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The Resources Agency
Department of Water Resources
Bay-Delta Office

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

Twenty-Eighth Annual Progress Report to the State Water Resources Control Board in Accordance with Water Right Decisions 1485 and 1641

October 2007

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Foreword

This is the 28th 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. This report is submitted annually by the Section to the California State Water Resources Control Board pursuant to its Water Right Decision 1485, Term 9, which is still active pursuant to its Water Right Decision 1641, Term 8.

This report was compiled by Ralph Finch, Senior Engineer, under the direction of Tara Smith, program manager for the Bay-Delta Evaluation Program.

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Acronyms and Abbreviations

ANN	Artificial Neural Network
CCF	Clifton Court Forebay
CVP	Central Valley Project (federal)
DETAW	Delta Evaporation of Applied Water
EC	electrical conductivity
HOS	Hydrology and Operations Section
MEC	Marginal Export Cost
NAD	North American Datum
ORRSL	Old River at Rock Slough (salinity station)
PRISM	Parameter elevations on Independent Slopes Model
SWP	State Water Project
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WRIMS	Water Resources Integrated Modeling System
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 following are brief summaries of work conducted during the past year by the Department of Water Resources' Bay-Delta Office. The names of contributing authors are in parentheses.

Chapter 2 – GIS Scripting to Calculate Monthly Spatially Averaged Precipitation Values for Delta Islands

Consumptive use of water in the Delta is a large and sometimes poorly estimated value. At the Hydrology and Operations Section, we are developing a model, Delta Evaporation of Applied Water (DETAW), that calculates a water budget based on precipitation, river and channel inflow and outflow, evapotranspiration, and agricultural and municipal pumping and discharge. In this chapter, we describe a way of improving the precipitation component estimate using GIS scripting. (*Jeff Galef*)

Chapter 3 – Enhanced Development of Flow-Salinity Relationships in the Delta Using Artificial Neural Networks: Incorporating Tidal Influence

Artificial Neural Networks (ANNs) have been used in the Modeling Support Branch since 1995 as a rapid and unbiased method of estimating Delta salinities, given flows and gate positions as input. In this chapter, we describe work performed to add the downstream tide boundary of DWR's 1D Delta simulation model DSM2 to improve ANN results. (*Sanjaya Seneviratne* and *Shengjun Wu*)

Chapter 4 – Extended 82-year Martinez Planning Tide

In this chapter, we describe work done as part of the Common Assumptions Long-term Update Project to develop a new, full-period planning tide for use in 82-year DSM2 planning studies. The planning tide closely follows the methodology described in Ateljevich (2001). In order to compensate for past sea level rise, we have normalized the tide to a 1993 level using National Ocean Service estimates of trends. (*Dr. Eli Ateljevich* and *Min Yu*)

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Chapter 2
GIS Scripting to Calculate Monthly Spatially Averaged Precipitation Values for Delta Islands

Author: Jeff Galef, Delta Modeling Section,
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2 GIS Scripting to Calculate Monthly Spatially Averaged Precipitation Values for Delta Islands

2.1 Introduction

The Hydrology and Operations Section (HOS) is working on a model that estimates the consumptive use of water in the Delta. Referred to as DETAW (Delta Evaporation of Applied Water), it calculates a water budget based on precipitation, river and channel inflow and outflow, evapotranspiration, and agricultural and municipal pumping and discharge. The precipitation component is approximated using the Thiessen Polygon method with seven precipitation stations throughout the Delta (Figure 2-1).

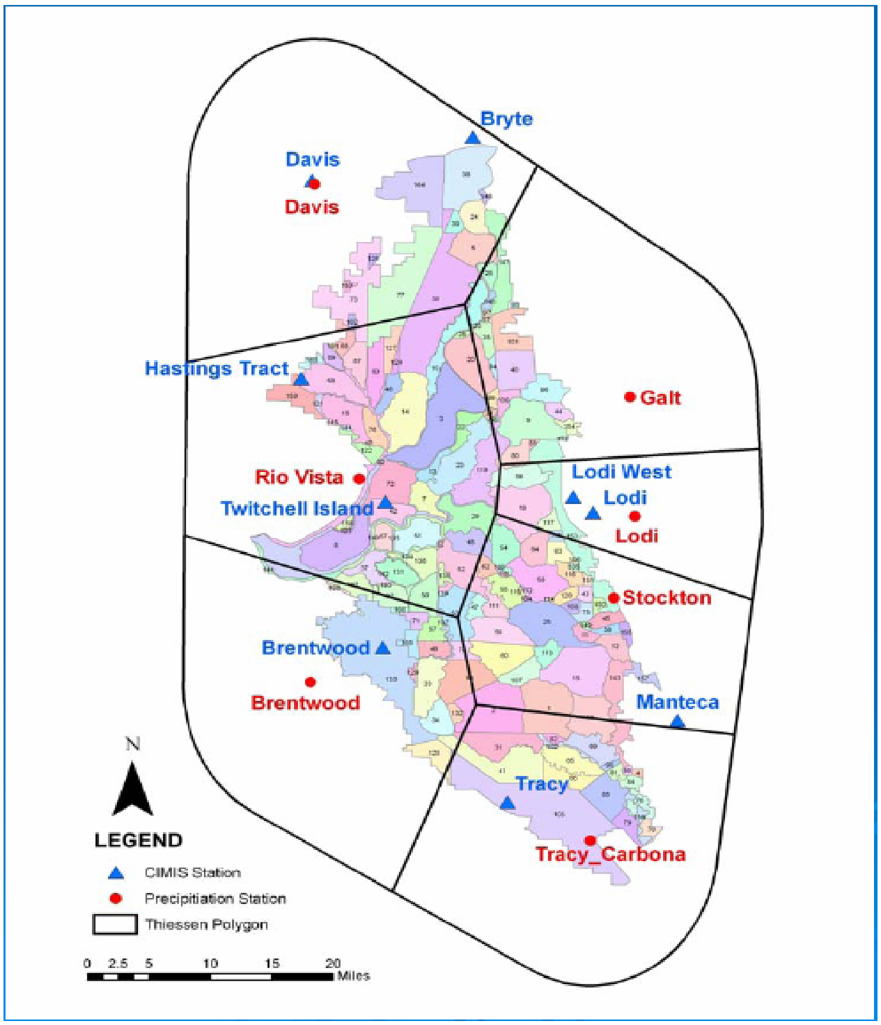

Figure 2-1 Map of the Delta with Thiessen polygons (Kadir and Snyder 2006)

As seen in Figure 2-1, the polygons represent relatively large areas, yielding only seven precipitation values for the entire Delta. The HOS decided to compare these values to those calculated from PRISM (Parameter elevations on Independent Slopes Model). PRISM used point-data along with a digital elevation model to generate gridded estimates of climate data (Daly et al. 1994).

PRISM generated grids of monthly precipitation values from January 1920 to December 2005. Each grid cell was roughly 4-km^2 in area. A given Delta island could encompass one or more precipitation values. The purpose of this project was to calculate area-weighted precipitation averages for each of the 168 islands of the Delta, from January 1920 to December 2005. With 1,020 months of data, 168 Delta islands, and numerous precipitation cells, an automated process was a necessity.

2.2 Methodology and Application

ArcGIS 9.2 exposes its geoprocessor object to any COM-compliant software language. The geoprocessor object contains the entire suite of geoprocessing tools. Python 2.4 was chosen as the scripting language due to its flexibility and ease of use. With any given task, the typical outline of the Python file began by importing the *arcgisscripting* module. With this module, the geoprocessor object could be instantiated. With looping, each file in a target list would be subjected to one or more geoprocessing tasks.

PRISM generated the precipitation values in the form of text files. The data were referenced in geographic coordinates using the World Geodetic System of 1972 (WGS72). However, this information was only in the metadata file, not in the data files themselves. With Python code, the *Define Projection* method of the geoprocessor object defined the projections for all 1,020 files. With defined projections, the text files were then regarded as raster files.

When performing any GIS analysis, it is imperative that all data have the same spatial reference. This analysis used UTM Zone 10 with the World Geodetic Datum of 1984 (WGS84). ArcGIS requires a custom geographic transformation file when transitioning between datums. This file was created using the *Create Custom Geographic Transformation* tool of ArcToolbox. With Python code, the *Project* method of the geoprocessor object reprojected all the precipitation data files to this spatial reference.

The Delta Islands were represented as a feature class. They were projected in UTM Zone 10 using the North American Datum of 1927 (NAD27). The *Create Custom Geographic Transformation* tool was again used to change the datum to WGS84. At this time, all the data were in a common spatial reference. The next steps entailed the main steps needed to calculate area-weighted mean precipitation values.

A common data format between the precipitation data and the Delta Islands was needed to perform the calculations. The precipitation data were in raster format, and the Delta Islands were in vector format. With Python code, the *Raster to Feature* method of the geoprocessor object transformed all of the precipitation raster data sets into feature classes.

The next step was to separate the Delta Islands into subareas of constant precipitation. For example, Bacon Island was divided into an area with 8 mm of precipitation and an area with 7 mm of precipitation. With Python code, the *Intersect* method of the geoprocessor object divided the islands for each of the monthly precipitation values.

The next step was to obtain values for the precipitation multiplied by the area of each subarea. For each of the intersected feature classes, a new field was needed to store these product values. With Python code, the *Add Field* method of the geoprocessor object added a field to the attribute tables of the intersected feature classes. Then, the *Calculate Field* method of the geoprocessor was used to multiply the precipitation values by their associated areas. The *Calculate Field* method required an SQL statement to perform mathematical functions on the database fields.

The next step was to recombine the divided islands to their original form. With Python code, the *Dissolve* method of the geoprocessor object performed this task. The *Dissolve* method also added all the product values (precipitation times subarea) for each of the islands. From here, the sum of the area-weighted precipitation values could be divided by the island area to obtain the area-weighted averages. The *Add Field* and *Calculate Field* methods along with SQL commands were again used, and the area-weighted averages were now stored in the dissolved feature classes.

2.3 Conclusion

The final portion of Python code wrote the results to a text file. These results were then given to the HOS. The HOS is reviewing the results and making comparisons to the results obtained from the Thiessen Polygon method.

It is noted that the different components of total consumptive use—direct precipitation, evaporation, transpiration, diversions, seepage, and return flows (and the quality of the latter)—have a wide range of measurement accuracy. Agricultural diversions and return flows (and their associated water quality) have the most uncertainty, to the point of affecting calibration and our ability to make the Department's 1D Delta model, DSM2, a predictive tool. Improving the reliability of those elements of consumptive use would be very beneficial to overall modeling accuracy.

2.4 References

Daly, C., R. Neilson, and D. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. J. Appl. Meteor. 33(2):140-158.

Kadir, T. and R. Snyder. 2006. DETAW: A SIMETAW-based model to estimate consumptive water demands in the Sacramento – San Joaquin Delta. In: California Water and Environmental Modeling Forum; February 28 to March 2, 2006; Pacific Grove (CA) Asilomar Conference Center. Sacramento: California Water and Environmental Modeling Forum.

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Chapter 3
Enhanced Development of Flow-Salinity Relationships in the Delta Using Artificial Neural Networks: Incorporating Tidal Influence

Authors: Sanjaya Seneviratne and Shengjun Wu, Hydrology and Operations Section, Bay-Delta Office, California Department of Water Resources

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3 Enhanced Development of Flow-Salinity Relationships in the Delta Using Artificial Neural Networks: Incorporating Tidal Influence

3.1 Introduction

The Sacramento-San Joaquin Delta (Figure 3-1) covers 738,000 acres interlaced with hundreds of miles of waterways. Much of the land is below sea level and relies on more than 1,000 miles of levees for protection against flooding. The Delta is unique, a valuable resource, and an integral part of California's water system. It receives runoff from 40 percent of the state's land area including Sacramento, San Joaquin, and east side streams. Its land and waterways support communities, agriculture, and recreation. The Delta is the nexus for water distribution throughout the state.

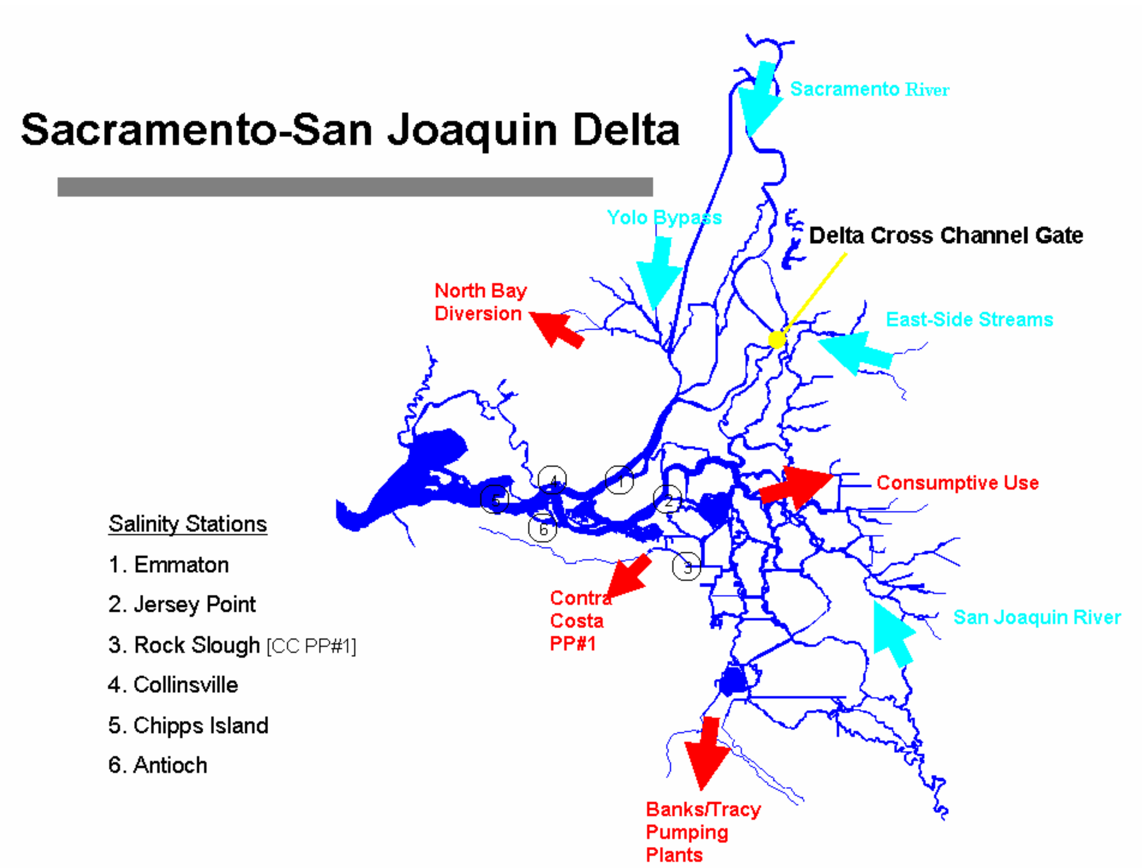


Figure 3-1 Sacramento-San Joaquin Delta

Water Resources Integrated Modeling System (WRIMS) is a generalized water resources simulation model for evaluating alternatives in a water resources system. CalSim II is an application of WRIMS, specifically used as a planning tool to simulate the State Water Project (SWP) and the U.S. Bureau of Reclamation Central Valley Project (CVP). CalSim II has been applied to simulate the SWP and CVP systems at various levels of development, system configurations, and demand scenarios and operations rules. One such operation rule is the salinity standards imposed at various locations in the Delta to protect the environment of the Delta. Currently, the controlling locations in CalSim II are Rock Slough, Jersey Point, Emmaton, Collinsville, Chipps Island, and Antioch.

DWR's 1D Delta simulation model DSM2 calculates stages, flows, and velocities; many mass transport processes, including salts, multiple non-conservative water quality constituents, temperature, THM formation potential; and particle tracking. To simulate 1 year of salinity in the Delta, DSM2 takes about 20 minutes of computing time in a 3.0 GHz Windows XP machine. This extensive computing time makes it infeasible to use DSM2 to calculate salinity at controlling locations in CalSim II.

Artificial Neural Networks (ANNs) were used to develop flow-salinity relationships in the Delta, enabling fast predictions of salinity at the controlling locations (Finch 1995; Sandhu and Finch 1995; Sandhu 1996; Sandhu and Wilson 1997; Wilson 1998; Sandhu and et al. 1999; Pranger 2000; Wilbur and Munevar 2001; Hutton and Seneviratne 2001; Mierzwa 2002). Because ANNs can accept multiple inputs of different units, carriage water need not be defined as zero and gate positions and other operations can potentially be modeled. ANNs are considered universal approximators, theoretically capable of modeling any continuous nonlinear function. With a proper network design and training (calibration), an ANN can be reasonably accurate and robust on new data.

3.2 Full Circle Analysis

The steps of a *full circle* analysis are:

1. Start with CalSim II with generic ANN or g-model, run a study, and generate output.
2. Run DSM2 with CalSim II outputs from step 1.
3. Train ANN with CalSim II and DSM2 outputs from steps 1 and 2.
4. Put newly trained ANN in CalSim II, run, and generate output.
5. Run DSM2 with output from step 4 and compare DSM2 output salinities with ANN salinities.

Several DSM2 studies with varied inflows and Delta operations were used to generate data for training of ANNs. Until 2005, four inputs (Northern and Eastern flows, San Joaquin flow, combined exports and consumptive use, and Delta Cross Channel operation) were used to train ANNs; these were implemented in CalSim II. The CalSim study that contains the trained ANN is used in DSM2 to calculate the electrical conductivity (EC) at some key locations in the Delta. Comparison between DSM2 results and ANN-generated EC in CalSim II will give an indication of the ability to mimic DSM2-simulated EC with ANNs. Of the six salinity standard locations in the Delta, we found that in the three western-most stations (Collinsville, Antioch and Chipps Island) ANNs always yielded good results. Hence, EC comparisons at Emmaton, Jersey Point, and Old River at Rock Slough (ORRSL) are shown (Figures 3-2—3-4). Although these results showed a fairly good comparison between DSM2 results and the ANN-generated CalSim II results, the scatter in the ORRSL station caused unacceptable and unpredicted water demand.

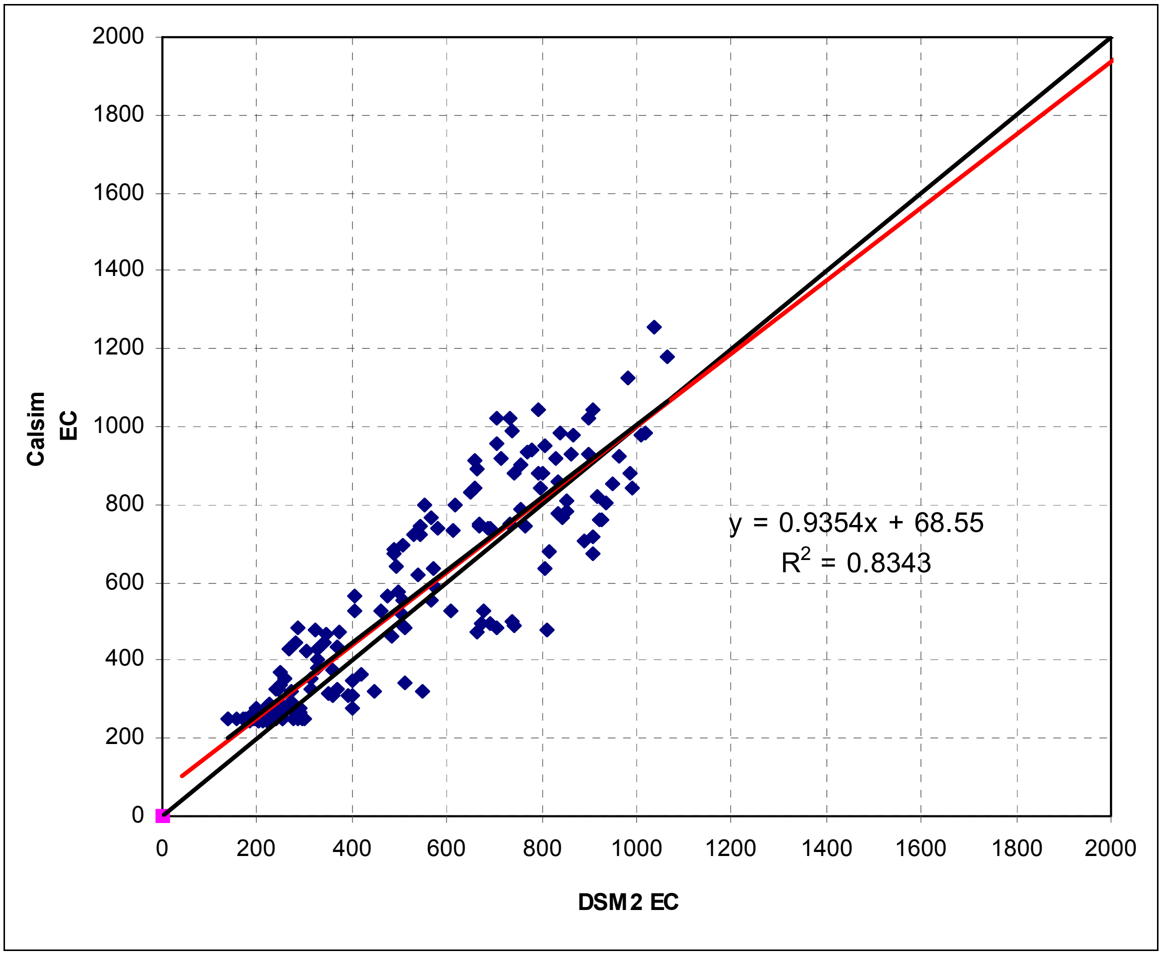


Figure 3-2 Four-Input ANN vs DSM2—Old River at Rock Slough

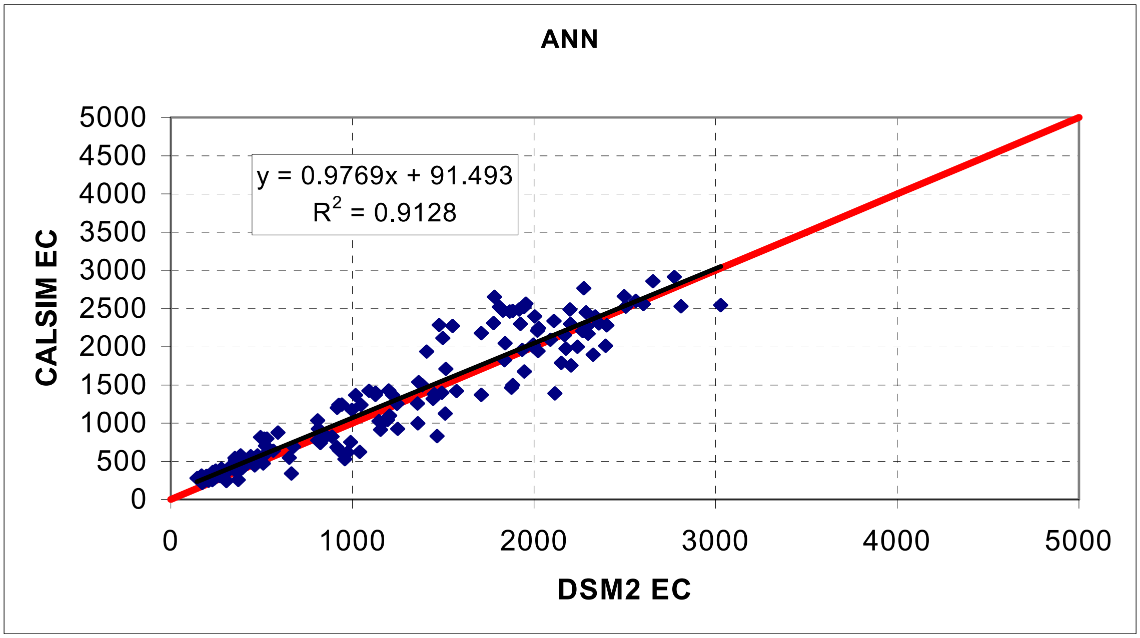


Figure 3-3 Four-Input ANN vs DSM2—Jersey Point

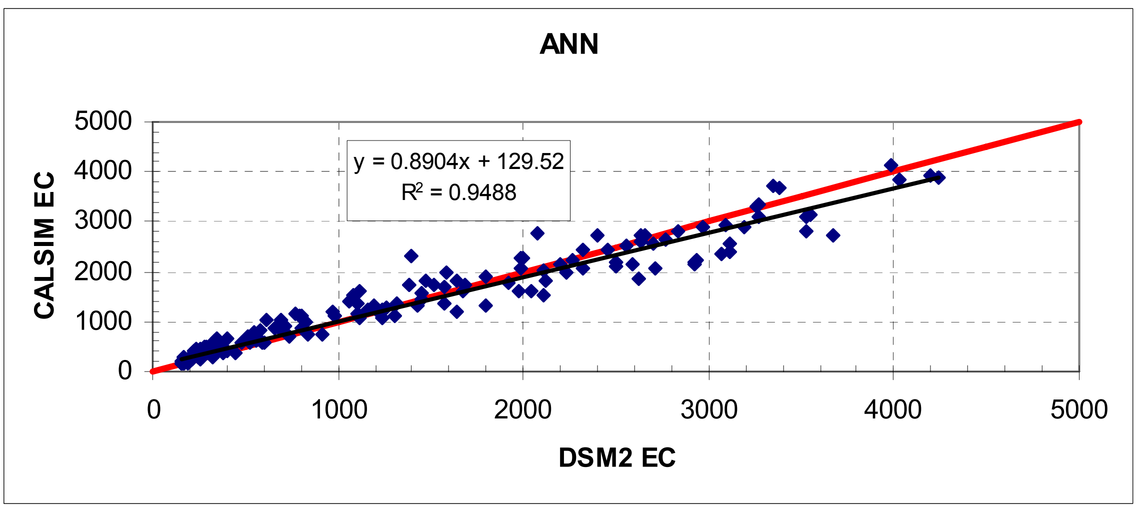


Figure 3-4 Four-Input ANN vs DSM2—Emmaton

3.3 Development of Enhanced Flow-Salinity Relationships

In February 2005, we began using the ANN toolkit in MATLAB to develop flow-salinity relationships because of high quality routines, software maintenance, and plotting capabilities. The following five scenarios were used in developing the hydrology for five different DSM2 studies between water years 1976 through 1991. We chose these scenarios to ensure that training (calibration) data encompassed a wide range of hydrology.

1. D1641
2. D1485
3. 2020 Level of Demand
4. Current level of Demand
5. 10,300 Banks pumping capacity

For the purpose of training the ANNs, each study was randomly perturbed up to ±30%. Of all the results, 80% were used for training ANNs, and 20% were used as verification. The data used for training were randomly selected. The following six inputs were used in ANNs to predict the salinity at the controlled locations. Other than separating the Delta consumptive use from exports, inclusion of tidal range was the major difference from the previous ANN.

1. Northern flows: Sacramento River + Yolo Bypass + East streams + Calaveras – (North Bay and Vallejo Exports)
2. San Joaquin River Flow
3. Exports: Banks, Tracy, Contra Costa diversions
4. Delta Cross Channel Gate: Open or Close
5. Net Delta Consumptive Use
6. Tidal Energy {(daily maximum – daily minimum), from NOAA forecast tide web site}

Full circle analysis for the study period (water years 1976 through 1991) yielded good results. In order to check the validity and robustness of the ANNs, the full circle study was expanded to include the data for water years 1923 through 1991. Results of the expanded full circle analysis are shown in Figures 3-5 through 3-7. These results show that the new six-input ANNs are better able to predict DSM2 results for any range of hydrology than the four-input ANNs.

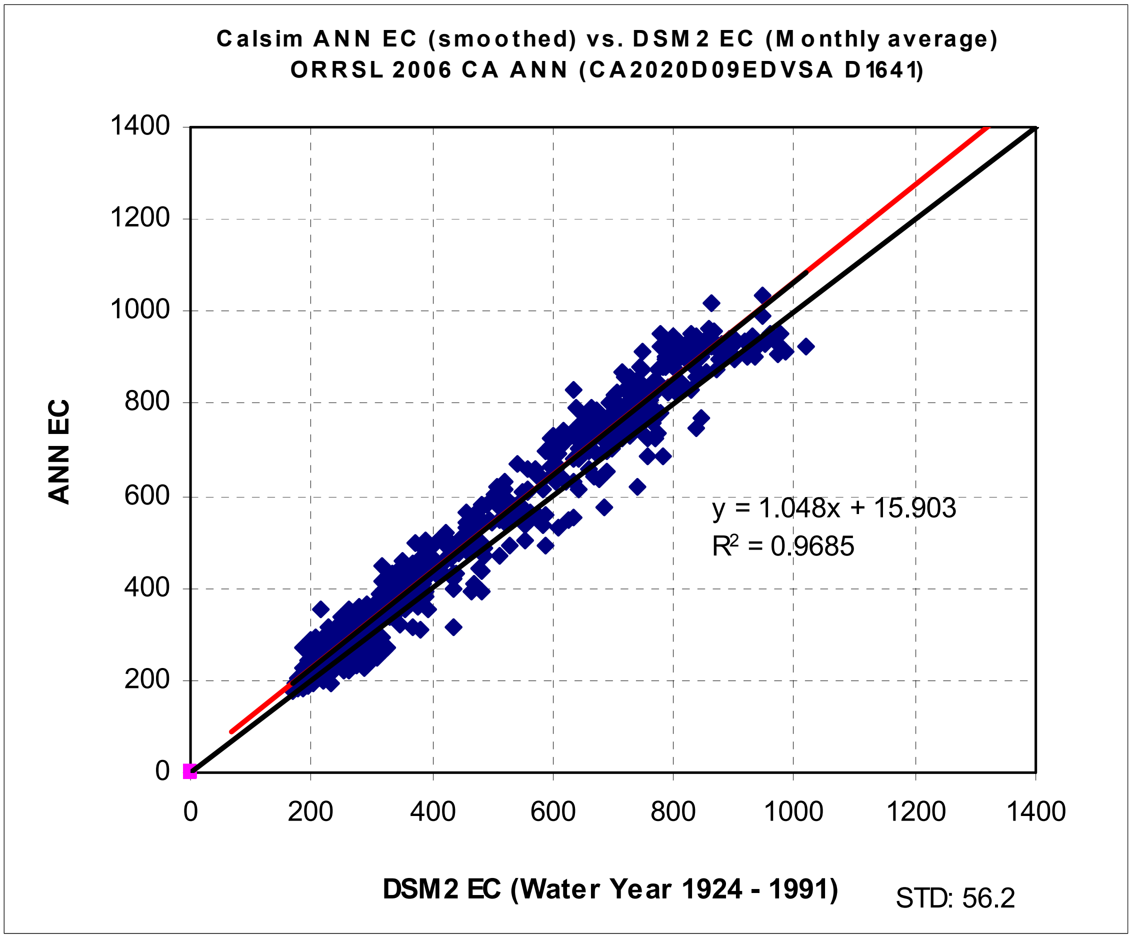


Figure 3-5 Six-Input ANN vs DSM2—Old River at Rock Slough

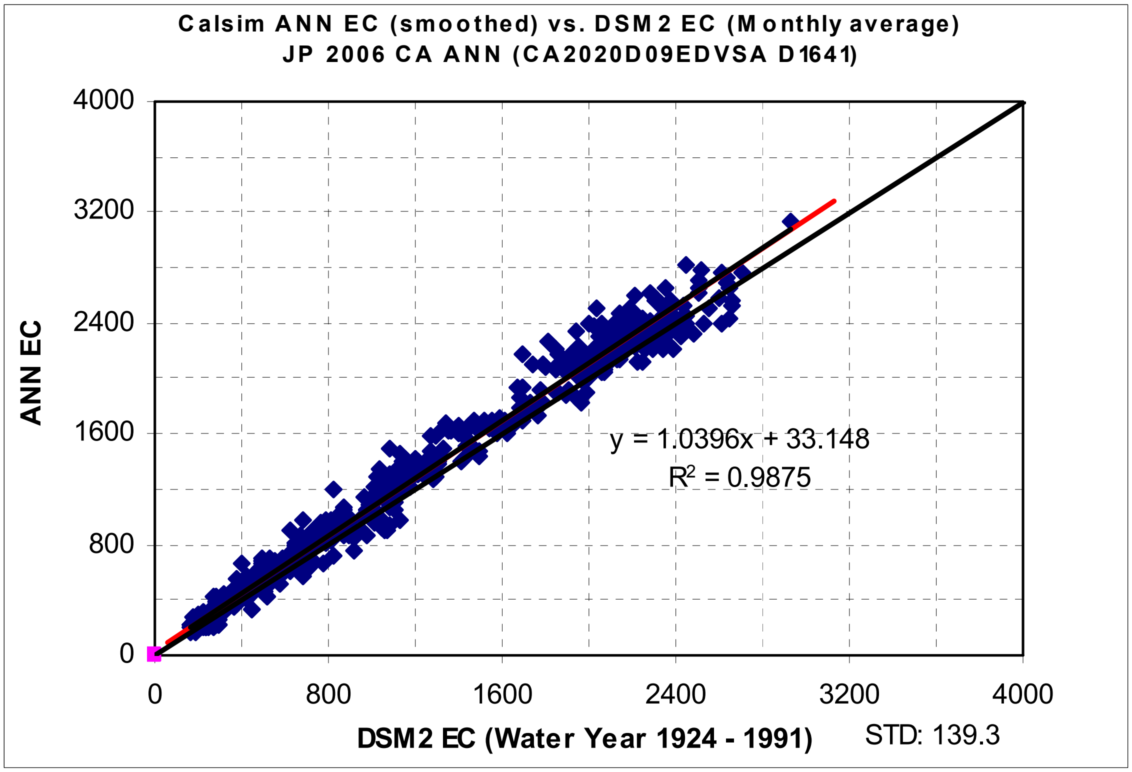


Figure 3-6 Six-Input ANN vs DSM2—Jersey Point

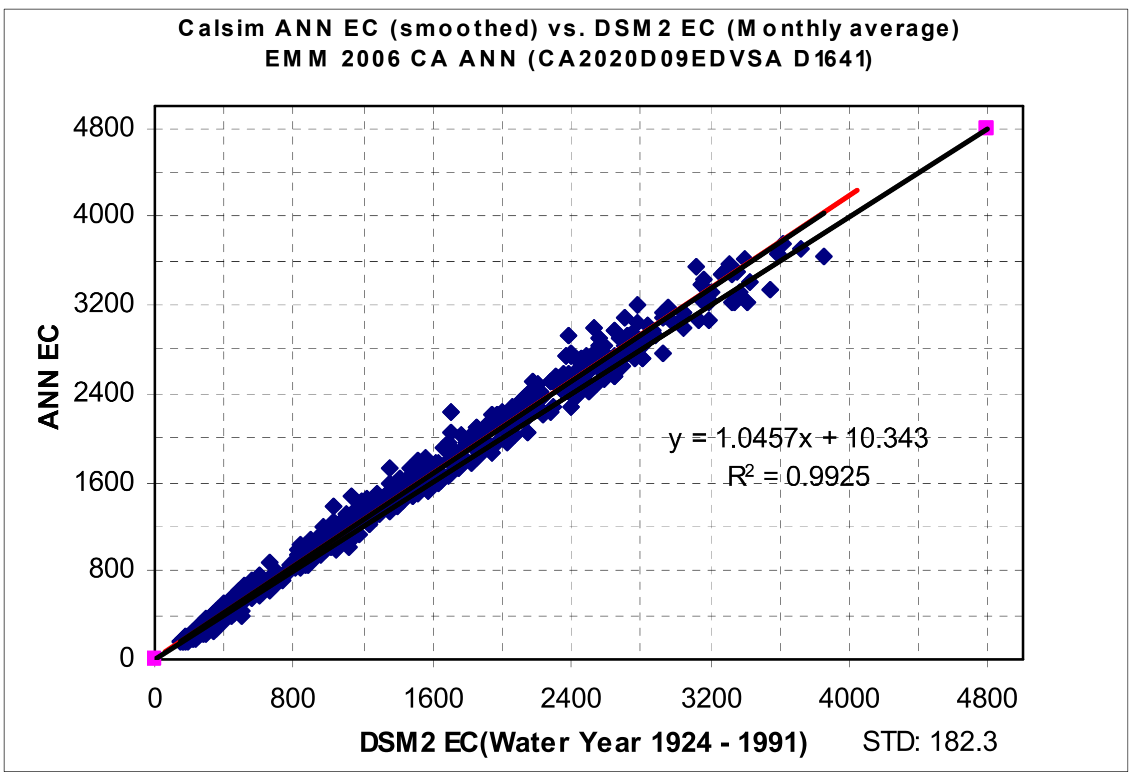


Figure 3-7 Six-Input ANN vs DSM2—Emmaton

While doing the study, we observed the scatter for the study period (water years 1976 through 1991) was much less than for the period water years 1923 through 1991. The following plots (Figures 3-8 through 3-11) show the comparison between ANN- and DSM2-simulated EC for the different study periods, all at Old River at Rock Slough.

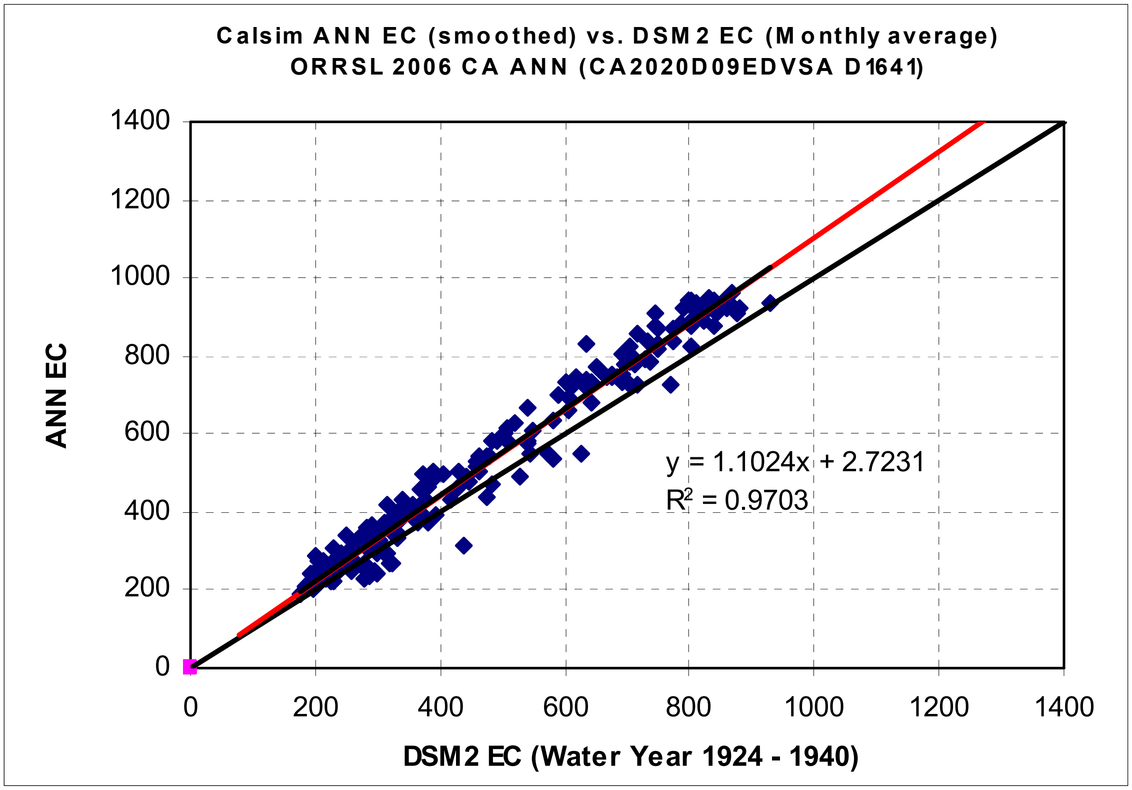


Figure 3-8 Six-Input ANN vs DSM2 WYs 1924-1940—Old River at Rock Slough

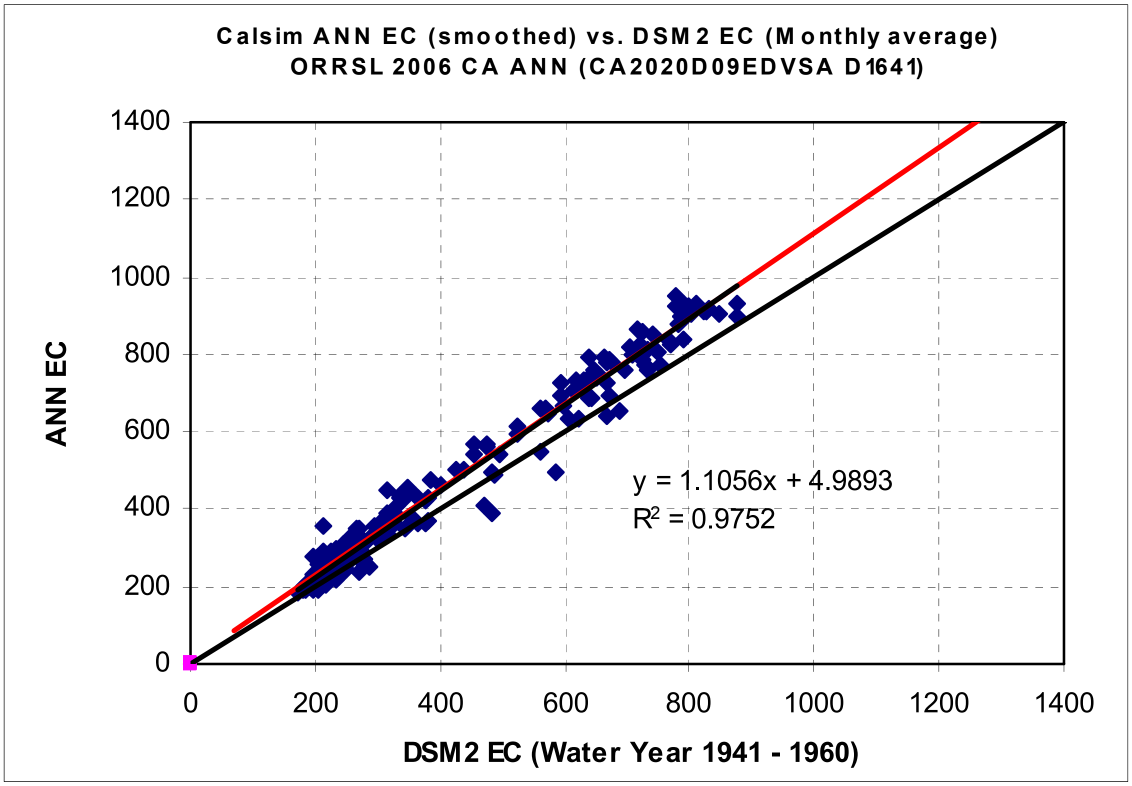


Figure 3-9 Six-Input ANN vs DSM2 WYs 1941-1960—Old River at Rock Slough

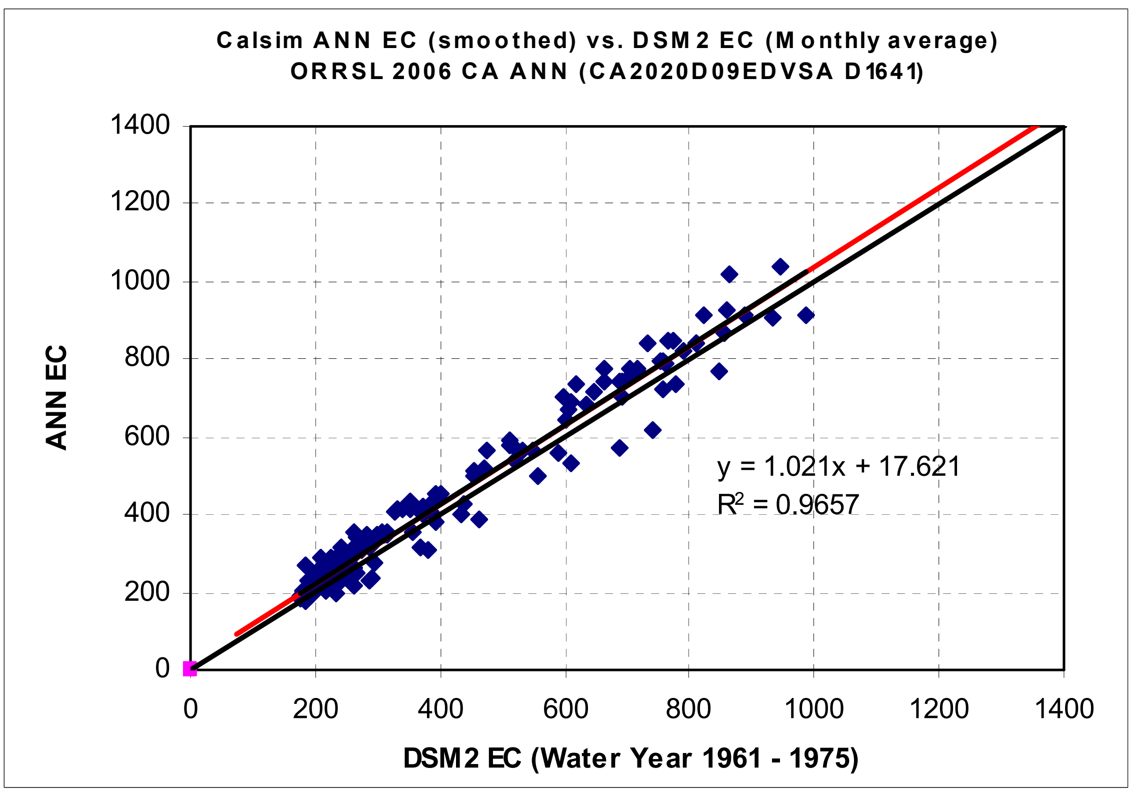


Figure 3-10 Six-Input ANN vs DSM2 WYs 1961-1975—Old River at Rock Slough

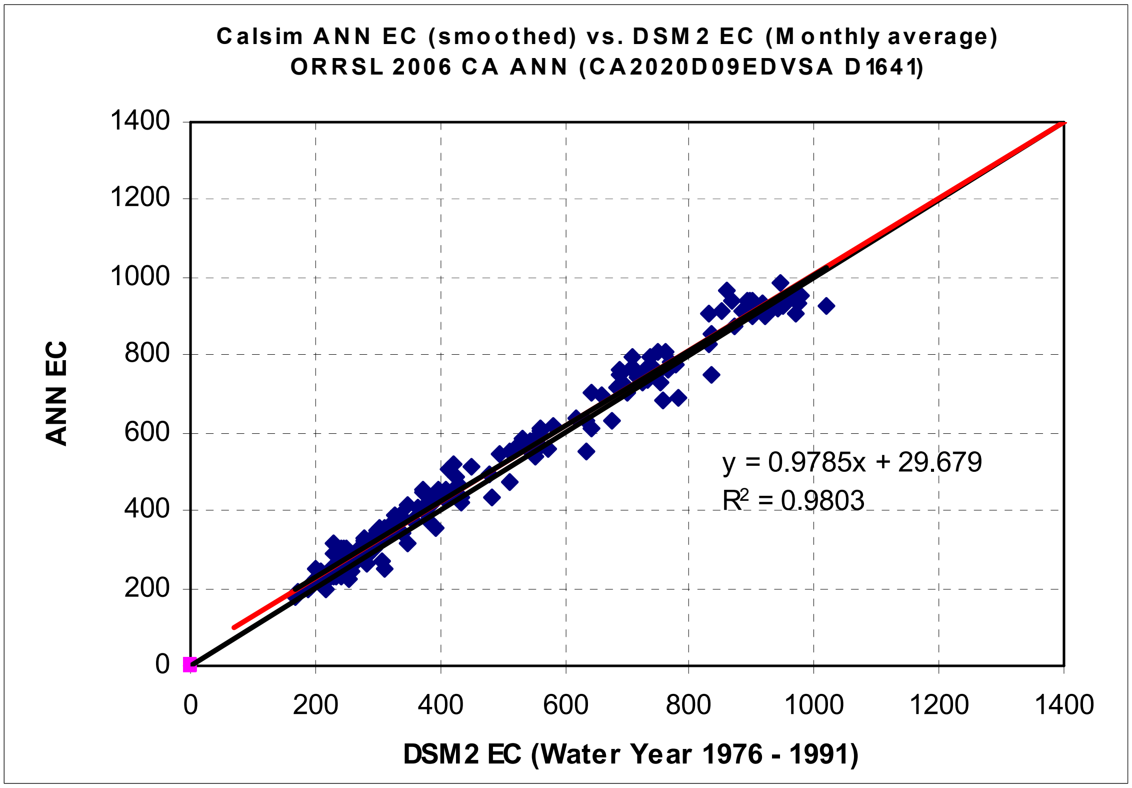
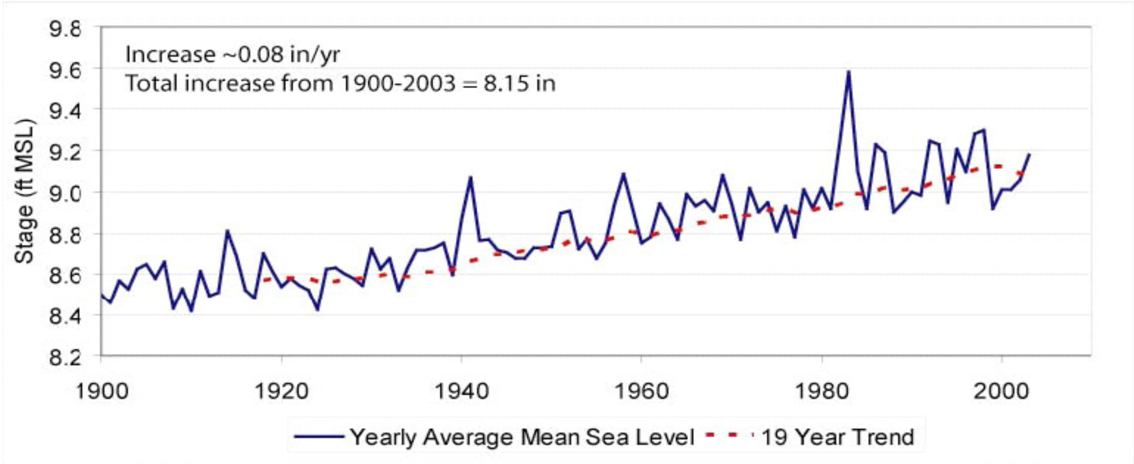


Figure 3-11 Six-Input ANN vs DSM2 WYs 1976-1991—Old River at Rock Slough

The four study periods show similar scatter (R^2 values). However the line of best fit (upper line) departs from the 45-degree slope line in the early part of the simulation, but in the last 16 years, the two lines are very close together. This means that DSM2 had lower EC values than the ANN in the first half of the simulation and, in the last 16 years, the DSM2-simulated EC was almost identical to the ANN-generated EC.

The effects of sea level rise were investigated to determine why DSM2 and ANN comparison differed over time. The mean sea level at Golden Gate is shown in Figure 3-12 (DWR 2006). This graph shows that in the early part of the century sea levels were more than 8 inches below the current levels, thus possibly leading to lower EC values.



Source: DWR 2006

Figure 3-12 Sea Level Rise and Trend—Golden Gate

To eliminate the effects of sea level rise, a new planning tide was developed (Ateljevich and Yu 2007). When this tide was used, DSM2-simulated EC values increased in the years prior to 1991 due to a higher boundary stage. The full circle study results with sea level rise removed are shown in Figures 3-13 through 3-16.

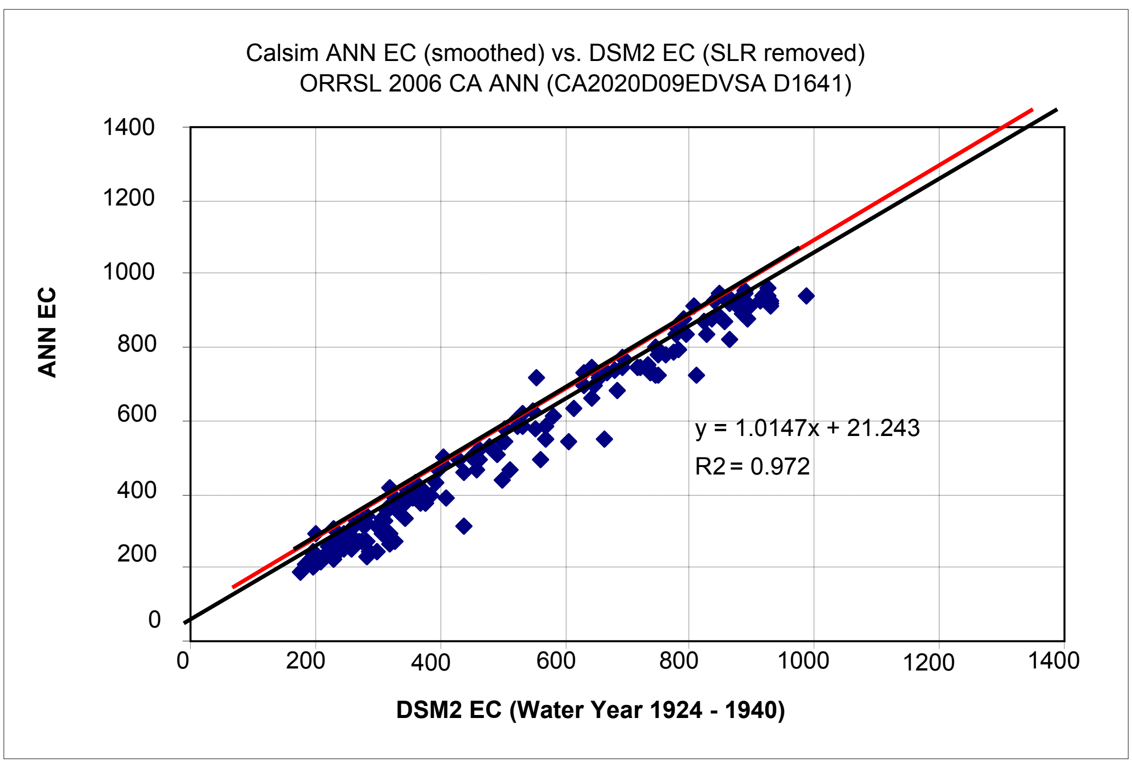


Figure 3-13 Six-Input ANN vs DSM2 WYs 1924-1940 Sea Level Rise Removed—Old River at Rock Slough

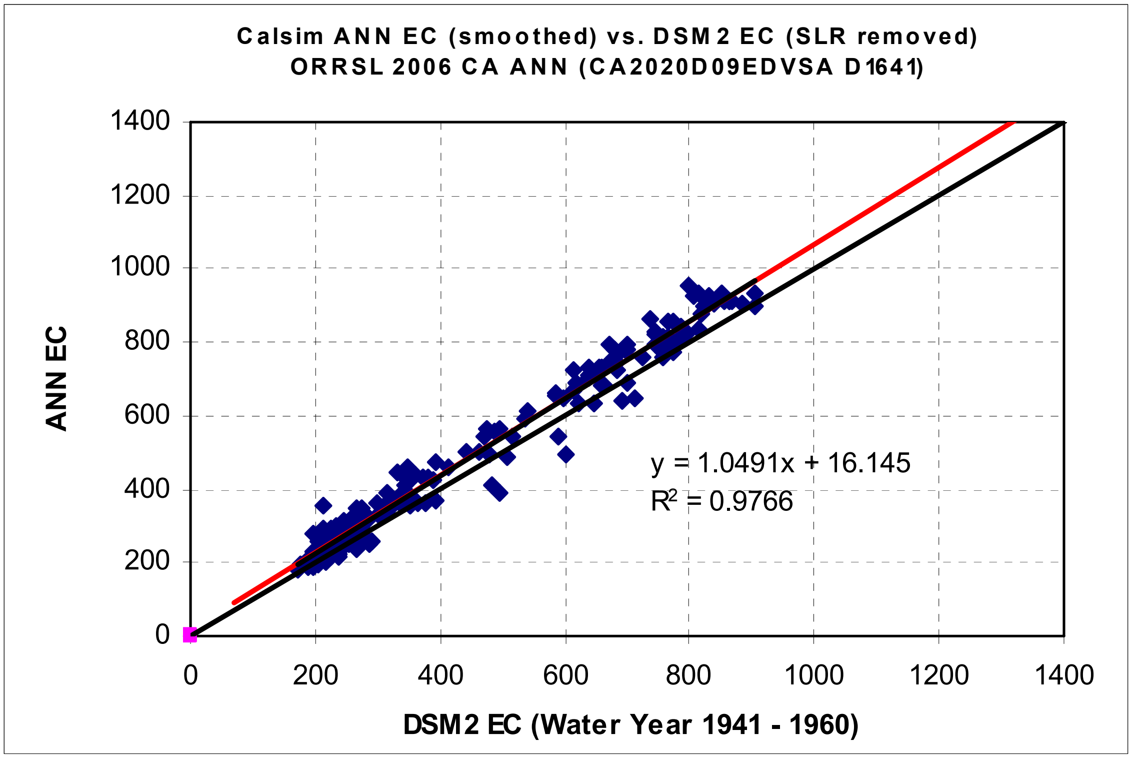


Figure 3-14 Six-Input ANN vs DSM2 WYs 1941-1960 Sea Level Rise Removed—Old River at Rock Slough

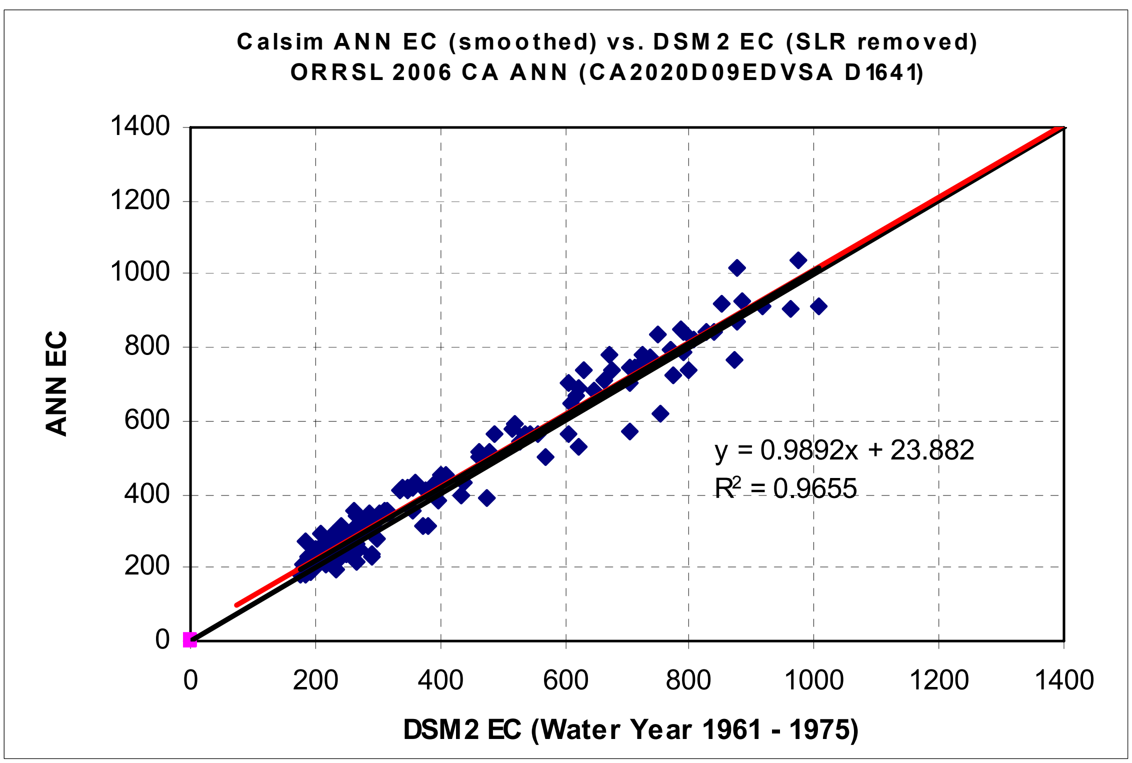


Figure 3-15 Six-Input ANN vs DSM2 WYs 1961-1975 Sea Level Rise Removed—Old River at Rock Slough

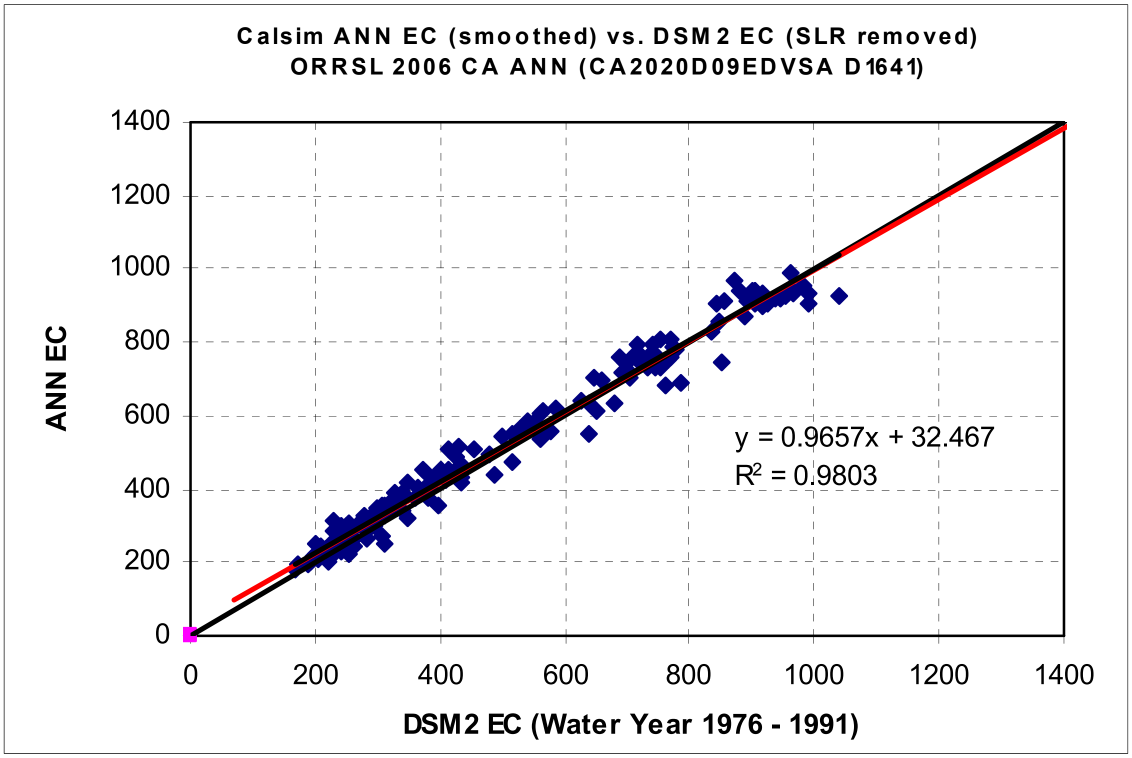


Figure 3-16 Six-Input ANN vs DSM2 WYs 1976-1991 Sea Level Rise Removed—Old River at Rock Slough

3.4 Marginal Export Cost Response

The marginal response of the ANN to a unit impulse is important to examine because CalSim II adjusts flows and exports each time-step in a marginal (incremental) manner. A useful diagnostic introduced in Sandhu et al. (1999) is the Marginal Export Cost. MEC is defined as "the extra water needed to carry a unit of water across the Delta … while maintaining a constant salinity at a given location." An MEC calculation is computationally costly because at each time-step the Sacramento River flow must be adjusted by trial and error to bring the salinity back to its former (pre-unit export increase) value. Here we simply introduce a constant unit increase of 500 cfs to the State and federal exports (250 cfs each) and an equal constant increase of 500 cfs to Sacramento flow. We then examine the salinity response at several locations by subtracting the base salinity from the alternative salinity. The unit input perturbation is constant. Following the terminology in Sandhu et al. (1999), we call this the continuous carriage water response.

To illustrate the responses, we show time-series graphs for a 4-year period (water years 1985 through 1988) out of the 16-year run for the three locations using daily values (Figures 3-17 through 3-19).

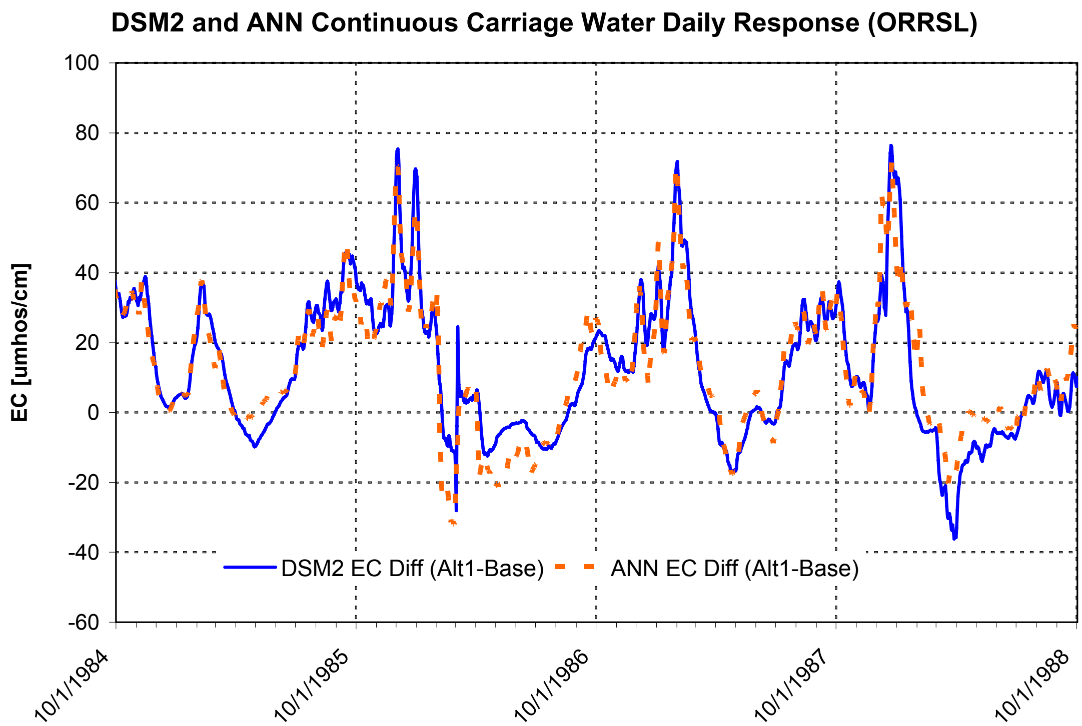


Figure 3-17 Continuous Carriage Water Response—Old River at Rock Slough

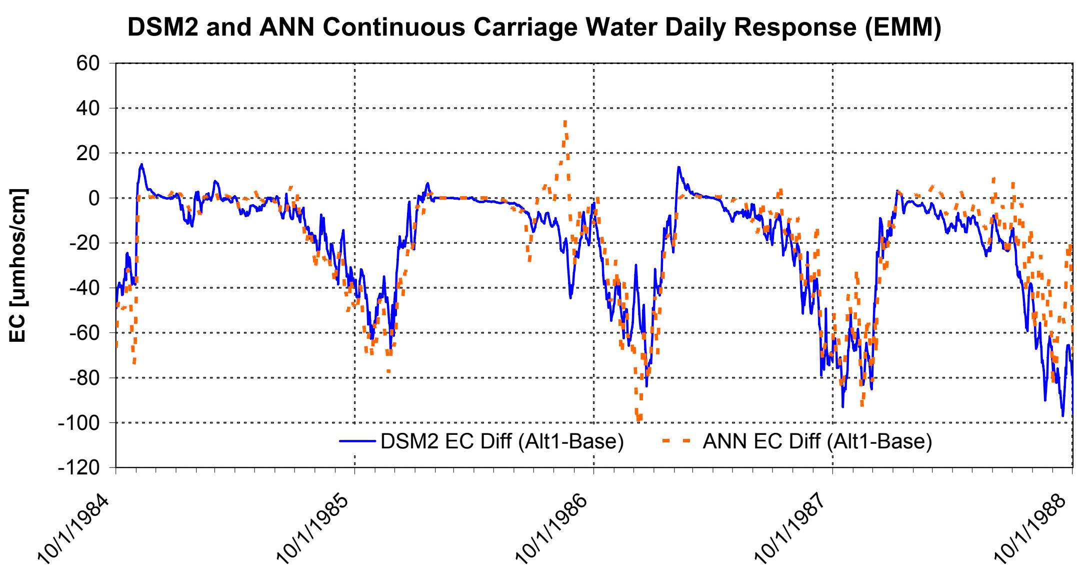


Figure 3-18 Continuous Carriage Water Response—Emmaton

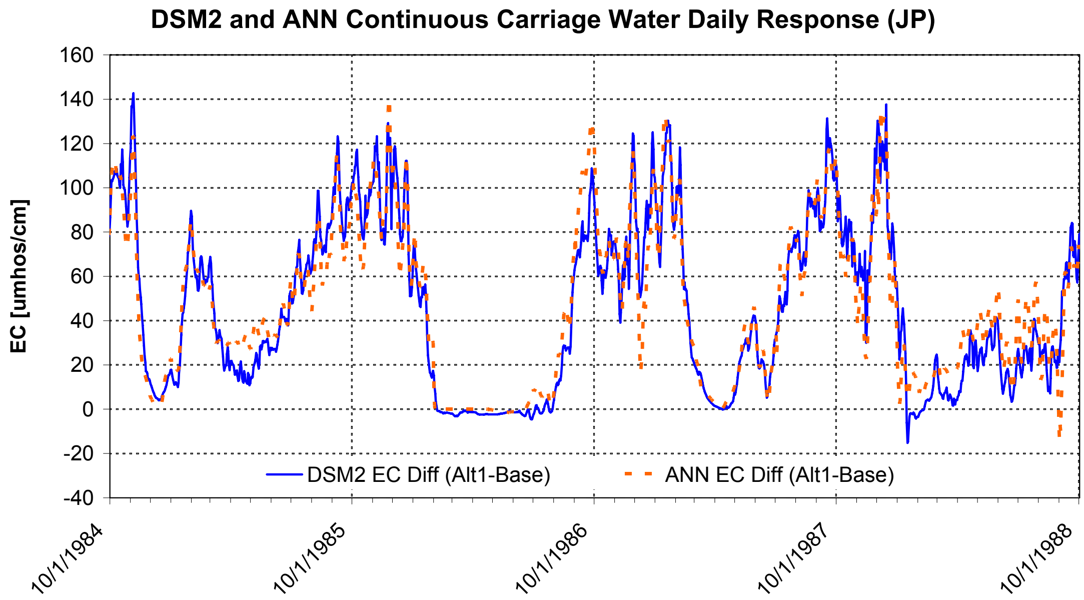


Figure 3-19 Continuous Carriage Water Response—Jersey Point

Ideally, the ANN salinity response to the unit flow changes would be a 1:1 correspondence to DSM2 salinity response with little scatter. Figures 3-20 through 3-22 compare the ANN salinity response to the DSM2 response at the three locations using daily values.

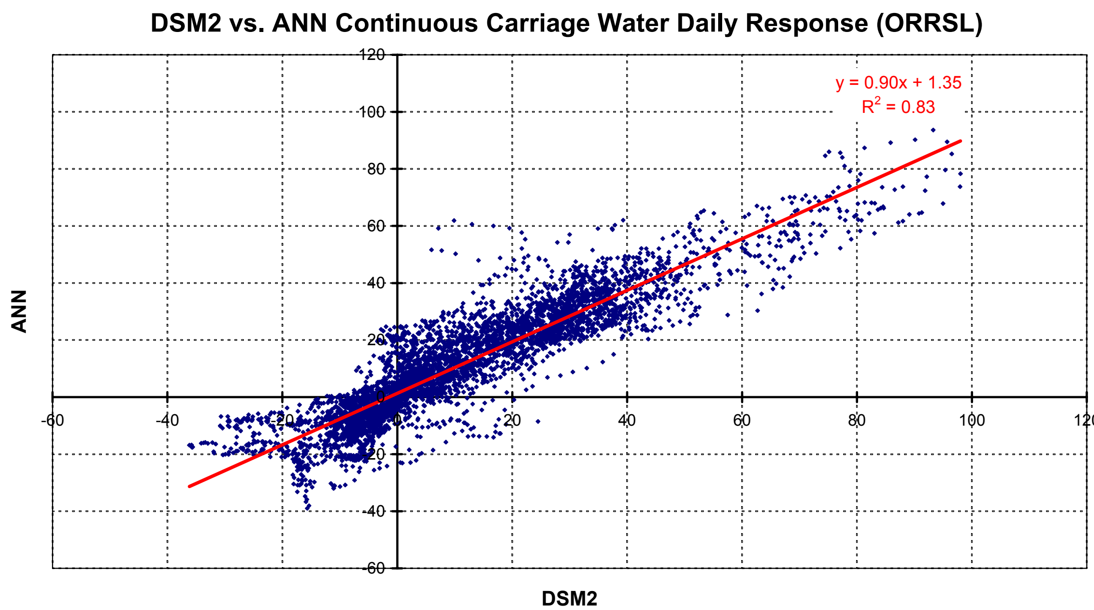


Figure 3-20 DSM2 vs ANN Continuous Response—Old River at Rock Slough

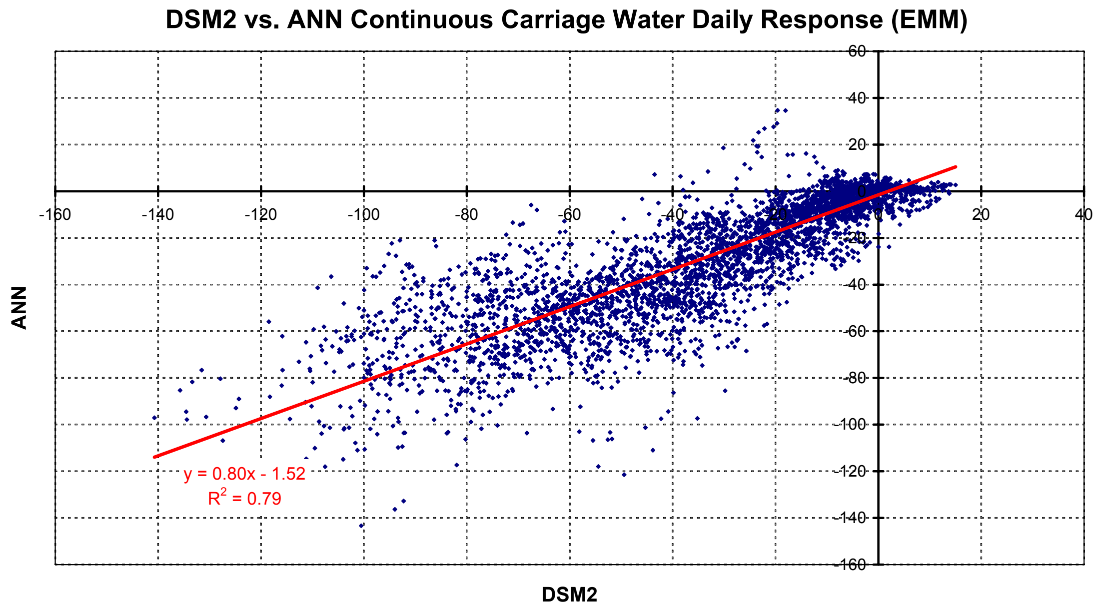


Figure 3-21 DSM2 vs ANN Continuous Response—Emmaton

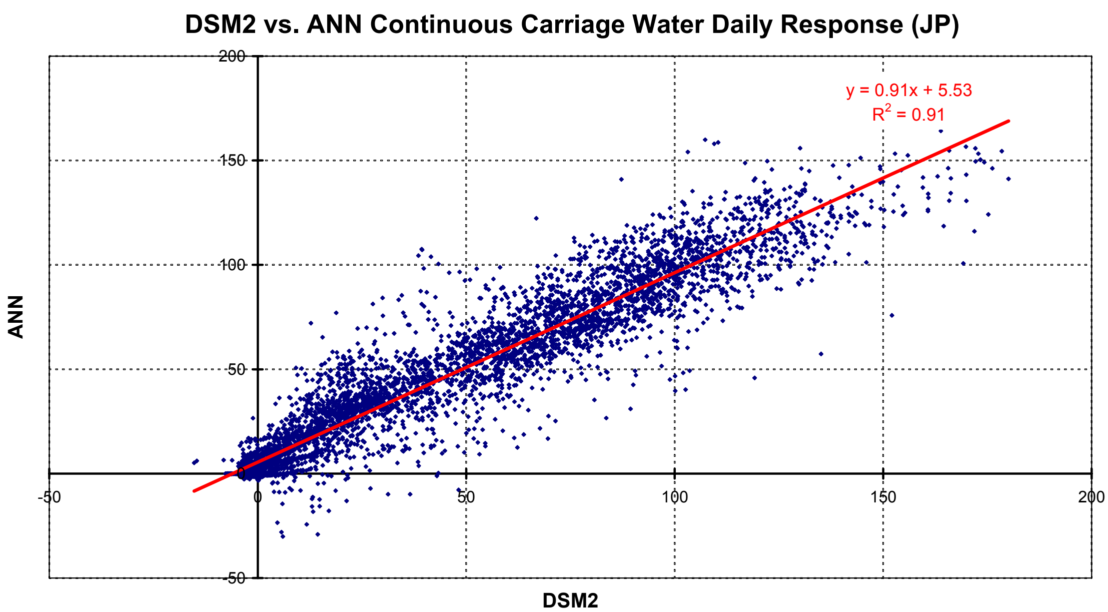


Figure 3-22 DSM2 vs ANN Continuous Response—Jersey Point

Another type of impulse-response test is a transient impulse. In this test, the unit flow perturbation is applied for a time, then removed, to examine the transient response of the system. This is a very difficult test, not only for the ANNs, but for DSM2. It is instructive to view the complex transient behavior that DSM2 exhibits on occasion. For instance, in summer 1988 the salinity response at Old River at Rock Slough first dropped below the base case, then increased, then dropped again during the 3-month 500-cfs Sacramento River flow and CVP/SWP-export increase. The ANN response is often good during the transient impulse, but shows more jitter than the DSM2 response after the transient (Figures 3-23—3-25).

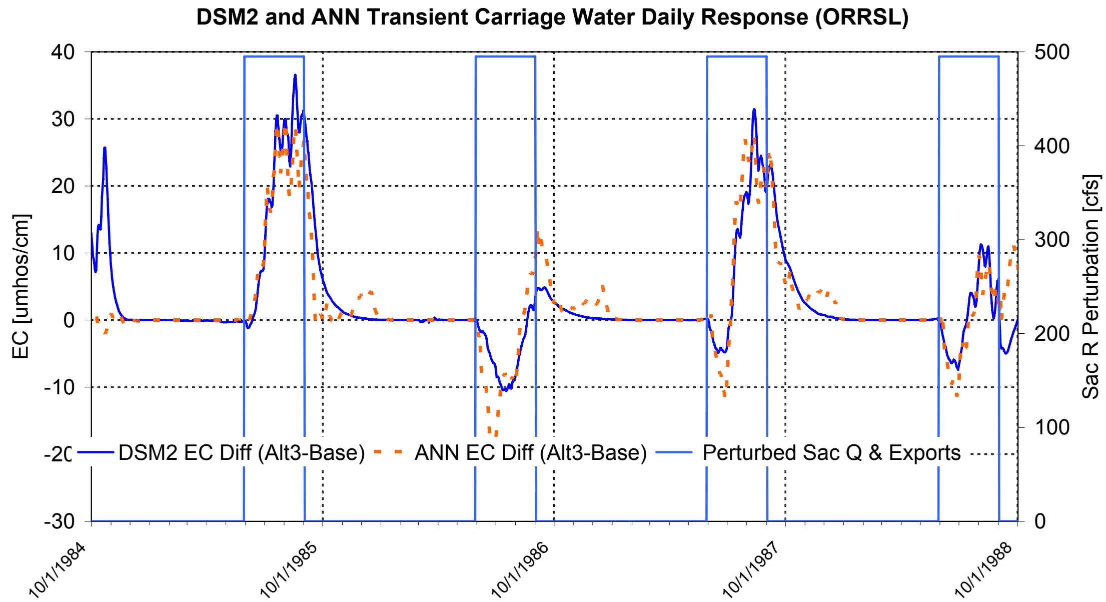


Figure 3-23 Transient Carriage Water—Old River at Rock Slough

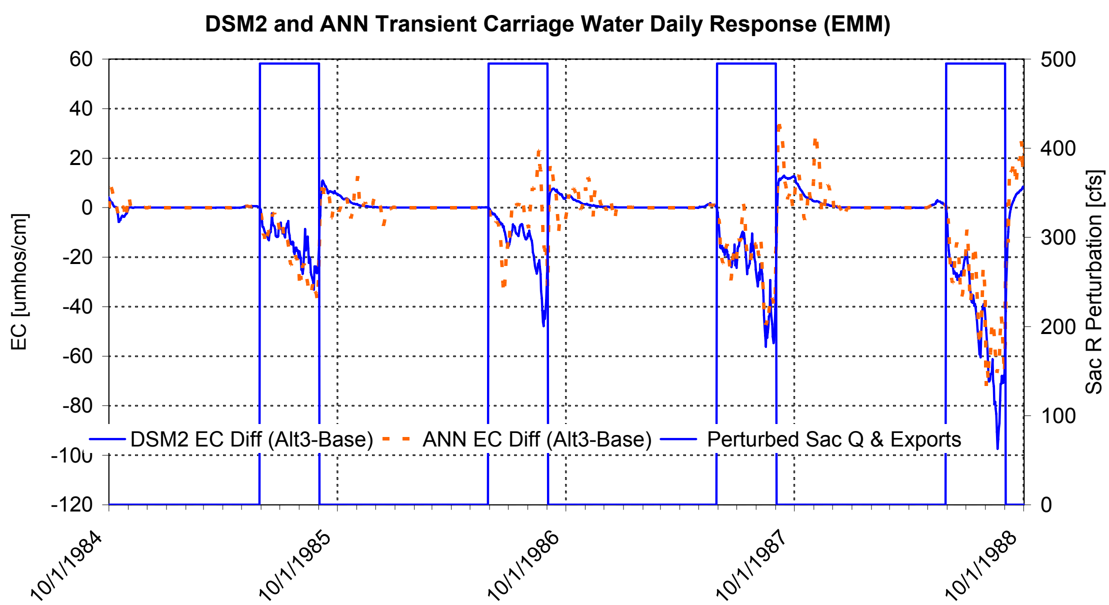


Figure 3-24 Transient Carriage Water—Emmaton

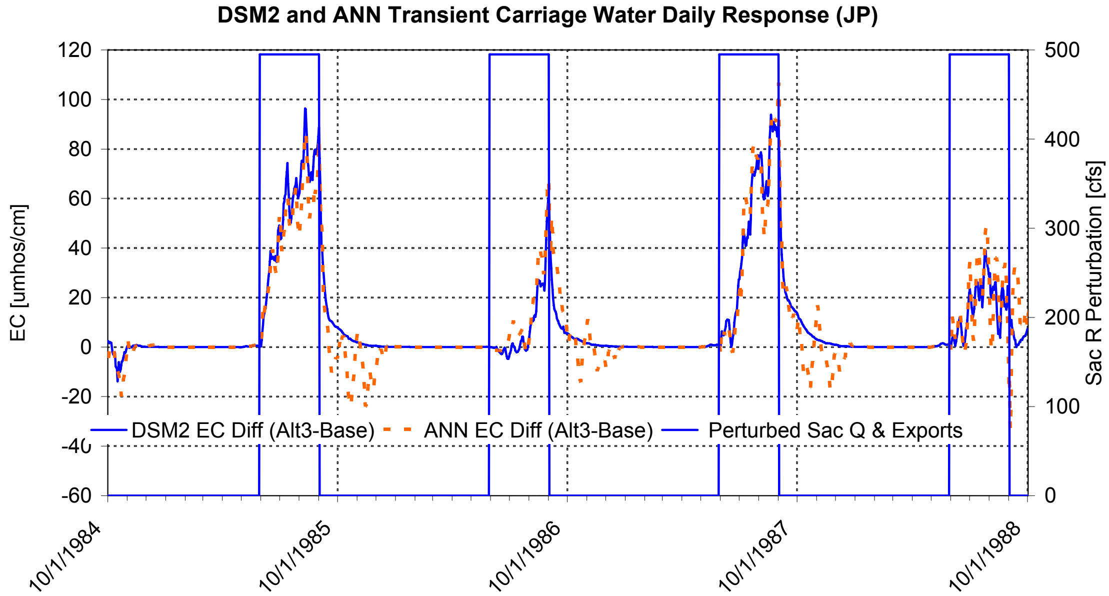


Figure 3-25 Transient Carriage Water—Jersey Point

As with the continuous impulse, we show the DSM2 and ANN responses using scatter plots (Figures 3-26—3-28). We consider the ANN response to generally follow the DSM2 response, especially given the demanding nature of the transient impulse test.

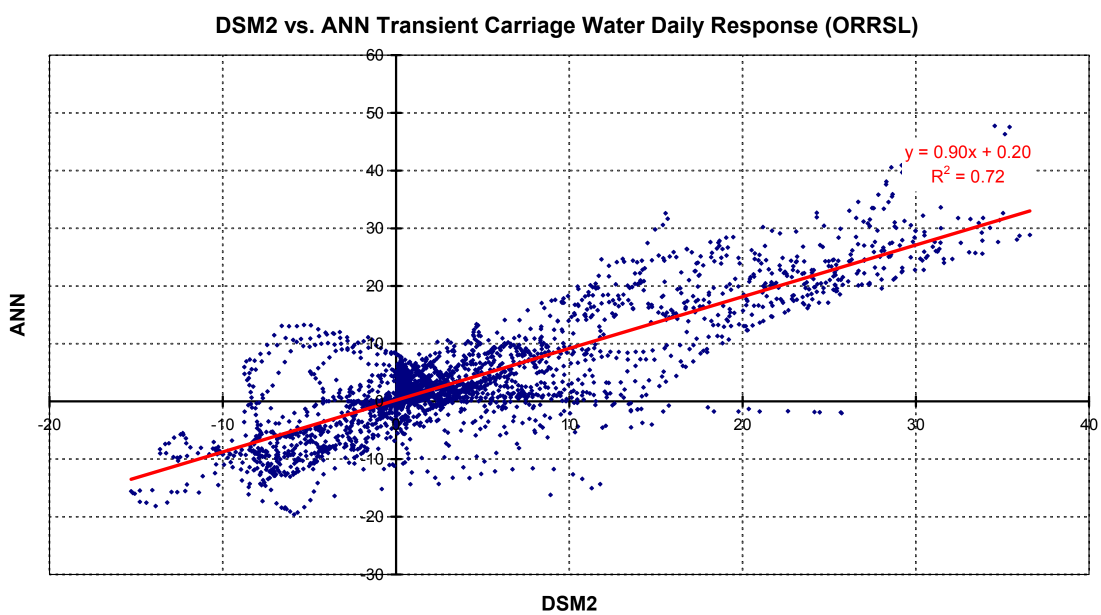


Figure 3-26 DSM2 vs ANN Transient Response—Old River at Rock Slough

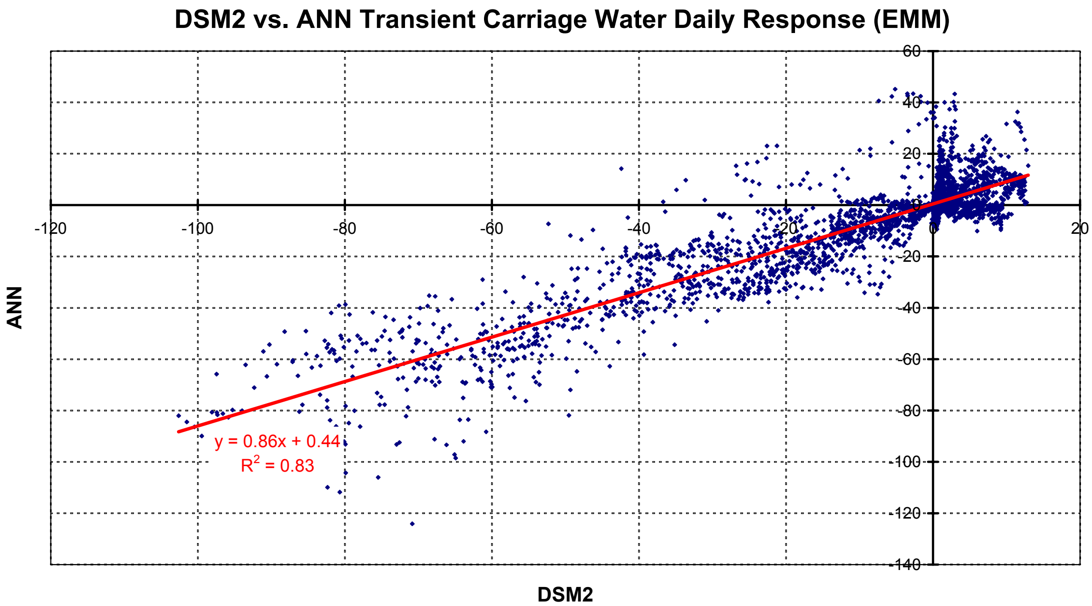


Figure 3-27 DSM2 vs ANN Transient Response—Emmaton

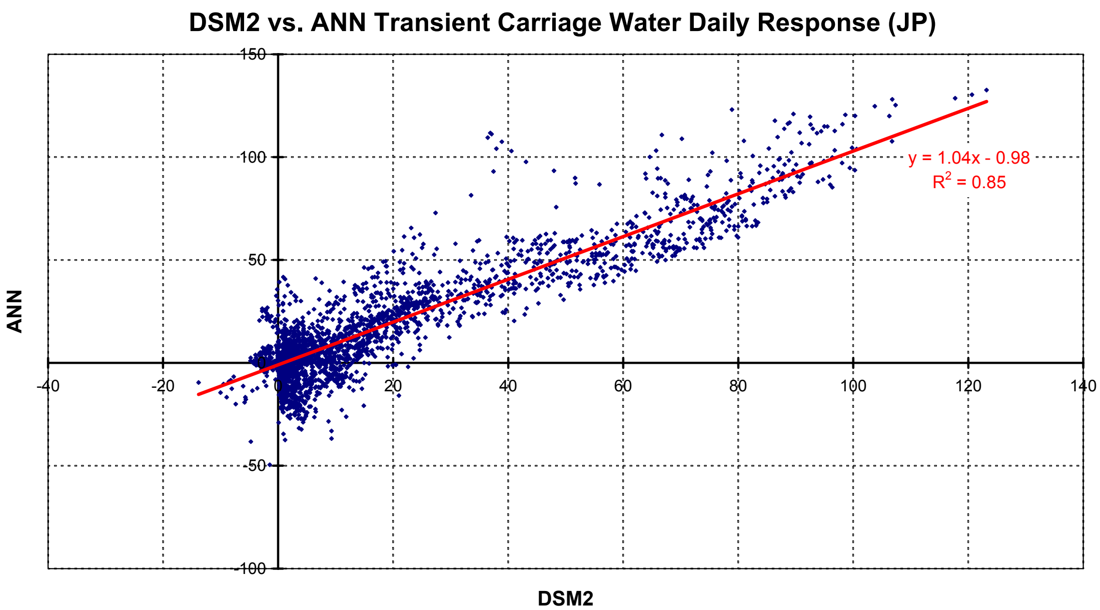


Figure 3-28 DSM2 vs ANN Transient Response—Jersey Point

3.5 Conclusion

ANNs (Artificial Neural Networks) trained well with six inputs that included the tidal range-mimicked, DSM2-simulated data. Good results were obtained in periods outside the calibration data period, proving the capability of these ANNs to handle a wide variety of hydrology. The marginal or incremental salinity response to a unit flow and export change was also generally faithful to the DSM2 response in both continuous and transient modes, lending more credibility to this version of the ANN Delta emulator.

3.6 References

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[DWR] California Department of Water Resources. 2006. *Progress on Incorporating Climate Change into Management of California's Water Resources.* Technical Memorandum Report. Available at: http://baydeltaoffice.water.ca.gov/climatechange.cfm. Figure 5.11, Historical Annual Mean Sea Level at Golden Gate, 1900-2003; p. 5-24.

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

28th Annual Progress Report
October 2007

Chapter 4
Extended 82-year Martinez Planning Tide

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4 Extended 82-year Martinez Planning Tide

4.1 Introduction

As part of the Common Assumptions Long-Term Update Project, the Delta Modeling Section developed a new, full-period planning tide for use in 82-year DSM2 planning studies. The planning tide closely follows the methodology described in Ateljevich (2001). To compensate for past sea level rise, we normalized the tide to a 1993-level using the National Oceanic and Atmospheric Administration’s National Ocean Service estimates of trends.

Full period tides are now available for simulations with and without sea level rise adjustment. Without the adjustment, the tide has more of a historical character; with the adjustment, the trends of the last century are frozen at mid-1990s levels. The Common Assumptions team and Delta Modeling Section adopted the sea level-adjusted version as a new standard. For consistency, the Delta Modeling Section bagan to use the new tide for 16-year studies as well. Because the 1975–1991 period of a 16-year planning simulation is very close to the 1990s date upon which the sea level normalization is based, the change during this period is very small.

4.2 Methods

4.2.1 Adjusted Astronomical Tide

The methodology used to develop the standard 82-year adjusted astronomical tide is similar to the methodology outlined in Ateljevich (2001). Specifically, the steps are as follows:

1. Astronomical tides are fitted to both San Francisco and Martinez observed data for a long common period (about 11 years in the original calibration, 16 years in the work presented here).
2. The residual tide (observed minus astronomical) is calculated for both San Francisco and Martinez.
3. Martinez residual, filtered tide is modeled on San Francisco residual, filtered tide using a moving average of two lagged values, as documented in Ateljevich (2001). This component of the model was not recalibrated.
4. Martinez water levels for 82 years are estimated by adding (a) Martinez astronomical estimate for 82 years and (b) an 82-year residual calculated from the San Francisco 82-year residual tide.

The methodology captures most of the longer period variation in the tide using information that is available over the full period: The Martinez astronomical estimate is a model, and data are available at San Francisco for well over 82 years.

The steps outlined above were retained for the new planning tides. The only modification is that the astronomical fits to both stations are calibrated over a longer period (16 years instead of 11). The ideal is to calibrate both stations over a full 18.6-year nodal cycle. However, there is no common period of record that long for both stations. Assuming that the longer the record the better, both stations are calibrated, in this case, about 16 years.

4.2.2 Sea Level Normalization

The historical record over the 82-year Common Assumptions period includes a discernable long-term trend of increasing sea levels. The lower sea levels in the early part of the twentieth century are of historical interest and important for climate change analyses, but are thought to have little relevance for scenarios involving current or future conditions. We decided, therefore, to remove this trend and normalize the tide to a recent sea level.

The trend we removed comes from a long-term sea level change study for San Francisco performed in Zervas (2001); it is linear with an estimated rate of 2.13 mm per year (approximately 0.70 feet per century) increase. The time point of zero adjustment in the NOAA-NOS study is the fractional year 1993.85, which is November 7, 1993, 0600 PST. Times that are close to this point will be adjusted very little; earlier periods such as the 1930s will be adjusted more.

4.2.3 Influence on Boundary EC

Boundary electrical conductivity (EC) estimates for planning studies are based on net delta outflow and pure astronomical tides. As such, the only influence on boundary EC estimates from the present project comes from the slightly extended calibration period. This change is exceedingly small compared to other factors affecting the EC boundary generation process.

4.3 Results

In assessing the new planning tide, the following questions are of interest:

- How realistic is the tide?
- How different is the new tide from that used in previous planning studies?
- Is the difference primarily due to the new astronomical tide calibration or to sea level normalization?
- What is the effect on study results?

The realism of the adjusted astronomical tide is discussed in Ateljevich (2001). Based on its construction, we expect it to capture most of the astronomical variation and medium-term (spring neap and seasonal) variation of a real tide. The results of the planning tide are compared to the observed tide in Figure 4-1. The plot is representative of periods when sea level normalization is not significant. As reported in Ateljevich (2001), the rms estimation error is approximately 0.2 feet.

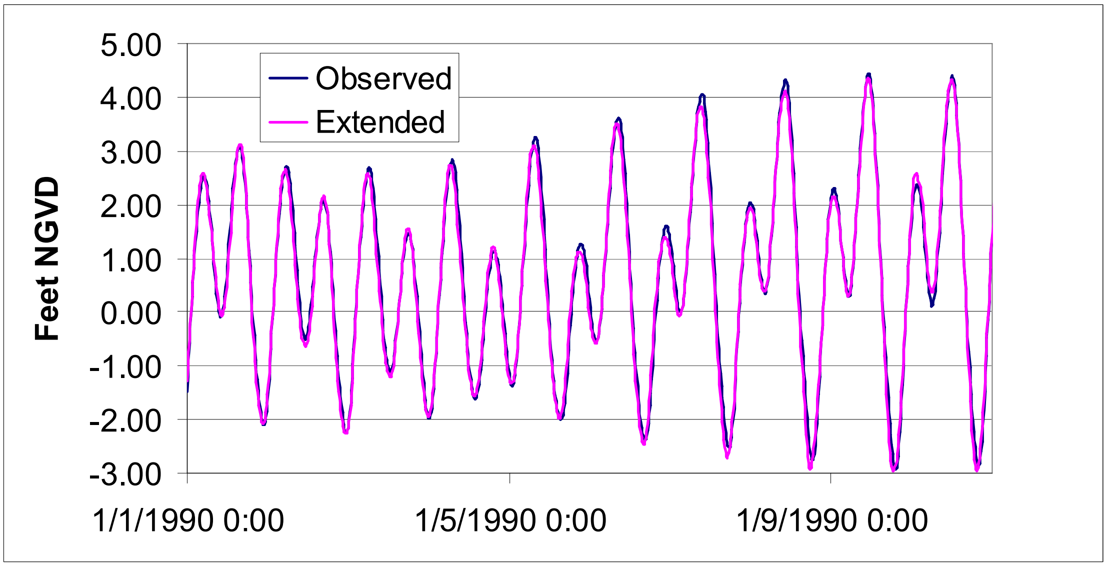

Figure 4-1 Observed and Extended Martinez Tide

Figure 4-2 compares the new 82-year extended tide to the previous planning tide used by the Delta Modeling Section. Two periods are depicted: one in the 1990s where sea level normalization is a very small adjustment and another in the 1960s where sea level adjustment plays a visible role. The figures demonstrate that neither the astronomical recalibration nor the sea level normalization is very significant during the 1974–1991 period, but the sea level normalization is larger.

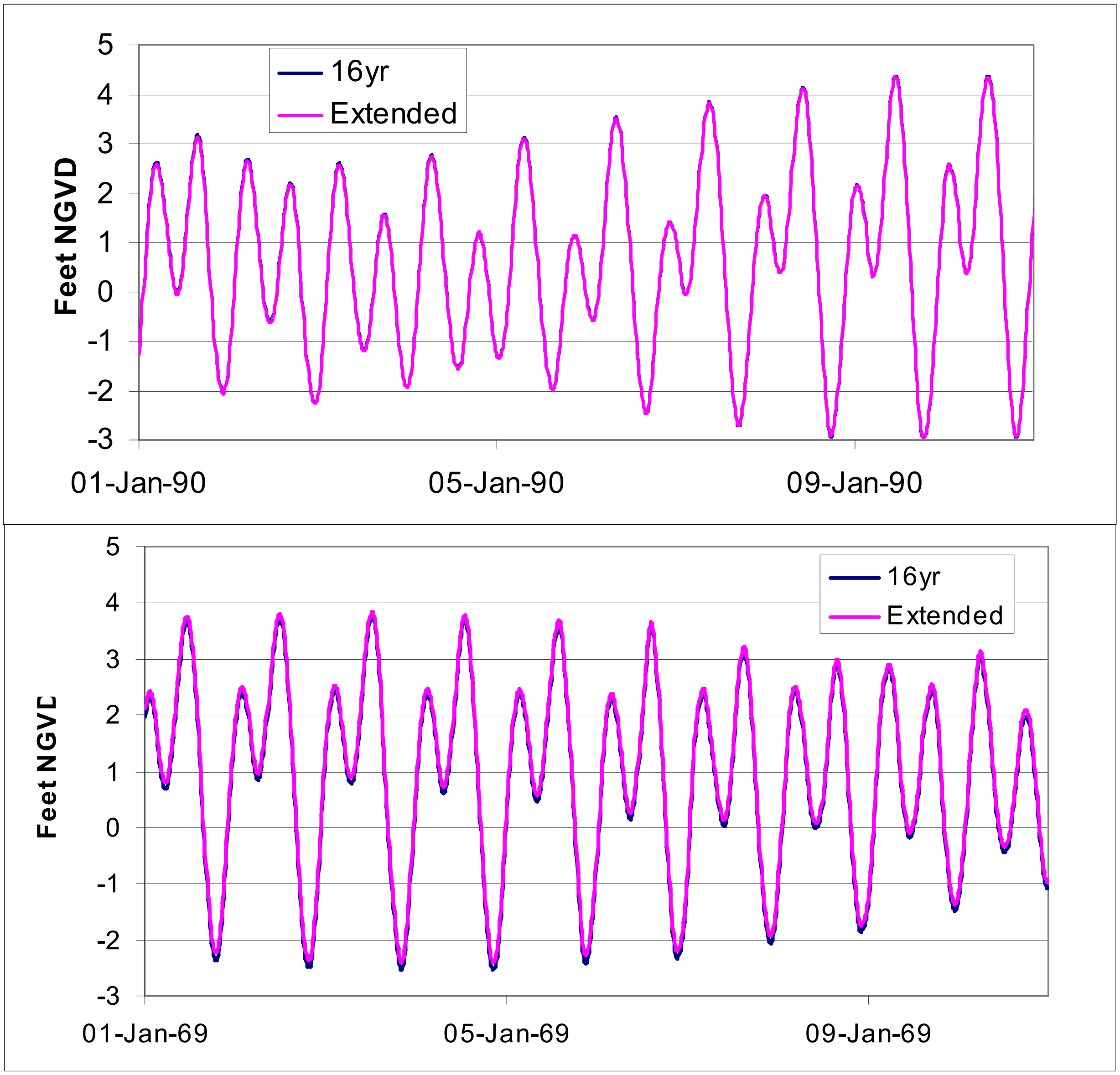

Figure 4-2 Previous and Extended Martinez Tide

To assess the impact of the new tides on studies (net of boundary EC generation and use in DSM2), we compare daily DSM2 EC results at Jersey Point and Clifton Court Forebay (CCF) generated from the previous planning tide and the new tide with and without sea level normalization (Figures 4-3 and 4-4). Differences between the 16-year planning and the extended no-sea-level-rise methodologies are typically less than 0.01%. Differences between these two methodologies and the sea level adjusted methodology are typically less than 2.0%.

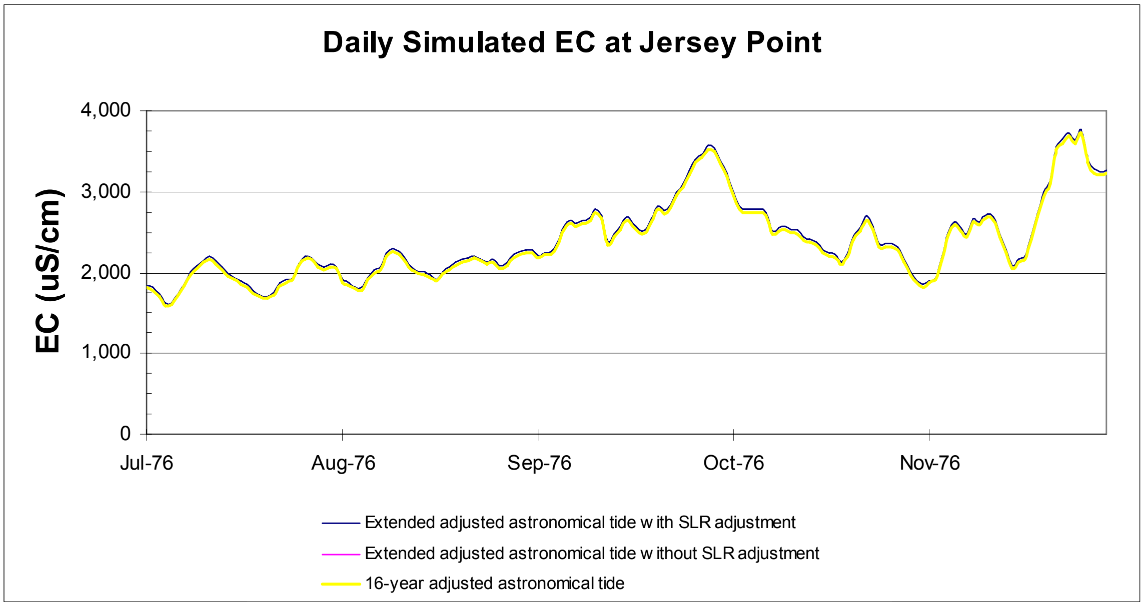

Figure 4-3 DSM2 EC Comparison at Jersey Point

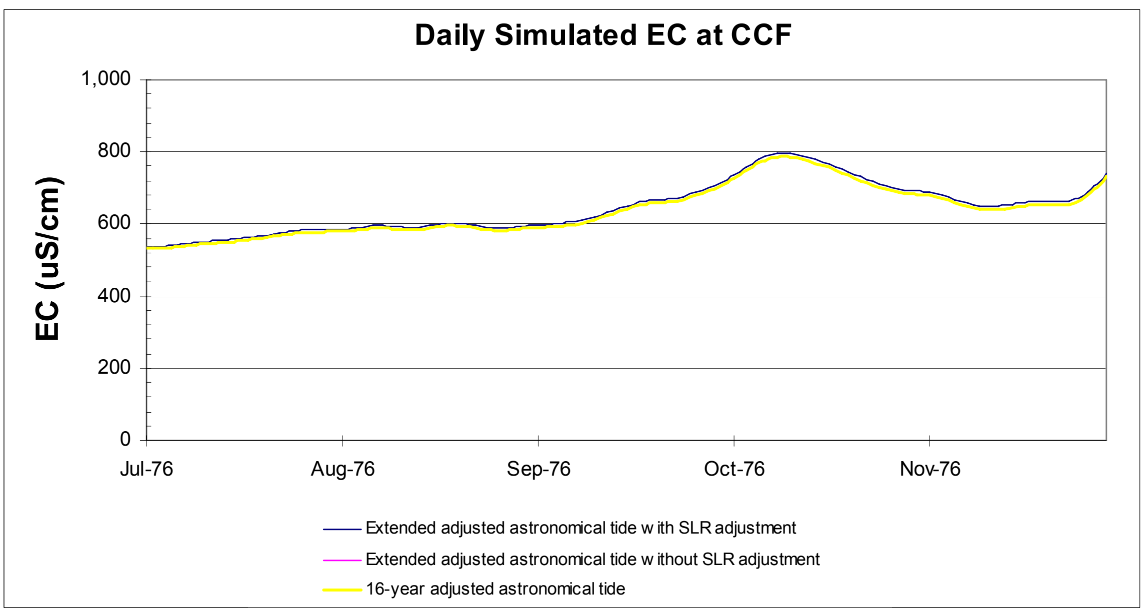

Figure 4-4 DSM2 EC Comparison at CCF

4.4 Summary

The new 82-year tide prepared for Common Assumptions work extends the previous adjusted astronomical tide methodology to a longer period and normalizes it for historical sea level changes. The new methods do not attempt to characterize sea level changes outside of historical adjustments. The new tides are very similar to previous 16-year tides when compared over the original 1974–1991 period because the sea level normalization is small near 1993.

The Delta Modeling Section and Common Assumptions Technical Coordination Team have moved toward the new tide as a standard, and it has been made available to the modeling community. To increase the transparency, the sea level trend, astronomical tide, and a version of the tide without sea level adjustment are packaged with the original tide.

4.5 Reference

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