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Artificial Neural Networks and MEC Estimates

Introduction

Artificial Neural Networks (ANNs) are used to predict salinity at various locations within the Delta. Work is continuing to improve the accuracy of the models and develop ANNs which are applicable over a wider range of inputs. These new ANNs were used to perform Marginal Export Cost (MEC) estimates.

Response of ANN-Generated Salinity to Varying SAC Flows and Exports

As part of the ANN evaluation process some plots were developed to help exhibit the relationship between Sacramento River flow, exports, and salinity at Contra Costa Canal and Jersey Point.

Figure 7.1 shows how Contra Costa EC differs with varying SAC flow and CVP pumping when all other inputs are kept constant. Figure 7.2 shows how Contra Costa EC varies with changing SAC flow and SWP pumping. Figures 7.3 and 7.4 show similar plots for Jersey Point salinity.

Marginal Export Cost (MEC) Estimates Using ANNs

ANN can be used to estimate MEC for changes in exports. The June 1997 Annual Report described how ANNs can be used to predict salinity and estimate MEC. This technique was used to estimate MEC for a continuous 500 cfs reduction in pumping. The same technique was used to estimate MEC with the pumping needed for the 1991 Drought Water Bank.

MEC has been defined as the extra water needed to carry a unit of water across the Delta to the pumping plants for export while maintaining a constant salinity at a given location. MEC varies widely and it is highly dependent on location and antecedent conditions. Incremental export increases may increase salinity in some areas while decreasing salinity in others. Modeling studies using DSM2 and ANNs can be used to study the complex interrelationship of flows and salinity in the Delta.

The Continuous Impulse Marginal Export Cost (CIMEC) method was used to study carriage water under historic conditions. Two investigations were performed. The first investigation looked at the effects of decreasing exports by 500 cfs, and then recalculated the SAC flow needed to maintain salinity at a constant level. The second experiment attempted to quantify the MEC associated with the pumping required by the 1991 Drought Water Bank.

Both investigations used ANNs which used CVP, DXC position, SAC, SJR, and SWP as inputs and both ANNs were trained with DSM2 salinity output. The period studied for the first investigation used historic data for the five-year time starting January 1989 to November 1994. The second study used 1991 historic data.

Jersey Point and Contra Costa Canal were chosen as the study locations because they represent two interior Delta locations which have salinity standards which often control Delta operations and where the salinity/outflow relationship is complex.

Effects of a 500 cfs Reduction in SWP Pumping

Jersey Point salinity, historic flows, and DXC gate position were used to obtain a baseline case by using the CIMEC SAC flow estimation methodology to calculate SAC flow for January 1989 through December 1994.

The historic SWP pumping data was modified by reducing the SWP exports by 500 cfs. SAC flow was then recalculated so that salinity at Jersey Point remained at historic levels. Figure 7.5 shows how the 500 cfs reduction affected the calculated SAC flow values. Monthly carriage water was calculated using the following equation:

> C.W.= (dExports-dCalculated SAC flow) or
>
> C.W.=((Hist.SWP pumping-500cfs)-(Hist. SWP pumping))-
>
> ((Calc SAC with exports reduced by 500cfs)-
>
> (Calc SAC for historic conditions))

Figure 7.6 shows monthly calculated carriage water at Jersey Pt. expressed in cfs and as a percentage of export reduction. Carriage water percentage can be zero, negative or positive. A zero value implies that there is a one-to -one correspondence between incremental increases in pumping and the incremental increase in SAC flow needed to maintain salinity levels at a given station. A negative percentage implies that dSAC flow is less than dExports, while a positive carriage water percentage implies that dSAC flow is greater than dExports when SAC flow is adjusted to keep salinity constant.

The monthly percent carriage water at Jersey Point is positive but showed some variation which may be attributed to the varying flows and DXC position.

The average carriage water value for the period was defined as:
Avg C.W. = Σ (monthly calculated C.W.)/Σ (Dexports) and was found to be about 9 percent.

This experiment was repeated for the same period using salinity at Contra Costa Canal. Figure 7.7 shows how the 500 cfs reduction affects the estimated SAC flow values when SAC flow is calculated using historic salinity at CCC. Monthly carriage water values were calculated and are shown in Figure 7.8.

When CCC salinity is assumed to be controlling, the monthly carriage water ratio varies from -90 percent to 60 percent. The monthly percent carriage water with CCC controlling is much more volatile than the carriage water value observed when Jersey Pt salinity is used. The average carriage water for the entire period with CCC controlling was 15 percent.

Estimate of Carriage Water for 1991 Drought Water Bank (DWB) Pumping

The second part of this experiment was to estimate the MEC associated with the 1991 Drought Water Bank (DWB) pumping. MEC was estimated once for Jersey Point EC controlling and for CCC EC controlling.

Jersey Pt. historical salinity, historic rim inflows and exports and DXC position were used to calculate SAC flow using the CIMEC method described previously in this report. This calculated SAC flow was used as the baseline case.

The 1991 historic exports for SWP were then modified by subtracting the SWP exports attributed to the 1991 Drought water Bank from the historic SWP export data, and SAC flow was recalculated. Monthly carriage water values were calculated and the results are shown in Figure 7.9. The plot shows the monthly pumping made for the 1991 Drought Water Bank (DWB), the carriage water attributable to the 1991 DWB pumping, and the ratio of (C.W. for DWB pumping)/(avg DWB pumping).

The average carriage water for the 1991 Drought Water Bank Pumping period with Jersey Point controlling came out to be 8.9 percent.

The process was repeated using CCC historic salinity. CCC historic salinity, historic rimflows and pumping, and DXC position were used to calculate SAC flow using the CIMEC method. The 1991 DWB exports were subtracted from SWP pumping and the new reduced SWP values were used to recalculate SAC flow. Carriage water was calculated monthly and the results are shown in Figure 7.10. Figure 7.9 and Figure 7.10 show how calculated carriage water estimates can vary depending on controlling location and changing monthly conditions.

The average carriage water for 1991 DWB pumping with CCC controlling was calculated to be 14 percent.

These studies show how existing models can be used to further examine the relationships between salinity at a given location, rimflows, and gate operations. These preliminary results show that as we continue to gain an understanding of these complex flow/salinity/gate operation relationships, opportunities to further optimize Delta operations will present themselves.

Synthetic ANN Development

Historic based flows and gate positions with DSM2 generated salinities have been used to train ANNs with considerable success. However, historic bias in the training set, or incomplete training data sets could adversely affect ANN development (see 1997 Annual Report).

Synthetic randomly generated training sets could be used to create ANNs which can give accurate results for a range of inputs without the errors associated with historic bias.

Synthetic input patterns will be generated by randomly varying all the flows and gate positions through each input's allowable range. These inputs will then be fed into DSM2 to generate salinity values. Finally, ANNs will then be trained on the synthetically generated inputs and salinities.

If the synthetic ANN training process is successful, and a methodology for randomly choosing input patterns and ensuring an adequately sized training pattern can developed, synthetic ANNs could be an important tool for modeling salinity in the Delta.

Figure 7.1 Contra Costa Canal EC (Sac, CVP)

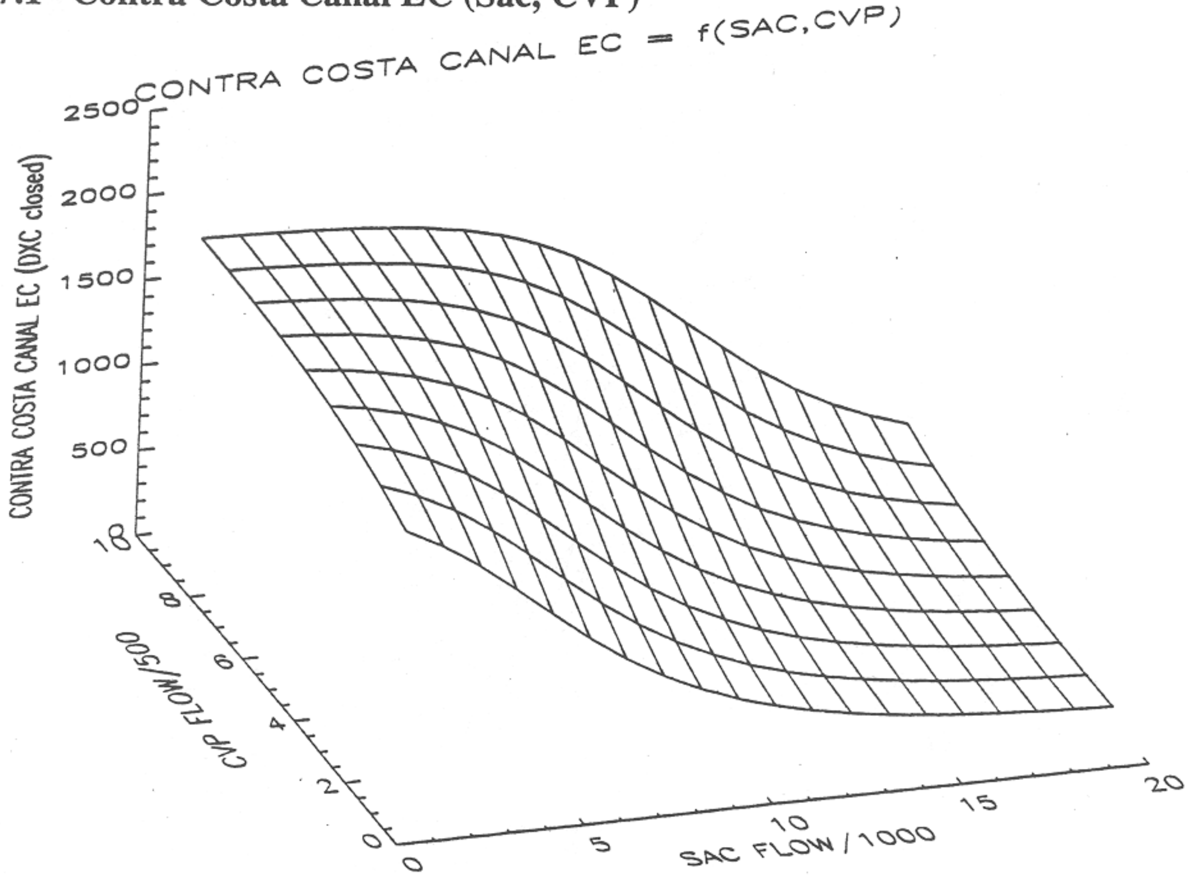


Figure 7.2 Contra Costa Canal EC (Sac, SWP)

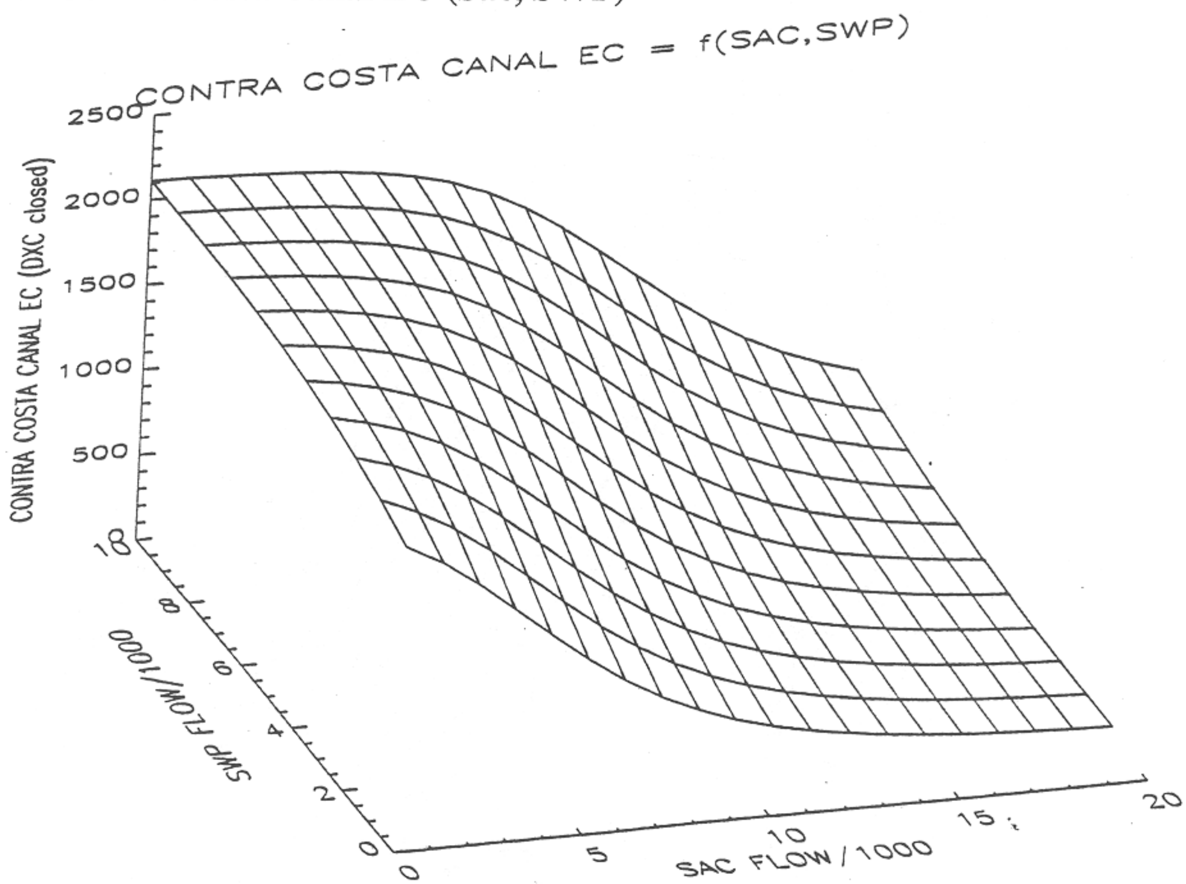


Figure 7.3 Jersey Point EC (Sac, CVP)

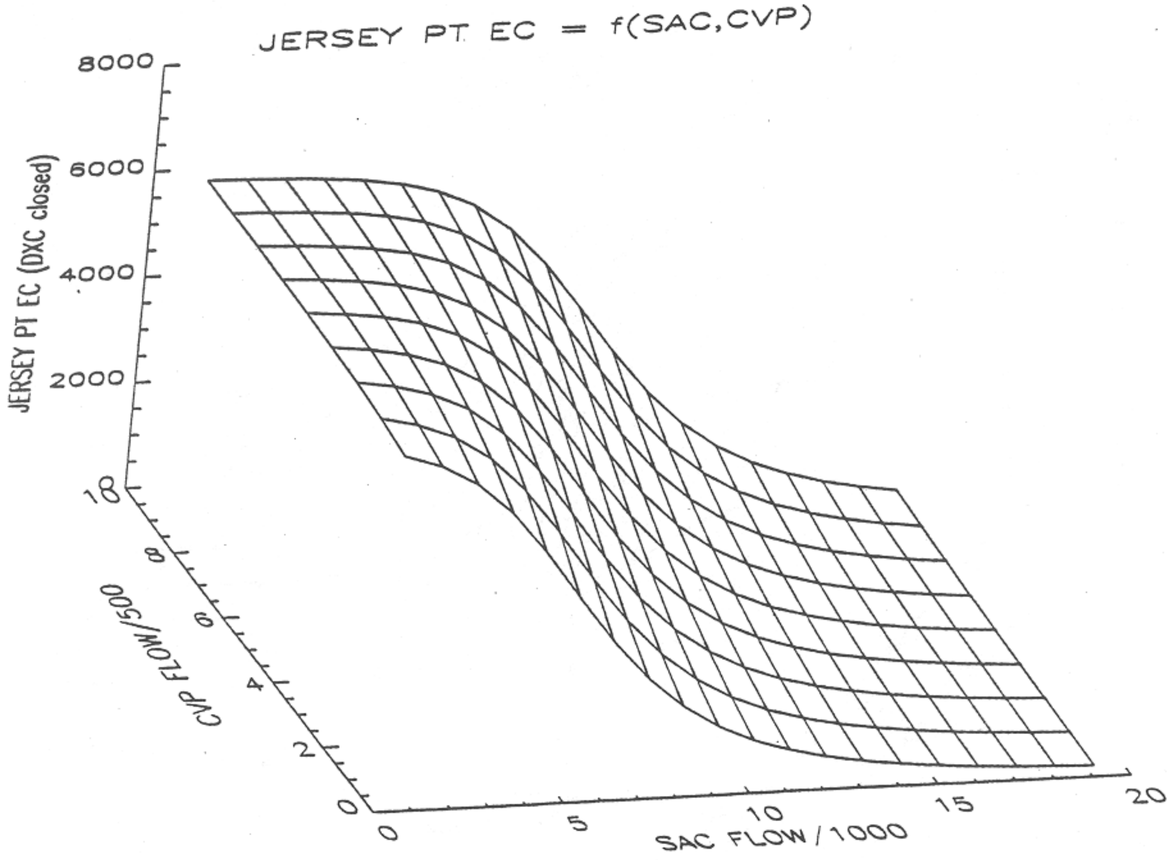
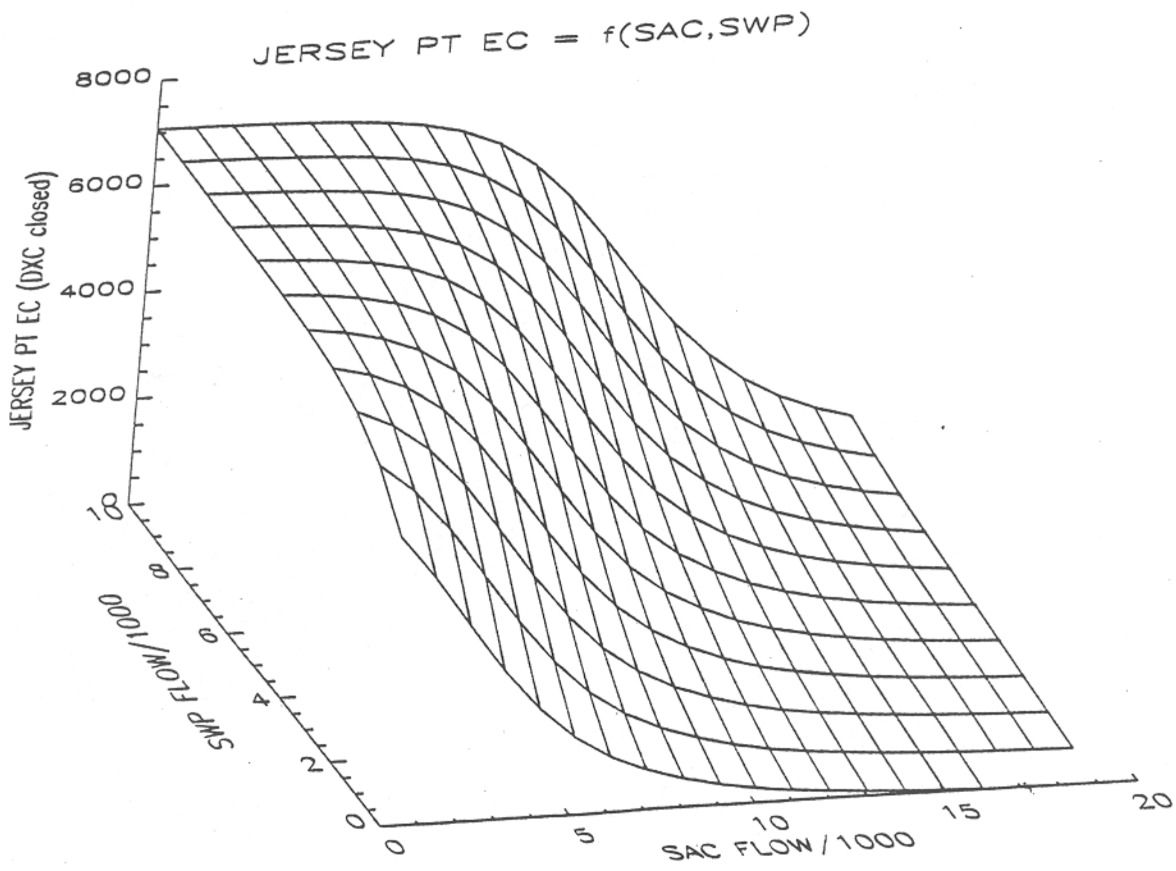


Figure 7.4 Jersey Point EC (Sac, SWP)



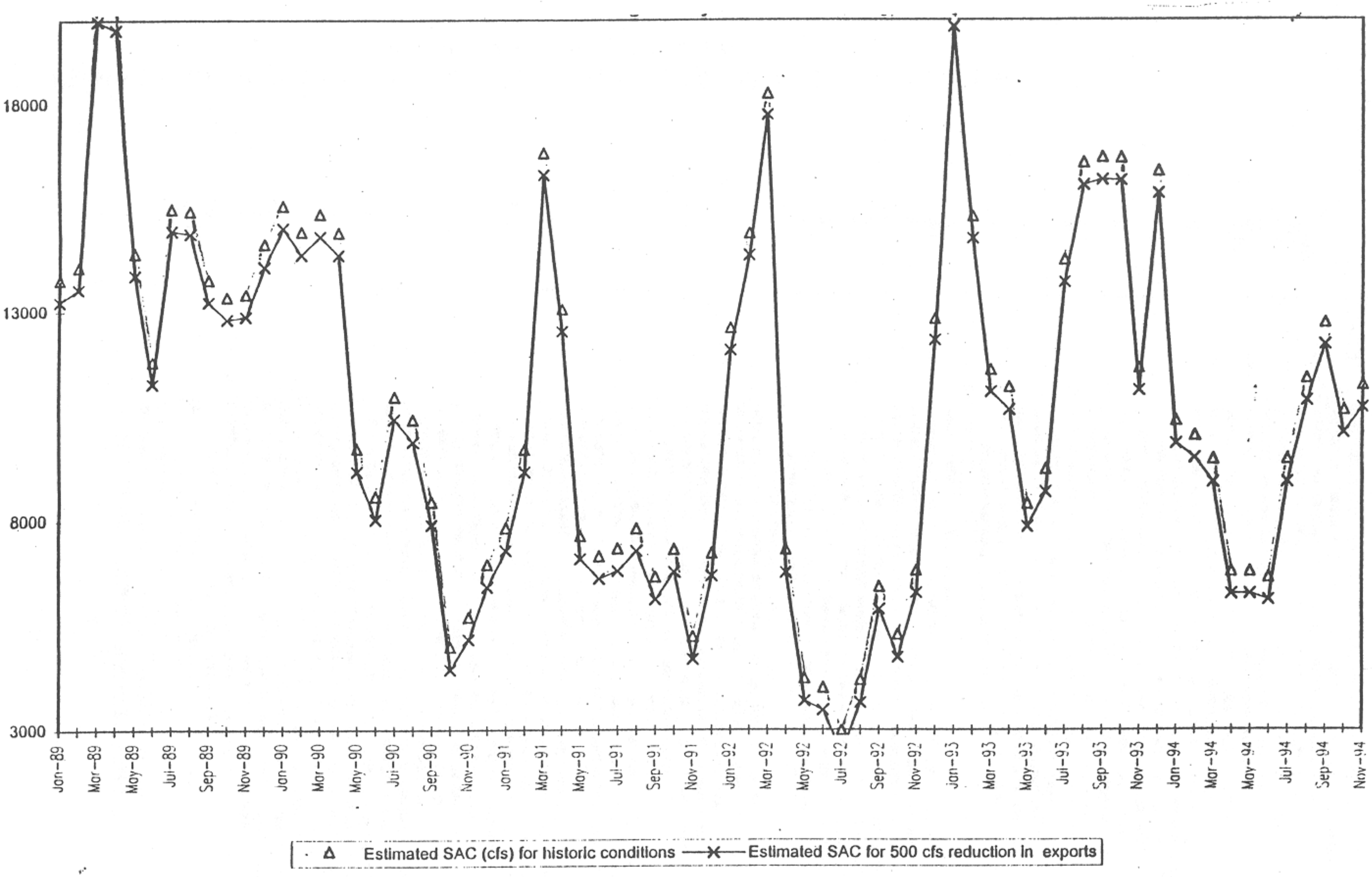


Figure 7.5 **Estimated SAC with Historic Exports vs. Estimated SAC when Historic Exports Reduced by 500 cfs (CIMEC method assuming Jersey Point EC controlling)**

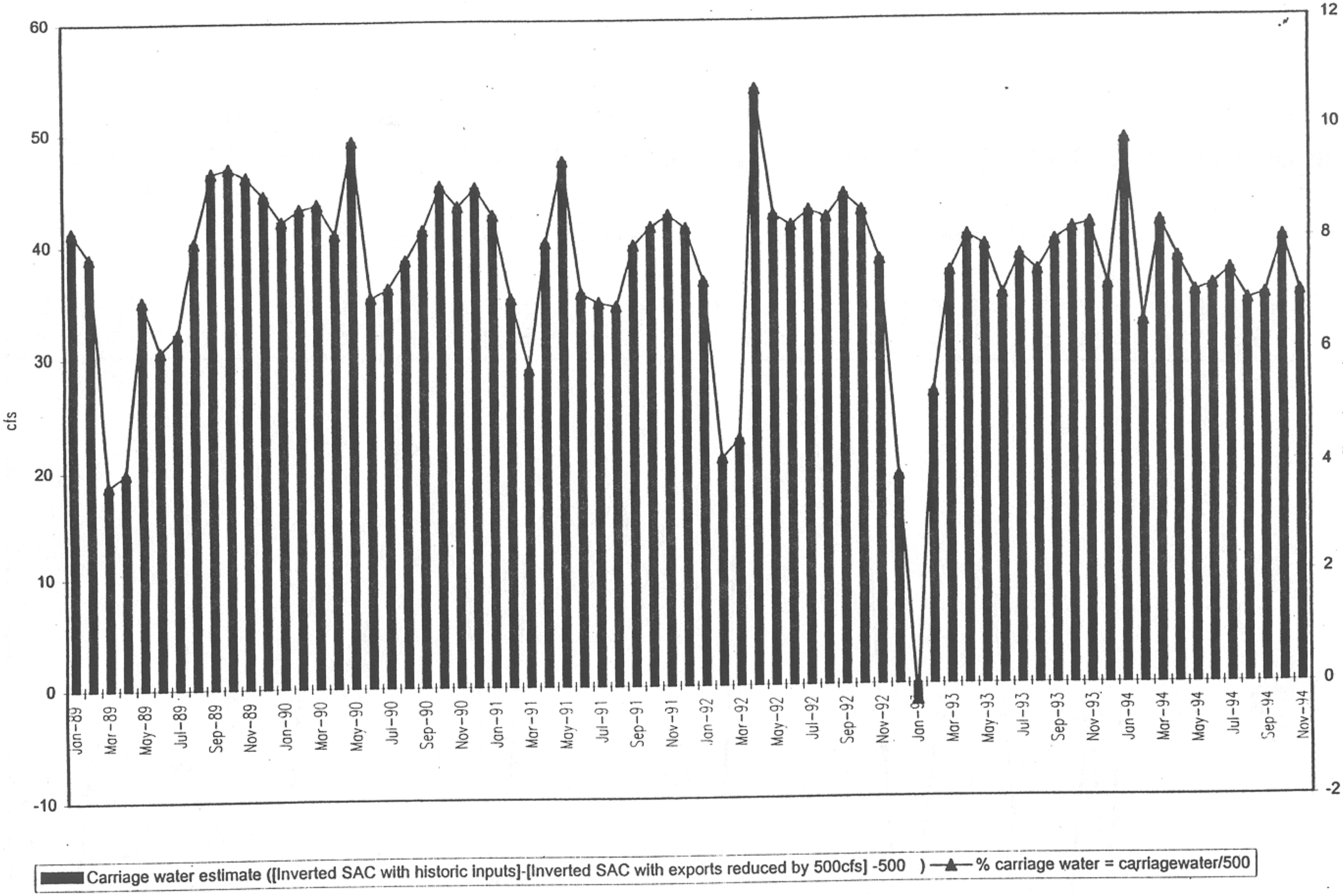


Figure 7.6 Monthly Carriage Water Estimate for a 500 cfs Reduction in Exports (CIMEC method with Jersey Point EC controlling)

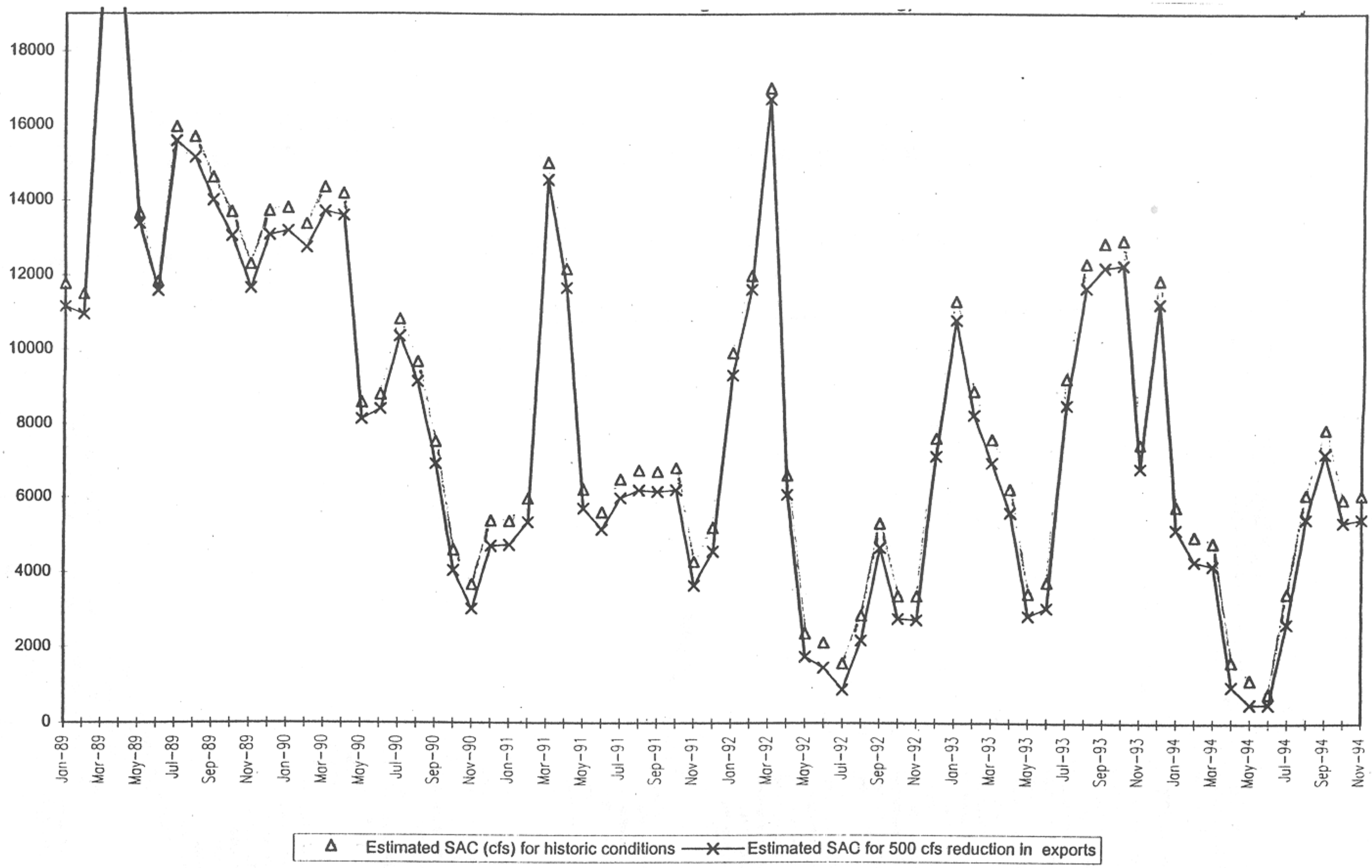


Figure 7.7 Estimated SAC with Historic Exports vs. Estimated SAC when Historic Exports Reduced by 500 cfs (CIMEC method assuming CCC EC controlling)

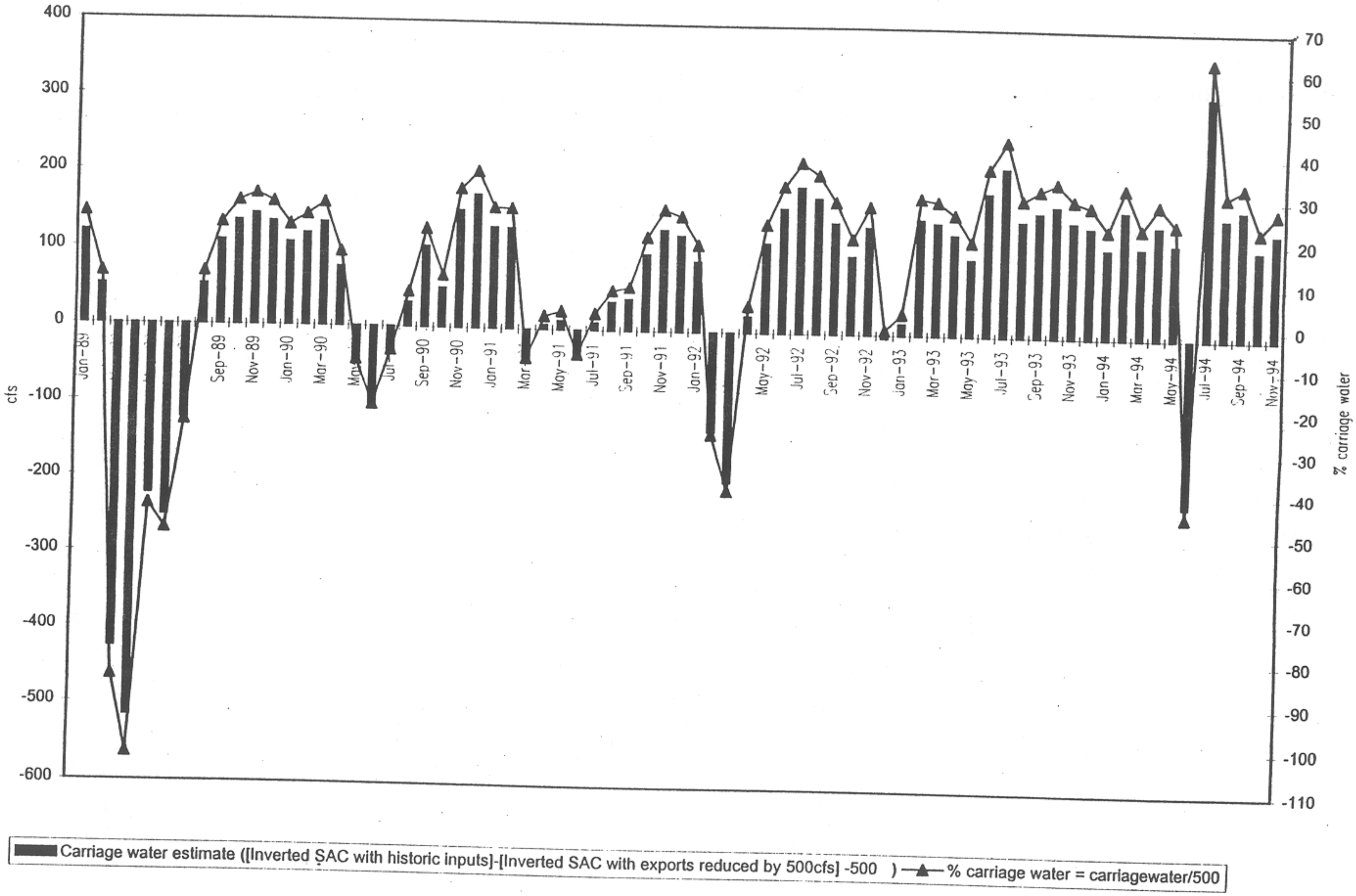


Figure 7.8 Monthly Carriage Water Estimate for a 500 cfs Reduction in Exports (CIMEC method with CCC EC controlling)

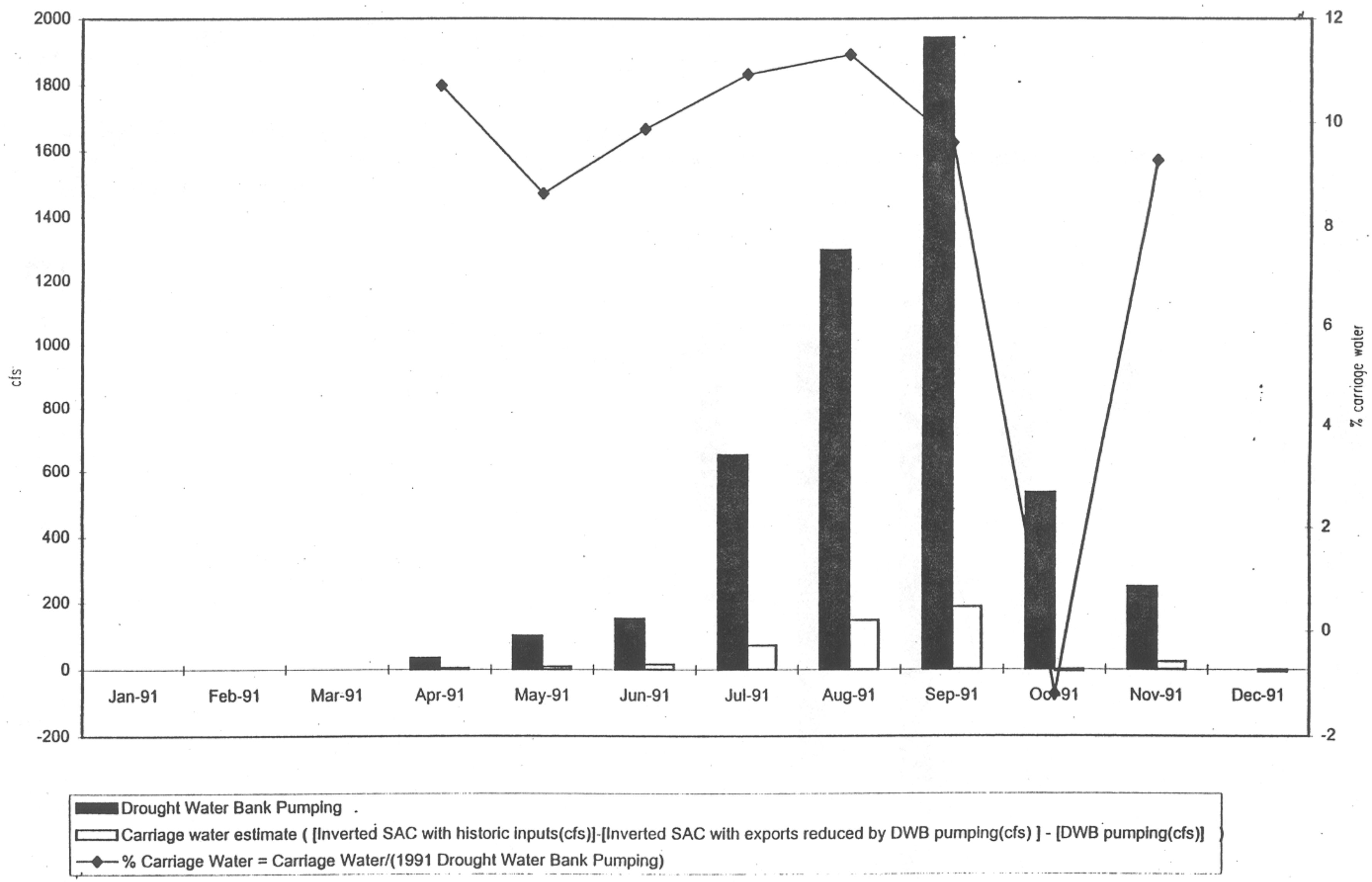


Figure 7.9 Carriage Water Estimate for 1991 DWB Pumping (CIMEC method with Jersey Point EC controlling)

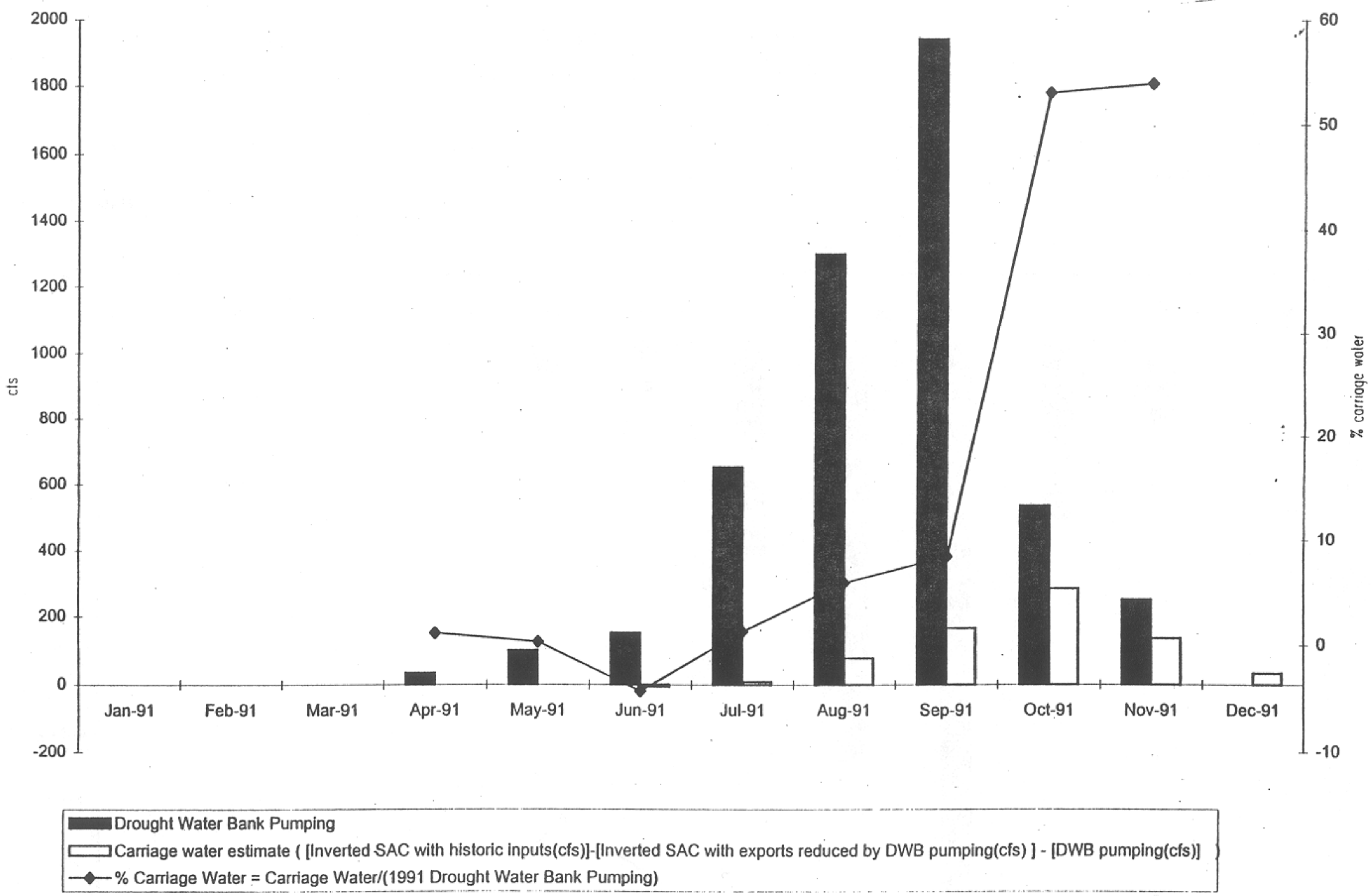


Figure 7.10 Carriage Water Estimate for 1991 DWB Pumping (CIMEC method with CCC EC controlling)