State of California
California Natural Resources Agency
Department of Water Resources
Bay-Delta Office

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report to the
State Water Resources Control Board in
Accordance with Water Right Decisions 1485 and 1641

June 2009

Arnold Schwarzenegger
Governor
State of California

Mike Chrisman
Secretary for Natural Resources
California Natural Resources Agency

Lester A. Snow
Director
Department of Water Resources

State of California

California Natural Resources Agency

Department of Water Resources

Bay-Delta Office

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report to the
State Water Resources Control Board in
Accordance with Water Right Decisions 1485 and 1641

June 2009

Arnold Schwarzenegger
Governor
State of California

Mike Chrisman
Secretary for Natural Resources
California Natural Resources Agency

Lester A. Snow
Director
Department of Water Resources

If you need this report in alternate format, call the Equal Opportunity and Management Investigations Office at (916) 653-6952 or TDD (916) 653-6934.

Foreword

This is the 30th annual progress report of the California Department of Water Resources' San Francisco Bay-Delta Evaluation Program, which is carried out by the Delta Modeling Section. The section submits the report annually to the California State Water Resources Control Board according to its Water Right Decision 1485, Term 9, which is still active pursuant to its Water Right Decision 1641, Term 8.

This report documents progress in the development and enhancement of the Bay-Delta Office's Delta Modeling Section's computer models and reports the latest findings of studies conducted as part of the program. This report was compiled under the direction of Tara Smith, program manager for the Bay-Delta Evaluation Program.

Online versions of previous annual progress reports are available at:
http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/annualreports.cfm

For more information contact:

Tara Smith

tara@water.ca.gov

(916) 653-9885

State of California
Arnold Schwarzenegger, Governor

California Natural Resources Agency
Mike Chrisman, Secretary for Natural Resources

Department of Water Resources
Lester A. Snow, Director

Susan Sims
Chief Deputy Director

Kasey Schimke
Asst. Dir. Legis. Affairs

Matt Notley
Acting Asst. Director of Public Affairs

David Sandino
Chief Counsel

Mark W. Cowin
Deputy Director

Timothy Haines
Deputy Director

Gerald E. Johns
Deputy Director

Jim Libonati
Deputy Director

Ralph Torres
Deputy Director

Bay-Delta Office
Kathy Kelly, Chief

Modeling Support Branch
Francis Chung, Principal Engineer

Prepared under the supervision of
Tara Smith, program manager for the Bay-Delta Evaluation Program

Prepared by

Ralph Finch ..... Senior Engineer ..... Bay-Delta Office
Carol DiGiorgio ..... Senior Environmental Scientist ..... Div. of Environmental Services
Subir Saha ..... Engineer ..... Bay-Delta Office
Lan Liang ..... Engineer ..... Bay-Delta Office
Kevin Kao ..... Engineer ..... Bay-Delta Office
Jamie Anderson ..... Senior Engineer ..... Bay-Delta Office
Kijin Nam ..... Engineer ..... Bay-Delta Office

Editorial review, graphics, and report production
Project Services Office, Technical Publications and Communication Media

Gretchen Goettl ..... Supervisor of Technical Publications
Marilee Talley ..... Research Writer

Report Contents

Foreword iii

1 Introduction 1-1

2 Data Quality Associated with EC Values in the DICU Model 2-1

2.1 Introduction 2-1

2.2 Methodology and Application 2-1

2.3 Other Data Sources for South Delta DICU Monthly EC Values 2-1

2.4 References 2-5

Figures

Figure 2-1 Islands and tracts used for 2000 revision of 1995 DICU data 2-3

Figure 2-2 Boxplot of MWQI data from 17 islands and tracts potentially used in 1995 DICU report 2-5

Figure 2-3 Cumulative probability and frequency of specific conductivity distributions for potential sites used in 1995 DICU report 2-6

Figure 2-4 Monthly distribution of specific conductivity data potentially used in 1995 DICU report 2-7

Figure 2-5 Calculated salt concentrations from DWR 1956 for subunits 25 (Union Island) and 27 (Pescadero or Stewart tract) 2-8

Table

Table 2-1 Comparison of specific conductivity summary statistics between data compiled from MWQI Water Data Library from 1982 to 1993 and summary statistics listed in 1995 DICU report 2-4

3 Comparison of Model Results between DSM2 Versions 6 and 7 without Gates and Barriers 3-1

3.1 Introduction 3-1

3.2 Model Inputs 3-1

3.3 Results Comparison 3-1

3.4 Conclusion 3-2

Figures

Figure 3-1 Modeled stage comparison in Sutter Slough 3-3

Figure 3-2 Modeled flow comparison in Sutter Slough 3-3

Figure 3-3 Modeled EC comparison in Sutter Slough 3-3

Figure 3-4 Modeled stage comparison in Steamboat Slough 3-4

Figure 3-5 Modeled flow comparison in Steamboat Slough 3-4

Figure 3-6 Modeled EC comparison in Steamboat Slough 3-4

Figure 3-7 Modeled stage comparison in Georgiana Slough 3-5

Figure 3-8 Modeled flow comparison in Georgiana Slough 3-5

Figure 3-9 Modeled EC comparison in Georgiana Slough 3-5
Figure 3-10 Modeled stage comparison in Sacramento River at Rio Vista 3-6
Figure 3-11 Modeled flow comparison in Sacramento River at Rio Vista 3-6
Figure 3-12 Modeled EC comparison in Sacramento River at Rio Vista 3-6
Figure 3-13 Modeled stage comparison in Old River Mouth 3-7
Figure 3-14 Modeled flow comparison in Old River Mouth 3-7
Figure 3-15 Modeled EC comparison in Old River Mouth 3-7
Figure 3-16 Modeled stage comparison at San Joaquin River in San Andreas Landing 3-8
Figure 3-17 Modeled flow comparison at San Joaquin River in San Andreas Landing 3-8
Figure 3-18 Modeled EC comparison at San Joaquin River in San Andreas Landing 3-8
Figure 3-19 Modeled stage comparison in Sacramento River at Emmaton 3-9
Figure 3-20 Modeled flow comparison in Sacramento River at Emmaton 3-9
Figure 3-21 Modeled EC comparison in Sacramento River at Emmaton 3-9
Figure 3-22 Modeled stage comparison in San Joaquin River at Jersey Point 3-10
Figure 3-23 Modeled flow comparison in San Joaquin River at Jersey Point 3-10
Figure 3-24 Modeled EC comparison in San Joaquin River at Jersey Point 3-10
Figure 3-25 Modeled stage comparison in Rock Slough 3-11
Figure 3-26 Modeled flow comparison in Rock Slough 3-11
Figure 3-27 Modeled EC comparison in Rock Slough 3-11
Figure 3-28 Modeled stage comparison in Old River at Bacon Island 3-12
Figure 3-29 Modeled flow comparison in Old River at Bacon Island 3-12
Figure 3-30 Modeled EC comparison in Old River at Bacon Island 3-12
Figure 3-31 Modeled stage comparison in Old River at Tracy Boulevard 3-13
Figure 3-32 Modeled flow comparison in Old River at Tracy Boulevard 3-13
Figure 3-33 Modeled EC comparison in Old River at Tracy Boulevard 3-13
Figure 3-34 Modeled stage comparison in Old River at Middle River 3-14
Figure 3-35 Modeled flow comparison in Old River at Middle River 3-14
Figure 3-36 Modeled EC comparison in Old River at Middle River 3-14
Figure 3-37 Modeled stage comparison in San Joaquin River at Antioch 3-15
Figure 3-38 Modeled flow comparison in San Joaquin River at Antioch 3-15
Figure 3-39 Modeled EC comparison in San Joaquin River at Antioch 3-15
Figure 3-40 Modeled stage comparison in Sacramento River at Collinsville 3-16
Figure 3-41 Modeled flow comparison in Sacramento River at Collinsville 3-16
Figure 3-42 Modeled EC comparison in Sacramento River at Collinsville 3-16
Figure 3-43 Modeled stage comparison in Montezuma Slough 3-17
Figure 3-44 Modeled flow comparison in Montezuma Slough 3-17
Figure 3-45 Modeled EC comparison in Montezuma Slough 3-17
Figure 3-46 Modeled stage comparison in Sacramento River at Mallard 3-18
Figure 3-47 Modeled flow comparison in Sacramento River at Mallard 3-18
Figure 3-48 Modeled EC comparison in Sacramento River at Mallard 3-18
Figure 3-49 Comparison of DSM2 version 6 and 7 modeled EC in Sutter Slough 3-19
Figure 3-50 Comparison of DSM2 version 6 and 7 modeled EC in Steamboat Slough 3-19
Figure 3-51 Comparison of DSM2 version 6 and 7 modeled EC in Georgiana Slough 3-19
Figure 3-52 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Rio Vista 3-20

Figure 3-53 Comparison of DSM2 version 6 and 7 modeled EC in Old River Mouth.....3-20
Figure 3-54 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at San Andreas Landing.....3-20
Figure 3-55 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Emmaton.....3-21
Figure 3-56 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at Jersey Point 3-21
Figure 3-57 Comparison of DSM2 version 6 and 7 modeled EC in Rock Slough.....3-21
Figure 3-58 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Bacon Island.....3-22
Figure 3-59 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Tracy Boulevard.....3-22
Figure 3-60 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Middle River.....3-22
Figure 3-61 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at Antioch.....3-23
Figure 3-62 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Collinsville....3-23
Figure 3-63 Comparison of DSM2 version 6 and 7 modeled EC in Montezuma Slough.....3-24
Figure 3-64 Comparison of DSMS version 6 and 7 modeled EC in Sacramento River at Mallard.....3-24

4 Comparison of Model Results between DSM2 Versions 6 and 7 in Historical Simulation.....4-1

4.1 Introduction.....4-1
4.2 Changes Required in DSM2 Version 7.....4-1
4.3 Comparison of Historical Simulations by the 2 DSM2 Versions.....4-4
4.4 Comparison of Flow, Stage, and Water Quality.....4-6
4.5 Comparison of Flow, Stage, and Water Quality Results in the South Delta.....4-14
4.6 Conclusion.....4-24

Appendixes

Appendix 1 Statistical Analysis of Flow Difference throughout the Delta.....4-25
Appendix 2 Statistical Analysis of Stage Difference throughout the Delta.....4-28
Appendix 3 Statistical Analysis of EC Difference throughout the Delta.....4-30
Appendix 4 Statistical Analysis of DOC Difference throughout the Delta.....4-31
Appendix 5 Statistical Analysis of Volumetric Fingerprint Difference throughout the Delta.....4-32
Appendix 6 Statistical Analysis of Flow Difference for South Delta Sites.....4-35
Appendix 7 Statistical Analysis of Stage Difference for South Delta Sites.....4-37
Appendix 8 Statistical Analysis of EC Difference for South Delta Sites.....4-39
Appendix 9 Statistical Analysis of DOC Difference for South Delta Sites.....4-40
Appendix 10 Statistical Analysis of Volumetric Fingerprint Difference for South Delta Sites.....4-41

Figures

Figure 4-1 The channels for comparing 2 DSM2 versions.....4-5
Figure 4-2 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged flow.....4-7
Figure 4-3 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged stage.....4-8
Figure 4-4 The 18-year medians of differences (Version 7 – Version 6) of daily averaged EC.....4-9
Figure 4-5 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged DOC.....4-10
Figure 4-6 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged volumetric fingerprint of Sacramento River inflow.....4-11

Figure 4-7 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged volumetric fingerprint of San Joaquin River inflow 4-12
Figure 4-8 The 18-year averages of the daily difference in maximum, average, minimum flow of Version 7 minus Version 6 at selected locations 4-13
Figure 4-9 Fifteen-minute flows at ROLD074 during February 2002 as simulated by Version 6 and Version 7 of DSM2 4-13
Figure 4-10 Average difference of daily averaged flows for 4-gate conditions 4-16
Figure 4-11 Averages difference of daily minimum stages for 4-gate conditions 4-17
Figure 4-12 Average difference of daily averaged EC for 4-gate conditions 4-18
Figure 4-13 Average difference of daily averaged DOCs for 4-gate conditions 4-19
Figure 4-14 Average difference of daily average volumetric fingerprints of Sacramento River for 4-gate conditions 4-20
Figure 4-15 Average difference of daily average volumetric fingerprints at SJR for 4-gate conditions 4-21
Figure 4-16 Stage near Old River Head barrier in 2001, Version 6 and Version 7 4-22
Figure 4-17 Stage near Old River barrier in 2002, Version 6 and Version 7 4-23
Figure 4-18 Stage near Grant Line Canal barrier in 2002, Version 6 and Version 7 4-23
Figure 4-19 Stage near Middle River barrier in 2002, Version 6 and Version 7 4-24

Tables

Table 4-1 Modification of cross sections in Version 7 4-1
Table 4-2 Comparison of gate parameters DSM2 versions 6 and 7 4-3
Table 4-3 Time intervals of 7 combinations of gate operations 4-15

5 A Proposed Method for Sea Level Rise Exceedance Probability 5-1

5.1 Introduction 5-1
5.2 Sea Level Projection with Historical Trend Extrapolation 5-2
5.3 Sea Level Projection with Rahmstorf's Method 5-3
5.4 Exceedance Probability for Sea Level Rise Projection 5-5
5.5 Uncertainty of the proposed method 5-8
5.6 Summary 5-8
5.7 Acknowledgement 5-8
5.8 References 5-9

Figures

Figure 5-1 A second order polynomial fit to historical sea level and extrapolations (normalized to year 2001 levels), 1870–2050 5-2
Figure 5-2 Positive correlation between rate of global sea level changes (mm/year) and global mean surface temperatures (°C) 5-3
Figure 5-3 Changes of global mean surface air temperature (°C) since year 2001; projected by global circulation models through 2100 5-4
Figure 5-4 Sea level projections based on 2 GHG emissions scenarios and 2 global circulation models through 2100 5-4
Figure 5-5 Historical sea levels near San Francisco Bay, 1902–2007 5-5
Figure 5-6 Sea level rise exceedance probability examples 5-7

Tables

Table 5-1 Rate of sea level change from peer-reviewed articles and government publications 5-1

6 Adjustment of Export Using DSM2-PTM and PEI 6-1
6.1 Introduction 6-1
6.2 Method 6-1
6.3 Test Results and Discussion 6-4
6.4 Limitations of DSM2-PTM 6-6
6.5 Conclusions 6-7
6.6 Acknowledgment 6-8
6.7 References 6-8

Figures

Figure 6-1 Voronoi diagram based on the 20-mm survey stations 6-2
Figure 6-2 Flow chart of computations 6-3
Figure 6-3 Locations of the 2 barriers in Delta configuration 6-4
Figure 6-4 Historical export and adjusted export over 20 days (Year 2003) 6-5
Figure 6-5 Historical and adjusted export over 20 days (Year 2008) 6-5

Acronyms and Abbreviations

CAT	Climate Action Team
CCC	Contra Costa Canal
CVP	Central Valley Project (federal)
DICU	Delta Island Consumptive Use
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DSM2	Delta Simulation Model 2
EC	electrical conductivity
GLC	Grant Line Canal
HYDRO	hydrodynamic model
MR	Middle River
MWQI	Municipal Water Quality Investigations
OR	Old River at Tracy Road
ORH	Old River at Head
PEI	Potential Entrainment Index
QUAL	water quality model
SWP	State Water Project
TDS	total dissolved solids
VAMP	Vernalis Adaptive Management Plan
VOL	volumetric fingerprint
WY	water year

Metric Conversion Table

Quantity	*To Convert from Metric Unit*	*To Customary Unit*	*Multiply Metric Unit By*	*To Convert to Metric Unit Multiply Customary Unit By*
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

1 Introduction

The California Department of Water Resources (DWR) uses the Delta Simulation Model II (DSM2) to simulate conditions in the Sacramento-San Joaquin River Delta (the Delta). The DSM2-Qual model simulates water quality—multiple conservative and non-conservative constituents—in a 15 minute time-step. CalSim II, an application of the generic CalSim model, simulates State Water Project and Central Valley Project operations.

The following are brief summaries of modeling work conducted during the past year. The names of contributing authors are in parentheses.

Chapter 2 – Data Quality Associated with EC Values in the DICU Model

DWR's Delta Modeling Section requested the Municipal Water Quality Investigations (MWQI) program to assess the feasibility of conducting an agricultural drainage study in the South Delta. Improved knowledge of agriculture drainage flows and specific electrical conductivity will improve the EC predictive capabilities of DSM2 or serve as a foundation for more complete modeling salinity studies in the South Delta. Currently, during the summer growing season, DSM2 consistently underestimates historical EC at one of the compliance points in the South Delta (Old River at Tracy Road). This error can be significant. Improving the Delta Island Consumptive Use (DICU) portion of the DSM2 model should improve DSM2's ability to predict EC in this area.

This report documents MWQI's background investigation into the DICU EC values currently used to characterize agricultural drainage for the DSM2 model. Before collecting any samples, it is important to understand how the DICU EC values used in the DSM2 model were derived. Understanding data gaps and patterns will help determine MWQI's field sampling locations. (*Carol DiGiorgio*)

Chapter 3 – Comparison of Model Results Between DSM2 Versions 6 and 7 without Gates and Barriers

This chapter compares model results between DSM2 text and database versions (v. 6 and 7, respectively) without gates or barriers installed in the Delta.

Gate and barrier hydraulic computations and operations are treated differently in version 7, compared to version 6. Other significant changes have been made to version 7, such as the addition of an operating rule language and the fixed input, which should not affect computations. A minor change was done to the nonlinear solver which results in better convergence, fewer iterations, and slightly different results. The intent of this chapter is to demonstrate that results change insignificantly between the 2 versions when the change in gate hydraulics are removed. Therefore, all gates and barriers are removed from these simulations. *(Subir Saha)*

Chapter 4 – Comparison of Model Results between DSM2 Versions 6 and 7 in Historical Simulation

This chapter compares historical simulation results using DSM2 Version 6 (text input) and Version 7 (database) variants. It describes the modifications required in Version 7 to match the input of Version 6, and compares simulation results of the 2 versions. *(Lan Liang)*

Chapter 5 – A Proposed Method for Sea Level Rise Exceedance Probability

Sea level rise is one of the major concerns for the management of California's water resources. Higher water levels and salinity intrusion into the Delta could affect water supplies, water quality, levee stability, and the habitat of local flora and fauna. For water planners, 2 related questions are raised on the uncertainty of future sea levels. First, what is the expected sea level at a specific time in the future, e.g., what is the expected sea level in 2050? Second, what is the expected time in the future when sea levels will exceed a certain height, e.g., what is the expected range of time when the sea level rises by one foot?

To project the long-term sea level rise trend, 2 different approaches are employed. To generate sea level rise trend exceedance probability, a lognormal cumulative probability function and a generalized extreme value cumulative probability function are used for interpolation between selected key values. The credibility of the generated exceedance probability curve depends on the choice of these key values, which may be subjective and inevitably involve uncertainties. *(Kevin Kao, Jamie Anderson, and Francis Chung)*

Chapter 6 – Adjustment of Export Using DSM2-PTM and PEI

Due to the population collapse of pelagic organisms—especially delta smelt—in the Delta, exports have been restricted to reduce possible harmful effects on endangered species. Various Delta management strategies have been proposed to reduce potential effects by exports. Before any strategies are adopted, their comparative effectiveness should be quantified, and likely changes to the state of the Delta must be considered. For example, the volume and timing of exports may need to be adjusted if new gate structures are introduced in Delta channels. Alternative management strategies may affect many different Delta conditions such as tidal or seasonal salinity, flow direction and magnitude, etc. Comparative evaluations of alternate schemes must be comprehensive. In this study, only potential entrainment of fish is examined, and a quantitative method of adjusting exports to reduce entrainment is proposed. Limitations of the Particle Tracking Model and this method are given. *(Kijin Nam)*

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report

June 2009

Chapter 2

Data Quality Associated with EC Values in the DICU Model

Author: Carol L. DiGiorgio, Municipal Water Quality Investigations Program, Division of Environmental Services, California Department of Water Resources

Contents

2 Data Quality Associated with EC Values in the DICU Model 2-1
2.1 Introduction 2-1
2.2 Methodology and Application 2-1
2.3 Other Data Sources for South Delta DICU Monthly EC Values 2-7
2.4 Conclusion 2-9
2.5 References 2-9

Figures

Figure 2-1 Islands and tracts used for 2000 revision of 1995 DICU data 2-3
Figure 2-2 Boxplot of MWQI data from 17 islands and tracts potentially used in 1995 DICU report 2-5
Figure 2-3 Cumulative probability and frequency of specific conductivity distributions for potential sites used in 1995 DICU report 2-6
Figure 2-4 Monthly distribution of specific conductivity data potentially used in 1995 DICU report 2-7
Figure 2-5 Calculated salt concentrations from DWR 1956 for subunits 25 (Union Island) and 27 (Pescadero or Stewart tract) 2-8

Table

Table 2-1 Comparison of specific conductivity summary statistics between data compiled from MWQI Water Data Library from 1982 to 1993 and summary statistics listed in 1995 DICU report 2-4

2 Data Quality Associated with EC Values in the DICU Model

2.1 Introduction

The Department of Water Resources' (DWR) Delta Modeling Section requested the Municipal Water Quality Investigations (MWQI) program to assess the feasibility of conducting an agricultural drainage study in the South Delta. Improved knowledge of agriculture drainage flows and specific electrical conductivity will improve the EC predictive capabilities of the Delta Simulation Model 2 (DSM2) or serve as a foundation for more complete modeling salinity studies in the South Delta. Currently, during the summer growing season, DSM2 consistently underestimates historical EC at one of the compliance points in the South Delta (Old River at Tracy Road). This error can be significant. Improving the estimate of the agricultural drainage quality and the Delta Island Consumptive Use (DICU) portion of the DSM2 model should improve DSM2's ability to predict EC in this area.

This report documents MWQI's background investigation into the EC values currently used to characterize agricultural drainage for the DSM2 model. Before collecting any samples, it is important to understand how the agricultural drainage EC values used in the DSM2 model were derived. Understanding data gaps and patterns will help determine MWQI's field sampling locations.

2.2 Methodology and Application

The agricultural drainage EC values used with DICU for DSM2 simulations consist of 12 monthly EC values calculated for 3 Delta subregions originally identified in Bulletin 123 *Delta and Suisun Bay Water Quality Investigation* (DWR 1967). This bulletin divided the Delta into North, West, and Southeast[1] sub-regions. The 12 monthly EC values used by the model are unique to each subregion. These 12 EC values are listed in the memorandum report titled *Representative Delta Island Return Flow Quality for Use in DSM2* (DWR 1995) and referred to here as the DICU report.

Most of the EC data in the 1995 DICU report were based on MWQI data collected from 1982 to 1993; however, the report did not specify the locations where the data were collected. In a 2000 update (Marvin Jung & Assoc) to the 1995 report, data collected from 1982 to 1997 from 17 islands, drains, and tracts were used to update the EC values for the South Delta.

The areas used for updating are listed below and shown in Figure 2-1:

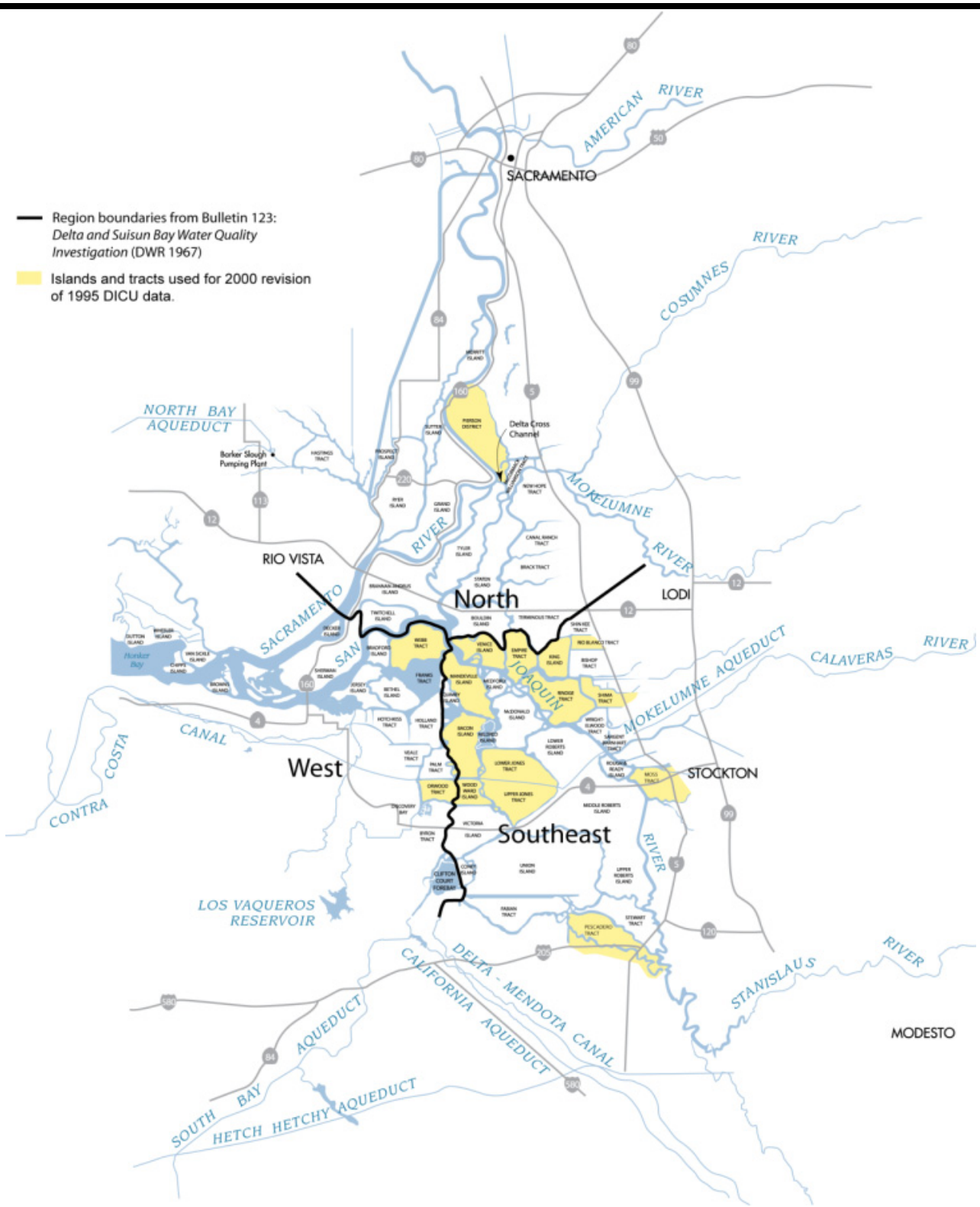
Bacon Island	Pescadero Tract
Empire Tract	Pierson Tract
King Island	Rindge Tract
Lower and Upper Jones Tracts	Rio Blanco Tract
Mandeville Island	Shima Tract
Moss Tract	Venice Island
Mossdale Tract	Webb Tract
Orwood Tract	Woodward Island

[1] The Southeast sub-region from Bulletin 123 was used to define the South Delta for use in modeling studies.

Although the 2000 report was written to update the values used in the 1995 report, the data were never incorporated into the actual model (Suits, pers comm 22 Aug 2008). However, using the 2000 report as a guideline suggests which areas were included in the original calculation of EC values used by the model for the South Delta.

The 12 monthly EC values were created using the total dissolved solids (TDS) data collected by MWQI and the TDS data in *Report No. 4, Quantity and Quality of Waters Applied to and Drained from the Delta Lowlands* (DWR 1956); these data were used to create smoothed monthly TDS values (DWR 1995). Once smoothed TDS values were calculated, TDS was correlated to EC using MWQI's TDS and EC data. These correlations were then used to create the smoothed EC values used by DICU (Hutton, pers comm. 5 Sep 2008).

To understand how EC values used with DICU could affect the modeled salinity results at a DWR compliance station, we examined the characteristics of the data used to generate the 12 monthly EC values for the South Delta. Because the locations and actual numbers used to generate these values were not listed in the 1995 DICU report, we assumed that the data and locations were the same as those used in the 2000 update (Marvin Jung & Assoc). To verify this assumption, summary statistics were generated for 2 data sets and were compared to the MWQI monthly summary statistics in Appendix 1 of the 1995 DICU report. The first data set used for comparisons consisted of MWQI EC data collected between 1982 and 1993 from the sites listed previously (Marvin Jung & Assoc 2000) and shown in Figure 2-1. The second data set used for comparisons consisted of MWQI data collected from 1982 to 1997 and was verified directly with the 2000 report. Statistics about each of these data sets was compared to the 1995 DICU report's Appendix 1 summary statistics to determine which approximated the EC data set used. Overall, there was very good agreement between both generated data sets and the 1995 summary statistics.



Map note: The Southeast sub-region from Bulletin 123 was used to designate the South Delta region

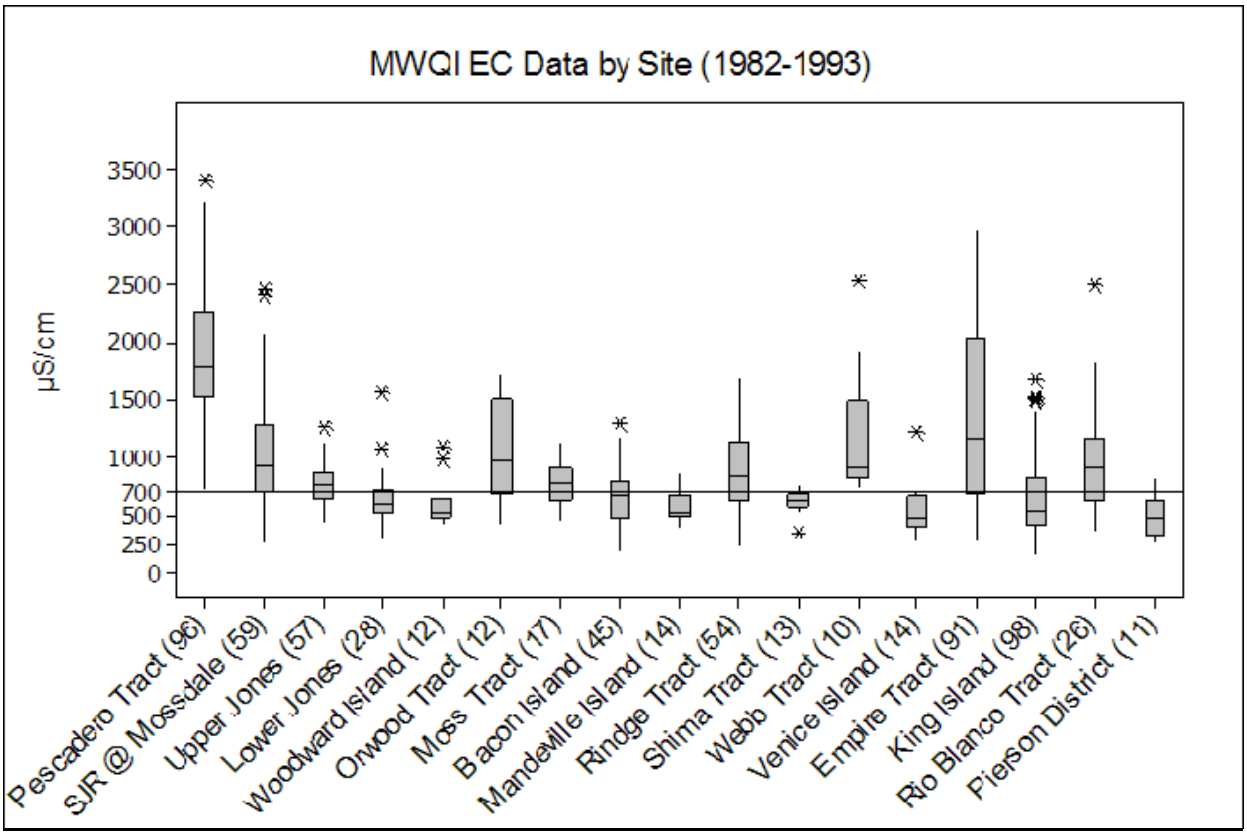
Figure 2-1 Islands and tracts used for 2000 revision of 1995 DICU data

Table 2-1 Comparison of specific conductivity summary statistics between data compiled from MWQI Water Data Library from 1982 to 1993 and summary statistics listed in 1995 DICU report

Count	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Count from WDL 17 sites 1982-1993	99	25	46	96	27	68	91	90	5	87	6
Count from Appendix 1 1995 DICU report	88	25	24	82	18	65	81	68	5	65	6
Count Difference	11	0	22	14	9	3	10	22	0	22	0
Means	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Means from WDL 17 sites 1982-1993	1193	1368	1158	1142	932	873	811	795	2083	1081	1111
Means from Appendix 1 1995 DICU report	1262	1412	1290	1144	956	878	826	780	2083	1152	1111
Differences between data sets	-69	-44	-132	-2	-24	-5	-15	15	0	-71	0
Medians	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Medians from WDL 17 sites 1982-1993	980	1260	980.5	898	900	673.5	678	666.5	2140	747	1079
Medians from Appendix 1 1995 DICU report	1035	1340	1130	786	855	673	667	594	2140	810	1079
Differences between data sets	-55	-80	-150	112	45	1	11	73	0	-63	0

Note that the 17 sites chosen for comparison came from Marvin Jung & Assoc 2000

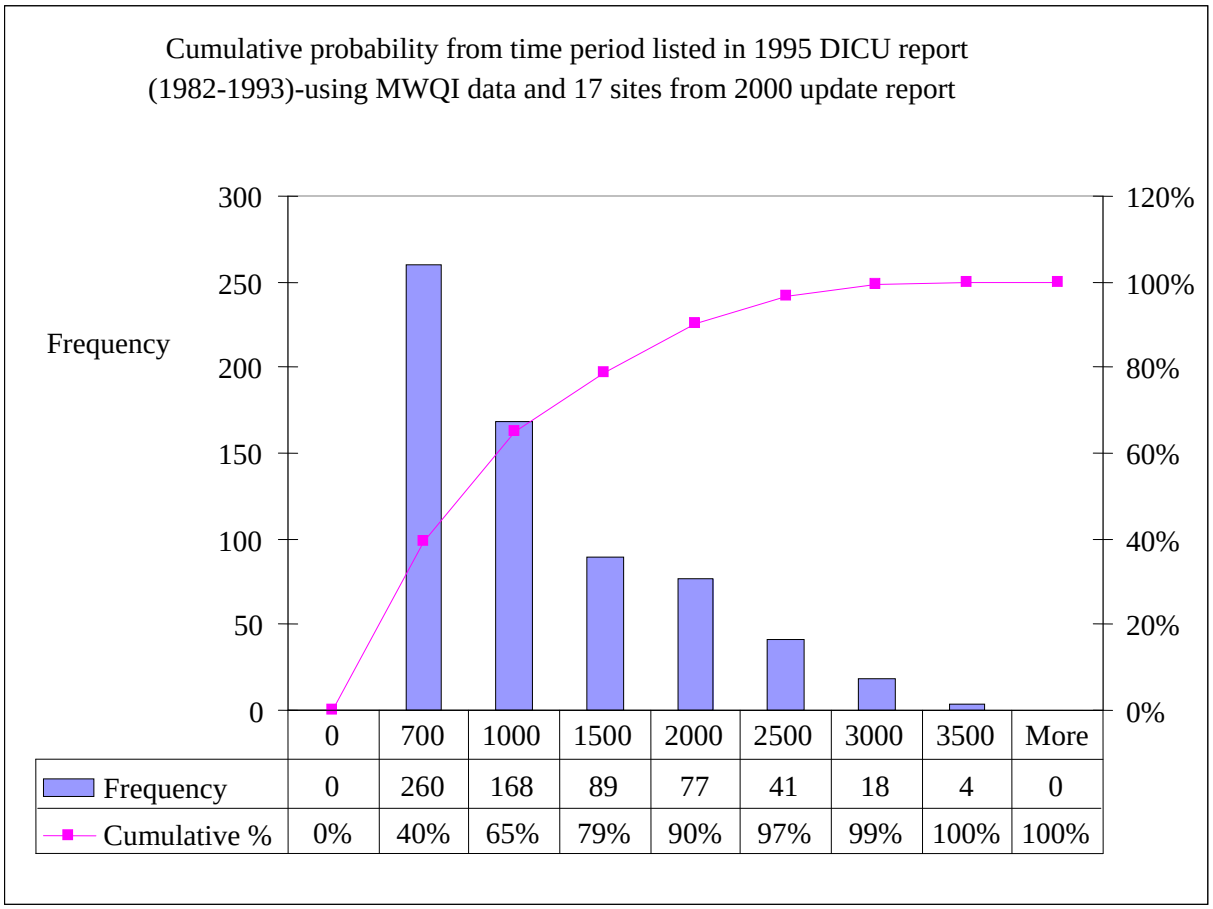
Although both data sets did a good job of matching the original summary statistics, the difference between data counts, means, and medians suggested that MWQI data collected between 1982 and 1993 did a slightly better job of matching the 1995 summary statistics than the data set used in the 2000 revision. Using the 1982–1993 data set, averages differed between the generated data set and Appendix 1 data by no more than 71 µS/cm in all months except March. During the April through August summer irrigation season, averages differed between the 2 data sets by no more than 24 µS/cm and medians differed by no more than 112 µS/cm (Table 2-1). The greatest difference was for March EC data in Appendix 1, which measured 132 µS/cm higher than the MWQI 1982-1993 data set. Based on these results, MWQI data collected from 17 locations from 1982 to 1993 were used to examine the patterns associated with the numbers used for DICU. As noted previously, EC values used with the DICU model were assigned based on geographic regions specified in Bulletin 123 and all EC samples collected in the Southeastern sub-region were considered part of the South Delta (DWR 1995). As shown in Figure 2-1, with the exception of Pescadero tract, all of the locations used to estimate EC values in the South Delta for DICU came from the central and eastern Delta.



Note that the number of samples is given in parenthesis and that the line within the boxplot is the median.

Figure 2-2 Boxplot of MWQI data from 17 islands and tracts potentially used in 1995 DICU report

Using salinities from areas outside the South Delta helps explain why DSM2 underestimates South Delta salinities. By law, DWR is required to meet a maximum 30-day running average of 700 µS/cm from April to August at several compliance points in the South Delta. Modeling is important for anticipating and understanding how DWR can meet this standard. The inclusion of lower EC values from areas outside the South Delta potentially contributes to this inaccuracy. For example, Figure 2-2 shows the variability in EC values from the 17 regions used to represent South Delta salinity.



	0	700	1000	1500	2000	2500	3000	3500	More
Frequency	0	260	168	89	77	41	18	4	0
Cumulative %	0%	40%	65%	79%	90%	97%	99%	100%	100%

Figure 2-3 Cumulative probability and frequency of specific conductivity distributions for potential sites used in 1995 DICU report

Only Pescadero tract and Webb tract had minimum salinities above 700 µS/cm. Of these 2 sites, only Pescadero tract is in the South Delta and accurately reflects salinity dynamics of the area. Webb tract is in the western Delta and is influenced by seawater dynamics. All other sites used to calculate South Delta salinities had minimum values ranging from 160 to 453 µS/cm. Median and mean values for more than half of the locations were also less than 700 µS/cm (8/17 locations for medians, and 8/17 locations for means). As shown in Figure 2-3, 40% of the 657 data points used to calculate South Delta's EC values were measured at or below 700 µS/cm.

These results suggest that, with a large proportion of low EC data, South Delta EC calculations could be biased low. Although monthly averages were always above 700 µS/cm, 50% of the data during the critical period from June to August was below 700 µS/cm (Figure 2-4).

The range of values illustrated in Figure 2-4 suggests that if only South Delta areas had been used for water quality calculations (that is, Pescadero tract), none of the resulting EC values in either the winter or the summer months would have been below 700 µS/cm. This suggests that the calculated EC values from the DICU report for the South Delta will be biased low due to the inclusion of low EC values from non-South Delta waters in the calculations.

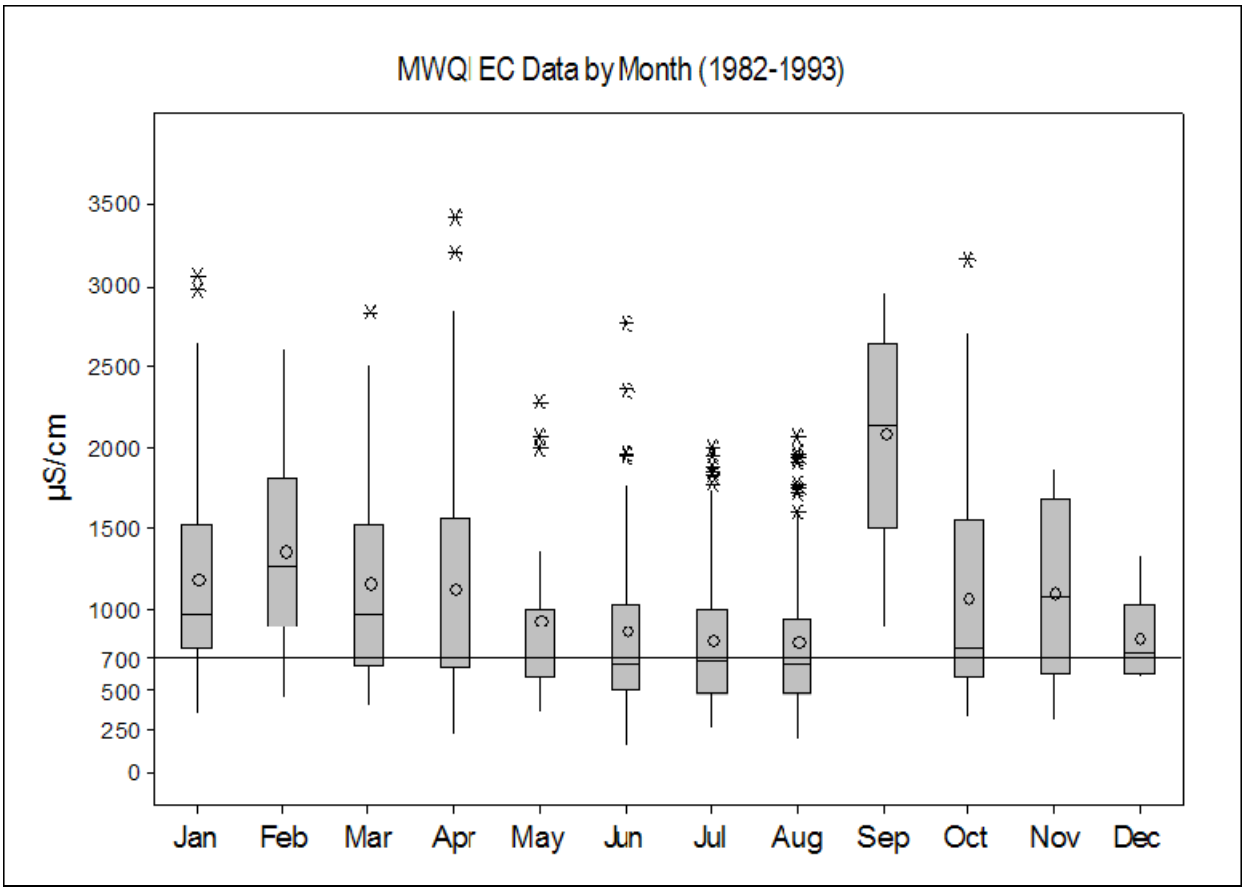


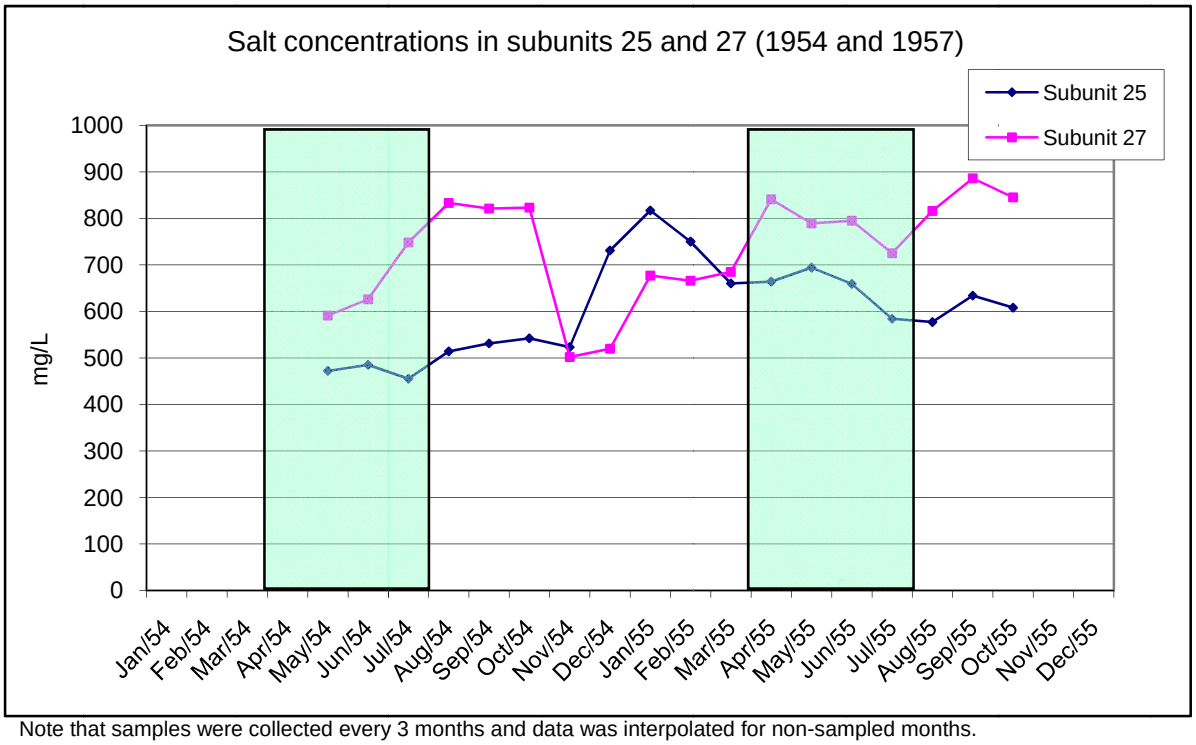
Figure note: Circle and line within the boxplot are the mean and median, respectively

Figure 2-4 Monthly distribution of specific conductivity data potentially used in 1995 DICU report

2.3 Other Data Sources for South Delta DICU Monthly EC Values

Most of the DICU Report EC calculations are based on data collected by the MWQI program; however, data from Report 4 (DWR 1956) and Bulletin 123 (DWR 1967) were also used. A brief summary of these 2 reports is provided below. Report 4 contains no EC data, only TDS data. Bulletin 123 contains EC data collected from Paradise Cut over 5 months from July to November 1964; however, the report only lists summary statistics. No monthly data were given.

Data from Report 4 were collected over 18 months from May 1954 (in 1955 water year) and October 1955 (1956 WY). For the San Joaquin Valley, the 1955 WY was classified as dry, and the 1956 WY was classified as wet. At approximately 6-week intervals, specific conductance measurements were made of agricultural drainage water at 196 sampling points. The sampling locations were not identified in the report. At 24 of these sampling points, water samples were collected at 3-month intervals and subjected to complete mineral analysis. Correlations between specific conductivity and TDS were calculated, and monthly agricultural drain discharges were interpolated for each sampling point. The final monthly results



Note that samples were collected every 3 months and data was interpolated for non-sampled months.
The shaded area represents the approximate growing season.

Figure 2-5 Calculated salt concentrations from DWR 1956 for subunits 25 (Union Island) and 27 (Pescadero or Stewart tract)

were presented in terms of tons of salt and milligrams per liter of salt per subunit of the Delta. No specific conductance data were presented in the report, and there was no record of the correlations or interpolation required to go from 24 samples collected every 3 months to the 196 drains sampled every 6 weeks. Subunits 25 and 27 bounded the South Delta area of interest (Union Island and Stewart Tract or Union Island and Pescadero Tract, respectively). Report 4's calculated salt weights in milligrams per liter are shown in Figure 2-5. For subunit 25, salt concentrations were similar during the summer irrigation period between the 2 water years. The results were counterintuitive for subunit 27 because summer salt concentrations were higher during the wet year than in the dry year.

As summarized in Bulletin 123 (DWR 1967), specific conductivity data were collected over a 5-month period from July to November 1964. Power meter readings were also used to calculate drainage flows. For EC, samples were collected biweekly. In the South Delta, samples were collected on Union Island, RD 2058 at Paradise Cut, and RD 1007 near Old River (see page 116 of Bulletin 123 for figure with locations. Note that the Old River location appears to be several miles downstream of the Old River at the Tracy compliance site). The report provides summary statistics for the analytes collected (minimum, maximum, and average); however, no monthly ECs were given for any of the sampling locations.

2.4 Conclusion

Using the data set re-created from the 1995 DICU report, there are 2 conclusions regarding monthly South Delta agricultural drainage EC values.

Almost no water quality data from the South Delta was used to create the monthly Delta EC values currently assumed for use with DICU. The only site used in the South Delta was Pescadero tract. All other sites were located in the central and eastern Delta.

Using lower EC central and eastern Delta data biases the overall monthly agricultural drainage EC values for the South Delta. Because the EC values in the central and eastern Delta are generally lower than in the South Delta, the EC of agricultural drainages in the South Delta is underestimated, resulting in lower DSM2-simulated EC.

2.5 References

(DWR) California Department of Water Resources. 1956. *Report No. 4, Quantity and Quality of Waters Applied to and Drained from the Delta Lowlands*.

_____. 1967. Bulletin No. 123, *Delta and Suisun Bay Water Quality Investigation*.

_____. 1995. *Representative Delta Island Return Flow Quality for Use in DSM2*. Memorandum Report.

Marvin Jung & Associates Inc. 2000. *Revision of Representative Delta Island Return Flow Quality for DSM2 and DICU Model Runs*. Prepared for the CALFED Ad-Hoc Workgroup to Simulate Historical Water Quality Conditions in the Delta. Consultants Report to the Department of Water Resources Municipal Water Quality Investigations Program. MWQI-CR#3.

Personal Communications

Hutton, Paul, Metropolitan Water District of Southern California. 2008. Telephone conversation with Carol DiGiorgio, MWQI, California Department of Water Resources. 5 Sep 2008.

Suits, Bob, DWR Delta Modeling Section. 2008. Telephone conversation with Carol DiGiorgio, MWQI, California Department of Water Resources. 22 Aug 2008.

This page left blank for 2-sided printing

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report

June 2009

Chapter 3

Comparison of Model Results between DSM2 Versions 6 and 7 without Gates and Barriers

Author: Subir Saha, Delta Modeling Section, Bay-Delta Office, California Department of Water Resources

Contents

3 Comparison of Model Results between DSM2 Versions 6 and 7 without Gates and Barriers 3-1
3.1 Introduction 3-1
3.2 Model Inputs 3-1
3.2.1 Channel Geometry 3-1
3.2.2 Boundary Conditions 3-1
3.2.3 Sources and Sinks 3-1
3.2.4 Gates and Barriers 3-1
3.3 Results Comparison 3-1
3.3.1 North Delta 3-2
3.3.2 Central Delta 3-2
3.3.3 South Delta 3-2
3.3.4 Western Delta 3-2
3.4 Conclusion 3-2

Figures

Figure 3-1 Modeled stage comparison in Sutter Slough 3-3
Figure 3-2 Modeled flow comparison in Sutter Slough 3-3
Figure 3-3 Modeled EC comparison in Sutter Slough 3-3
Figure 3-4 Modeled stage comparison in Steamboat Slough 3-4
Figure 3-5 Modeled flow comparison in Steamboat Slough 3-4
Figure 3-6 Modeled EC comparison in Steamboat Slough 3-4
Figure 3-7 Modeled stage comparison in Georgiana Slough 3-5
Figure 3-8 Modeled flow comparison in Georgiana Slough 3-5
Figure 3-9 Modeled EC comparison in Georgiana Slough 3-5
Figure 3-10 Modeled stage comparison in Sacramento River at Rio Vista 3-6
Figure 3-11 Modeled flow comparison in Sacramento River at Rio Vista 3-6
Figure 3-12 Modeled EC comparison in Sacramento River at Rio Vista 3-6
Figure 3-13 Modeled stage comparison in Old River Mouth 3-7
Figure 3-14 Modeled flow comparison in Old River Mouth 3-7
Figure 3-15 Modeled EC comparison in Old River Mouth 3-7
Figure 3-16 Modeled stage comparison at San Joaquin River in San Andreas Landing 3-8
Figure 3-17 Modeled flow comparison at San Joaquin River in San Andreas Landing 3-8
Figure 3-18 Modeled EC comparison at San Joaquin River in San Andreas Landing 3-8
Figure 3-19 Modeled stage comparison in Sacramento River at Emmaton 3-9
Figure 3-20 Modeled flow comparison in Sacramento River at Emmaton 3-9
Figure 3-21 Modeled EC comparison in Sacramento River at Emmaton 3-9
Figure 3-22 Modeled stage comparison in San Joaquin River at Jersey Point 3-10
Figure 3-23 Modeled flow comparison in San Joaquin River at Jersey Point 3-10
Figure 3-24 Modeled EC comparison in San Joaquin River at Jersey Point 3-10
Figure 3-25 Modeled stage comparison in Rock Slough 3-11
Figure 3-26 Modeled flow comparison in Rock Slough 3-11

Figure 3-27 Modeled EC comparison in Rock Slough 3-11
Figure 3-28 Modeled stage comparison in Old River at Bacon Island 3-12
Figure 3-29 Modeled flow comparison in Old River at Bacon Island 3-12
Figure 3-30 Modeled EC comparison in Old River at Bacon Island 3-12
Figure 3-31 Modeled stage comparison in Old River at Tracy Boulevard 3-13
Figure 3-32 Modeled flow comparison in Old River at Tracy Boulevard 3-13
Figure 3-33 Modeled EC comparison in Old River at Tracy Boulevard 3-13
Figure 3-34 Modeled stage comparison in Old River at Middle River 3-14
Figure 3-35 Modeled flow comparison in Old River at Middle River 3-14
Figure 3-36 Modeled EC comparison in Old River at Middle River 3-14
Figure 3-37 Modeled stage comparison in San Joaquin River at Antioch 3-15
Figure 3-38 Modeled flow comparison in San Joaquin River at Antioch 3-15
Figure 3-39 Modeled EC comparison in San Joaquin River at Antioch 3-15
Figure 3-40 Modeled stage comparison in Sacramento River at Collinsville 3-16
Figure 3-41 Modeled flow comparison in Sacramento River at Collinsville 3-16
Figure 3-42 Modeled EC comparison in Sacramento River at Collinsville 3-16
Figure 3-43 Modeled stage comparison in Montezuma Slough 3-17
Figure 3-44 Modeled flow comparison in Montezuma Slough 3-17
Figure 3-45 Modeled EC comparison in Montezuma Slough 3-17
Figure 3-46 Modeled stage comparison in Sacramento River at Mallard 3-18
Figure 3-47 Modeled flow comparison in Sacramento River at Mallard 3-18
Figure 3-48 Modeled EC comparison in Sacramento River at Mallard 3-18
Figure 3-49 Comparison of DSM2 version 6 and 7 modeled EC in Sutter Slough 3-19
Figure 3-50 Comparison of DSM2 version 6 and 7 modeled EC in Steamboat Slough 3-19
Figure 3-51 Comparison of DSM2 version 6 and 7 modeled EC in Georgiana Slough 3-19
Figure 3-52 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Rio Vista 3-20
Figure 3-53 Comparison of DSM2 version 6 and 7 modeled EC in Old River Mouth 3-20
Figure 3-54 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at San Andreas Landing 3-20
Figure 3-55 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Emmaton 3-21
Figure 3-56 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at Jersey Point 3-21
Figure 3-57 Comparison of DSM2 version 6 and 7 modeled EC in Rock Slough 3-21
Figure 3-58 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Bacon Island 3-22
Figure 3-59 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Tracy Boulevard 3-22
Figure 3-60 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Middle River 3-22
Figure 3-61 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at Antioch 3-23
Figure 3-62 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Collinsville 3-23
Figure 3-63 Comparison of DSM2 version 6 and 7 modeled EC in Montezuma Slough 3-24
Figure 3-64 Comparison of DSMS version 6 and 7 modeled EC in Sacramento River at Mallard 3-24

3 Comparison of Model Results between DSM2 Versions 6 and 7 without Gates and Barriers

3.1 Introduction

This chapter compares model results between Delta Simulation Model 2 (DSM2) text and database versions (v. 6 and 7, respectively) without gates or barriers installed in the Delta.

Gate and barrier hydraulic computations and operations are treated differently in version 7, compared to version 6. Other significant changes have been made to version 7, such as the addition of an operating rule language and the fixed input, which should not affect computations. A minor change was done to the nonlinear solver which results in better convergence, fewer iterations, and slightly different results. The intent of this chapter is to demonstrate that results change insignificantly between the 2 versions when the change in gate hydraulics are removed. Therefore, all gates and barriers are removed from these simulations. The key components to set up the model input for both versions are described below.

3.2 Model Inputs

A standard CALSIM II output file is pre-processed to obtain the inflows and exports. The pre-processed file is used in both models. Planning tides, Delta Island Consumptive Use (DICU) flows and electrical conductivity (EC) inputs are identical in both models.

3.2.1 Channel Geometry

All channels in the Delta are irregular in cross sections and are identical in both models.

3.2.2 Boundary Conditions

San Joaquin River boundary flow at Vernalis is defined by the Vernalis Adaptive Management Plan (VAMP) flow time series; Sacramento River boundary flow is defined by smoothing the monthly CALSIM flow. Calaveras River, Cosumnes River, Mokelumne River, and Yolo Bypass boundary flows are used in both models. All boundary flows and ECs are kept identical in both simulations. Both versions use the same stage and EC boundary conditions at Martinez.

3.2.3 Sources and Sinks

Agriculture sources and sinks in the Delta are from the DICU model for year 2020 demand level and are identical in both model versions. Exports such as Contra Costa Canal (CCC), Central Valley Project (CVP), North Bay, Vallejo, and State Water Project (SWP) from the Delta are also at 2020 demand level and are identical for versions 6 and 7.

3.2.4 Gates and Barriers

Because the gate formulation is different in the DSM2 version 7, all the gates and barriers are removed with the exception of Clifton Court Intake gate.

3.3 Results Comparison

The hydrodynamic (HYDRO) and water quality (QUAL) models are run for 5 years. Stage, flow, and EC results are compared at locations throughout the Delta. Version 7 uses more robust solvers and takes less computation time than version 6. Because the new solver requires fewer iterations, results differ by a trivial amount throughout the comparison period. Although model results are computed on a 15-minute time step, daily averages are compared in this report.

3.3.1 North Delta

North Delta refers to the Delta north of Rio Vista. The representative output locations in main channels in this region are Sutter Slough, Steamboat Slough, Georgiana Slough, and Sacramento River at Rio Vista. Stage, flow, and EC comparisons between versions of DSM2 are shown in Figure 3-1 through Figure 3-12. Stage and flow comparisons of these locations are almost identical. EC results at these locations are also in close agreement. Figure 3-49 through Figure 3-52 show version 7-modeled EC against version 6-modeled EC using scatterplots. The EC values from both models fall on a 45-degree line as expected, suggesting that version 7 reproduces version 6 results very well.

3.3.2 Central Delta

Sherman Island in the west, Fourteen-Mile Slough in the east, Brannan-San Andreas Landing Island in the north, and Holland Tract in the south form the Central Delta. San Joaquin River at San Andreas Landing Island, Old River Mouth, Sacramento River at Emmaton, and San Joaquin River at Jersey Point are the representative locations. Stage and flow are almost identical in the above locations (Figure 3-13 through Figure 3-24). Figure 3-53 through Figure 3-56 show modeled EC from both model versions, and the results are in close agreement.

3.3.3 South Delta

Areas south of Old River at Bacon Island, Middle River at Bacon Island, and San Joaquin River near Stockton are referred to as the South Delta. Stage and flow results in Rock Slough, Old River at Bacon Island, Old River at Tracy Boulevard, and Old River at Middle River locations are almost identical and are shown in Figure 3-25 through Figure 3-36. The modeled EC values in main channel locations in the South Delta from version 7 reproduce nearly the same results as version 6 and are shown in Figure 3-57 through Figure 3-60.

3.3.4 Western Delta

Areas between Martinez and Antioch are referred to as the Western Delta. The representative output locations in the main channels in the Western Delta are Montezuma Slough, Sacramento River at Mallard, Sacramento River at Collinsville, and San Joaquin River at Antioch. Stage and flow comparison in these locations are almost identical (Figure 3-37 through figure 3-48). As expected, EC values from both models are in close agreement and are shown in Figure 3-61 through Figure 3-64.

3.4 Conclusion

Version 7 of the DSM2 model reproduces nearly identical hydrodynamic and water quality results in the entire Delta as version 6 when both models are run without gates. The small differences are attributed to changes in the iterative solver for nonlinear systems of equations.

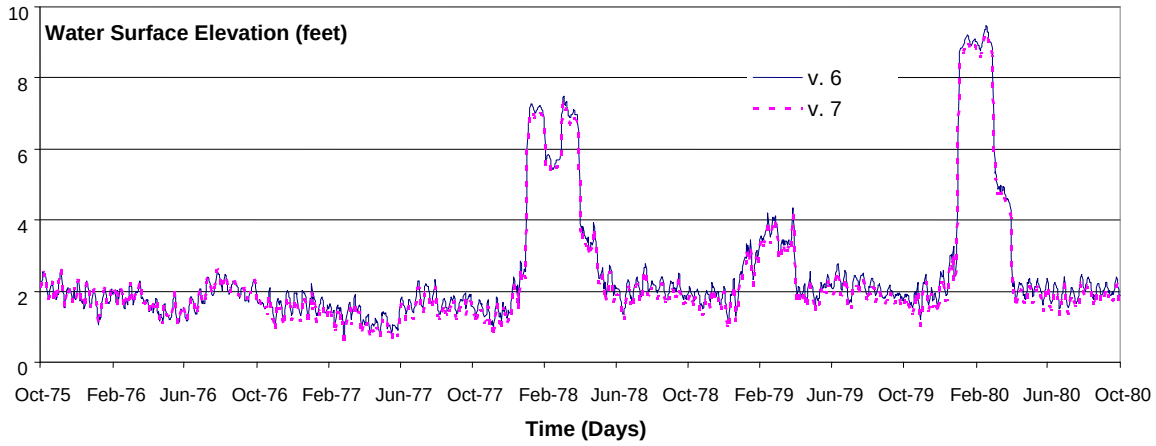


Figure 3-1 Modeled stage comparison in Sutter Slough

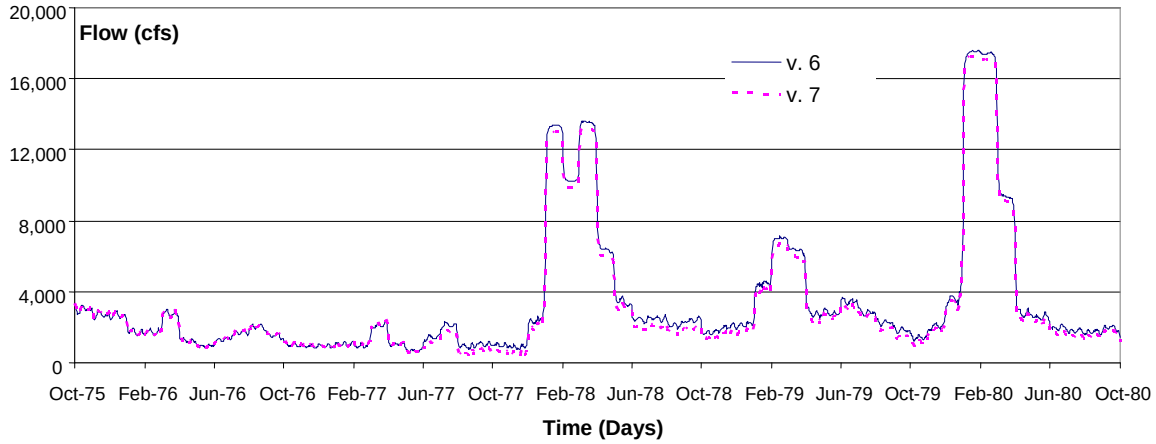


Figure 3-2 Modeled flow comparison in Sutter Slough

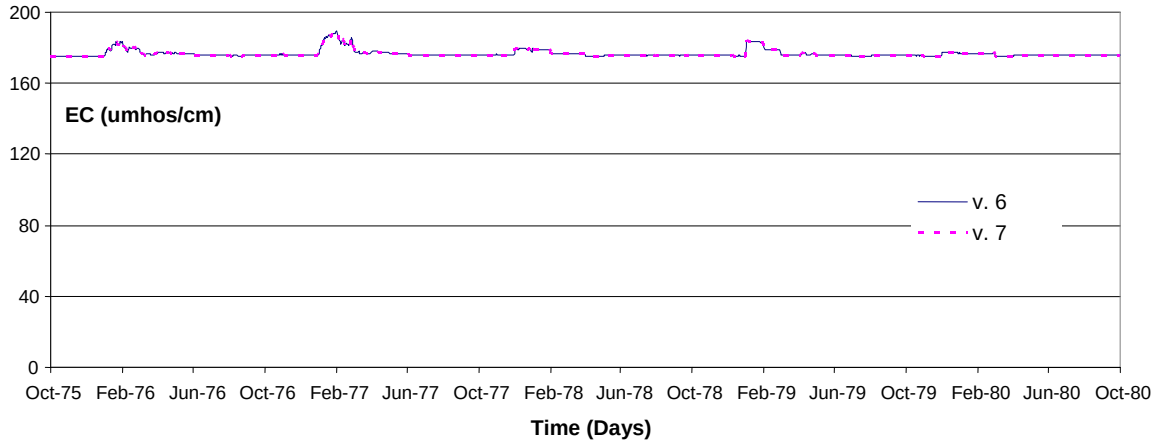


Figure 3-3 Modeled EC comparison in Sutter Slough

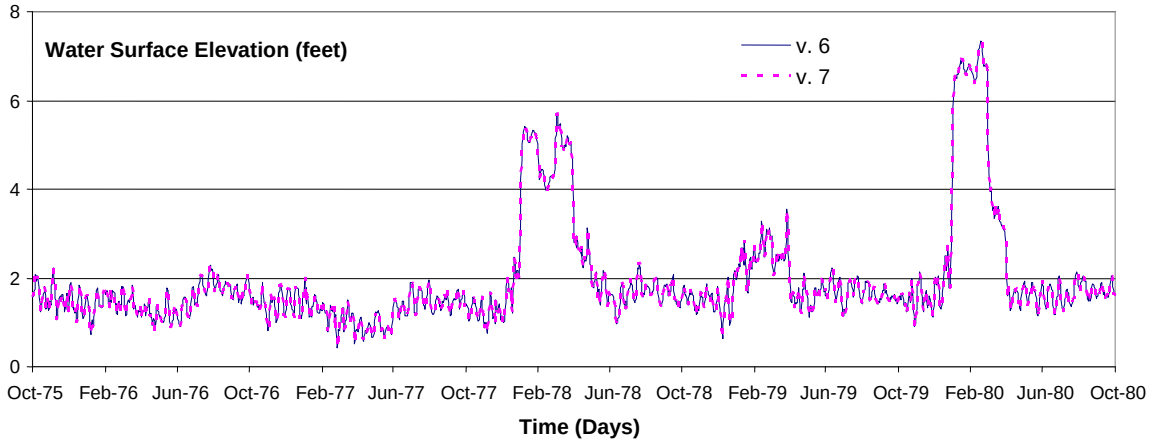


Figure 3-4 Modeled stage comparison in Steamboat Slough

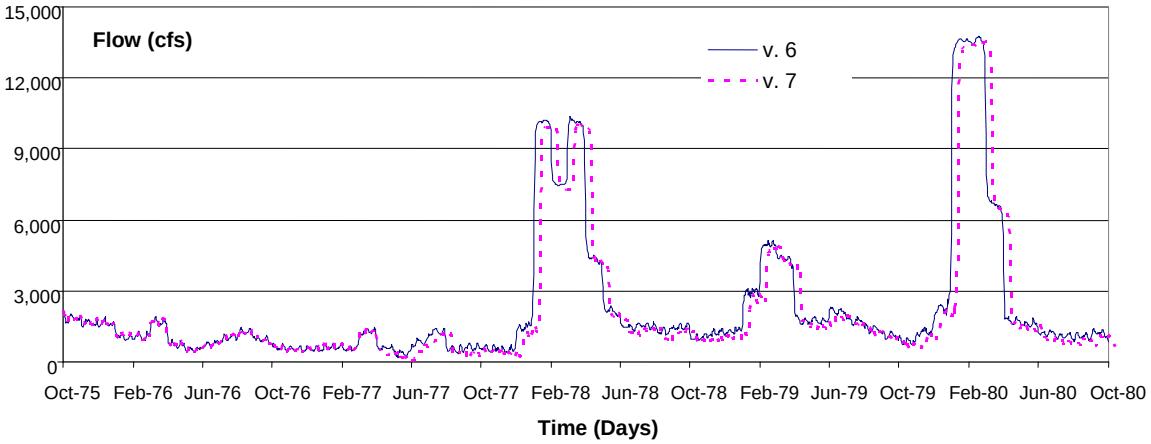


Figure 3-5 Modeled flow comparison in Steamboat Slough

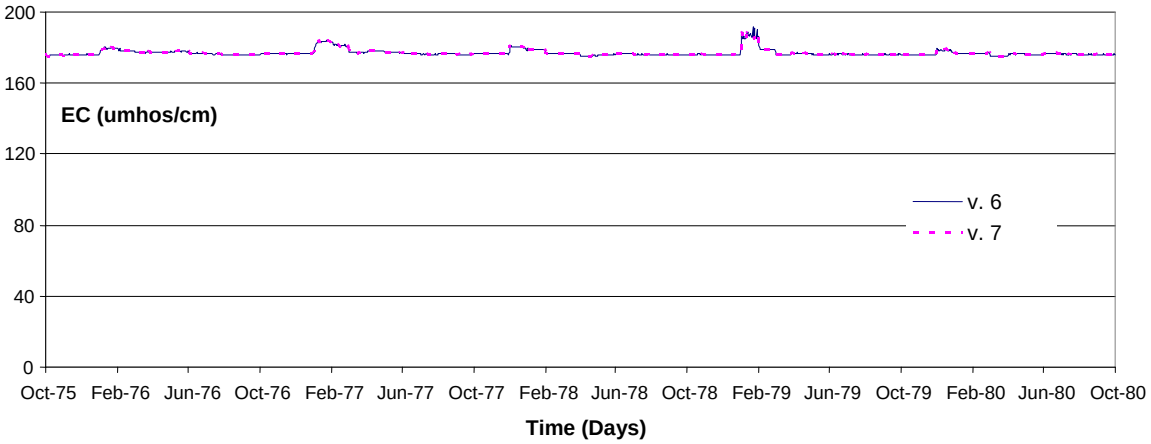


Figure 3-6 Modeled EC comparison in Steamboat Slough

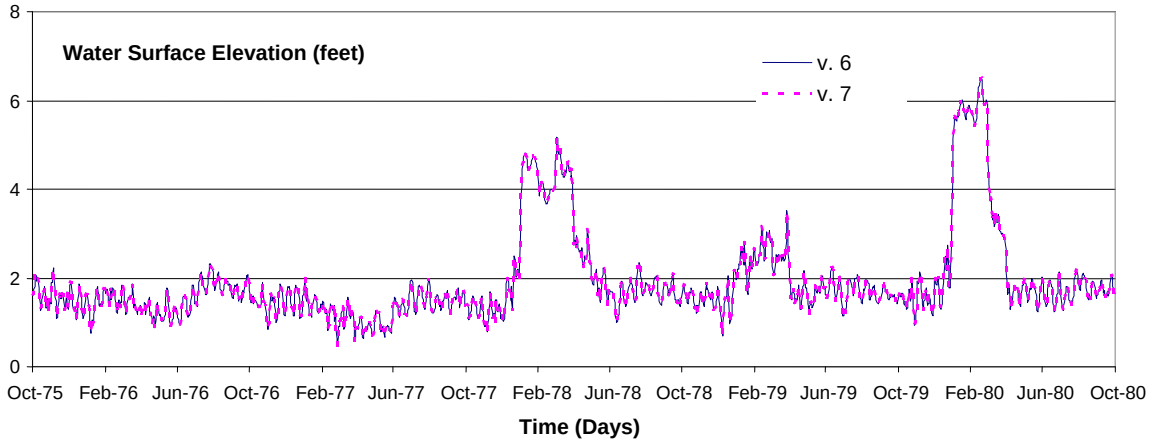


Figure 3-7 Modeled stage comparison in Georgiana Slough

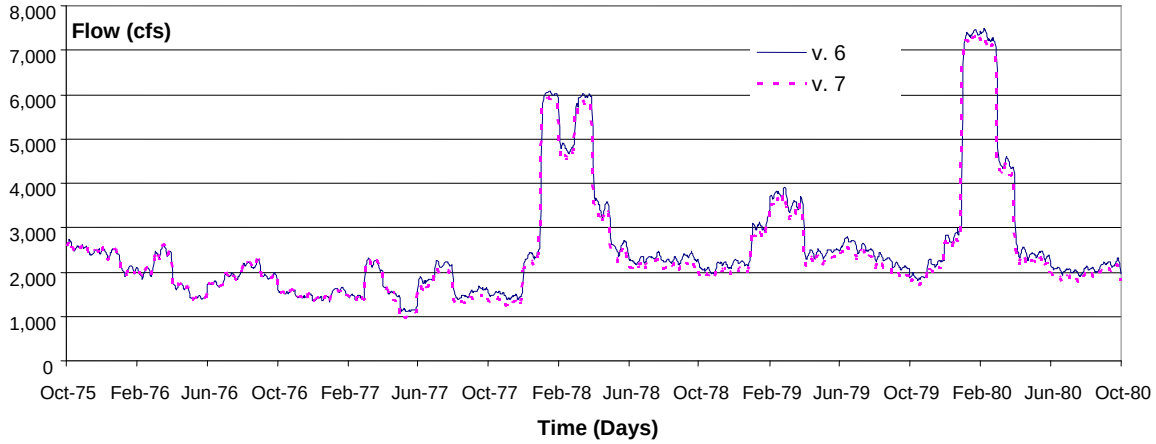


Figure 3-8 Modeled flow comparison in Georgiana Slough

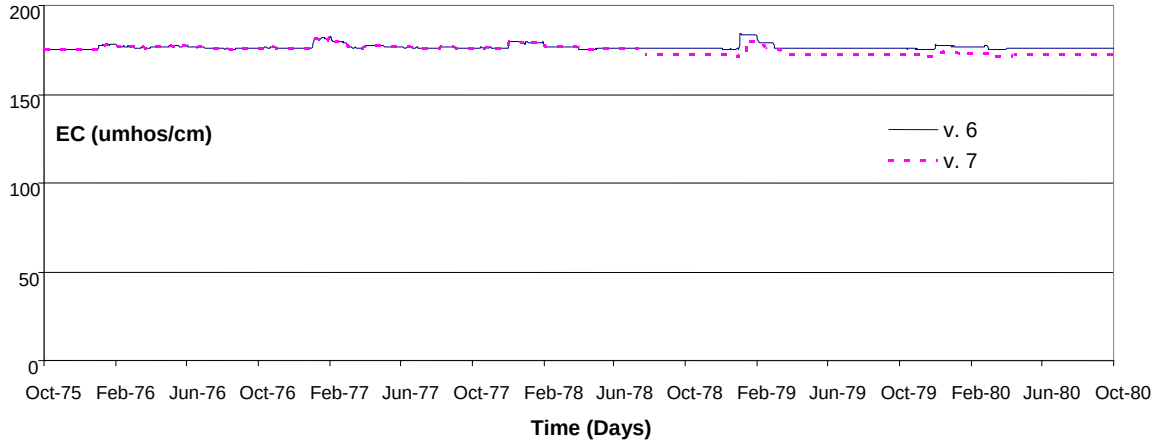


Figure 3-9 Modeled EC comparison in Georgiana Slough

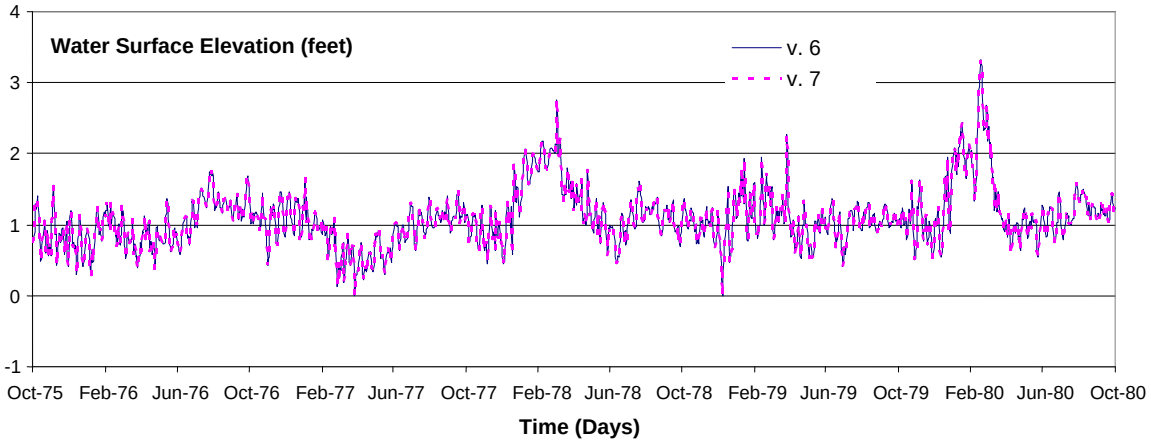


Figure 3-10 Modeled stage comparison in Sacramento River at Rio Vista

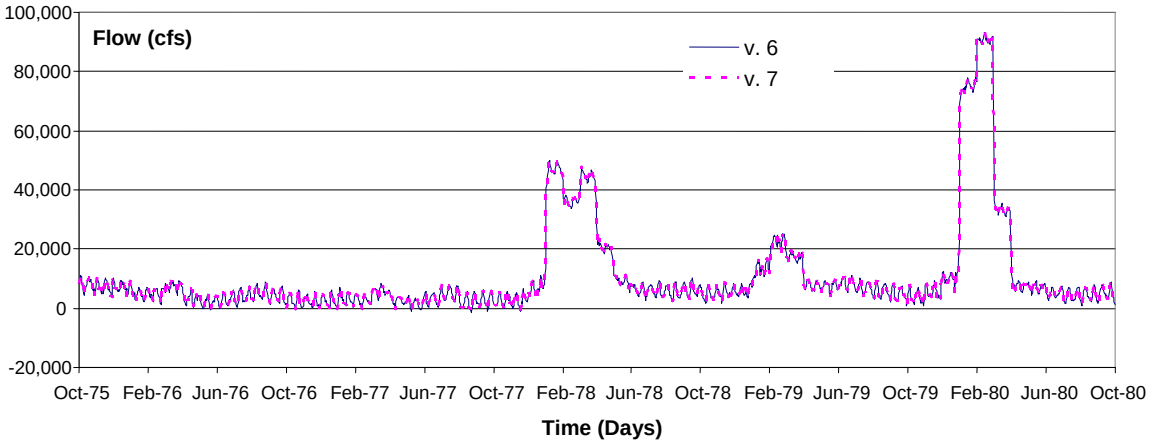


Figure 3-11 Modeled flow comparison in Sacramento River at Rio Vista

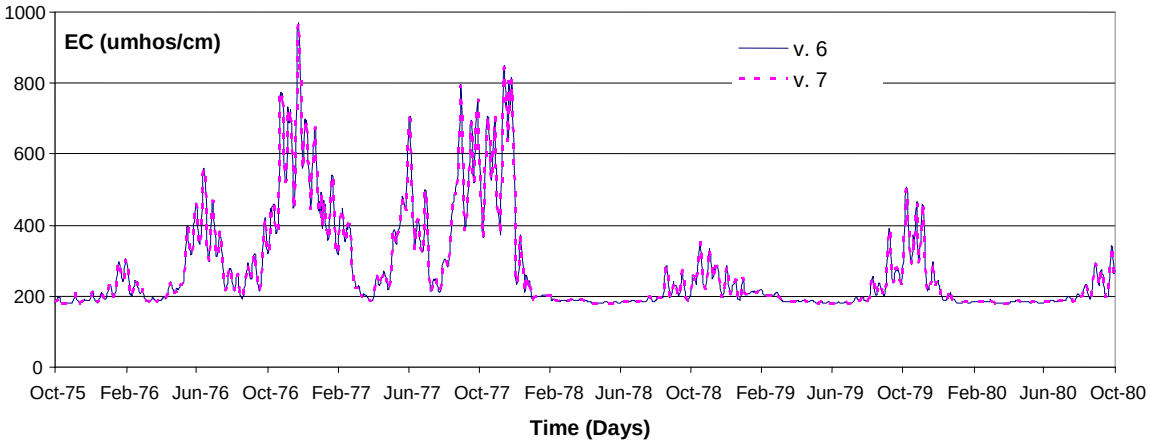


Figure 3-12 Modeled EC comparison in Sacramento River at Rio Vista

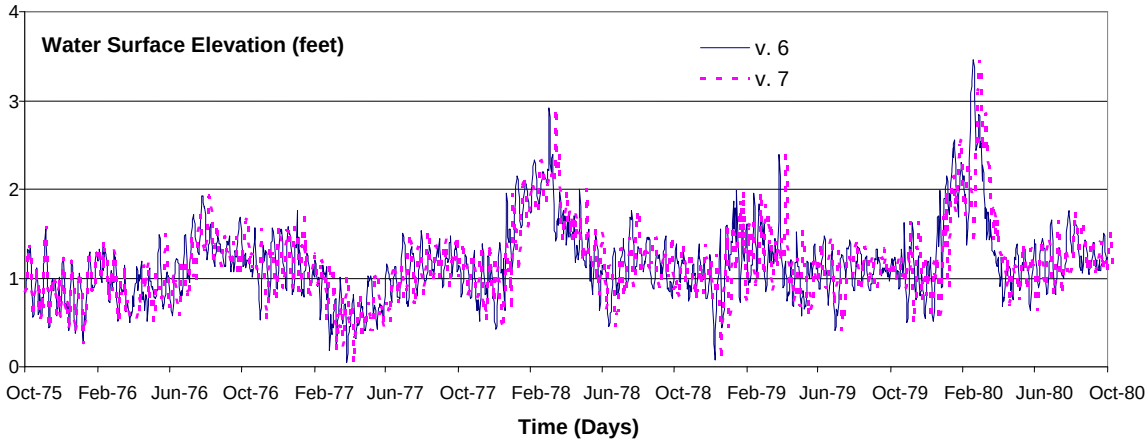


Figure 3-13 Modeled stage comparison in Old River Mouth

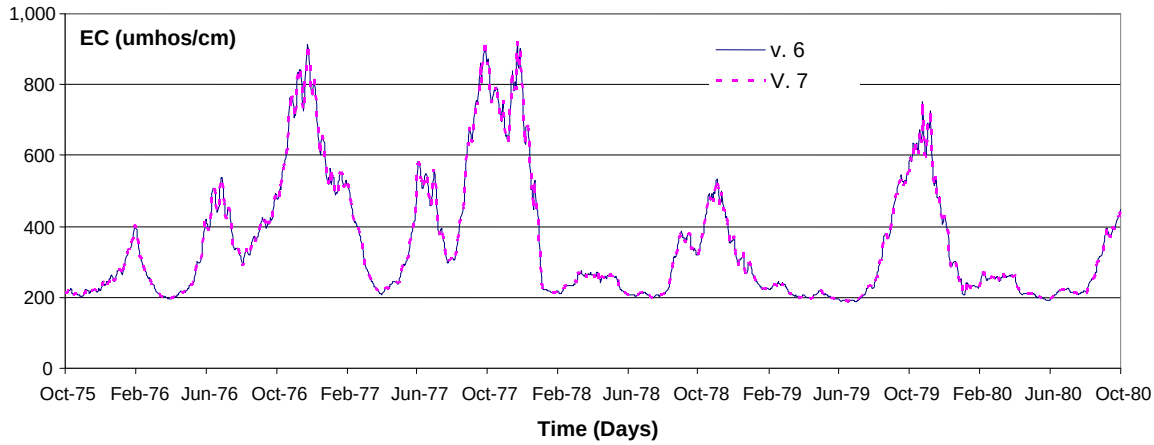


Figure 3-14 Modeled flow comparison in Old River Mouth

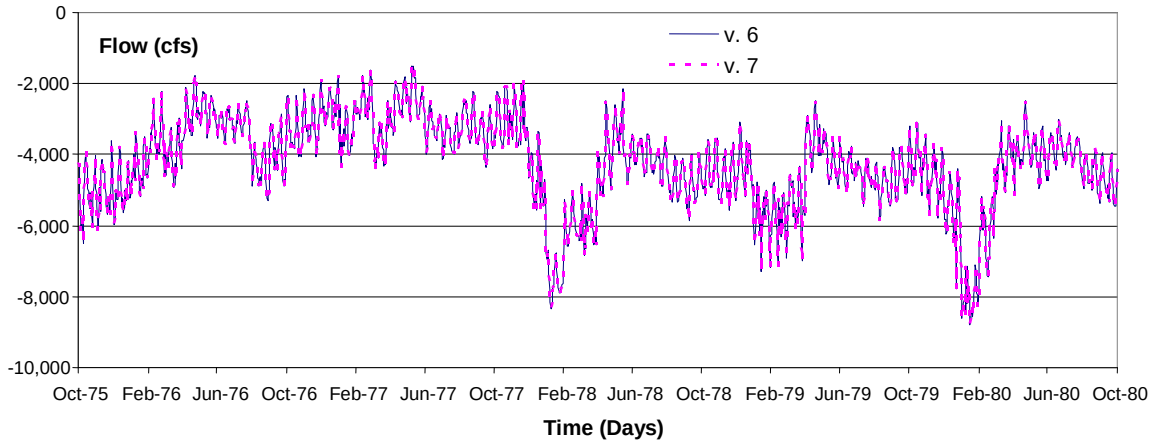


Figure 3-15 Modeled EC comparison in Old River Mouth

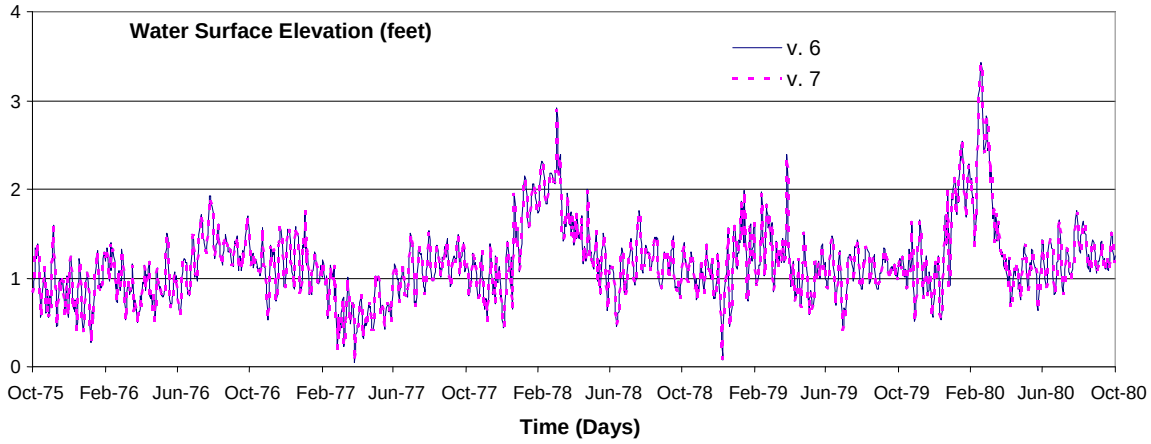


Figure 3-16 Modeled stage comparison at San Joaquin River in San Andreas Landing

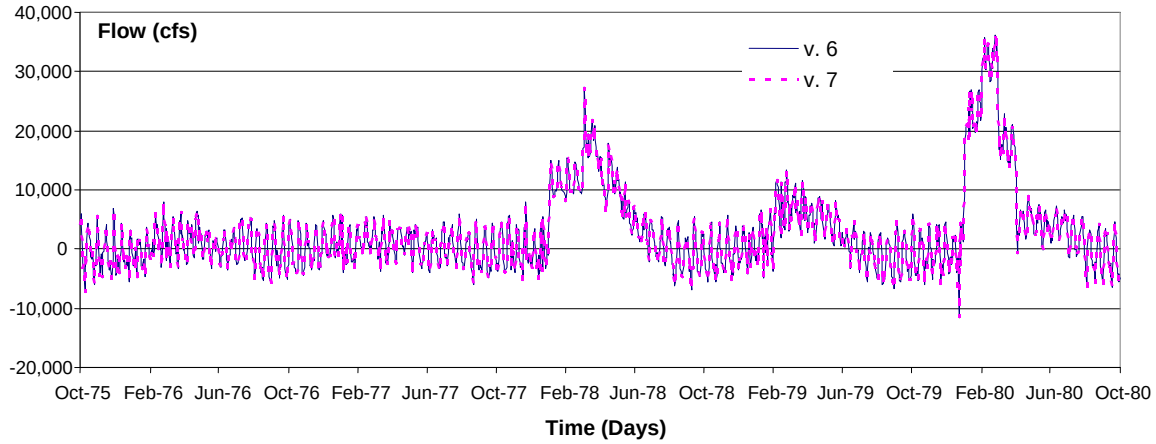


Figure 3-17 Modeled flow comparison at San Joaquin River in San Andreas Landing

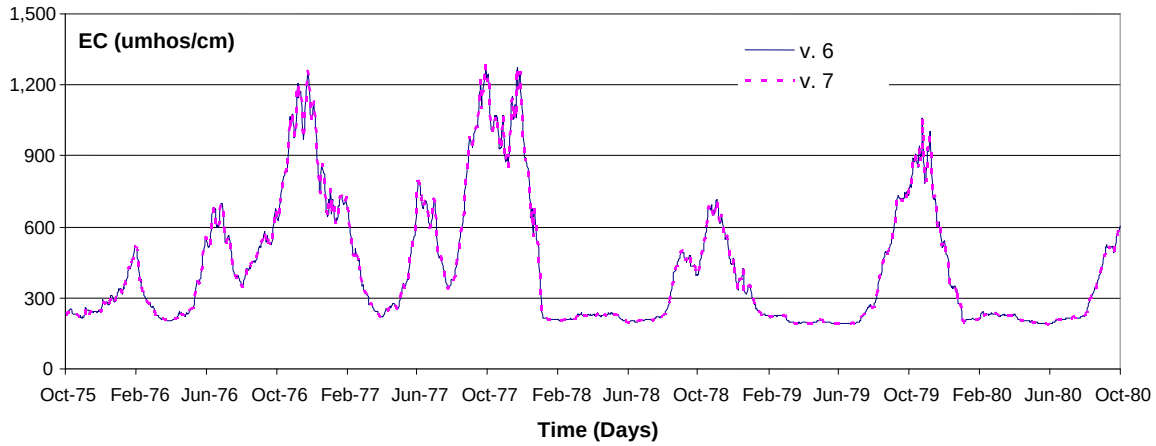


Figure 3-18 Modeled EC comparison at San Joaquin River in San Andreas Landing

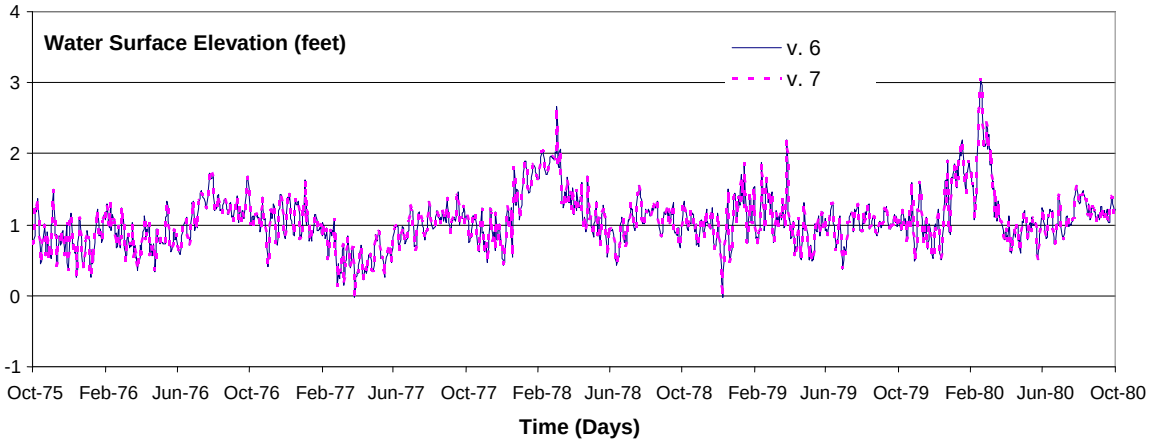


Figure 3-19 Modeled stage comparison in Sacramento River at Emmaton

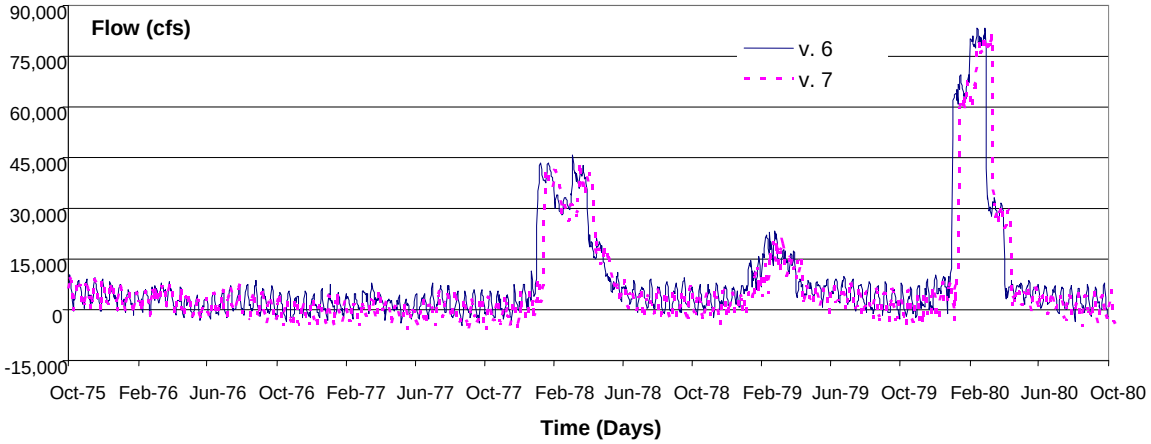


Figure 3-20 Modeled flow comparison in Sacramento River at Emmaton

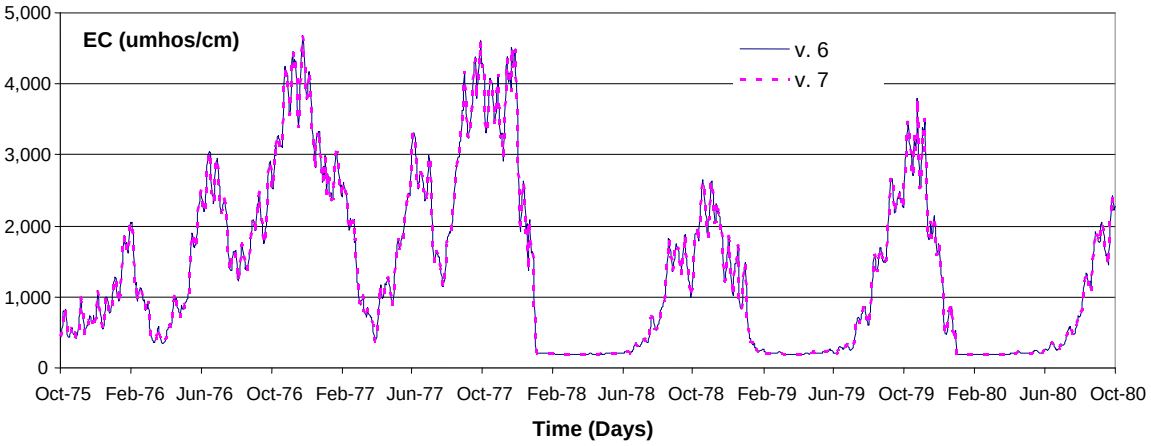


Figure 3-21 Modeled EC comparison in Sacramento River at Emmaton

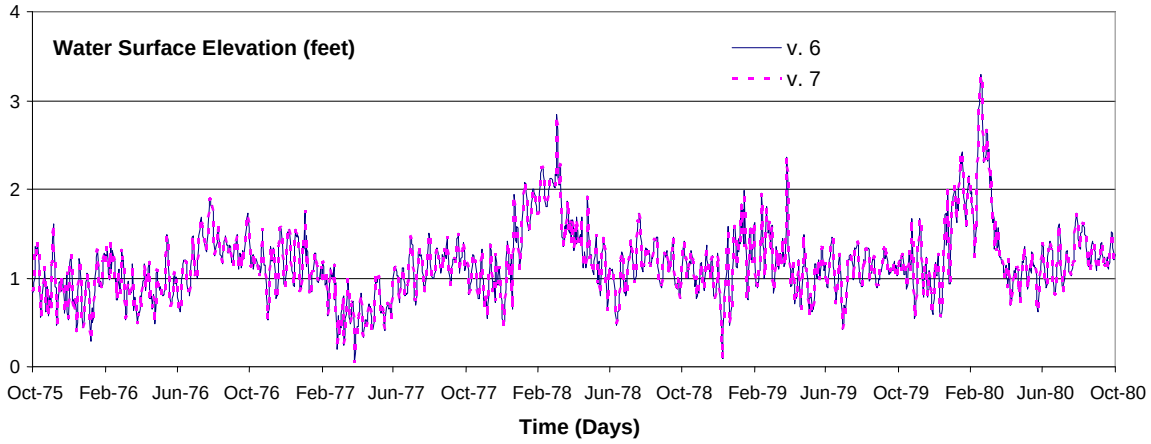


Figure 3-22 Modeled stage comparison in San Joaquin River at Jersey Point

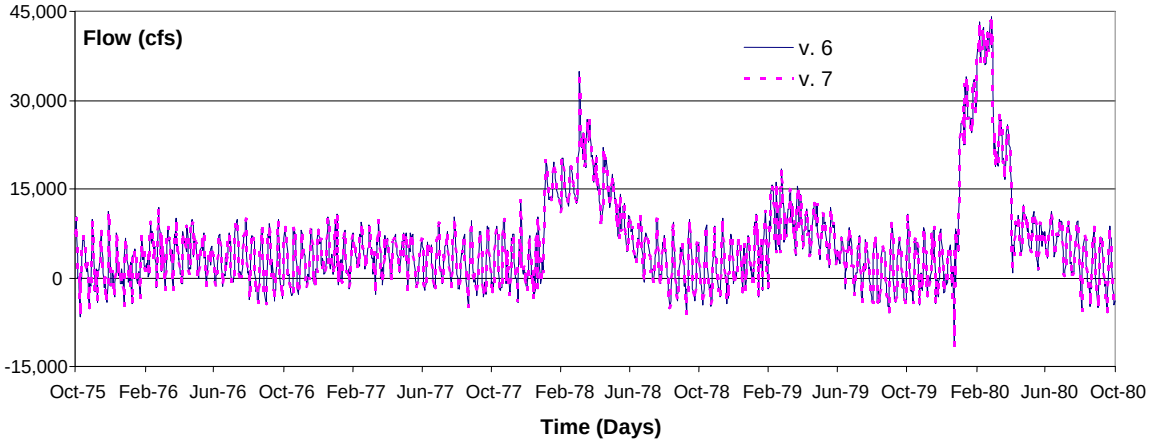


Figure 3-23 Modeled flow comparison in San Joaquin River at Jersey Point

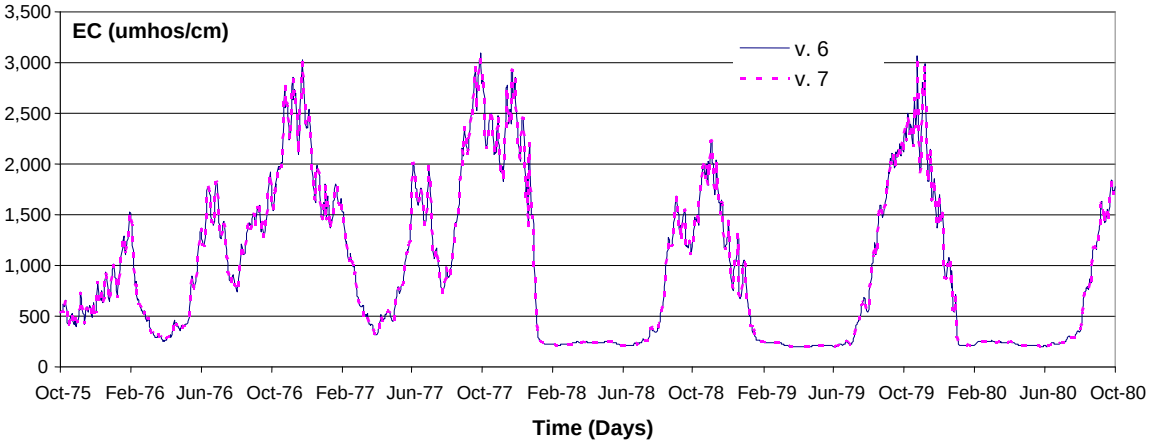


Figure 3-24 Modeled EC comparison in San Joaquin River at Jersey Point

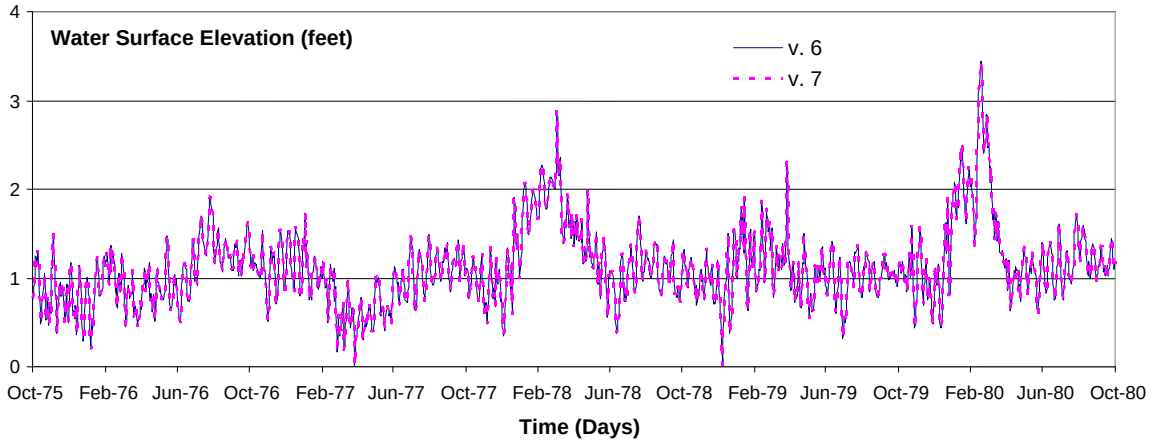


Figure 3-25 Modeled stage comparison in Rock Slough

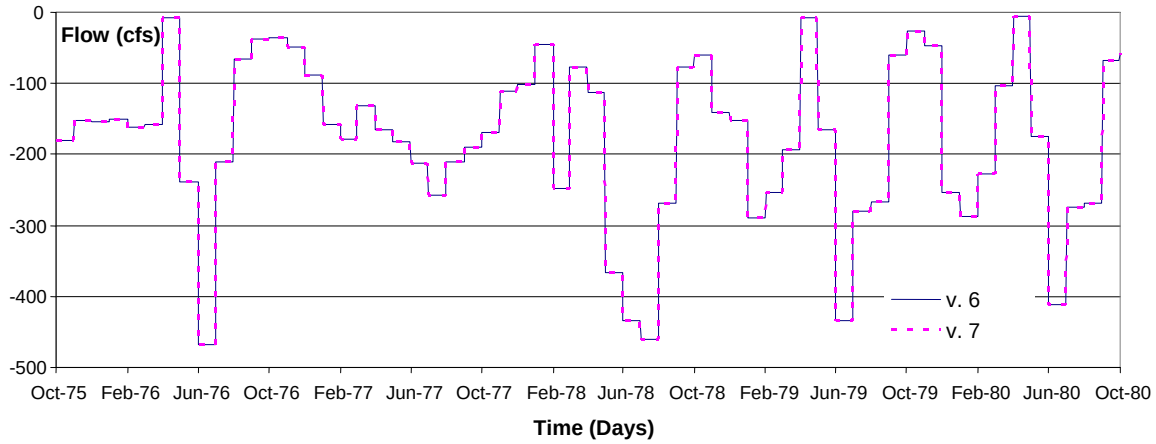


Figure 3-26 Modeled flow comparison in Rock Slough

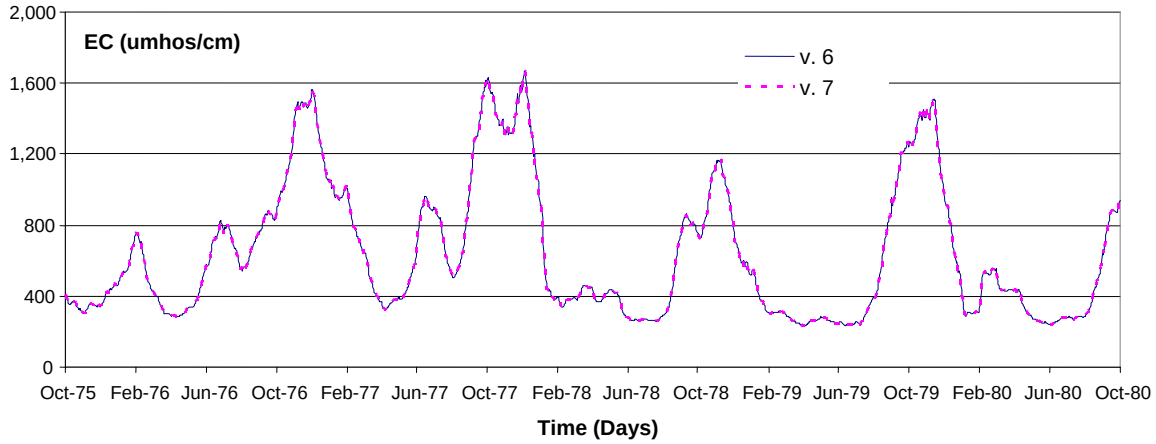


Figure 3-27 Modeled EC comparison in Rock Slough

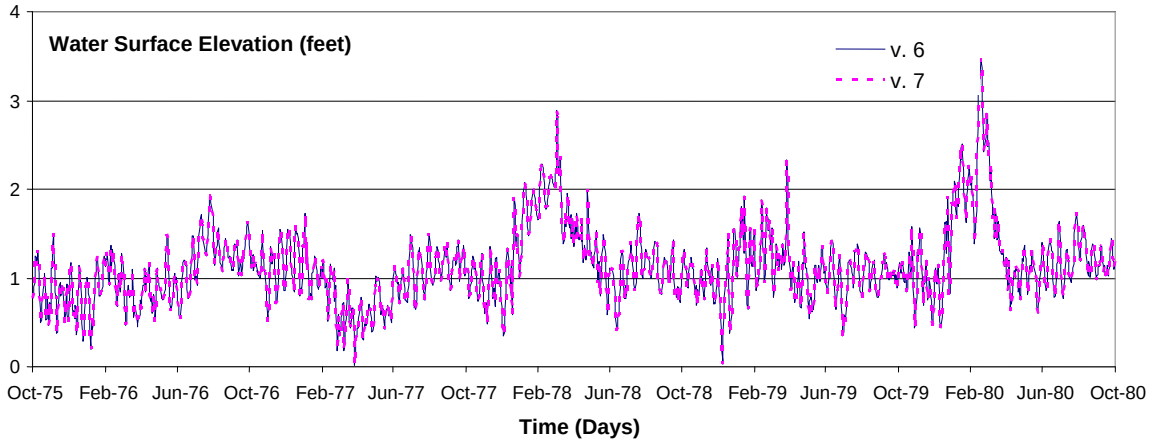


Figure 3-28 Modeled stage comparison in Old River at Bacon Island

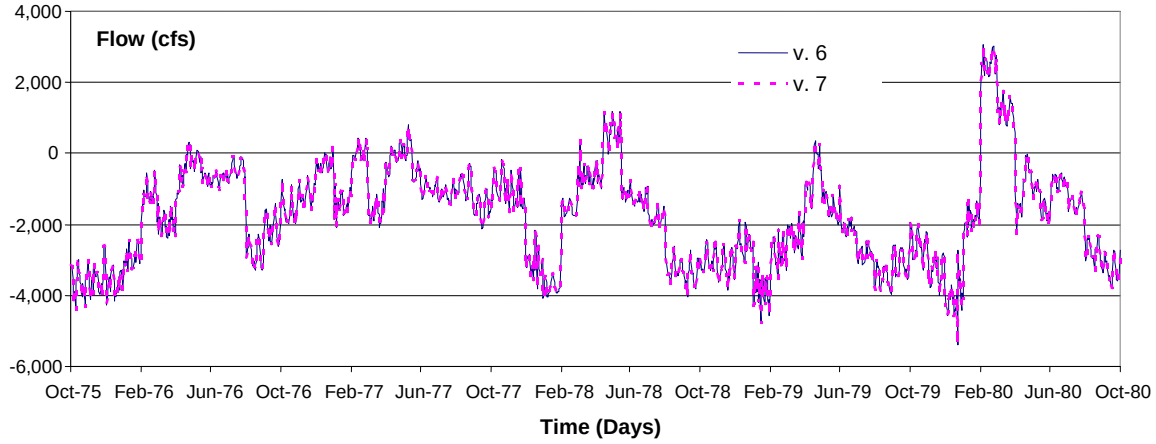


Figure 3-29 Modeled flow comparison in Old River at Bacon Island

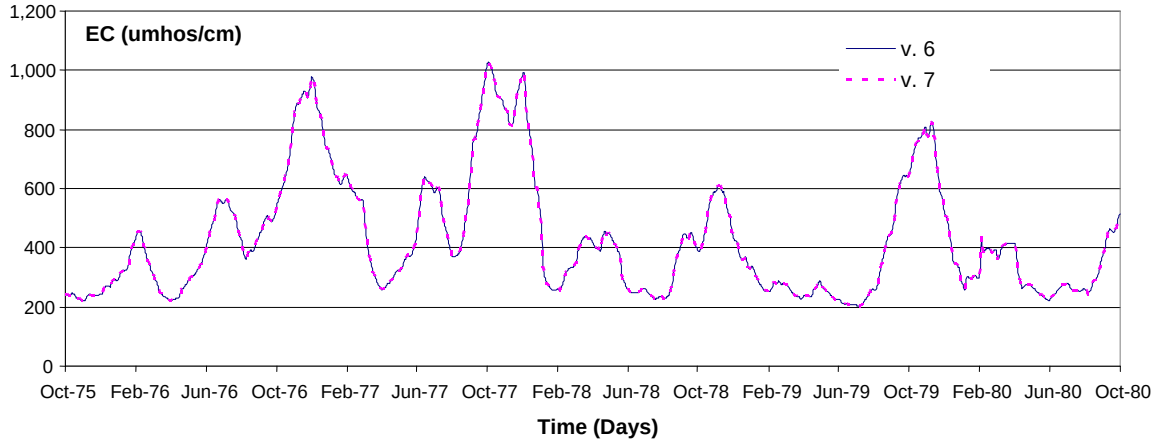


Figure 3-30 Modeled EC comparison in Old River at Bacon Island

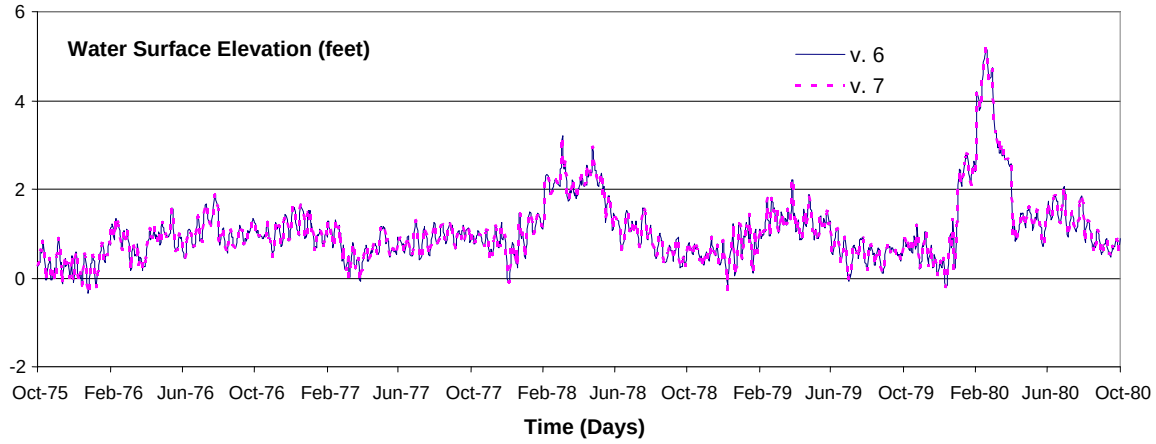


Figure 3-31 Modeled stage comparison in Old River at Tracy Boulevard

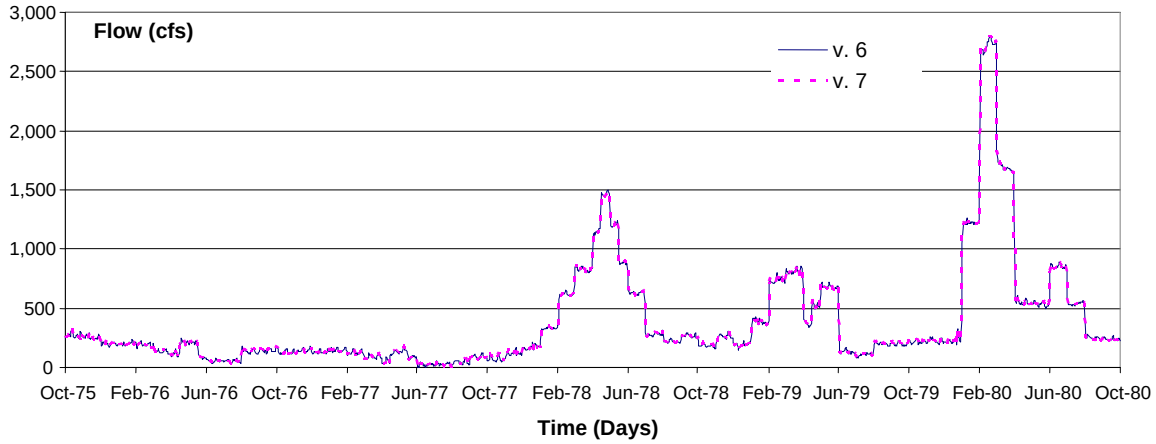


Figure 3-32 Modeled flow comparison in Old River at Tracy Boulevard

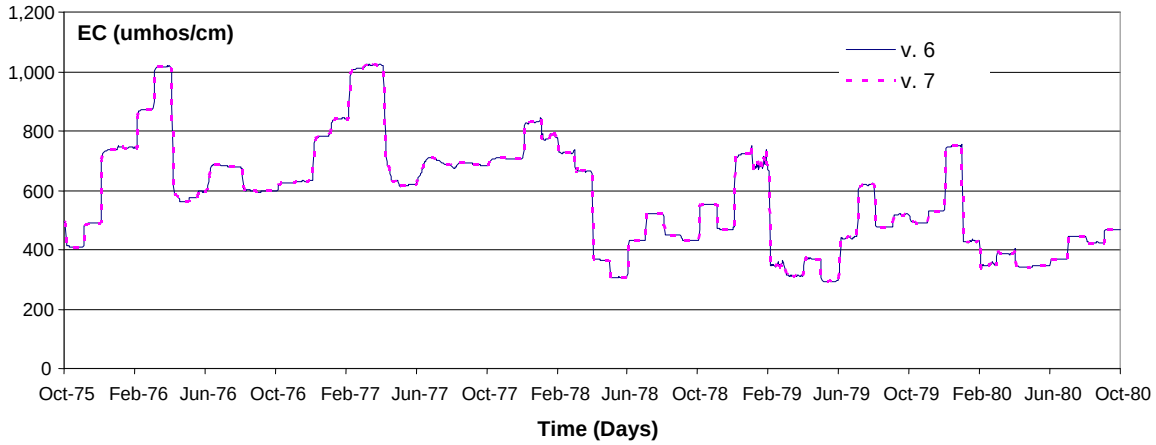


Figure 3-33 Modeled EC comparison in Old River at Tracy Boulevard

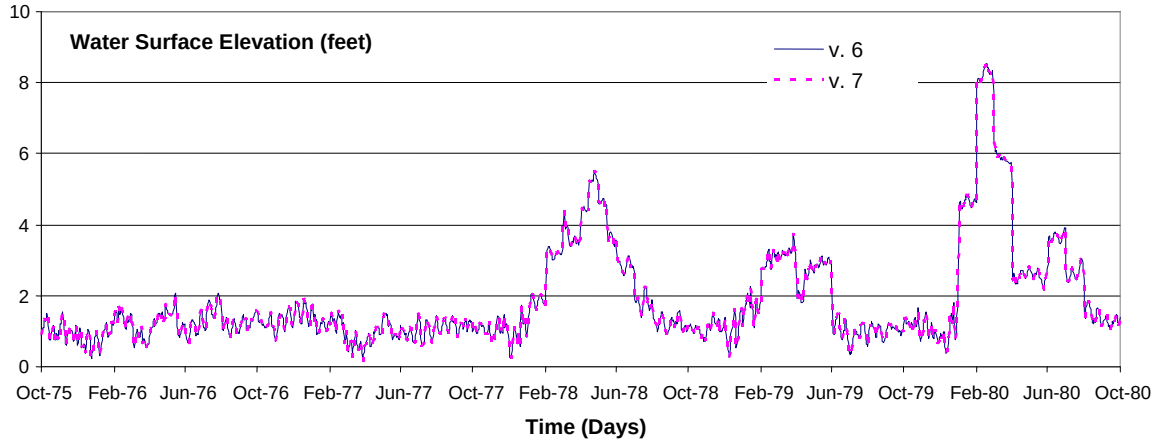


Figure 3-34 Modeled stage comparison in Old River at Middle River

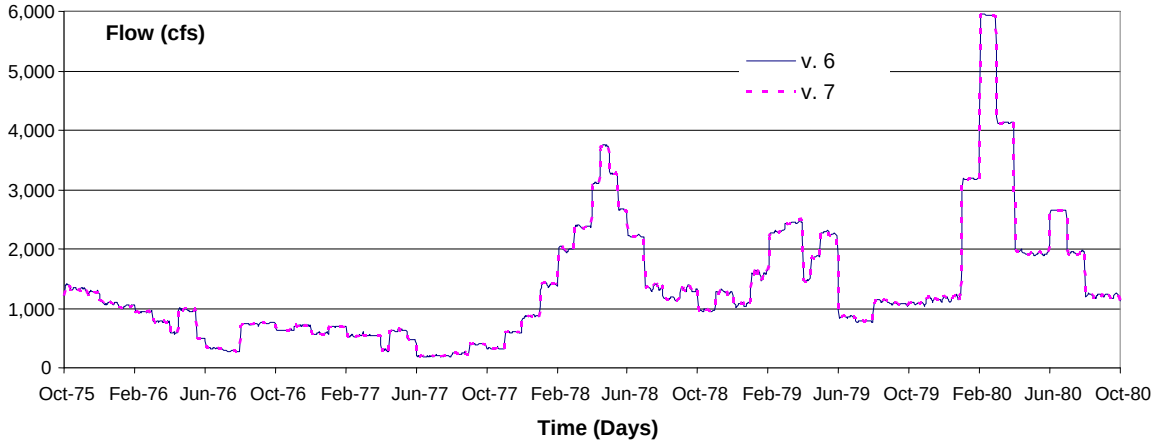


Figure 3-35 Modeled flow comparison in Old River at Middle River

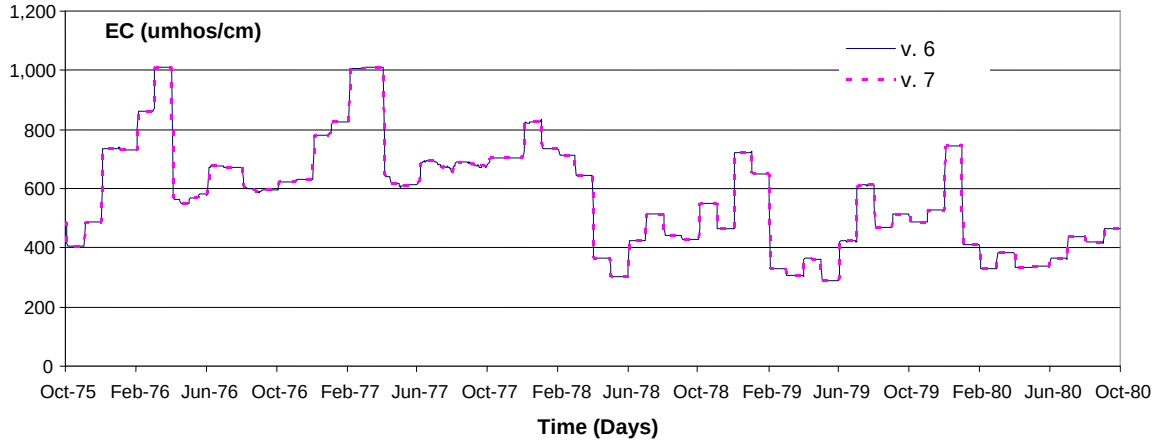


Figure 3-36 Modeled EC comparison in Old River at Middle River

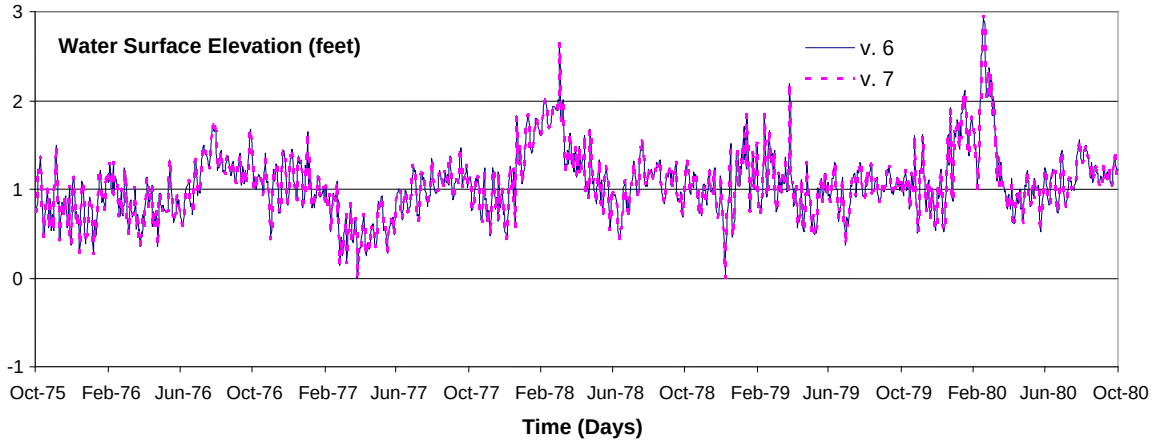


Figure 3-37 Modeled stage comparison in San Joaquin River at Antioch

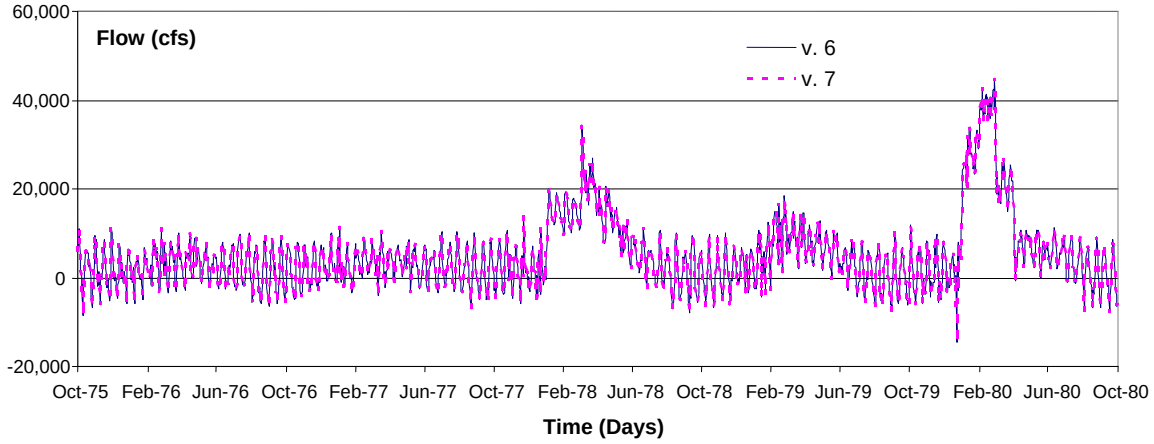


Figure 3-38 Modeled flow comparison in San Joaquin River at Antioch

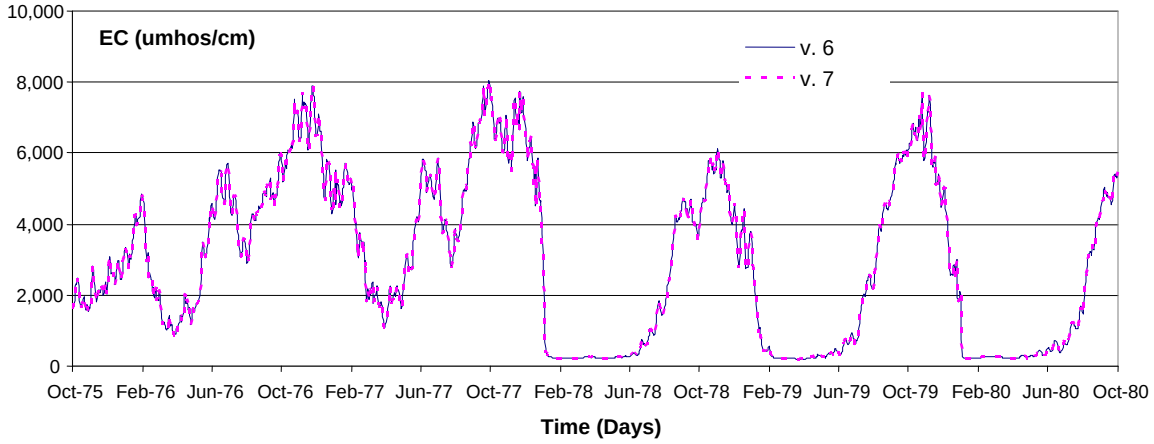


Figure 3-39 Modeled EC comparison in San Joaquin River at Antioch

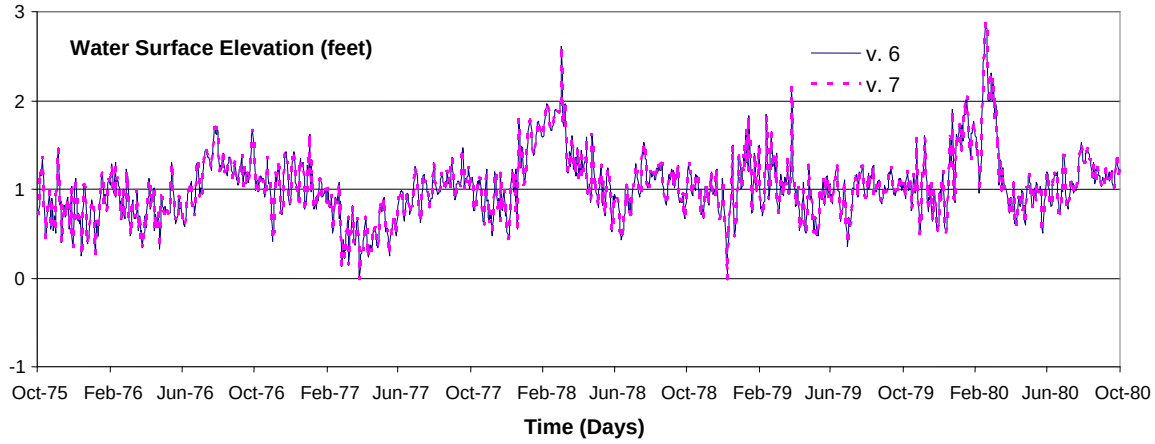


Figure 3-40 Modeled stage comparison in Sacramento River at Collinsville

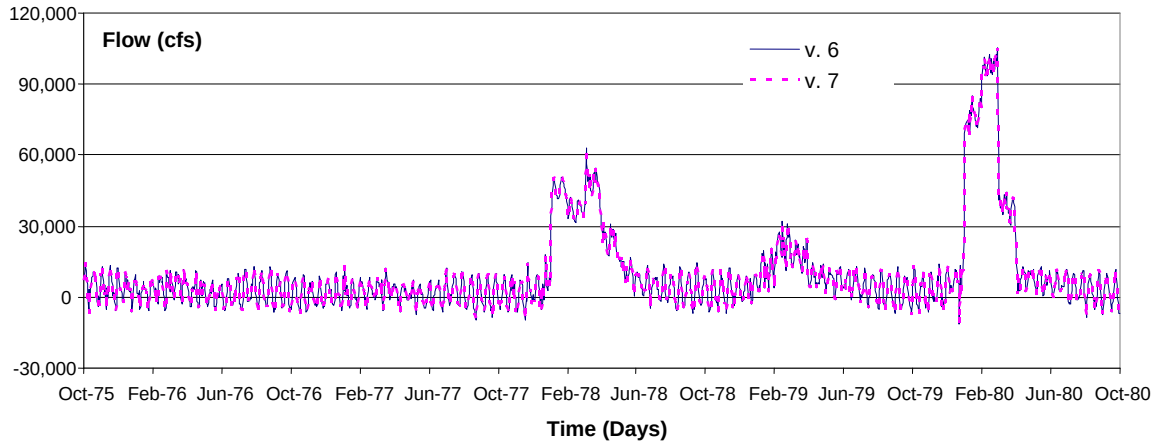


Figure 3-41 Modeled flow comparison in Sacramento River at Collinsville

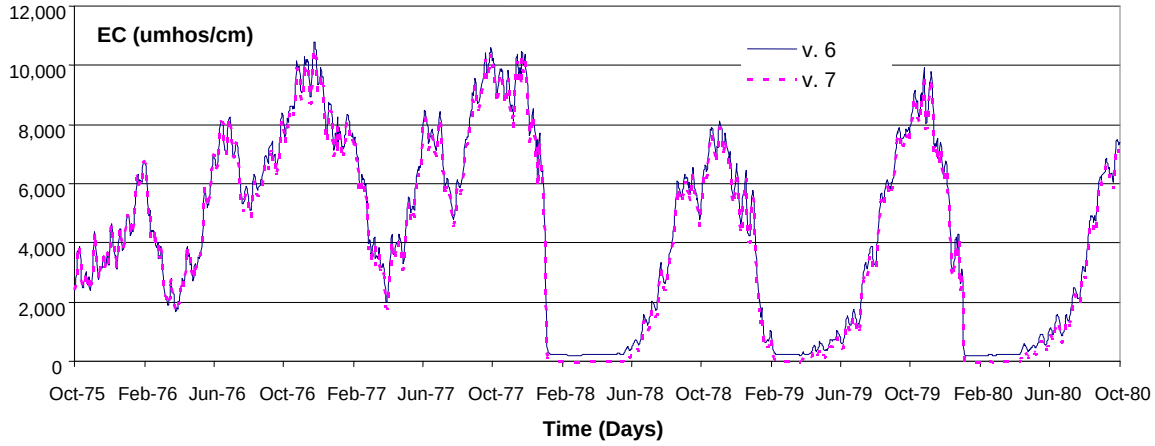


Figure 3-42 Modeled EC comparison in Sacramento River at Collinsville

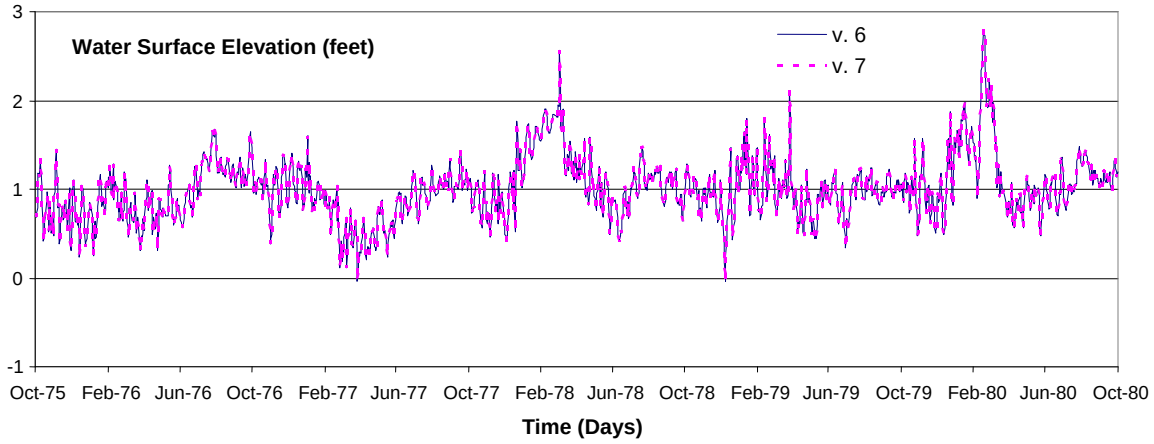


Figure 3-43 Modeled stage comparison in Montezuma Slough

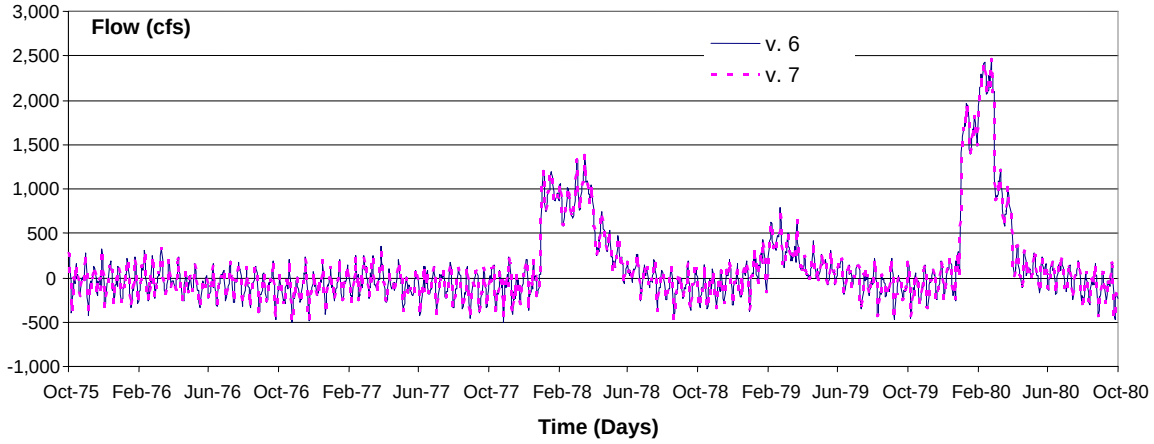


Figure 3-44 Modeled flow comparison in Montezuma Slough

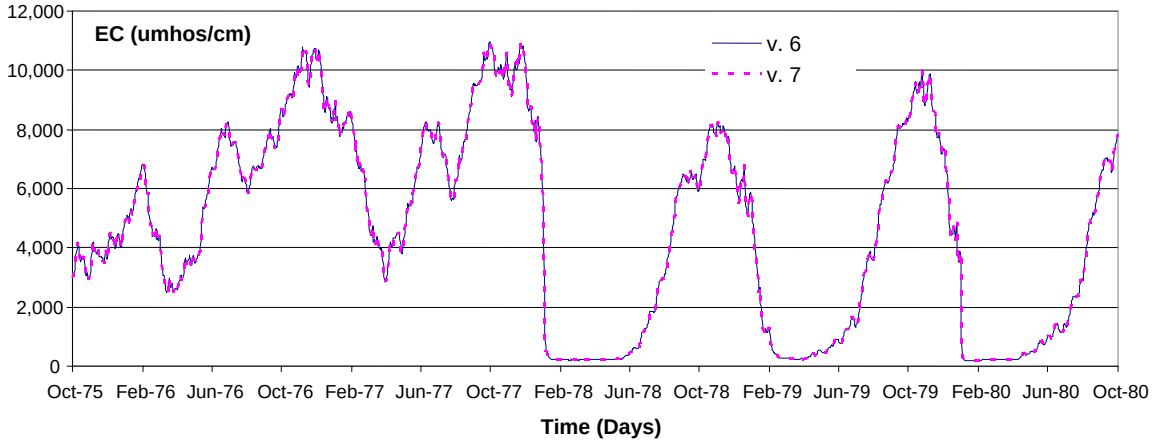


Figure 3-45 Modeled EC comparison in Montezuma Slough

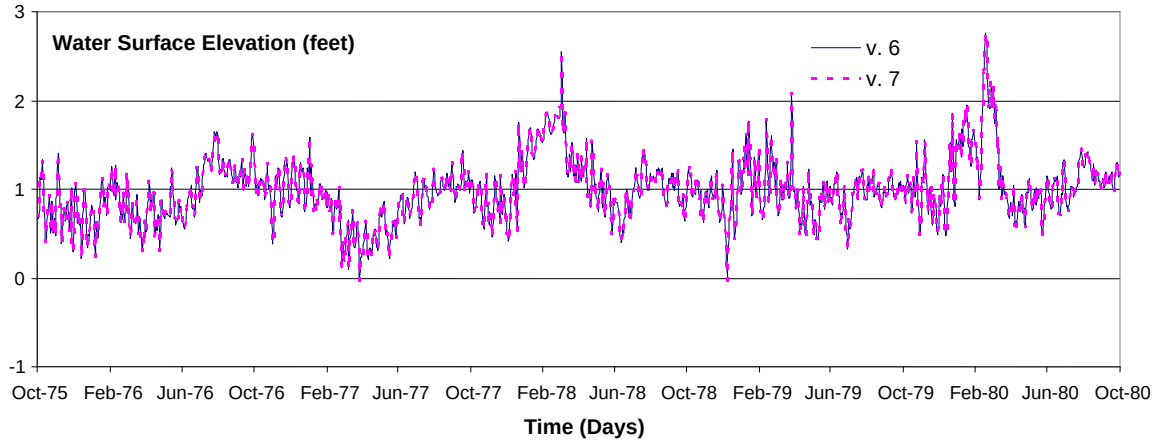


Figure 3-46 Modeled stage comparison in Sacramento River at Mallard

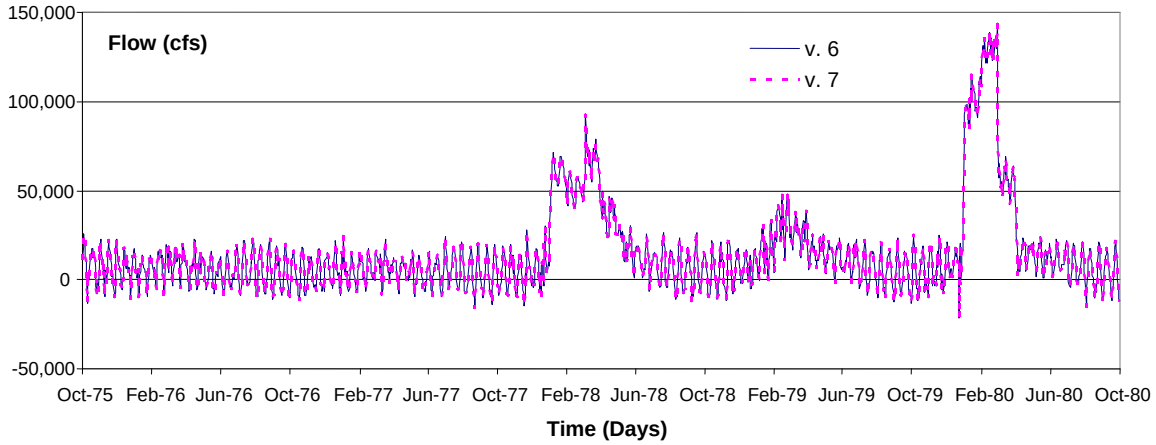


Figure 3-47 Modeled flow comparison in Sacramento River at Mallard

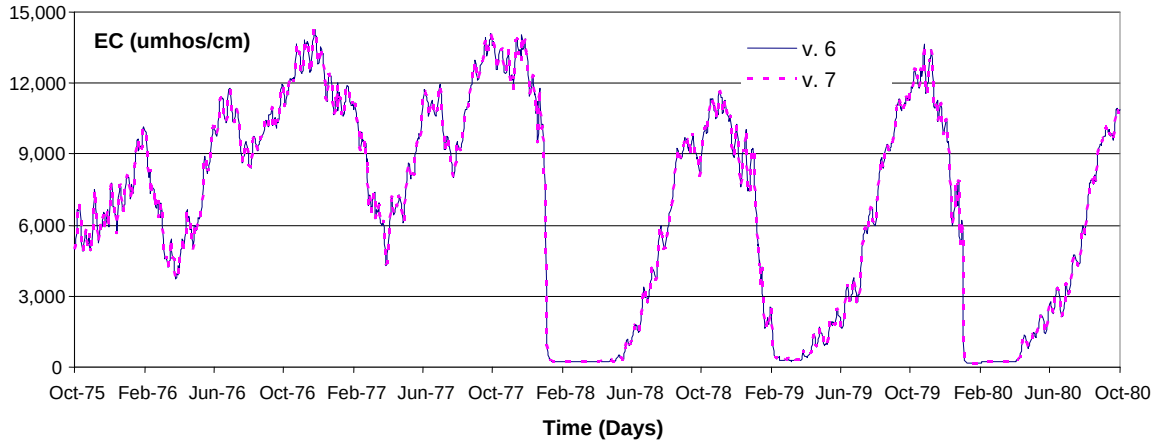


Figure 3-48 Modeled EC comparison in Sacramento River at Mallard

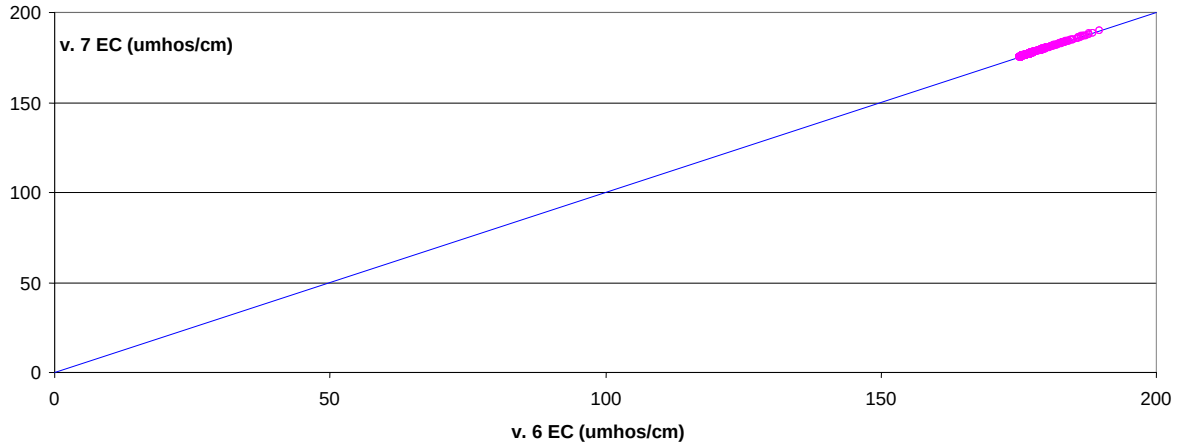


Figure 3-49 Comparison of DSM2 version 6 and 7 modeled EC in Sutter Slough

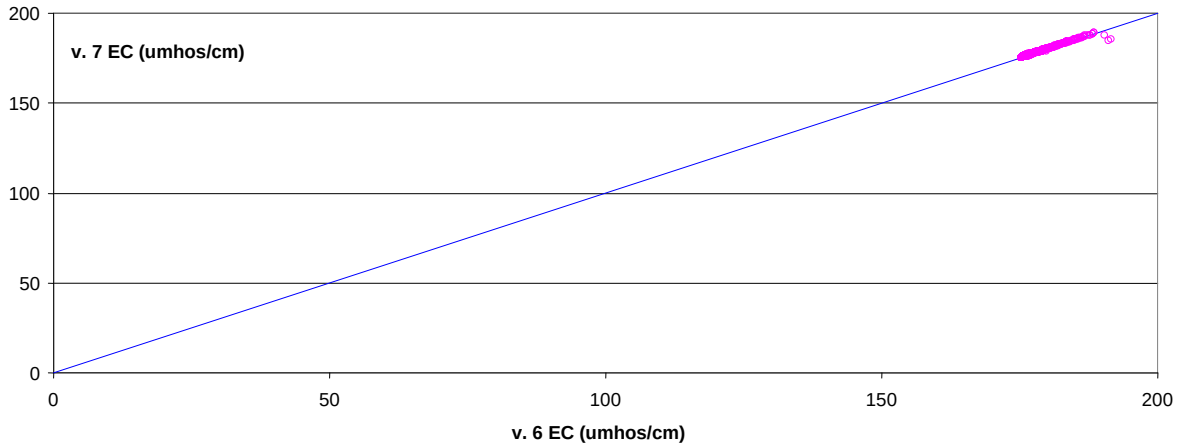


Figure 3-50 Comparison of DSM2 version 6 and 7 modeled EC in Steamboat Slough

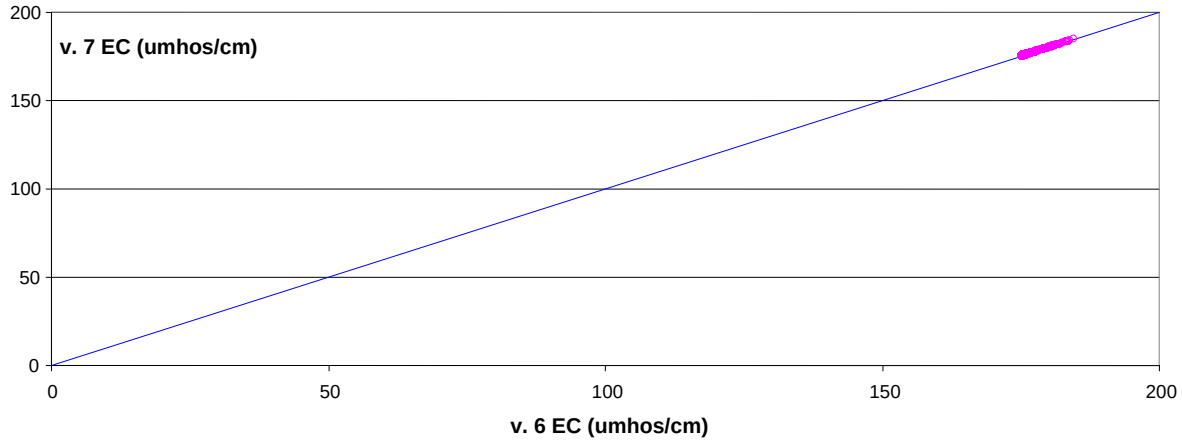


Figure 3-51 Comparison of DSM2 version 6 and 7 modeled EC in Georgiana Slough

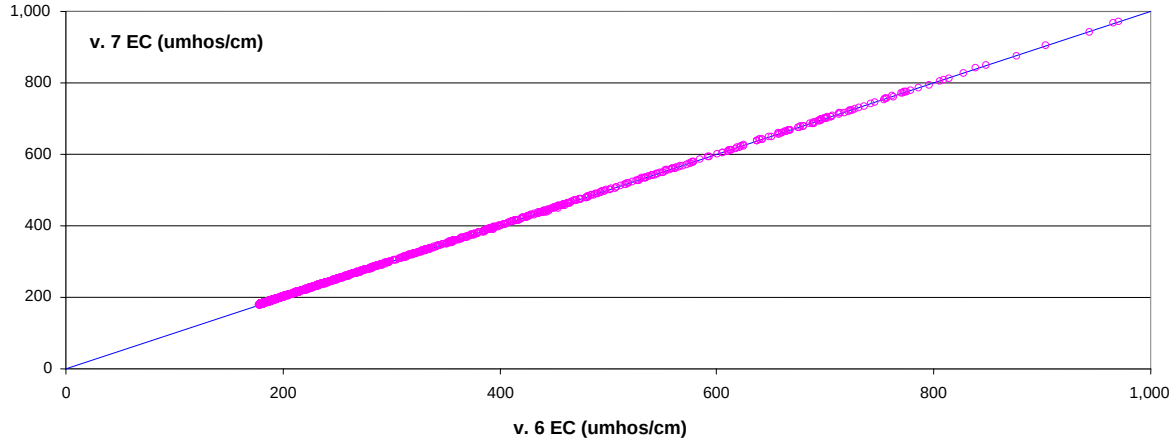


Figure 3-52 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Rio Vista

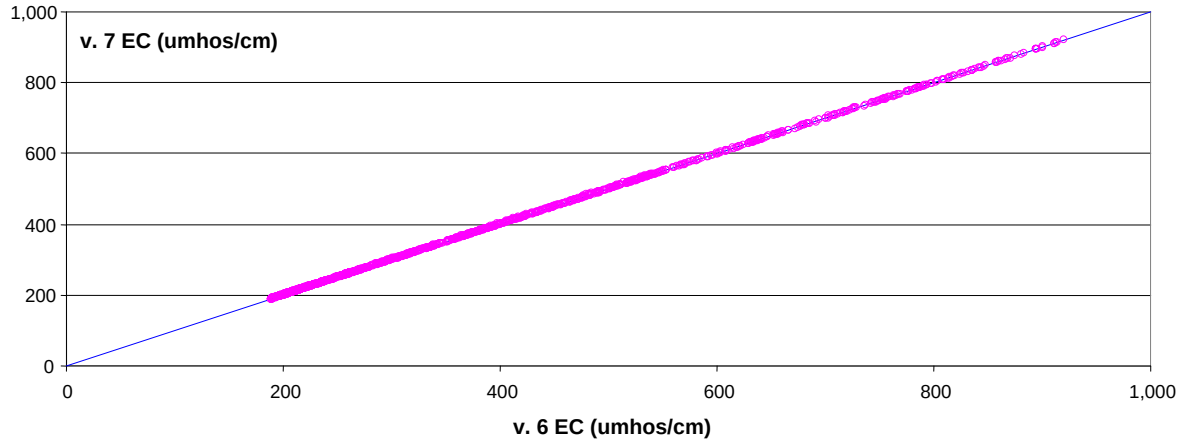


Figure 3-53 Comparison of DSM2 version 6 and 7 modeled EC in Old River Mouth

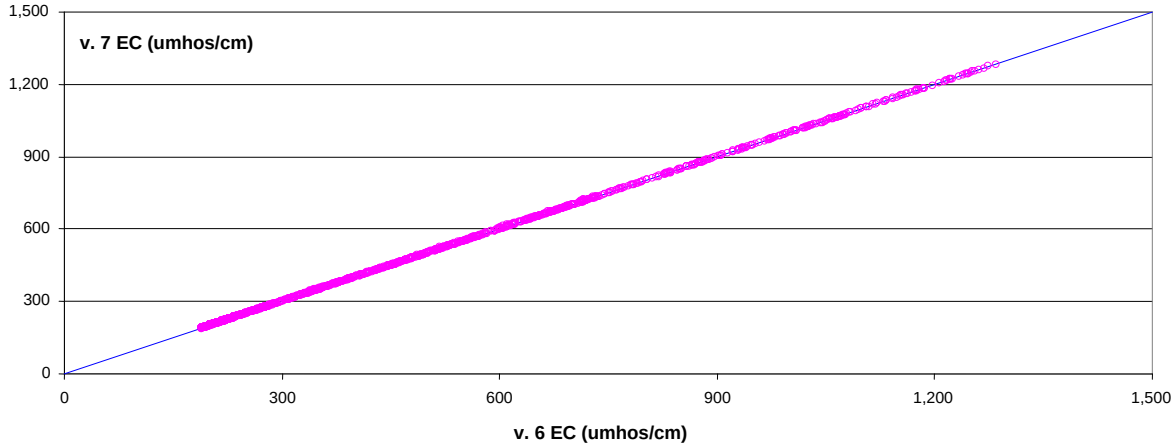


Figure 3-54 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at San Andreas Landing

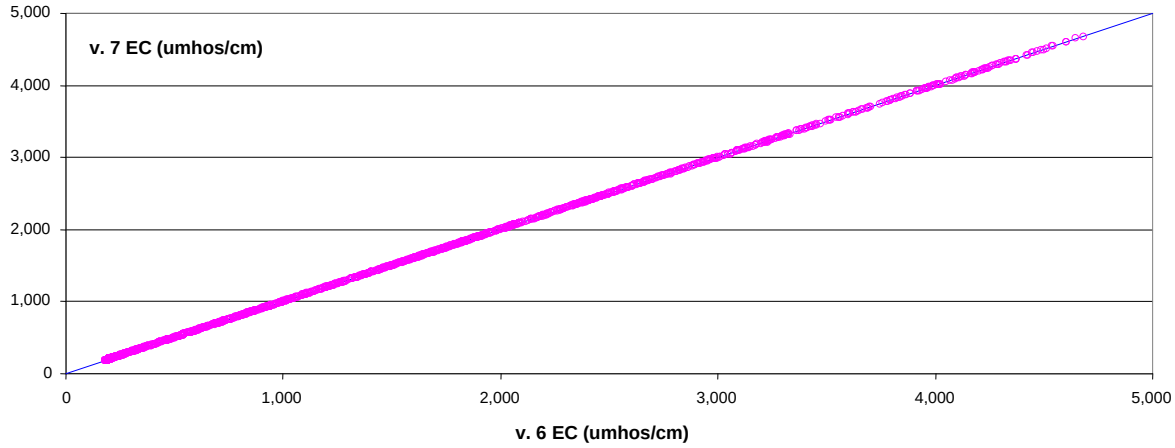


Figure 3-55 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Emmaton

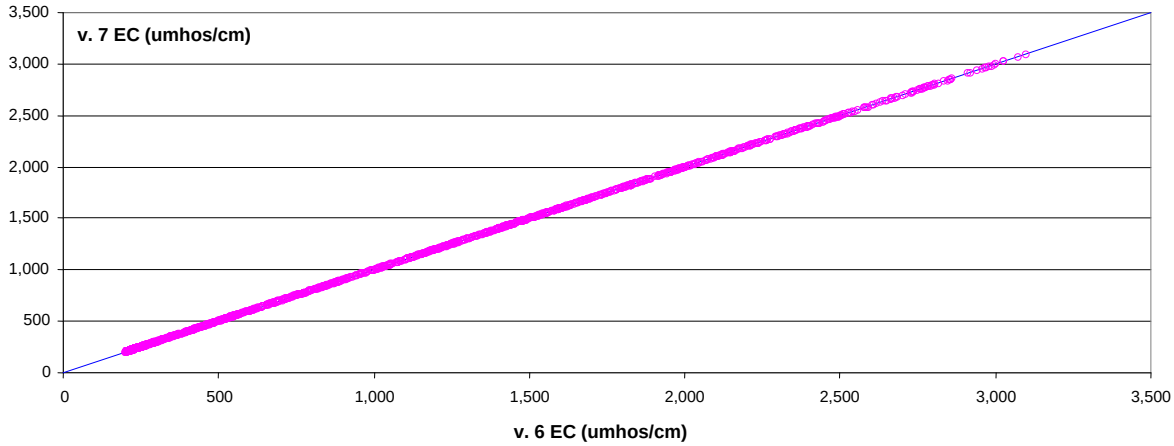


Figure 3-56 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at Jersey Point

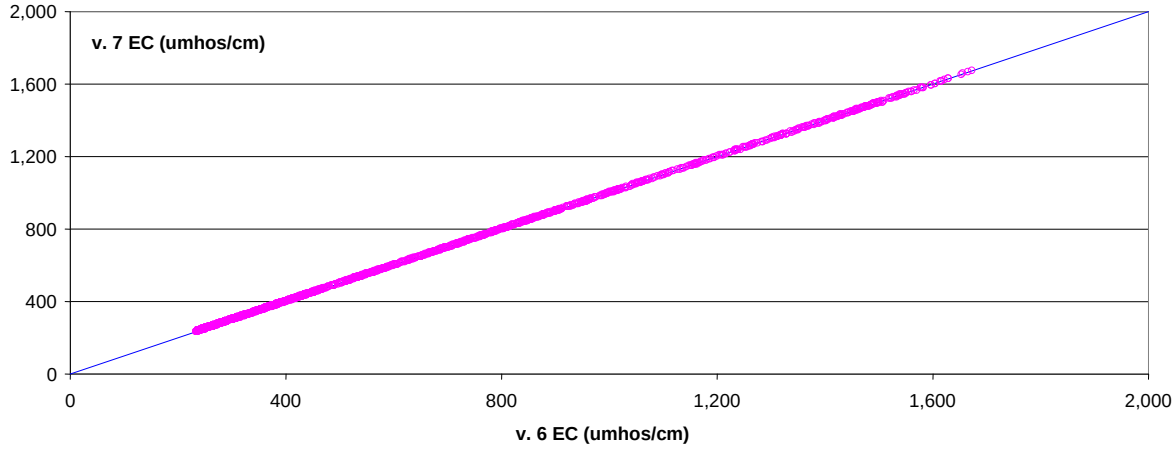


Figure 3-57 Comparison of DSM2 version 6 and 7 modeled EC in Rock Slough

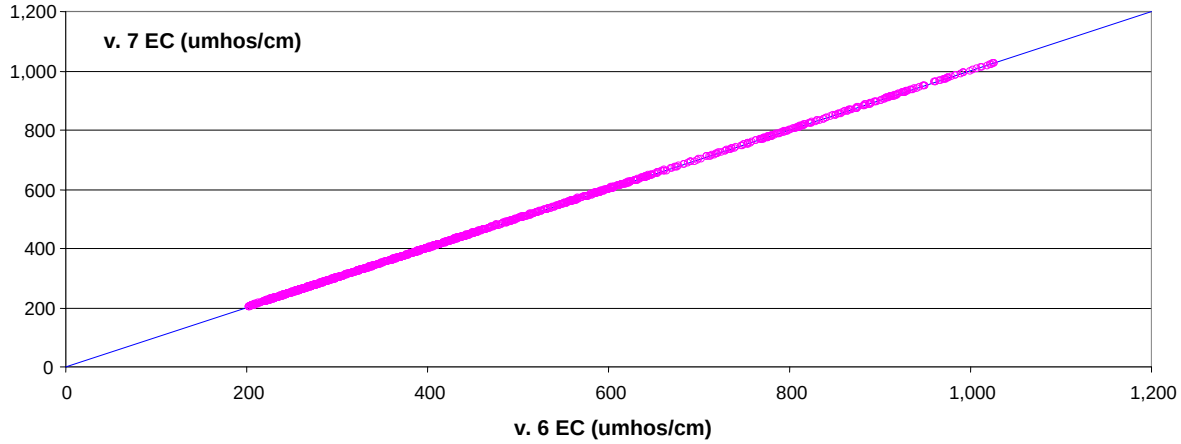


Figure 3-58 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Bacon Island

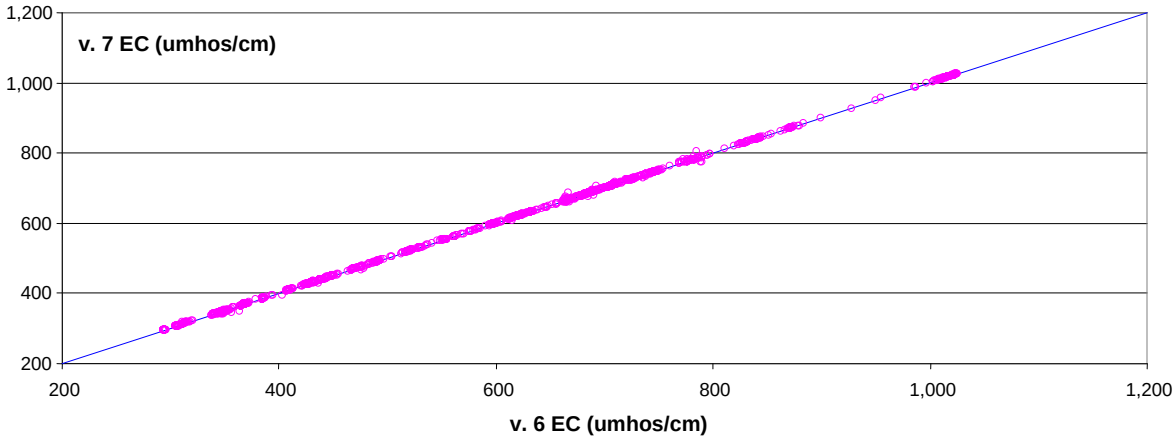


Figure 3-59 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Tracy Boulevard

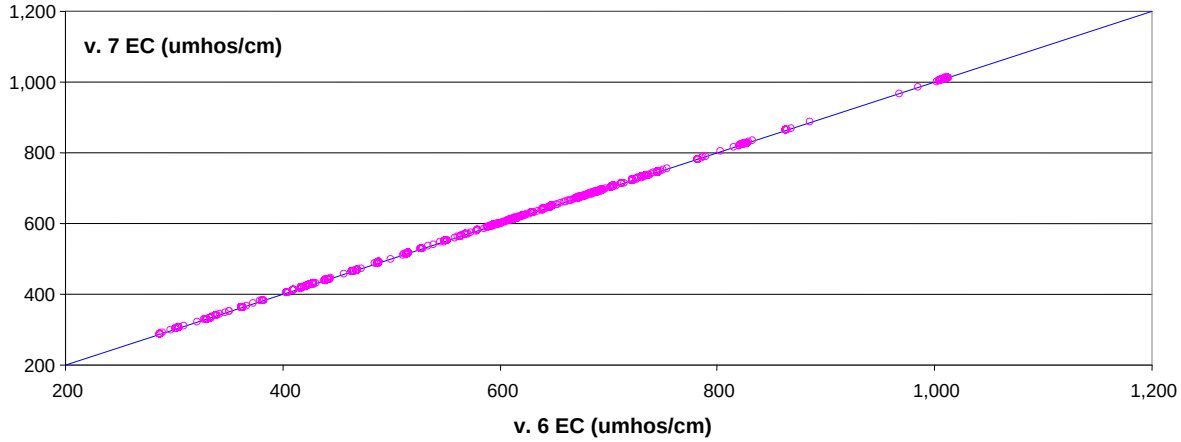


Figure 3-60 Comparison of DSM2 version 6 and 7 modeled EC in Old River at Middle River

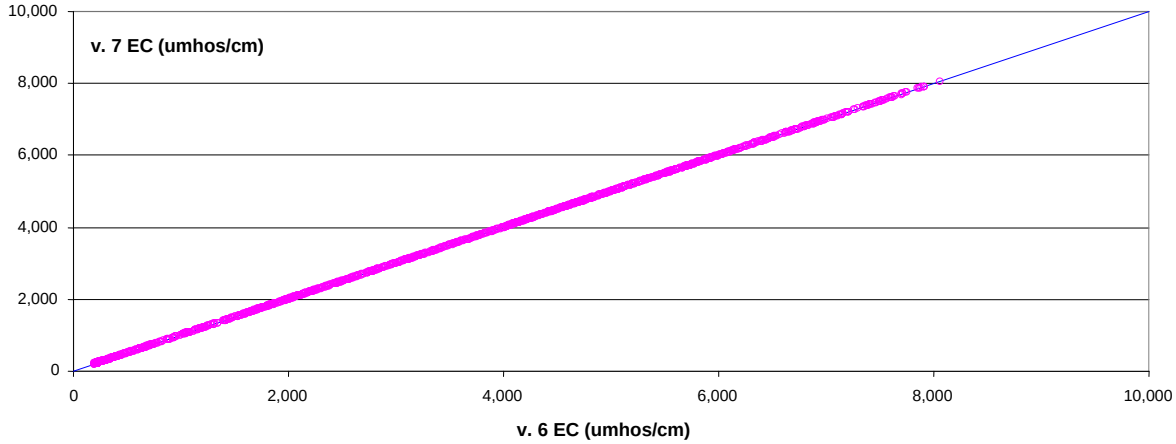


Figure 3-61 Comparison of DSM2 version 6 and 7 modeled EC in San Joaquin River at Antioch

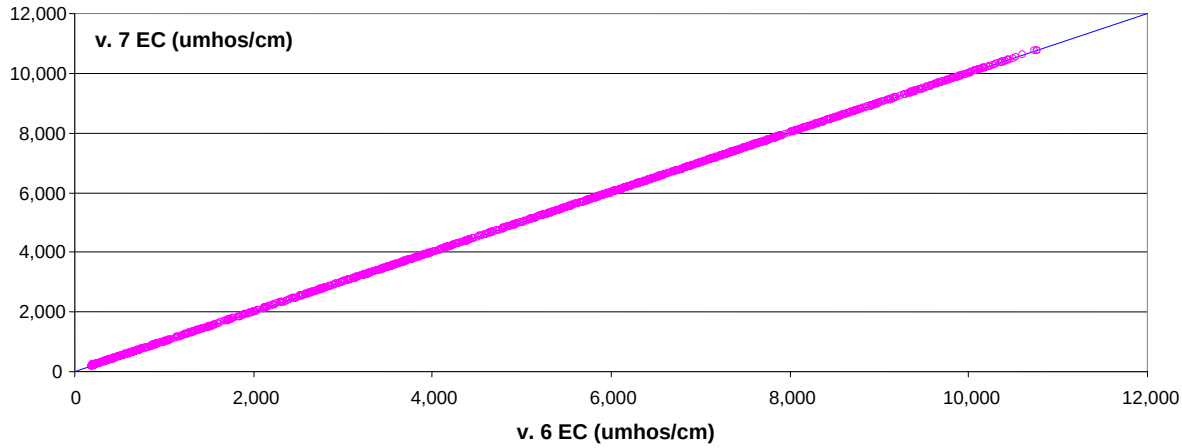


Figure 3-62 Comparison of DSM2 version 6 and 7 modeled EC in Sacramento River at Collinsville

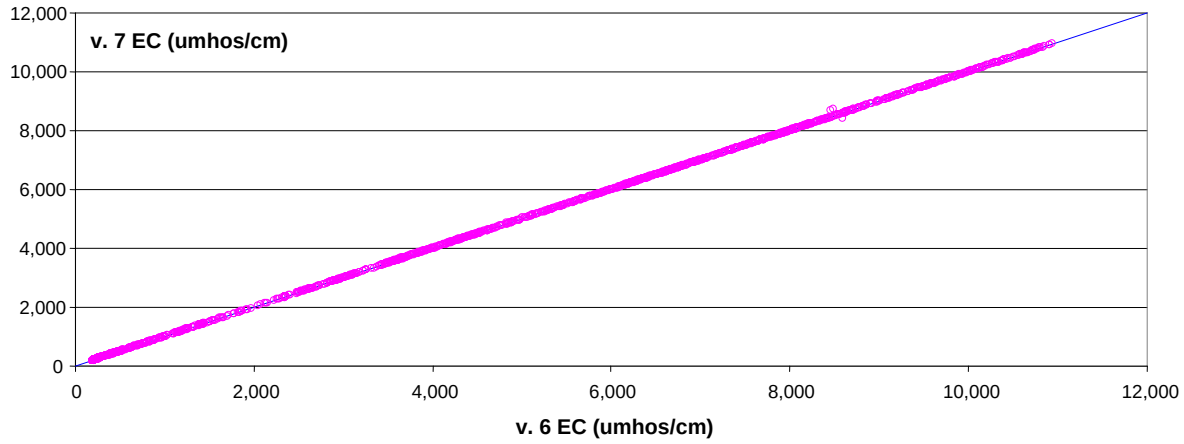


Figure 3-63 Comparison of DSM2 version 6 and 7 modeled EC in Montezuma Slough

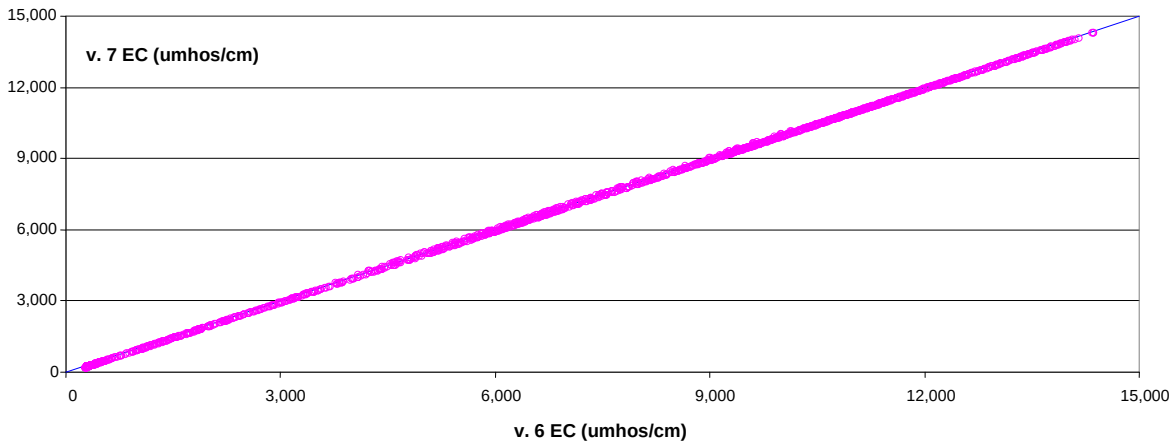


Figure 3-64 Comparison of DSMS version 6 and 7 modeled EC in Sacramento River at Mallard

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report

June 2009

Chapter 4

Comparison of Model Results between DSM2 Versions 6 and 7 in Historical Simulation

Author: Lan Liang, Delta Modeling Section, Bay Delta Office,
California Department of Water Resources

Contents

4 Comparison of Model Results between DSM2 Versions 6 and 7 in Historical Simulation.....4-1
4.1 Introduction.....4-1
4.2 Changes Required in DSM2 Version 7.....4-1
4.2.1 Adjustment of Cross Sections.....4-1
4.2.2 Modification of Gate Operating Rules and Related Time Series in Version 7.....4-1
4.3 Comparison of Historical Simulations by the 2 DSM2 Versions.....4-4
4.4 Comparison of Flow, Stage, and Water Quality.....4-6
4.5 Comparison of Flow, Stage, and Water Quality Results in the South Delta.....4-14
4.6 Conclusion.....4-24

Appendixes

Appendix 1 Statistical Analysis of Flow Difference throughout the Delta.....4-25
Appendix 2 Statistical Analysis of Stage Difference throughout the Delta.....4-28
Appendix 3 Statistical Analysis of EC Difference throughout the Delta.....4-30
Appendix 4 Statistical Analysis of DOC Difference throughout the Delta.....4-31
Appendix 5 Statistical Analysis of Volumetric Fingerprint Difference throughout the Delta.....4-32
Appendix 6 Statistical Analysis of Flow Difference for South Delta Sites.....4-35
Appendix 7 Statistical Analysis of Stage Difference for South Delta Sites.....4-37
Appendix 8 Statistical Analysis of EC Difference for South Delta Sites.....4-39
Appendix 9 Statistical Analysis of DOC Difference for South Delta Sites.....4-40
Appendix 10 Statistical Analysis of Volumetric Fingerprint Difference for South Delta Sites.....4-41

Figures

Figure 4-1 The channels for comparing 2 DSM2 versions.....4-5
Figure 4-2 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged flow.....4-7
Figure 4-3 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged stage.....4-8
Figure 4-4 The 18-year medians of differences (Version 7 – Version 6) of daily averaged EC.....4-9
Figure 4-5 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged DOC.....4-10
Figure 4-6 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged volumetric fingerprint of Sacramento River inflow.....4-11
Figure 4-7 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged volumetric fingerprint of San Joaquin River inflow.....4-12
Figure 4-8 The 18-year averages of the daily difference in maximum, average, minimum flow of Version 7 minus Version 6 at selected locations.....4-13
Figure 4-9 Fifteen-minute flows at ROLD074 during February 2002 as simulated by Version 6 and Version 7 of DSM2.....4-13
Figure 4-10 Average difference of daily averaged flows for 4-gate conditions.....4-16
Figure 4-11 Averages difference of daily minimum stages for 4-gate conditions.....4-17

Figure 4-12 Average difference of daily averaged EC for 4-gate conditions....4-18
Figure 4-13 Average difference of daily averaged DOCs for 4-gate conditions....4-19
Figure 4-14 Average difference of daily average volumetric fingerprints of Sacramento River for 4-gate conditions....4-20
Figure 4-15 Average difference of daily average volumetric fingerprints at SJR for 4-gate conditions....4-21
Figure 4-16 Stage near Old River Head barrier in 2001, Version 6 and Version 7....4-22
Figure 4-17 Stage near Old River barrier in 2002, Version 6 and Version 7....4-23
Figure 4-18 Stage near Grant Line Canal barrier in 2002, Version 6 and Version 7....4-23
Figure 4-19 Stage near Middle River barrier in 2002, Version 6 and Version 7....4-24

Tables

Table 4-1 Modification of cross sections in Version 7....4-1
Table 4-2 Comparison of gate parameters DSM2 versions 6 and 7....4-3
Table 4-3 Time intervals of 7 combinations of gate operations....4-15

4 Comparison of Model Results between DSM2 Versions 6 and 7 in Historical Simulation

4.1 Introduction

This chapter compares historical simulation results using Delta Simulation Model 2 (DSM2) Version 6 (text input) and Version 7 (database) variants. It describes the modifications required in Version 7 to match the inputs for Version 6 and compares simulation results of the 2 versions. Because gate computations and operations are substantially different between versions 6 and 7, differences in model results between the 2 versions are greater than the comparison with gates and barriers removed (2009 Annual Report, Chapter 3). Nevertheless, the differences here are still small and do not suggest a recalibration is needed because of the updated model.

4.2 Changes Required in DSM2 Version 7

4.2.1 Adjustment of Cross Sections

Several cross sections in Version 7 were found to be significantly different from those in Version 6. Over time, some Version 6 cross sections had been adjusted to prevent channels from drying up during low flows. Version 7 did not reflect all of these changes so some adjustment of the cross sections in Version 7 was made as shown in Table 4-1.

Table 4-1 Modification of cross sections in Version 7

Channel No.	Modification of cross sections at fractional channel distance
117	Deleted the cross section at 0.486
133	Deleted the cross sections at 0.133 and 0.332
281	Added a cross section at 0.06061 and 1
312	Altered cross section at 0.332
327	Altered cross sections at 0.354 and 0.845 Deleted cross sections at 0 and 1

4.2.2 Modification of Gate Operating Rules and Related Time Series in Version 7

The historical DSM2 simulation includes gate operations for the following 7 structures: Old River at Head, Middle River, Grant Line Canal, Old River at Delta-Mendota Canal (DMC), Montezuma Slough, Delta Cross Channel, and Clifton Court Forebay intake. Modeled Delta structures can be complicated and include up to 5 components: weir, gates, pipes, flashboard, and boat lock. In Version 6, each of the 5 gates is described through several parameters describing gate status: installed or not, weir elevation and width, number of pipes, pipe elevation and width, flashboard in or out, and boat lock in or out. Every parameter has a corresponding time series. Version 7 simplifies these parameters because some parameters are related. For example, the weir width and elevation of Old River at DMC barrier changes correspond to whether the gate is installed. In Version 7 operating rules describe the relation between the installation and the weir width and elevation. Therefore, in Version 7 one time series of the parameter

INSTALL (see below) can represent installation, width, and elevation, but 3 parameters are required in Version 6. Version 7 links the time series to the operating rules.

Specific similarities and differences in gate descriptions between 2 versions are as follows.

- Both Version 7 and Version 6 describe Delta Cross Channel and Clifton Court reservoir gates with the same Boolean parameter "POS," which indicates whether the gate is installed.
- For the other 5 structures, Version 6 uses 11 parameters to represent the status of each gate. Each gate is described by the same 11 parameters:

  CFPIPEDOWN
  CFPIPEUP
  CFWEIRDOWN
  CFWEIRUP
  CRESTELEV
  NPIPES
  PIPEELEV
  PIPERAD
  POS
  WIDTHDOWN
  WIDTHUP

  In Version 7, each gate has different parameters. They are listed as follows.

  Grant Line Canal gate (GL_CN):

  FULLPART
  INSTALL
  PIPE_OP_DOWN

  Middle River gate (MID_R):

  INSTALL
  PIPE_OP_DOWN

  Old River at DMC gate (OLD_R):

  INSTALL
  PIPE_OP_DOWN

  Old River Head Barrier (ORHRB):

  INSTALL
  PIPEELEV
  PIPE_OP
  WEIR_OP
  WEIR_OP(ORHRB_FALL)

  Montezuma gate (MTZSL):

  BOATLOCK_OP
  FLASHBOARD_OP
  RADIAL_FRACT
  RADIAL_OP

For both versions of DSM2, every gate parameter is linked to a time series as in Table 4-2.

Table 4-2 Comparison of gate parameters DSM2 versions 6 and 7

	No.	Version	B part in the DSS file of each version	Corresponding value in each version[2]					
				1	2	3	4	5	6
GL_CN[1]	1	7	INSTALL	0	1				
		6	POS	10	1				
	2	7	FULLPART	1	0				
		6	WIDTHDOWN / WIDTHUP	125	77				
	3	7	PIPE_OP_DOWN	0	1				
		6	CFPIPEDOWN	0	0.6				
MID_R	1	7	INSTALL	0	1				
		6	POS	10	1				
	2	7	PIPE_OP_DOWN	0	1				
		6	CFPIPEDOWN	0	0.6				
OLD_R	1	7	INSTALL	0	1				
		6	POS	10	1				
	2	7	PIPE_OP_DOWN	0	1				
		6	CFPIPEDOWN	0	0.6				
ORHRB	1	7	INSTALL	0	1				
		6	POS	10	1				
	2	7	PIPEELEV	-8	-5	-4			
		6	PIPEELEV	-8	-5	-4			
	3	7	PIPE_OP	0	0.5	0.833	1		
		6	NPIPES	0	3	5	6		
	4	7	WEIR_OP (spring)	0	1				
		7	WEIR_OP(ORHRB_FALL)	0	1				
		6	CRESTELEV	-5	10	0			
MTZSL	1	7	BOATLOCK_OP	0	1				
		7	FLASHBOARD_OP	0	1				
		6	CFWEIRDOWN	0.7	0.8				
	2	7	RADIAL_FRACT	0.333	0.667	0.333	1	0.667	1
		6	WIDTHDOWN	36	72	102	108	138	174
	3	7	RADIAL_OP	-10	1	0			
		6	POS	-10	1	0			

[1] The Grant Line Canal barrier installed has 2 conditions: partially installed and fully installed.
[2] The values are as follows
36 – One installed gate without flashboard (fb) and boat lock (bl)
72 – Two installed gates without fb and bl
102 – One installed gates with fb and bl
108 – Three installed gates without fb and bl
138 – Two installed gates with fb and bl
174 – Three installed gates with fb and bl

4.3 Comparison of Historical Simulations by the 2 DSM2 Versions

Historical simulations of the period October 1, 1990, through April 30, 2008, were conducted by both DSM2 versions. With the exception of the description of gate operations, Version 7 and Version 6 used the same input. Although the descriptions of gate operations in the 2 versions were different, they were based on the same actual operations and assume identical operation time intervals. Version 7 generated 15-minute flow, stage, and water quality outputs. Version 6 generated 15-minute flow and stage data and daily water quality data. In comparing results, daily average electrical conductivity (EC) and volumetric fingerprint and daily minimum, maximum, and average flow and stage were used. The simulations-generated output at locations measured data were available at least some time during the simulation period. These locations are shown in Figure 4-1.

Differences between results from the 2 model versions varied spatially and temporally; summary statistical analysis based on distributions of differences was conducted to describe the differences. The analysis was based upon both a Delta-wide view and a focused view of the South Delta area affected by the installation and operation of the temporary barriers. Values associated with 5%, 50%, and 95% probability of exceedance for each time series of differences are listed in the appendixes. Appendixes 1 through 5 show the differences of flow, stage, EC, dissolved organic carbon (DOC), and volumetric fingerprints Delta wide. Appendixes 6 through 10 show the differences of flow, stage, EC, DOC and volumetric fingerprints under 7 different gate conditions in South Delta.

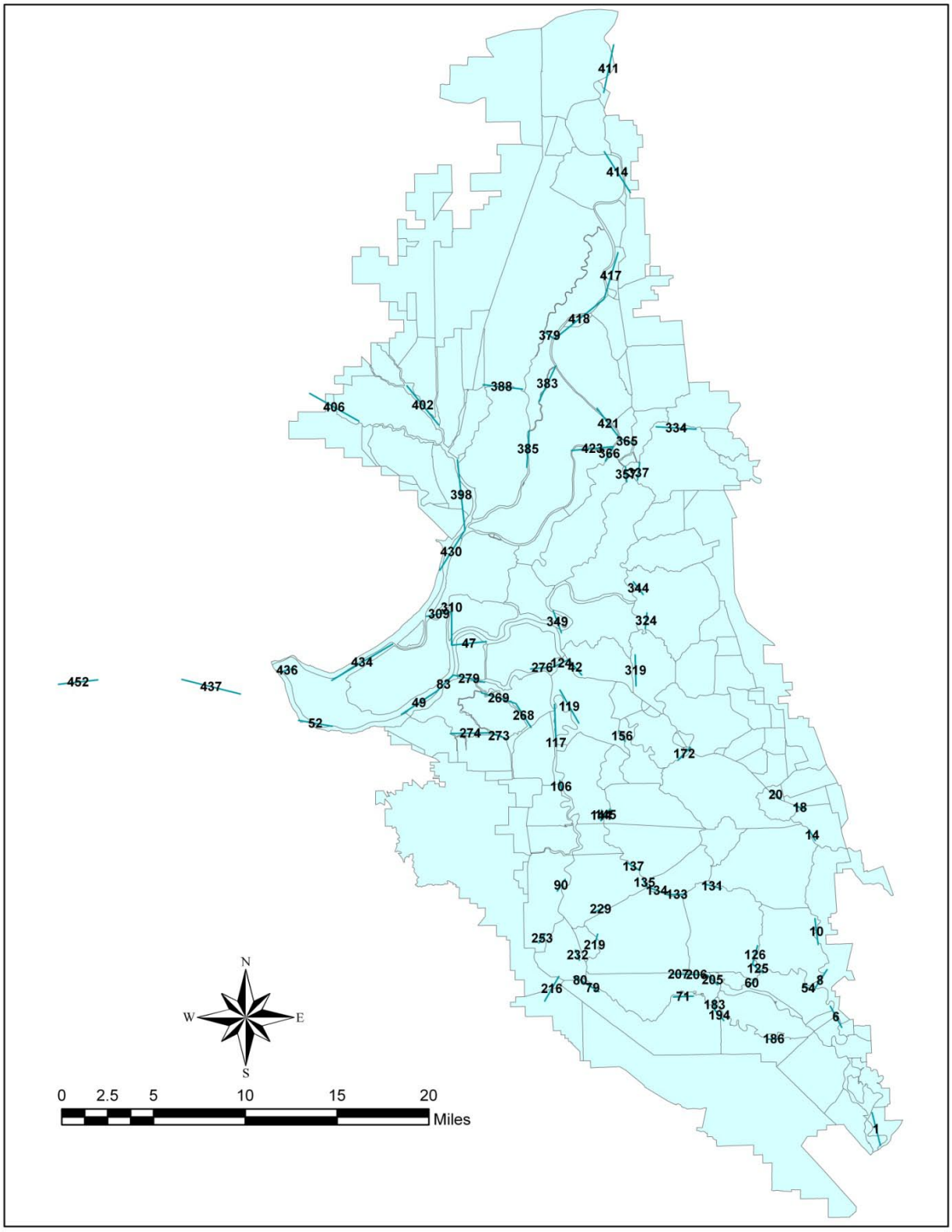


Figure 4-1 The channels for comparing 2 DSM2 versions

4.4 Comparison of Flow, Stage, and Water Quality

The median differences of 18-year daily averaged flow (cfs), stage, EC (µmhos/cm), DOC (mg/l), volumetric fingerprint (VOL) (percentage) of Sacramento River inflow (VOL_SAC) and San Joaquin River inflow (VOL_SJR) at selected locations are shown in Figure 4-2 through Figure 4-7. These figures show that the computation results from Version 7 and Version 6 are very close. While the flow differences in the west Delta are high compared to other locations, these differences relative to average flow are small, around 1% and less than 1% when compared to maximum flow.

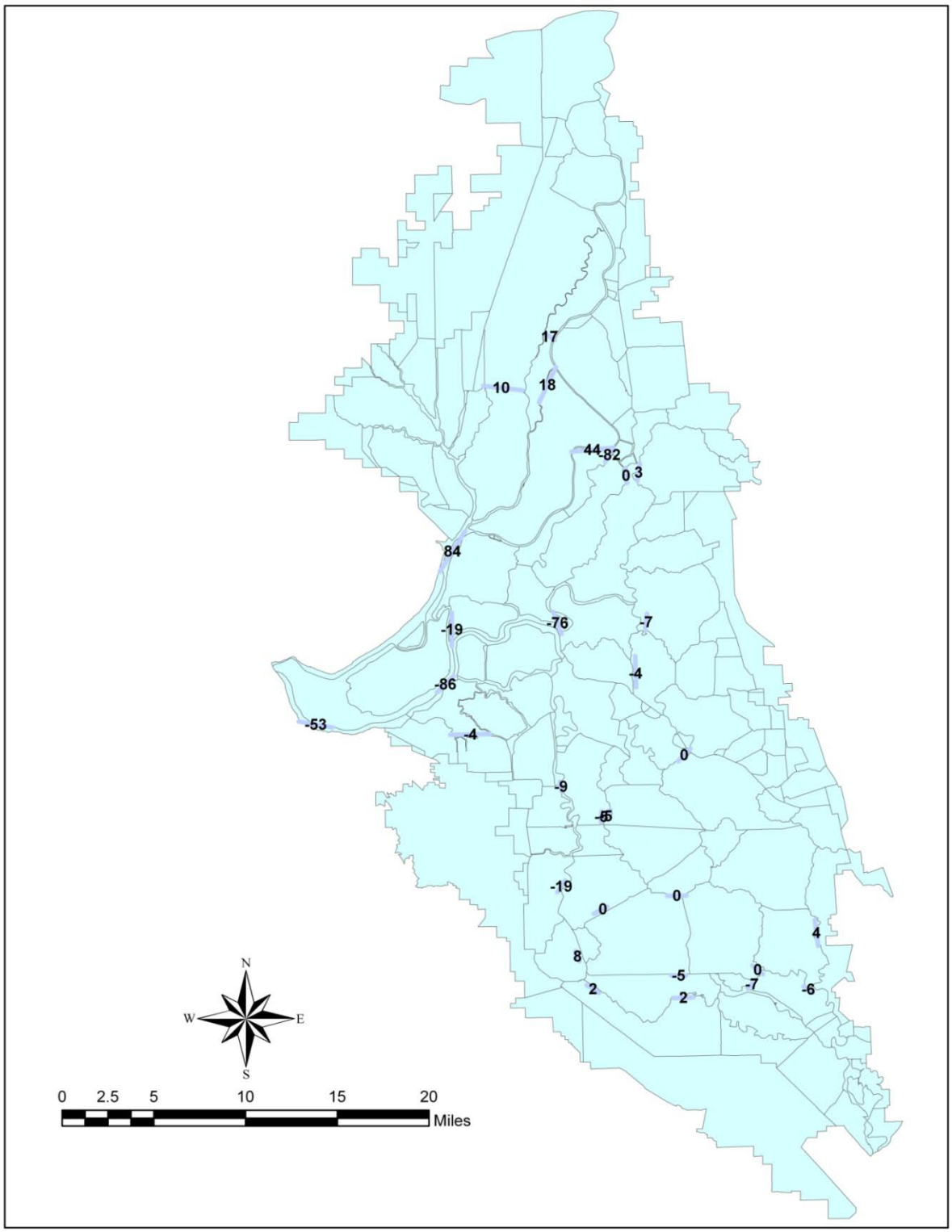


Figure 4-2 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged flow

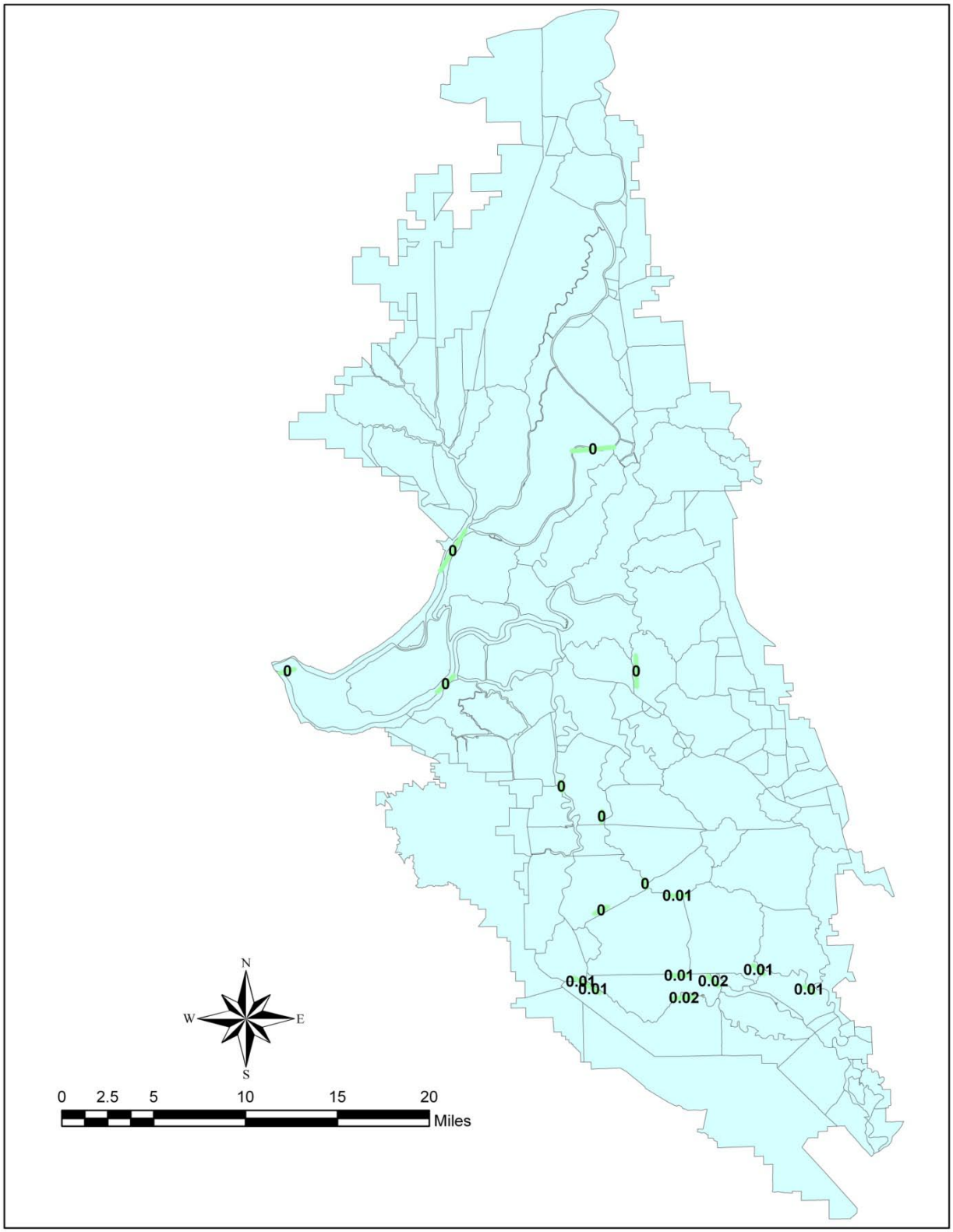


Figure 4-3 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged stage

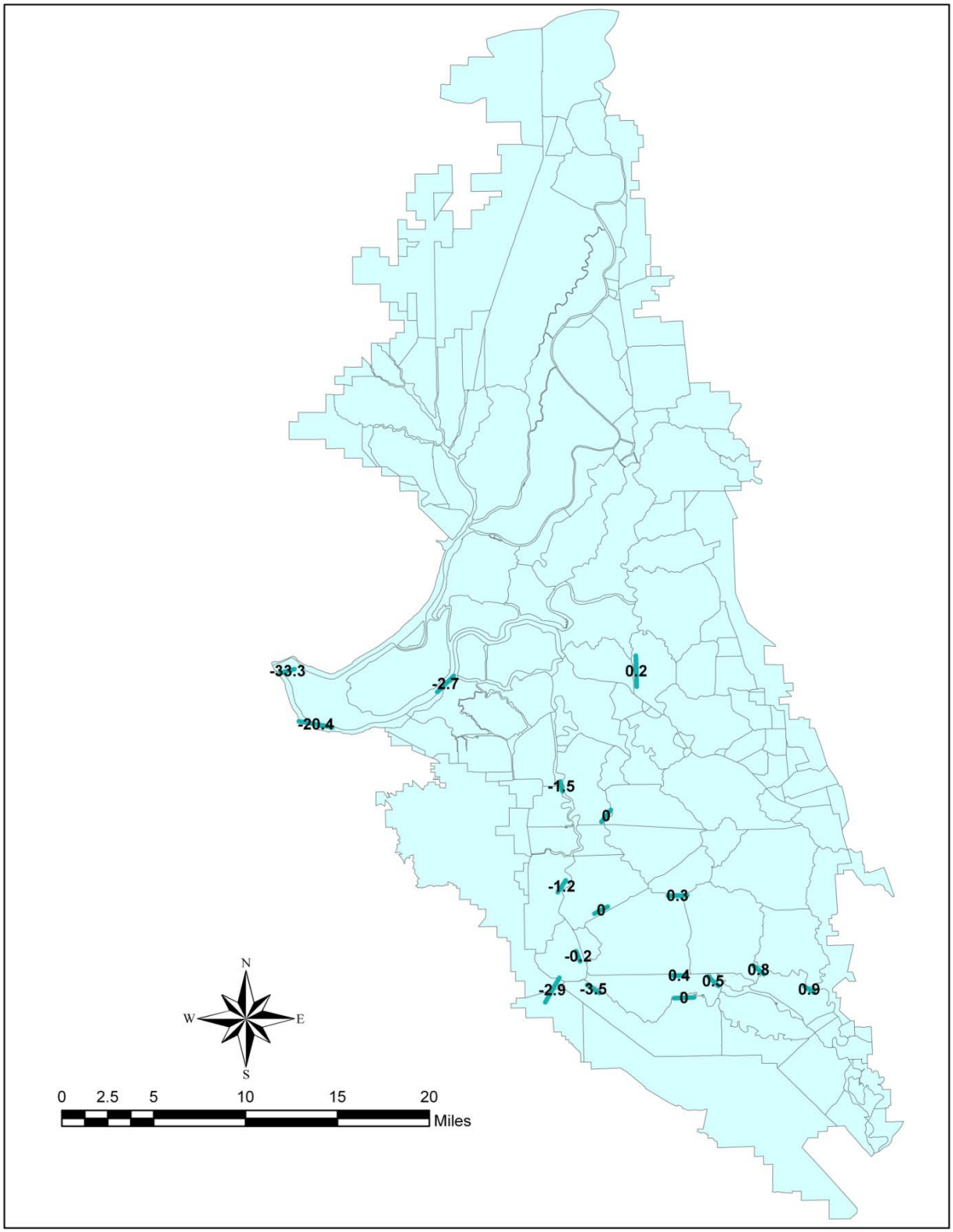


Figure 4-4 The 18-year medians of differences (Version 7 – Version 6) of daily averaged EC

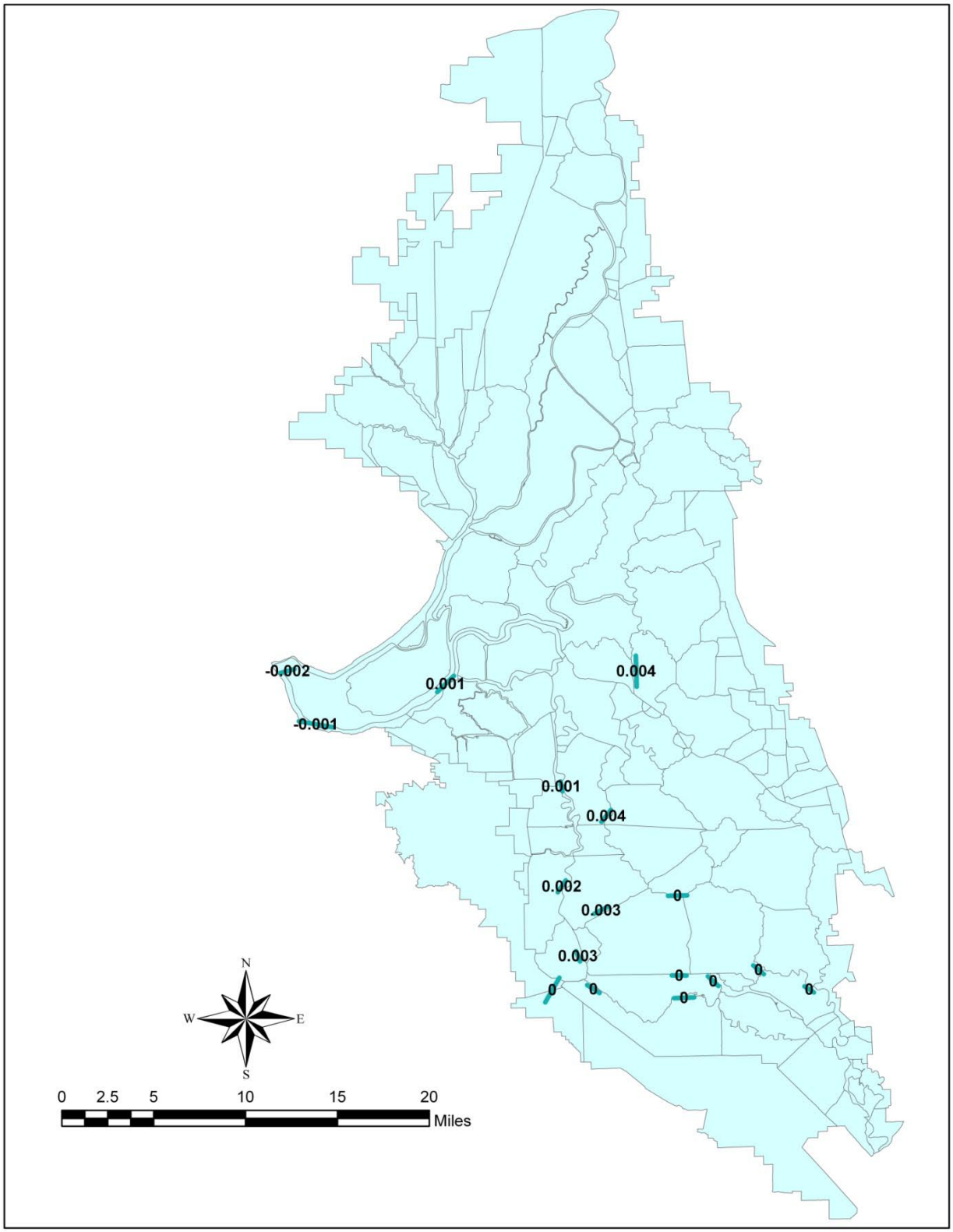


Figure 4-5 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged DOC

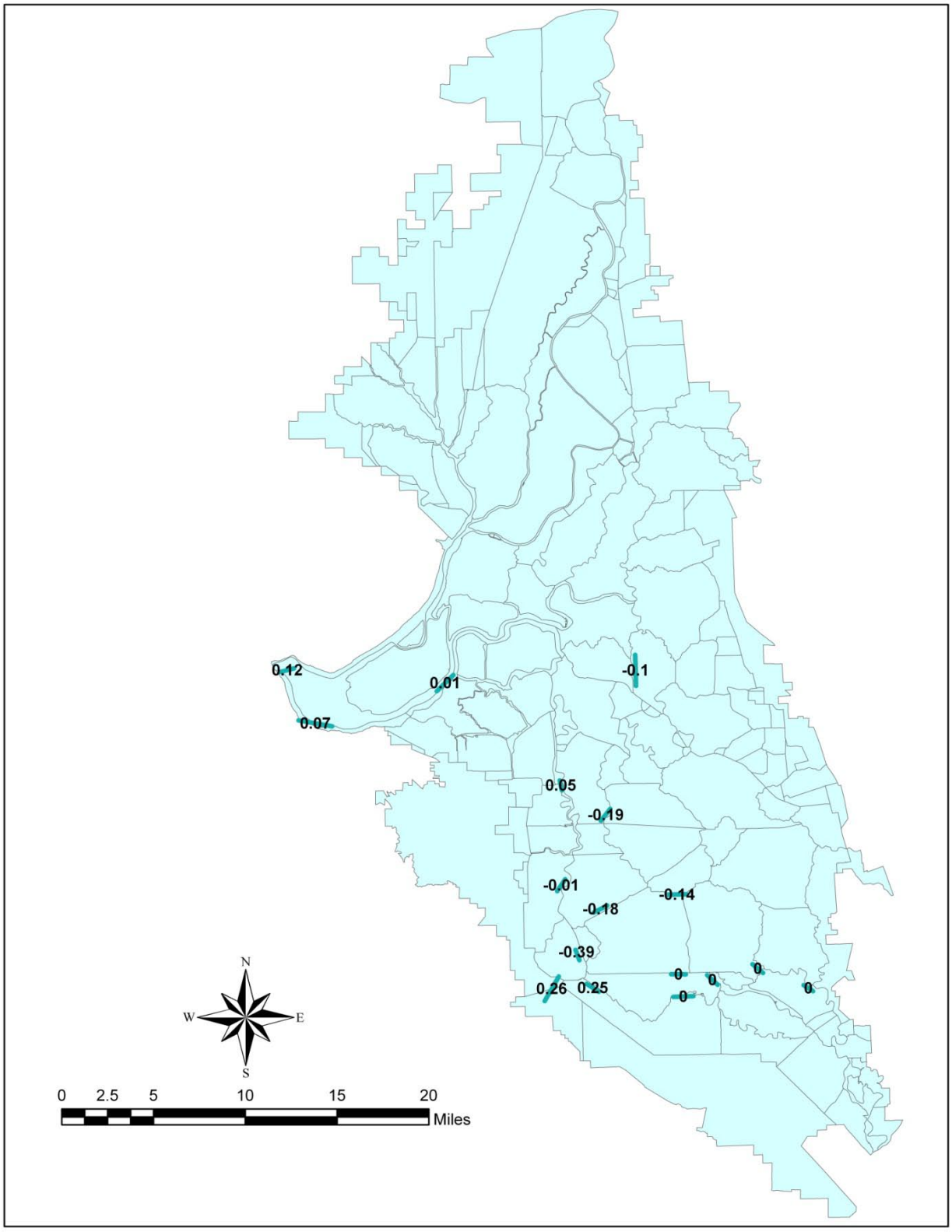


Figure 4-6 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged volumetric fingerprint of Sacramento River inflow

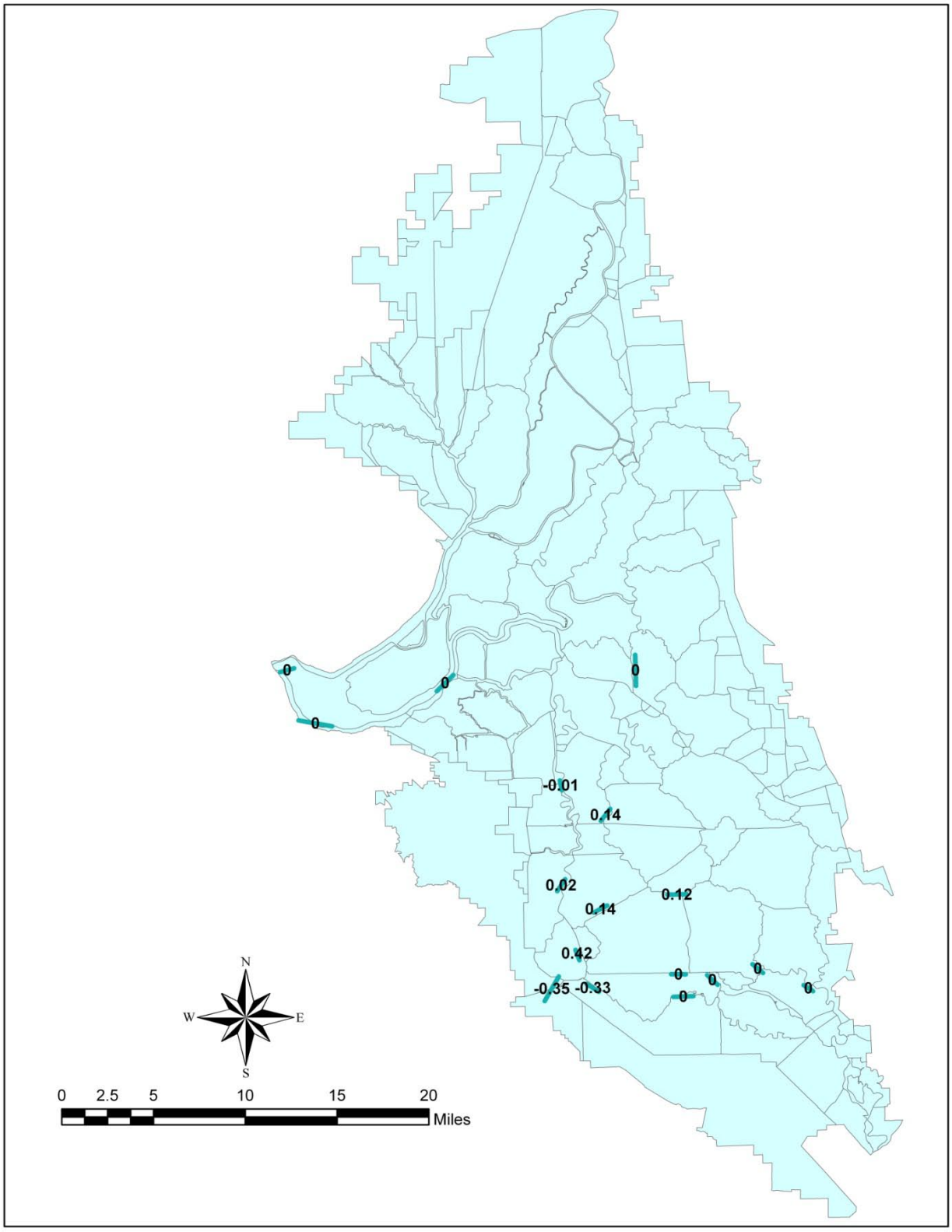


Figure 4-7 The 18-year medians of differences (Version 7 – Version 6) of daily-averaged volumetric fingerprint of San Joaquin River inflow

The differences in the flow and stage of Version 7 compared to Version 6 tend to follow the pattern that the differences in tidal peaks are greater than the differences in overall tide (Figure 4-8). In other words, the tidal range in flow and stage simulated by Version 7 of DSM2 tends to be smaller than the tidal range simulated by Version 6, as shown in Figure 4-9. This is seen in the South Delta regardless of temporary gate operation.

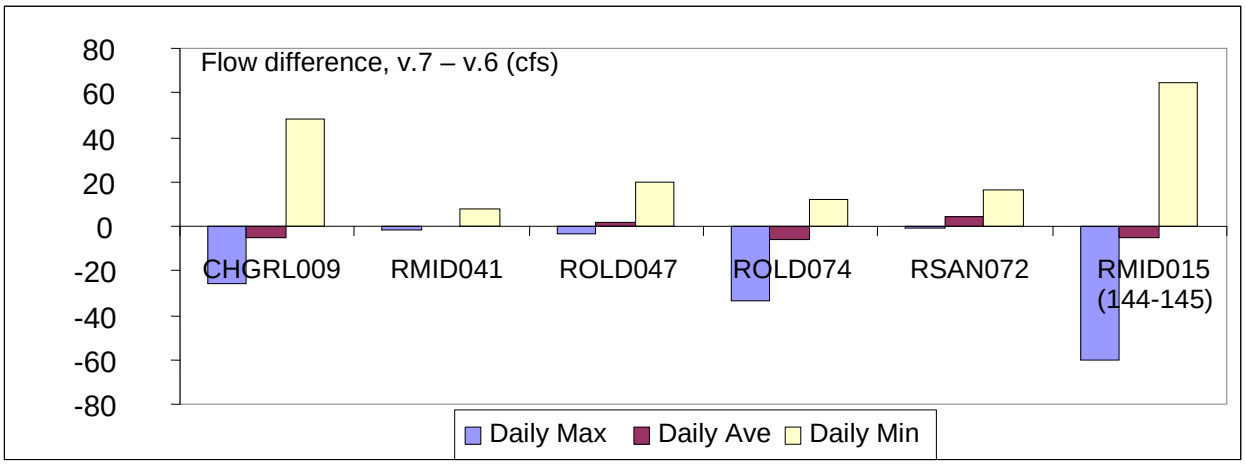


Figure 4-8 The 18-year averages of the daily difference in maximum, average, minimum flow of Version 7 minus Version 6 at selected locations

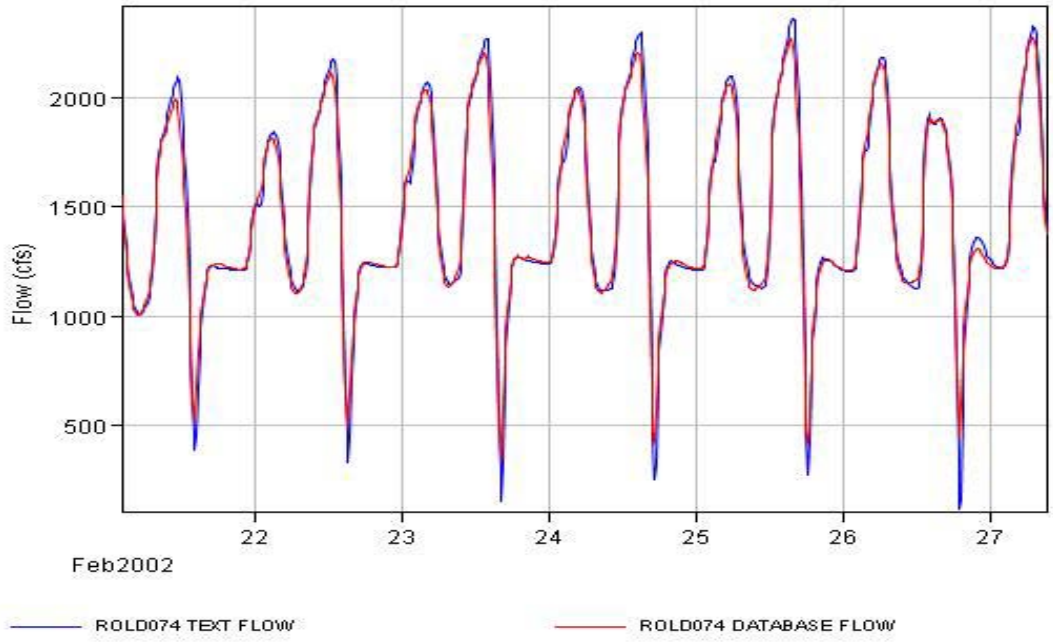


Figure 4-9 Fifteen-minute flows at ROLD074 during February 2002 as simulated by Version 6 and Version 7 of DSM2

4.5 Comparison of Flow, Stage, and Water Quality Results in the South Delta

In order to study how gate operations affect simulated hydrodynamics and water quality under Versions 6 and 7 of DSM2, model-generated daily hydrodynamic and water quality data were compared when barrier configurations were constant. A total of 7 combinations of barrier operations in the South Delta were examined:

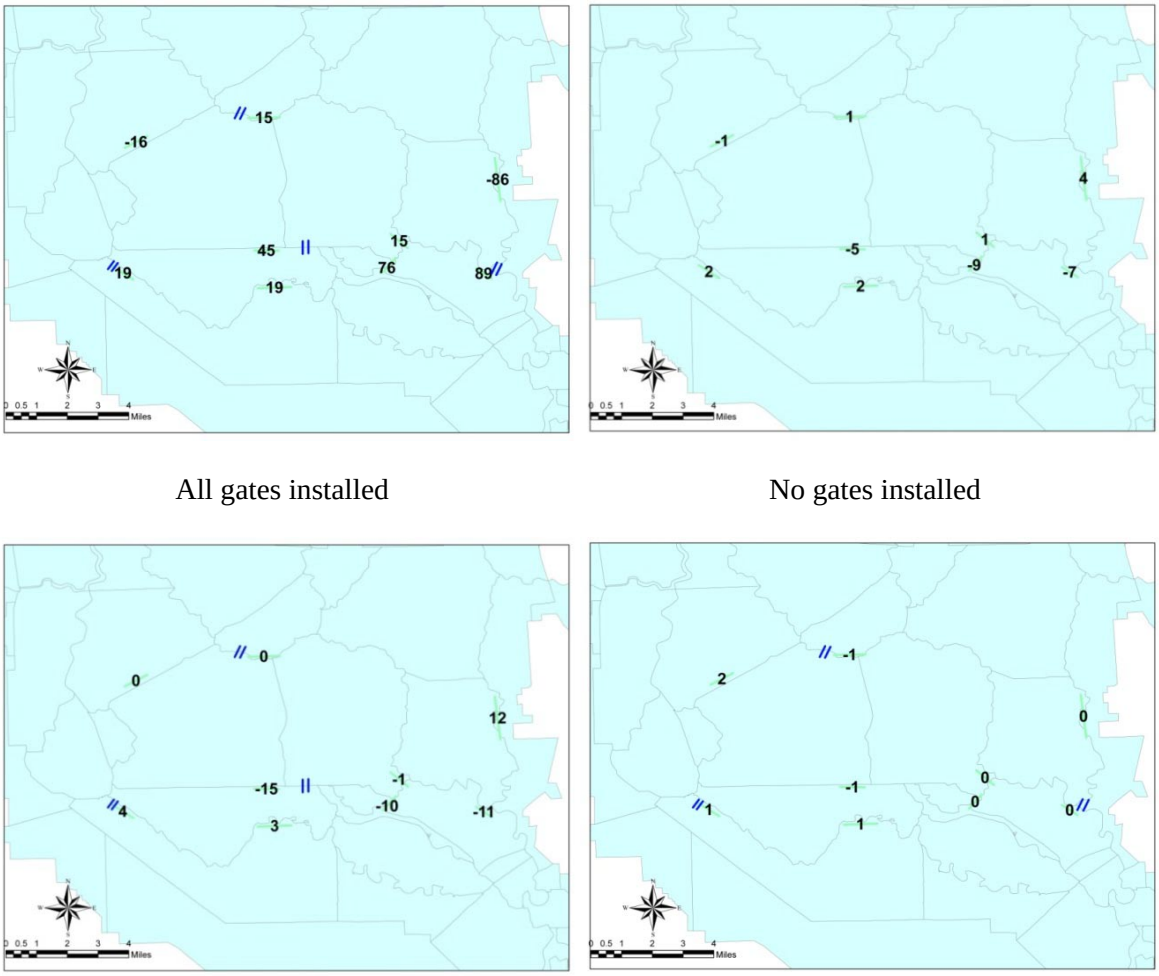
1. MR - Middle River barrier installed only;
2. ORH - Old River Head barrier installed only;
3. OR MR - Old River and Middle River barriers installed;
4. OR MR GLC - Old River, Middle River, and Grant Line Canal barriers installed;
5. OR MR ORH - Old River, Middle River and Head River barriers installed;
6. OR MR GLC ORH – all gates installed
7. No gate – removal of all the gates.

Model results compared were daily minimum stage and daily average flow, EC, DOC, and Sacramento River and San Joaquin River volumetric fingerprint. Table 4-3 lists the time intervals of 7 gate combinations during the simulation period of 1990 through 2008. The results are presented in Figures 4-10 through 4-15.

In the figures, the differences for fewer-than-2-gates conditions are similar to those for no-gate condition, but less than those for 4-or-3-gates-installed conditions. Figures 4-10 through 4-15 show the averages of differences in modeled parameters for 4 gate conditions: all gates installed, no gates installed, Old River (OR), Middle River (MR), and Grant Line Canal (GLC) gates installed, and OR and MR and Old River at Head (ORH) gates installed. It is apparent that the differences in simulation results under the all-gates-installed condition are much larger than those for the other 3 conditions. Version 7 tends to generate in the South Delta higher flow, higher minimum stage, lower EC, and higher DOC than Version 6 for all-gates-installed condition. Differences in modeled hydrodynamic and water quality results under the 3-gates-installed conditions are less than under the all-gates-installed condition.

Table 4-3 Time intervals of 7 combinations of gate operations

Gate(s)	From	To	Gate(s)	From	To
MR	4/5/1991	8/24/1991	No Gate	11/28/1990	12/31/1990
				1/1/1991	4/3/1991
ORH	10/2/1990	11/26/1990		11/24/1991	12/31/1991
	9/29/1991	11/22/1991		1/1/1992	4/7/1992
	10/1/1992	12/2/1992		12/5/1992	12/31/1992
	11/11/1993	12/5/1993		1/1/1993	5/31/1993
	10/5/1994	11/28/1994		9/29/1993	11/9/1993
	5/8/1996	5/15/1996		12/7/1993	12/31/1993
	10/4/1996	11/19/1996		1/1/1994	4/22/1994
	10/4/2000	12/7/2000		11/30/1994	12/31/1994
				1/1/1995	8/6/1995
OR MR	8/26/1991	9/11/1991		10/12/1995	12/31/1995
	6/6/1992	9/9/1992		1/1/1996	5/6/1996
	6/17/1993	9/22/1993		11/21/1996	12/31/1996
	5/19/1994	9/6/1994		1/1/1997	4/3/1997
	8/11/1995	9/28/1995		10/2/1997	12/31/1997
	6/6/1996	7/9/1996		1/1/1998	12/31/1998
	5/16/1997	6/3/1997		1/1/1999	5/17/1999
	5/25/2002	6/6/2002		10/1/1999	12/31/1999
	5/17/2003	6/9/2003		1/1/2000	4/14/2000
	5/22/2004	6/3/2004		12/9/2000	12/31/2000
	6/1/2005	7/11/2005		1/1/2001	4/20/2001
				11/26/2001	12/31/2001
OR MR GLC	7/11/1996	9/28/1996		1/1/2002	4/14/2002
	6/5/1997	9/22/1997		11/22/2002	12/31/2002
	6/4/1999	9/22/1999		1/1/2003	4/13/2003
	6/2/2000	9/27/2000		11/16/2003	12/31/2003
	6/1/2001	10/5/2001		1/1/2004	4/11/2004
	6/8/2002	10/3/2002		11/14/2004	12/31/2004
	6/11/2003	9/21/2003		1/1/2005	5/10/2005
	6/5/2004	9/26/2004		11/15/2005	12/31/2005
	7/13/2005	9/27/2005		1/1/2006	7/5/2006
	7/20/2006	11/14/2006		11/18/2006	12/31/2006
	5/23/2007	10/16/2007		1/1/2007	4/9/2007
				11/21/2007	12/31/2007
OR MR ORH	9/13/1991	9/26/1991			
	4/23/1992	6/4/1992	OR MR GLC ORH	5/10/2001	5/29/2001
	9/11/1992	9/27/1992		10/7/2001	11/11/2001
	4/25/1994	5/17/1994		10/5/2002	11/16/2002
	9/8/1994	9/28/1994		9/23/2003	11/4/2003
	4/17/1997	5/14/1997		9/28/2004	11/1/2004
	4/17/2000	5/30/2000		9/29/2005	11/5/2005
	4/27/2001	5/8/2001		5/11/2007	5/21/2007
	4/16/2002	5/23/2002		10/18/2007	11/5/2007
	4/16/2003	5/15/2003			
	4/16/2004	5/20/2004			
	4/21/2007	5/9/2007			



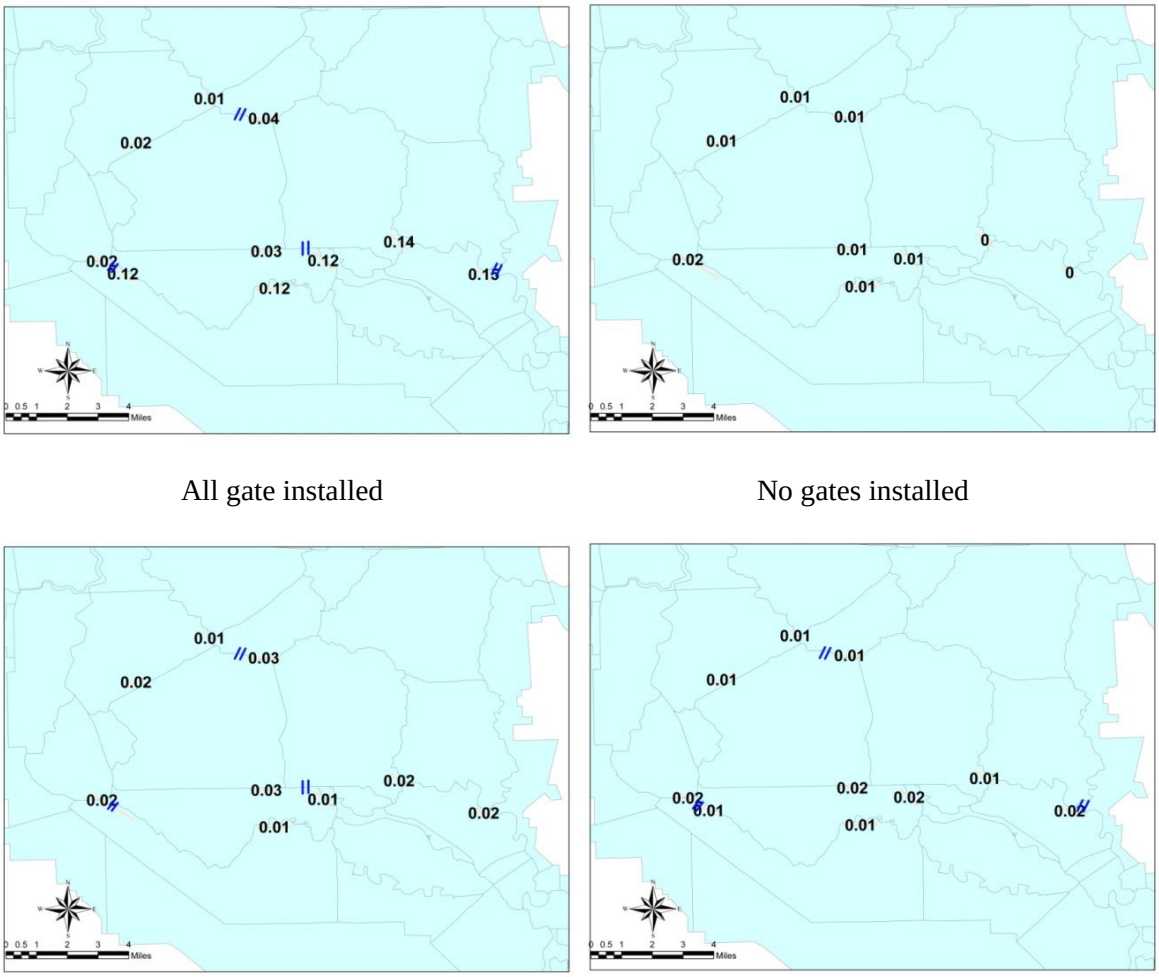
All gates installed

No gates installed

OR, MR, and GLC gates installed

OR, MR, and ORH gates installed

Figure 4-10 Average difference of daily averaged flows for 4-gate conditions



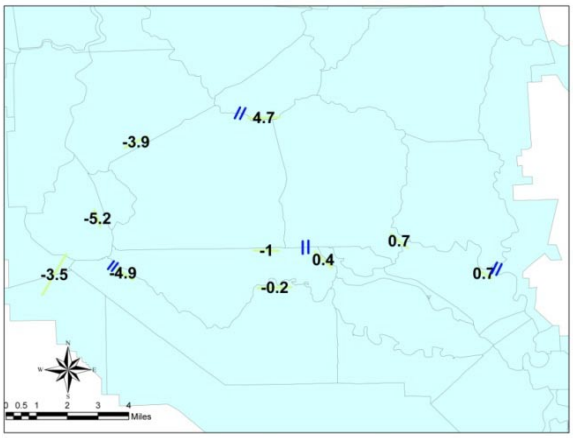
All gate installed

No gates installed

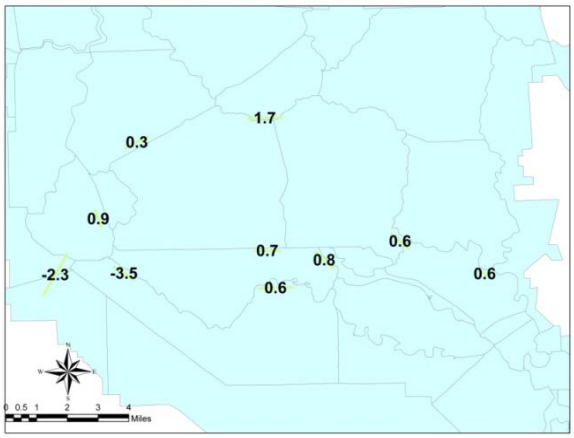
OR, MR, and GLC gates installed

OR, MR, and ORH gates installed

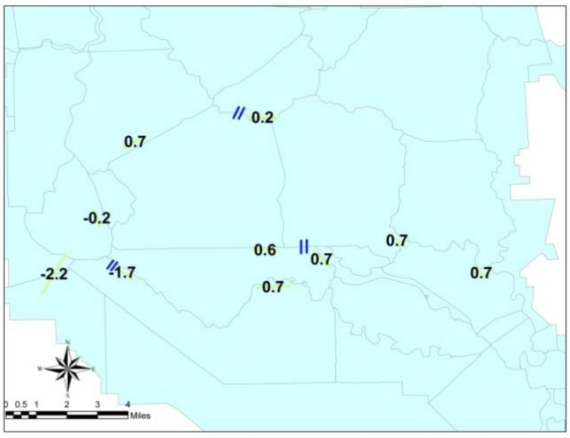
Figure 4-11 Averages difference of daily minimum stages for 4-gate conditions



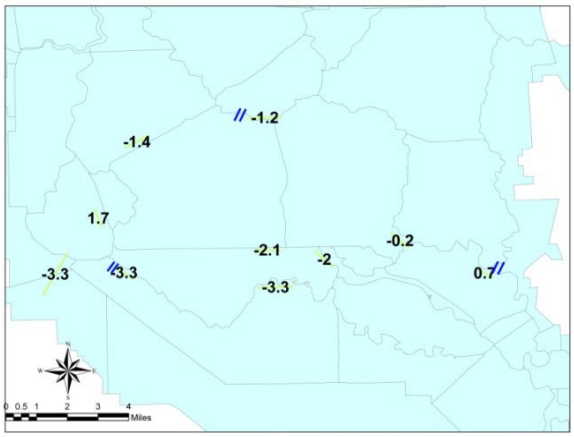
All gates installed



No gates installed

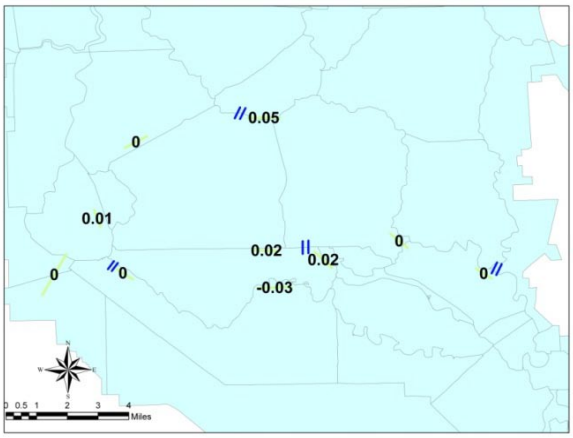


OR, MR, and GLC gates installed

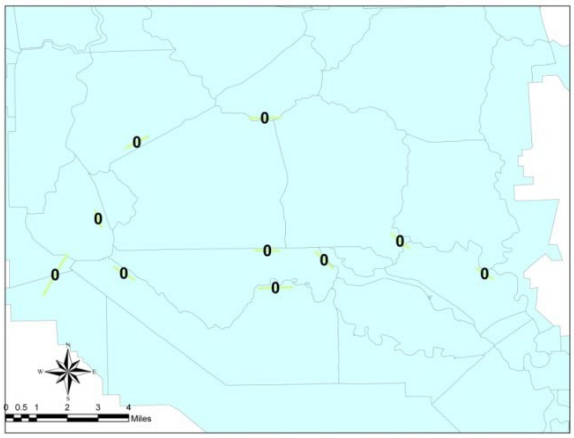


OR, MR, and ORH gates installed

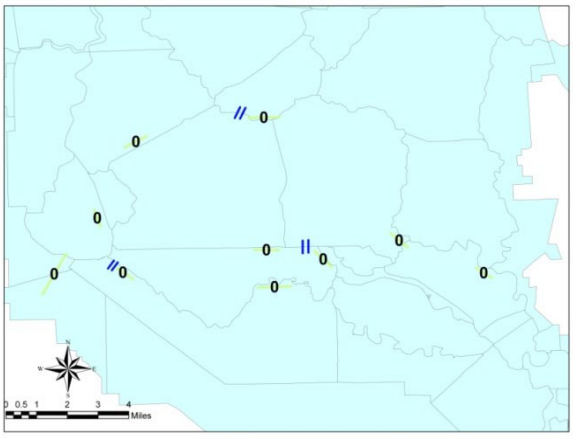
Figure 4-12 Average difference of daily averaged EC for 4-gate conditions



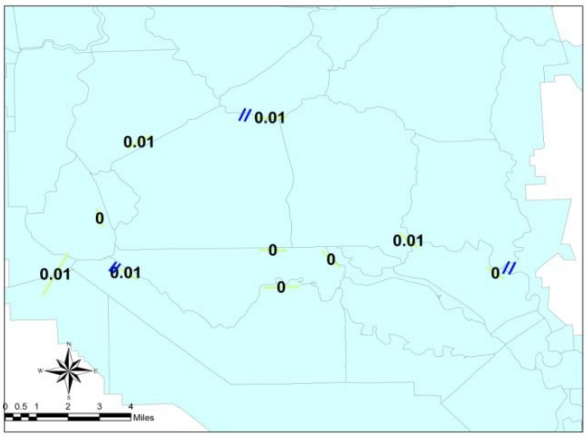
All gates installed



No gates installed

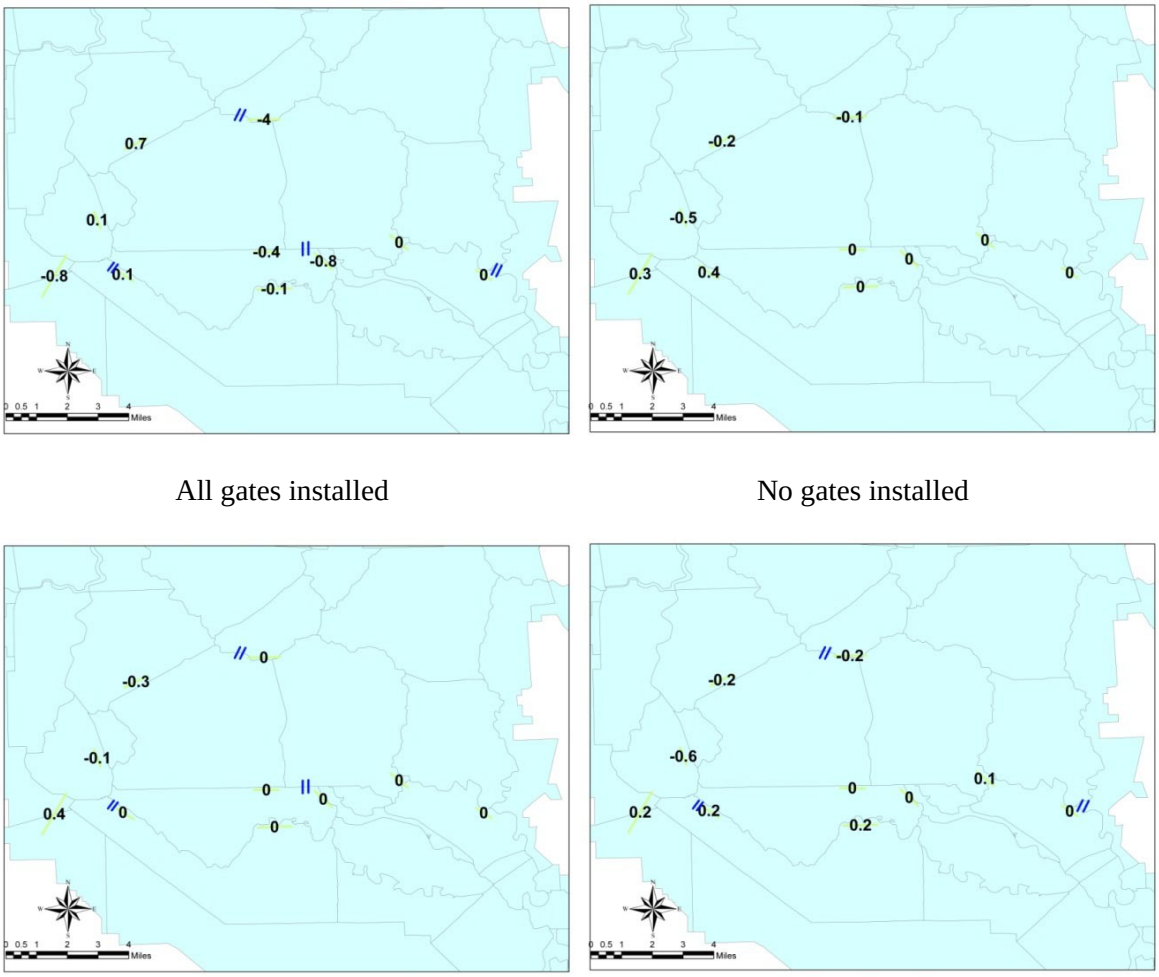


OR, MR, and GLC gates installed



OR, MR, and ORH gates installed

Figure 4-13 Average difference of daily averaged DOCs for 4-gate conditions



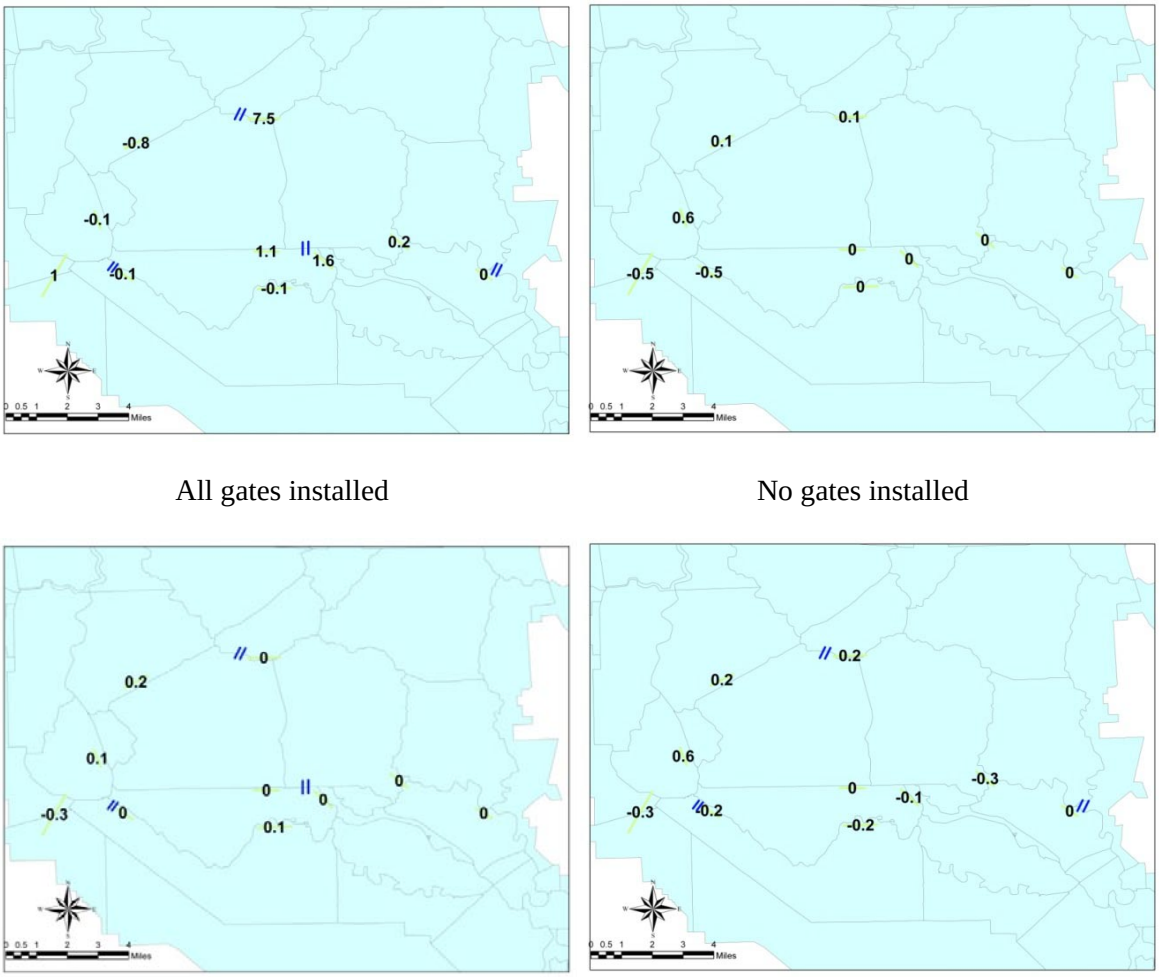
All gates installed

No gates installed

OR, MR, and GLC gates installed

OR, MR, and ORH gates installed

Figure 4-14 Average difference of daily average volumetric fingerprints of Sacramento River for 4-gate conditions



All gates installed

No gates installed

OR, MR, and GLC gates installed

OR, MR, and ORH gates installed

Figure 4-15 Average difference of daily average volumetric fingerprints at SJR for 4-gate conditions

Version 7 estimates higher minimum stages upstream of temporary barriers than does Version 6. Figures 4-16 through 4-19 show the stages of Version 7 are higher than those of Version 6 from May 2001 to November 2001. From Table 4-3, it can be found that,

> Four gates installed: 5/10/01–5/29/01 and 10/7/2001–11/11/2001,
> OR, MR and GLC installed: 6/1/2001–10/5/2001.

During May 10 to May 29, 2001, 4 gates were installed, but only Old River Head stage of Version 7 is noticeably higher than that of Version 6. The stages of the other 3 barriers are similar for the 2 versions. Starting in June 2001, the Old River Head barrier was removed. All 4 stages were higher in Version 7 when 3 barriers (OR, MR, and GLC) were installed. This shows how the difference in gate operations of the 2 versions affects the simulation results.

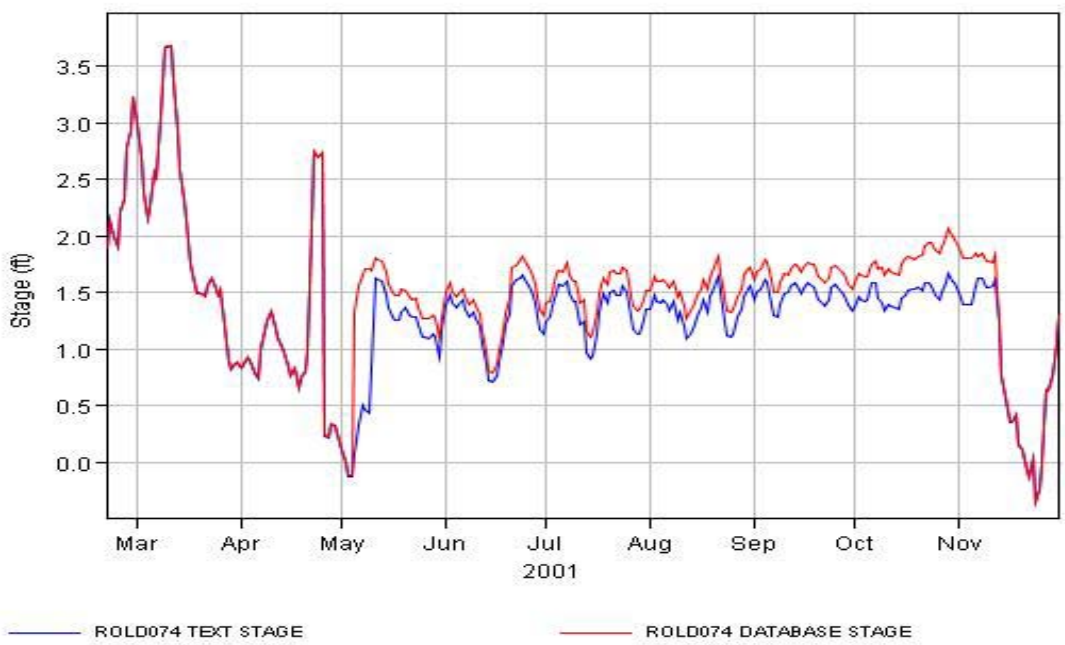


Figure 4-16 Stage near Old River Head barrier in 2001, Version 6 and Version 7

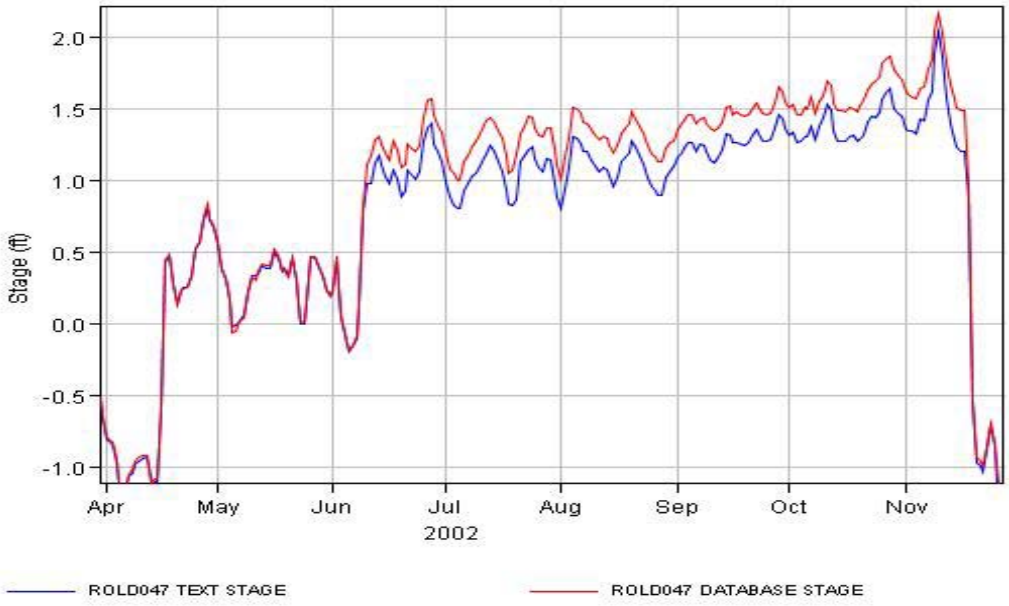


Figure 4-17 Stage near Old River barrier in 2002, Version 6 and Version 7

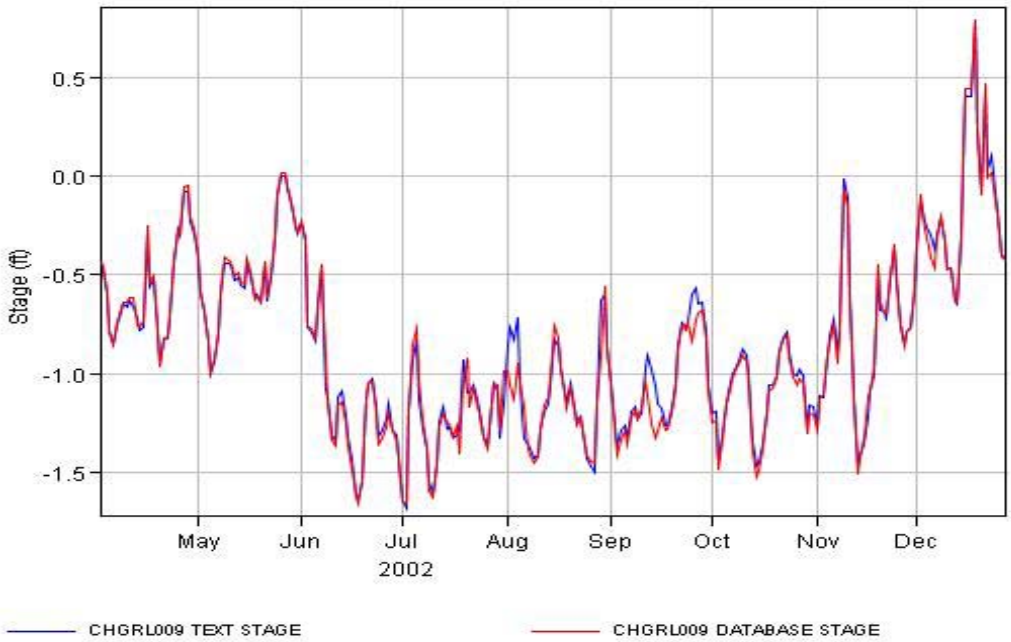


Figure 4-18 Stage near Grant Line Canal barrier in 2002, Version 6 and Version 7

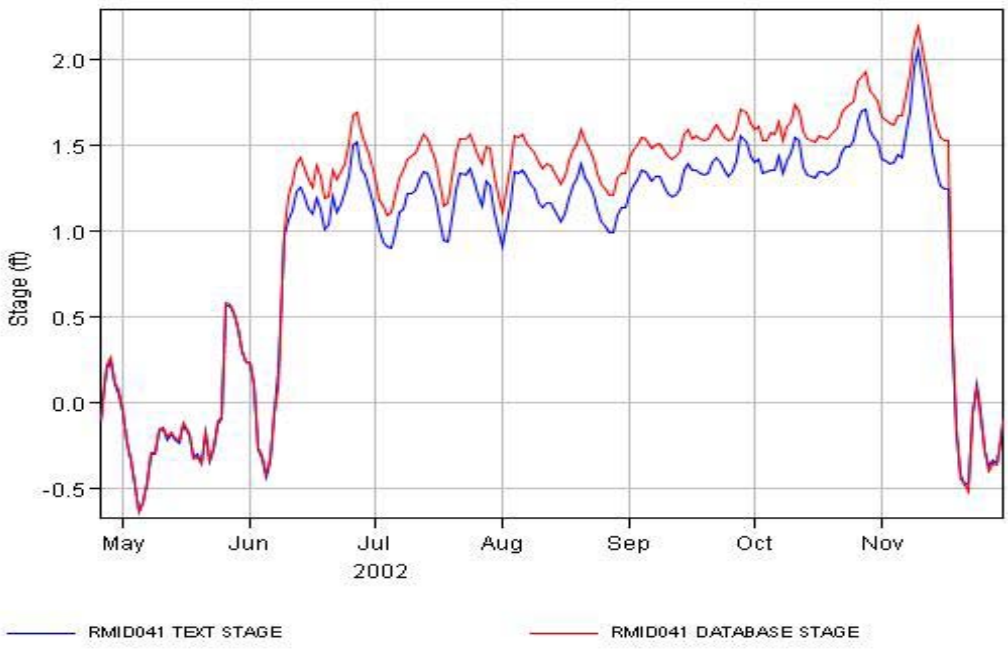


Figure 4-19 Stage near Middle River barrier in 2002, Version 6 and Version 7

4.6 Conclusion

In general, the simulation results of Version 7 of DSM2 are similar to those of Version 6. However, due to the different method of gate computation and operations, Version 7 tends to simulate higher daily average flow, higher minimum daily stage, lower daily average EC, and higher daily average DOC than does Version 6 when 3 or more temporary barriers are installed.

Appendix 1 Statistical Analysis of Flow Difference throughout the Delta

DSM2 Location	Statistic	P_5	P_{50}	P_{95}
060_0	ave_diff	-150.511	-6.660	13.947
	max_diff	-201.038	-29.510	25.652
	min_diff	-180.180	11.858	120.781
CHGRL009	ave_diff	-111.698	-5.395	83.041
	max_diff	-643.556	-25.602	122.926
	min_diff	-233.733	48.428	313.728
CHVCT000	ave_diff	-92.397	-0.463	95.582
	max_diff	-648.388	-290.986	31.873
	min_diff	-220.386	20.880	644.896
RMID027	ave_diff	-4.742	0.426	14.450
	max_diff	-122.635	-15.629	51.768
	min_diff	-42.270	9.742	62.537
RMID041	ave_diff	-3.222	0.415	13.892
	max_diff	-13.431	-2.127	12.253
	min_diff	-5.924	7.572	39.140
ROLD047	ave_diff	-11.274	1.750	36.882
	max_diff	-346.615	-3.686	99.452
	min_diff	-106.515	19.414	101.188
ROLD059	ave_diff	-7.039	1.650	37.004
	max_diff	-98.978	-24.552	31.451
	min_diff	-21.798	18.968	79.325
ROLD074	ave_diff	-140.421	-6.034	11.309
	max_diff	-155.603	-33.607	15.484
	min_diff	-160.481	12.216	198.740
RSAN072	ave_diff	-113.757	4.472	79.777
	max_diff	-93.781	-0.796	52.693
	min_diff	-127.631	16.621	80.618
RSAN007	ave_diff	-240.522	-53.207	134.305
	max_diff	-1203.581	-844.867	-377.872
	min_diff	389.984	1163.641	1844.038
RMID015_144 - RMID015_145	ave_diff	-155.934	-5.140	130.102
	max_diff	-1585.584	-60.076	226.116
	min_diff	-164.127	64.222	456.158
ROLD034	ave_diff	-217.461	-18.596	156.768
	max_diff	-1835.666	-16.963	159.059
	min_diff	-58.315	426.507	1021.657
RSAC101	ave_diff	9.083	83.622	192.850

DSM2 Location	Statistic	P_5	P_{50}	P_{95}
	max_diff	-1900.481	-1023.449	-75.210
	min_diff	211.272	1306.266	2421.951
RSAN018	ave_diff	-299.239	-85.858	124.795
	max_diff	-1556.406	-1080.313	-586.294
	min_diff	910.552	1625.305	2366.009
RSAN043	ave_diff	-22.872	-3.816	12.650
	max_diff	-63.279	-10.253	31.980
	min_diff	-96.790	5.984	90.423
SLTRM004	ave_diff	-77.445	-19.241	30.388
	max_diff	-324.627	-210.102	-66.536
	min_diff	65.519	260.188	423.438
SLDUT007	ave_diff	-18.006	-4.385	8.217
	max_diff	-99.490	-53.936	2.723
	min_diff	2.114	49.623	100.337
ROLD024	ave_diff	-137.724	-9.042	105.879
	max_diff	-1181.726	-13.517	179.414
	min_diff	-198.021	-6.707	201.456
172_990	ave_diff	-27.046	0.159	26.504
	max_diff	-324.762	-44.106	58.070
	min_diff	-72.010	-7.379	54.288
366_990	ave_diff	-176.258	-82.185	-51.455
	max_diff	-233.979	-173.630	-124.028
	min_diff	-140.730	-4.754	78.759
357_0	ave_diff	-7.932	-0.398	6.589
	max_diff	-127.045	-11.022	46.635
	min_diff	-72.739	8.767	82.871
337_0	ave_diff	-2.310	2.664	11.812
	max_diff	-101.205	-61.350	-21.208
	min_diff	-1.027	62.282	155.890
423_2216	ave_diff	15.715	43.590	112.410
	max_diff	-87.074	-19.236	93.671
	min_diff	20.012	129.763	237.510
349_1474	ave_diff	-160.080	-75.554	-39.620
	max_diff	-322.047	-119.625	53.839
	min_diff	-301.616	-136.224	45.355
324_3715	ave_diff	-22.780	-6.757	9.291
	max_diff	-218.098	-74.717	16.358
	min_diff	-30.963	72.799	205.837
379_500	ave_diff	8.859	16.716	25.947
	max_diff	-33.046	-12.530	20.873
	min_diff	35.473	81.391	127.053
383_9454	ave_diff	9.779	18.078	40.778

DSM2 Location	Statistic	P_5	P_{50}	P_{95}
388_8306	max_diff	-33.689	-17.272	34.316
	min_diff	-4.576	43.692	94.853
	ave_diff	4.642	9.526	16.157
	max_diff	-17.275	-5.181	10.680
	min_diff	18.175	44.555	74.744
CLFCT	ave_diff	-257.583	7.897	313.177
	max_diff	-5285.350	-1806.087	107.626
	min_diff	0.000	0.000	0.000

Appendix 2 Statistical Analysis of Stage Difference throughout the Delta

DSM2 Location	Statistic	P_5	P_{50}	P_{95}
205_2485	ave_diff	-0.017	0.016	0.137
	max_diff	-0.111	-0.012	0.135
	min_diff	-0.034	0.014	0.182
CHGRL009	ave_diff	-0.020	0.014	0.058
	max_diff	-0.108	-0.012	0.131
	min_diff	-0.044	0.015	0.084
CHVCT000	ave_diff	-0.014	0.004	0.024
	max_diff	-0.058	-0.003	0.084
	min_diff	-0.026	0.015	0.063
RMID023	ave_diff	-0.014	0.003	0.019
	max_diff	-0.048	-0.001	0.075
	min_diff	-0.049	0.011	0.049
RMID027	ave_diff	-0.012	0.006	0.051
	max_diff	-0.053	-0.003	0.072
	min_diff	-0.022	0.013	0.050
RMID041	ave_diff	-0.015	0.011	0.128
	max_diff	-0.087	-0.011	0.118
	min_diff	-0.033	0.007	0.177
ROLD046	ave_diff	-0.016	0.012	0.057
	max_diff	-0.085	-0.005	0.141
	min_diff	-0.041	0.018	0.088
ROLD047	ave_diff	-0.019	0.014	0.135
	max_diff	-0.076	0.002	0.139
	min_diff	-0.030	0.015	0.180
ROLD059	ave_diff	-0.019	0.016	0.136
	max_diff	-0.113	-0.007	0.139
	min_diff	-0.041	0.012	0.180
ROLD074	ave_diff	-0.061	0.007	0.107
	max_diff	-0.088	-0.002	0.064
	min_diff	-0.072	0.009	0.171
RMID015_144	ave_diff	-0.006	0.001	0.008
	max_diff	-0.018	-0.004	0.034
	min_diff	-0.043	0.002	0.021
ROLD024	ave_diff	-0.004	0.002	0.008
	max_diff	-0.011	0.000	0.021
	min_diff	-0.043	-0.004	0.013
RSAC101	ave_diff	0.001	0.003	0.005
	max_diff	-0.019	-0.010	0.000
	min_diff	-0.002	0.007	0.016

DSM2 Location	Statistic	P_5	P_{50}	P_{95}
RSAC081	ave_diff	0.001	0.003	0.004
	max_diff	-0.004	0.003	0.010
	min_diff	-0.006	0.000	0.007
RSAC123	ave_diff	0.002	0.005	0.036
	max_diff	-0.022	-0.004	0.028
	min_diff	0.001	0.021	0.043
RSAN018	ave_diff	-0.002	0.001	0.005
	max_diff	-0.004	0.006	0.015
	min_diff	-0.023	-0.011	0.003
RSAN043	ave_diff	-0.003	0.002	0.006
	max_diff	-0.016	-0.005	0.006
	min_diff	-0.026	-0.006	0.010

Appendix 3 Statistical Analysis of EC Difference throughout the Delta

DSM2 Location	P_5	P_{50}	P_{95}
ROLD074	-26.004	0.877	23.629
ROLD059	-25.085	-0.023	22.012
ROLD047	-29.277	-3.471	12.000
RMID041	-25.813	0.822	24.620
RMID027	-20.287	0.335	38.848
CLFCT	-12.654	-0.193	8.273
CHVCT000	-10.235	0.016	5.972
CHGRL009	-22.696	0.413	21.340
CHDMC004	-20.071	-2.940	7.097
205_2485	-22.331	0.544	21.767
RSAN043	-3.235	0.204	2.833
RSAN007	-123.825	-20.407	1.521
RSAC081	-151.697	-33.312	1.790
RSAN018	-64.346	-2.731	2.143
ROLD034	-17.550	-1.209	2.677
ROLD024	-23.651	-1.536	2.110
RMID015_145	-9.701	-0.045	5.844

Appendix 4 Statistical Analysis of DOC Difference throughout the Delta

DSM2 Location	P_5	P_{50}	P_{95}
ROLD074	-0.001	0.000	0.002
ROLD059	-0.062	0.000	0.053
ROLD047	-0.069	0.000	0.056
RMID041	-0.007	0.000	0.023
RMID027	-0.066	0.000	0.120
CLFCT	-0.028	0.003	0.039
CHVCT000	-0.025	0.003	0.046
CHGRL009	-0.013	0.000	0.024
CHDMC004	-0.040	0.000	0.041
205_2485	-0.008	0.000	0.018
RSAN043	-0.019	0.004	0.037
RSAN007	-0.006	-0.001	0.011
RSAC081	-0.008	-0.002	0.002
RSAN018	-0.004	0.001	0.011
ROLD034	-0.014	0.002	0.030
ROLD024	-0.011	0.001	0.021
RMID015_145	-0.025	0.004	0.051

Appendix 5 Statistical Analysis of Volumetric Fingerprint Difference throughout the Delta

DSM2 Location	Source	P_5	P_{50}	P_{95}
ROLD074	ag	-0.011	0.000	0.022
	east	0.000	0.000	0.000
	mtz	0.000	0.000	0.000
	sac	0.000	0.000	0.000
	sjr	-0.015	0.000	0.014
ROLD059	ag	-1.416	-0.006	1.168
	east	-0.076	0.000	0.098
	mtz	-0.022	0.000	0.001
	sac	-0.408	0.000	1.038
	sjr	-1.538	0.004	1.316
ROLD047	ag	-0.811	0.012	0.722
	east	-0.122	0.032	0.394
	mtz	-0.039	0.000	0.044
	sac	-1.212	0.250	4.395
	sjr	-4.901	-0.334	1.412
RMID041	ag	-0.355	0.001	0.212
	east	-0.002	0.000	0.005
	mtz	0.000	0.000	0.000
	sac	-0.007	0.000	0.000
	sjr	-0.311	-0.001	0.505
RMID027	ag	-2.431	0.012	1.708
	east	-0.536	0.000	0.166
	mtz	-0.049	0.000	0.003
	sac	-5.682	-0.137	0.549
	sjr	-0.703	0.123	6.340
CLFCT	ag	-0.198	-0.021	0.112
	east	-0.176	-0.017	0.089
	mtz	-0.053	-0.001	0.005
	sac	-1.622	-0.392	0.258
	sjr	-0.320	0.423	1.789
CHVCT000	ag	-0.104	0.009	0.211
	east	-0.143	0.014	0.160
	mtz	-0.036	0.000	0.009
	sac	-1.466	-0.182	0.643
	sjr	-0.794	0.139	1.448

DSM2 Location	Source	P_5	P_{50}	P_{95}
CHGRL009	ag	-0.295	0.003	0.466
	east	-0.016	0.000	0.013
	mtz	-0.003	0.000	0.000
	sac	-0.079	0.000	0.136
	sjr	-0.551	-0.003	0.461
CHDMC004	ag	-0.122	0.023	0.343
	east	-0.077	0.027	0.333
	mtz	-0.039	0.000	0.029
	sac	-0.657	0.257	2.543
	sjr	-3.048	-0.352	0.678
205_2485	ag	-0.191	0.001	0.252
	east	-0.020	0.000	0.015
	mtz	-0.002	0.000	0.000
	sac	-0.079	0.000	0.140
	sjr	-0.432	-0.001	0.345
RSAN043	ag	-0.071	0.021	0.183
	east	-0.197	0.037	0.577
	mtz	-0.009	0.000	0.007
	sac	-0.850	-0.098	0.147
	sjr	-0.326	0.002	0.688
RSAN007	ag	-0.040	-0.014	0.024
	east	-0.032	-0.001	0.134
	mtz	-0.289	-0.046	0.086
	sac	-0.455	0.067	0.284
	sjr	-0.012	0.000	0.293
RSAC081	ag	-0.039	-0.016	0.005
	east	-0.040	-0.006	0.001
	mtz	-0.298	-0.070	0.137
	sac	-0.135	0.118	0.310
	sjr	-0.084	-0.001	0.006
RSAN018	ag	-0.042	-0.008	0.027
	east	-0.032	0.000	0.154
	mtz	-0.214	-0.001	0.057
	sac	-0.424	0.009	0.197
	sjr	-0.010	0.001	0.294
ROLD034	ag	-0.113	-0.007	0.155
	east	-0.060	0.003	0.158
	mtz	-0.060	0.000	0.014
	sac	-0.493	-0.013	0.478
	sjr	-0.607	0.022	0.464

DSM2 Location	Source	P_5	P_{50}	P_{95}
ROLD024	ag	-0.095	-0.018	0.108
	east	-0.054	-0.003	0.192
	mtz	-0.084	0.000	0.018
	sac	-0.328	0.050	0.253
	sjr	-0.264	-0.007	0.151
RMID015_145	ag	-0.096	0.006	0.192
	east	-0.124	0.019	0.148
	mtz	-0.035	0.000	0.010
	sac	-1.412	-0.187	0.542
	sjr	-0.546	0.136	1.303

Appendix 6 Statistical Analysis of Flow Difference for South Delta Sites

Gate operation		or_mr_orh			or_mr_glc_orh			or_mr_glc			or_mr		
DSM2 location	Statistic	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
060_0	ave_diff	-177	0	5	-86	76	168	-143	-10	43	-24	-4	10
	max_diff	-267	-33	5	-95	42	149	-157	-55	45	-172	-26	9
	min_diff	-147	8	76	-150	3	228	-183	5	74	-40	13	78
CHGRL009	ave_diff	-173	-1	14	-117	45	137	-160	-15	7	-35	-2	22
	max_diff	-504	6	81	-301	42	187	-389	-114	102	-454	1	72
	min_diff	-98	32	193	26	156	393	-270	43	487	-259	38	234
CHVCT000	ave_diff	-51	2	88	-124	-16	84	-87	0	103	-85	0	69
	max_diff	-502	-34	289	-664	-327	72	-723	-427	-12	-621	-222	106
	min_diff	-160	2	146	-125	7	668	-43	175	1187	-224	0	329
RMID027	ave_diff	-7	-1	2	-3	15	38	-10	0	17	-3	0	4
	max_diff	-61	-9	21	-84	-22	41	-122	-30	50	-82	-4	48
	min_diff	-15	16	67	-11	35	72	-45	16	70	-30	13	68
RMID041	ave_diff	-7	0	2	-3	15	38	-9	-1	17	-2	0	3
	max_diff	-20	-2	3	-4	9	31	-11	-1	14	-14	-2	16
	min_diff	-3	0	29	4	23	37	-2	24	47	-2	1	41
ROLD047	ave_diff	-6	1	4	0	19	114	-9	4	88	-10	-1	4
	max_diff	-26	-1	18	0	34	242	-21	8	231	-37	0	29
	min_diff	-18	16	46	-56	52	120	-138	18	87	-56	13	64
ROLD059	ave_diff	-6	1	4	0	19	112	-9	3	88	-10	-1	4
	max_diff	-112	-42	-7	-65	4	153	-99	-41	24	-112	-40	18
	min_diff	-16	1	48	-4	41	87	-20	11	86	-34	8	68
ROLD074	ave_diff	-186	0	1	-69	89	181	-126	-11	33	-20	-4	7
	max_diff	-205	-1	0	-51	216	276	-95	-48	13	-96	-34	12
	min_diff	-159	2	26	-152	0	132	-152	3	58	-42	37	182
RSAN072	ave_diff	-3	0	184	-182	-86	67	-32	12	125	-6	4	19
	max_diff	-9	-1	171	-119	-65	22	-19	11	86	-18	2	22
	min_diff	-9	17	217	-319	-118	136	-7	31	97	-2	11	49

		no gate			orh			mr		
Gate operation		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
060_0	ave_diff	-308	-9	5	-16	-3	13	-19	-1	13
	max_diff	-330	-28	13	-194	-11	27	-135	2	35
	min_diff	-309	23	128	-76	5	93	-19	16	95
CHGRL009	ave_diff	-36	-5	113	-34	-3	39	-24	-2	20
	max_diff	-696	-21	123	-681	-30	125	-317	11	105
	min_diff	-219	67	259	-308	32	224	-263	38	186
CHVCT000	ave_diff	-92	-1	92	-114	0	109	-70	-1	101
	max_diff	-636	-291	0	-499	-220	54	-435	-105	229
	min_diff	-249	17	438	-237	8	329	-218	3	111
RMID027	ave_diff	-3	1	6	-6	0	8	-3	0	2
	max_diff	-135	-19	55	-116	-8	60	-46	-1	30
	min_diff	-46	6	59	-35	9	55	-48	13	44
RMID041	ave_diff	-3	1	5	-2	0	5	-2	0	2
	max_diff	-12	-2	4	-29	-3	13	-10	-3	7
	min_diff	-9	5	33	-13	4	31	-1	0	37
ROLD047	ave_diff	-11	2	38	-15	1	20	-10	0	12
	max_diff	-422	-22	104	-427	-12	120	-254	2	92
	min_diff	-104	24	112	-141	17	73	-136	15	62
ROLD059	ave_diff	-5	2	38	-5	1	10	-3	1	5
	max_diff	-93	-17	35	-107	-16	23	-84	-16	21
	min_diff	-14	30	83	-46	11	47	-33	11	50
ROLD074	ave_diff	-311	-7	3	-9	-2	5	-16	-2	9
	max_diff	-330	-43	2	-43	-10	15	-62	-23	22
	min_diff	-305	32	241	-18	13	117	-94	52	110
RSAN072	ave_diff	-150	4	19	-6	2	9	-7	2	15
	max_diff	-148	-4	20	-25	-3	6	-15	6	28
	min_diff	-142	15	61	-10	16	75	1	10	25

Appendix 7 Statistical Analysis of Stage Difference for South Delta Sites

		or_mr_orh			or_mr_glc_orh			or_mr_glc			or_mr		
Gate operation		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
205_2485	ave_diff	-0.04	0.00	0.03	0.00	0.12	0.28	-0.04	0.02	0.18	-0.01	0.01	0.05
	max_diff	-0.12	-0.02	0.03	-0.01	0.10	0.20	-0.09	-0.01	0.13	-0.13	-0.01	0.12
	min_diff	-0.05	0.02	0.04	0.00	0.12	0.35	-0.06	0.01	0.22	-0.03	0.02	0.04
CHGRL009	ave_diff	-0.05	0.00	0.02	-0.03	0.02	0.08	-0.03	0.02	0.06	-0.01	0.01	0.05
	max_diff	-0.10	-0.02	0.04	-0.05	0.00	0.05	-0.09	-0.01	0.20	-0.13	-0.01	0.12
	min_diff	-0.05	0.02	0.04	-0.05	0.03	0.13	-0.12	0.03	0.16	-0.03	0.02	0.04
CHVCT000	ave_diff	-0.01	0.00	0.01	-0.01	0.01	0.03	-0.01	0.01	0.03	-0.01	0.00	0.02
	max_diff	-0.08	-0.01	0.05	-0.04	0.00	0.08	-0.07	0.01	0.09	-0.09	-0.01	0.09
	min_diff	0.00	0.01	0.03	-0.02	0.02	0.08	-0.05	0.02	0.09	0.00	0.02	0.03
RMID023	ave_diff	-0.01	0.00	0.01	-0.01	0.01	0.03	-0.01	0.00	0.02	-0.01	0.00	0.02
	max_diff	-0.06	-0.01	0.05	-0.03	0.00	0.08	-0.05	0.02	0.09	-0.08	-0.01	0.07
	min_diff	-0.01	0.01	0.03	-0.04	0.01	0.06	-0.07	0.01	0.07	-0.01	0.01	0.03
RMID027	ave_diff	-0.02	0.01	0.03	0.02	0.04	0.07	0.01	0.03	0.06	0.00	0.01	0.04
	max_diff	-0.06	-0.02	0.04	-0.04	0.00	0.07	-0.05	0.01	0.09	-0.07	0.00	0.08
	min_diff	-0.02	0.01	0.02	0.02	0.04	0.08	-0.01	0.03	0.07	-0.02	0.00	0.03
RMID041	ave_diff	-0.09	0.00	0.03	0.00	0.13	0.28	-0.03	0.02	0.16	-0.01	0.01	0.05
	max_diff	-0.11	-0.02	0.03	-0.02	0.09	0.19	-0.07	0.00	0.11	-0.10	-0.01	0.10
	min_diff	-0.12	0.01	0.03	0.00	0.14	0.37	-0.05	0.02	0.21	-0.02	0.01	0.04
ROLD046	ave_diff	-0.02	0.00	0.02	-0.01	0.02	0.07	-0.01	0.03	0.07	-0.01	0.01	0.04
	max_diff	-0.10	-0.02	0.05	-0.04	0.00	0.06	-0.07	0.00	0.20	-0.10	-0.01	0.15
	min_diff	0.00	0.02	0.03	-0.08	0.02	0.12	-0.13	0.02	0.14	-0.02	0.02	0.04
ROLD047	ave_diff	-0.03	0.01	0.05	-0.05	0.12	0.27	-0.12	0.02	0.18	-0.01	0.01	0.07
	max_diff	-0.06	-0.01	0.07	-0.01	0.08	0.19	-0.06	0.02	0.13	-0.05	0.01	0.12
	min_diff	-0.03	0.01	0.03	-0.13	0.12	0.36	-0.20	0.02	0.21	-0.02	0.01	0.05
ROLD059	ave_diff	-0.04	0.01	0.05	0.00	0.12	0.27	-0.08	0.02	0.18	-0.01	0.01	0.06
	max_diff	-0.06	0.00	0.09	-0.01	0.09	0.19	-0.06	0.02	0.14	-0.06	0.01	0.12
	min_diff	-0.03	0.01	0.03	-0.06	0.12	0.36	-0.16	0.01	0.21	-0.03	0.01	0.04
ROLD074	ave_diff	-0.13	0.00	0.03	0.00	0.14	0.31	-0.02	0.01	0.11	-0.01	0.01	0.02
	max_diff	-0.15	-0.03	0.01	-0.02	0.10	0.20	-0.02	0.00	0.06	-0.03	0.00	0.04
	min_diff	-0.20	0.02	0.05	0.01	0.15	0.39	-0.04	0.02	0.20	0.00	0.01	0.04

Gate operation		no gate			orh			mr		
		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
205_2485	ave_diff	-0.01	0.02	0.06	-0.03	0.01	0.06	-0.02	0.01	0.03
	max_diff	-0.12	-0.02	0.12	-0.12	-0.01	0.13	-0.08	-0.01	0.10
	min_diff	-0.03	0.01	0.05	-0.07	0.01	0.06	-0.06	0.02	0.03
CHGRL009	ave_diff	-0.01	0.02	0.05	-0.03	0.01	0.06	-0.02	0.01	0.03
	max_diff	-0.11	-0.01	0.13	-0.11	-0.01	0.13	-0.08	-0.01	0.11
	min_diff	-0.02	0.01	0.05	-0.07	0.01	0.06	-0.06	0.02	0.03
CHVCT000	ave_diff	-0.01	0.00	0.02	-0.02	0.00	0.02	-0.02	0.00	0.01
	max_diff	-0.04	0.00	0.08	-0.04	-0.01	0.09	-0.11	-0.01	0.05
	min_diff	-0.03	0.01	0.04	-0.02	0.01	0.04	-0.01	0.02	0.03
RMID023	ave_diff	-0.01	0.00	0.02	-0.02	0.00	0.02	-0.02	0.00	0.01
	max_diff	-0.04	0.00	0.06	-0.04	-0.01	0.08	-0.10	-0.01	0.06
	min_diff	-0.05	0.01	0.03	-0.03	0.01	0.04	-0.01	0.01	0.03
RMID027	ave_diff	-0.01	0.00	0.02	-0.02	0.00	0.02	-0.01	0.01	0.03
	max_diff	-0.04	0.00	0.06	-0.05	-0.01	0.07	-0.06	-0.01	0.05
	min_diff	-0.04	0.01	0.03	-0.03	0.01	0.04	-0.01	0.01	0.02
RMID041	ave_diff	-0.01	0.01	0.04	-0.03	0.01	0.07	-0.01	0.01	0.03
	max_diff	-0.09	-0.01	0.10	-0.12	-0.02	0.13	-0.07	-0.01	0.09
	min_diff	-0.03	0.00	0.02	-0.07	0.00	0.05	-0.02	0.01	0.03
ROLD046	ave_diff	-0.01	0.01	0.05	-0.03	0.01	0.05	-0.02	0.01	0.03
	max_diff	-0.09	-0.01	0.13	-0.08	-0.01	0.14	-0.07	-0.01	0.13
	min_diff	-0.02	0.02	0.04	-0.06	0.02	0.04	-0.08	0.02	0.04
ROLD047	ave_diff	-0.01	0.01	0.05	-0.03	0.01	0.05	-0.02	0.01	0.03
	max_diff	-0.09	-0.01	0.13	-0.08	-0.01	0.14	-0.07	-0.01	0.13
	min_diff	-0.02	0.02	0.04	-0.06	0.02	0.04	-0.08	0.02	0.04
ROLD059	ave_diff	-0.01	0.02	0.06	-0.03	0.01	0.06	-0.02	0.01	0.03
	max_diff	-0.13	-0.02	0.13	-0.14	-0.02	0.13	-0.10	-0.02	0.11
	min_diff	-0.04	0.01	0.05	-0.06	0.01	0.04	-0.05	0.02	0.04
ROLD074	ave_diff	-0.11	0.01	0.02	-0.02	0.01	0.06	-0.01	0.01	0.02
	max_diff	-0.10	0.00	0.04	-0.13	-0.02	0.13	-0.05	0.00	0.06
	min_diff	-0.11	0.00	0.03	-0.05	0.01	0.05	-0.01	0.01	0.03

Appendix 8 Statistical Analysis of EC Difference for South Delta Sites

Gate	or_mr_orh			or_mr_glc_orh			or_mr_glc			or_mr		
operation	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
ROLD074	-35.5	0.7	23.6	-35.8	0.7	24.5	-17.1	0.7	16.2	-20.4	1.5	24.1
ROLD059	-29.5	-3.3	3.7	-114.0	-0.2	43.4	-16.7	0.7	25.4	-30.5	-6.8	11.3
ROLD047	-31.1	-3.3	4.6	-25.2	-4.9	9.4	-14.5	-1.7	30.0	-21.0	-5.8	8.0
RMID041	-17.8	-0.2	35.4	-42.5	0.7	22.5	-16.0	0.7	16.3	-21.5	1.8	24.0
RMID027	-12.4	-1.2	8.4	-156.2	4.7	166.5	-18.5	0.2	122.8	-15.0	-2.0	6.5
CLFCT	-22.1	1.7	7.7	-8.5	-5.2	-0.7	-5.0	-0.2	3.2	-15.8	-0.3	3.3
CHVCT000	-12.4	-1.4	4.6	-8.9	-3.9	3.3	-2.2	0.7	7.5	-14.9	-1.6	3.9
CHGRL009	-30.2	-2.1	104.1	-60.1	-1.0	29.2	-12.0	0.6	13.9	-17.8	0.6	18.7
CHDMC004	-21.4	-3.3	3.0	-15.2	-3.5	4.5	-10.9	-2.2	2.4	-19.7	-3.2	7.3
205_2485	-26.7	-2.0	110.3	-60.7	0.4	30.6	-13.7	0.7	13.9	-17.6	0.5	19.5

	no gate			orh			mr		
Gate operation	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
ROLD074	-28.1	0.6	25.0	-34.0	1.9	27.0	-42.6	5.0	31.9
ROLD059	-22.7	0.6	20.0	-22.7	0.6	17.9	-38.8	1.2	30.5
ROLD047	-36.0	-3.5	10.4	-21.9	-9.3	7.3	-27.2	-13.4	10.2
RMID041	-29.0	0.6	24.2	-31.6	2.3	34.5	-27.8	3.7	36.4
RMID027	-19.5	1.7	29.9	-12.9	-5.3	1.7	-13.8	-7.4	2.3
CLFCT	-7.7	0.9	10.0	-21.4	-6.8	-0.6	-16.9	-6.9	4.3
CHVCT000	-7.3	0.3	5.2	-13.1	-6.0	1.6	-13.9	-7.2	2.3
CHGRL009	-24.1	0.7	23.3	-22.9	0.8	17.2	-35.5	-0.2	29.5
CHDMC004	-20.9	-2.3	9.5	-21.5	-7.2	0.4	-28.4	-12.9	4.2
205_2485	-24.2	0.8	23.4	-27.0	1.4	18.1	-38.9	0.2	29.2

Appendix 9 Statistical Analysis of DOC Difference for South Delta Sites

Gate operation	or_mr_orh			or_mr_glc_orh			or_mr_glc			or_mr		
	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
ROLD074	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
ROLD059	-0.02	0.00	0.06	-0.40	-0.03	0.24	-0.05	0.00	0.39	-0.13	0.00	0.03
ROLD047	-0.02	0.01	0.07	-0.10	0.00	0.11	-0.09	0.00	0.06	-0.02	0.00	0.04
RMID041	-0.03	0.01	0.05	-0.03	0.00	0.04	-0.01	0.00	0.00	0.00	0.00	0.01
RMID027	-0.03	0.01	0.04	-0.21	0.05	0.57	-0.08	0.00	0.21	-0.01	0.00	0.07
CLFCT	-0.03	0.00	0.04	-0.02	0.01	0.03	-0.02	0.00	0.02	-0.02	0.00	0.04
CHVCT000	-0.02	0.01	0.04	-0.06	0.00	0.04	-0.02	0.00	0.04	-0.01	0.01	0.07
CHGRL009	-0.01	0.00	0.05	-0.12	0.02	0.18	-0.04	0.00	0.04	0.00	0.00	0.02
CHDMC004	-0.01	0.01	0.05	-0.04	0.00	0.05	-0.04	0.00	0.02	-0.01	0.00	0.04
205_2485	-0.01	0.00	0.03	-0.09	0.02	0.21	-0.02	0.00	0.03	-0.01	0.00	0.01

Gate operation	No gate			orh			mr		
	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
ROLD074	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
ROLD059	-0.04	0.00	0.04	-0.01	0.00	0.04	-0.01	0.00	0.02
ROLD047	-0.07	0.00	0.05	-0.08	-0.01	0.07	-0.04	0.01	0.02
RMID041	0.00	0.00	0.01	-0.01	0.00	0.06	-0.01	0.00	0.08
RMID027	-0.06	0.00	0.05	-0.08	0.00	0.03	-0.01	0.02	0.04
CLFCT	-0.04	0.00	0.05	-0.04	0.00	0.03	-0.01	0.00	0.02
CHVCT000	-0.02	0.00	0.04	-0.08	0.00	0.02	0.00	0.02	0.04
CHGRL009	-0.01	0.00	0.01	-0.01	0.00	0.01	0.00	0.00	0.01
CHDMC004	-0.04	0.00	0.04	-0.07	0.00	0.02	-0.02	0.01	0.02
205_2485	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01

Appendix 10 Statistical Analysis of Volumetric Fingerprint Difference for South Delta Sites

		or_mr_orh			or_mr_glc_orh			or_mr_glc			or_mr		
Gate operation		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
	ag	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1	-0.2	0.0	0.1
	east	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
ROLD074	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sjr	-0.3	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.3
	ag	-1.4	0.0	0.3	-13.8	1.2	13.6	-11.2	-0.1	2.0	-2.4	0.0	2.4
	east	-0.2	0.0	1.2	-1.4	0.0	0.3	-0.4	0.0	0.0	0.0	0.0	1.0
ROLD059	mtz	0.0	0.0	0.0	-0.4	0.0	0.1	-0.1	0.0	0.0	0.0	0.0	0.0
	sac	-1.2	0.2	3.8	-21.1	-0.1	7.8	-11.0	0.0	0.0	-0.2	0.2	4.6
	sjr	-4.4	-0.2	1.5	-12.1	-0.1	31.2	-1.1	0.1	17.6	-6.1	-0.2	0.3
	ag	-0.5	0.0	0.2	-1.0	0.0	0.8	-2.5	0.0	3.4	-0.2	0.0	0.3
	east	-0.1	0.1	1.5	-0.3	0.0	0.2	-0.6	0.0	0.2	-0.1	0.1	0.5
ROLD047	mtz	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
	sac	-0.5	0.2	4.7	-7.5	0.1	2.8	-6.3	0.0	2.3	-0.6	0.2	2.8
	sjr	-5.8	-0.2	0.6	-3.1	-0.1	8.4	-2.2	0.0	4.8	-3.4	-0.3	0.5
	ag	-0.7	0.0	3.7	-0.7	-0.2	0.4	-0.1	0.0	0.3	-0.4	0.0	0.1
	east	-0.1	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
RMID041	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	-0.8	0.1	2.4	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
	sjr	-6.8	-0.3	1.5	-0.4	0.2	0.7	-0.3	0.0	0.1	-0.2	0.0	1.3
	ag	-0.4	0.0	0.2	-14.9	-3.1	7.3	-6.8	0.1	5.8	-0.2	0.0	0.3
	east	-0.6	0.1	0.2	-2.6	-0.2	0.1	-2.3	0.0	0.6	-0.2	0.1	0.2
RMID027	mtz	0.0	0.0	0.0	-0.6	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0
	sac	-1.1	-0.2	0.0	-53.4	-4.0	0.0	-25.1	0.0	3.3	-0.7	-0.2	0.0
	sjr	-0.1	0.2	1.9	-1.3	7.5	53.1	-3.3	0.0	30.4	0.0	0.2	0.7
	ag	-0.2	0.0	0.1	-0.1	0.0	0.1	-0.1	0.0	0.1	-0.1	0.0	0.2
	east	-0.3	0.0	0.2	-0.1	0.0	0.1	-0.1	0.0	0.1	-0.2	0.0	0.1
CLFCT	mtz	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
	sac	-1.9	-0.6	-0.1	-1.5	0.1	1.0	-1.1	-0.1	0.4	-1.0	-0.3	0.0
	sjr	0.0	0.6	2.0	-1.1	-0.1	1.6	-0.5	0.1	1.2	-0.1	0.2	1.2
	ag	-0.3	0.0	0.1	-0.1	0.0	0.2	-0.1	0.0	0.2	-0.1	0.0	0.3
	east	-0.5	0.1	0.2	-0.2	0.0	0.2	-0.2	0.0	0.2	-0.2	0.1	0.2
CHVCT000	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
	sac	-1.0	-0.2	0.0	-2.8	0.7	2.3	-2.0	-0.3	0.7	-0.7	-0.3	0.0
	sjr	-0.1	0.2	1.6	-2.5	-0.8	2.9	-0.4	0.2	2.3	0.0	0.2	0.7
	ag	-0.4	0.0	8.4	-2.9	-0.4	0.8	0.0	0.0	0.9	-0.1	0.0	0.2
	east	-0.1	0.0	3.9	-0.3	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
CHGRL009	mtz	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	-0.2	0.0	8.1	-8.3	-0.4	0.0	0.0	0.0	0.0	-0.2	0.0	0.3
	sjr	-21.0	0.0	0.5	-0.4	1.1	10.1	-0.9	0.0	0.0	-0.5	0.0	0.3

Gate operation		or_mr_orh			or_mr_glc_orh			or_mr_glc			or_mr		
		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
CHDMC004	ag	-0.4	0.0	0.2	-0.3	-0.1	0.1	-0.1	0.0	0.2	-0.1	0.0	0.2
	east	-0.1	0.1	1.2	-0.1	-0.1	0.1	-0.1	0.0	0.2	-0.1	0.0	0.3
	mtz	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
	sac	-0.4	0.2	3.0	-2.8	-0.8	1.4	-0.6	0.4	2.3	-0.4	0.0	1.5
	sjr	-3.8	-0.3	0.4	-1.5	1.0	3.0	-2.5	-0.3	0.6	-1.8	-0.1	0.3
205_2485	ag	-0.3	0.0	9.6	-3.1	-0.5	0.7	-0.1	0.0	0.6	-0.1	0.0	0.3
	east	-0.1	0.0	3.9	-0.3	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
	mtz	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	-0.2	0.0	8.1	-9.7	-0.8	0.0	0.0	0.0	0.0	-0.2	0.0	0.4
	sjr	-21.7	-0.1	0.5	-0.1	1.6	11.9	-0.6	0.0	0.2	-0.7	0.0	0.3

		no gate			orh			mr		
gate operation		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
ROLD074	ag	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.2
	east	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	0.0	0.0
	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sjr	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.7
ROLD059	ag	-0.4	0.0	0.4	-0.2	0.0	0.4	-0.8	-0.2	0.2
	east	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	0.0	0.0	0.0	-0.3	0.0	0.1	-0.3	0.0	0.1
	sjr	-0.4	0.0	0.4	-0.5	0.0	0.6	-0.3	0.2	0.9
ROLD047	ag	-0.6	0.0	0.4	-0.3	0.0	0.2	-0.2	0.0	0.4
	east	0.0	0.0	0.4	-0.1	0.0	0.2	-0.1	0.0	0.2
	mtz	0.0	0.0	0.1	-0.1	0.0	0.1	-0.1	0.0	0.0
	sac	-0.3	0.4	5.0	-1.0	0.6	4.1	-0.4	0.2	3.0
	sjr	-5.5	-0.5	0.4	-4.3	-1.0	1.0	-3.4	-0.2	0.3
RMID041	ag	-0.2	0.0	0.0	-2.1	0.0	0.1	-0.9	0.0	0.4
	east	0.0	0.0	0.0	-0.3	0.0	0.0	-0.7	0.0	0.1
	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	0.0	0.0	0.0	-3.0	0.0	0.0	-2.5	0.0	1.0
	sjr	0.0	0.0	0.2	-0.1	0.0	5.6	-1.5	0.1	3.9
RMID027	ag	-1.5	0.0	1.2	-0.2	0.0	0.3	0.0	0.0	0.2
	east	-0.4	0.0	0.0	-0.1	0.0	0.1	0.0	0.0	0.1
	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	-4.1	-0.1	0.1	-1.6	-0.2	1.4	-0.4	-0.1	0.0
	sjr	-0.1	0.1	4.2	-2.1	0.1	0.7	-0.1	0.0	0.2
CLFCT	ag	-0.3	0.0	0.1	-0.1	0.0	0.1	0.0	0.1	0.2
	east	-0.2	0.0	0.0	-0.1	0.0	0.1	-0.1	0.0	0.0
	mtz	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0
	sac	-1.9	-0.5	0.0	-1.0	-0.3	0.6	-0.6	-0.2	0.1
	sjr	0.0	0.6	2.2	-0.6	0.3	0.8	0.0	0.1	0.6
CHVCT000	ag	-0.1	0.0	0.2	-0.1	0.0	0.1	0.0	0.0	0.2
	east	-0.1	0.0	0.1	-0.1	0.0	0.2	0.0	0.0	0.1
	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	-0.5	-0.2	0.1	-1.3	-0.1	1.6	-0.4	-0.1	0.0
	sjr	-0.3	0.1	0.5	-1.8	0.1	0.4	-0.1	0.0	0.2
CHGRL009	ag	-0.2	0.0	0.2	-0.2	0.0	0.1	-0.1	0.0	0.1
	east	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	0.0	0.0	0.0	-0.1	0.0	0.2	-0.1	0.0	0.8
	sjr	-0.2	0.0	0.2	-0.3	0.0	0.3	-0.9	0.0	0.4

		no gate			orh			mr		
gate operation		P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}	P_5	P_{50}	P_{95}
	ag	-0.1	0.0	0.4	-0.2	0.0	0.1	-0.1	0.0	0.1
	east	0.0	0.0	0.4	-0.1	0.0	0.1	0.0	0.0	0.2
CHDMC004	mtz	0.0	0.0	0.0	-0.1	0.0	0.0	-0.1	0.0	0.0
	sac	-0.2	0.3	2.8	-1.3	0.2	1.5	-0.2	0.2	2.2
	sjr	-3.4	-0.5	0.3	-2.0	-0.3	1.0	-2.5	-0.1	0.1
	ag	-0.1	0.0	0.1	-0.2	0.0	0.1	-0.2	0.0	0.1
	east	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
205_2485	mtz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	sac	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	0.0	0.3
	sjr	-0.1	0.0	0.1	-0.2	0.0	0.3	-0.3	0.0	0.5

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report

June 2009

Chapter 5

A Proposed Method for Sea Level Rise Exceedance Probability

Author: Kevin Kao, Jamie Anderson, and Francis Chung, Delta Modeling Section, Bay Delta Office, California Department of Water Resources

Contents

5 A Proposed Method for Sea Level Rise Exceedance Probability 5-1
5.1 Introduction 5-1
5.2 Sea Level Projection with Historical Trend Extrapolation 5-2
5.3 Sea Level Projection with Rahmstorf's Method 5-3
5.4 Exceedance Probability for Sea Level Rise Projection 5-5
5.4.1 Example #1: Interpolation with lognormal cumulative probability function 5-7
5.4.2 Example #2: Interpolation with generalized extreme value probability function 5-7
5.5 Uncertainty of the proposed method 5-8
5.6 Summary 5-8
5.7 Acknowledgement 5-8
5.8 References 5-9
5.8.1 Cited References 5-9
5.8.2 Selected Additional References 5-9

Figures

Figure 5-1 A second order polynomial fit to historical sea level and extrapolations (normalized to year 2001 levels), 1870–2050 5-2
Figure 5-2 Positive correlation between rate of global sea level changes (mm/year) and global mean surface temperatures (°C) 5-3
Figure 5-3 Changes of global mean surface air temperature (°C) since year 2001; projected by global circulation models through 2100 5-4
Figure 5-4 Sea level projections based on 2 GHG emissions scenarios and 2 global circulation models through 2100 5-4
Figure 5-5 Historical sea levels near San Francisco Bay, 1902–2007 5-5
Figure 5-6 Sea level rise exceedance probability examples 5-7

Tables

Table 5-1 Rate of sea level change from peer-reviewed articles and government publications 5-1

5 A Proposed Method for Sea Level Rise Exceedance Probability

5.1 Introduction

Sea level rise is one of the major concerns for the management of California's water resources. Higher water levels and salinity intrusion into the Sacramento-San Joaquin River Delta could affect water supplies, water quality, levee stability, and the habitat of local flora and fauna. Over the 20th century, sea levels near San Francisco Bay increased by more than 0.6 feet. Acceleration of global sea level change has been observed in both tide gauge and satellite altimeter data. Church and White (2006) found a global sea level change acceleration of 0.013 ± 0.006 mm/year^2 from 1870 to 2004 reconstructed tide gauge data with an average rate of 1.7 ± 0.3 mm/year; Beckley et al. (2007) detected an increase of sea level change from 2.53 ± 0.46 mm/year during 1993 to 2000 to 3.99 ± 0.47 mm/year during 2000 to 2007. The findings are summarized in Table 5-1.

Table 5-1 Rate of sea level change from peer-reviewed articles and government publications

Location	Source	Rate of sea level rise mm/year (inch/year)	Time	Data type
Global	Beckley et al. (2007)	3.36 ± 0.41 (0.13±0.02)	1993−2007	Satellite altimetry
		2.53 ± 0.46 (0.10±0.02)	1993−2000	Satellite altimetry
		3.99 ± 0.47 (0.16±0.02)[1]	2000−2007	Satellite altimetry
	Church et al. (2006)	1.7 ± 0.3 (0.07±0.01)	1870−2004	Gauge data + Satellite alt.
	Church et al. (2004)	1.8 ± 0.3 (0.07±0.01)	1950−2000	Gauge data + Satellite alt.
San Francisco	Snay et al. (2007)	1.30 ± 0.71 (0.05±0.03)	1906−1999	Gauge data with GPS correction[2]
	Zervas (2001)	1.12 ± 0.35 (0.04±0.01)	1854−1905	Gauge data, pre-earthquake
		2.13 ± 0.14 (0.08±0.01)	1906−1999	Gauge data, post-earthquake
		2.23 ± 0.40 (0.09±0.02)	1950−1999	Gauge data

1-The rate of sea level rise in 2000-2007 is higher than in 1993-2000, indicating an accelerating rate of rise.

2- Gauge data were corrected with a vertical land velocity of −0.83 ± 0.70 mm/year measured by Global Positioning System (GPS) for geodetic station "PBLI" at San Francisco during 1995−2005.

For water planners, 2 related questions are raised on the uncertainty of future sea levels. First, what is the expected sea level at a specific time in the future, e.g., what is the expected sea level in 2050? Second, what is the expected time in the future when sea levels will exceed a certain height, e.g., what is the expected range of time when the sea level rises by one foot? To address these questions, 2 factors need to be considered: (1) long-term sea level rise trend, and (2) local extreme sea level fluctuations. In this paper, a method is proposed for developing probability distributions for long-term global sea level rise trends, while not considering the local extreme sea level fluctuations due to effects of astronomical tides, changes in atmospheric pressure, wind stress, floods, and the El Niño/Southern Oscillation.

To project the long-term sea level rise trend, 2 different approaches are employed. One is extending the current rate of sea level rise into the future; the other is using a semi-empirical linear relationship between global mean temperature and rate of global sea level rise proposed by Rahmstorf (2007). This linear relationship and its uncertainty range approximated from the historical data are extrapolated into the higher temperature range. The 12 temperature projections (Cayan et al. 2009) selected by California's Climate Action Team (CAT) are applied to the extrapolated linear relationship to project future sea levels.

To generate sea level rise trend exceedance probability, a lognormal cumulative probability function and a generalized extreme value cumulative probability function are used for interpolation between selected key values. The credibility of the generated exceedance probability curve depends on the choice of these key values, which may be subjective and inevitably involve uncertainties.

5.2 Sea Level Projection with Historical Trend Extrapolation

Based on the reported accelerations by Church and White (2006) and Beckley et al. (2007), a second order polynomial fit during year 1870 to 2001 is performed on global tide gauge data, and the fitting uncertainty is also estimated.[1] The fitted acceleration, 0.0158 (mm/year^2), is within the uncertainty range of the observations by Church and White (2006). Both the fitted curve and the estimated uncertainty are extrapolated to future years as shown in Figure 5-1.

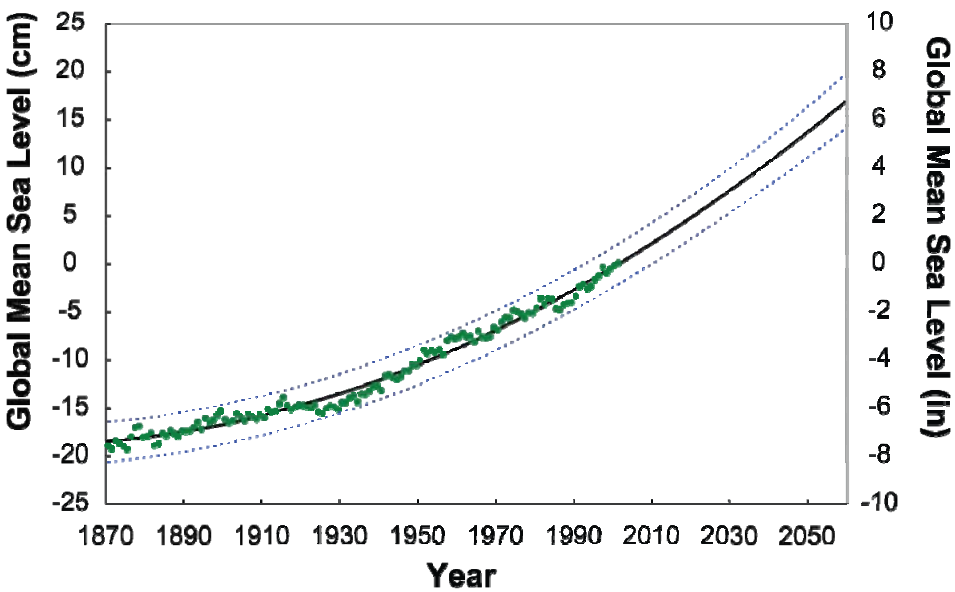


Figure 5-1 A second order polynomial fit to historical sea level and extrapolations (normalized to year 2001 levels), 1870–2050

[1] The simultaneous observation bounds of 95% confidence level are computed by MATLAB Curve Fitting toolbox.

5.3 Sea Level Projection with Rahmstorf's Method

Rahmstorf (2007) presents a significant correlation between the observed global sea level rise rate and global mean surface temperature during 1880 to 2001. He argued that (1) the physics of sea level change has complex mechanisms and is poorly understood and (2) present process-based physical models fail to fully simulate the sea level change of recent decades. Rahmstorf therefore proposed that the initial rise of global average sea level be proportional to the increase of global average near-surface air temperature,

$$\frac{dH}{dt} = a(T - T_0) \qquad (1)$$

where the rate of sea level change *dH/dt* is obtained from global average gauge observations from 1880 to 2002; the global mean near-surface air temperature T is estimated with the global mean surface temperature obtained from NASA from 1880 to 2002, T_o is the equilibrium temperature (on a millennia time scale); and a is a constant of proportionality. To fit Rahmstorf's equation above, the historical global mean sea level trend and global mean temperature trend are first computed with a singular spectrum analysis of a 15-year embedding period, and then subdivided into 5-year-averaged bins. The equation is fitted to these processed data by the least-squares method, and the fitting uncertainty[2] is also estimated as shown in Figure 5-2. This fitted linear equation is then applied to the global near-surface temperature projections from the CAT-selected 12 scenarios as shown in Figure 5-3. At mid-century, sea level rise estimates ranged from 0.8 feet to 1.0 foot (0.24 m to 0.30 m with an uncertainty range spanning 0.5 feet to 1.3 feet (0.15 m to 0.4 m). By the end of the century, sea level rise projections ranged from 1.8 feet to 3.1 feet (0.55 m to 0.94 m), with an uncertainty range spanning from 1.0 foot to 4.0 feet (0.3 m to 1.2 m), as shown in Figure 5-4.

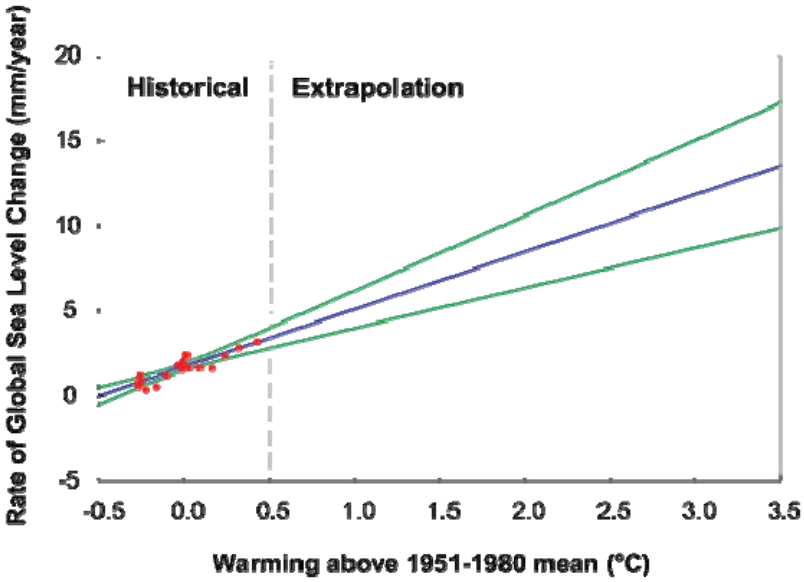


Figure 5-2 Positive correlation between rate of global sea level changes (mm/year) and global mean surface temperatures (°C)

[2] The functional bounds of 95% confidence level are computed with MATLAB Curve Fitting toolbox.

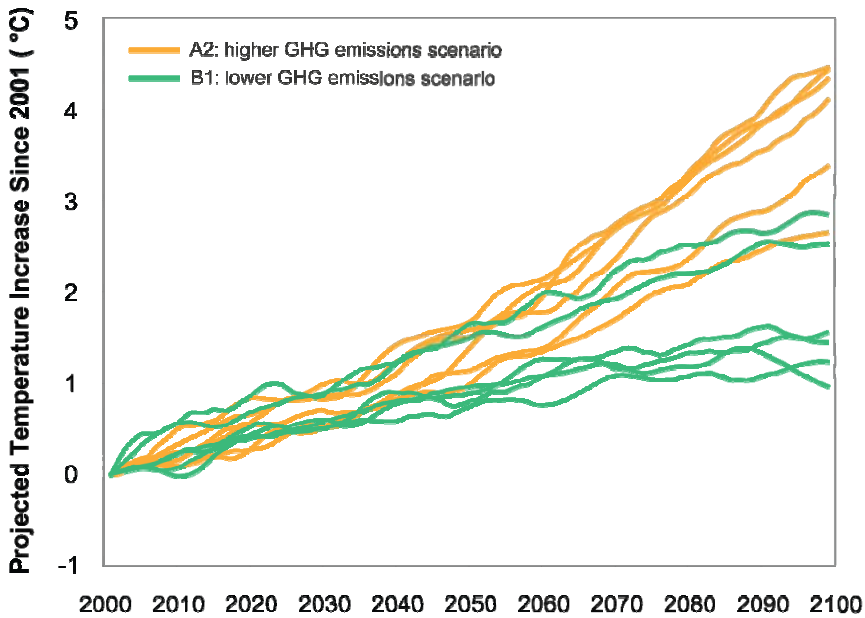


Figure 5-3 Changes of global mean surface air temperature (°C) since year 2001; projected by global circulation models through 2100

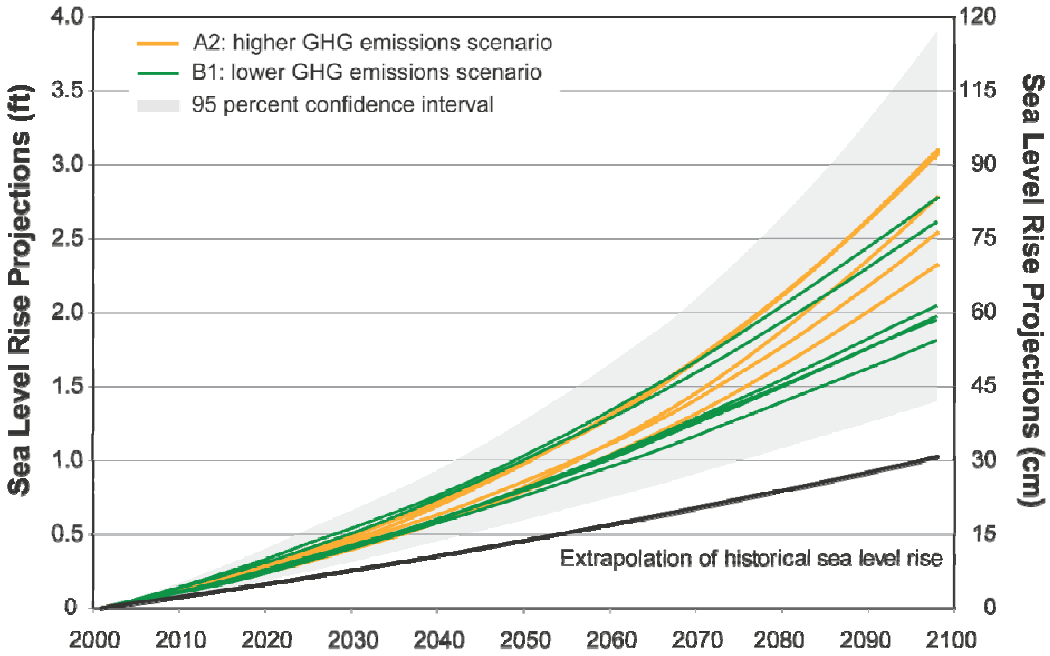


Figure 5-4 Sea level projections based on 2 GHG emissions scenarios and 2 global circulation models through 2100

Caution should be exercised when projecting long-term future sea level changes. The linear relationship between sea level rise rate and temperature is derived in the temperature range of -0.3 to 0.5 °C above 1951 to 1980 mean (Figure 5-2), while in some scenarios the projected global mean temperatures can rise appreciably above the fitted range (Figure 5-3). Moreover, the linear relationship (Equation 1) is fitted with long-term mean sea level trend in response to long-term global mean temperature trend. Therefore,

not discussed here are short-term variations resulting from tidal influences, anomalies during El Niño/La Niña years, and extreme events that arise from atmospheric forcing or other factors. See Figure 5-5 for difference between mean sea levels and extreme sea levels.

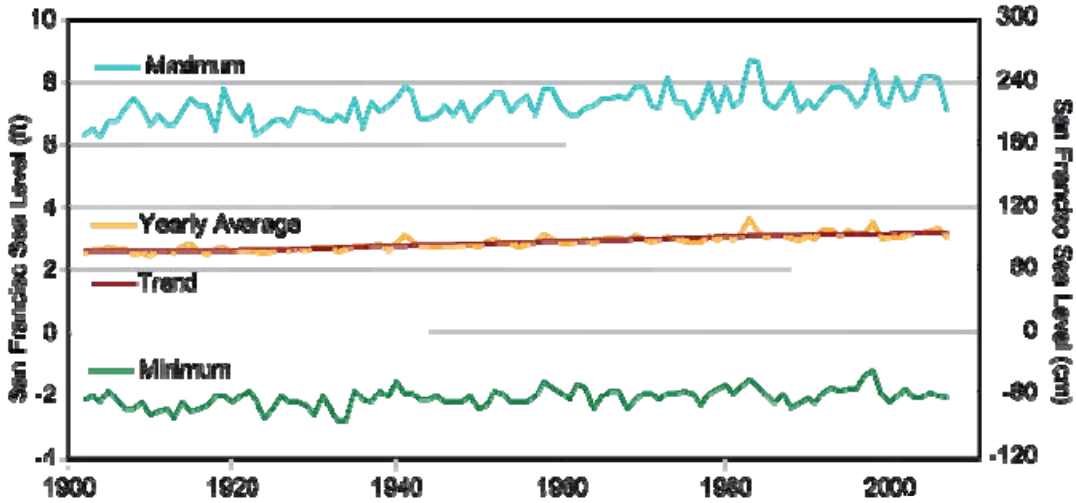


Figure 5-5 Historical sea levels near San Francisco Bay, 1902–2007

5.4 Exceedance Probability for Sea Level Rise Projection

For water resources planning in Sacramento-San Joaquin River Delta, a quantified probability distribution for future sea level rise is more informative than a single best-estimate of sea level rise scenario. Planning for sea level rise depends on quantitative economic analysis and financial feasibility, and will be more realistic if sea level rise projections are provided with probabilities rather than simple forecasts. However, it is difficult to quantify the probability because there are substantial uncertainties in climate modeling, sea level change mechanisms, and future greenhouse gas emissions. In spite of these uncertainties, the U.S. Environmental Protection Agency has published a report titled "The probability of sea level rise" (Titus and Narayanan 1995). The report investigates several components contributing to sea level rise including thermal expansion, Antarctic contribution, Greenland contribution, and small glacier contribution. Each component is modeled with key parameters formulated using subjective probability distribution functions based on expert judgments.

An alternative method is presented for sea level rise exceedance probability. This method interpolates the probability between specified sea level rise values and corresponding probabilities by solving simultaneous equations, where the simultaneous equations are probability cumulative functions. For example, if the sea level rises for cumulative probabilities p_1 and p_2 are respectively z_1 and z_2, then a cumulative probability function F with 2 unknown parameters μ and σ that satisfy each of these 2 criteria can be written as:

$$\begin{cases} \mathrm{F}(x = z_1|\mu,\sigma) = \mathrm{p}_1 \\ \mathrm{F}(x = z_2|\mu,\sigma) = \mathrm{p}_2 \end{cases}$$

If the solution exists for the 2 unknown parameters, μ and σ, then the probability curve between the 2 specified points (z_1, p_1) and (z_2, p_2) can be interpolated by this cumulative probability function. The uncertainty of this interpolation depends on the choice of the key values (z_1, p_1) and (z_2, p_2). For example,

if the values of sea level rise for 50% cumulative probability and 99% cumulative probability are specified as z_1 and z_2, then a lognormal cumulative function F can be written as:

$$\begin{cases} \mathrm{F}_{\mathrm{lognormal}}(x = z_1|\mu,\sigma) = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left[\frac{ln(z_1)-\mu}{\sigma\sqrt{2}}\right] = 50\% \\ \mathrm{F}_{\mathrm{lognormal}}(x = z_2|\mu,\sigma) = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left[\frac{ln(z_2)-\mu}{\sigma\sqrt{2}}\right] = 99\% \end{cases}$$

$$\text{and} \quad \mathrm{erf}(r) = \int_0^r e^{-t^2}\,\mathrm{dt}$$

The above equations imply that when the sea level rise value goes to zero ($x \to 0$), the cumulative probability also goes to zero ($\mathrm{F}_{\mathrm{lognormal}}(x) \to 0$). To consider a more general case, the simultaneous equations can be written as:

$$\begin{cases} \mathrm{F}_{\mathrm{lognormal}}(x = z_0 + z_1|\mu,\sigma) = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left[\frac{ln(z_1)-\mu}{\sigma\sqrt{2}}\right] = 50\% \\ \mathrm{F}_{\mathrm{lognormal}}(x = z_0 + z_1|\mu,\sigma) = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left[\frac{ln(z_2)-\mu}{\sigma\sqrt{2}}\right] = 99\% \end{cases}$$

where the sea level rise value z_0 corresponds to zero cumulative probability. To interpolate for 3 specified points, a cumulative function with 3 unknowns can be employed. For example, the generalized extreme value function that satisfies (z1, p1=50%), (z2, p2=80%), and (z3, p3=99%) can be written as,

$$\begin{cases} \mathrm{F}_{\mathrm{GEV}}(x = z_0 + z_1|\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{ln(z_1)-\mu}{\sigma\sqrt{2}}\right)\right]^{-\frac{1}{\xi}}\right\} = 50\% \\ \mathrm{F}_{\mathrm{GEV}}(x = z_0 + z_2|\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{ln(z_2)-\mu}{\sigma\sqrt{2}}\right)\right]^{-\frac{1}{\xi}}\right\} = 80\% \\ \mathrm{F}_{\mathrm{GEV}}(x = z_0 + z_3|\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{ln(z_3)-\mu}{\sigma\sqrt{2}}\right)\right]^{-\frac{1}{\xi}}\right\} = 99\% \end{cases}$$

$$\text{and} \quad 1 + \frac{\xi(x-\mu)}{\sigma} > 0$$

where the sea level rise value z_0 corresponds to zero cumulative probability. Based on the projected sea level rise scenarios in the previous section, 2 examples using this interpolation method to generate interpolated exceedance probabilities are demonstrated for year 2030, 2050, 2070, and 2090.

5.4.1 Example #1: Interpolation with lognormal cumulative probability function

(1) Cumulative probability of zero is selected to represent no sea level rise.

(2) Cumulative probability of 50% is selected to represent the average of the 12 projected sea level rise scenarios.

(3) Cumulative probability of 99% is selected to represent the upper uncertainty value of the 12 sea level rise scenarios.

Solve the cumulative distribution equation simultaneously using criteria (2) and (3) for parameters μ and σ. The interpolated exceedance probabilities are shown in Figure 5-6.

5.4.2 Example #2: Interpolation with generalized extreme value probability function

(1) Cumulative probability of zero is selected to represent no sea level change.

(2) Cumulative probability of 50% is selected to represent the average projected sea level change of the 12 CAT scenarios.

(3) Cumulative probability of 80% is selected to represent be the highest sea level change scenario of the 12 CAT scenarios.

(4) Cumulative probability of 99% is designed to be the highest 95% confidence level upper bound of the 12 CAT scenarios.

Solutions exist for the 3 unknown parameters for the generalized extreme value probability function. The interpolated exceedance probabilities are shown in Figure 5-6.

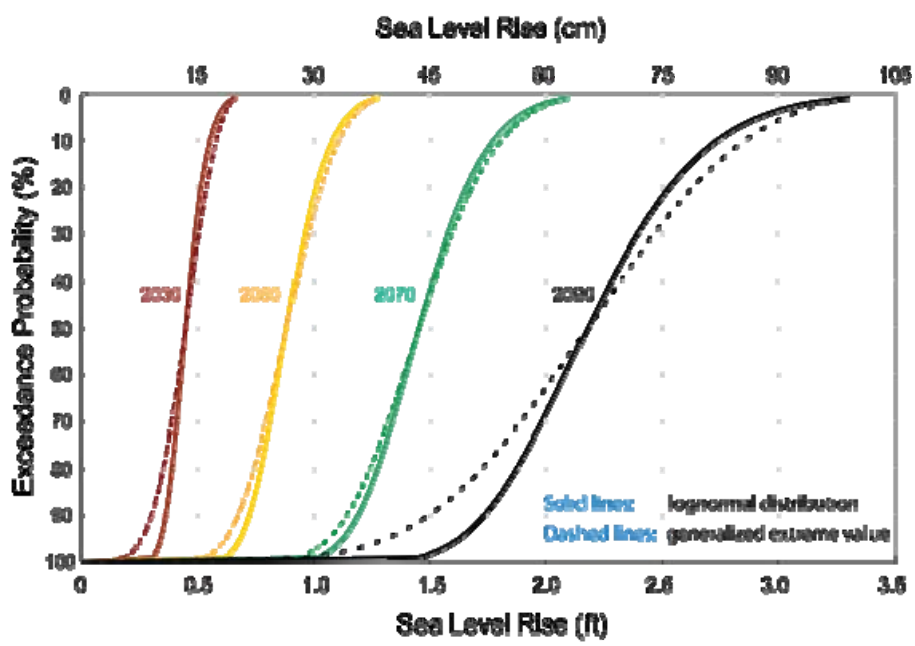


Figure 5-6 Sea level rise exceedance probability examples

5.5 Uncertainty of the proposed method

This proposed method interpolates between the 2 specified sea level rise values with predefined probability distributions. The selections of parameters in the above examples are not guidelines, and thus relevant experts should be consulted. In example #2 (section 5.4.2), for the lower end of the distribution, one can assign the sea level rise value z_0 to a negative, zero, or positive number to associate with the lower end of cumulative probability p_0; for the upper end, the selected value z_3 and associated cumulative probability p_3 determine the most extreme case; for the middle point, z_2 and p_2 determine the shape of the interpolation curve. Scientific evidence, rather than numerical manipulation, should guide the attempts to predict the parameters. Short of scientific research, the choice is subjective.

5.6 Summary

In some cases of water resources economics, planning for sea level rise with exceedance probability may be wiser than planning for an average or best estimate scenario. The economics of water resources is a complex, non-stationary system; therefore, the total cost or benefit could involve considerable uncertainties and surpass either the cost or benefit estimated in a planning which has little probability assessment. A method is proposed for sea level rise exceedance probability based on projections from global circulation models, Rahmstorf's method, probability functions, and, the most important factor, expert judgment. The examples presented in this paper should be viewed with caution because this is a preliminary attempt at exploring exceedance probabilities for long-term sea level trends. The effects of astronomical tides, sea level pressure, wind stress, and El Niño/Southern Oscillation were not included in this study. These factors will result in increases in extreme events (Cayan et al. 2008). Further study will be needed to assess these factors.

5.7 Acknowledgement

The authors acknowledge Nikki Blomquist, technical editor at California Dept. of Water Resources, for developing some of the figures for this paper.

5.8 References

5.8.1 Cited References

Beckley, B.D., F.G. Lemoine, S.B. Luthcke, R.D. Ray, and N.P. Zelensky. 2007. *A reassessment of global and regional mean sea level trends from TOPEX and Jason-1 altimetry based on revised reference frame and orbits*. Geophysical Research Letters, 34, L14608

Cayan, D.R., M. Tyree, M.D. Dettinger, H. Hidalgo, and T. Das. 2009. California climate change scenarios and sea level rise estimates. California 2008-2009 Climate Change Scenarios Assessment. California Energy Commission report CEC-500-2009-014-D. http://www.energy.ca.gov/2009publications/CEC-500-2009-014/CEC-500-2009-014-D.pdf

Cayan, D.R., P.D. Bromirski, K. Hayhoe, M. Tyree, M.D. Dettinger, and R.E. Flick. 2008. *Climate change projections of sea level extremes along the California coast*. Climatic Change, 87, (Suppl 1):S57-S73, doi:10.1007/s10584-007-9376-7

Church, J.A. and N.J. White. 2004. *Estimates of the Regional Distribution of Sea Level Rise over the 1950-2000 Period*. Journal of Climate, 17:2609-2625

Church, J.A. and N.J. White. 2006. *A 20th century acceleration in global sea-level rise.* Geophysical Research Letters, 33, L01602

Rahmstorf, S. 2007. *A Semi-Empirical Approach to Projecting Future Sea-Level Rise.* Science, 315: 368-370

Snay, R., M. Cline, W. Dillinger, R. Foote, S. Hilla, W. Kass, J. Ray, J. Rohde, G. Sella, and T. Soler. 2007. *Using global positioning system-derived crustal velocities to estimate rates of absolute sea level change from North American tide gauge records*. Journal of Geophysical Research, 112, B04409

The MathWorks, http://www.mathworks.com/access/helpdesk/help/helpdesk.html

Titus, J.G. and V. Narayanan. 1995. *The Probability of Sea level Rise*. U.S. Environmental Protection Agency. 186 pp. EPA 230-R95-008.

Zervas, C. 2001. *Sea level variations of the United States 1854-1999*. NOAA Technical Report NOS COOPS 36:34 & 63

5.8.2 Selected Additional References

Bader, D.C., C. Covey, W.J. Gutowski, I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian, and M.H. Zhang, 2008. *Climate Models: An Assessment of Strengths and Limitations*. U.S. Climate Change Science Program, Synthesis and Assessment Product 3.1

Moore, J.C., A. Grinsted, and S. Jevrejeva. 2005. *The new tools for analyzing the time series relationships and trends.* EOS: Transactions of the AGU, 86(24): 226

Oppenheimer, M., B.C. O'Neill, M. Webster, and S. Agrawala. 2007. *Climate change: The limits of consensus.* Science, 317:1505-1506.

Philip, M., A. Petersen, S. Reeder, H. Shipman, and L.W. Binder. 2008 *Sea Level Rise in the Coastal Waters of Washington State*. A report by the University of Washington Climate Impacts Group and the Washington Department of Ecology

Rahmstorf, S., A. Cazenave, J.A. Church, J.E. Hansen, R.F. Keeling, D.E. Parker, and R.C. J. Somerville. 2007. *Recent Climate Observations Compared to Projections.* Science, 316: 709

This page left blank for 2-sided printing

Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

30th Annual Progress Report
June 2009

Chapter 6

Adjustment of Export Using DSM2-PTM and PEI

Author: Kijin Nam, Delta Modeling Section, Bay Delta Office, California Department of Water Resources

Contents

6 Adjustment of Export Using DSM2-PTM and PEI....6-1
6.1 Introduction....6-1
6.2 Method....6-1
6.2.1 Potential Entrainment Index (PEI)....6-1
6.2.2 Water Volumes....6-2
6.2.3 Finding Adjustment of the Export....6-3
6.3 Test Results and Discussion....6-4
6.4 Limitations of DSM2-PTM....6-6
6.5 Conclusions....6-7
6.6 Acknowledgment....6-8
6.7 References....6-8

Figures

Figure 6-1 Voronoi diagram based on the 20-mm survey stations.... 6-2
Figure 6-2 Flow chart of computations.... 6-3
Figure 6-3 Locations of the 2 barriers in Delta configuration.... 6-4
Figure 6-4 Historical export and adjusted export over 20 days (Year 2003).... 6-5
Figure 6-5 Historical and adjusted export over 20 days (Year 2008).... 6-5

6 Adjustment of Export Using DSM2-PTM and PEI

6.1 Introduction

Due to the population collapse of pelagic organisms—especially delta smelt—in the Sacramento-San Joaquin River Delta (the Delta), exports have been restricted to reduce possible harmful effects on endangered species. Various Delta management strategies have been proposed to reduce potential effects by exports. Before any strategies are adopted, their comparative effectiveness should be quantified, and likely changes to the state of the Delta must be considered. For example, the volume and timing of exports may need to be adjusted if new gate structures are introduced in Delta channels. Alternative management strategies may affect many different Delta conditions such as tidal or seasonal salinity, flow direction and magnitude, etc. Comparative evaluations of alternate schemes must be comprehensive. In this study, only potential entrainment of fish is examined, and a quantitative method of adjusting exports to reduce entrainment is proposed.

6.2 Method

Estimating fish entrainment by exports is not easy because fish have behavior. In fact, no good numerical model simulating fish behaviors exists today. However, if fish larvae and eggs, which do not have strong behavior, are major concerns, they can be considered as particles. They can be considered as neutrally buoyant particles, which are subject to flow, and flow can be simulated with Delta Simulation Model 2 (DSM2) considering installment of hydrodynamic structures in the Delta or modification of operation. Then, DSM2-PTM can simulate transport of such particles and can be used to estimate entrainment of particles by the export.

6.2.1 Potential Entrainment Index (PEI)

Because the distribution of fish in the Delta is not uniform, an arithmetic average of entrainment of particles released at a few locations will not represent what may be entrained in the Delta. To consider the actual distribution of fish in the entrainment calculation, the concept of Potential Entrainment Index (PEI) was developed by Yiguo Liang. In short, PEI is an average of particle entrainment weighted by abundance as given in Equation 1:

$$\boldsymbol{PEI} = \sum_{i=1}^{n} (\boldsymbol{RA_i} \times \boldsymbol{E_i}) \tag{1}$$

where

$$\begin{aligned}
RA_i &= \text{relative abundance of region } i \\
&= (P_i \times V_i) \Big/ \sum_{i=1}^{n} (P_i \times V_i)\,; \\
P_i &= \text{the number of particles released at location } i; \\
V_i &= \text{the volume of region } i \text{ surrounding location } i; \\
E_i &= \text{fraction of particles entrained from location } i \\
&= \frac{(\text{\# of particles exported } D \text{ days after release at location } i)}{P_i}; \\
n &= \text{the number of locations and regions.}
\end{aligned}$$

As shown in Equation 1 and Figure 6-1, a system is divided into *n* regions, and the abundance of particles in each region is estimated by multiplying the number of particles at a representative location in the region by the water volume of the region. This assumes a uniform particle distribution in a region. The total number of particles in the system is the sum of abundances in all regions. Relative abundances of all the regions are used as weights in the averaging procedure.

The fraction of particles entrained from location *i*, denoted by E_i, can be estimated by DSM2-PTM simulations. DSM2-PTM can continuously count the accumulated number of particles at the Harvey 0. Banks Delta Pumping Plant (State Water Project) or C.W. Bill Jones Pumping Plant (Central Valley Project) export locations after injecting particles in the Delta. Of course, this value will vary depending on hydrology and particle distribution.

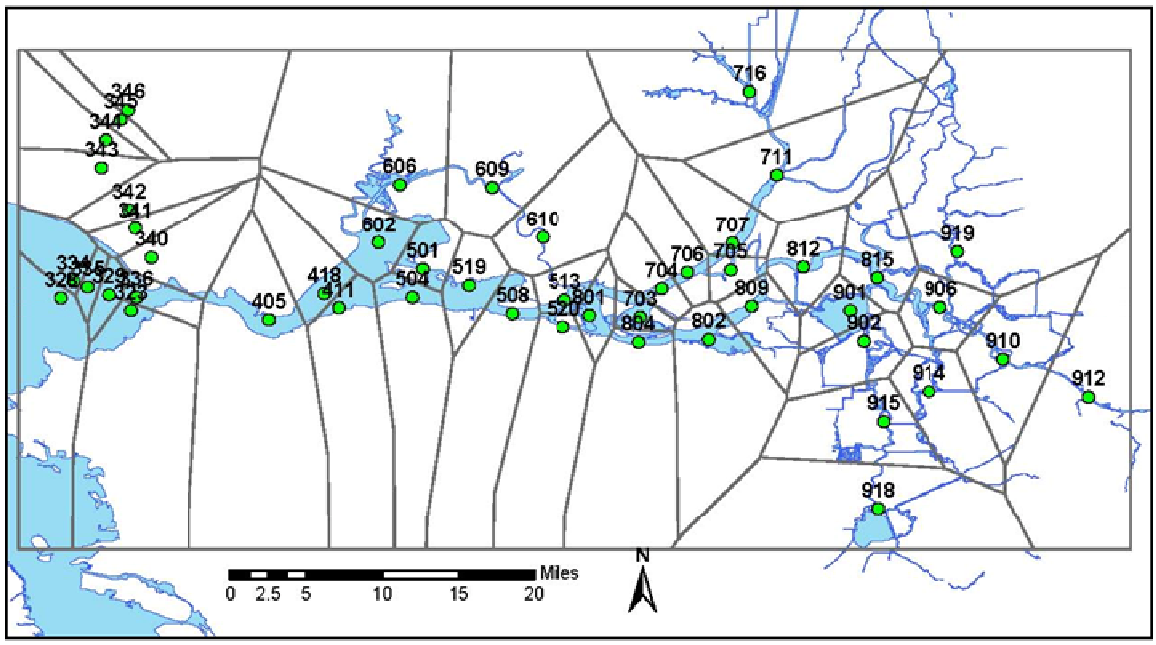


Figure 6-1 Voronoi diagram based on the 20-mm survey stations

6.2.2 Water Volumes

To calculate PEI, the water volume of each region is required. For the Delta, Miller (2005) estimated water volumes defined by the locations of 20-mm fish survey (DFG 2008a) or Spring Kodiak Trawl survey (DFG 2008b). To be more consistent for this study, the Delta was divided into Voronoi cells (Wikipedia 2009) by GIS-based software with the locations of the fish surveys as shown in Figure 6-1. The volume of each region is estimated with the computer software 'Gr' (Donovan 2008) that calculates water volumes of areas with given bathymetry data. The diagrams cannot be used directly for the software because the diagrams do not consider the topology of the river network. Hence, the regions were defined manually while considering the hydraulic connectivity of the regions.

6.2.3 Finding Adjustment of the Export

PEI can tell the potential number of particles entrained at export locations from an entire system that has a certain particle distribution. If a target PEI value is given, then one may find the amount of export that meets the given PEI inversely. In other words, one may formulate an optimization problem that maximizes exports under the constraint of a given PEI. The relationship between export and PEI is not defined in a simple equation, but generally it is positively monotonic. Then the solution—exports that meet a target PEI—can be solved by an iterative method with numerical simulations. The overall procedure of this iterative method is presented in Figure 6-2.

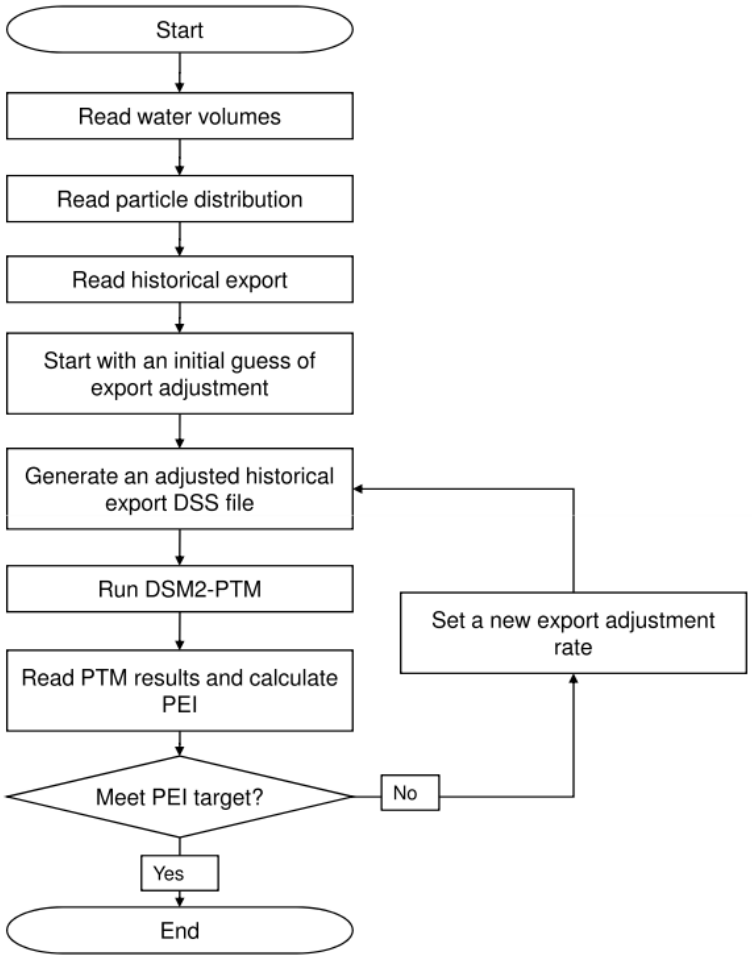


Figure 6-2 Flow chart of computations

Because the procedure is iterative and may require many hydrodynamics and particle tracking simulations, it is scripted with Python. Also, the procedure needs a rooting finding algorithm to efficiently find the export amount within a given precision. The Brent Algorithm is one of the best root-finding algorithms, and SciPy (Jones et al. 2001–) provides it in Python. In the script, the Brent algorithm calls DSM2-Hydro and DSM2-PTM after appropriate adjustment in an input variable, which is the export time

series in this case. Two key steps, modification of the export time series and collection of the DSM2-PTM results, are done with Vtools (Ateljevich and Shu 2008–), which is a Python library to handle time series from DSS files.

6.3 Test Results and Discussion

The proposed method was applied for the spring of years 2003 and 2008 with the historical hydrologic conditions and the delta smelt surveys for particle distribution. Each year had 9 periods with a length of 20 days each, and all the periods started at midday of a given survey period. Particles were released at every survey station continuously during a single day. The study used 34 stations. PEIs then were calculated with entrainment by Banks and Jones pumping plants up to 20 days after the releases.

The target PEI was 3.27%, which was derived from 15% loss over the periods. The iteration started with the time series of the historical export. If a historical export did not entrain up to the target PEI, the export was increased to maximize the export, and vice versa. Other Delta potential criteria such as water quality targets were not considered to limit the export except pumping capacities. The amount of the export was adjusted by multiplying a time series of the export by a uniform factor. The first 2 periods used Kodiak Trawl surveys, and the remainder used 20-mm surveys.

This procedure was applied for 2 different Delta configurations: (1) an unmodified Delta and (2) with 2 barriers in place. The 2 barriers blocked the water flow through Holland Cut and Connection Slough as shown in Figure 6-3.

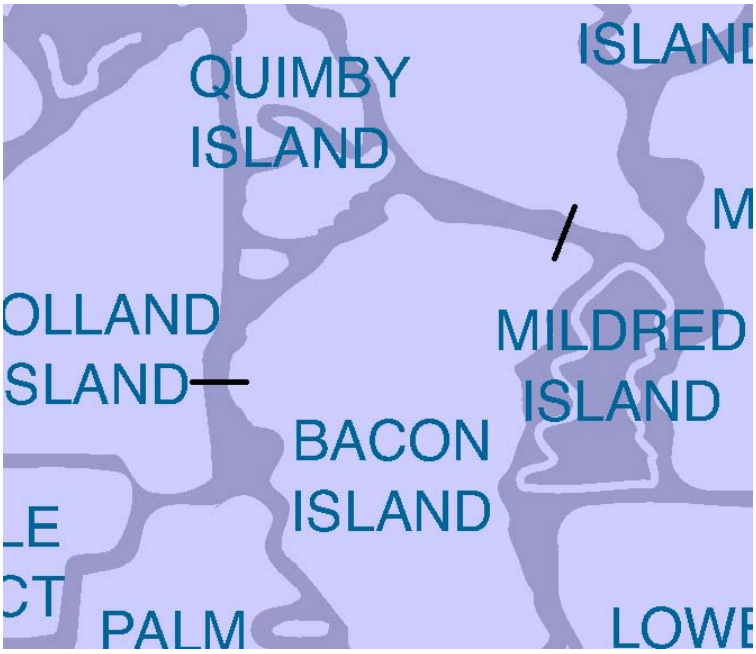


Figure 6-3 Locations of the 2 barriers in Delta configuration

The results are presented in Figures 6-4 and 6-5 with the unmodified historical export volume. In 2003 with or without the barriers, significant amount of curtailment on the export is required to meet the target PEI (Figure 6-4). However, in 2008, the export can be increased greatly, sometimes even up to the capacity of the export because not many fish were caught in the Central and Southern Delta (Figure 6-5).

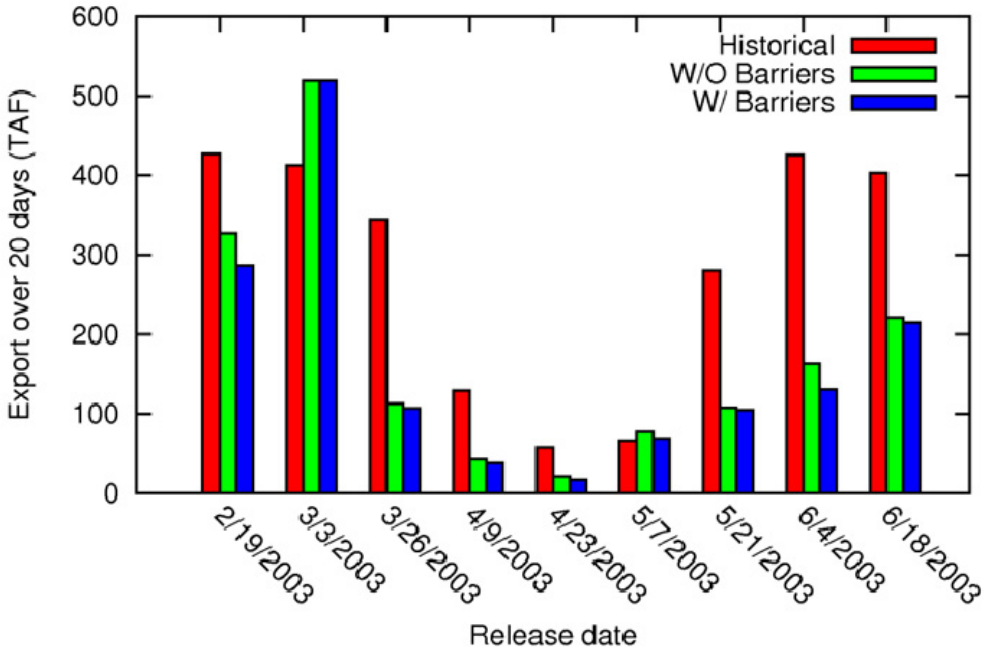


Figure 6-4 Historical export and adjusted export over 20 days (Year 2003)

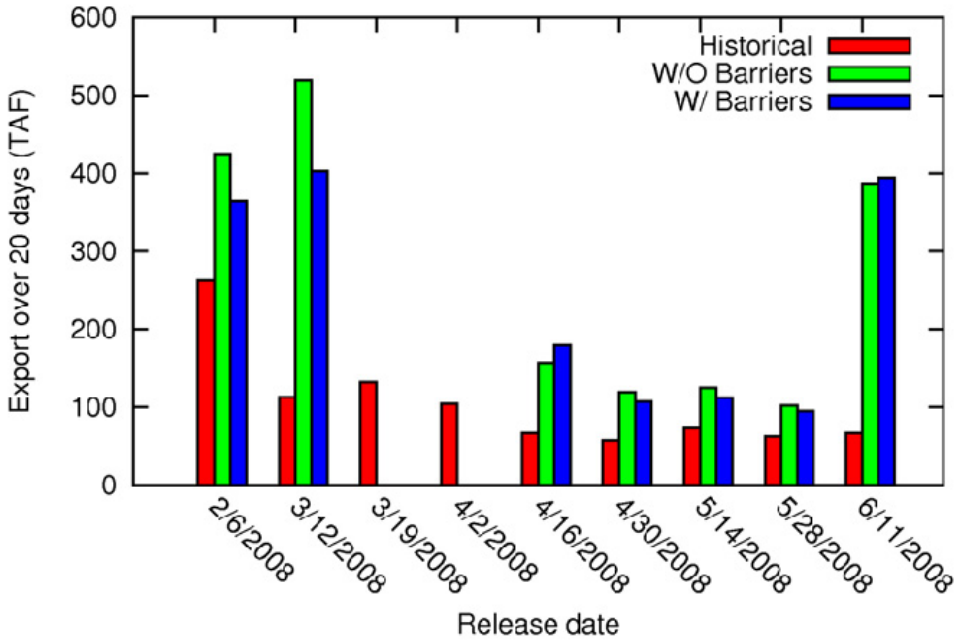


Figure 6-5 Historical and adjusted export over 20 days (Year 2008)

According to the survey data, no fish were caught in the third and fourth period of year 2008. In such cases, PEI becomes zero regardless of the exports, and adjusting export based on PEI is meaningless. Thus, no results are presented for those periods.

The difference between the cases with and without the barriers was not large. In fact, more water could be exported without the barriers while meeting the same level of the PEI value. This shows that the barriers may protect fish downstream of the barriers, but it will divert the flow to Middle River and the eastern Delta from Old River. This eventually will be detrimental to particle or fish population in those areas. Thus, the effectiveness of the hypothetical barriers is not conclusive.

The computational time for a single period varied from under one hour to several hours on a general desktop computer. The major computational time was spent simulating many particle tracking iterations. However, it still is possible to use it as close-to-real-time tool.

6.4 Limitations of DSM2-PTM

DSM2-PTM has several inherent limitations and care should be taken in interpreting the results of the model's applications. Chief among them is the fact that the model is one- dimensional (1D) while actual flows are 3-dimensional (3D). Certain assumptions and simplifications are made to extrapolate the 1D results to 3D representations; these assumptions introduce possibly significant but unquantified errors.

1. The PTM greatly simplifies particle movement in both channels and junctions. Particle calculations are assumed to be kinematic (without regard to mass or forces acting on the particle).

2. Within channels, equilibrium vertical and transverse velocity profiles are assumed and particles randomly moved with the assumed local velocity. These equilibrium velocity profiles are applicable to boundary layers developing over flat plates within channels that are assumed to be straight with no local velocity variations due to curves. Additionally, for channels in the Western Delta, the vertical velocity profiles utilized in the model do not represent the velocities in channels where there is bidirectional flow. This will affect how accurately PTM models dispersion.

3. Particles at junctions with 2 or more exit channels are assigned random channels in proportion to channel flows. The assumption of kinematic particles introduces potentially considerable error in PTM particle movement as compared to real particles. Actual particles, depending on their mass and other properties, would tend to migrate away from a uniform cross-sectional channel distribution even though neutrally buoyant. At junctions they would further depart from a proportional-flow split. Under some conditions all or nearly all particles would exit to a single channel in a real situation, but a simple flow split would simply allot particles by proportional flow. Open water areas such as Franks Tract are treated as fully mixed, and the particles do not follow a flow path to move to different areas within the open water area. The probability of a particle leaving is based on the ratio of the amount of flow leaving to the volume of water in the open water area.

4. Adding simple behavior to a PTM particle, such as a tendency to sink or float, does not reduce the error of PTM particle movement in channels and junctions. This error will occur throughout

the Delta, but especially in curved channels, higher velocities, and junctions with asymmetrical bathymetry.

The Delta Modeling Section has always recommended that DSM2 results be given in terms of incremental change of an alternative as compared to a base case. In this way the error in the DSM2 system, including input, model formulation and discretization, and output, tends to cancel. This assumes linear error within the modeling system. The total error in a single set of results may be considerable, but is assumed to be very similar between base and alternatives. This assumption may not be valid in the case of particle movement. The error between PTM and actual particle movement could be very high under some conditions.

PTM results are representative of advective and dispersive mass transport, much closer to QUAL results than the movement of actual particles.

6.5 Conclusions

The proposed method is a way to quantify the effect of alternative Delta configurations or operations on pseudo particle movement. The method may be useful for planning, evaluating, and predicting proposed management strategies. The method maximizes export based on a desired particle distribution. This may be important especially in dry years when the export may be critical.

The method was modeled in the Delta with and without a hypothetical set of gates to demonstrate the procedure. In the example, the method showed different results clearly according to the particle distribution and hydrodynamics.

However, this method has a few limitations in addition to the DSM2-PTM limitations mentioned above. Adult fish may move around freely regardless of flow, but the PTM assumes idealized particles with no behavior. The density of particles in a region may not be uniform; this becomes especially important when a region is large. The manual modification to the regionalization of the Delta channels should be examined further. The estimations of water volumes and the results of fish surveys may not be very accurate or representative. Since the method uses relative abundance, small errors in those values will not affect the end results much when the distribution of particles is uniform across a region. However, when the distribution of particles is highly non-uniform, even a small change in volume or particle survey in one region may cause a significant difference in the result. Finally, the method requires many simulations, and it may require substantial amount of computational time.

6.6 Acknowledgment

Subir Saha calculated the new water volumes with Gr software.

Dr. Bassam Younis, UC Davis, helped with and reviewed the discussion of DSM2-PTM limitations.

6.7 References

Ateljevich, Eli and Qiang (Jon) Shu. Vtools: Python library for time series data, 2008–.

(DFG) California Department of Fish and Game. 2008a. 20-mm survey: DFG-Bay Delta Region. http://www.delta.dfg.ca.gov/data/projects/?ProjectID=20mm.

_____, 2008b. Spring Kodiak survey: DFG-Bay Delta Region. http://www.delta.dfg.ca.gov/data/projects/?ProjectID=SKT.

Donovan, John. Gr graphing application, 2008. http://ca.water.usgs.gov/program/sfbay/gr/.

Jones, Eric, Travis Oliphant, Pearu Peterson, et al. SciPy: Open source scientific tools for Python, 2001–. http://www.scipy.org/.

Miller, B J. 2005. Estimating areas and volumes of water in the region, San Pablo Bay to Stockton and Walnut Grove. November 2005, paper for the December 2005 EWA Expert Panel meeting.

Wikipedia. "Voronoi diagram," *Wikipedia, The Free Encyclopedia*, http://en.wikipedia.org/w/index.php?title=Voronoi_diagram&oldid=285459001 (accessed May 5, 2009).

Printed by
DWR Printing Production
Services