CONTRA COSTA
WATER DISTRICT

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January 12, 2005

Ms. Debbie Irvin, Clerk to the Board
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812

RE: Issue 5a: Delta Outflow Objective – Development of the X2 Estuarine Habitat Objective

Dear Ms. Irvin:

Issue 5 of the State Water Resources Control Board's Periodic Review of the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 Plan) addresses the following questions:

- Should the SWRCB amend the Delta Outflow Objective in the Water Quality Objectives for Fish and Wildlife Beneficial Uses (Table 3 of the 1995 Plan) by adding flexibility to the value of the objective or by modifying footnote 14 to allow alternative methods to meet the objective?
- How should the value or footnote 14 be modified and what are the scientific and legal arguments in support of and against such modifications?

Contra Costa Water District (CCWD) participated with other Bay-Delta stakeholders in development of the February-June X2 estuarine habitat objective described in Table 23 of the 1995 Plan and the associated footnote 14. On April 7, 1996, CCWD submitted a letter to Tom Howard of the SWRCB transmitting a CCWD memorandum describing the details behind development of the X2 objective.

A copy of the April 7, 1996 letter and the memorandum is attached. CCWD is providing this material to the SWRCB as background material for your review of the X2 objective as part of the current Periodic Review.

As CCWD noted in CCWD's December 24, 2003 comment letter on the scope of the Periodic Review, any changes to the 1995 Plan must be considered in the context of the full revised plan or amendments to understand their interactions and impact on drinking water quality in the Delta. CCWD also noted that, in the absence of a genuine drinking water standard, the X2 fish protection standard is incidentally providing a limited form of protection of drinking water beneficial uses that must be maintained.

Dr. Gregory Gartrell, in his presentation to the SWRCB for CCWD on January 10 regarding potential new objectives (Issue 4c), pointed out that, in the absence of actual drinking water objectives, the X2 objective for protection of fish, currently provides more protection of drinking water quality than the current 150 mg/L and 250 mg/L municipal and industrial objectives at CCWD's Contra Costa Canal Pumping Plant #1 intake.

If you or your staff have any questions regarding these comments, please contact me at (925) 688-8187.

Sincerely,

Richard A. Denton
Water Resources Manager

Attachment: CCWD's April 7, 1996 letter to the SWRCB (Richard Denton to Tom Howard)

cc: Chester V. Bowling (USBR)
Alf Brandt (DOI)
Cathy Crothers (DWR)
Ken Landau (CVRWQCB)

CONTRA COSTA
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April 7, 1996

Tom Howard
Division of Water Rights
State Water Resources Control Board
P.O. Box 2000
Sacramento CA 95812

Subject: Memorandum describing development of X2 Requirements

Dear Tom,

Per your much earlier request, please find enclosed a Contra Costa Water District internal memorandum (Richard Denton to Greg Gartrell, dated April 7, 1996) describing the development of the X2 estuarine habitat standard that formed part of the SWRCB's May 1995 Water Quality Control Plan. This memorandum was prepared with input from Bruce Herbold (USEPA) and Austin Nelson (Water Resources Consulting).

If you have any questions or need any further information, please contact me at (510) 688-8187.

Sincerely yours,

Richard A. Denton
Water Resources Manager

cc: Bruce Herbold (USEPA)
Austin Nelson (WRC)
Greg Gartrell

CONTRA COSTA WATER DISTRICT
Interoffice Memorandum

Date : April 7, 1996

To : Greg Gartrell

From : Richard Denton

Subject: Development of 1995 WQCP X2 Requirements

Tom Howard of the California State Water Resources Control Board (SWRCB) asked me to provide him with information regarding the development of the numerical values for the estuarine habitat or X2 standards for the Bay-Delta. This memorandum outlines the development process and CCWD's role in their development.

"X2" is defined as the distance from the Golden Gate of the 2 ppt bottom isohaline. EPA's draft estuarine habitat standards, proposed in the Federal Register on January 6, 1994, defined the standards in terms of the number of days (based on a 14-day moving average) at or downstream of each of three locations: Port Chicago, Chipps Island and Collinsville.

During the development of the X2 standards, it was agreed that 2 ppt salinity at the bottom of the water column would be represented by a specific conductance of 2.64 mS/cm at the surface. This conversion was for convenience only and was made because the majority of continuous field salinity data have been measured as a surface electrical conductivity (EC) referenced to 25 degrees Celsius. The actual relationship between surface and bottom salinity will depend on a number of factors and may vary considerably. Likewise, the conversion between specific conductance (EC referenced to 25 °C) and salinity will depend on whether the source of salinity is from seawater intrusion, agricultural drainage, or some other source. However, while the range of salinities produced by agricultural drainage at Vernalis on the San Joaquin River sometimes reach as much as 1 ppt, the contribution of agricultural drainage to the total salinity measured in the western Delta is much less. Agricultural drainage tends to occur during times of high runoff when there is very little seawater intrusion but lots of dilution flows. A more detailed discussion of the relationship between bottom salinity and surface specific conductance was given in Sullivan and Denton (1994). These issues and their relationship to X2 and outflow were also described by John List in a March 10, 1994 letter to Lyle N. Hoag (California Urban Water Agencies).

The number of days when a maximum daily average electrical conductivity of 2.64 mS/cm or less must be maintained at Roe Island (as measured at Port Chicago), Chipps Island (as measured at Mallard Island) and the confluence (as measured at Collinsville) is specified in the Bay-Delta Water Quality Control Plan adopted by the State Water Resources Control Board on May 22, 1995.

Bruce Herbold (U.S. EPA) deserves much of the credit for developing the estuarine habitat or X2 standard. He defined the standard in terms of the number of days (based on a 14-day moving average) within the period February-June that X2 was at or downstream of each of the three locations. Bruce varied the required number of days depending upon the water year type. Bruce based the idea of an estuarine habitat standard on the 1993 report sponsored by EPA on "Managing freshwater discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary: The scientific basis for an estuarine standard." This report, edited by Professor Jerry Schubel, outlined the conclusions and recommendations of members of the scientific, policy, and management communities of the Bay/Delta estuary. In Alan Jassby's appendix to the Schubel report, estuarine protection was originally correlated with a multi-month averages of X2 location, e.g. striped bass survival versus April-May average X2 location.

In response to the EPA draft rule's Request for Comments, the SWRCB developed a sliding scale for the number of X2 days as a function of the annual Sacramento River index, and used a logarithmic regression fit (letter from Walt Pettit to Harry Seraydarian, EPA, November 15, 1993). This allowed for continuous variation of the number of X2 days rather than five steps tied to the January-December water year type. As CCWD's contribution to the CUWA technical review of the EPA standards, I refined the sliding scale so the number of days varied linearly with the February-June Sacramento 4 River Index, the period the standard was to be in effect. This sliding scale preserved Bruce's original concept of basing the level of protection on the period 1968 through 1978 but had a lower water supply impact (Sullivan and Denton, 1994).

Wim Kimmerer prepared a refinement of my linear February-June sliding scale that used a logistic equation to represent the smooth variation in the number of X2 days from zero for very low February-June flow to the maximum at high February-June flow (Kimmerer, March 1994). Wim Kimmerer also developed a model that incorporated year of development into the determination of X2 days. This approach built upon early ideas developed by DWR and reported by Francis Chung and George Barnes and by Water Resources Management, Inc. at a Bay-Delta Modeling Forum workshop in Palo Alto, February 15-16, 1994. At a subsequent Bay-Delta Modeling Forum workshop at CCWD on April 14, 1994, the participants agreed on a common approach to developing a sliding scale:

(1) basing the number of days on the 8 river unimpaired runoff from the Sacramento and San Joaquin valleys (east side streams were not included),
(2) using a logistic equation rather than the simple linear sliding scale,
(3) using 2.64 mS/cm surface specific conductance to represent the location of X2 (rather than the less practical approach of having to actually measure salinity in practical salinity units at the bottom of the shipping channel at the three locations),
(4) use of year of development as a parameter in formulating tables of X2 days (e.g. the presentation by Inês Ferriera of Water Resources Management, Inc.).

Other concepts such as the three ways to comply (daily EC, 14-day averaged EC or equivalent steady-state flow), the definition of a Roe Island trigger, and carryover credit for excess number of days of compliance were discussed in detail and refined at the April 14 Bay-Delta Modeling Forum workshop.

Prior to the April workshop, Bruce Herbold had developed the concept of basing the number of X2 days for a given month on the previous month's unimpaired runoff (PMI), rather than using a single February-June runoff index to define the number of days for the full February-June period. Bruce also developed the first set of tables for the number of days required in each of the five months at each of the three locations depending on the PMI. Austin Nelson (CCWD's former Water Resources Manager) redid Bruce's work and developed the tables that were the basis for the Joint California Water Users' proposal for Bay-Delta standards at the end of 1994 and incorporated by SWRCB into the May 1995 WQCP. Austin used estimates of the number of days of 2.64 mS/cm for the historical period 1930 through 1977 that I had generated using CCWD's salinity-outflow model (also referred to as the "G-model"; see Sullivan and Denton, 1994) and the California Department of Water Resources' DAYFLOW estimates of historical Delta outflows. The tabulated numbers of days for Collinsville were later increased in some months as part of the negotiations leading to the December 15, 1994 Principles for Agreement and development of the final X2 tables.

The tables for the estimated historical number of days of 2.64 mS/cm at the three X2 locations (Roe Island, Chipps Island, and the confluence at Collinsville) originally prepared by Austin Nelson are given in Appendix A. The corresponding tables as they appear in the May 1995 WQCP are given in Appendix B.

Austin fitted the estimated number of days using a logistic equation of the form:

$$\frac{N}{Max} = 1.0 - \frac{1.0}{(1 + EXP[A + B*Yr + C*LN(PMI)])}$$

where
N = required number of days of 2 ppt salinity or less
Max = maximum number of days in the present month
Yr = required level of development (31-92)
PMI = previous month's 8-River index
EXP = Exponential function
LN = Natural logarithm

and A, B, and C are fitting coefficients for the given monitoring location (Roe Island, Chipps Island or Collinsville). Additional details regarding the derivation and use of these coefficients are given in Appendix C.

There were only slight differences in Austin's and Bruce's sets of coefficients (A, B and C), the largest being for June at Roe Island. It should be noted that in preparing the tables of required X2 days, Austin Nelson used Yr = 71.5 representing the midpoint of the period 1968 through 1975, whereas Bruce Herbold had used Yr = 68. A more detailed discussion of these differences is given in the technical support memorandum to EPA's letter to the SWRCB on September 26, 1995 approving the 1995 WQCP as meeting the requirements of Section 303(c) of the Clean Water Act (Felicia Marcus to John Caffrey).

Austin Nelson built upon Wim Kimmerer's earlier approach of using a logistic equation with a build-in adjustment for level of development (Kimmerer, 1994). Austin used a non-linear least-squares regression program to find the values of the coefficients A, B and C that gave the best fit of the historical data. In a few cases, all of the data points were the maximum number of days for that month, except for 1977, and sometimes 1976, which were zero (e.g. February at Chipps Island and Collinsville). A logistic equation was not relevant in those cases, so a more simplified fit was made. In a couple of other cases, only one data point lay between zero or the maximum for that month (e.g. March at Chipps Island). In these cases a fit that passed through the single intermediate point and also followed the trend for the preceding and following months was used. The data fitted were the number of days based on one way to comply, i.e. the 14-day salinity value derived from CCWD's salinity-outflow model (G-model). These data are tabulated in Appendix D. The corresponding previous month's indices (PMIs) for the 8 major rivers in the Sacramento and San Joaquin valleys are tabulated in Appendix E.

Austin's coefficients were:

Roe Island

	February	March	April	May	June
A =	-14.325	-17.661	-25.606	-48.032	-81.796
B =	0	-0.0458	-0.0712	-0.0907	-0.1557
C =	2.0349	2.7410	3.7828	6.5709	10.6988

Chipps Island

	February	March	April	May	June
A =	-374.108	-47.431	-43.427	-93.642	-71.226
B =	-3.8273	-2.5520	-0.0548	-0.1903	-0.1439
C =	99.1090	33.2217	6.4396	13.6219	9.9632

Collinsville

	February	March	April	May	June
A =	-166.904	-112.1	-158.9	-621.700	-115.184
B =	-9.0534	-0.30	-0.75	-0.4995	-0.3031
C =	136.1890	20.0	30.0	89.4434	17.2815

References

Kimmerer, Wim, "A Sliding Scale for the EPA Salinity Standard," Report to California Urban Water Agencies, March 8, 1994, 10 pp.

Schubel, Jerry R., "Managing freshwater discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary: The scientific basis for an estuarine standard." The conclusions and recommendations of members of the scientific, policy, and management communities of the Bay/Delta estuary. Sponsored by EPA, 1993.

Sullivan, Greg D. and Denton. Richard A., "Report on Clean Water Act X2 Water Quality Standards," Contra Costa Water District Internal Report, February, 1994, 44 pp. [*Also included as Reference #9 in the California Urban Water Agencies comments to U.S. EPA on Water Quality Standards for Surface Waters of the Sacramento River, San Joaquin River, and the San Francisco Bay and Delta of the State of California, January 6, 1994*]

Appendix A

Austin Nelson's Interpolation Tables

Required Number of Days for Roe Island

PMI taf	February	March	April	May	June
0	0	0	0	0	0
250	1	0	0	0	0
500	4	1	0	0	0
750	8	2	0	0	0
1000	12	4	0	0	0
1250	15	6	1	0	0
1500	18	9	1	0	0
1750	20	12	2	0	0
2000	21	15	4	0	0
2250	22	17	5	1	0
2500	23	19	8	1	0
2750	24	21	10	2	0
3000	25	23	12	4	0
3250	25	24	14	6	0
3500	25	25	16	9	0
3750	26	26	18	12	0
4000	26	27	20	15	0
4250	26	27	21	18	1
4500	26	28	23	21	2
4750	27	28	24	23	3
5000	27	28	25	25	4
5250	27	29	25	26	6
5500	27	29	26	28	9
5750	27	29	27	28	13
6000	27	29	27	29	16
6250	27	30	27	29	19
6500	27	30	28	30	22
6750	27	30	28	30	24
7000	27	30	28	30	26
7250	27	30	28	30	27
7500	27	30	29	31	28
7750	27	30	29	31	28
8000	27	30	29	31	29
8250	28	30	29	31	29
8500	28	30	29	31	29
8750	28	30	29	31	30
9000	28	30	29	31	30
9250	28	30	29	31	30
9500	28	31	29	31	30
9750	28	31	29	31	30
10000	28	31	30	31	30

Required Number of Days for Chipps Island

PMI taf	February	March	April	May	June
500	0	0	0	0	0
750	28	0	0	0	0
800	28	0	0	0	0
1000	28	12	2	0	0
1250	28	31	6	0	0
1500	28	31	13	0	0
1750	28	31	20	0	0
2000	28	31	25	1	0
2250	28	31	27	3	0
2500	28	31	29	11	1
2750	28	31	29	20	2
3000	28	31	30	27	4
3250	28	31	30	29	8
3500	28	31	30	30	13
3750	28	31	30	31	18
4000	28	31	30	31	23
4250	28	31	30	31	25
4500	28	31	30	31	27
4750	28	31	30	31	28
5000	28	31	30	31	29
5250	28	31	30	31	29
5500	28	31	30	31	30

Required Number of Days for Collinsville

PMI taf	February	March	April	May	June
500	28	31	30	0	0
750	28	31	30	0	0
1000	28	31	30	0	0
1250	28	31	30	0	0
1500	28	31	30	1	0
1750	28	31	30	31	0
2000	28	31	30	31	0
2250	28	31	30	31	1
2500	28	31	30	31	5
2750	28	31	30	31	15
3000	28	31	30	31	25
3250	28	31	30	31	28
3500	28	31	30	31	30

Appendix B

May 1995 Bay-Delta Water Quality Control Plan Requirements

WQCP Requirements for Roe Island

PMI taf	February	March	April	May	June
0	0	0	0	0	0
250	1	0	0	0	0
500	4	1	0	0	0
750	8	2	0	0	0
1000	12	4	0	0	0
1250	15	6	1	0	0
1500	18	9	1	0	0
1750	20	12	2	0	0
2000	21	15	4	0	0
2250	22	17	5	1	0
2500	23	19	8	1	0
2750	24	21	10	2	0
3000	25	23	12	4	0
3250	25	24	14	6	0
3500	25	25	16	9	0
3750	26	26	18	12	0
4000	26	27	20	15	0
4250	26	27	21	18	1
4500	26	28	23	21	2
4750	27	28	24	23	3
5000	27	28	25	25	4
5250	27	29	25	26	6
5500	27	29	26	28	9
5750	27	29	27	28	13
6000	27	29	27	29	16
6250	27	30	27	29	19
6500	27	30	28	30	22
6750	27	30	28	30	24
7000	27	30	28	30	26
7250	27	30	28	30	27
7500	27	30	29	30	28
7750	27	30	29	31	28
8000	27	30	29	31	29
8250	28	30	29	31	29
8500	28	30	29	31	29
8750	28	30	29	31	30
9000	28	30	29	31	30
9250	28	30	29	31	30
9500	28	31	29	31	30
9750	28	31	29	31	30
10000	28	31	30	31	30

WQCP Requirements for Chipps Island

PMI taf	February	March	April	May	June
500	0	0	0	0	0
750	0	0	0	0	0
800	0	2.4	0.4	0	0
1000	28	12	2	0	0
1250	28	31	6	0	0
1500	28	31	13	0	0
1750	28	31	20	0	0
2000	28	31	25	1	0
2250	28	31	27	3	0
2500	28	31	29	11	1
2750	28	31	29	20	2
3000	28	31	30	27	4
3250	28	31	30	29	8
3500	28	31	30	30	13
3750	28	31	30	31	18
4000	28	31	30	31	23
4250	28	31	30	31	25
4500	28	31	30	31	27
4750	28	31	30	31	28
5000	28	31	30	31	29
5250	28	31	30	31	29
5500	28	31	30	31	30

WQCP Requirements at the Confluence

PMI taf	February	March	April	May	June
499	28	0 or 31	30	31	30
500	28	31	30	31	30
750	28	31	30	31	30
1000	28	31	30	31	30
1250	28	31	30	31	30
1500	28	31	30	31	30
1750	28	31	30	31	30
2000	28	31	30	31	30
2250	28	31	30	31	30
2500	28	31	30	31	30
2750	28	31	30	31	30
3000	28	31	30	31	30
3250	28	31	30	31	30
3500	28	31	30	31	30

Includes possible March relaxation if Feb 8-River Index < 500 TAF

Appendix C

Mathematical Manipulations of the Logistic Equation

50-Percentile Value

One characteristic of the X2 logistic equation is the previous month's unimpaired flow that corresponds to a requirement to meet X2 for half the number of days in a given month. The previous month's unimpaired flow, PMI_{50}, corresponding to N/Max = 0.5, can be derived from the X2 logistic equation, i.e. when N/Max = 0.5,

$$PMI_{50} = EXP(-(A + B * Yr) / C)$$

In the case of Collinsville,

	February	March	April	May	June
A =	-166.904	-112.1	-158.9	-621.700	-115.184
B =	-9.0534	-0.30	-0.75	-0.4995	-0.3031
C =	136.1890	20.0	30.0	89.4434	17.2815
PMI_{50} =	394.9	794.3	1192.9	1556.3	2749.2 taf

Visualizing the Goodness of Fit

An indication of the goodness of fit of the logistic equation can be obtained by defining a parameter X = LN(PMI) + (B/C)*Yr and plotting the number of historical days of X2 versus this parameter X. The logistic equation then has the form:

$$N = Max * (1 - (1 / [1 + EXP(A + C*X)]))$$

The "best fit" value of B/C should collapse the data for a given month into a single-valued relationship between the number of days of 2 ppt, N, and X. This single-valued curve for N/Max versus X can then be fitted to find A and C. As can be seen in the attached plot for Collinsville for the month of June (Figure C1), the best value of the ratio B/C is the one that minimizes the variation with level of development and leaves only variation with X (representing unimpaired flow).

Figure C1 shows N versus X for Collinsville in June for the historical period, 1930-1977. The historical number of days were estimated using the G-model relationship for Collinsville for 14-day averaged surface specific conductance and DAYFLOW estimates of Delta outflow. This analysis assumed only one way to comply, i.e. 14-day averaged specific conductance. Note that in this case A = -115.184, B = -0.3031, and C = 17.2815, so that PMI_{50} = 2749 TAF.

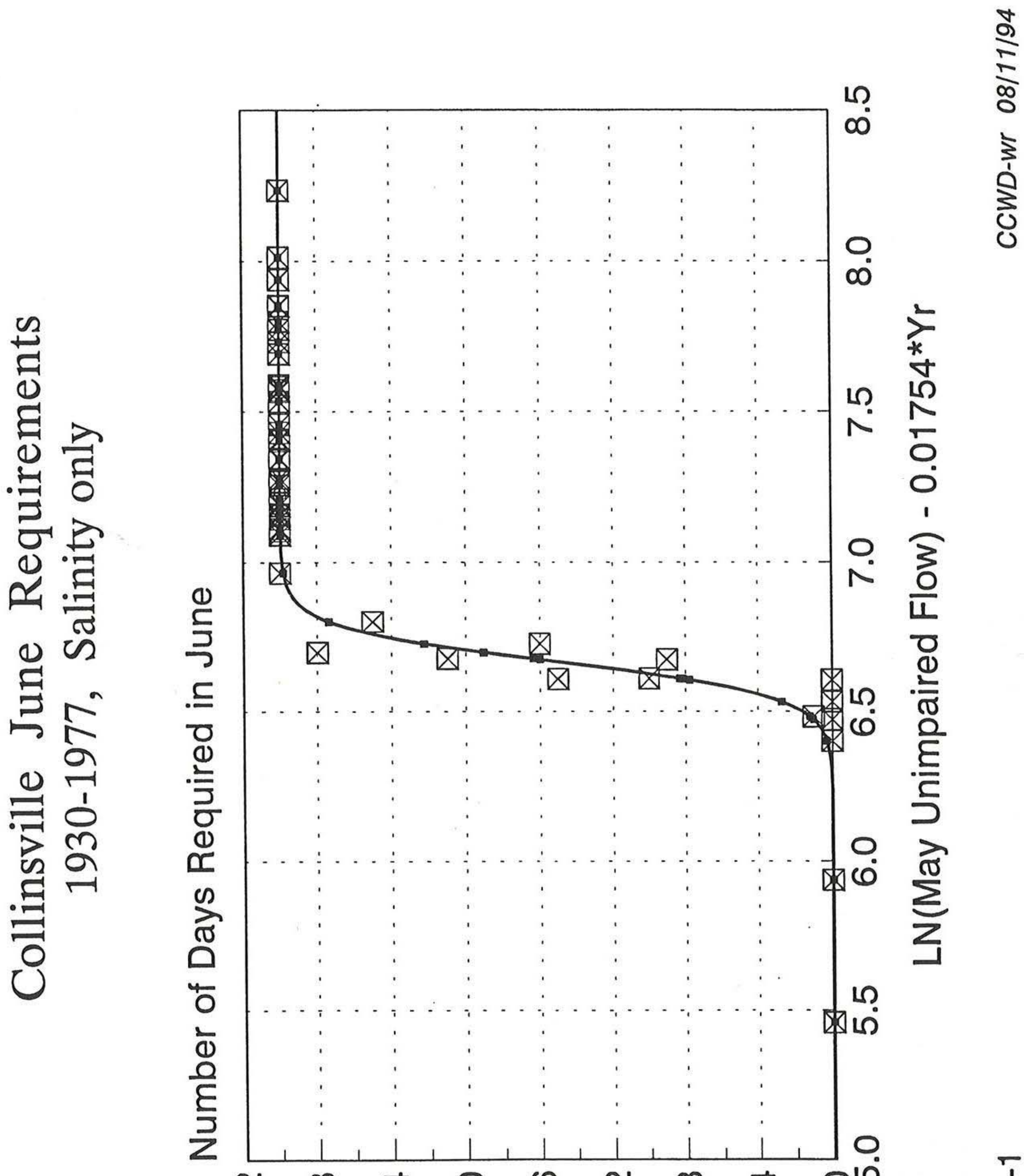
Collinsville June Requirements
1930-1977, Salinity only
Number of Days Required in June
32
28
24
20
16
12
8
4
0
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
LN(May Unimpaired Flow) - 0.01754*Yr
CCWD-wr 08/11/94

Figure C-1

Appendix D

Estimates of Historical Number of X2 Days per Month

Assumptions

- X2 Requirement met by salinity only, and not by equivalent outflow
- 2 ppt bottom salinity = 2.64 mS/cm surface specific conductance
- 14-day specific conductances simulated using CCWD's salinity outflow model

Port Chicago (Roe Island) Total number of X2 days per month

WYr	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1930	0	0	13	16	8	31	30	3	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	3	20	22	16	30	31	28	0	0	0
1933	0	0	0	0	0	7	11	0	0	0	0	0
1934	0	0	0	15	7	12	0	0	0	0	0	0
1935	0	0	0	24	17	30	30	31	23	0	0	0
1936	0	0	0	20	26	31	30	31	22	0	0	0
1937	0	0	0	0	23	31	30	31	20	0	0	0
1938	0	7	28	27	28	31	30	31	30	14	0	0
1939	0	0	0	0	0	12	7	0	0	0	0	0
1940	0	0	0	26	29	31	30	31	11	0	0	0
1941	0	0	9	31	28	31	30	31	30	3	0	0
1942	0	0	16	31	28	31	30	31	30	7	0	0
1943	0	0	7	26	28	31	30	31	15	0	0	0
1944	0	0	0	0	16	20	0	5	0	0	0	0
1945	0	0	6	4	27	28	30	28	1	0	0	0
1946	0	0	22	31	28	31	30	31	7	0	0	0
1947	0	0	0	0	10	19	12	0	0	0	0	0
1948	0	0	0	6	0	5	30	31	25	0	0	0
1949	0	0	0	0	0	28	30	14	0	0	0	0
1950	0	0	0	12	28	11	30	24	10	0	0	0
1951	0	12	31	31	28	31	21	28	1	0	0	0
1952	0	0	18	31	29	31	30	31	30	8	0	0
1953	0	0	23	31	23	10	10	31	27	0	0	0
1954	0	0	0	10	28	31	30	24	0	0	0	0
1955	0	0	11	10	0	0	0	0	0	0	0	0
1956	0	0	11	31	29	31	30	31	21	0	0	0
1957	0	0	0	0	2	31	0	11	9	0	0	0
1958	0	0	9	31	28	31	30	31	30	2	0	0
1959	0	0	0	18	26	15	0	0	0	0	0	0
1960	0	0	0	0	17	16	0	0	0	0	0	0
1961	0	0	0	0	25	11	2	0	0	0	0	0
1962	0	0	0	0	17	31	19	0	0	0	0	0
1963	15	0	13	7	28	11	30	31	8	0	0	0
1964	0	6	5	9	7	0	0	0	0	0	0	0
1965	0	0	9	31	28	16	23	28	0	0	0	0
1966	0	4	26	31	20	0	0	0	0	0	0	0
1967	0	0	30	24	28	26	30	31	30	14	0	0
1968	0	0	0	5	27	27	0	0	0	0	0	0
1969	0	0	3	31	28	31	30	31	30	0	0	0
1970	0	0	9	31	28	30	0	0	0	0	0	0
1971	0	1	31	31	22	5	26	4	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	3	10	31	28	31	10	0	0	0	0	0
1974	0	16	31	31	28	31	30	7	0	0	0	0
1975	0	0	13	0	22	31	21	10	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	18	25	31	30	28	0	0	0	0
1979	0	0	0	12	11	27	6	0	0	0	0	0
1980	0	0	1	31	29	31	17	0	0	0	0	0
1981	0	0	0	0	7	6	6	0	0	0	0	0
1982	0	7	31	31	28	31	30	31	17	0	0	0
1983	0	11	31	31	28	31	30	31	30	30	0	30
1984	27	23	31	31	29	27	4	0	0	0	0	0
1985	0	4	23	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	26	31	27	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	18	6	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	4	1	0	0	0	0	0
1992	0	0	0	0	11	0	0	0	0	0	0	0

Chipps Island (Mallard Island) Total number of X2 days per month

WYr	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1930	0	0	18	31	28	31	30	31	24	0	0	0
1931	0	0	0	25	28	31	14	0	0	0	0	0
1932	0	0	5	31	29	31	30	31	30	19	0	0
1933	0	0	0	8	28	31	30	31	30	3	0	0
1934	0	0	15	31	28	31	30	12	0	0	0	0
1935	0	0	15	31	28	31	30	31	30	13	0	0
1936	0	0	1	31	29	31	30	31	30	14	0	0
1937	0	0	0	31	28	31	30	31	30	13	0	0
1938	0	12	31	31	28	31	30	31	30	31	9	0
1939	0	28	31	31	28	31	30	14	0	0	0	0
1940	0	0	0	29	29	31	30	31	30	5	0	0
1941	0	0	12	31	28	31	30	31	30	30	0	0
1942	0	0	29	31	28	31	30	31	30	29	0	0
1943	0	13	31	31	28	31	30	31	30	9	0	0
1944	0	0	9	31	29	31	30	31	22	0	0	0
1945	0	19	31	31	28	31	30	31	30	17	0	0
1946	0	30	31	31	28	31	30	31	30	0	0	0
1947	0	10	31	31	28	31	30	21	0	0	0	0
1948	0	18	0	27	29	26	30	31	30	17	0	0
1949	0	4	21	31	28	31	30	31	21	0	0	0
1950	0	0	0	17	28	31	30	31	30	6	0	0
1951	1	30	31	31	28	31	30	31	26	0	0	0
1952	0	16	31	31	29	31	30	31	30	31	5	0
1953	0	15	31	31	28	31	30	31	30	17	0	0
1954	0	17	31	31	28	31	30	31	19	0	0	0
1955	0	16	31	31	28	31	11	31	17	0	0	0
1956	0	0	27	31	29	31	30	31	30	19	0	8
1957	31	30	31	31	28	31	30	31	26	0	0	0
1958	21	30	31	31	28	31	30	31	30	29	0	23
1959	31	30	31	31	28	31	20	0	0	0	0	0
1960	0	0	0	4	29	31	30	31	0	0	0	0
1961	0	0	30	31	28	31	28	0	0	0	0	0
1962	0	0	26	14	28	31	30	31	23	0	0	0
1963	18	30	31	31	28	31	30	31	30	7	0	11
1964	31	30	31	31	29	31	14	0	0	0	0	0
1965	0	18	31	31	28	31	30	31	30	7	0	15
1966	31	30	31	31	28	31	30	24	0	0	0	0
1967	0	11	31	31	28	31	30	31	30	31	16	30
1968	31	30	31	31	29	31	21	0	0	0	0	0
1969	0	0	19	31	28	31	30	31	30	31	20	30
1970	31	30	31	31	28	31	24	8	0	0	0	19
1971	31	30	31	31	28	31	30	31	30	31	16	30
1972	31	30	31	31	29	31	4	0	0	0	0	0
1973	5	30	31	31	28	31	30	23	12	0	0	0
1974	20	30	31	31	28	31	30	31	30	3	10	30
1975	31	30	31	31	28	31	30	31	30	31	7	28
1976	31	30	31	25	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	22	28	31	30	31	21	0	0	2
1979	16	0	0	20	28	31	30	26	6	0	0	0
1980	0	2	28	31	29	31	30	31	30	29	0	0
1981	0	0	3	5	28	31	20	0	0	0	0	0
1982	0	11	31	31	28	31	30	31	30	31	31	30
1983	31	30	31	31	28	31	30	31	30	31	31	30
1984	31	30	31	31	29	31	29	3	0	0	0	17
1985	28	17	31	31	28	11	0	0	0	0	0	0
1986	0	0	0	10	28	31	30	31	19	0	0	0
1987	21	0	0	0	14	26	11	0	0	0	0	0
1988	0	0	0	23	7	0	0	0	0	0	0	0
1989	0	0	0	0	0	21	24	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	23	13	0	0	0	0	0
1992	0	0	0	0	16	31	1	0	0	0	0	0

Collinsville Total number of X2 days per month

WYr	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1930	0	0	20	31	28	31	30	31	30	7	0	0
1931	0	13	31	31	28	31	30	12	0	0	0	0
1932	0	0	7	31	29	31	30	31	30	31	0	0
1933	0	0	9	31	28	31	30	31	30	14	0	0
1934	0	0	19	31	28	31	30	31	0	0	0	0
1935	0	8	31	31	28	31	30	31	30	26	0	0
1936	0	14	31	31	29	31	30	31	30	27	0	0
1937	0	0	16	31	28	31	30	31	30	26	0	0
1938	0	18	31	31	28	31	30	31	30	31	31	2
1939	31	30	31	31	28	31	30	31	10	0	0	0
1940	0	0	17	31	29	31	30	31	30	18	0	0
1941	0	28	31	31	28	31	30	31	30	31	16	0
1942	4	30	31	31	28	31	30	31	30	31	12	0
1943	18	30	31	31	28	31	30	31	30	24	0	0
1944	1	30	31	31	29	31	30	31	30	6	0	0
1945	0	24	31	31	28	31	30	31	30	31	8	6
1946	31	30	31	31	28	31	30	31	30	20	0	0
1947	31	30	31	31	28	31	30	31	25	0	0	0
1948	13	30	31	31	29	31	30	31	30	31	6	17
1949	31	30	31	31	28	31	30	31	30	7	0	0
1950	0	20	31	31	28	31	30	31	30	21	0	0
1951	8	30	31	31	28	31	30	31	30	13	0	0
1952	28	30	31	31	29	31	30	31	30	31	31	30
1953	31	30	31	31	28	31	30	31	30	30	0	12
1954	31	30	31	31	28	31	30	31	30	2	0	0
1955	22	30	31	31	28	31	30	31	30	0	0	0
1956	0	10	31	31	29	31	30	31	30	31	31	30
1957	31	30	31	31	28	31	30	31	30	9	0	8
1958	31	30	31	31	28	31	30	31	30	31	31	30
1959	31	30	31	31	28	31	30	29	0	0	0	3
1960	3	0	3	31	29	31	30	31	16	0	0	0
1961	0	14	31	31	28	31	30	31	15	0	0	0
1962	0	0	30	31	28	31	30	31	30	10	0	18
1963	31	30	31	31	28	31	30	31	30	29	0	25
1964	31	30	31	31	29	31	30	31	21	0	0	16
1965	31	30	31	31	28	31	30	31	30	29	19	30
1966	31	30	31	31	28	31	30	31	9	0	0	0
1967	0	29	31	31	28	31	30	31	30	31	31	30
1968	31	30	31	31	29	31	30	31	1	0	0	0
1969	0	16	31	31	28	31	30	31	30	31	31	30
1970	31	30	31	31	28	31	30	31	28	0	9	30
1971	31	30	31	31	28	31	30	31	30	31	31	30
1972	31	30	31	31	29	31	30	3	0	0	0	23
1973	31	30	31	31	28	31	30	31	30	1	0	24
1974	31	30	31	31	28	31	30	31	30	31	31	30
1975	31	30	31	31	28	31	30	31	30	31	31	30
1976	31	30	31	31	29	19	15	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	25	28	31	30	31	30	8	0	22
1979	31	30	31	31	28	31	30	31	23	0	0	0
1980	0	23	31	31	29	31	30	31	30	31	22	21
1981	31	30	31	31	28	31	30	31	13	0	0	0
1982	0	14	31	31	28	31	30	31	30	31	31	30
1983	31	30	31	31	28	31	30	31	30	31	31	30
1984	31	30	31	31	29	31	30	31	30	31	31	30
1985	31	30	31	31	28	31	30	10	11	0	0	0
1986	0	0	17	20	28	31	30	31	30	31	19	13
1987	31	30	31	31	28	31	30	7	0	0	0	0
1988	0	0	13	26	19	0	14	19	0	0	0	0
1989	0	0	5	9	0	27	30	31	23	0	0	0
1990	0	0	0	17	21	1	0	2	14	0	0	0
1991	0	0	0	0	5	27	27	0	0	0	0	0
1992	0	0	0	13	19	31	30	2	0	0	0	0

Appendix E

Eight River (Sacramento and San Joaquin) Unimpaired Runoff
(in thousand acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun
1922	1071.6	2625.1	2405.2	3661.0	6675.6	4847.7
1923	1746.9	1197.8	1509.7	3383.2	3658.8	2071.9
1924	556.6	1158.2	635.3	1068.1	1095.6	449.1
1925	940.1	4993.5	2175.0	3821.6	3704.6	2042.6
1926	763.2	3182.5	1733.4	3789.6	2175.1	915.1
1927	2217.2	6054.2	3527.4	4823.3	4275.6	3112.7
1928	1374.1	1944.1	5687.6	3730.7	3020.1	1169.6
1929	612.7	1122.8	1289.2	1627.8	2490.1	1454.8
1930	1411.7	1841.4	2777.2	2639.4	2287.0	1580.9
1931	801.7	775.3	1198.6	1234.9	1182.2	540.9
1932	1326.0	1836.9	2499.5	2730.1	4158.9	2988.2
1933	699.8	580.0	1891.9	1965.8	2363.3	2453.2
1934	1466.4	1593.5	1895.1	1614.8	1092.2	656.0
1935	1871.6	1559.2	2127.1	6177.5	4737.8	2943.6
1936	3221.5	5035.1	2770.1	3827.2	3711.8	2356.9
1937	541.8	2364.1	3277.0	3771.2	4919.0	2391.8
1938	1857.1	5268.0	7495.2	5978.0	7339.5	5044.1
1939	791.9	814.1	1905.8	2259.4	1471.0	723.0
1940	3877.2	5682.4	6224.2	4612.0	3773.3	1905.3
1941	4280.8	5073.7	4717.9	4616.5	5749.3	3339.0
1942	4181.6	5095.8	2229.6	4640.4	4759.1	4166.9
1943	4666.3	2835.2	5328.3	4233.2	3589.9	2267.9
1944	781.2	1442.4	1938.9	1879.7	3335.9	1811.0
1945	1072.8	4131.6	2170.3	2817.0	3818.1	2592.8
1946	2638.8	1312.2	2292.0	3449.9	3681.5	1731.6
1947	635.6	1568.9	2508.8	2204.6	2049.5	1200.5
1948	1910.6	700.5	1556.3	4343.1	4510.8	3317.6
1949	529.5	920.3	3321.8	3266.5	3386.4	1524.6
1950	1822.0	2544.7	2456.9	3735.3	3727.0	2102.8
1951	3395.4	3516.8	2662.2	2807.3	3148.6	1596.0
1952	3475.8	4026.1	3678.7	6351.9	7512.4	4557.5
1953	5397.2	1517.3	2063.7	3248.2	3379.0	3398.3
1954	2202.7	2836.4	3659.8	4560.1	3266.0	1455.6
1955	1161.9	960.5	1273.6	1972.8	3219.9	1892.9
1956	7524.5	3713.0	3066.9	3509.1	5241.3	3547.0
1957	794.3	2653.4	3408.5	2359.7	3850.8	2469.4
1958	2387.8	7613.1	4705.7	6040.5	6735.6	4186.2
1959	2248.7	2498.8	1979.6	2274.4	1820.3	1069.7
1960	903.9	3146.9	3221.2	2497.6	2389.0	1321.1
1961	859.7	2136.7	1932.6	2016.5	2160.3	1226.0
1962	781.2	4082.7	2390.1	3886.9	3141.5	2525.8
1963	1703.9	4656.1	2101.0	5604.0	4987.8	2663.7
1964	1548.1	1013.1	1147.2	1919.2	2436.4	1580.3
1965	5612.8	2255.3	1972.3	4737.0	3808.9	2778.2

Appendix E (continued)

Eight River (Sacramento and San Joaquin) Unimpaired Runoff (in thousand acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun
1966	1854.1	1561.9	2524.8	3327.3	2516.0	916.5
1967	3344.7	2517.3	4091.3	3819.3	6256.3	5444.1
1968	1494.2	3709.7	2554.4	2168.4	2152.7	1091.9
1969	7912.8	4731.2	3359.4	5438.5	7340.1	4278.3
1970	10681.0	3021.5	3119.5	1823.2	2765.9	1911.0
1971	3045.4	1833.9	3725.0	3403.1	4176.7	3332.6
1972	1395.5	1730.9	3297.8	2520.3	2610.4	1536.9
1973	4076.1	3657.0	3271.4	3079.8	4757.3	2258.1
1974	6933.4	2097.4	6175.8	5070.0	4687.7	3186.9
1975	1013.2	2924.3	4650.1	2890.7	5402.7	4076.4
1976	635.4	870.3	1334.1	1349.7	1435.1	597.5
1977	474.7	476.0	544.6	689.1	905.8	755.5
1978	5906.5	3478.2	5356.8	4397.9	4701.1	3782.1
1979	1444.9	2101.5	2897.1	2674.4	4504.2	1746.6
1980	6885.1	5927.4	3618.0	3107.9	3672.7	2905.6
1981	1571.1	1760.2	2476.4	2322.8	2112.7	1007.5
1982	3504.9	5568.1	4740.5	8047.6	5682.4	3333.7
1983	4247.9	6459.3	10569.1	4868.6	6964.2	7100.7
1984	2851.3	2286.8	3081.3	2504.2	3600.1	1989.2
1985	842.0	1209.5	1593.2	2786.1	2135.4	1013.3
1986	2616.0	11549.3	7090.0	3191.3	3559.0	2573.9
1987	779.4	1508.7	2544.1	1727.2	1469.7	639.7
1988	1835.4	1006.7	1258.1	1475.2	1583.7	926.7
1989	852.9	990.6	6154.7	3584.9	2212.6	1193.3
1990	1271.9	884.7	1825.7	1770.3	1772.5	1239.5
1991	359.6	450.1	2637.1	1944.0	2392.9	1614.7
1992	594.3	2416.1	2007.9	2184.9	1329.0	589.2

From Bruce Herbold (updated June 16, 1994)