TECHNICAL MEMORANDUM

To: Andy Hauge, HBA
Robin Cort, Parsons ES

From: John Hake, Parsons ES

Date: January 22, 1996

Subject: Analysis of Results from Daily and Monthly Water Balance Models

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BACKGROUND

The monthly water balance model was developed by CH2M Hill in 1987 to determine storage capacity and irrigation acreage for long-term wastewater disposal alternatives. The model was periodically refined by CH2M Hill through about 1991. Parsons ES obtained the model in December 1994, and has further refined the model since then. Operation of the monthly water balance model is explained in two technical memorandums: Water Balance Model Summary and Results (Parsons ES, 26 September 1995) and Water Balance Contingency Plan (Parsons ES, 27 October 1995).

The daily water balance model was developed in 1994 to support the water quality modeling of discharge impacts on the Laguna de Santa Rosa and Russian River. A daily water balance model was needed because the water quality model time step is hourly to daily (depending upon constituent), and use of monthly discharge volumes provided by the monthly water balance model would have been incompatible with a water quality impacts evaluation. The daily water balance model simulations were initially conducted for the three years in which water quality modeling was being conducted (1976, 1961, and 1982, which are dry, normal, and wet years, respectively).

In fall 1995, the following two events occurred independently:

1. Members of the public commented at roundtable discussions that the precision of the monthly water balance model is an inadequate basis for facilities sizing and project design. Andy Hauge requested that Merritt Smith Consulting (MSC) characterize differences between the two water balance models so that the City of Santa Rosa could respond to this comment.

2. MSC found that estimates of reclaimed water production, discharge volume, and storage utilization that were simulated by the two water balance models for each discharge rate in 1976, 1961, and 1982 differed.

As these differences appeared and concerns were voiced, discussions between the modelers at Merritt Smith, RMA, and Parsons ES were initiated to attempt to explain the differences in modeling results. It was decided to prepare a technical memorandum to summarize the differences between the daily and monthly water balance models.

PURPOSE

The purpose of this memorandum is to summarize the differences between the daily and monthly water balance models including assumptions, approaches, and results. This understanding is important to maintain the credibility of the project design basis and to validate assumptions and computations.

DISCUSSION

Storage

Table 1 summarizes results from both water balance models. Results are compared for the various design discharge options: 1, 5, 10, and 20 percent. The first three parameters listed for each design discharge rate are input data to the models. Storage volume (in millions of gallons) represents the active storage volume available for reclaimed water, including the existing storage of 1,200 MG. The storage curve is an annual series of monthly or daily target storage values. Target storage is a preset percentage of total storage to be utilized, at a certain period in time. The original storage curve is the curve used for all of the monthly water balance model results. This curve was later refined for the daily water balance model, which was run using both the original and refined curves.

Some flexibility may be introduced to storage curve operations. Both models will allow target storage to be exceeded temporarily. The monthly water balance model allows for contingency storage, which is an additional 5 percent of the total storage capacity (represented as 105 percent in the table). Contingency storage may be utilized once every discharge season under monthly water balance model operations. The daily water balance model's use of contingency storage is more sophisticated because contingency storage may be utilized numerous times over the course of a discharge season. The daily water balance model allows for discharge of contingency storage, when discharge conditions are more favorable (i.e., when the river has unused discharge capacity). The daily water balance model was run at both 5 and 10 percent contingency storage, or 105 and 110 percent of total capacity, respectively. The monthly water balance model did not utilize contingency storage for the 1 percent design discharge option because it was not necessary for disposal.

The storage characteristics are very important in determining discharge results. Increased contingency storage capacity and target storage flexibility will reduce the contingency discharge requirements of the system. As stated in the 27 October 1995, *Water Balance Contingency Plan Technical Memo*, "Another measure that may be undertaken to reduce contingency magnitude and frequency is operational. Actual operations could be modified slightly from the water balance model allocation priorities." Allocation priorities refers to guidelines that determine how the water balance model chooses to distribute reclaimed water to storage, irrigation, and discharge. These guidelines are built into the water balance model and described in detail in a memo addressed to Robin Cort on 25 August 1995, regarding contingency volumes results for the monthly water balance model. In other words, if the model has the flexibility to store more reclaimed water (in contingency storage) during periods of low river flow and discharge to the river when flow conditions are more favorable, then fewer discharges in excess of the design discharge rate would occur.

Contingency Discharge

The discharge results for each design discharge rate are given in Table 1. The total contingency discharge represents the total discharge to the Russian River in excess of the design discharge rate over the 70-year period of record. Monthly or daily contingency discharges (depending upon the water balance model) were totaled to obtain this figure. The number of months in which the contingency discharges occur over the 70-year (840 month) period of record are shown. Daily water balance model results (i.e., number of days for which there were contingency discharges) were converted to represent the number of months which have daily contingency discharges. This conversion was performed to directly compare contingency discharge frequency results between two models with different time steps.

The maximum monthly discharge rate is the maximum percentage of wastewater flow as a percentage of Russian River flow. Discharge rates for the daily water balance model were also converted to monthly figures for direct comparison. It should be noted that daily rates predicted by the daily water balance model fluctuate about this average, and are sometimes much higher than the monthly average. Both monthly and daily maximums for the daily water balance model are shown in Table 1. For example, the maximum daily discharge rates (52.3 and 55.3 percent) for the 20 percent design discharge are much greater than the maximum monthly average discharge rates (25.0 and 22.0 percent). Cumulative frequency curves for daily discharge rates and monthly averages of daily discharge rates are shown in Figures 1-8. These curves further show the effects of monthly averaging on daily rates. There are two curves for each design discharge rate, one showing cumulative frequency between 0 and 100 percent and the other between 99 and 100 percent. Monthly averaging of daily results attenuates the peak discharge rates. This is most evident in Figures 2, 4, 6, and 8.

The three contingency discharge parameters were chosen to compare the results between the daily and monthly water balance models and check for consistency. Because of differences in time-step and model construction, we would expect the daily and monthly water balance model results to be similar but not identical. The results are similar for the 5, 10, and 20 percent design discharge options but are noticeably different for the 1 percent option.

Monthly and daily contingency discharge results are compared in the "Monthly" and "Daily (1)" columns in Table 1 for each design discharge rate. Storage volume, curve type, and curve adherence are kept constant. Total contingency discharge, number of months with contingency discharge, and maximum monthly discharge rate are very similar for the 20 percent design discharge. This similarity decreases as the design discharge rate decreases. At 1 percent design discharge, the monthly water balance model shows no contingency discharge over the 70-year period of record and the daily water balance model shows a total of 262 MG of contingency discharge occurring in 5 months over the period of record. This discrepancy may be explained in part by differences in monthly average versus daily Russian River streamflows and discharge capacities. Some daily streamflows are very low (approximately 20 cfs), which provides very small discharge capacity. Some of these extreme daily flows may be masked by the monthly average in the monthly water balance model, reducing predictions of contingency flow occurrences. Lack of storage operational flexibility also substantially influences the daily model's 1 percent contingency discharge results. Because contingency storage was not required by the monthly model to accommodate contingency events (winter irrigation and emergency conservation were sufficient), the Daily (1) model run does not allow any exceedance of target storage. Storage curve flexibility is an important component of daily water balance model performance.

Further Improvements to Daily Water Balance Model Storage Operations

The daily water balance model operations were improved by allowing greater contingency storage (up to 10 percent of total storage) and by refining the target storage curve. The Daily (1) and Daily (2) columns in Table 1 illustrate the effects of these changes. Contingency volume and frequency decrease for all of the design discharge rates with the exception of the 5 percent design discharge rate, which had no contingency discharges under the 5 percent contingency storage and original storage curve. This confirms a conclusion reached in the *Water Balance Contingency Plan Technical Memo*, that contingency discharge magnitude and frequency could be reduced by refined operations.

Other Differences in Model Construction and Results

Both monthly and daily water balance models use linear regression equations and Russian River flows to estimate wastewater flows, however, some of the underlying assumptions are different. The monthly water balance model linear regression equation was constructed using annual Russian River flows as measured at the Hacienda Bridge gauging station. The Hacienda Bridge gauging station is presently used to measure Russian River flows for wastewater discharge to the Laguna. The annual Hacienda Bridge flows were used to predict annual wastewater flows. Annual wastewater flows were converted to monthly flows based on a historical distribution of annual flows. The daily water balance model linear regression equation was constructed using daily incremental Russian River flows. Incremental Russian River flows are calculated by subtracting Warm Springs Dam and Healdsburg gauging station flows from Hacienda Bridge flows. This refines the analysis by correlating wastewater flows with Russian River flow contributions that are more immediate to the project area and eliminating the effects of flows from outside the project area. The wastewater flows predicted by the two linear regression models are different; the daily model predicts flows that are up to 10 percent greater.

Discharge rates are also calculated differently by the two models. The monthly water balance model calculates discharge rate by dividing wastewater discharge by river flow. The daily water balance model divides discharge rate by the sum of river and discharge flows. This difference in calculation methods does not affect the discharge rate results as much at low discharge rates (1percent) as at the higher rates (20 percent). Because of this difference in methodology the monthly model calculates higher discharge rates than the daily model.

SUMMARY

The different assumptions and approaches used in the construction of the daily and monthly water balance models produce different but similar contingency discharge results for the 5, 10, and 20 percent design discharge options. The results for the one percent design discharge show greater differences, which may be explained by the lack of storage operations flexibility and sensitivity of the model to the time-step used for flow data at this low design discharge rate. However, modifications to daily water balance model storage operations yield contingency discharge results similar to those for the monthly water balance model. It was recognized in a previous technical memo that modifying storage operations would probably enhance system performance and this was confirmed by daily water balance model results.

There are other recognizable differences in model results. The daily model is more conservative in estimating higher wastewater flows. The monthly model is more conservative in calculating higher discharge rates. However, the contingency discharge results are similar under identical storage conditions for the 5, 10, and 20 percent discharge options and confirm that system requirements for storage as estimated by the monthly water balance model are an adequate basis for facilities sizing and project design. Subsequent daily water balance model runs under different storage operations show that increased system performance, in the form of fewer and smaller contingency discharges, is attainable. Detailed design of the reclamation system would further refine system requirements (including storage volume) estimated by the monthly water balance analysis. Presently, the system requirements as estimated by the monthly model are conservative and appropriate for two reasons:

1. Conservative sizing of storage facilities is necessary for a thorough and complete environmental impact analysis,

2. Conservative sizing in planning and pre-design phases is appropriate to preserve the City's options for cost and reliability/redundancy trade-offs that must be made during the final design phase.

cc: Dave Smith, Merritt Smith, Don Smith, RMA

TABLE 1
SUMMARY OF MONTHLY AND DAILY WATER BALANCE RESULTS

One Percent Design Discharge Option Models

Parameter	Monthly	Daily (1)	Daily (2)
Storage Volume (MG)[1]	5200	5200	5200
Storage Curve[2]	original	original	refined
Storage Curve Adherence[3]	100%	100%	110%
Total Contingency Discharge[4]	0	262	0
No. Months w/Contingency Discharge[5]	0	5	0
Max. Monthly Discharge Rate[6]	1.0%	1.2%	0.7%
Max. Daily Discharge Rate	NA	8.5%	1.0%

Five Percent Design Discharge Option Models

Parameter	Monthly	Daily (1)	Daily (2)
Storage Volume (MG)[1]	4100	4100	4100
Storage Curve[2]	original	original	refined
Storage Curve Adherence[3]	105%	105%	110%
Total Contingency Discharge[4]	77	0	0
No. Months w/Contingency Discharge[5]	2	0	0
Max. Monthly Discharge Rate[6]	7.3%	5.0%	5.0%
Max. Daily Discharge Rate	NA	5.0%	5.0%

Ten Percent Design Discharge Option Models

Parameter	Monthly	Daily (1)	Daily (2)
Storage Volume (MG)[1]	3100	3100	3100
Storage Curve[2]	original	original	refined
Storage Curve Adherence[3]	105%	105%	110%
Total Contingency Discharge[4]	118	86	0
No. Months w/Contingency Discharge[5]	2	3	0
Max. Monthly Discharge Rate[6]	13.4%	14.5%	10.0%
Max. Daily Discharge Rate	NA	24.9%	10.0%

Twenty Percent Design Discharge Option Models

Parameter	Monthly	Daily (1)	Daily (2)
Storage Volume (MG)[1]	1200	1200	1200
Storage Curve[2]	original	original	refined
Storage Curve Adherence[3]	105%	105%	110%
Total Contingency Discharge[4]	226	264	117
No. Months w/Contingency Discharge[5]	4	5	3
Max. Monthly Discharge Rate[6]	28.3%	25.0%	22.0%
Max. Daily Discharge Rate	NA	52.3%	55.3%

[1] Storage Volume represents total storage of both existing (1200 MG) and proposed new storage.
[2] The storage curve represents an annual series of monthly or daily target storage values.
[3] Storage curve adherence represents the percentage by which actual storage may exceed the target.
[4] Total contingency discharge represents the total discharge in excess of the design discharge rate over the 70-year period of record.
[5] Number of months over the 70-year period of record in which contingency discharges occur.
[6] Discharge rate represents reclaimed water discharge as a percentage of Russian River flow.
NA - Not Applicable

Figure 1
Daily Water Balance Model Results
1 Percent Design Discharge Rate

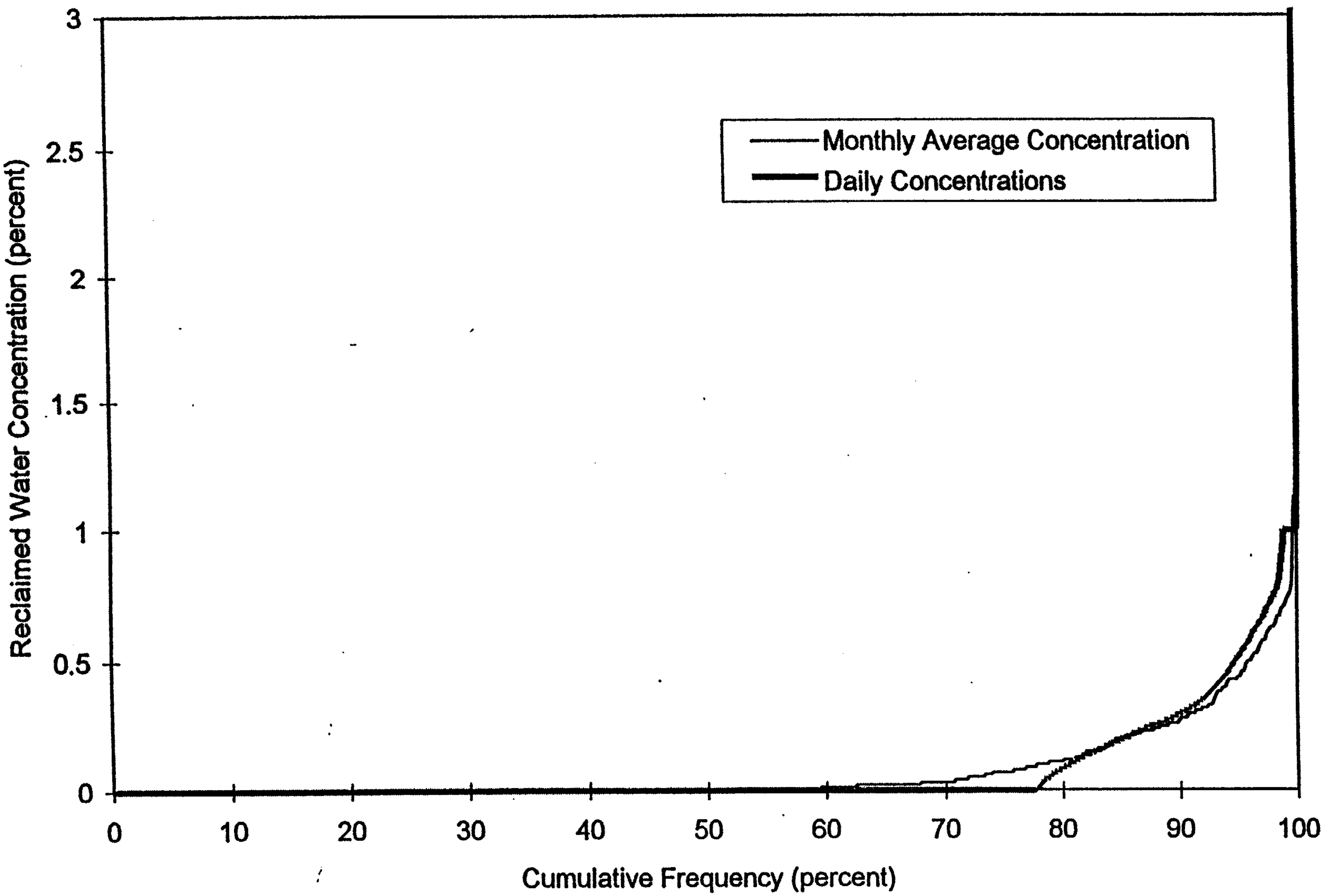

Figure 2
Daily Water Balance Model Results
1 Percent Design Discharge

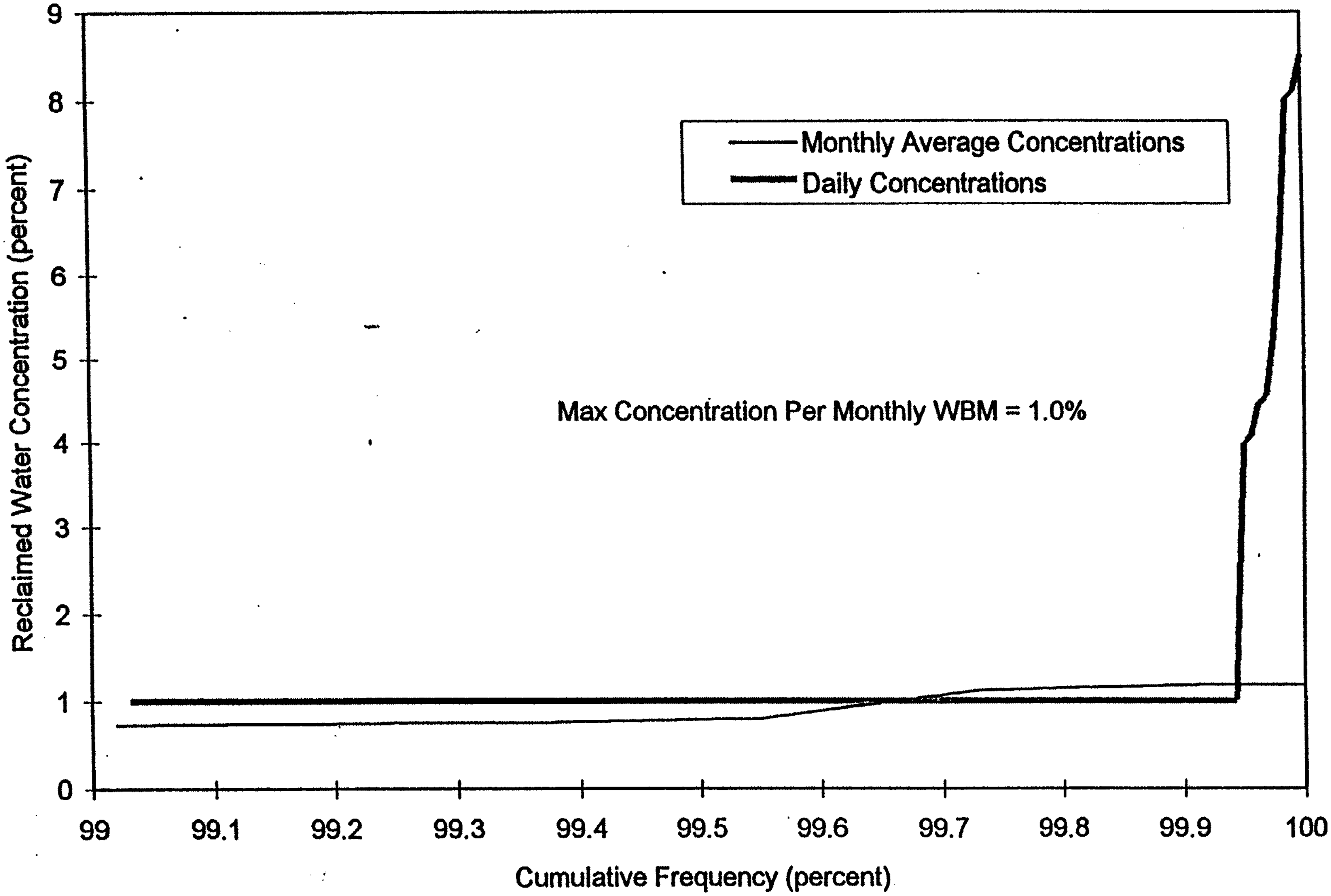

Figure 3
Daily Water Balance Model Results
5 Percent Design Discharge

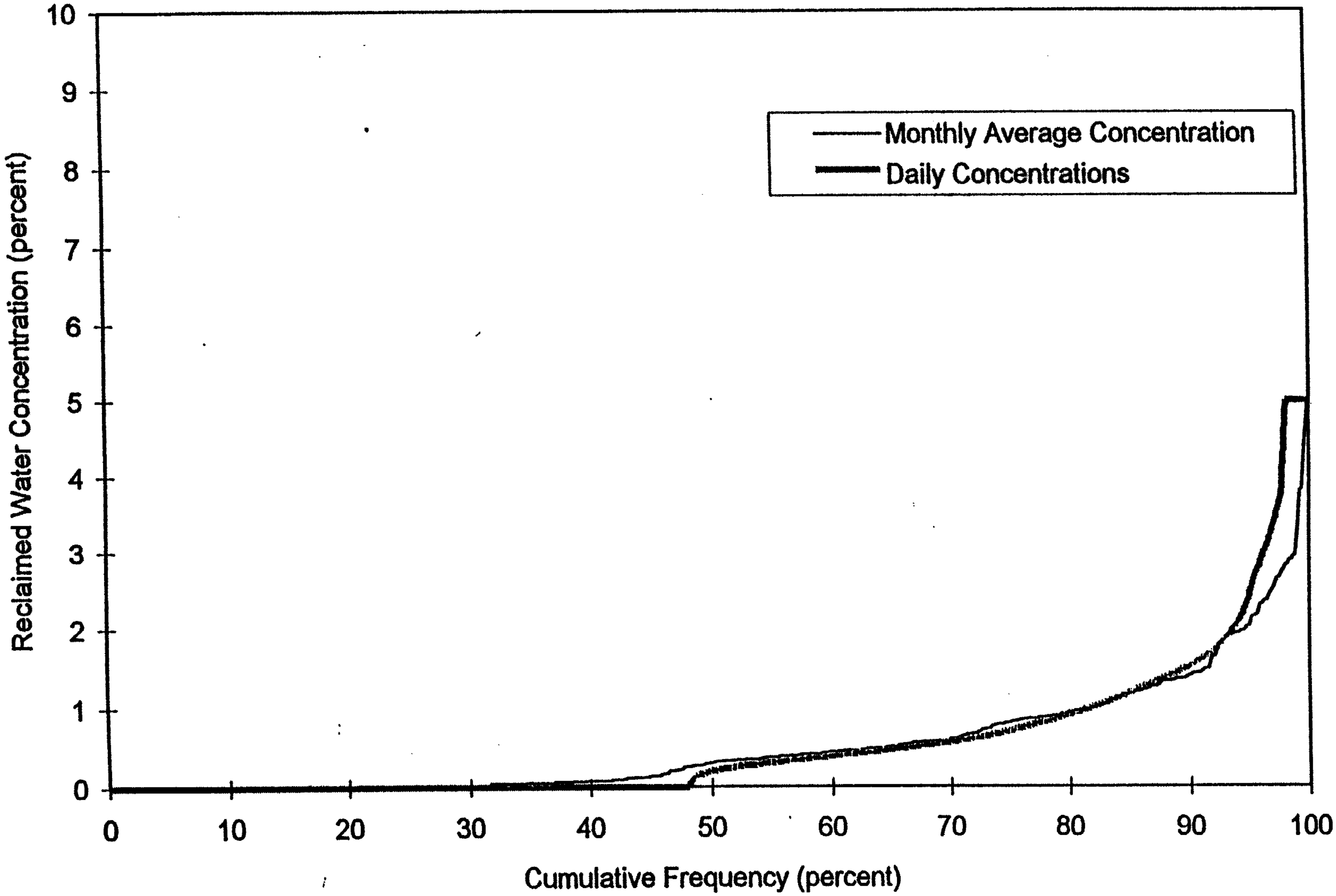

Figure 4
Daily Water Balance Model Results
5 Percent Design Discharge

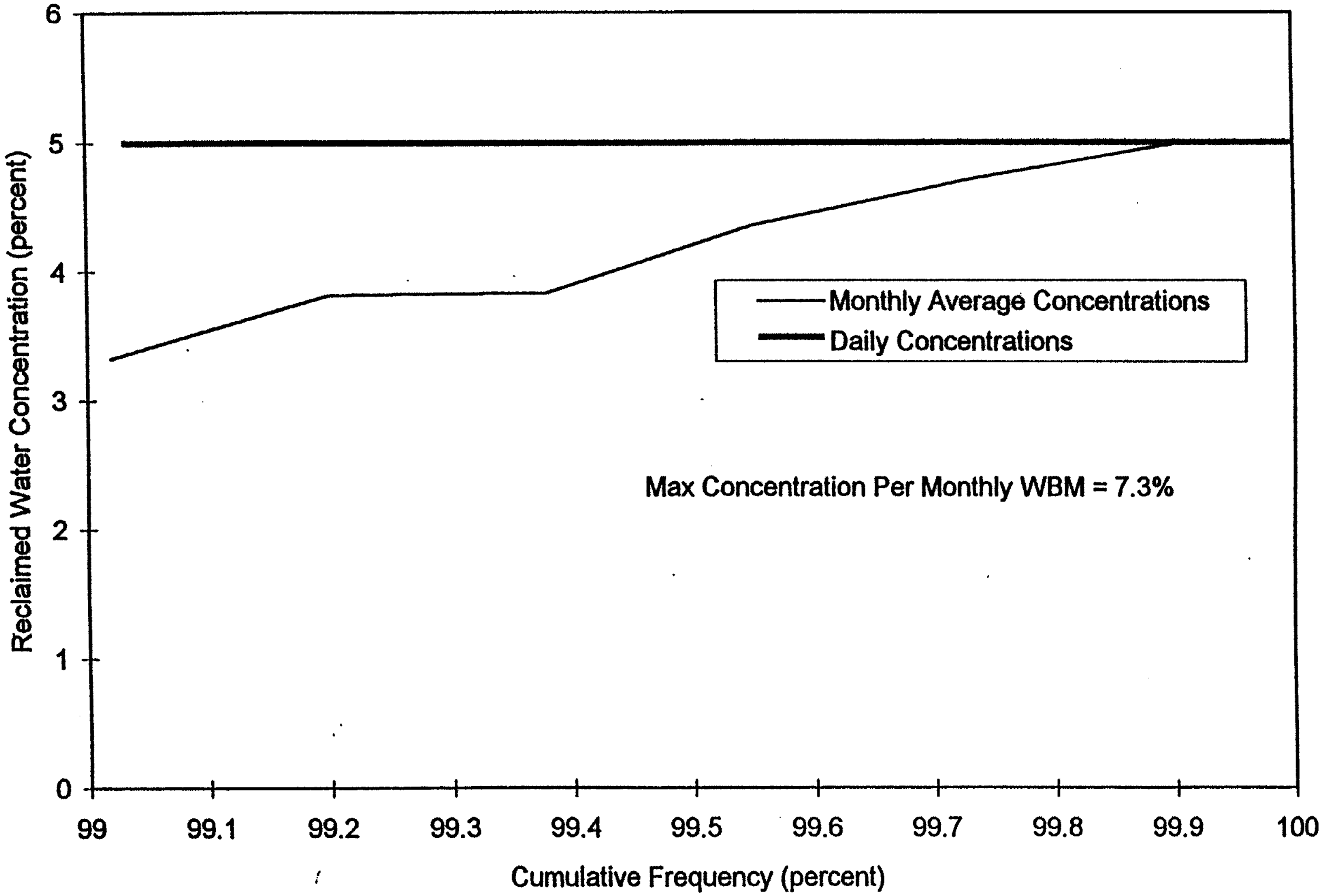

Figure 5
Daily Water Balance Model Results
10 Percent Design Discharge

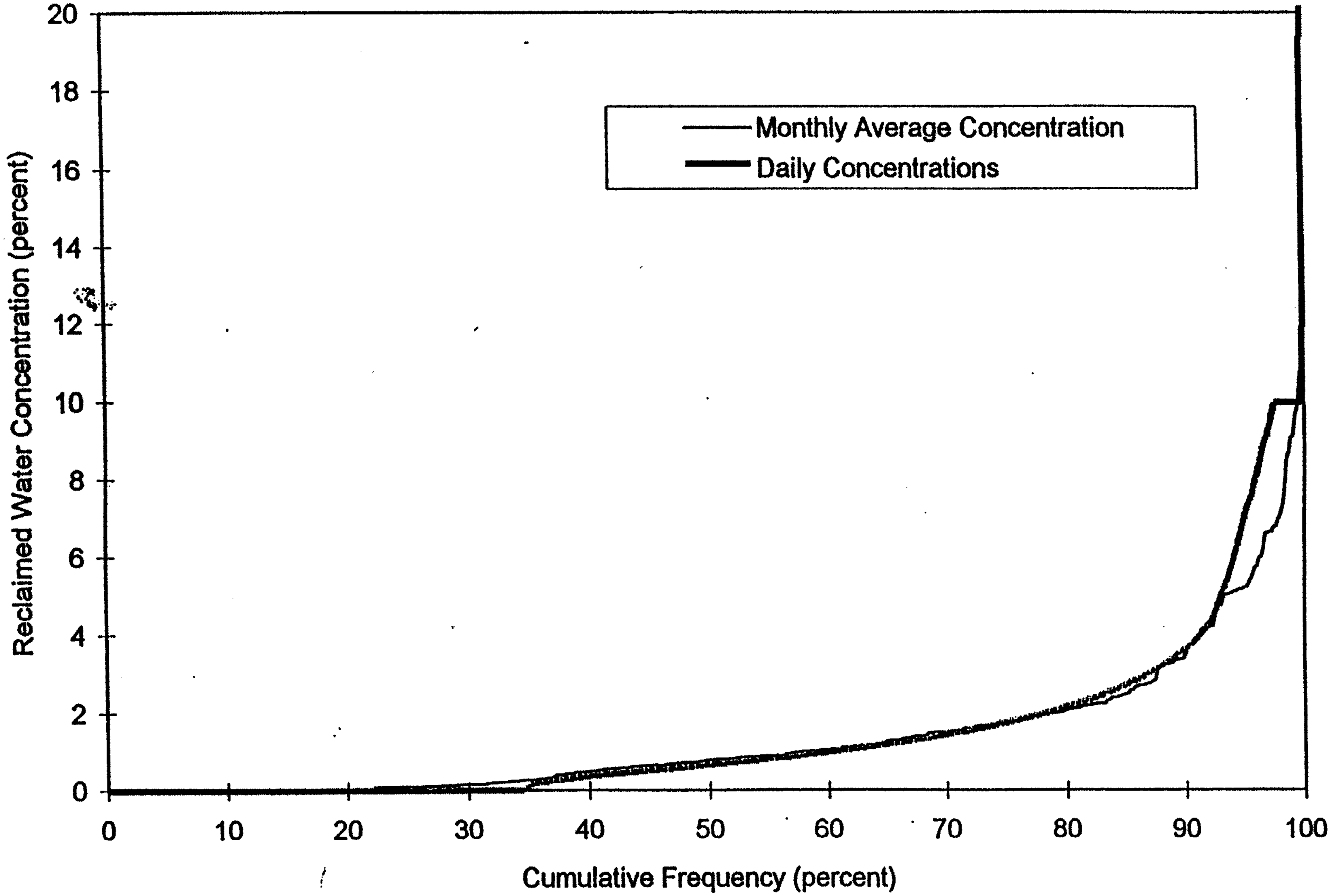

Figure 6
Daily Water Balance Model Results
10 Percent Discharge

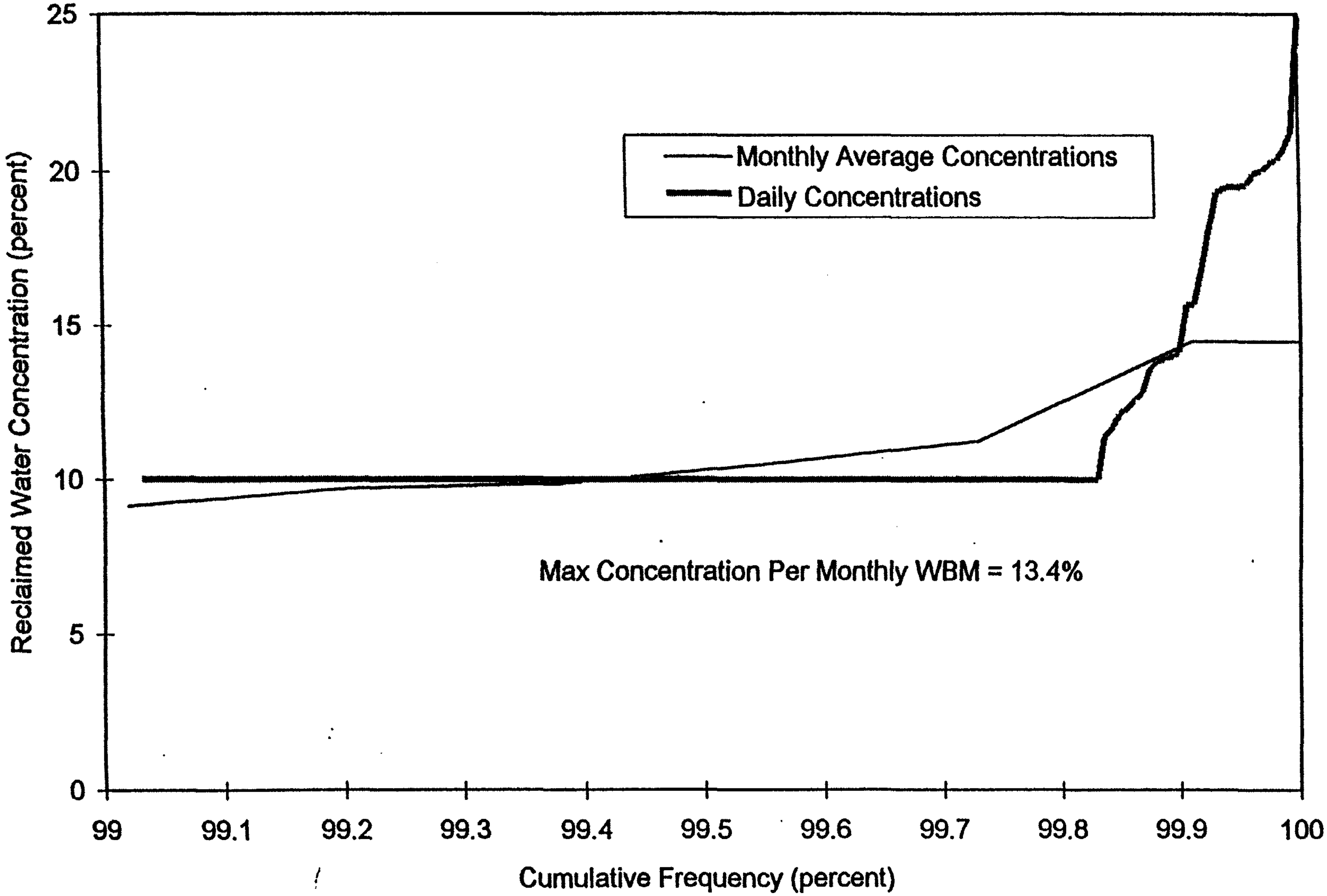

Figure 7
Daily Water Balance Model Results
20 Percent Discharge

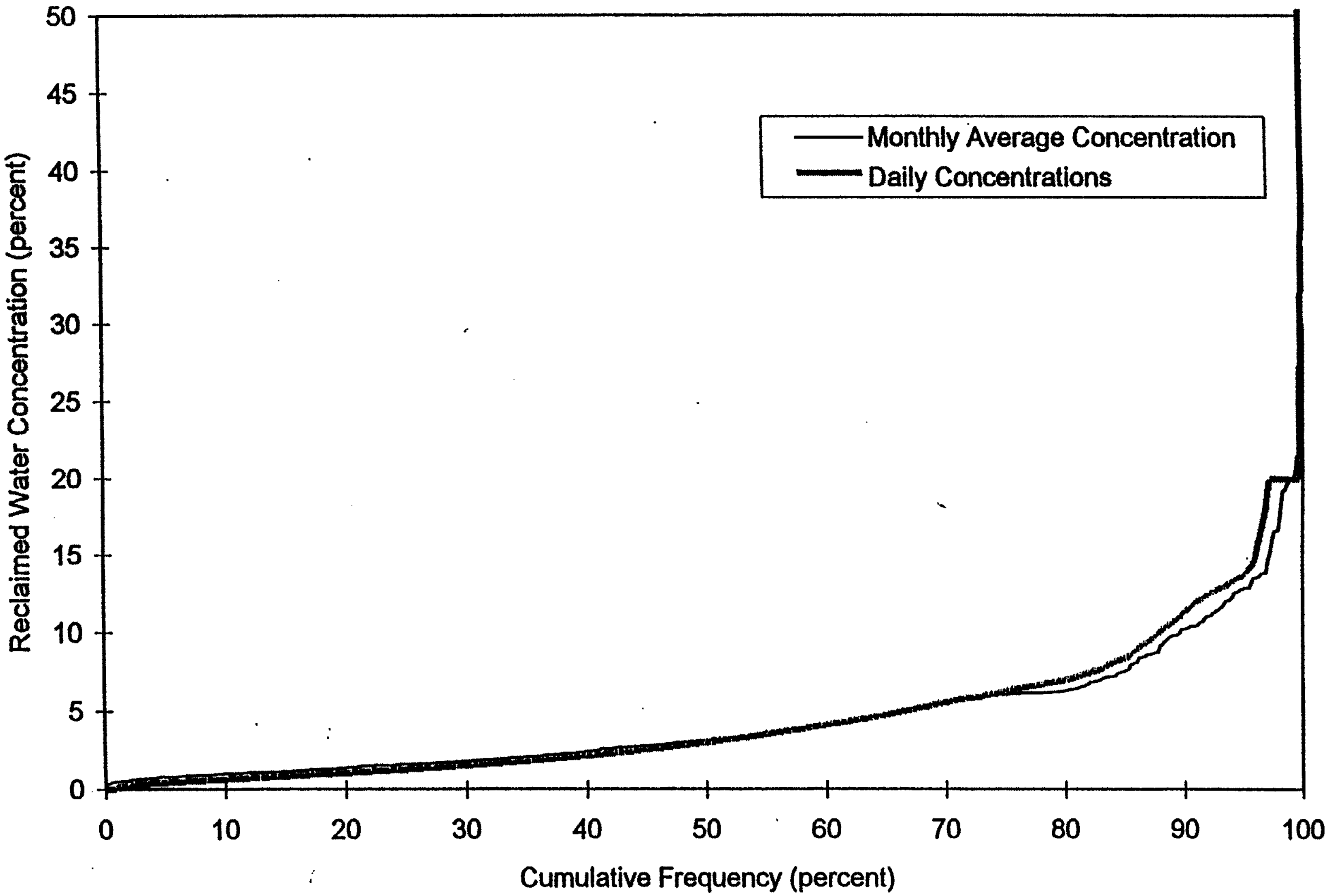

Figure 8
Daily Water Balance Model Results
20 Percent Discharge