State of California
The Resources Agency
Department of Water Resources
Office of State Water Project Planning

METHODOLOGY FOR FLOW AND SALINITY ESTIMATES IN THE SACRAMENTO—SAN JOAQUIN DELTA AND SUISUN MARSH

NINETEENTH ANNUAL PROGRESS REPORT TO THE STATE WATER RESOURCES CONTROL BOARD

In accordance with Water Right Decision 1485, Order 9

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FOREWORD

This is the nineteenth annual progress report of the California Department of Water Resources' San Francisco Bay-Delta Evaluation Program (Work Authority 1463), which is carried out by the Delta Modeling Section. It documents progress in the development and enhancement of the Delta Modeling Section's computer models and reports the latest findings of studies conducted as part of the program.

For the last five years, the Section has been developing the new Delta Simulation Model (DSM2). The model was recently made public through the Section's World Wide Web home page: http://wwwdelmod.water.ca.gov. This report contains a description of the theory behind the model and information on how to run the model and its support programs.

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Introduction

Chapter Summaries

The Delta Modeling section recently made public the new Delta Simulation Model—DSM2. This report describes the various modules necessary for running DSM2: its input and output system; its visualization tool and analyzer; and its calibration. This report also describes the section's artificial neural networks used to estimate marginal export cost. Following are brief summaries of each of the chapters contained in the report. (The name of each chapter's primary author is in parentheses.)

Chapter 2—*DSM2-Hydro*

Chapter 2 contains a brief description of the hydrodynamics portion of the model and a list of additional sources of information. (Parviz Nader-Tehrani)

Chapter 3—*DSM2-Qual*

Chapter 3 contains a description of the water quality portion of the model. It focuses mainly on the non-conservative constituent relationships modeled within DSM2-Qual. (Hari Rajbhandari)

Chapter 4—*DSM2-PTM*

Chapter 4 describes the theory used in the particle tracking portion of DSM2. (Tara Smith)

Chapter 5—*DSM2 Input and Output*

Chapter 5 gives a description and examples of the input and output files used by DSM2. (Parviz Nader-Tehrani and Ralph Finch)

Chapter 6—*Cross-Section Development Program (CSDP)*

Chapter 6 describes how CSDP converts bathymetry data to cross section data that can be used by DSM2. CSDP is used to develop irregular cross-sections for DSM2-Hydro. (Brad Tom)

Chapter 7—*Artificial Neural Networks (ANNs) and Marginal Export Cost Estimates (MEC)*

Chapter 7 describes the further development of the Artificial Neural Network used to determine salinity at various locations within the Delta. The chapter also describes how the ANN is used to estimate the Marginal Export Cost. (Don Wilson)

Chapter 8—*Visualization Tool and Analyzer (VISTA)*

Chapter 8 describes VISTA—the new data retrieval, management, manipulation, and visualization tool which was developed over the last year. (Nicky Sandhu)

Chapter 9—*Calibration*

Chapter 9 provides graphs of the July 1997 calibration. In this calibration, stage, flow, real tide, and multi-year planning comparisons were made in order to calibrate the model so that it had the capability of meeting a variety of conditions. (Ralph Finch)

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DSM2 Hydro

DSM2-Hydro is a modified version of the FourPt Model developed by Lew Delong et. al., (US Geological Survey). The FourPt Model is capable of simulating one-dimensional, unsteady, open-channel flow by solving the governing equations of continuity and momentum in an implicit form. Unlike DSM1, the FourPt Model is public domain. Other major advantages the FourPt Model has over DSM1 include:

- The ability to simulate irregular cross-sections and nonprismatic channels
- The ability to conserve mass within a channel
- The potential to incorporate baro-clinic term (density driven flow)

In 1992 the Delta Modeling Section started evaluating the performance of FourPt Model using the DWRDSM Delta Grid. The results of initial tests looked very promising. Since then, the model has undergone major revisions—the ultimate goal being to create a production level model able to simulate the complex conditions in the Sacramento-San Joaquin Delta. The model was successfully calibrated and verified in 1997 using flow data. In the summer of 1997, DSM2 replaced DSM1 as the official model utilized in the Delta Modeling Section. For more information about DSM2-Hydro, consult the sources below:

- Delta Modeling Section's DSM2 documentation
- USGS report (FourPt Manual) (Lew Delong)
- Delta Modeling Section's home-page: **http://wwwdelmod.water.ca.gov**
- Delta Modeling Section's previous annual reports (1992-1997)

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DSM2 Qual

Water Quality

The distribution of water quality variables in space and time is computed by solving the one-dimensional advection-dispersion equation in which non-conservative constituent relationships are considered to be governed, in general, by first order rates (see equations on page 3-5). The processes of chemical and biochemical transformations, including interaction among various parameters as represented in the model are shown in Figure 3.1 at the end of this chapter. These constituents include dissolved oxygen, carbonaceous BOD, phytoplankton, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, organic phosphorus, dissolved phosphorus, TDS, and temperature. The conceptual and functional descriptions of the constituent reactions are based generally on QUAL2E (Brown and Barnwell 1987); although in certain instances they were updated based on the work of Bowie et al., (1985). Mass balance equations are written for all quality constituents in each parcel of water (see equations on page 3-5). The reader is referred to Jobson and Scoellhamer (1987) for a description of the Lagrangian formulation which provides the basic framework for DSM2-Qual.

In applying the water quality model, changes in concentration due to advection and dispersion, including changes due to tributaries or agricultural drainage are first computed. Next, concentrations of each constituent in each parcel of water are updated, accounting for decay, growth, and biochemical transformations. New subroutines developed for modeling non-conservative constituents are structured in modular form to facilitate extension for simulation of additional constituents (in the case that such needs arise in the future). Subroutine KINETICS updates constituent concentrations at each time step. A single or any combination of the eleven water quality variables can be modeled to suit the needs of the user. KINETICS is called by the parcel tracking subroutine of DSM2-QUAL for every parcel at each time step. The model has also been extended to simulate kinetic interactions in reservoirs (extended open water bodies encountered in the Delta).

Subroutine CALSCSK builds a source/sink matrix within KINETICS for each non-conservative constituent simulated. For simulation of temperature, a subroutine that computes net transfer of energy at the air-water interface has been adapted from the QUAL2E model with some modification. Required meteorology data (obtained preferably at hourly intervals) include dry bulb and wet bulb atmospheric temperatures, wind speed, atmospheric pressure, and cloudiness.

Physical, chemical, and biological rate coefficients required for KINETICS are read as input. Some of these coefficients are constant throughout the system; some vary by location; and most are temperature-dependent. A list of these coefficients and sample values is provided in chapter 5.

The numerical scheme for updating kinetic interactions was developed considering properties of Lagrangian box models that are most accurate when time steps are small enough to define the dominant temporal variations in flow and concentration. A relatively simple scheme that takes advantage of small time steps—the Modified Euler method—is used to update concentrations. Concentration updating is done at least once in every time step, and more often if the parcel in question has passed a grid point before the current time step is fully accounted for. In the latter case, the reaction time step will be the increment of time remaining to be accounted for—less than the simulation time step (typically 15 minutes). Consequently, reaction time steps remain small, so the Modified Euler scheme for concentration updating is appropriate. Since changes in concentration of any constituent affect the other constituents, tests are included in DSM2-Qual to check whether corrections to constituent concentrations are necessary.

The ability of the model to simulate the dissolved oxygen sag on a reach of the San Joaquin River near Stockton was recently demonstrated. DSM2-Qual was capable of capturing diurnal variations of important constituents such as dissolved oxygen, phytoplankton, temperature, and nutrients under the unsteady conditions of the estuary. Variations were realistic, although lack of a large temporal variation in observed data was somewhat of an impediment to testing the model's full capacity to predict field conditions. Tests of the model's capability to distinguish between alternatives in terms of incremental changes in water quality were encouraging (Rajbhandari 1995). The model has great potential for use as a practical tool for analysis of the impacts of water management alternatives.

To enhance the predictive capability of the model, sensitivity analysis should be performed to determine the relative influence of rate coefficients on model response. Calibrated values of the rate coefficients which are most sensitive should be refined. Also, subject to a consistent expansion of the database, future extensions in the model to add additional variables (such as zooplankton) are likely to result in improvement in model performance. Extension of model to represent sediment transport capability should also be investigated such that a dynamic interaction of sediments with simulated constituents is possible. Other uses of the model would be in providing the spatial and temporal distributions of water quality variables for the Particle Tracking Model, so that aquatic species can be more accurately modeled.

References

Bowie, G. L., Mills, W. B., Porcella, D. B., Campbell, C. L., Pagenkopt, J. R., Rupp, G. L., Johnson, K. M., Chan, P. W. H., and Gherini, S. A. (1985). *Rates, Constants and Kinetics Formulations in Surface Water Quality Modeling*. 2nd Ed., US EPA, Athens, Georgia, EPA 600/3-85/040.

Brown, L. C., and Barnwell, T. O. (1987). *The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and Users Manual.* US EPA, Athens, Georgia, EPA 600/3-87/007.

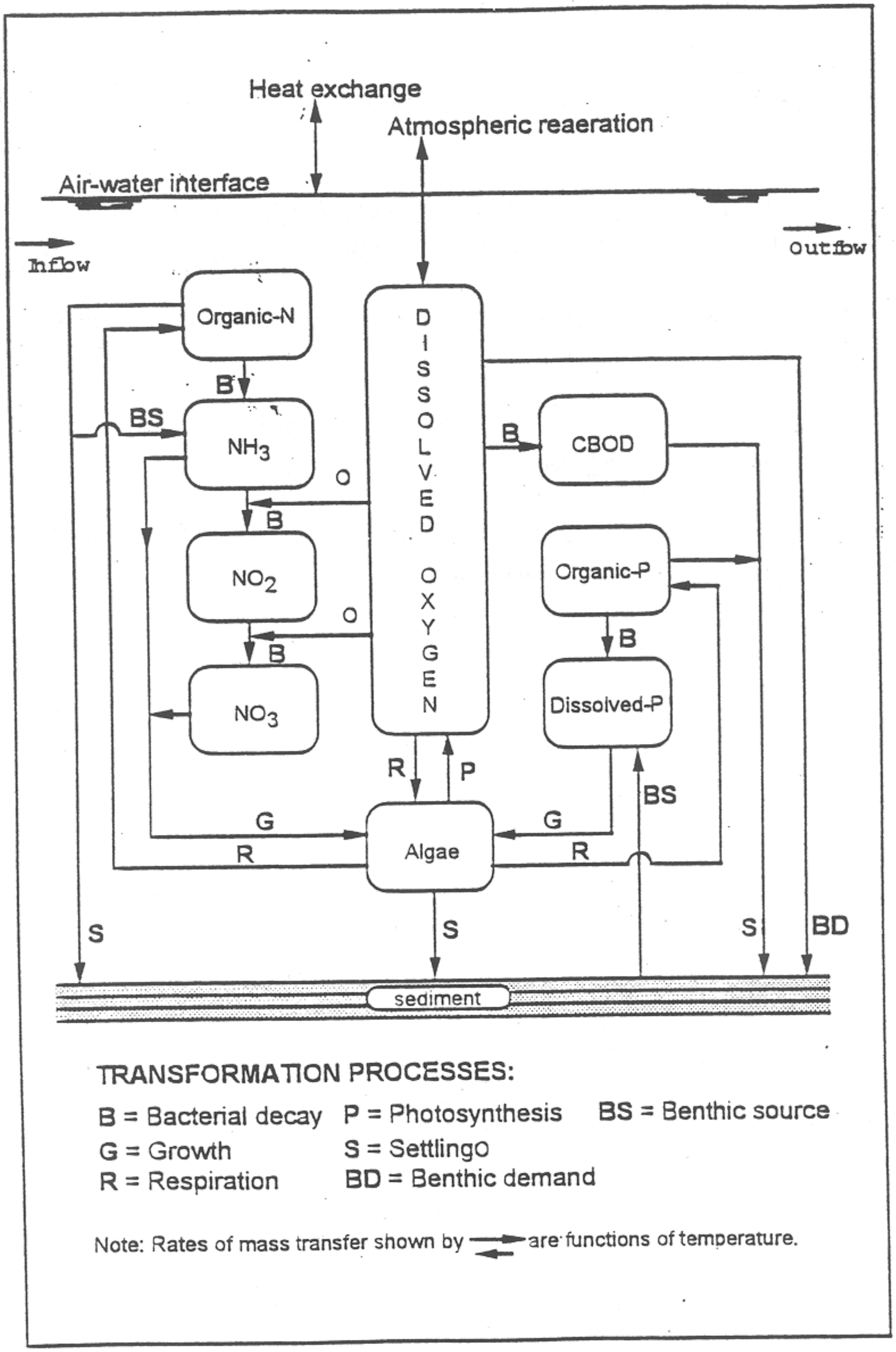
Jobson, H. E., and Schoellhamer, D. H. (1987). *Users Manual for a Branched Lagrangian Transport Model*. U.S. Geological Survey, Water Resources Investigation Report 87-4163.

O'Connor, D. J. and Dobbins, W. E. (1956). *Mechanism of Reaeration in Natural Streams.* J. Sanitary Engrg. Div., ASCE, 82(6), 1-30.

Orlob, G. T. and N. Marjanovic (1989) *Heat Exchange. Ch. 5 in Mathematical Submodels in Water Quality Systems*, ed. S.E. Jorgensen and M.J. Gromiec, Elsevier Pub.

Rajbhandari, H. L. (1995). *Dynamic Simulation of Water Quality in Surface Water Systems Utilizing a Lagrangian Reference Frame*. PhD Dissertation, Univ. of California, Davis, Calif.

Figure 3.1 Interaction Among Constituents



DSM2 Equations for Non-Conservative Constituents

This section lists the equations for each constituent written in a Lagrangian reference frame that moves with the cross-sectional mean velocity. Consequently, the advection term does not appear in these equations.

Dissolved Oxygen

The rate of change in DO concentration is given by:

$$\frac{\partial[O]}{\partial t} = \underset{\text{Diffusion}}{\frac{\partial}{\partial\xi}\left[E_x\frac{\partial(O)}{\partial\xi}\right]} - \underset{\text{CBOD}}{(k_1+k_3)\,L} + \underset{\text{Reaeration}}{k_2\,(O_s-[O])} - \underset{\text{Ammonia oxidation}}{\alpha_5\,k_n\,[NH_3]}$$

$$\underset{\text{Nitrite oxidation}}{-\,\alpha_6 k_{ni}[NO_2]} \underset{\text{Photosynthesis}}{+\,\alpha_3\,\mu\,[A]} \underset{\text{Respiration}}{-\,\alpha_4\,\rho[A]} \underset{\text{Benthic demand}}{-\,K_4/d} \qquad (A.1)$$

where

$[O]$ = dissolved oxygen concentration, mg/l or, g/m^3,

k_1 = CBOD decay rate at the ambient temperature, day^{-1},

k_3 = rate of loss of CBOD due to settling at the ambient temperature, day^{-1},

L = CBOD concentration, mg/l,

k_2 = reaeration coefficient, day^{-1},

O_s = dissolved oxygen concentration at saturation, mg/l,

k_n = ammonia decay rate at the ambient temperature, day^{-1},

$[NH_3]$ = ammonia concentration as N, mg/l,

α_5 = amount of oxygen consumed in conversion of ammonia to nitrite,

α_6 = amount of oxygen consumed in conversion of nitrite to nitrate,

k_{ni} = nitrite decay rate at the ambient temperature, day^{-1},

$[NO_2]$ = nitrite concentration as N, mg/l,

α_3 = amount of oxygen produced per unit of algal photosynthesis,

μ = phytoplankton growth rate at the ambient temperature, day^{-1},

α_4 = amount of oxygen consumed per unit of algae respired,

ρ = phytoplankton respiration rate at the ambient temperature, day^{-1},

$[A]$ = phytoplankton concentration, mg/l,

K_4 = benthic oxygen demand, $g/m^2\ day^{-1}$,

d = mean channel depth, ft (0.30m),

ξ = distance from the parcel, the Lagrangian distance coordinate.

$$\xi = x - x_o - \int_{t_o}^{t} u\, d\tau \qquad \text{(A.2)}$$

x_o = location of the fluid parcel at time t_o,

x = Eulerian distance coordinate.

E_x = longitudinal dispersion coefficient,

DO Saturation

DO Saturation concentration as a function of temperature is:

$$\ln O_{sf} = -139.34411 + \left(1.575701 * 10^5\right)/T_k - \left(6.642308 * 10^7\right)/T_k^2 + \left(1.243800 * 10^{10}\right)/T_k^3 - \left(8.621949 * 10^{11}\right)/T_k^4$$

where O_{sf} = "freshwater" DO saturation concentration in mg/L at 101 kPa (1 atm); and T_k = temperature in °K = T (°C) + 273.15.

Also, to extend the model's applicability to estuaries where salinity intrusion may be significant, the effect of salinity on DO saturation concentration has been incorporated as shown below

$$\ln O_{ss} = \ln O_{sf} - S\left[1.7674 * 10^{-2} - \left(1.0754 * 10^{1}\right)/T_k + \left(2.1407 * 10^{3}\right)/T_k^2\right]$$

where

O_{ss} = "saline water" DO saturation concentration in mg/L at 101 kPa (1 atm); and S = salinity in ppt. In test simulations using DSM2, where salinity was varied over a range of 5000 to 20,000 ppm, the changes in DO saturation were as much as 15-20%. Such salinity effects are not included in the QUAL2E model package.

The DO saturation value also increases with the increase in atmospheric pressure and is represented in the model by:

$$O_s = O_{ss} P \left[\frac{\left[1 - \left(P_{wv}/P\right)\right]\left(1 - \phi P\right)}{\left(1 - P_{wv}\right)\left(1 - \phi\right)}\right]$$

where

P = nonstandard pressure in atm (101 kPa); and P_{wv} = partial pressure of water vapor (atm or 101 kPa) calculated from:

$$\ln P_{wv} = 11.8571 - \left(3840.70/T_k\right) - \left(216961/T_k^2\right)$$

$$\phi = 0.000975 - \left(1.426 * 10^{-5} T_k\right) + \left(6.436 * 10^{-8}\, T_k^2\right)$$

$$T = \text{temperature } {}^{o}C = T_k - 273.15.$$

Other terms are as defined previously.

Reaeration

O'Connor and Dobbins (1956) equation is used:

$$k_2 = (D_m \bar{u})^{0.5} d^{-1.5}$$

(at 20°C)

where D_m = molecular diffusion coefficient = 0.000081 ft^2/hour, $\bar{u}$ = the mean velocity (ft/s), and d = average stream depth (ft).

Carbonaceous Biochemical Oxygen Demand (CBOD)

Accounting also for the removal of CBOD that may be due to settling of organic particles, the rate of change of CBOD due to both biochemical oxidation and settling can be expressed as:

$$\frac{\partial L}{\partial t} = \frac{\partial}{\partial \xi}\left[E_x \frac{\partial L}{\partial \xi}\right] - (k_1 + k_3) L \qquad (A.3)$$

Terms are as defined previously.

Algae (Phytoplankton)

The rate of increase in algal biomass is computed by:

$$\frac{\partial [A]}{\partial t} = \frac{\partial}{\partial \xi}\left[E_x \frac{\partial [A]}{\partial \xi}\right] + [A] (\mu - \rho) - \sigma_1 \frac{[A]}{d} \qquad (A.4)$$

σ_1 = phytoplankton settling rate at ambient temperature, ft/day,

[A] = phytoplankton concentration, mg/l.

$$\mu = \mu_{max} (FL) \text{ Min} \left(\frac{N}{K_N + N}, \frac{P}{K_P + P}\right) \qquad (A.5)$$

μ_{max} = maximum algal growth rate at the ambient temperature, day^{-1},
N = inorganic nitrogen concentration (NO3 + NH3), mg/l,
K_N = nitrogen half saturation constant, mg/l,
K_P = phosphorus half saturation constant, mg/l,
K_L = half saturation constant for light, $Kcal.m^{-2}.s^{-1}$ or Btu/ft^2 -hr (light intensity at which phytoplankton grows at half the maximum rate),
FL = algal growth limitation factor for light.

$$FL = \left(\frac{1}{\lambda d}\right) \ln \left[\frac{K_L + I}{K_L + Ie^{-\lambda d}}\right] \qquad (A.6)$$

Equation (A.6) is obtained when the variation of light intensity with depth represented by the relationship shown below is substituted in the Monod expression for light and integrated over the depth of flow.

$$I_z = I \exp(-\lambda z) \qquad (A.7)$$

where

I = light intensity at the surface, $Kcal.m^{-2}.s^{-1}$ or Btu/ft^2 -hr,
I_z = light intensity at a given depth (z), $Kcal.m^{-2}.s^{-1}$ or Btu/ft^2 -hr,
z = depth variable, ft,
λ = light extinction coefficient, ft^{-1}.

The light extinction coefficient is usually defined as the linear sum of several extinction coefficients representing each component of light absorption (Bowie et al., 1985). The light extinction coefficient (λ) will be computed using the expression:

$$\lambda = \lambda_0 + \lambda_1 \alpha_7 [A] + \lambda_2 (\alpha_7 [A])^{2/3} \qquad (A.8)$$

where

λ_0 = non-algal portion of the light extinction coefficient, ft^{-1},

λ_1 = linear algal self shading coefficient, $ft^{-1}(\mu g\text{-}Chla/l)^{-1}$,

λ_2 = nonlinear algal self shading coefficient, $ft^{-1}(\mu g\text{-}Chla/l)^{-2/3}$,

α_7 = conversion factor, (μg-Chla/mg [A]).

Other terms are as previously defined.

Chemical Oxidation: Nitrogen Series

The differential equations representing transformations of organic nitrogen to ammonia, ammonia to nitrite, and nitrite to nitrate are presented below.

Organic Nitrogen

$$\frac{\partial[N\text{-}org]}{\partial t} = \frac{\partial}{\partial \xi}\left[E_x \frac{\partial[N\text{-}org]}{\partial \xi}\right] + \alpha_1 \rho[A] - k_{n\text{-}org}\,[N\text{-}org] - \sigma_4[N\text{-}org] \quad (A.9)$$

where

$[N\text{-}org]$ = concentration of organic nitrogen, day^{-1},

$k_{n\text{-}org}$ = rate constant for hydrolysis of organic nitrogen to ammonia nitrogen at the ambient temperature, day^{-1},

α_1 = fraction of algal biomass, which is nitrogen,

σ_4 = organic nitrogen settling rate at the ambient temperature, day^{-1}.

Ammonia Nitrogen

$$\frac{\partial[NH_3]}{\partial t} = \frac{\partial}{\partial \xi}\left[E_x \frac{\partial[NH_3]}{\partial \xi}\right] + k_{n\text{-}org}[N\text{-}org] - k_n[NH_3] + \frac{\sigma_3}{d} - f\alpha_1\mu[A] \quad (A.10)$$

where

σ_3 = benthic release rate for ammonia nitrogen at the ambient temperature, mg/m^2day^{-1}, f = fraction of algal uptake of nitrogen which is ammonia.

$$= \frac{p[NH_3]}{P[NH_3]+(1-p)[NO_3]} \qquad (A.11)$$

p = preference factor for ammonia nitrogen (0 to 1.0).

Nitrite Nitrogen

$$\frac{\partial[NO_2]}{\partial t} = \frac{\partial}{\partial\xi}\left[E_x \frac{\partial[NO_2]}{\partial\xi}\right] + k_n\ [NH_3] - k_{ni}\ [NO_2] \qquad (A.12)$$

Nitrate Nitrogen

$$\frac{\partial[NO_3]}{\partial t} = \frac{\partial}{\partial\xi}\left[E_x \frac{\partial[NO_3]}{\partial\xi}\right] + k_{ni}\ [NO_2] - (1-f)\ \alpha_1\mu[A] \qquad (A.13)$$

2.2.3.5 Phosphorus Transformation

Organic Phosphorus

$$\frac{\partial[p\text{-}org]}{\partial t} = \frac{\partial}{\partial\xi}\left[E_x \frac{\partial[p\text{-}org]}{\partial\xi}\right] + \alpha_2\rho[A] - k_{p\text{-}org}\ [p\text{-}org] - \sigma_5[p\text{-}org] \qquad (A.14)$$

where

$[p\text{-}org]$ = concentration of organic phosphorus, mg/l,

α_2 = fraction of algal biomass which is phosphorus,

$k_{p\text{-}org}$ = organic phosphorus decay rate at the ambient temperature, day^{-1},

σ_5 = organic phosphorus settling rate at the ambient temperature, day^{-1}.

Dissolved Phosphorus

$$\frac{\partial[PO4]}{\partial t} = \frac{\partial}{\partial \xi}\left[E_x \frac{\partial[PO_4]}{\partial \xi}\right] + k_{p\text{-}org}\,[PO_4] - \alpha_2 \mu [A] + \frac{\sigma_2}{d} \qquad (A.15)$$

where

$[PO_4]$ = concentration of inorganic or dissolved phosphorus, mg/l,

σ_2 = benthic release rate for dissolved phosphorus at the ambient temperature, $mg/m^2\ day^{-1}$.

Temperature

The transport equation for heat as the constituent is:

$$\frac{\partial C_h}{\partial t} = \frac{\partial}{\partial \xi}\left(E_x \frac{\partial C_h}{\partial \xi}\right) + s \qquad (A.17)$$

Where

C_h = concentration of heat (HL^{-3}) which can be represented as

$$C_h = C\rho T \qquad (A.18)$$

where

C = specific heat of water (1 btu/lb-°F or 1 cal/g-°C),

ρ = density of water, 62.4 lb/ft^3 or $1 g/cm^3$,

T = water temperature, (deg C).

Other terms are as defined previously.

The source/sink term (s) accounts for heat exchanged through the air-water interface. Substituting equation (A.18) into equation (A.17) and representing s in the form of the net energy flux (Q_n) into the water surface finally leads to:

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial \xi}\left(E_x \frac{\partial T}{\partial \xi}\right) + \frac{Q_n}{\rho c d} \tag{A.19}$$

where

d = hydraulic depth of the water body.

Table A.1 Temperature Coefficients For Reaction Rates

Constituent	Reaction type	Temperature coefficient	Variable (FORTRAN)
BOD	decay	1.047	thet(1)
	settling	1.024	thet(2)
DO	reaeration	1.024	thet(3)
	SOD	1.060	thet(4)
ORGANIC-N	decay	1.047	thet(5)
	settling	1.024	thet(6)
AMMONIA-N	decay	1.083	thet(7)
	benthic source	1.074	thet(8)
NITRITE-N	decay	1.047	thet(9)
ORGANIC-P	decay	1.047	thet(10)
	settling	1.024	thet(11)
DISSOLVED-P	benthic source	1.074	thet(12)
ALGAE	growth	1.047	thet(13)
	respiration	1.047	thet(14)
	settling	1.024	thet(15)

IV.C.3.7 Components of Heat Exchange at the Air-Water Interface

Heat exchanges through the air-water interface depend upon both the internal hydromechanical behavior of the water body and the physics of its interaction with the overlying air mass.

Meteorological factors such as solar radiation, wind, humidity, pressure, and cloudiness figure prominently in the many physical processes involved . Accounting for the most important of these processes the rate of energy transfer is computed as:

$$Q_n = Q_{sn} + Q_{at} - Q_{ws} - Q_e - Q_h \tag{A.20}$$

where

Q_n = net heat energy transfer across the air-water interface,
Q_{sn} = net short wave solar radiation flux,
Q_{at} = net long wave atmospheric radiation flux,
Q_{ws} = water surface back radiation flux,
Q_e = evaporative heat flux,
Q_h = sensible heat flux.

All the above terms are in units such as Btu/ft^2-day or cal/cm^2-day. A table (Table A.2) on unit conversion of various terms appearing on this section is provided at the end of this section. The remainder of this section describes how each of the heat components is represented in the model.

Net Short Wave Solar Radiation, Q_{sn}

The net incoming solar radiation is short wave radiation which passes directly from the sun to the earth's surface. The attenuating effects of the absorption and scattering of the light in the atmosphere due to cloud cover and the reflection from the water surface must be considered in the computation of the solar radiation that penetrates the water surface. It may be represented by:

$$Q_{sn} = Q_o \, a_t \, (1-0.65\, C^2)(1-R_s) \tag{A.21}$$

where

Q_o = solar radiation intensity at the top of the atmosphere, a function of location and time,
a_t = atmospheric transmissivity term,
C = cloud cover in tenths of sky covered, from 0.0 to 1.0,

R_s = reflectivity of the water surface, a function of the solar altitude of the form:

$$R_s = A\alpha^B \tag{A.22}$$

where

α is the solar altitude in degrees and A and B are functions of cloudiness. Values for A and B are shown below (as reported in the QUAL2E manual).

Cloudiness C	0 Clear		0.1-0.5 Scattered		0.6-0.9 Broken		1.0 overcast	
Coefficient	A	B	A	B	A	B	A	B
	1.18	-0.77	2.20	-0.97	0.95	-0.75	0.35	-0.45

The reader is referred to the QUAL2E manual (Brown and Barnwell, 1987) for details on the representation of the atmospheric transmission term (a_t) and Q_o.

Net Atmospheric Radiation, Q_{at}

Some short-wave radiation from the sun plus radiation emitted by the ground or water surfaces enters the earth's atmosphere and is partly absorbed by water vapor, carbon dioxide, ozone and other atmospheric gases. These constituents, in turn, emit long wave radiation back to the ground and water surfaces, and outward to space. Such radiation is called atmospheric radiation. It is a function of absolute air temperature, cloudiness and water surface reflectivity (Orlob and Marjanovic, 1989) and is expressed as:

$$Q_{at} = C_{at}\,\sigma\,(T_a+460)^6\,(1+0.17\,C^2)(1 - R_a) \tag{A.23}$$

where

C_{at} = Swinbank's coefficient approximately equal to $2.89 * 10^{-6}\ {}^{o}R^{-2}$,

σ = Stefan-Boltzman constant = $1.73 * 10^{-9}$ Btu/ft^2/hr/^{o} Rankine^4,

T_a = temperature of the radiating air mass, °F,
R_a = water surface reflectivity of long wave radiation = 0.03.

Water Surface Back Radiation, Q_{ws}

The loss of energy from a water body by long wave radiation is expressed by the Stefan-Boltzman Fourth Power Radiation Law for a black body as:

$$q_{ws} = \varepsilon \sigma (T_s + 460)^4 \qquad (A.24)$$

where

ε = emissivity of the water surface, i.e., ratio of an actual radiation to that of a black body = 0.97,
T_s = water surface temperature, °F.

Evaporative Heat Flux, Q_e

The evaporative heat loss occurs due to water changing a liquid state to a gas state (vapor) and the heat loss associated with the latent heat of vaporization.

$$Q_e = \gamma L_v E \qquad (A.25)$$

where

γ = specific weight of water, lb/ft^3,
L_v = latent heat of vaporization, Btu/lb,
E = evaporation rate, ft/hr, often expressed as

$$(a+bW)\ (e_s - e_a) \qquad (A.26)$$

where

a,b = constants,
W = wind speed, miles/hr, measured 6 ft. above the water surface,
e_s = saturation vapor pressure of the air (in. of Hg) at the temperature of the water surface, as given by
e_s = $0.1001 \exp(0.03T_s) - 0.0837$
e_a = water vapor pressure (in. of Hg) at a height of 6 feet above the water surface, given as

e_a = $e_{wb} - 0.000367\ p_a\ (T_a - T_{wb})\ [1.0 + (T_{wb}-32)/1571]$
Other terms are as defined earlier.
e_{wb} = saturation vapor pressure (in. of Hg) at the wet bulb temperature,
T_{wb} = wet bulb temperature °F,
P_a = local barometric pressure, in. of Hg.

Sensible Heat Flux, Q_h

Sensible heat is transferred between air and water by conduction and transferred away from the air-water interface by the same mechanisms as for evaporation. It is convenient to relate sensible and evaporative heat fluxes using Bowen's ratio in the form:

$$Q_h = Bq_e$$

where

$$B = \text{Bowen's ratio} = 0.01\ \frac{T_s - T_a}{e_s - e_a}\ \frac{P_a}{29.92} \qquad (A.27)$$

Table A.2 Unit Conversion Related to Heat Equations
(Bowie et al., 1985)

1 BTU/ft^2/day	0.131 watt/m^2	0.271 Ly/day	0.113 kcal/m^2/hr1
Ly/day	0.483 watt/m^2	3.69 BTU/ft^2/day	0.42 kcal/m^2/hr1
kcal/m^2/hr	1.16 watt/m^2	2.40 Ly/day	8.85 BTU/ft^2/day
1 mb	0.1 kp	0.769 mm Hg	0.03 in Hg
1 mm Hg	1.3 mb	0.13 kp	0.039 in Hg
1 in Hg	33.0 mb	25.4 mm Hg	3.3 kp

4

DSM2 PTM

Background

In June 1992 the Department of Water Resources hired Gilbert Bogle of Water Engineering and Modeling to develop a nonproprietary particle tracking module that DWR could adapt to output and geometry of its DSM1 model. The original module provided by Dr. Bogle was a quasi two-dimensional model which simulated longitudinal dispersion by utilizing a vertical velocity profile, vertical mixing, and a dispersion coefficient (which was a function of velocity, depth, and width of the channel). Because of the tidal nature of the water system and because of the channel grid, some complications occurred when implementing the module. After some scrutiny, the model was further developed to be a quasi three-dimensional model. Dr. Bogle continued to give further suggestions on ways to improve the module. To contact Dr. Bogle, e-mail him at gib@bogle.co.nz.

The Particle Tracking model was originally written in Fortran. Due to the nature of the model, the code was rewritten in C++ and Java to take advantage of using an object-oriented approach. Among other developments, the code was modified to handle the new output from DSM2-HYDRO. Additionally, the input system was rewritten (in Fortran) to be consistent with the DSM2-HYDRO and DSM2-QUAL input system.

Summary

The Particle Tracking Model (DSM2-PTM) simulates the transport and fate of individual notional "particles" traveling throughout the Sacramento-San Joaquin Delta. The model utilizes velocity, flow, and stage output from a one-dimensional hydrodynamic model (DSM2-HYDRO). Time intervals for these hydrodynamic values can vary but are on the order of either 15 minutes or one hour. Input into the hydrodynamic model include inflows at various rivers, exports, agricultural return and diversions, and stage at Martinez.

The Delta's geometry is modeled as a network of channel segments and open water areas connected together by junctions; the particles move throughout the network under the influence of flows and random mixing effects.

The location of a particle at any time step within a channel is given by the channel segment number, the distance from the end of the channel segment (x), the distance from the centerline of the channel (y), and the distance from the channel bottom (z) (see Figure 4.1).

Particle Movement

Three-dimensional movement of neutrally buoyant particles within channels is depicted in Figure 4.2.

Longitudinal Movement

Transverse Velocity Profile

The average cross sectional velocity during a time step, which is supplied by the hydrodynamics portion of DSM, is adjusted by multiplying it by a factor which is dependent on the particle's transverse location in the channel. This results in a transverse velocity profile where the particles located closer to the shore move slower than those located near the centerline in the channel. The model uses a quartic function to represent the velocity profile.

Vertical Velocity Profile

The average cross sectional velocity is adjusted by multiplying it by a factor which is dependent on the particle's vertical location in the channel. This results in a vertical velocity profile where the particles located closer to the bottom of the channel move slower than particles located near the surface. The model use the Von Karman logarithmic profile to represent the velocity profile.
The longitudinal distance traveled by a particle is equal to a combination of the two velocity profiles multiplied by the time step.

Transverse Movement

Transverse Mixing

Particles move across the channel due to mixing. A gaussian random factor, a transverse mixing coefficient, and the length of the time step are used in the calculation of the distance a particle will move during a time step. The mixing coefficient is a function of the water depth and the velocity in the channel. When there are high velocities and deeper water, mixing is greater.

Vertical Movement

Vertical Mixing

Particles also move vertically in the channel due to mixing. A gaussian random factor, a vertical mixing coefficient, and the length of the time step are used in the calculation of the distance a particle will move during a time step. The mixing coefficient is a function of the water depth and the velocity in the channel. As with transverse mixing, when there are high velocities and deeper water, mixing is greater.

Capabilities

- Particles can be inserted at any node location within the Delta.

- History of each Particle's movement is available. In the model, the path each particle takes through the Delta is recorded. Output useful in determining the particle's movement includes:

    - Animation. Particles are shown moving through the Delta Channels. The effects of tides, inflows, barriers, and diversions are seen at hourly time steps.

    - Number of particles passing locations. The number of particles that pass specified locations are counted at each time step.

- Each particle has a unique identity and characteristics that can change over time. Since each particle is individually tracked, characteristics can be assigned to the particle. Examples of characteristics are additional velocities that represent behavior (self-induced velocities), or the state of the particle, such as age.

- Particles travel at different velocities at different locations within the cross section. The Particle Tracking Model takes the average one-dimensional channel velocity from the DSM hydrodynamics model and creates velocity profiles from it where higher velocities occur closer to the surface of the water and towards the middle of the channel. Therefore, if particles are heavy and tend to sink towards the bottom, they will move slower than if they were neutrally buoyant. As a result, their travel time through the channels is longer.

Future Directions

Until recently, PTM simulations have primarily been made using neutrally buoyant particles. Some studies have been made where settling velocities and mortality rates have been included. These studies have concentrated on Striped Bass eggs and larvae. As additional fish data become available, additional modifications to the model will be made for future studies. These modifications will be a function of the state of the particle and the particle's environment. These modifications will require the particles react to the following:

Position

If it is known that food exists at the sides of channels, then a transverse velocity component can be included so that particles can move towards the shore.
Example: Inland Silversides may swim towards the shore for food.

Time

When particles age, their behavior may change. If eggs, their density may be different. They may sink, swim, or die.
Example: Longfin larvae are found at the surface of the water column. Juveniles are found to wards the middle of the column.

Particles may react to a diurnal cycle. An option can be included so that the particles will rise and fall depending on the time of day. This will influence their longitudinal position.

Flow

Particles can react to the tidal velocity and direction of flow.
Example: Longfin and Striped Bass move up in the water column to ride the flood tide.

Particles can have an additional longitudinal velocity component.
Example: Salmon smolts swim with the flow.

Quality

Particles' growth rate and mortality can be a function of water quality. This can include temperature, dissolved oxygen level, pesticides, and food abundance.

Particles can swim towards a certain water quality.
Example: Adult Salmon swim towards fresher water.

Theory

Movement Within a Channel

Advection within the model is represented by the one-dimensional velocity determined by DSM2-Hydro. This velocity assumes that in a cross section of the channel, the velocity is constant throughout the cross section.

Longitudinal Dispersion is caused by shear at the bottom and sides of the channel. This shear creates differences in velocities and causes turbulence within the cross section. If a tracer is injected throughout the cross section, at a distance further downstream, its concentration can be approximated by a gaussian distribution (see Figure 4.3).

This approximation is used to define the dispersion coefficient K which is one half of the change in variance with respect to time (see Figure 4.4).

Column 4 in Figure 4.5, from *Mixing in Inland and Coastal Waters* shows observed dispersion from various Rivers. (Columns 5 and 6 show theoretical and DSM1 ptm dispersion, which will be explained later.)

In order to simulate dispersion, velocity profiles and mixing are included in the model. (Figure 4.2)

The vertical velocity profile is approximated using the Von Karman Logarithmic Velocity Profile and the transverse velocity profile is approximated using a quartic function. The quartic function was chosen because it closely approximated velocity profiles measured by USGS in the Delta.

Figure 4-7a shows the movement in the x direction, the direction of the flow, that is caused by the bottom and side shear of the channel. When F_T and F_V are equal to 1, the particle is traveling at the average velocity within the channel. Aq, Bq, and Cq are currently set to 1.62, -2.22, and 0.6. Aq is used as the free parameter with Bq and Cq being derived under the assumptions that velocity is zero at channel sides and the average value of the function is 1. (Figures 4.7a, 4.7b)

Mixing and movement in the vertical and transverse directions are necessary in modeling dispersion. If only velocity profiles resulting in movement in the x direction were modeled, K would not be a constant as it is defined to be, but continually growing larger.

The mixing coefficients are described similarly to the dispersion coefficient in that they are defined as the rate of change of the variance in position. Figure 4.8 shows how the z and y distance traveled is determined. Note in the derivation, that the variance and standard deviation for both position and velocity are shown. The subscripts v and w indicate velocities and the subscripts Y and Z indicate position.

Using the gaussian random number R, a concentration distribution is created with a standard deviation of $(2E_v dt)^{1/2}$. To expand, assume that there are a large number of particles at a particular point in the cross section at the beginning of a time step. At the end of the time step, approximately 95 percent of the particles will have moved a distance equal to or less than two standard deviations or $2(2E_v dt)^{1/2}$.

The derivation for the vertical mixing coefficient Ev is shown in Figure 4.9. It is derived from the Von Karman Logarithmic Velocity Profile and is a function of depth and velocity.

The transverse mixing coefficient was determined empirically. (Figure 4.10)

Figure 4.11 shows the mixing coefficients and how the vertical and transverse distance is calculated in the model. The 0.06 and the 0.0067 can be changed in the input file.

Encountering Boundaries

When the calculated distance of travel in the vertical or horizontal is greater than the actual distance a particle can move, the particle reflects off of the boundary the additional distance that it would have moved if the boundary was not there.

For example, a channel is 10 ft .deep and the neutrally buoyant particle is located at 9.5 ft. at the beginning of a time step. The vertical mixing results in a movement of 0.7 ft. upward. The particle moves up 0.5 ft. to the 10 ft. surface and then "bounces" back 0.2 ft to the 9.8 ft. level.

To avoid excessive bouncing, smaller sub-time steps are used. The sub-time steps are calculated based on the distance traveled by particles during a time step. If the particles travel a distance larger than ten percent of the width or the depth, then the time step is reduced so that the distance traveled is equal to or less than the limiting distance. For mixing, the distance traveled is based on a gaussian distribution. Time step calculations are made for particles that travel one standard deviation away from the zero mean.

Adjustment of Position After Longitudinal Movement

After the particle has moved in the longitudinal, x direction, its position is adjusted to reflect the change in depth or width of the channel.

new z position = z(dnew/dold)

new y position = y(wnew/wold)

Z and y are the calculated positions. The "old" depth and width corresponds to the depth and width at the x position at the beginning of the time step. The "new" depth and width correspond to the depth and width at the x position at the end of the time step.

Verification

Figure 4.12 shows the derived dispersion coefficient. This calculation is not used in the model but is used as a comparison to the dispersion the model generates. To determine if the 3D formulation is adequately modeling dispersion, tests are made of the formulation using one long rectangular channel with a constant velocity. Dispersion is determined in the model by calculating the variance of the concentration of particles over time. K is checked to see if it remains relatively constant (does not increase). Model K is also compared to the derived K and the observed K shown in Figure 4.12.

(The model K—shown in Figure 4.5— was determined using a different transverse velocity profile than what is currently being used in the model.)

Checking the validity of the model in the past has also included comparing the results of the particle tracking model to results of the mass tracking model on a Delta-wide scale. Presently DSM2-PTM has been tested for bugs but has not been validated.

Movement at Junctions

When a particle reaches a junction, the decision has to be made as to where the particle is to go. Flows out of nodes include flows into channels, open water areas, agricultural diversions, and exports. Within the model, these locations are referred to as water bodies. The probability of a particle entering another water body is proportional to amount of flow entering that water body.

chance of particle entering water body = flow leaving node into water body/total flow leaving node

Movement In and Out of Open Water Areas

Once a particle enters an open water area, it no longer retains its x, y or z position. The open water area is considered fully mixed. At the beginning of a time step the volume of the open water area the volume of water leaving at each opening of the open water area is determined. From that the probability of the particle leaving the open water area is calculated.

chance of particle leaving open water = flow leaving open water area at node *time volume of open water area

Exports and Agricultural Diversions

Particles entering exports or agricultural diversions are considered "lost" from the system. Their final destination is recorded.

Movement at Ocean Boundary

Once particles pass the Martinez boundary, they have no opportunity to return to the Delta.

References

Bogle, Gilbert V. 1995. *Simulation of Dispersion in Streams by Particle Tracking*, submitted for review to J. Hydraul, ASCE

Bogle, Gilbert V. 1997. *Stream Velocity Profiles and Longitudinal Dispersion*, ASCE Jnl. of Hyd. Eng. Vol. 123 No. 9

California Dept. of Water Resources. 1994. *Methodology For Flow and Salinity Estimates in the Sacramento - San Joaquin Delta and Suisun Marsh, Fifteenth Annual Progress Report to the State Water Resources Control Board.*

California Dept. of Water Resources. 1995. *Methodology For Flowand Salinity Estimates in the Sacramento - San Joaquin Delta and Suisun Marsh, Sixteenth Annual Progress Report to the State Water Resources Control Board.*

Fischer, H. B., List, E. J., Koh, R.C. Y., Imberger, J., and Brooks, N. H. 1979. *Mixing in Inland and Coastal Waters*, Academic Press., San Diego, California.

Figure 4.1 Defining Each Particle's Location

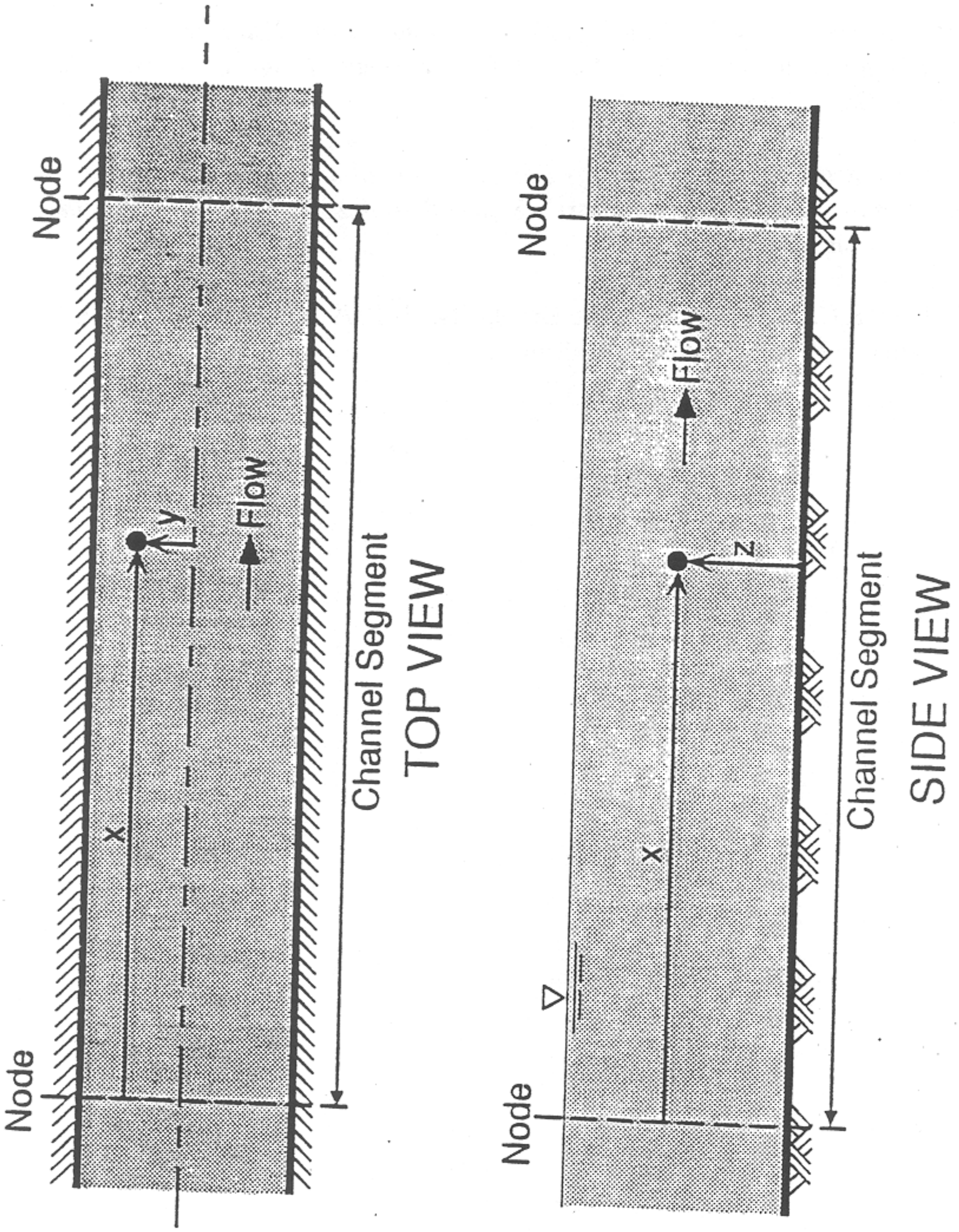


Figure 4.2 Dispersion

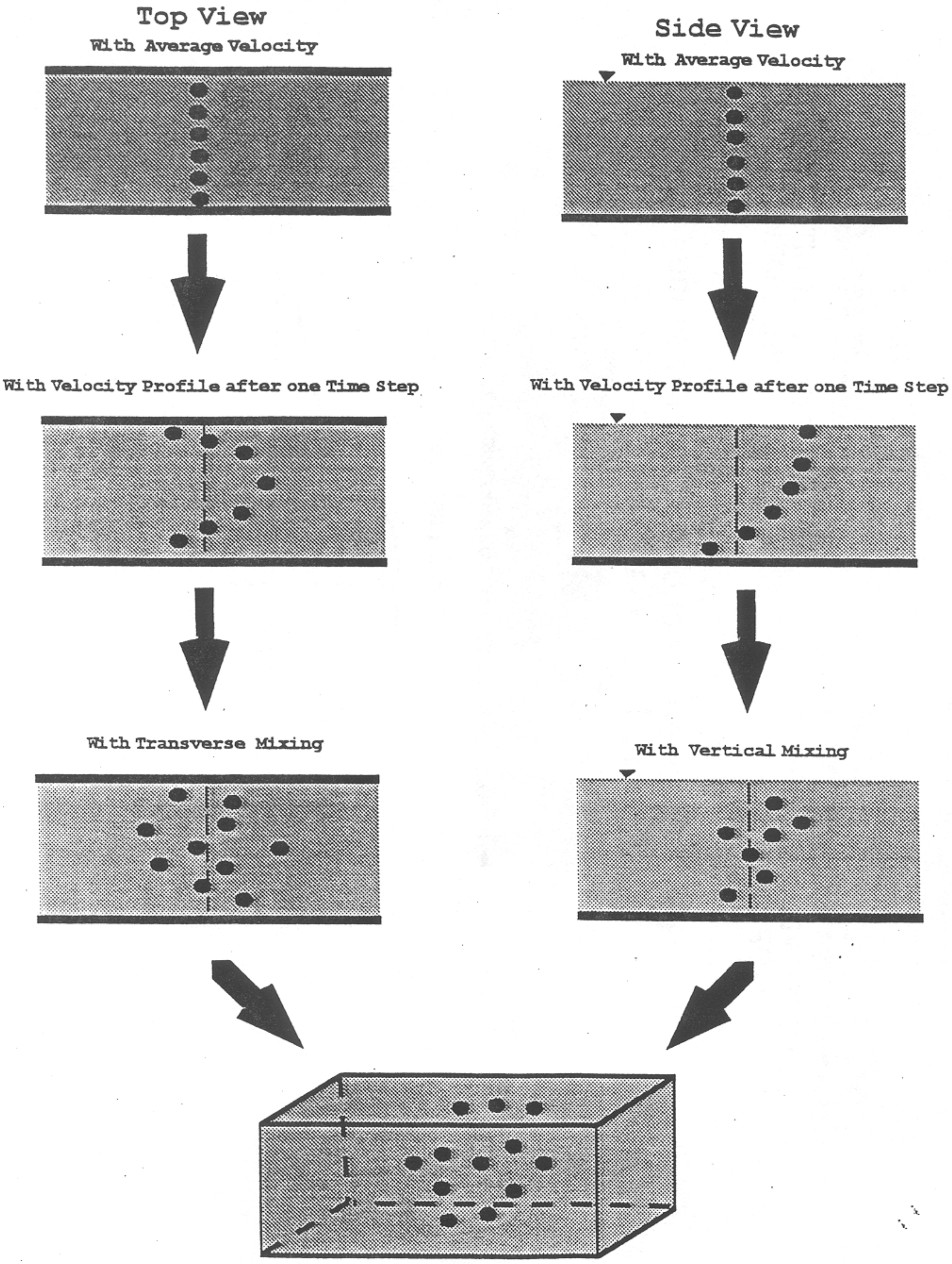


Figure 4.3 Longitudinal Dispersion

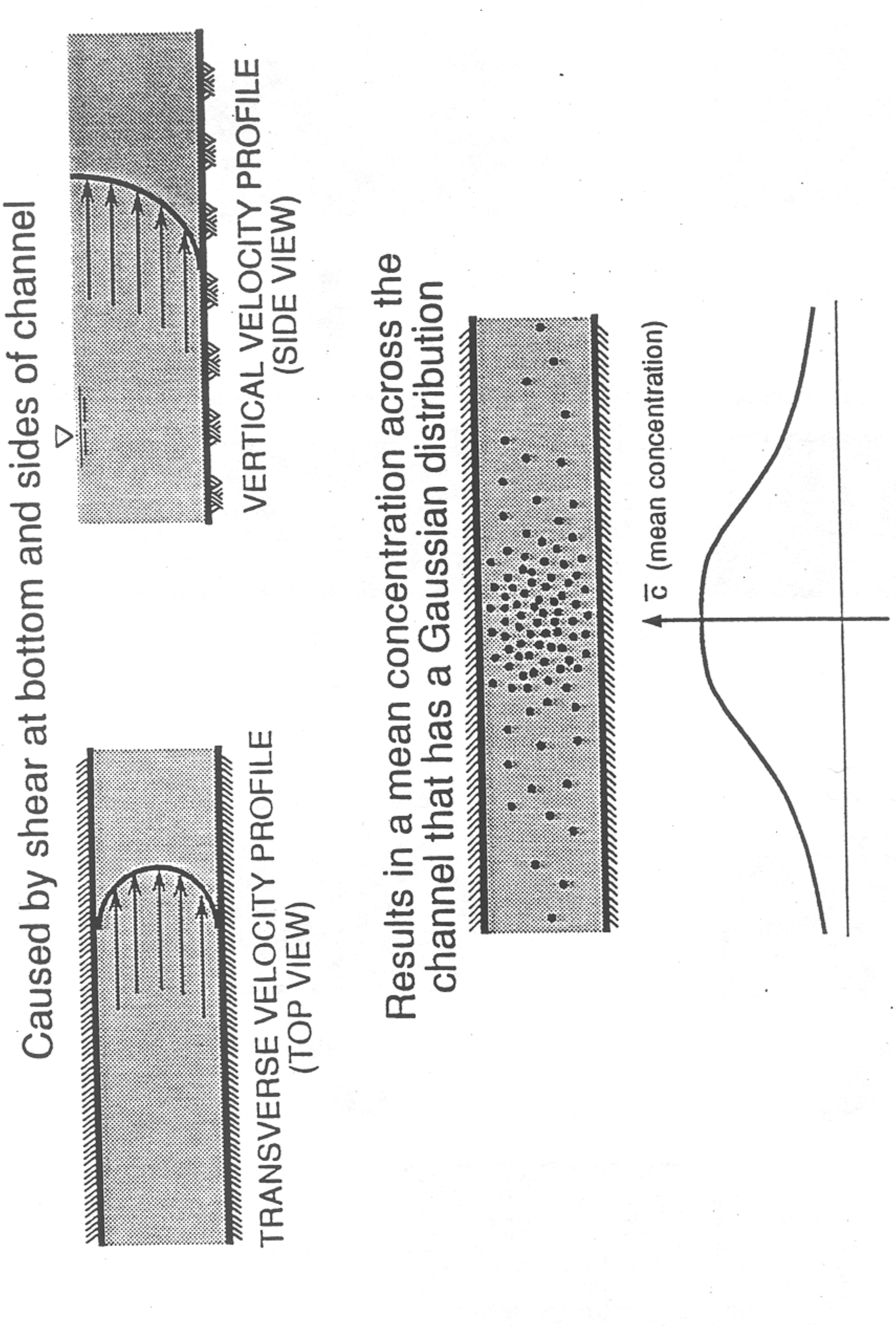
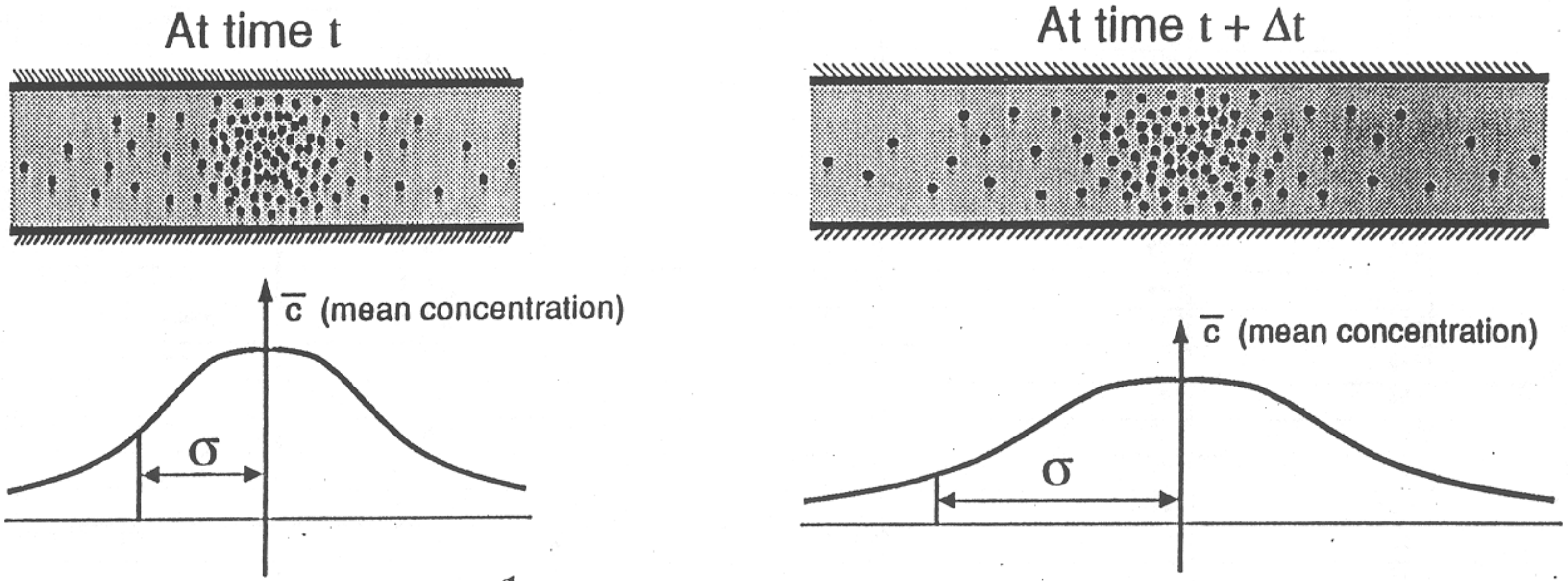


Figure 4.4 Longitudinal Dispersion (coefficient K)

The dispersion coefficient K is defined as:

$$K = \frac{1}{2}\frac{d\sigma^2}{dt}$$

where σ^2 is the variance in position with respect to the center of mass


At time t

At time t + Δt

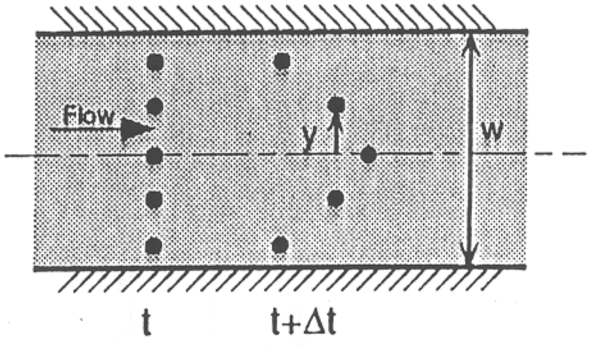
$$K = \frac{1}{2}\left[\,\sigma^2\,(t+\Delta t) - \sigma^2(t)\,\right]$$

Figure 4.5 Experimental Measurements of Longitudinal Dispersion in Open Channels

Experimental Measurements of Longitudinal Dispersion in Open Channels (p.126-127 in Fischer)

	Channel	Depth (ft) (1)	Width (ft) (2)	Mean vel (ft/s) (3)	Observed K (ft^2/s) (4)	K=.11u(w^2)/d (5)	Model K (6)
1	Chicago Ship Canal	26.48	160.11	0.89	32	94	107
2	Missouri River	8.86	656.20	5.09	16153	27191	22837
3	Copper Creek	1.61	52.50	0.89	215	167	160
4		2.79	59.06	1.97	226	271	323
5		1.61	52.50	0.85	102	161	149
6	Clinch River	2.79	154.21	1.05	151	985	844
7		6.89	196.86	3.08	582	1908	1797
8		6.89	173.89	2.72	506	1315	1252
9	Copper Creek	1.31	62.34	0.52	107	171	148
10	Powell River	2.79	111.55	0.49	102	242	207
11	Clinch River	1.90	118.12	0.69	87	556	464
12	Coachella Canal	5.12	78.74	2.33	103	310	374
13	Bayou Anacoco	3.08	85.31	1.12	355	290	278
14		2.99	121.40	1.31	420	713	636
15	Nooksack River	2.49	209.98	2.20	377	4276	3684
16	Wind Bighorn River	3.61	193.58	3.24	452	3702	3366
17		7.09	226.39	5.09	1723	4046	3749
18	John Day River	1.90	82.03	3.31	151	1289	1261
19		8.10	111.55	2.69	700	454	548
20	Comite River	1.41	52.50	1.21	151	261	241
21	Sabine River	6.69	341.22	1.90	3392	3641	3090
22		15.58	416.69	2.10	7215	2573	2301
23	Yadkin River	7.71	229.67	1.41	1185	1062	962
24		12.60	236.23	2.49	2800	1215	1181

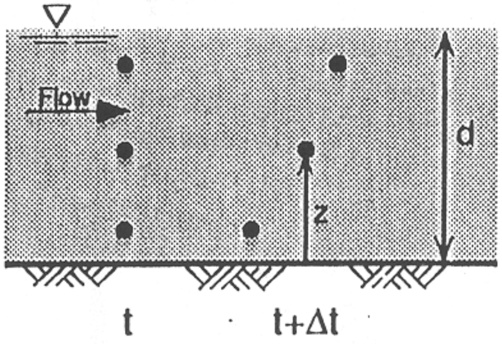
Figure 4.6 Longitudinal Movement


TRANSVERSE VELOCITY PROFILE (TOP VIEW)

$$F_T(y) = A_q + B_q\left(\frac{2y}{w}\right)^2 + C_q\left(\frac{2y}{w}\right)^4$$

$$A_q + B_q + C_q = 0, \quad A_q + \frac{B_q}{3} + \frac{C_q}{5} = 1$$

A_q, B_q and C_q are constants


VERTICAL VELOCITY PROFILE (SIDE VIEW)

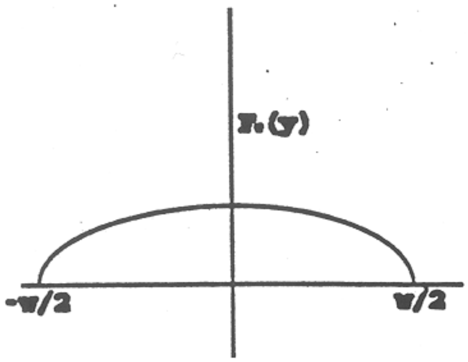
$$F_V(z) = 1 + \left(\frac{0.1}{\kappa}\right)\left[1 + \log_e\left(\frac{z}{d}\right)\right]$$

$\kappa = 0.4$

X Distance Traveled

$$\Delta X\ (\text{particle}) = \bar{u}_X\, F_T(y)\, F_V(z)\, \Delta t$$

Figure 4.7 DSM2-PTM Transverse Velocity Profile



$$\boxed{F_T(y) = A_q + B_q\left(2\frac{y}{w}\right)^2 + C_q\left(2\frac{y}{w}\right)^4} \tag{1}$$

Assume that velocity is zero at sides of channel.

$$F_T\left(\frac{w}{2}\right) = 0 \tag{2}$$

$$F_T\left(-\frac{w}{2}\right) = 0 \tag{3}$$

Substituting eq (2) (or eq (3)) into eq (1)

$$F_T\left(\frac{w}{2}\right) = A_q + B_q\left(\frac{2(w/2)}{w}\right)^2 + C_q\left(\frac{2(w/2)}{w}\right)^4 = 0 \tag{4}$$

$$\boxed{A_q + B_q + C_q = 0} \tag{5}$$

Set the average value of F_T to 1.

Figure 4.7 (continued)

$$\overline{F}=\frac{\int_{-w/2}^{w/2} F_T(y)}{w}=1 \tag{6}$$

Taking the Integral of F_T.

$$\int_{-w/2}^{w/2} A_q+B_q(2\frac{y}{w})^2+C_q(2\frac{y}{w})^4=A_q y+\frac{4B_q}{w^2}\frac{y^3}{3}+\frac{16C_q}{w^4}\frac{y^5}{5}\Big|_{-w/2}^{w/2} \tag{7}$$

$$\int_{-w/2}^{w/2} A_q+B_q(2\frac{y}{w})^2+C_q(2\frac{y}{w})^4=2(A_q\frac{w}{2}+\frac{4B_q}{w^2}\frac{(w/2)^3}{3}+\frac{16C_q}{w^4}\frac{(w/2)^5}{5})=A_q w+\frac{B_q w}{3}+\frac{C_q w}{5} \tag{8}$$

Substituting eq (8) in eq (6).

$$\overline{F}=\frac{A_q w+\frac{B_q w}{3}+\frac{C_q w}{5}}{w}=1 \tag{9}$$

$$\boxed{A_q+\frac{B_q}{3}+\frac{C_q}{5}=1} \tag{10}$$

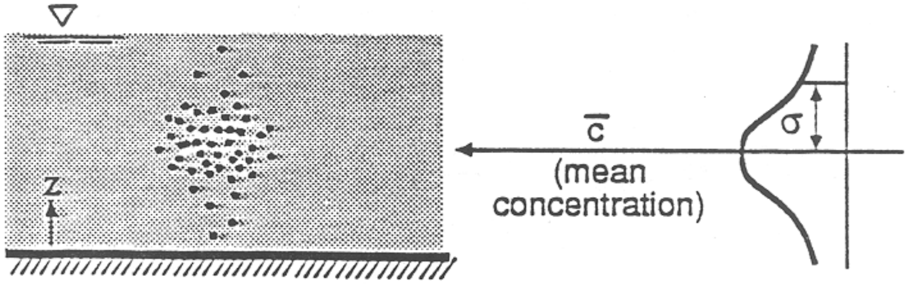
To determine the profile, use one of the coefficients as a free parameter and solve for the other two using eq (5) and eq (10). It is convenient to use Aq as the free parameter because it is equal to the centerline value.

Figure 4.8 Vertical and Transverse Displacements Due to Mixing

$$\overline{E_V} = \frac{1}{2}\frac{d\sigma_Z^2}{dt}, \quad \overline{E_T} = \frac{1}{2}\frac{d\sigma_Y^2}{dt}$$

E = mixing coefficient (vertical or transverse)

σ^2 = variance in position with respect to the center of mass



After time Δt the position is given by:

$Y(t+\Delta t) = Y(t)+v\Delta t$ (transverse position)

$Z(t+\Delta t) = Z(t)+w\Delta t$ (vertical position)

1

v and w are transverse and vertical velocities

Y and Z are transverse and vertical positions

Since the position and velocity are statistically independent, the variance of particle position after Δt is:

$\sigma_Y^2(t+\Delta t) = \sigma_Y^2(t) + (\sigma_v \Delta t)^2$ (transverse)

$\sigma_Z^2(t+\Delta t) = \sigma_Z^2(t) + (\sigma_w \Delta t)^2$

σ_v, σ_w = standard deviation of particles' velocity

Figure 4.8 (continued)

So the change in position variance over the timestep is:

$$\Delta\sigma_Y^2 = (\sigma_V \Delta t)^2$$

$$\Delta\sigma_Z^2 = (\sigma_W \Delta t)^2$$

which results in:

$$\overline{E_T} = \frac{1}{2}\,\frac{\Delta\sigma_y^2}{\Delta t} = \frac{1}{2}\,\frac{(\sigma_V \Delta t)^2}{\Delta t}$$

$$\overline{E_V} = \frac{1}{2}\,\frac{\Delta\sigma_z^2}{\Delta t} = \frac{1}{2}\,\frac{(\sigma_W \Delta t)^2}{\Delta t}$$

rearranging the equations give:

$$\sigma_V^2 = \frac{2\overline{E_T}}{\Delta t}, \qquad \sigma_W^2 = \frac{2\overline{E_V}}{\Delta t}$$

and then:

$$\sigma_V \Delta t = \sqrt{2\overline{E_T}\Delta t}$$

$$\sigma_W \Delta t = \sqrt{2\overline{E_V}\Delta t}$$

7.19

To calculate the distance traveled, a random component is introduced:

$$\text{ydist} = R\sigma_V \Delta t = R\sqrt{2\overline{E_T}\Delta t}$$

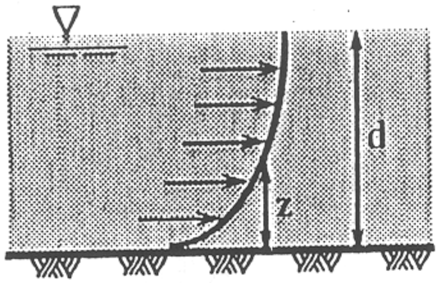
$$\text{zdist} = R\sigma_W \Delta t = R\sqrt{2\overline{E_V}\Delta t}$$

ydist, zdist = gaussian random distance traveled
R = gaussian random variable with mean 0 and variance 1 (normal distribution)

Figure 4.9 Vertical Mixing

Elder (1959) derivation for flow down an infinitely wide inclined plane

- Von Karman Logrithmic Velocity Profile



$$u' = \left(\frac{u^*}{\kappa}\right)\left(1 + \log_e \frac{z}{d}\right)$$

$u' = u - \bar{u}$
u = velocity at z location in channel
$\bar{u}$ = average velocity
κ = Von Karman constant = 0.4
$u^* = \sqrt{\frac{\tau_0}{\rho}}$ = shear velocity
τ_0 is shear stress on the bottom

- A Force Balance at any Distance from the bottom of the channel gives:

$$\tau = \rho E_V \frac{du}{dz} = \tau_0 \left(1 - \frac{z}{d}\right)$$

E_V = vertical mixing coefficient

From which

$$E_V = \kappa \frac{z}{d}\left(1 - \frac{z}{d}\right) du^*$$

Averaging over the depth and taking $\kappa = 0.4$ leads to

$$\overline{E_V} = 0.067\, du^*$$

Figure 4.10 Transverse Mixing

Transverse Mixing Coefficient is determined experimentally

$$E_T = C_T\, du^*$$

E_T = Transverse mixing coefficient
d = water depth
u* = shear velocity

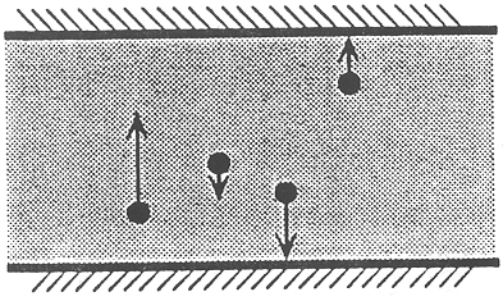
C_T = constant

for straight uniform channels
C_T is between 0.1 - 0.2

for slowly meandering streams
C_T is between 0.4 - 0.8

Figure 4.11 Mixing

TRANSVERSE MIXING
(TOP VIEW)

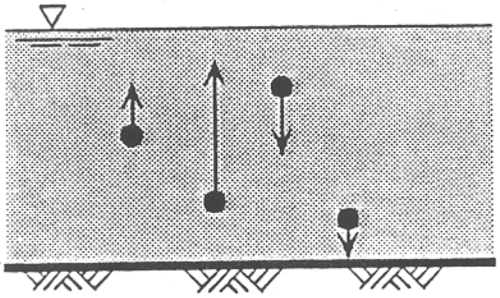


$E_T = 0.06\, d\bar{u}$

Δy_{ran} (particle) $= R\sqrt{2E_T\Delta t}$

R is a guassian random number with mean 0 and variance 1

VERTICAL MIXING
(SIDE VIEW)



$E_V = 0.0067\, d\bar{u}^*$

Δz_{ran} (particle) $= R\sqrt{2E_V\Delta t}$

$u^* =$ shear vel $= 0.1\bar{u}$

Figure 4.12 Derived Dispersion Coefficient K

The following is a result of a derivation analogous to the molecular diffusion derivation

$$K = \frac{h^2 \overline{u'^2} I}{\overline{E_T}}$$

K = dispersion coefficient
$u' = u - \bar{u}$
u = velocity
$\bar{u}$ = mean velocity
$\overline{u'^2}$ = expected square of the deviation of the depth-averaged velocity from the mean velocity $\approx 0.2\bar{u}^2$
h = characteristic length ≈ 0.7 W
W = channel width
$\overline{E_T}$ = transverse mixing coefficient $\approx 0.6\ du^*$
I = a dimensionless integral of the velocity profile, approximately constant for real streams ≈ 0.07 (Bogle, 1995 suggests $I \approx 0.01$)

$$K = \frac{0.011\,\bar{u}^2 W^2}{du^*}$$

for $\overline{u'^2} = 0.2\,\bar{u}^2$
$h = 0.7$ W
$I = 0.07$
$E_T = 0.6\ du^*$

$$u^* = \sqrt{\frac{\tau_0}{\rho}}$$

τ_0 = mean wall shear stress = $\dfrac{f\rho\bar{u}^2}{8}$
ρ = water density
f = Darcy-Weisbach friction factor

$u^* \approx 0.1\,\bar{u}$ for streams

$$K = \frac{0.11\,\bar{u}\,W^2}{d}$$

5

DSM2 Input and Output

Fixed Input

Fixed input is that data and information which does not vary with model time: such things as run start and stop dates, channel geometry, reservoir and gate information, runtime parameters, output locations, and so on. Fixed input is divided into sections. Sections can be in a single file, and sections may be duplicated, with new information overwriting previous information. This allows one to create a base set of files, overwriting only that information which changes for a particular run.

Each section starts with a section keyword. For most sections, the second line will be the field keywords, which tell the input system what data appears in which fields. Then the data itself follows, and finally an END keyword, which closes the section. Keywords and variable names be upper or lower case. For most sections, one field keyword is required (e.g. channel number), with the rest optional. This means if one is using a base file with a subsequent file to overlay some data changed from the base case, only the changed fields need to be listed.

Blank lines and comments may appear anywhere in any fixed input file; comments start with the pound (#) character and continue to the end of the line. Environment variables are denoted with a dollar sign ($), and may optionally be surrounded with parentheses or curly braces, for example: $STUDY $(STUDY) ${STUDY}. Environment variables are replaced with their value, then processed in the input system for on-the-fly input file customization.

Individual Files

Sections are described below with examples given. Full input files are also referenced. Required sections are marked with an asterisk (*); required field keywords are marked with an asterisk (*).

Sections Common to All Modes

Delta Configuration

- Channels *
- Channel Numbering *
- Reservoirs

I/O

* Include Input Files
* Input/Output Filenames
* Time-Varying Input *
* Time-Varying Output
* Translations
* Change Sign, Specify Type of Time-Varying Data

Miscellaneous

* Scalars*
* Titles

Sections for Hydro

Delta Configuration

* Rectangular Cross Sections *
* Irregular Cross Sections *
* Junctions *
* Gates
* Internal Flow Transfers

Sections for Qual

I/O

* Hydro Binary Tide Files for Qual and PTM

Miscellaneous

* Non-Conservative Rate Coefficients

Sections for PTM

I/O

* Flux
* Particle Insertion
* Hydro Binary Tide Files for Qual and PTM

Fixed Input Description

The following describes the use of various section keywords related to Fixed Input and includes examples of their use.

Channels

Section keyword: CHANNELS

Field keywords: CHAN* LENGTH MANNING DISP DOWNNODE UPNODE XSECT

Required: yes Overwrites: yes; By: CHAN

```
  8
  9
 10
 11
 12
 13
 14
 15
169
170
171
 16
 17
# etc.
END
```

Reservoirs

Section keyword: RESERVOIRS

Field keywords: NAME* AREA STAGE BOTELV NODE COEFF2RES COEFF2CHANMAXQ2RES

Required: no Overwrites: yes; By: NAME

Description: Describes the reservoirs to be used in the run.

NAME - name of reservoir
AREA - surface area, million square feet
STAGE - initial stage in feet, same datum as BOTELV in XSECTS section
BOTELV - bottom elevation in feet, same datum as BOTELV in XSECTS section

(Note: The following three keywords may be repeated for as many nodes the reservoir is connected to.)

NODE - node number the reservoir is connected to
COEFF2RES - flow coefficient from channel to reservoir
COEFF2CHAN - flow coefficient to channel from reservoir
MAXQ2RES - maximum allowed flow to reservoir

Example:

```
NAME    AREA      STAGE BOTELV  NODE  COEFF2RES COEFF2CHAN NODE COEFF2RES COEFF2CHAN
CLFCT    91.86800 5.02   -10.1   72    1200.              0.
 2       42.29960 5.02   -14.1   127   2000.     2000.                    129   2000.     2000.
FRANKS  141.17864 5.02   -10.1   219   2000.     2000.                    225   2000.     2000.
END
```

```
  8
  9
 10
 11
 12
 13
 14
 15
169
170
171
 16
 17
# etc.
END

# Clifton Court inflow restriction
RESERVOIRS
NAME    NODE    MAXQ2RES
CLFCT   72      15000.
END
```

Include Input Files

Section keyword: INP_FILES

Field keywords: none

Required: no

Description: Each line in the Include Input Files section is a filename (either full pathname or relative to the run directory) which directs the input system to read in that file and process it as part of the fixed input system. This allows different sections to be in different files for convenience and clarity. Also, for many sections, the same section can be read in multiple times, subsequent values overwriting previous values.

Example:

```
INP_FILES
# files that would tend to change for each run
runtime.inp                          # runtime control
scalar.inp                           # other scalar
data, constants

# files that would not be changed often
../dsm2-input-files/junctions.inp          # junction spec
../dsm2-input-files/reservoirs.inp         # reservoir info
END
```

Input/Output Filenames

Section keyword: IO_FILES

Field keywords: MODEL* TYPE* IO* INTERVAL FILENAME*

Required: no Overwrites: yes; By: MODEL+TYPE+IO

Description: This section specifies the filenames of input/output files, and if filenames are given for restart and binary input or output turns on processing for those files (general echo output is always on).

MODEL - input/output for which model
TYPE - NONE, RESTART (ASCII restart file) or BINARY (binary state file)
IO - whether IN (input, to be read) or OUT (output, to be written)
INTERVAL - NONE, or time interval to write (15 min, 1 hour, etc.)
FILENAME - filename to read or write

Example:

```
IO_FILES
MODEL      TYPE    IO     INTERVAL FILENAME
# general echo output
output     none    none   none     models/io/hydro.out
# restart output, 1 hour interval
hydro      restart out    1hour    models/io/hydro-rst.out
# restart input
hydro      restart in     none     models/io/hydro-rst.inp
# tidefile output, 15 minute interval
hydro      binary  out    15min    models/io/hydro-unf.out
END
```

Time-Varying Input

Section keyword: INPUTPATHS

Field keywords: NODE* NAME* MEAS_TYPE* INTERVAL*
A_PART B_PART C_PART* E_PART* F_PART
SDATE STIME ID
PRIORITY FILLIN FILENAME VALUE

Required: yes Overwrites: no

Description: Provides information to locate time-varying data (flows, stages, gate operations, water quality, etc.) in DSS during the run. All time-varying input for Hydro and Qual must come from DSS files. Time-varying input is given by node number, or a name which translates to a node number.

NODE - node number
NAME - location name, must translate to node number. Used for DSS B part.
MEAS_TYPE - type of data: flow, stage, gate, ec, tds, etc. Used for DSS C part.
INTERVAL - time interval: 15MIN, 1HOUR, 1DAY, 1MON, IR-DECADE. Used for DSS E part.
A_PART, B_PART, C_PART, E_PART, F_PART - DSS A, B, C, E, and F parts. Use instead of MEAS_TYPE, INTERVAL, and ID.
SDATE - optional start date, if different from model run start date
STIME - optional start time, if different from model run start time

(Note: If used, the data will start at the given date, regardless of the model start time. Use "GENERIC" to indicate the data starts at the standard generic time (01JAN3001 0000). Use "SYNC" to indicate that the data time should be synchronized to the model time based on the interval or e part. For instance, for a data interval of 1MON, the system will attempt to always use January data for a January model time, etc. Synchronized data must have a generic start date, and must not contain missing data.)

ID - identification, study name, etc. Used for DSS F part.
PRIORITY - optional priority of this path (integer between 0 and N). If a higher priority (lower number) path's data is missing or bad, then the next lower priority path at the same location will be used to replace it. Paths are assumed to be at the same location if they are at the same object (node, channel, or reservoir). This allows for filled-in data to automatically be used from a separate pathname, without having to create a single path for a location. A priority of 0 means ignore the priority system, always use the path.
FILLIN - use LAST data value, or INTERPolate between values, or use either last or interpolation based on whether the DATA is averaged or instantaneous.
FILENAME - DSS filename to find data
VALUE - numeric value to use as constant input value for entire run

Example:

```
INPUTPATHS
# input paths that have alternate start dates, and placename
NAME   MEAS_TYPE INTERVAL  SDATE      ID      FILLIN
FILENAME
SAC    flow    ir-decade 31may1994   test1     INTERP
/input-files/input.dss
SJR    flow    1hour     generic     test1     DATA
/input-files/input.dss
END

INPUTPATHS
# input path at a node, has first priority
NODE MEAS_TYPE  INTERVAL   ID   FILLIN  PRIORITY FILENAME
  3  EC        1day      Study1  LAST     1    input.dss
END
INPUTPATHS
# input path at a node, with constant value; use if main path's
# data is missing
```

```
NODE  MEAS_TYPE  INTERVAL   ID     FILLIN  PRIORITY   VALUE
  3  EC       1mon     Study1     LAST    2      200.0
END
```

Time-Varying Output

Section keyword: OUTPUTPATHS

Field keywords: CHAN* DIST* NODE* TYPE* INTERVAL* PERIOD*
MODIFIER
A_PART B_PART C_PART E_PART F_PART
FILENAME* FROM_NAME FROM_TYPE FROM_NODE

Required: no Overwrites: no

Description: Time-varying text and DSS output is specified in this section.

(Note: Provide either CHAN and DIST, or NODE, or NAME; either TYPE, or C_PART; either INTERVAL, or E_PART.)

CHAN - channel number
DIST - distance downstream along channel; LENGTH means to use channel length
NODE - node number

(Note: cannot use node number for Hydro output (stage, velocity, or flow); only Qual output. Qual output at a node will always be the mixed concentration at the node.)

NAME - location name, translation provided to translate to channel or node number. Used for DSS B part.
TYPE - type of data (stage, flow, etc.) Used for DSS C part.
INTERVAL - time interval (15MIN, 1HOUR, 1DAY, etc.) Used for DSS E part.
PERIOD - INST (instantaneous) or AVE (average over interval)
MODIFIER - study name, etc. If this is the string 'runtime', a model run date-time string will be used; this allows different runs to automatically be labeled differently.If 'none', no string will be used. If this field is not used, and the environment variable DSM2MODIFIER is set, that will be used instead.
A_PART, B_PART, C_PART, E_PART, F_PART - DSS A, B, C, E, and F parts. Use instead of TYPE, INTERVAL, and MODIFIER.
FILENAME - file to write to, if it ends in .DSS, use a DSS file,otherwise the output file will be a text file.

The following three fields are used only by Qual, to track conservative constituent input sources from location names, accounting types, and node numbers.

FROM_NAME - track conservative constituents from a location name.
FROM_TYPE - track conservative constituents from an accounting type.
FROM_NODE - track conservative constituents from a node number.

Example:

```
OUTPUTPATHS
CHAN       DIST       TYPE       INTERVAL     PERIOD   MODIFIER       FILENAME
1          0          stage      15min         inst    mrg_0718-rst    out.dss
82         0          stage      15min         inst    mrg_0718-rst    out.dss
83         LENGTH     stage      15min         inst    mrg_0718-rst    out.txt
END

# for Qual only
OUTPUTPATHS
NAME   FROM_NAME     TYPE   INTERVAL PERIOD FILENAME
union  mtz           ec     1day    ave   qual.txt
union  vernalis        ec     1day    ave   qual.txt
END

OUTPUTPATHS
NAME   FROM_TYPE TYPE  INTERVAL PERIOD FILENAME
union  rim      ec  1day    ave   qual.txt
ec5468 drain     ec  1day    ave   qual.txt
union  drain     ec  1day    ave   qual.txt
END
```

Translations

Section keyword: TRANSLATION

Field keywords: NAME* CHAN* DIST* NODE* RESERVOIR*

Required: no Overwrites: yes; By: NAME

Description: This section translates between place names and node or channel-distance. It allows the use of place names in input and output sections.

(Note: provide either CHAN and DIST, or NODE, or RESERVOIR.)

NAME - place name (location)
CHAN - DSM2 channel number
DIST - distance downstream along channel; LENGTH means to use channel length
NODE - node number
RESERVOIR - reservoir name

Example:

```
TRANSLATION
NAME   CHAN   DIST
cvp    216    0
dxc    365    0
mtz    441    LENGTH
sac    410    0
END

TRANSLATION
# translations to reservoir name
NAME   RESERVOIR
swp    clfct
bbid   clfct
END
```

Types

Section keyword: TYPE

Field keywords: STRING PART MATCH SIGN ACCOUNT VALUE_IN VALUE_OUT

Required: no Overwrites: no

Description: This section assigns accounting types to matching pathnames, for later use in Qual and PTM; changes the sign of specified time-series input values; and can change the incoming value itself. DSM2-Hydro requires that sinks (flows out of nodes and reservoirs) be negative and that sources be positive. Often sinks will be stored in a DSS file as a positive number (e.g. pumping values); the SIGN field will change the sign internally in DSM2 without changing the database. The ACCOUNT field can be used to assign a type to matching pathnames which can later be used by Qual and PTM for accounting purposes in the output. The VALUE_IN and VALUE_OUT fields are used to change incoming values, usually for gate codes or perhaps bogus values in the DSS input file.

STRING - String in pathname or label name to match.
PART - Part of pathname or label to match:
    a=A part; b=name or B part; c=measurement type or C part;
    e=interval or E part; f=modifier or F part; l=name label;
    p=entire pathname.
MATCH - An exact match, or a substring.
SIGN - Make the matching pathnames a negative or positive value
    (it does not invert the value).
ACCOUNT - Assign an accounting code to the match.
VALUE_IN - Incoming value to check.

VALUE_OUT - If string and incoming value match, assign VALUE_OUT to the value used. Codes are allowed (GATE_OPEN, GATE_CLOSE, and GATE_FREE), as well as any numeric value.

Example:

```
TYPE
STRING      PART   MATCH   SIGN
CCC         l      exact   -     # Contra Costa Canal
SWP         B      exact   -     # Banks pumping
DICU-IRR    F      sub     -     # Irrigation pumping
END

TYPE
STRING      PART   MATCH   ACCOUNT
CCC         B      exact   DIV
SWP         B      exact   EXPORT
SAC         B      exact   RIM
DICU-SEEP   F      sub     SEEP
DICU-IRR    F      sub     DIV
DICU-DRN    F      sub     DRAIN
END

TYPE
STRING  PART   MATCH   VALUE_IN VALUE_OUT
dxc     b      exact   1.0      gate_open
END
```

Scalars

Section keyword: SCALAR

Field keywords: none

Required: yes   Overwrites: yes;   By: scalar name

Description: This section is used to input the values of single variables (scalars) to DSM2. Each line in the scalars section consists of two fields: the variable name, and the value (in that order).

(Note: The flush_output interval should be kept at one day or greater; less than one day will result in long times to write to DSS at the end of a run.)

Example:

```
SCALAR
run_start_date          01jun1994
run_start_time          0000
#run_start_date         restart             # use restart file time to start the run
#run_start_date tidefile                    # use tidefile time to start run
#run_end_date  31aug1994                    # if used, comment out run_length
#run_end_time  1500
run_length     91DAY_15HOUR                 # if used, comment out run end
                                              date/time

flush_output   5day                         # interval to flush output;
                                            # better if >= 1day
display_intvl  1hour                        # how often to display model time progress
checkdata      false                        # check input data w/o simulation

cont_missing   true                         # continue on missing data (uses
                                            # previous value)
cont_unchecked  true                        # continue on unchecked data
cont_question   true                        # continue on questionable data
                                            # (use data value)
cont_bad       true                         # continue on bad data

warn_unchecked  false                       # warn about unchecked data
warn_question   false                       # warn about questionable data
warn_missing    t                           # warn about missing data

printlevel     1                            # amount of printing, 0 to 9,
                                            # increasing with number.
temp_dir       d:\temp                      # directory to use for scratch
                                            # files

# following all Hydro variables
hydro_time_step 5min                        # time step length
deltax         5000                         # spatial discretization, feet

repeating_tide  f                           # t = repeating tide run
max_tides      15                           # maximum number of tide cycles
                                            # to repeat
tide_length    25hour                       # tide length
toler_stage    0.0010                       # tolerance for error in sum of
                                            # repeated stages
toler_flow     0.0020                       # tolerance for error in indiv of
                                            # repeated flows
```

```
terms          dyn                  # Terms: dynamic, diffusion,
                                    # or kinematic
vardensity     f                    # f = constant density,
                                    # t = variable density.
varsinuosity   f                    # f = constant sinuosity,
                                    # t = variable sinuosity.

gravity        32.02                # acceleration due to gravity.
theta          0.6                  # time-weighting factor.
maxiter        9                    # maximum number of iterations
                                    # per time step.
luinc          2                    # interval for complete forward
                                    # eliminations.
toleranceq     0.5                  # tolerance for closure on
                                    # discharge.
tolerancez     0.005                # tolerance for closure on
                                    # water-surface elevation.

# following all Qual variables

Qual_time_step 15min                # Qual time step
Dispersion     t                    # true Activate dispersion
Init_Conc      100.0                # initial concentration value
tide_length    25hour               # tide length
END
```

Titles

Section keyword: TITLES

Field keywords: none

Required: no   Overwrites: no

Description: Each line in the Title section is used as a title or header for later printouts. Typically the user would enter a description of the run in this section.

Example:

```
TITLES
  Test run with full Sacramento-San Joaquin Delta network.
END
```

Rectangular Cross Sections

Section keyword: XSECTS

Field keywords: XSECT* WIDTH BOTELV INIT-STAGE INIT-FLOW

Required: yes Overwrites: yes; By: XSECT

Description: The cross sections given in the CHANNELS section are listed here. Only rectangular cross sections are specified in this section; irregular cross-sections are given in Irregular Cross-Sections. Initial stages and flows at the cross section are given; these can be overwritten with a restart file.

XSECT - cross section number
WIDTH - width in feet of rectangular section
BOTELV - bottom elevation of rectangular section, usually w.r.t. NGVD
INIT-STAGE - the initial stage in feet; same datum as BOTELV
INIT-FLOW - the initial flow, cubic feet per second

Example:

```
XSECTS
XSECT   WIDTH   BOTELV  INIT-STAGE    INIT-FLOW
  1    192.0   -5.10     5.25         0.01
  2    192.0   -5.10     5.25         0.01
END
```

Irregular Cross Sections

Section keyword: IRREG_GEOM

Field keywords: CHAN* DIST* FILENAME*

Required: yes Overwrites: yes; By: CHAN DIST

Description: The irregular cross sections, if any, are listed here. Only irregular cross sections are specified in this section; rectangular cross-sections are given in Rectangular Cross-Sections.

CHAN - DSM2 channel number.
DIST - distance downstream from upstream end, normalized between zero and one. The actual distance will be calculated internally, multiplying the normalized distance here with the channel length in the CHANNELS section.
FILENAME - the file containing cross-sectional area, wetted perimeter, top width, etc. in table form (example format). This file is produced by the Cross Section Display Program (CSDP).

Example:

```
IRREG_GEOM
CHAN    DIST     FILENAME
  6    0.62093  irregular_xsects/6_0.62093.txt
  7    0.25863  irregular_xsects/7_0.25863.txt
  7    0.86019  irregular_xsects/7_0.86019.txt
END
```

Junctions

Section keyword: JUNCTIONS

Field keywords: NODE* BOUNDARY*

Required: yes   Overwrites: Yes;   By: NODE

Description: Any junction that has a stage boundary (the stage is specified at the junction) must be listed here. Usually only one junction will have a stage boundary. Flow boundary junctions need not be listed.

Example:

```
JUNCTIONS
NODE   BOUNDARY
361    STAGE
END
```

Gates

Section keyword: GATES

Field keywords: NAME* OPER NODE CHAN LOC NGATES WIDTHUP WIDTHDOWN CRESTELEV NPIPES PIPERAD PIPEELEV CFWEIRUP CFWEIRDOWN CFPIPEUP CFPIPEDOWN WIDTHFREE ELEVFREE

Required: no   Overwrites: yes;   By: NAME

Description: Describes the gates to be used in the run. Weirs and pipes (culverts) can be used in the same gate. Multiple gates not allowed at the same location. A gate can have multiple gates and pipes. The number of gates open at any time can be controlled during the run from DSS values.

NAME - name of gate.
OPER - type of operation:
  TIME - get open/close timing from DSS, see note below.
  CALC - calculate open/close timing from operational criteria (stage difference, etc).
  OPEN - always opened: use the flow coefficients given, all gates open.

    CLOSE - always closed: set the flow coefficients to zero.
    IGNORE - ignore gate; same as commenting out line.
    FREE - gate installed but free-flow (no obstruction); produces similar but not identical results as IGNORE

NODE - node number, if reservoir gate.
CHAN - DSM2 channel number the gate is in.

LOC - UP or DOWN for upstream or downstream end of channel.
NGATES - number of gate openings for weir-type gate.
WIDTHUP - width of gate, upstream direction.
WIDTHDOWN - width of gate, downstream direction.
CRESTELEV - crest elevation in feet, same datum as channels.
NPIPES - number of pipes (culverts).
PIPERAD - pipe radius, feet.
PIPEELEV - pipe invert elevation in feet, same datum as channels.
CFWEIRUP - flow coefficient for weirs, upstream direction.
CFWEIRDOWN - flow coefficient for weirs, downstream direction.
CFPIPEUP - flow coefficient for pipes, upstream direction.
CFPIPEDOWN - flow coefficient for pipes, downstream direction.
WIDTHFREE - width to use for free-flow (gate installed but not an obstruction)
ELEVFREE - crest elevation to use for free-flow (gate installed but not an obstruction)

(Note: The number of gate (weir-type) openings is specified in NGATES and defaults to one. The number of gates open at any time can be read from DSS if the OPER value for a gate is TIME. Thus, for instance, for the Delta Cross Channel, NGATES should be 2, and possible values from DSS should be 0 (all gates closed; no low), 1 (one gate open, one gate closed), or 2 (both gates open). In addition, a value of 10 means to activate the 'free-flow' regime, which leaves the gate installed but with no flow impediment. Tests show this produces a very similar flow to leaving the gate out entirely. Consequently, gates can be installed and uninstalled during a single model run.)

Example:

```
GATES
# gates on reservoirs--the coeffs are given in the reservoir
# section
NAME   OPER  NODE
clfct  time   72
END

# gates that are weirs
GATES
NAME    OPER    CHAN    LOC  WIDTHDOWN WIDTHUP CRESTELEV CFWEIRDOWN
CFWEIRUP
dxc    open    365    up    120.0    120.0    -13.6    0.90    0.90 #DXC
gl_cn  ignore  213    down  359.0    359.0    -10.0    0.20    0.20
END
```

```
# gates that are pipes
GATES
NAME   OPER  CHAN LOC  NPIPES PIPERAD PIPEELEV CFPIPEDOWN CFPIPEUP
old_r  time    80 up    9     2.00     -0.10      0.00      0.60
END

# both weir and pipe
GATES
NAME   OPER  CHAN LOC WIDTHDOWN WIDTHUP CRESTELEV CFWEIRDOWN
CFWEIRUP NPIPES PIPERAD PIPEELEV CFPIPEDOWN CFPIPEUP
mid_r  ignore 134 up  140.00    140.00   -3.00       0.8
0.8    6     2.00     -4.00   0.00      0.60
# Above is just one long line of input
END

# multiple gate openings at a gate structure
GATES
NAME    NGATES
dxc     2
END

#  Widths and crest elevations for free flow
GATES
NAME    WIDTHFREE       ELEVFREE
gl_cn   500.0          -20.0
orhrb   150.0          -10.0
END
```

Internal Flow Transfer

Section keyword: OBJ2OBJ

Field keywords: FROM_TYPE* FROM_NAME* TO_TYPE* TO_NAME*
INPUT_LABEL FLOW
COEFF_POS COEFF_NEG ACCOUNT NAME

Required: no Overwrites: no

Description: Allows for internal flow transfer between object (nodes and reservoirs).

(Note: Use either INPUT_LABEL, or FLOW.)

FROM_TYPE - from what type of object (currently "reservoir" or "node").
FROM_NAME - "from" object name or number.
TO_TYPE - to what type of object (currently "reservoir" or "node").
TO_NAME - "to" object name or number.

INPUT_LABEL - the label (name) used for an input path. The value of the input path at each time step will be used for the flow transfer value.
FLOW - a constant value to use for the flow value.
COEFF_POS - for stage-driven flow between two reservoirs: the flow coefficient in the positive (FROM -> TO) direction.
COEFF_NEG - for stage-driven flow between two reservoirs: the flow coefficient in the negative (TO -> FROM) direction.

ACCOUNT - accounting label to give this transfer.
NAME - name to give this transfer.

Example:

```
# CALFED Isolated Facility using object-to-object flows
OBJ2OBJ
FROM_TYPE  FROM_NAME   TO_TYPE  TO_NAME    INPUT_LABEL    NAME
node       IF_in       reservoir  clfct    IF_flow        if
END
```

Tides

Section keyword: TIDEFILE

Field keywords: START_DATE* START_TIME END_DATE* END_TIME FILENAME*

Required: yes (for Qual and PTM) Overwrites: no

Description: This section lets Qual and PTM know what order to use the binary output files from Hydro which contain channel flows and stages, reservoir flows, and external flows. Each time-averaged set of flows, along with its timestamp, is called a 'tide block'; a single tidefile will typically contain several of these tideblocks, along with some preliminary header information. If the tidefile was generated by a repeating tide, then the tideblocks will usually be 15 minutes or 1 hour in length, and the collection of tideblocks in a single tidefile will span exactly one tidal day (the length of a tidal day is specified in the SCALAR section, keyword TIDE_LENGTH.

START_DATE - starting date of tidefile. Use a date spec if desired (e.g. 05JAN1987), or use 'generic' to ignore the tidefile time stamp and simply start with the model run. Use 'runtime' or leave empty to try to find the model start runtime in the tidefile. Use 'last' or 'previous' to start right after the previous tidefile ends (not allowed on first tidefile).
START_TIME - starting time of tidefile. If 'generic' or 'last' was given for START_DATE, this can be 'none', or leave out the field, otherwise use a time spec (e.g. 1700).
END_DATE - ending date of tidefile. Use either a date spec, or a time length (e.g. 3day_5hour), or 'length' to mean use the entire length of the tidefile. If the tidefile is repeating (if it was generated by a repeating tide run in Hydro), and 'length' is given, then the tidefile will be recycled an integer number of times.

END_TIME - ending time of tidefile; use a time spec or 'none', or leave out the field.

Example:

```
TIDEFILE
START_DATE END_DATE    FILENAME
generic   6day       ../output-files/hydro-unf-rpt-1h.out
last      length     ../output-files/hydro-unf-rpt-15m.out
END
```

Non-Conservative Constituents RateCoefficients

Section keyword: RATE_COEFFS

Field keywords: CHANNEL* RESERVOIR* TYPE* CONSTITUENT* VALUE*

Required: no   Overwrites: yes; By: channel number and reservoir name

Description: Reaction coefficients for non-conservative constituents in channels and reservoirs are specified in this section.

(Note: CHANNEL and/or RESERVOIR are required.)

CHANNEL - channel number(s); may use grouping, for instance: 1-5,7,11-20.
RESERVOIR - reservoir name(s); may use comma-separated list
TYPE - type of coefficient. Allowed values are DECAY, SETTLE, BENTHIC, ALG_GROW, ALG_RESP.
CONSTITUENT - non-conservative constituent name. Allowed values are ALGAE, BOD, DO, NH3, NO2, NO3, ORGANIC_N, ORGANIC_P, PO4, TEMP
VALUE - the rate coefficient value

Example:

```
rate_coeffs
channel      reservoir    type       constituent    value
1-55,60,61    CLFCT,2,3     decay        BOD        1.1
1-55,60,61    CLFCT,2,3     settle      BOD       0.24
1-55,60,61    CLFCT,2,3     benthic      DO        200.
1-55,60,61    CLFCT,2,3     decay        ORGANIC_N  0.1
END
```

Flux Output

Section keyword: PARTICLE_FLUX

Field keywords: FROM_WB* TO_WB* INTERVAL* PERIOD* MODIFIER FILENAME*

Required: no Overwrites: no

Description: PTM Flux text and DSS output is specified in this section.

FROM_WB - a list of waterbody types and IDs. The waterbody types are separated by whitespace (space or tab); the IDs follow each waterbody type separated by commas. This tells the PTM to track particles passing from the specified waterbody types/IDs. IDs are either numbers (for channels and nodes), or names (for reservoirs and flow types), or accounting labels. If no waterbodies are given, then all particles passing to the TO_WB waterbodies are counted. 'All' for an ID means to count all waterbodies of that kind (e.g. all external flows). A waterbody ID preceeded with a minus sign "-" means to remove that from the list.

TO_WB - same as FROM_WB, except this tells the PTM to track particles going to the waterbodies.

(Note: Separate the above two fields of data with the pipe "|" character.)

INTERVAL - time interval (15MIN, 1HOUR, 1DAY, etc.)

B_PART - DSS B part for flux.

MODIFIER - study name, etc. If this is the string 'runtime', a model run date-time string will be used; this allows different runs to automatically be labeled differently. If 'none', no string will be used. If this field is not used, and the environment variable DSM2MODIFIER is set, that will be used instead.

FILENAME - file to write to, if it ends in .DSS, use DSS file, otherwise text file.

Example:

```
PARTICLE_FLUX
FROM_WB      TO_WB        INTERVAL    FILENAME    b_part
chan,436,53 | chan,442,437 |   1day      flux.txt   past_Chipps
chan, 441 | stage, mtz |     1day      flux.txt   past_MTZ
res,clfct | qext,swp |      1day      flux.txt   past_SWP
chan,83,217,82 | res, clfct |  1day      flux.txt   past_72
chan, 216 | qext,cvp |      1day      flux.txt   past_CVP
 | qext,div,-cvp,-nb,-ccc |   1day      flux.txt  Ag_Diversions
 | qext,div |              1day      flux.txt All_Diversions
END
```

Particle Insertion Input

Section keyword: PARTINP

Field keywords: NODE* NPARTS* SDATE* STIME EDATE* ETIME SLENGTH LENGTH

Required: yes Overwrites: no

Description: Specifies to the PTM when and where to insert particles into the system.

(Note: Provide either SDATE and STIME, or SLENGTH; and either EDATE and ETIME, or LENGTH.)

NODE - node number to insert particles at.
NPARTS - number of particles to insert each time step.
SDATE,STIME - when to start inserting particles; 'runtime' indicates to start at model runtime (same as SLENGTH==0).
EDATE,ETIME - when to stop inserting particles.
SLENGTH - how long after start of run to start inserting particles.
LENGTH - how long an interval to insert particles (e.g. 1DAY or 23HOUR)

Example:

```
PARTINP
NODE   NPARTS  SDATE       STIME   EDATE       ETIME
330    100     29dec1992   0100    29dec1992   0200
330    100     runtime     none    29dec1992   0200
END
```

```
PARTINP
NODE   NPARTS  SLENGTH LENGTH
361    100     1hour   5day_3hour
END
```

Time-Varying Input and Output

Time-varying input and output are data such as boundary stage ,external and internal flows, gate positions, and water quality concentrations. For this information, we use the Hydrologic Engineering Center Data Storage System (HECDSS) database written by the U.S. Army Corps of Engineers for hydrologic data.

HECDSS

HECDSS was chosen for the time-varying database system because compared to relational databases it is fast and does not consume excessive storage or computing resources; it is available for a wide variety of computers (PCs, Unix, and mainframes); and may be used interactively and as subroutine calls from Fortran. With HECDSS the timing of events are known precisely during the model run, and can be displayed clearly in the input and the output, reducing ambiguity.

Regular and Irregular Time-Varying Data

HECDSS supports two types of time-varying data: irregular and regular intervals. Irregular time-series data does not occur at regularly spaced intervals. For each event, the DSS file stores the date and time, and the data value. Regular time-series data occurs at timed intervals, for example, every hour or every day. Regularly spaced data can be stored more compactly, because the starting date and time, and the interval, are stored only once. Each event stores only the data value.

Note that regular time-series data can be stored as irregular, but irregular data cannot be stored as regular. Thus, one could store all data as irregular, but this would be inefficient for file size and retrieval time.

DSS Pathnames

DSS stores data by using pathnames. A DSS pathname is composed of the six following parts: 1) general grouping name; 2) location; 3) parameter (flow, stage, etc.); 4) block start date; 5) time interval or block length; 6) descriptor

A typical pathname now used by DSM2:

/DELTA/BANKSPP/FLOW/01JAN1997/1HOUR/OBS-DWR-OM/

IEP equivalent:

/HIST+CHAN/CLFCT000/FLOW-EXPORT/01JAN1997/1HOUR/DWR-OM-DFD/

Converting from ASCII to DSS

Before a model run, the user prepares ASCII files containing the time-varying data values, then runs preprocessors on the ASCII files to convert the data into DSS files. The preprocessors are included in the DSS package available from HEC: they are dssits and dssts, as well as dssts2, developed from dssts by DWR. The ASCII input files are different for each preprocessor.

Use dssits for irregular-time data. Dssts should be used for regular interval data that have no time gaps in the list. Dssts2 should be used for regular interval data that have gaps in the list.

dssits Input File Explanation

```
/tmp/input.dss                                   name of DSS file to receive data
/DELTA/DXC/GATE/01JUN1994/IR-DECADE//            DSS pathname for this data stream
POS                                              data units (here, gate position)
INST-VAL                                          instantaneous value or period average
31May1994 2400  1                                date, time, value for each event
01Jun1994 1200  0
02Jun1994 0500  1
END                                              end of this data stream

/DELTA/CLFCT/GATE/01JUN1994/IR-DECADE//          pathname for new data stream
POS
INST-VAL
31May1994 2400  1
END
FINISH                                            end of file
```

dssts Input File Explanation

```
/tmp/input.dss                                   name of DSS file to receive data
/DELTA/MTZ/STAGE/01JUN1994/1HOUR// DSS           pathname for this data stream
FEET                                             data units (here, feet of stage)
PER-AVER                                         instantaneous value or period average
01JUN1994 0000                                   date and time of first value
 -0.08                                           values for events at each interval
 -0.52
   M                                             missing data must be explicitly marked
 -0.26
  0.76
  0.54
END                                              end of this data stream
/DELTA/SWP/FLOW/01JUN1994/1HOUR//                pathname for new data stream
CFS
PER-AVER
01JUN1994 0000
  381
  400
  500
END
FINISH                                           end of file
```

dssts2 Input File Explanation

```
/tmp/input.dss                                  name of DSS file to receive data
/DELTA/MTZ/STAGE/01JUN1994/1HOUR// DSS          pathname for this data stream
FEET                                            data units (here, feet of stage)
PER-AVER                                        instantaneous value or period average
01JUN1994 0000 -0.08                            date, time, value for events at each interval
01JUN1994 0100 -0.52
01JUN1994 0200   M                              missing data can be explicitly marked
01JUN1994 0300 -0.26
01JUN1994 0600  0.76                            note time gap in input stream
01JUN1994 0700  0.54
END                                             end of this data stream
FINISH                                          end of file
```

Running the Utilities

All three utilities are run from a command line prompt in this manner:

<utility> IN=<input filename> OUT=<output log filename>, for instance, dssts IN=test.dat OUT=test.log

In unix, instead of IN and OUT, you can use redirection: dssts < test.dat > test.log

Be sure to check the log files for any error messages pertaining to the conversion. The utilities will check for dates and times that are out of sequence, invalid characters in the value fields, etc.

For more information on DSS, consult the following URL: http://www.wrchec.usace.army.mil/publications/pubs_distrib/hecdss.html

Input Specification Section

Time-varying input to Hydro and Qual is specified in the INPUTPATHS section of the fixed input. This section has the following components:

Section keyword:	INPUTPATHS
Field keywords:	NODE NAME MEAS_TYPE INTERVAL A_PART B_PART C_PART E_PART F_PART SDATE STIME ID PRIORITY FILLIN FILENAME VALUE

(Note: Provide either NODE, or NAME; either MEAS_TYPE or C_PART; either INTERVAL or E_PART; and either FILENAME or VALUE.)

Section required: yes Overwrite: no

Description: Provides information to locate and access time-varying input data (flows, stages, gate operations, water quality, etc.) from DSS during the run. All time-varying input for Hydro and Qual must come from DSS files. Time-varying input is applied to a node number, or a name which translates to a node number.

Field Keyword Description
NODE - node number.
NAME - location name, must translate to node number. Used for DSS B part.
MEAS_TYPE - type of data: flow, stage, gate, ec, tds, etc. Used for DSS C part.
INTERVAL - time interval: 15MIN, 1HOUR, 1DAY, 1MONTH,
IR-DECADE. Used for DSS E part.
ID - identification, study name, etc. Used for DSS F part.
A_PART, B_PART, C_PART, E_PART, F_PART - DSS A, B, C, E, and F parts. (Use instead of MEAS_TYPE, INTERVAL, and ID.)
SDATE - optional start date, if different from model run start date.
STIME - optional start time, if different from model run start time.

(Note: If used, the data will start at the given date, regardless of the model start time. Use "GENERIC" to indicate the data starts at the standard generic time (01JAN3001 0000). Use "SYNC" to indicate that the data time should be synchronized to the model time based on the interval or E part. For instance, for a data interval of 1MON, the system will attempt to always use January data for a January model time, etc. Synchronized data must have a generic start date, and must not contain missing data.)

PRIORITY - optional priority of this path (integer between 0 and N). This allows for alternate or filled-in data to automatically be used from separate pathnames, without having to create a path for a location. If a higher priority (lower number) path's data is missing or bad, then the next lower priority path at the same location will be used to replace it. Paths are assumed to be at the same location if they are at the same object (node, channel, or reservoir). A priority of 0 means ignore the priority system, always use the path.
FILLIN - use LAST data value, or INTERPolate between values, or use either last or interpolation based on whether the DATA is averaged or instantaneous.
FILENAME - DSS filename to find data.
VALUE - numeric value to use as constant input value for entire run.

Examples:

```
INPUTPATHS—
# input paths that have alternate start dates, and placename.

NAME        MEAS_TYPE   INTERVAL SDATE      ID      FILLIN          FILENAME
SAC         flow        ir-decade  31may1994  test1   INTERP /inputfiles/input.dss
SJR         flow        1hour      generic    test1   DATA   /input-files/input.dss
END
```

```
INPUTPATHS—
# input path at a node, has first priority.
NODE        MEAS_TYPE   INTERVAL    ID          FILLIN    PRIORITY     FILENAME
  3         EC          1day        Study1      LAST      1      /input-files/input.dss
END
```

```
INPUTPATHS—
# input path at a node, with constant value; use if main path's data is missing.
NODE        MEAS_TYPE   INTERVAL    ID          FILLIN    PRIORITY     VALUE
     3      EC          1mon        Study1      LAST      2            200.0
END
```

Output Specification Section

Time-varying output from Hydro and Qual is specified in the OUTPUTPATHS section of the fixed input. This section has the following components:

Section keyword:	OUTPUTPATHS
Field keywords:	CHAN DIST NODE TYPE INTERVAL PERIOD MODIFIER A_PART B_PART C_PART E_PART F_PART FILENAME FROM_NAME FROM_TYPE FROM_NODE

Section required: no Overwrite: no

Description: Time-varying text and DSS output is specified in this section.

(Note: provide either CHAN and DIST, or NODE, or NAME; either TYPE, or C_PART; either INTERVAL, or E_PART.)

Field Keyword Description
CHAN - channel number.
DIST - distance downstream along channel; LENGTH means to use the channel length.
NODE - node number.

(Note: cannot use node number for Hydro output (stage, velocity, or flow); only Qual output. Qual output at a node will always be the mixed concentration at the node.)

NAME - location name, translation provided in TRANSLATION section to translate to channel or node number. Used for DSS B part.

TYPE - type of data (stage, flow, etc.) Used for DSS C part.

INTERVAL - time interval (15MIN, 1HOUR, 1DAY, etc.) Used for DSS E part.

PERIOD - INST (instantaneous) or AVE (average over interval).

MODIFIER - study name, etc. If this is the string 'runtime', a model run date-time string will be used; this allows different runs to automatically be labeled differently. If 'none', no string will be used. If this field is not used, and the environment variable DSM2MODIFIER is set, that will be used instead.

A_PART, B_PART, C_PART, E_PART, F_PART - DSS A, B, C, E, and F parts. (Use instead of TYPE, INTERVAL, and MODIFIER.)

FILENAME - file to write to, if it ends in DSS, use a DSS file, otherwise the output file will be a text file.

Example:

```
OUTPUTPATHS
CHAN   DIST     TYPE    INTERVAL  PERIOD   MODIFIER      FILENAME
1      0        stage   15min     inst     mrg_0718-rst  out.dss
82     0        stage   15min     inst     mrg_0718-rst  out.dss
83     LENGTH   flow    1hour     ave      mrg_0718-rst  out.txt
END
```

Input Sign and Value, Output Account Name Section

Hydro requires that sinks (flows out of nodes and reservoirs) be negative, and that sources be positive. Often sinks will be stored in a DSS file as a positive number (e.g. pumping values); this section is used to change the sign internally in DSM2 without changing the database.

Also, incoming values can be changed to other values; this is typically used to ensure proper gate code values, or perhaps fix the occasional psuedo value in a DSS file that one cannot edit.

This section is also used to assign an accounting type to matching pathnames which can be used by Qual and PTM for accounting purposes in the output.

This section has the following components:

Section keyword: TYPE

Field keywords: STRING PART MATCH SIGN ACCOUNT VALUE_IN VALUE_OUT

Section required: no Overwrite: no

Description: This section changes the sign of specified time-series input values, and assigns accounting types to matching pathnames, for later use in Qual and PTM. Hydro requires that sinks (flows out of nodes and reservoirs) be negative, and that sources be positive. Often sinks will be stored in a DSS file as a positive number (e.g. pumping values); the SIGN field will change the sign internally in Hydro without changing the database. The ACCOUNT field can be used to assign a type to matching pathnames which can later be used by Qual and PTM for accounting purposes in the output.

Field Keyword Description

STRING - string in pathname or label name to match.

PART - part of pathname or label to match (a=A part; b=name or B part;c=measurement type or C part; e=interval or E part; f=modifier or F part; l=name label; p=entire pathname).

MATCH - an exact match, or just a substring.

SIGN - make the matching pathnames a negative or positive value (it does not invert the value).

ACCOUNT - assign an accounting code to the match.

VALUE_IN - incoming value to check.

VALUE_OUT - if string and incoming value match, assign the VALUE_OUT value.

Example:

```
TYPE
STRING      PART        MATCH       SIGN
CCC         L           exact         -    # Contra Costa Canal
SWP         B           exact         -    # Banks pumping
DICU-IRR     F          sub           -    # Irrigation pumping
END
```

In the above example, Contra Costa, Banks, and agricultural diversion pumping are assigned a negative value (regardless of their sign in the DSS file) to ensure that they will be treated as sinks in Hydro.

```
TYPE
STRING      PART        MATCH       ACCOUNT
CCC         B           exact       DIV
SWP         B           exact       EXPORT
SAC         B           exact       RIM
DICU-SEEP   F           sub         SEEP
DICU-IRR    F           sub         DIV
DICU-DRN    F           sub         DRAIN
END
```

In the above example, Contra Costa Canal pumping is assigned an accounting type of DIV (diversion), Banks pumping is assigned EXPORT, all agricultural seepages are assigned SEEP, and so on. These accounting labels are written into the tidefile produced by Hydro and subsequently read by Qual and PTM.

```
TYPE
STRING      PART        MATCH       VALUE_IN    VALUE_OUT
dxc         b           exact       1.0         gate_open
END
```

In the above example, if dxc is found with a gate value of 1.0 from the DSS file, it will be changed to the GATE_OPEN value. Allowable codes are GATE_OPEN, GATE_CLOSE, and GATE_FREE. Any numeric value is also allowed.

Running the DSM2 Modules

On Unix or NT, simply type the executable name from a shell command line:

```
% hydro
% qual
% ptm
```

Command line arguments and environment variables may be used to specify the starting input file for each run.

If an argument is given on the command line, for example “”% qual qual.inp” then that is used as the first input file.

If no file name is given on the command line, the environment variable DSM2INPUT can be used to specify the first input file to read. The environment variables HYDROINPUT or QUALINPUT override DSM2INPUT. If no environment variable or command line argument is used, the default filename is dsm2.inp.

Examining DSM2 Output

Hydro, Qual, and PTM can produce output in either text files or DSS files. Additionally, Hydro produces tidefiles to convey hydrodynamic information to Qual and PTM, and both Hydro and Qual produce restart files so a run can be interrupted and restarted later. PTM can produce special files intended for graphical display of the data. None of these special purpose files will be discussed here. Only text and DSS files, produced in the OUTPUTPATHS section, are considered.

Text output files consist of blocks of data, one block for each output path requested. Each block is composed of 3 lines of DSS-style headers, followed by lines of data values. Each data value line has the date, time, and value of the output. For example:

```
/DELTA/134_3800/STAGE//15MIN/CMP-5D-1H/ DSS    pathname
INST-VAL                                       Instantaneous value or period average
FEET                                           Data value units
31DEC1992 2400   1.36                          Date, time, and value: initial value of run
01JAN1993 0015   1.56                          Computed values from run follow
01JAN1993 0030   1.75
01JAN1993 0045   1.97
01JAN1993 0100   2.20
/DELTA/133_1100/STAGE//15MIN/CMP-5D-1H/        New output block
INST-VAL
FEET
31DEC1992 2400   1.14
01JAN1993 0015   1.35
01JAN1993 0030   1.59
01JAN1993 0045   1.82
01JAN1993 0100   2.06
```

Text files can be examined with any text editor, or with some editing can be loaded into spreadsheets for more processing. Text files have a simple format so that the user can process the data further for their own purposes. The intent of DSM2 is to calculate results and output those results in a basic format for other utilities and programs to process. We will not be adding post-processing routines to DSM2 itself.

DSM2 can also output results into DSS files. DSS files are written in Fortran binary format and cannot be examined directly. Instead, the data must by downloaded from the DSS file into text (ASCII) files, or utilities which work directly with DSS files should be used. For instance, the HEC program DSSUTL can be used to view data in DSS files, print the data to files, delete or rename pathnames, and so on.

HEC also has a program called DSPLAY to produce line plots of DSS data. The Delta Modeling Section is developing a data viewer (VISTA-VISualization Tool and Analyzer) to plot data in DSS files in a variety of plotting styles.

The advantage of using DSS files, instead of text files, are that the data is stored more compactly, and for large amounts of data it is easier to use a data manager utility to select pathnames, time frames, etc., rather than trying to manipulate huge text files. IV.B. Multiple Conservative Constituent Source Output.

Multiple Conservative Constituent Source Output

Conservative constituent concentrations from multiple sources can be calculated and output in a single Qual run. The setup for this is in two parts: first, specifying any accounting names desired in the Hydro run, and second, specifying the output from Qual. Conservative constituents can be specified by three source types: named source, node source, and accounting type source. A name source must translate to a node number. Neither name sources or node sources require an accounting name specification in Hydro. However, output by accounting name does require that an accounting name be given in the Hydro run.

To specify an accounting name for Hydro, the TYPE section is used. TYPE can be used to change the sign of flows or specify accounting names. Here, only accounting name usage is reviewed. For example:

```
TYPE
STRING      PART      MATCH      ACCOUNT
CCC          B        exact      DIV
SWP          B        exact      EXPORT
SAC          B        exact      RIM
VERNALIS     L        exact      RIM
DICU-SEEP    F        sub        SEEP
DICU-IRR     F        sub        DIV
DICU-DRN     F        sub        DRAIN
END
```

The STRING field is the character string to search for in the input paths. The PART field can be one of several letter codes: a=A part; b=name or B part; c=measurement type or C part; e=interval or E part; f=modifier or F part; l=name label; p=entire pathname. MATCH can be either exact string match, or just a substring. ACCOUNT will assign any accounting label string desired by the user to those input paths matching the string.

In the example, Contra Costa Canal pumping is assigned an accounting type of DIV (diversion), Banks pumping is assigned EXPORT, all agricultural seepages are assigned SEEP, and so on. These accounting labels are written into the tidefile produced by Hydro and read by Qual and PTM.

In Qual, the standard output concentration specification is asfollows. First, the input concentrations are shown:

```
# Time-varying EC input for Qual

INPUTPATHS
NAME          MEAS_TYPE            INTERVAL ID       FILLIN       FILENAME
MTZ           EC     1hour         obs-dwr-eso       interp       input.dss
SAC           EC     1day          obs-usbr          data         input.dss
VERNALIS      EC     1day          obs-usbr          last         input.dss
END

INPUTPATHS
NAME          MEAS_TYPE     INTERVAL         ID      FILLIN       VALUE
CSMR          EC                1day         xx            last           130.
MOKE          EC                1day         xx            last           130.
END

INPUTPATHS
NODE          MEAS_TYPE     INTERVAL ID                 FILLIN SDATE      FILENAME
1             EC            1MON    DICU-DRN-HIST  LAST    GENERIC divdrn_qual.dss
3             EC            1MON    DICU-DRN-HIST  LAST    GENERIC divdrn_qual.dss
5             EC            1MON    DICU-DRN-HIST  LAST    GENERIC divdrn_qual.dss
etc.
END
```

Next, a basic output specification:

```
OUTPUTPATHS
NAME          TYPE          INTERVAL    PERIOD       FILENAME
union         ec            1day        ave          qual.txt
END
```

This tells Qual to output one pathname at the Union Island station (translated elsewhere to channel 125, 2,700 feet downstream). Since no source qualification is used, the concentration output will be from all sources, by default. However, by adding one of three field keywords, this can be qualified by source:

```
OUTPUTPATHS
NAME          FROM_NAME         TYPE          INTERVAL    PERIOD       FILENAME
union         mtz               ec            1day          ave        qual.txt
union         vernalis          ec             1day         ave        qual.txt
END
```

```
OUTPUTPATHS
NAME       FROM_NODE        TYPE       INTERVAL   PERIOD     FILENAME
union      1                ec         1day       ave        qual.txt
union      330              ec         1day       ave        qual.txt
END
```

```
OUTPUTPATHS
NAME       FROM_TYPE        TYPE       INTERVAL   PERIOD     FILENAME
union      drain            ec         1day       ave        qual.txt
END
```

In these examples, output at the same UNION location is requested. In the first pair of outputs, EC from Martinez and Vernalis, and from no other sources, is requested. In the second pair, EC from nodes 1 and 330 only is requested. Since Vernalis translates to node 1, those two outputs should be identical. In the last example, EC from flows with the accounting label DRAIN is requested. This would be all 258 agricultural drainage sources, as given in the input-ag.inp file.

Not yet available is a method for conveniently combining different sources in a single output path. This capability could be added if the need arises.

DSM2 on the Internet

The main URL for DSM2 is: http://wwwdelmod.water.ca.gov/

DSM2 files (source code, executables, auxiliary programs, example input, and so on) are stored in several different places. The following URL points to a collection of URLs to allow easy downloading of individual components:

http://wwwdelmod.water.ca.gov/docs/dsm2/dsm2.html#URL Collection

An e-mail discussion list is available. To join, send e-mail to majordomo@osp.water.ca.gov, and in the text area (not the subject),type in “”subscribe dsm2”.

Planning Studies

Planning studies usually use the 19-year mean tide repeatedly and monthly averaged input values, involve several variations of the same theme, and are run during several years.

Hints for Organizing Runs

- Have a shell or program loop over each year and period, setting environment variables and creating temporary files, which are then read by the input system.

- To read a temporary file, use the INP_FILES section.

- To access environment variables in the input, use dollar sign notation:

```
# rim flows from DWRSIM run
INPUTPATHS
name  a_part         b_part  c_part               e_part  f_part   fillin  filename
sac   $DWRSIMSTUDY   137     FLOW-DOWNSTREAM      1MON    OUTPUT   last    $DWRSIMFILE
sjr   $DWRSIMSTUDY   682     FLOW-DOWNSTREAM      1MON    OUTPUT   last    $DWRSIMFILE
yolo  $DWRSIMSTUDY   55      FLOW-LOCAL_INFLOW    1MON    OUTPUT   last    $DWRSIMFILE
ccc   $DWRSIMSTUDY   528     DIVERSION-ACTUAL     1MON    OUTPUT   last    $DWRSIMFILE
nb    $DWRSIMSTUDY   55      DIVERSION-ACTUAL     1MON    OUTPUT   last    $DWRSIMFILE
END
```

- Organize input data by common factors:

  - input common to all studies and times, e.g. scalar constants, reservoir and gate names
  - input common to a particular study, e.g. channel configuration, pumping amounts

6

Cross-Section Development Program

Introduction

This chapter provides an update on efforts to refine the DSM2 representation of channel geometry, which includes the development of the Cross-Section Development Program (CSDP). The CSDP is used to develop irregular cross-sections for DSM2-Hydro. The CSDP is written in Java, an object-oriented, platform-independent language.

Bathymetry Data

Bathymetry data are not used directly by DSM2-Hydro; they are used by the CSDP to draw cross-sections which are approximations to the actual shape of each channel. The cross-section drawings are used by the CSDP to calculate cross-section property tables, which are used by Hydro. Cross-section properties used by Hydro include area, width, and wetted perimeter (Figure 6.1). This process allows the user to reduce the amount of data to a minimal representative data set, which is the smallest amount of data required to describe the general shape of the Delta's channels. In addition, the user has the ability to change the shapes of cross-sections to simulate proposed changes in geometry, such as dredging.

The most important part of the process is the selection of data used to draw each cross-section. The data selection process allows the user to place more emphasis on data that are most reliable and most representative. The bathymetry database contains more than 400,000 points, and has been divided into four files (Figure 6.2 shows the location of each of the four areas).

Filename	*Location*
area1.cdp	western Delta, Suisun Bay, Suisun Marsh
area2.cdp	north Delta
area3.cdp	central Delta
area4.cdp	south Delta

The CSDP is designed to work with three-dimensional bathymetry data, which have two horizontal coordinates in UTM zone 10, and a vertical coordinate in feet with respect to Mean Sea Level (MSL) (Figure 6-3). It is also possible to use data that are not referenced to a global coordinate system (non-georeferenced data), but some manipulation is required. Examples of non-georeferenced data that can be used include cross-section plots and cross-section station and elevation coordinates.

Bathymetry data can be stored in ascii(.prn) files, binary(.cdp) files, or Gzipped binary files(.cdp.gz). The use of binary files allows faster access. Gzipped files are smaller, but take more time to read.

Landmark Data: .cdl

Landmark files are only read by the CSDP, and are not used directly by DSM2. A landmark file consists of labels and UTM coordinates. Landmark files can be used to label any feature, such as a node or a cross-section. The file delta.cdl is created by the CSDP when the Network-Calculate menu item is selected and is used to label cross-sections drawn by the user. It can be used to help locate cross-section lines. The file node.cdl contains coordinates for every node in the May 1995 version of the DSM model grid. This file is used by the create DSM chan function which is in the Centerline menu.

Network Data: .cdn

Network files are only read by the CSDP, and are not used directly by DSM2. A network file contains the data set that is created by the user, including centerline names, centerline coordinates, and cross-section coordinates.

Channel Connectivity Data: *.inp

The file channels.inp contains the CHANNELS input section (Chapter 5). The CHANNELS input section includes the numbers of all channels in the model grid and the numbers of the upstream and downstream nodes of each channel. The file channels.inp is used by the CSDP to draw centerlines for specified DSM channel numbers.

Using the CSDP

Loading Bathymetry Data

To load a bathymetry file, select the File-Open menu item and select the file you wish to load. The file should be an ascii file with a .prn extension, a binary file with a .cdp extension, or a Gzipped binary file with a .cdp.gz extension. After loading a .prn file, you can save it as a .cdp file for faster access.

After specifying a filename, the file will be read and the data will be displayed in plain view (Figure 6.4). The points will be colored by elevation by default. Points can also be colored by year, source, or uniformly by selecting the Display-Color By menu item.

Loading Network Data

To work with an existing network file, select the Network-Read menu item and select the file you wish to load. If there is any unsaved network information in memory, you will have the opportunity to save it. A network file will always have a .cdn extension.

Loading Landmark Data

To load a landmark file, select the Display-Landmark menu item and select the file you wish to load. A landmark file will always have a .cdl extension.

Selecting Data

It is the user's responsibility to select data for drawing cross-sections with the CSDP. Criteria for selection include year, source, and location. Because cross-sections are interpolated along channels, cross-sections should be representative of the overall shape of the portion of the channel that they represent. There should generally not be large changes in area, width, wetted perimeter, or bottom elevation among the set of cross-sections used to describe any given channel. Data are selected by using two perpendicular lines to define a rectangular region. All of the data contained within this region are then displayed in the cross-section view.

1. To zoom in on the display, select the Zoom-Factor menu item. Use the scroll bar to select a new zoom factor. Entering a zoom factor greater than 1 will increase the size of the display. Use the scrollbars to scroll through the data display.

2. To increase the bathymetry point size after zooming, select the Display-Parameters menu item. Enter an integer.

3. To filter the data display, select Display-Group and/or Display-Year. This will allow you to "turn off" the display of undesirable data. (Note: this step is optional. Filtering the data display may or may not facilitate the selection of appropriate data).

4. Select a rectangular region of data to be displayed in cross-section view (Figure 6.5). The region will have a length, width, and direction. The location, length, width, and direction are used to select data to be displayed in cross-section view. The direction defines the positive flow direction for the channel. The direction also determines the order in which points will be displayed, which will always be from left bank to right bank (Figure 6.7a). DSM2 currently does not require points on the left to be on the left bank, but in the future, some DSM2 models may have this requirement. The length of the region is defined by the cross-section thickness, which can be adjusted by selecting Display-Parameters. The width is defined by the length of the cross-section line. The direction is defined by the order of the points in the centerline. The location of the center of the region is defined by the intersection of the centerline and the cross-section line.

    a. *Create a centerline*: Select Centerline-Create DSM Chan. You will be asked to select a channel connectivity file, if one is not already loaded. The channel connectivity file is the file that contains the CHANNELS input section(Chapter 5), and will typically be named channels.inp. You will then be asked to enter the DSM channel number for the centerline you wish to create. Enter a number from the DSM model grid. Finally, you will be asked to select a landmark file, if one is not loaded or if one or both of the nodes for the specified channel number are not found. Select the file node.cdl, which contains the locations of the nodes in the DSM model grid. A Centerline will be drawn from the upstream node of the specified channel to the downstream node (Figure 6.6a).

b. *Insert centerline points*: Insert points into the centerline to create centerline segments which follow the shape of the channel (Figure 6.6b). To insert points, select the centerline by clicking on it, click on the insert button to turn the insert mode on, and then click at various locations along the channel to insert points. It is not necessary for the centerline to follow the exact shape of the channel; it is only necessary to have line segments which are aligned with the data.

5. Add cross-section

a. *Add cross-section line(s)*: To add a cross-section line, click on the Add Xsect button to turn the add cross-section mode on. Click on a location near the data you wish to use. A cross-section line will be drawn perpendicular to the nearest centerline segment. The cross-section line should be aligned with the data you wish to view. If it is not, you may need to move the endpoints of the centerline segment which intersects the cross-section line.

b. *Adjust the cross-section width*: If desired, change the cross-section width using the Display-Parameters menu item.

Drawing Cross-sections

Displaying the data in cross-section view allows the user to draw a line through the points. The coordinates of these points are used by the CSDP to calculate cross-section properties.

A line is drawn through the bathymetry points displayed in cross-section view (Figure 6.7b). The line is an approximation to the shape of the cross-section. The line can also be modified to simulate proposed changes in geometry, such as dredging. Each cross-section will then be saved along with its channel number and its normalized distance along the channel from the upstream end. The normalized distance is the distance from the upstream end of the centerline to the cross-section line divided by the length of the cross-section line (Figure 6.8).

1. Display the data in the cross-section view by selecting Xsect-View. The data are displayed with respect to a relative coordinate system. The origin of the coordinate system is located at the intersection of the centerline and the cross-section line. The horizontal axis is the distance in feet along the cross-section line. The vertical axis is the elevation in feet with respect to Mean Sea Level.

2. Add points: click on the Add button to turn on the add point mode.

3. Edit points: To insert, move, or delete points, click on the appropriate buttons and click on the point(s) to be inserted, moved, or deleted. The Keep button will save all of your changes in memory (not to a file). The Restore button will undo all of your changes since the last time the Keep button was clicked.

4. Draw a cross-section through the data points by clicking on locations with the mouse. Try to use no more than 10 points. Using more than 10 points could increase Hydro's memory requirements and reduce its speed.

a. Avoid negative dconveyance between -5 and +15 feet (MSL) (Section 5).

b. Horizontal line segments above the bottom of the channel are acceptable. When cross-section properties are calculated, one of the elevations of the line segment will be increased by 0.01 ft (Horizontal line segments above the bottom are not allowed in cross-section property calculations because only one layer is allowed per elevation). A line segment that appears to be horizontal on the screen may not be exactly horizontal.

c. Avoid large changes in bottom elevation and area(MSL) within channels. Large changes in area within a channel could prevent Hydro from converging.

d"W" shaped cross-sections are acceptable (Figure 6-9a).

e. Avoid "J" shaped cross-sections. A "J" shaped cross-section will have low wetted perimeter values at higher elevations (Figure 6-9b).

5. Exit cross-section view by selecting the Xsect-Close menu item. If you have made any changes to the cross-section, you will be asked if you want to save these changes. At this point, changes will only be saved in memory and will not be written to a file.

6. Save your work to a network file by selecting Network-Save. A network file should have a .cdn extension.

Cross-section Plots

Cross-section plots consist of a series of points plotted on a graph (Figure 6.10). To use the CSDP to calculate cross-section properties for a given cross-section plot, estimate station and elevation coordinates of each point in the plot and follow the following procedure for processing cross-section station and elevation coordinates.

Cross-section Station and Elevation Coordinates

To use cross-section station and elevation coordinates, it is necessary to make a network file (Figure 6.11).

Preparing Irregular Cross-Section Data for DSM2

The output from the CSDP is used as input for DSM2. DSM2 irregular cross-section input files consist of cross-section property tables (*.txt files) and files containing IRREG_GEOM input sections. For more information on DSM2 input files, see Chapter 5.

Load a network file (.cdn) using Network-Read. The file delta.cdn is the main network file that is used by the Delta Modeling Section. Select Network-Calculate. You will be asked to select a directory for cross-section output files(*.txt). After selecting the directory, enter 1 or more characters in the "filename" text field (your entry will not be used, but Java's FileDialogBox will not accept your input unless you do this). This will write all of the cross-section files(*.txt), a new landmark file(*.cdl), and a file called irregular_xsects.inp, which contains the IRREG_GEOM input section. The new landmark file can be used in the future for locating cross-sections when you use the CSDP. All files will be written to the directory in which you started the application (with the exception of the cross-section files, which will be written to the directory that you selected). Using a text editor, open the file irregular_xsects.inp and change the path name in the FILENAME field.

DSM2 Input (output files from the CSDP)

To use irregular cross-sections, Hydro requires an IRREG_GEOM input section and irregular cross-section files (Chapter 5).

IRREG_GEOM Input Section

The irregular_xsects.inp file contains the IRREG_GEOM input section (Chapter 5). This file is used to assign cross-sections to DSM channels and to locations within the channels.

The IRREG_GEOM input section is typically stored in a file called irregular_xsects.inp and is created by the CSDP when the Network-Calculate menu item is selected. The IRREG_GEOM section that is written by the CSDP will always assign cross-sections to the locations defined by their filenames. The filename of a cross-section describes the DSM channel number and the normalized distance along the channel (Figure 6.13).

To prevent interpolation or the use of rectangular cross-sections, it is sometimes desirable to copy cross-sections to other locations. Cross-sections can be copied to other locations in the same channel or in other channels. To do this, an additional IRREG_GEOM input section(Figure 6-14) can be created manually and stored in a separate file, which might be called irregular_xsects_copy.inp. The file can also be used to include cross-sections which are not included in the network file.

All files which contain IRREG_GEOM input sections that you wish to use for a model run must be listed in the INP_FILES input section (Chapter 5).

Irregular Cross-section Files(*.txt)

A cross-section file is written for every cross-section drawn by the user. The file consists of a table of area, width, wetted perimeter, hydraulic radius, x centroid, and z centroid values for each unique elevation in the cross-section(Figure 6.15).

Using Irregular Cross-Sections with DSM2-Hydro

This section describes how DSM2-Hydro uses irregular cross-sections. Some of the problems which can cause a model run to fail are negative dConveyance, interpolated negative dConveyance, and convergence.

Cross-section Interpolation

Cross-sections have to be interpolated by Hydro for every computational point in the model grid before they can be used by FourPt. Interpolated cross-sections are also known as virtual cross-sections (Figure 6.16). The number of computational points in each channel depends on the actual value of delta X, which depends on the channel length and the requested value of delta X.

Actual vs. Requested Deltax

The scalar input variable deltax (Chapter 5) is called the requested value of deltax (ΔXr). The actual value of deltax used by hydro (Δ Xa) in each channel depends on ΔXr and the channel length. The following equation is used to calculate ΔXa:

ΔXa = length/(2 * int(length/Δ Xr) (Note: the int function truncates)

Rectangular cross-sections are used in channels which do not have irregular cross-sections. To limit the use of rectangular cross-sections, Hydro moves and copies cross-sections (Note: even with the use of irregular cross-sections, it is still necessary to define at least two rectangular cross-sections for every channel in the model grid). The following rules apply to the moving and copying of cross-sections:

Rules for Copying, Moving, and Interpolating Cross-sections

1. Any channel with one or more irregular cross-sections will not use rectangular cross-sections (Figure 6.17). A channel with no irregular cross-sections will only use rectangular cross-sections for interpolation. It is possible to assign two or more different rectangular cross-sections to a channel, but this is not typically done.

2. For each node: If the distance from the node to the nearest cross-section is within 5 percent of the channel length, then the cross-section will be moved to the end of the channelwhich is adjacent to the node(Figure 6-18). This is done to prevent interpolation from adjacent channels.

3. Cross-sections can only be interpolated across nodes if the node is connected to 2 channels (Figure 6.19).

4. If a channel hasone or more irregular cross-sections which cannot be moved (rule 2) and no cross-sections are available for interpolation in the adjacent channel (rule 3), the cross-section(s) nearest to the nodes will be copied to end of the channel adjacent the node. A moved cross-section can be used by an adjacent channel for interpolation; a copied cross-section cannot.

Interpolation occurs in three stages. The first two stages occur while Hydro is processing input data. The purpose of the first two stages is to create a lookup table (Figure 6.20) that is used to reduce the number of interpolations that occur while FourPt is running. The three stages are:

1. A list of all unique elevations is made for each channel. Cross-section properties are interpolated in the vertical direction for every elevation in this list. If necessary, cross-sections are extrapolated in the vertical direction using the levee_slope value that is specified in the SCALAR input section (Chapter 5).

2. Cross-section properties and bottom elevations are interpolated in the horizontal direction to create virtual cross-sections.

3. During a model run, cross-section properties are interpolated in the vertical direction for the specified water surface elevation value.

To create a virtual cross-section for each computational point, the nearest two cross-sections on either side are interpolated. Cross-sections from adjacent channels are used if there are two channels connected to the adjacent node. Cross-sections that are interpolated or are copies of other cross-sections are never used for interpolation.

For a listing of virtual cross-sections, change the value of printlevel in the SCALAR input section to 5, change the length of the run to 1 hour, and run Hydro (Chapter 5). (Note: When printlevel is set to 5, Hydro will produce a large output file that could fill your hard disk. For this reason, it is best to avoid running Hydro for more than 1 hour with printlevel set to 5). An ascii file will be written which contains a listing of all cross-section properties in all virtual cross-sections.

Problems to Avoid when Using Irregular Cross-sections with DSM2

Convergence

If Hydro fails to converge in a channel, the run will fail. Hydro will not converge if there are large changes in cross-sectional area between virtual cross-sections that are in the same channel. To avoid convergence problems, make sure that for every channel, the ratio of the largest virtual cross-sectional area to the smallest is less than 2.0. Running Hydro with printlevel set to 5 produces a list of all channels that may have convergence problems.

Negative dconveyance

A Hydro run will fail if the water level in any virtual cross-section enters a portion of the cross-section that has negative dConveyance. dConveyance is the derivative of conveyance with respect to height. dConveyance can be negative if a line segment has a very small slope (close to horizontal), which causes a large change in wetted perimeter with respect to elevation. It is the user's responsibility to eliminate negative dConveyance in portions of cross-sections which are in the anticipated water surface elevation range.

To detect negative dConveyance, set printlevel to 5 or greater (Chapter 5), include a line in the IO_FILES input section to write output to an ascii file of TYPE none, and run Hydro. The ascii file will contain the list of interpolated layers with negative dConveyance.

If any cross-sections have negative dConveyance in the range of -5<Z<15 ft, they will be identified by this list. It is acceptable to have negative dConveyance only if the water level will never enter the portion of the cross-section that has negative dConveyance. If it is necessary to eliminate negative dConveyance, look at the magnitude of the negative dConveyance. The magnitudes of dConveyance for each layer are listed in the cond 0 and cond 1 columns. If it is very large, then a change must be made. Negative dConveyance is adjusted in two ways:

1. Change the slope of a line segment by adding, moving, or removing points.
2. Adjusting bottom elevations and/or changing the slopes of line segments if the problem is caused by interpolated negative dConveyance.

Interpolated negative dConveyance

The CSDP will identify layers between -5 and +15 ft(MSL) in all virtual (interpolated) cross-sections that have negative dConveyance (a layer is a row of data in the cross-section property table). The virtual cross-sections that Hydro uses may contain negative dConveyance at elevations between -5 and +15 ft even if the two cross-sections used in the interpolation do not. Before cross-sections are interpolated (Figure 6.23a), the bottom elevation is subtracted from all the elevations in the cross-sections, which converts the elevations to heights. The bottoms of the cross-sections are now at the same height (zero). If there is a big difference in bottom elevations, the interpolated cross-section could have negative dConveyance between -5 and +15 (Figure 6.23b).

The best solution to this problem is to adjust the bottom elevations in one or both of the cross-sections so that they are not so far apart (Figure 6.24a). The resulting interpolated cross-section (Figure 6.24b) would not have negative dConveyance in the range of -5 ft to 15 ft. Large changes in bottom elevation within a channel could indicate that one or more of the cross-sections may not be representative.

To detect interpolated negative dConveyance, it is necessary to run Hydro with the scalar variable printlevel set to 5 or greater (Chapter 5).

Figure 6.1 CSDP Used to Convert #D Bathymetry Date for Use by DSM2-Hydro

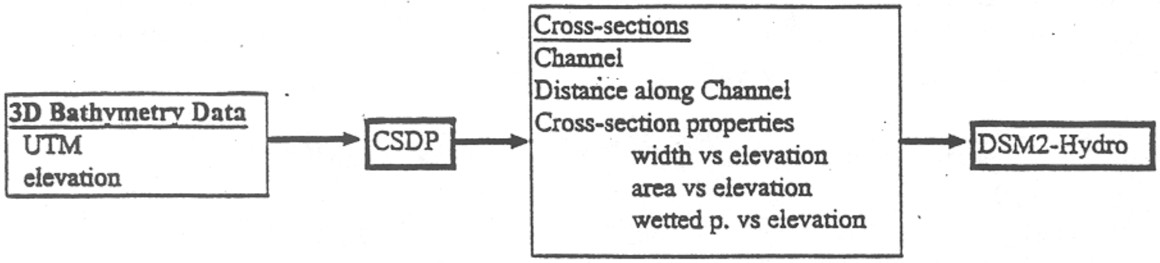


Figure 6.2 Delta Bathymetry Data Locations

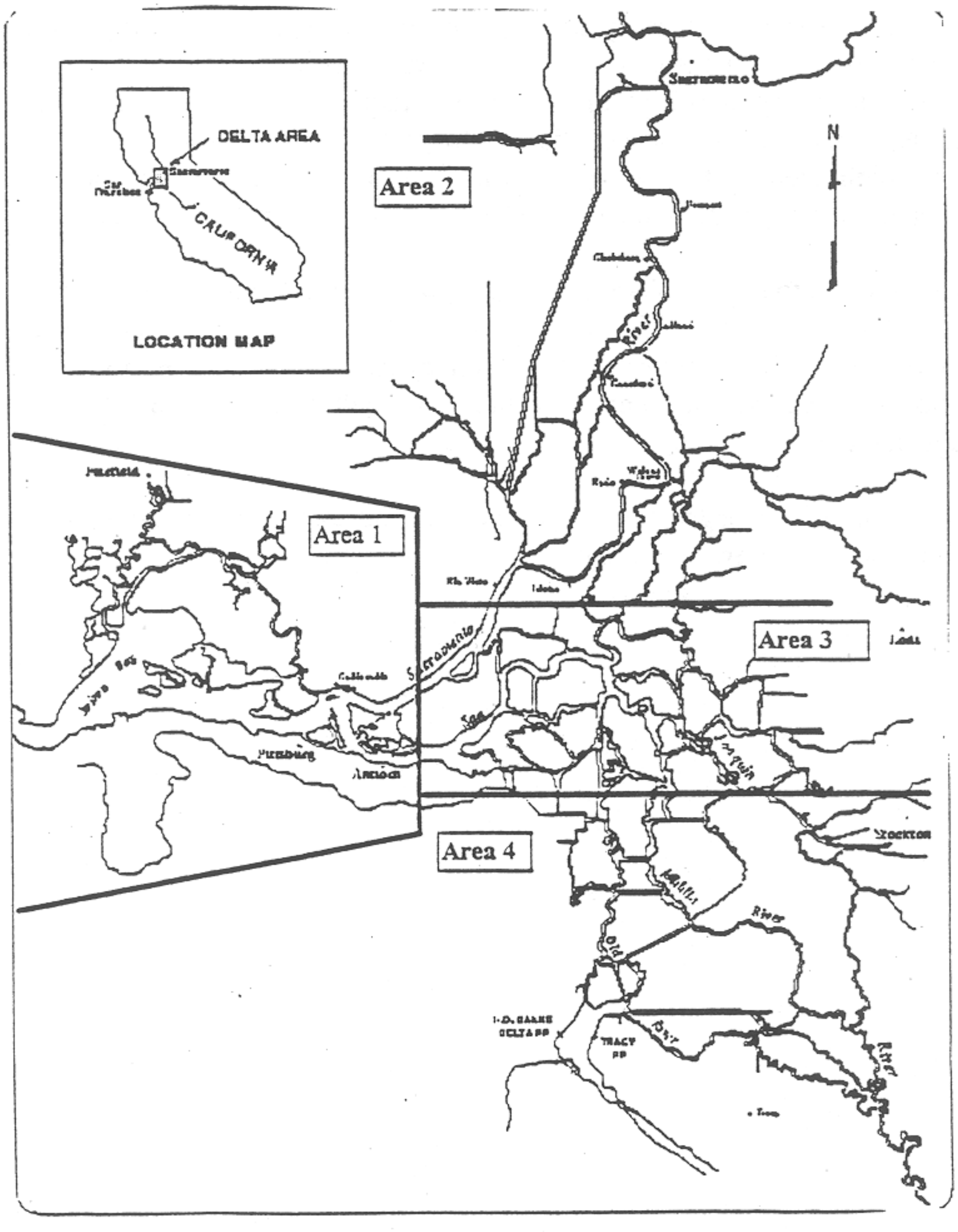


Figure 6.3 Three-dimensional Bathymetry Data

```
9
626955.4555 4186009.9708   2.60 1990 DWR-CD.MAY D-DC100
626955.7598 4186009.9874   1.60 1990 DWR-CD.MAY D-DC100
626957.2816 4186010.0705   0.90 1990 DWR-CD.MAY D-DC100
626958.8033 4186010.1536   0.60 1990 DWR-CD.MAY D-DC100
626960.3250 4186010.2367   0.20 1990 DWR-CD.MAY D-DC100
626961.8468 4186010.3198  -0.10 1990 DWR-CD.MAY D-DC100
626963.3685 4186010.4029  -0.16 1990 DWR-CD.MAY D-DC100
626964.8902 4186010.4861  -0.47 1990 DWR-CD.MAY D-DC100
626966.4120 4186010.5692  -0.94 1990 DWR-CD.MAY D-DC100
```

Column	Description
1	west/east UTM zone 10 coordinate
2	north/south UTM zone 10 coordinate
3	elevation, ft(MSL)
4	year of survey
5	source of data or name of survey
6	description of data point(currently not used)

Figure 6.4 CSDP. Bathymetry Data, Plan View

(Centerline for DSM Channel 309 with cross-section line)

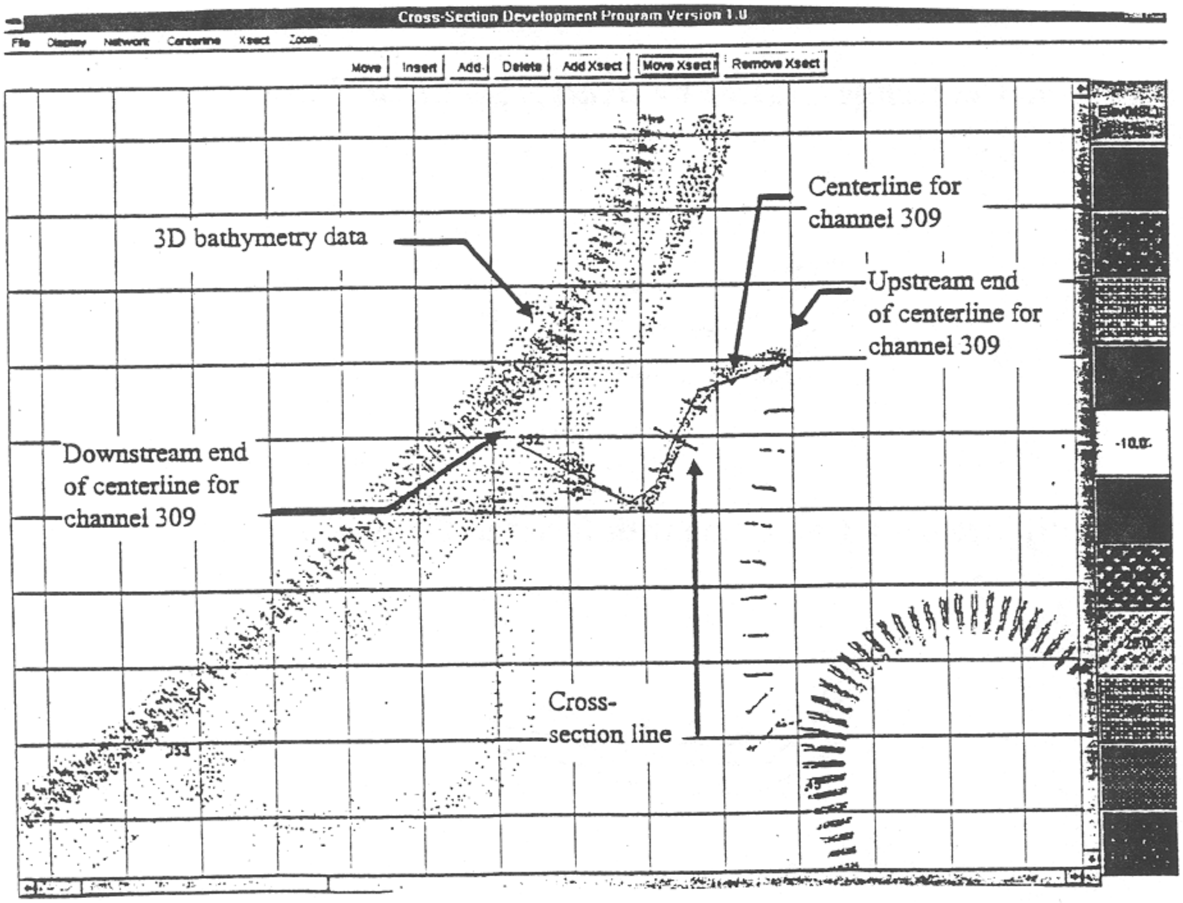


Figure 6.5 Rectangular Region
(Defined by centerline and cross-section line used to select data for display in cross-section view)

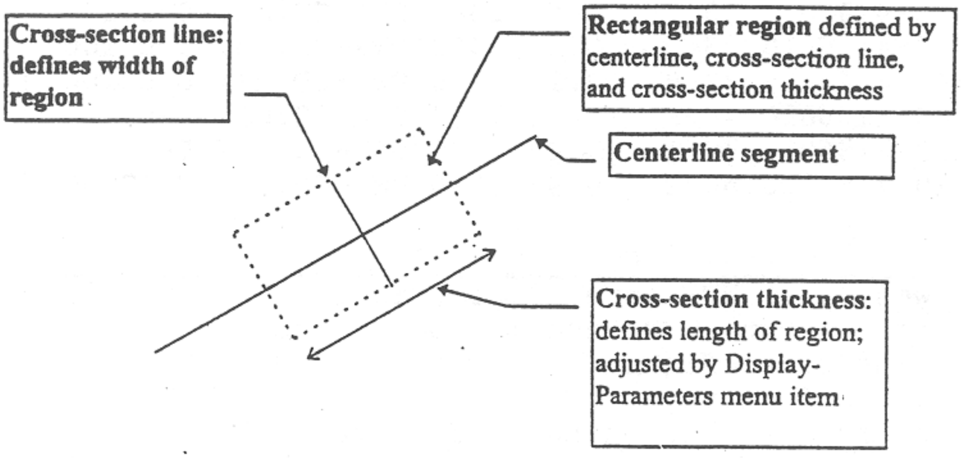
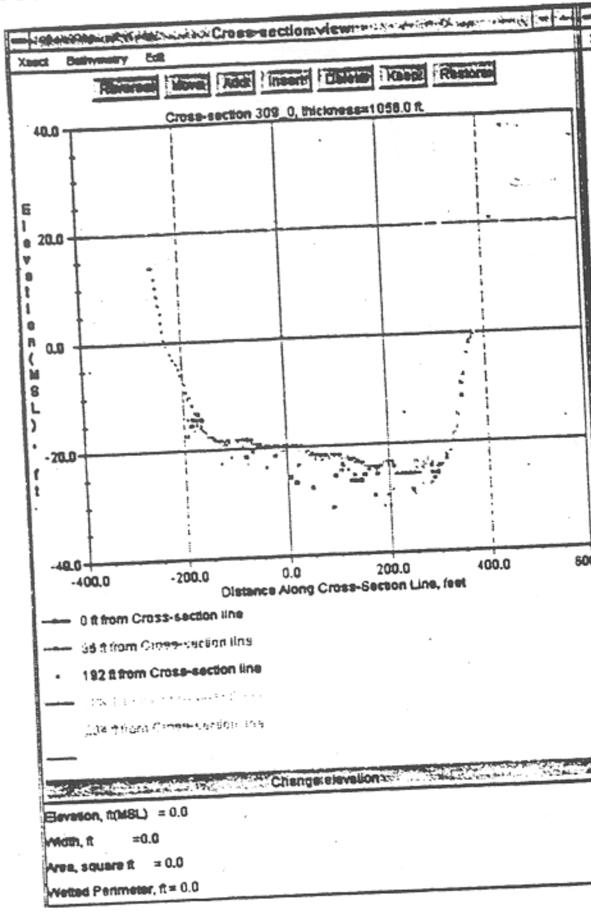


Figure 6.6a Centerline Created by *create DSM Chan* Feature

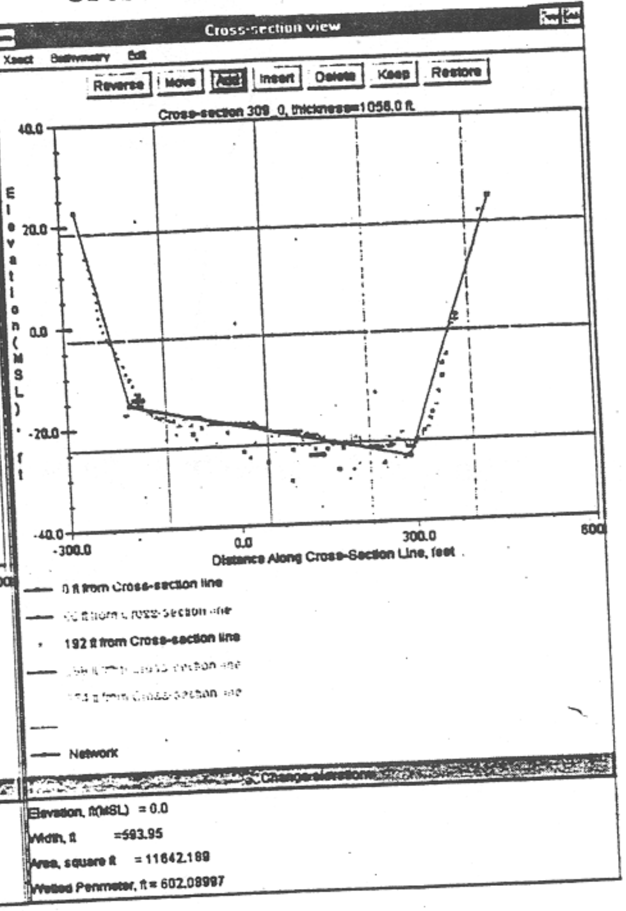
Figure 6.6b Centerline with Inserted Points

Figure 6.7a Bathymetry Data, Cross Section View



Elevation, ft(MSL) = 0.0
Width, ft =0.0
Area, square ft = 0.0
Wetted Perimeter, ft= 0.0

Figure 6.7b Bathymetry Data, Cross Section View with Drawing



Elevation, ft(MSL) = 0.0
Width, ft =593.95
Area, square ft = 11642.189
Wetted Perimeter, ft= 602.09997

Figure 6.8 Cross-section Line Measurements
(Distance from upstream end of centerline to cross-section line and length of cross-section line)

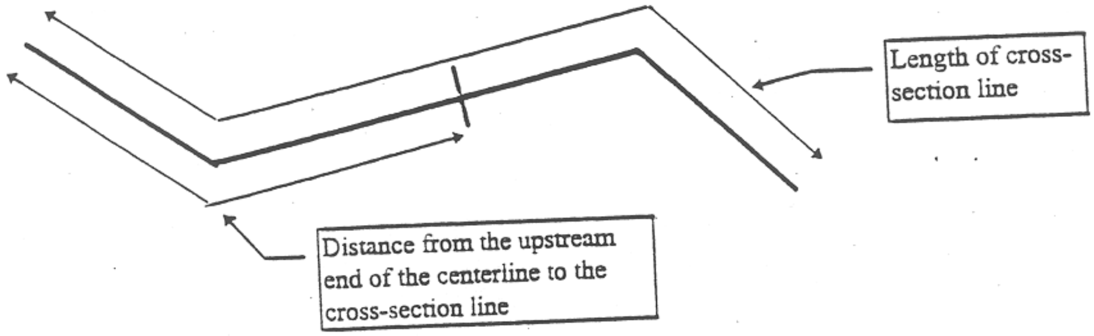


Figure 6.9a "W" Shaped Cross-sections (Acceptable)

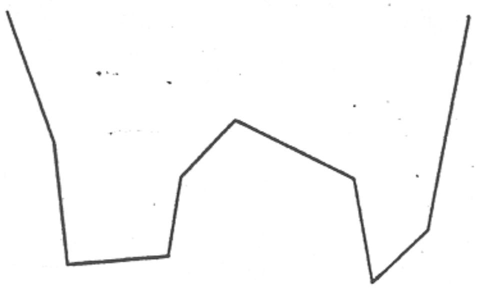


Figure 6.9b "J" Shaped Cross-sections (Should be avoided)

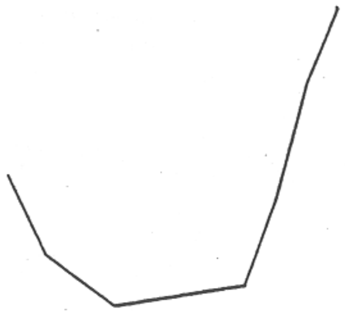


Figure 6.10 Cross-section Plot (User needs to estimate station and elevation coordinates.)

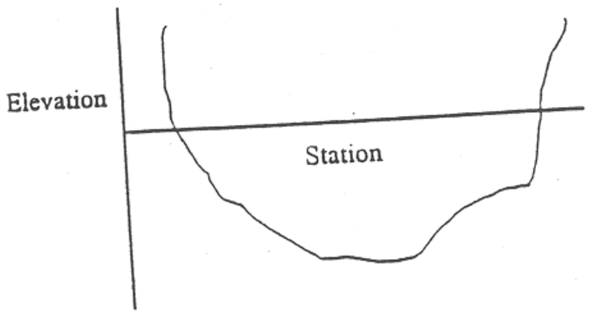
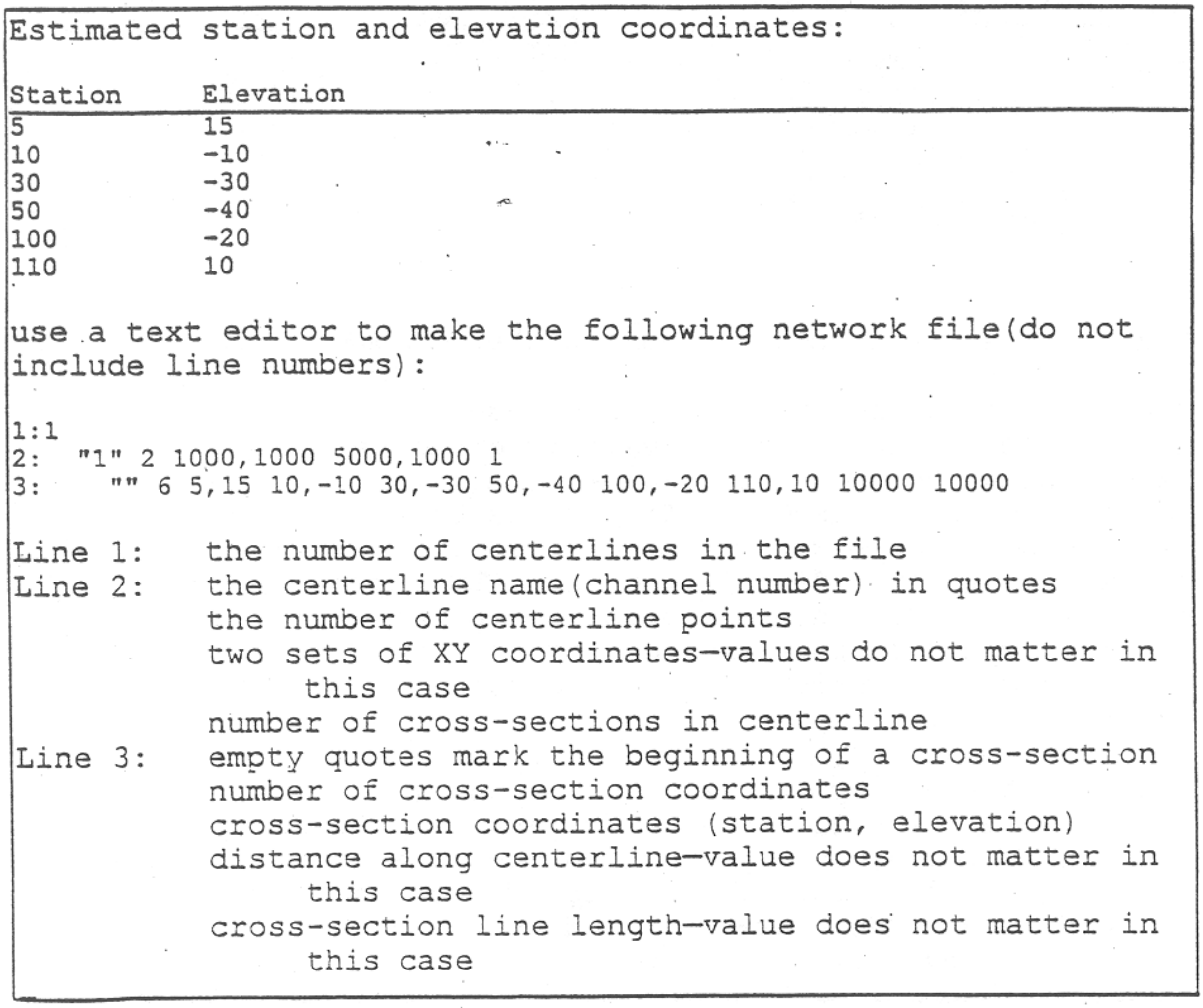
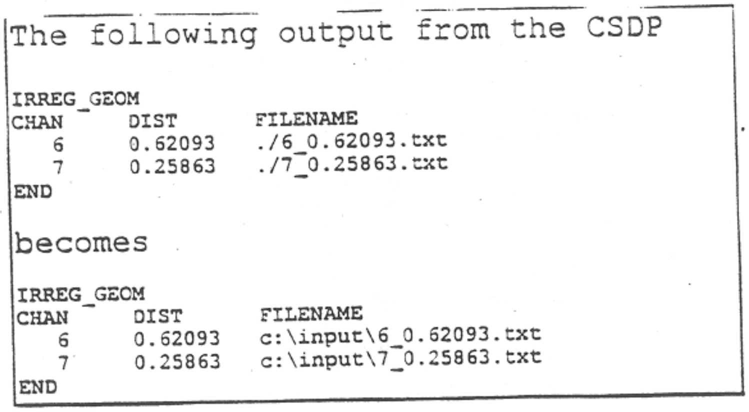


Figure 6.11 Using Station and Elevation Coordinates to Make a Network File



```
Estimated station and elevation coordinates:

Station      Elevation
5            15
10           -10
30           -30
50           -40
100          -20
110          10

use a text editor to make the following network file(do not
include line numbers):

1:1
2:  "1" 2 1000,1000 5000,1000 1
3:    "" 6 5,15 10,-10 30,-30 50,-40 100,-20 110,10 10000 10000

Line 1:    the number of centerlines in the file
Line 2:    the centerline name(channel number) in quotes
           the number of centerline points
           two sets of XY coordinates—values do not matter in
                this case
           number of cross-sections in centerline
Line 3:    empty quotes mark the beginning of a cross-section
           number of cross-section coordinates
           cross-section coordinates (station, elevation)
           distance along centerline—value does not matter in
                this case
           cross-section line length—value does not matter in
                this case
```

Figure 6.12 Change the Pathname in the FILENAME Field



```
The following output from the CSDP

IRREG_GEOM
CHAN      DIST       FILENAME
   6      0.62093    ./6_0.62093.txt
   7      0.25863    ./7_0.25863.txt
END

becomes

IRREG_GEOM
CHAN      DIST       FILENAME
   6      0.62093    c:\input\6_0.62093.txt
   7      0.25863    c:\input\7_0.25863.txt
END
```

Figure 6.13 IRREG_GEOM Input Section

```
IRREG_GEOM
CHAN     DIST       FILENAME
   6     0.62093    ./6_0.62093.txt
   7     0.25863    ./7_0.25863.txt
   7     0.86019    ./7_0.86019.txt
   8     0.13301    ./8_0.13301.txt
   9     0.18331    ./9_0.18331.txt
   9     0.89620    ./9_0.89620.txt
  11     0.05921    ./11_0.05921.txt
END
```

CHAN defines the channel number in the DSM model grid.

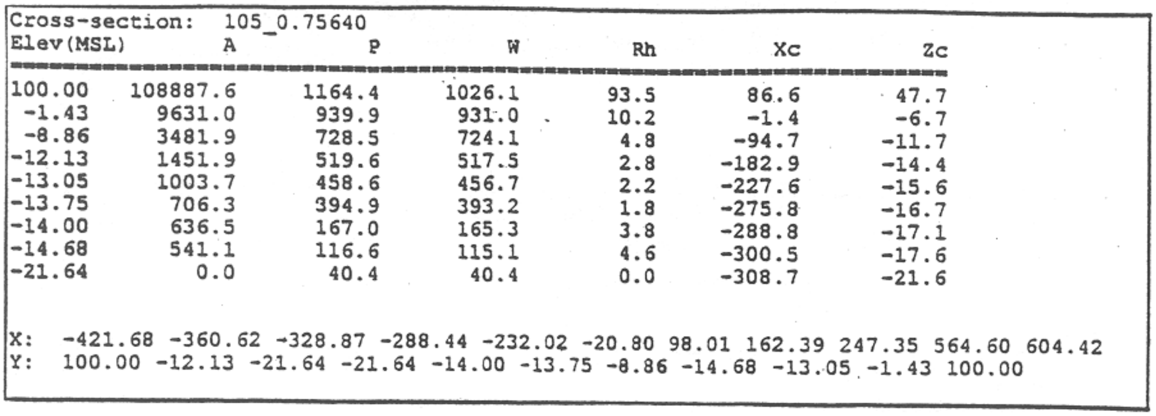
DIST defines the location of a cross-section within a channel. DIST can be the *normalized* distance along the channel measured from the upstream end(a value between 0 and 1), 0, MID, or LENGTH. If DIST is between 0 and 1, the normalized distance will be multiplied by the actual channel length specified in the CHANNELS input section. The normalized distance is calculated by dividing the distance from the upstream end of the centerline(Figure 6-6) to the cross-section line by the total length of the centerline.

FILENAME is the complete pathname of the irregular cross-section file. It will usually be necessary to change the pathname to the directory in which the cross-section files are stored. The filename consists of a channel number followed by an underscore followed by the normalized distance followed by a txt extension.

Figure 6.14 IRREG_GEOM Input Section

```
IRREG_GEOM
CHAN     DIST     FILENAME
# COPIED CROSS-SECTIONS
327      0        C:\input\327_0.44122.txt
327      LENGTH   C:\input\327_0.44122.txt
366      0        C:\input\366_0.54505.txt
366      LENGTH   C:\input\366_0.54505.txt
422      0        C:\input\422_0.88014.txt

# NON-GEOREFERENCED CROSS-SECTIONS
# USGS bathymetry for Upper SJR; not in
CSDP
1        0        C:\input\1u.txt
1        MID      C:\input\1m.txt
2        0        C:\input\2u.txt
3        0        C:\input\3u.txt
3        MID      C:\input\3m.txt
3        LENGTH   C:\input\3d.txt
4        0        C:\input\3d.txt
4        LENGTH   C:\input\3d.txt
5        0        C:\input\6m.txt
5        LENGTH   C:\input\6m.txt

# Three-Mile Sl. averaged cross-sections
309      LENGTH   C:\input\tmsred.txt
309      0        C:\input\tmsavg.txt
310      LENGTH   C:\input\tmsavg.txt
310      0        C:\input\tmsavg.txt
END
```

Figure 6.15 Table of Cross-section Properties (created by CSDP, used by Hydro)



```
Cross-section:  105_0.75640
Elev(MSL)          A             P             W            Rh           Xc           Zc
==========================================================================================
100.00   108887.6        1164.4        1026.1          93.5         86.6         47.7
 -1.43     9631.0         939.9         931.0          10.2         -1.4         -6.7
 -8.86     3481.9         728.5         724.1           4.8        -94.7        -11.7
-12.13     1451.9         519.6         517.5           2.8       -182.9        -14.4
-13.05     1003.7         458.6         456.7           2.2       -227.6        -15.6
-13.75      706.3         394.9         393.2           1.8       -275.8        -16.7
-14.00      636.5         167.0         165.3           3.8       -288.8        -17.1
-14.68      541.1         116.6         115.1           4.6       -300.5        -17.6
-21.64        0.0          40.4          40.4           0.0       -308.7        -21.6


X:   -421.68 -360.62 -328.87 -288.44 -232.02 -20.80 98.01 162.39 247.35 564.60 604.42
Y:   100.00 -12.13 -21.64 -21.64 -14.00 -13.75 -8.86 -14.68 -13.05 -1.43 100.00
```

Figure 6.16 DSM Channel (with user-generated Irregular Cross-Sections and Virtual Cross-Section)

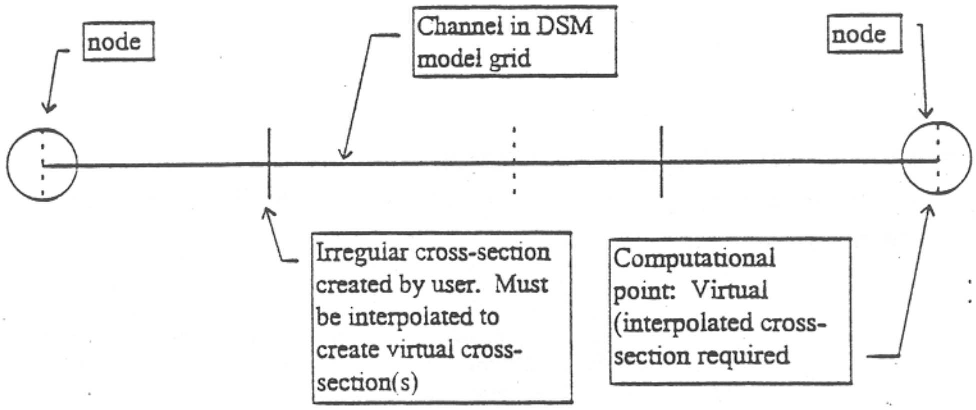


Figure 6.17 Irregular Cross-sections

(A channel with one of more irregular cross-sections will not use any rectangular cross-sections. The irregular cross-section (s) in the channel will be copied, moved, and/or used for interpolation with cross-sections in adjacent channels.)

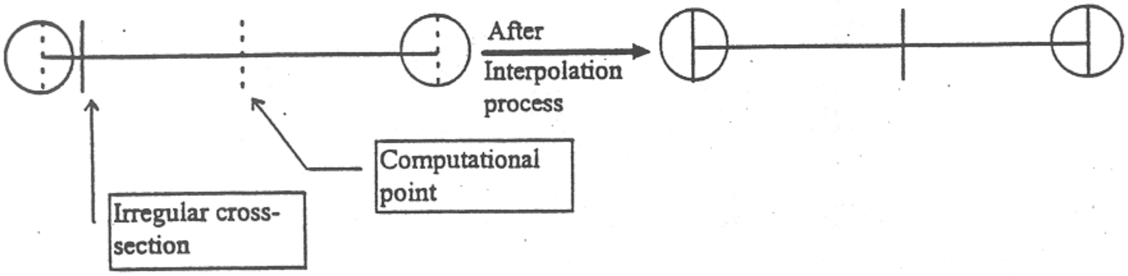


Figure 6.18 Node to Cross-section Distance

(If the distance from the node to the nearest cross-section is within a distance of 5 percent of the channel length, then the cross-section will be moved to the node.)

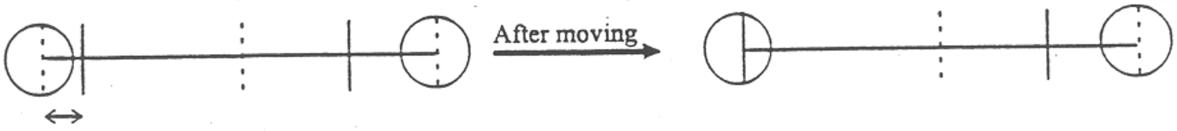


Figure 6.19 Interpolation from Adjacent Channels

(Interpolation from adjacent channels (across nodes) is only allowed if the node is connected to two channels.)

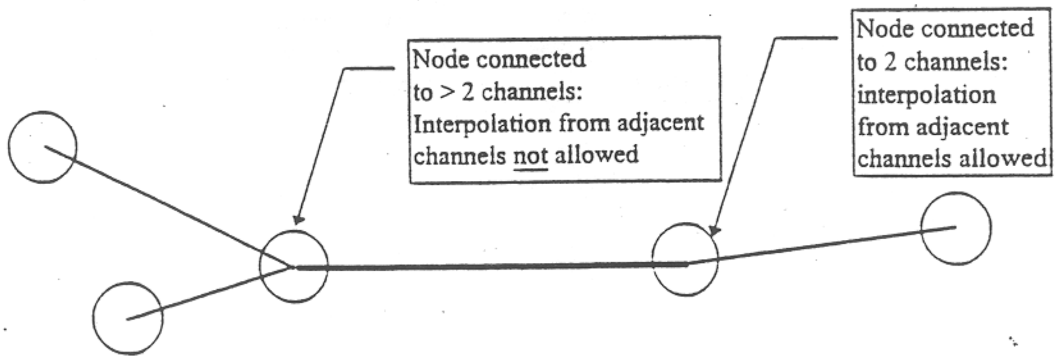


Figure 6.20 Virtual Cross-section Look-up Table for Channel 1

```
VIRTUAL CROSS-SECTION LOOKUP TABLE
 Channel    1,Virtual Section   1
  Height          Width            Area          Wet_p     Z Centroid        min_elev
---------------------------------------------------------------------------------------
  0.00         192.00           0.00        192.00          0.00           -5.10
  5.10         192.00         979.20        202.20          2.55           -5.10
100.00         192.00       19200.00        392.00         50.00           -5.10
 Channel    1,Virtual Section   2
  Height          Width            Area          Wet_p     Z Centroid        min_elev
---------------------------------------------------------------------------------------
  0.00         192.00           0.00        192.00          0.00           -5.10
  5.10         192.00         979.20        202.20          2.55           -5.10
100.00         192.00       19200.00        392.00         50.00           -5.10
 Channel    1,Virtual Section   3
  Height          Width            Area          Wet_p     Z Centroid        min_elev
---------------------------------------------------------------------------------------
  0.00         192.00           0.00        192.00          0.00           -5.10
  5.10         192.00         979.20        202.20          2.55           -5.10
100.00         192.00       19200.00        392.00         50.00           -5.10
```

Figure 6.21 Negative dConveryance and Slope of Line Segment

(Negative dConveyance can occur if the slope of a line segment is very small.)

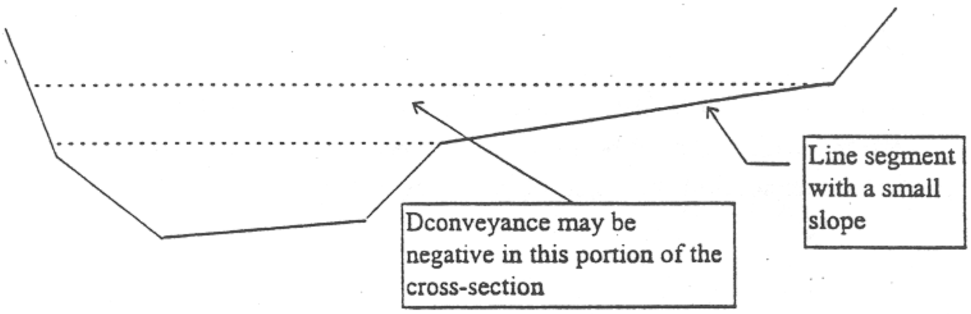


Figure 6.22 Output from Hydro (List of virtual cross-sections with negative dConveyance)

```
Warning:  The following cross-sections have negative dconveyance
 channo   vsecno     depth      min_elev   elevation     cond 0     cond 1
-------------------------------------------------------------------------
        86          2      20.51     -26.23       -5.72  10160.62**********
        86          2      20.52     -26.23       -5.71**********  15889.29
        91          2      28.06     -29.19       -1.13  14857.46-302624.69
        91          2      28.07     -29.19       -1.12-286844.50  15631.51
        95          3      19.58     -25.83       -6.25  12255.03-856674.94
        95          3      19.59     -25.83       -6.24-667307.25  16002.04
```

Figure 6.23a Cross-sections Before Subtracting Bottom Elevations
(Cross-sections with different bottom elevations before subtracting bottom elevation. Negative dConveyance (-dk) exists below -5 ft.)

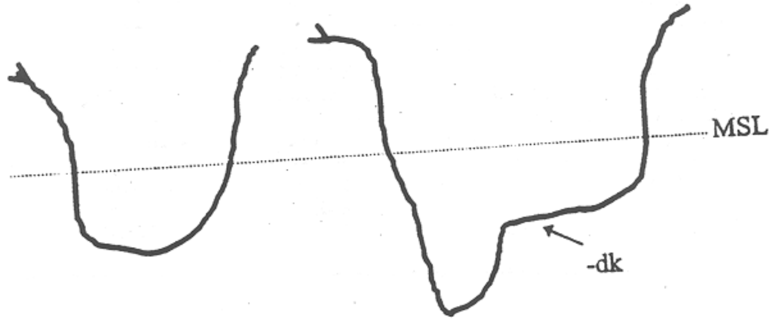


Figure 6.23b Cross-sections After Subtracting Bottom Elevations
(Cross-sections with different bottom elevations after subtracting bottom elevation; interpolated cross-section with interpolated negative dConveyance near MSL.)

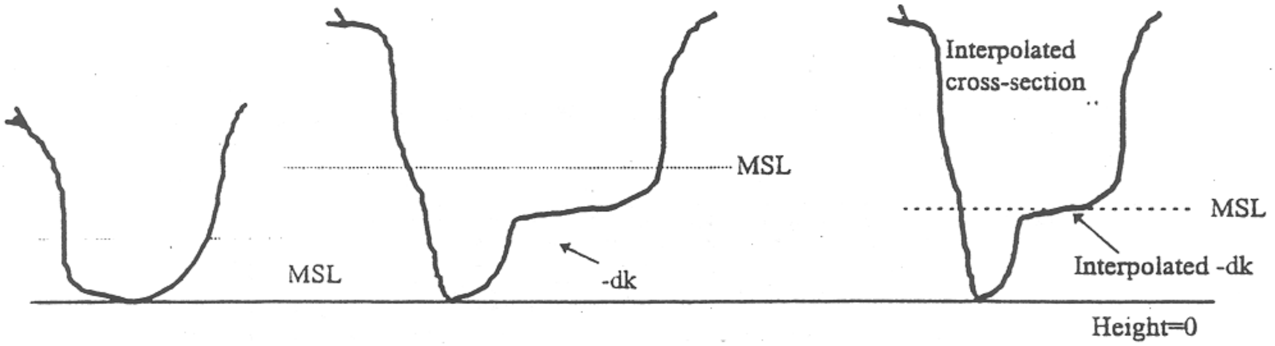


Figure 6.24a Cross-sections Before Subtracting Bottom Elevation (with shaded area)
(Cross-sections with different bottom elevations before subtracting bottom elevation: shaded area could be removed to prevent interpolated negative dConveyance.)

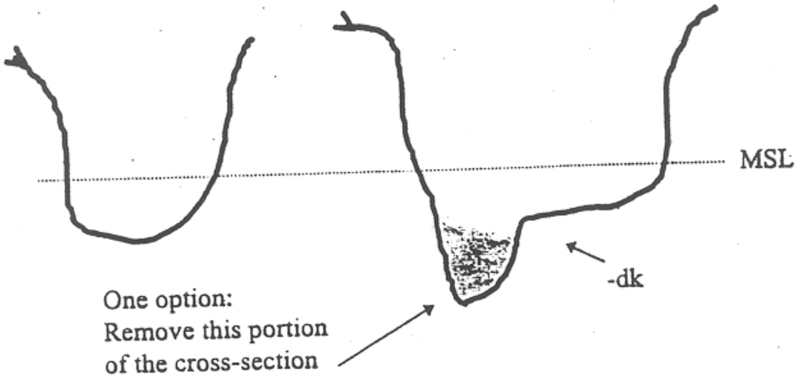
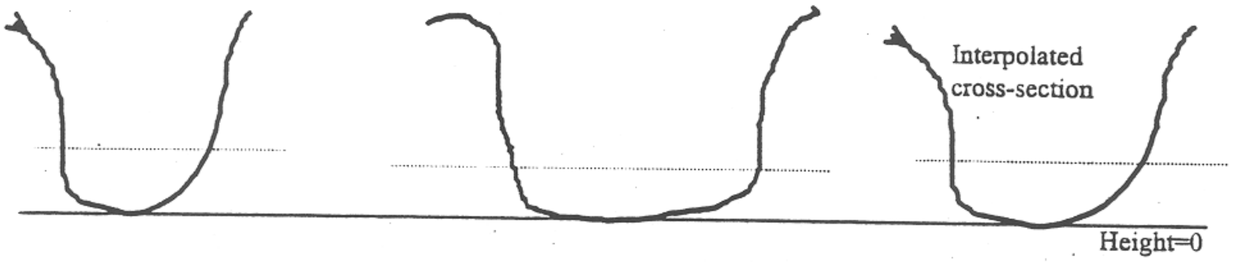


Figure 6.24b Cross-sections Before Subtracting Bottom Elevation (shaded area removed)
(Cross-sections before subtracting bottom elevation-shaded area was removed to prevent interpolated negative dConveyance.)



7

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. = ≨ (monthly calculated C.W.)/≨ (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)

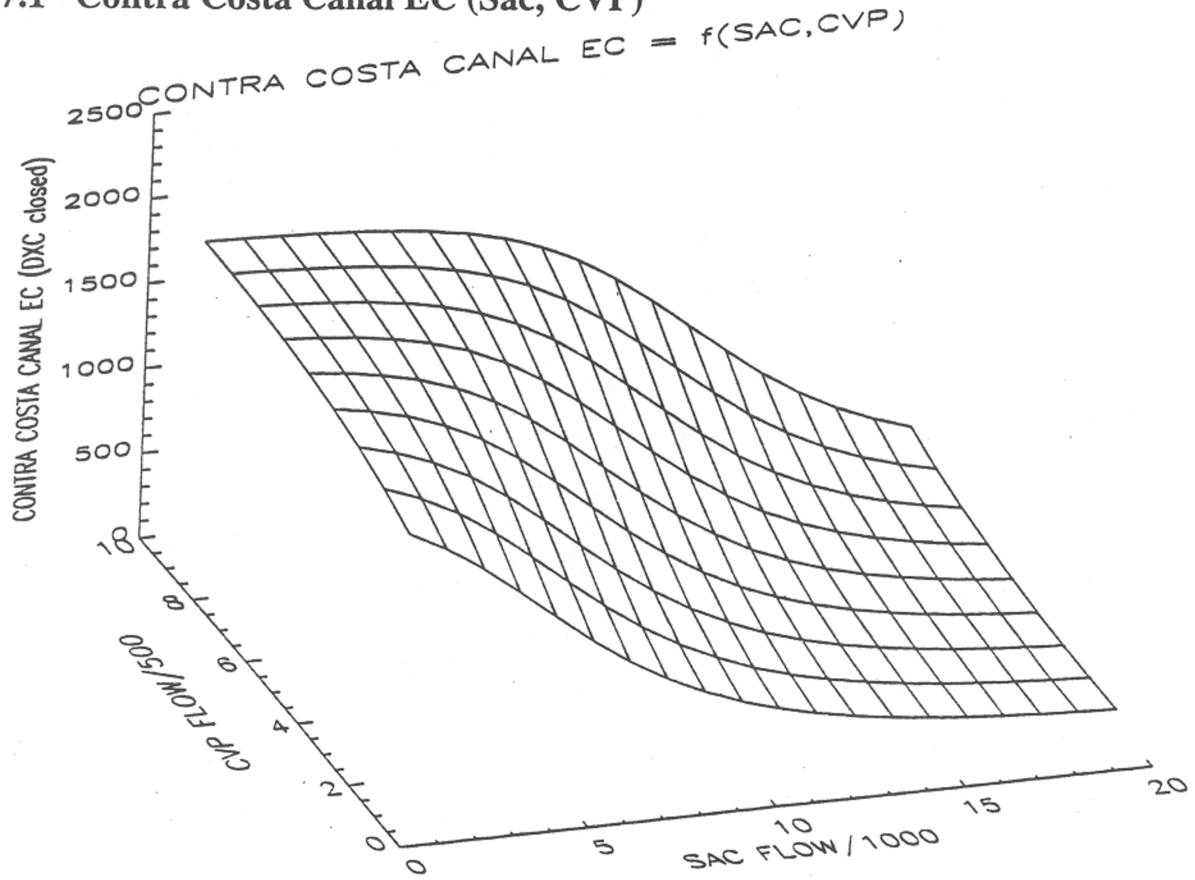


Figure 7.2 Contra Costa Canal EC (Sac, SWP)

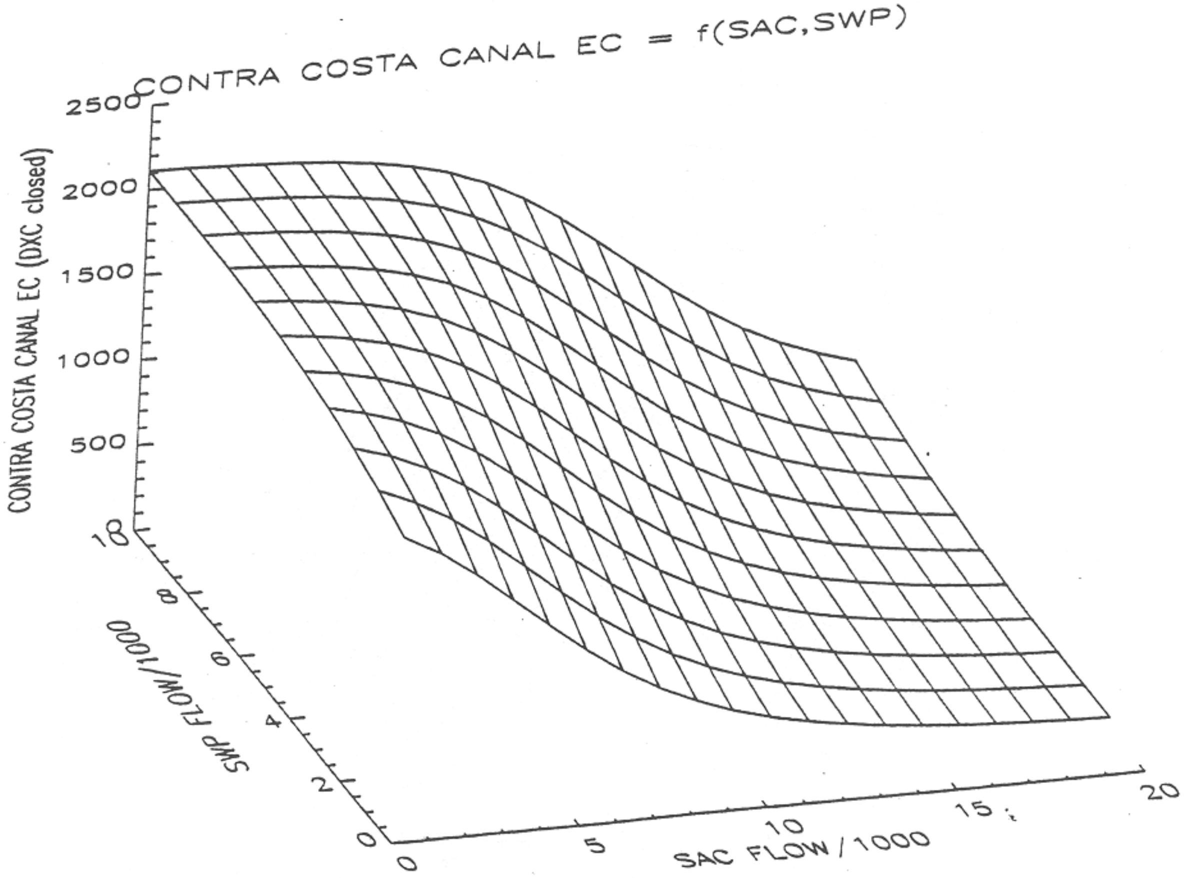


Figure 7.3 Jersey Point EC (Sac, CVP)

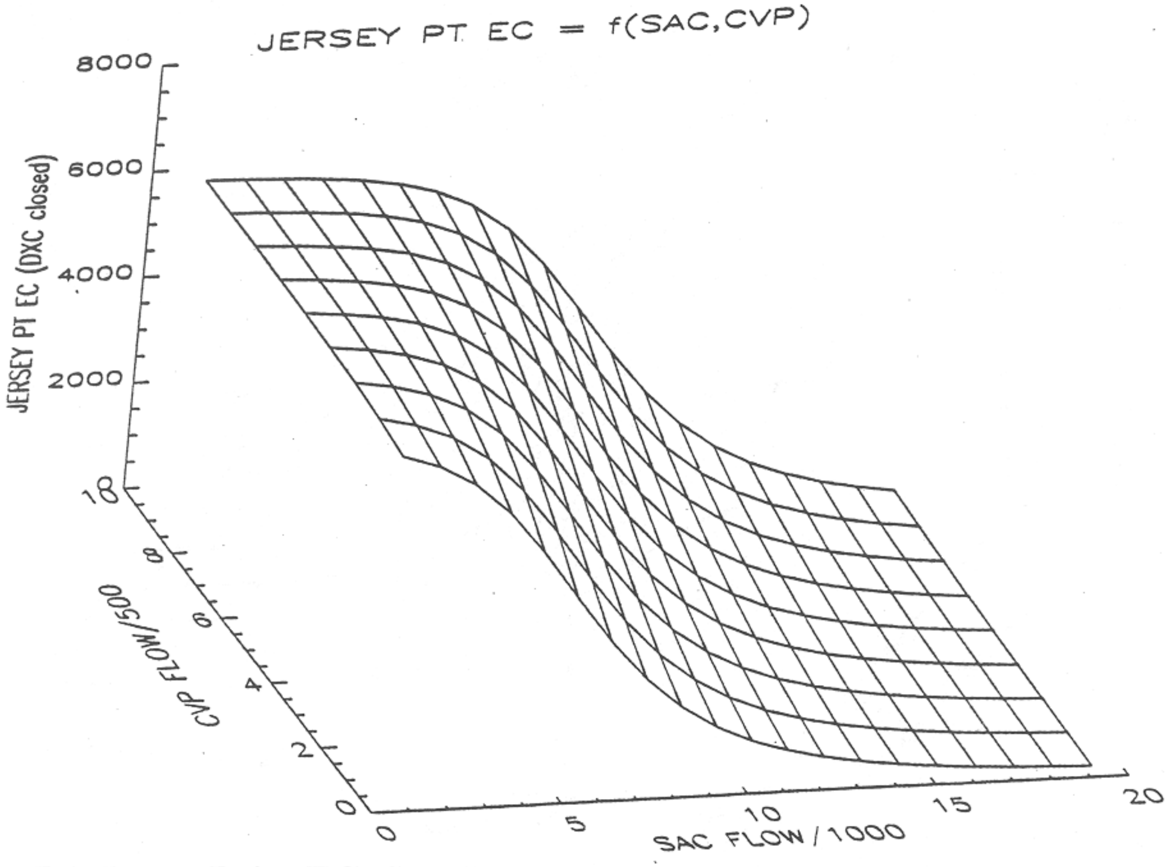
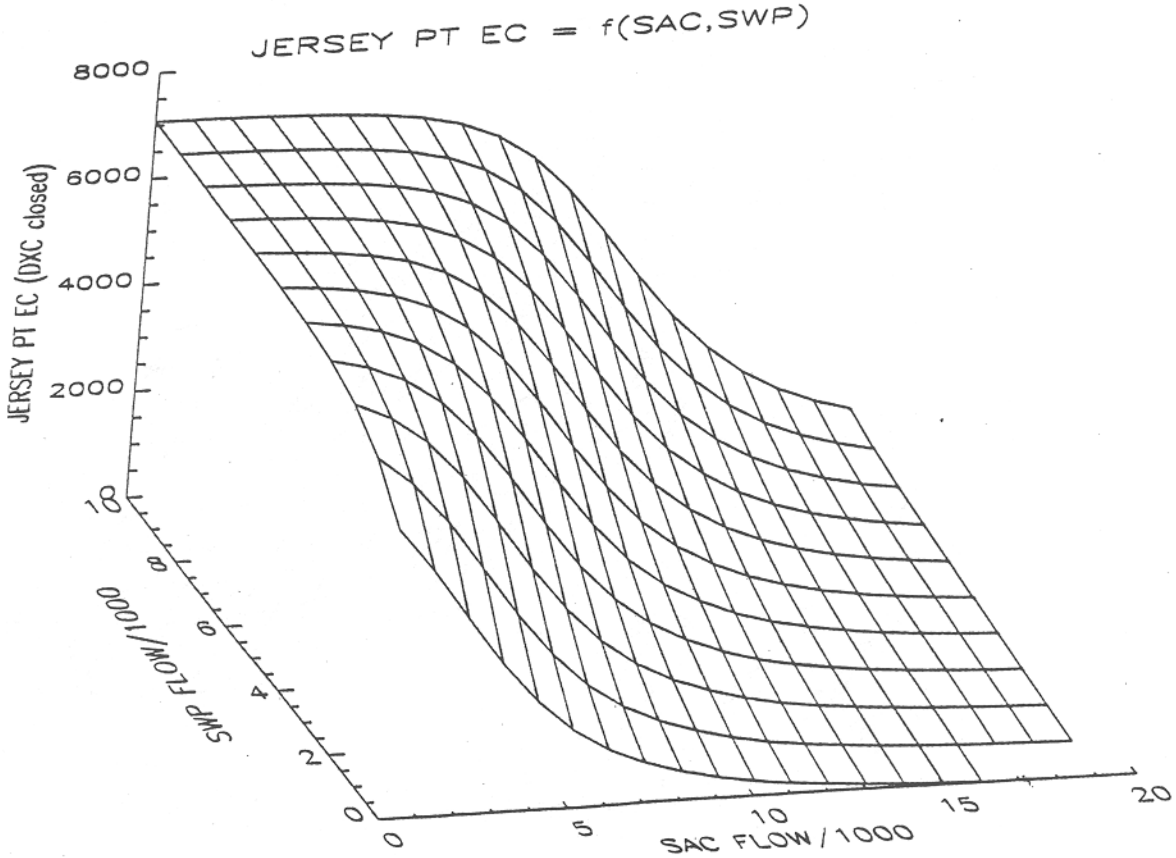


Figure 7.4 Jersey Point EC (Sac, SWP)



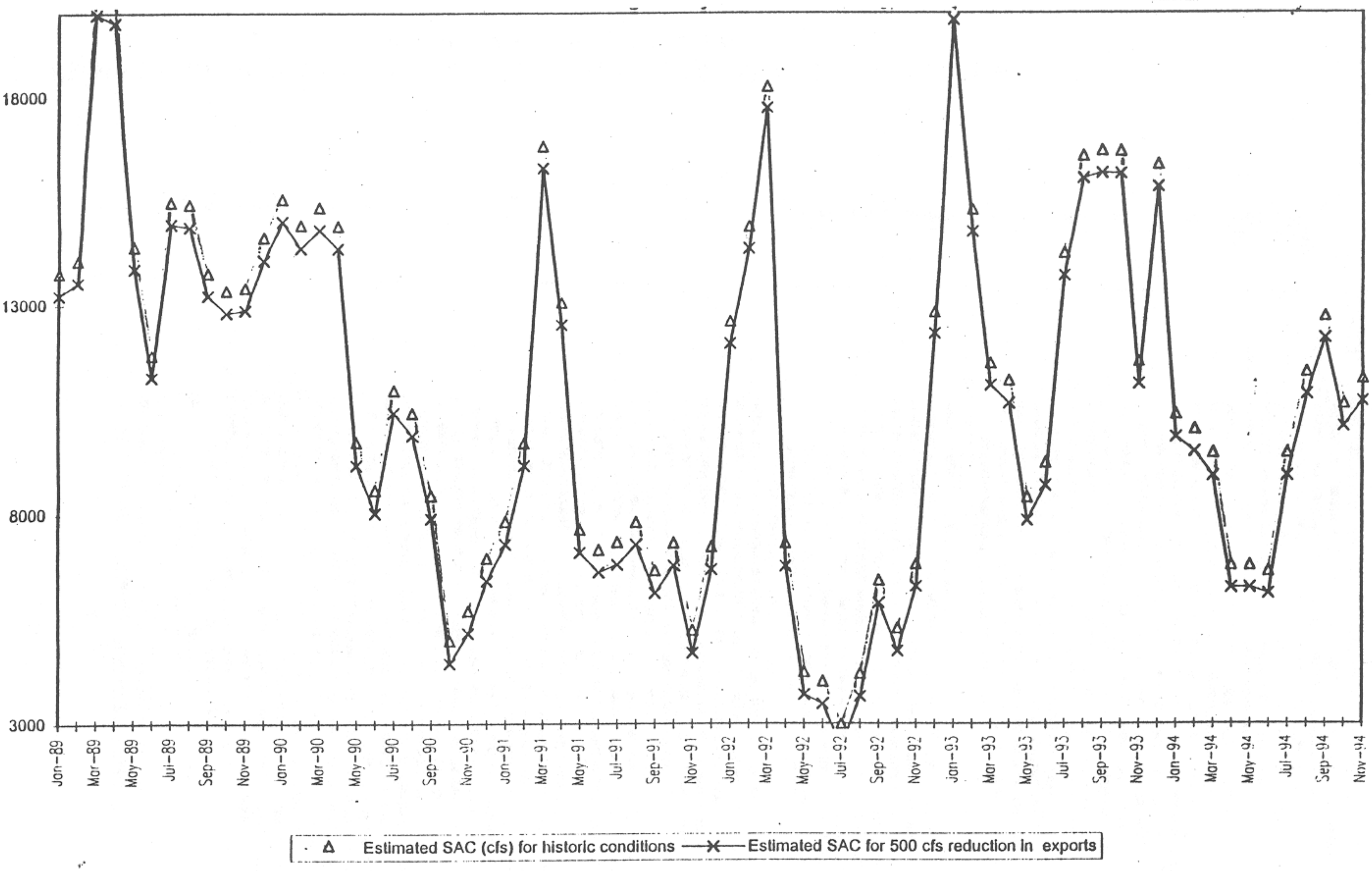


Figure 7.5 Estimated SAC with Historic Exports vs. Estimated SAC when Historic Exports Reduced by 500 cfs (CIMEC method assuming Jersey Point EC controlling)

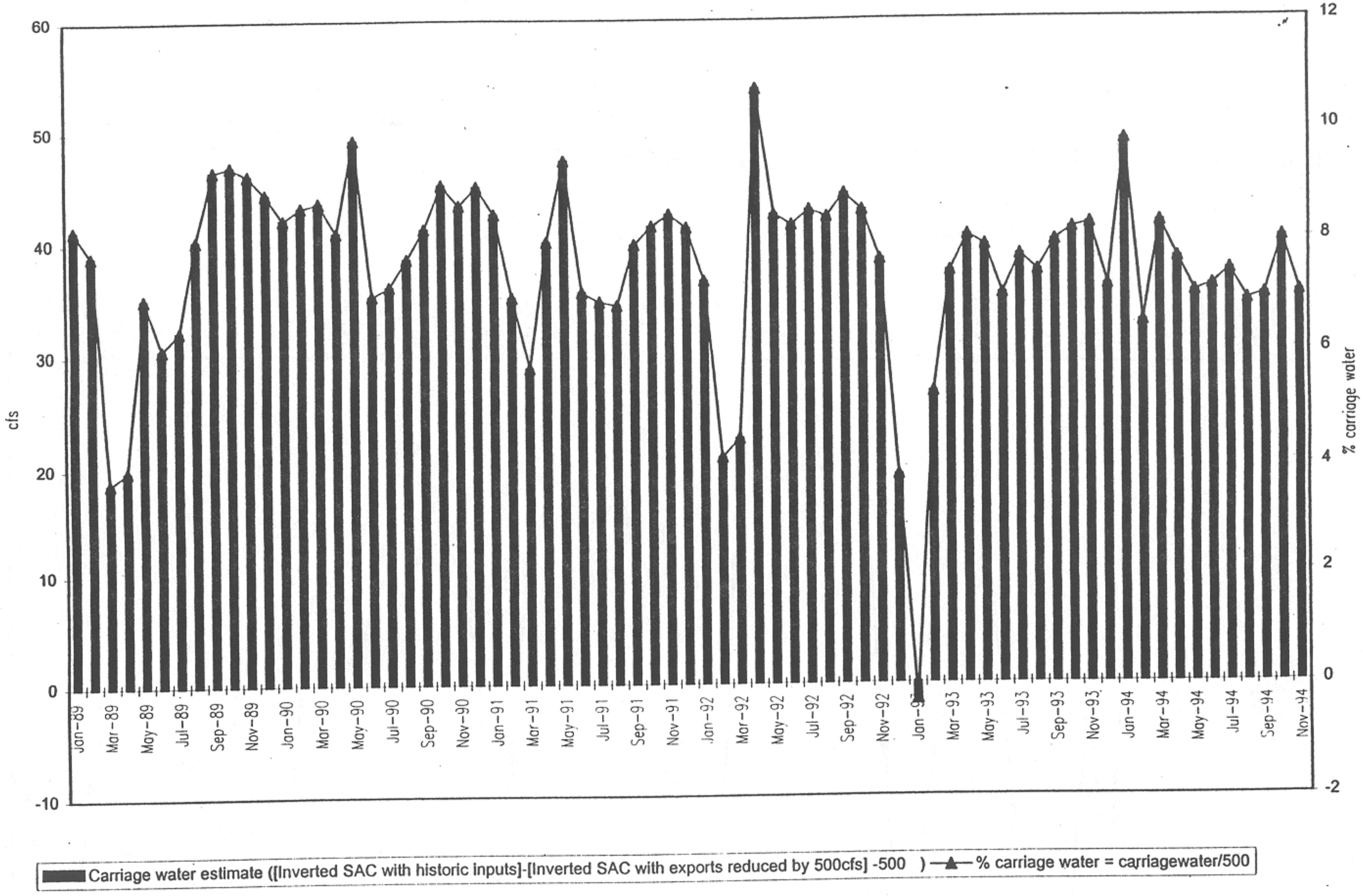


Figure 7.6 Monthly Carriage Water Estimate for a 500 cfs Reduction in Exports (CIMEC method with Jersey Point EC controlling)

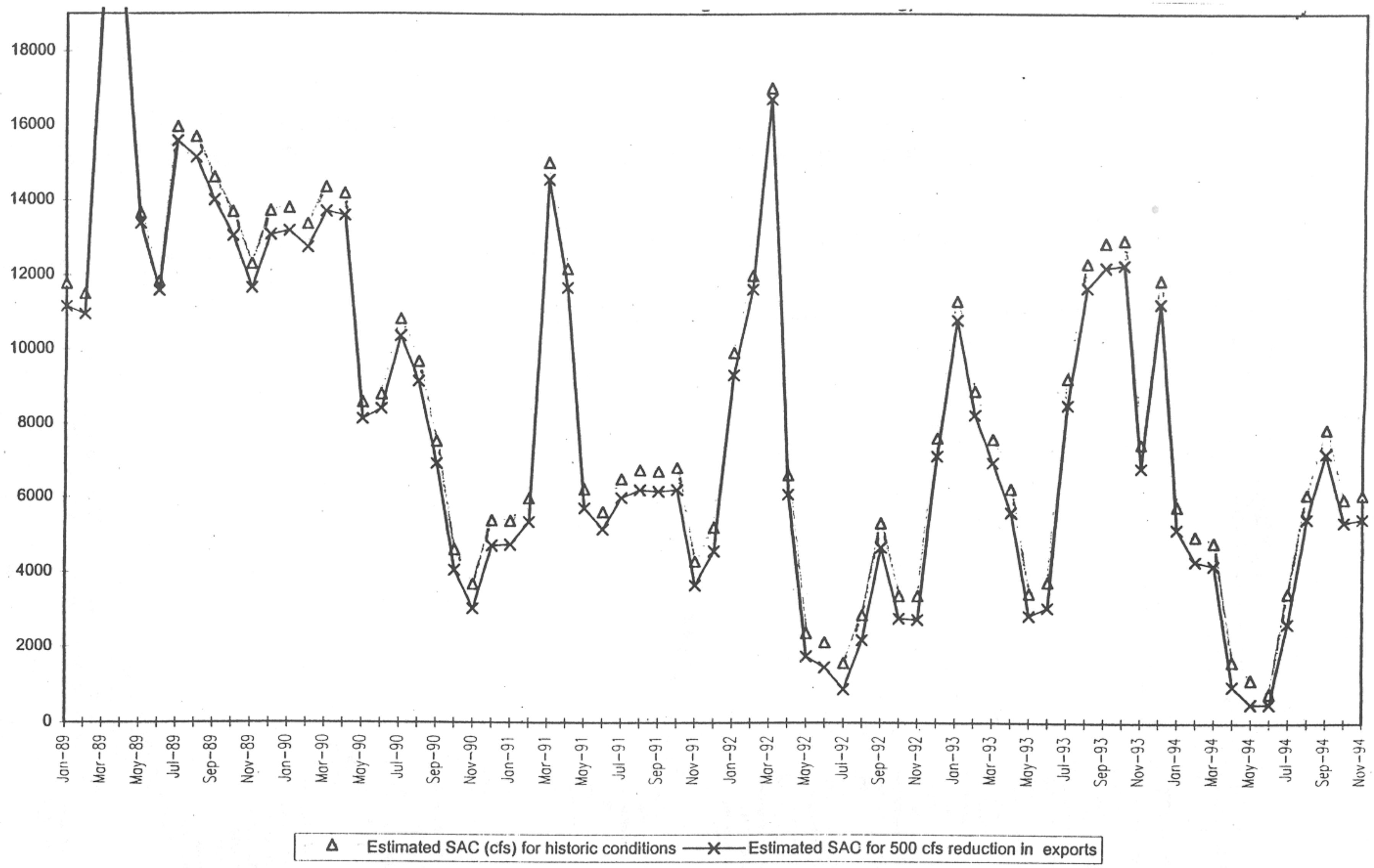


Figure 7.7 Estimated SAC with Historic Exports vs. Estimated SAC when Historic Exports Reduced by 500 cfs (CIMEC method assuming CCC EC controlling)

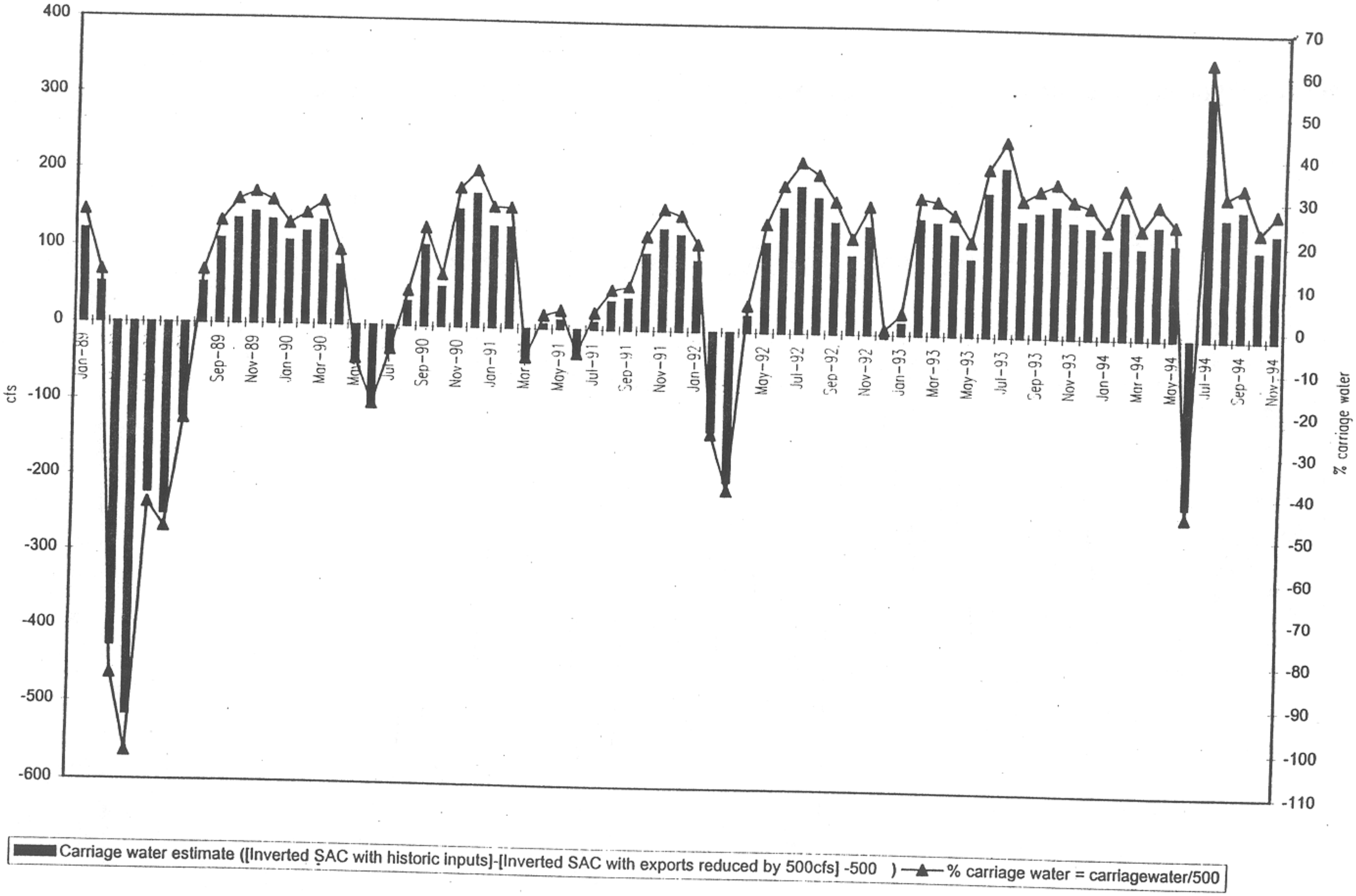


Figure 7.8 Monthly Carriage Water Estimate for a 500 cfs Reduction in Exports (CIMEC method with CCC EC controlling)

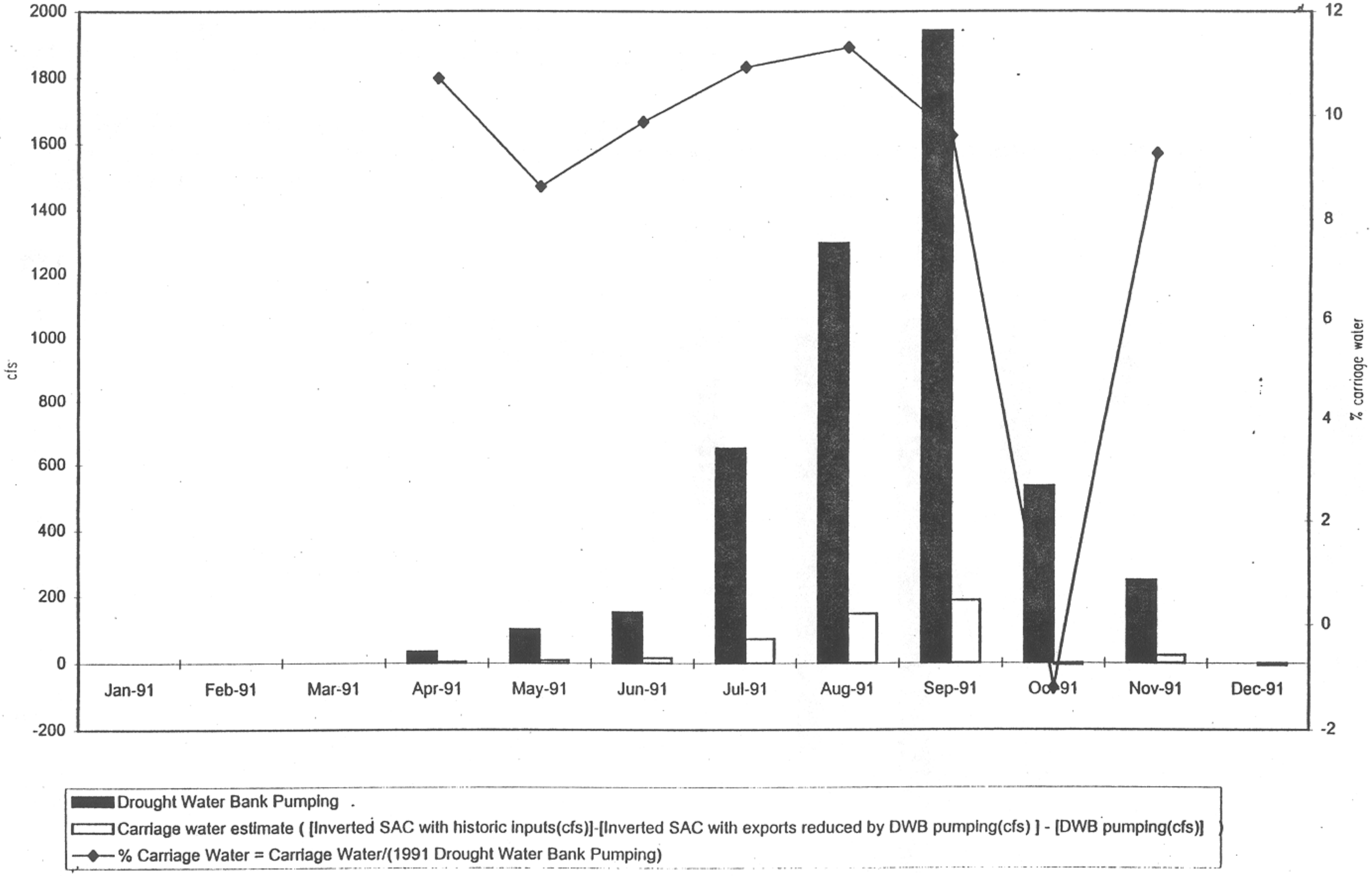


Figure 7.9 **Carriage Water Estimate for 1991 DWB Pumping (CIMEC method with Jersey Point EC controlling)**

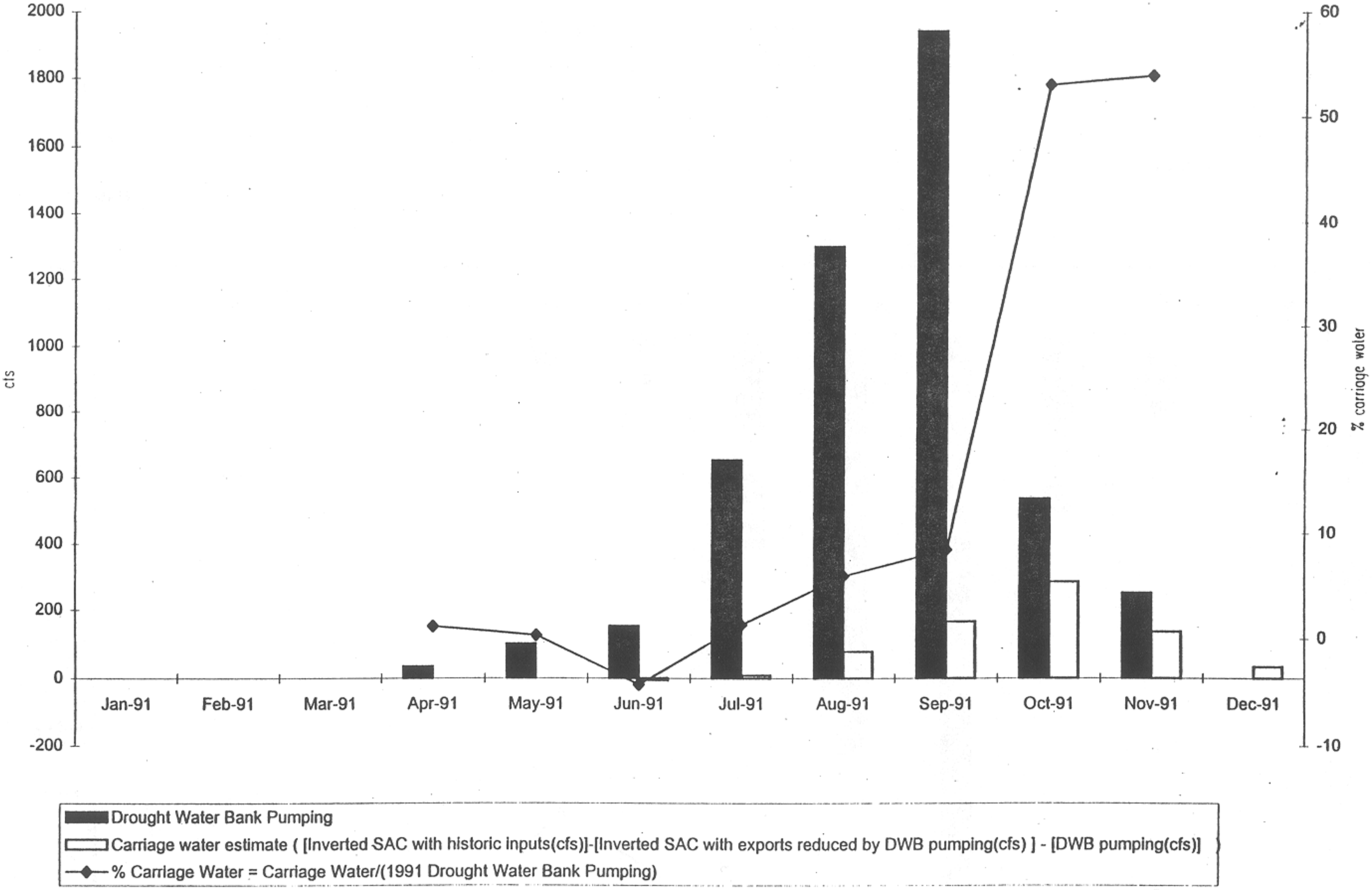


Figure 7.10 Carriage Water Estimate for 1991 DWB Pumping (CIMEC method with CCC EC controlling)

8

VISTA (Visualization Tool and Analyzer)

Introduction

VISTA provides data retrieval, management, manipulation and visualization. The philosophy is to access, manipulate and visualize data with ease. A graphical user interface is provided for first time and occasional users. A scripting language will be provided for power users to automate batch production.

Data retrieval is accomplished using a two-tier client server architecture. The data resides on a server and the bulk of the application resides on the client. The server can serve data locally and over the network.

Data management is accomplished using data reference. A data reference is to the location of the data set and its characteristics. For instance, a time series data is referred to by a server address, filename, pathname, time window, and a time interval. Some data references do not refer to actual data but to the set of data references and the operations to be performed on them to construct the data set. This provides transparency to the user. For the user there is no difference between such virtual data sets and the actual data sets.

Data references can be aggregated in to a Group (Figure 2). The default view on a database file is a Group. Furthermore, one or more Groups form a Session (Figure 1). A Session can be saved and loaded from a file once created. The initial Session is created by opening a connection to a server and directory. The directory of database files then becomes a Session and each file becomes a Group containing data references.

Data manipulation is done by creating virtual data references which contain the set of data references and the operations to be performed. The actual operations on the data are performed when the data for the reference is requested. Math operation such as division, multiplication, addition and subtraction are available between data sets. Period average and moving average, and merging are data references which are some other examples of manipulations on data sets.

Data visualization is done by two-dimensional plots (Figure 3). Examples of such plots are time series plots and scatter plots. Zooming in and out and paging while zooming are some of the tools that are available. Printing is available in gif and postscript formats. A user has control of the attributes of each element in the graph. The user can change the text, font, size, color and background color of the title. Most of these attributes can be saved to a file and applied to subsequent plots. Data can also be displayed and manipulated in tabular format (Figure 4).

A graphical user interface is used to display a group of data references. The GUI is a view onto the application and does not contain information about the application other than the way the application desires to be displayed. This separation lets support of undo/redo commands and the recording of macros which can be replayed on different sessions.

Scripting is an efficient way of accomplishing repetitive tasks. Scripting would use the same application as the GUI and could use some of the GUI components.

Implementation

This application was done in Java. Java was chosen for ease of development and wide industry support. This ensures long-term support and multiplatform portability. Java is ideal for a client-server architecture. One of the disadvantages of Java is efficiency of memory and cpu resources. Just-In-Time Compilers and better virtual machine implementations are bringing the efficiency of Java closer to traditional languages such as C++ and Fortran. The client side GUI is in Java and will run as-is on platforms supporting Java. This effort was made to allow the client to run embedded in a web browser. This will enable anyone on the Internet with a web browser to use the latest version of the client and manage and visualize the data in the form that they desire. The server side is written using Java, FORTRAN and C languages and as such will be made available and supported on Solaris and Windows NT platforms. The database used to store data is HEC-DSS, however all the details of database specific access are isolated on the server side. This makes the client unware of the actual mechanisms of data storage. Object-oriented analysis and design techniques with an evolutionary prototype approach was used throughout this project.

Future

The concept of client-server is new in the modeling world. Many new concepts are being tried here for the first time. Other than a few minor glitches work has progressed to the implementation and distribution of the first beta version of VISTA. A second beta version with flag editing and writing data back to the server will be made available in the early part of June.

Some ideas for the future are :

1. Improving the 2D graphics by using the latest library from Java

2. Improving the postscript printing to provide production quality printouts

3. Graph editing tools

4. Scripting language for batch processing of data

5. A schematic as an alternative view of a Group

6. Report generation for the automatic formatted generation of reports

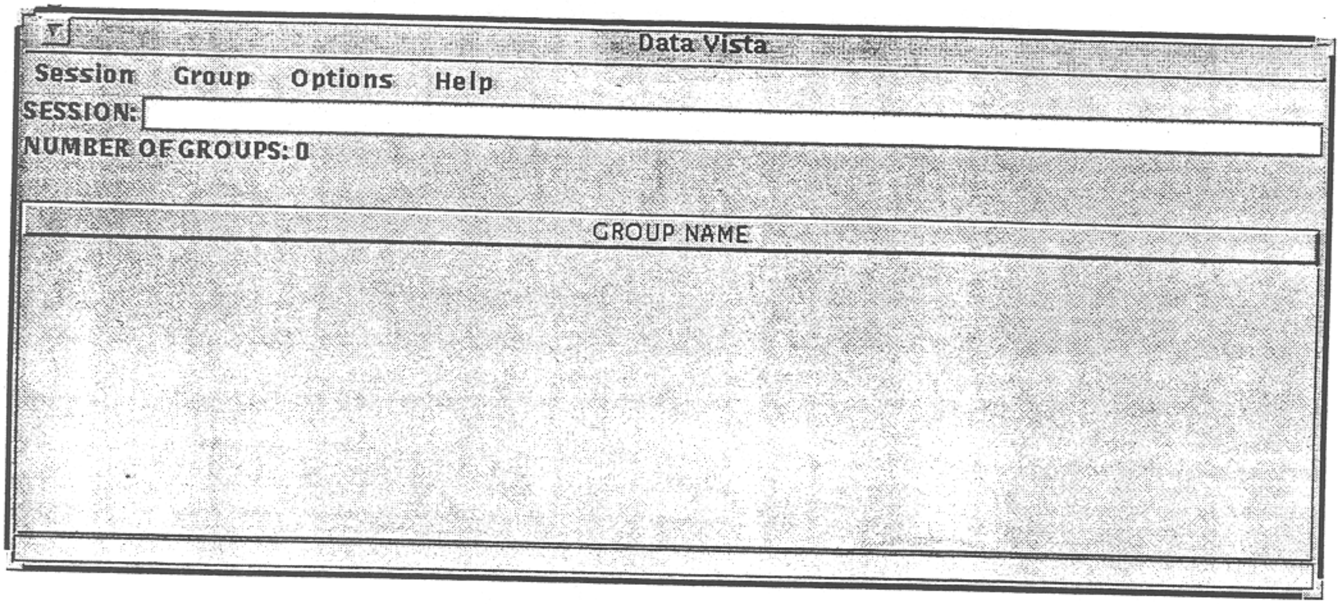
7. Animation facilities for easy set up of animation of time varying data

8. Online context sensitive help for the application

9. Security and access control levels as fine as individual data sets

A first beta version of VISTA was released to the Modeling Section in April 1998. A second beta version of VISTA with more features will be released in early June 1998. A first version of VISTA with all the features will be released in 1999.

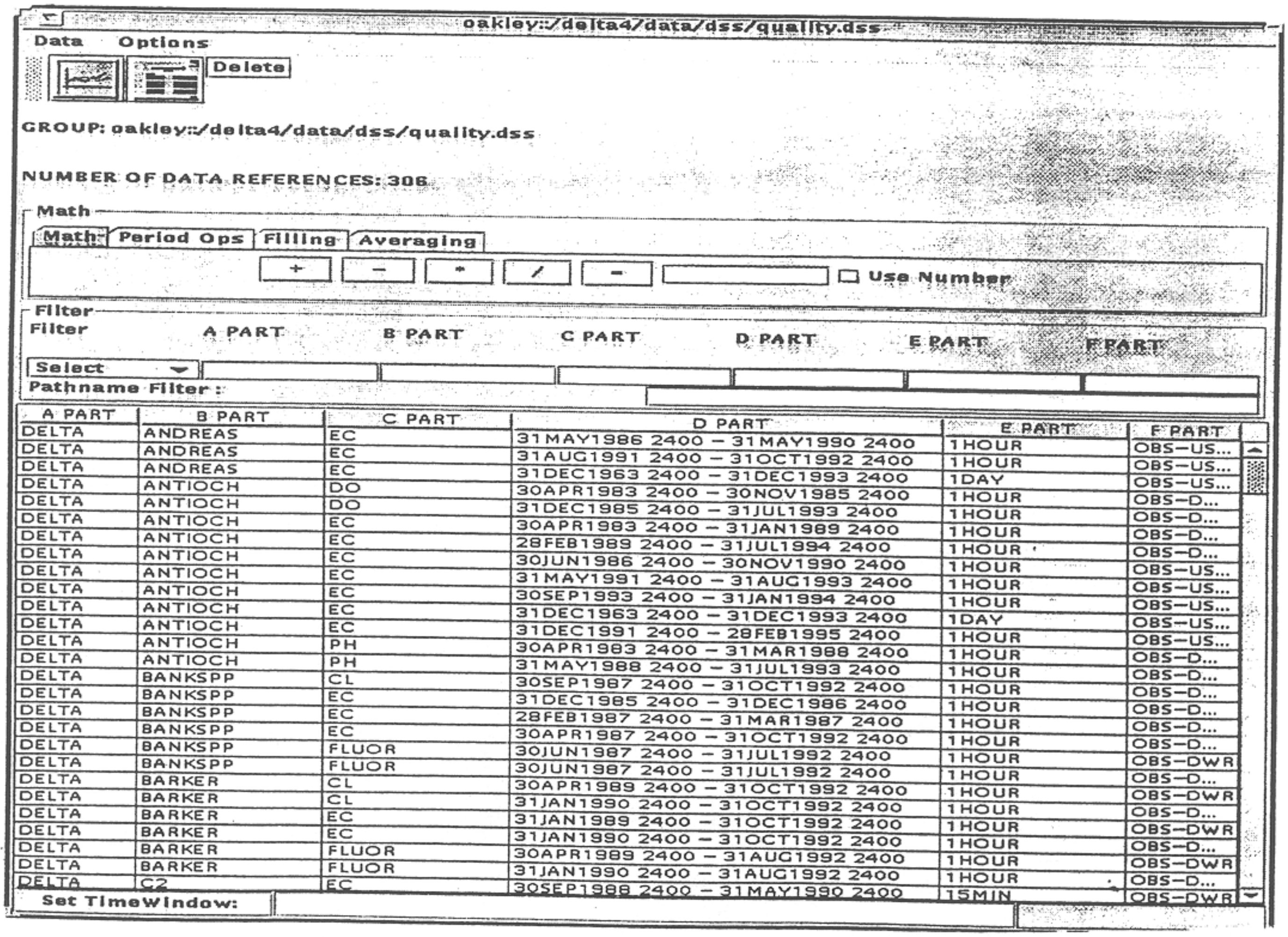
Figure 8.1 Data Sessions



SESSION:

NUMBER OF GROUPS: 0

Figure 8.2 Data Reference Groups

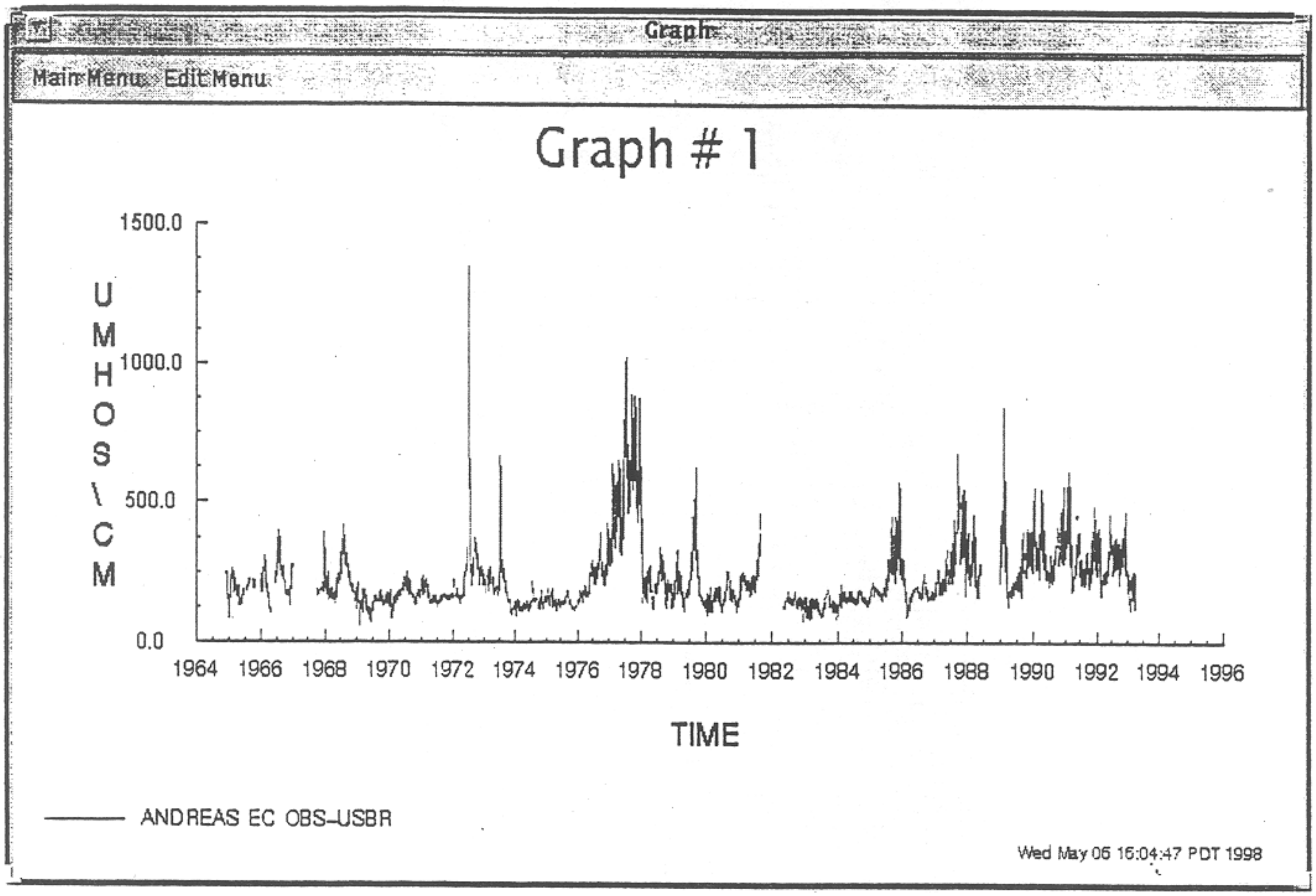


GROUP: oakley::/delta4/data/dss/quality.dss

NUMBER OF DATA REFERENCES: 306

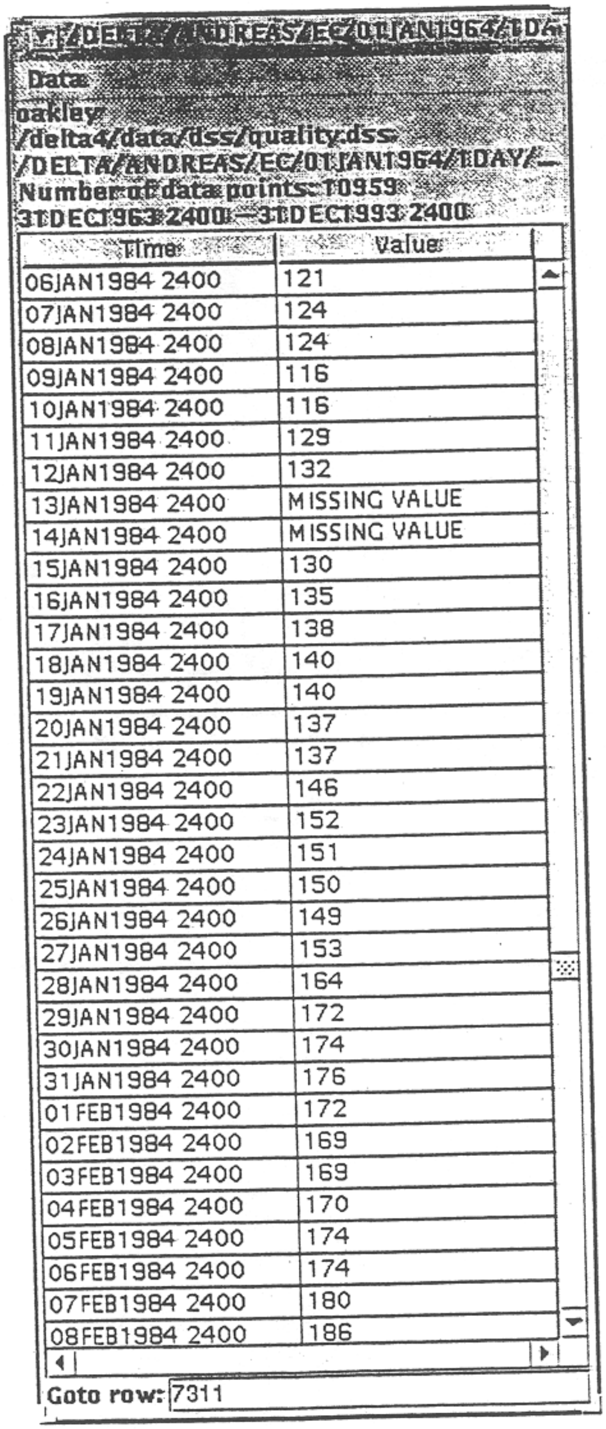
A PART	B PART	C PART	D PART	E PART	F PART
DELTA	ANDREAS	EC	31MAY1986 2400 – 31MAY1990 2400	1HOUR	OBS–US...
DELTA	ANDREAS	EC	31AUG1991 2400 – 31OCT1992 2400	1HOUR	OBS–US...
DELTA	ANDREAS	EC	31DEC1963 2400 – 31DEC1993 2400	1DAY	OBS–US...
DELTA	ANTIOCH	DO	30APR1983 2400 – 30NOV1985 2400	1HOUR	OBS–D...
DELTA	ANTIOCH	DO	31DEC1985 2400 – 31JUL1993 2400	1HOUR	OBS–D...
DELTA	ANTIOCH	EC	30APR1983 2400 – 31JAN1989 2400	1HOUR	OBS–D...
DELTA	ANTIOCH	EC	28FEB1989 2400 – 31JUL1994 2400	1HOUR	OBS–D...
DELTA	ANTIOCH	EC	30JUN1986 2400 – 30NOV1990 2400	1HOUR	OBS–US...
DELTA	ANTIOCH	EC	31MAY1991 2400 – 31AUG1993 2400	1HOUR	OBS–US...
DELTA	ANTIOCH	EC	30SEP1993 2400 – 31JAN1994 2400	1HOUR	OBS–US...
DELTA	ANTIOCH	EC	31DEC1963 2400 – 31DEC1993 2400	1DAY	OBS–US...
DELTA	ANTIOCH	EC	31DEC1991 2400 – 28FEB1995 2400	1HOUR	OBS–US...
DELTA	ANTIOCH	PH	30APR1983 2400 – 31MAR1988 2400	1HOUR	OBS–D...
DELTA	ANTIOCH	PH	31MAY1988 2400 – 31JUL1993 2400	1HOUR	OBS–D...
DELTA	BANKSPP	CL	30SEP1987 2400 – 31OCT1992 2400	1HOUR	OBS–D...
DELTA	BANKSPP	EC	31DEC1985 2400 – 31DEC1986 2400	1HOUR	OBS–D...
DELTA	BANKSPP	EC	28FEB1987 2400 – 31MAR1987 2400	1HOUR	OBS–D...
DELTA	BANKSPP	EC	30APR1987 2400 – 31OCT1992 2400	1HOUR	OBS–D...
DELTA	BANKSPP	FLUOR	30JUN1987 2400 – 31JUL1992 2400	1HOUR	OBS–DWR
DELTA	BANKSPP	FLUOR	30JUN1987 2400 – 31JUL1992 2400	1HOUR	OBS–D...
DELTA	BARKER	CL	30APR1989 2400 – 31OCT1992 2400	1HOUR	OBS–DWR
DELTA	BARKER	CL	31JAN1990 2400 – 31OCT1992 2400	1HOUR	OBS–D...
DELTA	BARKER	EC	31JAN1989 2400 – 31OCT1992 2400	1HOUR	OBS–DWR
DELTA	BARKER	EC	31JAN1990 2400 – 31OCT1992 2400	1HOUR	OBS–D...
DELTA	BARKER	FLUOR	30APR1989 2400 – 31AUG1992 2400	1HOUR	OBS–DWR
DELTA	BARKER	FLUOR	31JAN1990 2400 – 31AUG1992 2400	1HOUR	OBS–D...
DELTA	C2	EC	30SEP1988 2400 – 31MAY1990 2400	15MIN	OBS–DWR

Figure 8.3 Two-dimensional Plots



Wed May 06 15:04:47 PDT 1998

Figure 8.4 Data Displayed in Tabular Format



/DELTA/ANDREAS/EC/01JAN1964/1DA

Data

oakley
/delta4/data/dss/quality.dss
/DELTA/ANDREAS/EC/01JAN1964/1DAY/—
Number of data points: 10959
31DEC1963 2400 — 31DEC1993 2400

Time	Value
06JAN1984 2400	121
07JAN1984 2400	124
08JAN1984 2400	124
09JAN1984 2400	116
10JAN1984 2400	116
11JAN1984 2400	129
12JAN1984 2400	132
13JAN1984 2400	MISSING VALUE
14JAN1984 2400	MISSING VALUE
15JAN1984 2400	130
16JAN1984 2400	135
17JAN1984 2400	138
18JAN1984 2400	140
19JAN1984 2400	140
20JAN1984 2400	137
21JAN1984 2400	137
22JAN1984 2400	146
23JAN1984 2400	152
24JAN1984 2400	151
25JAN1984 2400	150
26JAN1984 2400	149
27JAN1984 2400	153
28JAN1984 2400	164
29JAN1984 2400	172
30JAN1984 2400	174
31JAN1984 2400	176
01FEB1984 2400	172
02FEB1984 2400	169
03FEB1984 2400	169
04FEB1984 2400	170
05FEB1984 2400	174
06FEB1984 2400	174
07FEB1984 2400	180
08FEB1984 2400	186

Goto row: 7311

9

DSM2 Calibration/Verification

Calibration-Validation Scheme

Two types of model runs are used to calibrate and validate DSM2. For both Hydro and Qual, a realtide run, based on historic, observed data, may be used. In this mode, 15 minute or hourly historic stages and ECs are used for Hydro and Qual at the downstream boundary (Martinez), and hourly or daily historic flows and water quality values are used for rim locations, pumping, and internal sources and sinks such as agricultural diversions, drainages, and seepage from channels to islands. Gates are operated according to historic timing data. Typically realtide runs are several months or a year in length.

A planning run is used primarily to calibrate and validate Qual. In this mode, a 19-year repeating mean tide is used as the Martinez stage boundary in Hydro. Monthly averaged flows and exports are used instead of daily flows. Gates are fixed in one position for each month. A tidefile is generated for each month, representing the average tidal flows for that month. A series of tidefiles are thus generated, and Qual run over the series. Planning runs are usually 15-25 years in length.

Calibration Description

The most recent calibration, finished in July 1997, is a relatively small adjustment to the first calibration of DSM2, finished in June 1997 and documented in our 1997 Annual Progress Report. This recalibration was needed because of a generalization and more accurate treatment of irregular cross-sections within DSM2-Hydro. The changes made with respect to the previous calibration were to decrease Manning's N coefficients in the Suisun Bay and lower Sacramento River, and to increase the dispersion coefficients in the lower San Joaquin River. Both coefficients in those areas are now somewhat more realistic, and it illustrates indirectly once again the importance of having a realistic channel bathymetry. Additional information on the calibration and validation of the model can be found ont he section's world wide web home page: http://wwwdelmod.water.ca.gov.

DWR/Delta Modeling Section

Delta Simulation Model II - Calibration Plots

This section provides detailed plots of the DSM2 Hydro and Qual calibration periods.

Delta Simulation Model II - Hydro Calibration

Hydro: Stage amplitude, instantaneous flow, and residual flows are provided for comparison to observed data.

Stage Amplitudes

We find it helpful to plot the daily maximum and minimum amplitudes of stages to see how well the downstream boundary tidal stage at Martinez propagates upstream into the estuary. Flows, and thus salinity, are quite sensitive to how the stage is propagated—an attenuated propagation will reduce tidal flow excursions and reduce ocean salt intrusion. Stages are easily attenuated by increasing channel friction (Manning's N coefficient).

- Martinez-Mallard Is.
- Antioch-Three Mile Slough
- Collinsville-Rio Vista

Flows

Four different time periods were used to compare computed with observed flows: May 1988 (mostly tide cycle measurements), December 1992-January 1993, May 1994-July 1994, and October 1994. Different periods were required to cover a range of barrier operations and available data.

May 1988-Instantaneous Measurements

- San Joaquin R. @ Hwy 4-Old R. blw Tracy Rd.
- Old & Middle R. @ Bacon Is.
- Columbia & Turner Cuts
- Grantline Canal-Old R. nr. Clifton Ct. Forebay
- Piper & Dutch Sl.
- Three Mile Sl.-Jersey Pt.
- Potato Sl.-Honker Cut
- North & South Fork Mokelumne R.
- Georgiana Sl.
- Miner & Steamboat Sl.
- Sacramento R. South of Decker Is.

North Delta

- Sacramento R. abv DXC, blw Georgiana Sl. (resid)
- Delta Cross Channel (resid)
- Steamboat+Sutter Sl.-Cross Delta (resid)
- Sacramento R. @ Freeport,DXC,Georgiana Sl. (inst)
- Sacramento R. @ Freeport,DXC,Georgiana Sl. (resid)
- Sacramento R. abv DXC, blw Georgiana Sl. (inst)
- Sacramento R. abv DXC, blw Georgiana Sl. (resid)

Jersey Point—Three Mile Slough

- Three Mile Sl.-Jersey Pt. (inst)
- Three Mile Sl.-Jersey Pt. (resid)
- Three Mile Sl.-Jersey Pt. (inst)
- Three Mile Sl.-Jersey Pt. (resid)

Central Delta

- Central Delta (resid)
- Old R.-Middle R. (inst)
- Old R.-Middle R. (resid)

Delta Simulation Model II - Qual Calibration

Qual: In general the plots for this run are an improvement over the previous calibration, more so in the Western Delta where the exaggerated increased salinity in the Suisun Bay has been tempered to only a moderate increase. As a result, salinities in the lower Sacramento River are lower than observed, and a little lower even than the previous run, though we believe still acceptable.

Real-Tide EC

The period January to August 1992 was chosen to calibrate DSM2 using real (observed) tides (stages) at Martinez, along with observed hourly salinity at Martinez. Daily rim hydrologies were used, as well as historic gate timings. However, we may have incorrect data or model operation with respect to the barriers in the Southern Delta (Old and Middle River); see the Union Island plot as an example.

- Mallard Island and Collinsville
- Emmaton and Rio Vista
- Antioch and Jersey Point
- Holland Tract and Contra Costa Canal Pumping Plant #1
- Victoria Island and Union Island
- Stockton and Mossdale

Planning EC

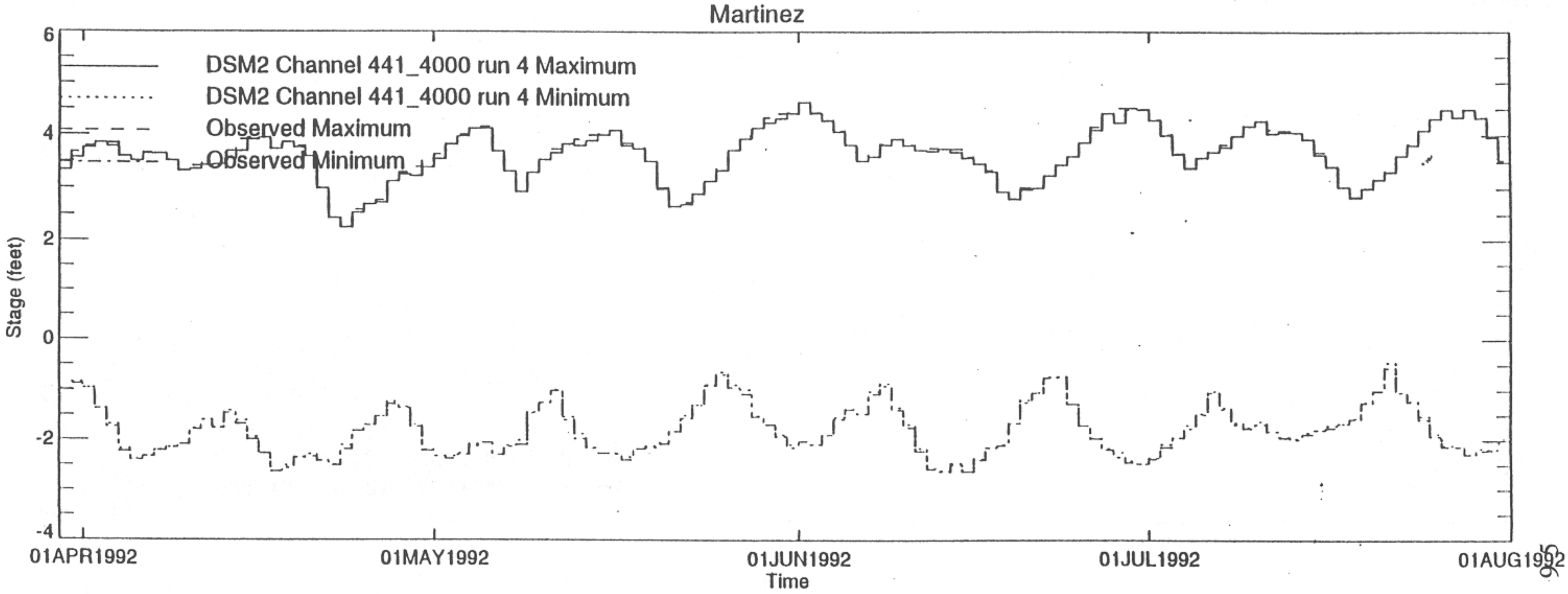
A Planning EC run differs from a real tide run in two significant respects: the downstream stage is a 19-year averaged stage, period 25 hours, in which the stage at t=26 hours is equal to the stage at t=1 hour; and rim flows and gate operations are monthly averages or approximations of historic data. Thus, a Planning Qual run is not intended to strictly simulate a historic condtion. Nevertheless it is still useful to compare such a run to historic data to see general trends over many years of different hydrologies.

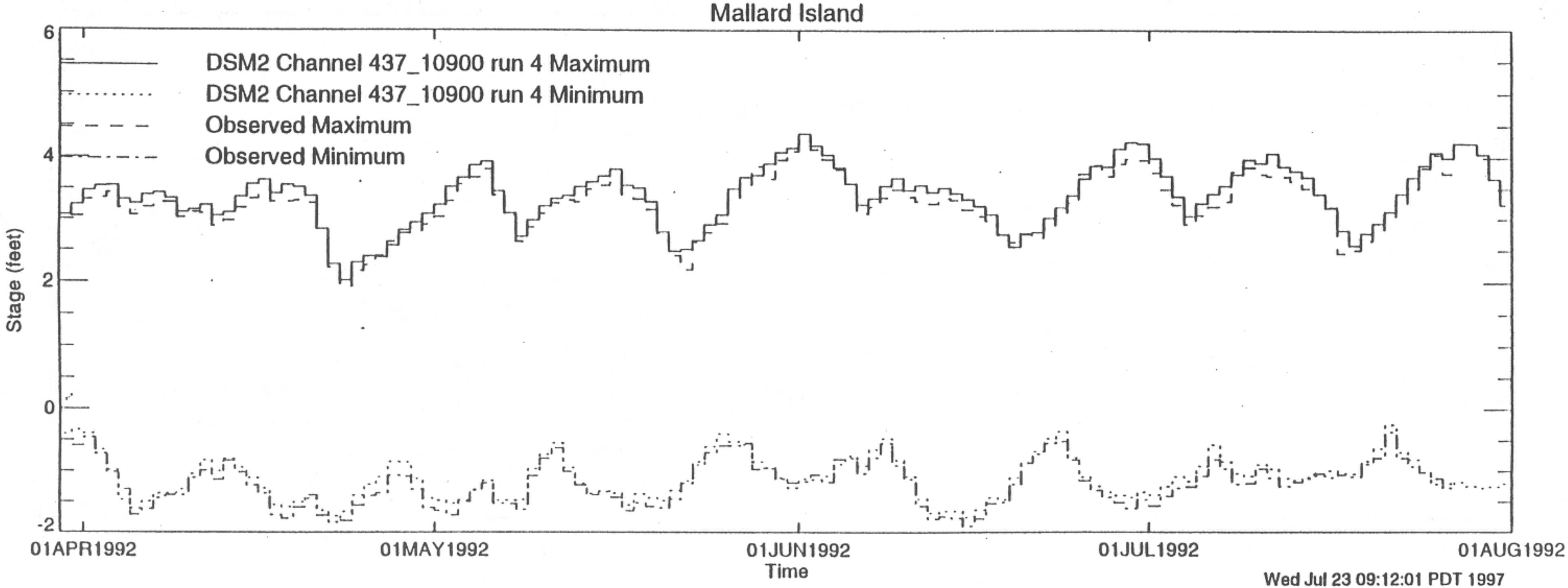
1968-1991

- Mallard Island and Collinsville
- Emmaton and Rio Vista
- Antioch and Jersey Point
- Holland Tract and Contra Costa Canal Pumping Plant #1
- Victoria Island and Union Island
- Stockton and Mossdale

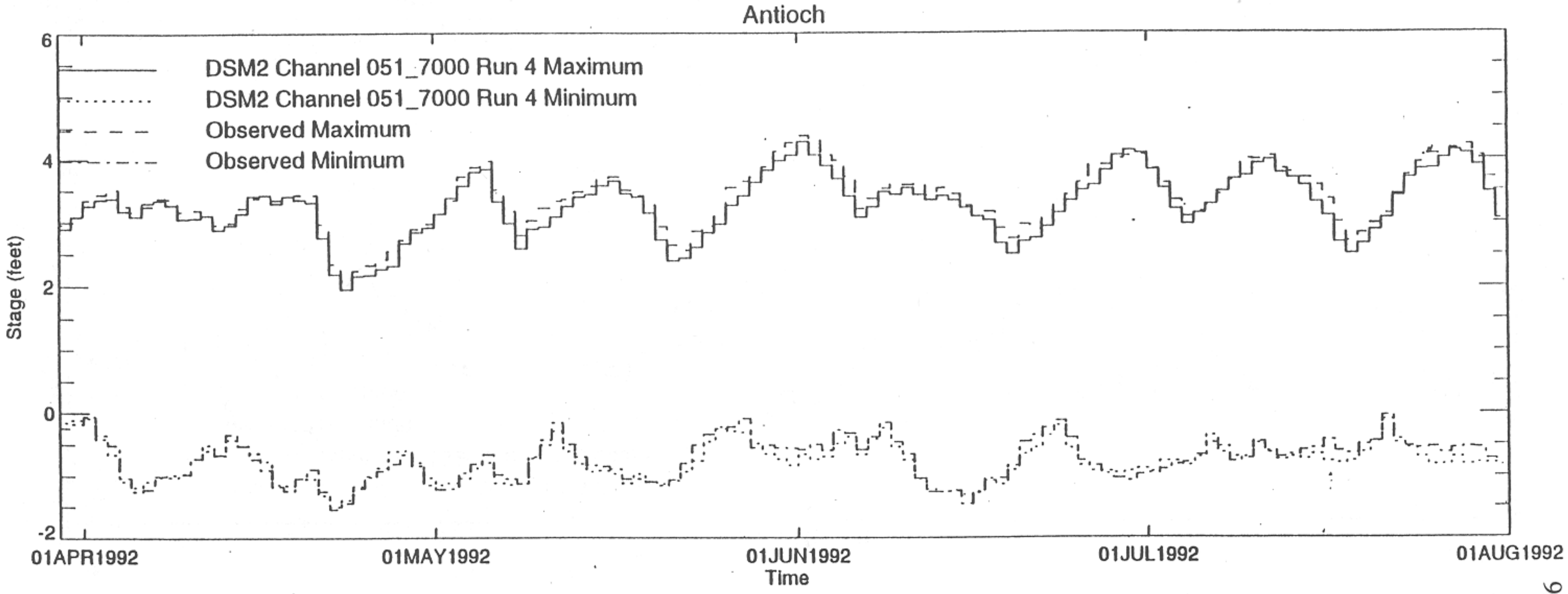
1985-1991

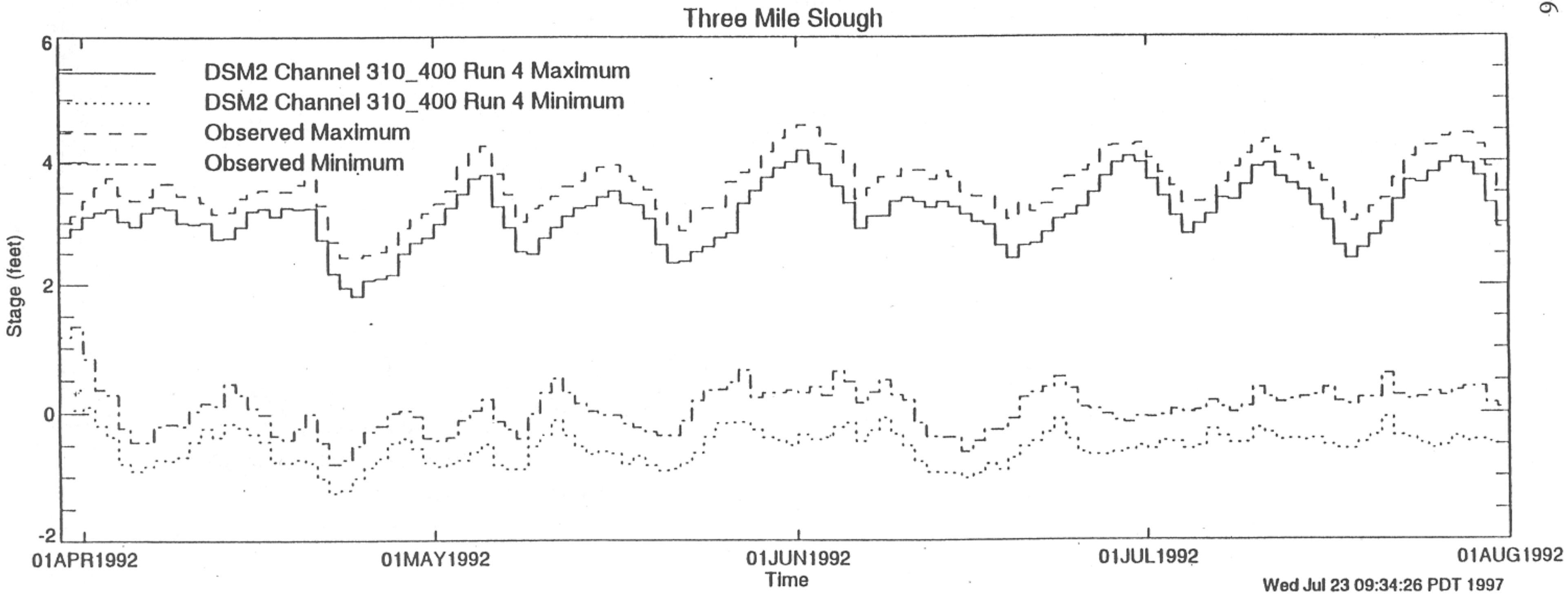
- Mallard Island and Collinsville
- Emmaton and Rio Vista
- Antioch and Jersey Point
- Holland Tract and Contra Costa Canal Pumping Plant #1
- Victoria Island and Union Island
- Stockton and Mossdale
- CCC Mismatch Comparison: 1968-1991



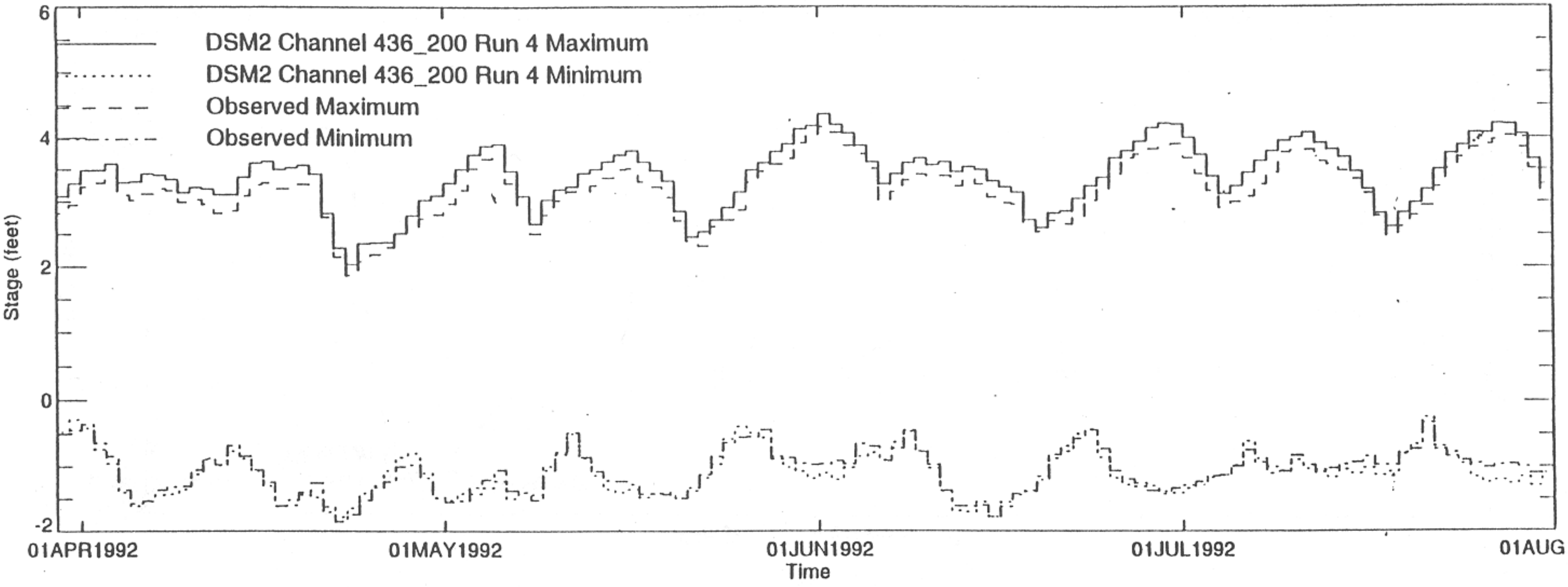


Wed Jul 23 09:12:01 PDT 1997

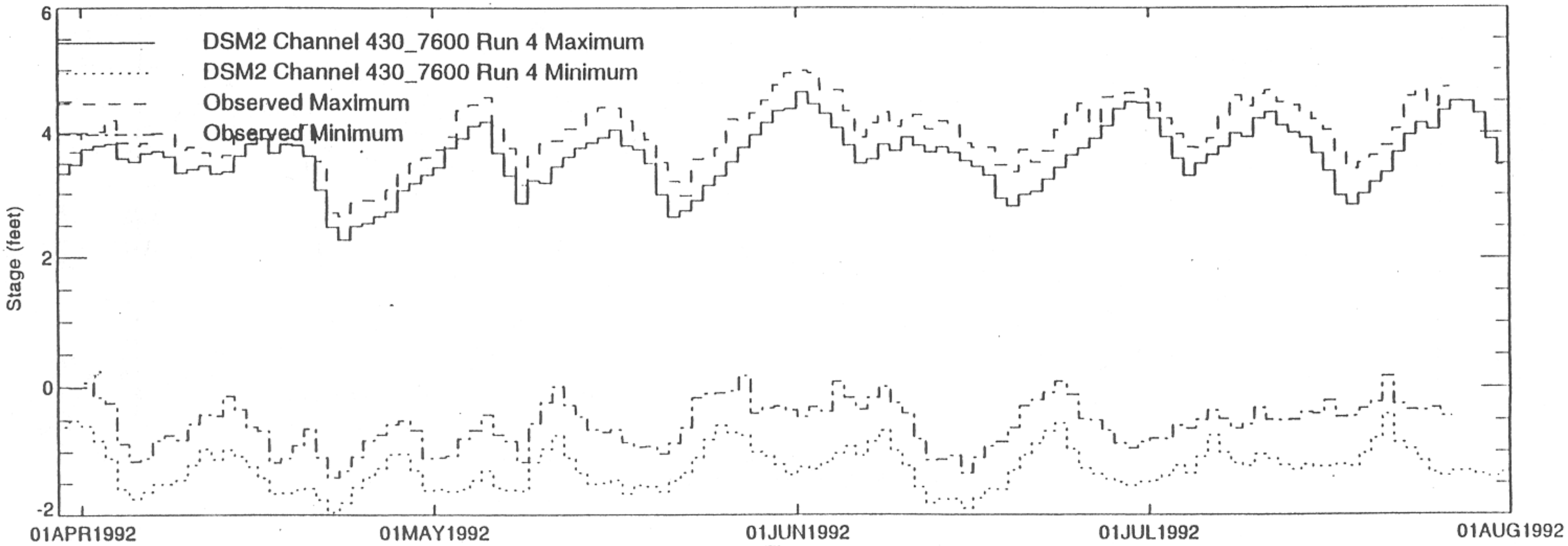

Antioch
Stage (feet)
6
4
2
0
-2
DSM2 Channel 051_7000 Run 4 Maximum
DSM2 Channel 051_7000 Run 4 Minimum
Observed Maximum
Observed Minimum
01APR1992
01MAY1992
01JUN1992
01JUL1992
01AUG1992
Time


Three Mile Slough
Stage (feet)
6
4
2
0
-2
DSM2 Channel 310_400 Run 4 Maximum
DSM2 Channel 310_400 Run 4 Minimum
Observed Maximum
Observed Minimum
01APR1992
01MAY1992
01JUN1992
01JUL1992
01AUG1992
Time
Wed Jul 23 09:34:26 PDT 1997

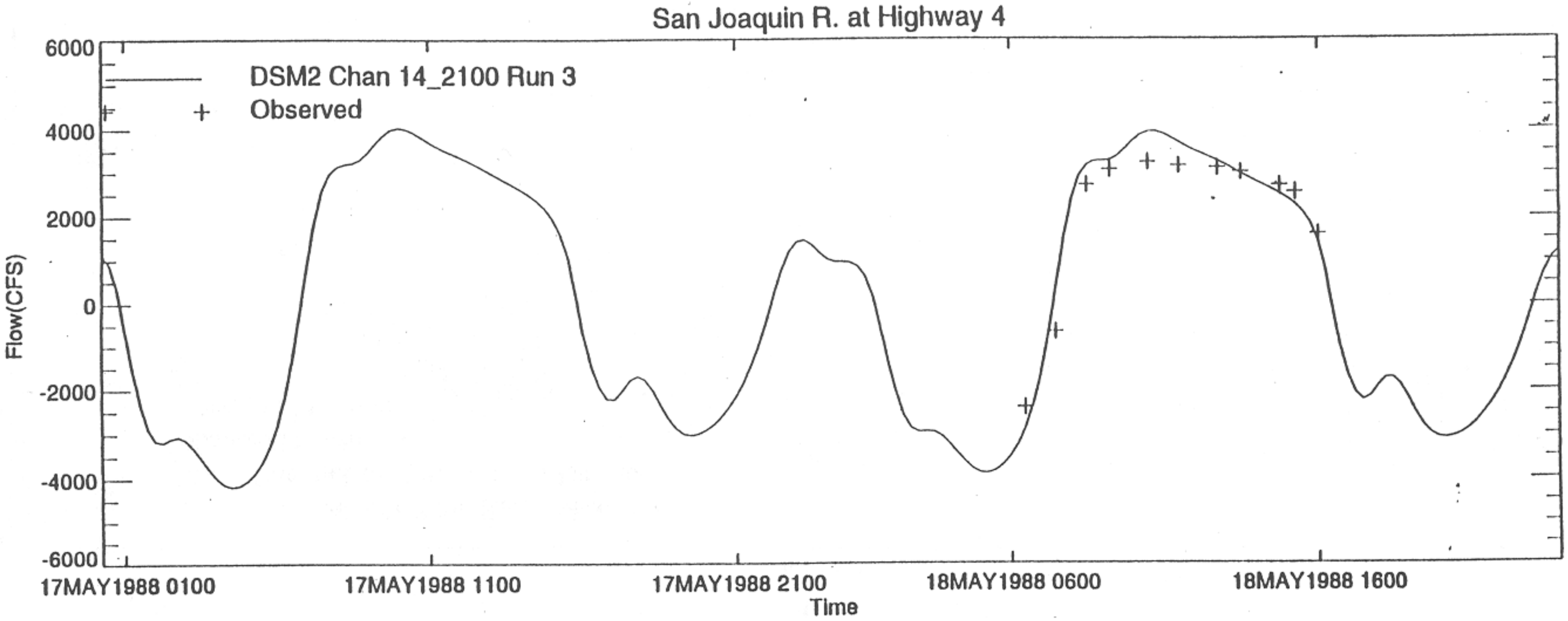
Collinsville

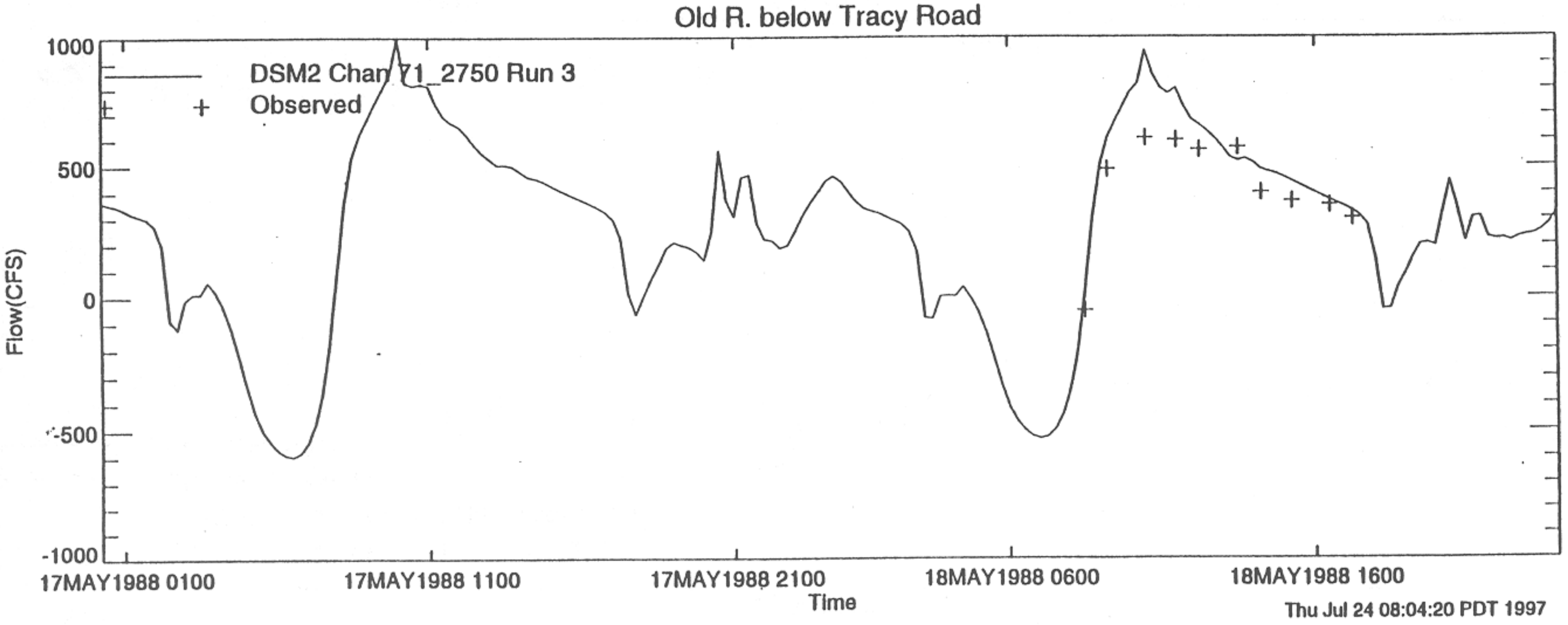


Rio Vista

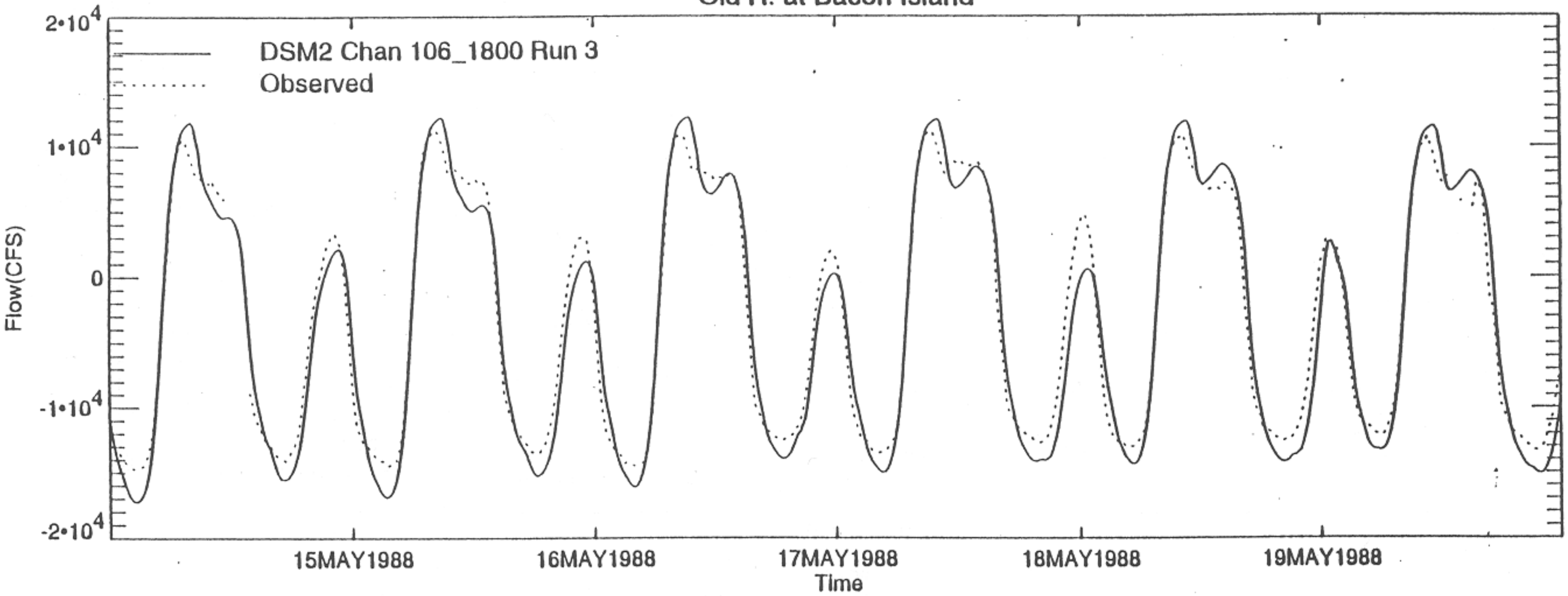


Wed Jul 23 09:46:36 PDT 1997

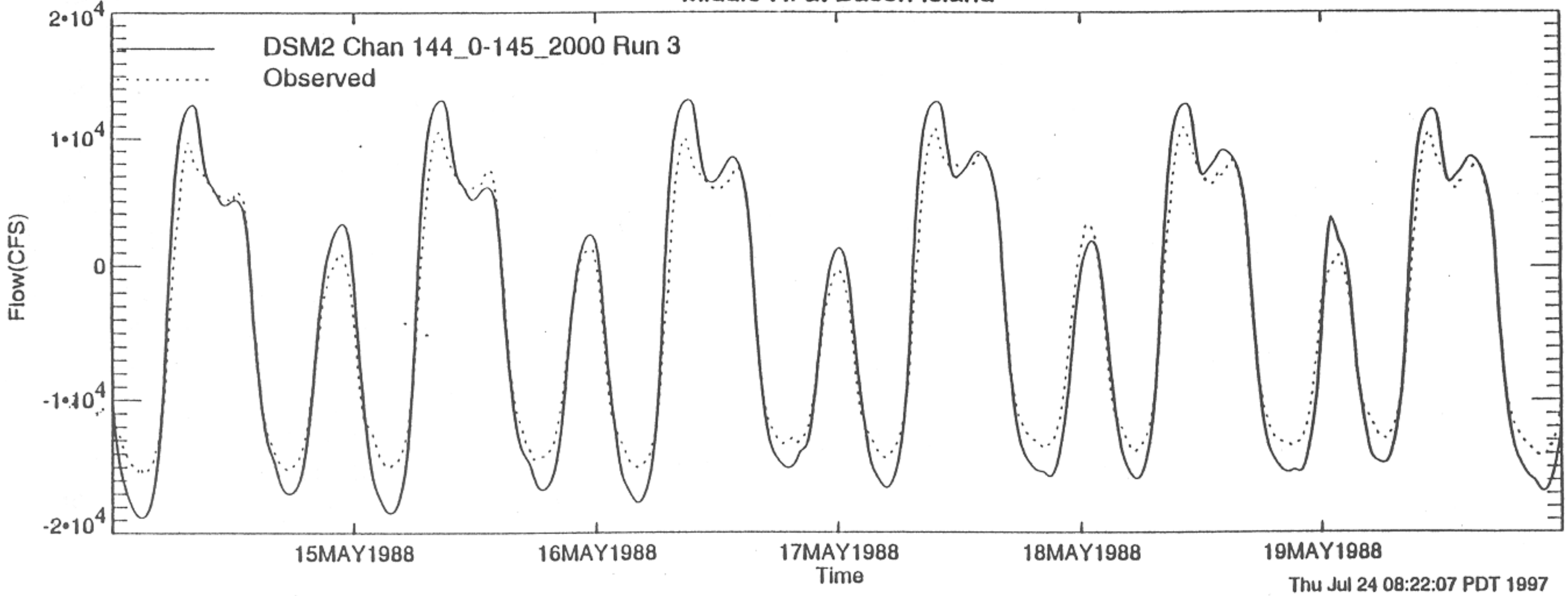

San Joaquin R. at Highway 4


Old R. below Tracy Road

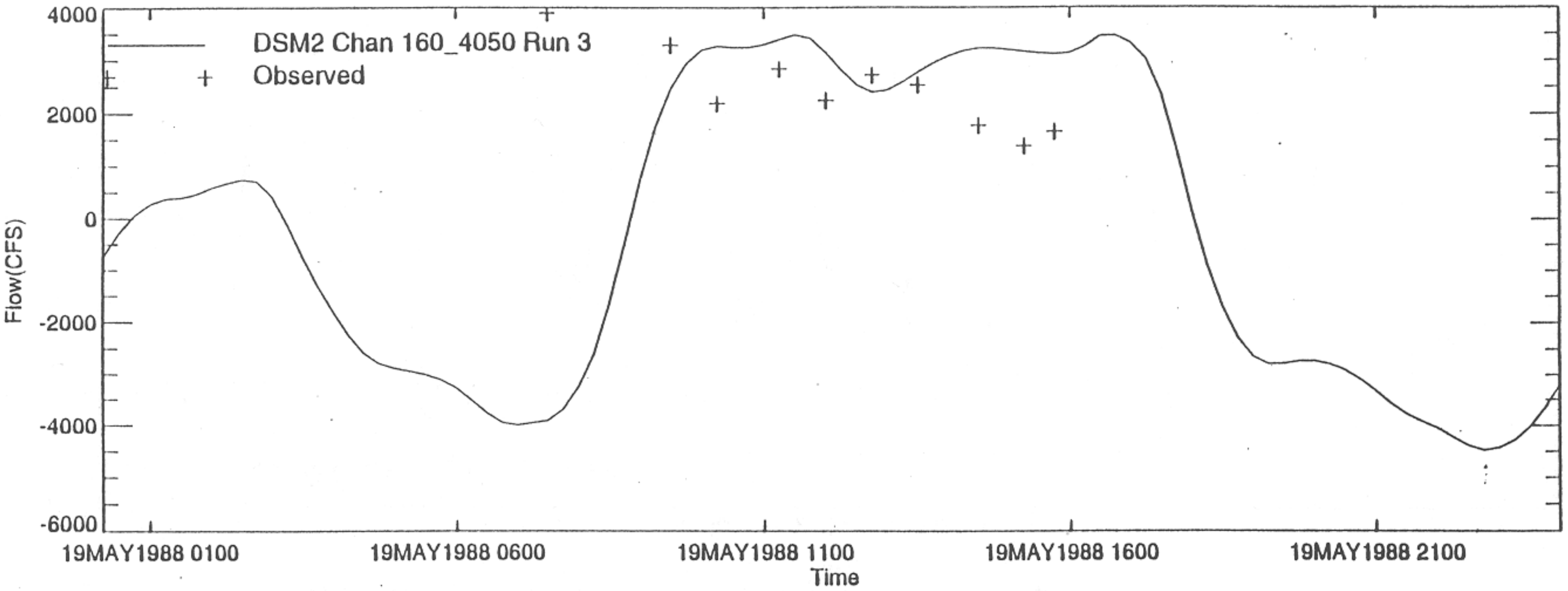
Old R. at Bacon Island



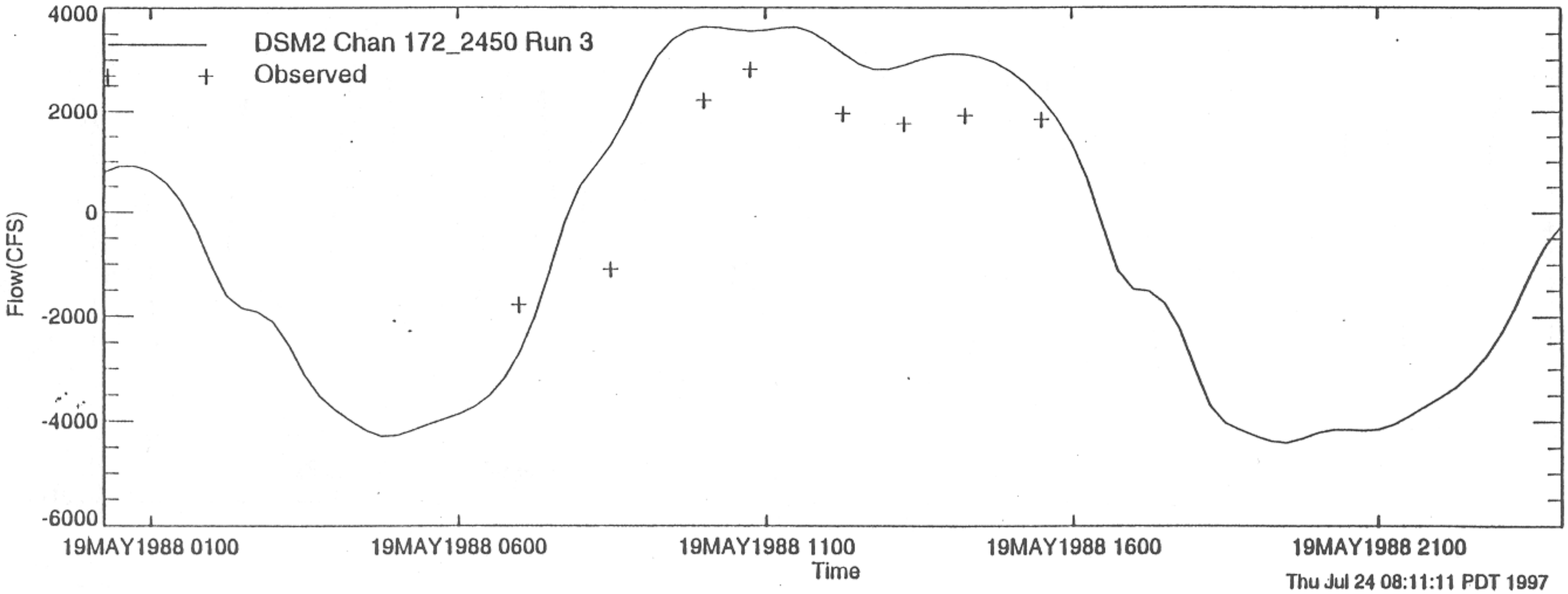
Middle R. at Bacon Island



Columbia Cut



Turner Cut



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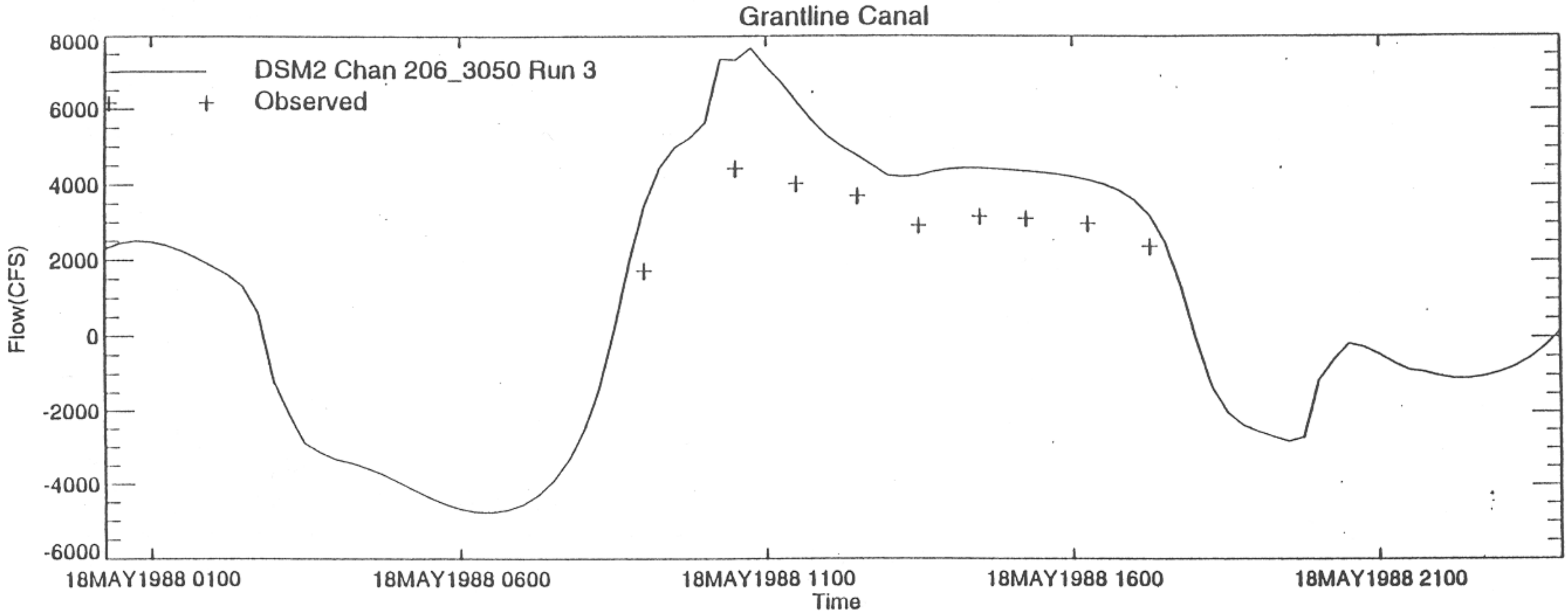
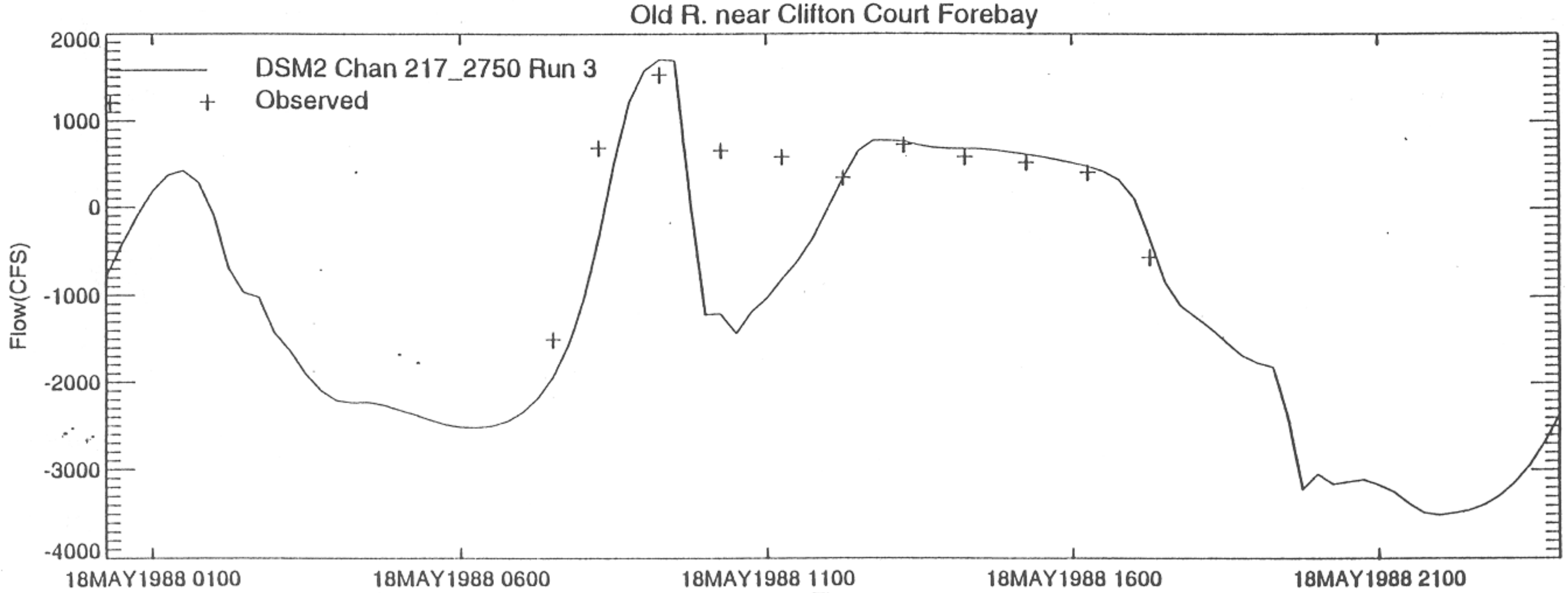

Grantline Canal


Old R. near Clifton Court Forebay

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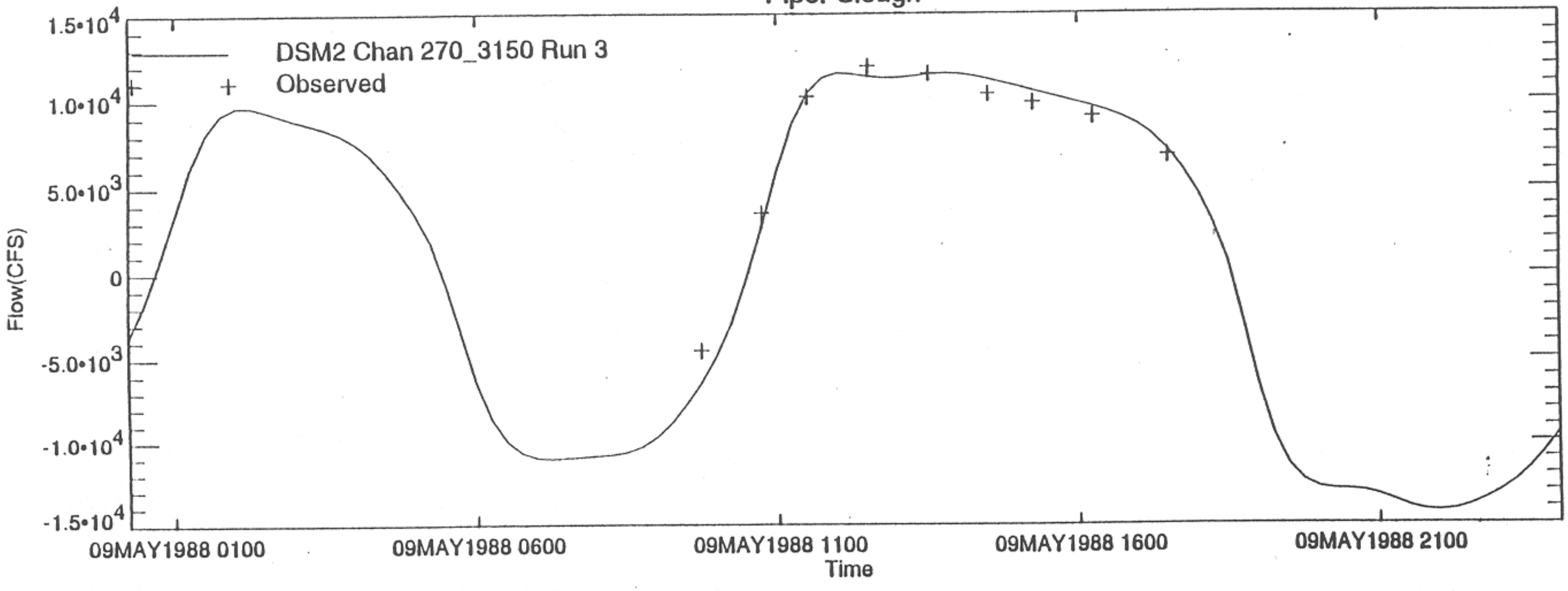
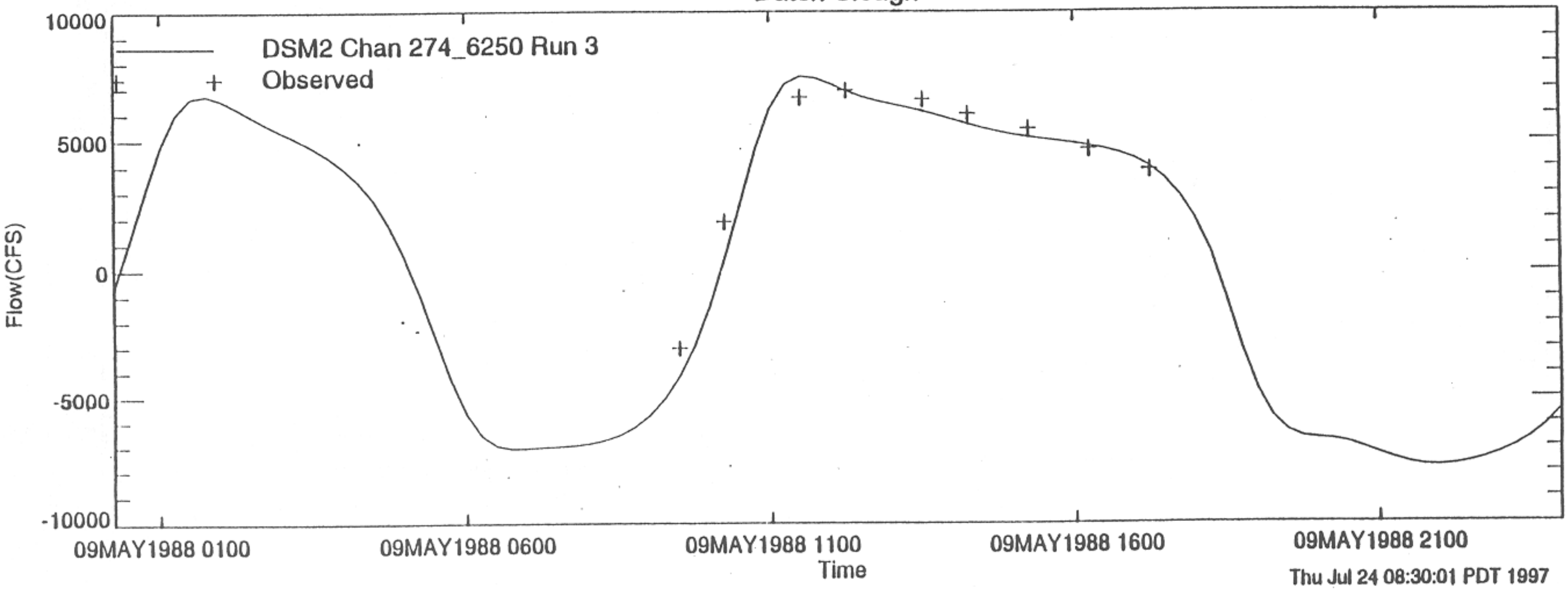
Piper Slough



Dutch Slough



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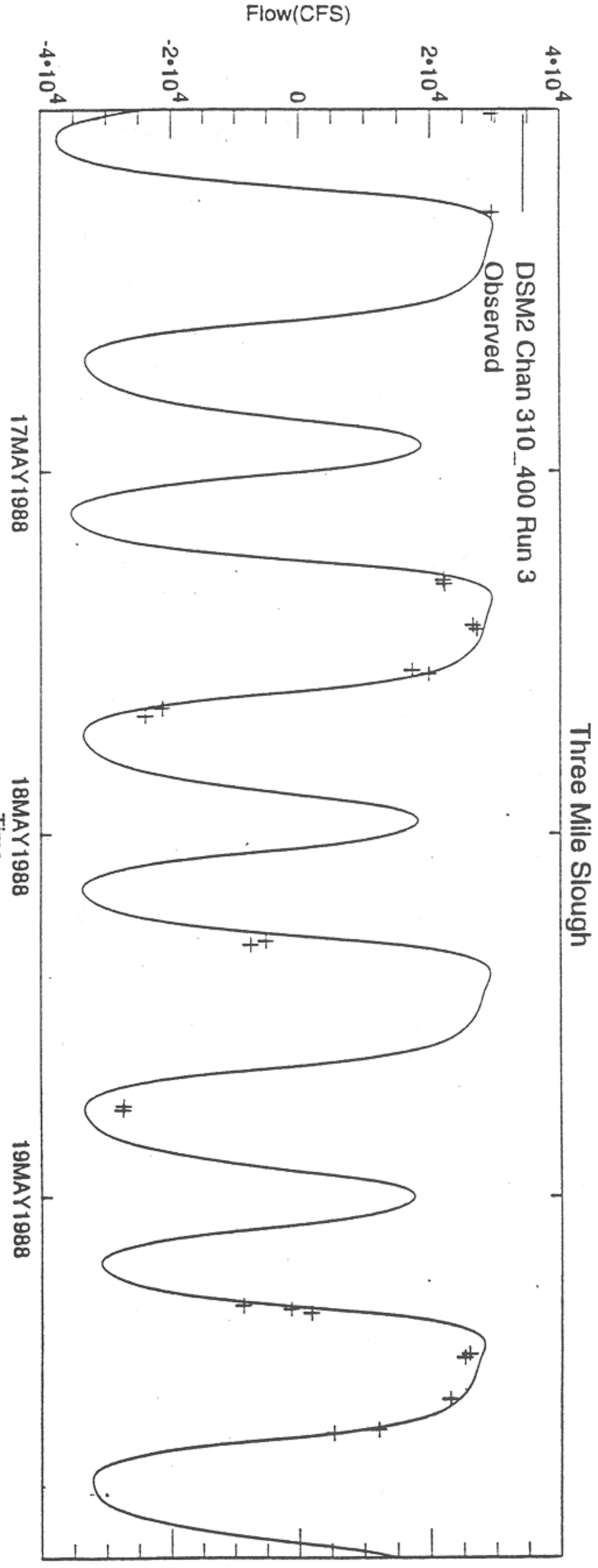
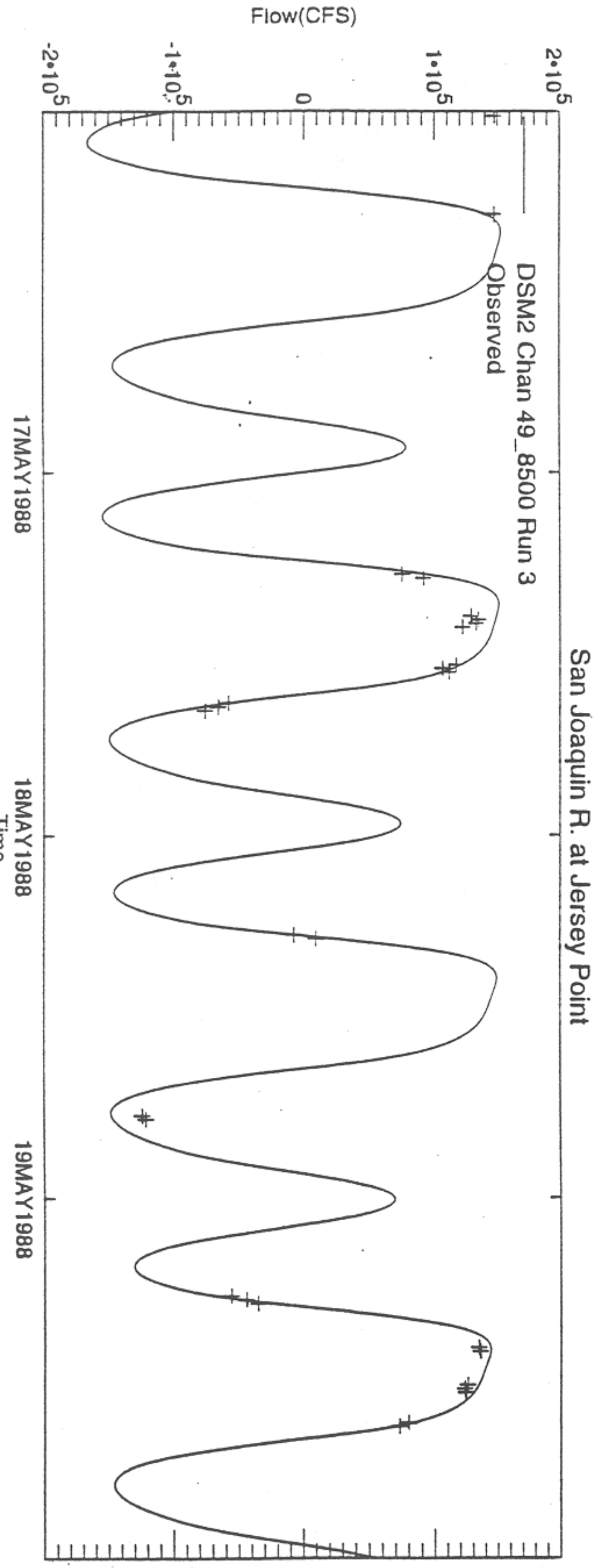
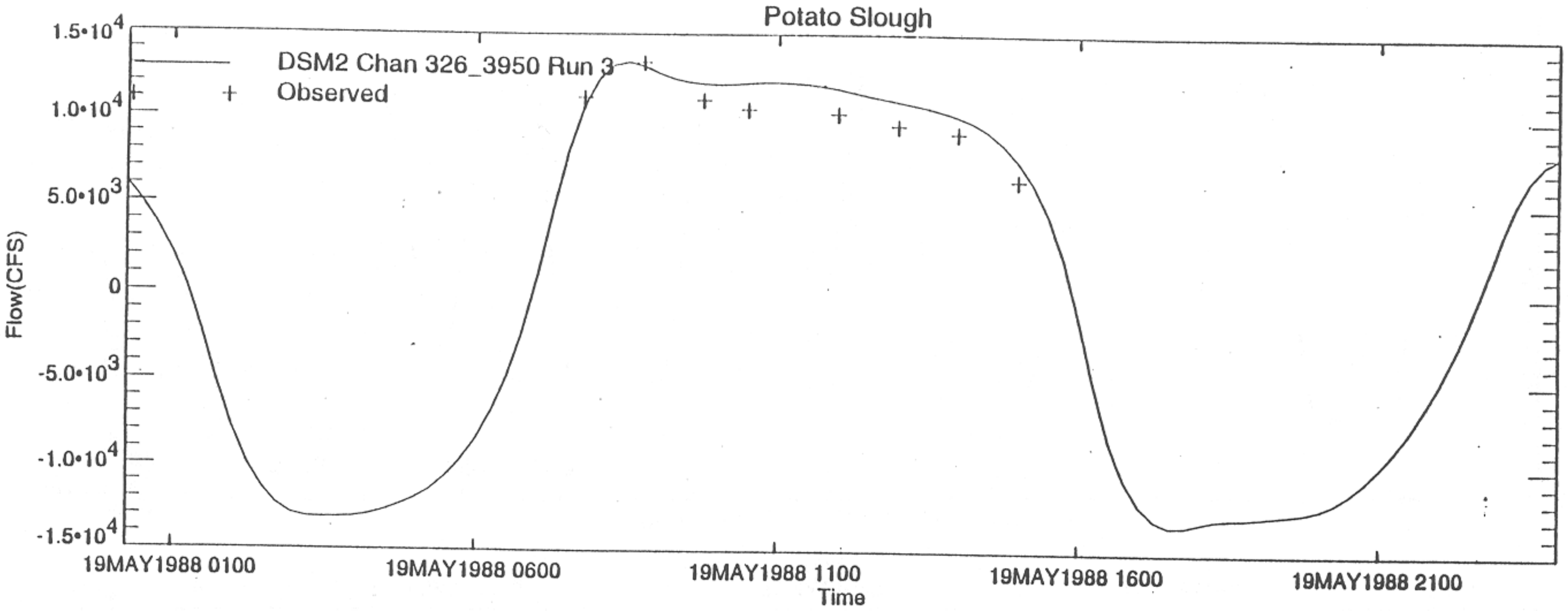
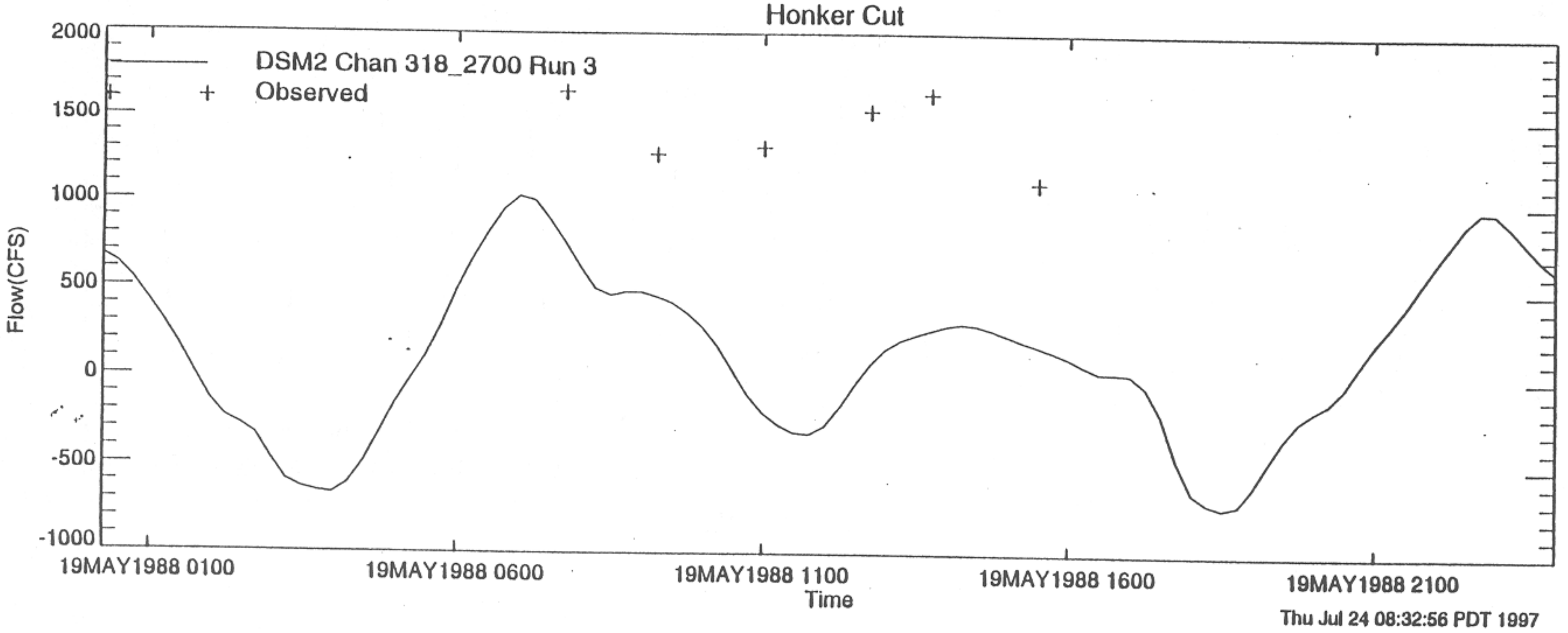


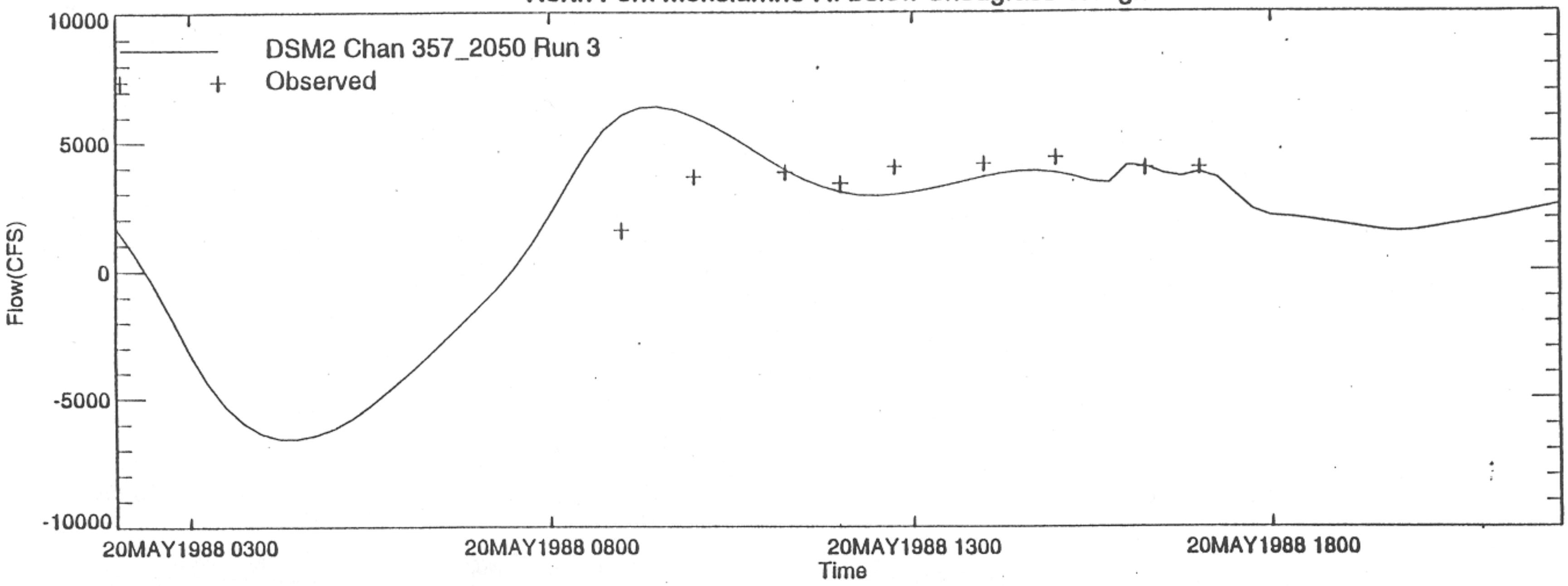


Wed Jul 23 16:00:59 PDT 1997

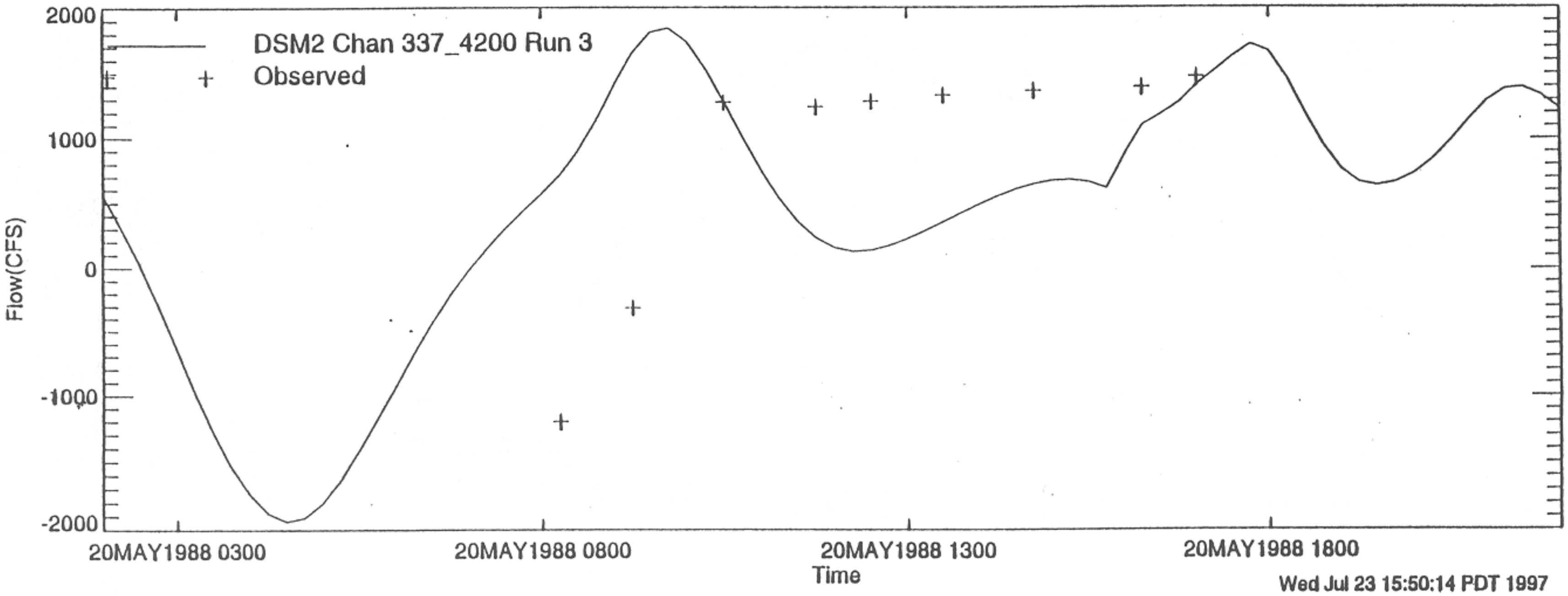

Potato Slough
DSM2 Chan 326_3950 Run 3
Observed
Flow(CFS)
1.5•10^4
1.0•10^4
5.0•10^3
0
-5.0•10^3
-1.0•10^4
-1.5•10^4
19MAY1988 0100
19MAY1988 0600
19MAY1988 1100
19MAY1988 1600
19MAY1988 2100
Time


Honker Cut
DSM2 Chan 318_2700 Run 3
Observed
Flow(CFS)
2000
1500
1000
500
0
-500
-1000
19MAY1988 0100
19MAY1988 0600
19MAY1988 1100
19MAY1988 1600
19MAY1988 2100
Time
Thu Jul 24 08:32:56 PDT 1997

North Fork Mokelumne R. below Snodgrass Slough

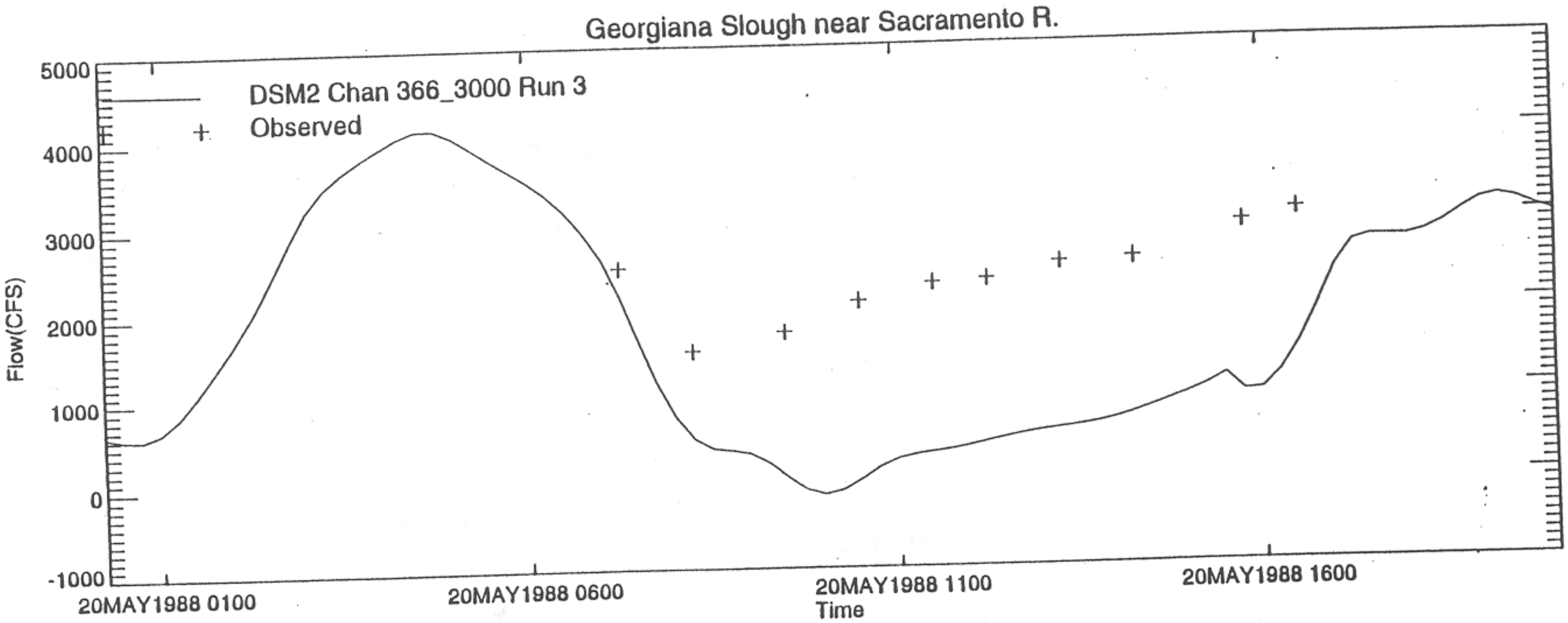


South Fork Mokelumne R.



Wed Jul 23 15:50:14 PDT 1997

9-3



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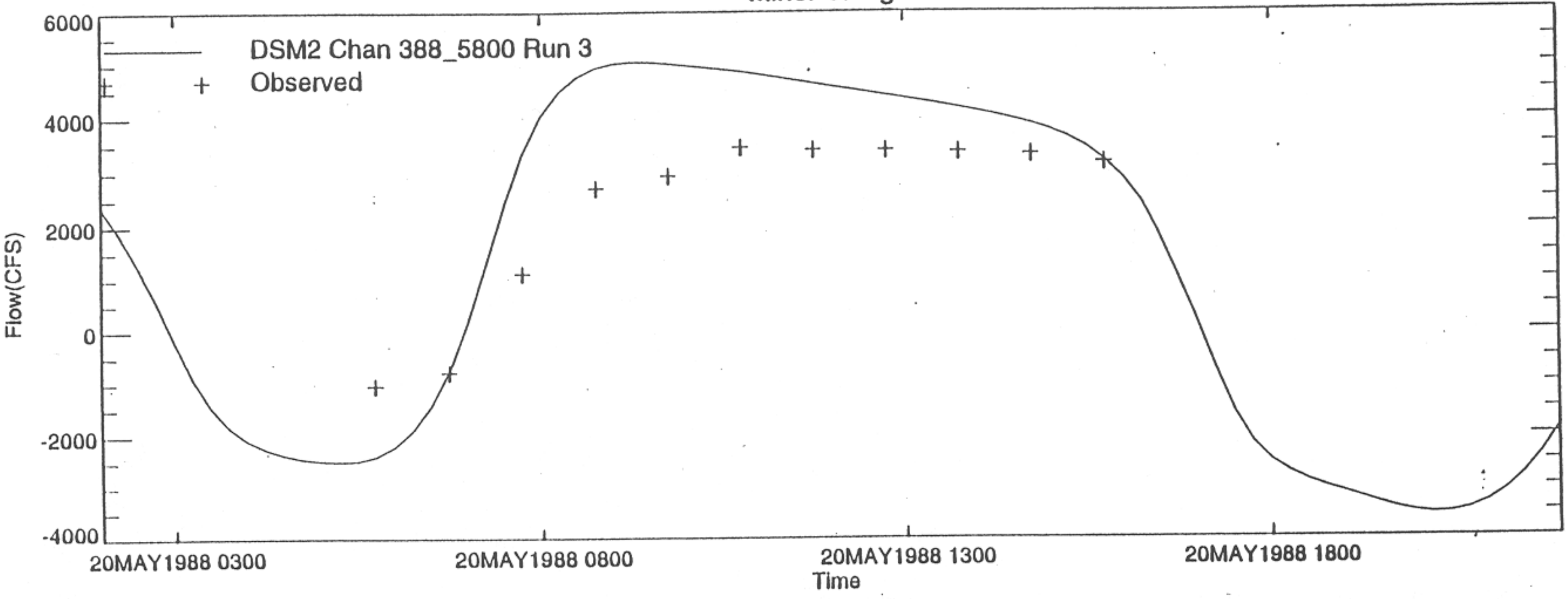
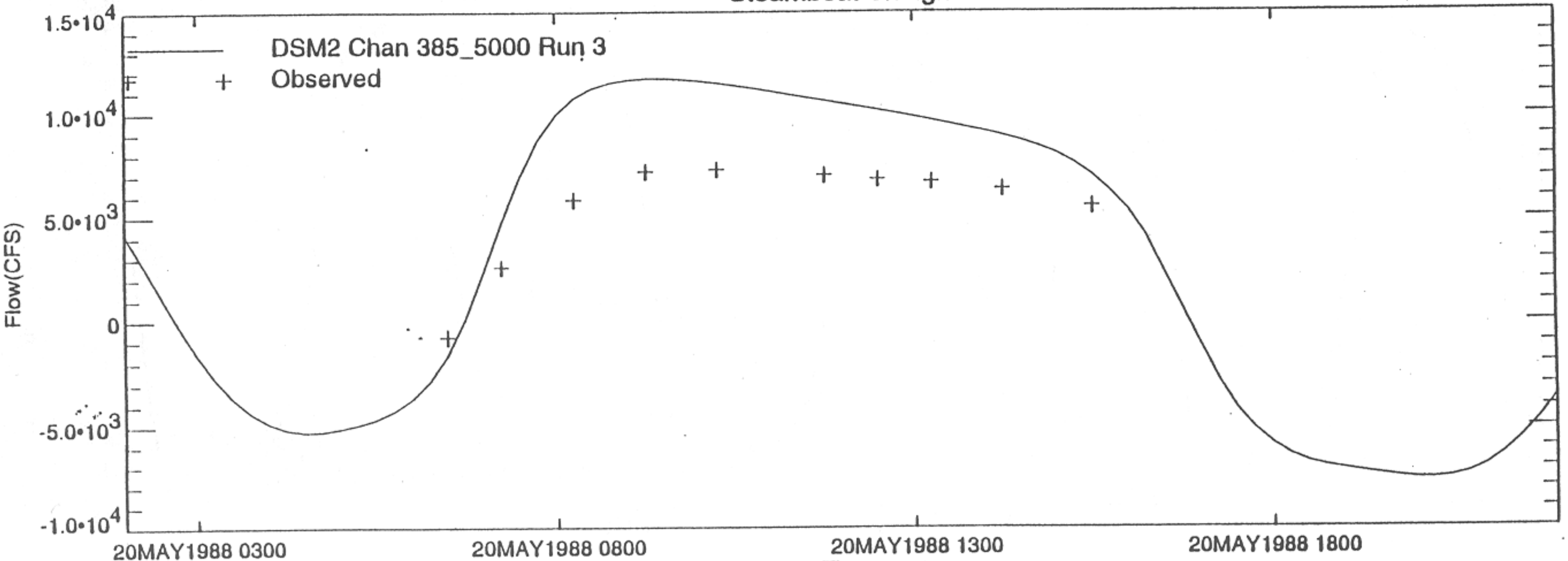
Miner Slough



Steamboat Slough



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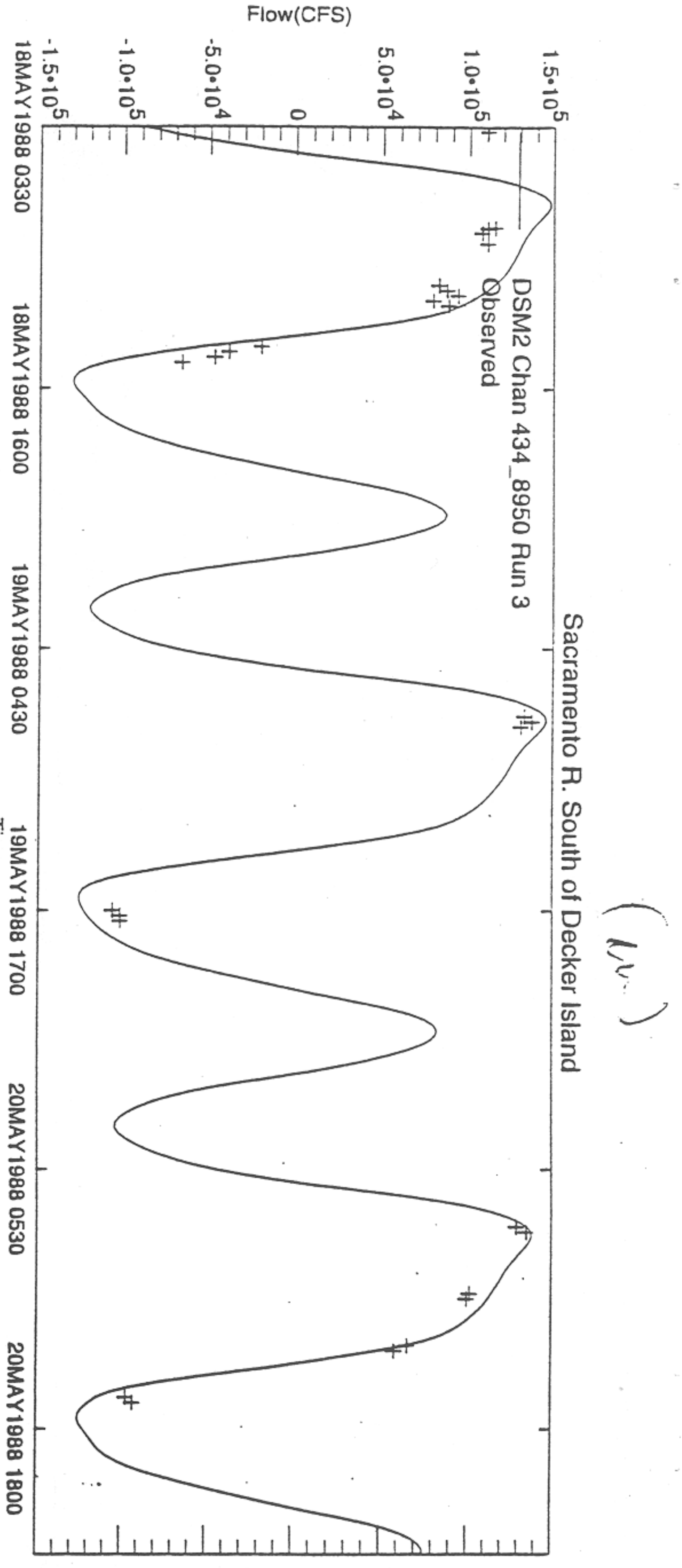
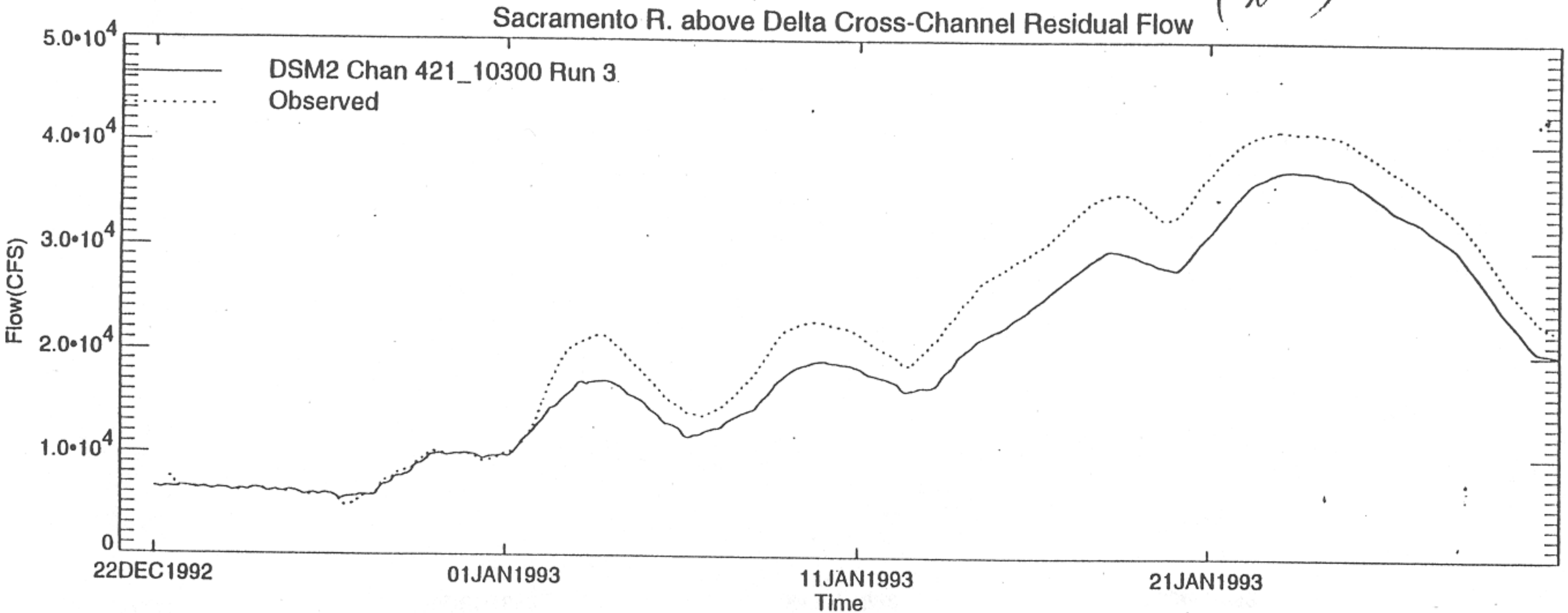


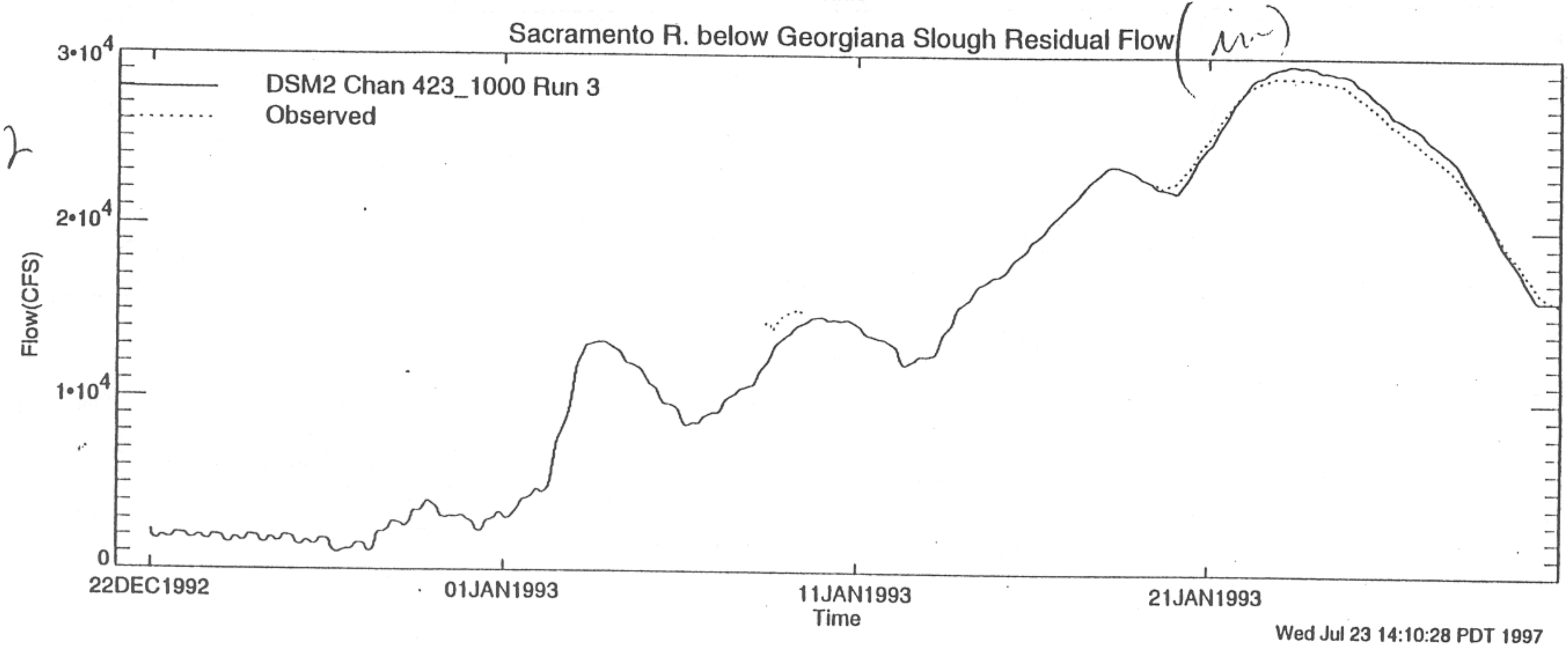
Wed Jul 23 16:04:37 PDT 1997

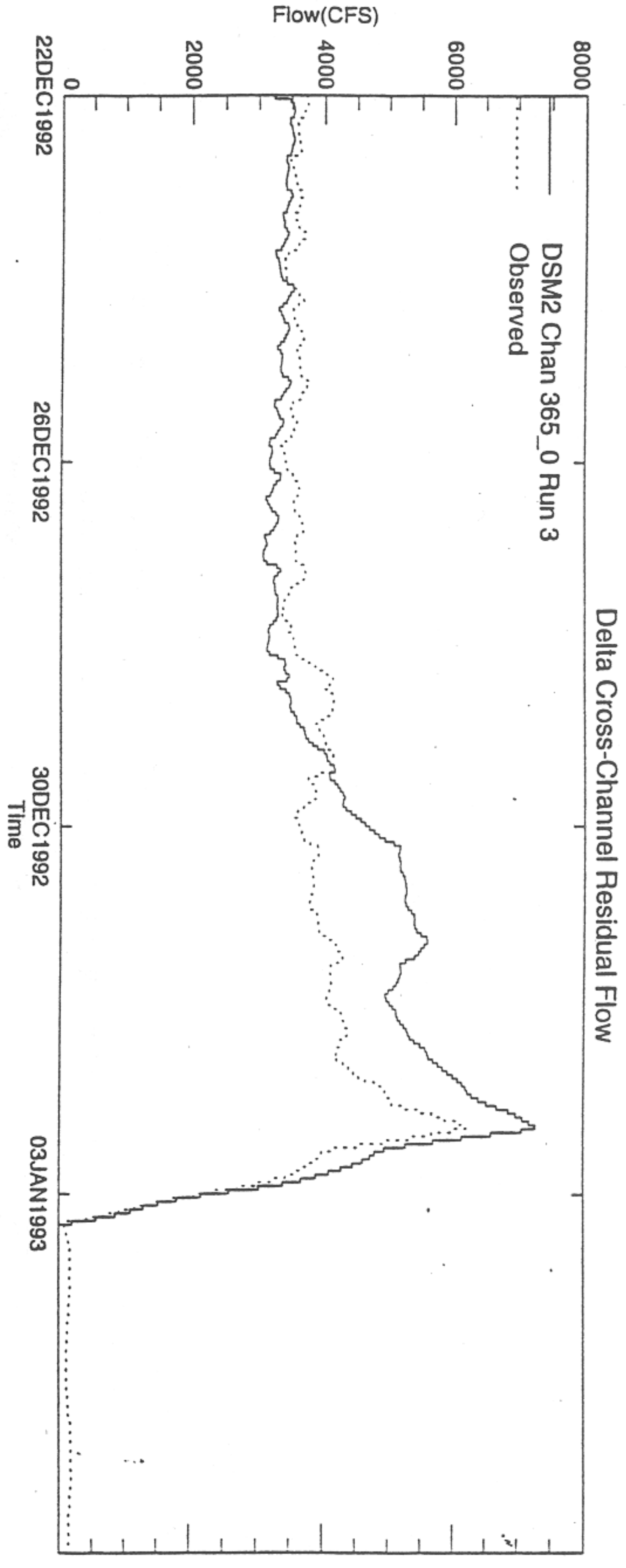
(in)


Sacramento R. above Delta Cross-Channel Residual Flow

(in)

9-2


Sacramento R. below Georgiana Slough Residual Flow



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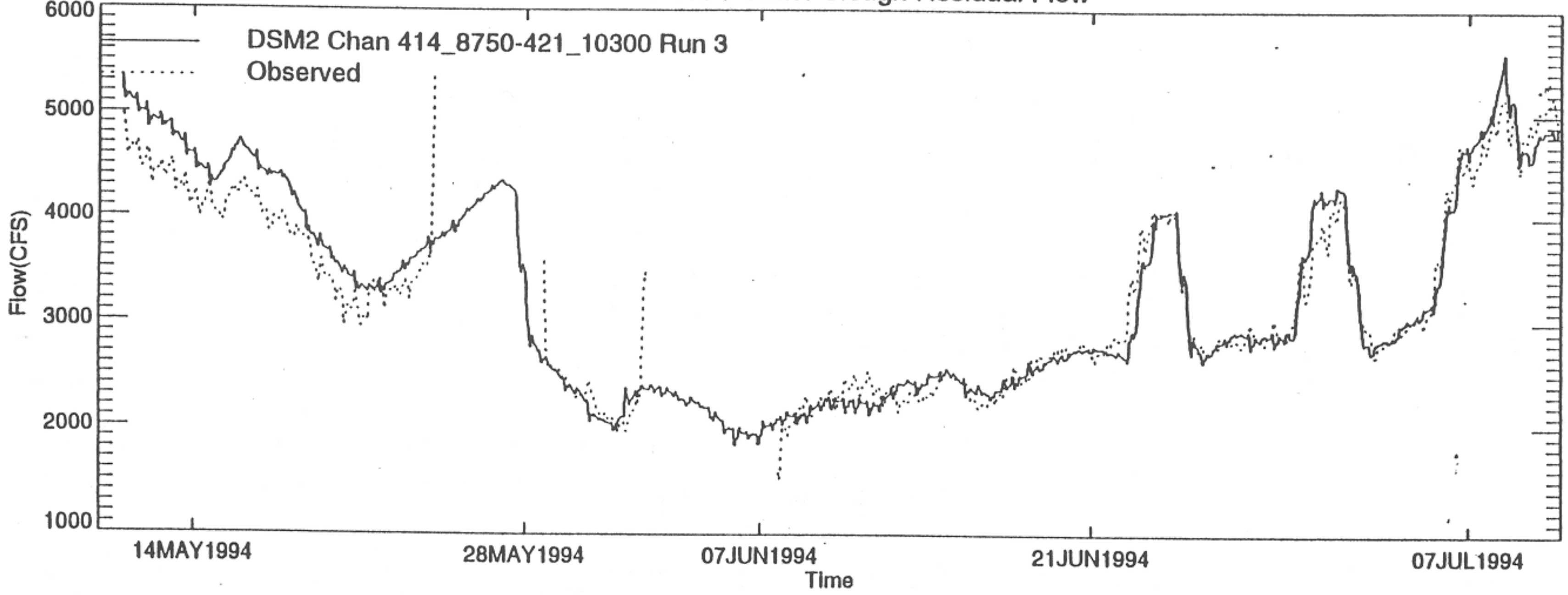
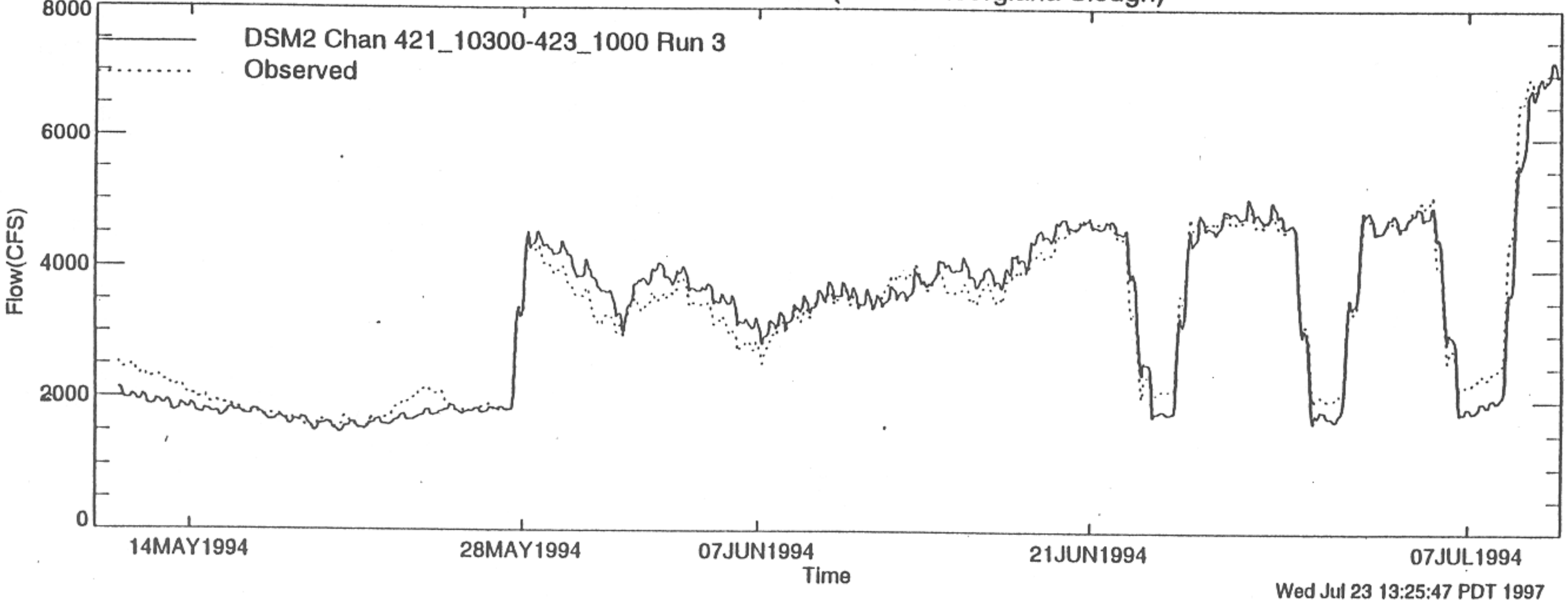
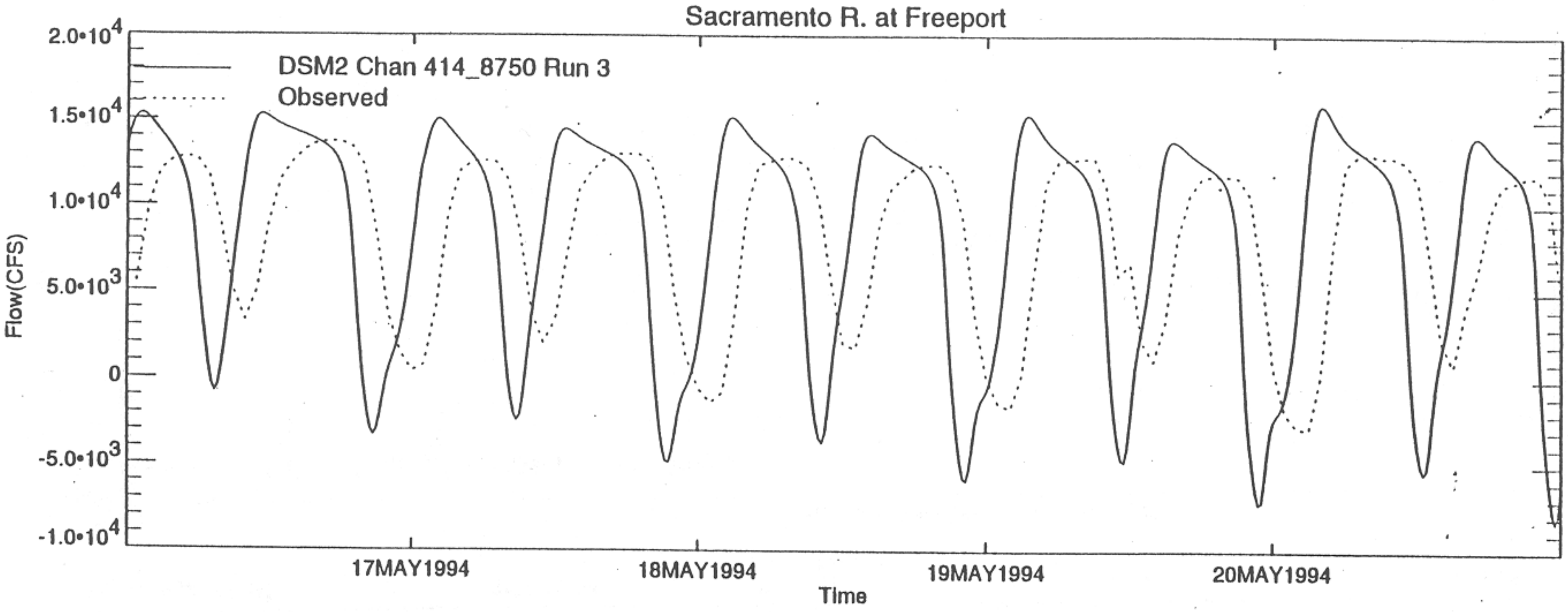
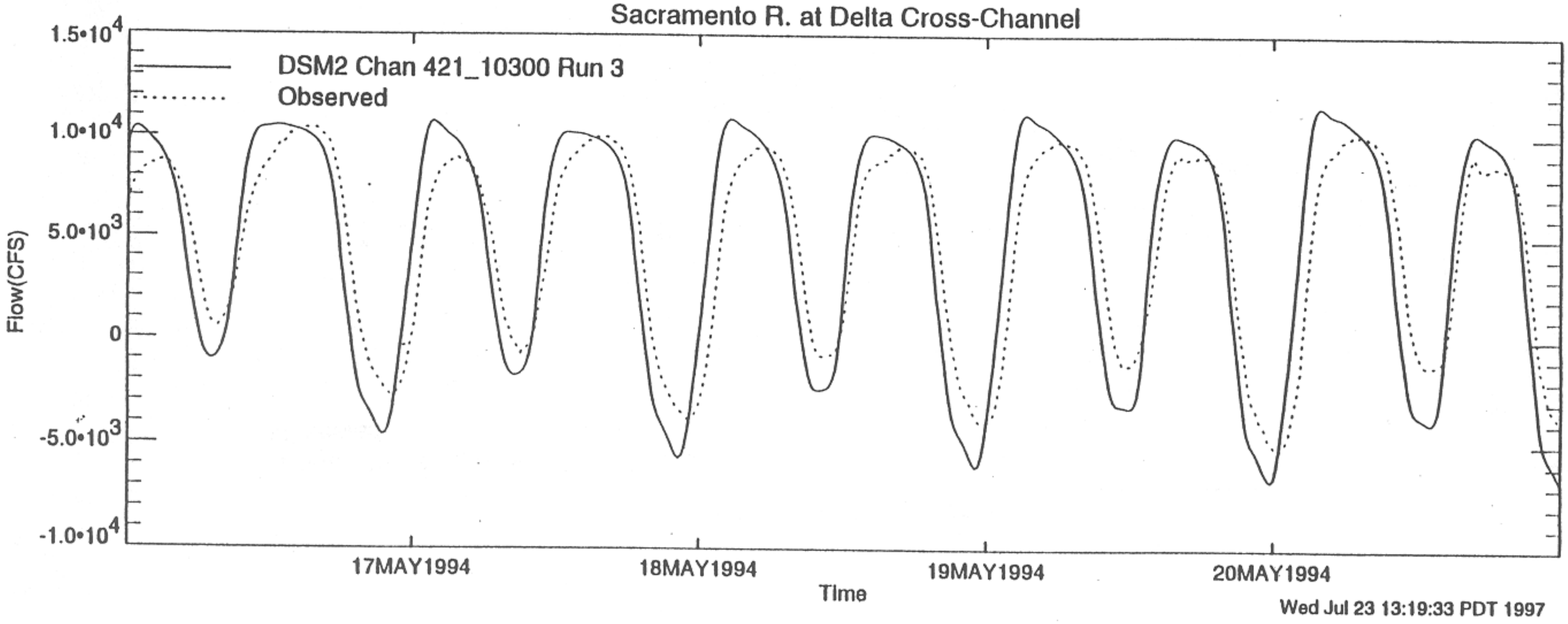

Steamboat + Sutter Slough Residual Flow


Cross Delta Residual Flow (DXC + Georgiana Slough)

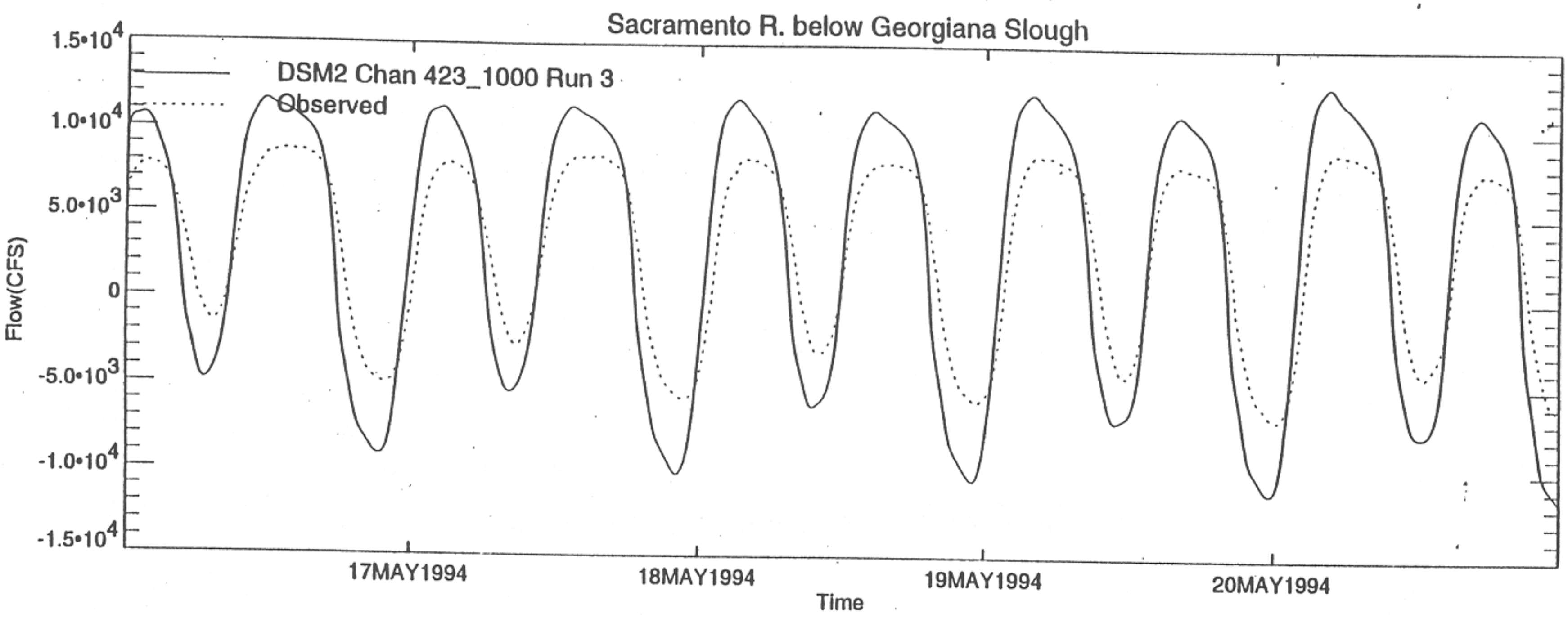
Wed Jul 23 13:25:47 PDT 1997


Sacramento R. at Freeport


Sacramento R. at Delta Cross-Channel

(m)

(Figure 9.1)



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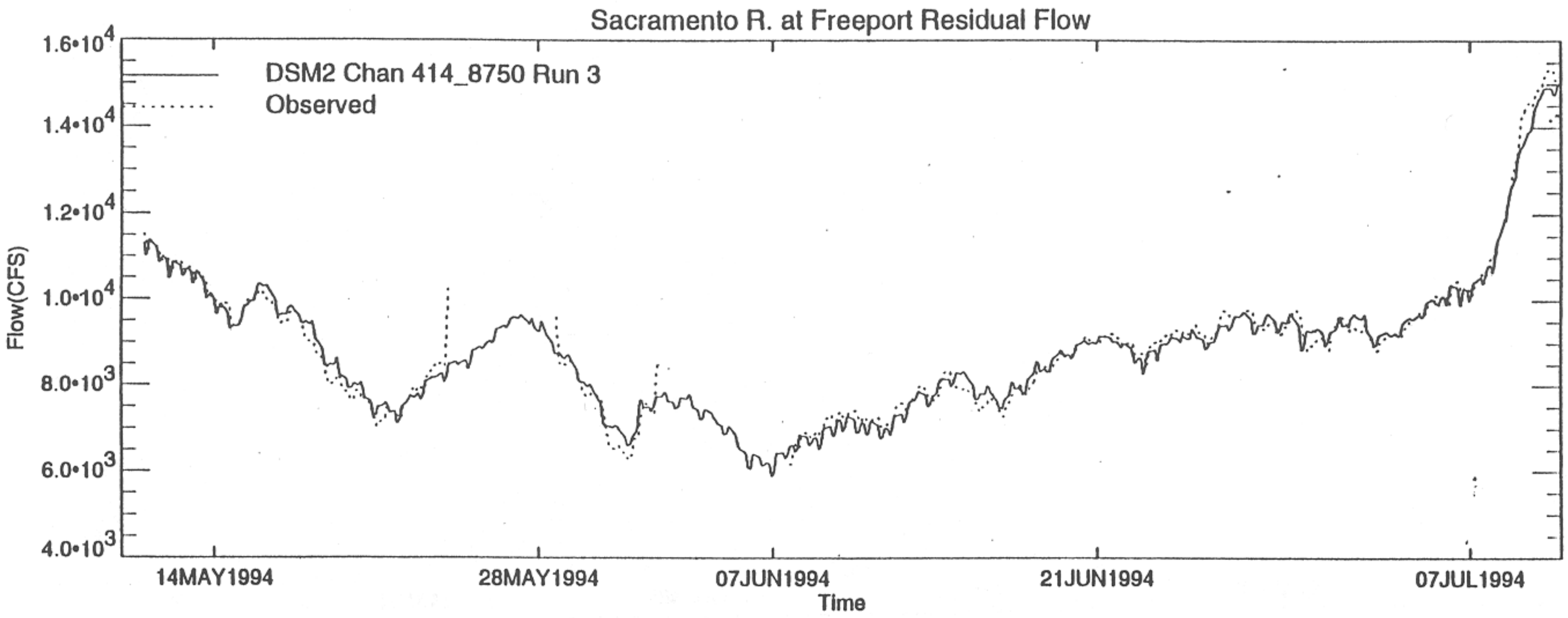
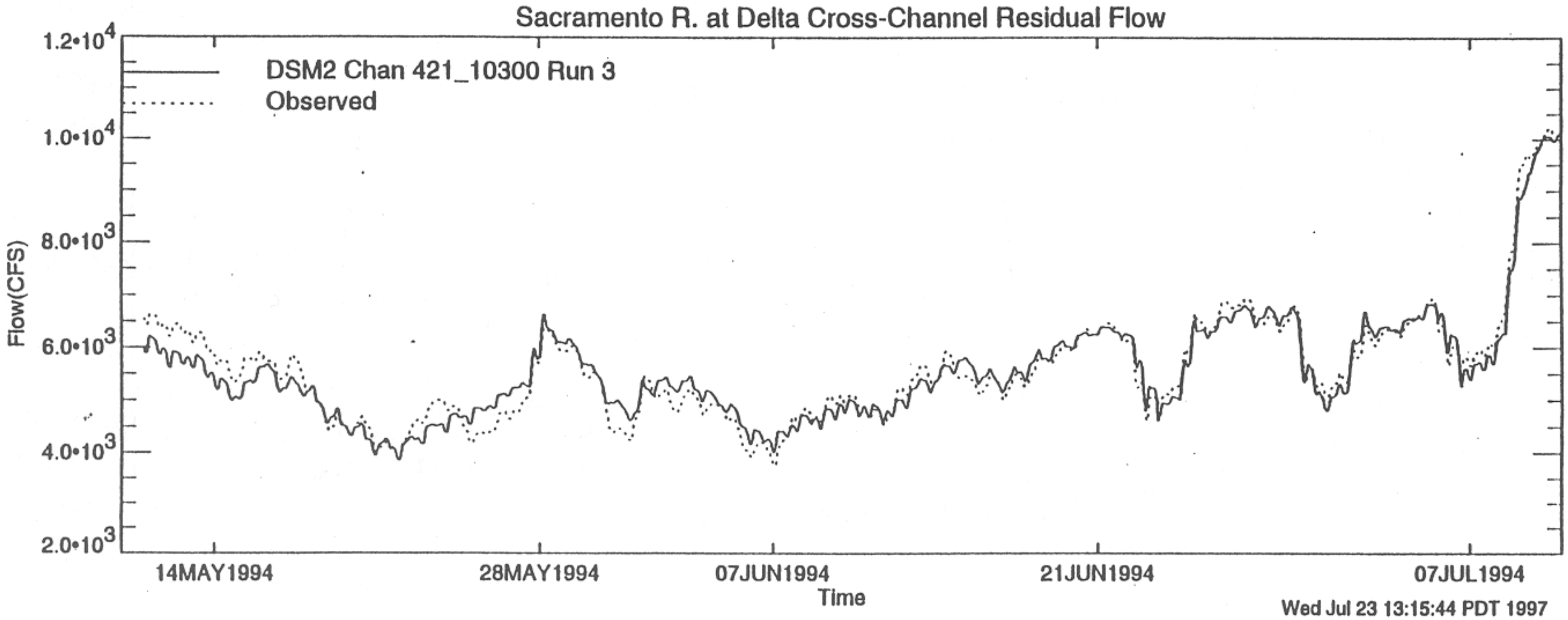
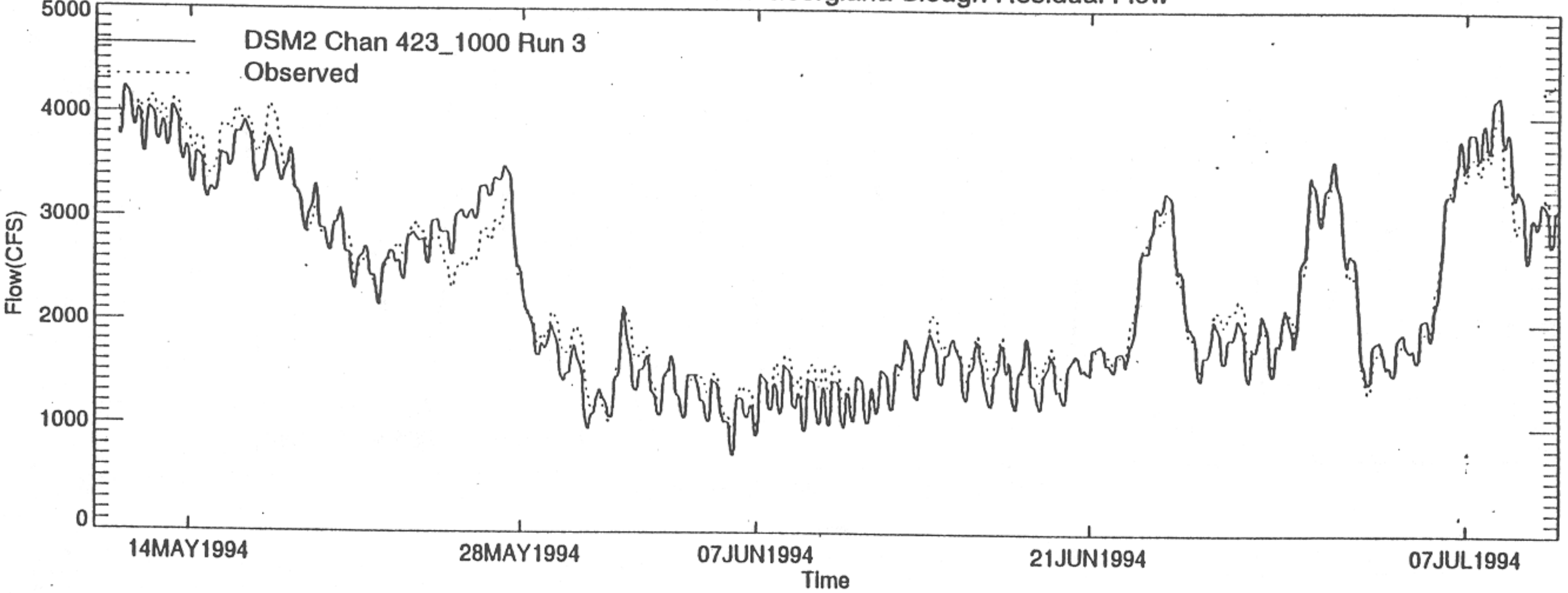

Sacramento R. at Freeport Residual Flow


Sacramento R. at Delta Cross-Channel Residual Flow

Wed Jul 23 13:15:44 PDT 1997

Sacramento R. below Georgiana Slough Residual Flow



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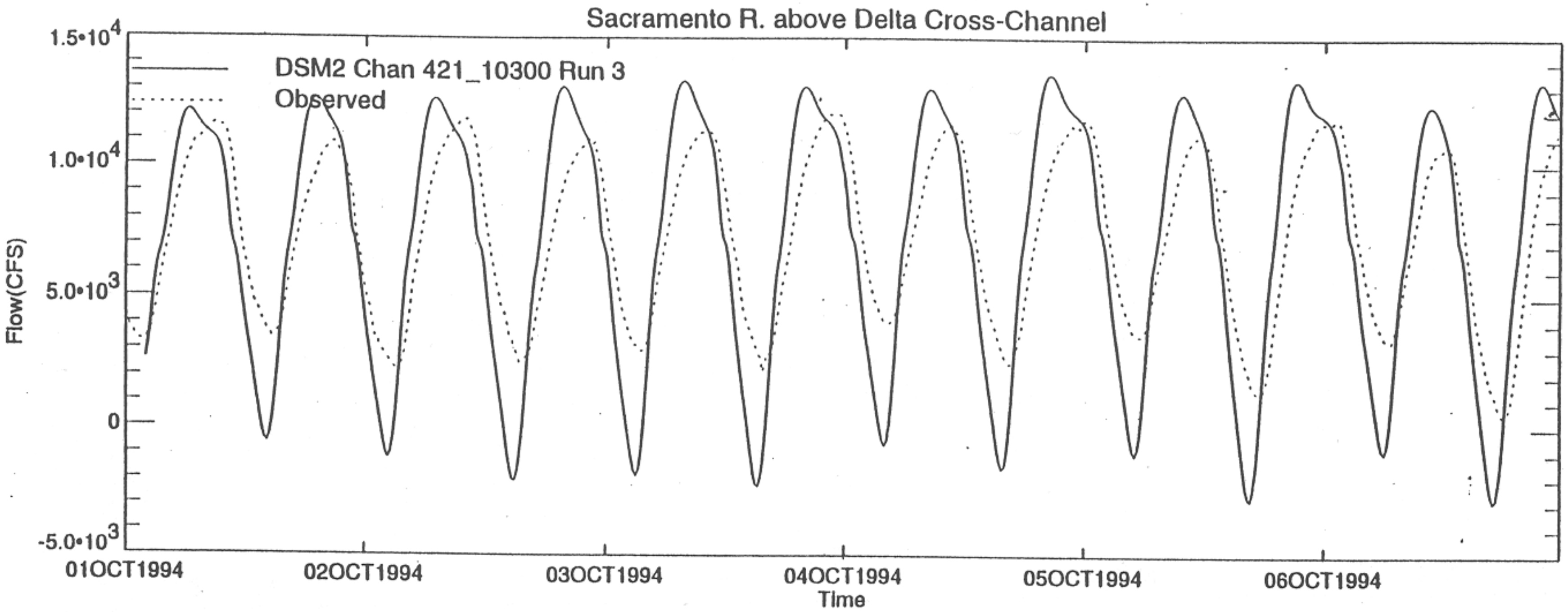
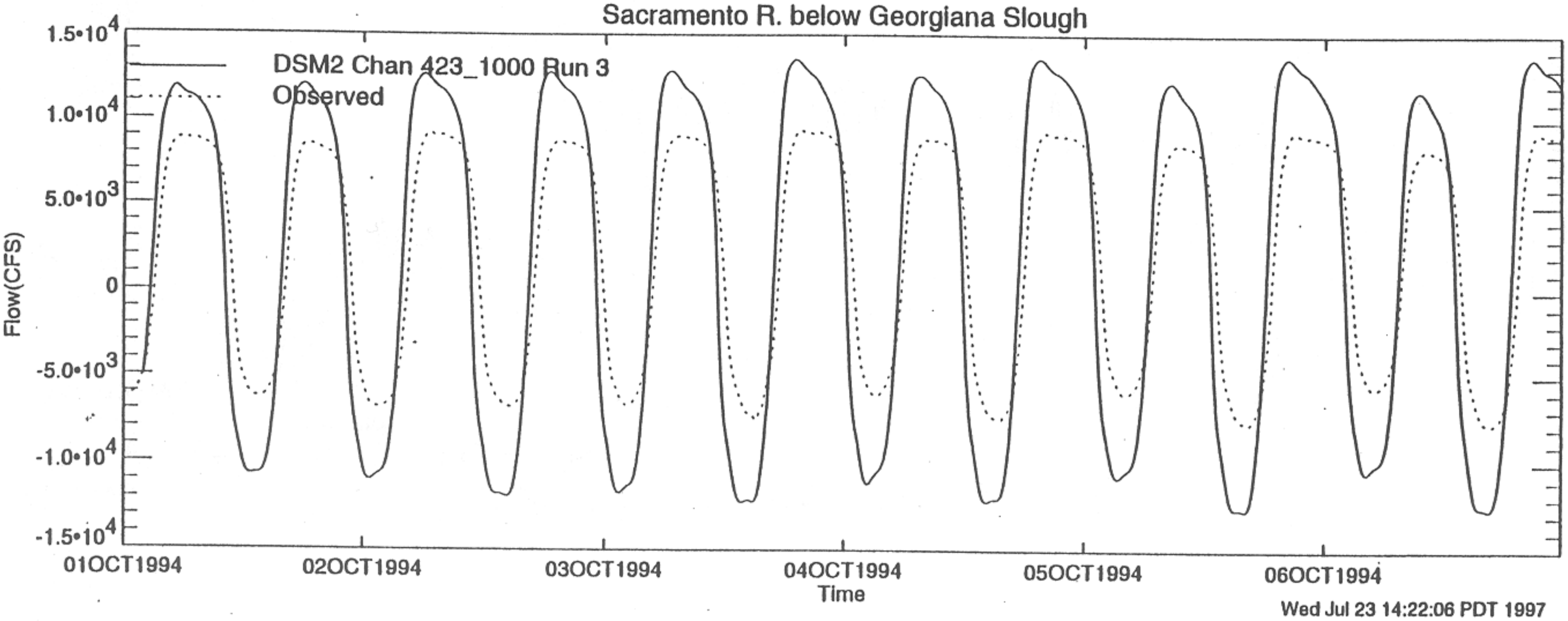
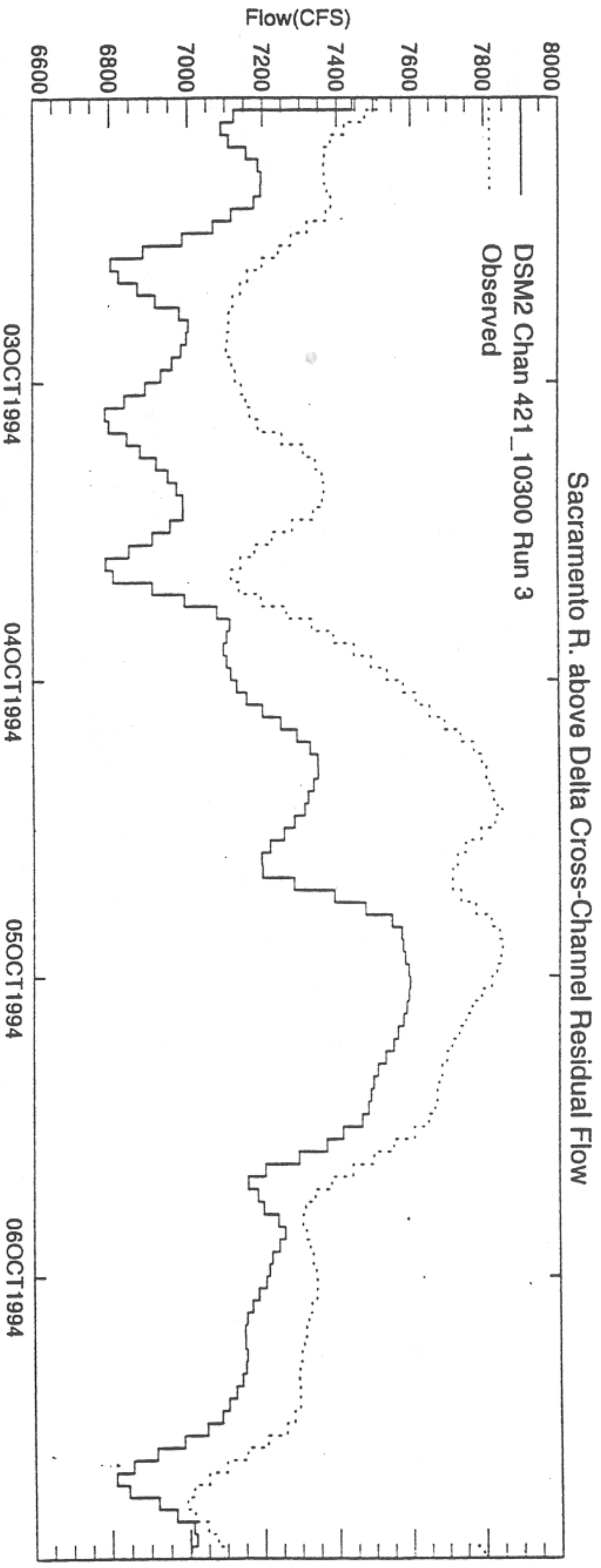
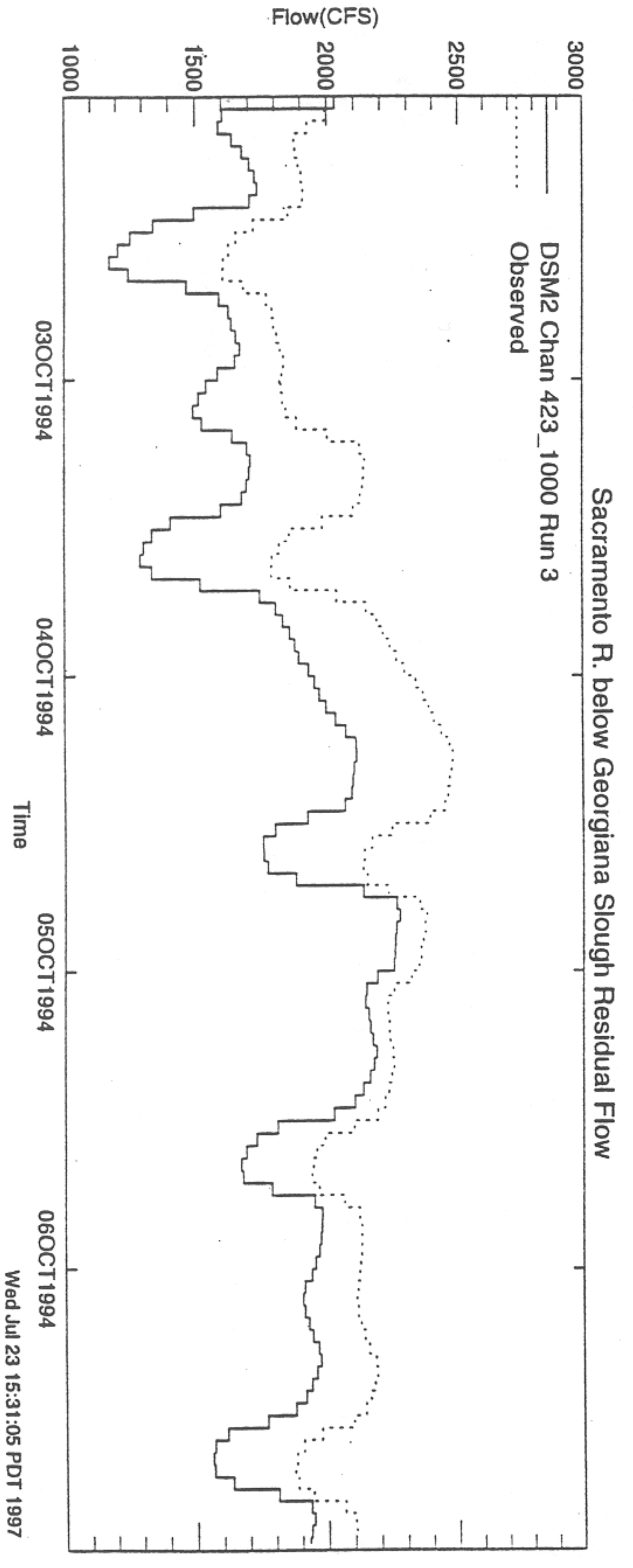
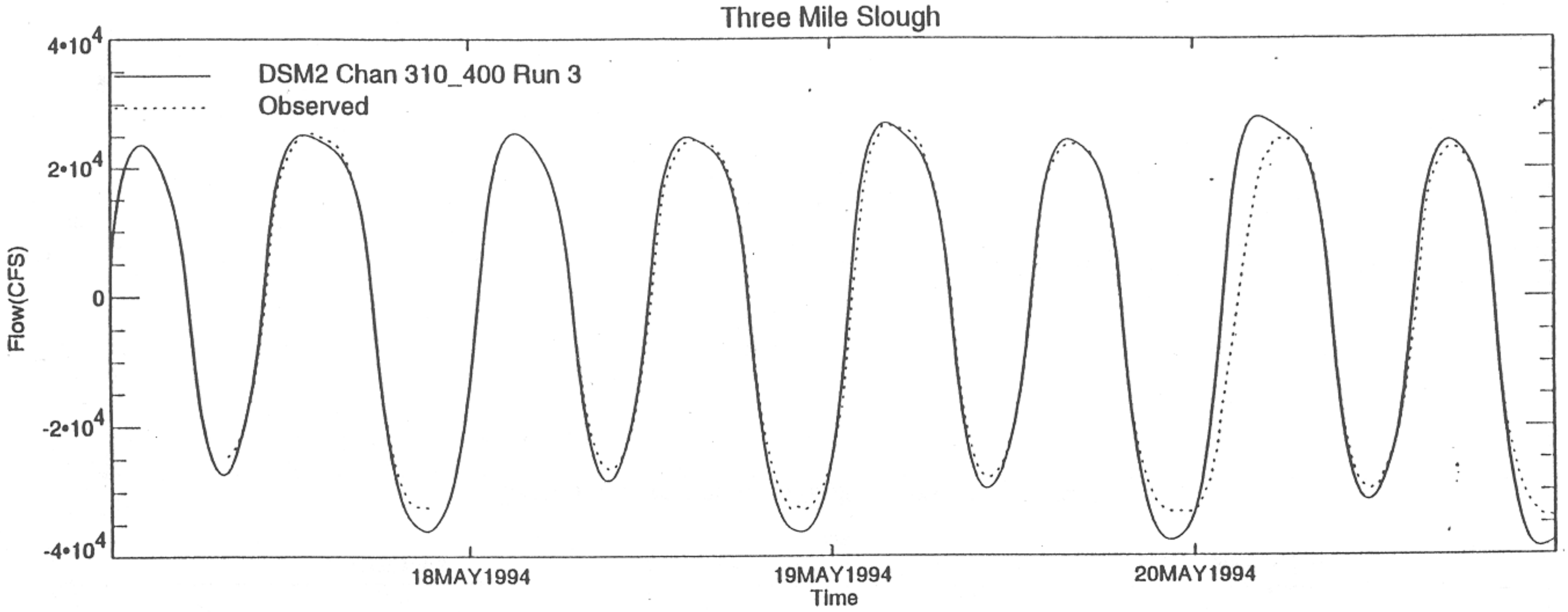

Sacramento R. above Delta Cross-Channel

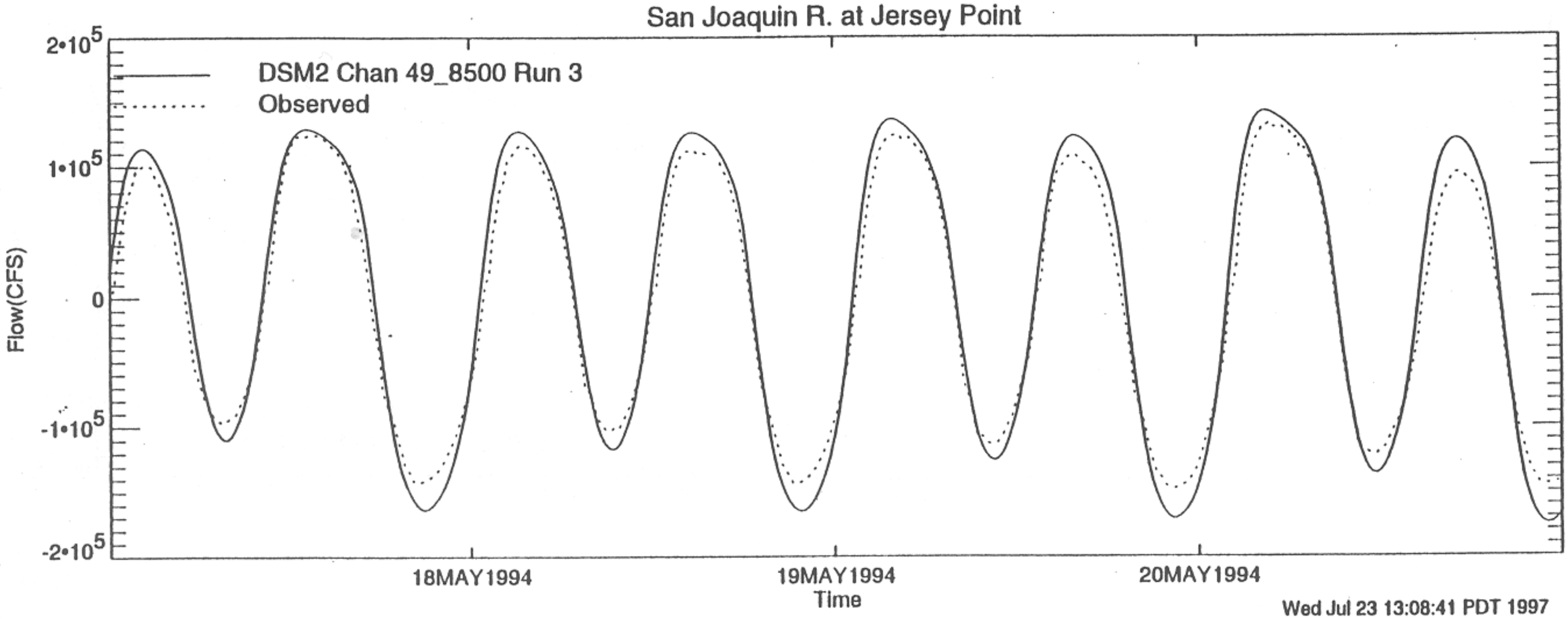

Sacramento R. below Georgiana Slough

Wed Jul 23 14:22:06 PDT 1997


Sacramento R. above Delta Cross-Channel Residual Flow
DSM2 Chan 421_10300 Run 3
Observed
Flow(CFS)
8000
7800
7600
7400
7200
7000
6800
6600
03OCT1994
04OCT1994
05OCT1994
06OCT1994
Time

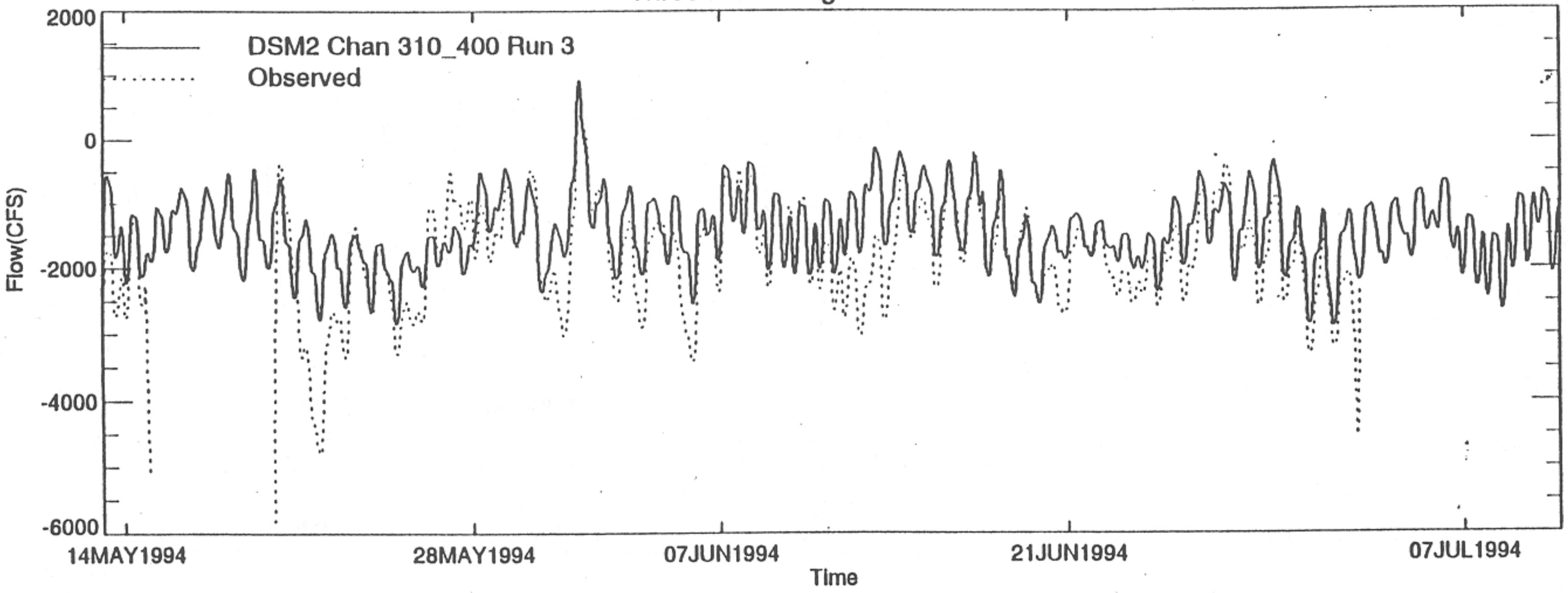

Sacramento R. below Georgiana Slough Residual Flow
DSM2 Chan 423_1000 Run 3
Observed
Flow(CFS)
3000
2500
2000
1500
1000
03OCT1994
04OCT1994
05OCT1994
06OCT1994
Time
Wed Jul 23 15:31:05 PDT 1997


Three Mile Slough

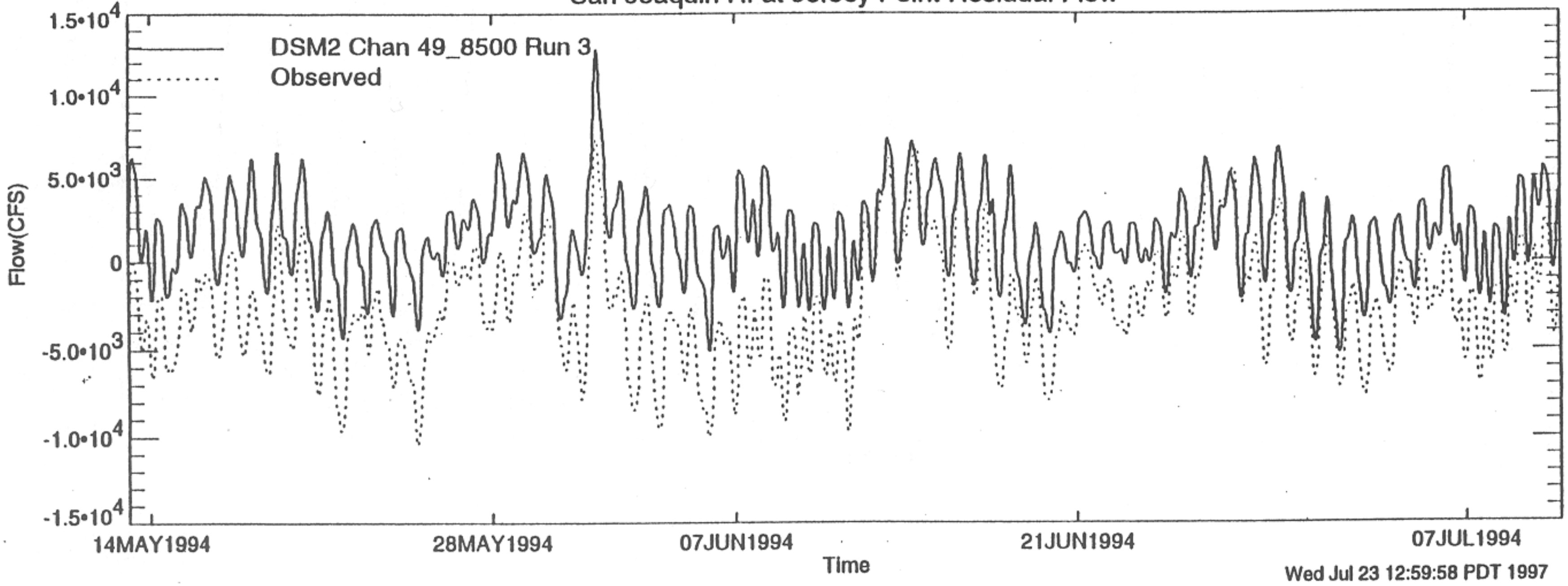

San Joaquin R. at Jersey Point

Wed Jul 23 13:08:41 PDT 1997

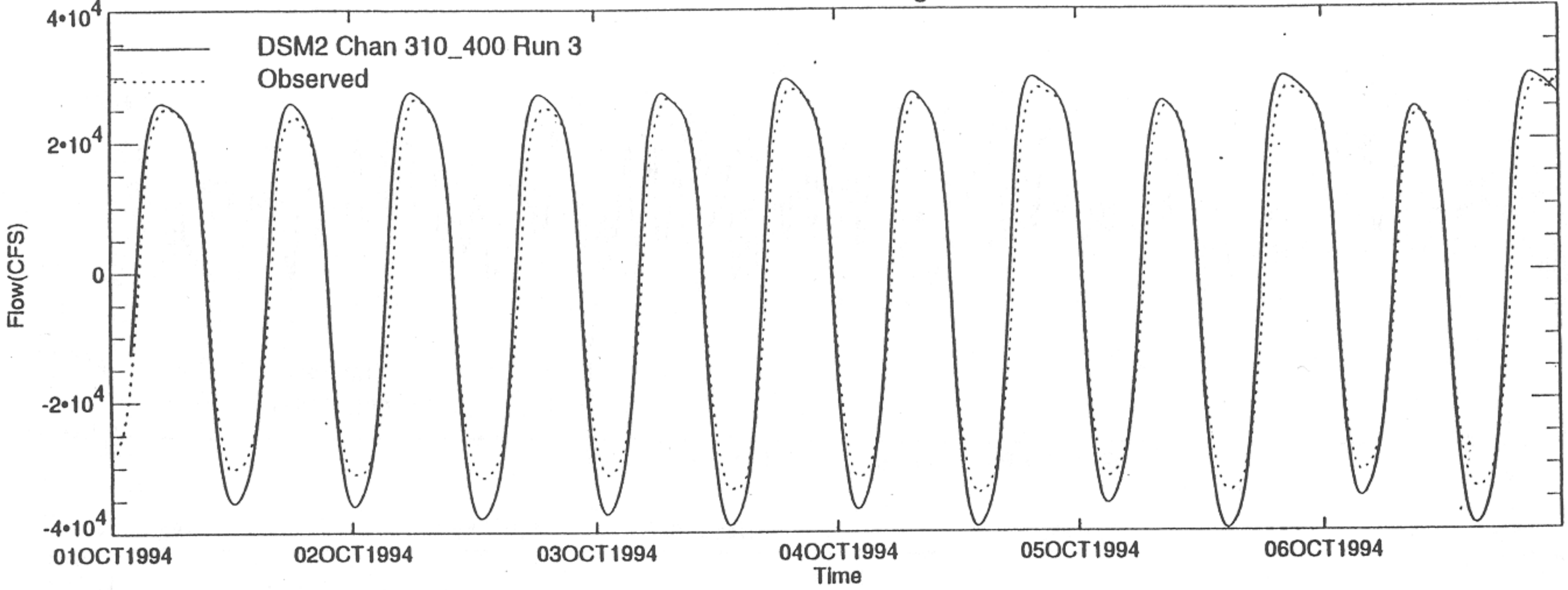
Three Mile Slough Residual Flow

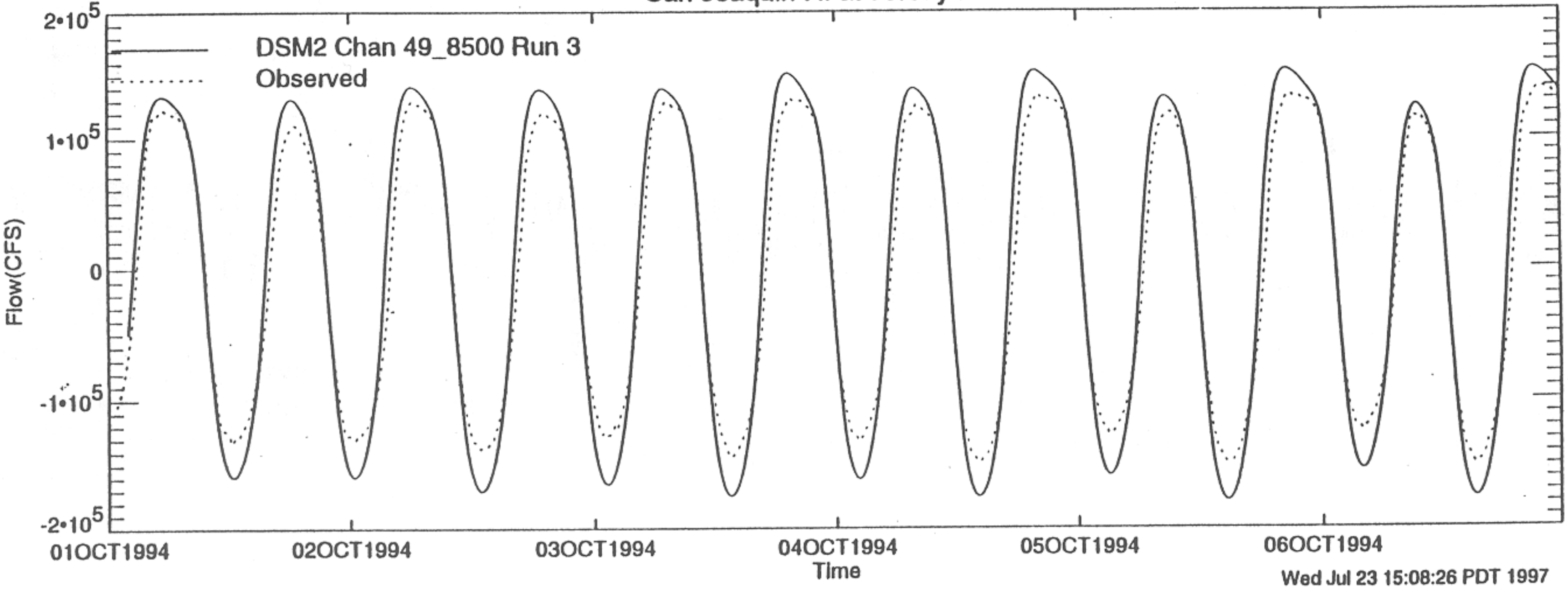


San Joaquin R. at Jersey Point Residual Flow

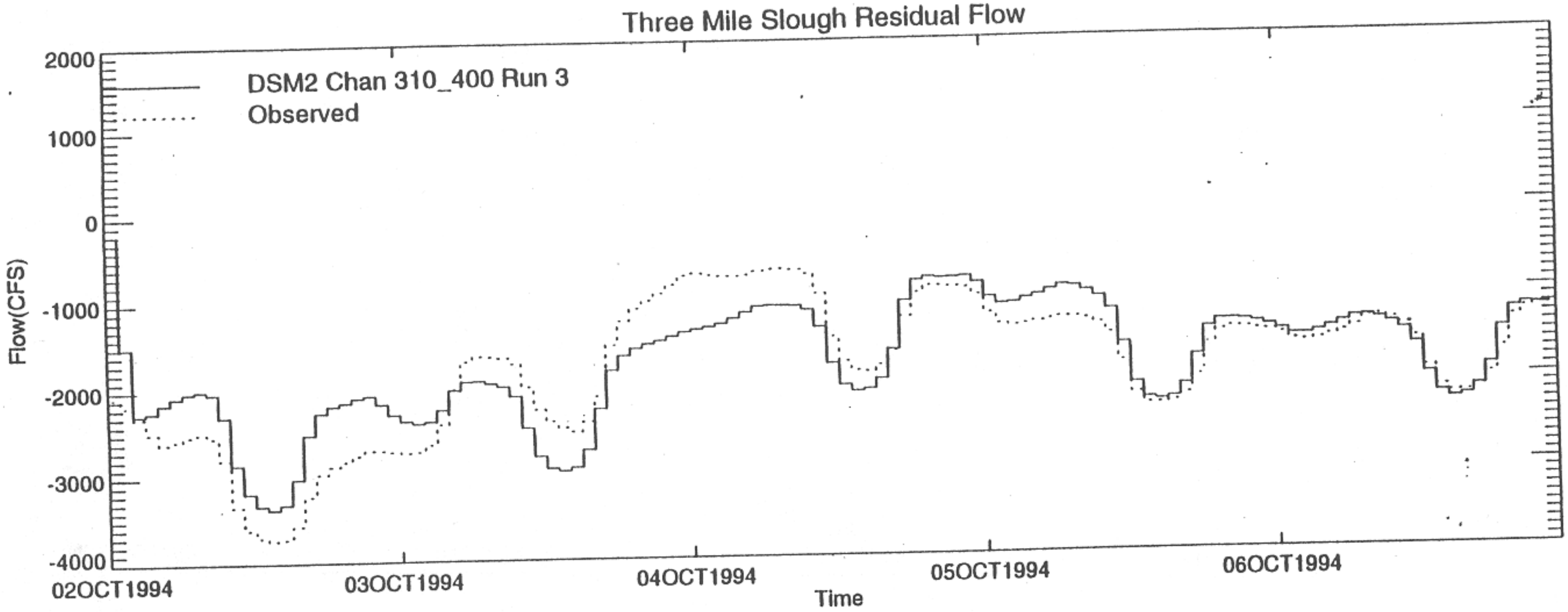


Wed Jul 23 12:59:58 PDT 1997

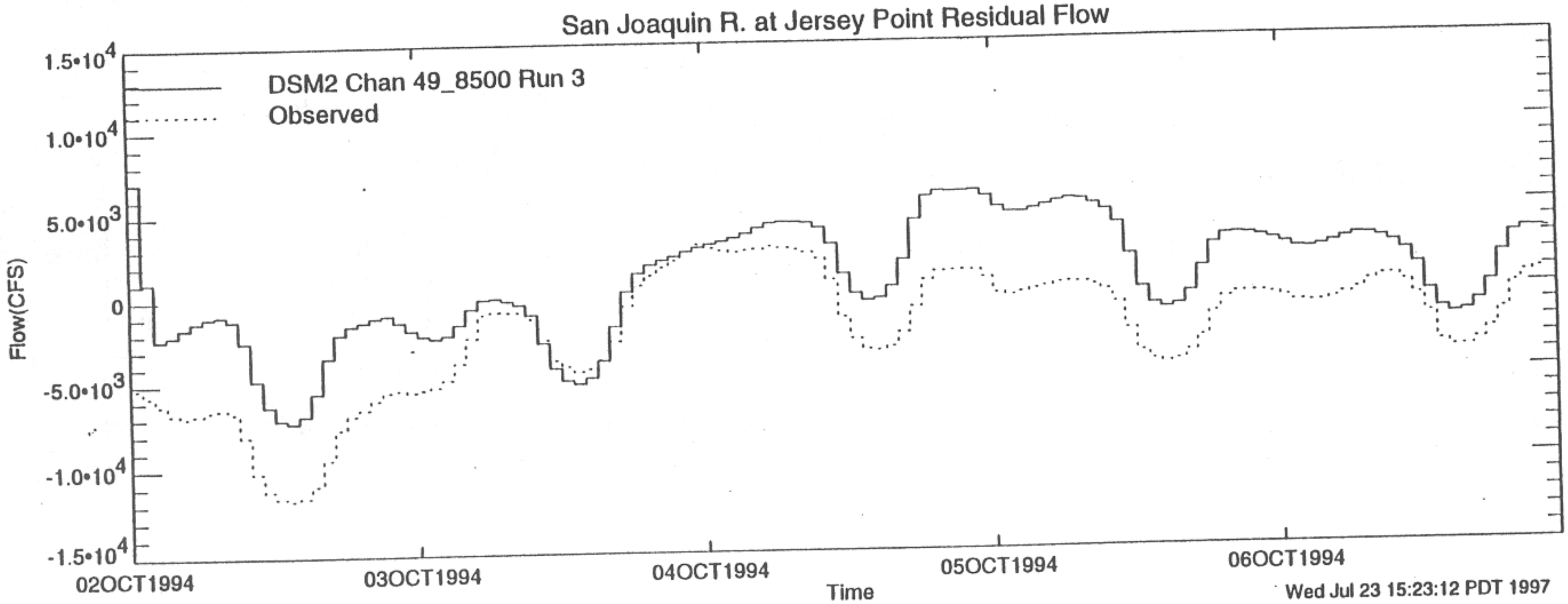

Three Mile Slough


San Joaquin R. at Jersey Point

Wed Jul 23 15:08:26 PDT 1997

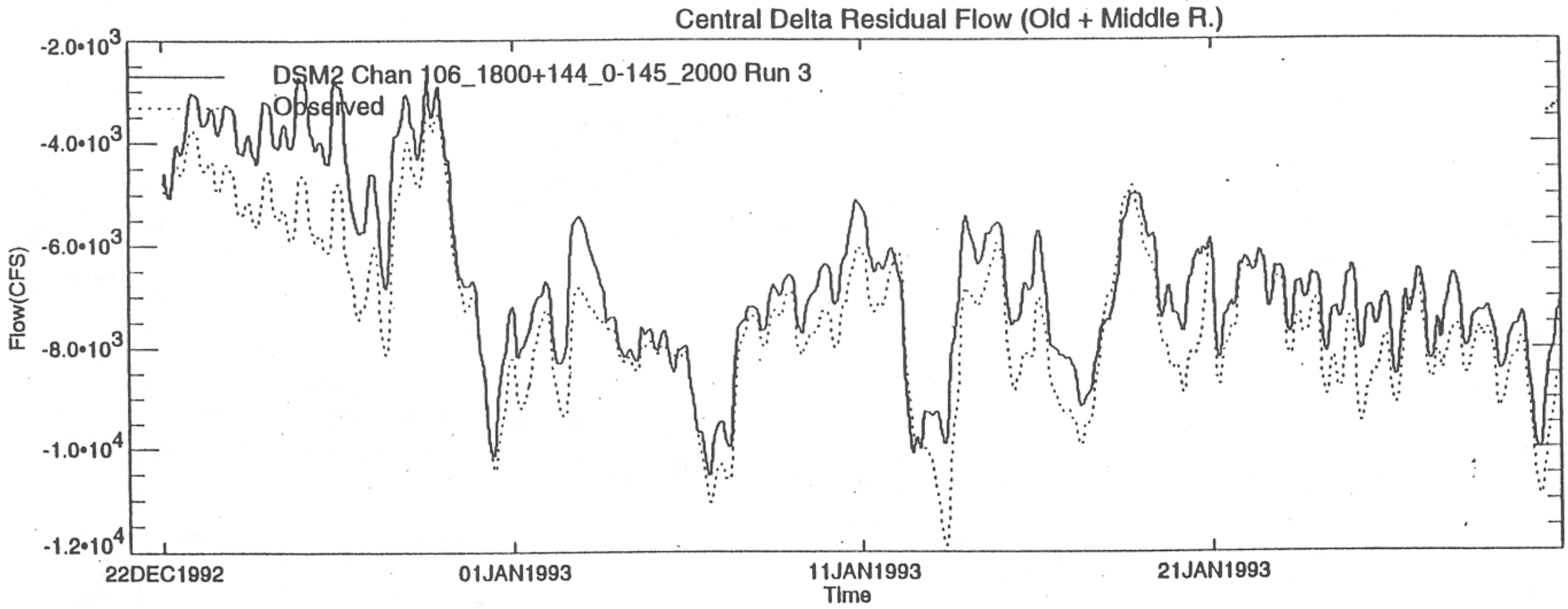


Three Mile Slough Residual Flow

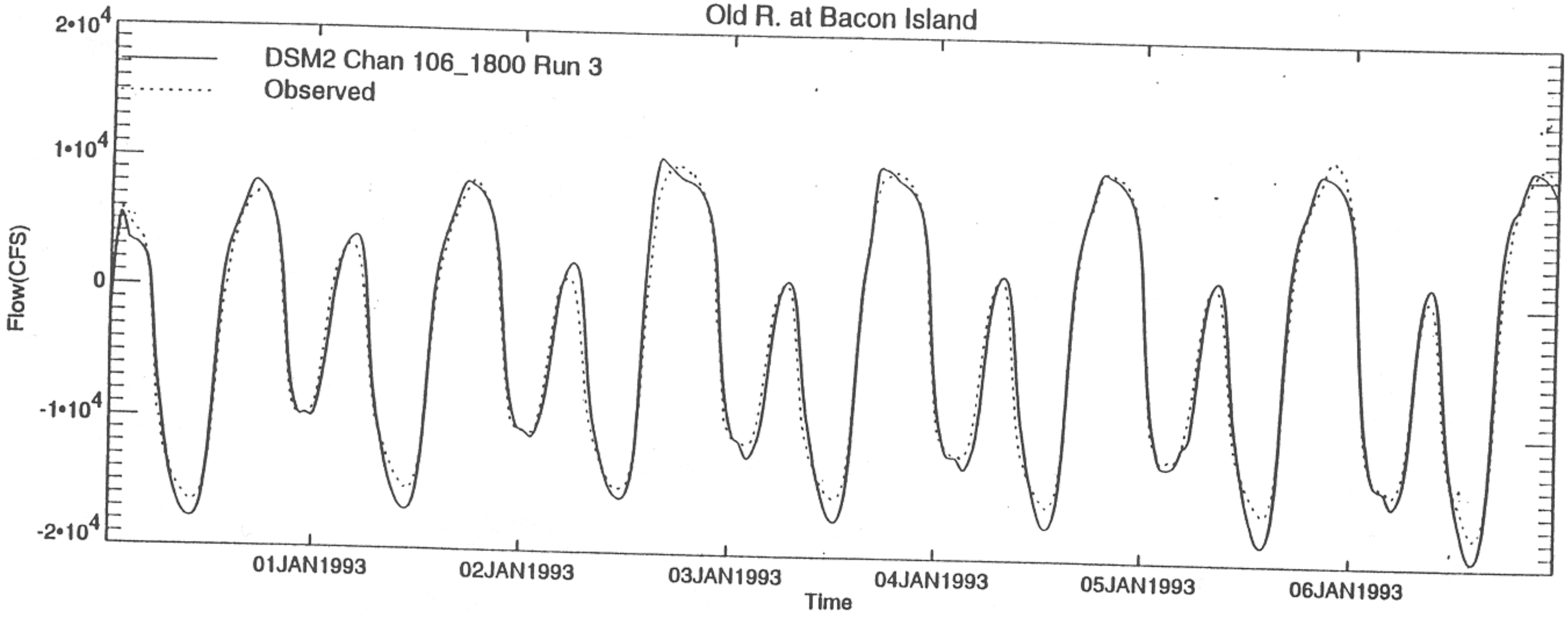


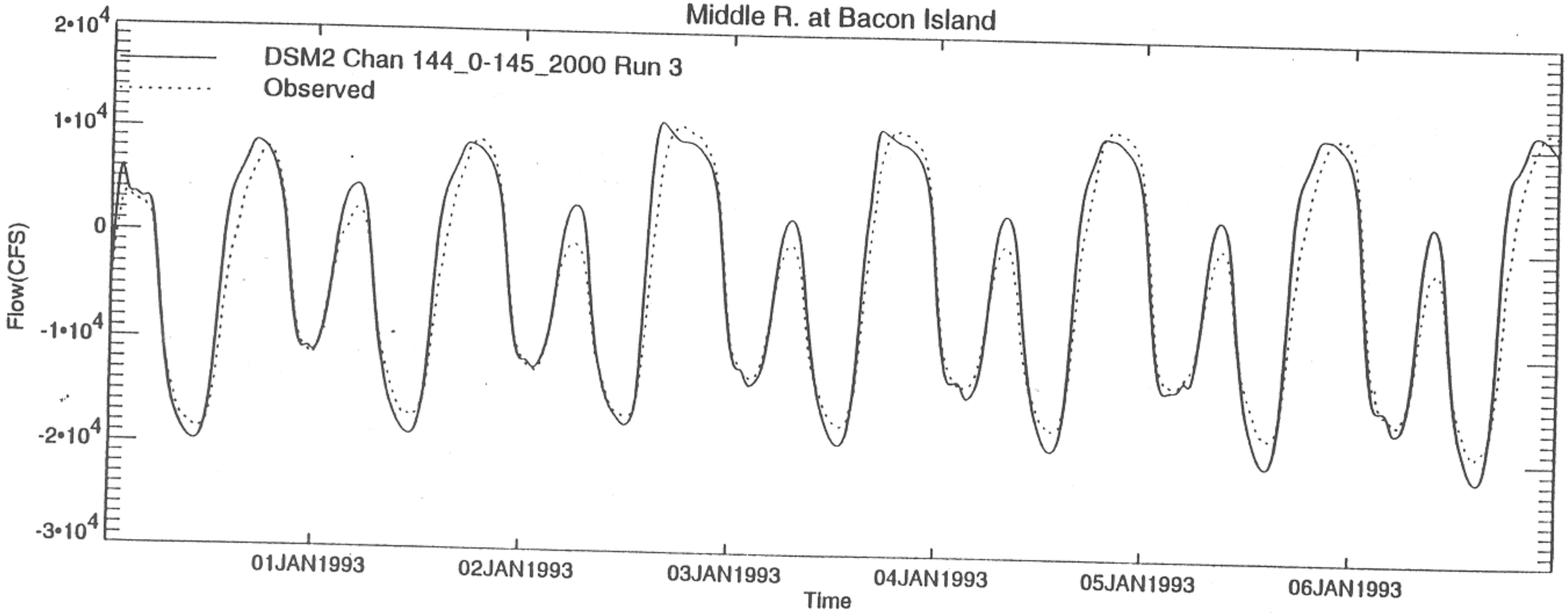
San Joaquin R. at Jersey Point Residual Flow

Wed Jul 23 15:23:12 PDT 1997

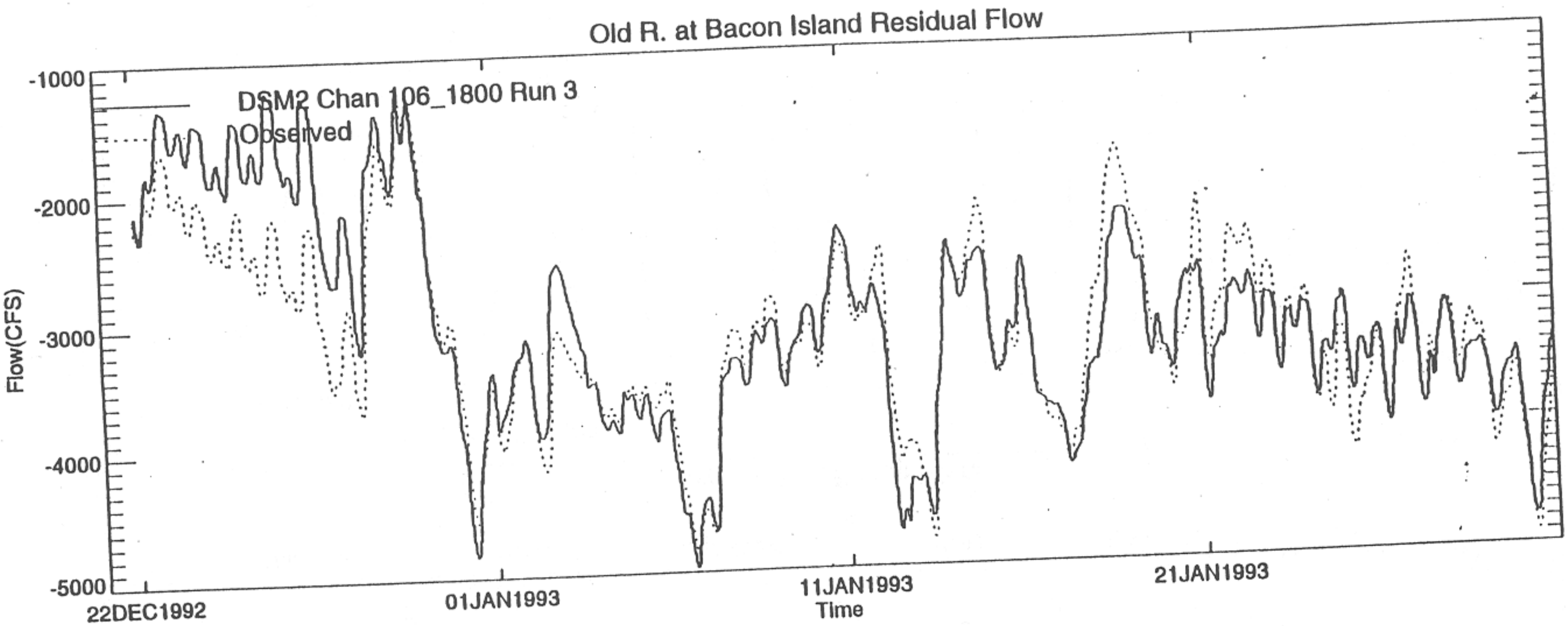


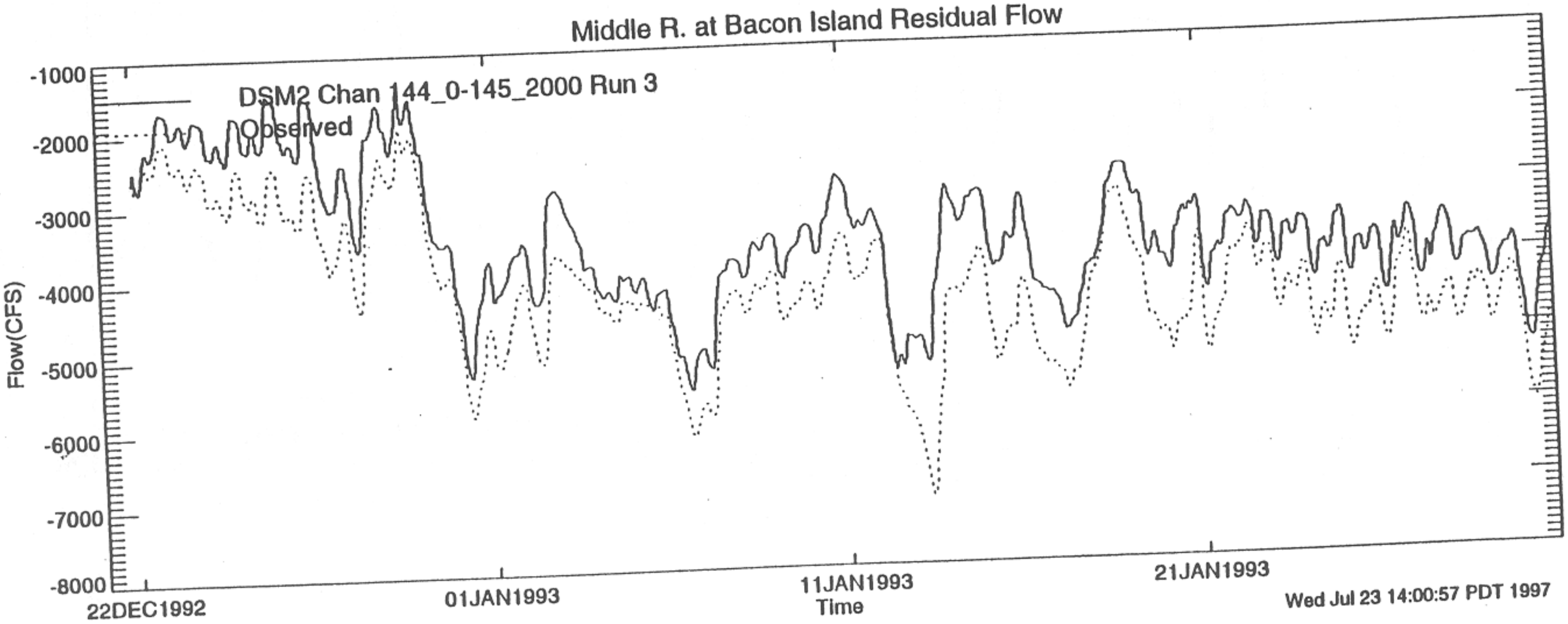
Wed Jul 23 14:03:53 PDT 1997

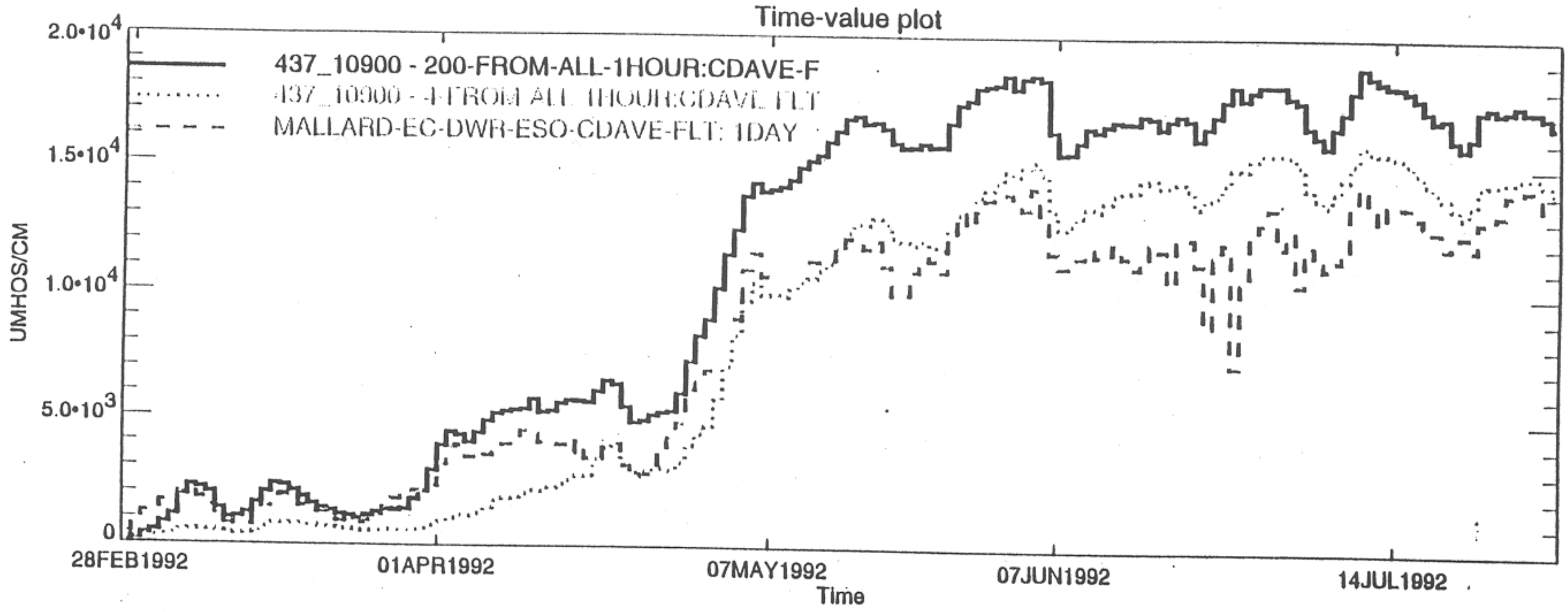

Old R. at Bacon Island

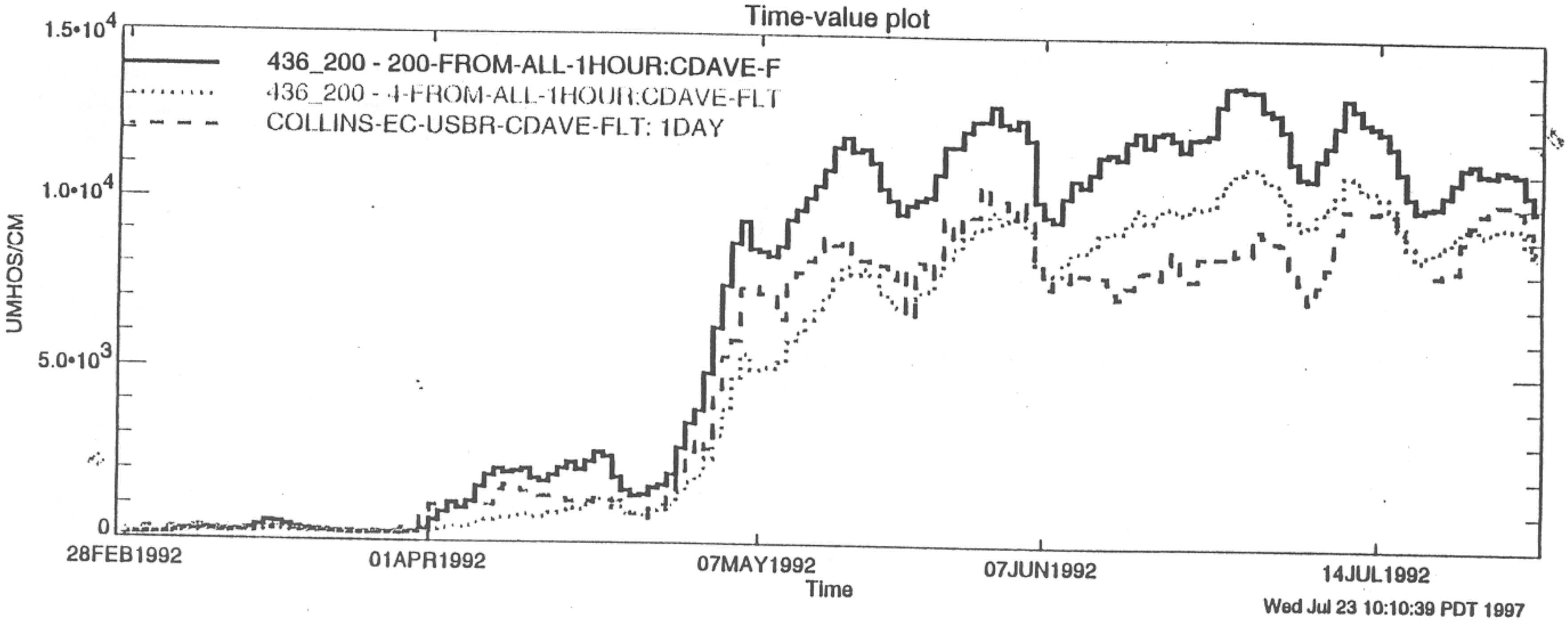

Middle R. at Bacon Island

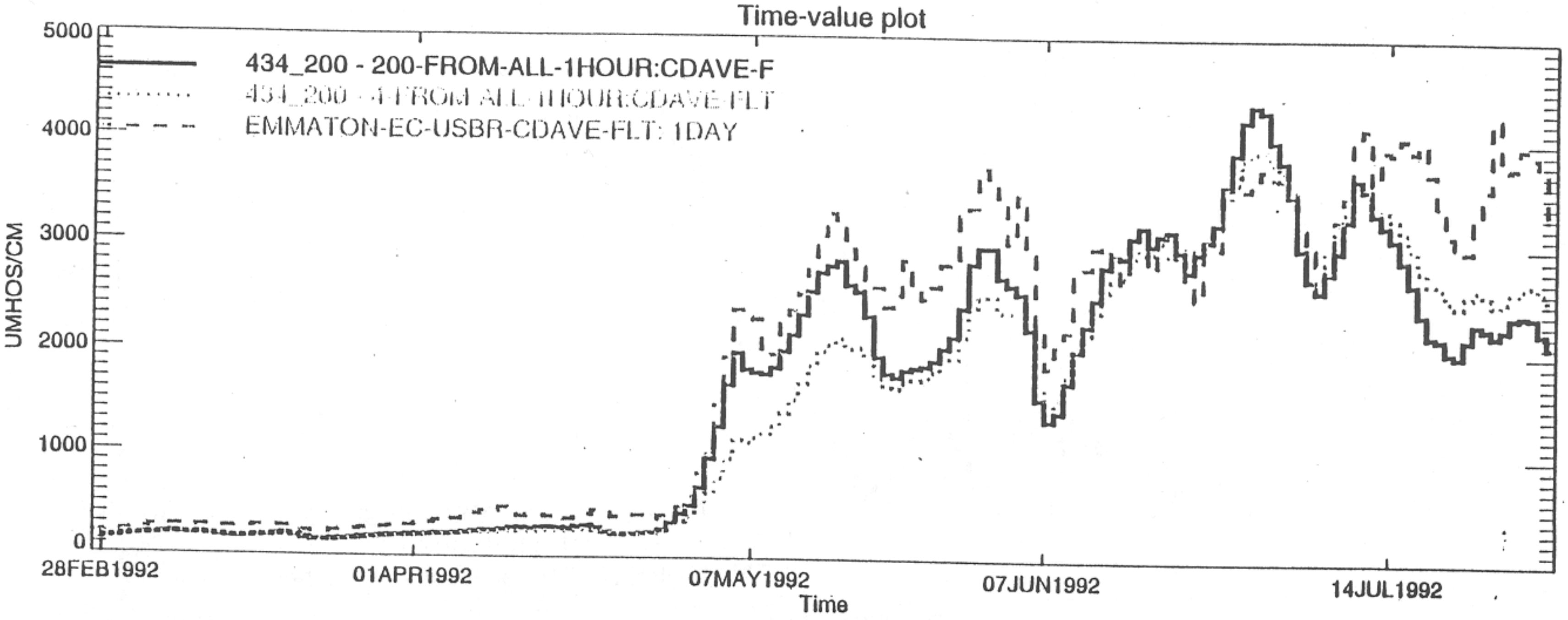
Wed Jul 23 13:51:07 PDT 1997

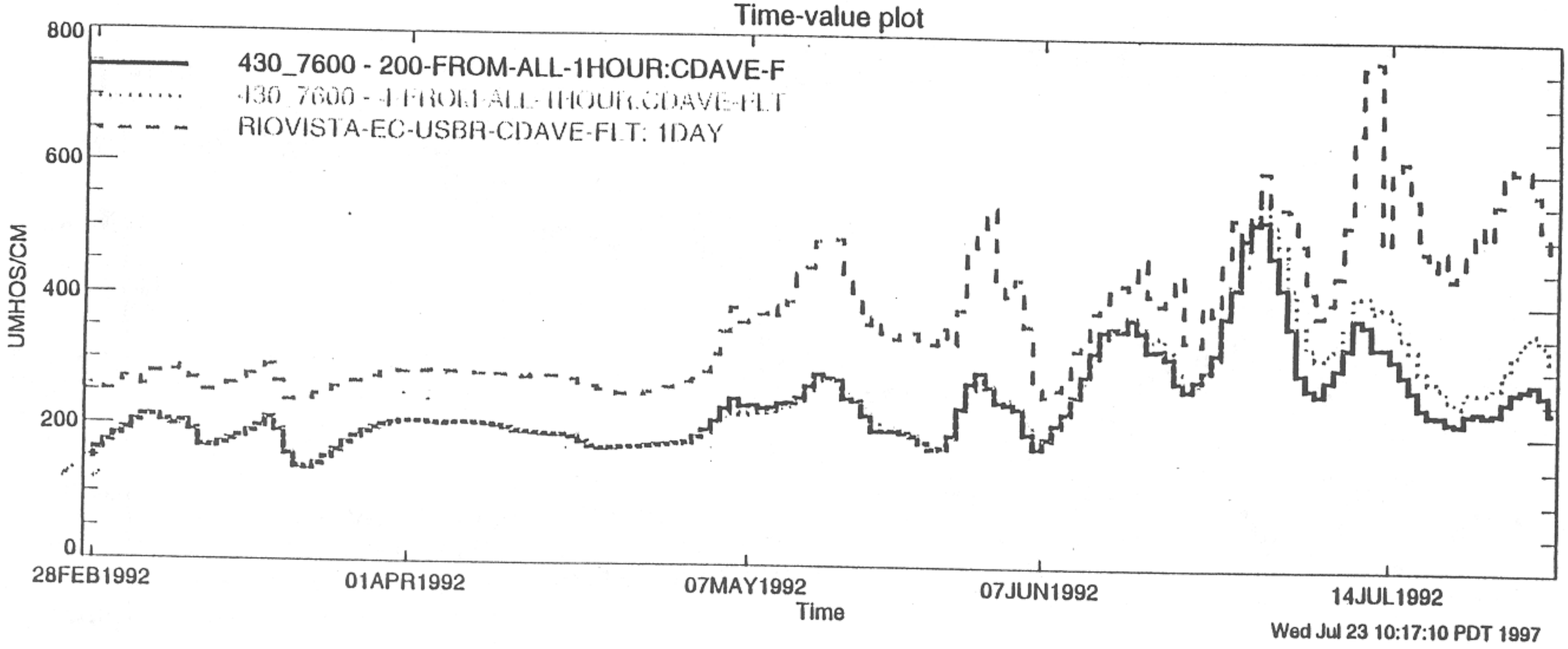

Old R. at Bacon Island Residual Flow

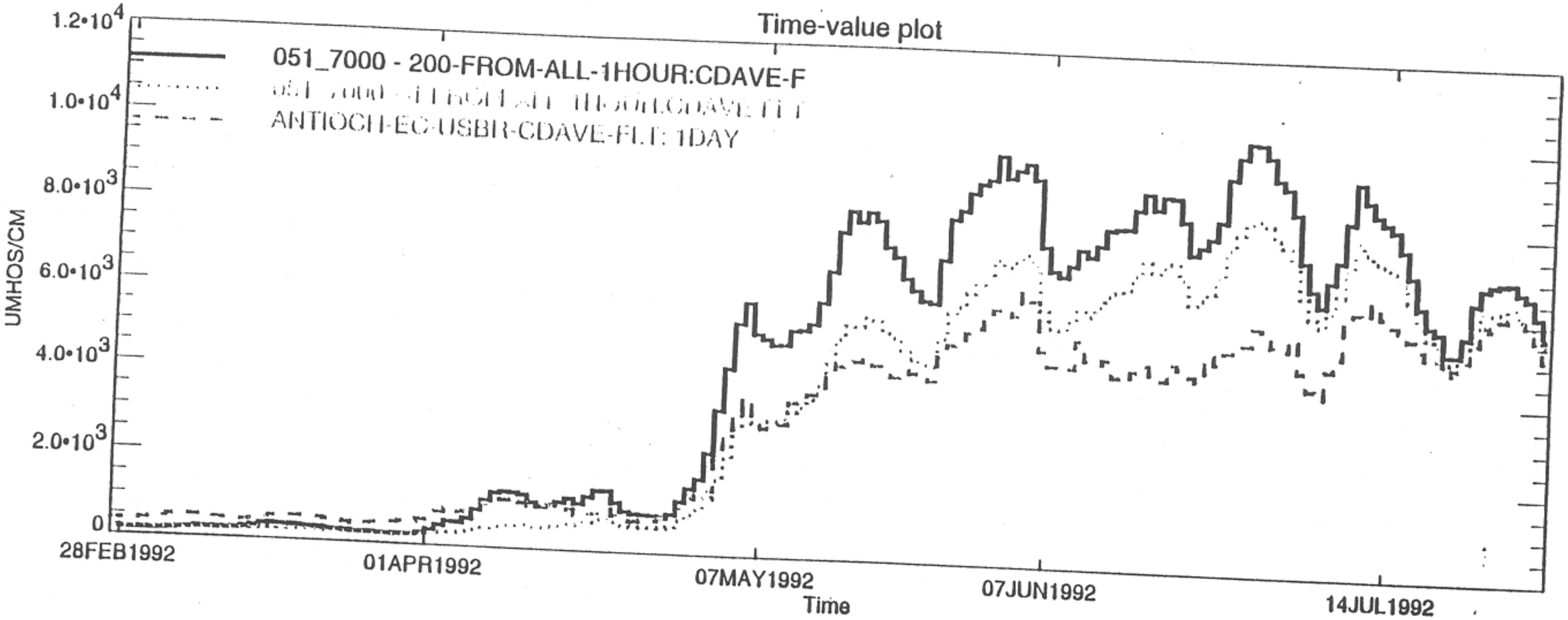

Middle R. at Bacon Island Residual Flow

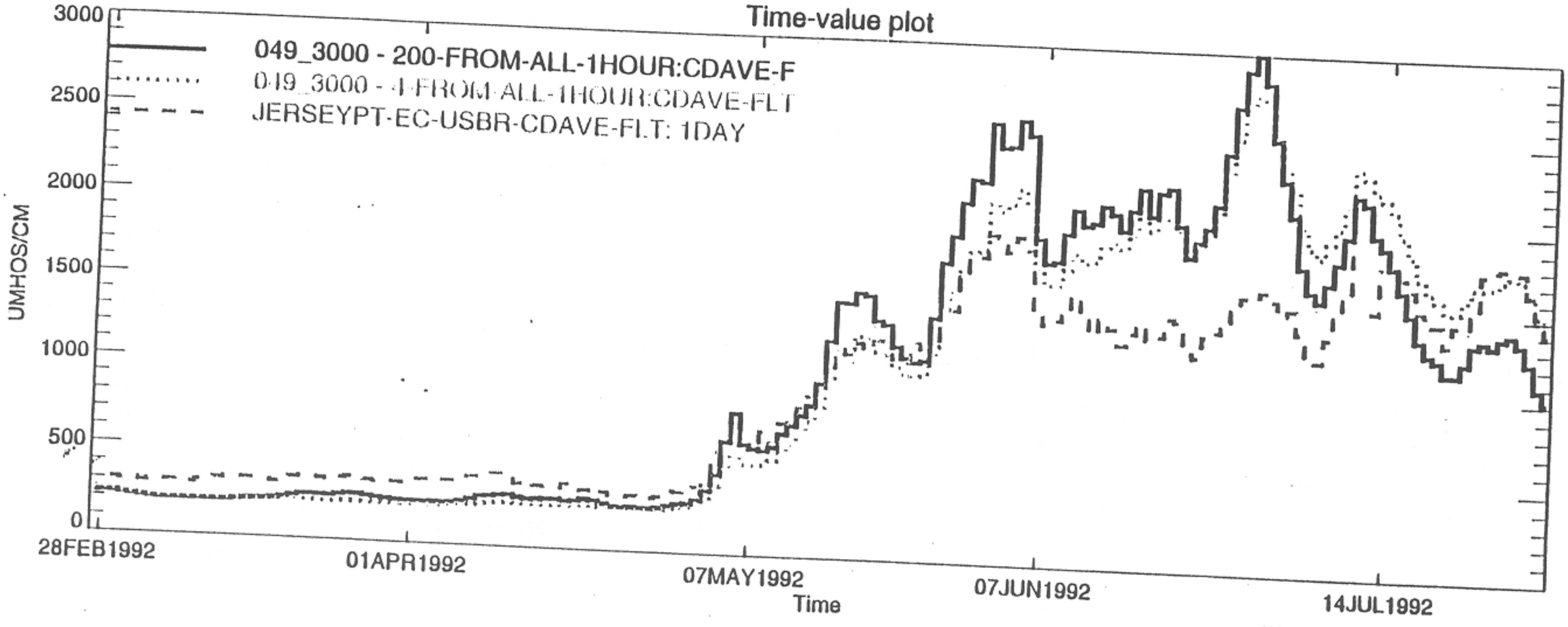

Time-value plot
437_10900 - 200-FROM-ALL-1HOUR:CDAVE-F
437_10900 - 4-FROM-ALL-1HOUR:CDAVE-FLT
MALLARD-EC-DWR-ESO-CDAVE-FLT: 1DAY
UMHOS/CM
2.0•10^4
1.5•10^4
1.0•10^4
5.0•10^3
0
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time


Time-value plot
436_200 - 200-FROM-ALL-1HOUR:CDAVE-F
436_200 - 4-FROM-ALL-1HOUR:CDAVE-FLT
COLLINS-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
1.5•10^4
1.0•10^4
5.0•10^3
0
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time
Wed Jul 23 10:10:39 PDT 1997

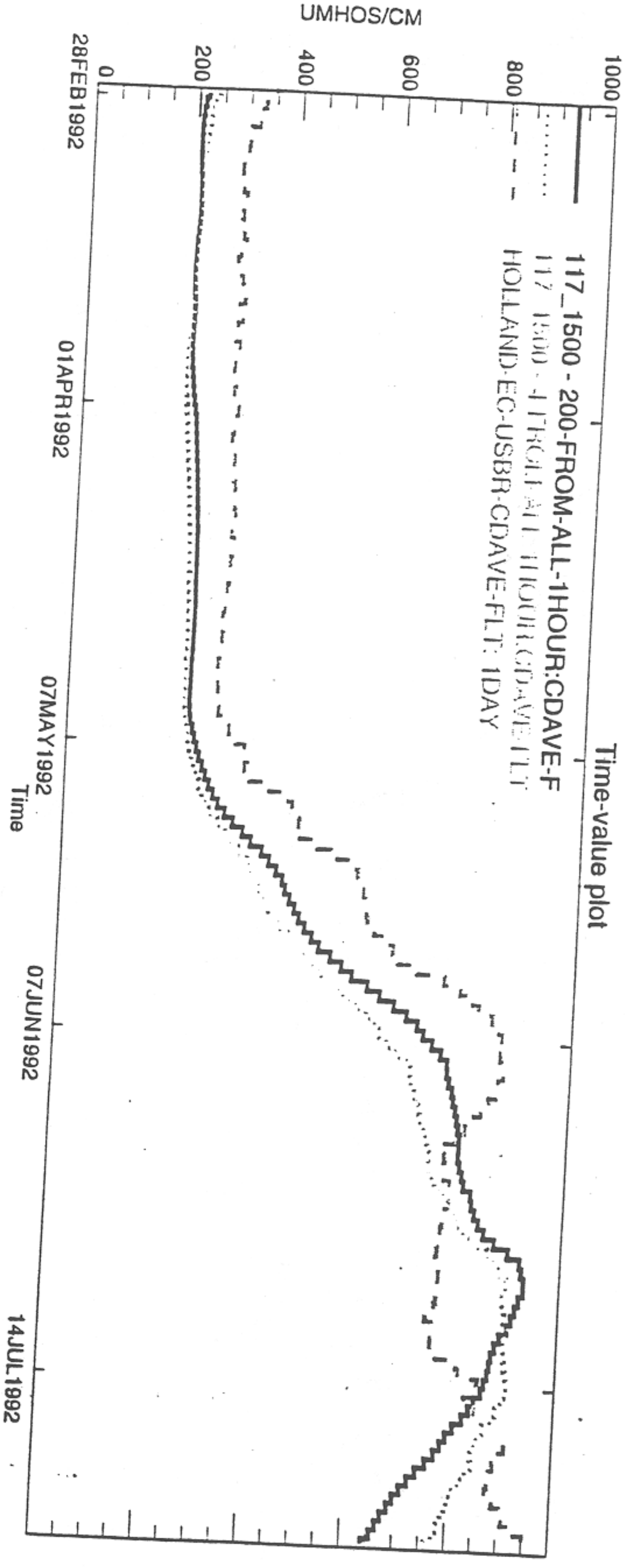

Time-value plot
434_200 - 200-FROM-ALL-1HOUR:CDAVE-F
434_200 - 4-FROM-ALL-1HOUR:CDAVE-FLT
EMMATON-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
5000
4000
3000
2000
1000
0
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time

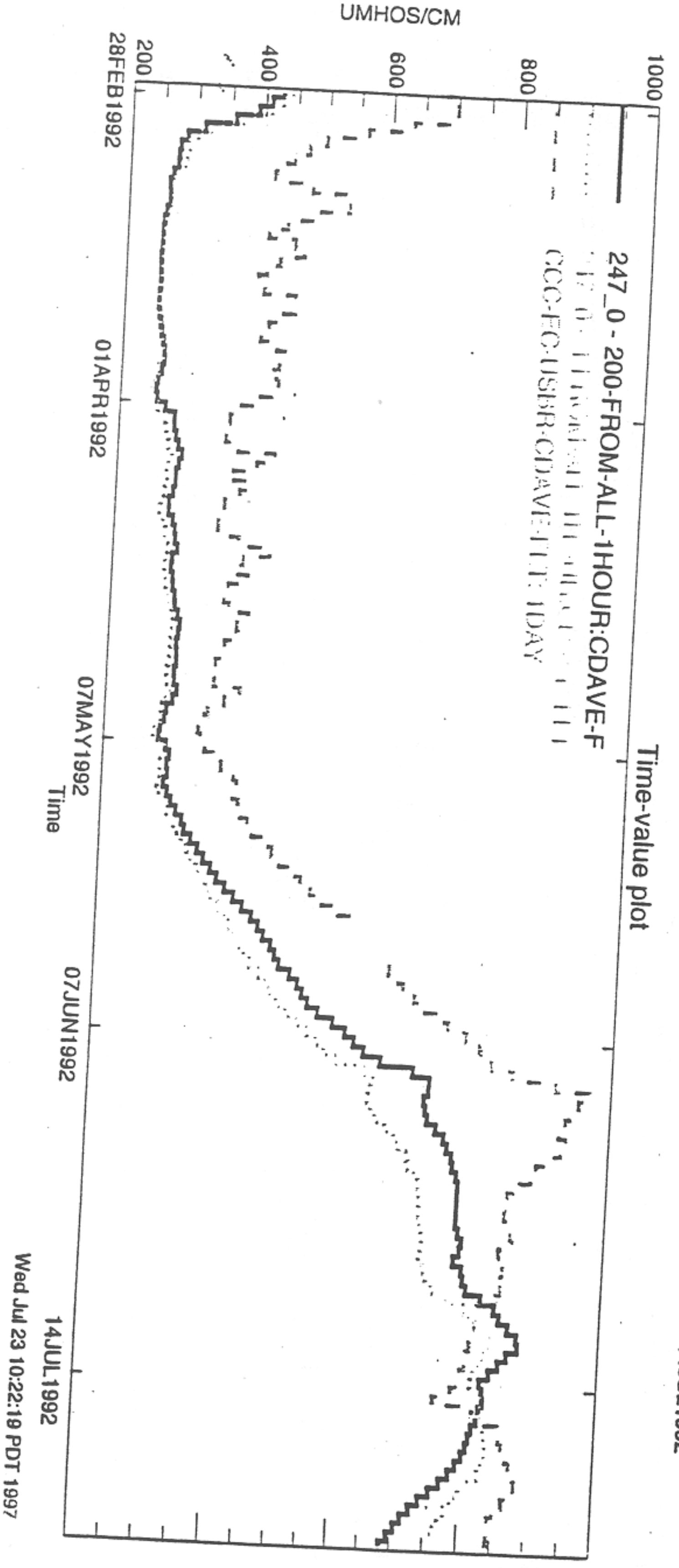

Time-value plot
430_7600 - 200-FROM-ALL-1HOUR:CDAVE-F
430_7600 - 4-FROM-ALL-1HOUR:CDAVE-FLT
RIOVISTA-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
800
600
400
200
0
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time
Wed Jul 23 10:17:10 PDT 1997

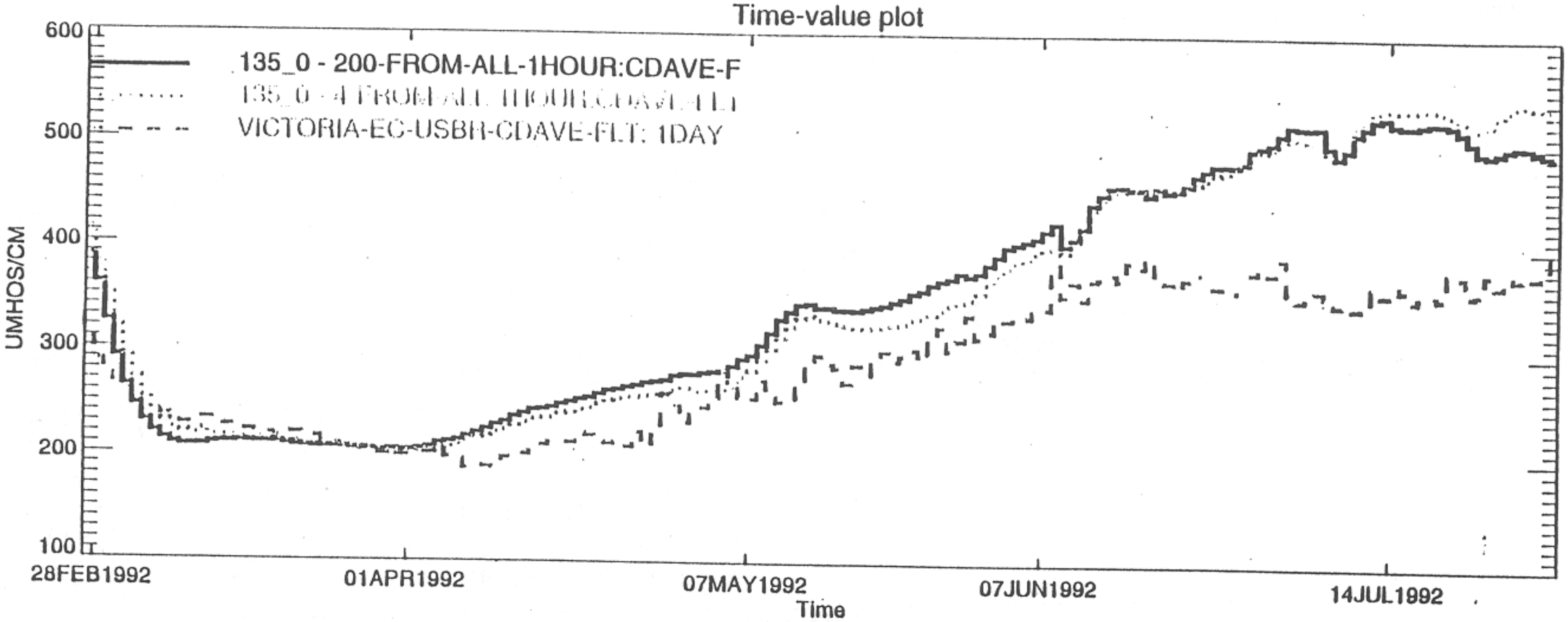


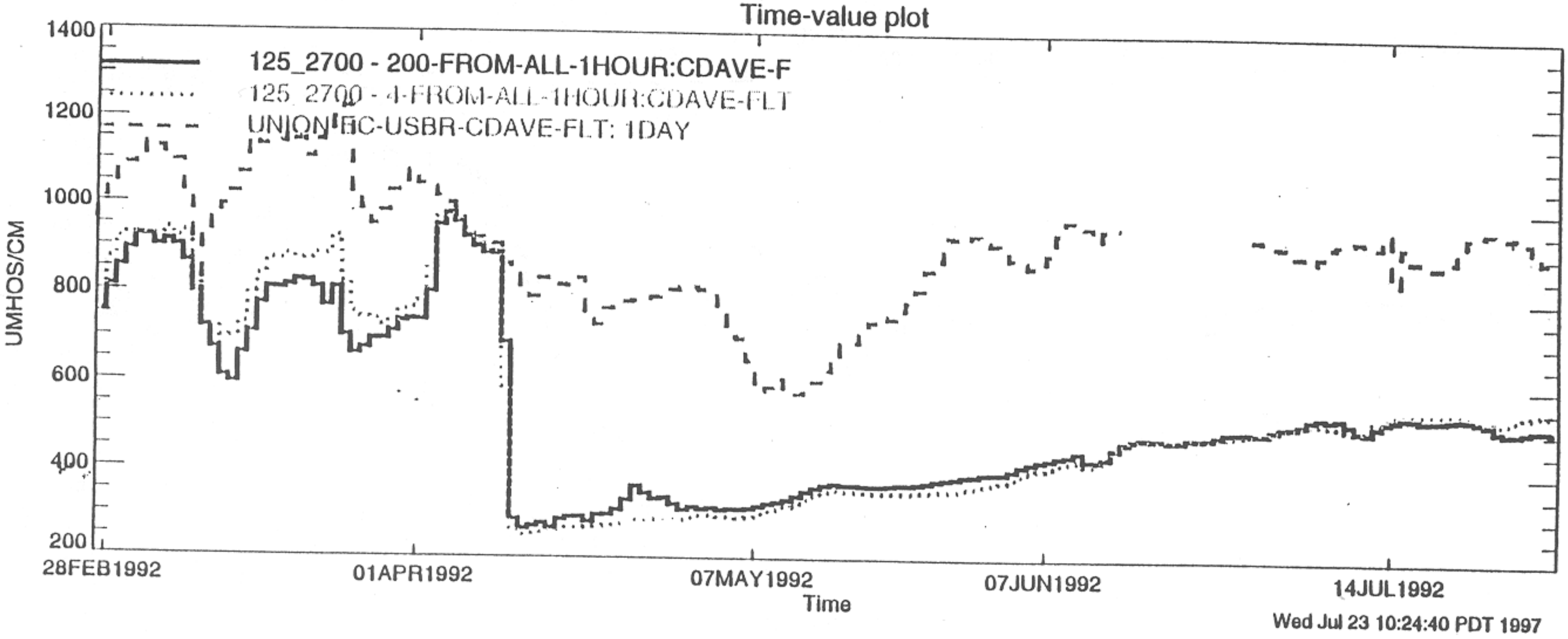


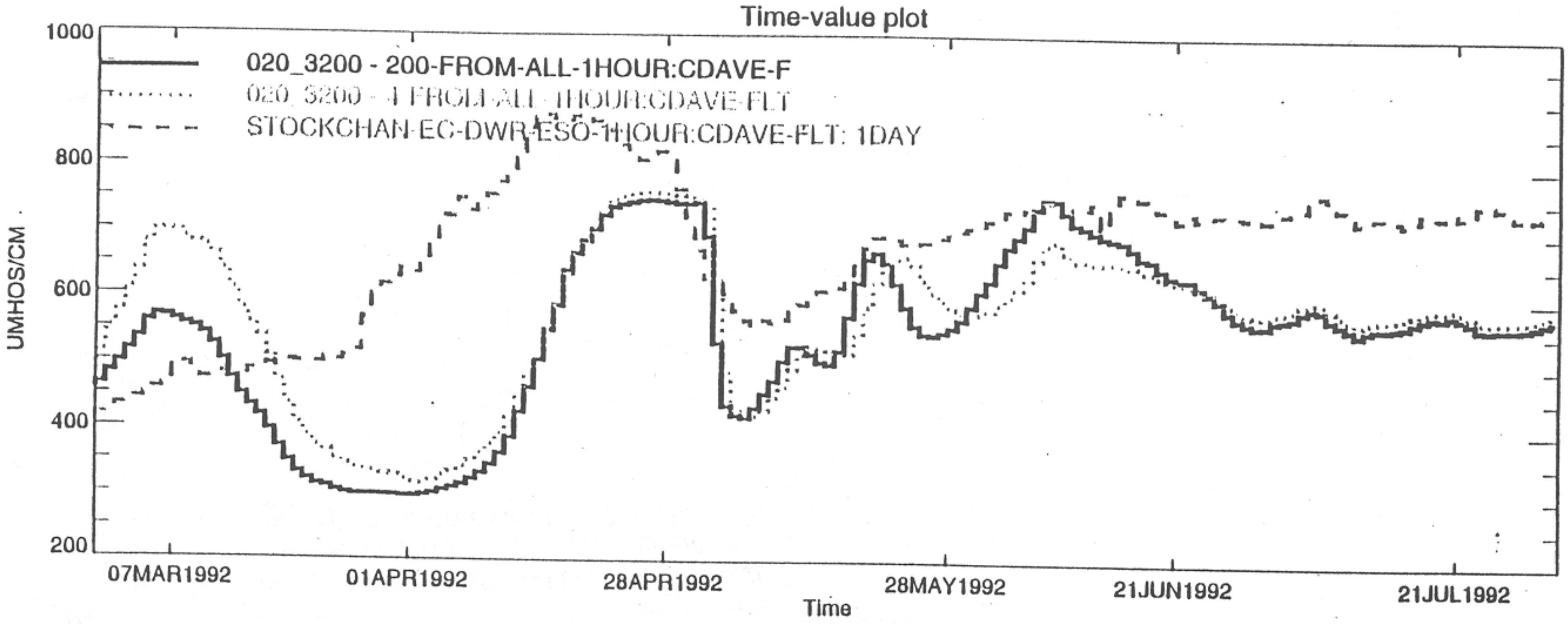
Wed Jul 23 10:20:00 PDT 1997

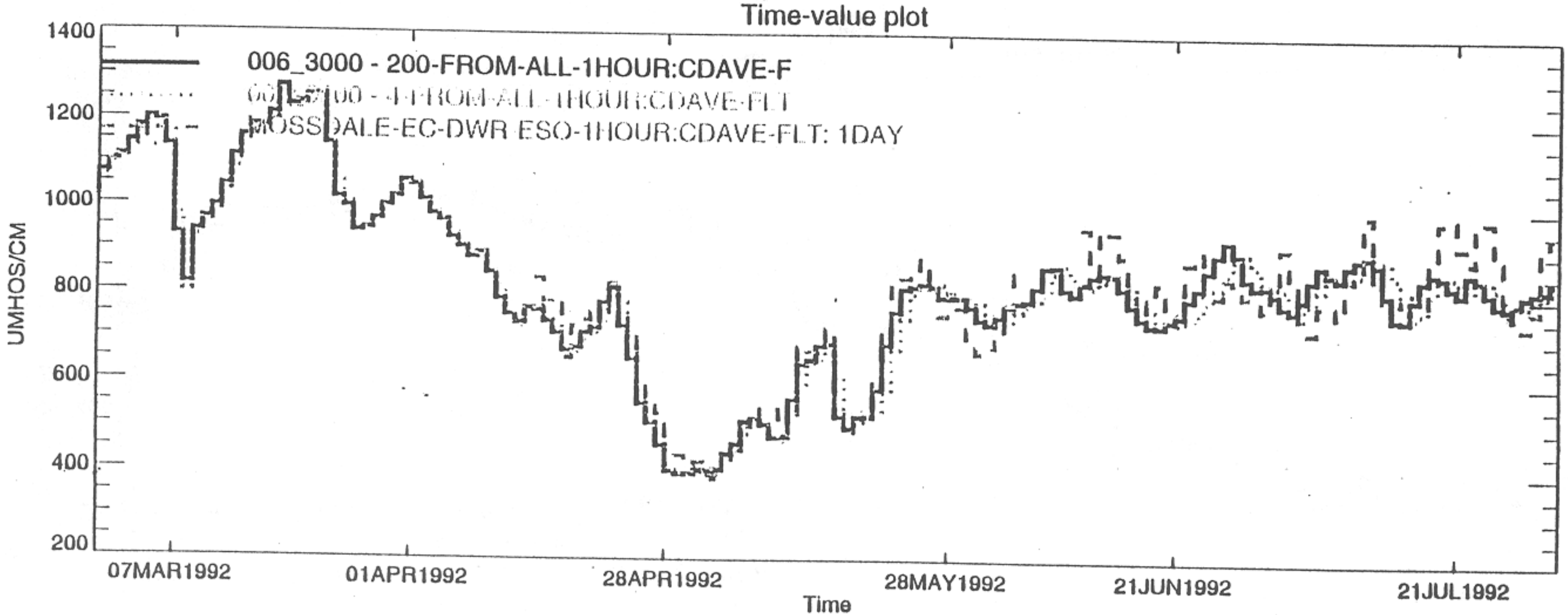

Time-value plot
117_1500 - 200-FROM-ALL-1HOUR:CDAVE-F
HOLLAND-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
0
200
400
600
800
1000
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time


Time-value plot
247_0 - 200-FROM-ALL-1HOUR:CDAVE-F
CCC-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
200
400
600
800
1000
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time
Wed Jul 23 10:22:19 PDT 1997

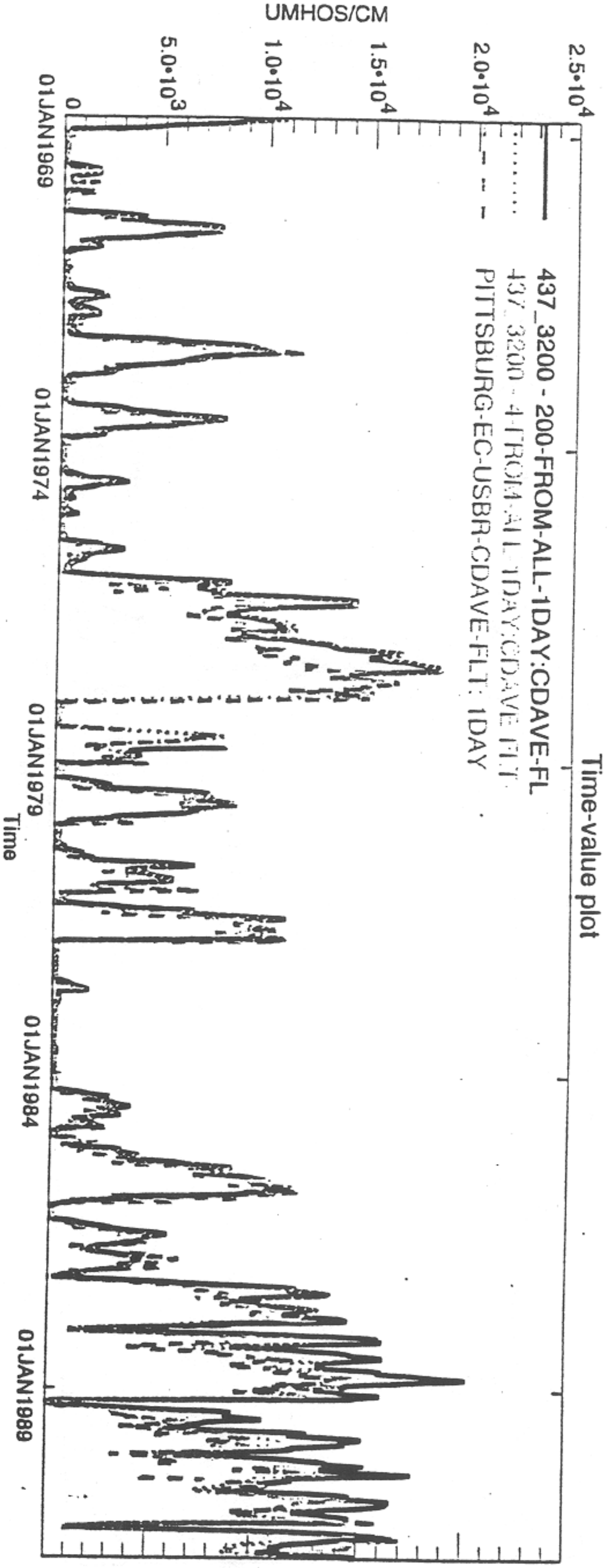

Time-value plot
135_0 - 200-FROM-ALL-1HOUR:CDAVE-F
135_0 - 4-FROM-ALL-1HOUR:CDAVE-FLT
VICTORIA-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
600
500
400
300
200
100
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time

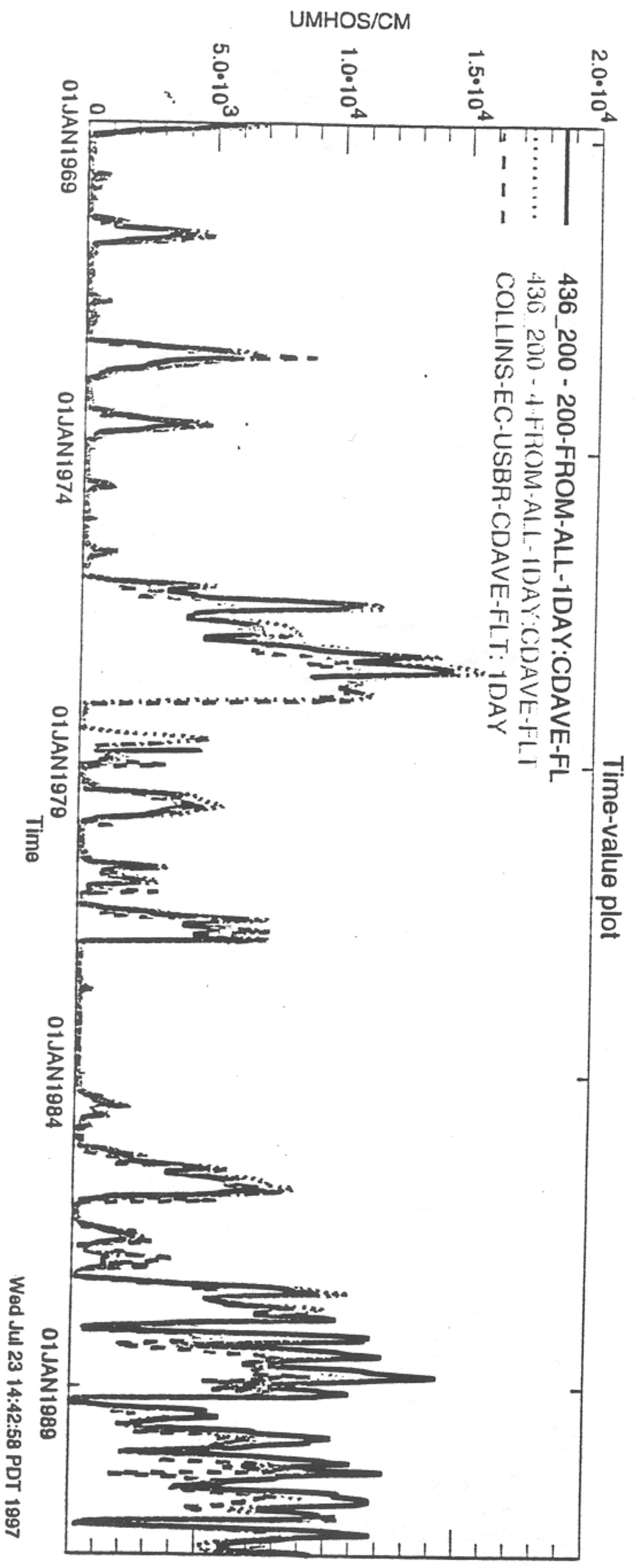

Time-value plot
125_2700 - 200-FROM-ALL-1HOUR:CDAVE-F
125_2700 - 4-FROM-ALL-1HOUR:CDAVE-FLT
UNION-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
1400
1200
1000
800
600
400
200
28FEB1992
01APR1992
07MAY1992
07JUN1992
14JUL1992
Time
Wed Jul 23 10:24:40 PDT 1997

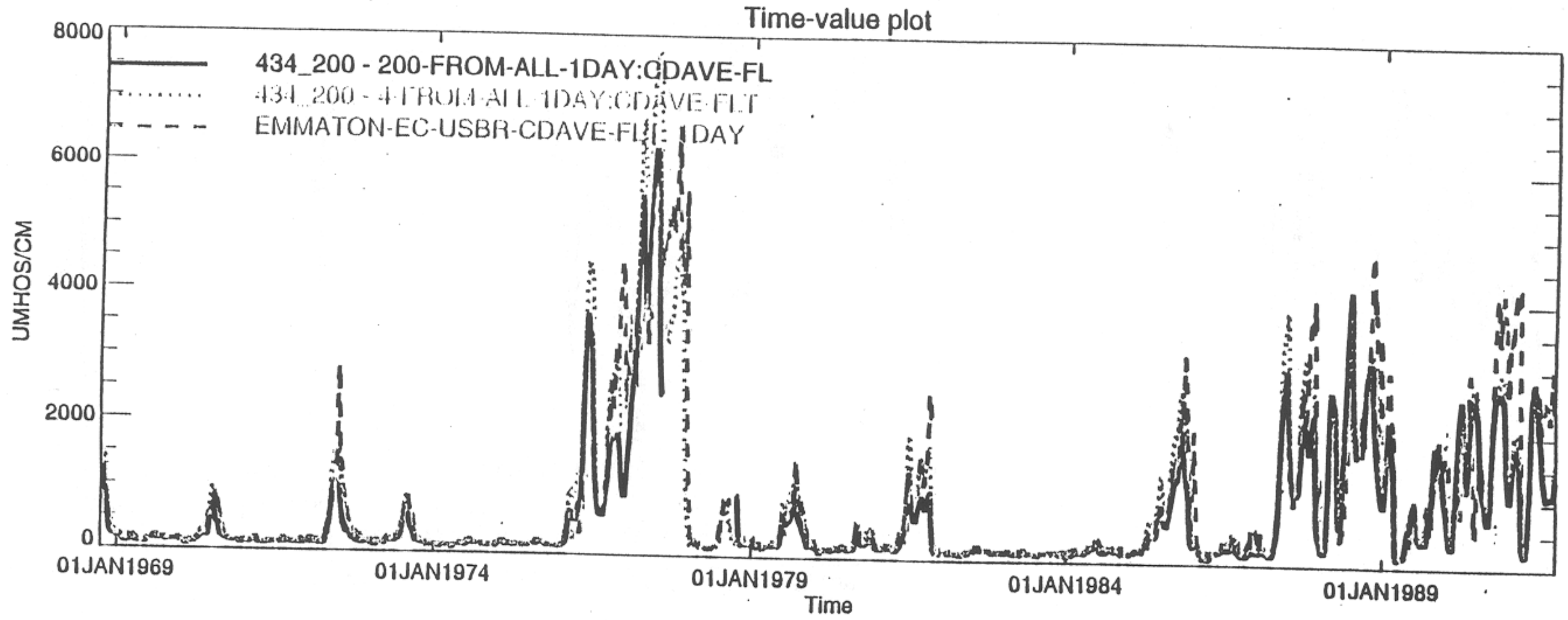


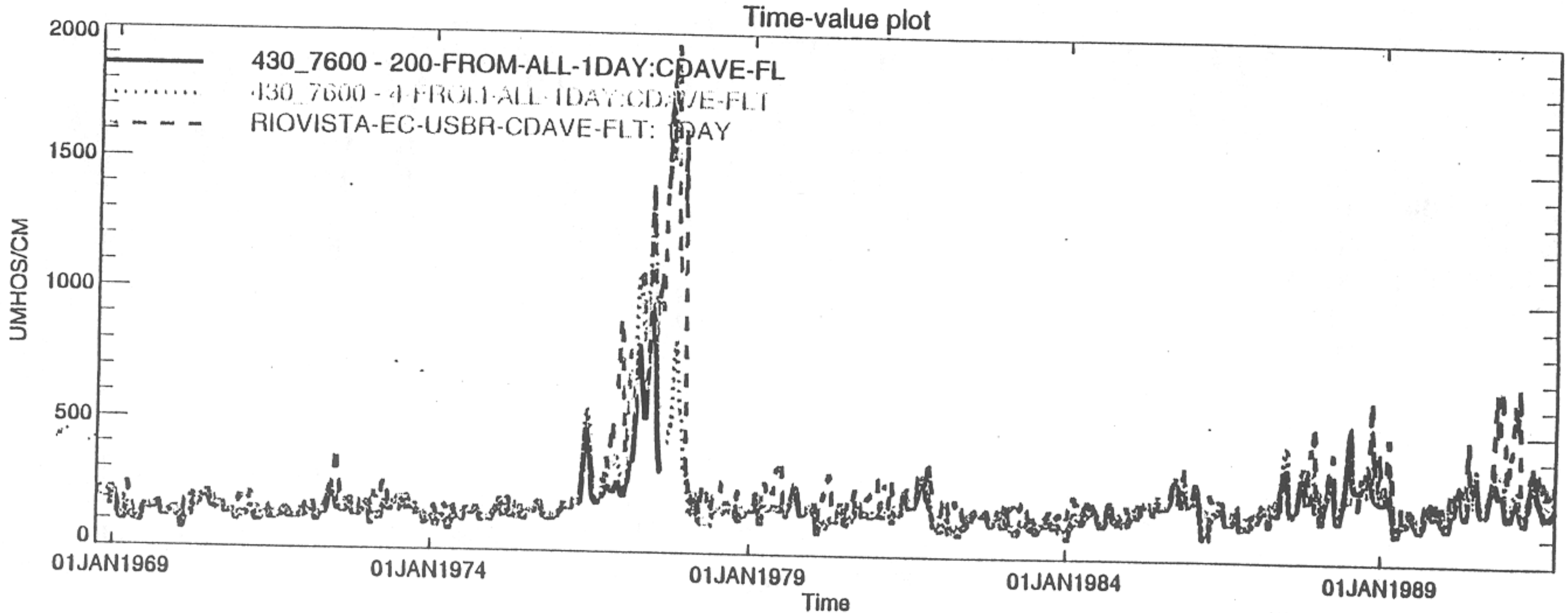


Wed Jul 23 10:27:03 PDT 1997

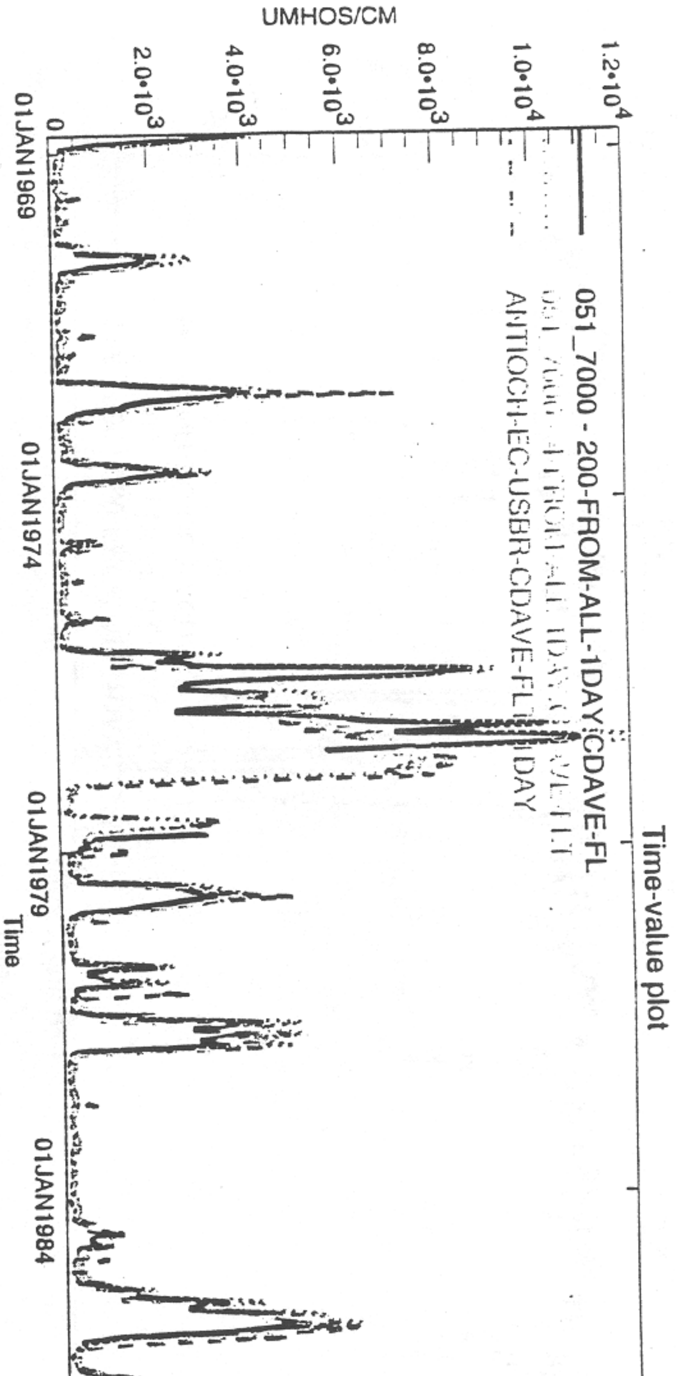

Time-value plot
UMHOS/CM
2.5•10^4
2.0•10^4
1.5•10^4
1.0•10^4
5.0•10^3
0
437_3200 - 200-FROM-ALL-1DAY:CDAVE-FL
437_3200 - 4-FROM-ALL-1DAY:CDAVE-FLT
PITTSBURG-EC-USBR-CDAVE-FLT: 1DAY
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time

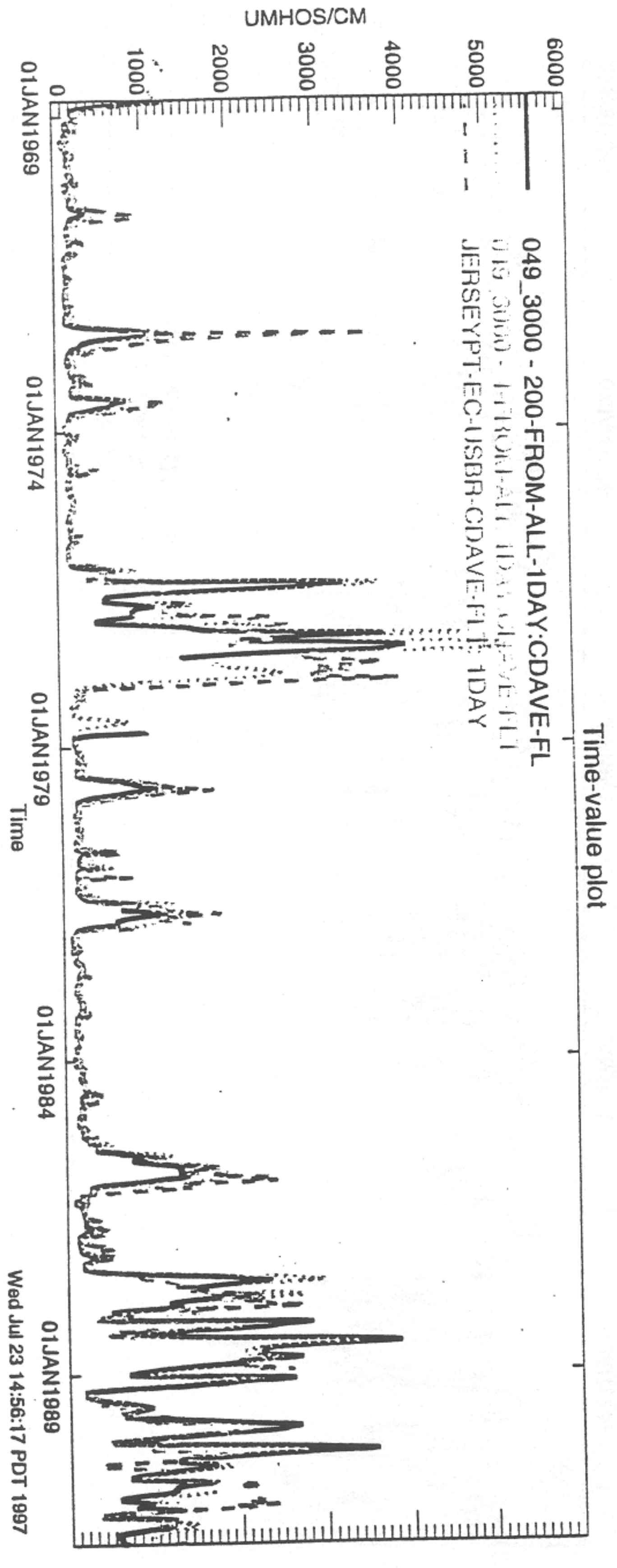

Time-value plot
UMHOS/CM
2.0•10^4
1.5•10^4
1.0•10^4
5.0•10^3
0
436_200 - 200-FROM-ALL-1DAY:CDAVE-FL
436_200 - 4-FROM-ALL-1DAY:CDAVE-FLT
COLLINS-EC-USBR-CDAVE-FLT: 1DAY
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time
Wed Jul 23 14:42:58 PDT 1997

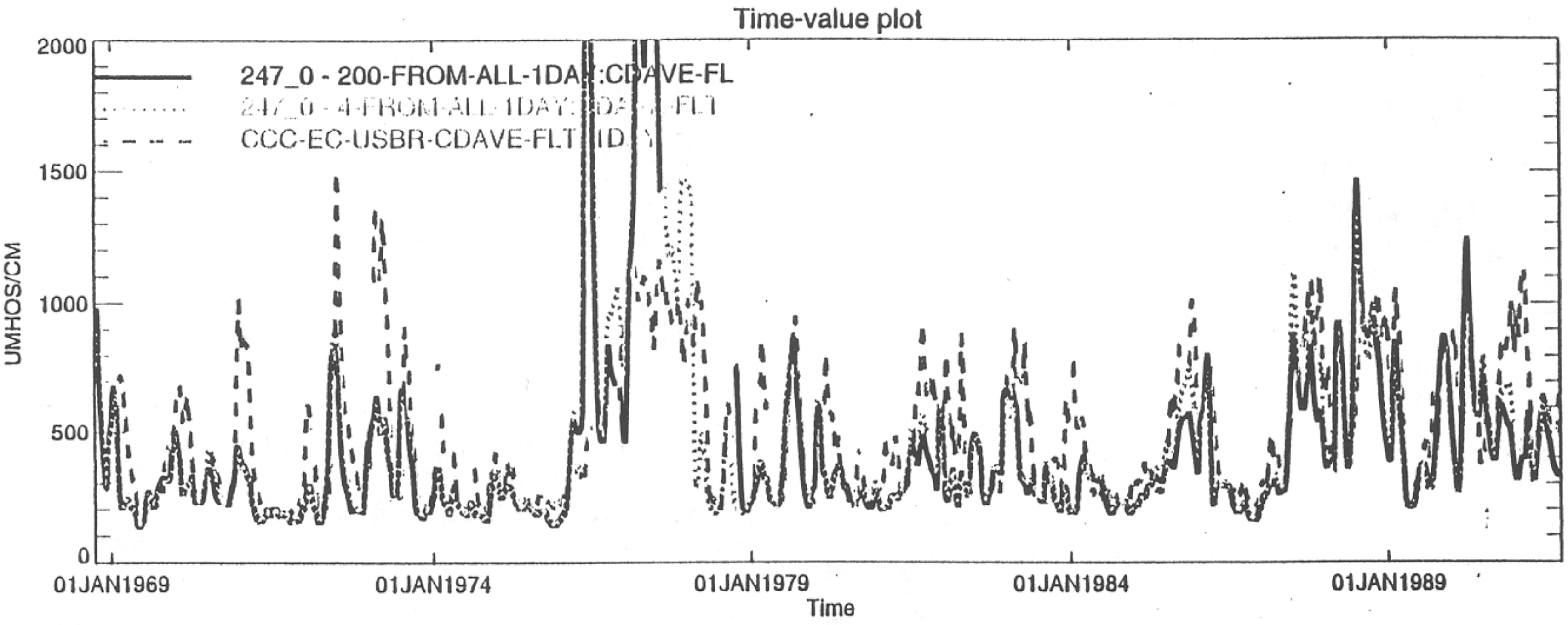

Time-value plot

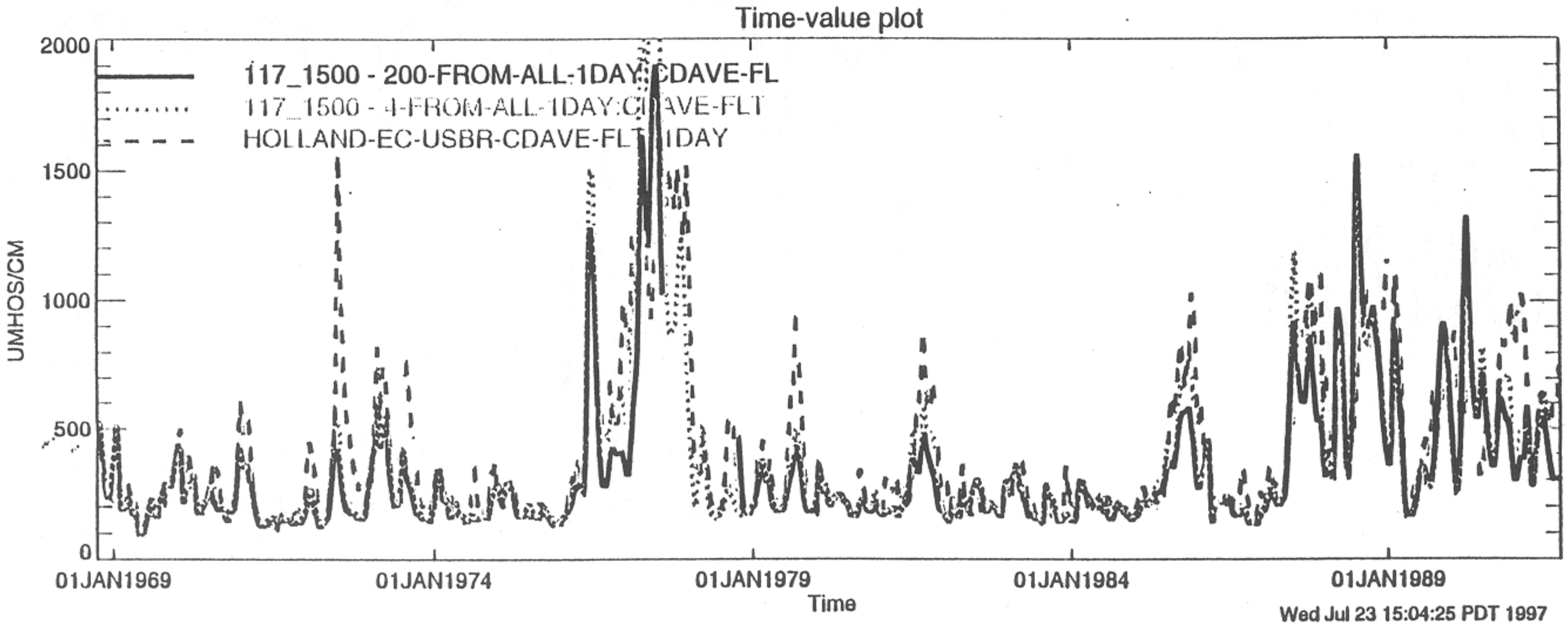

Time-value plot

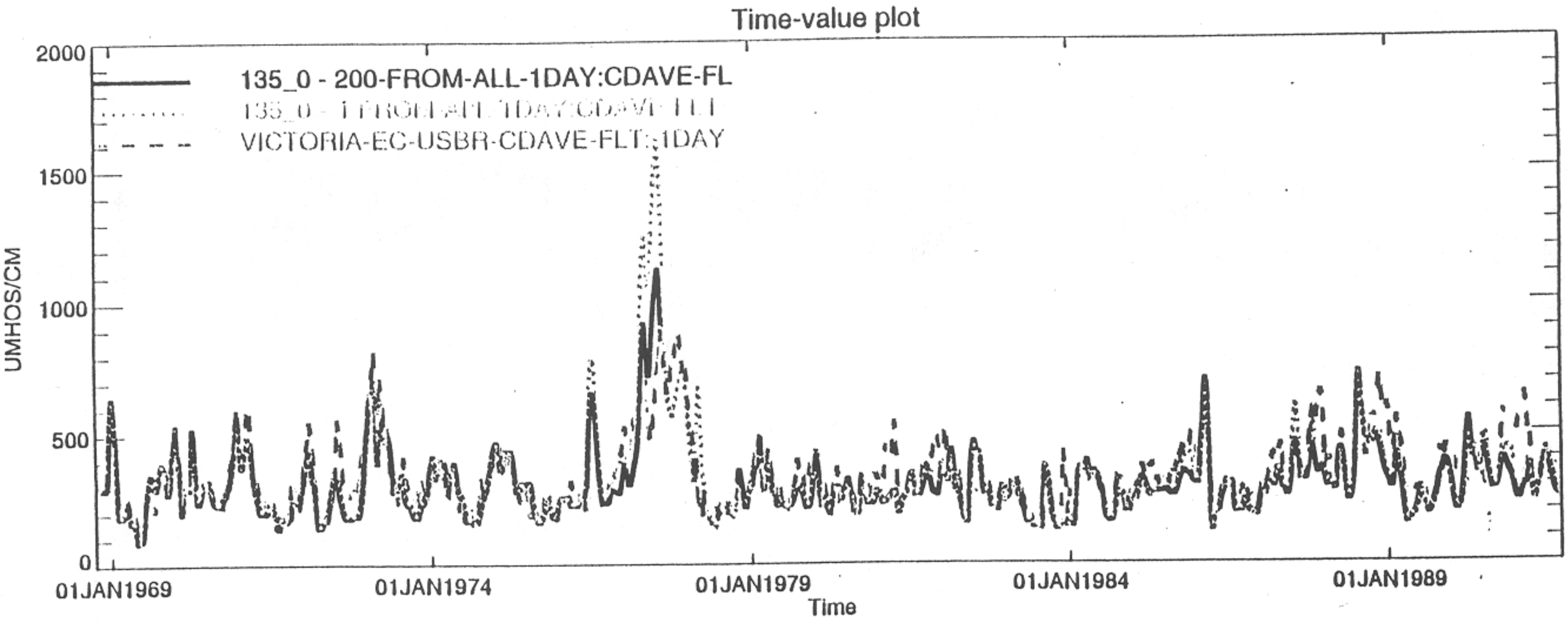
Wed Jul 23 14:48:31 PDT 1997

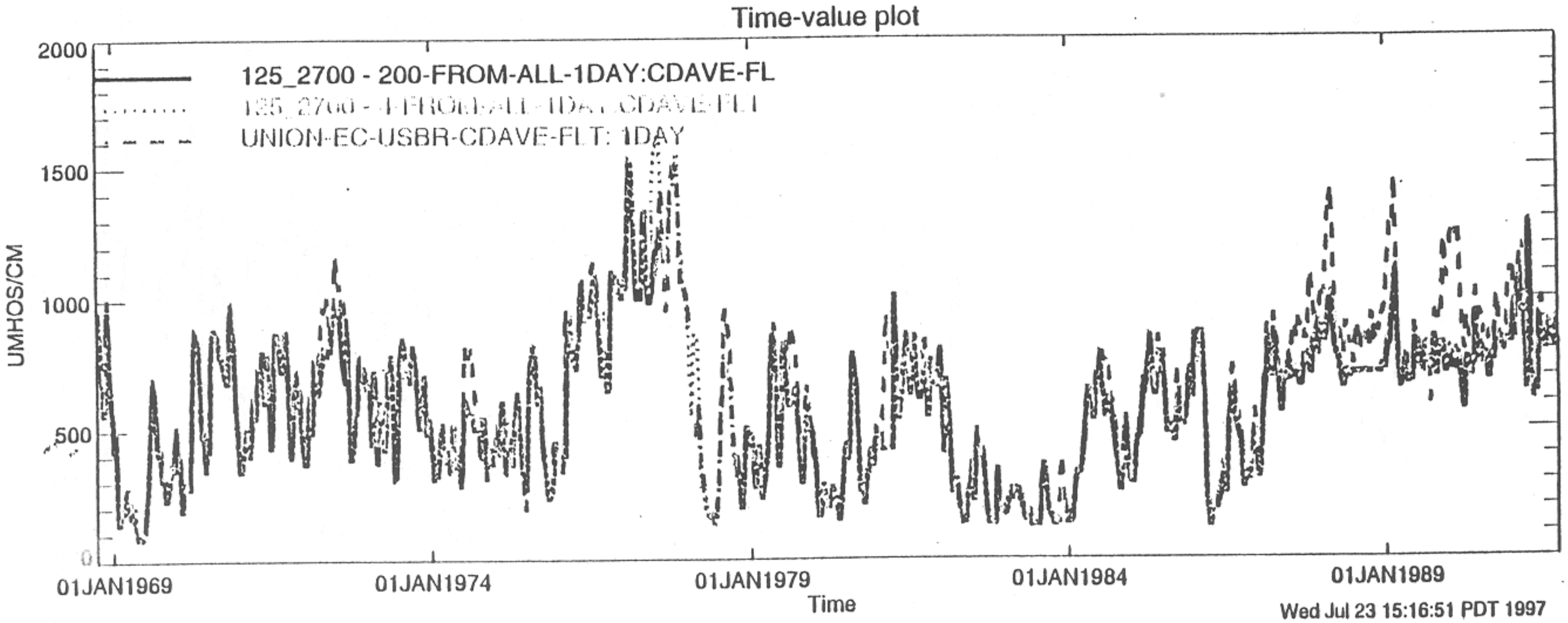

Time-value plot
051_7000 - 200-FROM-ALL-1DAY:CDAVE-FL
051_7000 - 1-FROM-ALL-1DAY:CDAVE-FLT
ANTIOCH-EC-USBR-CDAVE-FLT-1DAY
UMHOS/CM
1.2•10^4
1.0•10^4
8.0•10^3
6.0•10^3
4.0•10^3
2.0•10^3
0
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time


Time-value plot
049_3000 - 200-FROM-ALL-1DAY:CDAVE-FL
049_3000 - 1-FROM-ALL-1DAY:CDAVE-FLT
JERSEYPT-EC-USBR-CDAVE-FLT-1DAY
UMHOS/CM
6000
5000
4000
3000
2000
1000
0
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time
Wed Jul 23 14:56:17 PDT 1997

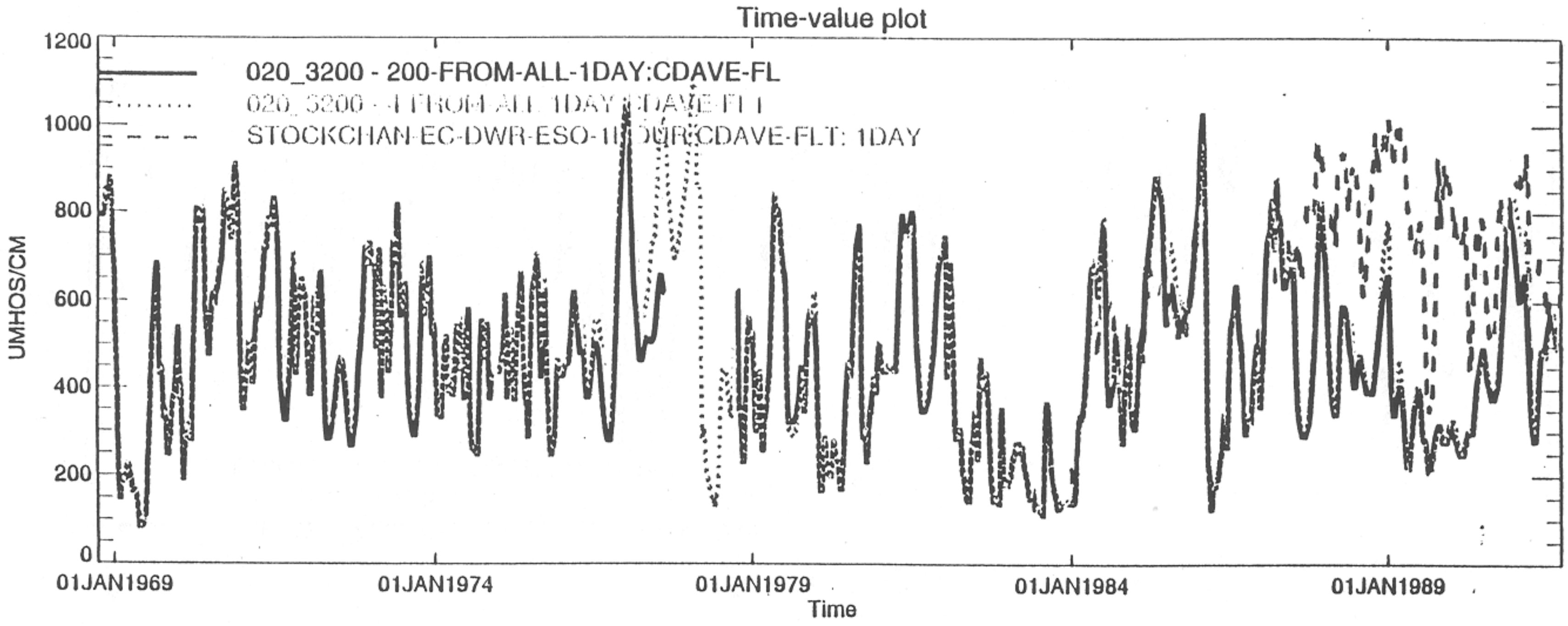

Time-value plot
247_0 - 200-FROM-ALL-1DAY:CDAVE-FL
247_0 - 4-FROM-ALL-1DAY:CDAVE-FLT
CCC-EC-USBR-CDAVE-FLT-1DAY
UMHOS/CM
2000
1500
1000
500
0
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time

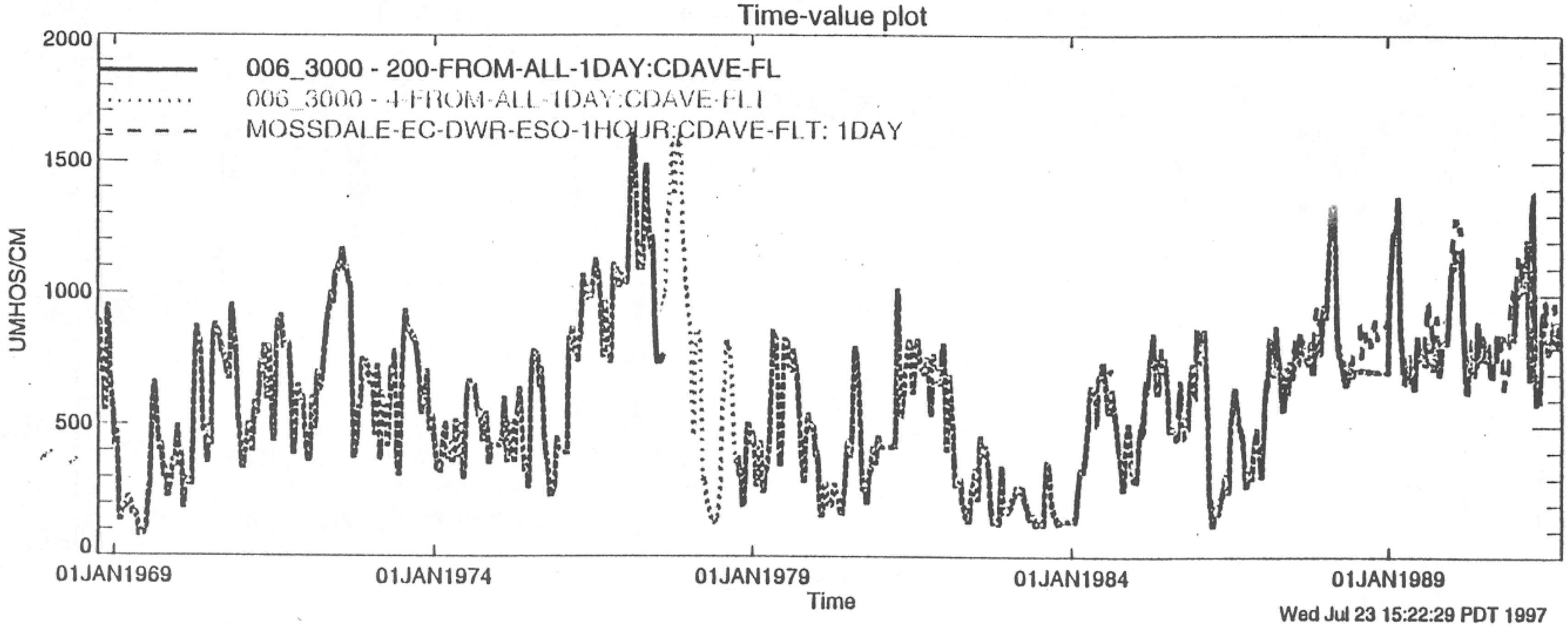

Time-value plot
117_1500 - 200-FROM-ALL-1DAY:CDAVE-FL
117_1500 - 4-FROM-ALL-1DAY:CDAVE-FLT
HOLLAND-EC-USBR-CDAVE-FLT-1DAY
UMHOS/CM
2000
1500
1000
500
0
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time
Wed Jul 23 15:04:25 PDT 1997

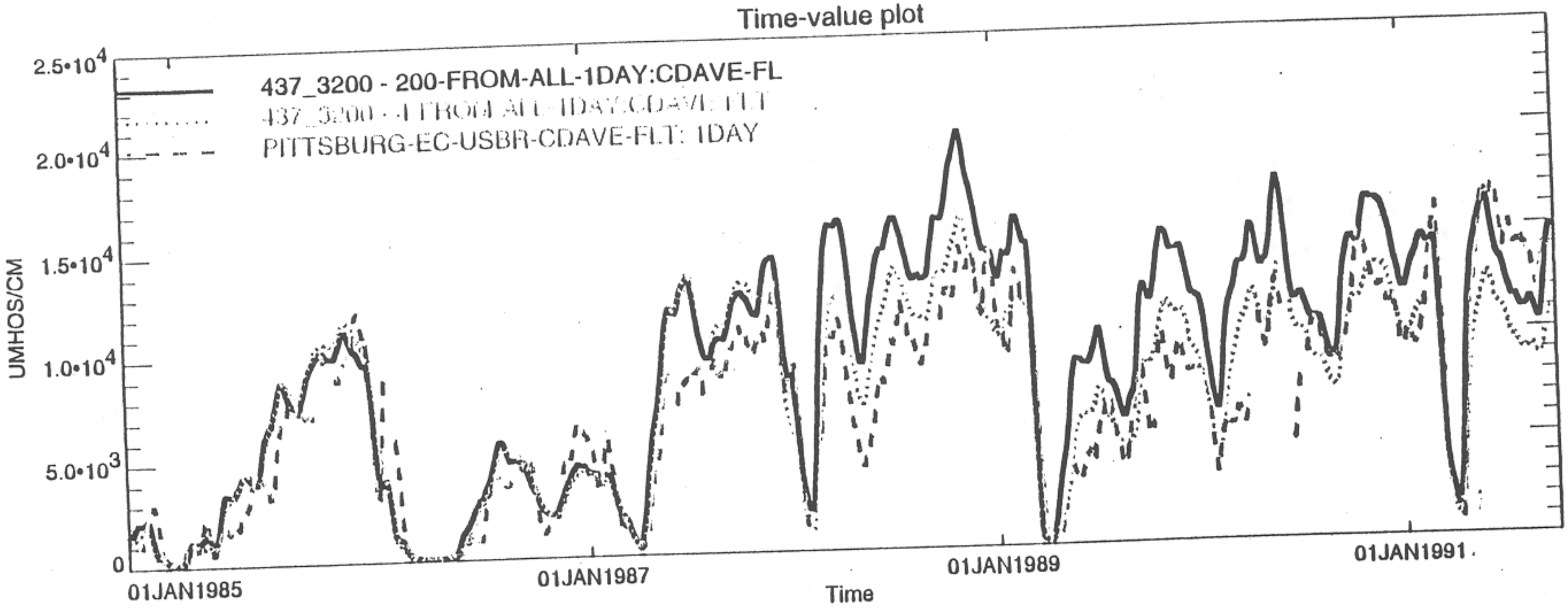


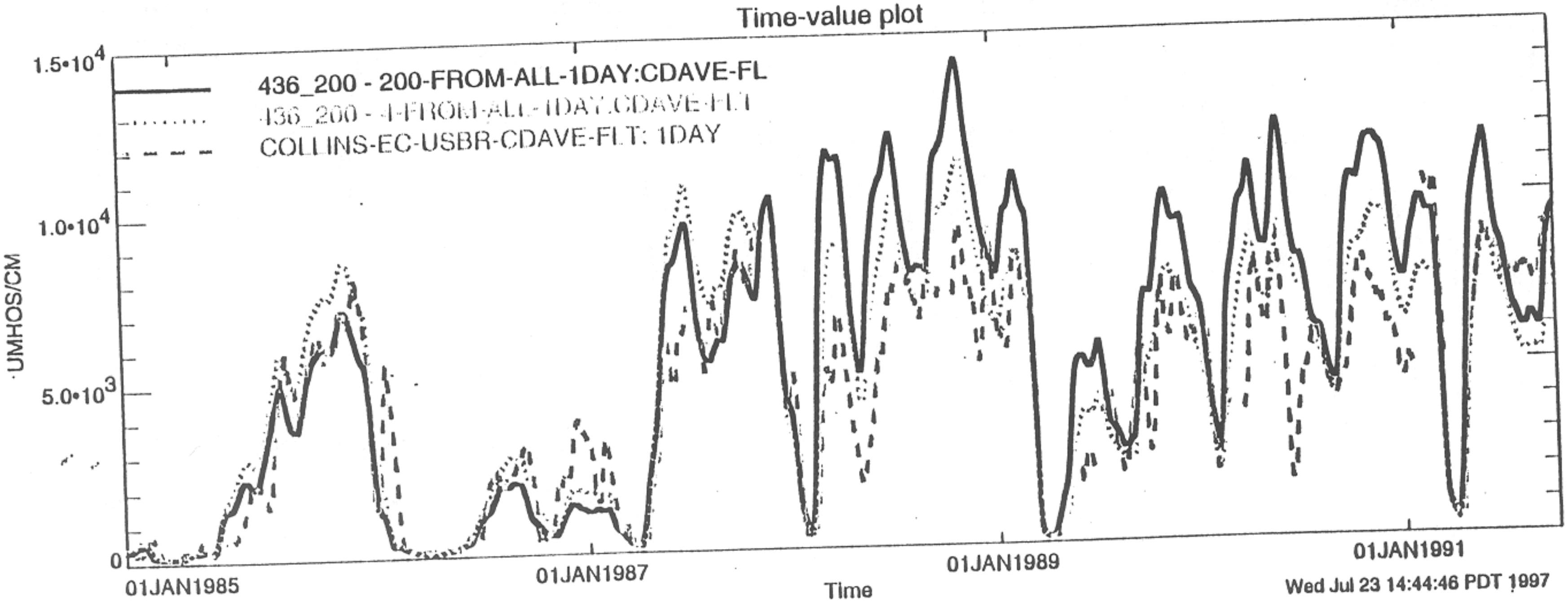


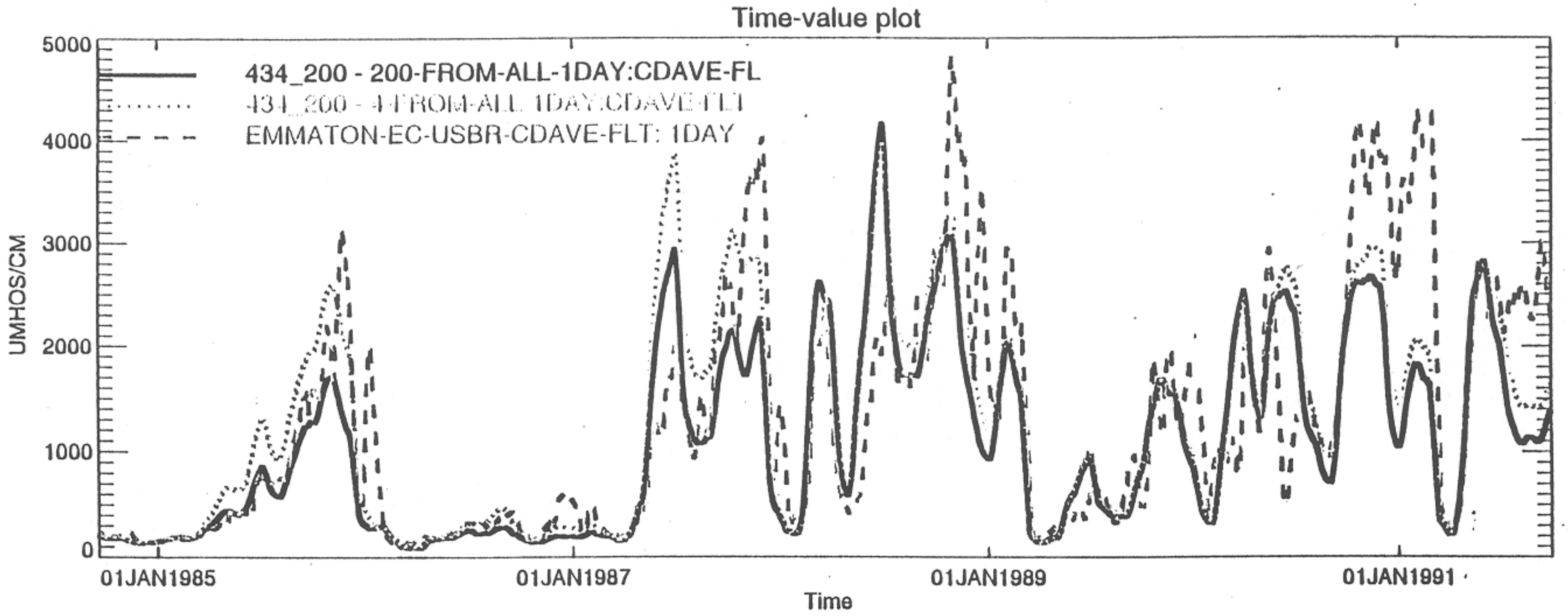
Wed Jul 23 15:16:51 PDT 1997

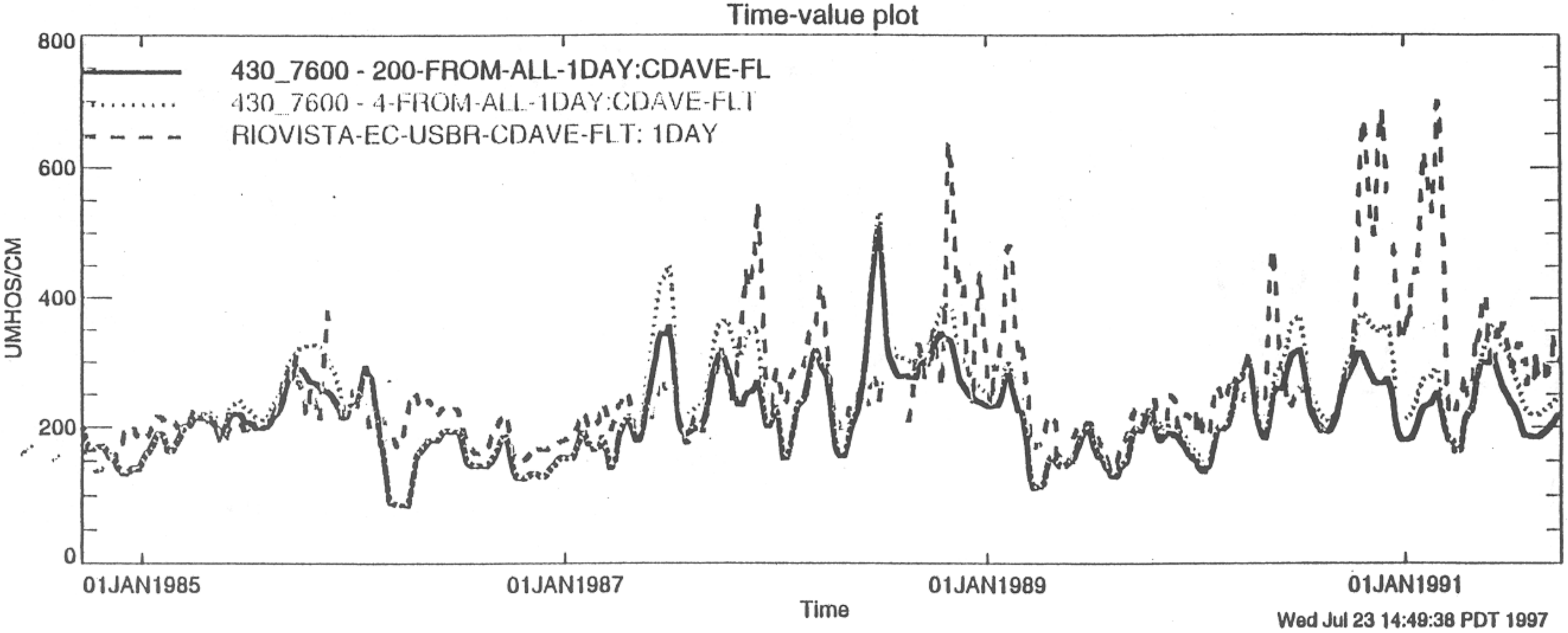

Time-value plot
020_3200 - 200-FROM-ALL-1DAY:CDAVE-FL
020_3200 - 4-FROM-ALL-1DAY:CDAVE-FLT
STOCKCHAN-EC-DWR-ESO-1HOUR:CDAVE-FLT: 1DAY
UMHOS/CM
0
200
400
600
800
1000
1200
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time

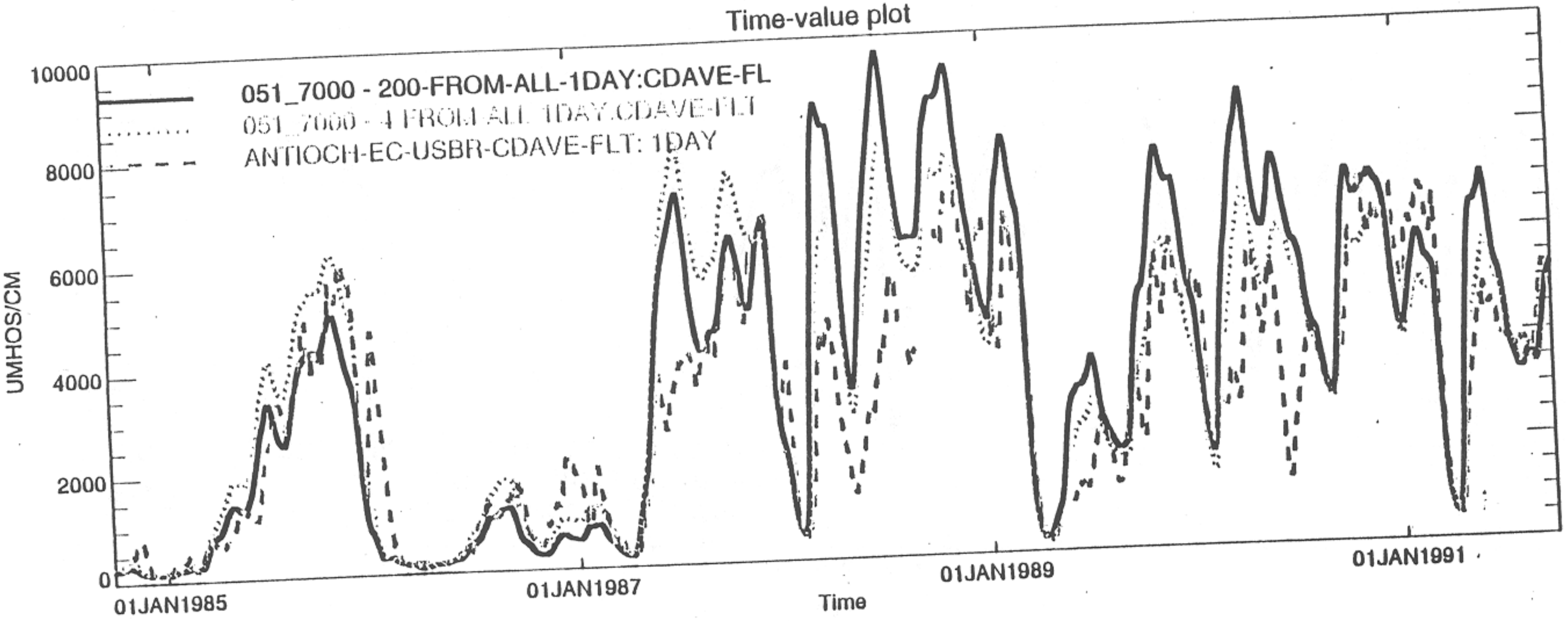

Time-value plot
006_3000 - 200-FROM-ALL-1DAY:CDAVE-FL
006_3000 - 4-FROM-ALL-1DAY:CDAVE-FLT
MOSSDALE-EC-DWR-ESO-1HOUR:CDAVE-FLT: 1DAY
UMHOS/CM
0
500
1000
1500
2000
01JAN1969
01JAN1974
01JAN1979
01JAN1984
01JAN1989
Time
Wed Jul 23 15:22:29 PDT 1997

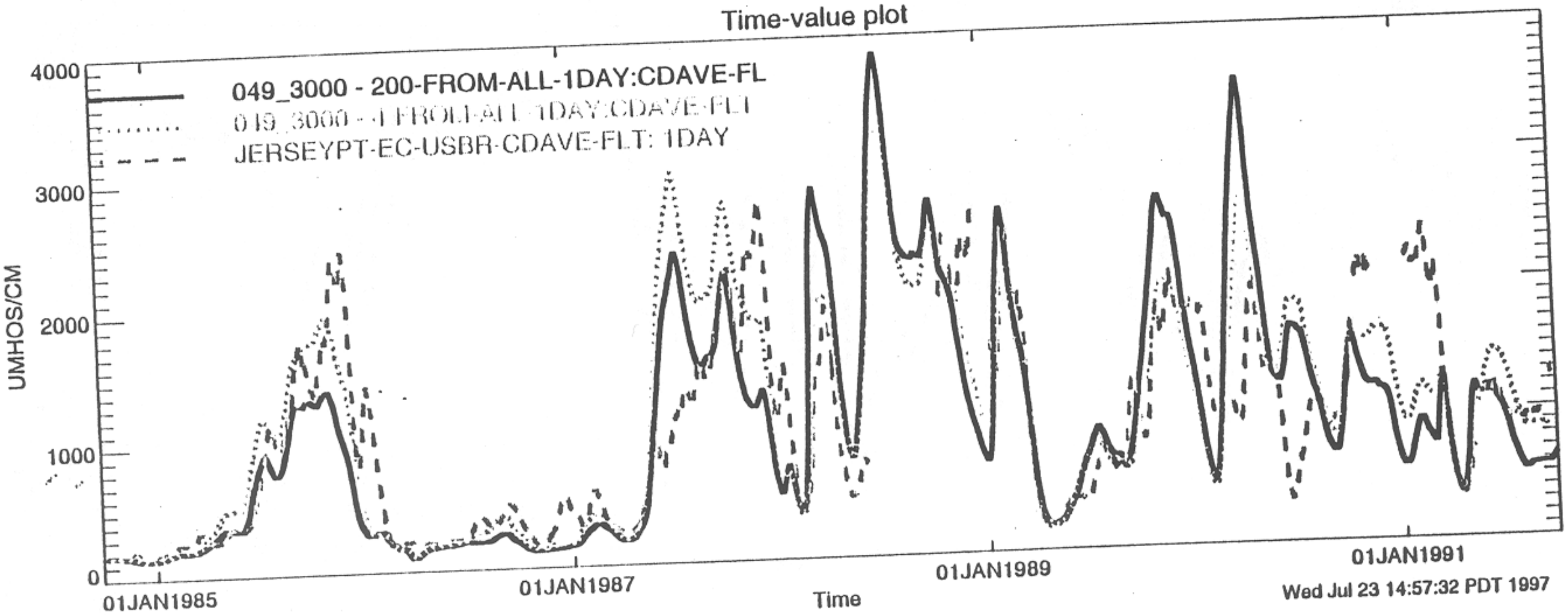

Time-value plot
2.5•10^4
2.0•10^4
1.5•10^4
1.0•10^4
5.0•10^3
0
UMHOS/CM
437_3200 - 200-FROM-ALL-1DAY:CDAVE-FL
437_3200 - 4-FROM-ALL-1DAY:CDAVE-FLT
PITTSBURG-EC-USBR-CDAVE-FLT: 1DAY
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time

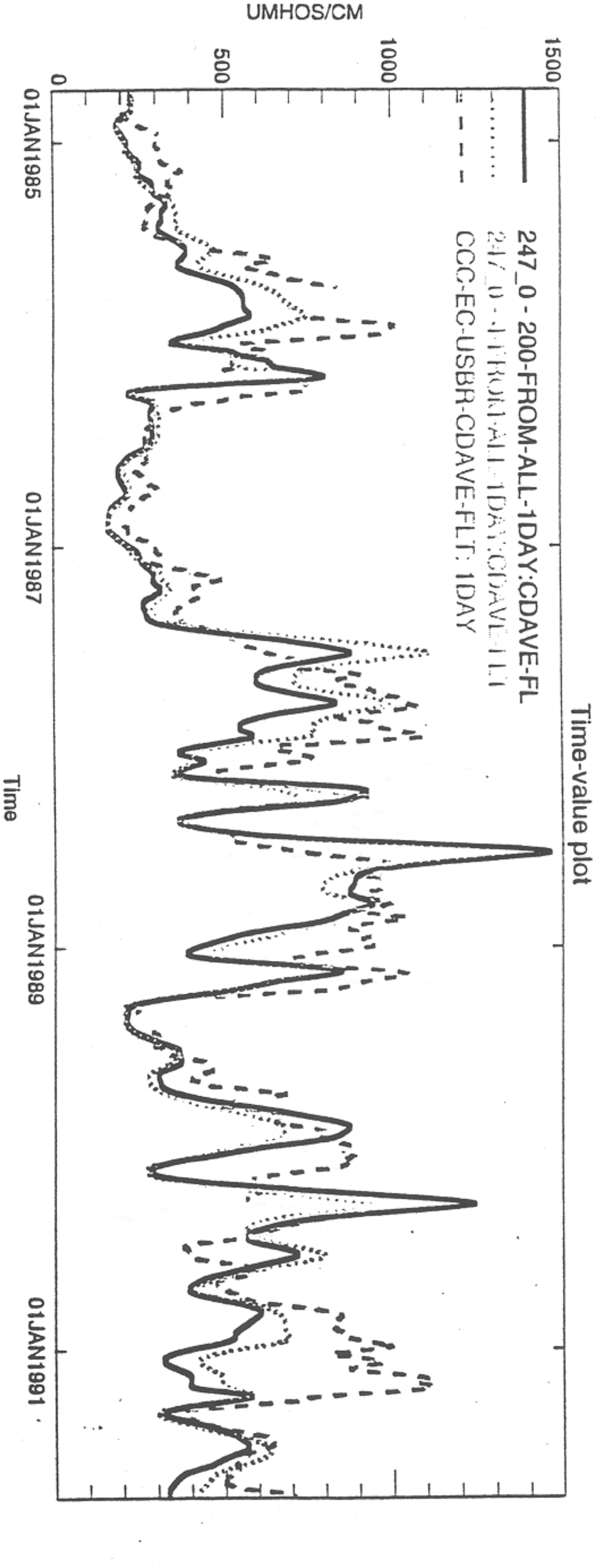

Time-value plot
1.5•10^4
1.0•10^4
5.0•10^3
0
UMHOS/CM
436_200 - 200-FROM-ALL-1DAY:CDAVE-FL
436_200 - 4-FROM-ALL-1DAY:CDAVE-FLT
COLLINS-EC-USBR-CDAVE-FLT: 1DAY
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time
Wed Jul 23 14:44:46 PDT 1997


Time-value plot
434_200 - 200-FROM-ALL-1DAY:CDAVE-FL
434_200 - 4-FROM-ALL-1DAY:CDAVE-FLT
EMMATON-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
0
1000
2000
3000
4000
5000
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time

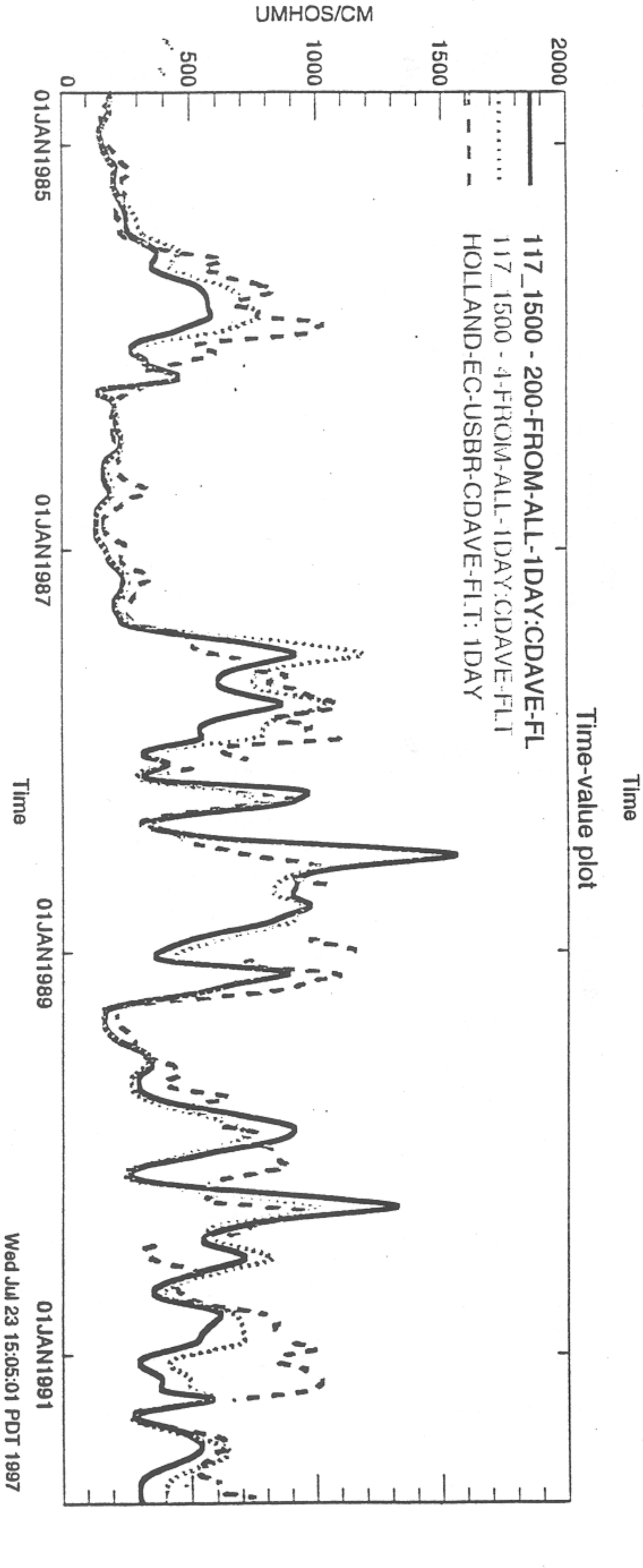

Time-value plot
430_7600 - 200-FROM-ALL-1DAY:CDAVE-FL
430_7600 - 4-FROM-ALL-1DAY:CDAVE-FLT
RIOVISTA-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
0
200
400
600
800
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time
Wed Jul 23 14:49:38 PDT 1997


Time-value plot
051_7000 - 200-FROM-ALL-1DAY:CDAVE-FL
051_7000 - 4 FROM ALL 1DAY:CDAVE-FLT
ANTIOCH-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
10000
8000
6000
4000
2000
0
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time

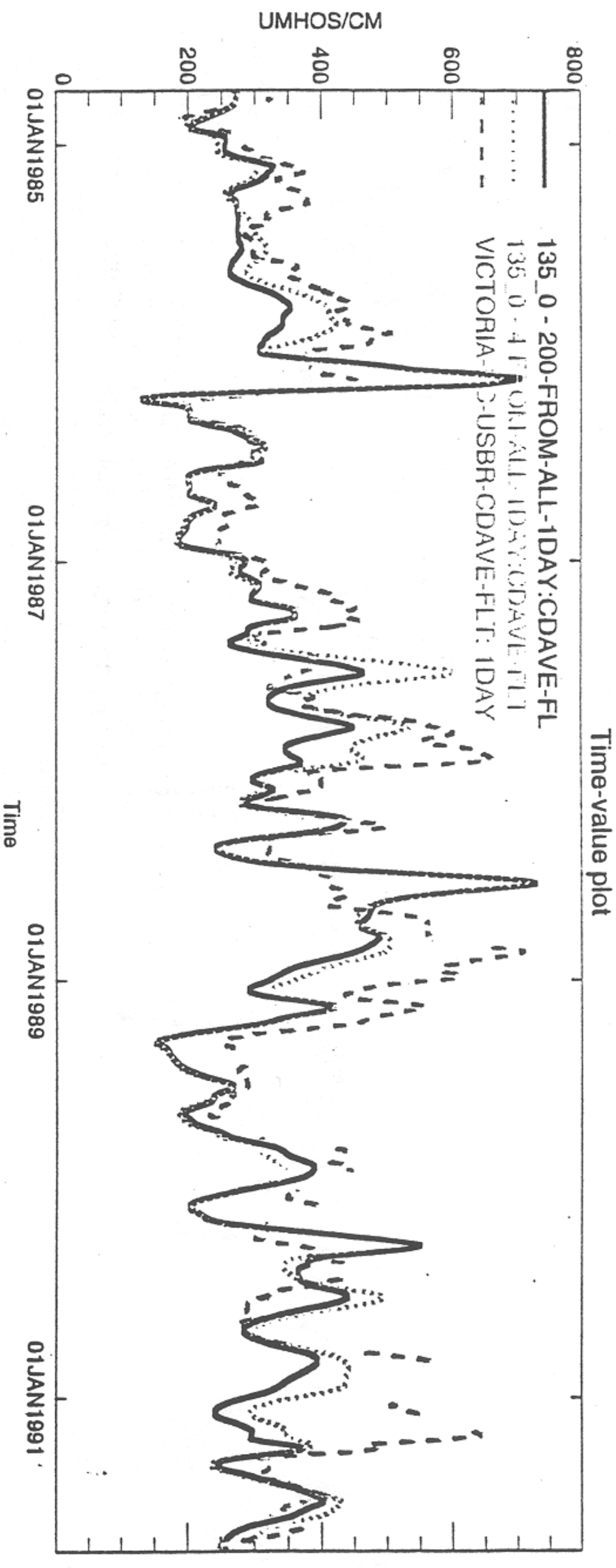

Time-value plot
049_3000 - 200-FROM-ALL-1DAY:CDAVE-FL
049_3000 - 4 FROM ALL 1DAY:CDAVE-FLT
JERSEYPT-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
4000
3000
2000
1000
0
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time
Wed Jul 23 14:57:32 PDT 1997

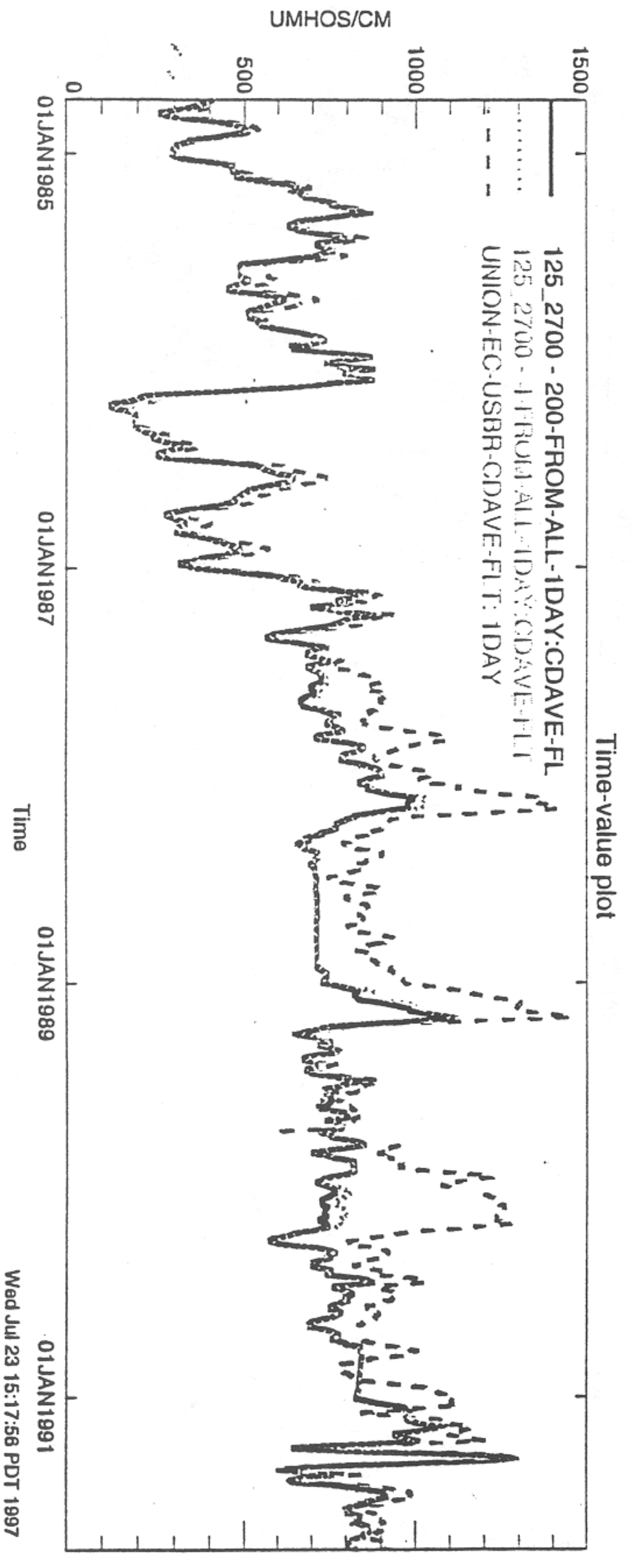


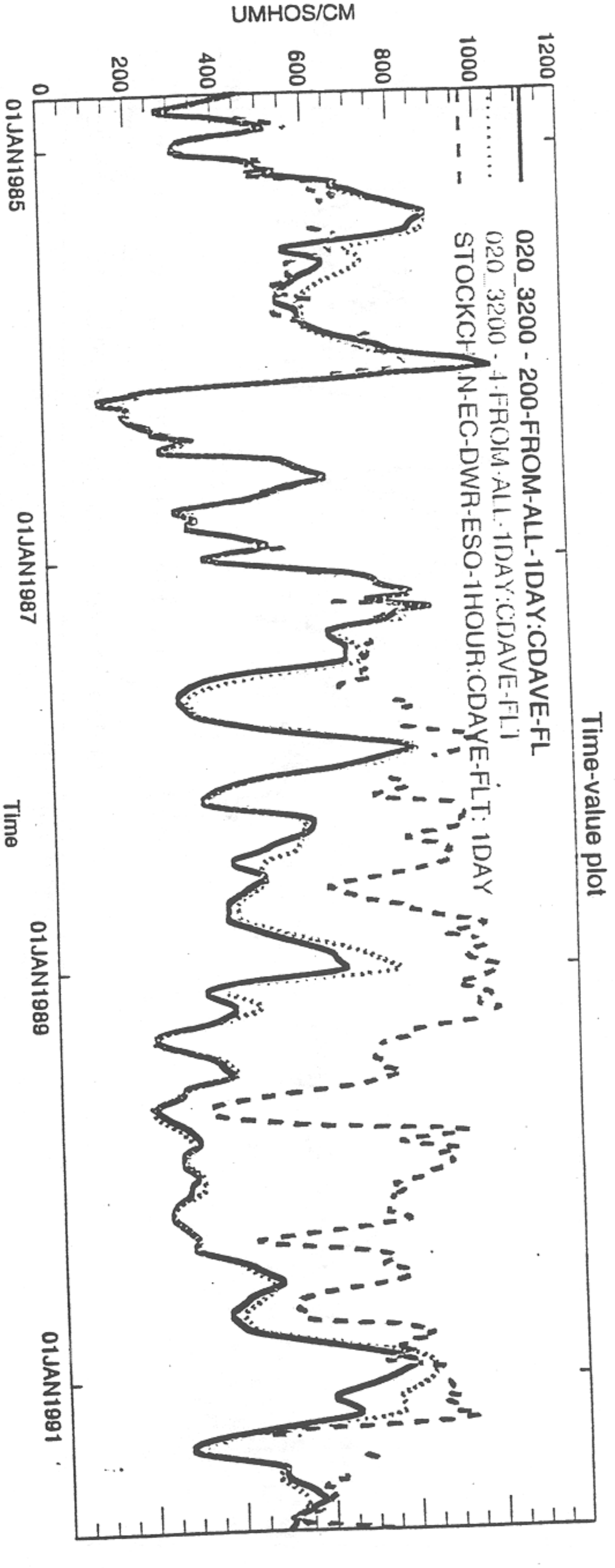
Time-value plot
247_0 - 200-FROM-ALL-1DAY:CDAVE-FL
247_0 - 4-FROM-ALL-1DAY:CDAVE-FLT
CCC-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
0
500
1000
1500
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time

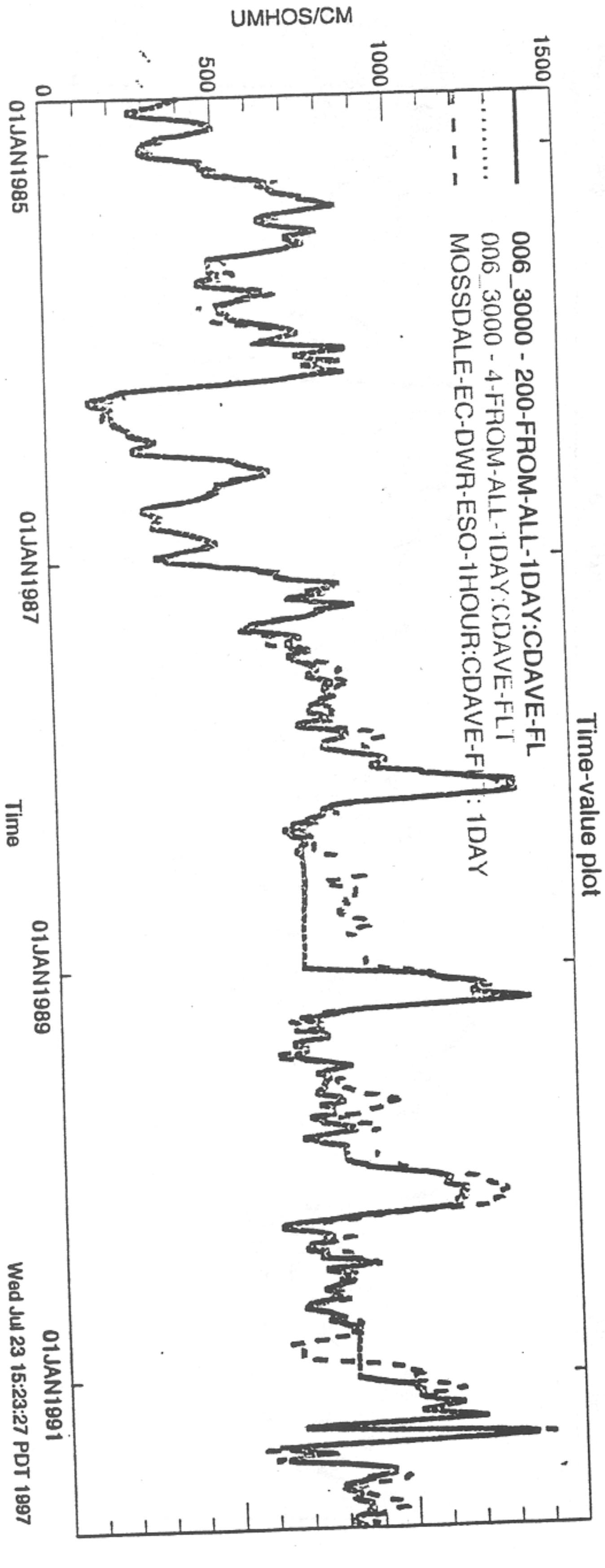


Time-value plot
117_1500 - 200-FROM-ALL-1DAY:CDAVE-FL
117_1500 - 4-FROM-ALL-1DAY:CDAVE-FLT
HOLLAND-EC-USBR-CDAVE-FLT: 1DAY
UMHOS/CM
0
500
1000
1500
2000
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time
Wed Jul 23 15:05:01 PDT 1997


Time-value plot
UMHOS/CM
800
600
400
200
0
135_0 - 200-FROM-ALL-1DAY:CDAVE-FL
135_0 - 4 FROM-ALL-1DAY:CDAVE-FLT
VICTORIA-EC-USBR-CDAVE-FLT: 1DAY
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time


Time-value plot
UMHOS/CM
1500
1000
500
0
125_2700 - 200-FROM-ALL-1DAY:CDAVE-FL
125_2700 - 4 FROM-ALL-1DAY:CDAVE-FLT
UNION-EC-USBR-CDAVE-FLT: 1DAY
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time
Wed Jul 23 15:17:56 PDT 1997


Time-value plot
UMHOS/CM
0
200
400
600
800
1000
1200
020_3200 - 200-FROM-ALL-1DAY:CDAVE-FL
020_3200 - 4-FROM-ALL-1DAY:CDAVE-FLT
STOCKCHAN-EC-DWR-ESO-1HOUR:CDAVE-FLT: 1DAY
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time


Time-value plot
UMHOS/CM
0
500
1000
1500
006_3000 - 200-FROM-ALL-1DAY:CDAVE-FL
006_3000 - 4-FROM-ALL-1DAY:CDAVE-FLT
MOSSDALE-EC-DWR-ESO-1HOUR:CDAVE-FLT: 1DAY
01JAN1985
01JAN1987
01JAN1989
01JAN1991
Time
Wed Jul 23 15:23:27 PDT 1997