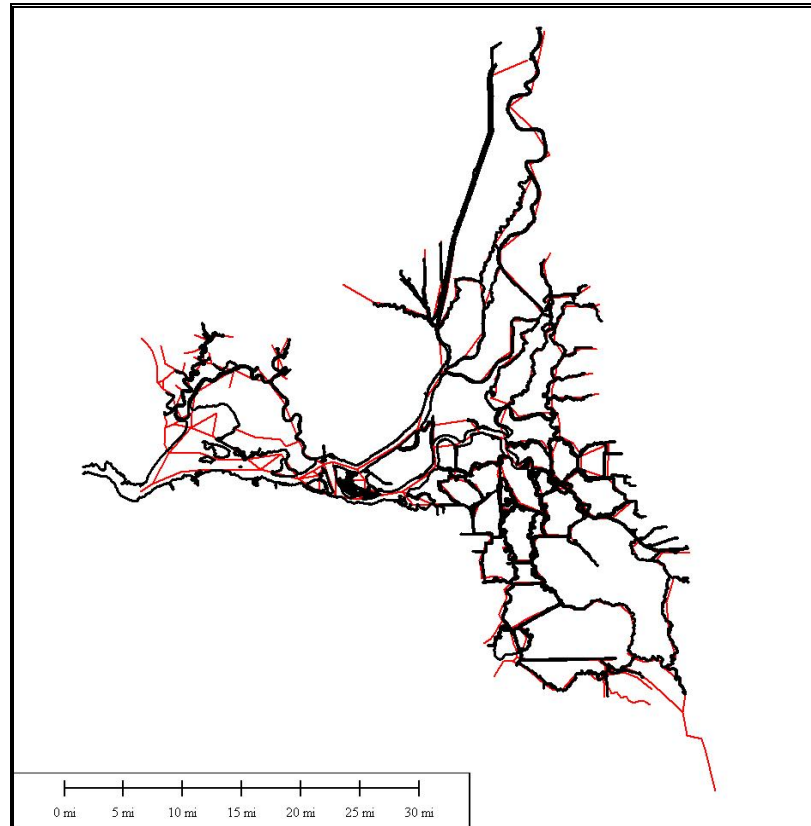


Modeling the Fate and Transport of Nutrients Using DSM2: Calibration/Validation Report

Version 6 Appendices

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Author's Note on Appendices II – V:

During the course of the project of calibrating the QUAL nutrient model, the model grid (representing the Delta) for DSM2 was revised substantially, requiring a “mini-recalibration” of the hydrodynamics module, HYDRO, after the initial DRAFT calibration documentation was written. The DSM2-QUAL nutrient model formulation and numerical solution were also revised several times, with the changes incorporated in the current Version 8.0.6 of DSM2. As a consequence of these revisions, the QUAL nutrient model was recalibrated several times after the initial DRAFT documentation was written, creating a quandary in how to organize the final document.

To this end, three separate documents were created: (1) a stand-alone expanded Executive Summary document was created to summarize the available documentation; (2) a Main document, containing the expanded Executive Summary, the entire text written for the project, and a detailed Appendix that includes calibration information ONLY for the latest revision of the QUAL nutrient model (Version 8.0.6); and, (3) a separate document containing only DSM2 Version 6 nutrient model calibration information, comprised of a series of appendices, Appendix II – Appendix V, containing the details of the Version 6 nutrient model calibration which are no longer relevant as Version 6 has been superseded.

This document is that third set of documentation, which contains solely information related to the calibration details of the Version 6 nutrient model. The Appendices are collated in the PDF sequentially.

Calibration of the DSM2-QUAL Version 6 Nutrient Model

In this document we assume the simple definition that calibration is the process of adjusting a set of model parameters so that model agreement with respect to a set of experimental data is maximized (Trucano et al., 2005). Similarly, validation is the quantification of the predictive ability of the model through comparison with a set of experimental data (Trucano et al., 2005). These definitions assume that a set of criteria for assessing the goodness-of-fit of the model to the data has been selected. For our purposes, the general methodology discussed in Moriasi (2007) was employed for this assessment. A set of statistics were calculated separately for calibration and validation for all available data of sufficient quality - detailed statistics are documented in these Appendices.

The statistics used to assess model calibration and validation at each Delta location were calculated from model residuals – a residual is the difference between a data value and the corresponding calculated model value (*i.e.*, data - model). Several statistics were calculated, but only three statistical measures were used as measures of the quality of the calibration and validation – Nash-Sutcliffe Efficiency (NSE), RMSE-Standard deviation Ratio (RSR), and

Percent Bias (PBIAS). These three statistics give an overall view of the quality of the calibration (Moriasi *et.al.*, 2007).

At each location where calibration data was available, model statistics were calculated and ranked categorically as Very Good, Good, Satisfactory or Unsatisfactory using ranges for model calibration performance ratings for the NSE, RSR and PBIAS statistics (Moriasi *et.al.*, 2007). There was no data available within the Delta for calibrating the organic-P constituent and only a few data points along the San Joaquin River for calibrating CBOD. Therefore, neither organic-P nor CBOD are considered calibrated.

Water temperature and nutrient calibration were considered separately, and the methodology for calculating calibration statistics was different due to the large difference in the availability of data both for setting boundary conditions and for calibration and validation. In order to ascertain that model calibration and validation were sufficient for both low and high inflow conditions, calibration and validation were considered separately by Water Year (WY) Type.

Calibration was obtained by varying the minimal numbers of sensitive parameters needed to obtain an acceptable level of accuracy, as assessed by the set of calibration statistics. A sensitive parameter in the context of this report is one where +/- 10% changes in the parameter produced measureable changes in concentration of at least one constituent. Due to time and budgetary constraints, although parameter sensitivity was assessed iteratively at the early stages of model calibration, the results were not formally documented.

Numerical statistics were calculated for the residuals for each constituent at each available location. Categorical ranges for NSE, PBIAS and RSR – Very Good, Good, Satisfactory and Unsatisfactory - were modified from ranges discussed in Moriasi (2007) and used to assess the quality of the calibration and predictive value of the validation. Water temperature statistics were assessed hourly on an annual basis using five hydrological Water Year types from critically dry to wet. Nutrient statistics were also assessed annually.

Both graphical and statistical model evaluation techniques were used in the analysis of calibration and validation results. Different techniques and strategies were used for temperature calibration and validation than for the nutrient model, as the data availability was very different between the two. In either case – nutrients or water temperature – calibration was carried out “by hand”, as funding was not sufficient to employ software to automate the calibration.

The combined effects of nutrient data variability between agencies and sparse measurement intervals, generally monthly, meant that some measure of uncertainty needed to be included in assessing the quality of model calibration and validation. For example, the monthly nutrient boundary conditions and in-Delta measurements were not all collected at time intervals to allow the direct comparison between a model calculation and a data value at a calibration location made during that month. As a consequence, there was a mismatch between the timing of the boundary condition and the timing of the downstream data. The variability between measurement data sets from different agencies indicated that daily fluctuations, tidal influences and extreme could influence the measurement.

To capture this variability for nutrient model calibration, an “envelope” of model values was used to incorporate these different sources of uncertainty. The maximum and minimum monthly values of 15 minute model output were calculated to create the upper and lower bounds of the envelope, respectively. At a given location, if the calibration data fell within that max/min envelope, then the residual was calculated as zero. Values falling outside of the envelope were calculated as residuals using either the maximum of the envelope (data higher than maximum value) or the minimum value of the envelope (data less than the minimum value) for that month.

Evaluation of the statistics indicates that the water temperature model calibration is generally ranked very good when considered for the Delta as a whole, although the quality differs by region and location within a region. Modeled water temperature in the south Delta was generally biased low in the summer months, while modeled water temperature along the Sacramento River was consistent with measurement data. Validation statistics for water temperature are consistent with the use of the model on a daily to hourly time scale.

Calibration and validation statistics were calculated for all non-conservative constituents (except organic-P and CBOD) at a monthly time scale. Ranges for the calibration statistics for the N-constituents and dissolved oxygen were generally very good, except at a few locations. Calibration for the other constituents varied from very good to acceptable. Results were poorest where measurements were sparse spatially and/or temporally. Validation statistics mirrored calibration statistics, indicating the appropriate use of the nutrient model for calibrated parameters (i.e., excluding organic-P and CBOD) on a monthly time scale.

References

- Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Vieth. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE*. Vol. 50(3).
- Trucano, T.G., L.P. Swiler, T. Igusa, W.L. Oberkampf, M. Pilch. 2005. Calibration, validation and sensitivity analysis: What’s what. *Reliability Engr.& Sys. Safety*. Vol. 91: 1331-1357.

APPENDIX II

This document contains model calibration results in comparison with ammonia and nitrate+nitrite measurements.

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A. Figures for Ammonia

Figures were produced at all locations where there was sufficient data to plot more than a couple years. Where data was available for (nearly) the full model term, here plots were produced the full time span and the spans 1990 – 1999 and 2000 – 2009. Model plots sometimes begin in May or June 1990, as at some locations the initial condition values were somewhat too high or too low and model required spin-up at those locations for the first few months. The figures are organized by constituent.

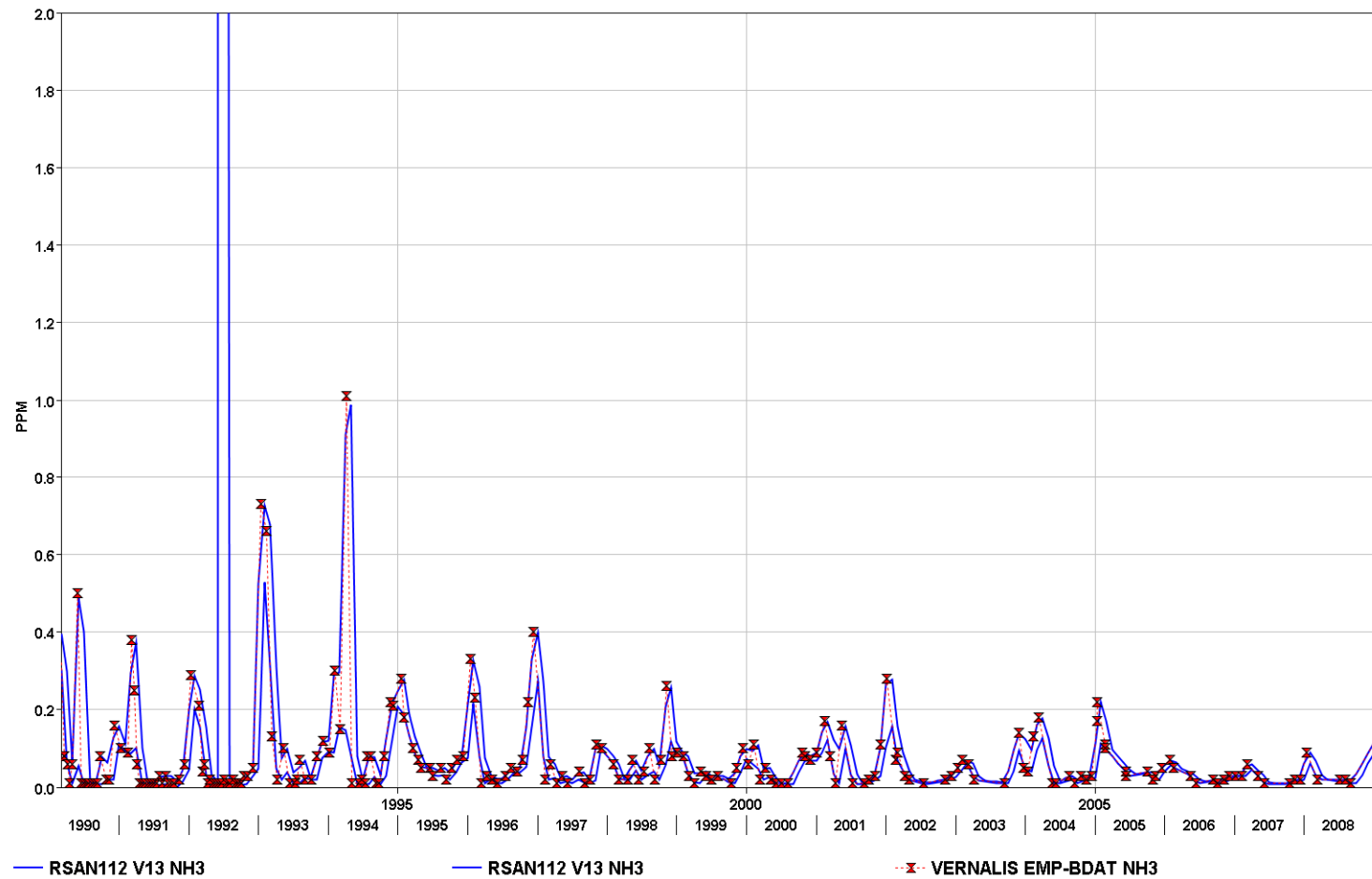


Figure A II. 1 Ammonia at RSAN112 all years.

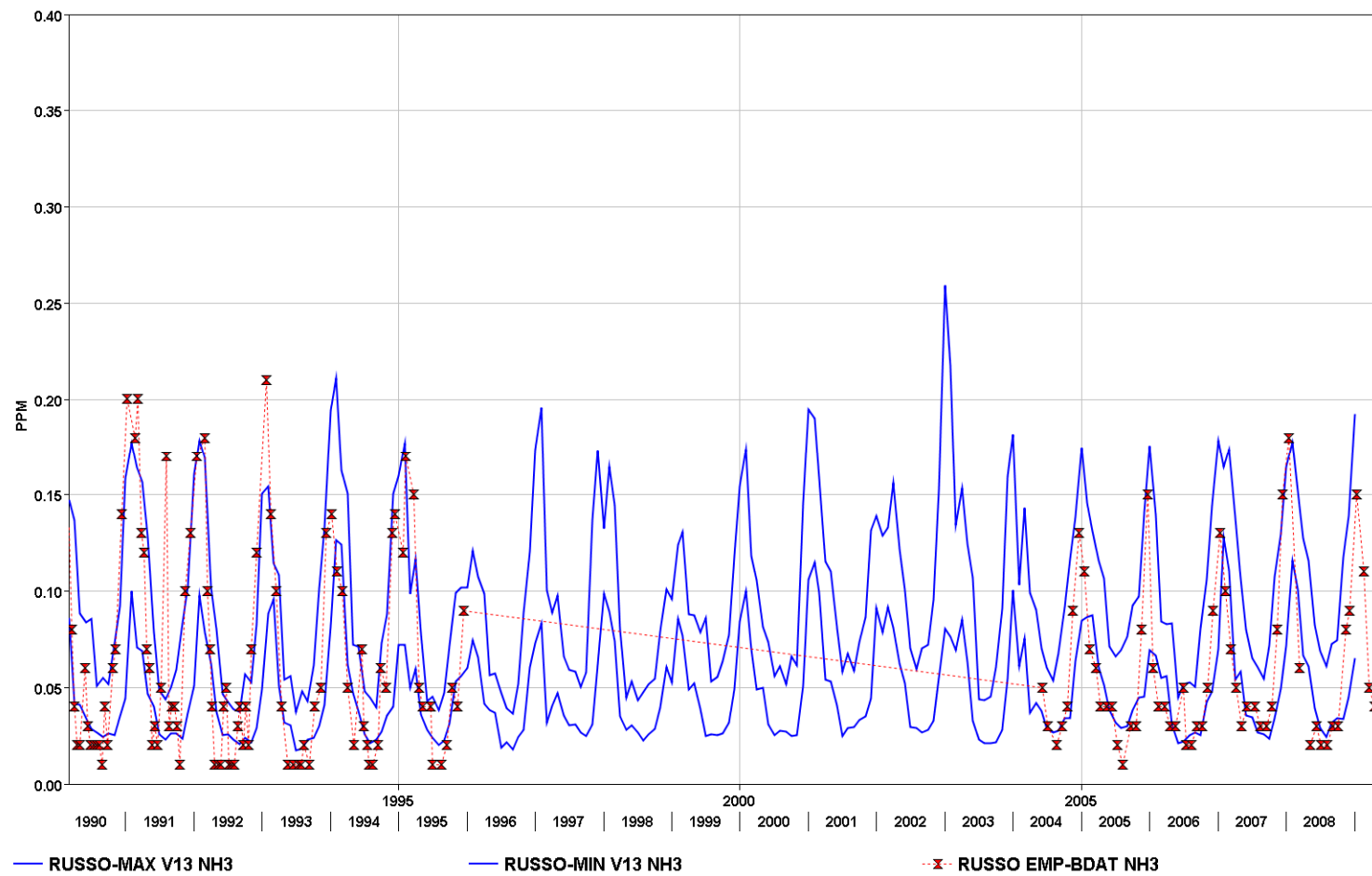


Figure A II. 2 Ammonia at Russo all years.

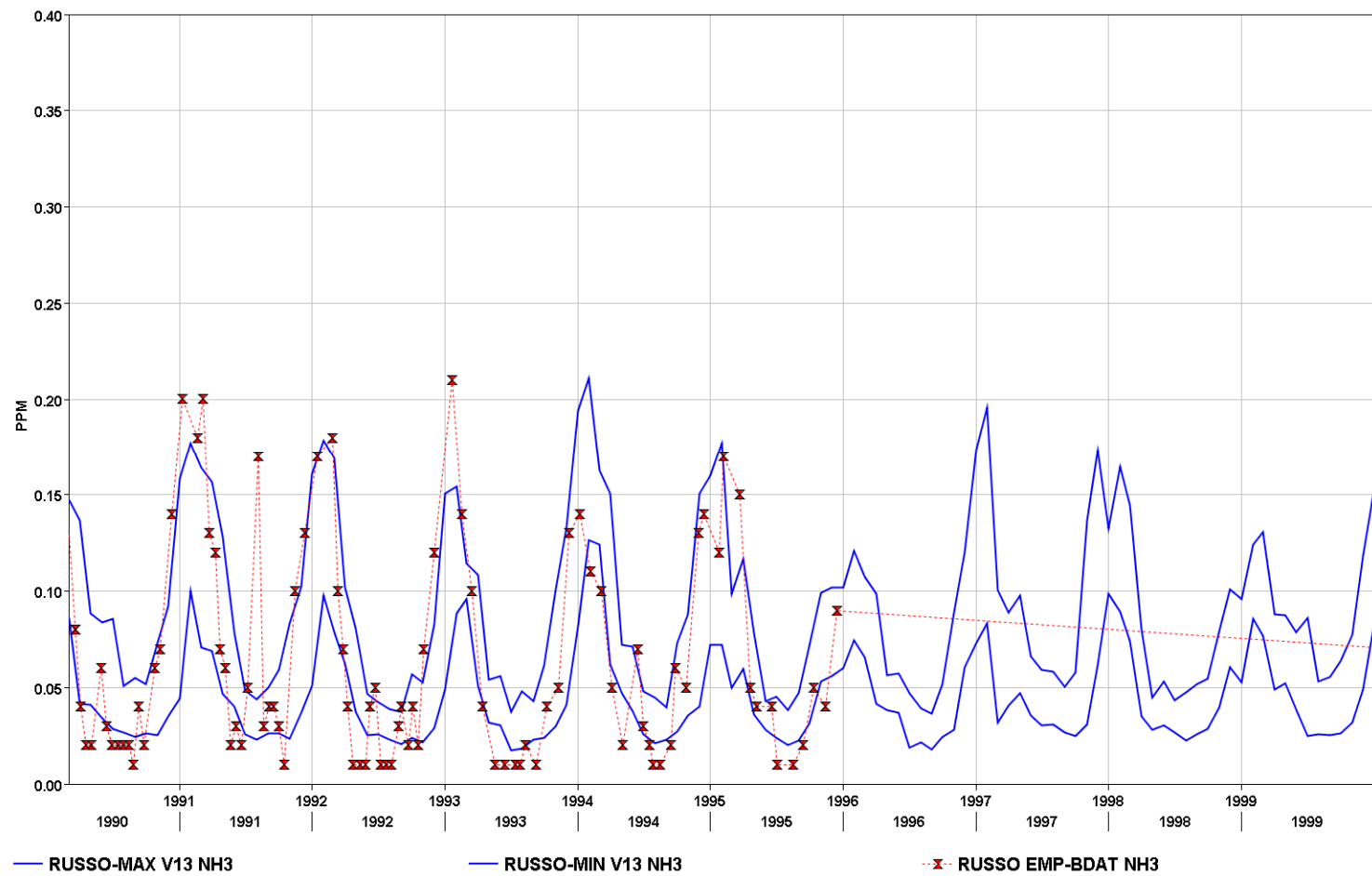


Figure A II. 3 Ammonia at Russo early years.

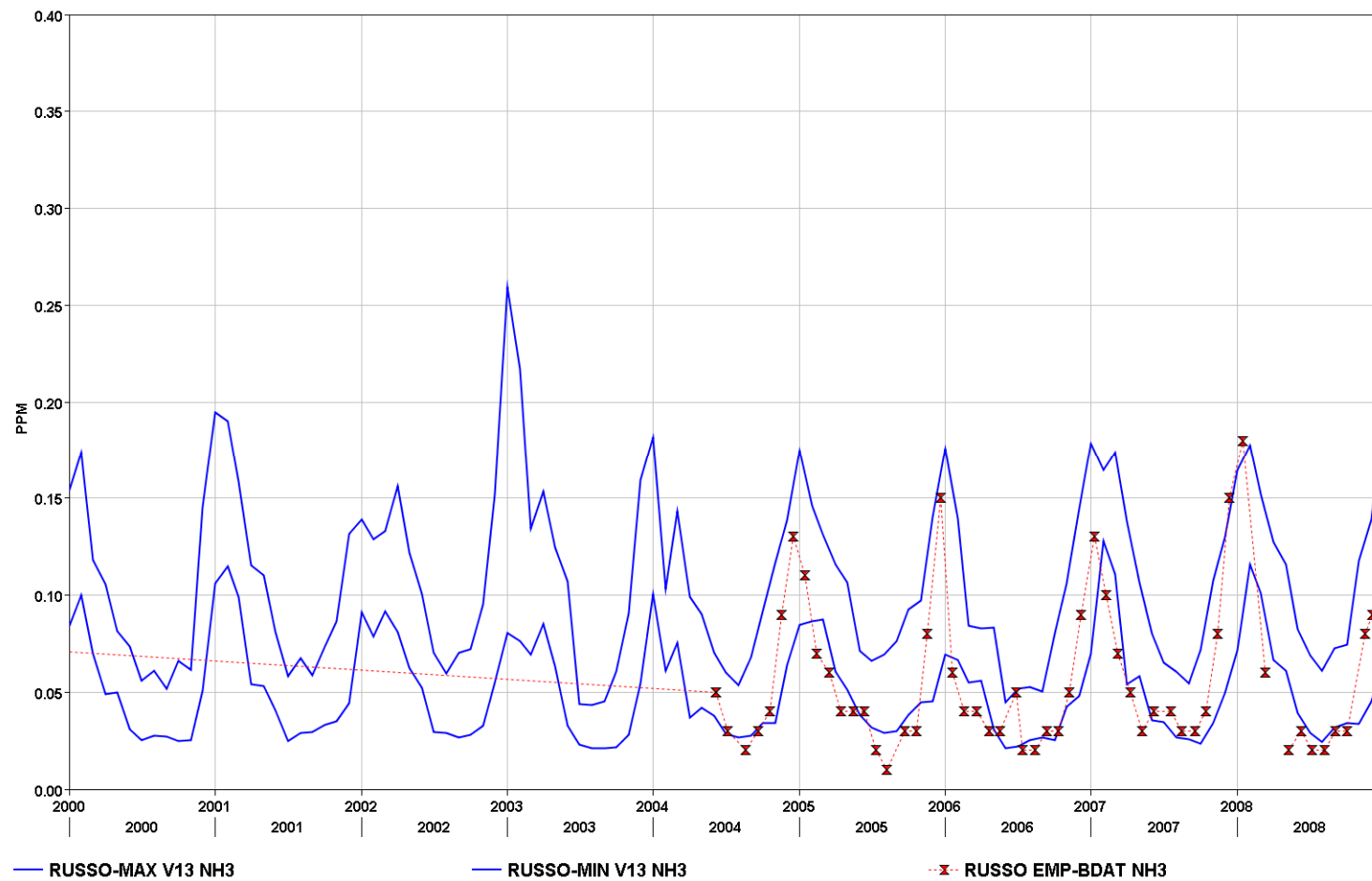


Figure A II. 4 Ammonia at Russo late years.

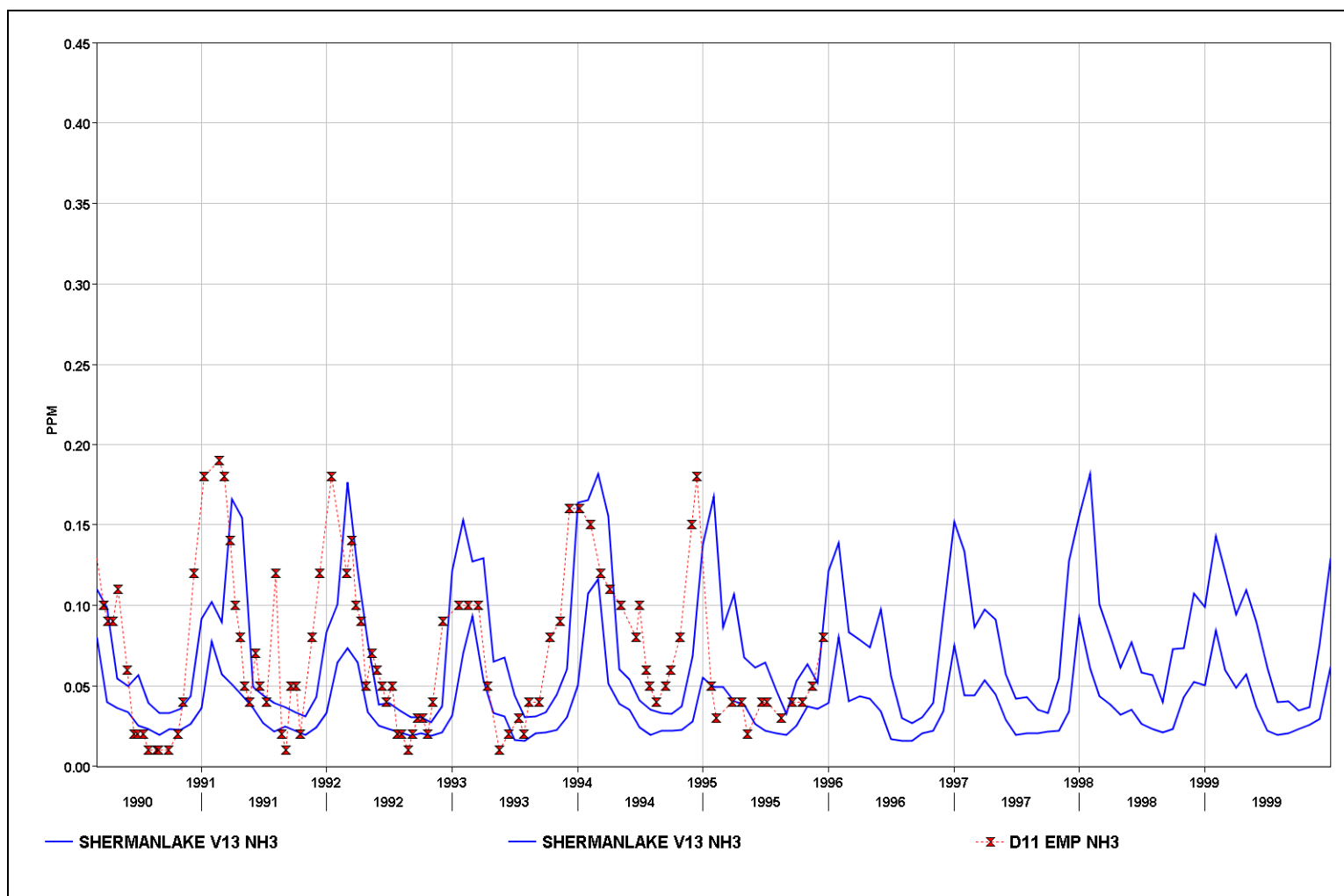


Figure A II. 5 Ammonia at Sherman Lake early years.

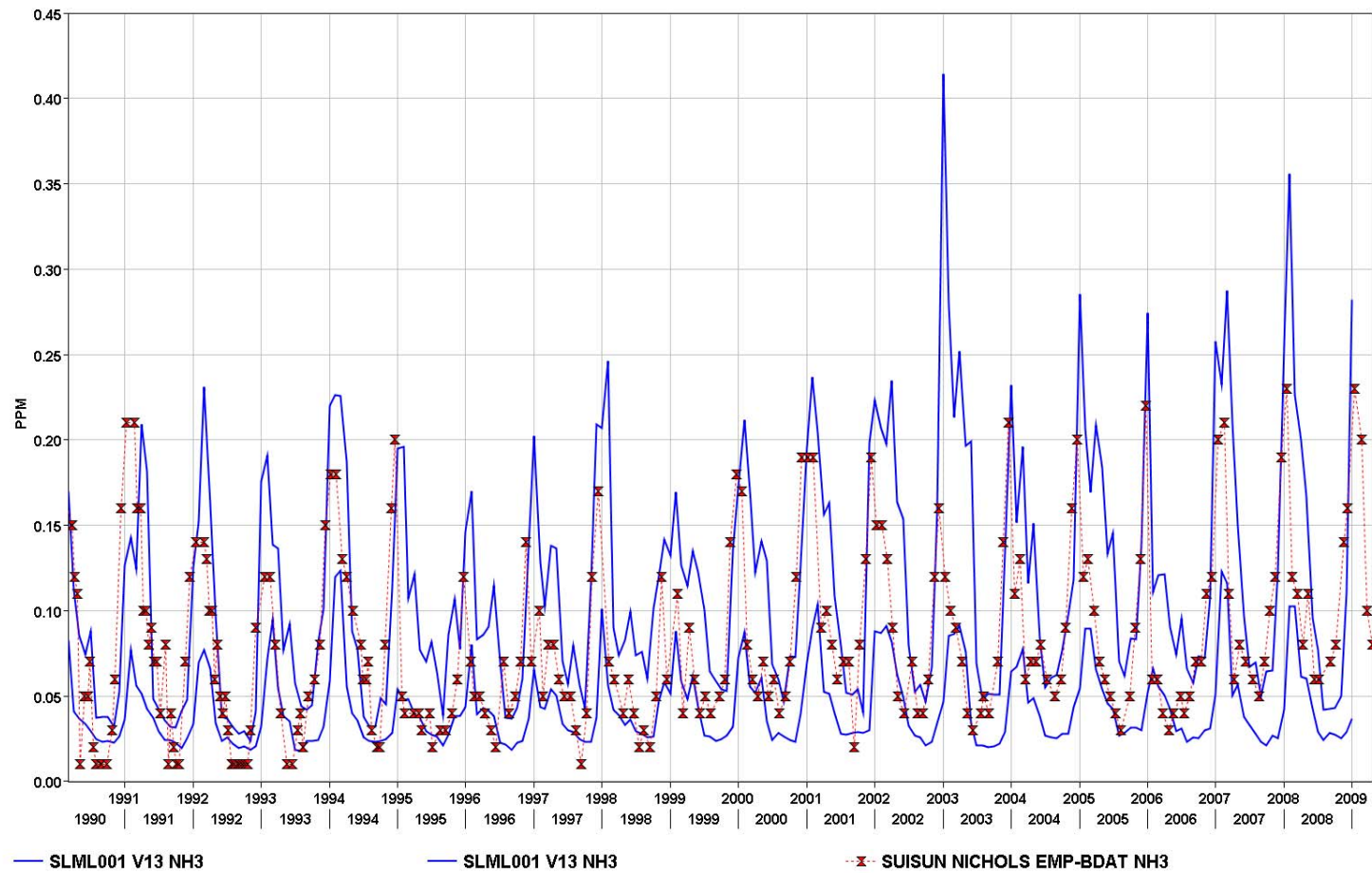


Figure A II. 6 Ammonia at SLM001 all years.

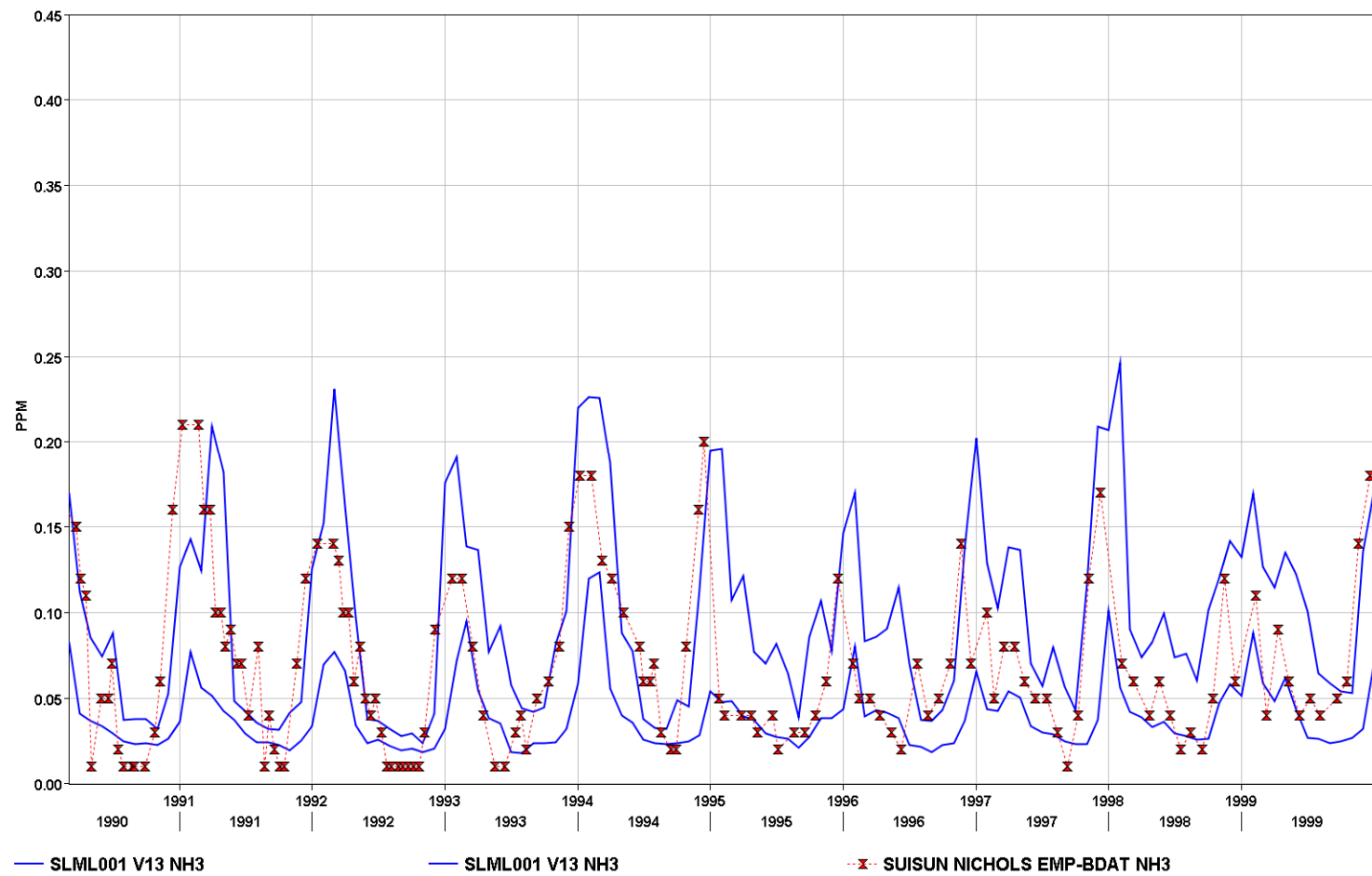


Figure A II. 7 Ammonia at SLM001 early years.

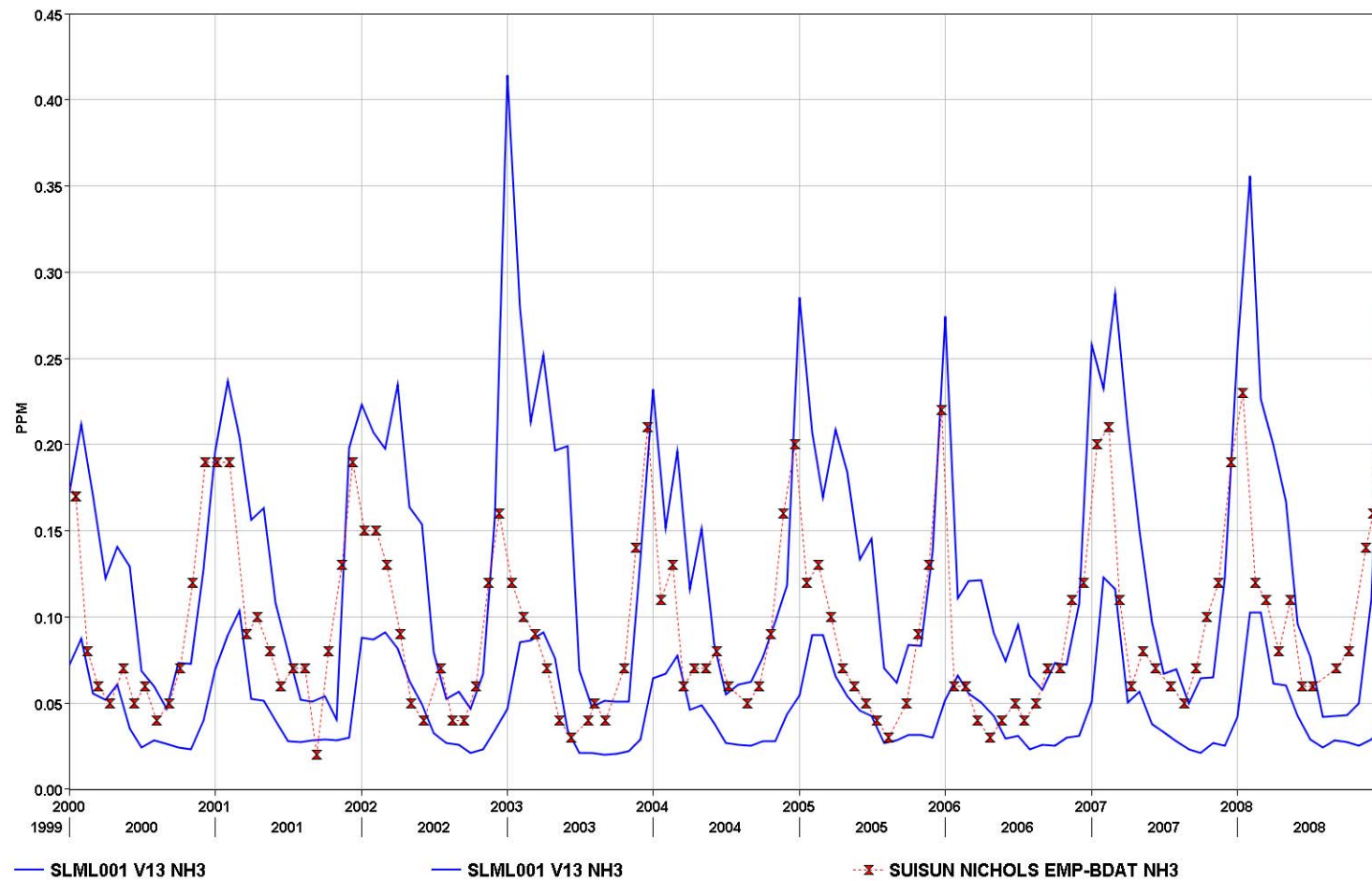


Figure A II. 8 Ammonia at SLM001 later years.

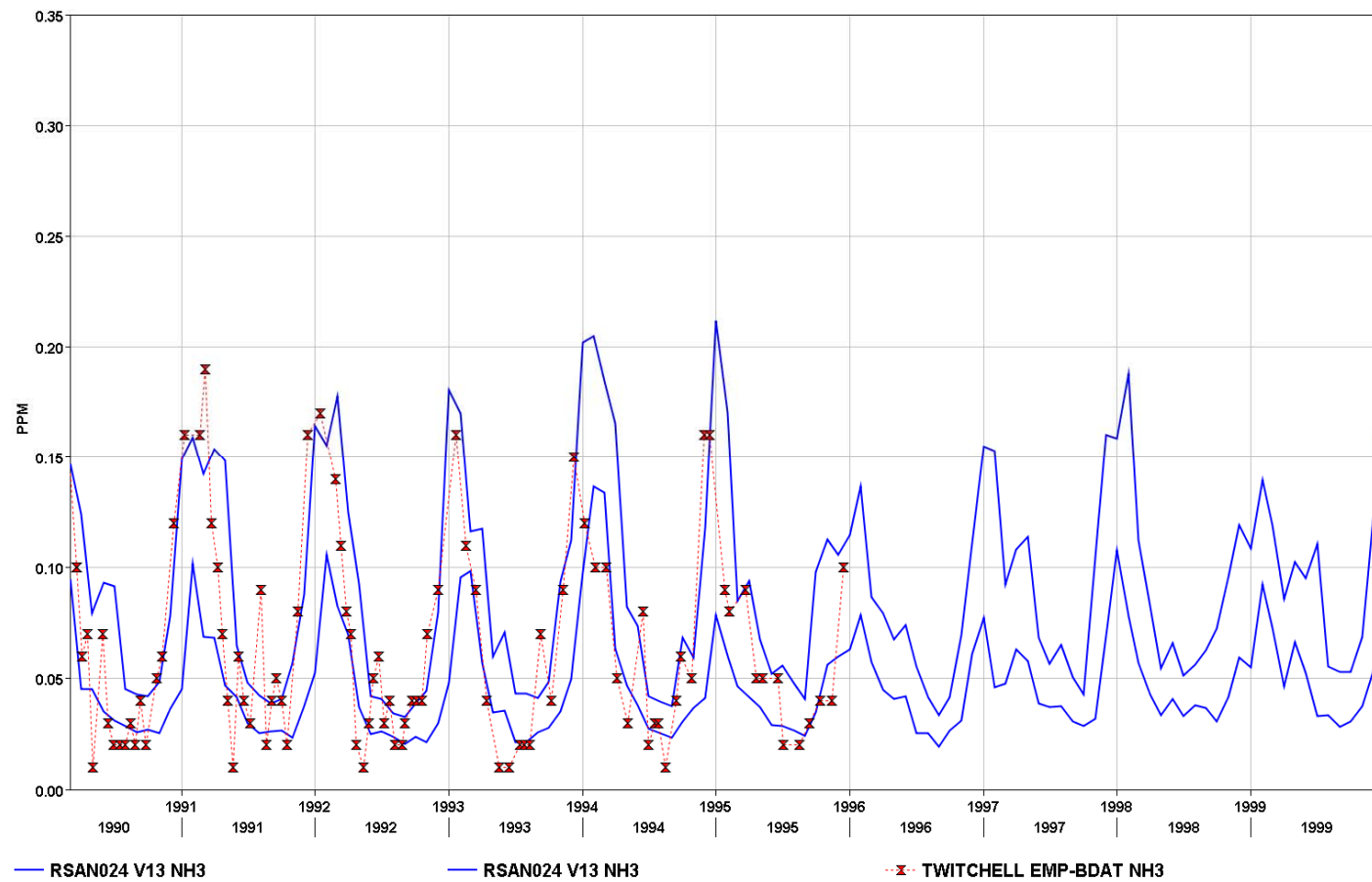


Figure A II. 9 Ammonia at RSAN024 early years.

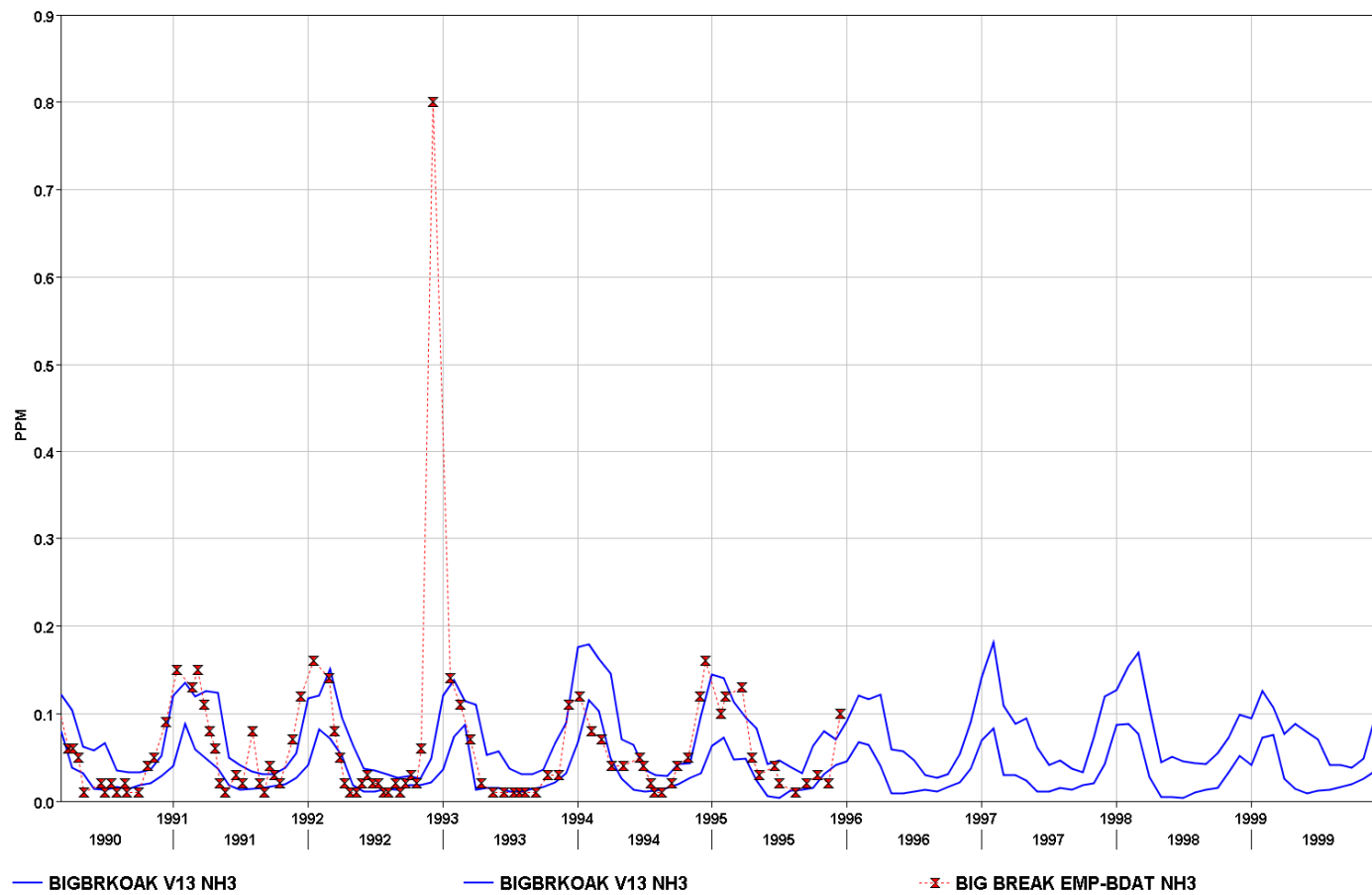


Figure A II. 10 Ammonia at BIG BREAK early years.

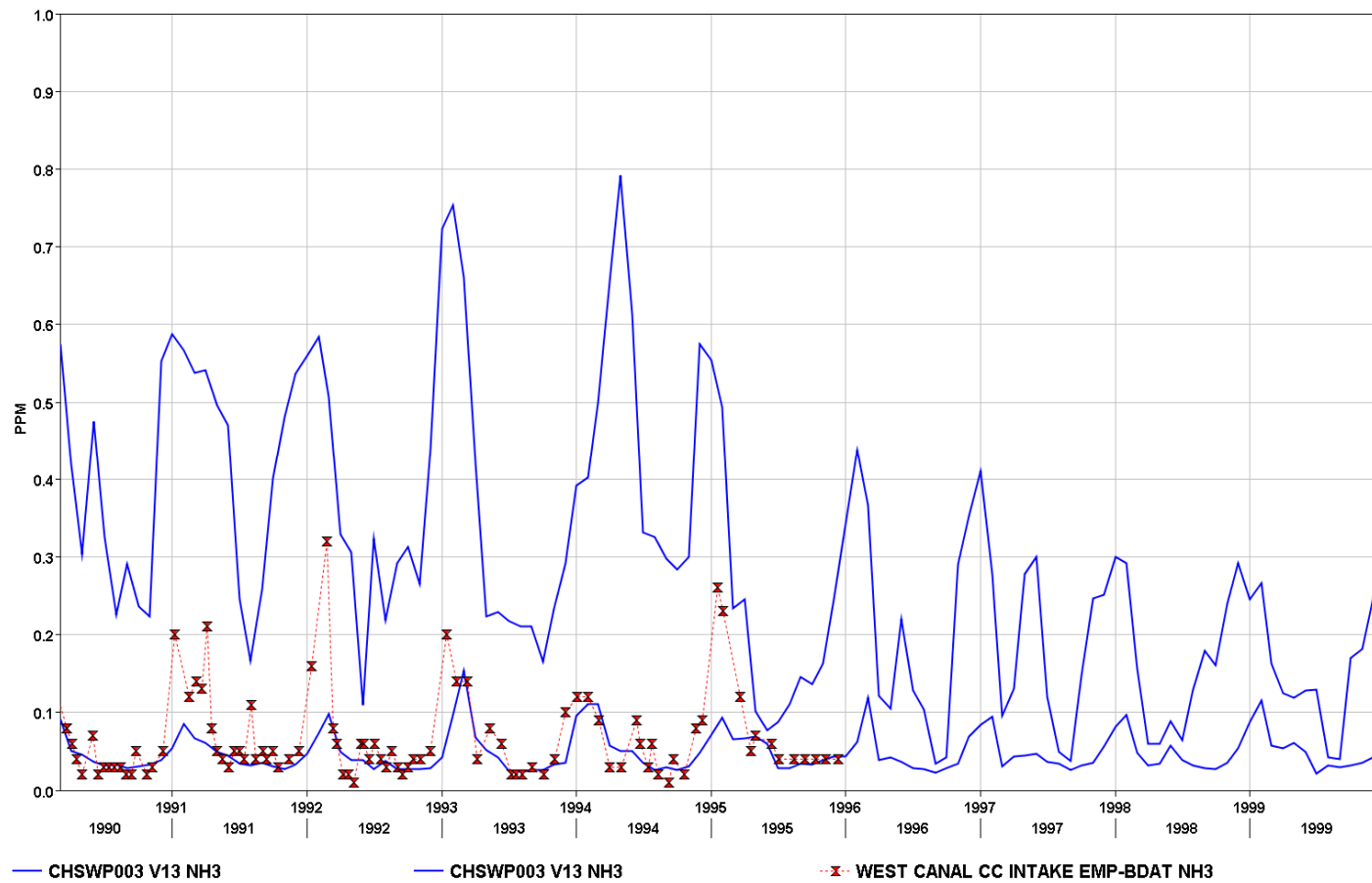


Figure A II. 11 Ammonia at CHSWP003 early years.

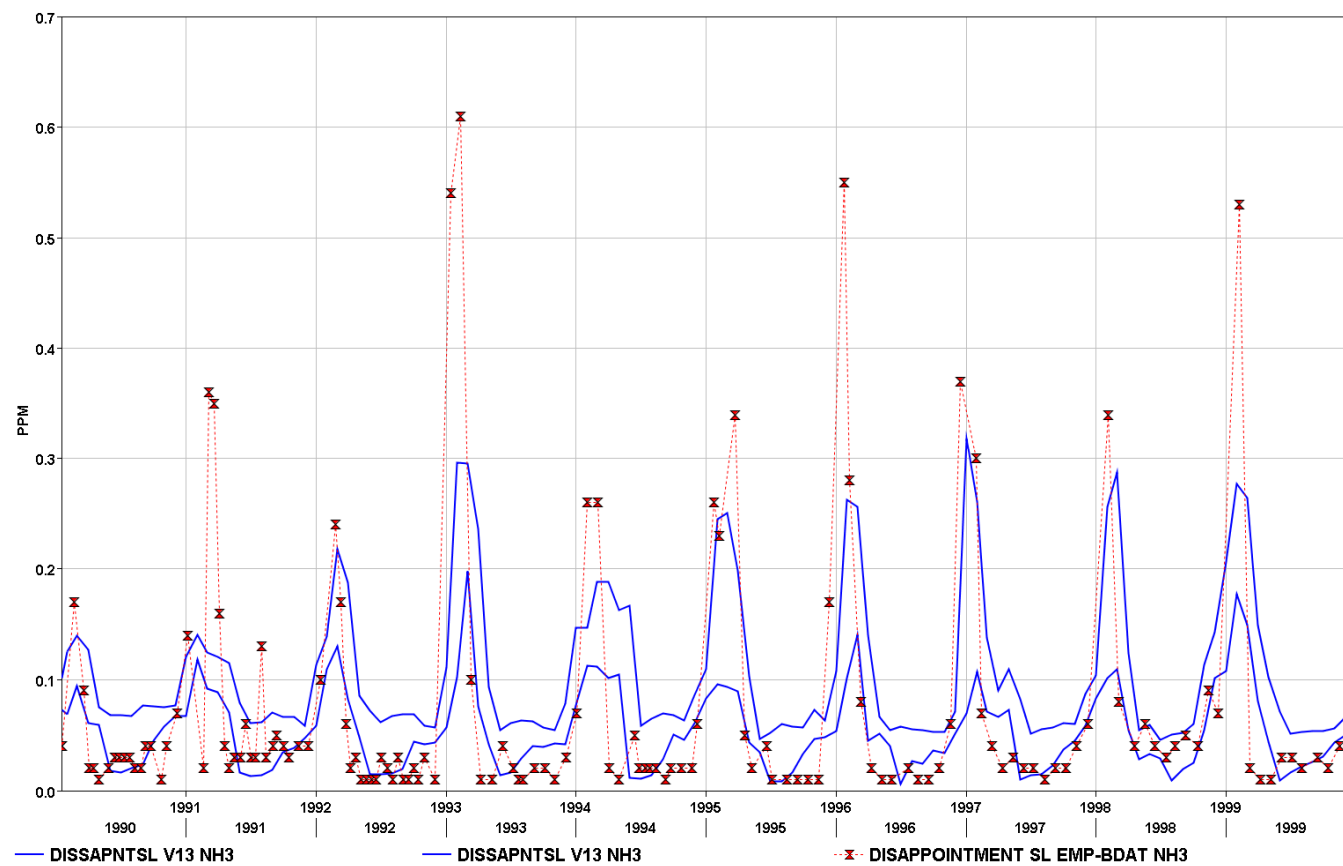


Figure A II. 12 Ammonia at DISAP SL early years.

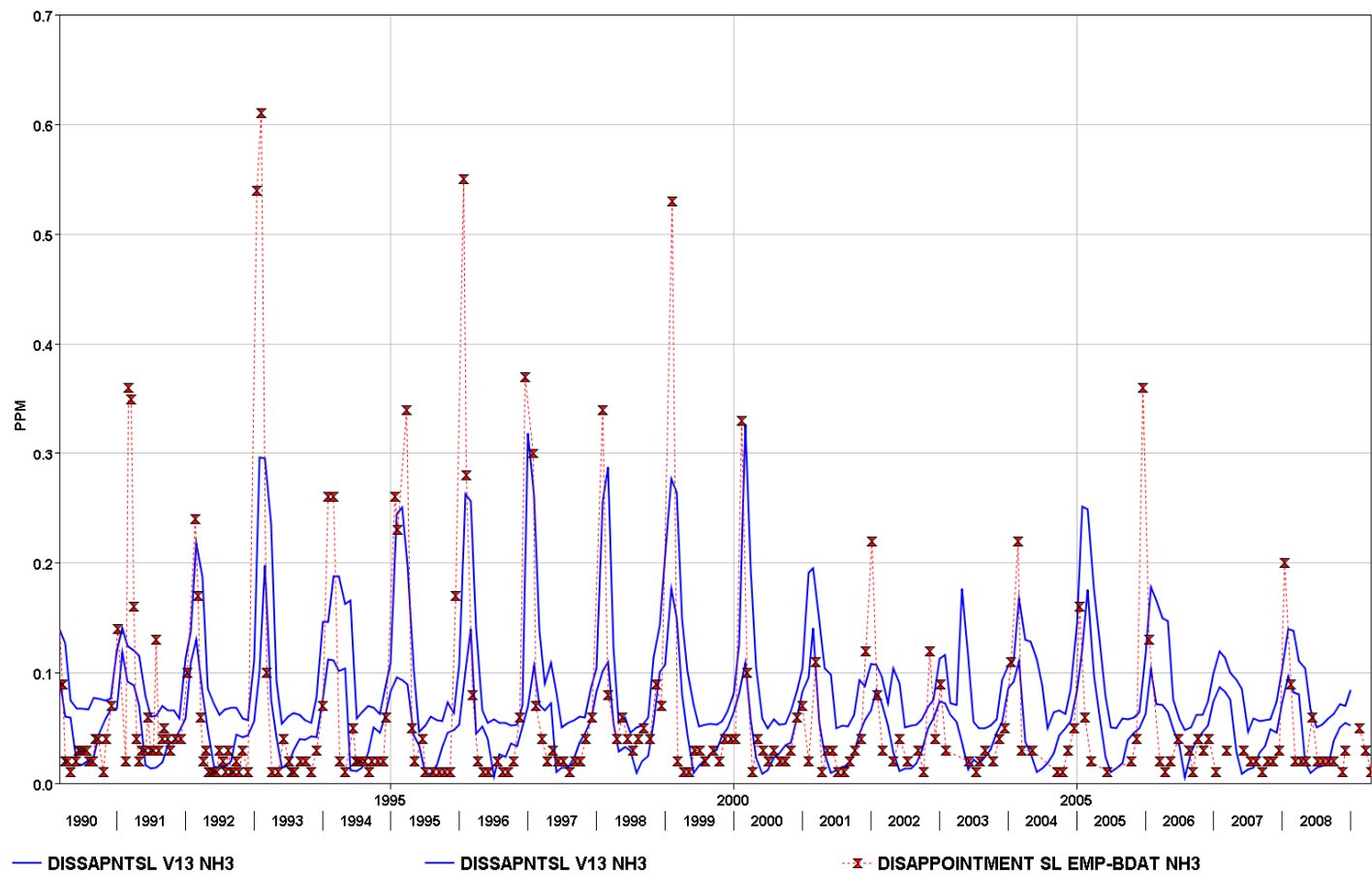


Figure A II. 13 Ammonia at DISAP SL all years.

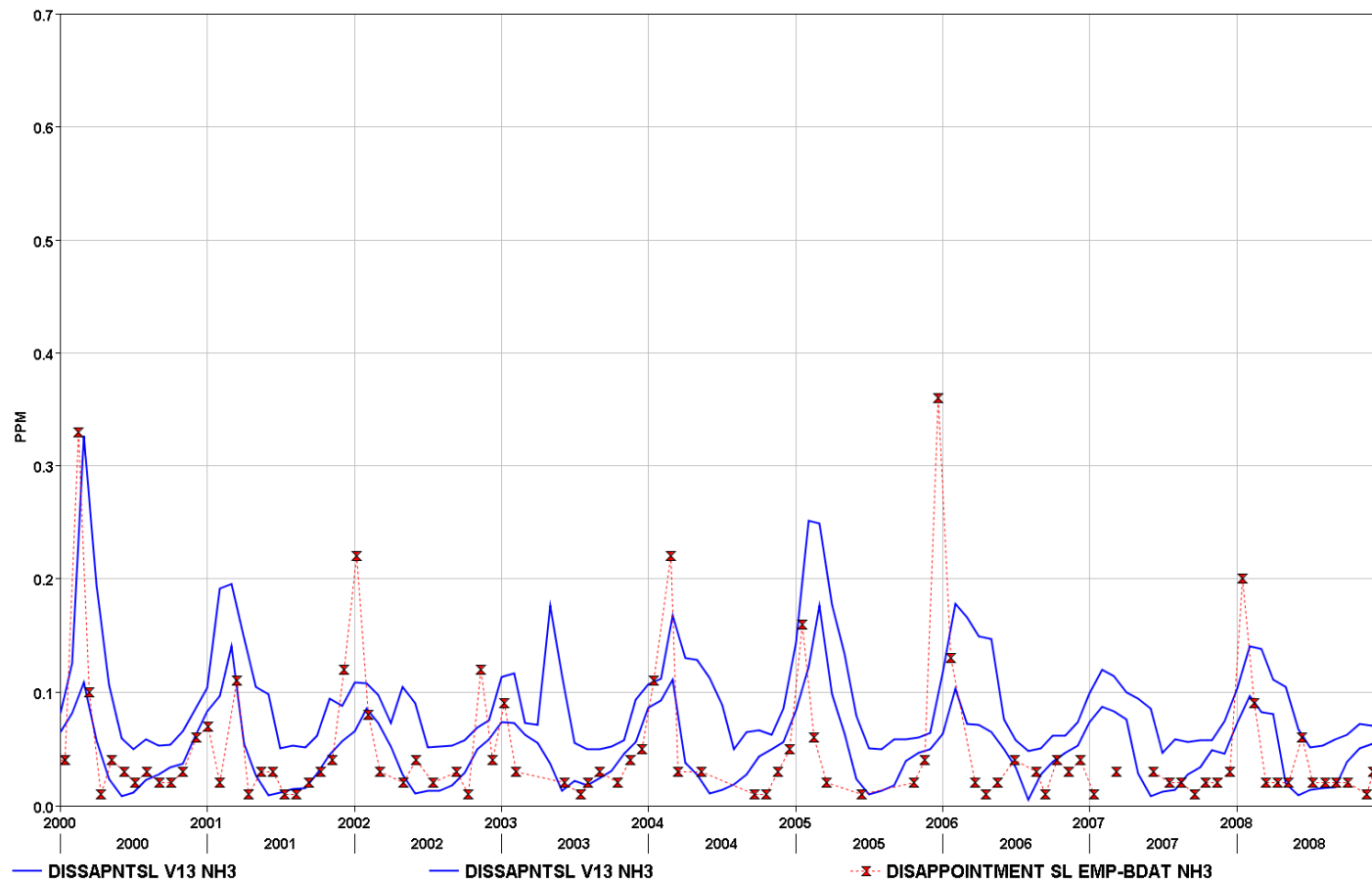


Figure A II. 14 Ammonia at DISAP SL later years.

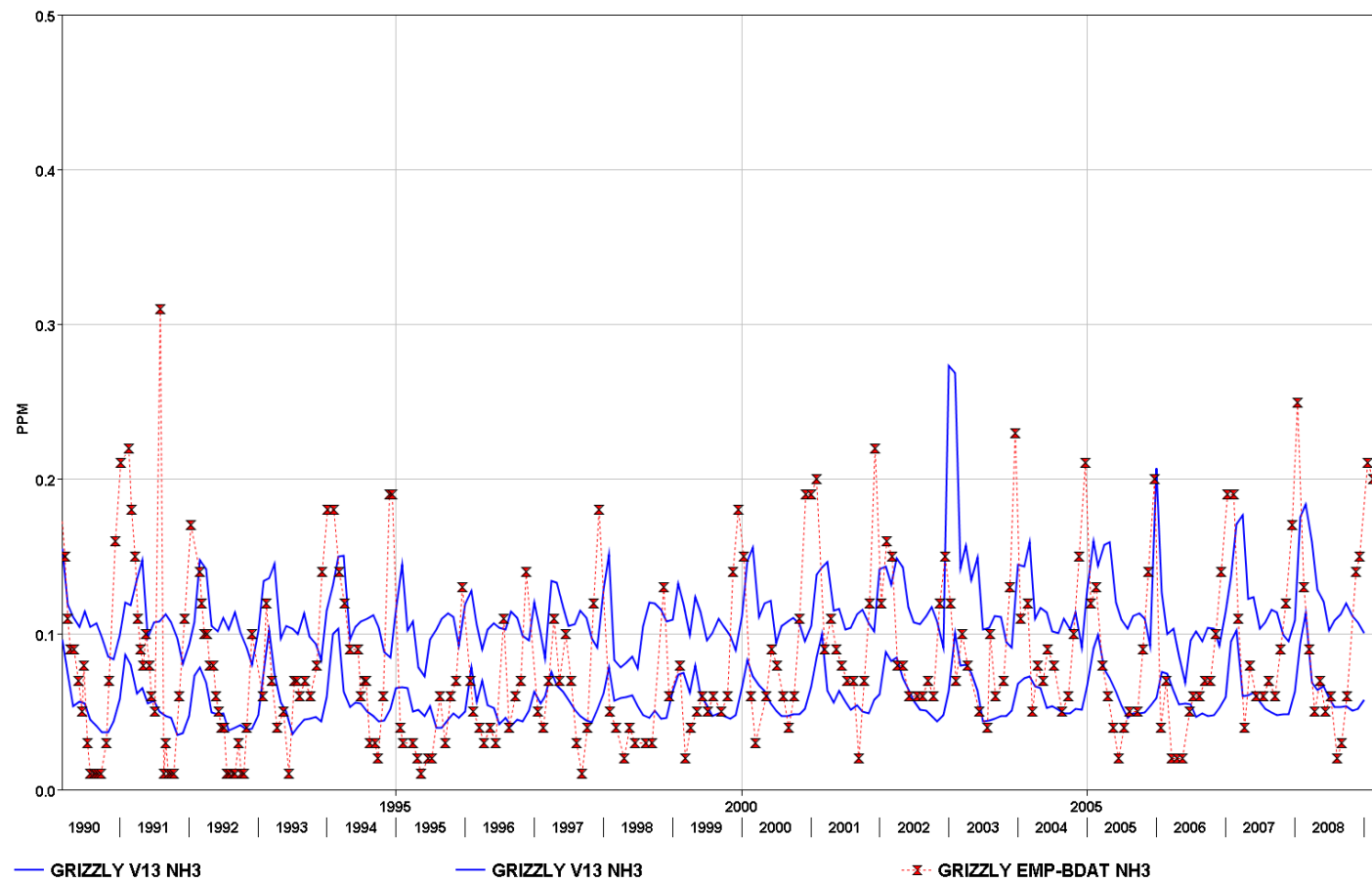


Figure A II. 15 Ammonia at GRIZZLY all years.

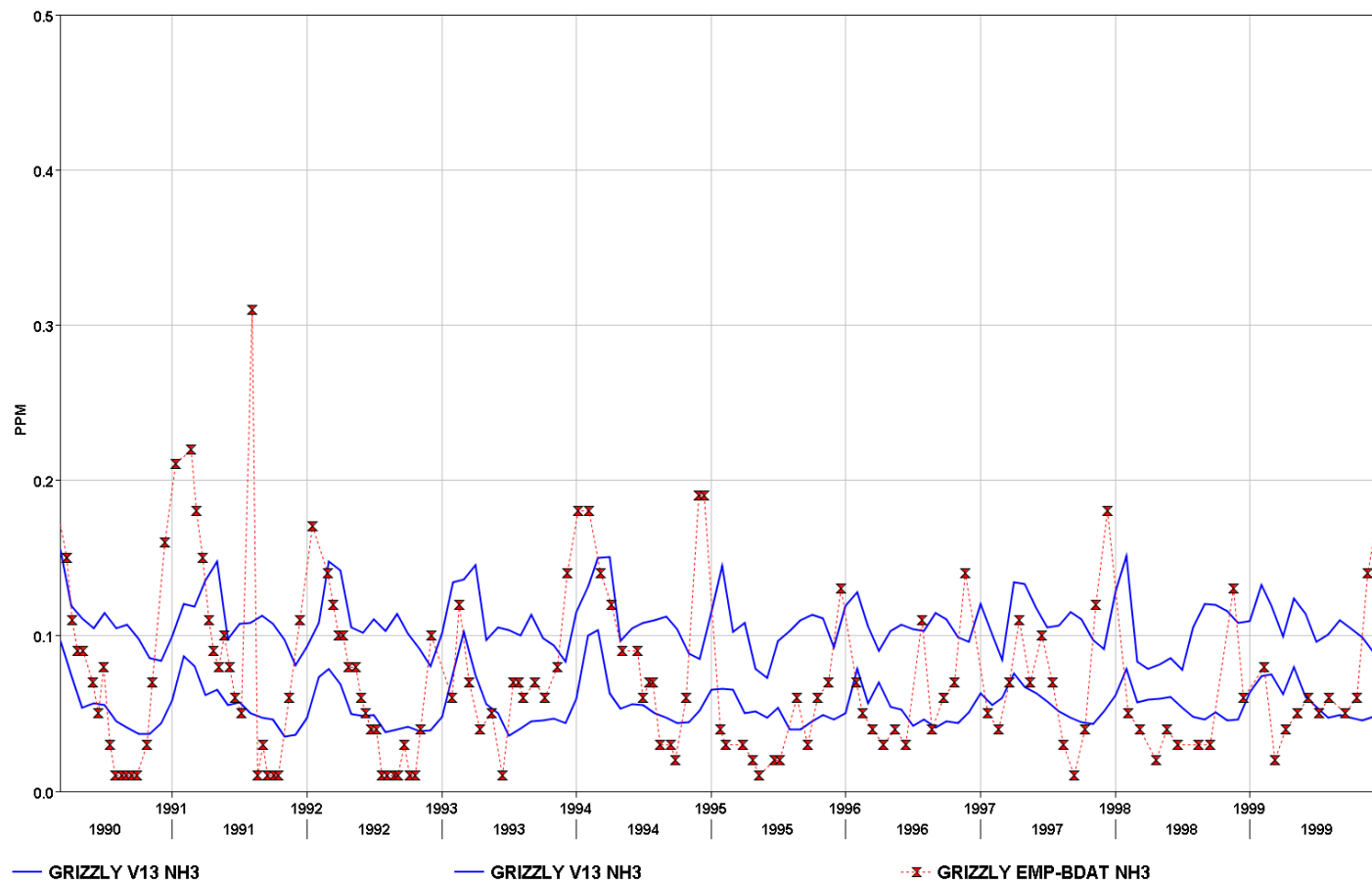


Figure A II. 16 Ammonia at GRIZZLY early years.

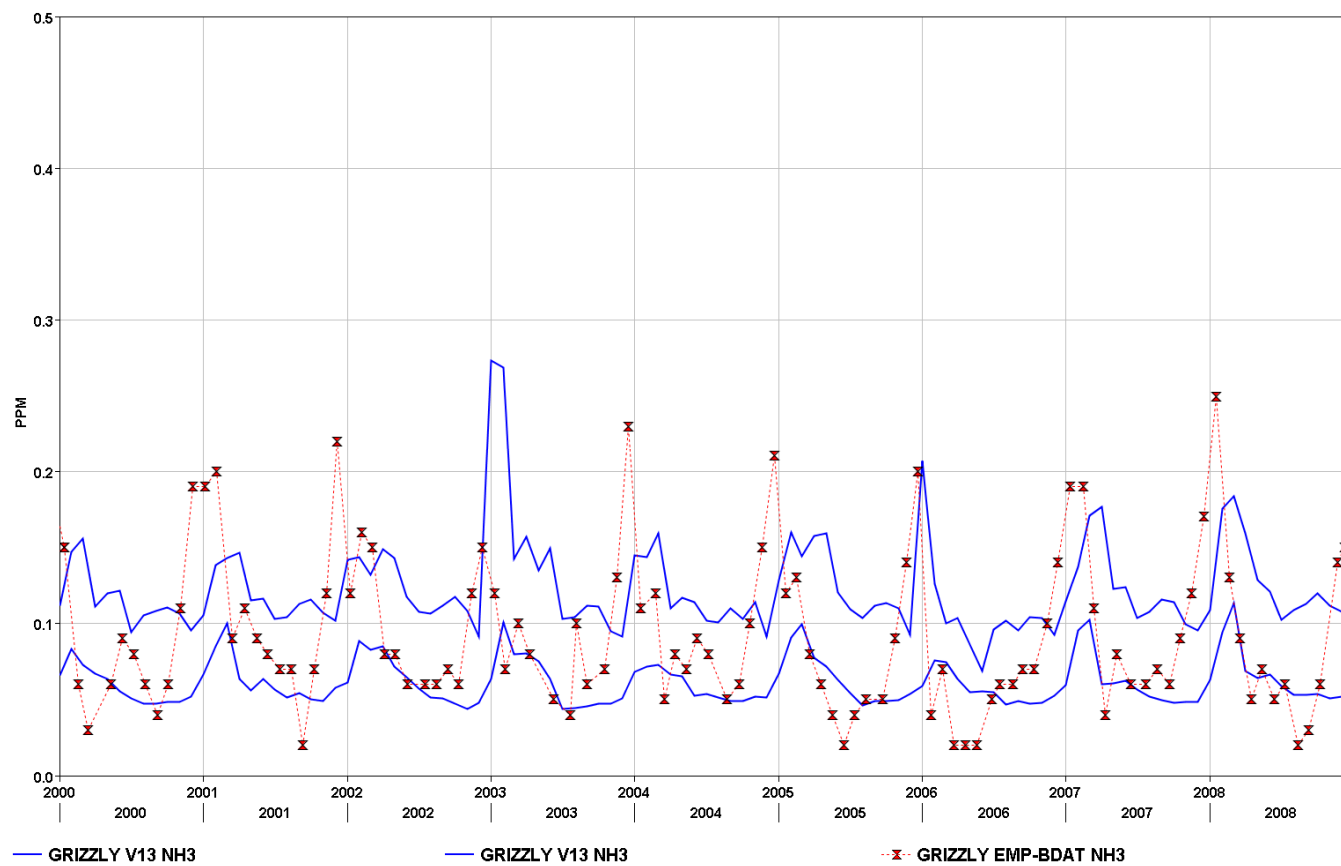


Figure A II. 17 Ammonia at GRIZZLY later years.

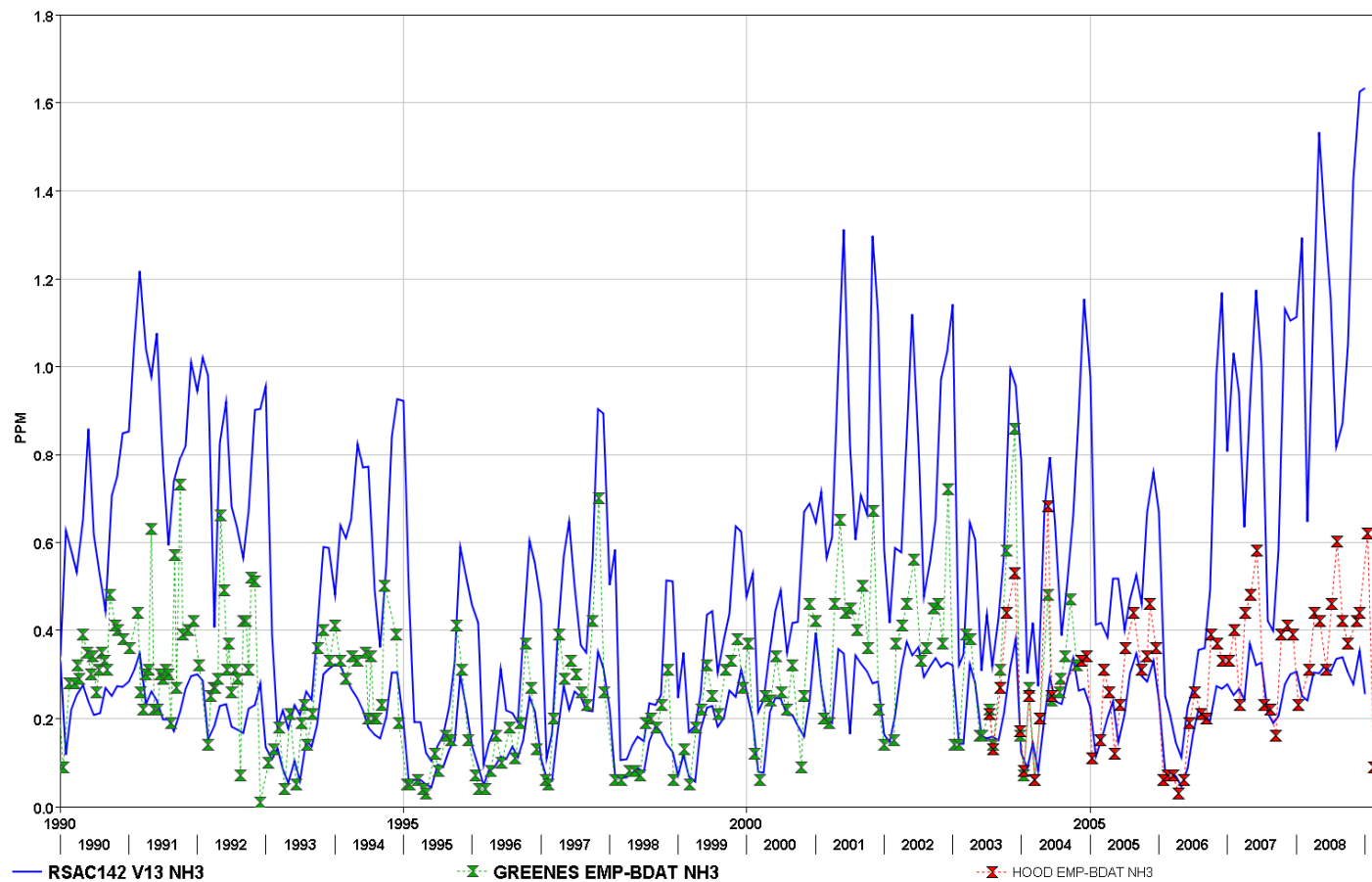


Figure A II. 18 Ammonia at RSAC142 all years

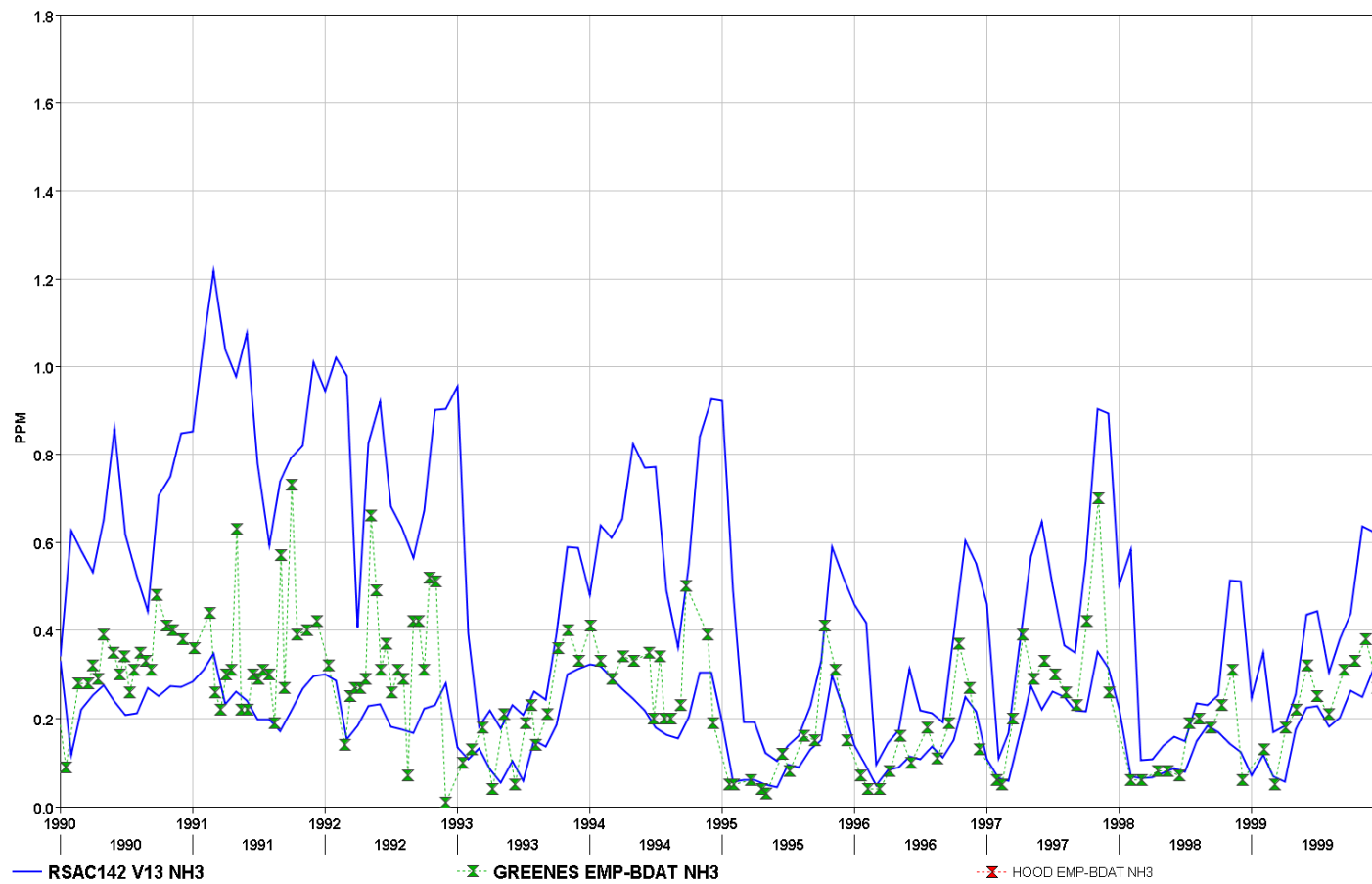


Figure A II. 19 Ammonia at RSAC142 early years

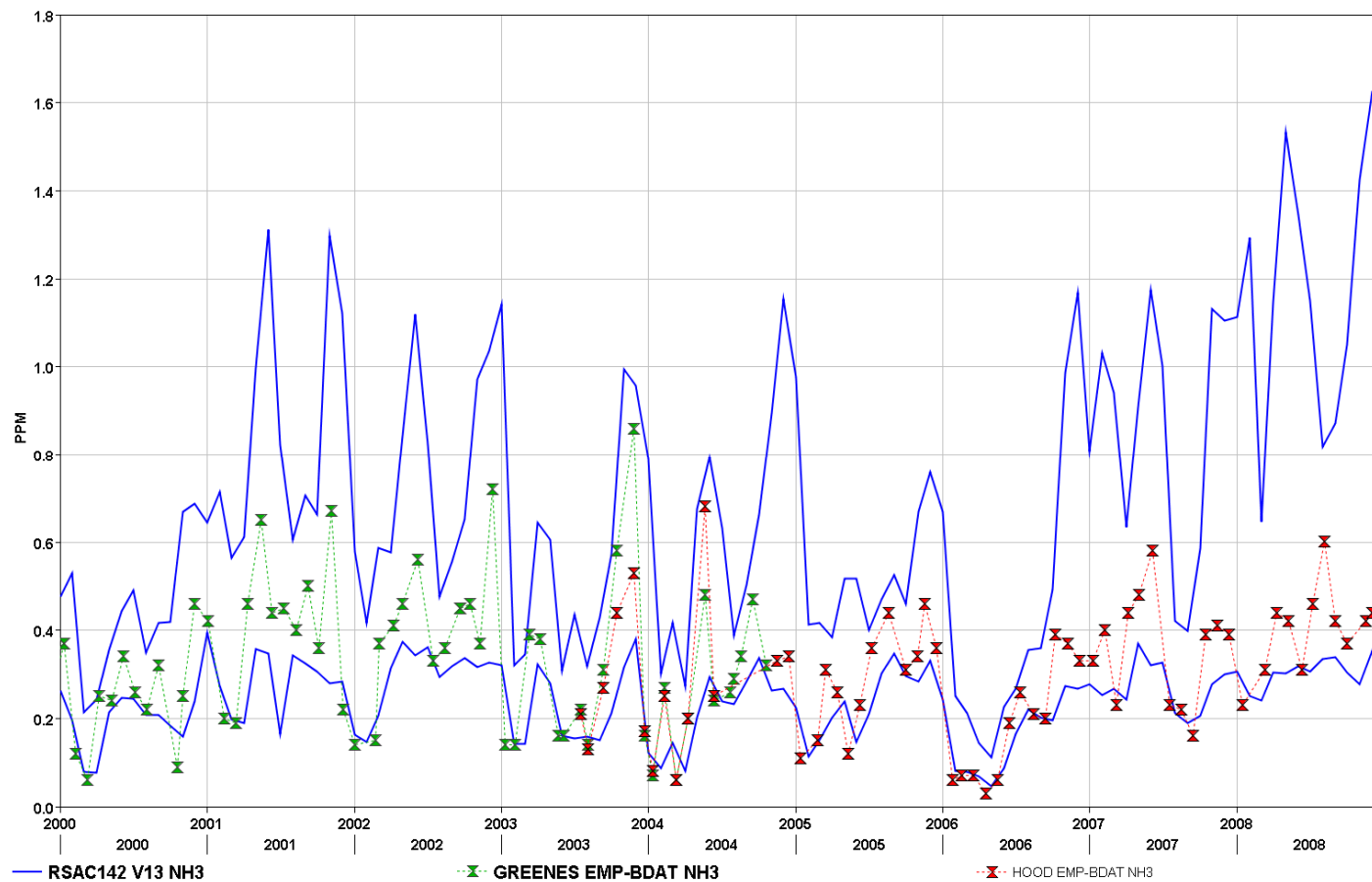


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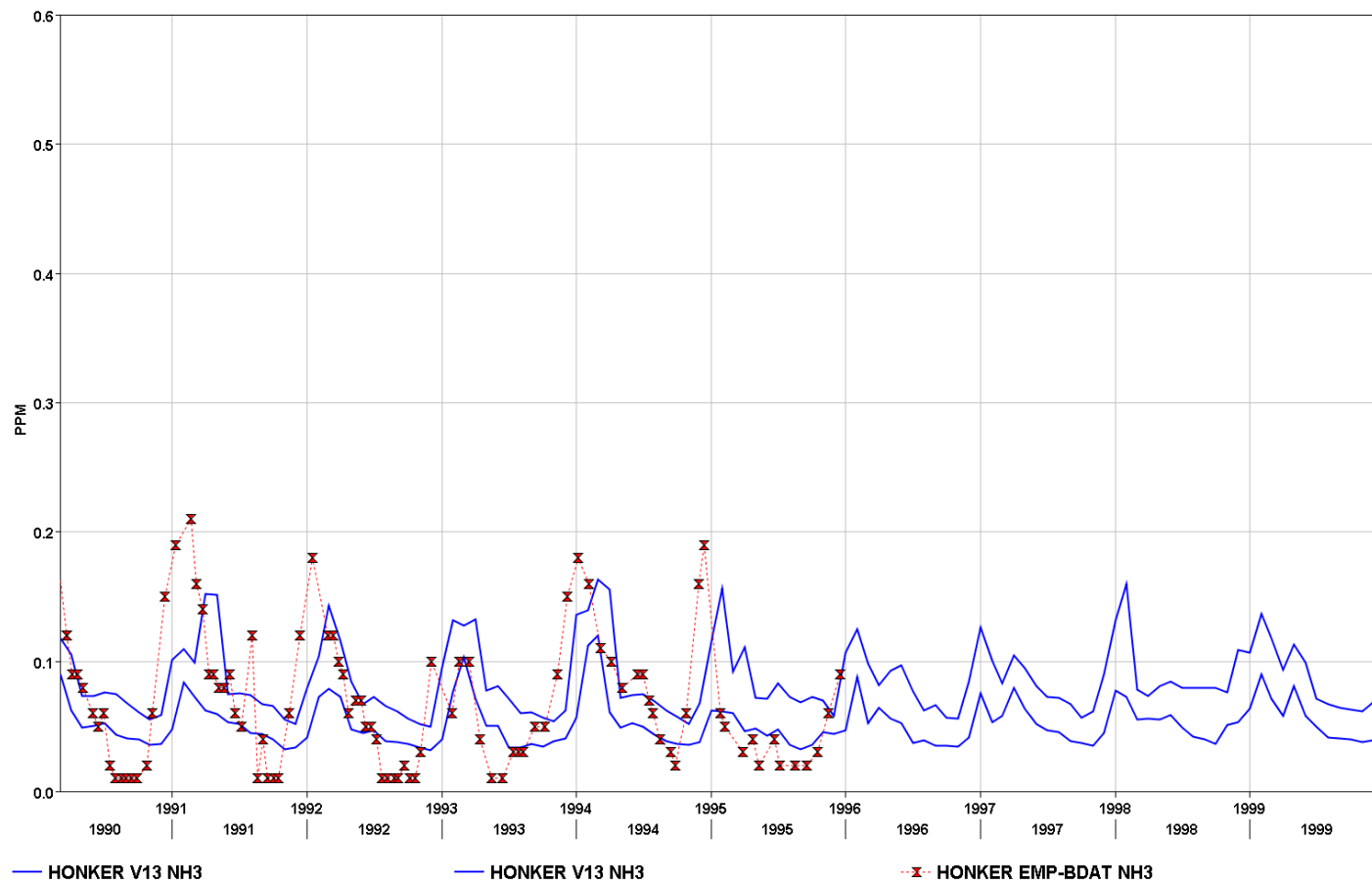


Figure A II. 21 Ammonia at HONKER early years

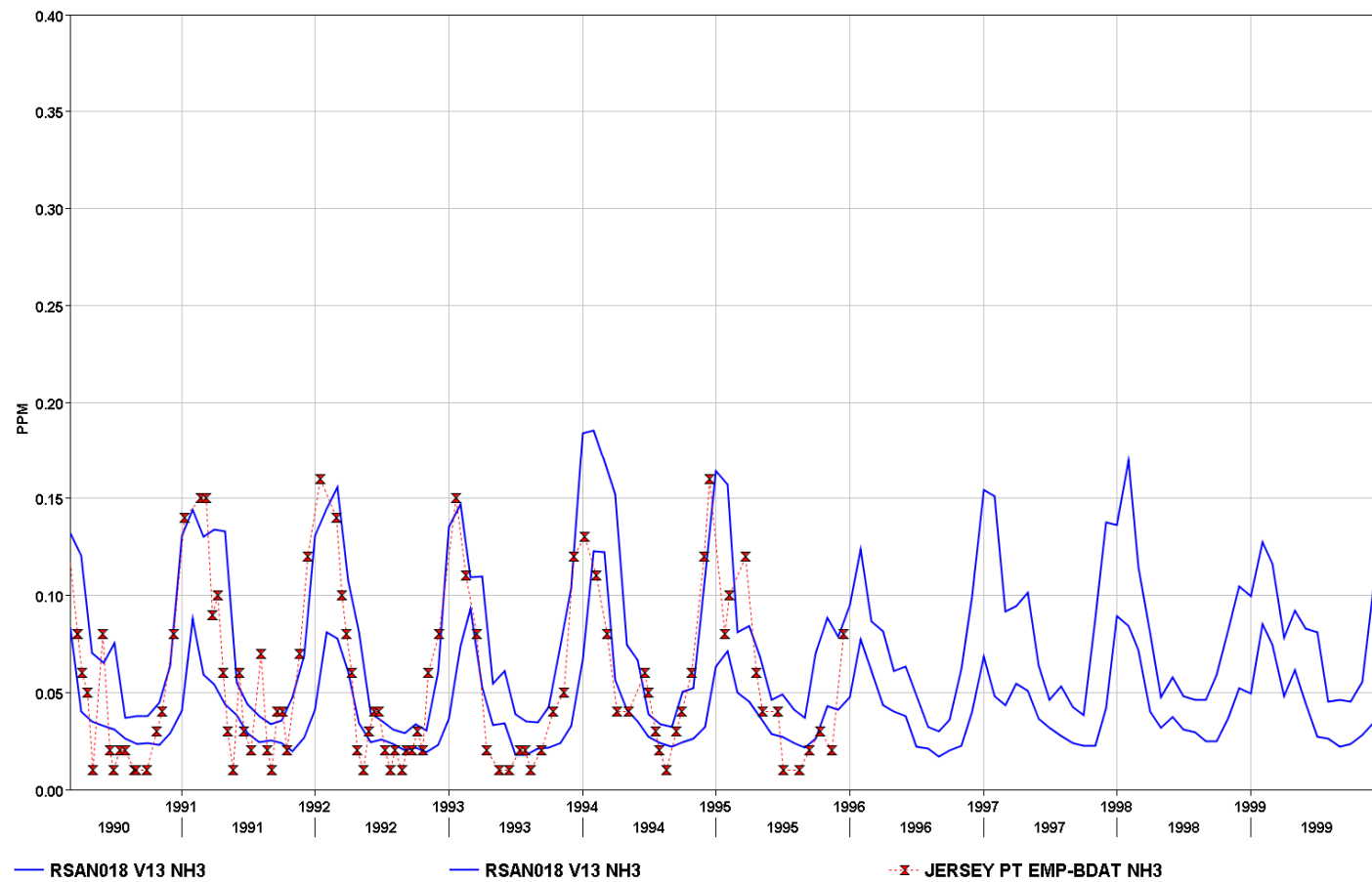


Figure A II. 22 Ammonia at RSAN018 early years

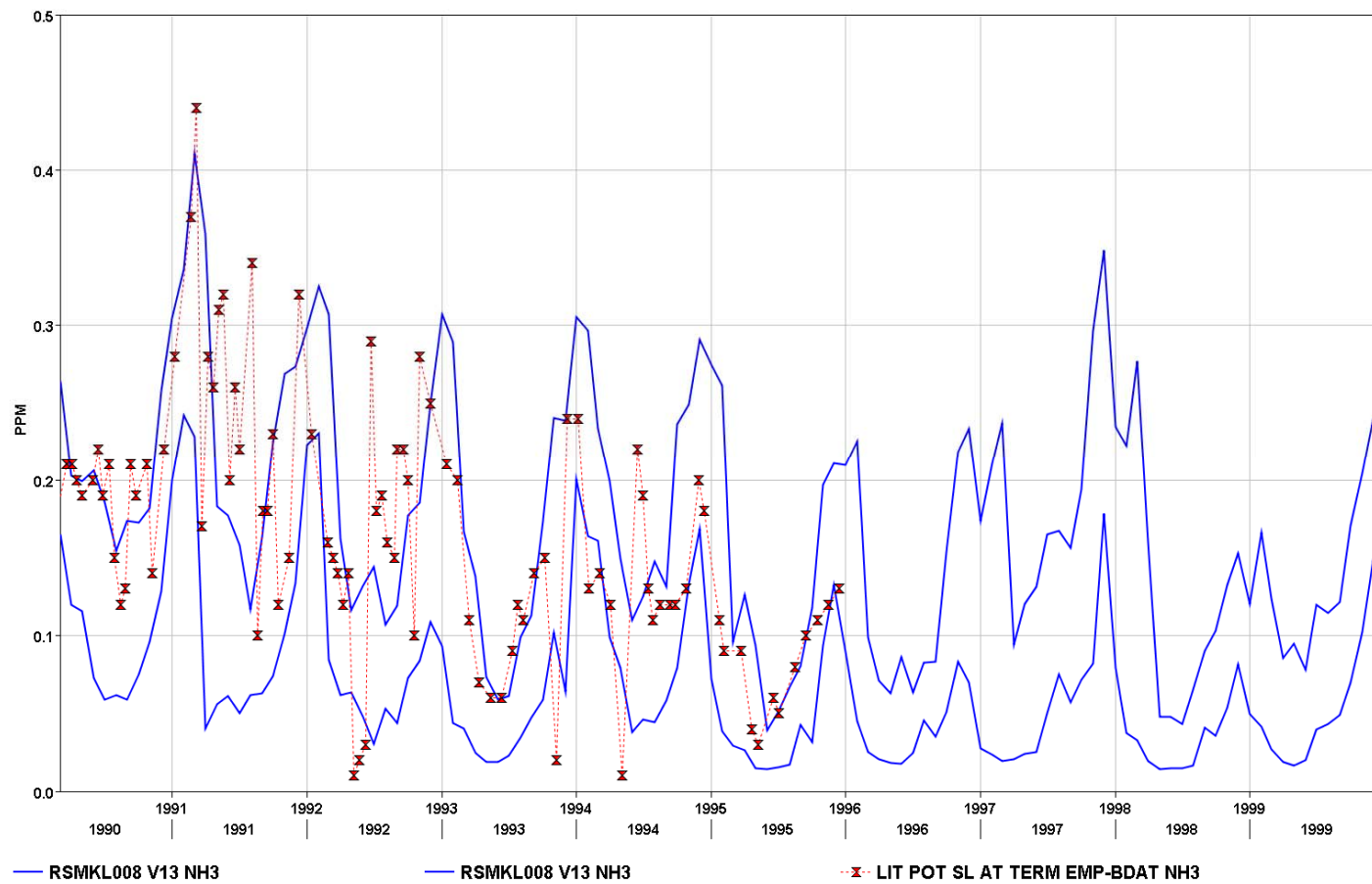


Figure A II. 23 Ammonia at RSMKL008 early years

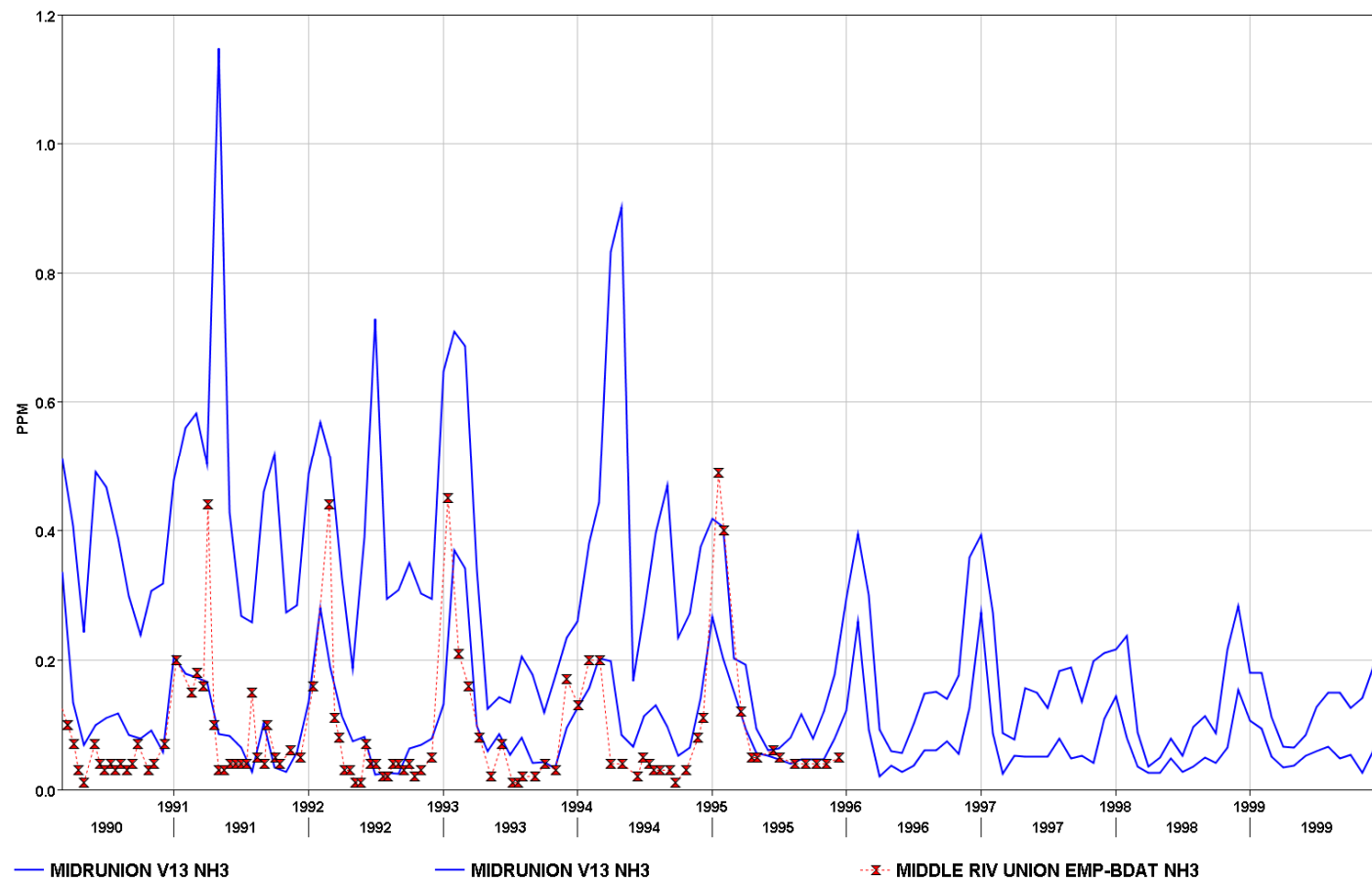


Figure A II. 24 Ammonia at MID RIV UNION early years

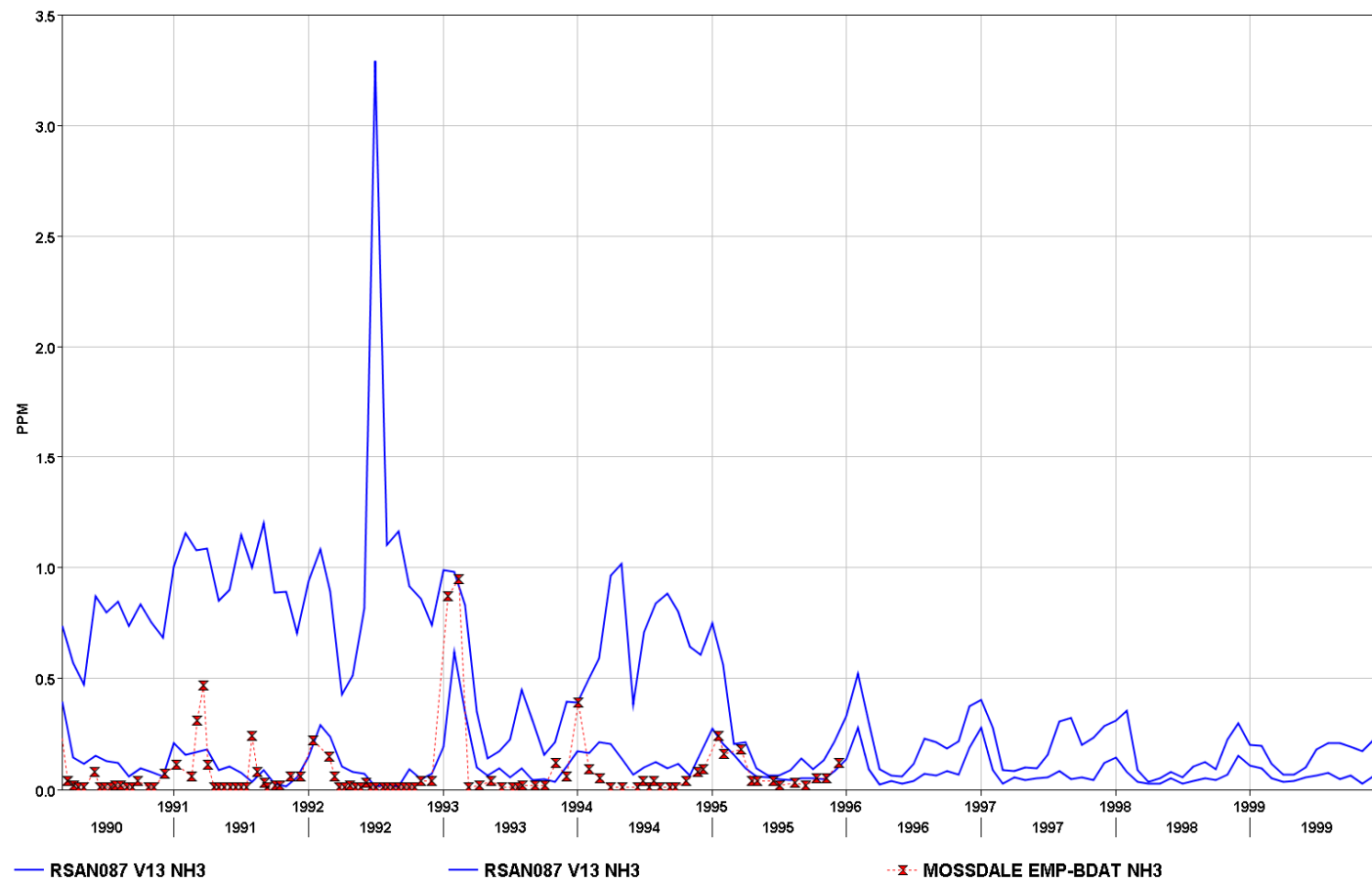


Figure A II. 25 Ammonia at RSAN087 early years

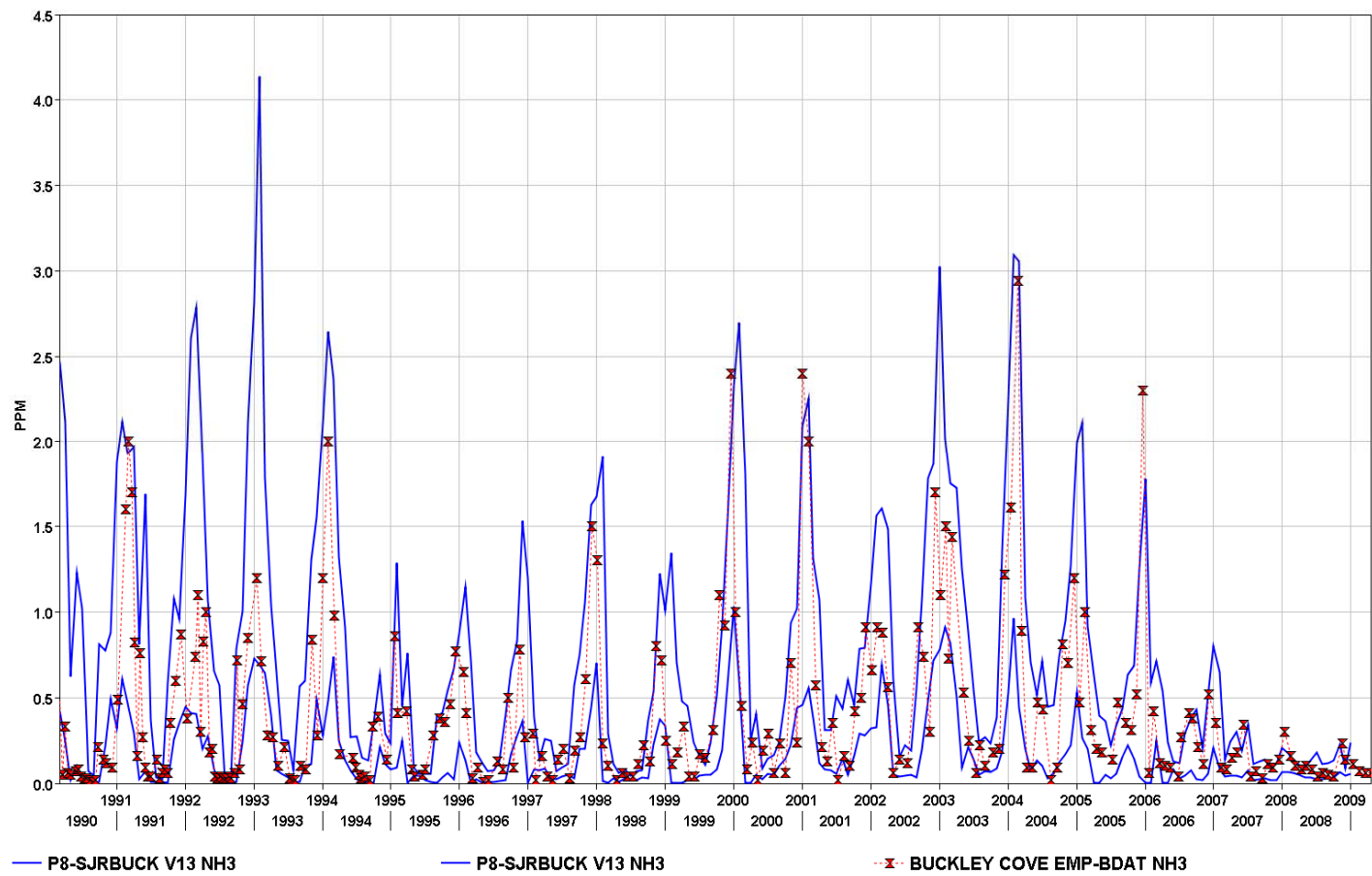


Figure A II. 26 Ammonia at SJR BUCKLEY all years

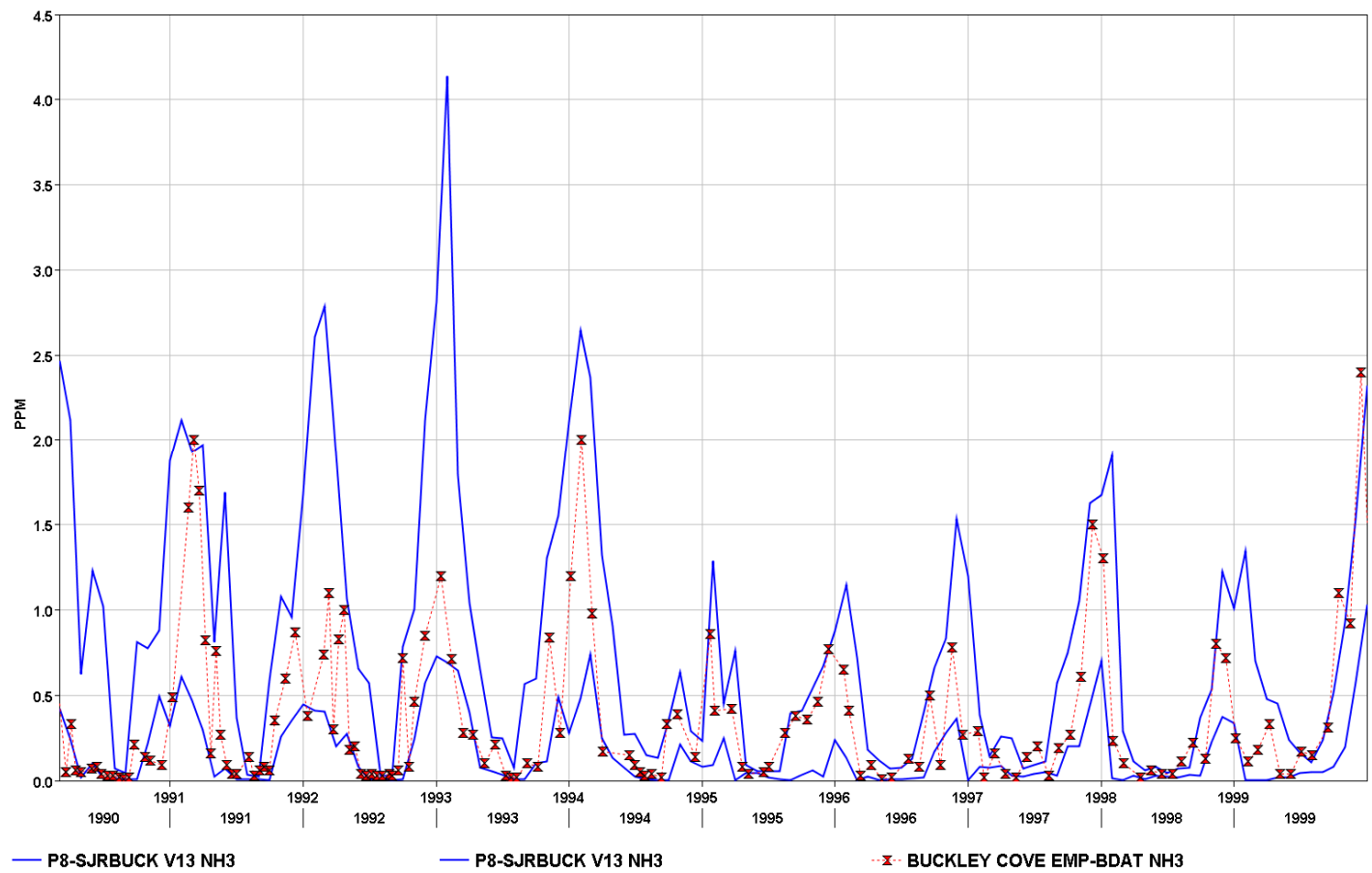


Figure A II. 27 Ammonia at SJR BUCKLEY early years

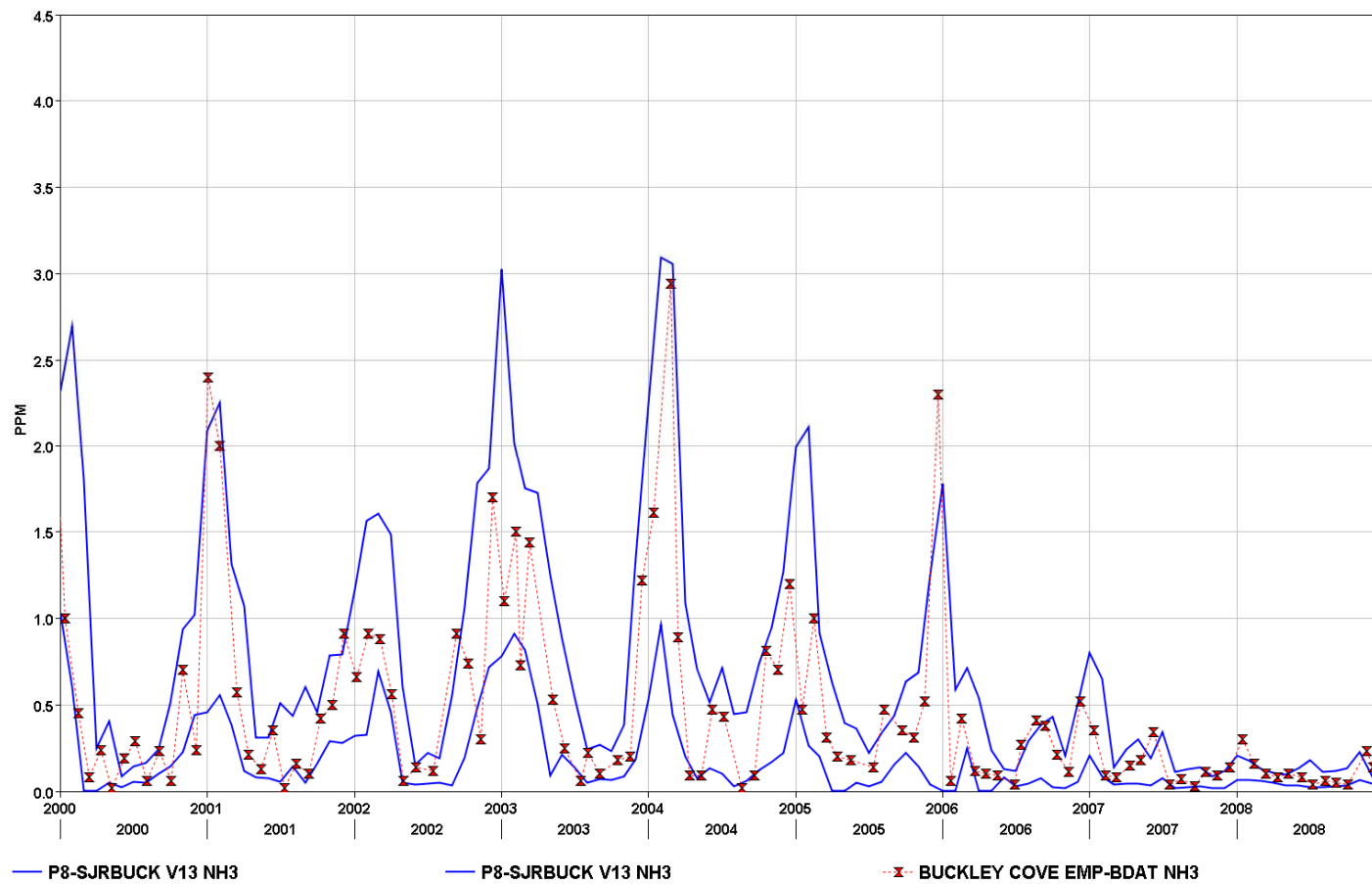


Figure A II. 28 Ammonia at SJR BUCKLEY later years

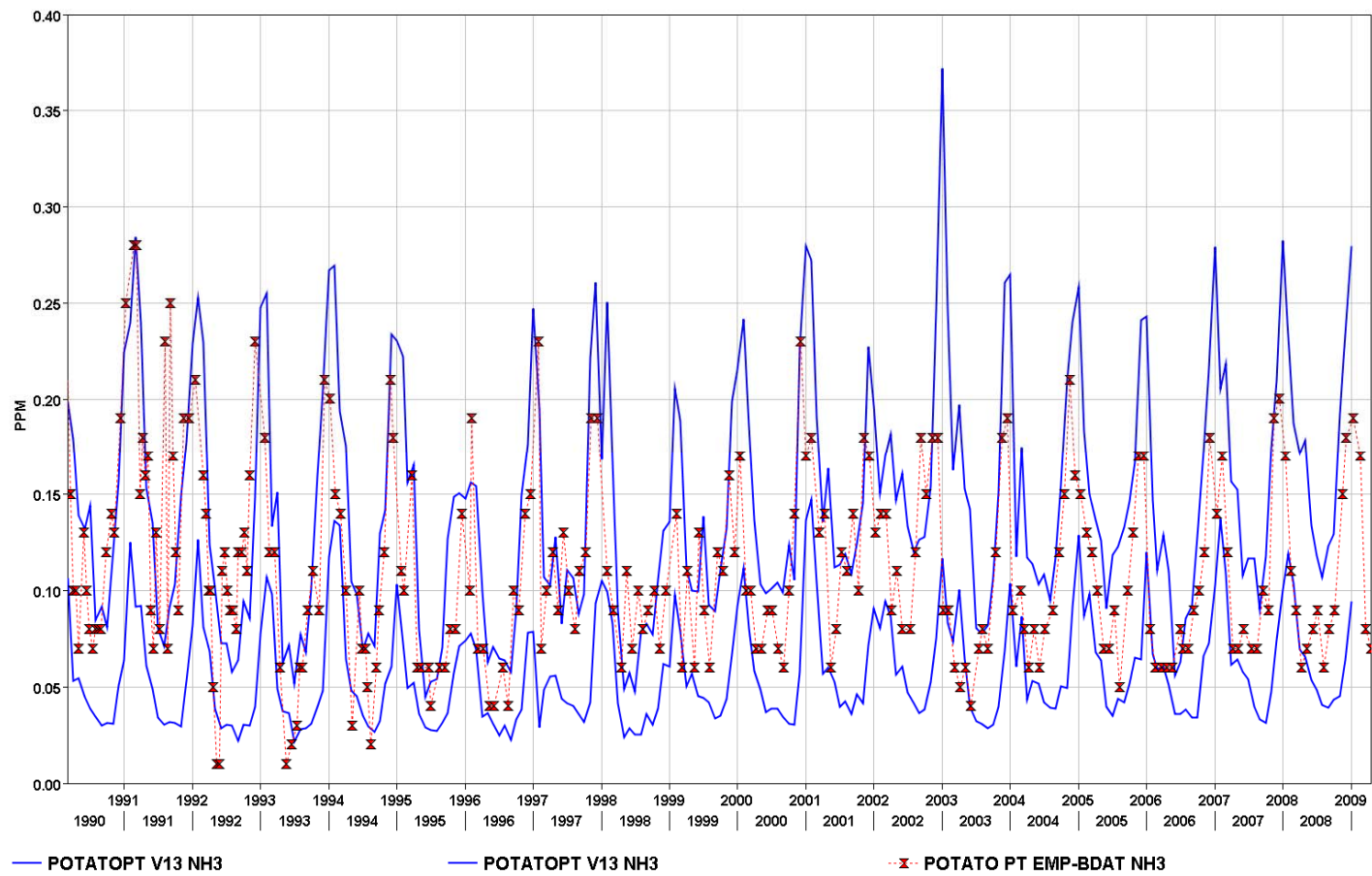


Figure A II. 29 Ammonia at POTATO PT all years

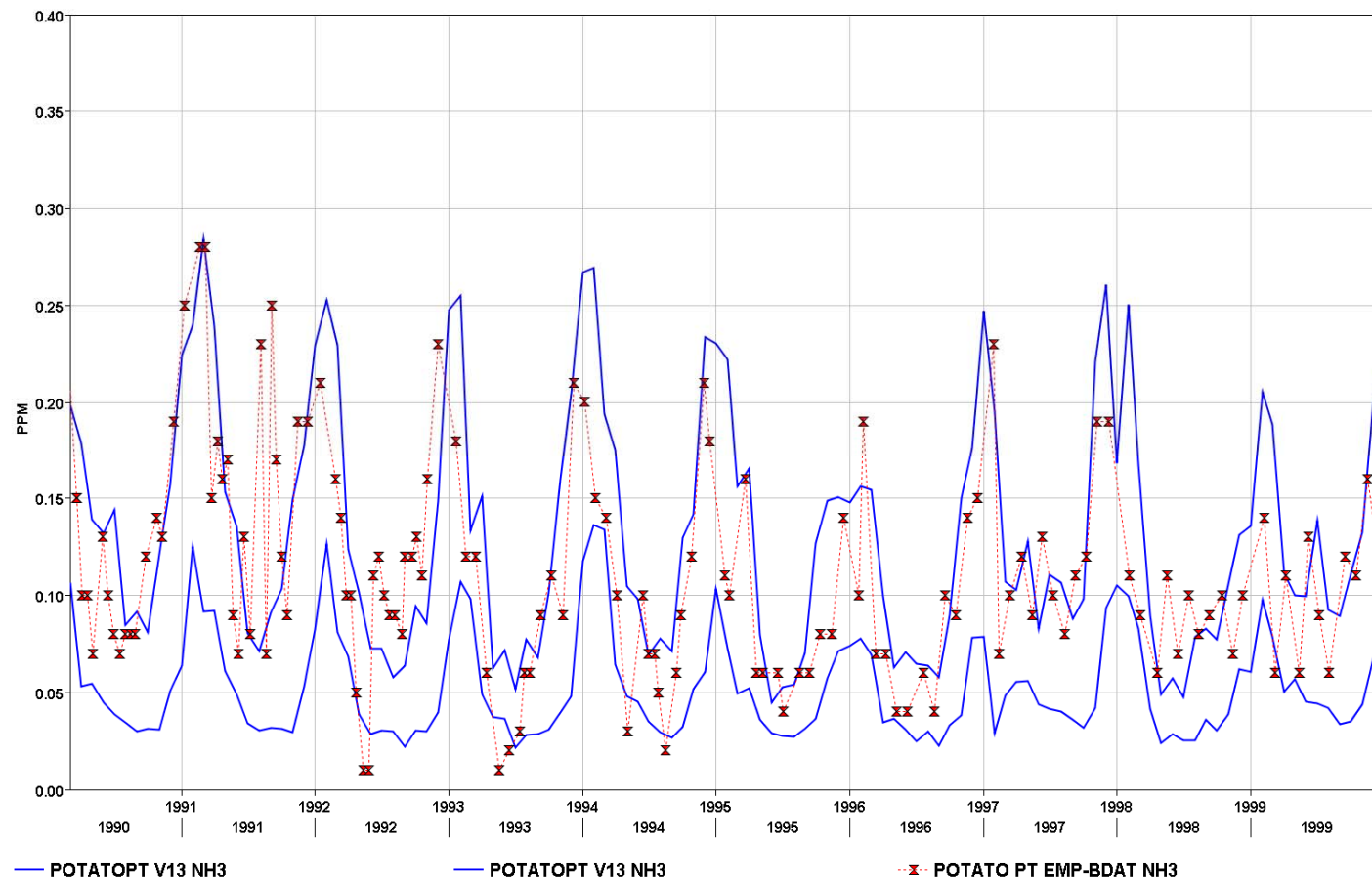


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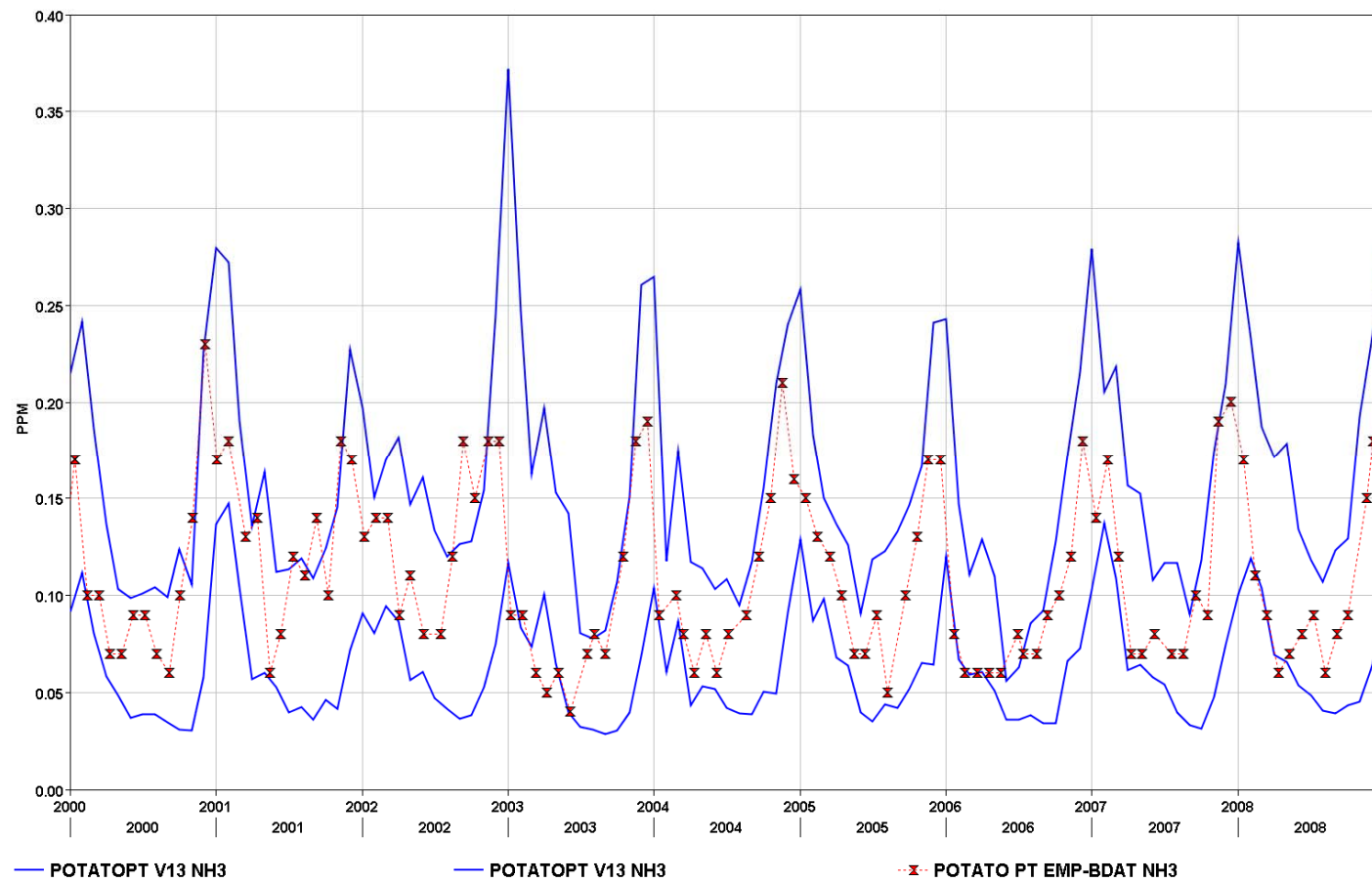


Figure A II. 31 Ammonia at POTATO PT later years

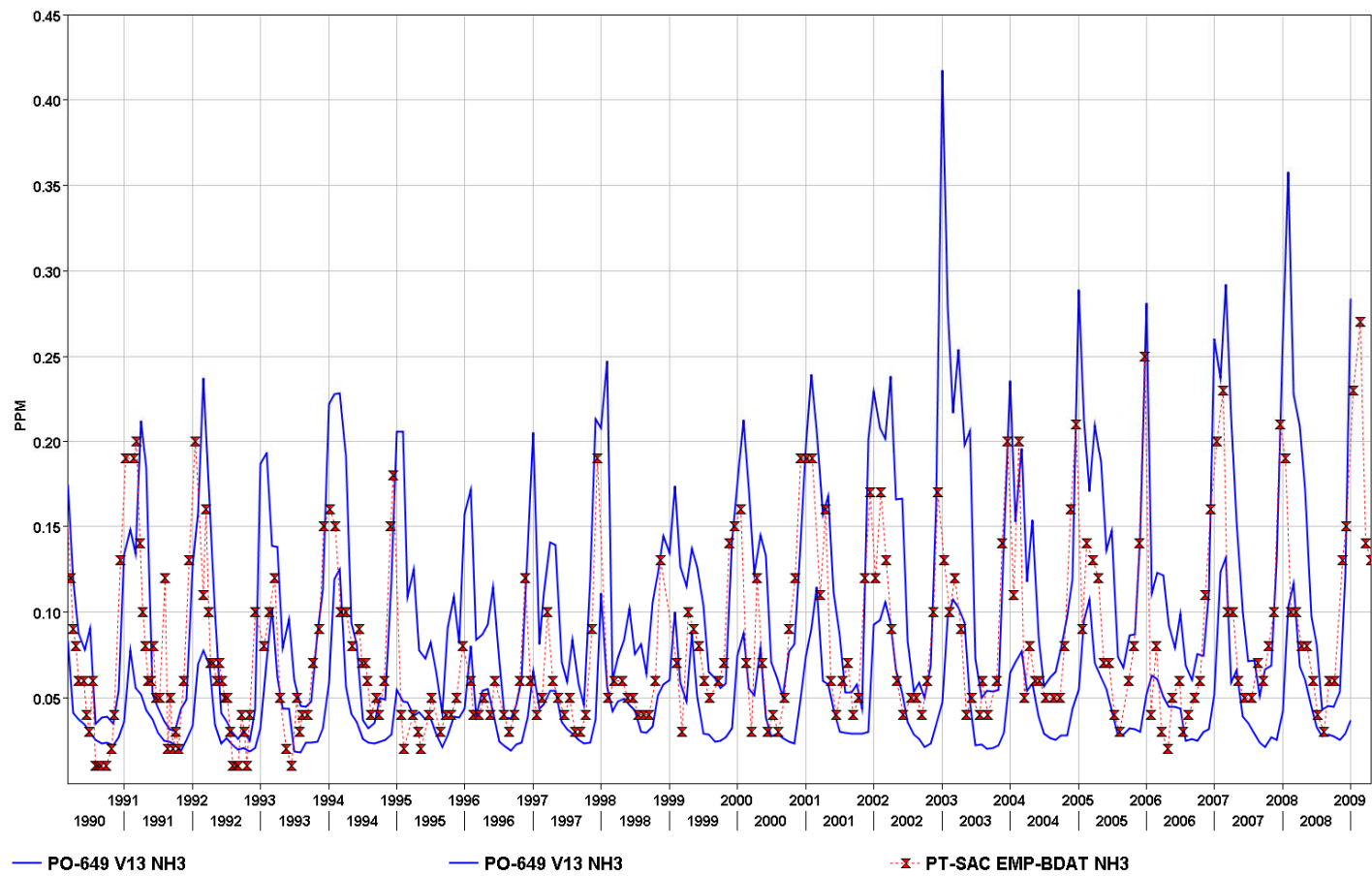


Figure A II. 32 Ammonia at PT SAC all years

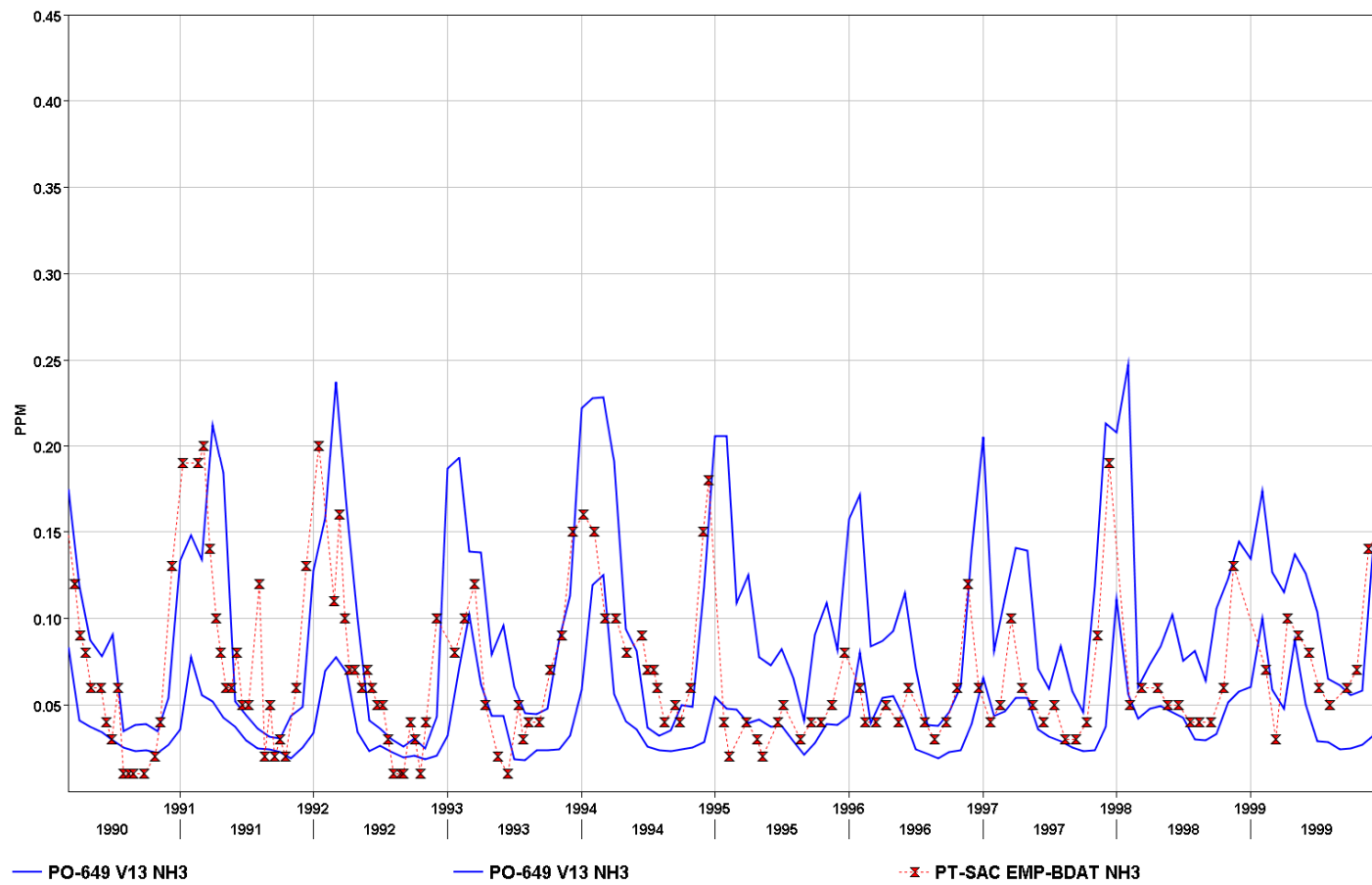


Figure A II. 33 Ammonia at PT SAC early years

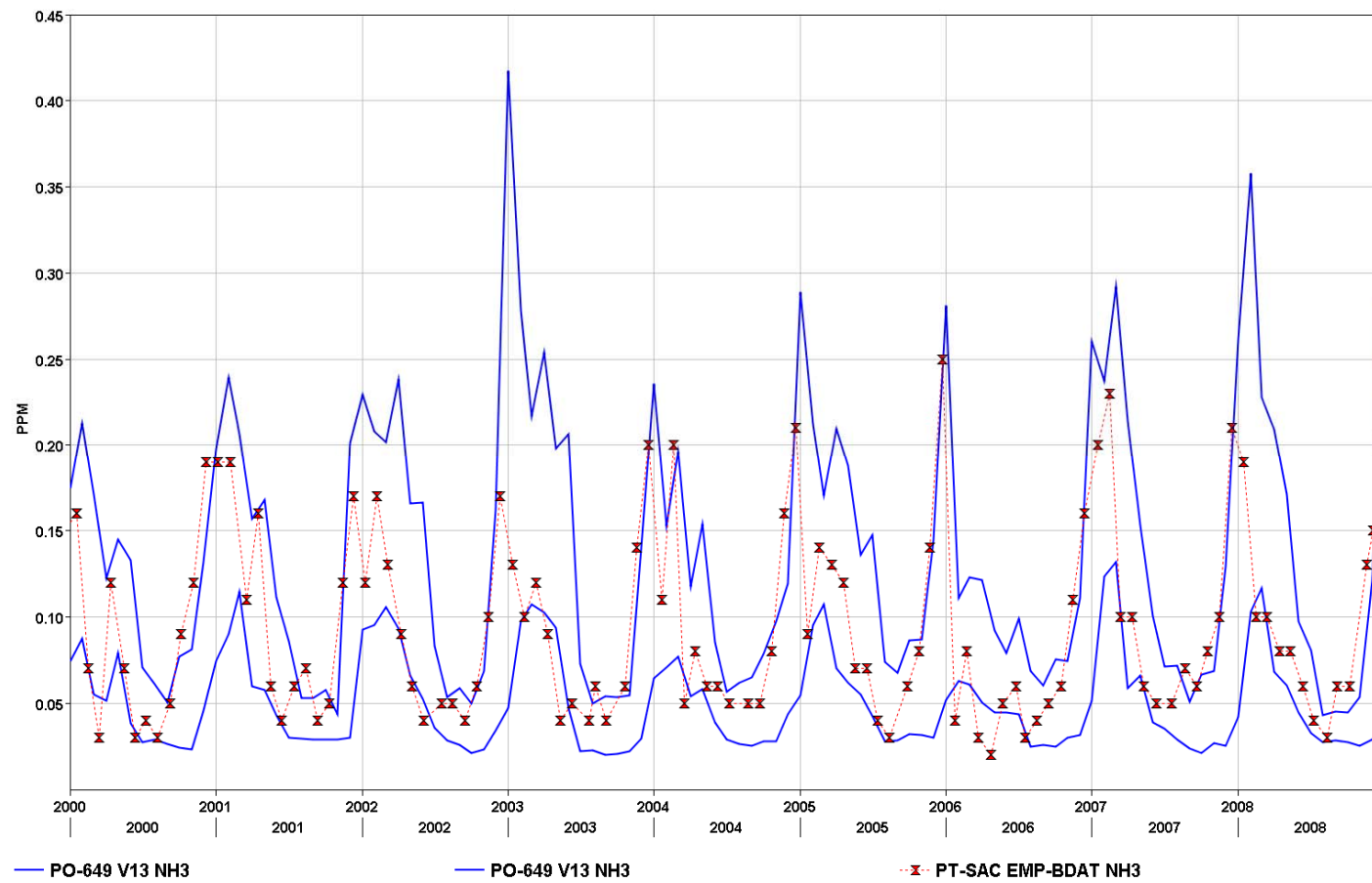


Figure A II. 34 Ammonia at PT SAC later years

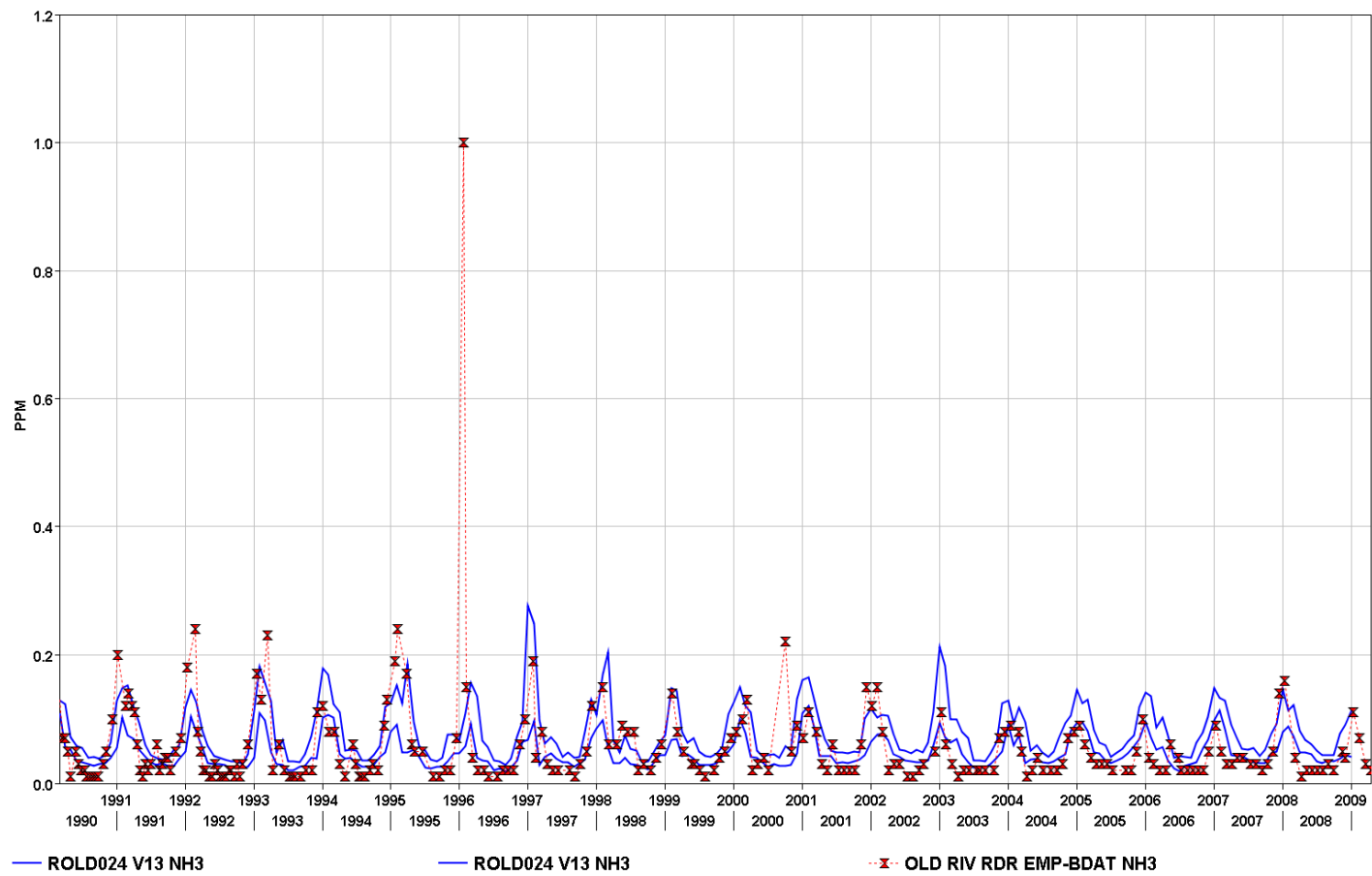


Figure A II. 35 Ammonia at ROLD024 all years

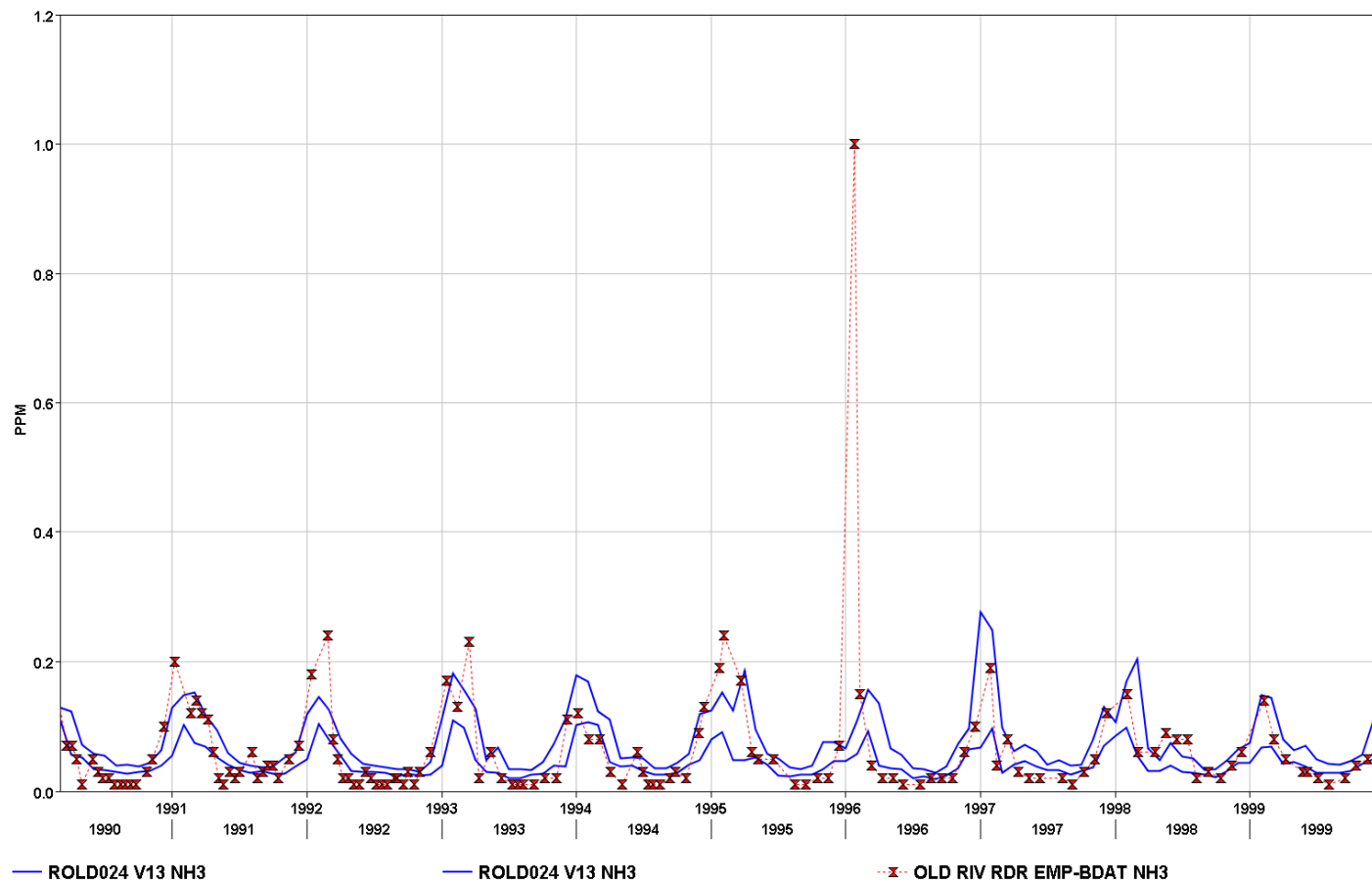


Figure A II. 36 Ammonia at ROLD024 early years

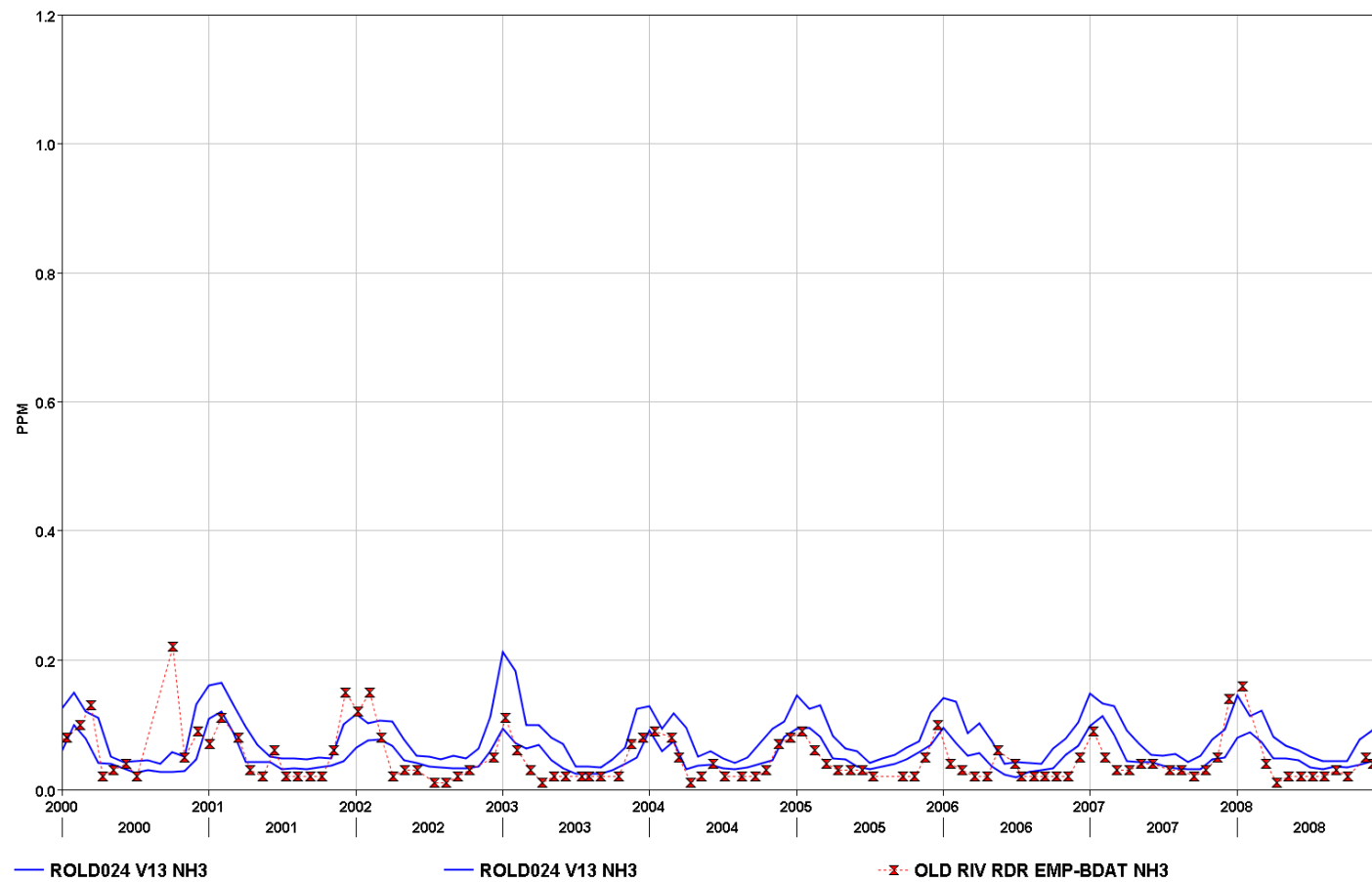


Figure A II. 37 Ammonia at ROLD024 later years

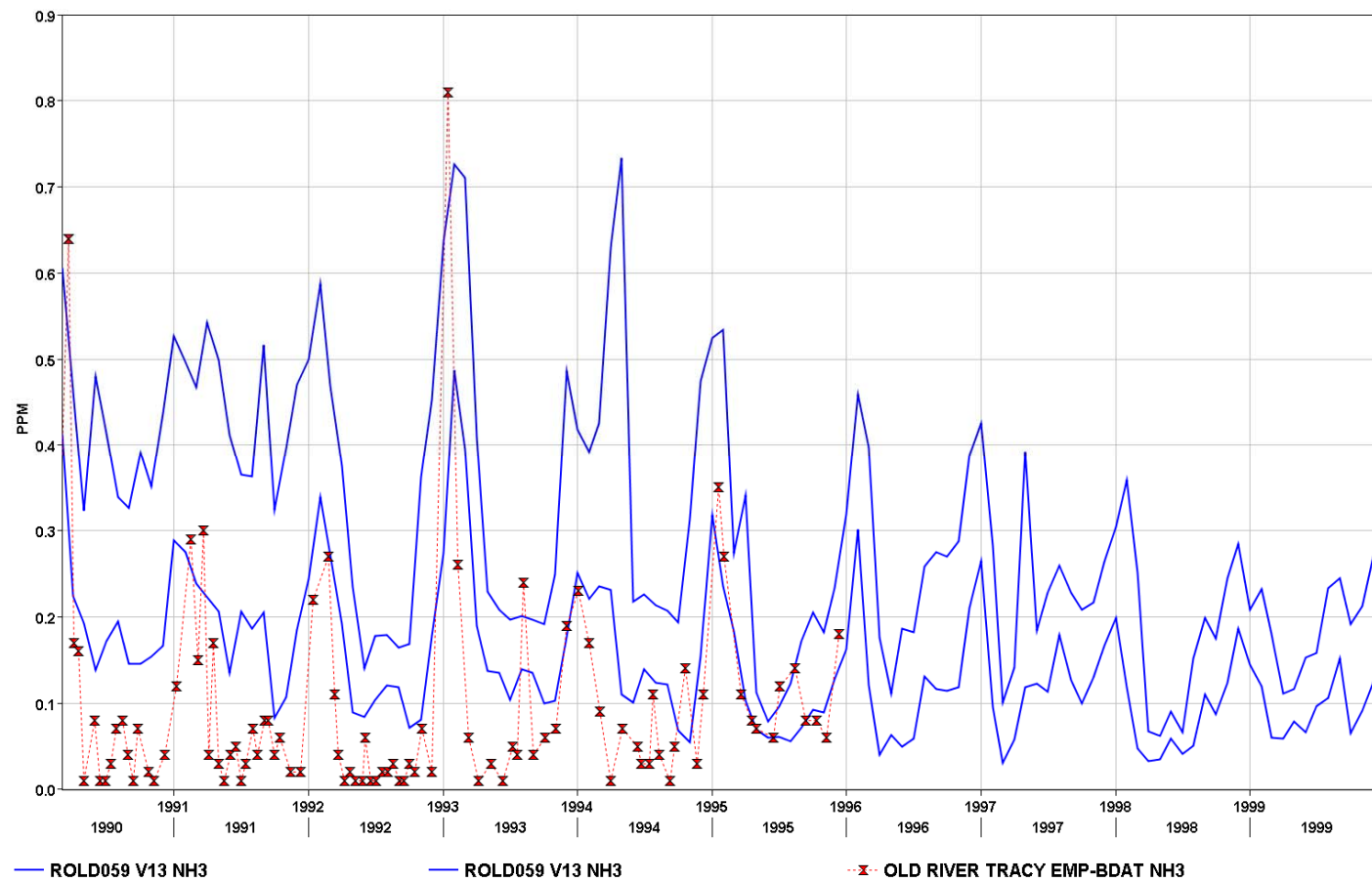


Figure A II. 38 Ammonia at ROLD059 early years

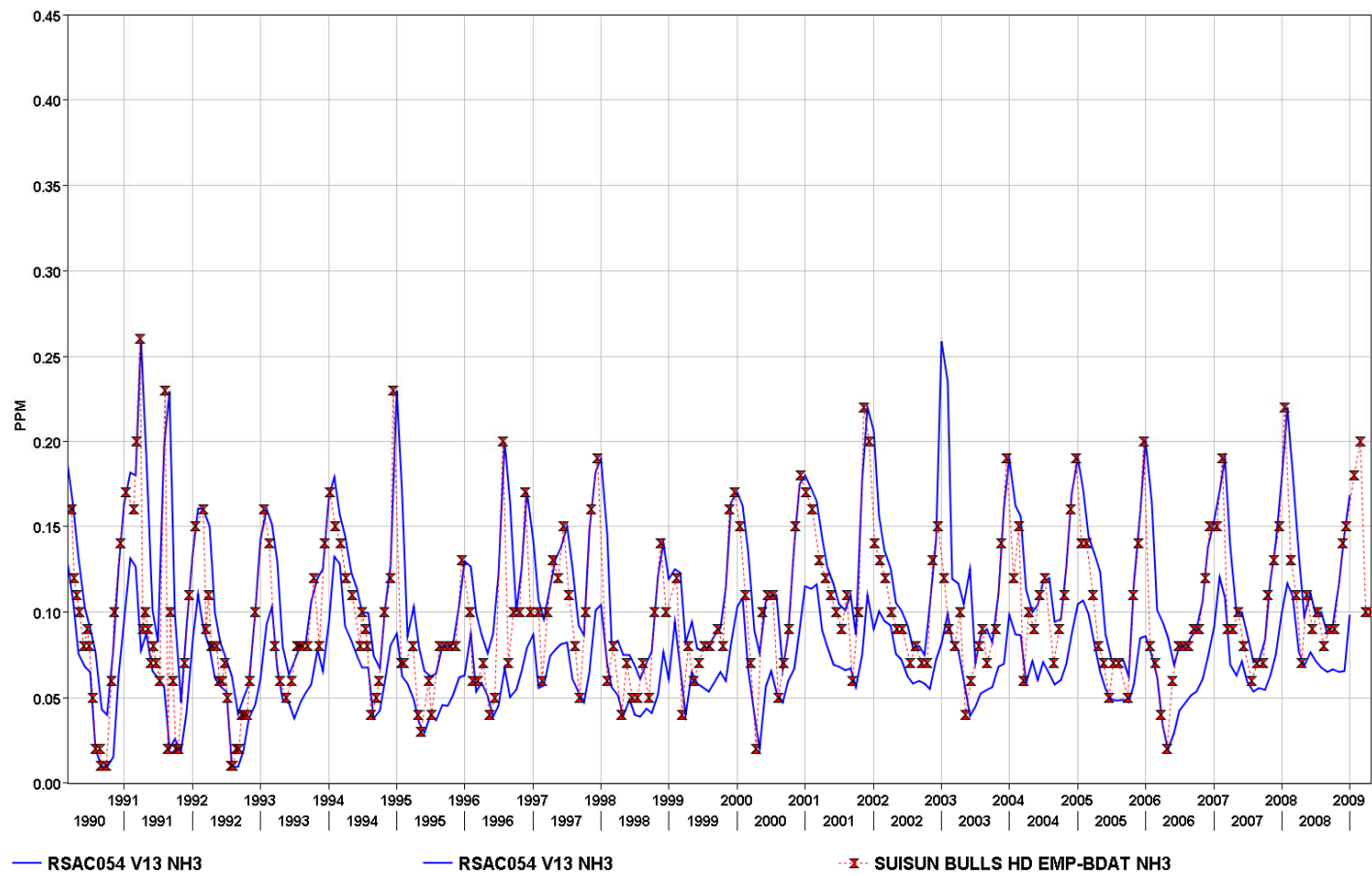


Figure A II. 39 Ammonia at RSAC054 all years

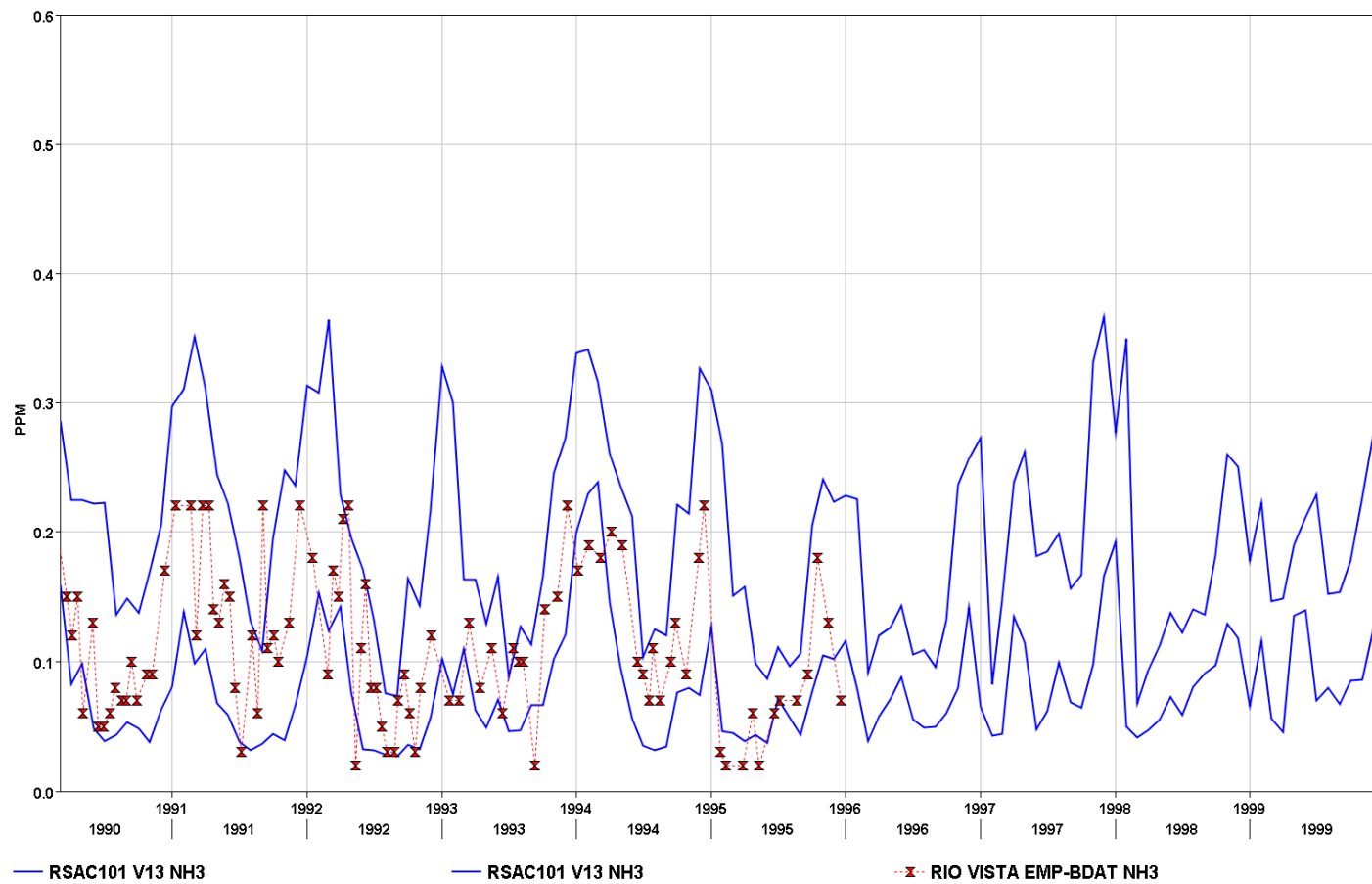


Figure A II. 40 Ammonia at RSAC101 early years

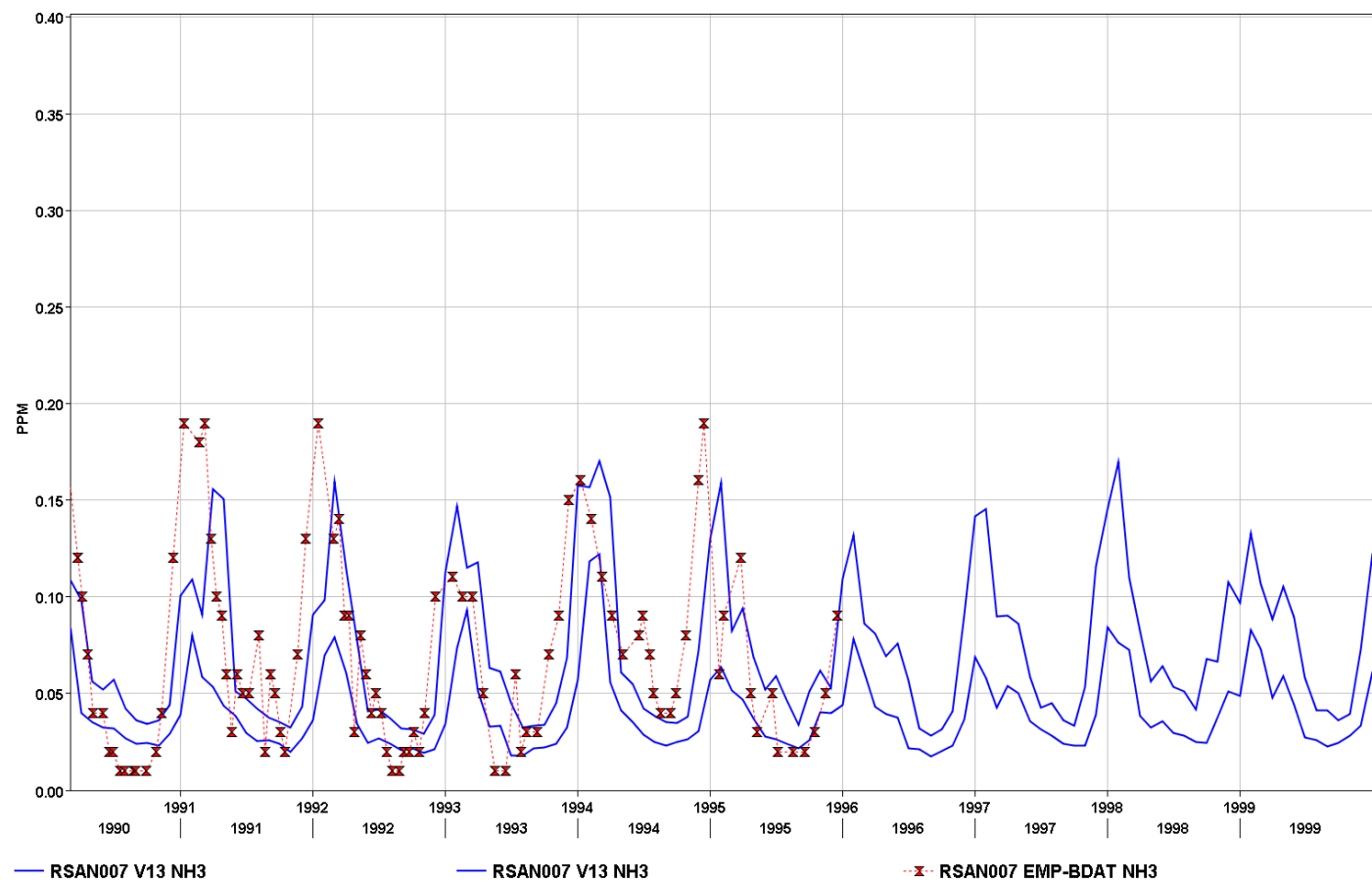


Figure A II. 41 Ammonia at RSAN007 early years

B. Figures for Nitrate+Nitrite

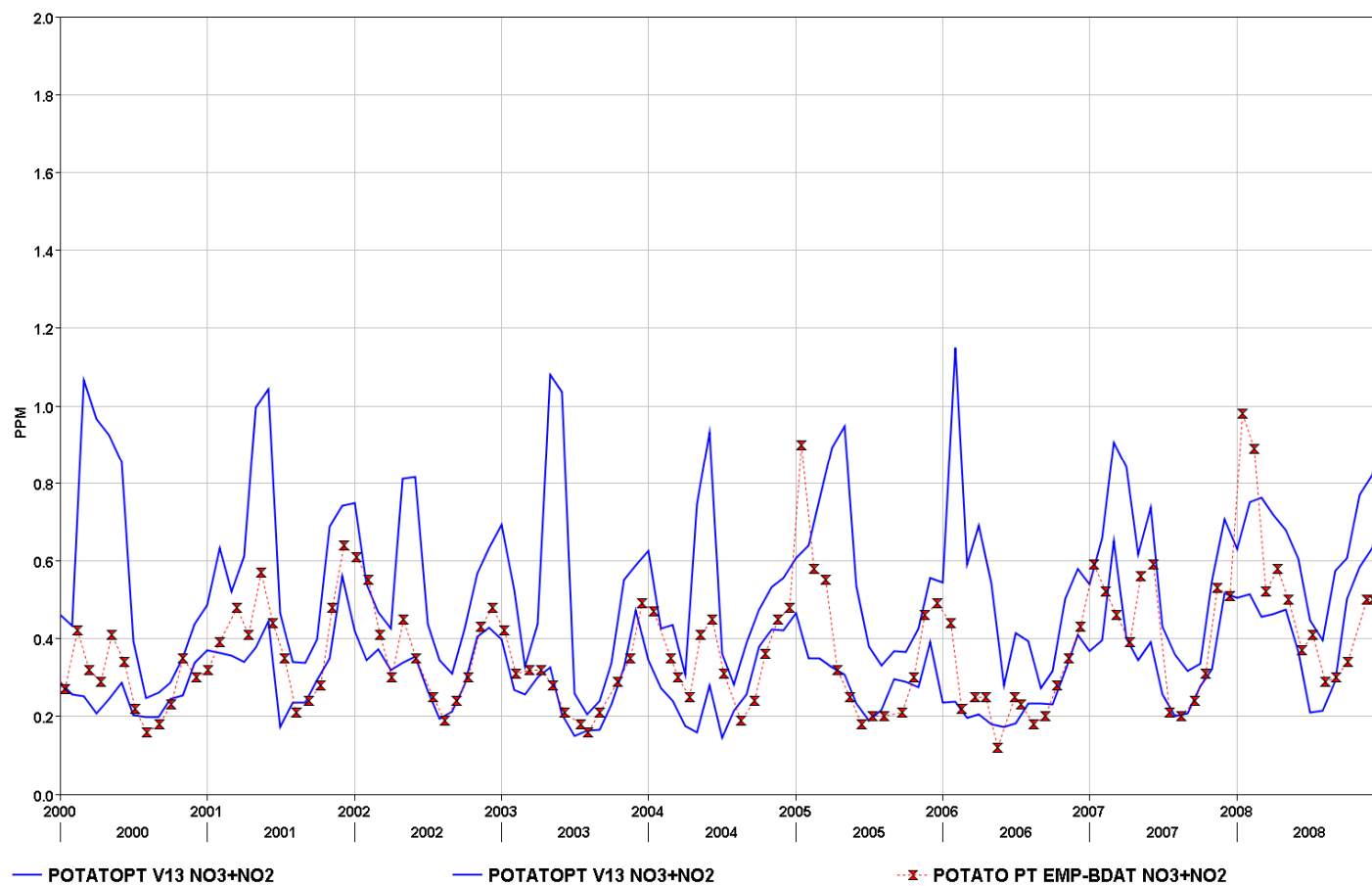


Figure A II. 42 Nitrate+Nitrite at Potato Pt. later years.

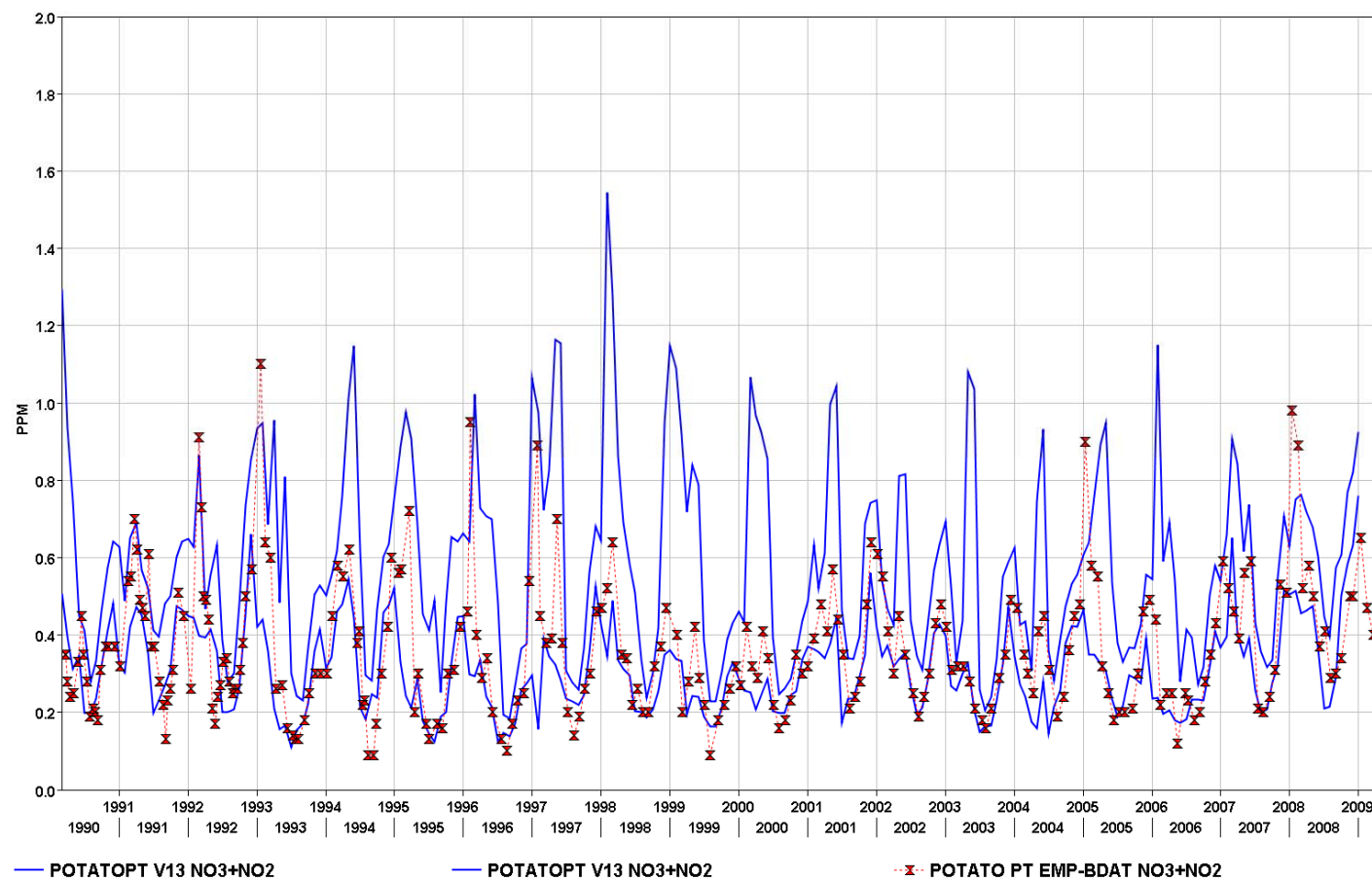


Figure A II. 43 Nitrate+Nitrite at Potato Pt. all years.

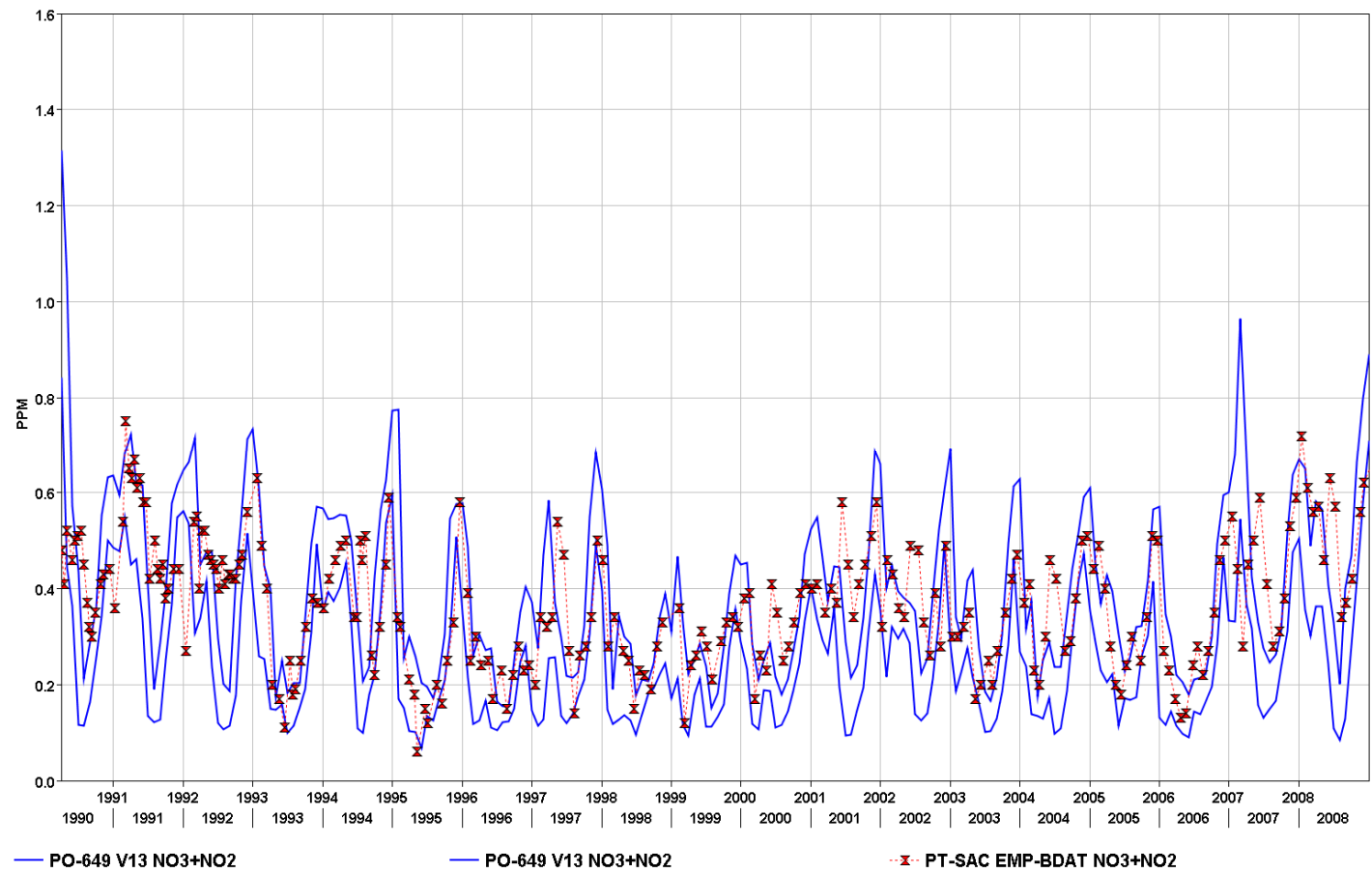


Figure A II. 44 Nitrate+Nitrite at PT SAC all years.

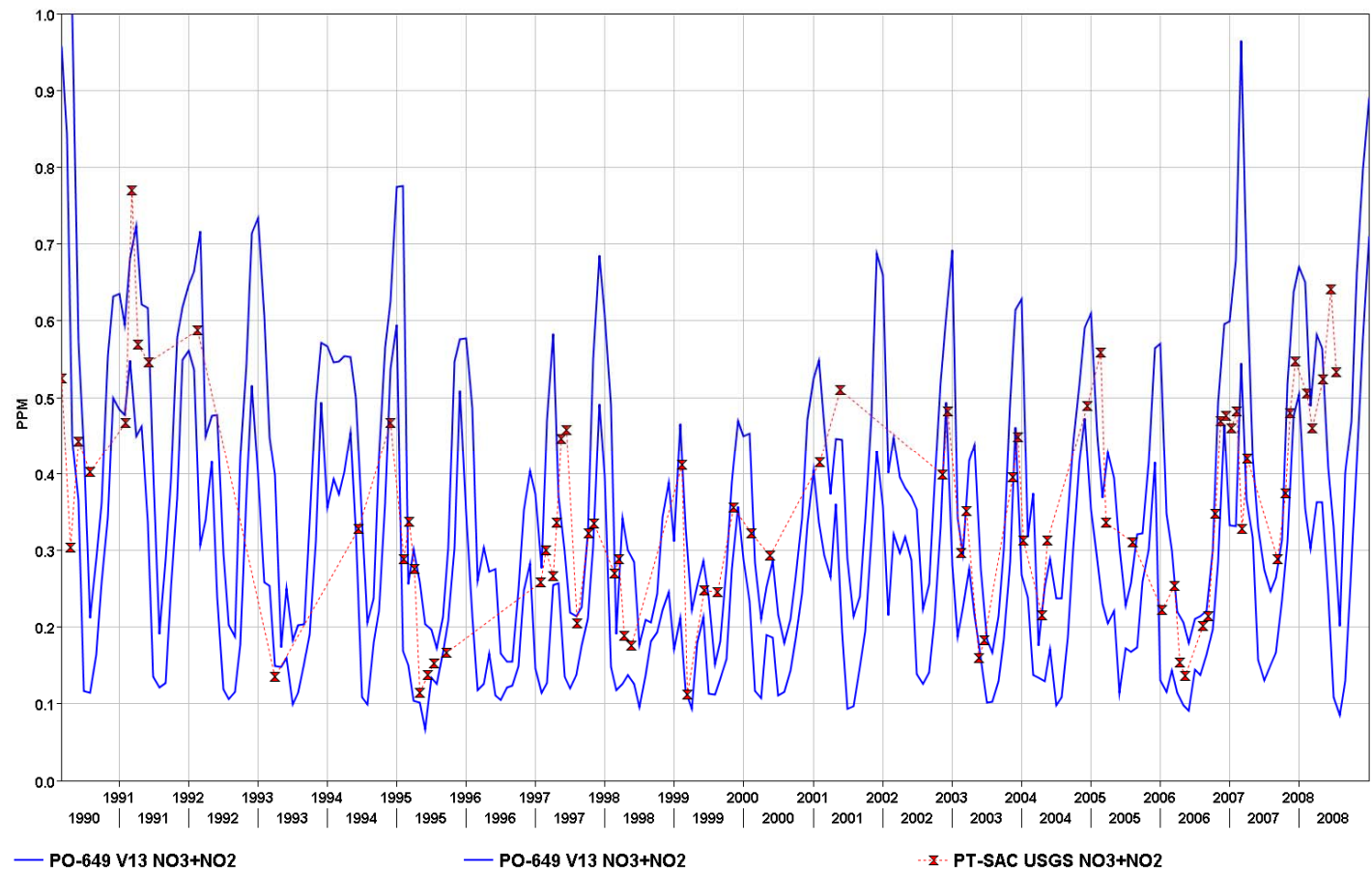


Figure A II. 45 Nitrate+Nitrite at PT SAC USGS all years.

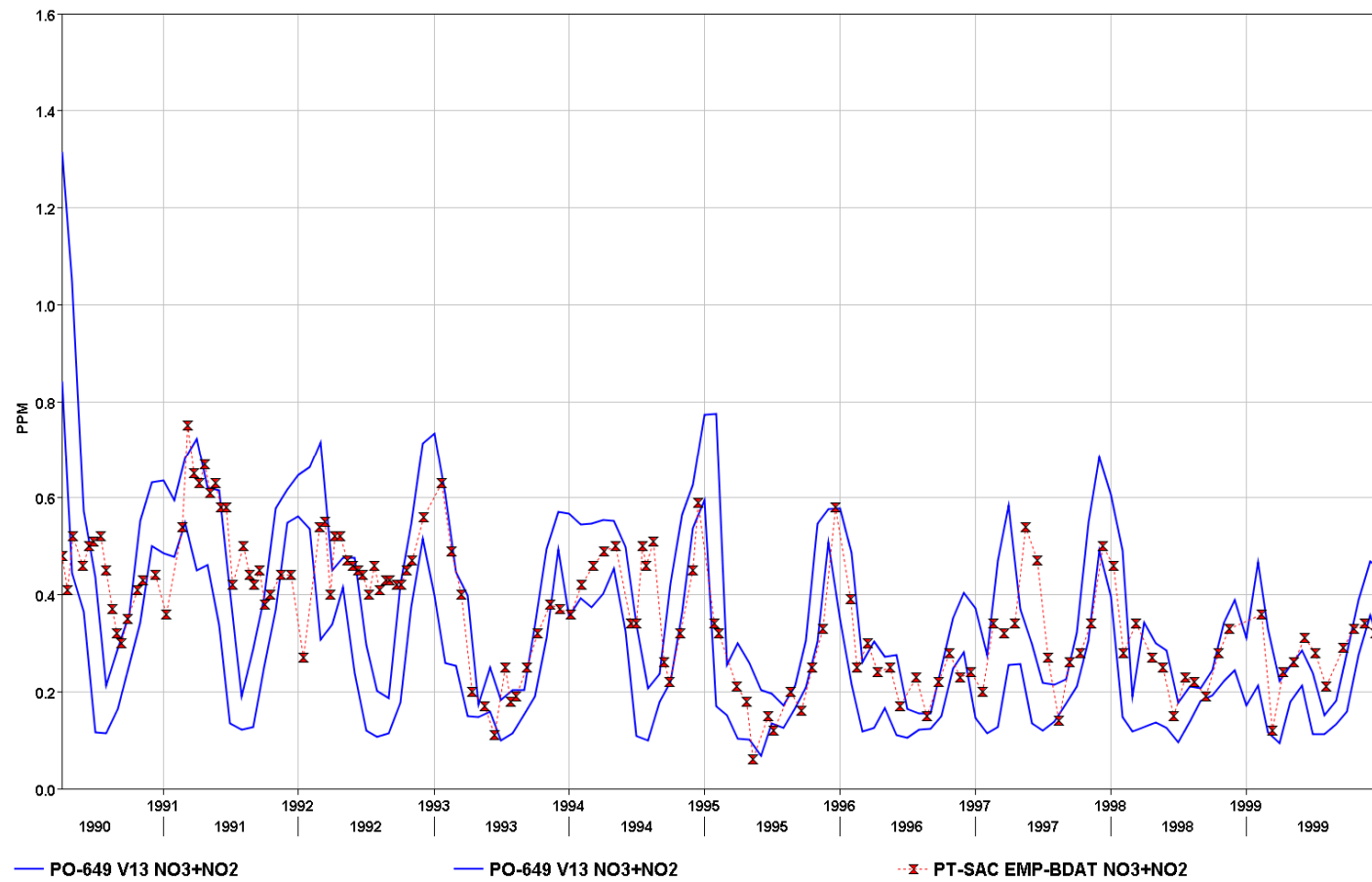


Figure A II. 46 Nitrate+Nitrite at PT SAC early years.

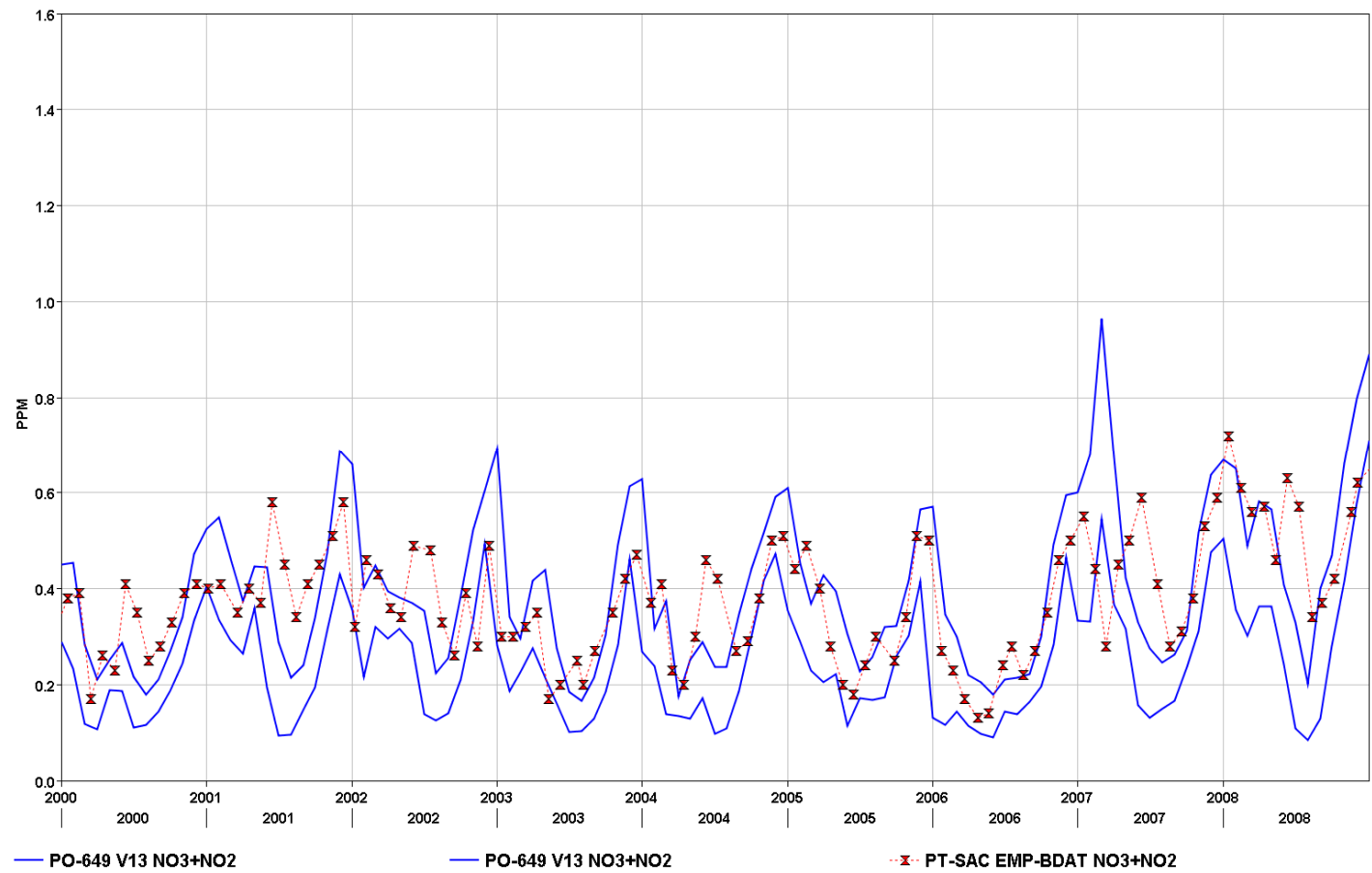


Figure A II. 47 Nitrate+Nitrite at PT SAC later years.

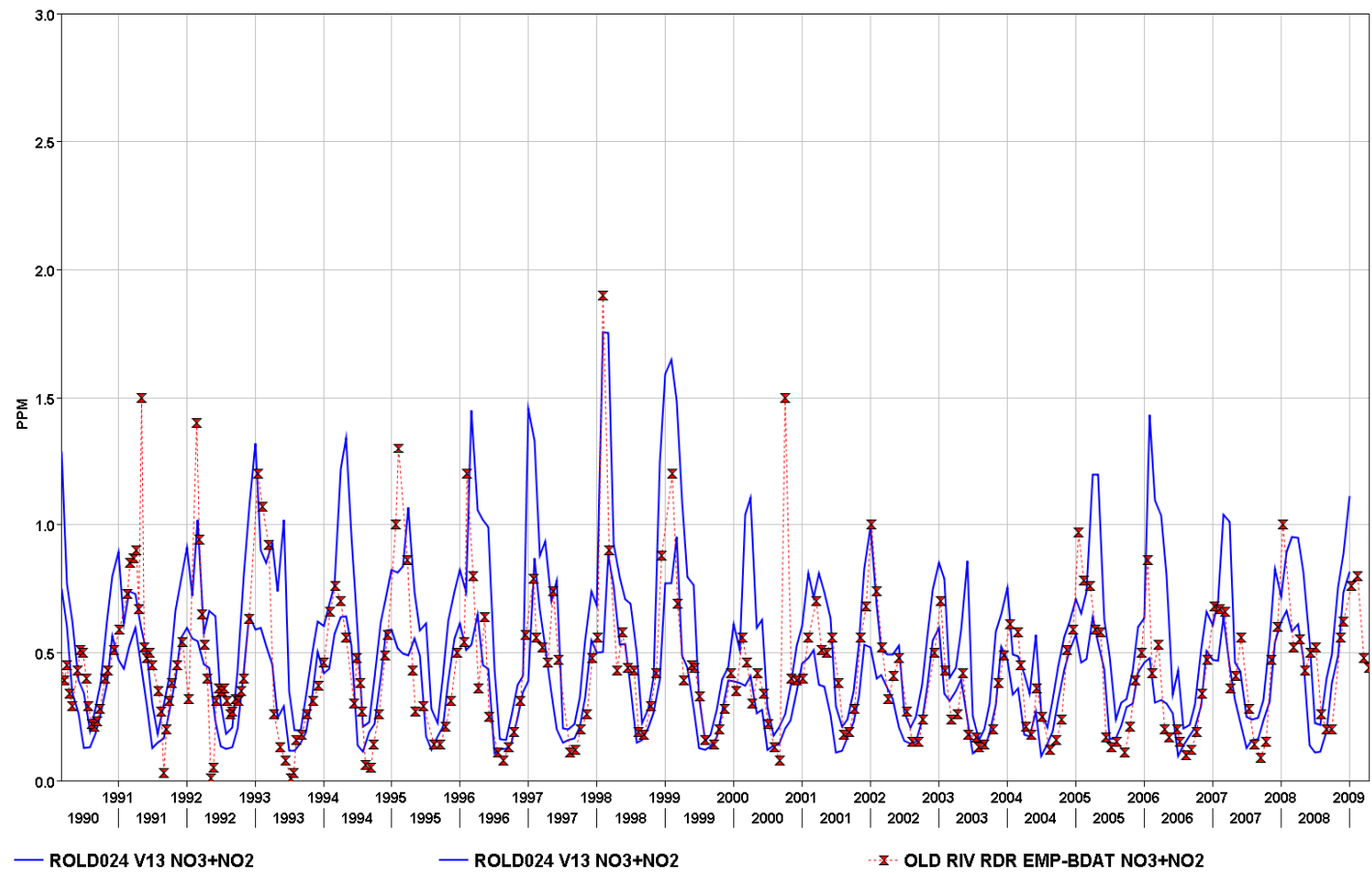


Figure A II. 48 Nitrate+Nitrite at ROLD024 all years.

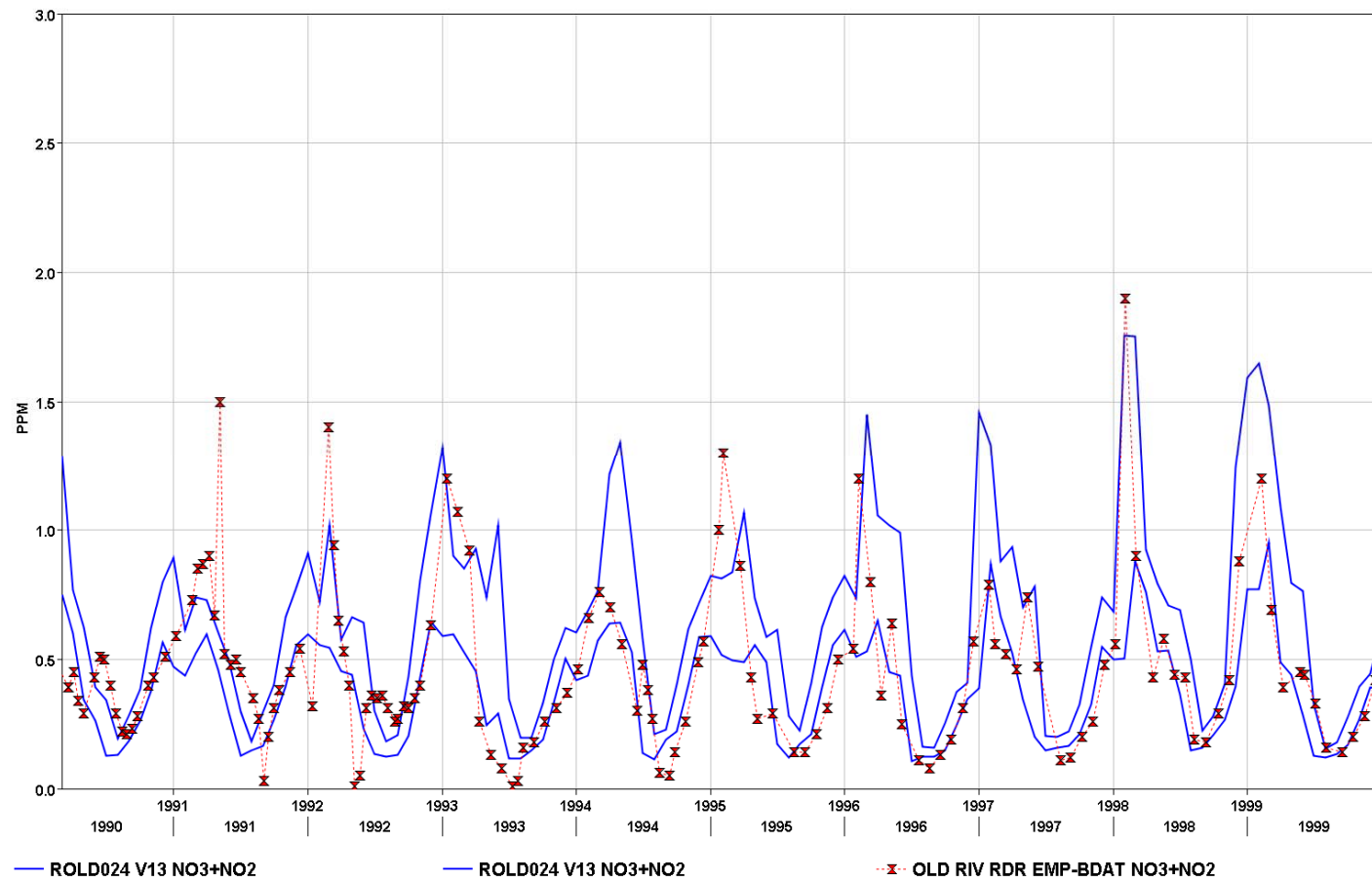


Figure A II. 49 Nitrate+Nitrite at ROLD024 early years.

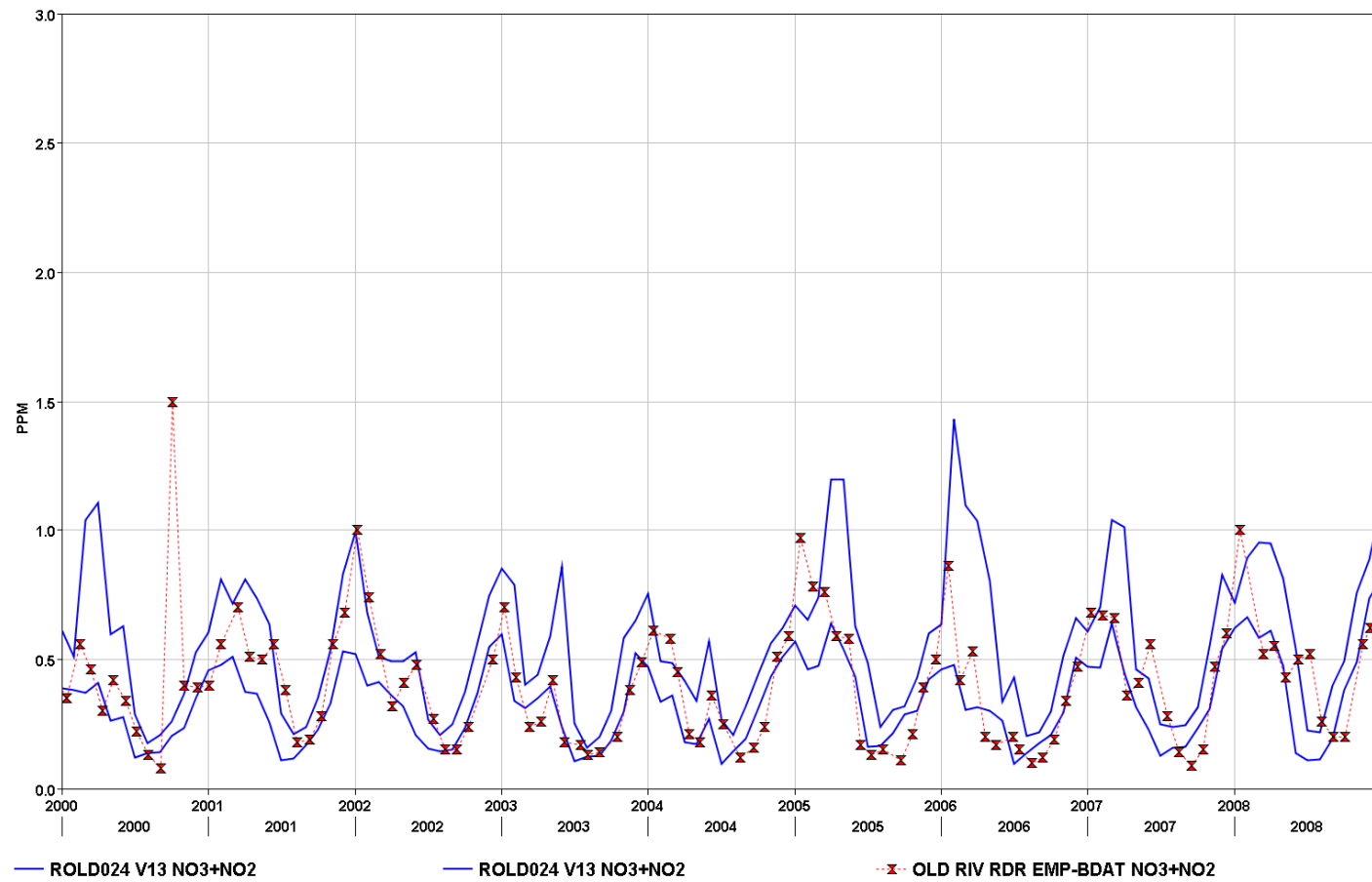


Figure A II. 50 Nitrate+Nitrite at ROLD024 later years.

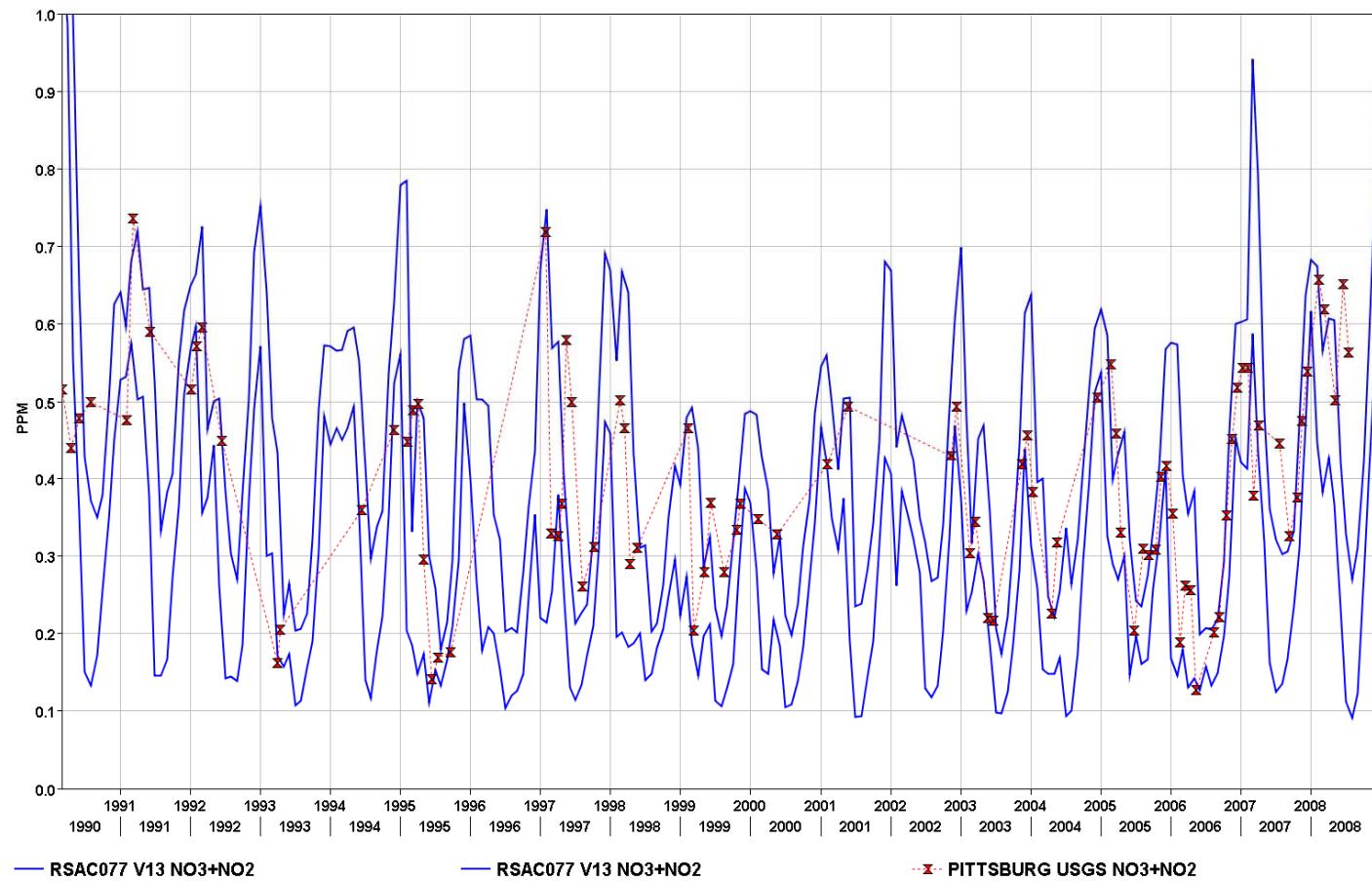


Figure A II. 51 Nitrate+Nitrite at RSAC077 all USGS years.

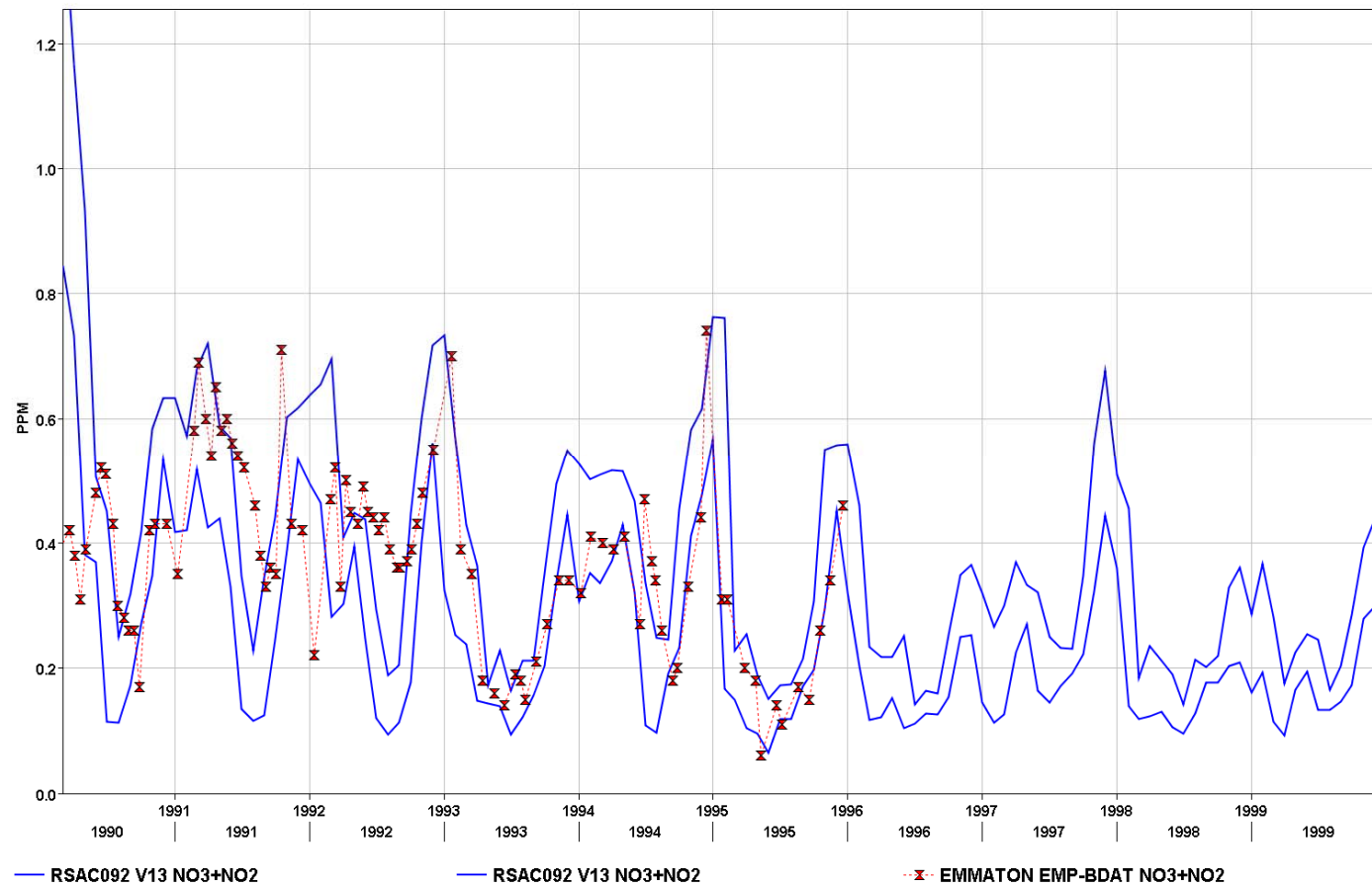


Figure A II. 52 Nitrate+Nitrite at RSAC092 early years.

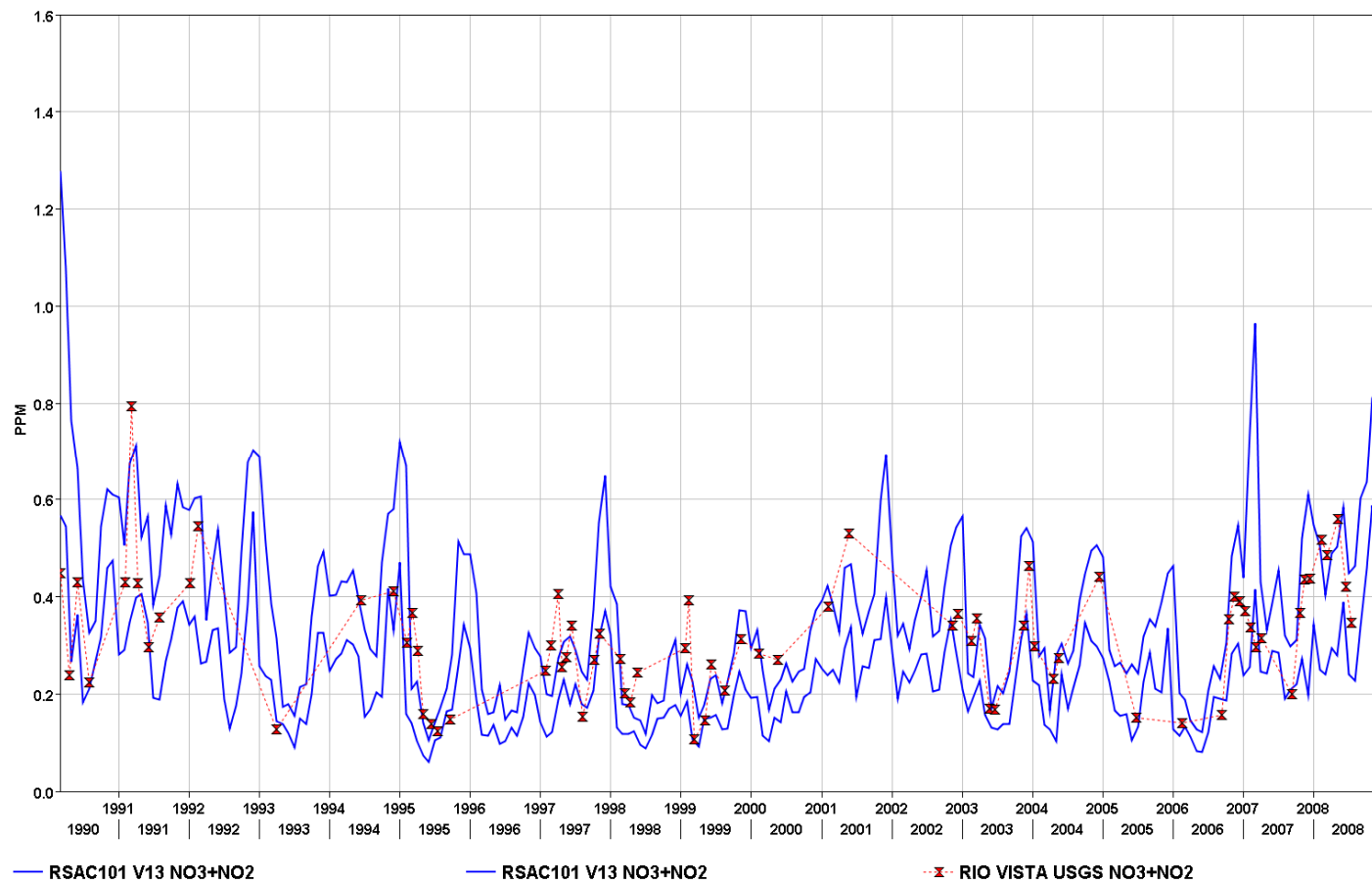


Figure A II. 53 Nitrate+Nitrite at RSAC101 USGS all years.

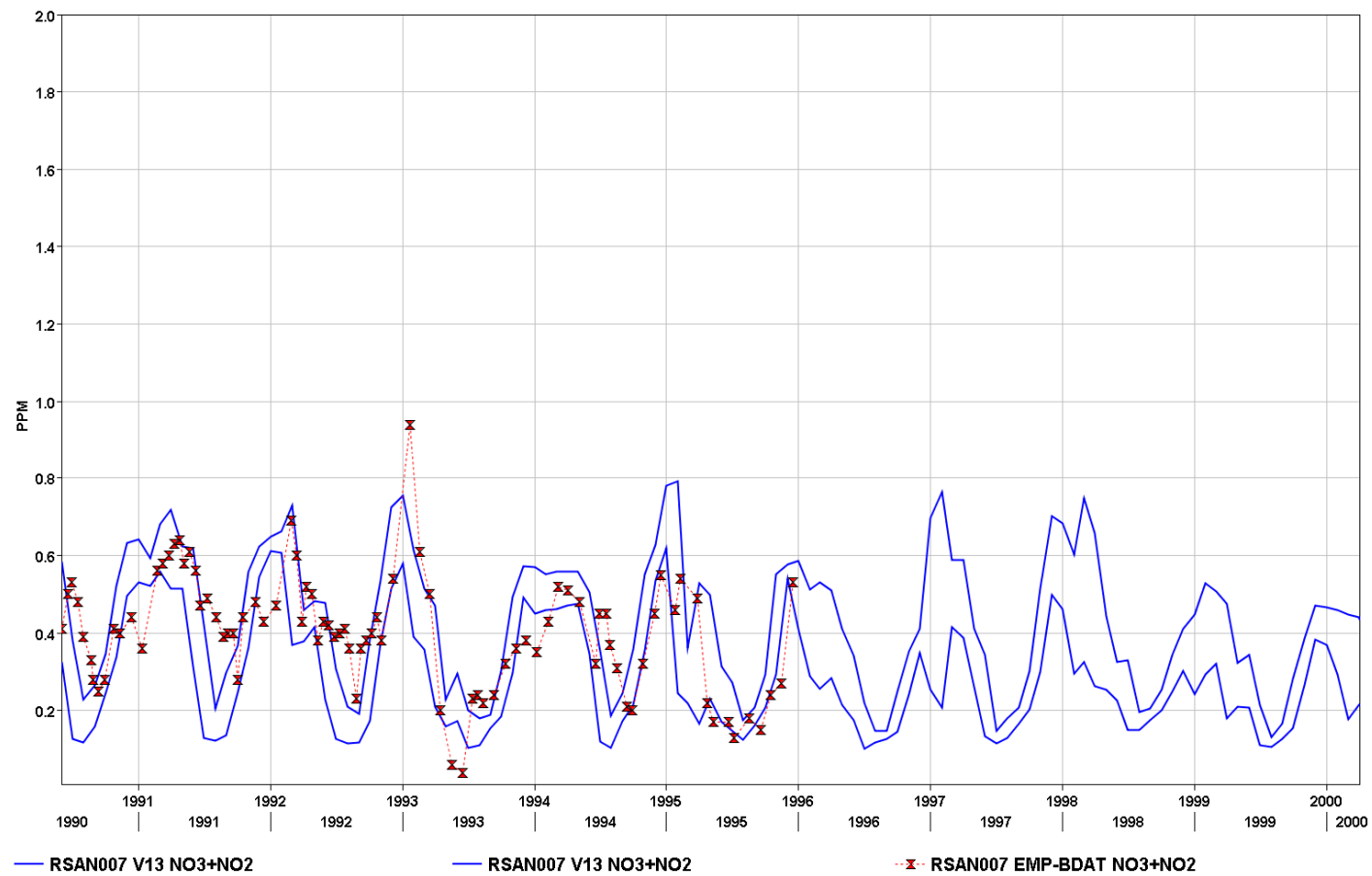


Figure A II. 54 Nitrate+Nitrite at RSAN007 early years.

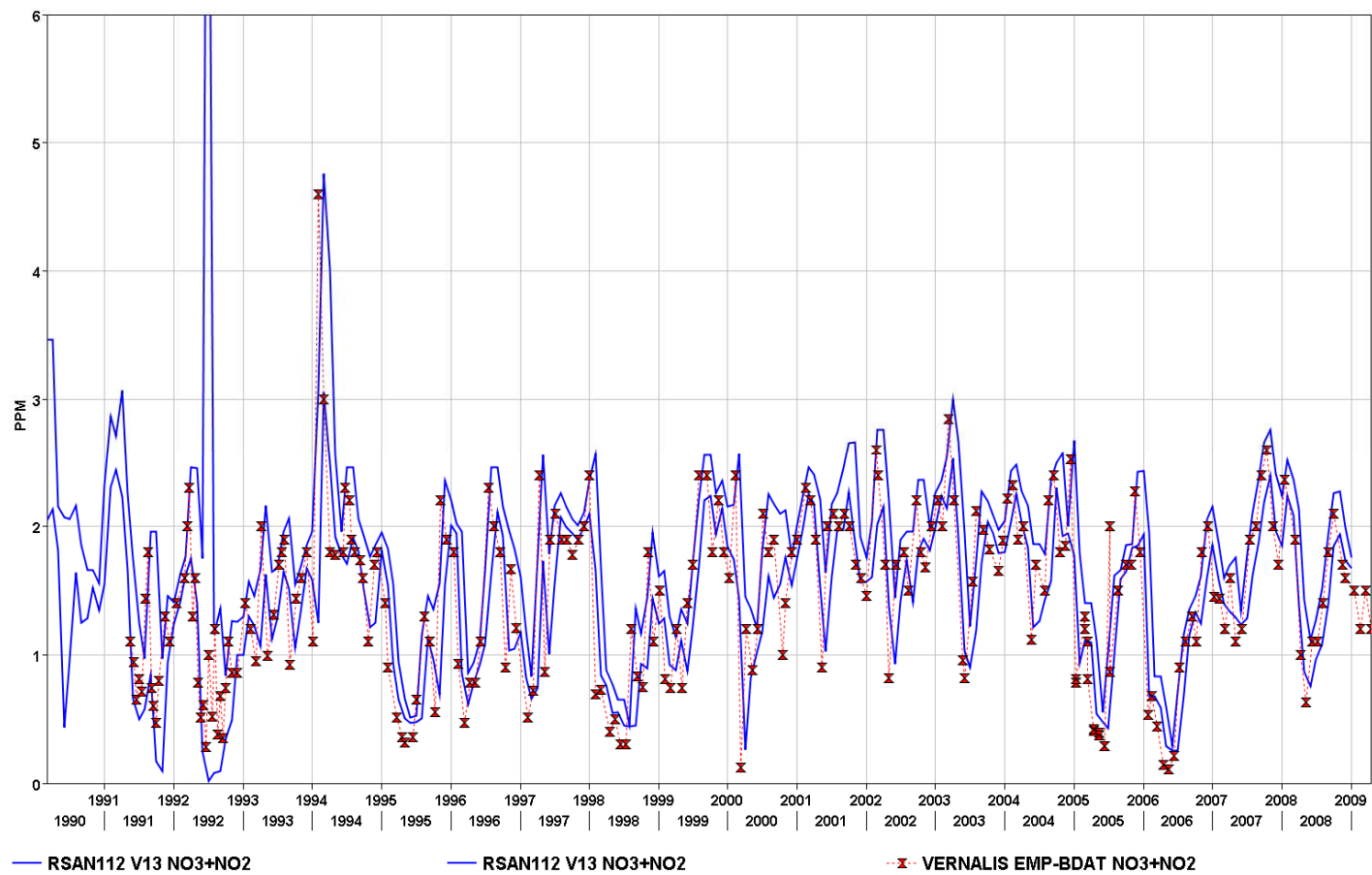


Figure A II. 55 Nitrate+Nitrite at RSAN112 all years.

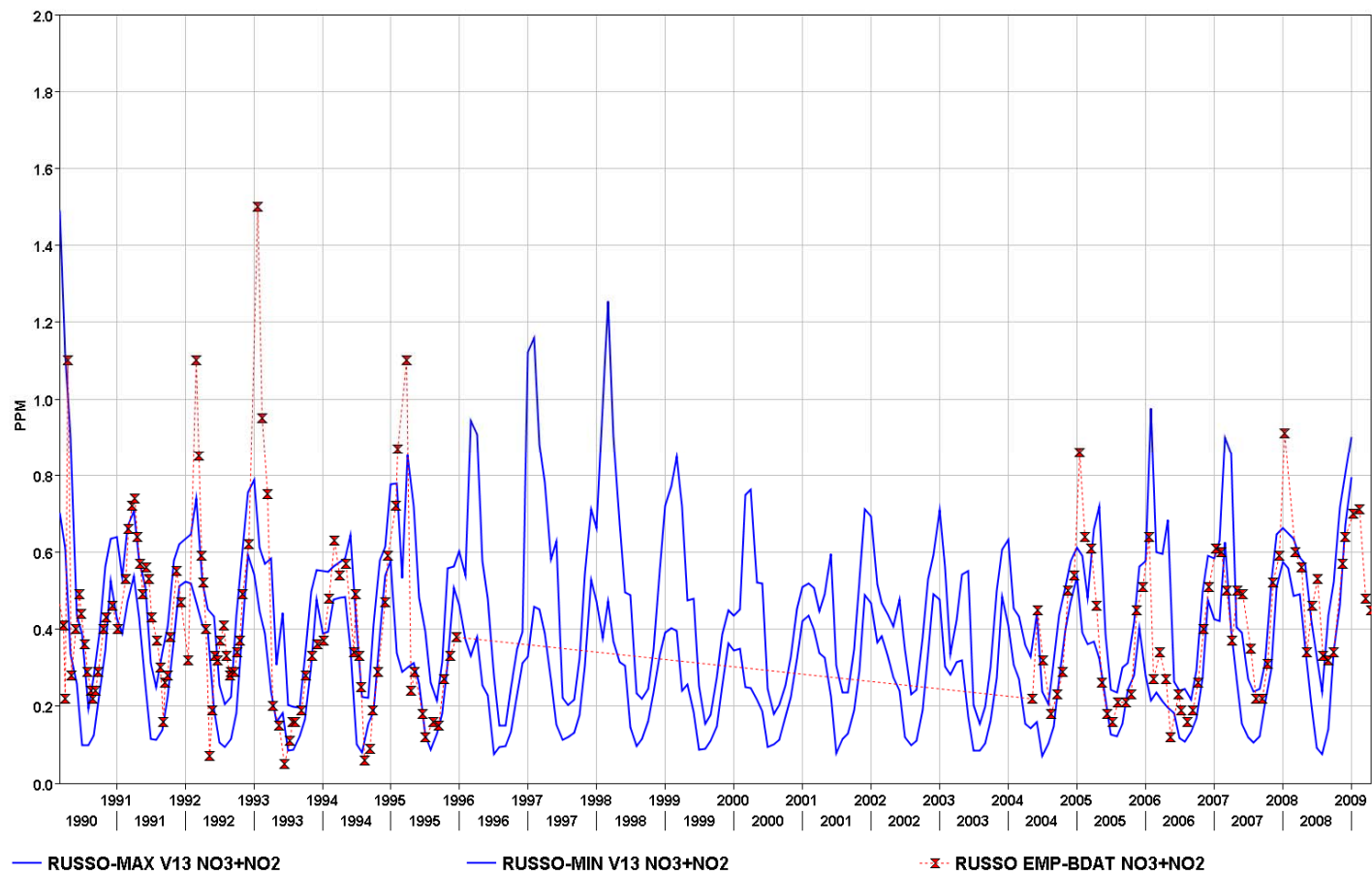


Figure A II. 56 Nitrate+Nitrite at RUSSO all years.

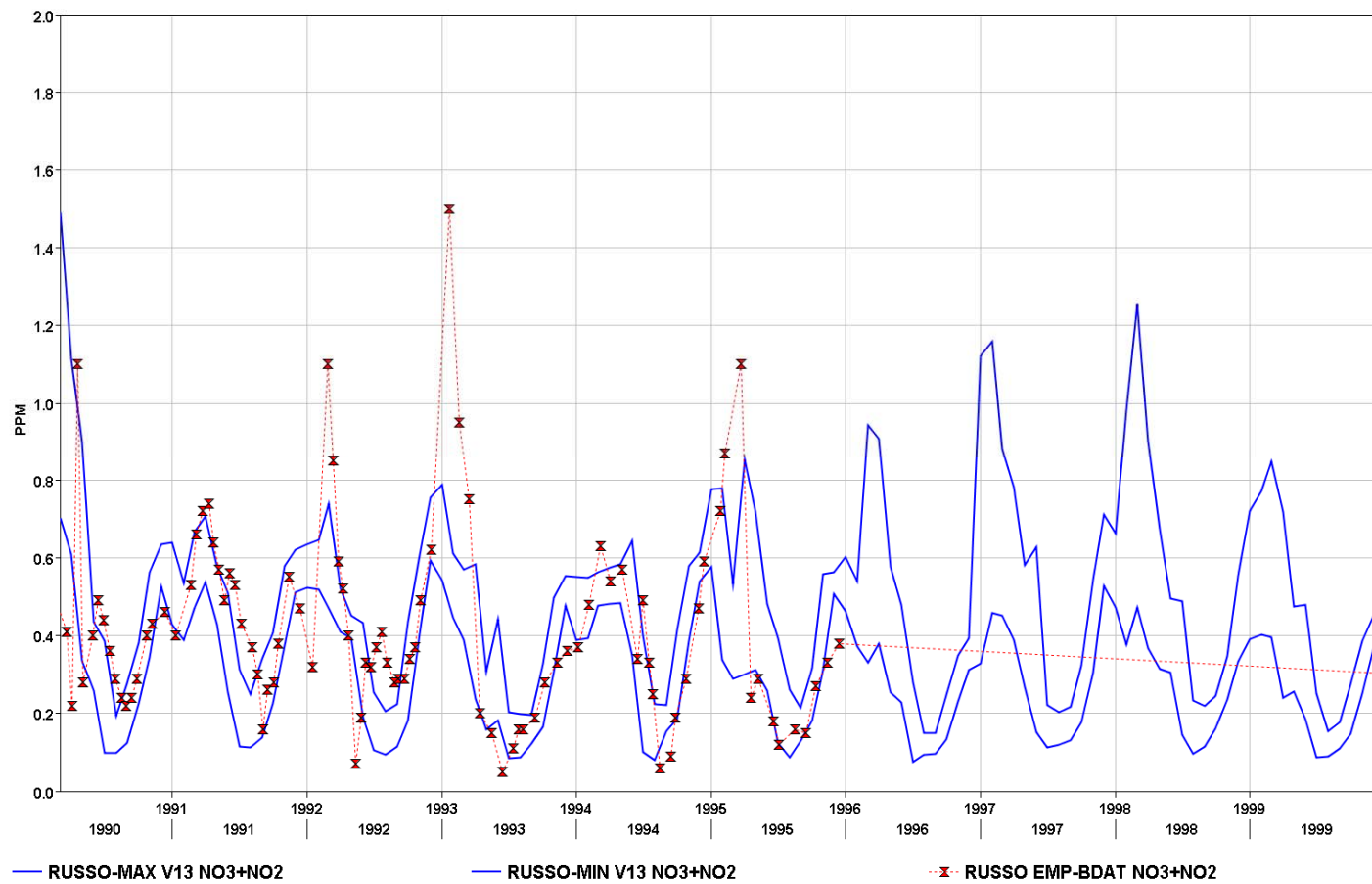


Figure A II. 57 Nitrate+Nitrite at RUSSO early years.

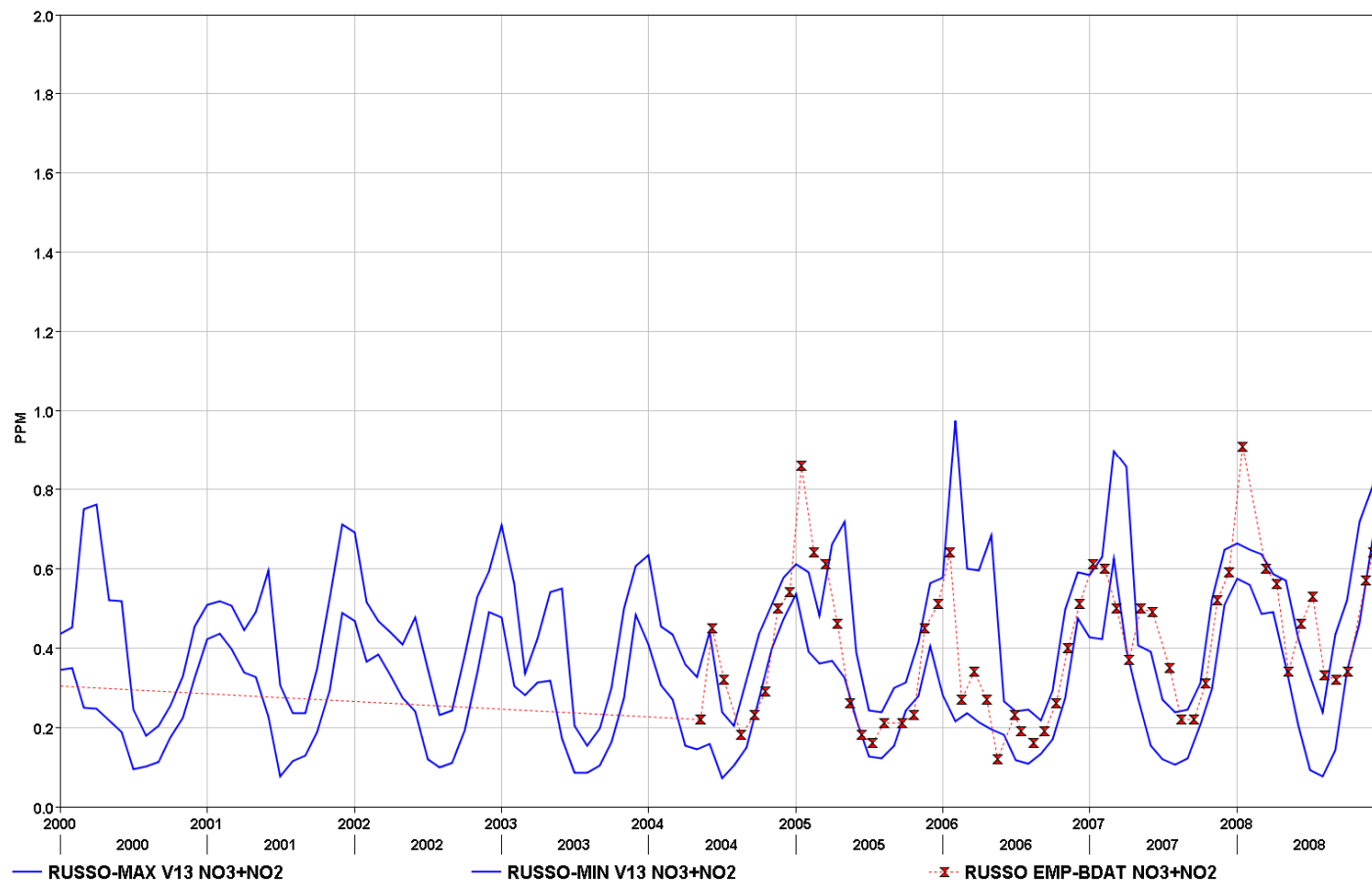


Figure A II. 58 Nitrate+Nitrite at RUSSO later years.

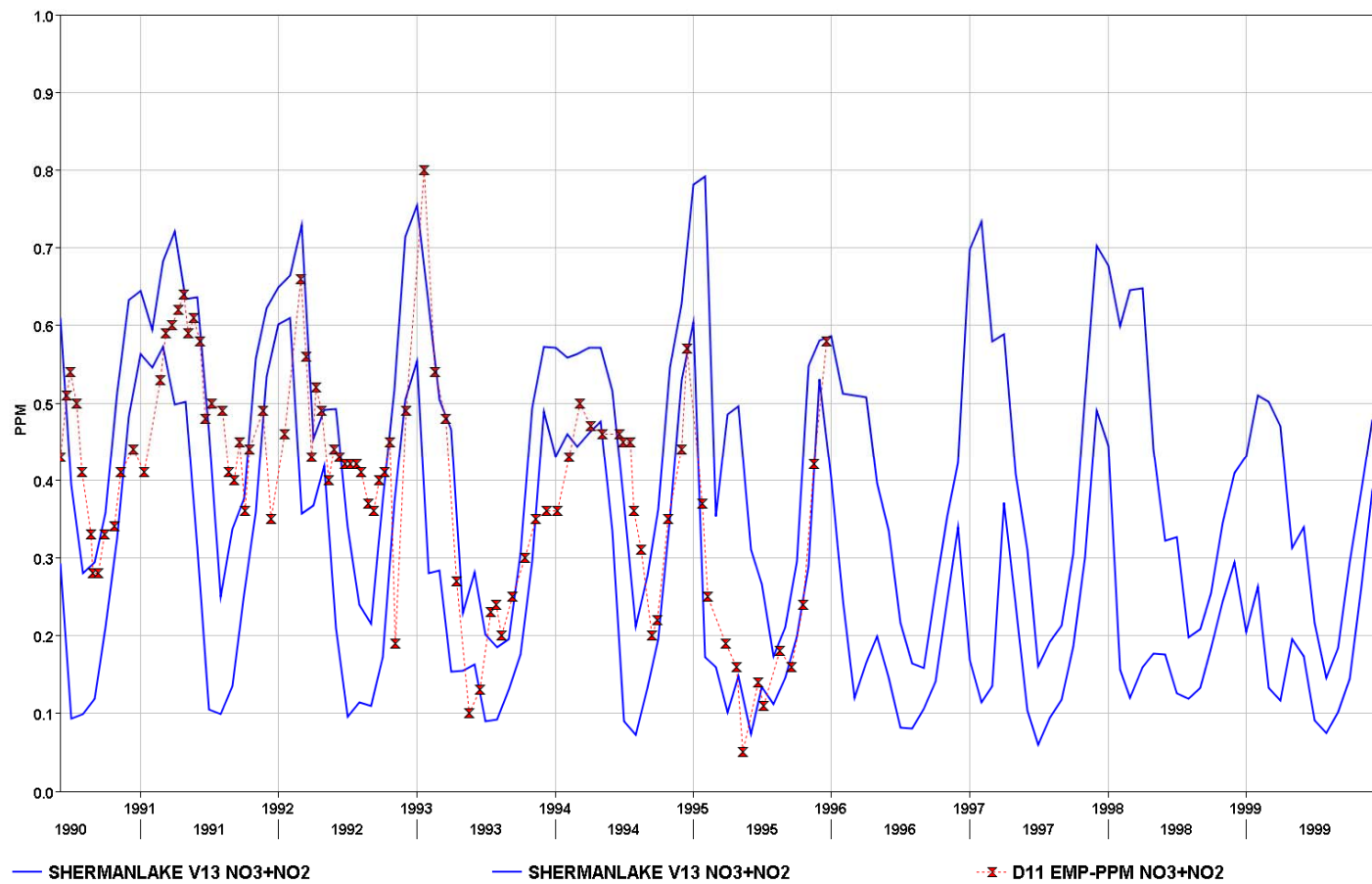


Figure A II. 59 Nitrate+Nitrite at SHERMAN early years.

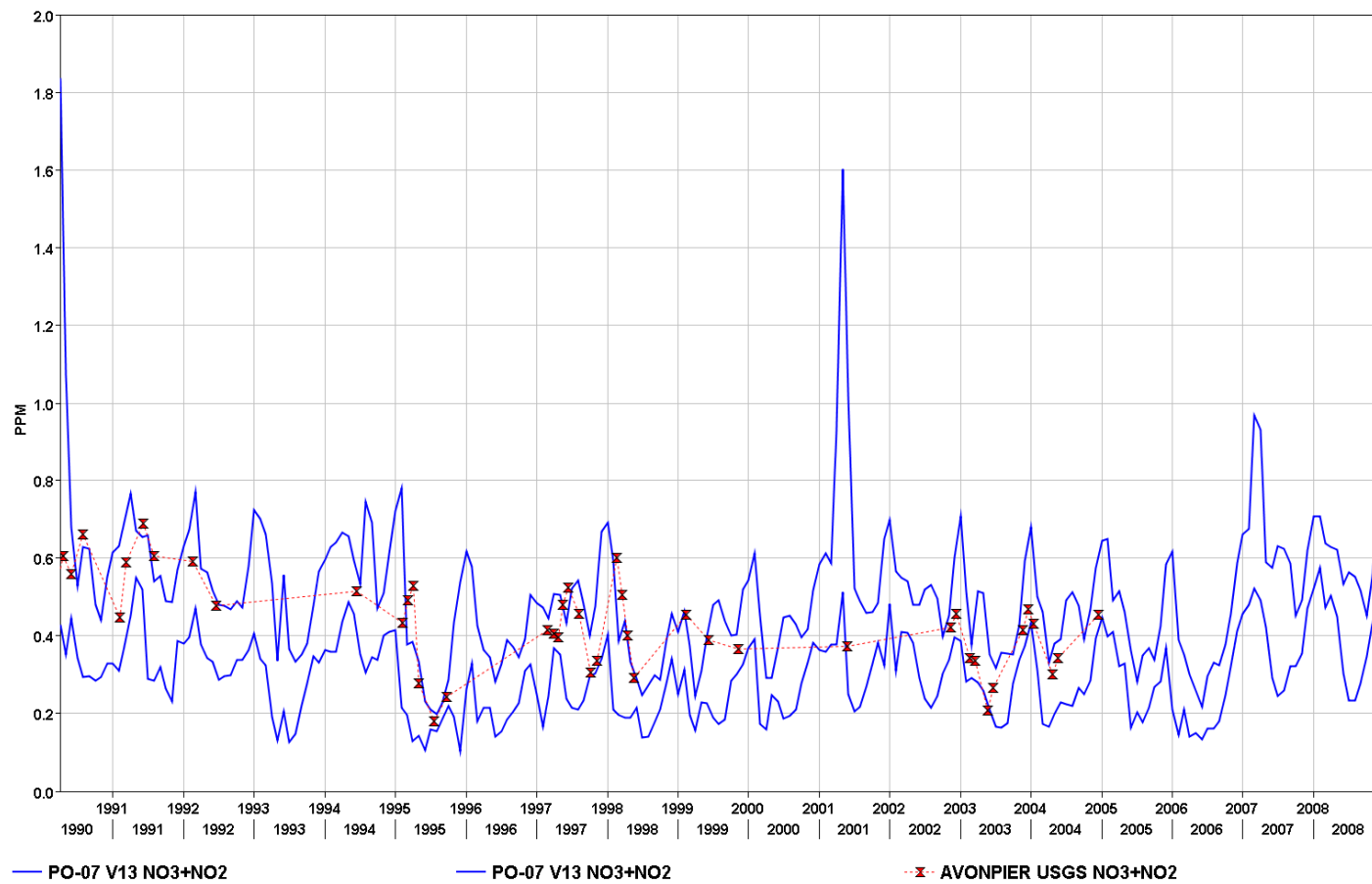


Figure A II. 60 Nitrate+Nitrite at PO-07 all years.

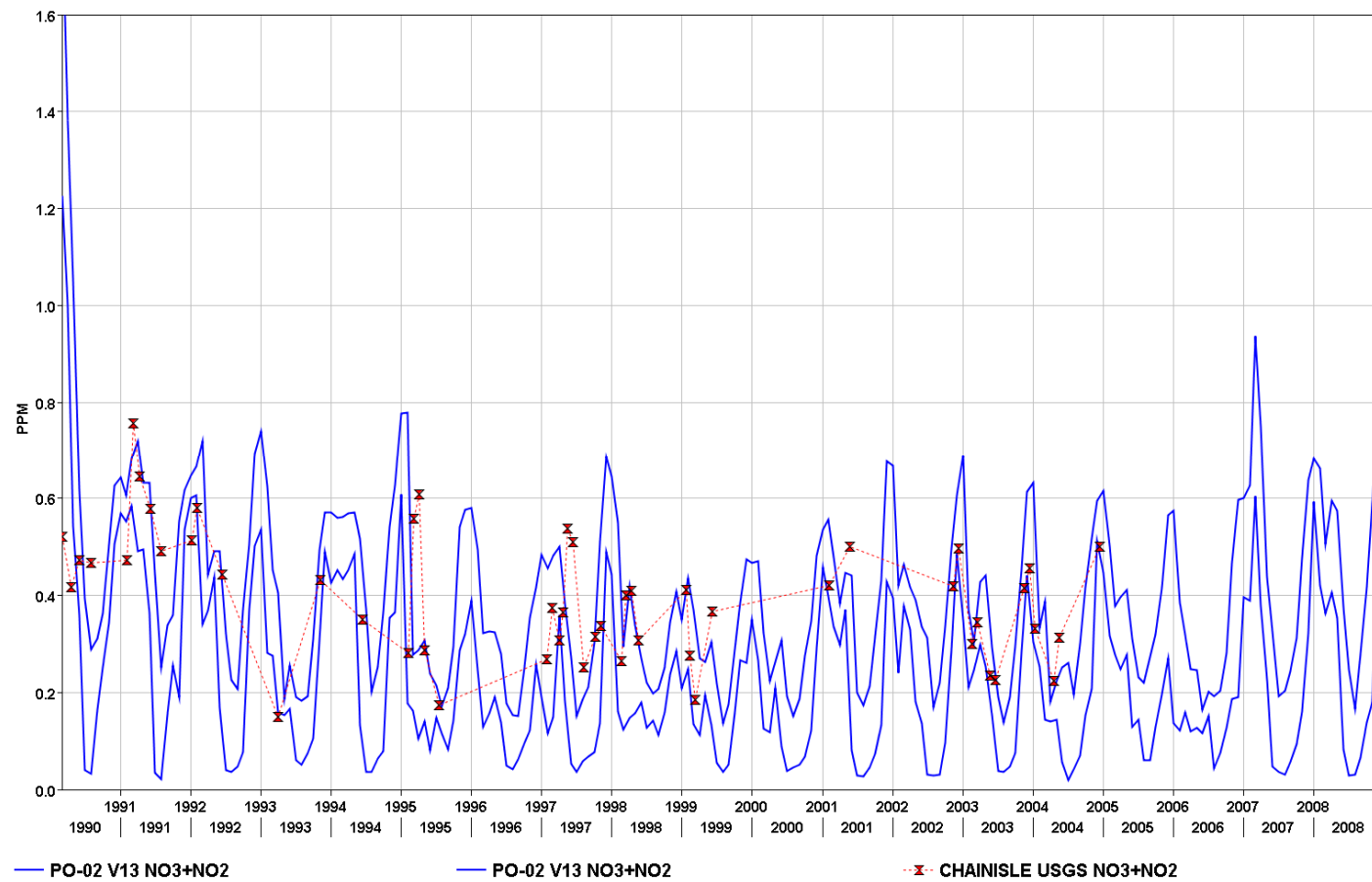


Figure A II. 61 Nitrate+Nitrite at PO-02 all years.

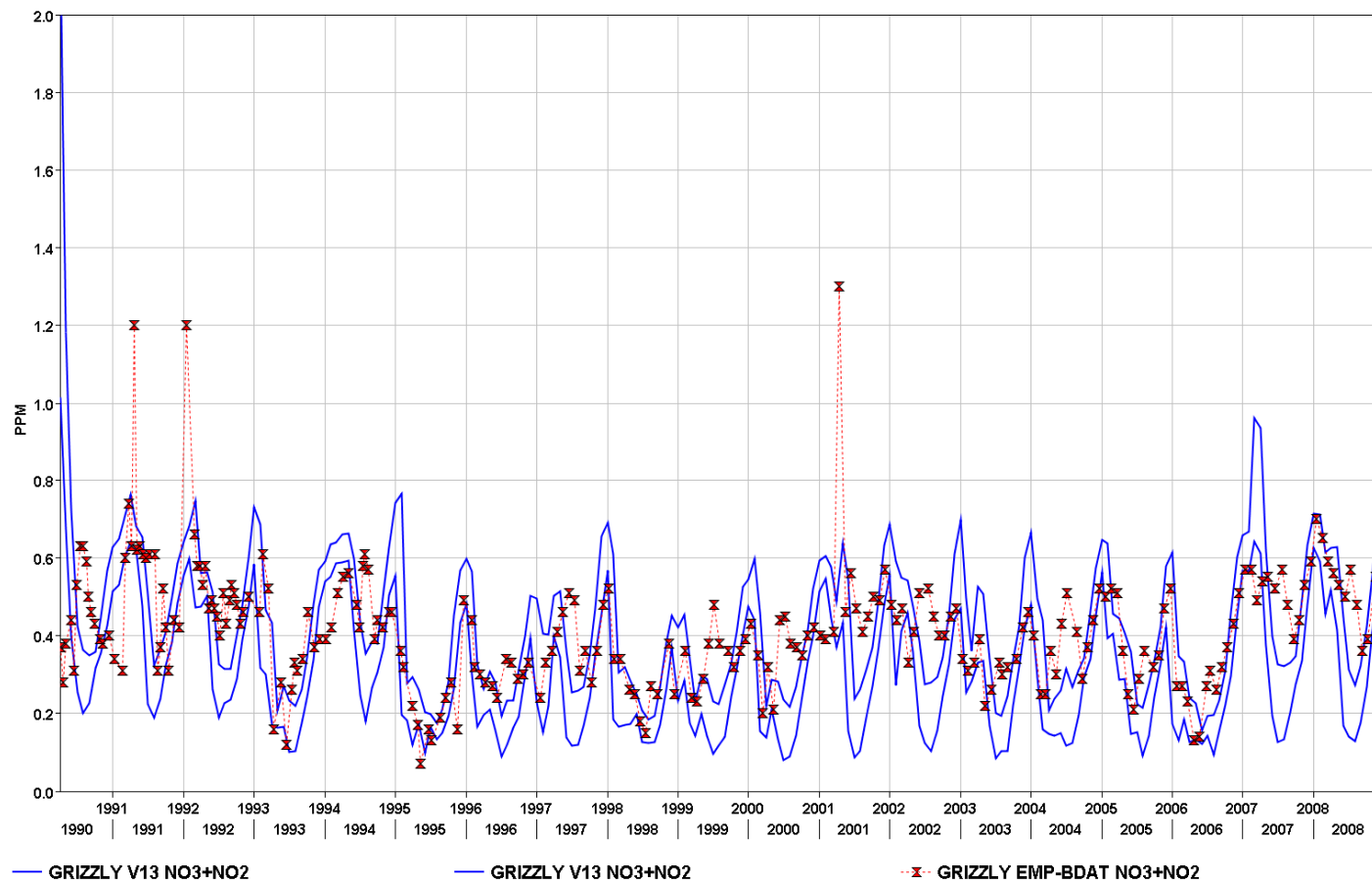


Figure A II. 62 Nitrate+Nitrite at GRIZZLY all years.

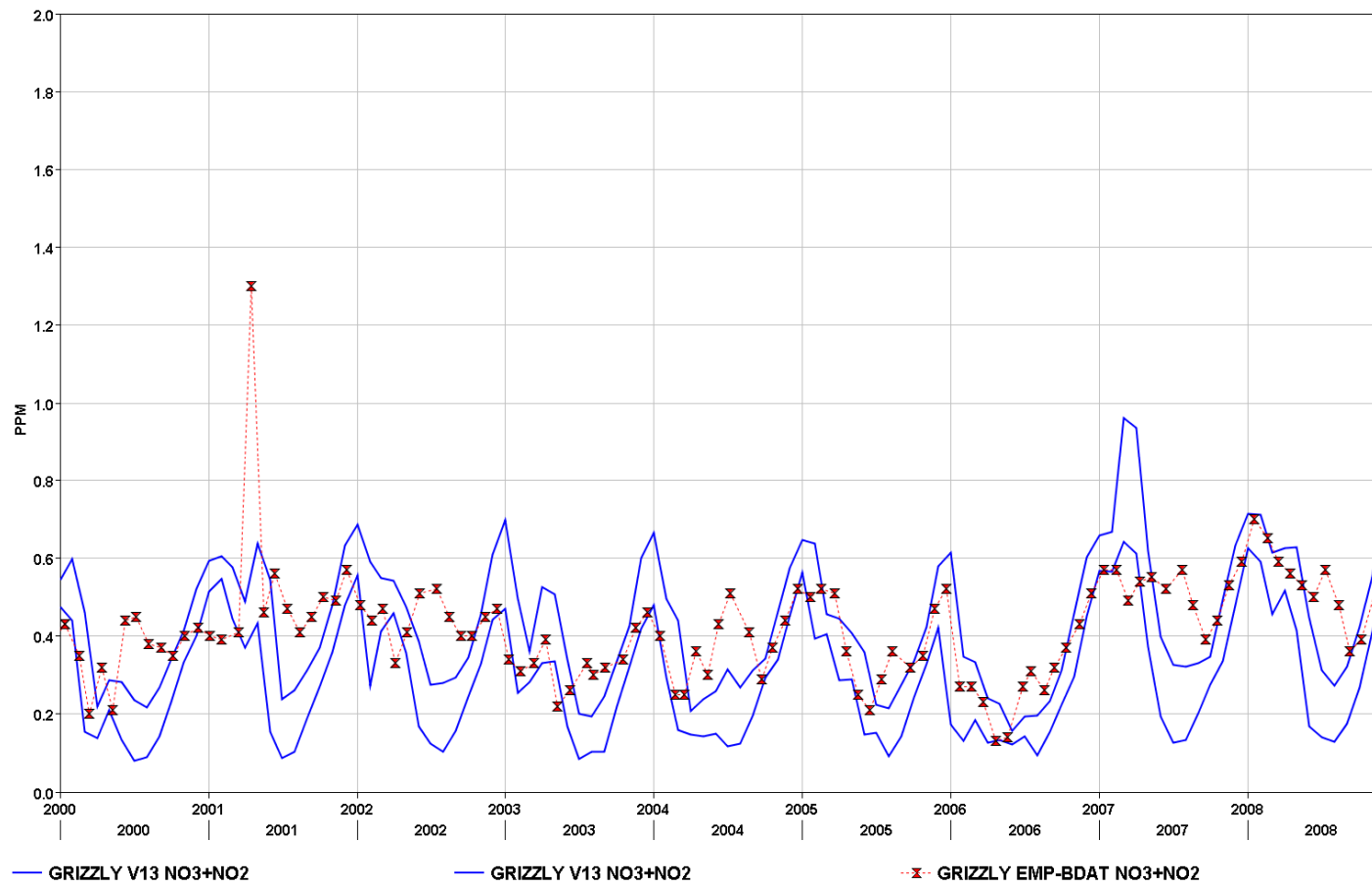


Figure A II. 63 Nitrate+Nitrite at GRIZZLY later years.

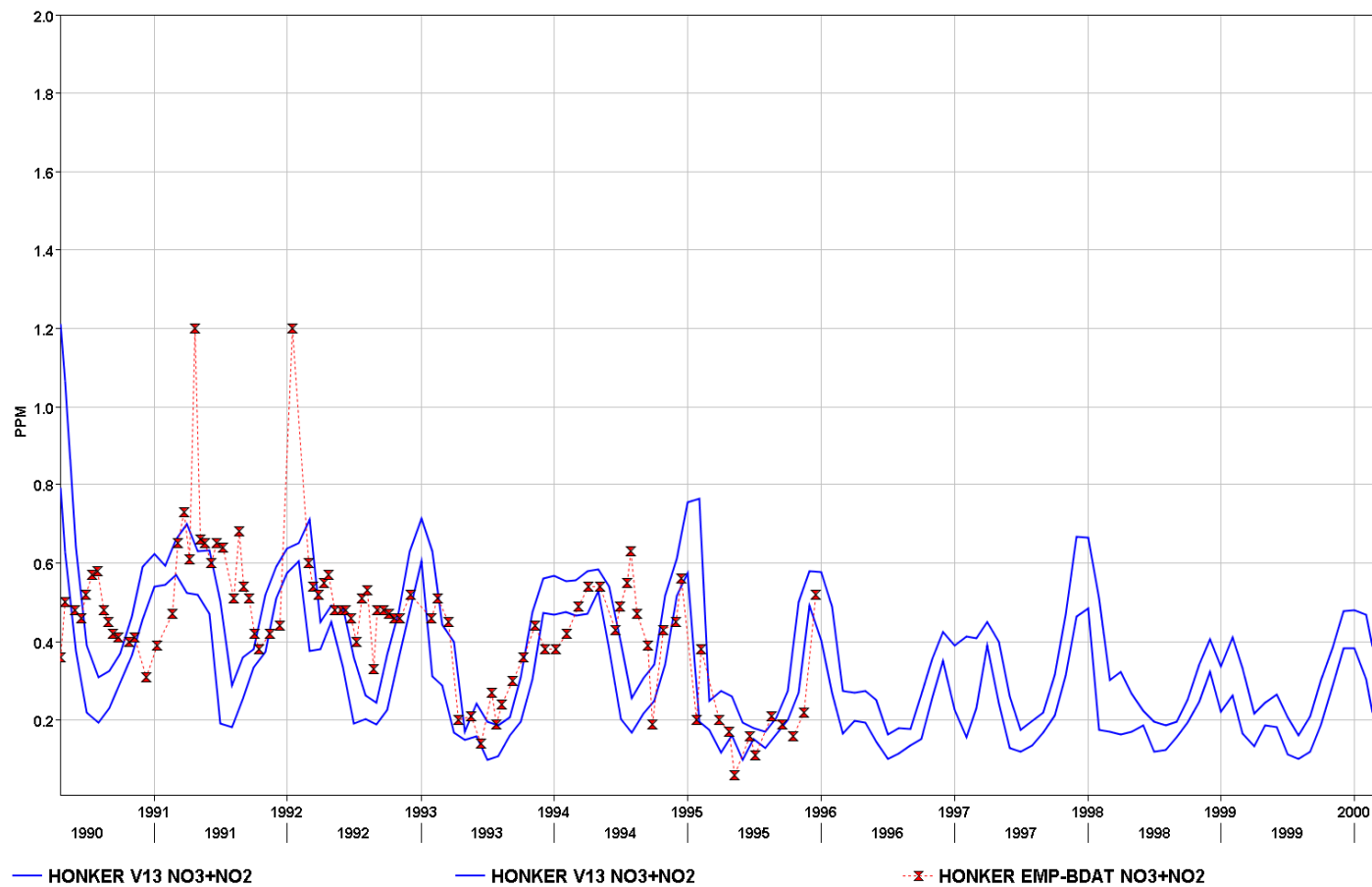


Figure A II. 64 Nitrate+Nitrite at HONKER early years.

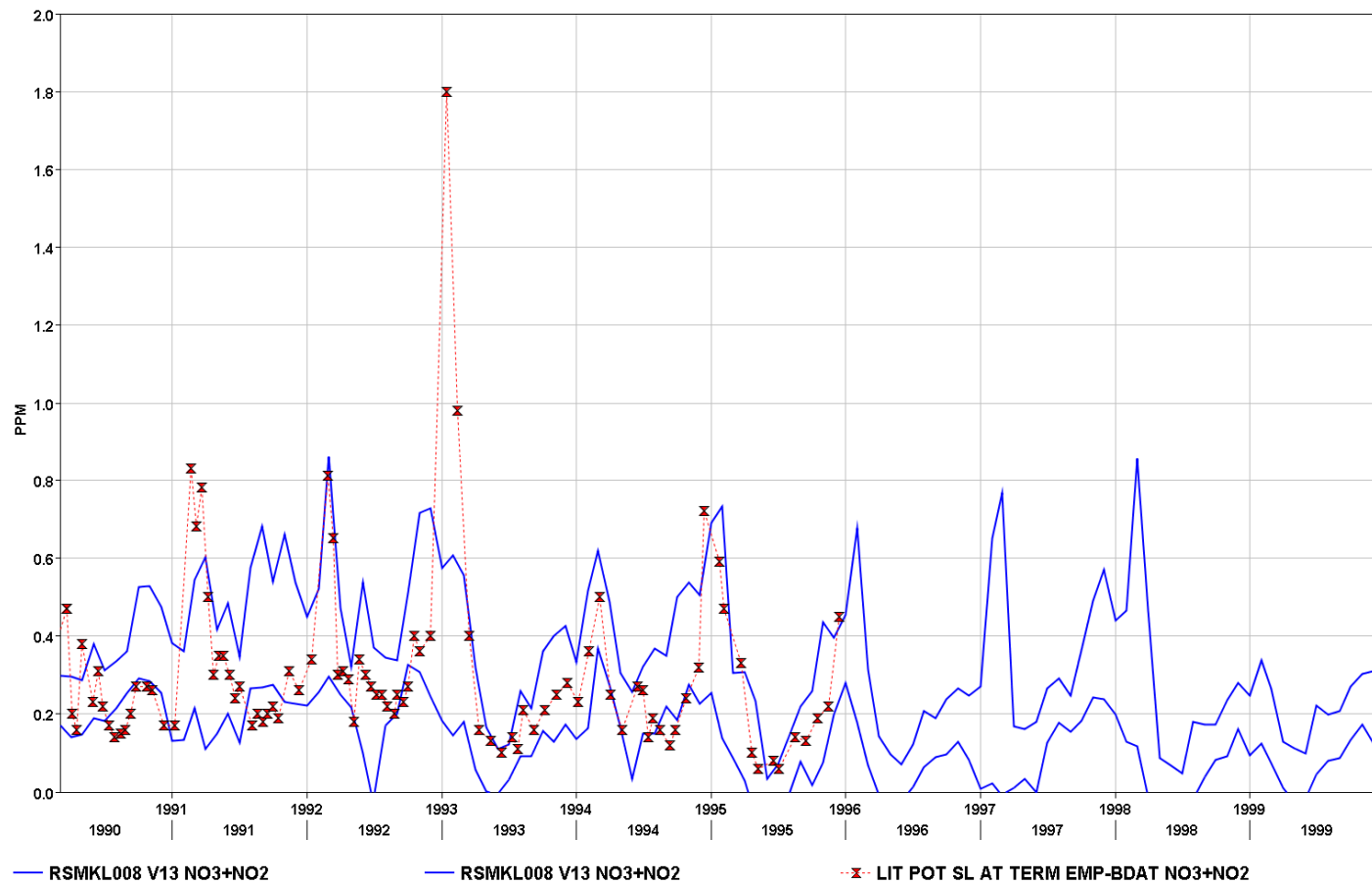


Figure A II. 65 Nitrate+Nitrite at RSMKL008 early years.

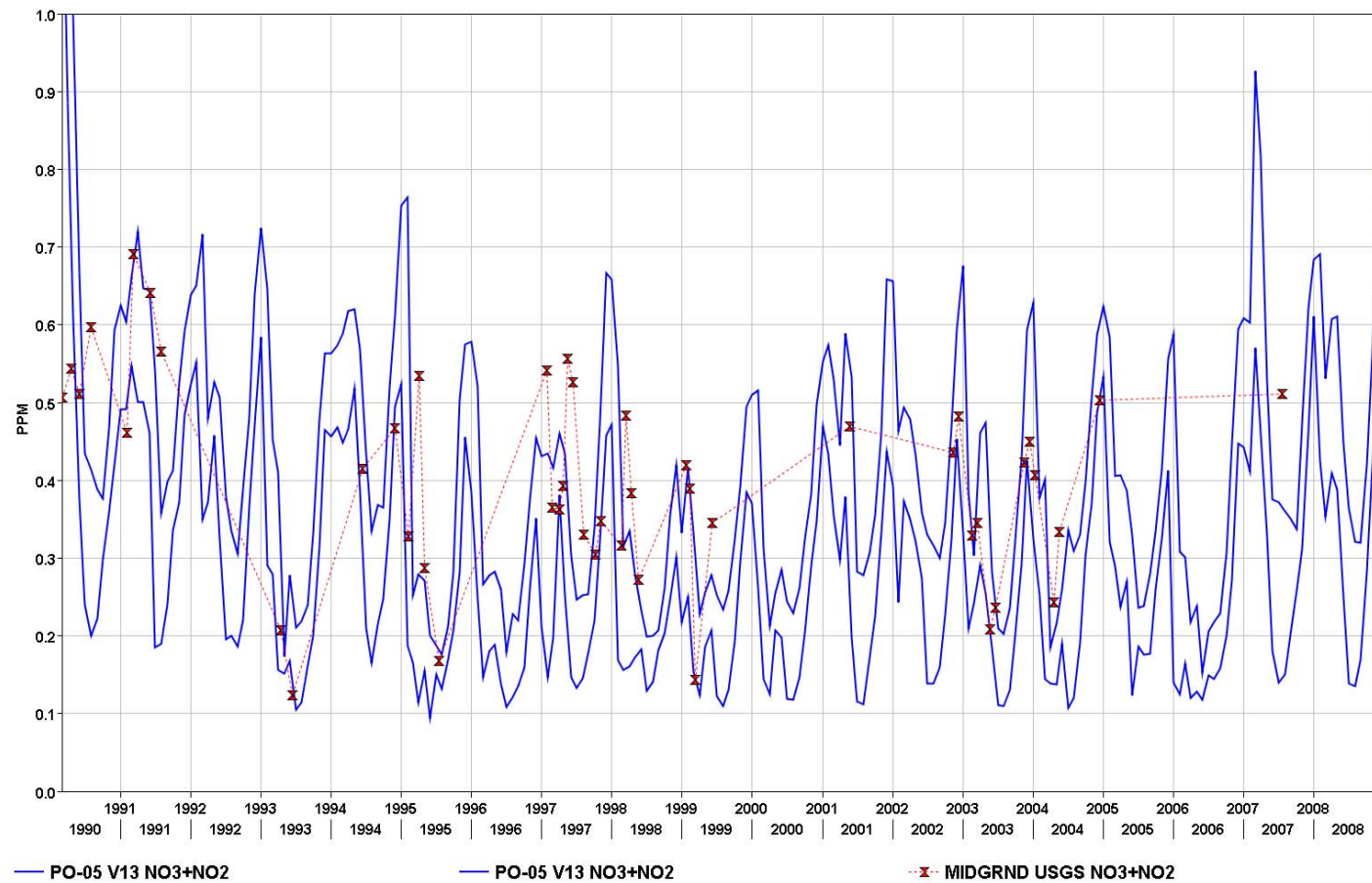


Figure A II. 66 Nitrate+Nitrite at PO-05 all years.

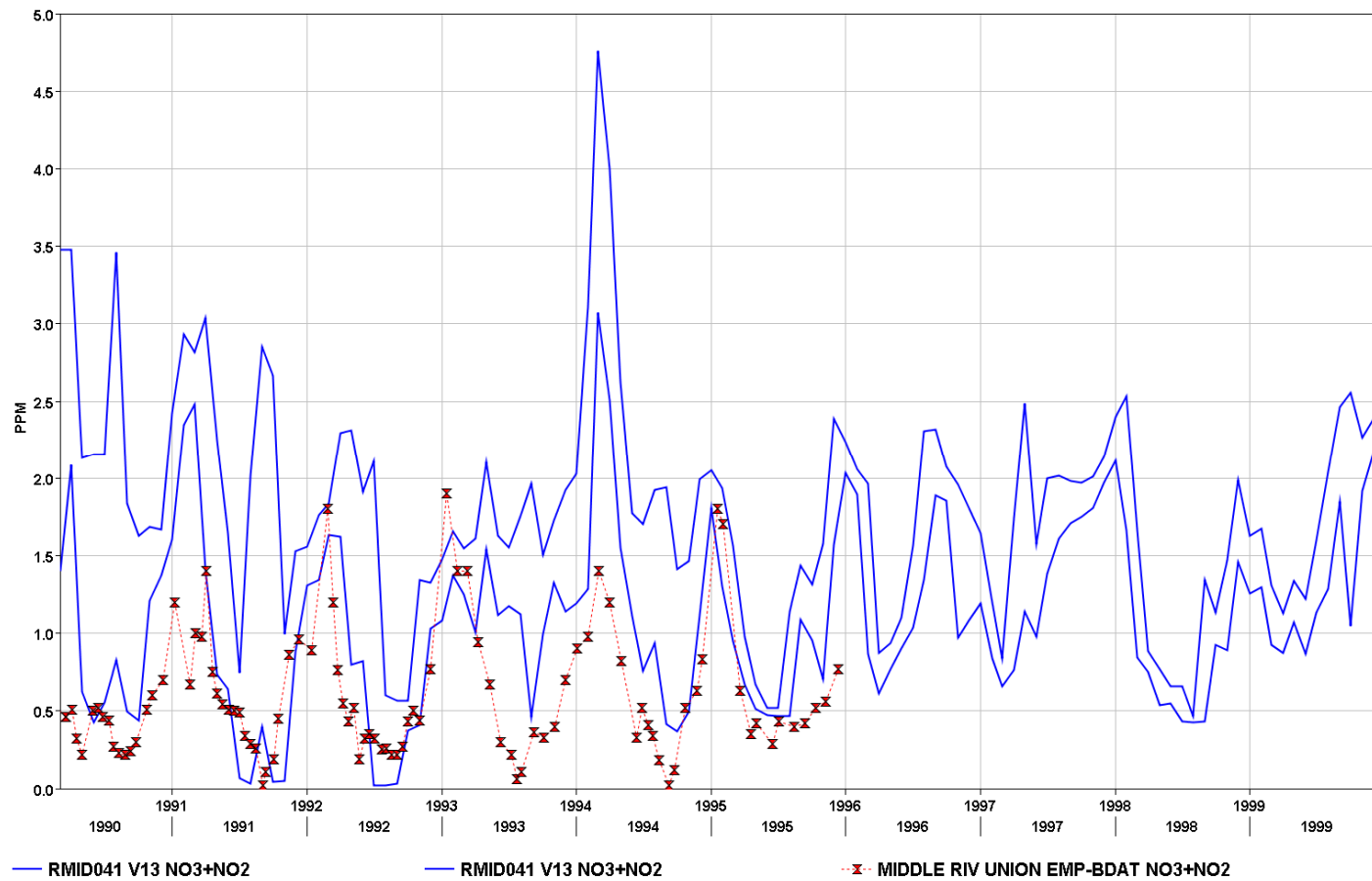


Figure A II. 67 Nitrate+Nitrite at RMOD041 early years.

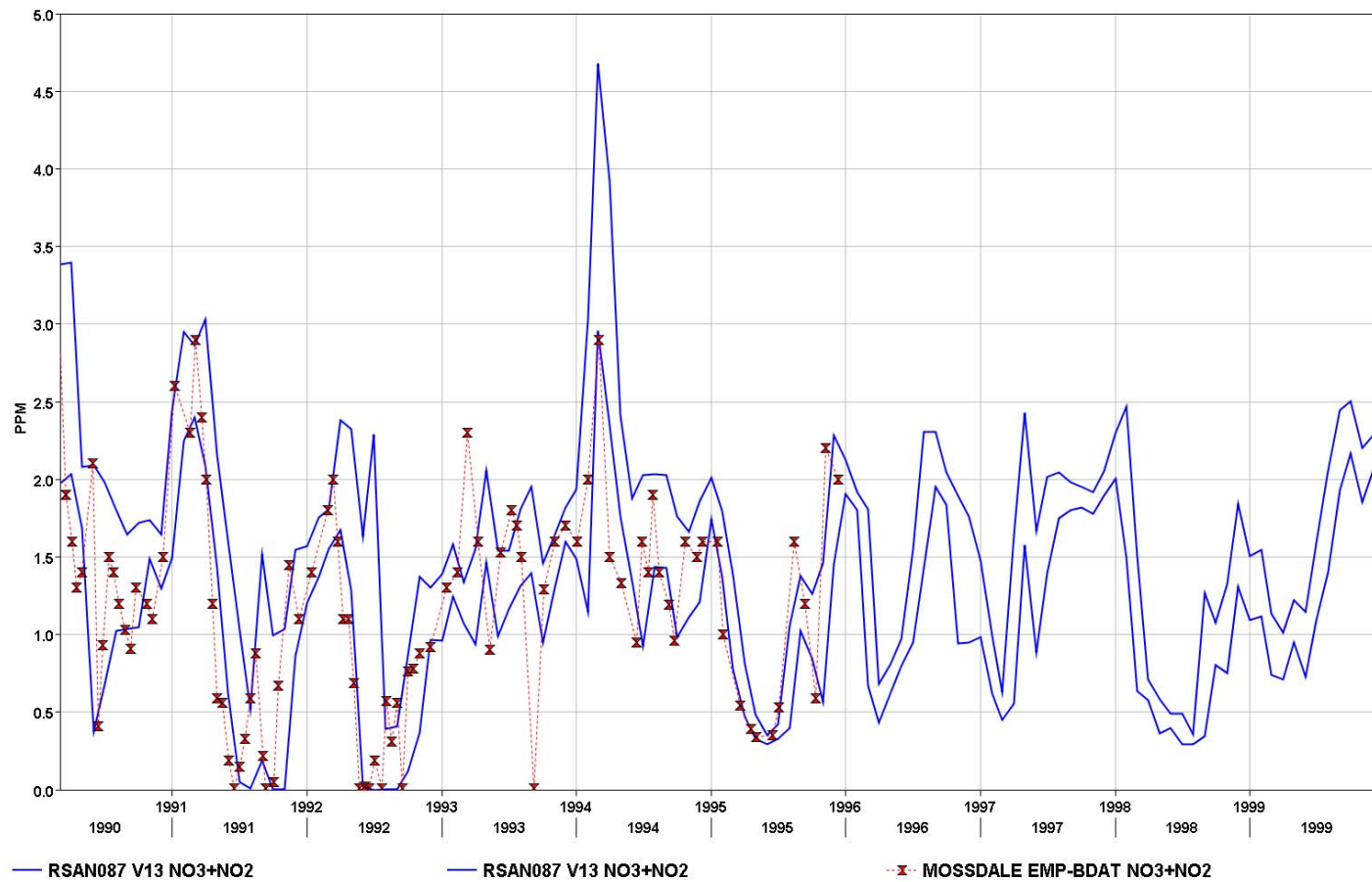


Figure A II. 68 Nitrate+Nitrite at RSAN087 early years.

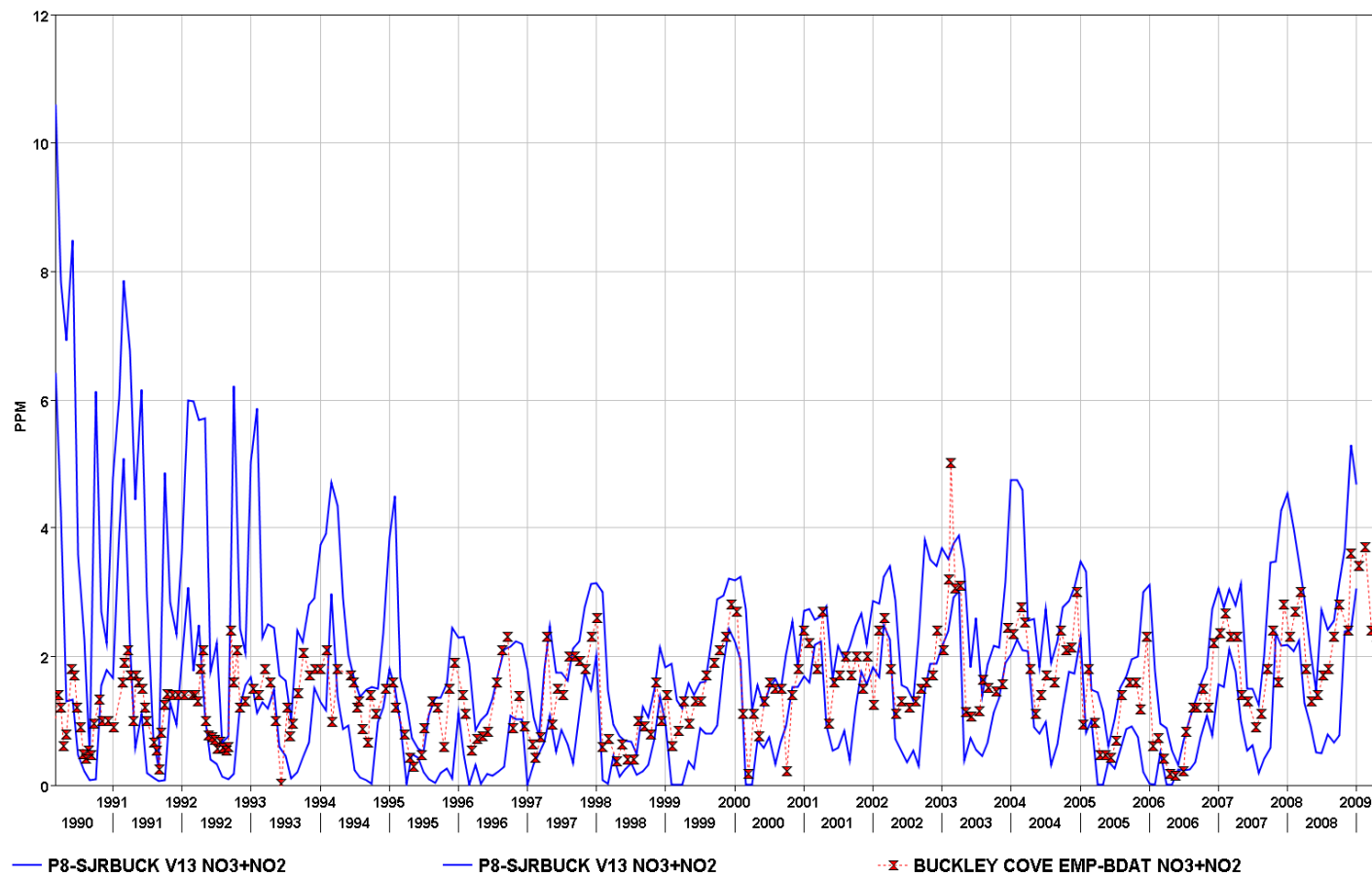


Figure A II. 69 Nitrate+Nitrite at SJR BUCKLEY all years.

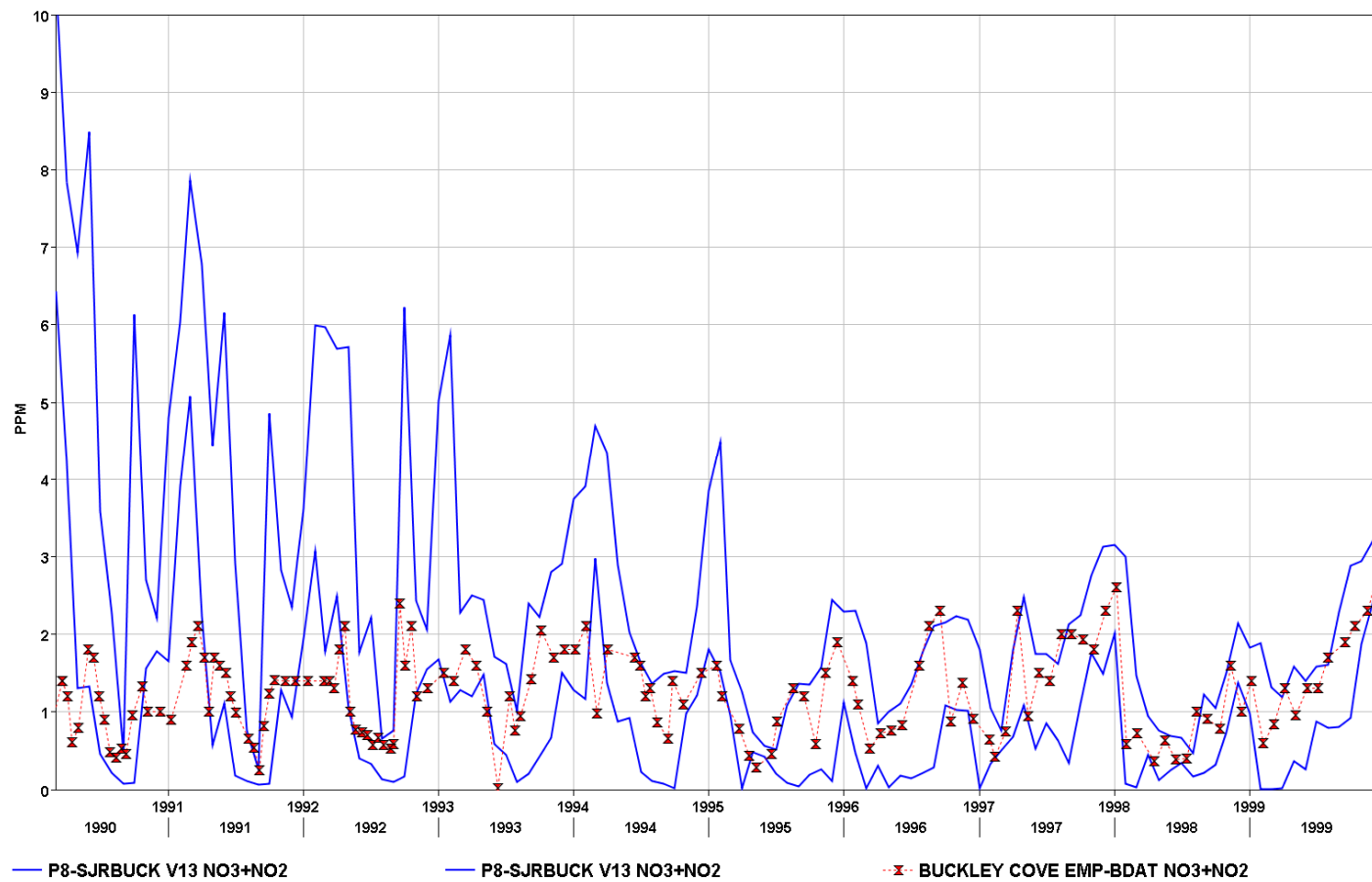


Figure A II. 70 Nitrate+Nitrite at SJR BUCKLEY early years.

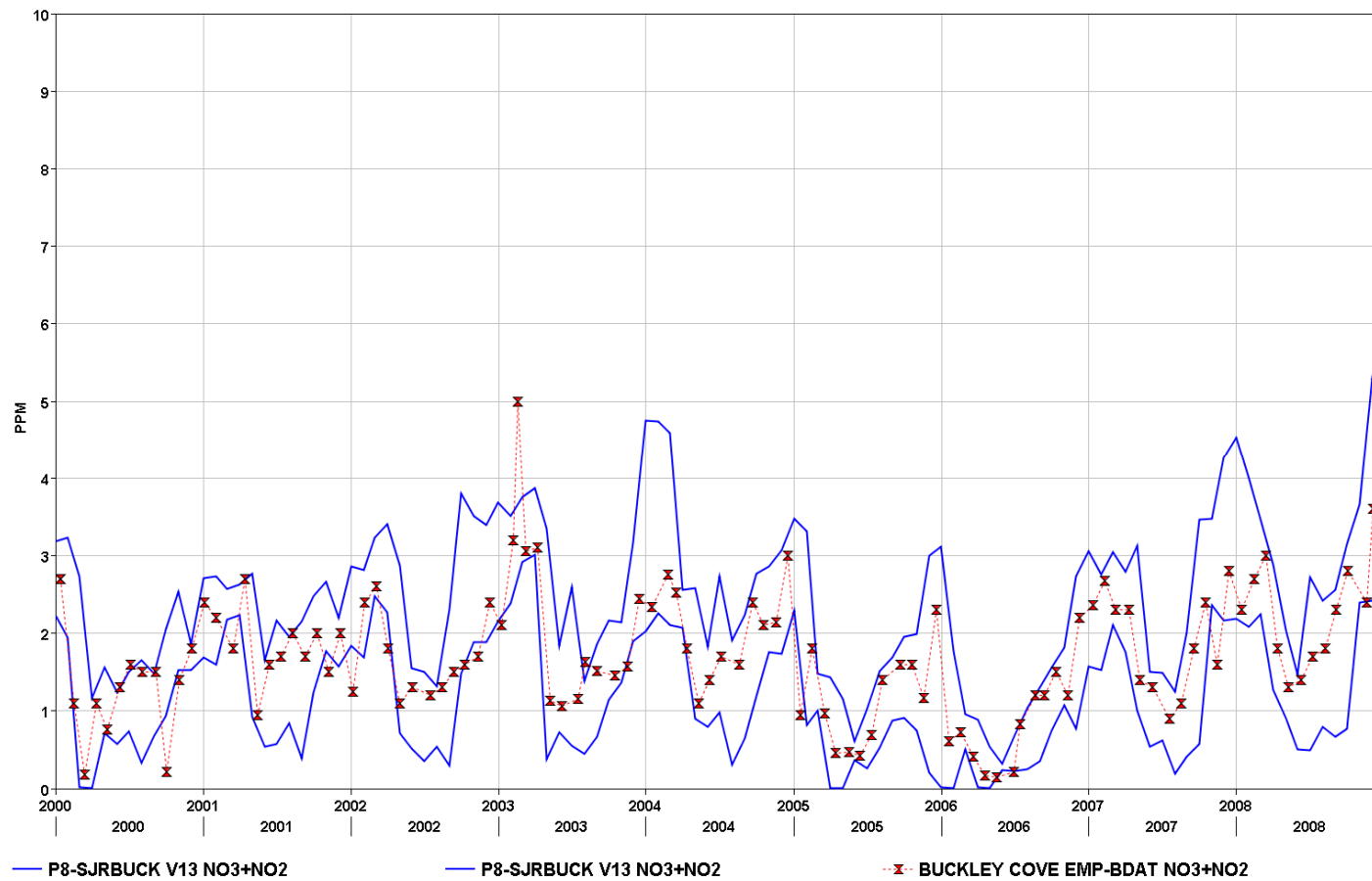


Figure A II. 71 Nitrate+Nitrite at SJR BUCKLEY later years.

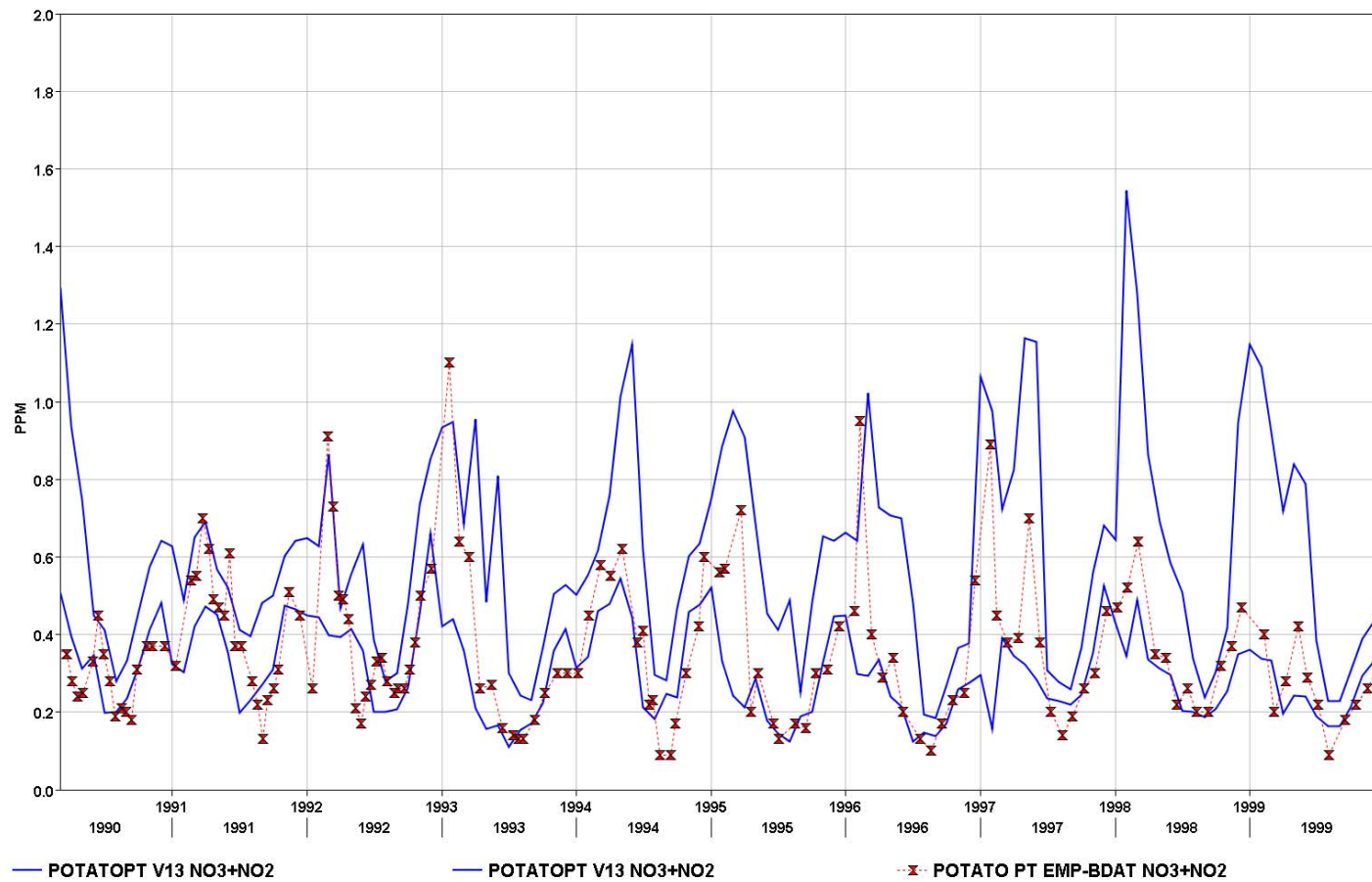


Figure A II. 72 Nitrate+Nitrite at Potato Pt. early years.

APPENDIX III

This document contains model calibration results in comparison with DO and algae measurements.

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A. DO

Figures were produced at all locations where there was sufficient data to plot more than a couple years. Where data was available for (nearly) the full model term, here plots were produced the full time span and the spans 1990 – 1999 and 2000 – 2009. Model plots sometimes begin in May or June 1990, as at some locations the initial condition values were somewhat too high or too low and model required spin-up at those locations for the first few months. The figures are organized by constituent.

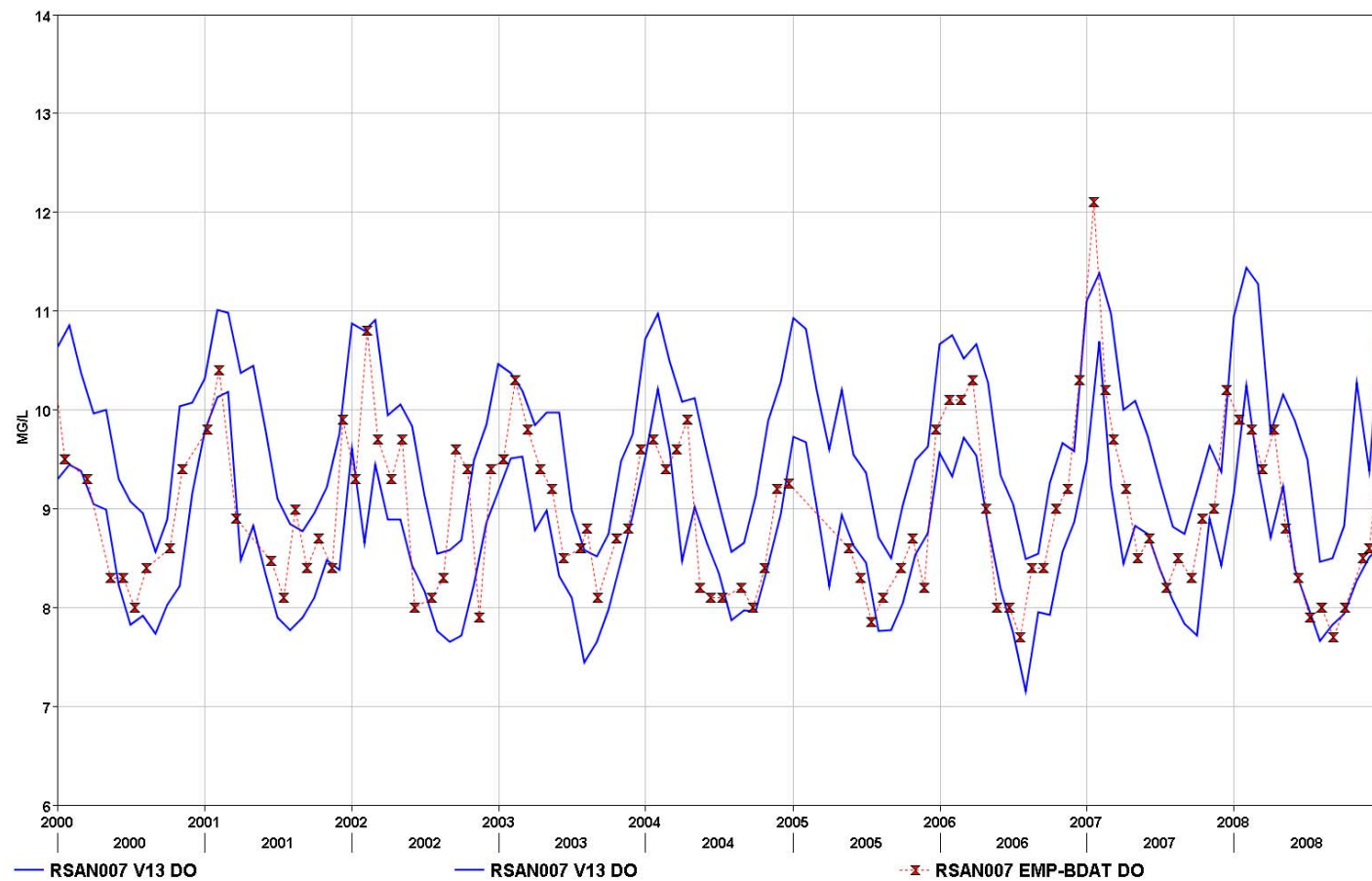


Figure A III. 1 DO at RSAN007 later years.

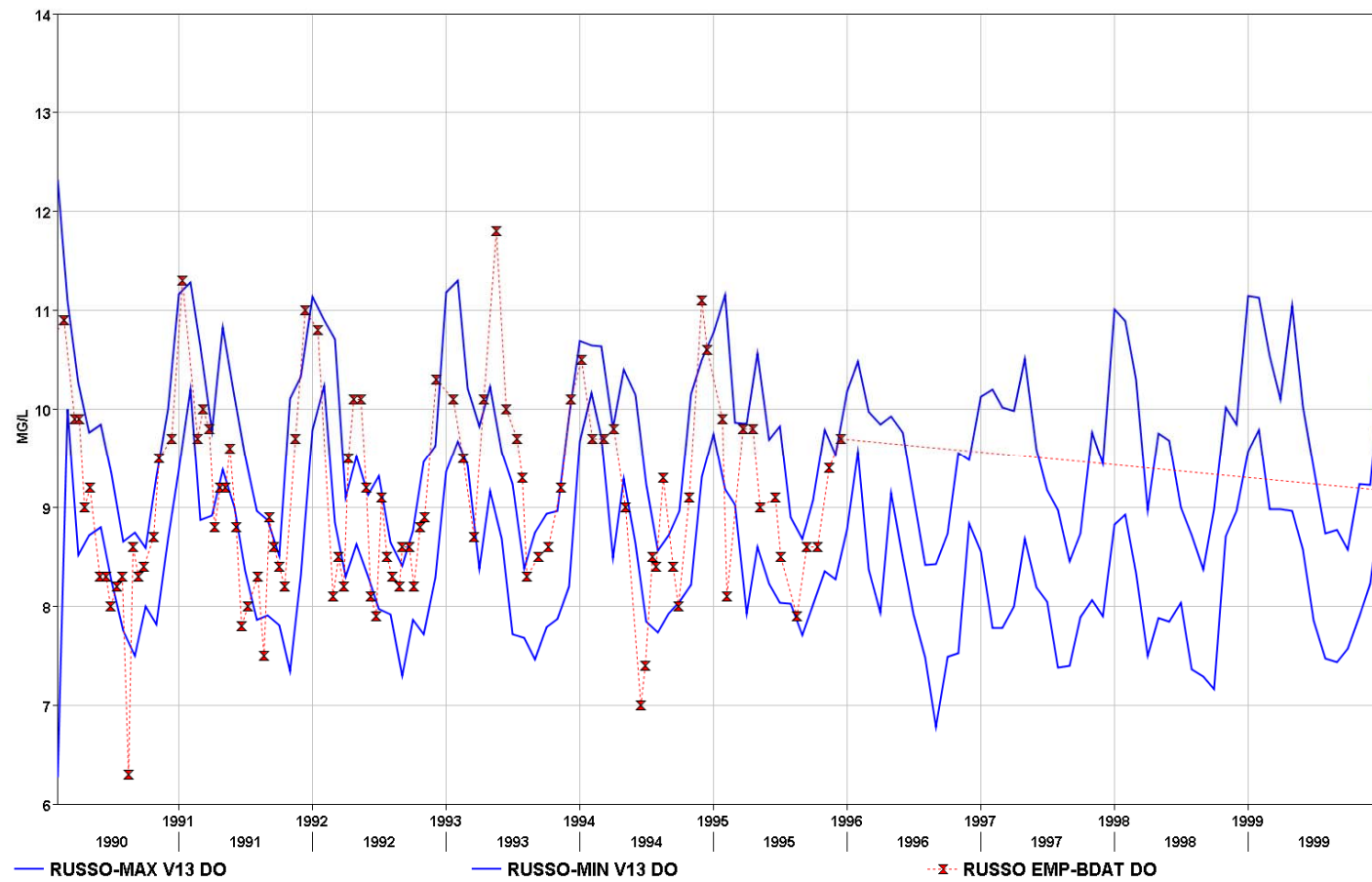


Figure A III. 2 DO at RUSSO early years.

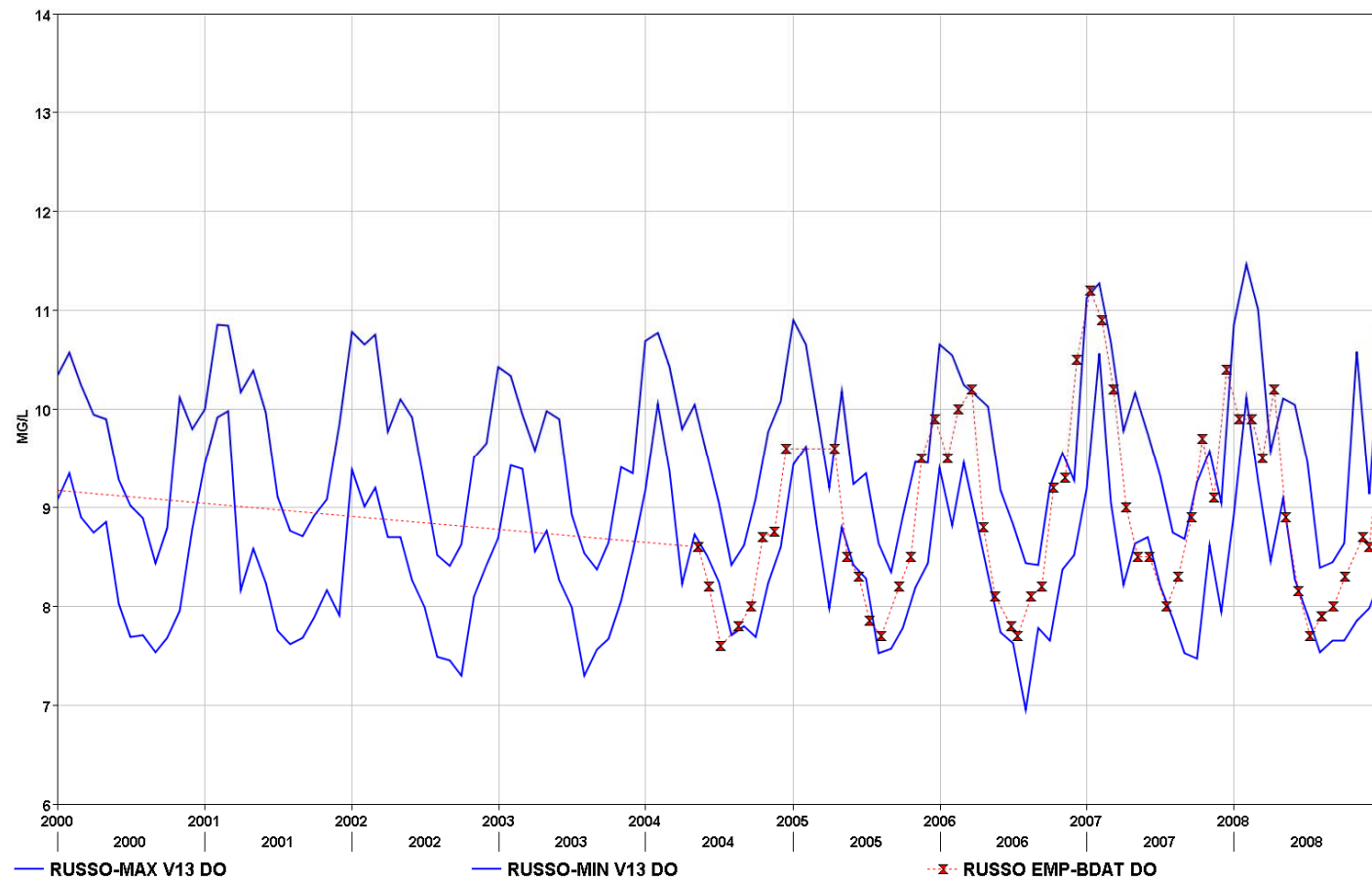


Figure A III. 3 DO at RUSSO later years.

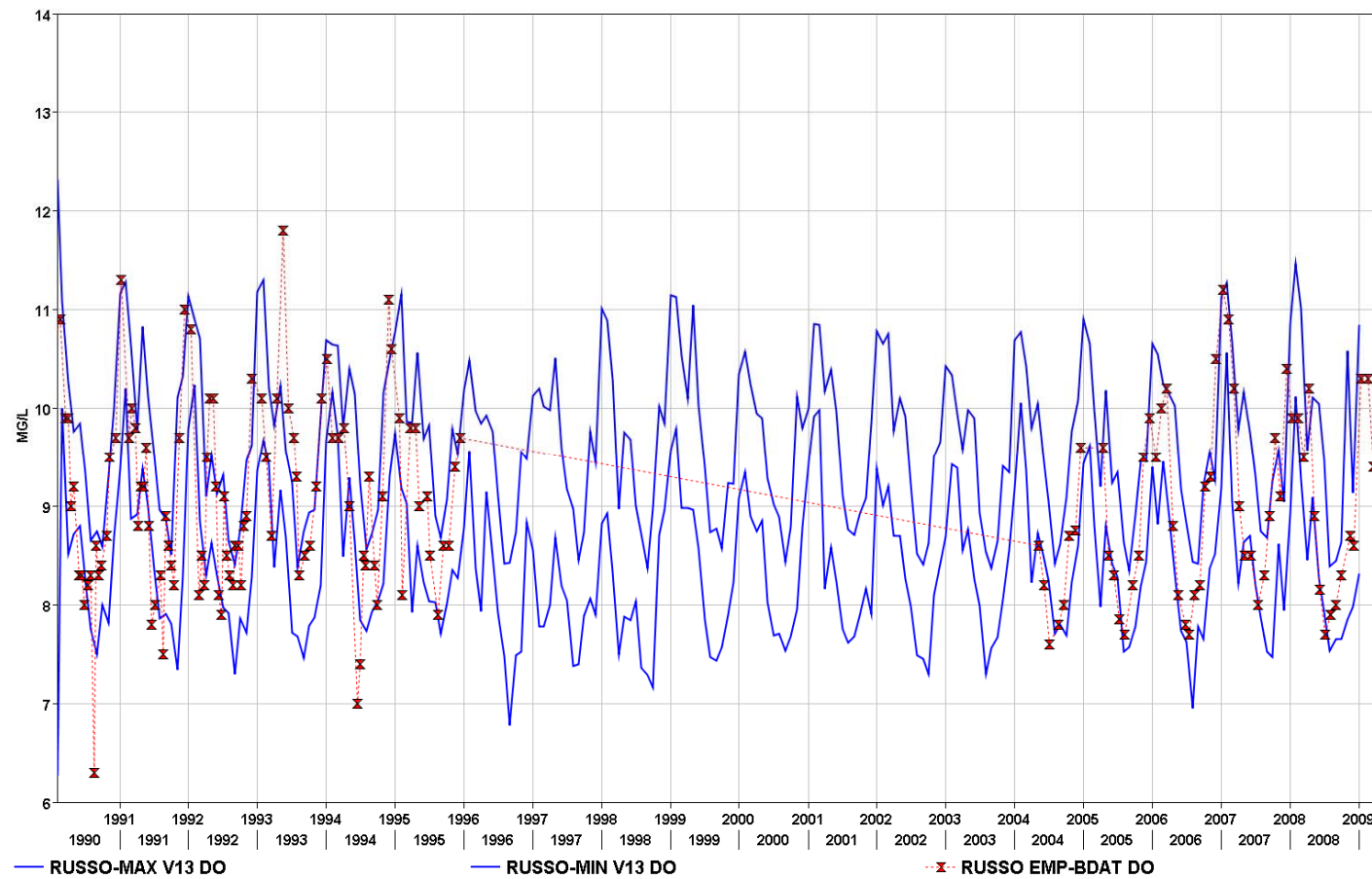


Figure A III. 4 DO at RUSSO all years.

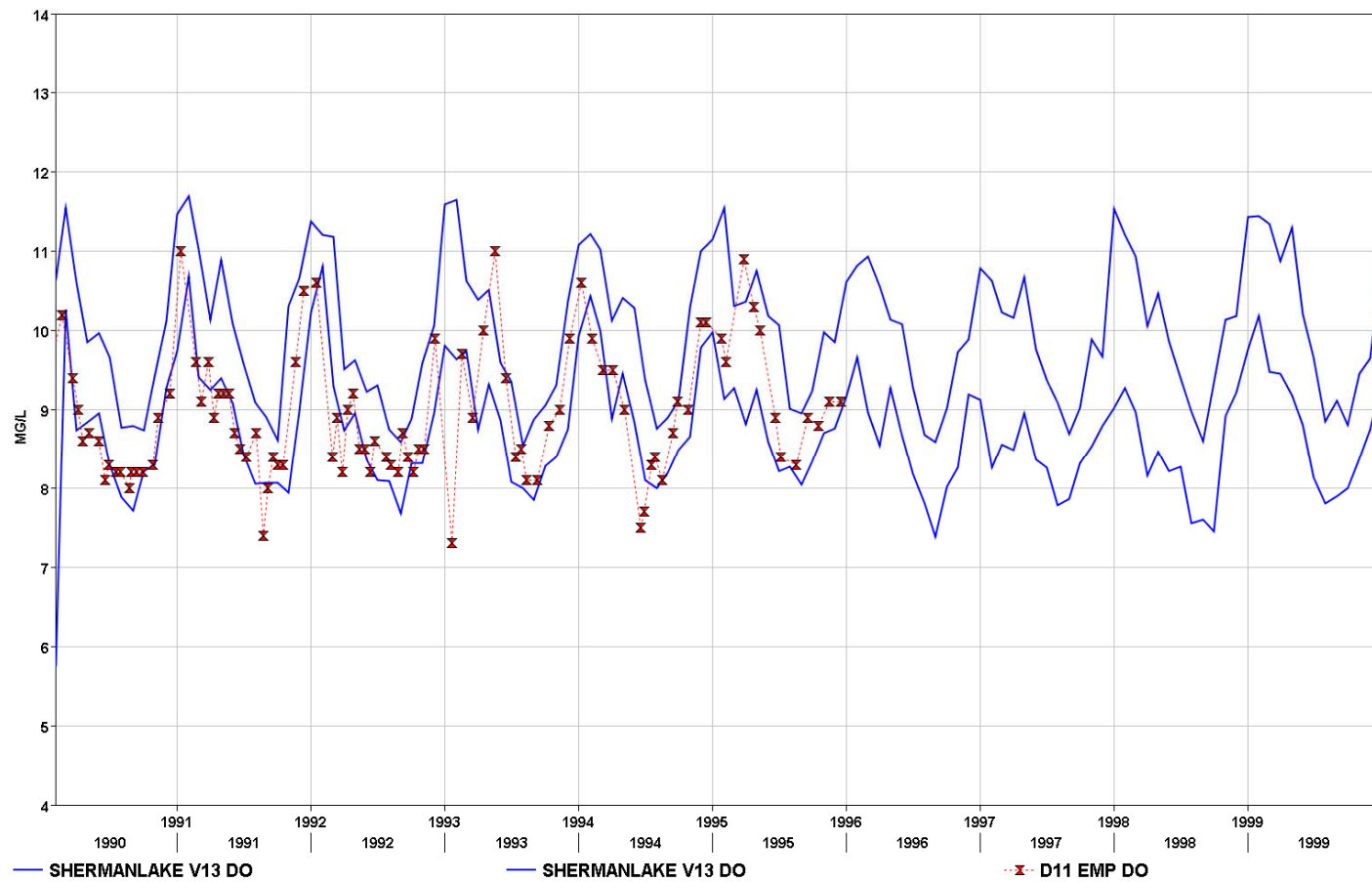


Figure A III. 5 DO at SHERMAN early years.

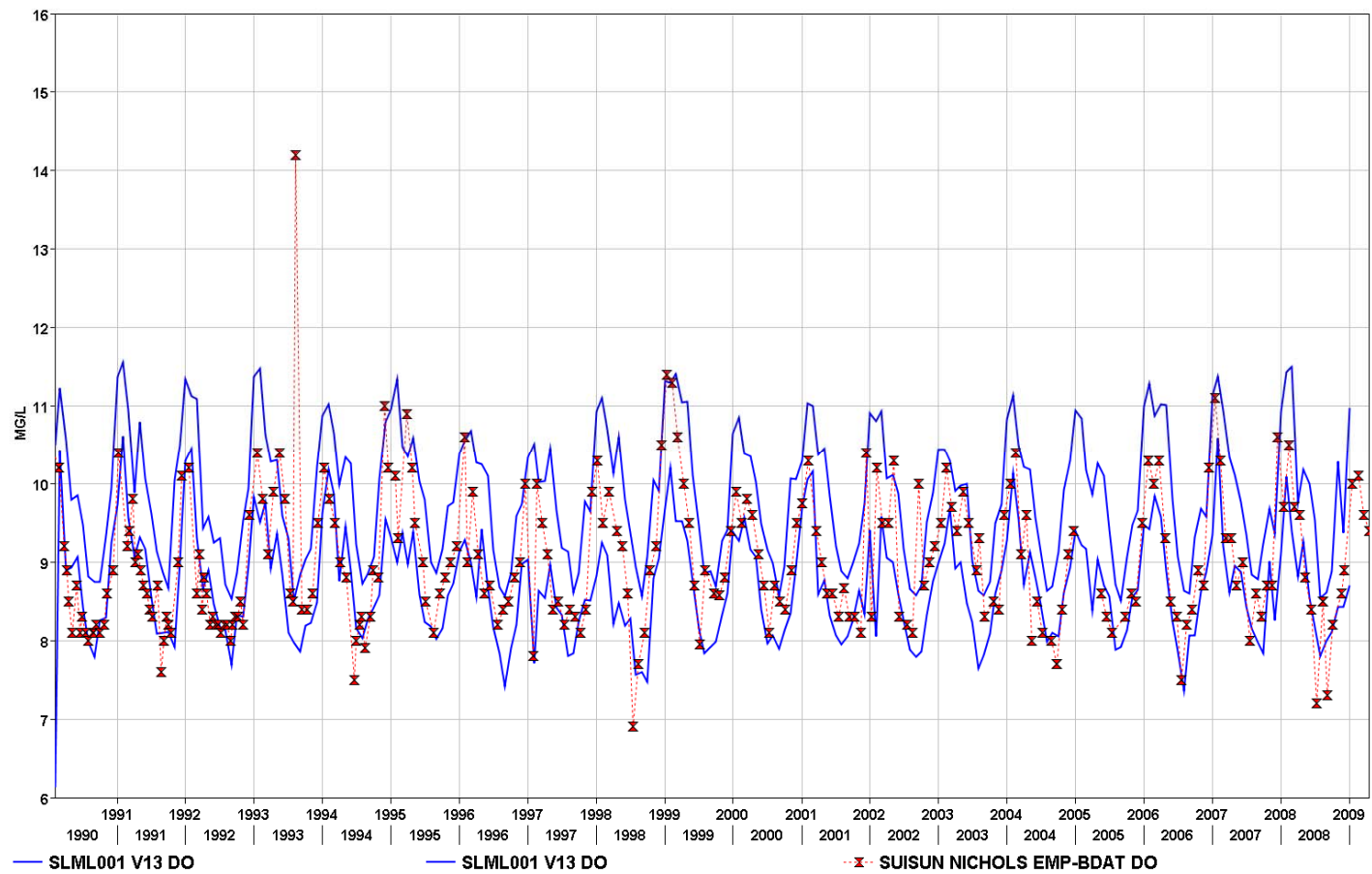


Figure A III. 6 DO at SLM001 all Years.

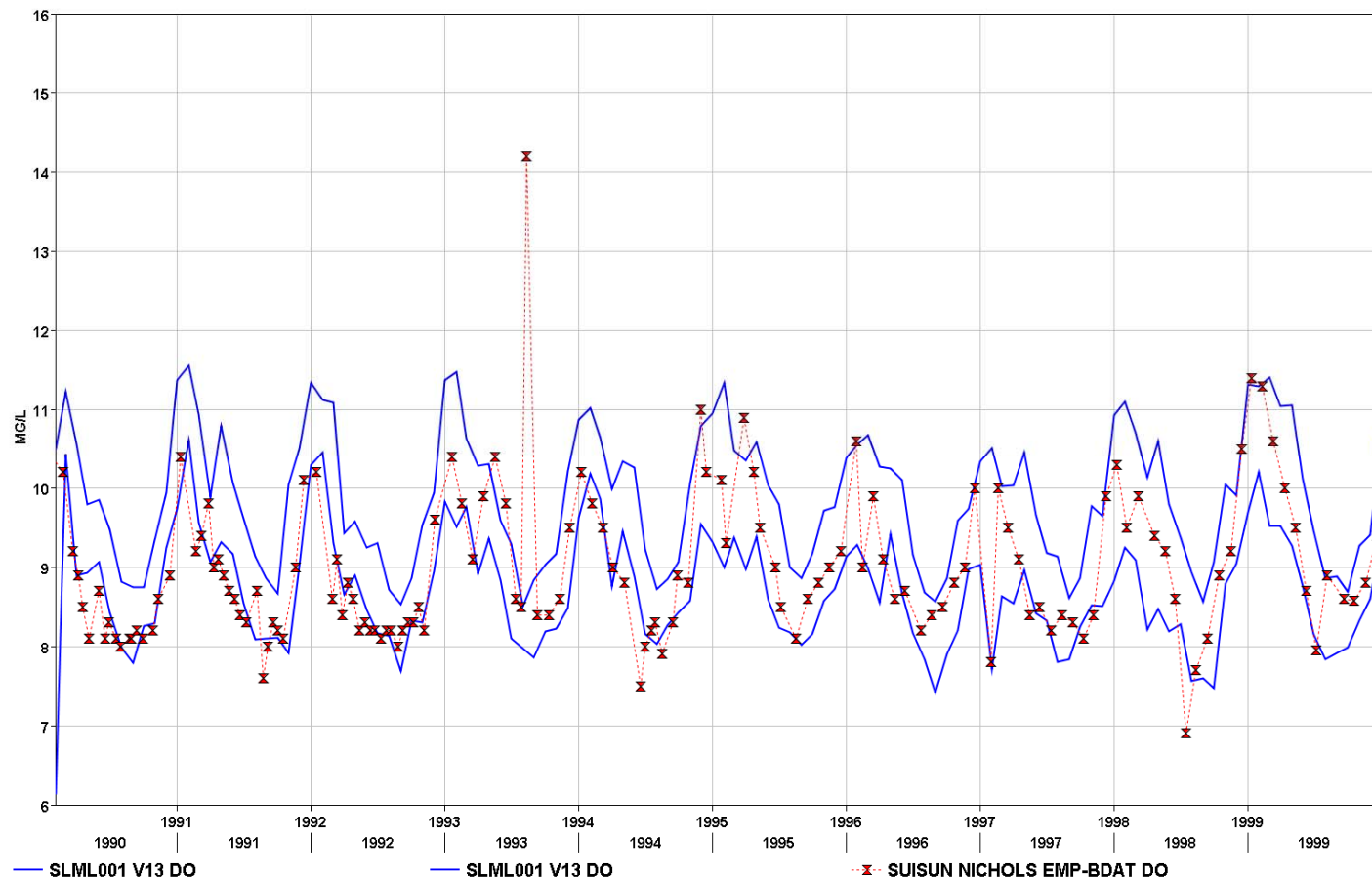


Figure A III. 7 DO at RLM001 early years.

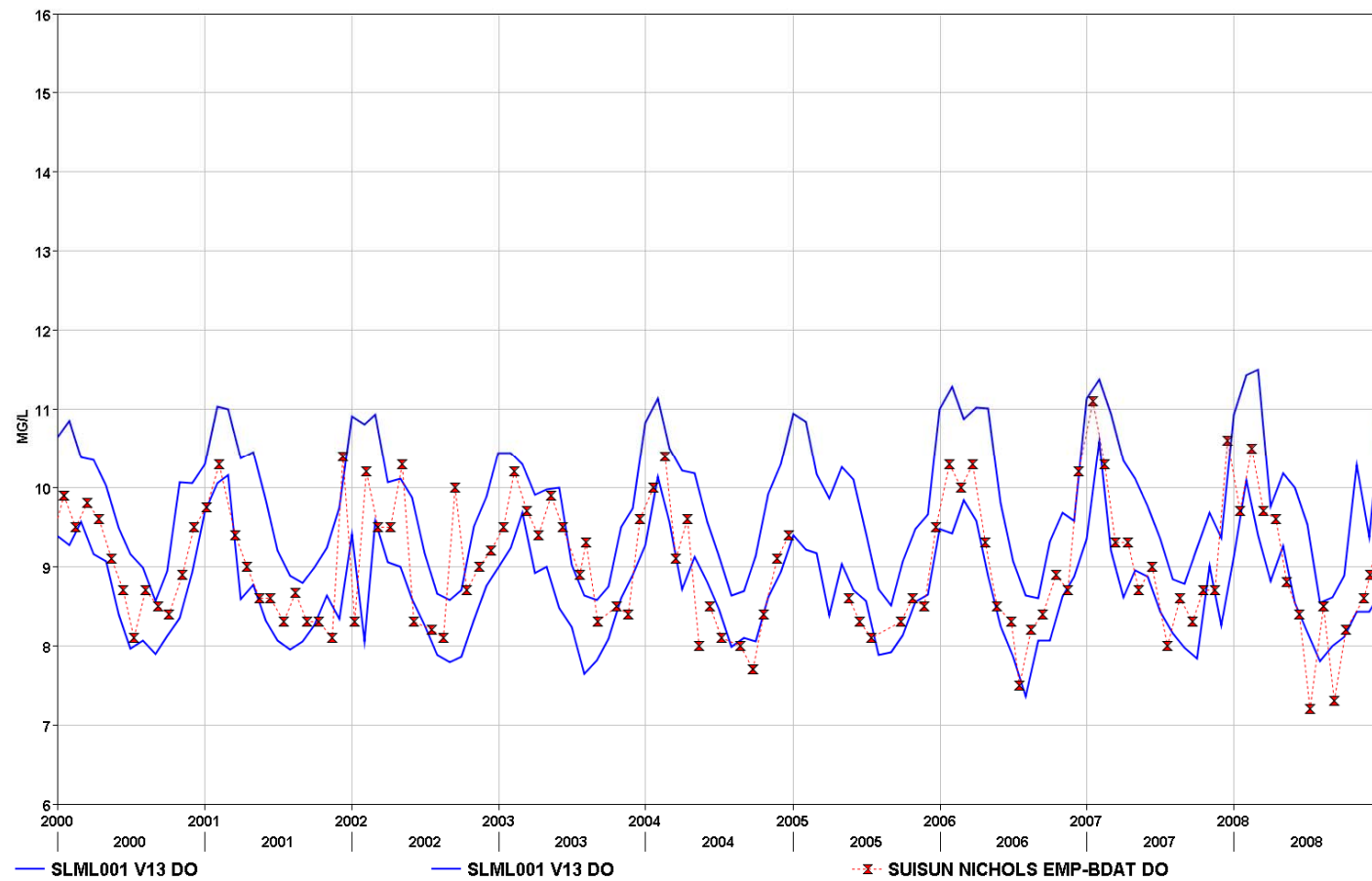


Figure A III. 8 DO at SLM001 laterR years.

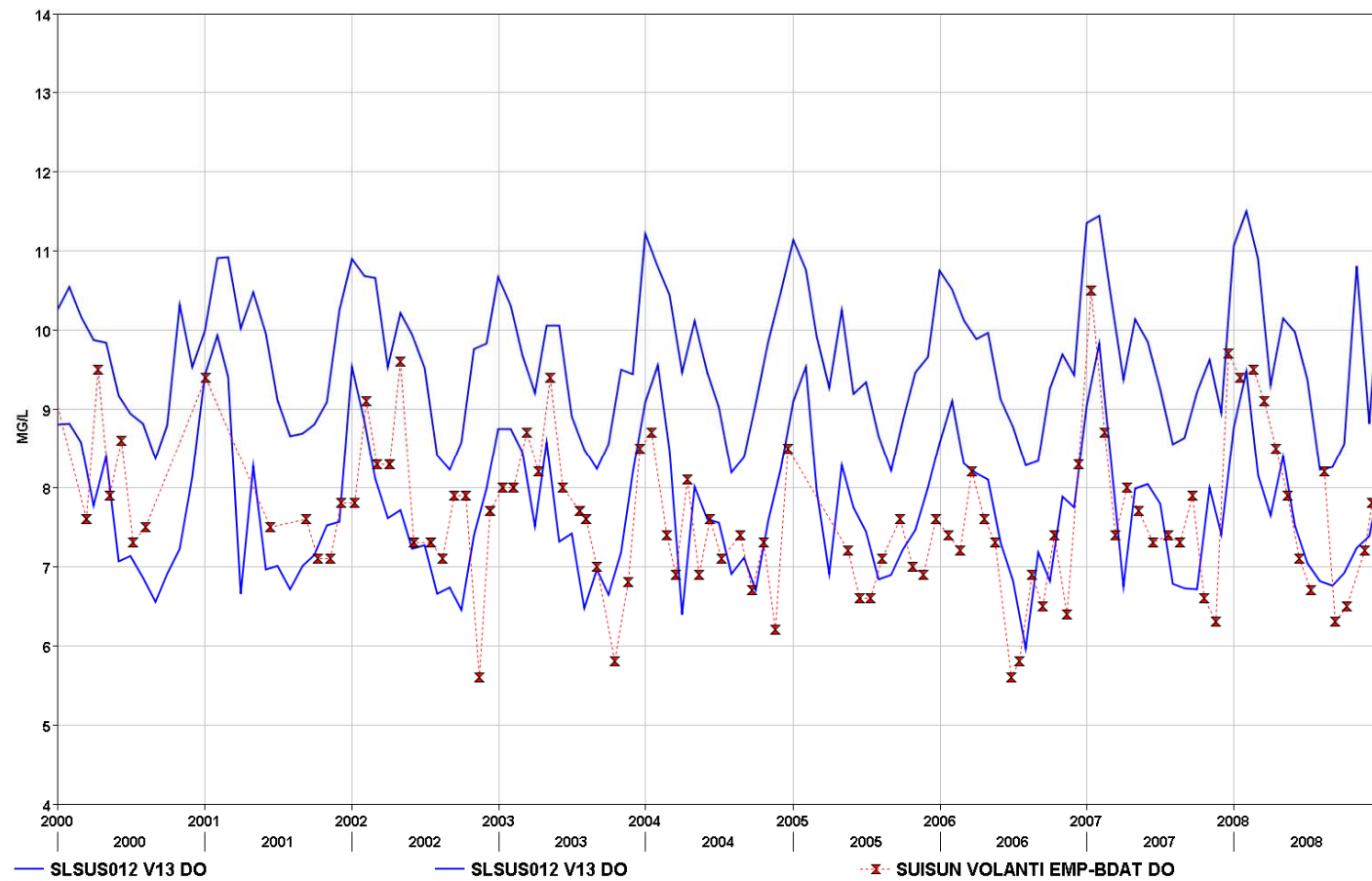


Figure A III. 9 DO at SLSUS012 (Suisun Volanti) later years.

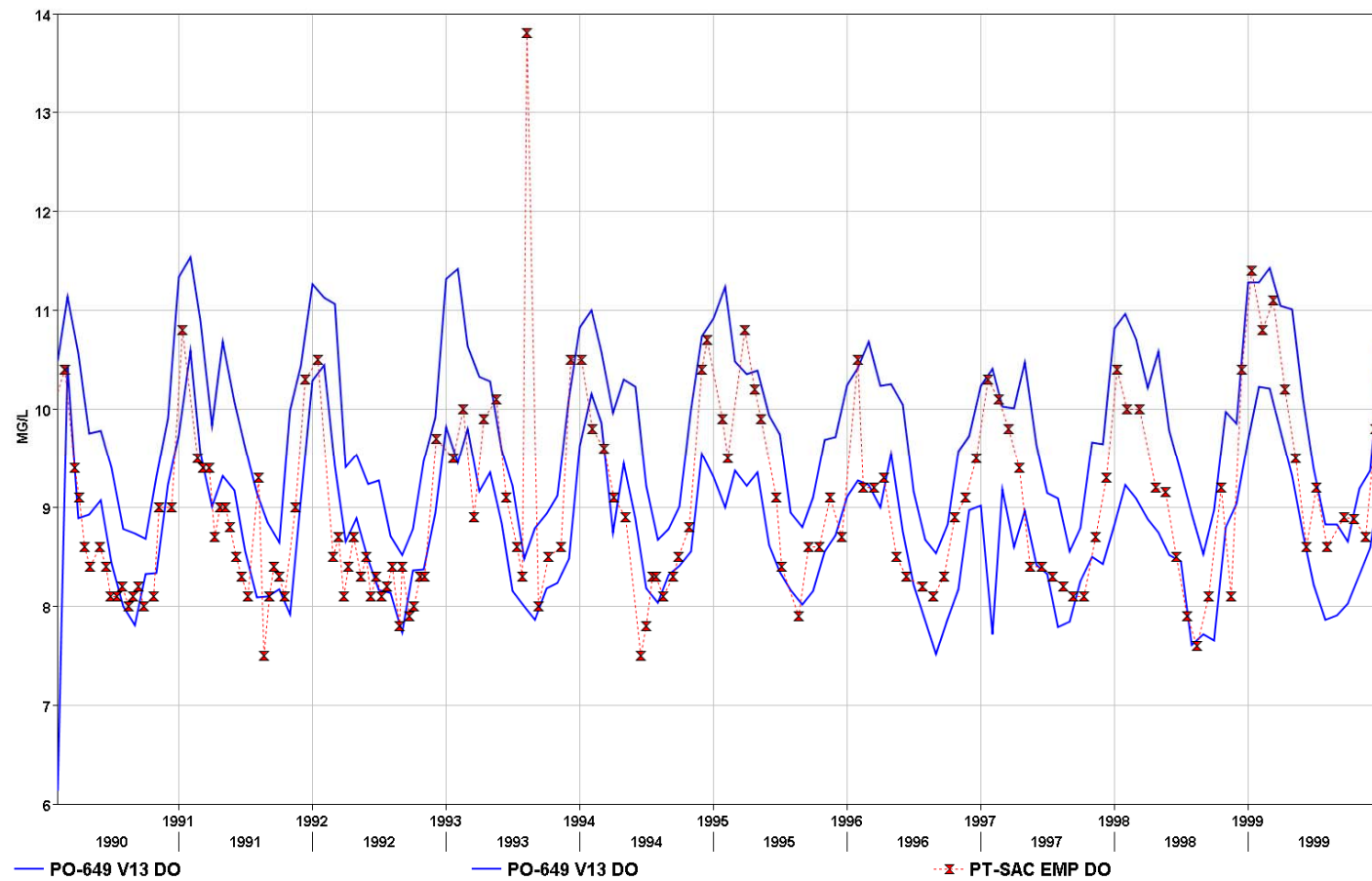


Figure A III. 10 DO at Pt. Sac. early years.

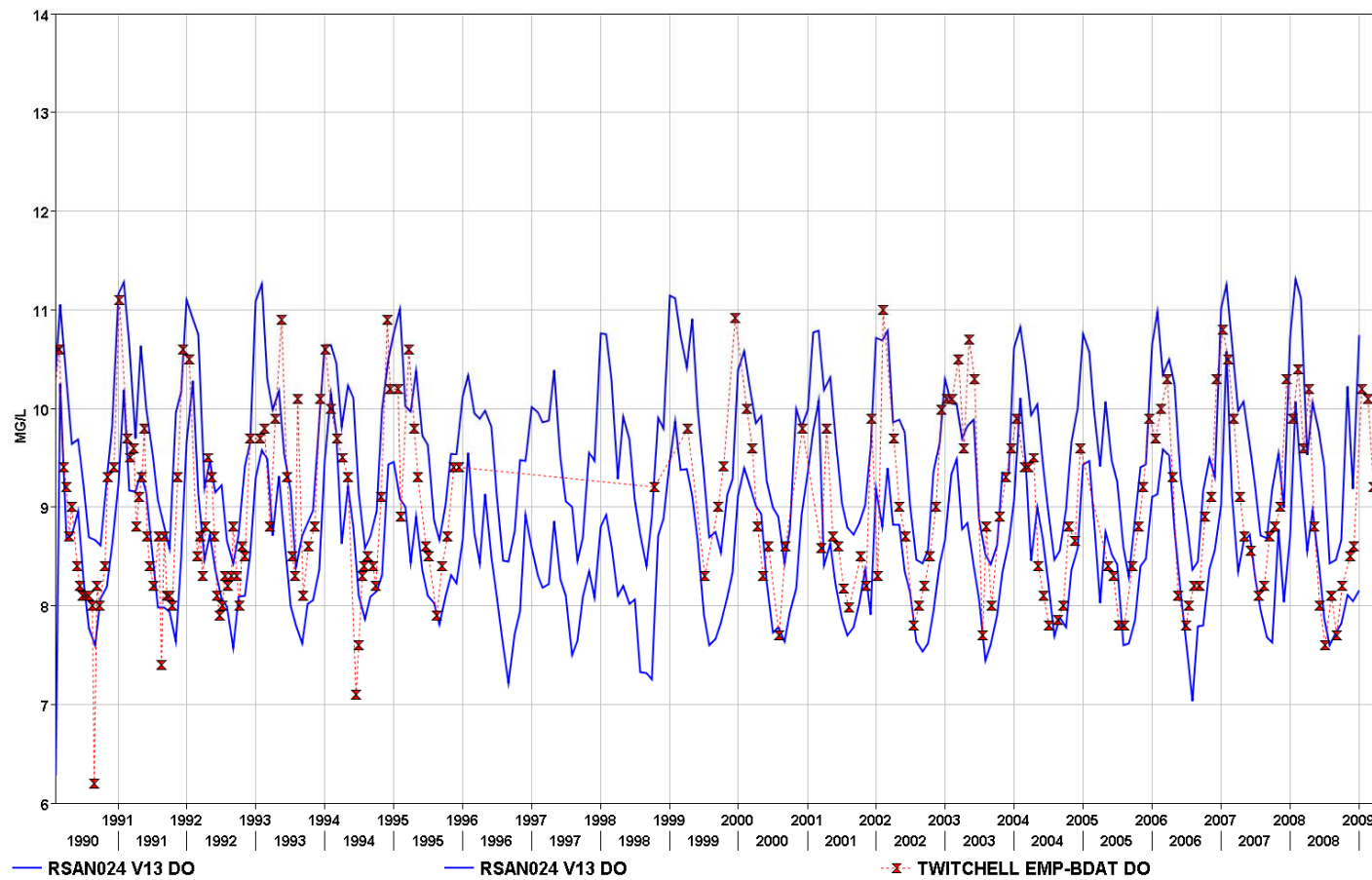


Figure A III. 11 DO at RSAN024 all years.

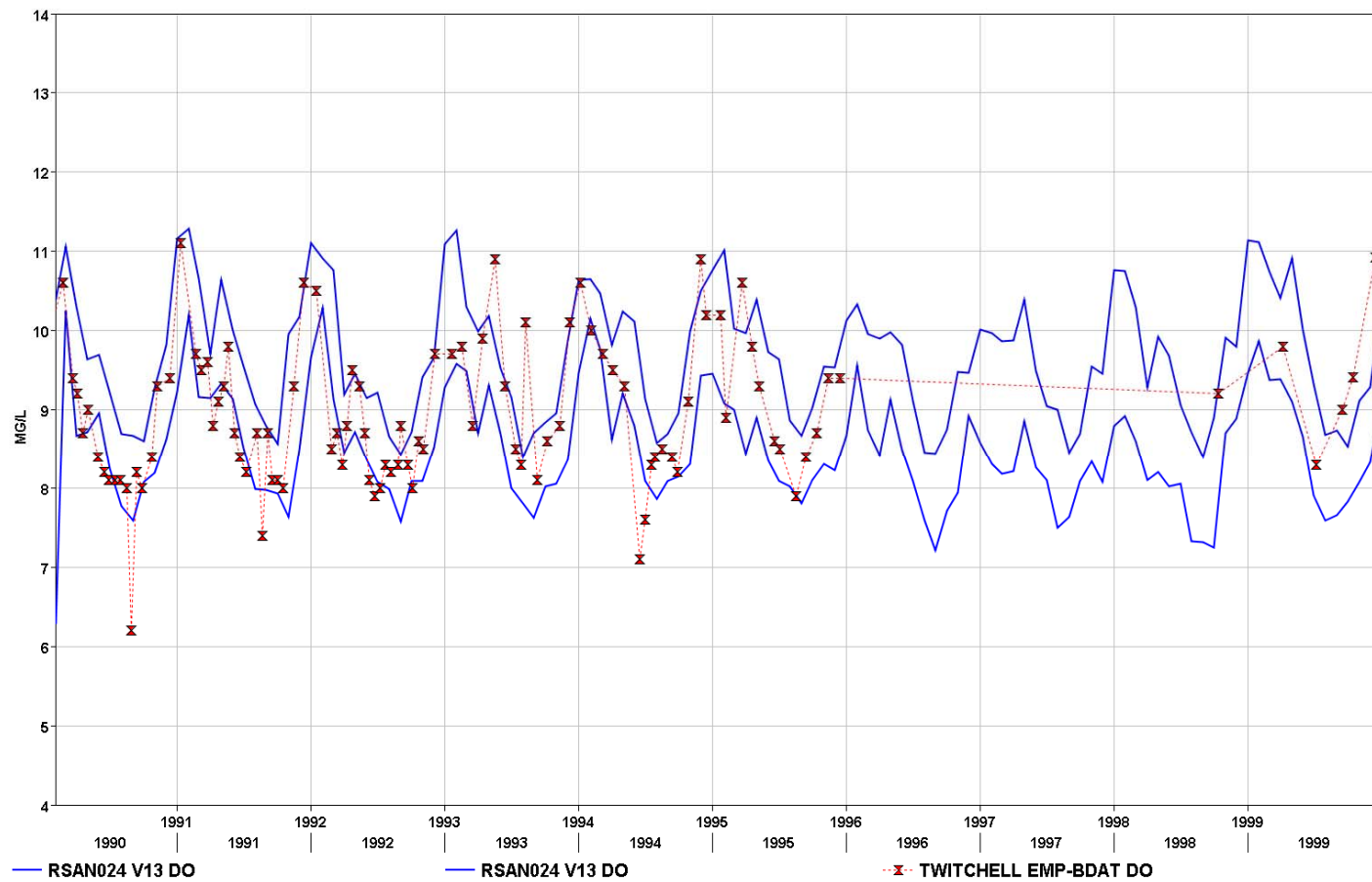


Figure A III. 12 DO at RSAN024 early years.

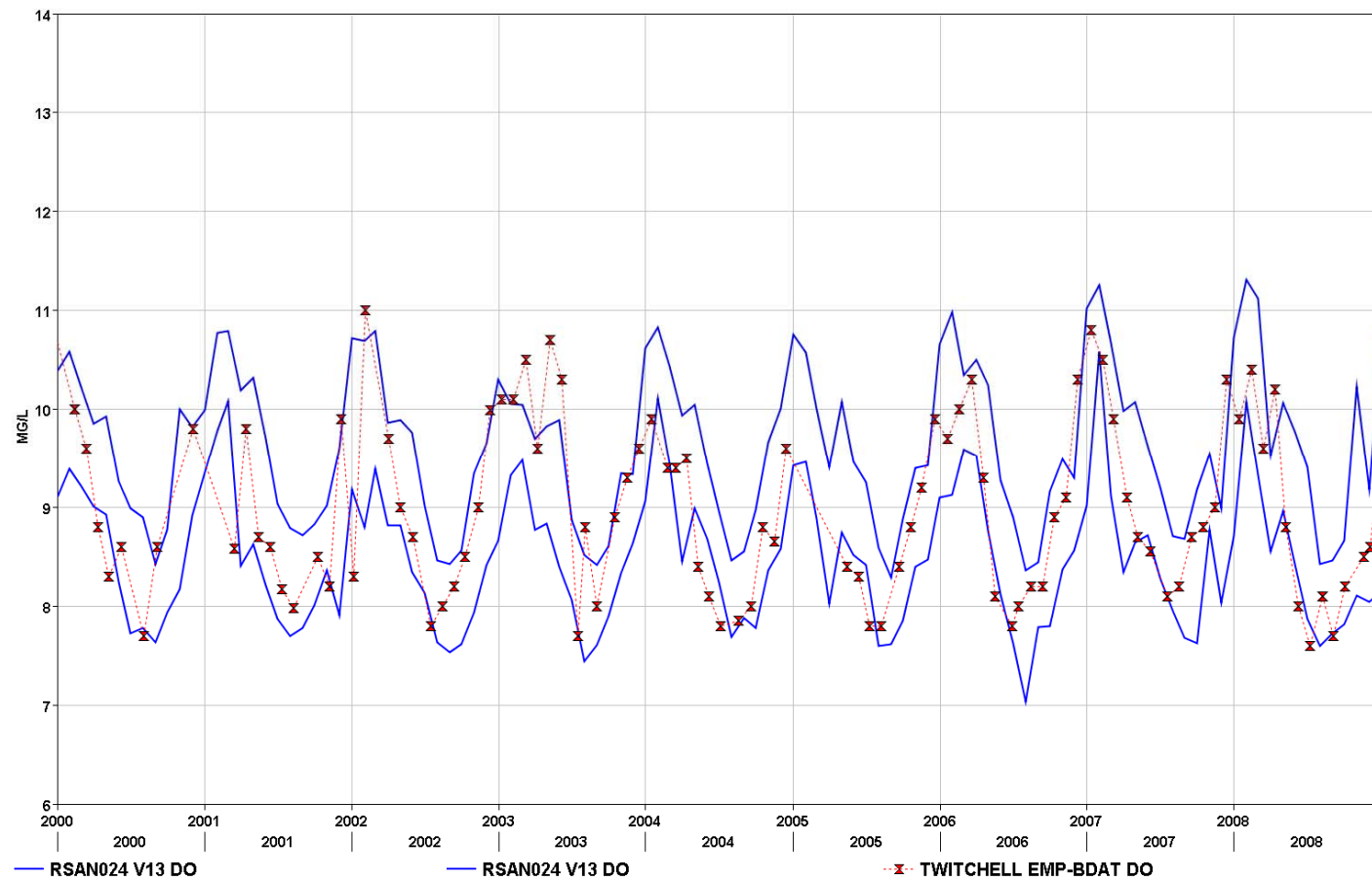


Figure A III. 13 DO at RSAN024 later years.

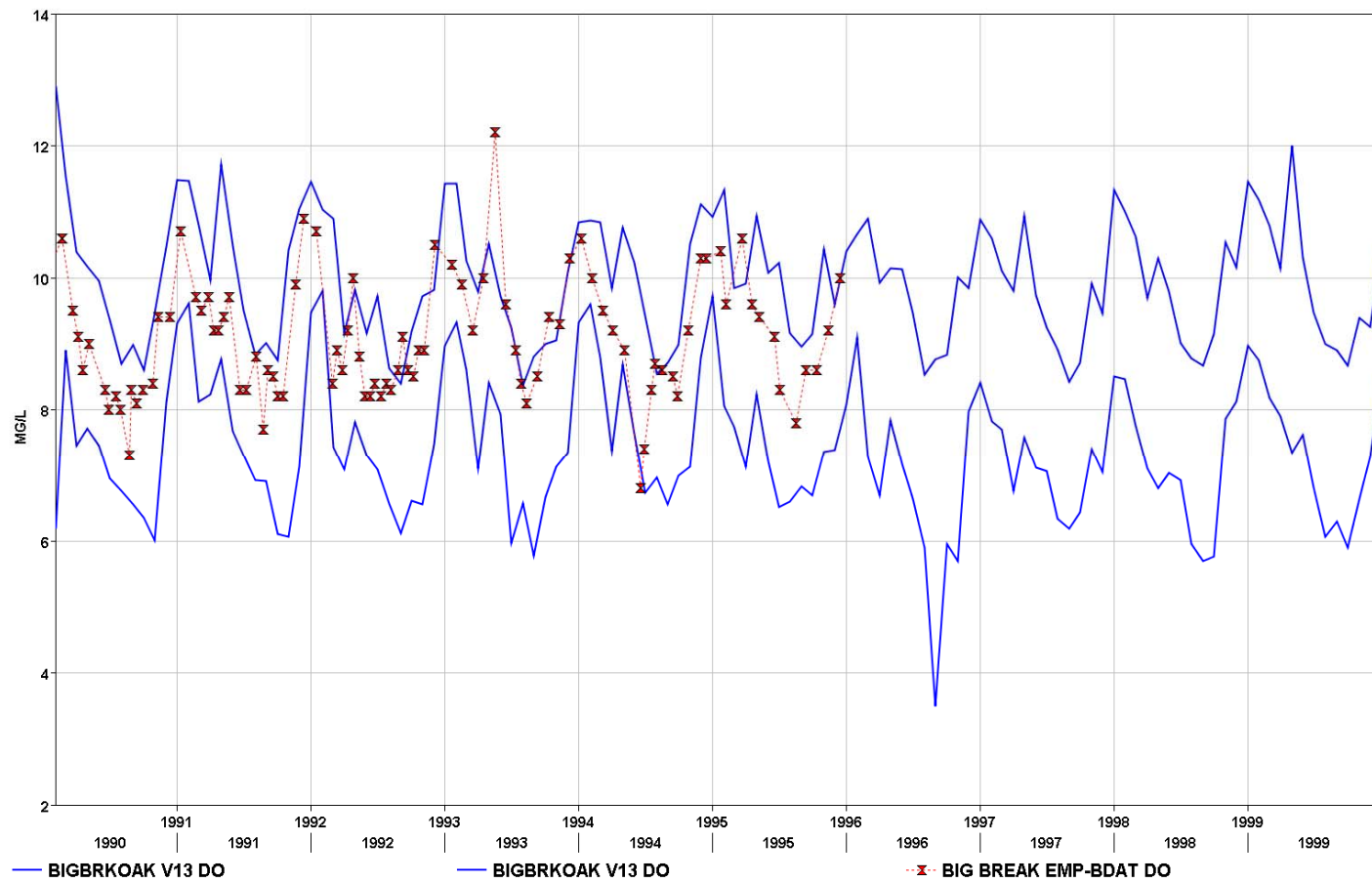


Figure A III. 14 DO at Big Break early years.

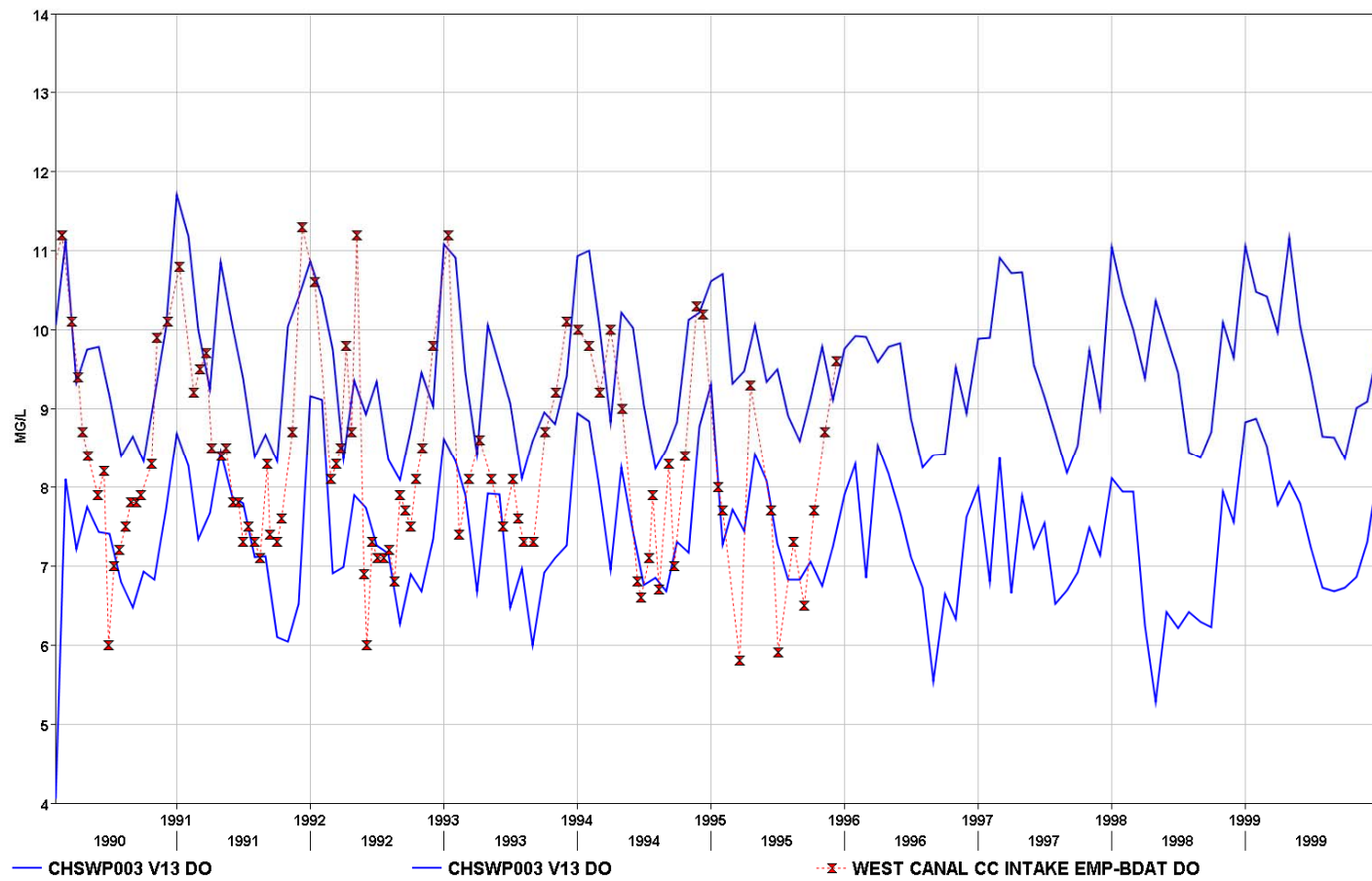


Figure A III. 15 DO at CHSWP003 early years.

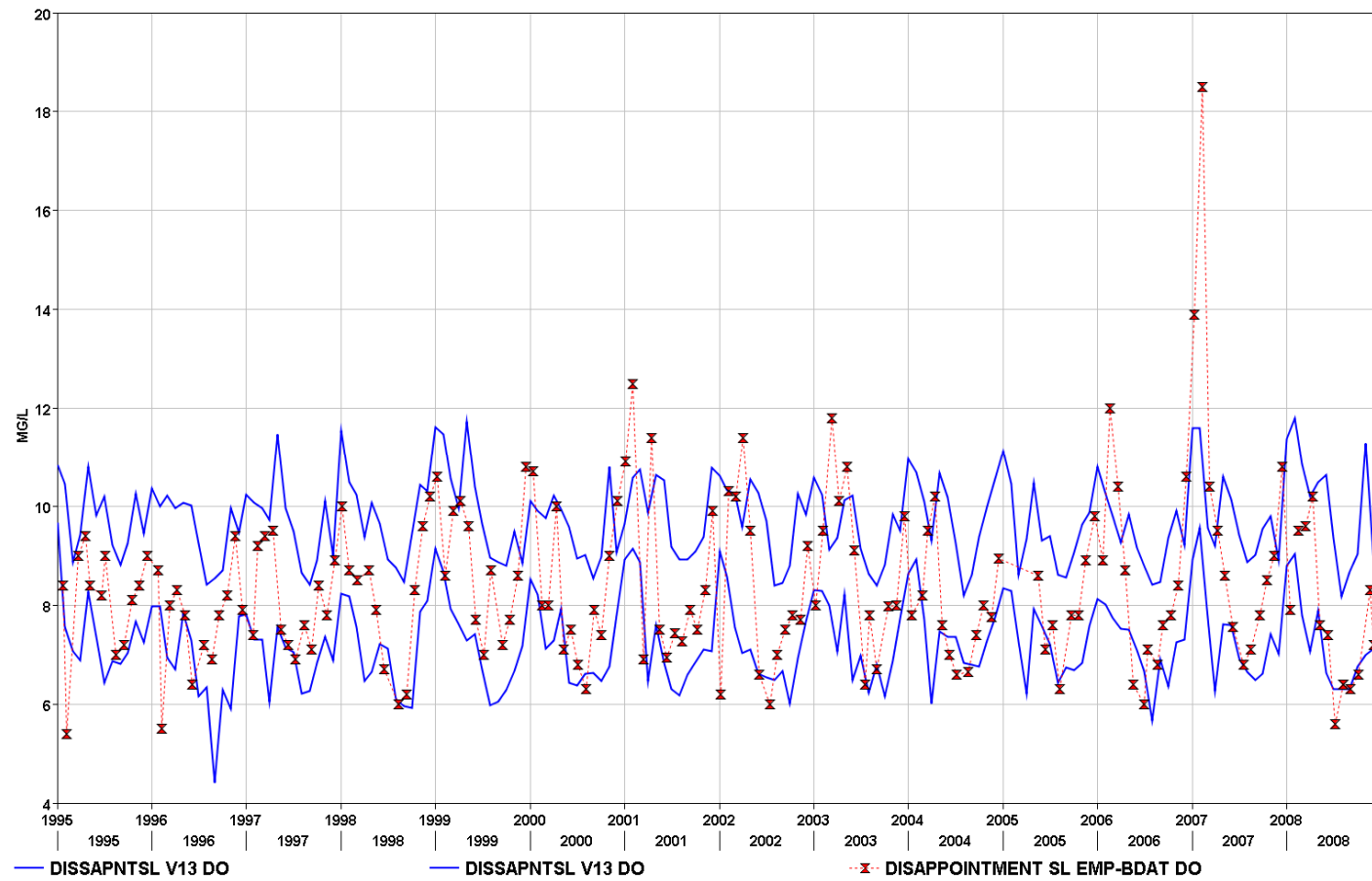


Figure A III. 16 DO at DISAP SL all years.

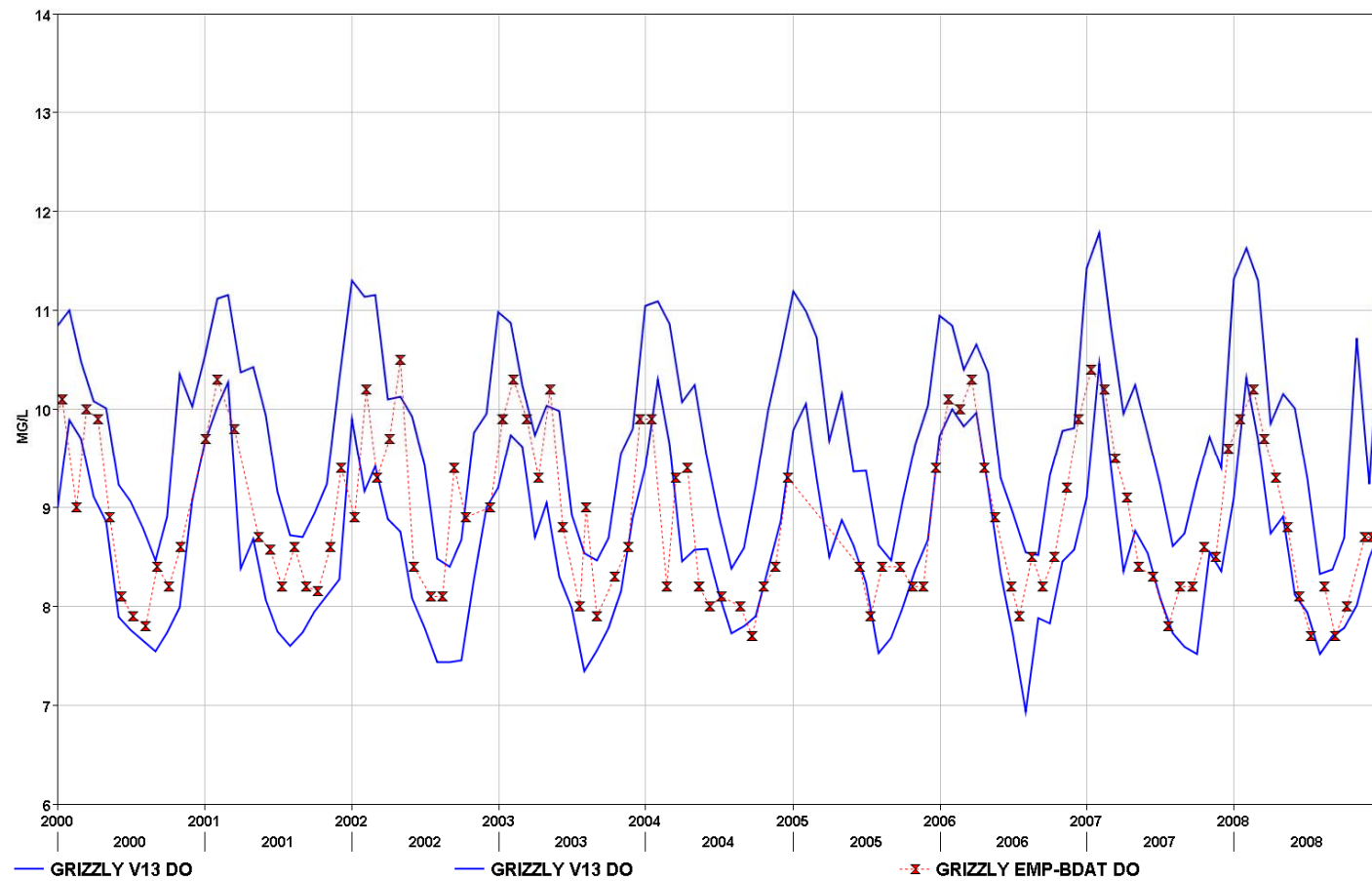


Figure A III. 17 DO at GRIZZLY later years.

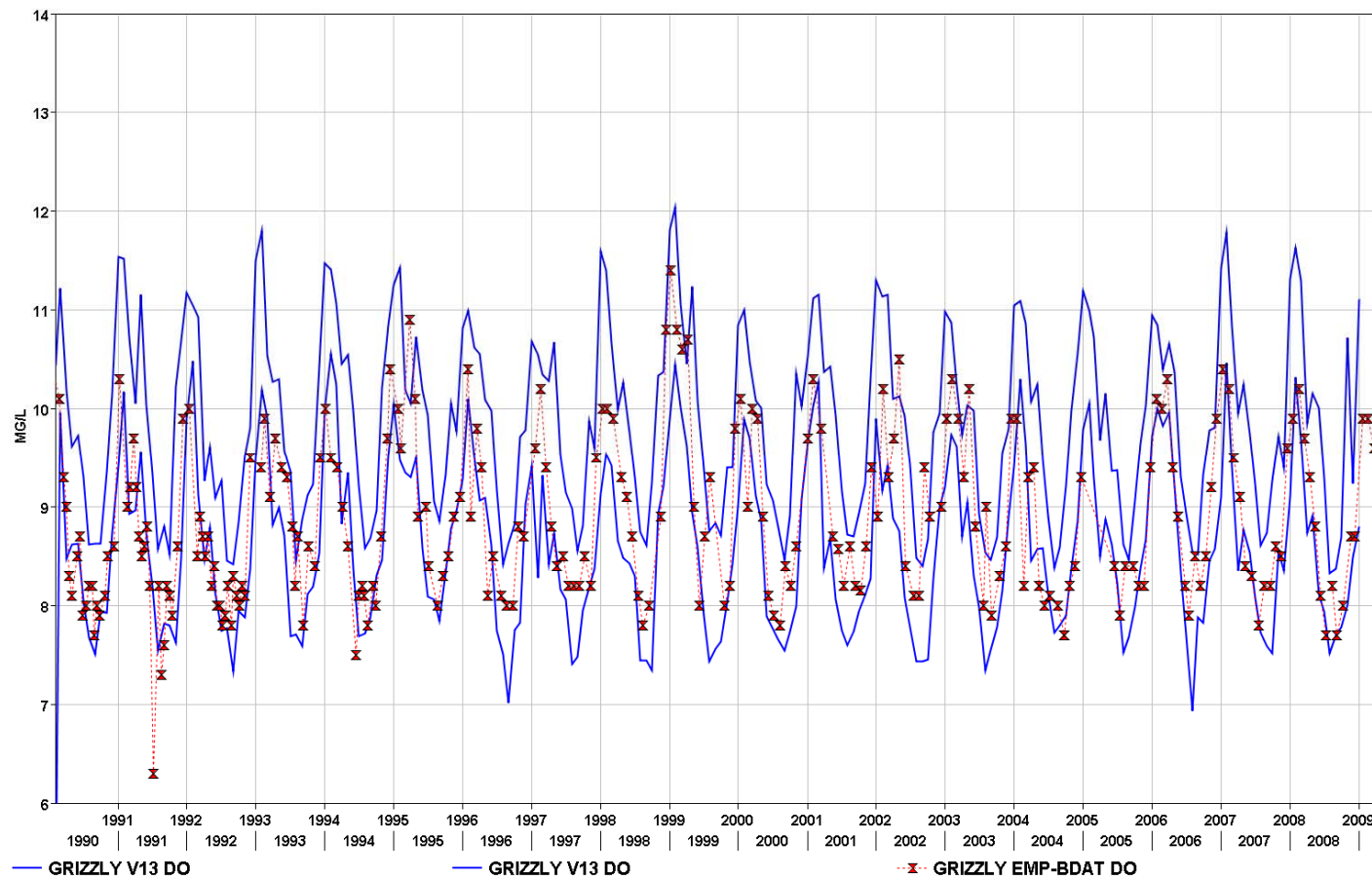


Figure A III. 18 DO at GRIZZLY all years.

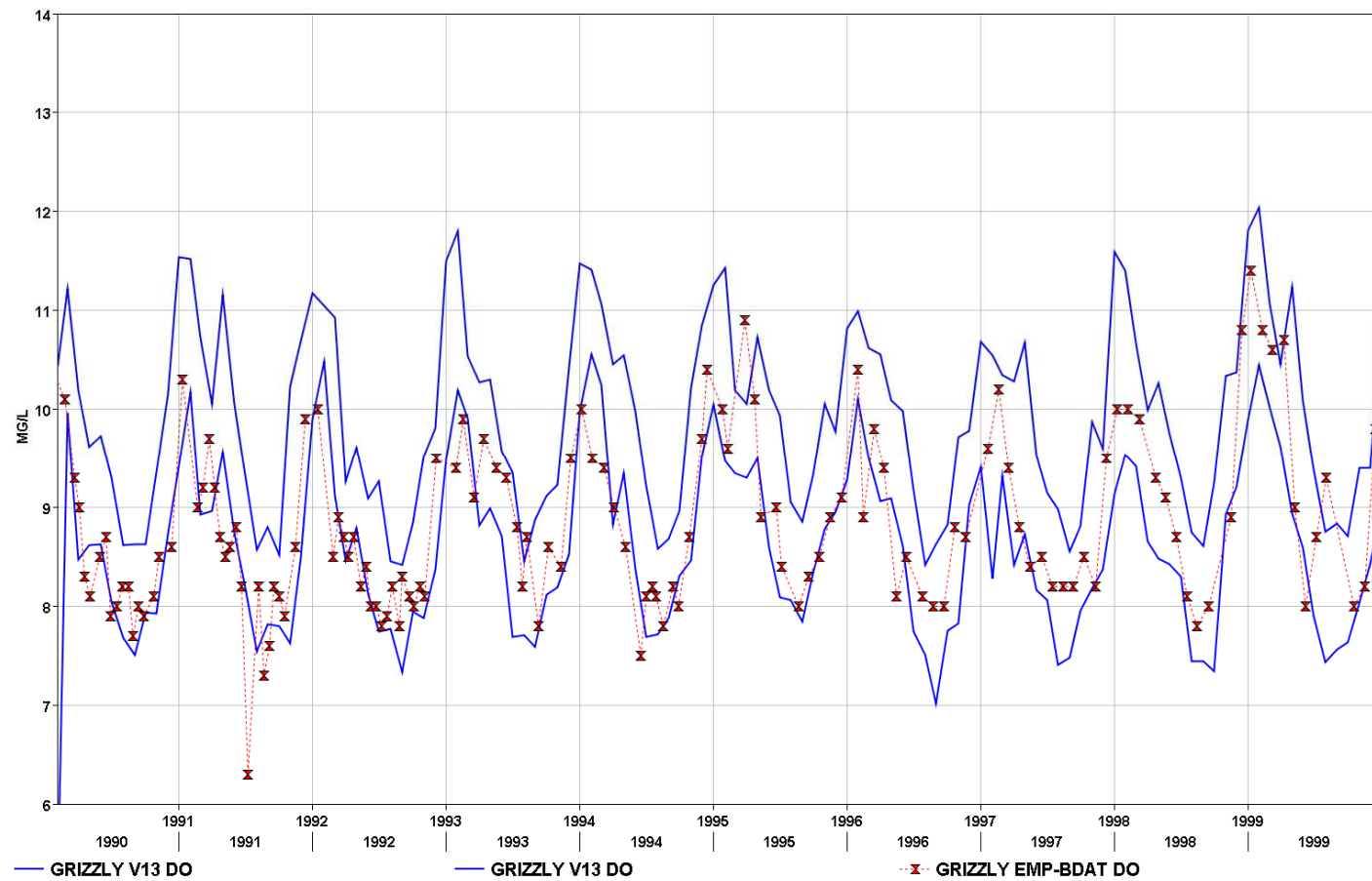


Figure A III. 19 DO at GRIZZLY early years.

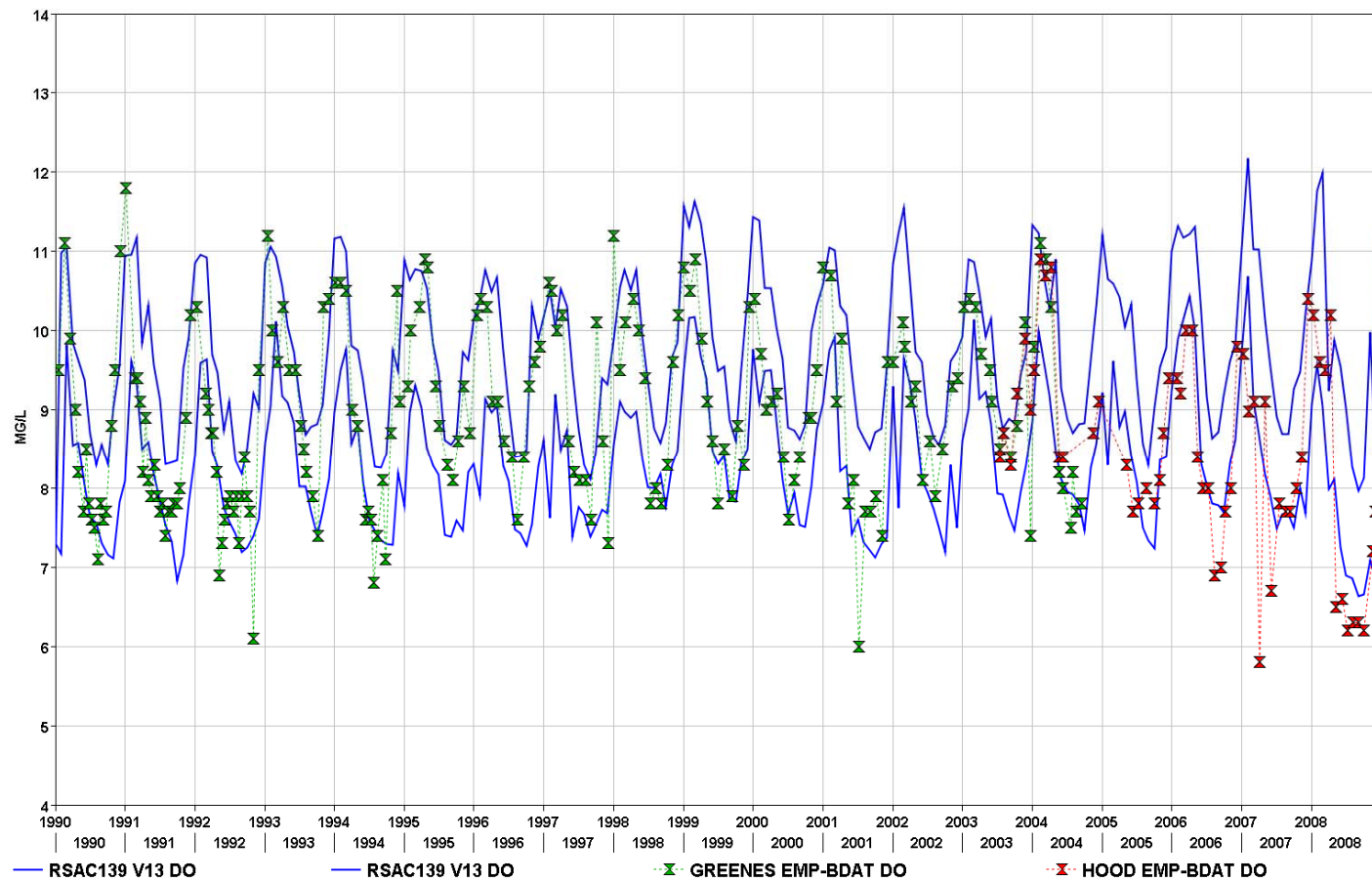


Figure A III. 20 DO at RSAC139 all years.

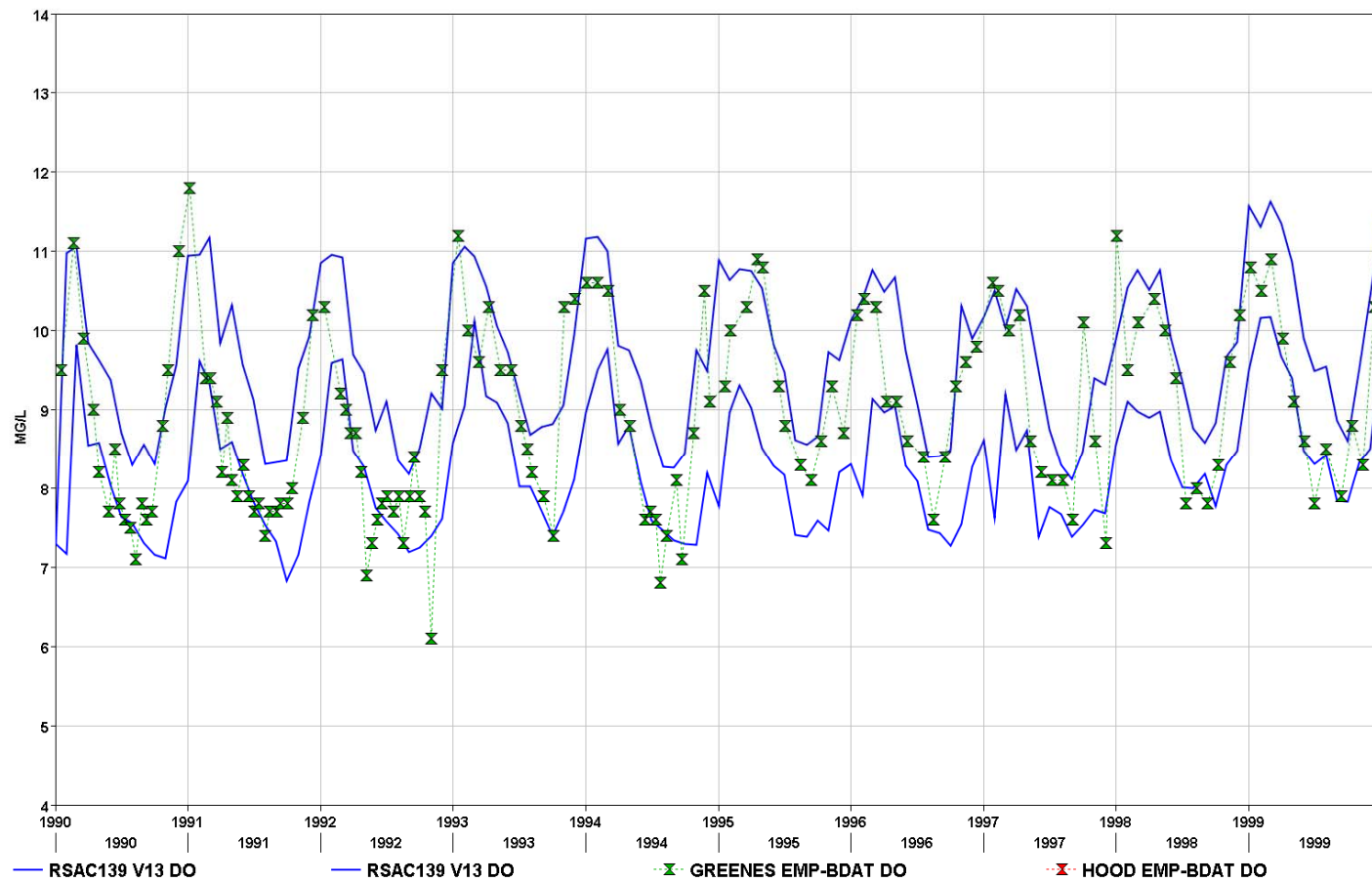


Figure A III. 21 DO at RSAC130 early years.

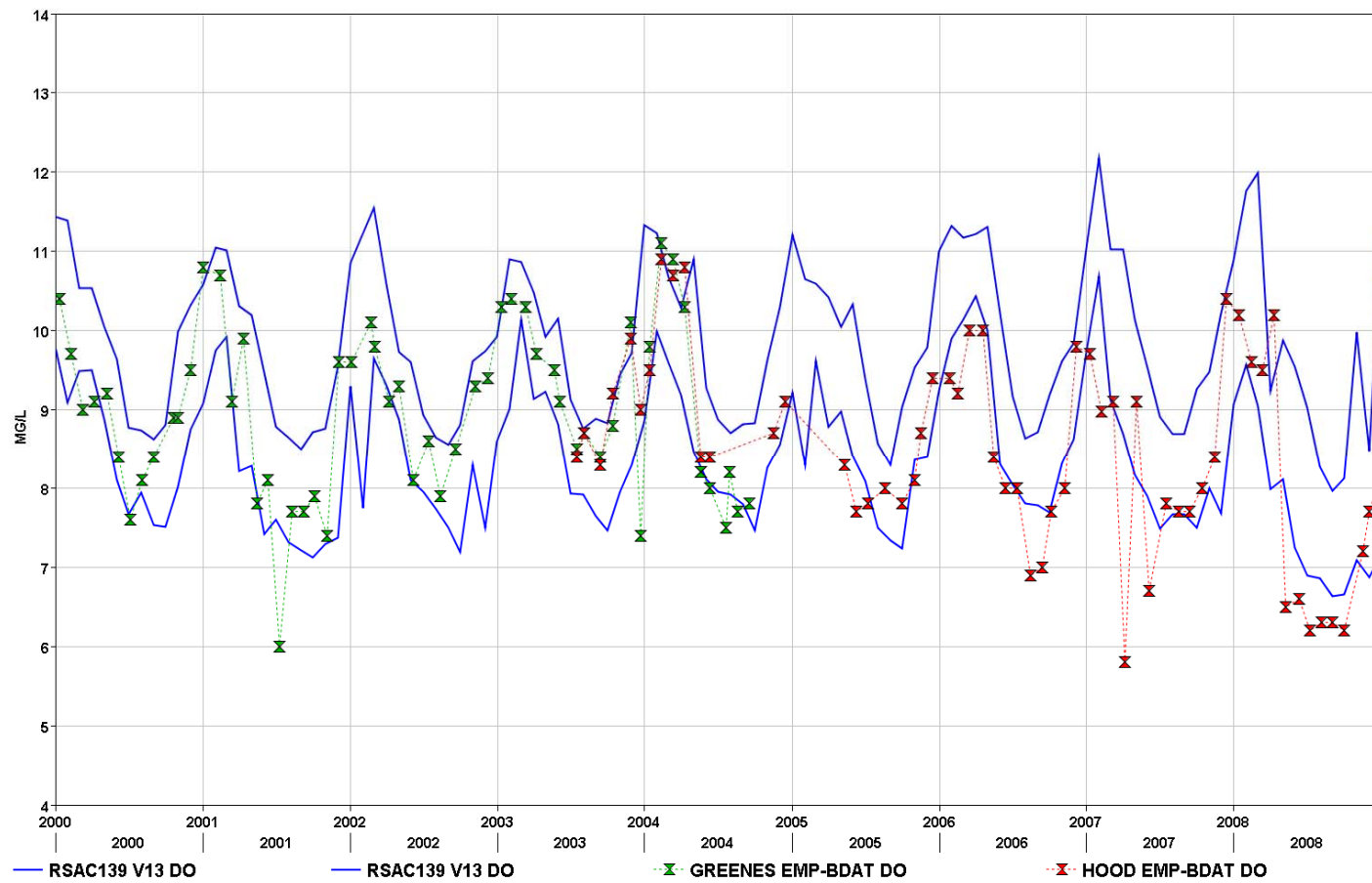


Figure A III. 22 DO at RSAC139 later years.

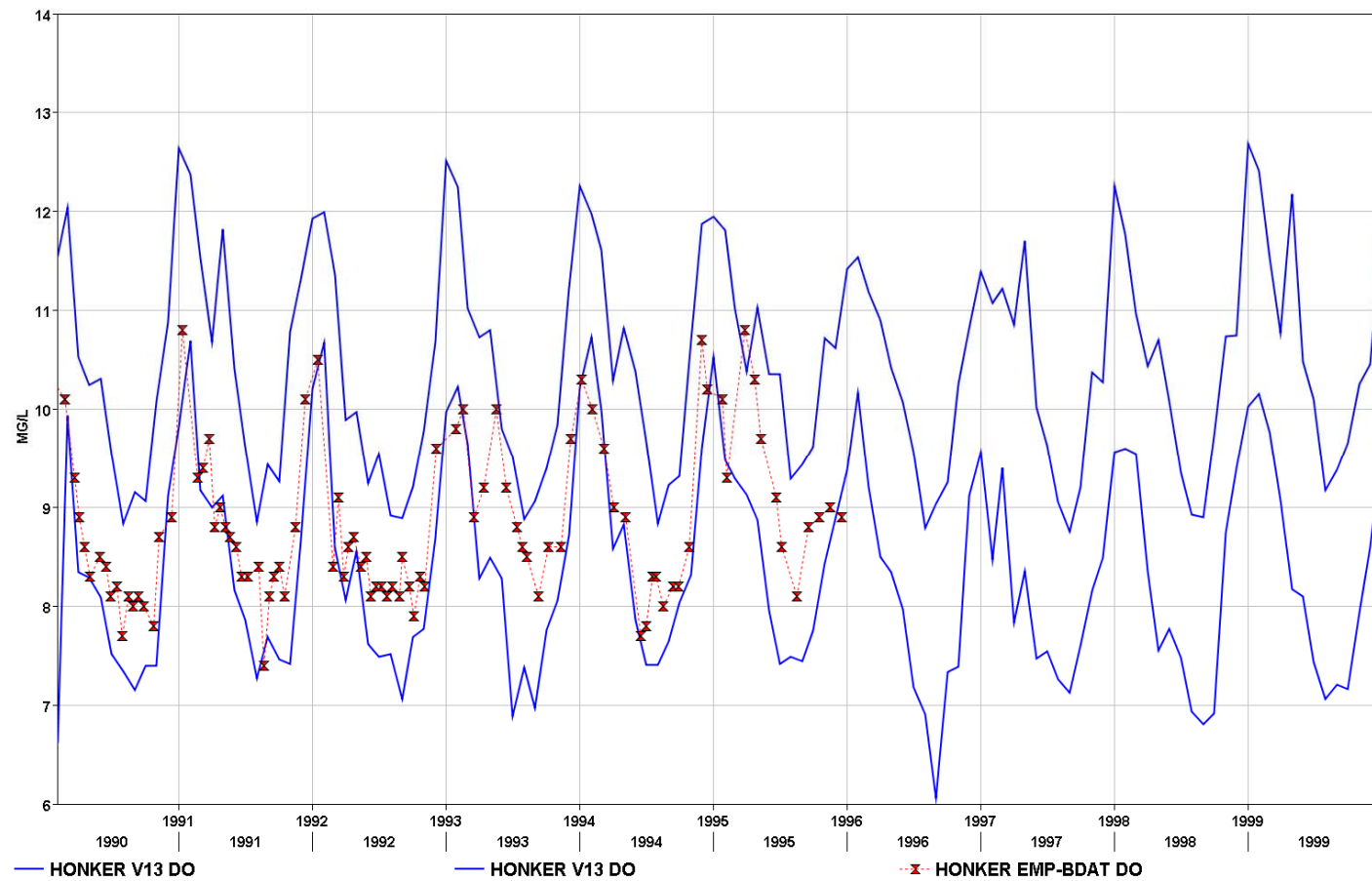


Figure A III. 23 DO at HONKER early years.

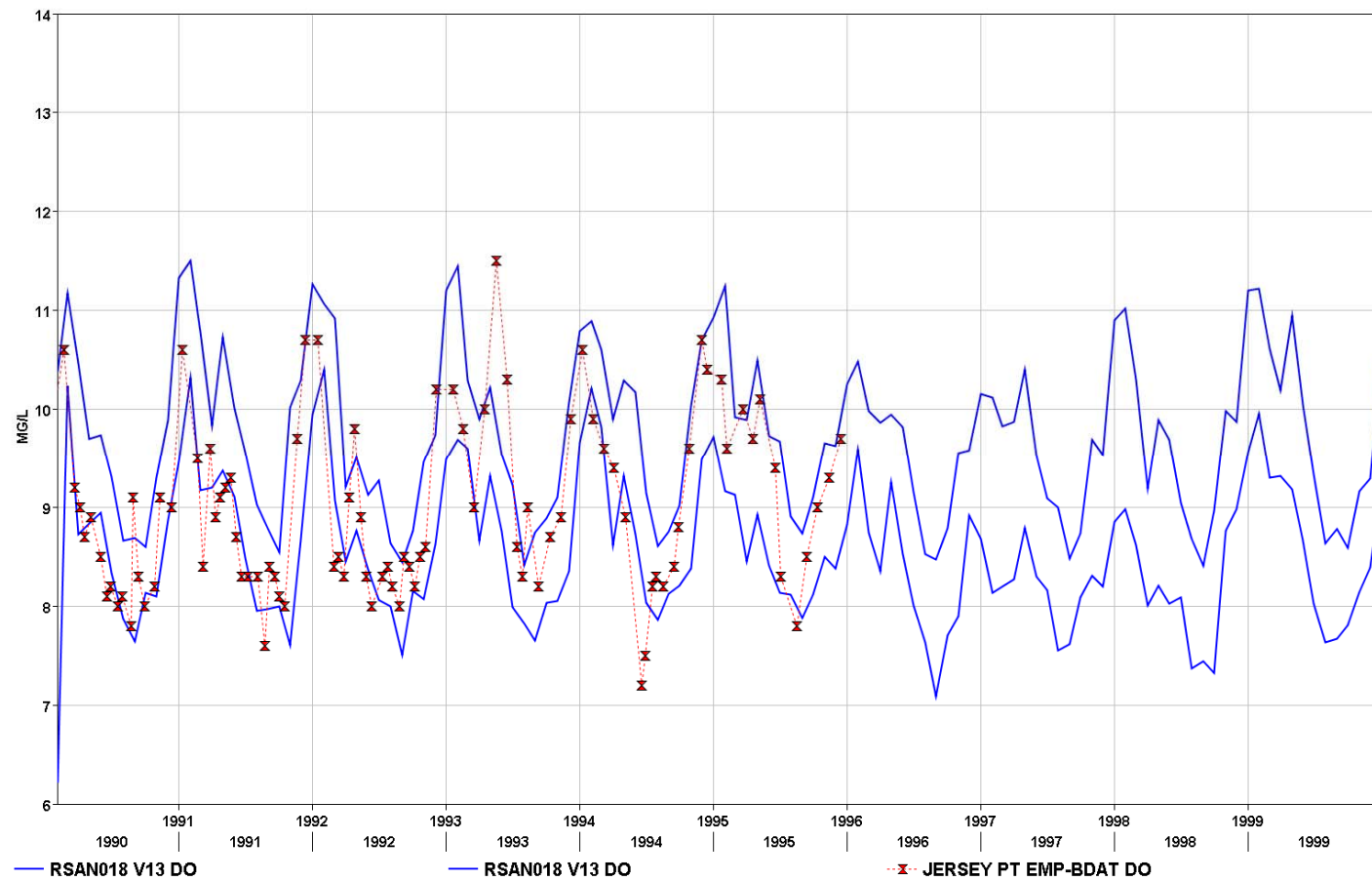


Figure A III. 24 DO at RSAN018 early years.

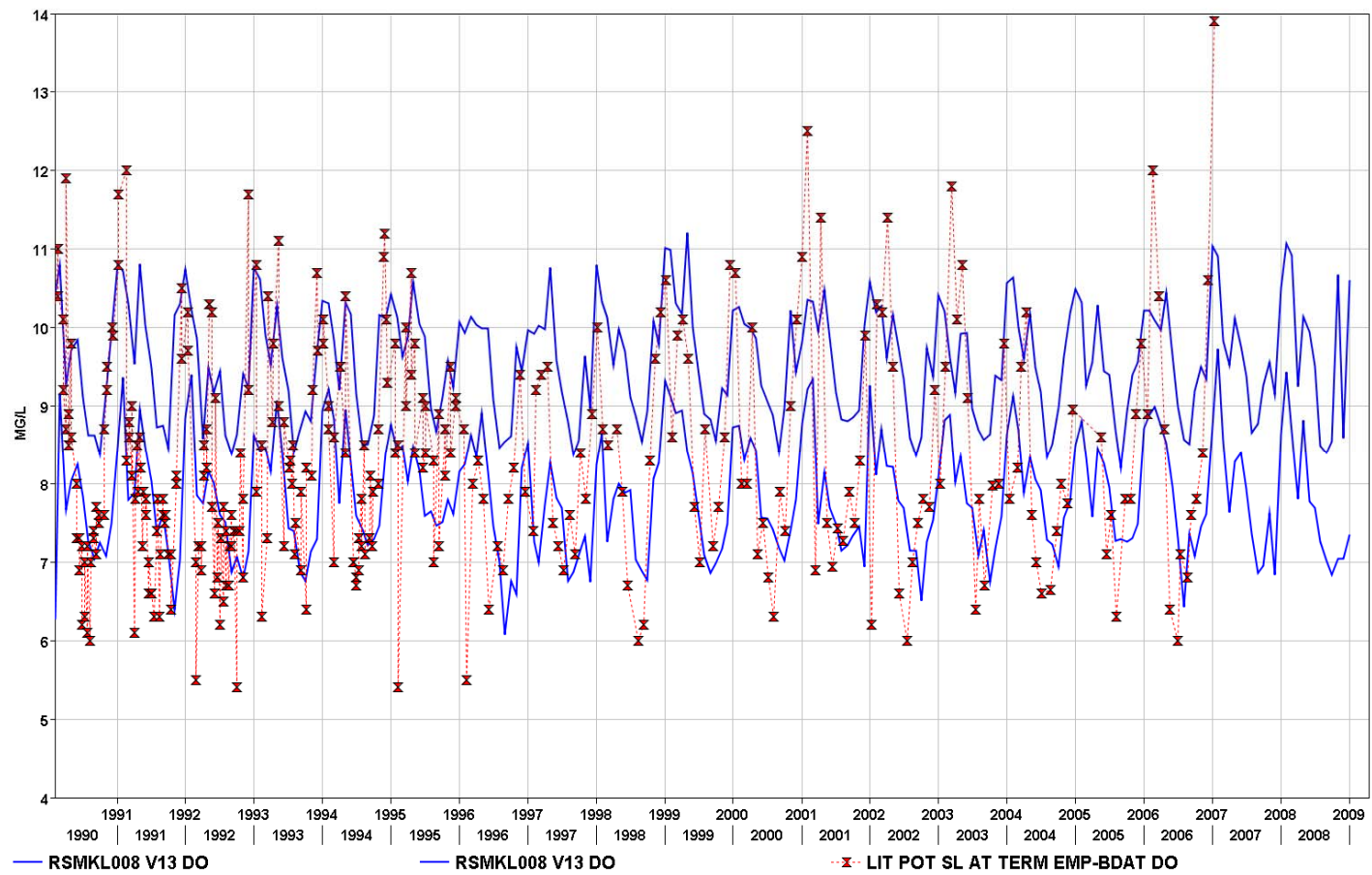


Figure A III. 25 DO at RSMKL008 all years.

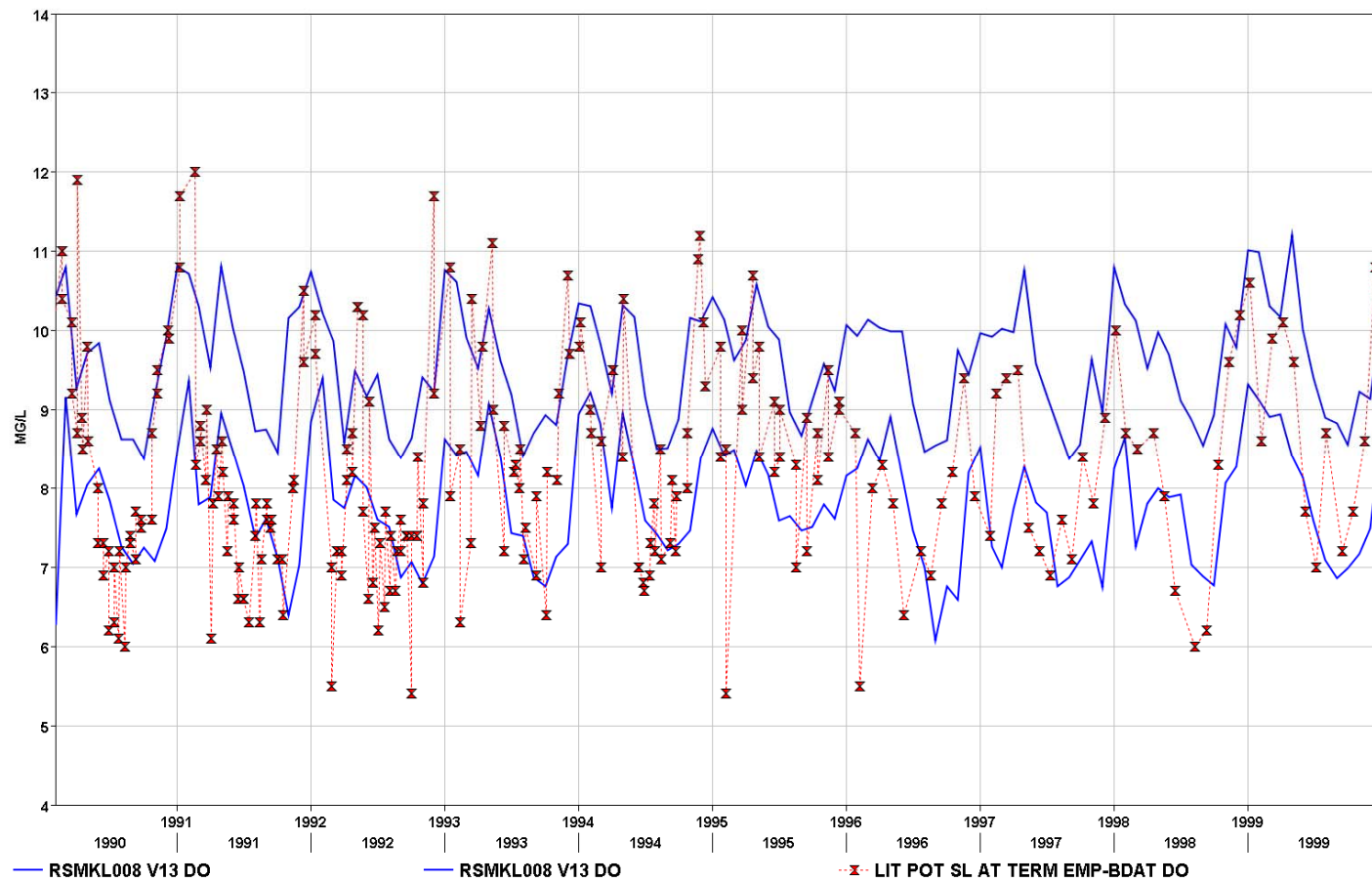


Figure A III. 26 DO at RSMKL008 early years.

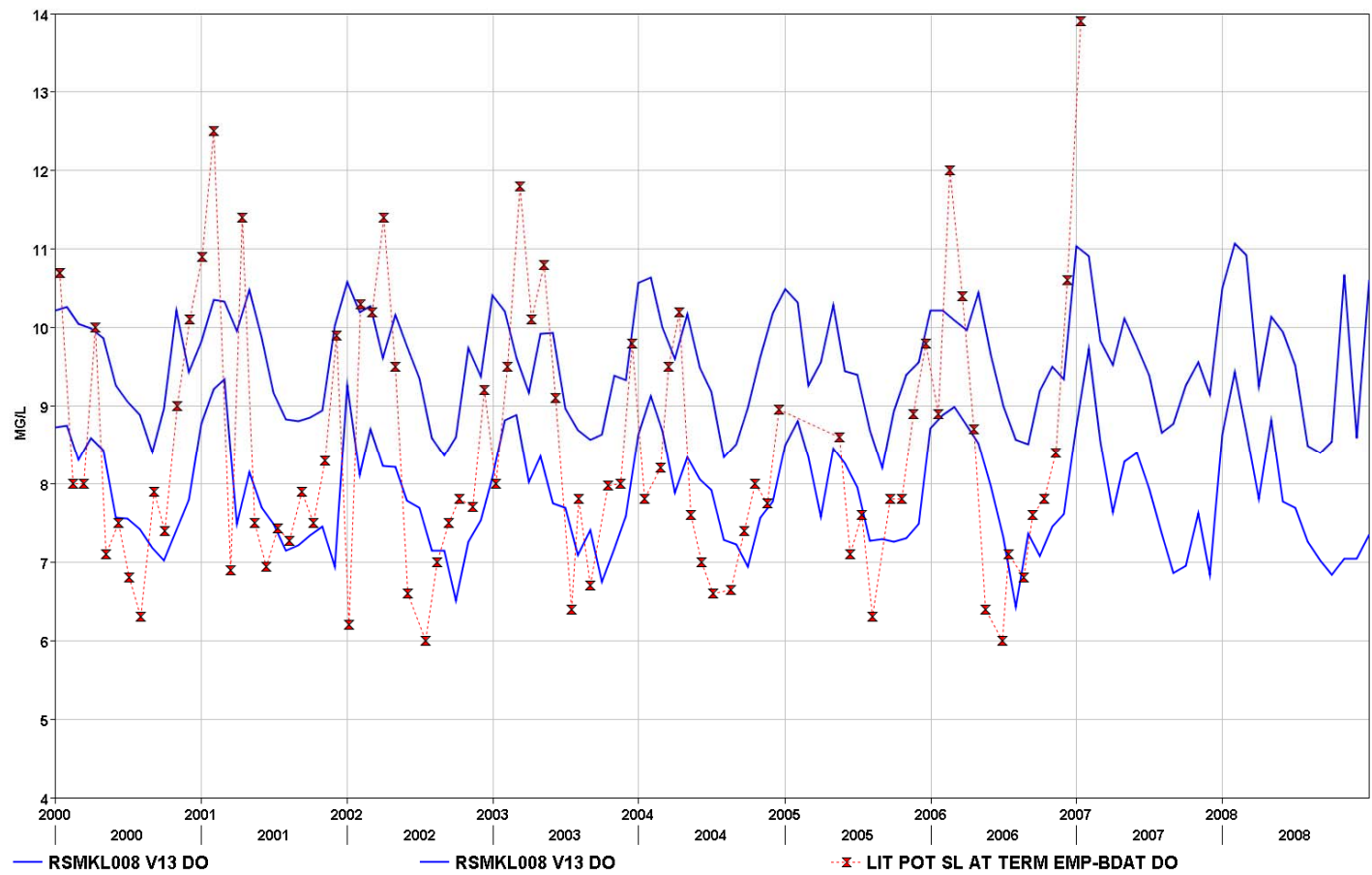


Figure A III. 27 DO at RSMKL008 later years.

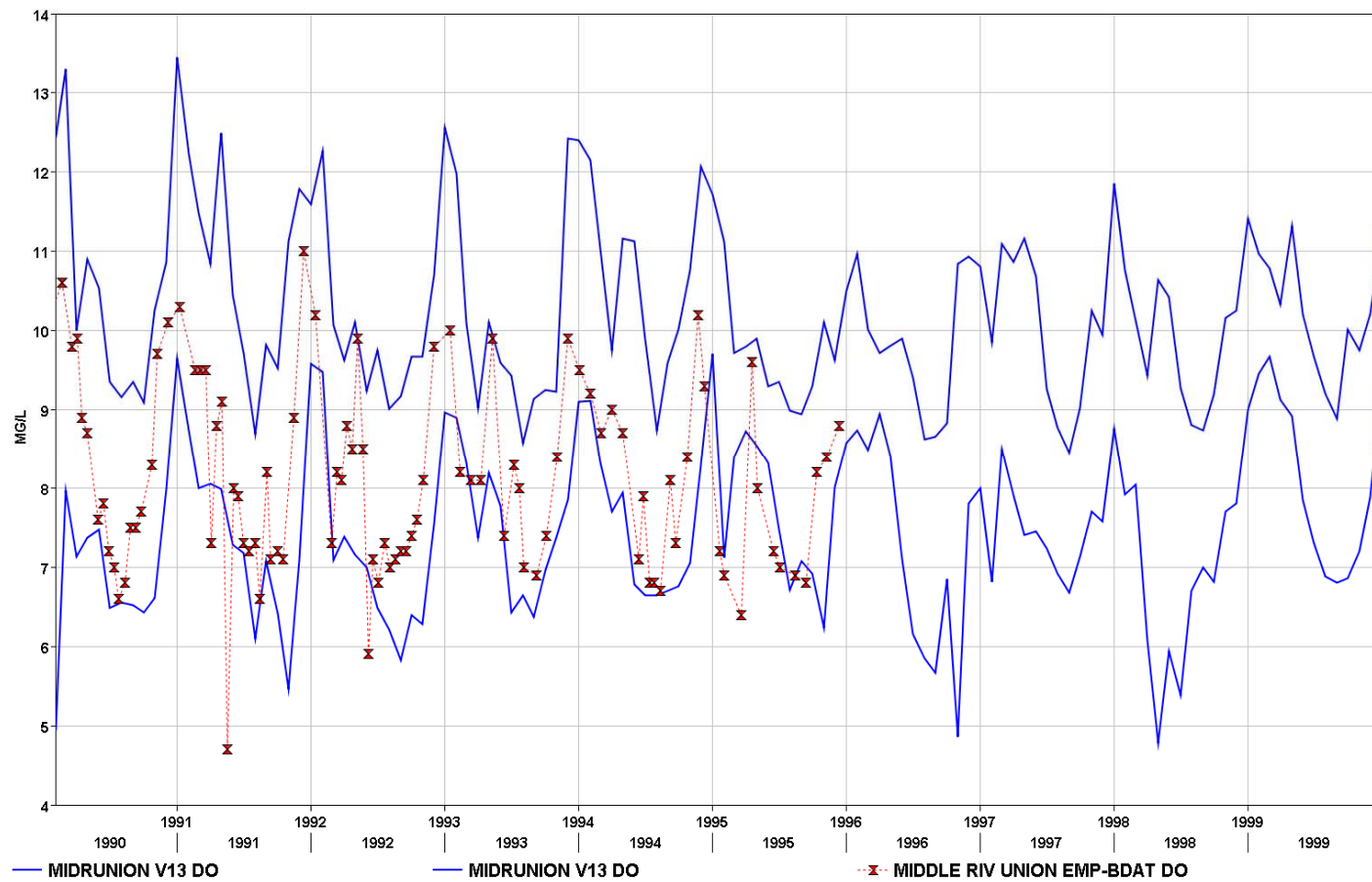


Figure A IIL. 28 DO at MID RIV UNION early years.

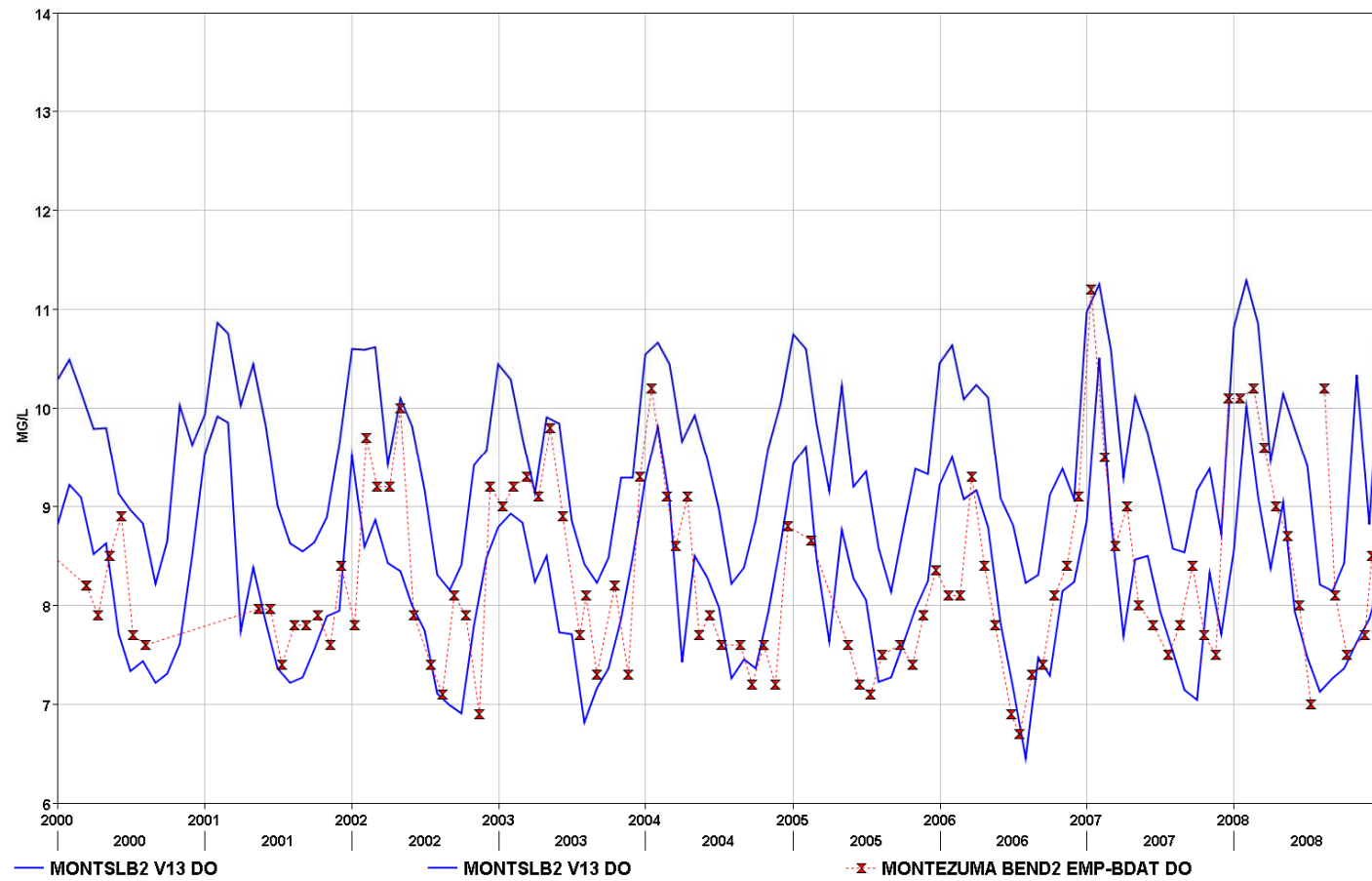


Figure A III. 29 DO at MONTEZUMA SL BEND 2 later years.

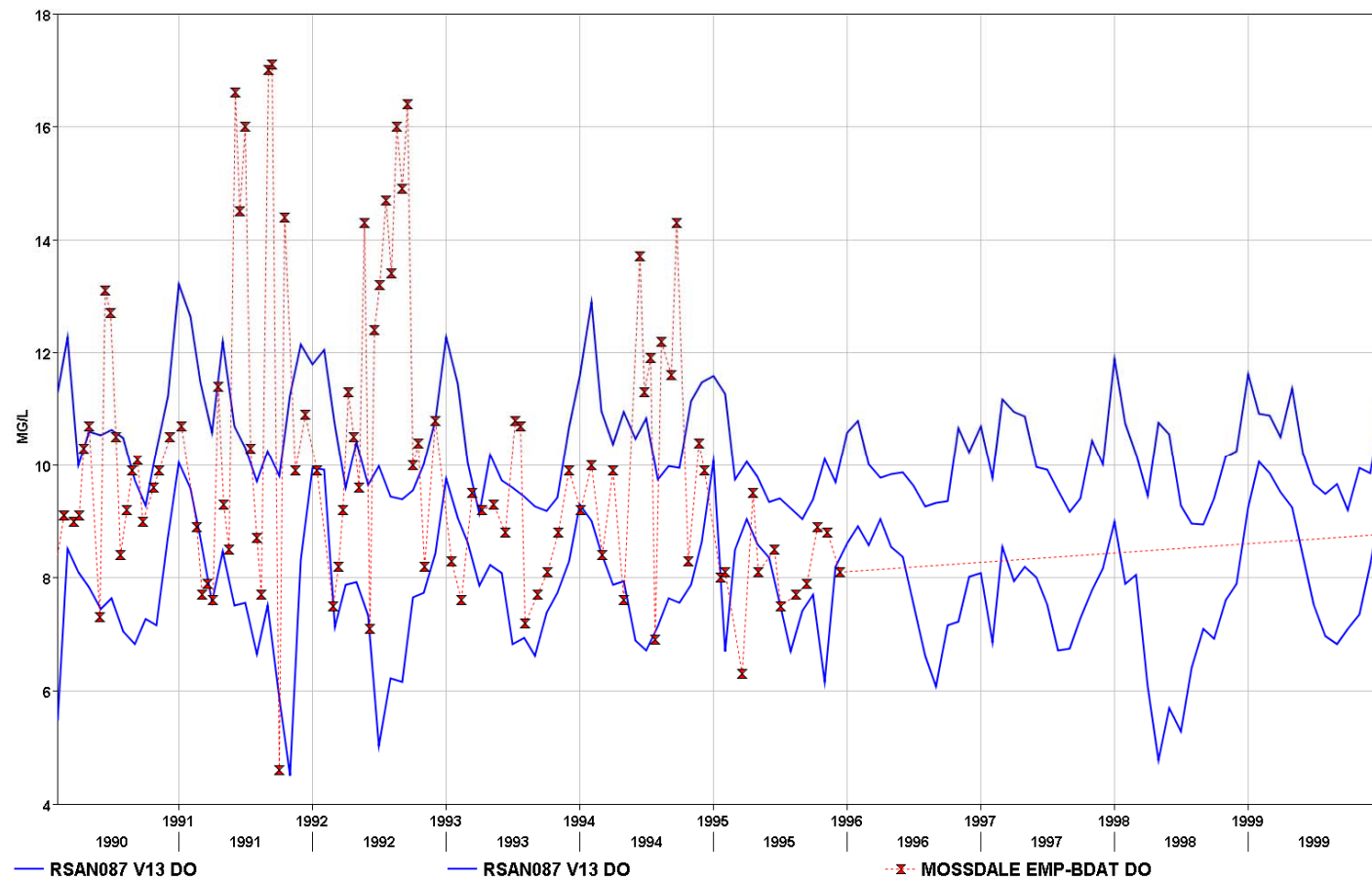


Figure A III. 30 DO at RSAN087 early years.

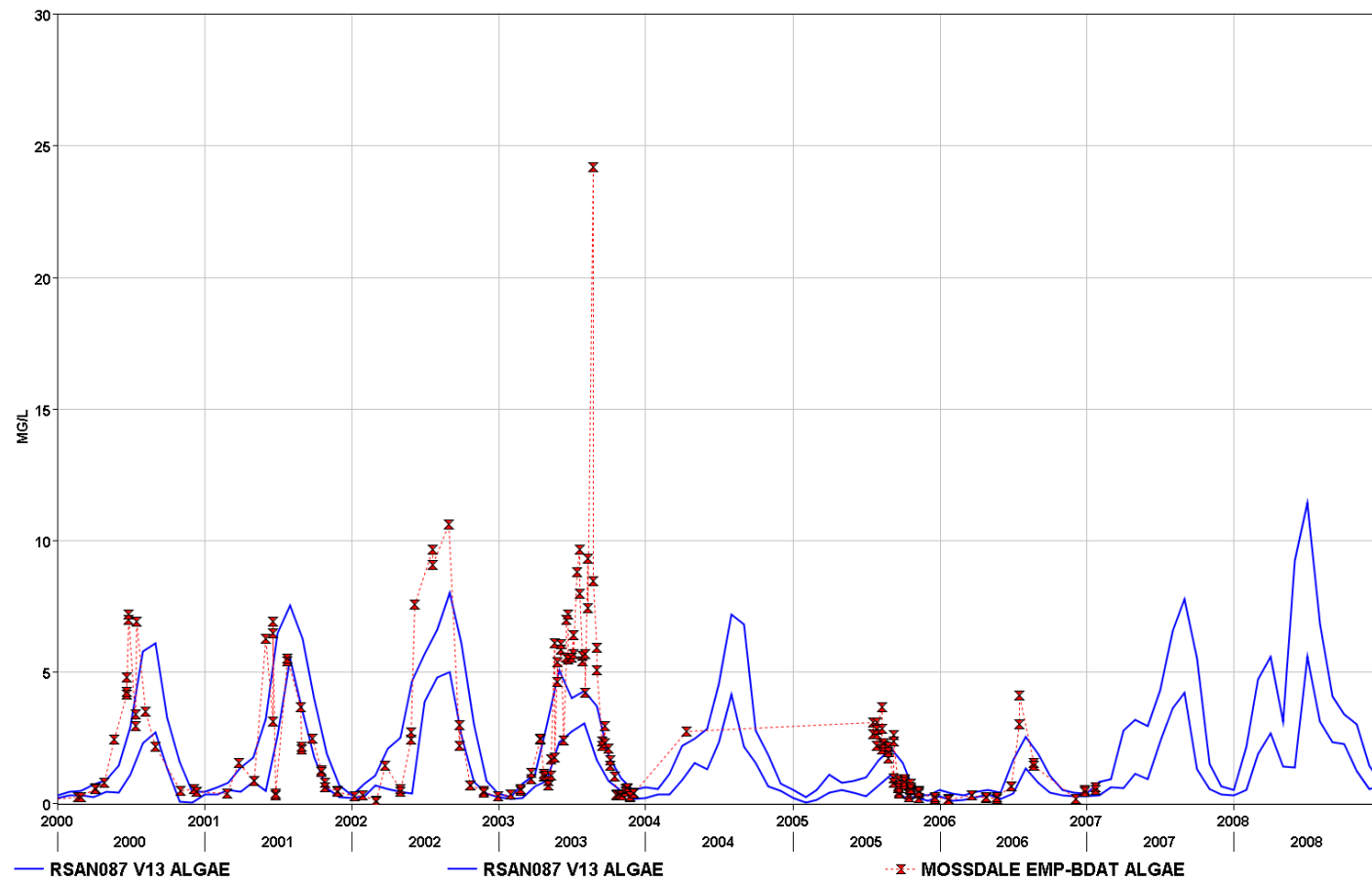


Figure A III. 31 DO at RSAN087 later years.

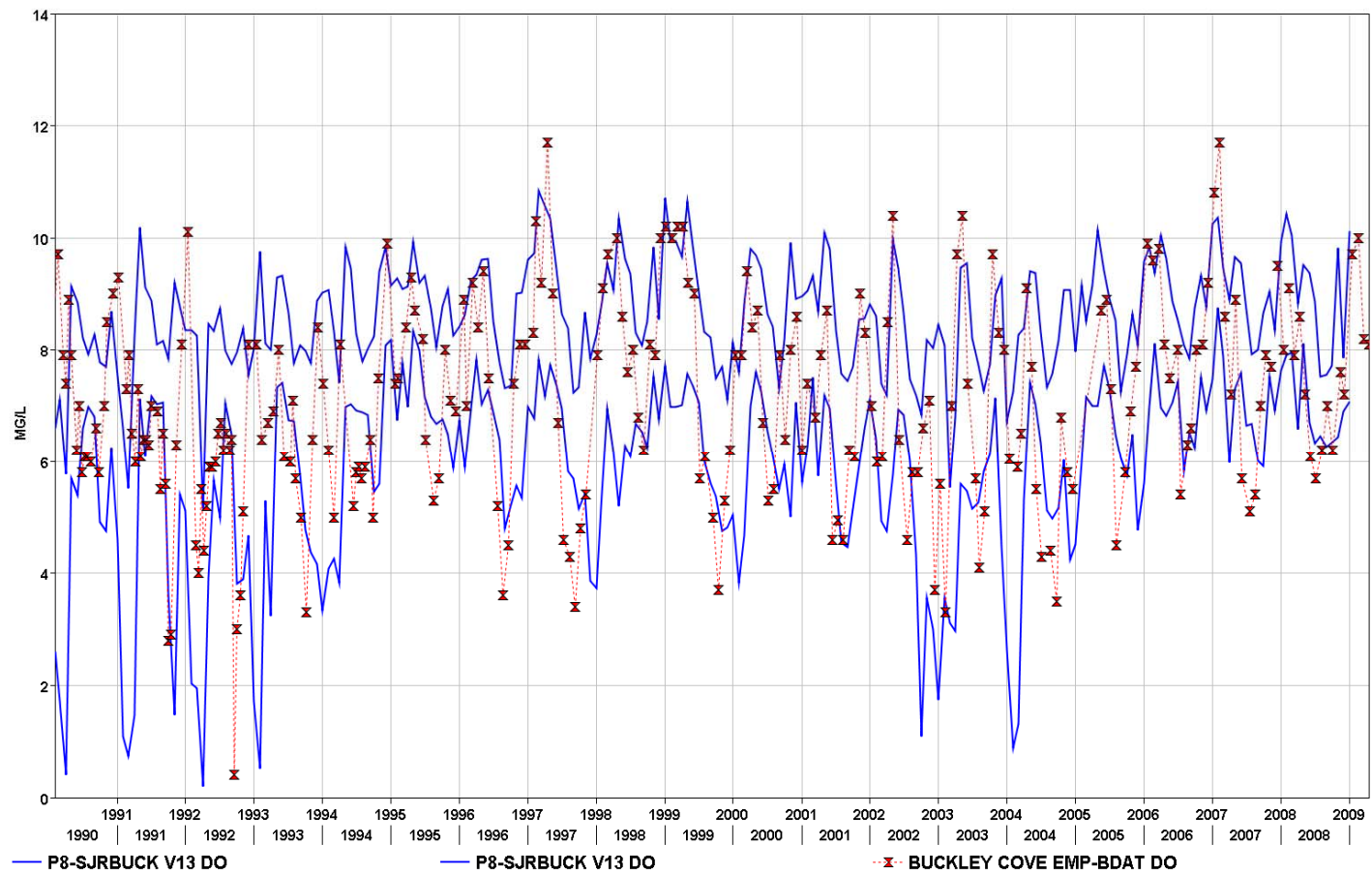


Figure A III. 32 DO at SJR BUCKLEY all years.

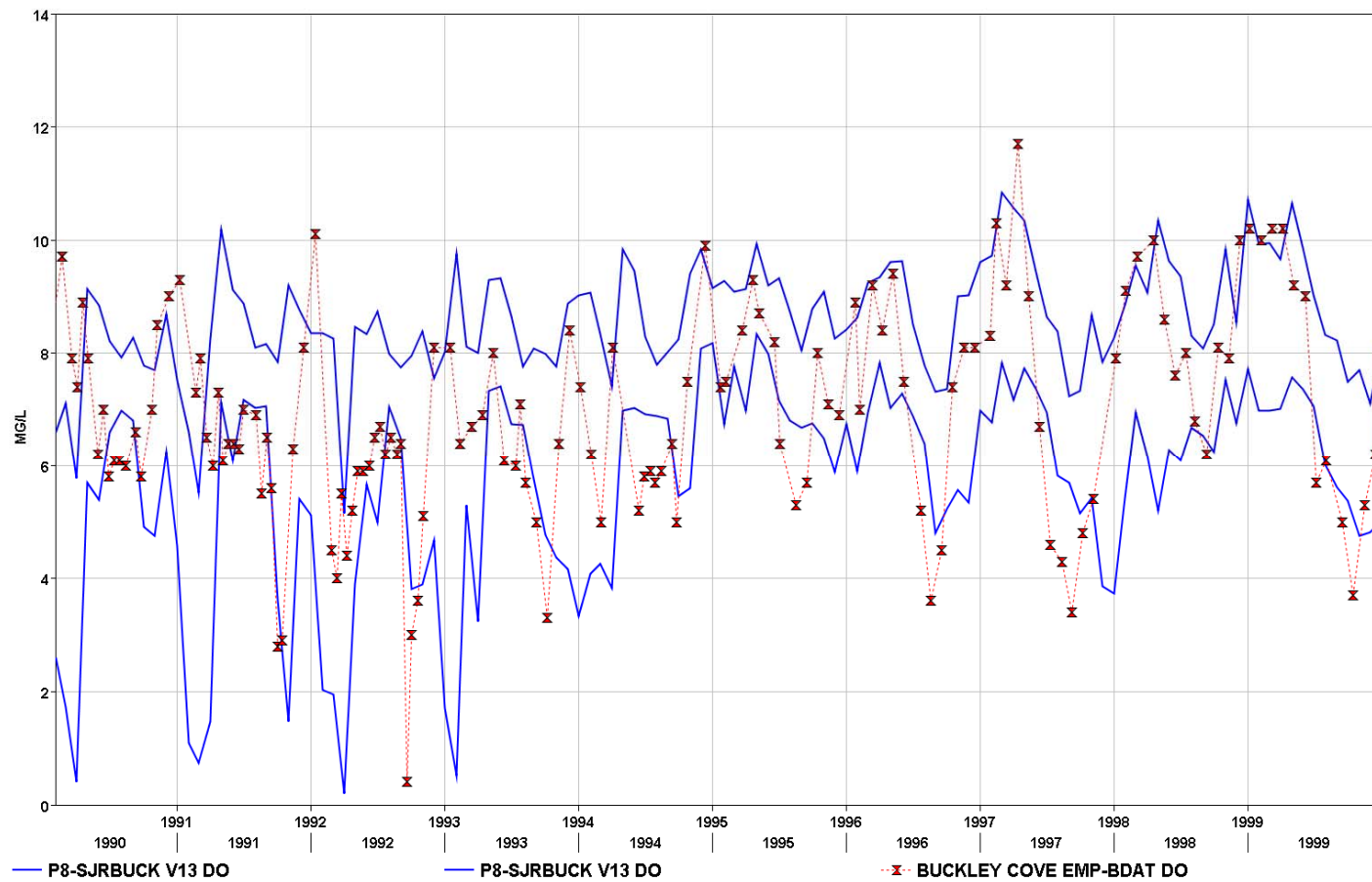


Figure A III. 33 DO at SJR BUCKLEY all years.

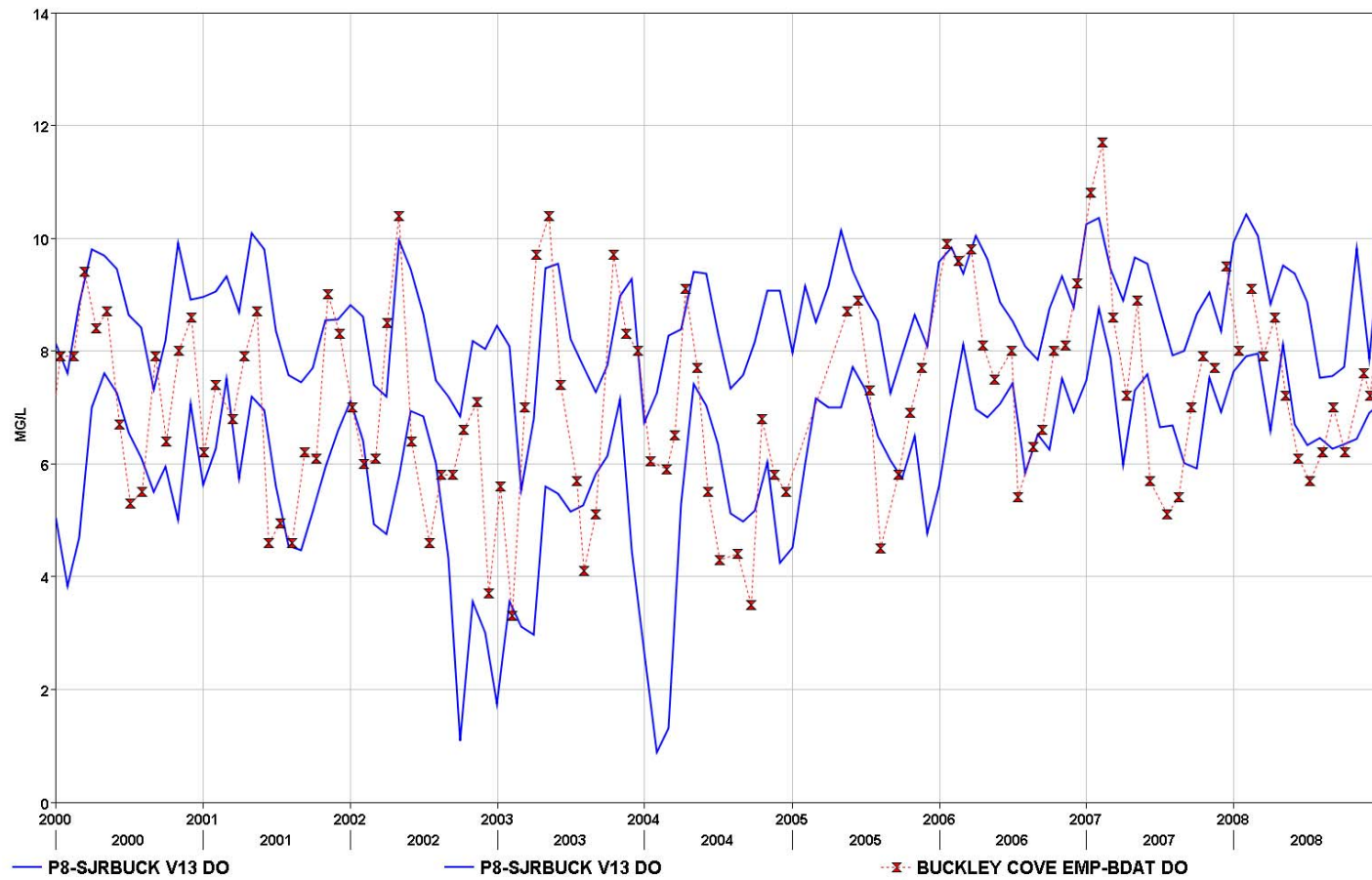


Figure A III. 34 DO at SJR BUCKLEY later years.

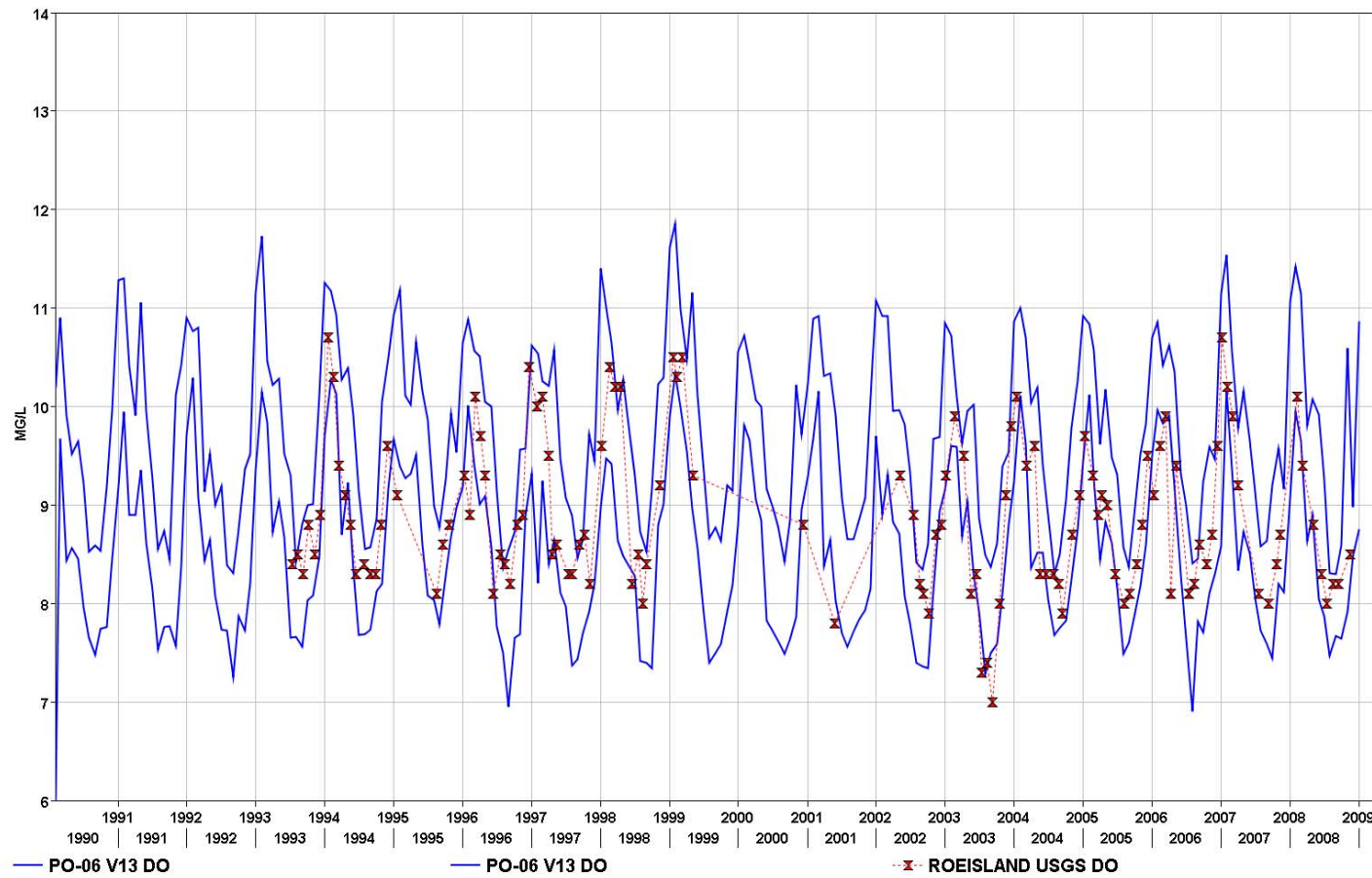


Figure A III. 35 DO at PT SAC all years.

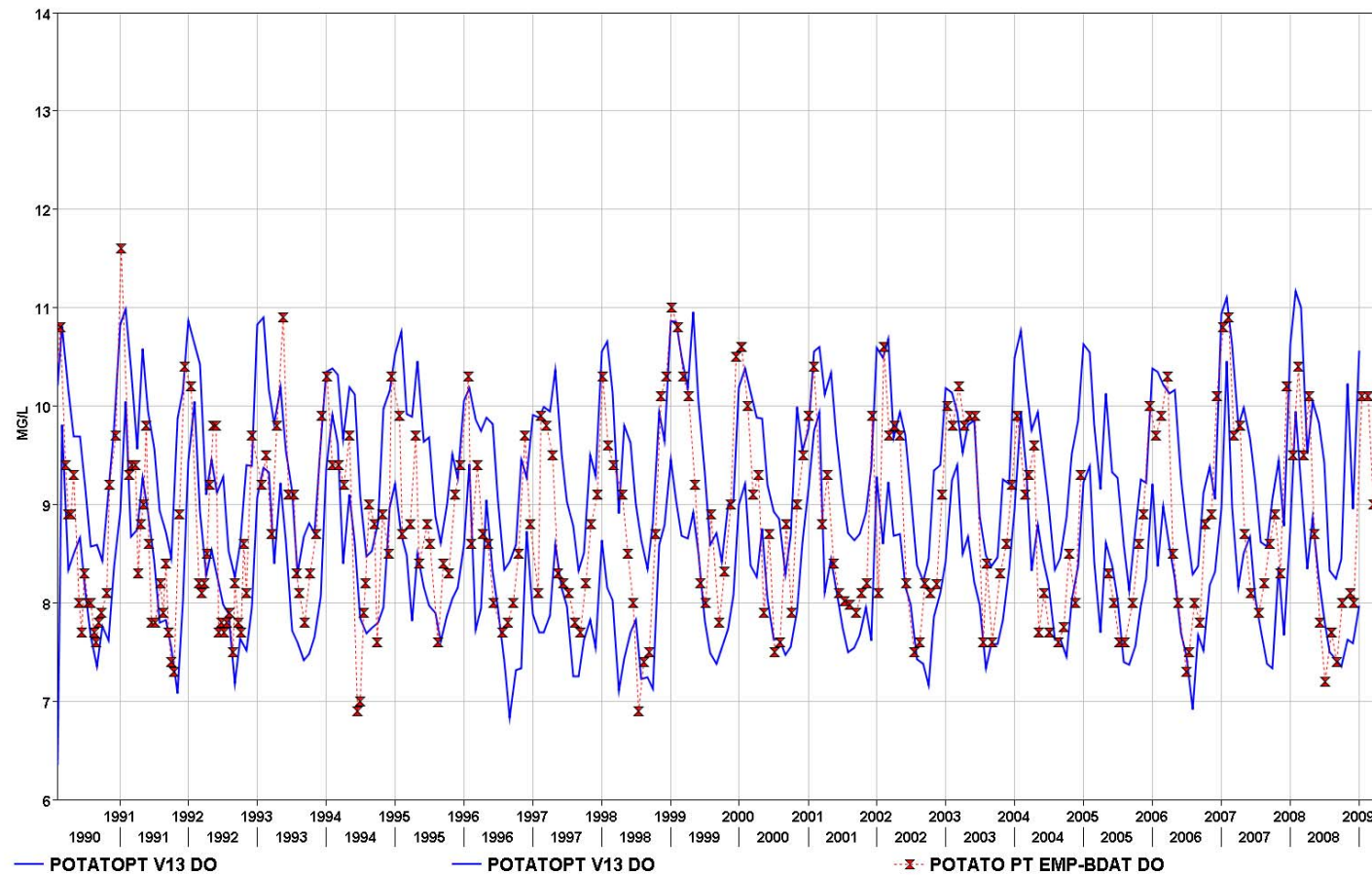


Figure A III. 36 DO at POTATO PT. all years.

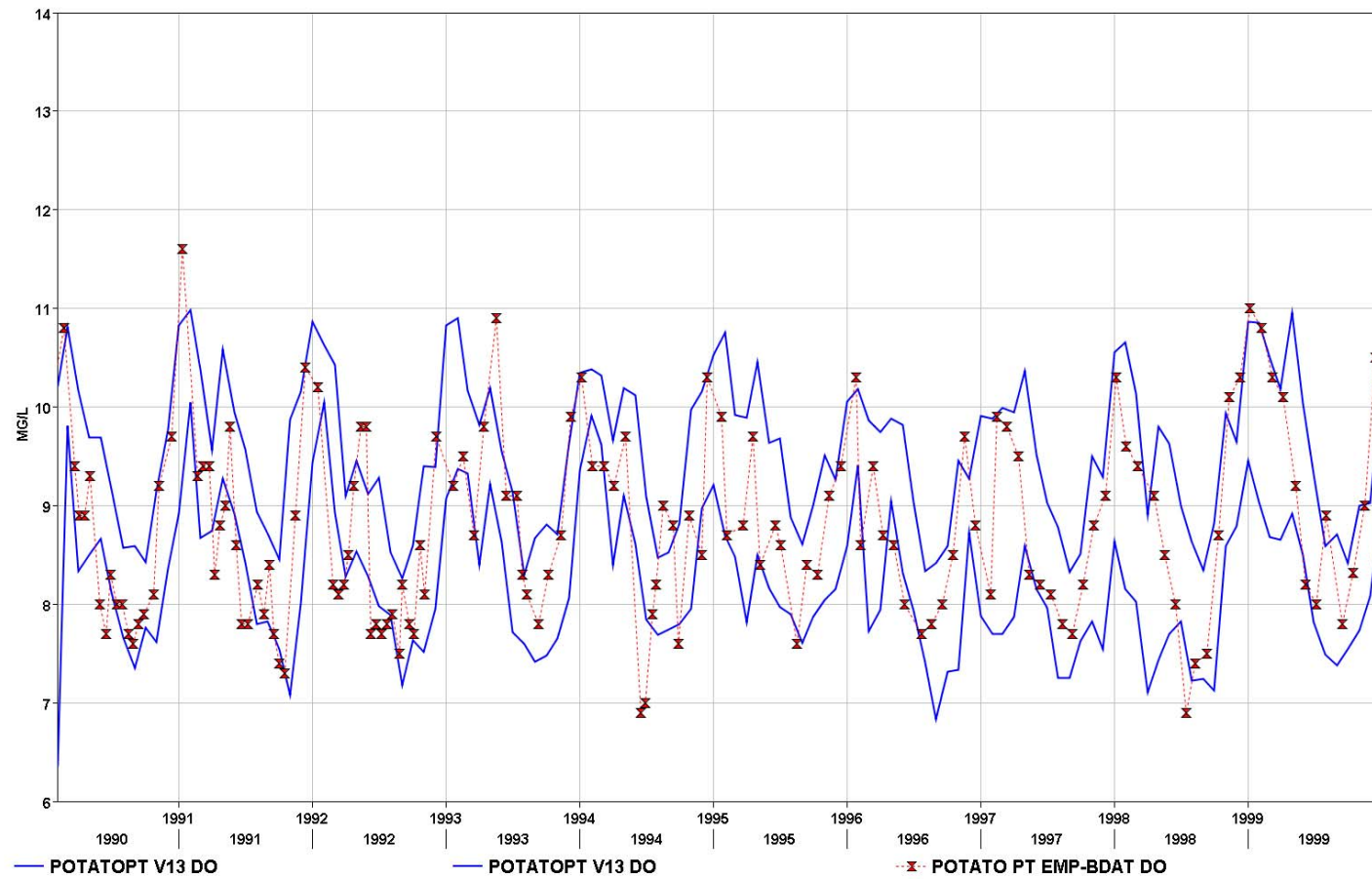


Figure A III. 37 DO at POTATO PT early years.

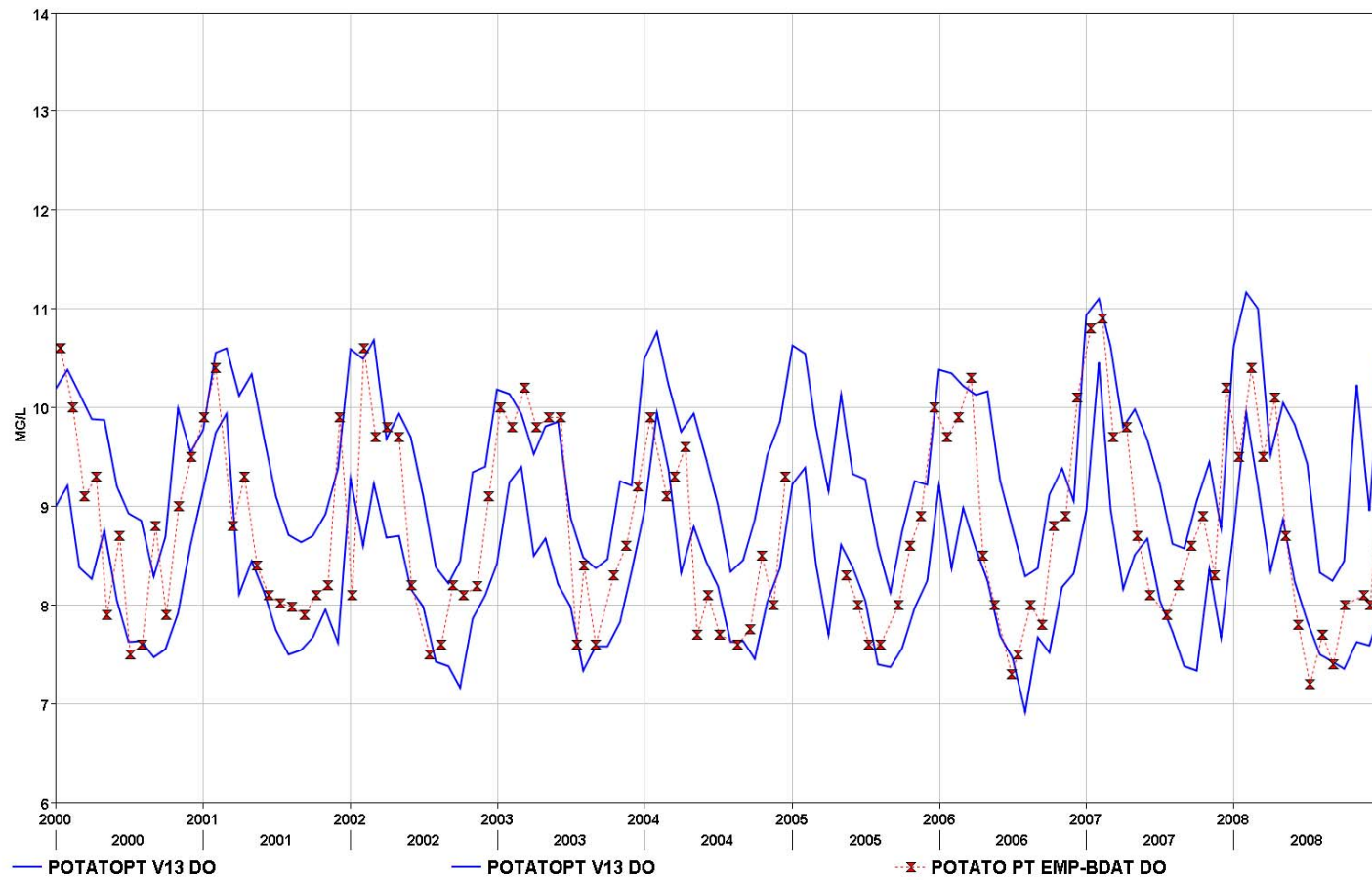


Figure A III. 38 DO at POTATO PT. later years.

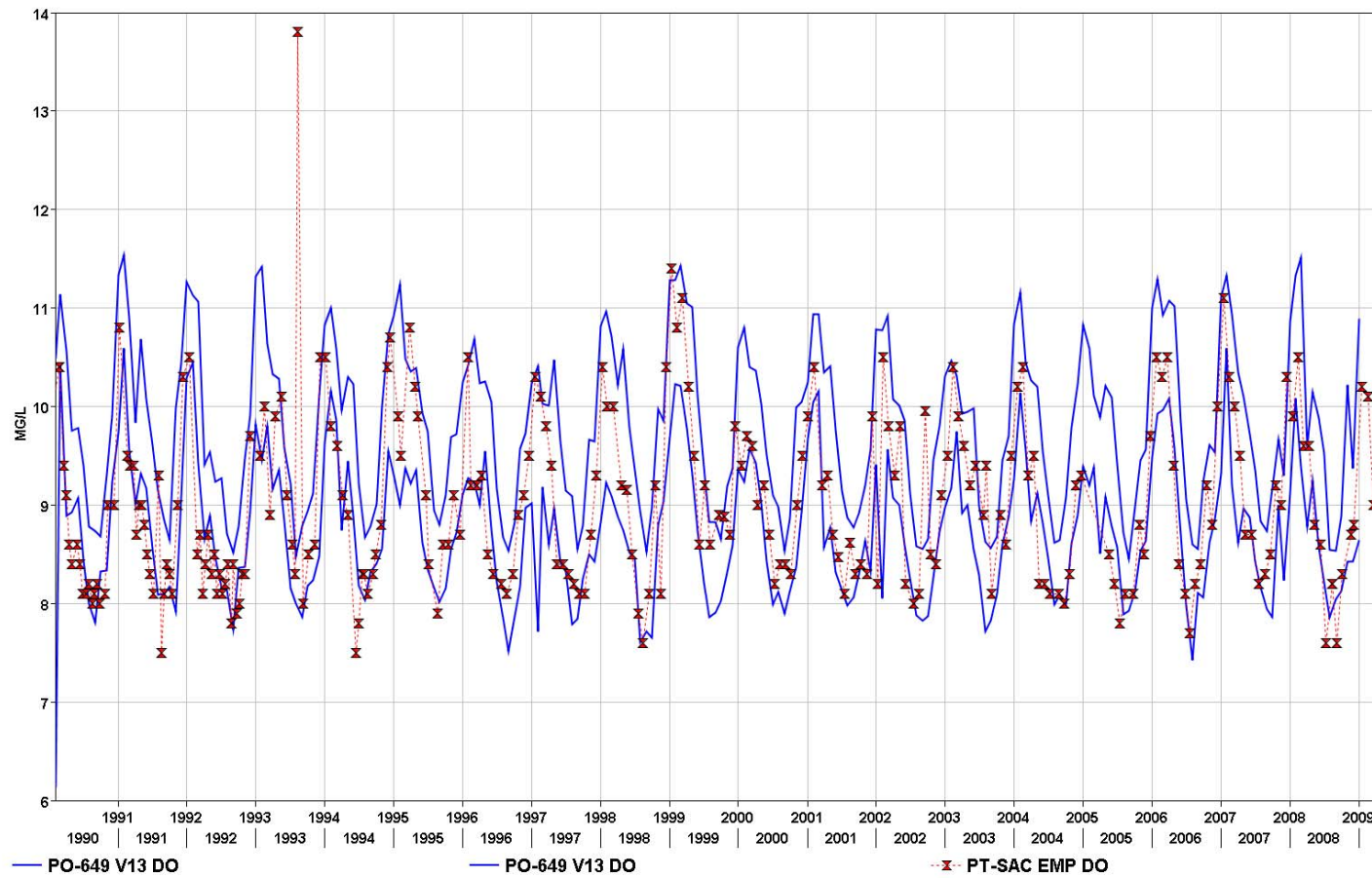


Figure A III. 39 DO at PT SAC all years.

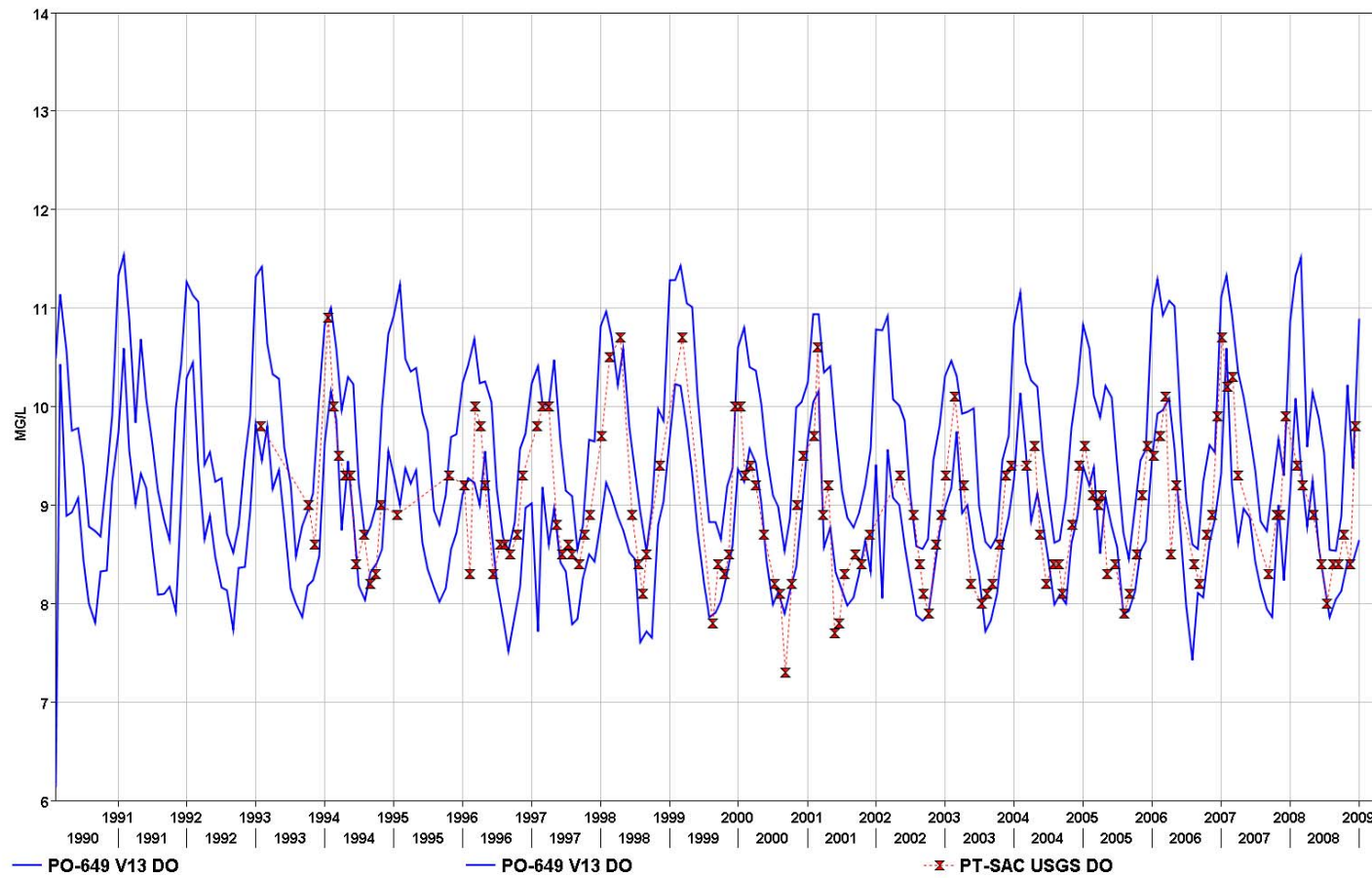


Figure A III. 40 DO at PT SAC early years.

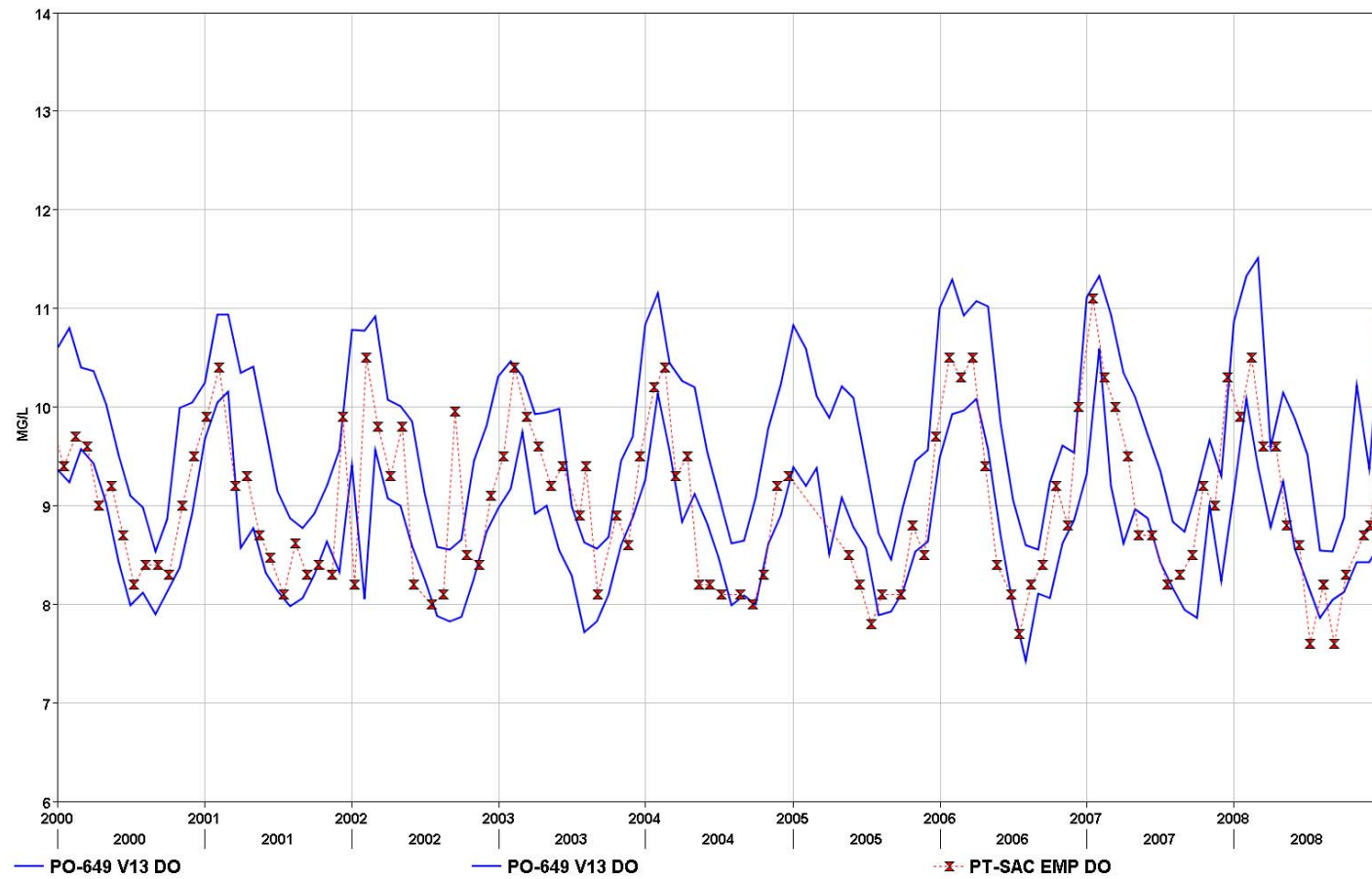


Figure A III. 41 DO at PT SAC later years.

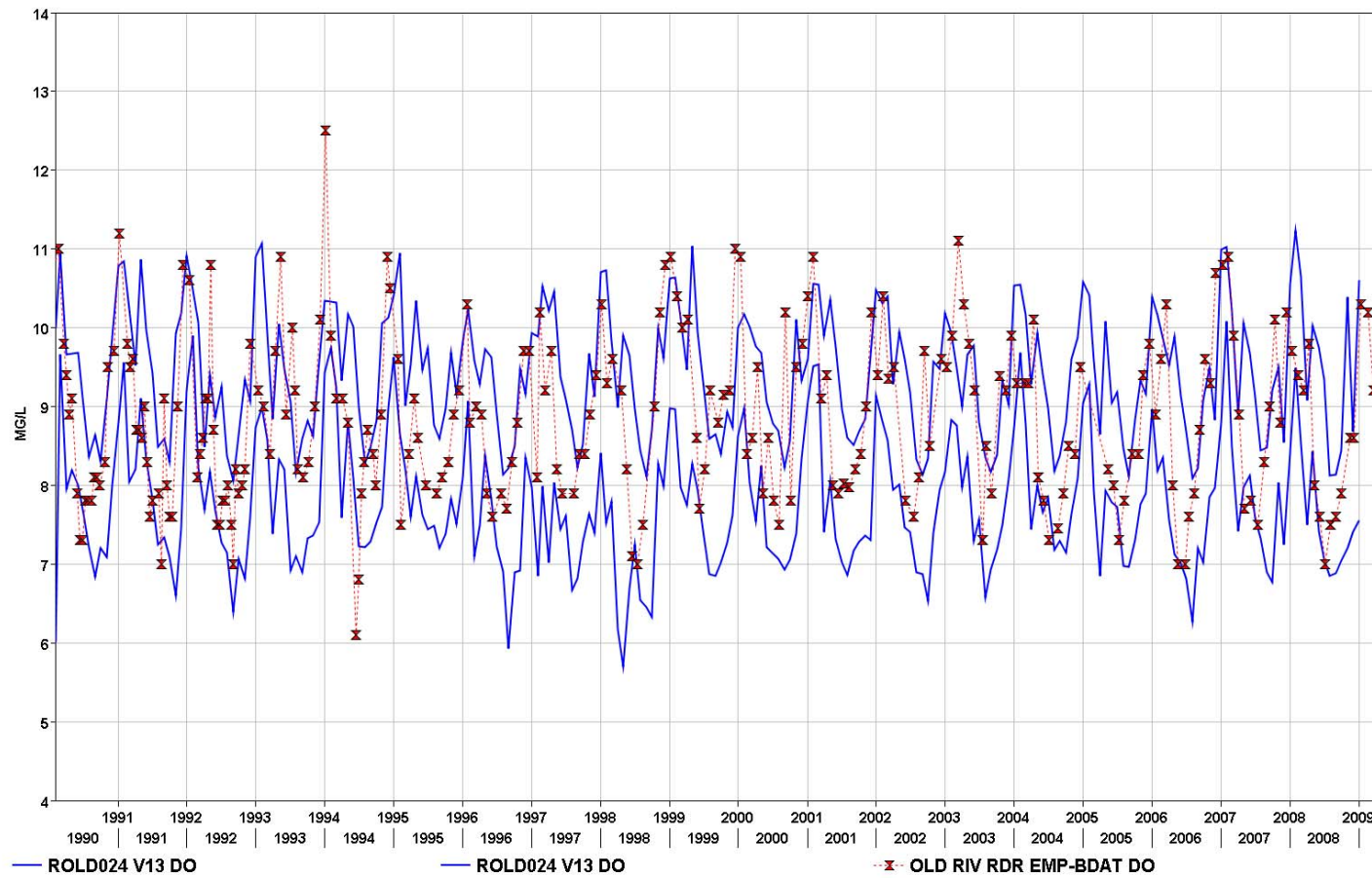


Figure A III. 42 DO at ROLD024 all years.

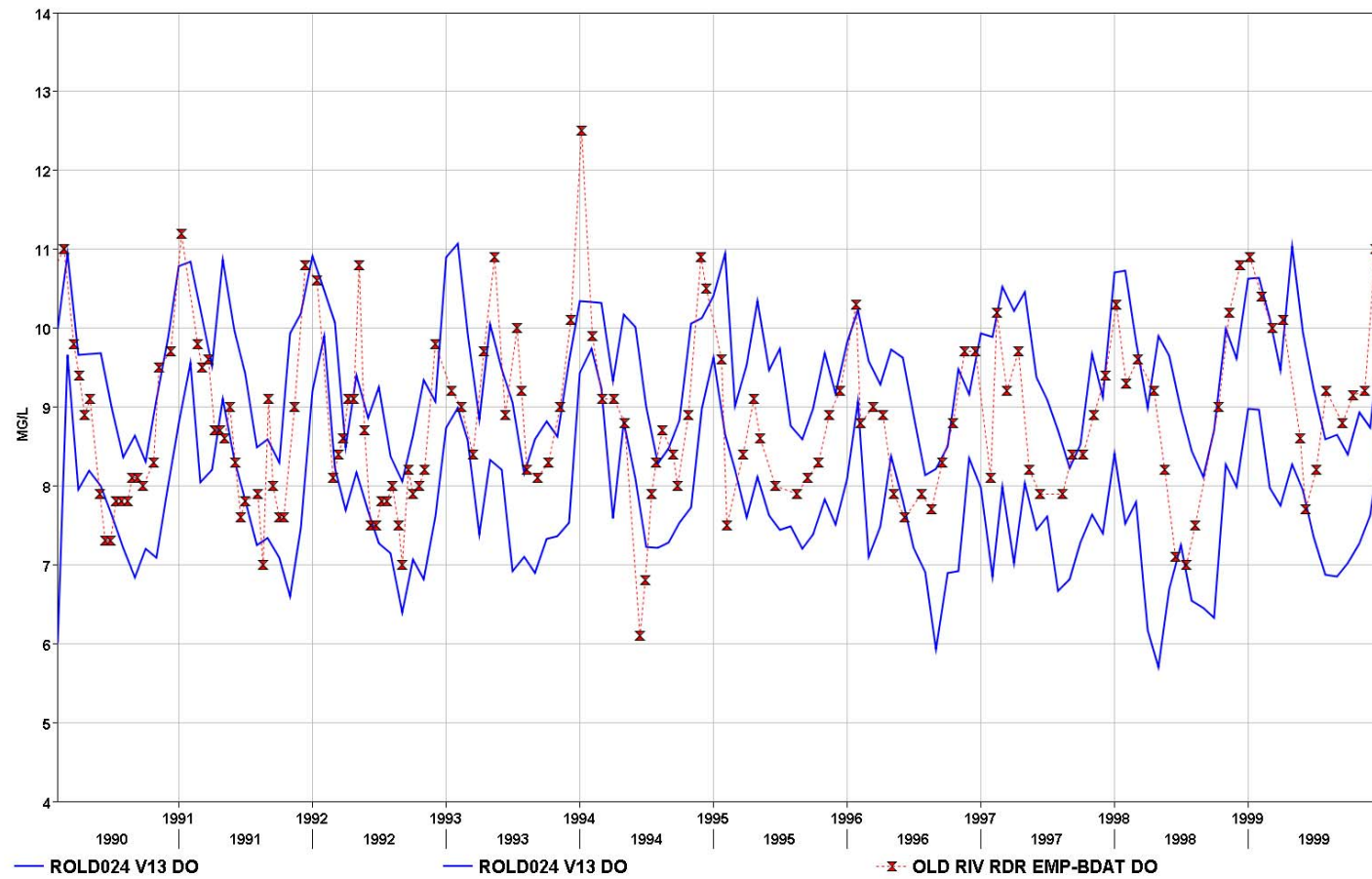


Figure A III. 43 DO at ROLD024 early years.

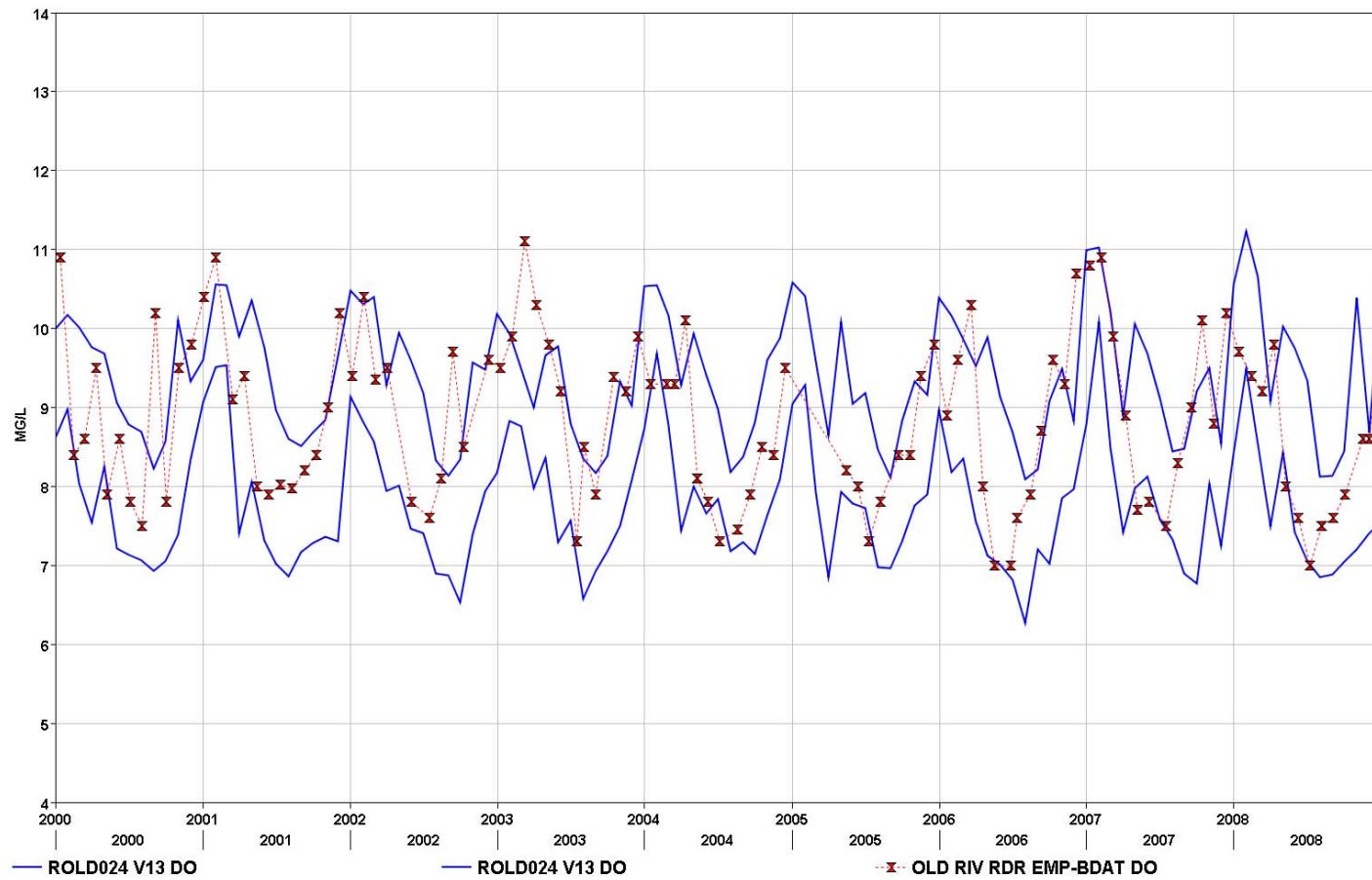


Figure A III. 44 DO at ROLD024 later years.

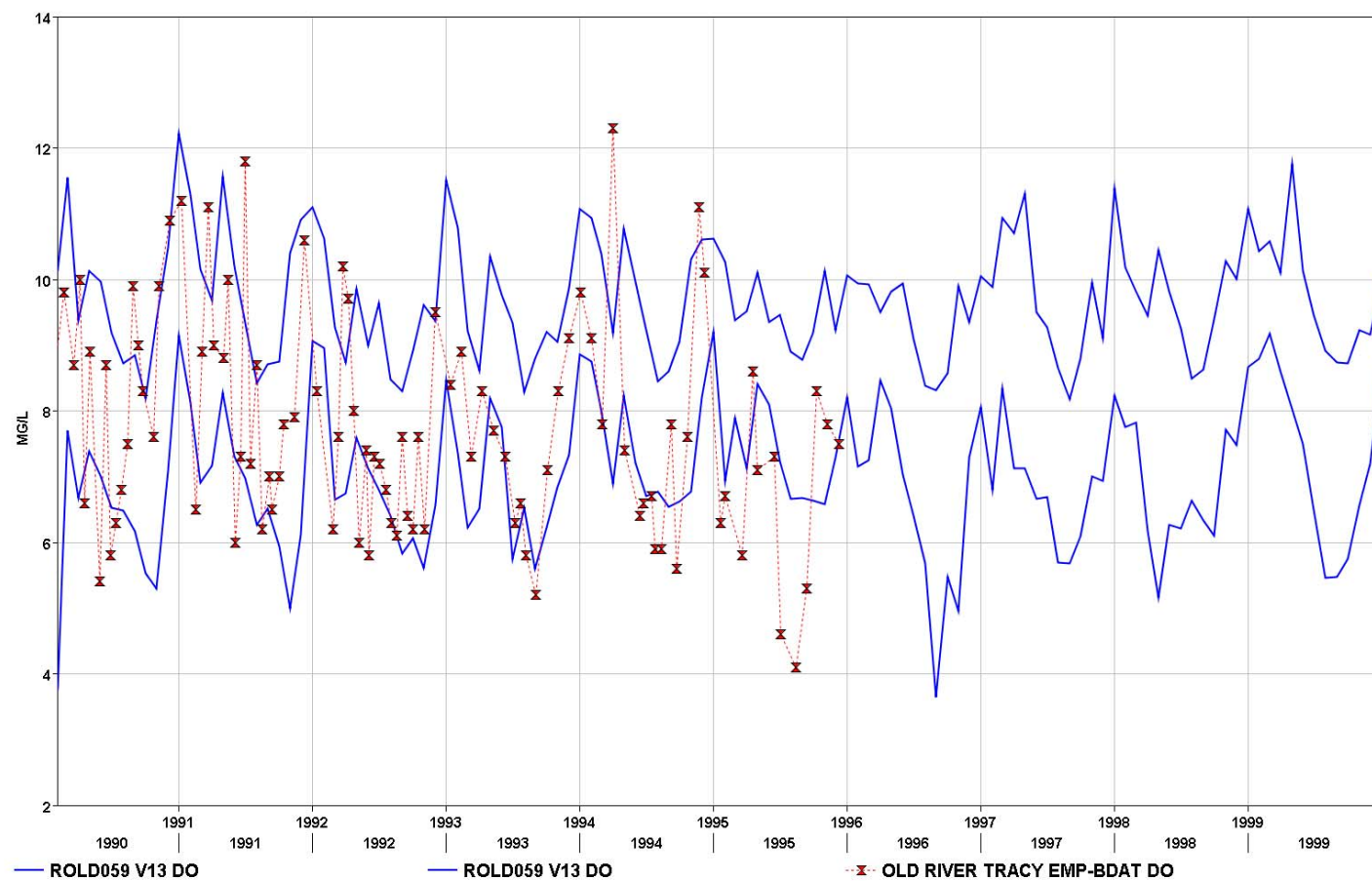


Figure A III. 45 DO at ROLD059 early years.

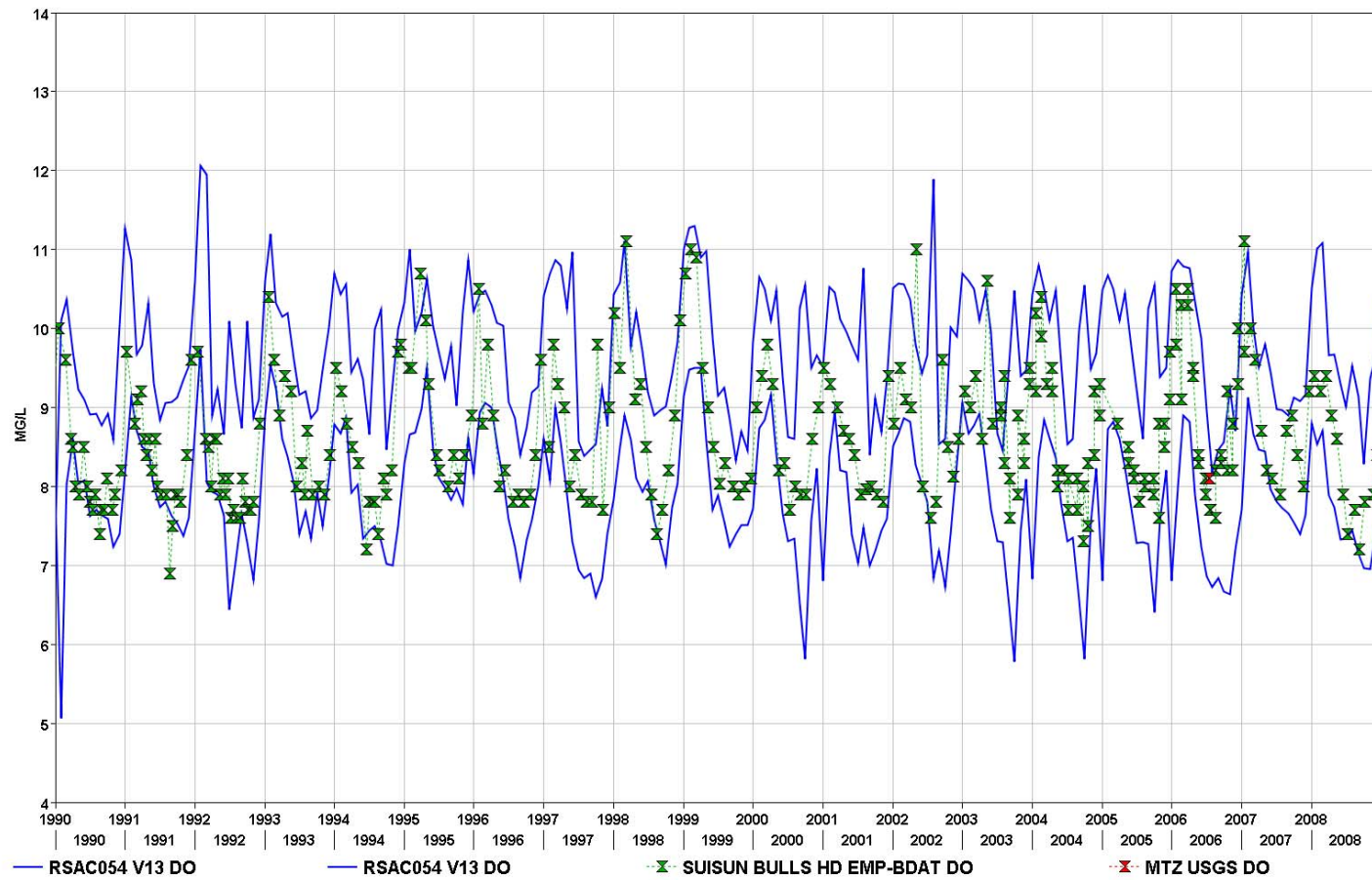


Figure A III. 46 DO at RSAC054 all years.

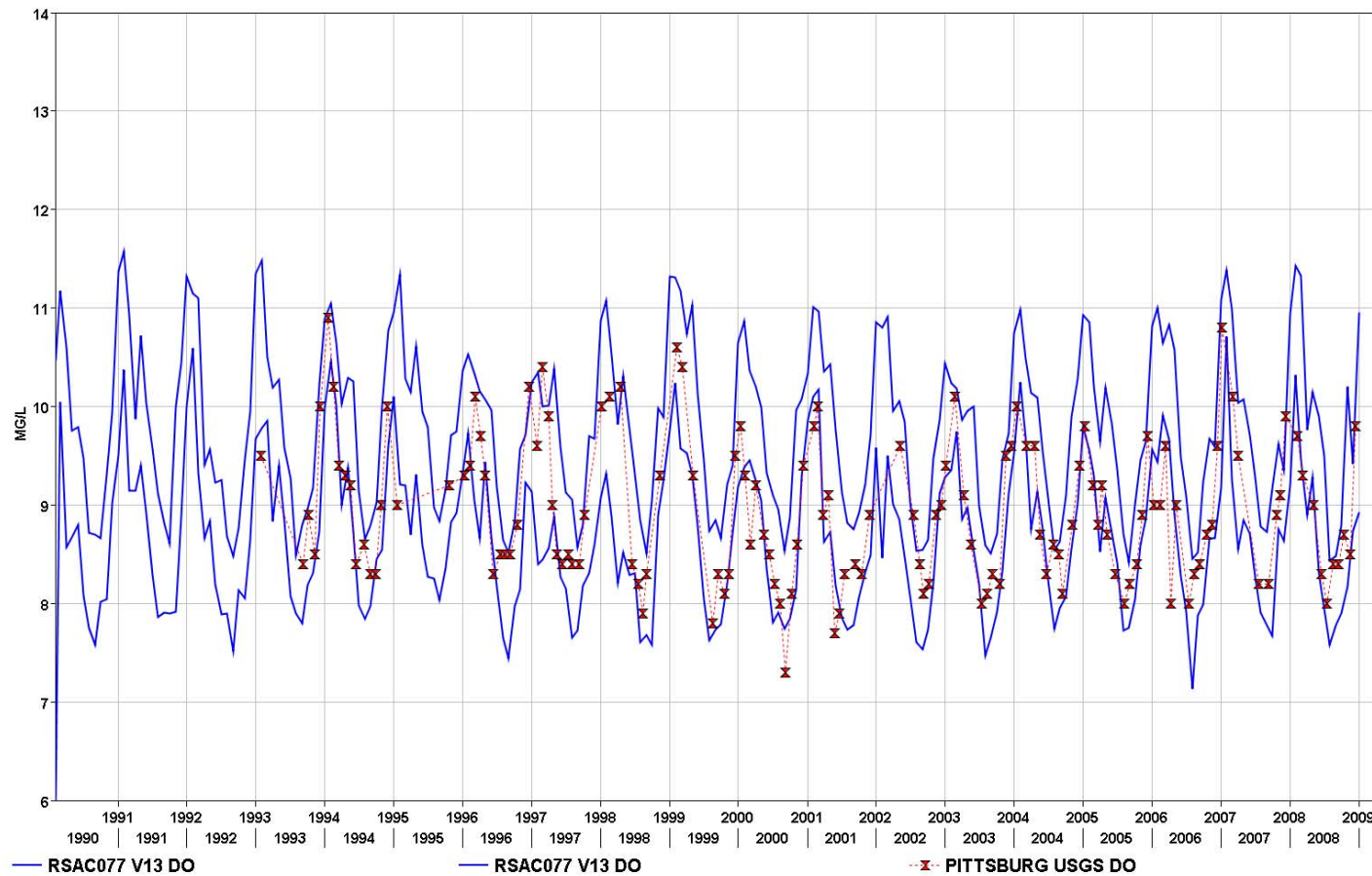


Figure A III. 47 DO at RSAC077 all years.

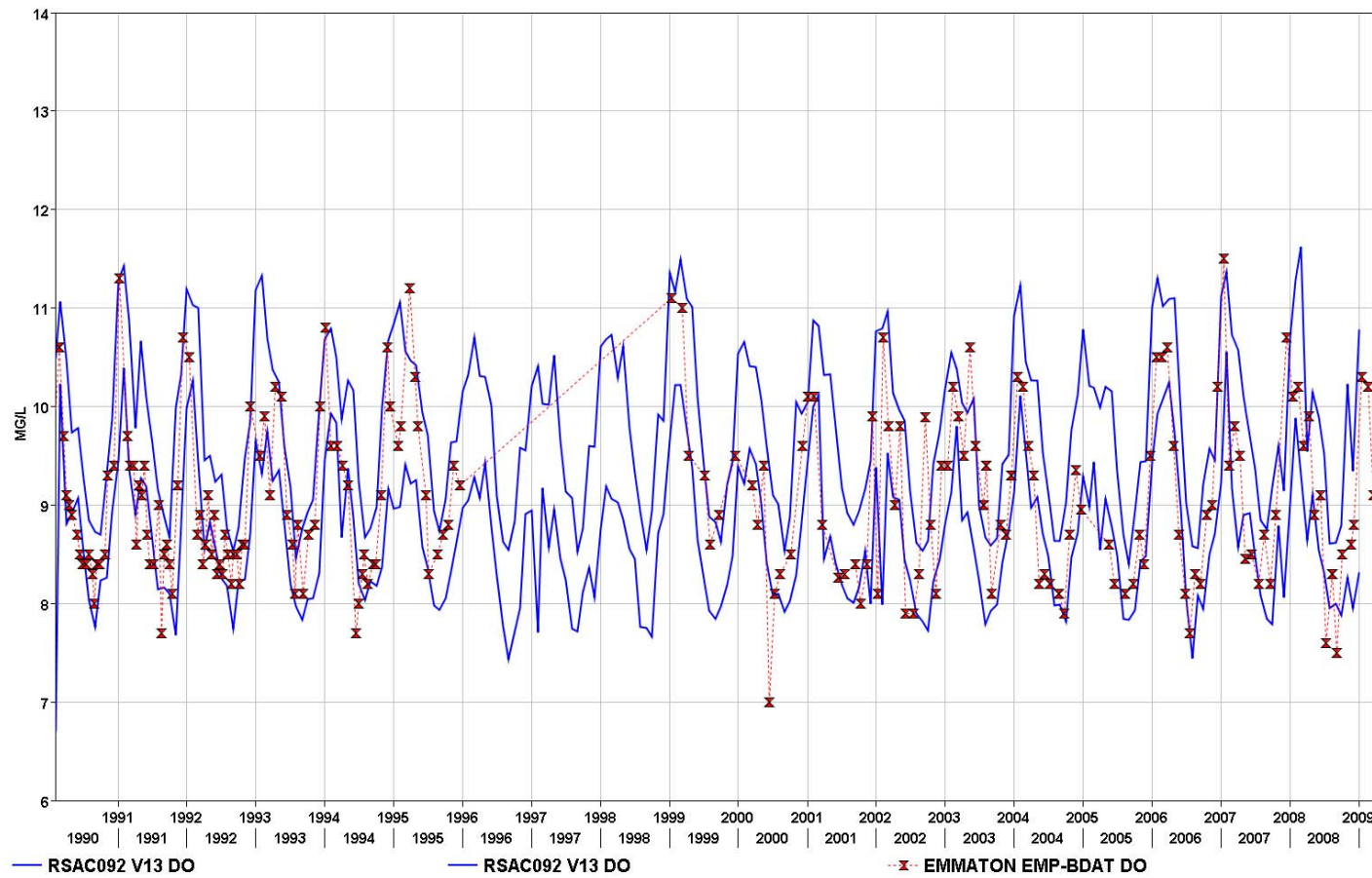


Figure A III. 48 DO at RSAC092 all years.

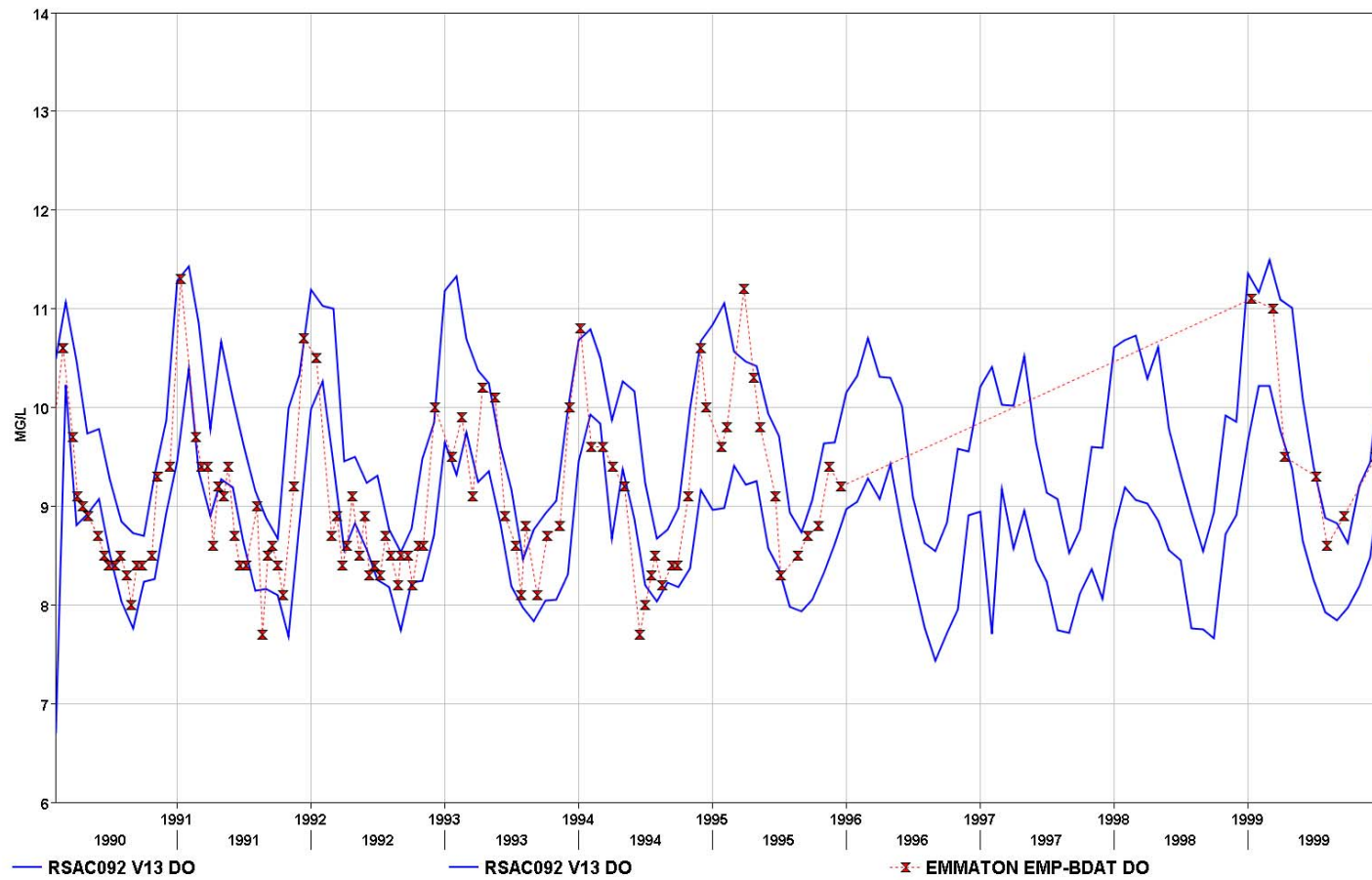


Figure A III. 49 DO at RSAC092 early years.

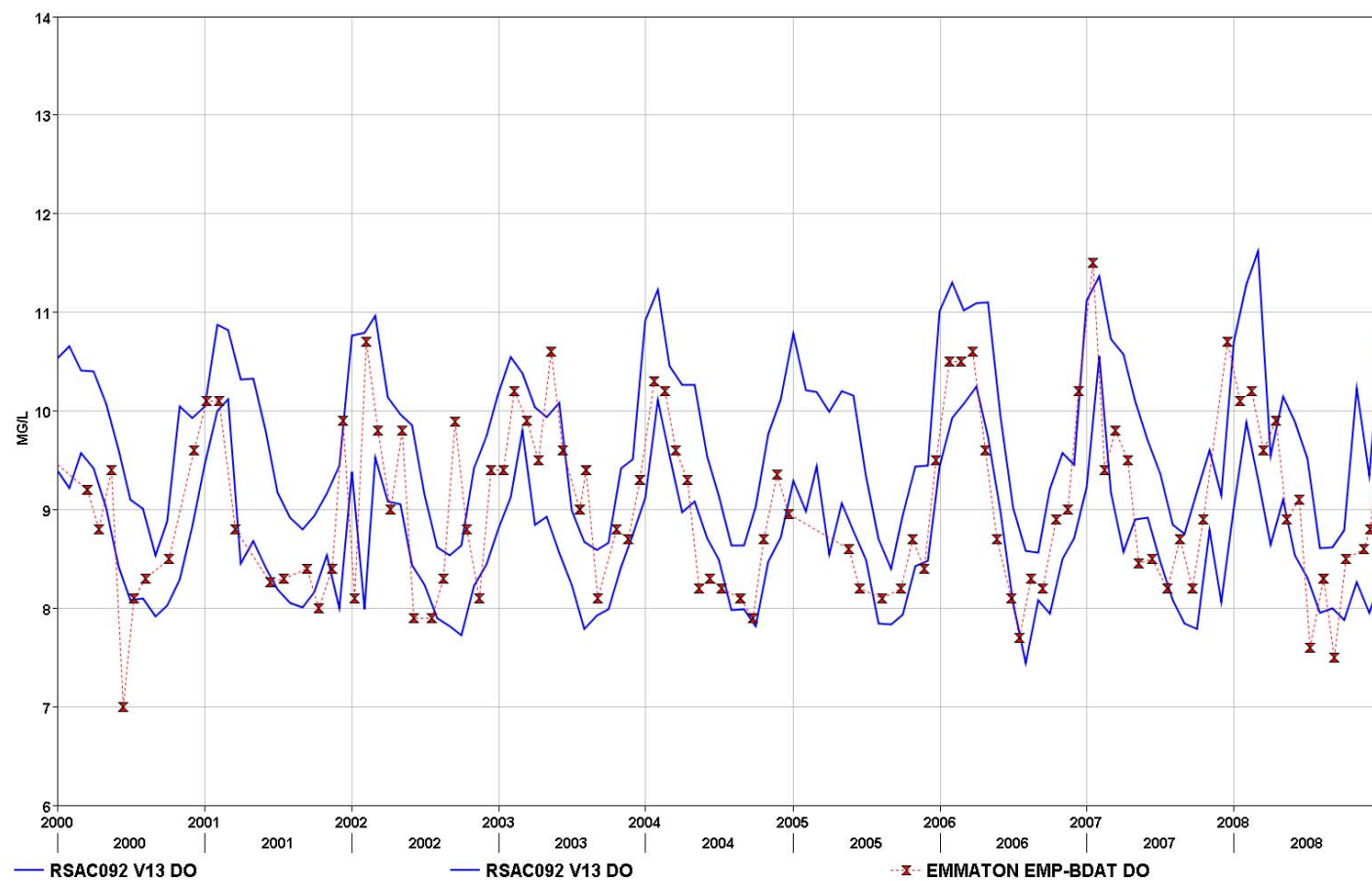


Figure A III. 50 DO at RSAC092 later years.

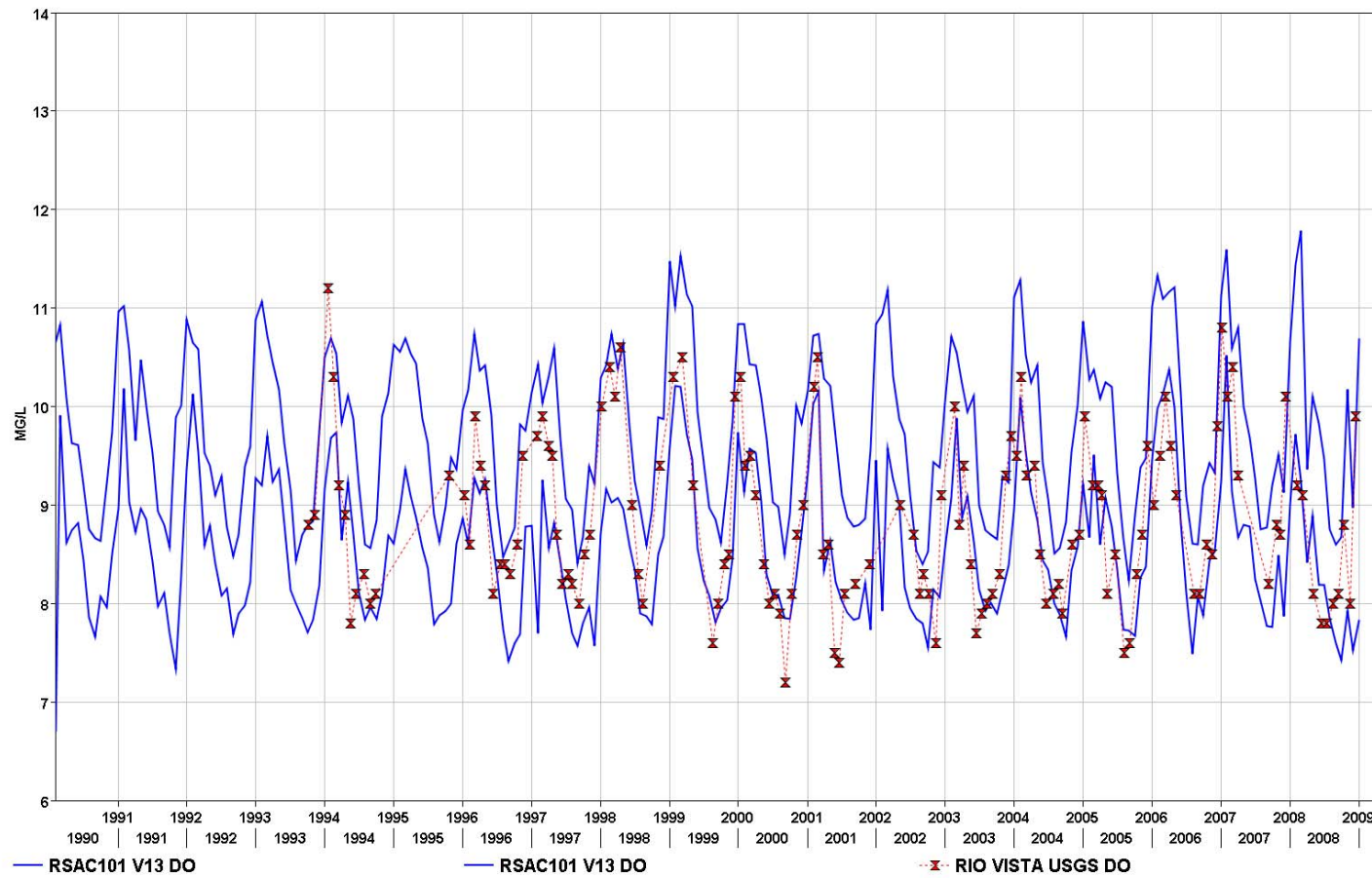


Figure A III. 51 DO at RSAC101 all years.

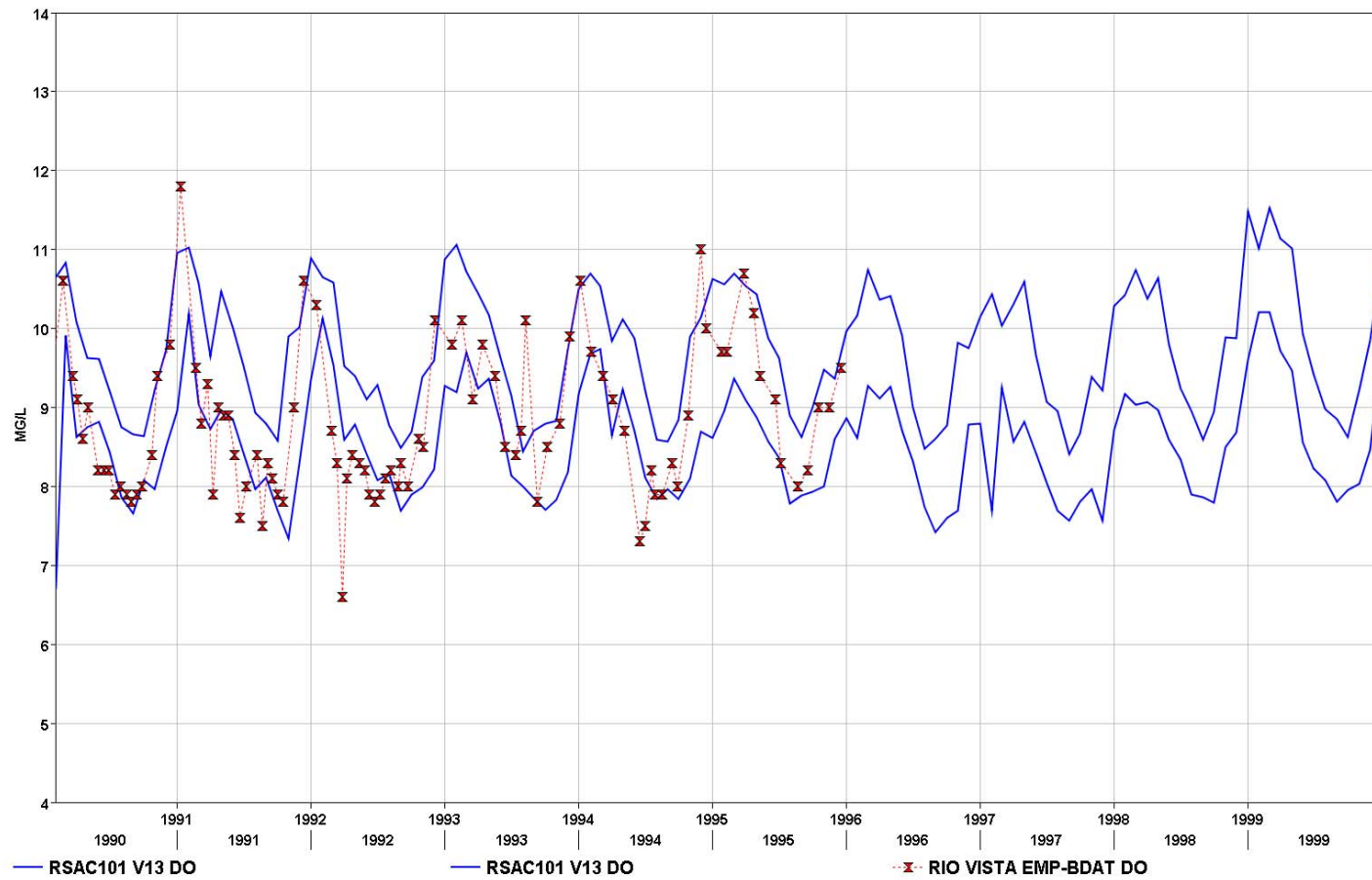


Figure A III. 52 DO at RSAC101 early years.

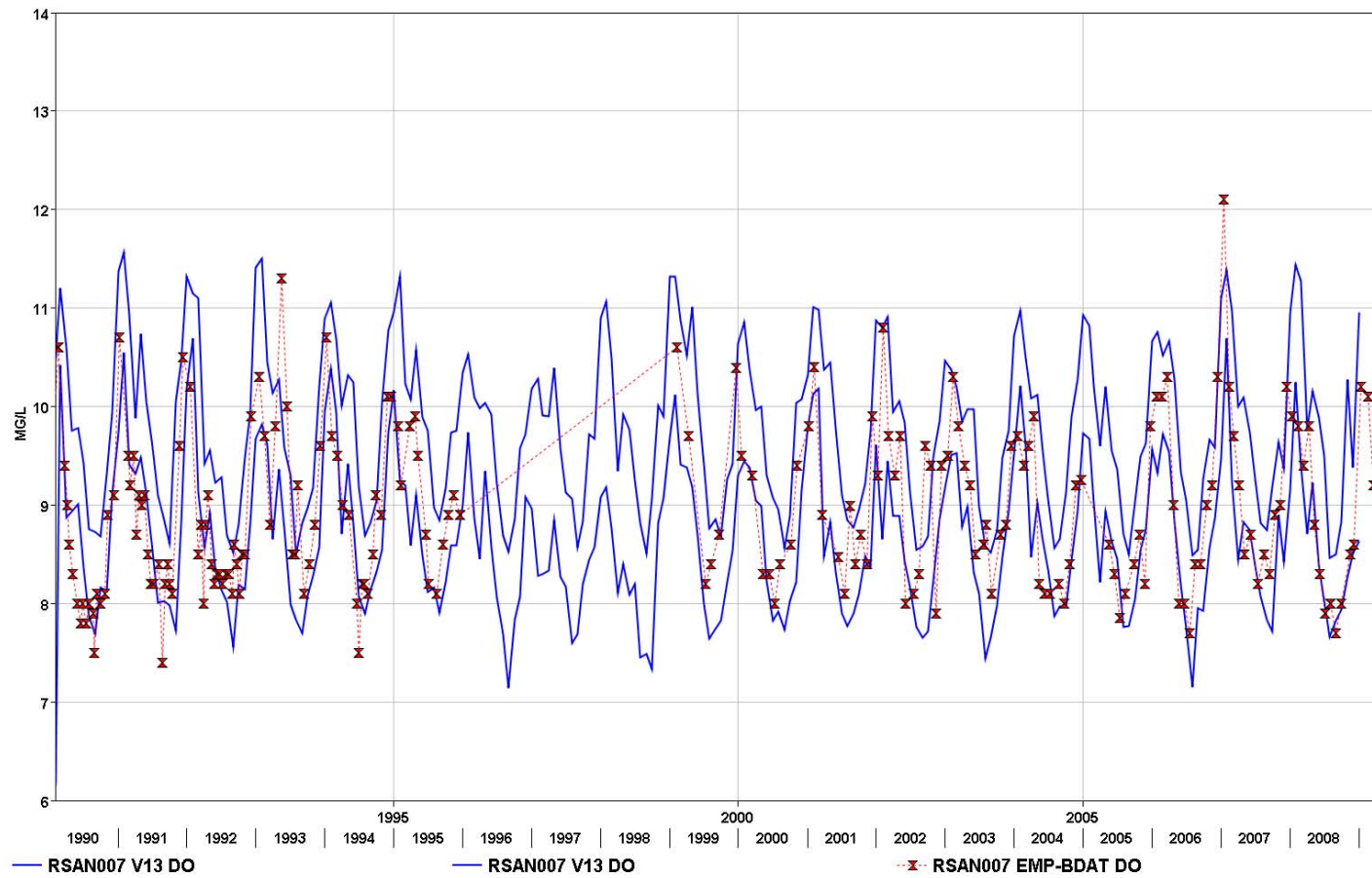


Figure A III. 53 DO at RSAN007 all years.

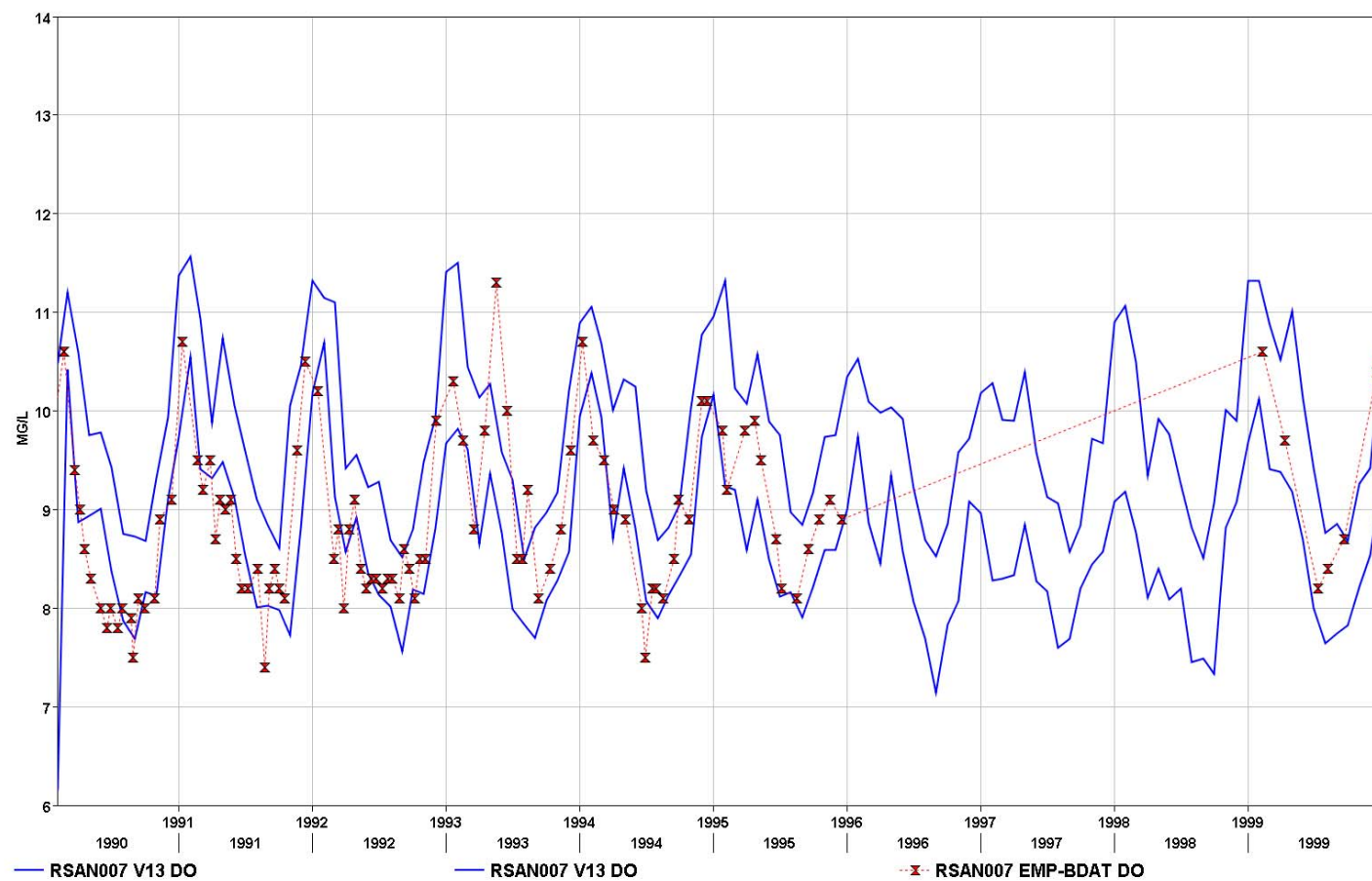


Figure A III. 54 DO at RSAN007 early years.

B. Algal Biomass

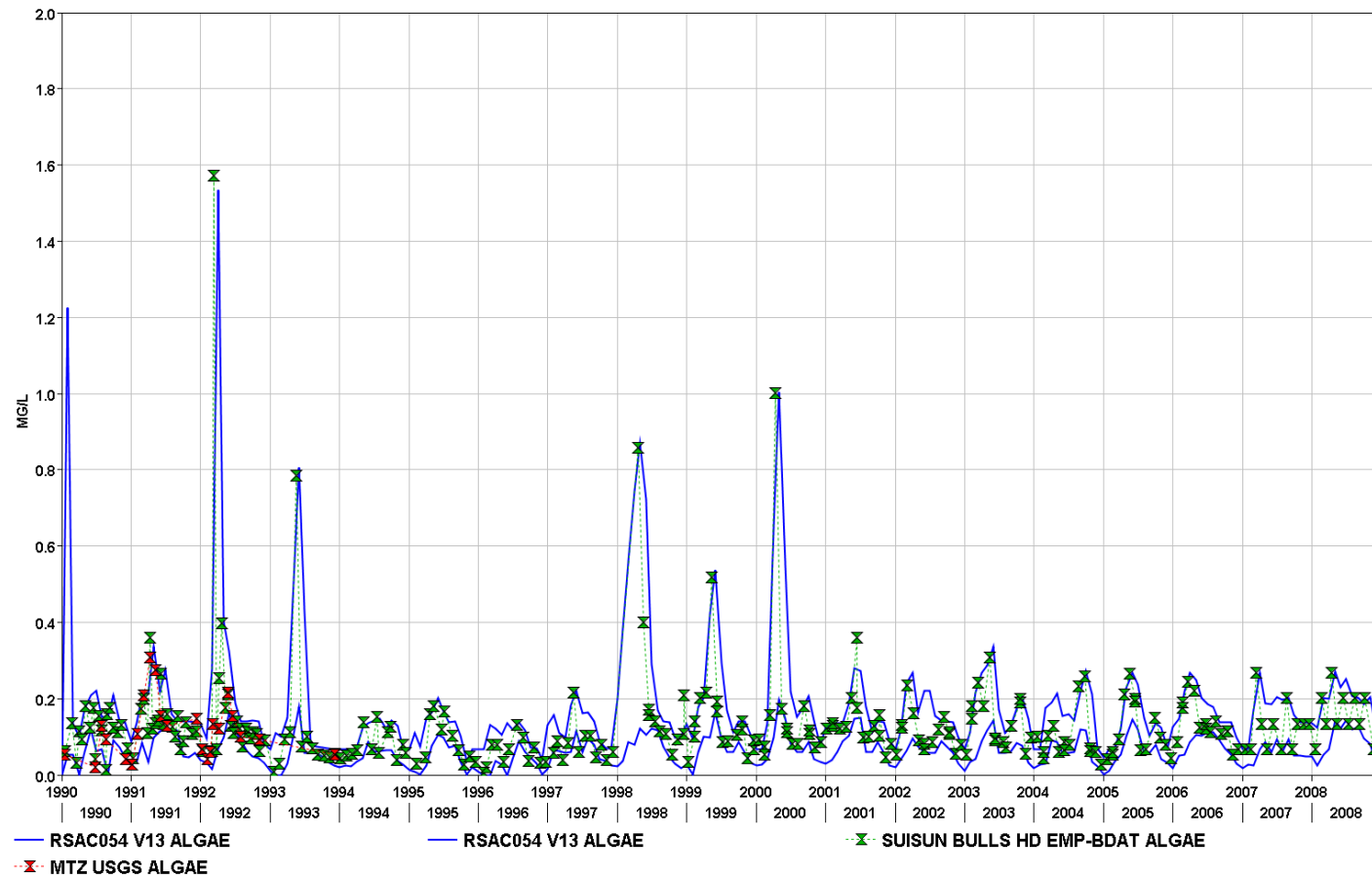


Figure A III. 55 Algae biomass at RSAC054 all years.

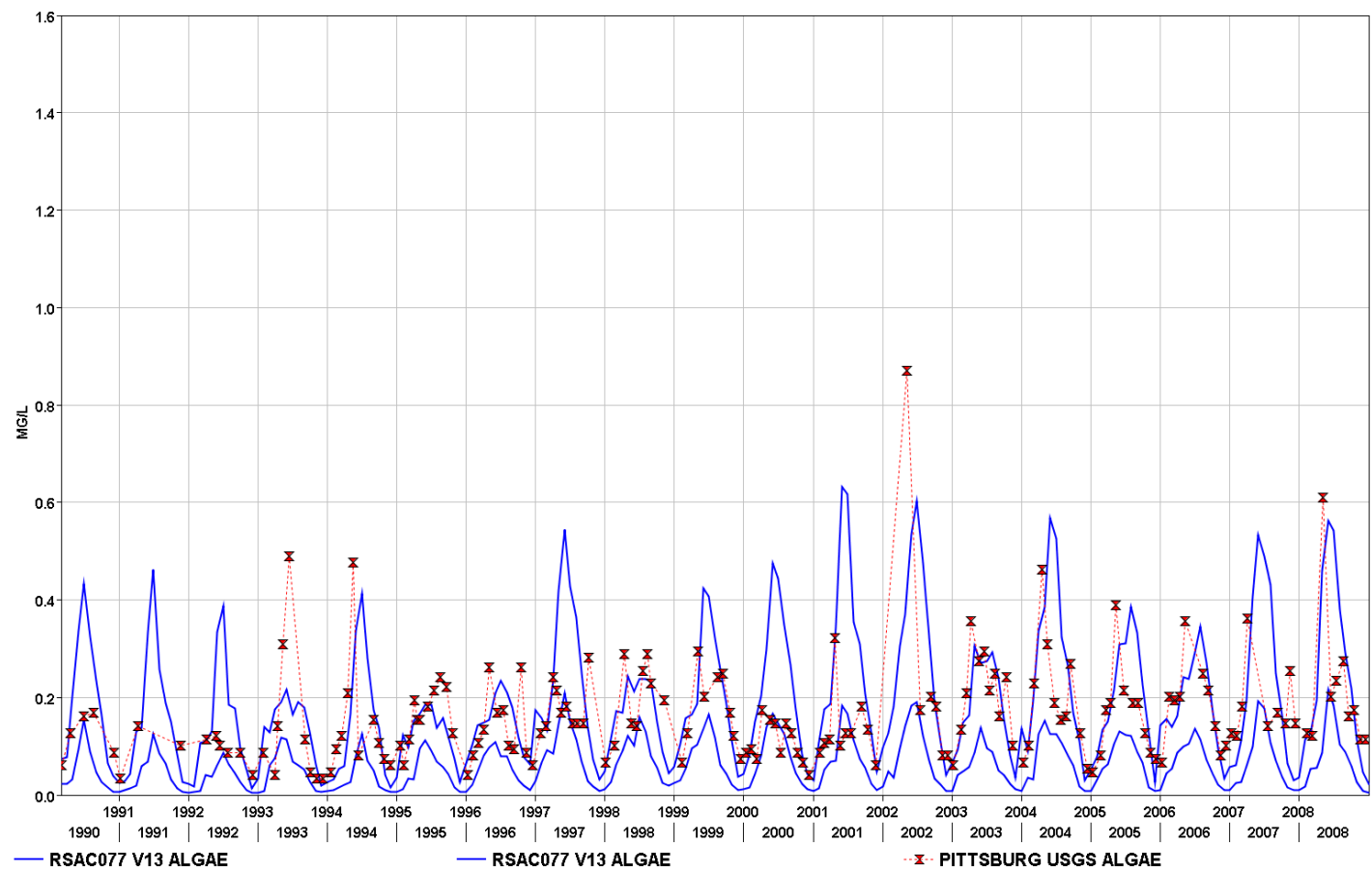


Figure A III. 56 Algae biomass at RSAC077 all years.

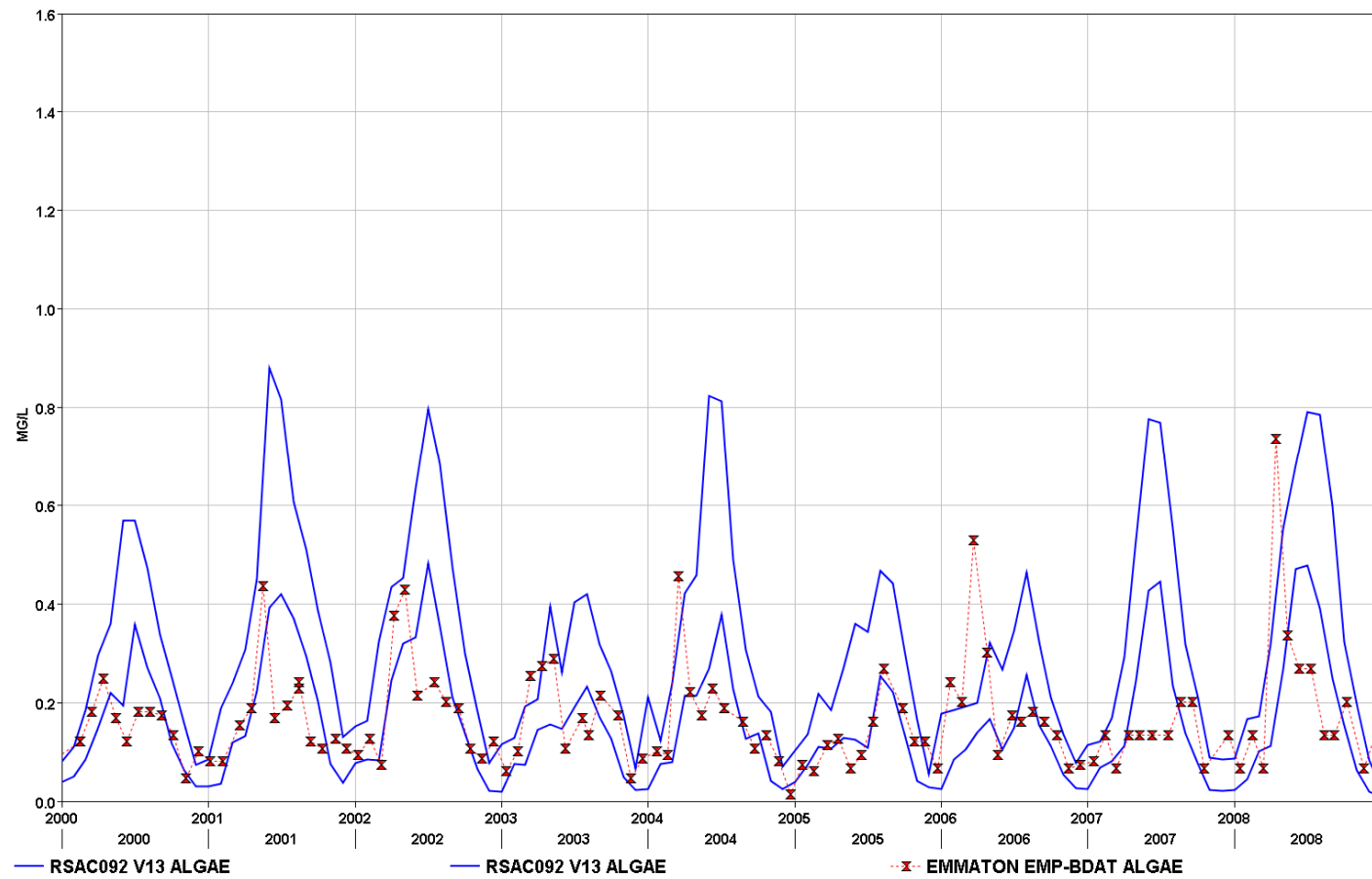


Figure A III. 57 Algae biomass at RSAC092 laterR years.

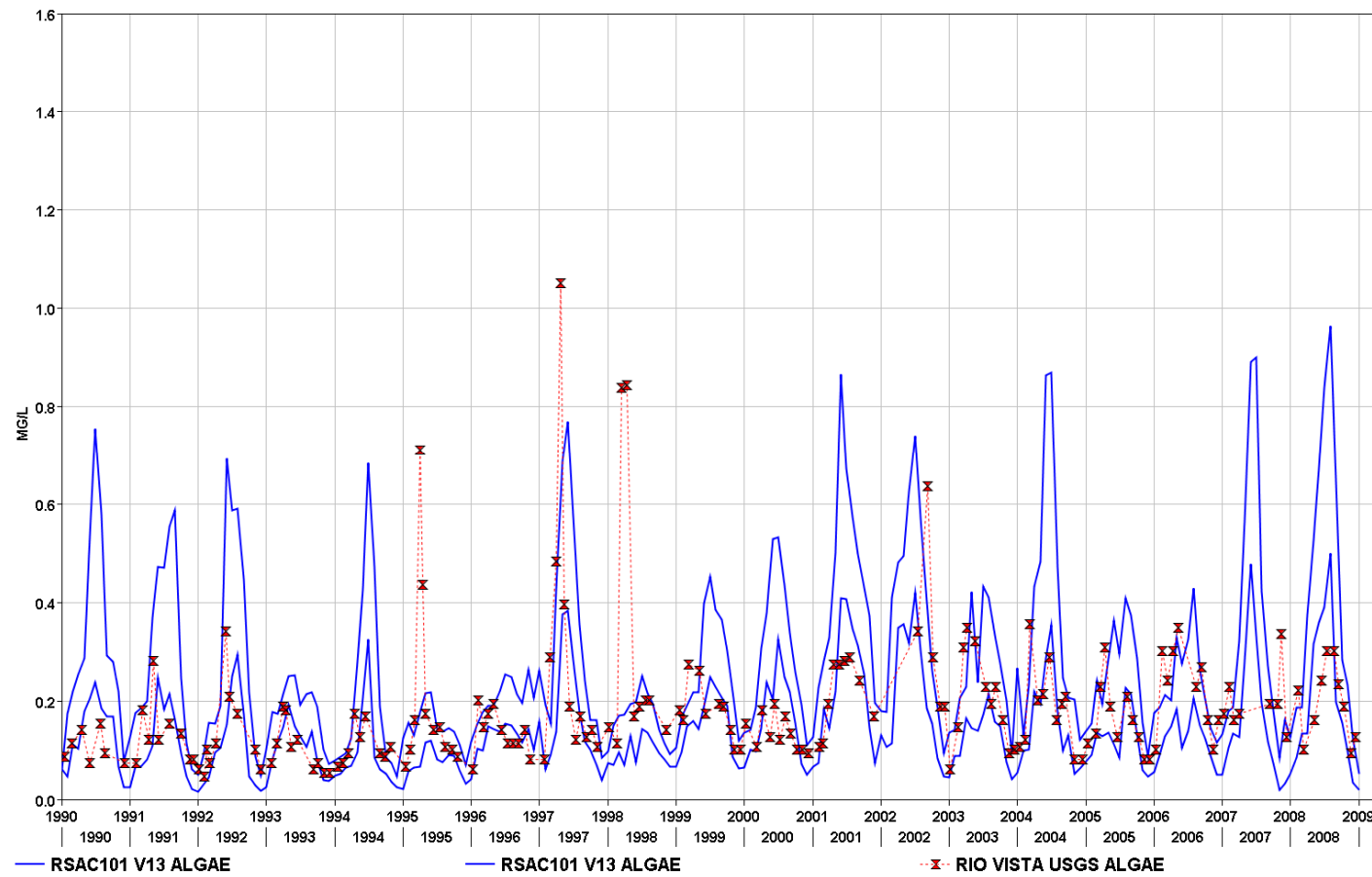


Figure A III. 58 Algae biomass at RSAC101 USGS all years.

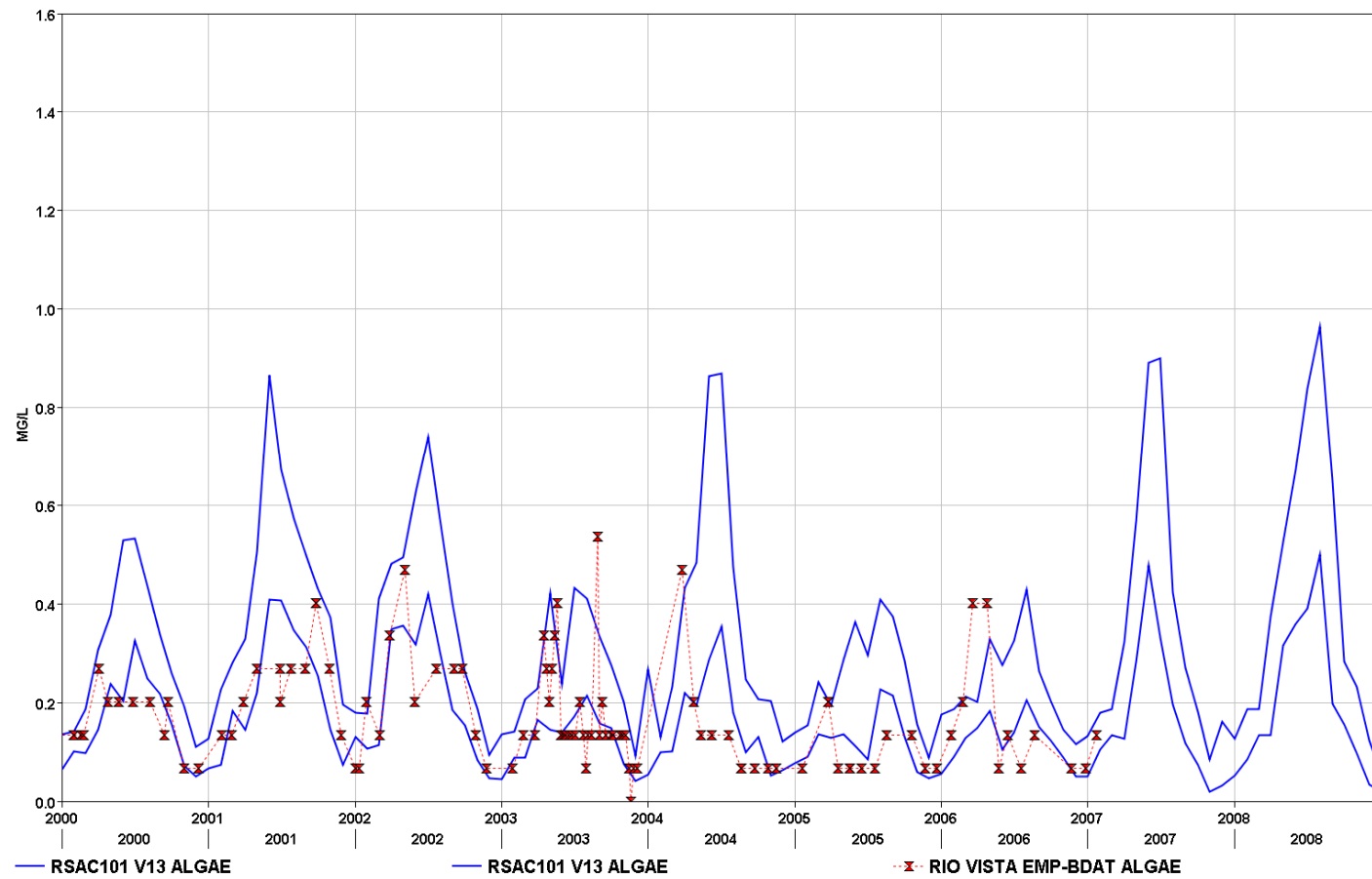


Figure A III. 59 Algae biomass at RSAC0101 laterR years.

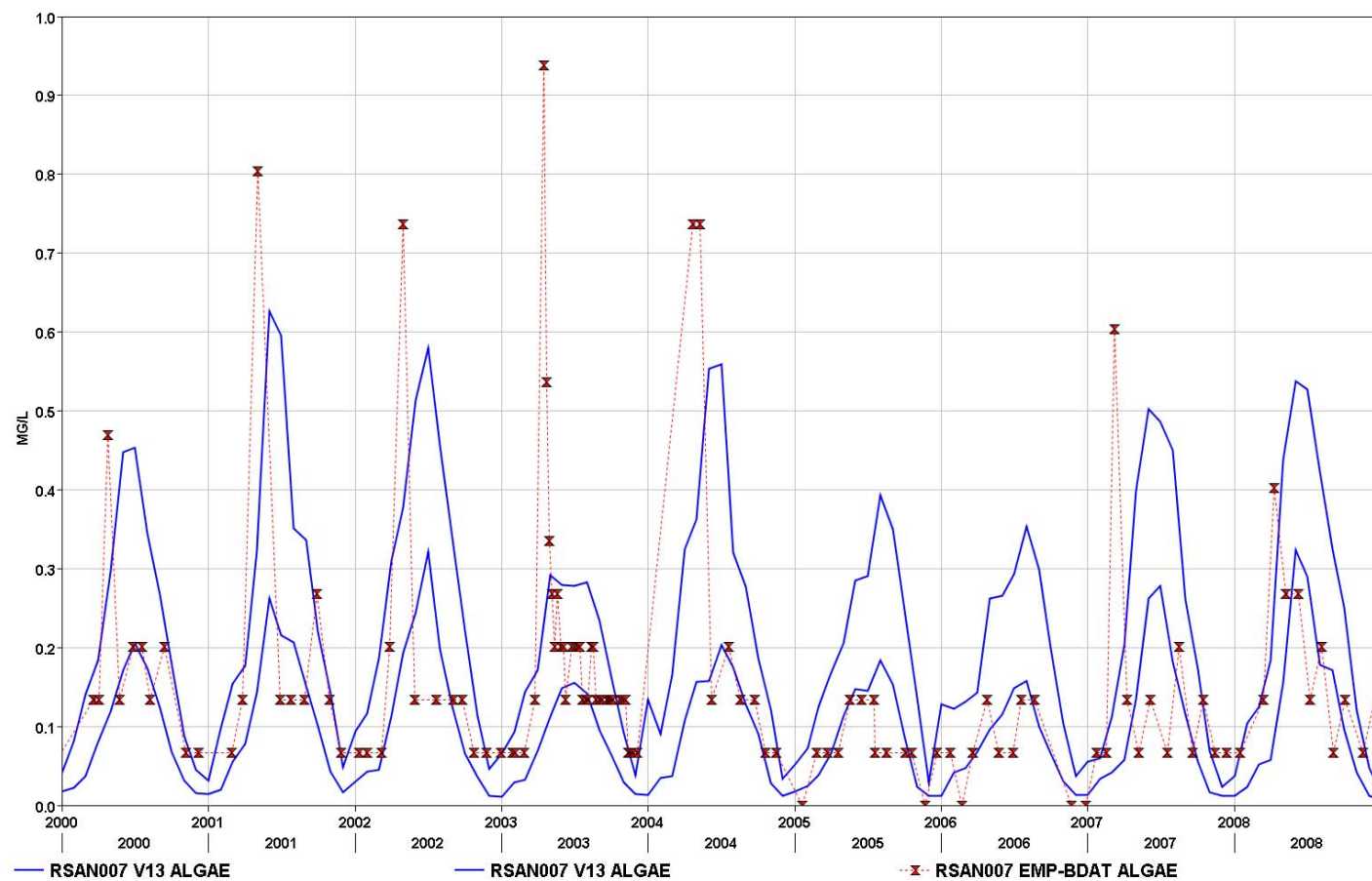


Figure A III. 60 Algae biomass at RSAN007 laterR years.

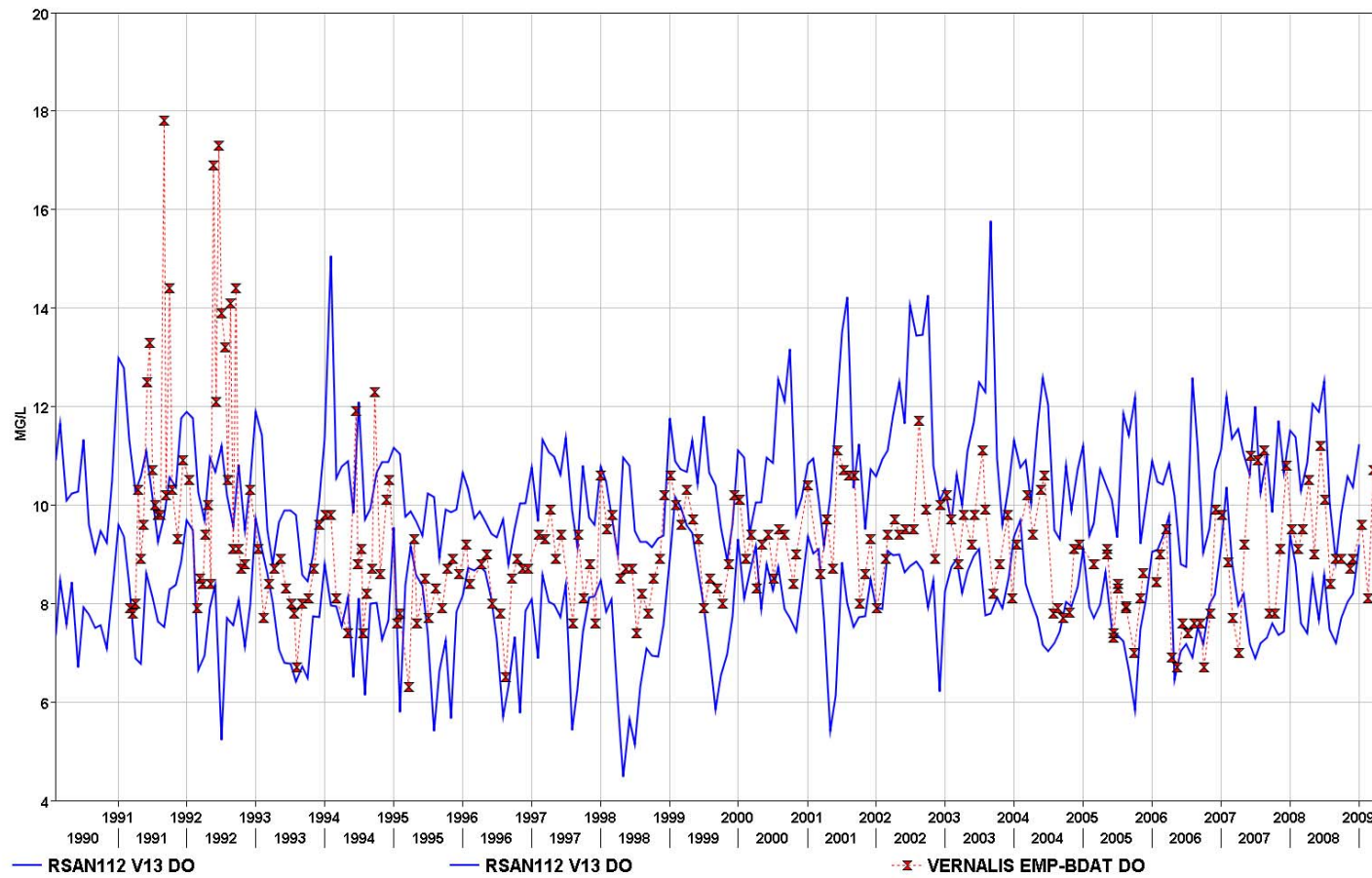


Figure A III. 61 Algae biomass at RSAN112 all years.

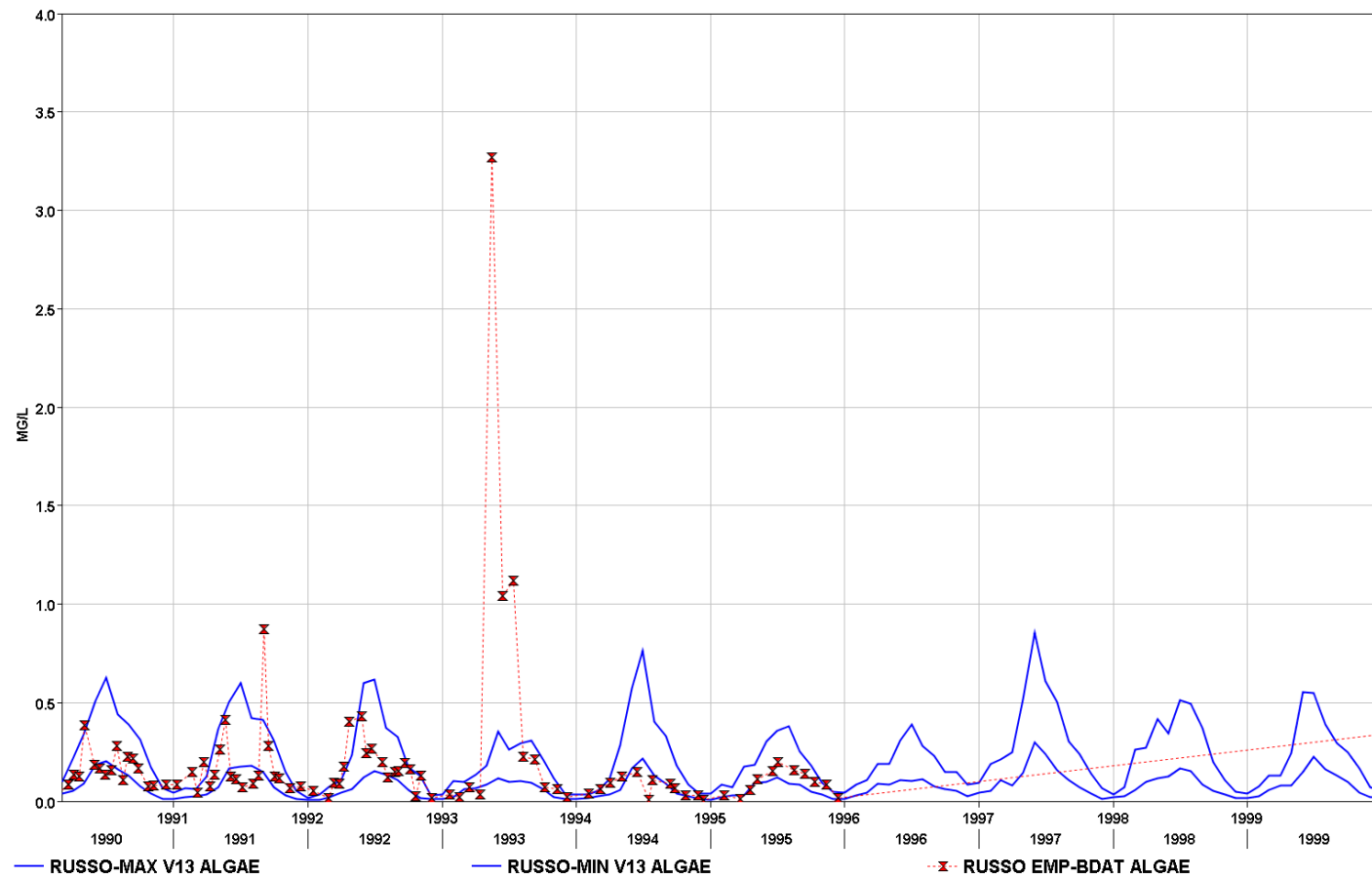


Figure A III. 62 Algae biomass at RUSSO early years.

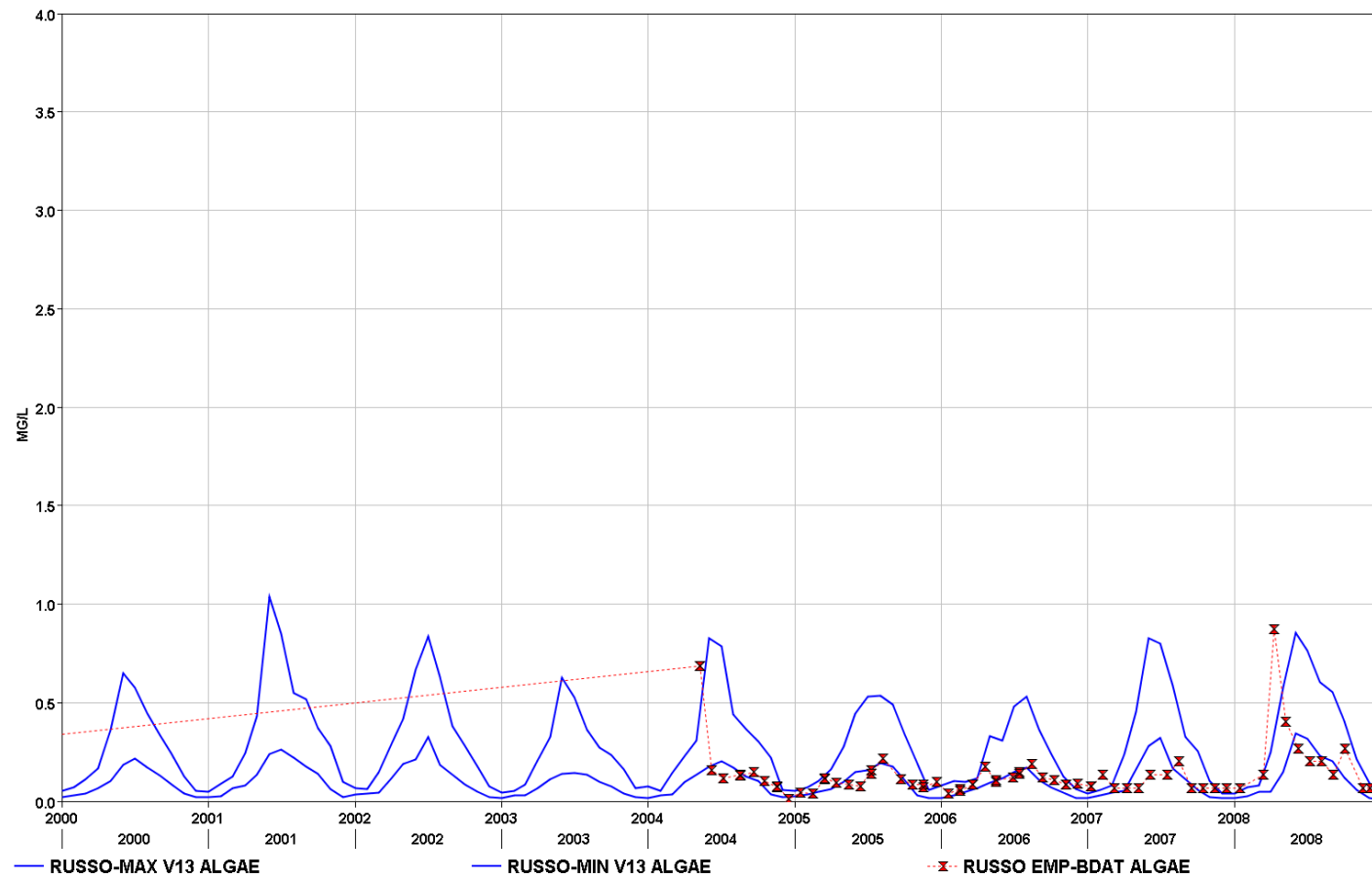


Figure A III. 63 Algae biomass at RUSSO later years.

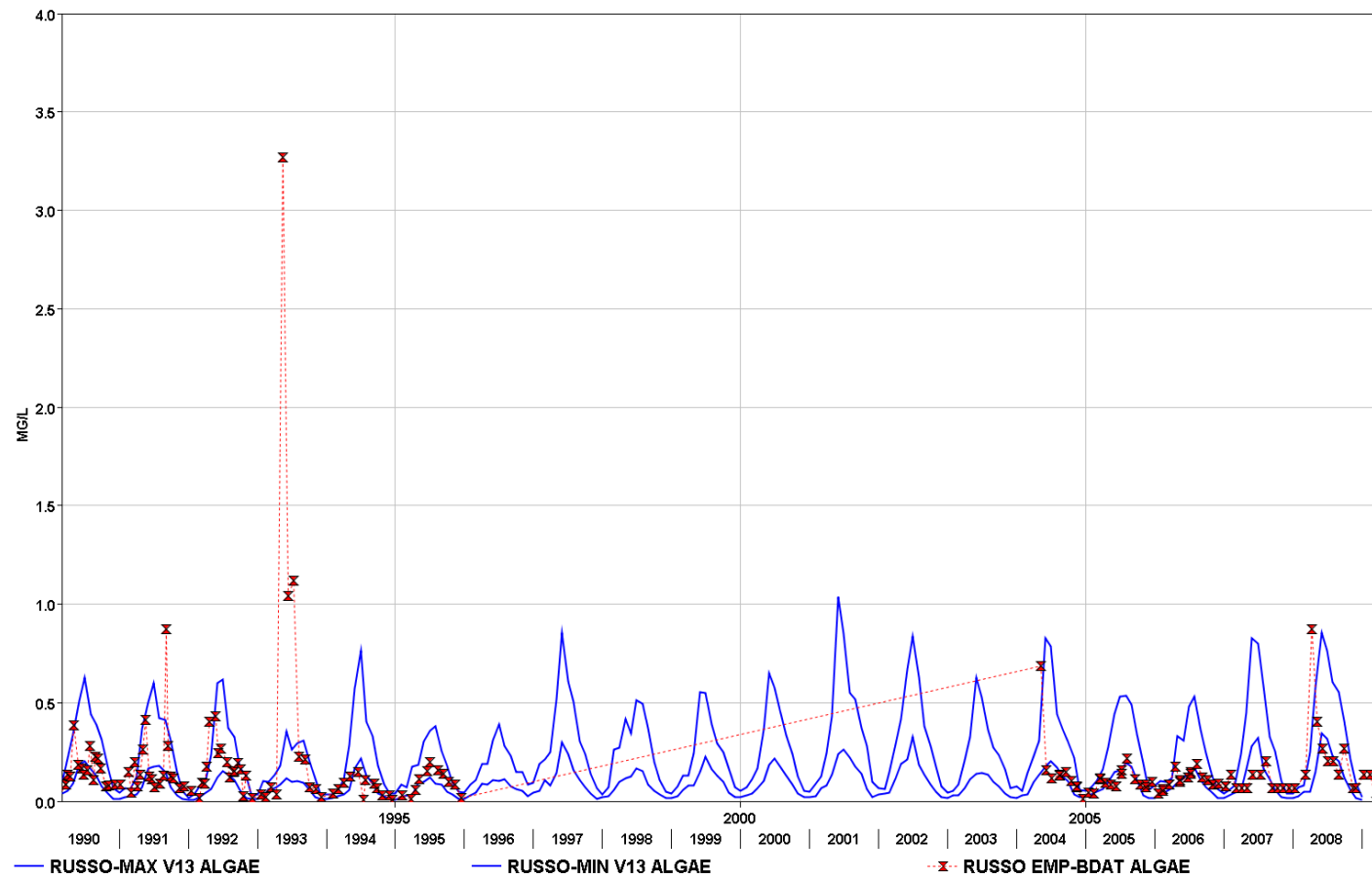


Figure A III. 64 Algae biomass at RUSSO all years.

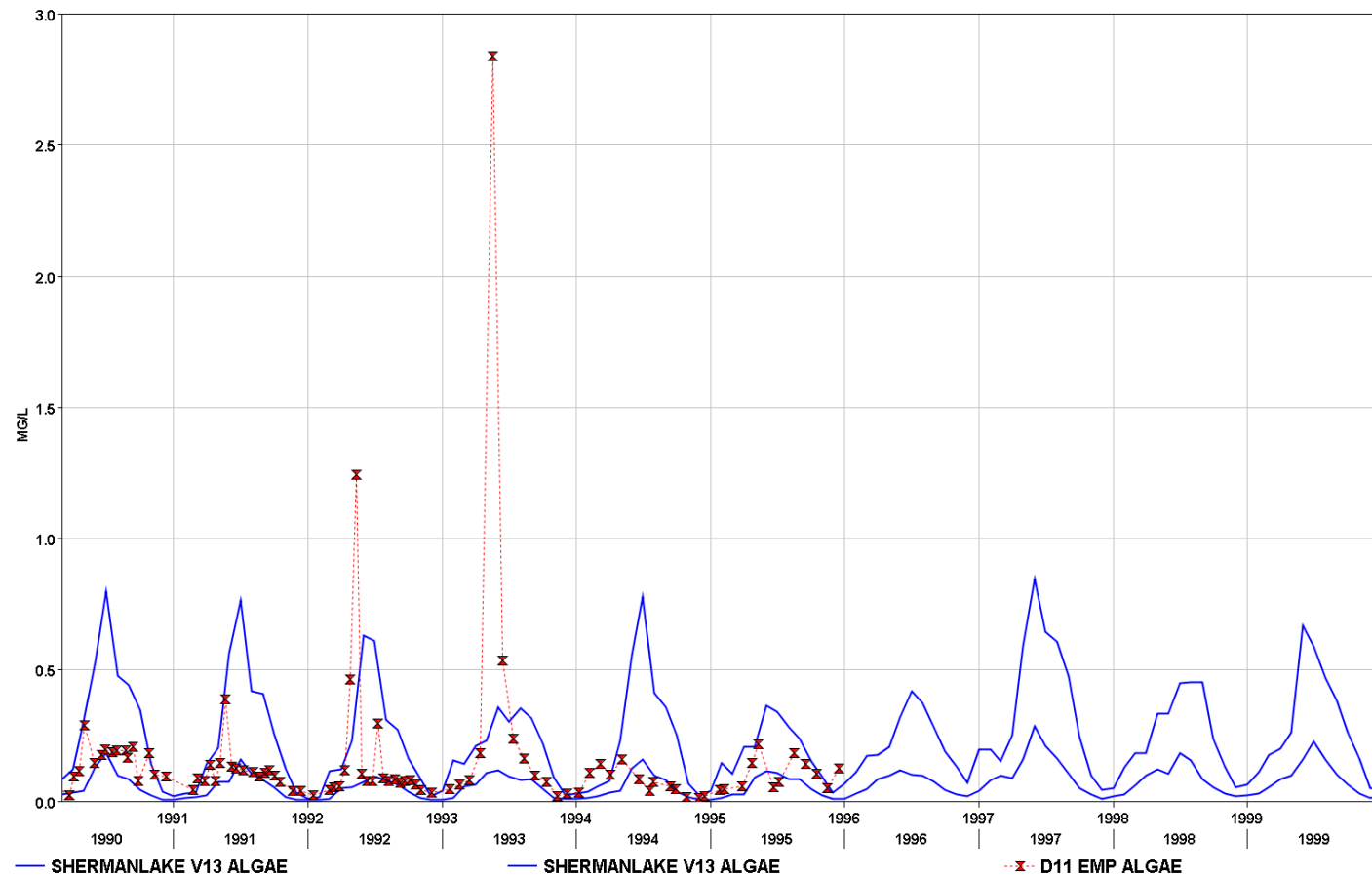


Figure A III. 65 Algae biomass at SHERMAN early years.

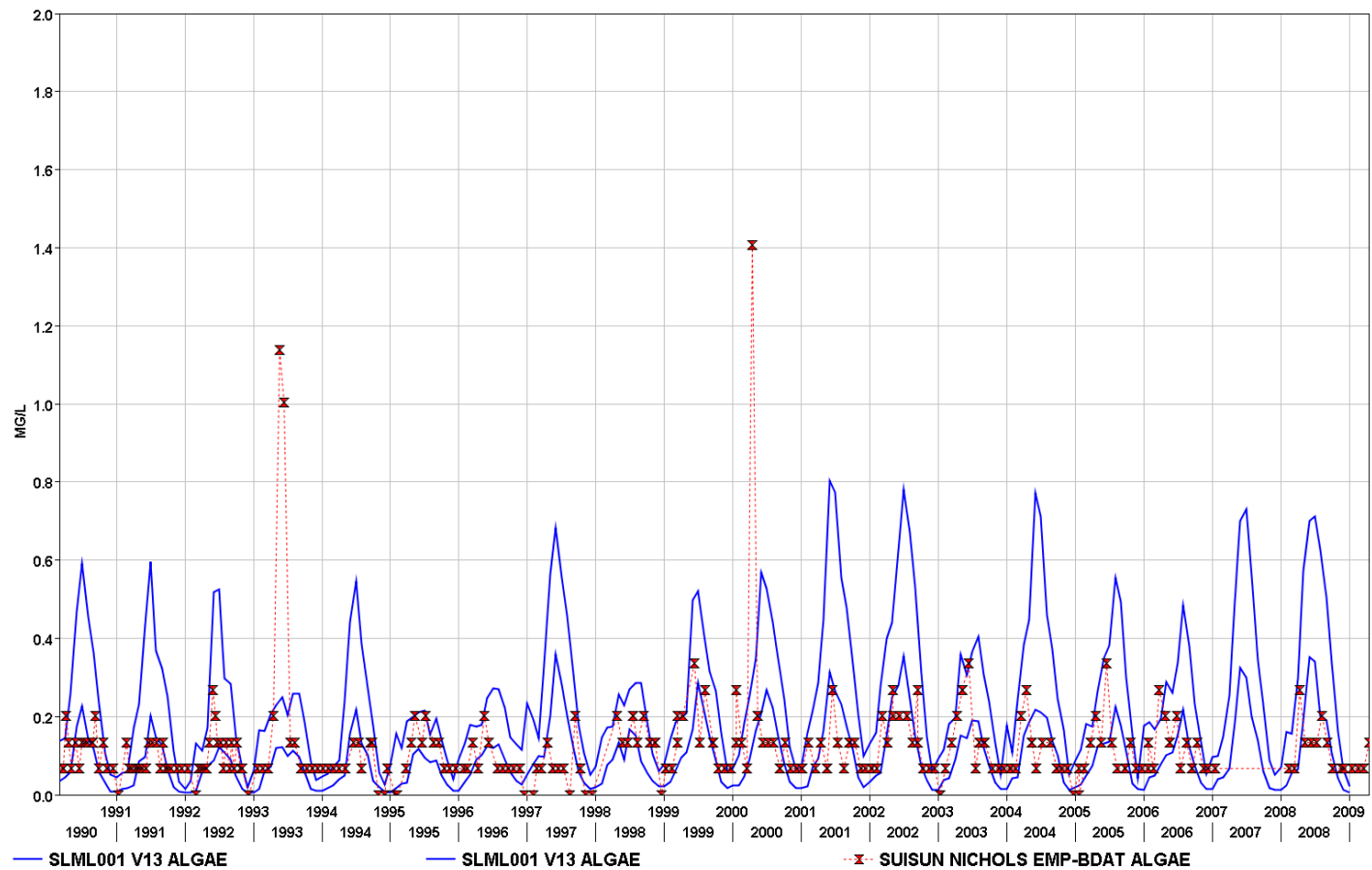


Figure A III. 66 Algae biomass at SLM001 all years.

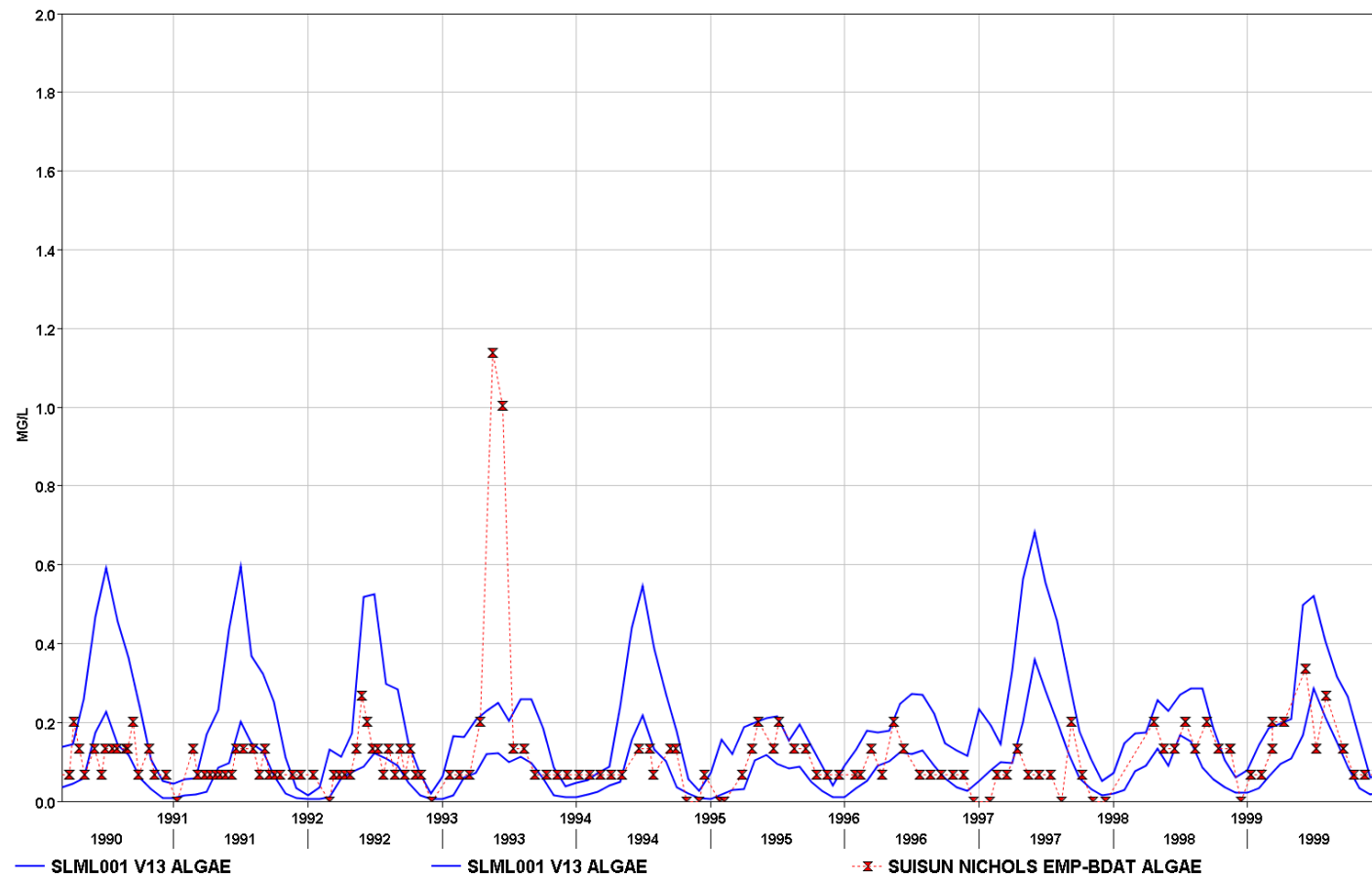


Figure A III. 67 Algae biomass at SLM001 early years.

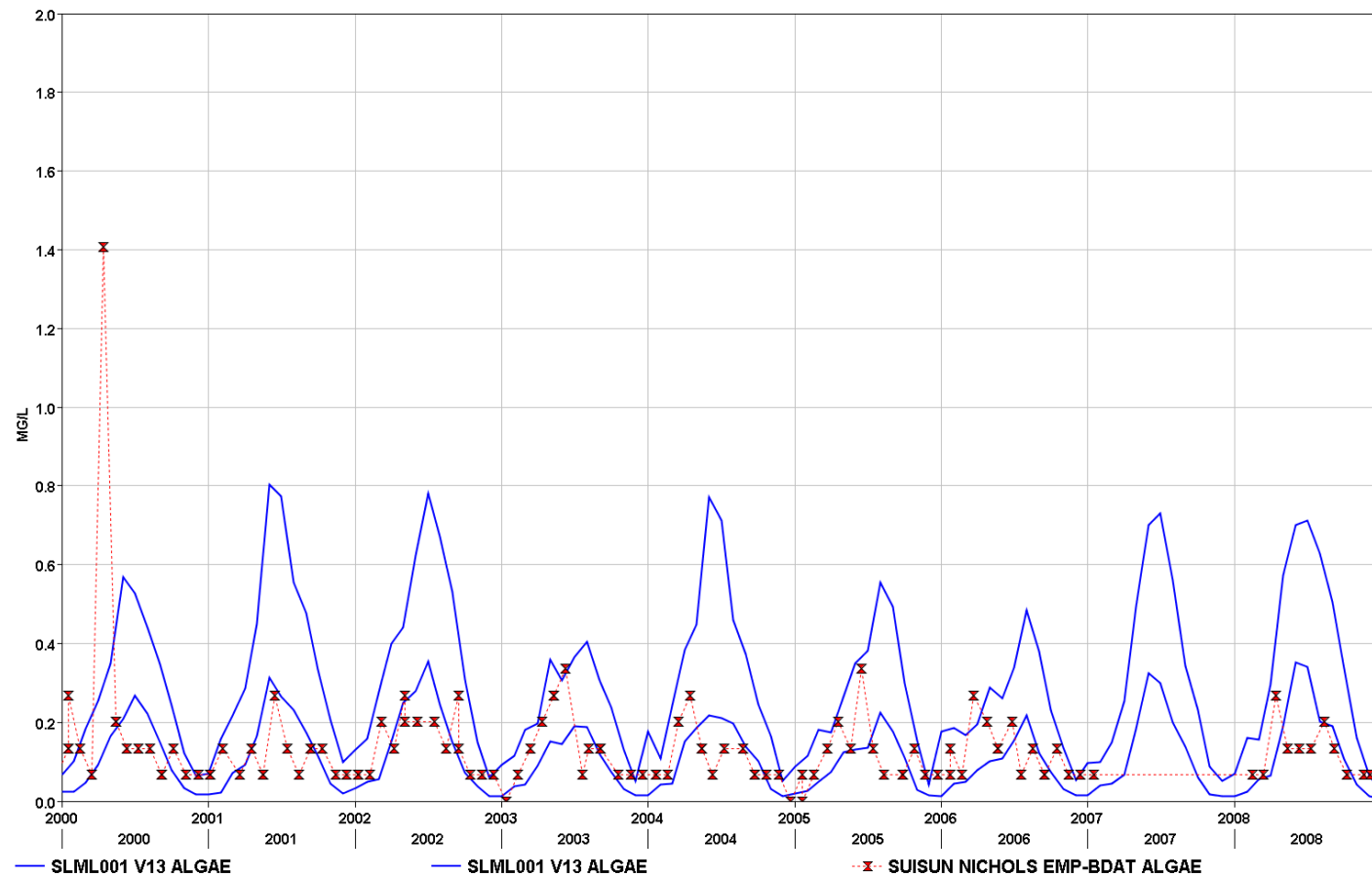


Figure A III. 68 Algae biomass at SLM001 later years.

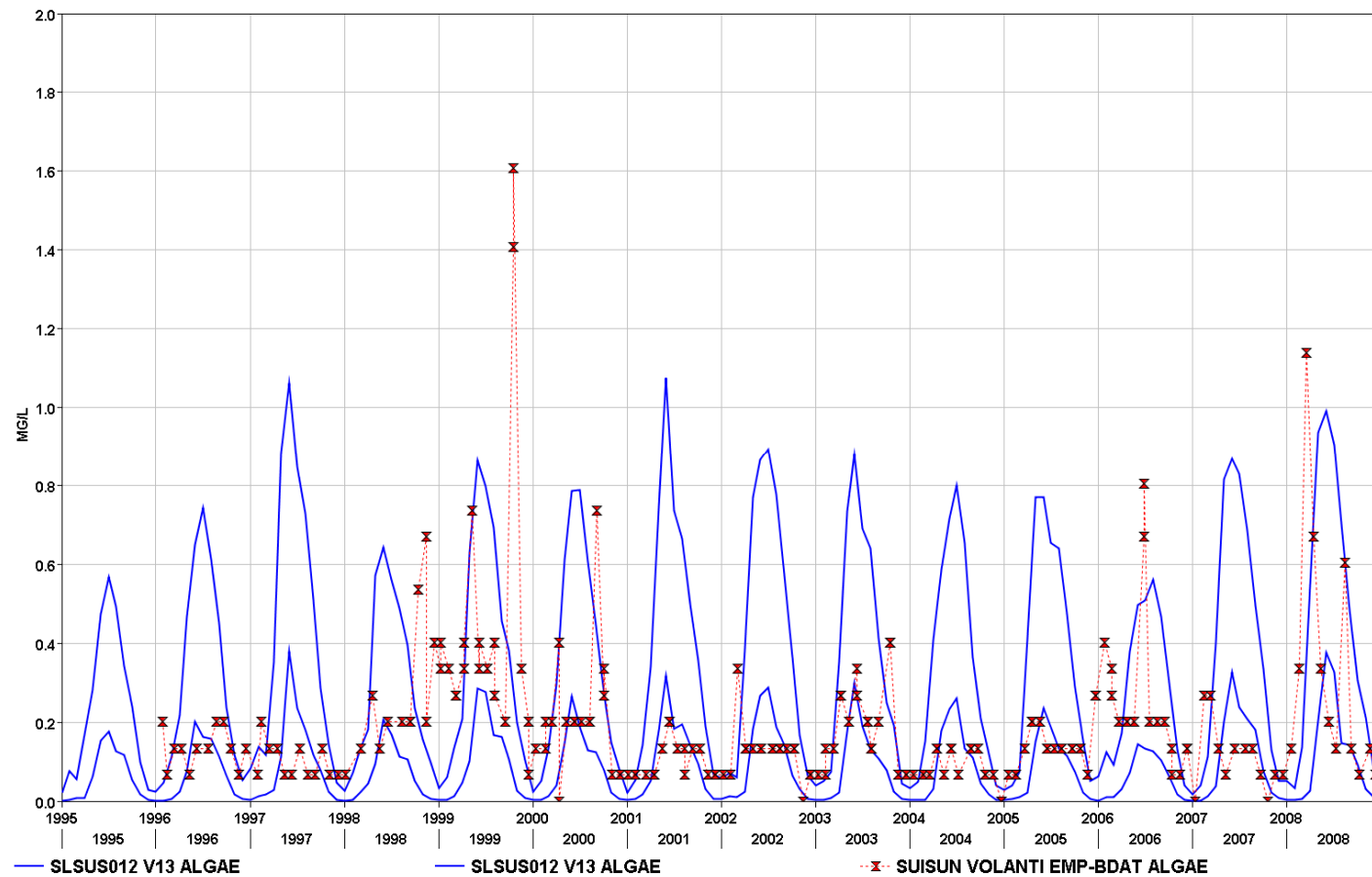


Figure A III. 69 Algae biomass at SLSUS012 (Suisun Volanti) all years.

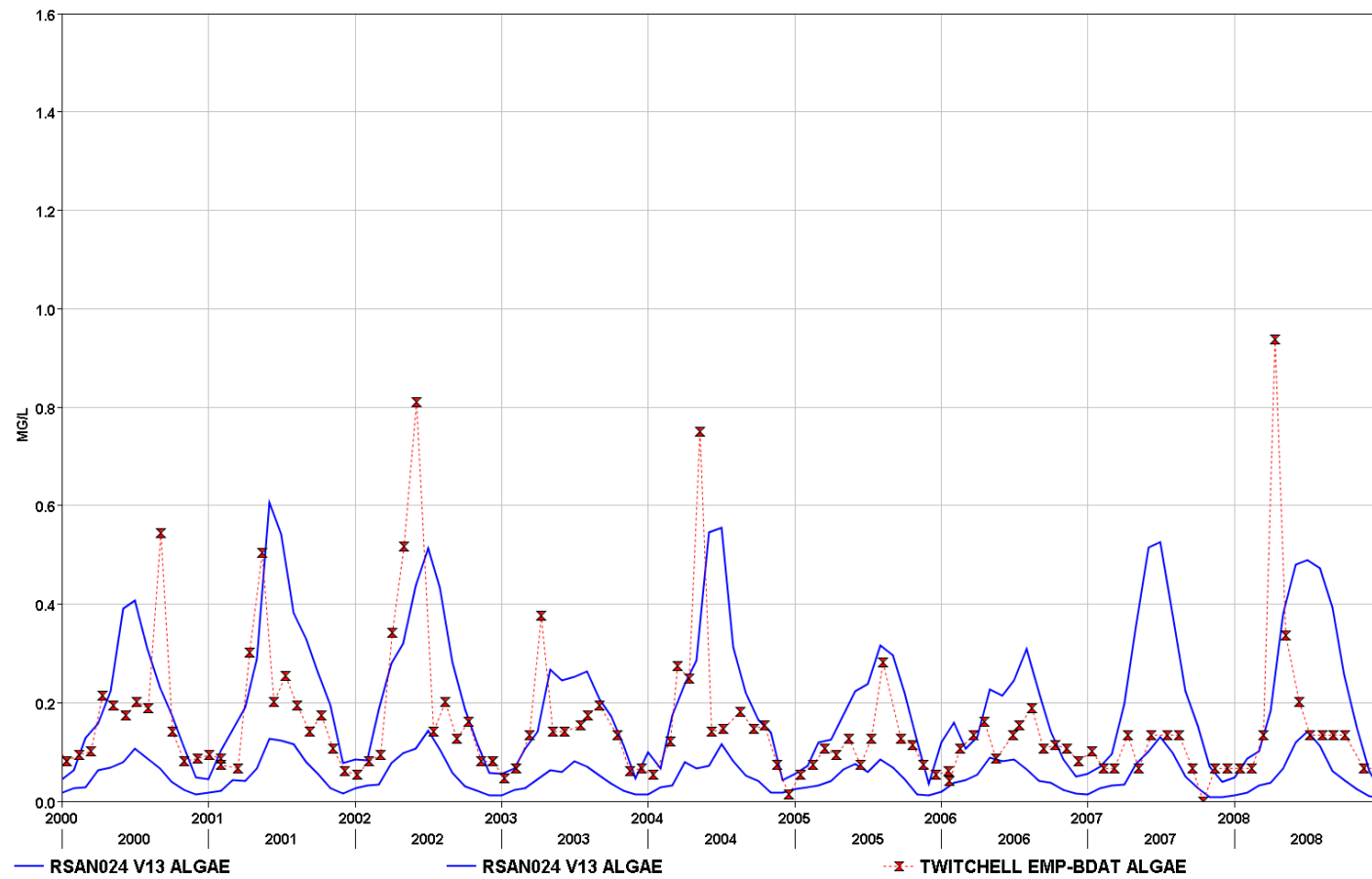


Figure A III. 70 Algae biomass at RSN024 later years.

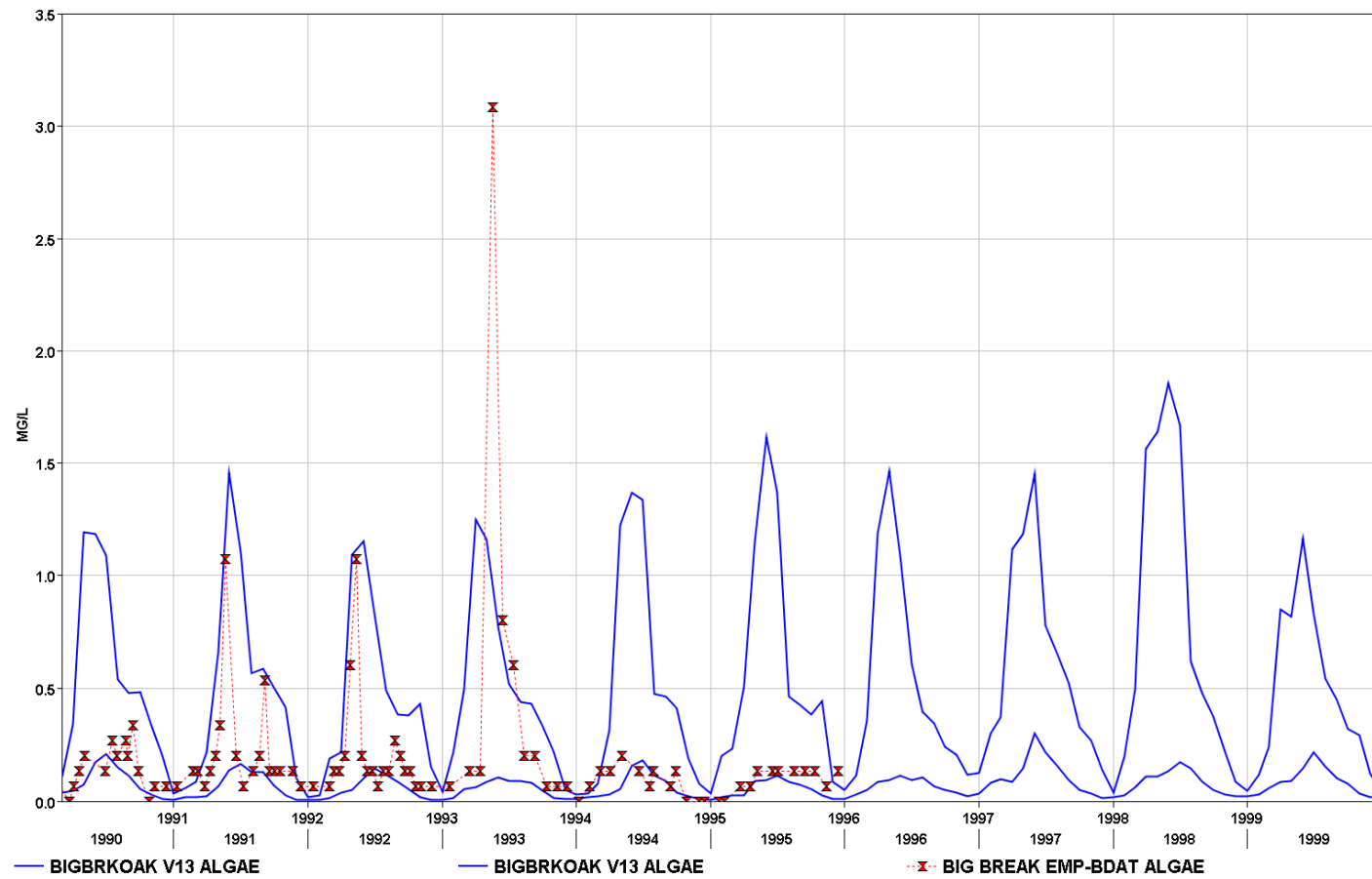


Figure A III. 71 Algae biomass at BIG BREAK early years.

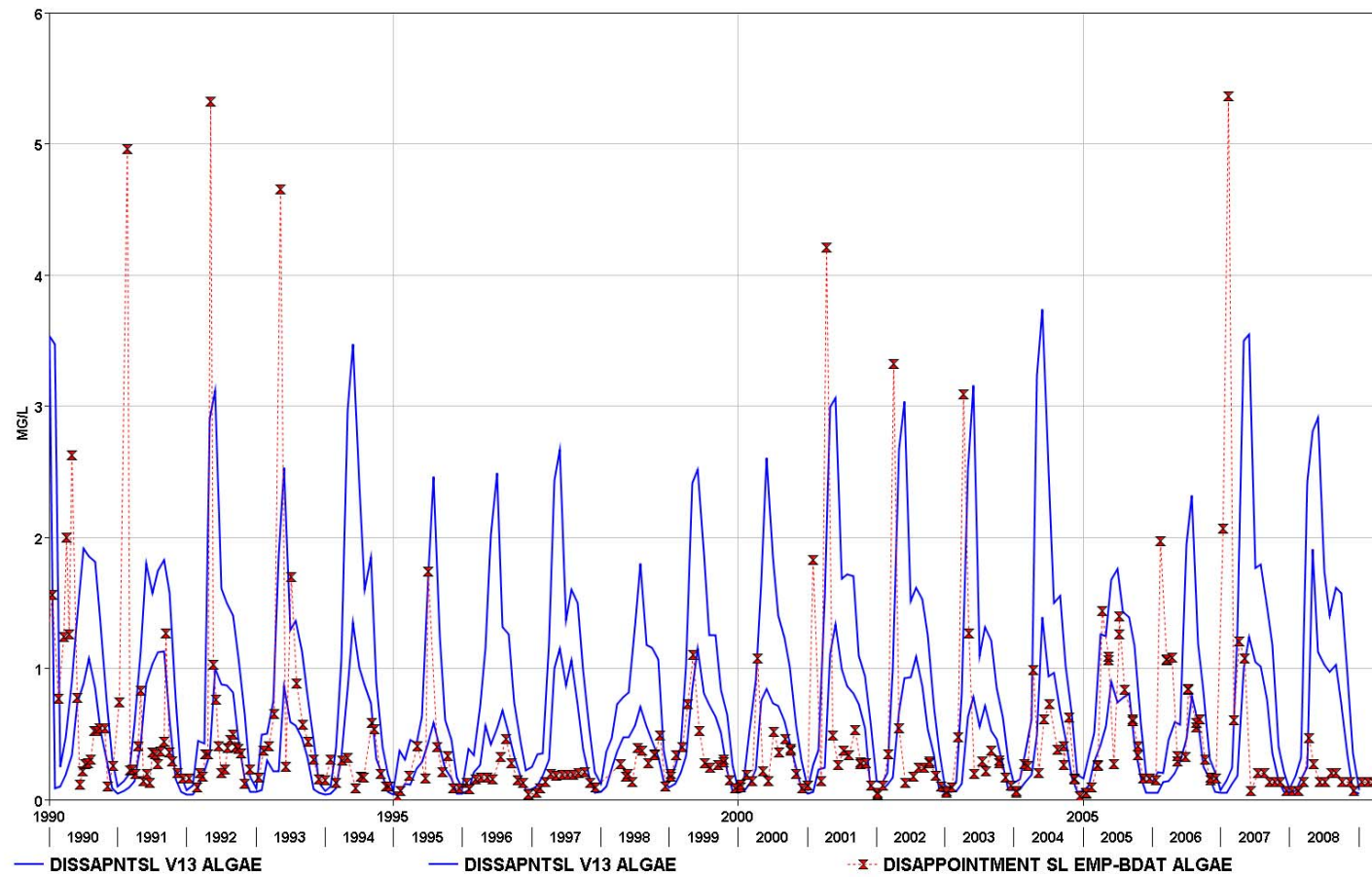


Figure A III. 72 Algae biomass a DISAP SL all years.

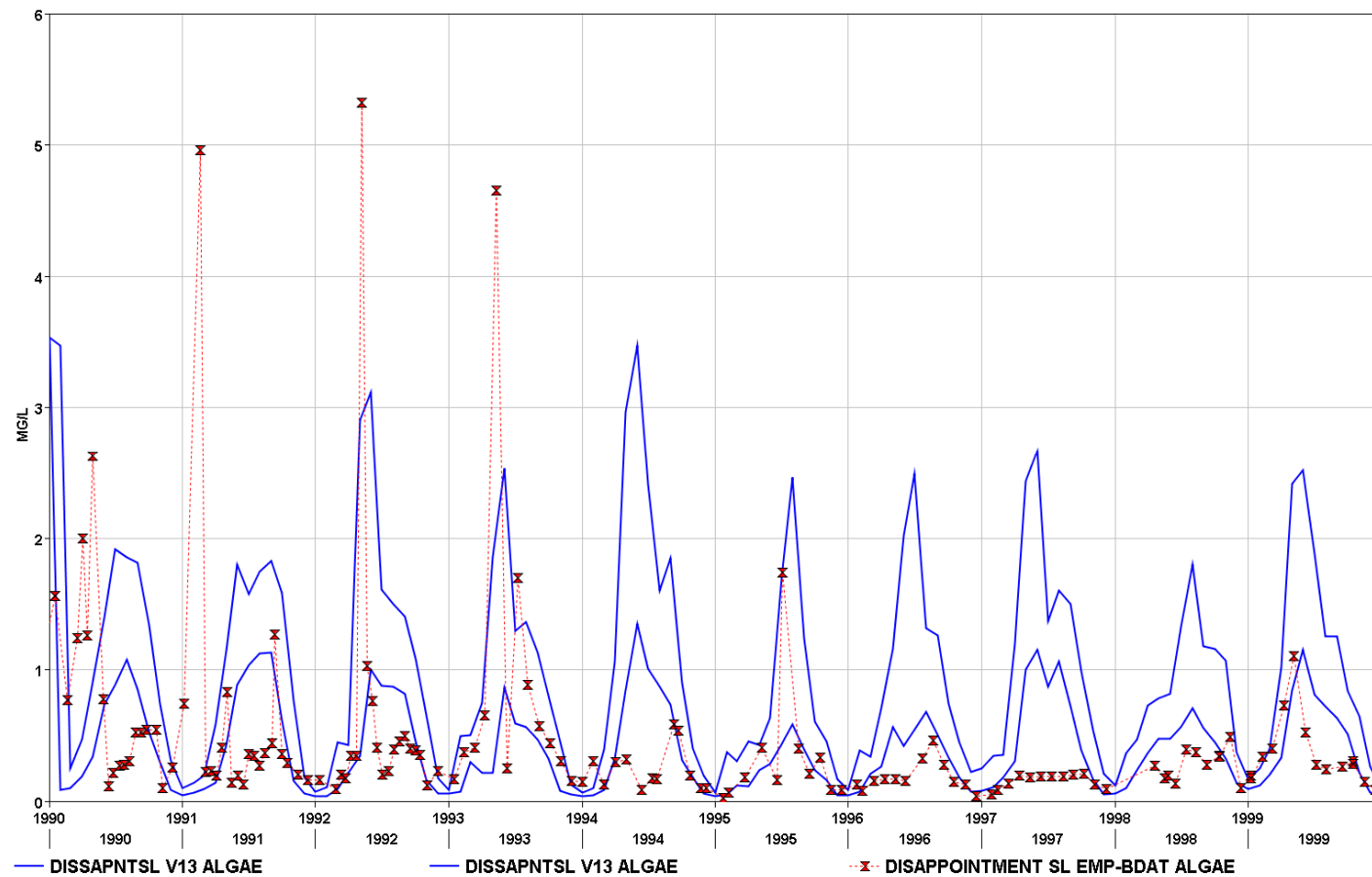


Figure A III. 73 Algae biomass at DISAP SL early years.

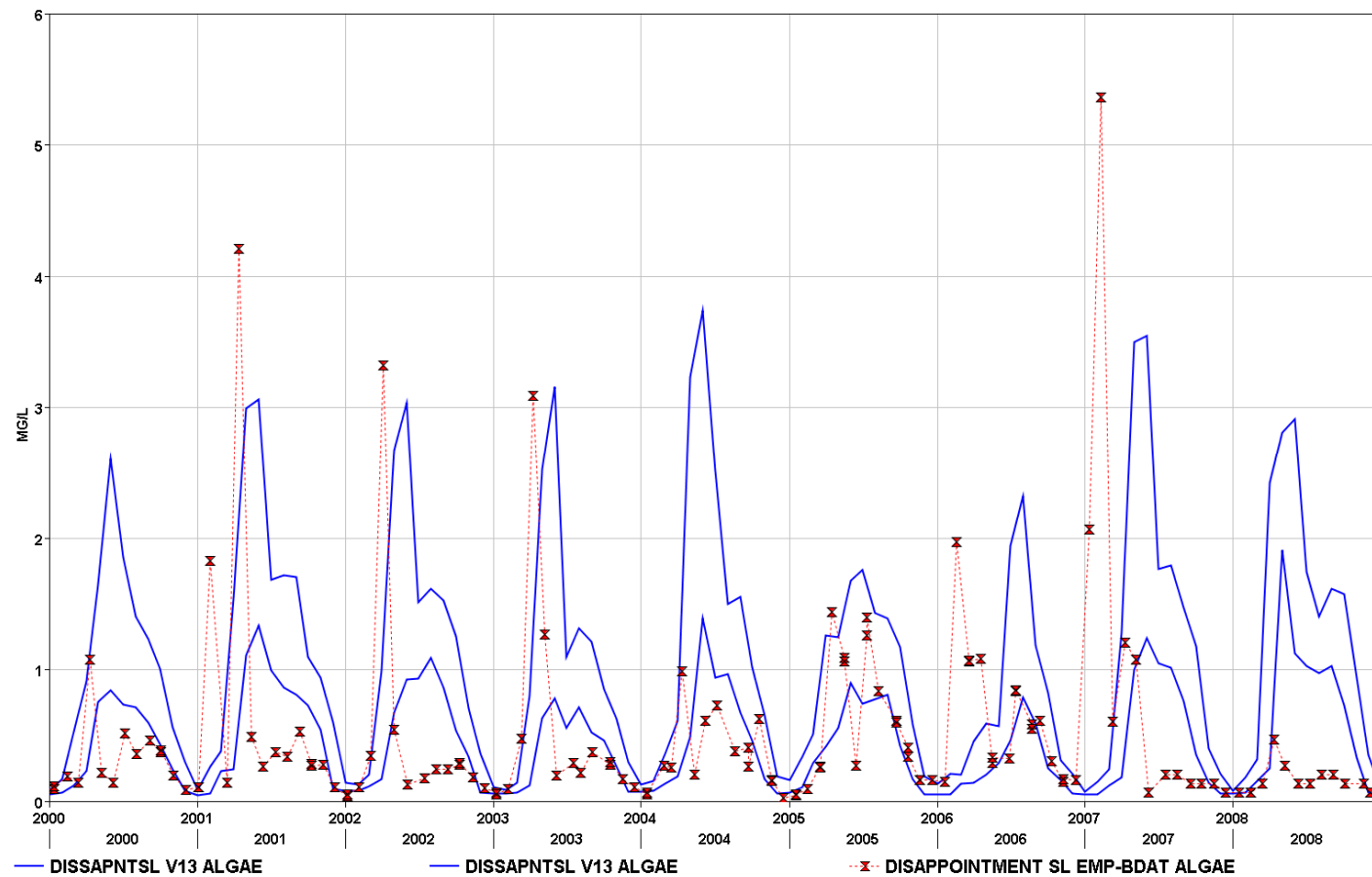


Figure A III. 74 Algae biomass at DISAP SL later years.

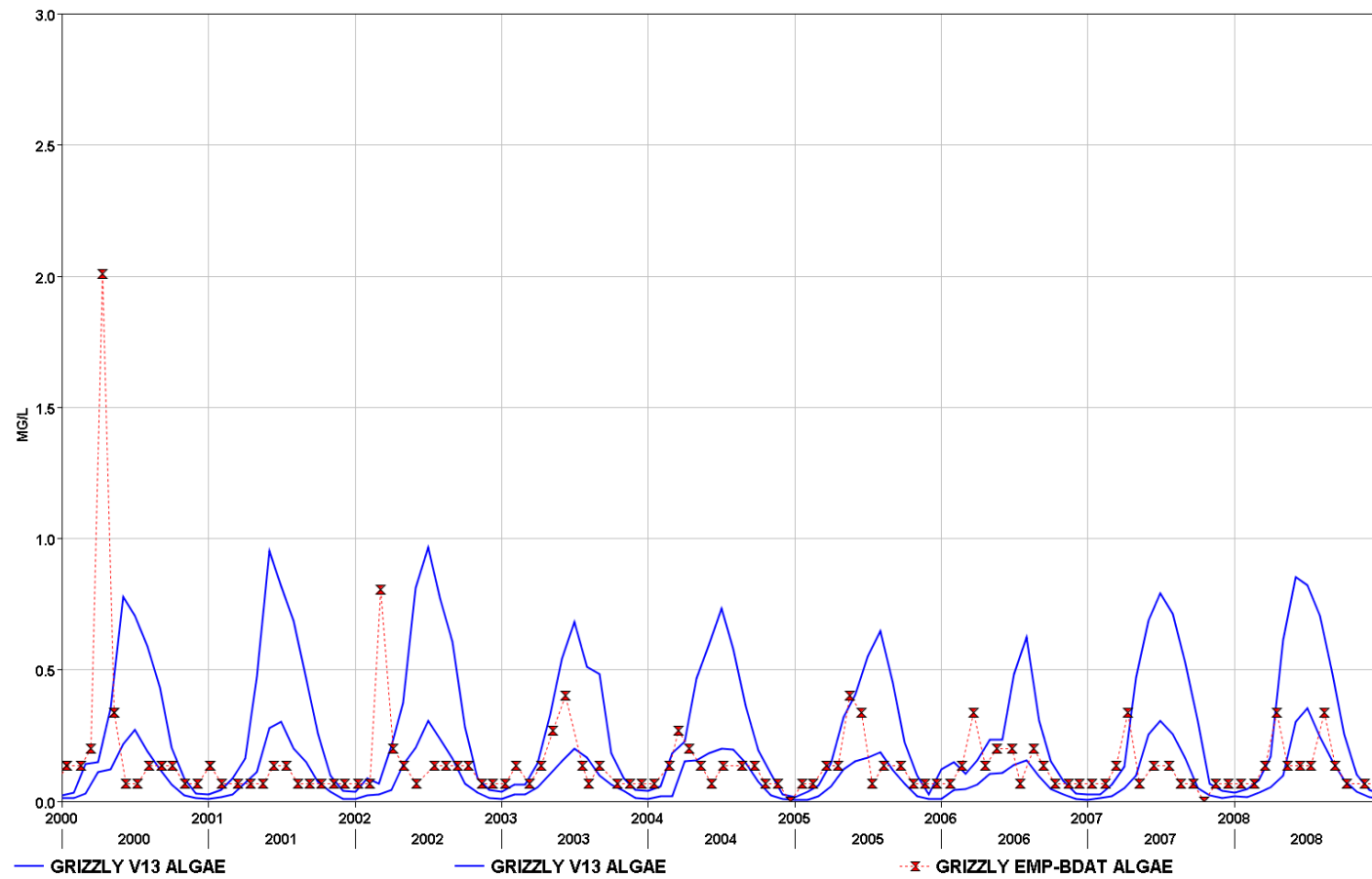


Figure A III. 75 Algae biomass at GRIZZLY later years.

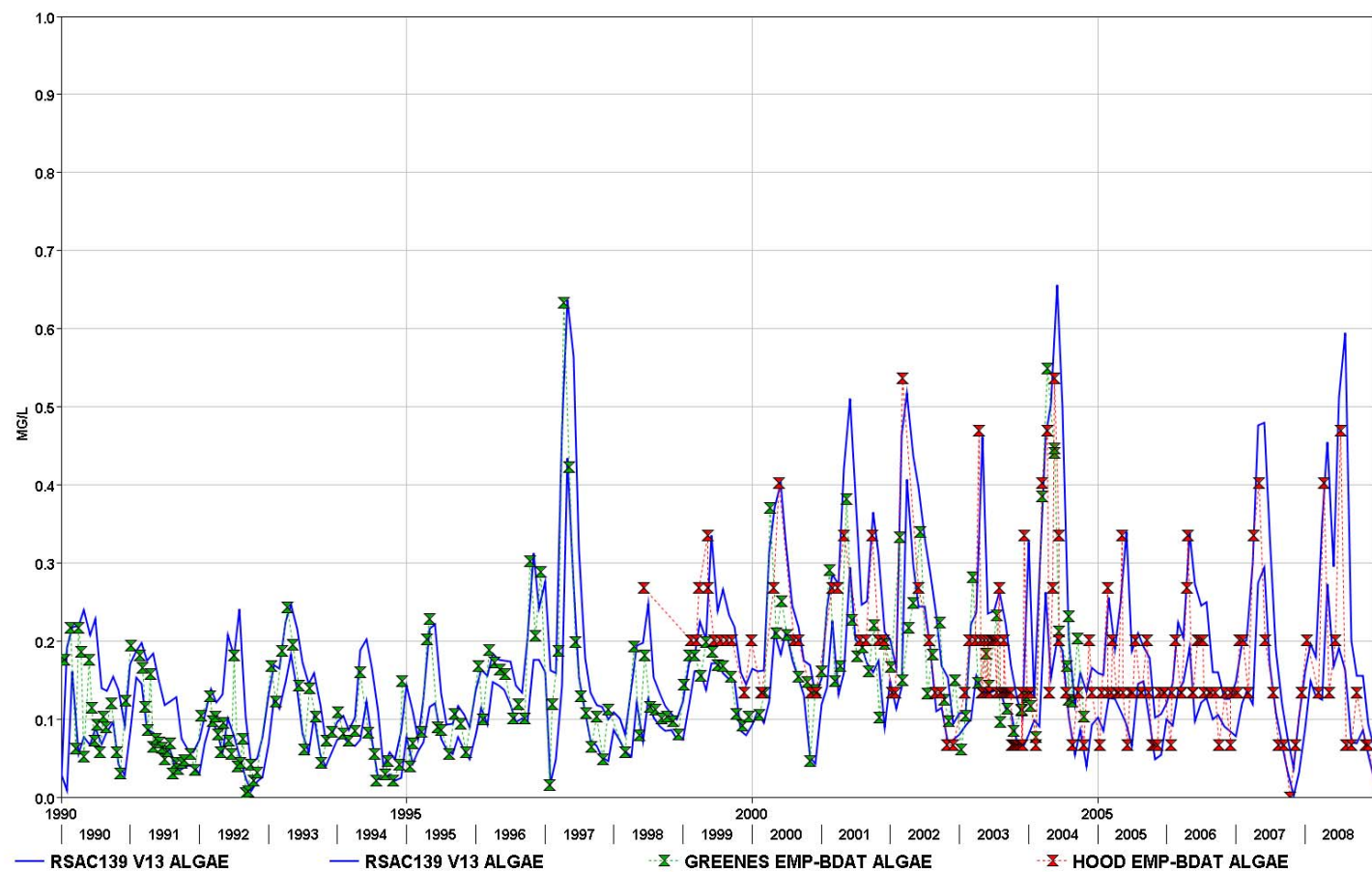


Figure A III. 76 Algae biomass at RSAC139 all years.

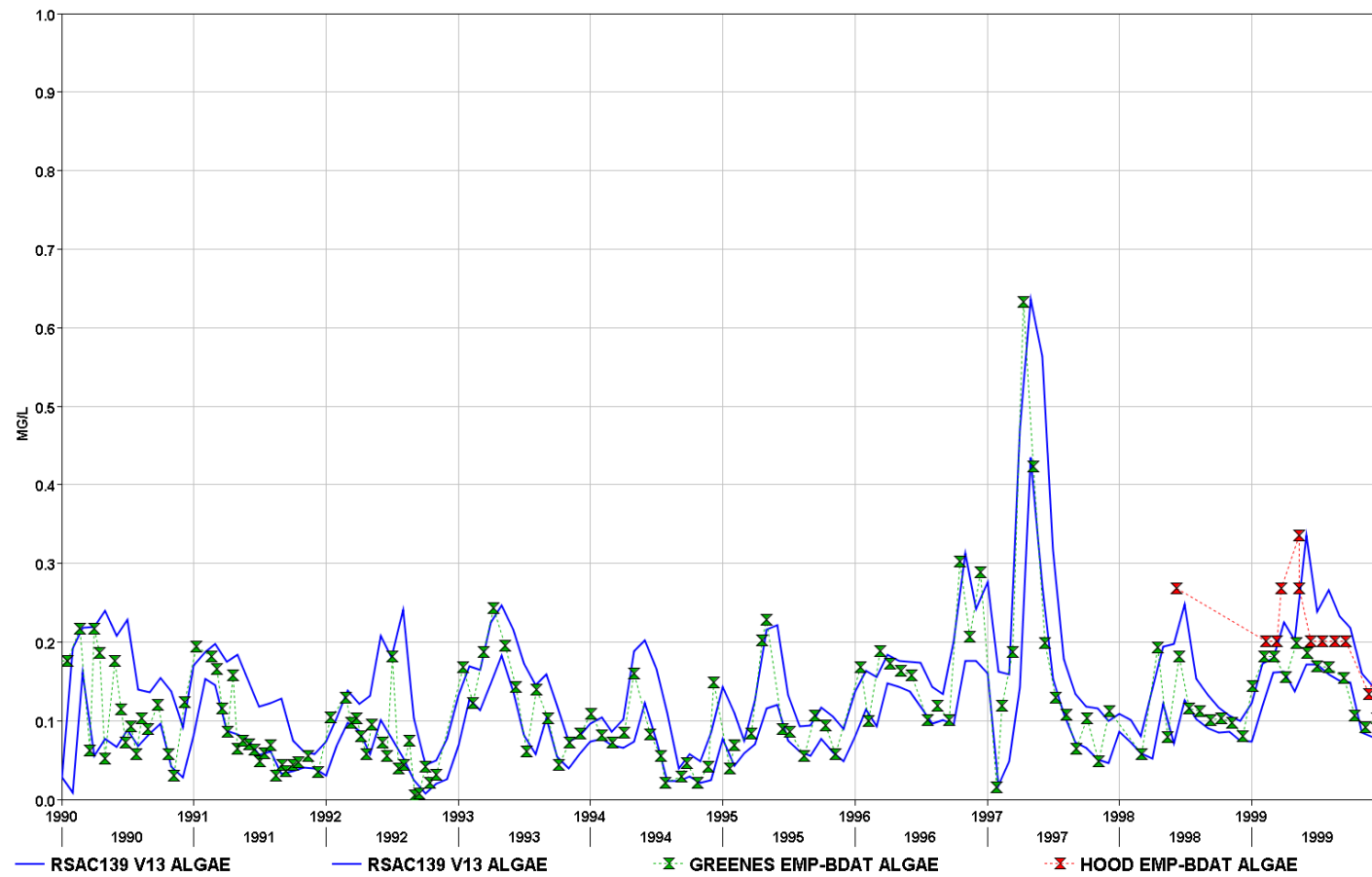


Figure A III. 77 Algae biomass at RSAC139 early years.

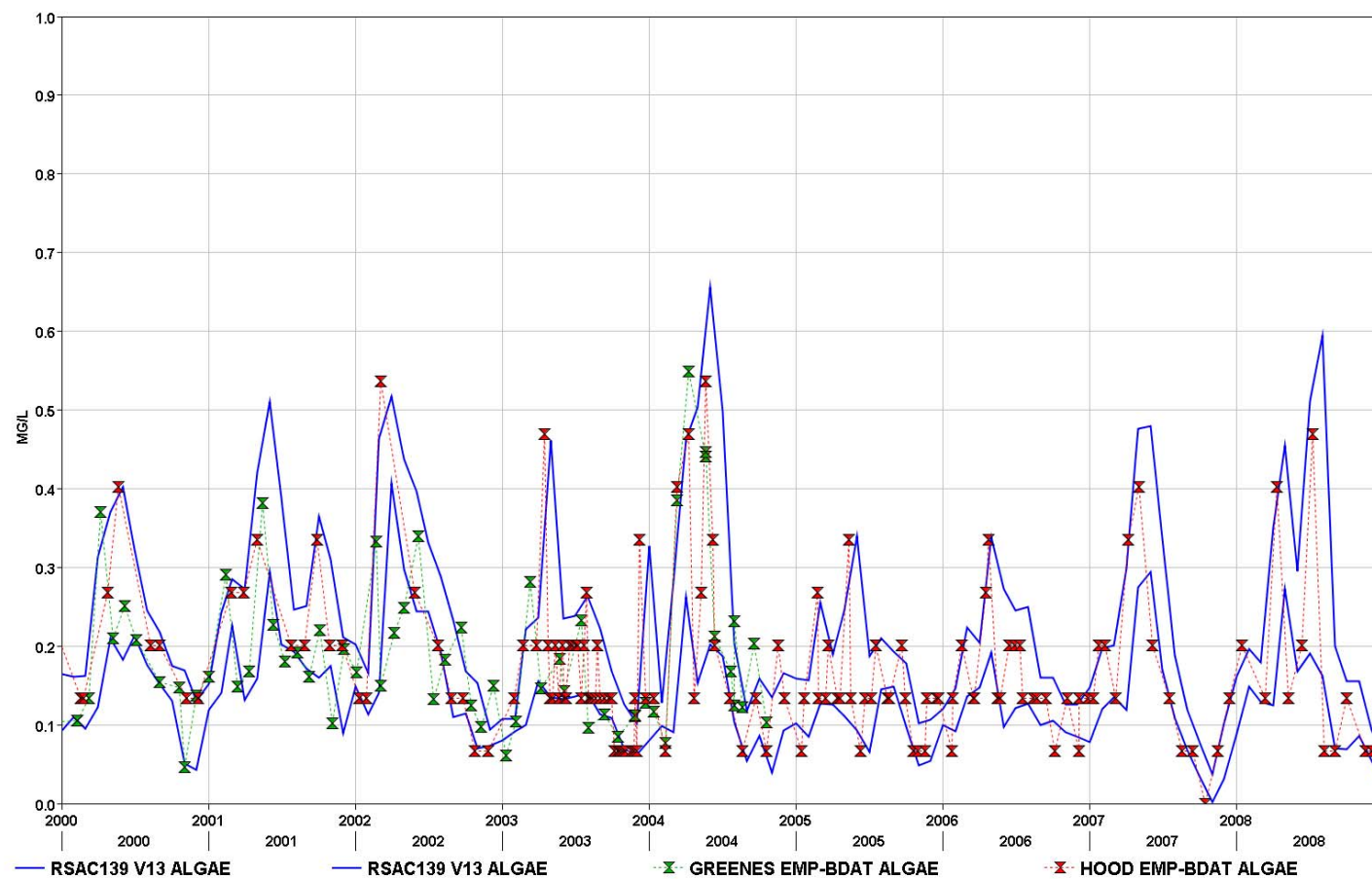


Figure A III. 78 Algae biomass at RSAC139 laterR years.

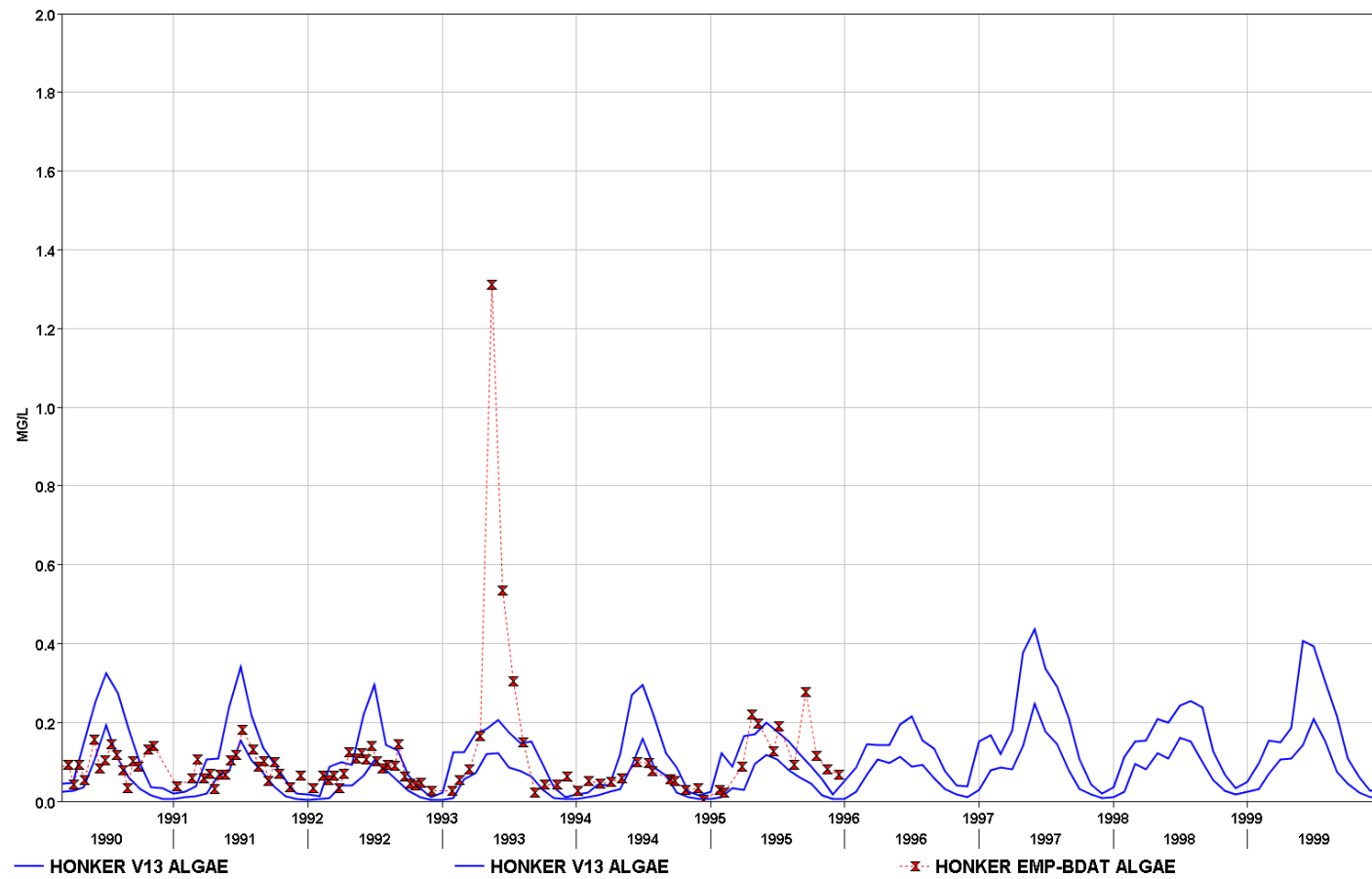


Figure A III. 79 Algae biomass at HONKER early years.

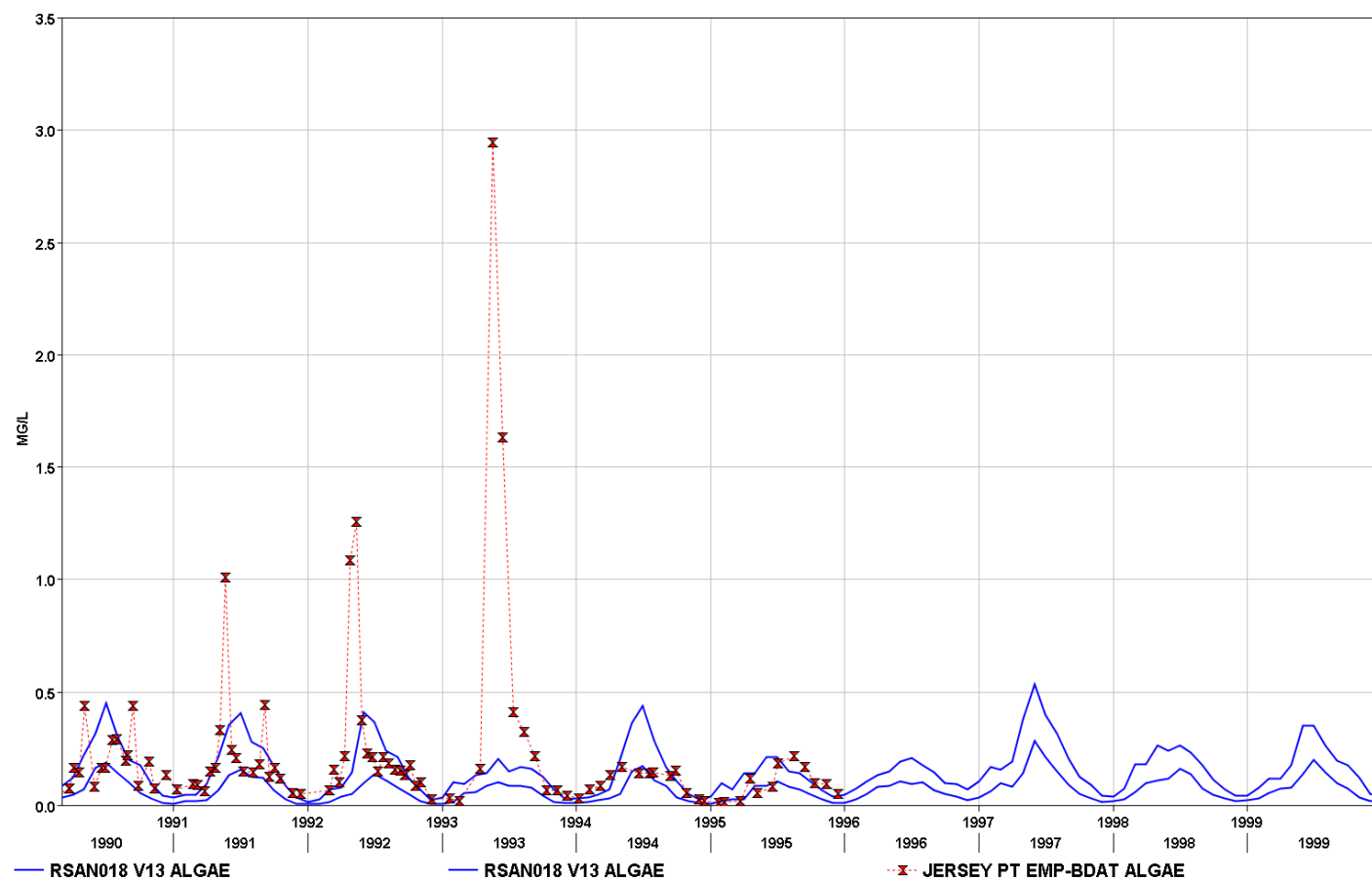


Figure A III. 80 Algae biomass at RSAN018 early years.

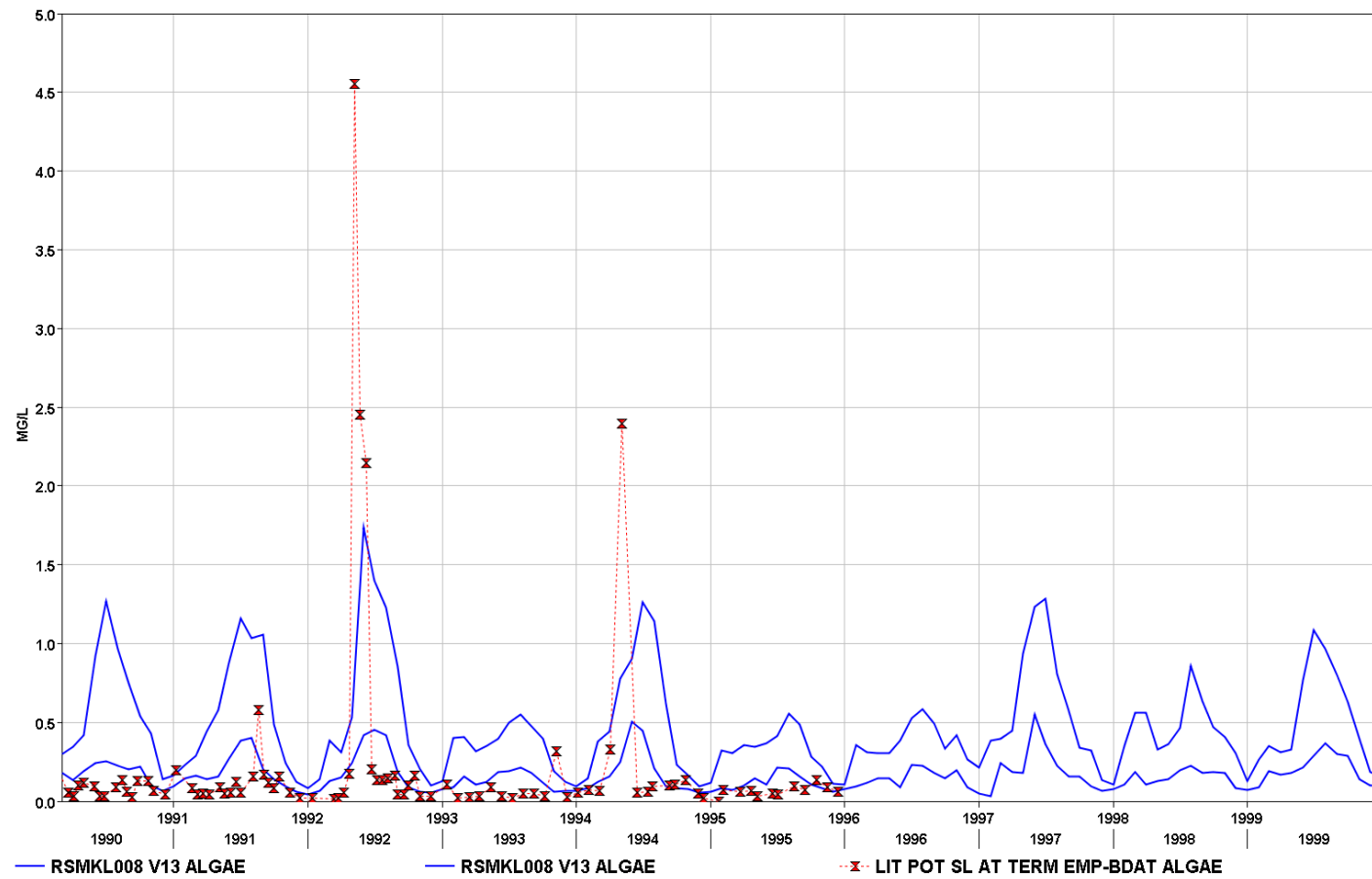


Figure A III. 81 Algae biomass at RSMKL008 early years.

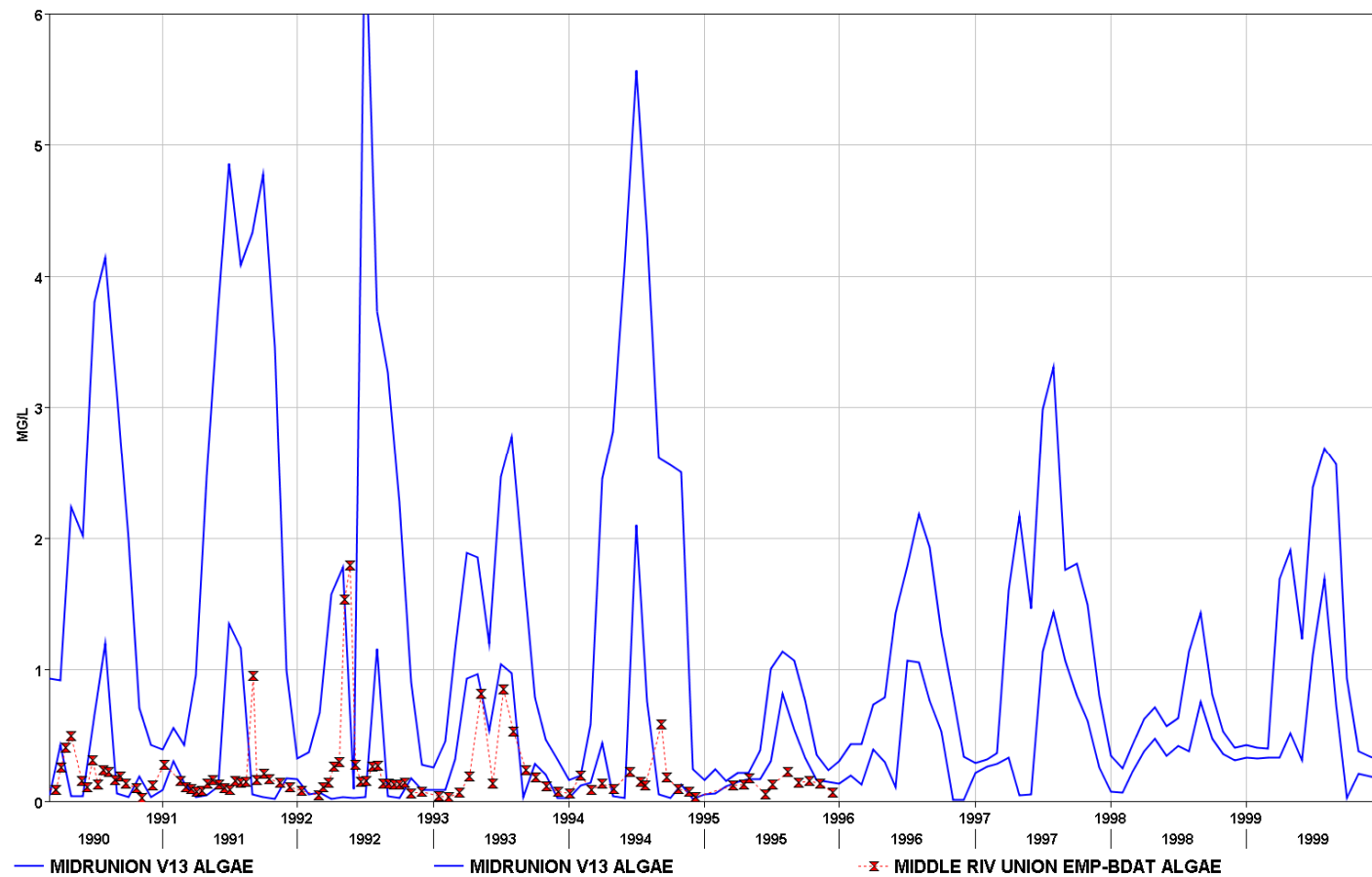


Figure A III. 82 Algae biomass at MID RIV UNION early years.

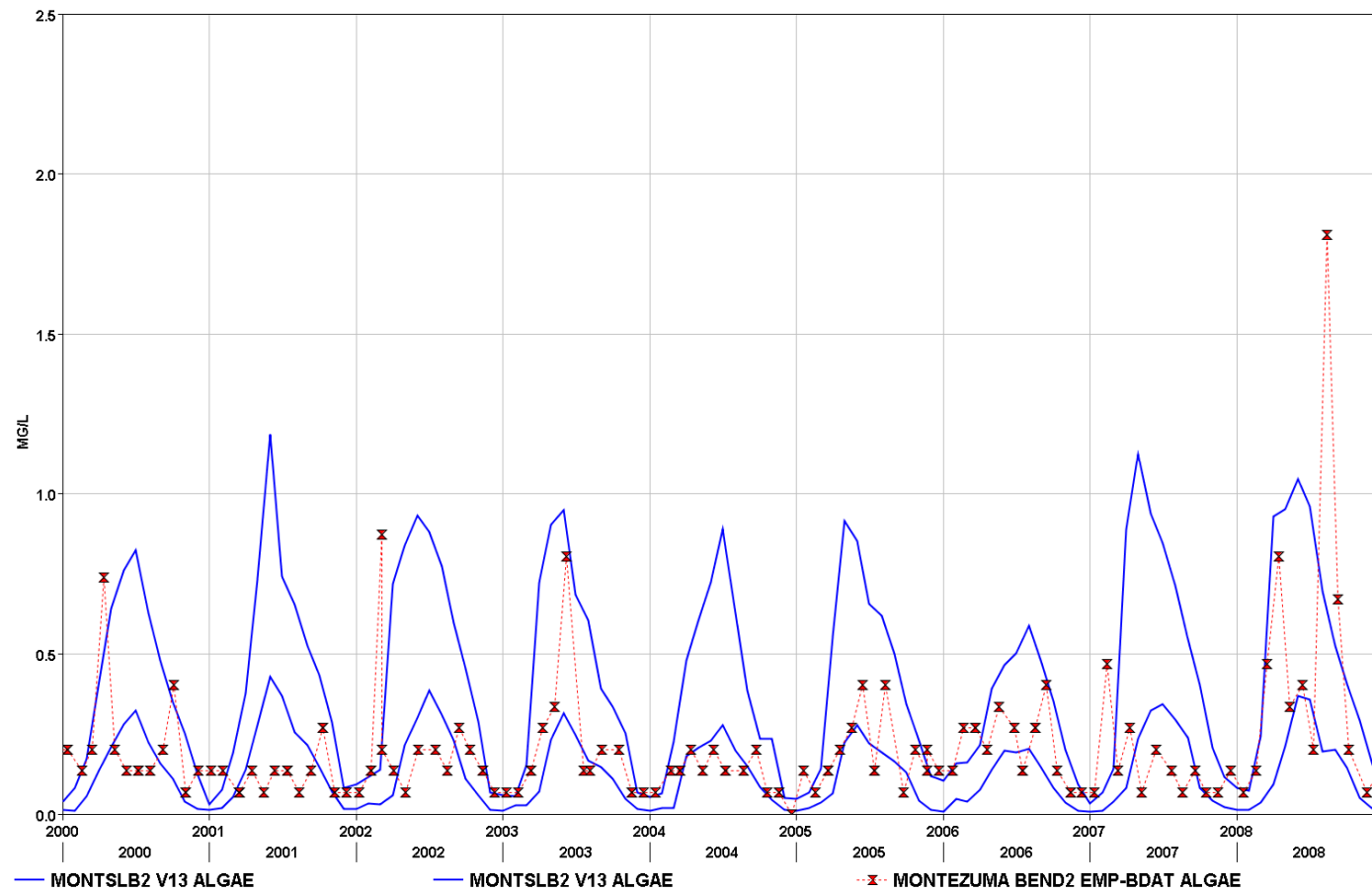


Figure A III. 83 Algae biomass at MONTEZUMA SL. BEND 2 laterR years.

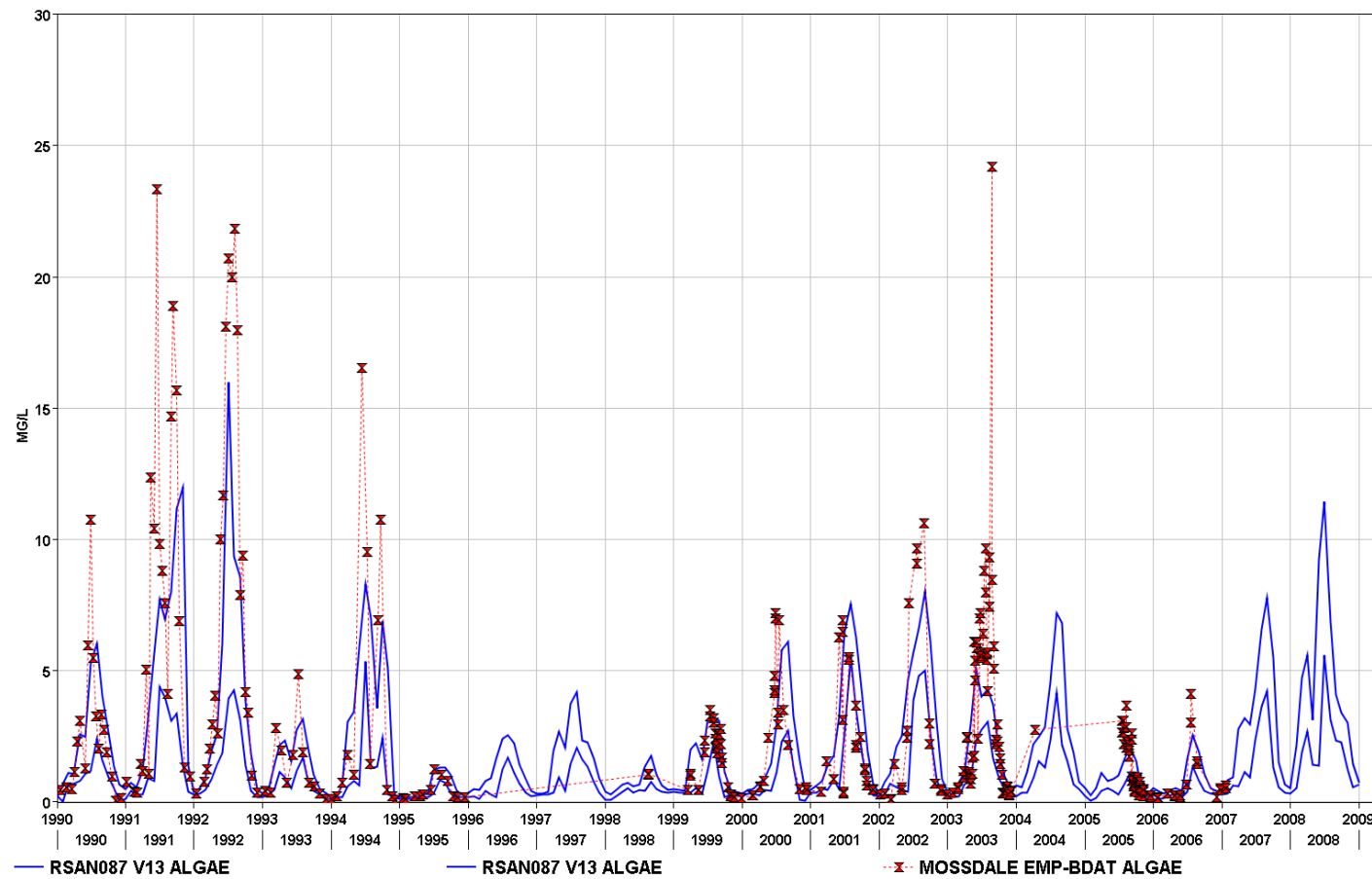


Figure A III. 84 Algae biomass at RSAN087all years.

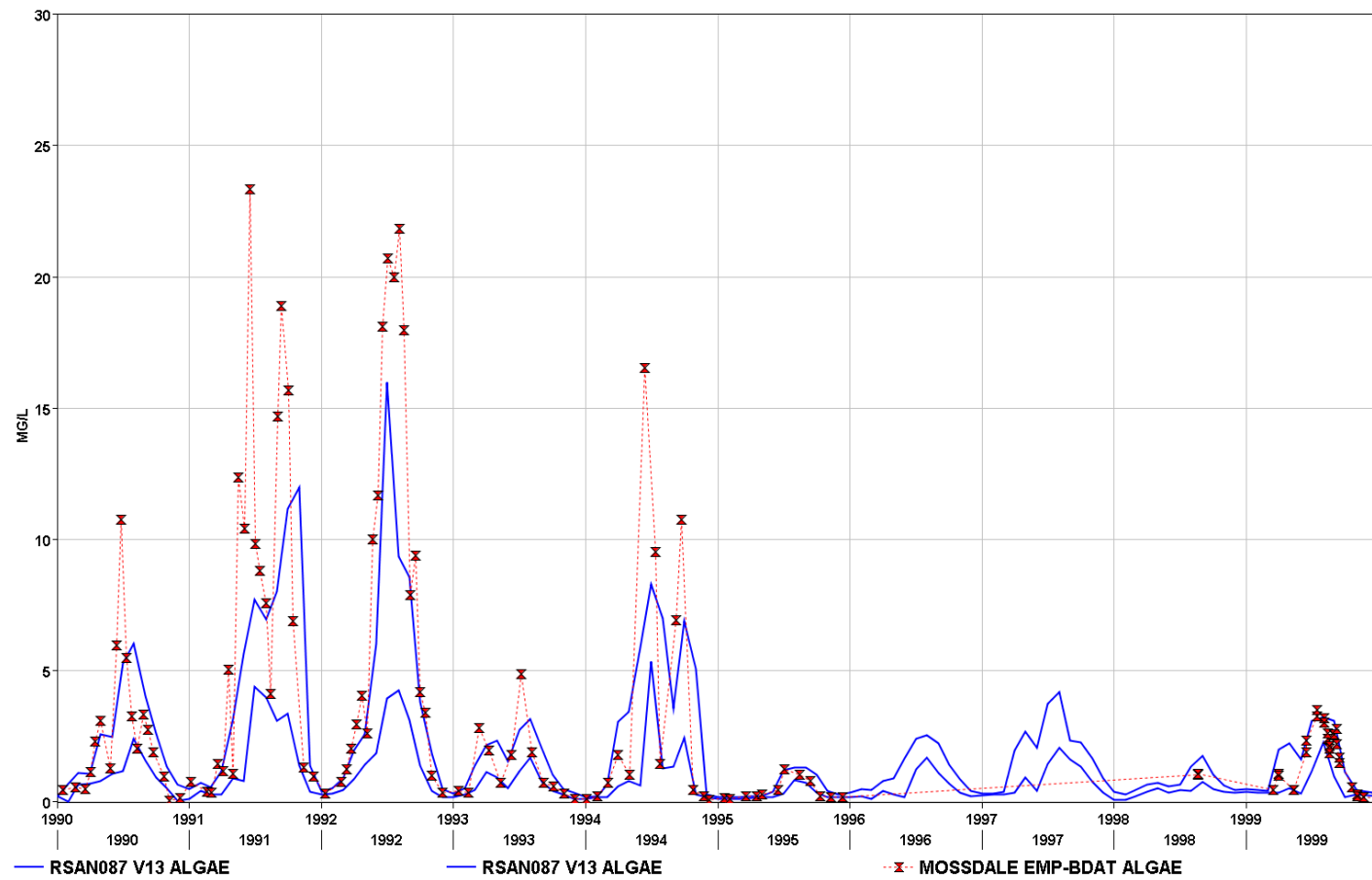


Figure A III. 85 Algae biomass at RSN087 early years.

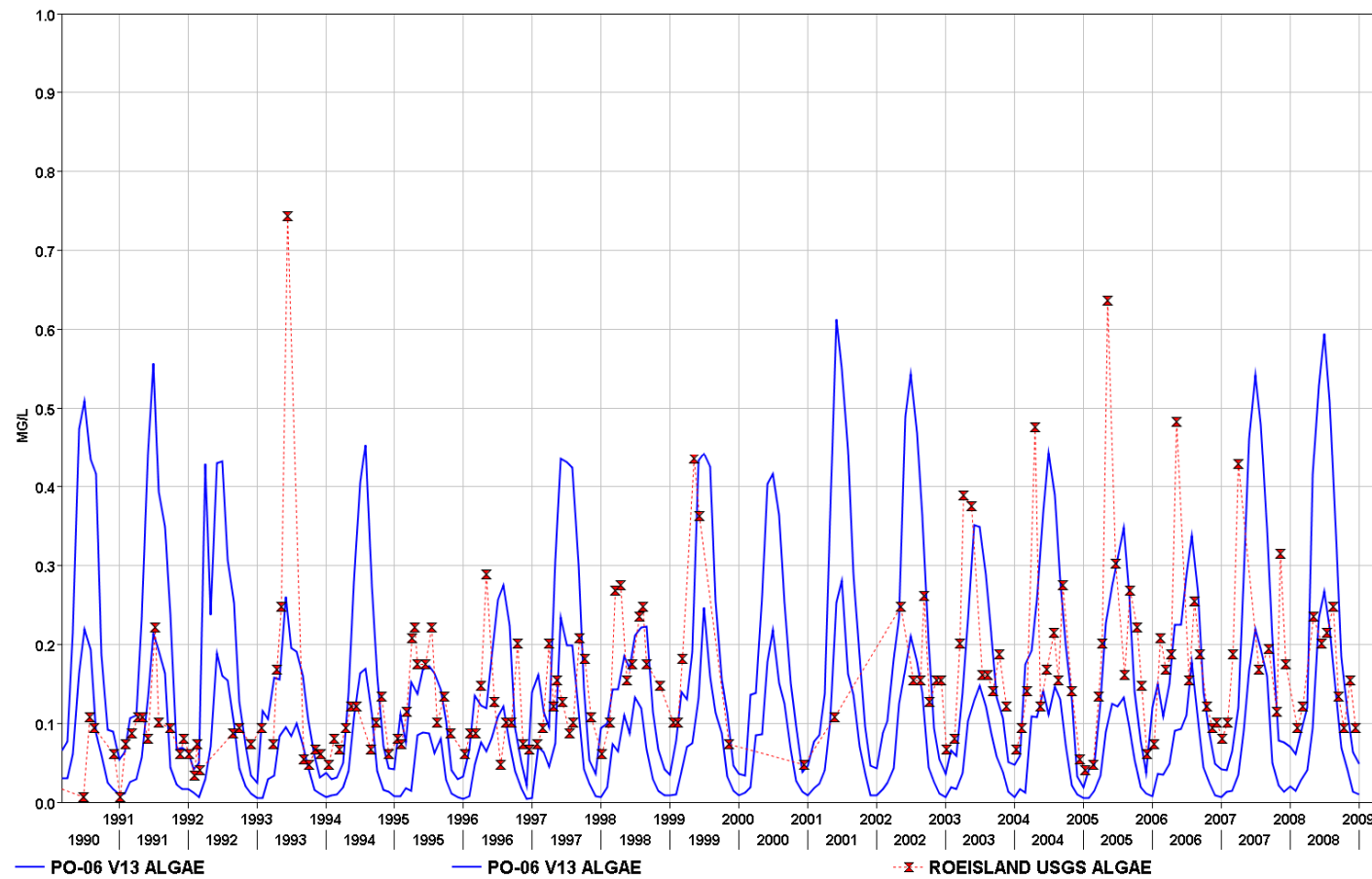


Figure A III. 86 Algae biomass at PO-06 all years.

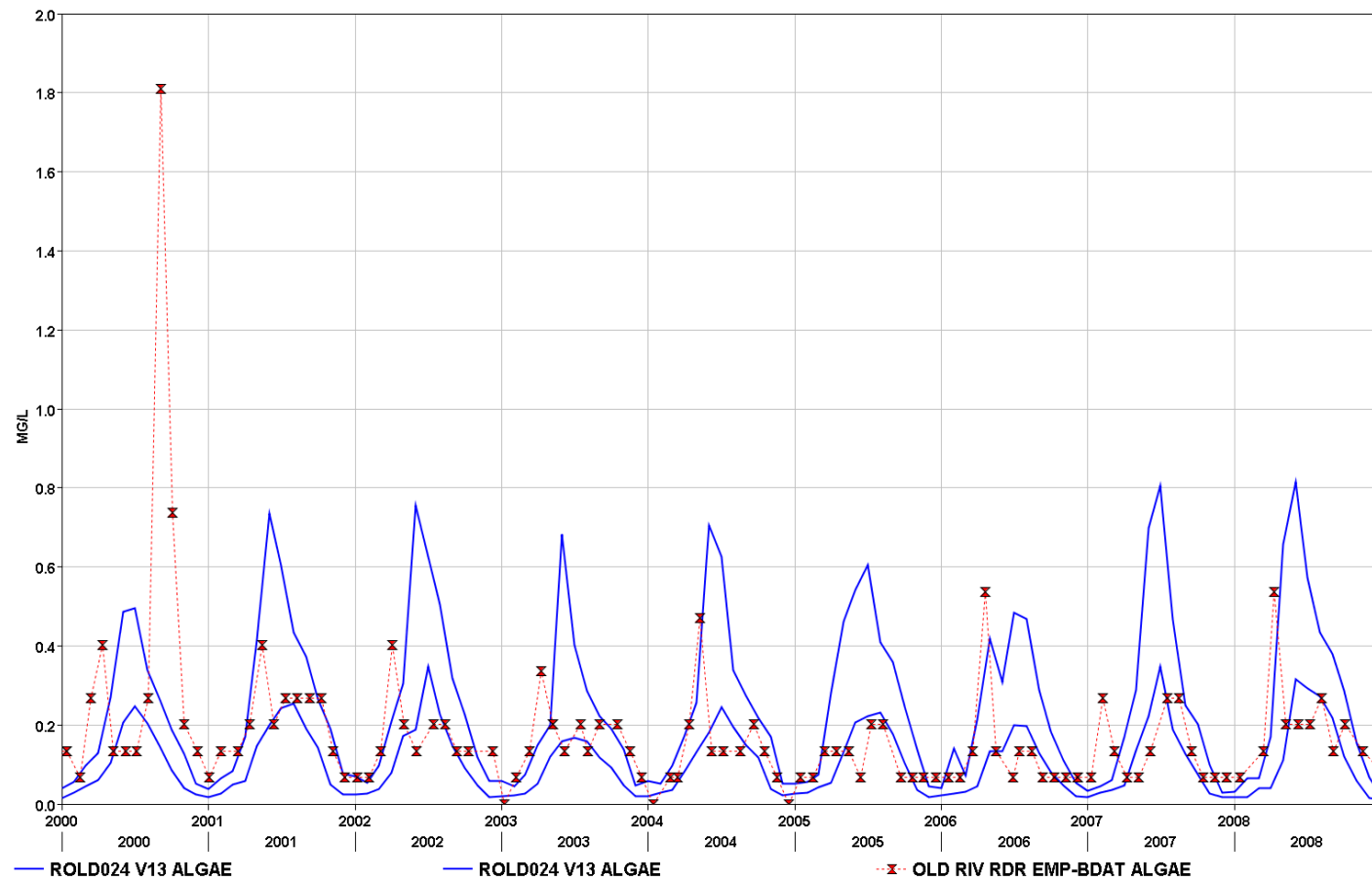


Figure A III. 87 Algae biomass at ROLD024 laterR years.

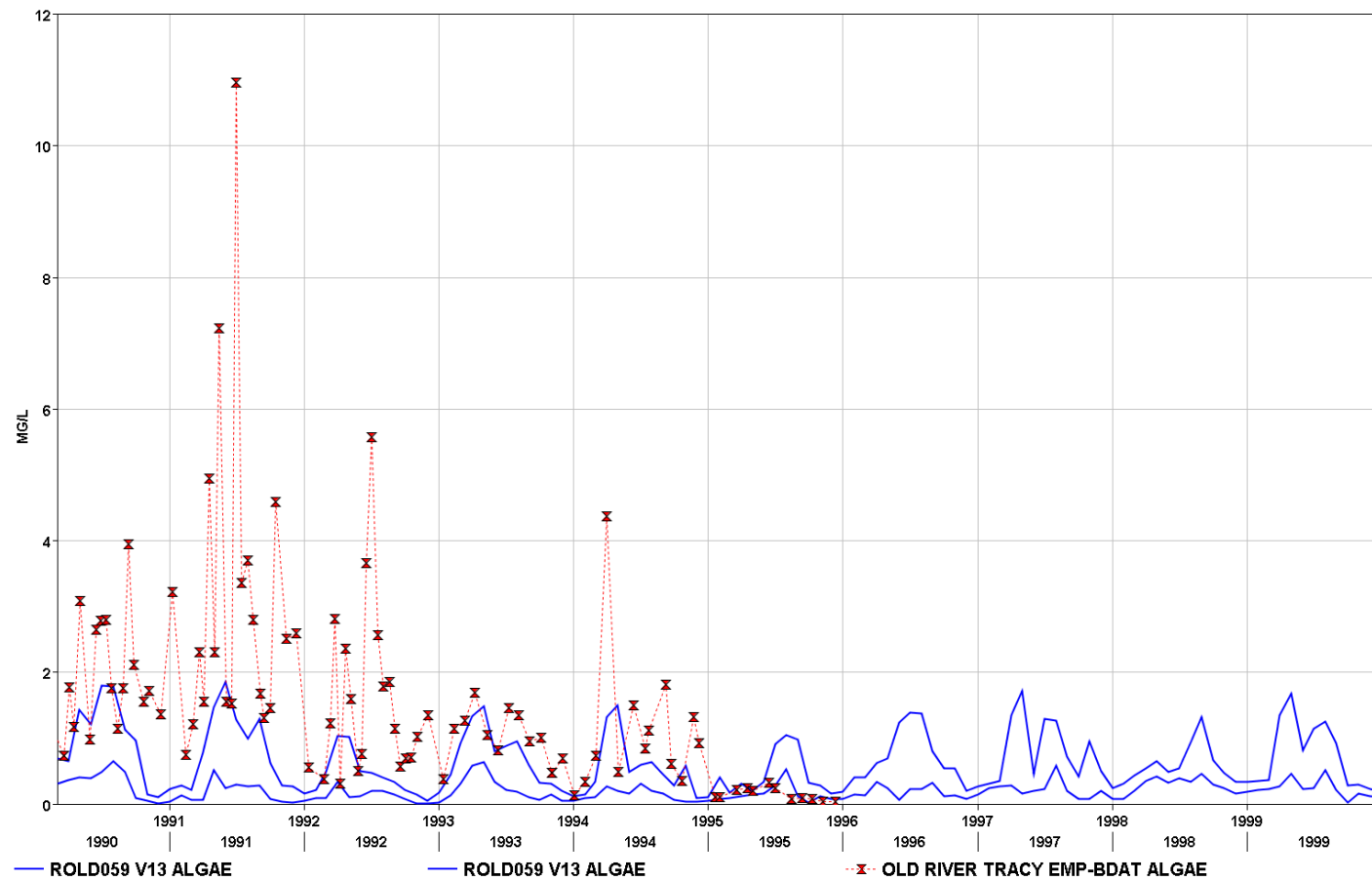


Figure A III. 88 Algae biomass at ROLD059 early years.

APPENDIX IV.

This document contains calibration model output in comparison with PO₄ and organic-N measurements.

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A. Organic-N

Figures were produced at all locations where there was sufficient data to plot more than a couple years. Where data was available for (nearly) the full model term, here plots were produced the full time span and the spans 1990 – 1999 and 2000 – 2009. Model plots sometimes begin in May or June 1990, as at some locations the initial condition values were somewhat too high or too low and model required spin-up at those locations for the first few months. The figures are organized by constituent.

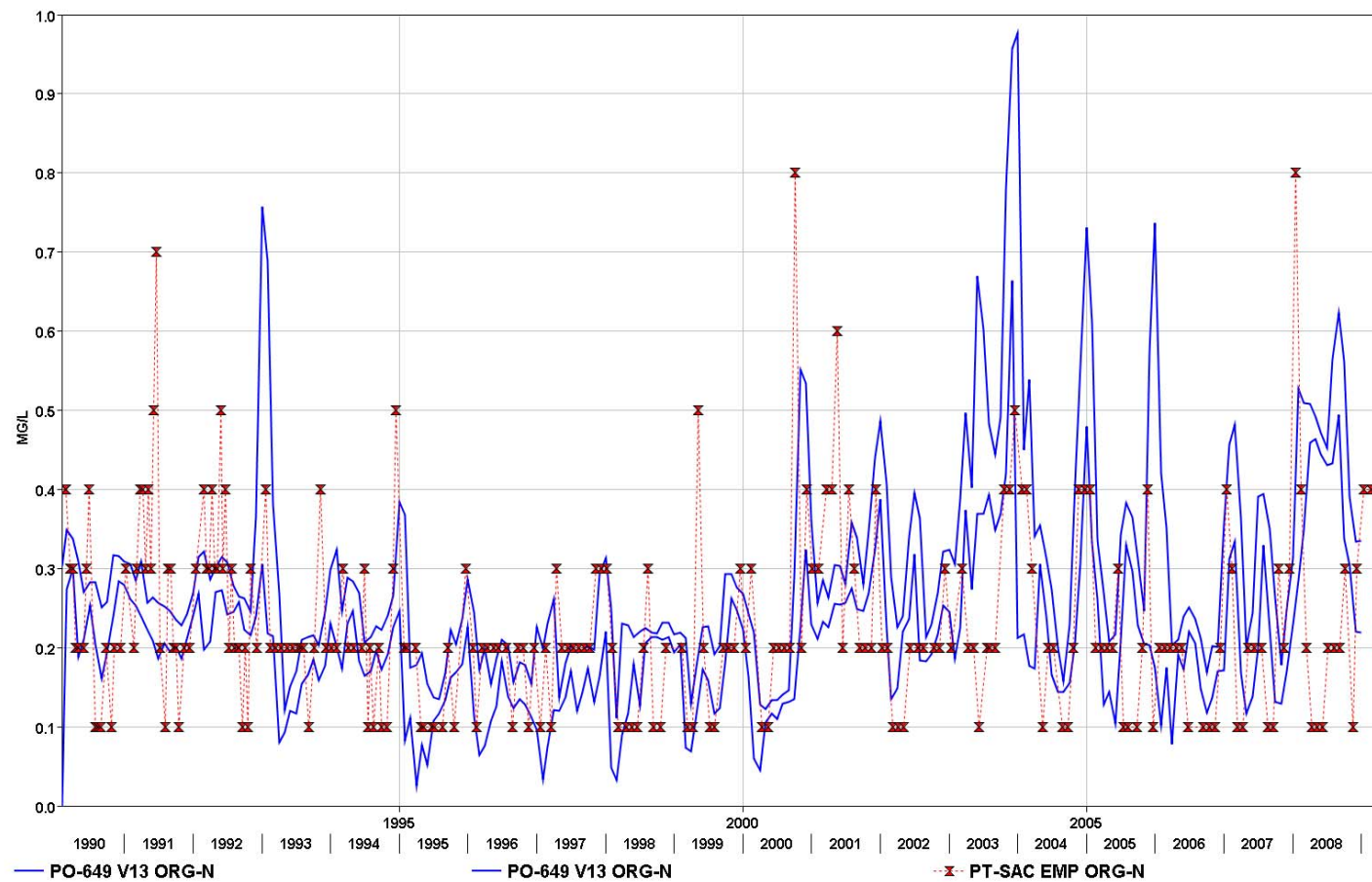


Figure A IV. 1 Organic-N at Pt Sacramento all years.

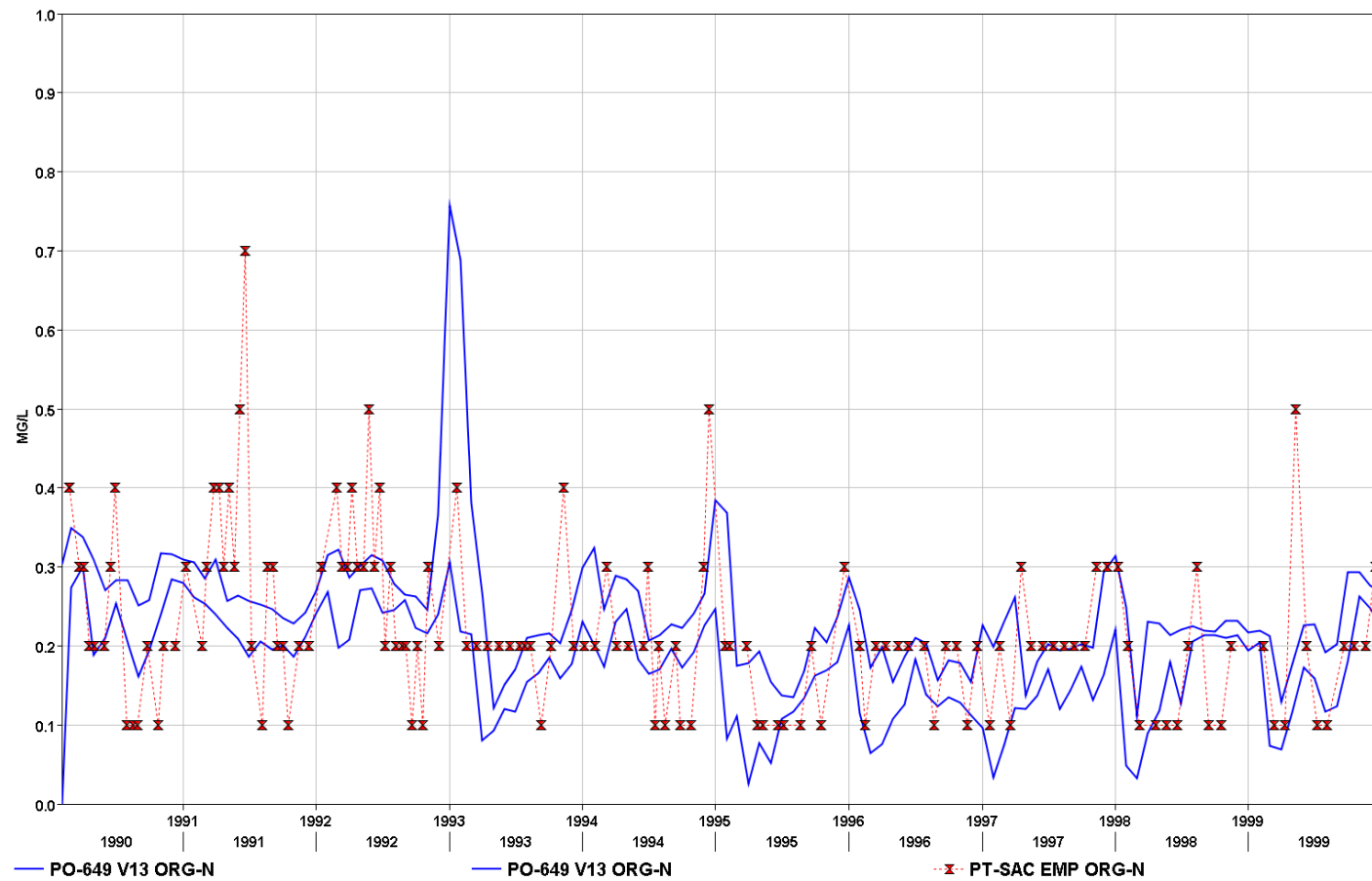


Figure A IV. 2 Organic-N at Pt Sacramento early years.

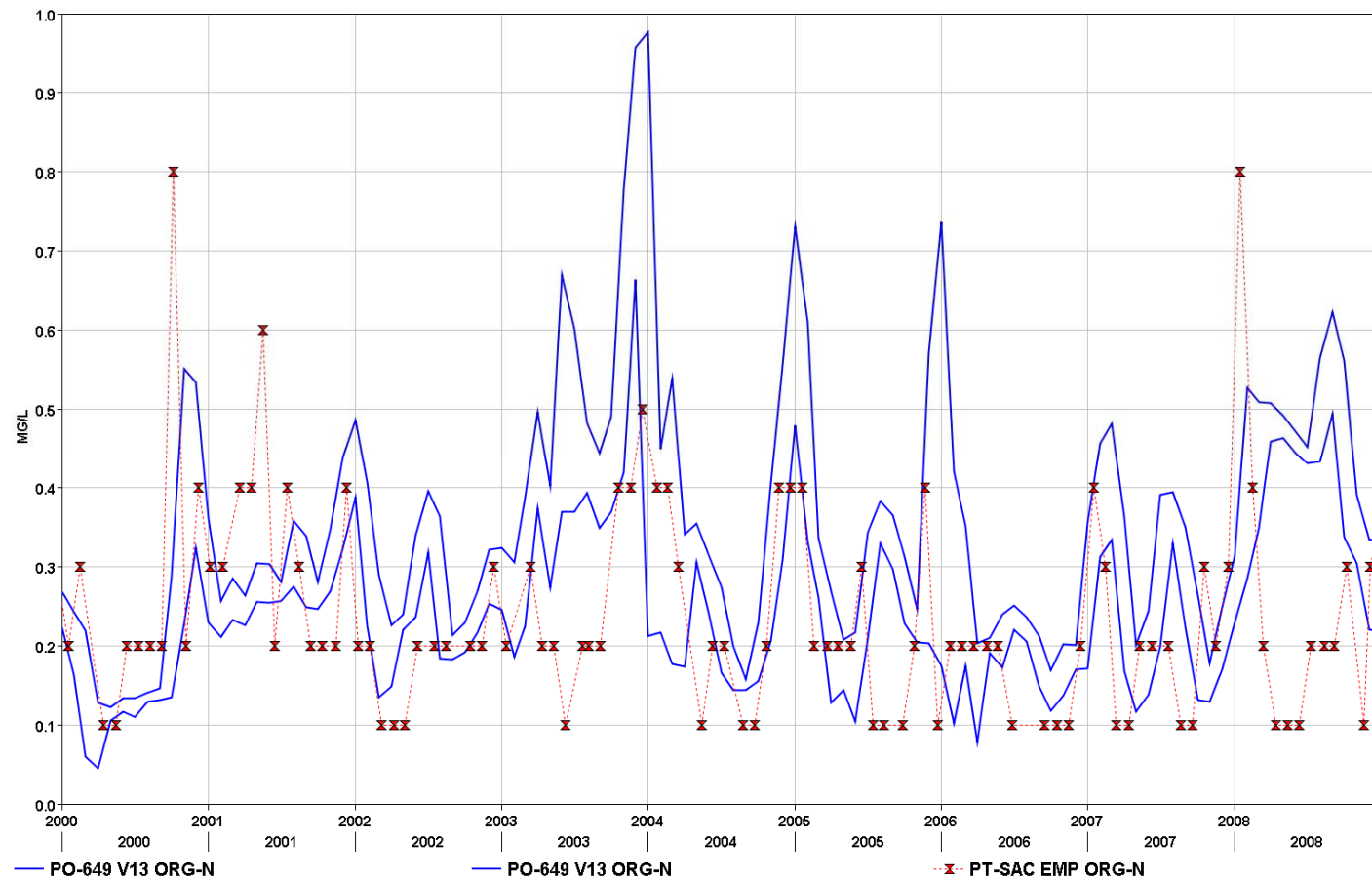


Figure A IV. 3 Organic-N at Pt Sacramento late years.

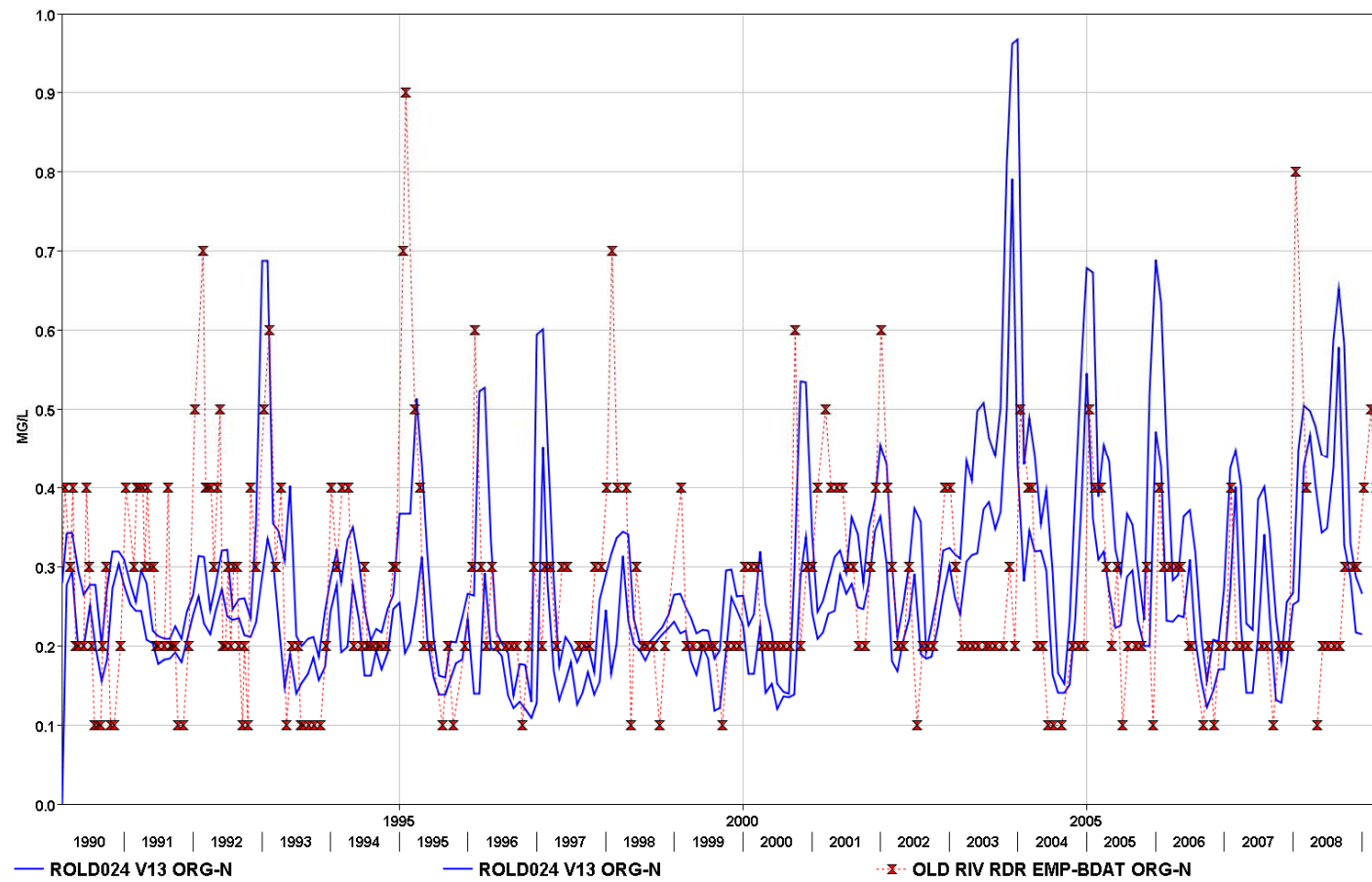


Figure A IV. 4 Organic-N at ROL024 all years.

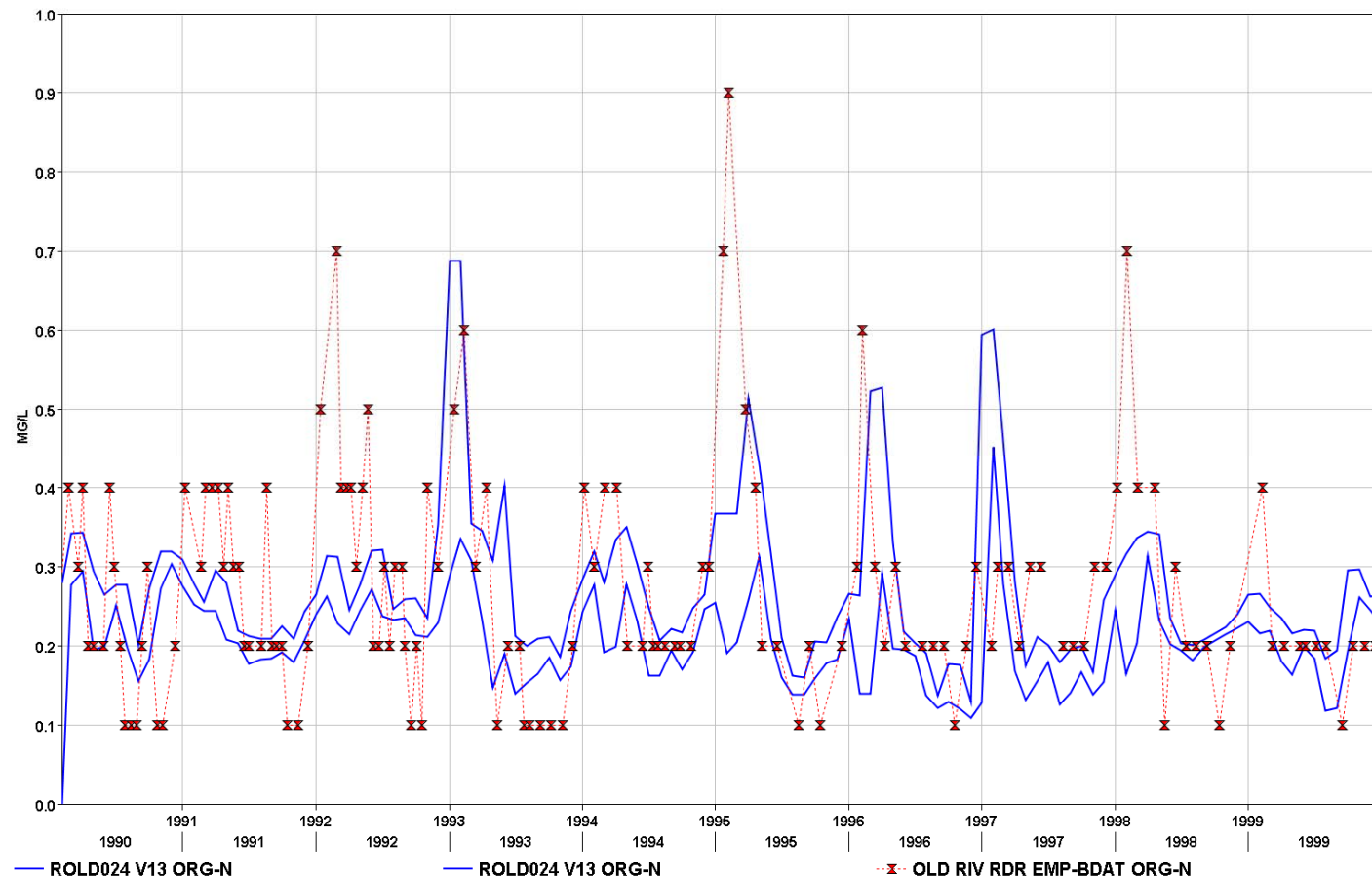


Figure A IV. 5 Organic-N at ROLD024 early years.

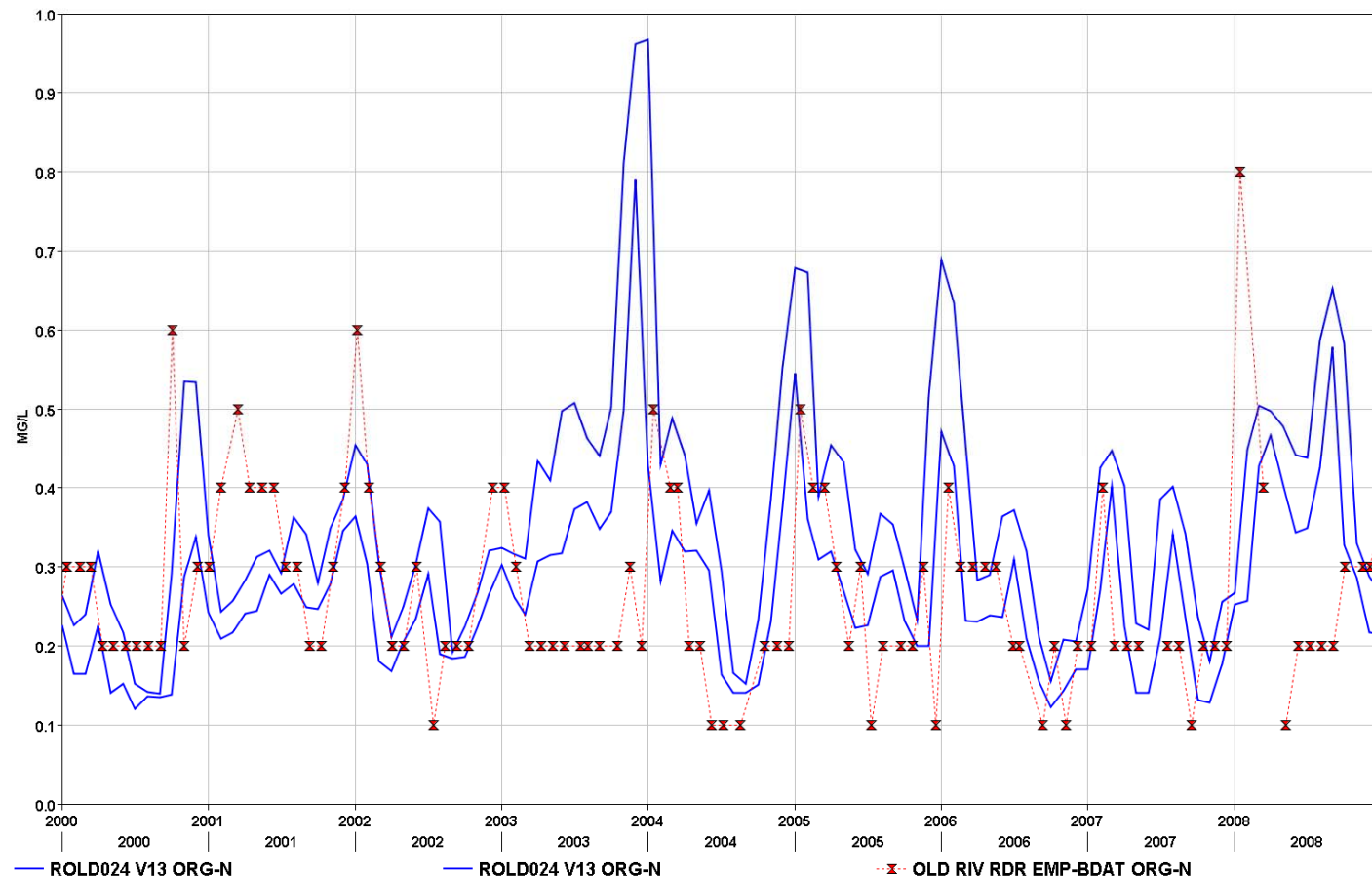


Figure A IV. 6 Organic-N at ROLD024 late years.

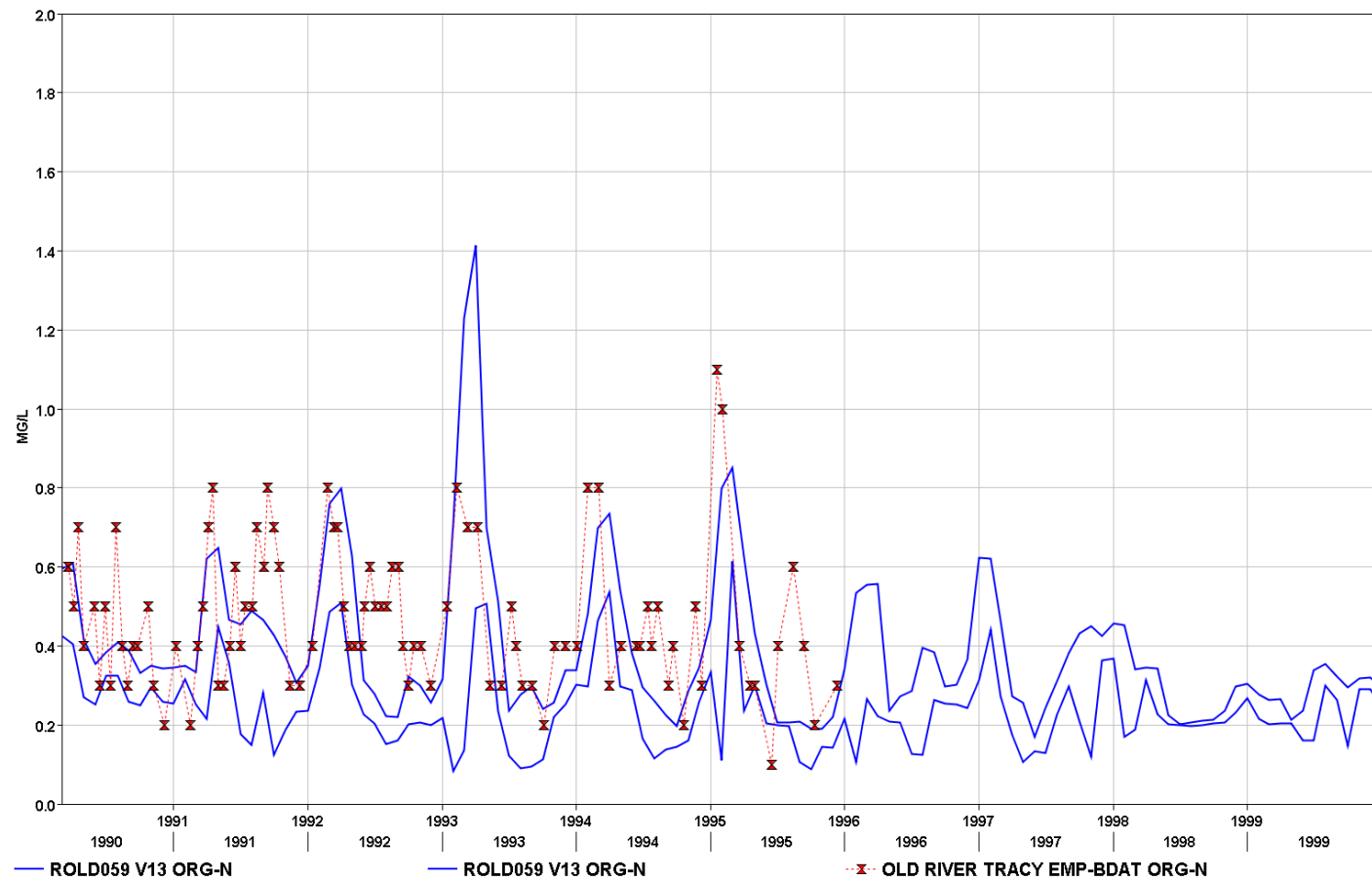


Figure A IV. 7 Organic-N at ROLD059 early years.

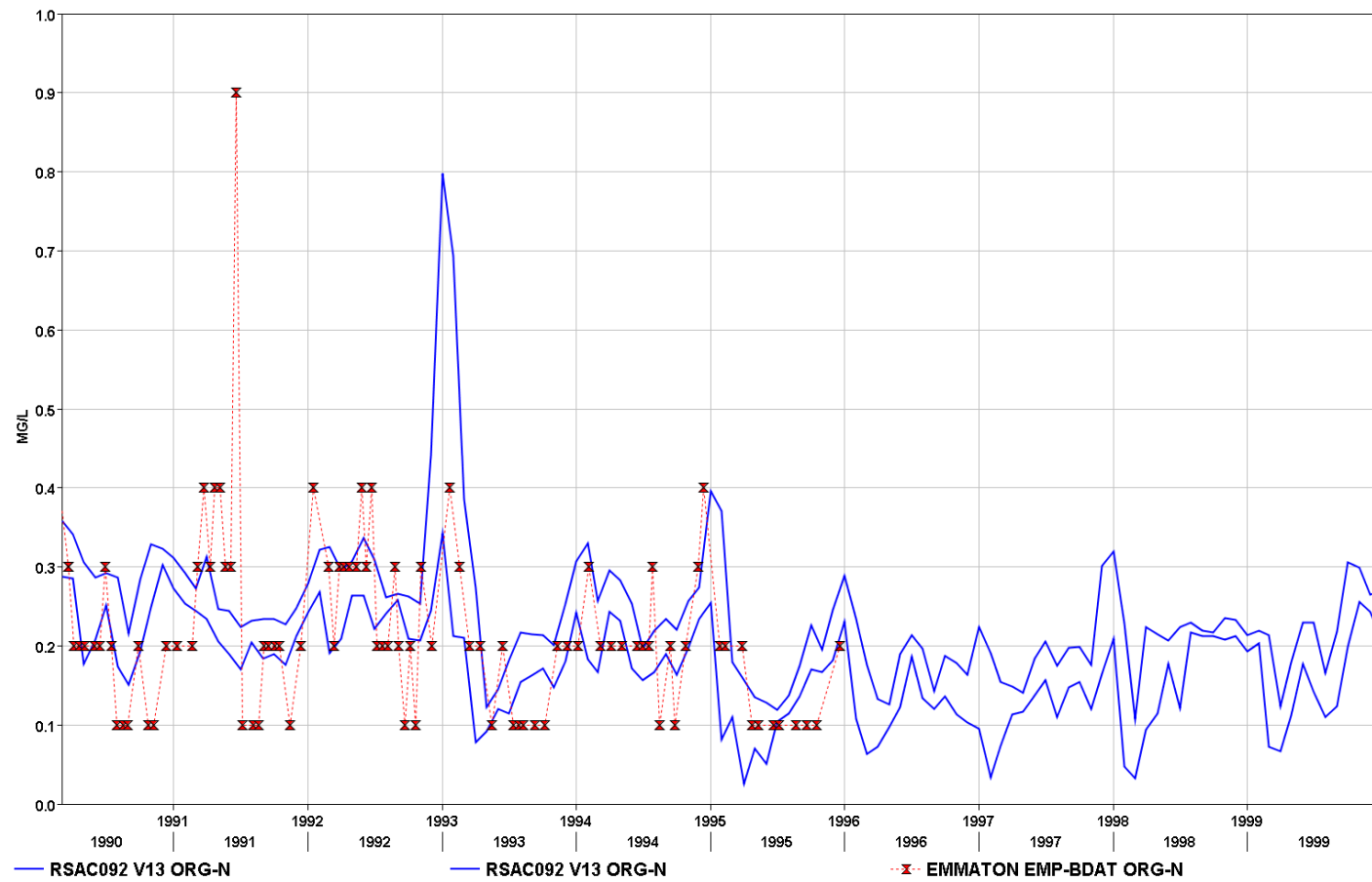


Figure A IV. 8 Organic-N at RSAC092 early years.

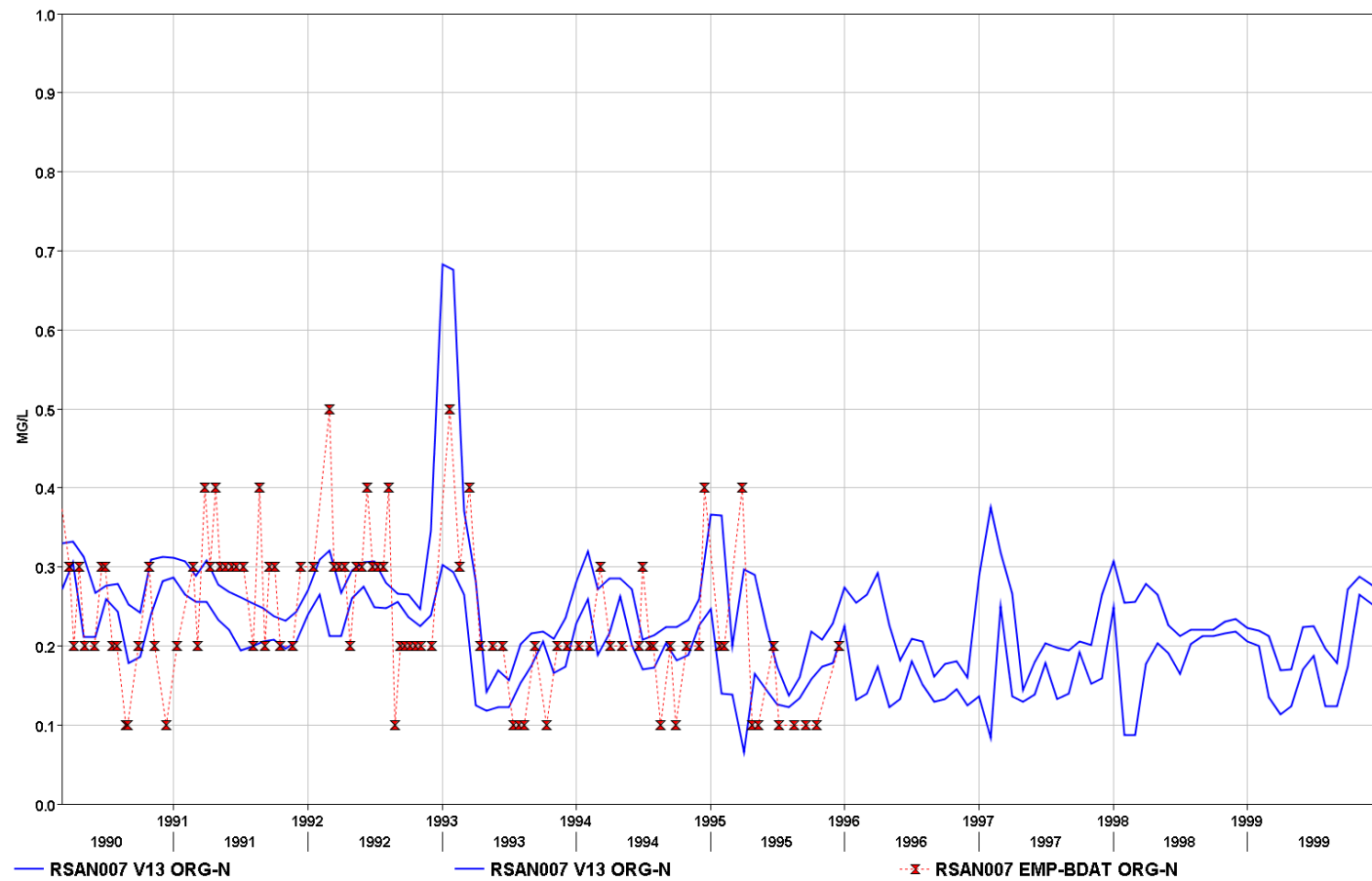


Figure A IV. 9 Organic-N at RSAN007 early years.

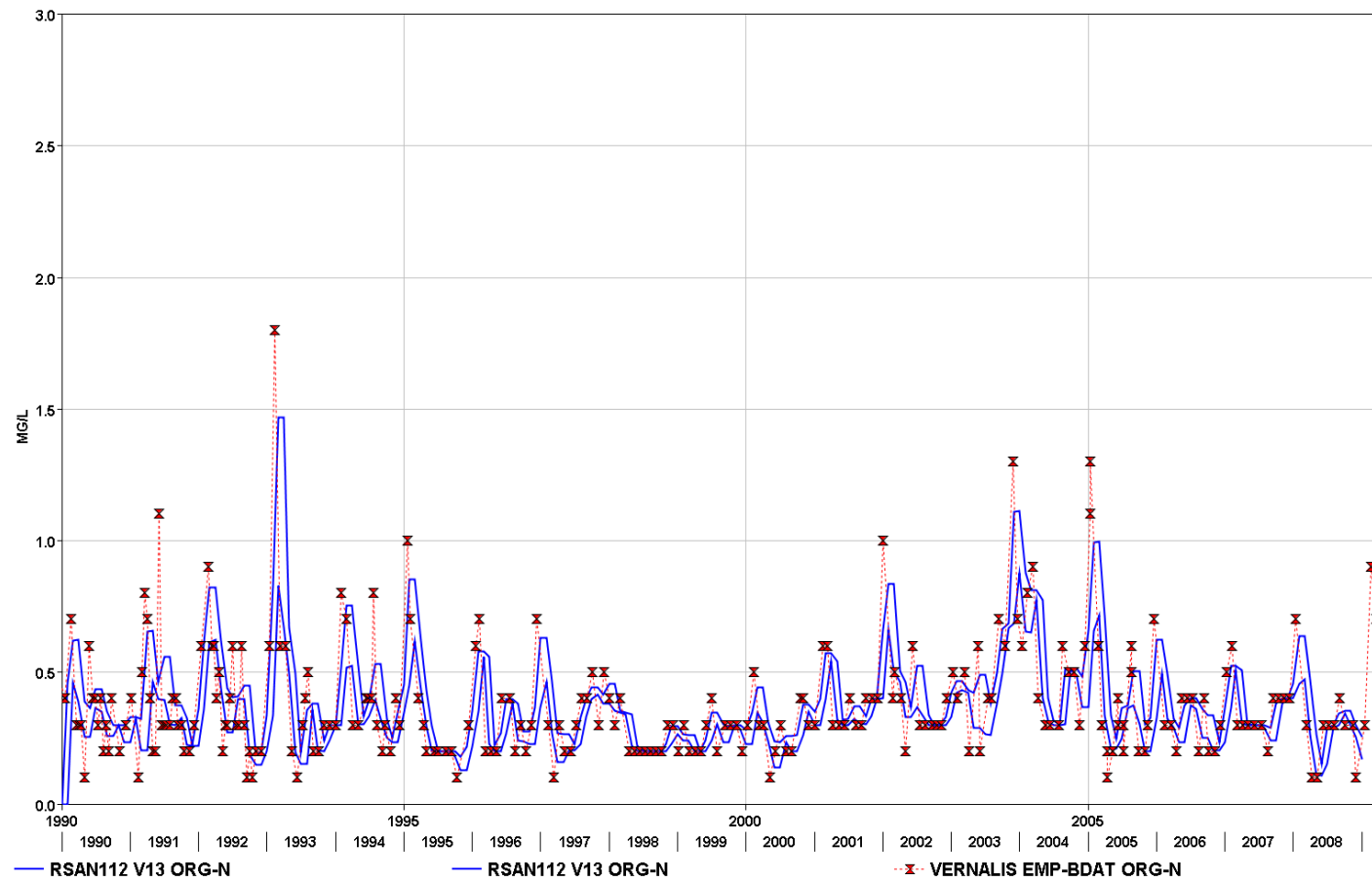


Figure A IV. 10 Organic-N at RSAN112 all years.

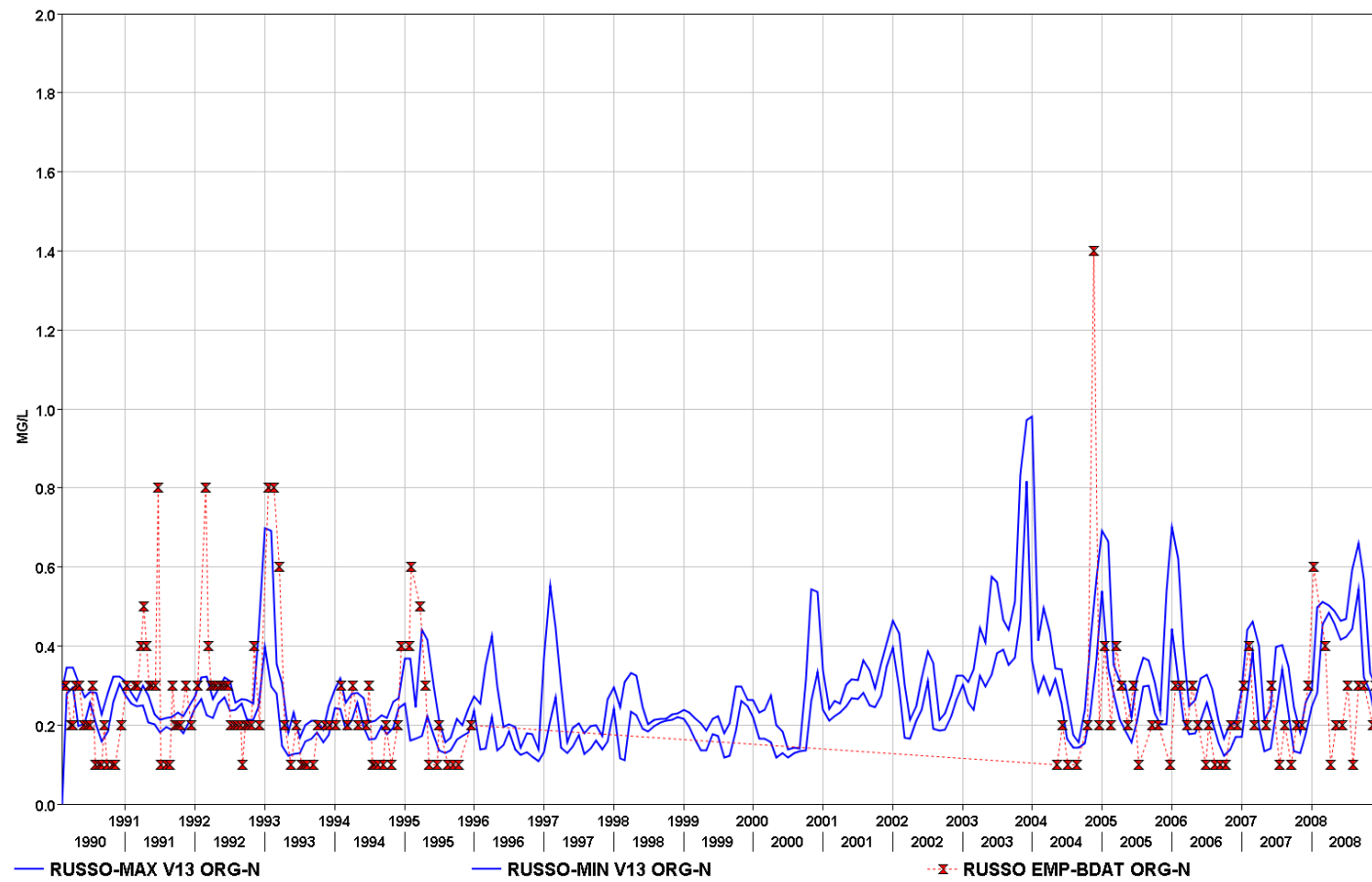


Figure A IV. 11 Organic-N at RUSSO all years.

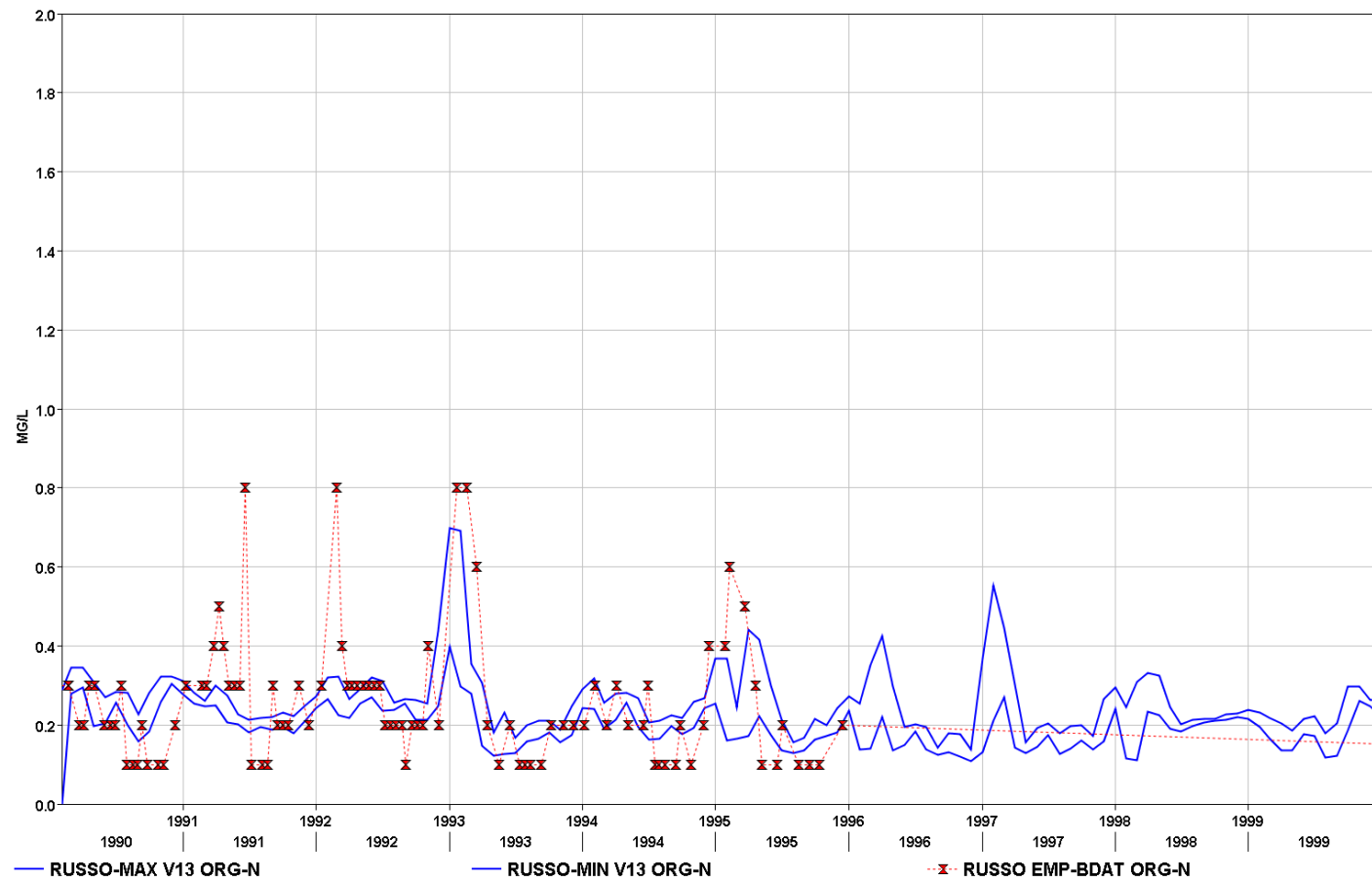


Figure A IV. 12 Organic-N at RUSSO early years.

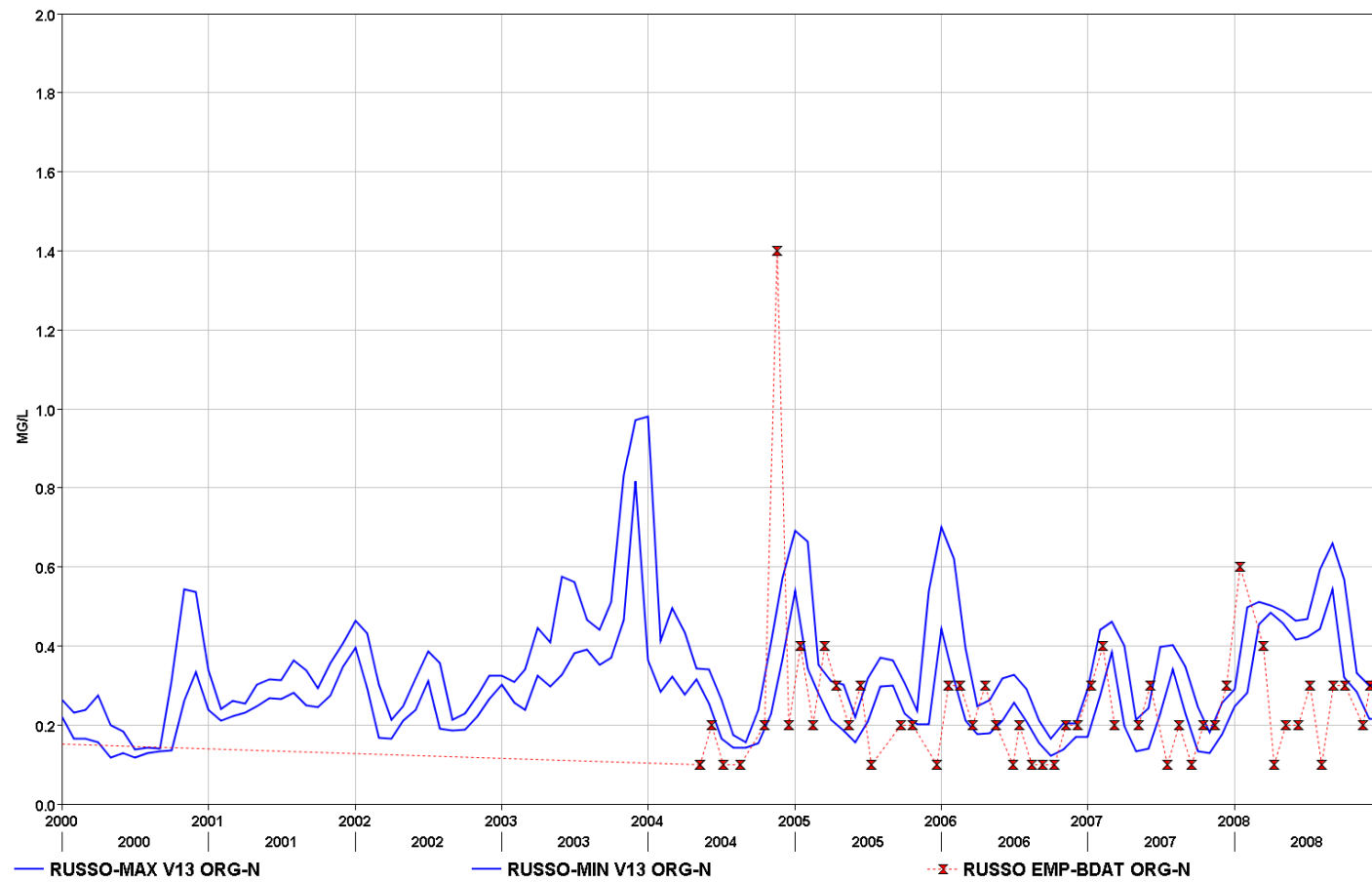


Figure A IV. 13 Organic-N at RUSSO later years.

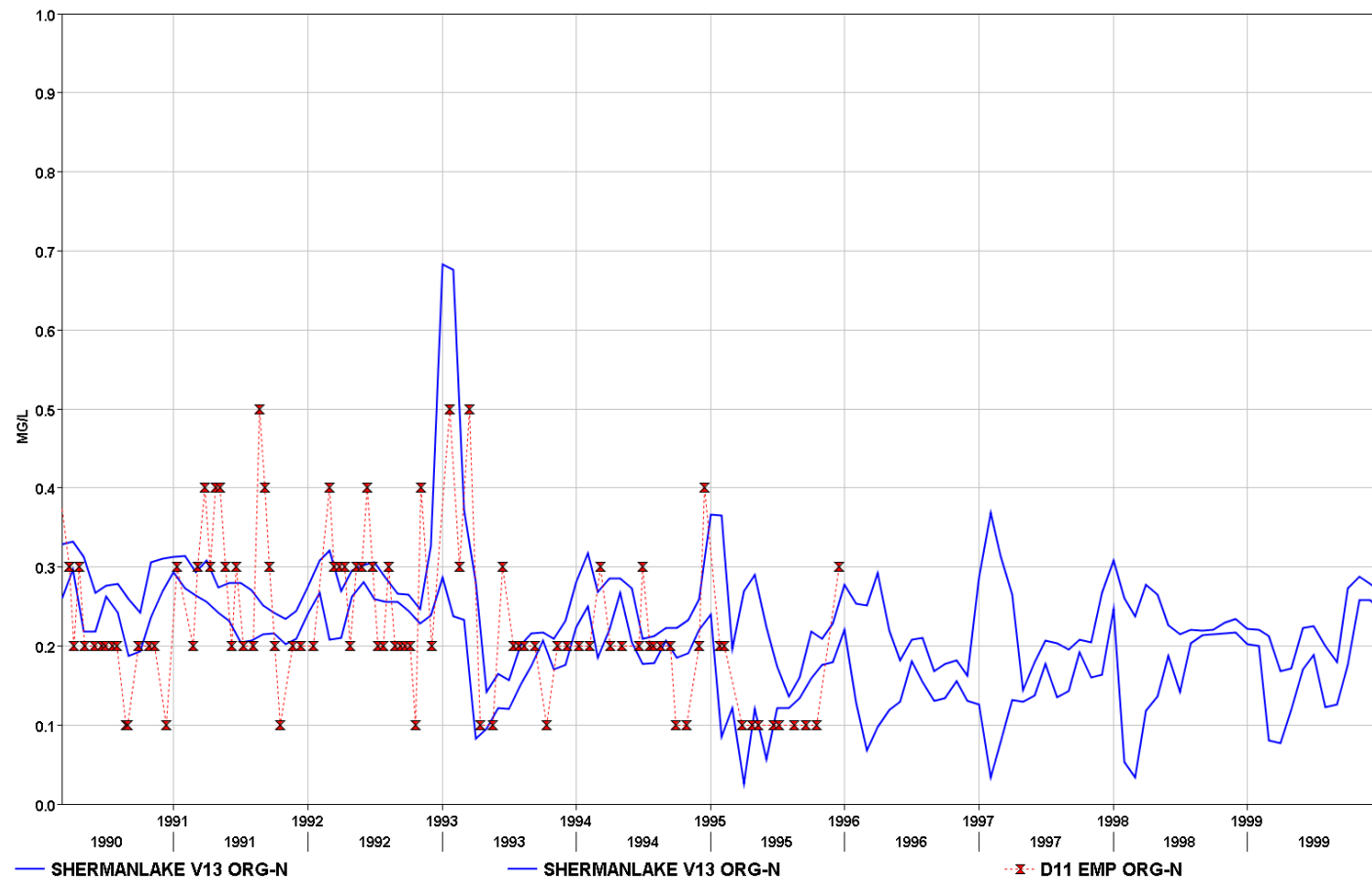


Figure A IV. 14 Organic-N at SHERMAN early years.

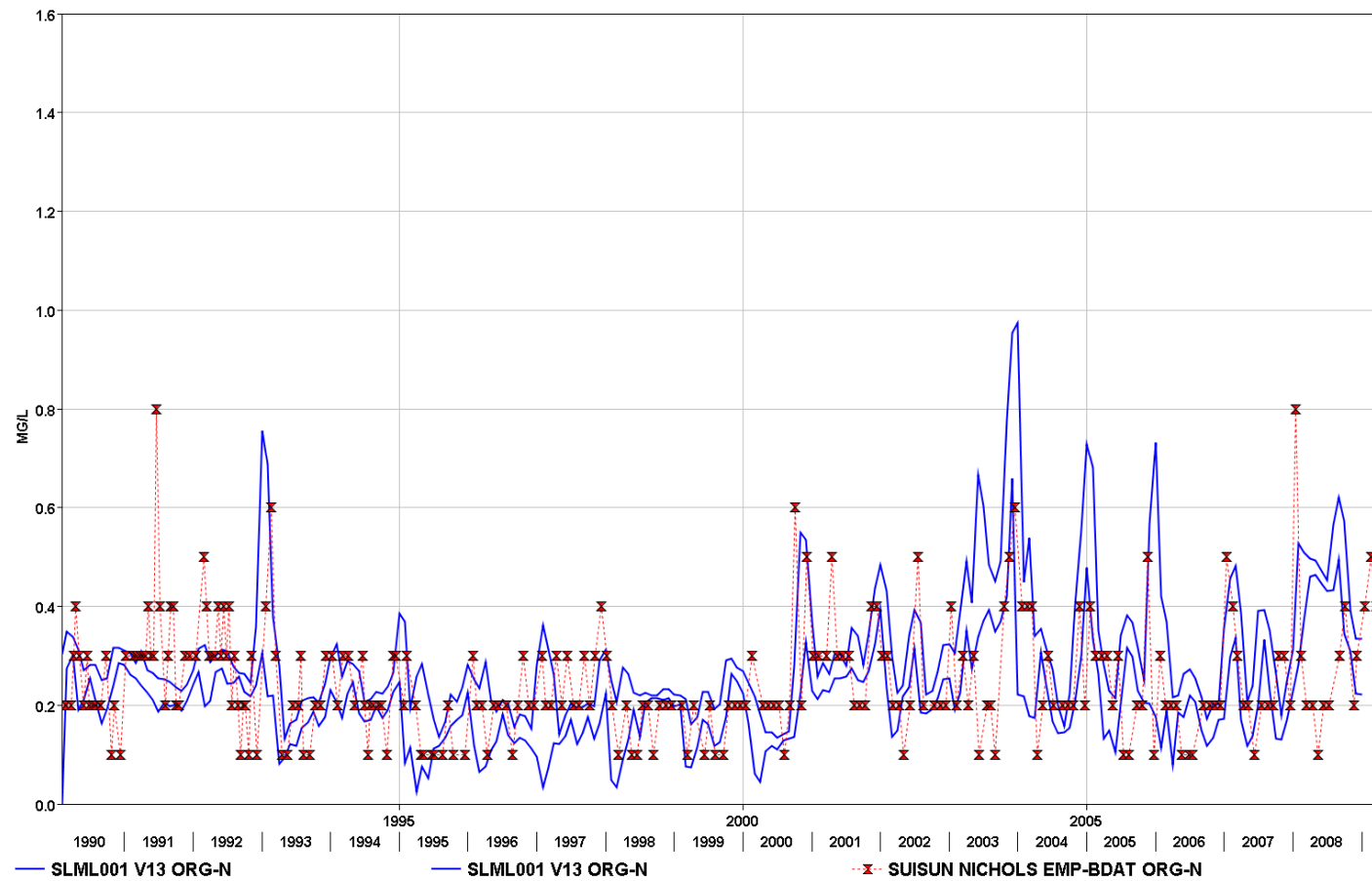


Figure A IV. 15 Organic-N at SLM001 all years.

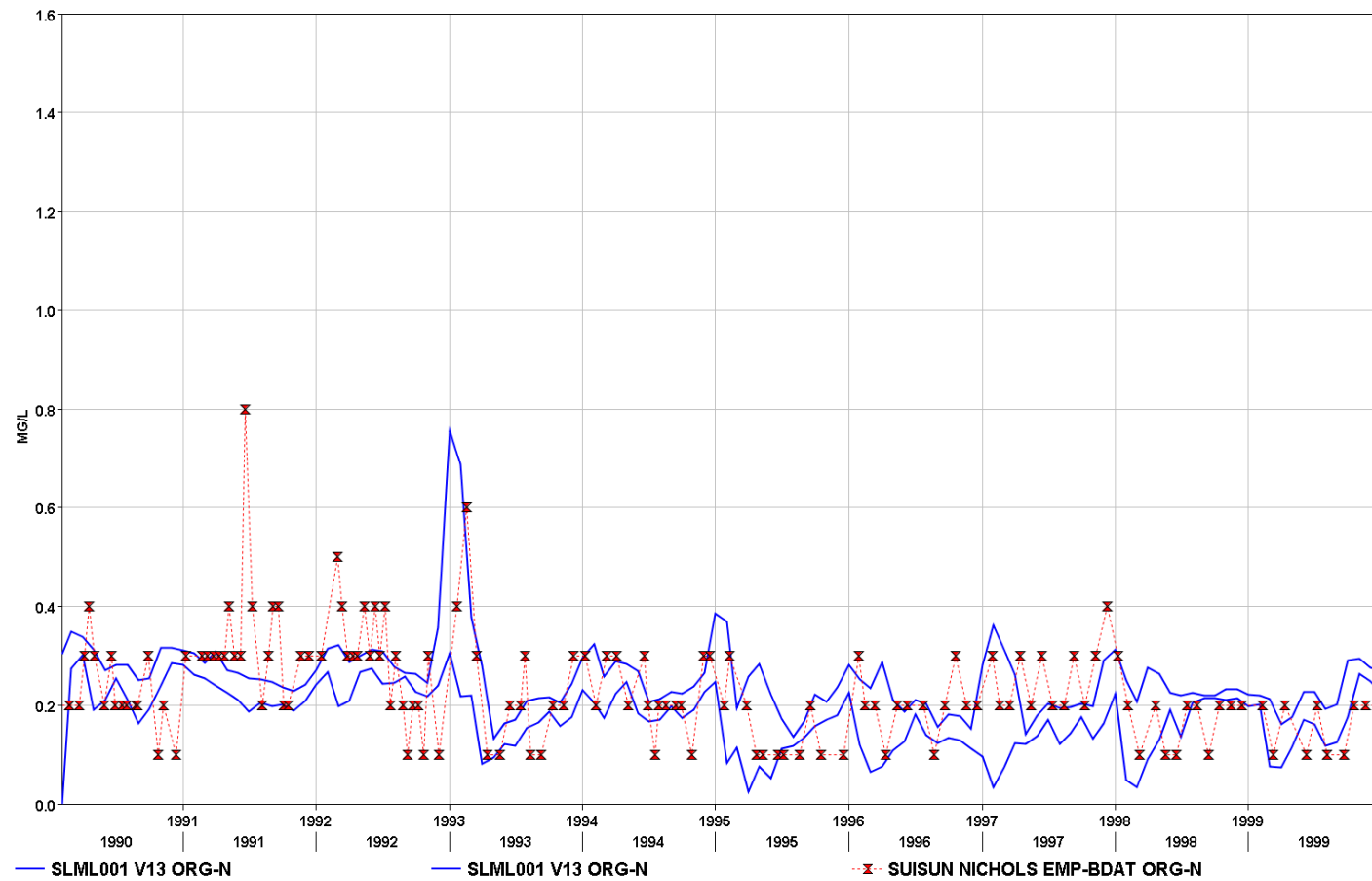


Figure A IV. 16 Organic-N at SLM001 early years.

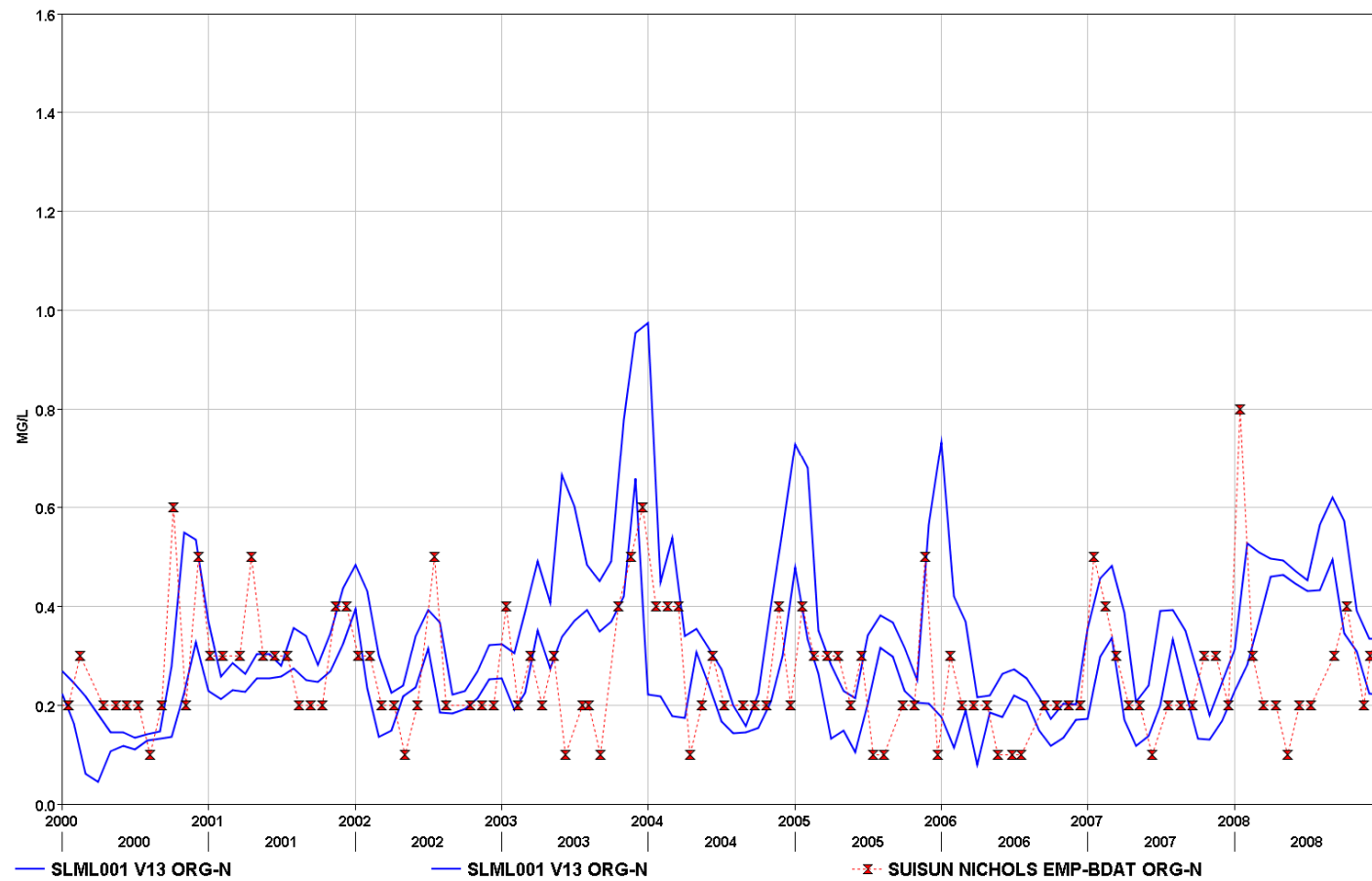


Figure A IV. 17 Organic-N at SLM001 later years.

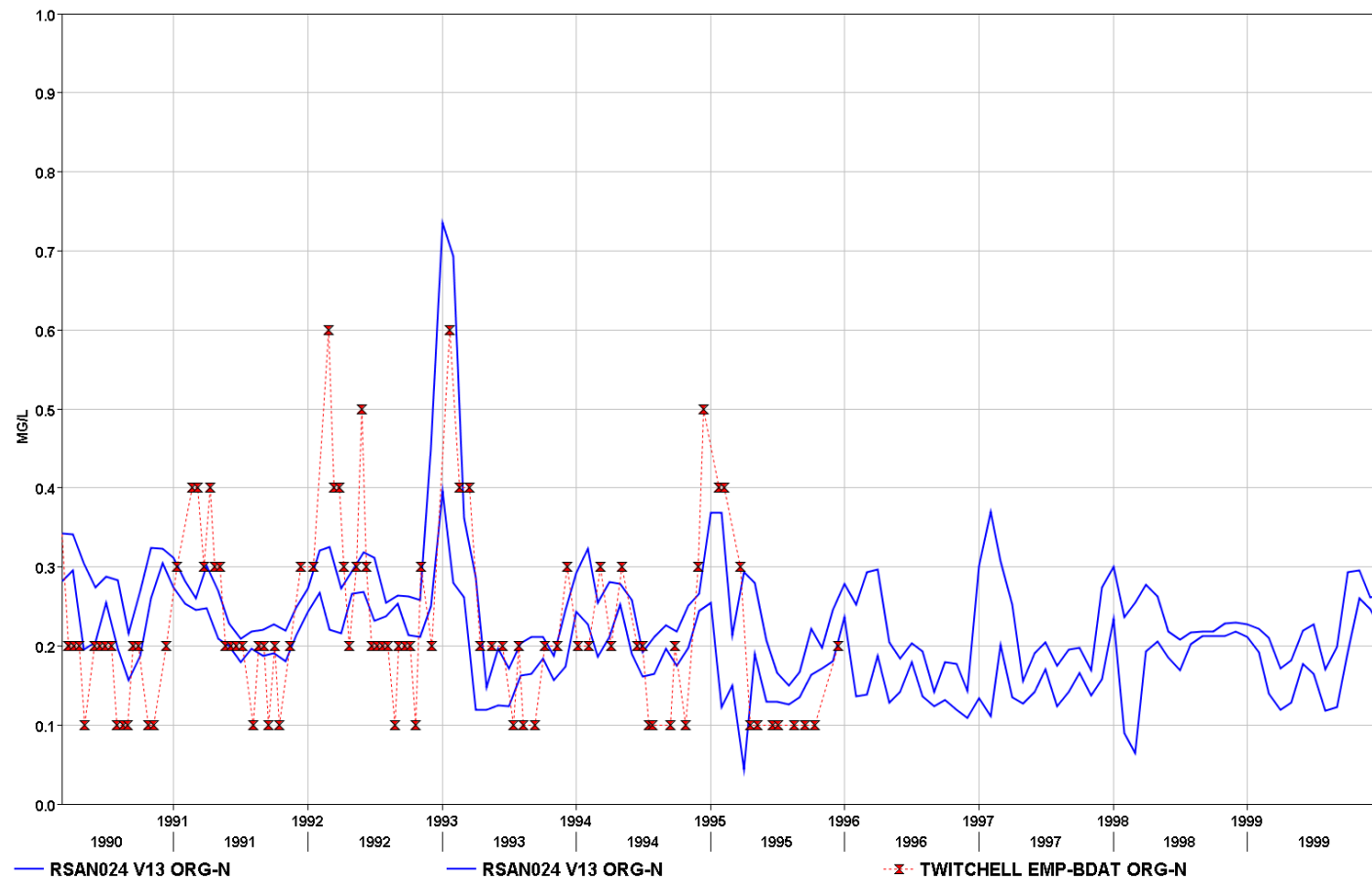


Figure A IV. 18 Organic-N at RSAN024 early years.

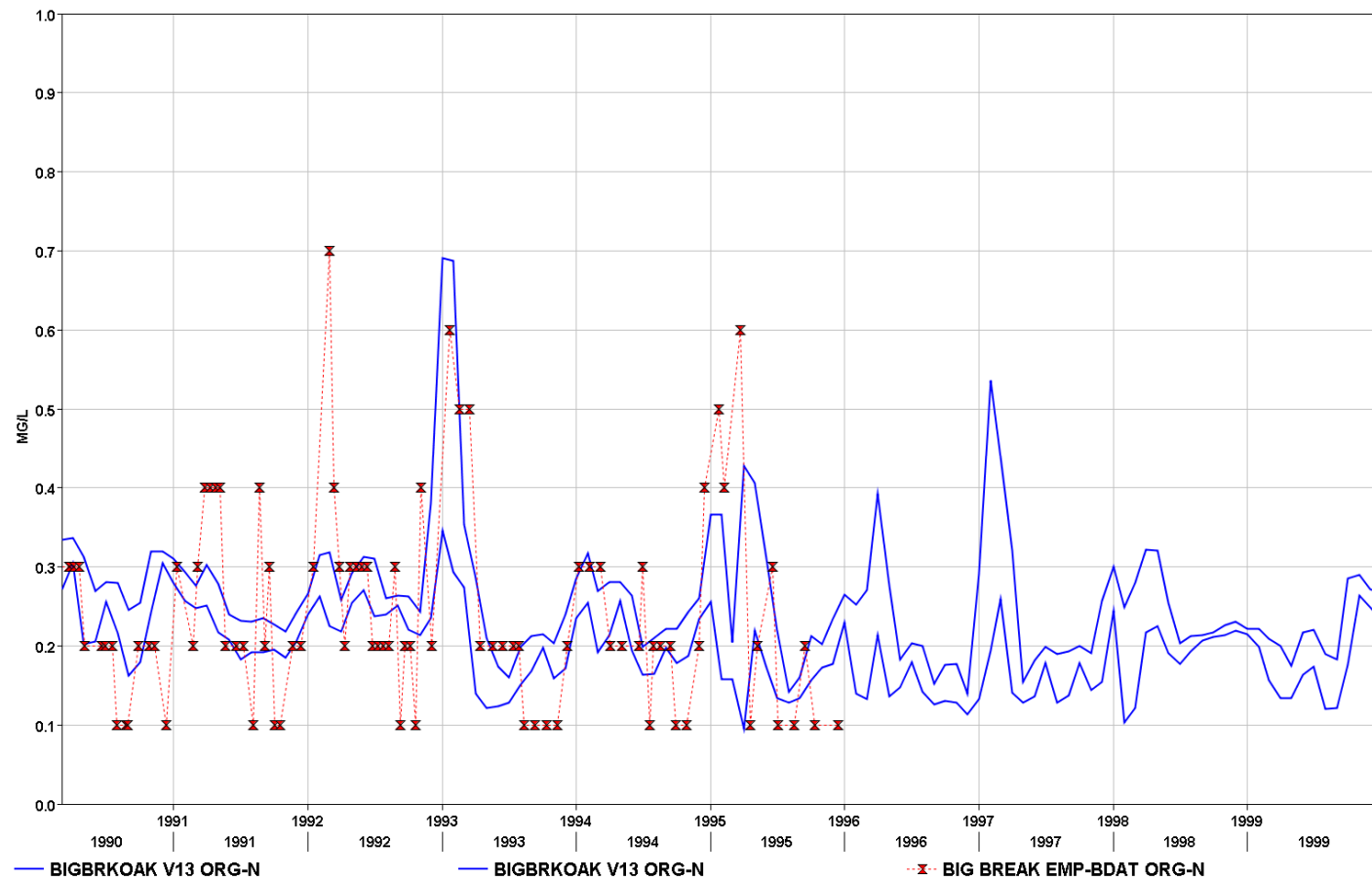


Figure A IV. 19 Organic-N at BIG BREAK early years.

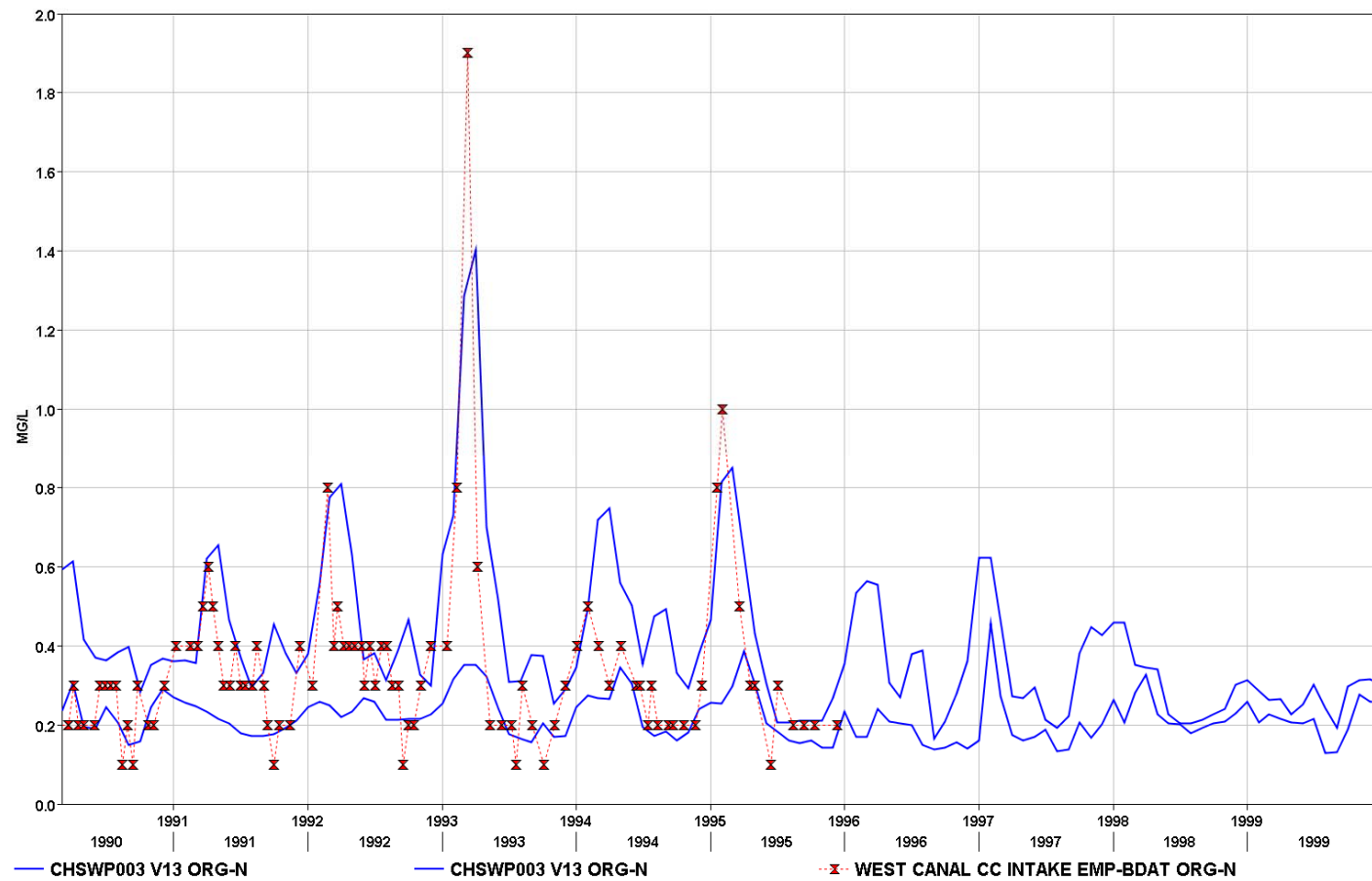


Figure A IV. 20 Organic-N at CHSWP003 early years.

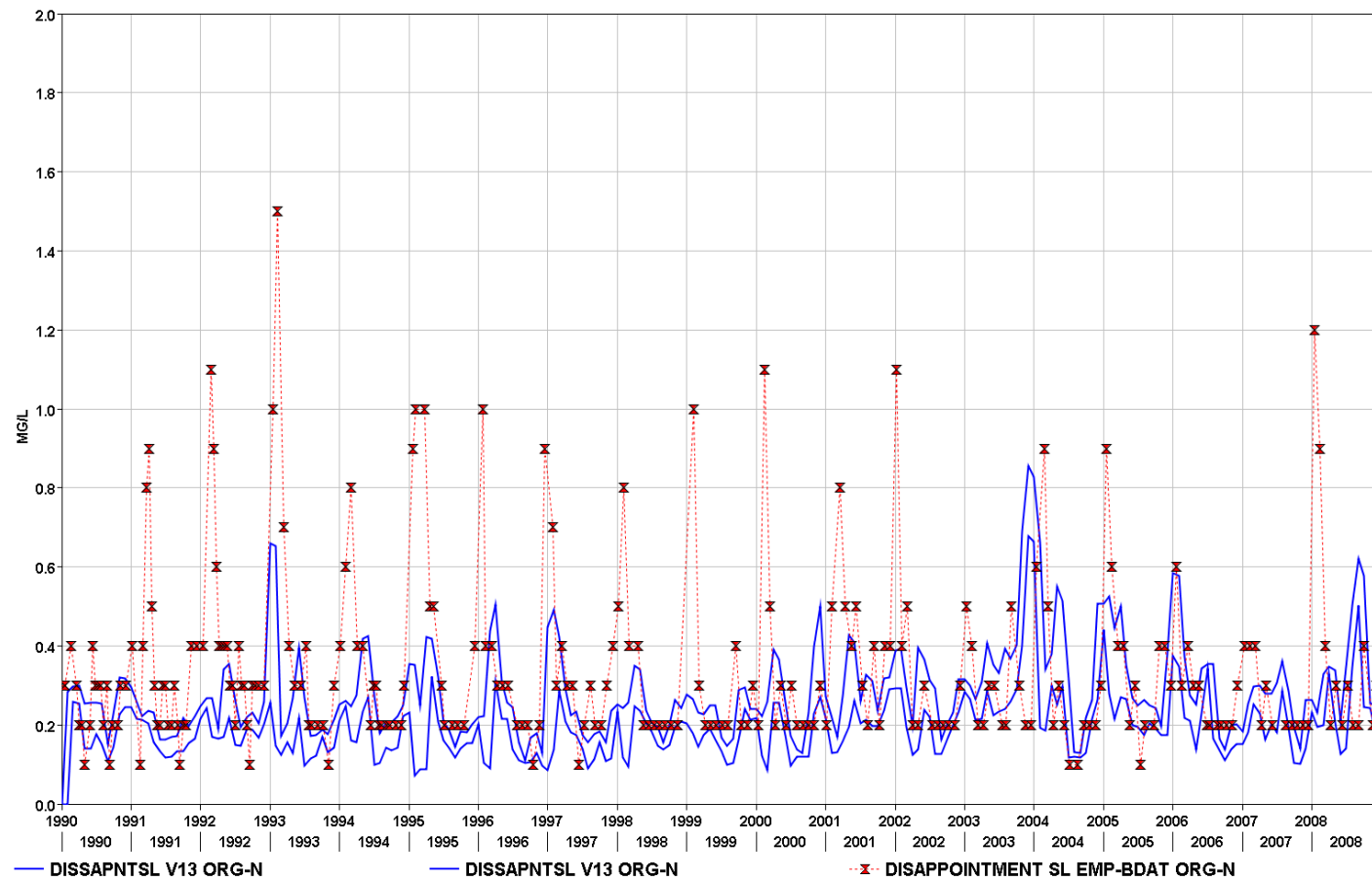


Figure A IV. 21 Organic-N at DISAP SL. all years.

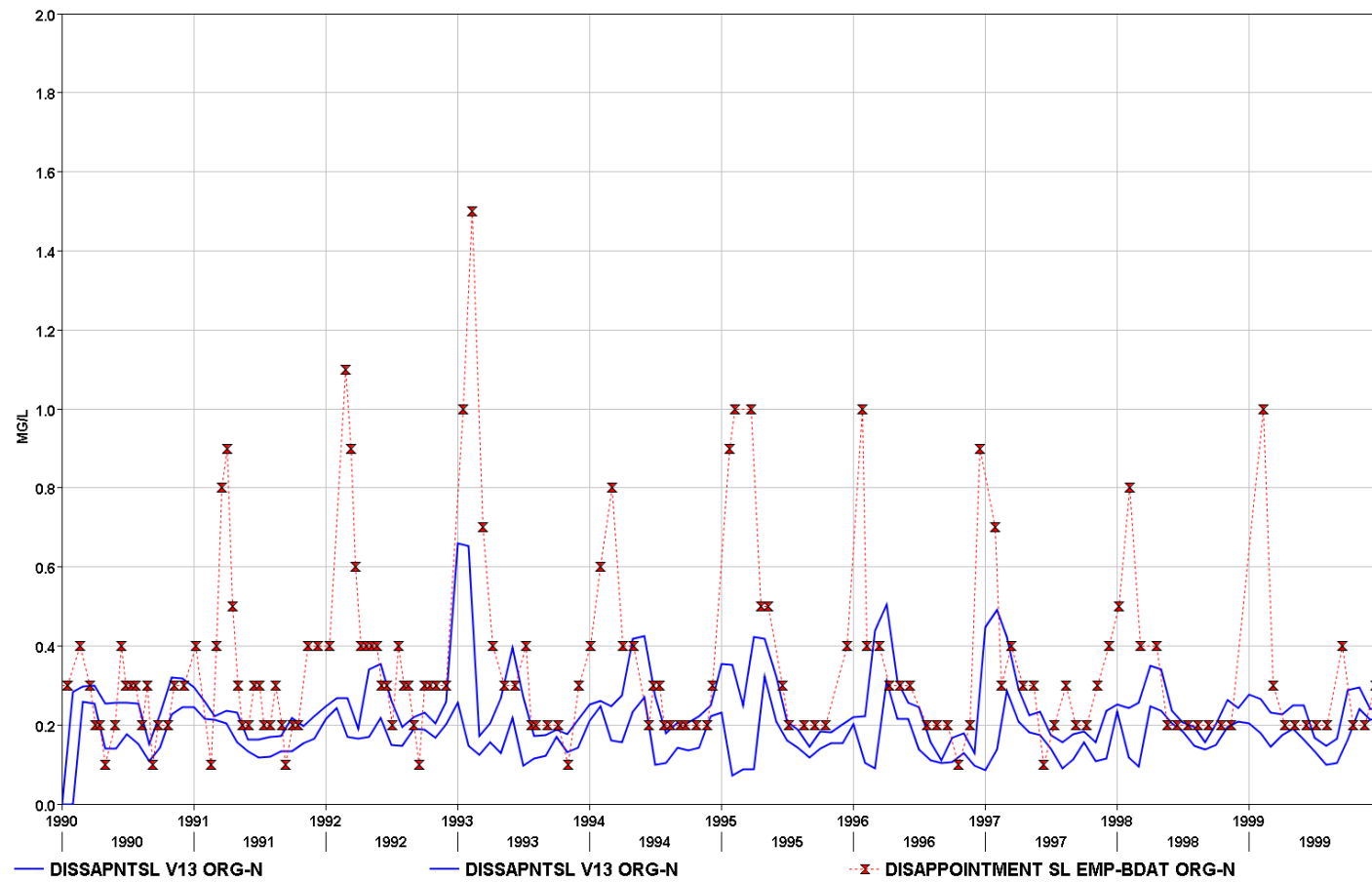


Figure A IV. 22 Organic-N at DISAP SL early years.

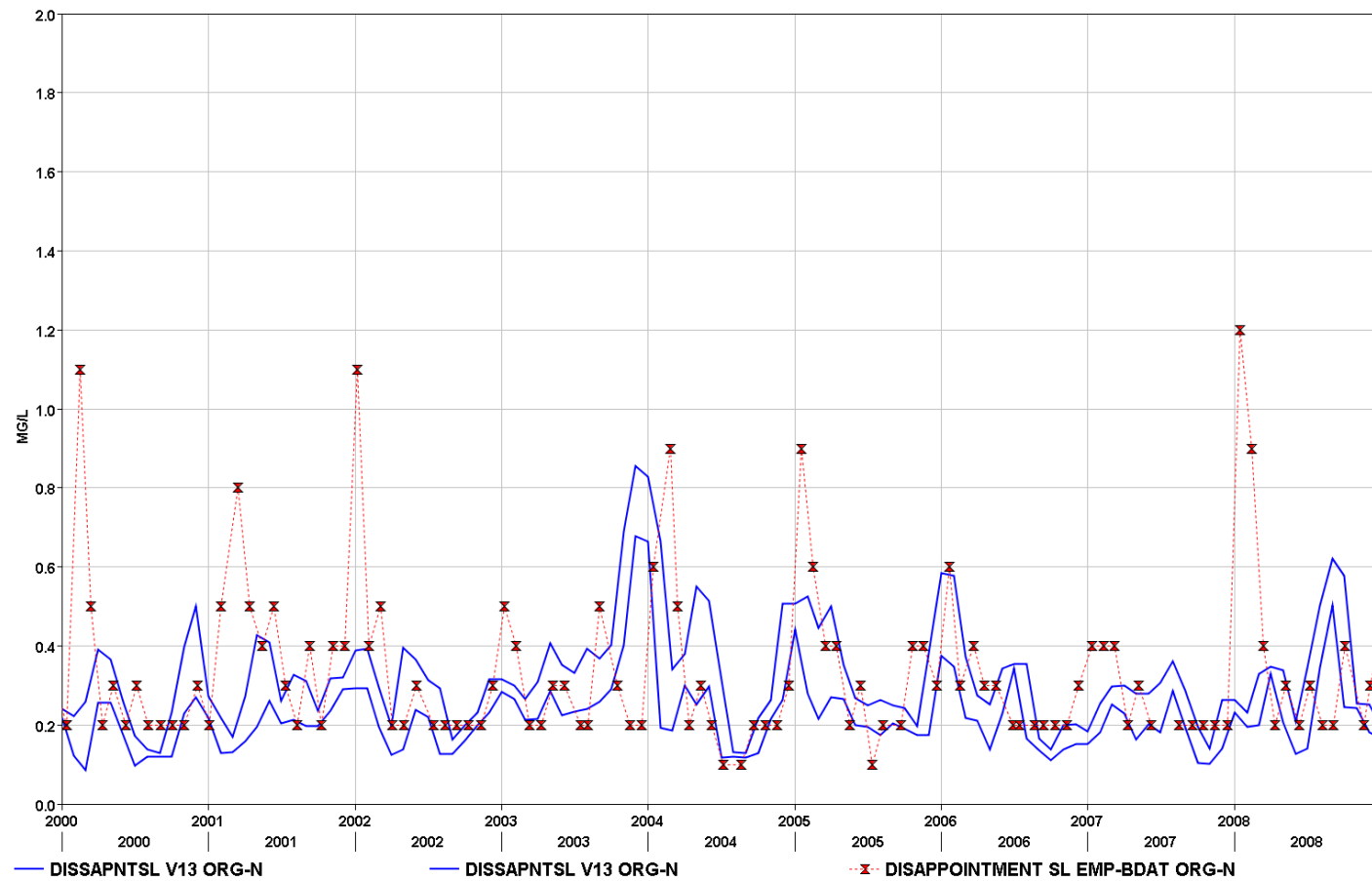


Figure A IV. 23 Organic-N at DISAP SL later years.

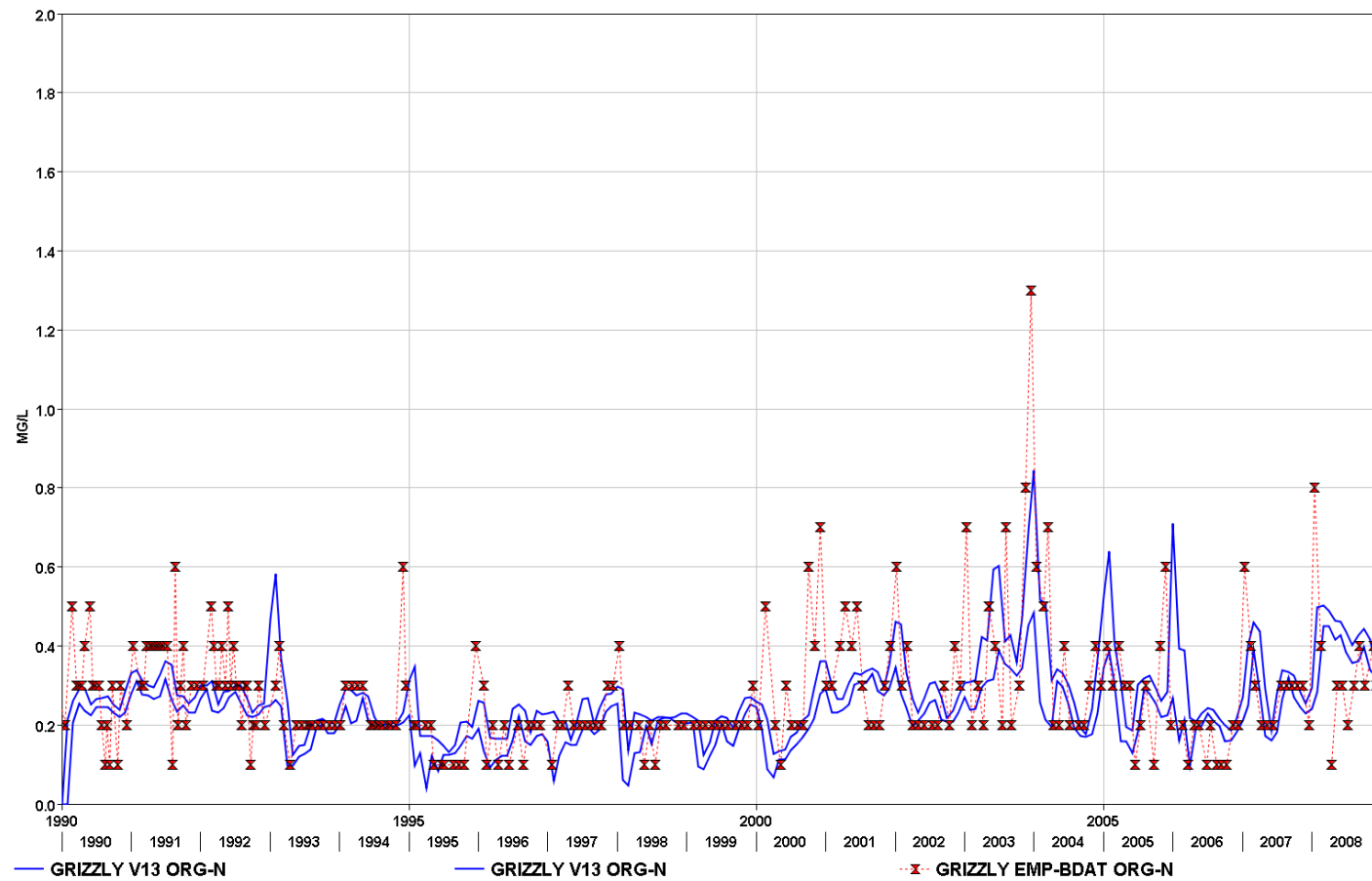


Figure A IV. 24 Organic-N at GRIZZLY all years

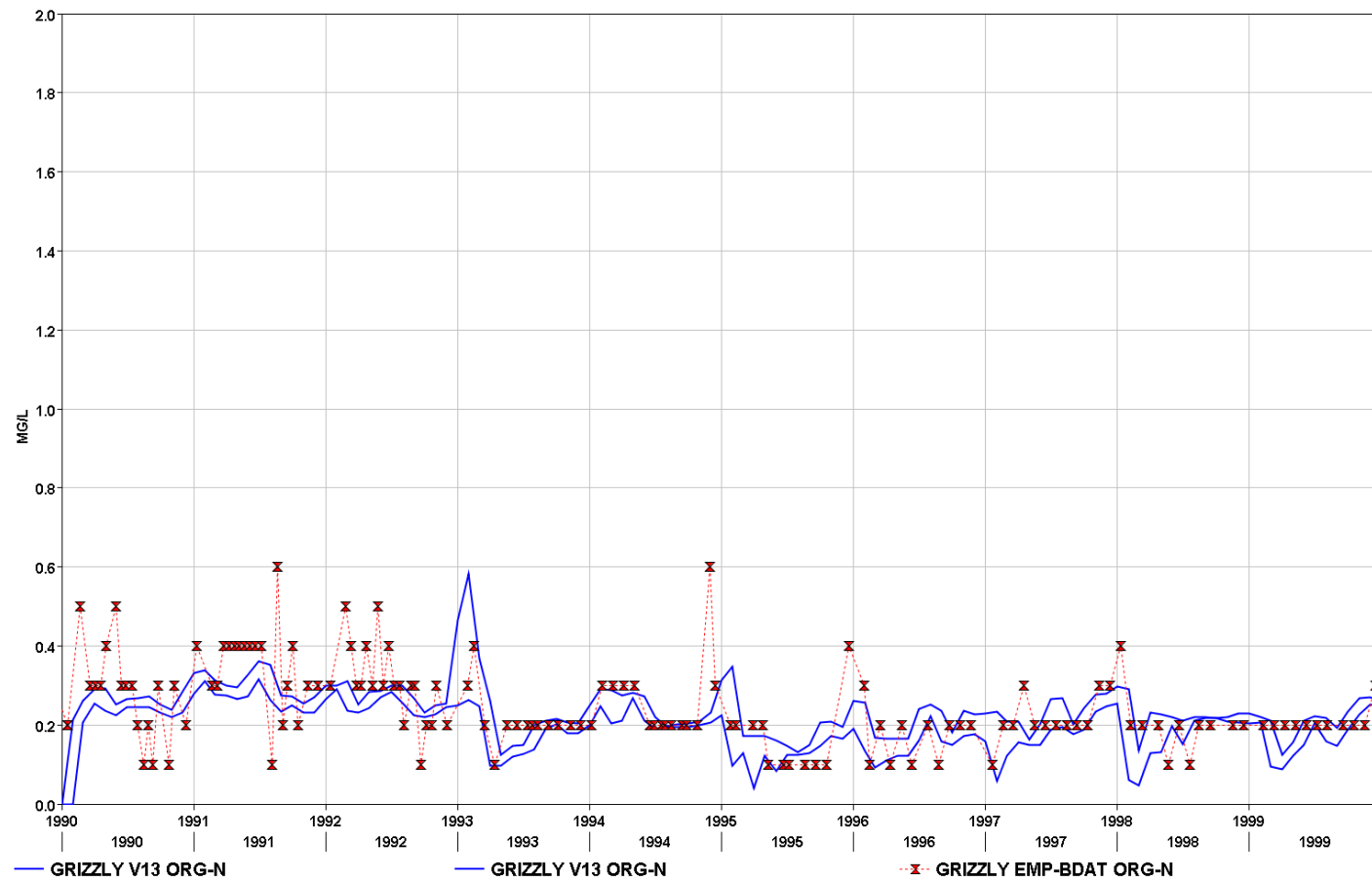


Figure A IV. 25 Organic-N at GRIZZLY early years.

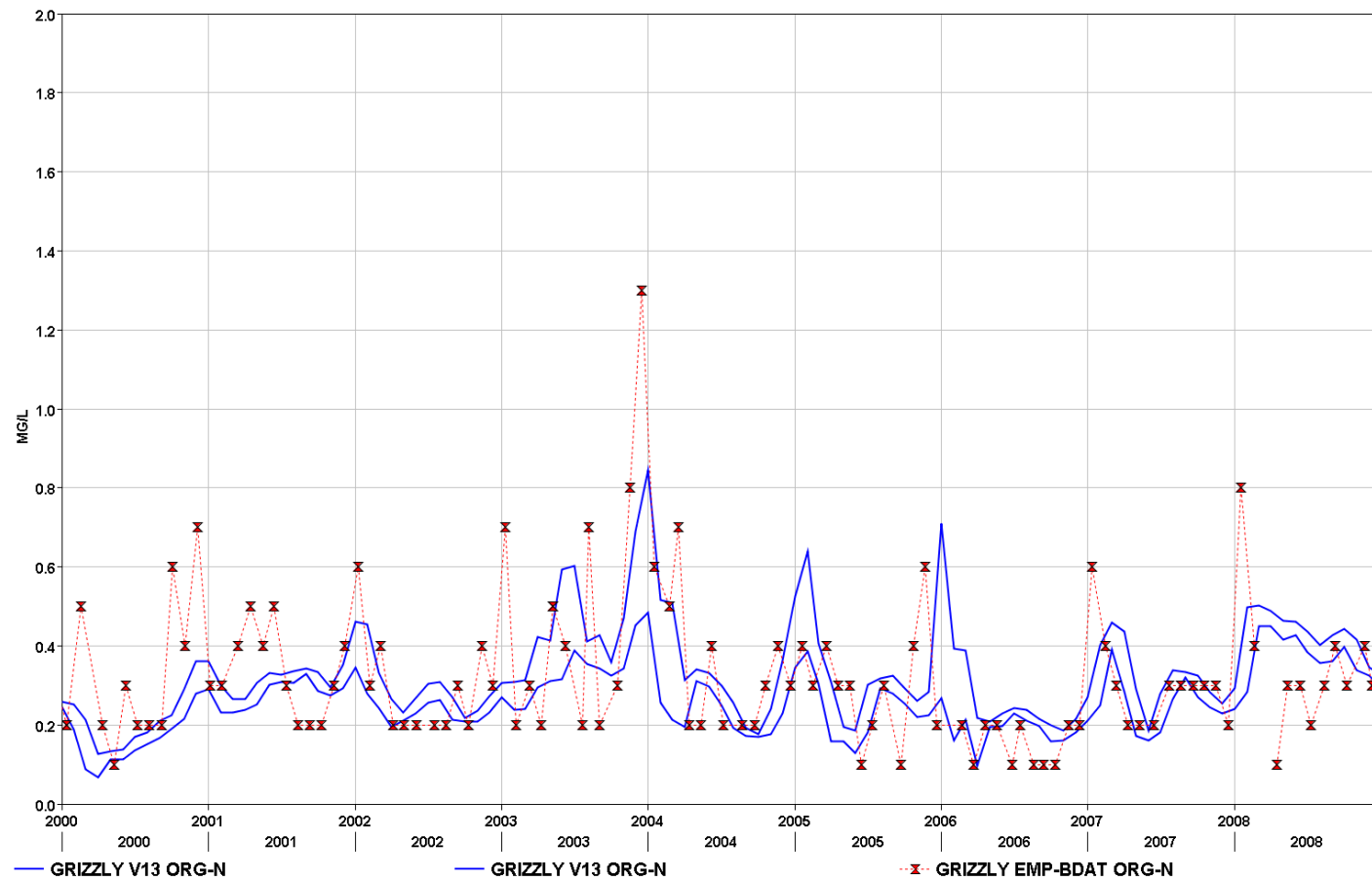


Figure A IV. 26 Organic-N at GRIZZLY later years.

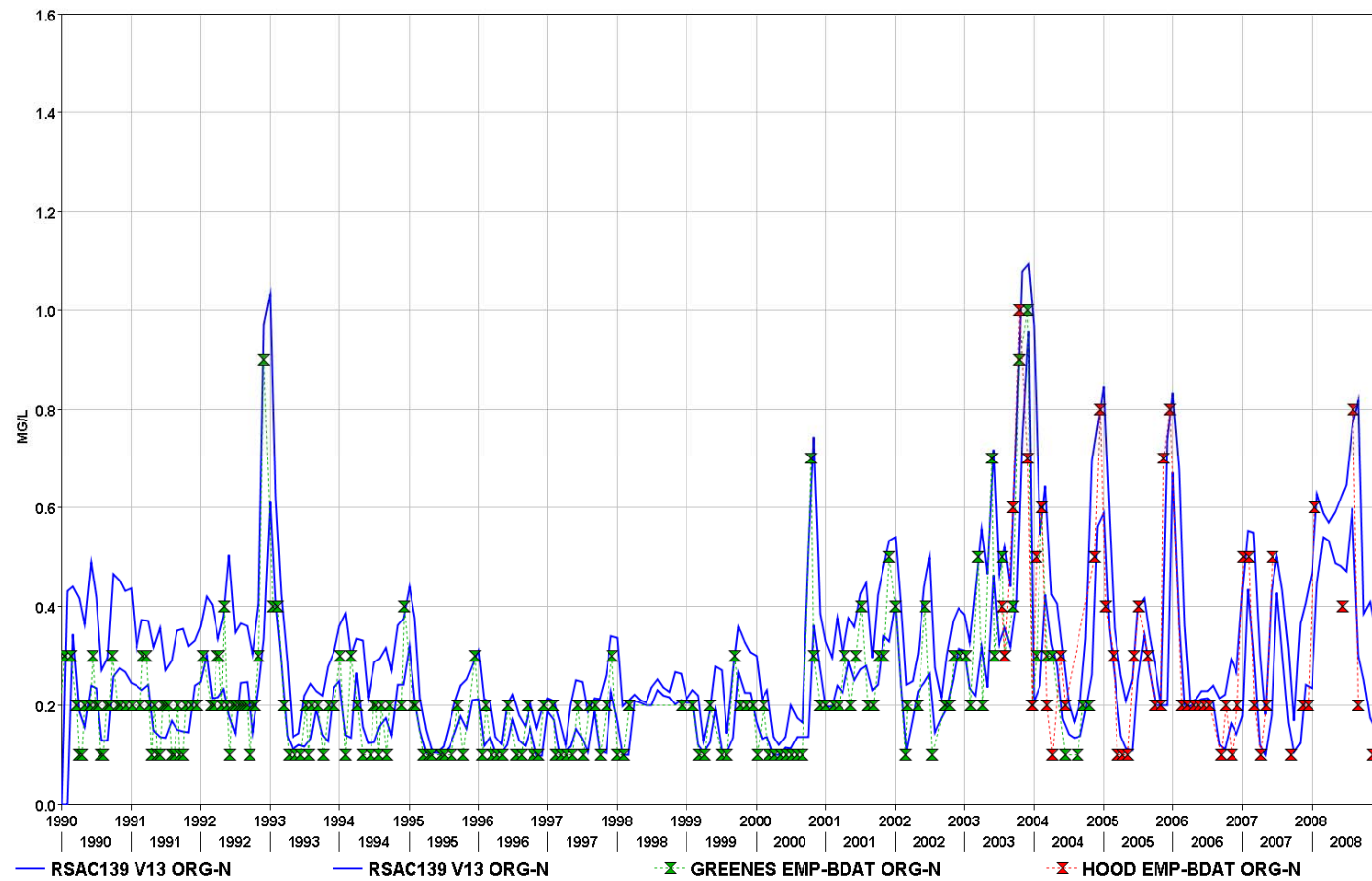


Figure A IV. 27 Organic-N at RSAC139 all years.

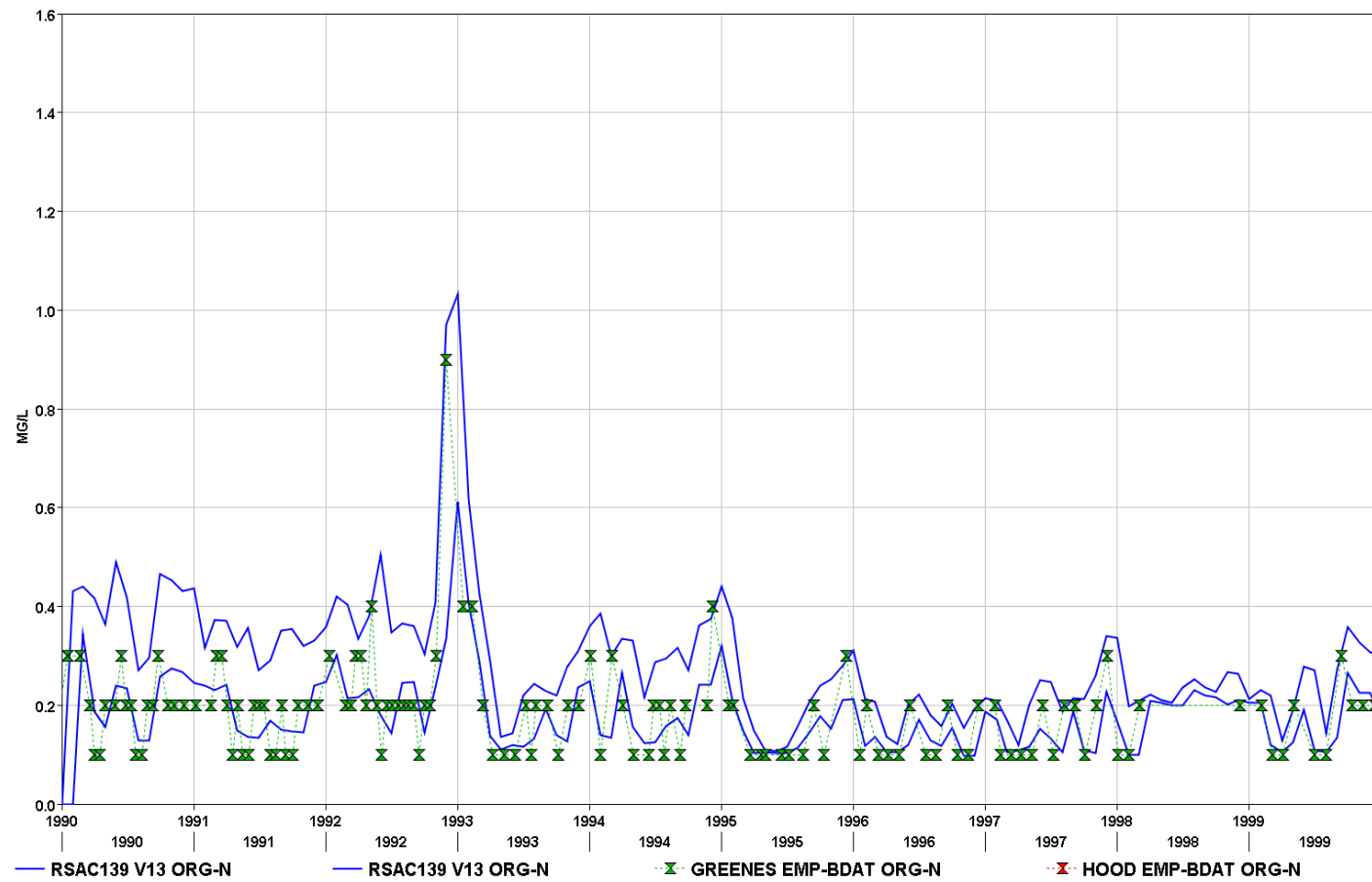


Figure A IV. 28 Organic-N at RSAC139 early years.

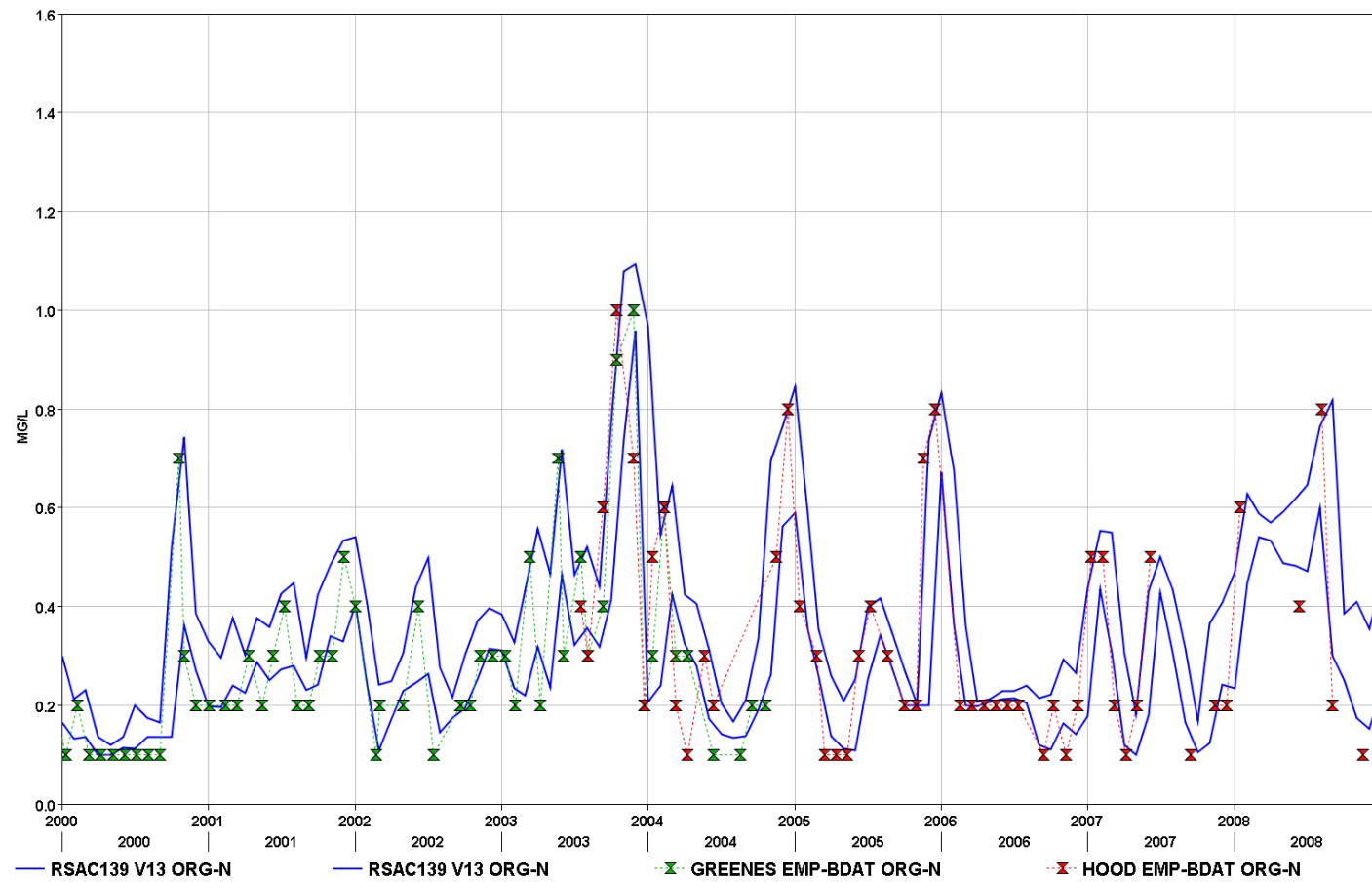


Figure A IV. 29 Organic-N at RSAC139 later years.

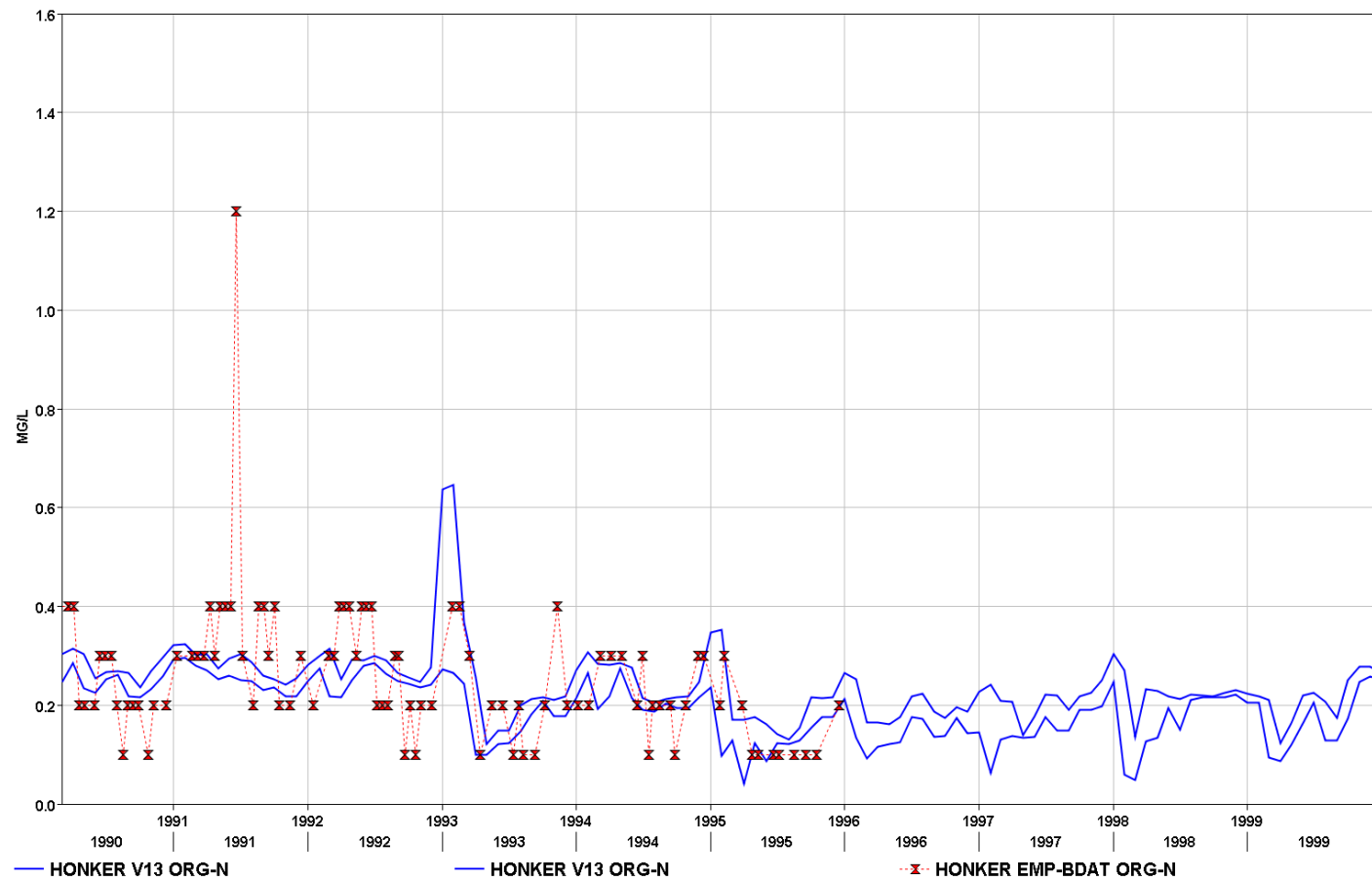


Figure A IV. 30 Organic-N at HONKER early years.

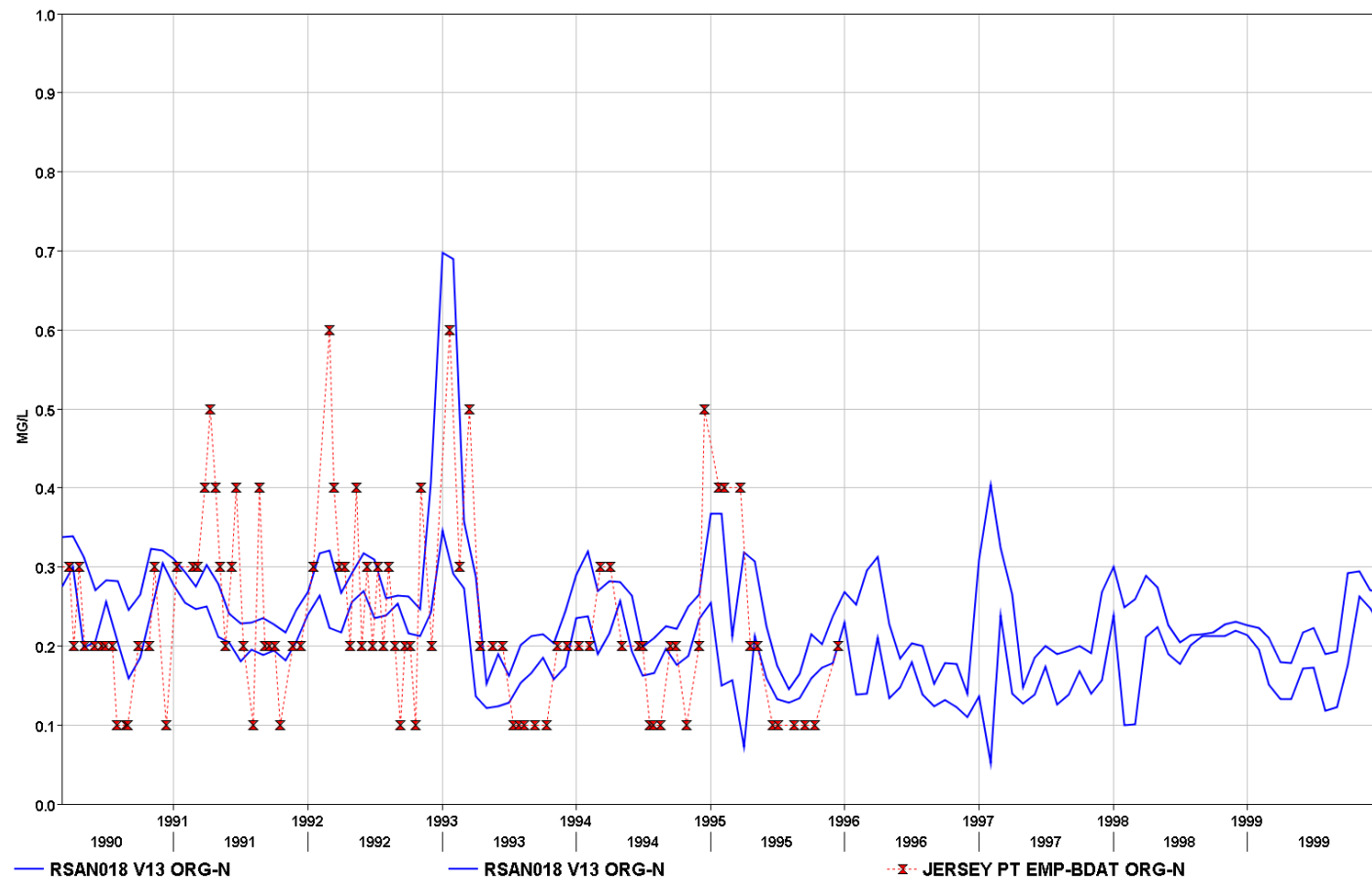


Figure A IV. 31 Organic-N at RSAN018 early years.

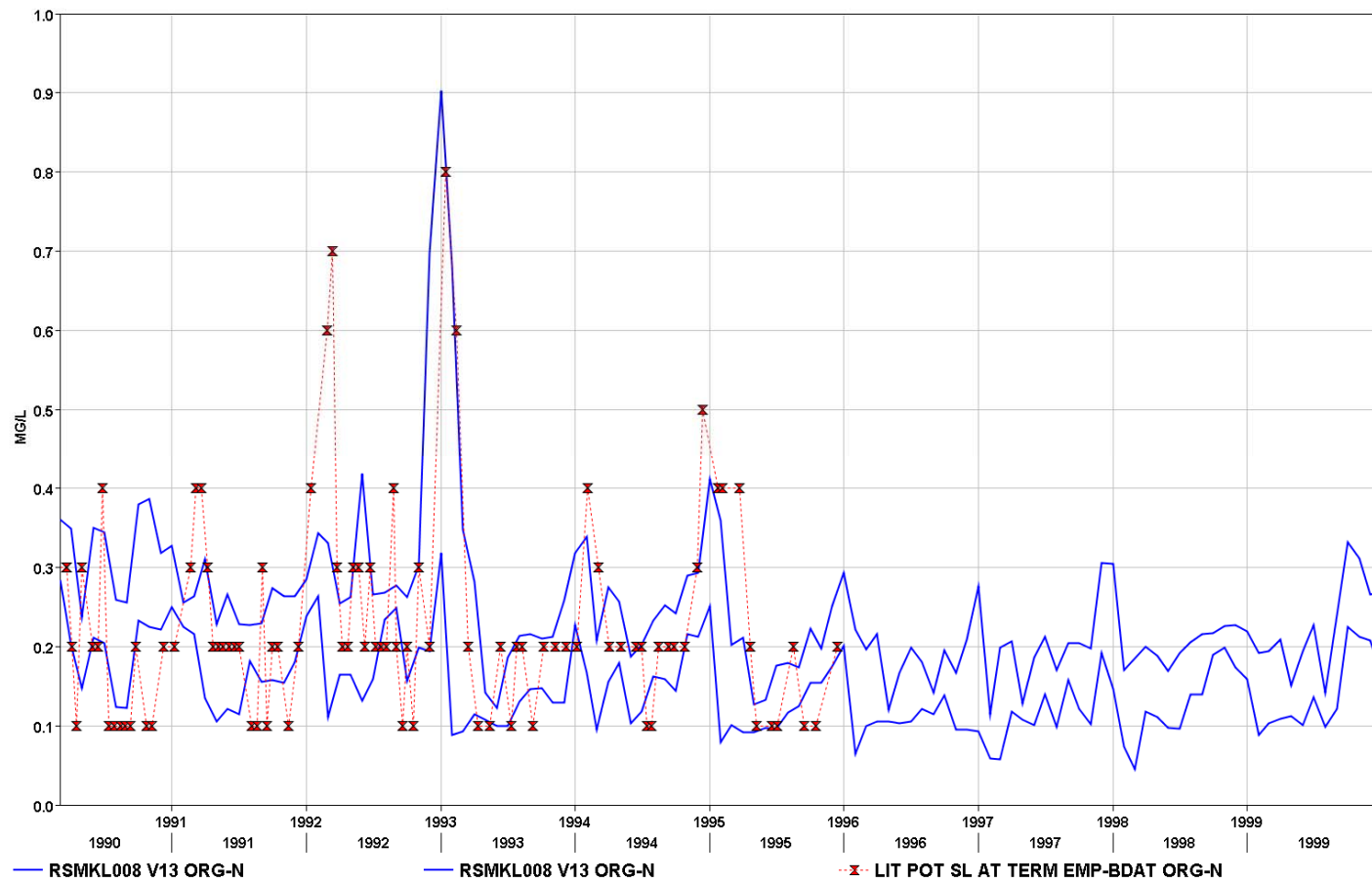


Figure A IV. 32 Organic-N at RSMKL008 early years.

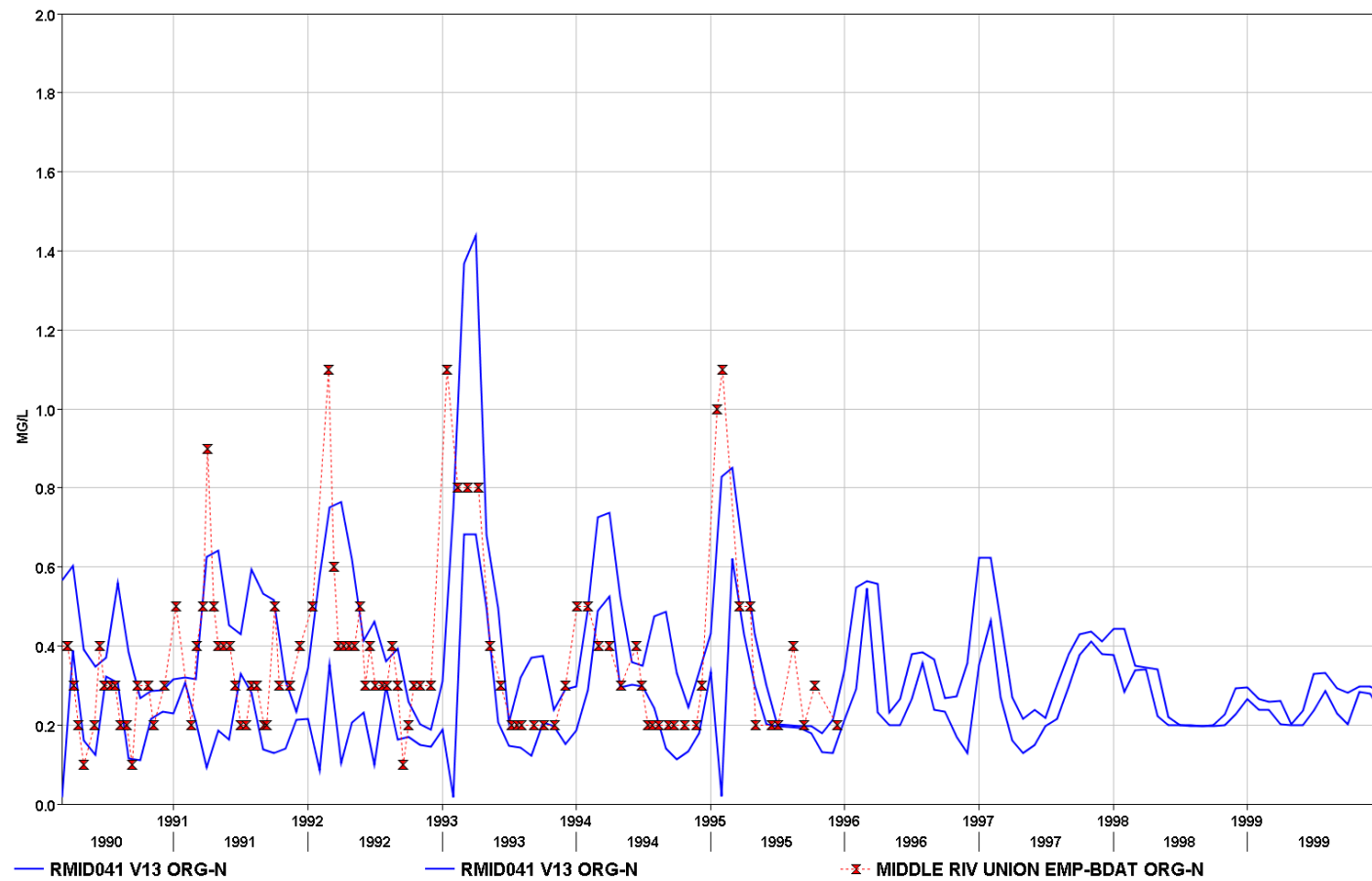


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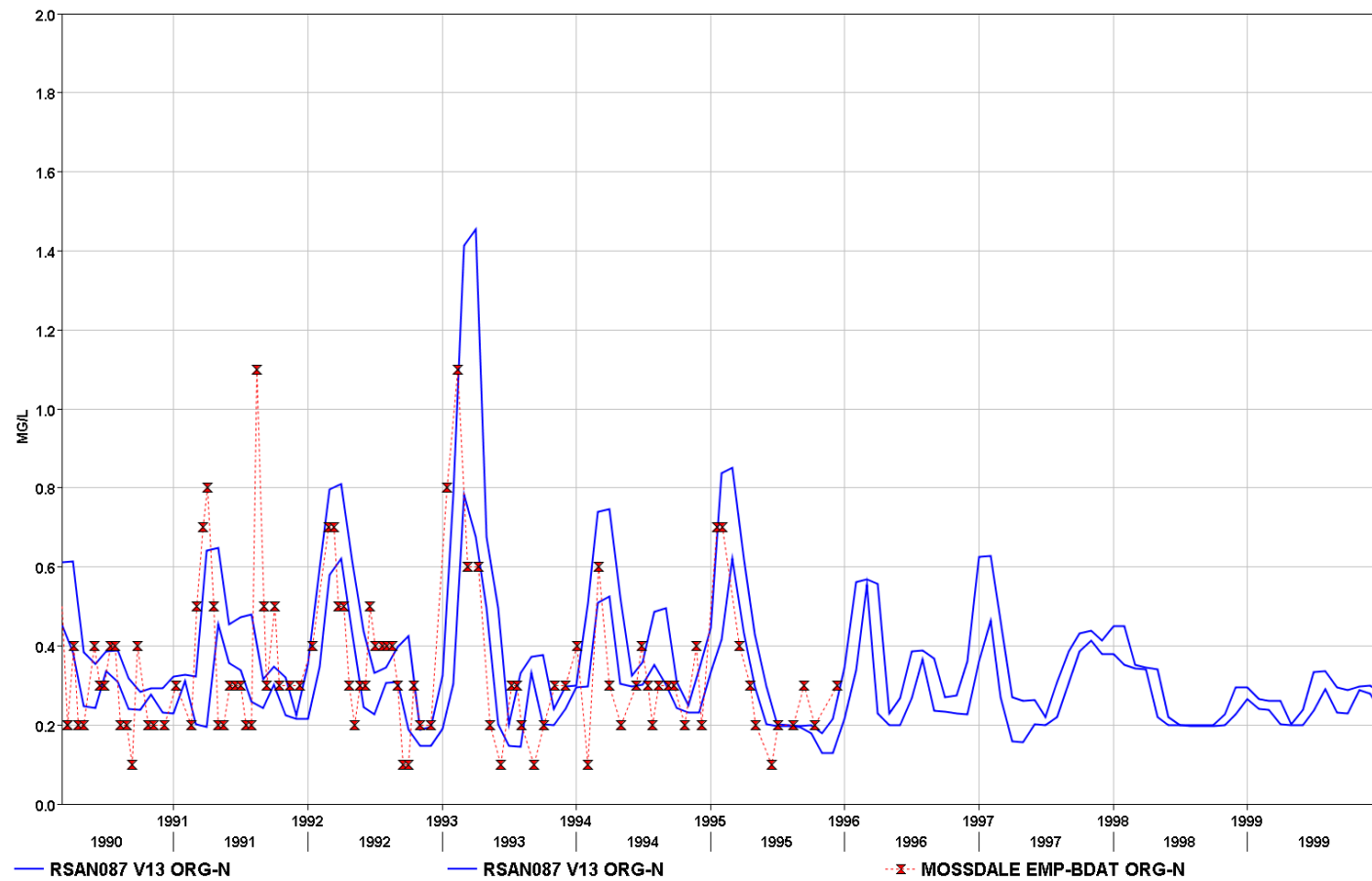


Figure A IV. 34 Organic-N at RSAN087 early years.

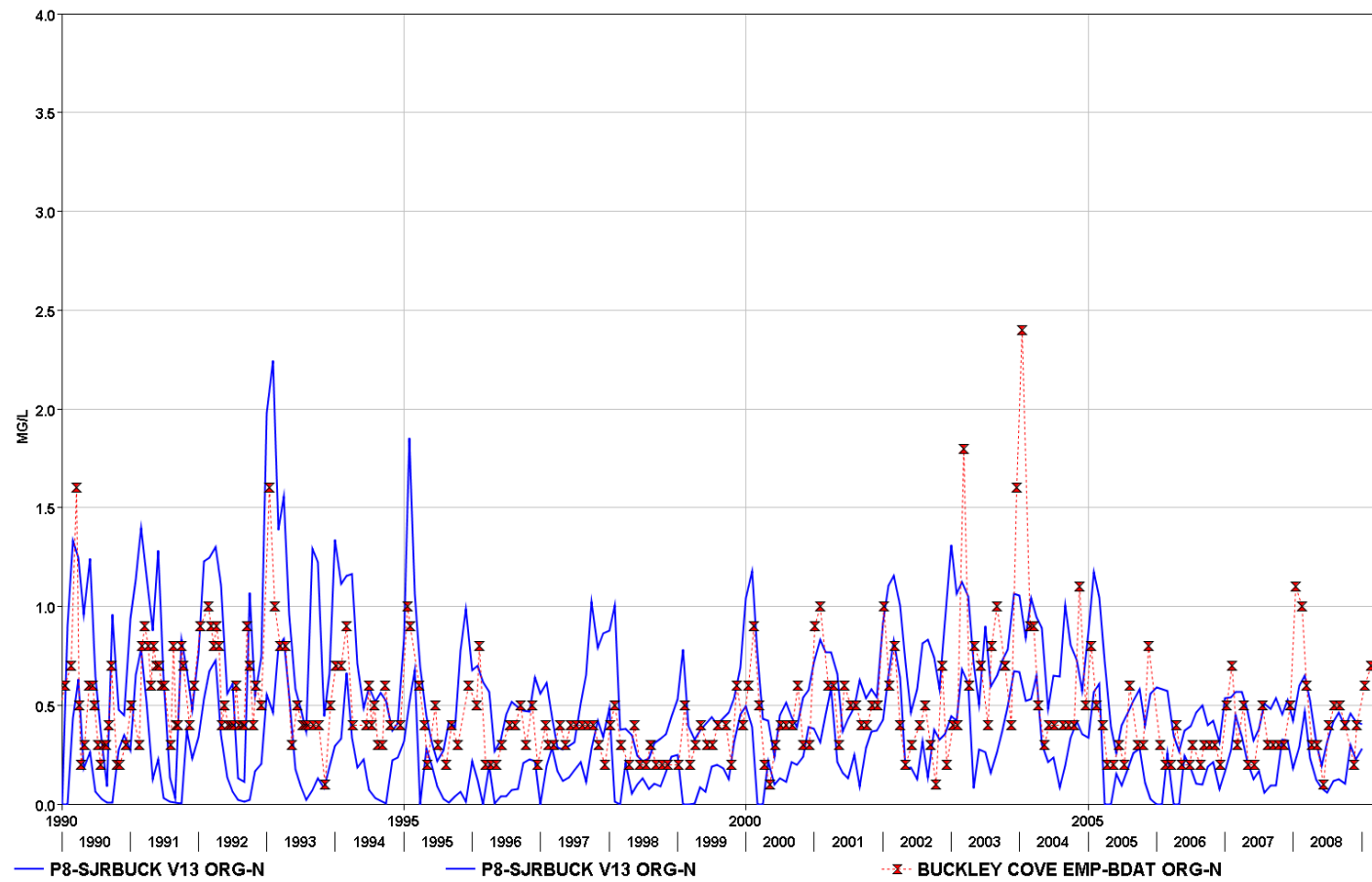


Figure A IV. 35 Organic-N at SJR BUCKLEY all years.

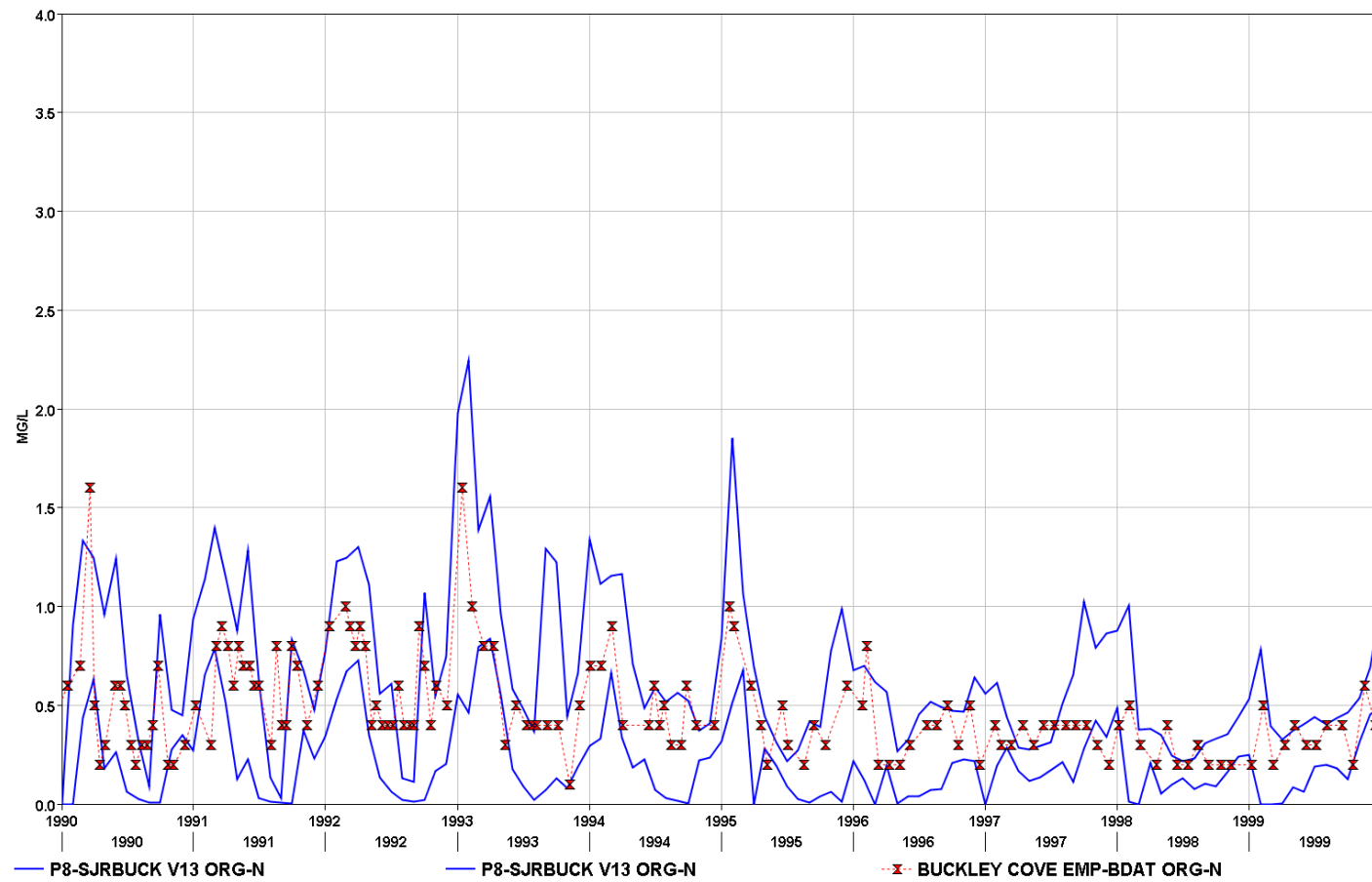


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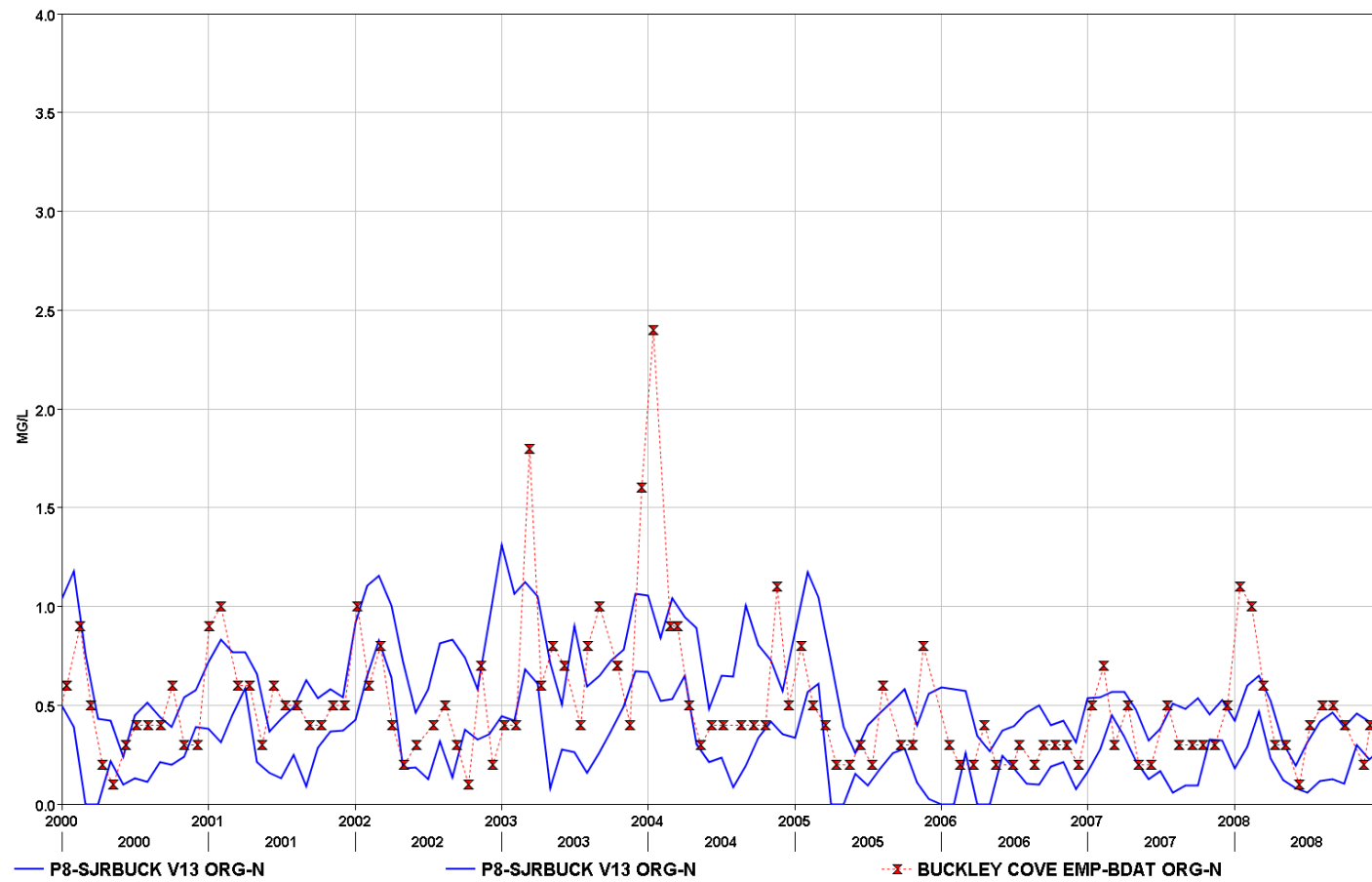


Figure A IV. 37 Organic-N at SJR BUCKLEY later years.

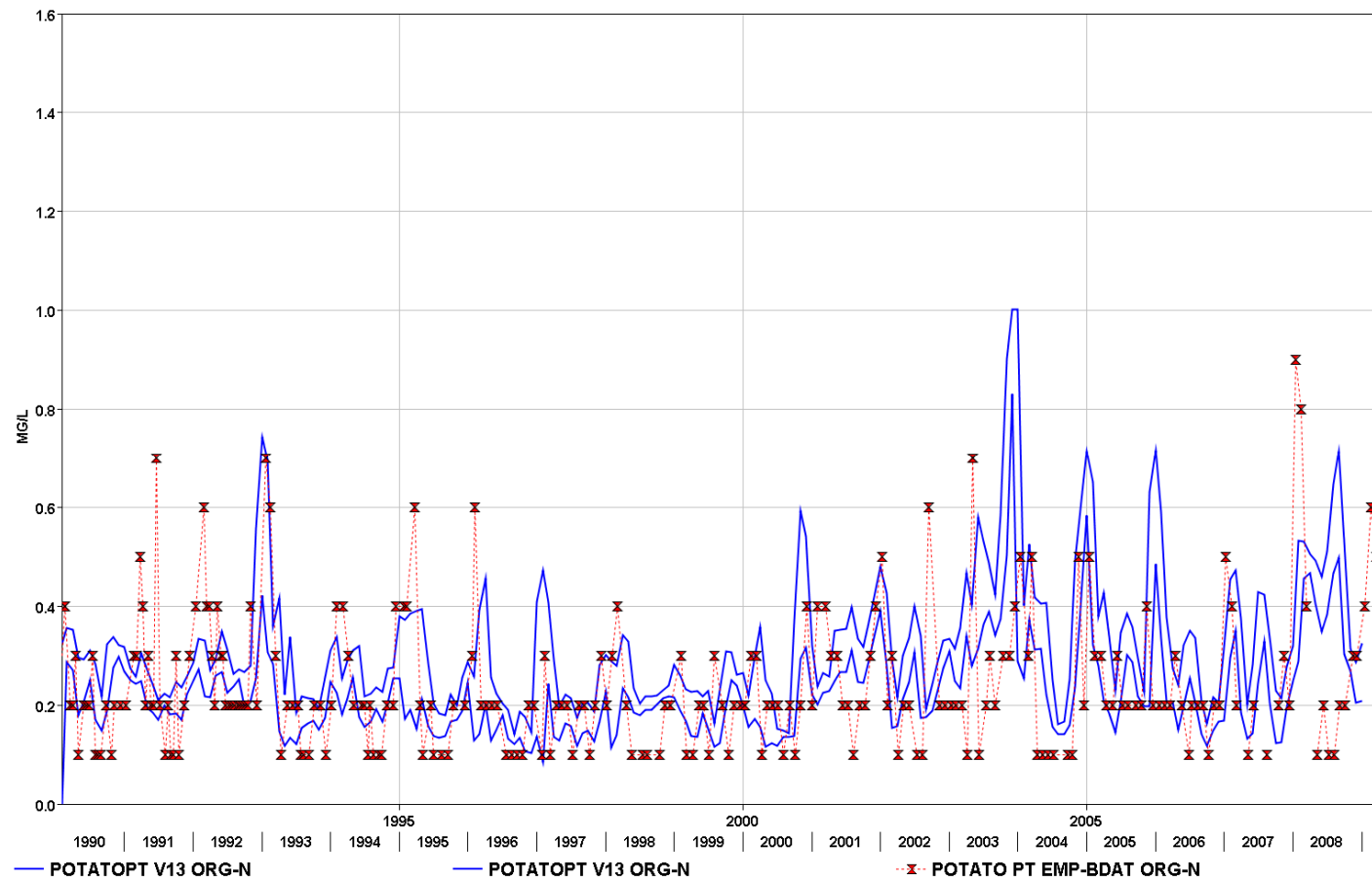


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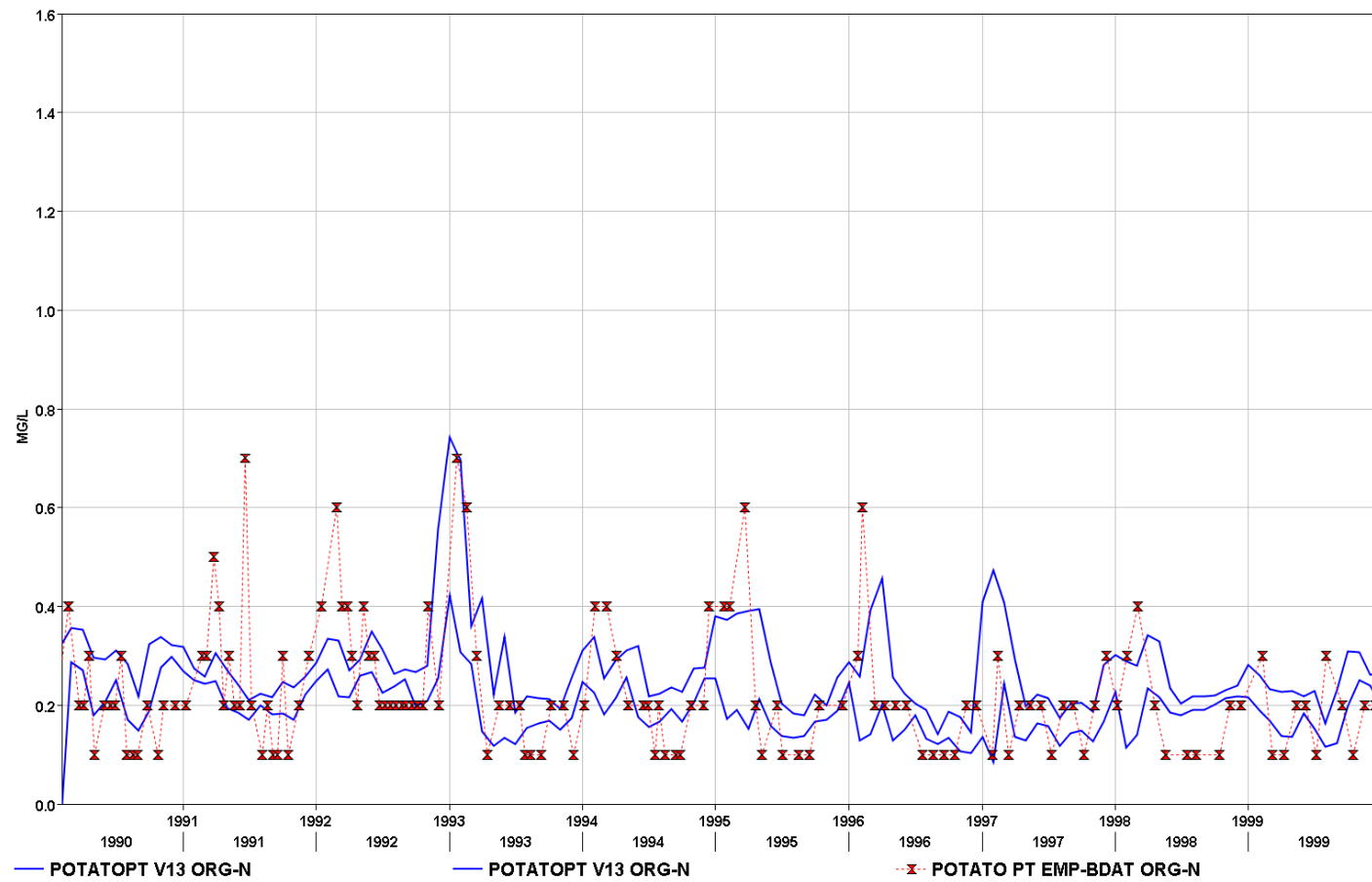


Figure A IV. 39 Organic-N at POTATO PT. early years.

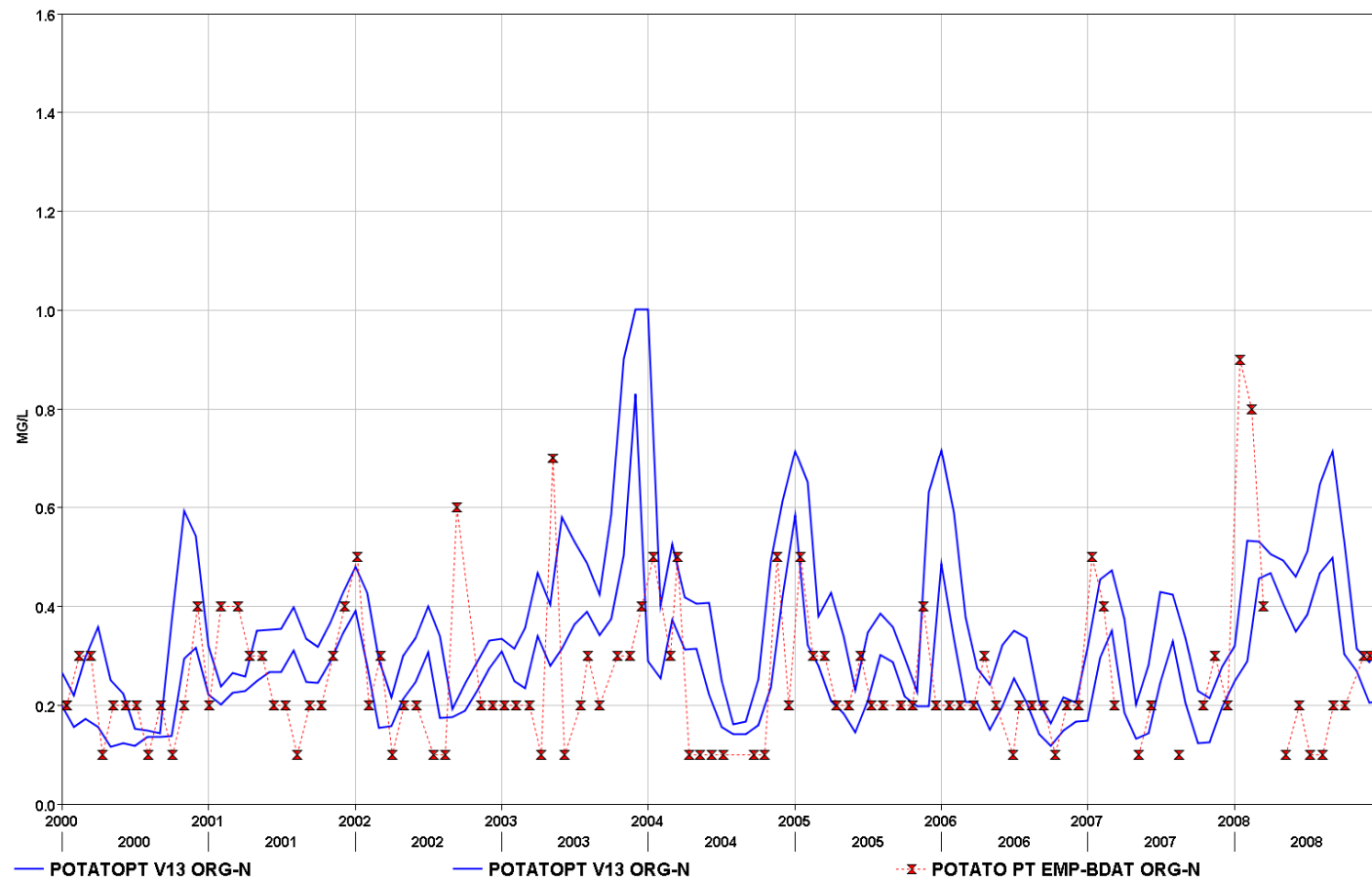


Figure A IV. 40 Organic-N at POTATO PT. later years.

B. PO_4

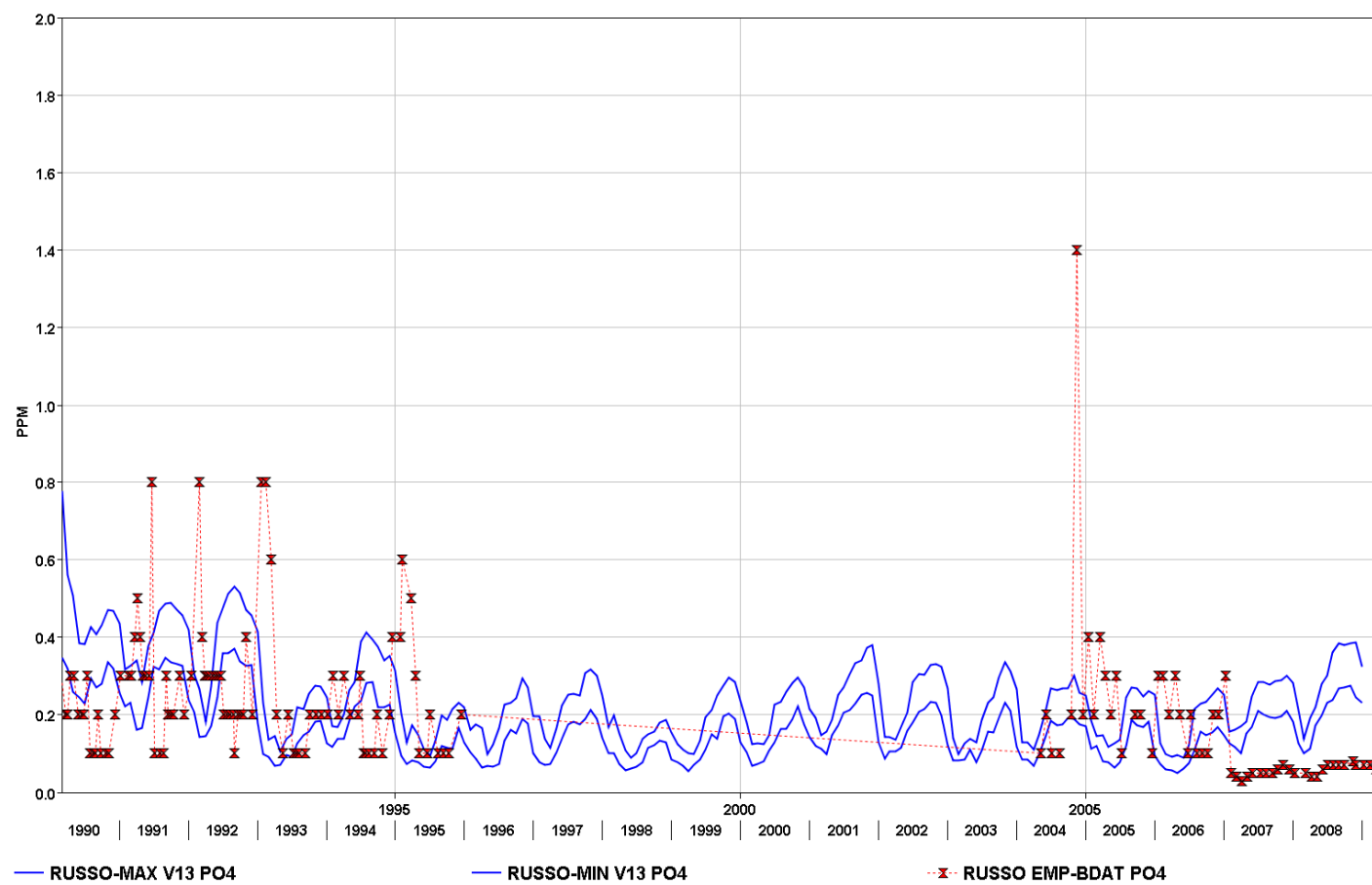


Figure A IV. 41 PO_4 at Russo all years.

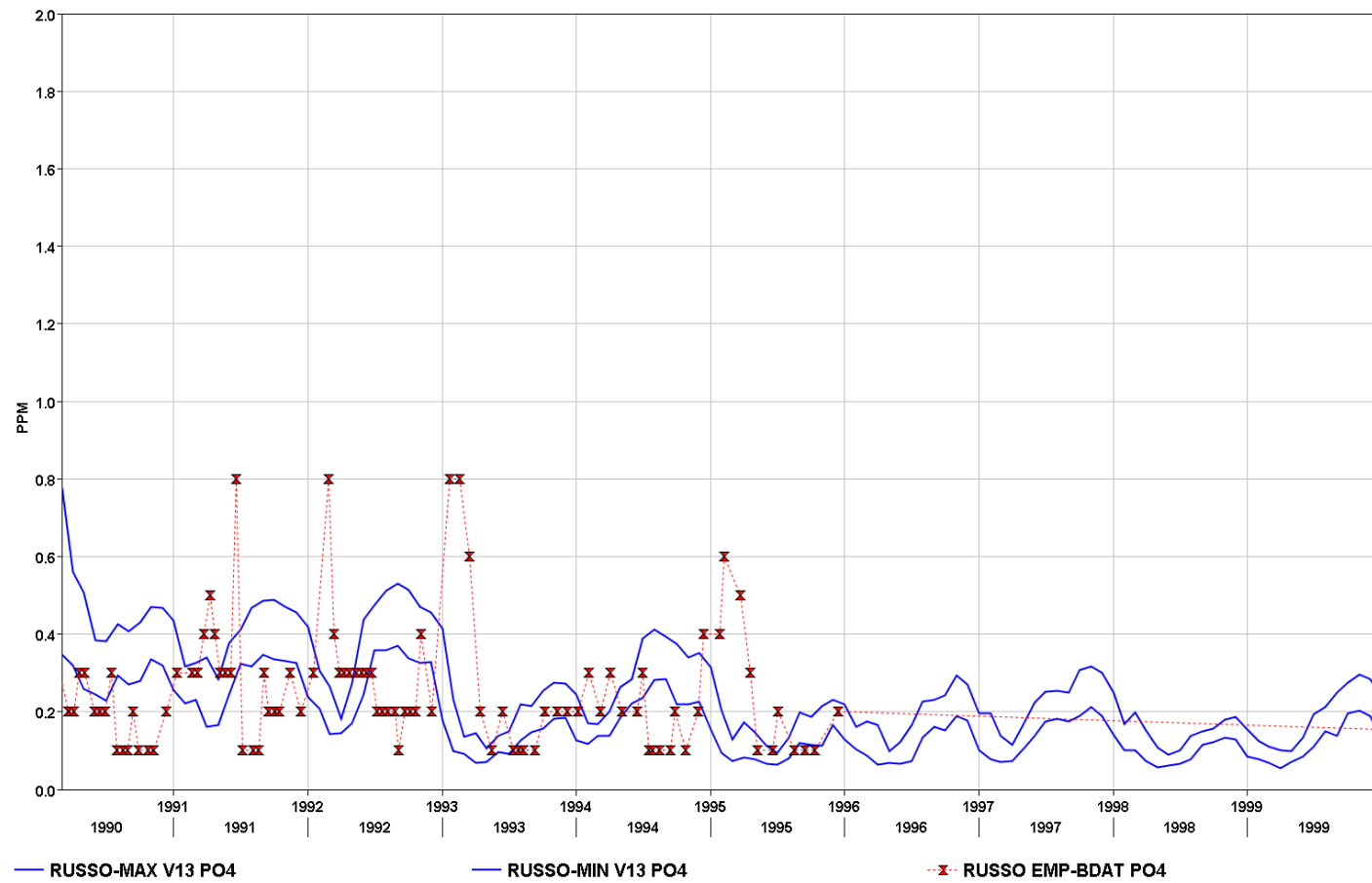


Figure A IV. 42 PO₄ at Russo early years.

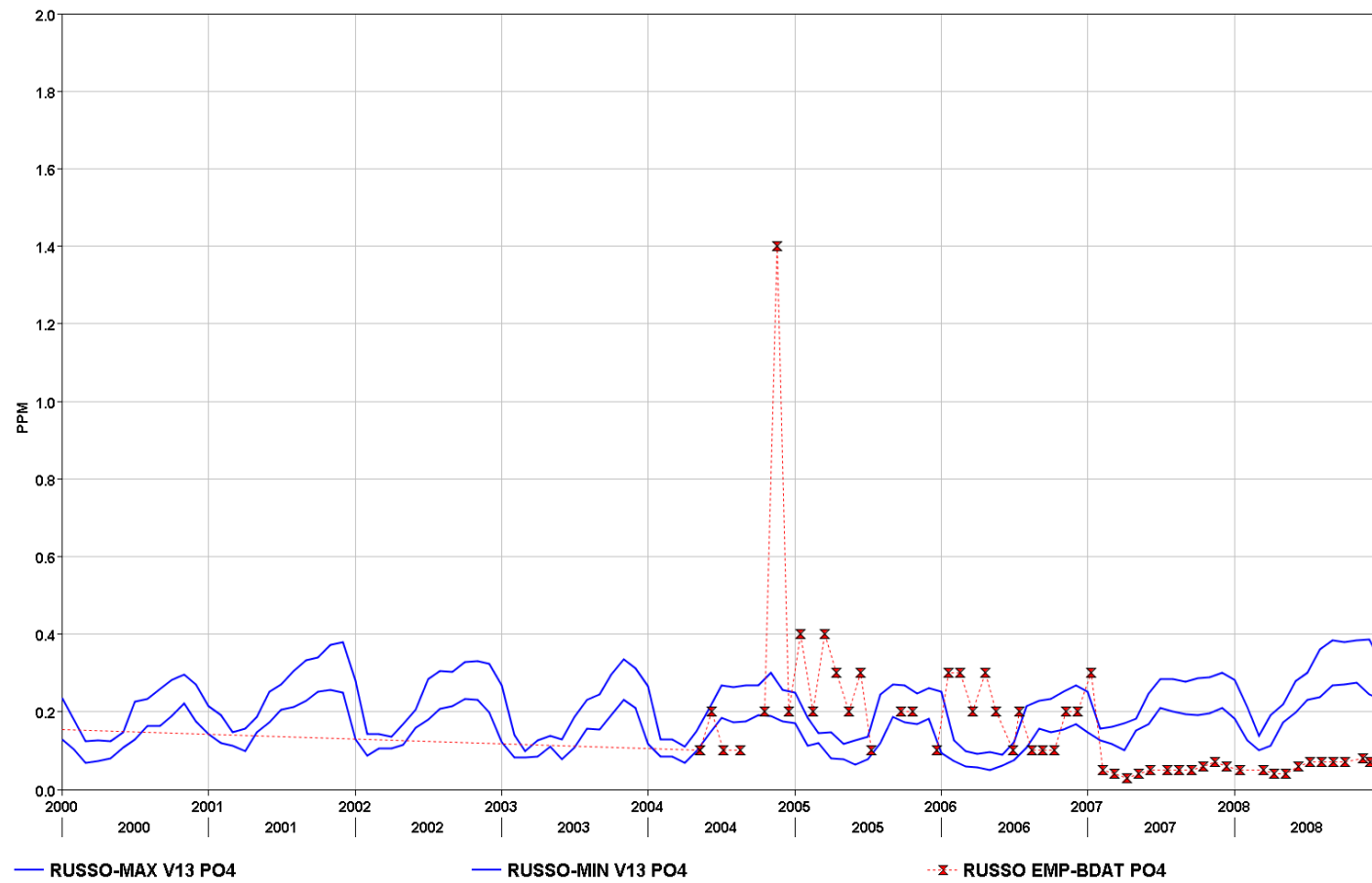


Figure A IV. 43 PO₄ at Russo later years.

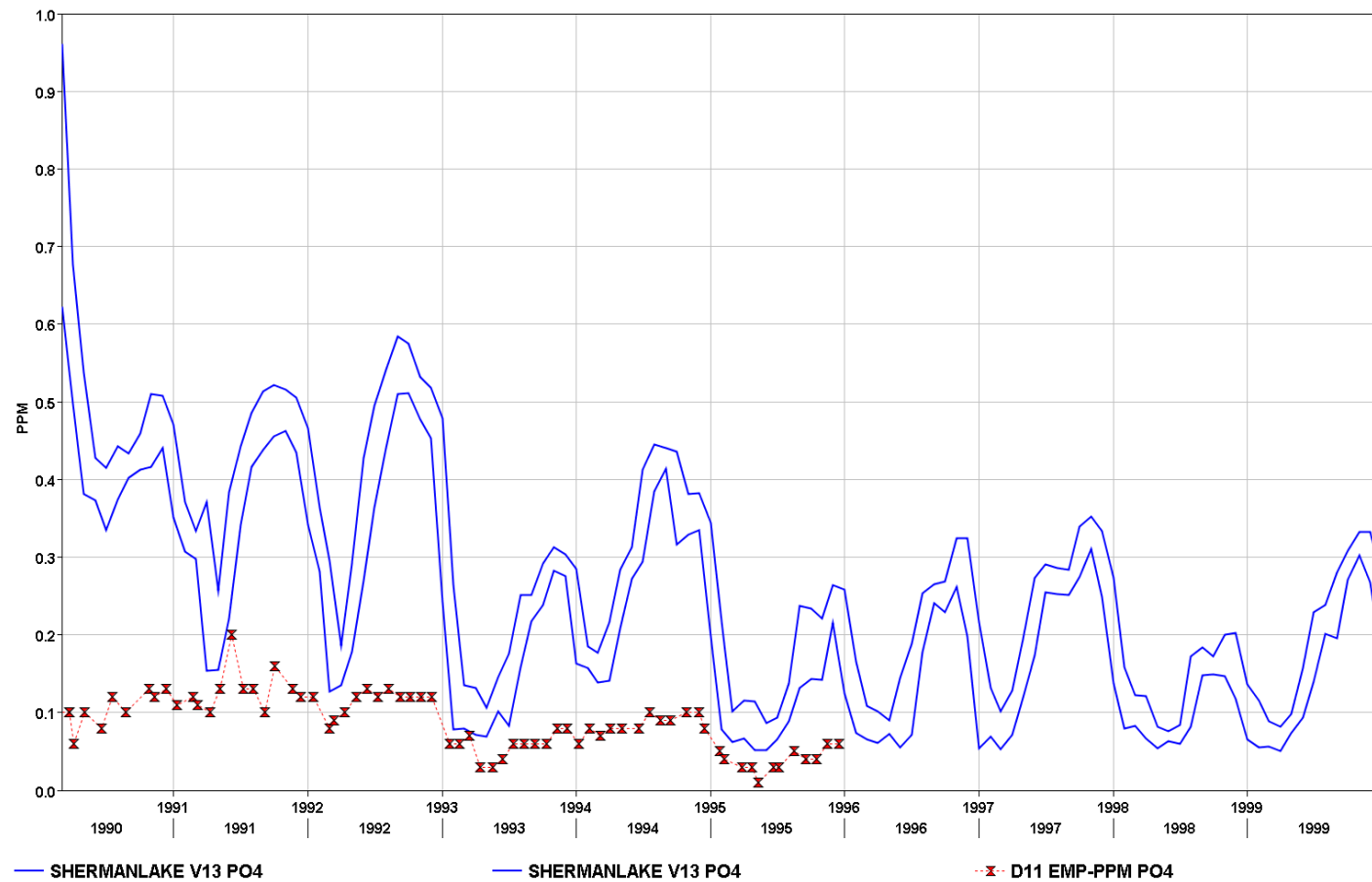


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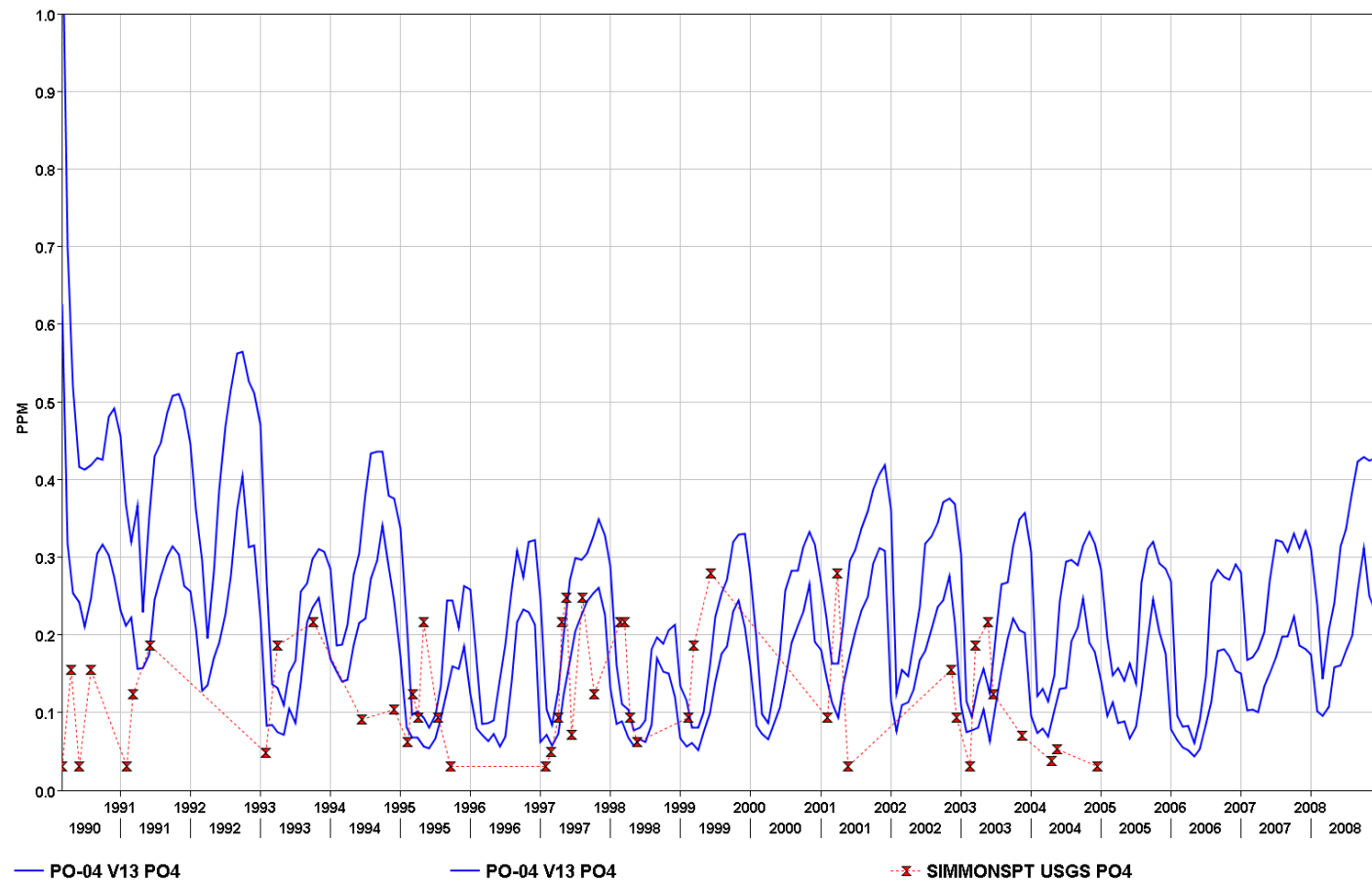


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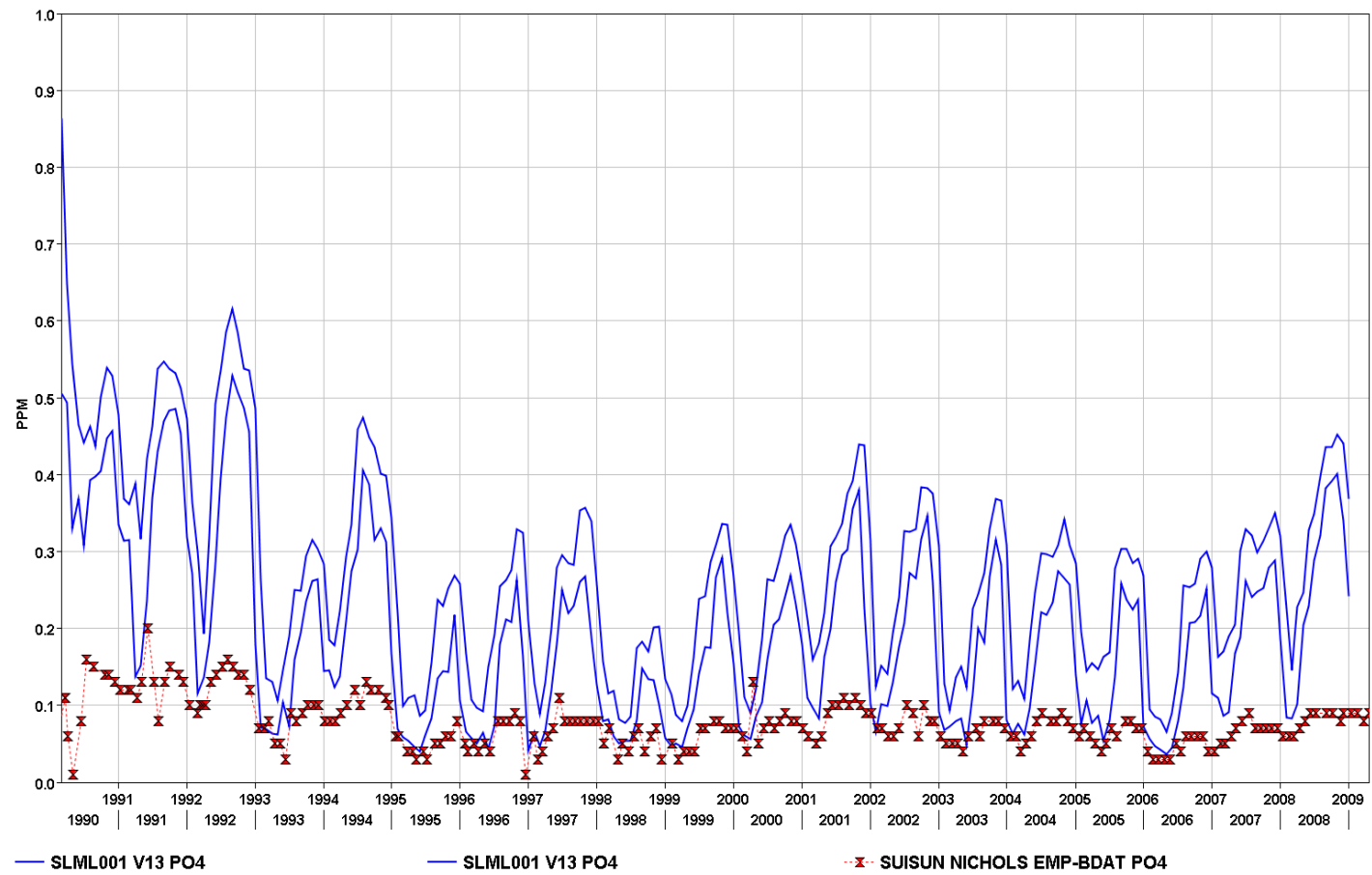


Figure A IV. 46 PO₄ at SLM001 all years.

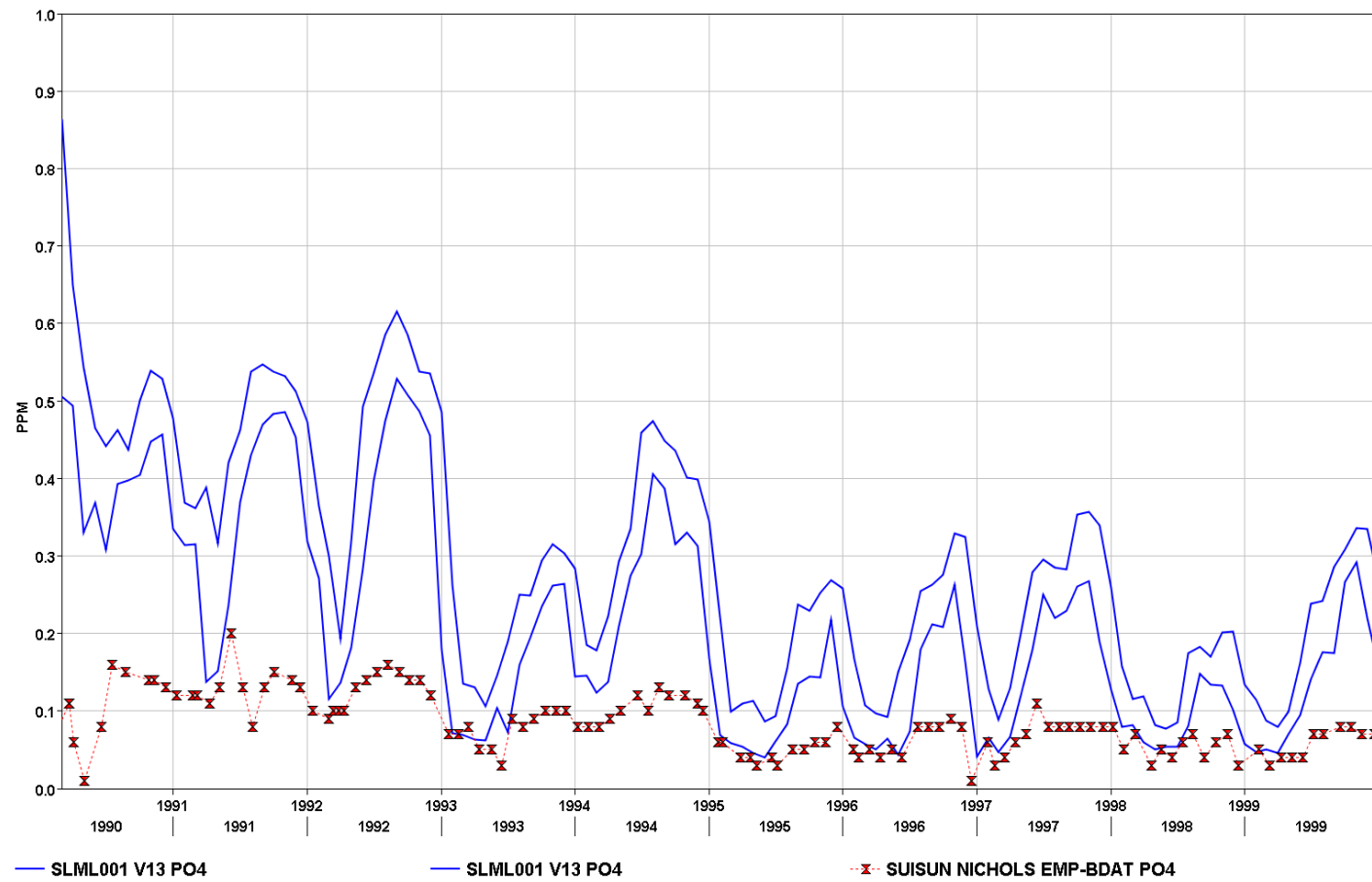


Figure A IV. 47 PO₄ at SLM001 early years.

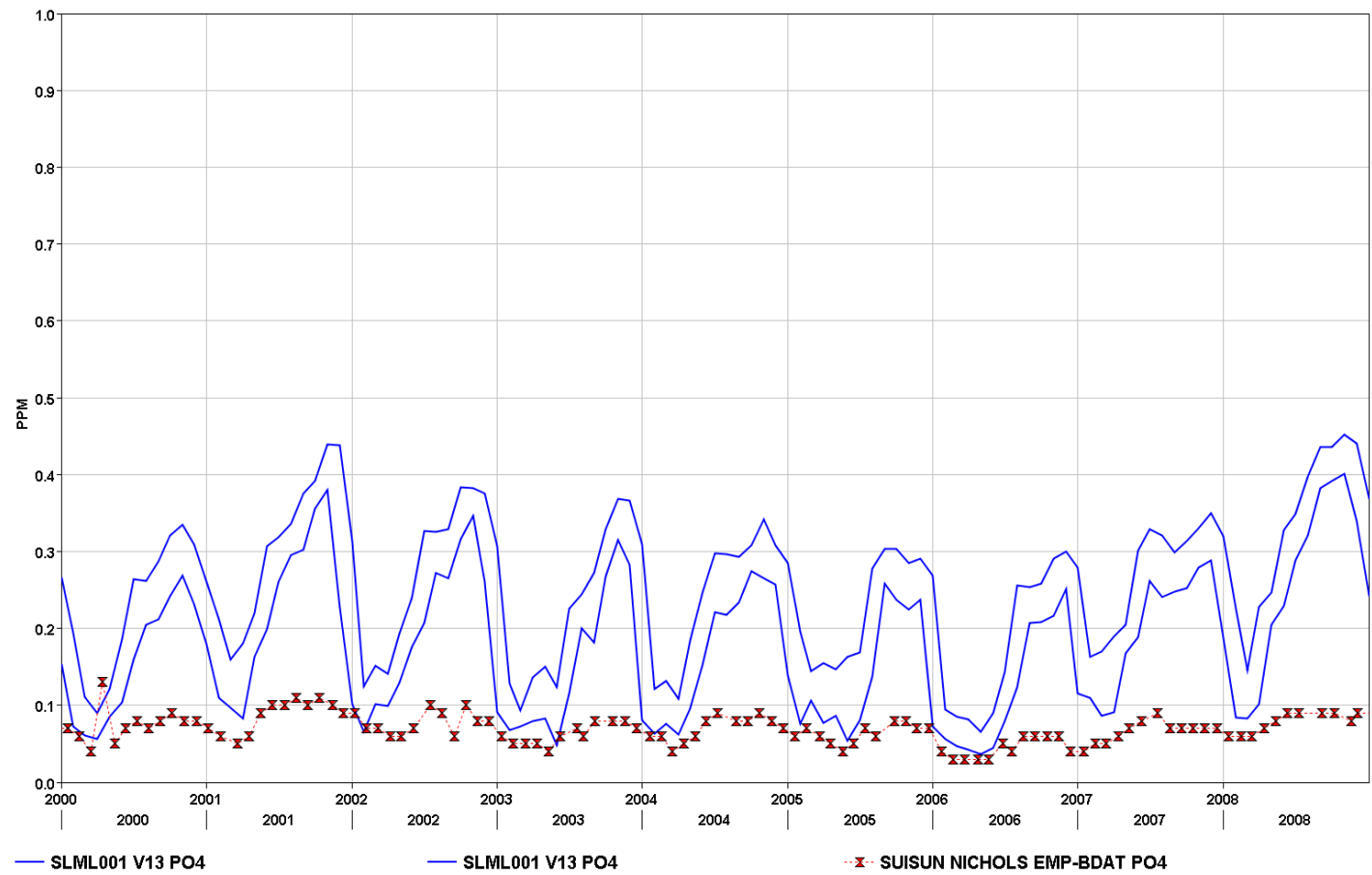


Figure A IV. 48 PO₄ at SLM001 later years.

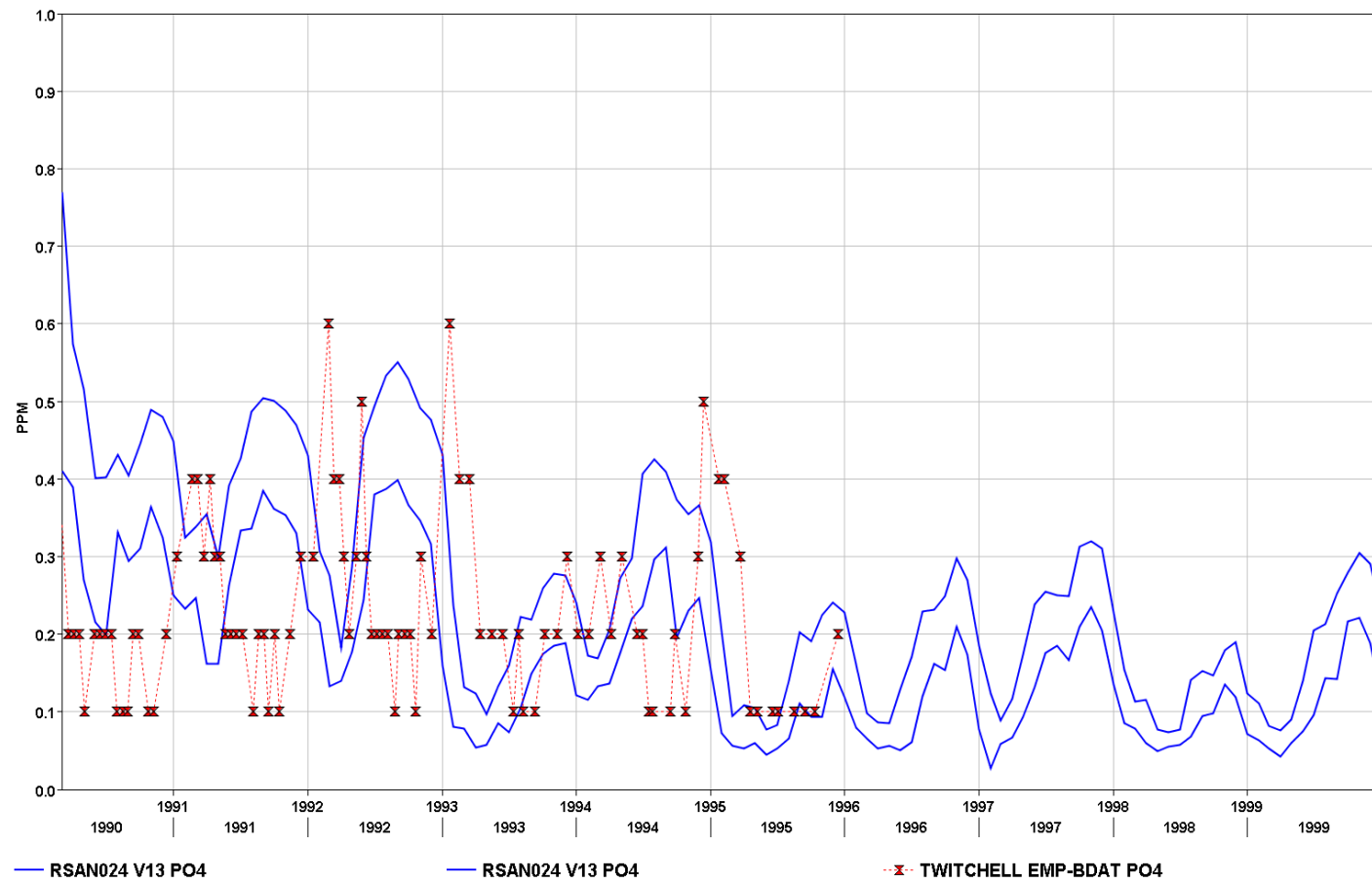


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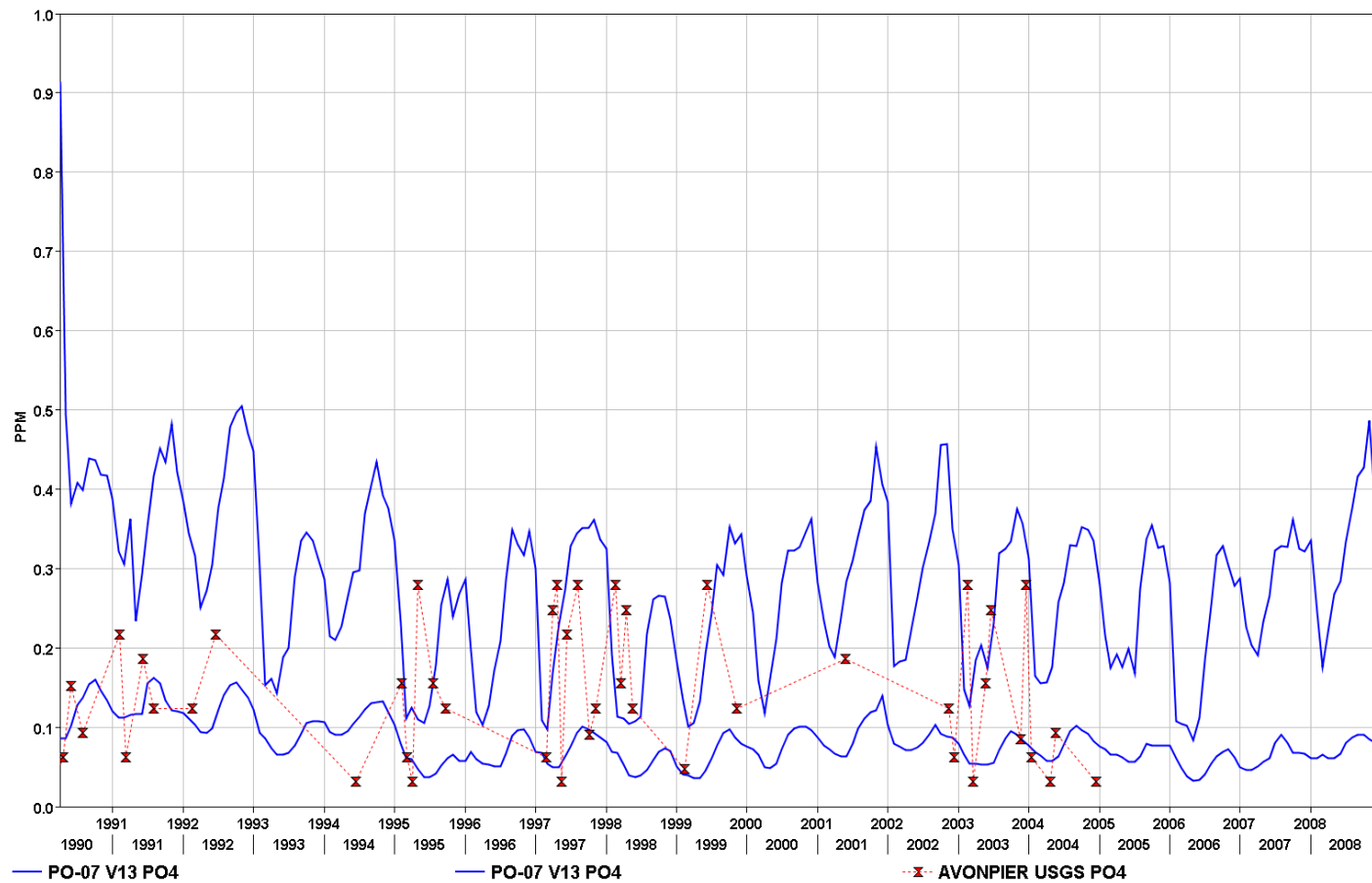


Figure A IV. 50 PO₄ at PO-07 all years.

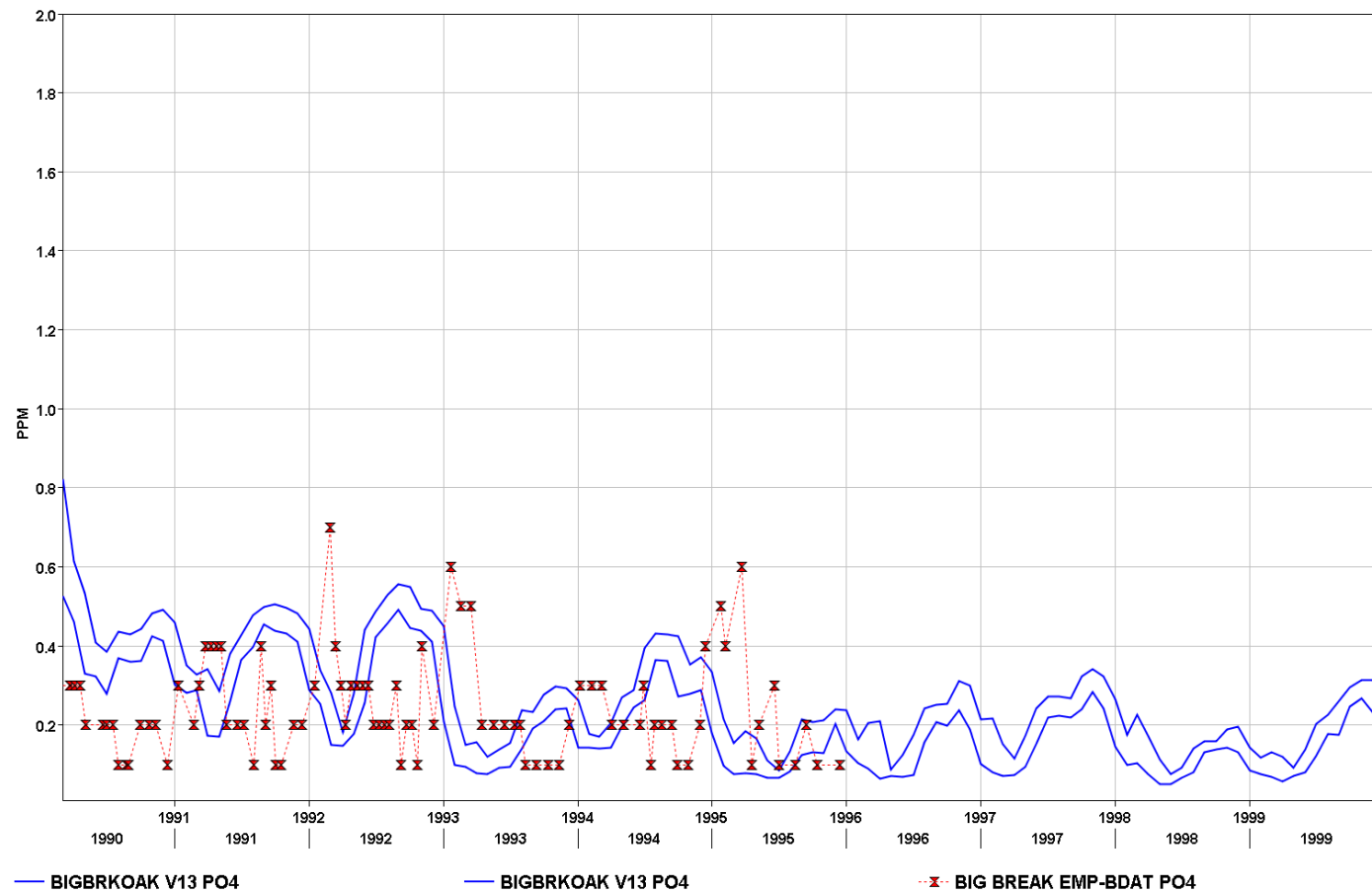


Figure A IV. 51 PO₄ at BIR BREAK early years.

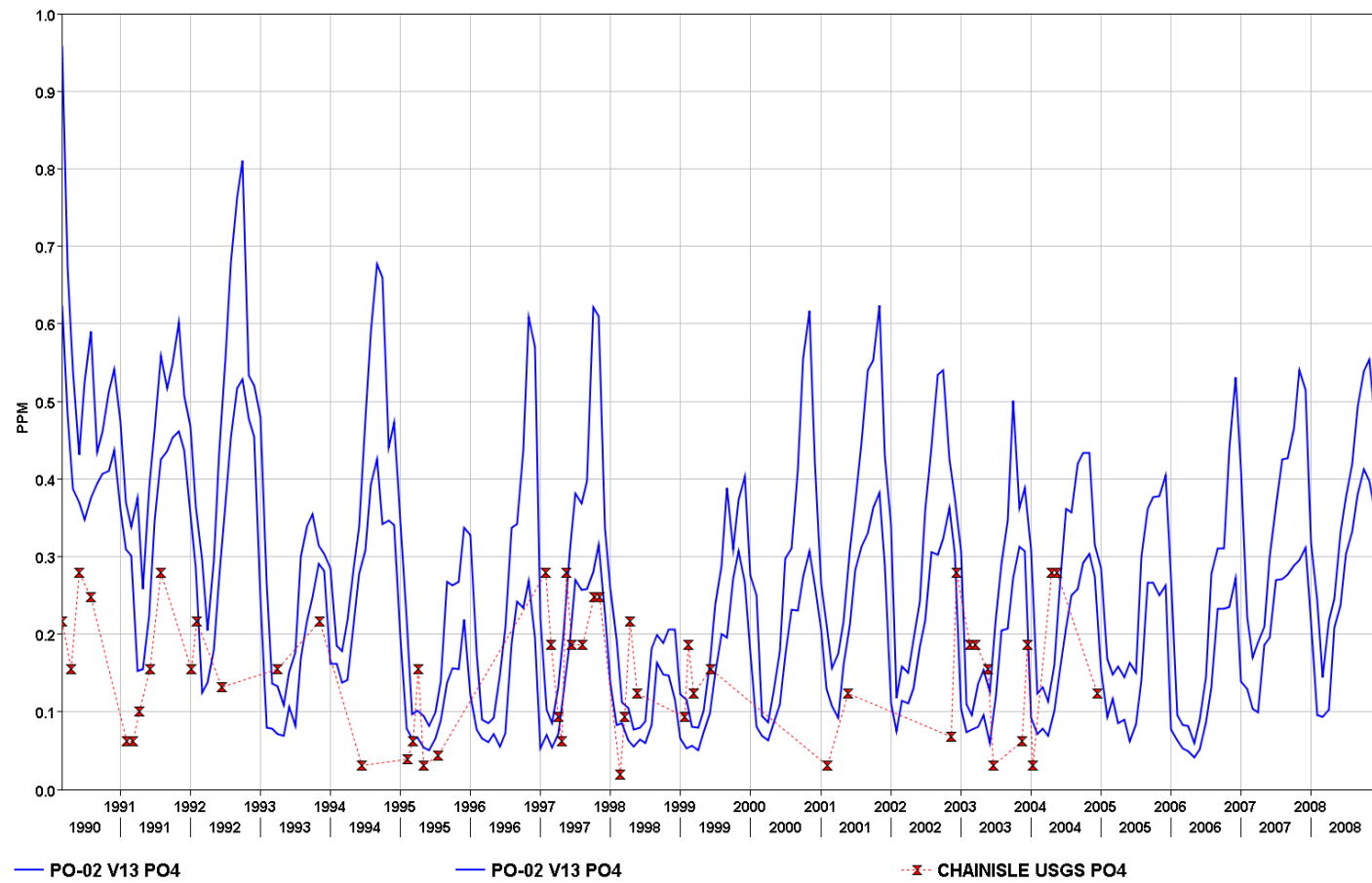


Figure A IV. 52 PO₄ at PO-02 all years.

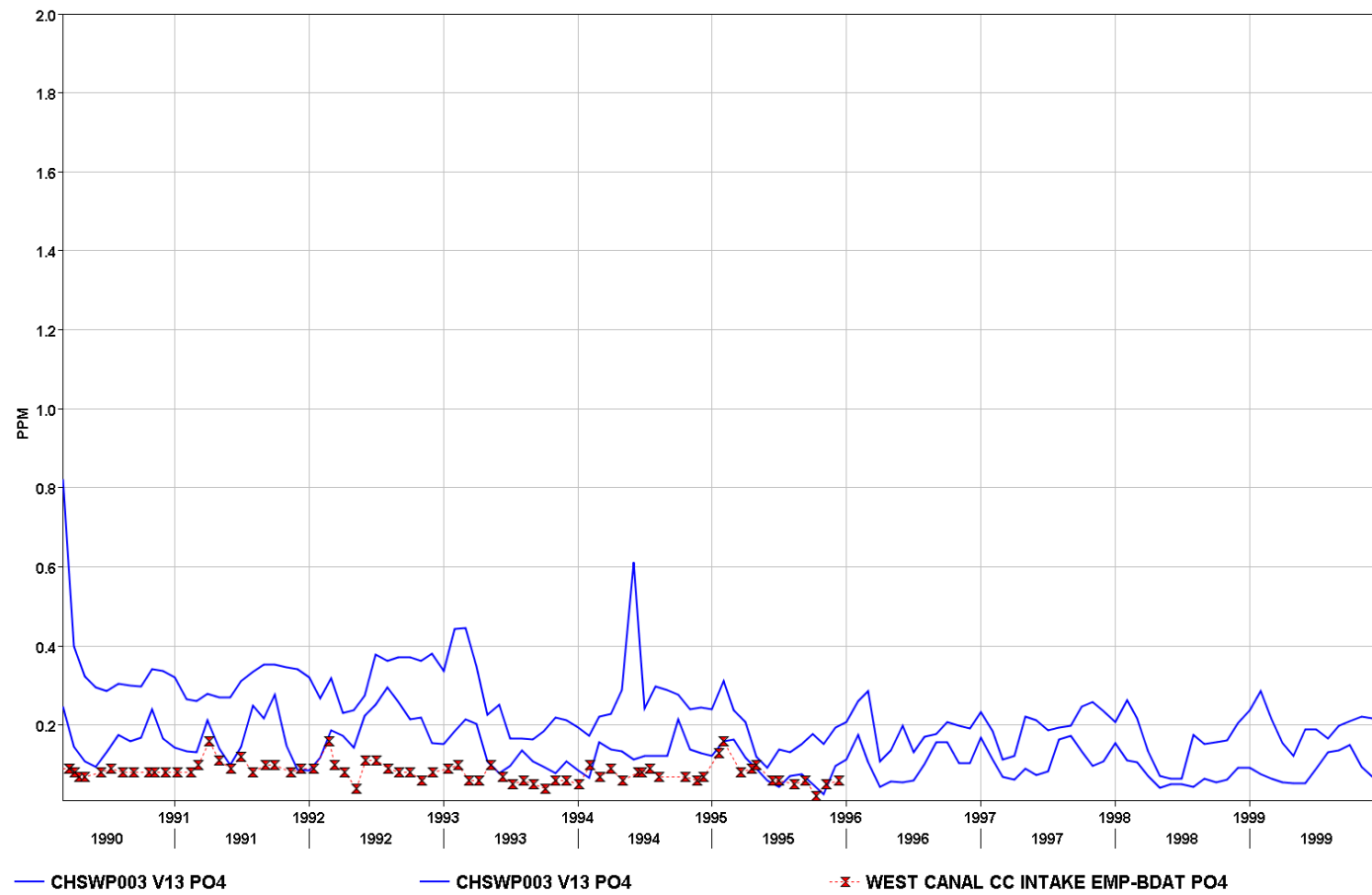


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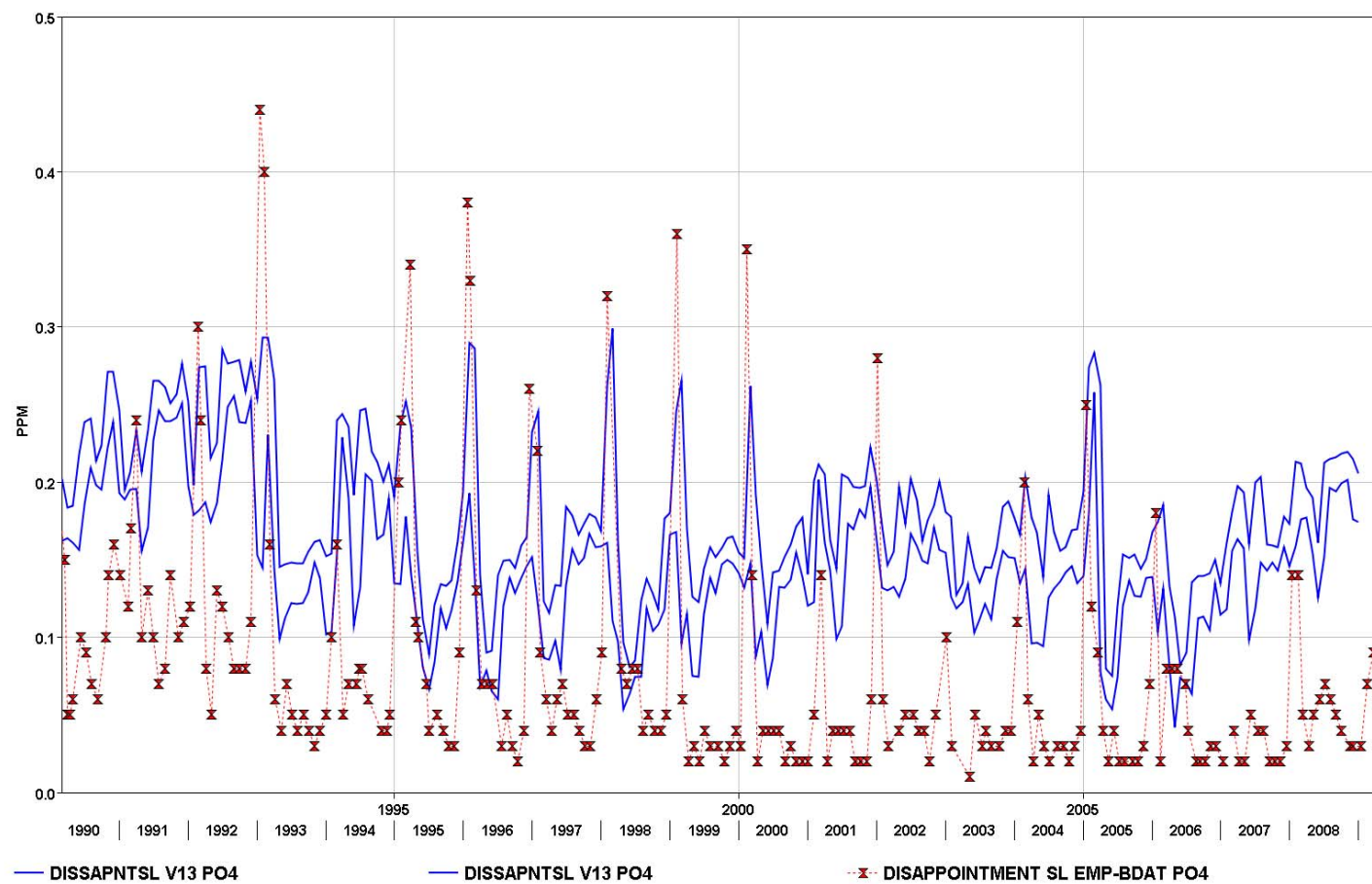


Figure A IV. 54 PO₄ at DISAP SL all years.

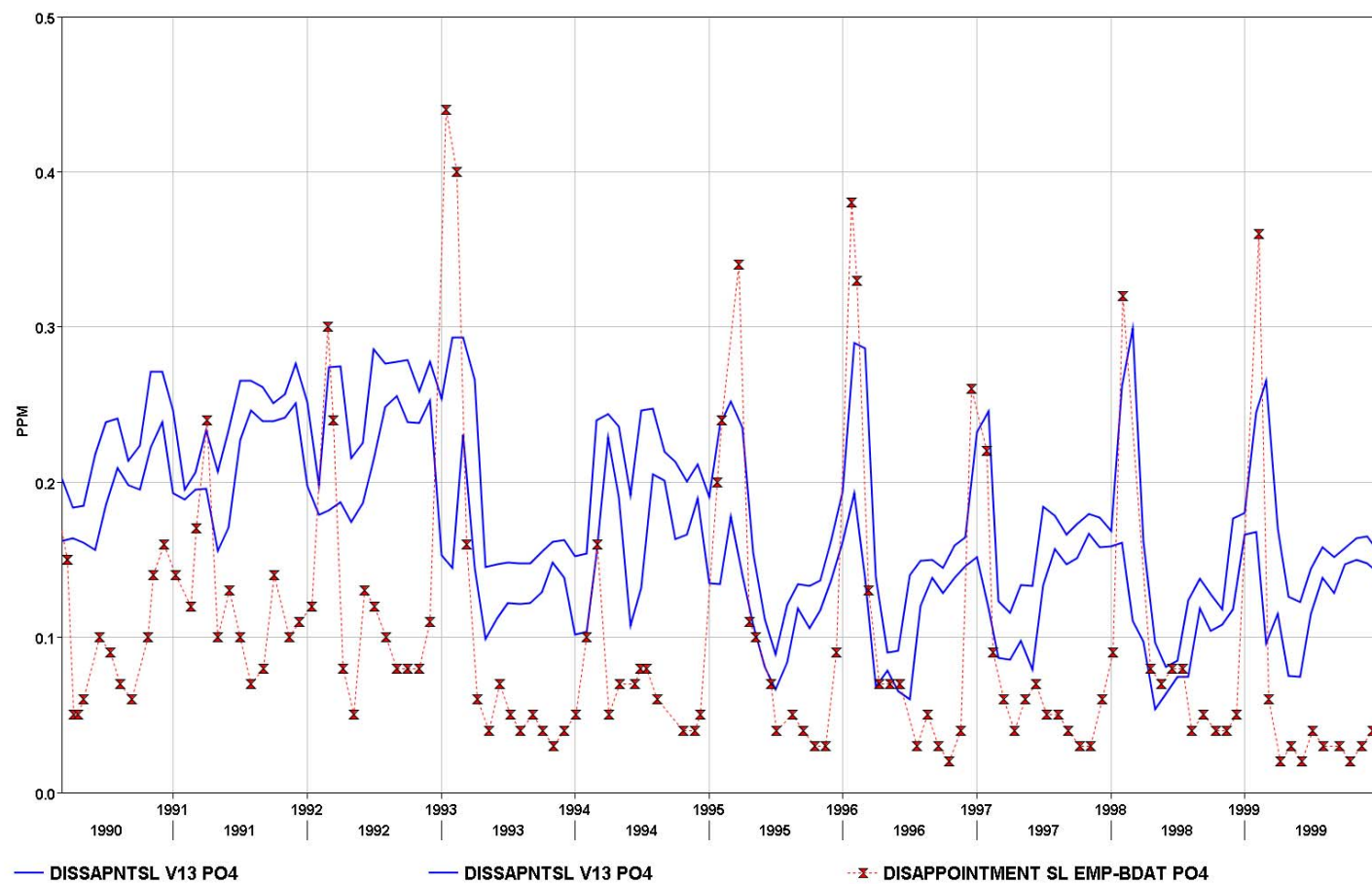


Figure A IV. 55 PO₄ at DISAP SL early years.

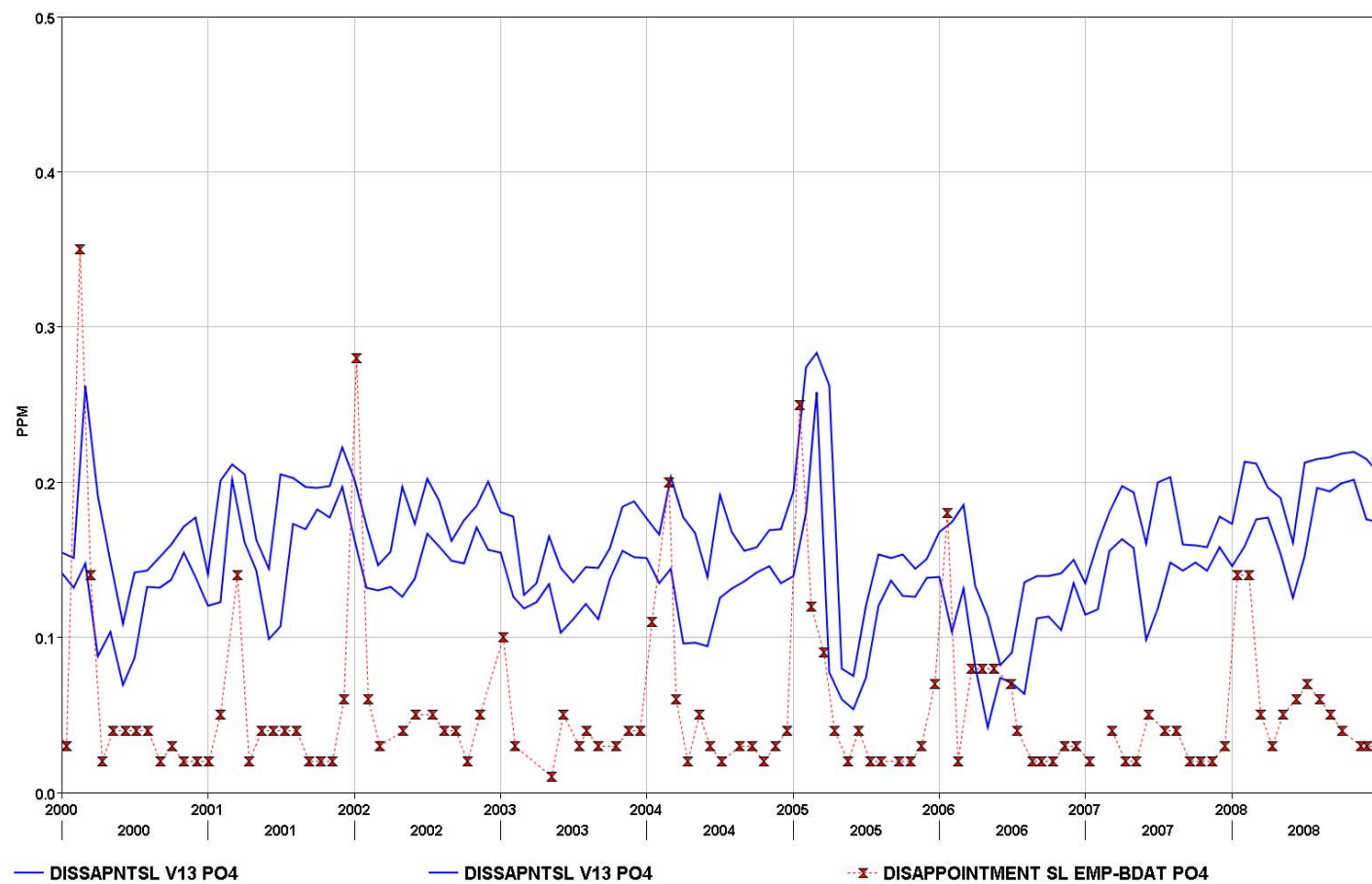


Figure A IV. 56 PO₄ at DISAP SL later years.

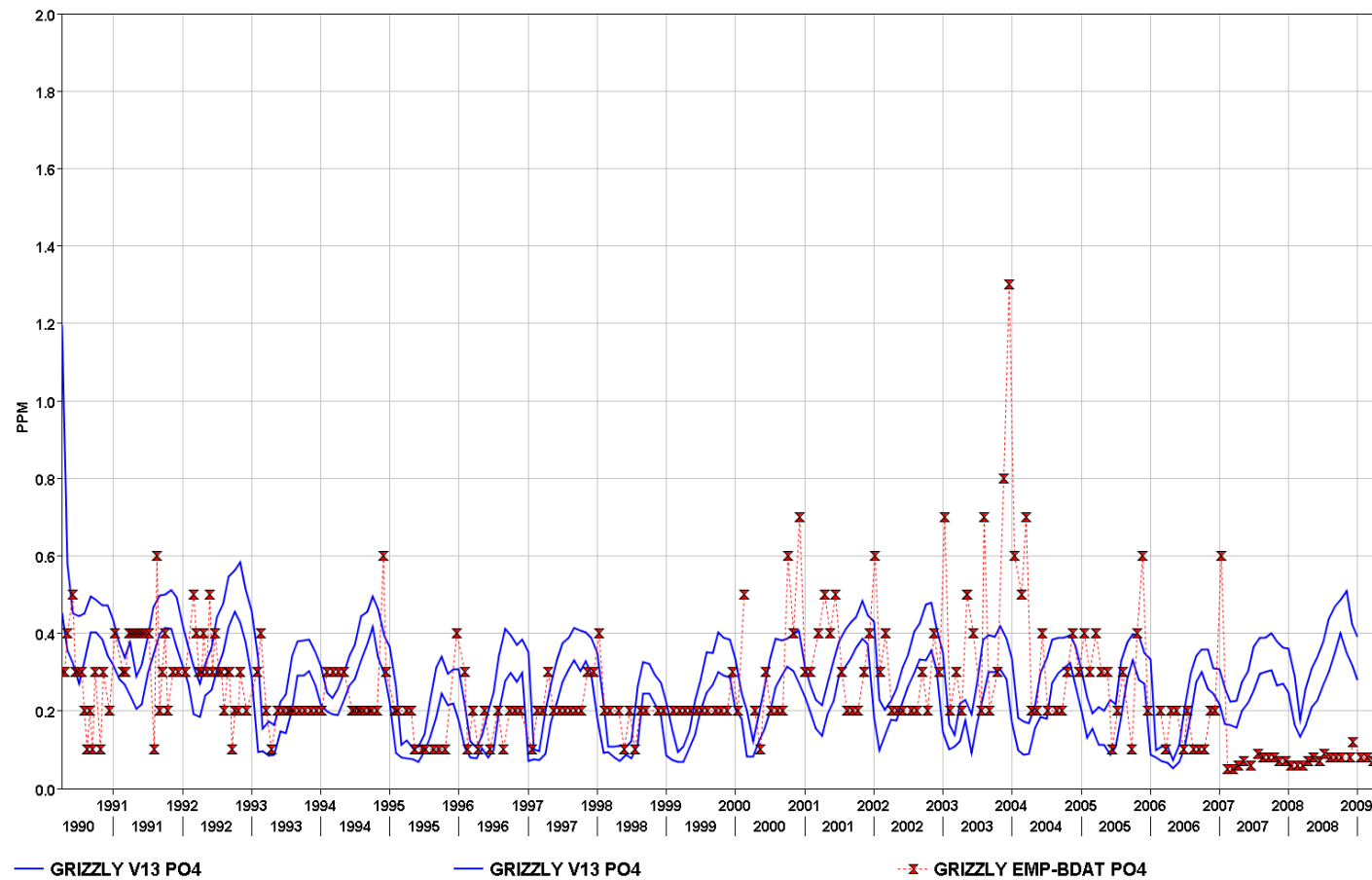


Figure A IV. 57 PO₄ at GRIZZLY all years.

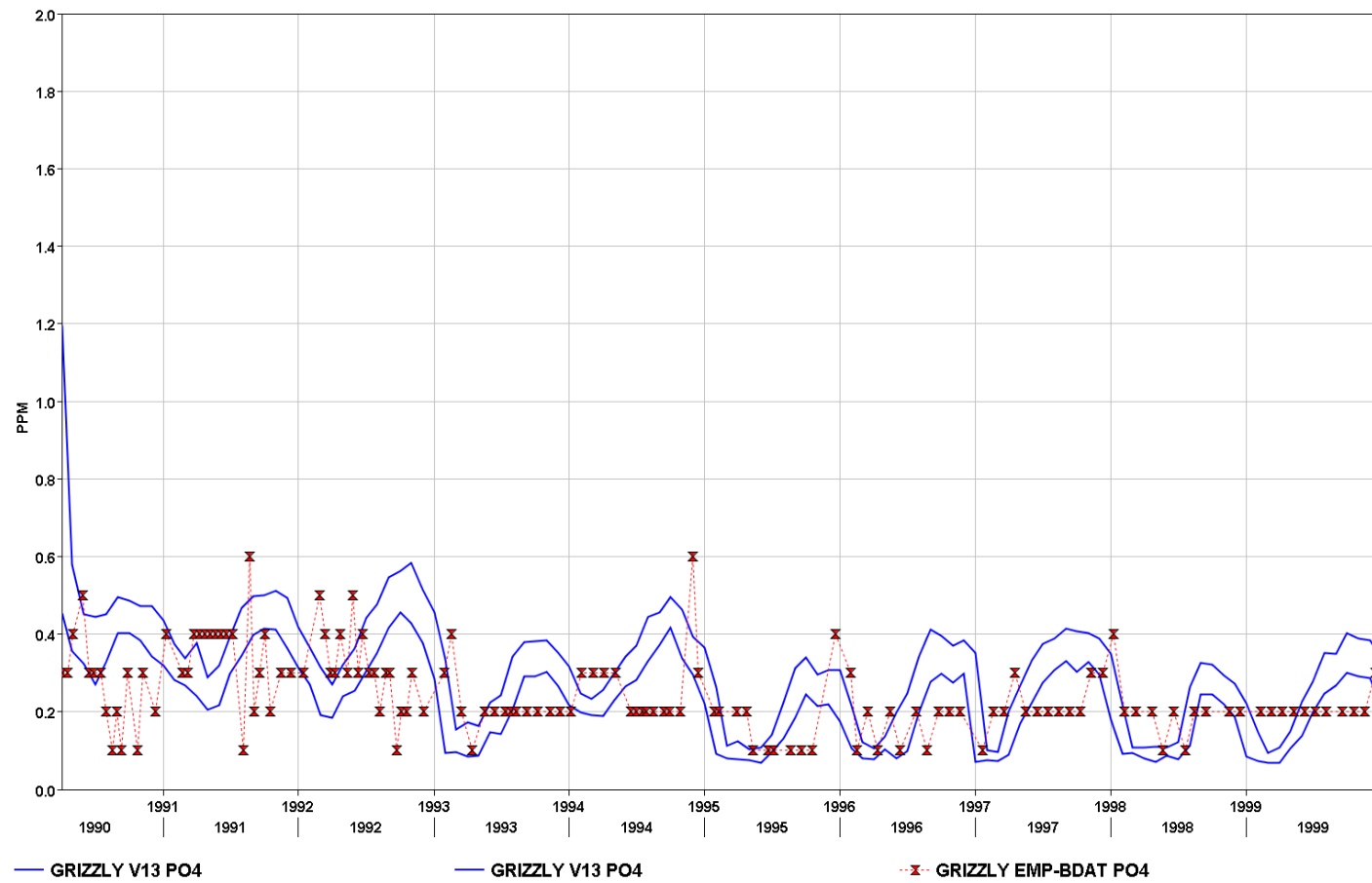


Figure A IV. 58 PO₄ at GRIZZLY early years.

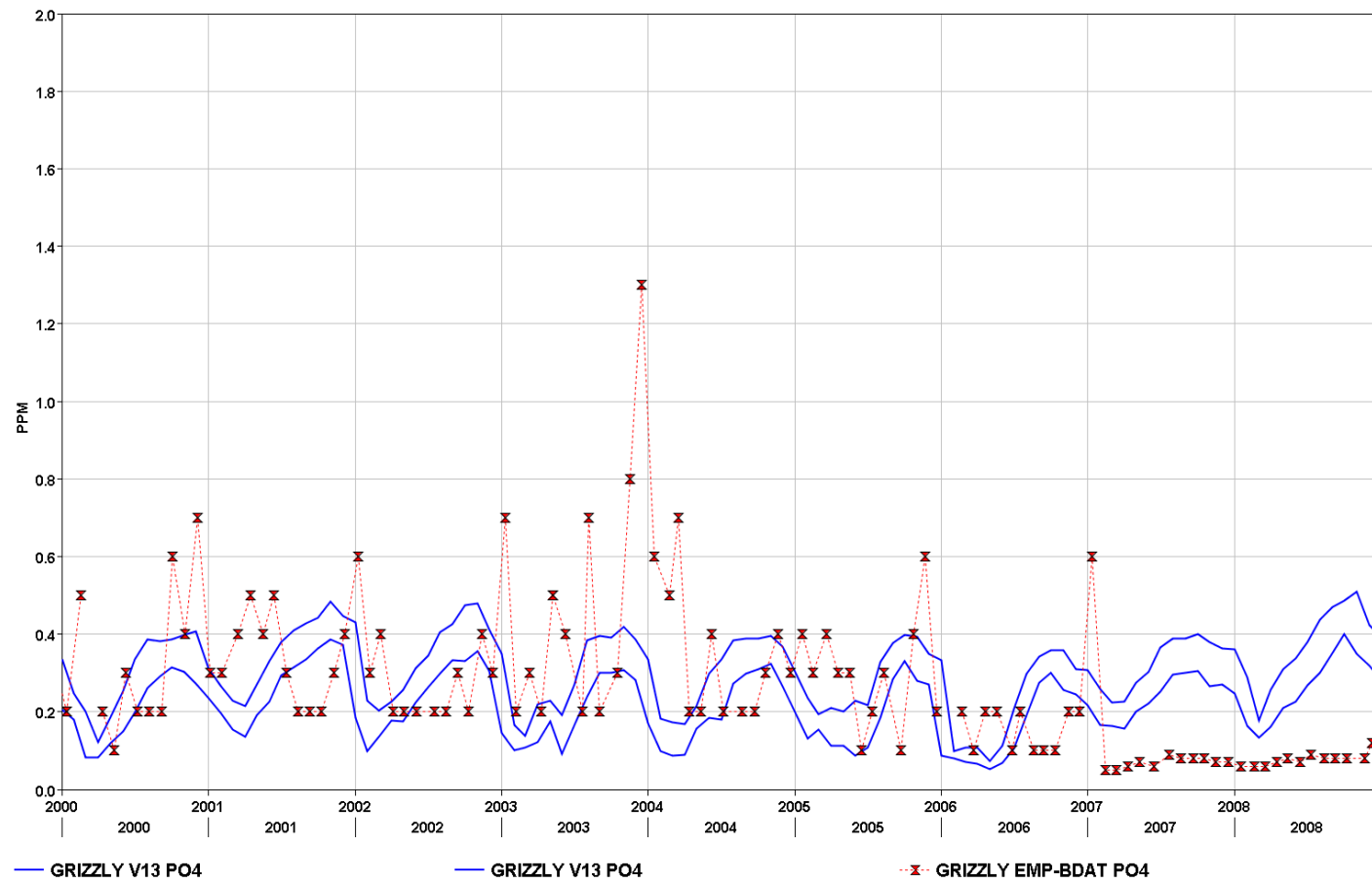


Figure A IV. 59 PO₄ at GRIZZLY later years.

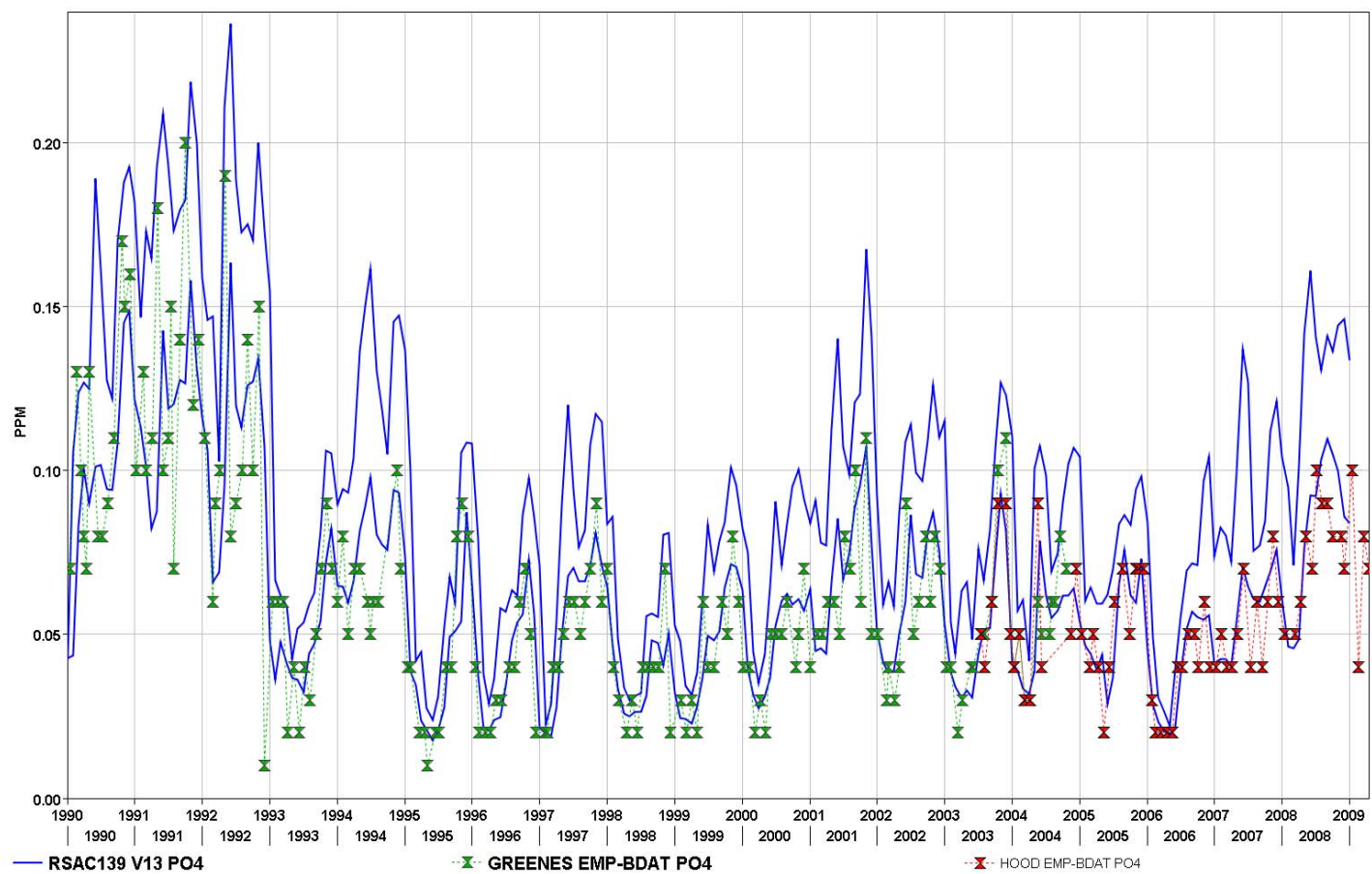


Figure A IV. 60 PO₄ at RASC139 all years.

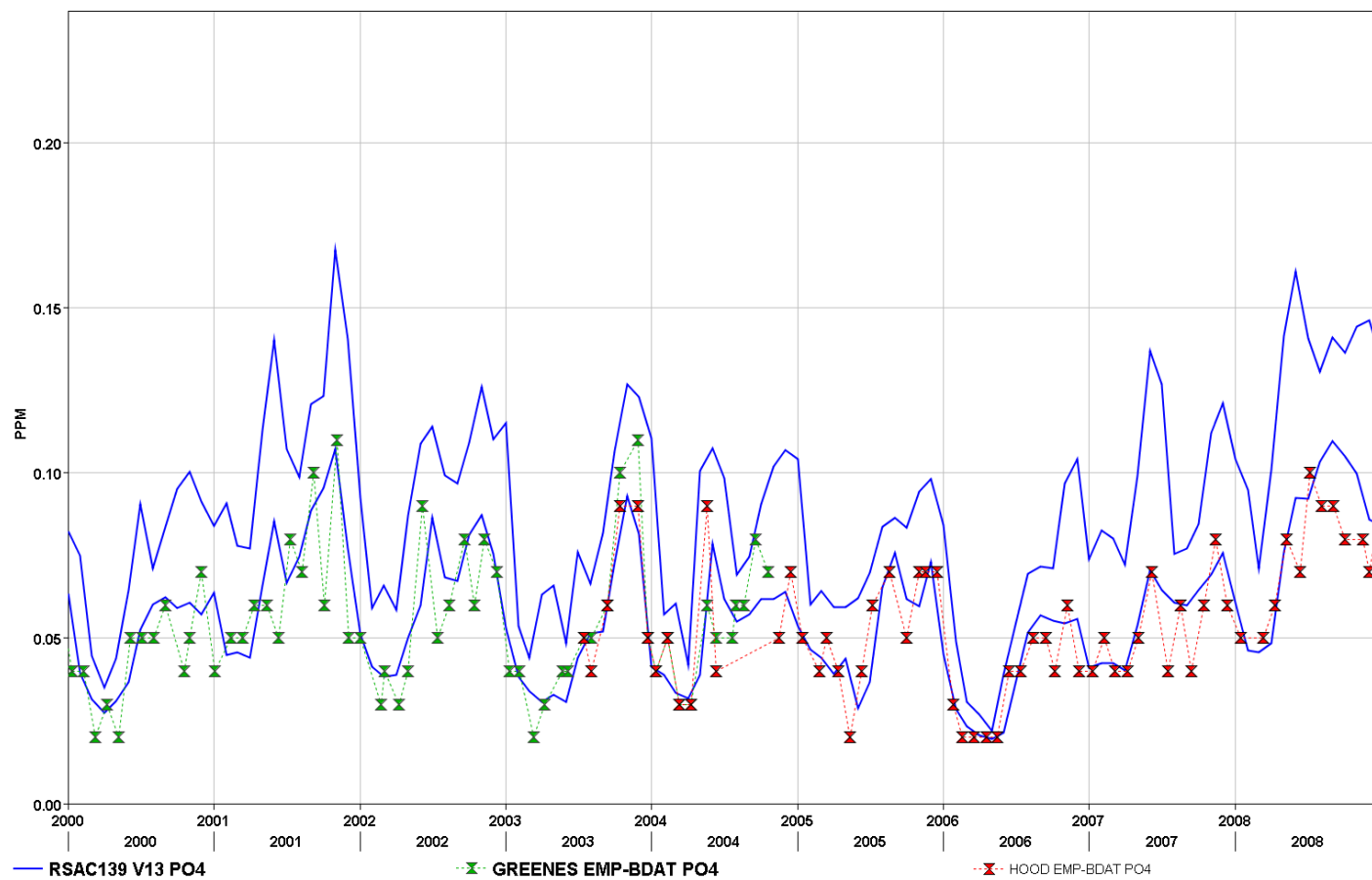


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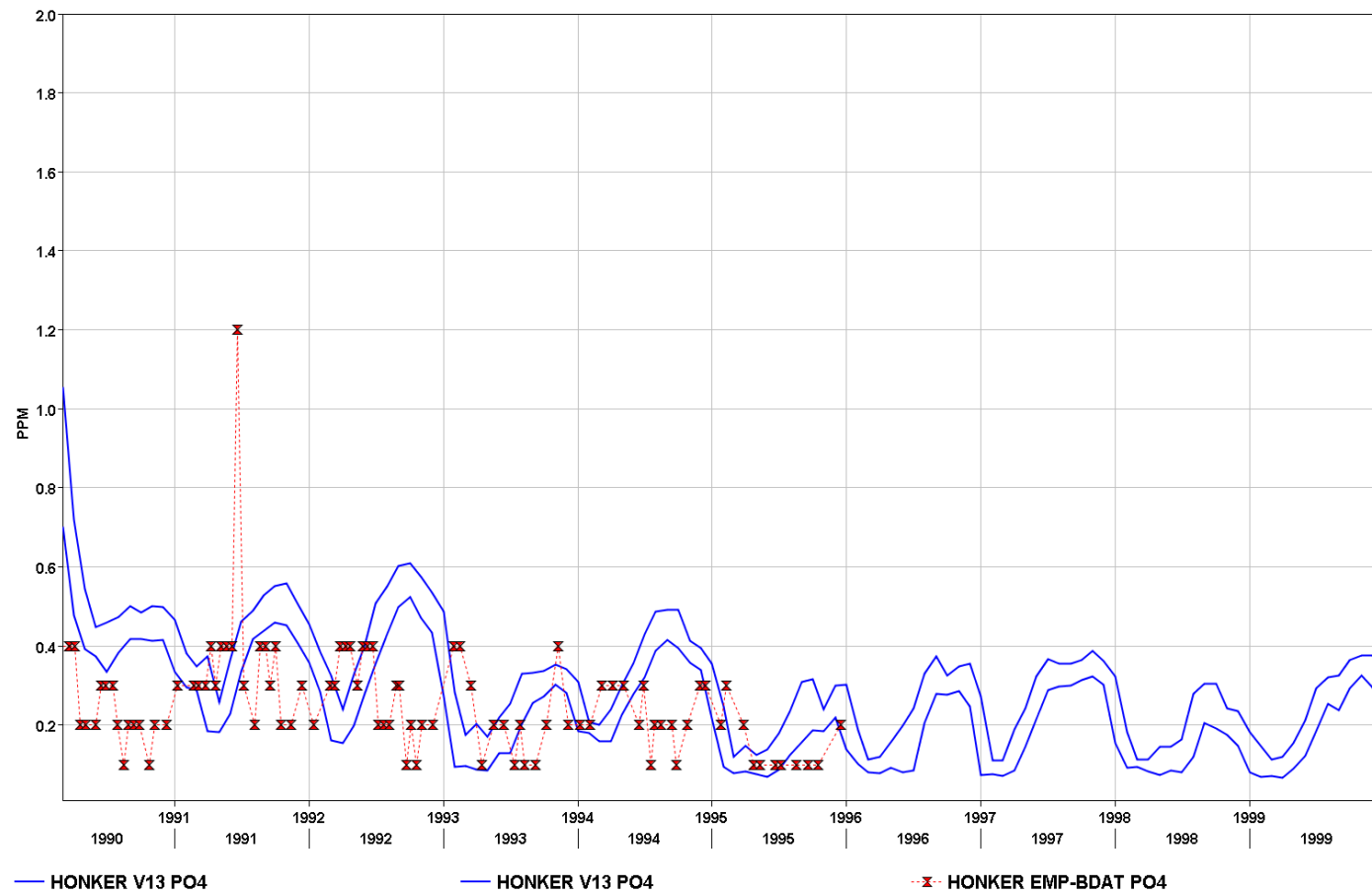


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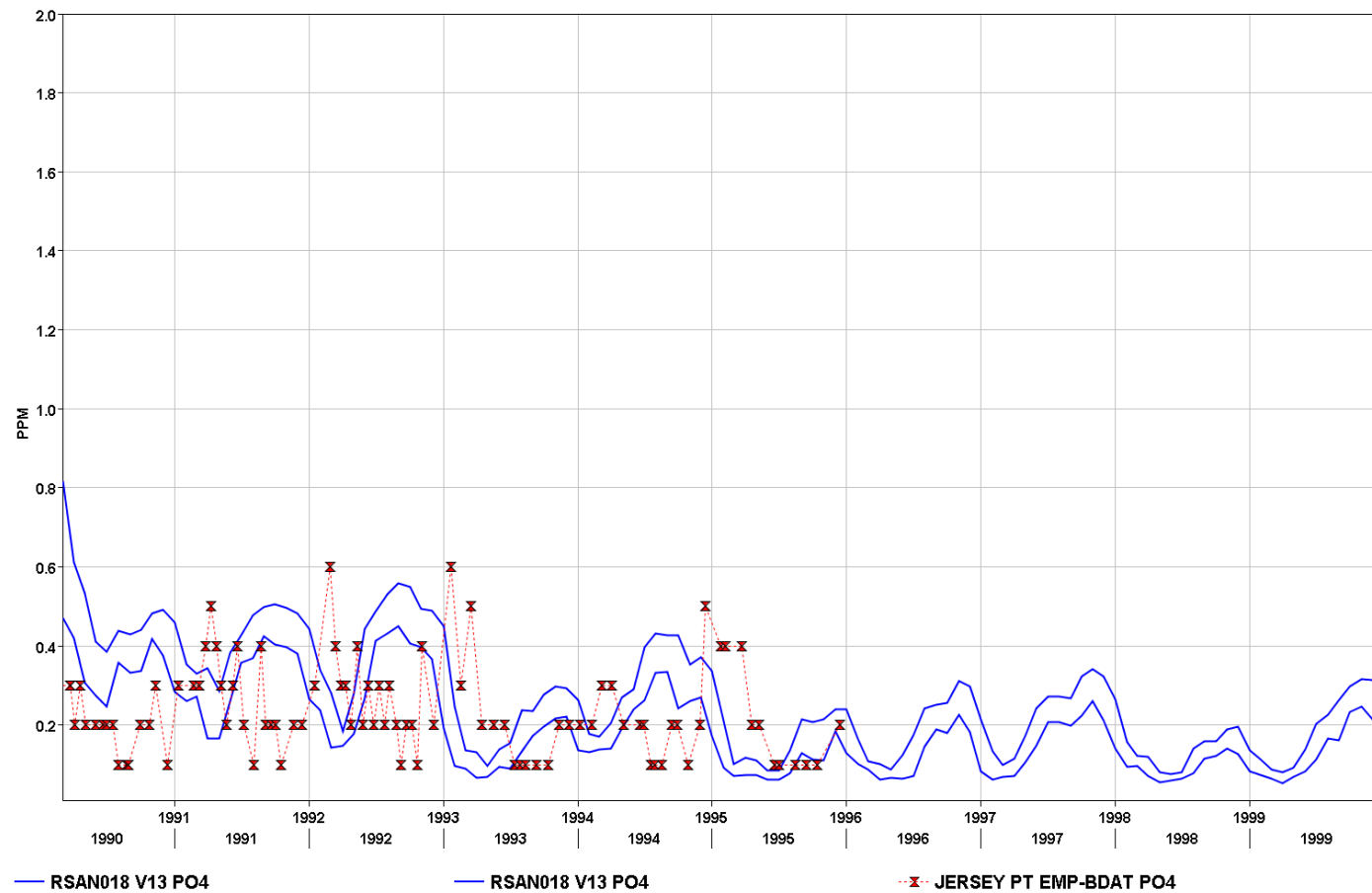


Figure A IV. 63 PO₄ at RSAN018 early years.

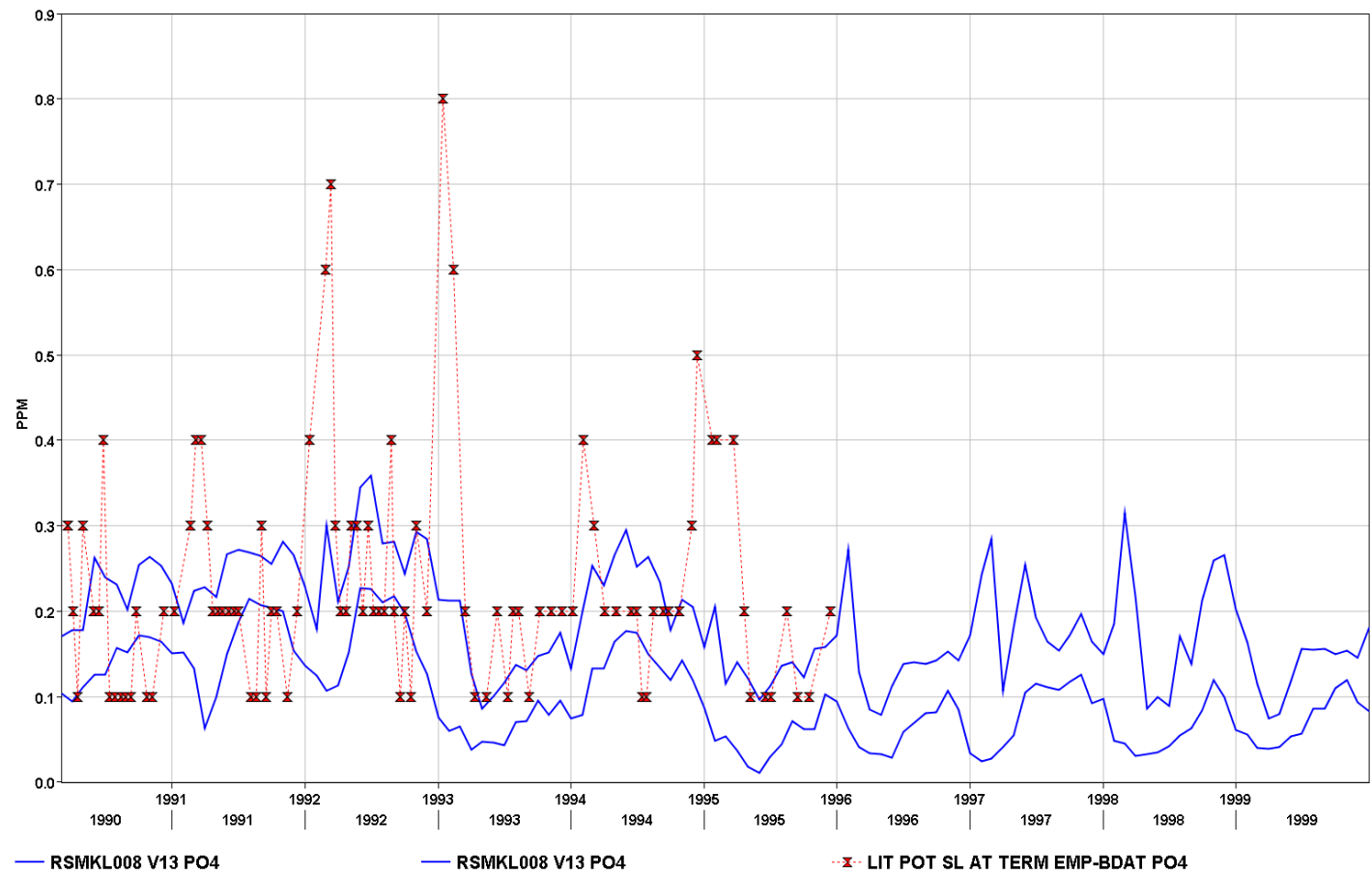


Figure A IV. 64 PO₄ at RSMKL008 early years.

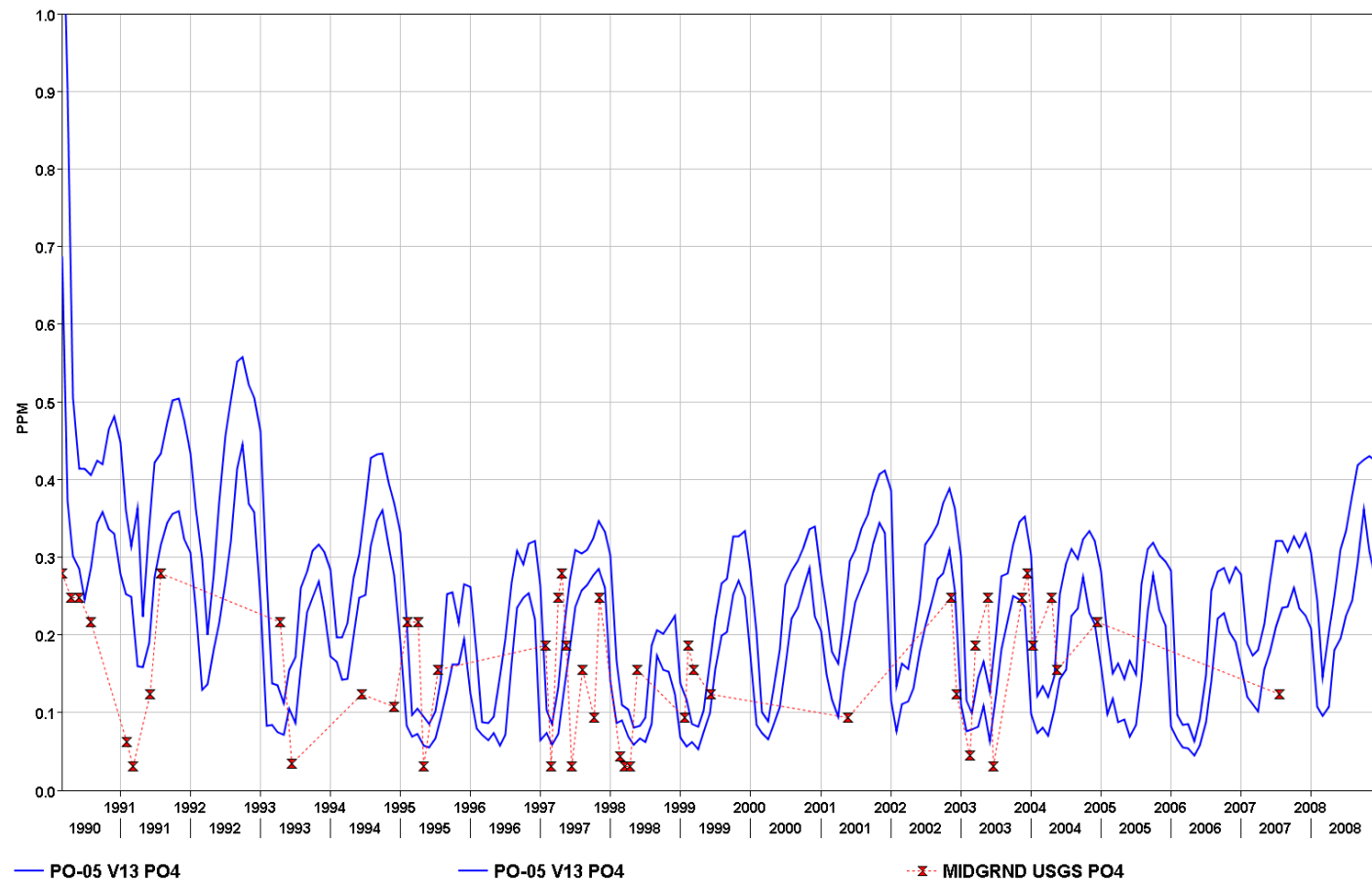


Figure A IV. 65 PO₄ at PO-05 all years.

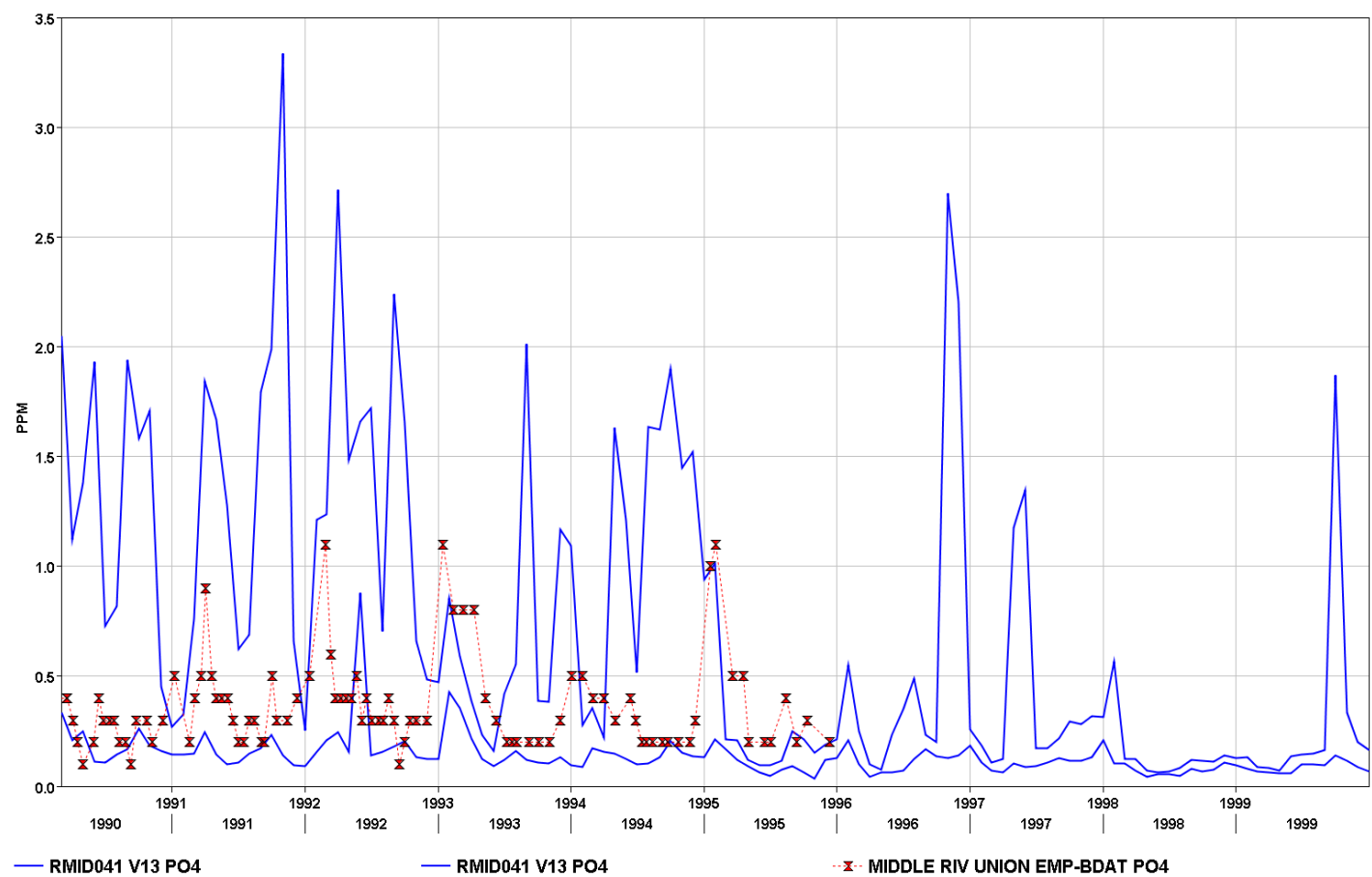


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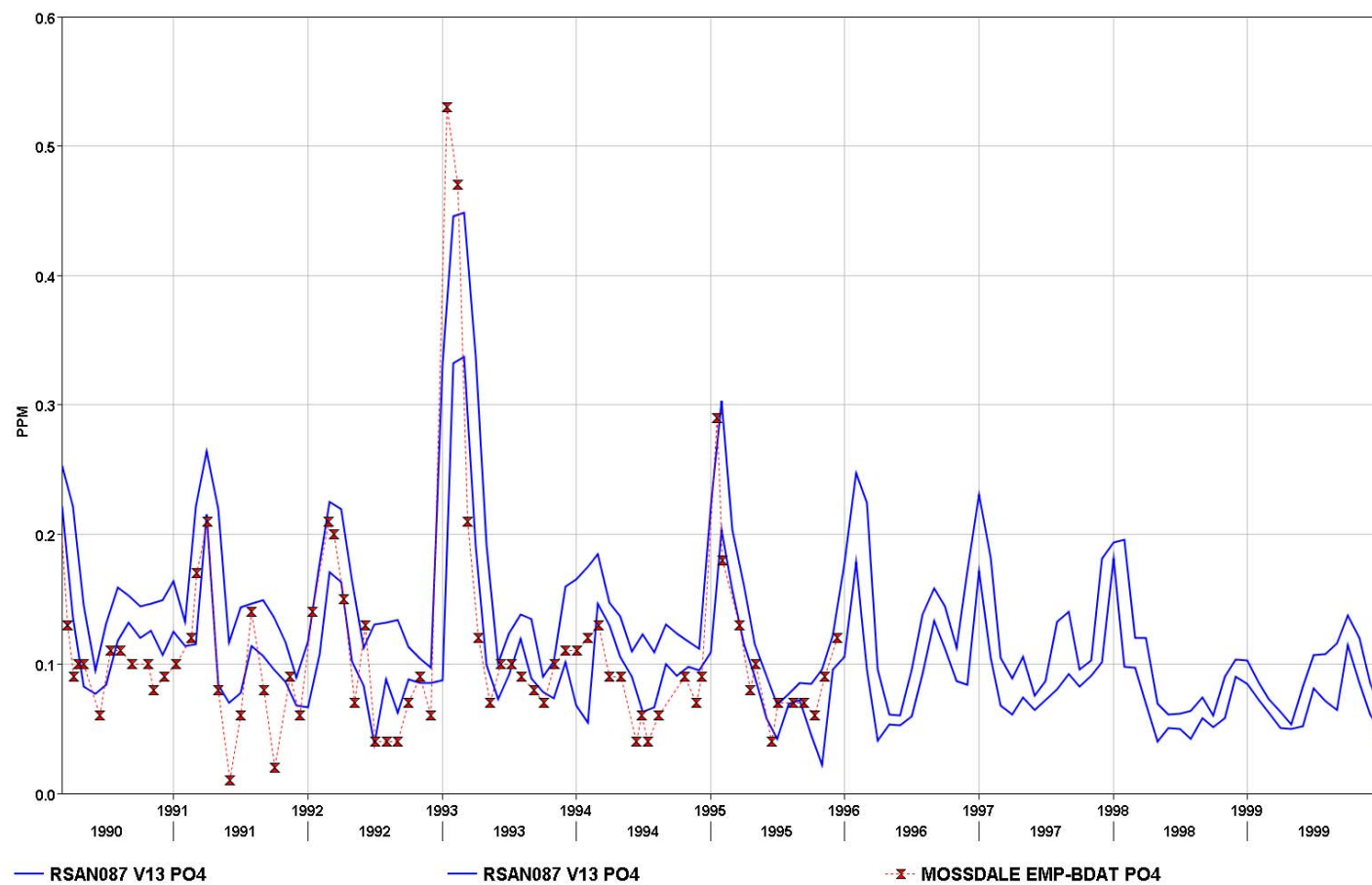


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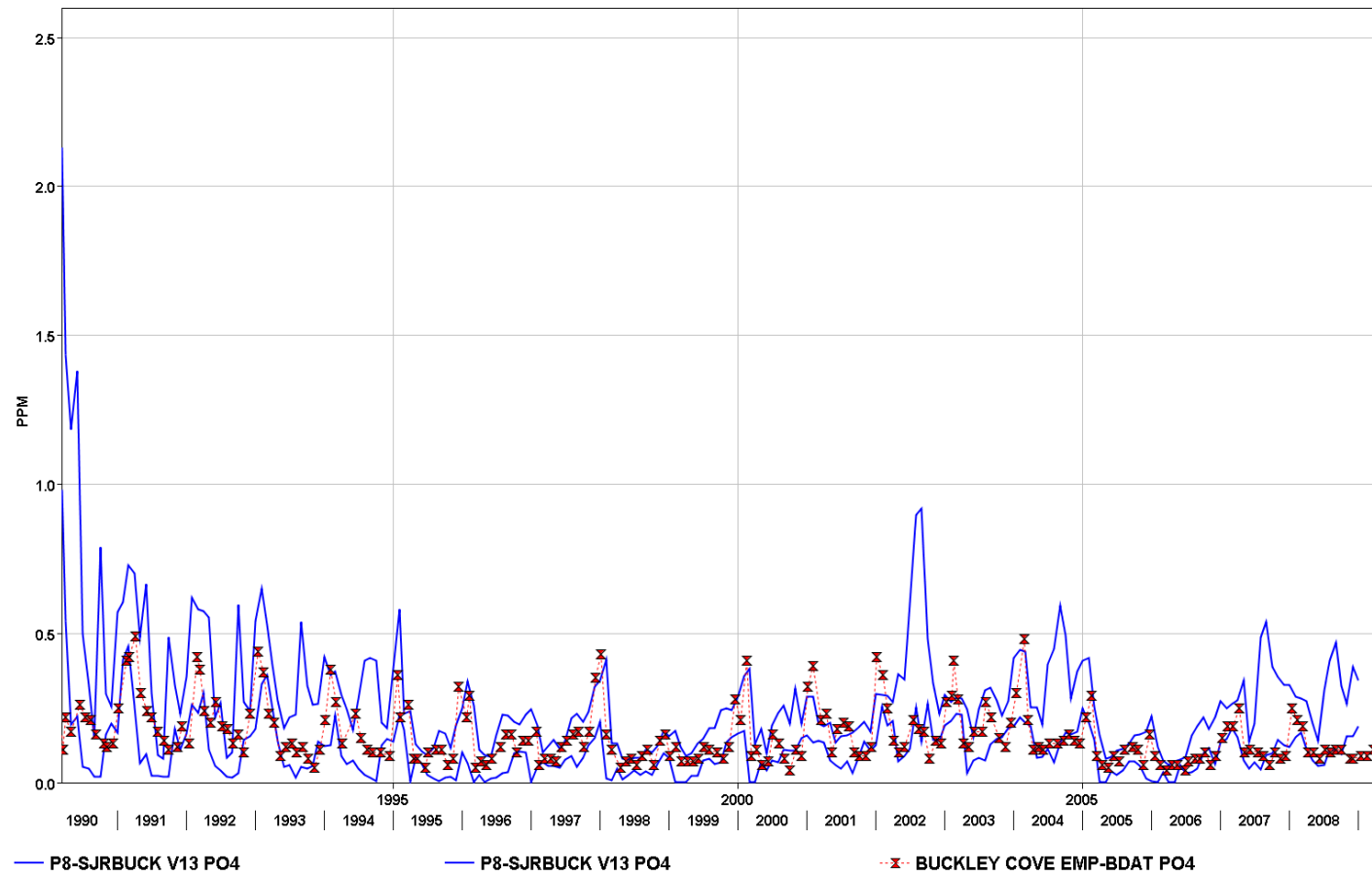


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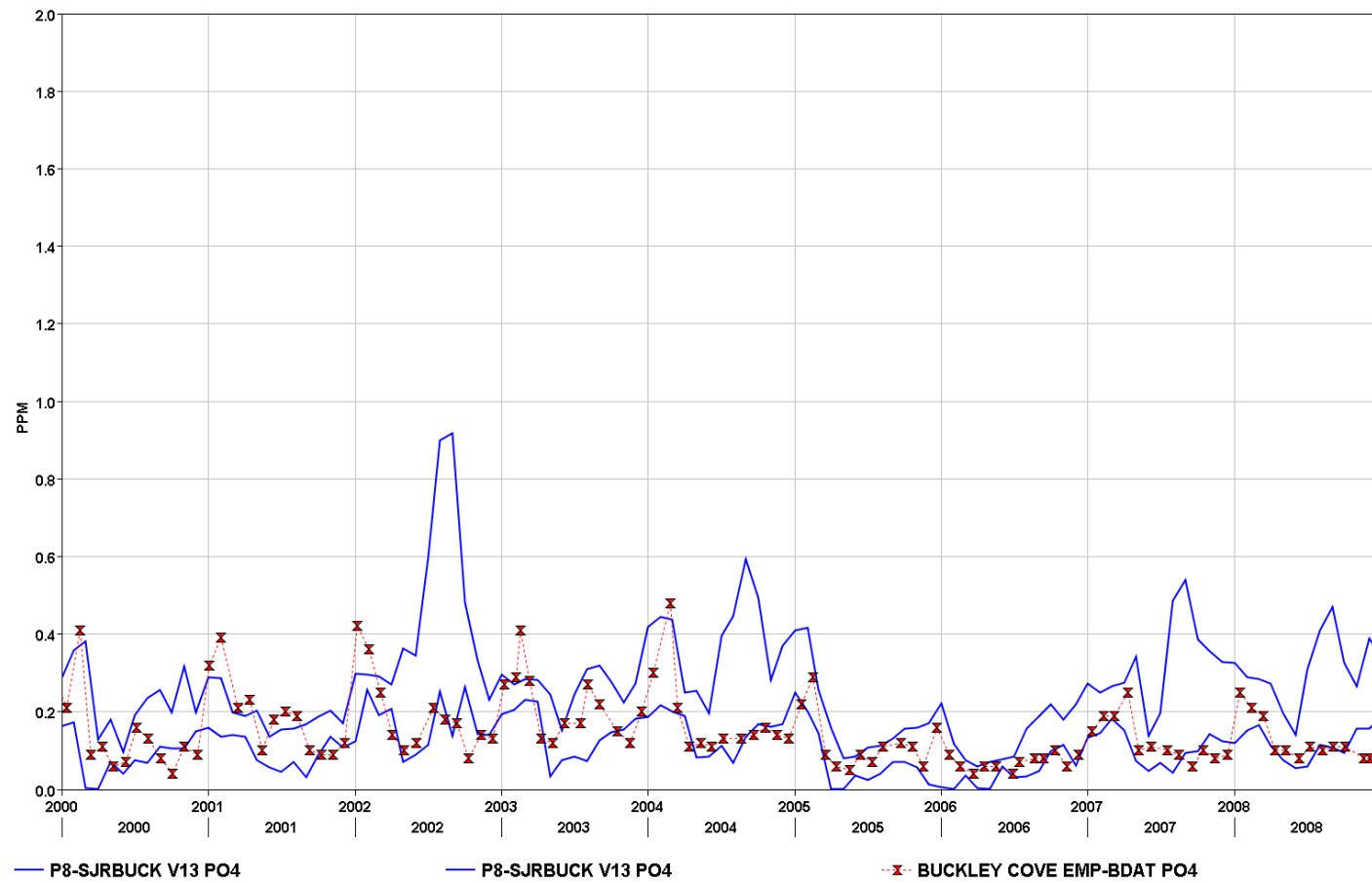


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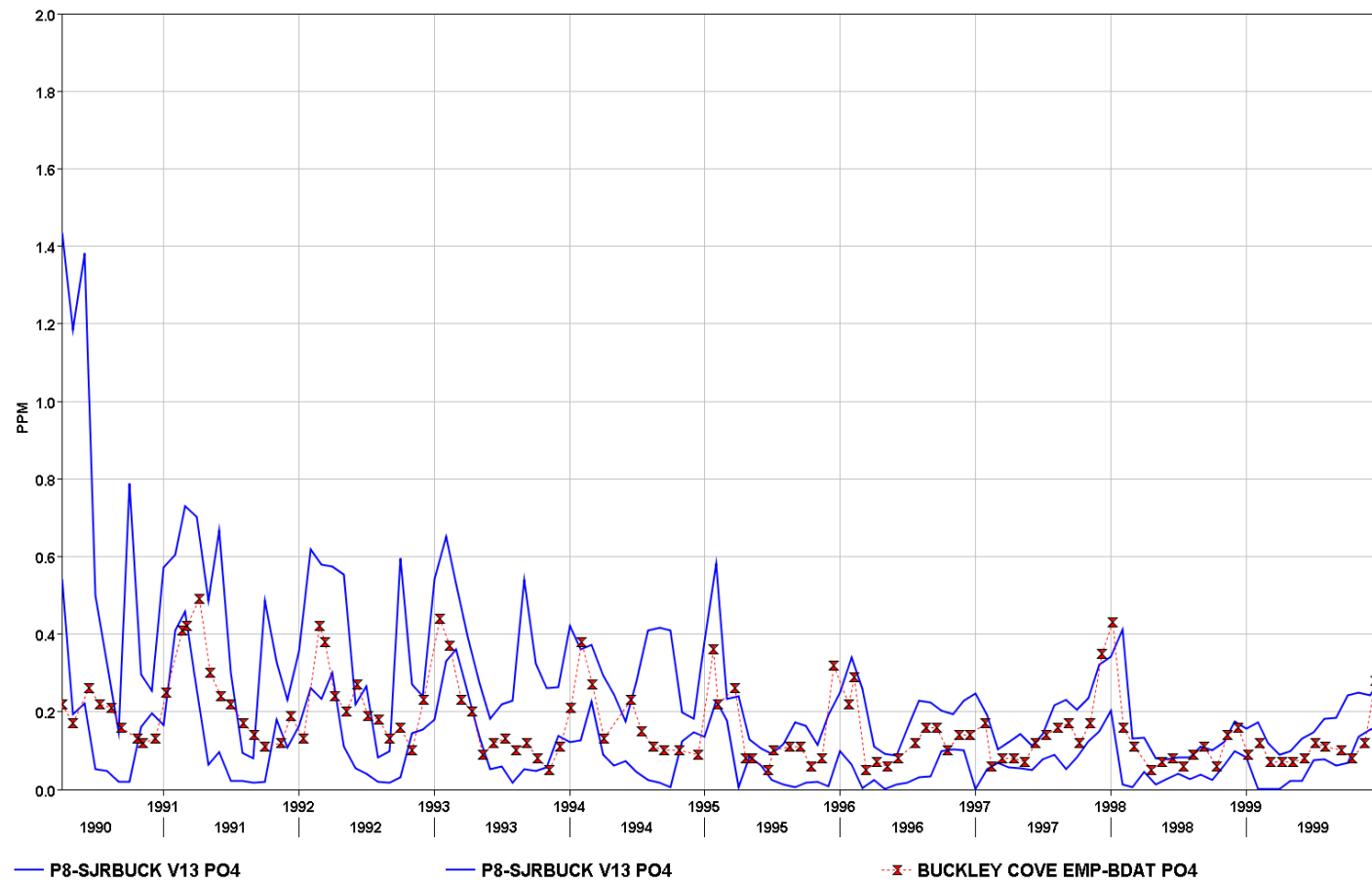


Figure A IV. 70 PO₄ at SJR BUCKLEY early years.

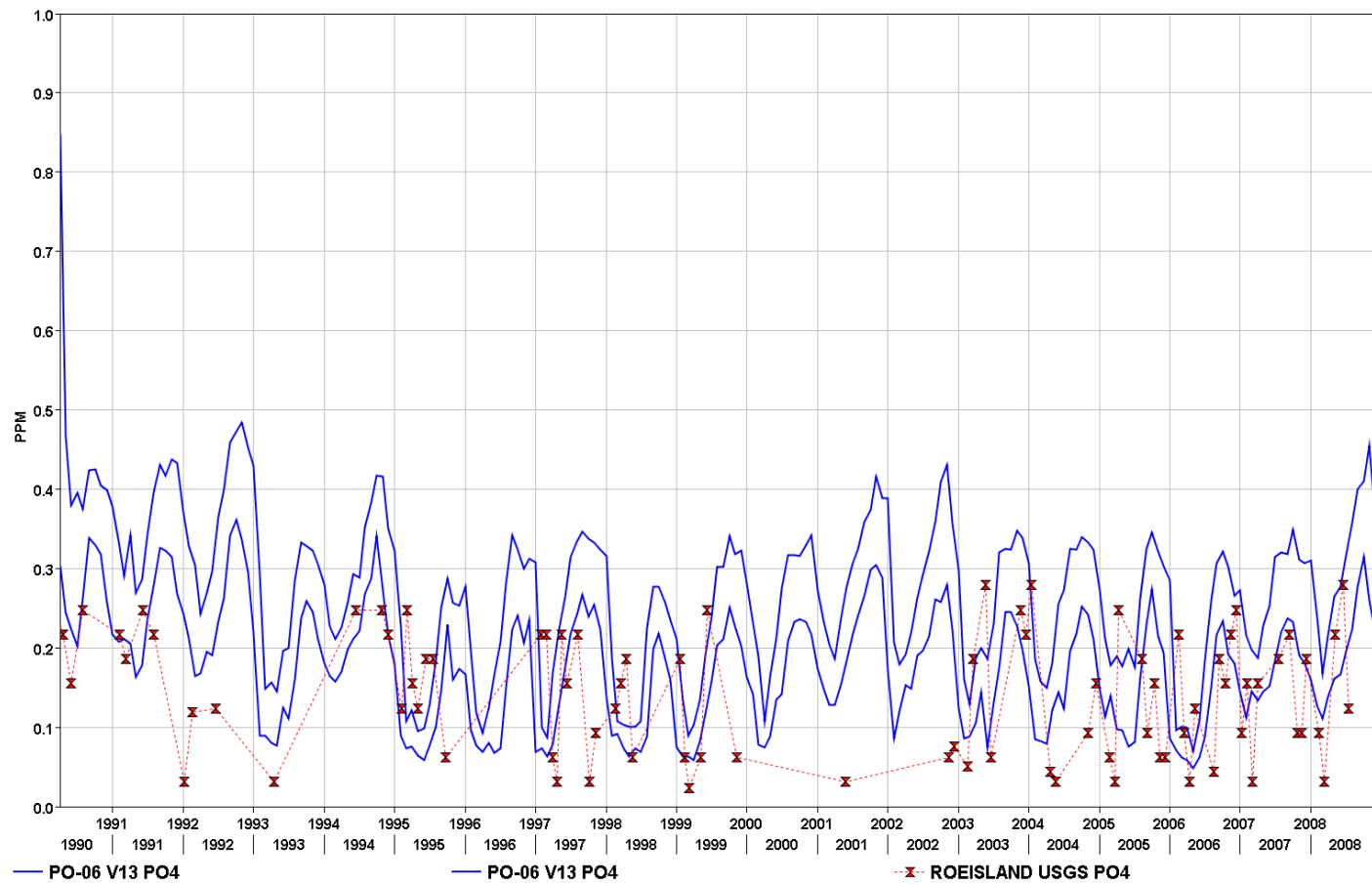


Figure A IV. 71 PO₄ at PO-06 all years.

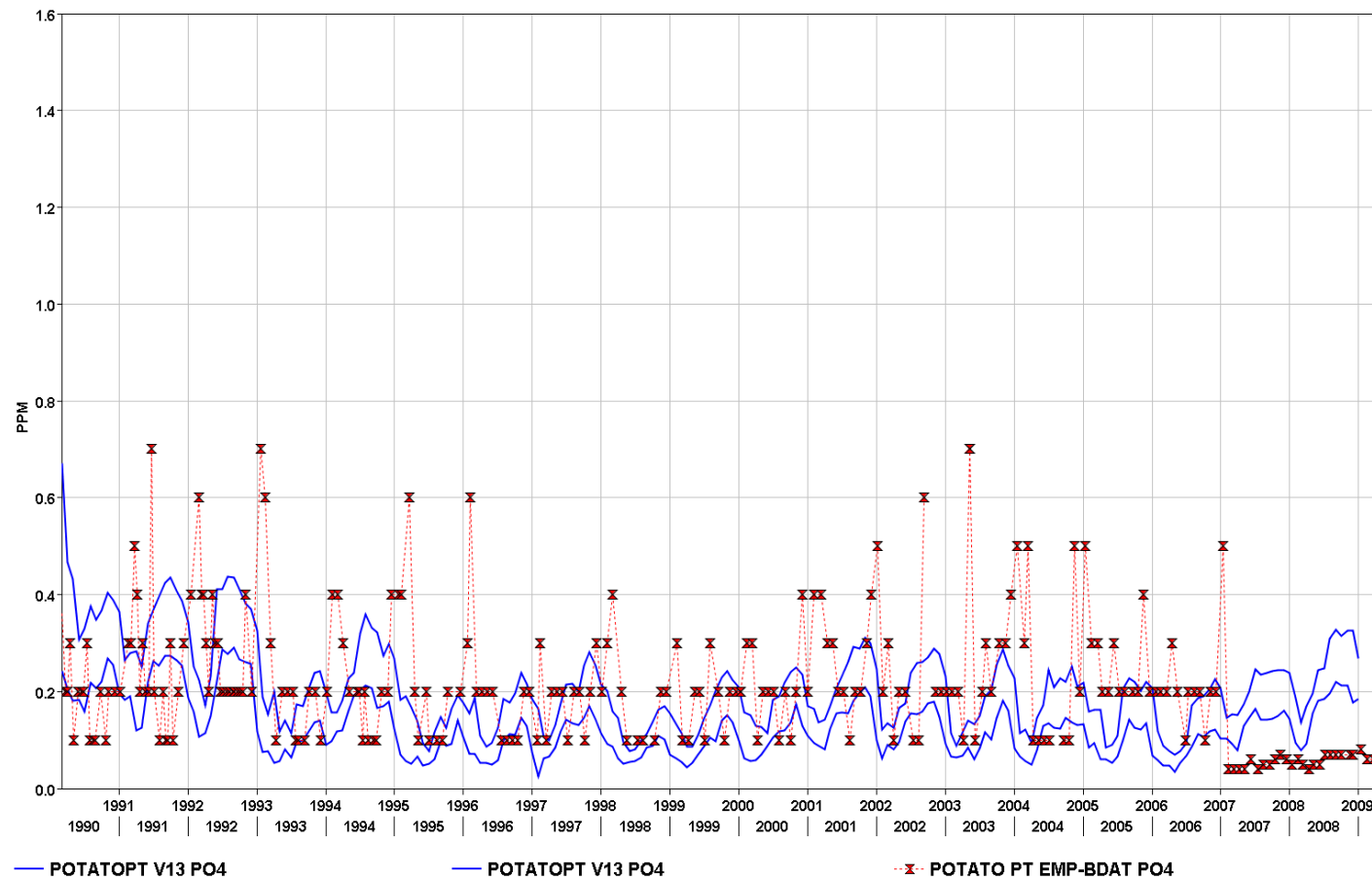


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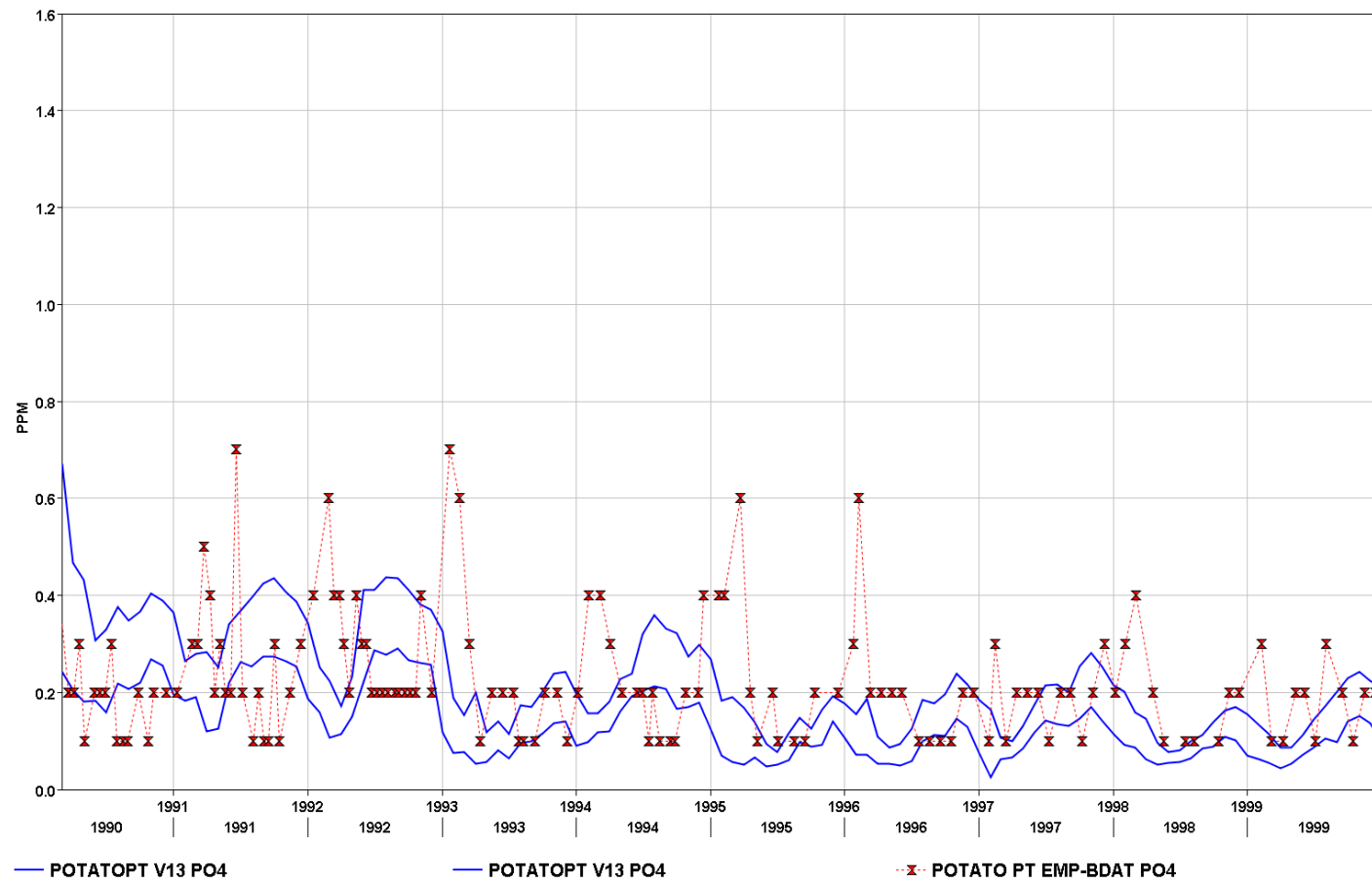


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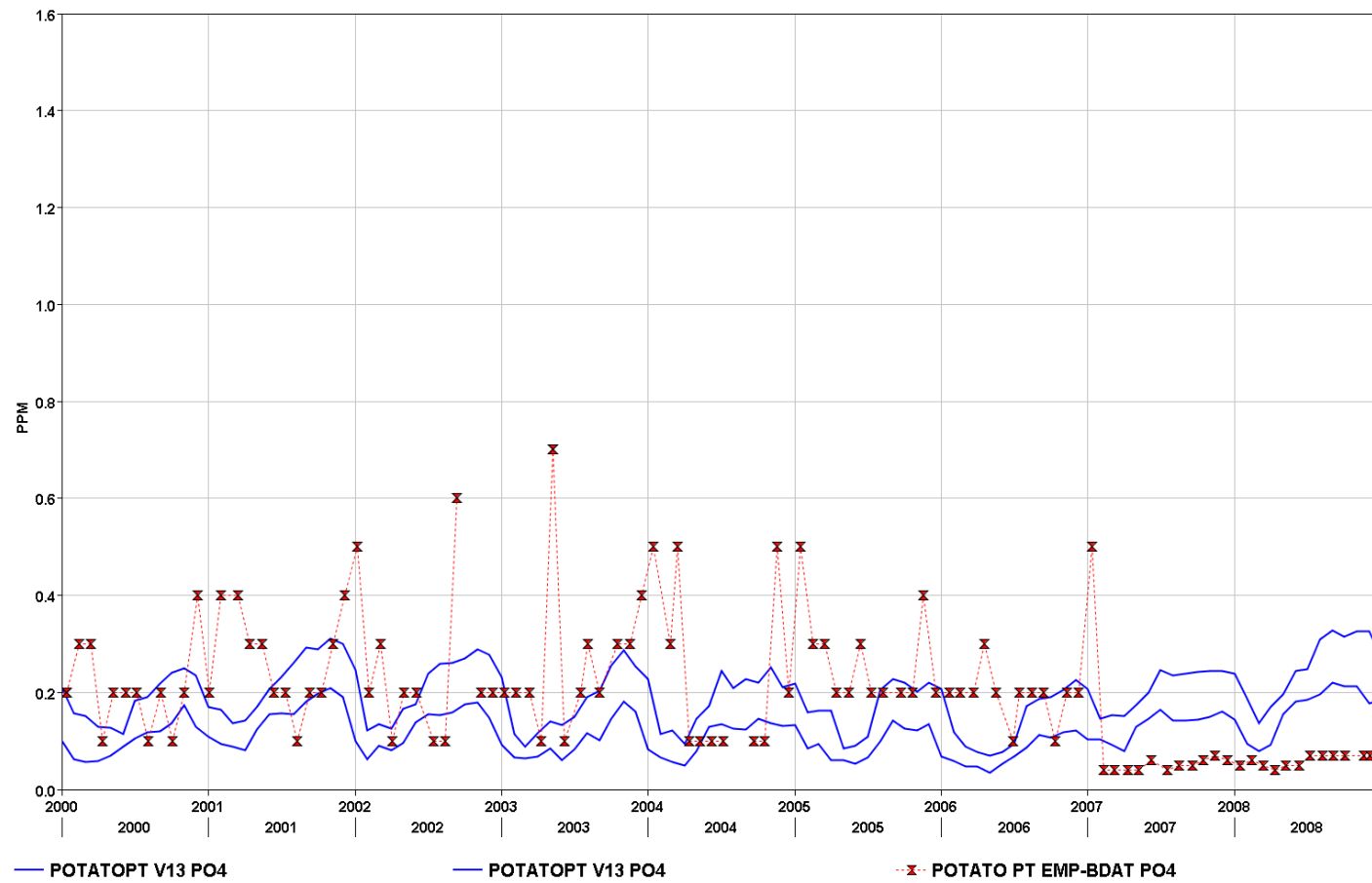


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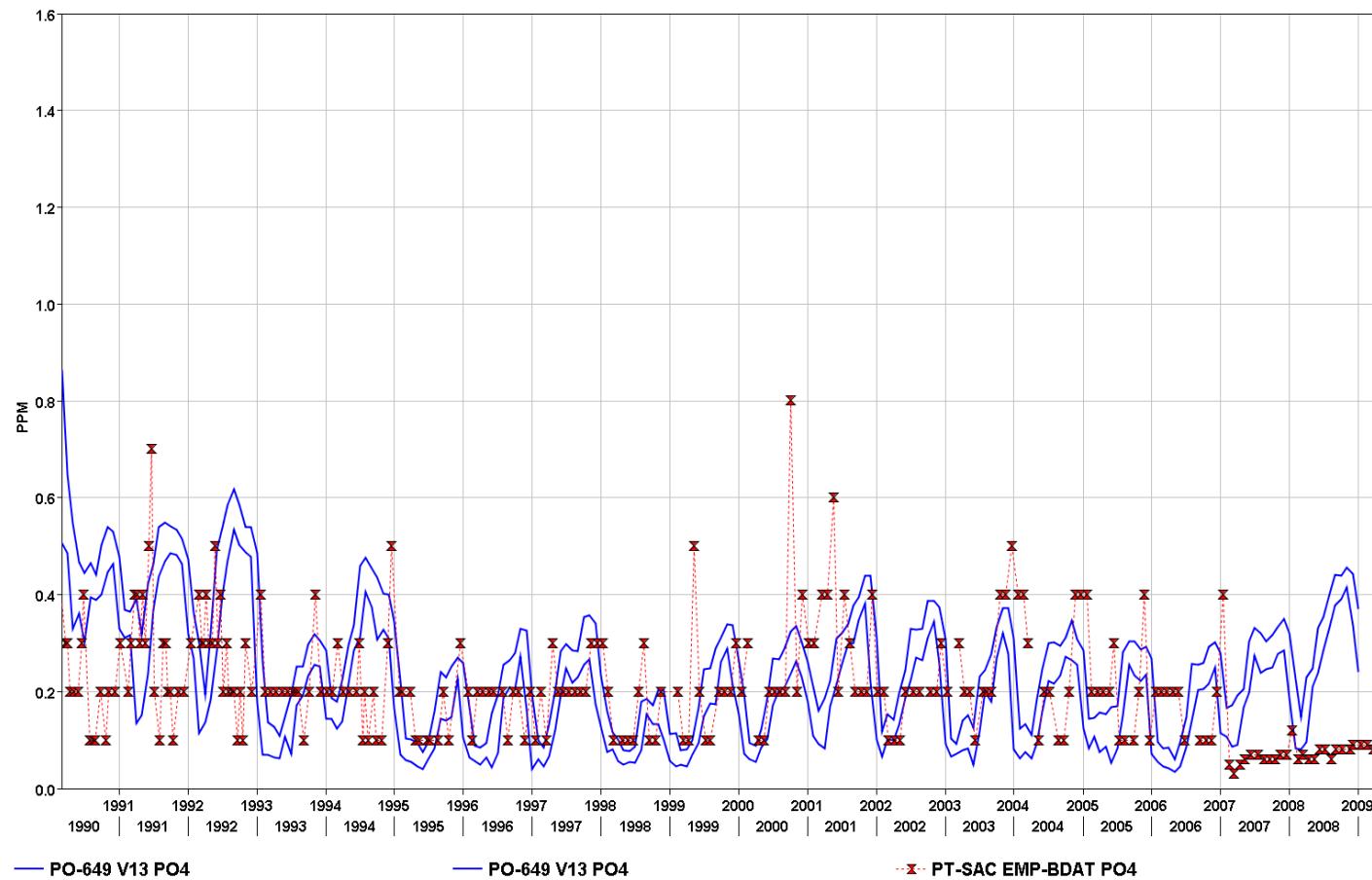


Figure A IV. 75 PO₄ at PT. SACRAMENTO all years.

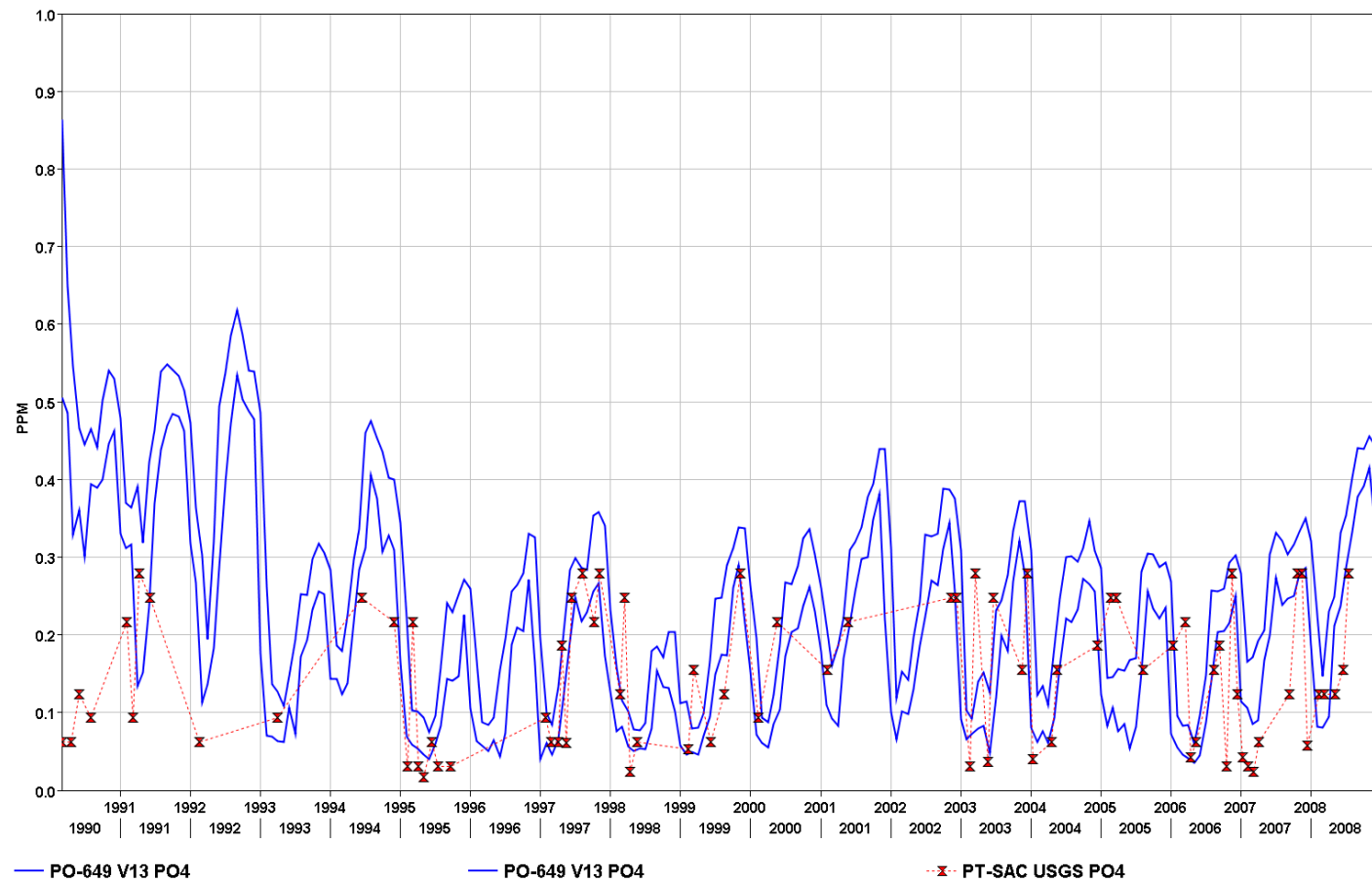


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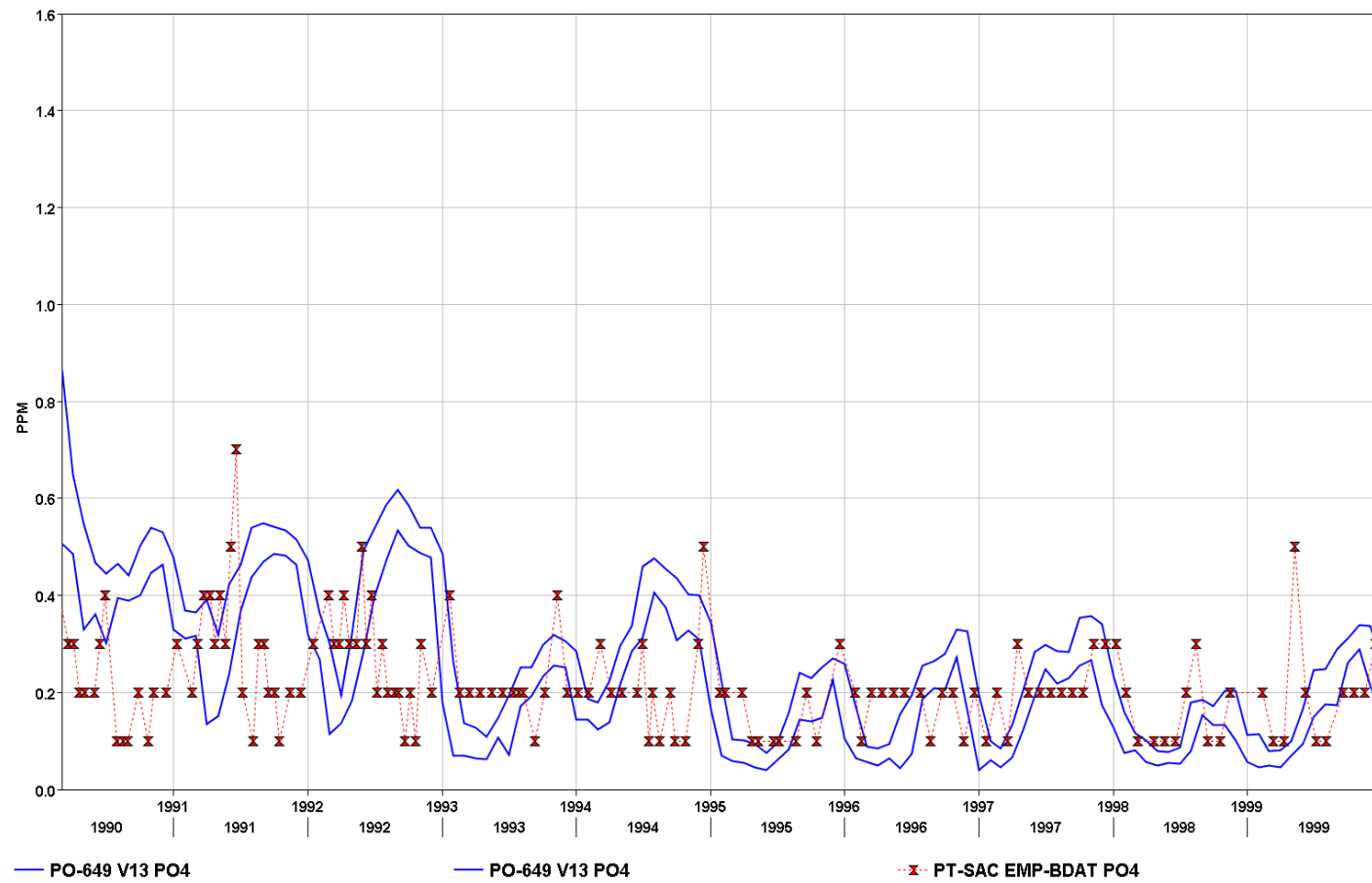


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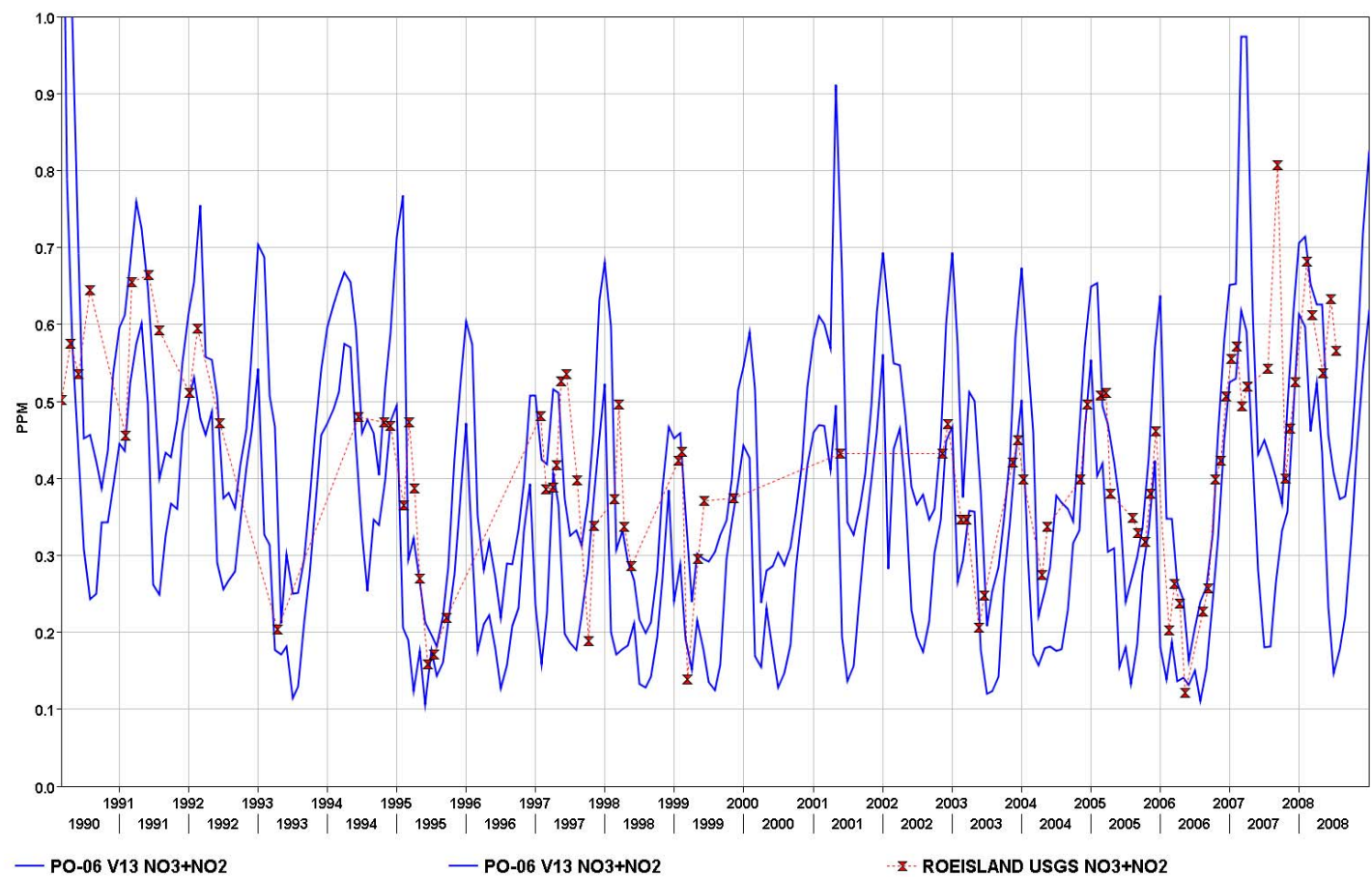


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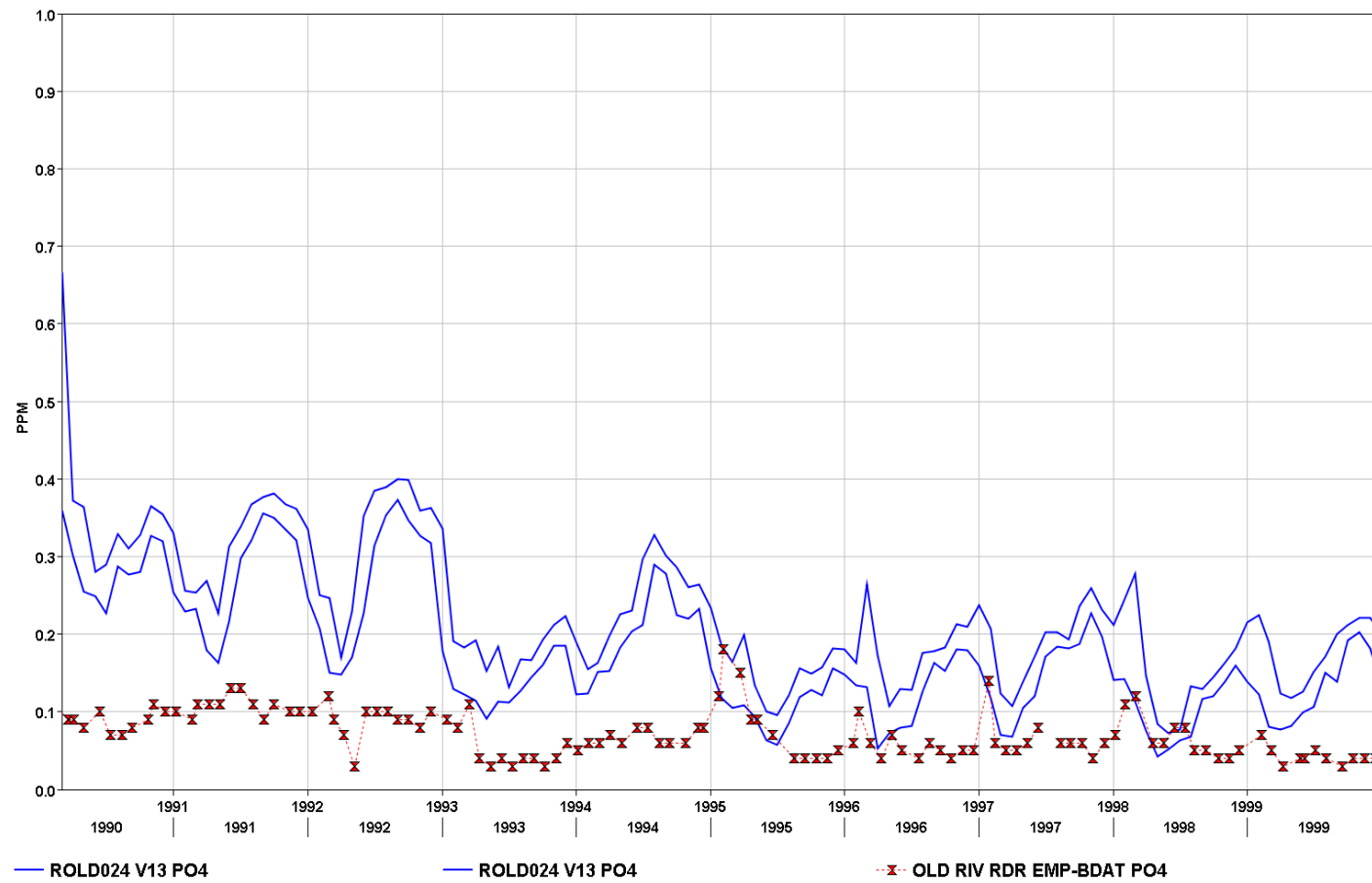


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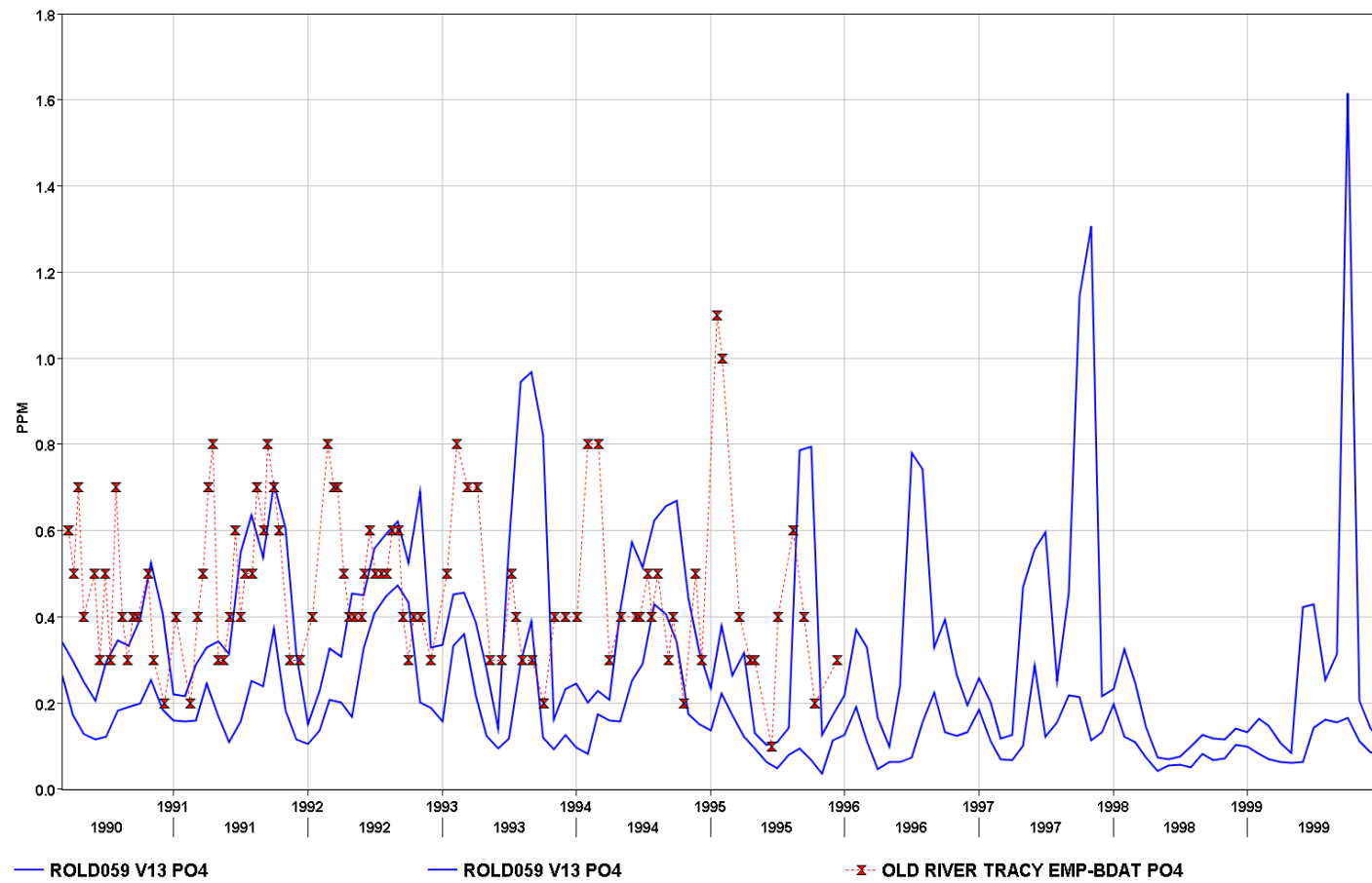


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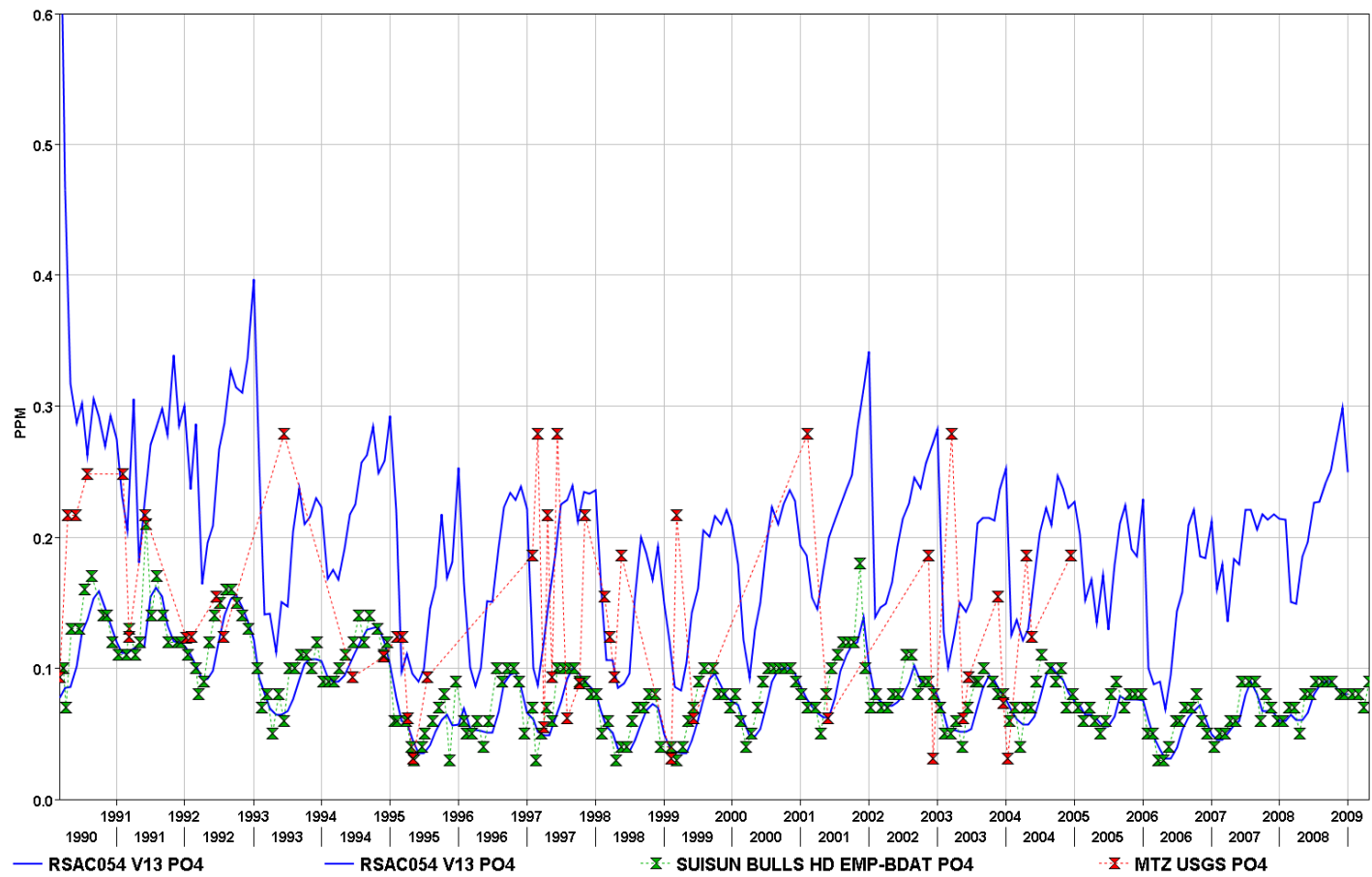


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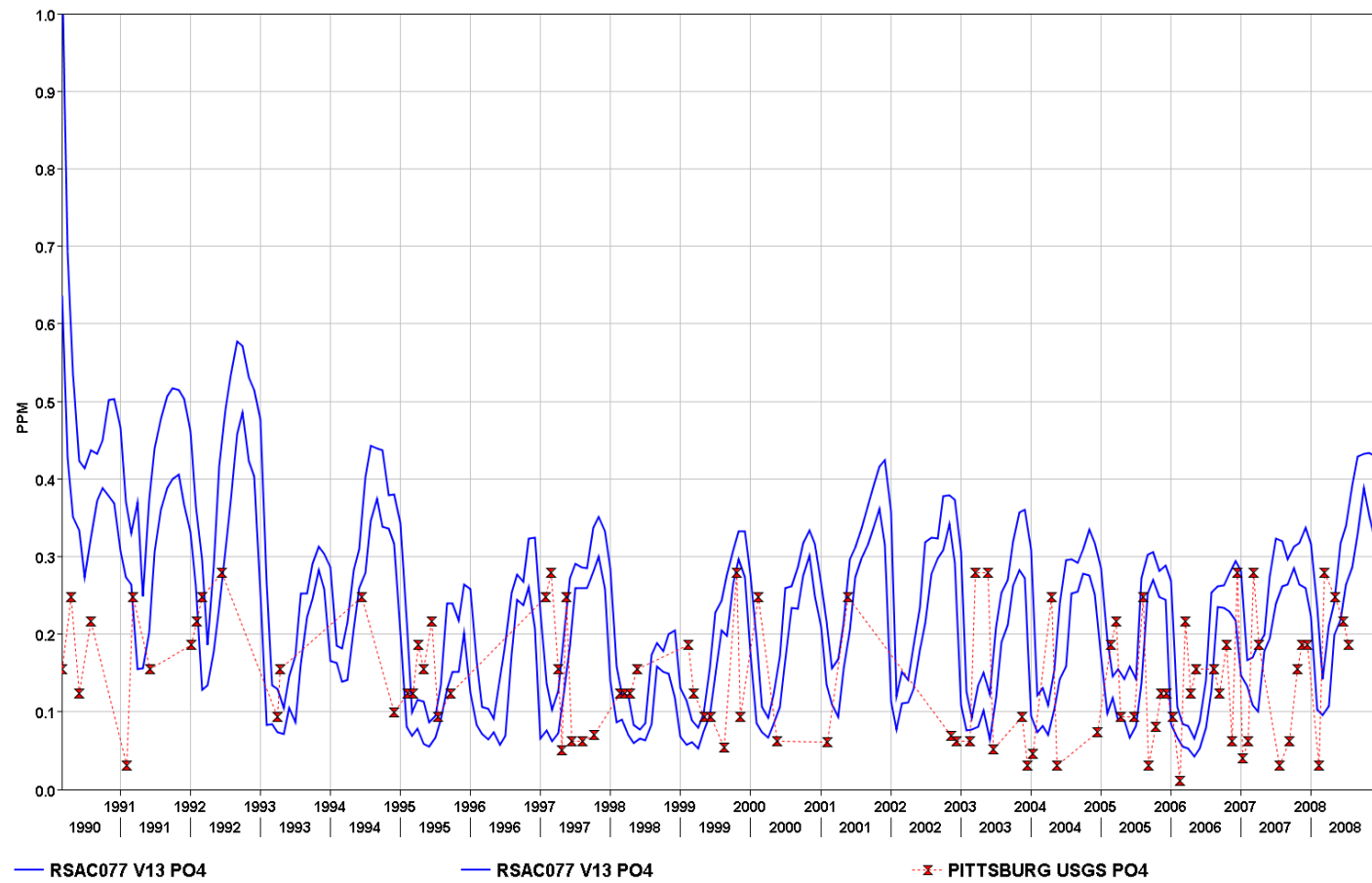


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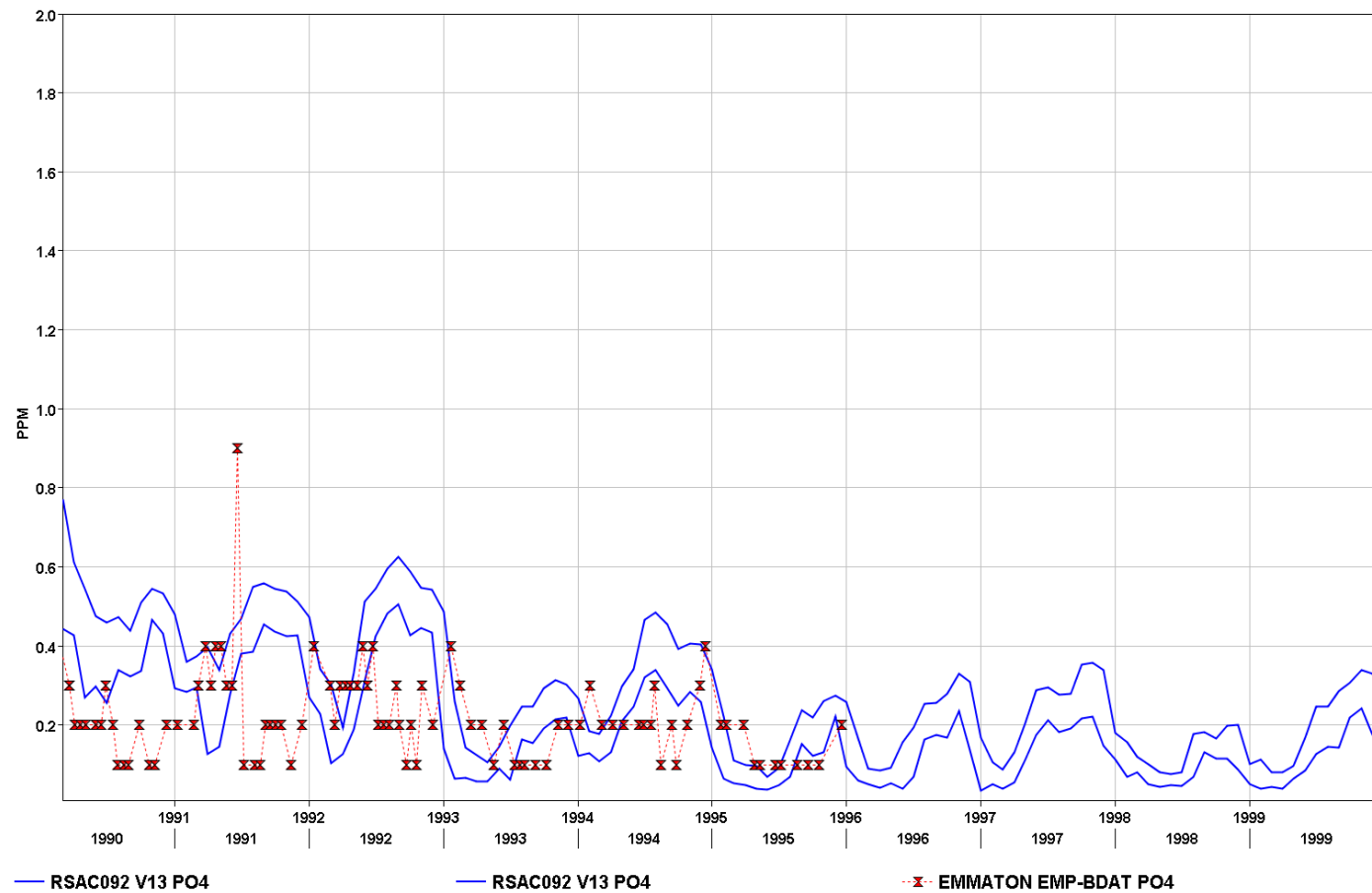


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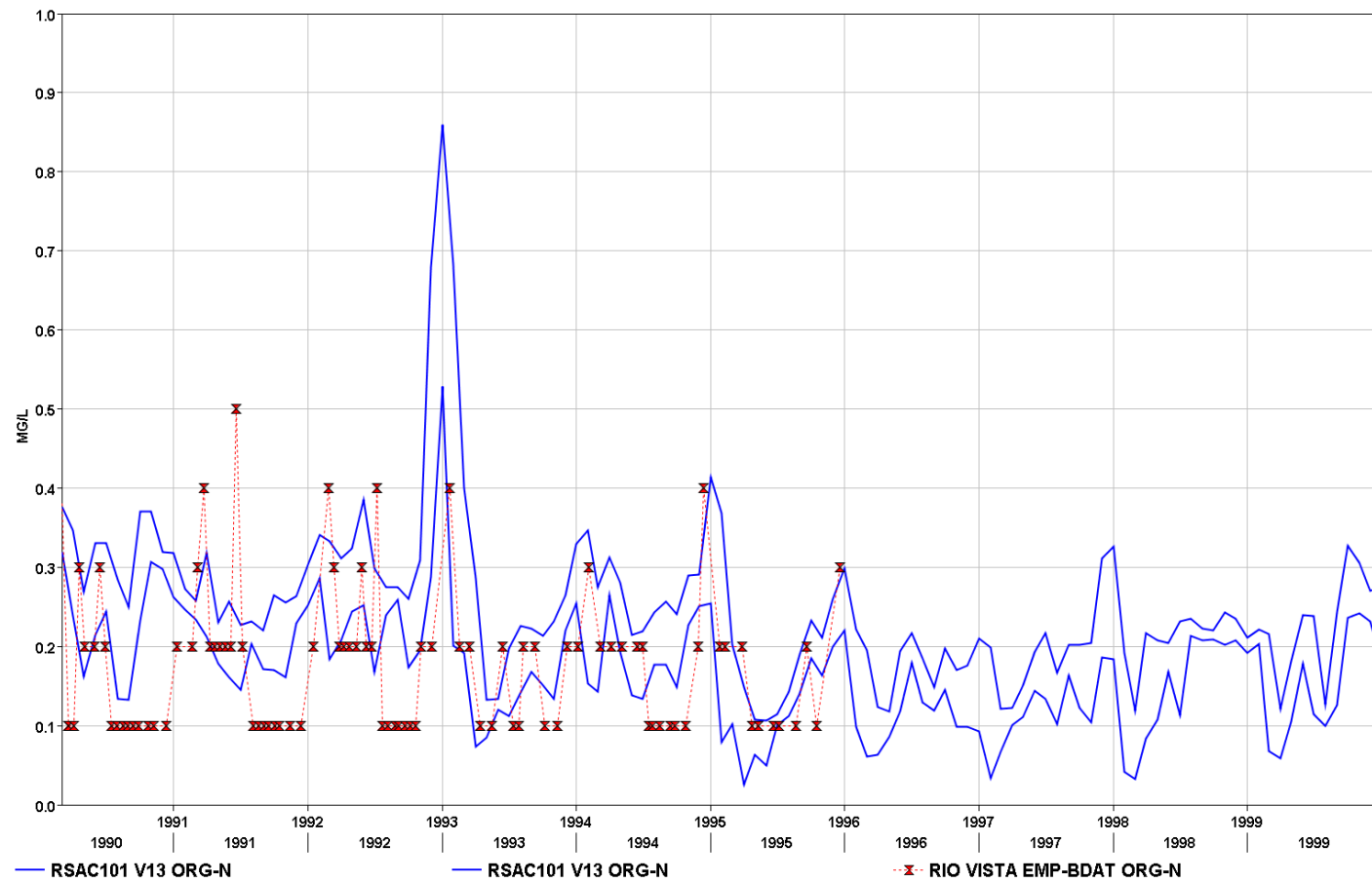


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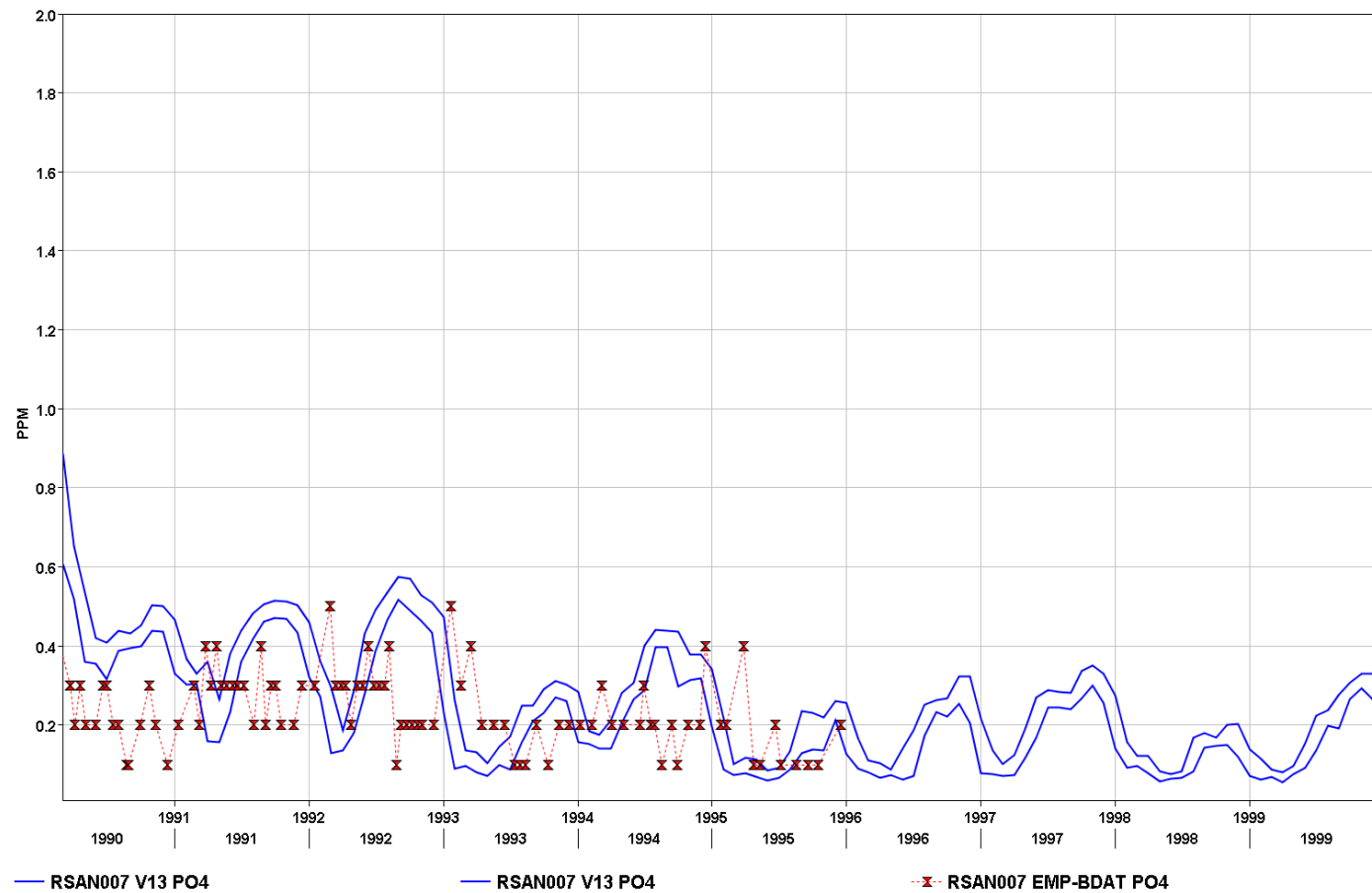


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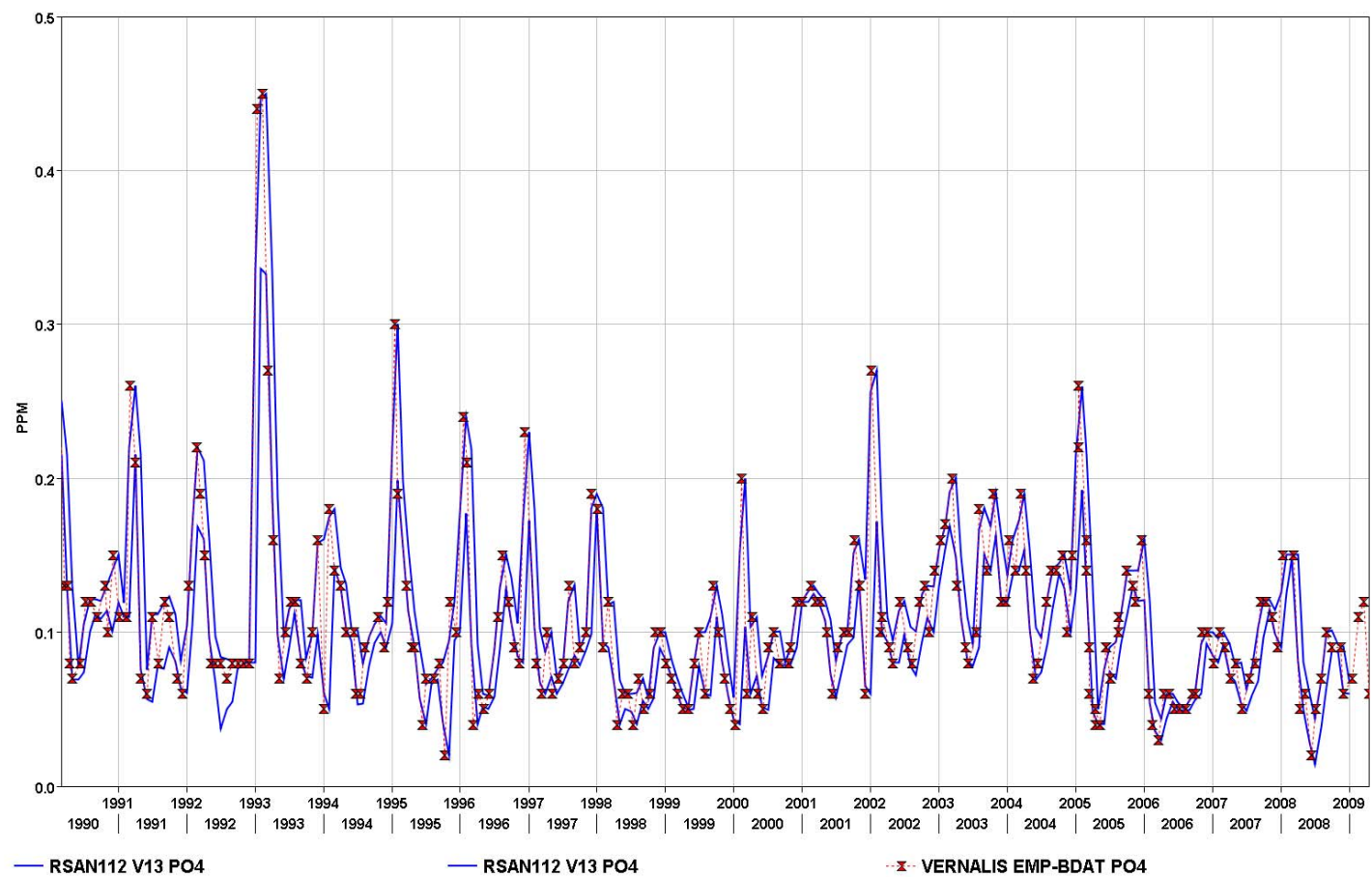


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A. Ammonia calibration

This section contains the figures with ammonia calibration histograms and calibration and validation residuals for wet and dry years for each location.

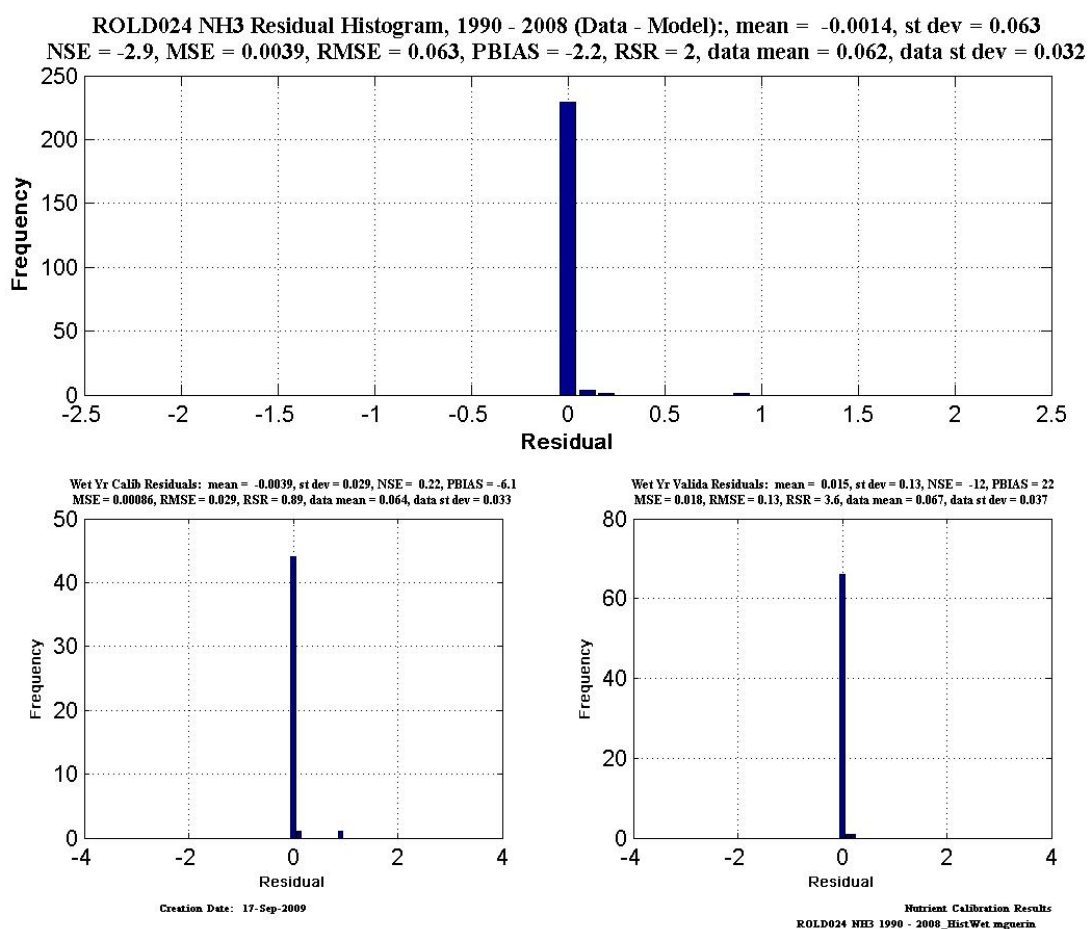


Figure A V. 1 ROLD024 ammonia dry years.

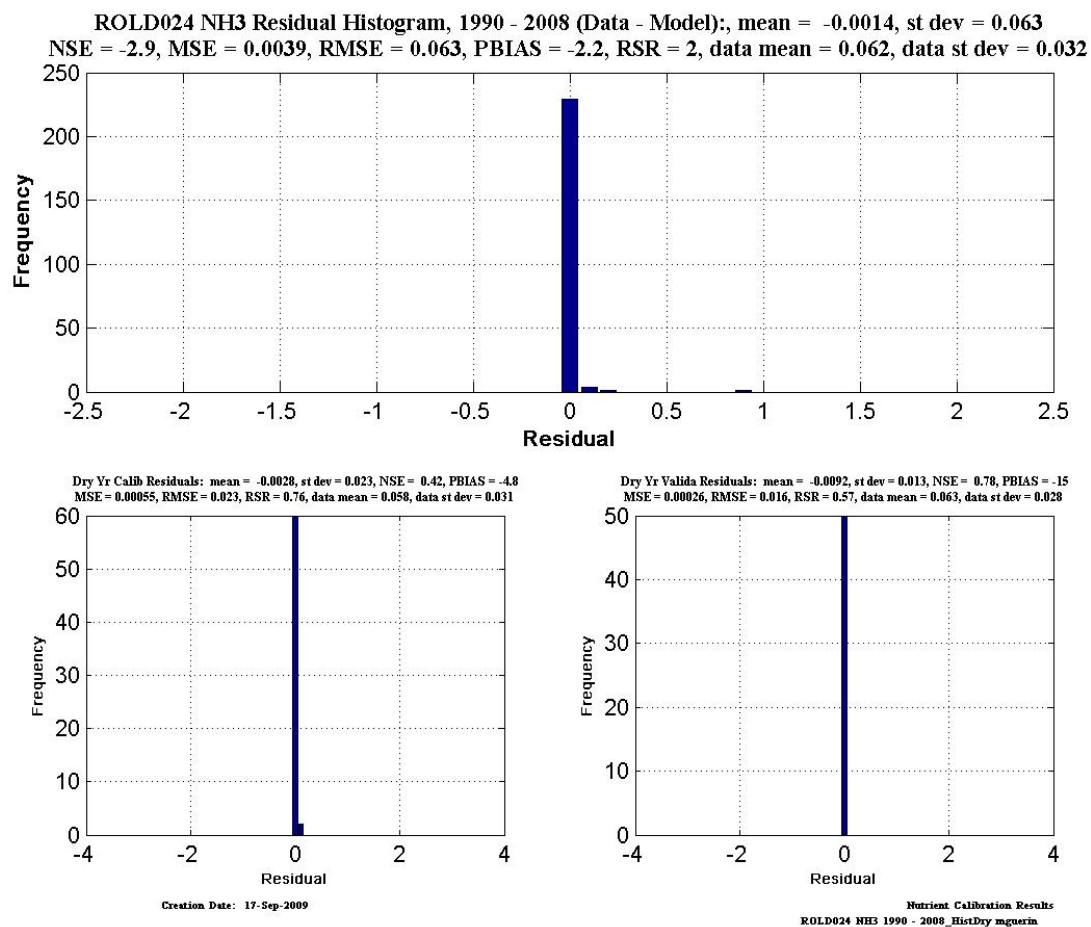


Figure A V. 2 ROLD024 ammonia wet years.

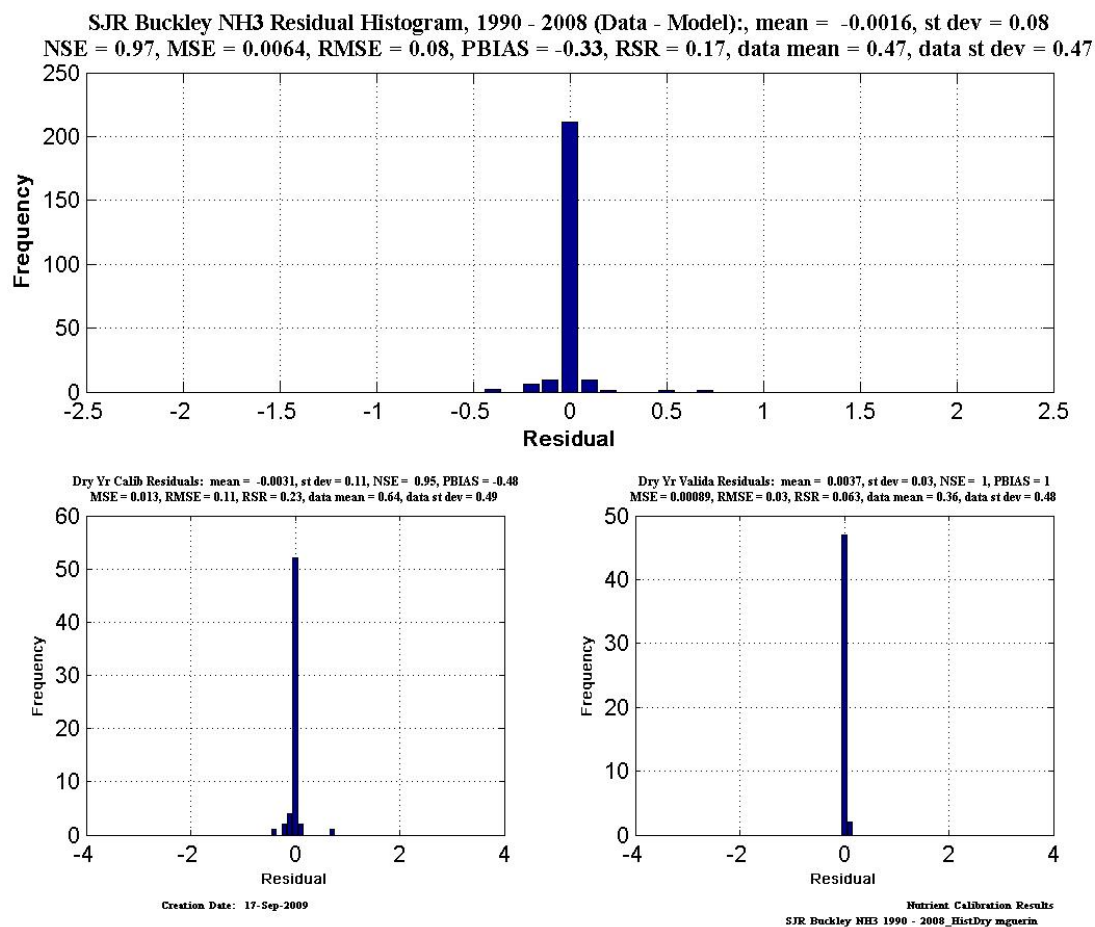


Figure A V. 3 SJR Buckley ammonia dry years.

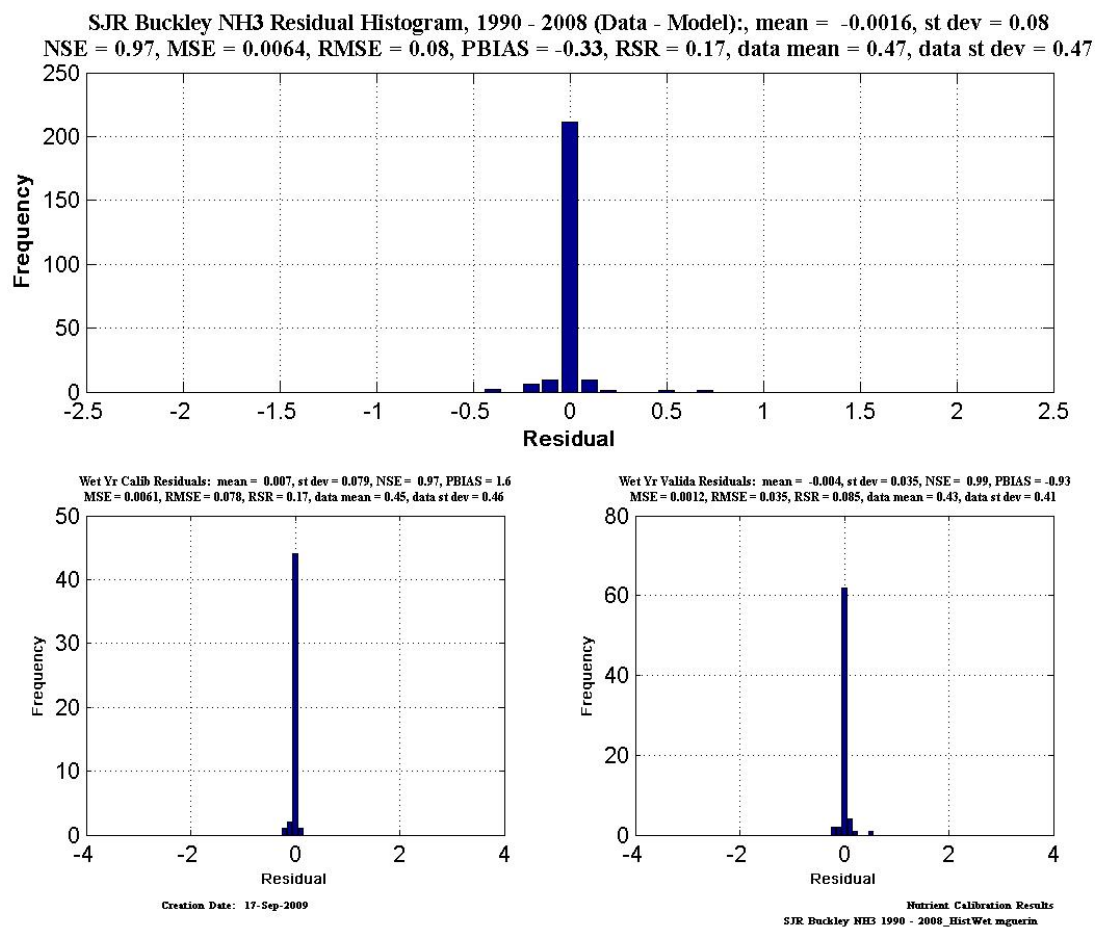


Figure A V. 4 SJR Buckley ammonia wet years.

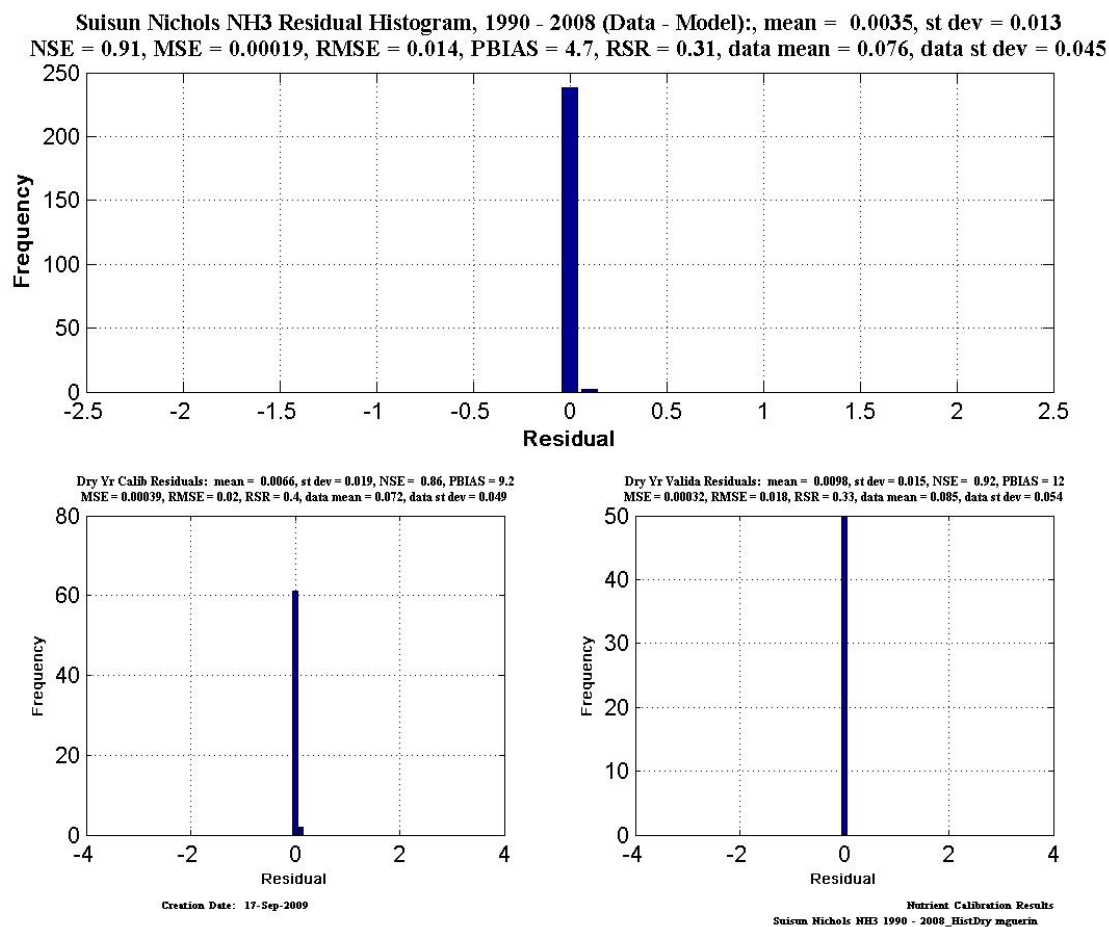


Figure A V. 5 Suisun Nichols (SLM001) ammonia dry years.

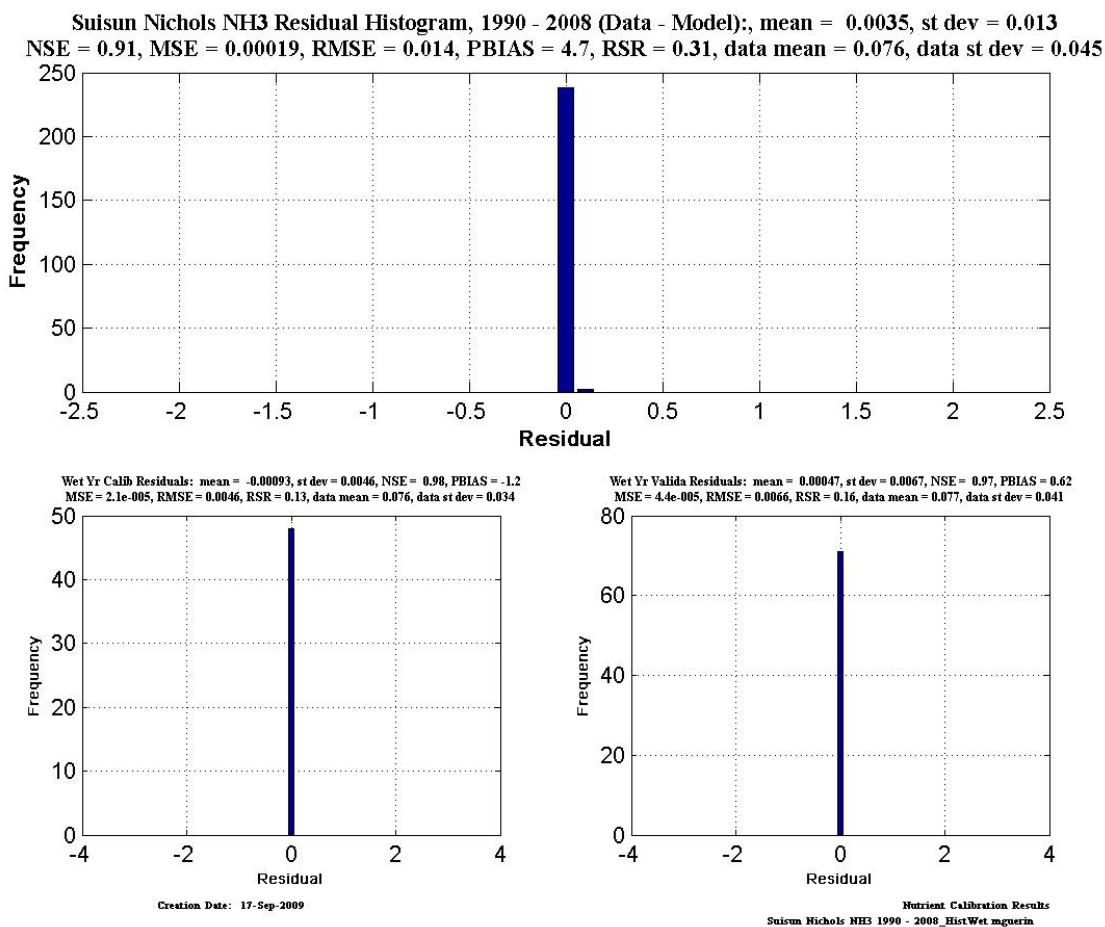


Figure A V. 6 Suisun Nichols ammonia wet years.

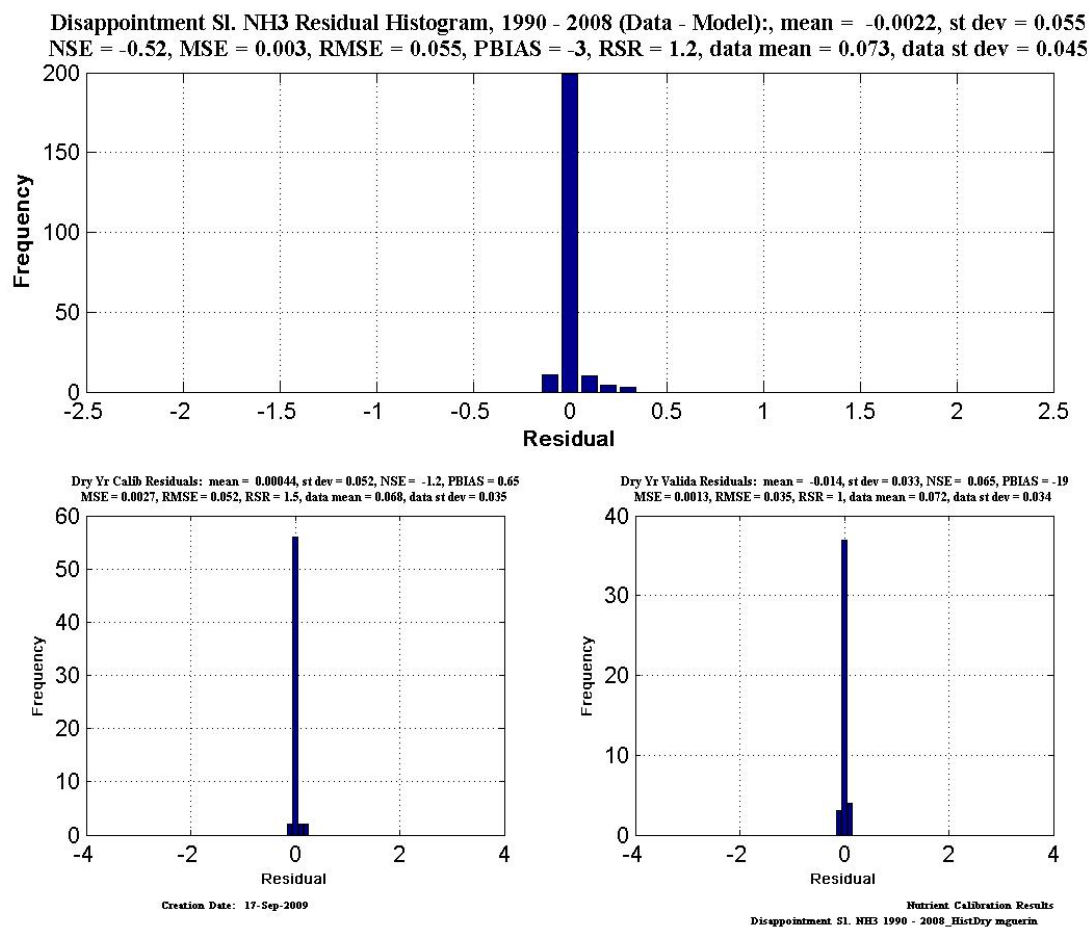


Figure A V. 7 Disappointment SL ammonia dry years.

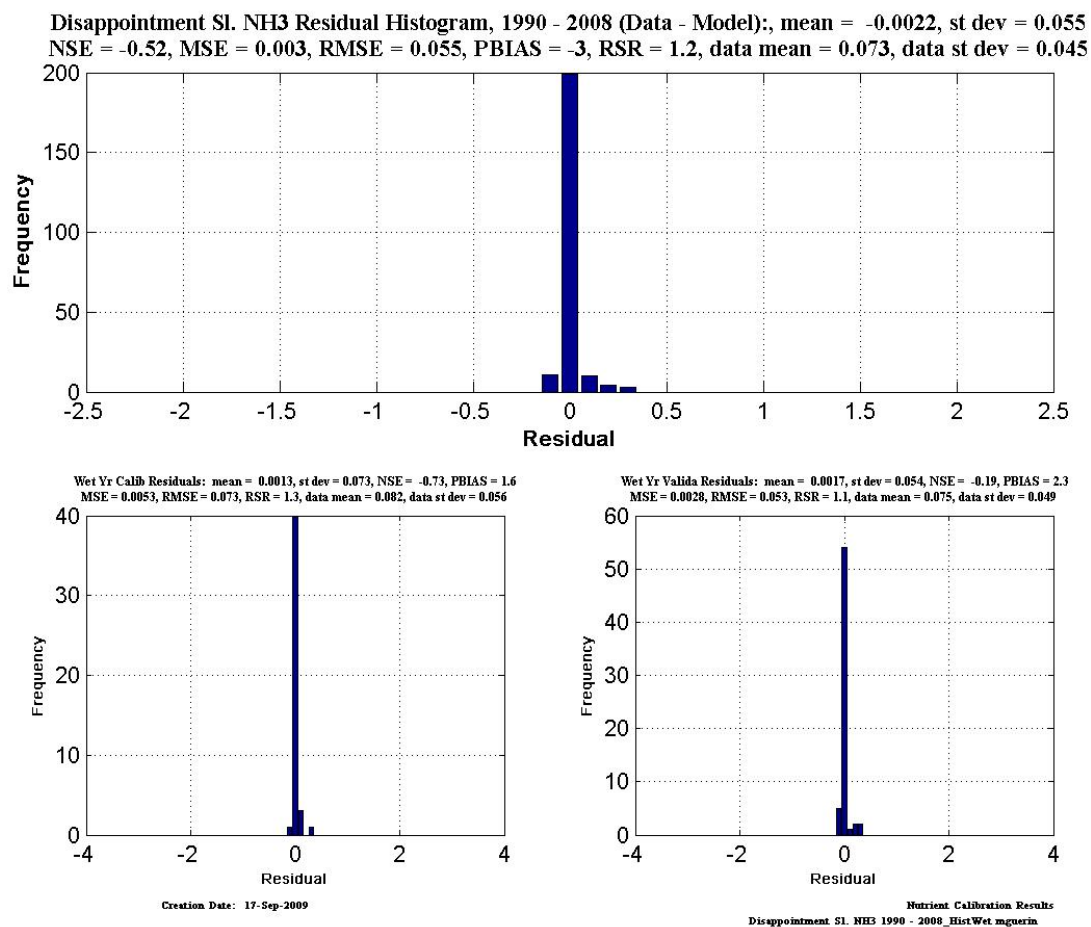


Figure A V. 8 Disappointment Sl. ammonia wet years.

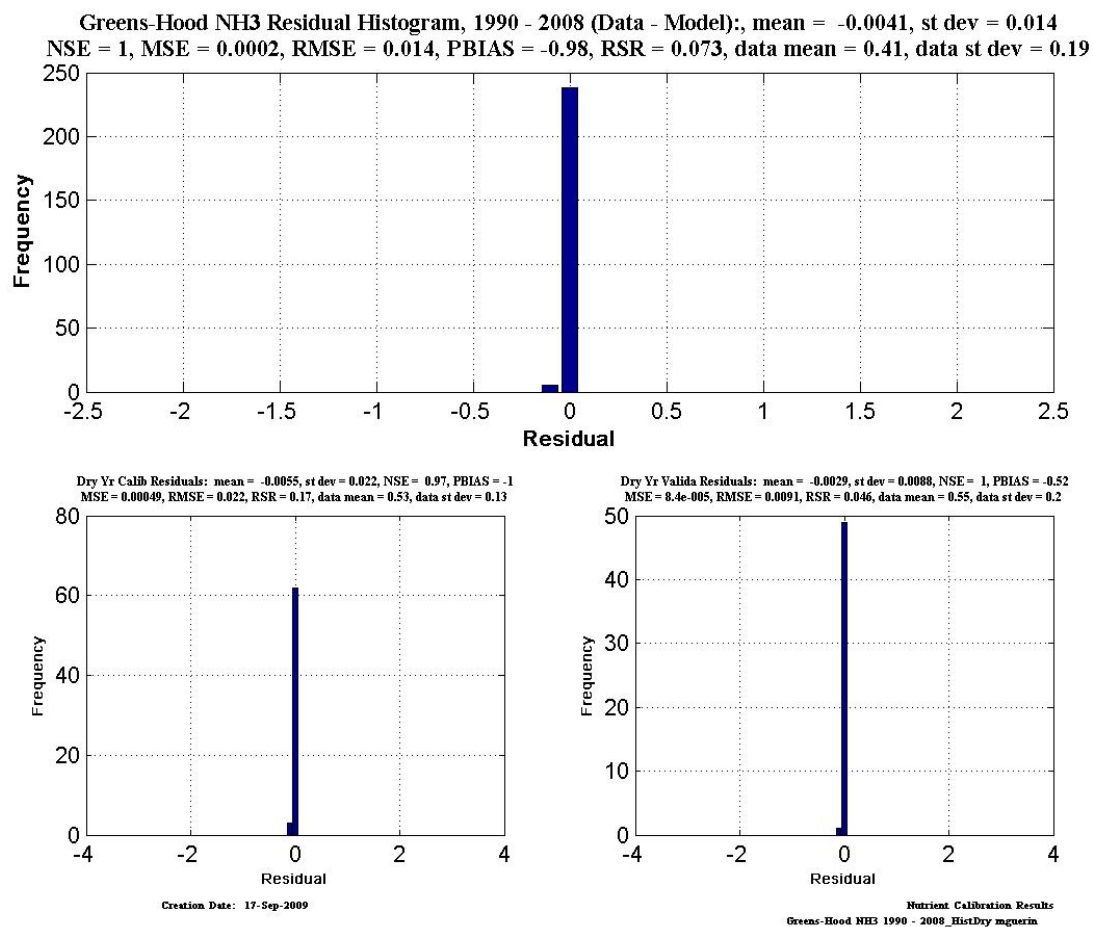


Figure A V. 9 Greenes-Hood ammonia dry years.

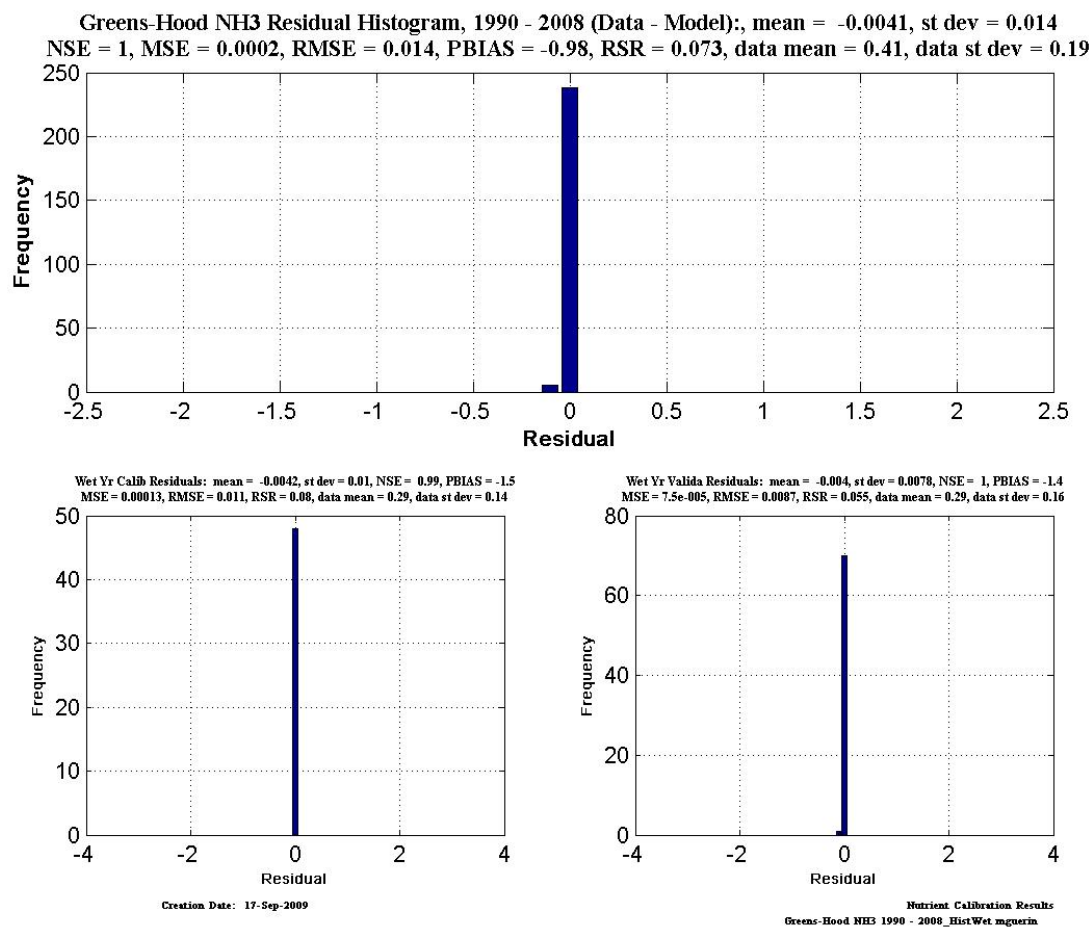


Figure A V. 10 Greenes-Hood ammonia wet years.

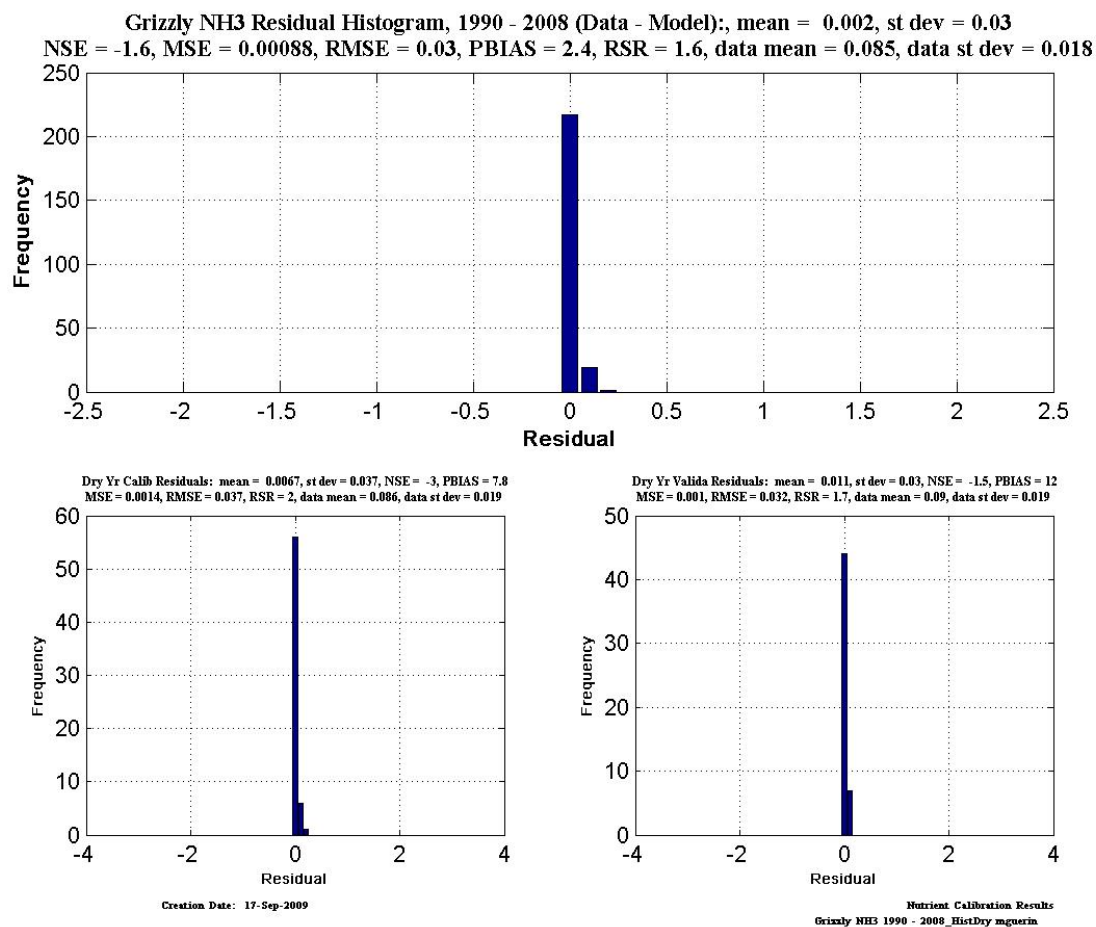


Figure A V. 11 Grizzly ammonia dry years.

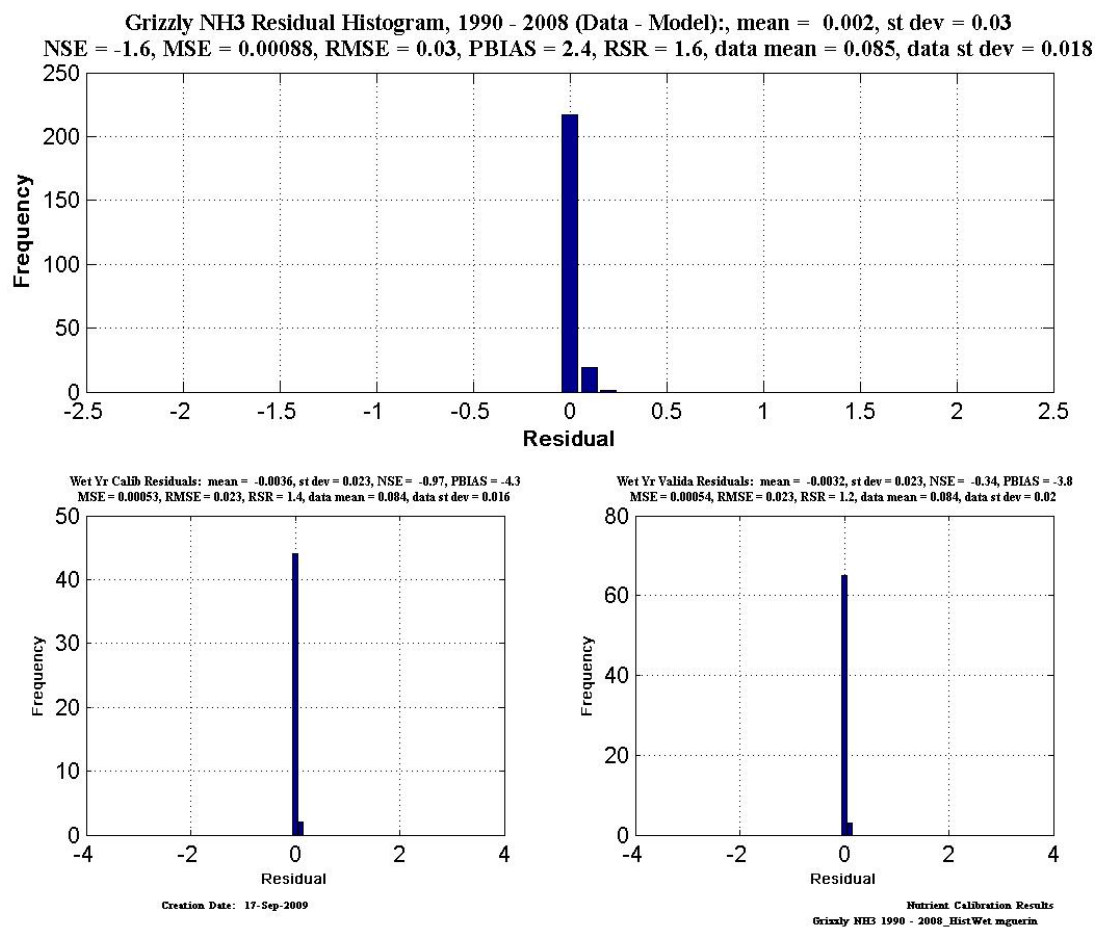


Figure A V. 12 Grizzly ammonia wet years.

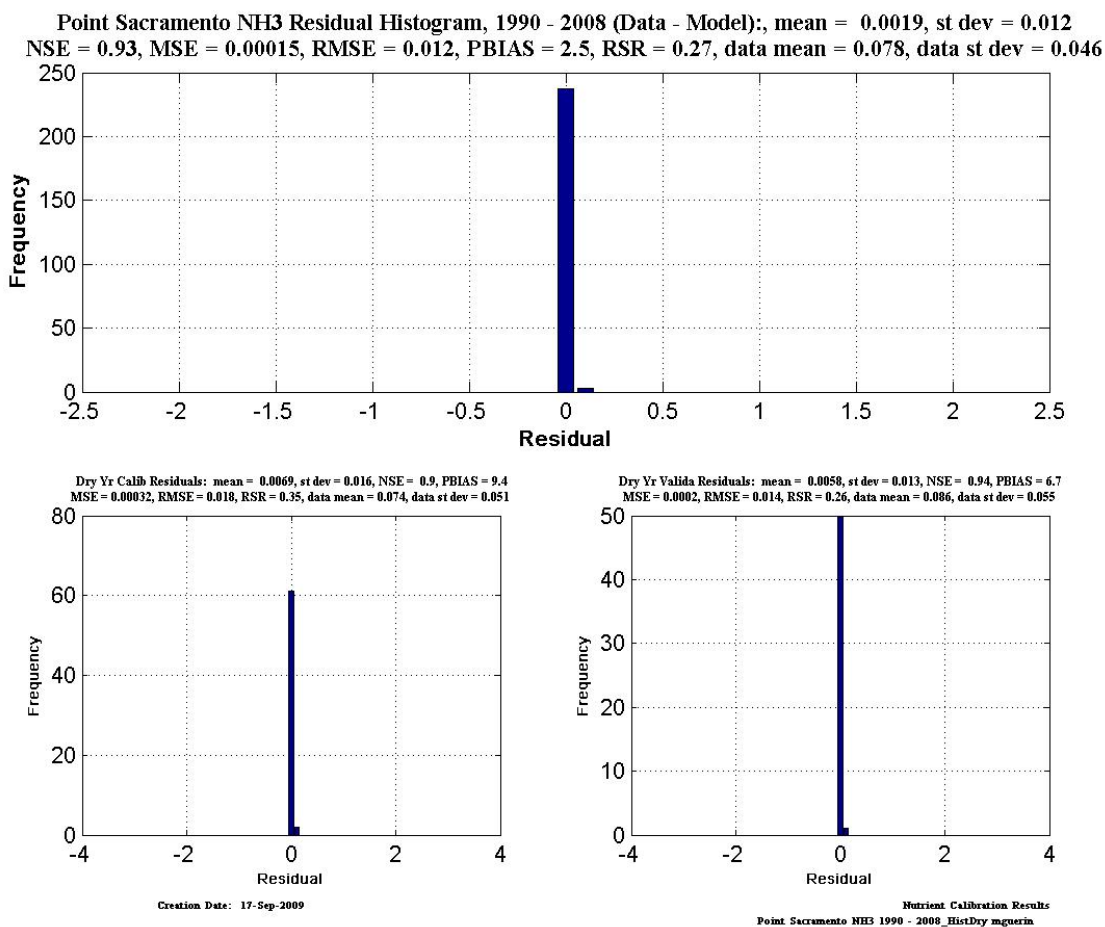
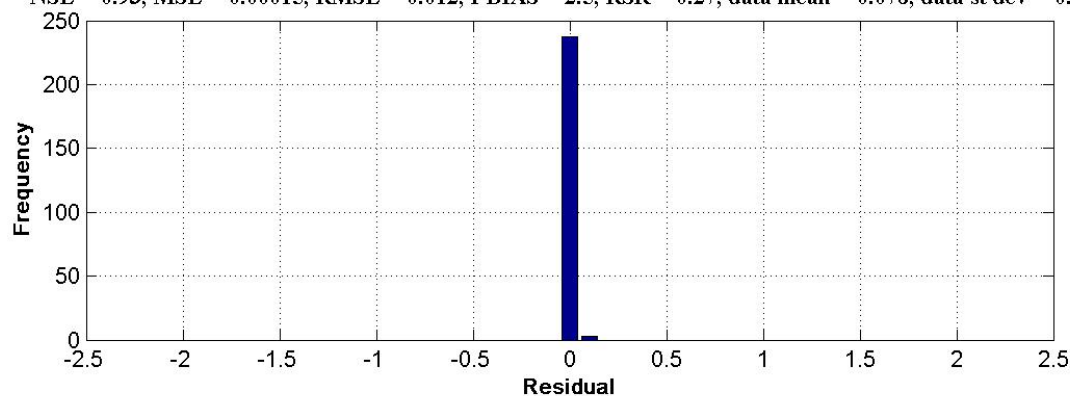
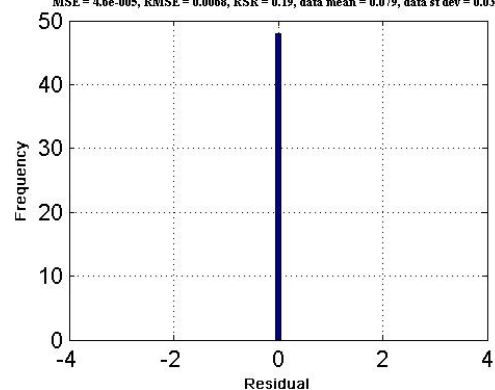


Figure A V. 13 Pt. Sacramento ammonia dry years.

Point Sacramento NH3 Residual Histogram, 1990 - 2008 (Data - Model);, mean = 0.0019, st dev = 0.012
 NSE = 0.93, MSE = 0.00015, RMSE = 0.012, PBIAS = 2.5, RSR = 0.27, data mean = 0.078, data st dev = 0.046

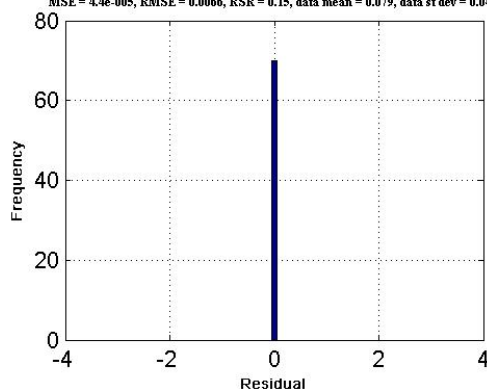


Wet Yr Calib Residuals: mean = -0.0017, st dev = 0.0067, NSE = 0.96, PBIAS = -2.1
 MSE = 4.6e-005, RMSE = 0.0068, RSR = 0.19, data mean = 0.079, data st dev = 0.035



Creation Date: 17-Sep-2009

Wet Yr Valid Residuals: mean = -0.0025, st dev = 0.0062, NSE = 0.98, PBIAS = -3.1
 MSE = 4.4e-005, RMSE = 0.0066, RSR = 0.15, data mean = 0.079, data st dev = 0.043



Nutrient Calibration Results
 Point Sacramento NH3 1990 - 2008_HistWet.mgwerin

Figure A V. 14 Pt. Sacramento ammonia wet years.

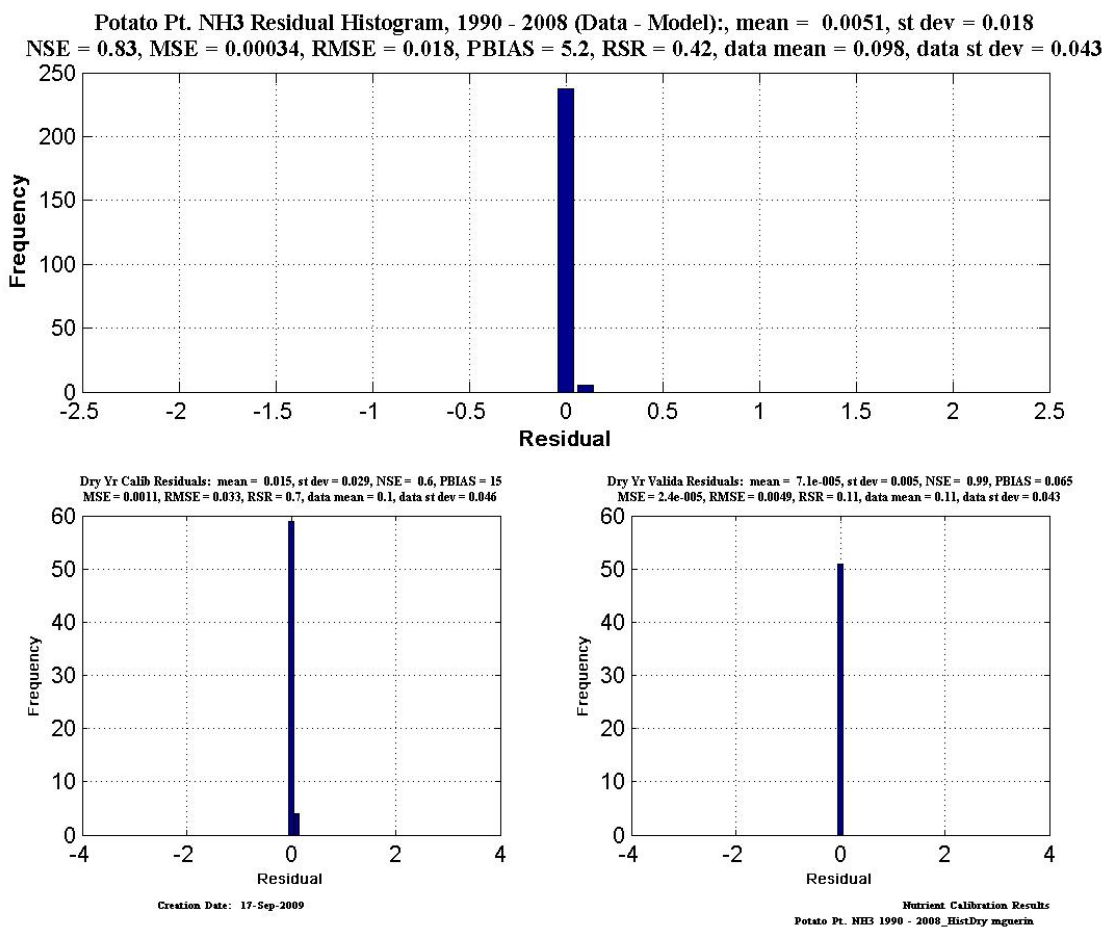


Figure A V. 15 Potato Pt. ammonia dry years.

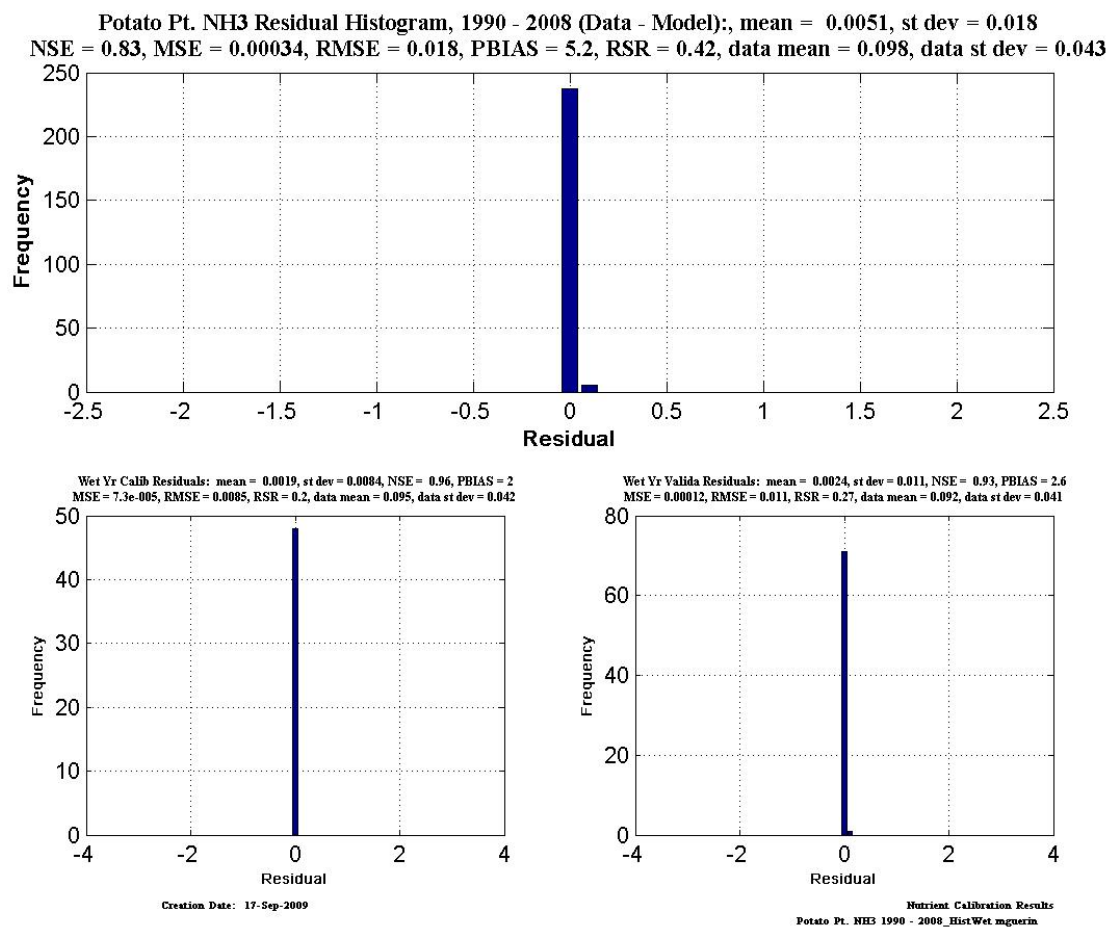


Figure A V. 16 Potato Pt. ammonia wet years.

B. Nitrate+nitrite calibration

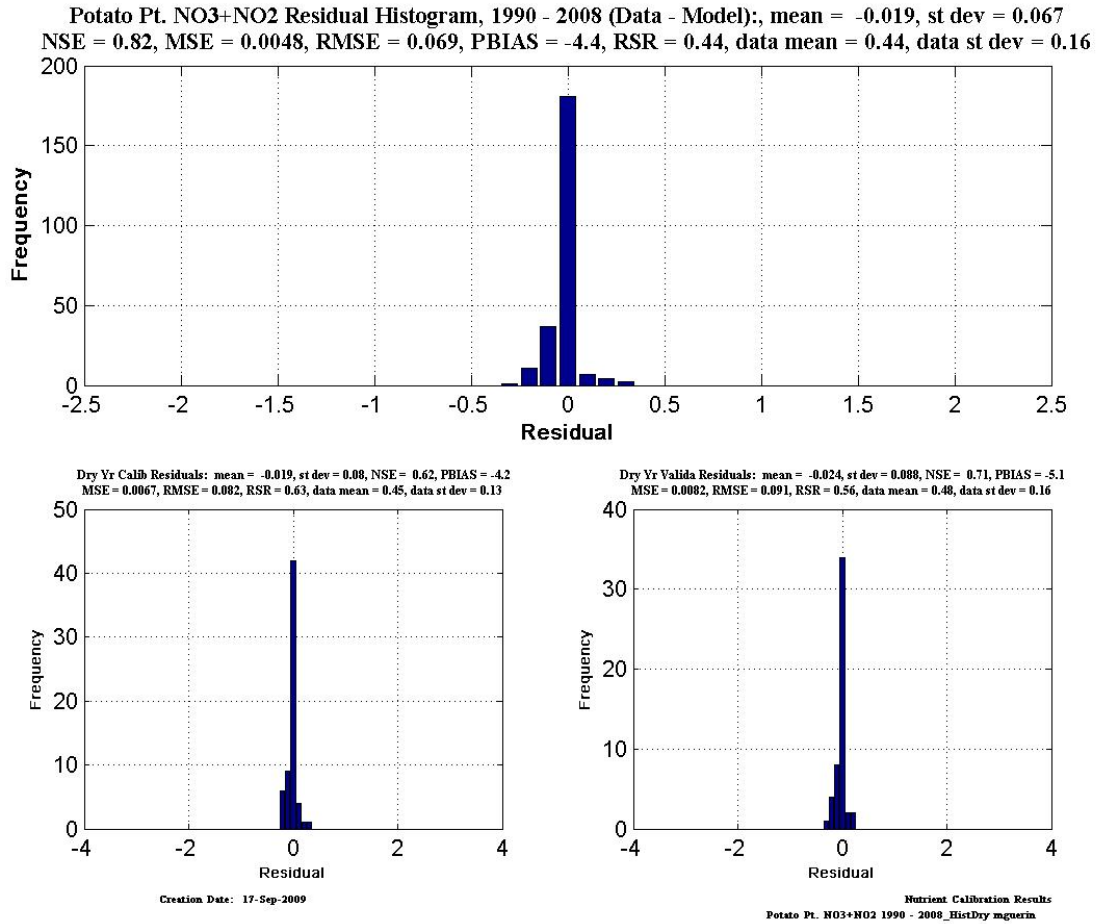


Figure A V. 17 Potato Pt. nitrate+nitrite dry years.

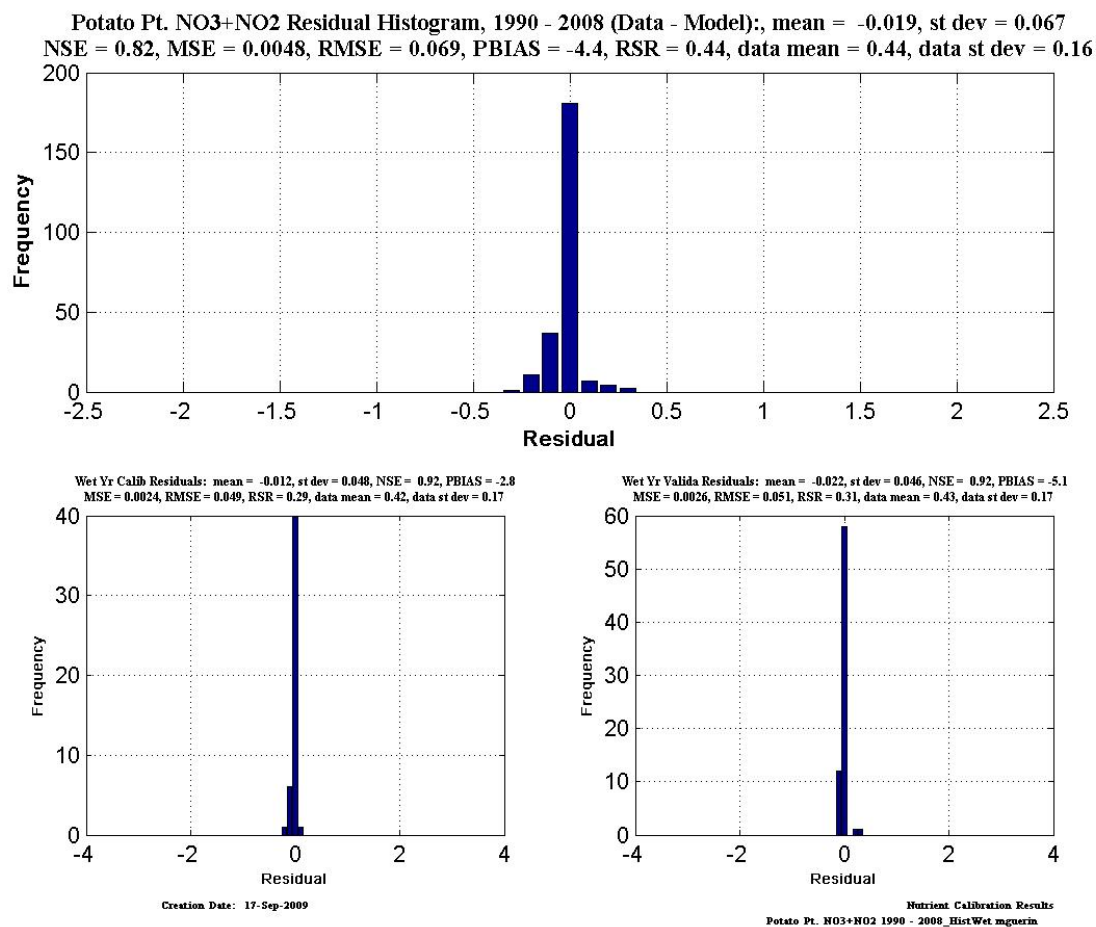


Figure A V. 18 Potato Pt. nitrate+nitrite wet years.

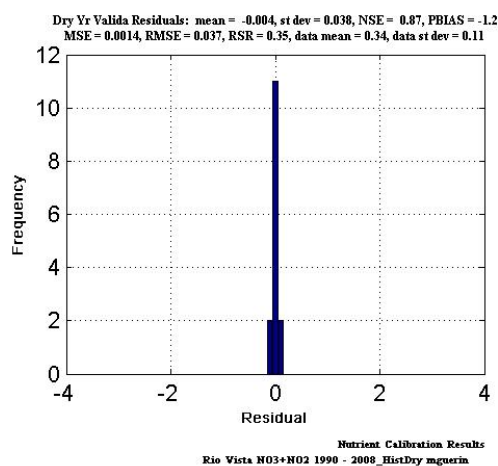
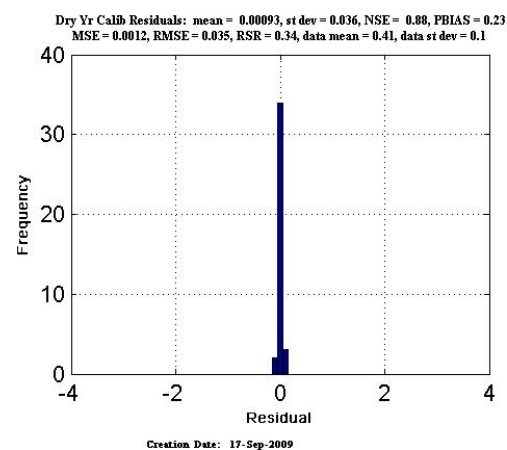
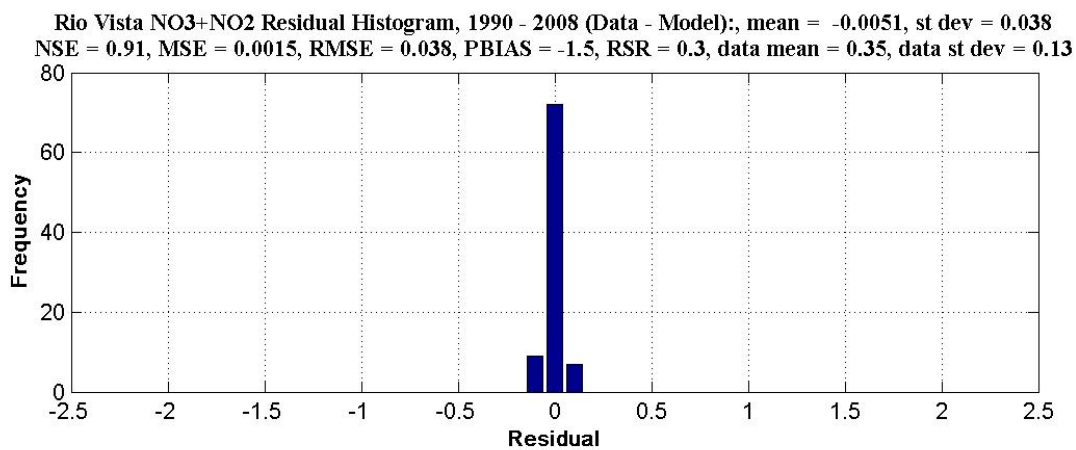


Figure A V. 19 Rio Vista nitrate+nitrite dry years.

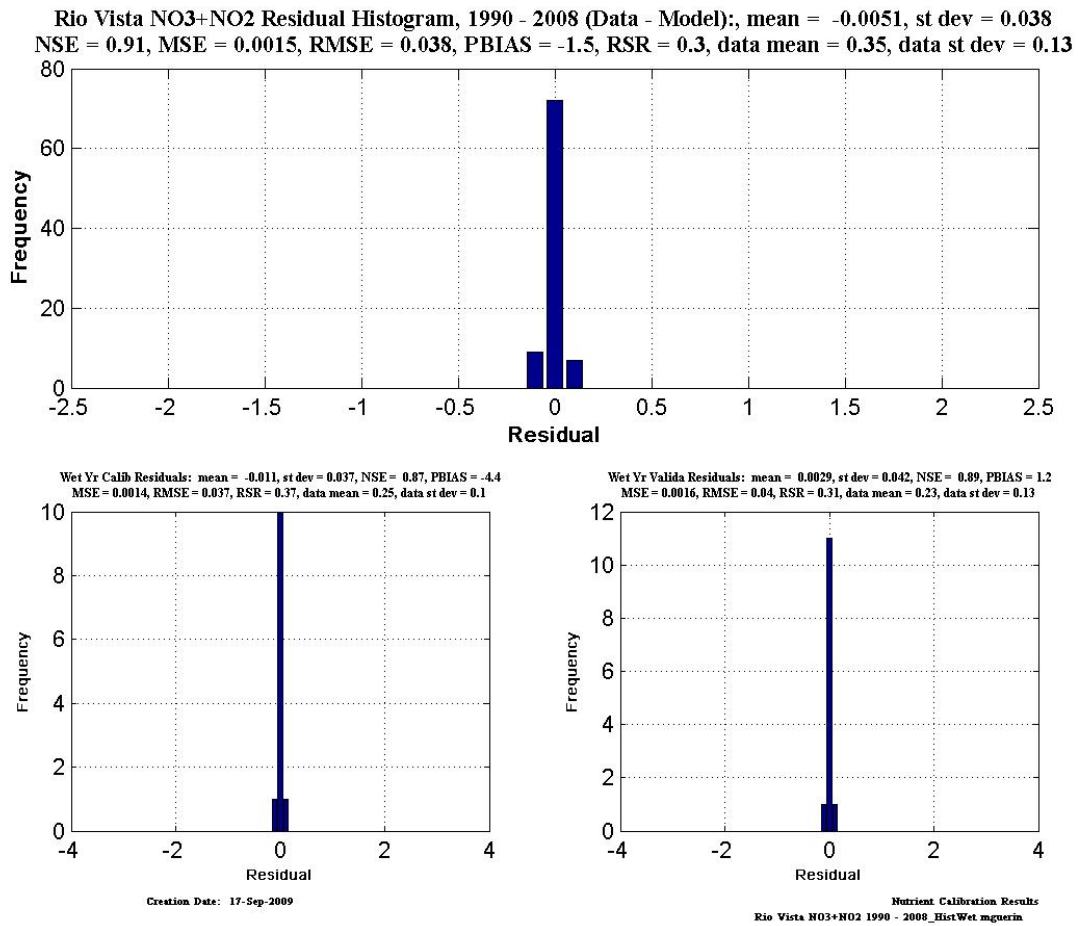


Figure A V. 20 Rio Vista nitrate+nitrite wet years.

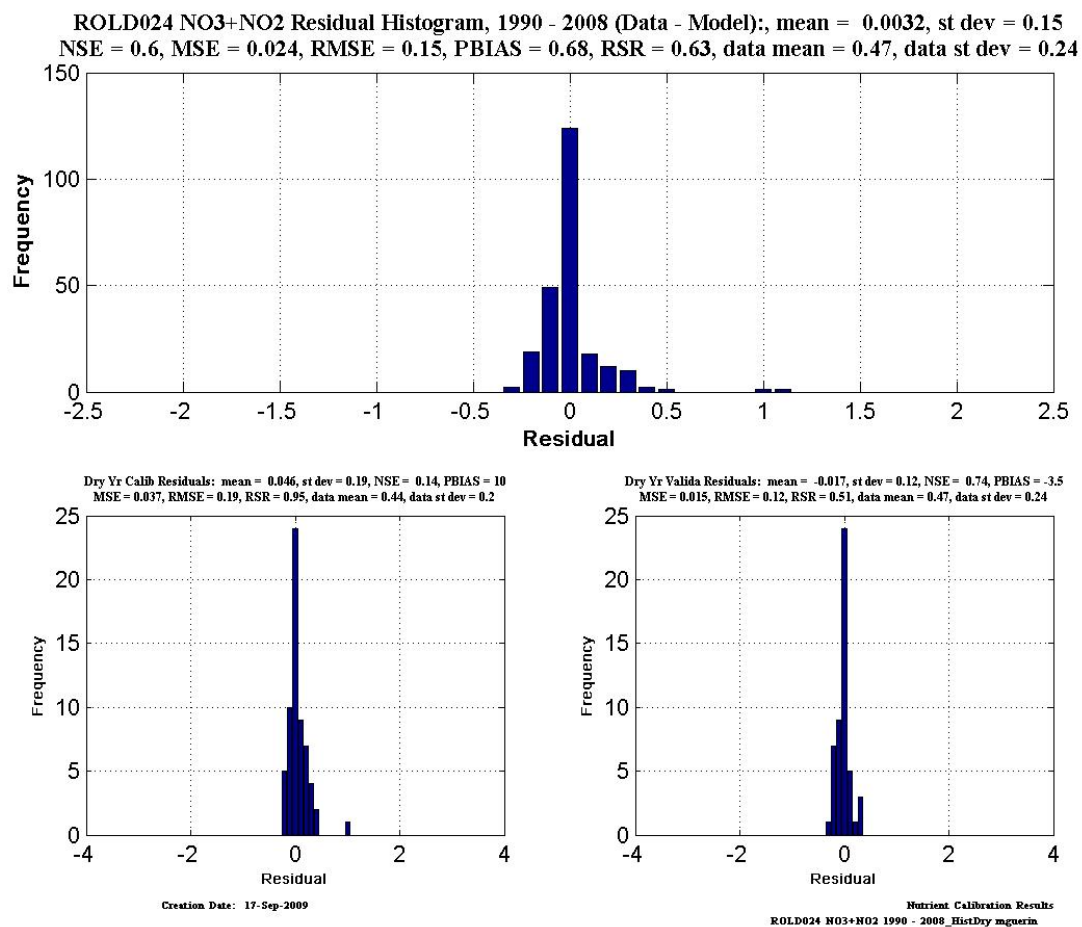


Figure A V. 21 ROLD024 nitrate+nitrite dry years.

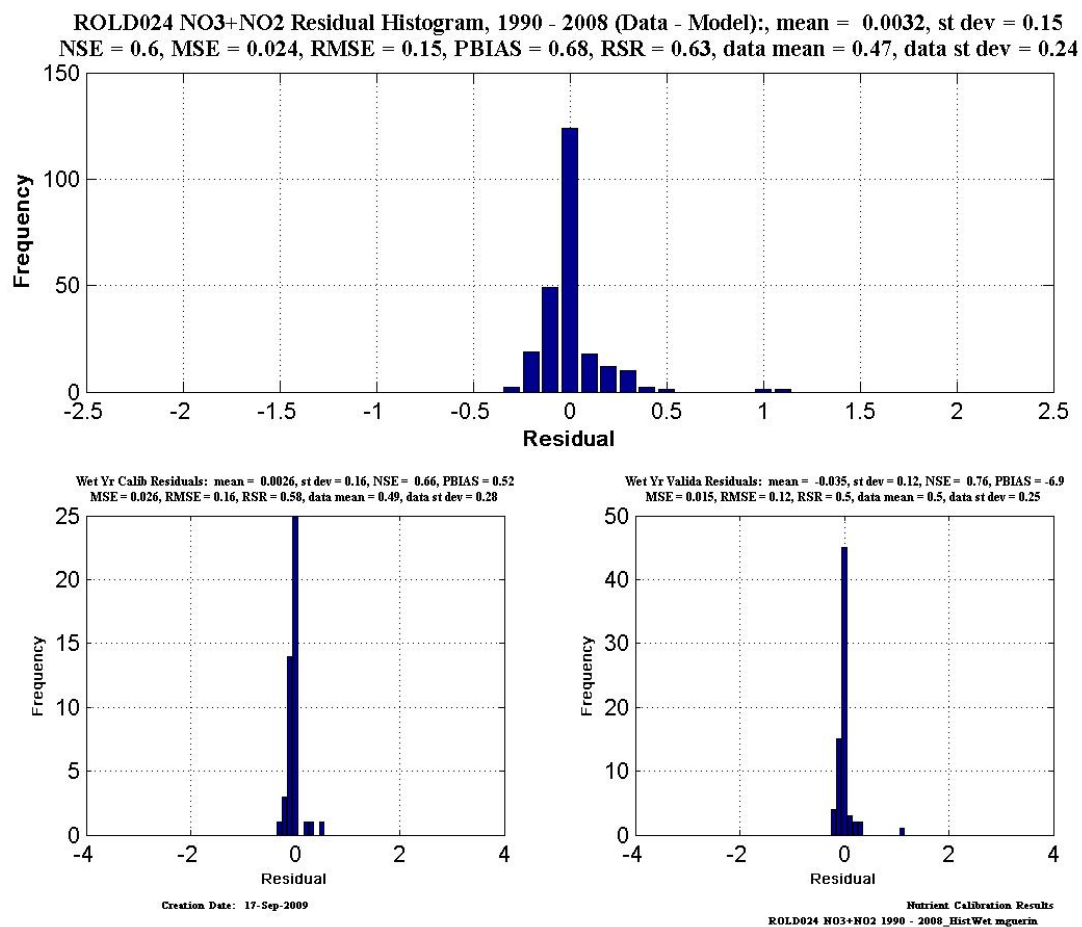


Figure A V. 22 ROLD024 nitrate+nitrite wet years.

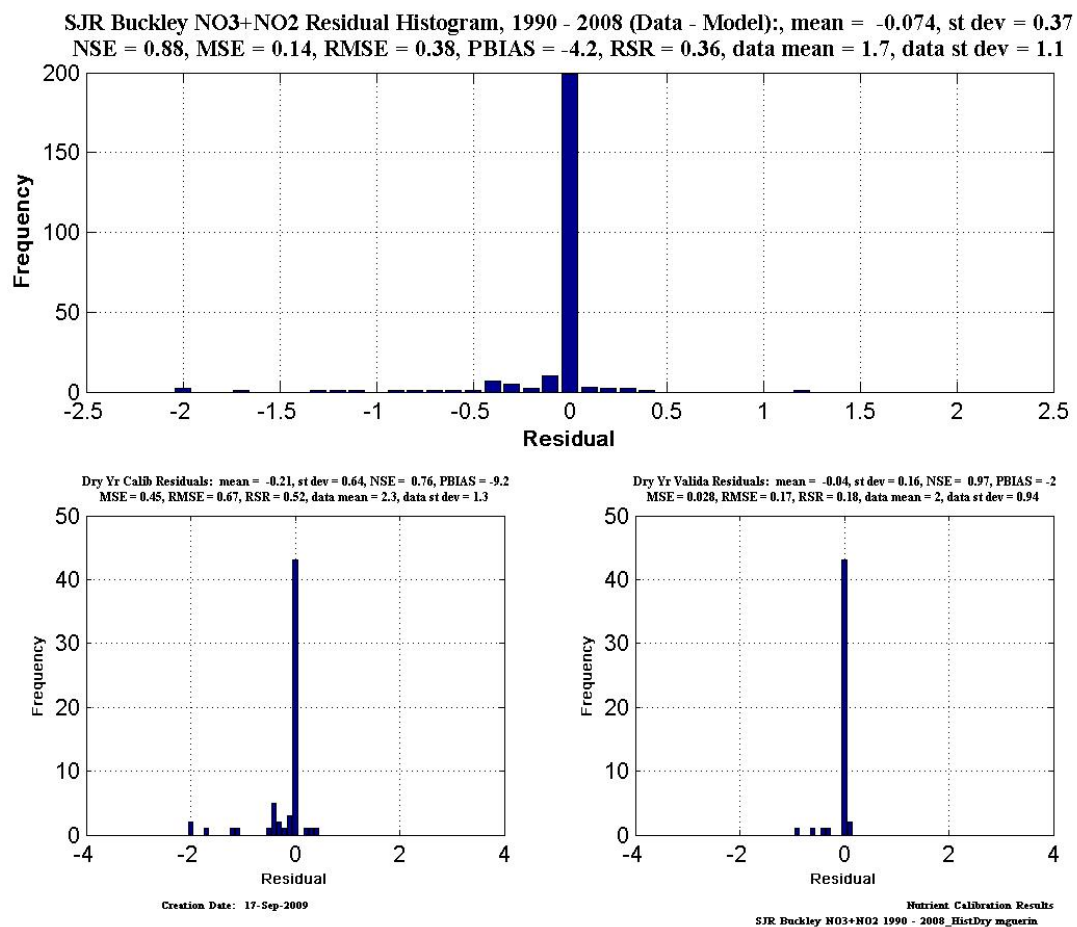


Figure A V. 23 SJR Buckley nitrate+nitrite dry years.

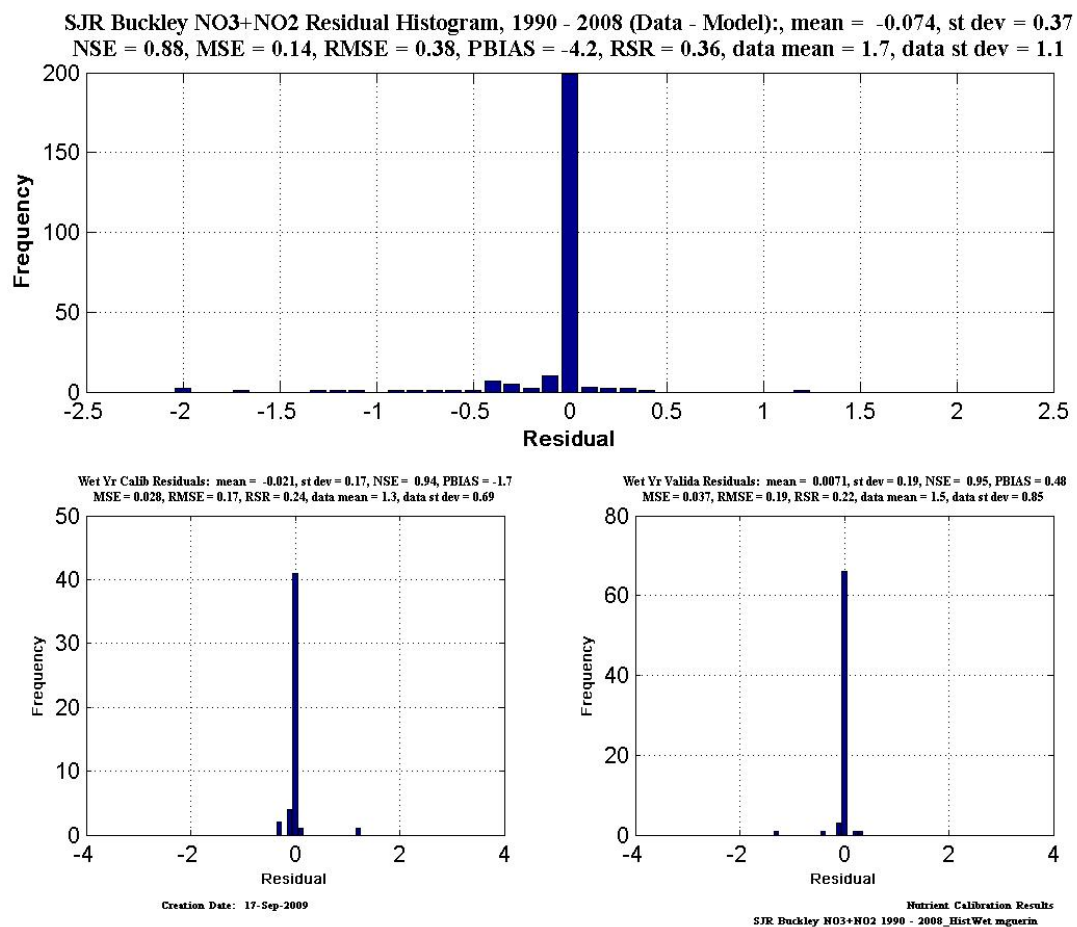


Figure A V. 24 SJR Buckley nitrate+nitrite wet years.

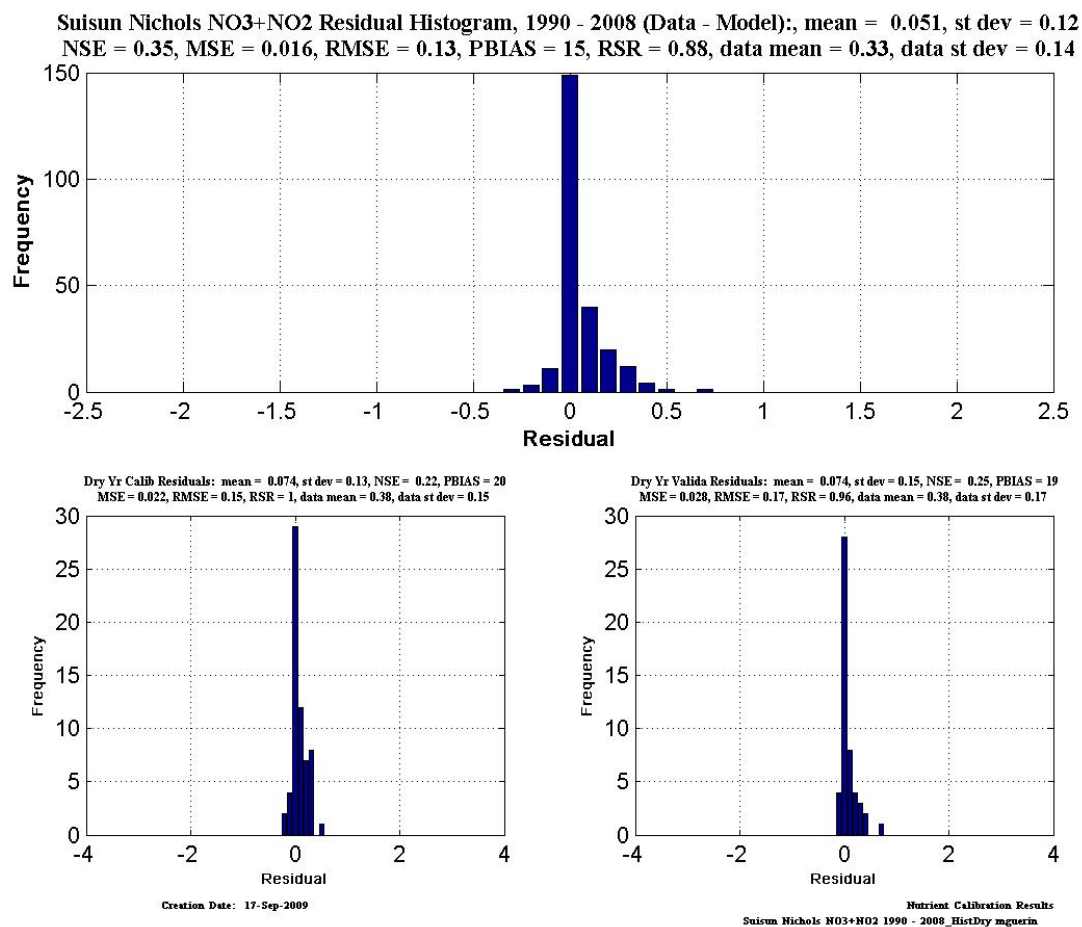


Figure A V. 25 Suisun-Nichols nitrate+nitrite dry years.

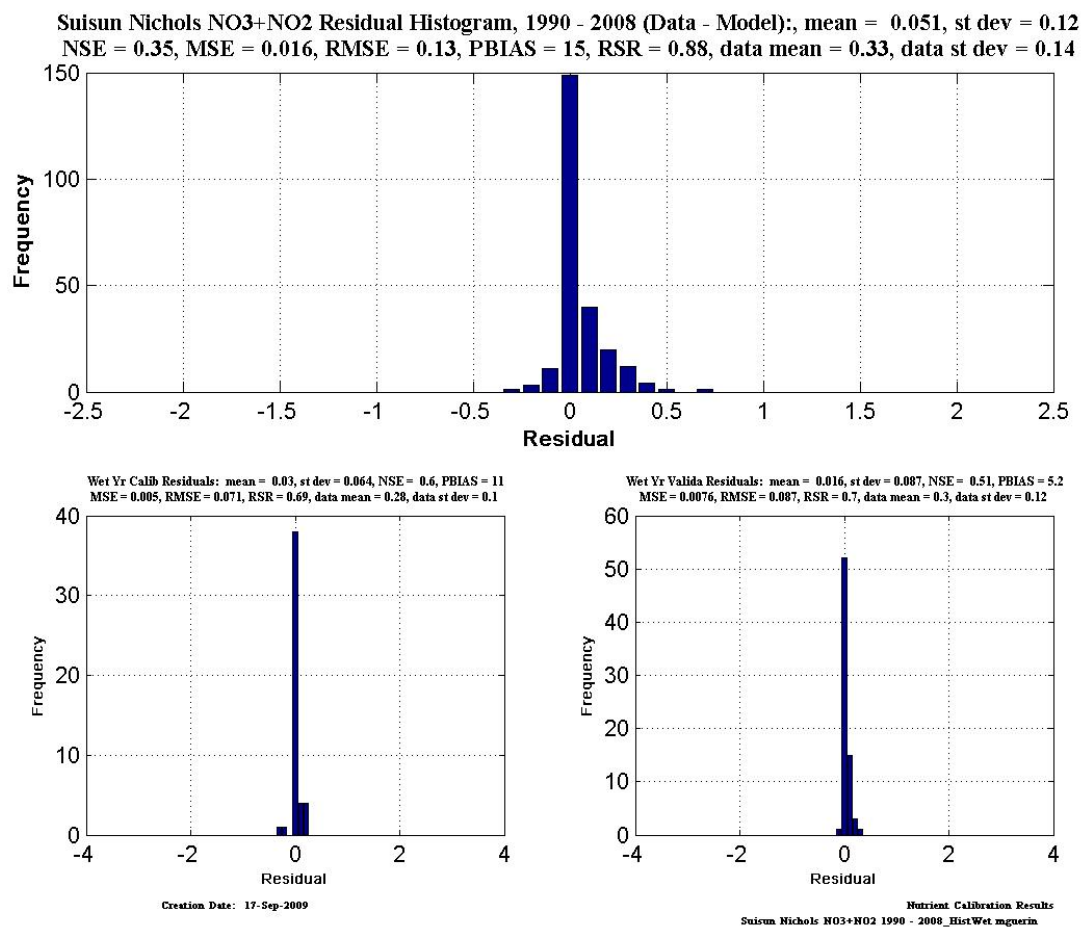


Figure A V. 26 Suisun-Nichols nitrate+nitrite wet years.

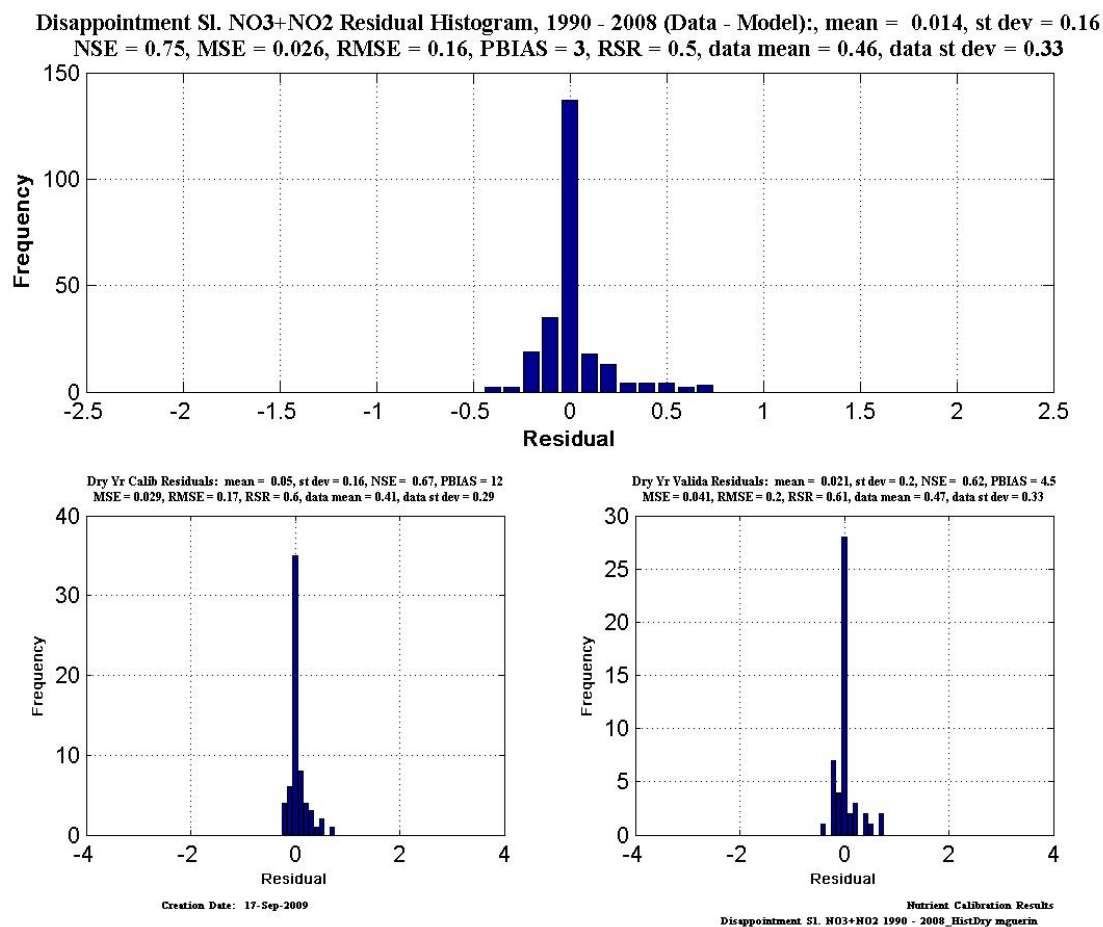


Figure A V. 27 Disappointment SL. nitrate+nitrite dry years.

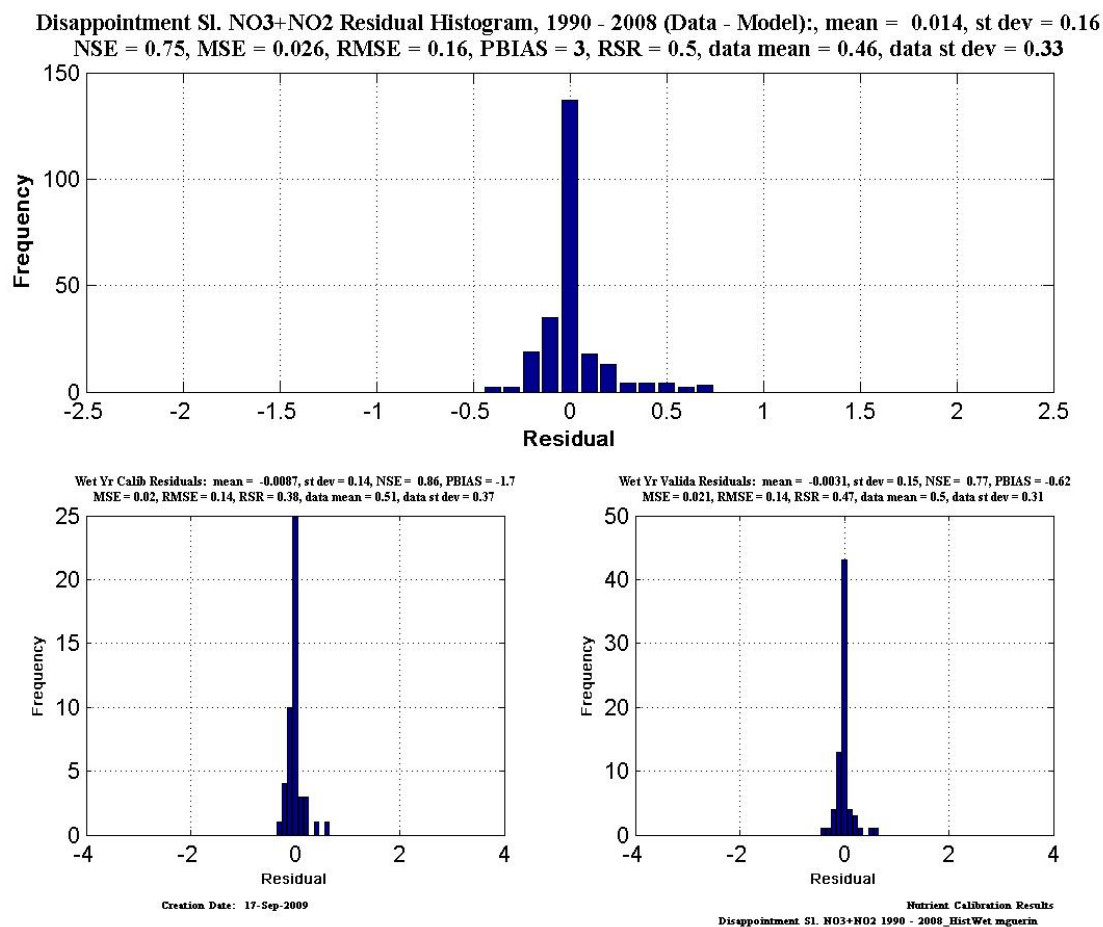


Figure A V. 28 Disappointment SL. nitrate+nitrite wet years.

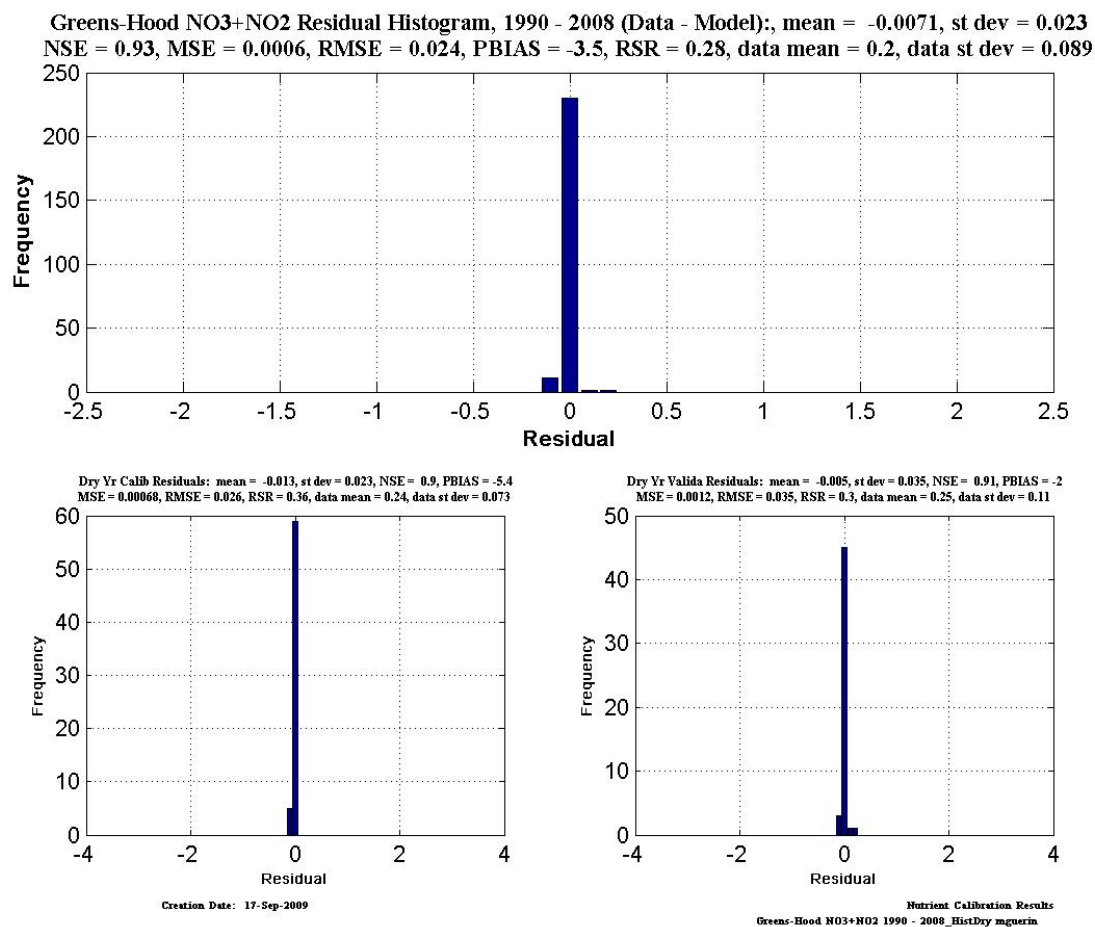


Figure A V. 29 Greenes-Hood nitrate+nitrite dry years.

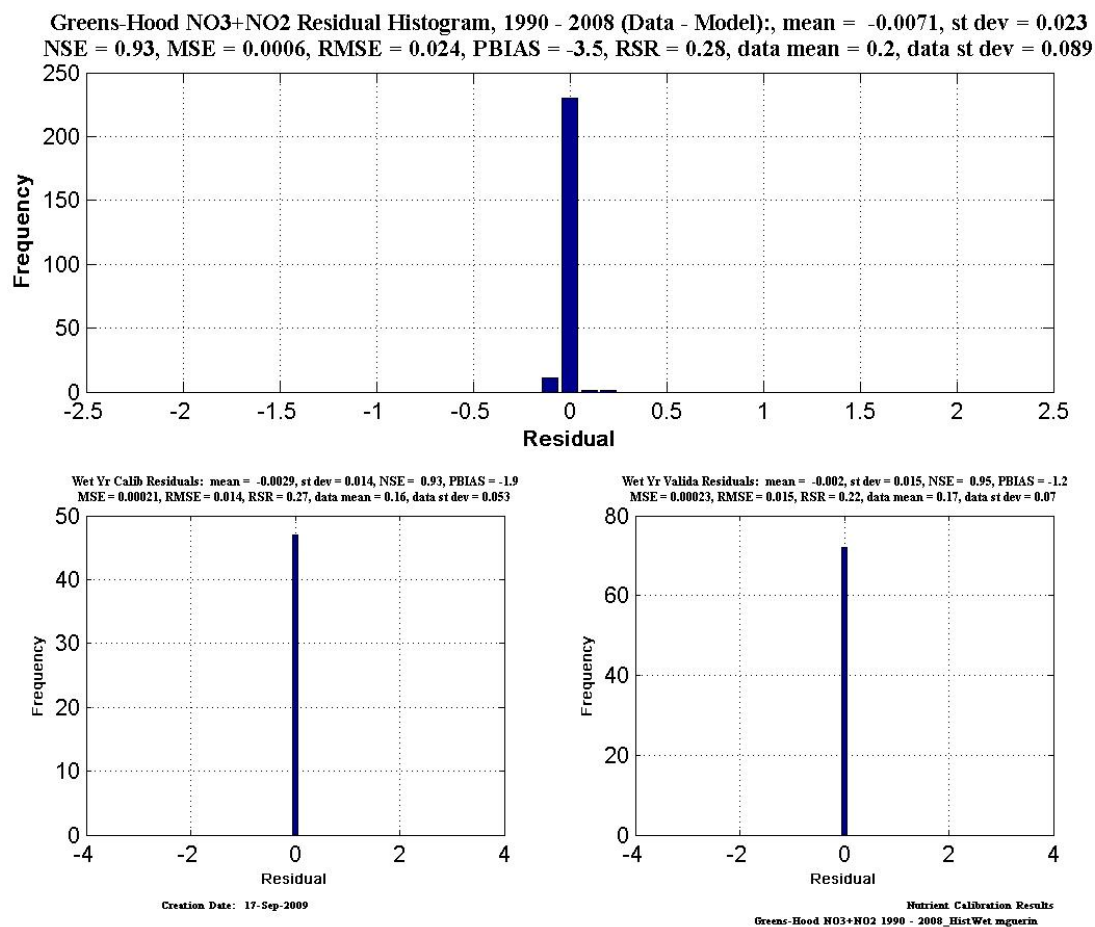


Figure A V. 30 Greenes-Hood nitrate+nitrite wet years.

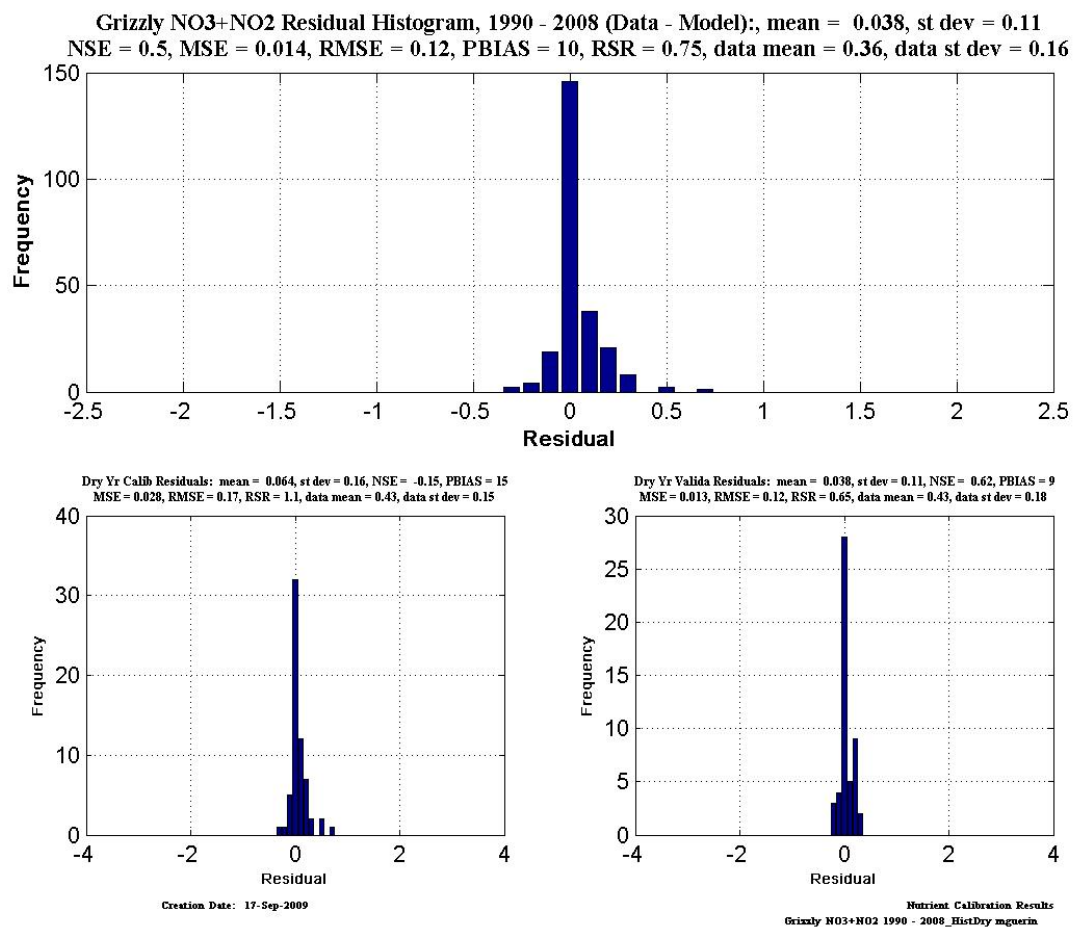


Figure A V. 31 Grizzly nitrate+nitrite dry years.

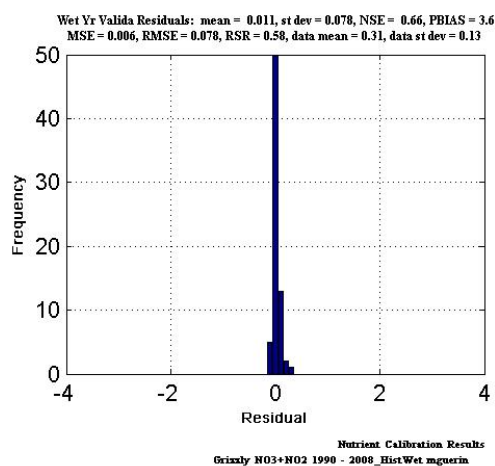
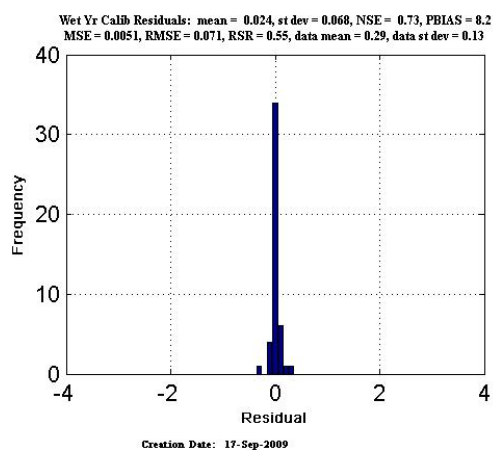
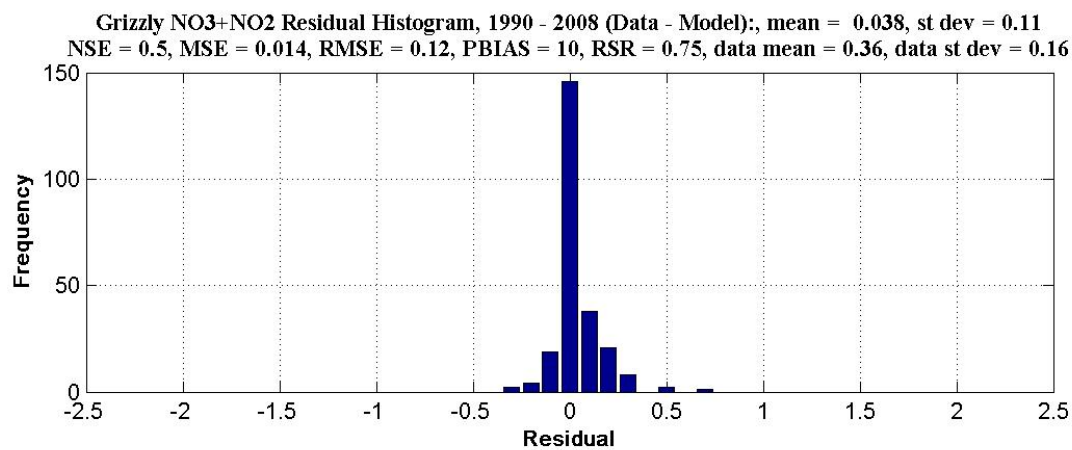


Figure A V. 32 Grizzly nitrate+nitrite wet years.

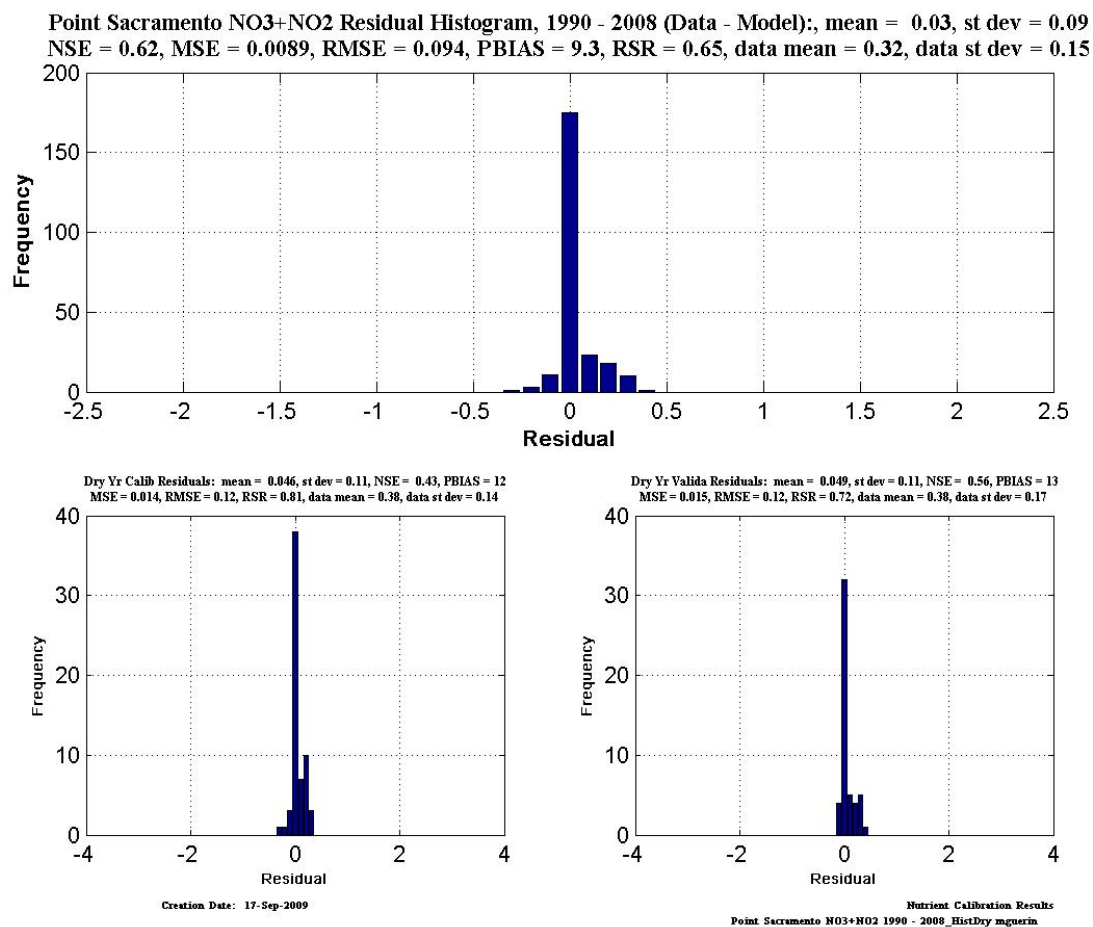


Figure A V. 33 Pt Sacramento nitrate+nitrite dry years.

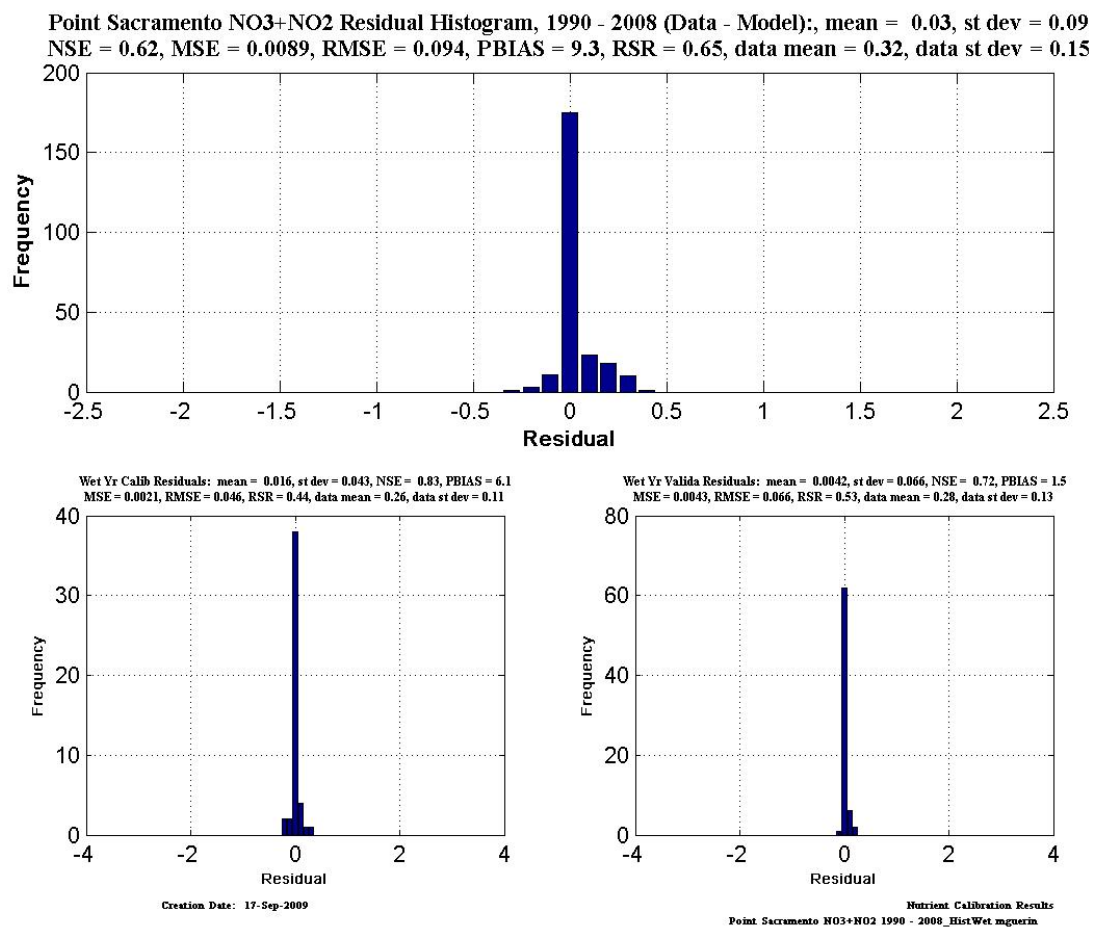


Figure A V. 34 Pt. Sacramento nitrate+nitrite wet years.

C. DO calibration

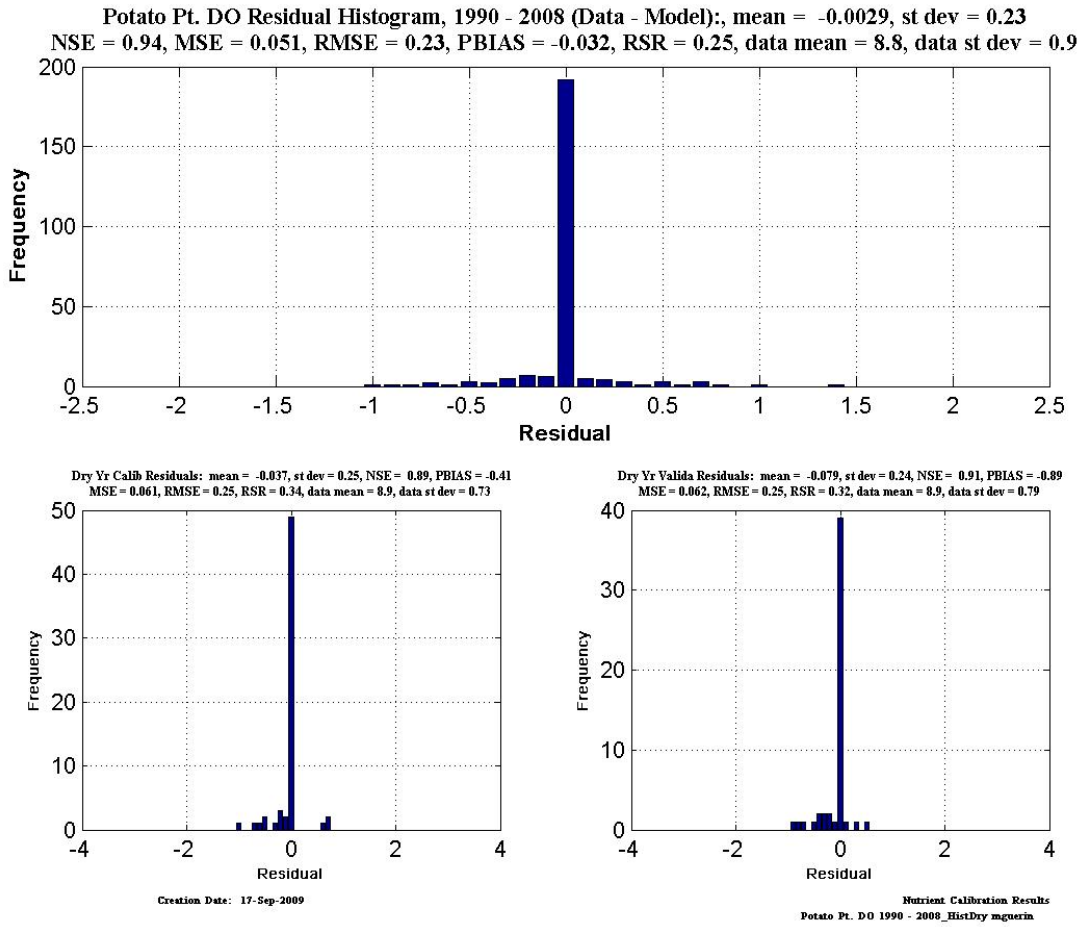


Figure A V. 35 Potato Pt. DO dry years.

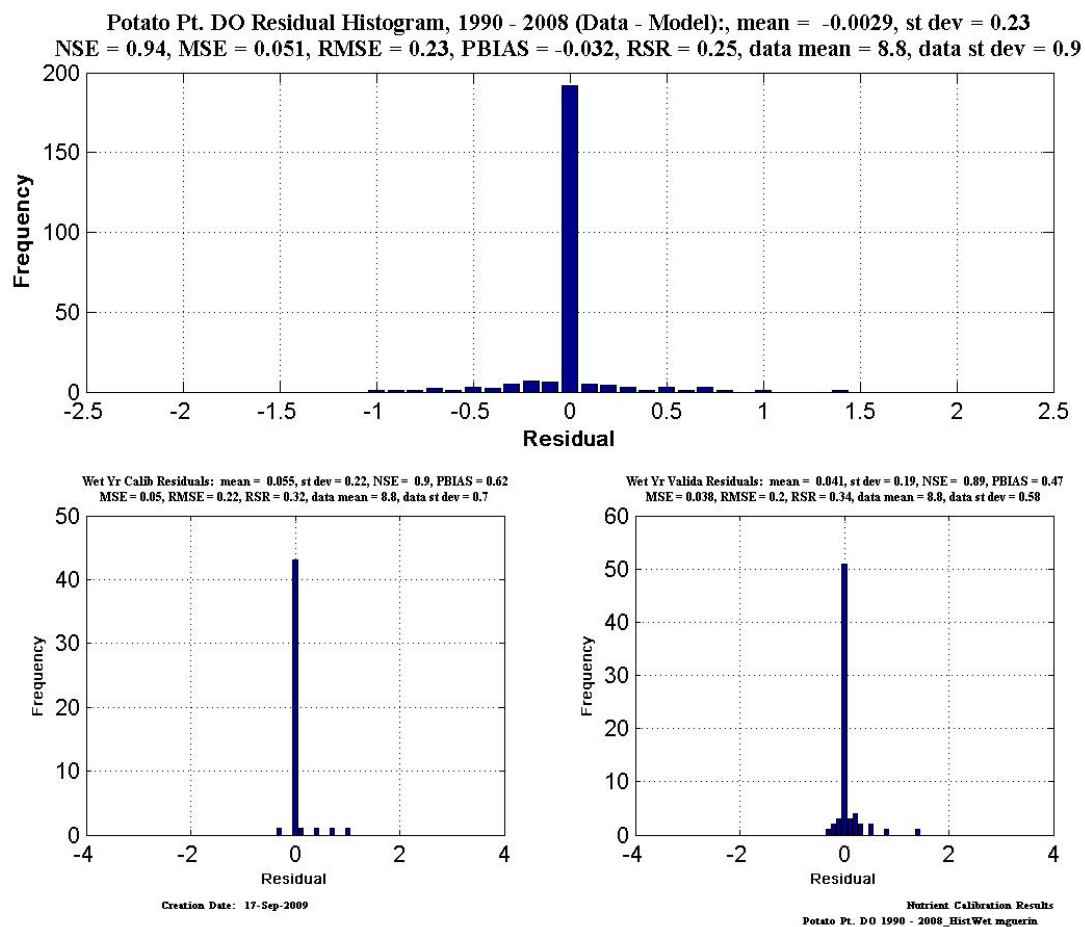


Figure A V. 36 Potato Pt. DO wet years.

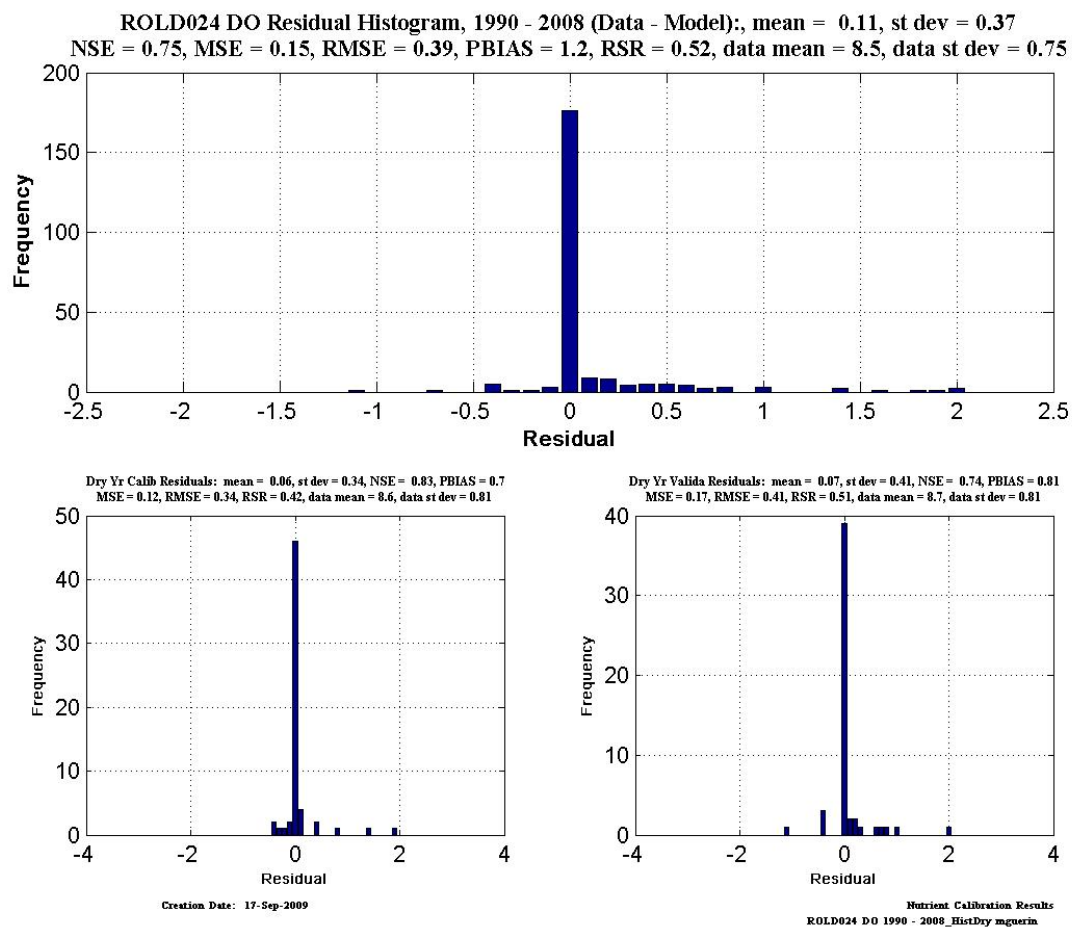


Figure A V. 37 ROLD024 DO dry years.

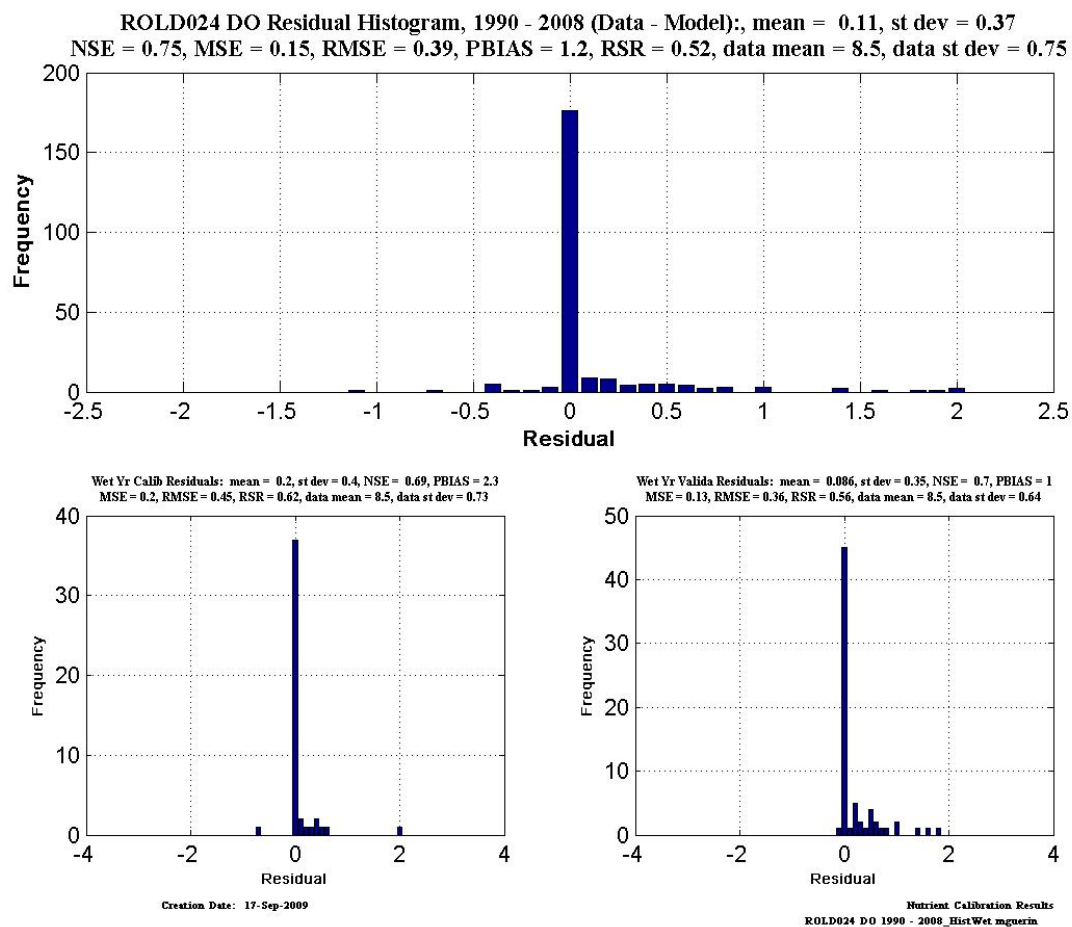


Figure A V. 38 ROLD024 DO wet years.

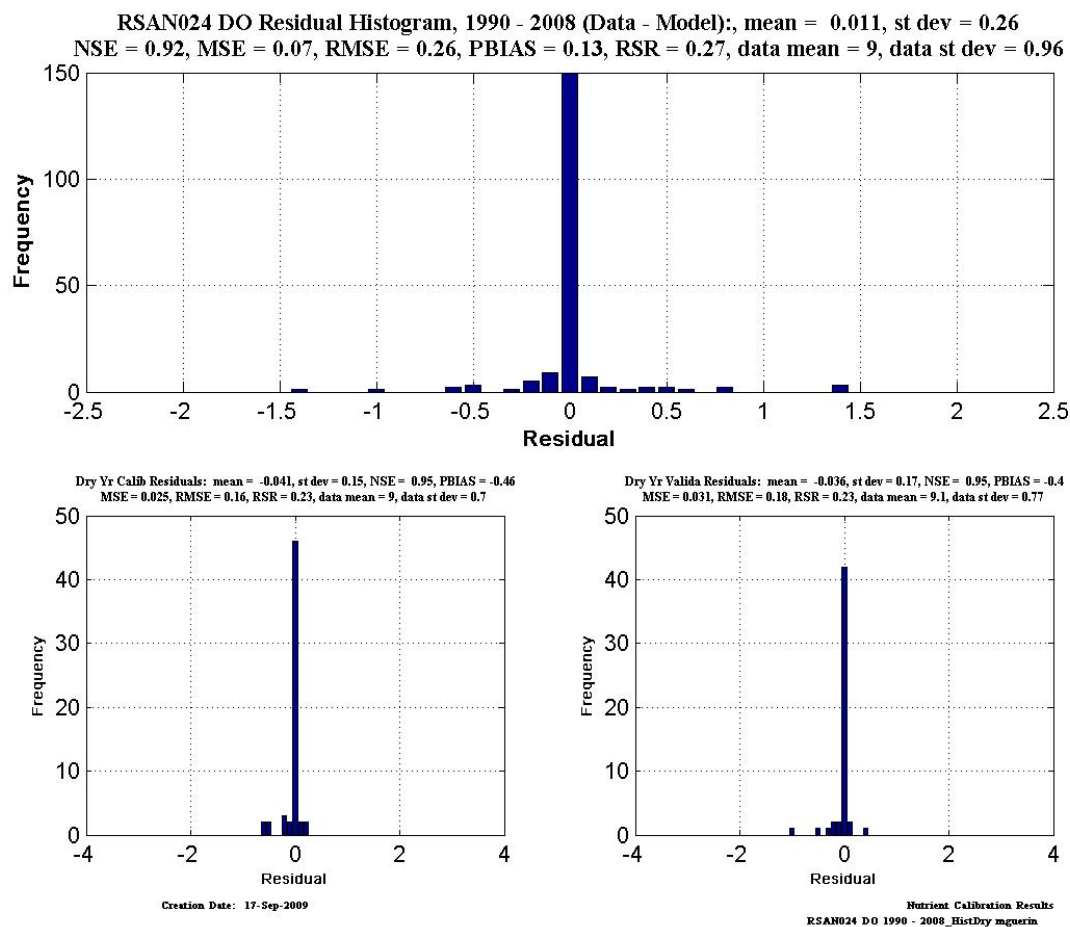


Figure A V. 39 RSAN024 DO dry years.

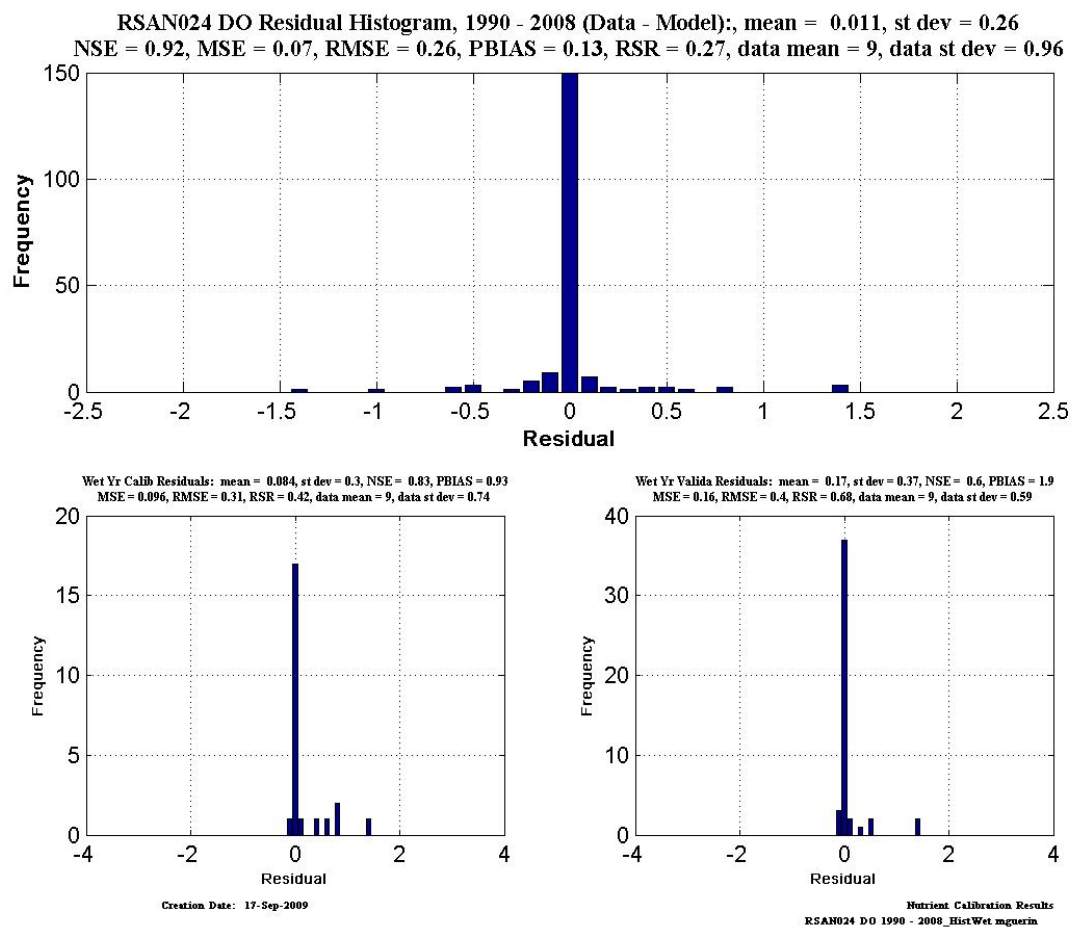


Figure A V. 40 RSAN024 DO wet years.

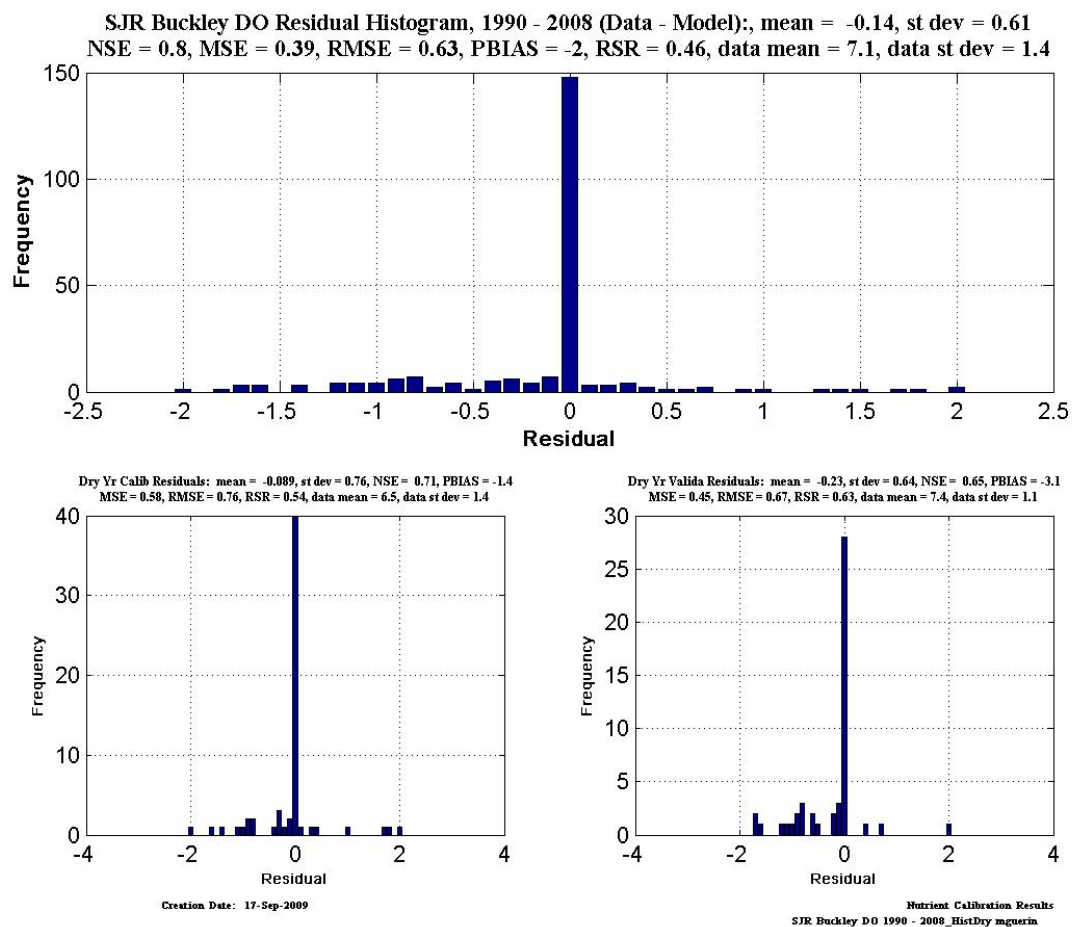


Figure A V. 41 SJR Buckley DO dry years.

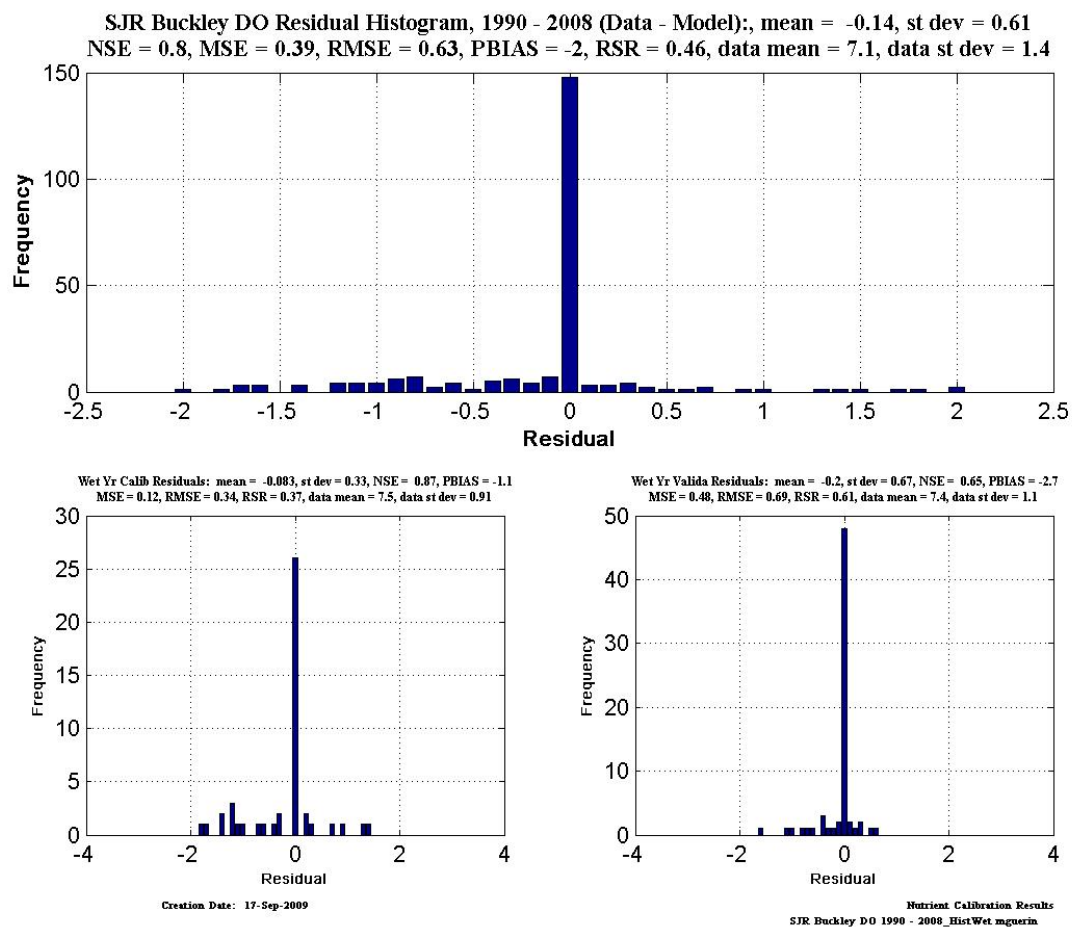


Figure A V. 42 SJR Buckley DO wet years.

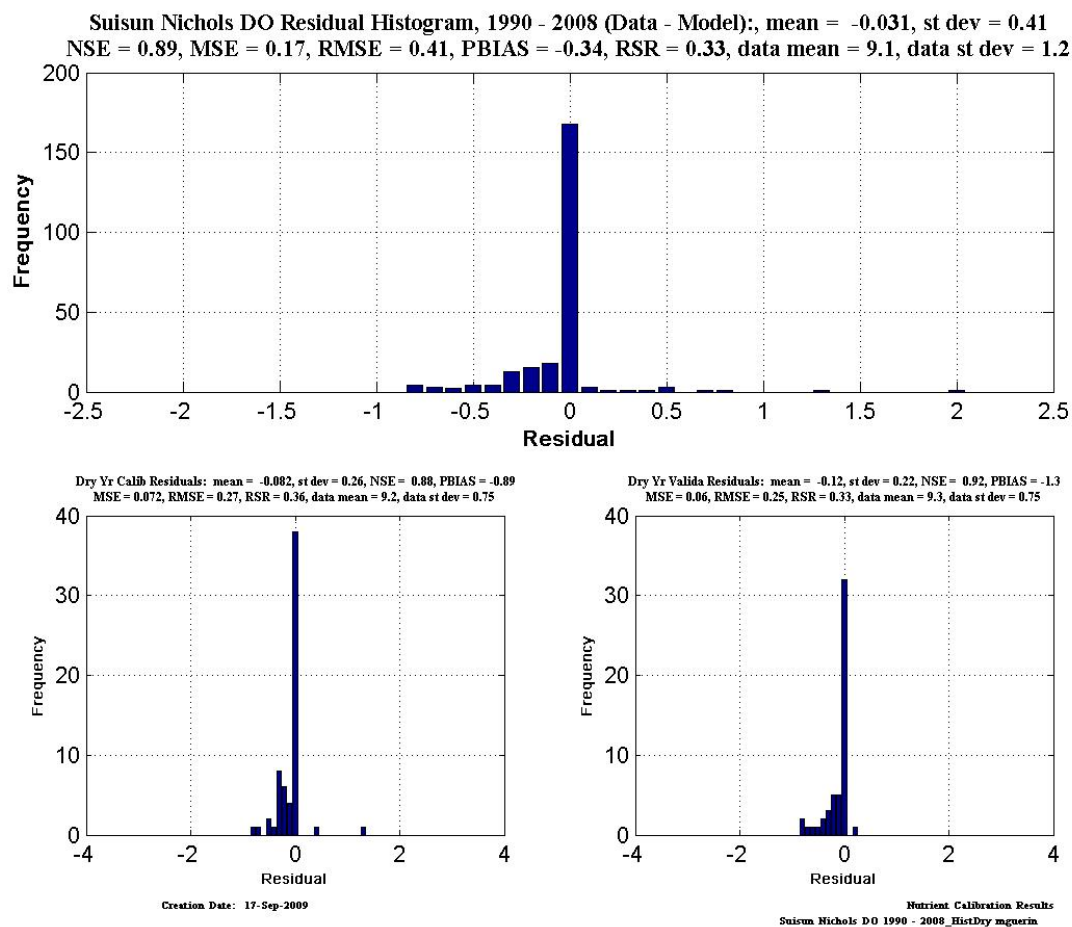


Figure A V. 43 Suisun-Nichols DO dry years.

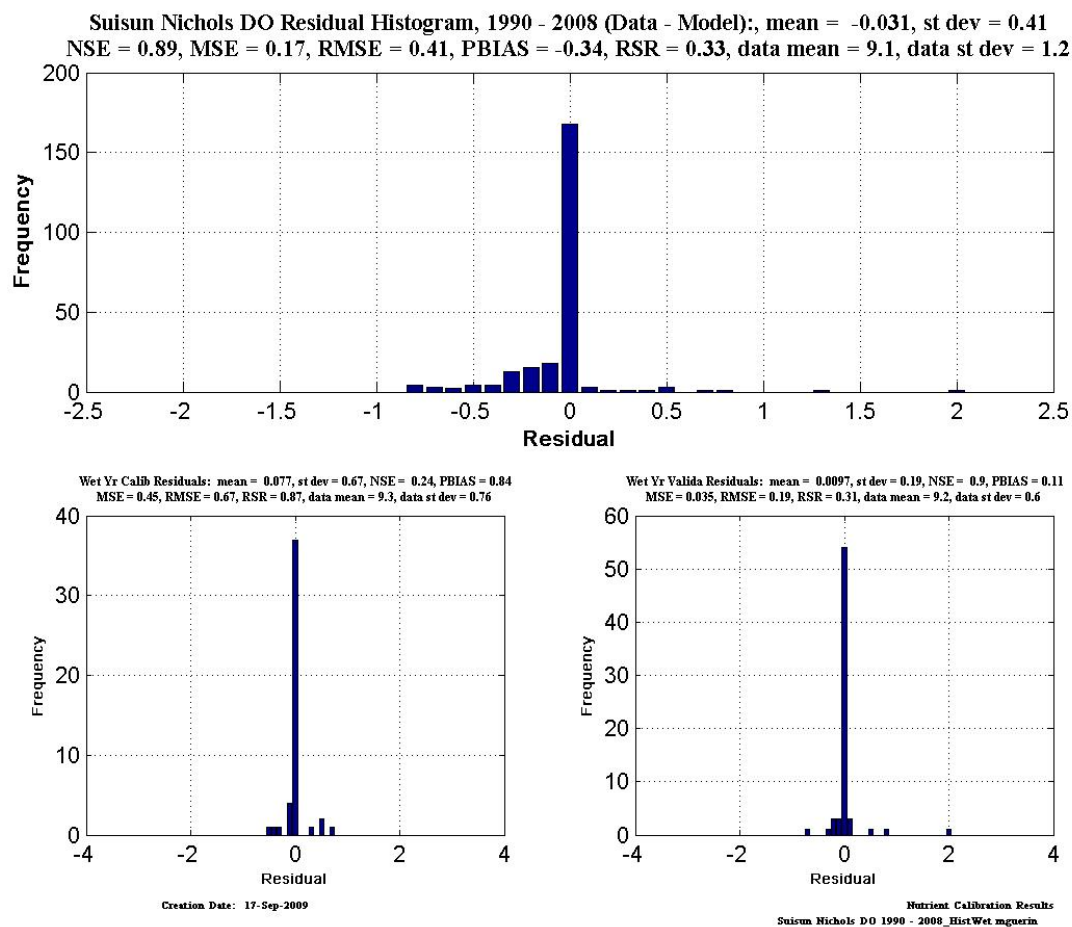


Figure A V. 44 Suisun-Nichols DO wet years.

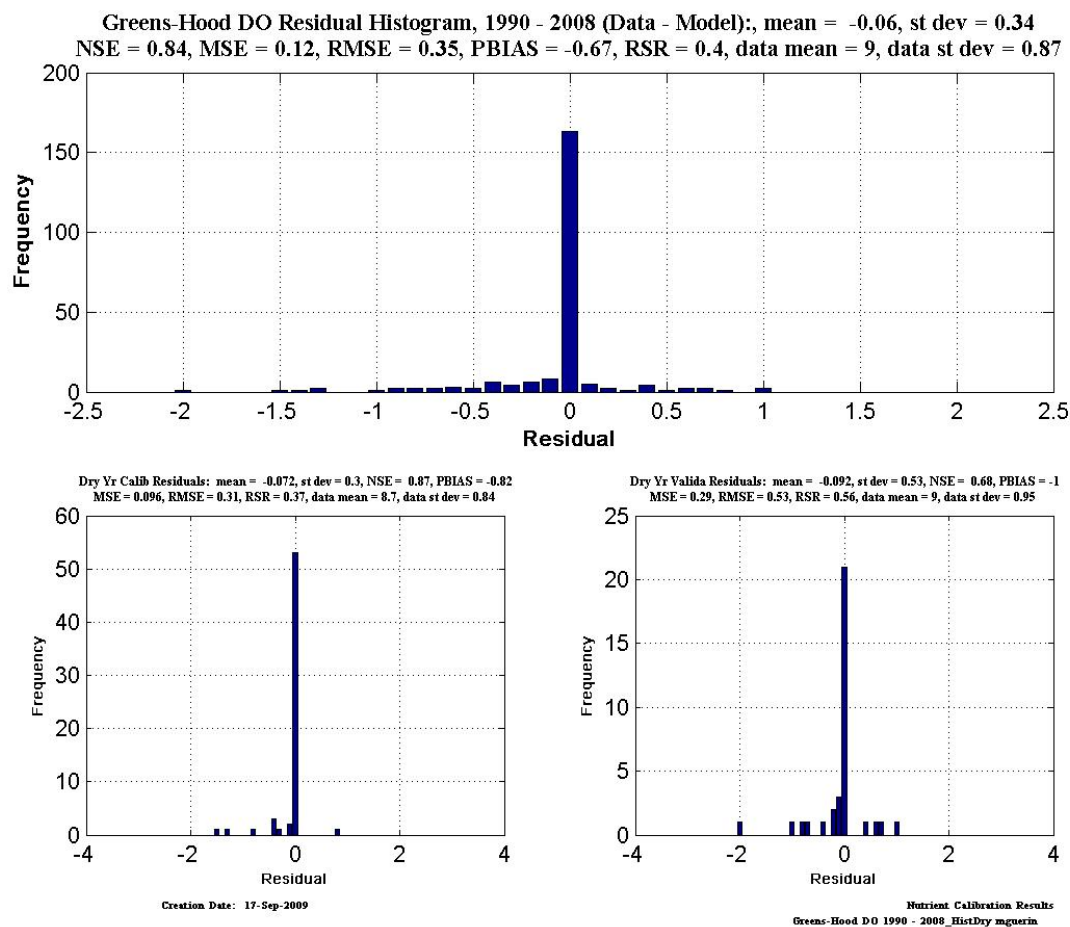


Figure A V. 45 Greenes-Hood DO dry years.

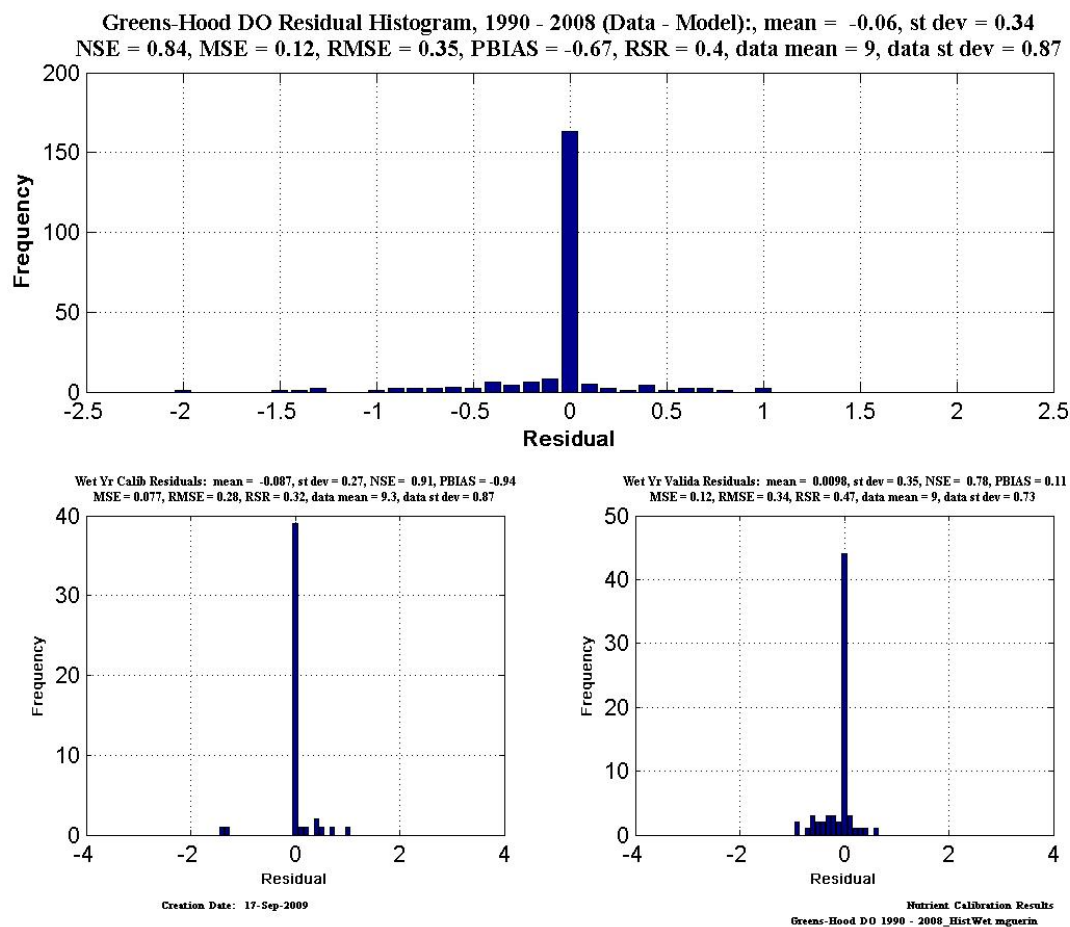


Figure A V. 46 Greenes-Hood DO wet years.

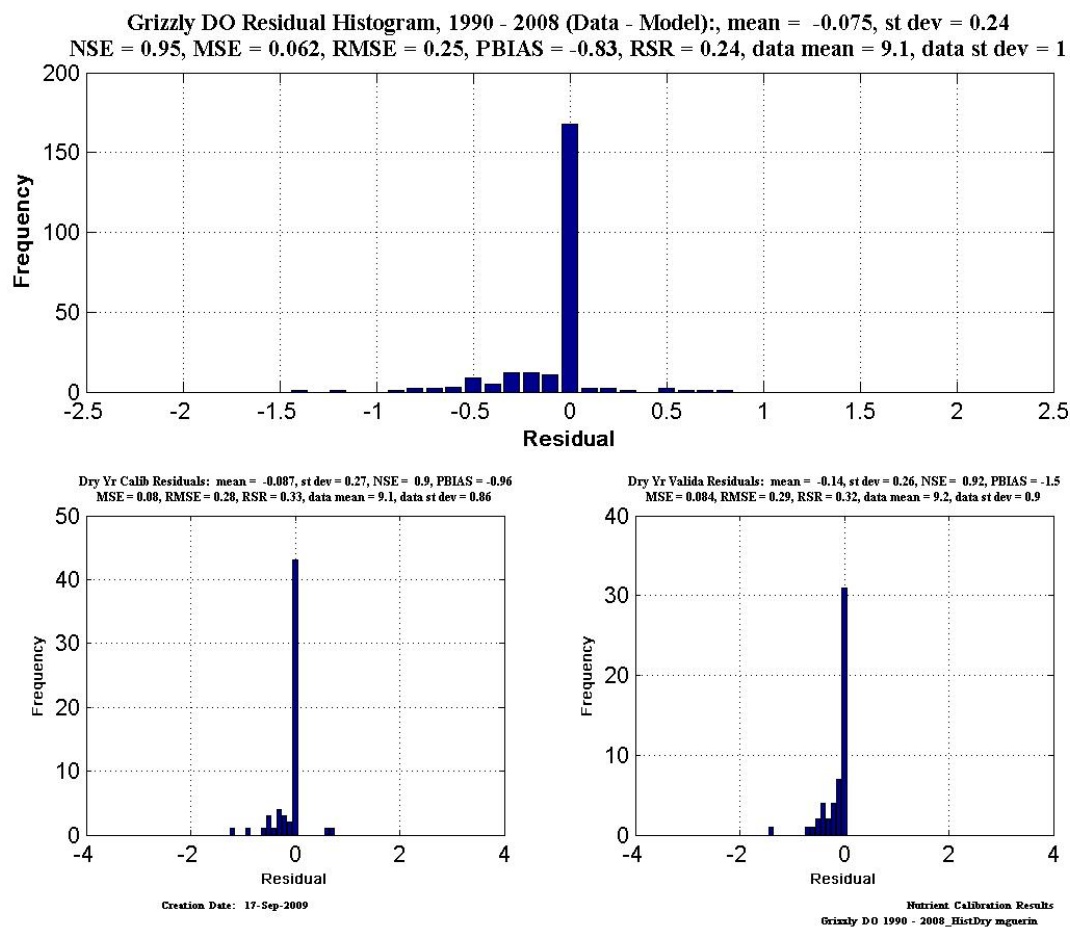


Figure A V. 47 Grizzly DO dry years.

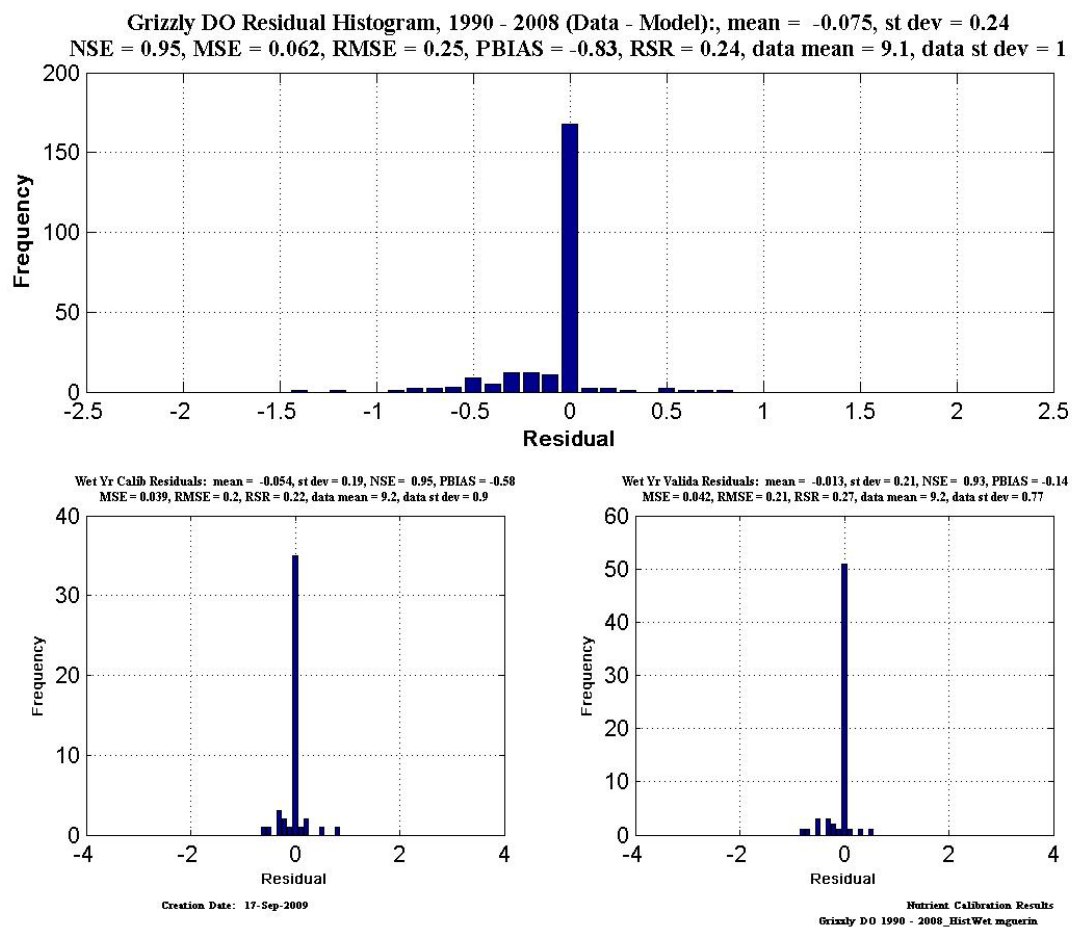


Figure A V. 48 Grizzly DO wet years.

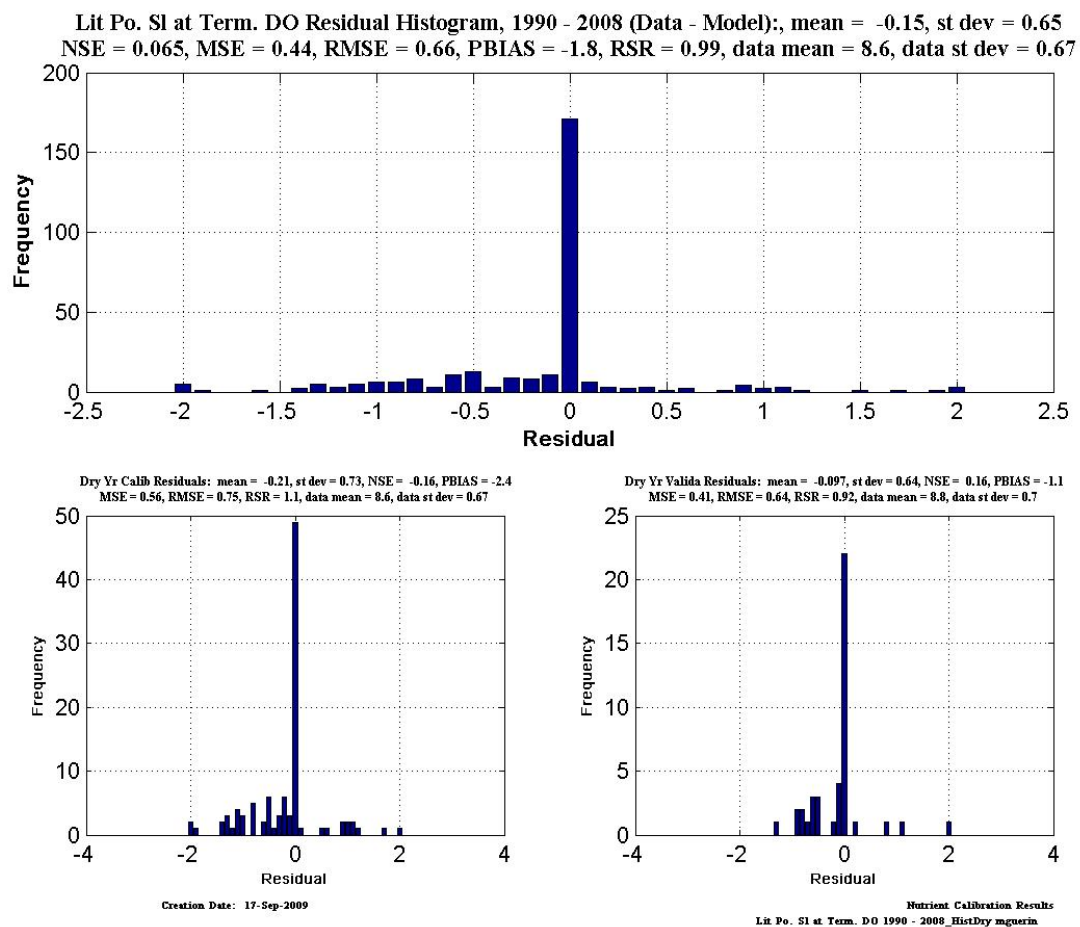


Figure A V. 49 Lit Potato Sl. at Terminous DO dry years.

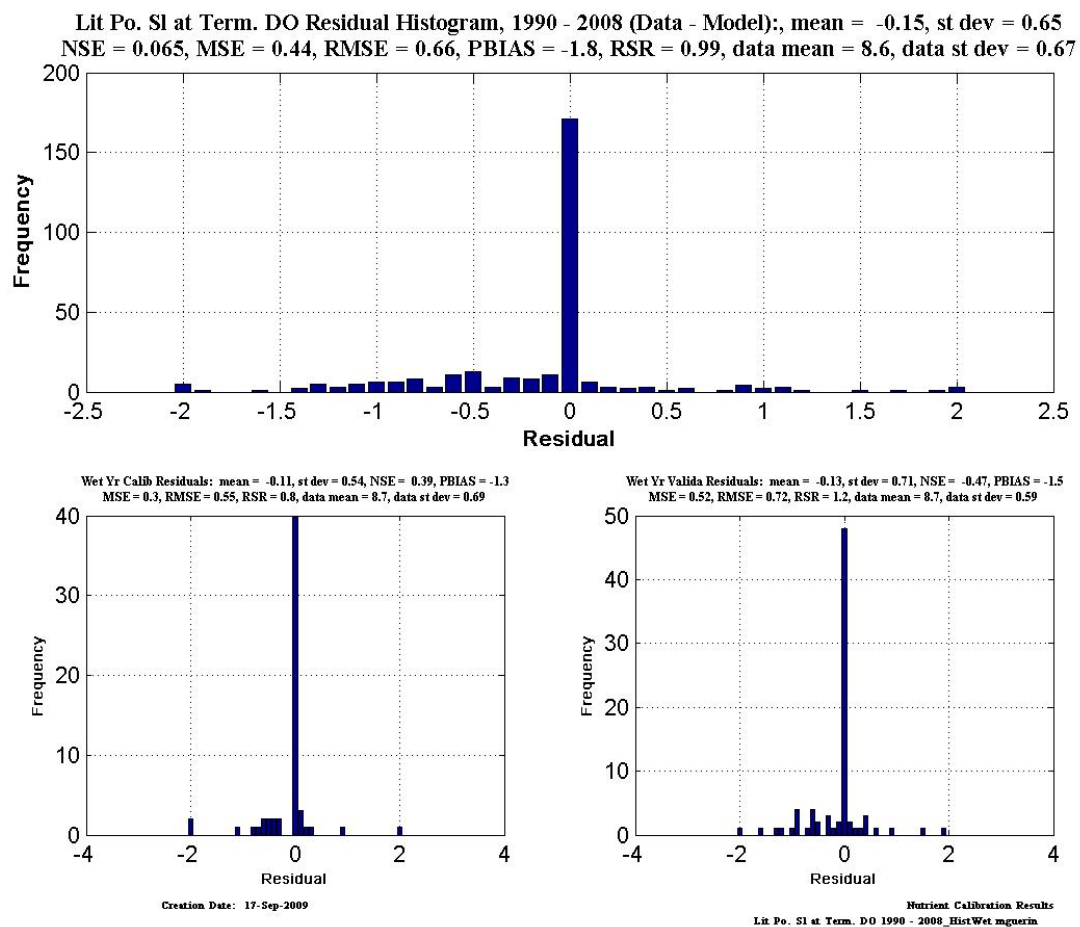


Figure A V. 50 Lit Potato Sl. at Terminous DO wet years.

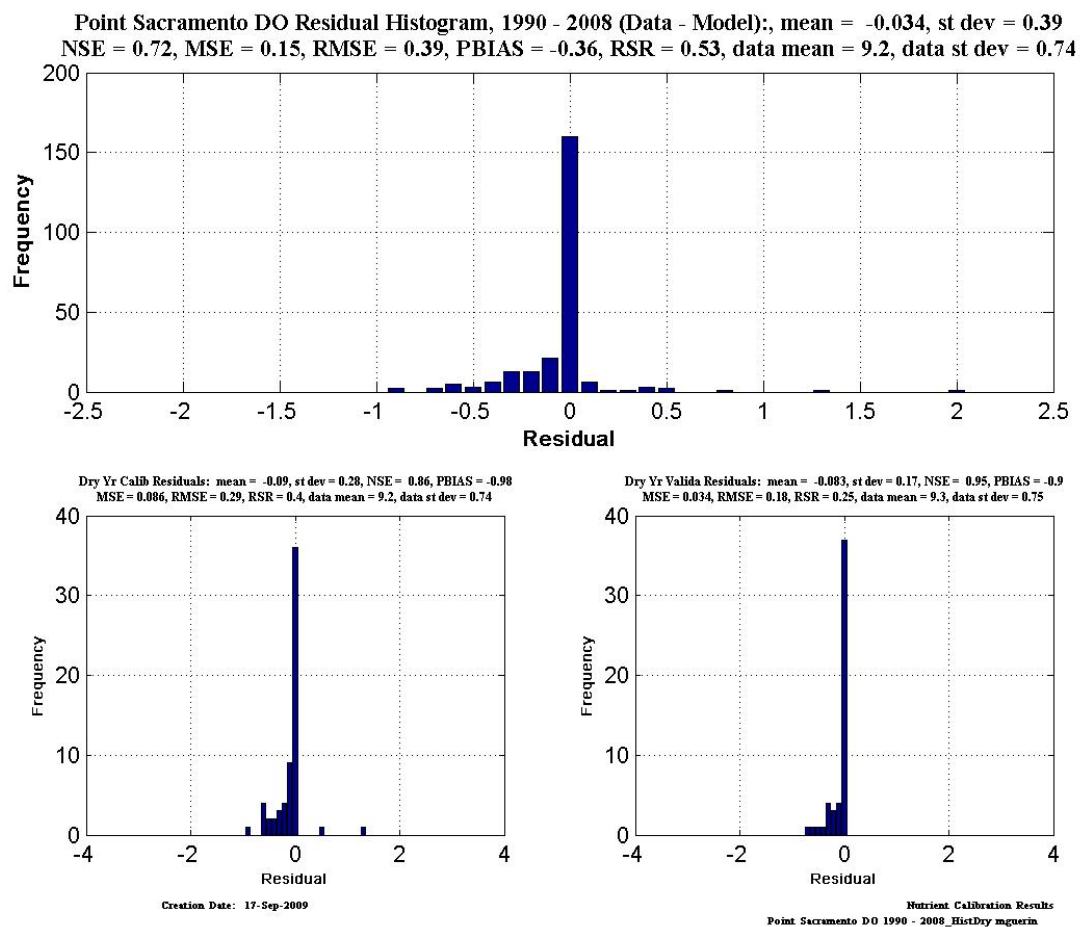


Figure A V. 51 Pt Sacramento DO dry years.

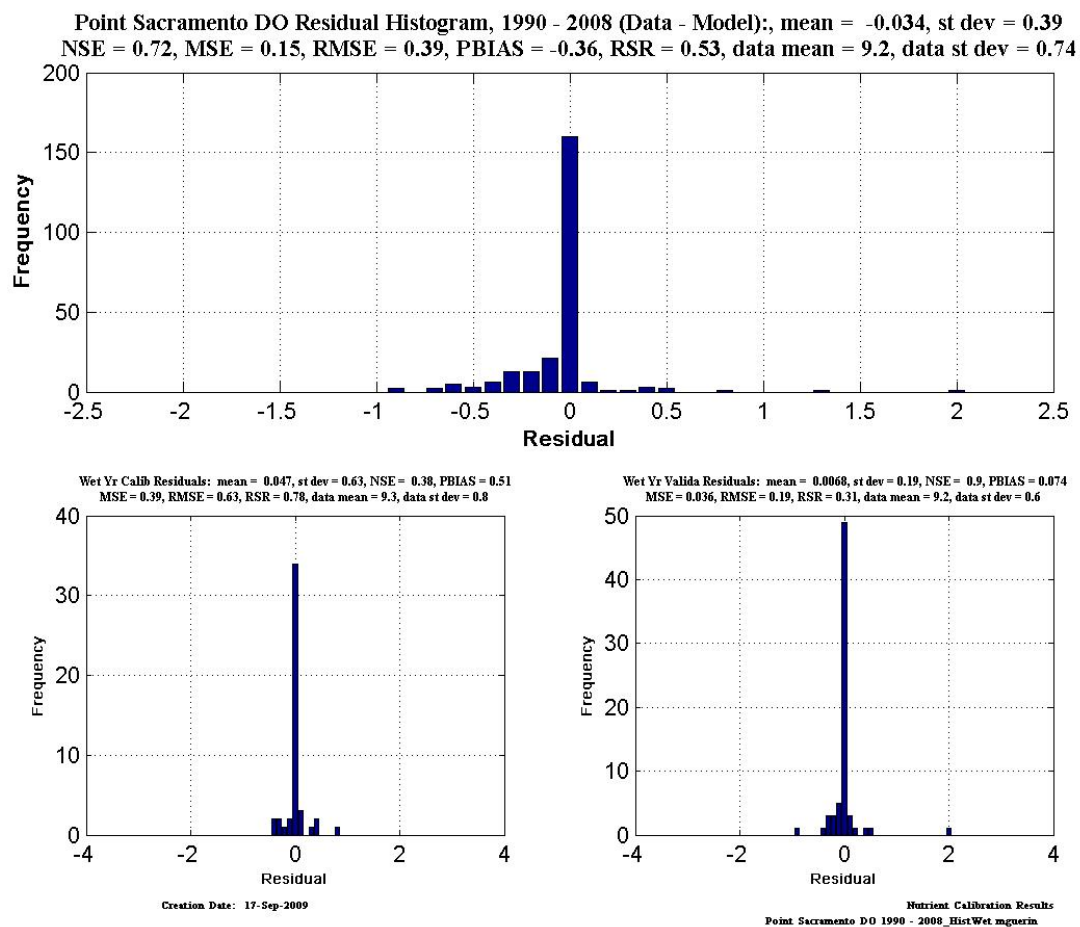


Figure A V. 52 Pt Sacramento DO wet years.

D. Algal Biomass calibration

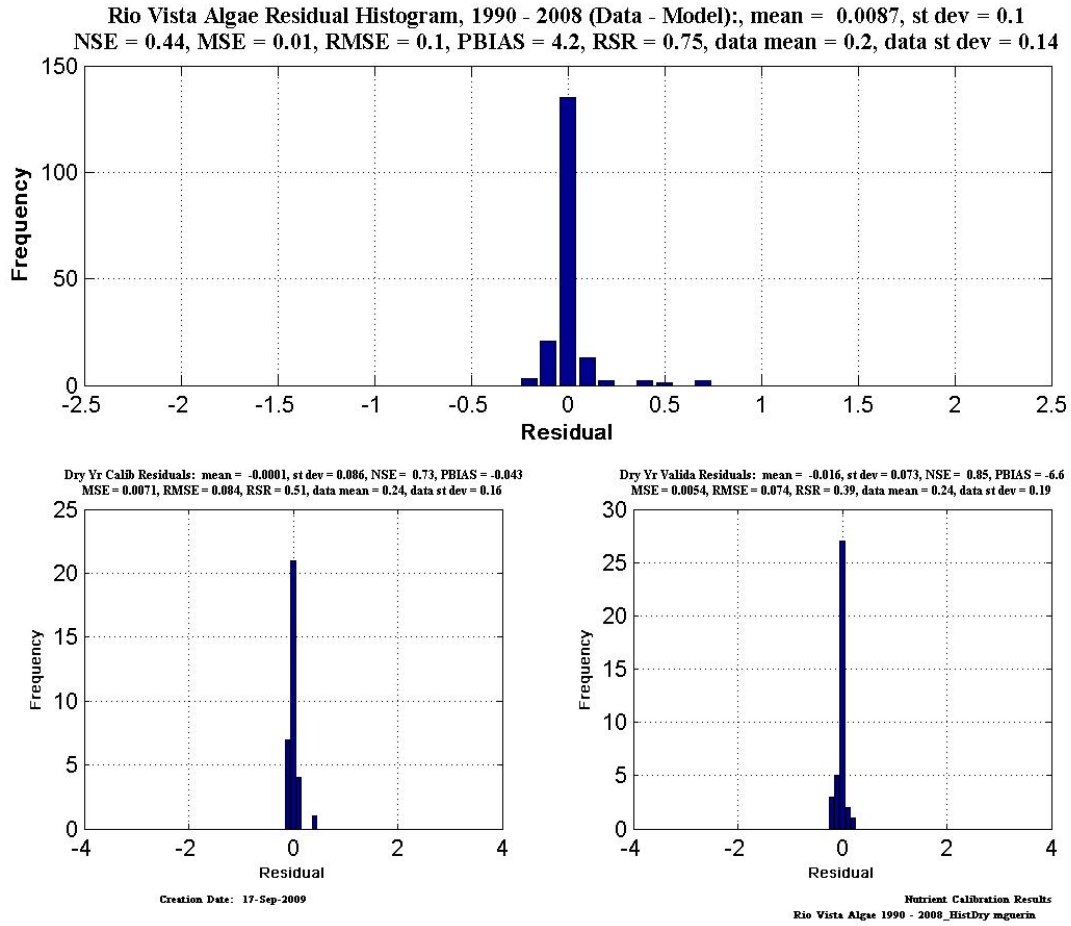


Figure A V. 53 Rio Vista algae dry years.

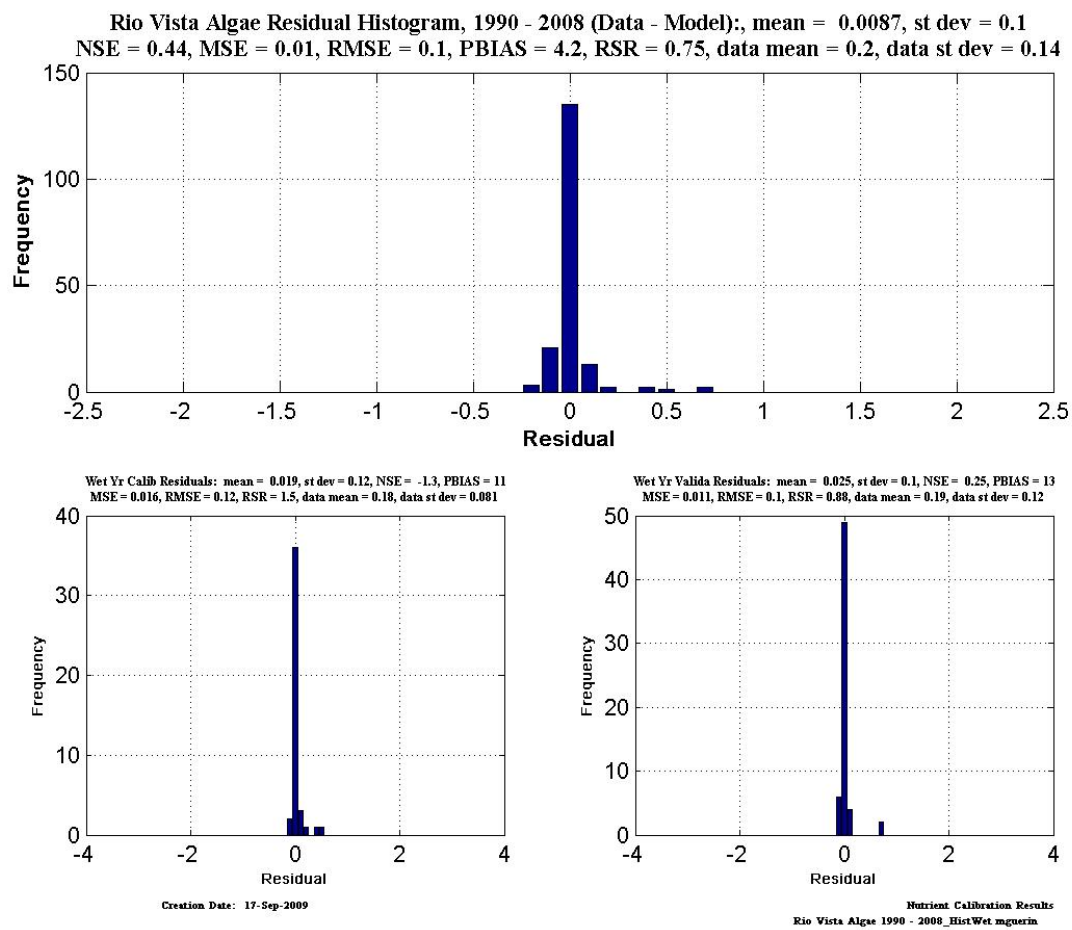


Figure A V. 54 Rio Vista algae wet years.

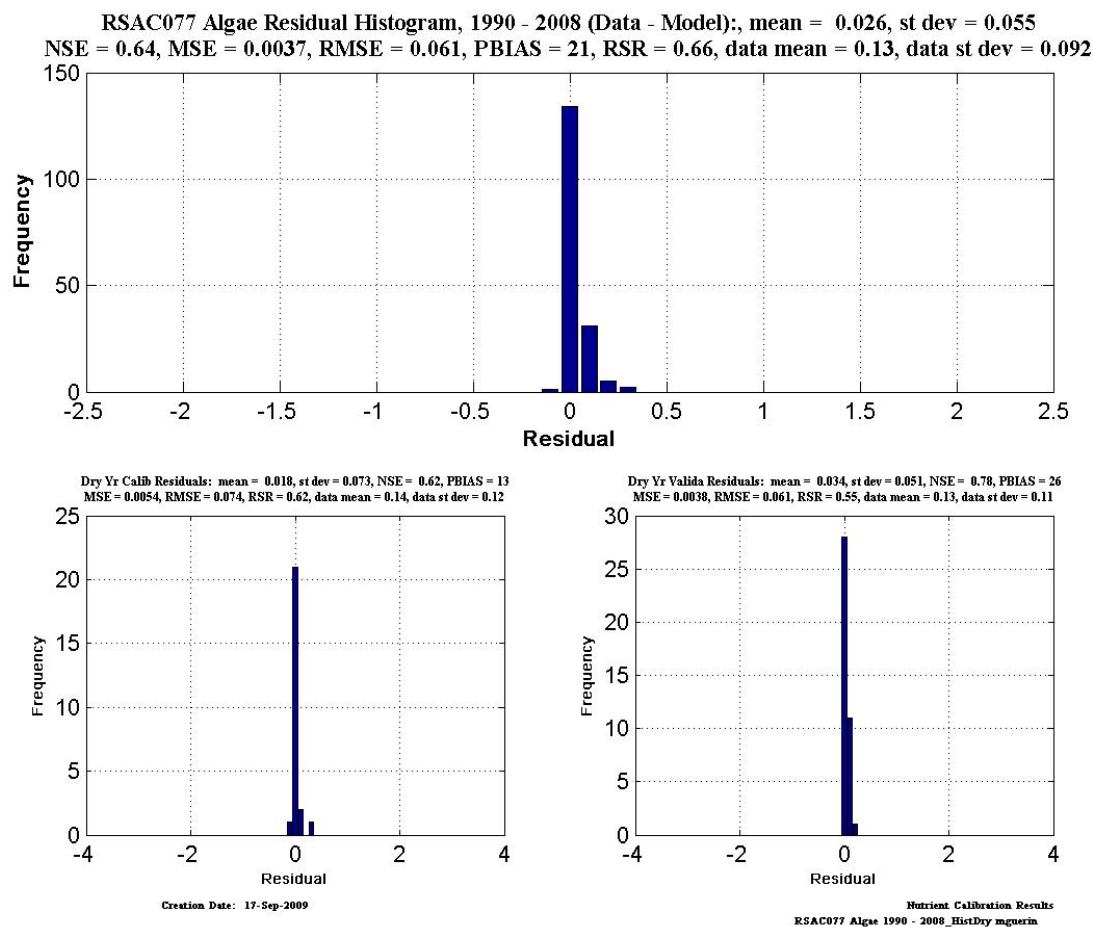


Figure A V. 55 RSAC077 algae dry years.

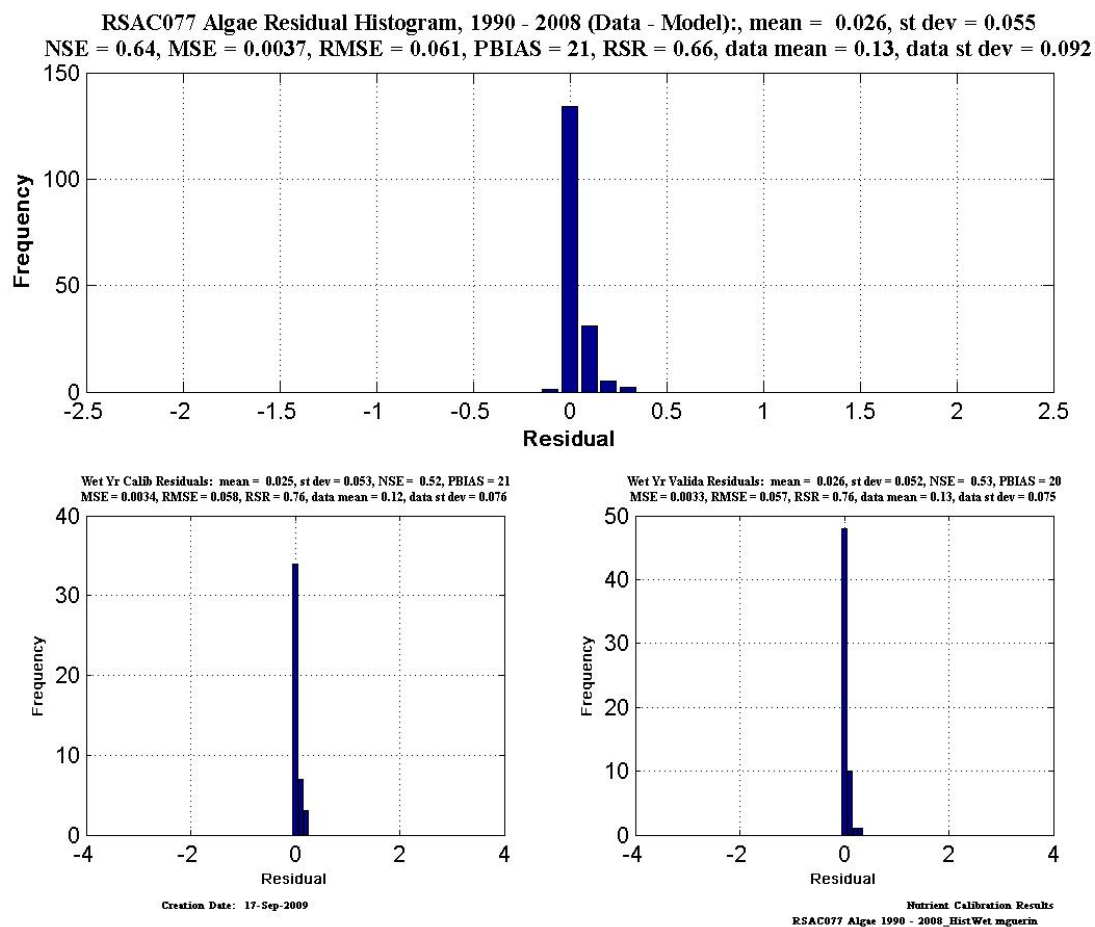


Figure A V. 56 RSAC077 algae wet years.

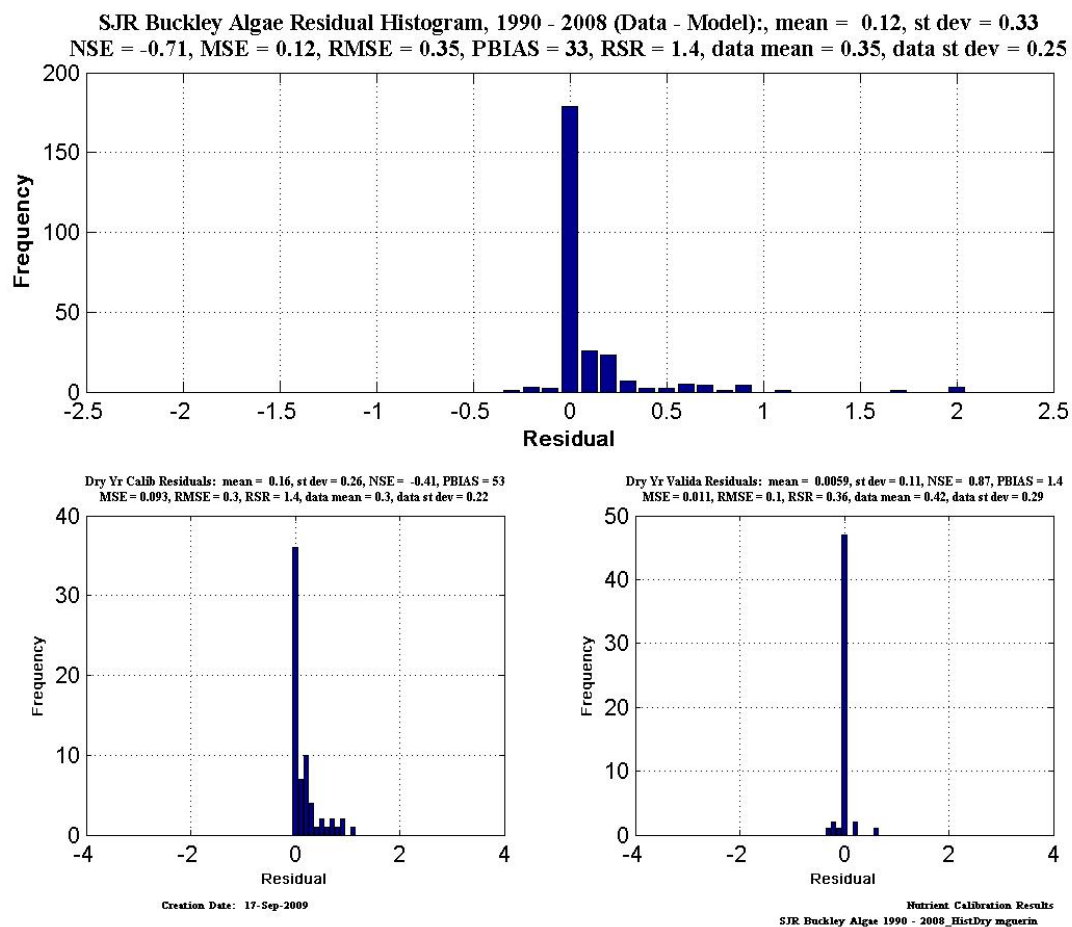


Figure A V. 57 SJR Buckley algae dry years.

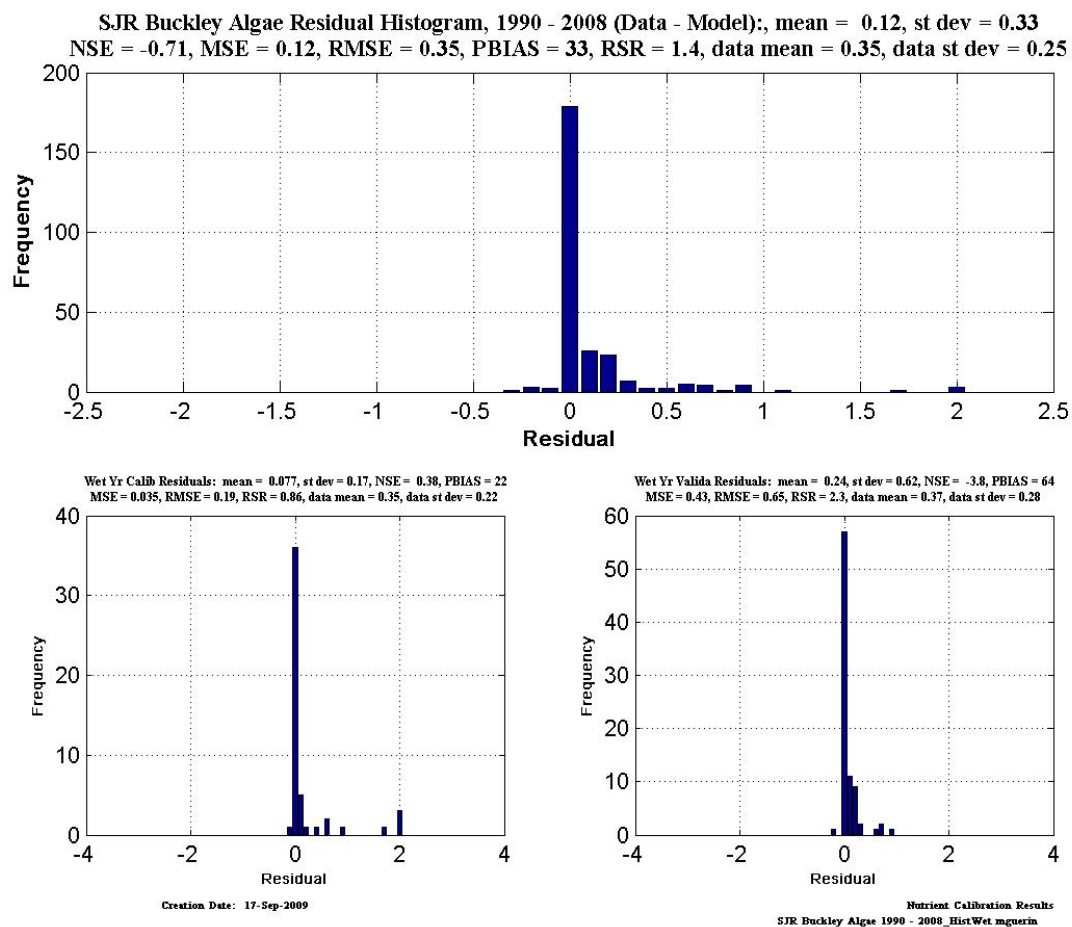


Figure A V. 58 SJR Buckley algae wet years.

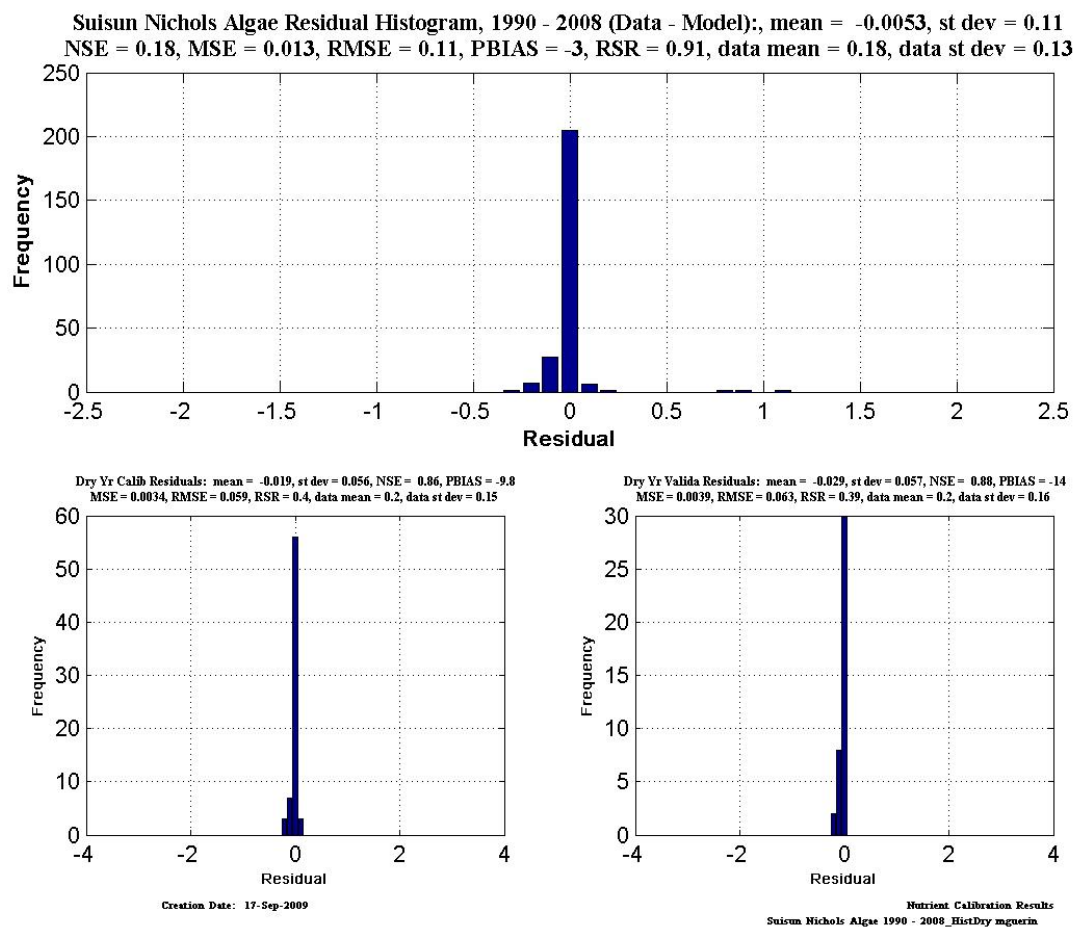


Figure A V. 59 Suisun-Nichols algae dry years.

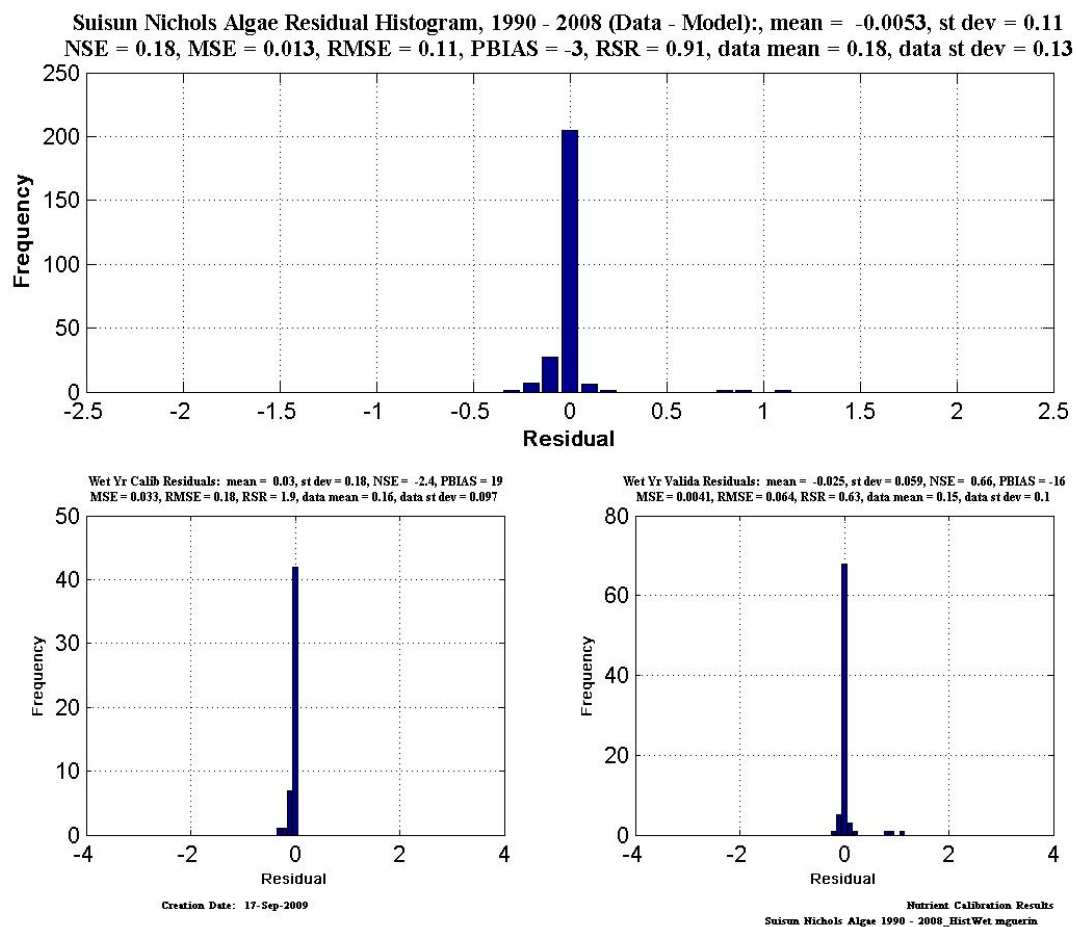


Figure A V. 60 Suisun-Nichols algae wet years.

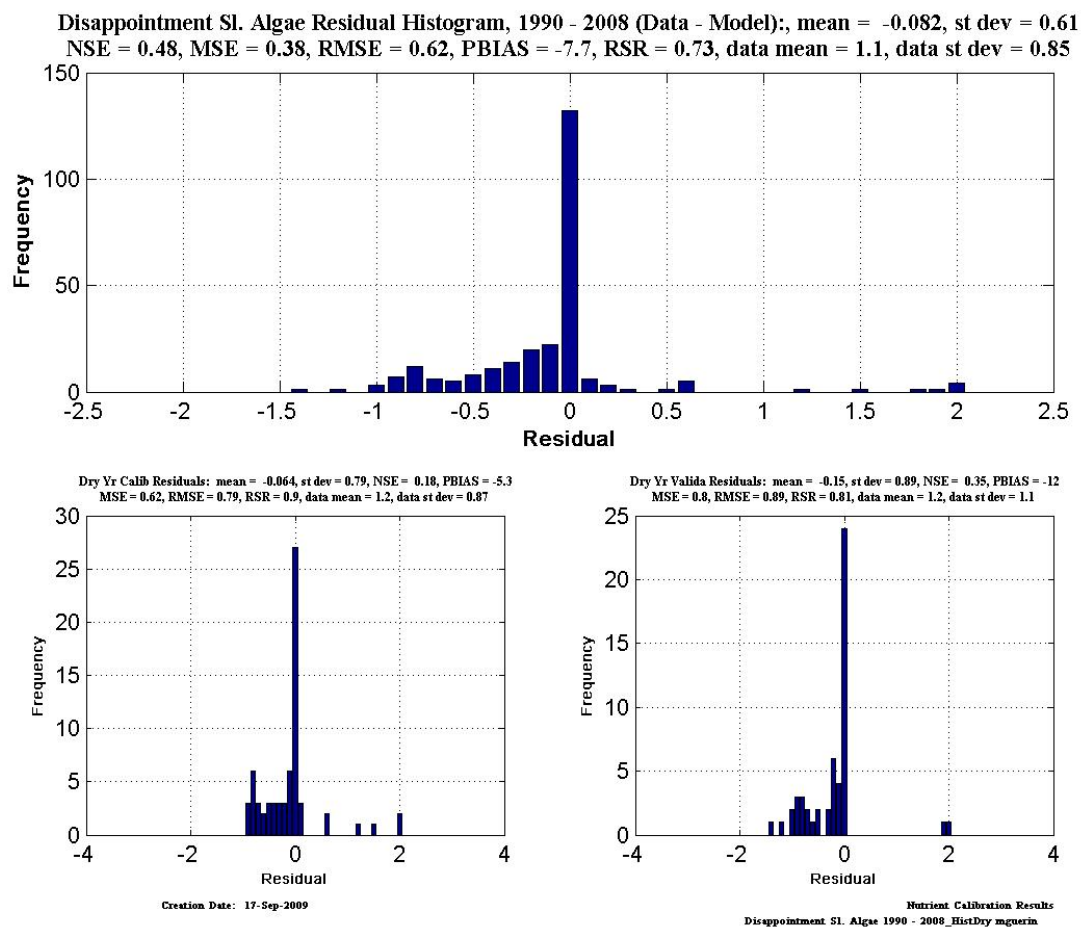


Figure A V. 61 Disap. Sl. algae dry years.

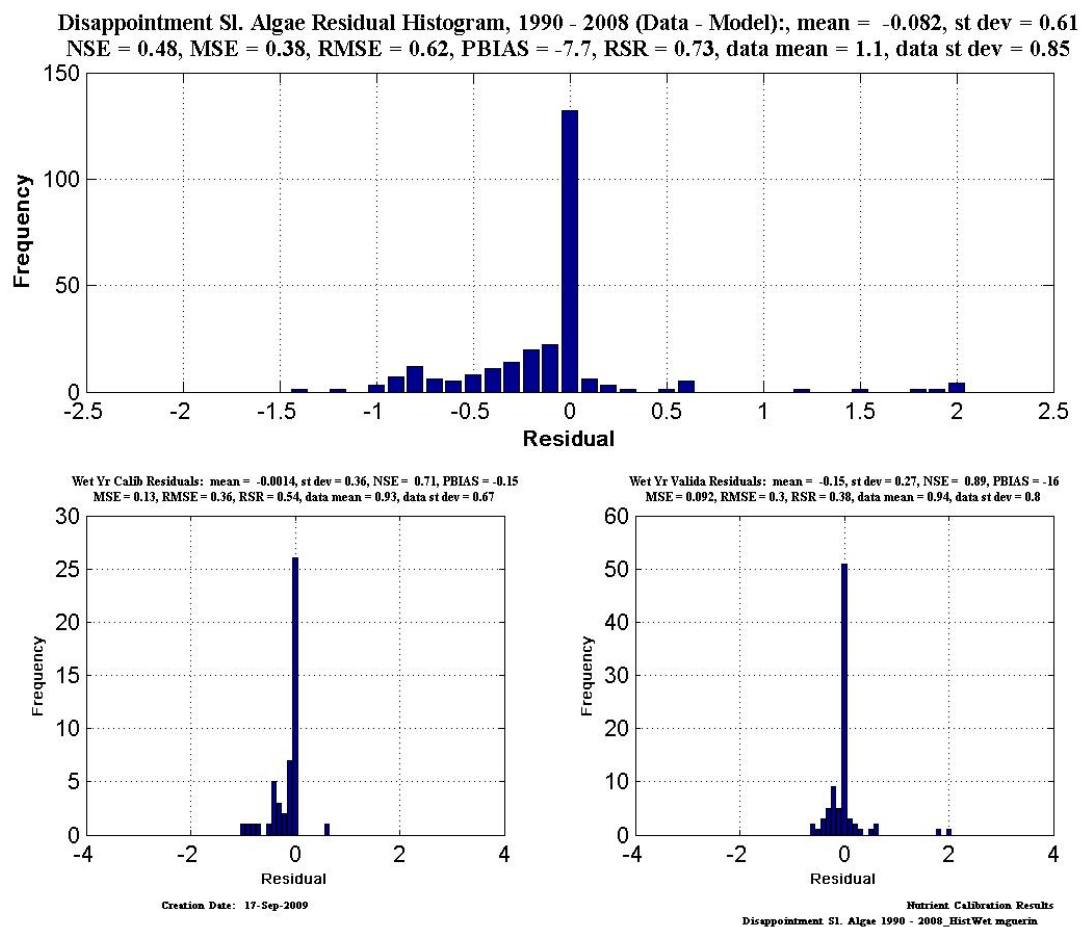
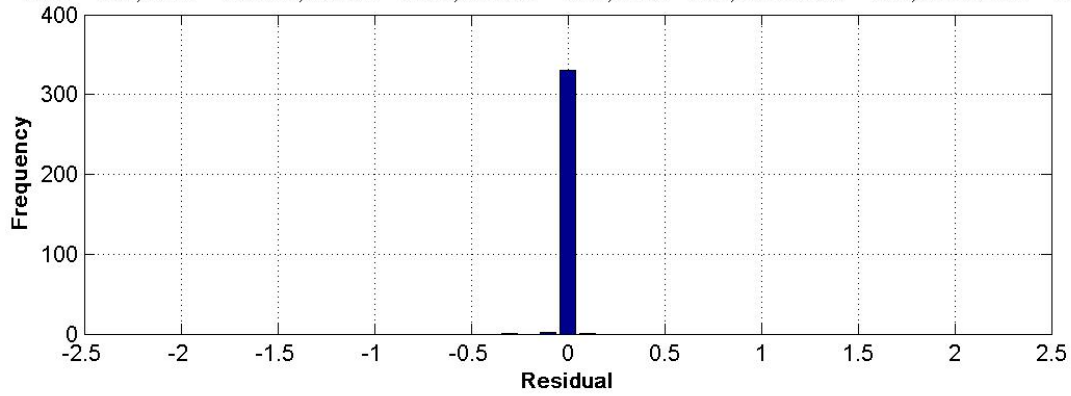
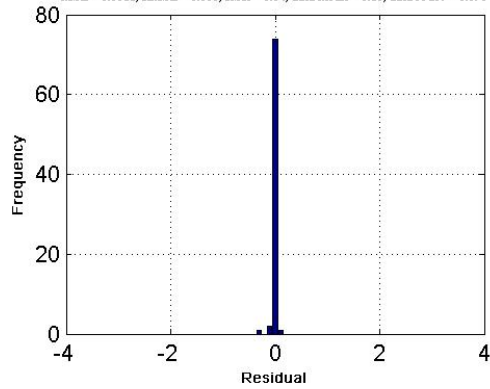


Figure A V. 62 Disap Sl. algae wet years.

Greens-Hood Algae Residual Histogram, 1990 - 2008 (Data - Model):, mean = -0.00033, st dev = 0.018
 NSE = 0.96, MSE = 0.00031, RMSE = 0.018, PBIAS = -0.21, RSR = 0.21, data mean = 0.16, data st dev = 0.085

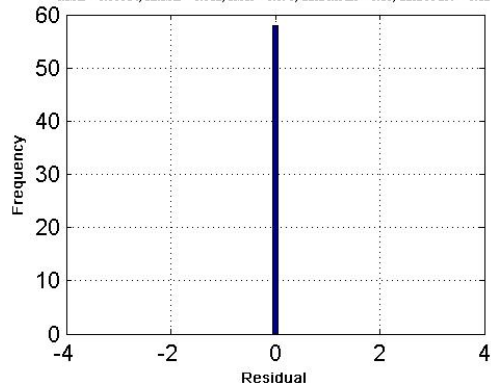


Dry Yr Calib Residuals: mean = -0.0048, st dev = 0.032, NSE = 0.99, PBIAS = -3
 MSE = 0.0011, RMSE = 0.033, RSR = 0.34, data mean = 0.16, data st dev = 0.096



Creation Date: 17-Sep-2009

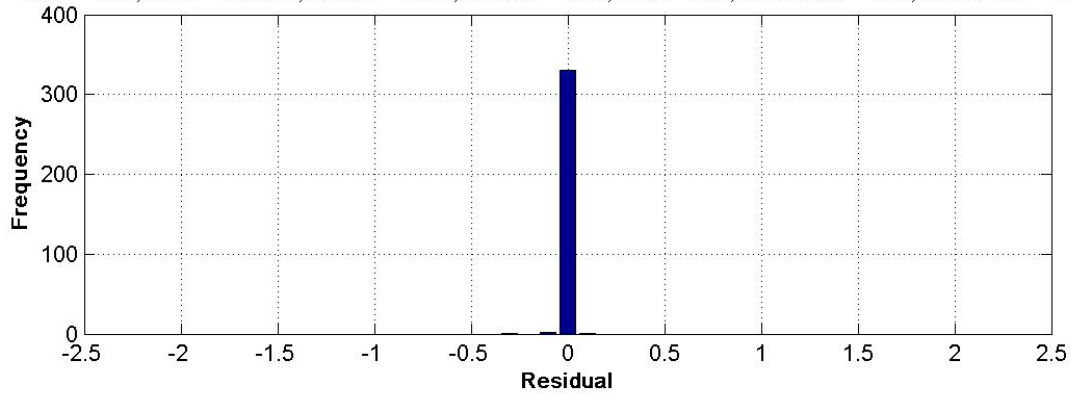
Dry Yr Valida Residuals: mean = 0.0018, st dev = 0.012, NSE = 0.99, PBIAS = 1
 MSE = 0.00014, RMSE = 0.012, RSR = 0.098, data mean = 0.18, data st dev = 0.12



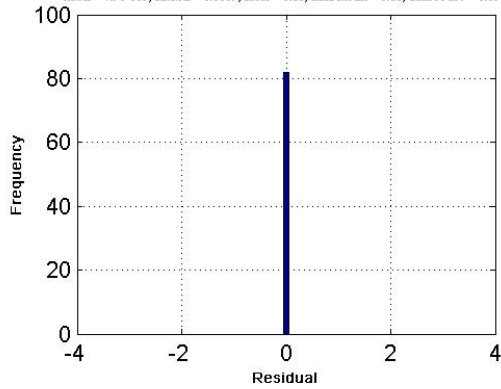
Nutrient Calibration Results
 Greens-Hood Algae 1990 - 2008_HistDry.mgwerin

Figure A V. 63 Greenes-Hood algae dry years.

Greens-Hood Algae Residual Histogram, 1990 - 2008 (Data - Model):, mean = -0.00033, st dev = 0.018
 NSE = 0.96, MSE = 0.00031, RMSE = 0.018, PBIAS = -0.21, RSR = 0.21, data mean = 0.16, data st dev = 0.085

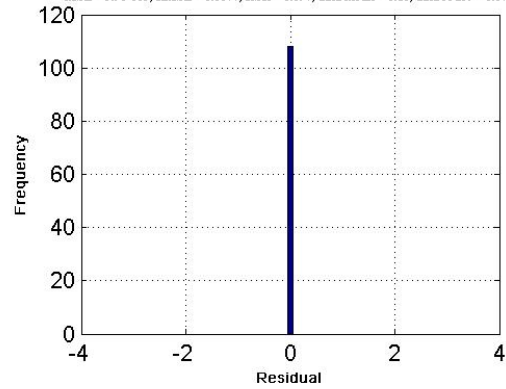


Wet Yr Calib Residuals: mean = 0.00089, st dev = 0.0089, NSE = 0.97, PBIAS = 0.56
 MSE = 7.9e-005, RMSE = 0.0089, RSR = 0.16, data mean = 0.16, data st dev = 0.054



Creation Date: 17-Sep-2009

Wet Yr Valid Residuals: mean = 0.0009, st dev = 0.0076, NSE = 0.99, PBIAS = 0.57
 MSE = 5.9e-005, RMSE = 0.0077, RSR = 0.097, data mean = 0.16, data st dev = 0.079



Nutrient Calibration Results
 Greens-Hood Algae 1990 - 2008_HistWet.mgwerin

Figure A V. 64 Greenes-Hood algae wet years.

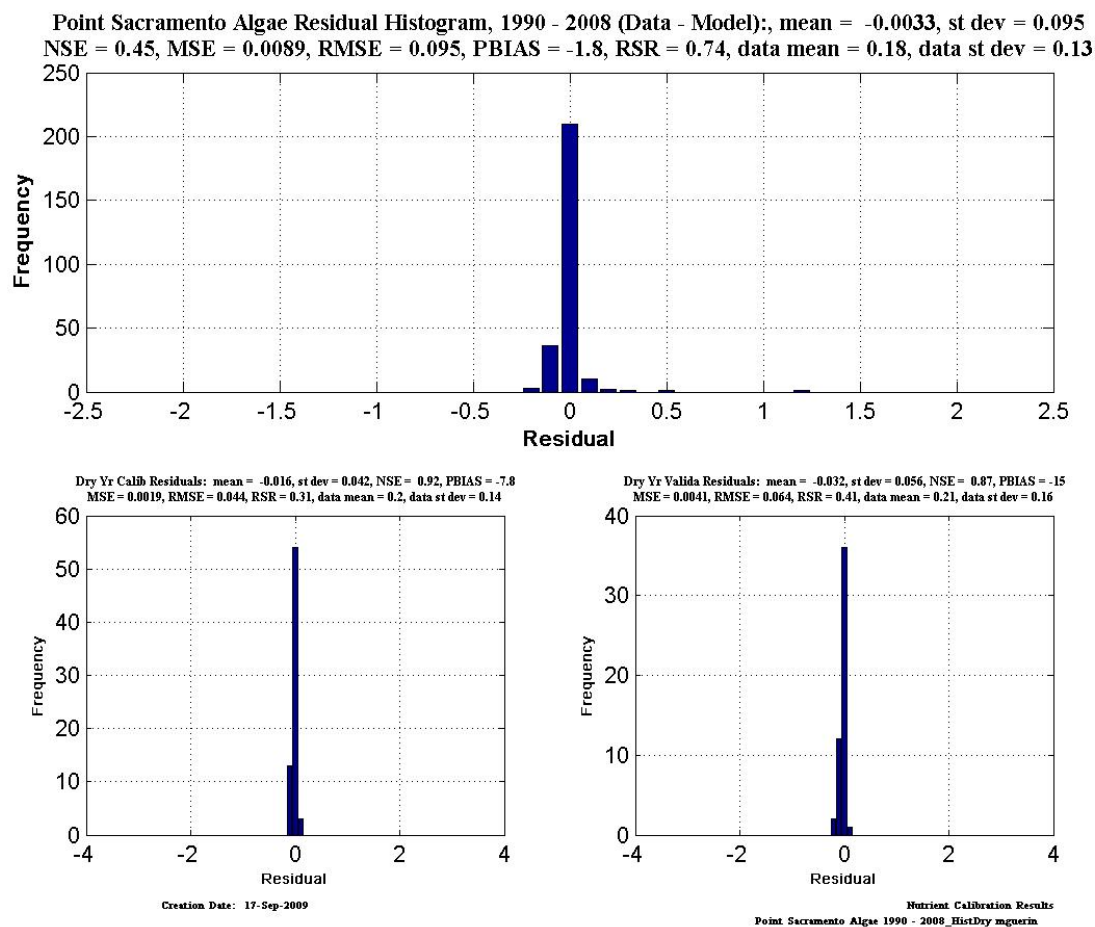


Figure A V. 65 Pt Sacramento algae dry years.

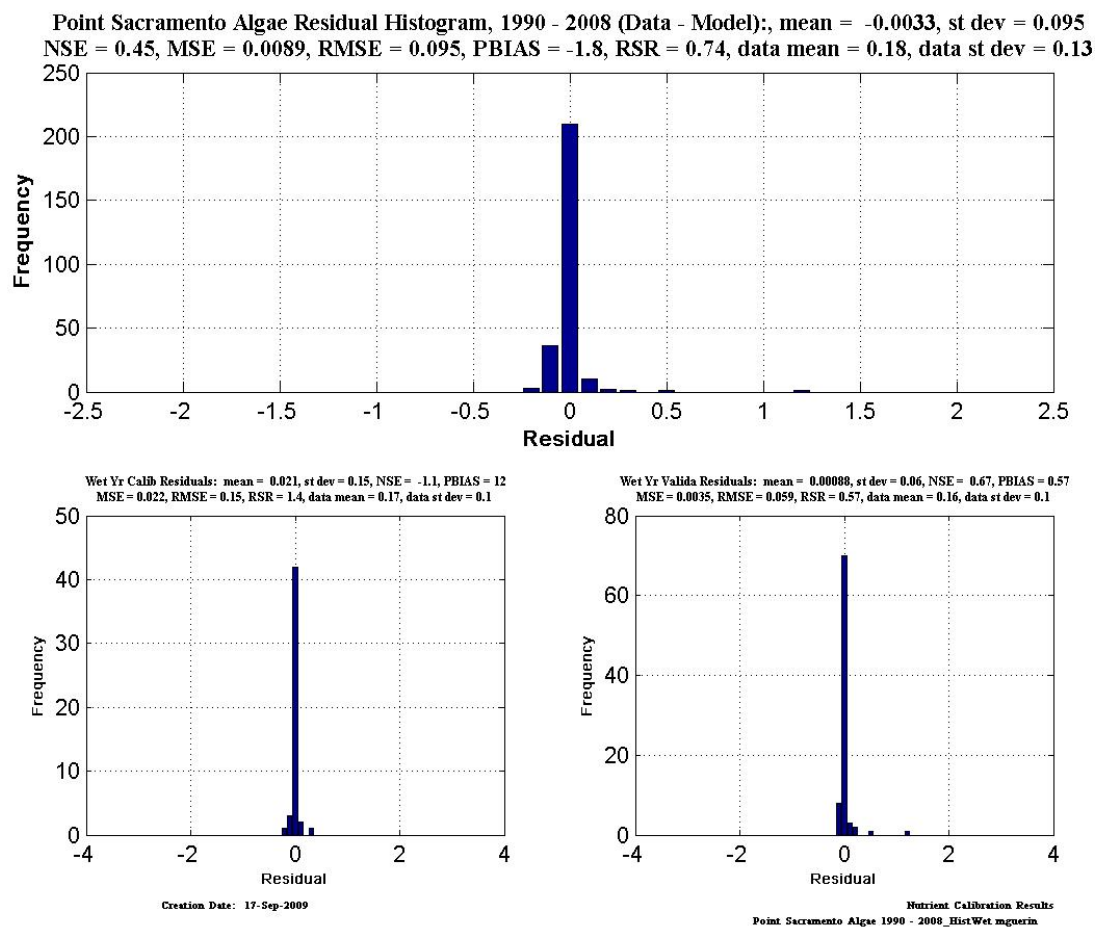


Figure A V. 66 Pt. Sacramento algae wet years.

E. Organic-N calibration

Point Sacramento ORG-N Residual Histogram, 1990 - 2008 (Data - Model);, mean = -0.017, st dev = 0.096
NSE = 0.2, MSE = 0.0095, RMSE = 0.098, PBIAS = -6.6, RSR = 0.91, data mean = 0.25, data st dev = 0.11

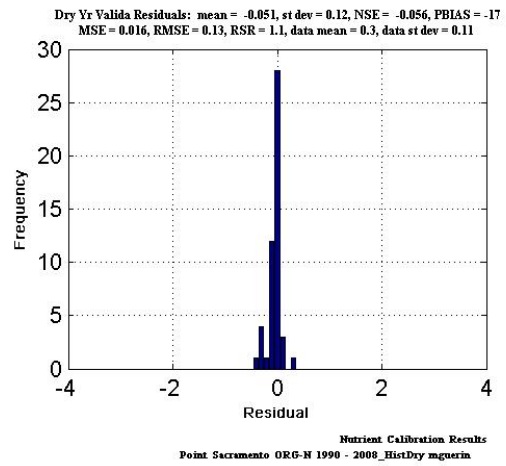
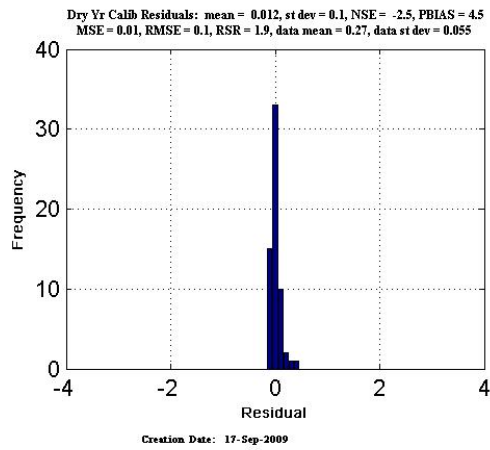
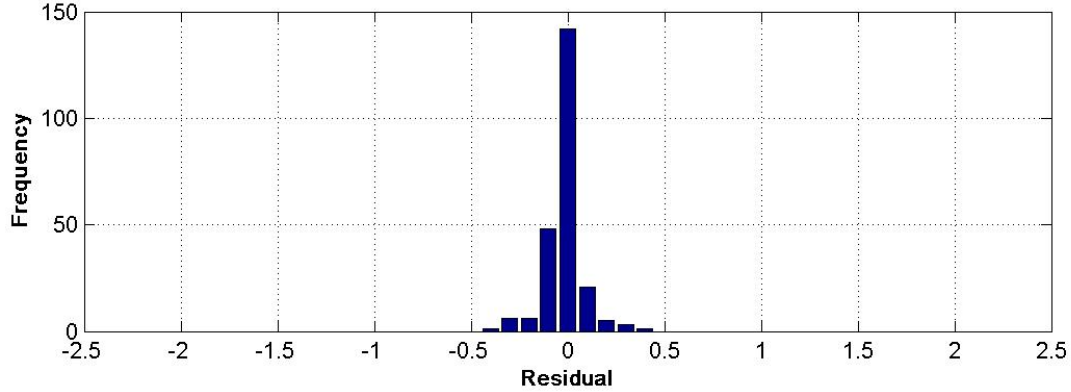


Figure A V. 67 Pt Sacramento organic-N dry years.

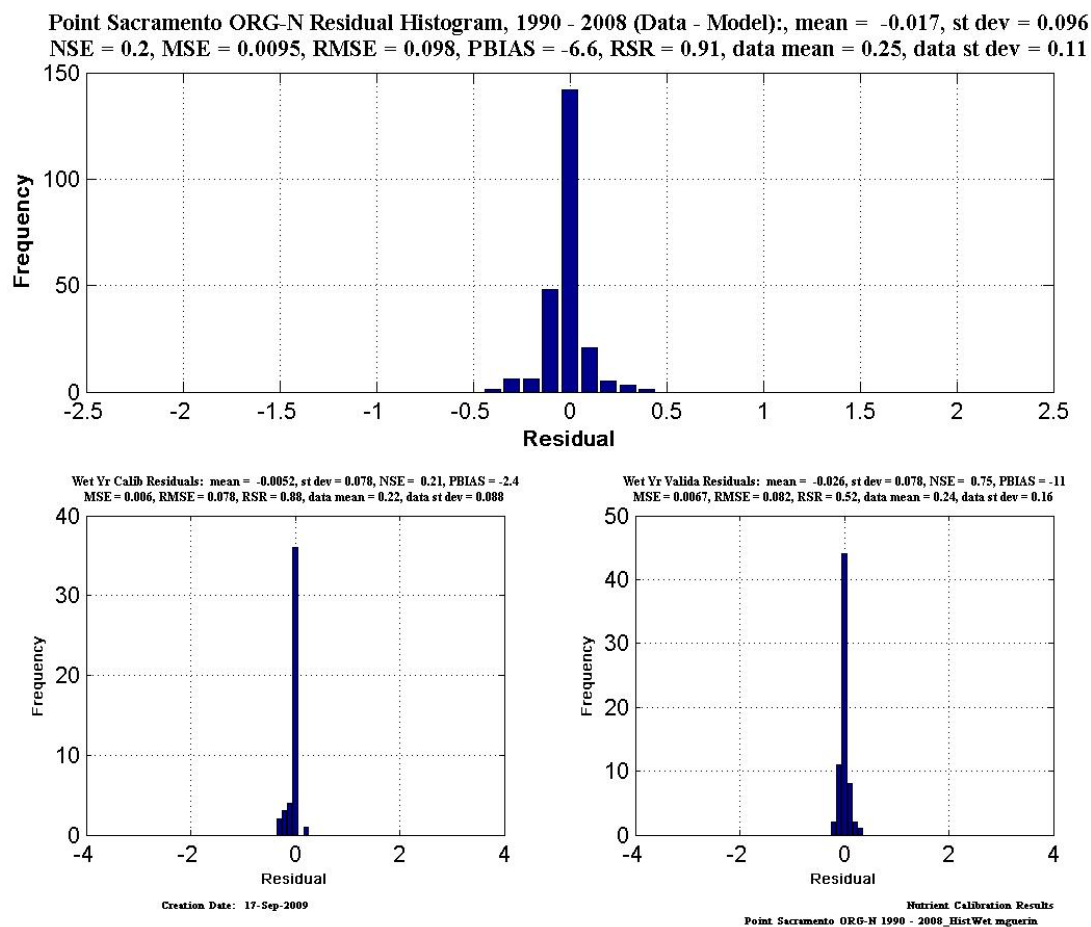


Figure A V. 68 Pt Sacramento organic-N wet years.

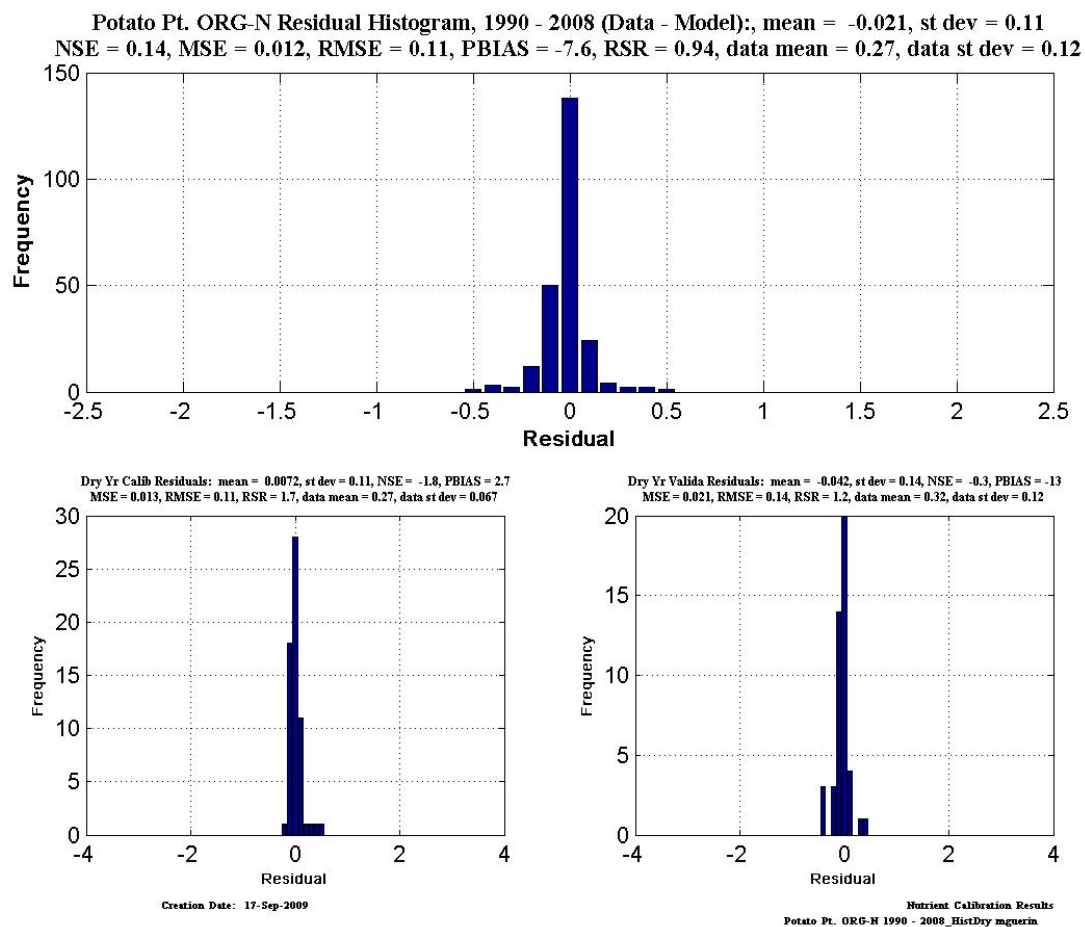


Figure A V. 69 Potato Pt. organic-N dry years.

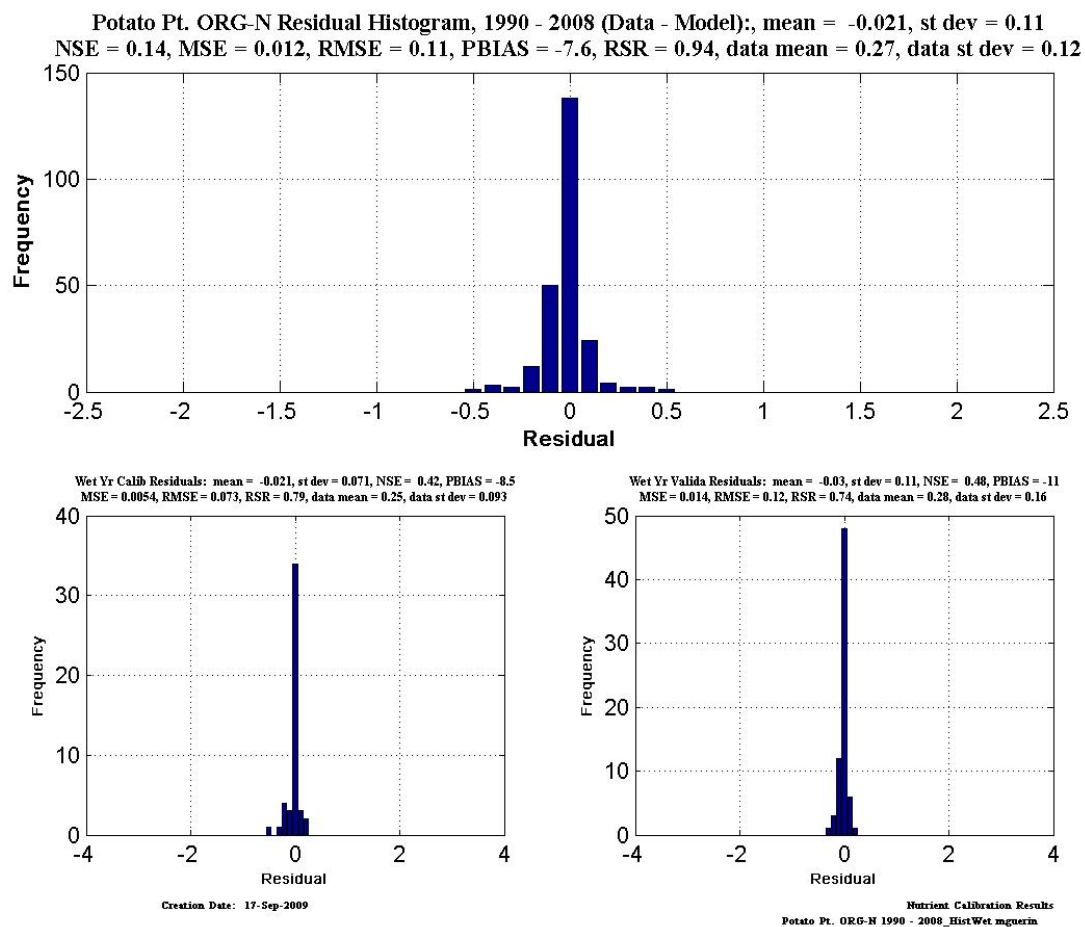


Figure A V. 70 Potato Pt. organic-N wet years.

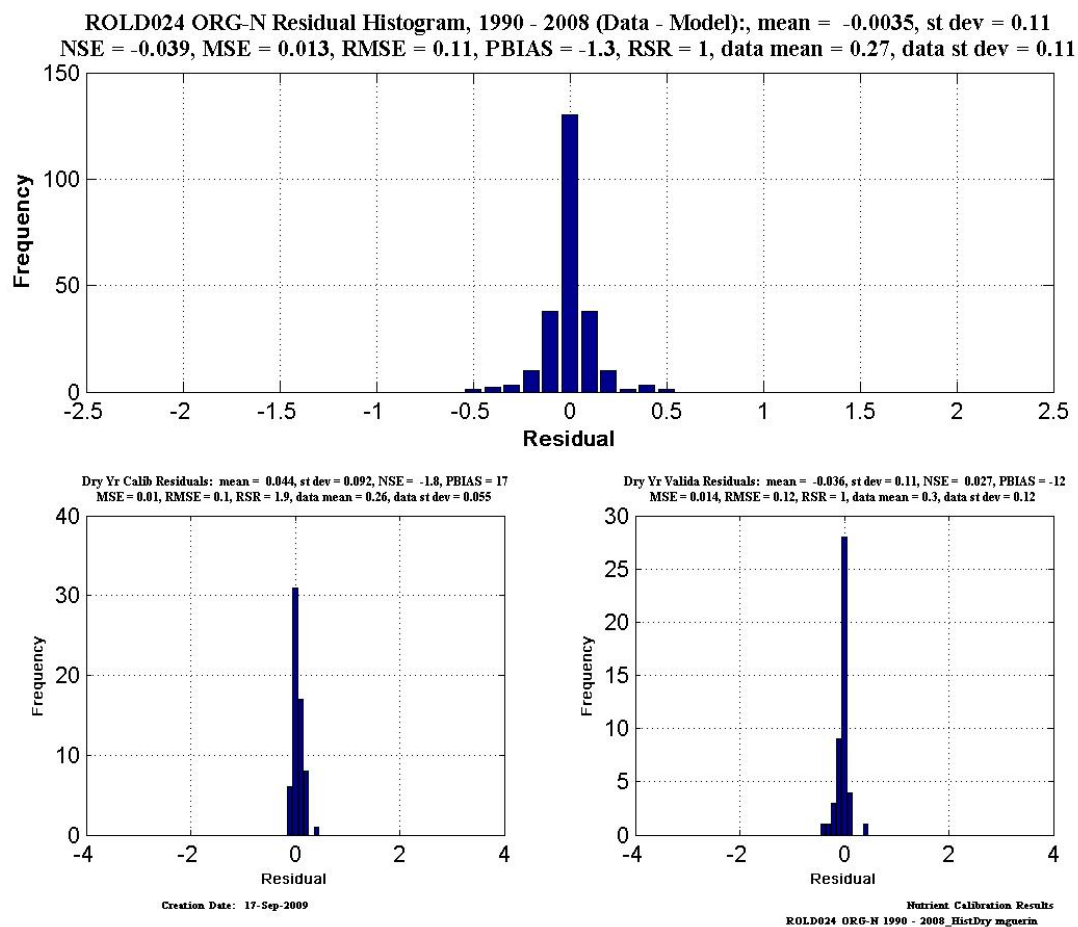


Figure A V. 71 ROLD024 organic-N dry years.

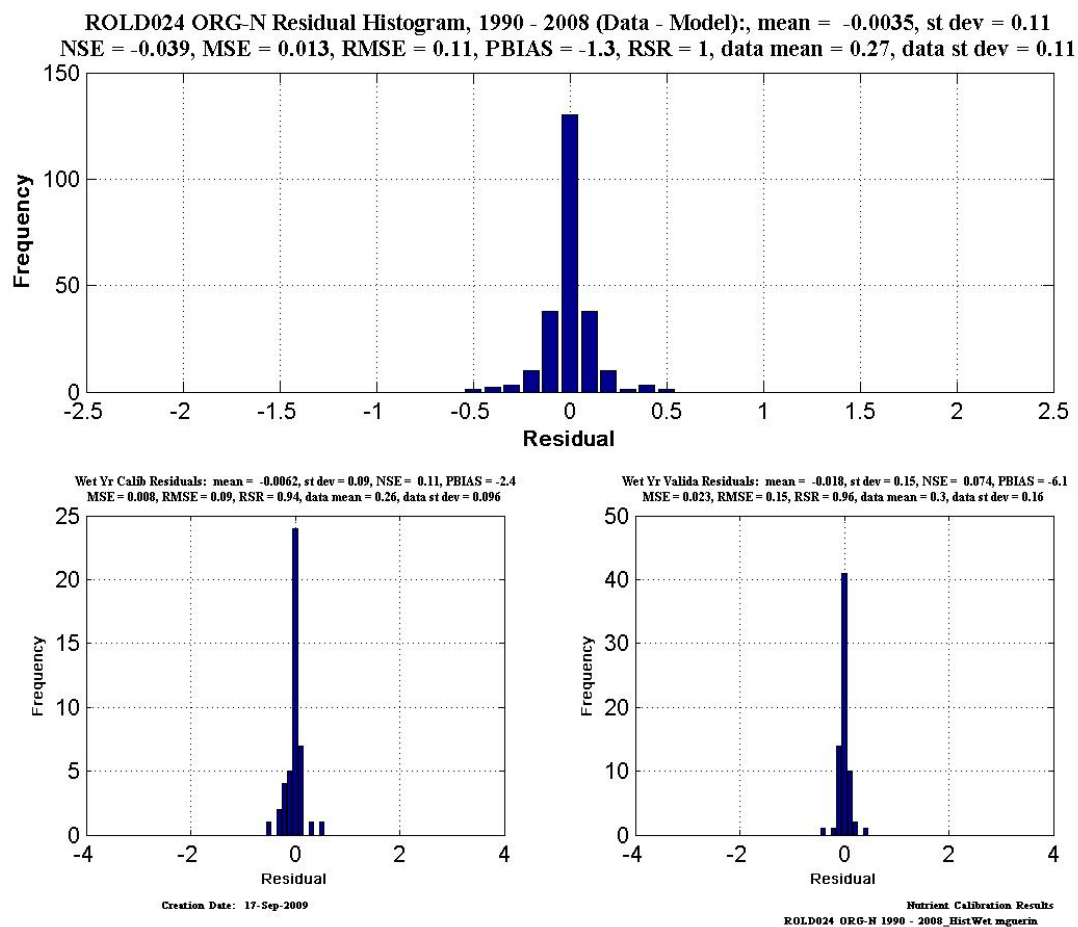


Figure A V. 72 ROLD024 organic-N wet years.

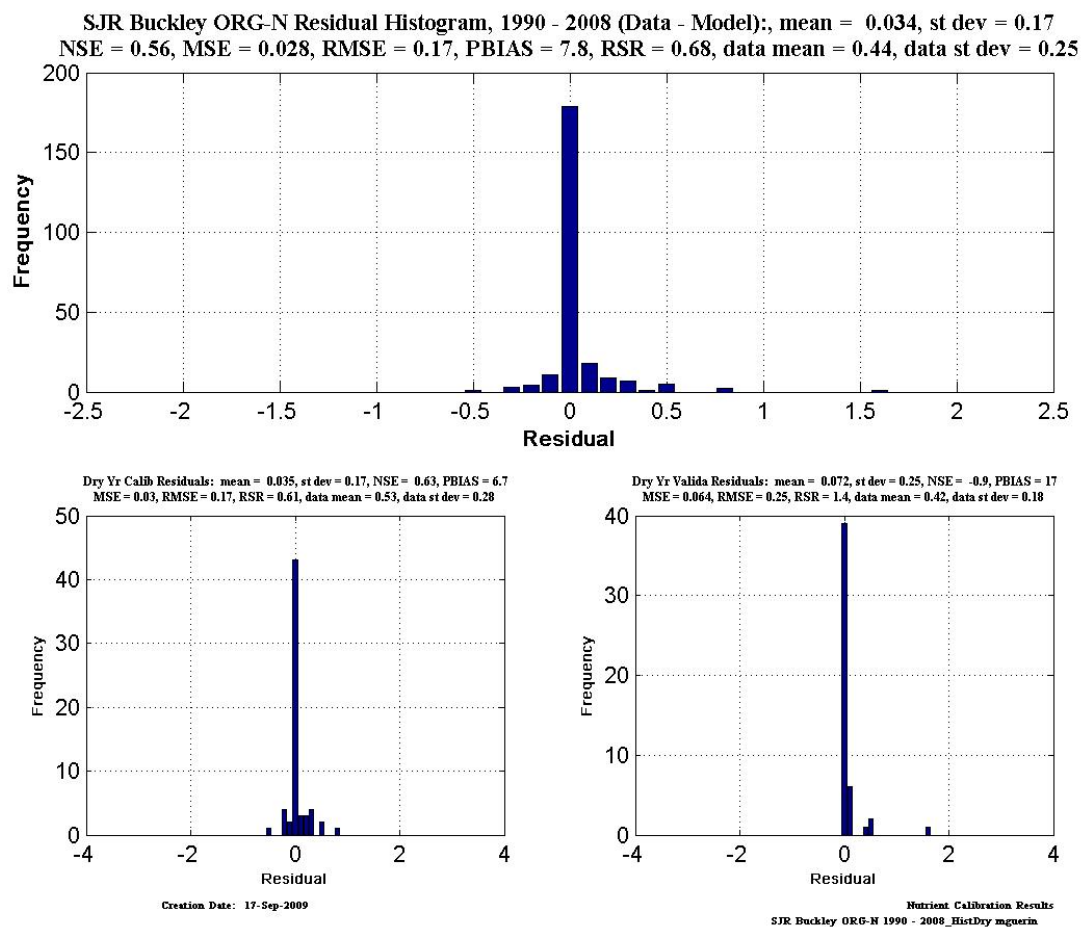


Figure A V. 73 SJR Buckley organic-N dry years.

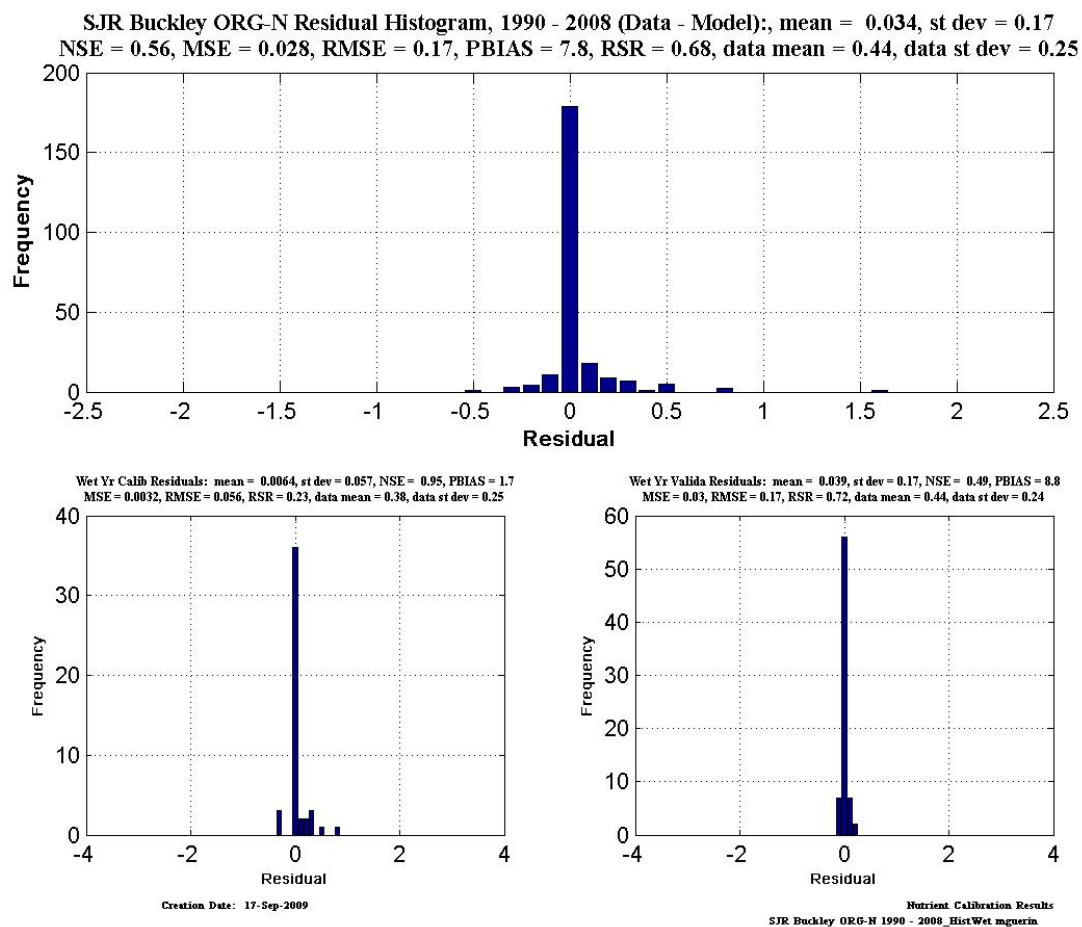


Figure A V. 74 SJR Buckley organic-N wet years.

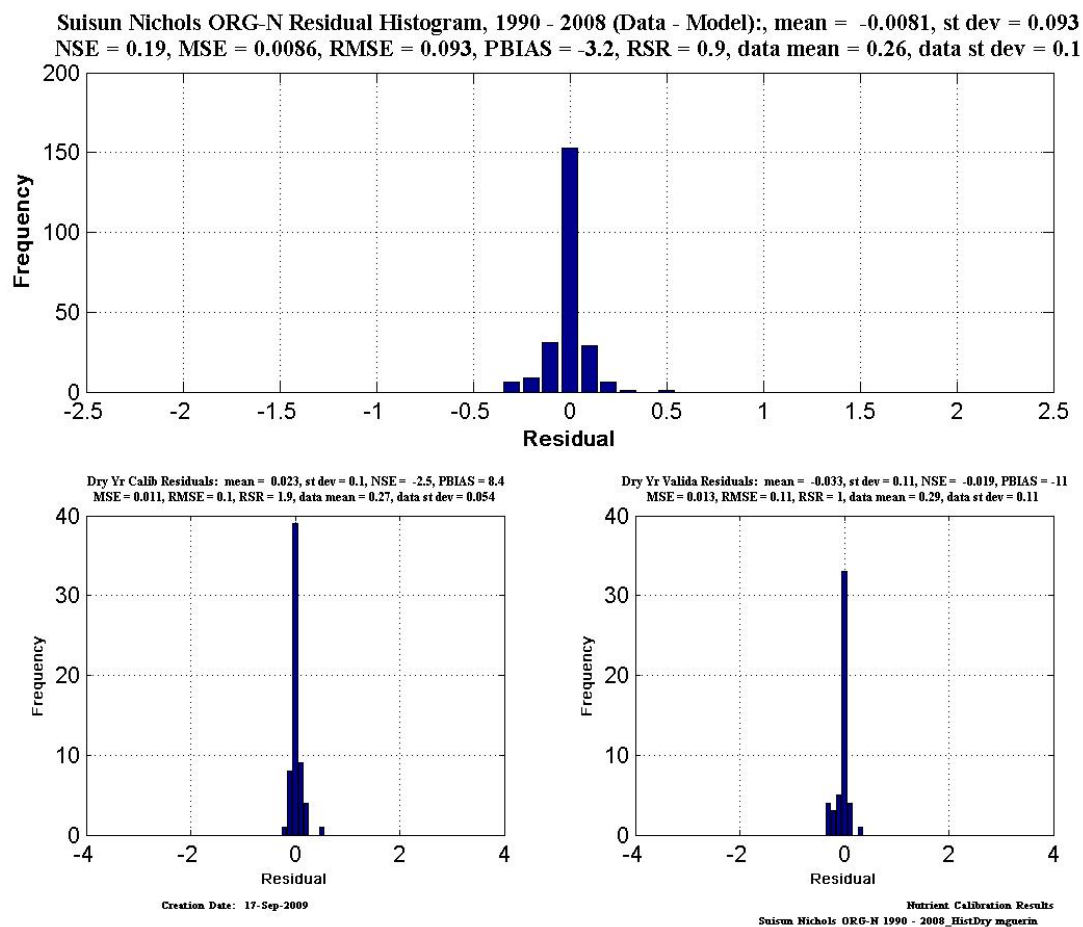


Figure A V. 75 Suisun-Nichols organic-N dry years.

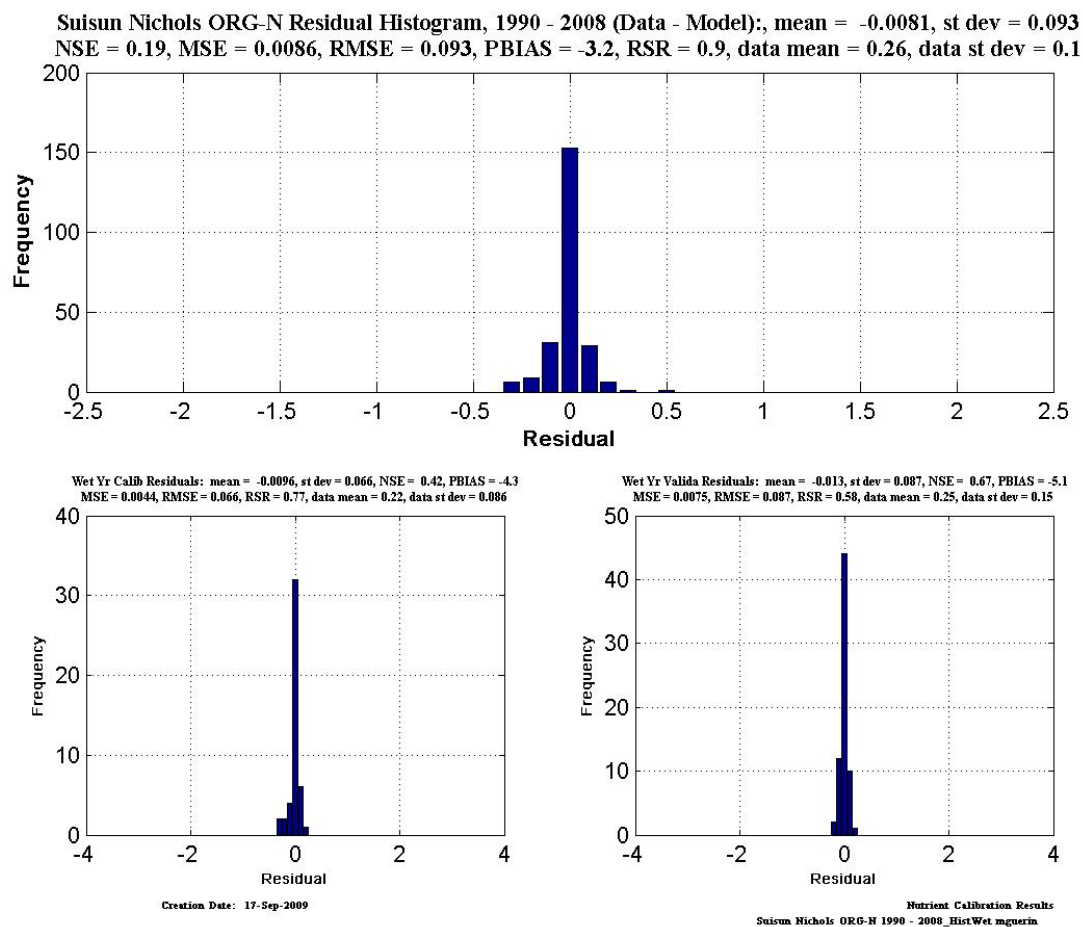


Figure A V. 76 Suisun-Nichols organic-N wetyears.

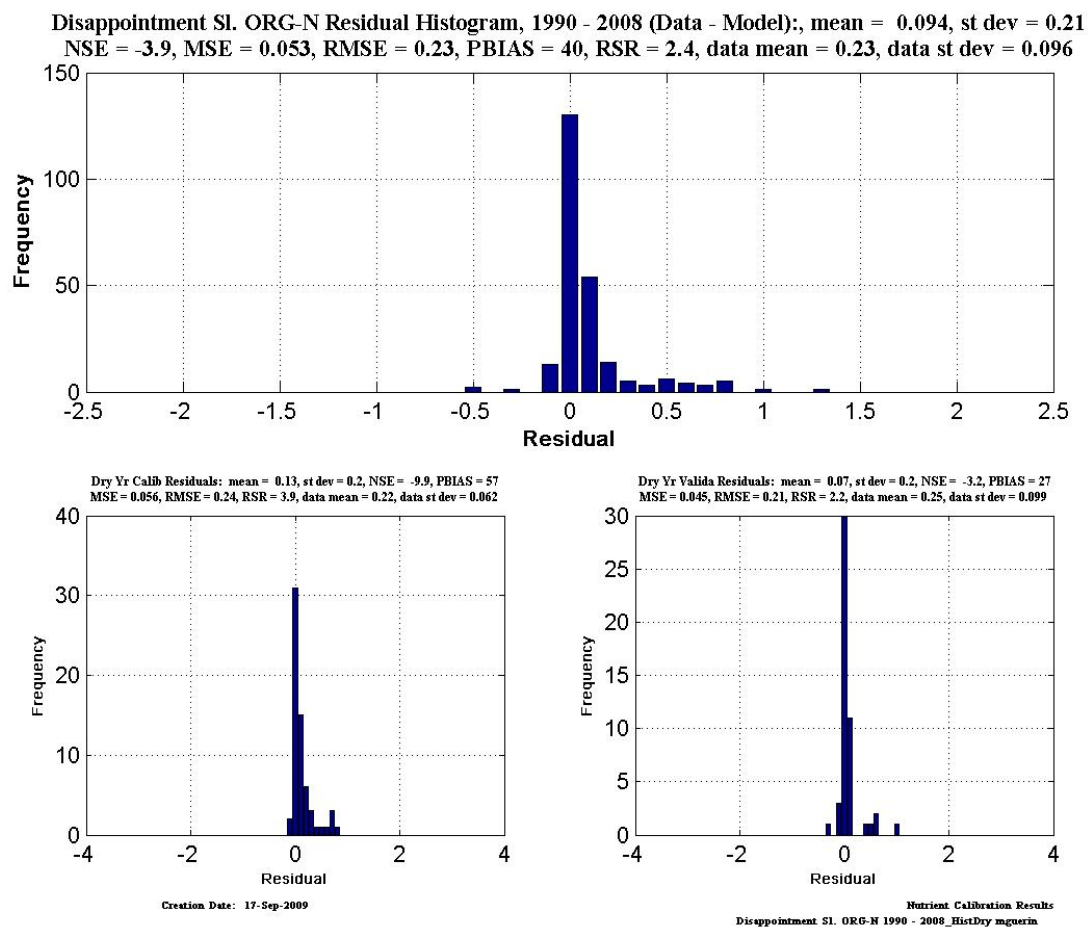


Figure A V. 77 Disap Sl organic-N dry years.

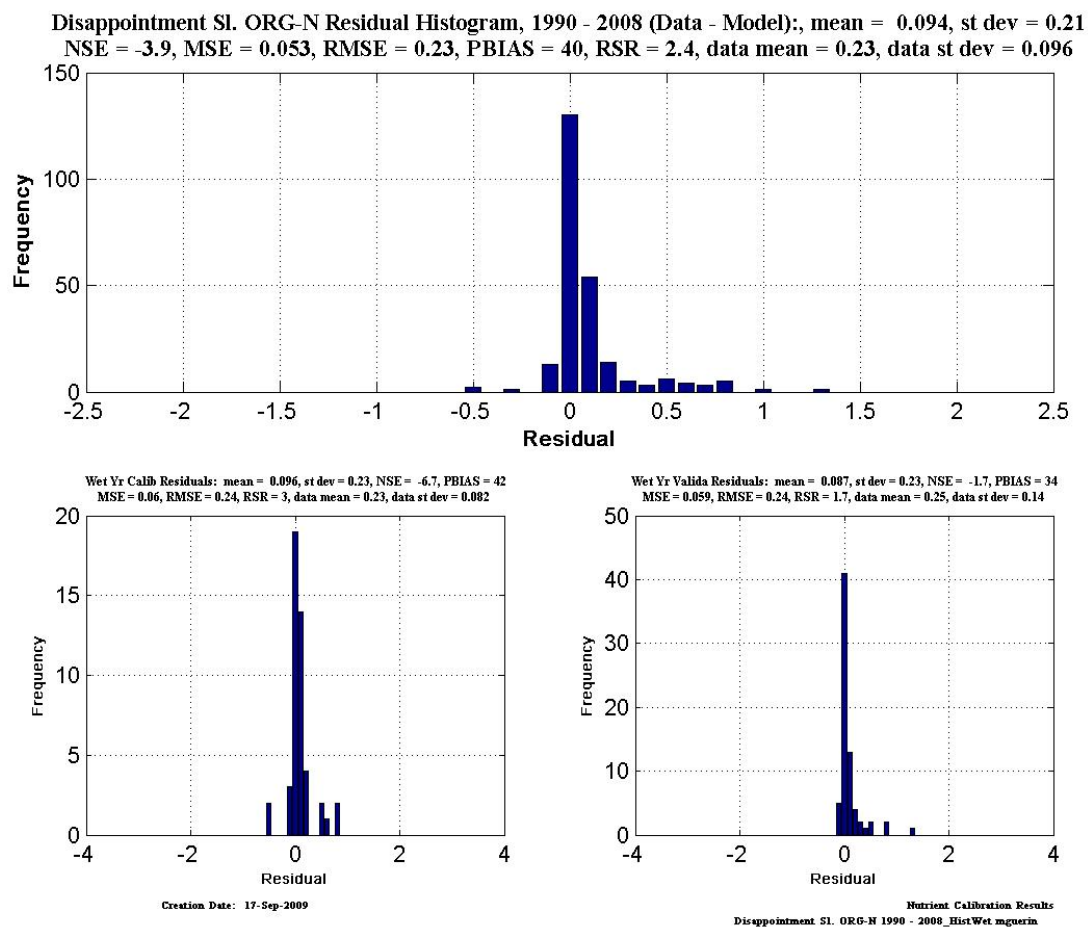


Figure A V. 78 Disap SL organic-N wet years.

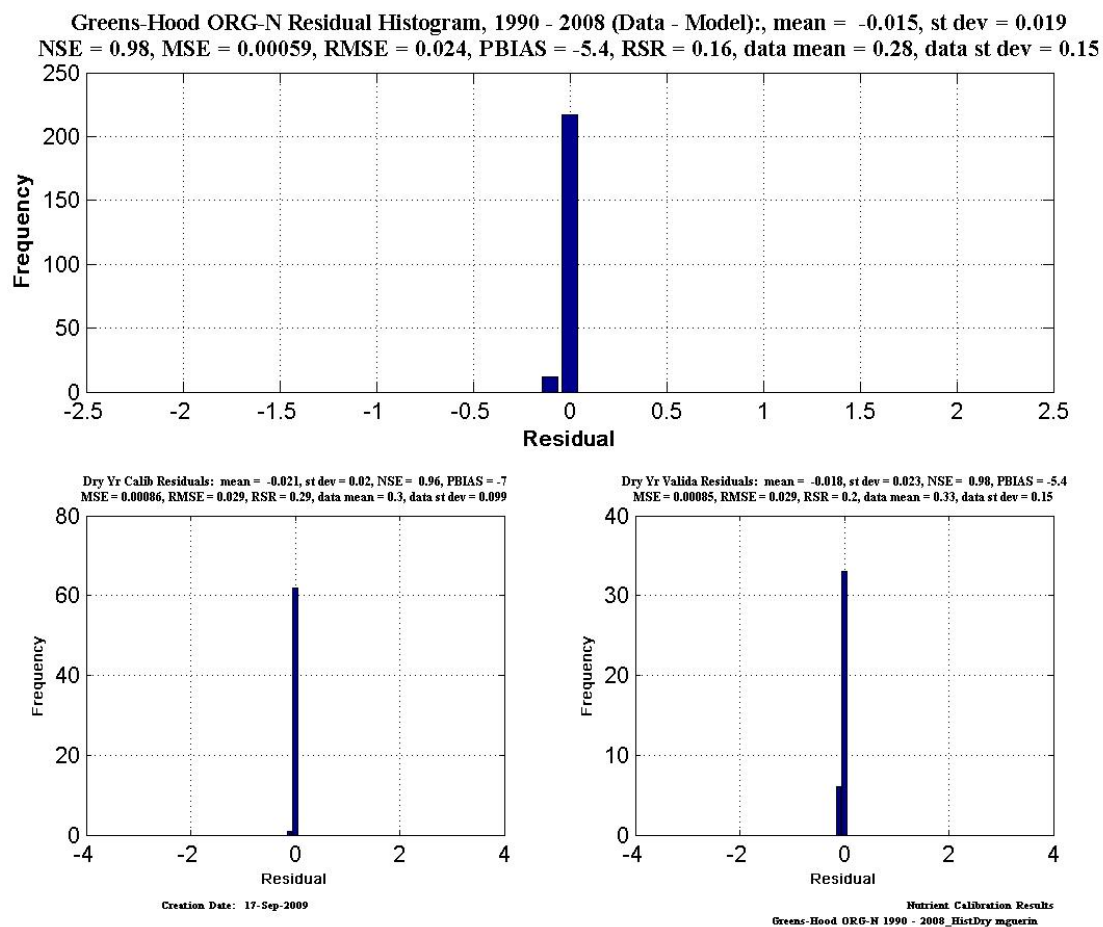


Figure A V. 79 Greenes-Hood organic-N dry years.

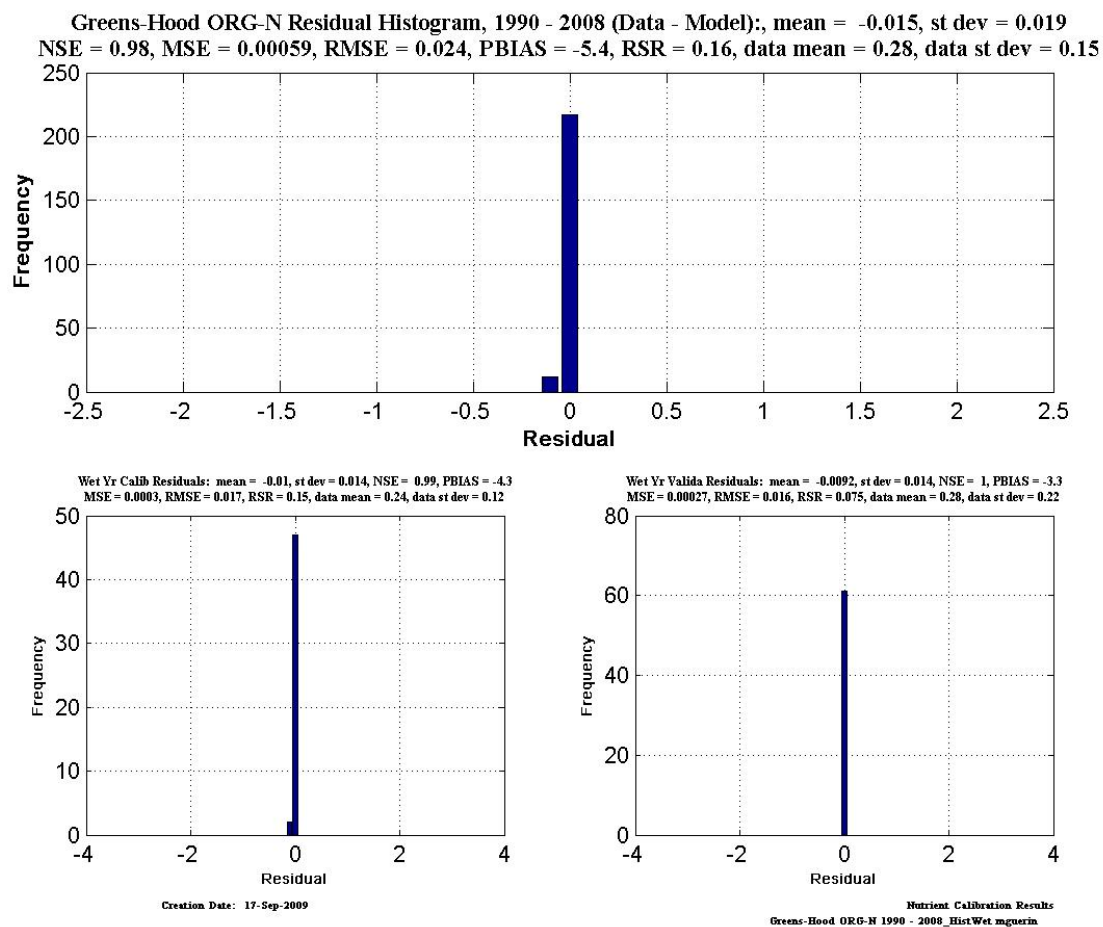


Figure A V. 80 Greenes-Hood organic-N wet years.

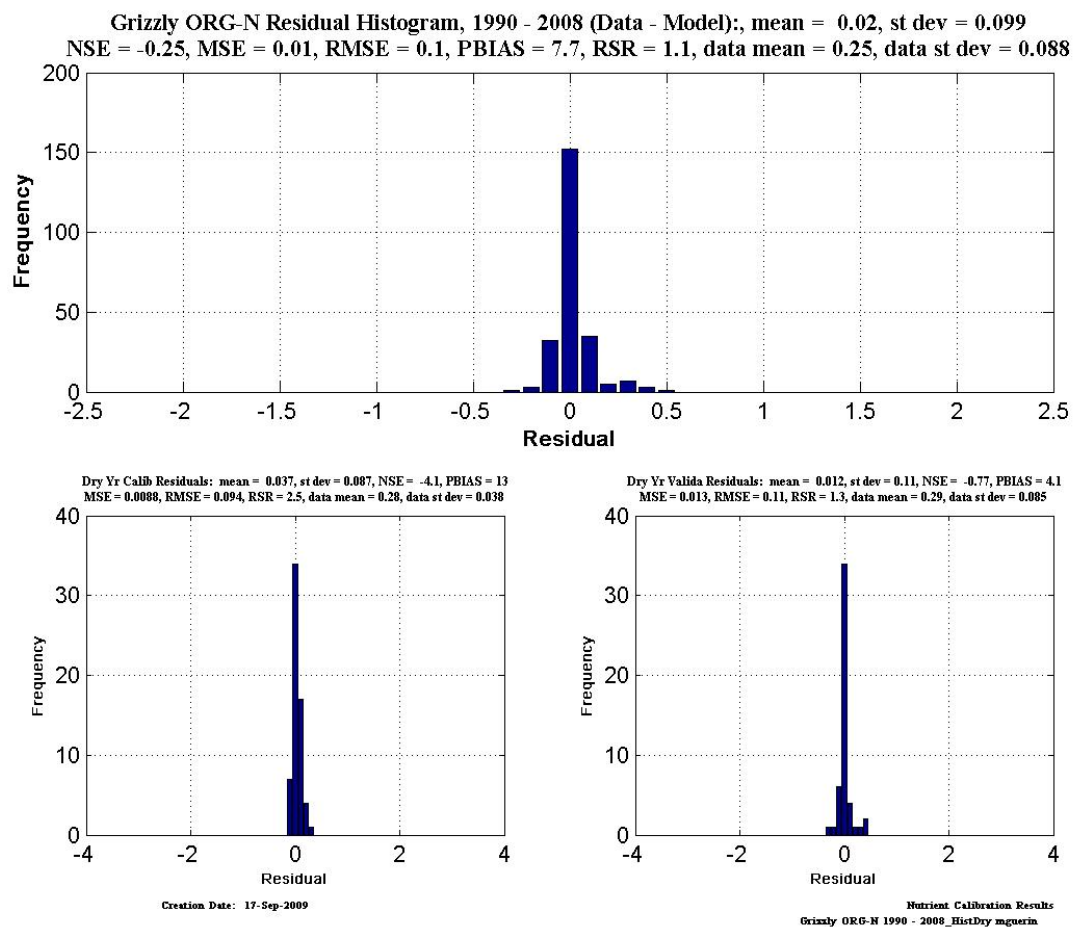


Figure A V. 81 Grizzly organic-N dry years.

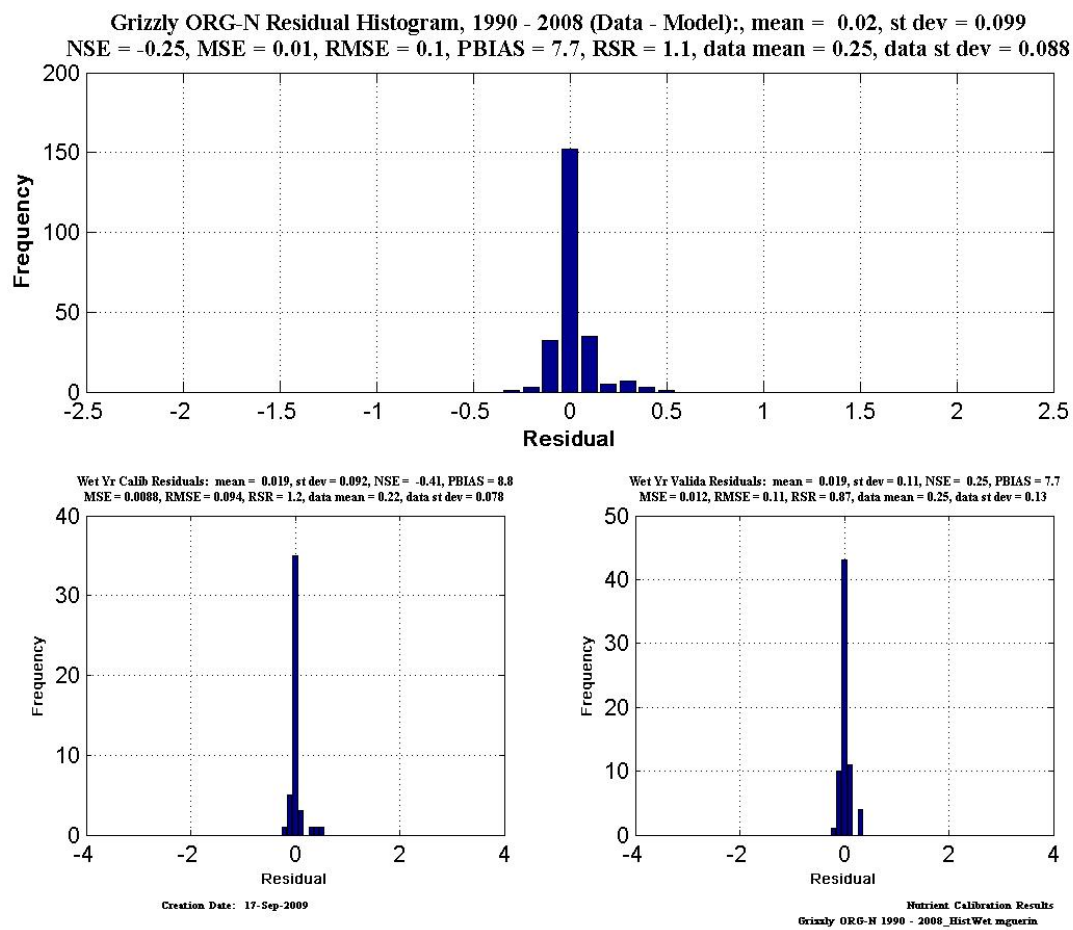


Figure A V. 82 Grizzly organic-N wet years.

F. PO₄ calibration

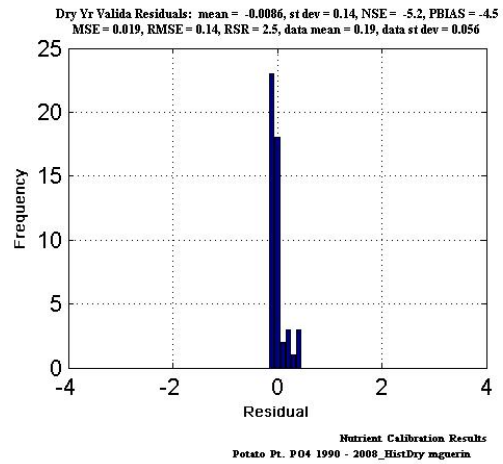
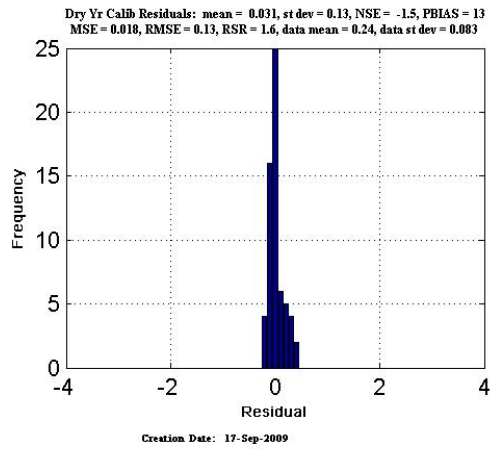
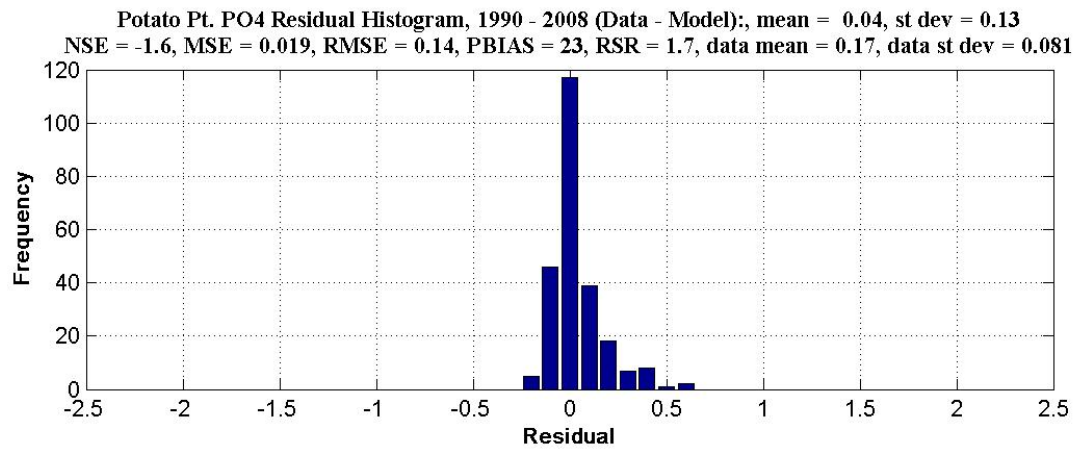


Figure A V. 83 Potato Pt PO₄ dry years.

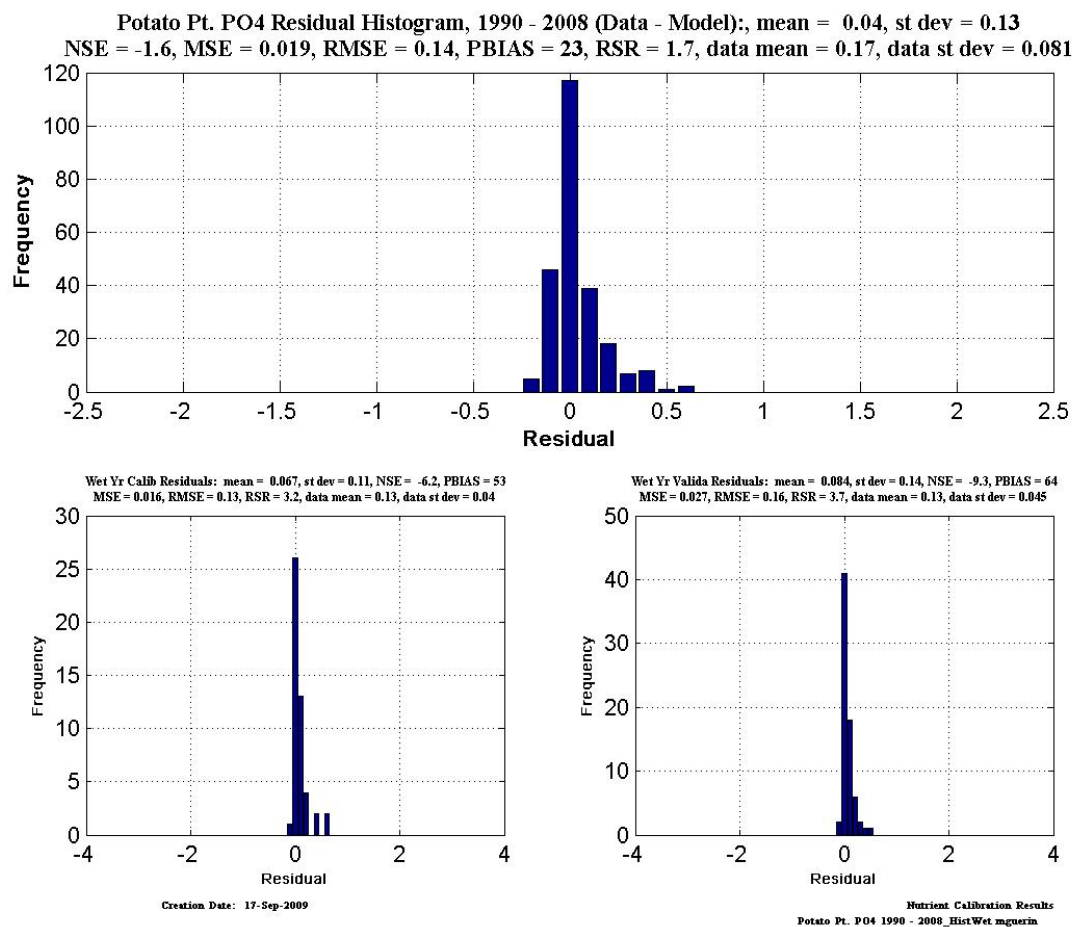


Figure A V. 84 Potato Pt PO₄ wet years.

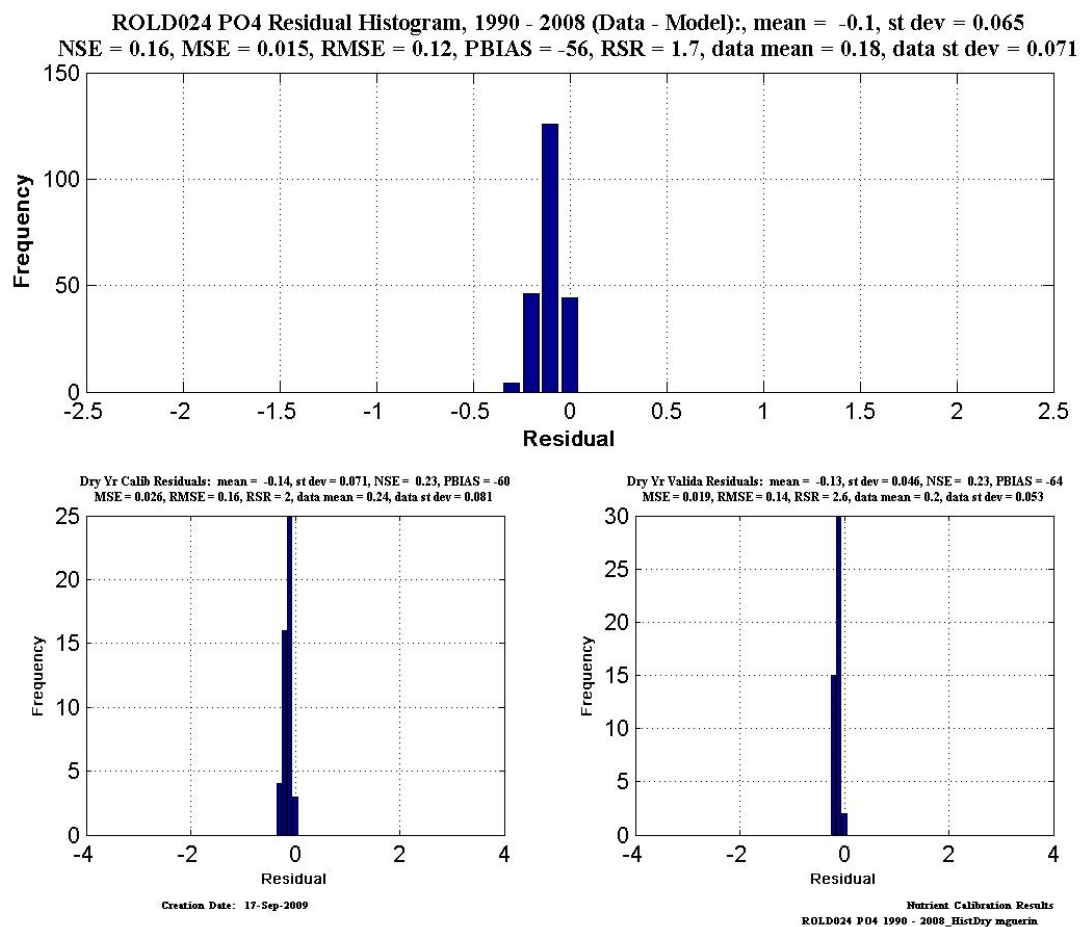


Figure A V. 85 ROLD024 PO₄ dry years.

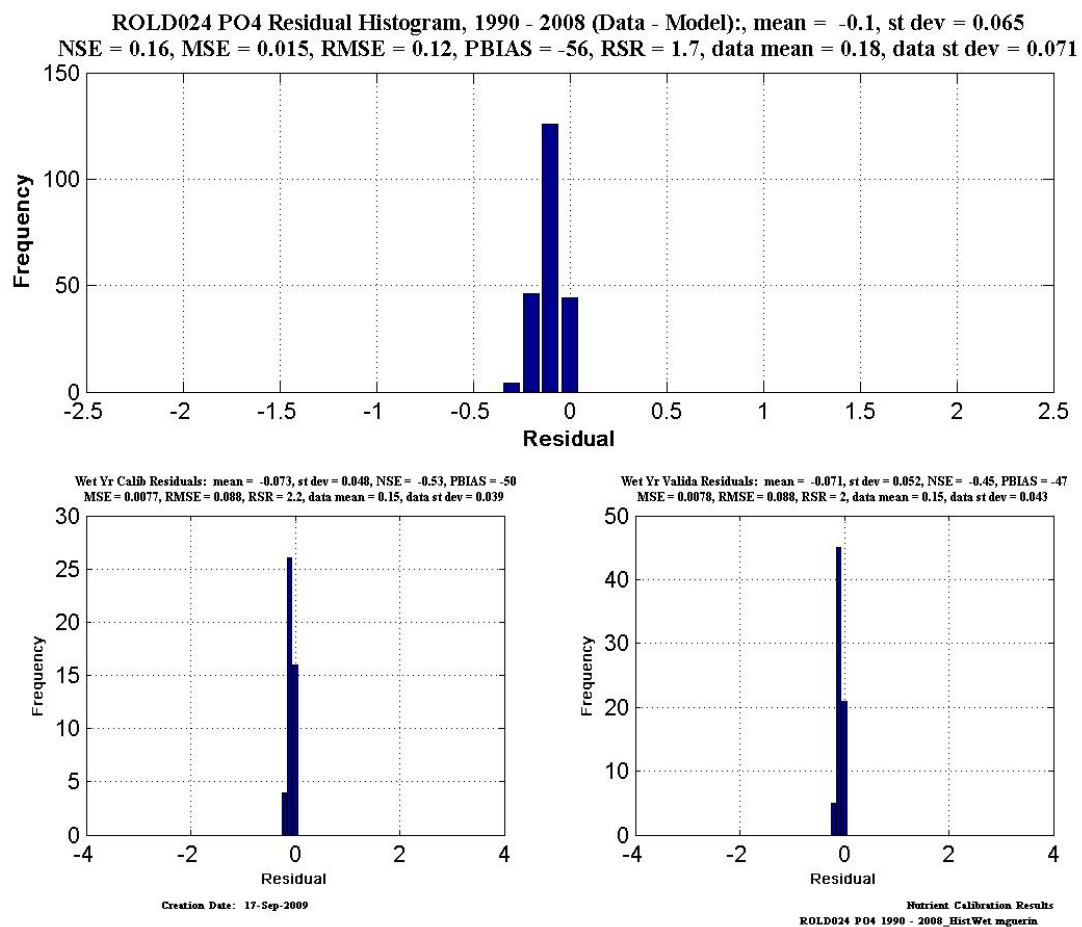


Figure A V. 86 ROLD024 PO₄ wet years.

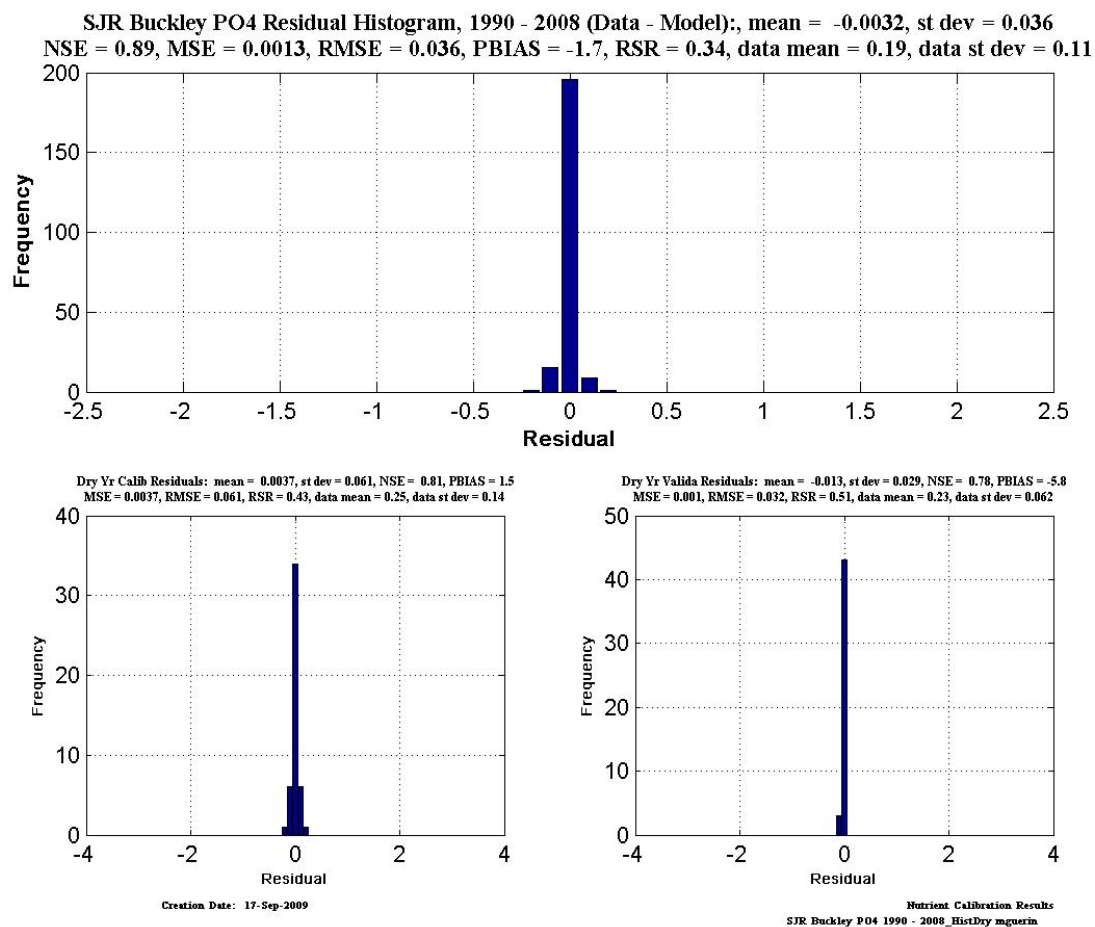


Figure A V. 87 SJR Buckley PO₄ dry years.

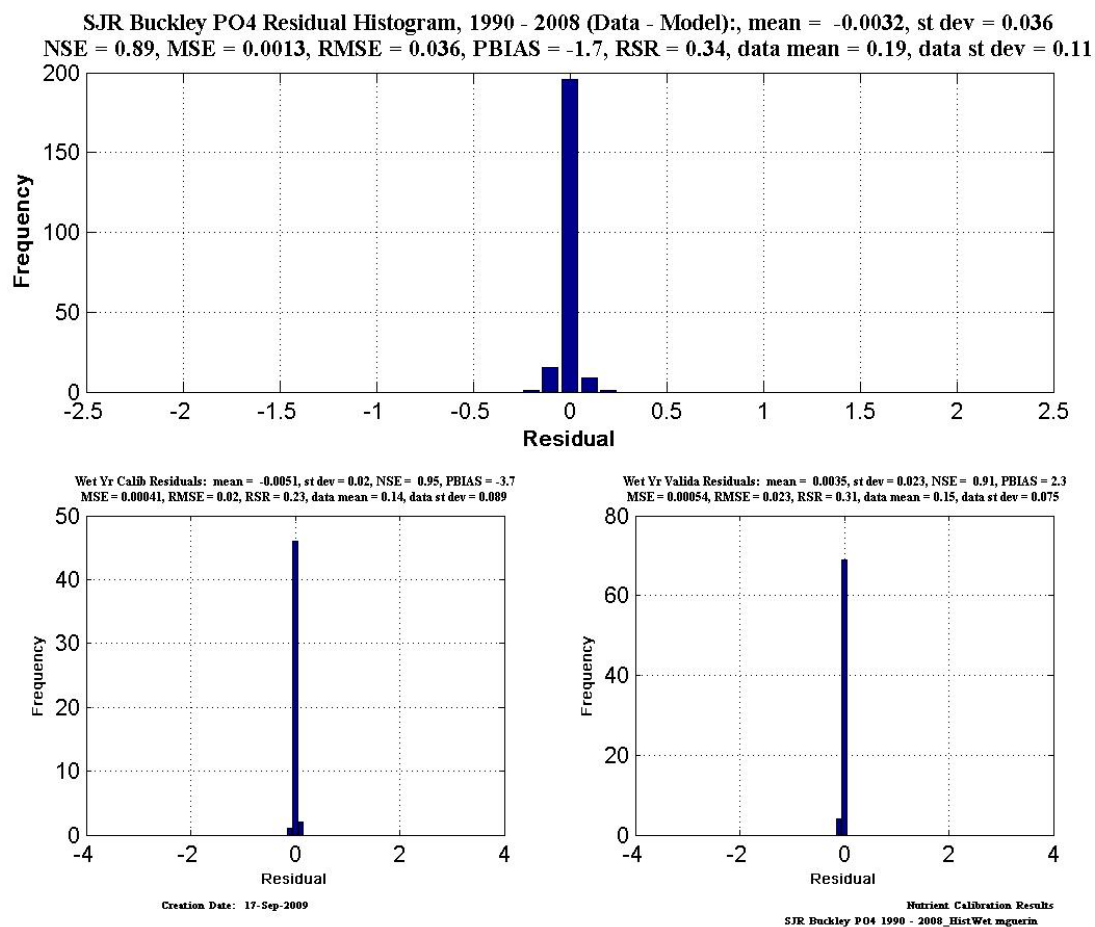


Figure A V. 88 SJR Buckley PO₄ wet years.

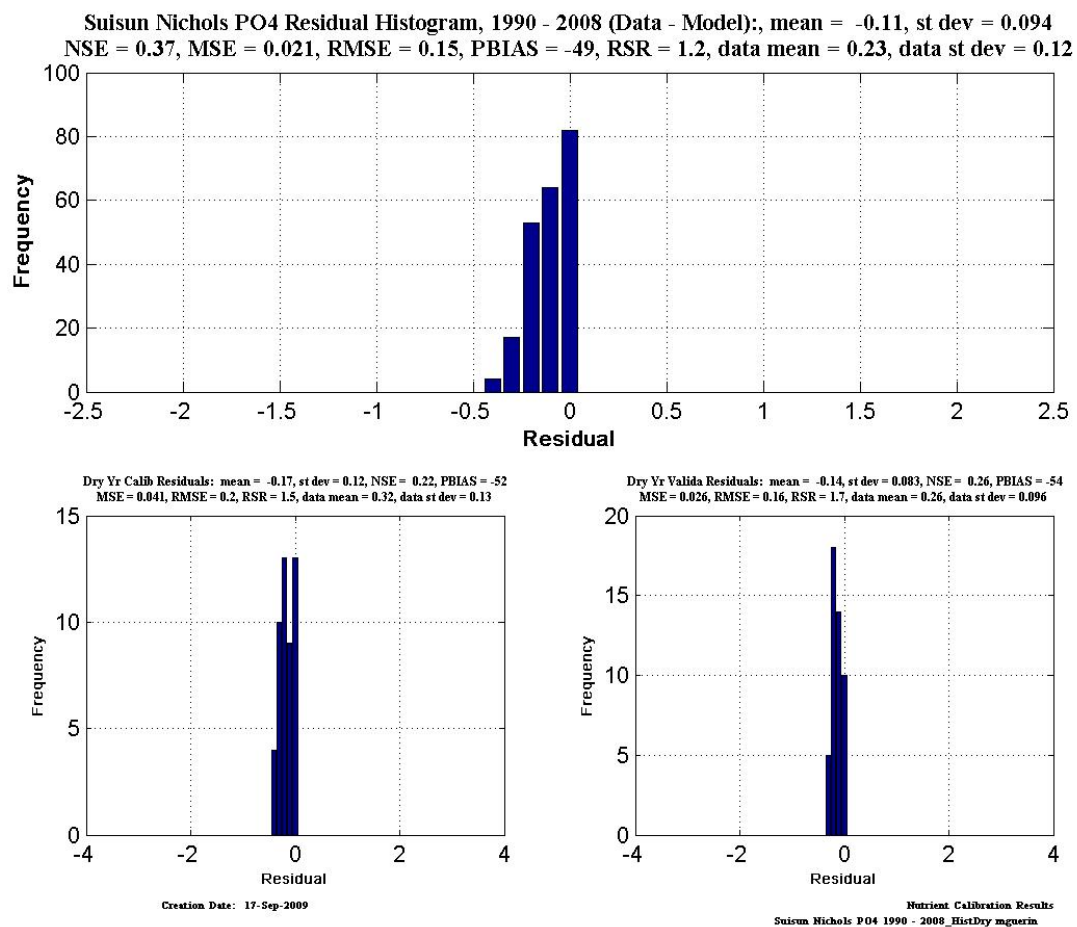


Figure A V. 89 Suisun-Nichols PO₄ dry years.

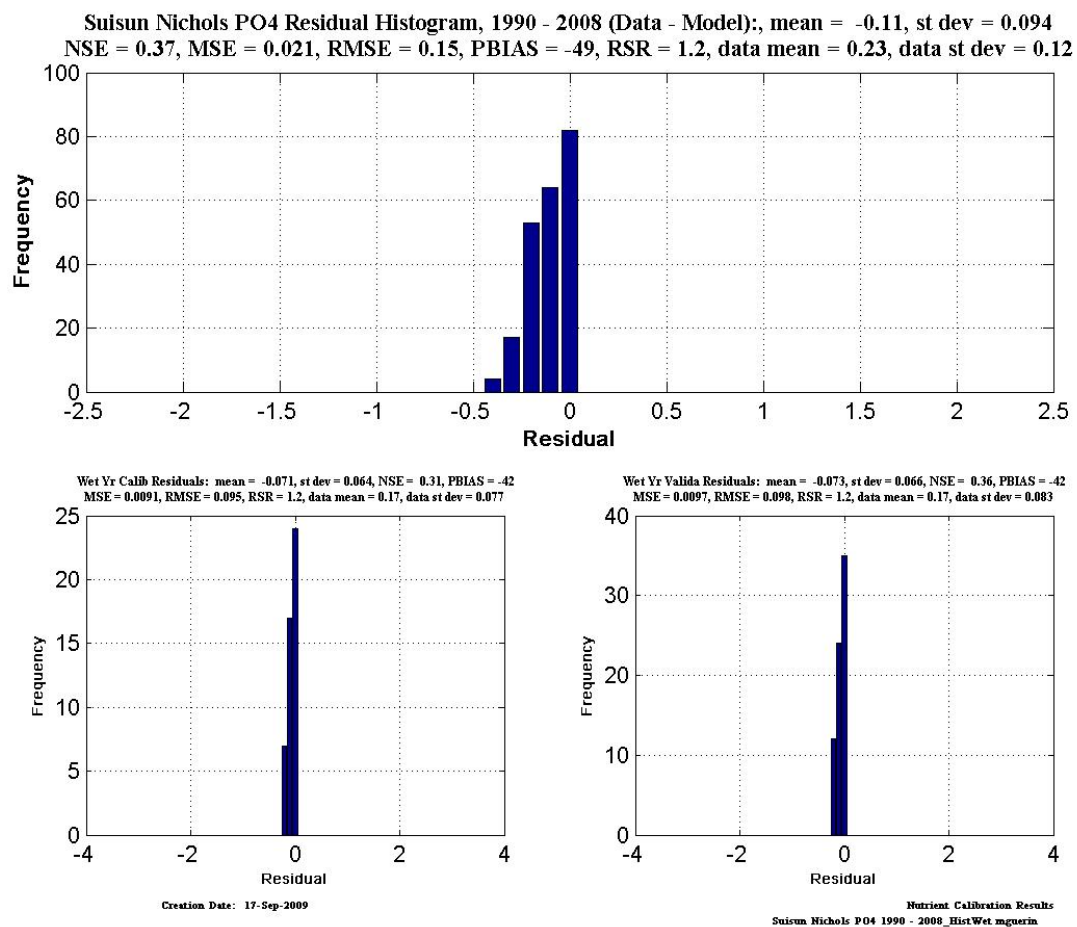


Figure A V. 90 Suisun-Nichols PO₄ wet years.

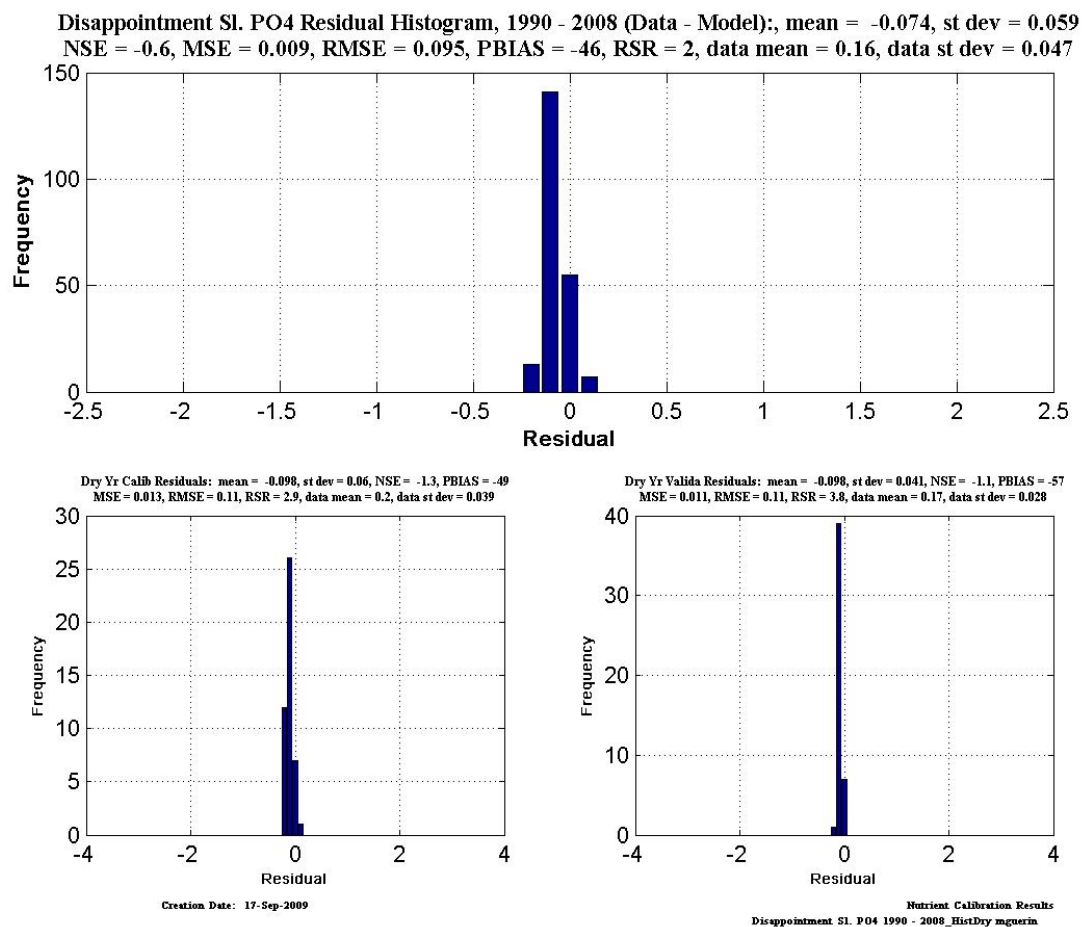


Figure A V. 91 Disap Sl PO₄ dry years.

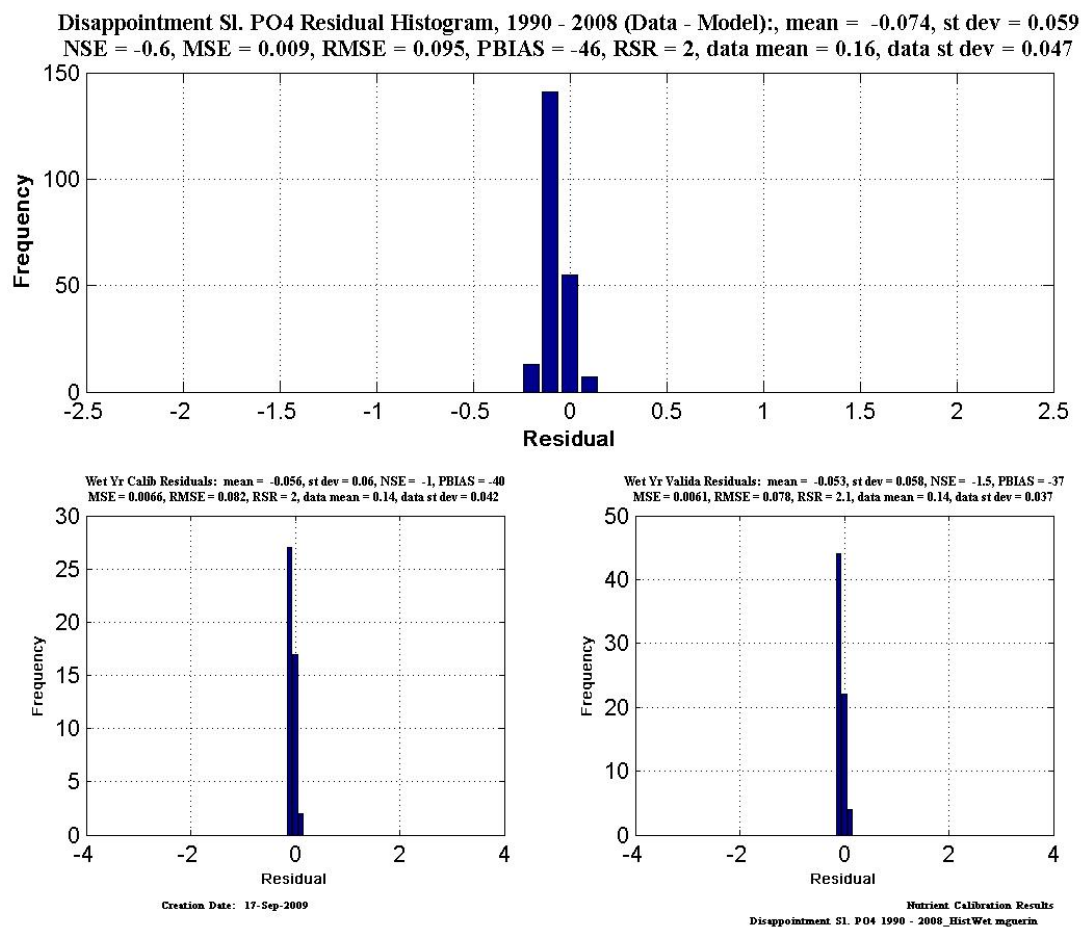


Figure A V. 92 Disap SL. PO₄ wet years.

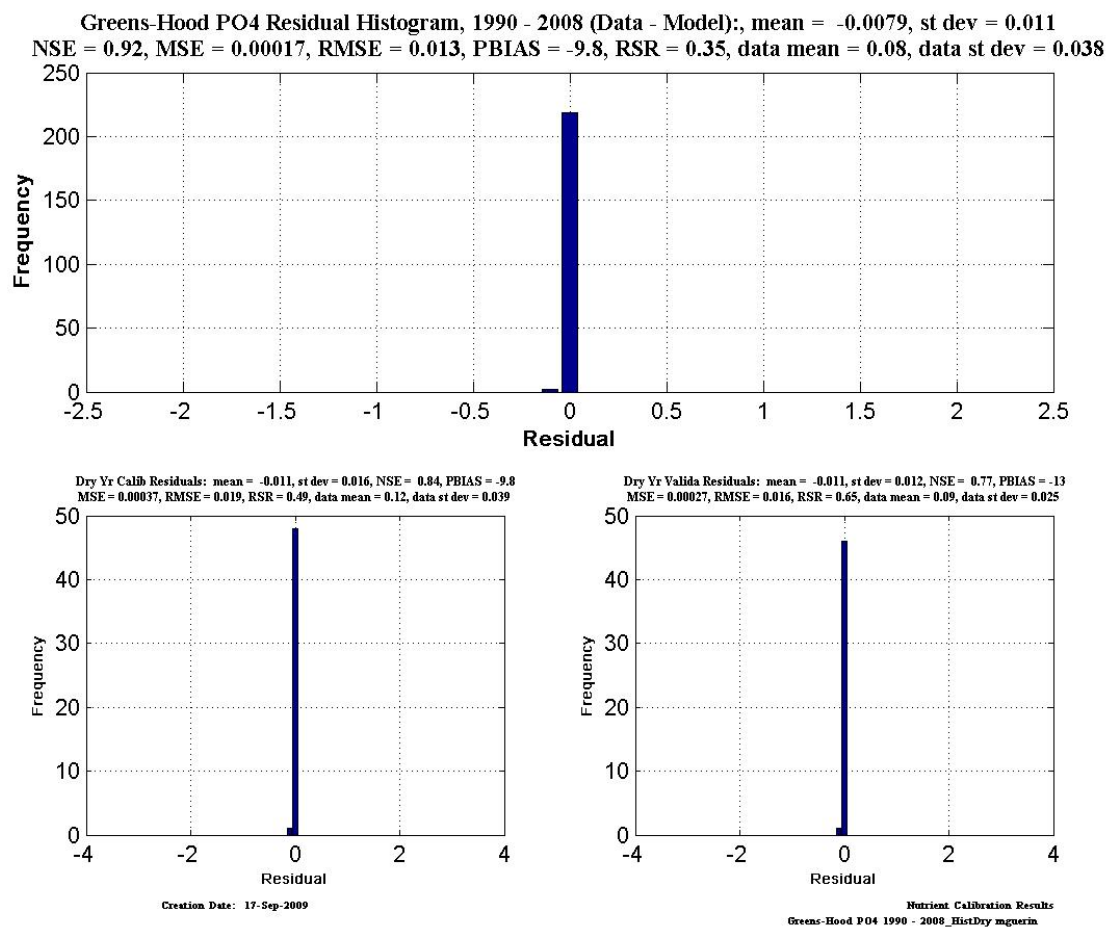


Figure A V. 93 Greenes-Hood PO₄ dry years.

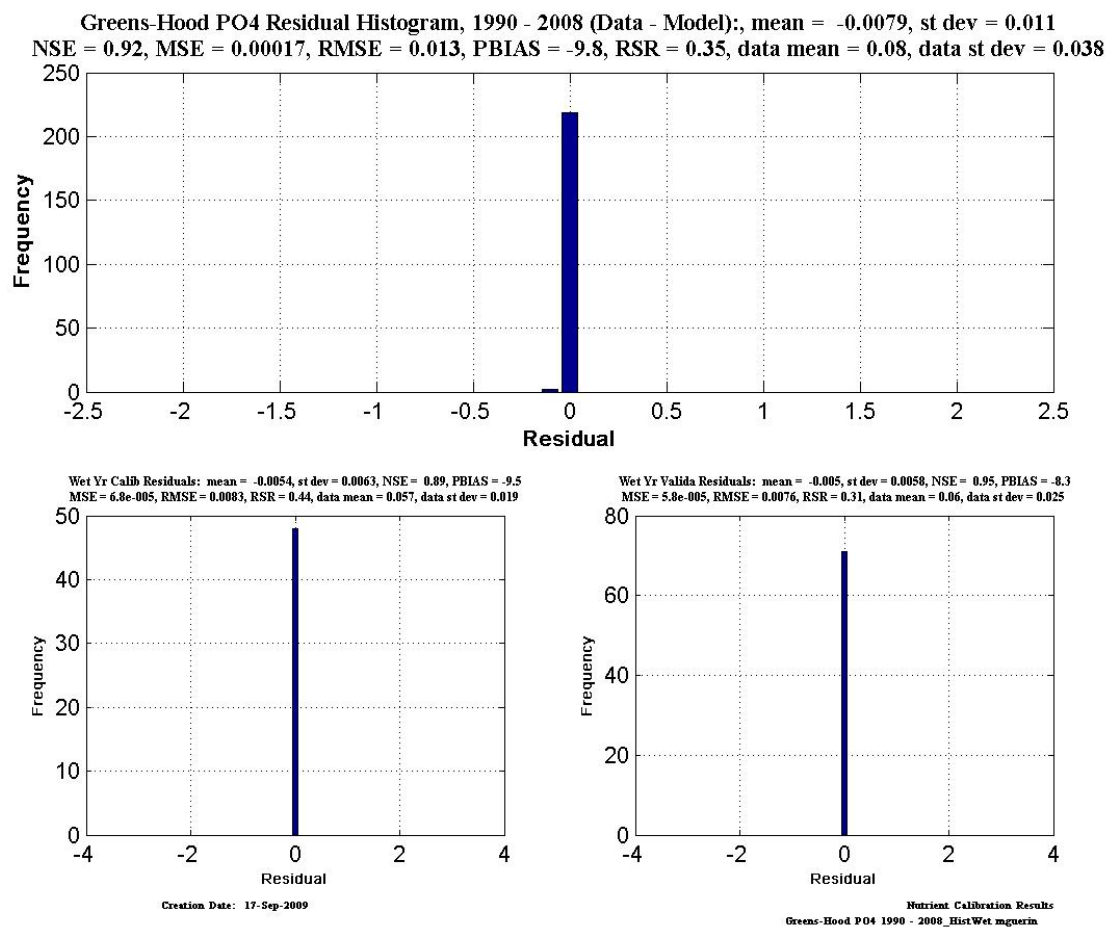


Figure A V. 94 Greenes-Hood PO₄ wet years.

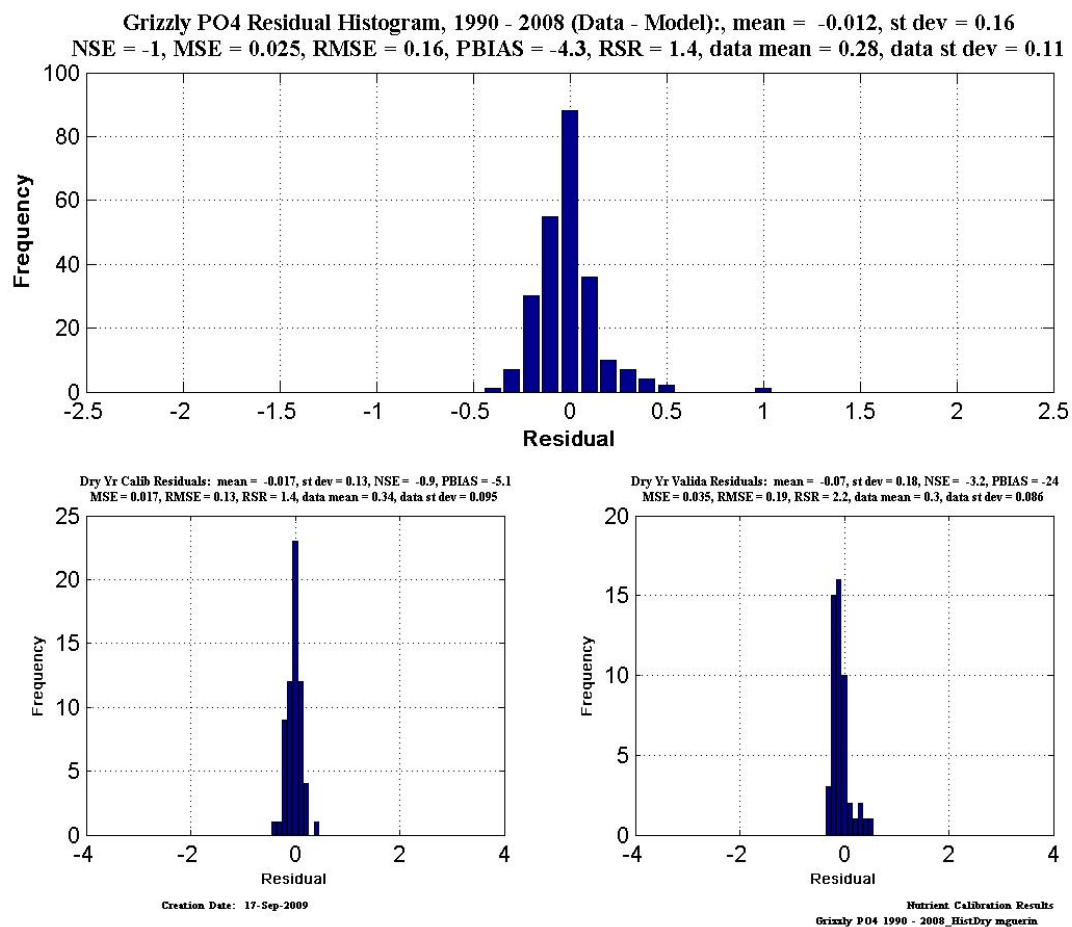


Figure A V. 95 Grizzly PO₄ dry years.

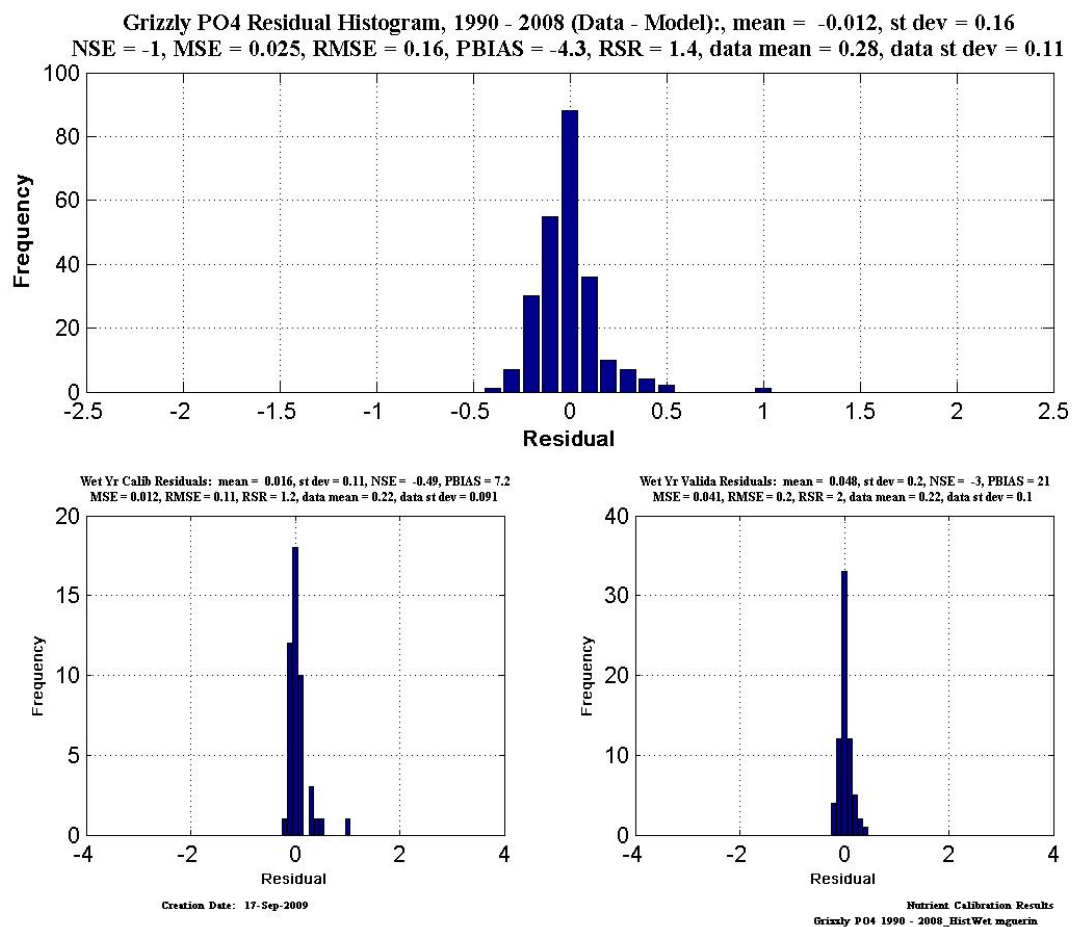


Figure A V. 96 Grizzly PO₄ wet years.

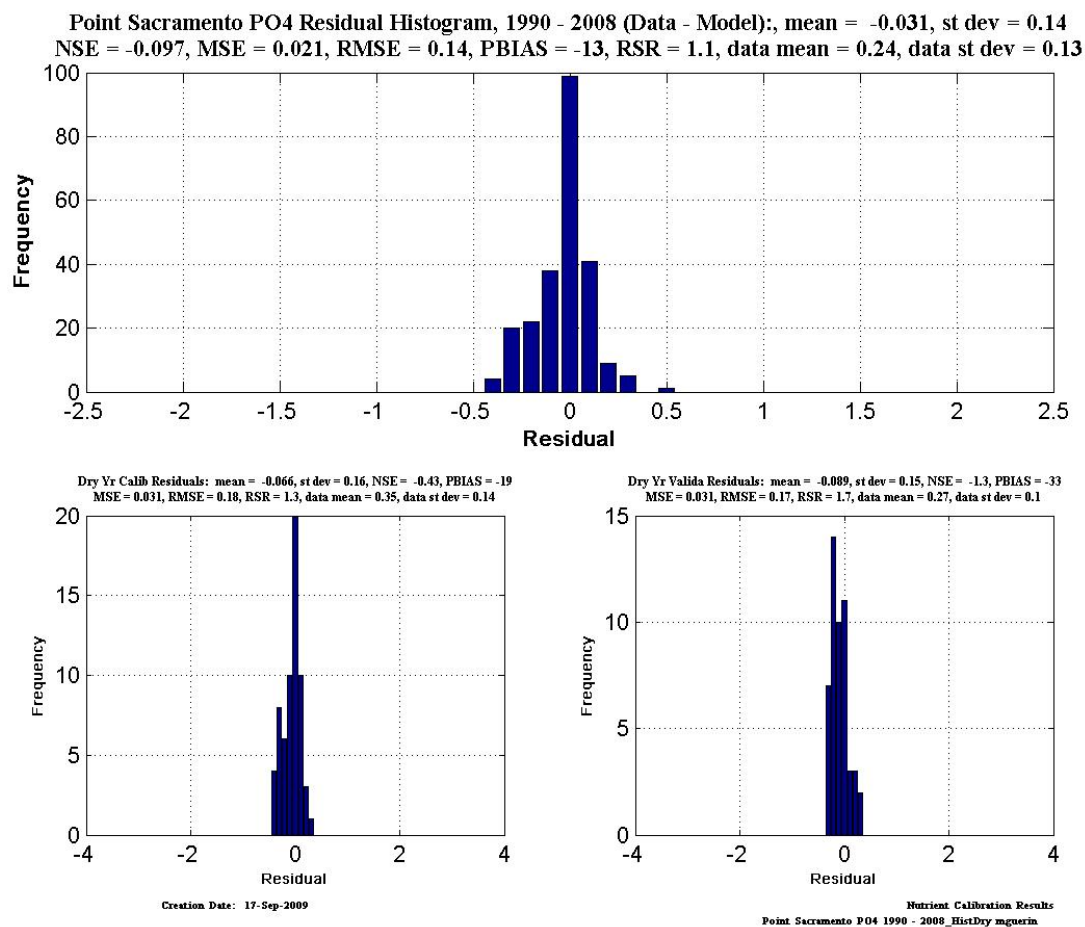


Figure A V. 97 Pt Sacramento PO₄ dry years.

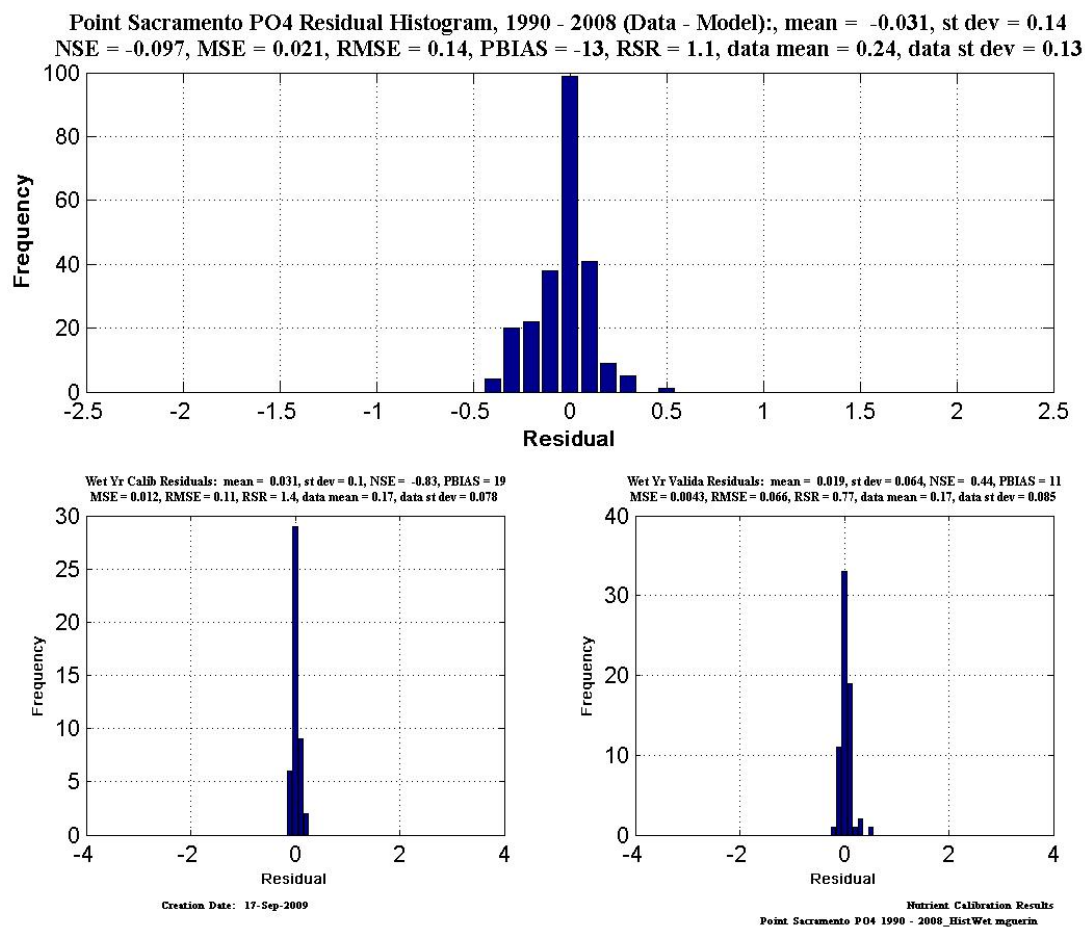


Figure A V. 98 Pt Sacramento PO₄ wet years.