# M e m o r a n d u m

Date: September 3, 2004

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From: **Department of Water Resources**

Subject: **DSM2-San Joaquin River Extension Simulation over the 1990 – 1999 Period**

## Background

DSM2 with the San Joaquin River extension (DSM2-SJR) has been used to model the historical hydrodynamics and electrical conductivity (EC) for the Delta and the San Joaquin River (SJR) up to Bear Creek (Figure 1) for the period of January 1990 through September 1999. The development the input data for the San Joaquin River upstream of Vernalis builds upon the methods used in the previous DSM2-SJR extension calibration by Pate (2001). Pate's original calibration of the SJR module covered June of 1997 through September of 1999 and included a constant add-water amount of 350 cfs with an EC of twice that for Orestemba Creek. Also, none of the tributaries were modeled in this SJR module. These two features were maintained in the extended simulation. The results generally match the measured flow and salinity on the San Joaquin River near Vernalis. However, the model performance during the relatively dry periods in the 1990's indicates that there is significant room for improvement, particularly concerning the add-water applied. Future use of the DSM2-SJR extension to update the simulation period to the present as well as using the model for real-time simulations will require additional inflow data and a better understanding of the unmonitored hydrology of the Lower SJR basin—the source of the need for having add water.

## SJR Hydrology

DSM2 is a data-driven model requiring significant information along the San Joaquin River. As shown in Figure 1, there are three major tributaries in the reach modeled: the Stanislaus, Tuolumne and the Merced rivers, all which contribute continuous flow from the eastern lower SJR basin. At the Bear Creek confluence, the upper boundary for the model grid, flow is minimal in the dry months but can be significant in the winter. From the west, continuous flows are contributed by Salt and Mud sloughs. More ancillary are the intermittent westside creeks Del Puerto, Orestimba and Hospital/Ingram creeks, which can carry high storm water runoff but otherwise mainly serve as agricultural drainages. San Joaquin River inflows of less certainty from the west are agricultural returns, groundwater inflow and tile drainage. In addition, there are unmonitored riparian diversions and groundwater sinks. These sources and sinks were estimated from data generated by or assumed in the San Joaquin River Input-Output model (SJRIO).

## Data Development

Because of incomplete data, assumptions were used to estimate some flows and salinity as electrical conductivity (EC) of unmonitored sources. Of particular importance in this analysis is the impact of unmonitored flow and salinity estimations. The unmonitored sources include groundwater, agricultural returns, agricultural diversions, missing periods of stream data, as well as the use of “add-water” to make up a flow/salinity imbalance in the calibration. DSM2-SJR historical simulation performance was based on comparing model results to historical flow and EC monitored in the San Joaquin River near Vernalis where there is a continuous set of field data during the 1990 through 1999 simulation.

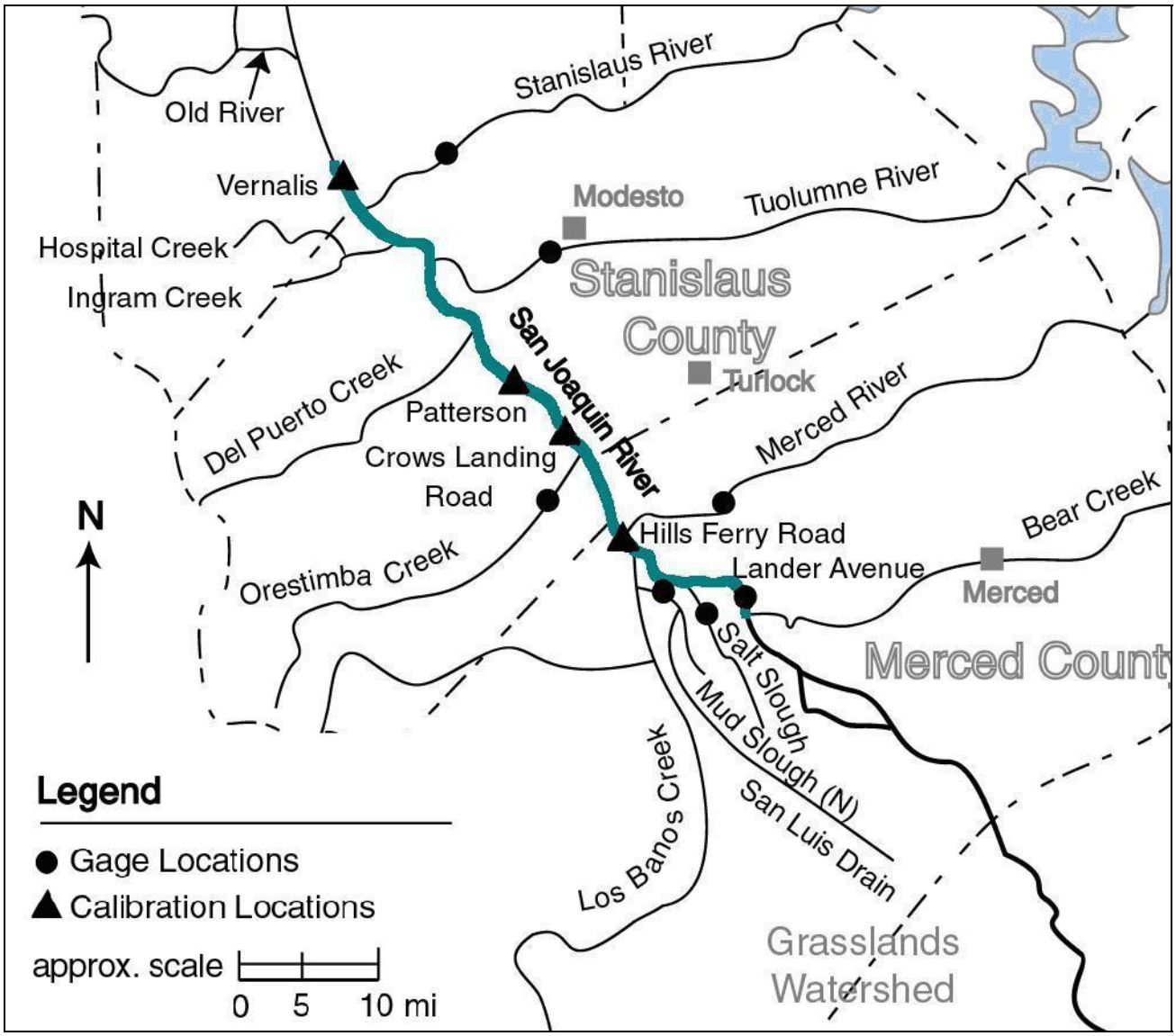


Figure 1. Boundary of the DSM2-SJR extension module.

## Model Input

### Hydrology

The sources of data for inflows to the San Joaquin River, including the assumptions for any estimated flows, are presented in Table 1. Major inflows, when available, were daily or hourly. The minor water district returns and diversions as well as the SJRIO estimations were provided monthly. The resulting modeled flow down the SJR was compared to measured values in the SJR at Newman and Patterson. Graphs of the input flow data are shown in Figures 8 - 21.

Table 1. Data Sources for Inflows and Diversions for DSM2-SJR Simulation of January 1990 – September 1999 Historical Flows in SJR.

| Inflow | Time Period | Data Source |
|---|---|---|
| Stanislaus River | Jan 1990 – May 1997<br>Jun 1997 – Sep 1999 | USGS<br>CDEC |
| Tuolumne River | Jan 1990 – Dec 1994<br>Jan 1995 – Sep 1999 | USGS<br>CDEC |
| Merced River | Jan 1990 – Oct 1995<br>Nov 1995 – May 1997<br><br>Jun 1997 – Sep 1999 | USGS<br>Estimate based on flow relationship with Tuolumne River<br>CDEC |
| SJR near Stevinson | Jan 1990 – May 1997<br>Jun 1997 – Sep 1999 | Estimate from flow continuity at SJR near Newman<br>CDEC |
| Salt Slough | Jan 1990 – Sep 1994<br>Oct 1994 – Oct 1995<br><br>Nov 1995 – Sep 1999 | USGS<br>Estimate from average daily flow from the same water year type<br>USGS |
| Mud Slough | Jan 1990 – Sep 1999 | USGS |
| Orestimba Creek | Jan 1990 – Oct 1992<br><br>Nov 1992 – Sep 1999 | Estimate based on flow relationship with Orestimba flow further upstream<br>USGS |
| Del Puerto Creek | Jan 1990 – Sep 1999 | USGS |
| Hospital/Ingram Creeks | Jan 1990 – Dec 1996<br><br>Jan 1997 – Sep 1999 | Estimate based on flow relationship with Del Puerto Creek flow<br>DWR-Pate |
| Westside Irrigation District<br>Patterson Water District<br>El Solyo Water District<br>Modesto Irrigation District<br>Turlock Irrigation District<br>Modesto Wastewater Treatment Plant | Jan 1990 – Sep 1999 | Regional Water Quality Control Board |
| Groundwater sources & sinks (29 locations)<br>Tile drainage (9 locations)<br>Agricultural Diversions (17 locations)<br>Agricultural Drainage (19 locations) | Jan 1990 – Sep 1999 | SJRIO Estimates |
| Add-water | Jan 1990 – Sep 1999 | DWR-Pate: 200 cfs at Vernalis and 150 cfs at Patterson (constant total of 350 cfs) |

Water Quality

The sources of salinity data for major flows into the San Joaquin River and any assumptions are presented in Table 2. When EC values were available, the time resolution was daily or hourly average. Graphs of the salinity input data are shown in Figures 22 - 30.

Table 2. Data Sources for EC in Inflows for DSM2-SJR Simulation of January 1990 – September 1999 Historical Flows in SJR.

| Inflow | Time Period | Source of Data |
|---|---|---|
| Stanislaus River | Jan 1990 – Sep 1999 | CDEC |
| Tuolumne River | Jan 1990 – May 1997<br>Jan 1997 – Sep 1999 | Estimate from flow-salinity relationship<br>SJRIO (Pate) |
| Merced River | Jan 1990 – Oct 1995<br>Nov 1995 – Oct 1997<br>Sep 1998 – Jun 1999<br>Other times | Regional Water Quality Control Board<br>USGS<br>SJRIO (Pate)<br>Estimate by seasonal average |
| SJR near Stevinson | Jan 1990 – Sep 1999 | Regional Water Quality Control Board (Pate) |
| Salt Slough | Jan 1990 – Dec 1996<br>Jan 1997 – Sep 1999 | Regional Water Quality Control Board (Pate)<br>USGS |
| Mud Slough | Jan 1990 – Oct 1996<br>Nov 1996 – Sep 1999 | Estimate from available data w/sinusoidal trend<br>USGS |
| Orestimba Creek | Jan 1990 – Dec 1991<br>Jan 1992 – Mar 1995<br>Apr 1995 – Dec 1996<br>Jan 1997 – Sep 1999 | 700 uS/cm (estimated)<br>USGS<br>800 uS/cm (estimated)<br>USGS |
| Del Puerto Creek | Jan 1990 – Sep 1999 | Assume Orestimba values |
| Hospital/Ingram Creek | Jan 1990 – Sep 1999 | Assume Orestimba values |
| Add water | Jan 1990 – Sep 1999 | Assume double Orestimba values |

As in the earlier calibration by Pate, constant EC values were assumed for many of the smaller irrigation drainage ditches as well as the Modesto sewage outfall (see Table 3). The SJRIO model estimated monthly water quality values for groundwater, tile drainage, and agricultural drainage from Vernalis up to Bear Creek (see Figures 29, 30). For the add-water at Vernalis and Patterson, double the Orestimba EC values were applied.

Table 3. Constant EC Values in Inflows for DSM2-SJR Simulation of January 1990 – September 1999 Historical Flows in SJR.

| Location | EC, uS/cm | Location | EC, uS/cm |
|---|---|---|---|
| Modesto Wastewater Treatment Plant | 1000 | Turlock Irrigation District Lateral #2 | 400 |
| Newman Wasteway | 1000 | Turlock Irrigation District Lateral #3 | 650 |
| Modesto Irrigation District Lateral #4 | 250 | Turlock Irrigation District Lateral #5 | 870 |
| Modesto Irrigation District Lateral #5 | 75 | Turlock Irrigation District Lateral #6&7 | 700 |
| Modesto Irrigation District Lateral #6 | 150 | Turlock Irrigation District Lower Stevinson Spill | 750 |
| Modesto Irrigation District Main Drain | 300 | | |

## DSM2-SJR Results at Vernalis

Flow

Modeled daily average DSM2 flow and measured field data in the San Joaquin River at Vernalis are shown in Figure 2. The chart reveals the dry 1990 -1995 period compared to the much wetter late 1990's. On average, the modeled flow is 241 cfs higher than the field data. The field data in January and February of 1997, however, is suspect since it does not correlate well with a stage/flow relationship at Brant Bridge which indicates a much higher flow at Vernalis. With adjustments to the field data for January and February of 1997 reflecting this relationship, the modeled flow is 157 cfs higher than the field data. The standard deviation of the residual flow is 1,262 cfs. Figure 3 shows the extreme residual values in the winter of 1995, 1997, and 1998 that are driving the large deviation. Residuals for the early 1990's, shown in Figure 4, are less extreme. The simulated flow from 1990 through 1994 is 250 cfs higher than historical values. Apart from the exceedingly high modeled flow in early January of 1997, the modeled flow is 57 cfs less than the field data on average from January of 1995 through October of 1999.

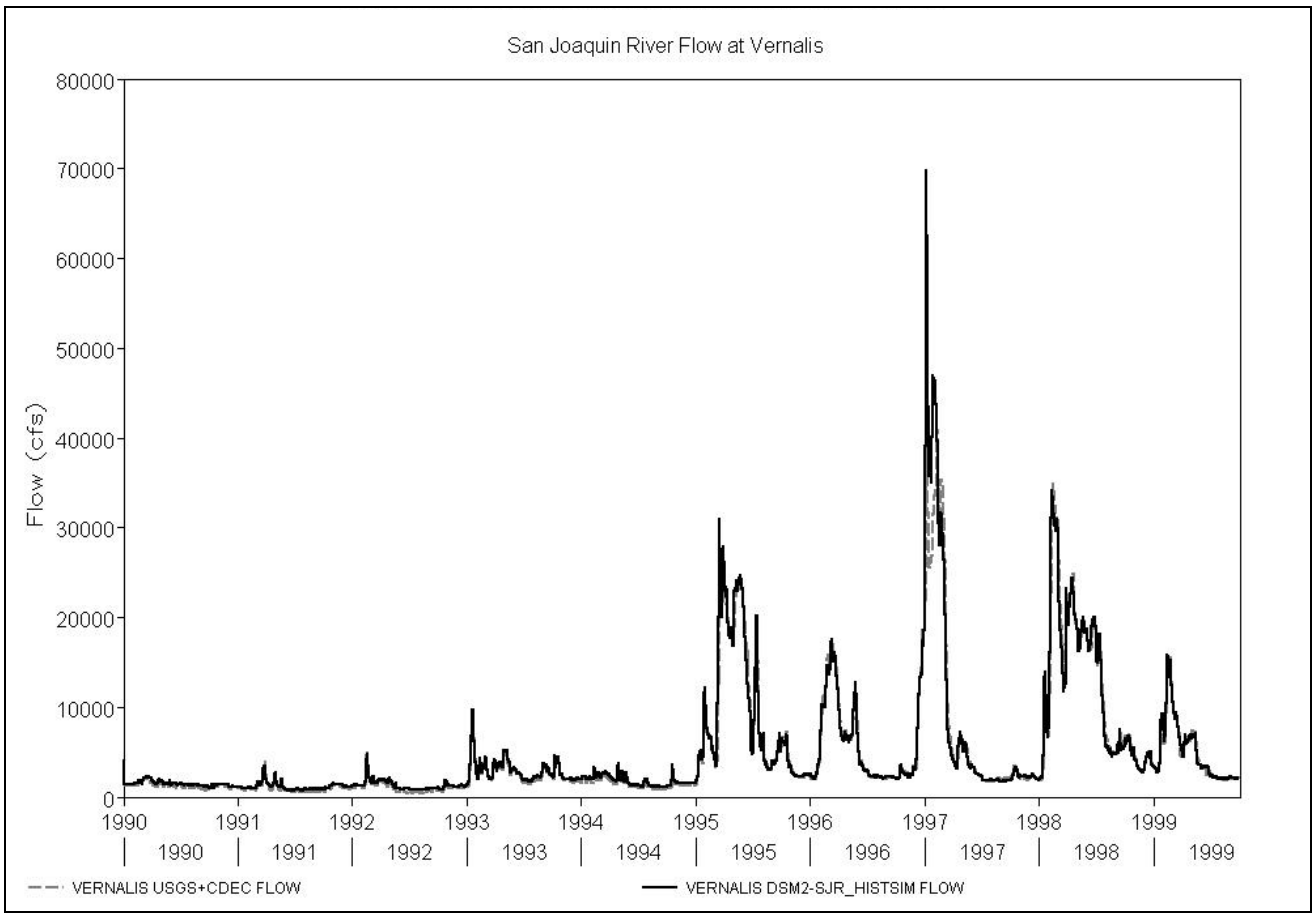



Figure 2. Historical Simulated and Measured Flow at Vernalis, January 1990 – September 1999.

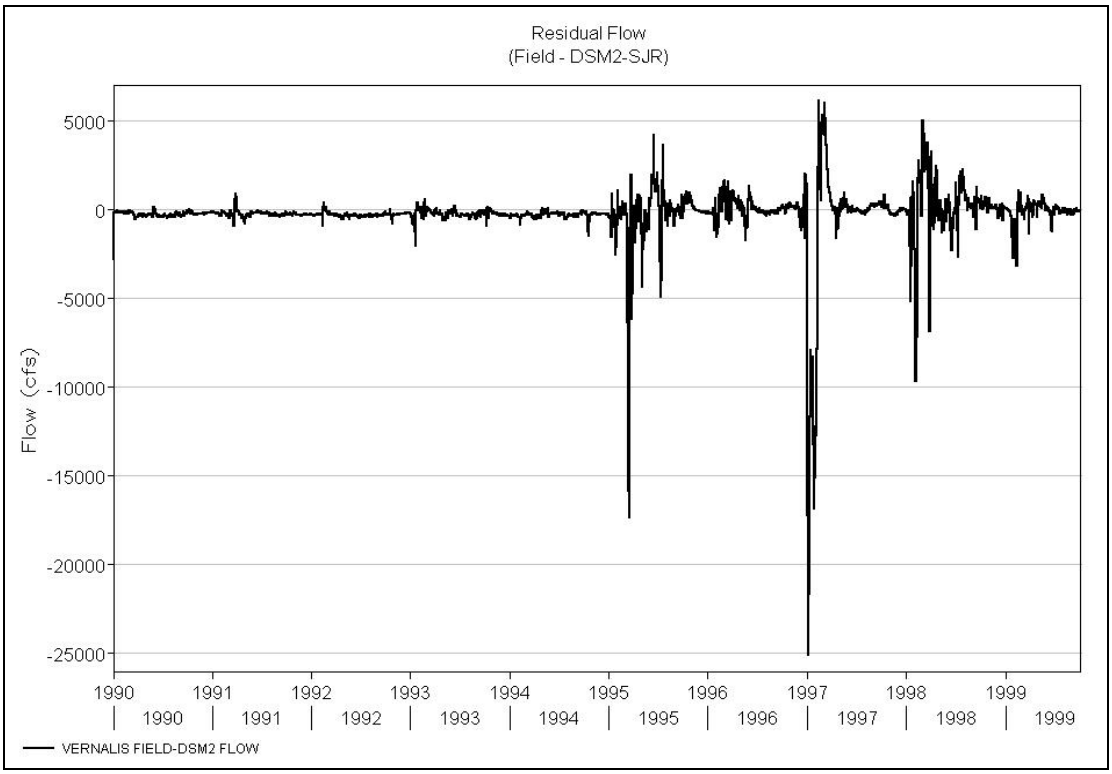



Figure 3. Residual flow at Vernalis from DSM2-SJR Simulation of Historical January 1990 – September 1999.

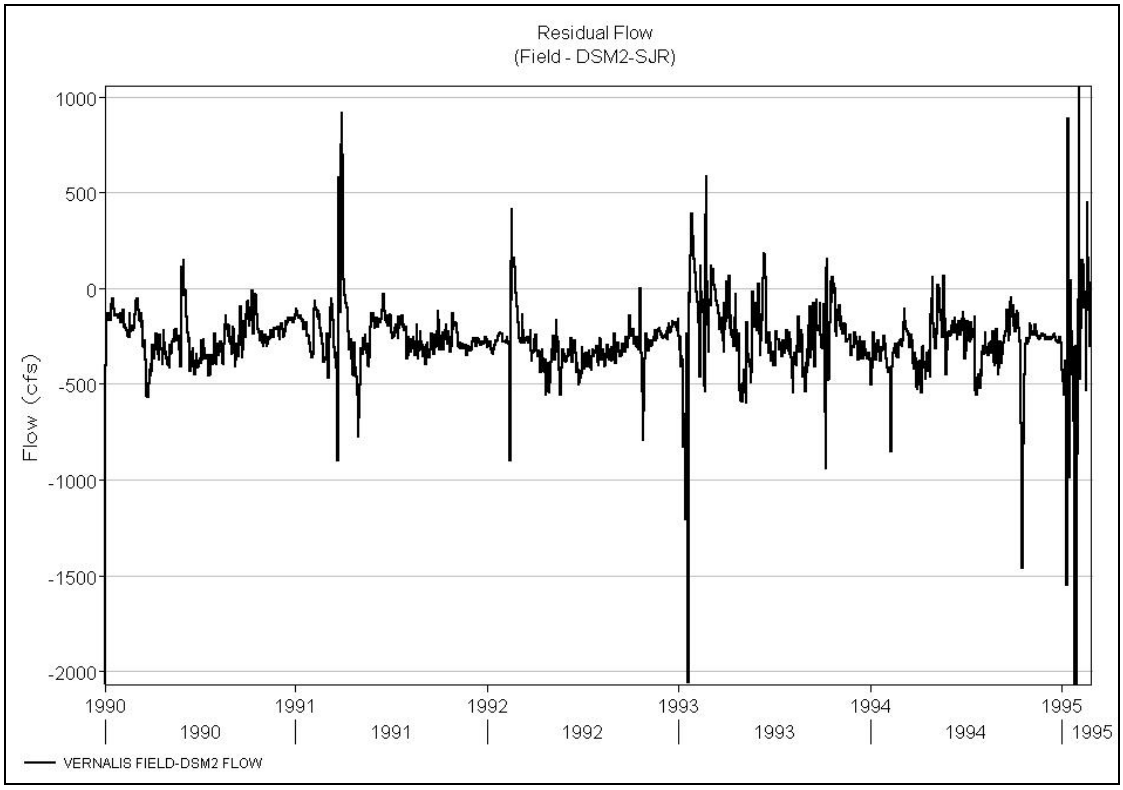



Figure 4. Residual flow at Vernalis from DSM2-SJR Simulation of Historical January 1990 – December 1995.

The daily volumetric fingerprint in Figure 5 indicates the relatively large contribution to SJR flow near Vernalis from eastside streams (35-90%). Of lesser contribution are the westside inflows from creeks, sloughs, groundwater, and agricultural returns (5-40% combined). With a continual flow rate for add-water of 350 cfs, the contribution of add-water to the SJR flow is considerably higher in the early 1990's when conditions were drier than during the calibration period.

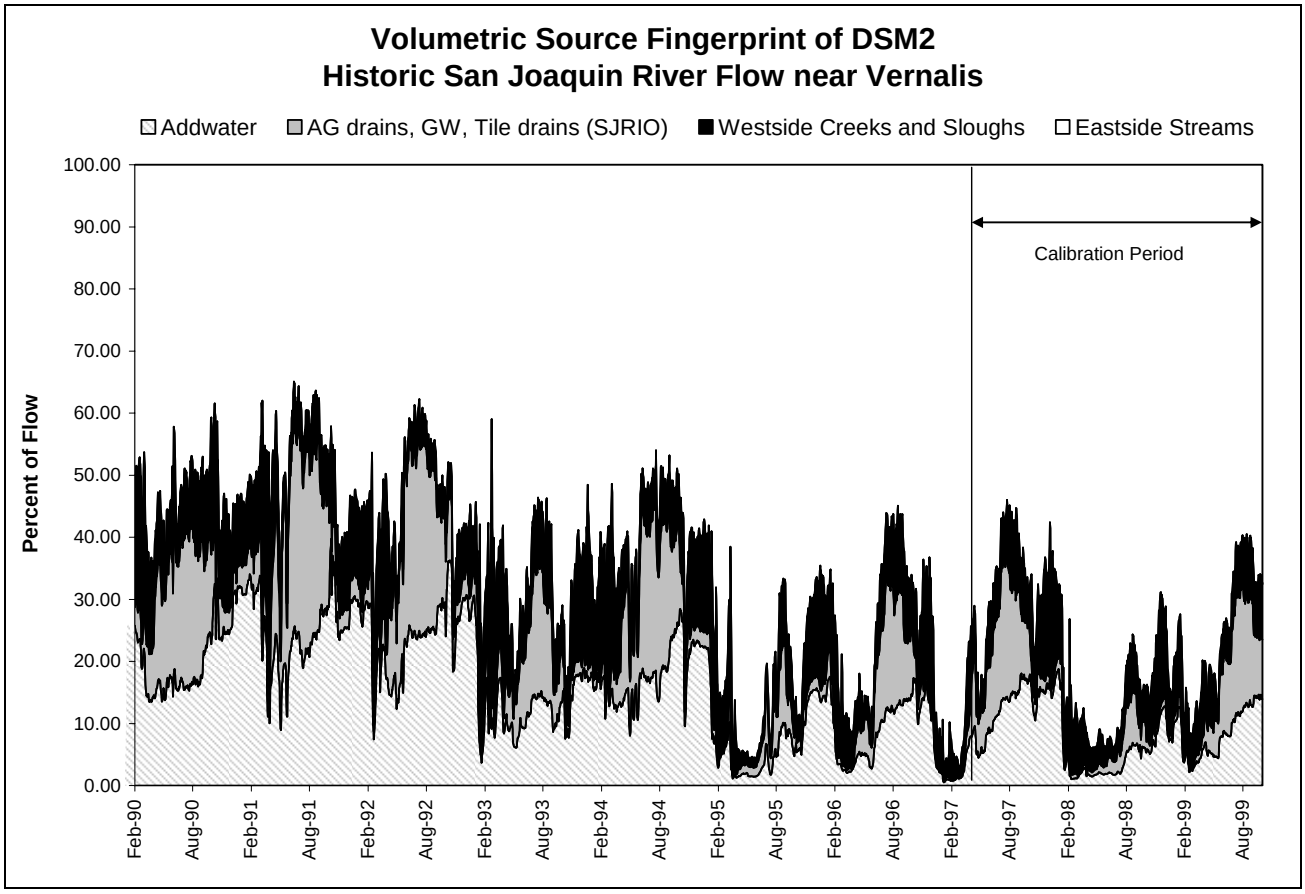



Figure 5. DSM2-SJR generated volumetric fingerprint at Vernalis indicating the relative flow contribution from grouped sources.

The average monthly flow contribution at Vernalis over the 1990 - 1999 period (see Figure 6) shows that 60 to 75% of the water is derived from the large tributaries in the eastside of the basin. The creeks and the sloughs contribute between 5% in the late spring and summer and 14% in the winter. The sloughs in particular are highly managed with a fairly continuous release and a higher winter release to take advantage of blending with winter runoff. The groundwater and agriculture returns in the Westside make up the SJRIO inputs which can contribute up to 20% of the flow in the summer months. Add-water adds 9 to 19% of the average monthly flow at Vernalis.

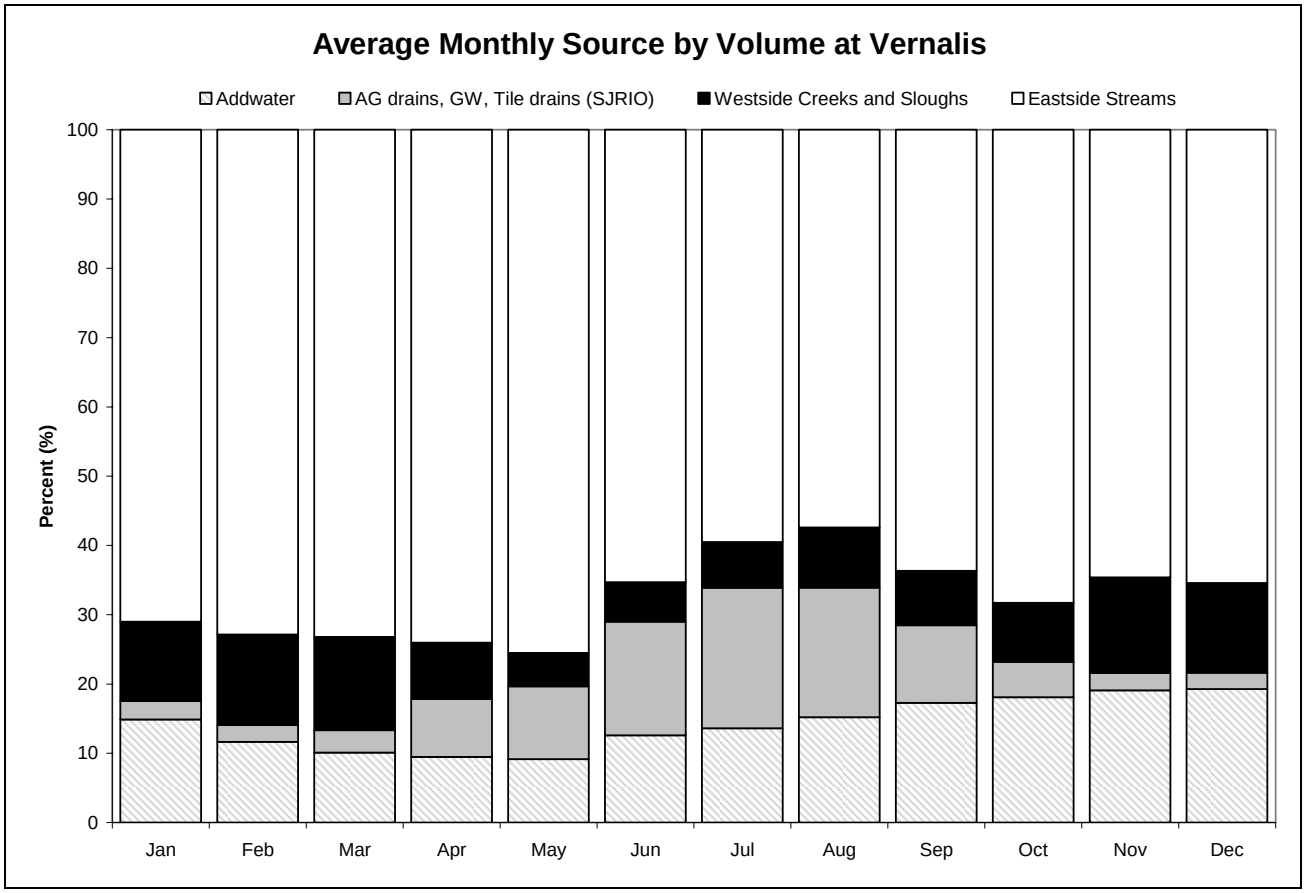



Figure 6. DSM2-SJR generated average monthly volumetric source contribution at Vernalis over the January 1990 – September 1999 simulation period.

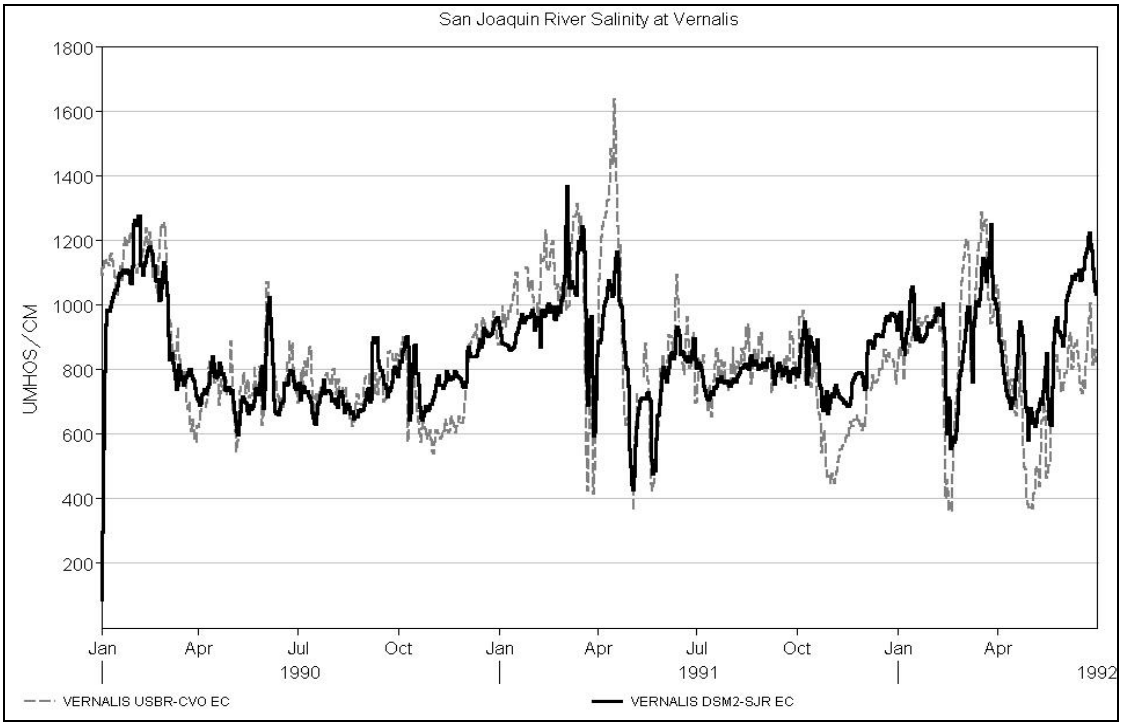
Salinity

Daily average DSM2-generated EC versus field data in the San Joaquin River at Vernalis is shown in Figure 7. On average, the modeled EC is 41 uS/cm higher than field data. The standard deviation of the residual is 122 uS/cm and 588 uS/cm is the maximum difference.

The daily mass fingerprint, shown in Figure 8, reveals the relatively large amount of SJR salinity near Vernalis attributed to add-water, particularly in the early 1990's (30-60%). Lesser flows from other sources in these periods increase the relative flow and salt contribution of the constant 350 cfs flow of add-water. In the late 1990's, modeled add-water contributed between 10% in the early spring and 40% in the fall. The salt load at Vernalis from groundwater, tile drains and agricultural returns was 5% in winter and spring to 35% in summer and early fall. The contribution from the westside creeks and sloughs were 10 to 50%. In the summers of 1991 and 1992 it was about half that of other summers seasons. The eastside streams added 10 to 60% of the salt at Vernalis. The contribution from wet year to dry changes considerably, however. In the early 1990's the eastside streams contribute between 10 and 30% while in the late 1990's the contribution is between 20 and 60%.

Figure 9 shows add-water salt load contribution to be between 20 and 40% on an average monthly bases with the higher values in the late summer and early fall. The summer and fall 20% salt contribution from westside flows increases to 45% in the winter and early spring. This may due to precipitation runoff flushing out accumulated salinity in farm lands. SJRIO inputs (groundwater and agricultural drainage) are increased in the summer some 20 to 30%, when demand for irrigation water is at its peak. Eastside tributaries consistently contribute between 20 and 30% of the EC at Vernalis. The average

monthly eastside load contribution can be misleading. As shown in Figure 6, the relative contribution was low in the early 1990's, between 10 and 20%; however, in the relatively wet late 1990's, the load contribution from the eastside tributaries was much higher, between 20 and 60%.



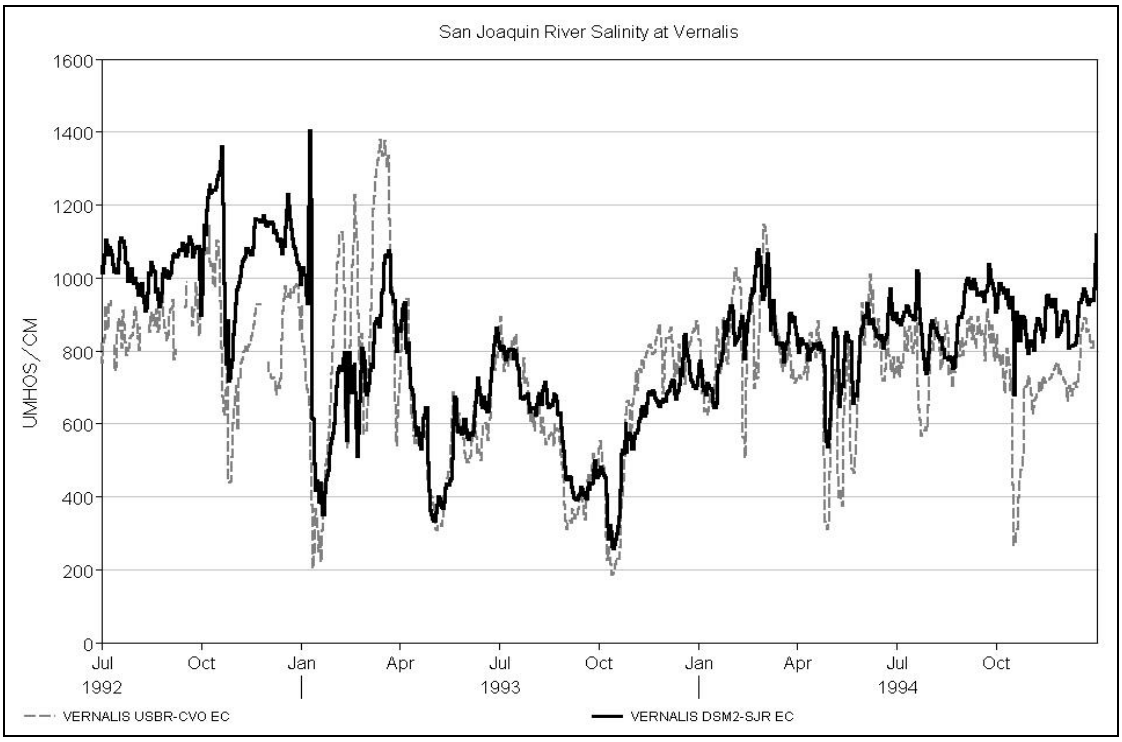
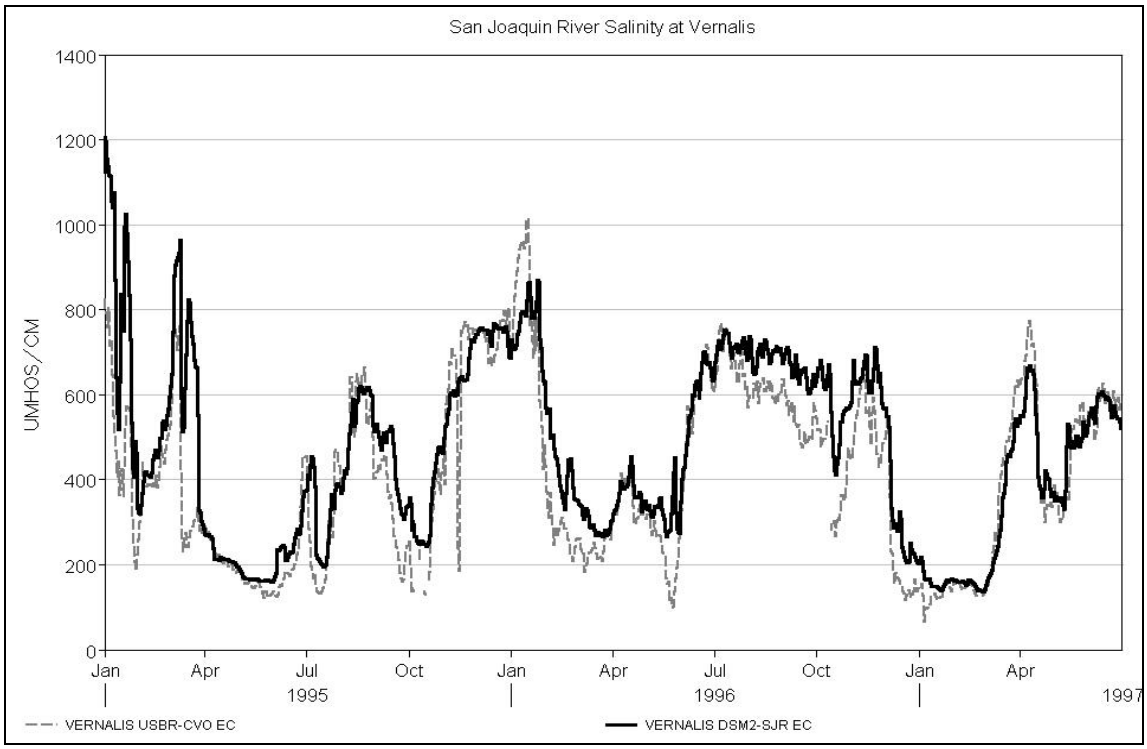




Figure 7. DSM2-SJR simulated EC and measured EC at Vernalis, January 1990 – September 1999.



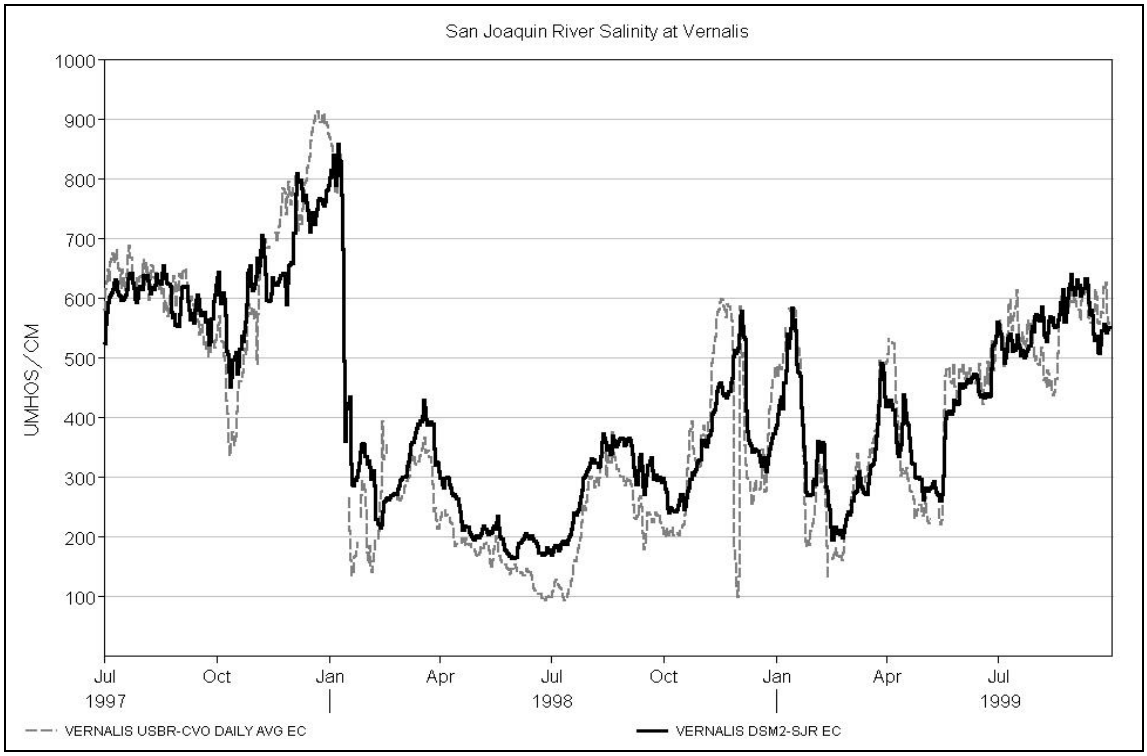




Figure 7 – cont. DSM2-SJR simulated EC and measured EC at Vernalis, January 1990 – September 1999.

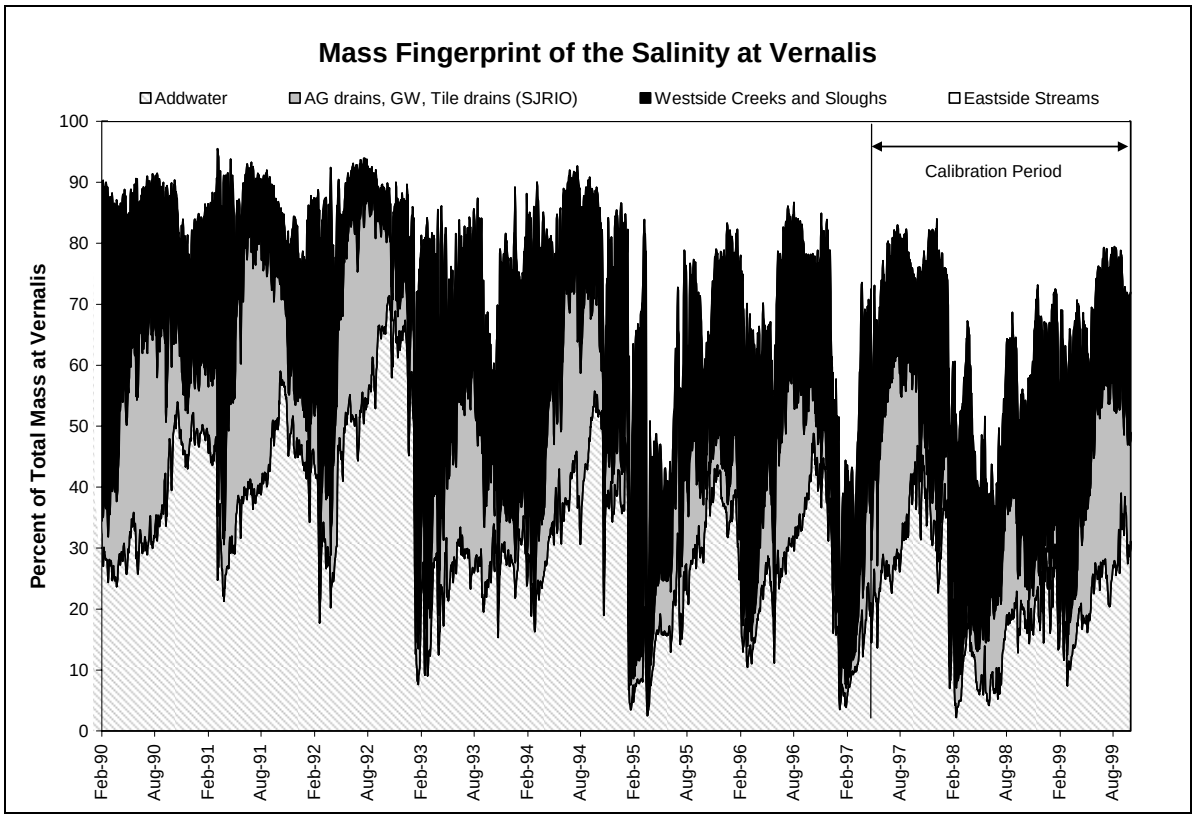



Figure 8. DSM2-SJR generated mass fingerprint at Vernalis indicating the relative load contribution from grouped sources.

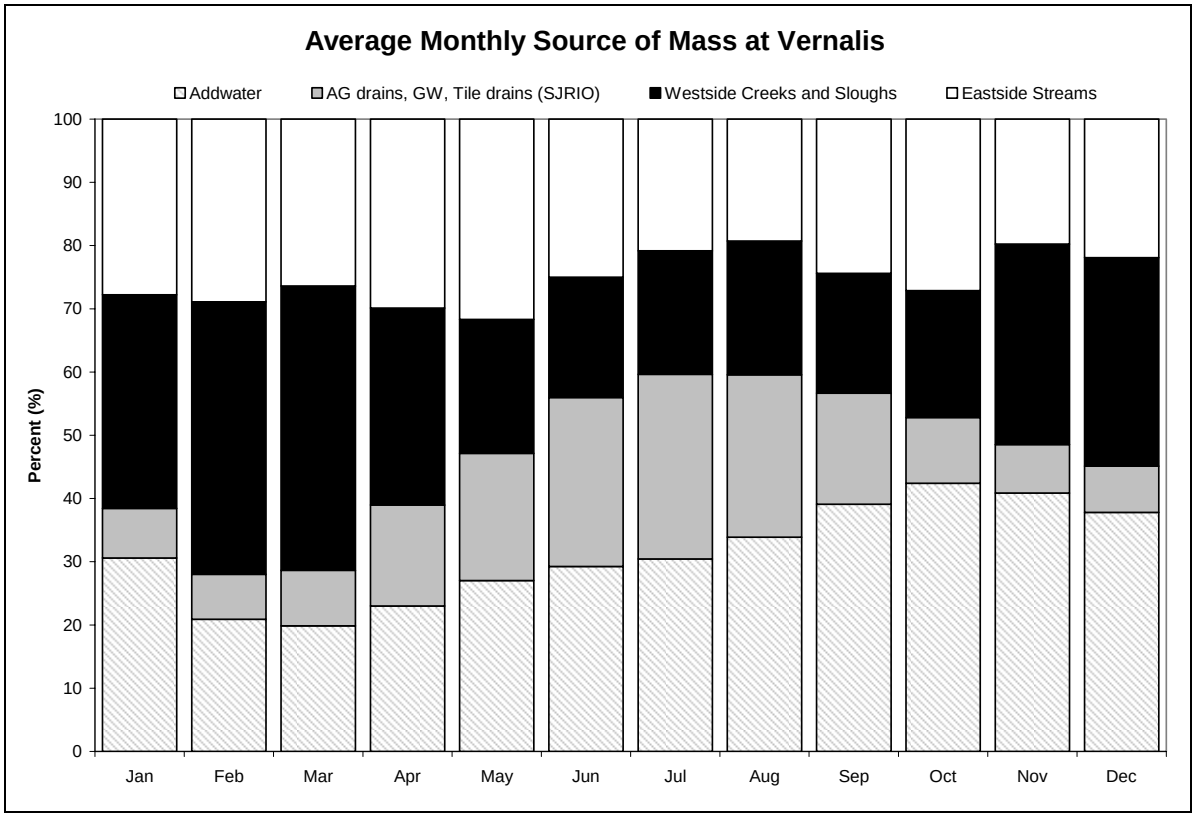



Figure 9. DSM2-SJR generated average monthly percent contribution by mass of salinity at Vernalis.

## Discussion

The above simulation of flow and EC in the San Joaquin River used the constant 350 cfs add-water amount developed by Pate for the calibration period of 1997 – 1999. This value was reexamined by comparing the modeled flow at Vernalis without add-water to the historical flow for the extended period. As shown in Table 4 and Figure 10, DSM2-SJR tends to underestimate flow at Vernalis over the January 1990 through September 1999 study period by amounts consistent with Pate's value 350 cfs. The values shown do not include January of 1997 since the data reflecting the record high flows in the San Joaquin River are suspect as mentioned above.

Table 4. Average DSM2-SJR error in flow at Vernalis when add-water not modeled.

| Month | Average Error (cfs) | Month | Average Error (cfs) | Month | Average Error (cfs) |
|---|---|---|---|---|---|
| January* | 56 | May | -103 | September | -246 |
| February | -59 | June | -331 | October | -331 |
| March | -404 | July | -197 | November | -225 |
| April | -280 | August | -211 | December | -189 |

*January 1997 not included.

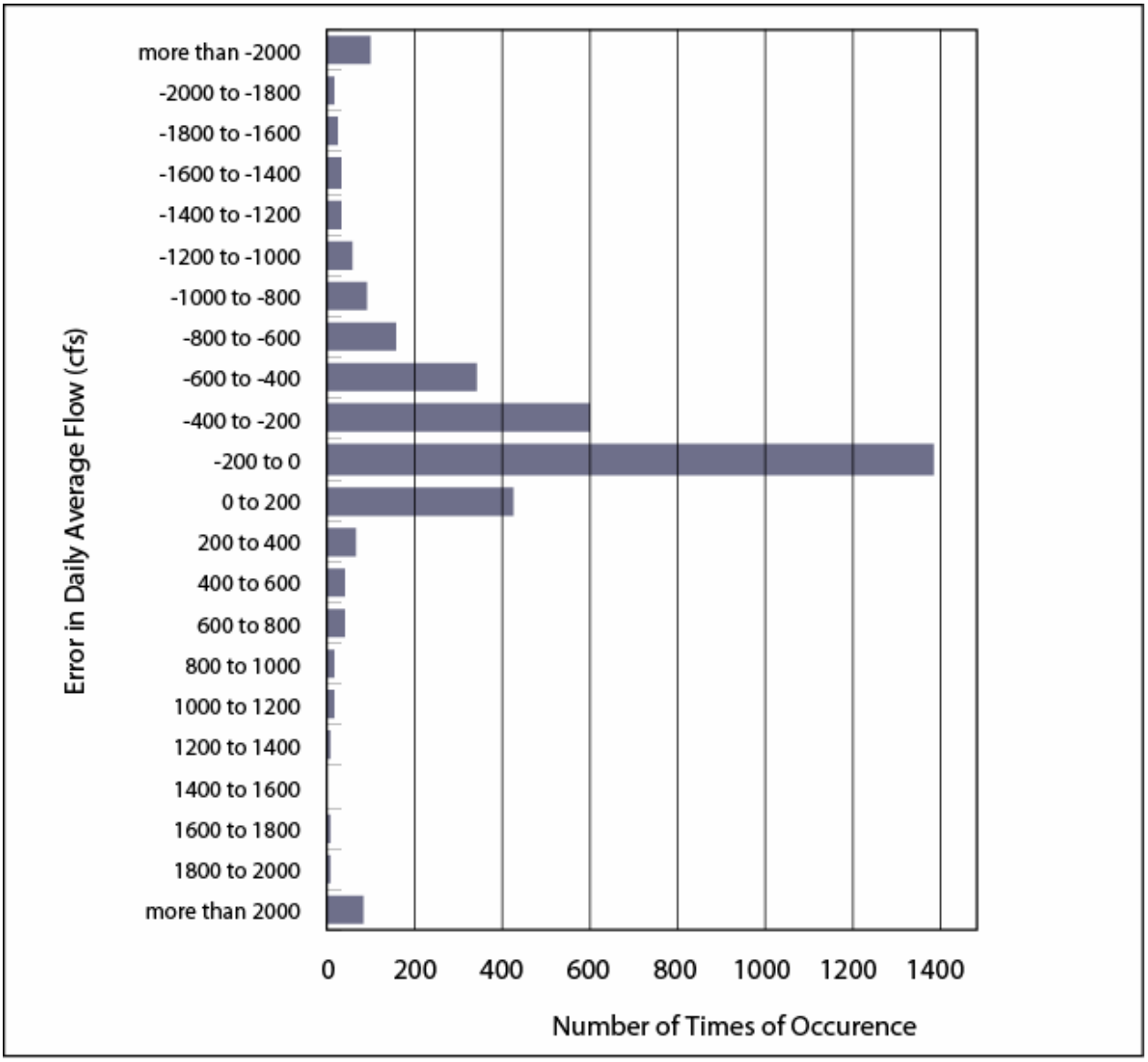



Figure 10. Distribution of DSM2-SJR errors in daily average flow at Vernalis over January 1990 – September 1999 period (excluding January of 1997).

The shortage of flow at Vernalis as modeled by DSM2-SJR without add-water isn't dependent upon the flow itself (Figure 11), and additional investigation is needed to determine the source of the error.

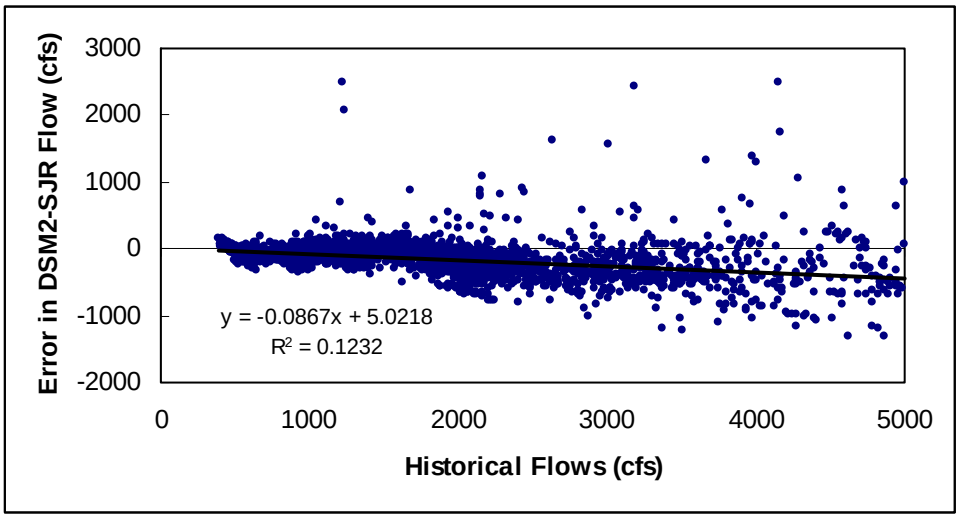



Figure 11. Error in DSM2-SJR modeled daily average flow versus Measured flow for flows below 5,000 cfs.

If the flow amounts required to make up the deficiencies in the DSM2-SJR simulation, as indicated by flows at Vernalis, are assumed added, an estimation of the EC needed in this flow can be made. Focusing on only those days when modeled EC at Vernalis was less than the measured values, the EC that would be needed in this additional water was calculated and averaged in Table 5. The high EC values in Table 5 imply that the salt loading from the other source in the simulation are too low. The very high EC values in February are probably indicating that the EC in the San Joaquin River tributaries was too low since these flows contribute most of the salt loading in this month, while the high EC values in August may indicate that the EC in one or several sources may have been too low since total flow tends to be low. Therefore, even if the source for the flow imbalance at Vernalis is identified, EC assigned to various inflows may need some refinement.

Table 5. Estimated EC required in missing water to recreate historic EC at Vernalis*

| Month | Estimated EC needed (uS/cm) | Month | Estimated EC needed (uS/cm) | Month | Estimated EC needed (uS/cm) |
|---|---|---|---|---|---|
| January | 3649 | May | 7052 | September | 5296 |
| February | 58834 | June | 5422 | October | 1919 |
| March | 2730 | July | 7277 | November | 3970 |
| April | 5887 | August | 13160 | December | 2820 |

* Only considers days when modeled EC at Vernalis was less than historical EC.

## Future Direction

### Model Improvements

An improved understanding and modeling of the unmonitored sources, including the add-water, would greatly enhance the model for historical simulations as well as planning simulations where source control and source shifting may be integral to flow and salinity control at Vernalis. The add-water contribution, as currently modeled as a constant 350 cfs, can be a considerable portion of the San Joaquin River flow and salt load in drier periods. Considering that in the calibration, Pate determined the best estimate of the EC concentration in the add-water was high (double Orestimba Creek), a summertime agricultural drain, groundwater and/or tile drainage are likely components of this water. If the source is mainly agriculture return, perhaps continuous flow is unreasonable. The flow and quality may vary throughout the year, higher in the summer and early fall. Agricultural returns, groundwater, and tile drains are all approximations assessed with a SJRIO mass balance and the data is being updated by USBR. Perhaps other means of estimating unmonitored flow and quality could be explored, namely a groundwater model capable of groundwater-stream interaction. Ultimately, this modeled interaction may be necessary for accurate assessment and planning along the heavily irrigated Lower San Joaquin River basin.

### Extension beyond 1999

Though there are better monitoring efforts that will aid extending the SJR simulation from 1999 to present, there are some deficiencies in the data. The SJRIO-derived data Pate gathered does not currently extend beyond 1999. SJRIO or another model to estimate groundwater, agriculture returns and diversions, as well as tile drainage will have to be acquired. In the calibration of DSM2-SJR, Pate acquired monthly flow and EC data for Turlock and Merced irrigation returns, the Modesto Wastewater Treatment Plant inflow and from the Regional State Resources Control Board. The contact has since been lost and it is unclear of the availability or the existence of current data. Though the data would contribute to the accuracy of the model, the sources are not large contributors and can be assumed, given historical patterns. The flow and salinity for Orestimba, Del Puerto and Hospital/Ingram creeks will need to be estimated if the data is not available. From correspondence with USGS via their website, I believe some of these creeks are monitored and useful information should be available. There is, however, a considerable time lag in distribution of the information. Otherwise, the monitoring and data dissemination has improved beyond the calibration period. As in the 1990-1999 period, flow and EC can be found at the CDEC website for the Stanislaus and Tuolumne Rivers. Since 2000, there is more monitoring along the San Joaquin River. Specifically, the Merced River and the San Joaquin River near Stevinson (1999 to present) are monitored for flow and EC and the data is provided through CDEC. Also, there is data collection and dissemination on the Internet for Mud and Salt sloughs through the Grass Lands Bypass Monitoring Program (USBR and SFEI). The USBR also has installed several more monitoring locations along the west side of the SJR in the summer of 2004. This will aid the understanding of groundwater and agriculture drainage along the river as the simulation period is extended beyond 2004.

Real-time Modeling

Real-time modeling will require considerable effort among agencies in order to gather streams of real-time data and make them readily available via the Internet. Once the input data is available, the Delta Modeling Section will need to provide an efficient means of retrieving the data. The basis for a retrieval tool can be provided by the Section's real-time simulation construction for short-term forecasting using VPlotter and Python scripts. Data dissemination seems to be the more difficult task, but it is continually improving. There are now more stations readily available than in the past. Some information can be obtained via the website from the California Data Exchange Center (CDEC). This includes flow and EC at the Stanislaus River, Tuolumne River, Merced River, and San Joaquin River near Stevinson. As of June 2004, Salt and Mud sloughs can also be retrieved from CDEC. Moreover, daily average flow for 31 days prior to the access day can be found at the USGS website for Orestimba Creek and Del Puerto Creek.

Though much progress has been achieved, there are still gaps in the collection as well as the dissemination of data. The weaknesses in the real-time input database are similar to those of the 1999 to present model extension. The Turlock and Merced Irrigation Districts' agricultural drains and the Modesto Wastewater Treatment Plant outfall were monthly values gathered from the Regional State Resources Control Board. A finer time interval may not be available for a real-time simulation and values may have to be assumed. The SJRIO model supplying Pate with values also was on a monthly time-step. There is a daily version of the SJRIO model that DWR's San Joaquin Field Division has acquired. Perhaps this could aid a real-time simulation. The data dissemination of salinity for the west side creeks will involve cooperation from the USGS to expeditiously publish the data they are collecting. The USGS's latest monitoring efforts, managed by Nigel Quinn, may provide real-time flow and salinity data for some of the sources of flow on the west side of the SJR.

**References**

CDEC, internet data disseminator, http://cdec4gov.water.ca.gov/

Pate, Thomas, Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 22nd Annual Progress Report August 2001, Chapter 5, available at http://modeling.water.ca.gov/delta/reports/annrpt/2001/2001Ch5.pdf

SFEI, Grassland Bypass Compliance Monitoring Program, Current Data Reports http://www.sfei.org/grassland/reports/gbppdfs.htm

USGS, internet data disseminator at http://nwis.waterdata.usgs.gov/ca/nwis/discharge and general San Joaquin Basin information at http://ca.water.usgs.gov/sanj/sw_cycle1.html

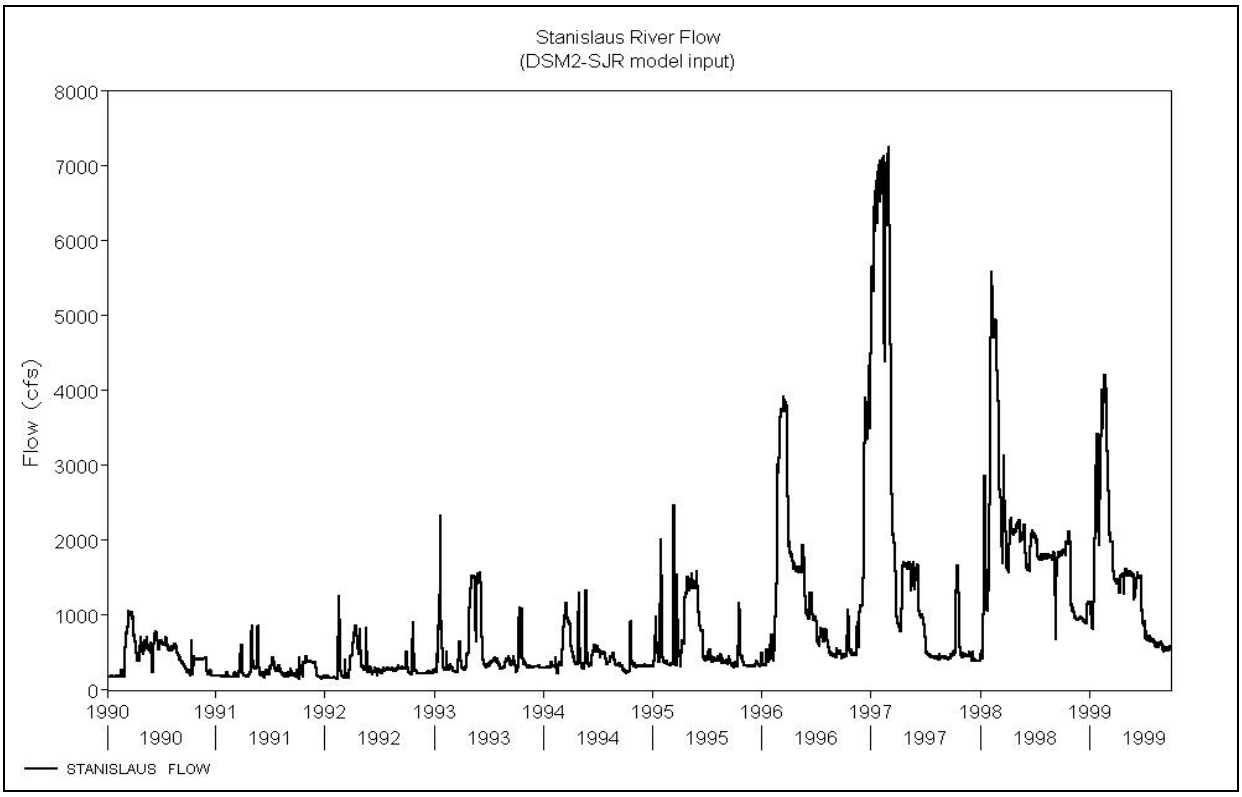



Figure A-1. Stanislaus River flow used in January 1990 – September 1999 simulation.

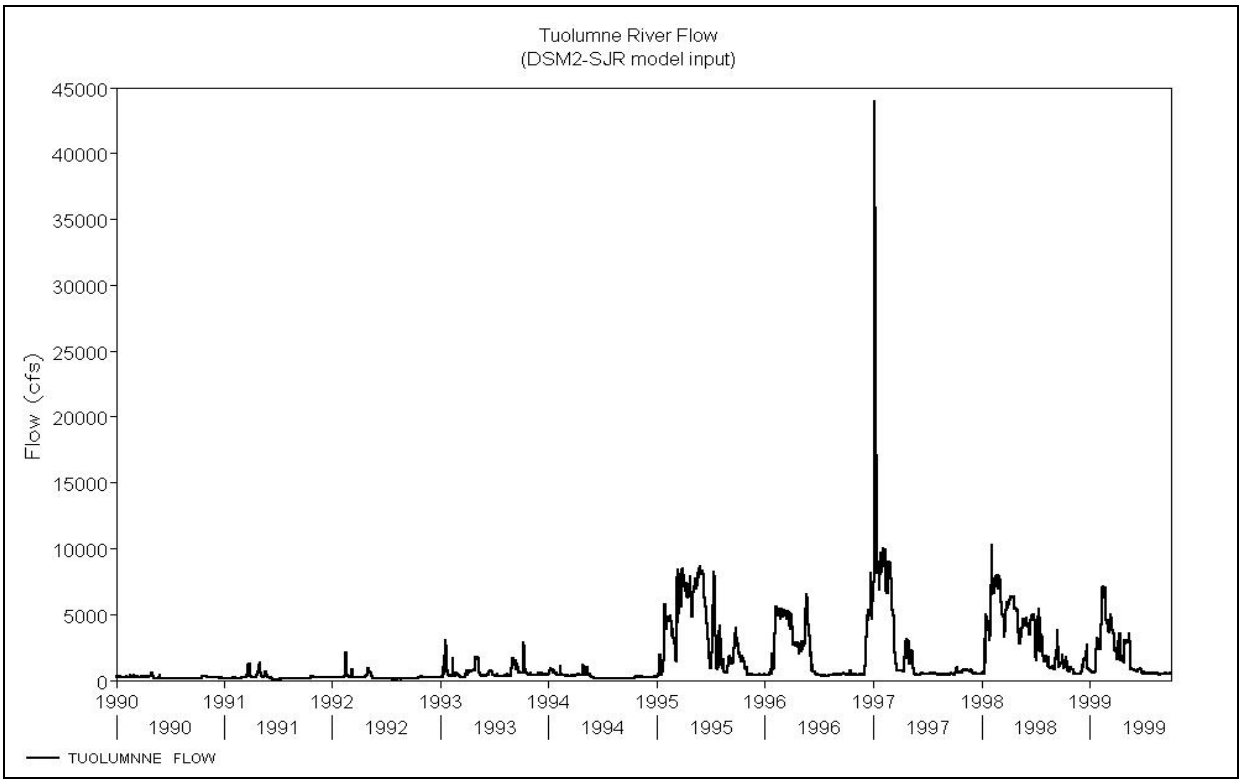



Figure A-2. Tuolumne River flow used in January 1990 – September 1999 simulation.

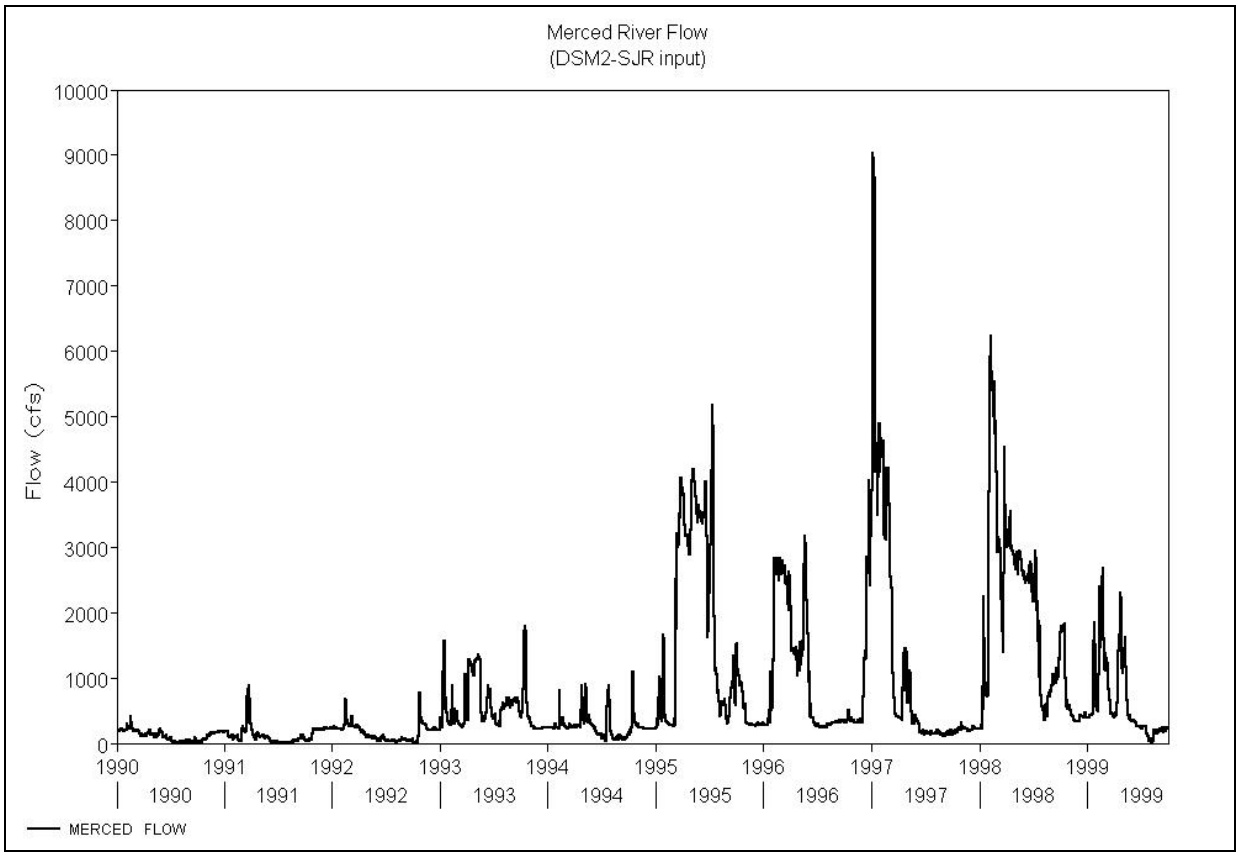



Figure A-3. Merced River flow used in January 1990 – September 1999 simulation.

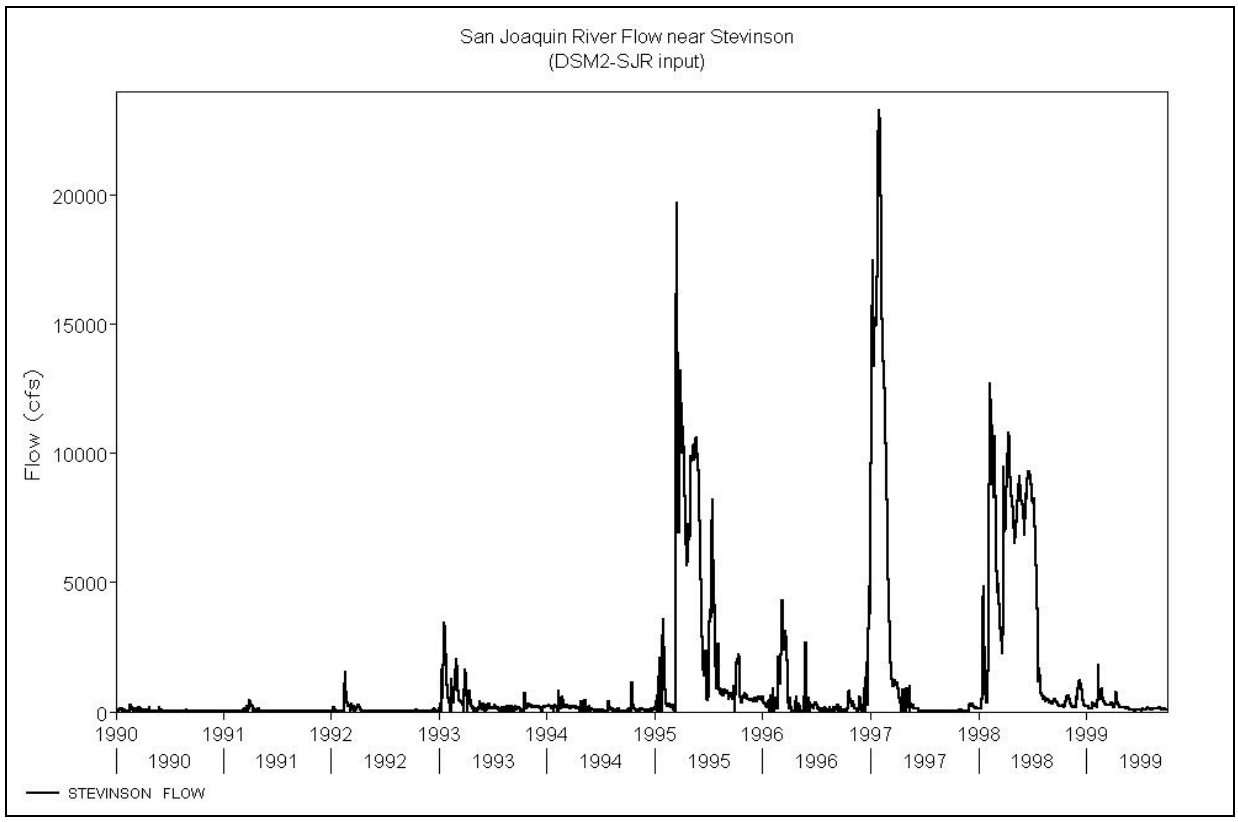



Figure A-4. San Joaquin River flow at Stevinson used in January 1990 – September 1999 simulation.

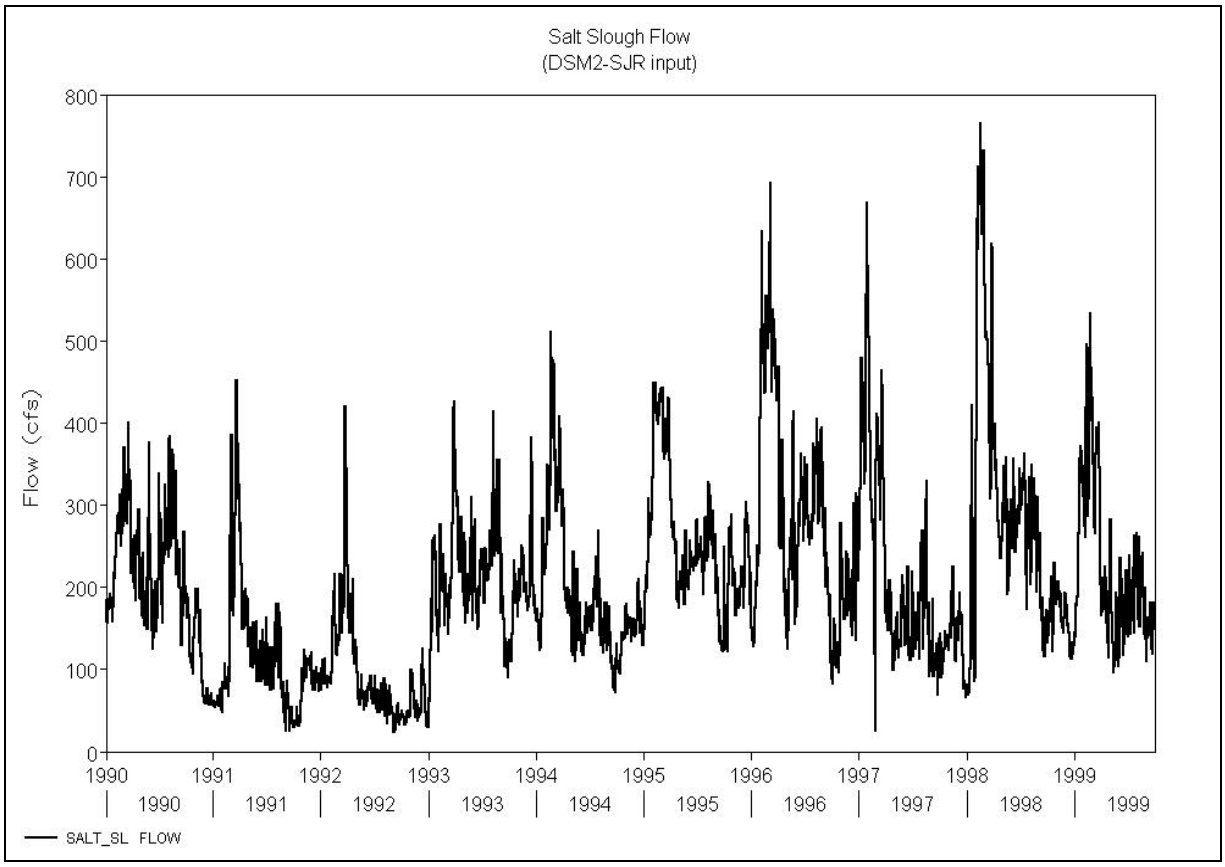



Figure A-5. Salt Slough flow used in January 1990 – September 1999 simulation.

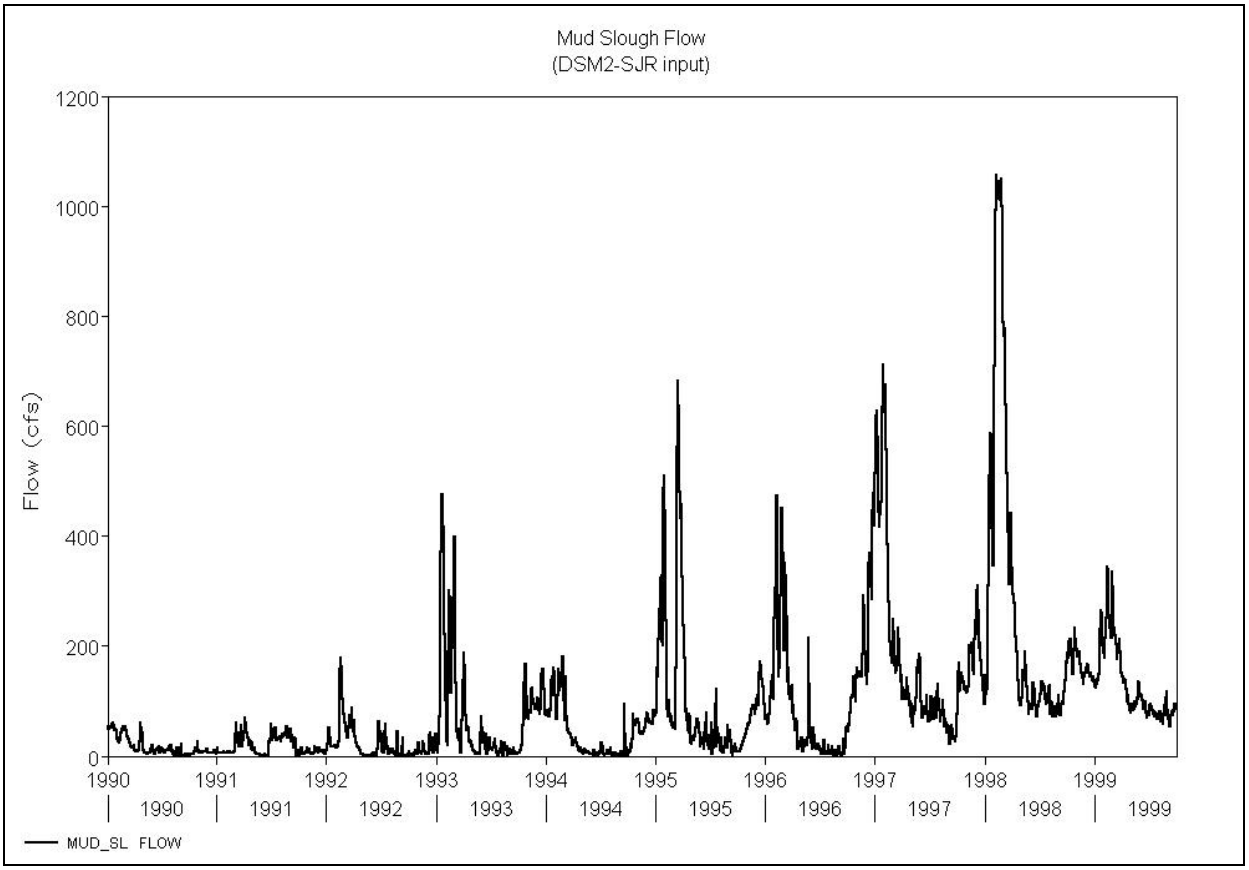



Figure A-6. Mud Slough flow used in January 1990 – September 1999 simulation.

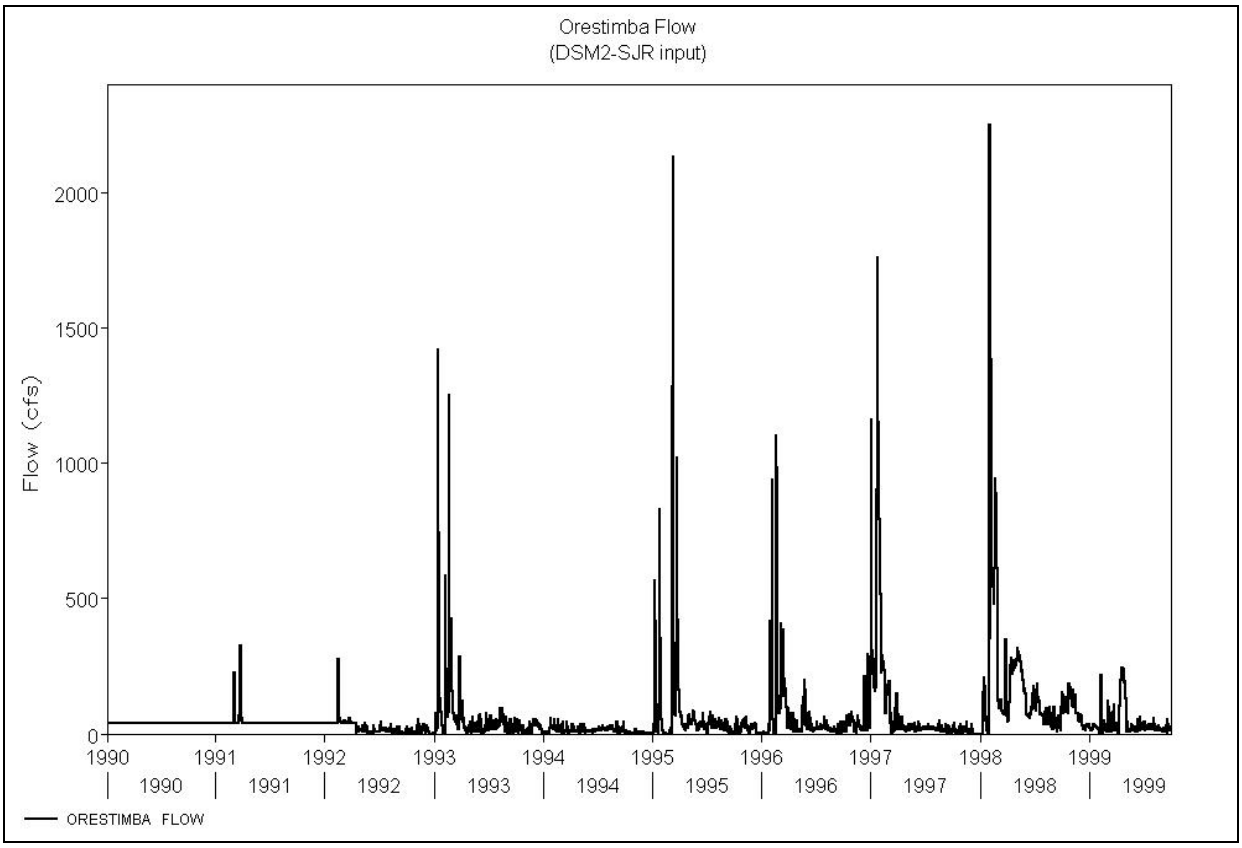



Figure A-7. Orestimba Creek flow used in January 1990 – September 1999 simulation.

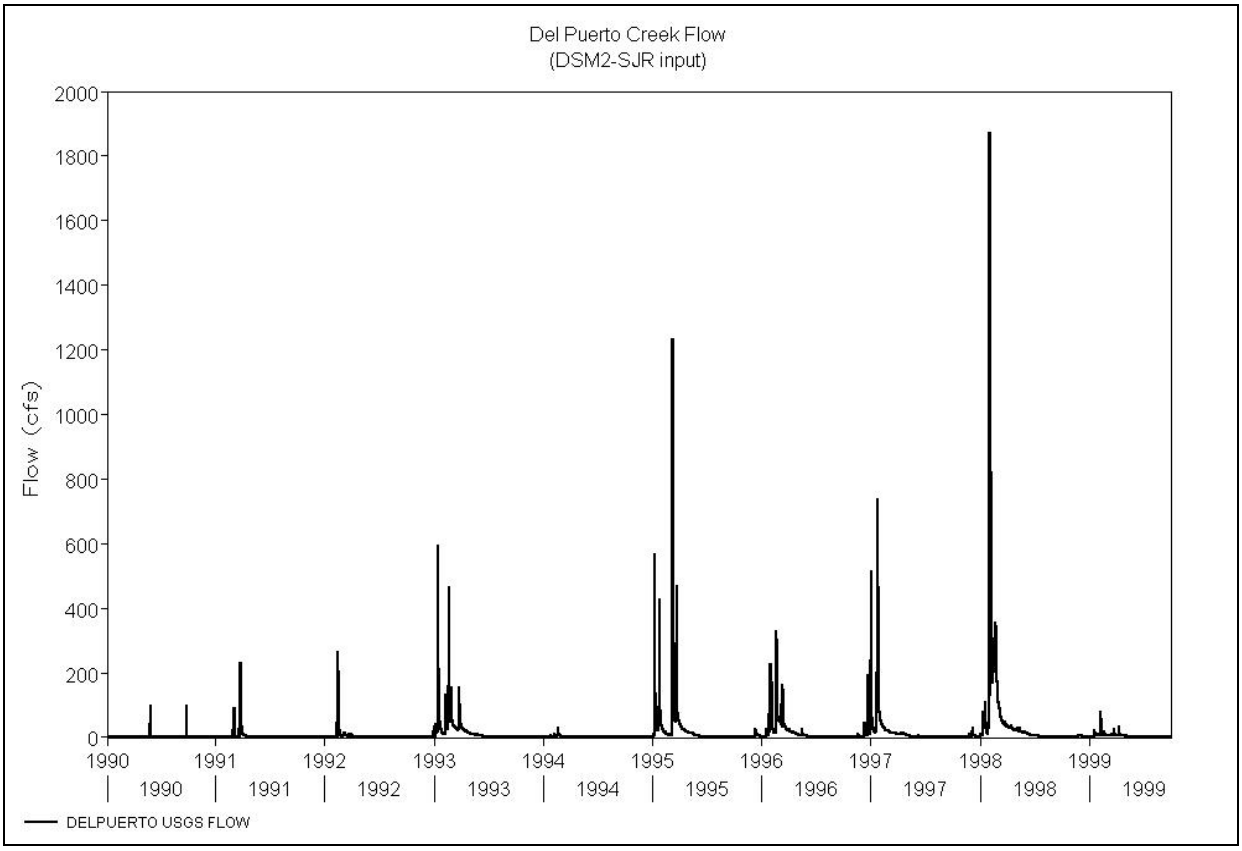



Figure A-8. Del Puerto Creek flow used in January 1990 – September 1999 simulation.

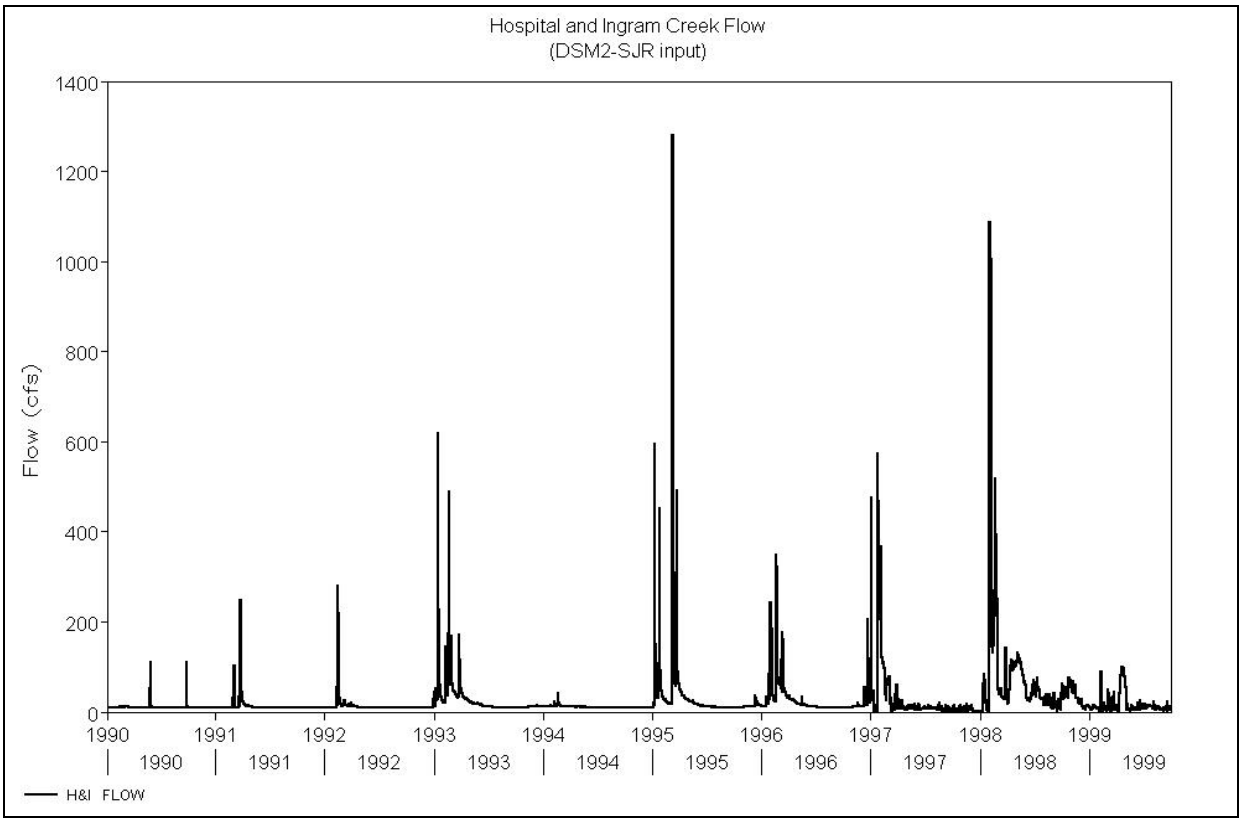



Figure A-9. Hospital and Ingram creeks flow used in January 1990 – September 1999 simulation.

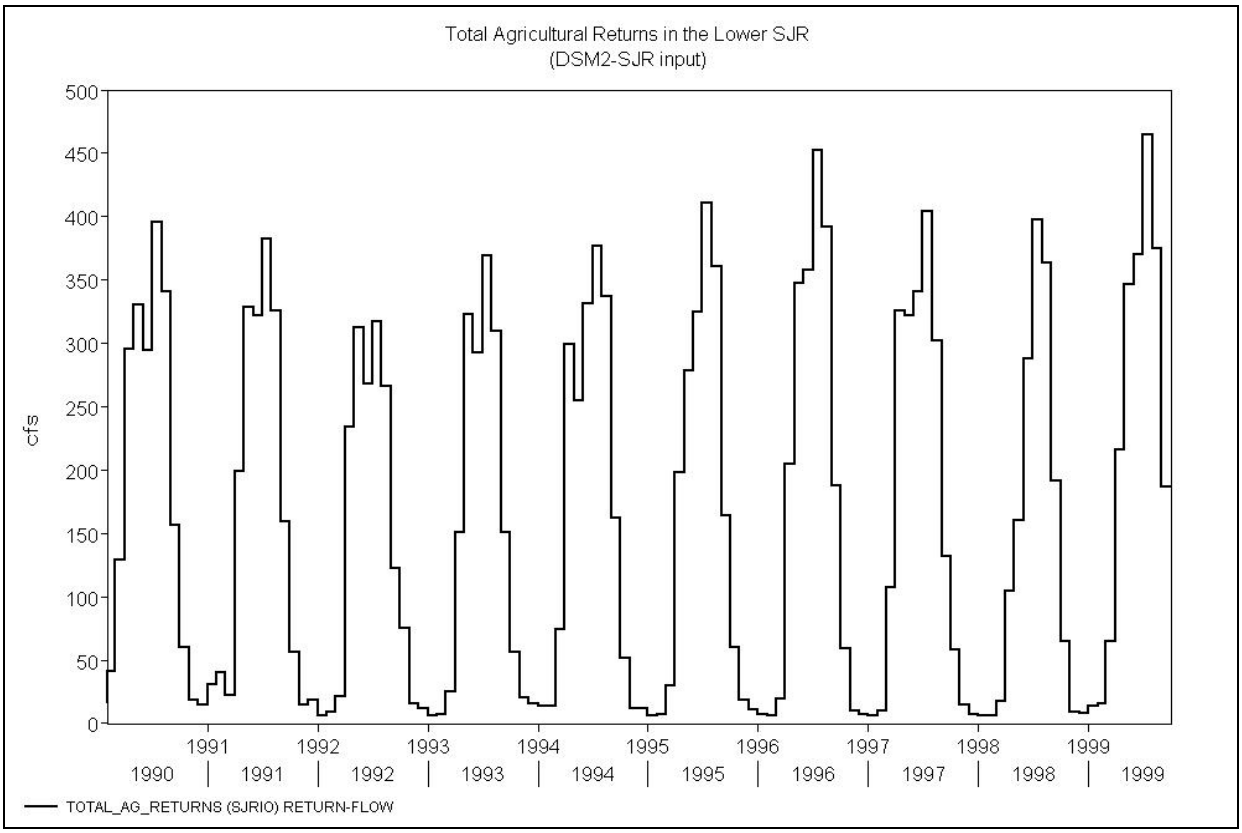



Figure A-10. Agricultural return flows used in January 1990 – September 1999 simulation (source: SJRIO).

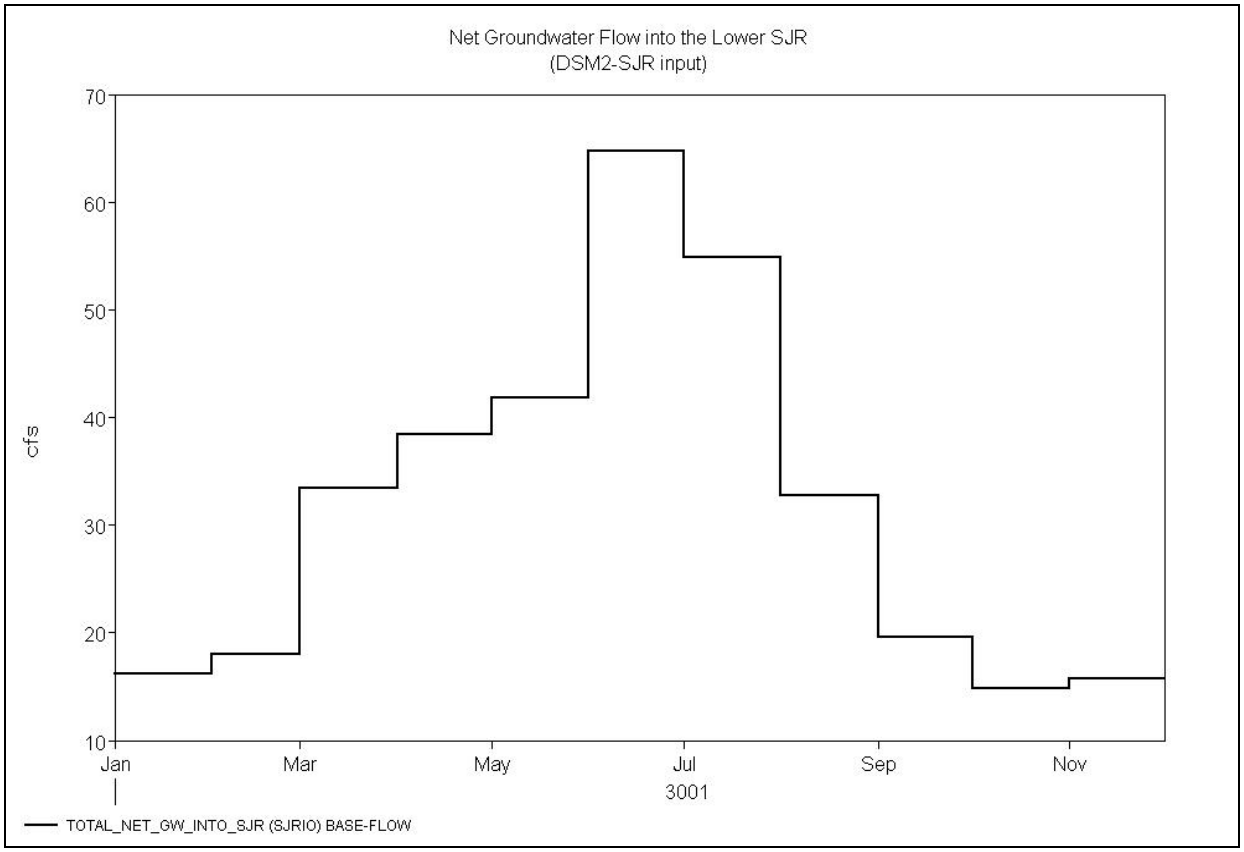



Figure A-11. Net groundwater flow used in January 1990 – September 1999 simulation (source: SJRIO).

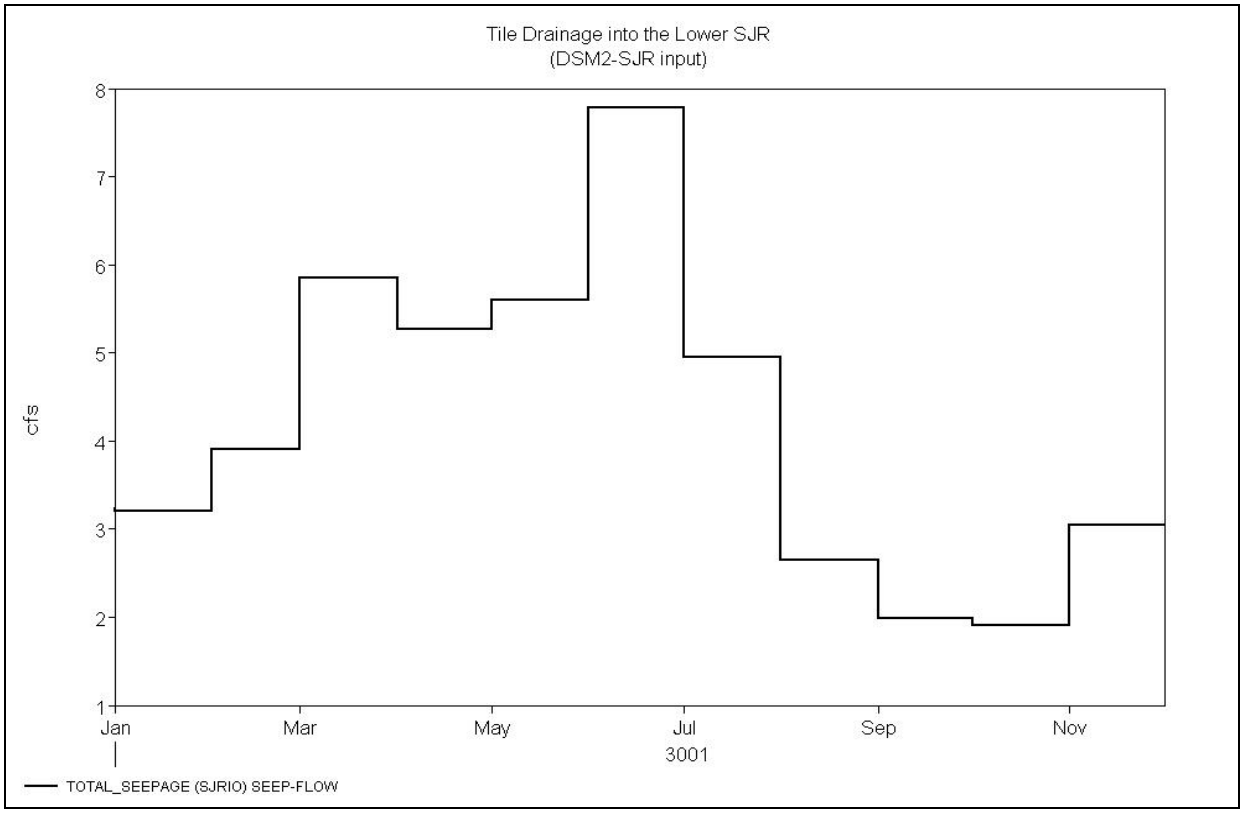



Figure A-12. Tile drainage used in January 1990 – September 1999 simulation (source: SJRIO).

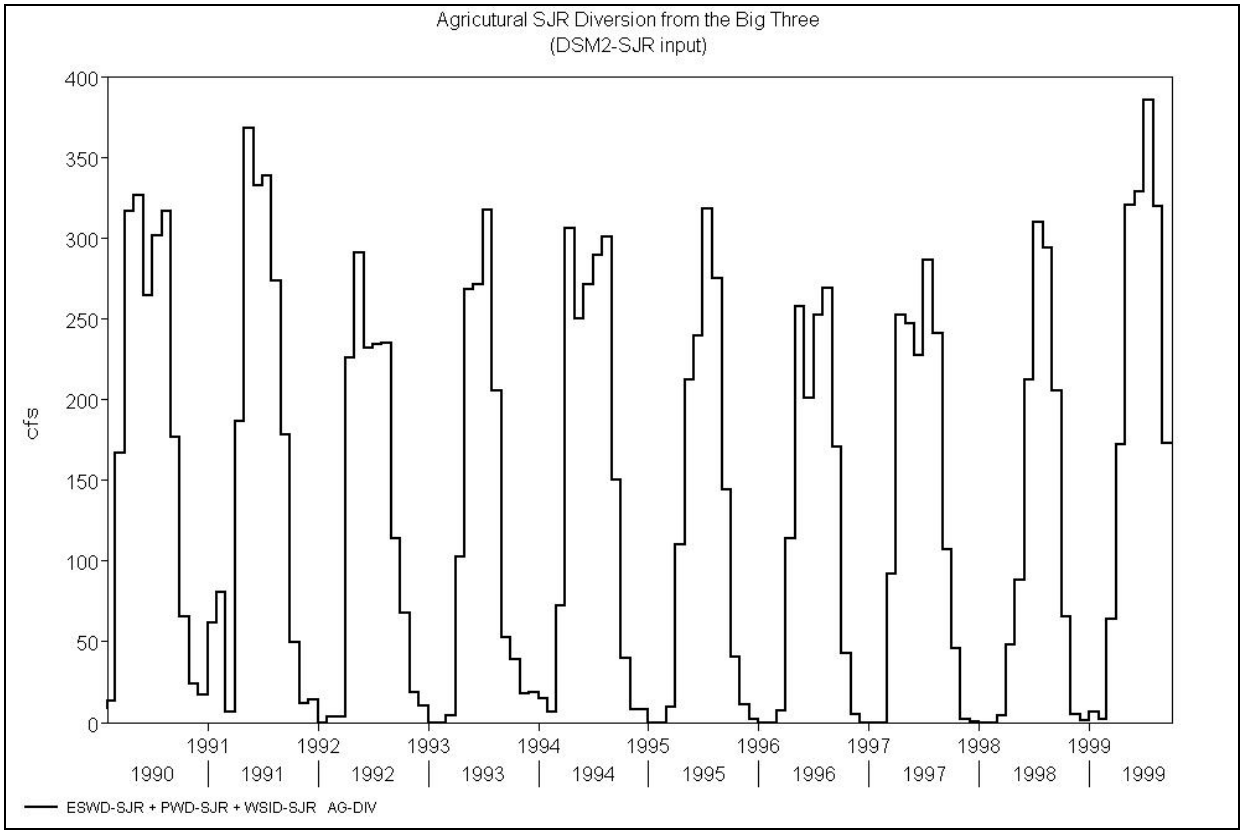



Figure A-13. Combined Westside Agricultural Diversions from El Soyo Water District, West Stanislaus Irrigation District and Patterson Water District used in January 1990 – September 1999 simulation.

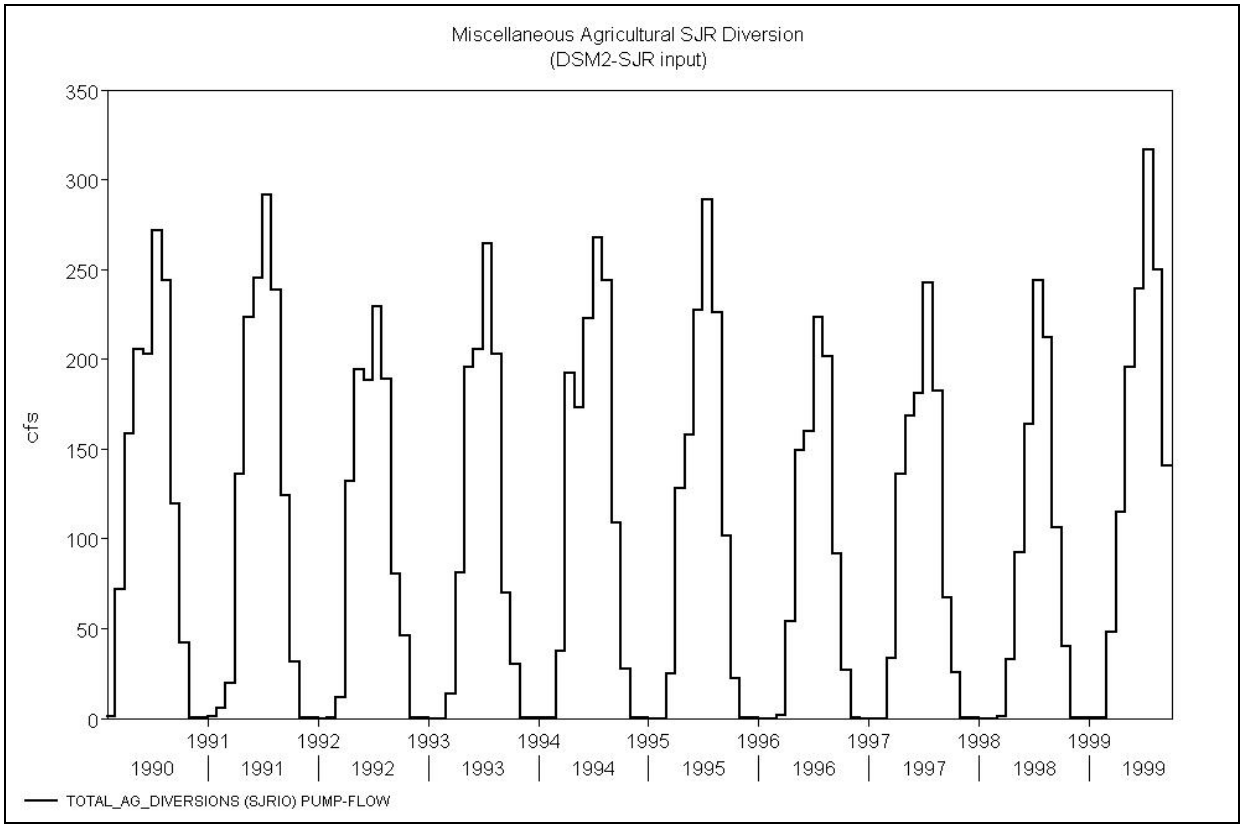



Figure A-14. Total miscellaneous agricultural diversions used in January 1990 – September 1999 simulation (source: SJRIO).

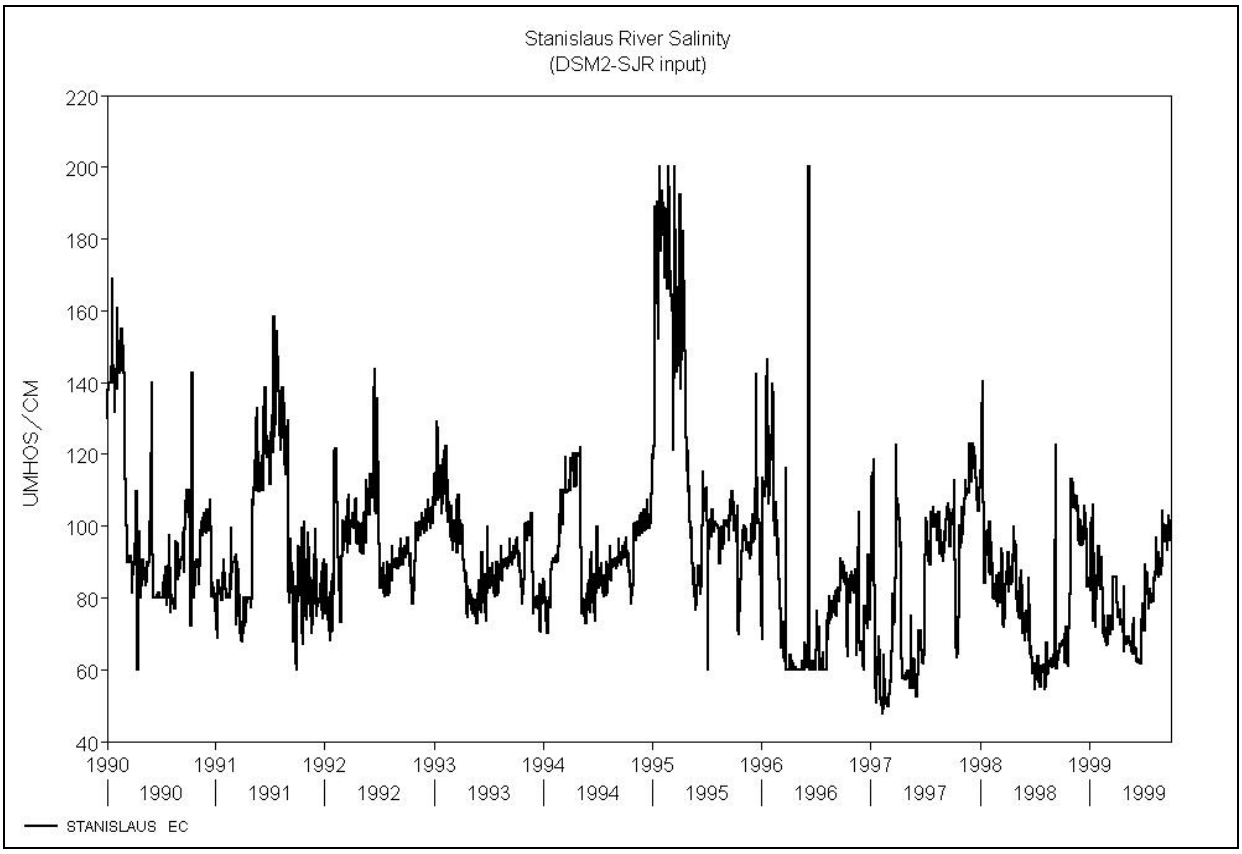



Figure A-15. Stanislaus River EC used in January 1990 – September 1999 simulation.

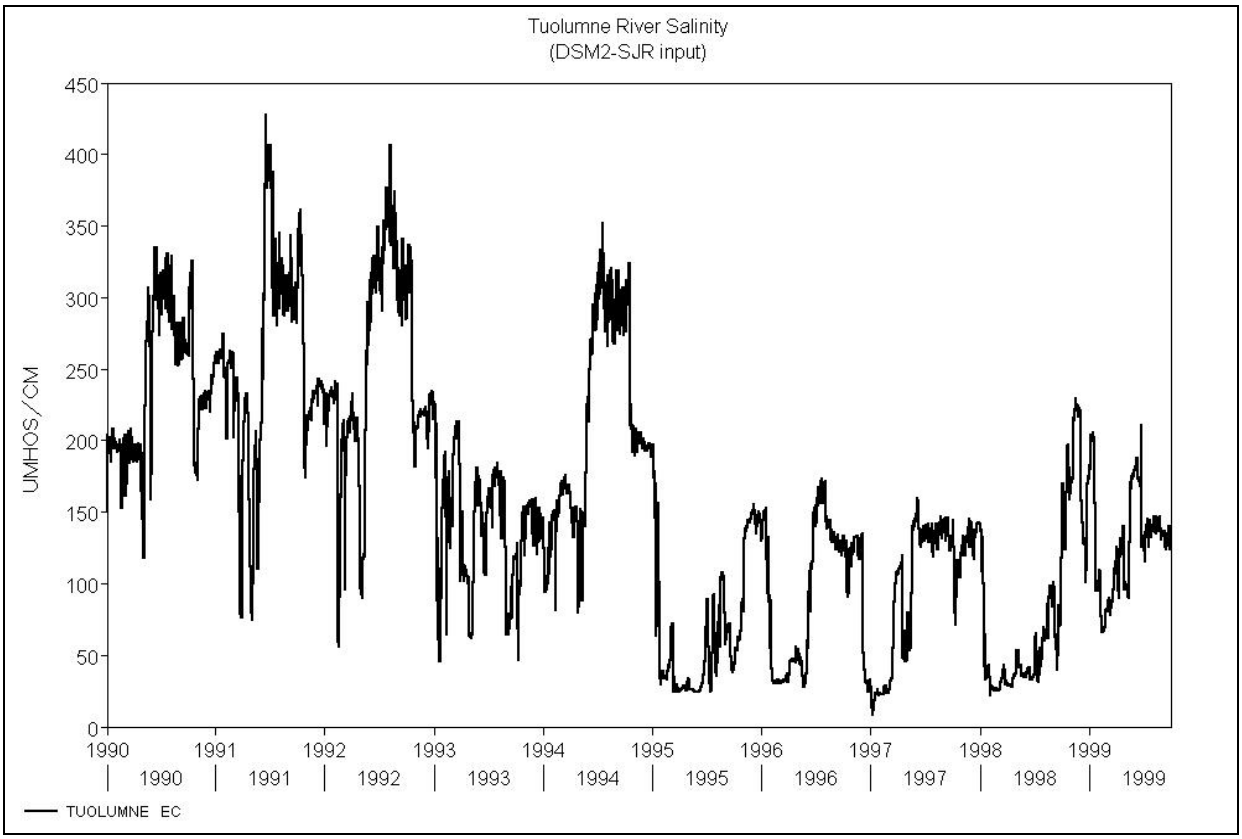



Figure A-16. Tuolumne River EC used in January 1990 – September 1999 simulation.

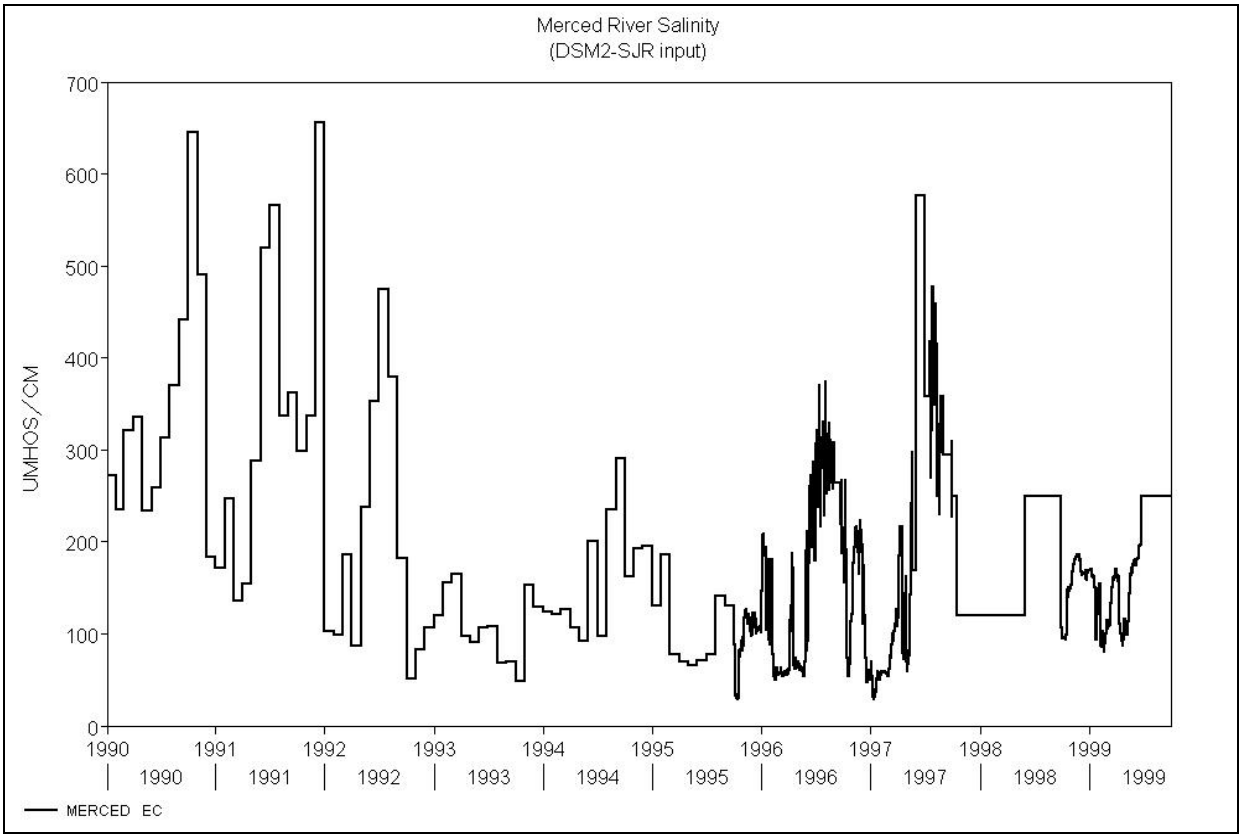



Figure A-17. Merced River EC used in January 1990 – September 1999 simulation.

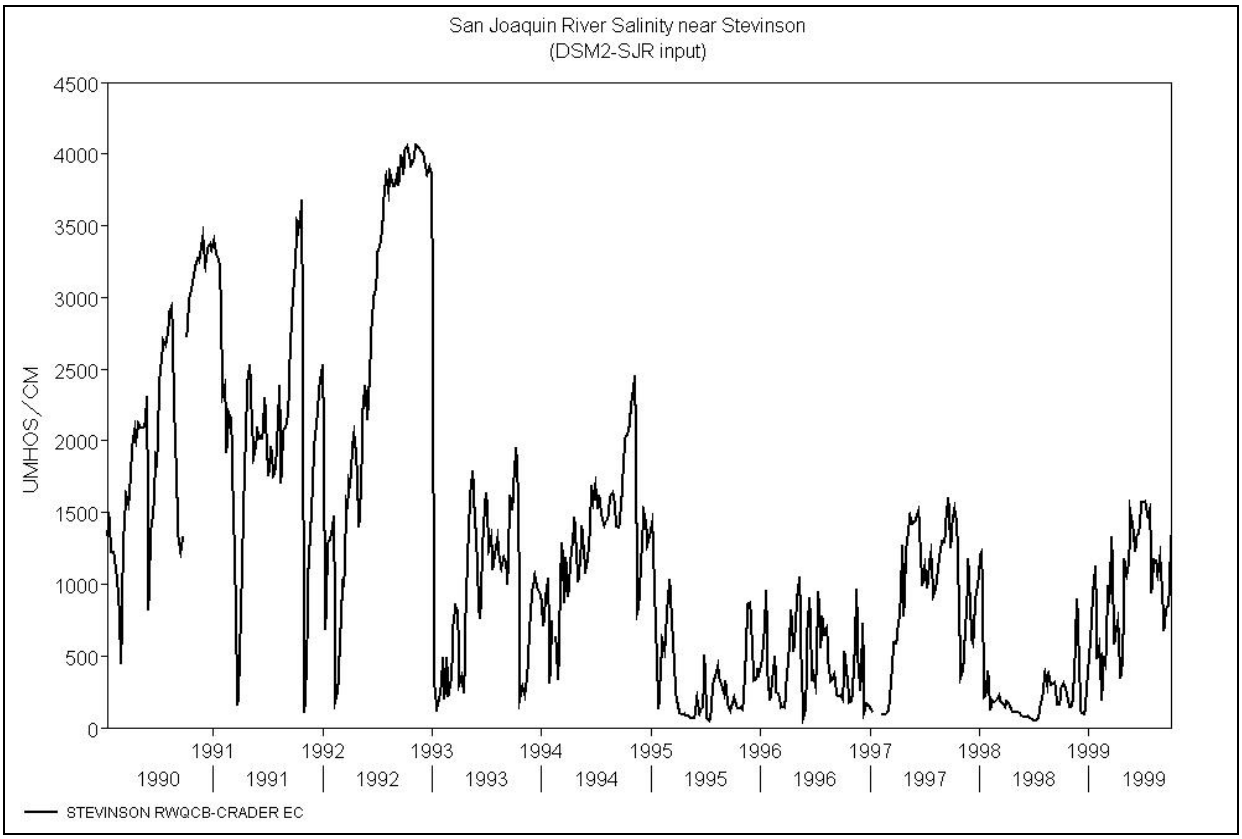



Figure A-18. San Joaquin River near Stevinson EC used in January 1990 – September 1999 simulation.

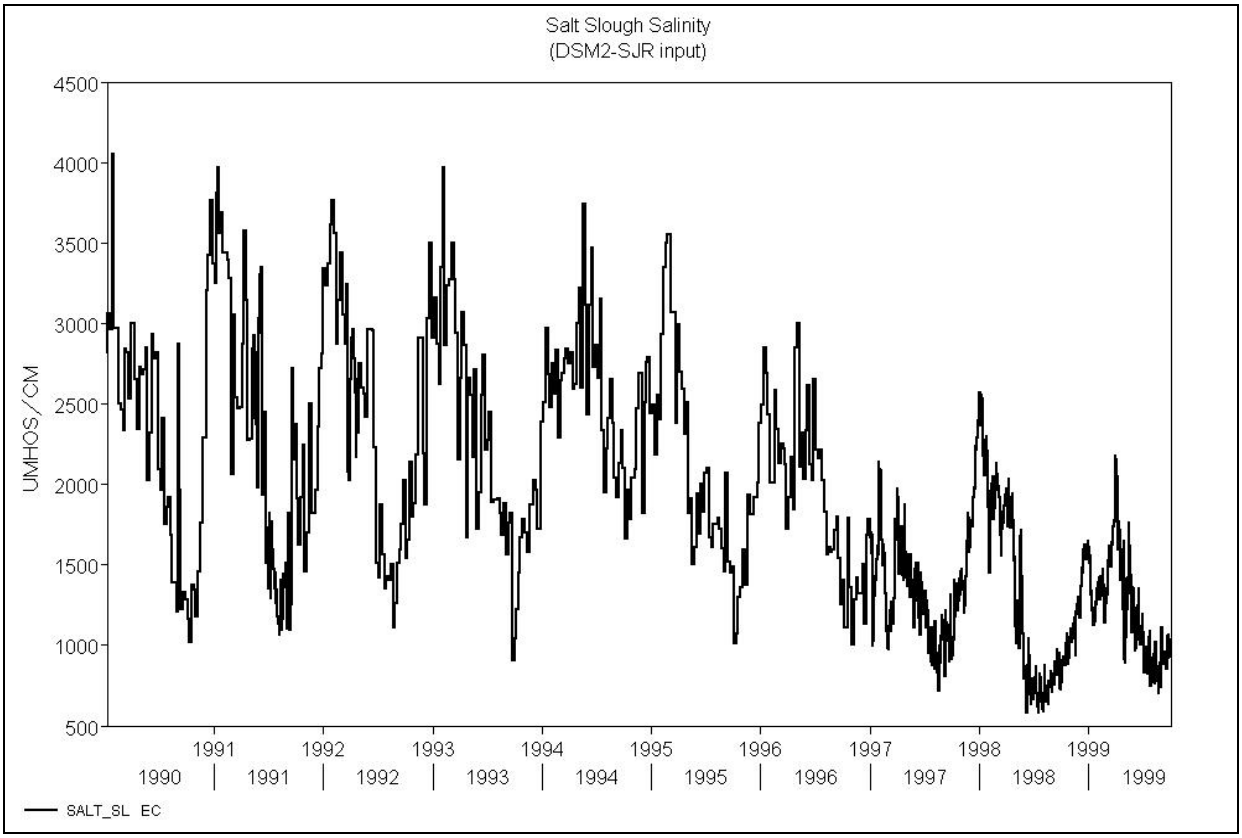



Figure A-19. Salt Slough River EC used in January 1990 – September 1999 simulation.

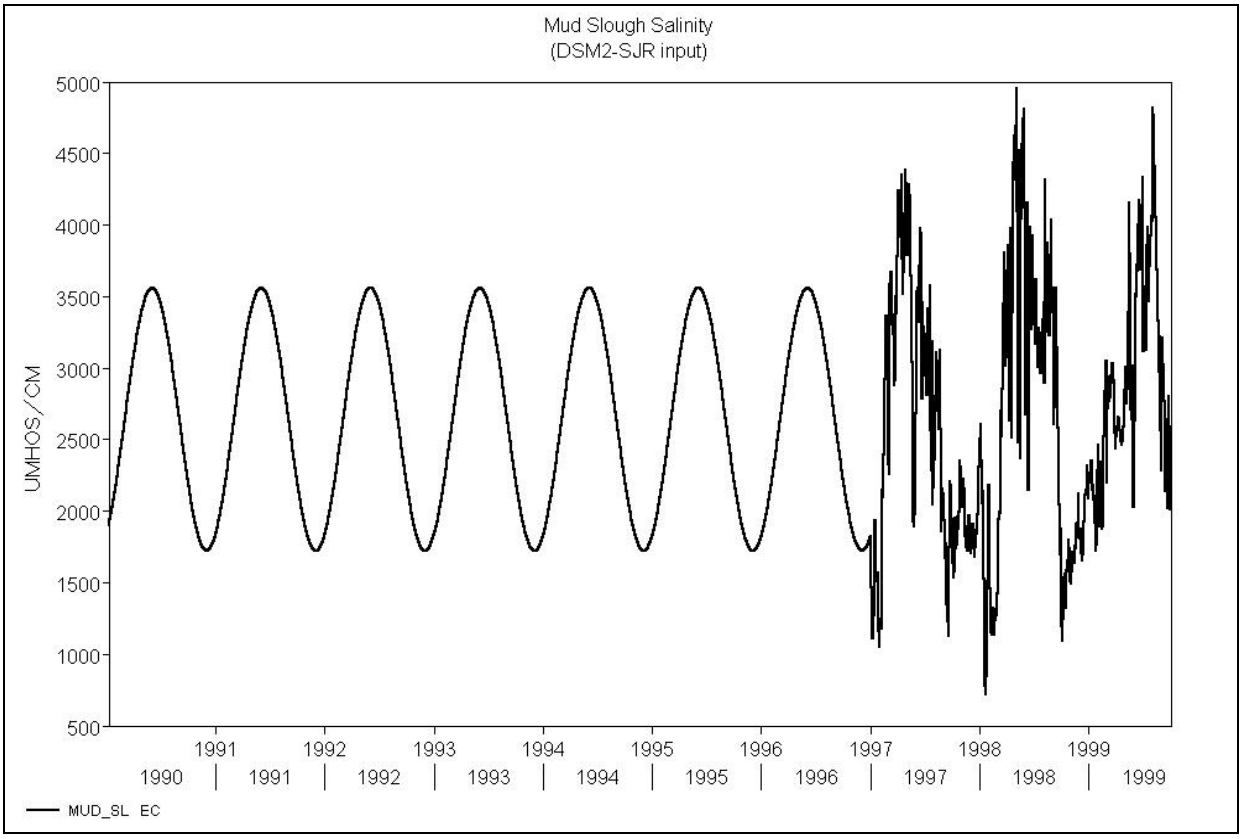



Figure A-20. Mud Slough River EC used in January 1990 – September 1999 simulation.

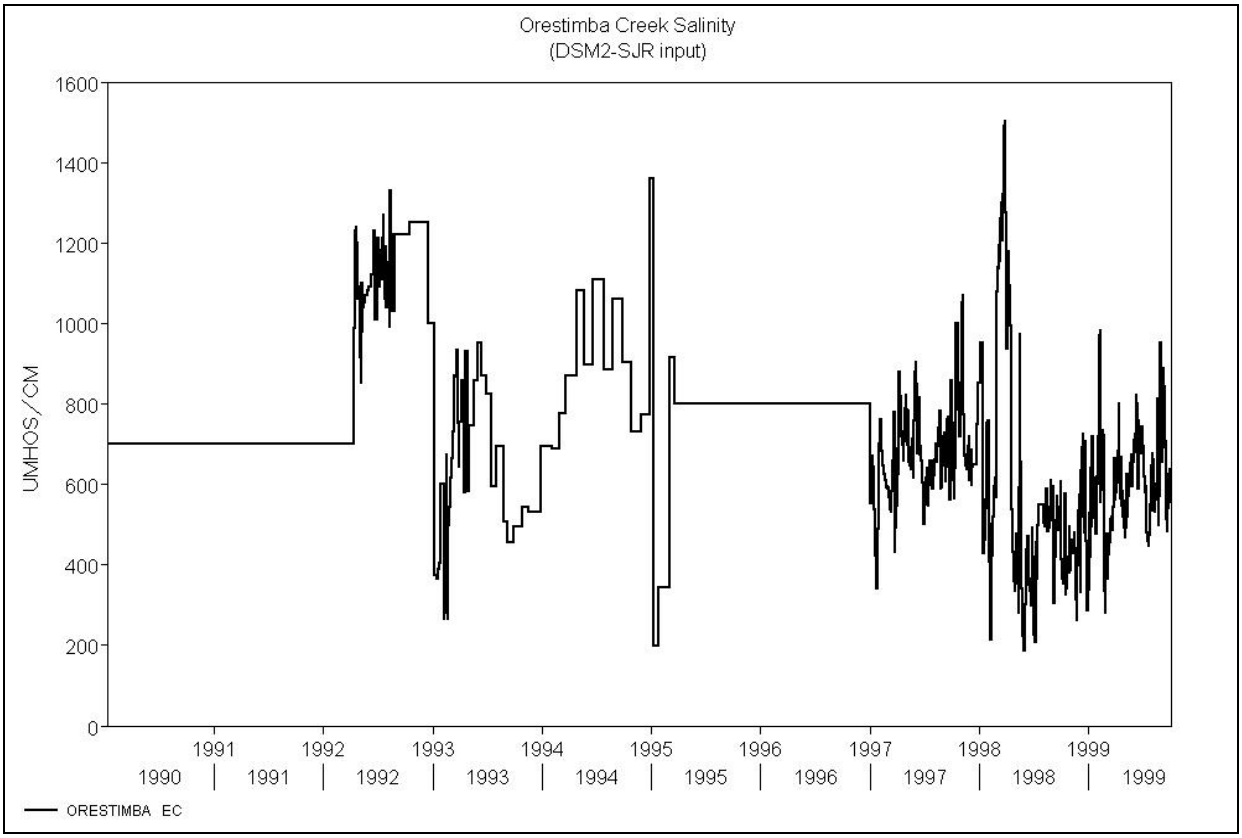



Figure A-21. Orestimba Creek EC used in January 1990 – September 1999 simulation.

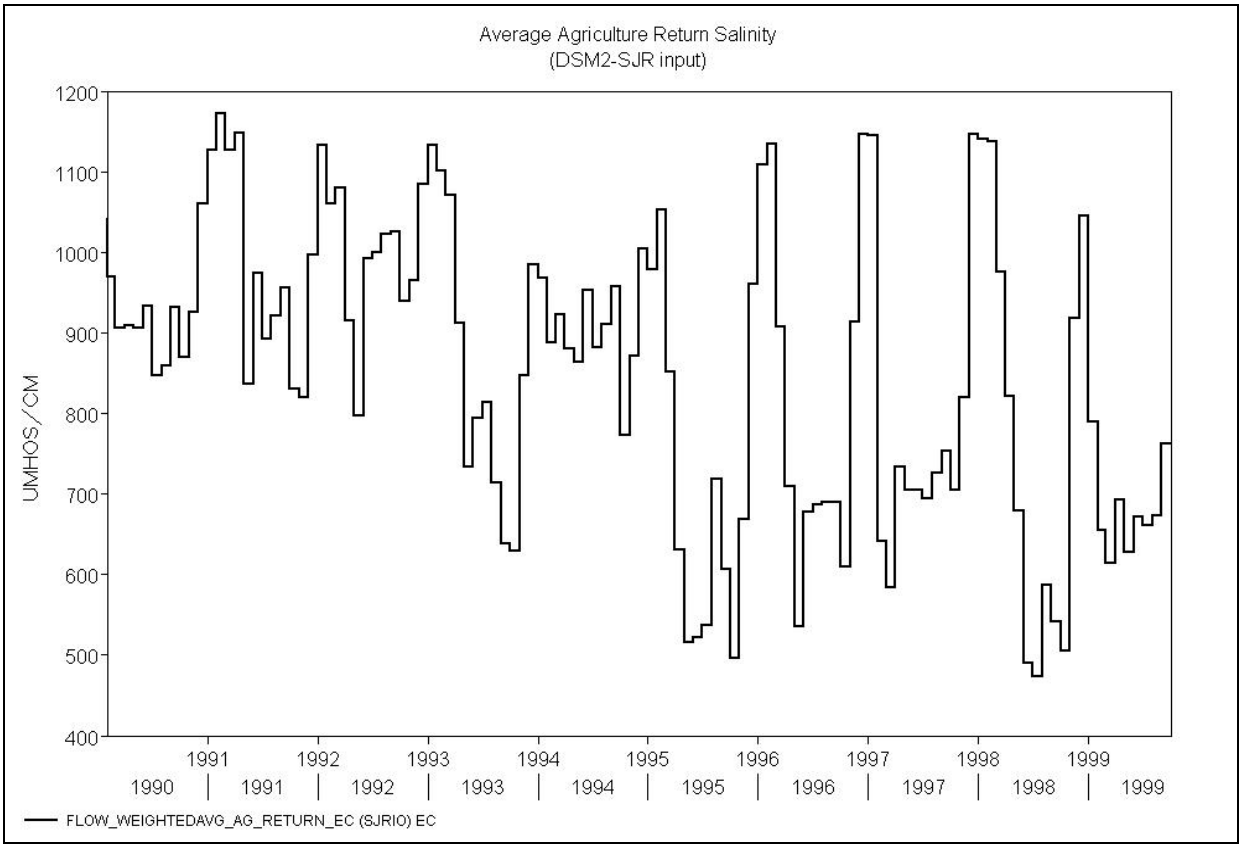



Figure A-22. Flow weighted average of EC in the agricultural returns as estimated with SJRIO as used in January 1990 – September 1999 simulation.

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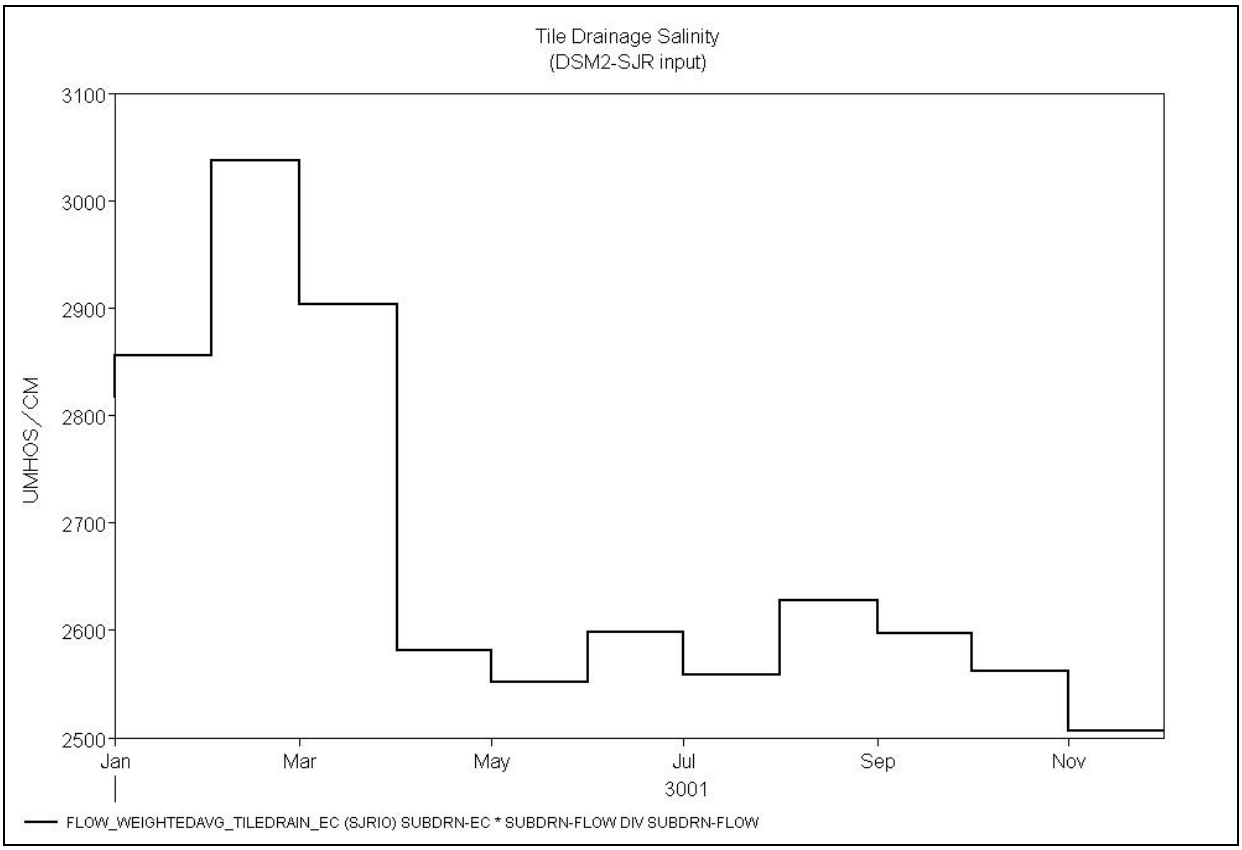


Figure A-23. Flow weighted average tile drainage into the Lower San Joaquin River as estimated with SJRIO as used in January 1990 – September 1999 simulation.

The average groundwater salinity is 3,600 uS/cm. It varies, however, between 550 near Vernalis and 8000 uS/cm near Stevinson. The values are constant at each location throughout the year with no change from year to year.