Industrial Wastewater and Dye-Contaminant Discharges to the CWW Sewerage System and Approaches to Enhanced Treatment

Final Report to Columbus Water Works

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Introduction

The water and wastewater reclamation systems of Columbus Water Works (CWW) in Columbus Georgia include advanced systems with extensive water management and protection systems. The wastewater reclamation systems include stormwater, domestic-wastewater and industrial-wastewater systems. The focus of this report is the impacts of selected wastewater discharges from major discharges of dyes on the wastewater reclamation facilities of the CWW.

A total of five (5) industrial operations were included within the study. These facilities and plants are referred herein as Plants A through E due to data confidentiality issues.

Plant A. This industrial plant has two outfall discharges to the CWW system and effluent monitoring by CWW is focused on flow, BOD_5, COD, TP, TS, TSS, temperature, chlorine and conductivity. Plant A produces textile materials for a variety of consumer products. The plant A is the most diverse of the plants examined in this study, based on the variety and colors of dyes used and ultimately discharged to the CWW system. Plant A has a pretreatment system prior to direct discharge. The pretreatment system has a heat-recovery system and a pH-neutralization system and the overall purpose of the pretreatment system is attenuation of pH and prevention of acidic- and basic-surges on the CWW sewerage system.

Plant B. Plant B is a major producer of 100% cotton yarns and denim fabrics. The plant is operated on a continuous basis and has a continuous wastewater discharge to the CWW system. The plant maintains an extensive heat-recovery system and an equalization basin for wastewaters. The equalization basin attenuates the effluent flow rate, pH and temperature of the wastewaters. There is measurable water evaporation from the basin but there are no managed physicochemical or biological processes employed to address wastewater components.

Plants C & D. Plant C is a major facility for the weaving, dyeing and finishing of denim and, with an associated facility (referred to as Plant D), is a producer of cotton and polyester yarns and dye yarn. Plant C has a pretreatment system for treatment of wastewater prior to discharge. The pretreatment system included (i) pH adjustment, (ii) nutrient addition (trace level of nitrogen and phosphorus), (iii) activated sludge aeration, and (iv) clarification, prior to discharge to the CWW system. In addition, the pretreatment plant has a thickener/holding tank for the underflow from the clarifier and a plate-and-frame dewatering press for sludge-solids dewatering. Plant D had a pH neutralization system prior to discharge to the CWW system.

Plant E. Plant E was a textile plant producing denim and other fabrics. The plant included both batch and continuous dyeing operation. The wastewater fro the plant was treated in system by screening and pH neutralization, prior to discharge to the CWW system.

A preliminary assessment of the plants was made to refine the study. The flows from the above plants were examined as to volumetric flow, as presented below.

Plant	**Estimated wastewater flow** 10^3 gallons/day
A	2,830
B	426
C	838
D	365
E	815

In parallel with study development, plant E was designated for closure and complete shut-down at the Columbus location. In addition, plant D was identified as a relatively low-flow system with a well-controlled wastewater discharge. This assessment then left three plants (A, B, C) as the primary focus of the project.

Project Approach

The project was to intensely investigate the impacts of industrial dyeing facilities in Columbus on the wastewater reclamation systems through examination of the wastewater discharges from the representative plants, i.e., Plants A, B, and C. The data for the study were those provided by the respective plants and CWW monitoring data sets.

Industrial Plant Data

Water and Wastewater Characteristics: The investigative activity required the provision of two sets of data from the plants. The initial set was for plant data on water and wastewater constituents. The water data included water use, consumption and releases from the plants for a 12-month period, as available. The data for wastewater constituents were provided for the same period and included data for raw wastewaters (those discharged to pretreatment facilities and receiving no prior treatment) and wastewaters discharges to the CWW system (i.e., those wastewaters reflecting the impacts of any pretreatment system employed by the plant).

Dye and Chemical Usage: The second data set required, and provided by the plants to CWW, was a total inventory of chemicals purchased and used by the individual plants over a 6- or 12-month period. These data were typically provided in terms of (i) dye chemicals and (ii) non-dye chemicals and were based on the chemical purchased by the plants over the indicated period. The data set did not include information as to the time sequence of usage at the plants and consequently could not be linked directly to the wastewater discharges into the CWW system. The chemical inventory however was an exceptional data source because of the details provided as to the nature of the chemicals used at the plants and of those potentially released into the CWW system.

CWW Plant-monitoring data

CWW has an intensive wastewater industrial monitoring program focused on the many industrial customers using the sewer and wastewater reclamation systems. To compliment and reinforce the data sets provided by the individual plants, the CWW monitoring data for the 3 plants were integrated into the project. These data sets were those collected by CWW personnel at plant discharge points over a 24-hour period. The wastewater monitoring is done without prior notice to the plants and is performed on a regular basis to assure adherence to sewer-use codes and to establish sewer-use charges and fees.

The overall project approach was to use the above data sets to (i) assess the impact of the industrial plants on the wastewaters discharged to the overall sewer system, as received for reclamation by the South CWW Plant, which discharges to the Chattahoochee River through an NPDES permit and (ii) identify the primary industrial chemicals in the discharges responsible for the color-components in the influent and effluent wastewaters of the South plant. An additional ancillary aspect of the project was a review of the potential innovations that could be implemented at the South plant to biologically address the color on the reclaimed wastewaters, using existing treatment systems.

The results are presented in two sections. The initial section is focused on the wastewater flows and characteristics and the subsequent section presents analysis of chemical and dye data and analysis. In both sections, the data and analysis format is presented on a plant by plant basis, followed by a summary for each section.

Results and Discussion

Flow and wastewater analysis

The following section includes an assessment of water and wastewater data sets provided by CWW and Plant personnel for the indicated 12-month, and more, periods of investigation. The data are presented on a plant-by-plant basis and include a critical evaluation of the independent data sets and the impacts on the overall discharges.

The results are presented in terms of the time period of data availability, flow data assessment and composition of the wastewaters discharged. Data availability covered periods of 1998 to 2000. Flow data were represented as the following components: (i) water consumed by the plant for potable and industrial purposes and supplied by CWW was Q_c, (ii) wastewater discharges to a plant pretreatment system was Q_p, and (iii) wastewater discharged to the CWW system was Q_w. The principal wastewater compositional data examined were those for organic contaminants, as measured with BOD_5 and COD measurements. The data analysis include assessment of the concentrations of BOD_5 and COD, as well as assessment of the organic loadings (i.e., *(flow) x (concentration)*, expressed in units of kg/day), as well as an assessment of the level of biodegradability of effluent organics using the BOD_5/COD ratio. Data examined in addition usually included phosphorus, solids, chlorine residual, temperature and conductivity.

Plant A

Data Availability. Data provided by CWW and Plant A covered an overall period of approximately three years. As shown in Figure 1, the data were continuous throughout this period for CWW flow and BOD data, while flow and characteristics data from plant A were only available for portions of the 3-year period. The indicated "dye period" is the period over which the chemical inventory was conducted, which was October 1999 to September 2000.

Wastewater flow. Wastewater flow data are included using monthly wastewater discharge data from CWW and Plant A in Figures 2 and 3. These wastewater flows are compared in Figure 4. While there are variations in the two data sets, they were in general agreement, indicating wastewater discharges ranged from 1.25 to 6.8 million gallons per day (mgd).

Wastewater Composition. Organic composition of the wastewater included a BOD_5 of 509 mg/L (std. dev. = 331 mg/L) and a COD 1714 mg/L (std. dev. = 508mg/L) as presented in Figures 5 and 6, based on CWW monitoring data. The average loadings for BOD_5 and COD were 4,968 kg/d (std. dev. = 2,461 kg/d) and 19,349 kg/d (std.dev. = 9,877 kg/d), as included in Figures 7 and 8. The ratio of COD to BOD_5 in Figure 9 for the full data period was 3.42 (std. dev. = 0.77) which indicates that BOD_5 was approximately equal to 29.3% of the COD concentration or organic loading. Hence, there is considerable organic matter in the effluent that would be non-biodegradable or resistant to rapid

Figure 1. Wastewater Characteristics Data Availability in Plant A

Dye Period - Oct. 99 ~ Sep. 00

(Source: CWW & Plant A)

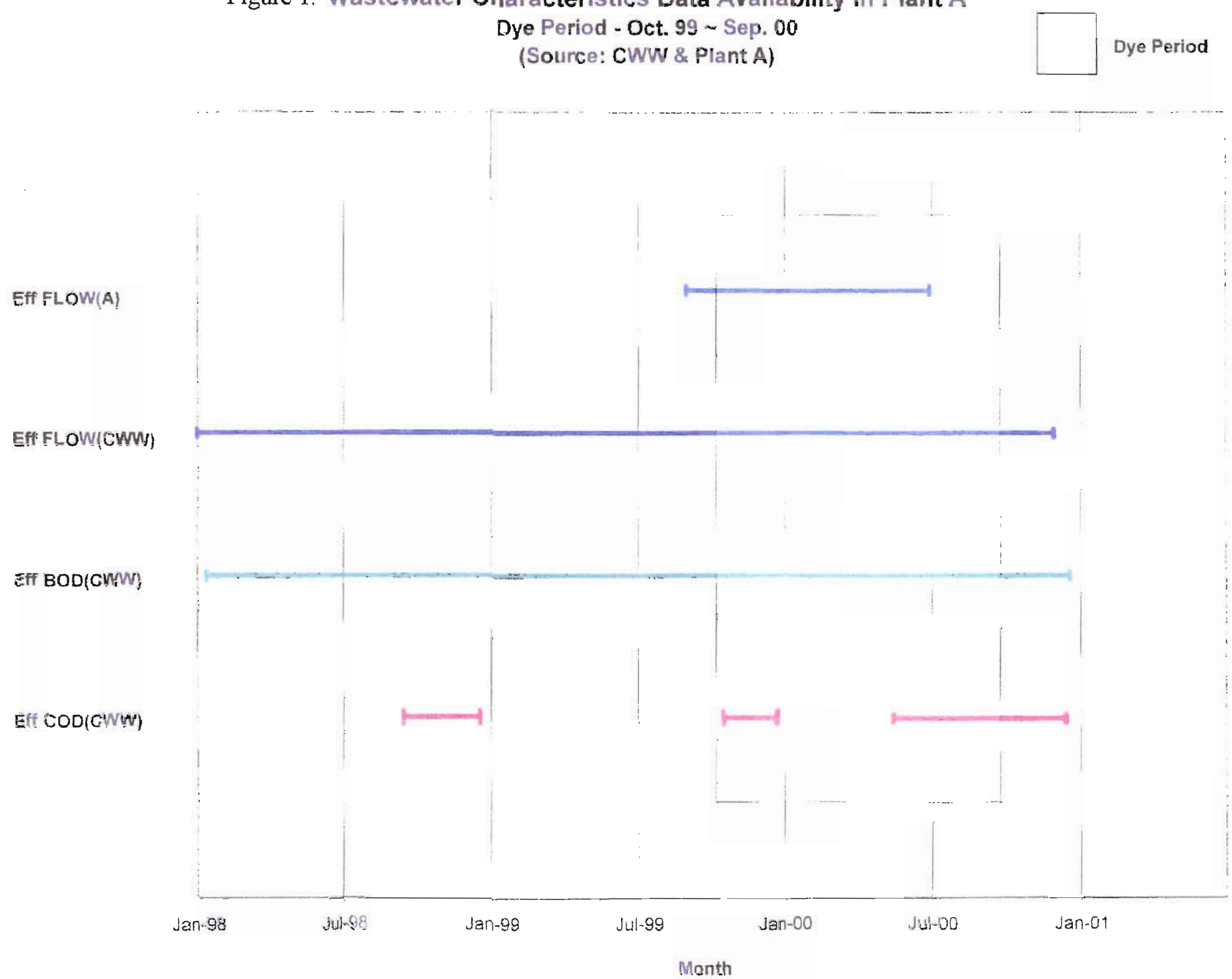


Figure 2. WASTEWATER DISCHARGE (Q_W)
PLANT A - 1/98 ~ 12/00
(Source: Monthly Discharge from CWW)

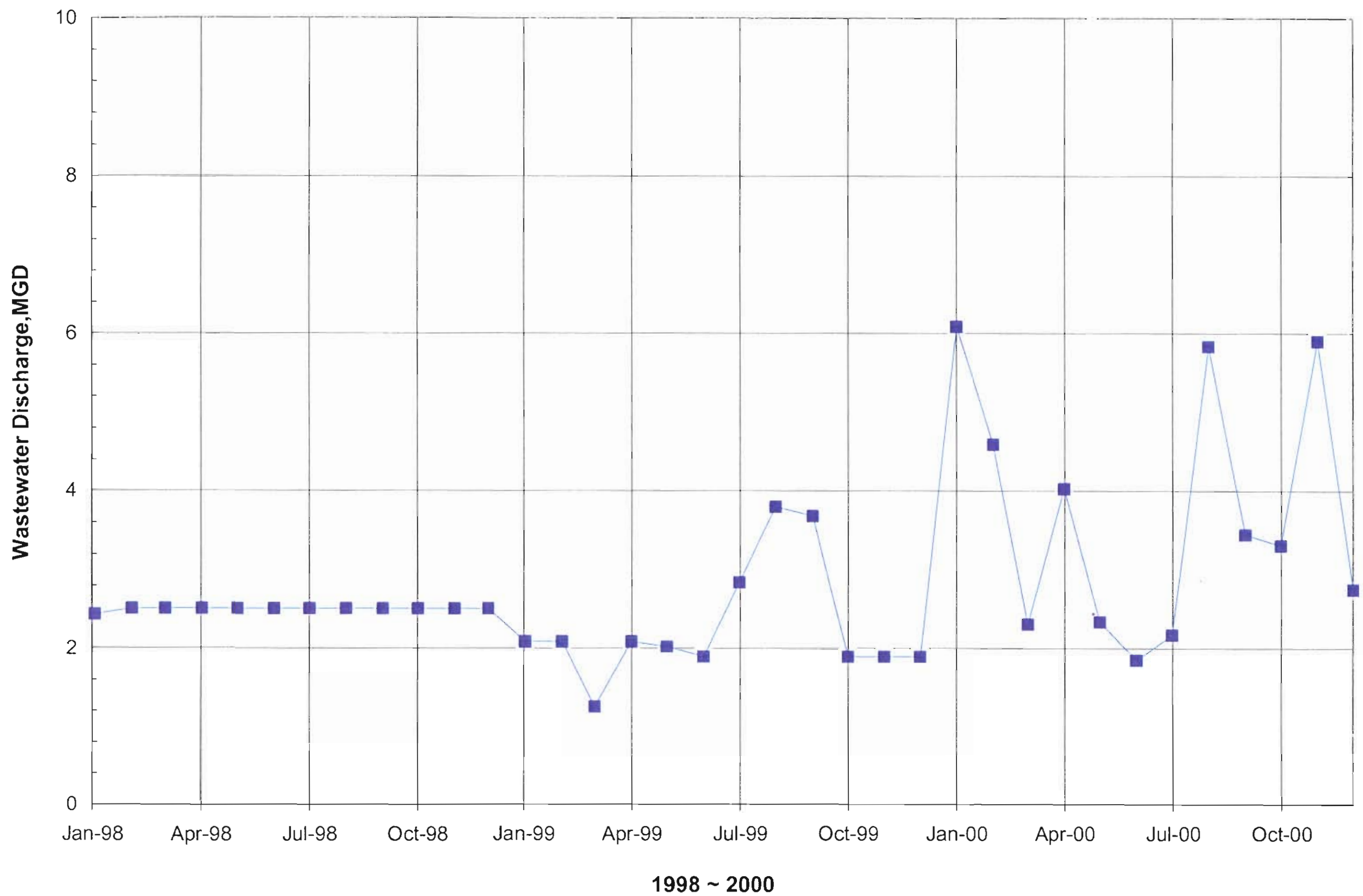
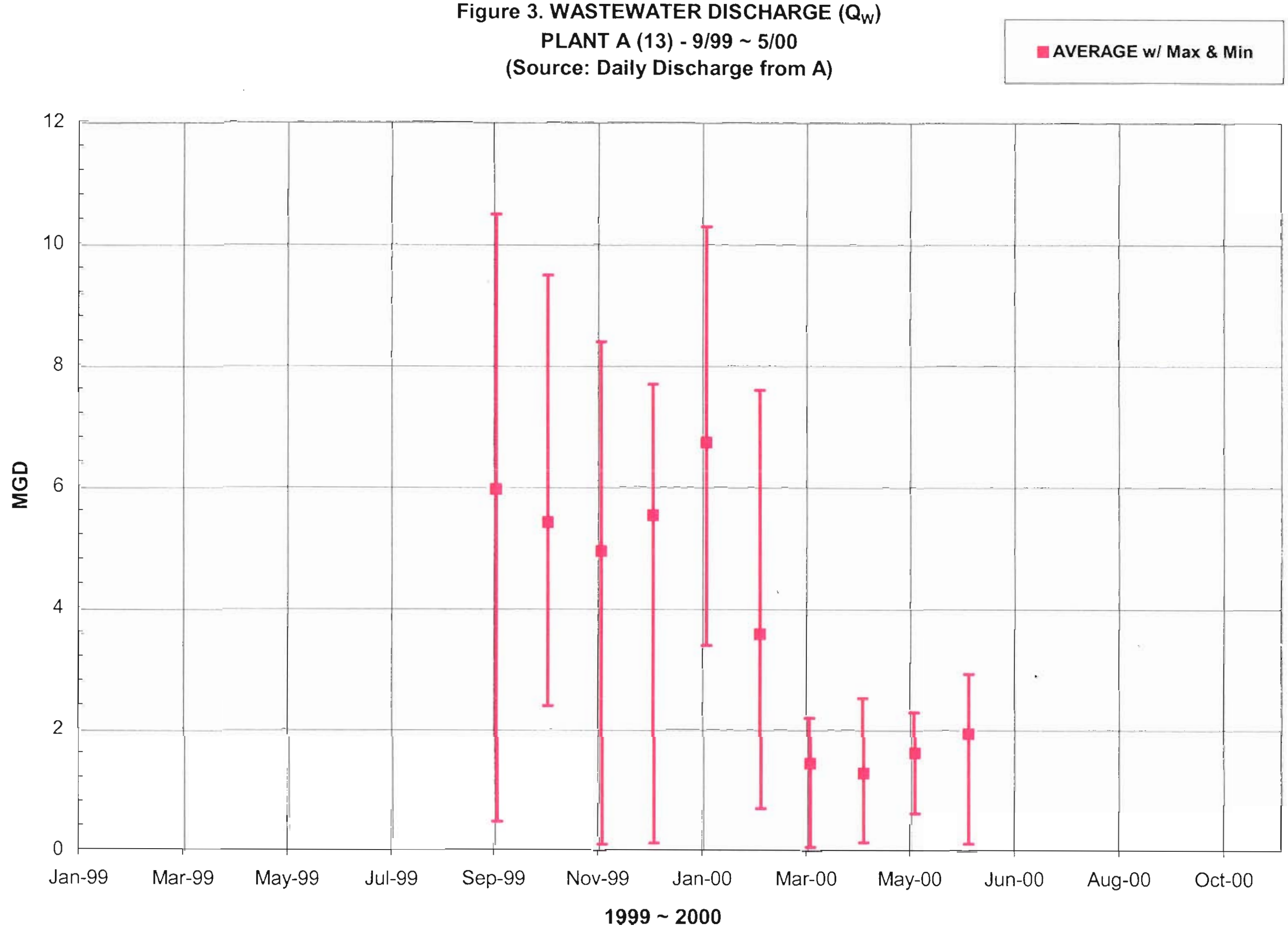


Figure 3. WASTEWATER DISCHARGE (Q_W)
PLANT A (13) - 9/99 ~ 5/00
(Source: Daily Discharge from A)



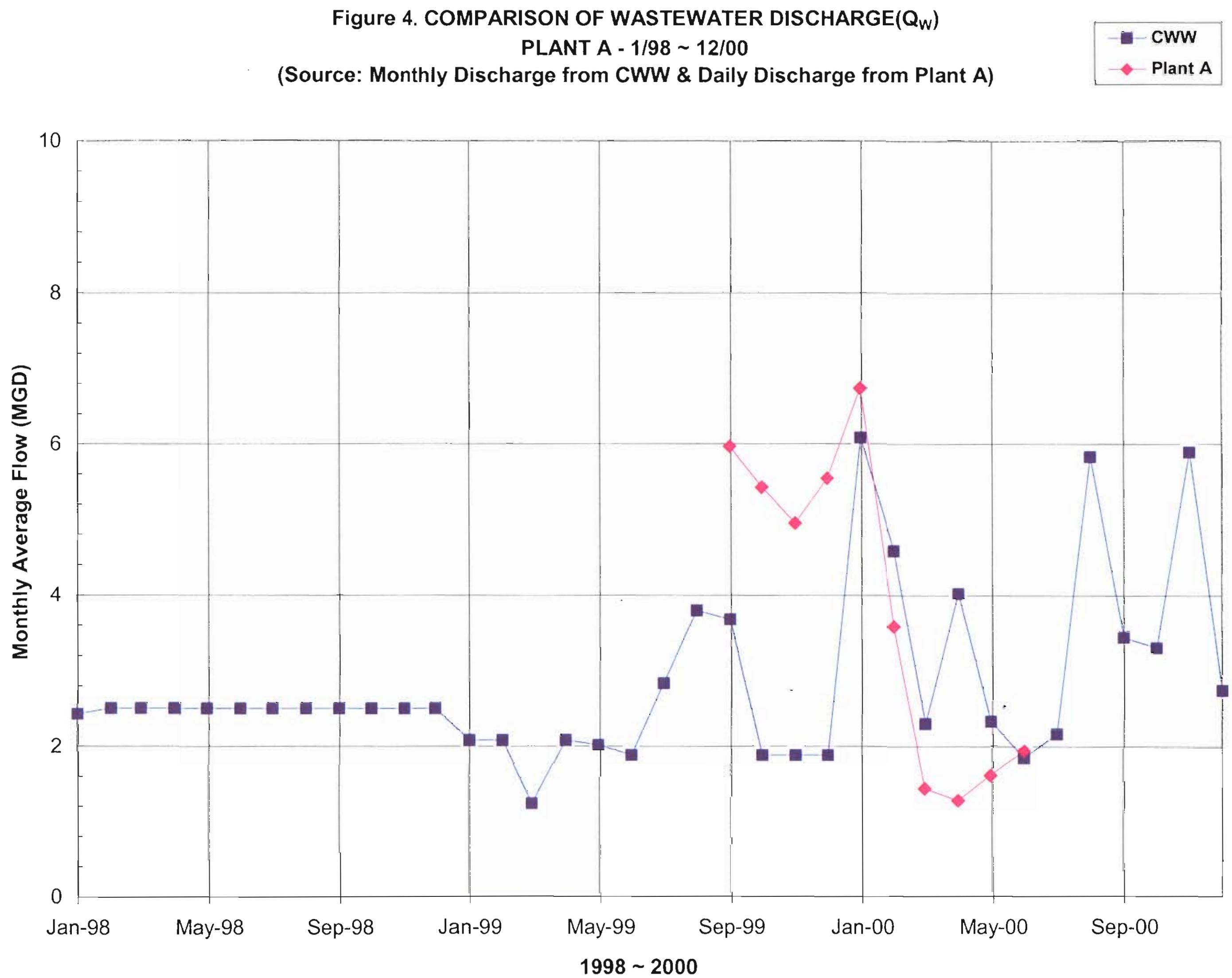


Figure 4. COMPARISON OF WASTEWATER DISCHARGE(Q_W)
PLANT A - 1/98 ~ 12/00
(Source: Monthly Discharge from CWW & Daily Discharge from Plant A)
CWW
Plant A
Monthly Average Flow (MGD)
10
8
6
4
2
0
Jan-98
May-98
Sep-98
Jan-99
May-99
Sep-99
Jan-00
May-00
Sep-00
1998 ~ 2000

Figure 5. BOD_5 in WASTEWATER DISCHARGE (Qw)
PLANT A - 1/98 ~ 12/00
(Source: 24-hr composite from random monitoring by CWW)

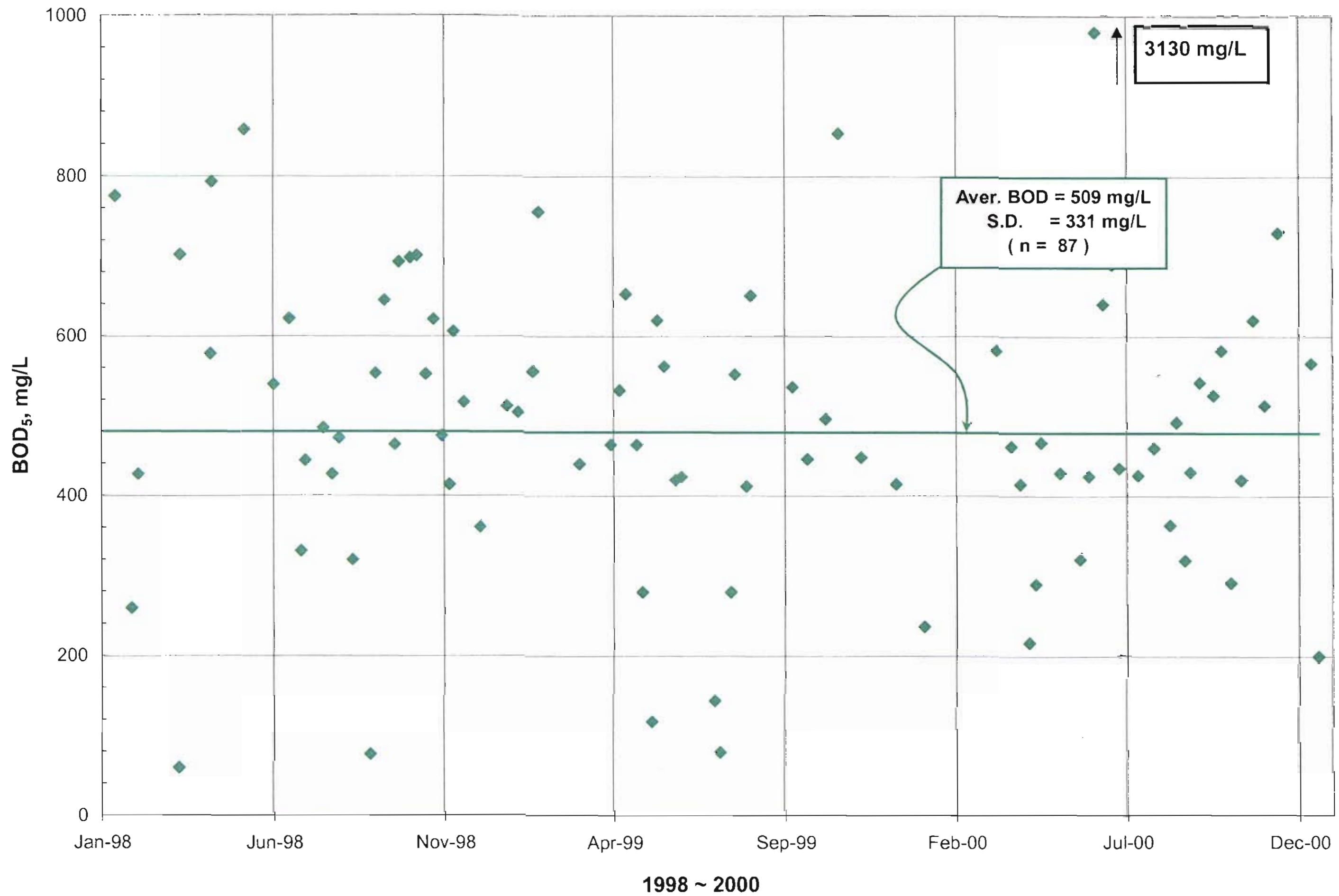


Figure 6. COD in WASTEWATER DISCHARGE (Qw)
PLANT A - 9/98 ~ 12/00
(Source: 24-hr composite from random monitoring by CWW)

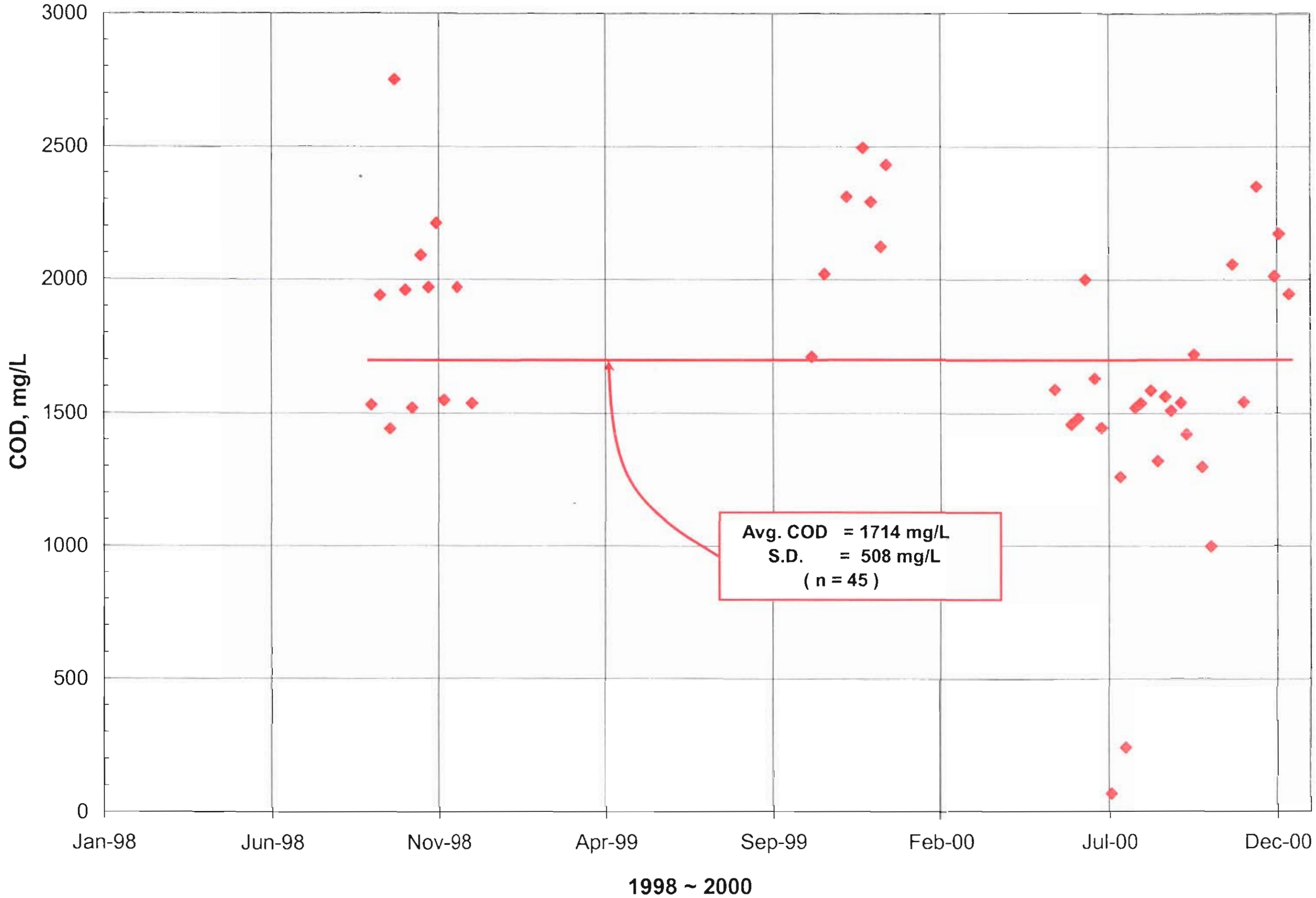


Figure 7. BOD_5 LOADING in WASTEWATER DISCHARGE (Qw)
PLANT A - 1/98 ~ 12/00
(Source: BOD_5 conc. = 24-hr composite (CWW); &
Flow = Average Daily Flow from Total Monthly Discharge Data of CWW & Plant A)

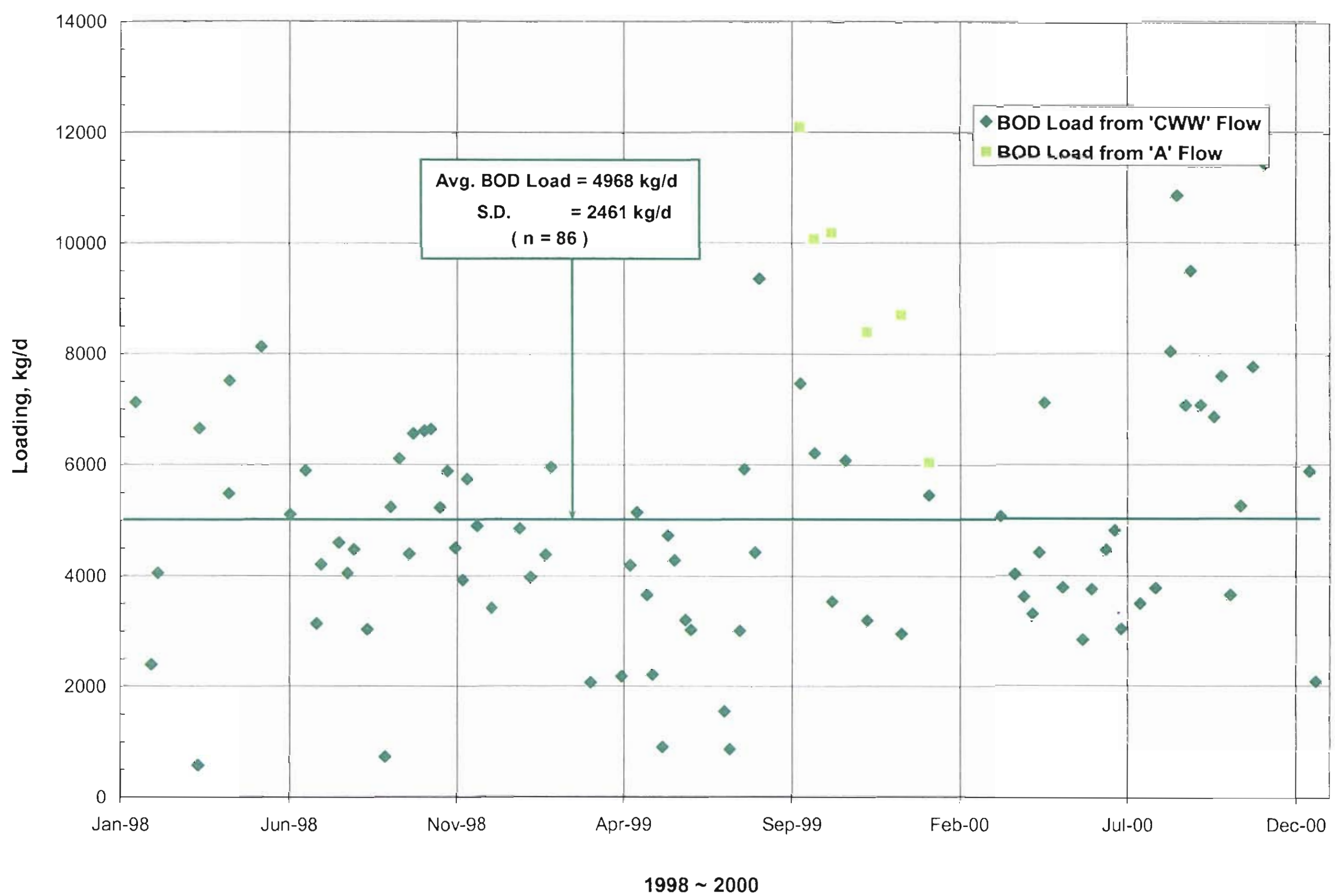


Figure 8. COD LOADING in WASTEWATER DISCHARGE (Qw)
PLANT A - 9/98 ~ 12/00
(Source: COD conc. = 24-hr composite (CWW); &
Flow = Average Daily Flow from Plant A and Total Monthly Discharge Data of CWW)

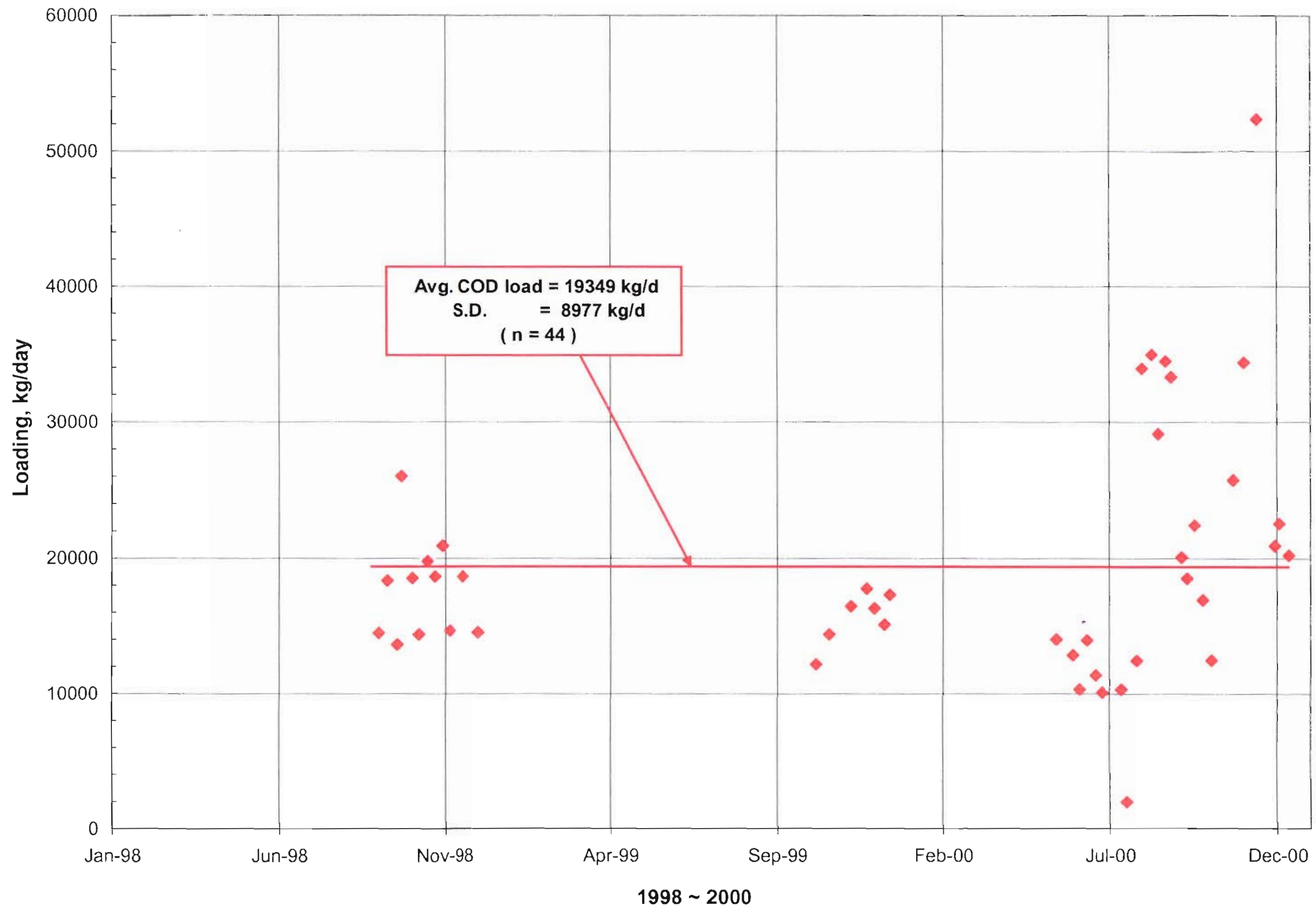
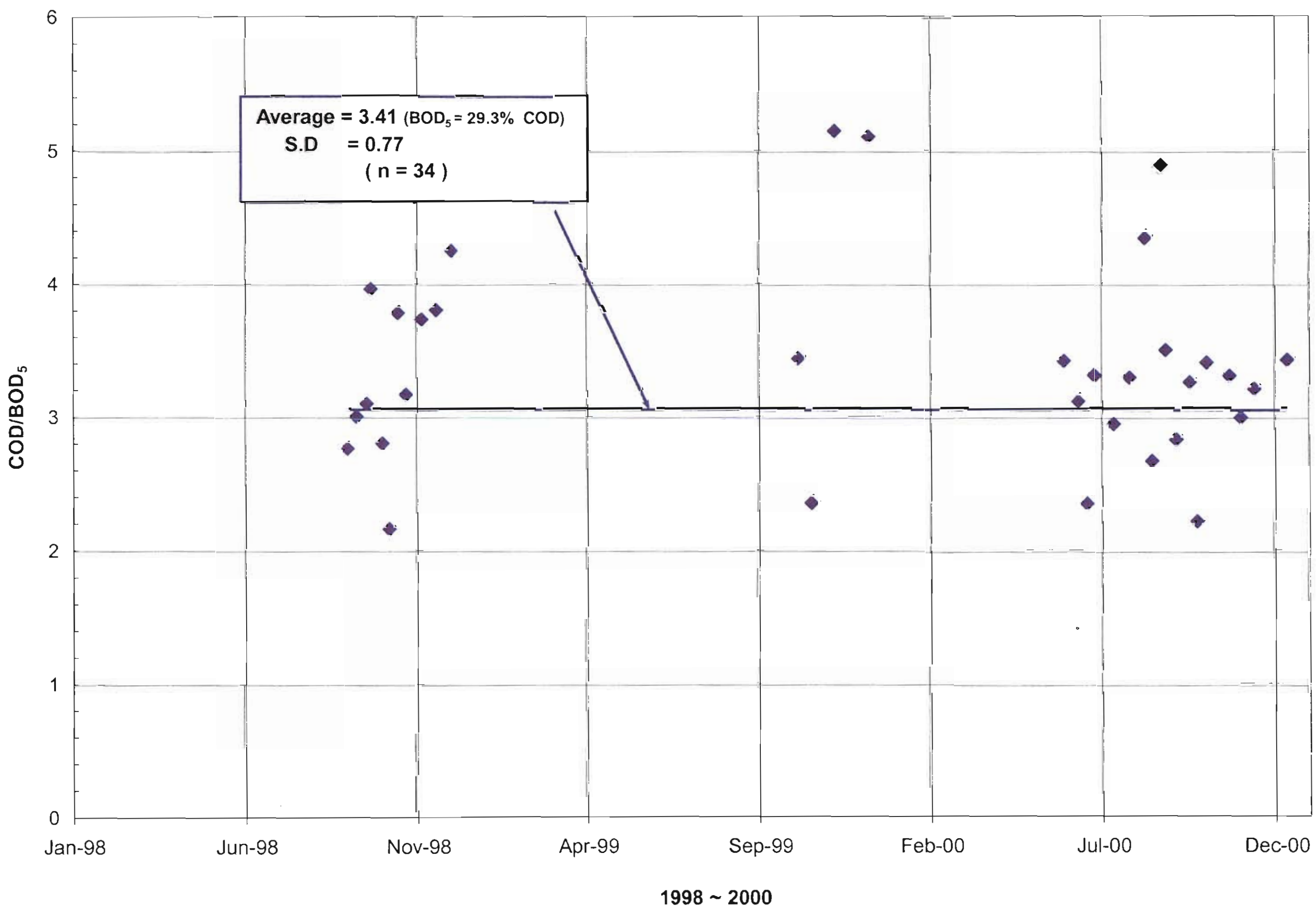


Figure 9. COD/BOD_5 RATIO in WASTEWATER DISCHARGE (Q_W)
PLANT A - 9/98 ~ 12/00
(Source: 24-hr composite from random monitoring by CWW)



degradation. This is not unexpected for this type of plant, and many other industrial plants, using high levels of dyes and their associated organic formulations.

The time period for which specific chemical inventory data were provided by the plant covered a period of October 1999 to September 2000. This period was referred to herein as the dye period. Therefore, these organic loading data above were examined over this same period and are compared to the full period for which data were available below. BOD_5 and COD concentration and loading data are included in Figures 10-13 and summarized below.

Plant A: Organic Content of Wastewater Effluent Discharged to CWW System

Parameter	1998 – 2000		Dye Period	
BOD_5				
Conc., mg/L	509	(331)*	559	(531)
Loading, kg/d	4968	(2461)	5,213	(2,174)
COD				
Conc., mg/L	1,714	(508)	1,599	(555)
Loading, kg/d	19,349	(8,977)	18,014	(8,725)

* ( ) = standard deviation in appropriate units

Within the statistical limits of the variability, the data for the dye period were consistent with the data for the 2-year period of 1998 to 2000.

The wastewater discharged from Plant A to the CWW system was characterized by additional water quality data that were provided in limited summary data sets. Nonetheless, these data indicate other properties of Plant A wastewaters.

Figure 10. BOD_5 in WASTEWATER DISCHARGE (Qw) for DYE PERIOD
PLANT A - 10/99 ~ 9/00
(Source: 24-hr composite from random monitoring by CWW)

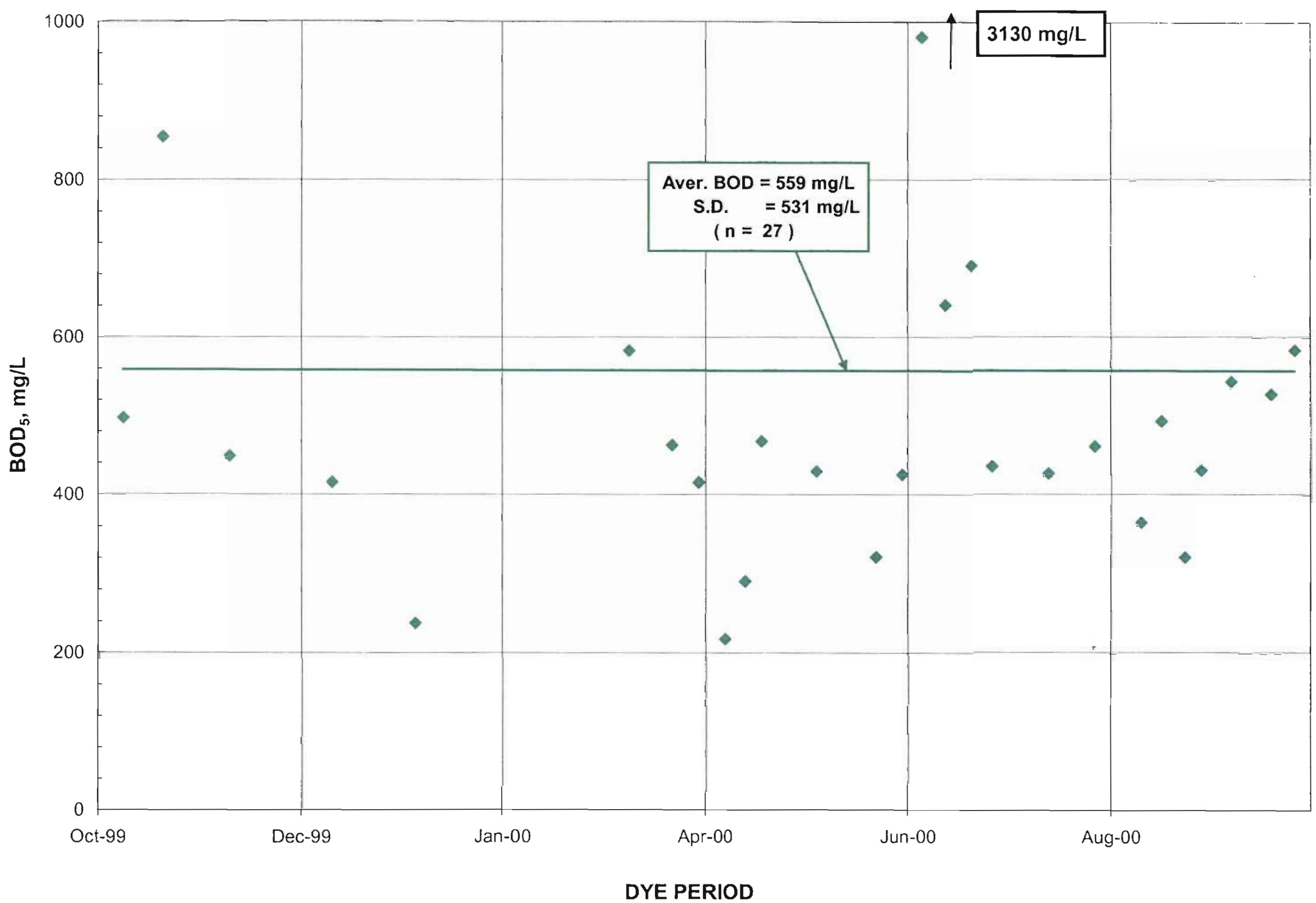


Figure 11. BOD_5 LOADING in WASTEWATER DISCHARGE (Qw) for DYE PERIOD
PLANT A - 10/99 ~ 9/00
(Source: BOD_5 conc. = 24-hr composite (CWW); &
Flow = Average Daily Flow from Total Monthly Discharge Data of CWW & Plant A)

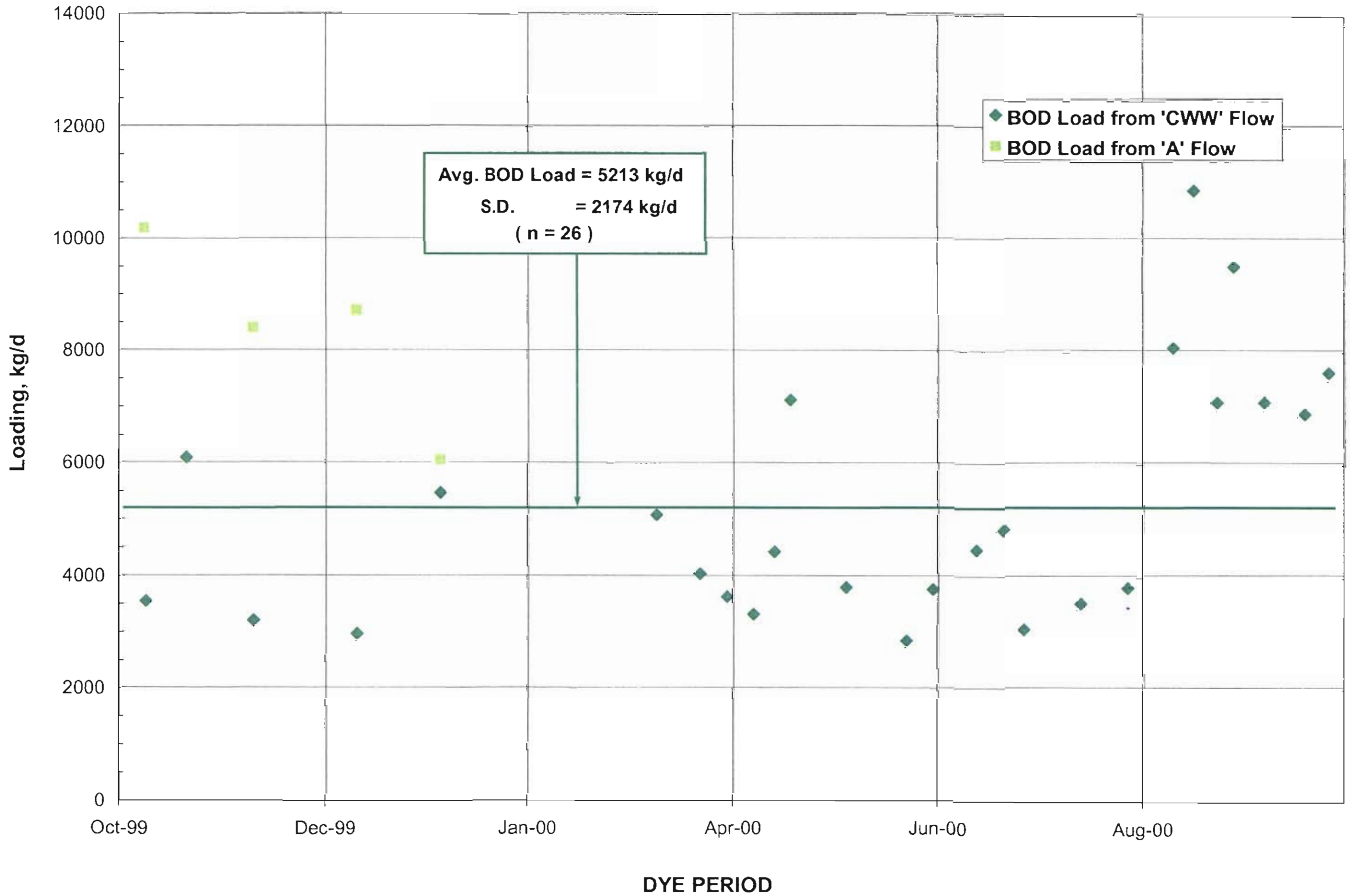


Figure 12. COD in WASTEWATER DISCHARGE (Qw) for DYE PERIOD
PLANT A - 10/99 ~ 9/00
(Source: 24-hr composite from random monitoring by CWW)

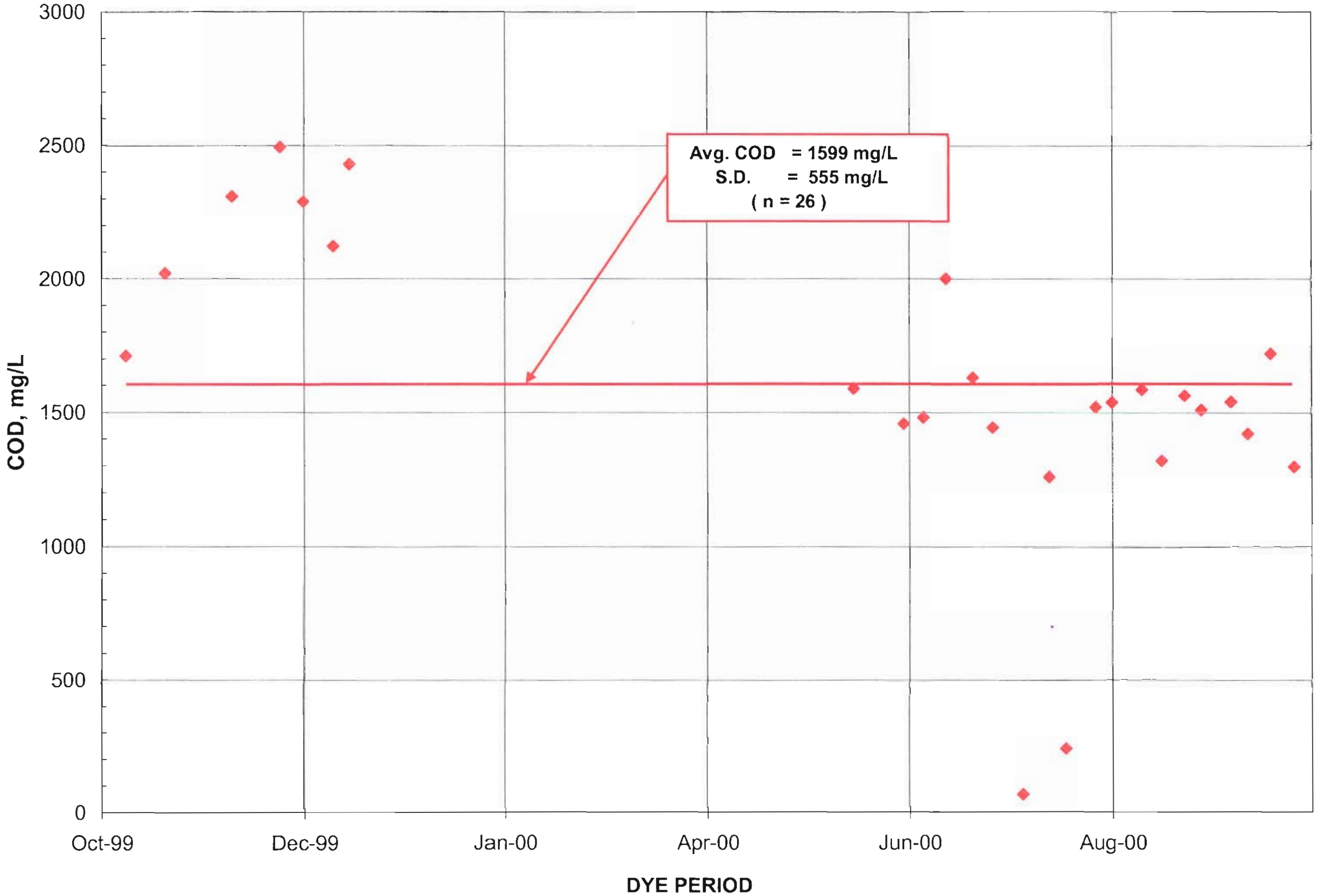
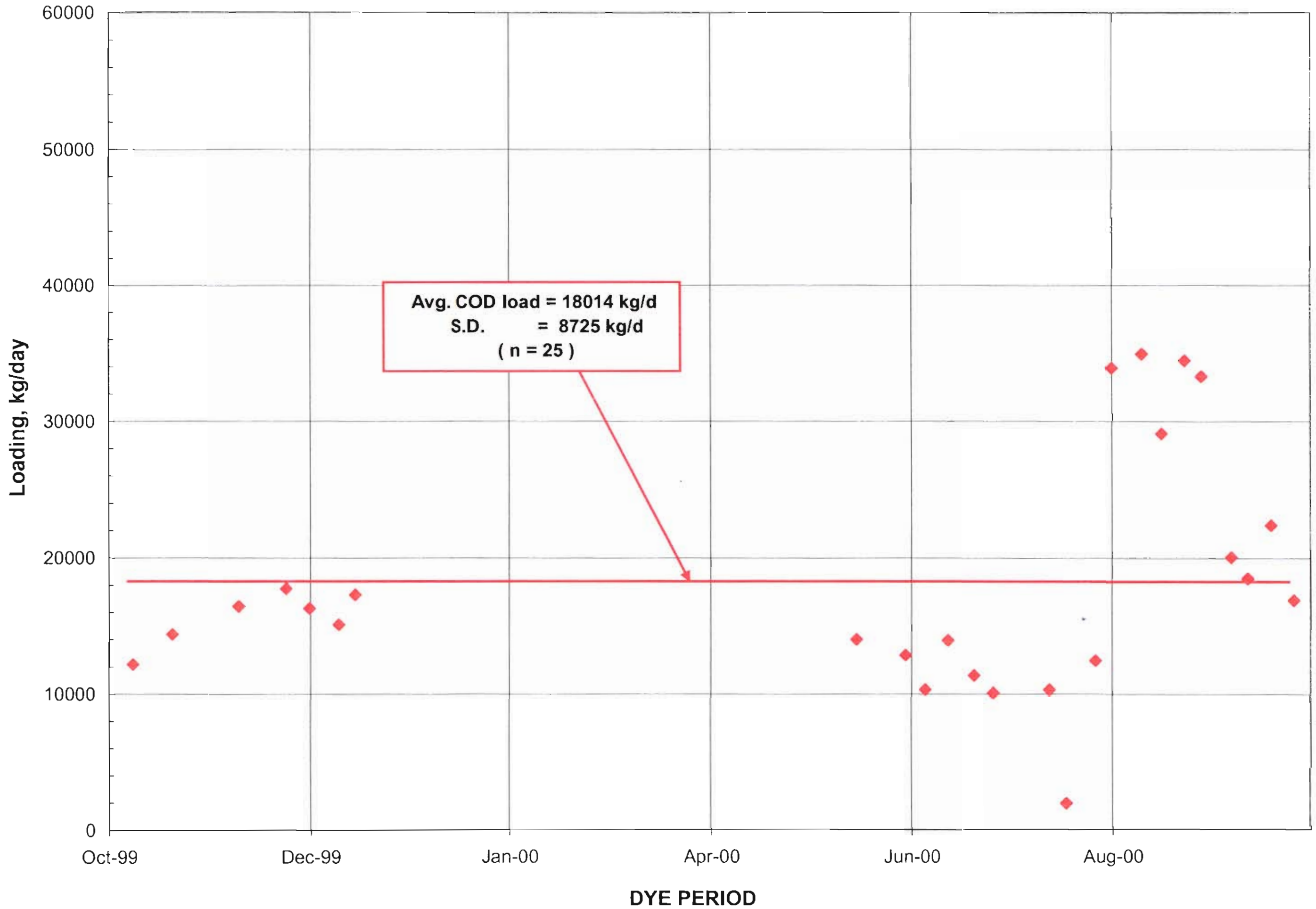


Figure 13. COD LOADING in WASTEWATER DISCHARGE (Qw) for DYE PERIOD
PLANT A - 10/99 ~ 9/00
(Source: COD conc. = 24-hr composite (CWW); &
Flow = Average Daily Flow from Plant A and Total Monthly Discharge Data of CWW)



Plant A: Characteristics of Wastewater Effluent Discharged to CWW System

Parameter	Average (n; std. dev.)*		Min/Max
Phosphorus-total, mg/L as P	2.7	(5; 0.96)	1.7 / 4.0
Total Solids, mg/L	*5,838*	*(32; 1,994)*	*371 / 10,358*
Suspended Solids, mg/L	217	(53; 113)	5 / 305
Cl_2 residual, mg/L	160	(86; 104)	5 / 366
Temperature, ^{0}C	47.5	(108; 6)	29 / 59

* n=number of individual measurements; std. dev. = standard deviation

Plant A wastewater therefore represents a wastewater with (i) very high temperatures, at least 20^{0}C above domestic wastewaters, (ii) high organic strength of moderate degradability, (iii) high dissolved solids levels, (iv) elevated chlorine-residual levels, (v) suspended solids concentrations typical of a domestic wastewater, and (vi) low phosphorus concentrations.

The challenges and opportunities with respect to treatment of this wastewater would have to be focused on the elevated temperatures of the wastewater and the elevated concentrations of organic matter. Ancillary to this information is the fact that the wastewater from Plant A contains an extensive array of dyes that are addressed in a subsequent section.

Plant B

Data Availability. Data provided by Plant B included influent and effluent BOD_5, COD, conductivity, TSS and pH values as well as effluent flow data. CWW data included water consumption and discharge data, as well as BOD_5, TS, TSS, phosphorus, pH and conductivity data for the plant effluent, based on industry-pretreatment surveys.

The periods of availability for the indicated data are summarized in Figure 14. The dye period for plant B was December 1999 to November 2000.

Wastewater flow. The initial wastewater flow data are those provided by CWW regarding the water consumed, i.e., the water provided and metered by CWW to the plant and referred to as Q_c, and the effluent wastewater flow discharged to CWW sewers, and referred to as Q_w. In Figure 15, data for Q_c and Q_w are provided. The Q_c data on the June 1998 –February 1999 period indicate a start-up phase at the plant. As indicated, the water consumption in the subsequent period (February 1999 – December 2000) averaged 0.36 mgd and the wastewater effluent flow averaged 0.27 mgd. In general, wastewater discharges equaled ~75% of the water consumption, with the remained lost as evaporative, product and runoff components.

In Figure 16, data from Plant B are provided for their measurements of effluent wastewater flows, showing minimum, maximum and average values. These Plant B data are presented in Figure 17 and compared to average values from CWW (the CWW values listed as "original points" are those raw data that were edited to be consistent with a recalibration of the metering system). In general, the Plant B and CWW data were highly compatible.

Wastewater Composition. Organic composition of the pretreatment influent and wastewater discharge is included in Figures 18 and 19 for COD and BOD_5. The COD data appeared to indicate a steady decline in concentration in both the influent and

Figure 14. Wastewater Characteristics Data Availability in Plant B
Dye Period - Oct. 99 ~ Sep. 00
(Source: CWW & Plant B)

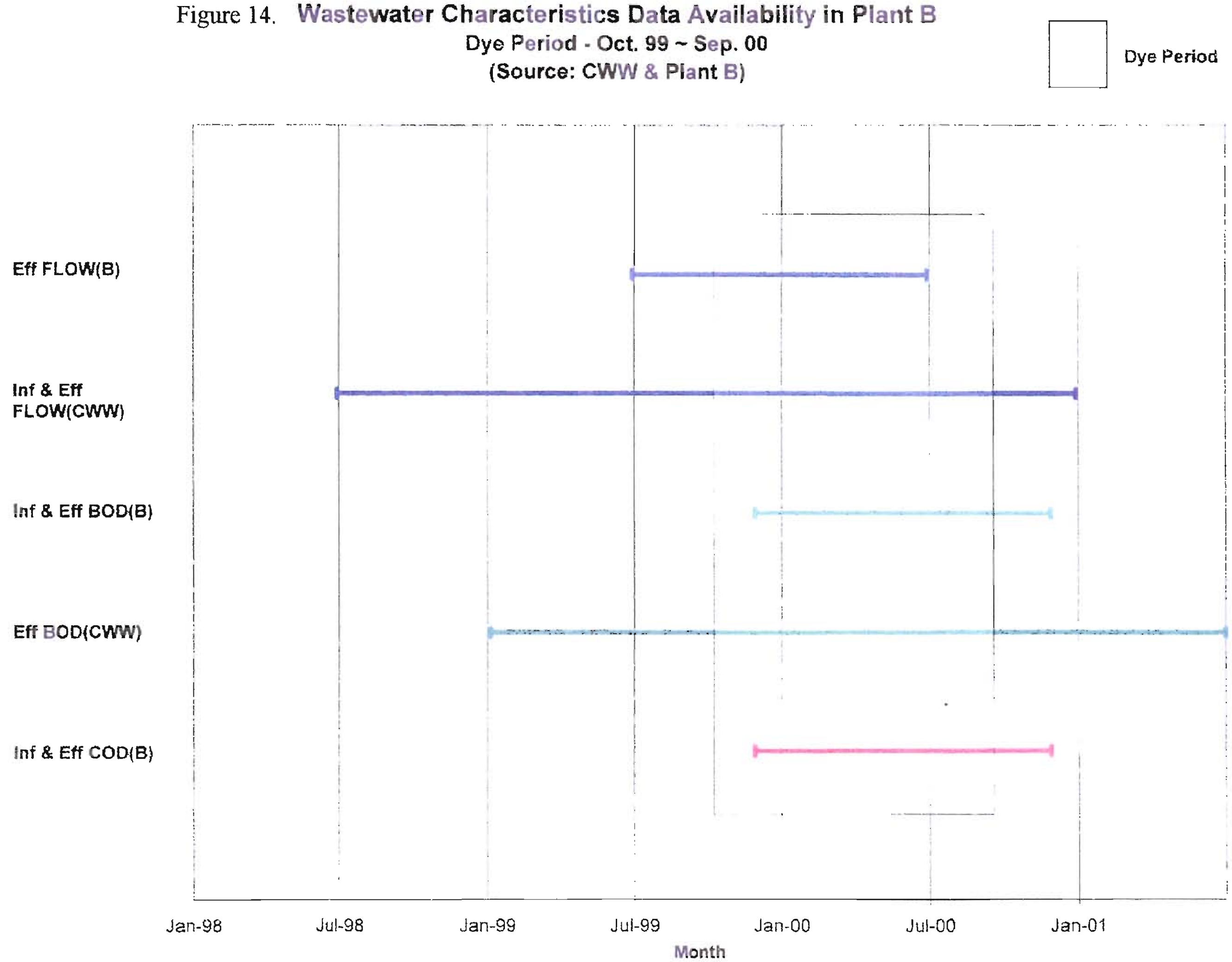


Figure 15. WATER CONSUMPTION & DISCHARGE (Q_C,Q_W)
PLANT B - 6/98 ~ 12/00
(Source: Monthly Flow from CWW)

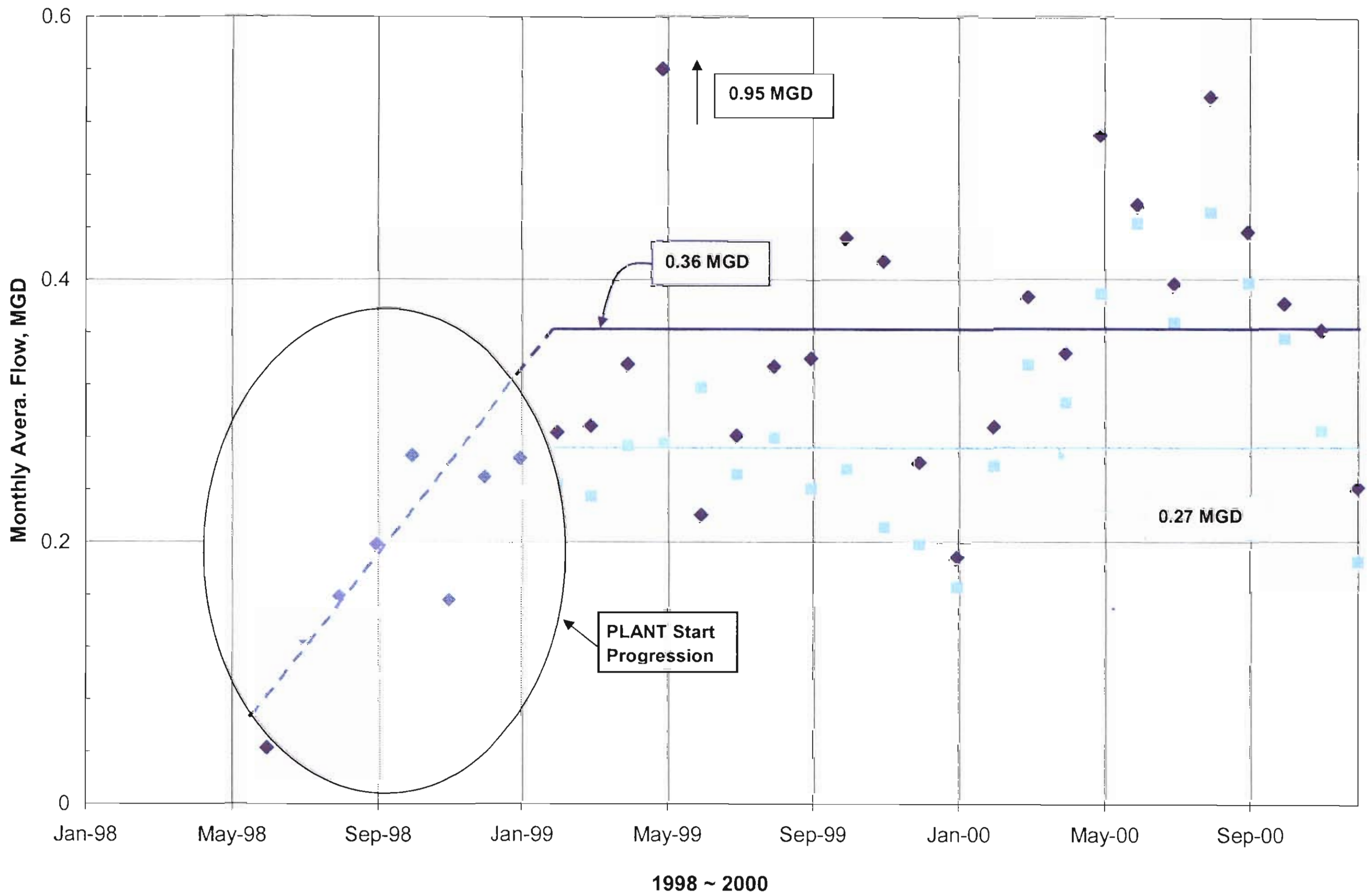


Figure 16. WASTEWATER DISCHARGE (Q_W)
PLANT B - 7/98 ~ 12/00
(Source: Monthly Discharge from CWW)

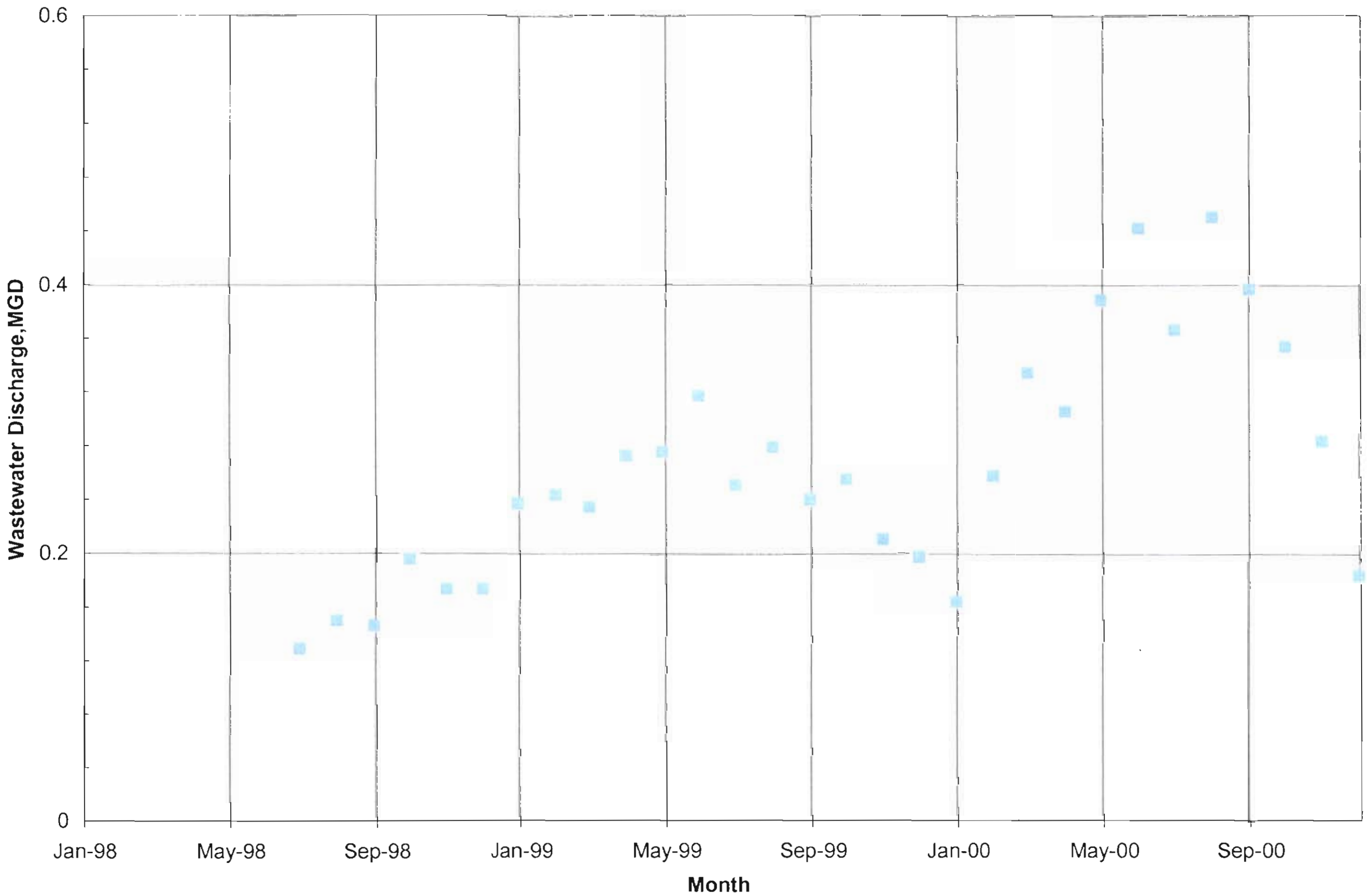


Figure 17. COMPARISON OF WASTEWATER DISCHARGE (Q_W)
PLANT B - 07/99 ~ 06/00
(Source: Monthly Discharge from CWW & Daily Discharge from B)

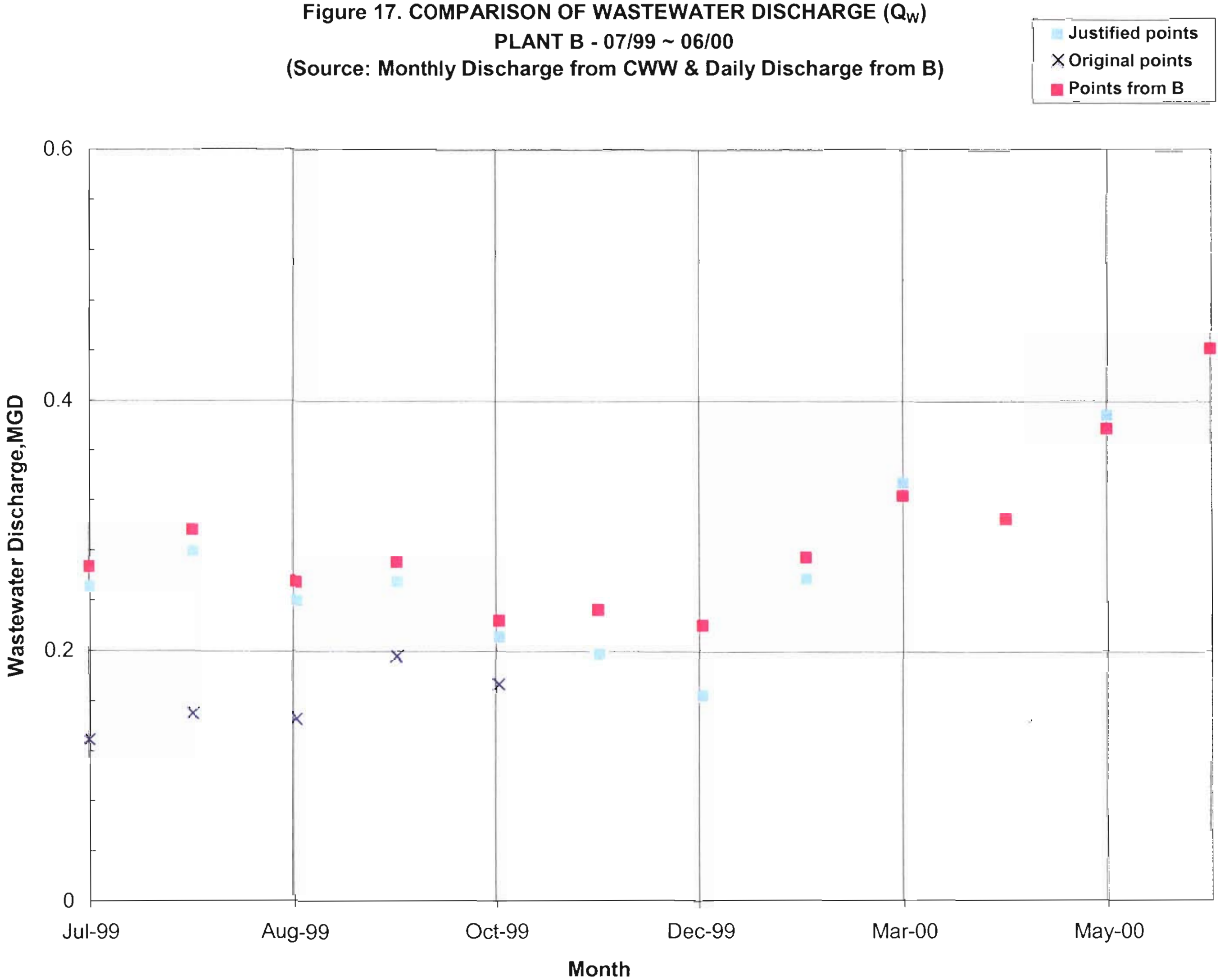


Figure 18. COD in PRETREATMENT INFLUENT & WASTEWATER DISCHARGE (Q_P, Q_W)
PLANT B - 12/99 ~ 11/00
(Source: Random self-monitoring from B)

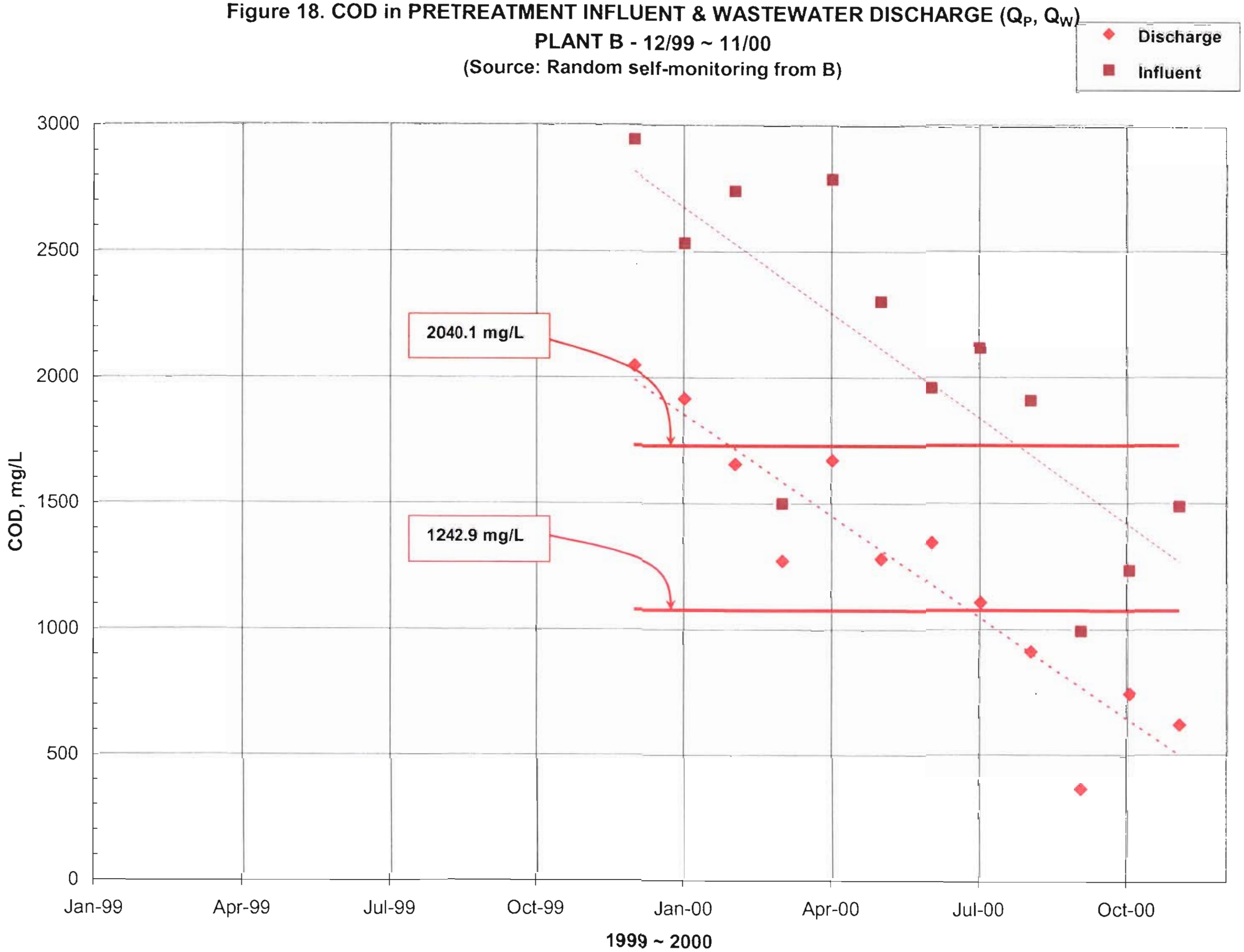
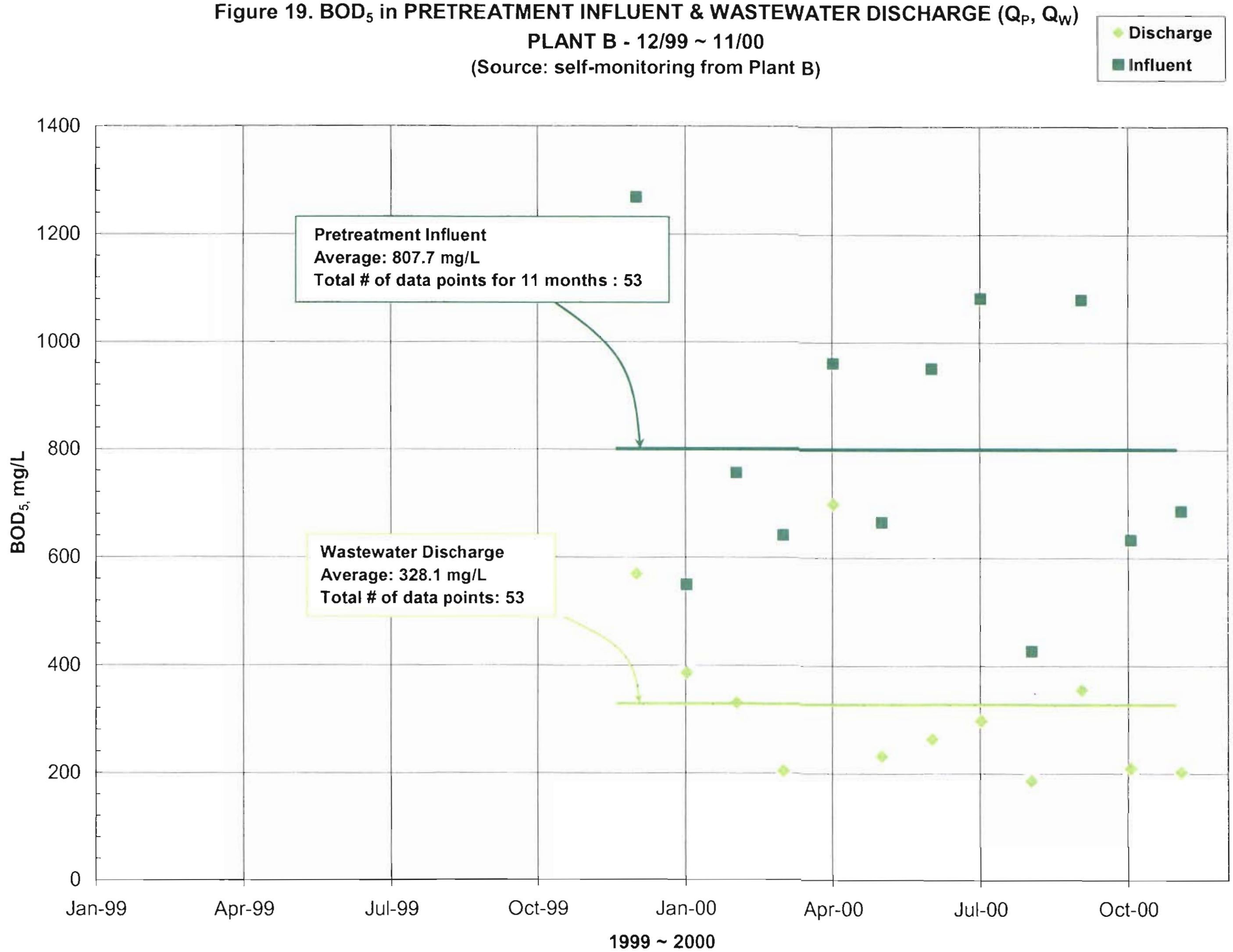


Figure 19. BOD_5 in PRETREATMENT INFLUENT & WASTEWATER DISCHARGE (Q_P, Q_W)
PLANT B - 12/99 ~ 11/00
(Source: self-monitoring from Plant B)



effluent of the pretreatment system. This change was unexplained but could have been attributable to alteration in chemical use (e.g., change to a component that was stripped to the atmosphere in the equalization basin, or an elimination of a non-biodegradable component) or actual treatment efficiency improvement over a 12 month period following start-up. The BOD_5 data in Figure 19 indicated no similar change in concentrations of biodegradable organic matter but did reflect a BOD_5 reduction of approximately 59% across the pretreatment system.

BOD_5 data from CWW are presented in Figure 20, indicating that the BOD_5 concentrations of 24-hr composites averaged 201 mg/L with standard deviation of 97mg/L. These effluent data are compared to Plant B data in Figure 21 for the full period of each data set. While there is general agreement, given the diversity of number of measurements and the periods over which they were collected, the average values were 322 mg/L (Plant B) vs. 201mg/L (CWW) for a ratio of ~1.6.

The organic loadings to the pretreatment and CWW systems are summarized in Figures 22 and 23 using organic concentration data from Plant B and CWW flow data. BOD_5 and COD loadings for the pretreatment system were:

Plant B: Organic Loadings on & Performance of Pretreatment System

BOD_5 loading:	Influent = 996 kg/d	Effluent = 384 kg/d	Eff. = 61%
COD loading:	Influent = 2,429 kg/d	Effluent = 1,442 kg/d	Eff. = 41%

The pretreatment system, which includes mixing, pH neutralization and retention of the flow, is therefore serving to attenuate the organic composition of the plant wastewater effluent.

Figure 20. BOD$_5$ in WASTEWATER DISCHARGE (Q_W)
PLANT B - 1/99 ~ 7/01
(Source: 24-hr composite from random monitoring by CWW)

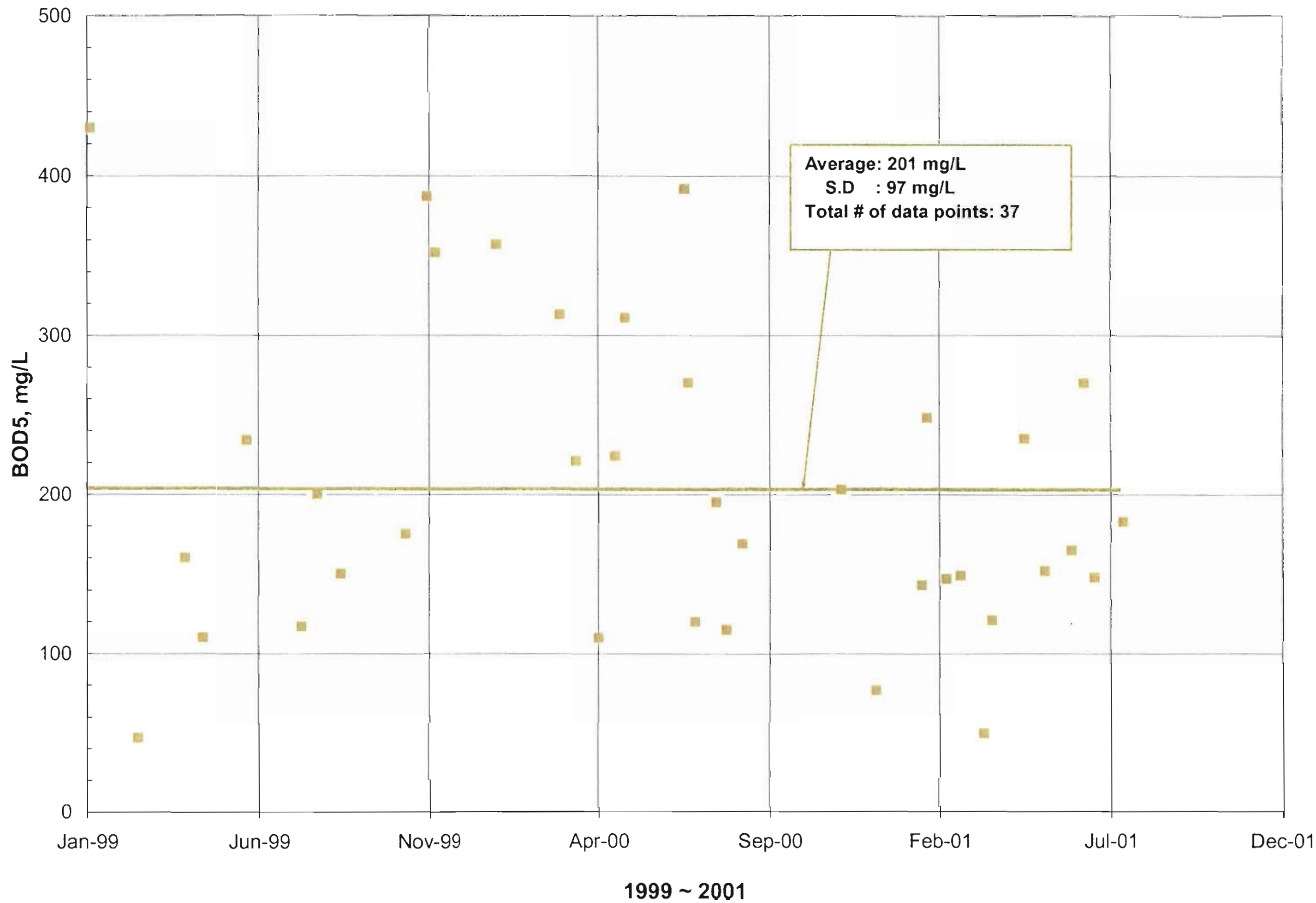


Figure 21. BOD_5 in WASTEWATER DISCHARGE (Q_W)
PLANT B - 1/99 ~ 7/01
(Source: 24-hr composite random monitoring by CWW &
Self monitoring by Plant B)

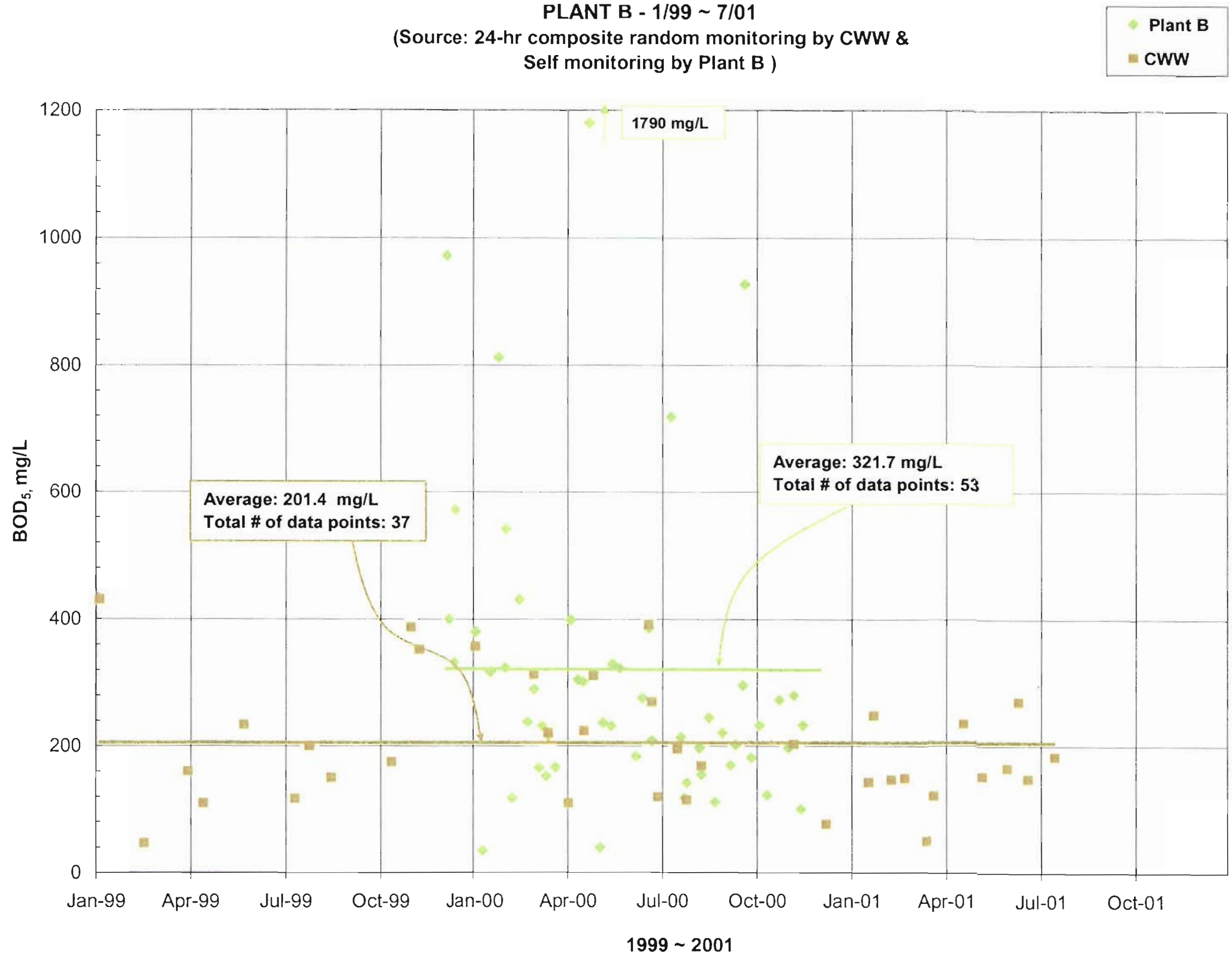


Figure 22. BOD$_5$ LOADING in PRETREATMENT INFLUENT & DISCHARGE WASTEWATER (Q_P, Q_W): PLANT B - 12/99 ~ 11/00
(Source: BOD$_5$ Self-monitoring from B and monthly average flow from CWW)

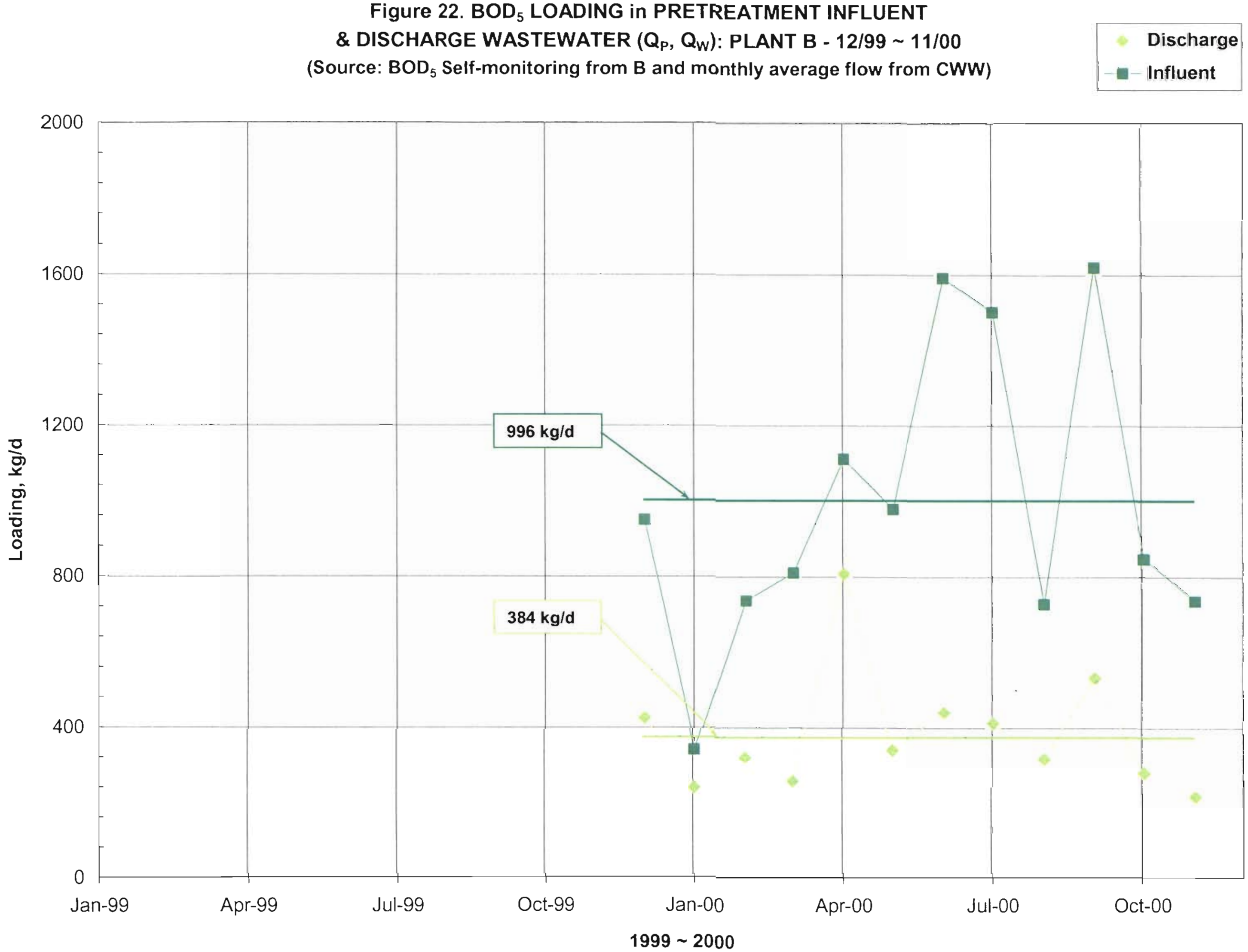
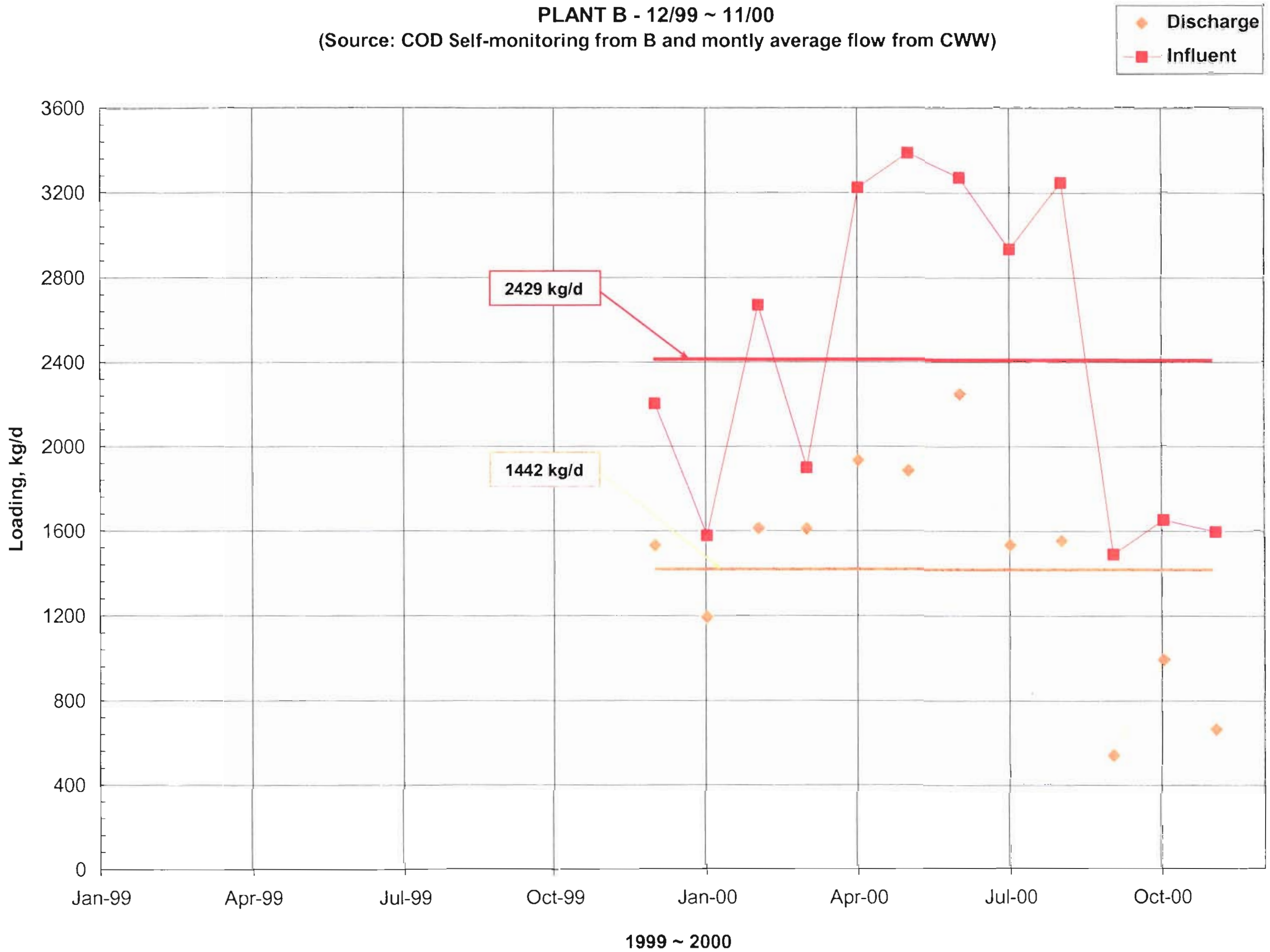


Figure 23. COD LOADING in PRETREATMENT INFLUENT & DISCHARGE WASTEWATER (Q_P, Q_W)
PLANT B - 12/99 ~ 11/00
(Source: COD Self-monitoring from B and montly average flow from CWW)



The assessments of BOD_5 and COD ratios are presented in Figures 24 and 25. The influent wastewater has a COD/BOD_5 ratio of 2.73 indicating that BOD_5 is ~37% of COD. In the pretreatment effluent, this ratio is 4.04, indicating that BOD_5 was 25% of effluent COD. It is therefore clear that the removal processes are directed at those compounds that are more biodegradable, leaving more bio-resistant organic matter in the effluent and being discharged to the CWW system.

BOD_5 and COD reductions across the pretreatment system are included in Figure 26. A COD reduction of 40.6% and a BOD_5 reduction of 58.9% are excellent for an equalization basin system, especially since there is no nutrient addition or focus on enhancing any biological activity. Since sulfite and other reducing agents are routinely used in the textile processes and discharged to the equalization basin, these removals could reflect on the simple oxidation of reducing agents with molecular oxygen and not biodegradation.

Wastewater constituents of the pretreatment effluent that is discharged to the CWW sewers were assessed over the period of December 1999 to November 2000. These data are summarized below. From the data it appears that the plant is a significant contributor of phosphorus (relative to concentrations typically found in domestic wastewaters) and that suspended solids appear to increase within pretreatment, although statistically it could be indicated the values are not dissimilar. However, coupled with the considerable reduction in BOD_5 routinely achieved (e.g., 796 mg/L to 295 mg/L), the increase in TSS

Figure 24. COD/BOD_5 RATIO in PRETREATMENT INFLUENT (Q_P)
PLANT B - 12/99 ~ 11/00
(Source: Self-monitoring from B)

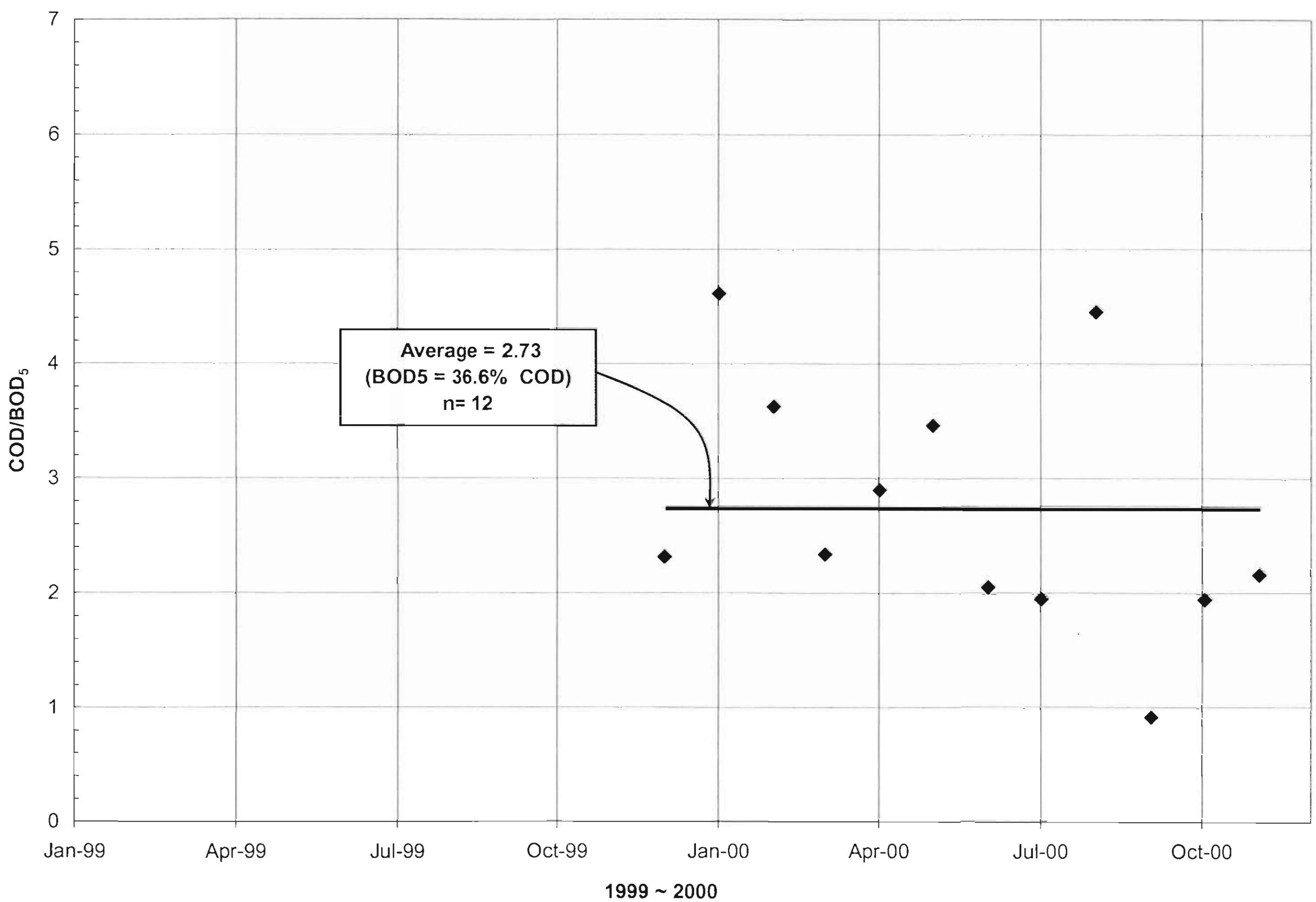


Figure 25. COD/BOD_5 RATIO in WASTEWATER DISCHARGE (Q_W)
PLANT B - 12/99 ~ 11/00
(Source: self-monitoring from B)

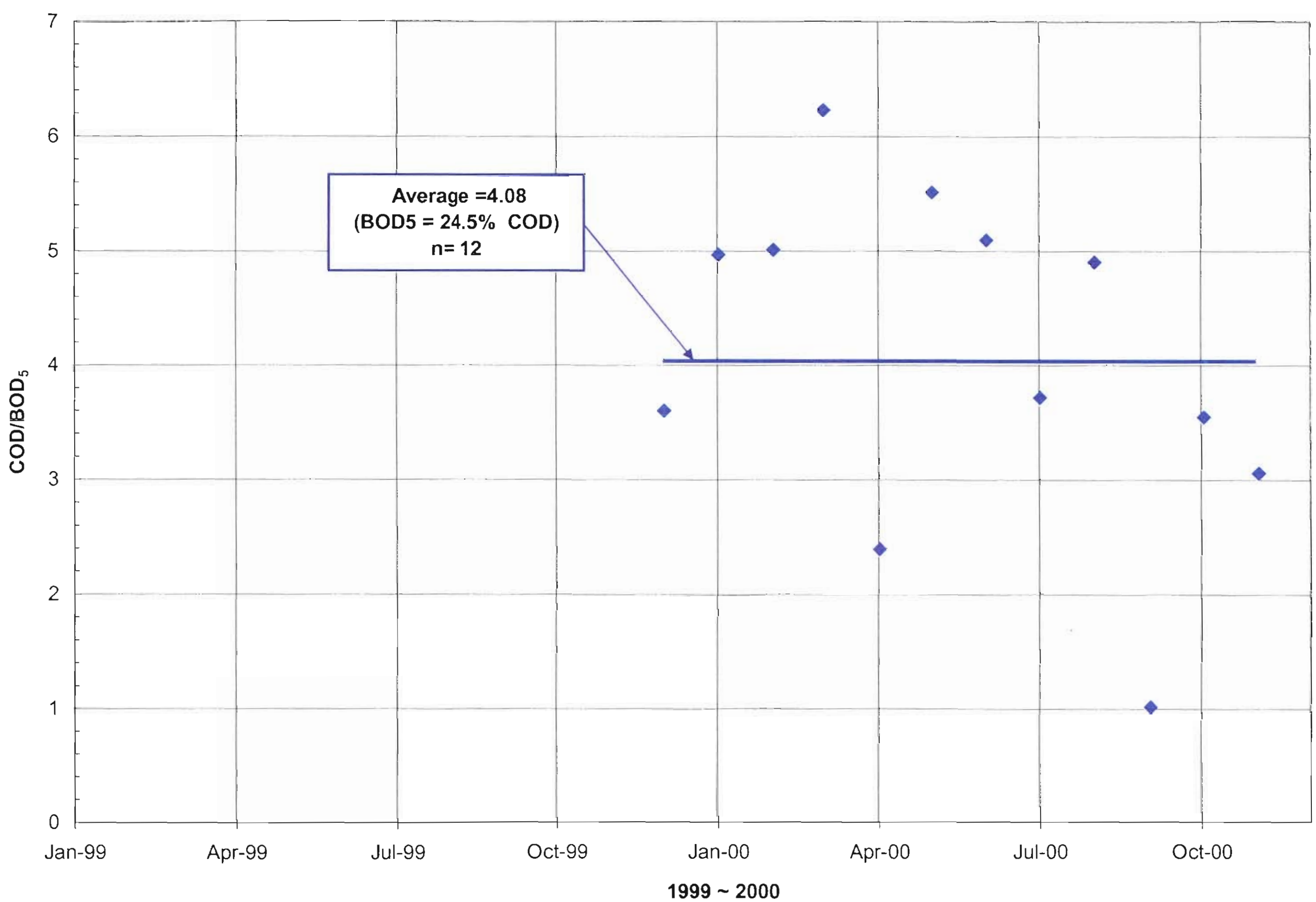
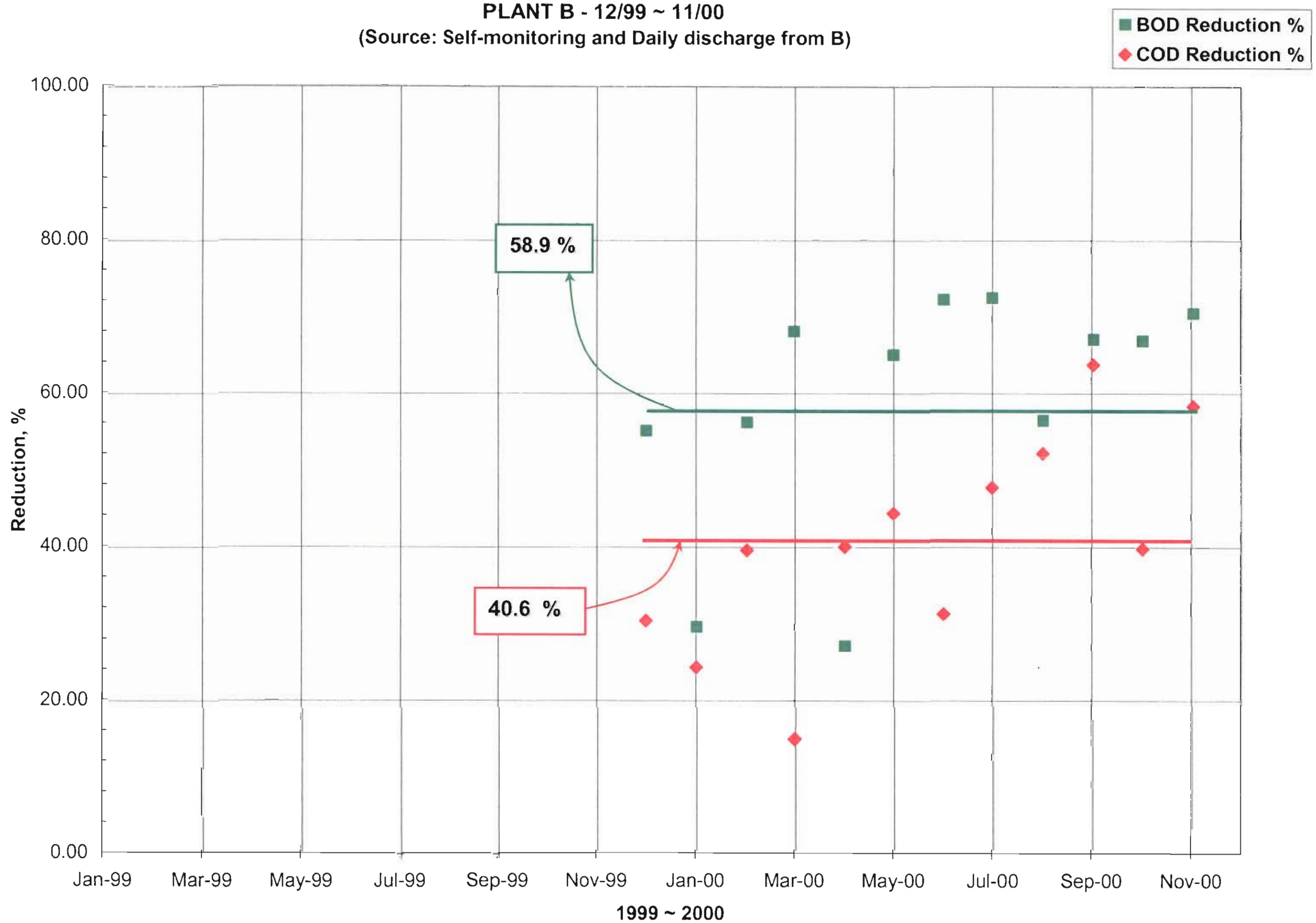


Figure 26. BOD_5 & COD REDUCTION IN PRETREATMENT SYSTEM
PLANT B - 12/99 ~ 11/00
(Source: Self-monitoring and Daily discharge from B)



Plant B: Characteristics of Wastewater Effluent Discharged to CWW System

Parameter	Average (n; std. dev.)*			
	Pretreatment Influent		**Pretreatment Effluent**	
Flow, gpd	na	na	290,000 (344, na)	
BOD_5, mg/L	796	(53; 536)	295	(53; 304)
COD, mg/L	1,782	(53; 965)	947	(53; 558)
Phosphorus-total, mg/L as P	16	(29; 6.5)	16	(28; 5.2)
Suspended Solids, mg/L	217	(53; 113)	406	(53; 186)
Conductivity (us/Cm)	3,752	(53; 1,316)	3,492	(53; 976)

* n=number of individual measurements; std. dev. = standard deviation

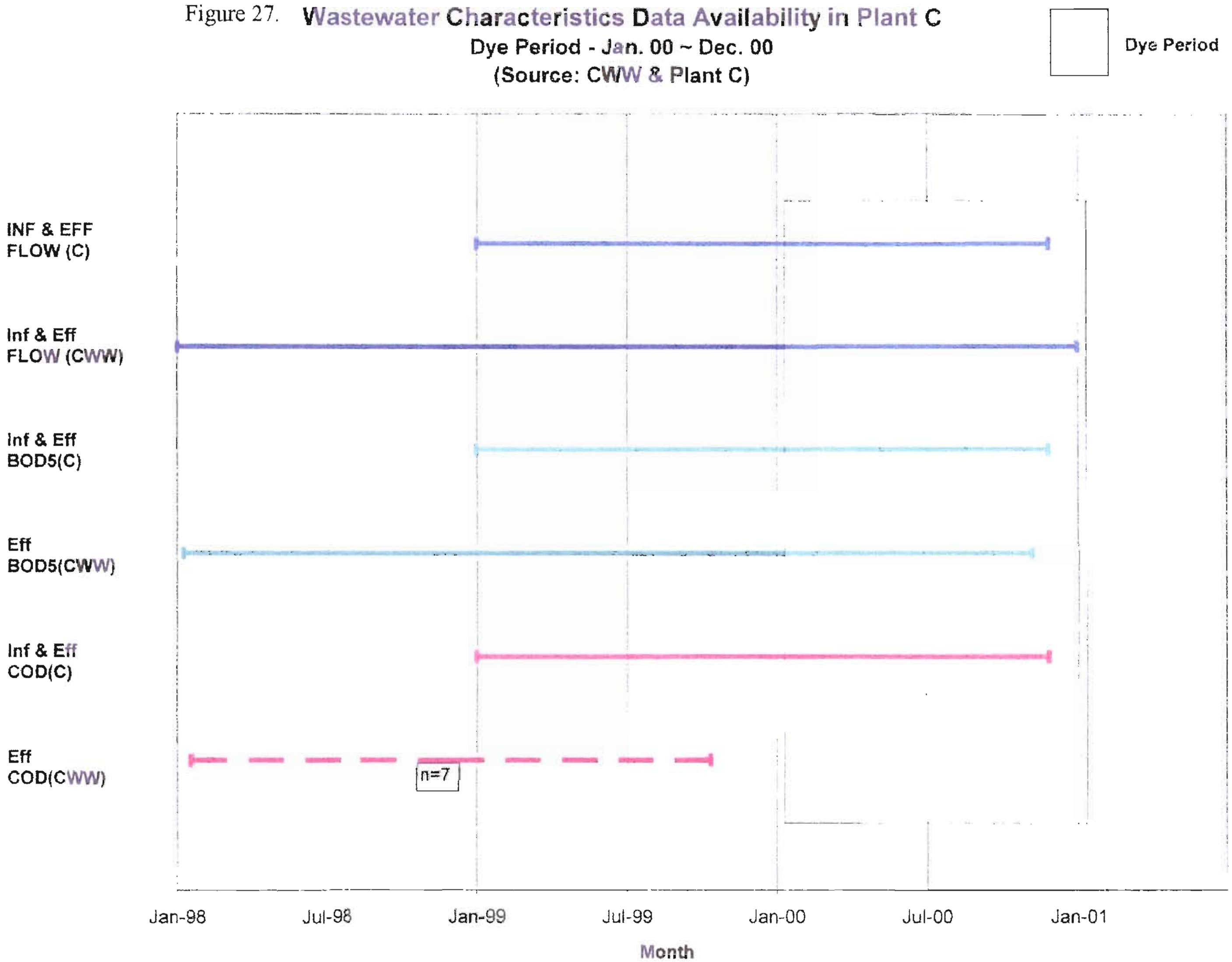
could reflect an increase in biomass within the no-recycle equalization basin. This is however not reflected in the phosphorus data, i.e., there is no significant change in P-concentration.

Plant C

Data Availability. Plant C has an extensive pretreatment system, including pH adjustment and biological treatment. The data provided by the plant included pretreatment influent and effluent data for flow, BOD_5, COD, TS, TSS, VSS, nitrogen, phosphorus and pH. CWW data included water consumption and discharge data and BOD_5, COD, TS, TSS, phosphorus, pH and conductivity data for the plant effluent, based on industry-pretreatment surveys.

The periods of availability for the indicated data are summarized in Figure 27. The data period for plant C was 1998 through 2000. The dye period for the plant was the year 2000. The data from plant C for wastewaters covered a 2-year period while the CWW data covered a 3-year period in most sets.

Figure 27.



Wastewater Characteristics Data Availability in Plant C
Dye Period - Jan. 00 ~ Dec. 00
(Source: CWW & Plant C)
Dye Period
INF & EFF FLOW (C)
Inf & Eff FLOW (CWW)
Inf & Eff BOD5(C)
Eff BOD5(CWW)
Inf & Eff COD(C)
Eff COD(CWW)
n=7
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Month

Wastewater flow. There were extensive data from Plant C and CWW for the pretreatment influent and effluent wastewaters covering multiple years. Using monthly average flow from CWW in Figure 28, the average water consumption (Q_c) for Plant C was 0.82 mgd, i.e., this represents the water used by the plant in all areas, including potable, process and sanitary uses. The average wastewater flow (Q_w) received by CWW was 0.46 mgd over the 3-year period, indicating that approximately 56.8% of water consumption was discharged as wastewater to CWW and that 43.2% was lost through evaporation, incorporation into products and other water uses. This pattern is presented for annual periods in Figure 29 and 30, wherein the annual wastewater discharge represented from 40.3 to 64.3 % of water consumption. The pattern of wastewater discharge is represented in Figure 30, indicating with the same data from the earlier figure that wastewater flow is partially seasonal (i.e., flow for two years was higher in the fall months).

Regarding the pretreatment system, the influent flow to this system is presented in Figures 31 and 32 with Plant C data, on an individual-day and monthly-average basis. Variations in influent flow again appear to follow a pattern of higher discharge in summer-fall months than other periods, at least for 1999 and 2000. Pretreatment effluent flow data are included in Figures 33 and 34 on a daily- and monthly-average basis. These influent and effluent flows are compared using the monthly-average values in Figure 35. From an assessment of the data from the pretreatment system, it appeared that the influent flow for much of 2000 (i.e., March through August) was significantly above the

Figure 28. WATER CONSUMPTION & DISCHARGE (Q_C,Q_W)
PLANT C - 1/98 ~ 12/00
(Source: Monthly Flow from CWW)

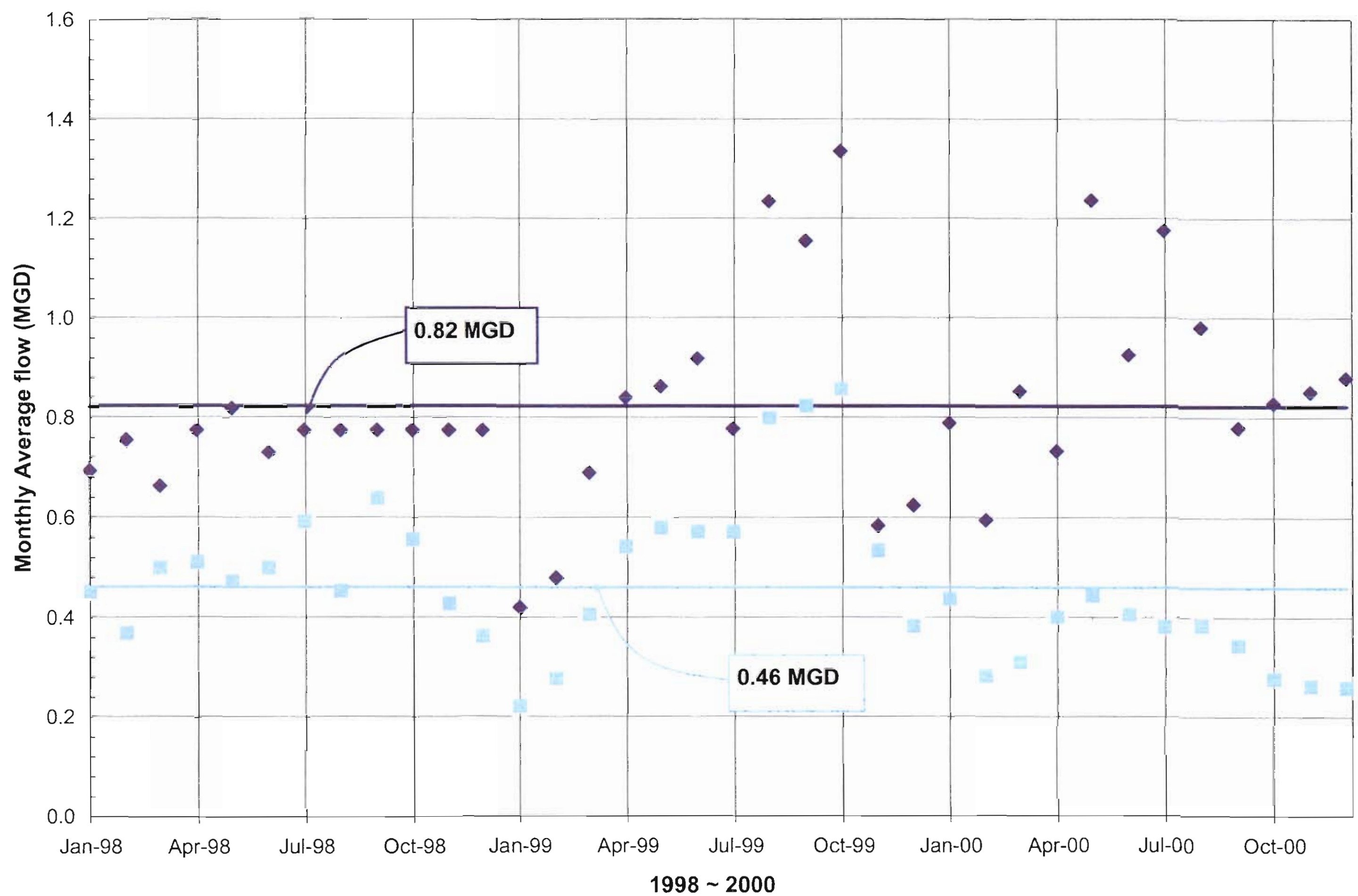


Figure 29. PERCENTAGE of DISCHARGE vs CONSUMPTION (%)
PLANT C - 1/98 ~ 12/00
(Source: Monthly Consumption & Discharge from CWW)

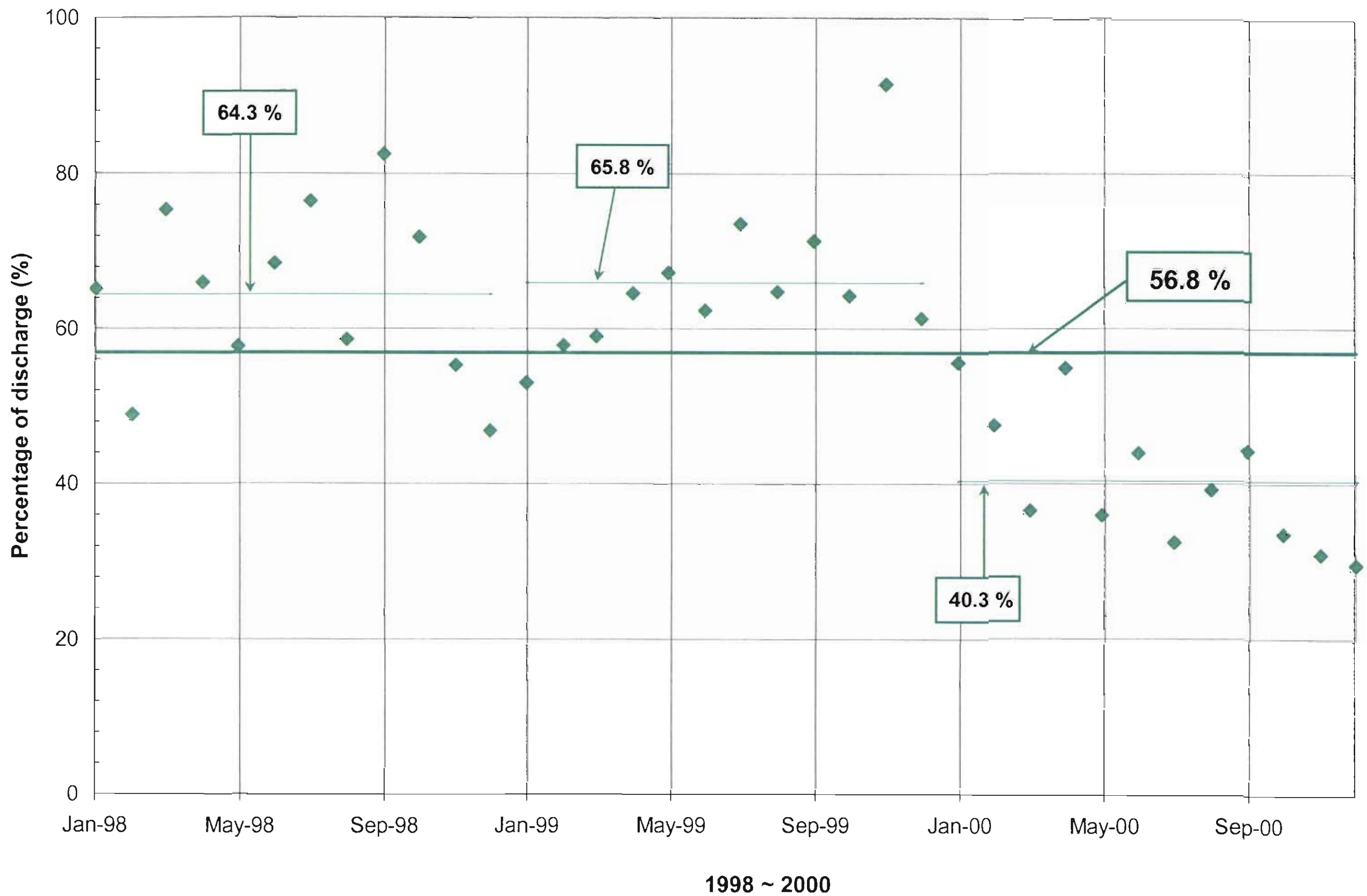


Figure 30. WASTEWATER DISCHARGE PATTERN (Q_W)
PLANT C - 1/98 ~ 12/00
(Source: Monthly Discharge from CWW)

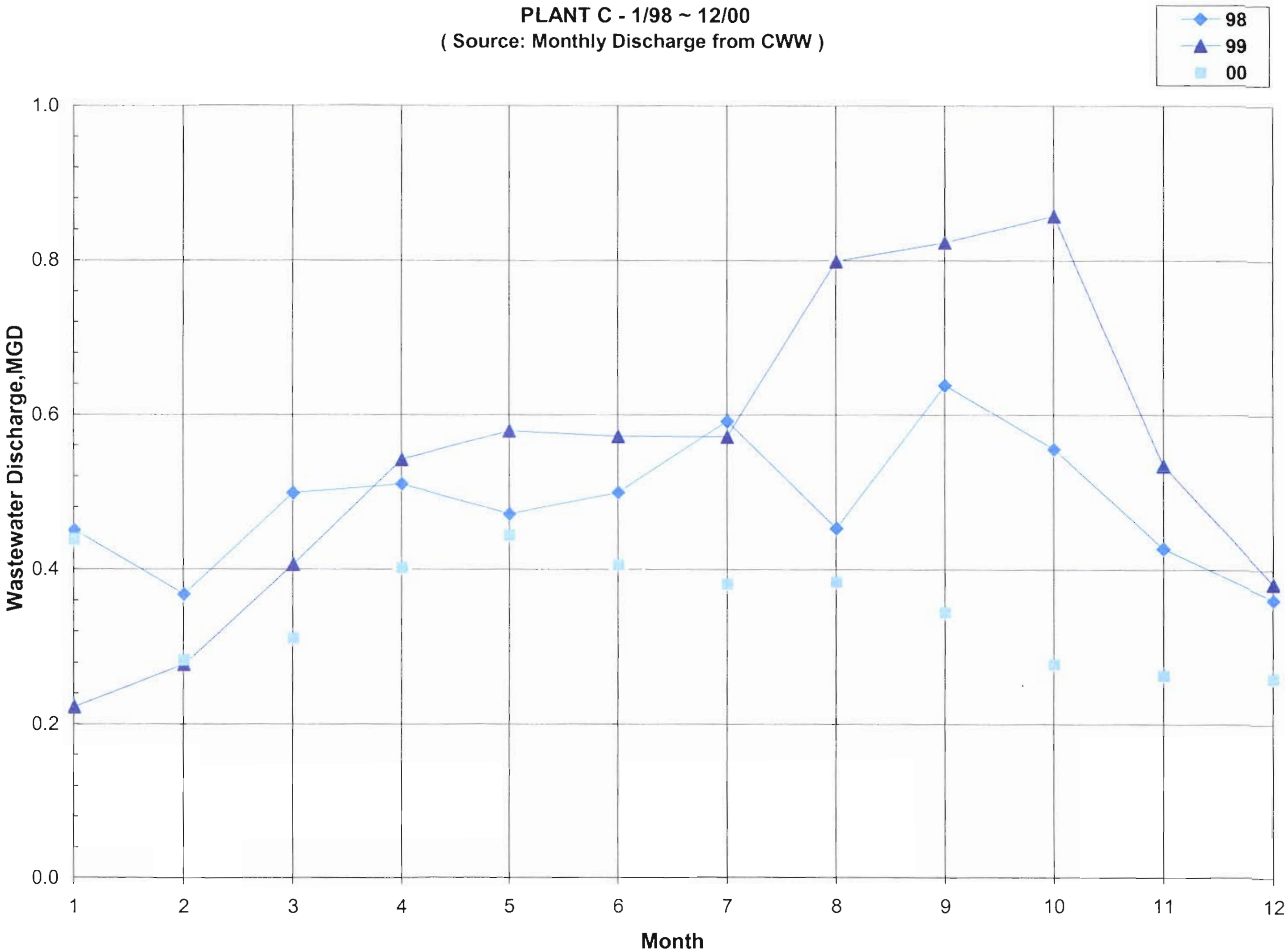


Figure 31. PRETREATMENT INFLUENT (Q_P) DATA with Monthly Average Flow
PLANT C - 1/99 ~ 11/00
(Source: Daily Pretreatment Influent from C.)

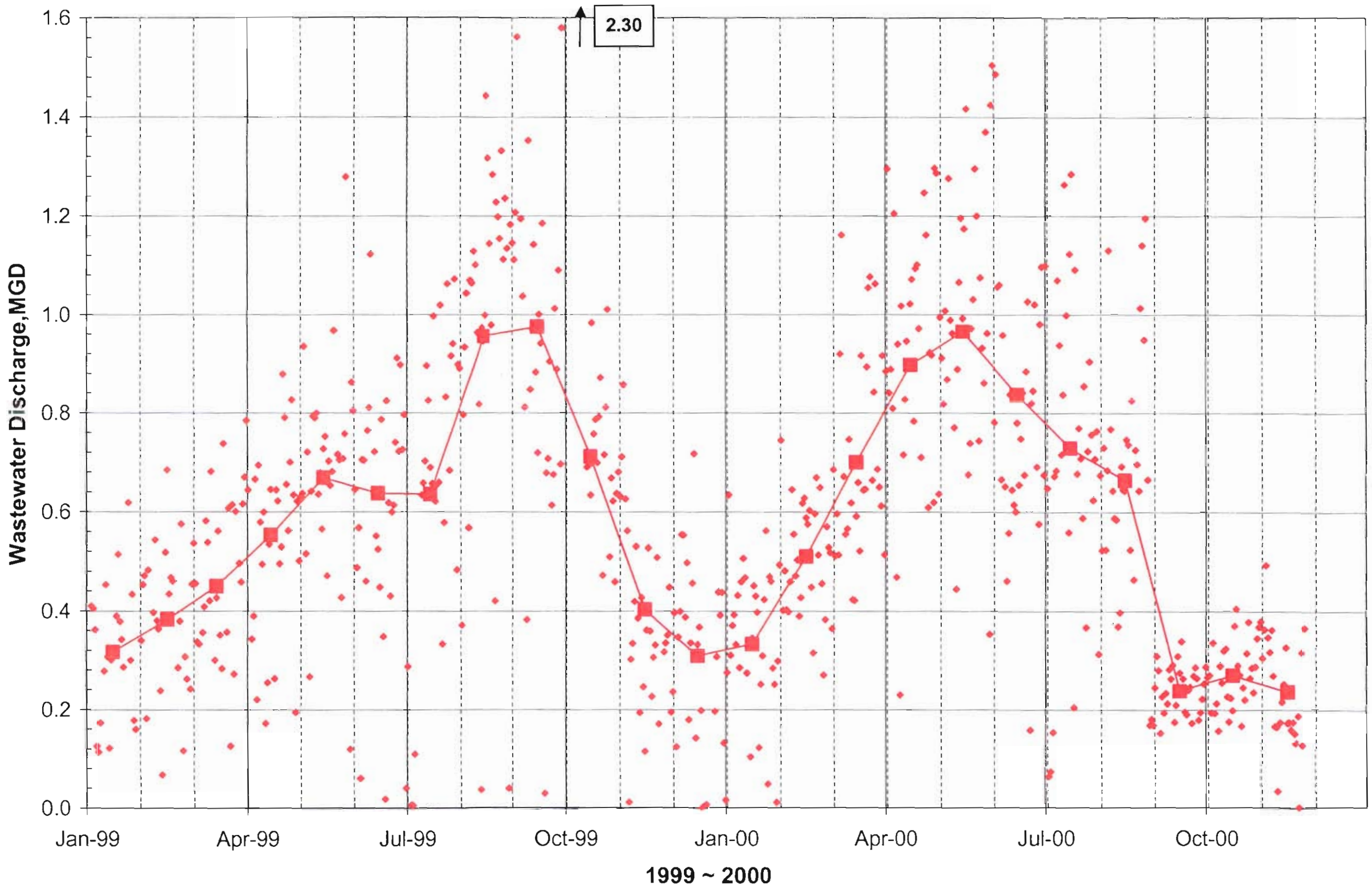


Figure 32. PRETREATMENT INFLUENT (Qp) with s.d.
PLANT C - 1/99 ~ 11/00
(Source: Daily Self-Monitoring from C)

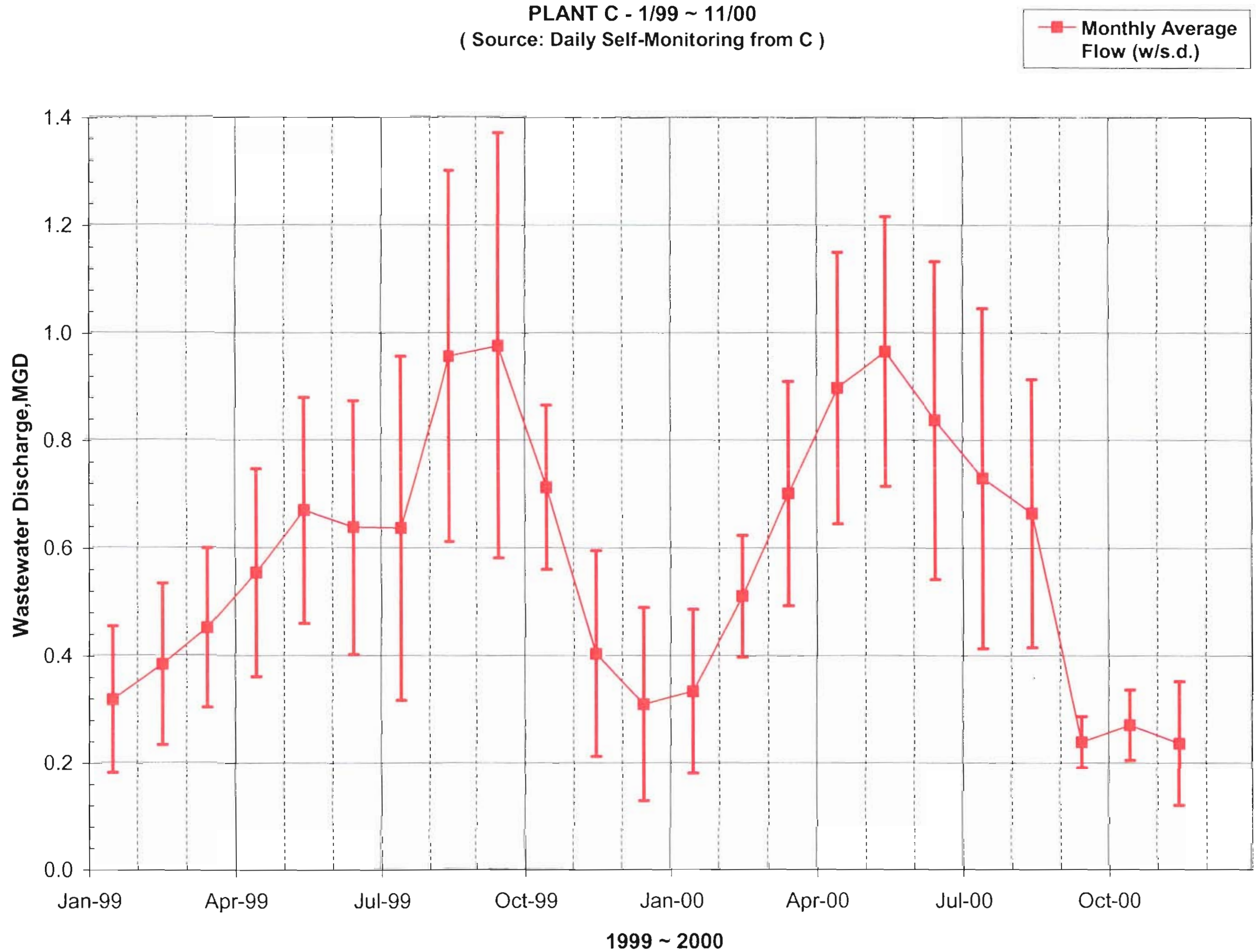


Figure 33. WASTEWATER DISCHARGE (Q_W) DATA with Monthly Average Flow
PLANT C - 07/99 ~ 06/00
(Source: Daily Discharge from C.)

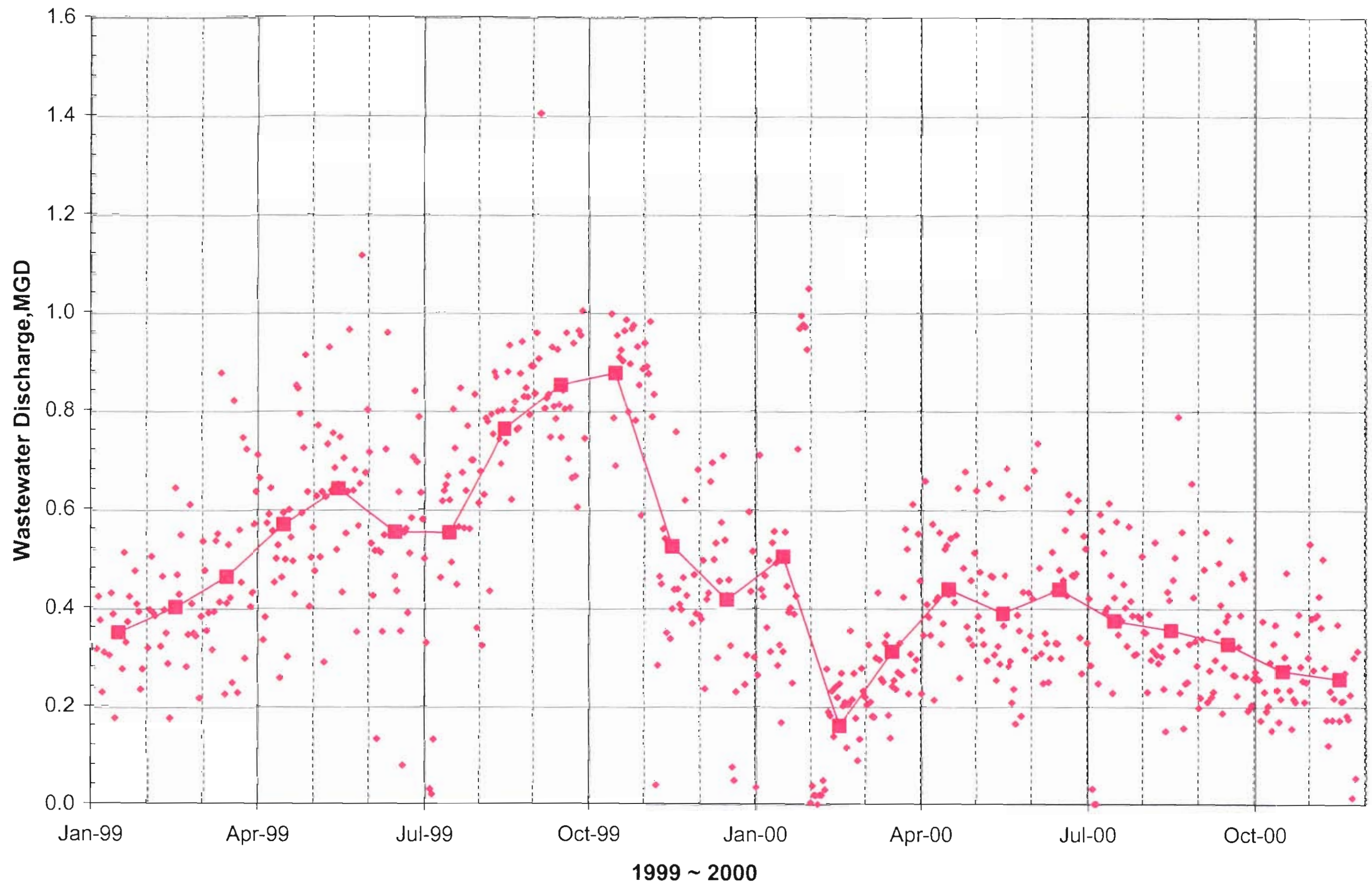
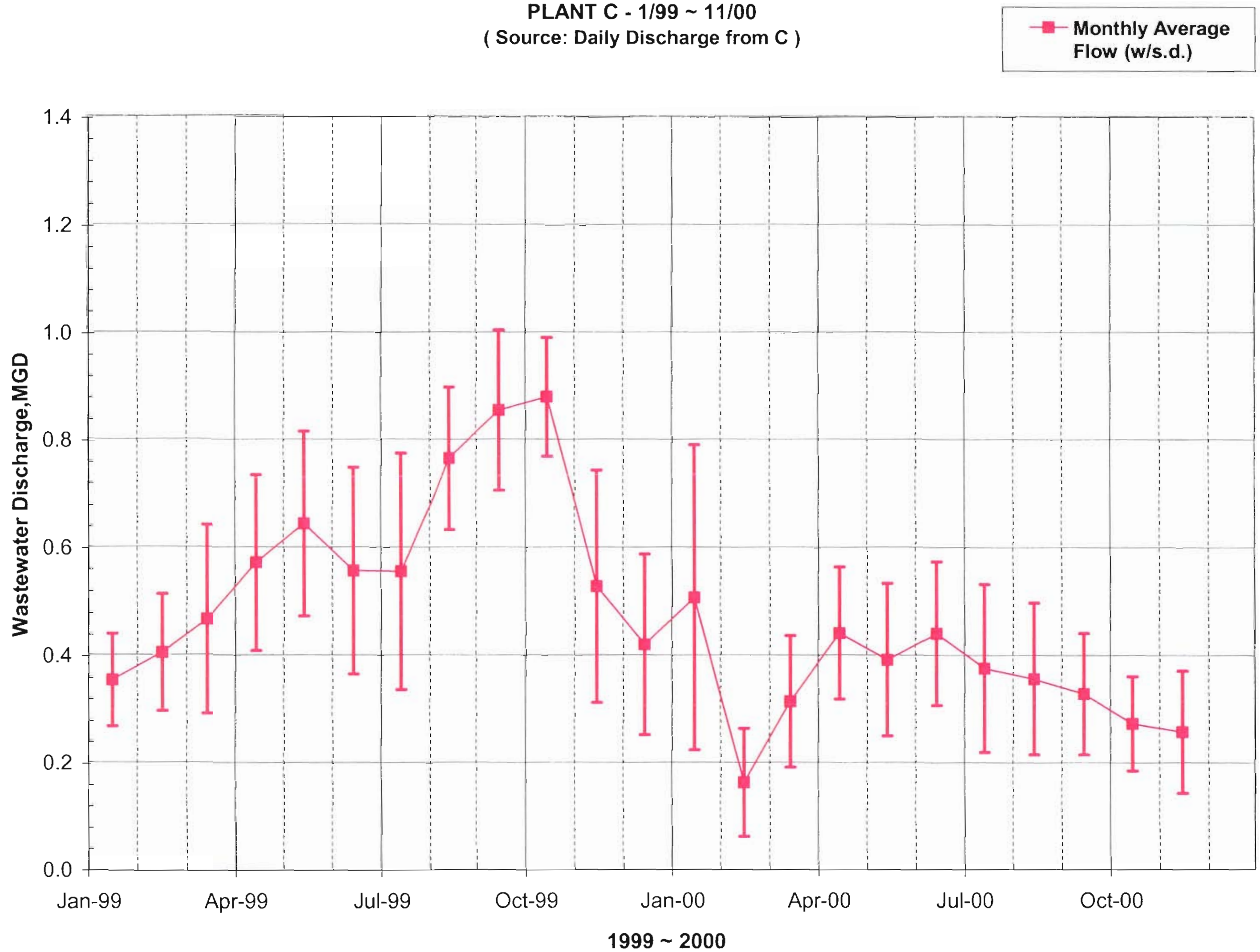


Figure 34. WASTEWATER DISCHARGE (Q_W) with s.d.
PLANT C - 1/99 ~ 11/00
(Source: Daily Discharge from C)



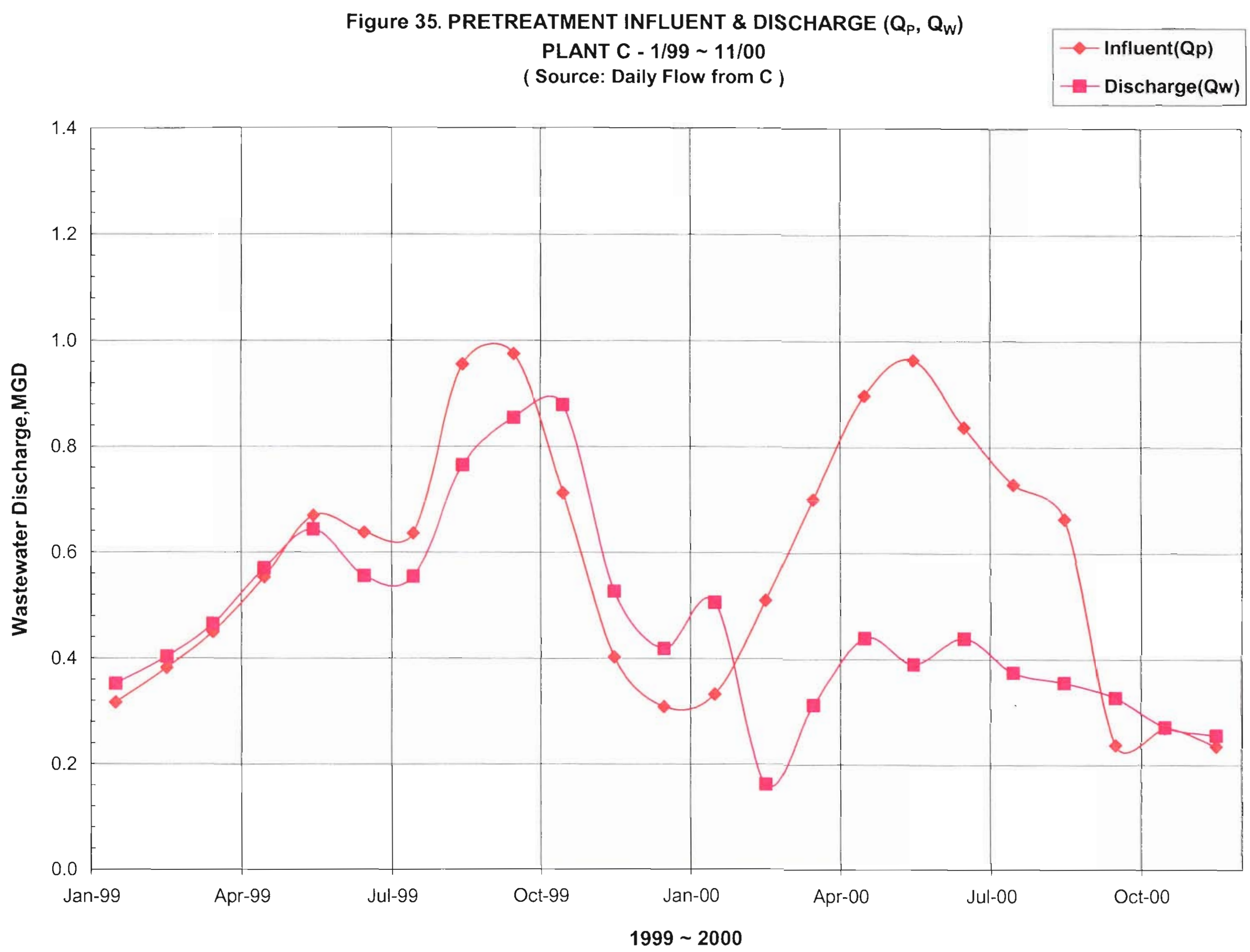


Figure 35. PRETREATMENT INFLUENT & DISCHARGE (Q_P, Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily Flow from C)
Influent(Qp)
Discharge(Qw)
Wastewater Discharge,MGD
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jan-99
Apr-99
Jul-99
Oct-99
Jan-00
Apr-00
Jul-00
Oct-00
1999 ~ 2000

effluent. Subsequent analysis herein will indicate this was probably a flow-measurement error.

Annual wastewater discharges to the CWW system using both CWW and Plant C data are presented in Figures 36 and 37. The flow data for 1999 indicate average daily discharges of 0.582mgd and 0.547mgd, for Plant-C and CWW data, respectively. The daily flow for 2000 was 0.349 mgd for both data sources. The daily flows are used in establishing the organic loading for organic parameters.

Wastewater Composition. The performance of the pretreatment systems relative to BOD_5 and COD is critical to understanding the impacts of dye-plant wastewaters on CWW systems. This facility at Plant C is an aerated lagoon with extended aeration times and recycle of biosolids to facilitate enhanced biological decomposition of this industrial wastewater.

BOD_5 concentrations in the pretreatment influent flow are presented in Figures 38 and 39 for 1999-2000. The data indicate the expected variations in daily concentrations (Figure 38) and represent an average value of 1095 mg/L (std. dev. = 385mg/L) and peak value of a 5,132mg/L. On a monthly basis the average BOD_5 concentrations indicate a consistent pattern with time. The effluent BOD_5 data are presented in Figures 40-41, indicating an average effluent-flow concentration of 62mg/L (std. dev. = 46mg/L). These collective data are represented in Figure 42 to indicate the extensive organic removal achieved and the equally exceptional attenuation of the concentration of BOD_5 finally discharged to the

Figure 36. ANNUAL PRETREATMENT INFLUENT (Q_p)
PLANT C - 1/99 ~ 11/00
(Source: Daily Pretreatment Influent from C)

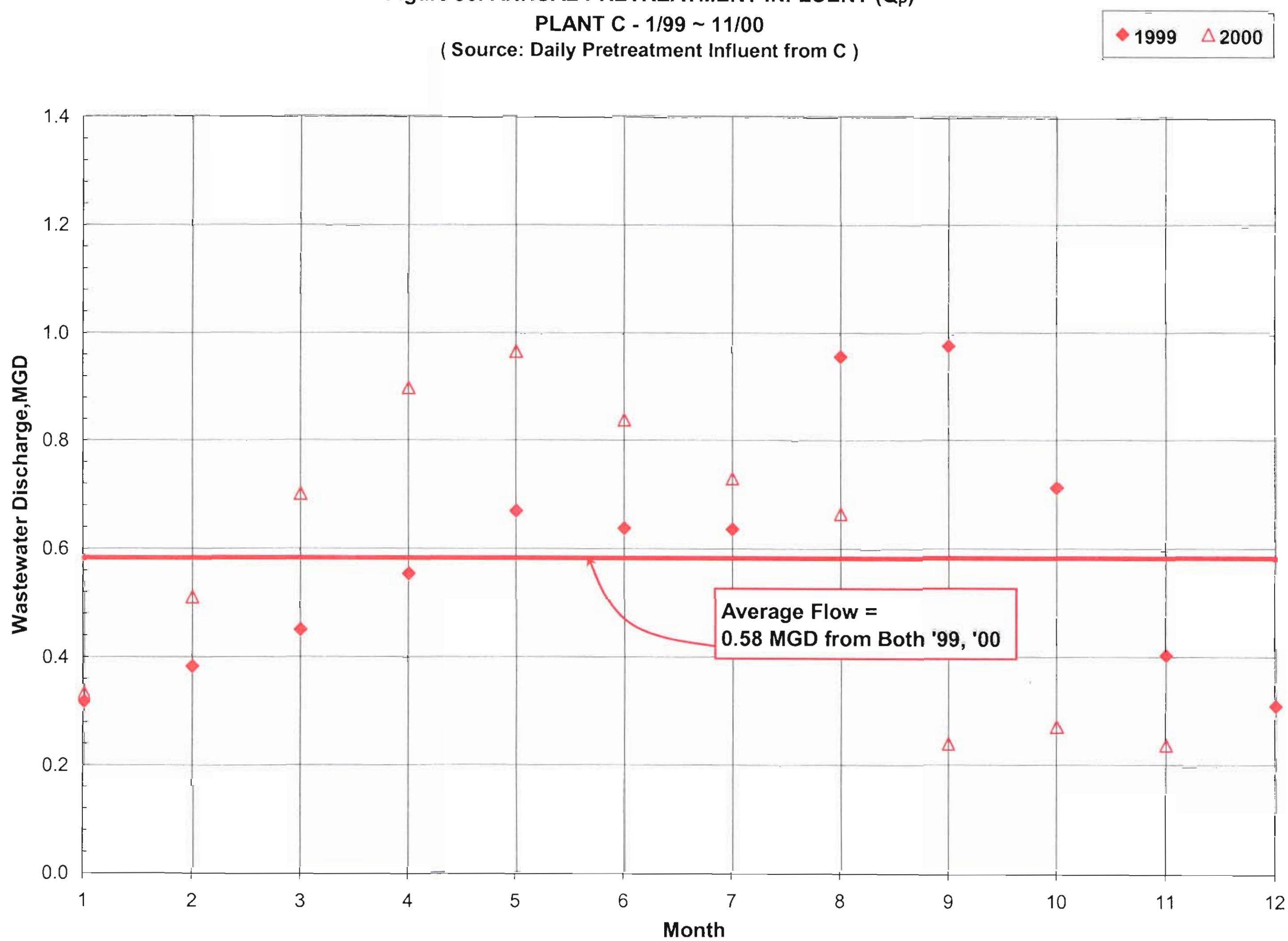


Figure 37. ANNUAL WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily Discharge from C)

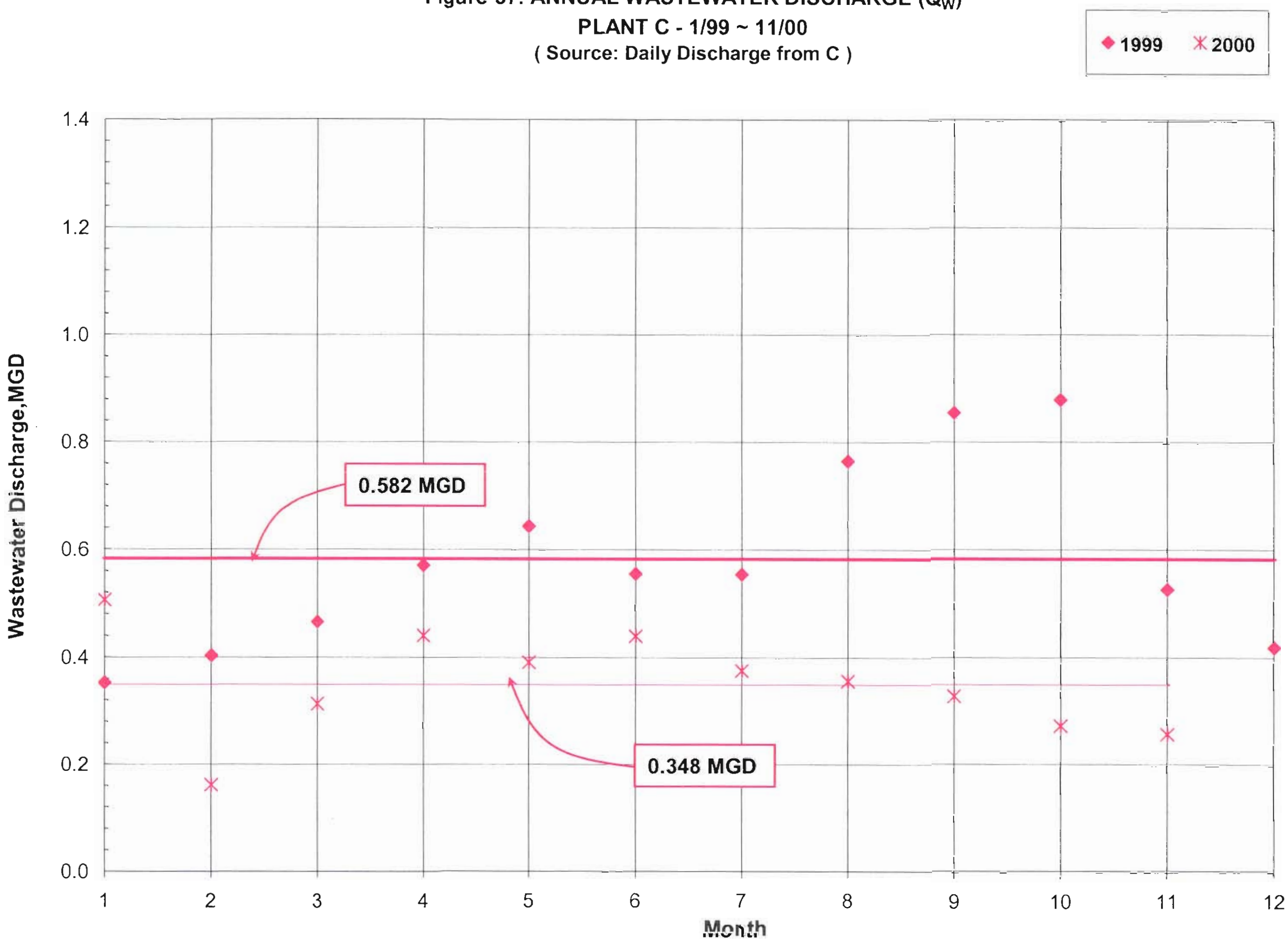


Figure 38. BOD_5 in PRETREATMENT INFLUENT (Q_P)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

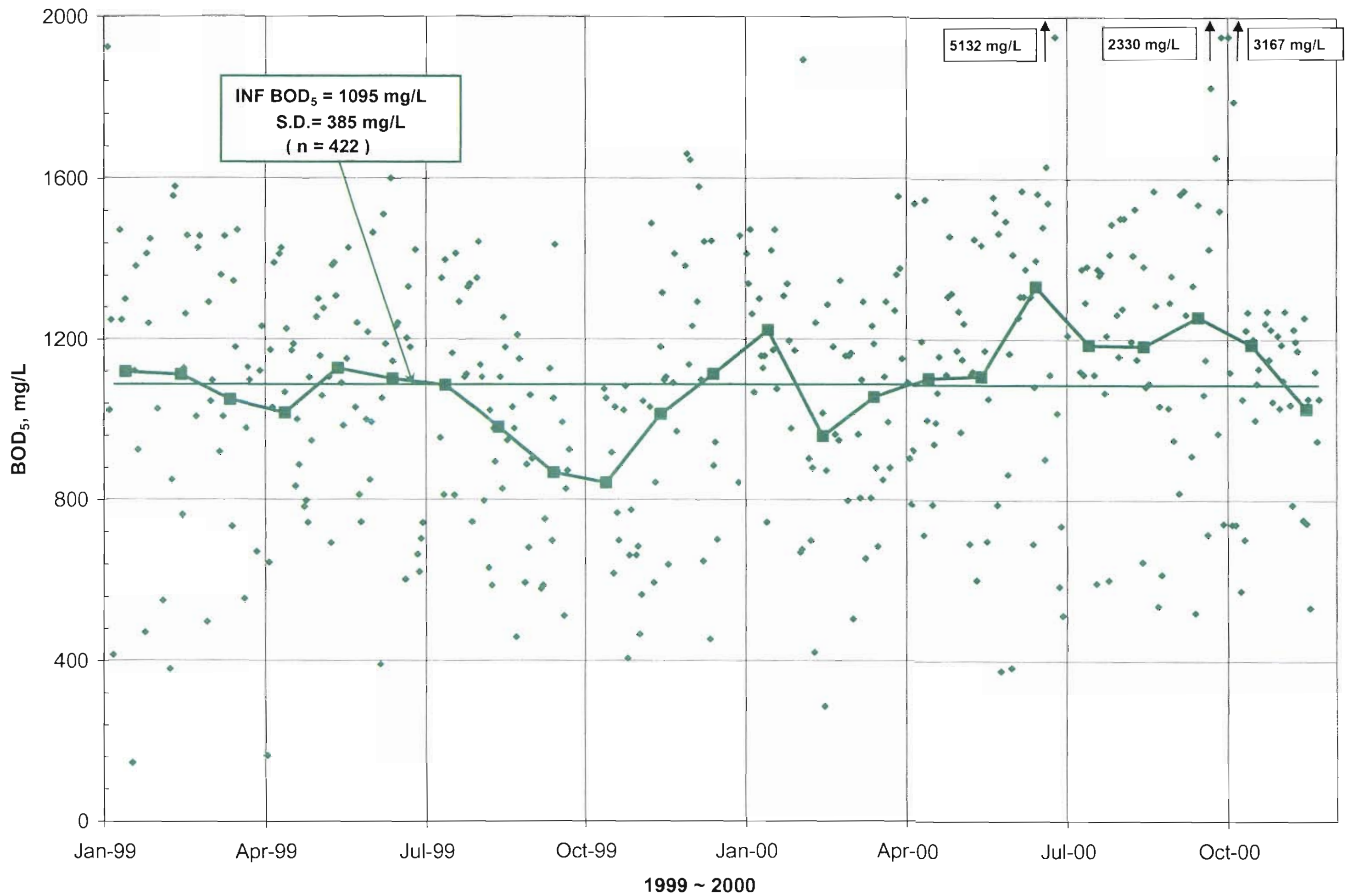


Figure 39. Average Monthly BOD_5 with S.D. in PRETREATMENT INFLUENT (Q_P)
PLANT C - 1/99 ~ 11/00
(Source: Daily monitoring from C)

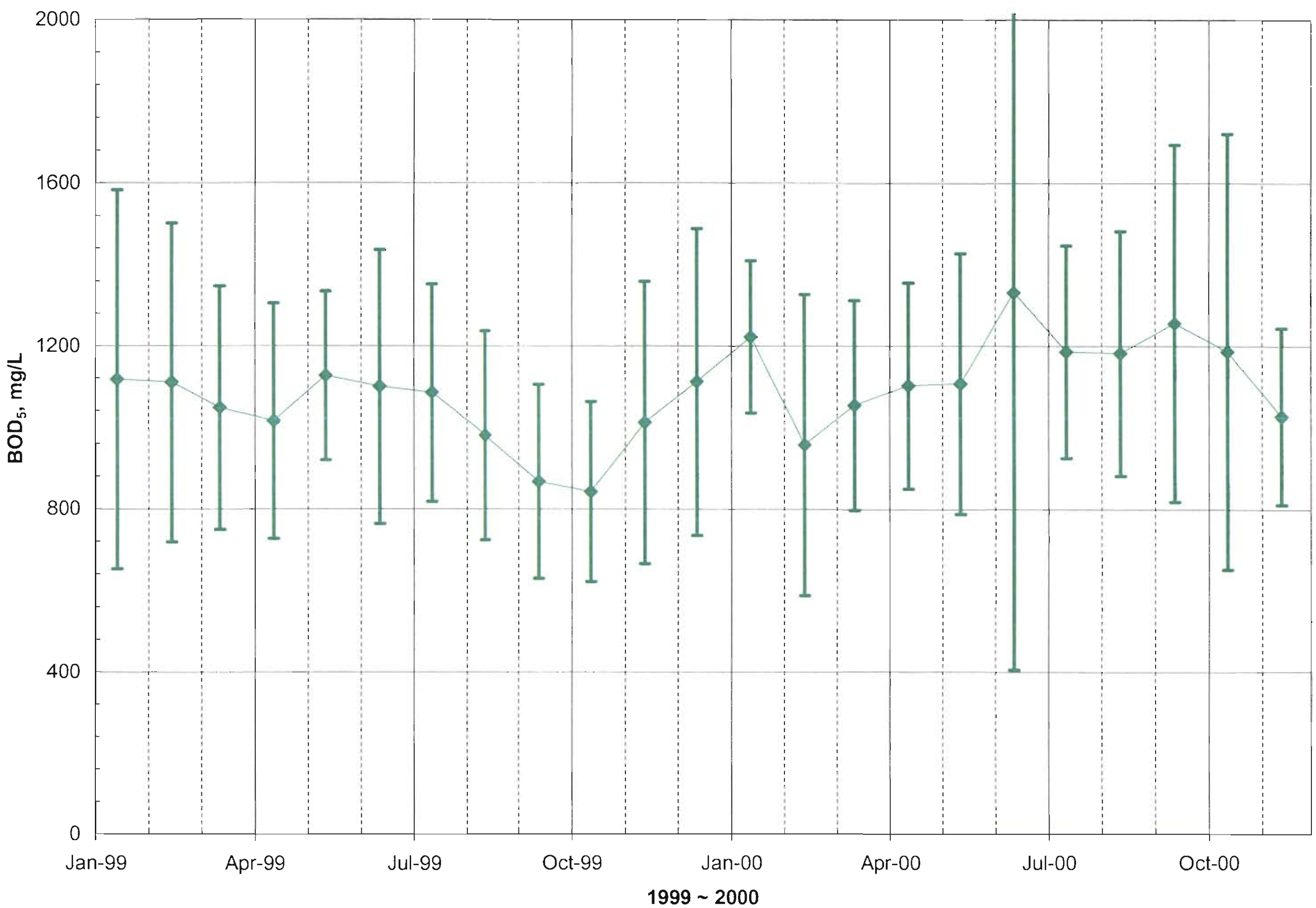


Figure 40. BOD_5 in WASTEWATER DISCHARGE (Q_w)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

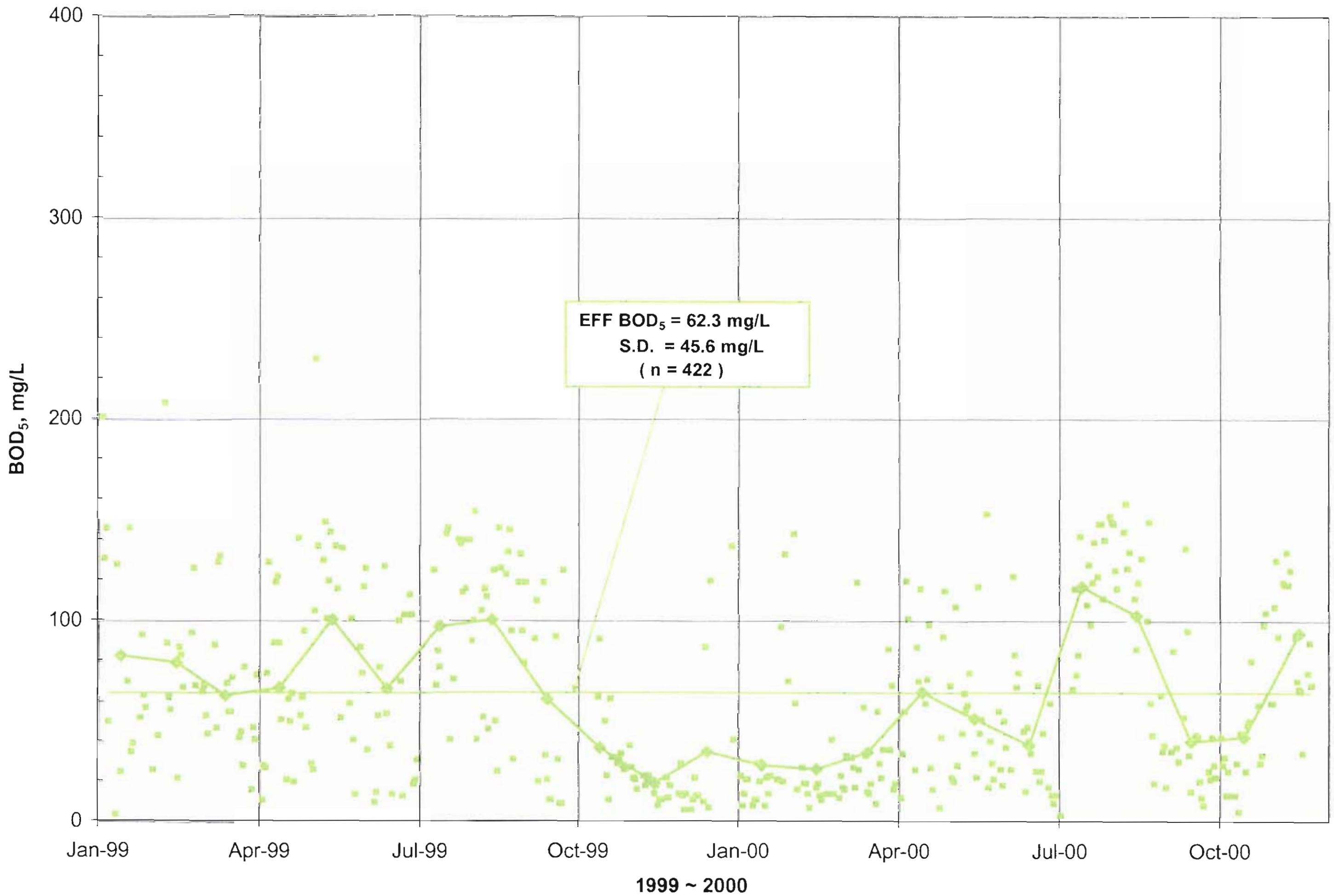


Figure 41. Average Monthly BOD_5 with S.D. in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily monitoring from C)

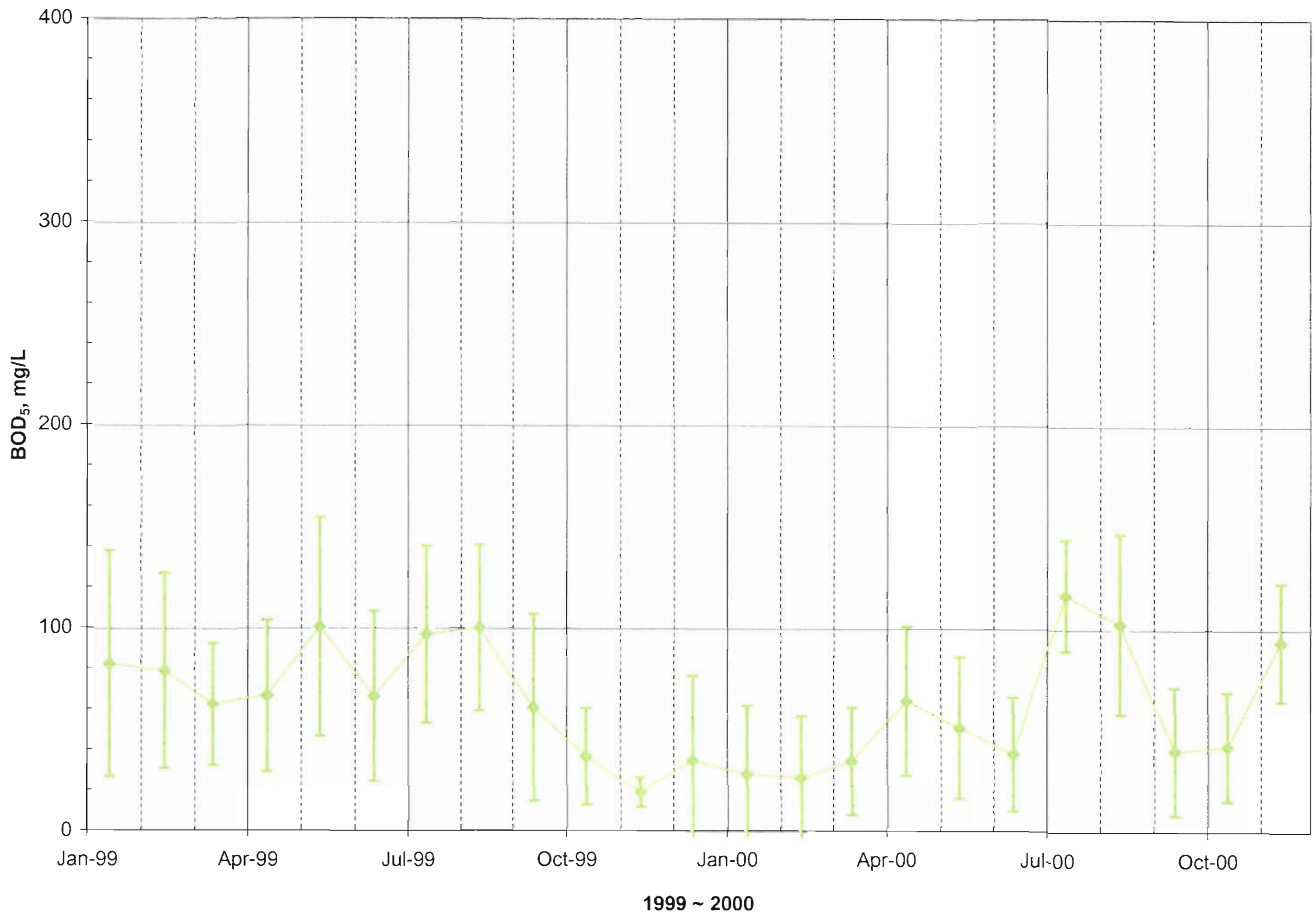
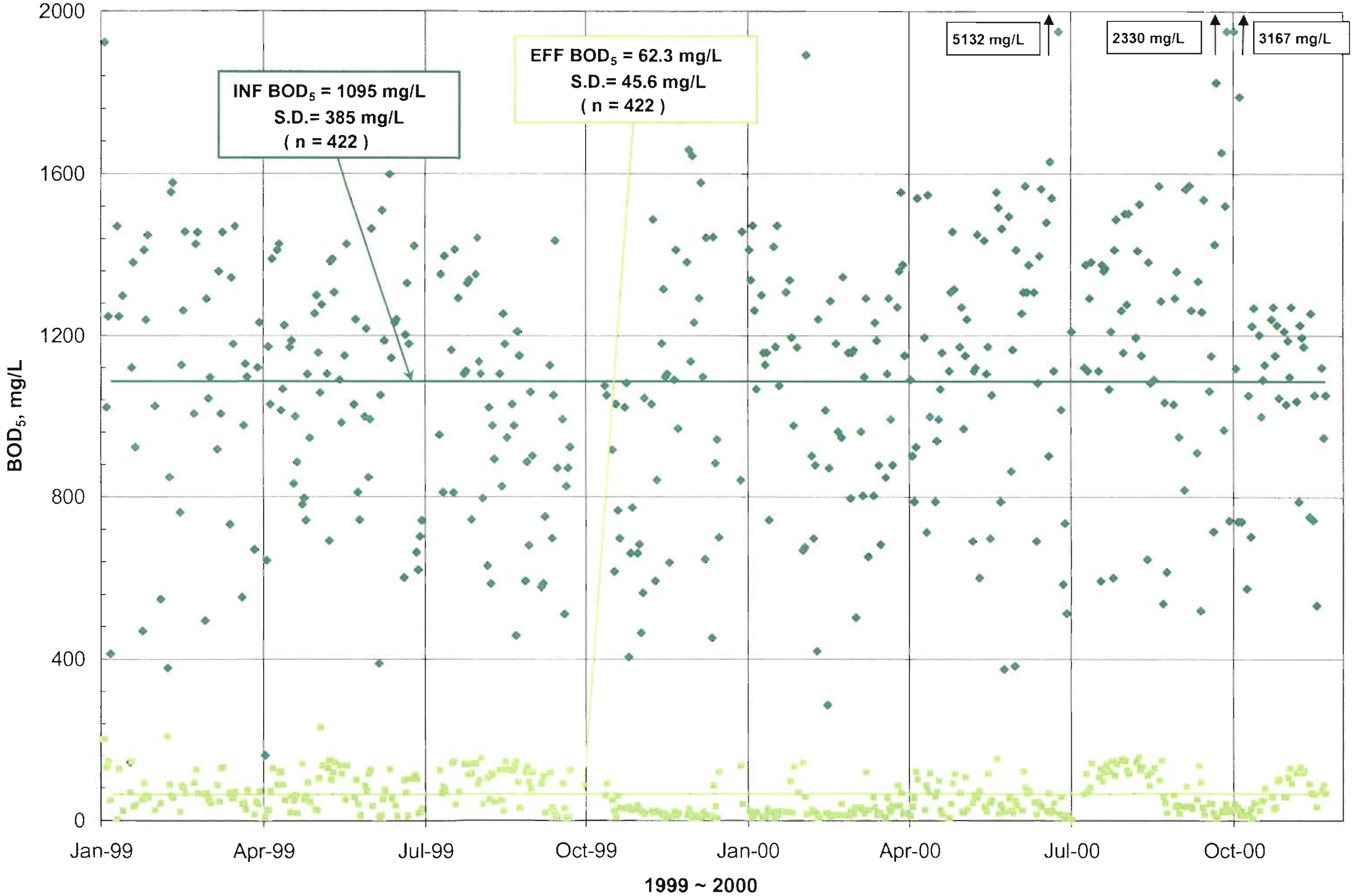


Figure 42. BOD_5 in PRETREATMENT INFLUENT (Q_P) and WASTEWATER DISCHARGE (Q_w)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)



CWW sewer system. Data in Figure 43 represent a comparison of the CWW data and those from Plant C. The two data sources are similar and both indicate the variations in effluent organic composition.

Organic loading data from Plant C for the pretreatment system based on BOD_5 are presented in Figure 44-45, demonstrating the extensive load reduction achieved by the pretreatment system. Data in Figure 46 in addition indicate the BOD_5 reduction to average 93.7 % (std. dev. = 5.77%) for the 2-year period of 1999 to 2000. Data for the pretreatment effluent, as discharged to CWW sewers and presented in Figure 44, show the average organic loading to CWW was equal to 118.9 kg/d of biodegradable organic matter.

COD data for the pretreatment facility are presented in Figures 47-50. The influent COD concentration is 4,413 mg/L (std. dev. = 2,540 mg/L) and the effluent COD concentration is 1,056mg/L (std. dev. = 1,135mg/L). The composite data set for influent and effluent COD are included in Figure 51, reflecting an overall COD reduction of ~76% for the indicated 2-year period. While not discharged to the CWW sewer without pretreatment, these data, in concert with the above BOD_5 data, do indicate that the raw wastewater could place a significant loading on the South plant (if not treated) and indicate the extensive removal that can be achieved with a relatively-simple pretreatment system at an industrial plant such as that at Plant C.

Figure 43. Average Monthly BOD_5 in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/98 ~ 11/00
(Source: 24-hr composite random monitoring by CWW &
Daily self-monitoring from C)

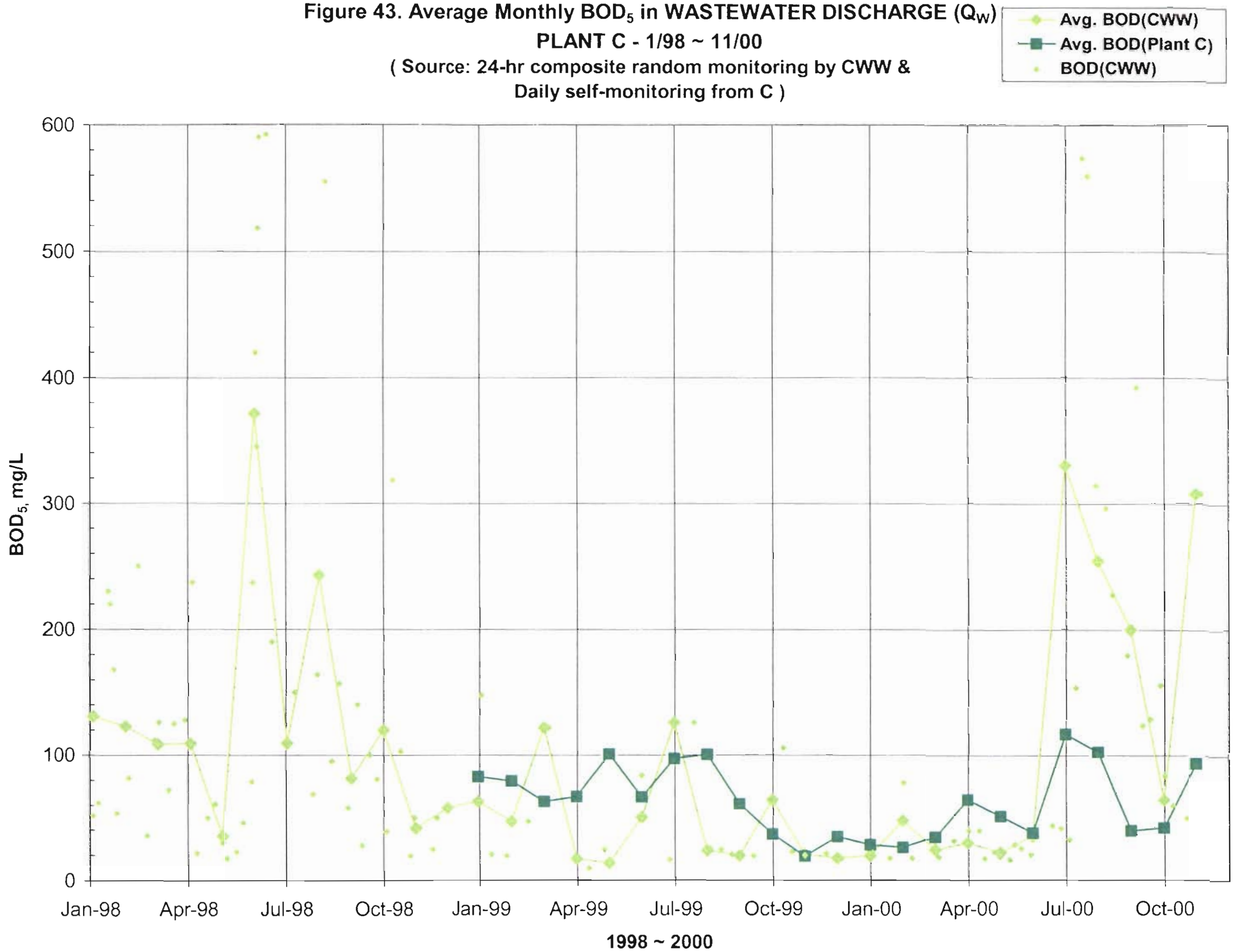


Figure 44. BOD_5 LOADING in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

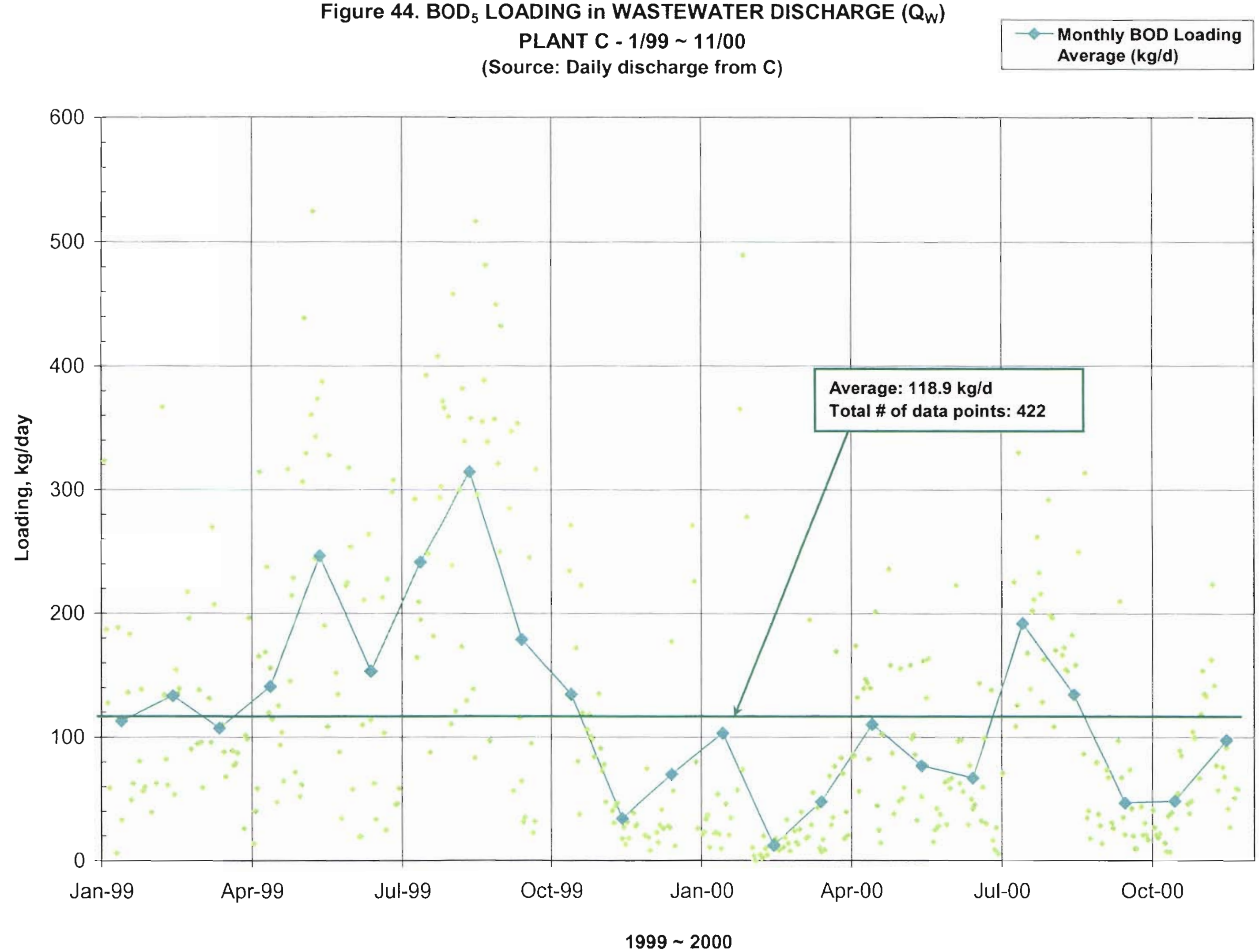


Figure 45. BOD_5 LOADING in PRETREATMENT INFLUENT & DISCHARGE WASTEWATER (Q_P, Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

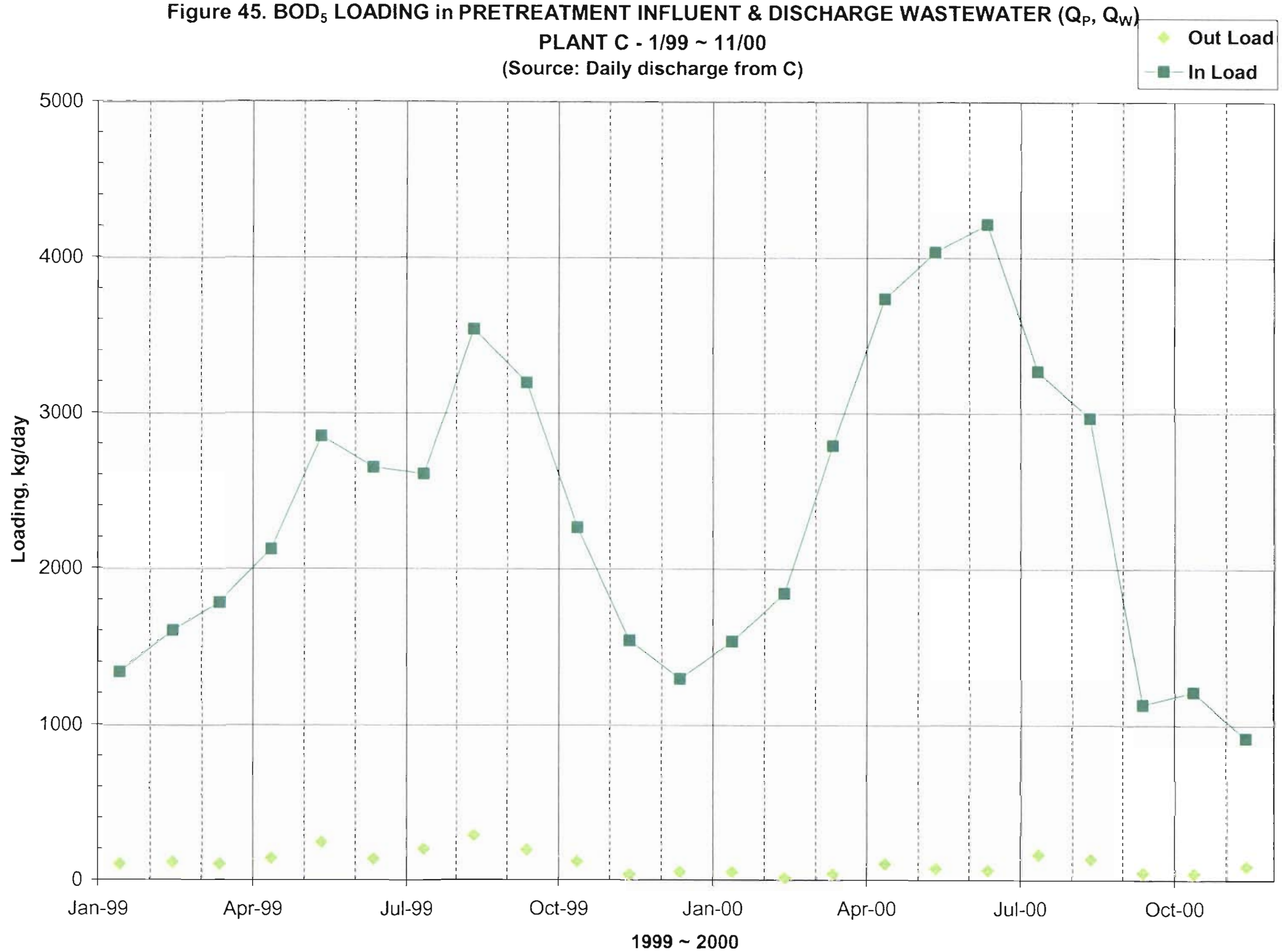


Figure 46. BOD_5 Reduction in PRETREATMENT SYSTEM
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

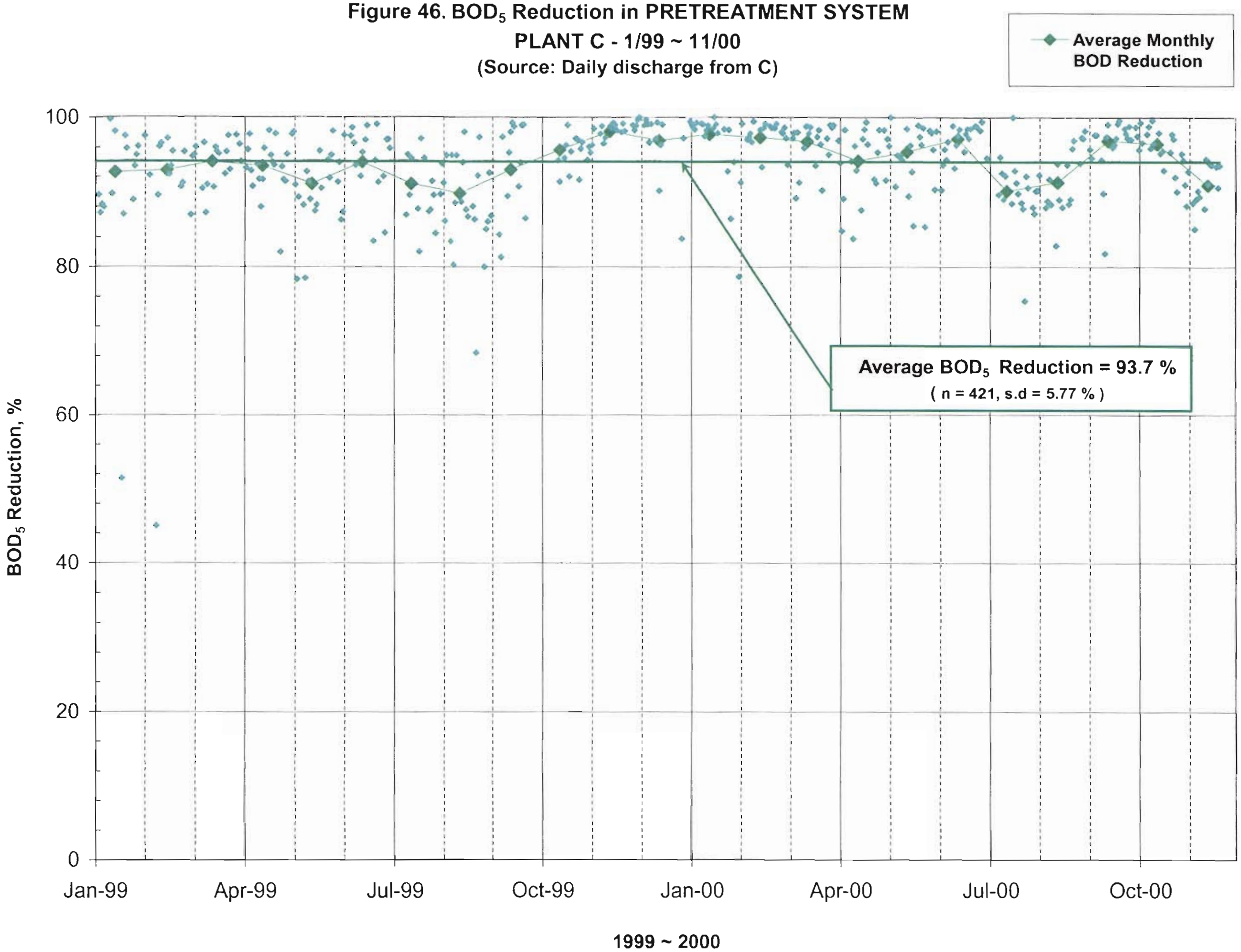


Figure 47. COD in PRETREATMENT INFLUENT (Q_P)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

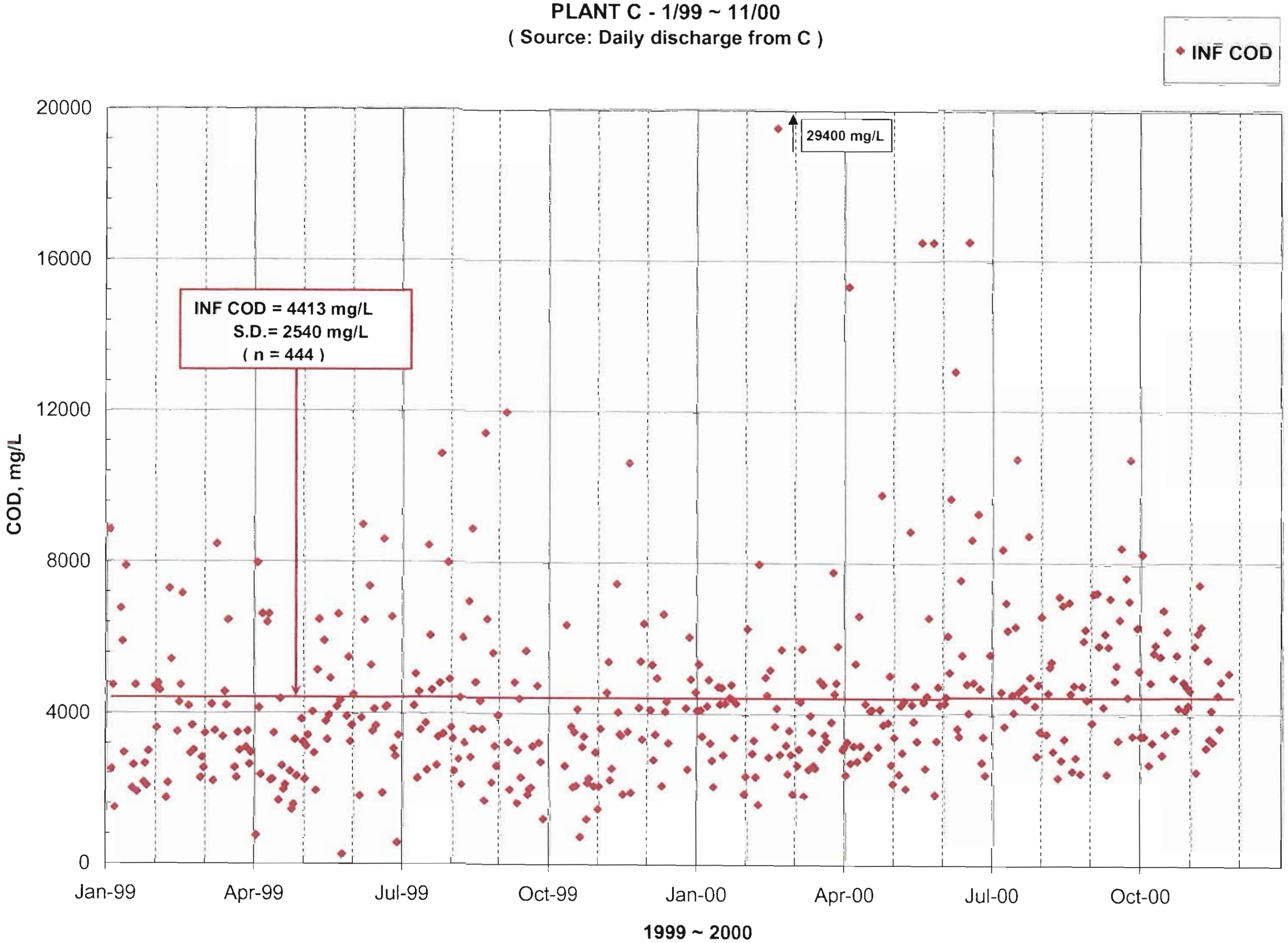


Figure 48. Average Monthly COD with S.D. in PRETREATMENT INFLUENT (Q_P)
PLANT C - 1/99 ~ 11/00
(Source: Daily monitoring from C)

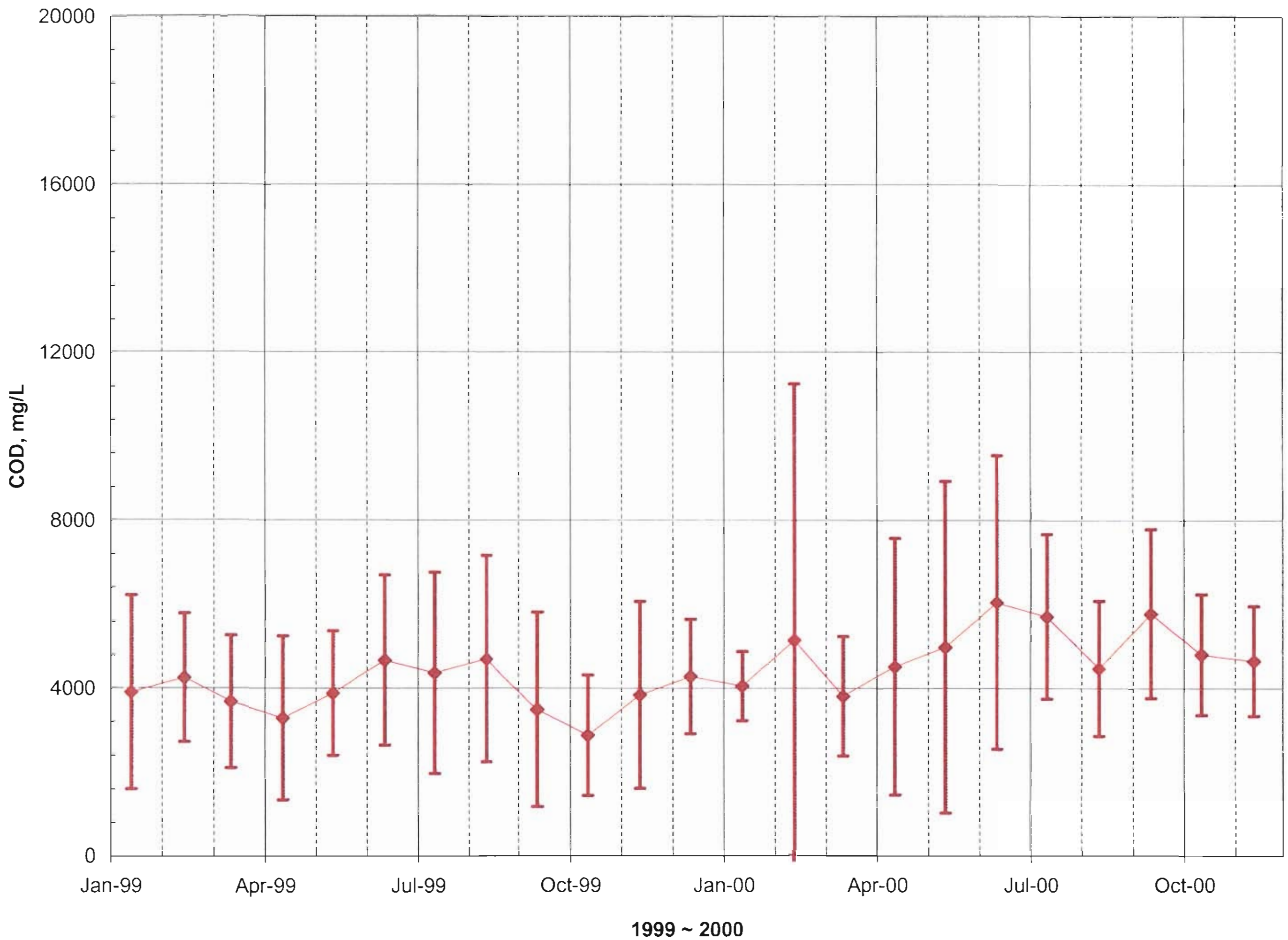


Figure 49. COD in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

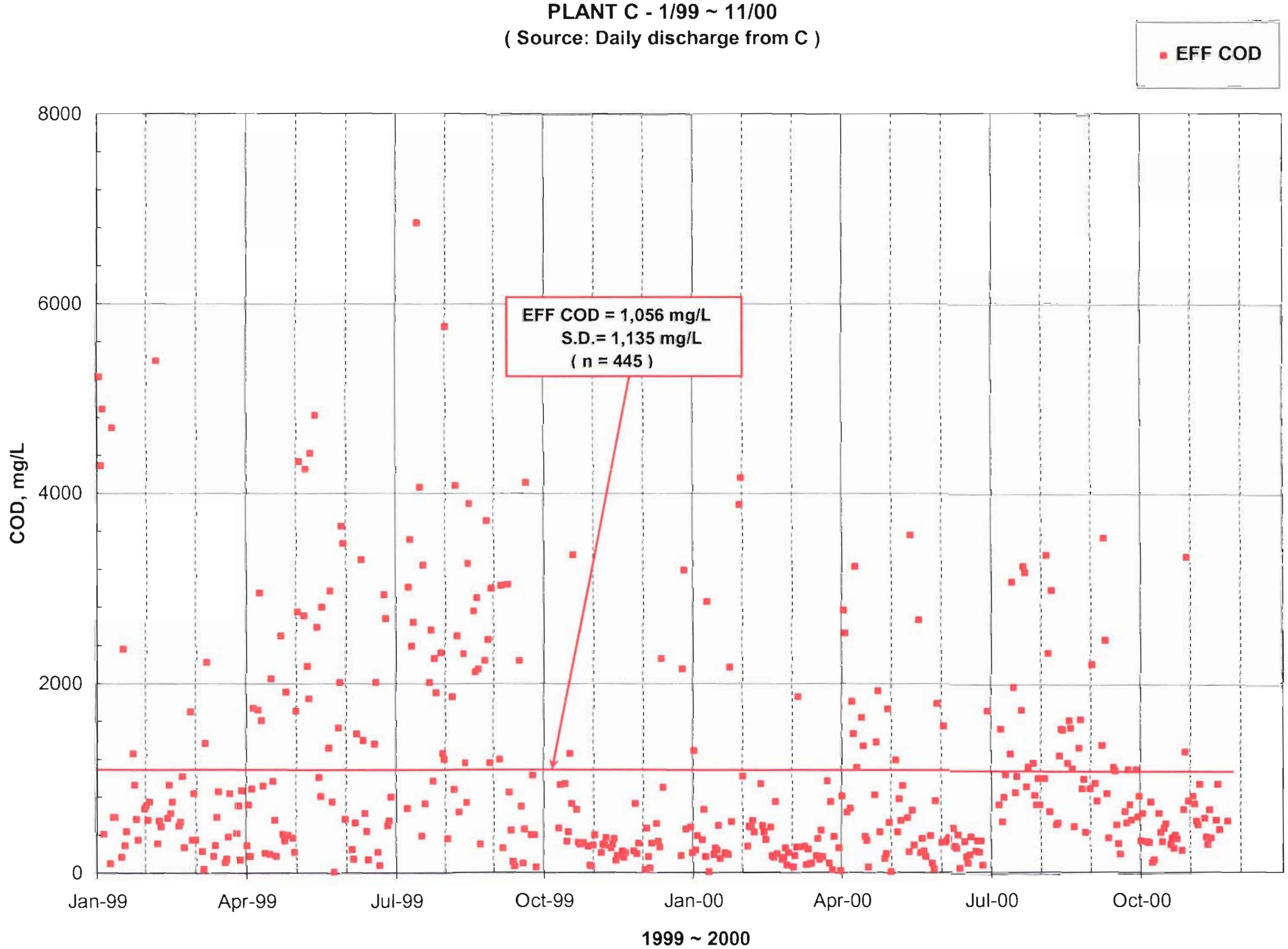


Figure 50. Average Monthly COD with S.D. in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily monitoring from C)

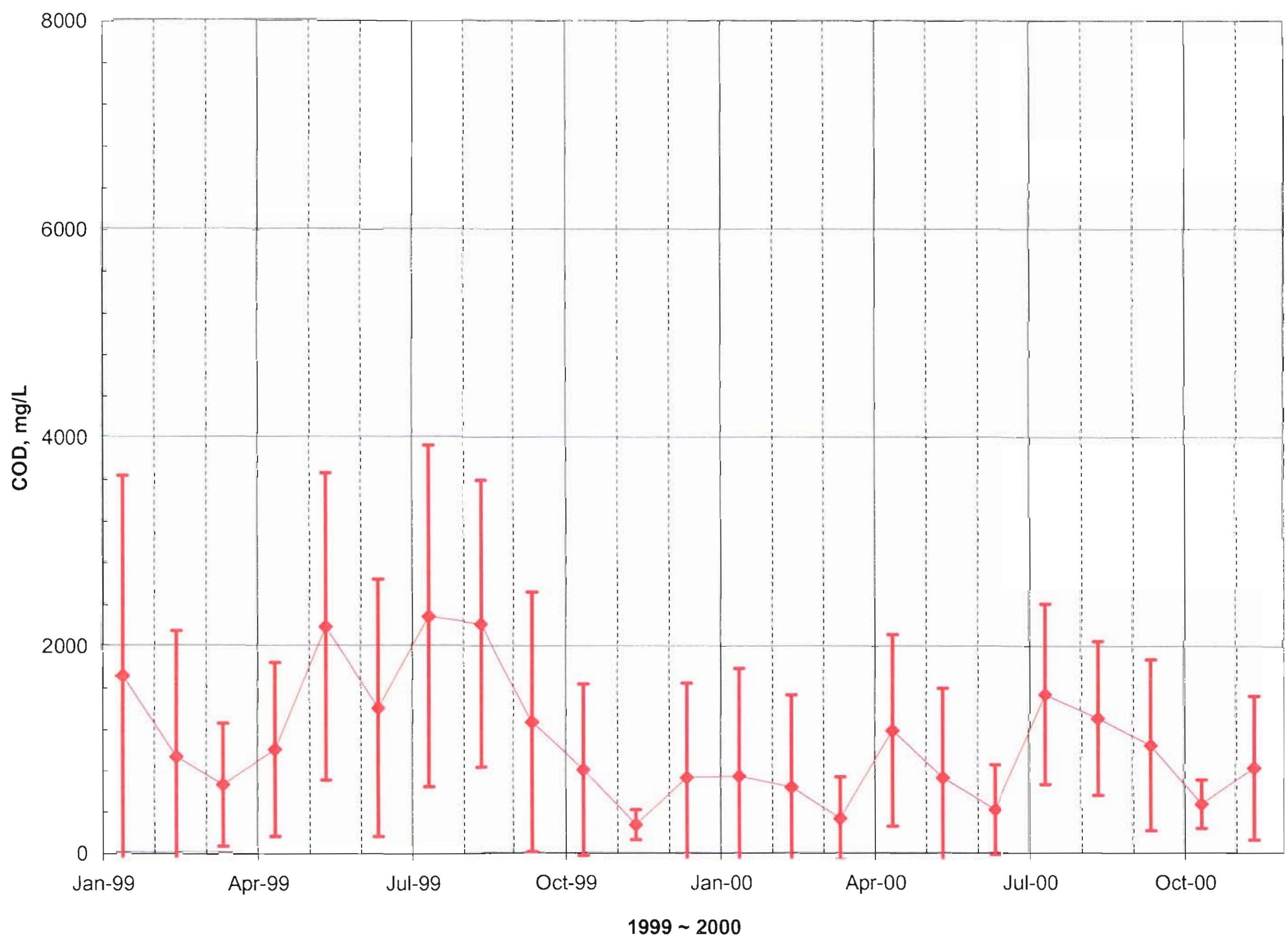
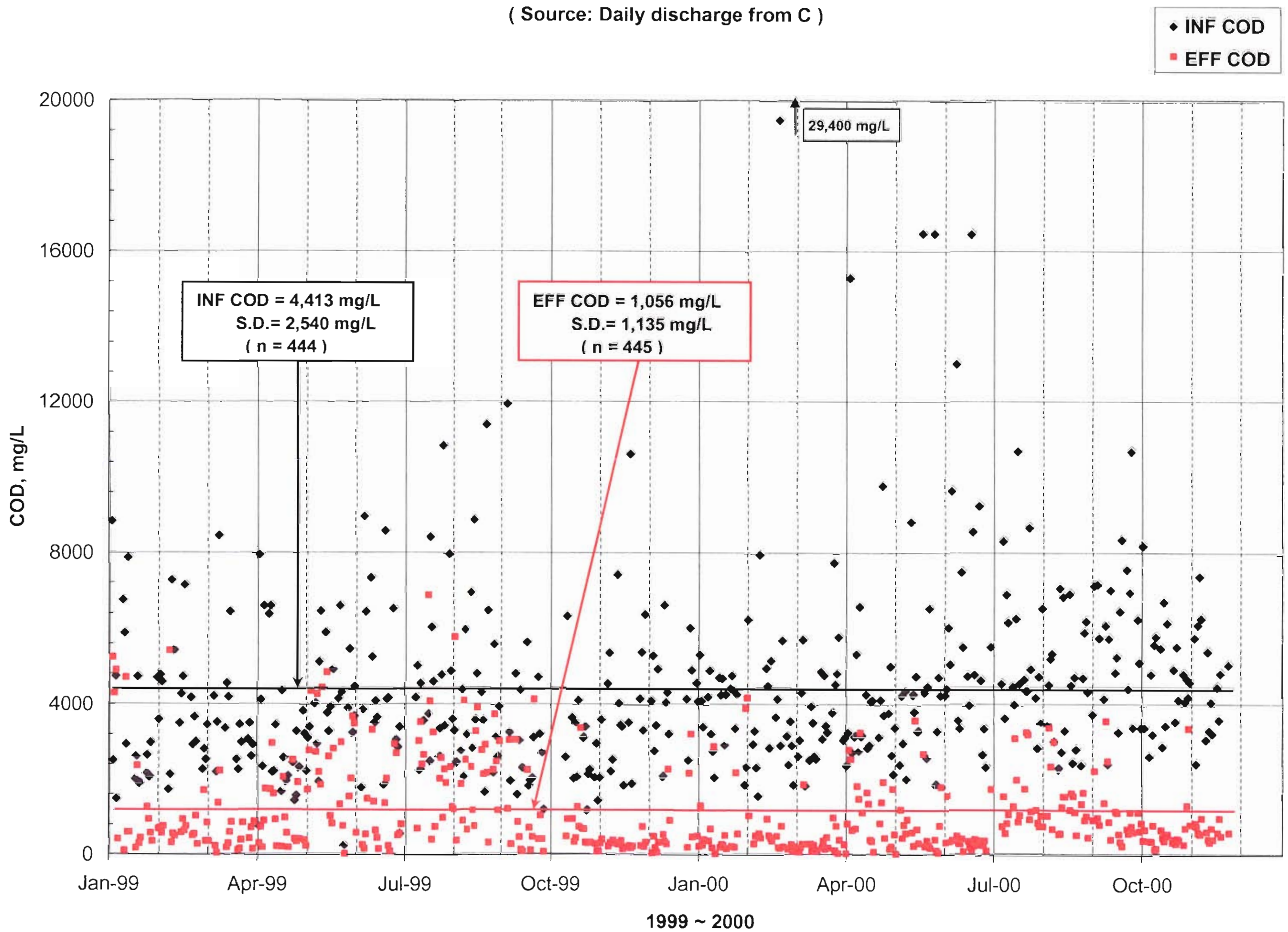


Figure 51. COD in PRETREATMENT INFLUENT (Q_P) and WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)



COD loadings are presented in Figures 52 and 53. For the 2-year period in Figure 52, the average COD loading to CWW was 2126.2 kg/d, while for the dye period of 2000, the COD loading was 1,147 kg/d (std. dev. = 1,529 kg/d), as indicated in Figure 53. Using the loading data for the pretreatment system as summarized in Figure 53, the COD reduction over the 2-year period varied on a monthly-average basis from ~42% to 93% and averaged 70.3% (std. dev = 43%), as presented in Figure 54. Data for the dye period of year 2000 in Figure 55 indicated that the average COD reduction in the pretreatment system to be 79.5% (std. dev. = 25.8%). It is therefore clear that the pretreatment system including an activated-sludge lagoon provides considerable treatment of dye chemicals from Plant C.

A comparison of the COD and BOD_5 data for the pretreatment system was facilitated with an examination of the COD to BOD_5 ratio. In Figure 56, the COD/BOD_5 ratio averaged 4.11 and BOD_5 was 24.3% of COD. The effluent from the pretreatment system (Figure 57) had a COD to BOD_5 ratio of 17.59, indicating the bio-resistant nature of the effluent, reflective of extensive biotreatment in the activated-sludge lagoon system. The effluent biodegradable organics discharged to the CWW system therefore represented only 5.7% (i.e., 100/17.59) of the total organics discharged.

Additional wastewater constituents discharged in the pretreatment effluent to the CWW sewers were assessed over the period of 1999 to 2000. These data are summarized below.

Figure 52. COD LOADING in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

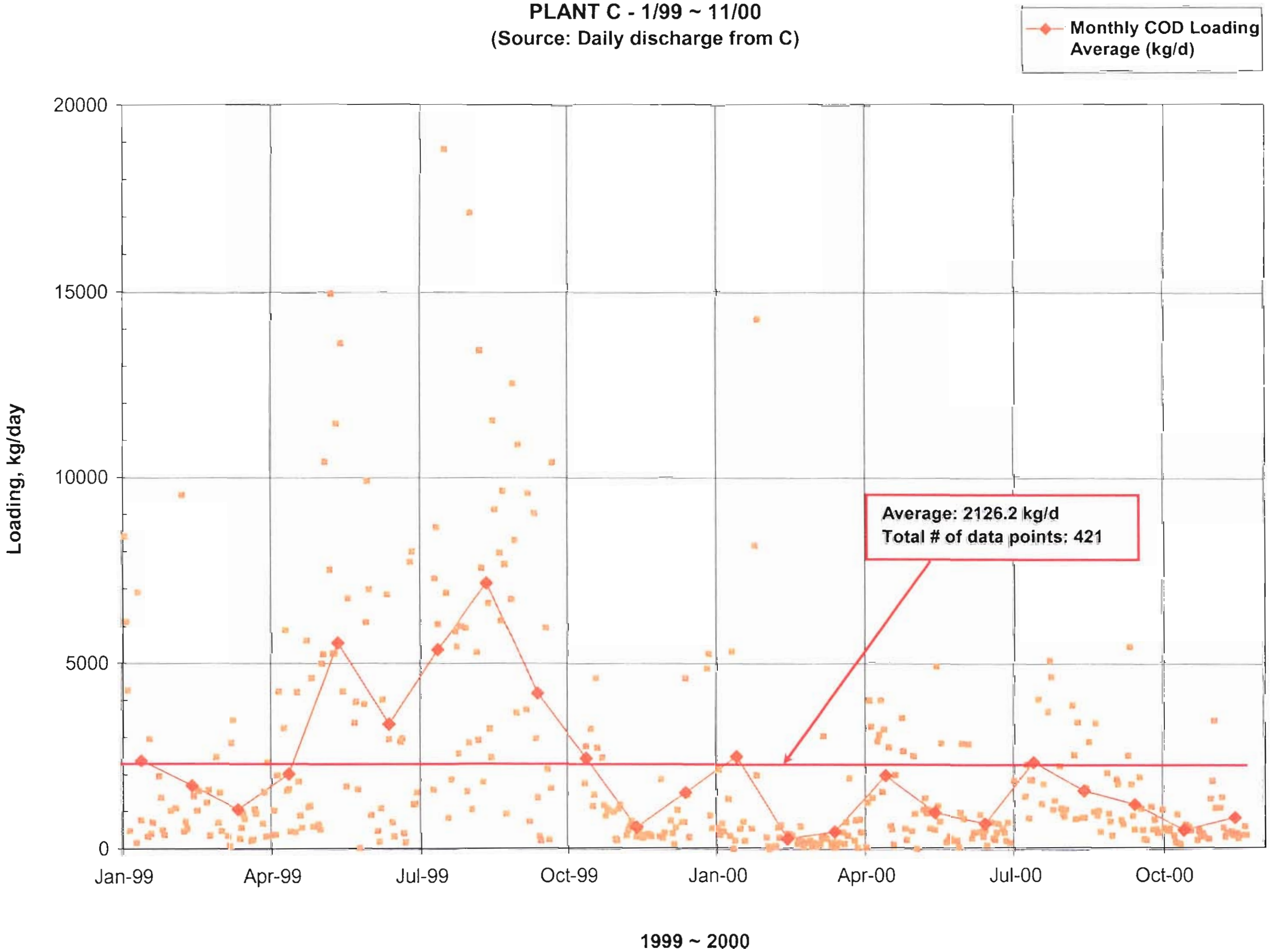


Figure 53. COD LOADING in WASTEWATER DISCHARGE (Q_W) for DYE PERIOD
PLANT C - 1/00 ~ 11/00
(Source: Daily discharge from C)

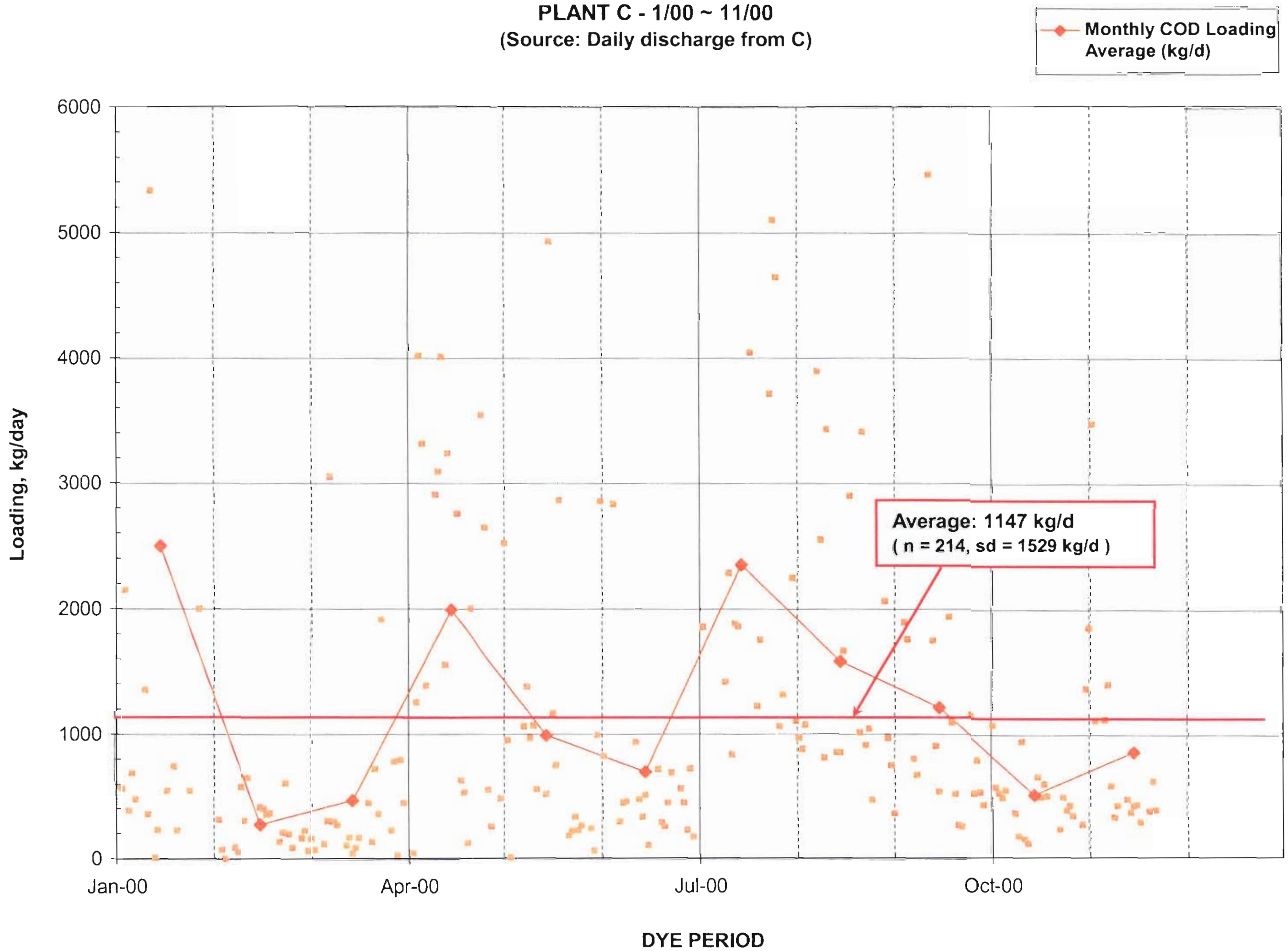


Figure 54. COD Reduction in PRETREATMENT SYSTEM
PLANT C - 1/99 ~ 11/00
(Source: Daily discharge from C)

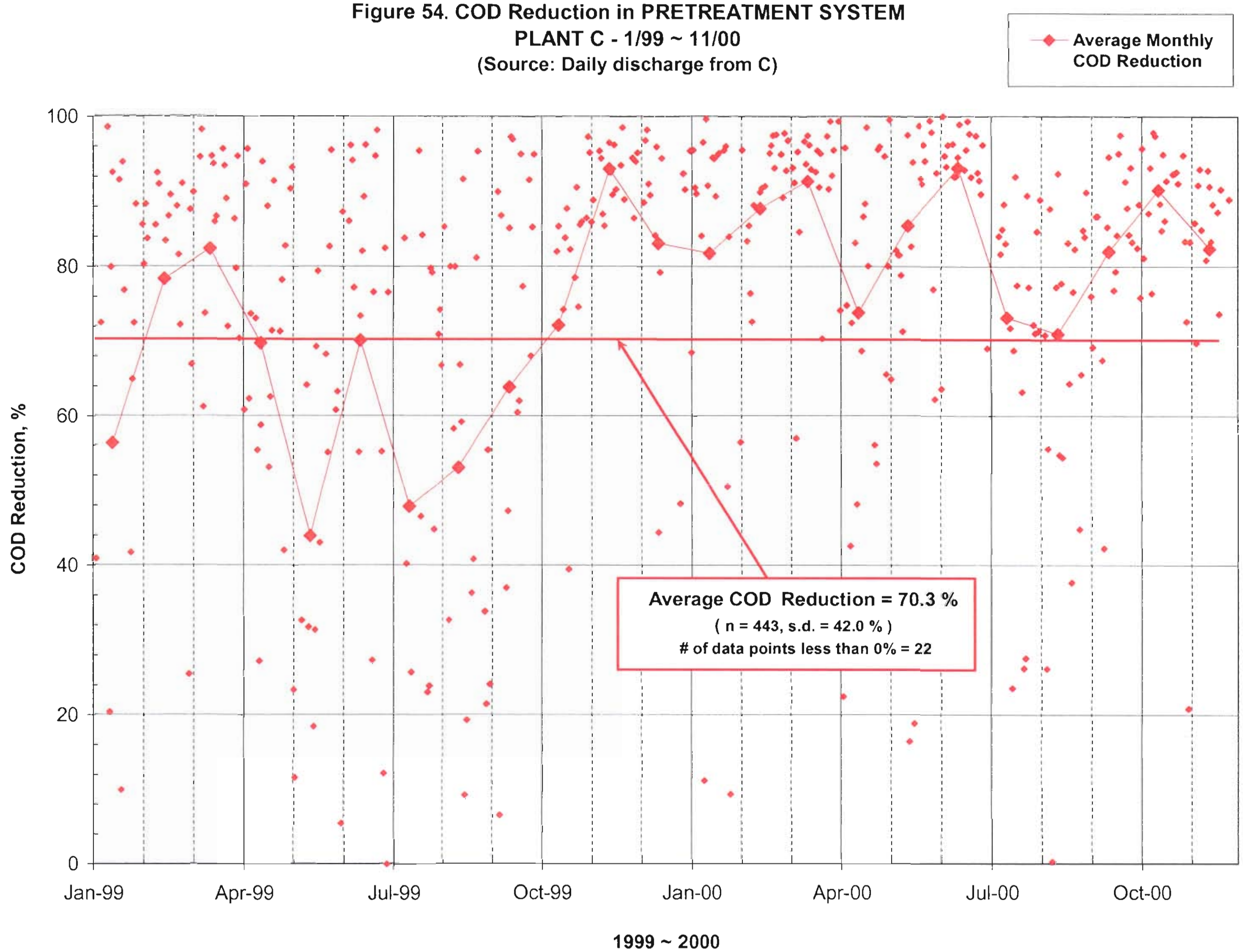


Figure 55. COD Reduction in PRETREATMENT SYSTEM for DYE PERIOD
PLANT C - 1/00 ~ 11/00
(Source: Daily discharge from C)

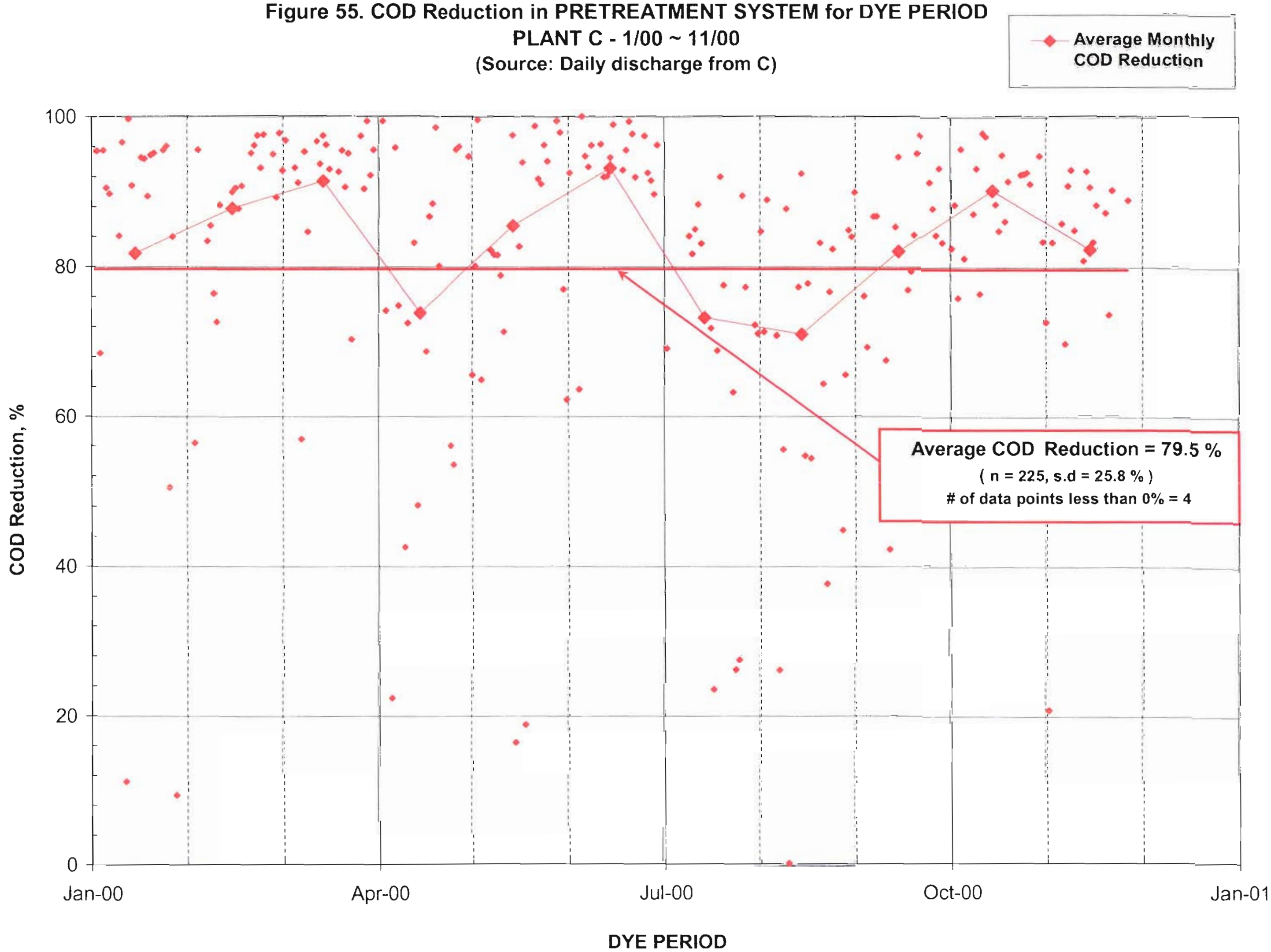


Figure 56. COD/BOD_5 RATIO in PRETREATMENT INFLUENT (Q_P)
PLANT C - 1/99 ~ 11/00
(Source: Daily Discharge from C)

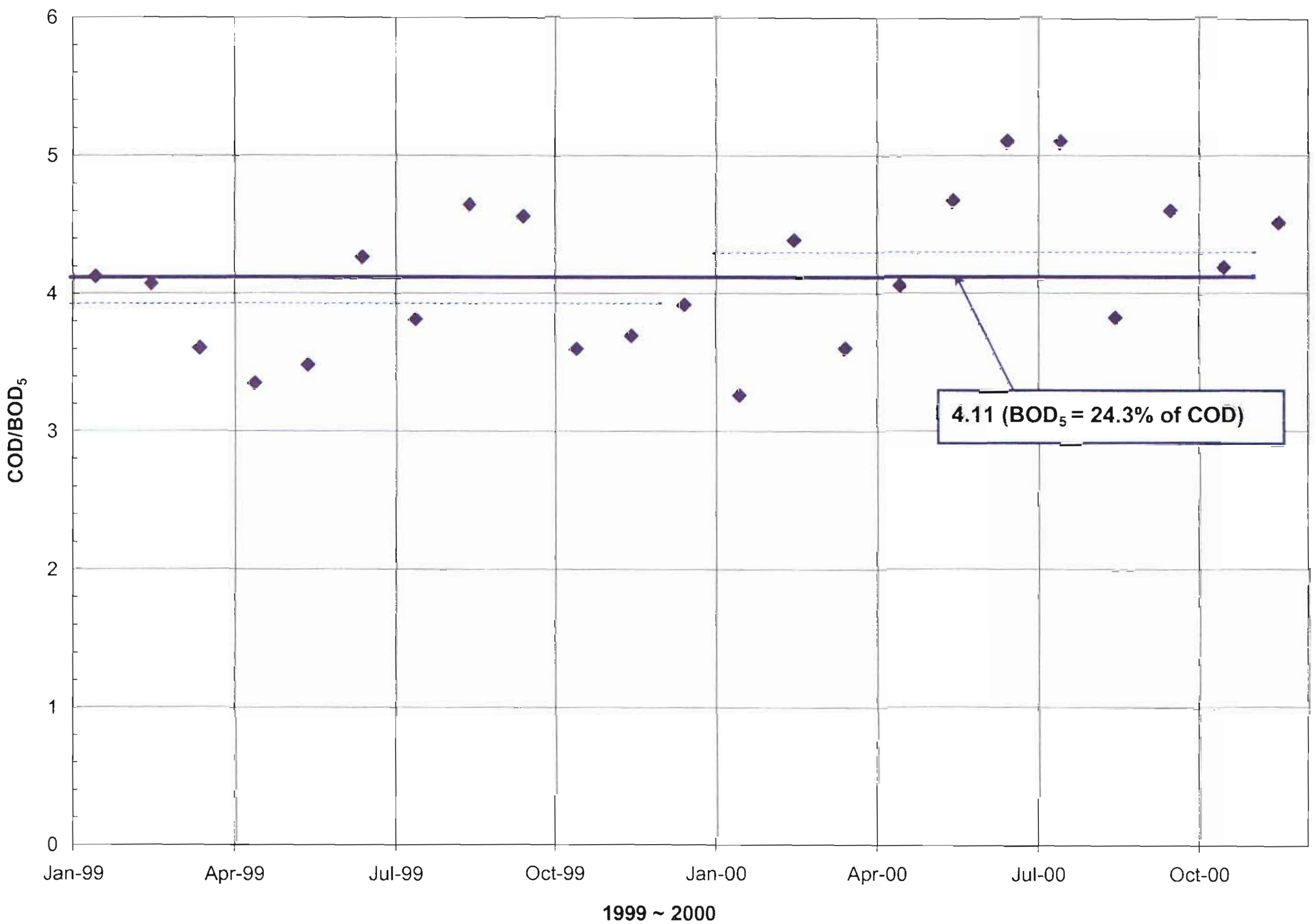
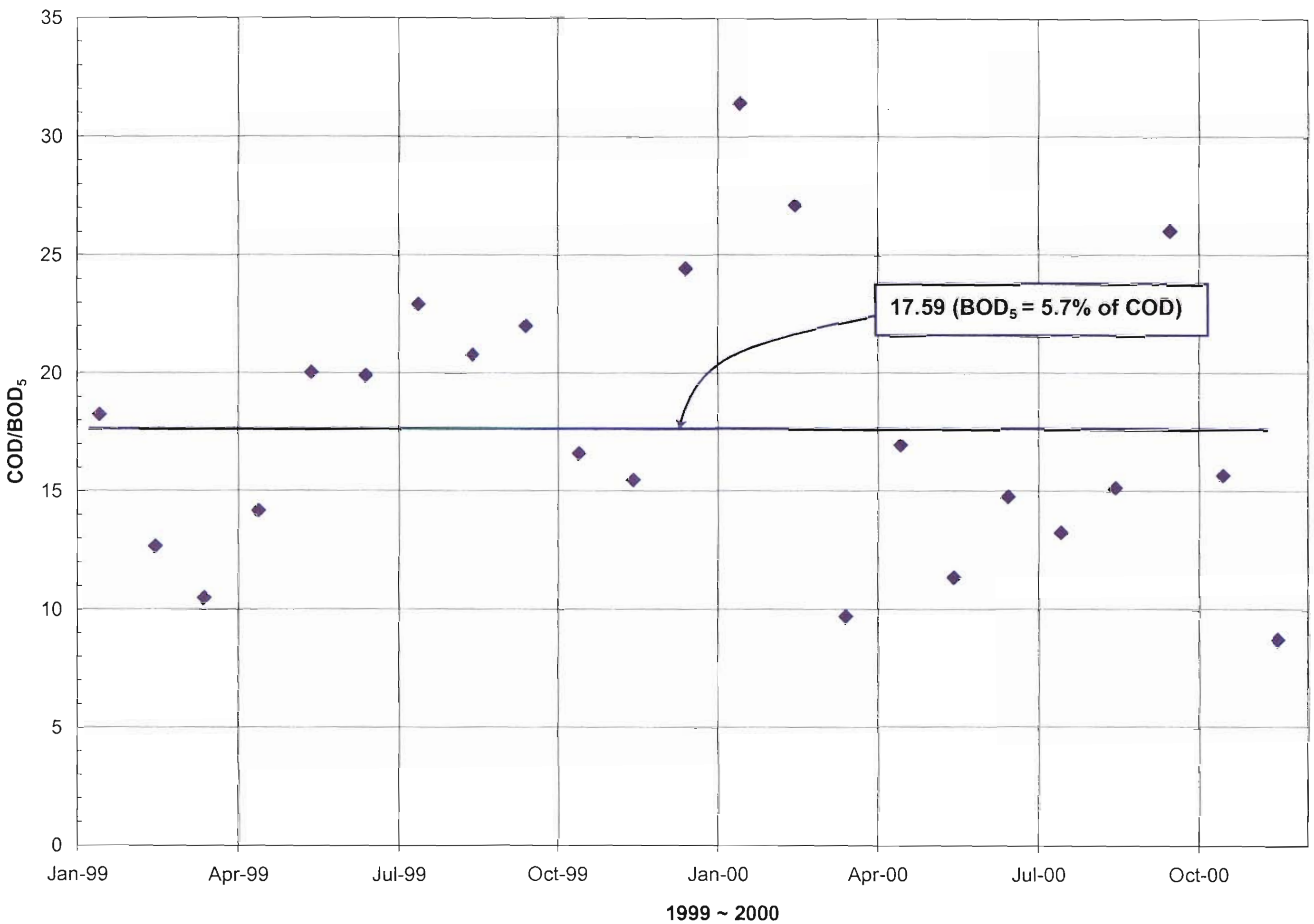


Figure 57. COD/BOD_5 RATIO in WASTEWATER DISCHARGE (Q_W)
PLANT C - 1/99 ~ 11/00
(Source: Daily Discharge from C)



Plant C: Characteristics of Wastewater Effluent Discharged to CWW System

Parameter	Average (n; std. dev.)*			
	Pretreatment Influent		**Pretreatment Effluent**	
Flow, gpd	59×10^4	(647; 33×10^4)	48×10^4	(646; 52×10^4)
BOD_5, mg/L	1,082	(421; 316)	62	(422; 46)
COD, mg/L	4,393	(444; 2,540)	1,063	(445; 1,131)
TS	10,097	(447; 4,227)	8,450	(453; 1,749)
TSS	777	(450; 880)	551	(489; 715)
VSS	599	(448; 794)	---	(---; ---)
Nitrogen, mg/L as N	---	(--- ;---)	2.45	(492; 0.56)
Phosphorus-total, mg/L as P	---	(--- ;---)	3.22	(485; 5.04)

* n=number of individual measurements; std. dev. = standard deviation

From these data, the plant is a significant contributor of dissolved solids to the CWW system, in that a TS of 8,450 mg/L is 10^+-fold greater than the TS for the CWW potable and wastewater systems. These dissolved constituents represent non-degradable constituents used at the plant that are not typically subject to significant removal in the South plant of CWW. Effluent suspended solids are relatively high at 551 mg/L but not unusual relative to domestic wastewaters. The effluent nitrogen and phosphorus concentrations of 2.45 mg/L and 3.22 mg/L, respectively, represent nutrient additions of ammonia-N and phosphate-P made to enhance the performance of the biological pretreatment system. These concentrations are typically below levels in domestic wastewaters and should present no concerns to the South plant.

Dye and Chemical Analysis

An assessment of dye and chemical use at the plants in the CWW system was conducted based on data provided by plant personnel for their respective 12-month periods. The data are presented on a plant-by-plant basis and include a critical evaluation of the independent data sets and impacts on the previous plant effluent data sets and on the CWW system.

Data for four plants are included in this section as follows:

Plant	Dye Period
A	Oct. 1999 - Sept. 2000
B	Oct. 1999 - Sept. 2000
C,D	Jan. 2000 - Dec. 2000

The data for Plants C and D were provided together since the chemical inventory and purchasing were done by the same administrative unit. Plant D, while not examined in the wastewater above analysis, was a minor contributor of wastewaters (relative to other selected plants). Regardless, the impacts of dye use and discharge are included in the data set in that plant A and D inventories were presented to CWW in inseparable form.

Plant A

This plant used an extensive array of dyes and chemicals due to the primary focus of towel stock of a wide variety of colors. Overall the plant inventory included 3.48×10^7 pounds/year (15,805 metric tons/year) as included in 77 specific dyes and chemicals. As summarized in Figure 58, inorganic chemicals accounted for 82.6% (i.e., 2.88×10^7 pounds/yr) of the total mass inventory purchased in this period. The inorganic chemicals

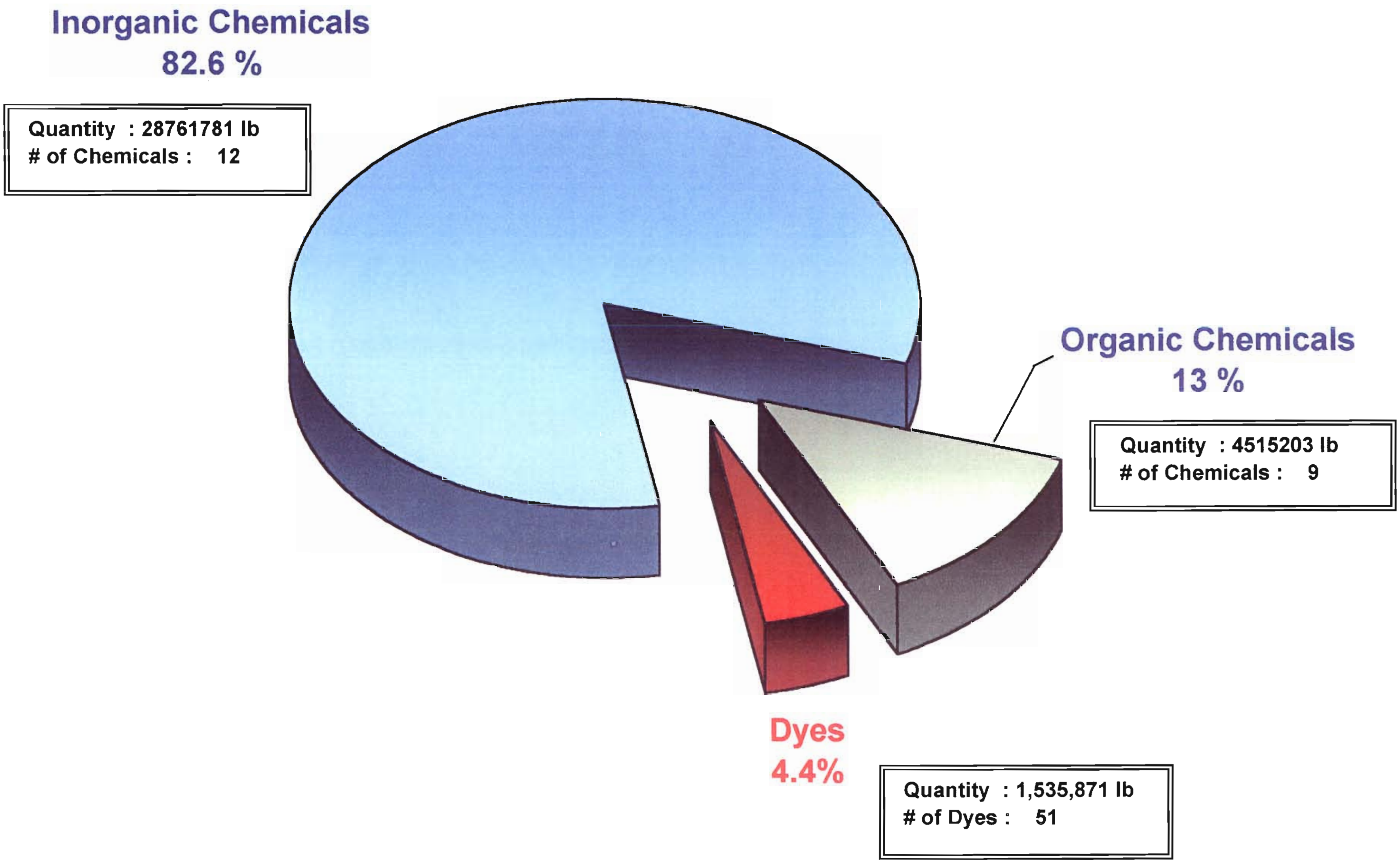
Figure 58

PERCENTAGE OF DYES USAGE in PLANT A

Dye Period : OCT. 99 ~ SEP. 00

Total Chemical Quantity : 34,812,855 lb

Number of Dyes + Chemicals : 77



were 12 specific chemicals. As summarized in Table 1, sodium chloride, sodium hydroxide, sodium hydrosulfite, hydrogen peroxide, sodium silicate and soda ash represented the major chemicals, each accounting for at least one million pounds per year, or more. These chemicals add to the TDS of the CWW wastewaters and represent some reducing- and oxidizing-chemicals (i.e., sodium sulfite and hydrogen peroxide, respectively) that have impacts on the immediate-sewer system (i.e., at the point of discharge) but do not represent chemicals that have a major effect on the operation of the South plant.

Organic chemical accounted for 13% (i.e., 4.5×10^6 pounds/yr) of the total chemical inventory at Plant A, as indicated in Figure 58 and Table 1. Nine organic chemicals were included in this fraction and were represented by several polymers and surfactants, sodium acetate, acetic acid and naphthol. These compounds would represent biodegradable and non-biodegradable organic compounds in the sewer system.

From Figure 58, dyes represented 4.4% (1.54×10^6 pounds/yr) of the chemical inventory in a total of 51 specific dyes, as presented in Table 2. This was the most diverse group of chemicals and represented the potential for high variability in the plant discharge. The dyes used included the classifications and quantities presented below. It is clear that azo dyes represented the majority of the dyes employed at Plant A.

Dye Type	Mass (lb/yr)	Number of Dyes	% of total (mass)
Azo	1.47×10^6	32	96.3%
Vat	34,461	13	2.2%
Direct	19,360	3	1.3%
Reactive	3,204	3	0.2%
Total	1.54×10^6	51	100%

Table 1.

List of Non-Dye Chemicals & Quantity during Dye Period in Plant A

Dye Period: OCT. 99 ~ SEP. 00

Product Name	Chemical Family	Vendor	Quantity (lb)	Form
Salt (Flo-Ever Evaporated Salt)(7647-14-5)	Sodium Chloride	CARGILL SALT	15,540,500	Solid
CAUSTIC SODA	Alkali, Base	Oxychem	4,567,478	Viscous liquid
SURESOFT E-4	Cationic	FIELDCREST CANNON INC.	3,690,990	Liquid
REDUCTONE Sodium Hydrosulfite	Inorganic sulfur compou	OLIN CHEMICAL	3,687,234	Clear Yellow solution
HYDROGEN PEROXIDE 50%	PEROXIDE	ATOCHEM NORTH AMERIC	2,453,134	Liquid
Sodium Silicate Liquid Siliceouse(7632-00-0)	Sodium Silicate Liquid	Oxychem	1,256,160	Turbid Liquid
SODA ASH.100%.POWDER.ALKALI			1,103,046	
ULTRASOFT 2000 (BULK)			332,060	
MONOLIN RA		CLARK CHEMICAL INCORP	254,800	Light amber liquid
KAROX RTM-4 BLEACHING STABILIZER(450#/DRUM)			98,500	
CLAREX SCR-2 (WETTER/SCOUR)			76,500	
Sodium Acetate		ACETO CHEMICAL	36,000	White solid
HP EVAPARATED SALT(HPE-99.9)50#OR80#/BAG			34,600	
MURIATIC ACID.20%.LIQUID.ACID			32,050	
56% Acetic Acid		MAYO CHEMICAL COMPAN	24,200	Clear colorless solution
Naphthol AS-FC solution	Naphthol	PFISTER CHEMICAL INC.	20,550	green to brown liquid
ULTRAVON SFN	Proprietary Blend of Sur	CIBA-GEIGY CORPORATIO	17,170	Liquid
CIBACEL DBC WETTER			12,320	
DISCOL 1593 ENZYME			8,952	
REMOL DC NEW	Surfactant Mixture	CLARIANT, LTD	6,459	Yellow Liquid
PFISCOLENE CP		PFISTER CHEMICAL INC.	5,400	Clear Amber Liquid
CALLAWAY 1667	Surfactant Alcohol	CALLAWAY CHEMICAL	4,978	Liquid
Sodium Nitrite(7632-00-0)	INORGANIC SALT	DUPONT	4,620	Solid
ALBEGIN A NEW	Pyrrolidone	BASF CORPORATION	4,180	Clear Liquid
GLO TEX DP	Nonionic Surfactant	Glo-Tax Chemicals, Inc.	3,150	Clear Liquid
ALBATEX FFC	Alkyl Aryl - ETHOXYLAT	CIBA-GEIGY CORPORATIO	1,953	Liquid

Table 2.

List of Dye Chemicals & Quantity during Dye Period in Plant A

Dye Period: OCT. 99 ~ SEP. 00

Product Name	Chemical Family	Vendor	Quantity (lb)	Form	Group
ISOZOL RED 37 LIQUID (500#DRUM)	Azo Dye	ISOCHEM INC.	485,250	Red Liquid	Azo Dye
ISOZOL NAVY BL-2 LIQUID (500#DRUM)	Azo Dye	ISOCHEM INC.	251,243	Blue Liquid	Azo Dye
ISOZOL GREEN GN32 LIQUID 500#DRUM	Azo Dye	ISOCHEM INC.	125,700	Green liquid	Vat Dye
RHODAZOL BLACK KAX LIQ	AZO DYESTUFF	Hoechst Celanese	82,350	Black Liquid	Azo Dye
CIBACRON BLUE C-R LIQ 33	FORMAZINE METAL C	CIBA-GEIGY CORPORATION	72,990	Blue Liquid	Reactive Dye
CIBACRON RED C-2G LIQ 33	MONOAZO DYE	CIBA-GEIGY CORPORATION	69,440	RED LIQUID	Azo Dye
CIBACRON.RED C-F 01.33%.LIQUID.REACTIVE	Mixture of azo dyes	CIBA SPECIALTY CHEMICAL	44,880	Red liquid	Azo Dye
FAST RED B BASE 40% SOLUTION	Aromatic amine	PFISTER CHEMICAL INC.	43,600	Deep red liquid	Azo Dye
CIBACRON ORANGE C-G LIQ 33	AZO DYE	CIBA-GEIGY CORPORATION	41,360	Blue Liquid	Azo Dye
CIBACRON RED C-R.25%.LIQUID.REACTIVE	Azo Dye	CIBA-GEIGY CORPORATION	33,890	Red Liquid	Azo Dye
CIBACRON BLACK C-R LIQ 33	MIXTURE AZO DYES	CIBA-GEIGY CORPORATION	31,680	LIQUID	Azo Dye
CIBACRON BLACK C-FC LIQUID	AZO DYE MIXTURE	CIBA SPECIALTY CHEMICAL	30,800	Black Liquid	Azo dye
CIBACRON BURGUNDY RD 59 LIQ	AZO DYE MIXTURE	CIBA-GEIGY CORPORATION	30,420	Liquid	Azo Dye
CIBACRON GREEN LS-3B HIGH CONC GRANU	Azo dye	CIBA SPECIALTY CHEMICAL	25,146	Green Powder	Azo Dye
CIBACRON YELLOW C-R-01	AZO DYE	CIBA SPECIALTY CHEMICAL	20,064	Yellow Powder	Azo Dye
CIBACRON.YELLOW C-5G.33%LIQUID.REACTIVE		CIBA SPECIALTY CHEMICAL	17,600	Yellow liquid	Azo Dye
ISOZOL BLUE 38 LIQUID (REACTIVE MIX)	Azo dye	ISOCHEM INC.	17,500	Navy Blue Liquid	Azo Dye
CIBACRON ORANGE C-G LIQ 33	AZO DYE	CIBA-GEIGY CORPORATION	16,280	Orange Liquid	Azo Dye
CIBANONE GREY P2R DP	MIXTURE	CIBA-GEIGY CORPORATION	12,144	BLACK LIQUID	Vat Dye
CIBACRON TURQUOISE 3097 LIQ 33	PHTHALOCYANINE DY	CIBA-GEIGY CORPORATION	10,560	Turquoise Liquid	Direct Dye
CIBACRON BLUE F-R POWDER(198#drum)	FORMAZINE METAL C	CIBA SPECIALTY CHEMICAL	9,900	Blue powder	Azo dye
ISOZOL RED 37 ACCLAIN LIQUID,56511 (500#D	Azo Dye	ISOCHEM INC.	9,000	Red Liquid	Azo Dye
CIBACRON NAVY W-GAS L-50	Azo Dye	CIBA SPECIALTY CHEMICAL	7,040	Dark Blue liquid	Azo Dye
CIBANONE OLIVE T-C PST	Anthraquinone	CIBA-GEIGY CORPORATION	6,688	LIQUID	Vat Dye
REMAZOL TURQUOISE G-A LIQ 50	COPPER PHTHALOCY	DyStar L.P.	6,300	Dark Blue Liquid	Reactive Dye
CIBANONE RED BROWN RRF PST	Anthraquinone Dye	CIBA-GEIGY CORPORATION	3,960	PASTE	Vat Dye
ROYCEVAT OLIVE GREEN B DOUBLE PASTE		Passaic Color & Chemical	3,750	Aqueous paste	
CIBACRON BLUE C-4R POWDER	FORMAZINE METAL C	CIBA SPECIALTY CHEMICAL	2,573	Blue powder	Azo dye
ISOZOL TURQUOISE GA 50% LIQ	PHTHALOCYANINE DY	ISOCHEM INC.	2,500	Turquoise Liquid	Azo Dye
REMAZOL BRILL RED 3BS-A LIQ 25	REACTIVE DYE	DyStar L.P.	2,250	Red Orange Liquid	Reactive Dye

Table 2. (continued)

CIBACRON.ORANGE C-3R.33%.LIQUID.REACT	Azo Dye	CIBA-GEIGY CORPORATIO	2,200	Orange Liquid	Azo dye
PALANTHRENE BRILLIANT GREEN T-FFB LIQU	Violanthrone Dyes	BASF CORPORATION	2,112	Dark Green Liquid	Vat Dye
CIBACRON YELLOW F-3R POWDER(176#DRU	Azo Dye	CIBA-GEIGY CORPORATIO	1,760	Yellow Powder	Azo Dye
CIBACRON PLUM C-L68 LIQUID	AZO DYE MIXTURE	CIBA SPECIALTY CHEMICA	1,760	Violet liquid	Azo Dye
Camvat Brown ARN Double Paste	Anthraquinone	CAMPBELL COLORS, INC	1,639	Mild Liquid	Vat Dye
CIBACRON RED F-B POWDER(#220DRUM)	Azo Dye	CIBA-GEIGY CORPORATIO	1,320	Powder	Reactive Dye
INTRACRON NAVY BLUE VS-RGBP LIQ 50	Azo/vinyl sulfone dye	YORKSHIRE AMERICAS, IN	900	Dark blue liquid	Azo dye
CIBACRON NAVY W-B EXTRA, LIQUID 50%	Azo Dye	CIBA SPECIALTY CHEMICA	880	Black Liquid	Azo dye
CIBANONE.KHAKI2G.200%.PASTE.VAT	Anthraquinone Dye	CIBA SPECIALTY CHEMICA	880	Paste	Azo Dye
PALANTHRENE BROWN T 5170 COLL LIQUID	Anthraquinone Dye	BASF CORPORATION	792	Brown Liquid	Vat Dye
PALANTHRENE BLUE T-CLF LIQUID	Anthraquinone	BASF CORPORATION	792	Dark Blue Liquid	Vat Dye
NAVINON BROWN BR PASTE	Anthraquinone	SUNBELT CORPORATION	500	Brownish paste	Vat Dye
INDANTHREN.YELLOW F3GC..PASTE.VAT	Vat Dye	DyStar L.P.	500	Yellow Brown Powd	Vat Dye
SUMMAFIX.BLUE R.25%.LIQUID.REACTIVE	REACTIVE DYE	BLACKMAN UHLER CHEMIC	500	Blue Liquid	Reactive Dye
ISOZOL BLUE R LIQUID 25 %	REACTIVE DYE	ISOCHEM INC.	454	Blue Liquid	Reactive Dye
REMAZOL BRILL ORANGE R2G LIQ 25	FIBER REACTIVE AZO	DyStar L.P.	450	Orange Liquid	Azo Dye
REMAZOL BRILL YELLOW 4GL-A LIQ 25	AZO DYE	DyStar L.P.	450	Yellow Liquid	Azo Dye
CIBANONE ORANGE 5G DP	Anthraquinone Dye	CIBA-GEIGY CORPORATIO	440	PASTE	Vat Dye
CIBACRON RED C-2BL POWDER(110#DRUM)	Azo Dye	CIBA SPECIALTY CHEMICA	310	Dark red powder	Azo Dye
PALANTHRENE RED T-FBB COLLOISOL LIQ	Anthraquinone heterocy	BASF CORPORATION	264	Dark Red Liquid	Vat Dye
LEVAFIX NAVY CA GRANULAR	Azo Dye	DyStar L.P.	110	Dark Blue Powder	Direct Dye

An enhanced examination of the dyes is included in Table 3, where the non-azo dyes are listed. Because they appear to represent a major concern at the South plant, the red dyes in the chemical inventory at Plant A are summarized in Table 4.

The impacts of the dye discharges were visible at the South plant based on the apparent color of the wastewaters received. The contributions to color changes in wastewaters can be represented in the colors of the dyes used at Plant A. Red dyes represented 45.2% of the dyes used at Plant A, as shown in Figure 59 and below. The red dyes are summarized in Table 4.

Dye Color	% of total mass
Red	45.2%
Blue	23.8%
Green	10.2%
Black	9.4%
Orange	4.4%
Yellow	2.5%
Violet	2.1%
Turquoise	1.3%
Brown	1.0%

The pretreatment system at Plant A was focused on pH neutralization and on minimization of the effluent level of reducing-chemicals (i.e., sulfite) in the discharge. The pretreatment system would not however attenuate or degrade the dyes discharged to the pretreatment system. The uptake rates for the dyes on the textile materials was not specified but it was clear that (i) counter-current rinse waters were discharged to CWW sewer and (ii) batch-dumps of concentrated dye solution/suspension were released at the termination of a dye-range cycle and there were 5-10 range turnover per day at Plant A.

Table 3.

List of Non-Azo dye Chemicals & Quantity during Dye Period in Plant A

Product Name	Chemical Family	Vendor	Quantity (lb)	Form	Group
ISOZOL GREEN GN32 LIQUID 500#DRUM	Azo Dye	ISOCHEM INC.	125,700	Green liquid	Vat Dye
CIBACRON BLUE C-R LIQ 33	FORMAZINE METAL C	CIBA-GEIGY CORPORATIO	72,990	Blue Liquid	Reactive Dye
CIBANONE GREY P2R DP	MIXTURE	CIBA-GEIGY CORPORATIO	12,144	BLACK LIQUID	Vat Dye
CIBACRON TURQUOISE 3097 LIQ 33	PHTHALOCYANINE DY	CIBA-GEIGY CORPORATIO	10,560	Turquoise Liquid	Direct Dye
CIBANONE OLIVE T-C PST	Anthraquinone	CIBA-GEIGY CORPORATIO	6,688	LIQUID	Vat Dye
REMAZOL TURQUOISE G-A LIQ 50	COPPER PHTHALOCY	DyStar L.P.	6,300	Dark Blue Liquid	Reactive Dye
CIBANONE RED BROWN RRF PST	Anthraquinone Dye	CIBA-GEIGY CORPORATIO	3,960	PASTE	Vat Dye
ROYCEVAT OLIVE GREEN B DOUBLE PASTE		Passaic Color & Chemical	3,750	Aqueous paste	
REMAZOL BRILL RED 3BS-A LIQ 25	REACTIVE DYE	DyStar L.P.	2,250	Red Orange Liquid	Reactive Dye
PALANTHRENE BRILLIANT GREEN T-FFB LIQU	Violanthrone Dyes	BASF CORPORATION	2,112	Dark Green Liquid	Vat Dye
Camvat Brown ARN Double Paste	Anthraquinone	CAMPBELL COLORS, INC	1,639	Mild Liquid	Vat Dye
CIBACRON RED F-B POWDER(#220DRUM)	Azo Dye	CIBA-GEIGY CORPORATIO	1,320	Powder	Reactive Dye
PALANTHRENE BROWN T 5170 COLL LIQUID	Anthraquinone Dye	BASF CORPORATION	792	Brown Liquid	Vat Dye
PALANTHRENE BLUE T-CLF LIQUID	Anthraquinone	BASF CORPORATION	792	Dark Blue Liquid	Vat Dye
NAVINON BROWN BR PASTE	Anthraquinone	SUNBELT CORPORATION	500	Brownish paste	Vat Dye
INDANTHREN.YELLOW F3GC..PASTE.VAT	Vat Dye	DyStar L.P.	500	Yellow Brown Powd	Vat Dye
SUMMAFIX.BLUE R.25%.LIQUID.REACTIVE	REACTIVE DYE	BLACKMAN UHLER CHEMIC	500	Blue Liquid	Reactive Dye
ISOZOL BLUE R LIQUID 25 %	REACTIVE DYE	ISOCHEM INC.	454	Blue Liquid	Reactive Dye
CIBANONE ORANGE 5G DP	Anthraquinone Dye	CIBA-GEIGY CORPORATIO	440	PASTE	Vat Dye
PALANTHRENE RED T-FBB COLLOISOL LIQ	Anthraquinone heterocy	BASF CORPORATION	264	Dark Red Liquid	Vat Dye
LEVAFIX NAVY CA GRANULAR	Azo Dye	DyStar L.P.	110	Dark Blue Powder	Direct Dye
		Total =	253,765		

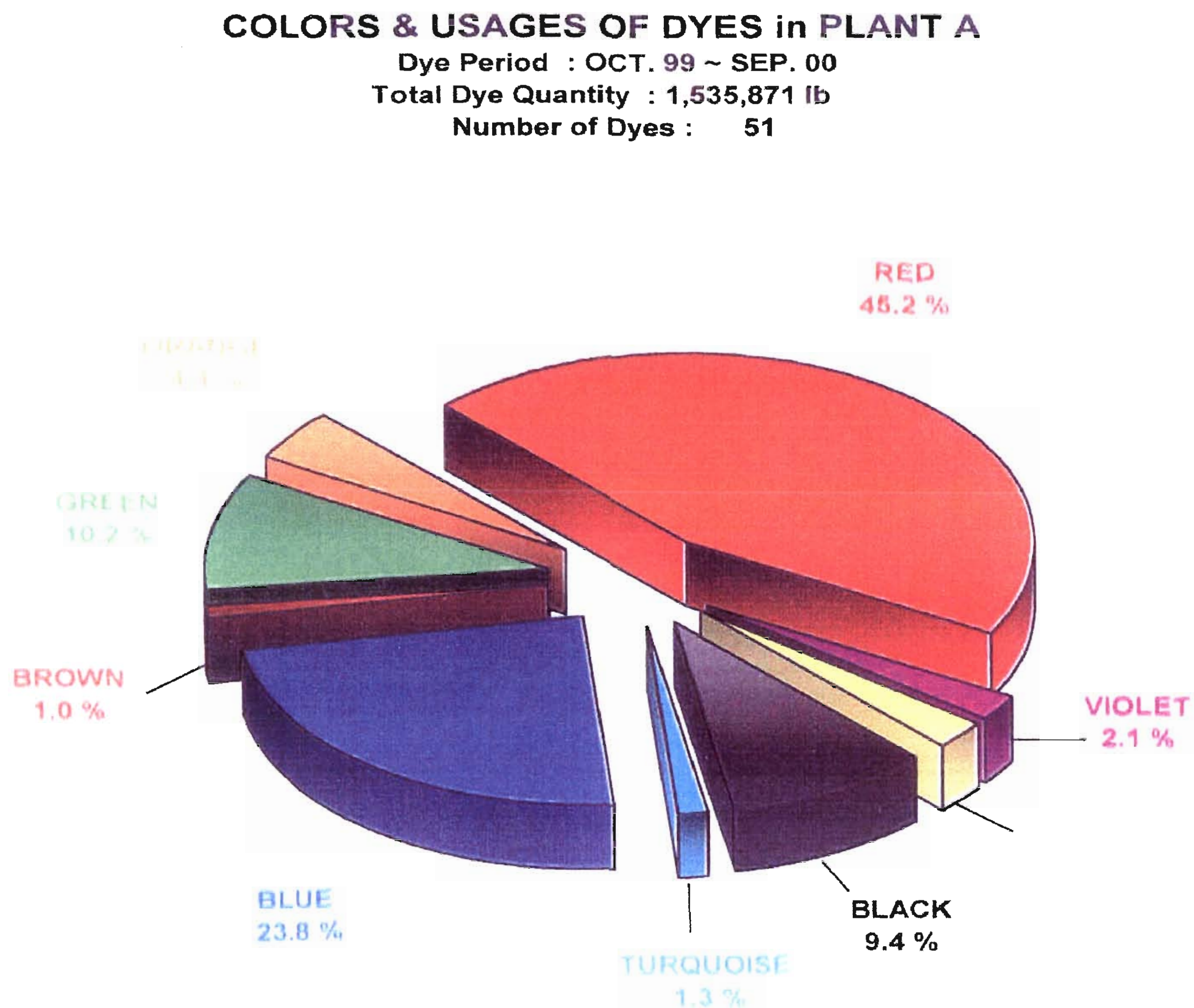
Table 4.

List of Red-color dye Chemicals & Quantity during Dye Period in Plant A

Dye Period: OCT. 99 ~ SEP. 00

Product Name	Chemical Family	Vendor	Quantity (lb)	Form	Group
ISOZOL RED 37 LIQUID (500#DRUM)	Azo Dye	ISOCHEM INC.	485,250	Red Liquid	Azo Dye
CIBACRON RED C-2G LIQ 33	MONOAZO DYE	CIBA-GEIGY CORPORATION	69,440	RED LIQUID	Azo Dye
CIBACRON.RED C-F 01.33%.LIQUID.REACTIVE	Mixture of azo dyes	CIBA SPECIALTY CHEMICAL	44,880	Red liquid	Azo Dye
FAST RED B BASE 40% SOLUTION	Aromatic amine	PFISTER CHEMICAL INC.	43,600	Deep red liquid	Azo Dye
CIBACRON RED C-R.25%.LIQUID.REACTIVE	Azo Dye	CIBA-GEIGY CORPORATION	33,890	Red Liquid	Azo Dye
ISOZOL RED 37 ACCLAIN LIQUID,56511 (500#DRUM)	Azo Dye	ISOCHEM INC.	9,000	Red Liquid	Azo Dye
CIBANONE RED BROWN RRF PST	Anthraquinone Dye	CIBA-GEIGY CORPORATION	3,960	PASTE	Vat Dye
REMAZOL BRILL RED 3BS-A LIQ 25	REACTIVE DYE	DyStar L.P.	2,250	Red Orange Liquid	Reactive Dye
CIBACRON RED F-B POWDER(#220DRUM)	Azo Dye	CIBA-GEIGY CORPORATION	1,320	Powder	Reactive Dye
CIBACRON RED C-2BL POWDER(110#DRUM)	Azo Dye	CIBA SPECIALTY CHEMICAL	310	Dark red powder	Azo Dye
PALANTHRENE RED T-FBB COLLOISOL LIQ	Anthraquinone heterocycle	BASF CORPORATION	264	Dark Red Liquid	Vat Dye

Figure 59



COLORS & USAGES OF DYES in PLANT A
Dye Period : OCT. 99 ~ SEP. 00
Total Dye Quantity : 1,535,871 lb
Number of Dyes : 51
RED
45.2 %
GREEN
10.2 %
BROWN
1.0 %
VIOLET
2.1 %
BLUE
23.8 %
BLACK
9.4 %
TURQUOISE
1.3 %

Plant B

Plant B used a modest array of dyes and chemicals due to the primary focus on denim as a final product fabric. The plant inventory included 1.35×10^7 pounds/year (6,218 metric tons/year) as included in 34 specific dyes and chemicals, as summarized in Figure 60. In comparison to Plant A above, this was a mass inventory that was <40% of that for plant A. The number of chemicals used was less as well (i.e., <45% of the number for plant A). As summarized in Figure 60, inorganic chemicals, organic chemical and dyes accounted for similar portions of the inventory. Inorganic chemicals were 43.5%, while organic chemicals and dyes were 34.7% and 21.8% respectively.

The dyes included eight (8) specific dyes with one dye, i.e., indigo dye (Dark Blue), representing over 67% of the dye inventory, as presented in Figure 61. This indigo dye was classified as a vat dye, while all others (i.e., &) were sulfur dyes. The colors of the 7 remaining dyes were green (2), black (3) and brown (2) as included in Figure 62 and Table 5. It is therefore obvious that Plant B discharges would, based on dye usage, contribute a blue-black or dark color to the South plant, and was not a source of red, or other vivid, colors.

Inorganic and organic chemicals were presented as those used on the dye range and in slashing and finishing in Table 5. The primary chemicals in terms of mass usage were: a reducing agent (Reductone), sodium hydroxide and slashing and finishing surfactants and surface finishes.

Figure 60

PERCENTAGE OF DYES USAGE IN PLANT B

Dye Period : Oct. 99 ~ Sep. 00
Total Chemical Quantity : 13,497,694 lb
Number of Dyes + Chemicals : 34

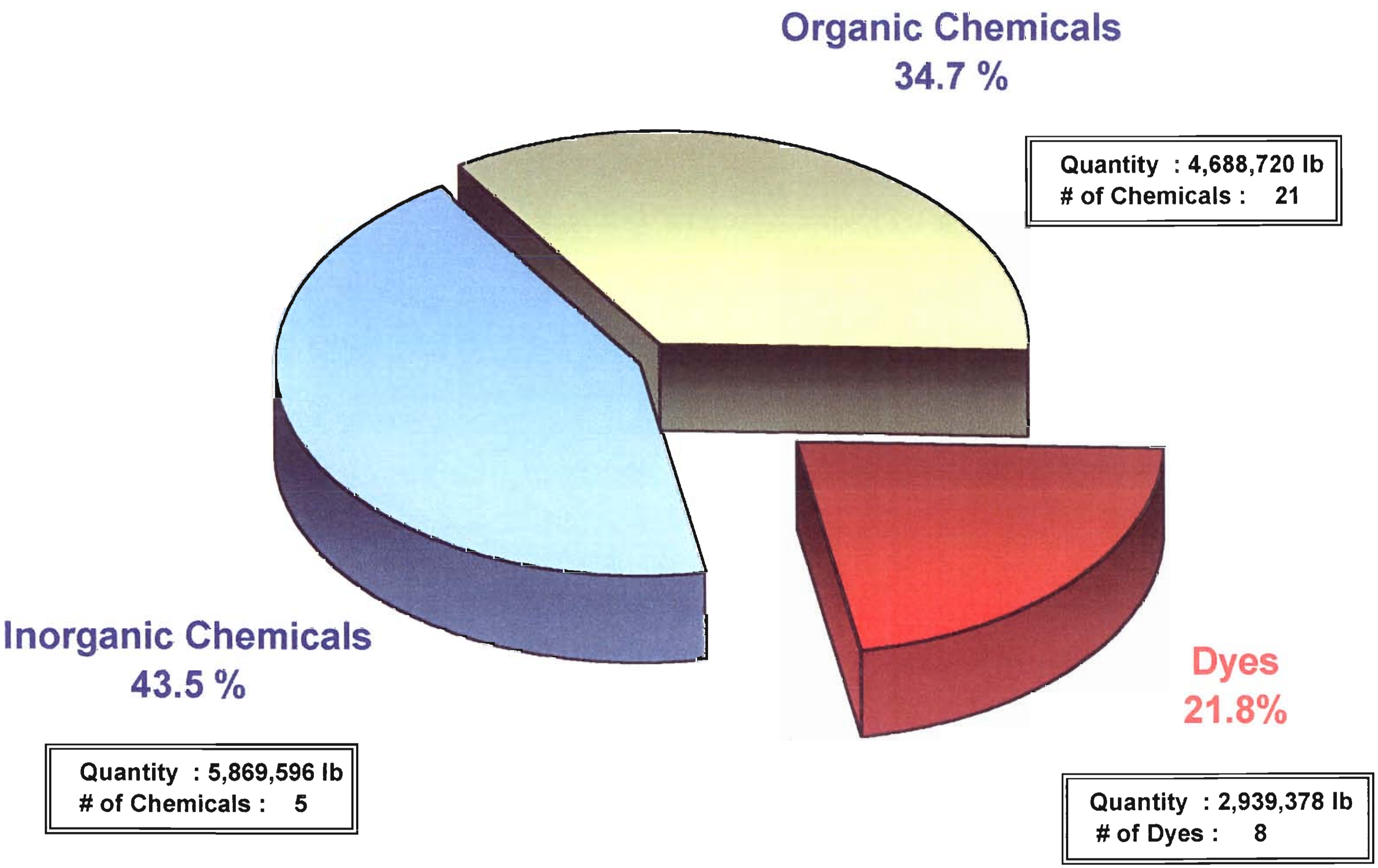


Figure 61

TYPES & USAGES OF DYES IN PLANT B

Dye Period : Oct. 99 ~ Sep. 00
Total Dye Quantity : 2,939,378 lb
Number of Dyes : 8

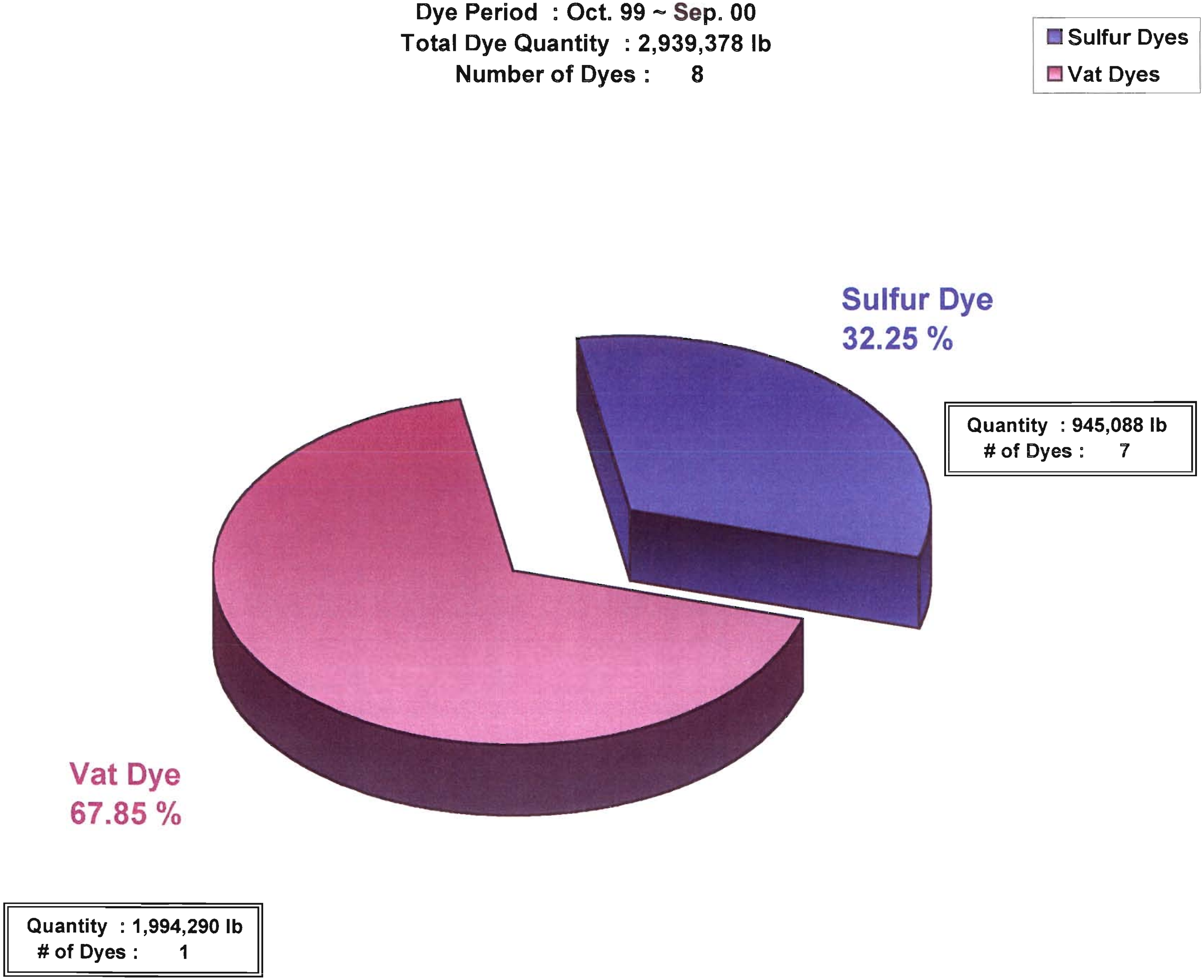


Figure 62

COLORS & USAGES OF DYES IN PLANT B

Dye Period : Oct. 99 ~ Sep. 00

Total Dye Quantity : 2,939,378 lb

Number of Dyes : 8

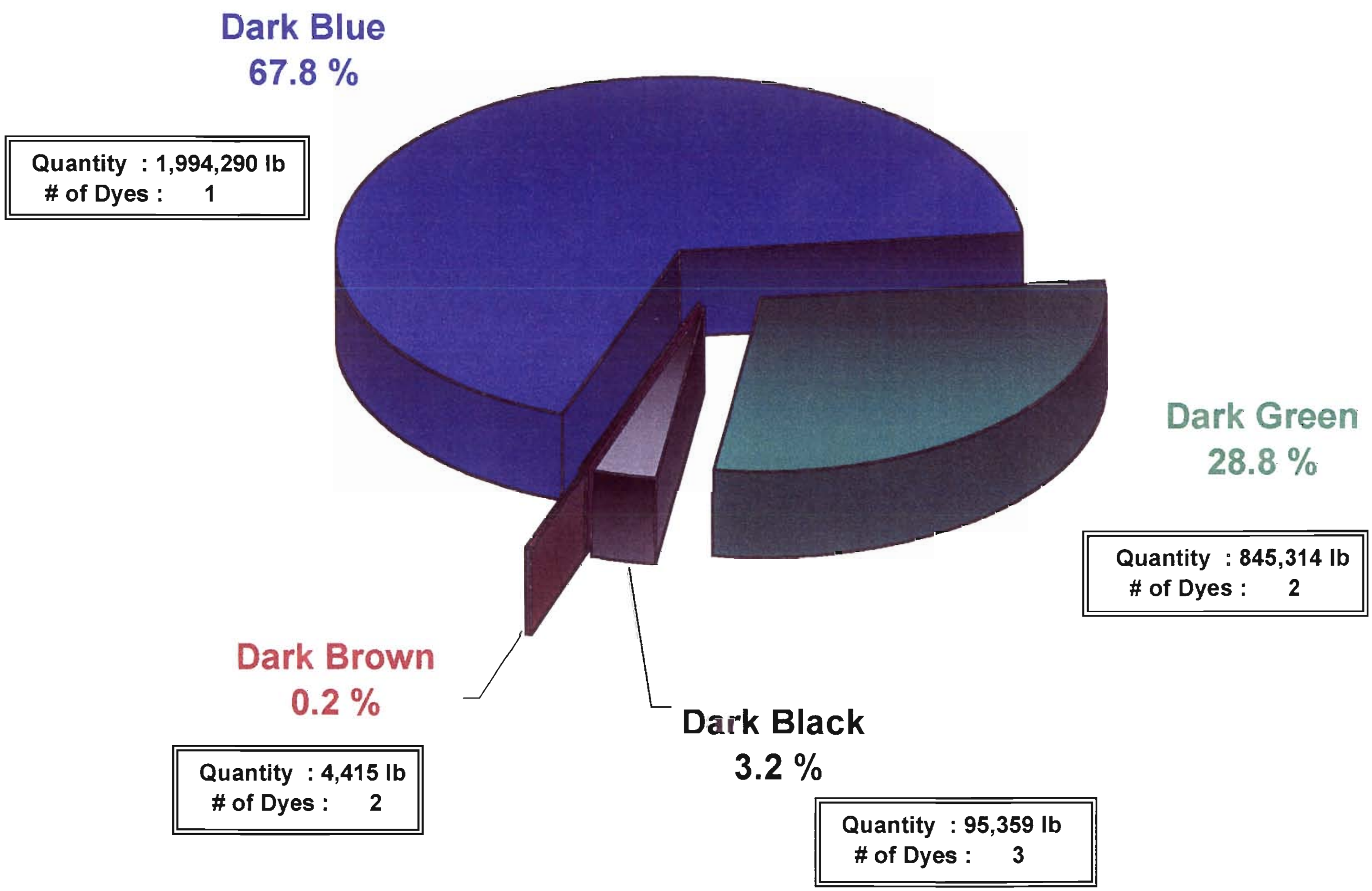


Table 5.

List of DYES & CHEMICALS QUANTITY during Dye Period in Plant B

Dye Period: OCT. 99 ~ SEP. 00

DYE RANGE

- Dye chemicals

Product Name	Chemical Family	Vendor	Quantity(lb)	Form
20% INDIGO PASTE	Vat Dye	C.H. PATRICK & COMPANY, INC.	1,994,290	Dark Liquid
GREEN BLACK GX	Mixture of Dyes(Sulfur dy	C.H. PATRICK & COMPANY, INC.	839,110	Black Liquid
BLACK 4RB	Mixture of Dyes	C.H. PATRICK & COMPANY, INC.	92,998	Black Liquid
SODYESUL GREEN 3BCF	Leuco Sulfur Dye	CLARIANT, LTD	6,204	Dark Greenish Liquid
SANDOZOL BROWN DB-RDT	Leuco Sulfur Dye	CLARIANT, LTD	2,355	Dark Brown Liquid
SODYESUL BROWN GNCF	Leuco Sulfur Dye	CLARIANT, LTD	2,060	Dark Brown Liquid
SODYESUL BLACK 4GCF	Leuco Sulfur Dye	CLARIANT, LTD	1,241	Dark Black Liquid
SODYESUL BLACK PLCF	Leuco Sulfur Dye	CLARIANT, LTD	1,120	Dark Black Liquid

- Non-Dye chemicals

Product Name	Chemical Family	Vendor	Quantity(lb)	Form
REDUCTONE 125GPL			4,394,142	
CAUSTIC 50%	ALKALI	ELF ATOCHEM NORTH AMERICA	1,125,946	Water white to slightly turbid Liquid
CALLAWAY 1806	Polyethylene Emusion Bl	VULCAN PERFERMANCE CHEMICALS	600,154	Liquid
SODYEFIDE B	Sulfide Solution	CLARIANT, LTD	181,032	YELLOW ORANGE LIQUID
ARROQUEST 2210	Salt of Organic Acid	ARROW ENGINEERING, INC.	172,166	Straw colored liquid
DRY HYDRO			164,066	
ARROWET 2634	Organic Hydrocarbon Ble	ARROW ENGINEERING, INC.	93,494	Clear Liquid
OXIDIZER B	Catalyzed Sodium Broma	CLARIANT, LTD	4,410	Water white to light yellow Liquid
56%ACETIC ACID	Acetic Acid	INDUSTRIAL CHEMICALS, INC.	4,375	Clear Colorless mobile Liquid
PENETRANT EH-MOD	Anionic Surfactant	CLARIANT, LTD	765	Pale Yellow Clear Liquid

Table 5. (continued)

SLASHING

Product Name	Chemical Family	Vendor	Quantity(lb)	Form
PHILBLEND 528	Warp Size	PROCESS CHEMICALS, LLC	1,446,104	White Granular Powder
PHILBIND 918	Warp Size (styrene/butad	PROCESS CHEMICALS, LLC	587,059	White Liquid
PHILWAX 126	Fatty lubricant (Fatty Gly	PROCESS CHEMICALS, LLC	118,560	Pale white/yellow waxy solid
PHILCHEM 823	Size	PROCESS CHEMICALS, LLC	31,200	White Granular Powder
OTHER			20,020	

FINISHING RANGE

Product Name	Chemical Family	Vendor	Quantity(lb)	Form
ARROSOFT DFS	Organic complex	ARROW ENGINEERING, INC.	454,111	White Liquid
ARROTEX CHS	Organic complex	ARROW ENGINEERING, INC.	409,500	Liquid
DISCOL 716	Cationic Polymer(Polyam	VULCAN PERFERMANCE CHEMICALS	234,312	Dark, amber Liquid
CALLAWAY 1839	Polyethylene Emulsion B	VULCAN PERFERMANCE CHEMICALS	143,540	Milky, light-colored Liquid
CALLAWAY 4600	Nonionic Polyacrylamide	VULCAN PERFERMANCE CHEMICALS	109,200	Clear Liquid
CALLAWAY 1668	Nonionic Surfactant (use	VULCAN PERFERMANCE CHEMICALS	84,240	Liquid
ARROPOL MPS	Proprietary	ARROW ENGINEERING, INC.	69,628	Off White Liquid
ARROWET ZR3	Organic complex	ARROW ENGINEERING, INC.	69,212	Clear Liquid
PENETRANT EH	Anionic Surfactant	CLARIANT, LTD	41,080	Pale Yellow Clear Liquid

The pretreatment system at Plant B was focused on pH neutralization and on minimization of the effluent level of reducing-chemicals (i.e., sulfite) in the discharge. The pretreatment system included aeration of the wastewater, and previous data indicated that biological degradation probably occurred within the systems. While dye degradation was not expected, several of the organic chemicals could have been degraded in this system. It is also possible that sulfite oxidation could have occurred in the aeration system. Given that this is an inorganic reducing agent, it would easily represent "COD" discharged to the equalization basin. Sulfite oxidation would furthermore proceed at a rapid rate in an aeration system and it is anticipated that this would represent a significant portion of the apparent organic reduction noted and would furthermore minimize this reducing-power loading on the CWW sewer system and the South plant.

Plants C,D

The chemical inventories for plants C & D (referred to hereafter as Plant C,D) were provided without separation by plant. Plant C was examined intensely with respect to its wastewater reclamation system, which included a pH neutralization, nutrient-addition, biological-oxidation and final sedimentation systems, as well as a sludge dewatering systems. Plant D was a smaller facility and its wastewaters were neutralized and discharged.

Plant C,D used a modest array of dyes and chemicals due to the primary focus on denim as a final product fabric. The plant inventory included 3.84×10^7 pounds/year (17,454 metric tons/year) as included in 45 specific dyes and chemicals, as summarized in Figure

63 and Table 6. This mass inventory was similar in mass inventory to Plant A, but incorporated about half as many specific chemicals (being similar in this regard to Plant B, a denim producer as well).

The dyes included seven (7) specific dyes with vat and sulfur dyes being dominant (see Figure 64). Indigo (42%) was the dominant dye compound used. Dark blue (4) and dark black (2) dyes accounted for >99% of the dye inventory, with one dark green (1) dye accounting for the balance (see Figure 65). The indigo paste and a dark-navy dye were vat dyes and the balance were sulfur (4) and azo-dyes (1), as summarized in Figure 64. It is therefore obvious that Plant C,D discharges would, based on dye usage, contribute a blue-black or dark color to the South plant.

Sodium hydroxide (i.e., caustic) accounted for ~85% of the inorganic chemical inventory, with sulfite being the next most significant inorganic chemical in the C,D inventory. Acetic acid and starch and softeners were the primary organic chemicals, totaling 1.35×10^7 lb/yr.

The pretreatment system at Plant C was focused on pH neutralization, nutrient-addition, biological-oxidation and final sedimentation systems, as well as a sludge dewatering systems. This system removed over 70% of the influent COD, representing major removal of dyes and organic chemicals. While not quantified, it was abundantly clear from site visits that the dewatered sludge from the plant containing considerable indigo and other dark dyes within the biomass matrix.

Figure 63

PERCENTAGE OF DYES USAGE IN PLANT C,D

Dye Period : Jan. 00 ~ Dec. 00

Total Chemical Quantity : 38,444,089 lb

Number of Dyes + Chemicals : 45

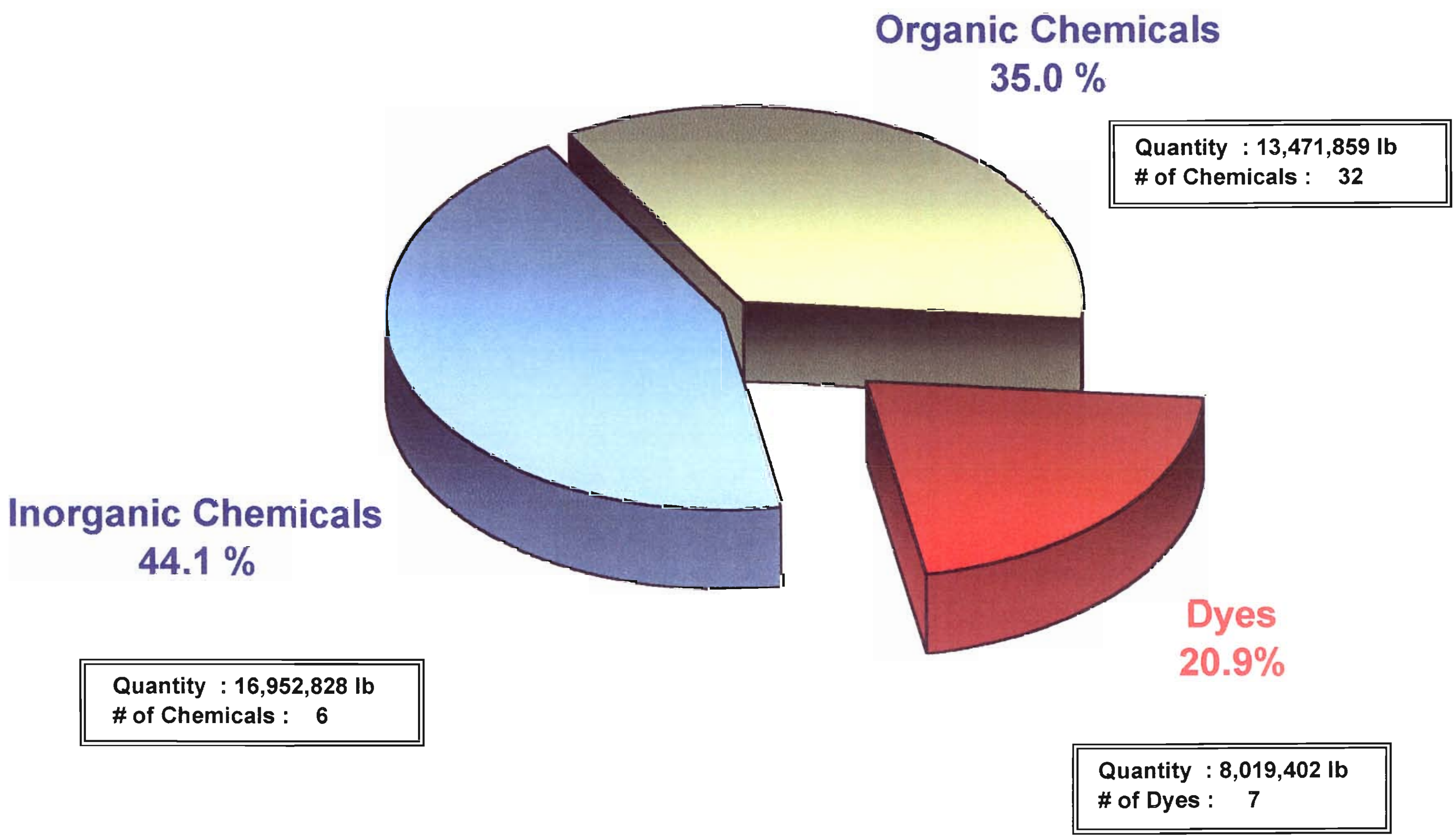


Table 6.

List of Dye Chemicals & Quantity during Dye Period in Plant C, D

Dye Period: JAN. 00 ~ DEC. 00

Product Name	Chemical Family	Vendor	Quantity(lb)	Form
INDIGO PASTE	Indigoid	BUFFALO COLOR CORPORATION	3,387,321	Thin, dark blue aqueous paste
PATCO DENIM BLACK SC	Mixture of Dyes	BFGOODRICH	2,969,169	Black corrosive liquid
SODYESUL BLACK 4GCF	LEUCO SULFUR DYE	CLARIANT, LTD	1,479,232	Dark black liquid
SODYESUL NAVY GFCF	Reduced Vat Dye	CLARIANT, LTD	160,000	Dark Navy liquid
SODYESUL GREEN 3BCF	LEUCO SULFUR DYE	BFGOODRICH	18,000	Dark greenish liquid
AMECRON NAVY ABBA	AZO	RITE INDUSTRIES, INC.	4,180	Dark Powder
SODYESUL NAVY GICF	LEUCO SULFUR DYE	CLARIANT, LTD	1,500	Dark Blue Liquid
		Total =	8,019,402	

List of Non-Dye Chemicals & Quantity during Dye Period in Plant C, D

Dye Period: JAN. 00 ~ DEC. 00

Product Name	Chemical Family	Vendor	Quantity(lb)	Form
CAUSTIC SODA 50%	Alkali, Base (Neutralizing agent, sodium source)	WESTLAKE CA AND O CORPORATION	4,467,965	Clear, viscous liquid
		P B S CHEMICAL COMPANY, INC.	3,624,040	
		INDUSTRIAL CHEMICALS, INC.	529,235	
CAUSTIC LIQ 50% BULK-FINISH		P B S CHEMICAL COMPANY, INC.	2,885,820	
		INDUSTRIAL CHEMICALS, INC.	2,337,355	
		WESTLAKE CA AND O CORPORATION	506,955	
STARCH, CALIBER 120-BULK		CARGILL, INC.	4,594,990	White powder
		GRAIN PROCESSING CORPORATION	181,240	
FABRITONE RM SPECIAL BULK	Nonionic Softener	BFGOODRICH	1,418,035	Milky white liquid
ACETIC ACID 56% - Bulk	Acid	INDUSTRIAL CHEMICALS, INC.	1,090,220	Clear, colorless mobile liquid
CLARATE 100	Chelating Agent	BFGOODRICH	888,345	Liquid
Sodium Hydrosulfite solution	Sulfite(reducing agent)	OLIN CHEMICAL	824,409	clear yellow liquid
D SIZE 527C	Blend	CELANESE CHEMICALS	387,350	Amorphrous powder
		CLARIANT, LTD	399,500	
SULFADYE 31 - DYE	Inorganic Sulfide	BFGOODRICH	775,678	Clear yellow
SULFADYE 31 - FINISH	Inorganic Sulfide	BFGOODRICH	709,399	to yellow-green liquid
FABRITONE MM-18-DRUM	Cationic Softener	BFGOODRICH	419,900	Translucent Liquid

Table 6. (continued)

DISCOL 2007	Cationic, Polyamine Resin	VULCAN PERFERMANCE CHEMICALS	379,280	Liquid
FLEXGRIP S	Synthetic and Natural Polymer Blend	CALGATI CHEMICAL CO. LTD.	342,000	Off-white Powder
		CALGATI CHEMICAL COMPANY LTD.	28,000	
NORPOL 7352	Water Soluble Polymer	CELANESE CHEMICALS	321,750	Mobile liquid
FLEXBIND 312	Vinyl Polymer	CALGATI CHEMICAL CO. LTD.	270,250	Light amber Liquid
		CALGATI CHEMICAL COMPANY LTD.	37,600	
SEYCOSIZE SGL		SEYDEL WOOLLEY AND COMPANY	305,000	Powder
KARALUBE T	Nonionic Softener	BFGOODRICH	258,400	Opaque, off-white emulsion
FABRITONE MC-25HD-DRUM	Cationic Polyethylene Softener	BFGOODRICH	248,400	Translucent Liquid
Airvol Plus 7256B	Vinyl Polymer, Starch	CELANESE CHEMICALS	226,700	Amorphous powder
ACETIC ACID 56%		INDUSTRIAL CHEMICALS, INC.	198,900	
PENETROL STC-2	Anionic Surfactant	BFGOODRICH	163,800	Clear, light amber liquid
WETAID SR SPECIAL	Anionic Surfactant	BFGOODRICH	160,200	Clear liquid
WETAID 27-E	Wetting agent for textile applications.	BFGOODRICH	144,000	Liquid
ST WAX	Hydrogenated Tallow	CALGATI CHEMICAL CO. LTD.	122,000	Solid
	glyceride Compound	CALGATI CHEMICAL COMPANY LTD.	10,000	
HYDROSULFITE	Sodium dithionite	BENCO INTERNATIONAL LLC	113,728	White powder
PATCO REDUCER DXL	Saccharide	BFGOODRICH	109,000	Dark Brown Liquid
ANTISTAT S	Polyoxyethylene Tallow	CALGATI CHEMICAL CO. LTD.	95,400	Yellow to amber liquid
	Amine Solution Blend	RITE INDUSTRIES, INC.	5,569	
		CALGATI CHEMICAL COMPANY LTD.	5,400	
Plasticryl SA-PL	Polyacrylate salt in water	ABCO INDUSTRIES, INC.	99,900	Clear to hazy liquid
(DRY HYDRO) DRUM	and Stabilizing agents	INDUSTRIAL CHEMICALS, INC.	95,000	
HCI DEFOAMER	Surfactant Hydrocarbon Blend	CALGATI CHEMICAL CO. LTD.	86,640	Opaque white liquid
		CALGATI CHEMICAL COMPANY LTD.	7,600	
CAUSTIC SODA 50% DR/TOTE		INDUSTRIAL CHEMICALS, INC.	91,744	
KAROX VSO	Textile Dyeing Auxiliary	BFGOODRICH	73,500	Clear , colorless liquid
CLARATE 100 - DRUM	Chelating Agent	BFGOODRICH	70,400	Liquid
ANTISTAT N-50	Nonionic Surfactant	UNITED ANILINE CHEMICAL COMPAN	64,500	light yellow, clear liquid
UNIWET-WRW-4	Anionic Acid Ester	UNITED ANILINE CHEMICAL COMPAN	60,140	Clear to light yellow liquid
FOAMEX		ABCO INDUSTRIES, INC.	55,800	White viscous liquid
WETAID NI CONC	Nonionic Surfactant	BFGOODRICH	51,750	Clear Colorless Liquid
WAX 528P	Blend of lubricants and emulsifiers	ABCO INDUSTRIES, INC.	32,000	White granules
KARAFAC 505	Textile Preparation Mixture	BFGOODRICH	22,500	Clear colorless liquid
SULFADYE 31 - DRUM	Inorganic Sulfide	BFGOODRICH	13,000	Yellow to yellow-green liquid
Sandofix TP Liquid	CATION ORGANIC CHEMICAL	CLARIANT, LTD	8,500	Colorless to yellow liquid
Swift Special Mix	Textile Auxiliary chemical Mixture	CLARIANT, LTD	3,200	Clear Viscous Liquid
WETAID FRS	Anionic/Non-ioninc Surfactant	BFGOODRICH	2,700	Clear yellow liquid
		Total =	30,424,687	

Figure 64

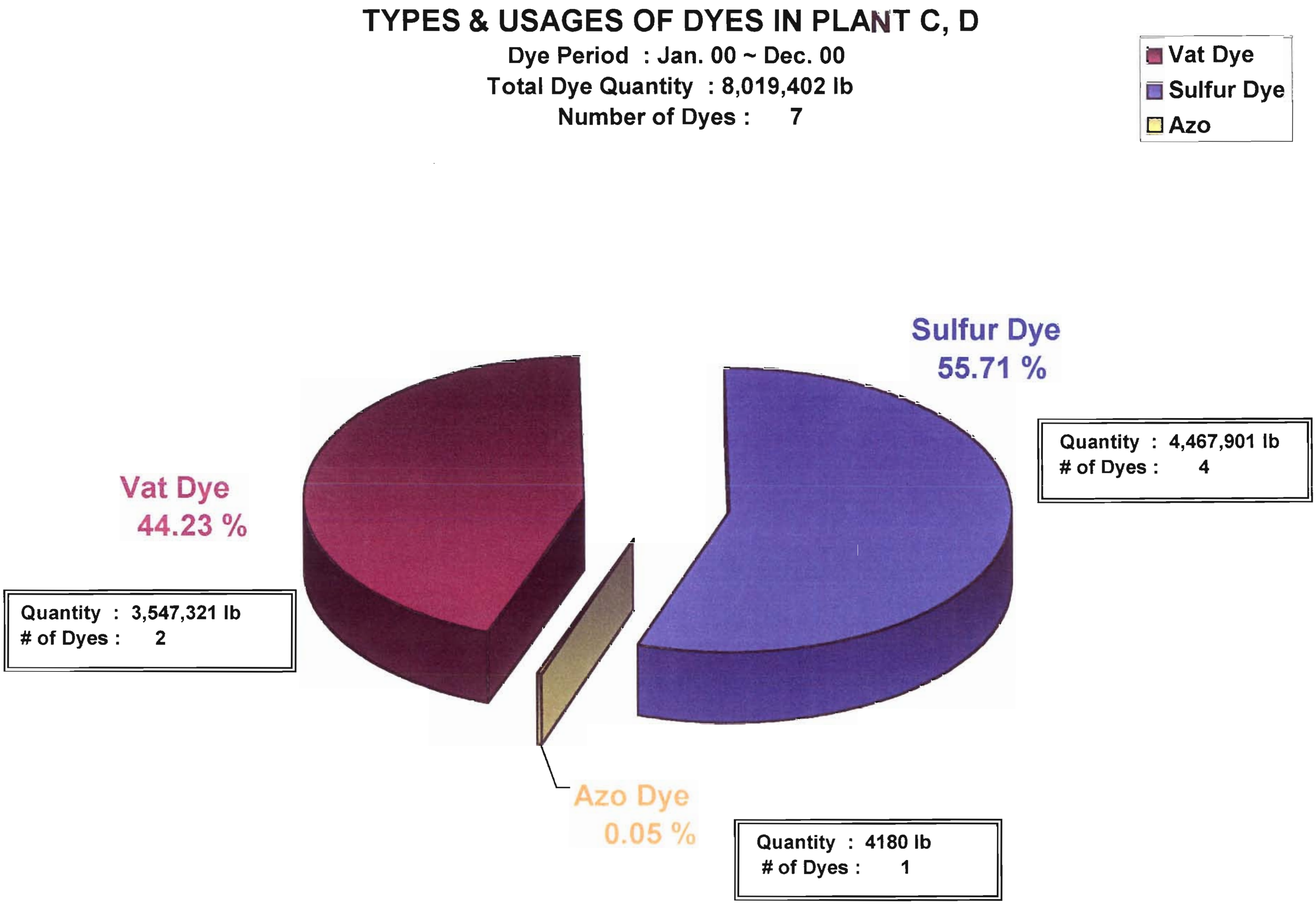
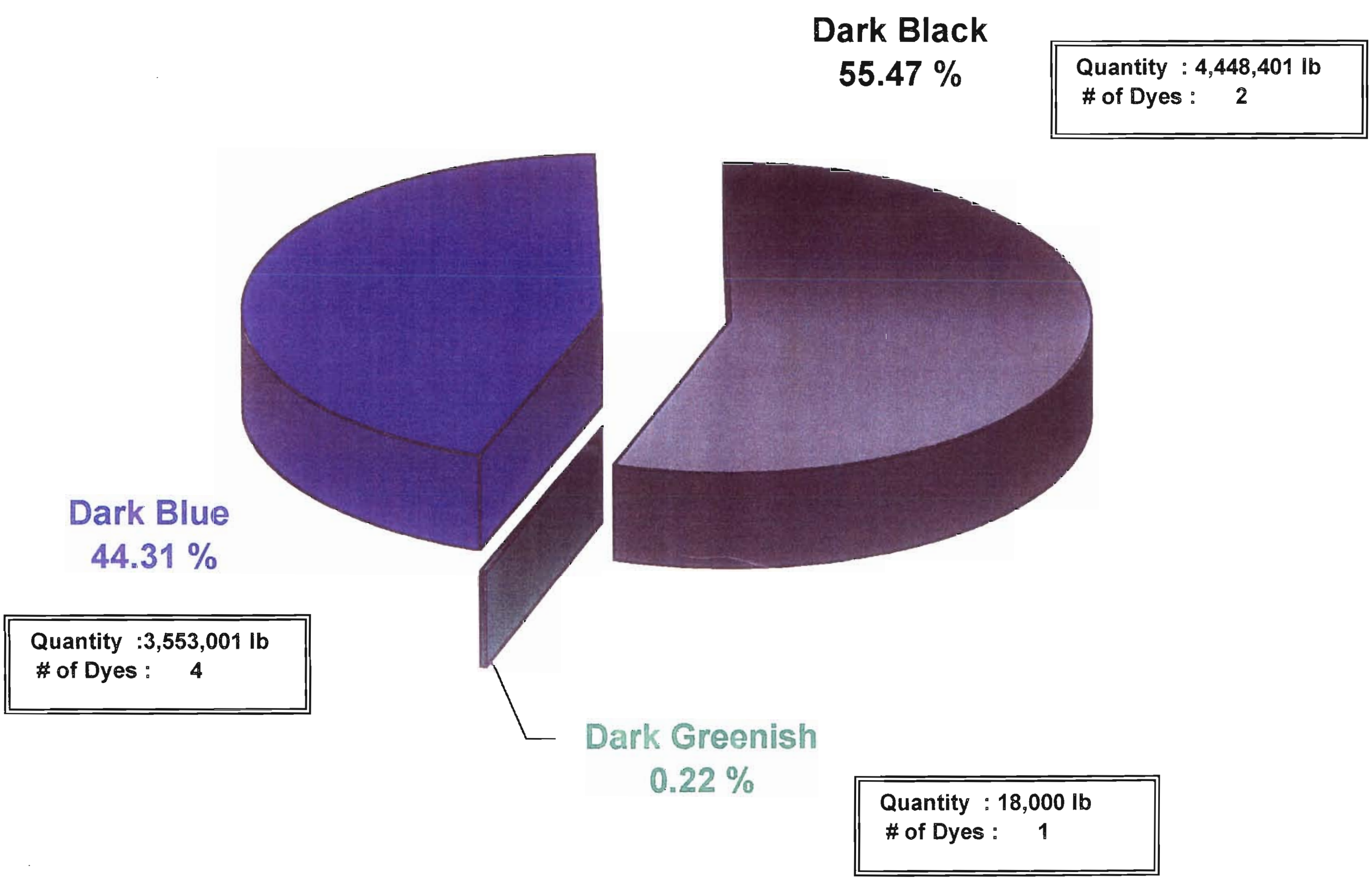

TYPES & USAGES OF DYES IN PLANT C, D
Dye Period : Jan. 00 ~ Dec. 00
Total Dye Quantity : 8,019,402 lb
Number of Dyes : 7
Vat Dye
Sulfur Dye
Azo
Sulfur Dye
55.71 %
Quantity : 4,467,901 lb
# of Dyes : 4
Vat Dye
44.23 %
Quantity : 3,547,321 lb
# of Dyes : 2
Azo Dye
0.05 %
Quantity : 4180 lb
# of Dyes : 1

Figure 65

COLORS & USAGES OF DYES IN PLANT C, D

Dye Period : Jan. 00 ~ Dec. 00
Total Dye Quantity : 8,019,402 lb
Number of Dyes : 7



Impacts and Recommendations

The wastewater flows from Plants A, B and C represented a total average annual flow of approximately 3.3 mgd (i.e., Plants A, B and C at 2.6mgd, 0.27mgd and 0.46mgd, respectively). Using the annual flow data from Figure 66, the average annual flow at the South plant was assumed to be approximately 30 mgd. The projected flow from the three textile plants was therefore equal to approximately 11% of the total wastewater flow into the South Plant of CWW. Based on hydraulic loadings, the textile plants do not represent a major concern with respect to flow.

The primary concern regarding the three textile plants is the organic-chemical and dye loading placed on the South plant and the river discharge. Using COD data from the individual plants, the plants represented a total COD mass loading of 22,917 kg/day. These data are included in Figure 67 with the COD monitoring data available from CWW and are summarized below.

COD loadings at South Plant and Contributed by Textile Plants

Plant	COD load, kg/d	(std. dev)	% of South-CWW
South – CWW	72,655	(23,152)	---
Textile Plants			
A	19,349	(8,977)	26.6
B	2,126	(2,884)	2.9
C	1,442	(659)	2.0
Total	22,917		31.5

Plants A, B and C accounted for 22,917 kg/d of COD loading which was 31.5% of the total COD loading on the South plant, when compared to the COD loading (based on

Figure 66. EFFLUENT DISCHARGE PATTERN
SOUTH PLANT - 1/00 ~ 8/01
(Source: Daily monitoring from South Plant)

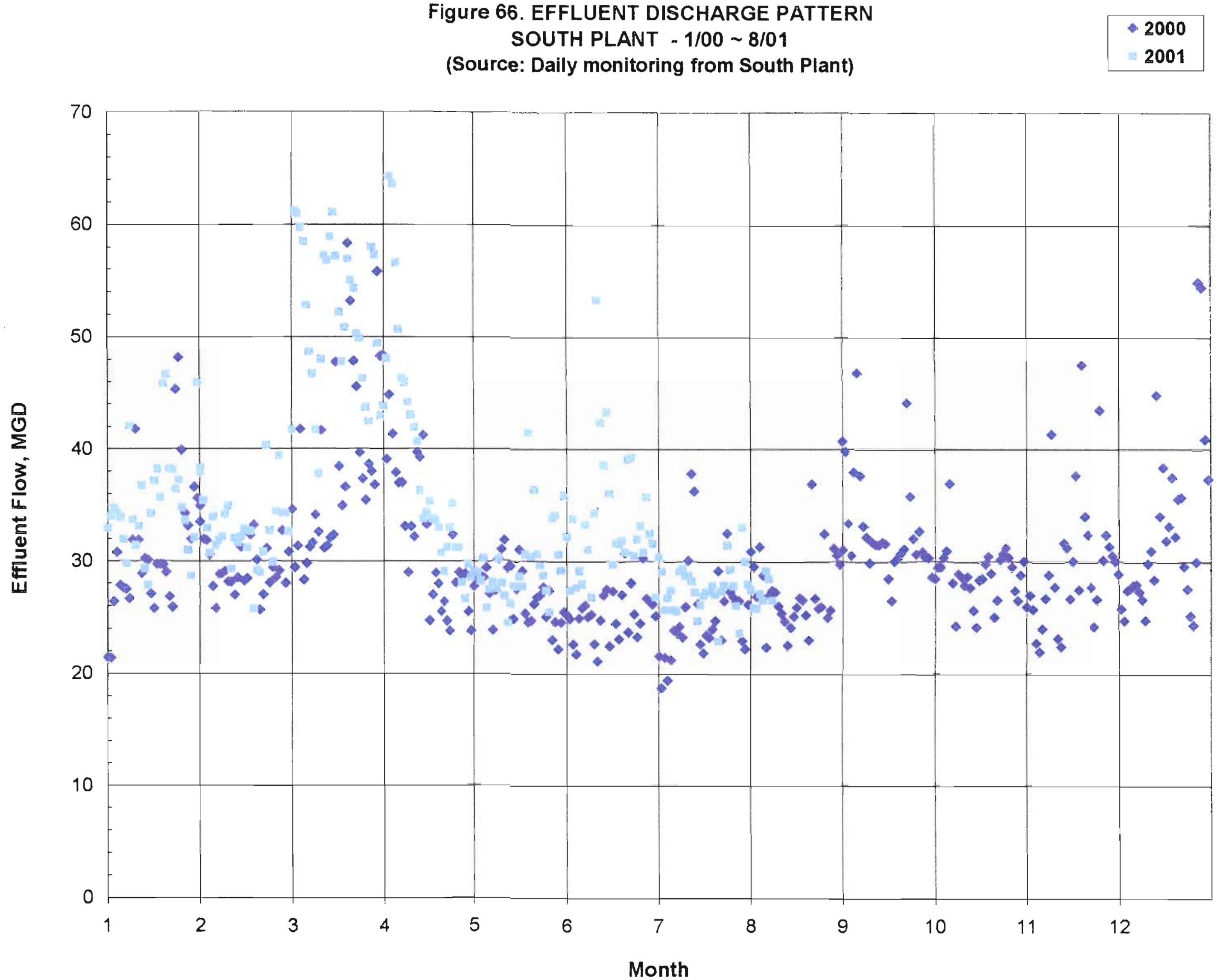
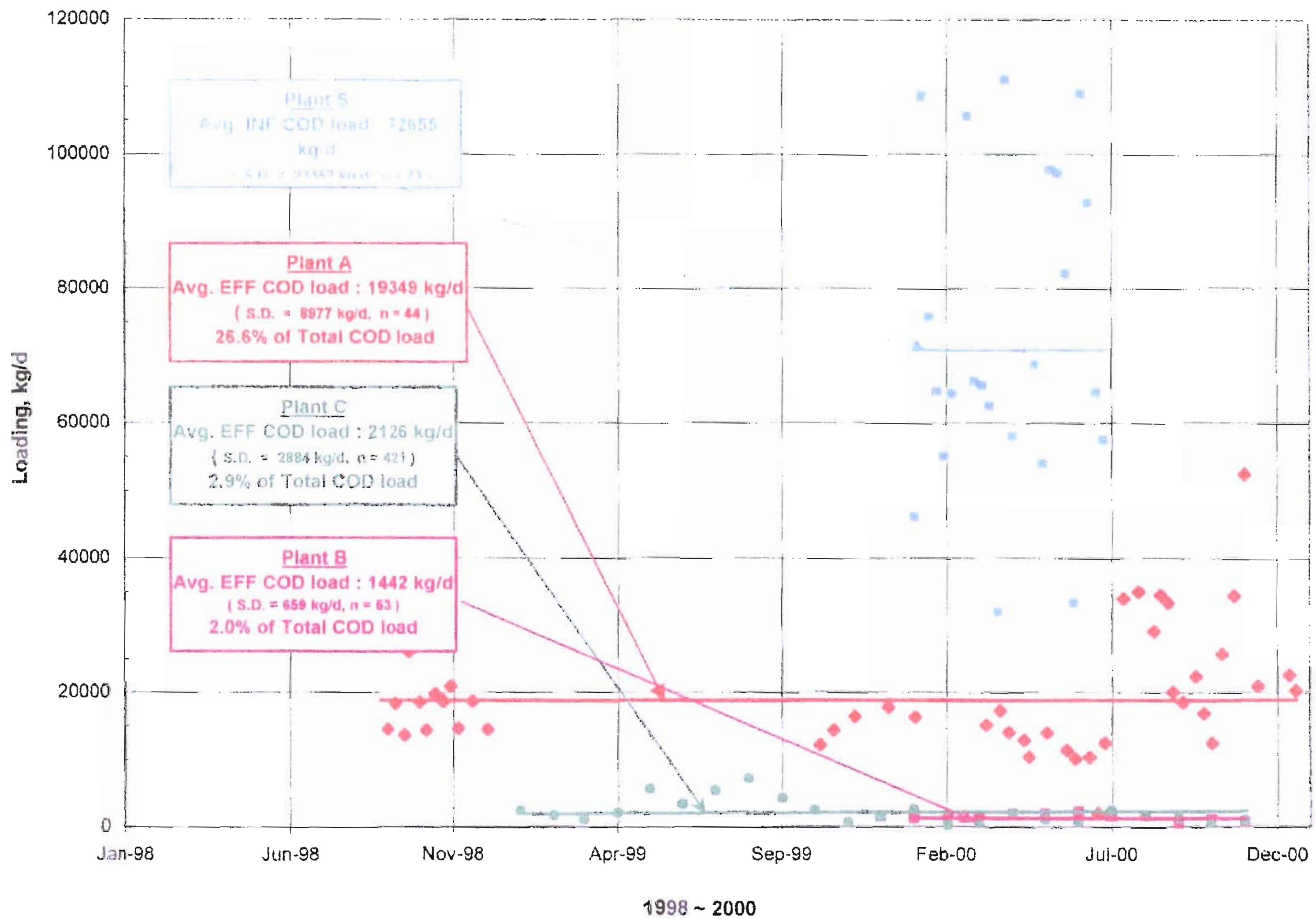


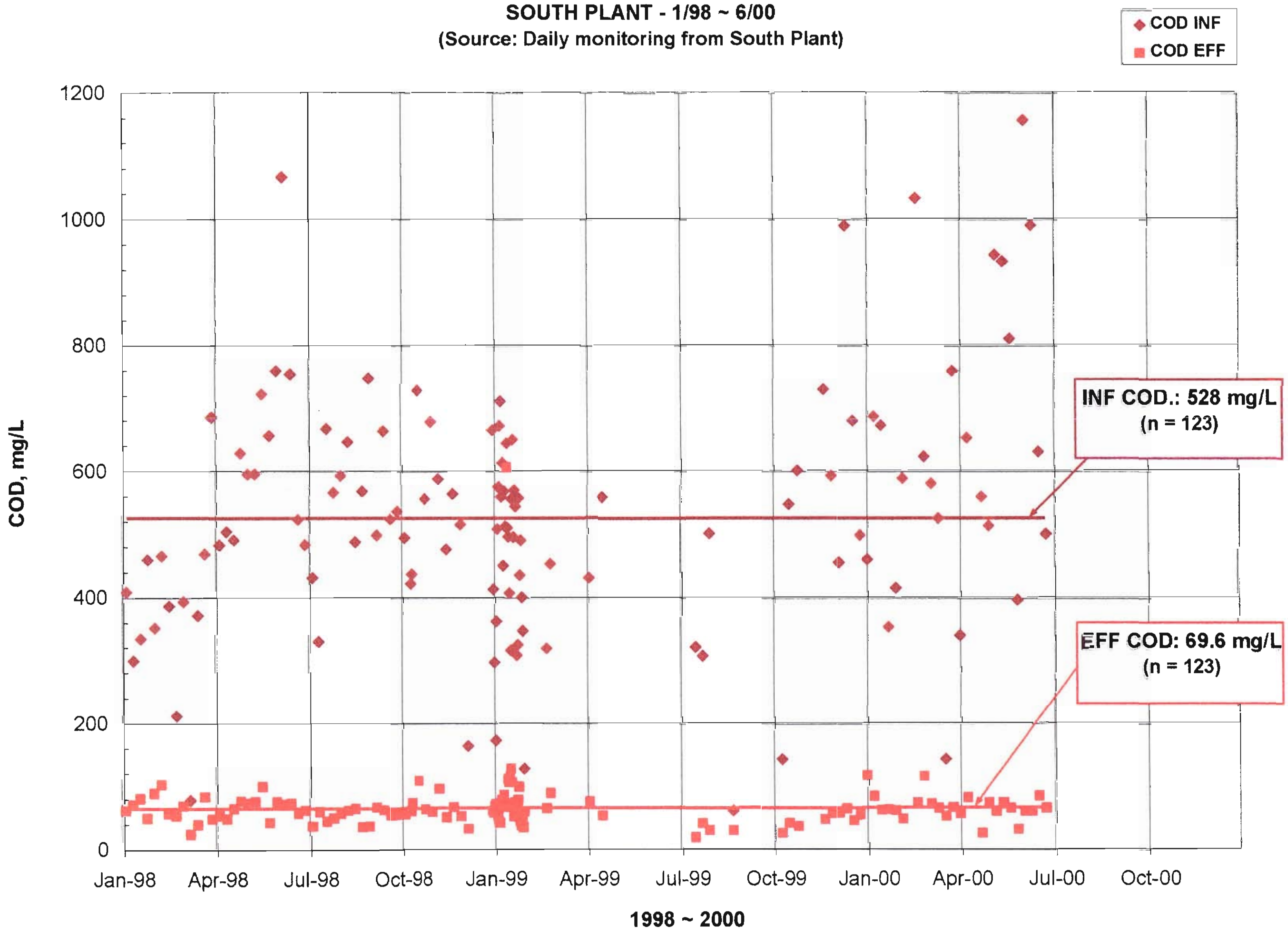
Figure 67. **COMPARISON of COD LOADING in WASTEWATER DISCHARGE (Qw) from EACH PLANT**
PLANT A,B,C and S - 9/98 ~ 12/00
(Source: COD conc. = 24-hr composite (CWW) and Self Monitoring (Plant) &
Flow = Average Daily Flow from Plant and Total Monthly Discharge Data of CWW)



limited CWW data in the period of early 2000) of 72,655kg/day. Finally, when the three textile-plant effluents are examined with respect to the projected base domestic/commercial loading, the COD discharges of the textile plants raised the COD loading from 49,738 kg/day to 72,655kg/d. This thereby represents a 46% increase over the base domestic/commercial loading on the plant.

If the South plant COD loading is reduced by the textile plant loading, the remaining estimated domestic and commercial loading would be approximately 49,738kg/d (i.e., 72,655kg/day minus 22,917kg/d). Using a South-plant flow of 27.7 mgd (i.e., 30mgd minus 3.3mgd of textile plants), this would represent a COD concentration of approximately 475 mg/L, which is comparable to a medium-strength domestic wastewater (COD ~430mg/L). Data in Figure 68 indicate that the average influent COD at the South plant was 528 mg/L in the period of 1998 through June 2000, indicating that background COD values are potentially similar to those with the textile flows. Other factors to enter into this comparison however include the potential dissipation in COD in transit to the South plant caused by stripping of volatile organic compounds in the sewer system, bio-degradation taking place in the sewer system during transit and oxidation of sulfite and other inorganic reducing-chemical compounds in the sewer system. These reducing-inorganic chemicals are a significant part of the industrial chemicals employed at the three plants and must be recognized for their potential impacts. It is clear that these reducing-chemicals can disrupt disinfection processes as experienced with a previous study by CWW of the impacts on stormwater reclamation.

Figure 68. COD in INFLUENT & EFFLUENT
SOUTH PLANT - 1/98 ~ 6/00
(Source: Daily monitoring from South Plant)



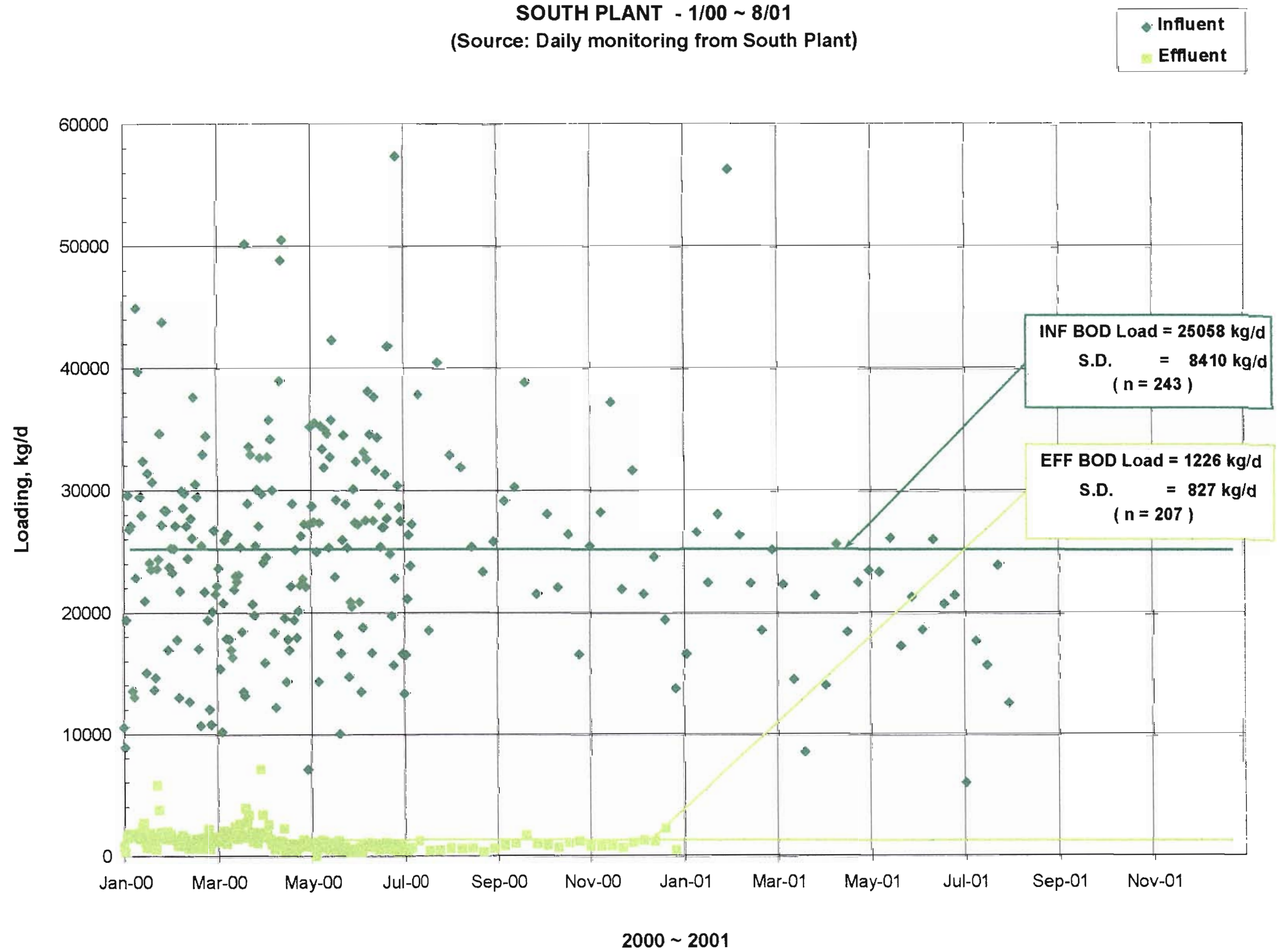
To examine the performance of the South plant, data in Figure 69 provide BOD_5 loading data at both influent and effluent discharges. These data clearly indicate that the CWW effluent at the South plant contains low levels of biodegradable organic matter as measured with BOD_5. The overall removal in the period of 2000-2001 indicated an average removal of 97.9% with an effluent BOD_5 of <11mg/L. The South plant therefore must be recognized as an excellent reclamation facility and that, while affected by the textile effluents, the facility is effectively operated to produce an excellent reclaimed wastewater.

Plant A was the major contributor to COD organic loading on the South plant. Its COD load of 19,349 kg/d was equal to 26.6% of the total COD loading at the South plant. Plant A in addition accounted for 83% of the total load provided by the 3 textile plants and represented a 40% increase in organic loading over the base domestic/commercial loading. However, it is dye use and discharge into the CWW system that was a primary concern.

The monitoring of dyes in pretreated wastewaters discharged into the CWW system is not done and there is no effective way to monitor this component given the diversity of dyes employed. Analysis of dye usage below indicates that Plant C,D had the highest mass inventory of dyes.

Textile Plant	Dye Chemical Inventory (lb/yr)	No. of dyes
A	1.535×10^6 lb/yr	51
B	2.939×10^6 lb/yr	8
C,D	8.019×10^6 lb/yr	7

Figure 69. BOD$_5$ LOADING in INFLUENT & EFFLUENT
SOUTH PLANT - 1/00 ~ 8/01
(Source: Daily monitoring from South Plant)



This mass inventory represented that which is used in the dyeing of textile products by the industries and is not indicative of the mass discharged to CWW. Based on operational approaches, it is realistic to assume that the objectives at the plants are to place the overwhelming majority of the dye on textile products and to otherwise conserve the dye. There are spills and discharges of concentrated dye solutions and suspensions that are expected to occur. These and the dye removed in countercurrent washing systems account for the discharges to CWW. Study of these dye losses in a quantifiable manner would require a massive study of hourly monitoring at multiple points within the individual plants and was outside the limits of this study.

Regarding dye in plant discharges, Plant C has an extensive pretreatment system in which COD removals (representing all organic chemicals, inclusive of dyes) were typically >70%. It is also evident that the dyes employed at Plant C are natural organic macromolecules (i.e., indigo paste dyes) and would be expected to be effectively (but not completely) removed with a biomass flocculation process in the pretreatment system. This is confirmed with data presented in Figure 67, indicating that the COD loading into the CWW system was approximately 2% of the total plant loading at the South plant. Furthermore inspection of the dewatering facility at Plant C indicates blue-black dyes were an integral part of the biosolids that are disposed into landfill systems. Hence, dye removal is an integral part of this plants pretreatment system, when operated. Plant B has an equalization basin that removed organic matter, based on COD differentials across the system. However it is unlikely that any significant dye removal was achieved. This is because of the relatively short aeration time, no apparent mechanism for enhancing biomass accumulation within the systems and no system for the removal of suspended matter from the wastewater discharge. Hence, the strength of the pretreated wastewater is attenuated, but the mass of dye discharged to CWW is expected to be unaltered with pretreatment.

Dyes employed within the three plants include a variety of dyes and the use rates and discharges are highly variable. Plant A had the most diverse array of dyes, with 51 included within their annual inventory. Plants B and C,D had 8 and 7 dyes, respectively, within their inventory and these dyes were very similar.

Previous examination of processes for dye removal at the South plant identified chemical oxidation and adsorption processes as having the potential for use in attenuating effluent dye concentrations. These processes can be employed but at elevated costs and operational complexities. They are also potentially affected by variations in dye types and concentrations discharged. Biological processes for the focused degradation of dyes such as used by Plant A, B, C and D are successful in attenuating the associated biodegradable organics and in bio-flocculation of some suspended dye molecules. Adsorption of dyes can be enhanced with the addition of activated carbon within the biological process. This does not enhance the biodegradation of the dyes but does remove them from the processes wastewater.

As a part of this study, the potential application of biological nutrient removal (BNR) at the South plant was examined and presented to CWW personnel in summary reports and documents on BNR at the South plant. BNR systems can be implemented at the South plant, based on the use of the six bio-reactors at the plant (four were in use during this study as fully-aerated bioreactors). BNR process systems in general have the three following components:

(a) an aerobic basin in which (i) organics are oxidized, (ii) ammonia-N is oxidized to nitrate N and (iii) phosphorus removal is enhanced by phosphorus-accumulating organisms (PAOs) present in the activated-sludge suspension;

(b) an anoxic basin, devoid of O_2, in which microbes reduce nitrate to N_2 in the processes of removing biodegradable organic matter, and

(c) an anaerobic basin, which is devoid of O_2 but is, more importantly, operated under reducing conditions (as opposed to oxidizing conditions employed in the two above bioreactors); bioprocesses within this anaerobic reactor include the fermentation of wastewater organics to acetic acid and other volatile fatty acids (VFAs) and the stimulation of the growth of PAOs on these VFAs produced in the bioreactor.

The unique combination of these processes is possible in numerous configurations (e.g., A_2O, UCT, VIP and Bardenpho) many of which could be implanted operationally within the six-basin configuration at the South plant. The implementation of these processes could provide numerous potential benefits for the South plant. These include removal of influent ammonia as nitrogen gas (N_2); the potential reduction in aeration-compressor costs by using recycled nitrate as a final electron acceptor (as opposed for O_2) in an anoxic portion of the activated sludge system; the reduction of total nitrogen in the South plant effluent; and the removal of phosphorus from the wastewater. The South plant has no regulatory requirement at the present time to enhance nutrient removal from its discharge and current effluent limits are routinely met by the facility. There may however be some operational advantages that could be achieved in implementing such BNR processes. The BNR system does however provide a potential application regarding the removal of dyes and textile chemicals at the South plant. For BNR to be successful in addressing phosphorus removal, the anaerobic bioreactor must achieve true reducing conditions and achieve a low level of oxidation-reduction potential (ORP). It is this aspect of the BNR system that has application to treatment of the textile wastewaters at the South plant.

Dyes are used in the three textile plants under a variety of conditions, using reducing and oxidizing agents, like sulfite and peroxide respectively, to alter dye chemistry and affinity for various textile substrates. Under these changing conditions, dye molecules have altered chemical properties that potentially make them more biologically available. Imposing a series of reducing and oxidizing conditions on dye molecules in contact with the microbial populations of a BNR activated-sludge has potential for enhanced attack of the dyes in the CWW system. While not demonstrated to date in this regard, the key aspect of implementation of such a BNR system would be the multiple benefits of nitrogen and phosphorus removal in the existing tankage and the potential for developing conditions conducive to enhanced removal of dyes and refractory compounds in the wastewater flow.

Implementation of a BNR system at the South plant would require the development of a PAO population system within the current activated sludge system. An approach to investigating this is with a bench-scale system initially to confirm the potential for developing a PAO population, followed by a pilot-scale system which simulates the current bioreactor systems and would be done with the current influent wastewaters. To confirm PAO development, a bench-scale sequencing batch reactor (SBR) of 4-L volume and 24-hr hydraulic retention time is recommended. Investigative simulations have indicated that PAOs would be expected to be developed in a 90-day operational period using a solids retention time of 8-12 days and the following operational cycle: fill, anaerobic, aerobic, anoxic, aerobic, settling and decant cycle-times of 0.7h, 5h, 6h, 5.8h, 4h and 2.5h. If the PAO population is enhanced within the system, investigation of dye removal would be recommended.

Recommendations for further pursuit and implementation by CWW as documented in this study include the following.

(1.) Develop an annual reporting of the annual loads placed by the textile plants on the South plant, in conjunction with Plants A, B, C, and D. This would enhance the understanding of the impacts of various plants on the South plant.

(2.) Initiate development of a dye-monitoring program in conjunction with the textile plants. The assessment of dyes in plant discharges could be coupled to quality-control procedures used within the plants to more effectively monitor dyes actually discharged to CWW. The textile plants use numerous dye-monitoring techniques as quality-control measures that can effectively monitor dye fixation to textile products.

With an integrated and collaborative program, CWW could begin the development of a dye discharge and fate program that would enhance their water reclamation systems and provide and an enhanced perspective of dyes in its treated discharges as needed to address potential regulatory control of this discharge.

(3) Examine the expanded role of industrial pretreatment plants within the CWW system. The pretreatment systems of Plants A, B, and C appear to provide a variety of positive impacts on the plant discharges and on CWW systems. While it is indicated that Plant A has discontinued all plant operations and Plant C has requested that its pretreatment system be bypassed, consideration of continued operation of the pretreatment systems as collaborative systems is encouraged. The biological treatment plant at Plant C has excellent potential for investigative study of the fate of dyes with alternative technologies and additives and could benefit the South plant. Currently these are industry-operated systems; there are potential benefits for collaborative operation of these systems.

(4) The potential for BNR systems at the South plant should be investigated for the benefits regarding enhanced dye removal. Collaborative study with industrial plant personnel on the properties of the dyes used and their fate could have mutual benefits.