 7 and 8 to the volumes of channel losses and loss credits read from the *SIM* simulation results output file. Thus, loads of channel losses are directly connected to volumes of channel losses. The loads thus computed are multiplied by the factor *CLF* entered in *CC* field 12. With a default *CLF* of 1.0, loads are loss to channel losses in direct proportion to volumes. With a *CLF* less than 1.0, channel losses result in a lesser loss of load than volume. With a *CLF* greater than 1.0, channel losses result in a greater proportion of the salinity load being loss than the loss in water volume.

## SALT Input

### RC Record – Reservoir Outflow Concentration

field	columns	variable	format	value	description
1	1-2	CD	A2	JD	Record identifier
2	3-8		6x		Not read.
<u>Reservoir Release Concentration Parameters</u>					
3	9-16	RCF1 (CP,IC)	F8.0	+ blank,0 -1.0	Regulated flow concentration adjustment factor. Default = 1.0 RCF1(I,IC) = 0.0
4	17-24	RCF2 (CP,IC)	F8.0	+ blank,0 -1.0	Regulated flow concentration adjustment factor. Default = 1.0 RCF2(I,IC) = 0.0
<u>Reservoir Diversion Concentration Parameters</u>					
5	25-32	RCD1 (CP,IC)	F8.0	+ blank,0 -1.0	Diversion concentration adjustment factor. Default = 1.0 RCD1(I,IC) = 0.0
6	33-40	RCD2 (CP,IC)	F8.0	+ blank,0 -1.0	Diversion concentration adjustment factor. Default = 1.0 RCD2(I,IC) = 0.0
<u>Storage Capacity for Both Equations</u>					
7	41-48	RCVOL (CP,IC)	F8.0	+	Storage volume capacity in concentration adjustment equations is required if field 4 and/or 6 is used.

Optional *CC* and/or *RC* records follow directly behind a *CP* record. *CP* record field 2 defines the control point location for the *CC* and *RC* record data. Unlike the *CC* record, the parameters on the *RC* record are not repeated for other control points by the feature controlled by REPEAT in *SC* record field 11.

Various options for setting concentrations of reservoir outflows (downstream releases and lakeside diversions) are controlled by *CP* record fields 6, 7, and 8 (lag options), *CC* record field 5 (diversion concentration options), and the *RC* record. An initial reservoir outflow concentration COUT is computed as a beginning-of-month or estimated mean storage concentration for the current month (TM in *CP* record field 6) or a previous month (as defined by lag options in *CP* record fields 7 and 8). Regulated flow concentrations REGC(cp) representing downstream releases from the reservoir are set equal to the storage concentration COUT unless the adjustments activated by the *RS* record are adopted. Concentrations of diversions CDIV representing withdrawals from reservoir storage are also set equal to the storage concentration COUT unless otherwise specified by *CC* record field 5 or adjusted by *RC* record features.

The concentration COUT of total outflows is an initially computed reservoir storage concentration. Depending on *CP* record parameter TM, COUT may be computed as either the beginning-of-month storage concentration or an initially estimated mean storage concentration during the month. The mean reservoir storage concentration is subject to change due to the adjustments to outflow concentrations outlined here.

Initial values of the concentrations of diversions CDIV representing either lakeside or downstream withdrawals from reservoir storage may be set by *CC* record field 5 with the default being to set  $CDIV = COUT$ . Thus, an initial value for CDIV is set at either COUT, CDI from *CC* field 5, or zero. This initial CDIV may be revised by the optional *RS* record diversion concentration adjustment equation described below.

The reservoir outflow concentration *RC* record activates optional features which apply the following equations to compute the regulated flow concentration REGC(cp) and diversion concentration CDIV. The *RC* record applies only to control points with reservoirs. Without an *RC* record, the regulated flow (downstream release) and lakeside diversion concentrations are the COUT and  $CDIV_{INITIAL}$ .

$$REGC(cp) = COUT \times RCF1 \left[ 1.0 + \left( \frac{V}{RCVOL} \right) (RCF2 - 1.0) \right]$$

$$CDIV = CDIV_{INITIAL} \times RCD1 \left[ 1.0 + \left( \frac{VOL}{RCVOL} \right) (RCD2 - 1.0) \right]$$

The parameters RCF1 and RCF2 are entered in *RC* record fields 3 and 4. The parameters RCD1 and RCD2 are entered in *RC* record fields 5 and 6. RCVOL is a storage volume entered in *RC* record field 7 which is typically the storage capacity of the reservoir. VOL is the average storage contents of the reservoir during the current month computed within *WRAP-SALT*. The ratio  $VOL/RCVOL$  represents storage contents as a fraction of capacity or other specified volume. With no *RC* record or the default of 1.0 for the factors RCF1, RCF2, RCD1, and RCD2, the regulated flow and diversion concentrations are as follows.

$$REGC(cp) = COUT$$

$$CDIV = CDIV_{INITIAL}$$

where COUT is a defined representation of reservoir storage concentration in the current or an earlier (lagged) month and  $CDIV_{INITIAL}$  is either CDI from *CC* field 5, zero, or COUT.

## **SALT Input**

### **C1 Record – Regulated Flow Concentrations Used for Comparison**

field	columns	variable	format	value	description
1	1-2	CD	A2	C1	Record identifier
2	3-8	CCP	A6	AN	Optional control point identifier (PCCP in SC field 17)
3	9-16	CFYR(K1)	4x,I4	+	Year
4	17-24	CFX(K1,1)	F8.0	+	Flow concentration during month 1
5	25-32	CFX(K1,2)	F8.0	+	Flow concentration during month 2
6	33-40	CFX(K1,3)	F8.0	+	Flow concentration during month 3
7	41-48	CFX(K1,4)	F8.0	+	Flow concentration during month 4
8	49-56	CFX(K1,5)	F8.0	+	Flow concentration during month 5
9	57-64	CFX(K1,6)	F8.0	+	Flow concentration during month 6
10	65-72	CFX(K1,7)	F8.0	+	Flow concentration during month 7
11	73-80	CFX(K1,8)	F8.0	+	Flow concentration during month 8
12	81-88	CFX(K1,9)	F8.0	+	Flow concentration during month 9
13	89-96	CFX(K1,10)	F8.0	+	Flow concentration during month 10
14	97-104	CFX(K1,11)	F8.0	+	Flow concentration during month 11
15	105-112	CFX(K1,12)	F8.0	+	Flow concentration during month 12

### **C2 Record – Reservoir Storage Concentrations Used for Comparison**

field	columns	variable	format	value	description
1	1-2	CD	A2	C2	Record identifier
2	3-8	CCP	A6	AN	Optional control point identifier (PCCP in SC field 17)
3	9-16	CSYR(K2)	4x,I4	+	Year
4-15	17-112	CSX(K2,M)	F8.0	+	End-of-month storage concentrations for month 1–12

*C1* and *C2* records are read only if the parameter calibration PC switch is activated in *SC* record field 16. *C1* and *C2* records are designed for reservoir routing parameter calibration analyses. SALT creates a table in the message SMS file with summary statistics comparing concentrations provided on *C1* records with the computed regulated flow concentrations and comparing the concentrations provided on *C2* records with the computed reservoir storage concentrations.

The concentrations from the *C1* and *C2* records are compared with regulated flow and storage concentrations at control point PCCP specified in *SC* record field 17. Optional control point identifiers CCP may be specified in *C1* and *C2* record field 2 for user information, but warning messages will be written to the message SMS file if a CCP identifier does not match PCCP.

The years CFYR(K1) and CSYR(K2) entered in *C1* and *C2* record field 3 are required and are used in the comparison computations. *C1* and or *C2* records may be provided for any number of years, as long as the years fall within the period defined by YRST and NYRS on the *JC* record. Only years with *C1* or *C2* records are included in the comparisons. Only months with zero or positive CFX(K1,M) or CFX(K2,M) are used in the comparison. Thus, particular months may be excluded with a negative number (-1) for CFX(K1,M) or CFX(K2,M) on the *C1* or *C2* record.

**S** Record (S1, S2, ... , S9, SA, SB, ...) – Salt Concentrations or Loads

field	columns	variable	format	value	description
1	1-2	CD	A2	S_	Record identifier (second character is optional)
2	3-8	ID	A6	AN	Control point identifier
3	9-16	YR	4x,I4	+	Year
4	17-24	SM(1)	F8.0	+	Mean concentration or load during month 1
5	25-32	SM(2)	F8.0	+	Mean concentration or load during month 2
6	33-40	SM(3)	F8.0	+	Mean concentration or load during month 3
7	41-48	SM(4)	F8.0	+	Mean concentration or load during month 4
8	49-56	SM(5)	F8.0	+	Mean concentration or load during month 5
9	57-64	SM(6)	F8.0	+	Mean concentration or load during month 6
10	65-72	SM(7)	F8.0	+	Mean concentration or load during month 7
11	73-80	SM(8)	F8.0	+	Mean concentration or load during month 8
12	81-88	SM(9)	F8.0	+	Mean concentration or load during month 9
13	89-96	SM10)	F8.0	+	Mean concentration or load during month 10
14	97-104	SM(11)	F8.0	+	Mean concentration or load during month 11
15	105-112	SM(12)	F8.0	+	Mean concentration or load during month 12

S records follow behind the *ED* record.

The switch variable *TSC* in *CP* record field 3 specifies whether or not *S* records are read for a particular control point. The salt data are defined by the variable *ISALT* in *CP* record field 4. *GROUP* in *SC* record field 11 indicates whether the *S* records are sequenced by grouping all control point records together for a particular year or by grouping all annual records together for a particular control point.

Each water quality constituent may be assigned a different two-character record identifier such as *S1*, *S2*, *S3*, ... , *S9* or *SA*, *SB*, *SC*. The first character of the CD must be *S* but the optional second character is arbitrary. Data may be read for up to 15 different water quality constituents. The data are grouped by constituent, with the set of all *S* records (*S2* records) for the second salt constituent following behind the set of all *S* records (*S1* records) for the first salt constituent. The set of all *S3* records follow after the set of all *S2* records.

The salt data entered on *S* or *CC* records may be either concentrations or loads for either local incremental naturalized flows or the total regulated flows at an assigned upstream boundary. A boundary has other control points located upstream that are not included in the salinity tracking computations. The concentrations or loads may be for local incremental naturalized flows at any control point, which in the case of the most upstream control point on any stream branch are also the total naturalized flows. Upstream boundaries may also be defined at the most upstream control point on a stream branch that is included in the salt tracking simulation even though other *SIM* control points are located upstream. In this case, the concentration or load on the *S* records are for the regulated flow leaving the control point.

## *SALT Input*

### **ED** Record – End of Data

field	columns	variable	format	value	Description
1	1-2	CD	A2	ED	Record identifier

The *ED* record signals the end of the set of all records except *S* records. The set of optional *S* records follow behind the *ED* record. All records except *S* records are read at the beginning of model execution, and *S* records are read later in the *SALT* simulation loops.

**APPENDIX B  
INSTRUCTIONS FOR PREPARING SALIN INPUT RECORDS**

A table of known salt loads and flow volumes is read as input by program *SALIN* along with *IN* record monthly streamflow volumes to develop a set of *SALT* salinity input SIN file *S* records for a longer simulation period. For example a table of loads and volumes for October 1963 through September 1986 could be used to synthesize concentrations for the period from January 1940 through December 2007. Salinity records are extended using either regression or linear interpolation of the load-volume table.

A monthly volume versus load table is provided as an input file with filename extension VLT. The VLT input file consists of two columns, with each column being ten characters wide. The first column contains flow volumes, and the second column contains the corresponding loads. The table will typically be a time sequence of volumes and corresponding loads covering a period-of-record of observed data, for example October 1963 through September 1986. However, the volume-load table does not necessarily have to be related to a particular time series. The volume-load table is read with the Fortran format specification 2F10.0, meaning two real numbers in fields 10 characters wide with any number of digits to the right of a decimal point. Right justification is required only if a decimal point is not included in the numbers.

The only other *SALIN* input file has the filename extension SAI and contains the job control *JC* record and a set of *IN* records. The *JC* record is outlined on the following pages. *IN* records are the same as the *IN* records read by programs *SIM* or *HYD* as described in the *Users Manual*.

SIN file *S* records are created for a single control point in an execution of *SALIN*. Program *SALIN* is executed multiple times with different input datasets to develop sets of *S* records for multiple control points. The flow volumes, loads, and concentrations may be totals at a single control point or incrementals between control points. For total flows, the *IN* record flows for a single control point are read. For incremental flows, *IN* record flows at two or more control points are read. Incremental flows are computed as total flows at a specified control point less total flows at one or more adjacent upstream control points.

Program *SALIN* reads two required input files with filename extensions SAI and VLT and automatically creates two output files with filename extensions SAM and SSS.

*SALIN* Input and Output Files

Filename Extension	Input or Output	File Contents
SAI	input	<i>SC</i> record followed by set of <i>IN</i> records
VLT	input	volume versus load table as two columns
SAM	output	trace, warning and error messages, and statistics tables
SSS	output	<i>S</i> records to be inserted in <i>SALT</i> SIN file



## *SALIN Input*

### **JC Record – Job Control**

field	columns	variable	format	value	description
1	1-2	CD	A2,2x	JC	Record identifier
<i>Hydrologic Period-of-Analysis</i>					
2	7-8	YRST	I4	+	First year of the hydrologic period-of-analysis.
3	9-12	NYRS	I4	+	Number of years in the hydrologic period-of-analysis.
<i>Number of Control Points</i>					
4	16	NCP	I4	blank, 0, 1 +	Default = one control point (total flows) Total number of control points (incremental flows)
<i>Concentrations or Loads Synthesized</i>					
5	20	JC(1)	I4	blank, 0, 1 2	Concentrations are computed and recorded in output. Loads are computed and recorded in output file.
<i>Computational Method</i>					
6	24	JC(2)	I4	blank, 0, 1 2 3	Linear interpolation of volume-load table. Linear regression is applied. Nonlinear regression is applied.
7	28	JC(3)	I4	blank, 0, 1 2	All concentrations are computed by JC(2) method. Load-volume table concentrations are adopted.
<i>Period Covered by Volume-Load Input</i>					
8	29-32	JC(4)	I4	+	Number of data pairs in volume-load table. Dates in fields 9-12 are not required.
9	35-36	BEGMON	I4	+	First month in volume-load table.
10	37-40	BEGYR	I4	+	First year in volume-load table.
11	43-44	ENDMON	I4	+	Last month in volume-load table.
12	45-48	ENDYR	I4	+	Last year in volume-load table.
<i>Record Identifier</i>					
13	51-52	CCD	2x,A2	blank, S1 AN	Default = S1 Record identifier for salinity records created.
<i>Extrapolation of Volume-Load Table</i>					
14	53-60	NEG	F8.0	blank, 0 +	Load is 0.0 for a negative stream flow volume. Concentration assigned to a negative flow volume.
15	61-68	HIGH	F8.0	blank, 0 +	Computed from load with greatest flow volume. Concentration for flow volumes exceeding table.
<i>Unit Conversion Factor</i>					
16	69-76	CF	F8.0	blank, 0 +	Default conversion factor = 735.48 Concentration conversion factor.

The SAI file consists of a *JC* record followed by a set of *IN* records. Comment \*\* records may be inserted before or after the *JC* record.

**Explanation of JC record Fields**

**Fields 2 and 3:** The hydrologic period-of-analysis is the period of years covered by the *IN* records provided as input to *SALIN* and the *S* records created by *SALIN*.

**Field 4:** NCP is the total number of control points for which *IN* records are provided in the SAI file. NCP also defines whether flow volumes and loads are incrementals or totals. If NCP is 2 or greater, flow volumes and loads are incrementals. The volumes, loads, and concentrations are for a particular control point. For total flow volumes and loads, *IN* records are provided for only one control point. However, incremental flow volumes and loads require *IN* records at one or more upstream control points in order to compute incrementals.

**Field 5:** *SALIN* produces *S* records recorded in a SSS file designed to be inserted in a *SALT* salinity input SIN file. The default JC(1) option 1 is for the created records to contain concentrations. JC(1) option 2 is for the created records to contain loads.

**Field 6:** The following alternative methods are provided for synthesizing loads as a function of stream flow volumes. Concentrations are computed by combining loads and volumes.

Option 1. The volume-load table (array) is sorted in ascending order of flow volume. Linear interpolation is applied to the resulting array to obtain loads for the given flow volumes from the *IN* records.

Option 2. Conventional least-square linear regression is applied to the volume-load table to determine the regression coefficient  $\alpha$ . The regression equation is then applied to determine loads for given flow volumes from the *IN* records.

$$\text{load} = \alpha (\text{volume})$$

Option 3. Conventional least-square linear regression using a logarithmic variable transformation is applied to determine the regression coefficients  $\alpha$  and  $\beta$ . The regression equation is then applied to determine loads for given flow volumes from the *IN* records.

$$\text{load} = \alpha (\text{volume})^\beta$$

**Field 7:** The time period covered by the volume-load table may be specified in fields 9, 10, 11, and 12. Two options are available for determining concentrations (JC(1)=1) or loads (JC(1)=2) for this time period.

Option 1 consists of applying the linear interpolation or regression method selected by JC(2) in field 6 to the entire period-of-analysis defined by YRST and NYRS (fields 2 and 3) including this period covered by the volume-load table. With this option, the dates in fields 9-12 are unnecessary and may be replaced by JC(4) in field 8.

Option 2 consists of computing concentrations (JC(1)=1) directly from the volumes and loads in the volume-load table or adopting the loads (JC(1)=2) from the volume-load table for the period specified in *JC* record fields 9-12.

**Field 8:** JC(4) is the number of pairs of volumes and loads in the volume-load table. JC(4) is used if and only if fields 9-12 are blank meaning the time period covered is not specified.

## ***SALIN Input***

***Fields 9, 10, 11, 12:*** The beginning and ending dates (month and year) covered by the volume-load table may be entered in fields 9-12. If these dates are not specified (blank fields 9-12), the length of the volume-load table must be specified by JC(4) in field 8. Using fields 9-12 to specify the dates covered by the volume-load table serves the following purposes.

- JC(3) option 2 (field 7) requires this information. (JC(3) option 1 does not.)
- The JC(4) count is not needed (blank field 8) if field 9-12 information is provided.
- SALIN automatically creates tables with the statistical information listed below for comparing synthesized data versus the given volume-load table data. Tables are repeated for the following sets of volumes, loads, and concentrations.
  1. Data for the complete period-of-analysis defined by fields 2 and 3.
  2. Data from the volume-load table.
  3. Data for the portion of the period-of-analysis that is not covered by the volume-load table.

The third table is not constructed if the time period covered by the load-volume table is not specified in fields 9-12.

These tables recorded in the SALIN message SAM file include the following statistics.

- number of months
- mean of volumes
- mean of loads
- mean of concentrations
- standard deviation of volumes
- standard deviation of loads
- standard deviation of concentrations
- autocorrelation coefficient for volumes
- autocorrelation coefficient for loads
- autocorrelation coefficient for concentrations
- linear correlation coefficient for volume-load
- smallest concentration
- greatest concentration

***Field 13:*** A two-character identifier is placed at the beginning of each of the records written to the SSS file. The default is S1.

***Field 14:*** The total or incremental flow volume from the *IN* records may be smaller than the smallest volume in the volume-load table. If the smallest volume in the volume-load table is greater than zero, *SALIN* automatically extrapolates to zero volume and zero load. The smallest volume in the volume-load table may also be a negative number. NEG in field 14 specifies options for dealing with the situation in which the total or incremental flow volume from the *IN* records is both: (1) a negative number and (2) smaller than the smallest volume in the volume-load table. The two NEG options are (1) to assign a load and concentration of zero and (2) to assign the concentration entered for NEG in field 14.

***Field 15:*** The *IN* record volume may be greater than the largest volume in the volume-load table. The options are to adopt the (1) the concentration of the largest volume the table or (2) the concentration entered in field 15.

## APPENDIX C

### INSTRUCTIONS FOR PREPARING TABLES INPUT RECORDS

Instructions for applying program *TABLES* provided in Chapter 4 of the *Users Manual* are supplemented as follows to cover salinity modeling features of the expanded WRAP. The *TABLES* input record types included in Appendix C are listed in the following table. *TABLES* input records are entered in a file with the filename extension TIN. These input records provide specifications for creating tables and data listings that organize the simulation results read by *TABLES* from the program *SALT* output SAL file.

Record Identifier	Type of Information	Data File	Page Number
8SAL	Time Series Tables of <i>SALT</i> Results	SAL	80
8FRE	Frequency Relationships	SAL	81
8FRQ	Frequency Relationships	SAL	82
8SUM	Control Point Summary	SAL	83
8REL	Diversion Reliability Summary	SAL	83
8CON	Maximum Concentration Limits	SAL	83
IDEN	Control point identifiers		84

*8SAL*, *8FRE*, *8FRQ*, *8SUM*, and *8REL* records activate *TABLES* routines that read the SAL file containing the *SALT* simulation results. The *8SAL* record and resulting table have formats that are similar the time series tables described in the *Users Manual*. Explanations provided for the time series records in the *Users Manual* are also valid for the *8SAL* record. Likewise, the *8FRE* and *8FRQ* records are salinity counterparts of the *2FRE* and *2FRQ* records described in the *Users Manual*. The *8REL* record table extends the *2REL* record table to include water supply diversion reliabilities with and without considering salinity constraints. The *IDEN* record described below for use with type 8 (*8SAL*, *8FRE*, *8FRQ*) records also serves the same purpose as when used with type 2 records.

The variables that may be included in *8SAL*, *8FRE*, *8FRQ* tables are defined in Table 13 of this manual and selected by parameter ID in *8SAL* record field 4 and *8FRE* or *8FRQ* record field 2. Tables may be developed for volumes, loads, and concentrations of control point inflows (ID=1,2,3), storage (ID=4,5,6), or aggregated total outflows (ID=7,8,9), or for downstream river flow (regulated flow and other flows) concentrations (ID=10) and diversion concentrations (ID=11). Inflows volumes (ID=1) and loads (ID=2) are the total of all inflows to a control point and the concentrations (ID=3) are means. Outflow volumes (ID=7) and loads (ID=8) are summations of regulated flows, diversions, and other releases for hydropower and instream flow requirements. The total loads (ID=8) may also include load gains or losses not having corresponding water volumes. The concentrations of regulated flows and other flows (ID=10) may be different than diversion concentrations (ID=11).

## TABLES Input

### 8SAL Record – Time Series Tables for SAL T Simulation Results

field	columns	variable	format	value	description
1	1-4	CD	A4	8SAL	Record identifier
<i>Tables or DSS Records to be Created</i>					
2	8	TA	I4	blank, 0 1	Do not develop annual row/monthly column table. Develop table with annual rows and monthly columns.
3	12	PT	I4	blank, 0 1 2 3 4 5	Do not activate either HEC-DSS or text file option. Develop columns of monthly data in text file. Develop columns of annual totals or means in text file. Develop columns of 12 monthly means in text file. Develop HEC-DSS monthly time series records. Develop HEC-DSS annual time series records.
4	16	MORE	I4	0 1	Write columns; next record starts a new table Add more columns to existing table or start first table.
<i>Variable as Defined in Table 13</i>					
5	20	ID	I4	1 2 3 4 5 6 7 8 9 10 11	Inflow volumes. Inflow loads. Inflow concentrations. Storage volumes. Storage loads. Storage concentrations. Outflow volumes. Outflow loads. Outflow concentrations. Downstream stream flow concentrations. Diversion concentrations.
<i>Water Quality Constituent</i>					
6	24	SC	I4	blank, 0, 1 2, 3, ... , 15	Tables are for first or only water quality constituent. Selection of constituent for which to build tables.
<i>Control Points</i>					
7	28	NUM	I4	0 – +	Develop tables for all control points in SAL file. Develop tables for the NUM cpts on previous record. Number of control points to follow on IDEN record(s).

**8FRE** Record –Volume, Load, or Concentration Frequency Relationships

field	columns	variable	format	value	description
1	1-4	CD	A4	8FRE	Record identifier
2	5-8	ID	I4	1 2 3 4 5 6 7 8 9 10 11	Inflow volumes. Inflow loads. Inflow concentrations. Storage volumes. Storage loads. Storage concentrations. Outflow volumes. Outflow loads. Outflow concentrations. Downstream stream flow concentrations. Diversion concentrations.
3	9-12	SC	I4	blank, 0, 1 2, 3, ... , 15	Tables are for first or only water quality constituent. Selection of constituent for which to build table.
4	13-16	CC	I4	blank, 0, 1 -1, 2	All months are counted for concentrations. Months with zero volume are not counted.
5	20	NUM	I4	0 - +	Develop tables for all control points in SAL file. Develop tables for the NUM cpts on previous record. Number of control points to follow on IDEN record(s).

The *8FRE* and *8FRQ* records are salinity versions of the *2FRE* and *2FRQ* records. The following fields in the *8FRE* and *8FRQ* records deal specifically with salinity.

**Field 2:** Frequency tables are developed for volumes, salt loads, and concentrations of control point inflows (ID=1,2,3), storage (ID=4,5,6), or aggregated total outflows (ID=7,8,9), or for downstream stream flow (regulated flow and other flows) concentrations (ID=10) and diversion concentrations (ID=11). These variables are defined in Table 5.13 of Chapter 5.

**Field 3:** Salt constituent  $SC = 1, 2, 3, \dots, 15$ . Each individual *8FRE* or *8FRQ* record is for one specific salinity constituent defined in field 3. Constituent 1 is the first constituent in the SAL file and may be the only constituent. An entry of 2 refers to the second constituent in the SAL file.

**Field 4:** The concentration count CC switch in field 4 is pertinent only for concentrations (ID = 3, 6, 9, 10, or 11). In performing the frequency analysis computations for concentrations, the concentration in a month is set equal to zero if the volume is zero. With the default CC (blank *8FRE* field 4), all months are included in the total number of months (MONTHS = 12×NYRS) used in the concentration frequency, mean, and standard deviation computations. With a -1 or 2 for CC, months with zero or negative volume are not counted in the total number of months.

## TABLES Input

### 8FRQ Record – Frequency for Specified Volume, Load, or Concentration

field	columns	variable	format	value	description
1	1-4	CD	A4	8FRQ	Record identifier
2	8	ID	I4	1 2 3 4 5 6 7 8 9 10 11	Inflow volumes. Inflow loads. Inflow concentrations. Storage volumes. Storage loads. Storage concentrations. Outflow volumes. Outflow loads. Outflow concentrations. Downstream stream flow concentrations. Diversion concentrations.
3	9-12	SC	I4	blank, 0 +	Tables are for first or only water quality constituent. Selection of constituent for which to build table.
4	13-16	CC	I4	blank, 0, 1 -1, 2	All months are counted for concentrations. Months with zero volume are not counted.
5	20	NM	I4	+	Number of quantities entered for which to determine frequencies. NM may range from 1 to 7.
6	21-28	IDCP(1)	2x,A6	AN	Identifier of control point.
7-13	29-84	QF(I) I=1,NM	7F8.0	+	Inflow, storage, or outflow volumes (ID=1,4,7), loads (ID=2,5,8), or concentrations (ID=3,6,9,10,11) for which to compute frequencies.

With either 2FRE, 8FRE, 2FRQ, or 8FRQ records, exceedance frequencies are defined based on the concept counting the relative frequency of amounts being equaled or exceeded.

$$\text{exceedance frequency} = \text{relative frequency} = \frac{n}{N}(100\%)$$

where n is the number of months that a specified amount is equaled or exceeded in the simulation and N is the total number of months considered.

2FRE and 8FRE records build frequency tables using the same procedures to compute the mean, standard deviation and exceedance frequencies for equaling or exceeding specified amounts, regardless of the particular variable represented by the data amounts. Amounts are determined corresponding to set exceedance frequencies.

2FRQ and 8FRQ records determine amounts corresponding to user-specified exceedance frequencies. 2FRQ and 8FRQ records use the same computational methods.

**8SUM** Record – Control Point Summary

field	columns	variable	format	value	description
1	1-4	CD	A4	8SUM	Record identifier
2	8	SC	I4	blank, 0 +	Table is for first or only water quality constituent. Selection of constituent for which to build table.

**8REL** Record – Water Supply Diversion Reliability Summary

field	columns	variable	format	value	description
1	1-4	CD	A4	8REL	Record identifier
2	8	NUMC	I4	blank,0,1 +	Default = one water quality constituent considered. Number of constituents to be considered.
3	12	RFLAG	I4	blank, 0 1,+	N = number of months with non-zero targets N = NYRS×MONTHS for $R_p = (n/N) \times 100\%$
4	15-16	NUM	I4	0 – +	Develop tables for all control points in SAL file. Develop tables for the NUM cpts on previous record. Number of control points to follow on IDEN record(s).
5	17-24	CONC	F8.0	+	Maximum allowable concentration limit (NUMC=1).

**8CON** Record – Maximum Allowable Concentration Limits

field	columns	variable	format	value	description
1	1-4	CD	A4	8CON	Record identifier
2	5-8		4x		Field is not read.
3	9-16	CONC(I) I=1,NUMC	F8.0	+	Maximum allowable concentration limits.

The *8CON* record is used if and only if more than one water quality constituent is being used to constrain reliabilities, as indicated by NUMC in the preceding *8REL* record being 2 or greater. If only one constituent is considered, the maximum allowable concentration is entered in *8REL* record field 5. If two or more constituents are considered, the maximum allowable concentrations for all constituents are provided on the *8CON* record.



## ***TABLES Input***

### **IDEN** Record – Control Point Identifiers

field	columns	variable	format	value	description
1	1-4	CD	A4	IDEN	Record identifier
2-9	5-68	IDCP(I) I=1,NUM	8(2x,A6)	AN	Control point identifiers (up to 80, eight per record).

The IDEN record contains the NUM control point identifiers specified by an *8SAL*, *8FRE*, and/or *8FRQ* record. IDEN records are used only if NUM is a positive integer on one or more *8SAL*, *8FRE*, or *8FRQ* records.

The IDEN record is used in the same manner with either the Type 2 records described in Chapter 4 of the *Users Manual* or the Type 8 records described here in this *Salinity Manual*.