SALINITY ROUTING IN RESERVOIR SYSTEM MODELING

A Thesis

by

MI AE HA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Civil Engineering

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Approved by:

Chair of Committee,	Ralph Wurbs
Committee Members,	Anthony Cahill
	Hongbin Zhan
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ABSTRACT

Salinity Routing in Reservoir System Modeling.

(December 2006)

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Chair of Advisory Committee: Dr. Ralph Wurbs

This research evaluates and improves capabilities incorporated in the Water Rights Analysis Package (WRAP) modeling system for tracking salt loads, particularly for applications dealing with natural salt pollution problems that are prevalent in several major river basins in Texas and neighboring states. WRAP is the river/reservoir system simulation model incorporated in the Water Availability Modeling (WAM) System applied by agencies and consulting firms in Texas in planning and water right regulatory activities. A salinity simulation component of WRAP called WRAP-SALT was developed recently at Texas A&M University. WRAP-SALT was based on the premise of complete mixing within the monthly computational time step. However, salt concentrations actually have time variation throughout a reservoir. This thesis research investigates more realistic salinity routing methods.

Historical gauged data provide a basis for calibration of routing parameters. The timing of the inflow load to determine outflow concentration is calculated by lag parameters with the monthly time steps. Complete mixing occurs during the lag months. Two options are incorporated into WRAP-SALT for setting the lag parameter. With the first option, the model-user sets a constant that is applied during every month of the simulation. This option requires calibration studies to determine the lag. With the alternative option, a variable lag is computed within the model in each month based on the concept of retention time, which is a representation of the time required for a monthly volume of water and its salt load to flow through a reservoir. When the lag is activated, the accuracy between observed and computed mean monthly salinity concentrations through the reservoir is generally improved. The basin-wide simulation was performed for the Brazos River Basin for conditions with and without salt control dams proposed by the Corps of Engineers. The proposed salt control impoundments improve water quality throughout the basin.

DEDICATION

To my parents

ACKNOWLEDGMENTS

I would like to express my sincere thanks and appreciation to my advisor Dr. Ralph Wurbs of the Department of Civil Engineering at Texas A&M University. The door to Dr. Wurbs's office was always open whenever I ran into a trouble spot or had a question about my research or writing. Without his brilliant guidance, this thesis could not be done. I would like to thank Dr. Cahill and Dr. Zhan for agreeing to serve on my committee.

I must also express my appreciation to all my friends and colleagues in Water Resources Engineering for their support and well wishes. I would like to thanks Richard Hoffpauir, Taejin Kim, Hector Olmos and Chihun Lee for the knowledge they passed to me and for being friends when I needed them. There are too many of you to name without omissions, but I am grateful for you all.

I am deeply grateful for the love and support of my parents, Jaeho and Namsu, and my friends. To my younger brother Sangwoong, thank you for making me proud to be your sister.

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CHAPTER I

INTRODUCTION

Scope of Research

The research evaluates and improves capabilities incorporated in the Water Rights Analysis Package (WRAP) modeling system for tracking salt loads, particularly for applications dealing with natural salt pollution problems that are prevalent in several major river basins in Texas and neighboring states. WRAP is the river/reservoir system simulation model incorporated in the Water Availability Modeling (WAM) System applied by agencies and consulting firms in Texas in planning and water right regulatory activities. The Texas WAM System addresses only water quantities, not quality. A salinity simulation component of WRAP called WRAP-SALT was developed recently at Texas A&M University. The initial developmental test version of WRAP-SALT was based on the premise of complete mixing within the monthly computational time step. However, in reality, stream inflows and their salt loads may require long periods of time to move through a reservoir and reach the outlet. Salt concentrations vary spatially, both horizontally and vertically, throughout a reservoir. The thesis research investigates more realistic salinity routing methods.

This thesis follows the style of *Journal of Water Resources Planning and Management*.

The research focuses on developing techniques for routing dissolved solids through large reservoirs within the framework of the WRAP modeling system. Within WRAP, water management in a river/reservoir system is simulated based on a monthly computational time step for a hydrologic period-of-analysis of 50 or more years. The problem addressed by the thesis consists of simulating salinity loads and concentrations of reservoir releases, water supply diversions, and end-of-month storage for each month of a simulation given sequences of monthly salt inflows and the quantities defining the monthly water volume budget. Salt routing methodologies are developed and incorporated into WRAP-SALT. The research tests and evaluates the salinity modeling capabilities of WRAP-SALT in general as well as the new reservoir routing component being developed through a case study application to the Brazos River Basin.

Objectives of Research

The research objectives are as follows.

1. The literature related to modeling methods for tracking salinity in reservoir/river system simulation models is reviewed. The literature review also addresses characteristics of salinity in reservoir/river systems, particularly natural salt pollution in the Southwestern United States.
2. Analyses are performed of gauged stream flow, reservoir storage, and salt concentration data for selected reservoir/river systems compiled by the U.S. Geological Survey to develop an understanding of the timing and load balance characteristics of

the movement of salts through reservoirs.

3. Salinity routing algorithms for inclusion in the WRAP-SALT simulation model component of the Water Rights Analysis Package (WRAP) are developed, tested, and incorporated into WRAP-SALT.
4. The effects of alternative premises and methods for salinity routing on water availability assessments are investigated through a case study application of the WRAP modeling system to the Brazos River Basin. The case study serves as a basis to evaluate capabilities for incorporating salinity considerations into water availability modeling in general as well as a means to explore the effects of the new salinity routing methodologies on simulation results.

Organization of Thesis

This thesis consists of six chapters. Chapter I is an introduction, which explains the scope, objectives and organization of thesis. Chapter II is a literature review of pertinent textbooks, research papers published in journal and conference proceedings, graduate student theses and dissertations, and unpublished agency reports. Chapter III introduces the Brazos River Basin which serves as a case study for the analysis presented in Chapter IV and Chapter VI. Chapter IV describes volume and mass balances for reservoirs on the upper Brazos River based on data collected by the U.S. Geological Survey. Chapter V provides an overview of WRAP-SALT and explains the salinity routing methodology incorporated into the model. Chapter VI presents the WRAP-SALT simulation study of the Brazos River

Basin focusing on evaluation of the salinity routing options. Chapter VII presents the summary and conclusions of this research.

CHAPTER II

LITERATURE REVIEW

This chapter begins with a general introduction overview of water quality considerations. The literature review then focuses on two topics: (1) actual characteristics of salt transport through river/reservoir systems and (2) methods for modeling salt transport in river/reservoir systems.

Water Quality

Drinking water is annually tested a specific number of times for microbes and 80 chemicals in the U.S.A. The parameters to determine acceptable water for multiple purposes include pH, alkalinity, hardness, suspended solids (SS), biochemical oxygen demand (BOD), pathogens, total dissolved solids (TDS), heavy metals, nutrients, priority organic pollutants, and odor. Water quality standards are mainly divided into drinking water standards, effluent standards, and surface water-quality standards (Vesilind and Morgan 2004).

A river is a complicated and diverse ecosystem and water quality analysis must be based on diversity. A water quality analysis for a river/reservoir system addresses physical, chemical, and biological perspectives. The principal characteristics of rivers are tabulated in Table 2.1 (Thomann and Mueller 1987).

Table 2.1 The principal characteristics of river systems

The principal characteristics of river systems	Special significance
Physical characteristics	- Geometry: width, depth. - River Slope, Bed roughness, “tortuosity.” - Velocity. - Flow. - Mixing characteristics (dispersion in the river). - River water temperature. - Suspended solids and sediment transport.
Chemical characteristics	- DO variations including associated effects of oxidizable nitrogen on the DO regime. - Ph, acidity, alkalinity relationships in area subjected to such discharges, for example, drainage from abandoned mines. - Total dissolved solids and chlorides in certain river systems, for example, natural salt springs in the Arkansas-White-Red River basins and TDS buildup in the Colorado River Basin. -Chemicals are potentially toxic.
Biological Characteristics	- Bacteria and viruses. - Fish populations. - Rooted aquatic plants. - Biological slimes; *Sphaerotilus*.

Physical characteristics of water are represented by turbidity, solids, odors, temperature and color. Chemical characteristics of water quality are explained in terms of inorganic matter, organic matter and gases. Biological characteristics of water quality are microorganisms in water and wastewater, enumeration of bacteria, estimation of bacterial densities, the use of Escherichia coli as an indicator organism and bioassays. The rate of eutrophication can be increased due to several reasons, such as human activities, societal development, natural degradation and growing fish populations. Flow has little impact on eutrophication related to water quality in the river/reservoir system. However, wind and temperature might be important causes of water quality changes. In shallow lakes, water is well-mixed. Well-mixed storage has only one circulation, which is mainly affected by wind.

In the deep lakes, one more circulation is the balancing of the stress with a hydrostatic pressure gradient. Flow in and flow out is not a significant factor for mixing in the reservoir, compared to long residence times. As mentioned previously, temperature variation and density variation are more important factors for controlling mixing in reservoirs. Modeling of a reservoir is complicated, but can be explained by one-dimensional models, vertical modeling, multidimensional models, and ecological modeling. The difficulty of reservoir modeling lies in lengthy response time, the difficulty of control and measurement, and unexpected weather (Tchobanoglous and Schroeder 1985).

Lakes and reservoirs rarely receive discharges of organic matter large enough to cause serious oxygen depletion. They have greater retention time and response time. Pollution and recovery are easily shown through a river and reservoir system. Principle water quality gradients are more vertical in direction than longitudinal. Models of water quality phenomenon may include thermal satisfaction and eutrophication. Moreover, biochemical oxygen demand (BOD) and dissolved oxygen (DO) are of secondary importance. Some factors used to determine water quality in lakes and reservoirs are influent quality, mixing pattern, physical and chemical processes during storage, biological growths and their role in the removal and release of substances. Moreover, temperature, thermal structure, and hydrodynamics affect both the planning and operation of the lake and reservoirs. The temperature pattern is used to predict the flow of the altitude, latitude, and temperature distribution model using eddy diffusivity model or energy budget model. Hydrodynamics of lakes and reservoirs can be separated into 10 parts: mixing in lakes and reservoirs, wind at the top 2-3m of the water column, limits, mixing causes, lentic body/inflow/outflow for mixing, retention period, mass transport two-dimensional/two-direction vector, and transport based on depth, the specific gravity, and displacement. Mass balance load is used only for planning and retention times are for horizontal mixing. The components of the system have three layers: epilimnion (mixed), hypolimnion (mixed) and mud (not mixed) from top to bottom. Top layers focus on inflow/outflow and sedimentation eutrophication is important for both planning and operations. Algal growth plays a secondary role of dependence on light and nutrients with temperature. A significant proportion of the organic material in algal cells is the rate of respiration. Some algal cells have a tendency to either be buoyant or sink. A problem associated with the elimination of algae is sedimentation. Predation in reservoirs and rivers controls the population levels of algae in eutrophication. Nutrient recycles result in the decomposition of algal cells in the bottom mud. A water body has several layers based on oxygen balance of other processes such as photosynthesis, respiration, re-aeration and inflow and outflow. Lake models of long-term planning have oligotrophic, eutrophic and dystrophic aspects by time. The model also has vertical and horizontal layers. In contrast, short-term planning represents the kenetics of the specific dominant area, affected by solar radiation, temperature, and nutrient inflow (James 1993).

If the substance is conservative in water quality downstream of point source, there is no change in concentration between tributaries or waste inputs. The concentration is changed from new source of the substance (Thomann and Mueller 1987). Moreover, many substances consist of decay or nonconservative substances. Assumptions are used to explain decay or nonconservative substances. Substance decays with time, due to chemical reactions, bacterial degradation, radioactive decay, or perhaps settling of particulates out of the water column. Decay or nonconservative substances include oxidizable organic matter, nutrients, volatile chemicals, and bacteria. The substance decays are based on a first-order reaction and the rate of loss of the substance is proportional to the concentration at any time (Thomann and Mueller 1987). Then, the mass balance equation, at steady state, is a first-order linear differential equation (O'Connor 1967). Source or sinks of a substance in streams are distributed along the length of the stream. The time variable of water quality in a river downstream of an outfall or tributary input describes the downstream transport of a peak in a wastewater discharge load, an accidental spill of a chemical, or the day-to-day variation in water quality to day-to-day changes in waste load inputs. The basic assumption is that the body of water is completely mixed horizontally and vertically. Wind stress on the water surface results in internal mixing. Also, the seasonal mixing process completely mixes the lake over the years if the scale is adequately long. The discharge W [*M/T*] into the lake from a point source explains the relationship between lake inputs like residual discharges or tributary inputs, flow through the lake and resulting concentration with many estimates (Thomann and Mueller 1987). The total mass input, W, is represented as:

$$W = Q_e\, s_e + Q_r\, s_r + Q_T\, s_T + PA_s s_p + S_D V$$

Where, $W = Q_e\, s_e$, for Q_e = effluent flow and s_e = effluent concentration from the source, $Q_r\, s_r$ = inputs from a main river discharging into the lake, $Q_T\, s_T$ = inputs from tributary discharging into the lake, $S_D V$ = internal sources such as releases of substances from the sediements, and s_p = the concentration in the precipitation.

The lake concentration is given by s [M/L^3], the volume by V [L^3], and outflow by Q. It may have to include other sources or sinks of water. This process is shown in Figure 2.1. The outflow is represented as follows:

$$Q = Q_e + Q_r + Q_T + PA_s - E_vA_s$$

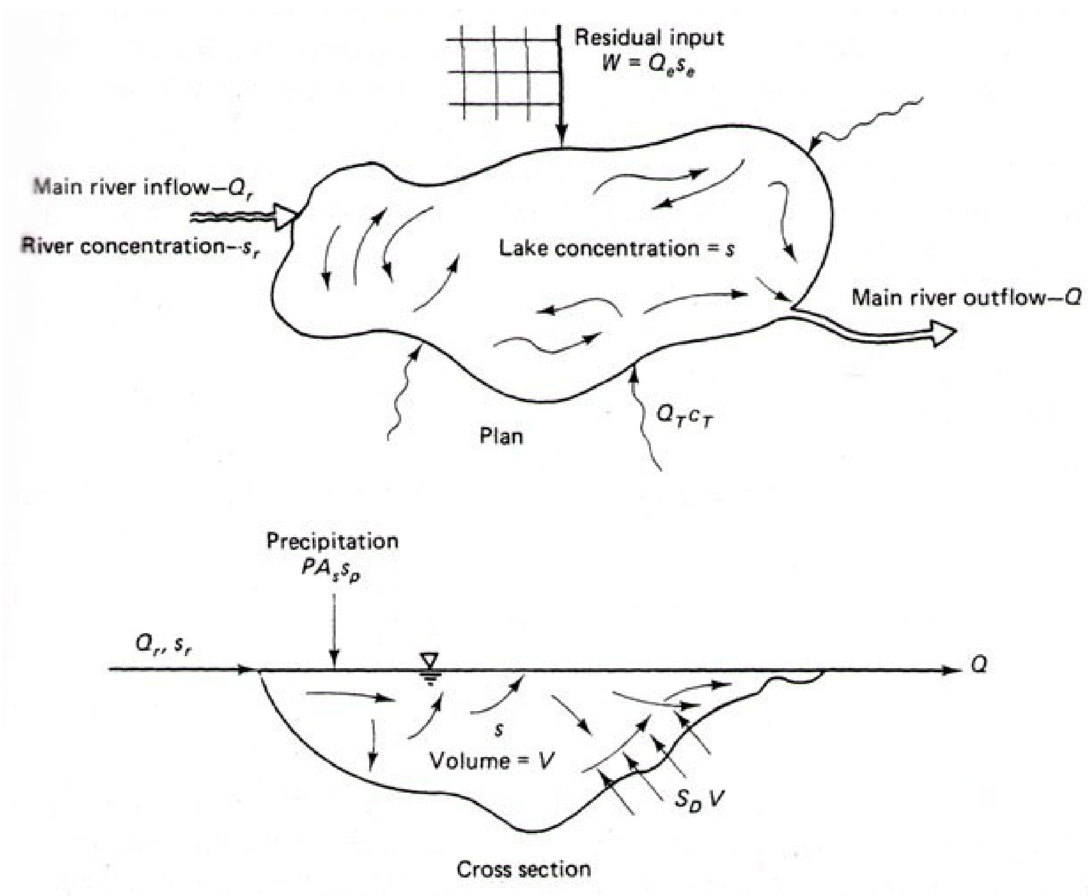

Figure 2.1 Notation for completely mixed lake (Thomann and Mueller 1987)

The primary organizing principle of water-quality modeling is based on the mass balance. In addition to a completely mixed system, a lake may have stratified due to temperature differences during the summer months into two layers. In other words, the lake is isothermal and completely mixed vertically and horizontally during the winter. The two layers are divided into epilimnion and hypolimnion. The epilimnion layer is receiving an incoming flow and load, which mixes and exchanges with the hypolimnion. The hypolimnion layer also receives a source of the substance as from sediment releases of nutrients. The two equations are combined under a steady state condition (Thomann and Mueller 1987).

Characteristics of Salt Transport

Lake systems are steady-state or in dynamic equilibrium. Flows in lakes can be put into two general categories: advection and diffusion. Advection is the unidirectional flow that does not change the identity of the substance being transported. (i.e., flow through a lake's outlet). Another example is transport by an imposed current system. The rate of flow and concentration can be represented as follows (Chapra and Reckhow 1983):

$$[\text{Transport}]_{\text{advection out}} = -Qc$$

Where Q = the rate at which water flows through the volume $[L^3T^{-1}]$, c = the concentration of the substance in the volume $[ML^{-3}]$, and the negative sign denotes a loss of mass from the system.

$$[\text{Transport}]_{\text{advection in}} = Q_a\, c_a$$

Where Q_a = the rate of flow from the adjacent volume [L^3T^{-1}], and c_a = the concentration of the adjacent volume [ML^{-3}].

Diffusion is the movement of mass due to random water motion or mixing. For example, sloshing motion is diffusive transport which is caused by seiches and eddys in lakes. After a long enough time period, the substance being mixed has a uniform concentration throughout the lake. The trend to minimize gradients (i.e., differences in concentration) by moving mass from regions of high to low concentration is also indicated by a simple mathematical representation of the process (Chapra and Reckhow 1983):

$$[\text{transport}]_{\text{diffusion}} = E' \,(c_a - c)$$

Where E' = a bulk diffusion coefficient [L^3T^{-1}], the magnitude of the mixing process between two volumes. The rate might decrease as the concentration in the volumes becomes more over a period of time. As time progresses diffusion would decrease because difference of C_a and C would decrease. The concentrations would be so close that random movements would actually be equivalent and the net transport of matter would be zero. In many cases, within-lake transport is considered a combination of the two modes; dynamics in-lake subsystems and completely mixed lakes, which include river-run lakes, embayments and near shore zones.

Applications of advection-diffusion equations simulate the long-term horizontal distribution of substances, which are divided into exact (or analytical) solutions and approximate numerical methods. Simulations of substance dynamics in lake subsystems and incompletely mixed lakes take into account river-run lakes, embayments and the nearshore zone. The simplest example of the general long-term approach to modeling horizontal subareas of lakes is a well-mixed bay connected to a large lake. The mass balance for the bay is shown below. The basic assumption is that the main lake is not unaffected by the bay (Chapra 1997).

$$V_b \frac{dc_b}{dt} = W_b(t) - Q_{bm}c_b - k_b V_b c_b + E'(\bar{c}_m - c_b)$$

(accumulation) = (loading) – (advection) – (reaction) ± (diffusion)

Where b = indicates that the quantity refers to the bay, Q_{bm} = the magnitude of the advective flow from the bay to the main lake $[L^3T^{-1}]$, $\bar{c}_m$ = the constant concentration of the main lake$[ML^{-3}]$, E' = a bulk diffusion coefficient $[L^3T^{-1}] = E A_c/l$, E = the turbulent diffusion coefficient at the interface between the bay and lake $[L^2T^{-1}]$, A_c = the cross-sectional area of the interface $[L^2]$, and l = the mixing length of the interface [L].

Diffusive transport could be positive or negative depending on the direction of the gradient. The plug flow model in exact solutions idealizes the characteristics of a river system, which is based on mass balance around an element of thickness over a time interval. The equation is as follows:

$$V_x \Delta c = Qc\Delta t - Q(c + \frac{\partial c}{\partial x}\Delta x)\Delta t - kV_x c\Delta t$$

Where V_x = the volume of the element = Δx Ac [L^3], c = concentration [ML^{-3}], k = a first-order decay rate[T^{-1}], and A_c = the cross-sectional area [L^2] . Both advection and diffusion in lakes play a role in the idealization of complex mixing and plug flow. The alternative model, the river-run lake model, is typically used for long and narrow lakes, with a major tributary at one end and an outlet at the other.

An important consideration for transport in incompletely mixed systems is the diffusion process, which allows a continuous stirred tank reactor (CSTR) to be applied to systems composed of segments linked by open boundaries. Analytical solutions for streams (plug-flow reactor) and estuary (mixed-flow reactor) water-quality models are based on closed-form solutions for idealized elongated reactors. These systems are analyzed by mass balances and steady-state solutions or time-variable solutions. Furthermore, there are steady-state solutions (control-volume approach), simple time-variable solutions, and advanced time-variable solutions for computer-oriented methods for an incompletely mixed system (Chapra 1997). Although analytical solutions explain the dynamics of incompletely mixed systems, their simplicity has some limitations. Numerical solutions also suggest some specific techniques such as finite difference approximation of partial differential equations and Thomann's control volume approach.

Methods for Modeling Water Quality and Salt Transport in River/Reservoir Systems

Water quality models are applicable to river/reservoir systems. These models simulate specific pollutants and their state for specific water quality variables in water bodies. The water quality models control the transport and transformation of these variables in physical, chemical, and biological perspectives. Water quality models determine point and nonpoint source loadings, hydrodynamics, and environmental functions like temperature, solar radiation, wind speed, pH, and light attenuation coefficients (USEPA, 2005).

QUAL2K stream water quality model

QUAL2E is a water quality model and steady-state model for simulating well-mixed rivers and streams. It simulates up to 15 water quality constituents: dissolved oxygen, biochemical oxygen demand, temperature, algae as chlorophyll a, organic nitrogen as N, ammonia as N, nitrite as N, nitrate as N, organic phosphorus as P, dissolved phosphorus as P, coliforms, arbitrary nonconservative constituent and three conservative constituents. The model analyzes the effect of nutrients on algal concentration and dissolved oxygen.

QUAL2K is the upgraded version of QUAL2E (Brown and Barnwell 1987), which has been modernized, changed to the environment, and has additional functions. QUAL2E is a disk operation system (DOS) version program. However, QUAL2K supports all Microsoft Windows operating systems. In addition to QUAL2E functions, QUAL2K is programmed in Visual Basic for Applications (VBA) of the Windows macro language; Excel is used for graphical user interface. Both QUAL2K and QUAL2E are based on one dimensional, steady state hydraulics, and non-uniform, steady flow. The channel is completely mixed in the river and stream network system. Both water-quality models are based on kinetics. The model is simulated as a function of meteorology such as heat budget and temperature. The input data contains non-point sources' load, as well as point sources of heat and mass. The time series are diurnal (USEPA 2005).

At the model segmentation, QUAL2E was equally spaced in elements of the river reaches and in the river and stream system. However, QUAL2K makes possible unequally spaced reaches of each element. Input sources to reaches might be multiple loadings and abstractions for each control point. QUAL2K uses carbonaceous BOD speciation (Organic carbon). QUAL2K simulates anoxia, sediment-water interactions, and bottom algae. Light extinction is related to algae, detritus and inorganic solids. The pH is simulated to alkalinity and total inorganic carbon. Pathogens are simulated and related to temperature, light and settling. This model is widely applied in the United States and elsewhere.

QUAL2E-UNCAS is an enhanced version of QUAL2E that allows analyses of uncertainty in the steady state water quality modeling. Three options can be adopted for uncertainty analysis: sensitivity analysis, first order error analysis, and Monte Carlo simulations. Uncertainty analysis makes it possible to forecast the assessment of risk or probability of water quality variables (USEPA 2005). CE-QUAL-RIV1 is intended for simulating the dynamics of highly unsteady stream flows like during flood events.

WASP

The Water Quality Analysis Simulation Program (WASP) is the flexible model used for interpreting and predicting water quality for analyzing a wide variety of pollution in almost any type of water body (The World Bank 1998). Water quality assessments are applicable for rivers and streams. The basic principle of mechanistic models follows laws of conservation. Conservative properties such as water mass, constituent mass, momentum and heat are usually not changed through normal reactions. The main point of interest is gains or losses during the process. WASP7 has various variables; ammonia, nitrate, orthophosphate, dissolved oxygen, salinity, phytoplankton, periphyton, particulate detritus (carbon, nitrogen, and phosphorus), and dissolved organic matter (CBOD (1), CBOD (2), CBOD (3), DON, DOP). Based on these variables, the simulations are analyzed into water quality from each mode below the Table 2.2.

Table 2.2 WASP7 Water Quality Modules

Modules	File name	Details
Eutrophication	Eutro.dll	Dissolved oxygen, CBOD (three forms), phytoplankton, periphyton, detritus (C, N, P), dissolved organic nitrogen, ammonia/ammonium, nitrate, dissolved organic phosphorus, orthophosphate, salinity, solids, sediment disagensis.
Simple Toxicant	Toxi.dll	Pertitioning and first order decay Simple metal or organic chemical, solids
Non-ionic organic toxicants	Toxi.dll	Detailed fate processes, reaction products and solids
Organic toxicants	Toxi.dll	Detailed fate processes, ionization, reaction products, solids
Mercury	Mercury.dll	Elemental, Hg0, divalent, HgII, methyl, MeHg, solids
Heat	Heat.dll	Temperature, salinity, coliform, conservative 1 and 2

WASP processes apply to the conceptual ideas of phytoplankton kinetics, periphyton kinetics, phosphorus cycling, nitrogen cycling, dissolved oxygen balance, and sediment digenesis. The modeling system provides flexibility for simulating the process of advection, dispersion, point and diffuse mass loading, and water boundary exchange during various time steps. Water exchanges are mainly separated into two parts; 1) water from outside with the model network to the inside, 2) from inside with the model network to the outside. These points are called boundaries. Mass loading of entering network is related to flow and concentration. WASP calculates mass leaving and determines boundaries to user specified flow paths, user specified dispersion paths, and read from hydrodynamic interface file. Units of model network are kg/day. Loading originates from atmospheric deposition, groundwater infiltration, municipal, industrial discharge and watershed runoff and erosion. These loads include both point sources from direct discharges and non-point sources from external loadings such as ASCII file, created LWWM, created HSPF, combined sewer overflow, and groundwater infiltration. WASP is the process of sediment transport and bookkeeping, based on kinetics. The time series are analyzed by steady, seasonal, monthly, daily and hourly intervals (USEPA 2005).

IQQM

The New South Wales (NSW) Department of Land and Water Conservation (DLWC) and the Queensland Department of Natural Resources (QDNR) in Australia developed a hydrologic modeling tool, which is called Integrated Quantity and Quality

Model (IQQM). IQQM is used for water quality as well as water quantity. This model is based on the QUAL2E model. The contents of IQQM consist of movement of conservative and non-conservative substances, such as salinity and pesticides, nitrogen cycle, dissolved oxygen (DO), biochemical oxygen demand (BOD), phosphorus cycle, coliforms, and algae. This basic model's assumption is that reservoirs and routing reaches at each pertinent location are fully mixed flow. The modified Streeter-Phelps equation is used for modeling parameters like DO and BOD. The pollutant constituents such as nitrogen and phosphorus are analyzed based on the first order kinetics.

MIKE SHE

The MIKE SHE modeling system has been further developed and extended by DHI (Danish Hydrologic Institute, Inc.) Water & Environment since the mid 1980's. MIKE SHE is a flexible integrated hydrological modeling system of water and solutes, based on the hydrological cycle. The MIKE SHE code is a powerful, physically based, distributed parameter, fully integrated code for three dimensional simulations of hydrologic systems. It has been successfully applied at multiple scales, using spatially distributed and continuous climate data to simulate a broad range of integrated hydrologic, hydraulic, and transport problems in humid as well as in more arid areas (USEPA 2005). The model operates for water needs for multiple purposes of surface water as well as ground water, dynamics in wetland, and water quality connecting point source and non point sources. The details of the MIKE SHE also include equilibrium and kinetic sorption, first-order decay, sequential biodegradation and plant uptake. Advection/dispersion methods are used for the exchange of contaminants between the hydrologic process, which transport and exchange in the network system, channel flow (MIKE 11), unsaturated flow and saturated groundwater flow. The equation for advection/dispersion method is derived from the explicit QUICKEST method (Leonard 1979). A random walk particle tracking method is also applied for the saturated groundwater flow. Ecologic modeling can become complex in the complicated network system. A general ecological modeling tool (ECOLab) makes it possible not only for engineers but also ecosystem experts to develop their own ecosystem models proper to site-specific ecological conditions. The ECOLab is flexible to calculate water quality in surface water, which is executed in MIKE SHE. ECOLab is integrated in MIKE 11, which coveres the problem related to eutrophicaiton, and retention of nutrients and pollutants and their elimination in wetland (Graham and Butts 2006). Demonstration versions of MIKE SHE can be downloaded form the MIKH SHE web site, www.mikeshe.com, along with more detailed technical information.

RiverWare

The RiverWare is a generalized tool for complex reservoir system modeling. This model applies to the Tennessee valley, Colorado River, Upper Rio Grande, and San Juan Basin. The U.S. Bureau of Reclamation’s (USBR) Colorado River Simulation System and Tennessee Valley Authority’s (TVA) have developed and maintain specific models for planning and operating river basins to solve widely varying basin problems (Zagona et al.

2006). The main development center of the RiverWare is located in the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) of the University of Colorado. RiverWare provides streamflow inflows routing of a river/reservoir system based on hydrologic information. River system nodes are input included in watershed runoff. The main process depends on volume mass balance; reservoir, river reaches based on hydrologic routing, evaporation, diversion, return flows and other losses. The model can also be combined with groundwater model and electric power generation. The objects of the storage reservoir process have mass balance, evaporation, bank storage, sill, and water quality. The upgraded version of RiverWare's water quality modeling makes it possible to model a conservative substance such as total dissolved solids (TDS) during monthly time step. TDS concentration is simulated based on water quantity constituents such as inflow, diversion, reservoir, and return flow in the reservoir. However, temperature, precipitation, and chemical changes are ignored. TDS concentration flows in return flows from diversions and salt load from local flows. There are three options of reservoir mixing models; a simple, well-mixed reservoir or a two-layered reservoir model. Riparian habitat and recreation are currently interest issues in addition to flood control, water supply, hydropower production, and navigation, water quality (Zagona et al. 2001).

MODSIM

The MODSIM modeling system was developed and upgraded at Colorado State University. The recent version, MODSIM-DSS is a generalized river basin and network flow model. This model is used for water supply and hydropower energy production with physical, hydrological, and institutional/administrative aspects while considering water quality. MODSIM-DSS is designed to meet population growth and increased needs with water rights, based on netflow programming. It can be simulated in a certain period of monthly, weekly, and daily time step. MODSIM-DSS is linked with stream-aquifer models, which analyzes groundwater as well as surface water. In addition, water quality simulation models explain the effectiveness of pollution control strategies. The programs and more details are available on the Web page, http://modsim.engr.colostate.edu/.

The MODSIM river basin water rights planning model has incorporated constraints on water quality loading and concentrations. The extended model MODSIMQ combines a Lagrangian relaxation network solver with the Frank-Wolfe nonlinear programming algorithms to satisfy water right priorities, while mitigating salinization. The MODSIMQ methods include conservative routing of water quality constituents, maintenance of salt load mass balance, and standards of constrains on water quality constituents. Surface water routing of water quality constituents is combined with MODSIMQ and QUAL2E. Irrigation return flows, canal seepage, reservoir seepage, deep percolation, and river depletion due to groundwater pumping are modeled using stream depletion factors developed by USGS (Dai and Labadie 2001).

The city of Sao Paulo intrabasin is one of its applications for the purposes of water supply needs and acceptable water quality by recommended criteria. MODSIM simulation results can be used as input of QUAL2E-UNCAS, which is linked to QUAL2E-UNCAS. MODSIM processes to focus on targets and priority in the river system, which is sufficient for water quantity and water quality in the network system. System Impact Assessment Model (SIAM) for the Klamath River Basin, Oregon and California, is developed by the U.S Geological Survey, which develops a data storage system (DSS). SIAM improves water quality conditions for summer/winter in the Klamath River as decreasing anadromous fish populations (Campbell et al. 2001). Also, MODSIM is linked to HEC-5Q reservoir water quality model, an aquatic habitat model, and the SALMOD fish production model (Labadie 2006).

The Colorado Water Resources Research Institute developed a case study application for Lower Arkansas River Basin below the Pueblo Dam, for the purpose of improving water quality in Lower Arkansas River. Groundwater and surface water modeling are integrated in the Lower Arkansas River, using the same concepts as the previous study. Water quality models such as QUAL2E stream quality model and a ground return flow salinity model are analyzed within water quantity model, MODSIM (Dai and Labadie 2001).

HEC-5Q

HEC -5Q is the expanded version of HEC-5 and the Water Quality Version of simulation of Flood Control and Conservation Systems developed by the U.S Army Corps of Engineers at the Hydrologic Engineering Center at Davis, California (USACE 1986). HEC-5Q analyzes water flows and water quality in reservoirs with downstream river reaches. The model operates regulating outflows through gates and turbines, and vertical temperature gradients in reservoirs.

HEC-5Q has two alternative simulation options based on water quality constituents. The first option is water temperature to run simulation. HEC-5Q simulates up to 3 conservative constituents, and non-conservative constitutes with restrictions, and dissolved oxygen simulated with restrictions by federal and state agencies. Available constituents follow as water temperature, total dissolved solids (TDS), nitrate nitrogen, phosphate phosphorus, phytoplankton, carbonaceous BOD, ammonia nitrogen, and dissolved oxygen. Water quality is related to load or concentration at downstream control points in the river basin network system. The system is based on system flow and the vertical distribution of temperature and other constituents in the reservoirs. The model in water quality has the various gate openings for withdrawal structures concerning sufficient water quality standard at each control point. Otherwise, the increased flow will be computed in flow balance for recommended water quality. Water quality objectives are also fulfilled with proposed reservoir-stream system modification and reservoir intake structure decision in the reservoirs. The water quality simulation is operated in alternative modules such as a calibration, an annual simulation, and a long-term mode. Reservoir operation, historical flow, and water quality can be calibrated to provide a more realistic representation with the parameters such as decay rates and dispersion coefficients. The HEC-5Q is modified and evaluated by reservoir regulation, reservoir discharges, and point or non-point sources with different hydrologic and meteorological conditions (USACE 1986).

WRAP / WRAP-SALT

The Texas Water Availability Modeling (WAM) system was developed by the Texas Commission on Environmental Quality (TCEQ), its partner agencies, and contractors under authority of water management legislature enacted by the Texas Legislature as the 1997 senate Bill 1. WRAP is the river/reservoir system simulation model incorporated in the Water Availability Modeling (WAM) System applied by agencies and consulting firms in Texas in planning and water right regulatory activities. The TCEQ WAM system includes 21 datasets for the 23 river basins of Texas. Application of WRAP in Texas involves modifying existing data files for a river basin of concern. The ongoing issues of the WAM systems are water resources operations, water management during drought, defining optimal levels of reliability, storage priorities, instream flow needs, return flows, interstate/international rivers, ground/surface water interactions and water quality considerations.

The WRAP-SIM simulates the river/reservoir water allocation/management system for input sequences of monthly naturalized flows and net evaporation rates during a hypothetical repetition of historical natural hydrology. The model provides tracking of stream flow network, based on reservoir storage capabilities and net reservoir evaporation-precipitation and specified diversion, instream flow, and hydroelectric power requirement. The simulations combine with water rights of multi-purposes and multi-users.

A salinity simulation component of WRAP called WRAP-SALT was developed recently at Texas A&M University. The WRAP-SALT program reads water quantity data from the main WRAP-SIM simulation results along with additional input data regarding salt concentrations and loads of flows entering the river system. The model computes concentrations of conservative water quality constituents in the regulated stream flows, diversions, and reservoir storage throughout the river system. Concentration frequency and supply reliability analyses of simulation results are performed within the post-simulation program TABLES. Water quality throughout a river basin system of numerous stream reaches and reservoirs may be simulated in planning studies for alternative scenarios of water use, reservoir system operation policies, and salt control measures. The model evaluates the salinity modeling capabilities based on monthly stream mass and load budget in the river/reservoir system.

Prior Salinity Modeling Research at Texas A&M University

Karama (1993) and Sanchez-Torres (1994) developed reservoir/river system simulation models at Texas A&M University that included salinity tracking. The reservoir salt routing components of these models were based on the premise of complete mixing during the computational time step. Ganze (1990) compiled and analyzed salt data for the Brazos River Basin. Sayger (1992) investigated the interaction of surface and subsurface flows and loads in the upper Brazos River. Saleh (1993) developed methods for synthesizing sequences of stream flows and salt loads. Krishnamurthy (2005) developed a dataset of inflow salt loads and concentrations for the Brazos River Basin and performed a WRAP simulation study using recently developed salinity modeling features. As previously noted, this simulation was also based on the premise of complete mixing during the monthly time step.

The REServoirSALT (RESSALT) is a generalized model for conservation purposes, simulating both water quantity and water quality in a river basin system. The case study of the Brazos River Basin analyzes system operation reliabilities constrained by salt pollutant in the reservoirs. The case study includes 21 control points and 13 reservoirs. Control points include both reservoir point and non-reservoir sites. The simulation study is based on a 85-year historic period-of-analysis using monthly time steps. The simulations study is based alternatively on 1984 and 2010 sediment conditions and, considers three quality constituents: total dissolved solids (TDS), chloride (CL), and sulfate (SO4) (Karama 1993).

The original WRAPSALT (Sanchez-Torres 1994) is a generalized computer model operating the river/reservoir system for the allocation of water resources among various water users considering salinity constituents under water rights based on the priority system. The WRAPSALT program is one part of the TAMUWRAP package. The simulation process is based on water rights and salinity with different approaches for increasing water supply yields, considering water rights, and evaluating water management strategies. Water salinity is a major problem affecting water supply for municipal, agricultural, and industrial purposes. The main natural salt pollutions are total dissolved solids (TDS), chloride (CL), and sulfate (SO4). The total reliabilities of the river basin and BRA rights decrease 66.45% and 64.58% each, because of salinity constrains.

CHAPTER III

BRAZOS RIVER BASIN CASE STUDY

Natural Salt Pollution in the Southwestern United States

Salinity is a major determinant of water supply capabilities in river basins throughout the world. The Brazos River Basin of Texas is representative of a particular type of natural salt pollution situation that occurs in several major river basins of Texas and neighboring states. Portions of the upper watersheds of the Arkansas, Brazos, Canadian, Colorado, Pecos, and Rio Grande Basins in the states of Arkansas, Louisiana, Oklahoma, New Mexico, and Texas are located within the geologic region known as the Permian Basin. Millions of years ago, this area was covered by a shallow inland sea. Salt-bearing geologic formations were formed by salts precipitated from evaporating seawater (Wurbs 2002). The primary sources of salt loads in the rivers are geologic formations of halite underlying portions of their upper watersheds. Salt springs and salt flats located in salt source areas of the upper watersheds are created as water percolates through salt-bearing geologic strata. The mineral pollutants consist largely of sodium chloride with moderate amounts of calcium sulfate and other dissolved solids. Salt concentrations in the downstream reaches of the rivers decrease with dilution from low-salinity tributary inflows. The natural salt pollution greatly impacts water resources development and management, severely limiting the use of large quantities of water in major river/reservoir systems.

The U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, river authorities, water districts, and other agencies and their consultants have conducted extensive studies in several river basins since the 1950's investigating strategies for dealing with natural salt pollution (Wurbs 2002). Several salt control projects have been implemented and others have been proposed but never implemented due to economic and environmental concerns. The U.S. Geological Survey (USGS) has conducted data collection programs in support of the natural salt pollution control studies in the various river basins.

Brazos River Basin

The Brazos River Basin extends southeasterly from eastern New Mexico across the state of Texas to the Gulf of Mexico. The basin drainage area is 45,600 square miles, of which about 45,000 square miles lies in Texas with the remainder in New Mexico. The climate, geography, and economy of the basin vary dramatically along its 640 mile length. The mean annual precipitation varies from 16 inches/year in the upper basin in and near New Mexico, to over 50 inches/year in the lower basin near the Gulf of Mexico. The 23 river basins of Texas are shown in Figure 3.1.

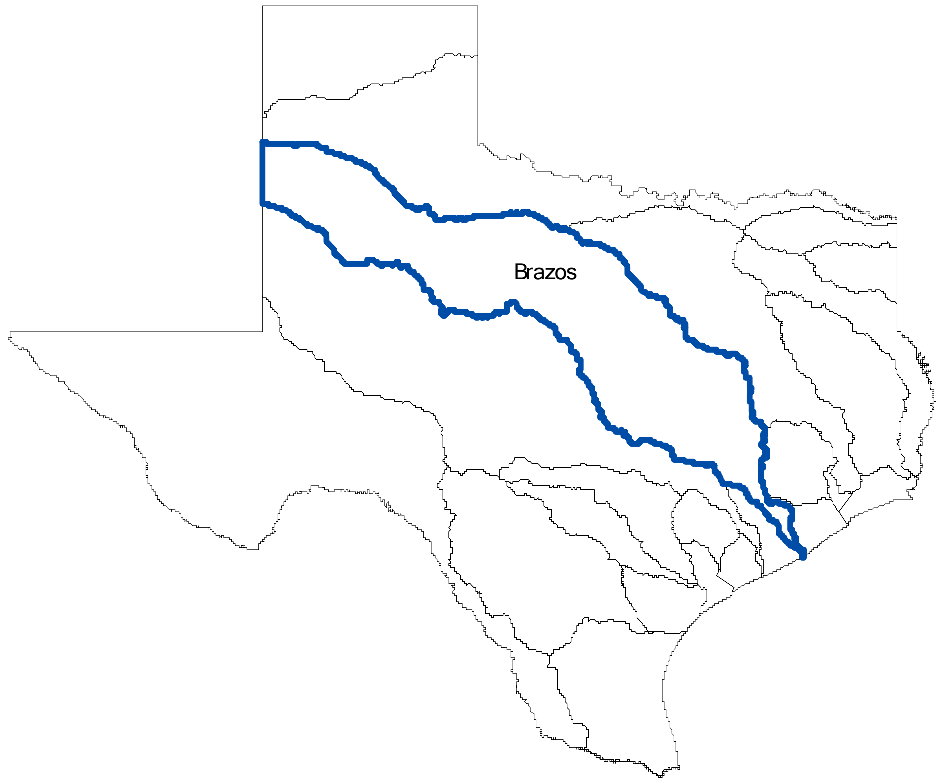

Figure 3.1 The 23 major river basins of Texas, within the state boundary

The Brazos River Basin covers 118,000 km^2 from eastern New Mexico across Texas to the Gulf of Mexico. There are hundreds of reservoirs in the Brazos River Basin, but most of the total storage capacity is contained in the 13 largest reservoirs listed in Table 3.1. Hubbard creek Reservoir is owned by the West Central Texas Municipal Water District (WCTMWD). The Fort Worth District (FWD) of U.S. Army Corps of Engineering (USACE) owns the nine reservoirs, which are Whitney, Aquilla, Waco, Proctor, Belton, Stillhouse Hollow, Georgetown, Granger, and Somerville reservoirs for water supply, flood control, and recreation. Brazos River Authority (BRA) owns Possum Kingdom, Granbury, Limestone reservoirs, which services water supply and recreation. Possum Kingdom and Whitney Reservoirs also generate hydroelectric power. Table 3.1 shows multiple purposes and owners for each reservoir.

Table 3.1 Reservoirs purposes and owner

Lake and Dam	Flood Control	Water Supply	Hydroelectric power	Recreation	Operated by
Whitney	O	O	O	O	FWD
Aquilla	O	O	-	O	FWD
Waco	O	O	-	O	FWD
Proctor	O	O	-	O	FWD
Belton	O	O	-	O	FWD
Stillhouse Hollow	O	O	-	O	FWD
Georgetown	O	O	-	O	FWD
Granger	O	O	-	O	FWD
Somerville	O	O	-	O	FWD
Possum Kingdom	-	O	O	O	BRA
Granbury	-	O	-	O	BRA
Limestone	-	O	-	O	BRA
Hubbard Creek	-	O	-	O	WCTMWD

Natural Salt Pollution Control for the Brazos River Basin, Texas

Salt problems in the Brazos and other river basins in the Southwest are a major issue in water resources planning and management addressed by universities, state/federal agencies, and consulting firms since the mid of 1950's. Water quality is poor at the main stem Brazos River from stonewall County, Texas to the Gulf of Mexico, because of natural mineral pollutants. The poor water quality in the Brazos River Basin severely constrains water supply for municipal, irrigation, and industrial purposes. The U.S Geological Survey (USGS) documented the natural salt pollution in the upper Brazos River Basin from 1961 to 1968. The natural salt pollution stems from the formation of mineral pollutants: sodium chloride (common table salt), moderate amounts of calcium sulfate (gypsum), and other dissolved solids. Poor water quality occurs because of natural salt pollution(McCrory 1984).

The upper streams of the Brazos River Basin contain high salinity. The primary source of salinity is an approximately 1,500 square mile area in the Salt Fork of the Brazos River watershed and the portions of the adjacent Double Mountain Fork and North Croton Creek watersheds. Croton Creek, North Croton Creek, and the Salt Fork are major sources of salt water in the upper Brazos River Basin. Water of these areas comes from Hot Springs, Croton salt flats, Dove Creek, Dove Creek salt flat, and Haystack Creek. The daily load of chloride from Salt Croton Creek at the upper Brazos River Basin during the period from 1957 to 1966 was estimated in U.S. Geological Survey studies to be 480 tons per day. The Croton Creek area contributed about 68 tons of chloride per day during the same period. Salt control damsites and stream gauge stations are figured in Figure 3.2.

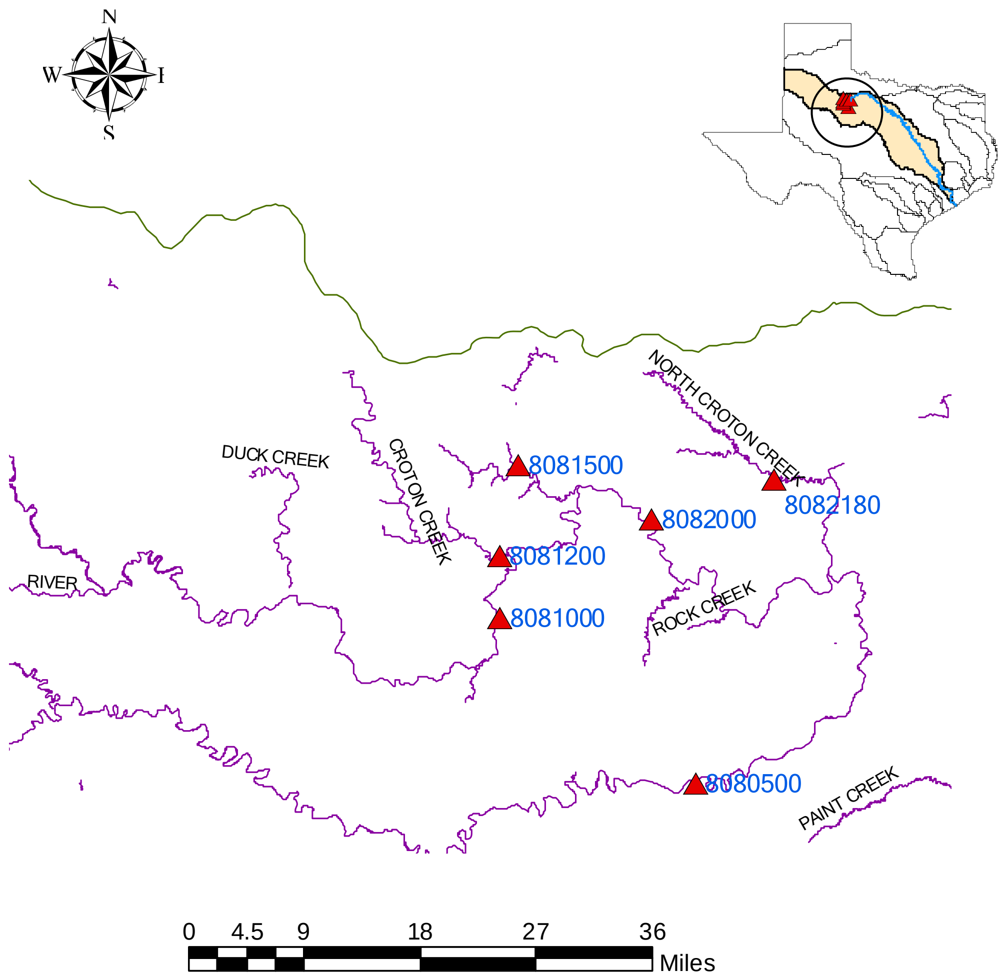

Figure 3.2 Salt control damsites and stream gauge stations

At a point above Peacock, Texas on the Salt Fork Brazos River, chloride emission is estimated at about 195 tons per day by the USGS. This amount of chloride salt pollution does not included less significant tributaries. (e.g. Stinking Creek contributed about 2 tons of chloride per day.) A chloride contribution of about 45 tons per day comes from North Croton Creek located downstream and tributary to the Brazos River (McCrory 1984). The salt loads to the river system result from groundwater flow and surface water runoff from this region into the tributary streams and the Brazos River. With dilution from good quality tributaries, water quality improves greatly in the lower Brazos River (Wurbs and Karama 1995).

Table 3.2 Salt control USGS gauging station number and locations in the Brazos River Basin

USGS Gauging station number	Location
8080500	Double Mountain Fork Brazos River near Aspermont
8081000	Salt Fork Brazos River near Peacock
8081200	Croton Creek near Jayton
8081500	Salt Croton Creek near Aspermont
8082000	Salt Fork Brazos River near Aspermont
8082180	North Croton Creek near Knox City

The U.S. Army Corps of Engineers (USACE) conducted Brazos River Basin natural salt pollution control studies during the 1960's-1980's with assistance from the Environmental Protection Agency (EPA) and U.S. Geological Survey (USGS). Salt control USGS gauging stations and locations in the Brazos River Basin are tabulated in Table 3.2. These studies focused on improving the quality of water in the main stem of the Brazos River by controlling salt loads from upper basin sub-watersheds. A system of three salt control dams to control the runoff from the primary salt source areas was recommended but never implemented.

The USGS conducted a major water quality sampling program during 1964-1986 to support the United States Army Corps of Engineers (USACE) studies. Monthly total dissolved solids, chloride, and sulfate concentrations for 1964-1986 or sub-periods thereof are available at over 30 sampling stations in the Brazos River Basin. A lesser number of gauging stations were operated during periods before and after 1964-1986.

The USACE contracted with Texas A&M University (Wurbs et al. 1993) to compile the USGS water quality data into a readily usable format. The Brazos River Basin salinity data has been used in past research at Texas A&M University in developing salinity modeling capabilities and is used again in this thesis research. Most collected data by USGS gauging stations are from the period of 1964 to 1986. Some missing data is analyzed by multiple linear and nonlinear regressions based on the period from 1964 to 1986 (Wurbs et al. 1995). Adjustments of measured discharges and salt loads have removed the effects of the storages and evaporation at Stations located on the main stem in the Brazos River Basin: Hubbard, Possum Kingdom, Granbury, and Whitney reservoirs. The reservoir storage and evaporation are associated with gauged monthly storage levels, evaporation rates, and storage/area relationship (Ganze and Wurbs 1989).

The Texas Water Availability Modeling (WAM) System dataset for the Brazos River Basin includes 650 reservoirs. Possum Kingdom, Granbury, and Whitney reservoirs are the major reservoirs on the main stem in the Brazos River Basin system shown in Figure 3.3. Mean total dissolved solids concentrations are about 3,600 mg/l at the Seymour gauge which is the nearest USGS stream gauging station on the Brazos River above Possum Kingdom Reservoir and 340 mg/l at the Richmond gauging station located 750 miles downstream on the lower Brazos River near the Gulf of Mexico. The other 647

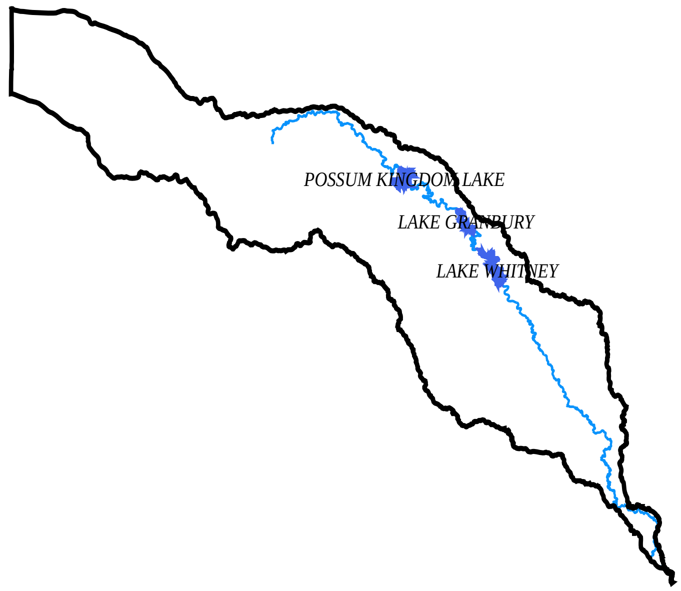

Figure 3.3 Major rivers and three major upper reservoirs in the Brazos River Basin

reservoirs are located on tributaries, with mean total dissolved solids concentrations ranging from 200 mg/l to 400 mg/l. The three main stem Brazos River reservoirs account for about 41 percent of the total conservation storage capacity of the 650 reservoirs. The Environmental Protection Agency (EPA) secondary drinking water regulations recommend maximum limits of 250 mg/l, 250 mg/l, and 500 mg/l for chloride, sulfate, and dissolved solids.

The movement of salt loads from the upstream locations of the Brazos River Basin may require a long time period to reach downstream sites that may be a few months or years. Analyses of Possum Kingdom and Whitney reservoirs are based on the following two assumptions related to the discharge and salt loads. Firstly, discharge and salt load reductions of the totals or long-term means occur at the downstream gauges in the river basin. For the second assumption, reductions of the discharge and salt load for each month are directly proportional to each control point of the downstreams. The same conceptual ideas based on the two assumptions are applied to both Possum Kingdom and Whitney gauges for the three main constituents: total dissolved solids (TDS), chloride (CL), and sulfate (SO4). At Whitney reservoir, a small amount of water supply provides for water demands of municipal purpose under contract. Natural salt pollutant concentrations at the upstream flows are divided according to salinity concentrations based on the rates of the discharge at the downstream gauges for each month. College Station and Richmond gauges have the same amount of streamflow and salt loads during the same month, which is from reductions of discharge and salt load at the Whitney gauge. The Whitney gauge computes reductions with units of discharges in cubic feet per second (cfs) and salt loads in tons/day. Salinity concentration is reduced as it moves toward the downstream stem.

The drainage area at the upper Brazos River Basin releases the main source of natural salt pollutant. The average discharge above Possum Kingdom reservoir is 14 to 18 percent of the entire river flow. However, the salinity constituent emissions of the same drainage area above Possum Kingdom reservoir are 45% to 55 % for total dissolved solids, 75% to 85% of the chloride, and 65% to 75 percent of the sulfate on the Richmond gauge at the downstream end of the Brazos River Basin (McCrory 1984).

Table 3.3 Mean concentration of total dissolved solids (TDS), chlorides (CL), and sulfates (SO4) during availability dataset

Location (USGS Gauging station number)	TDS (mg/l)	CL (mg/l)	SO4 (mg/l)	Data availability	Time periods (months)
Possum Kingdom (08088600)	1601	647	313	Oct. 1963 – Sep. 1986	276
Granbury (08090800)	1461	576	293	Oct. 1970 – Sep. 1986	192
Whitney (08092600)	950	352	183	Oct. 1963 – Sep. 1986	276
Richmond (08114000)	418	108	71	Oct. 1963 – Sep. 1986	276

The monthly mean concentrations in Table 3.3 are computed from USGS datasets covering specific periods. Figures 3.4-3.6 show TDS, chloride, and sulfate concentrations at Seymour gauge observed by USGS.

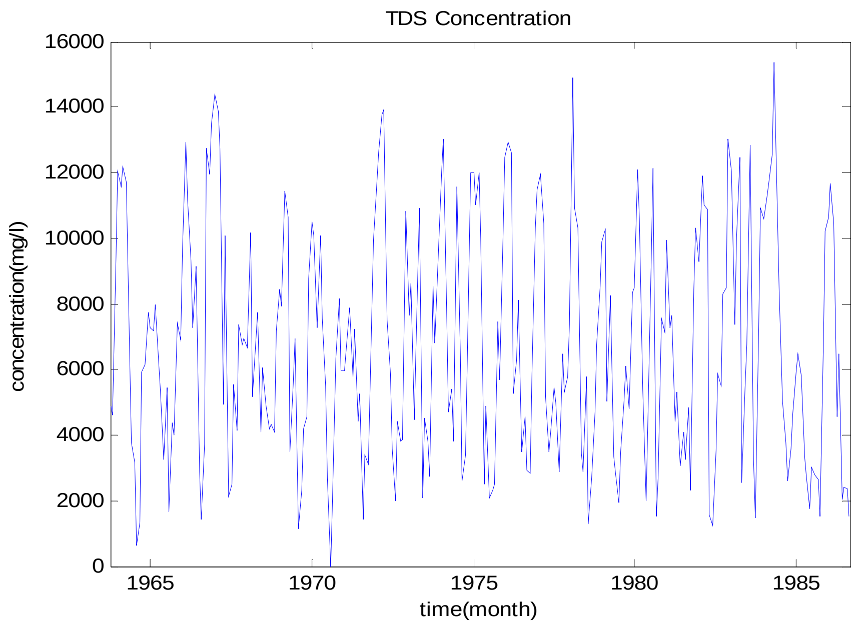

Figure 3.4 TDS concentration at Seymour gauge observed by USGS

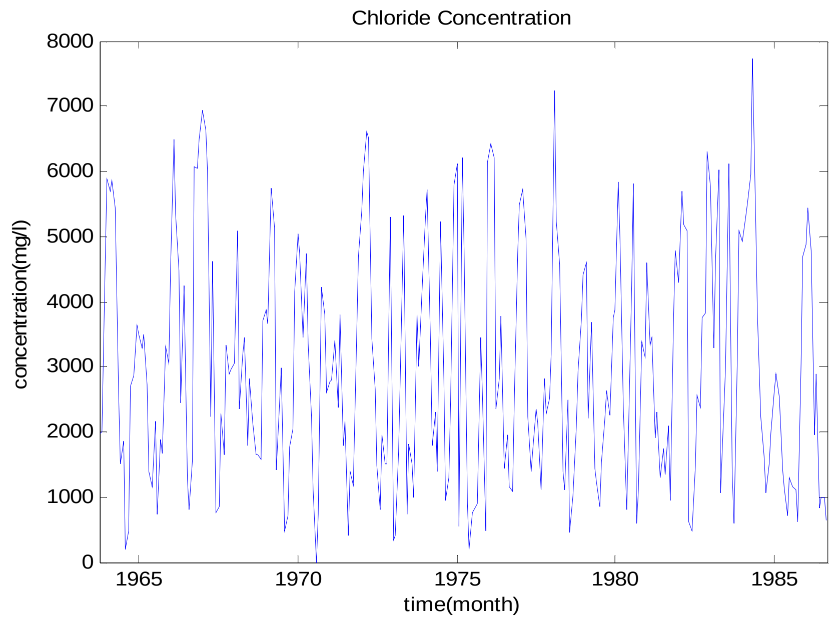

Figure 3.5 Chloride concentration at Seymour gauge observed by USGS

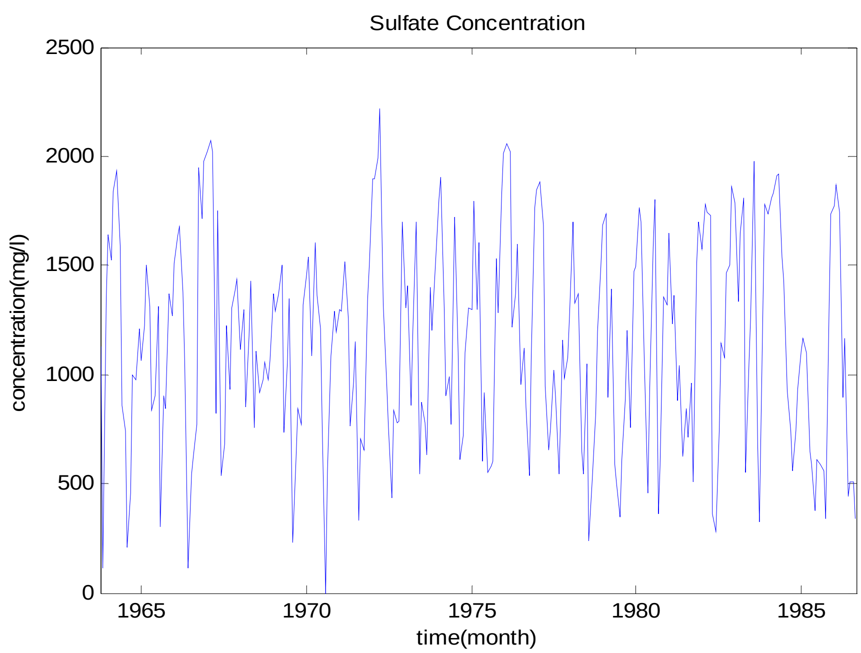

Figure 3.6 Sulfate concentration at Seymour gauge observed by USGS

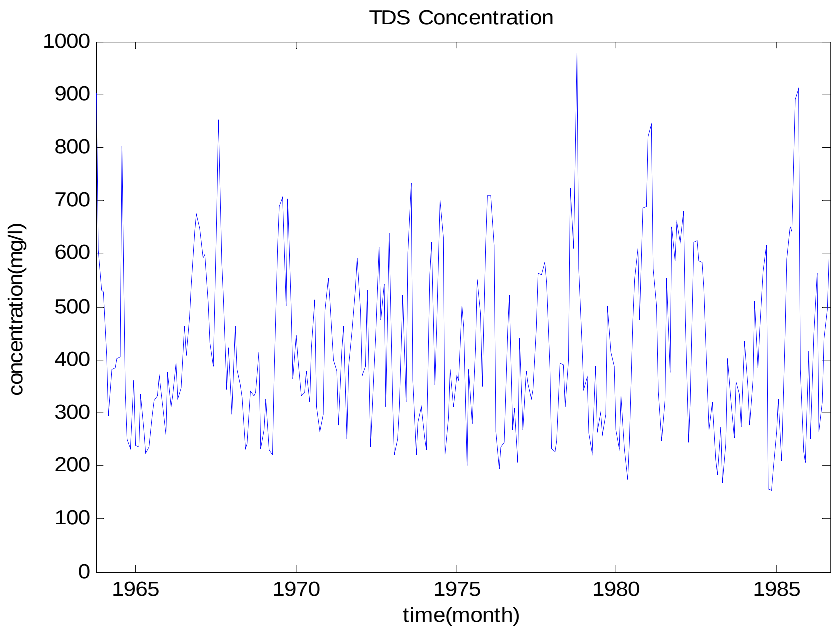

Figure 3.7 TDS concentration at Richmond gauge observed by USGS

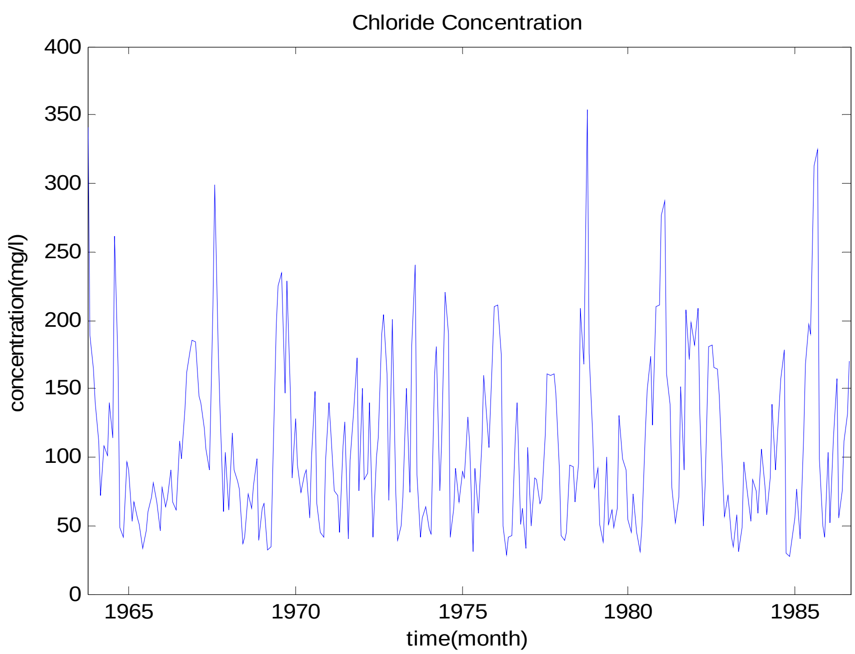

Figure 3.8 Chloride concentration at Richmond gauge observed by USGS

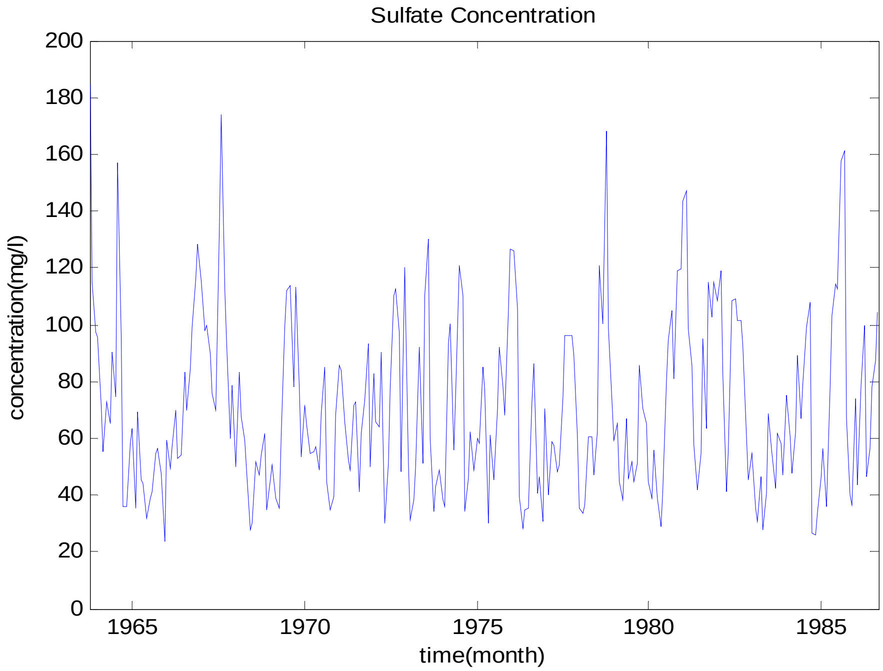

Figure 3.9 Sulfate concentration at Richmond gauge observed by USGS

Figures 3.7-3.9 show TDS, chloride, and sulfate concentrations at Richmond gauge observed by USGS. Salt concentrations at the upstream gauging stations are decreased by the computations and adjustments to the downstream gauging stations. The mean total dissolved solids concentration is 1,601 mg/l at Possum Kingdom reservoir. The mean chloride and sulfate concentration are 647 mg/l and 313 mg/l at the Possum Kingdom reservoir. At the Granbury reservoir located on the downstream of Possum Kingdom reservoir, the mean total dissolved solids, chloride and sulfate are 1,461 mg/l, 576 mg/l, and 293 mg/l, respectively. The Whitney reservoir, the downstream of Granbury reservoir, has 950 mg/l, 352 mg/l, and 183 mg/l of mean total dissolved solids, chloride and sulfate, in turns. The mean total dissolved solids, chloride and sulfate concentration are 418 mg/l, 108 mg/l, and 71 mg/l at the Richmond gauging station around the mouth in the Brazos River Basin, respectively (Ganze and Wurbs 1989).

The box plots represent the distribution of natural salt pollutant for each salt constituent at the pertinent point. The calculation period of the Figure 3.10 has the same as Table 3.3. The box plots are a means of visualizing data from different population, especially comparing them. The middle line of the red box is the median value. The upper line of the box is the point of 75th percentile, and the bottom line of the box is the 25th percentile. The salt concentration at the upper stream is more significant than the salt concentration at the downstream in the Brazos River Basin. Actually, the main source of natural salt load is the upper River Basin; it contributes to the poor water quality. The mean concentration decreases form upstream gauges to downstream gauges as shown in Figure 3.10. The gauging station near Granbury reservoir has fluctuations, because these gauges are located before the reservoir. The gauging stations of the Possum Kingdom and Whitney reservoirs are located after each reservoir and both indicate more constant concentration of salt than if the gauging station were placed before the reservoirs.

The measured data of discharge, salt loads, and concentration has temporal and spatial variations not only over time but also through the locations in the Brazos River Basin. Temporal variation is related to changes over time, seasonal variations, and long-period trends. The natural salt pollution was 618 mg/l in August 1964 and 15,400 mg/l in May 1984 for total dissolved solids, 190 mg/l in June 1975 to 7,740 mg/l in May 1984 for chloride and 112mg/l in November 1963 and 2,225 mg/l in March 1976 for sulfate at the Seymour gauge during the period of 1964 to 1986. The mean salt concentration was 153

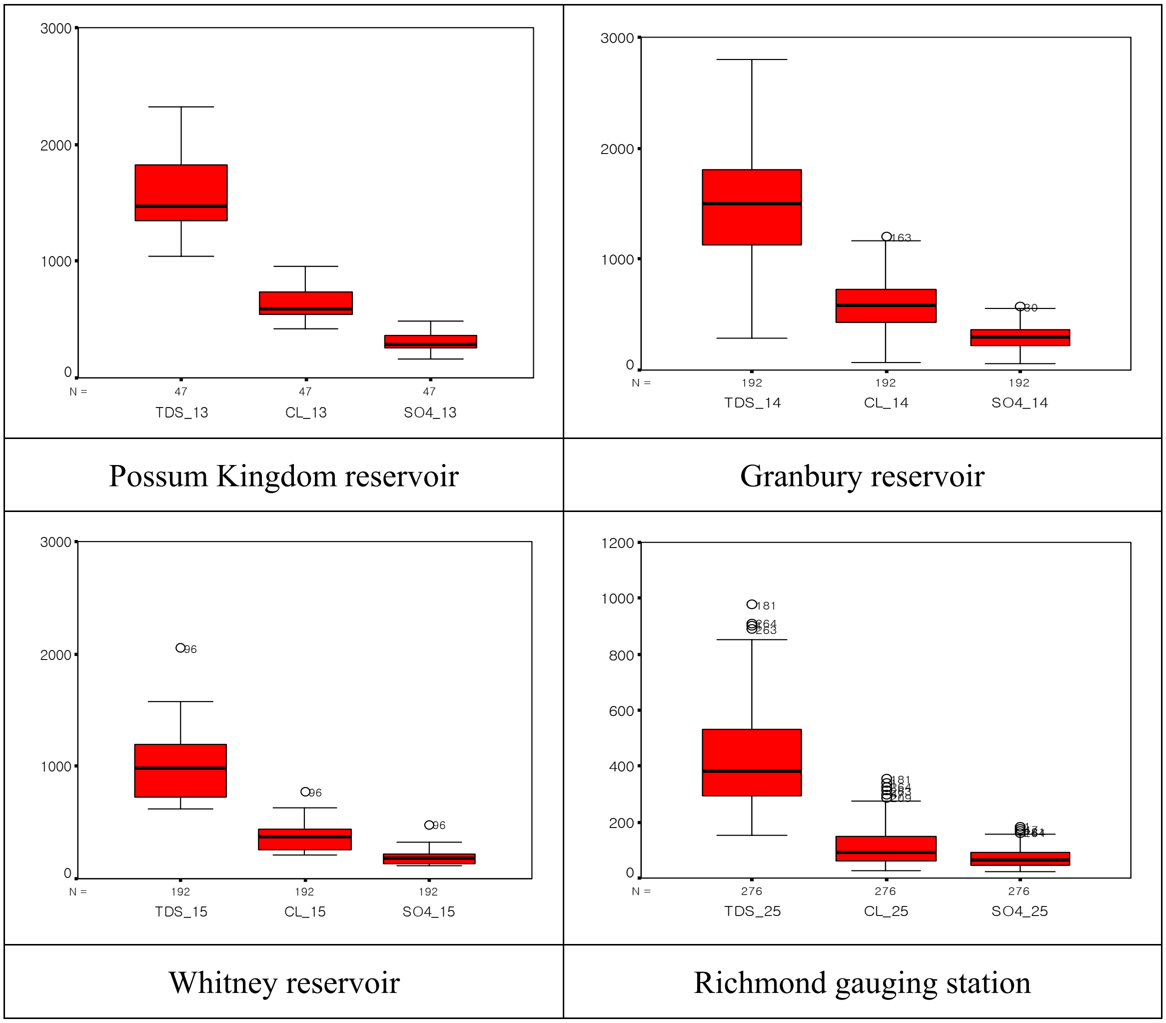

Figure 3.10 Box plots for the major 4 locations in the Brazos River Basin

mg/l in November 1984 and 978 mg/l in October 1978 for total dissolve solids, 28 mg/l in November 1984 to 355 mg/l in October 1978 for chloride and 24 mg/l in December 1965 and 185 mg/l in October 1963 for sulfate at the Richmond gauge during the period of 1964 to 1986.

At the Seymour gauge, the mean salt concentrations of total dissolved solids, chloride and sulfate was 11,900 mg/l, 5,760 mg/l, and 1,800mg/l and frequency analysis of the mean salt concentrations was 10 percent of equaled or exceeded over 276 months during the period of 1964 to 1986. The mean salt concentrations of total dissolved solids, chloride and sulfate at the Seymour gauge was 1,290 mg/l, 851 mg/l, and 539 mg/l and frequency analysis of the mean salt concentrations was 99 percent of the 276 months equaled or exceeded during the period of 1964 to 1986. At the Richmond gauge, the mean salt concentrations of total dissolved solids, chloride and sulfate was 635 mg/l, 192 mg/l, and 113mg/l and frequency analysis of the mean salt concentrations was 10 percent of equaled or exceeded over 276 months during the period of 1964 to 1986. The mean salt concentrations of total dissolved solids, chloride and sulfate at the Richmond gauge was 169 mg/l, 33 mg/l, and 27 mg/l and frequency analysis of the mean salt concentrations was 99 percent of equaled or exceeded during the period of 1964 to 1986.

Seasonally, variation has a tendency to show high concentration in winter and spring and low concentrations in summer and fall. The year maximum salt concentrations occur in February (40.6%), January (17.4%), and March (13.0%) at the Seymour gauge. The minimum concentrations occur in August (27.5%), September (22.5%), and October (15.2%) at the Seymour gauge. This percentage is the rate of each month over the year. The highest salt concentrations for the year occurred in September (30.4%), August (23.2%), and October (20.3%) at Richmond gauging station. The lowest salt concentrations through the year occurred in May (23.5%), December (16.2%), and June (14.7%) (Ganze 1990). The concentration has tremendous variation for the long-term period.

CHAPTER IV

VOLUME AND MASS BALANCES FOR UPPER BRAZOS RIVER/RESERVOIRS

Analyses of gauged stream flow, reservoir storage, and salt concentration data compiled by the U.S. Geological Survey (USGS) are performed for selected reservoir/river systems to develop an understanding of the timing and load balance characteristics of the movement of salts through reservoirs. As discussed in Chapter V, salinity routing methods in WRAP-SALT are based on setting reservoir outflow concentrations equal to storage concentrations adjusted for timing effects based on the concept of lag. Thus, the water and load budget analyses presented in Chapter IV based on observed data focus on exploring lag effects.

Basic Observed and Computed Data

An extensive water quality sampling program was conducted by the USGS from 1964 through 1986. The compilations and analyses of monthly salt loads and concentrations in the Brazos River Basin were documented by Wurbs and Ganze (1989). Ganze (1990) complied the USGS data into an electronic format as Lotus 1-2-3 spreadsheets and was exported to Microsoft Excel for the future studies. The dataset performed various analyses for the U.S. Army Corps of Engineers (USACE).

Table 4.1 Data availabilities and study period at USGS gauging stations

USGS Gauging Station number	Data availability	Study period
08088000	Nov.1977 – Sep. 1981	Nov. 1977 – Sep. 1981
08088600	Oct. 1963 – Sep. 1986	
08090800	Oct. 1970 – Sep. 1986	Oct. 1970 – Sep. 1986
08092600	Oct. 1964 – Sep. 1986	

The monthly mean salt concentrations and load published by the USGS are based on computed observed mean daily specific conductance and discharge and combined relationships between specific conductance and salt concentrations during the simulation period tabulated in Table 4.1. Salt concentrations were usually taken directly from water samples at the laboratory. Laboratory analyses of water samples provide data for developing the specific conductance versus salt concentration relationships. This data is collected and updated to determine salt concentrations. Discharges and loads of inflow, outflow and storage at the end month are from the USGS datasets. Net evaporation is imported from EV records in WRAP-SIM input files. Volume difference (Vdiff) is calculated by adding and subtracting parameters based on the mass balance equation. A net evaporation minus precipitation combines evaporation from a reservoir and precipitation falling directly on the reservoir water surface. The depths for the precipitation runoff from the reservoir site are adjusted, for which the precipitation is already reflected in the naturalized streamflows (Wurbs 2006a). WRAP hydrology computations perform reservoir adjustments for converting gauged streamflow to naturalized streamflows. Net evaporation minus precipitation volume is computed by calculating the reservoir water surface area by net evaporation precipitation rates, provided on EV records in WRAP-SIM. Reservoir names and IDs for EV records are tabulated in Table 4.2.

Table 4.2 Reservoir names and IDs for EV records

Reservoir ID	Reservoir Control Point (WAM)	Reservoir Name
POSDOM	515531	Possum Kingdom Lake
GRNBRY	515631	Lake Granbury
WHITNY	515731	Lake Whitney

Units include evaporation-precipitation rates in feet/month, water surface area in acres, and discharge in acre-feet/month. The Texas Water Development Board (TWDB) maintained the monthly database of precipitation rates and reservoir evaporation rates from 1940 to the present for each of 75 one-degree quadrangles covering the states. The Texas Commission on Environmental Quality Water Availability Models (TCEQ WAM) uses the database as mentioned above (Wurbs 2006a).

Ganze and Wurbs (1989) documented mean monthly and annual discharges, loadings and salt concentrations for total dissolved solids (TDS), dissolved chloride (CL), and dissolved sulfate (SO4) at 26 selected gauging stations out of the 39 USGS gauging stations in the Brazos River Basin during the period of 1964-86. This research focuses on four main gauging stations on the main stem of the Brazos River Basin.

In conjunction with the USGS datasets, annual *Water Resources Data* (WDR TX) reports the reservoir storage table (gauge height, in feet, and total contents, in acre-feet) and water-discharge records with extremes and instantaneous observation in acre-feet at each

USGS gauging station during the period of each water year from October to September. Figure 4.1 shows three main reservoirs and four USGS gauging stations in the Brazos River Basin.

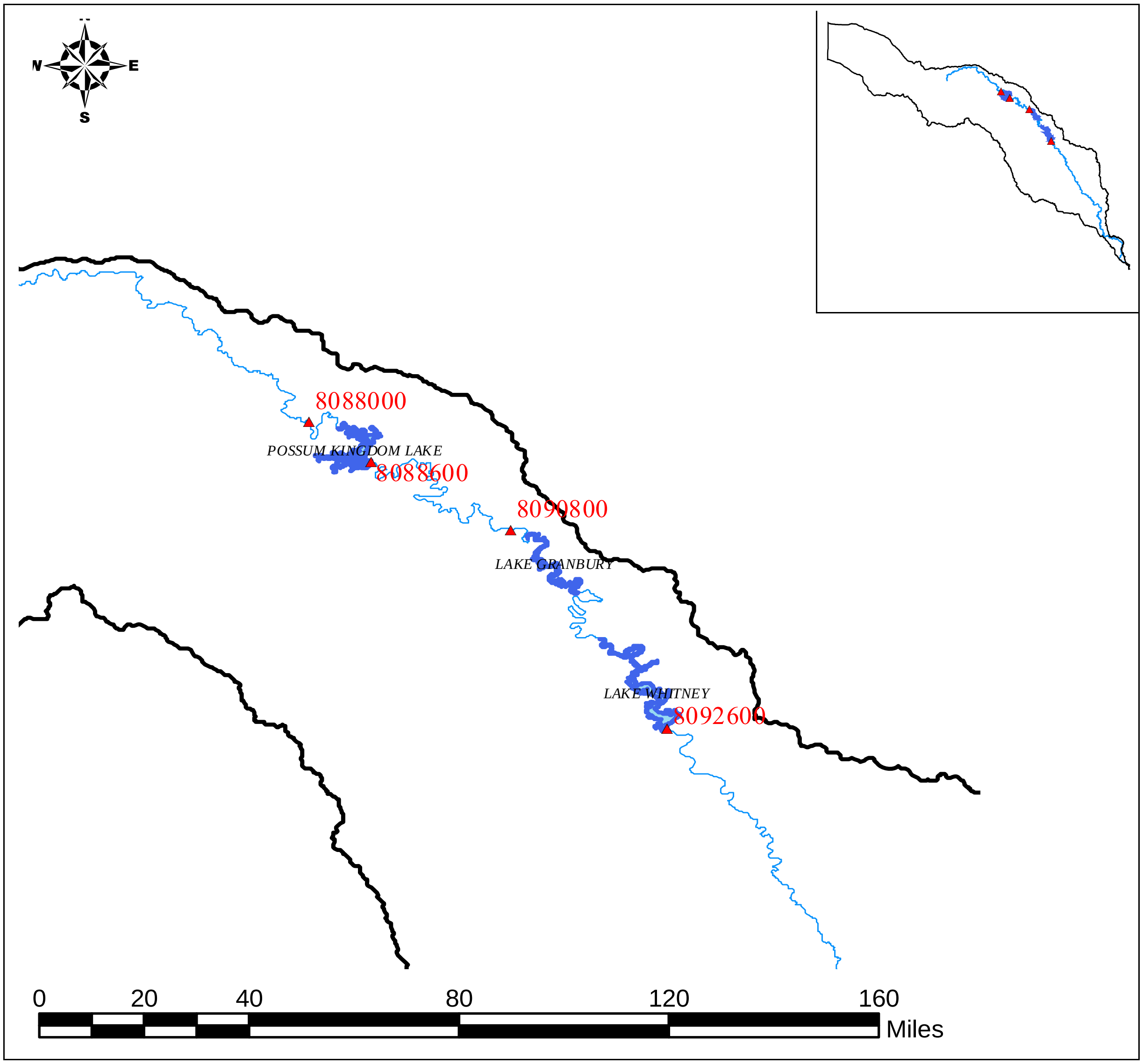

Figure 4.1 Three main reservoirs and 4 USGS gauging stations in the Brazos River Basin

Table 4.3 USGS gauging station number and locations of study area in the Brazos River Basin

USGS Gauging station number	Location
08088000	Brazos River Near South Bend
08088600	Brazos River at Possum Kingdom Dam Near Graford
08090800	Brazos River Near Dennis
08092600	Brazos River at Whitney Dam Near Whitney

USGS gauging stations and locations of study area in the Brazos River Basin are tabulated in Table 4.3. *Water Resources Data - Texas* is annually published in Austin, Texas by the Department of the Interior, Geological Survey—National Technical Information Service. *Water Resources Data* had three or four volumes per year published before 1999 and six volumes per year published between 1999 and 2005. Record of gauging stations are tabulated in Table 4.4. All of the volumes contain records of stage, discharge, water level,

Table 4.4 Water Resources Data Texas Volume contents

Volume	Record of gauging station
1	Arkansas River Basin, Red River Basin, Sabine River Basin, Neches River Basin, Trinity River Basin, and Intervening Coastal Basin
2	San Jacinto River Basin, Brazos River Basin, San Bernard River Basin, and Intervening Coastal Basins
3	Colorado River Basin, Lavaca River Basin, Guadalupe River Basin, Nueces River Basin, Rio Grande Basin, and Intervening Coastal Basins

and water quality of lakes, reservoirs and groundwater wells. The study area is located in the Brazos River Basin, which is described in Volume 2. Volume 2 records contain 74 gauging stations for water discharge, 9 gauging stations for stage, 21 lakes and reservoirs, and 32 gauging stations for water quality.

Possum Kingdom reservoir, Granbury reservoir and Whitney reservoir are located on the upper Brazos River. The relationship between storage volume in acre-feet and storage area in acres is tabulated on SV/SA records in the WRAP-SIM input file. Evaporation volume is calculated based on net evaporation and the relationship between storage volume and storage area. The unit of evaporation-precipitation rates is in feet/month. For the purpose of this study, the upstream major reservoirs- Granbury and Whitney reservoirs are considered as one reservoir, because of surrounding gauging stations. Two downstream reservoirs in the upper Brazos River Basin are considered as one main reservoir because of data availability. The four gauging stations are located upstream of the Possum Kingdom reservoir (USGS 08088000) and downstream of the Possum Kingdom reservoir (USGS 08088600), upstream of Granbury reservoir (USGS 08090800), and downstream of the Whitney reservoir (USGS 08092600). Granbury reservoir and Whitney reservoir are united to one large reservoir, which for the purpose of this study will be referred to as Granbury-Whitney reservoir. Granbury-Whitney reservoir is located in between USGS 08090800 and USGS 080926005.

Fundamental Mass Balance

The mass balance equation is used for routing streamflows through the reservoir as follows:

$$S2 = S1 + I - O - E + Vdiff$$

In which, S2 = storage at the end of the current month (ac-ft), S1 = storage at the end of the previous month (ac-ft), I = inflow volume during the month (ac-ft), O = outflow volume during the month (ac-ft), E = net evaporation during the month (ac-ft), and Vdiff = streamflow volume difference (ac-ft).

The equation for load balance follows the same concept as the equation for flow volume balance. However, the net evaporation factor is the only difference between flow volume mass balance and load mass balance. At the load mass balance, salinity is not included with the net evaporation. The salt loads are routed through the reservoir using the mass balance equation as follows:

$$Ls_2 = Ls_1 + Li - Lo + Ldiff$$

In which, Ls_2 = load at the end of the current month (tons), Ls_1 = load at the end of the previous month (tons), Li = inflow Load during the month (tons), Lo = outflow Load during the month (tons), and Ldiff = Load difference (tons).

The salt load concentration is analyzed by gauged streamflow, reservoir storage, and salt concentration data for selected reservoir/river systems compiled by the USGS. The research study deals with only conservative materials for water quality purposes. No biological, chemical affects are included in this study. It considers three water quality constituents; total dissolved solids (TDS), chlorides (CL), and sulfates (SO4). This model foresees that complete mixing of salt and water takes place in the reservoir. The concentration and salt loads of each constituent are computed as follows:

$$C = \frac{L}{Q} CF \quad \text{or} \quad L = \frac{CQ}{CF}$$

In which, C = Salt Concentration (mg/l), L = Salt Loads (tons), Q = Discharge for flow or storage (ac-ft), and CF = Conversion Factor.

Salt concentrations are units of milligrams of salt solute per liter of water (mg/l) or parts of salt solute per million parts of water (ppm). One liter of water equals the mass of one kilogram. The conversion factor is derived as follows:

$$\frac{\text{tons sec}}{\text{ft}^3\ \text{day}} \frac{1\ \text{day}}{86,400\ \text{s}} \frac{2,000\ \text{lb}}{1\ \text{ton}} \frac{453.59\ \text{g}}{1\ \text{lb}} \frac{1,000\ \text{mg}}{1\ \text{gram}} \frac{1\ \text{ft}^3}{28.316\ \text{l}} = \text{mg/l}$$

$$\frac{\text{tons}}{\text{ac - ft}} \frac{2,000\ \text{lb}}{1\ \text{ton}} \frac{453.59\ \text{g}}{1\ \text{lb}} \frac{1,000\ \text{mg}}{1\ \text{gram}} \frac{\text{ac - ft}}{43,560\ \text{ft}^3} \frac{1\ \text{ft}^3}{28.316\ \text{l}} = \text{mg/l}$$

For units of mg/l, the conversion factor (CF) is 370.8 for units of tons sec and ft^3 day and the conversion factor (CF) is 735.48 for units of tons and acre-feet.

$$\frac{\text{tons sec}}{\text{ft}^3\ \text{day}} (370.8) = \text{mg/l} \qquad \frac{\text{tons}}{\text{ac - ft}} (735.48) = \text{mg/l}$$

Basic data for this study is based on the measured data such as streamflow and salt loads for TDS, CL, and SO4 at the pertinent USGS gauging stations.

Mean Storage Concentration

Concentrations of diversions and other flows leaving a reservoir control point in the current month are set equal to the concentration of reservoir storage in the current month. There are two alternative methods related to storage concentration. The mean storage concentration is determined as follows where CF is the conversion factor in the equation mentioned on the previous page.

$$MC1 = \frac{Ls_1 + Ls_2}{S1 + S2} CF$$

In which, MC1 = mean concentration of the storage during a month, Ls_1 = Load at the end of the previous month, Ls_2 = Load at the end of the current month, S1 = Storage at the end of the previous month, S2 = Storage at the end of the current month, and CF = Conversion Factor (735.48).

For the alternative method, the storage concentration is determined as follows:

$$MC2 = \frac{2 \times Ls_1 + Li}{S1 + S2 + O} CF$$

In which, MC2 = mean concentration of the storage during a month, Ls_1 = Load at the end of the previous month, Li = inflow Load during the month, S1 = storage at the end of the previous month, S2 = storage at the end of the current month, and O = outflow volume during the month.

The variables in each column of Table 4.6 and Table 4.7 are explained as follows in Table 4.5.

Table 4.5 Each column details for table contents

Column Number	Variable	Details
3	I	inflow volume, USGS gauging station measured inflow (just upstream) of the reservoir
4	O	outflow volume, USGS gauging station measured outflow (directly downstream) of the reservoir
5	S	storage at the end of the month, provided by *Water Resources Data – Texas* (USGS)
6	E	evaporation volume during the month, computations of EV records and storage/area relationships in WRAP-SIM input file (WAM dataset)
7	Vdiff	streamflow volume difference, based on mass balance Column: $(7) = (5)_{\text{previous month}} - (5)_{\text{current month}} - (3) + (4) + (6)$
8	S2	salt load at the end of the current month Column: (8) = (9) + (10) - (11) + (12)
9	S1	salt load at the end of the previous month
10	I2	inflow salt load, USGS gauging station
11	O2	outflow salt load, USGS gauging station
12	Diff	salt load difference, based on load balance
13	Computed Storage Concentration by MC1 or MC2 methods	

Table 4.6 Volume and load balance for TDS at Possum Kingdom Reservoir using mean concentration method 1 (MC1) during 1977-79

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				489000								
1977	11	561	4984	477700	2662	-4215	1384853	1408000	3430	14400	-12177	2125
1977	12	1081	6938	467200	4188	-455	1367688	1384853	4960	20800	-1326	2142
1978	1	1319	7236	459200	942	-1141	1349171	1367688	6530	21700	-3347	2157
1978	2	2882	4270	459900	-930	1158	1358479	1349171	21400	13100	1008	2167
1978	3	4443	2253	462500	3257	3668	1375540	1358479	20800	6930	3192	2179
1978	4	5784	1190	474400	4624	11931	1393822	1375540	11600	3700	10382	2171
1978	5	13273	6609	478500	2405	-160	1434148	1393822	61600	20800	-474	2178
1978	6	18298	4011	481700	7062	-4025	1470770	1434148	61200	12400	-12177	2220
1978	7	177	4094	466500	10476	-807	1456889	1470770	1510	12900	-2491	2266
1978	8	575722	79537	555300	4420	-402965	711626	1456889	330000	220000	-855263	1558
1978	9	27959	33068	549100	4424	3333	709527	711626	85100	90100	2900	944
1978	10	14091	21225	540200	5444	3679	716328	709527	59300	55700	3201	960
1978	11	8658	12891	535400	-348	-915	736592	716328	50000	28500	-1236	990
1978	12	6532	6514	530300	3092	-2026	764738	736592	45300	14300	-2854	1033
1979	1	8231	10451	527300	-1045	-1826	800934	764738	55300	16400	-2704	1085
1979	2	5831	7226	526200	894	1189	836669	800934	45800	11100	1034	1140
1979	3	18732	10266	541000	168	6503	914027	836669	91500	19800	5658	1202
1979	4	10336	21110	533400	2262	5437	934858	914027	54500	38400	4731	1259
1979	5	65234	70562	533400	-483	4845	954274	934858	115000	99800	4216	1295
1979	6	70221	58695	538700	4853	-1373	1017648	954274	152000	86100	-2526	1345
1979	7	24740	7486	549400	6994	440	1059131	1017648	52700	11600	383	1396
1979	8	22455	14112	552700	5102	60	1116283	1059131	80200	23100	52	1444
1979	9	2122	25363	523600	7140	1280	1084996	1116283	10900	43300	1114	1496
1979	10	446	10988	507600	6330	872	1069066	1084996	3010	19700	759	1527
1979	11	2507	5655	498000	2915	-3538	1060622	1069066	9350	10300	-7494	1548
1979	12	2763	3646	499000	-741	1142	1073096	1060622	18300	6820	994	1564

Table 4. 7 Volume and load balance for TDS at Possum Kingdom Reservoir using mean concentration method 1 (MC1) during 1980-81

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1980	1	3717	9408	492300	577	-432	1076758	1073096	23400	18800	-937	1585
1980	2	3798	6605	490300	1515	2322	1096579	1076758	30400	12600	2020	1617
1980	3	2047	4655	484100	4205	613	1102902	1096579	15100	9310	534	1649
1980	4	1260	4370	478000	5588	2598	1104903	1102902	8460	8720	2261	1676
1980	5	129209	46659	559100	-2137	-3587	1263412	1104903	260000	93300	-8191	1669
1980	6	28600	47772	535400	9579	5051	1313907	1263412	144000	97900	4395	1721
1980	7	2309	36730	490600	12437	2058	1254298	1313907	18700	80100	1791	1828
1980	8	577	19440	463700	9927	1890	1216253	1254298	5110	44800	1645	1890
1980	9	101310	33150	497700	-1023	-35183	1140903	1216253	88000	77100	-86250	1789
1980	10	252565	266003	538200	5077	59015	865256	1140903	262000	589000	51354	1404
1980	11	17726	11230	542500	1990	-206	930614	865256	86400	20700	-343	1195
1980	12	37743	50700	534200	438	5094	1007747	930614	164000	91300	4433	1296
1981	1	14612	44071	503700	2311	1270	1017152	1007747	88000	79700	1105	1405
1981	2	8848	15858	497700	1634	2644	1053152	1017152	63300	29600	2301	1489
1981	3	26132	26214	505600	936	8918	1149012	1053152	137000	48900	7760	1581
1981	4	52201	13902	556300	3441	15843	1286698	1149012	150000	26100	13786	1653
1981	5	28719	45890	541400	2796	5067	1301807	1286698	96800	86100	4409	1698
1981	6	109634	104263	551100	1567	5896	1279938	1301807	182000	209000	5130	1701
1981	7	11439	37488	515000	9160	-891	1246527	1279938	45000	76300	-2111	1704
1981	8	13694	12764	506400	7240	-2290	1254520	1246527	40300	26700	-5607	1760
1981	9	9235	11300	499100	4316	-919	1254127	1254520	25800	23900	-2293	1794

Table 4.6 and Table 4.7 show the volume, load, and concentration of inflow, outflow, and storage, respectively, for total dissolved solids at Possum Kingdom reservoir, using mean concentration method 1 (MC1) during the period of 1977 to 1981. The mean storage concentration method 1 (MC1) is provided to determine volume, load, and concentration of inflow, outflow, and storage for chlorides and sulfate at Possum Kingdom Reservoir during the period of 1977 to 1981 and for TDS, chlorides and sulfate at Granbury-Whitney reservoir during the period of 1970 to 1986 shown in appendix A. The

mass balance equation is used to explain the streamflow routing. The mean monthly water balance, in ac-ft/month, is as follows;

At the Possum Kingdom reservoir,

$$I - O = S2 - S1 + E - Vdiff$$

$$1{,}769{,}774 - 1{,}288{,}850 = 499{,}100 - 489{,}000 + 167{,}683 + 303{,}142$$

$$480{,}924 = 480{,}924$$

At the Granbury-Whitney Reservoir,

$$I - O = S2 - S1 + E - Vdiff$$

$$10{,}331{,}363 - 13{,}346{,}870 = 781{,}700 - 515{,}600 + 814{,}519.33 - 4{,}096{,}126$$

$$- 3{,}015{,}507 = - 3{,}015{,}507$$

The variables in the system water volume balance are calculated independently shown in column 3 to 7 of Tables 4.6-4.7. Streamflow volume difference (Vdiff) includes any gains or losses at each reservoir which might be positive or negative. When streamflow volume difference is positive values, which is the flow-in source from watershed area and stream reaches at each reservoir, is more than the outflow. On the other hand, when streamflow volume difference is negative values, which is the flow-out source to be diverted or released, is more than inflow volume. Computed storage concentrations are tabulated in column 13 of Tables 4.6-4.7. Storage loads for a current month are determined based on the summation of inflow load, outflow load, storage concentration for the previous month, and load difference. When calculating storage load in column 8 of Tables 4.6-4.7, load difference in column 12 is the only unknown value. Monthly storage mean concentration is related to storage loads, storage streamflow volume, and the conversion factor, which are based on mass and load balance.

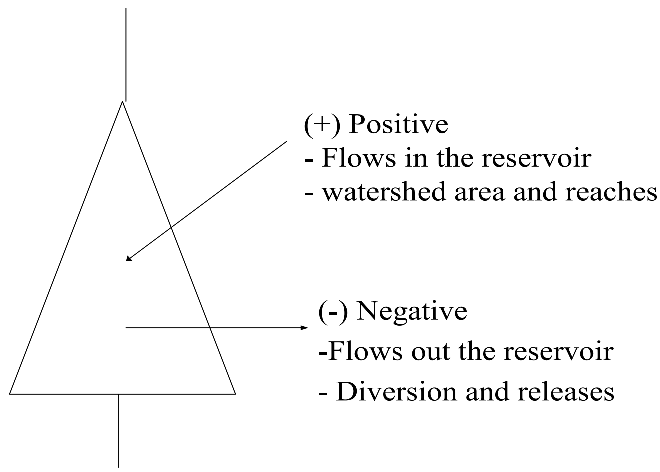

Figure 4.2 Streamflow volume difference with positive/negative value in the reservoir

Load difference (Diff) is determined by discharge volume difference (Vdiff) and mean storage concentration. Mean storage concentration is divided by two approaches following as flow sources; inflow or outflow shown in Figure 4.2. Load difference is adopted to mean concentration from watershed area and reaches with the positive value of the discharge volume difference (Vdiff). In contrast, load difference is adopted to mean storage concentration to determine salt loads with the negative value of the discharge volume difference. In this case, mean storage concentration is calculated iteratively until reservoir storage concentration is the same at the reservoir each month. If there is more inflow into the reservoir, the mean concentration to determine mean concentration from local flows for TDS load difference in column 12 of Tables 4.6-4.7 is adopted to 500 mg/l at the Possum Kingdom reservoir. On the other hand, if the more water is out of the reservoir, the mean concentration to determine the TDS load in column 8 of Tables 4.6-4.7 is set the same as the mean storage concentration in the reservoir. If there is more inflow into the reservoir, the mean concentration to determine chloride load difference in column 8 in appendix A is 100 mg/l. The mean concentration of inflow from watershed area and reach is also 100 mg/l to determine sulfate load difference in column 12 of appendix A at Possum Kingdom reservoir. The computed storage concentration in column 13 of Tables 4.6-4.7 is calculated by the equation of mean concentration method 1 (MC1). If there is more inflow into the Granbury-Whitney reservoir, 276 mg/l, 61 mg/l, and 28 mg/l are the mean concentration to determine TDS, chloride and sulfate load difference, respectively, in column 12 of appendix A. If the more water is out of the reservoir, the mean concentration to determine salt load difference in column 8 in appendix A is equal to the mean storage concentration in the Granbury-Whitney reservoir system.

Table 4.8 Volume and load balance for TDS at Possum Kingdom Reservoir using mean concentration method 2 (MC2) during 1977-79

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (tons)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			489000					1402000			
1977	11	561	477700	4984	2662	-4215	3430	1378851	2125	2125	14401
1977	12	1081	467200	6938	4188	-455	4960	1362330	2135	2135	20138
1978	1	1319	459200	7236	942	-1141	6530	1344307	2152	2152	21167
1978	2	2882	459900	4270	-930	1158	21400	1353961	2159	2159	12533
1978	3	4443	462500	2253	3257	3668	20800	1370605	2170	2170	6649
1978	4	5784	474400	1190	4624	11931	11600	1386824	2158	2158	3492
1978	5	13273	478500	6609	2405	-160	61600	1428432	2173	2173	19529
1978	6	18298	481700	4011	7062	-4025	61200	1465558	2226	2226	12138
1978	7	177	466500	4094	10476	-807	1510	1451926	2265	2265	12607
1978	8	575722	555300	79537	4420	-402965	330000	494761	2160	2160	233545
1978	9	27959	549100	33068	4424	3333	85100	550885	695	695	31241
1978	10	14091	540200	21225	5444	3679	59300	590495	769	769	22191
1978	11	8658	535400	12891	-348	-915	50000	624907	832	832	14578
1978	12	6532	530300	6514	3092	-2026	45300	659951	888	888	7868
1979	1	8231	527300	10451	-1045	-1826	55300	699510	947	947	13456
1979	2	5831	526200	7226	894	1189	45800	736276	1002	1002	9842
1979	3	18732	541000	10266	168	6503	91500	817294	1068	1068	14903
1979	4	10336	533400	21110	2262	5437	54500	842941	1134	1134	32548
1979	5	65234	533400	70562	-483	4845	115000	849508	1165	1165	111727
1979	6	70221	538700	58695	4853	-1373	152000	903264	1204	1204	96079
1979	7	24740	549400	7486	6994	440	52700	943560	1248	1248	12703
1979	8	22455	552700	14112	5102	60	80200	998928	1296	1296	24873
1979	9	2122	523600	25363	7140	1280	10900	964452	1341	1341	46246
1979	10	446	507600	10988	6330	872	3010	947686	1363	1363	20369
1979	11	2507	498000	5655	2915	-3538	9350	939653	1385	1385	10651
1979	12	2763	499000	3646	-741	1142	18300	951816	1395	1395	6913

Table 4.9 Volume and load balance for TDS at Possum Kingdom Reservoir using mean concentration method 2 (MC2) during 1980-81

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1980	1	3717	492300	9408	577	-432	23400	956264	1416	1416	18116
1980	2	3798	490300	6605	1515	2322	30400	975270	1445	1445	12973
1980	3	2047	484100	4655	4205	613	15100	981440	1477	1477	9346
1980	4	1260	478000	4370	5588	2598	8460	982753	1500	1500	8913
1980	5	129209	559100	46659	-2137	-3587	260000	1140634	1510	1510	95815
1980	6	28600	535400	47772	9579	5051	144000	1186638	1562	1562	101429
1980	7	2309	490600	36730	12437	2058	18700	1124066	1655	1655	82671
1980	8	577	463700	19440	9927	1890	5110	1085477	1702	1702	44984
1980	9	101310	497700	33150	-1023	-35183	88000	1021449	1671	1671	75294
1980	10	252565	538200	266003	5077	59015	262000	852635	1302	1302	470934
1980	11	17726	542500	11230	1990	-206	86400	920284	1207	1207	18427
1980	12	37743	534200	50700	438	5094	164000	997601	1308	1308	90146
1981	1	14612	503700	44071	2311	1270	88000	1001611	1416	1416	84853
1981	2	8848	497700	15858	1634	2644	63300	1034494	1494	1494	32215
1981	3	26132	505600	26214	936	8918	137000	1121387	1576	1576	56169
1981	4	52201	556300	13902	3441	15843	150000	1251237	1636	1636	30921
1981	5	28719	541400	45890	2796	5067	96800	1247179	1672	1672	104303
1981	6	109634	551100	104263	1567	5896	182000	1200020	1645	1645	233167
1981	7	11439	515000	37488	9160	-891	45000	1159890	1629	1629	83055
1981	8	13694	506400	12764	7240	-2290	40300	1165817	1678	1678	29128
1981	9	9235	499100	11300	4316	-919	25800	1163271	1705	1705	26198

Table 4.8 and Table 4.9 show volume, load and concentration of inflow, outflow and storage for total dissolved solids at Possum Kingdom reservoir, using mean concentration method 2 (MC2) during the period of 1977-81. As indicated in Appendix A, the mean storage concentration method 2 (MC2) is used to determine salt loads and concentrations of outflow and storage for chlorides and sulfates at Possum Kingdom reservoir during the period of 1977-81. The mass and load balance details at Granbury-

Whitney reservoir are shown in appendix A, using MC2 to determine storage load. The data for MC2 approach is the same as the data for MC1 by the USGS. Water volume is also equal both MC1 and MC2. Volume Streamflow volume difference (Vdiff) includes any gains or losses at each reservoir. Storage concentration in column 10 in Tables 4.8-4.9 is associated with storage load in tons and storage volume in ac-ft/month, which is calculated by MC2. The reservoir outflow concentration in column 11 is set equal to the storage concentration in column 10 of Tables 4.8-4.9. Storage loads for a current month are determined based on the summation of inflow load, outflow load, storage concentration for the previous month, and load difference. The unknown value to calculate storage load is only load difference. Monthly mean storage concentration is related to storage loads, storage streamflow volume, and the conversion factor, which is based on mass and load balance.

As indicated in Figure 4.2, streamflow volume difference (Vdiff) has a positive or negative value in the reservoir each month. When there is more inflow into the Possum Kingdom reservoir, the mean concentration from inflow, 500 mg/l, is adopted to determine storage load for total dissolved solids. On the other hand, the mean concentration to determine storage load is equal to the storage mean concentration at Possum Kingdom reservoir. Mean storage concentration is calculated iteratively until reservoir storage concentration is the same at the reservoir each month. The mean concentration from watershed area and reaches, 340 mg/l is adopted to determine storage load for chloride if more water comes in the Possum Kingdom reservoir. Generally, watershed salinity concentration range of runoff is approximately 100 mg/l to 500 mg/l at Navasota River above Groesbeck. For the mean TDS concentration from watershed area and reaches, 100 mg/l is adopted to determine storage load for sulfate, which is between 100 mg/l and 500 mg/l. At Granbury-Whitney reservoir, the mean concentration using MC2 method is 269 mg/l, 63 mg/l, and 27 mg/l to determine natural salt pollution loads of the TDS, chloride, and sulfate if there is more inflow into the reservoir. The concentrations from watershed areas are based on the mass balance. As mentioned previously, if there is more outflow in the reservoir, the mean concentration to determine salt loads is set equal to the mean storage concentration. Two alternative approaches have the same volume mass balance in ac-ft/month. However, the Table 4.10 shows different load budget for TDS, CL, and SO4 to determine mean concentration using MC1 method and MC2 method.

Table 4.10 Load balance using mean storage concentration methods MC1 and MC2 at the Possum Kingdom Reservoir

Salt constituent	Load Balance	MC1(tons)	MC2(tons)
TDS	Load in	3,385,060	3,385,060
	Load out	2,671,680	2,541,446
	Load in storage change	- 182,055	- 238,729
	Load difference	- 895,435	- 1,082,343
CL	Load in	1,406,029	1,406,029
	Load out	1,076,510	1,035,439
	Load in storage change	- 63,774	74,085
	Load difference	- 393,293	- 324,831
SO4	Load in	725,930	725,930
	Load out	514,678	537,657
	Load in storage change	14,986	- 40,474
	Load difference	- 196,266	- 228,747

Table 4.11 Observed vs computed concentration
for the total dissolved solids at Possum Kingdom Reservoir during 1977-79

YEAR	M	Observed Outflow Concentration (mg/l)	MC1	MC2
			Computed Storage Concentration (mg/l)	Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)
1977	11	2125	2125	2125
1977	12	2205	2142	2135
1978	1	2206	2157	2152
1978	2	2256	2167	2159
1978	3	2262	2179	2170
1978	4	2287	2171	2158
1978	5	2315	2178	2173
1978	6	2274	2220	2226
1978	7	2318	2266	2265
1978	8	2034	1558	2160
1978	9	2004	944	695
1978	10	1930	960	769
1978	11	1626	990	832
1978	12	1615	1033	888
1979	1	1154	1085	947
1979	2	1130	1140	1002
1979	3	1418	1202	1068
1979	4	1338	1259	1134
1979	5	1040	1295	1165
1979	6	1079	1345	1204
1979	7	1140	1396	1248
1979	8	1204	1444	1296
1979	9	1256	1496	1341
1979	10	1319	1527	1363
1979	11	1340	1548	1385
1979	12	1376	1564	1395

Table 4.12 Observed vs computed concentration
for the total dissolved solids at Possum Kingdom Reservoir during 1980-81

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)
1980	1	1470	1585	1416
1980	2	1403	1617	1445
1980	3	1471	1649	1477
1980	4	1468	1676	1500
1980	5	1471	1669	1510
1980	6	1507	1721	1562
1980	7	1604	1828	1655
1980	8	1695	1890	1702
1980	9	1711	1789	1671
1980	10	1629	1404	1302
1980	11	1356	1195	1207
1980	12	1324	1296	1308
1981	1	1330	1405	1416
1981	2	1373	1489	1494
1981	3	1372	1581	1576
1981	4	1381	1653	1636
1981	5	1380	1698	1672
1981	6	1474	1701	1645
1981	7	1497	1704	1629
1981	8	1539	1760	1678
1981	9	1556	1794	1705

Table 4.11 and Table 4.12 show observed and computed concentration for the total dissolved solid at Possum Kingdom Reservoir during 1977-1981. As indicated in the Figures 4.3-4.8, the measured and computed outflow concentrations of each salt constituent at Possum Kingdom reservoir are plotted based on the locations of the USGS gauging station 08088000 and the USGS gauging station 08088600.

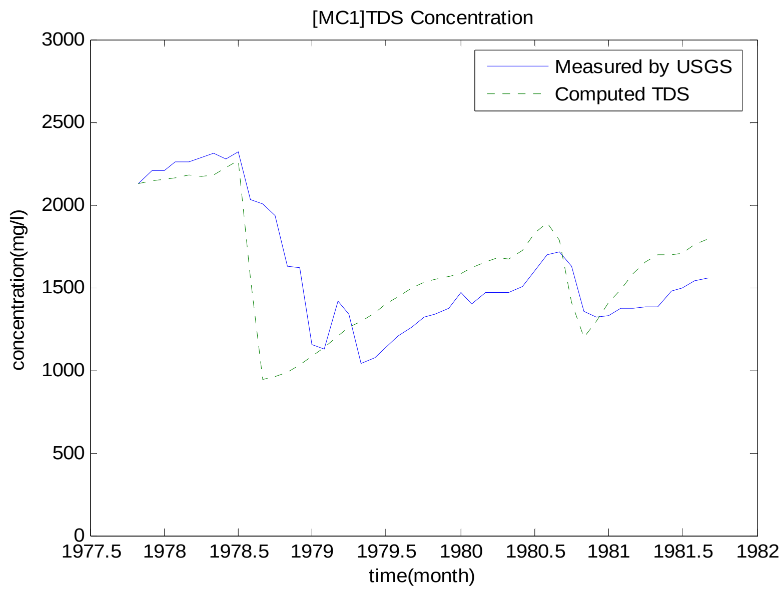

Figure 4.3 TDS concentrations at Possum Kingdom Reservoir for MC1 mean storage and observed releases

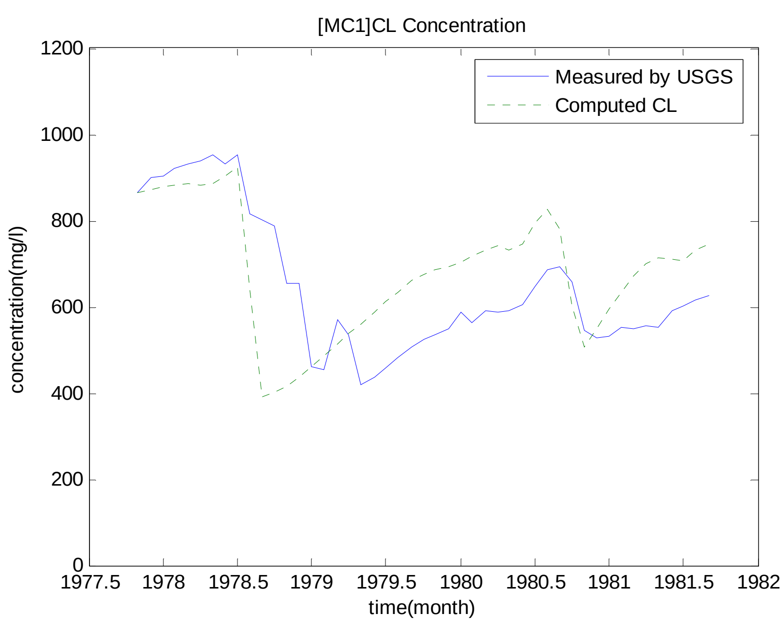

Figure 4.4 Chloride concentrations at Possum Kingdom Reservoir for MC1 mean storage and observed releases

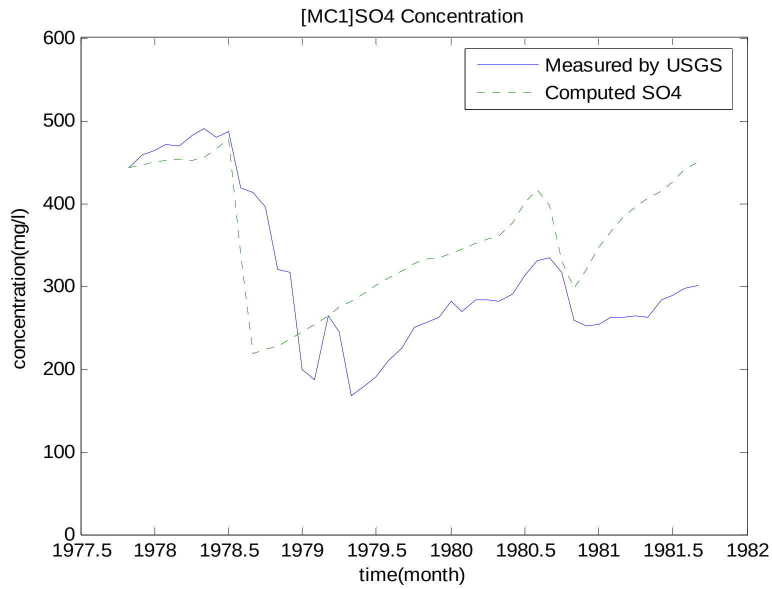

Figure 4.5 Sulfate concentrations at Possum Kingdom Reservoir for MC1 mean storage and observed releases

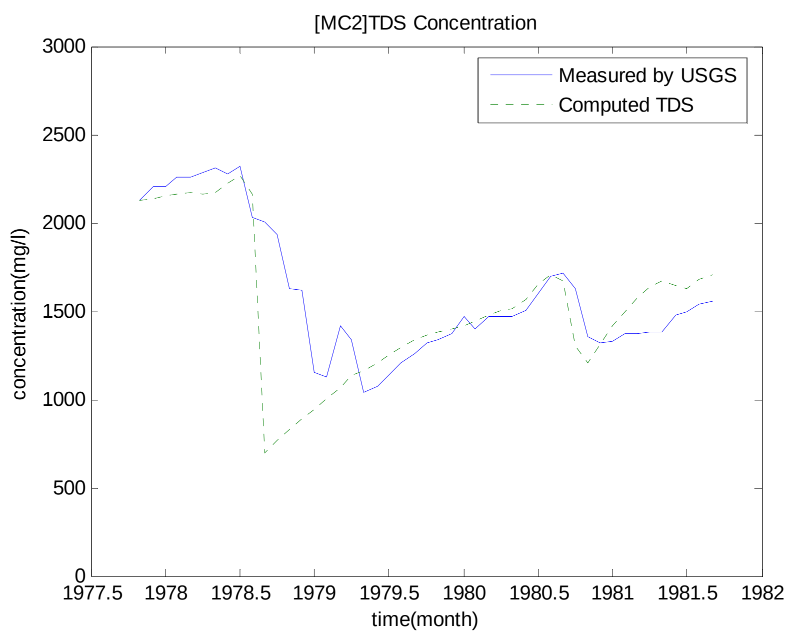

Figure 4.6 TDS concentrations at Possum Kingdom Reservoir for MC2 mean storage and observed releases

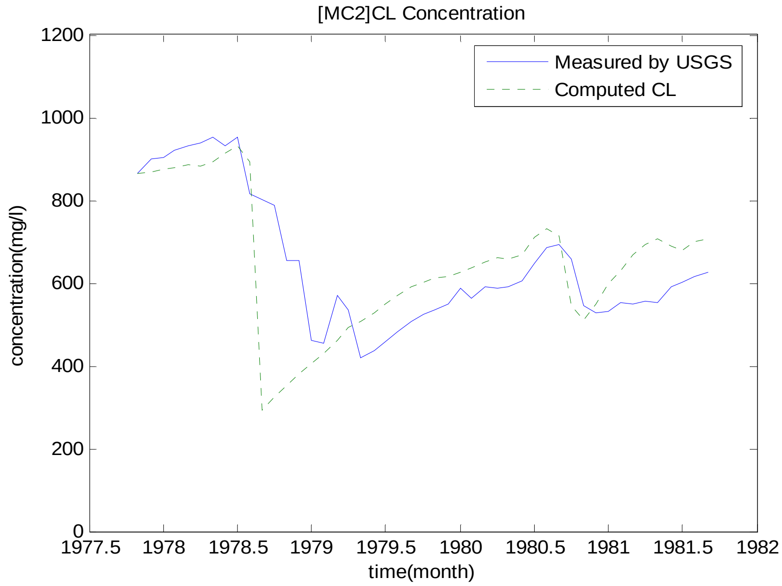

Figure 4.7 Chloride concentrations at Possum Kingdom Reservoir for MC2 mean storage and observed releases

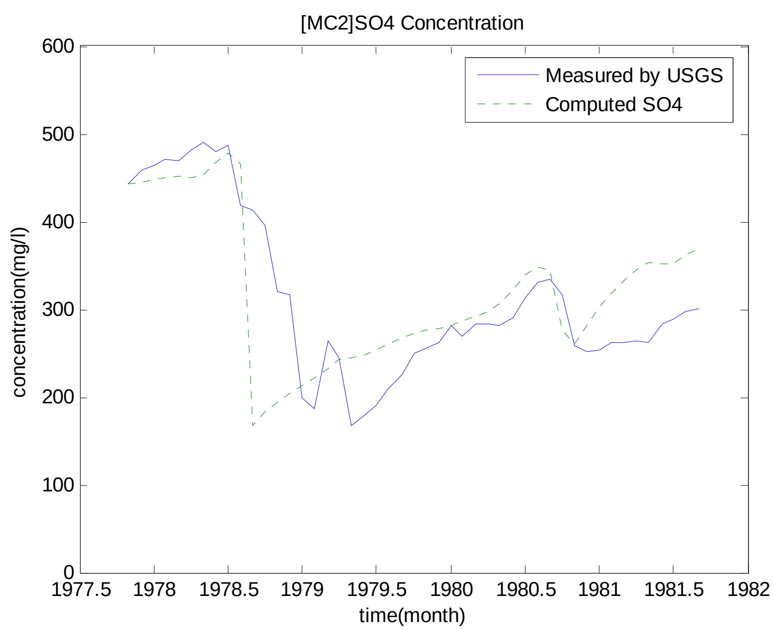

Figure 4.8 Sulfate concentrations at Possum Kingdom Reservoir for MC2 mean storage and observed releases

The same procedure is applied for Granbury-Whitney reservoir. The Table 4.13 shows load balance details of each salinity constituent using the mean concentration method 1 and 2 at Granbury-Whitney reservoir.

Table 4.13 Load balance using mean concentration methods MC1 and MC2 at Granbury-Whitney Reservoir

Salinity source	Load Balance	MC1(ton)	MC2(ton)
TDS	Load in	18,120,280	18,120,280
	Load out	18,302,975	18,302,969
	Load in storage change	768,749	854,547
	Load difference	951,444	1,037,236
CL	Load in	7,038,675	7,038,675
	Load out	6,854,300	6,852,328
	Load in storage change	265,207	335,487
	Load difference	80,832	149,140
SO4	Load in	3,635,373	3,635,373
	Load out	3,517,726	3,519,062
	Load in storage change	140,830	163,166
	Load difference	23,183	46,855

The Figures 4.9-4.14 shows the observed and computed outflow concentration of the TDS, CL, and SO4 at Granbury–Whitney reservoir, which are based on load balance equation.

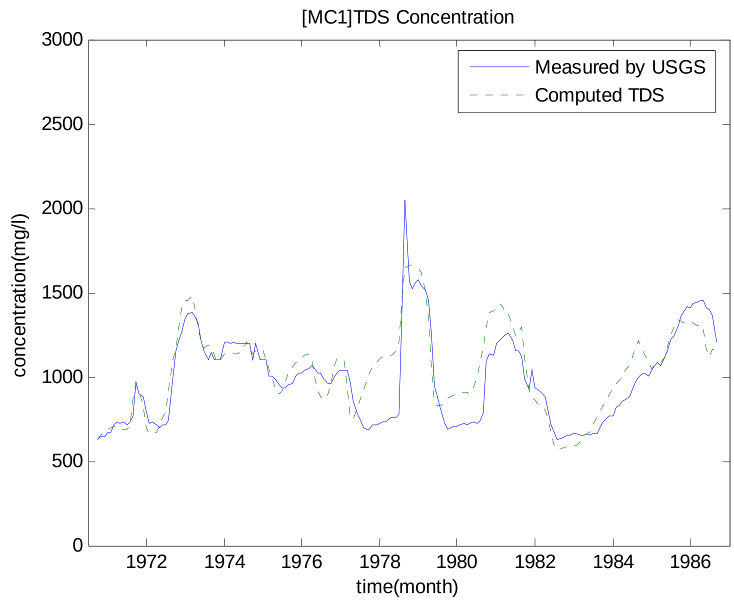

Figure 4.9 TDS concentrations at Granbury-Whitney Reservoir for MC1 mean storage and observed releases

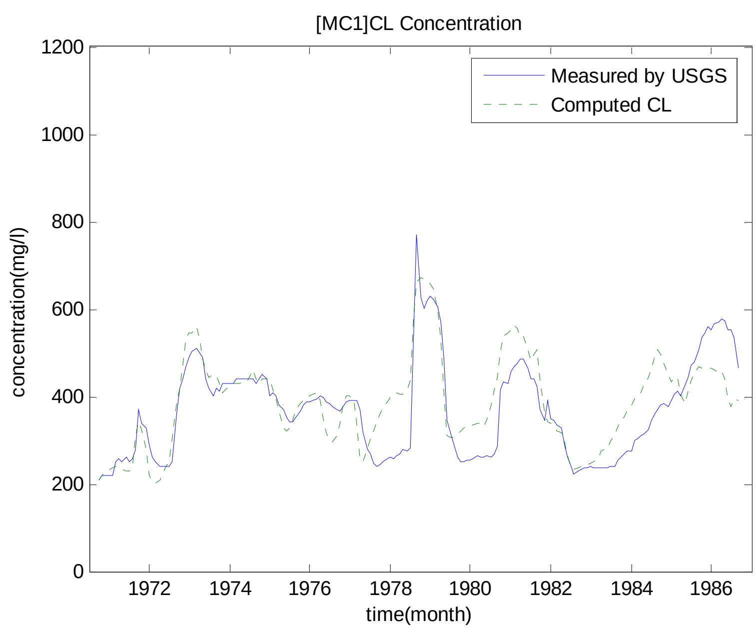

Figure 4.10 Chloride concentrations at Granbury-Whitney Reservoir for MC1 mean storage and observed releases

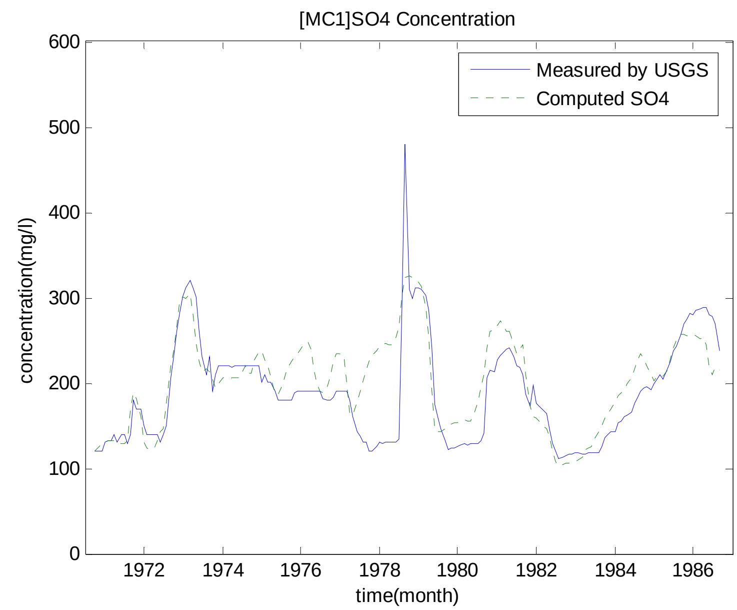

Figure 4.11 Sulfate concentrations at Granbury-Whitney Reservoir for MC1 mean storage and observed releases

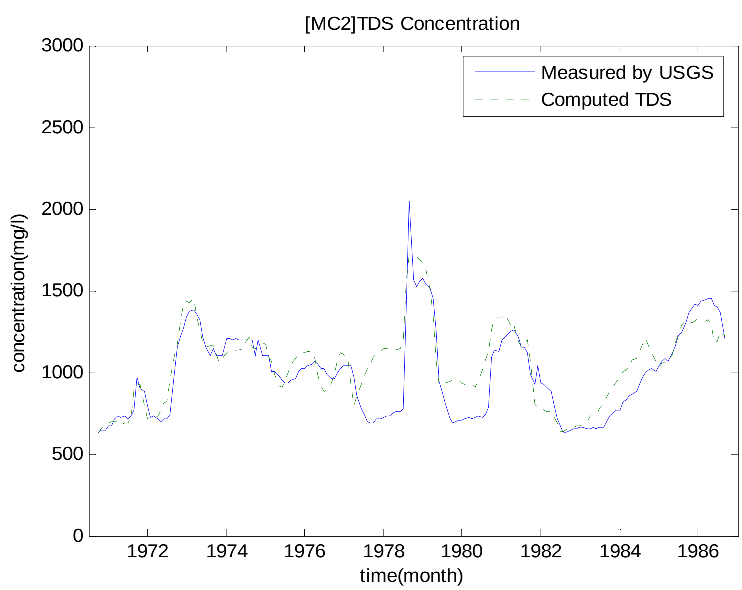

Figure 4.12 TDS concentrations at Granbury-Whitney Reservoir for MC2 mean storage and observed releases

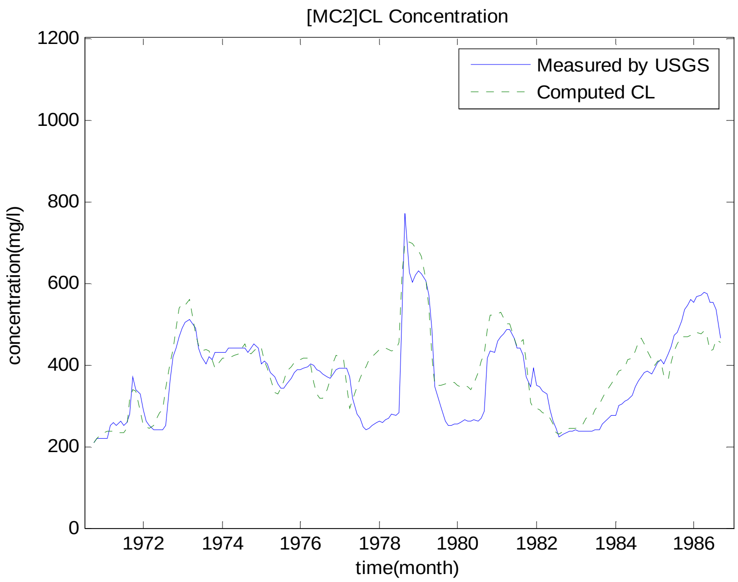

Figure 4.13 Chloride concentrations at Granbury-Whitney Reservoir for MC2 mean storage and observed releases

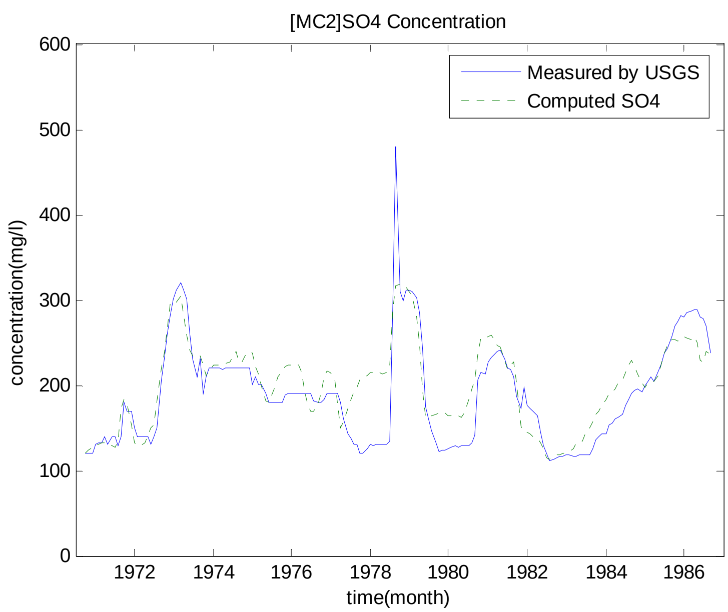

Figure 4.14 Sulfate concentrations at Granbury-Whitney Reservoir for MC2 mean storage and observed releases

Lag Application in the Reservoir

In the real-world, stream inflows and their salt loads may require long periods of time to move through a reservoir and reach the outlet. Salt concentrations vary spatially, both horizontally, and vertically, throughout a reservoir. The monthly lag represents physically the time required for the salt load to reach the reservoir outlet once it has entered the reservoir system. The inflow load in a particular month leaves over multiple months. The calculations are based on the premise of complete mixing at each study location. The lag is based on a constant time step in months. The timing of the inflow load to determine outflow concentration is calculated by lag parameters with the monthly time steps. Several lag applications based on lag parameters is applied until the calculated storage concentration fits observed outflow concentration. The calculated storage concentration is compared with the observed concentration during specific periods where data is available from the USGS. The model is applied each month to obtain the method which best simulates the true reservoir conditions.

Table 4.14 Correlation coefficient of each lagged month for TDS, CL, and SO4 at Possum Kingdom Reservoir, using MC1 and MC2 methods

R	MC1			MC2		
Lag(month)	TDS	CL	SO4	TDS	CL	SO4
0	0.657	0.585	0.573	0.683	0.585	0.532
1	0.752	0.683	0.680	0.770	0.683	0.657
2	0.820	0.754	0.765	0.834	0.754	0.783
3	0.846	0.787	0.808	0.836	0.787	0.853
4	0.841	0.791	0.816	0.841	0.791	0.889
5	0.791	0.752	0.776	0.743	0.752	0.822
6	0.672	0.644	0.659	0.621	0.644	0.736

Table 4.15 Correlation coefficient of each lagged month for TDS, CL, and SO4 at Granbury-Whitney Reservoir, using MC1 and MC2 methods

R	MC1			MC2		
Lag(month)	TDS	CL	SO4	TDS	CL	SO4
0	0.858	0.816	0.788	0.843	0.816	0.849
1	0.874	0.832	0.811	0.859	0.832	0.857
2	0.849	0.804	0.792	0.829	0.804	0.819
3	0.806	0.757	0.753	0.788	0.757	0.773
4	0.741	0.687	0.689	0.727	0.687	0.706
5	0.662	0.601	0.613	0.651	0.601	0.624
6	0.576	0.511	0.528	0.568	0.511	0.534

For Possum Kingdom and Granbury-Whitney reservoir, the correlation coefficient (R) between measured outflow concentration and computed storage concentration is shown in Table 4.14 and Table 4.15 by lag months for MC methods and water quality constituents. The outflow concentration is compared with the observed concentrations considering a lag of one month to 6 months during the period of the year 1977-81. The correlation coefficient between observed and computed concentration started decreasing when the reservoir lag timing was greater than 4 months at Possum Kingdom reservoir. The computed storage concentration for the 4 lagged month-time-step is the best fit for the observed data at Possum Kingdom reservoir during the corresponding period. True mean concentration of TDS, CL, and SO4 are best represented by the 4 lagged months at Possum Kingdom reservoir and the 1 lagged month at Granbury-Whitney reservoir in both methods MC1 and MC2. Then these values with highest correlation coefficient are used to determine mean concentration at Possum Kingdom reservoir shown in Figure 4.15 through Figure 4.20.

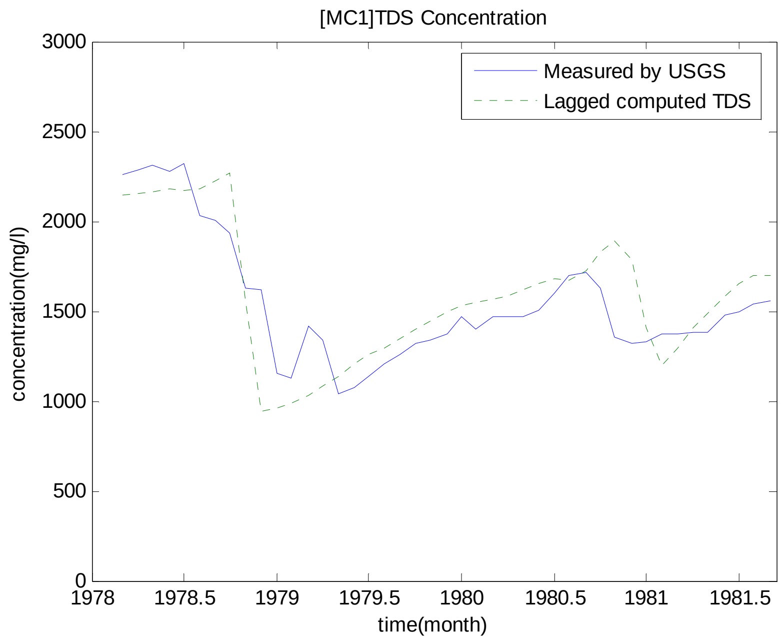

Figure 4.15 TDS concentrations at Possum Kingdom Reservoir for lagged MC1 mean storage and observed releases

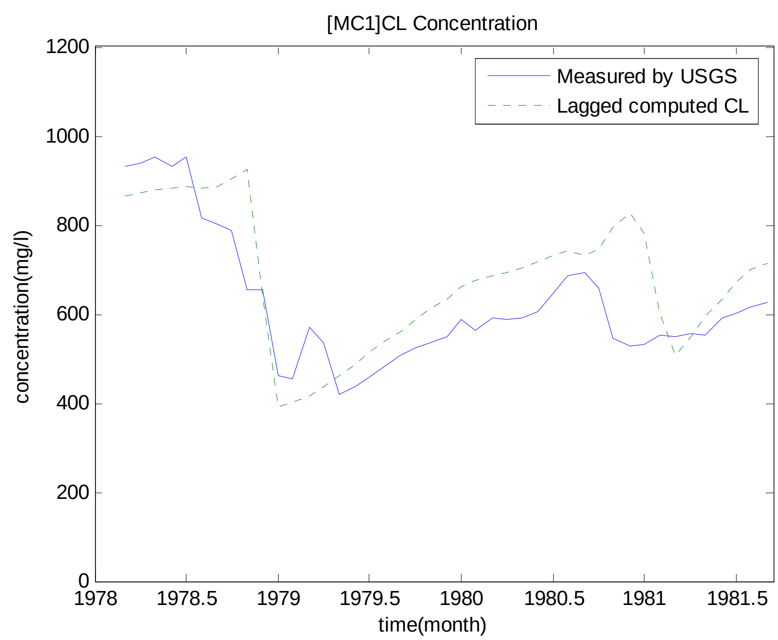

Figure 4.16 Chloride concentrations at Possum Kingdom Reservoir for lagged MC1 mean storage and observed releases

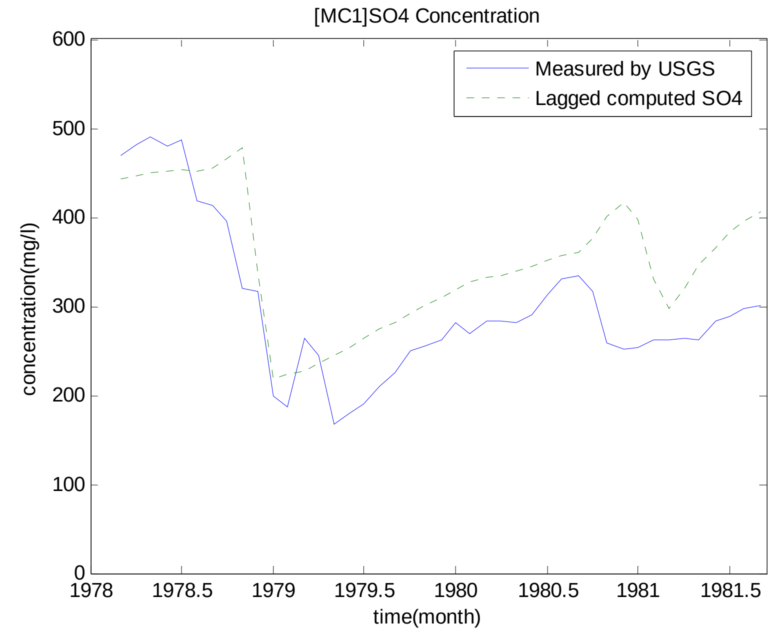

Figure 4.17 Sulfate concentrations at Possum Kingdom Reservoir for lagged MC1 mean storage and observed releases

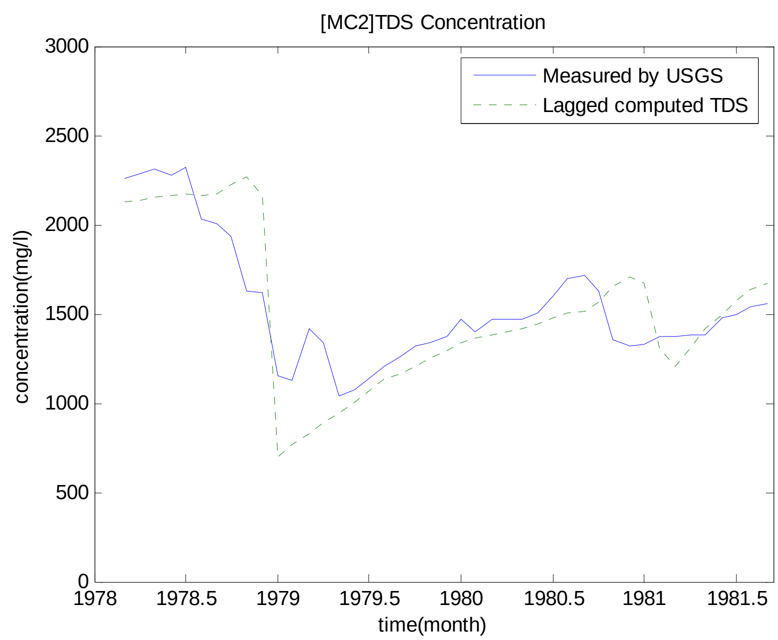

Figure 4.18 TDS concentrations at Possum Kingdom Reservoir for lagged MC2 mean storage and observed releases

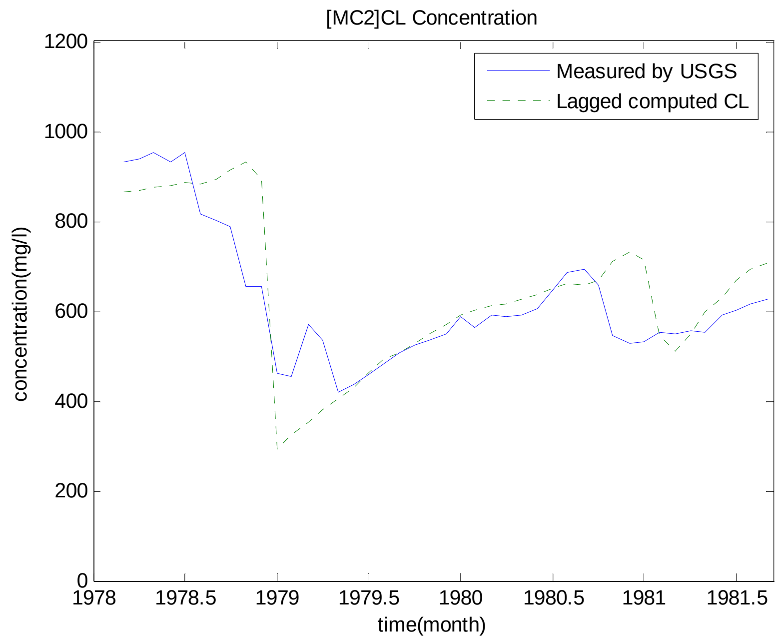

Figure 4.19 Chloride concentrations at Possum Kingdom Reservoir for lagged MC2 mean storage and observed releases

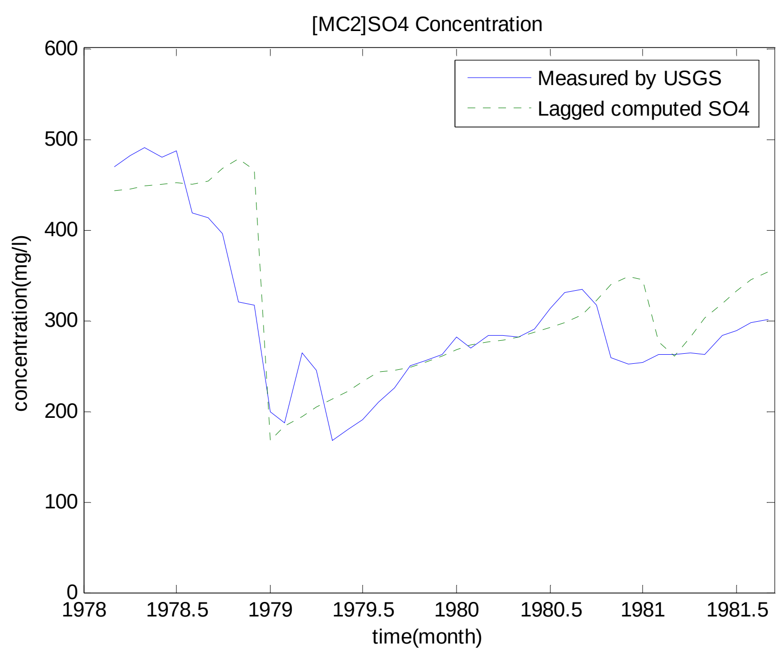

Figure 4.20 Sulfate concentrations at Possum Kingdom Reservoir for lagged MC2 mean storage and observed releases

The same procedures to determine the mean concentration for each water quality constituent are iteratively suggested for the Granbury-Whitney reservoir. For this study area, the correlation coefficient is increased as lag timing in month is closet 1. Therefore, the highest R is obtained when lag month is one. Figures 4.21-4.26 shows the observed and lagged computed concentration and best explains salinity routing at the Granbury-Whitney reservoir in the Brazos River Basin. At Granbury-Whitney Reservoir, a comparison of TDS observed outflow concentration and mean storage concentration for MC1 and MC2 are tabulated appendix A. Also, comparisons of observed outflow concentration and mean storage concentration for MC1 and MC2 for chlorides and sulfate at Granbury-Whitney reservoir during the period of 1970 to 1986 are shown in appendix A.

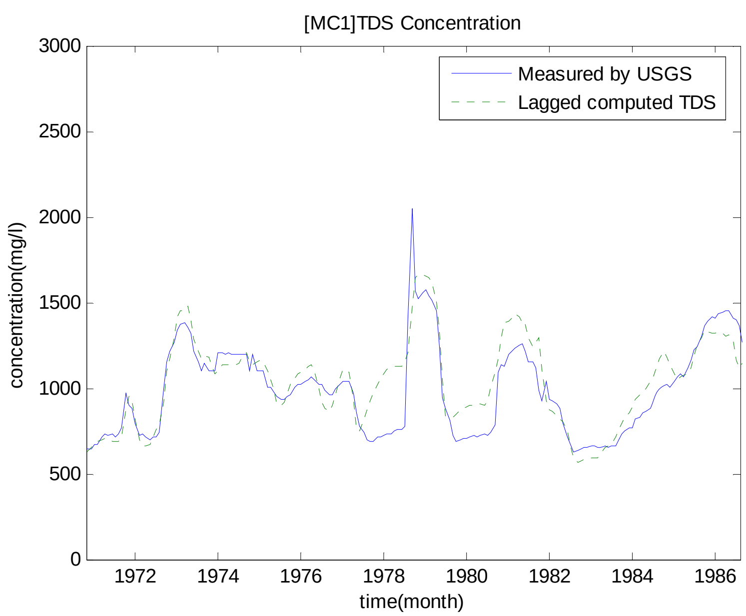

Figure 4.21 TDS concentrations at Granbury -Whitney Reservoir
for lagged MC1 mean storage and observed releases

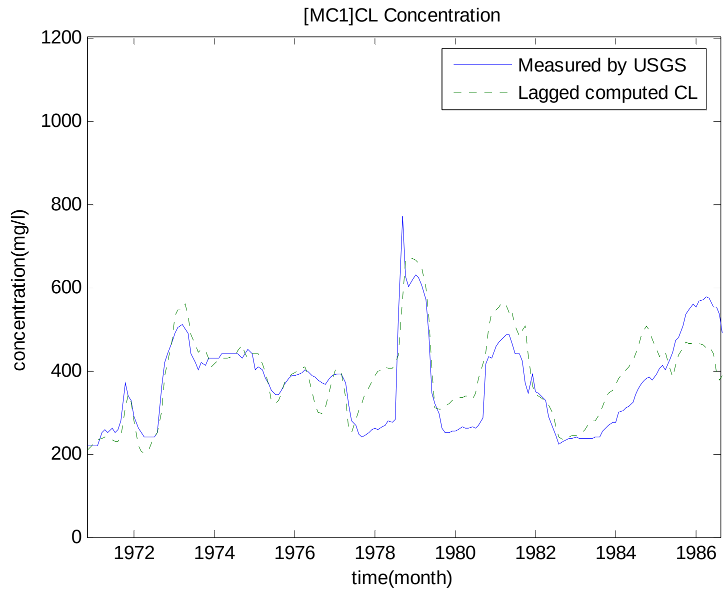

Figure 4.22 Chloride concentrations at Granbury -Whitney Reservoir for lagged MC1 mean storage and observed releases

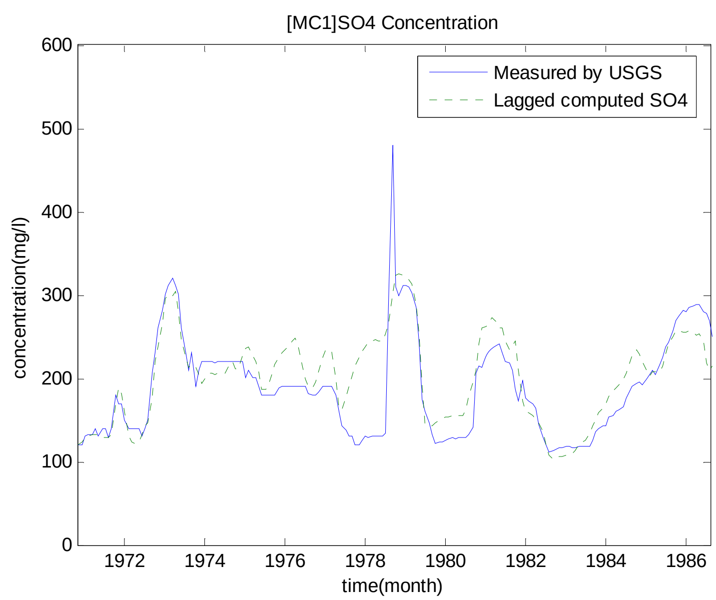

Figure 4.23 Sulfate concentrations at Granbury -Whitney Reservoir for lagged MC1 mean storage and observed releases

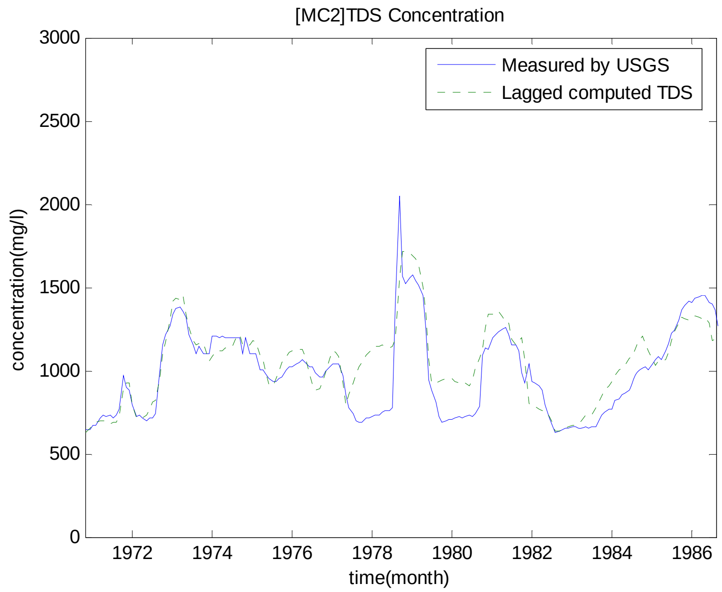

Figure 4.24 TDS concentrations at Granbury -Whitney Reservoir for lagged MC2 mean storage and observed releases

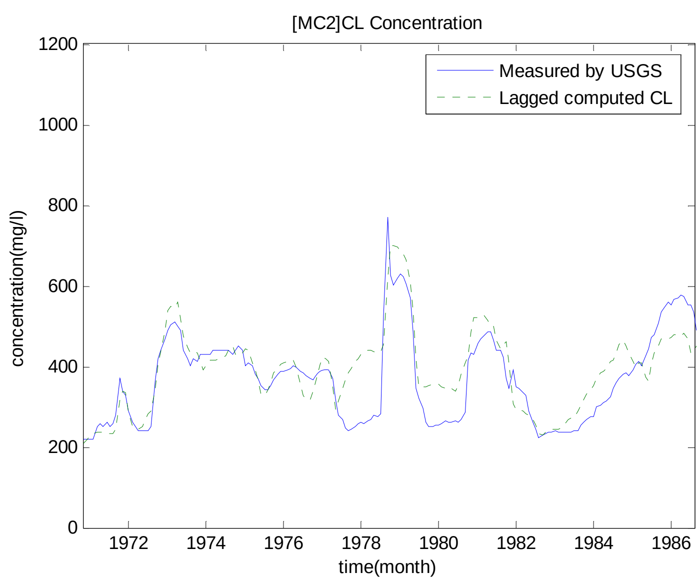

Figure 4.25 Chloride concentrations at Granbury -Whitney Reservoir for lagged MC2 mean storage and observed releases

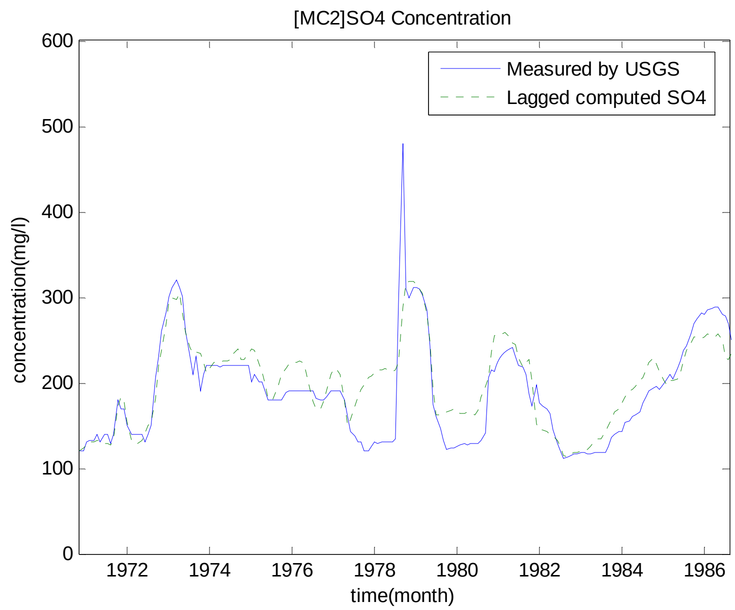

Figure 4.26 Sulfate concentrations at Granbury -Whitney Reservoir for lagged MC2 mean storage and observed releases

CHAPTER V

SALINITY ROUTING IN WRAP

Salinity Component of WRAP Modeling System

The Water Rights Analysis Package (WRAP) simulates management of the water resources of a river basin or multiple-basin region under a priority-based water allocation system (Wurbs 2005, 2006a, 2006b). The model facilitates assessments of hydrologic and institutional water availability and reliability in satisfying requirements for instream flows, water supply diversions, hydroelectric energy generation, and reservoir storage.

The Texas Water Availability Modeling (WAM) System consists of the generalized WRAP simulation model and hydrology and water rights input datasets for the 23 river basins of Texas (Wurbs 2006a). The Texas Legislature enacted comprehensive water management legislation in 1997 that authorized development of the WAM System and established a process of regional water resources planning. The Texas Commission on Environmental Quality (TCEQ) was the lead agency for implementing the WAM System in conjunction with administration of the state’s water rights permit system. The modeling system is routinely applied by applicants in preparation of permit applications and by TCEQ staff in evaluating applications. The Texas Water Development Board (TWDB) is the lead agency for regional and statewide planning activities, which represent another major application of the WAM System.

In WRAP-SALT, salt loads entering a reservoir are completely mixed within a monthly computational time step. The thesis research project continues the Brazos River Basin simulation studies. The effects of improvements in salt routing methods on the various aspects of simulation results are evaluated. The research also provides further testing of the WRAP salinity modeling capabilities in general.

The WRAP-SALT simulation includes 3,892 control points of WAM dataset in the Brazos River Basin. Flow volumes are read from the WRAP-SIM output file. The period of simulation has 696 months starting in the year 1940. The complete WAM System Brazos Basin dataset contains 650 reservoirs and over 1,200 water rights. Salt loads or concentrations at four stations have the input file (extension SIN) of WRAP-SALT as shown in Table 5.1.

Table 5.1 Organization of WRAP simulation components

WRAP simulation	SIM/SIMD	SALT	TABLES
Input	bwam3.DAT bwam3.FLO(IN records) bwam3.EVA(EV records) bwam3.DIS(FD,FC,WP records) bwam3.BES	bwam3.OUT bwam3.SIN Bwam3.BRS bwam3.BRC	bwam3.DAT bwam3.OUT bwam3.SAL bwam3.TIN
Output	bwam3.OUT	bwam3.SAL bwam3.SMS	bwam3.TAB Bwam3.TMS

Krishnamurthy (2005) developed WRAP-SALT salinity input datasets for the Brazos River Basin reflecting conditions with and without the salt control impoundments previously proposed by the Corps of Engineers. The salinity input is used in combination with the TCEQ WAM System Brazos River Basin dataset to perform a water availability study.

The fundamental simulation computations for WRAP-SALT are volume and load balance equations. The definition of change in reservoir storage is the volume difference between inflow streamflow and outflow streamflow. The change in reservoir storage load is the load difference between inflow load and outflow load. The WRAP-SALT model runs monthly simulations at each control point. The WRAP-SIM output data such as diversion shortage, diversion target, net evaporation, reservoir storage content, return flow, naturalized flow, regulated flow, channel loss credit and channel loss provides the WRAP-SALT input data. All simulation datasets and results are mainly based on a monthly time series.

Organization of WRAP-SALT

A simulation begins with development of the necessary input datasets. WRAP-SALT combines water quantity data with concentrations or loads of inflows. A WRAP SIM/SIMD simulates water quantities through the river/reservoir system. A WRAP-SALT simulates water quality regarding salt constraints using the results of the WRAP SIM/SIMD simulations. *TABLES* organizes and summarizes volumeous simulation results.

- Prior to beginning the three computational loops -

1. The required *SIM* input (DAT) and output (OUT) and *SALT* input (SIN) and output (SAL, SMS) files are initiated.
2. The optional beginning reservoir storage volume (BRS) and concentration (BRC) files are initiated after reading *JC* 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 *CS* 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 downstream *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 5.1 WRAP-SALT simulation algorithm

The WRAP-SALT simulation repeats within a constituent loop, monthly loop, and control point loop for up to 15 different water quality constituents. The model simulation is based on the monthly time step. Figure 5.1 shows the outline of the WRAP-SALT simulation algorithm (Wurbs et al. 2006). *Reference* and *Users manuals* of the *Expanded WRAP modeling capabilities Conditional Reliability, Sub-Monthly Time Step, Flood Control and Salinity* mention about variables and their details.

Volume, loads, and concentrations of inflows, outflows, and reservoir storage at each control point are included in the WRAP-SALT output. The salt load and water volume are based on the mass balance at each control point.

TABLES routines read the WRAP-SALT results in the SAL file, provides *TABLES*, and rearranges data in alternative formats. The *TABLES* input records are entered in a file with the file extension TIN. The 8SAL, 8FRE, 8FRQ, and 8REL records are components of the *TABLES* input file (TIN file). The 8SAL record and time series *TABLES* have the same format as the 2NAT, 2REG, 2STO, and other time series *TABLES*. Also, the 8FRE and 8FRQ records have the same format of the 2FRE and 2FRQ records. In addition to the 2REL record table, the 8REL record table extends reliabilities with and without considering salinity constraints. Input records build *TABLES* in the same optional formats. The only difference is the selected variable to be tabulated, the variable of input records, is linked to a control point, water right, and/or reservoir. The 8SAL record develops time series *TABLES* for volumes, salt loads, and concentrations of the specific control point inflows, storage, or outflows in three alternative formats: each time series organized into a table with annual rows and monthly columns with headings, each time series variable of interest tabulated as one column of a table, and each times series variable of interest stored as a HEC-DSS record. The 8REL record creates a volume and period reliability table including the percentage of months during the simulation for which a specified demand target is met without shortage under the maximum allowable concentration limit. The 8FRE records create a frequency relationship table for volume, load, or concentration and the 8FRQ records also develop frequency *TABLES* for specified volume, load, or concentration. Period reliability (Rp) is defined as the percentage of months during the simulation for which a specified demand target is met without shortage. Period reliability is represented as follows:

$$Rp = \left(\frac{n}{N}\right)100\%$$

In which, n = the number of months during the simulation for which the demand is met, and N = the total number of months in a simulation.

Volume reliability (Rv) is defined as the percentage of the total demand volume that can be actually supplied. Volume reliability is computed as follows:

$$Rv = \left(\frac{n}{N}\right)100\%$$

In which, n = the number of months during the simulation for which the demand is met, N = the total number of months in a simulation.

The 8FRE record determines the mean, standard deviation, and frequency relationships of volume, load, or concentration for inflow, outflow or storage associated with a specified control point or the reservoir storage. The frequencies are defined as the percentage of months in the simulation for which the flow or storage equaled or exceeded the amount. The specified frequency is set based on 100%, 99%, 98%, 95%, 90%, 75%, 60%, 50%, 40%, 25%, and 10% in the *TABLES* output file.

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

In which, n = the number of months equaled or exceeded, and N = the total number of months during the period of simulation.

The 8FRQ record also develops a frequency relationship for volume, load or concentration which is associated with a specified control point or the reservoir storage. The frequencies associated with up to seven user-specified concentrations are calculated. The 8FRQ and 8FRE records both provide frequency relationships for the specific control point; however, the 8FRE table provides the frequency relationship for control points or water rights set by the user. Each 8FRQ table is limited to a single control point under a specific concentration. The 8SUM records summarize the mean monthly volume, mean monthly load, and mean monthly concentration for the constituent selected to build a table.

Lag Concept in Salinity Routing

In the WRAP-SALT modeling strategy, the concentration of water supply diversions, spills, and releases leaving reservoir storage is 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. The WRAP-SALT simulation procedures are based on the premise of complete mixing at each control point. However, in the new routing method, the timing of the load inflows used to determine outflow concentrations are set by lag parameters. The lag options are based on the premise that salt entering the reservoir in a particular month reaches 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 begin LAG months after the month in which the quantity of salt entered the reservoir.

The lag options are activated for analysis for control points with significant reservoir storage. The lag parameters, LAG1(cp) and LAG2(cp), for the specific control point are judgmental and determined by basis on understanding study area. Lag parameters may be treated as calibration parameters during specific periods when observed data are available for calibration. They are determined by calibration for each reservoir with high correlation values between observed data and simulation data. The retention time option also allows the model to be applied without calibration if necessary.

Two options are incorporated into WRAP-SALT for setting the LAG parameter. In one option, the model-user sets a constant LAG that is applied during every month of the simulation. This option requires calibration studies to determine the LAG. In the second option, a variable LAG is computed within the model in each month based on the concept of retention time. Retention time is a representation of the time required for a monthly volume of water and its salt load to flow through a reservoir and is computed as follows:

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

The lag is the retention time multiplied by a factor which is treated as a calibration parameter. The LAG of CP record has two lag parameters: LAG1(cp) and LAG2(cp). The LAG1(cp) default is 0, which means the lag option is not activated. LAG1(cp) is based on retention time. The outflow concentration is equal to storage concentration for the applied lag month. LAG2(Cp) is the multiplier factor with a positive number or a blank, which is not activated for this option. A negative number for LAG2(cp) is flow retention option of computing lag not used, and LAG is considered as only LAG1(cp).

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

In which, ZLAG = flow retention times (= storage volume/flow rate) for various lengths, L of time extending back from the current month that are used to compute LAG, BSTO = beginning-of-month storage volume for the current month, FOUT = total outflow volume leaving control point (Σ REG + DIV + FOTH), L = count of number of Lag option, and LAG2(cp) = retention multiplier parameter.

The parameter ZLAG is used to calculate the LAG1(cp) option, which includes each cumulative set of L months. The month L consists of each month of LAG1 (cp) which is equal to the variable, MAXL. The LAG calculation of each of the L months is repeated to the MAXL. For the first month, the ZLAG, which is an integer value, is 0 or 1. If the LAG is less than one, then LAG is 0. Otherwise, LAG is set or has the longer period time; it is calculated for the case of one month. The integer, one month, of ZLAG value is greater than or equal to 1 and less than 2. For the next month, the ZLAG has less than 3, and LAG is 2 months. If ZLAG is less than 4, LAG has 3 months. In the process of the LAG1(cp) option, this procedure is continued to the month of MAXL (the same month as LAG1(cp)). Examples are provided in the WRAP manual (Wurbs et al. 2006).

Salt load budgets result in an 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 reflects 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 parameter. Sensitivity analyses with lag option may affect simulation results.

CHAPTER VI

BRAZOS RIVER BASIN SIMULATION

Simulation Background

The TCEQ WAM system WRAP input dataset is used in combination with the WRAP-SALT salinity input dataset previously developed by Krishnamurthy (2005). Flow data is provided by WRAP-SIM for the Brazos River Basin. TCEQ WAM predicts the amount of water for a specified set of conditions based on a computer-based simulation in a river/reservoir system. The basic input datasets of the WAM have been developed for the river basins in Texas, and model applications involve modifying the input data to reflect alternative water management systems. For this study, the full authorization simulation is used, which is to maximize users' authorized amount of all water rights, and evaluate application for water rights and amendments. TCEQ WAM dataset is rearranged to establish the upstream-to-downstream sequential order. All reservoir and flows are based on control points and Table 6.1 explains gauging stations for each control point in WRAP-SALT salinity input dataset. The basin-wide simulation was performed for conditions with and without the salt control dams previously proposed by the Corps of Engineers. Moreover, concentration-frequency relationships for reservoir storage and regulated flows at locations throughout the river basin have been determined.

WRAP-SALT Input Records

The WRAP-SALT input files consist of a set of JC, CO, CP, CC, and ED records, which has the filename extension SIN. After reading this set of records, salt concentrations or loads follow in S records. JC records represent Job control records, which includes details about first year of simulation, number of water quality constituents, maximum number of CP records in WRAP-SALT input file, maximum number of upstream control points, beginning-of-simulation storage volume, beginning reservoir concentration file, sequencing of WRAP-SALT input data on S records, options for repeating salt data, control points included in SALT output file, adjustments for negative inflow volume and load and concentration conversion factor by column. For adjusting for negative inflow volume and load, it has three alternative options. Adjustments for negative inflow volume and load would be explained more details later in this chapter.

CO Record consists of the control points included in WRAP-SALT output file. CP records contain control point salt data specifications, which deal with water quality data options related to the S and CC records, parameters for concentration of reservoir outflows, and the storage volume at the beginning of simulation. The lag features are included in the parameters for concentration of reservoir outflows, and have also been explained in more details in the next section. CC records is water quality constituent concentrations at each control point, which has each field for constant naturalized flow concentration of load, storage concentration at the beginning of simulation, concentration of return flows, concentration of CI records (constant inflows and/or outflows), minimum/maximum concentration limits for return flows, CI record, channel credits/losses, storage, and reservoir outflow, and multiplier factor for loads of channel credits/losses. The concentrations or loads of incremental naturalized flows or regulated flows can be entered in a constant in CC records, which are assumed based on concentrations or loads from the watershed area or neighboring gauging stations. Also concentrations or loads of increment naturalized flows or regulated flows are provided on S records. Control points of S records are explained in Table 6.1 and simulated for the Brazos River Basin.

Table 6.1 Control points for WRAP-SALT input file

BWAM_ID	USGS gauging station number	Station Name
BRSE11	08082500	Brazos River at Seymour
CFEL22	08087300	Clear Fork Brazos River at Eliasville
LRCA58	08106500	Little River at Cameron
BRGM73		Brazos River at Gulf of Mexico

The storage concentration at the beginning of simulation may be either entered in CC records, set to zero, or provided by BRC (beginning reservoir concentration) file. The storage at the end of simulation is written to the BRC file, and storage concentration at the beginning of simulation is read from BRC file. So, BRC file is also both written and read. WRAP-SALT executes iteratively until reservoir storage concentrations are the same at the beginning and at the end of the simulation. The option of BRC file is provided in JC records. The concentration of return flows may be entered in CC records or determined by WRAP-SALT. The change in return flow concentration is not much affected at each control point, but mass balance is affected by concentration of return flows.

Concentration limits for return flows, CI records inflows, storage, reservoir outflow and channel credits/losses are set to on the basis of control point locations and water sources. Aberrant numbers from the computations was not considered because of maximum limits. Simulations for minimum/maximum limits in each record are executed to maintain reservoir load balance. Minimum/maximum concentration limit for return flows and CI record inflows are set up based on observed data by the USGS. For the initial value for the simulations, beginning-of simulation storage concentration and concentration of return flows are set equal to mean monthly salt concentration.

The salt loads of channel losses and channel loss credits are computed from the upstream outflow concentration within the minimum/maximum limits, and the volumes of channel losses and loss credits are read from the WRAP-SIM output file. Therefore, loads of channel losses are directly proportional to volumes of channel losses. The multiplier factor for loads of losses/credits is less than 1.0, channel losses result in a lesser proportion of the salinity load than volume. On the other hand, channel losses have a larger loss of load than volume with the multiplier factor greater than 1.0. Changes in loads of channel losses/credits affect load balance.

Volume and Load Balance in the River/Reservoir System

A volume and load balances for the entire river basin system for the period-of-analysis are summarized and provided in the WRAP-SALT message file. 3,829 control points are reflected in the SMS file and some of the control points are also included in WRAP-SALT input file. The summation of all of the inflows and outflows for each month during the simulation period equals the change in reservoir storage, which is the total storage at the end of the simulation minus the total storage at the beginning (Wurbs et al. 2006).

Table 6.2 SMS file Table of total volume and load

	Description of Variable	2nd Line Volume	3rd Line Load
1	Incremental naturalized Flows	Σ FNAT	Σ LNAT
2	Regulated flows at upstream boundary	Σ REG(cp)	Σ REGL(cp)
3	Return flows	Σ RET(cp)	Σ LRET
4	CI record constant Inflows	Σ CINF(cp,m)	Σ LCIN
5	Channel loss credits	Σ FCLC	Σ LCLC
6	Channel losses	Σ FCL	Σ LCL
7	Regulated flows leaving outlet	Σ REG(cp)	Σ REGL(cp)
8	Water supply diversions	Σ DIV	Σ LDIV
9	Hydropower and inst flow	Σ FOTH	Σ LOTH
10	Net reservoir evaporation	Σ EVAP(cp)	0
11	Summation of inflows minus outflows (Inflows – outflows)	= (1) + (2) + (3) + (4) + (5) – (6) – (7) – (8) – (9) – (10)	= (1) + (2) + (3) + (4) + (5) – (6) – (7) – (8) – (9)
12	Beginning-of-simulation storage	Σ BSTO(cp)	Σ BSL(cp)
13	End-of-simulation storage	Σ STO(cp)	Σ STOL(cp)
14	Storage change	= (13) - (12)	= (13) - (12)
15	Volume and load balance differences	= (11) – (14)	= (11) – (14)
16	Negative inflows to control Point	Σ FINNEG	Σ LINNEG
17	Negative incremental naturalized flows	Σ FNAT if < 0	-
18	Naturalized flows at river basin outlet(s)	Σ NAT(cp)	-

Table 6.2 shows the summary of volume and load balance in the SMS file. Table 6.3 shows volume and load balance summaries for the total dissolved solids in the entire Brazos River Basin for each month during the years 1940-97. The analyses related to negative volumes and loads are complicated due to various different conditions (Wurbs et al. 2006).

Table 6.3 SALT message SMS file for TDS at Possum Kingdom Reservoir

	Volume (ac-ft)	Load (tons)	Concentration (mg/l)
Naturalized flows	338,996,768	139,661,360	303
Regulated flows at boundary	13,419,922	76,169,056	4,174
Return flows	2,268,593	1,015,502	329
CI record constant inflows	-	-	-
Channel loss credits	17,706,106	16,198,432	673
Channel losses	285,666	164,471	423
Regulated flows at outlet	237,921,344	125,741,296	389
Diversions	114,996,184	109,414,928	700
Other flows at control points	- 1,788,282	- 1,289,419	530
Net evaporation	22,024,166	-	-
Inflows – Outflows	- 1,047,689	- 986,926	693
Beginning reservoir storage	4,346,915	5,782,034	978
Ending reservoir storage	3,787,966	5,065,350	983
Change in storage	- 558,949	- 716,684	943
Water balance difference	- 488,740	- 270,241	407
Negative inflows to cpts	1,262,650	1,731,312	1,008
Negative incremental nat flows	102,125,024		
Naturalized flows at outlet	354,103,648		

Negative Incremental Naturalized Flow

The incremental inflow between two control points is the naturalized flow at the downstream location minus the simultaneous flow at the upstream locations. Incremental inflows are typically positive. However, when flows at upstream locations exceed concurrent flows at a downstream location, this situation is described in terms of negative incremental inflows. Negative incrementals might occur for the reasons below (Wurbs, 2006a);

- Channel seepage and evapotranspiration losses
- Recorded or unrecorded diversions
- Large travel times causing the effects of precipitation events to reach adjacent control points in different time periods
- Measuring inaccuracies or data recording errors

Negative incremental naturalized flows and associated adjustments are related to the effects on the amount of water available to water rights and the unappropriate flows. In WRAP-SIM computations, negative incremental flows happen primarily because downstream flow conditions affect the amount of water available at upstream locations. The impacts of negative incremental inflows in the simulations may or may not properly represent the real world being modeled. Factors to determine negative incremental naturalized flows are complicated and include some difficulties in deciding how to deal with them. WRAP-SIM has negative incremental naturalized flow options to be adjusted to remove negative incrementals. Negative incremental naturalized flow, the variable ADJINC, has five options in the WRAP-SIM input file. Only two options (ADJINC 4 & 5) are used to analyze WRAP-SALT simulations for different negative incremental naturalized flows. ADJINC controls the negative incremental naturalized flows with optional computation methods.

When negative incremental naturalized flow adjustment option 4 (ADJINC 4) is activated, flow adjustments are considered downstream of the control point. As each water right is considered, upstream negative incremental flow adjustments are applied at the downstream control point but not at the control point of the right.

Negative incremental naturalized flow adjustment option 5 (ADJINC 5) is the alternative simulation approach that upstream flow must be committed to satisfying downstream negative incremental flows along with senior downstream water right requirements. ADJINC 5 is equal to ADJINC 1 (no negative incremental flow adjustments) with senior rights located downstream and no flow discontinuity. The negative incremental flow options and examples are provided in the *Reference Manual for the Water Rights Analysis Package (WRAP) Modeling System* (Wurbs 2006a).

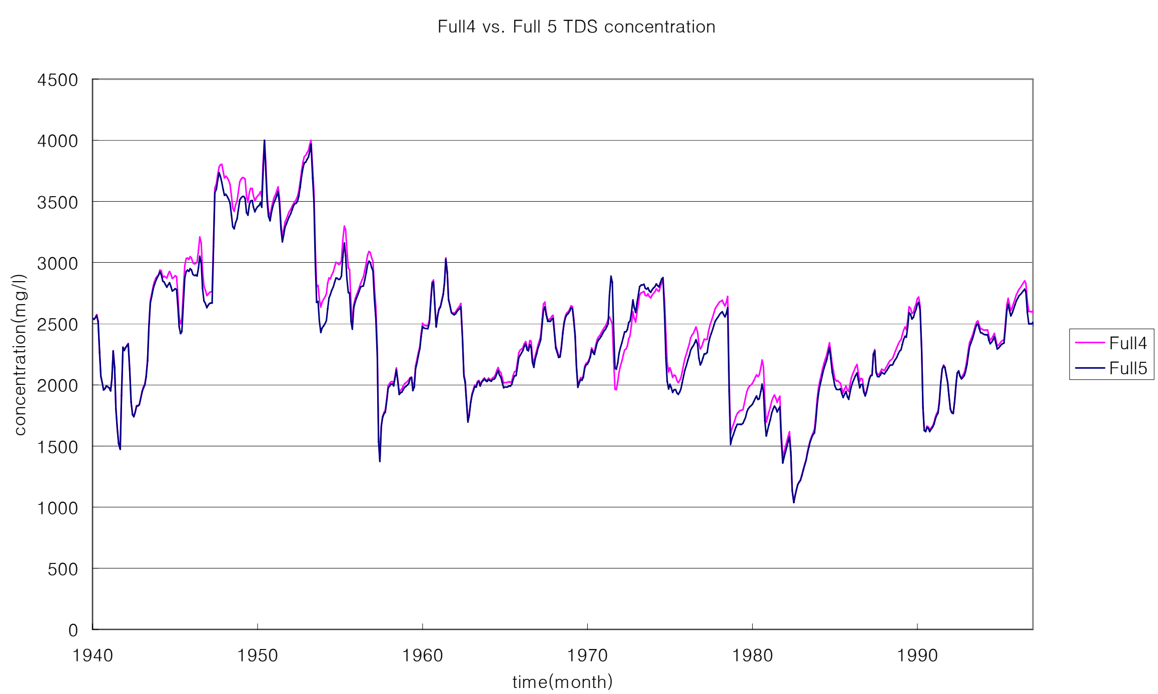

Figure 6.1 Full4 & full5 TDS concentration at Possum Kingdom Reservoir

Figure 6.1 compares two TDS concentrations at Possum Kingdom reservoirs using the negative incremental flow options ADJINC 4 and ADJINC 5. The two simulations have exactly the same input datasets except the different ADJINC option. The different negative incremental flow does not have a significant impact on outflow concentration at Possum Kingdom and Whitney reservoirs. Comparison between ADJINC 4 and ADJINC 5 at the Whitney reservoir is plotted in Appendix B.

The TCEQ WAM dataset is voluminous in order to understand its behavior, update the dataset with new information, experiment new operating strategies and track computational procedures (Olmos 2004). The Brazos River Basin TCEQ WAM dataset (referred as the full dataset) has 3,811 control points, 1,810 water rights, and 695 reservoirs. Simplified dataset (referred as the simple dataset) has 27 control points, 129 water rights, and 14 major reservoirs on the basis of interests such as gauging stations at confluence points or locations of interest. Theoretically, the results obtained from the full and the simple dataset should be identical. For the simplified data, unappropriated flows and streamflow depletions are made during the WAM dataset simulation, and extracted for each one of the control points of concern.

However, the formats of the full and simple datasets are the same for running the WRAP programs. The components of the simple dataset are the file extensions DAT, INF, and EVA files, which are not included in the DIS file because they have been already done in the TCEQ WAM full dataset. New evaporation depths are adjusted to the simple dataset, and calculated through full simulations. Simplified datasets were built for the Brazos River Basin, using negative incremental naturalized flow options (ADJINC 4 and 5 in WRAP-

SIM).

Table 6.4 Volume summary tables for the full vs. simple datasets

		Full	Simple
1	Naturalized flows	338,996,768	282,606,720
2	Regulated flows at boundary	13,419,922	6,784,081
3	Return flows	2,268,593	-
4	CI record constant inflows	-	-
5	Channel loss credits	17,706,106	10,081,420
6	Channel losses	285,666	-
7	Regulated flows at outlet	237,921,344	238,036,784
8	Diversions	114,996,184	46,482,508
9	Other flows at control points	- 1,788,282	4,557
10	Net evaporation	22,024,166	15,171,627
11	Inflows – Outflows	- 1,047,689	- 223,255
12	Beginning reservoir storage	4,346,915	3,324,940
13	Ending reservoir storage	3,787,966	3,102,360
14	Change in storage	- 558,949	- 222,580
15	Water balance difference	- 488,740	- 675
16	Negative inflows to cpts	1,262,650	51,135
17	Negative incremental nat flows	102,125,024	23,943,300
18	Naturalized flows at outlet	354,103,648	289,682,400

Volume summary tables for the full and simple datasets are tabulated in Table 6.4. Using the simple dataset, the water balance difference is decreased from -488,740 ac-ft to -675 ac-ft. Negative inflows difference is also decreased from 1,262,650 ac-ft to 51,135 ac-ft. As mentioned previously, negative inflows result from channel seepage, evapotranspiration losses, recorded or unrecorded diversions, large travel times causing the effects of precipitation events to reach adjacent control points in different time periods (flood discharges), and measuring inaccuracies or data recording errors. The full simulations include more variables such as more control points, reservoirs and water rights than the simple simulation. These complexities in the full simulation might explain the reality well, but it has higher negative inflows at each control point in the Brazos River Basin.

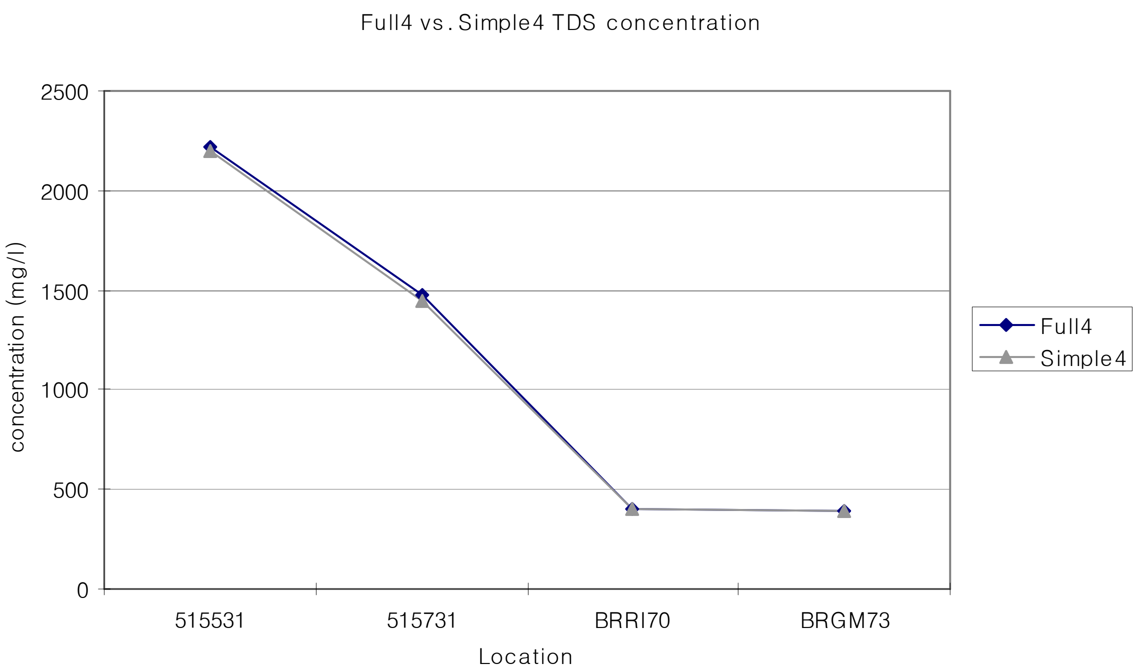

Figure 6.2 Full4 and simple4 mean concentration at each control point

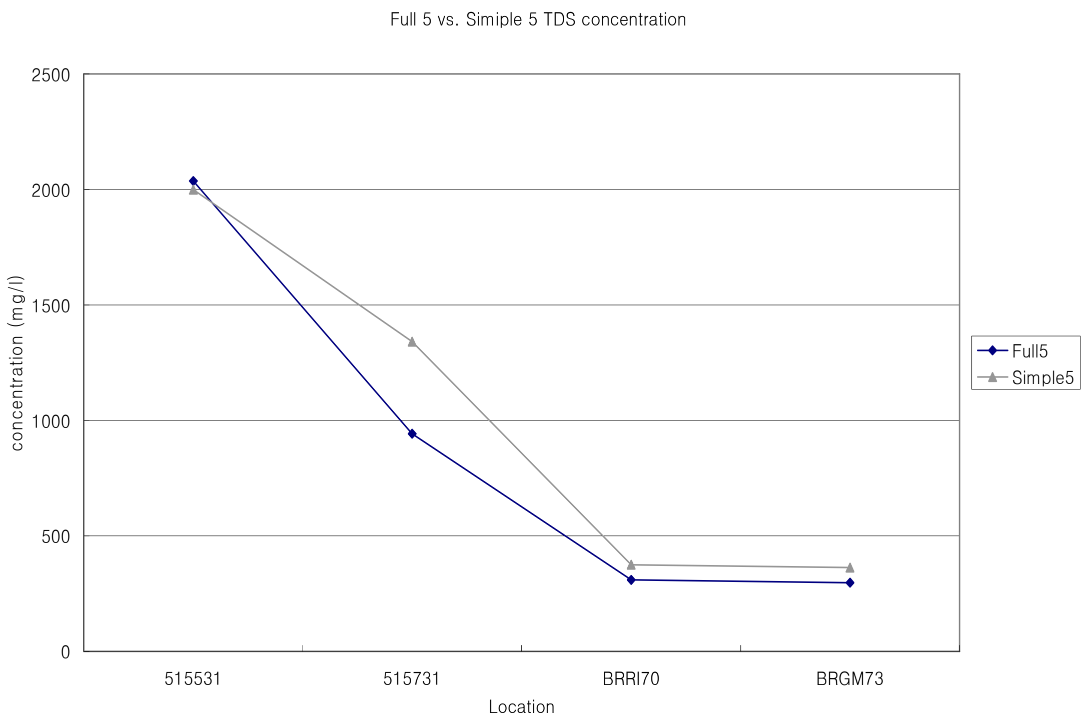

Figure 6.3 Full5 and simple 5 mean concentration at each control point

Figures 6.2-6.3 show the mean monthly TDS concentrations for the full and simple simulations with the different negative incremental naturalized flow options, ADJINC 4 and ADJINC 5, respectively, at each study area. Although there are water volume and load differences between the full and simple simulations, the mean monthly TDS concentrations of the full and simple simulations are similar to each location. 'Full' and 'Simple' indicated the full simulation (using TCEQ WAM datasets) and the simple simulation (using simplified datasets) in each table and plot. For the Possum Kingdom reservoir, duration-concentration relationships for the full and simple simulations with ADJINC 4 and ADJINC 5 are tabulated in Appendix B and plotted in Figures 6.4-6.5 Duration-concentration relationships and curves between the full and simple simulations for the Whitney reservoir are tabulated and plotted in Appendix B.

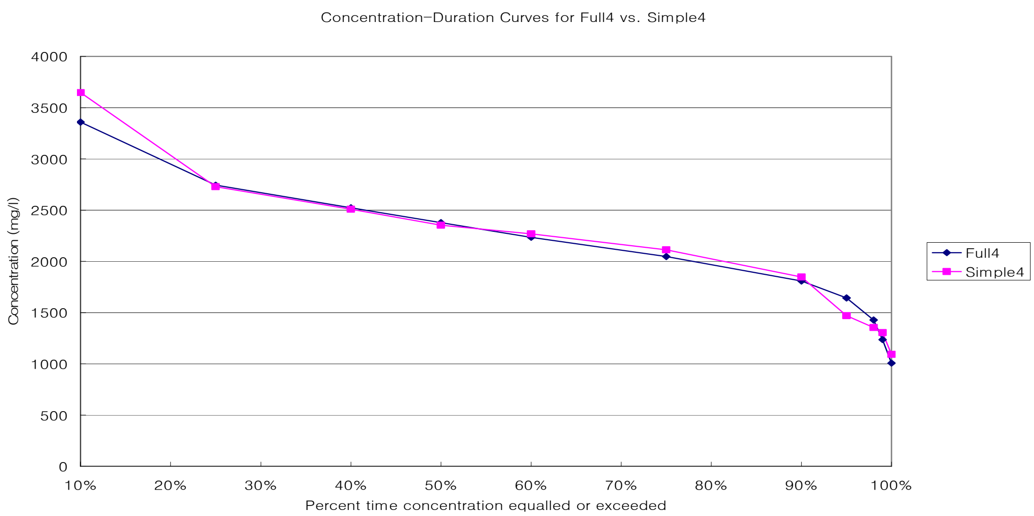

Figure 6.4 Concentration-Duration curves for full 4 and simple 4 at Possum Kingdom Reservoir

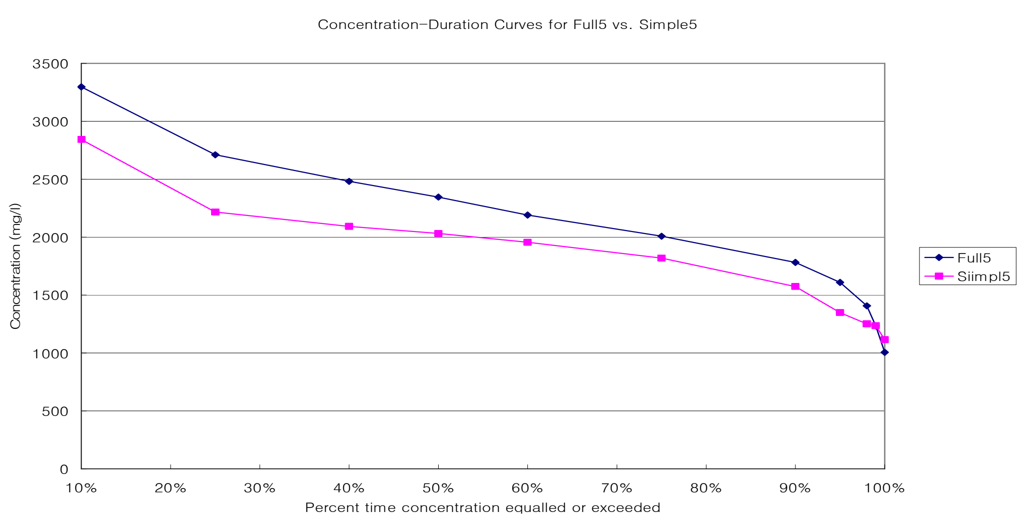

Figure 6.5 Concentration-Duration curves for full 5 and simple 5 at Possum Kingdom Reservoir

The mean monthly TDS concentration for full 4 and simple 4 of 1,808 mg/l and 1,848 mg/l at the Possum Kingdom reservoir are equaled to or exceed 90 % of the 696 months during the period of 1940-1997. The mean monthly TDS concentration for full 5 and simple 5 of 1,782 mg/l and 1,574 mg/l at the Possum Kingdom reservoir are equaled to or exceed 90% of the 696 months during the simulation period. The mean monthly TDS concentrations of the full 4 and simple 4 have 90 % frequency of the 696 months equaled to or exceed of the concentration 1,156 mg/l and 1,145 mg/l at the Possum Kingdom reservoir. The mean monthly TDS concentration for full 5 and simple 5 of 1,133 mg/l and 1,099 mg/l at the Whitney reservoir are equaled to or exceed 90% of the 696 months during the period of 1940-1997. The duration-concentration curves between full 4 and simple 4 are similar both at the Possum Kingdom reservoir and at the Whitney reservoir.

The difference between full 5 and simple 5 of the frequency curve is decreased as the duration is increased. The mean monthly concentrations and duration-concentration relationships show that the simplified simulations are similar to the full simulations, but there are some differences for some of the upstream reservoirs and control points. Figure 6.6 shows the full simulation with ADJINC 4, the simple simulation with ADJINC 4 and their difference concentrations for their comparison. The comparison between the full simulation with ADJINC 5 and the simple simulation with ADJINC 5 is also shown in Appendix B.

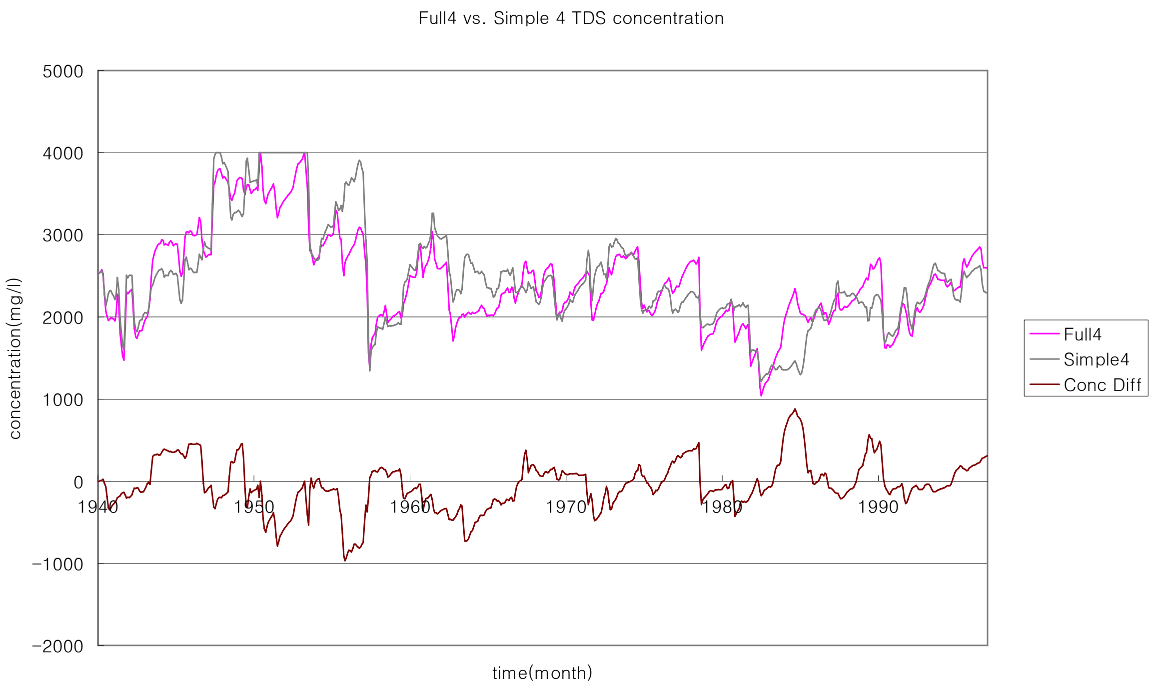

Figure 6.6 Full4 & simple4 at Possum Kingdom Reservoir

The concentration differences between the full and simple simulations plotted in Figure 6.6 are not directly related to water in storage at each reservoir. Storage load during this month is calculated by the storage load during the previous month. Load for the previous month is an important factor to determine salt concentration than the water volume. The concentration difference is 880.09 mg/l (maximum) and -967 mg/l (minimum) using ADJINC 4, and 998.65 mg/l (maximum) and -374.86 (minimum) mg/l using ADJINC5.

The negative incremental naturalized flow option (ADJINC) does not make a big difference. However, control points, reservoirs, and water rights for the study area are important. Simulation input data is set on the basis of comprehensive understanding of the study area and gauging stations at confluence points of locations of interest.

Negative salt loads result from negative inflows or from computations between flows and concentrations. For adjusting for negative total inflow volume and load, WRAP-SALT has three alternative options: (1) No adjustments are made to negative inflows. The negative load is simulated forward in the computations without adjustment, which data is obtained directly from the WRAP-SIM output file. (2) Adjustments are made to the negative total inflows, based on beginning-of-period storage volume. The adjustments of the negative total inflow loads do not exceed loads in reservoir storage at the beginning of the month. (3) Negative inflow volumes and loads are set to zero. This option might create additional load. It was also observed that the presence of negative inflows give rise to unreasonably low or high concentrations. This is countered by setting minimum and maximum limiting concentration values for the salt constituents. JC record controls negative inflow volume and load using three options.

Tables 6.5-6.6 show total volume and load summary tables for each NEGINF option. Adjustments for negative inflow volume and load are only related to other flows at control points. Compared to the NEGINF 1 option, NEGINF 2 and NEGINF 3 have more other flows at control points. Negative inflows are ignored (turned to positive value or set to zero) at NEGINF 2 and 3, respectively. However, the volume and load balance difference of NEGINF 1 has a smaller value than the water balance differences of the other two.

Table 6.5 Total volume summary tables based on NEGINF option

	NEGINF option (Volume ac-ft)	NEGINF1	NEGINF2	NEGINF3
1	Naturalized flows	338,996,768	338,996,768	338,996,768
2	Regulated flows at boundary	13,419,922	13,419,922	13,419,922
3	Return flows	2,268,593	2,268,593	2,268,593
4	CI record constant inflows	-	-	-
5	Channel loss credits	17,706,106	17,706,106	17,706,106
6	Channel losses	285,666	285,666	285,666
7	Regulated flows at outlet	237,921,344	237,921,344	237,921,344
8	Diversions	114,996,184	114,996,184	114,996,184
9	Other flows at control points	- 1,788,282	- 525,889	- 525,636
10	Net evaporation	22,024,166	22,024,166	22,024,166
11	Inflows – Outflows	- 1,047,689	- 2,310,082	- 2,310,336
12	Beginning reservoir storage	4,346,915	4,346,915	4,346,915
13	Ending reservoir storage	3,787,966	3,787,966	3,787,966
14	Change in storage	- 558,949	- 558,949	- 558,949
15	Water balance difference	- 488,740	- 1,751,134	- 1,751,387
16	Negative inflows to cpts	1,262,650		
17	Negative incremental nat flows	102,125,024		
18	Naturalized flows at outlet	354,103,648		

Table 6.6 Total TDS load summary tables based on NEGINF option

	NEGINF option (Load tons)	NEGINF1	NEGINF2	NEGINF3
1	Naturalized flows	139,661,360	139,661,360	139,661,360
2	Regulated flows at boundary	76,169,056	76,169,056	76,169,056
3	Return flows	1,015,502	1,015,502	1,015,502
4	CI record constant inflows	-	-	-
5	Channel loss credits	16,198,432	16,205,947	16,206,001
6	Channel losses	164,471	164,568	164,571
7	Regulated flows at outlet	125,741,296	125,745,072	125,745,264
8	Diversions	109,414,928	110,222,784	110,223,448
9	Other flows at control points	-1,289,419	- 2,005,374	- 2,005,044
10	Net evaporation	-	-	-
11	Inflows – Outflows	- 986,926	- 1,075,185	- 1,076,320
12	Beginning reservoir storage	5,782,034	5,782,034	5,782,034
13	Ending reservoir storage	5,065,350	5,087,440	5,087,692
14	Change in storage	- 716,684	- 694,595	- 694,342
15	Water balance difference	- 270,241	- 380,590	- 381,977
16	Negative inflows to cpts	1,731,312	1,176,077	1,175,934

TDS concentration differences between the three options are 0.01 or 0.02 (minimum) and -8.65 or -8.91 (maximum) at the Possum Kingdom reservoirs. When the TDS concentrations of each NEGINF option are plotted, they look almost the same, due to small differences. Thus, for simulations in this chapter, NEGINF 1 option is selected.

The New Salinity Routing Methodology

The WRAP-SALT simulations are based on the premise of complete mixing within the monthly computational time step. In reality, stream inflows and their salt loads may require long period of time to move through a reservoir and reach the outlet. Salt concentrations vary spatially, both horizontally and vertically, throughout a reservoir. The concept of lag is based on the premise that salt entering the reservoir in a particular month begins to reach the outlet LAG months later. As discussed in Chapter V, salinity routing methods in WRAP-SALT are based on setting reservoir outflow concentrations equal to storage concentrations adjusted for timing effects based on the lag parameters.

The WRAP-SALT simulation procedures are based on the premise of complete mixing at each control point. Salt entering the reservoir in a particular month begins to reach the outlet LAG months later on the basis of lag concepts. The salt leaves the reservoir over the time of multiple months that begins in the LAG months after the month in which salt loads entered the reservoir. The timing of the load inflows used to determine outflow concentrations is set by lag parameters such as LAG1(cp) and LAG2(cp).

The lag options are significant only for control points with considerable reservoir storage. Lag determined by calibration for reservoirs with observed data may be relevant to other reservoirs as well. If the observed data is available, calibration studies are performed for interested areas. As mentioned previously in Chapter IV, LAG was determined by calibration for reservoirs with observed data. As calibration studies for the Possum Kingdom and Whitney reservoirs are done in Chapter IV, the lag months are applied for the Brazos River Basin simulation: 4 months for the Possum Kingdom reservoir and 1 month for the Whitney reservoir. The lag options are based on the variable LAG and controlled by LAG1(cp) and LAG2(cp). LAG option is determined by column number 33-40 for LAG1(cp) and column number 41-48 for LAG2(cp) in the CP record. This is an example set of lag options shown in Table 6.7.

Table 6.7 LAG options and their formats

	Column number	40	48	
	Variable	LAG1(cp)	LAG2(cp)	
CP515531	…	0	0	LAG0
CP515531	…	4	-1	LAG1
CP515531	…	8	0	LAG2

(LAG0) Lag is not activated.

The reservoir outflow concentration (diversion, release, and regulated flow concentration) is set equal to storage concentration for the month set by the lag defined in LAG1(cp) and LAG2(cp). LAG1(cp) is applied differently in the two alternative lag options.

(LAG1) With a negative number for LAG2(cp), the LAG1(cp) is a fixed constant lag. Lag concept is based on constant lag month(s). A negative number entered in LAG2(cp) switches to the alternative option in which the lag option is set equal to LAG1(cp) for all months.

(LAG2) Lag concept is based on retention time. Parameters from the CP record serves as the multiplier in the flow retention. With the LAG2 option activated by a non-zero LAG1(cp) and a blank or positive number for LAG2(cp), the lag is computed each month based on retention time with LAG1(cp) being the optional upper limit on the lag. LAG2(cp) is the multiplier factor in the equation of Chapter V. The retention time option provides a theoretical basis that allows the model to be applied without calibration. However, in some cases, outflow from the storage is not significant; the retention time might generate an enormous number. Thus, the LAG2 option sets the upper limit which is twice the lag months from the calibration study.

Consequentially, the lag concept has alternative options. LAG may be treated as a monthly varying variable set based on retention time. Otherwise, LAG may be a constant set by the model-user. LAG is applied in the same way for all simulation months, regardless of the option adopted for its determination.

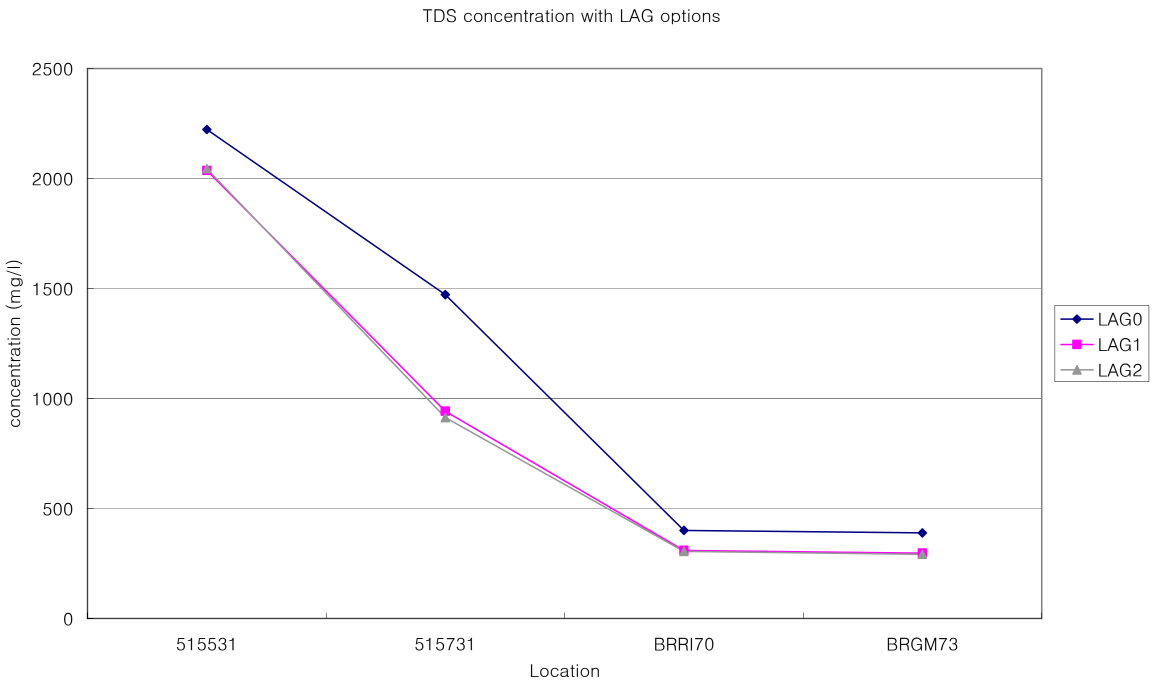

Figure 6.7 TDS Concentration with/without LAG options at each control point

TDS concentration with/without LAG options at each control point is shown in Figure 6.7. Chloride and sulfate concentrations with/without LAG options at four major control points are plotted in Appendix B. Salt concentration trends of TDS, chloride and sulfate are similar. When the lag options are activated, mean monthly concentrations are decreased. The differences between lag options for Whitney reservoir are slightly more than those for Possum Kingdom reservoir. For sulfate, mean monthly concentrations at Richmond gauging station and the outlet at the Gulf of Mexico are the same.

Table 6.8 Frequency table for salt constituents at Possum Kingdom Reservoir

Salt Constituent	TDS (mg/l)			CL (mg/l)			SO4 (mg/l)		
Lag option	LAG0	LAG1	LAG2	LAG0	LAG1	LAG2	LAG0	LAG1	LAG2
Mean	2444	2583	2504	952	1210	562	475	616	268
Standard Deviation	564	814	769	221	288	259	102	149	132
100%	1007.3	104.5	144.4	389.3	582.1	183	211.3	306.8	94
99%	1236.2	650.6	901.5	501.4	660.6	183	256.2	360.6	94
98%	1428.4	854.9	1196.6	552.9	722.9	183	288.3	385.7	94
95%	1643.2	1384.5	1501	634	819.9	217.8	337.2	421	106.8
90%	1808	1657	1671	697	871	268	366	449	125
75%	2048	1968	1966	796	1006	379	401	504	170
60%	2235	2317	2225	871	1111	445	436	564	213
50%	2378	2523	2350	933	1170	497	464	601	241
40%	2523	2799	2500	992	1232	579	488	631	267
25%	2744	3144	2982	1067	1380	712	528	688	336
10%	3359	3796	3901	1306	1672	952	636	820	457
Maximum	4105	4000	4000	1646	2214	1393	766	1297	975

A concentration duration analysis explains the temporal variation in salt concentration at Possum Kingdom reservoir tabulated in Table 6.8 and at Whitney reservoir tabulated in Table 6.9. A mean TDS concentration for the LAG options (LAG0, LAG1, and LAG2) is 2,444 mg/l, 2,583 mg/l, and 2504 mg/l, respectively. At Possum Kingdom reservoir, mean monthly TDS concentrations of 1,808 mg/l (LAG0), 1,657 mg/l (LAG1), and 1,671 mg/l (LAG2) equaled or exceeded 90 % of the 696 months of the simulation period. Mean monthly chloride concentrations of 697 mg/l (LAG0), 871 mg/l (LAG1), and 268 mg/l (LAG2) and mean monthly sulfate concentrations of 366 mg/l (LAG0), 449 mg/l (LAG1), and 125 mg/l (LAG2) equaled or exceed 90 % of the 696 months during the simulation period. The water quality at Possum Kingdom reservoir is poor. Mean monthly salt concentrations exceeded EPA standards for secondary drinking water. When the lag is activated (LAG1 or LAG2), mean monthly TDS, chloride and sulfate concentrations are slightly decreased.

Table 6.9 Frequency table for salt constituents at Whitney Reservoir

Salt Constituent	TDS (mg/l)			CL (mg/l)			SO4 (mg/l)		
Lag option	LAG0	LAG1	LAG2	LAG0	LAG1	LAG2	LAG0	LAG1	LAG2
Mean	1570	1315	1339	573	567	554	303	297	321
Standard Deviation	456	511	680	173	182	267	86	106	171
100%	978.9	271.1	7	331.4	222.9	139	190.8	116.4	78
99%	1049.7	449.7	55.5	359.5	307.4	180	200.6	158.6	90.9
98%	1061	530.2	334.6	364	315.4	212.4	204.2	164.6	102.2
95%	1110.5	691.9	527.6	382.9	337.2	239.5	211.4	177.9	148
90%	1156	781	662	401	363	295	222	193	184
75%	1288	928	856	465	426	359	249	221	213
60%	1375	1103	997	505	480	426	265	249	243
50%	1418	1184	1137	525	531	464	275	270	269
40%	1490	1305	1305	544	575	569	291	292	297
25%	1731	1608	1695	643	712	693	333	358	363
10%	2371	2082	2291	887	834	928	446	417	601
Maximum	3121	3000	3000	1122	1371	1604	595	901	1080

Mean TDS concentrations for the lag options (LAG0, LAG1, and LAG2) are 1,570 mg/l, 1,315 mg/l, and 1,229 mg/l, respectively, tabulated in Table 6.9. At Whitney reservoir, mean monthly TDS concentrations of 1,156 mg/l (LAG0), 781 mg/l (LAG1), and 662 mg/l (LAG2) equaled or exceeded 90 % of the 696 months of the simulation period. Mean monthly chloride concentrations of 401 mg/l (LAG0), 363 mg/l (LAG1), and 295 mg/l (LAG2) and mean monthly sulfate concentrations of 222 mg/l (LAG0), 193 mg/l (LAG1), and 184 mg/l (LAG2) equaled or exceed 90 % of the 696 months during the simulation period. The water quality at Whitney reservoir is poor, but it is better than water quality at Possum Kingdom reservoir. When the lag is activated (LAG1 or LAG2), mean monthly TDS concentrations are slightly decreased.

Table 6.10 Frequency table for salt constituents at Possum Kingdom Reservoir

Salt Constituent	Lag option	Concentration frequency (%) constrained by a specific concentration						
		100 mg/l	200 mg/l	250 mg/l	500 mg/l	750 mg/l	1000 mg/l	2000 mg/l
TDS	LAG0	100	100	100	100	100	100	81.33
	LAG1	100	99.71	99.71	99.13	98.26	97.4	73.52
	LAG2	100	99.86	99.86	99.71	99.28	98.55	73.08
CL	LAG0	100	100	100	98.84	85.09	37.48	0
	LAG1	99.71	99.13	98.7	95.8	76.7	46.45	0
	LAG2	99.86	99.86	99.71	97.4	72.21	31.84	0
SO4	LAG0	100	100	99.28	33.14	0.14	0	0
	LAG1	99.13	97.54	95.95	47.76	8.1	0	0
	LAG2	99.71	98.41	97.97	35.75	9.26	0	0

Table 6.10 shows the flow frequency for the maximum allowable concentration limits for TDS, chlorides and sulfates at Possum Kingdom reservoir. The monthly mean concentration of TDS has 100 % frequency of 696 months equal to or exceeding the maximum allowable concentration 1,000 mg/l at Possum Kingdom reservoir. The duration-concentration relationships under the specific constraints for TDS, chlorides and sulfates at Whitney reservoir are tabulated in Appendix B.

Table 6.11 Reliability table for TDS at Possum Kingdom Reservoir

Lag option	Constraint (mg/l)	TDS reliability	
		Volume (%)	Period (%)
-	Quantity	100	100
LAG0	1500	2.55	2.59
	1000	0	0
	500	0	0
LAG1	1500	7.49	7.04
	1000	3.04	2.59
	500	1.17	0.86
LAG2	1500	5.07	5.03
	1000	1.38	1.44
	500	0.36	0.29

Volume and period reliabilities for TDS are tabulated in Table 6.11 as a function of LAG.. Specifying a maximum allowable TDS concentration of 1,500 mg/l at Possum Kingdom reservoir results in a volume reliability of 2.55 % and a period reliability of 2.59 % without lag option. With a TDS concentration of 1,500 mg/l, the volume and period reliabilities are 7.49 % and 7.04 % for LAG1 option. With the same constraint, the volume and period reliabilities are 5.07 % and 5.03 % for LAG2 option. With lag option, the volume and period reliabilities are slightly improved. A TDS constraint of 500 mg/l results in period and volume reliabilities of 0 % and 0 % for LAG0, 1.17 % and 0.86 % for LAG1, and 0.36% and 0.29% for LAG2. Reliabilities generally decrease with increasing salt constraint. The volume and period reliabilities are 100% and 100% for water quantity. Water supply is severely constrained by salinity standards. Concentration limits for TDS, chlorides and sulfates of 500 mg/l, 250 mg/l, and 250 mg/l are recommended in the Environmental Protection Agency (EPA) drinking water standards.

Volume and period reliabilities for chlorides and sulfates are tabulated in Appendix B as a function of LAG. Specifying a maximum allowable chloride concentration of 1,000 mg/l at Possum Kingdom reservoir results in a volume reliability of 62.15 % and a period reliability of 62.5 % without lag option. With a chloride concentration of 1,000 mg/l, the volume and period reliabilities are 55.35 % and 53.45 % for LAG1 option. With the same constraint, the volume and period reliabilities are 68.06 % and 67.96 % for LAG2 option. When the lag is activated, the volume and period reliabilities are slightly improved. A chloride constraint of 250 mg/l results in period and volume reliabilities of 0 % and 0 % for LAG0 option, 1.7 % and 1.29 % for LAG1 option, and 0.36% and 0.29% for LAG2 option.

Specifying a maximum allowable sulfate concentration of 1,000 mg/l at Possum Kingdom reservoir results in a volume reliability of 100 % and 100 % with/without lag option. However, a sulfate constraint of 250 mg/l results in period and volume reliabilities of 0.89 % and 0.72 % for LAG0, 4.58 % and 4.02 % for LAG1, and 2.01 % and 2.01 % for LAG2. The volume and period reliabilities for chlorides and sulfates as well as water quantity are 100 %. In this case, water supply is constrained by salinity standards.

Volume and period reliabilities for TDS at Whitney reservoir are tabulated in Appendix B as a function of LAG. Specifying a maximum allowable TDS concentration of 1,000 mg/l at Whitney reservoir results in a volume reliability of 99.11 % and a period reliability of 95.69 % without lag option. With a TDS concentration of 1,000 mg/l, the volume and period reliabilities at Whitney reservoir are 99.33 % and 99.28 % for LAG1 option. With the same constraint, the volume and period reliabilities are 94.82 % and 94.54 % for LAG2 option. A TDS constraint of 500 mg/l results in period and volume reliabilities of 39.44 % and 37.93 % for LAG0, 54.82 % and 53.59 % for LAG1, and 62.93 % and 61.93 % for LAG2. Reliabilities generally decrease with increasing salt constraint. Although the volume and period reliabilities are 99.2 % and 98.85 % for water quantity, water supply is constrained by salinity.

Volume and period reliabilities for chlorides and sulfates at Whitney reservoir are tabulated in Appendix B as a function of LAG. Specifying a maximum allowable chloride concentration of 1,000 mg/l at Whitney reservoir results in a volume reliability of 96.11 % and a period reliability of 95.69 % without lag option. With a chloride concentration of 1,000 mg/l, the volume and period reliabilities are 99.33 % and 99.28 % for LAG1 option.

With the same constraint, the volume and period reliabilities are 94.82 % and 94.54 % for LAG2 option. When the lag is activated, the volume and period reliabilities are slightly improved. A chloride constraint of 250 mg/l results in period and volume reliabilities of 0 % and 0 % for LAG0 option, 2.74 % and 2.59 % for LAG1 option, and 13.14 % and 12.07 for LAG2 option. Specifying a maximum allowable sulfate concentration of 1,000 mg/l at Whitney reservoir results in a volume reliability of 100 % and 100 % with/without lag option. However, a sulfate constraint of 250 mg/l results in period and volume reliabilities of 26.21 % and 24.86 % for LAG0, 51.09 % and 48.85 % for LAG1, and 57.86 % and 56.18 % for LAG2. The volume and period reliabilities for chlorides and sulfates at Whitney reservoir are also 99.2 % and 98.85 % for water quantity. Water supply is constrained by salinity standards.

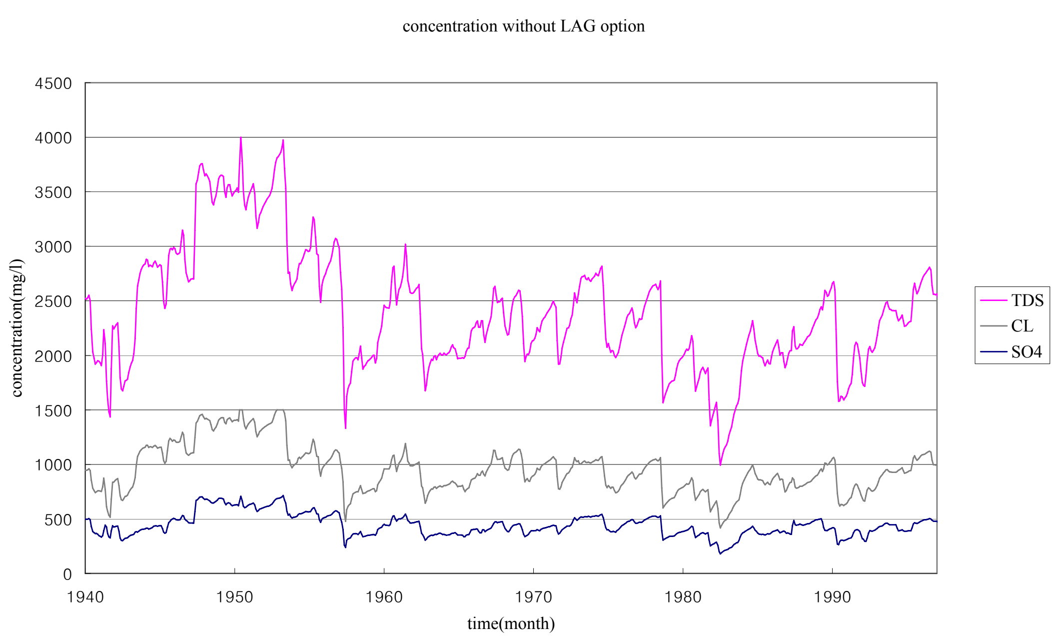

Figure 6.8 Concentrations without LAG option at Possum Kingdom

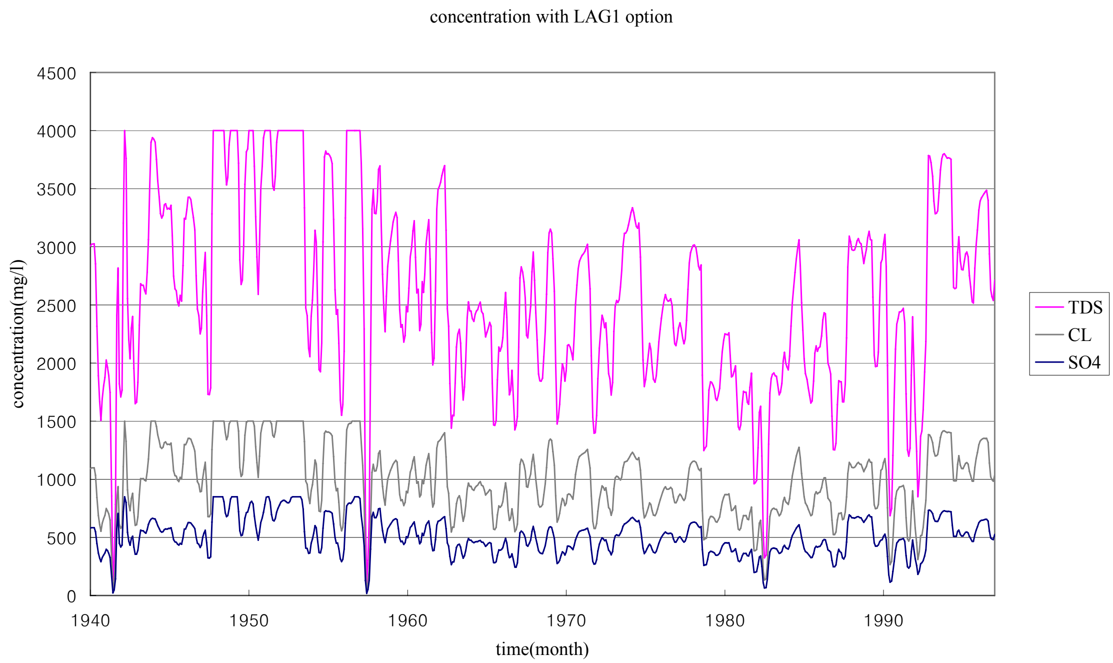

Figure 6.9 Concentrations with LAG1 option at Possum Kingdom

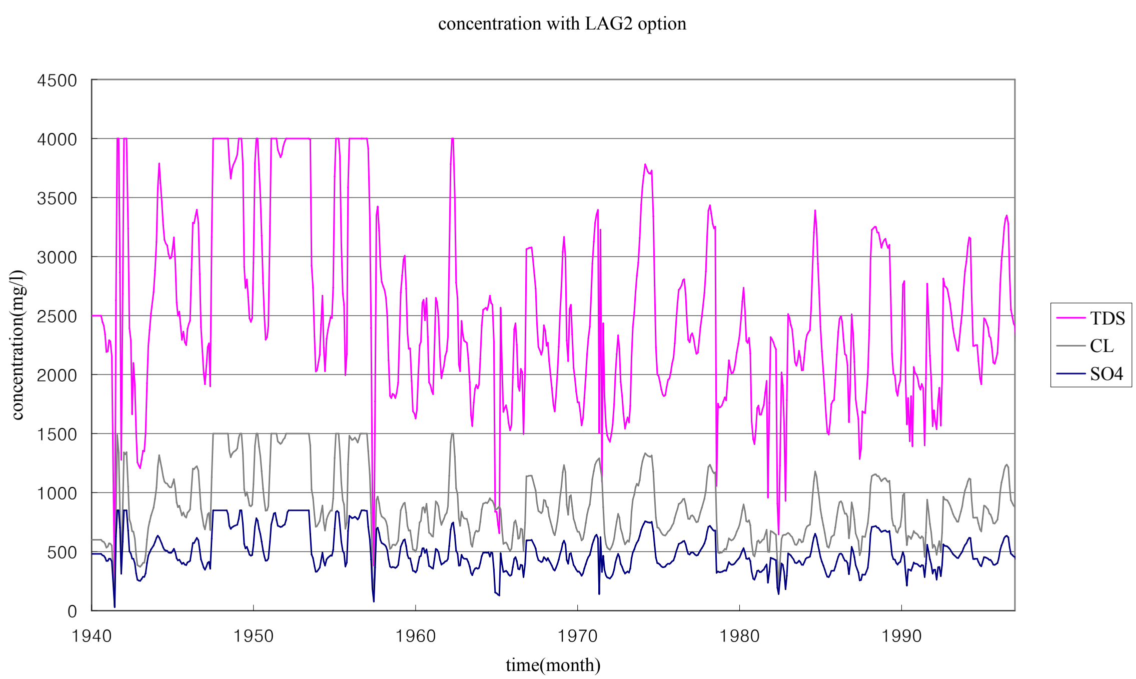

Figure 6.10 Concentrations with LAG2 option at Possum Kingdom

Figures 6.8-6.10 show TDS, chlorides and sulfates concentration with/without the lag option. Trends in salt constituents are similar when the same lag option is activated. Lag month is longer, therefore, mean monthly concentration has more fluctuations.

Salt Control Dams

The Brazos River Basin Natural Salt Pollution Control Study (USACE 1973 and 1983) formulates and evaluates a comprehensive collection of strategies for dealing with the salt pollution. Proposed salt control dams with numerous alternative plans are located in the primary salt source areas of the upper basin. Much of the salt load in the Brazos River originates from isolated areas of the upper basin.

The proposed salt control impoundments are constructed in Croton Lake on Croton Creek, Dove Lake on Salt Croton Creek, and Kiowa Peak Lake on North Croton Creek. The locations of the three dam sites are shown in Figure 3.2 along with stream gauging stations. Croton Creek and Salt Croton Creek are tributaries of the Salt Fork of the Brazos River. Dove Creek is a tributary of Salt Croton Creek. North Croton Creek enters the main stem of the Brazos River just below the Salt Fork confluence. As indicated in Figure 3.2, the three salt control dam sites are located near the stream flow gauges on Croton Creek near Jayton (8081200, USGS gauging station), Salt Croton Creek near Aspermont (8081500, USGS gauging station), and North Croton Creek near Knox city (8082180, USGS gauging station). The analyses assume that the salt control dams permanently store or eliminate all of the discharges and salt loads at the corresponding stations (Wurbs et al.

1993).

The salt control dam plan consists of permanent storage or removal of all discharge and salt loads occurring at stations (Croton Creek near Jayton, Salt Croton Creek near Aspermont, and North Croton Creek near Knox city). The discharges and salt loads at five downstream stations (Brazos River at Seymour, Brazos River at Possum Kingdom Dam near Graford, Brazos River at Whitney Dam near Whitney, Brazos River near College Station, and Brazos River at Richmond) were adjusted to reflect the impacts of the upstream salt control dams. The mean monthly concentrations were computed by dividing adjusted salt load by adjusted discharge.

Table 6.12 Concentration-duration relationships considering salt control dams at Possum Kingdom Reservoir

Salt Constituent	TDS (mg/l)			CL (mg/l)			SO4 (mg/l)		
Lag option	LAG0	LAG1	LAG2	LAG0	LAG1	LAG2	LAG0	LAG1	LAG2
Mean	1641	2136	884	593	712	283	363	485	197
Standard Deviation	342	492	411	117	143	124	74	110	99
100%	745.6	1062.7	300	312.8	387.5	100	166.3	256.5	50
99%	926.2	1257.7	300	361.4	436.3	100	202	301.5	50
98%	1024.1	1314.9	300	393.7	458	100	226.3	314.9	50
95%	1142.1	1474.9	326.5	421.9	512.7	113.2	259.3	345.1	66.3
90%y	1266	1583	406	464	537	138	286	362	82
75%	1392	1754	554	508	605	198	310	398	123
60%	1501	1961	727	543	658	229	335	451	159
50%	1621	2048	811	580	699	254	354	477	187
40%	1703	2192	896	612	731	293	374	501	202
25%	1829	2419	1090	659	805	348	406	534	247
10%	2185	2838	1531	780	923	466	479	630	328
Maximum	2629	3557	2392	940	1058	690	572	1003	747

Exceedence frequency versus salt concentration relationships were developed in a

TAB file of the WRAP programs. Concentration-duration curves for TDS, chlorides and sulfates are presented in Table 6.12. With adjustments reflecting the impacts of the proposed salt control dam plan, mean monthly TDS concentrations of 1,266 mg/l (LAG0), 1,583 mg/l (LAG1), and 406 mg/l (LAG2), at Possum Kingdom reservoir, are equaled or exceeded during 90 % of the 696 months in the 1940-1997 simulation period. With construction of the salt control dam plan, chloride concentrations of 464 mg/l (LAG0), 537 mg/l (LAG1), and 138 mg/l (LAG2) are predicted to equal or exceed 90 % of the months during the simulation period. With salt control dams, the computed mean monthly sulfate concentrations equaled or exceeded 286 mg/l (LAG0), 362 mg/l (LAG1), and 82 mg/l (LAG2) during 90 % of the 696 months in the period of 1940-1997.

Concentration-duration relationships for the Whitney reservoir are presented as tables in Appendix B. With construction of the salt control dam plan, TDS concentrations of 927 mg/l (LAG0), 738 mg/l (LAG1), and 655 mg/l (LAG2) are predicted to equal or exceed 90 % of the months during the simulation period. With salt control dams, the computed mean monthly chloride concentrations equaled or exceeded 376 mg/l (LAG0), 311 mg/l (LAG1), and 248 mg/l (LAG2) during 90 % of the 696 months in the period of 1940-1997. At Whitney reservoir, mean monthly sulfate concentrations of 182 mg/l (LAG0), 191 mg/l (LAG1), and 189 mg/l (LAG2) equaled or exceeded during 90% of the 696 months in the 1940-1997 simulation periods. Based on EPA standards, water quality at Whitney reservoir is still poor. However, with salt control impoundments, the computed mean monthly sulfate concentrations equaled or exceeded 215 mg/l (LAG0), 247 mg/l (LAG1), and 250 mg/l (LAG2) during 50% of the 696 months during the simulation period.

Concentration limit for sulfates of 250 mg/l is recommended in the EPA drinking water standards. With construction of salt control dam plan, concentration-duration relationships for TDS, chlorides and sulfates under the specific salt concentrations are tabulated in appendix B.

As indicated in Table 6.13, with a TDS limit of 500 mg/l, the salt control impoundments slightly increase the volume reliabilities from 1.17 % (LAG1) to 2.05 % (LAG1), from 0.36 % (LAG2) to 0.75 % (LAG2), and also increase the period reliabilities from 0.86 % (LAG1) to 1.58 % (LAG1), from 0.29 % (LAG2) to 0.72 % (LAG2). At Possum Kingdom reservoir, volume and reliabilities with a 500 mg/l salinity constraint are 0 % when lag option is not activated. Under 1,500 mg/l salinity constraint, the volume reliabilities with the salt control impoundments are increased from 2.55 % to 41.01 % (LAG0), from 7.49 % to 35.84 % (LAG1), and from 5.07 % to 44.78 % (LAG2). Under the same constraint, the period reliabilities are increased from 2.59 % to 40.52 % (LAG0), from 7.04 % to 34.2 % (LAG1), and from 5.03 and 44.54 (LAG2).

Table 6.13 Reliability table for TDS at Possum Kingdom Reservoir

Lag option	Constraint (mg/l)	TDS reliability without Dam		TDS reliability with Dam	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	100	100	100	100
LAG0	1500	2.55	2.59	41.01	40.52
	1000	0	0	1.57	1.58
	500	0	0	0	0
LAG1	1500	7.49	7.04	35.84	34.2
	1000	3.04	2.59	6.56	6.18
	500	1.17	0.86	2.05	1.58
LAG2	1500	5.07	5.03	44.78	44.54
	1000	1.38	1.44	6.02	5.89
	500	0.36	0.29	0.75	0.72

Table 6.14 Reliability table for chlorides at Possum Kingdom Reservoir

Lag option	Constraint (mg/l)	CL reliability without Dam		CL reliability with Dam	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	100	100	100	100
LAG0	1000	62.15	62.5	100	100
	750	14.92	14.8	87.56	87.64
	500	1.29	1.15	20.13	19.97
	250	0	0	0	0
LAG1	1000	55.35	53.45	98.91	98.71
	750	24.5	23.13	80.83	79.17
	500	4.78	4.17	33.38	31.18
	250	1.7	1.29	3.33	2.87
LAG2	1000	68.06	67.96	97.5	97.56
	750	28.36	27.59	86.84	86.35
	500	2.65	2.59	45.54	45.11
	250	0.36	0.29	1.49	1.44

As indicated in Table 6.14, with a chloride limit of 500 mg/l, the proposed salt control impoundments increase the volume reliabilities from 1.29 % to 20.13 % (LAG0), from 4.78 % to 33.38 % (LAG1), and from 2.65 % to 45.54 % (LAG2), and also increase the period reliabilities from 1.15 % to 19.97 % (LAG0), from 4.17 % to 31.18 % (LAG1), and from 2.59 % to 45.11 % (LAG2). At Whitney reservoir, volume and reliabilities with a 250 mg/l chloride constraint are 0 % when lag option is not activated.

Table 6.15 shows reliability table for sulfates at Possum Kingdom Reservoir. With a sulfate limit of 250 mg/l, the proposed salt control impoundments increase the volume reliabilities from 0.89 % to 3.93 % (LAG0), from 4.58 % to 5.58 % (LAG1), and from 2.01 % to 9.89 % (LAG2), and also increase the period reliabilities from 0.72 % to 3.74 % (LAG0), from 4.02 % to 9.34 % (LAG1), and from 2.01 % to 10.06 % (LAG2). Under maximum allowable sulfate concentration, volume and period reliabilities are 100 % regardless of the lag option. With the salt control impoundments, volume and period reliabilities at Whitney reservoir are following the similar trends to volume and period reliabilities at Possum Kingdom reservoir. Water quality at Whitney reservoir is better than water quality at Possum Kingdom reservoir, because Whitney reservoir is located downstream. When the proposed salt control impoundments are constructed, volume and period reliabilities at Whitney reservoir are tabulated in Appendix B.

Table 6.15 Reliability table for sulfates at Possum Kingdom Reservoir

Lag option	Constraint (mg/l)	SO4 without Dam		SO4 reliability with Dam	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	100	100	100	100
LAG0	1000	100	100	100	100
	750	99.87	99.86	100	100
	500	66.39	66.52	93.47	93.68
	250	0.89	0.72	3.93	3.74
LAG1	1000	100	100	100	100
	750	92.66	91.95	99.88	99.86
	500	53.79	52.16	79.26	77.44
	250	4.58	4.02	9.98	9.34
LAG2	1000	100	100	100	100
	750	91.16	90.8	99.42	99.43
	500	64.12	63.94	82.49	82.04
	250	2.01	2.01	9.89	10.06

For Possum Kingdom reservoir and Whitney reservoir, TDS concentrations with/without salt control dams are shown in Figures 6.11-6.13. Chloride and sulfate concentrations with/without salt control impoundments are plotted in Appendix B. The trends of TDS, chlorides and sulfates are similar when the same lag option is activated.

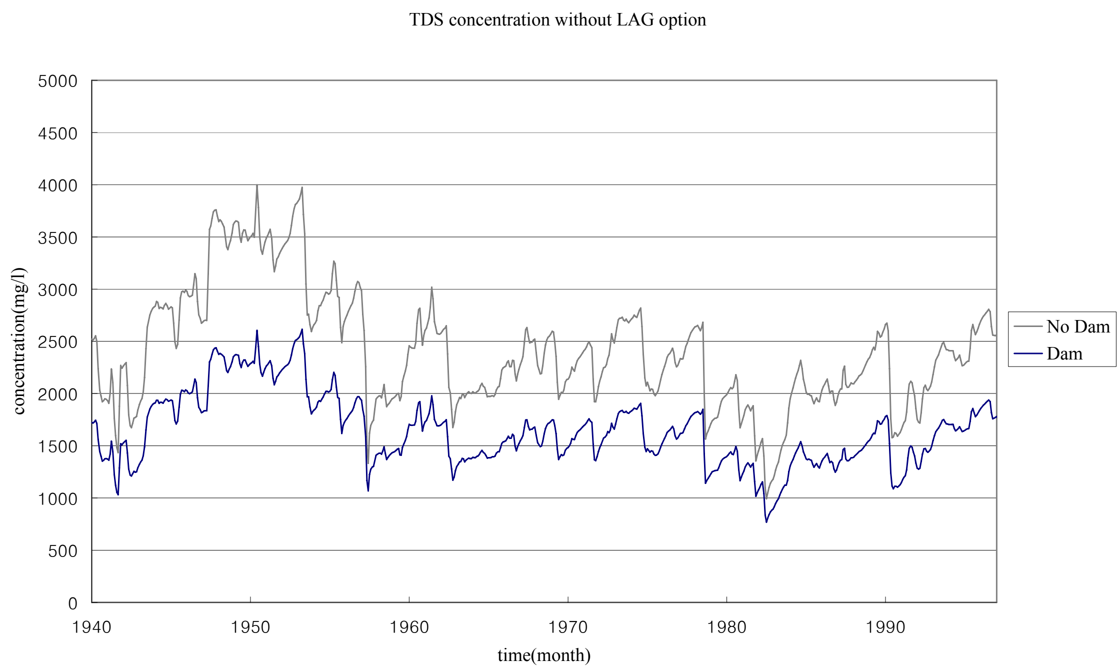

Figure 6.11 TDS concentration without LAG option at Possum Kingdom Reservoir

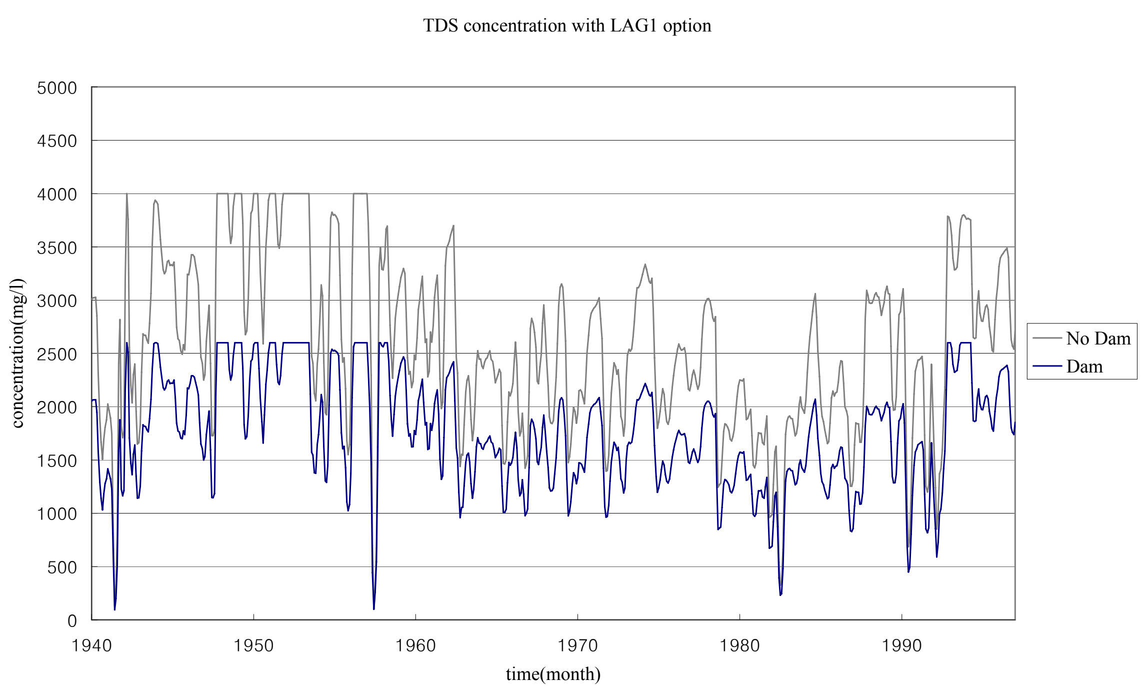

Figure 6.12 TDS concentration with LAG1 option at Possum Kingdom Reservoir

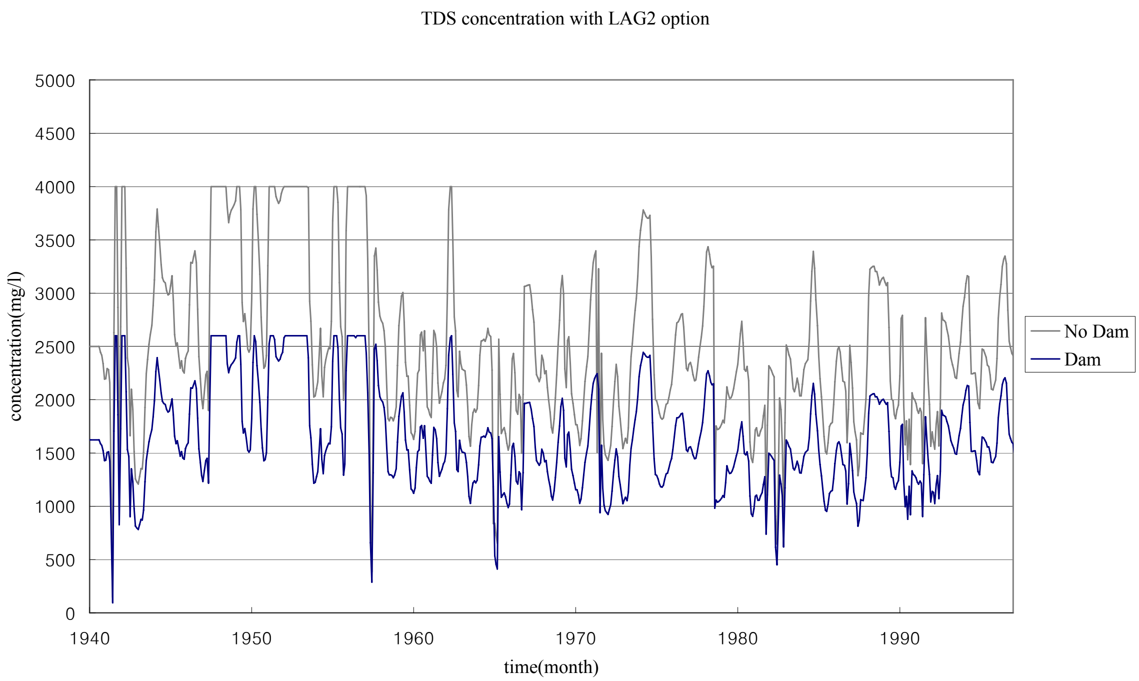

Figure 6.13 TDS concentration with LAG2 option at Possum Kingdom Reservoir

CHAPTER VII

SUMMARY AND CONCLUSIONS

The Water Rights Analysis Package (WRAP) simulates management of the water resources of a river basin or multiple-basin region under a priority-based water allocation system. The model facilitates assessments of hydrologic and institutional water availability and reliability in satisfying requirements for instream flows, water supply diversions, hydroelectric energy generation, and reservoir storage. The Texas Commission on Environmental Quality (TCEQ) was the lead agency for implementing the WAM System in conjunction with administration of the state's water rights permit system. A salinity component was recently added to WRAP which consists of the simulation model WRAP-SALT and salinity-related routines in the post-simulation program TABLES. The model computes concentrations of conservative water quality constituents in the regulated stream flows, diversions, and reservoir storage throughout the river system.

Salinity Routing in WRAP

Salinity routing methods in WRAP-SALT are based on setting the reservoir outflow concentrations equal to the storage concentrations adjusted for timing effects based on the concept of lag. The end-of-month storage concentration computed by WRAP-SALT is a volume-weighted mean reflecting the total salt load and volume of the reservoir.

WRAP-SALT program reads water quantity data from the main WRAP-SIM simulation results along with additional input data regarding salt concentrations and loading of flows entering the river system. Concentration frequency and supply reliability analyses of simulation results are performed within the post-simulation program TABLES.

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 parameter.

Two options are incorporated into WRAP-SALT. The timing of the load inflows used to determine outflow concentrations is set by lag parameters such as LAG1(cp) and LAG2(cp). In one option, the model-user sets a constant LAG that is applied during every month of the simulation. This option requires calibration studies to determine the LAG. If the observed data is available, calibration studies are performed for interested areas. In the second option, a variable LAG is computed within the model in each month based on the concept of retention time. Retention time is a representation of the time required for a monthly volume of water and its salt load to flow through a reservoir

Lag Analysis of Observed Data

The observed stream flow, reservoir storage, and salt concentration data for selected reservoir/river systems complied by the USGS develops an understanding of the timing and load balance characteristics of the movement of salts through reservoirs. Concentrations are related to salt loads and discharge for flow or storage. 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.

Historical gauged data provide a basis for calibration of routing parameters. The monthly lag represents physically the time required for the salt load to reach the reservoir outlet once it has entered the reservoir system. The calculations are based on the premise of complete mixing at each study location. The timing of the inflow load to determine outflow concentration is calculated by lag parameters with the monthly time steps.

The true mean concentrations of TDS, chlorides, and sulfates are best represented by the 4 lagged months at the Possum Kingdom reservoir and the 1 lagged month at the Granbury-Whitney reservoir in both methods MC1 and MC2.

Brazos River Basin Simulation

As calibration studies for the Possum Kingdom and Whitney reservoirs are done in Chapter IV, the lag months are applied for the Brazos River Basin simulation: 4 months for the Possum Kingdom reservoir and 1 month for the Whitney reservoir.

A concentration duration analysis explains the temporal variation in salt concentration. At the Possum Kingdom reservoir, mean monthly TDS concentrations of

1,808 mg/l (LAG0), 1,657 mg/l (LAG1), and 1,671 mg/l (LAG2) equaled or exceeded 90 % of the 696 months of the simulation period.

Reliabilities generally decrease with increasing salt constraint. The volume and period reliabilities are 100 % and 100 % for water quantity. Water supply is severely constrained by salinity standards. Concentration limits for TDS, chlorides and sulfates of 500 mg/l, 250 mg/l, and 250 mg/l are recommended in the Environmental Protection Agency (EPA) drinking water standards. A TDS constraint of 500 mg/l at the Possum Kingdom reservoir results in period and volume reliabilities of 0 % and 0 % for LAG0, 1.17 % and 0.86 % for LAG1, and 0.36 % and 0.29 % for LAG2. For the Whitney reservoir, a TDS constraint of 500 mg/l results in period and volume reliabilities of 39.44 % and 37.93 % for LAG0, 54.82 % and 53.59 % for LAG1, and 62.93 % and 61.93 % for LAG2. Although the volume and period reliabilities at the Whitney reservoir are 99.2 % and 98.85 % for water quantity, water supply is severely constrained by salinity. The trends of TDS, chlorides and sulfates are similar when the same lag option is activated. Lag month is longer, therefore, the mean monthly concentration has more fluctuations.

Proposed salt control dams improve water quality throughout the basin. Proposed salt control dams with numerous alternative plans are located in the primary salt source areas of the upper basin. With a sulfate limit of 250 mg/l, the proposed salt control impoundments increase the volume reliabilities from 0.89 % to 3.93 % (LAG0), from 4.58 % to 5.58 % (LAG1), and from 2.01 % to 9.89 % (LAG2), and they also increase the period reliabilities from 0.72 % to 3.74 % (LAG0), from 4.02 % to 9.34 % (LAG1), and from 2.01 % to 10.06 % (LAG2). With a chloride limit of 500 mg/l at the Whitney reservoir, the proposed salt control impoundments increase the volume reliabilities from 1.29 % to 20.13 % (LAG0), from 4.78 % to 33.38 % (LAG1), and from 2.65 % to 45.54 % (LAG2), and they also increase the period reliabilities from 1.15 % to 19.97 % (LAG0), from 4.17 % to 31.18 % (LAG1), and from 2.59 % to 45.11 % (LAG2). In this case, volume and period reliabilities are considerably improved when the proposed salt control dam is considered.

Conclusions

With the lag features, the accuracy between observed and computed mean monthly salinity concentrations is usually improved through the reservoir. Proposed salt control impoundments improve water quality throughout the basin. A WRAP-SALT model is generalized for application to any river/reservoir system, with input files being developed for the specific river basin. The flexible model might be used by water resources experts in universities, private consulting firms, and state/federal agencies in the development of water resources planning and management in the river basin. The future research of the river basin will continue to study applications of water quality concerning water use, water rights permits, various contracts, evaluation of reservoir system operating policies, and planning for construction of new facilities.

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APPENDIX A

Table A.1 Volume and load balance for chloride at Possum Kingdom reservoir using mean concentration method 1 (MC1) during 1977-79

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				489000								
1977	11	561	4984	477700	2662	-4215	563549	572900	1460	5860	-4951	865
1977	12	1081	6938	467200	4188	-455	556579	563549	2050	8480	-540	872
1978	1	1319	7236	459200	942	-1141	549027	556579	2690	8880	-1362	878
1978	2	2882	4270	459900	-930	1158	554005	549027	9320	5350	1008	883
1978	3	4443	2253	462500	3257	3668	563486	554005	9140	2850	3192	891
1978	4	5784	1190	474400	4624	11931	577218	563486	4870	1520	10382	895
1978	5	13273	6609	478500	2405	-160	594876	577218	26400	8550	-192	905
1978	6	18298	4011	481700	7062	-4025	610665	594876	25800	5080	-4931	923
1978	7	177	4094	466500	10476	-807	605015	610665	669	5310	-1009	943
1978	8	575722	79537	555300	4420	-402965	308254	605015	140000	88300	-348461	657
1978	9	27959	33068	549100	4424	3333	310754	308254	35700	36100	2900	412
1978	10	14091	21225	540200	5444	3679	317755	310754	26500	22700	3201	424
1978	11	8658	12891	535400	-348	-915	328141	317755	22400	11500	-514	442
1978	12	6532	6514	530300	3092	-2026	341457	328141	20300	5790	-1194	462
1979	1	8231	10451	527300	-1045	-1826	358440	341457	24700	6580	-1137	487
1979	2	5831	7226	526200	894	1189	375495	358440	20500	4480	1034	512
1979	3	18732	10266	541000	168	6503	414103	375495	40900	7950	5658	544
1979	4	10336	21110	533400	2262	5437	427834	414103	24400	15400	4731	576
1979	5	65234	70562	533400	-483	4845	443050	427834	51300	40300	4216	600
1979	6	70221	58695	538700	4853	-1373	475367	443050	68400	35000	-1083	630
1979	7	24740	7486	549400	6994	440	494690	475367	23600	4660	383	656
1979	8	22455	14112	552700	5102	60	521372	494690	35900	9270	52	678
1979	9	2122	25363	523600	7140	1280	509876	521372	4890	17500	1114	705
1979	10	446	10988	507600	6330	872	504085	509876	1310	7860	759	723
1979	11	2507	5655	498000	2915	-3538	500664	504085	3960	4120	-3261	735
1979	12	2763	3646	499000	-741	1142	506997	500664	8070	2730	994	743

Table A.2 Volume and load balance for chloride at Possum Kingdom reservoir using mean concentration method 1 (MC1) during 1980-81

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1980	1	3717	9408	492300	577	-432	509149	506997	10100	7540	-408	754
1980	2	3798	6605	490300	1515	2322	519809	509149	13700	5060	2020	770
1980	3	2047	4655	484100	4205	613	523283	519809	6680	3740	534	787
1980	4	1260	4370	478000	5588	2598	525764	523283	3720	3500	2261	802
1980	5	129209	46659	559100	-2137	-3587	583433	525764	98700	37500	-3531	787
1980	6	28600	47772	535400	9579	5051	609428	583433	61000	39400	4395	802
1980	7	2309	36730	490600	12437	2058	587369	609428	8450	32300	1791	858
1980	8	577	19440	463700	9927	1890	573263	587369	2350	18100	1645	895
1980	9	101310	33150	497700	-1023	-35183	537329	573263	32100	31200	-36834	850
1980	10	252565	266003	538200	5077	59015	447883	537329	97000	237800	51354	699
1980	11	17726	11230	542500	1990	-206	475036	447883	35600	8310	-136	628
1980	12	37743	50700	534200	438	5094	510169	475036	67200	36500	4433	673
1981	1	14612	44071	503700	2311	1270	516774	510169	37400	31900	1105	728
1981	2	8848	15858	497700	1634	2644	534974	516774	27800	11900	2301	772
1981	3	26132	26214	505600	936	8918	581534	534974	58400	19600	7760	818
1981	4	52201	13902	556300	3441	15843	644920	581534	60100	10500	13786	849
1981	5	28719	45890	541400	2796	5067	653129	644920	38300	34500	4409	870
1981	6	109634	104263	551100	1567	5896	642360	653129	68100	84000	5130	872
1981	7	11439	37488	515000	9160	-891	628936	642360	18100	30700	-823	877
1981	8	13694	12764	506400	7240	-2290	631948	628936	15900	10700	-2189	908
1981	9	9235	11300	499100	4316	-919	631513	631948	10100	9640	-895	924

Table A.3 Volume and load balance for sulfate at Possum Kingdom reservoir using mean concentration method 1 (MC1) during 1977-79

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				489000								
1977	11	561	4984	477700	2662	-4215	288603	293400	742	3000	-2539	443
1977	12	1081	6938	467200	4188	-455	285227	288603	1230	4330	-277	447
1978	1	1319	7236	459200	942	-1141	281568	285227	1600	4560	-698	450
1978	2	2882	4270	459900	-930	1158	283976	281568	4130	2730	1008	453
1978	3	4443	2253	462500	3257	3668	289728	283976	4000	1440	3192	457
1978	4	5784	1190	474400	4624	11931	302192	289728	2860	778	10382	465
1978	5	13273	6609	478500	2405	-160	311184	302192	13500	4410	-98	473
1978	6	18298	4011	481700	7062	-4025	321635	311184	15600	2620	-2529	485
1978	7	177	4094	466500	10476	-807	318674	321635	269	2710	-520	497
1978	8	575722	79537	555300	4420	-402965	175630	318674	85800	45300	-183545	356
1978	9	27959	33068	549100	4424	3333	181430	175630	21500	18600	2900	238
1978	10	14091	21225	540200	5444	3679	183731	181430	10500	11400	3201	247
1978	11	8658	12891	535400	-348	-915	186671	183731	8820	5600	-280	253
1978	12	6532	6514	530300	3092	-2026	191222	186671	8000	2810	-639	261
1979	1	8231	10451	527300	-1045	-1826	197561	191222	9760	2820	-601	270
1979	2	5831	7226	526200	894	1189	204835	197561	8080	1840	1034	281
1979	3	18732	10266	541000	168	6503	222904	204835	16100	3690	5658	295
1979	4	10336	21110	533400	2262	5437	230205	222904	9600	7030	4731	310
1979	5	65234	70562	533400	-483	4845	238621	230205	20200	16000	4216	323
1979	6	70221	58695	538700	4853	-1373	250687	238621	26900	14300	-534	336
1979	7	24740	7486	549400	6994	440	258460	250687	9330	1940	383	344
1979	8	22455	14112	552700	5102	60	268581	258460	14100	4030	52	352
1979	9	2122	25363	523600	7140	1280	263835	268581	1930	7790	1114	364
1979	10	446	10988	507600	6330	872	261418	263835	564	3740	759	375
1979	11	2507	5655	498000	2915	-3538	259745	261418	1850	1960	-1563	381
1979	12	2763	3646	499000	-741	1142	262789	259745	3350	1300	994	385

Table A.4 Volume and load balance for sulfate at Possum Kingdom reservoir using mean concentration method 1 (MC1) during 1980-81

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1980	1	3717	9408	492300	577	-432	263504	262789	4520	3610	-195	390
1980	2	3798	6605	490300	1515	2322	268454	263504	5350	2420	2020	398
1980	3	2047	4655	484100	4205	613	269948	268454	2750	1790	534	406
1980	4	1260	4370	478000	5588	2598	272088	269948	1560	1680	2261	414
1980	5	129209	46659	559100	-2137	-3587	314067	272088	61600	17900	-1722	416
1980	6	28600	47772	535400	9579	5051	328262	314067	28700	18900	4395	432
1980	7	2309	36730	490600	12437	2058	317703	328262	3250	15600	1791	463
1980	8	577	19440	463700	9927	1890	311463	317703	855	8740	1645	485
1980	9	101310	33150	497700	-1023	-35183	299702	311463	21900	15100	-18561	468
1980	10	252565	266003	538200	5077	59015	300355	299702	63900	114600	51354	426
1980	11	17726	11230	542500	1990	-206	314318	300355	18000	3960	-78	418
1980	12	37743	50700	534200	438	5094	335851	314318	34500	17400	4433	444
1981	1	14612	44071	503700	2311	1270	339056	335851	17300	15200	1105	478
1981	2	8848	15858	497700	1634	2644	347406	339056	11700	5650	2301	504
1981	3	26132	26214	505600	936	8918	372636	347406	26800	9330	7760	528
1981	4	52201	13902	556300	3441	15843	414432	372636	33000	4990	13786	545
1981	5	28719	45890	541400	2796	5067	423941	414432	21500	16400	4409	562
1981	6	109634	104263	551100	1567	5896	432672	423941	43800	40200	5130	577
1981	7	11439	37488	515000	9160	-891	427231	432672	9740	14700	-481	593
1981	8	13694	12764	506400	7240	-2290	429818	427231	9020	5150	-1283	617
1981	9	9235	11300	499100	4316	-919	430532	429818	5870	4630	-526	629

Table A.5 Volume and load balance for the TDS at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1970-72

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				515600								
1970	10	30184	25587	526300	-1205	4898	457838	434500	43400	21900	1838	630
1970	11	13129	9402	529500	6766	6239	479149	457838	27200	8230	2341	653
1970	12	11254	10453	530200	3908	3807	492998	479149	21600	9180	1429	675
1971	1	5988	34909	501200	5357	5278	473978	492998	10700	31700	1980	690
1971	2	1884	1444	503600	3494	5454	477601	473978	2900	1324	2047	697
1971	3	1640	1845	497400	9394	3399	479707	477601	2630	1800	1275	703
1971	4	1611	5950	505900	3848	16688	482858	479707	2840	5951	6262	706
1971	5	6742	14880	520200	5883	28321	482996	482858	4110	14600	10628	692
1971	6	3669	20231	498100	11484	5946	471017	482996	5890	20100	2231	689
1971	7	2493	30684	485800	8143	24034	454586	471017	4450	29900	9019	692
1971	8	27679	3997	495900	5332	-8251	496529	454586	53900	3970	-7988	713
1971	9	158628	57779	568800	6114	-21836	771221	496529	361000	60300	-26008	876
1971	10	125395	162942	690800	-11574	147973	860320	771221	249000	215430	55529	953
1971	11	49720	163636	604900	4764	32781	765421	860320	92700	199900	12302	923
1971	12	31436	219511	625600	-4398	204377	608917	765421	30800	264000	76696	821
1972	1	29032	159868	579900	-283	84853	527059	608917	59300	173000	31842	693
1972	2	4491	28213	575100	5189	24111	517807	527059	9600	27900	9048	665
1972	3	1995	27608	559100	10034	19647	501880	517807	4100	27400	7373	661
1972	4	14834	26896	552000	6764	11726	517080	501880	37000	26200	4400	674
1972	5	37599	37384	557200	2565	7551	562614	517080	78300	35600	2834	716
1972	6	12282	41712	520100	10453	2784	548159	562614	25100	40600	1045	758
1972	7	5728	87312	443700	9807	14991	480684	548159	12200	85300	5626	785
1972	8	121698	56692	483200	9740	-15766	672270	480684	268000	56800	-19615	915
1972	9	129439	51423	587000	5387	31171	926297	672270	312000	69670	11697	1099
1972	10	25720	25611	600500	340	13731	963450	926297	72100	40100	5153	1170
1972	11	164176	60309	693000	-140	-11506	1306953	963450	463000	99300	-20197	1291
1972	12	45808	57118	678300	2604	-786	1341735	1306953	135000	98700	-1518	1421

Table A.6 Volume and load balance for TDS at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1973-75

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1973	1	37515	37139	707600	-2388	26535	1393993	1341735	110000	67700	9958	1452
1973	2	41107	20061	766300	-459	37195	1506551	1393993	136000	37400	13958	1447
1973	3	70760	94282	772400	4389	34011	1594314	1506551	252000	177000	12763	1482
1973	4	82393	265041	802900	-6420	206728	1409892	1594314	225000	487000	77578	1403
1973	5	42774	99967	789500	5846	49639	1377520	1409892	129000	180000	18628	1287
1973	6	77462	256979	774500	-1732	162784	1213607	1377520	198000	423000	61087	1218
1973	7	86408	112380	779100	-934	29637	1259729	1213607	211000	176000	11122	1171
1973	8	16378	77937	729900	18251	30610	1170515	1259729	16300	117000	11487	1184
1973	9	3614	27777	713700	-332	7630	1139679	1170515	9400	43100	2863	1177
1973	10	34518	39913	752900	-10929	33666	1115112	1139679	22600	59800	12634	1131
1973	11	5357	28822	742400	4195	17159	1083382	1115112	5030	43200	6439	1081
1973	12	36389	38408	744800	6442	10862	1143958	1083382	114000	57500	4076	1102
1974	1	17570	30902	744600	613	13746	1153616	1143958	55000	50500	5158	1135
1974	2	1904	24662	729800	6050	14008	1123493	1153616	4920	40300	5257	1136
1974	3	6478	63810	679500	9046	16078	1044927	1123493	19400	104000	6034	1132
1974	4	10310	35554	651200	9776	6720	1008948	1044927	19600	58100	2522	1135
1974	5	5349	20582	635000	7053	6087	983022	1008948	5390	33600	2284	1139
1974	6	11925	38705	603200	12889	7870	945476	983022	22700	63200	2953	1146
1974	7	18405	56745	558500	17112	10752	920411	945476	63600	92700	4035	1181
1974	8	26729	41958	572900	-4258	25371	941432	920411	80000	68500	9521	1210
1974	9	21842	33606	615000	-3297	50567	927208	941432	21700	54900	18976	1157
1974	10	202901	34102	781800	-4695	-6694	1224795	927208	359000	51100	-10312	1133
1974	11	297509	428495	771900	317	121403	1218354	1224795	648000	700000	45558	1157
1974	12	29528	67049	757200	712	23533	1191485	1218354	64300	100000	8831	1159
1975	1	47220	79244	754000	1323	30146	1186798	1191485	103000	119000	11313	1157
1975	2	130915	250844	775400	-2551	138778	1094876	1186798	232000	376000	52078	1097
1975	3	58998	85819	771200	3683	26304	1115747	1094876	128000	117000	9871	1051
1975	4	37097	151244	775700	-1828	116818	982885	1115747	29300	206000	43838	998
1975	5	38767	66653	795800	-10646	37340	958697	982885	50700	88900	14012	909
1975	6	175422	278733	761700	12283	81494	939279	958697	310000	360000	30582	896
1975	7	28251	44672	742700	10379	7800	943306	939279	57700	56600	2927	920
1975	8	50083	58752	731300	15359	12628	996645	943306	123000	74400	4739	968
1975	9	37402	23423	744800	6124	5644	1060064	996645	91600	30300	2118	1025
1975	10	7041	21596	718200	9486	-2560	1045878	1060064	17800	28300	-3686	1059
1975	11	4834	15505	691900	6583	-9046	1023506	1045878	12000	21100	-13271	1079
1975	12	7105	39124	653400	96	-6385	976417	1023506	16900	54500	-9489	1093

Table A.7 Volume and load balance for TDS at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1976-78

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1976	1	13983	52520	617000	7370	9507	940685	976417	33700	73000	3568	1110
1976	2	7755	53909	575700	6437	11290	888322	940685	19700	76300	4237	1128
1976	3	2158	33271	551100	3988	10500	849902	888322	5140	47500	3940	1135
1976	4	7162	14061	592100	-6411	41487	854671	849902	9500	20300	15569	1097
1976	5	44507	36440	675800	-1644	73990	858437	854671	28100	52100	27766	994
1976	6	22419	54190	674400	4670	35041	830387	858437	34000	75200	13150	920
1976	7	21929	60615	681300	-3025	42560	788558	830387	26100	83900	15971	878
1976	8	25983	71540	637300	14598	16154	767720	788558	69500	96400	6062	868
1976	9	41149	25087	656900	162	3700	820908	767720	84700	32900	1388	903
1976	10	84716	29833	719000	-3723	3494	979220	820908	196000	39000	1311	962
1976	11	92565	53603	766600	3530	12169	1157186	979220	246000	72600	4567	1058
1976	12	15330	57408	752900	272	28650	1126637	1157186	38600	79900	10751	1105
1977	1	37230	68862	743100	-1035	20797	1115142	1126637	77800	97100	7804	1102
1977	2	21427	35036	771300	2475	44283	1125260	1115142	43200	49700	16618	1088
1977	3	130744	181418	881600	-2737	158237	978941	1125260	50300	256000	59381	936
1977	4	93410	370929	789100	-5348	179671	747365	978941	191000	490000	67424	760
1977	5	125447	151993	780900	3127	21474	846423	747365	267000	176000	8058	747
1977	6	20505	46038	742200	14936	1770	852787	846423	54100	48400	664	821
1977	7	17361	51761	689700	18127	26	850097	852787	49400	52100	10	875
1977	8	5615	49083	628400	9043	-8789	806749	850097	14300	46600	-11048	924
1977	9	9620	32747	584500	16021	-4752	797663	806749	27700	30500	-6286	973
1977	10	10011	18635	556800	6564	-12512	790652	797663	27800	17400	-17412	1024
1977	11	10153	9453	552800	400	-4301	803931	790652	28600	9140	-6181	1057
1977	12	8108	7843	545900	5024	-2142	816701	803931	23600	7670	-3160	1085
1978	1	8975	8148	545200	1773	245	828993	816701	20200	8000	92	1109
1978	2	6750	6379	551400	-3518	2312	840340	828993	16800	6320	867	1120
1978	3	3925	6472	545300	4655	1102	842764	840340	8470	6460	414	1129
1978	4	23105	5421	561000	4670	2685	851752	842764	13500	5520	1008	1127
1978	5	8388	16711	555900	2190	5413	853783	851752	17300	17300	2031	1123
1978	6	4314	37815	511300	13583	2483	824705	853783	9190	39200	932	1157
1978	7	2275	1757	491100	16498	-4219	823973	824705	8060	1850	-6942	1210
1978	8	467300	93499	766400	11098	-87403	1709855	823973	1240000	178000	-176118	1482
1978	9	22038	23581	745800	9399	-9658	1679315	1709855	56900	65800	-21640	1648
1978	10	31569	36351	735300	12734	7016	1676747	1679315	72000	77200	2633	1667
1978	11	14977	40483	722500	-4582	8123	1623796	1676747	27700	83700	3048	1665
1978	12	6742	49648	682600	4055	7061	1534446	1623796	13000	105000	2650	1653

Table A.8 Volume and load balance for TDS at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1979-81

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1979	1	12230	60347	643200	-1097	7620	1425505	1534446	17200	129000	2859	1642
1979	2	8731	61222	601800	-1162	9928	1314131	1425505	12900	128000	3726	1618
1979	3	28742	28489	678800	-4626	72120	1308195	1314131	25600	58600	27064	1506
1979	4	63239	26761	761000	4724	50446	1317425	1308195	43000	52700	18930	1341
1979	5	124816	359758	808400	-7625	274717	928517	1317425	120000	612000	103092	1053
1979	6	76695	155367	779500	10429	60201	872109	928517	120000	199000	22591	834
1979	7	8301	55087	731400	8635	7321	823256	872109	14600	66200	2747	825
1979	8	11312	63427	687800	4729	13245	778526	823256	20500	70200	4970	830
1979	9	23760	51356	661400	9459	10655	776225	778526	44300	50600	3998	848
1979	10	14212	34514	650400	5661	14963	772840	776225	23300	32300	5615	869
1979	11	4695	28116	623800	5602	2423	755159	772840	8110	26700	909	882
1979	12	8249	62630	586700	-2267	15014	714893	755159	14100	60000	5634	893
1980	1	9531	48545	560700	-1116	11899	685959	714893	13300	46700	4465	898
1980	2	14261	2493	578000	2313	7845	710783	685959	24300	2420	2944	902
1980	3	5324	1716	582700	1908	3000	720518	710783	10300	1690	1126	907
1980	4	4465	2293	596000	4059	15187	732737	720518	8760	2240	5699	907
1980	5	37860	4556	668900	-566	39030	808204	732737	65300	4480	14646	896
1980	6	55561	31010	678500	15964	1013	890884	808204	113000	30700	380	927
1980	7	37696	55006	634900	21459	-4831	910456	890884	80200	54000	-6628	1009
1980	8	26793	49692	582000	16916	-13085	902357	910456	61300	49900	-19498	1096
1980	9	43472	37333	572400	3409	-12330	929993	902357	87200	40000	-19565	1167
1980	10	257276	31224	766700	9227	-22525	1432739	929993	589000	46500	-39754	1298
1980	11	18960	26063	755500	3201	-896	1428456	1432739	37600	40200	-1683	1382
1980	12	47944	47552	760500	-801	3806	1442084	1428456	85000	72800	1428	1393
1981	1	41401	59246	739300	2558	-797	1435655	1442084	91300	96200	-1529	1411
1981	2	15110	49267	708100	1467	4425	1389216	1435655	33300	81400	1660	1435
1981	3	40419	38051	737900	-1670	25762	1393083	1389216	58000	63800	9667	1415
1981	4	17341	37660	724200	4387	11005	1351513	1393083	18400	64100	4130	1381
1981	5	65566	42934	742800	1498	-2533	1388480	1351513	115000	73300	-4733	1374
1981	6	114936	218519	774600	-15203	120180	1289579	1388480	216000	360000	45099	1298
1981	7	35121	55646	750400	10957	7282	1283912	1289579	79000	87400	2733	1241
1981	8	20563	55698	709800	13375	7910	1240981	1283912	41500	87400	2968	1272
1981	9	11786	34762	681900	8517	3594	1210929	1240981	21300	52700	1349	1296
1981	10	1087577	756522	904400	-10700	-119255	1188541	1210929	1173000	1015000	-180388	1113
1981	11	95923	295287	781800	3634	80398	929712	1188541	83000	372000	30171	924
1981	12	17185	43236	762600	5008	11859	898662	929712	25400	60900	4450	871

Table A.9 Volume and load balance for TDS at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1982-84

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1982	1	17724	62483	723600	2213	7972	840954	898662	19000	79700	2992	861
1982	2	29635	64268	715400	1872	28306	804976	840954	34300	80900	10622	841
1982	3	17808	59913	702000	1177	29882	769290	804976	26900	73800	11214	817
1982	4	8374	27663	694900	4054	16243	756485	769290	14300	33200	6095	803
1982	5	615854	593100	813000	-5109	90237	782348	756485	630000	638000	33863	751
1982	6	802750	696397	942600	2558	25804	803031	782348	691000	680000	9683	664
1982	7	269044	498655	774800	14628	76438	586716	803031	211000	456000	28685	595
1982	8	28889	47581	735200	18166	-2742	570413	586716	26200	40400	-2103	564
1982	9	7367	29762	696000	11095	-5709	548080	570413	7930	25800	-4464	575
1982	10	4278	21441	668800	6386	-3651	531103	548080	4810	18900	-2887	582
1982	11	15408	19870	659100	-2129	-7367	526433	531103	18800	17600	-5869	586
1982	12	14733	19097	649600	-1184	-6320	521472	526433	17100	17000	-5061	589
1983	1	11341	49513	602800	214	-8415	484116	521472	14000	44600	-6756	591
1983	2	15421	25488	590400	-1474	-3807	481136	484116	22900	22800	-3080	595
1983	3	38118	24444	599700	1060	-3314	514365	481136	57800	21800	-2771	615
1983	4	33614	24748	596700	9995	-1871	550299	514365	59600	22000	-1665	654
1983	5	63108	17080	651800	-959	8113	578844	550299	40800	15300	3044	665
1983	6	33384	16994	658900	9586	297	613955	578844	50200	15200	111	669
1983	7	42046	40534	637100	12094	-11218	638311	613955	71700	36500	-10844	711
1983	8	24246	34800	611500	7605	-7441	645063	638311	45800	31400	-7648	756
1983	9	20731	5435	608500	11832	-6464	674907	645063	42000	5160	-6996	796
1983	10	27995	1619	623700	2178	-8998	721206	674907	58100	1610	-10191	833
1983	11	9449	1222	623400	1268	-7260	730716	721206	19200	1240	-8449	856
1983	12	46368	1781	654300	2383	-11303	809150	730716	93900	1850	-13616	886
1984	1	33907	1075	687800	3378	4046	888148	809150	78600	1120	1518	930
1984	2	12738	899	700600	3584	4544	932154	888148	43300	1000	1705	964
1984	3	7989	11135	712200	1690	16436	944522	932154	18700	12500	6168	977
1984	4	8622	25458	679200	12424	-3741	942746	944522	32800	29500	-5076	998
1984	5	3679	43511	617700	9054	-12614	884778	942746	10700	50900	-17768	1036
1984	6	19987	18543	608400	10891	147	897533	884778	34900	22200	55	1069
1984	7	11268	29821	569900	15686	-4261	891362	897533	38000	37700	-6471	1117
1984	8	4491	29266	525800	12082	-7242	856312	891362	15000	38500	-11550	1173
1984	9	885	1948	509100	10625	-5012	848350	856312	2920	2630	-8252	1211
1984	10	25948	4798	555400	-10662	14488	862456	848350	15300	6630	5437	1182
1984	11	13021	2696	566100	1111	1485	868094	862456	8830	3750	557	1135
1984	12	41702	6177	627100	-7256	18218	892790	868094	26300	8440	6837	1085

Table A.10 Volume and load balance for TDS at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1985-86

YEAR	M	VOLUME					TDS LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1985	1	104136	69421	685500	1446	25131	981421	892790	177000	97800	9431	1050
1985	2	31273	54107	667400	-317	4417	986179	981421	81700	78600	1658	1070
1985	3	106421	64669	769100	-1314	58634	1120582	986179	208000	95600	22003	1079
1985	4	93384	94856	830400	6565	69337	1235602	1120582	226000	137000	26020	1083
1985	5	110912	200953	777800	5749	43190	1215810	1235602	270000	306000	16208	1121
1985	6	105217	120549	772700	7524	17756	1291473	1215810	260000	191000	6663	1189
1985	7	38531	46875	755000	15877	6521	1298420	1291473	82300	77800	2447	1247
1985	8	33509	62259	712100	22671	8521	1283818	1298420	87200	105000	3198	1295
1985	9	20523	37599	695000	5687	5662	1267143	1283818	47800	66600	2125	1333
1985	10	49736	23147	731300	-3145	6566	1303507	1267143	76700	42800	2464	1326
1985	11	28036	23101	738700	1863	4328	1328431	1303507	66900	43600	1624	1317
1985	12	14551	38662	719000	-3877	534	1287131	1328431	32900	74400	200	1320
1986	1	17835	35580	691900	5954	-3401	1258094	1287131	45200	68100	-6137	1327
1986	2	26941	33985	695100	905	11149	1227778	1258094	31800	66300	4184	1318
1986	3	13460	23877	682300	9389	7007	1217407	1227778	33900	46900	2629	1306
1986	4	5649	22336	663900	6042	4329	1187432	1217407	12500	44100	1625	1314
1986	5	11913	37131	677500	-2065	36753	1144424	1187432	16400	73200	13792	1279
1986	6	123247	152955	779200	-5290	126118	1152752	1144424	253000	292000	47328	1160
1986	7	59322	58846	765500	18797	4621	1192486	1152752	150000	112000	1734	1117
1986	8	21384	43611	729200	13738	-335	1166657	1192486	55500	80800	-529	1161
1986	9	84242	125330	781700	1257	94845	1203249	1166657	207000	206000	35592	1154

Table A.11 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1970-72

YEAR	M	VOLUME					CL LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				515600								
1970	10	30184	25587	526300	-1205	4898	153506	144000	16400	7300	406	210.0
1970	11	13129	9402	529500	6766	6239	162114	153506	10900	2810	517	219.9
1970	12	11254	10453	530200	3908	3807	167749	162114	8450	3130	316	228.9
1971	1	5988	34909	501200	5357	5278	161807	167749	4060	10440	438	235.0
1971	2	1884	1444	503600	3494	5454	162899	161807	1070	430	452	237.7
1971	3	1640	1845	497400	9394	3399	163516	162899	965	630	282	239.8
1971	4	1611	5950	505900	3848	16688	163870	163516	1070	2100	1384	240.0
1971	5	6742	14880	520200	5883	28321	162429	163870	1270	5060	2349	233.9
1971	6	3669	20231	498100	11484	5946	158063	162429	2290	7150	493	231.5
1971	7	2493	30684	485800	8143	24034	151476	158063	1840	10420	1993	231.4
1971	8	27679	3997	495900	5332	-8251	168773	151476	21400	1410	-2692	239.9
1971	9	158628	57779	568800	6114	-21836	279570	168773	142000	22000	-9204	309.7
1971	10	125395	162942	690800	-11574	147973	305542	279570	95600	81900	12273	341.6
1971	11	49720	163636	604900	4764	32781	267861	305542	35200	75600	2719	325.5
1971	12	31436	219511	625600	-4398	204377	196712	267861	10300	98400	16951	277.7
1972	1	29032	159868	579900	-283	84853	163650	196712	22900	63000	7038	219.9
1972	2	4491	28213	575100	5189	24111	159409	163650	3730	9970	2000	205.7
1972	3	1995	27608	559100	10034	19647	153239	159409	1580	9380	1630	202.7
1972	4	14834	26896	552000	6764	11726	160131	153239	14700	8780	973	207.4
1972	5	37599	37384	557200	2565	7551	178758	160131	30200	12200	626	224.7
1972	6	12282	41712	520100	10453	2784	175089	178758	9700	13600	231	241.6
1972	7	5728	87312	443700	9807	14991	152592	175089	4760	28500	1243	250.1
1972	8	121698	56692	483200	9740	-15766	230775	152592	104000	19300	-6517	304.2
1972	9	129439	51423	587000	5387	31171	331060	230775	123000	25300	2585	386.1
1972	10	25720	25611	600500	340	13731	346299	331060	28700	14600	1139	419.5
1972	11	164176	60309	693000	-140	-11506	485799	346299	183000	36100	-7400	473.1
1972	12	45808	57118	678300	2604	-786	502333	485799	53600	36500	-566	530.0

Table A.12 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1973-75

YEAR	M	VOLUME					CL LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1973	1	37515	37139	707600	-2388	26535	523634	502333	43900	24800	2201	544.5
1973	2	41107	20061	766300	-459	37195	567819	523634	54800	13700	3085	544.6
1973	3	70760	94282	772400	4389	34011	606140	567819	101000	65500	2821	561.1
1973	4	82393	265041	802900	-6420	206728	532986	606140	89700	180000	17146	531.8
1973	5	42774	99967	789500	5846	49639	521603	532986	51200	66700	4117	487.1
1973	6	77462	256979	774500	-1732	162784	459104	521603	78000	154000	13501	461.2
1973	7	86408	112380	779100	-934	29637	479562	459104	82300	64300	2458	444.4
1973	8	16378	77937	729900	18251	30610	445501	479562	5800	42400	2539	450.9
1973	9	3614	27777	713700	-332	7630	433973	445501	3740	15900	633	448.1
1973	10	34518	39913	752900	-10929	33666	421046	433973	6580	22300	2792	428.8
1973	11	5357	28822	742400	4195	17159	407319	421046	1750	16900	1423	407.4
1973	12	36389	38408	744800	6442	10862	430820	407319	45100	22500	901	414.5
1974	1	17570	30902	744600	613	13746	436060	430820	22200	18100	1140	428.1
1974	2	1904	24662	729800	6050	14008	424822	436060	2000	14400	1162	429.4
1974	3	6478	63810	679500	9046	16078	395805	424822	7850	38200	1334	428.3
1974	4	10310	35554	651200	9776	6720	382362	395805	7300	21300	557	430.1
1974	5	5349	20582	635000	7053	6087	372457	382362	1890	12300	505	431.6
1974	6	11925	38705	603200	12889	7870	358350	372457	8440	23200	653	434.1
1974	7	18405	56745	558500	17112	10752	350342	358350	25100	34000	892	448.7
1974	8	26729	41958	572900	-4258	25371	360046	350342	32700	25100	2104	461.8
1974	9	21842	33606	615000	-3297	50567	352270	360046	7730	19700	4194	441.0
1974	10	202901	34102	781800	-4695	-6694	465947	352270	138000	20400	-3923	430.8
1974	11	297509	428495	771900	317	121403	465016	465947	251000	262000	10069	440.7
1974	12	29528	67049	757200	712	23533	452468	465016	25700	40200	1952	441.3
1975	1	47220	79244	754000	1323	30146	452368	452468	40500	43100	2500	440.4
1975	2	130915	250844	775400	-2551	138778	411178	452368	87300	140000	11510	415.3
1975	3	58998	85819	771200	3683	26304	415660	411178	49000	46700	2182	393.2
1975	4	37097	151244	775700	-1828	116818	356739	415660	9590	78200	9689	367.2
1975	5	38767	66653	795800	-10646	37340	345736	356739	19500	33600	3097	328.8
1975	6	175422	278733	761700	12283	81494	334495	345736	115000	133000	6759	321.2
1975	7	28251	44672	742700	10379	7800	336742	334495	22300	20700	647	328.2
1975	8	50083	58752	731300	15359	12628	357589	336742	47000	27200	1047	346.4
1975	9	37402	23423	744800	6124	5644	382957	357589	36100	11200	468	369.0
1975	10	7041	21596	718200	9486	-2560	378086	382957	7260	10800	-1331	382.6
1975	11	4834	15505	691900	6583	-9046	370159	378086	4860	7990	-4797	390.3
1975	12	7105	39124	653400	96	-6385	352870	370159	6840	20700	-3429	395.3

Table A.13 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1976-78

YEAR	M	VOLUME					CL LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1976	1	13983	52520	617000	7370	9507	339658	352870	13700	27700	789	400.9
1976	2	7755	53909	575700	6437	11290	319815	339658	8020	28800	936	406.7
1976	3	2158	33271	551100	3988	10500	304866	319815	2080	17900	871	407.7
1976	4	7162	14061	592100	-6411	41487	304137	304866	3500	7670	3441	391.8
1976	5	44507	36440	675800	-1644	73990	299243	304137	8770	19800	6137	350.0
1976	6	22419	54190	674400	4670	35041	286850	299243	13200	28500	2906	319.3
1976	7	21929	60615	681300	-3025	42560	268269	286850	9690	31800	3530	301.2
1976	8	25983	71540	637300	14598	16154	261509	268269	28500	36600	1340	295.5
1976	9	41149	25087	656900	162	3700	282916	261509	33700	12600	307	309.4
1976	10	84716	29833	719000	-3723	3494	347506	282916	79200	14900	290	337.0
1976	11	92565	53603	766600	3530	12169	422015	347506	101000	27500	1009	381.0
1976	12	15330	57408	752900	272	28650	409891	422015	15700	30200	2376	402.7
1977	1	37230	68862	743100	-1035	20797	406116	409891	31100	36600	1725	401.2
1977	2	21427	35036	771300	2475	44283	408189	406116	17100	18700	3673	395.5
1977	3	130744	181418	881600	-2737	158237	341413	408189	16400	96300	13124	333.5
1977	4	93410	370929	789100	-5348	179671	246615	341413	76300	186000	14902	258.9
1977	5	125447	151993	780900	3127	21474	289896	246615	107000	65500	1781	251.3
1977	6	20505	46038	742200	14936	1770	294643	289896	22100	17500	147	282.3
1977	7	17361	51761	689700	18127	26	296145	294643	20300	18800	2	303.5
1977	8	5615	49083	628400	9043	-8789	281627	296145	5830	16500	-3848	322.4
1977	9	9620	32747	584500	16021	-4752	280124	281627	11400	10700	-2203	340.6
1977	10	10011	18635	556800	6564	-12512	279643	280124	11800	6140	-6141	360.7
1977	11	10153	9453	552800	400	-4301	286430	279643	12200	3220	-2193	375.2
1977	12	8108	7843	545900	5024	-2142	292750	286430	10200	2750	-1130	387.7
1978	1	8975	8148	545200	1773	245	298150	292750	8260	2880	20	398.3
1978	2	6750	6379	551400	-3518	2312	303082	298150	6990	2250	192	403.2
1978	3	3925	6472	545300	4655	1102	304303	303082	3450	2320	91	407.3
1978	4	23105	5421	561000	4670	2685	306606	304303	4070	1990	223	406.1
1978	5	8388	16711	555900	2190	5413	307765	306606	7060	6350	449	404.6
1978	6	4314	37815	511300	13583	2483	297431	307765	3660	14200	206	417.1
1978	7	2275	1757	491100	16498	-4219	297853	297431	3600	671	-2507	436.8
1978	8	467300	93499	766400	11098	-87403	685721	297853	523000	66800	-68332	575.3
1978	9	22038	23581	745800	9399	-9658	676028	685721	23700	24700	-8693	662.3
1978	10	31569	36351	735300	12734	7016	674410	676028	28700	30900	582	670.6
1978	11	14977	40483	722500	-4582	8123	652784	674410	10800	33100	674	669.6
1978	12	6742	49648	682600	4055	7061	616589	652784	5120	41900	586	664.4

Table A.14 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1979-81

YEAR	M	VOLUME					CL LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1979	1	12230	60347	643200	-1097	7620	571961	616589	6440	51700	632	659.3
1979	2	8731	61222	601800	-1162	9928	525975	571961	4890	51700	823	648.6
1979	3	28742	28489	678800	-4626	72120	517616	525975	9060	23400	5982	599.4
1979	4	63239	26761	761000	4724	50446	516300	517616	15300	20800	4184	528.1
1979	5	124816	359758	808400	-7625	274717	344785	516300	43700	238000	22785	403.5
1979	6	76695	155367	779500	10429	60201	322778	344785	45700	72700	4993	309.2
1979	7	8301	55087	731400	8635	7321	304965	322778	5680	24100	607	305.6
1979	8	11312	63427	687800	4729	13245	288534	304965	7970	25500	1099	307.6
1979	9	23760	51356	661400	9459	10655	288417	288534	17300	18300	884	314.5
1979	10	14212	34514	650400	5661	14963	287128	288417	9170	11700	1241	322.7
1979	11	4695	28116	623800	5602	2423	280879	287128	3200	9650	201	327.9
1979	12	8249	62630	586700	-2267	15014	265965	280879	5540	21700	1245	332.3
1980	1	9531	48545	560700	-1116	11899	255241	265965	5190	16900	987	334.1
1980	2	14261	2493	578000	2313	7845	264582	255241	9570	880	651	335.8
1980	3	5324	1716	582700	1908	3000	268307	264582	4090	614	249	337.7
1980	4	4465	2293	596000	4059	15187	272234	268307	3480	813	1260	337.3
1980	5	37860	4556	668900	-566	39030	299641	272234	25800	1630	3237	332.5
1980	6	55561	31010	678500	15964	1013	333425	299641	44800	11100	84	345.6
1980	7	37696	55006	634900	21459	-4831	343335	333425	32000	19600	-2490	379.0
1980	8	26793	49692	582000	16916	-13085	342370	343335	24600	18200	-7365	414.4
1980	9	43472	37333	572400	3409	-12330	355126	342370	34800	14600	-7444	444.4
1980	10	257276	31224	766700	9227	-22525	558651	355126	236600	17700	-15375	501.9
1980	11	18960	26063	755500	3201	-896	557495	558651	14900	15400	-656	539.3
1980	12	47944	47552	760500	-801	3806	563611	557495	33600	27800	316	543.9
1981	1	41401	59246	739300	2558	-797	562612	563611	36600	37000	-598	552.3
1981	2	15110	49267	708100	1467	4425	545079	562612	13400	31300	367	562.9
1981	3	40419	38051	737900	-1670	25762	545416	545079	22800	24600	2137	554.7
1981	4	17341	37660	724200	4387	11005	528729	545416	7200	24800	913	540.3
1981	5	65566	42934	742800	1498	-2533	543976	528729	45400	28300	-1853	537.8
1981	6	114936	218519	774600	-15203	120180	501543	543976	85900	138300	9968	506.8
1981	7	35121	55646	750400	10957	7282	500447	501543	31700	33400	604	483.2
1981	8	20563	55698	709800	13375	7910	484303	500447	16600	33400	656	496.0
1981	9	11786	34762	681900	8517	3594	473041	484303	8440	20000	298	505.9
1981	10	1087577	756522	904400	-10700	-119255	467046	473041	445300	380600	-70696	435.9
1981	11	95923	295287	781800	3634	80398	366514	467046	31100	138300	6668	363.6
1981	12	17185	43236	762600	5008	11859	354297	366514	9700	22900	984	343.3

Table A.15 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1982-84

YEAR	M	VOLUME					CL LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1982	1	17724	62483	723600	2213	7972	332408	354297	7150	29700	661	339.8
1982	2	29635	64268	715400	1872	28306	317956	332408	13300	30100	2348	332.4
1982	3	17808	59913	702000	1177	29882	303335	317956	10300	27400	2478	322.4
1982	4	8374	27663	694900	4054	16243	297892	303335	5510	12300	1347	316.6
1982	5	615854	593100	813000	-5109	90237	307976	297892	236800	234200	7484	295.5
1982	6	802750	696397	942600	2558	25804	321016	307976	258100	247200	2140	263.5
1982	7	269044	498655	774800	14628	76438	240656	321016	78100	164800	6340	240.5
1982	8	28889	47581	735200	18166	-2742	235051	240656	9760	14500	-865	231.7
1982	9	7367	29762	696000	11095	-5709	226891	235051	2980	9300	-1840	237.4
1982	10	4278	21441	668800	6386	-3651	220685	226891	1810	6820	-1196	241.2
1982	11	15408	19870	659100	-2129	-7367	218986	220685	7100	6360	-2439	243.5
1982	12	14733	19097	649600	-1184	-6320	217190	218986	6450	6140	-2105	245.1
1983	1	11341	49513	602800	214	-8415	203584	217190	5320	16100	-2826	247.1
1983	2	15421	25488	590400	-1474	-3807	202828	203584	8780	8240	-1297	250.5
1983	3	38118	24444	599700	1060	-3314	216100	202828	22300	7860	-1167	258.9
1983	4	33614	24748	596700	9995	-1871	230572	216100	23100	7930	-698	274.6
1983	5	63108	17080	651800	-959	8113	241115	230572	15400	5530	673	277.9
1983	6	33384	16994	658900	9586	297	254930	241115	19300	5510	25	278.3
1983	7	42046	40534	637100	12094	-11218	264930	254930	27700	13200	-4499	295.0
1983	8	24246	34800	611500	7605	-7441	268254	264930	17800	11300	-3177	314.1
1983	9	20731	5435	608500	11832	-6464	279883	268254	16400	1870	-2900	330.4
1983	10	27995	1619	623700	2178	-8998	298085	279883	23000	577	-4221	345.0
1983	11	9449	1222	623400	1268	-7260	301686	298085	7540	445	-3494	353.7
1983	12	46368	1781	654300	2383	-11303	332511	301686	37100	666	-5609	365.1
1984	1	33907	1075	687800	3378	4046	364141	332511	31700	405	336	381.8
1984	2	12738	899	700600	3584	4544	382453	364141	18300	365	377	395.5
1984	3	7989	11135	712200	1690	16436	386826	382453	7580	4570	1363	400.5
1984	4	8622	25458	679200	12424	-3741	388041	386826	14100	10800	-2085	409.6
1984	5	3679	43511	617700	9054	-12614	366541	388041	4440	18600	-7340	427.9
1984	6	19987	18543	608400	10891	147	372713	366541	14300	8140	12	443.4
1984	7	11268	29821	569900	15686	-4261	372019	372713	16000	14000	-2694	464.9
1984	8	4491	29266	525800	12082	-7242	359184	372019	6300	14300	-4835	490.8
1984	9	885	1948	509100	10625	-5012	355969	359184	1230	984	-3462	508.2
1984	10	25948	4798	555400	-10662	14488	360340	355969	5660	2490	1202	494.9
1984	11	13021	2696	566100	1111	1485	362233	360340	3180	1410	123	473.9
1984	12	41702	6177	627100	-7256	18218	370194	362233	9610	3160	1511	451.5

Table A.16 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1985-86

YEAR	M	VOLUME					CL LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1985	1	104136	69421	685500	1446	25131	405779	370194	70300	36800	2084	434.8
1985	2	31273	54107	667400	-317	4417	409545	405779	33100	29700	366	443.2
1985	3	106421	64669	769100	-1314	58634	460408	409545	82200	36200	4863	445.4
1985	4	93384	94856	830400	6565	69337	423519	460408	9060	51700	5751	406.4
1985	5	110912	200953	777800	5749	43190	419301	423519	108700	116500	3582	385.4
1985	6	105217	120549	772700	7524	17756	452474	419301	104600	72900	1473	413.5
1985	7	38531	46875	755000	15877	6521	455815	452474	32800	30000	541	437.3
1985	8	33509	62259	712100	22671	8521	451321	455815	35300	40500	707	454.8
1985	9	20523	37599	695000	5687	5662	444891	451321	19100	26000	470	468.4
1985	10	49736	23147	731300	-3145	6566	458836	444891	30200	16800	545	466.0
1985	11	28036	23101	738700	1863	4328	468895	458836	26800	17100	359	464.2
1985	12	14551	38662	719000	-3877	534	452639	468895	13100	29400	44	465.0
1986	1	17835	35580	691900	5954	-3401	441884	452639	18200	26800	-2155	466.3
1986	2	26941	33985	695100	905	11149	429008	441884	12400	26200	925	461.8
1986	3	13460	23877	682300	9389	7007	424690	429008	13600	18500	581	455.8
1986	4	5649	22336	663900	6042	4329	412499	424690	4950	17500	359	457.4
1986	5	11913	37131	677500	-2065	36753	392877	412499	6330	29000	3048	441.6
1986	6	123247	152955	779200	-5290	126118	389337	392877	101100	115100	10460	394.9
1986	7	59322	58846	765500	18797	4621	406320	389337	60700	44100	383	378.8
1986	8	21384	43611	729200	13738	-335	396840	406320	22400	31700	-180	395.2
1986	9	84242	125330	781700	1257	94845	409207	396840	83800	79300	7866	392.4

Table A.17 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1970-72

YEAR	M	VOLUME					SO4 LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
				515600								
1970	10	30184	25587	526300	-1205	4898	87046	82700	8330	4170	186	119.8
1970	11	13129	9402	529500	6766	6239	90994	87046	5240	1530	238	124.0
1970	12	11254	10453	530200	3908	3807	93709	90994	4270	1700	145	128.2
1971	1	5988	34909	501200	5357	5278	89930	93709	2190	6170	201	131.0
1971	2	1884	1444	503600	3494	5454	90453	89930	576	260	208	132.0
1971	3	1640	1845	497400	9394	3399	90777	90453	524	330	129	133.2
1971	4	1611	5950	505900	3848	16688	90863	90777	581	1130	635	133.2
1971	5	6742	14880	520200	5883	28321	90241	90863	930	2630	1078	129.8
1971	6	3669	20231	498100	11484	5946	87748	90241	1130	3850	226	128.6
1971	7	2493	30684	485800	8143	24034	83646	87748	823	5840	915	128.1
1971	8	27679	3997	495900	5332	-8251	92665	83646	11200	700	-1481	132.1
1971	9	158628	57779	568800	6114	-21836	152547	92665	75900	11000	-5018	169.4
1971	10	125395	162942	690800	-11574	147973	169481	152547	51200	39900	5633	188.0
1971	11	49720	163636	604900	4764	32781	151929	169481	19000	37800	1248	182.4
1971	12	31436	219511	625600	-4398	204377	115429	151929	6420	50700	7781	159.8
1972	1	29032	159868	579900	-283	84853	98360	115429	12300	32600	3230	130.4
1972	2	4491	28213	575100	5189	24111	95928	98360	2020	5370	918	123.7
1972	3	1995	27608	559100	10034	19647	92295	95928	869	5250	748	122.1
1972	4	14834	26896	552000	6764	11726	95701	92295	8080	5120	446	124.4
1972	5	37599	37384	557200	2565	7551	105279	95701	16400	7110	287	133.3
1972	6	12282	41712	520100	10453	2784	103195	105279	5180	7370	106	142.3
1972	7	5728	87312	443700	9807	14991	89665	103195	2500	16600	571	147.2
1972	8	121698	56692	483200	9740	-15766	132332	89665	58000	11560	-3773	176.2
1972	9	129439	51423	587000	5387	31171	187759	132332	68700	14460	1187	220.0
1972	10	25720	25611	600500	340	13731	196062	187759	15800	8020	523	237.7
1972	11	164176	60309	693000	-140	-11506	271600	196062	101000	21300	-4161	265.9
1972	12	45808	57118	678300	2604	-786	278785	271600	29300	21800	-315	295.2

Table A.18 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1973-75

YEAR	M	VOLUME					SO4 LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1973	1	37515	37139	707600	-2388	26535	288595	278785	24000	15200	1010	301.1
1973	2	41107	20061	766300	-459	37195	311241	288595	29700	8470	1416	299.3
1973	3	70760	94282	772400	4389	34011	326336	311241	54900	41100	1295	304.8
1973	4	82393	265041	802900	-6420	206728	271506	326336	49300	112000	7870	279.1
1973	5	42774	99967	789500	5846	49639	260496	271506	27900	40800	1890	245.7
1973	6	77462	256979	774500	-1732	162784	218893	260496	43200	91000	6197	225.4
1973	7	86408	112380	779100	-934	29637	230722	218893	45900	35200	1128	212.8
1973	8	16378	77937	729900	18251	30610	212707	230722	3120	22300	1165	216.1
1973	9	3614	27777	713700	-332	7630	206318	212707	2020	8700	290	213.5
1973	10	34518	39913	752900	-10929	33666	201059	206318	3760	10300	1282	204.3
1973	11	5357	28822	742400	4195	17159	194421	201059	948	8240	653	194.5
1973	12	36389	38408	744800	6442	10862	206634	194421	23300	11500	414	198.3
1974	1	17570	30902	744600	613	13746	209407	206634	11500	9250	523	205.4
1974	2	1904	24662	729800	6050	14008	203591	209407	1040	7390	533	206.0
1974	3	6478	63810	679500	9046	16078	189163	203591	4060	19100	612	205.0
1974	4	10310	35554	651200	9776	6720	182609	189163	3790	10600	256	205.5
1974	5	5349	20582	635000	7053	6087	177700	182609	1020	6160	232	206.0
1974	6	11925	38705	603200	12889	7870	170780	177700	4380	11600	300	207.0
1974	7	18405	56745	558500	17112	10752	166989	170780	12800	17000	409	213.8
1974	8	26729	41958	572900	-4258	25371	172055	166989	16700	12600	966	220.4
1974	9	21842	33606	615000	-3297	50567	168040	172055	4160	10100	1925	210.6
1974	10	202901	34102	781800	-4695	-6694	233220	168040	77300	10200	-1920	211.3
1974	11	297509	428495	771900	317	121403	247842	233220	138000	128000	4622	227.7
1974	12	29528	67049	757200	712	23533	242738	247842	14100	20100	896	236.0
1975	1	47220	79244	754000	1323	30146	244785	242738	22500	21600	1148	237.3
1975	2	130915	250844	775400	-2551	138778	228269	244785	49900	71700	5283	227.5
1975	3	58998	85819	771200	3683	26304	233170	228269	27300	23400	1001	219.4
1975	4	37097	151244	775700	-1828	116818	202477	233170	6060	41200	4447	207.1
1975	5	38767	66653	795800	-10646	37340	197799	202477	11100	17200	1422	187.3
1975	6	175422	278733	761700	12283	81494	197101	197799	64500	68300	3103	186.5
1975	7	28251	44672	742700	10379	7800	198798	197101	12300	10900	297	193.5
1975	8	50083	58752	731300	15359	12628	210779	198798	25900	14400	481	204.4
1975	9	37402	23423	744800	6124	5644	225154	210779	19900	5740	215	217.2
1975	10	7041	21596	718200	9486	-2560	222601	225154	3530	5300	-783	225.1
1975	11	4834	15505	691900	6583	-9046	218182	222601	2370	3960	-2829	229.9
1975	12	7105	39124	653400	96	-6385	209400	218182	3350	10100	-2031	233.8

Table A.19 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1976-78

YEAR	M	VOLUME					SO4 LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1976	1	13983	52520	617000	7370	9507	202852	209400	6690	13600	362	238.7
1976	2	7755	53909	575700	6437	11290	193282	202852	3900	13900	430	244.3
1976	3	2158	33271	551100	3988	10500	186112	193282	1020	8590	400	247.6
1976	4	7162	14061	592100	-6411	41487	185961	186112	1920	3650	1579	239.4
1976	5	44507	36440	675800	-1644	73990	185158	185961	5840	9460	2817	215.3
1976	6	22419	54190	674400	4670	35041	179302	185158	6810	14000	1334	198.5
1976	7	21929	60615	681300	-3025	42560	170503	179302	5280	15700	1620	189.8
1976	8	25983	71540	637300	14598	16154	167118	170503	13700	17700	615	188.3
1976	9	41149	25087	656900	162	3700	178018	167118	16900	6140	141	196.1
1976	10	84716	29833	719000	-3723	3494	210041	178018	39200	7310	133	207.4
1976	11	92565	53603	766600	3530	12169	245805	210041	48700	13400	463	225.7
1976	12	15330	57408	752900	272	28650	239715	245805	7620	14800	1091	235.0
1977	1	37230	68862	743100	-1035	20797	238307	239715	15600	17800	792	235.0
1977	2	21427	35036	771300	2475	44283	239543	238307	8610	9060	1686	232.1
1977	3	130744	181418	881600	-2737	158237	209067	239543	10300	46800	6024	199.6
1977	4	93410	370929	789100	-5348	179671	163207	209067	38200	90900	6840	163.9
1977	5	125447	151993	780900	3127	21474	184225	163207	53500	33300	818	162.8
1977	6	20505	46038	742200	14936	1770	186032	184225	10700	8960	67	178.8
1977	7	17361	51761	689700	18127	26	186073	186032	9750	9710	1	191.1
1977	8	5615	49083	628400	9043	-8789	177797	186073	2830	8680	-2426	203.0
1977	9	9620	32747	584500	16021	-4752	176062	177797	5450	5800	-1386	214.6
1977	10	10011	18635	556800	6564	-12512	174287	176062	5110	3040	-3845	225.8
1977	11	10153	9453	552800	400	-4301	176634	174287	5250	1540	-1362	232.6
1977	12	8108	7843	545900	5024	-2142	178941	176634	4330	1330	-693	238.0
1978	1	8975	8148	545200	1773	245	181251	178941	3740	1440	9	242.8
1978	2	6750	6379	551400	-3518	2312	183329	181251	3110	1120	88	244.5
1978	3	3925	6472	545300	4655	1102	183801	183329	1580	1150	42	246.2
1978	4	23105	5421	561000	4670	2685	185554	183801	2610	959	102	245.6
1978	5	8388	16711	555900	2190	5413	186020	185554	3220	2960	206	244.7
1978	6	4314	37815	511300	13583	2483	181134	186020	1710	6690	95	253.0
1978	7	2275	1757	491100	16498	-4219	180751	181134	1460	320	-1523	265.5
1978	8	467300	93499	766400	11098	-87403	336603	180751	229000	37200	-35949	302.6
1978	9	22038	23581	745800	9399	-9658	327461	336603	10500	15400	-4241	323.0
1978	10	31569	36351	735300	12734	7016	326828	327461	14400	15300	267	324.9
1978	11	14977	40483	722500	-4582	8123	316068	326828	5430	16500	309	324.3
1978	12	6742	49648	682600	4055	7061	297926	316068	2590	21000	269	321.4

Table A.20 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1979-81

YEAR	M	VOLUME					SO4 LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1979	1	12230	60347	643200	-1097	7620	276017	297926	3300	25500	290	318.4
1979	2	8731	61222	601800	-1162	9928	253114	276017	2520	25800	378	312.6
1979	3	28742	28489	678800	-4626	72120	248800	253114	4640	11700	2746	288.3
1979	4	63239	26761	761000	4724	50446	248111	248800	7790	10400	1920	253.8
1979	5	124816	359758	808400	-7625	274717	161869	248111	22300	119000	10459	192.1
1979	6	76695	155367	779500	10429	60201	150661	161869	23300	36800	2292	144.8
1979	7	8301	55087	731400	8635	7321	141820	150661	2880	12000	279	142.4
1979	8	11312	63427	687800	4729	13245	133654	141820	4030	12700	504	142.8
1979	9	23760	51356	661400	9459	10655	133570	133654	8810	9300	406	145.7
1979	10	14212	34514	650400	5661	14963	133059	133570	4620	5700	570	149.5
1979	11	4695	28116	623800	5602	2423	130042	133059	1610	4720	92	151.9
1979	12	8249	62630	586700	-2267	15014	122803	130042	2790	10600	572	153.6
1980	1	9531	48545	560700	-1116	11899	117606	122803	2630	8280	453	154.1
1980	2	14261	2493	578000	2313	7845	122285	117606	4810	430	299	154.9
1980	3	5324	1716	582700	1908	3000	124149	122285	2050	300	114	156.2
1980	4	4465	2293	596000	4059	15187	126070	124149	1740	397	578	156.1
1980	5	37860	4556	668900	-566	39030	139760	126070	13000	796	1486	154.6
1980	6	55561	31010	678500	15964	1013	156749	139760	22400	5450	39	161.8
1980	7	37696	55006	634900	21459	-4831	161999	156749	16000	9580	-1169	178.5
1980	8	26793	49692	582000	16916	-13085	161812	161999	12200	8900	-3487	195.7
1980	9	43472	37333	572400	3409	-12330	168522	161812	17400	7170	-3521	210.5
1980	10	257276	31224	766700	9227	-22525	269981	168522	117600	8760	-7381	240.8
1980	11	18960	26063	755500	3201	-896	269523	269981	7470	7610	-318	260.7
1980	12	47944	47552	760500	-801	3806	272768	269523	16900	13800	145	263.1
1981	1	41401	59246	739300	2558	-797	272378	272768	18200	18300	-289	267.3
1981	2	15110	49267	708100	1467	4425	263597	272378	6650	15600	168	272.3
1981	3	40419	38051	737900	-1670	25762	263878	263597	11500	12200	981	268.3
1981	4	17341	37660	724200	4387	11005	255637	263878	3640	12300	419	261.3
1981	5	65566	42934	742800	1498	-2533	263441	255637	22800	14100	-896	260.2
1981	6	114936	218519	774600	-15203	120180	242316	263441	43000	68700	4575	245.1
1981	7	35121	55646	750400	10957	7282	241694	242316	15700	16600	277	233.4
1981	8	20563	55698	709800	13375	7910	233655	241694	8260	16600	301	239.4
1981	9	11786	34762	681900	8517	3594	228091	233655	4230	9930	137	244.0
1981	10	1087577	756522	904400	-10700	-119255	223503	228091	221400	192100	-33889	209.4
1981	11	95923	295287	781800	3634	80398	172464	223503	15400	69500	3061	172.7
1981	12	17185	43236	762600	5008	11859	166155	172464	4840	11600	451	161.3

Table A.21 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1982-84

YEAR	M	VOLUME					SO4 LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1982	1	17724	62483	723600	2213	7972	155009	166155	3550	15000	304	158.9
1982	2	29635	64268	715400	1872	28306	147606	155009	6620	15100	1078	154.7
1982	3	17808	59913	702000	1177	29882	140094	147606	5150	13800	1138	149.3
1982	4	8374	27663	694900	4054	16243	137312	140094	2760	6160	618	146.1
1982	5	615854	593100	813000	-5109	90237	141148	137312	117300	116900	3435	135.8
1982	6	802750	696397	942600	2558	25804	146830	141148	127500	122800	982	120.6
1982	7	269044	498655	774800	14628	76438	106540	146830	38500	81700	2910	108.5
1982	8	28889	47581	735200	18166	-2742	103810	106540	4820	7170	-380	102.5
1982	9	7367	29762	696000	11095	-5709	99865	103810	1470	4600	-815	104.7
1982	10	4278	21441	668800	6386	-3651	96867	99865	899	3370	-526	106.0
1982	11	15408	19870	659100	-2129	-7367	96176	96867	3520	3140	-1072	106.9
1982	12	14733	19097	649600	-1184	-6320	95408	96176	3200	3040	-928	107.7
1983	1	11341	49513	602800	214	-8415	88842	95408	2640	7970	-1236	108.2
1983	2	15421	25488	590400	-1474	-3807	88578	88842	4380	4080	-564	109.4
1983	3	38118	24444	599700	1060	-3314	95374	88578	11200	3890	-514	113.7
1983	4	33614	24748	596700	9995	-1871	102744	95374	11600	3920	-310	121.8
1983	5	63108	17080	651800	-959	8113	107952	102744	7640	2740	309	124.1
1983	6	33384	16994	658900	9586	297	114874	107952	9640	2730	11	125.0
1983	7	42046	40534	637100	12094	-11218	120215	114874	13900	6530	-2029	133.4
1983	8	24246	34800	611500	7605	-7441	122079	120215	8930	5620	-1447	142.7
1983	9	20731	5435	608500	11832	-6464	128071	122079	8250	930	-1327	150.8
1983	10	27995	1619	623700	2178	-8998	137439	128071	11600	299	-1933	158.5
1983	11	9449	1222	623400	1268	-7260	139429	137439	3830	231	-1609	163.3
1983	12	46368	1781	654300	2383	-11303	155180	139429	18700	345	-2605	169.6
1984	1	33907	1075	687800	3378	4046	170824	155180	15700	210	154	178.7
1984	2	12738	899	700600	3584	4544	179449	170824	8640	188	173	185.6
1984	3	7989	11135	712200	1690	16436	181444	179449	3720	2350	626	187.9
1984	4	8622	25458	679200	12424	-3741	181448	181444	6550	5570	-976	191.8
1984	5	3679	43511	617700	9054	-12614	170558	181448	2130	9590	-3430	199.6
1984	6	19987	18543	608400	10891	147	173343	170558	6970	4190	6	206.3
1984	7	11268	29821	569900	15686	-4261	172522	173343	7590	7160	-1251	215.9
1984	8	4491	29266	525800	12082	-7242	165947	172522	2990	7330	-2235	227.2
1984	9	885	1948	509100	10625	-5012	164425	165947	583	503	-1601	234.8
1984	10	25948	4798	555400	-10662	14488	166747	164425	3040	1270	552	228.8
1984	11	13021	2696	566100	1111	1485	167846	166747	1760	718	57	219.4
1984	12	41702	6177	627100	-7256	18218	172169	167846	5240	1610	694	209.6

Table A.22 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 1 (MC1) during 1985-86

YEAR	M	VOLUME					SO4 LOAD					Computed Storage Conc. (mg/l)
		I (ac-ft)	O (ac-ft)	S (ac-ft)	E (ac-ft)	Vdiff (ac-ft)	S2 (tons)	S1 (tons)	I2 (tons)	O2 (tons)	Diff (tons)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1985	1	104136	69421	685500	1446	25131	189726	172169	35400	18800	957	202.8
1985	2	31273	54107	667400	-317	4417	191094	189726	16300	15100	168	207.0
1985	3	106421	64669	769100	-1314	58634	216326	191094	41400	18400	2232	208.6
1985	4	93384	94856	830400	6565	69337	237666	216326	45000	26300	2640	208.8
1985	5	110912	200953	777800	5749	43190	234010	237666	53900	59200	1644	215.7
1985	6	105217	120549	772700	7524	17756	249586	234010	51800	36900	676	229.4
1985	7	38531	46875	755000	15877	6521	251034	249586	16400	15200	248	241.0
1985	8	33509	62259	712100	22671	8521	248259	251034	17400	20500	324	250.3
1985	9	20523	37599	695000	5687	5662	244914	248259	9540	13100	216	257.8
1985	10	49736	23147	731300	-3145	6566	252084	244914	15400	8480	250	256.3
1985	11	28036	23101	738700	1863	4328	256999	252084	13400	8650	165	254.7
1985	12	14551	38662	719000	-3877	534	248809	256999	6590	14800	20	255.2
1986	1	17835	35580	691900	5954	-3401	243176	248809	9050	13500	-1184	256.5
1986	2	26941	33985	695100	905	11149	236780	243176	6380	13200	424	254.5
1986	3	13460	23877	682300	9389	7007	234477	236780	6770	9340	267	251.6
1986	4	5649	22336	663900	6042	4329	228352	234477	2500	8790	165	252.9
1986	5	11913	37131	677500	-2065	36753	218441	228352	3290	14600	1399	245.0
1986	6	123247	152955	779200	-5290	126118	215842	218441	50700	58100	4801	219.3
1986	7	59322	58846	765500	18797	4621	223918	215842	30100	22200	176	209.4
1986	8	21384	43611	729200	13738	-335	218919	223918	11100	16000	-99	217.9
1986	9	84242	125330	781700	1257	94845	223530	218919	41400	40400	3611	215.4

Table A.23 Volume and load balance for chloride at Possum Kingdom reservoir using mean concentration method 2 (MC2) during 1977-79

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			489000					570500			
1977	11	561	477700	4984	2662	-4215	1460	561142	865	864.7	5860
1977	12	1081	467200	6938	4188	-455	2050	554450	869	868.8	8196
1978	1	1319	459200	7236	942	-1141	2690	547147	876	875.7	8615
1978	2	2882	459900	4270	-930	1158	9320	551899	879	879.0	5104
1978	3	4443	462500	2253	3257	3668	9140	560022	885	885.2	2712
1978	4	5784	474400	1190	4624	11931	4870	568980	882	882.0	1427
1978	5	13273	478500	6609	2405	-160	26400	587171	893	892.5	8020
1978	6	18298	481700	4011	7062	-4025	25800	603072	915	915.4	4992
1978	7	177	466500	4094	10476	-807	669	597510	932	932.1	5188
1978	8	575722	555300	79537	4420	-402965	140000	207501	892	891.5	96413
1978	9	27959	549100	33068	4424	3333	35700	231639	291	291.4	13103
1978	10	14091	540200	21225	5444	3679	26500	250478	324	324.4	9361
1978	11	8658	535400	12891	-348	-915	22400	266252	354	353.6	6198
1978	12	6532	530300	6514	3092	-2026	20300	282177	379	379.2	3358
1979	1	8231	527300	10451	-1045	-1826	24700	300136	406	405.6	5764
1979	2	5831	526200	7226	894	1189	20500	316956	430	430.4	4229
1979	3	18732	541000	10266	168	6503	40900	354433	461	460.6	6430
1979	4	10336	533400	21110	2262	5437	24400	367216	492	492.3	14130
1979	5	65234	533400	70562	-483	4845	51300	372009	508	508.1	48747
1979	6	70221	538700	58695	4853	-1373	68400	397292	528	528.4	42169
1979	7	24740	549400	7486	6994	440	23600	415505	549	549.3	5590
1979	8	22455	552700	14112	5102	60	35900	440472	571	571.2	10960
1979	9	2122	523600	25363	7140	1280	4890	425560	591	591.4	20394
1979	10	446	507600	10988	6330	872	1310	418285	602	601.6	8988
1979	11	2507	498000	5655	2915	-3538	3960	414574	611	611.3	4700
1979	12	2763	499000	3646	-741	1142	8070	420122	615	615.4	3050

Table A.24 Volume and load balance for chloride at Possum Kingdom reservoir using mean concentration method 2 (MC2) during 1980-81

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1980	1	3717	492300	9408	577	-432	10100	421859	625	625.0	7994
1980	2	3798	490300	6605	1515	2322	13700	430907	637	637.5	5725
1980	3	2047	484100	4655	4205	613	6680	433741	652	652.4	4130
1980	4	1260	478000	4370	5588	2598	3720	434723	663	663.0	3939
1980	5	129209	559100	46659	-2137	-3587	98700	488952	657	657.0	41682
1980	6	28600	535400	47772	9579	5051	61000	508838	669	668.9	43449
1980	7	2309	490600	36730	12437	2058	8450	482775	710	710.1	35465
1980	8	577	463700	19440	9927	1890	2350	466675	731	731.1	19323
1980	9	101310	497700	33150	-1023	-35183	32100	433606	714	714.0	32180
1980	10	252565	538200	266003	5077	59015	97000	360881	545	544.7	197006
1980	11	17726	542500	11230	1990	-206	35600	388554	510	510.1	7789
1980	12	37743	534200	50700	438	5094	67200	420140	551	550.8	37969
1981	1	14612	503700	44071	2311	1270	37400	422378	597	596.6	35750
1981	2	8848	497700	15858	1634	2644	27800	437798	631	630.9	13602
1981	3	26132	505600	26214	936	8918	58400	476539	667	667.2	23781
1981	4	52201	556300	13902	3441	15843	60100	530870	693	692.7	13093
1981	5	28719	541400	45890	2796	5067	38300	527370	707	707.5	44142
1981	6	109634	551100	104263	1567	5896	68100	500373	690	690.0	97823
1981	7	11439	515000	37488	9160	-891	18100	482998	679	679.0	34609
1981	8	13694	506400	12764	7240	-2290	15900	484596	698	698.3	12119
1981	9	9235	499100	11300	4316	-919	10100	482920	708	708.3	10883

Table A.25 Volume and load balance for sulfate at Possum Kingdom reservoir using mean concentration method 2 (MC2) during 1977-79

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			489000					292000			
1977	11	561	477700	4984	2662	-4215	742	287204	443	442.6	3000
1977	12	1081	467200	6938	4188	-455	1230	283958	445	444.8	4196
1978	1	1319	459200	7236	942	-1141	1600	280438	449	448.6	4414
1978	2	2882	459900	4270	-930	1158	4130	282113	450	450.0	2613
1978	3	4443	462500	2253	3257	3668	4000	285227	452	452.0	1385
1978	4	5784	474400	1190	4624	11931	2860	288982	449	449.5	727
1978	5	13273	478500	6609	2405	-160	13500	298311	453	453.4	4074
1978	6	18298	481700	4011	7062	-4025	15600	308872	467	467.0	2547
1978	7	177	466500	4094	10476	-807	269	305950	477	477.3	2657
1978	8	575722	555300	79537	4420	-402965	85800	119344	466	465.9	50387
1978	9	27959	549100	33068	4424	3333	21500	133733	168	168.2	7564
1978	10	14091	540200	21225	5444	3679	10500	139420	184	184.1	5313
1978	11	8658	535400	12891	-348	-915	8820	144595	194	194.4	3407
1978	12	6532	530300	6514	3092	-2026	8000	150237	204	203.9	1805
1979	1	8231	527300	10451	-1045	-1826	9760	156442	214	213.6	3036
1979	2	5831	526200	7226	894	1189	8080	162497	223	222.5	2186
1979	3	18732	541000	10266	168	6503	16100	176231	233	232.8	3250
1979	4	10336	533400	21110	2262	5437	9600	179593	243	243.1	6977
1979	5	65234	533400	70562	-483	4845	20200	176915	245	245.3	23537
1979	6	70221	538700	58695	4853	-1373	26900	183602	248	247.6	19762
1979	7	24740	549400	7486	6994	440	9330	190419	253	252.8	2573
1979	8	22455	552700	14112	5102	60	14100	199534	260	260.2	4993
1979	9	2122	523600	25363	7140	1280	1930	192406	268	267.7	9232
1979	10	446	507600	10988	6330	872	564	189025	272	272.0	4063
1979	11	2507	498000	5655	2915	-3538	1850	187408	276	276.3	2124
1979	12	2763	499000	3646	-741	1142	3350	189536	278	278.0	1378

Table A.26 Volume and load balance for sulfate at Possum Kingdom reservoir using mean concentration method 2 (MC2) during 1980-81

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1980	1	3717	492300	9408	577	-432	4520	190283	282	281.9	3606
1980	2	3798	490300	6605	1515	2322	5350	193372	287	286.9	2577
1980	3	2047	484100	4655	4205	613	2750	194354	293	292.6	1852
1980	4	1260	478000	4370	5588	2598	1560	194502	297	297.0	1764
1980	5	129209	559100	46659	-2137	-3587	61600	235455	306	305.8	19400
1980	6	28600	535400	47772	9579	5051	28700	243947	322	321.7	20895
1980	7	2309	490600	36730	12437	2058	3250	230502	340	339.9	16975
1980	8	577	463700	19440	9927	1890	855	222393	349	348.8	9221
1980	9	101310	497700	33150	-1023	-35183	21900	213016	345	345.1	15555
1980	10	252565	538200	266003	5077	59015	63900	184838	277	276.8	100102
1980	11	17726	542500	11230	1990	-206	18000	198781	261	261.1	3987
1980	12	37743	534200	50700	438	5094	34500	214543	282	281.9	19430
1981	1	14612	503700	44071	2311	1270	17300	213834	303	303.4	18182
1981	2	8848	497700	15858	1634	2644	11700	219044	318	317.7	6849
1981	3	26132	505600	26214	936	8918	26800	235219	332	332.1	11837
1981	4	52201	556300	13902	3441	15843	33000	263868	344	344.2	6506
1981	5	28719	541400	45890	2796	5067	21500	264017	353	353.2	22040
1981	6	109634	551100	104263	1567	5896	43800	258800	351	351.4	49819
1981	7	11439	515000	37488	9160	-891	9740	250179	351	351.4	17913
1981	8	13694	506400	12764	7240	-2290	9020	251781	362	362.3	6287
1981	9	9235	499100	11300	4316	-919	5870	251526	368	368.5	5661

Table A.27 Volume and load balance for the total dissolved solid at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1970-72

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			515600					435000			
1970	10	30184	526300	25587	-1205	4898	43400	458298	629	629	21893
1970	11	13129	529500	9402	6766	6239	27200	479450	652	652	8330
1970	12	11254	530200	10453	3908	3807	21600	492865	674	674	9577
1971	1	5988	501200	34909	5357	5278	10700	472874	687	687	32621
1971	2	1884	503600	1444	3494	5454	2900	476407	693	693	1361
1971	3	1640	497400	1845	9394	3399	2630	478523	701	701	1757
1971	4	1611	505900	5950	3848	16688	2840	481807	700	700	5659
1971	5	6742	520200	14880	5883	28321	4110	482442	684	684	13833
1971	6	3669	498100	20231	11484	5946	5890	471596	687	687	18911
1971	7	2493	485800	30684	8143	24034	4450	456176	687	687	28660
1971	8	27679	495900	3997	5332	-8251	53900	498569	721	721	3918
1971	9	158628	568800	57779	6114	-21836	361000	770520	890	890	69909
1971	10	125395	690800	162942	-11574	147973	249000	868604	925	925	205036
1971	11	49720	604900	163636	4764	32781	92700	768105	922	922	205189
1971	12	31436	625600	219511	-4398	204377	30800	636433	795	795	237223
1972	1	29032	579900	159868	-283	84853	59300	570787	718	718	155980
1972	2	4491	575100	28213	5189	24111	9600	561757	716	716	27449
1972	3	1995	559100	27608	10034	19647	4100	546247	714	714	26795
1972	4	14834	552000	26896	6764	11726	37000	560841	730	730	26695
1972	5	37599	557200	37384	2565	7551	78300	602777	770	770	39125
1972	6	12282	520100	41712	10453	2784	25100	583022	809	809	45874
1972	7	5728	443700	87312	9807	14991	12200	502832	824	824	97873
1972	8	121698	483200	56692	9740	-15766	268000	681014	952	952	73411
1972	9	129439	587000	51423	5387	31171	312000	927665	1098	1098	76750
1972	10	25720	600500	25611	340	13731	72100	964097	1169	1169	40691
1972	11	164176	693000	60309	-140	-11506	463000	1304566	1299	1299	106523
1972	12	45808	678300	57118	2604	-786	135000	1328326	1413	1413	109729

Table A.28 Volume and load balance for the total dissolved solid at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1973-75

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1973	1	37515	707600	37139	-2388	26535	110000	1375827	1430	1430	72204
1973	2	41107	766300	20061	-459	37195	136000	1486655	1422	1422	38775
1973	3	70760	772400	94282	4389	34011	252000	1564877	1453	1453	186217
1973	4	82393	802900	265041	-6420	206728	225000	1382344	1341	1341	483143
1973	5	42774	789500	99967	5846	49639	129000	1358572	1258	1258	170928
1973	6	77462	774500	256979	-1732	162784	198000	1204721	1177	1177	411388
1973	7	86408	779100	112380	-934	29637	211000	1249798	1157	1157	176763
1973	8	16378	729900	77937	18251	30610	16300	1153734	1166	1166	123559
1973	9	3614	713700	27777	-332	7630	9400	1122187	1158	1158	43738
1973	10	34518	752900	39913	-10929	33666	22600	1097040	1107	1107	60061
1973	11	5357	742400	28822	4195	17159	5030	1066759	1061	1061	41586
1973	12	36389	744800	38408	6442	10862	114000	1128150	1084	1084	56582
1974	1	17570	744600	30902	613	13746	55000	1141197	1118	1118	46981
1974	2	1904	729800	24662	6050	14008	4920	1113609	1122	1122	37631
1974	3	6478	679500	63810	9046	16078	19400	1041574	1122	1122	97316
1974	4	10310	651200	35554	9776	6720	19600	1008912	1132	1132	54719
1974	5	5349	635000	20582	7053	6087	5390	984662	1139	1139	31867
1974	6	11925	603200	38705	12889	7870	22700	949858	1147	1147	60382
1974	7	18405	558500	56745	17112	10752	63600	925956	1185	1185	91435
1974	8	26729	572900	41958	-4258	25371	80000	946151	1211	1211	69084
1974	9	21842	615000	33606	-3297	50567	21700	933688	1152	1152	52658
1974	10	202901	781800	34102	-4695	-6694	359000	1231634	1144	1144	53060
1974	11	297509	771900	428495	317	121403	648000	1251468	1154	1154	672569
1974	12	29528	757200	67049	712	23533	64300	1216533	1183	1183	107842
1975	1	47220	754000	79244	1323	30146	103000	1204200	1173	1173	126359
1975	2	130915	775400	250844	-2551	138778	232000	1114914	1091	1091	372043
1975	3	58998	771200	85819	3683	26304	128000	1128580	1062	1062	123955
1975	4	37097	775700	151244	-1828	116818	29300	996965	990	990	203642
1975	5	38767	795800	66653	-10646	37340	50700	978130	918	918	83191
1975	6	175422	761700	278733	12283	81494	310000	973927	908	908	344010
1975	7	28251	742700	44672	10379	7800	57700	976644	952	952	57836
1975	8	50083	731300	58752	15359	12628	123000	1024676	996	996	79587
1975	9	37402	744800	23423	6124	5644	91600	1084899	1050	1050	33442
1975	10	7041	718200	21596	9486	-2560	17800	1067009	1084	1084	31822
1975	11	4834	691900	15505	6583	-9046	12000	1041719	1107	1107	23340
1975	12	7105	653400	39124	96	-6385	16900	989083	1116	1116	59356

Table A.29 Volume and load balance for the total dissolved solid at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1976-78

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1976	1	13983	617000	52520	7370	9507	33700	946389	1119	1119	79872
1976	2	7755	575700	53909	6437	11290	19700	887514	1128	1128	82704
1976	3	2158	551100	33271	3988	10500	5140	845440	1129	1129	51055
1976	4	7162	592100	14061	-6411	41487	9500	849454	1081	1081	20660
1976	5	44507	675800	36440	-1644	73990	28100	856367	974	974	48249
1976	6	22419	674400	54190	4670	35041	34000	835783	915	915	67400
1976	7	21929	681300	60615	-3025	42560	26100	804793	882	882	72656
1976	8	25983	637300	71540	14598	16154	69500	793792	888	888	86410
1976	9	41149	656900	25087	162	3700	84700	848045	932	932	31799
1976	10	84716	719000	29833	-3723	3494	196000	1005168	990	990	40155
1976	11	92565	766600	53603	3530	12169	246000	1177041	1078	1078	78578
1976	12	15330	752900	57408	272	28650	38600	1139014	1116	1116	87106
1977	1	37230	743100	68862	-1035	20797	77800	1120752	1107	1107	103669
1977	2	21427	771300	35036	2475	44283	43200	1128486	1084	1084	51662
1977	3	130744	881600	181418	-2737	158237	50300	1008466	925	925	228194
1977	4	93410	789100	370929	-5348	179671	191000	864037	795	795	401144
1977	5	125447	780900	151993	3127	21474	267000	962794	852	852	176097
1977	6	20505	742200	46038	14936	1770	54100	959457	928	928	58084
1977	7	17361	689700	51761	18127	26	49400	940198	976	976	68669
1977	8	5615	628400	49083	9043	-8789	14300	873327	1019	1019	68021
1977	9	9620	584500	32747	16021	-4752	27700	847281	1048	1048	46646
1977	10	10011	556800	18635	6564	-12512	27800	828372	1092	1092	27670
1977	11	10153	552800	9453	400	-4301	28600	836290	1108	1108	14237
1977	12	8108	545900	7843	5024	-2142	23600	844587	1127	1127	12022
1978	1	8975	545200	8148	1773	245	20200	852206	1144	1144	12671
1978	2	6750	551400	6379	-3518	2312	16800	859897	1148	1148	9954
1978	3	3925	545300	6472	4655	1102	8470	858631	1152	1152	10139
1978	4	23105	561000	5421	4670	2685	13500	864674	1145	1145	8439
1978	5	8388	555900	16711	2190	5413	17300	858206	1133	1133	25748
1978	6	4314	511300	37815	13583	2483	9190	809252	1149	1149	59052
1978	7	2275	491100	1757	16498	-4219	8060	807513	1191	1191	2847
1978	8	467300	766400	93499	11098	-87403	1240000	1757832	1554	1554	197588
1978	9	22038	745800	23581	9399	-9658	56900	1737114	1711	1711	54856
1978	10	31569	735300	36351	12734	7016	72000	1726729	1719	1719	84951
1978	11	14977	722500	40483	-4582	8123	27700	1663341	1709	1709	94059
1978	12	6742	682600	49648	4055	7061	13000	1564946	1688	1688	113978

Table A.30 Volume and load balance for the total dissolved solid at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1979-81

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1979	1	12230	643200	60347	-1097	7620	17200	1447921	1670	1670	137011
1979	2	8731	601800	61222	-1162	9928	12900	1328121	1638	1638	136331
1979	3	28742	678800	28489	-4626	72120	25600	1321736	1507	1507	58363
1979	4	63239	761000	26761	4724	50446	43000	1334166	1347	1347	49021
1979	5	124816	808400	359758	-7625	274717	120000	1034662	1063	1063	519980
1979	6	76695	779500	155367	10429	60201	120000	981559	924	924	195122
1979	7	8301	731400	55087	8635	7321	14600	929266	929	929	69570
1979	8	11312	687800	63427	4729	13245	20500	874225	932	932	80386
1979	9	23760	661400	51356	9459	10655	44300	856685	941	941	65737
1979	10	14212	650400	34514	5661	14963	23300	840936	949	949	44522
1979	11	4695	623800	28116	5602	2423	8110	813447	954	954	36485
1979	12	8249	586700	62630	-2267	15014	14100	752311	948	948	80727
1980	1	9531	560700	48545	-1116	11899	13300	708348	933	933	61615
1980	2	14261	578000	2493	2313	7845	24300	732370	929	929	3148
1980	3	5324	582700	1716	1908	3000	10300	741590	933	933	2177
1980	4	4465	596000	2293	4059	15187	8760	753008	929	929	2897
1980	5	37860	668900	4556	-566	39030	65300	826943	910	910	5639
1980	6	55561	678500	31010	15964	1013	113000	900565	943	943	39749
1980	7	37696	634900	55006	21459	-4831	80200	898288	1011	1011	75624
1980	8	26793	582000	49692	16916	-13085	61300	866503	1079	1079	72890
1980	9	43472	572400	37333	3409	-12330	87200	878016	1123	1123	57021
1980	10	257276	766700	31224	9227	-22525	589000	1387787	1259	1259	53433
1980	11	18960	755500	26063	3201	-896	37600	1376386	1336	1336	47356
1980	12	47944	760500	47552	-801	3806	85000	1376474	1335	1335	86304
1981	1	41401	739300	59246	2558	-797	91300	1358204	1342	1342	108086
1981	2	15110	708100	49267	1467	4425	33300	1302607	1351	1351	90515
1981	3	40419	737900	38051	-1670	25762	58000	1301745	1320	1320	68285
1981	4	17341	724200	37660	4387	11005	18400	1258332	1286	1286	65838
1981	5	65566	742800	42934	1498	-2533	115000	1294211	1282	1282	74830
1981	6	114936	774600	218519	-15203	120180	216000	1201143	1188	1188	353023
1981	7	35121	750400	55646	10957	7282	79000	1195454	1155	1155	87353
1981	8	20563	709800	55698	13375	7910	41500	1150474	1180	1180	89373
1981	9	11786	681900	34762	8517	3594	21300	1116496	1197	1197	56592
1981	10	1087577	904400	756522	-10700	-119255	1173000	1042443	1069	1069	1099831
1981	11	95923	781800	295287	3634	80398	83000	831783	805	805	323065
1981	12	17185	762600	43236	5008	11859	25400	815526	782	782	45995

Table A.31 Volume and load balance for the total dissolved solid at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1982-84

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1982	1	17724	723600	62483	2213	7972	19000	770868	784	784	66573
1982	2	29635	715400	64268	1872	28306	34300	748142	771	771	67379
1982	3	17808	702000	59913	1177	29882	26900	724198	758	758	61773
1982	4	8374	694900	27663	4054	16243	14300	716035	755	755	28404
1982	5	615854	813000	593100	-5109	90237	630000	796929	722	722	582110
1982	6	802750	942600	696397	2558	25804	691000	848439	685	685	648927
1982	7	269044	774800	498655	14628	76438	211000	658087	633	633	429309
1982	8	28889	735200	47581	18166	-2742	26200	640826	634	634	41007
1982	9	7367	696000	29762	11095	-5709	7930	617228	649	649	26271
1982	10	4278	668800	21441	6386	-3651	4810	599500	658	658	19168
1982	11	15408	659100	19870	-2129	-7367	18800	593646	665	665	17954
1982	12	14733	649600	19097	-1184	-6320	17100	587648	667	667	17322
1983	1	11341	602800	49513	214	-8415	14000	548214	672	672	45230
1983	2	15421	590400	25488	-1474	-3807	22900	544169	676	676	23410
1983	3	38118	599700	24444	1060	-3314	57800	575895	694	694	23068
1983	4	33614	596700	24748	9995	-1871	59600	609139	730	730	24550
1983	5	63108	651800	17080	-959	8113	40800	635914	732	732	16992
1983	6	33384	658900	16994	9586	297	50200	669301	732	732	16922
1983	7	42046	637100	40534	12094	-11218	71700	686445	776	776	42771
1983	8	24246	611500	34800	7605	-7441	45800	685424	813	813	38468
1983	9	20731	608500	5435	11832	-6464	42000	713876	848	848	6266
1983	10	27995	623700	1619	2178	-8998	58100	759728	886	886	1949
1983	11	9449	623400	1222	1268	-7260	19200	768575	907	907	1506
1983	12	46368	654300	1781	2383	-11303	93900	846928	938	938	2271
1984	1	33907	687800	1075	3378	4046	78600	925589	971	971	1419
1984	2	12738	700600	899	3584	4544	43300	969325	1003	1003	1225
1984	3	7989	712200	11135	1690	16436	18700	978730	1011	1011	15307
1984	4	8622	679200	25458	12424	-3741	32800	970380	1033	1033	35761
1984	5	3679	617700	43511	9054	-12614	10700	897917	1071	1071	63347
1984	6	19987	608400	18543	10891	147	34900	905595	1082	1082	27275
1984	7	11268	569900	29821	15686	-4261	38000	891179	1126	1126	45646
1984	8	4491	525800	29266	12082	-7242	15000	847146	1175	1175	46758
1984	9	885	509100	1948	10625	-5012	2920	838538	1204	1204	3188
1984	10	25948	555400	4798	-10662	14488	15300	851543	1164	1164	7594
1984	11	13021	566100	2696	1111	1485	8830	856811	1120	1120	4105
1984	12	41702	627100	6177	-7256	18218	26300	880814	1067	1067	8960

Table A.32 Volume and load balance for the total dissolved solid at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1985-86

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1985	1	104136	685500	69421	1446	25131	177000	969625	1032	1032	97381
1985	2	31273	667400	54107	-317	4417	81700	975224	1056	1056	77717
1985	3	106421	769100	64669	-1314	58634	208000	1111685	1058	1058	92984
1985	4	93384	830400	94856	6565	69337	226000	1225921	1063	1063	137124
1985	5	110912	777800	200953	5749	43190	270000	1209387	1107	1107	302331
1985	6	105217	772700	120549	7524	17756	260000	1282634	1179	1179	193247
1985	7	38531	755000	46875	15877	6521	82300	1288501	1237	1237	78819
1985	8	33509	712100	62259	22671	8521	87200	1270360	1281	1281	108458
1985	9	20523	695000	37599	5687	5662	47800	1252864	1318	1318	67367
1985	10	49736	731300	23147	-3145	6566	76700	1290725	1310	1310	41240
1985	11	28036	738700	23101	1863	4328	66900	1318233	1305	1305	40976
1985	12	14551	719000	38662	-3877	534	32900	1282359	1312	1312	68969
1986	1	17835	691900	35580	5954	-3401	45200	1257058	1327	1327	64197
1986	2	26941	695100	33985	905	11149	31800	1232046	1318	1318	60889
1986	3	13460	682300	23877	9389	7007	33900	1225945	1311	1311	42564
1986	4	5649	663900	22336	6042	4329	12500	1199807	1324	1324	40221
1986	5	11913	677500	37131	-2065	36753	16400	1164574	1289	1289	65075
1986	6	123247	779200	152955	-5290	126118	253000	1218336	1180	1180	245365
1986	7	59322	765500	58846	18797	4621	150000	1275103	1186	1186	94924
1986	8	21384	729200	43611	13738	-335	55500	1256146	1246	1246	73871
1986	9	84242	781700	125330	1257	94845	207000	1289547	1222	1222	208288

Table A.33 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1970-72

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			515600					144000			
1970	10	30184	526300	25587	-1205	4898	16400	153523	210	209.7	7296
1970	11	13129	529500	9402	6766	6239	10900	162151	220	219.5	2806
1970	12	11254	530200	10453	3908	3807	8450	167677	229	228.7	3250
1971	1	5988	501200	34909	5357	5278	4060	161078	234	234.1	11112
1971	2	1884	503600	1444	3494	5454	1070	162151	236	236.3	464
1971	3	1640	497400	1845	9394	3399	965	162809	239	238.5	598
1971	4	1611	505900	5950	3848	16688	1070	163382	238	238.1	1926
1971	5	6742	520200	14880	5883	28321	1270	162389	232	231.8	4689
1971	6	3669	498100	20231	11484	5946	2290	158817	232	231.6	6372
1971	7	2493	485800	30684	8143	24034	1840	153054	232	231.6	9662
1971	8	27679	495900	3997	5332	-8251	21400	170579	244	244.4	1328
1971	9	158628	568800	57779	6114	-21836	142000	281161	317	316.6	24870
1971	10	125395	690800	162942	-11574	147973	95600	314075	340	340.2	75360
1971	11	49720	604900	163636	4764	32781	35200	277701	334	334.3	74382
1971	12	31436	625600	219511	-4398	204377	10300	219869	287	286.9	85639
1972	1	29032	579900	159868	-283	84853	22900	195868	249	249.2	54169
1972	2	4491	575100	28213	5189	24111	3730	192234	246	245.8	9430
1972	3	1995	559100	27608	10034	19647	1580	186323	244	244.4	9174
1972	4	14834	552000	26896	6764	11726	14700	192873	250	250.3	9155
1972	5	37599	557200	37384	2565	7551	30200	210158	267	266.8	13562
1972	6	12282	520100	41712	10453	2784	9700	204067	283	282.6	16029
1972	7	5728	443700	87312	9807	14991	4760	175813	289	288.9	34298
1972	8	121698	483200	56692	9740	-15766	104000	247815	341	340.7	26261
1972	9	129439	587000	51423	5387	31171	123000	345123	406	405.7	28363
1972	10	25720	600500	25611	340	13731	28700	359821	436	435.9	15178
1972	11	164176	693000	60309	-140	-11506	183000	496636	490	490.4	40211
1972	12	45808	678300	57118	2604	-786	53600	507799	539	539.0	41861

Table A.34 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1973-75

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1973	1	37515	707600	37139	-2388	26535	43900	526322	548	547.6	27651
1973	2	41107	766300	20061	-459	37195	54800	569437	545	545.2	14871
1973	3	70760	772400	94282	4389	34011	101000	601765	558	558.4	71586
1973	4	82393	802900	265041	-6420	206728	89700	522925	517	516.8	186248
1973	5	42774	789500	99967	5846	49639	51200	513575	477	476.8	64802
1973	6	77462	774500	256979	-1732	162784	78000	449559	446	446.4	155960
1973	7	86408	779100	112380	-934	29637	82300	468195	433	433.3	66202
1973	8	16378	729900	77937	18251	30610	5800	430345	437	436.7	46272
1973	9	3614	713700	27777	-332	7630	3740	418420	432	432.1	16319
1973	10	34518	752900	39913	-10929	33666	6580	405538	412	411.8	22345
1973	11	5357	742400	28822	4195	17159	1750	393387	392	392.2	15371
1973	12	36389	744800	38408	6442	10862	45100	418475	401	401.0	20943
1974	1	17570	744600	30902	613	13746	22200	424389	416	415.6	17464
1974	2	1904	729800	24662	6050	14008	2000	413592	417	417.4	13997
1974	3	6478	679500	63810	9046	16078	7850	386648	417	416.9	36171
1974	4	10310	651200	35554	9776	6720	7300	374211	420	420.2	20313
1974	5	5349	635000	20582	7053	6087	1890	364804	422	422.3	11818
1974	6	11925	603200	38705	12889	7870	8440	351547	425	425.1	22372
1974	7	18405	558500	56745	17112	10752	25100	343654	440	439.6	33913
1974	8	26729	572900	41958	-4258	25371	32700	352781	451	451.3	25747
1974	9	21842	615000	33606	-3297	50567	7730	345218	429	429.5	19624
1974	10	202901	781800	34102	-4695	-6694	138000	460519	426	425.8	19744
1974	11	297509	771900	428495	317	121403	251000	468556	435	434.9	253362
1974	12	29528	757200	67049	712	23533	25700	455827	444	443.6	40445
1975	1	47220	754000	79244	1323	30146	40500	451469	440	440.3	47441
1975	2	130915	775400	250844	-2551	138778	87300	411128	409	409.1	139528
1975	3	58998	771200	85819	3683	26304	49000	416577	393	392.5	45803
1975	4	37097	775700	151244	-1828	116818	9590	361116	365	365.0	75058
1975	5	38767	795800	66653	-10646	37340	19500	353635	333	333.0	30179
1975	6	175422	761700	278733	12283	81494	115000	350798	329	329.3	124817
1975	7	28251	742700	44672	10379	7800	22300	352891	344	343.7	20876
1975	8	50083	731300	58752	15359	12628	47000	372117	361	361.2	28855
1975	9	37402	744800	23423	6124	5644	36100	396512	383	382.7	12189
1975	10	7041	718200	21596	9486	-2560	7260	390717	396	396.5	11642
1975	11	4834	691900	15505	6583	-9046	4860	381917	406	405.7	8552
1975	12	7105	653400	39124	96	-6385	6840	363246	409	409.4	21779

Table A.35 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1976-78

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1976	1	13983	617000	52520	7370	9507	13700	348374	412	411.5	29386
1976	2	7755	575700	53909	6437	11290	8020	326884	416	415.8	30477
1976	3	2158	551100	33271	3988	10500	2080	311054	416	415.8	18810
1976	4	7162	592100	14061	-6411	41487	3500	310506	398	397.6	7601
1976	5	44507	675800	36440	-1644	73990	8770	308019	355	355.1	17595
1976	6	22419	674400	54190	4670	35041	13200	299941	330	329.5	24280
1976	7	21929	681300	60615	-3025	42560	9690	287188	317	316.5	26088
1976	8	25983	637300	71540	14598	16154	28500	286047	319	319.0	31025
1976	9	41149	656900	25087	162	3700	33700	308544	338	337.7	11519
1976	10	84716	719000	29833	-3723	3494	79200	373266	364	364.3	14777
1976	11	92565	766600	53603	3530	12169	101000	445793	405	405.0	29516
1976	12	15330	752900	57408	272	28650	15700	430917	423	423.2	33030
1977	1	37230	743100	68862	-1035	20797	31100	424505	420	419.7	39294
1977	2	21427	771300	35036	2475	44283	17100	425813	411	411.1	19585
1977	3	130744	881600	181418	-2737	158237	16400	369918	348	348.0	85850
1977	4	93410	789100	370929	-5348	179671	76300	313330	294	294.0	148278
1977	5	125447	780900	151993	3127	21474	107000	357413	313	313.4	64757
1977	6	20505	742200	46038	14936	1770	22100	358043	345	345.4	21621
1977	7	17361	689700	51761	18127	26	20300	352655	365	365.0	25690
1977	8	5615	628400	49083	9043	-8789	5830	328022	383	382.6	25530
1977	9	9620	584500	32747	16021	-4752	11400	319209	394	394.1	17547
1977	10	10011	556800	18635	6564	-12512	11800	313390	412	412.3	10446
1977	11	10153	552800	9453	400	-4301	12200	317754	420	420.0	5398
1977	12	8108	545900	7843	5024	-2142	10200	322131	429	429.2	4576
1978	1	8975	545200	8148	1773	245	8260	325575	437	436.6	4837
1978	2	6750	551400	6379	-3518	2312	6990	328957	439	438.9	3806
1978	3	3925	545300	6472	4655	1102	3450	328621	441	440.9	3880
1978	4	23105	561000	5421	4670	2685	4070	329696	438	437.5	3225
1978	5	8388	555900	16711	2190	5413	7060	327396	432	432.4	9824
1978	6	4314	511300	37815	13583	2483	3660	308735	438	438.3	22533
1978	7	2275	491100	1757	16498	-4219	3600	308596	455	454.9	1087
1978	8	467300	766400	93499	11098	-87403	523000	717493	621	620.7	78909
1978	9	22038	745800	23581	9399	-9658	23700	709504	699	698.6	22398
1978	10	31569	735300	36351	12734	7016	28700	704125	702	701.7	34680
1978	11	14977	722500	40483	-4582	8123	10800	677279	697	696.6	38342
1978	12	6742	682600	49648	4055	7061	5120	636600	687	687.4	46404

Table A.36 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1979-81

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1979	1	12230	643200	60347	-1097	7620	6440	587982	679	679.0	55710
1979	2	8731	601800	61222	-1162	9928	4890	538377	665	664.9	55346
1979	3	28742	678800	28489	-4626	72120	9060	529985	610	610.0	23630
1979	4	63239	761000	26761	4724	50446	15300	529985	539	539.2	19621
1979	5	124816	808400	359758	-7625	274717	43700	391400	421	420.8	205817
1979	6	76695	779500	155367	10429	60201	45700	368417	350	349.5	73839
1979	7	8301	731400	55087	8635	7321	5680	348605	349	348.7	26120
1979	8	11312	687800	63427	4729	13245	7970	327541	350	349.8	30168
1979	9	23760	661400	51356	9459	10655	17300	321099	353	353.1	24655
1979	10	14212	650400	34514	5661	14963	9170	314852	356	355.8	16699
1979	11	4695	623800	28116	5602	2423	3200	304596	357	357.4	13664
1979	12	8249	586700	62630	-2267	15014	5540	281181	355	355.1	30241
1980	1	9531	560700	48545	-1116	11899	5190	264352	349	349.0	23038
1980	2	14261	578000	2493	2313	7845	9570	273418	347	346.9	1176
1980	3	5324	582700	1716	1908	3000	4090	276952	349	348.6	813
1980	4	4465	596000	2293	4059	15187	3480	280651	347	347.1	1082
1980	5	37860	668900	4556	-566	39030	25800	307687	340	340.1	2107
1980	6	55561	678500	31010	15964	1013	44800	337722	352	352.2	14852
1980	7	37696	634900	55006	21459	-4831	32000	338715	380	380.2	28437
1980	8	26793	582000	49692	16916	-13085	24600	328157	408	407.7	27543
1980	9	43472	572400	37333	3409	-12330	34800	334238	427	426.5	21650
1980	10	257276	766700	31224	9227	-22525	236600	540396	486	485.8	20623
1980	11	18960	755500	26063	3201	-896	14900	536210	520	520.5	18444
1980	12	47944	760500	47552	-801	3806	33600	536499	520	520.3	33637
1981	1	41401	739300	59246	2558	-797	36600	530354	523	523.5	42167
1981	2	15110	708100	49267	1467	4425	13400	508776	528	527.8	35358
1981	3	40419	737900	38051	-1670	25762	22800	507108	516	515.6	26675
1981	4	17341	724200	37660	4387	11005	7200	489602	501	500.9	25649
1981	5	65566	742800	42934	1498	-2533	45400	504198	499	499.1	29134
1981	6	114936	774600	218519	-15203	120180	85900	462642	464	463.6	137751
1981	7	35121	750400	55646	10957	7282	31700	461275	445	445.3	33690
1981	8	20563	709800	55698	13375	7910	16600	444046	456	455.7	34507
1981	9	11786	681900	34762	8517	3594	8440	430946	462	462.2	21848
1981	10	1087577	904400	756522	-10700	-119255	445300	397315	410	410.4	422106
1981	11	95923	781800	295287	3634	80398	31100	312249	306	306.5	123053
1981	12	17185	762600	43236	5008	11859	9700	305694	294	293.8	17271

Table A.37 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1982-84

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1982	1	17724	723600	62483	2213	7972	7150	288571	294	293.7	24956
1982	2	29635	715400	64268	1872	28306	13300	279053	289	288.9	25243
1982	3	17808	702000	59913	1177	29882	10300	268861	283	283.0	23052
1982	4	8374	694900	27663	4054	16243	5510	265213	280	280.5	10549
1982	5	615854	813000	593100	-5109	90237	236800	293159	269	268.6	216583
1982	6	802750	942600	696397	2558	25804	258100	313645	253	253.3	239825
1982	7	269044	774800	498655	14628	76438	78100	239566	234	234.1	158726
1982	8	28889	735200	47581	18166	-2742	9760	233498	231	230.9	14935
1982	9	7367	696000	29762	11095	-5709	2980	224988	237	236.6	9574
1982	10	4278	668800	21441	6386	-3651	1810	218582	240	239.7	6988
1982	11	15408	659100	19870	-2129	-7367	7100	216689	242	242.4	6550
1982	12	14733	649600	19097	-1184	-6320	6450	214705	244	243.6	6326
1983	1	11341	602800	49513	214	-8415	5320	200495	246	245.6	16533
1983	2	15421	590400	25488	-1474	-3807	8780	199412	247	247.3	8570
1983	3	38118	599700	24444	1060	-3314	22300	212134	255	255.0	8476
1983	4	33614	596700	24748	9995	-1871	23100	225502	269	269.4	9066
1983	5	63108	651800	17080	-959	8113	15400	235303	271	271.0	6294
1983	6	33384	658900	16994	9586	297	19300	248358	271	271.4	6271
1983	7	42046	637100	40534	12094	-11218	27700	255780	289	288.6	15904
1983	8	24246	611500	34800	7605	-7441	17800	256114	303	303.4	14354
1983	9	20731	608500	5435	11832	-6464	16400	267449	317	317.3	2344
1983	10	27995	623700	1619	2178	-8998	23000	285859	333	332.6	732
1983	11	9449	623400	1222	1268	-7260	7540	289503	341	341.3	567
1983	12	46368	654300	1781	2383	-11303	37100	320744	354	354.2	858
1984	1	33907	687800	1075	3378	4046	31700	352252	369	368.6	539
1984	2	12738	700600	899	3584	4544	18300	370474	383	382.6	467
1984	3	7989	712200	11135	1690	16436	7580	373608	387	386.6	5854
1984	4	8622	679200	25458	12424	-3741	14100	371971	395	395.2	13679
1984	5	3679	617700	43511	9054	-12614	4440	344522	411	410.6	24293
1984	6	19987	608400	18543	10891	147	14300	348356	416	415.6	10479
1984	7	11268	569900	29821	15686	-4261	16000	344158	434	433.9	17593
1984	8	4491	525800	29266	12082	-7242	6300	327648	454	454.1	18071
1984	9	885	509100	1948	10625	-5012	1230	324419	466	465.7	1233
1984	10	25948	555400	4798	-10662	14488	5660	328383	450	450.2	2937
1984	11	13021	566100	2696	1111	1485	3180	330108	432	431.8	1582
1984	12	41702	627100	6177	-7256	18218	9610	337829	411	410.7	3449

Table A.38 Volume and load balance for chloride at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1985-86

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1985	1	104136	685500	69421	1446	25131	70300	372811	397	397.0	37471
1985	2	31273	667400	54107	-317	4417	33100	376343	407	407.1	29946
1985	3	106421	769100	64669	-1314	58634	82200	427599	409	409.0	35966
1985	4	93384	830400	94856	6565	69337	9060	394215	375	375.2	48384
1985	5	110912	777800	200953	5749	43190	108700	406965	365	364.7	99649
1985	6	105217	772700	120549	7524	17756	104600	446823	404	404.3	66263
1985	7	38531	755000	46875	15877	6521	32800	452601	433	432.7	27580
1985	8	33509	712100	62259	22671	8521	35300	450344	452	452.3	38287
1985	9	20523	695000	37599	5687	5662	19100	445991	468	468.3	23938
1985	10	49736	731300	23147	-3145	6566	30200	462027	468	467.9	14727
1985	11	28036	738700	23101	1863	4328	26800	474486	468	468.4	14712
1985	12	14551	719000	38662	-3877	534	13100	462774	473	472.9	24857
1986	1	17835	691900	35580	5954	-3401	18200	455486	480	479.9	23214
1986	2	26941	695100	33985	905	11149	12400	446757	478	477.9	22084
1986	3	13460	682300	23877	9389	7007	13600	445500	476	476.1	15457
1986	4	5649	663900	22336	6042	4329	4950	436198	482	481.5	14623
1986	5	11913	677500	37131	-2065	36753	6330	422008	469	468.8	23668
1986	6	123247	779200	152955	-5290	126118	101100	444103	432	431.8	89808
1986	7	59322	765500	58846	18797	4621	60700	470377	435	435.2	34822
1986	8	21384	729200	43611	13738	-335	22400	465255	460	460.5	27305
1986	9	84242	781700	125330	1257	94845	83800	479487	456	455.9	77693

Table A.39 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1970-72

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
			515600					82700			
1970	10	30184	526300	25587	-1205	4898	8330	87046	120	119.7	4164
1970	11	13129	529500	9402	6766	6239	5240	90932	124	123.8	1583
1970	12	11254	530200	10453	3908	3807	4270	93524	128	127.9	1818
1971	1	5988	501200	34909	5357	5278	2190	89712	131	130.5	6195
1971	2	1884	503600	1444	3494	5454	576	90230	132	131.6	258
1971	3	1640	497400	1845	9394	3399	524	90546	133	132.7	333
1971	4	1611	505900	5950	3848	16688	581	90668	132	132.4	1071
1971	5	6742	520200	14880	5883	28321	930	90033	129	128.8	2605
1971	6	3669	498100	20231	11484	5946	1130	87851	128	128.3	3530
1971	7	2493	485800	30684	8143	24034	823	84218	128	128.0	5339
1971	8	27679	495900	3997	5332	-8251	11200	93288	134	134.0	728
1971	9	158628	568800	57779	6114	-21836	75900	152096	172	172.0	13511
1971	10	125395	690800	162942	-11574	147973	51200	168021	184	183.7	40708
1971	11	49720	604900	163636	4764	32781	19000	148413	179	178.9	39811
1971	12	31436	625600	219511	-4398	204377	6420	116429	154	153.8	45907
1972	1	29032	579900	159868	-283	84853	12300	103139	132	132.1	28705
1972	2	4491	575100	28213	5189	24111	2020	101077	129	129.5	4967
1972	3	1995	559100	27608	10034	19647	869	97843	129	128.5	4824
1972	4	14834	552000	26896	6764	11726	8080	101538	132	131.7	4816
1972	5	37599	557200	37384	2565	7551	16400	111059	141	140.8	7156
1972	6	12282	520100	41712	10453	2784	5180	107868	149	149.4	8473
1972	7	5728	443700	87312	9807	14991	2500	92790	153	152.7	18128
1972	8	121698	483200	56692	9740	-15766	58000	133723	182	182.1	14039
1972	9	129439	587000	51423	5387	31171	68700	188156	220	220.4	15411
1972	10	25720	600500	25611	340	13731	15800	196182	238	237.7	8278
1972	11	164176	693000	60309	-140	-11506	101000	271947	268	268.0	21978
1972	12	45808	678300	57118	2604	-786	29300	278011	295	295.1	22920

Table A.40 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1973-75

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1973	1	37515	707600	37139	-2388	26535	24000	287848	300	299.8	15137
1973	2	41107	766300	20061	-459	37195	29700	310784	298	298.0	8129
1973	3	70760	772400	94282	4389	34011	54900	327876	305	304.7	39057
1973	4	82393	802900	265041	-6420	206728	49300	283225	282	281.8	101540
1973	5	42774	789500	99967	5846	49639	27900	277840	258	258.3	35108
1973	6	77462	774500	256979	-1732	162784	43200	242501	242	241.9	84515
1973	7	86408	779100	112380	-934	29637	45900	253677	234	234.4	35812
1973	8	16378	729900	77937	18251	30610	3120	232851	237	236.6	25070
1973	9	3614	713700	27777	-332	7630	2020	226321	234	233.8	8830
1973	10	34518	752900	39913	-10929	33666	3760	219225	223	222.8	12092
1973	11	5357	742400	28822	4195	17159	948	212494	212	212.0	8309
1973	12	36389	744800	38408	6442	10862	23300	224907	216	216.1	11286
1974	1	17570	744600	30902	613	13746	11500	227534	223	223.2	9377
1974	2	1904	729800	24662	6050	14008	1040	221585	224	223.8	7504
1974	3	6478	679500	63810	9046	16078	4060	206863	223	223.3	19373
1974	4	10310	651200	35554	9776	6720	3790	200034	225	224.8	10865
1974	5	5349	635000	20582	7053	6087	1020	194960	226	225.7	6317
1974	6	11925	603200	38705	12889	7870	4380	187677	227	227.1	11952
1974	7	18405	558500	56745	17112	10752	12800	182795	234	234.3	18077
1974	8	26729	572900	41958	-4258	25371	16700	186756	240	239.6	13670
1974	9	21842	615000	33606	-3297	50567	4160	182382	227	227.4	10390
1974	10	202901	781800	34102	-4695	-6694	77300	247585	227	227.2	10535
1974	11	297509	771900	428495	317	121403	138000	253168	235	234.9	136874
1974	12	29528	757200	67049	712	23533	14100	246270	240	239.8	21862
1975	1	47220	754000	79244	1323	30146	22500	244215	238	238.2	25662
1975	2	130915	775400	250844	-2551	138778	49900	223357	222	222.4	75853
1975	3	58998	771200	85819	3683	26304	27300	226703	214	213.6	24920
1975	4	37097	775700	151244	-1828	116818	6060	196129	199	199.0	40922
1975	5	38767	795800	66653	-10646	37340	11100	192188	181	181.1	16412
1975	6	175422	761700	278733	12283	81494	64500	191542	180	179.8	68138
1975	7	28251	742700	44672	10379	7800	12300	192727	188	187.7	11402
1975	8	50083	731300	58752	15359	12628	25900	203323	197	197.4	15768
1975	9	37402	744800	23423	6124	5644	19900	216767	209	209.2	6663
1975	10	7041	718200	21596	9486	-2560	3530	213167	217	216.5	6358
1975	11	4834	691900	15505	6583	-9046	2370	208087	221	221.2	4663
1975	12	7105	653400	39124	96	-6385	3350	197548	223	222.9	11856

Table A.41 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1976-78

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1976	1	13983	617000	52520	7370	9507	6690	188636	223	223.4	15951
1976	2	7755	575700	53909	6437	11290	3900	176467	225	224.9	16484
1976	3	2158	551100	33271	3988	10500	1020	167721	224	224.4	10151
1976	4	7162	592100	14061	-6411	41487	1920	167065	214	214.4	4099
1976	5	44507	675800	36440	-1644	73990	5840	166123	192	191.7	9498
1976	6	22419	674400	54190	4670	35041	6810	161137	178	177.6	13083
1976	7	21929	681300	60615	-3025	42560	5280	153960	170	170.1	14018
1976	8	25983	637300	71540	14598	16154	13700	151702	170	170.2	16551
1976	9	41149	656900	25087	162	3700	16900	162647	179	178.6	6091
1976	10	84716	719000	29833	-3723	3494	39200	194240	191	190.7	7736
1976	11	92565	766600	53603	3530	12169	48700	228162	209	208.9	15225
1976	12	15330	752900	57408	272	28650	7620	219944	216	216.4	16890
1977	1	37230	743100	68862	-1035	20797	15600	216263	214	214.1	20044
1977	2	21427	771300	35036	2475	44283	8610	216524	209	209.4	9975
1977	3	130744	881600	181418	-2737	158237	10300	188785	178	177.8	43848
1977	4	93410	789100	370929	-5348	179671	38200	158042	150	149.8	75538
1977	5	125447	780900	151993	3127	21474	53500	179709	158	157.9	32622
1977	6	20505	742200	46038	14936	1770	10700	179615	173	173.5	10859
1977	7	17361	689700	51761	18127	26	9750	176493	183	182.9	12873
1977	8	5615	628400	49083	9043	-8789	2830	164081	191	191.4	12774
1977	9	9620	584500	32747	16021	-4752	5450	159426	197	197.0	8770
1977	10	10011	556800	18635	6564	-12512	5110	155749	205	205.4	5205
1977	11	10153	552800	9453	400	-4301	5250	157112	208	208.2	2676
1977	12	8108	545900	7843	5024	-2142	4330	158567	212	211.7	2258
1978	1	8975	545200	8148	1773	245	3740	159938	215	214.7	2378
1978	2	6750	551400	6379	-3518	2312	3110	161265	215	215.4	1868
1978	3	3925	545300	6472	4655	1102	1580	160984	216	216.1	1901
1978	4	23105	561000	5421	4670	2685	2610	162110	215	214.7	1583
1978	5	8388	555900	16711	2190	5413	3220	160702	212	212.4	4827
1978	6	4314	511300	37815	13583	2483	1710	151446	215	215.1	11057
1978	7	2275	491100	1757	16498	-4219	1460	151072	223	222.9	533
1978	8	467300	766400	93499	11098	-87403	229000	326084	289	289.2	36759
1978	9	22038	745800	23581	9399	-9658	10500	322186	317	317.3	10175
1978	10	31569	735300	36351	12734	7016	14400	321063	319	319.3	15781
1978	11	14977	722500	40483	-4582	8123	5430	309294	318	317.9	17497
1978	12	6742	682600	49648	4055	7061	2590	290944	314	314.1	21200

Table A.42 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1979-81

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1979	1	12230	643200	60347	-1097	7620	3300	269047	310	310.5	25477
1979	2	8731	601800	61222	-1162	9928	2520	246593	304	304.4	25338
1979	3	28742	678800	28489	-4626	72120	4640	243047	280	279.7	10834
1979	4	63239	761000	26761	4724	50446	7790	243677	248	247.7	9012
1979	5	124816	808400	359758	-7625	274717	22300	181019	194	194.3	95042
1979	6	76695	779500	155367	10429	60201	23300	172186	163	162.6	34343
1979	7	8301	731400	55087	8635	7321	2880	163120	163	163.1	12215
1979	8	11312	687800	63427	4729	13245	4030	153507	164	163.8	14129
1979	9	23760	661400	51356	9459	10655	8810	151127	166	165.8	11581
1979	10	14212	650400	34514	5661	14963	4620	148430	168	167.6	7867
1979	11	4695	623800	28116	5602	2423	1610	143685	169	168.6	6444
1979	12	8249	586700	62630	-2267	15014	2790	132752	168	167.6	14274
1980	1	9531	560700	48545	-1116	11899	2630	124935	165	164.9	10884
1980	2	14261	578000	2493	2313	7845	4810	129476	164	164.1	556
1980	3	5324	582700	1716	1908	3000	2050	131251	165	165.1	385
1980	4	4465	596000	2293	4059	15187	1740	133036	165	164.6	513
1980	5	37860	668900	4556	-566	39030	13000	146467	162	161.7	1002
1980	6	55561	678500	31010	15964	1013	22400	161810	168	168.3	7094
1980	7	37696	634900	55006	21459	-4831	16000	162927	183	182.5	13652
1980	8	26793	582000	49692	16916	-13085	12200	158201	196	196.3	13263
1980	9	43472	572400	37333	3409	-12330	17400	161737	206	206.0	10457
1980	10	257276	766700	31224	9227	-22525	117600	264535	237	236.7	10050
1980	11	18960	755500	26063	3201	-896	7470	262659	255	254.9	9032
1980	12	47944	760500	47552	-801	3806	16900	263209	255	255.1	16490
1981	1	41401	739300	59246	2558	-797	18200	260429	257	256.9	20696
1981	2	15110	708100	49267	1467	4425	6650	249876	259	259.2	17365
1981	3	40419	737900	38051	-1670	25762	11500	249214	253	253.4	13108
1981	4	17341	724200	37660	4387	11005	3640	240650	246	246.2	12607
1981	5	65566	742800	42934	1498	-2533	22800	248296	246	245.5	14334
1981	6	114936	774600	218519	-15203	120180	43000	227783	229	228.6	67924
1981	7	35121	750400	55646	10957	7282	15700	227160	219	219.3	16591
1981	8	20563	709800	55698	13375	7910	8260	218714	224	224.4	16996
1981	9	11786	681900	34762	8517	3594	4230	212313	228	227.7	10763
1981	10	1087577	904400	756522	-10700	-119255	221400	197109	203	202.8	208608
1981	11	95923	781800	295287	3634	80398	15400	154418	152	152.0	61042
1981	12	17185	762600	43236	5008	11859	4840	151151	145	145.3	8542

Table A.43 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1982-84

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1982	1	17724	723600	62483	2213	7972	3550	142653	145	145.3	12340
1982	2	29635	715400	64268	1872	28306	6620	137832	143	142.8	12481
1982	3	17808	702000	59913	1177	29882	5150	132691	140	139.8	11388
1982	4	8374	694900	27663	4054	16243	2760	130840	138	138.4	5207
1982	5	615854	813000	593100	-5109	90237	117300	144469	133	132.7	106984
1982	6	802750	942600	696397	2558	25804	127500	154643	125	124.9	118273
1982	7	269044	774800	498655	14628	76438	38500	117690	115	115.4	78258
1982	8	28889	735200	47581	18166	-2742	4820	114734	113	113.4	7338
1982	9	7367	696000	29762	11095	-5709	1470	110558	116	116.3	4705
1982	10	4278	668800	21441	6386	-3651	899	107420	118	117.8	3434
1982	11	15408	659100	19870	-2129	-7367	3520	106520	119	119.2	3219
1982	12	14733	649600	19097	-1184	-6320	3200	105573	120	119.8	3110
1983	1	11341	602800	49513	214	-8415	2640	98609	121	120.8	8131
1983	2	15421	590400	25488	-1474	-3807	4380	98137	122	121.7	4216
1983	3	38118	599700	24444	1060	-3314	11200	104619	126	125.6	4176
1983	4	33614	596700	24748	9995	-1871	11600	111415	133	133.0	4475
1983	5	63108	651800	17080	-959	8113	7640	116243	134	133.9	3110
1983	6	33384	658900	16994	9586	297	9640	122794	134	134.1	3099
1983	7	42046	637100	40534	12094	-11218	13900	126663	143	142.8	7870
1983	8	24246	611500	34800	7605	-7441	8930	126940	150	150.3	7111
1983	9	20731	608500	5435	11832	-6464	8250	132679	157	157.3	1163
1983	10	27995	623700	1619	2178	-8998	11600	142002	165	165.1	363
1983	11	9449	623400	1222	1268	-7260	3830	143896	170	169.6	282
1983	12	46368	654300	1781	2383	-11303	18700	159684	176	176.2	427
1984	1	33907	687800	1075	3378	4046	15700	175264	183	183.5	268
1984	2	12738	700600	899	3584	4544	8640	183839	190	190.1	232
1984	3	7989	712200	11135	1690	16436	3720	185258	192	191.8	2904
1984	4	8622	679200	25458	12424	-3741	6550	184013	196	195.7	6775
1984	5	3679	617700	43511	9054	-12614	2130	170369	203	203.1	12016
1984	6	19987	608400	18543	10891	147	6970	172164	205	205.5	5180
1984	7	11268	569900	29821	15686	-4261	7590	169780	214	214.2	8687
1984	8	4491	525800	29266	12082	-7242	2990	161520	224	224.0	8911
1984	9	885	509100	1948	10625	-5012	583	159905	230	229.6	608
1984	10	25948	555400	4798	-10662	14488	3040	162028	222	222.1	1449
1984	11	13021	566100	2696	1111	1485	1760	163062	213	213.2	781
1984	12	41702	627100	6177	-7256	18218	5240	167264	203	203.2	1706

Table A.44 Volume and load balance for sulfate at Granbury-Whitney reservoir using mean concentration method 2 (MC2) during 1985-86

YEAR	M	Volume					Computation of Outflow Concentration				Computed Outflow Load (tons)
		Inflow (ac-ft)	EOM Storage (ac-ft)	Outflow (ac-ft)	Evap. (ac-ft)	Vdiff. (ac-ft)	Inflow Load (ac-ft)	Storage Load (tons)	Storage Conc. (mg/l)	Outflow Conc. (mg/l)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1985	1	104136	685500	69421	1446	25131	35400	185005	197	196.9	18582
1985	2	31273	667400	54107	-317	4417	16300	186611	202	201.9	14856
1985	3	106421	769100	64669	-1314	58634	41400	212302	203	203.1	17862
1985	4	93384	830400	94856	6565	69337	45000	233557	204	203.8	26290
1985	5	110912	777800	200953	5749	43190	53900	231171	212	211.8	57872
1985	6	105217	772700	120549	7524	17756	51800	246532	226	226.3	37090
1985	7	38531	755000	46875	15877	6521	16400	248005	238	238.0	15167
1985	8	33509	712100	62259	22671	8521	17400	244817	247	246.9	20901
1985	9	20523	695000	37599	5687	5662	9540	241574	254	254.1	12991
1985	10	49736	731300	23147	-3145	6566	15400	249253	253	253.0	7962
1985	11	28036	738700	23101	1863	4328	13400	254892	252	252.2	7920
1985	12	14551	719000	38662	-3877	534	6590	248160	254	253.8	13342
1986	1	17835	691900	35580	5954	-3401	9050	243559	257	257.0	12431
1986	2	26941	695100	33985	905	11149	6380	238546	255	255.4	11803
1986	3	13460	682300	23877	9389	7007	6770	237328	254	254.0	8245
1986	4	5649	663900	22336	6042	4329	2500	232200	256	256.4	7788
1986	5	11913	677500	37131	-2065	36753	3290	224242	250	249.5	12597
1986	6	123247	779200	152955	-5290	126118	50700	232137	228	228.1	47434
1986	7	59322	765500	58846	18797	4621	30100	244265	227	226.7	18142
1986	8	21384	729200	43611	13738	-335	11100	241088	239	238.9	14164
1986	9	84242	781700	125330	1257	94845	41400	245866	235	235.3	40104

Table A.45 Observed vs. computed outflow concentration for chloride at Possum Kingdom reservoir during 1977-81

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1977	11	864.7	864.6	864.7	1980	1	589.5	702.1	625.0
1977	12	898.9	871.9	868.8	1980	2	563.4	716.7	637.5
1978	1	902.6	877.8	875.7	1980	3	590.9	731.7	652.4
1978	2	921.4	882.0	879.0	1980	4	589.1	743.8	663.0
1978	3	930.3	887.5	885.2	1980	5	591.1	731.3	657.0
1978	4	939.4	883.0	882.0	1980	6	606.6	746.7	668.9
1978	5	951.5	885.7	892.5	1980	7	646.8	795.6	710.1
1978	6	931.6	904.5	915.4	1980	8	684.8	825.3	731.1
1978	7	954.0	923.8	932.1	1980	9	692.2	779.5	714.0
1978	8	816.5	638.6	891.5	1980	10	657.5	603.3	544.7
1978	9	802.9	392.4	291.4	1980	11	544.2	506.4	510.1
1978	10	786.6	400.7	324.4	1980	12	529.5	548.3	550.8
1978	11	656.1	415.9	353.6	1981	1	532.4	595.1	596.6
1978	12	653.8	436.1	379.2	1981	2	551.9	632.9	630.9
1979	1	463.1	460.5	405.6	1981	3	549.9	672.9	667.2
1979	2	456.0	485.4	430.4	1981	4	555.5	699.3	692.7
1979	3	569.5	513.7	460.6	1981	5	552.9	714.2	707.5
1979	4	536.5	540.1	492.3	1981	6	592.5	710.5	690.0
1979	5	420.1	558.7	508.1	1981	7	602.3	708.4	679.0
1979	6	438.6	586.1	528.4	1981	8	616.6	731.8	698.3
1979	7	457.9	612.1	549.3	1981	9	627.4	745.2	708.3
1979	8	483.1	634.8	571.2					
1979	9	507.5	659.7	591.4					
1979	10	526.1	675.1	601.6					
1979	11	535.9	685.1	611.3					
1979	12	550.8	692.5	615.4					

Table A.46 Observed vs. computed outflow concentration for sulfate at Possum Kingdom reservoir during 1977-81

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1977	11	442.7	442.8	442.6	1980	1	282.2	339.1	281.9
1977	12	459.0	446.7	444.8	1980	2	269.5	345.1	286.9
1978	1	463.5	450.0	448.6	1980	3	282.8	351.2	292.6
1978	2	470.2	451.9	450.0	1980	4	282.8	356.7	297.0
1978	3	470.0	453.9	452.0	1980	5	282.2	360.8	305.8
1978	4	480.8	452.2	449.5	1980	6	291.0	377.1	321.7
1978	5	490.8	454.4	453.4	1980	7	312.4	401.1	339.9
1978	6	480.5	465.9	467.0	1980	8	330.7	416.1	348.8
1978	7	486.9	477.5	477.3	1980	9	335.0	397.8	345.1
1978	8	418.9	337.3	465.9	1980	10	316.9	330.2	276.8
1978	9	413.7	218.3	168.2	1980	11	259.3	297.0	261.1
1978	10	395.0	223.3	184.1	1980	12	252.4	319.8	281.9
1978	11	319.5	227.9	194.4	1981	1	253.7	346.0	303.4
1978	12	317.3	235.2	203.9	1981	2	262.0	364.9	317.7
1979	1	198.5	244.5	213.6	1981	3	261.8	382.6	332.1
1979	2	187.3	254.4	222.5	1981	4	264.0	395.4	344.2
1979	3	264.3	264.7	232.8	1981	5	262.8	406.6	353.2
1979	4	244.9	274.3	243.1	1981	6	283.6	415.3	351.4
1979	5	166.8	281.8	245.3	1981	7	288.4	424.9	351.4
1979	6	179.2	292.1	247.6	1981	8	296.8	441.3	362.3
1979	7	190.6	300.9	252.8	1981	9	301.4	450.6	368.5
1979	8	210.0	308.8	260.2					
1979	9	225.9	319.2	267.7					
1979	10	250.3	326.9	272.0					
1979	11	254.9	331.8	276.3					
1979	12	262.3	335.0	278.0					

Table A.47 Observed vs. computed outflow concentration for TDS at Granbury-Whitney reservoir during 1970-75

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1970	10	630	630	629	1973	1	1341	1452	1430
1970	11	644	653	652	1973	2	1371	1447	1422
1970	12	646	675	674	1973	3	1381	1482	1453
1971	1	668	690	687	1973	4	1351	1403	1341
1971	2	674	697	693	1973	5	1324	1287	1258
1971	3	718	703	701	1973	6	1211	1218	1177
1971	4	736	706	700	1973	7	1152	1171	1157
1971	5	722	692	684	1973	8	1104	1184	1166
1971	6	731	689	687	1973	9	1141	1177	1158
1971	7	717	692	687	1973	10	1102	1131	1107
1971	8	731	713	721	1973	11	1102	1081	1061
1971	9	768	876	890	1973	12	1101	1102	1084
1971	10	972	953	925	1974	1	1202	1135	1118
1971	11	898	923	922	1974	2	1202	1136	1122
1971	12	885	821	795	1974	3	1199	1132	1122
1972	1	796	693	718	1974	4	1202	1135	1132
1972	2	727	665	716	1974	5	1201	1139	1139
1972	3	730	661	714	1974	6	1201	1146	1147
1972	4	716	674	730	1974	7	1201	1181	1185
1972	5	700	716	770	1974	8	1201	1210	1211
1972	6	716	758	809	1974	9	1202	1157	1152
1972	7	719	785	824	1974	10	1102	1133	1144
1972	8	737	915	952	1974	11	1201	1157	1154
1972	9	996	1099	1098	1974	12	1097	1159	1183
1972	10	1152	1170	1169	1975	1	1104	1157	1173
1972	11	1211	1291	1299	1975	2	1102	1097	1091
1972	12	1271	1421	1413	1975	3	1003	1051	1062
					1975	4	1002	998	990
					1975	5	981	909	918
					1975	6	950	896	908
					1975	7	932	920	952
					1975	8	931	968	996
					1975	9	951	1025	1050
					1975	10	964	1059	1084
					1975	11	1001	1079	1107
					1975	12	1025	1093	1116

Table A.48 Observed vs. computed outflow concentration for TDS at Granbury-Whitney reservoir during 1976-81

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1976	1	1022	1110	1119	1979	1	1572	1642	1670
1976	2	1041	1128	1128	1979	2	1538	1618	1638
1976	3	1050	1135	1129	1979	3	1513	1506	1507
1976	4	1062	1097	1081	1979	4	1448	1341	1347
1976	5	1052	994	974	1979	5	1251	1053	1063
1976	6	1021	920	915	1979	6	942	834	924
1976	7	1018	878	882	1979	7	884	825	929
1976	8	991	868	888	1979	8	814	830	932
1976	9	965	903	932	1979	9	725	848	941
1976	10	961	962	990	1979	10	688	869	949
1976	11	996	1058	1078	1979	11	698	882	954
1976	12	1024	1105	1116	1979	12	705	893	948
1977	1	1037	1102	1107	1980	1	708	898	933
1977	2	1043	1088	1084	1980	2	714	902	929
1977	3	1038	936	925	1980	3	724	907	933
1977	4	972	760	795	1980	4	719	907	929
1977	5	852	747	852	1980	5	723	896	910
1977	6	773	821	928	1980	6	728	927	943
1977	7	740	875	976	1980	7	722	1009	1011
1977	8	698	924	1019	1980	8	739	1096	1079
1977	9	685	973	1048	1980	9	788	1167	1123
1977	10	687	1024	1092	1980	10	1095	1298	1259
1977	11	711	1057	1108	1980	11	1134	1382	1336
1977	12	719	1085	1127	1980	12	1126	1393	1335
1978	1	722	1109	1144	1981	1	1194	1411	1342
1978	2	729	1120	1148	1981	2	1215	1435	1351
1978	3	734	1129	1152	1981	3	1233	1415	1320
1978	4	749	1127	1145	1981	4	1252	1381	1286
1978	5	761	1123	1133	1981	5	1256	1374	1282
1978	6	762	1157	1149	1981	6	1212	1298	1188
1978	7	774	1210	1191	1981	7	1155	1241	1155
1978	8	1400	1482	1554	1981	8	1154	1272	1180
1978	9	2052	1648	1711	1981	9	1115	1296	1197
1978	10	1562	1667	1719	1981	10	987	1113	1069
1978	11	1521	1665	1709	1981	11	927	924	805
1978	12	1555	1653	1688	1981	12	1036	871	782

Table A.49 Observed vs. computed outflow concentration for TDS at Granbury-Whitney reservoir during 1982-86

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1982	1	938	861	784	1985	1	1036	1050	1032
1982	2	926	841	771	1985	2	1068	1070	1056
1982	3	906	817	758	1985	3	1087	1079	1058
1982	4	883	803	755	1985	4	1062	1083	1063
1982	5	791	751	722	1985	5	1120	1121	1107
1982	6	718	664	685	1985	6	1165	1189	1179
1982	7	673	595	633	1985	7	1221	1247	1237
1982	8	624	564	634	1985	8	1240	1295	1281
1982	9	638	575	649	1985	9	1303	1333	1318
1982	10	648	582	658	1985	10	1360	1326	1310
1982	11	651	586	665	1985	11	1388	1317	1305
1982	12	655	589	667	1985	12	1415	1320	1312
1983	1	662	591	672	1986	1	1408	1327	1327
1983	2	658	595	676	1986	2	1435	1318	1318
1983	3	656	615	694	1986	3	1445	1306	1311
1983	4	654	654	730	1986	4	1452	1314	1324
1983	5	659	665	732	1986	5	1450	1279	1289
1983	6	658	669	732	1986	6	1404	1160	1180
1983	7	662	711	776	1986	7	1400	1117	1186
1983	8	664	756	813	1986	8	1363	1161	1246
1983	9	698	796	848	1986	9	1209	1154	1222
1983	10	732	833	886					
1983	11	746	856	907					
1983	12	764	886	938					
1984	1	766	930	971					
1984	2	819	964	1003					
1984	3	826	977	1011					
1984	4	852	998	1033					
1984	5	860	1036	1071					
1984	6	881	1069	1082					
1984	7	930	1117	1126					
1984	8	968	1173	1175					
1984	9	993	1211	1204					
1984	10	1016	1182	1164					
1984	11	1023	1135	1120					
1984	12	1005	1085	1067					

Table A.50 Observed vs. computed outflow concentration for Chlorides at Granbury-Whitney reservoir during 1970-75

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1970	10	209.8	210.0	209.7	1973	1	491.1	544.5	547.6
1970	11	219.8	219.9	219.5	1973	2	502.3	544.6	545.2
1970	12	220.2	228.9	228.7	1973	3	511.0	561.1	558.4
1971	1	220.0	235.0	234.1	1973	4	499.5	531.8	516.8
1971	2	219.0	237.7	236.3	1973	5	490.7	487.1	476.8
1971	3	251.2	239.8	238.5	1973	6	440.8	461.2	446.4
1971	4	259.6	240.0	238.1	1973	7	420.8	444.4	433.3
1971	5	250.1	233.9	231.8	1973	8	400.1	450.9	436.7
1971	6	259.9	231.5	231.6	1973	9	421.0	448.1	432.1
1971	7	249.8	231.4	231.6	1973	10	410.9	428.8	411.8
1971	8	259.5	239.9	244.4	1973	11	431.3	407.4	392.2
1971	9	280.0	309.7	316.6	1973	12	430.9	414.5	401.0
1971	10	369.7	341.6	340.2	1974	1	430.8	428.1	415.6
1971	11	339.8	325.5	334.3	1974	2	429.4	429.4	417.4
1971	12	329.7	277.7	286.9	1974	3	440.3	428.3	416.9
1972	1	289.8	219.9	249.2	1974	4	440.6	430.1	420.2
1972	2	259.9	205.7	245.8	1974	5	439.5	431.6	422.3
1972	3	249.9	202.7	244.4	1974	6	440.8	434.1	425.1
1972	4	240.1	207.4	250.3	1974	7	440.7	448.7	439.6
1972	5	240.0	224.7	266.8	1974	8	440.0	461.8	451.3
1972	6	239.8	241.6	282.6	1974	9	431.1	441.0	429.5
1972	7	240.1	250.1	288.9	1974	10	440.0	430.8	425.8
1972	8	250.4	304.2	340.7	1974	11	449.7	440.7	434.9
1972	9	361.9	386.1	405.7	1974	12	441.0	441.3	443.6
1972	10	419.3	419.5	435.9	1975	1	400.0	440.4	440.3
1972	11	440.2	473.1	490.4	1975	2	410.5	415.3	409.1
1972	12	470.0	530.0	539.0	1975	3	400.2	393.2	392.5
					1975	4	380.3	367.2	365.0
					1975	5	370.8	328.8	333.0
					1975	6	350.9	321.2	329.3
					1975	7	340.8	328.2	343.7
					1975	8	340.5	346.4	361.2
					1975	9	351.7	369.0	382.7
					1975	10	367.8	382.6	396.5
					1975	11	379.0	390.3	405.7
					1975	12	389.1	395.3	409.4

Table A.51 Observed vs. computed outflow concentration for Chlorides at Granbury-Whitney reservoir during 1976-81

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1976	1	387.9	400.9	411.5	1979	1	630.1	659.3	679.0
1976	2	392.9	406.7	415.8	1979	2	621.1	648.6	664.9
1976	3	395.7	407.7	415.8	1979	3	604.1	599.4	610.0
1976	4	401.2	391.8	397.6	1979	4	571.7	528.1	539.2
1976	5	399.6	350.0	355.1	1979	5	486.6	403.5	420.8
1976	6	386.8	319.3	329.5	1979	6	344.1	309.2	349.5
1976	7	385.9	301.2	316.5	1979	7	321.8	305.6	348.7
1976	8	376.3	295.5	319.0	1979	8	295.7	307.6	349.8
1976	9	369.4	309.4	337.7	1979	9	262.1	314.5	353.1
1976	10	367.3	337.0	364.3	1979	10	249.3	322.7	355.8
1976	11	377.3	381.0	405.0	1979	11	252.4	327.9	357.4
1976	12	386.9	402.7	423.2	1979	12	254.8	332.3	355.1
1977	1	390.9	401.2	419.7	1980	1	256.0	334.1	349.0
1977	2	392.6	395.5	411.1	1980	2	259.6	335.8	346.9
1977	3	390.4	333.5	348.0	1980	3	263.2	337.7	348.6
1977	4	368.8	258.9	294.0	1980	4	260.8	337.3	347.1
1977	5	316.9	251.3	313.4	1980	5	263.1	332.5	340.1
1977	6	279.6	282.3	345.4	1980	6	263.3	345.6	352.2
1977	7	267.1	303.5	365.0	1980	7	262.1	379.0	380.2
1977	8	247.2	322.4	382.6	1980	8	269.4	414.4	407.7
1977	9	240.3	340.6	394.1	1980	9	287.6	444.4	426.5
1977	10	242.3	360.7	412.3	1980	10	416.9	501.9	485.8
1977	11	250.5	375.2	420.0	1980	11	434.6	539.3	520.5
1977	12	257.9	387.7	429.2	1980	12	430.0	543.9	520.3
1978	1	260.0	398.3	436.6	1981	1	459.3	552.3	523.5
1978	2	259.4	403.2	438.9	1981	2	467.3	562.9	527.8
1978	3	263.6	407.3	440.9	1981	3	475.5	554.7	515.6
1978	4	270.0	406.1	437.5	1981	4	484.3	540.3	500.9
1978	5	279.5	404.6	432.4	1981	5	484.8	537.8	499.1
1978	6	276.2	417.1	438.3	1981	6	465.5	506.8	463.6
1978	7	280.8	436.8	454.9	1981	7	441.4	483.2	445.3
1978	8	525.5	575.3	620.7	1981	8	441.0	496.0	455.7
1978	9	770.4	662.3	698.6	1981	9	423.1	505.9	462.2
1978	10	625.2	670.6	701.7	1981	10	370.0	435.9	410.4
1978	11	601.4	669.6	696.6	1981	11	344.5	363.6	306.5
1978	12	620.7	664.4	687.4	1981	12	389.6	343.3	293.8

Table A.52 Observed vs. computed outflow concentration for Chlorides at Granbury-Whitney reservoir during 1982-86

YEAR	M	Observed Outflow Concentration (mg/l)	MC1	MC2	YEAR	M	Observed Outflow Concentration (mg/l)	MC1	MC2
			Computed Storage Concentration (mg/l)	Computed Storage Concentration (mg/l)				Computed Storage Concentration (mg/l)	Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1982	1	349.6	339.8	293.7	1985	1	389.9	434.8	397.0
1982	2	344.5	332.4	288.9	1985	2	403.7	443.2	407.1
1982	3	336.4	322.4	283.0	1985	3	411.7	445.4	409.0
1982	4	327.0	316.6	280.5	1985	4	400.9	406.4	375.2
1982	5	290.4	295.5	268.6	1985	5	426.4	385.4	364.7
1982	6	261.1	263.5	253.3	1985	6	444.8	413.5	404.3
1982	7	243.1	240.5	234.1	1985	7	470.7	437.3	432.7
1982	8	224.1	231.7	230.9	1985	8	478.4	454.8	452.3
1982	9	229.8	237.4	236.6	1985	9	508.6	468.4	468.3
1982	10	233.9	241.2	239.7	1985	10	533.8	466.0	467.9
1982	11	235.4	243.5	242.4	1985	11	544.4	464.2	468.4
1982	12	236.5	245.1	243.6	1985	12	559.3	465.0	472.9
1983	1	239.2	247.1	245.6	1986	1	554.0	466.3	479.9
1983	2	237.8	250.5	247.3	1986	2	567.0	461.8	477.9
1983	3	236.5	258.9	255.0	1986	3	569.9	455.8	476.1
1983	4	235.7	274.6	269.4	1986	4	576.2	457.4	481.5
1983	5	238.1	277.9	271.0	1986	5	574.4	441.6	468.8
1983	6	238.5	278.3	271.4	1986	6	553.5	394.9	431.8
1983	7	239.5	295.0	288.6	1986	7	551.2	378.8	435.2
1983	8	238.8	314.1	303.4	1986	8	534.6	395.2	460.5
1983	9	253.1	330.4	317.3	1986	9	465.4	392.4	455.9
1983	10	262.2	345.0	332.6					
1983	11	267.9	353.7	341.3					
1983	12	275.0	365.1	354.2					
1984	1	277.1	381.8	368.6					
1984	2	298.8	395.5	382.6					
1984	3	301.8	400.5	386.6					
1984	4	312.0	409.6	395.2					
1984	5	314.4	427.9	410.6					
1984	6	322.9	443.4	415.6					
1984	7	345.3	464.9	433.9					
1984	8	359.4	490.8	454.1					
1984	9	371.6	508.2	465.7					
1984	10	381.7	494.9	450.2					
1984	11	384.7	473.9	431.8					
1984	12	376.3	451.5	410.7					

Table A.53 Observed vs. computed outflow concentration for Sulfates at Granbury-Whitney reservoir during 1970-75

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1970	10	119.9	119.8	119.7	1973	1	301.0	301.1	299.8
1970	11	119.7	124.0	123.8	1973	2	310.5	299.3	298.0
1970	12	119.6	128.2	127.9	1973	3	320.6	304.8	304.7
1971	1	130.0	131.0	130.5	1973	4	310.8	279.1	281.8
1971	2	132.4	132.0	131.6	1973	5	300.2	245.7	258.3
1971	3	131.6	133.2	132.7	1973	6	260.4	225.4	241.9
1971	4	139.7	133.2	132.4	1973	7	230.4	212.8	234.4
1971	5	130.0	129.8	128.8	1973	8	210.4	216.1	236.6
1971	6	140.0	128.6	128.3	1973	9	230.4	213.5	233.8
1971	7	140.0	128.1	128.0	1973	10	189.8	204.3	222.8
1971	8	128.8	132.1	134.0	1973	11	210.3	194.5	212.0
1971	9	140.0	169.4	172.0	1973	12	220.2	198.3	216.1
1971	10	180.1	188.0	183.7	1974	1	220.2	205.4	223.2
1971	11	169.9	182.4	178.9	1974	2	220.4	206.0	223.8
1971	12	169.9	159.8	153.8	1974	3	220.1	205.0	223.3
1972	1	150.0	130.4	132.1	1974	4	219.3	205.5	224.8
1972	2	140.0	123.7	129.5	1974	5	220.1	206.0	225.7
1972	3	139.9	122.1	128.5	1974	6	220.4	207.0	227.1
1972	4	140.0	124.4	131.7	1974	7	220.3	213.8	234.3
1972	5	139.9	133.3	140.8	1974	8	220.9	220.4	239.6
1972	6	129.9	142.3	149.4	1974	9	221.0	210.6	227.4
1972	7	139.8	147.2	152.7	1974	10	220.0	211.3	227.2
1972	8	150.0	176.2	182.1	1974	11	219.7	227.7	234.9
1972	9	206.8	220.0	220.4	1974	12	220.5	236.0	239.8
1972	10	230.3	237.7	237.7	1975	1	200.5	237.3	238.2
1972	11	259.8	265.9	268.0	1975	2	210.2	227.5	222.4
1972	12	280.7	295.2	295.1	1975	3	200.5	219.4	213.6
					1975	4	200.4	207.1	199.0
					1975	5	189.8	187.3	181.1
					1975	6	180.2	186.5	179.8
					1975	7	179.5	193.5	187.7
					1975	8	180.3	204.4	197.4
					1975	9	180.2	217.2	209.2
					1975	10	180.5	225.1	216.5
					1975	11	187.8	229.9	221.2
					1975	12	189.9	233.8	222.9

Table A.54 Observed vs. computed outflow concentration
for Sulfates at Granbury-Whitney reservoir during 1976-81

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1976	1	190.5	238.7	223.4	1979	1	310.8	318.4	310.5
1976	2	189.6	244.3	224.9	1979	2	309.9	312.6	304.4
1976	3	189.9	247.6	224.4	1979	3	302.1	288.3	279.7
1976	4	190.9	239.4	214.4	1979	4	285.8	253.8	247.7
1976	5	190.9	215.3	191.7	1979	5	243.3	192.1	194.3
1976	6	190.0	198.5	177.6	1979	6	174.2	144.8	162.6
1976	7	190.5	189.8	170.1	1979	7	160.2	142.4	163.1
1976	8	182.0	188.3	170.2	1979	8	147.3	142.8	163.8
1976	9	180.0	196.1	178.6	1979	9	133.2	145.7	165.8
1976	10	180.2	207.4	190.7	1979	10	121.5	149.5	167.6
1976	11	183.9	225.7	208.9	1979	11	123.5	151.9	168.6
1976	12	189.6	235.0	216.4	1979	12	124.5	153.6	167.6
1977	1	190.1	235.0	214.1	1980	1	125.4	154.1	164.9
1977	2	190.2	232.1	209.4	1980	2	126.8	154.9	164.1
1977	3	189.7	199.6	177.8	1980	3	128.6	156.2	165.1
1977	4	180.2	163.9	149.8	1980	4	127.3	156.1	164.6
1977	5	161.1	162.8	157.9	1980	5	128.5	154.6	161.7
1977	6	143.1	178.8	173.5	1980	6	129.3	161.8	168.3
1977	7	138.0	191.1	182.9	1980	7	128.1	178.5	182.5
1977	8	130.1	203.0	191.4	1980	8	131.7	195.7	196.3
1977	9	130.3	214.6	197.0	1980	9	141.3	210.5	206.0
1977	10	120.0	225.8	205.4	1980	10	206.3	240.8	236.7
1977	11	119.8	232.6	208.2	1980	11	214.8	260.7	254.9
1977	12	124.7	238.0	211.7	1980	12	213.4	263.1	255.1
1978	1	130.0	242.8	214.7	1981	1	227.2	267.3	256.9
1978	2	129.1	244.5	215.4	1981	2	232.9	272.3	259.2
1978	3	130.7	246.2	216.1	1981	3	235.8	268.3	253.4
1978	4	130.1	245.6	214.7	1981	4	240.2	261.3	246.2
1978	5	130.3	244.7	212.4	1981	5	241.5	260.2	245.5
1978	6	130.1	253.0	215.1	1981	6	231.2	245.1	228.6
1978	7	133.9	265.5	222.9	1981	7	219.4	233.4	219.3
1978	8	292.6	302.6	289.2	1981	8	219.2	239.4	224.4
1978	9	480.3	323.0	317.3	1981	9	210.1	244.0	227.7
1978	10	309.6	324.9	319.3	1981	10	186.8	209.4	202.8
1978	11	299.8	324.3	317.9	1981	11	173.1	172.7	152.0
1978	12	311.1	321.4	314.1	1981	12	197.3	161.3	145.3

Table A.55 Observed vs. computed outflow concentration for Sulfates at Granbury-Whitney reservoir during 1982-86

YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)	YEAR	M	Observed Outflow Concentration (mg/l)	MC1 Computed Storage Concentration (mg/l)	MC2 Computed Storage Concentration (mg/l)
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
1982	1	176.6	158.9	145.3	1985	1	199.2	202.8	196.9
1982	2	172.8	154.7	142.8	1985	2	205.3	207.0	201.9
1982	3	169.4	149.3	139.8	1985	3	209.3	208.6	203.1
1982	4	163.8	146.1	138.4	1985	4	203.9	208.8	203.8
1982	5	145.0	135.8	132.7	1985	5	216.7	215.7	211.8
1982	6	129.7	120.6	124.9	1985	6	225.1	229.4	226.3
1982	7	120.5	108.5	115.4	1985	7	238.5	241.0	238.0
1982	8	110.8	102.5	113.4	1985	8	242.2	250.3	246.9
1982	9	113.7	104.7	116.3	1985	9	256.3	257.8	254.1
1982	10	115.6	106.0	117.8	1985	10	269.4	256.3	253.0
1982	11	116.2	106.9	119.2	1985	11	275.4	254.7	252.2
1982	12	117.1	107.7	119.8	1985	12	281.5	255.2	253.8
1983	1	118.4	108.2	120.8	1986	1	279.1	256.5	257.0
1983	2	117.7	109.4	121.7	1986	2	285.7	254.5	255.4
1983	3	117.0	113.7	125.6	1986	3	287.7	251.6	254.0
1983	4	116.5	121.8	133.0	1986	4	289.4	252.9	256.4
1983	5	118.0	124.1	133.9	1986	5	289.2	245.0	249.5
1983	6	118.1	125.0	134.1	1986	6	279.4	219.3	228.1
1983	7	118.5	133.4	142.8	1986	7	277.5	209.4	226.7
1983	8	118.8	142.7	150.3	1986	8	269.8	217.9	238.9
1983	9	125.9	150.8	157.3	1986	9	237.1	215.4	235.3
1983	10	135.9	158.5	165.1					
1983	11	139.1	163.3	169.6					
1983	12	142.5	169.6	176.2					
1984	1	143.7	178.7	183.5					
1984	2	153.9	185.6	190.1					
1984	3	155.2	187.9	191.8					
1984	4	160.9	191.8	195.7					
1984	5	162.1	199.6	203.1					
1984	6	166.2	206.3	205.5					
1984	7	176.6	215.9	214.2					
1984	8	184.2	227.2	224.0					
1984	9	189.9	234.8	229.6					
1984	10	194.7	228.8	222.1					
1984	11	195.9	219.4	213.2					
1984	12	191.7	209.6	203.2					

APPENDIX B

Table B.1 Full & simple TDS concentration at Possum Kingdom reservoir

Input data	Full4	Simple4	Full5	Simiple5
Mean	2444	2522	2398	2108
Standard Deviation	564	740	551	526
100%	1007.3	1091.7	1006	1115.1
99%	1236.2	1304.2	1233.3	1236.6
98%	1428.4	1354	1407.9	1251.8
95%	1643.2	1469.7	1609.1	1348.1
90%	1808	1848	1782	1574
75%	2048	2113	2008	1818
60%	2235	2269	2191	1955
50%	2378	2352	2346	2031
40%	2523	2509	2482	2093
25%	2744	2729	2711	2216
10%	3359	3648	3297	2843
Maximum	4105	5458	4030	3840

Table B.2 Full & simple TDS concentration at Whitney reservoir

Input data	Full4	Simple4	Full5	Simiple5
Mean	1570	1570	1537	1469
Standard Deviation	456	438	423	404
100%	978.9	1016.9	985.6	982.5
99%	1049.7	1076.5	1036.2	1027.1
98%	1061	1087	1049.6	1048.1
95%	1110.5	1120.6	1092	1072.6
90%	1156	1145	1133	1099
75%	1288	1264	1266	1188
60%	1375	1360	1360	1276
50%	1418	1425	1398	1354
40%	1490	1541	1465	1440
25%	1731	1751	1710	1574
10%	2371	2244	2312	2014
Maximum	3121	3052	2850	2939

Table B.3 Frequency table for salt constituents at Whitney reservoir

Salt Constituent	Lag option	Concentration frequency (%) constrained by a specific concentration						
		100 mg/l	200 mg/l	250 mg/l	500 mg/l	750 mg/l	1000 mg/l	2000 mg/l
TDS	LAG0	100	100	100	100	100	99.86	12.23
	LAG1	100	100	100	98.42	91.65	67.63	13.96
	LAG2	98.85	98.56	98.42	95.25	85.9	59.57	18.99
CL	LAG0	100	100	100	62.01	11.94	4.17	0
	LAG1	100	98.71	97.41	46.33	16.12	0.72	0
	LAG2	98.42	93.81	87.91	37.99	16.55	5.47	0
SO4	LAG0	100	98.99	75.11	4.89	0	0	0
	LAG1	98.71	78.42	51.08	3.6	0	0	0
	LAG2	94.96	66.19	43.74	10.22	3.31	0	0

Table B.4 Reliability table for chlorides and sulfates at Possum Kingdom reservoir

Lag option	Constraint (mg/l)	CL		SO4	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	100	100	100	100
LAG0	1000	62.15	62.5	100	100
	750	14.92	14.8	99.87	99.86
	500	1.29	1.15	66.39	66.52
	250	0	0	0.89	0.72
LAG1	1000	55.35	53.45	100	100
	750	24.5	23.13	92.66	91.95
	500	4.78	4.17	53.79	52.16
	250	1.7	1.29	4.58	4.02
LAG2	1000	68.06	67.96	100	100
	750	28.36	27.59	91.16	90.8
	500	2.65	2.59	64.12	63.94
	250	0.36	0.29	2.01	2.01

Table B.5 Reliability table for TDS at Whitney reservoir

Lag option	Concentration (mg/l)	TDS reliability	
		Volume (%)	Period (%)
-	Quantity	99.2	98.85
LAG0	1000	0.29	0.14
	750	0	0
	500	0	0
	250	0	0
LAG1	1000	33.99	32.33
	750	9.08	8.33
	500	1.58	1.58
	250	0	0
LAG2	1000	42.31	40.37
	750	15.17	14.08
	500	6.34	4.74
	250	2.36	1.58

Table B.6 Reliability table for chlorides and sulfates at Whitney reservoir

Lag option	Constraint (mg/l)	CL		SO4	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	99.2	98.85	99.2	98.85
LAG0	1000	96.11	95.69	100	100
	750	88.17	87.93	100	100
	500	39.44	37.93	94.99	94.97
	250	0	0	26.21	24.86
LAG1	1000	99.33	99.28	100	100
	750	85.14	83.91	100	100
	500	54.82	53.59	96.46	96.41
	250	2.74	2.59	51.09	48.85
LAG2	1000	94.82	94.54	100	100
	750	84.57	83.48	100	100
	500	62.93	61.93	89.76	89.8
	250	13.14	12.07	57.86	56.18

Table B.7 Frequency table with Dam at Whitney reservoir

Salt Constituent	TDS (mg/l)			CL (mg/l)			SO4 (mg/l)		
Lag option	1106	1002	1010	433	388	354	222	247	265
Mean	291	340	495	95	98	165	65	78	134
Standard Deviation	749.3	389.2	300	294.9	190.6	70	137.5	108.2	42.9
100%	770.7	521.4	364.2	318	219.8	91.3	140	140.2	62.5
99%	780.3	539	383.6	321.7	246.8	130.1	143.4	146	83.8
98%	815.4	596.7	436.7	334.6	260.3	184.7	148.6	161	127.3
95%	841	640	572	347	279	206	159	170	158
90%	927	738	655	376	311	248	182	191	189
75%	980	825	764	395	343	281	193	208	207
60%	1009	923	841	405	375	307	202	229	229
50%	1052	1032	972	418	396	349	215	247	250
40%	1203	1248	1236	450	448	404	244	294	292
25%	1604	1453	1821	611	534	637	326	339	471
10%	2089	2601	2921	732	737	963	446	751	932
Maximum	1106	1002	1010	433	388	354	222	247	265

Table B.8 Frequency table with salt control dam at Possum Kingdom reservoir

Salt Constituent	Lag option	Frequency (%) constrained by a specific concentration (mg/l)						
		100	200	250	500	750	1000	2000
TDS	LAG0	100	100	100	100	100	98.41	13.6
	LAG1	99.71	99.57	99.28	98.41	97.11	93.78	32.85
	LAG2	99.86	99.86	99.86	99.28	98.55	94.07	22.14
CL	LAG0	100	100	100	79.88	12.45	0	0
	LAG1	99.13	97.83	97.11	68.74	20.98	1.3	0
	LAG2	99.71	98.99	98.55	54.56	13.6	2.46	0
SO4	LAG0	100	99.13	96.24	6.37	0	0	0
	LAG1	98.55	95.95	90.59	22.72	0.14	0	0
	LAG2	99.57	98.41	89.87	17.8	0.58	0	0

Table B.9 Frequency table with salt control dam at Whitney reservoir

Salt Constituent	Lag option	Frequency (%) constrained by a specific concentration (mg/l)						
		100	200	250	500	750	1000	2000
TDS	LAG0	100	100	100	100	100	54.1	1.15
	LAG1	100	99.86	99.57	95.4	63.88	34.96	0.29
	LAG2	98.71	97.99	97.55	87.19	49.64	30.22	4.75
CL	LAG0	100	100	100	16.26	0	0	0
	LAG1	99.42	97.12	90.22	12.37	0	0	0
	LAG2	96.12	81.73	58.99	10.79	1.73	0	0
SO4	LAG0	100	51.22	22.3	0	0	0	0
	LAG1	98.13	58.27	32.81	0.29	0	0	0
	LAG2	91.94	51.37	32.95	6.47	0	0	0

Table B.10 Reliability table for TDS at Whitney reservoir

Lag option	Constraint (mg/l)	TDS reliability without Dam		TDS reliability with Dam	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	99.2	98.85	99.2	98.85
LAG0	1000	0.29	0.14	48.39	45.83
	750	0	0	0	0
	500	0	0	0	0
	250	0	0	0	0
LAG1	1000	33.99	32.33	66.18	64.94
	750	9.08	8.33	37.61	36.06
	500	1.58	1.58	4.99	4.6
	250	0	0	0.47	0.43
LAG2	1000	42.31	40.37	71.4	69.68
	750	15.17	14.08	52.2	50.29
	500	6.34	4.74	14.03	12.79
	250	2.36	1.58	3.37	2.44

Table B.11 Reliability table for chlorides at Whitney reservoir

Lag option	Constraint (mg/l)	CL reliability without Dam		CL reliability with Dam	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	99.2	98.85	99.2	98.85
LAG0	1000	96.11	95.69	100	100
	750	88.17	87.93	100	100
	500	39.44	37.93	84.17	83.62
	250	0	0	0	0
LAG1	1000	99.33	99.28	100	100
	750	85.14	83.91	100	100
	500	54.82	53.59	88.43	87.64
	250	2.74	2.59	10.44	9.77
LAG2	1000	94.82	94.54	100	100
	750	84.57	83.48	98.37	98.28
	500	62.93	61.93	89.23	89.22
	250	13.14	12.07	43.32	40.95

Table B.12 Reliability table for sulfates at Whitney reservoir

Lag option	Constraint (mg/l)	SO4 without Dam		SO4 reliability with Dam	
		Volume (%)	Period (%)	Volume (%)	Period (%)
-	Quantity	99.2	98.85	99.2	98.85
LAG0	1000	100	100	100	100
	750	100	100	100	100
	500	94.99	94.97	100	100
	250	26.21	24.86	77.58	77.59
LAG1	1000	100	100	100	100
	750	100	100	100	100
	500	96.46	96.41	99.56	99.71
	250	51.09	48.85	68.23	67.1
LAG2	1000	100	100	100	100
	750	100	100	100	100
	500	89.76	89.8	93.6	93.53
	250	57.86	56.18	68.86	66.95

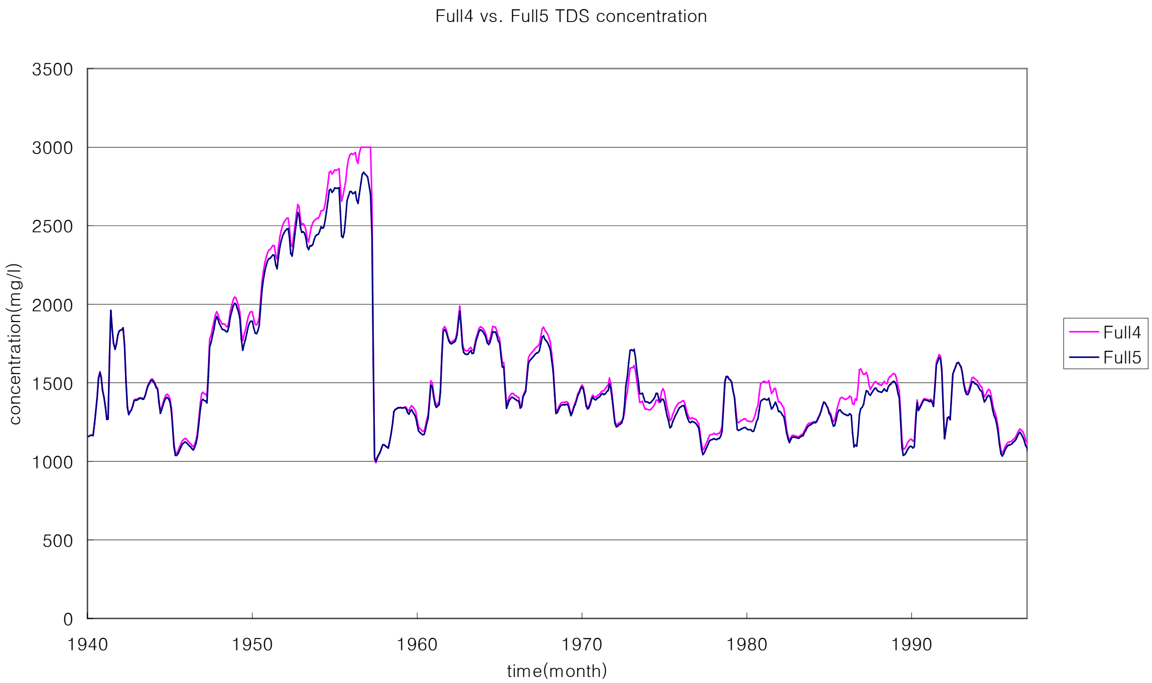

Figure B.1 Full4 and full5 TDS concentration at Whitney reservoir

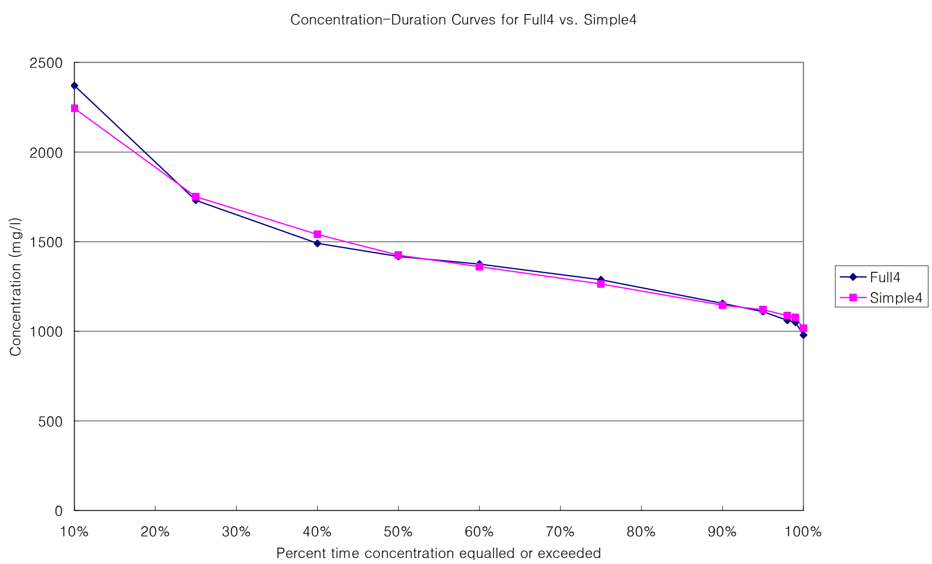

Figure B.2 Concentration-Duration curves for full 4 and simple 4 at Whitney reservoir

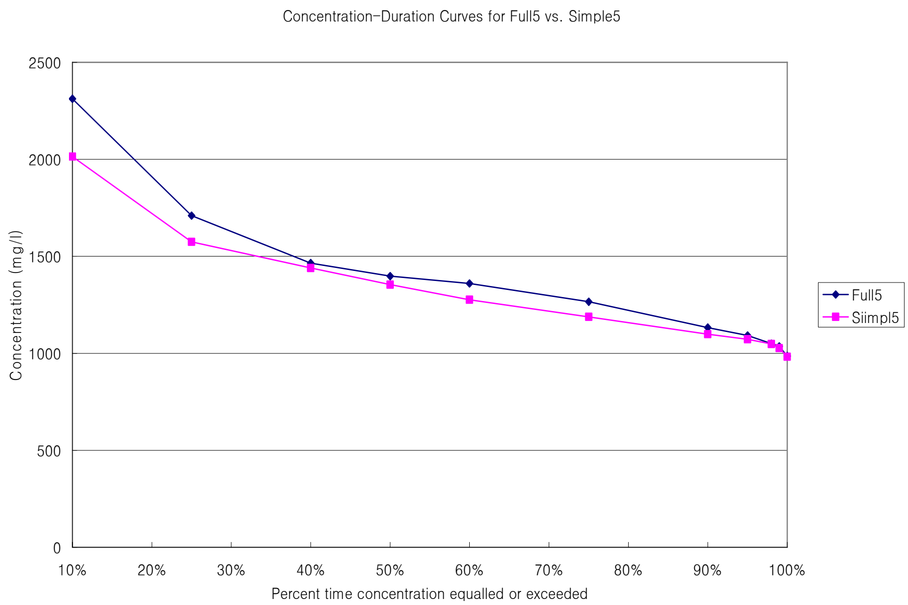

Figure B.3 Concentration-Duration curves for full 5 and simple 5 at Whitney reservoir

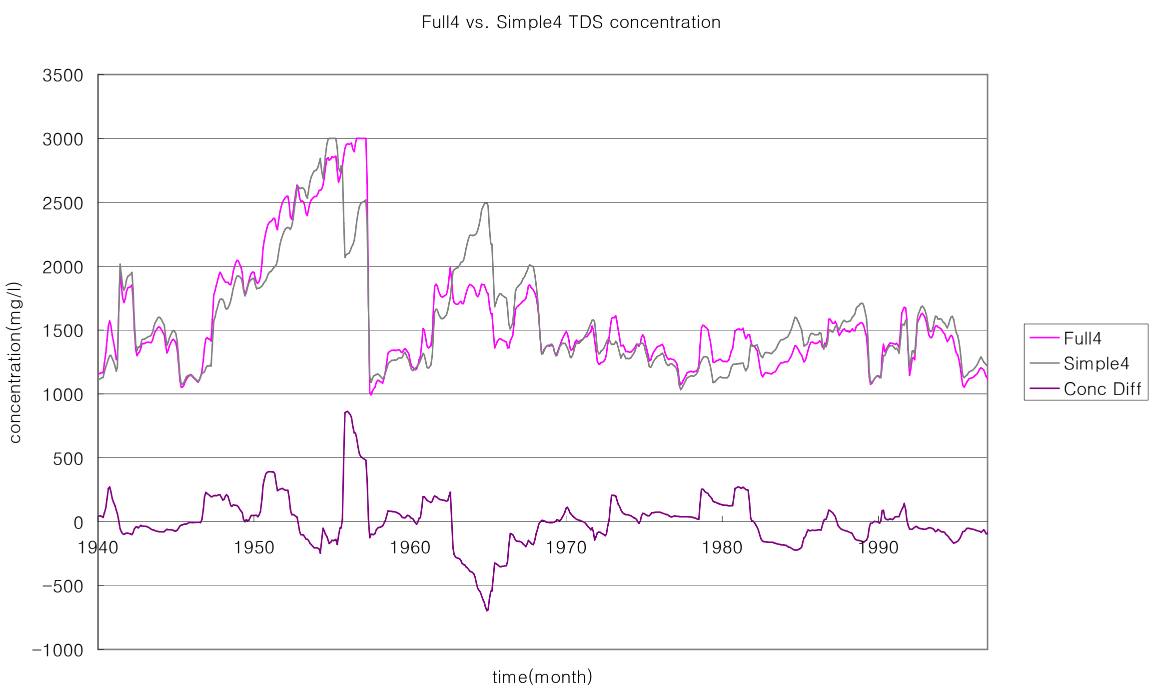

Figure B.4 Full4 & simple4 at Whitney reservoir

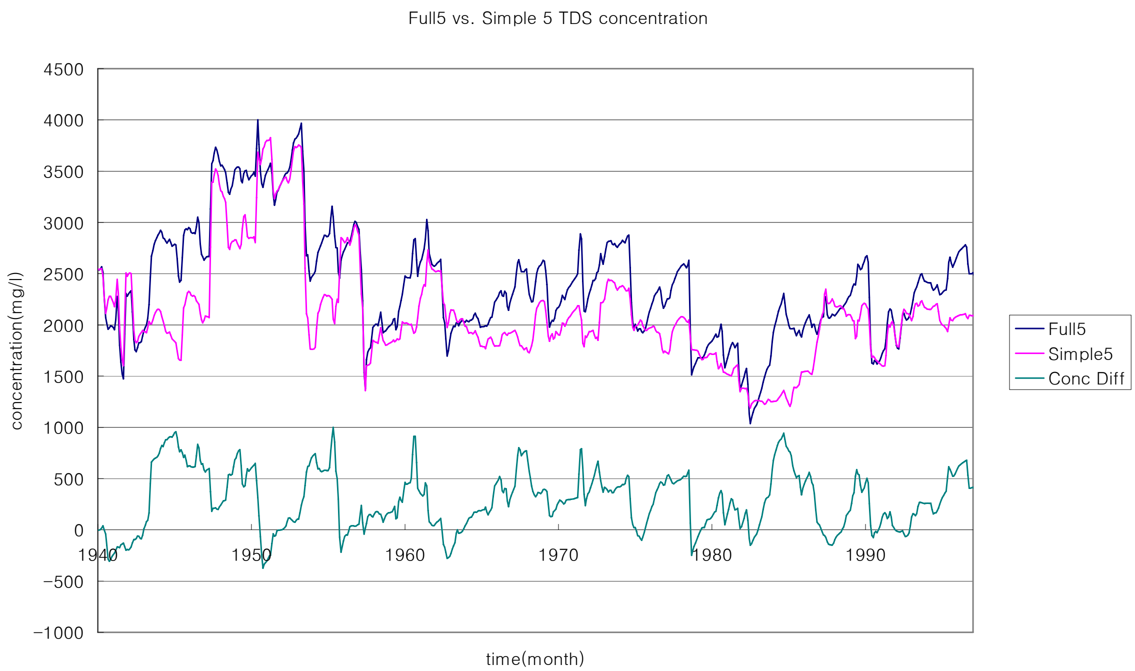

Figure B.5 Full5 & simple5 at Possum Kingdom reservoir

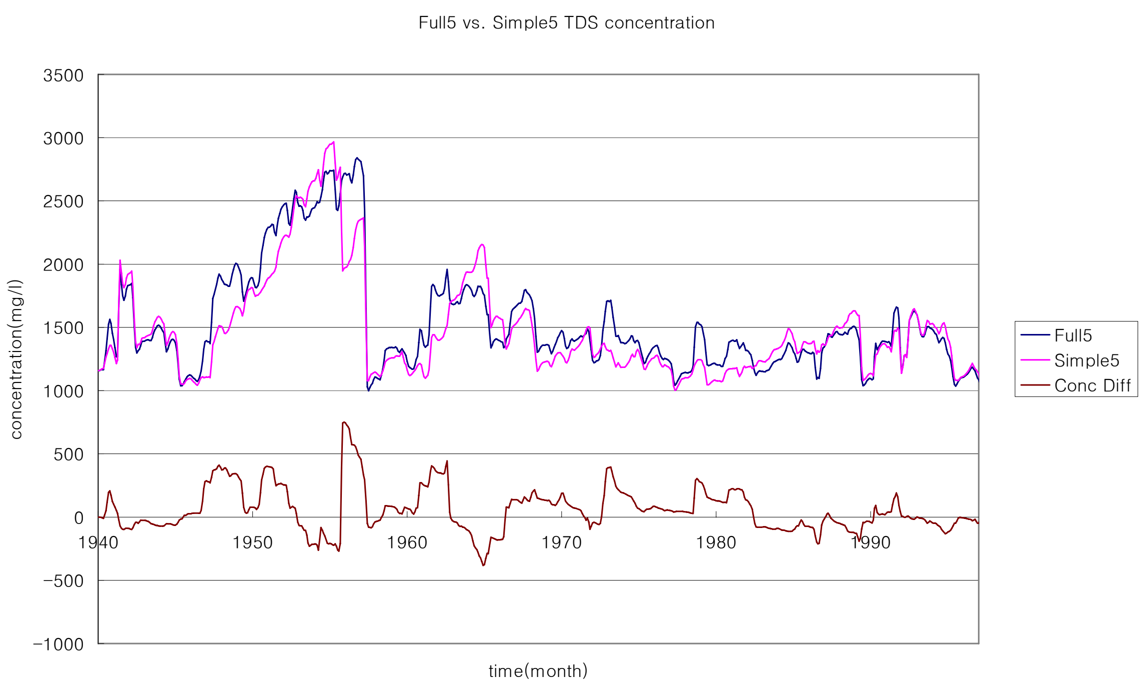

Figure B.6 Full5 & simple5 at Whitney reservoir

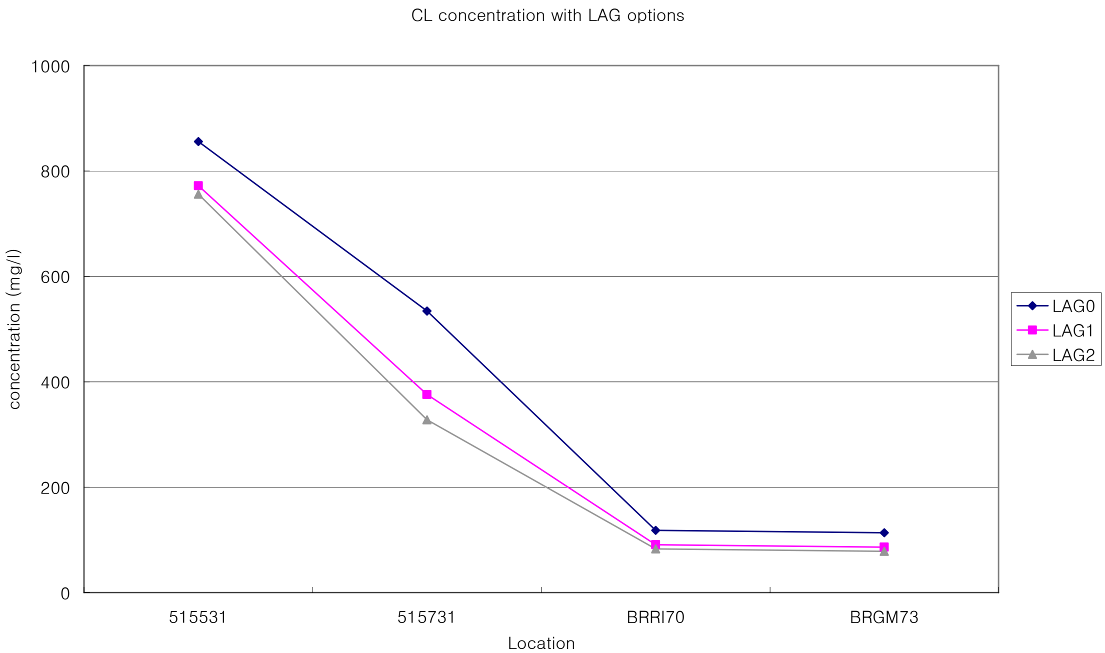

Figure B.7 Chloride concentration with/without LAG options at each control point

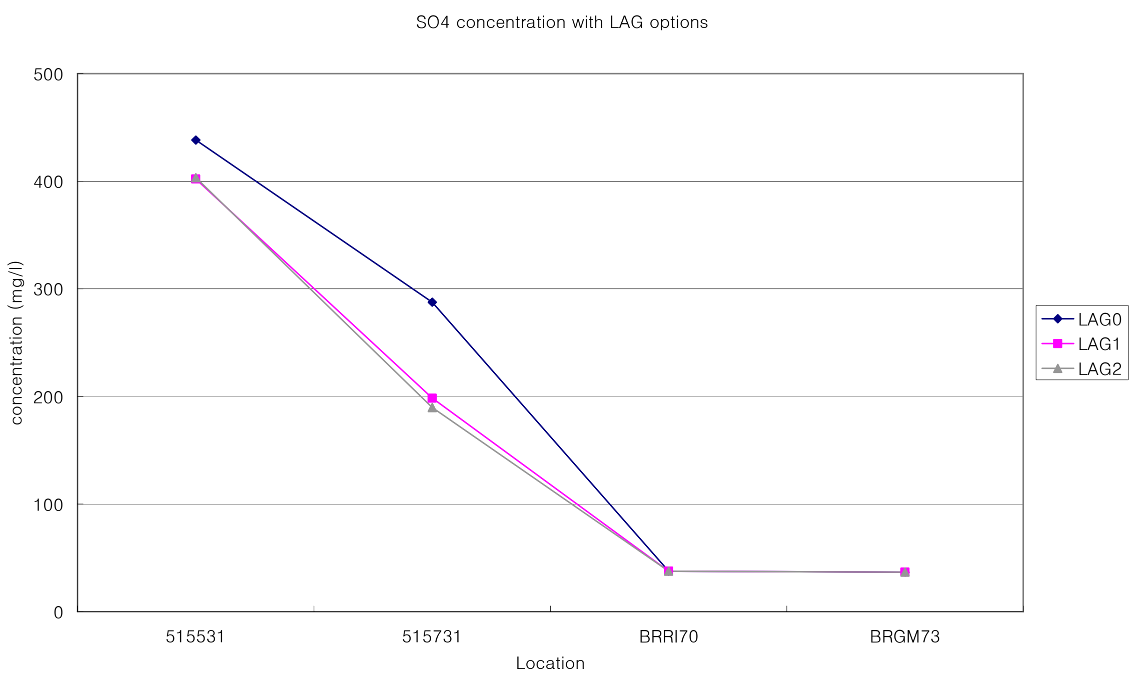

Figure B.8 Sulfate concentration with/without LAG options at each control point

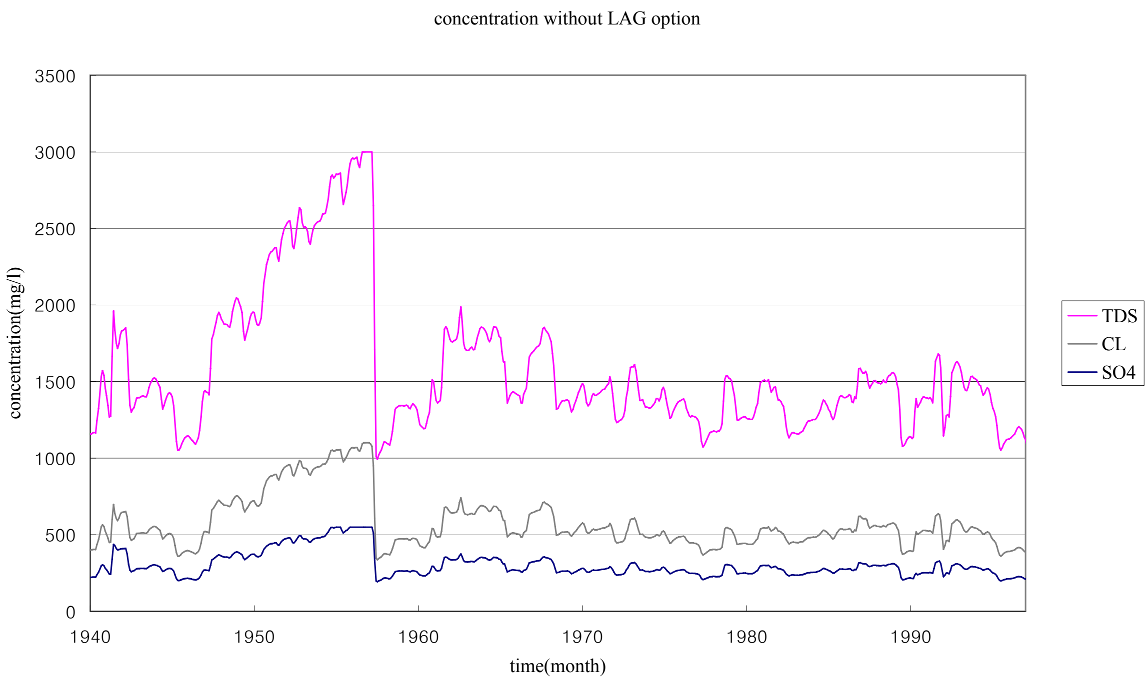

Figure B.9 TDS concentration without LAG at Whitney reservoir

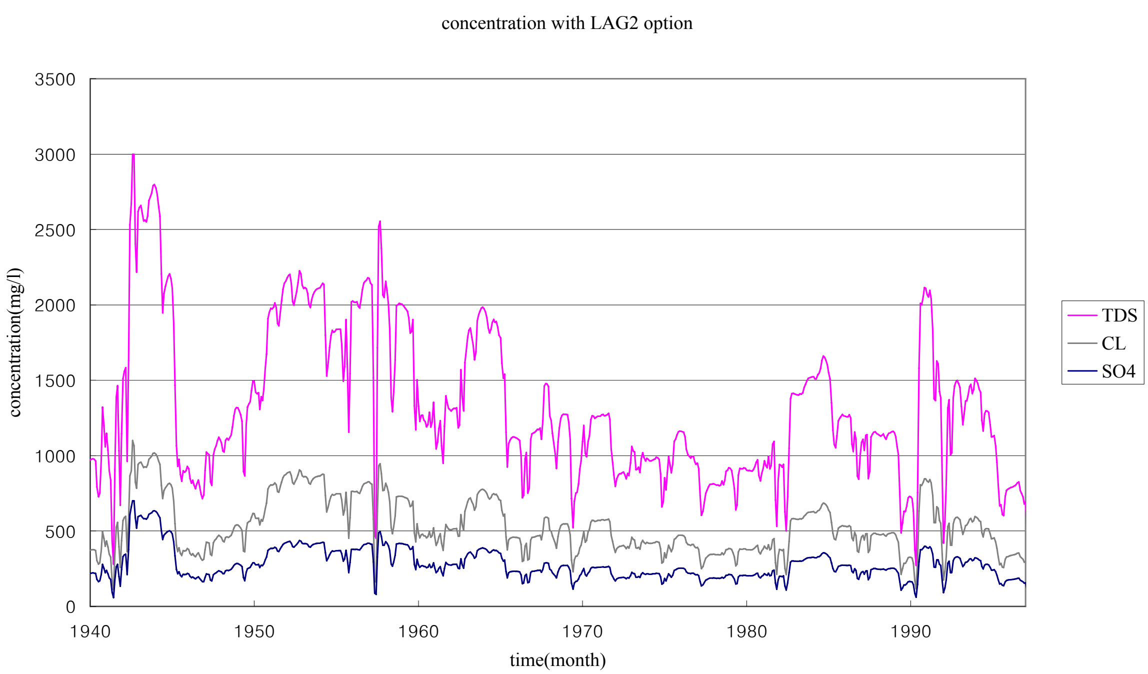

Figure B.10 TDS concentration with LAG1 at Whitney reservoir

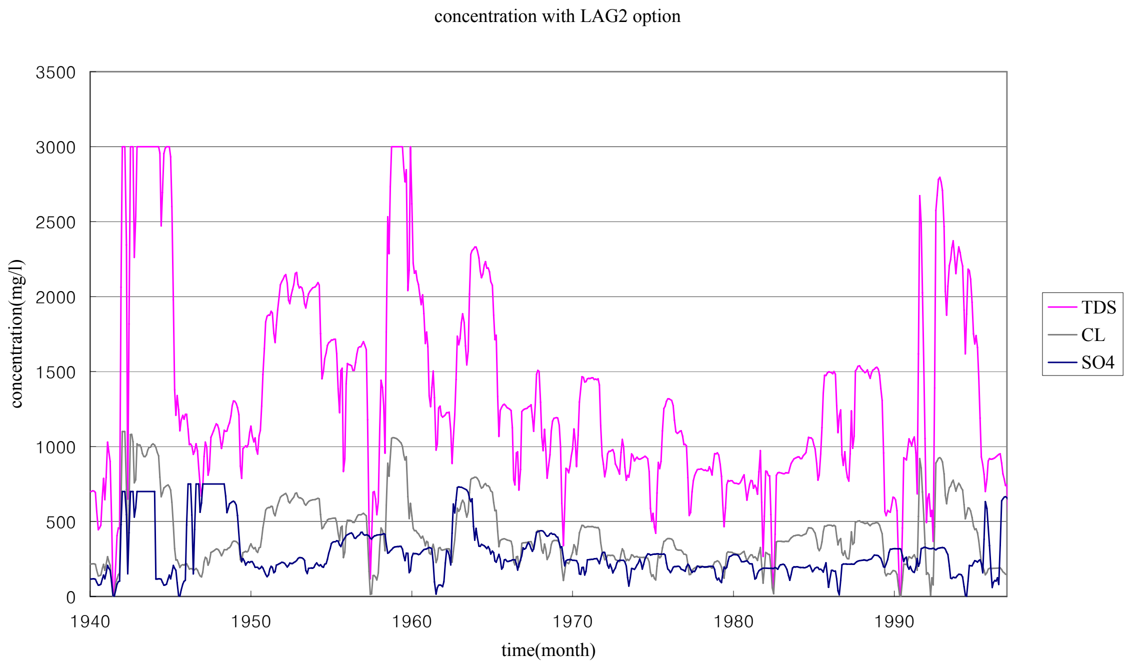

Figure B.11 TDS concentration with LAG2 at Whitney reservoir

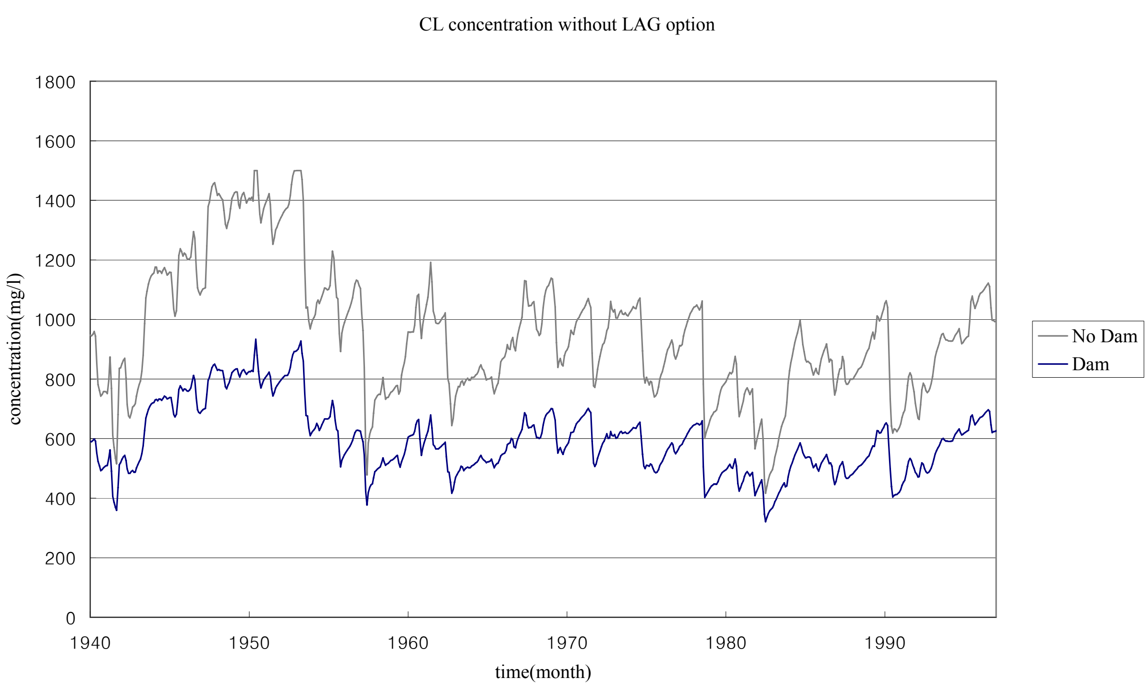

Figure B.12 Chloride concentration without LAG option at Possum Kingdom reservoir

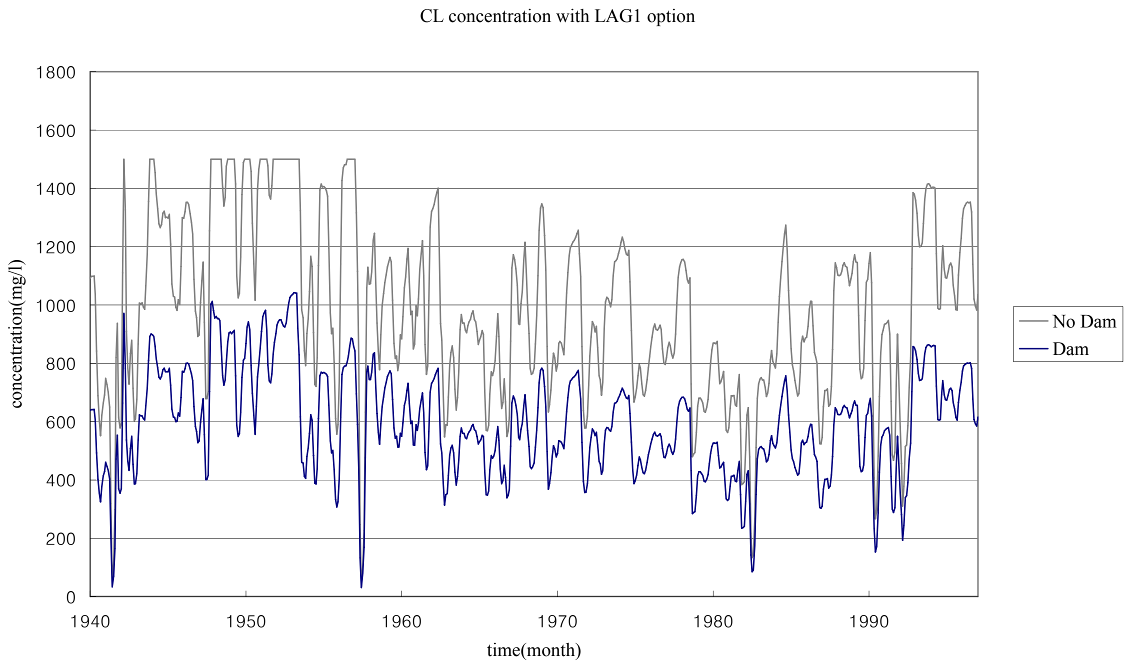

Figure B.13 Chloride concentration with LAG1 option at Possum Kingdom reservoir

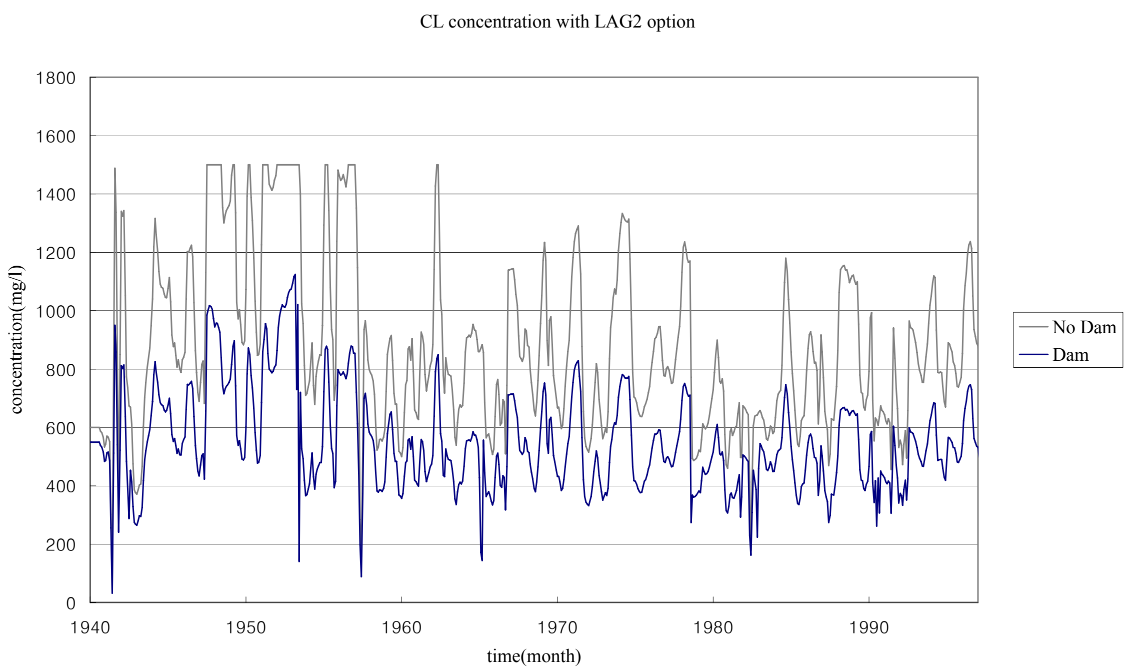

Figure B.14 Chloride concentration with LAG2 option at Possum Kingdom reservoir

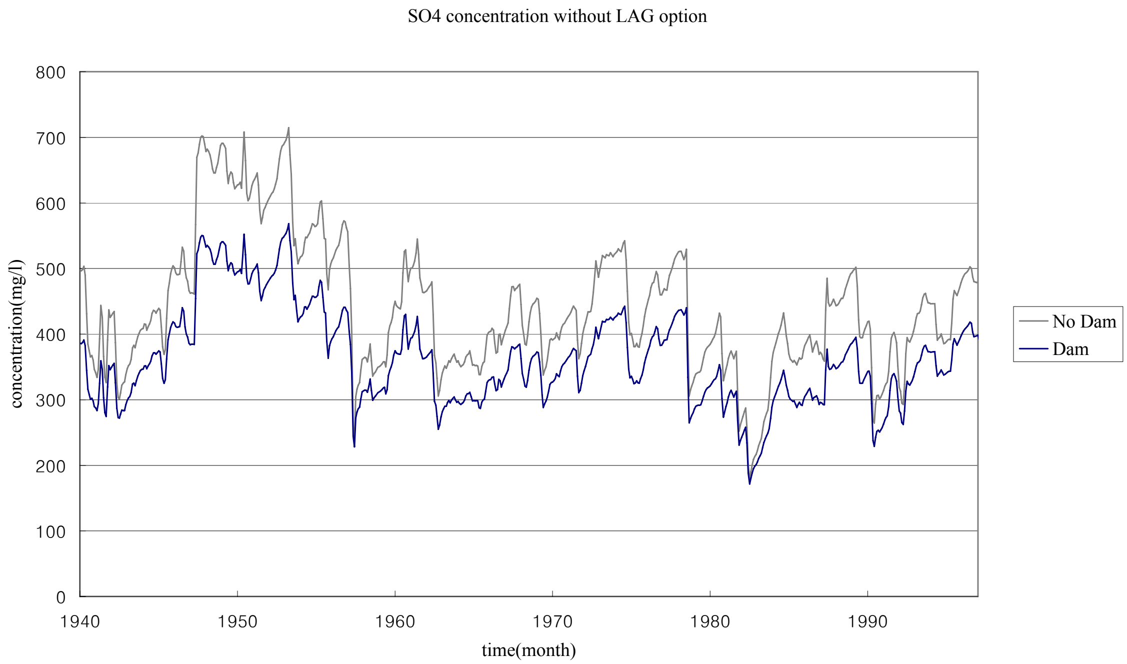

Figure B.15 Sulfate concentration without LAG option at Possum Kingdom reservoir

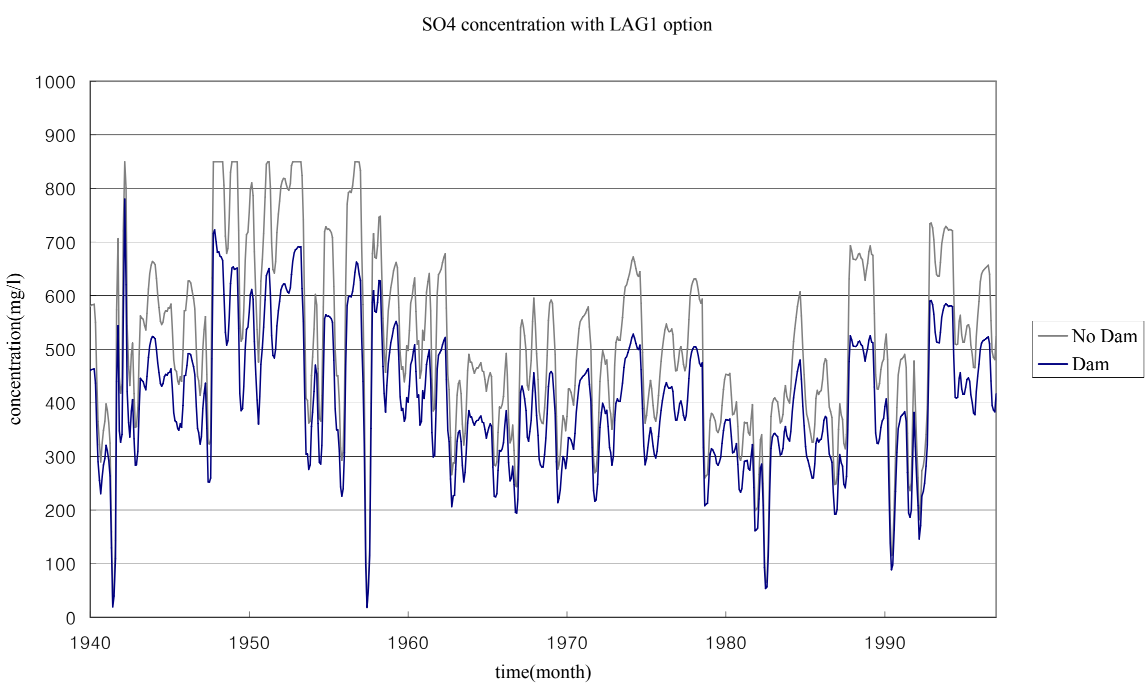

Figure B.16 Sulfate concentration with LAG1 option at Possum Kingdom reservoir

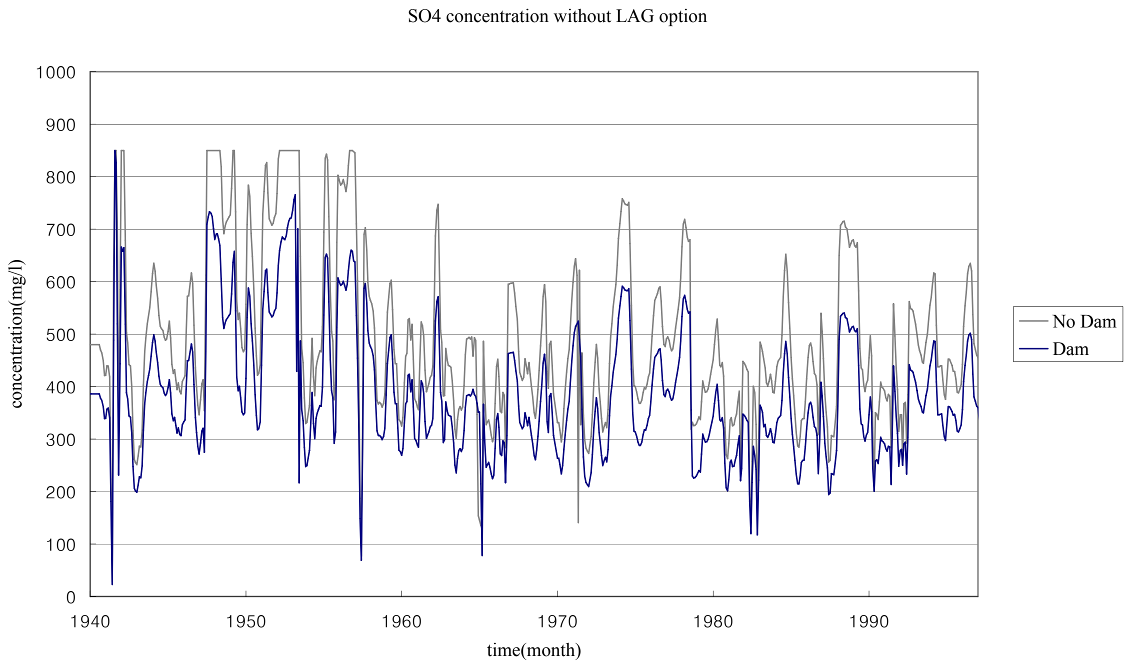

Figure B.17 Sulfate concentration with LAG2 option at Possum Kingdom reservoir

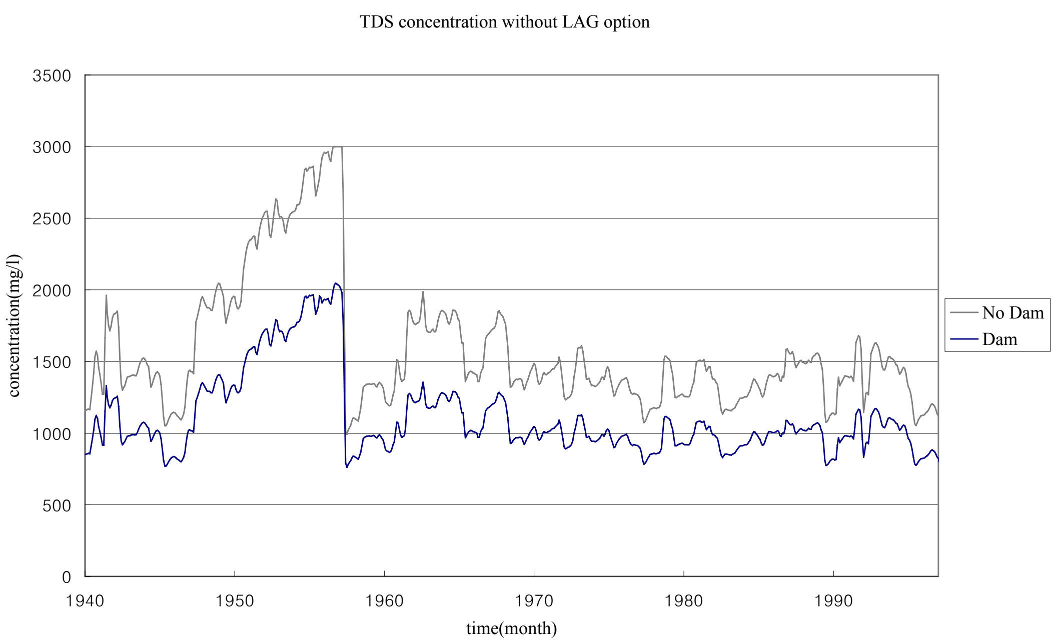

Figure B.18 TDS concentration without LAG option at Whitney reservoir

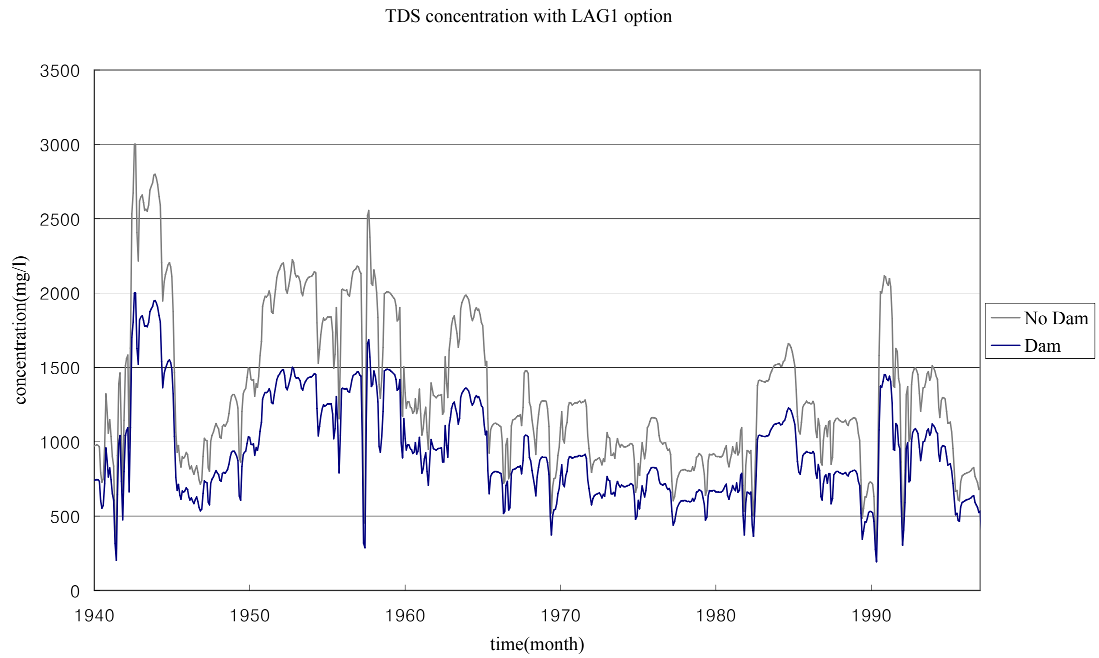

Figure B.19 TDS concentration with LAG1 option at Whitney reservoir

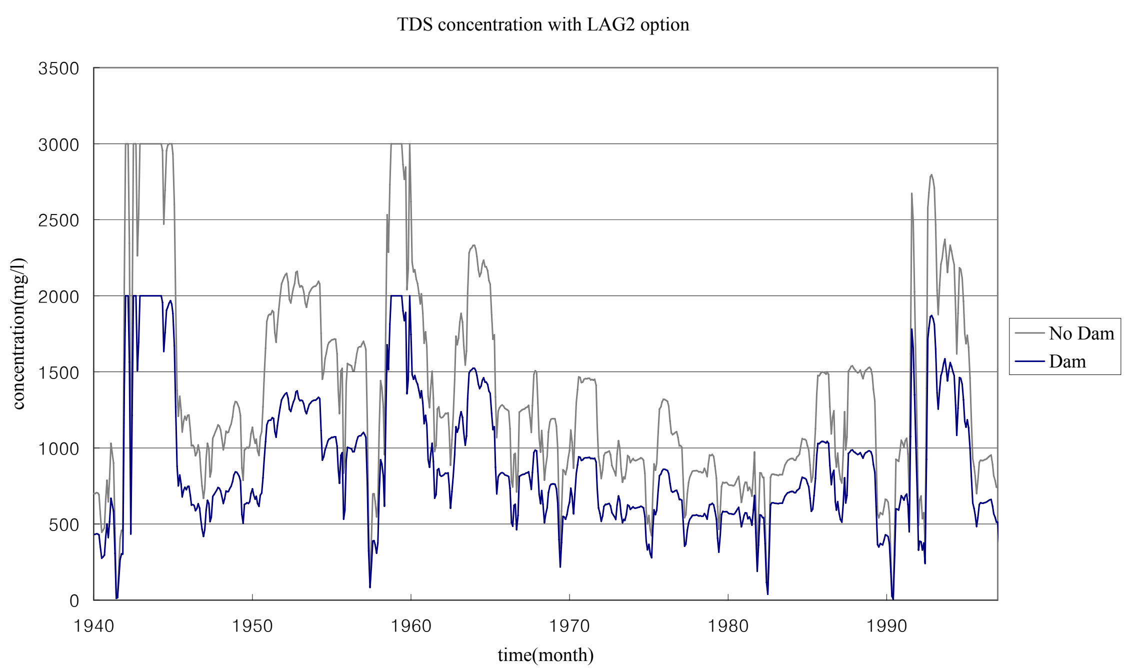

Figure B.20 TDS concentration with LAG2 option at Whitney reservoir

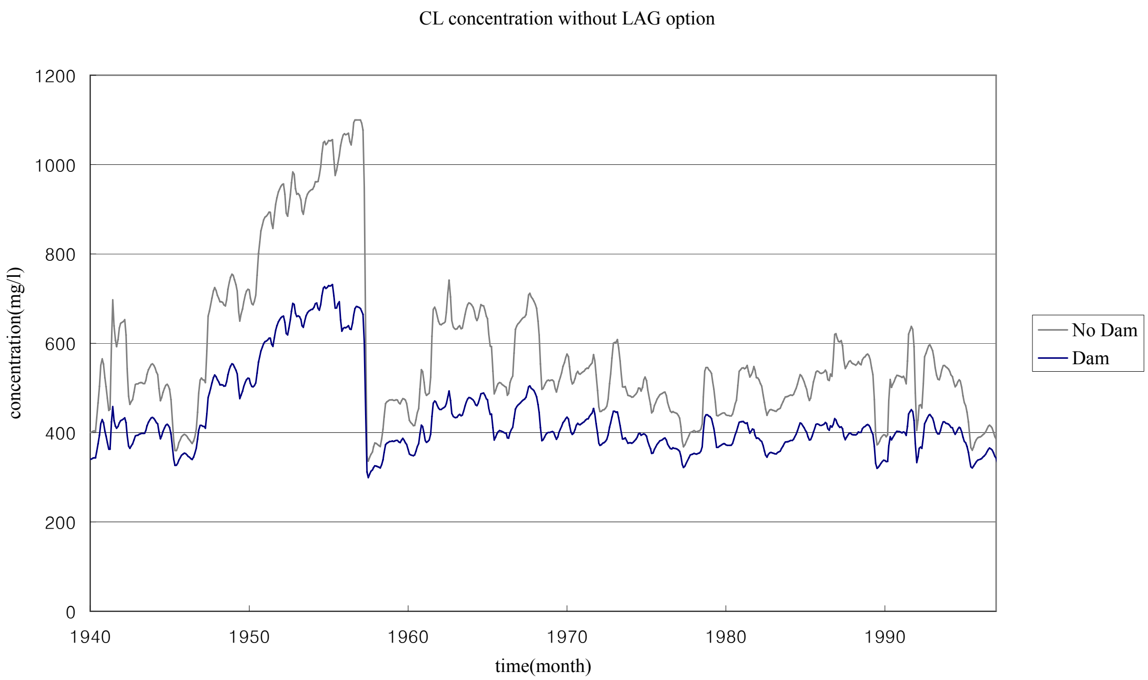

Figure B.21 Chloride concentration without LAG option at Whitney reservoir

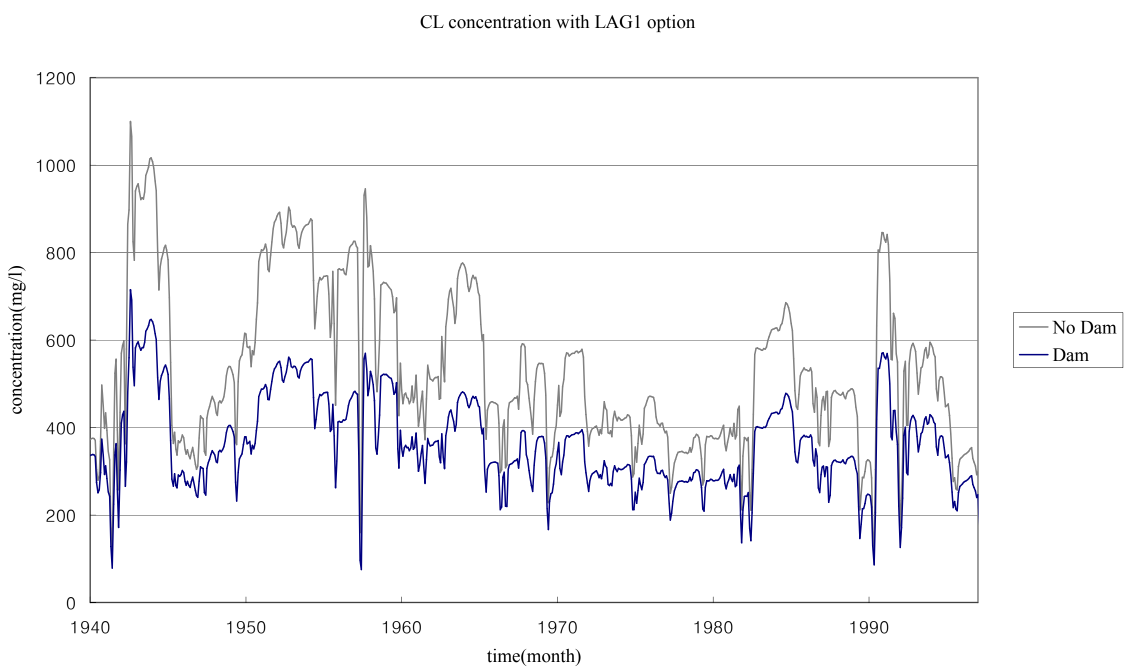

Figure B.22 Chloride concentration with LAG1 option at Whitney reservoir

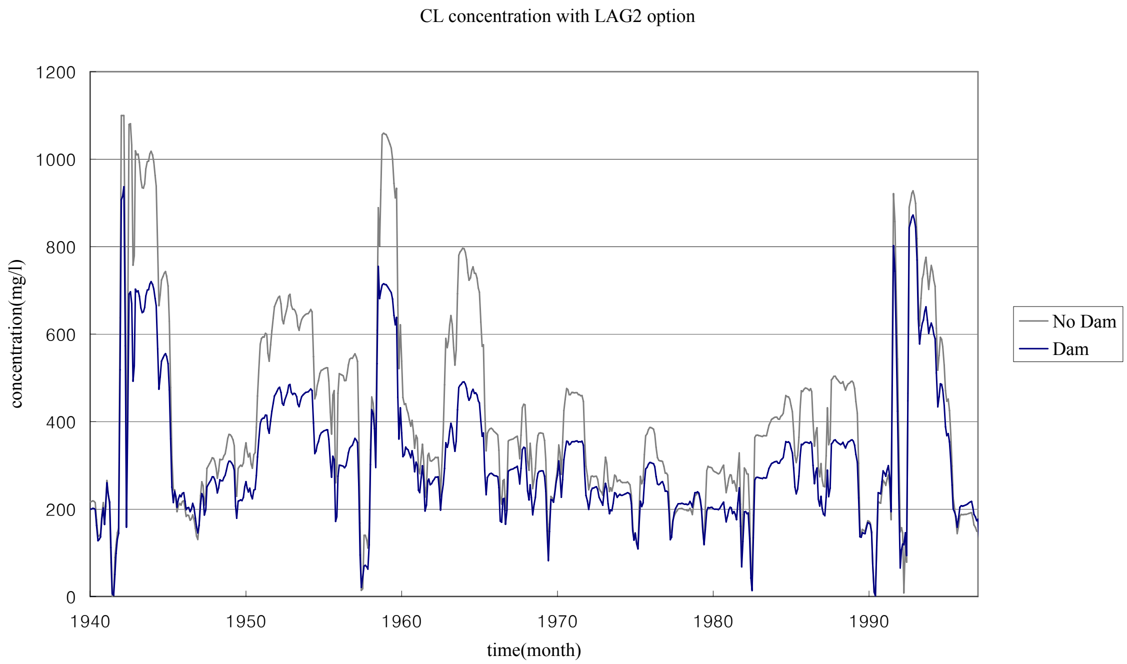

Figure B.23 Chloride concentration with LAG2 option at Whitney reservoir

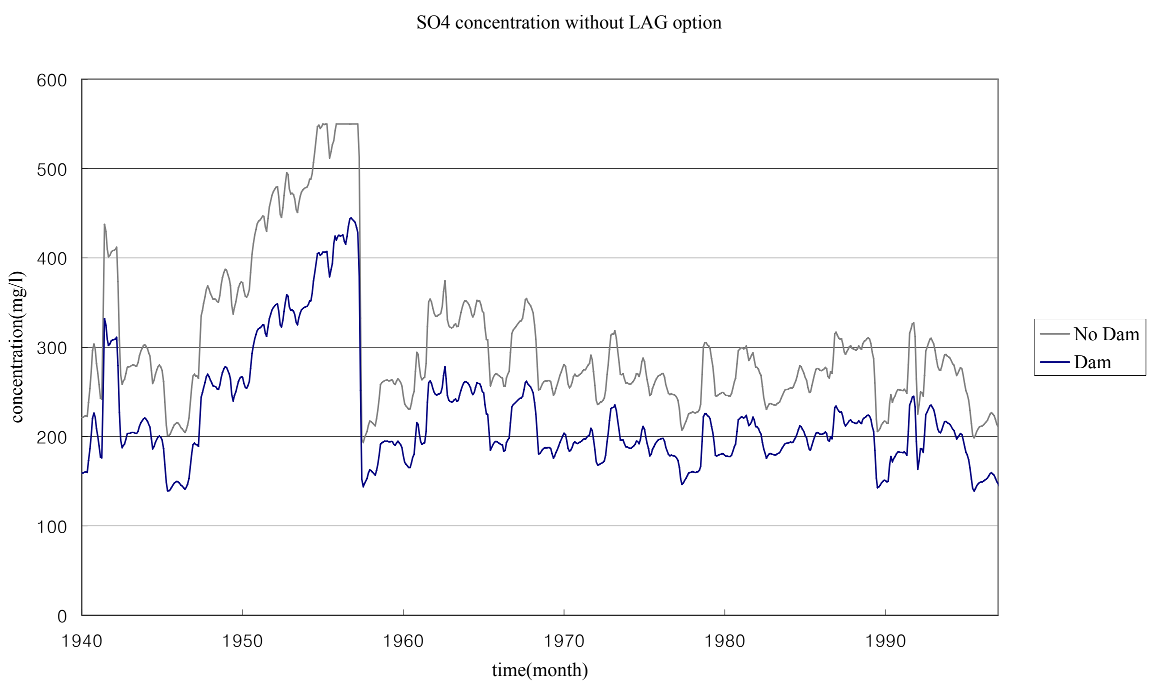

Figure B.24 Sulfate concentration without LAG option at Whitney reservoir

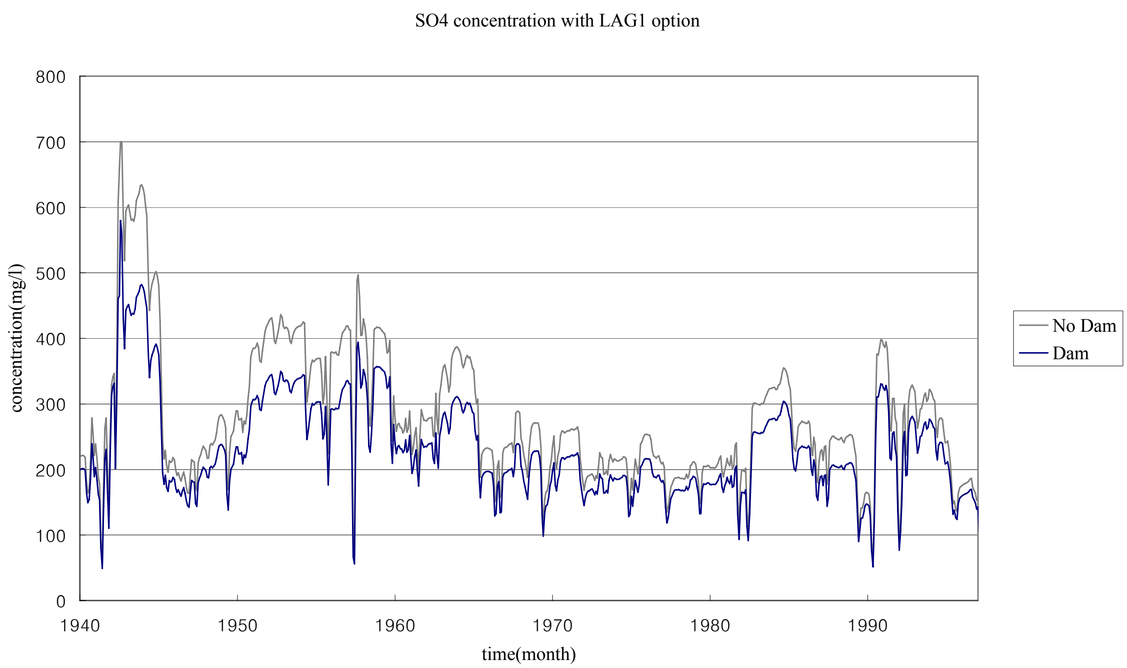

Figure B.25 Sulfate concentration with LAG1 option at Whitney reservoir

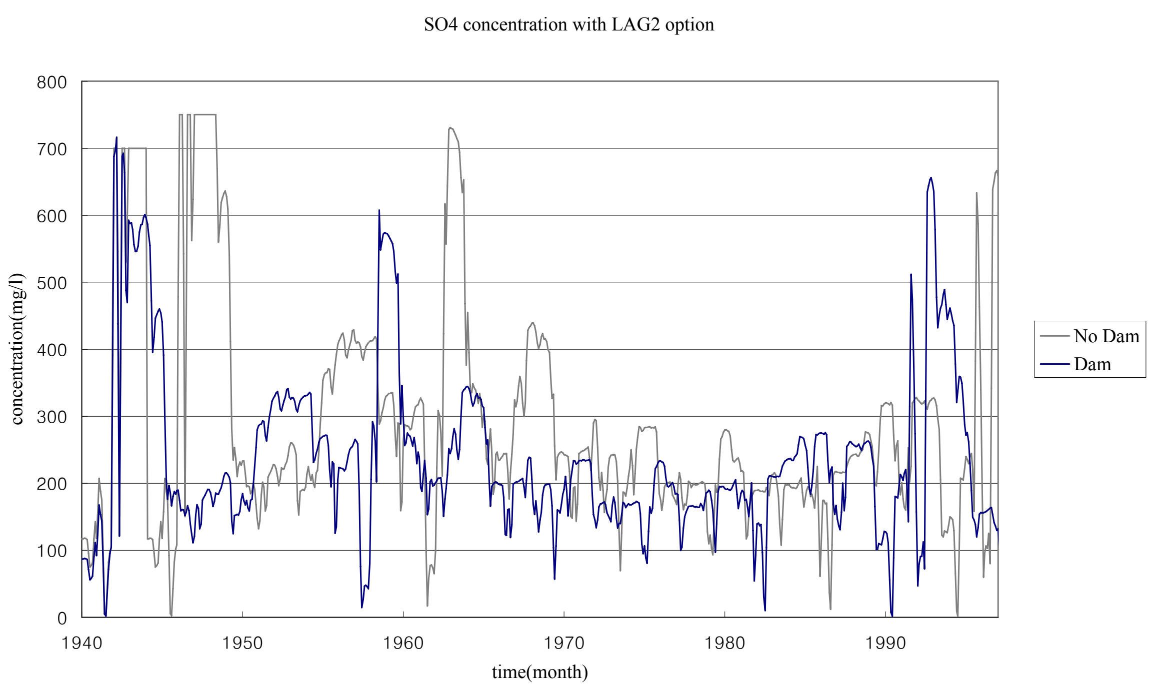

Figure B.26 Sulfate concentration with LAG2 option at Whitney reservoir

VITA

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