BNWL-2140
UC-41

Thermoluminescent Dosimeter (CaF_2:Dy) Measurement of the Hanford Environs, 1971-1975

by
J. J. Fix
P. J. Blumer

January 1977

Prepared for the Energy Research and Development Administration under Contract EY-76-C-06-1830

Battelle
Pacific Northwest Laboratories

BNWL-2140

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Pacific Northwest Laboratories
Richland, Washington 99352

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THERMOLUMINESCENT DOSIMETER (CaF_2:Dy) MEASUREMENT OF THE HANFORD ENVIRONS, 1971-1975

INTRODUCTION

Thermoluminescent dosimeters (TLD-200)* were introduced into the Hanford Surveillance Program in 1970 and were available for full-year use beginning in 1971. Each environmental dosimeter consists of three chips of CaF_2:Dy encased in an opaque plastic capsule lined with 0.010 in. of tantalum and 0.002 in. of lead to flatten the lower energy response.[1] The dosimeters were mounted approximately one meter above ground level at numerous locations in the Hanford environs. The dosimeters were changed either bi-weekly or monthly, depending on their location.

This document presents a summary of the 1971-1975 external dose measurements recorded with the thermoluminescent dosimeters at 20 locations in the Hanford environs. The data are evaluated and used to determine the approximate average dose and the variability of individual measurements observed at each location. The average background dose received in the Hanford environs was estimated from the measured external dose and from information available in the literature for the dose received from the neutron component of cosmic radiation and the internal dose due to naturally occurring radionuclides.

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* Harshaw Chemical Company, CaF_2:Dy

SUMMARY

The average external dose rate measured at locations in the Hanford environs was 72 mrad/year, based on analysis of thermoluminescent dosimeter data collected from 1971 through 1975. The maximum dose observed, 84 mrad/year, occurred approximately 100 feet north of the Vernita rest stop on Hanford Site property. This location is free of pedestrian or vehicular traffic and the increased dose is attributed to the greater abundance of naturally occurring radionuclides, primarily ^{40}K, at this location. The lowest dose measured, 62 mrad/year, occurred at Sunnyside. The dosimeter at this location is affixed to a wooden building and the shielding provided by the building is expected to account for the lower observed dose.

The average dose received from naturally occurring radioactivity in the Hanford environs was estimated from the external dose measured by the thermoluminescent dosimeters and from information available in the literature. Terrestrial and cosmic ionizing radiation each contribute approximately 36 mrad/year. The neutron component of cosmic radiation contributes an additional 0.8 mrad/year or, utilizing a quality factor of 8, a dose equivalent of about 6 mrem/year. The combination of the terrestrial and cosmic ionizing doses and the neutron dose yields an overall estimate of 78 mrem/year due to external radiation. The dose received from internally deposited radionuclides was estimated from the literature to be 25 mrem/year. Therefore, the total radiation dose received from natural causes was estimated to be 103 mrem/year. For convenience, an estimate of 100 mrem/year is suggested.

THERMOLUMINESCENT DOSIMETER DATA

The annual average dose rate measured at numerous monitoring locations in the Hanford environs has been reported each year in the annual environmental surveillance report.[2] The data for 20 of these locations, shown in Figure 1, are included in this report. The thermoluminescent dosimeter (TLD) used was introduced into the Environmental Surveillance Program in 1970 and was available for full-year use from 1971 through 1975, the period analyzed in this report. Each environmental dosimeter consists of three chips of CaF_2:Dy encased in an opaque plastic capsule lined with 0.010 in. of tantalum and 0.002 in. of lead to flatten the lower energy response.[1] The dosimeters were mounted approximately one meter above ground level and were changed either biweekly or monthly, depending on the location of the dosimeter.

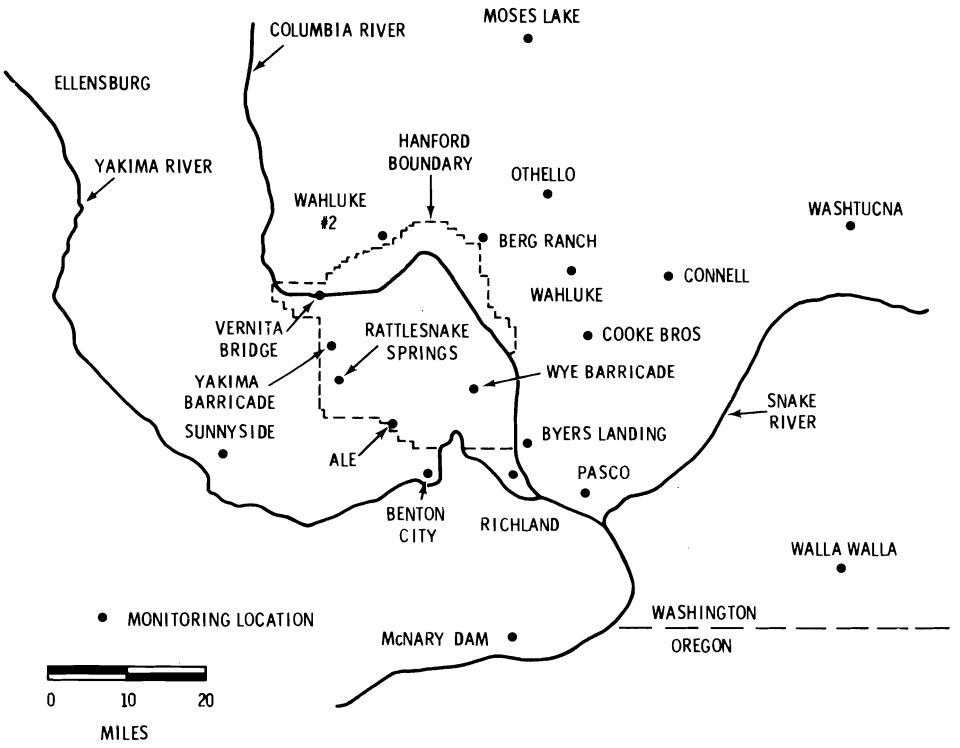


FIGURE 1. Hanford Environs Thermoluminescent Dosimeter Monitoring Locations

The dose measured at a given location is expected to vary from monitoring period to period due to the variability inherent in the placement of the dosimeter, the preparation and calibration of the dosimeters, and the temporal dependence of the background radiation dose rate. In addition, the background dose measured from location to location is expected to vary primarily because of the spatial dependence of the naturally occurring ^{40}K, uranium plus daughter radionuclides, and thorium plus daughter radionuclides in the underlying soil. The methods used to analyze the TLD data were first, to plot the data for each location as it was collected, on a biweekly or monthly basis; and second, to group and plot on lognormal probability paper all of the data for each location. From the lognormal plots the geometric mean (x_g: 50% intercept) and geometric standard deviation or slope (σ_g: ratio of 84% to 50% intercept) were determined. Appendix A contains the frequency and lognormal probability plots for each location.

Table 1 is a summary of the mean daily dose rates, the slope of the plots, and the 95% probability intercepts obtained from Appendix A. The mean daily dose rate measured at each of the locations appears to be quite consistent. The highest rate, 0.23 mrad/day, was observed at Vernita Bridge. This station is approximately 100 feet due west of the Vernita Bridge rest stop, on Hanford Site property, and removed from all pedestrian or vehicular traffic. The frequency and lognormal plots for this location are shown in Appendix A on page A-14. These graphs show no obvious difference from the graphs for other locations, and we conclude that the dose rate observed at Vernita is attributable to a greater abundance of natural radioactivity at this particular sampling location. This conclusion is consistent with results from a 1974 analysis of a soil sample taken in the immediate vicinity of the TLD location; the analysis showed the highest ^{40}K concentration (17 pCi/g) of any location sampled.[3]

The lowest mean daily dose rate observed, 0.17 mrad/day, was found at Sunnyside. The data for Sunnyside are plotted on page A-13 of Appendix A and appear to be consistent with the data observed at the other locations. This particular station is located near the entryway into an irrigation supply company's fenced storage area. The dosimeter is affixed to a wooden building. The shielding provided by the building is assumed to have caused the lower observed dose rate.

Also shown in Table 1 is the 95% probability intercept of the plotted data for each location from Appendix A. This value represents a specific daily dose rate, as determined from the biweekly or monthly dose measurements: 95% of all measurements are expected to be less than this value. This number provides a comparison for any new incoming data; since only 5% of the data are expected to be greater than the 95% intercept, this 5% can be inspected to insure that there is nothing unusual about it.

TABLE 1. Average Observed Levels of Background Radiation in the Hanford Environs, 1971 Through 1975[a]

Location	Dose (mrad/day)		
	Mean	95% Intercept	Slope
ALE	0.21	0.27	1.2
Benton City	0.18	0.22	1.1
Berg Ranch	0.21	0.27	1.1
Byers Landing	0.21	0.28	1.1
Connell	0.18	0.22	1.1
Cooke Brothers	0.20	0.26	1.2
McNary Dam	0.20	0.24	1.1
Moses Lake	0.18	0.22	1.1
Othello	0.18	0.22	1.1
Pasco	0.18	0.24	1.3
Rattlesnake Springs	0.20	0.24	1.1
Richland	0.19	0.24	1.1
Sunnyside	0.17	0.21	1.1
Vernita Bridge	0.23	0.29	1.1
Walla Walla	0.20	0.25	1.1
Wahluke #2	0.20	0.25	1.2
Wahluke Watermaster	0.20	0.25	1.2
Washtucna	0.20	0.28	1.2
Wye Barricade	0.19	0.23	1.1
Yakima Barricade	0.22	0.29	1.2

(a) Mean dose, 95% intercept and slope obtained from lognormal probability plots contained in Appendix A.

Table 2 shows the mean annual dose for each of the 20 locations. The average of these doses from all locations is 72 mrad/year. This number can be used to estimate the approximate annual background dose equivalent (mrem) received in the Hanford environs, as shown in Table 3. Table 3 consists of two parts: an estimate of the external dose measured by the TLD system, with the addition of the neutron component of cosmic radiation which was not included in calibration of the TLD system; and an estimate of the average internal dose received, as published by the Environmental Protection Agency.[4] The background dose measured by the TLDs (72 mrem) was divided into terrestrail and cosmic components (36 mrem each) based on the expected cosmic dose received at an elevation of 500 feet.[5] The values in the table are given in mrem (milliroentgen equivalent in man) to account for the greater biological effect characteristic of neutron radiation. To arrive at the approximate 6 mrem/year dose attributed to neutrons, a quality factor of about 8 was used.[5]

TABLE 2. Average Annual Dose from Natural Background Radiation(a)

Location	Annual Dose (mrad/yr)
ALE	77
Benton City	66
Berg Ranch	77
Byers Landing	77
Connell	66
Cooke Brothers	73
McNary Dam	73
Moses Lake	66
Othello	66
Pasco	66
Rattlesnake Springs	73
Richland	69
Sunnyside	62
Vernita Bridge	84
Walla Walla	73
Wahluke #2	73
Wahluke Watermaster	73
Washtucna	73
Wye Barricade	69
Yakima Barricade	80
Average	72

(a) Expected annual dose obtained from Table 1 by multiplying average daily dose rate by 365.25, the number of days in a year.

As shown in Table 3, a background dose of about 100 mrem/year would be expected from all causes. The actual dose received by members of the population would vary about this estimate because of variations in diets, recreational habits, housing, community of residence (Table 2), etc.

TABLE 3. Background Dose Received in the Hanford Environs from Natural Causes

	millirem/year	
External Irradiation:		78
Terrestrial	36	
Cosmic: ionizing component	36	
neutron component[a]	6	
Internal Irradiation:[b]		25
^{40}K	17	
^{14}C	1	
^{210}Po	3	
^{222}Rn	3	
Other (^{3}H, ^{87}Rb)	1	
TOTAL		103

(a) The present TLD system is not calibrated to include an estimate of the neutron component of cosmic radiation (~0.8 mrad/yr, or 6 mrem/yr because of a quality factor of 8).[5]

(b) Adopted from U.S. Environmental Protection Agency Publication ORP/CSD 72-1.[4]

REFERENCES

1) D. H. Denham, et al., A CaF_2:Dy Thermoluminescent Dosimeter for Environmental Monitoring. BNWL-SA-4191, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1972.

2) D. R. Speer, J. J. Fix, and P. J. Blumer, Environmental Surveillance at Hanford for CY-1975. BNWL-1979, Rev., Battelle, Pacific Northwest Laboratories, Richland, WA, 1976.

3) J. J. Fix, Environmental Surveillance at Hanford for CY-1974. BNWL-1910, Battelle, Pacific Northwest Laboratories, Richland, WA, 1975.

4) U. S. Environmental Protection Agency, Estimates of Ionizing Radiation Doses in the United States 1960 - 2000. ORP/CSD 72-1, Rockville, MD, August 1972.

5) D. T. Oakley, Natural Radiation Exposure in the United States. ORP/SID 72-1, Environmental Protection Agency, Washington, DC, June 1972.

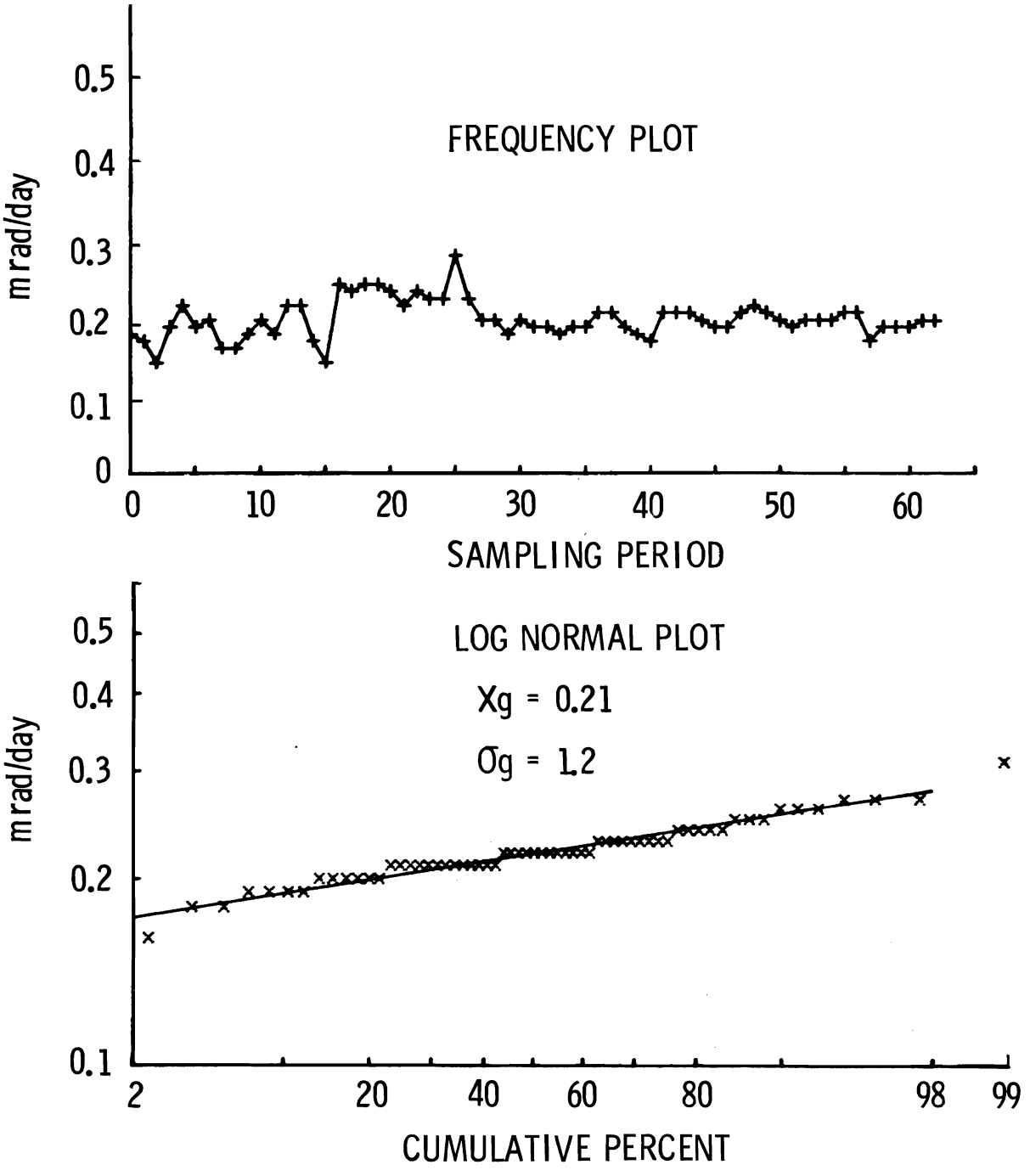
APPENDIX

DATA PLOTS

DATA PLOTS

The following pages present frequency and lognormal probability plots for each sampling location in the Hanford environs included in the study. For all locations except Richland, the dosimeters were changed monthly. For Richland, the dosimeters were changed biweekly during 1971-1974 and monthly during 1975. The plots are presented alphabetically by location. Locations are:

ALE


FREQUENCY PLOT
mrad/day
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.21
σg = 1.2
mrad/day
0.5
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0.2
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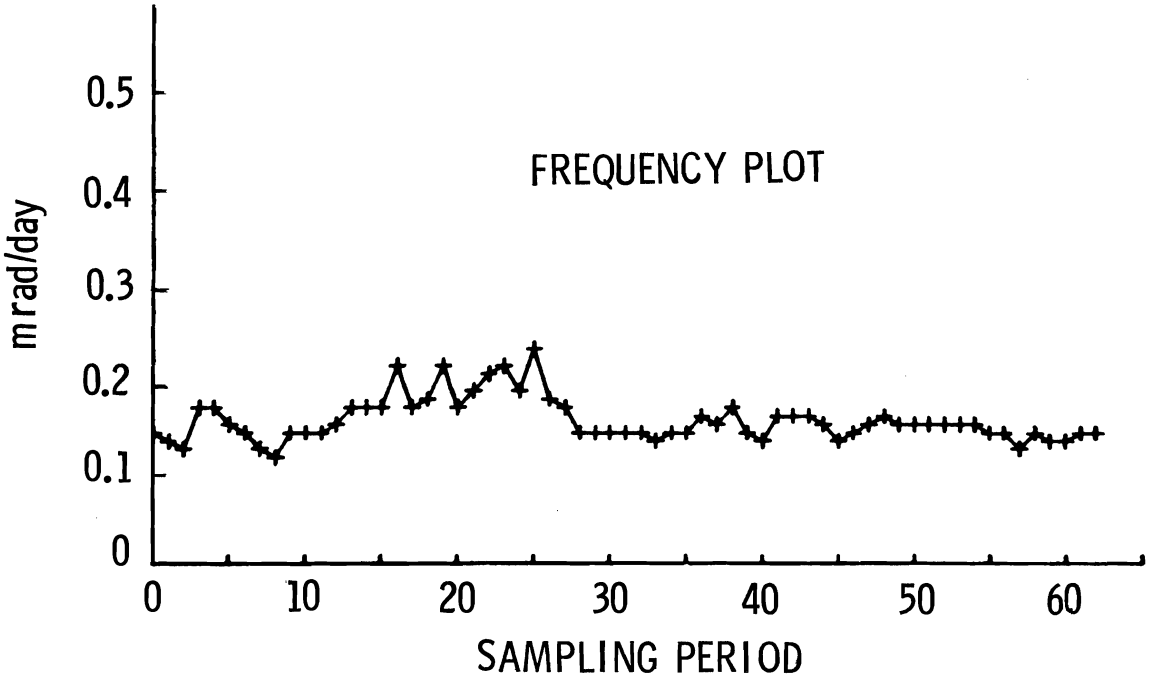
40
60
80
98
99
CUMULATIVE PERCENT

BENTON CITY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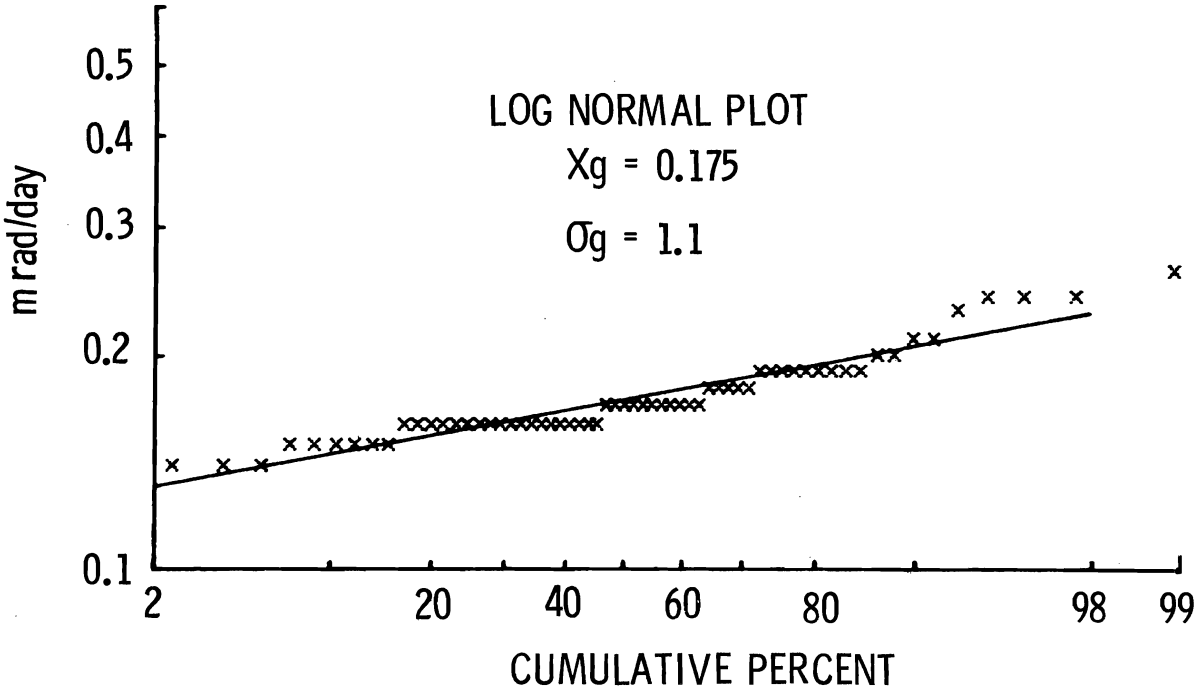
60
SAMPLING PERIOD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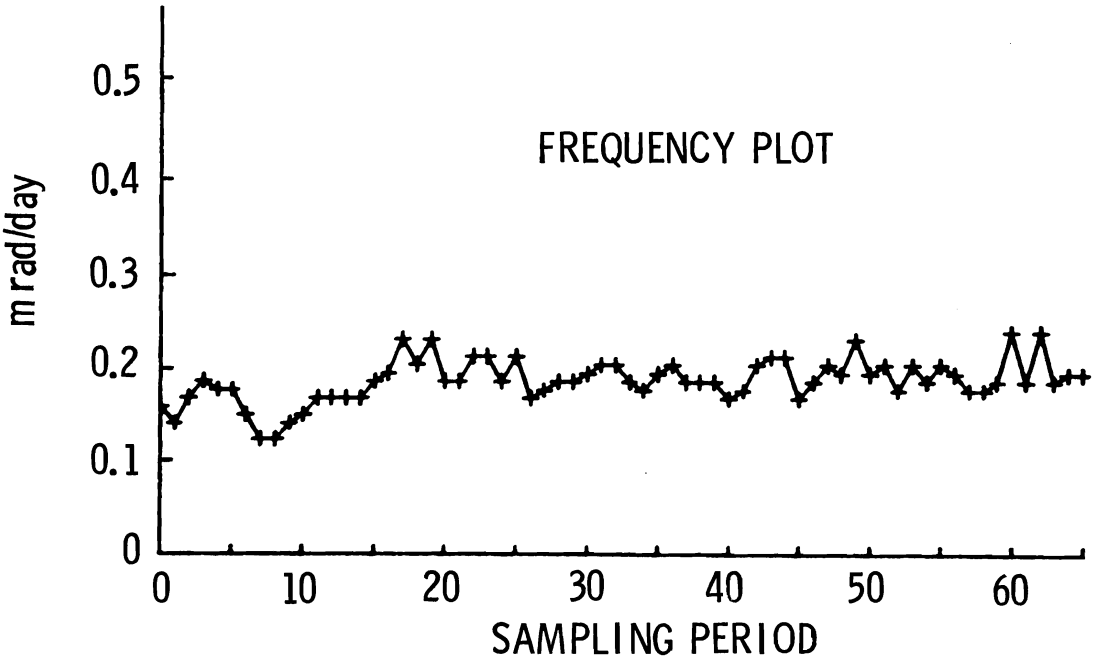
98
99
CUMULATIVE PERCENT

BERG RANCH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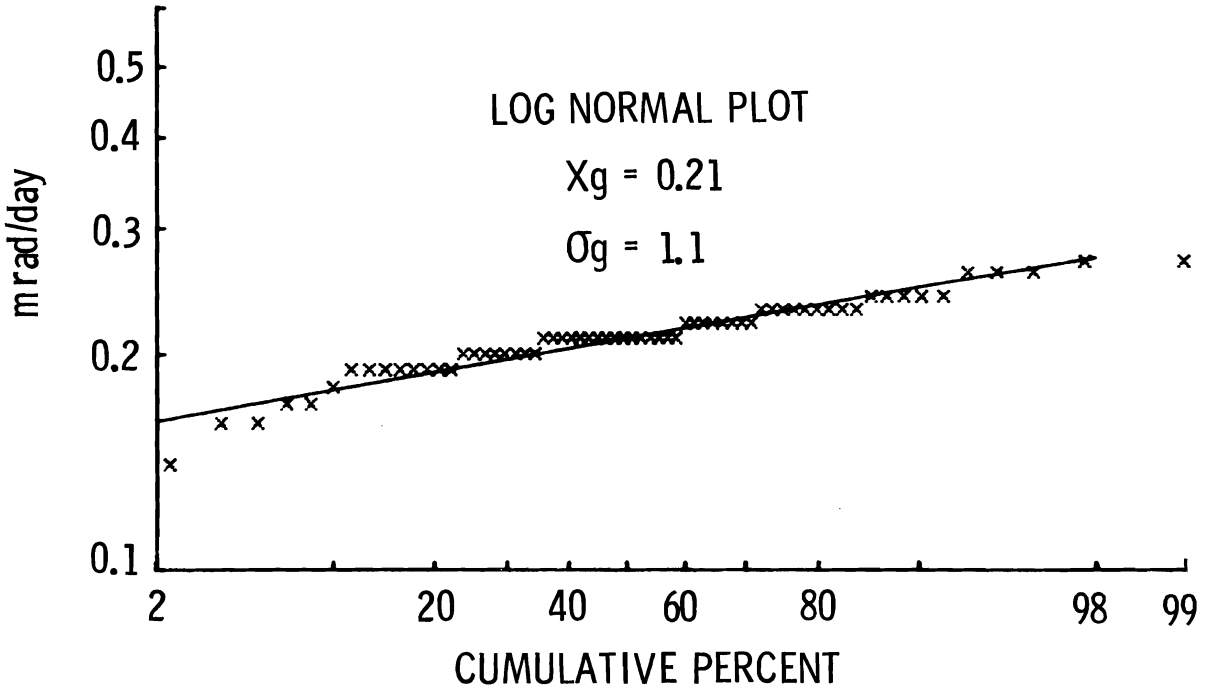
20
30
40
50
60
SAMPLING PERIOD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σg = 1.1
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20
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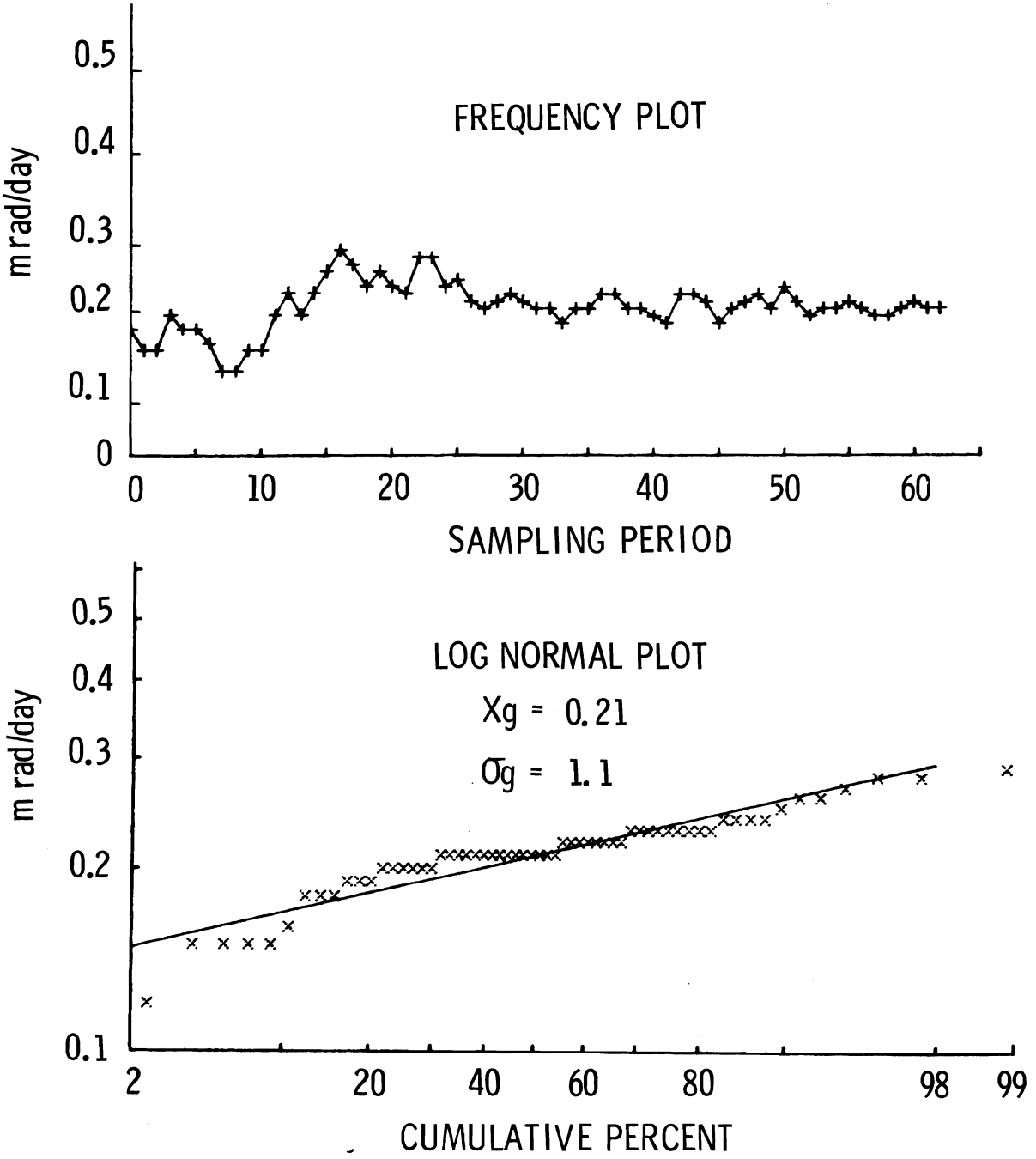
60
80
98
99
CUMULATIVE PERCENT

BYERS LANDING



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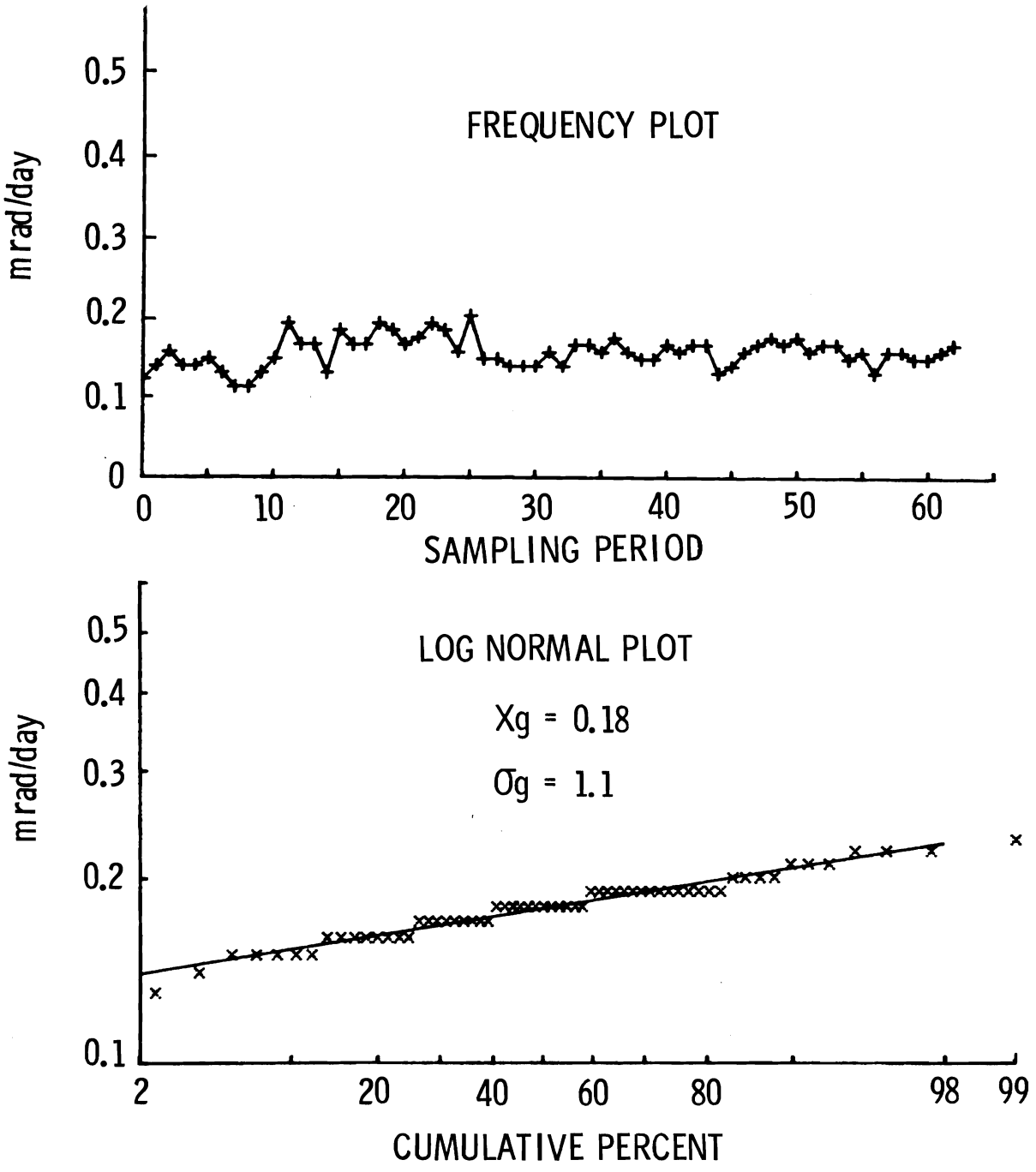
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50
60
SAMPLING PERIOD
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99
CUMULATIVE PERCENT

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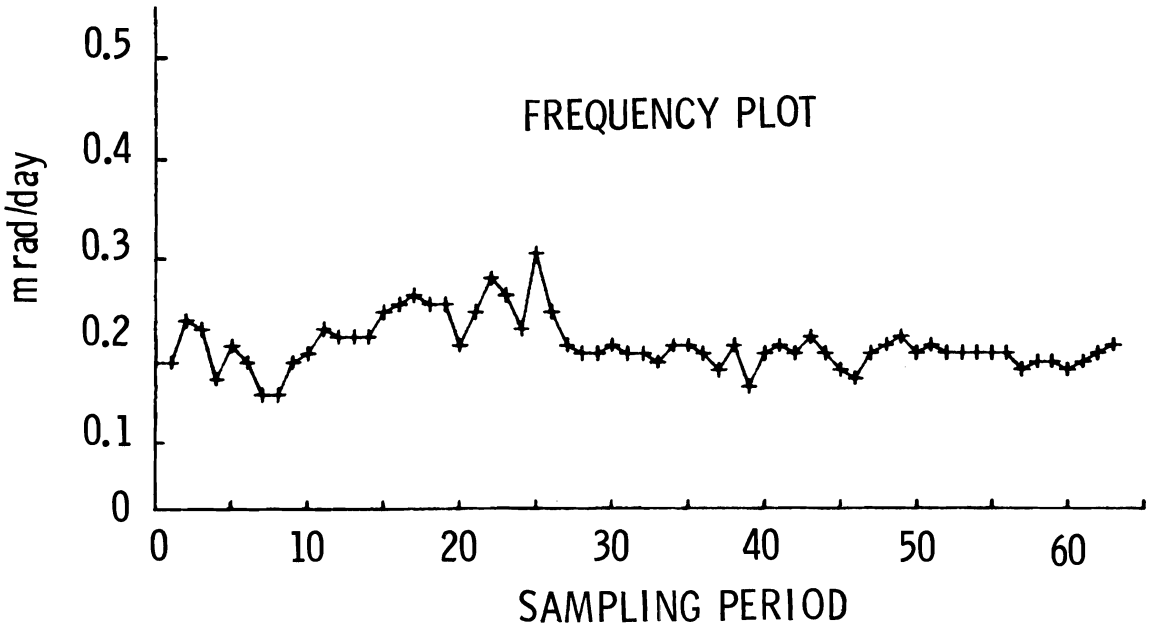

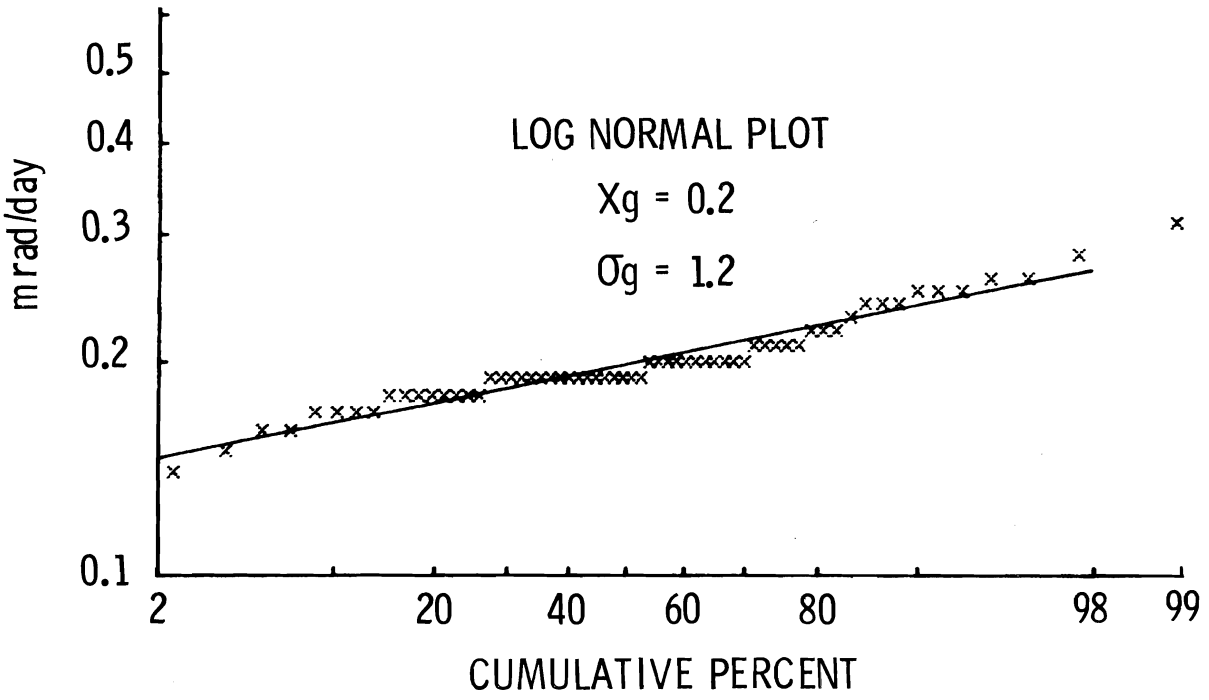

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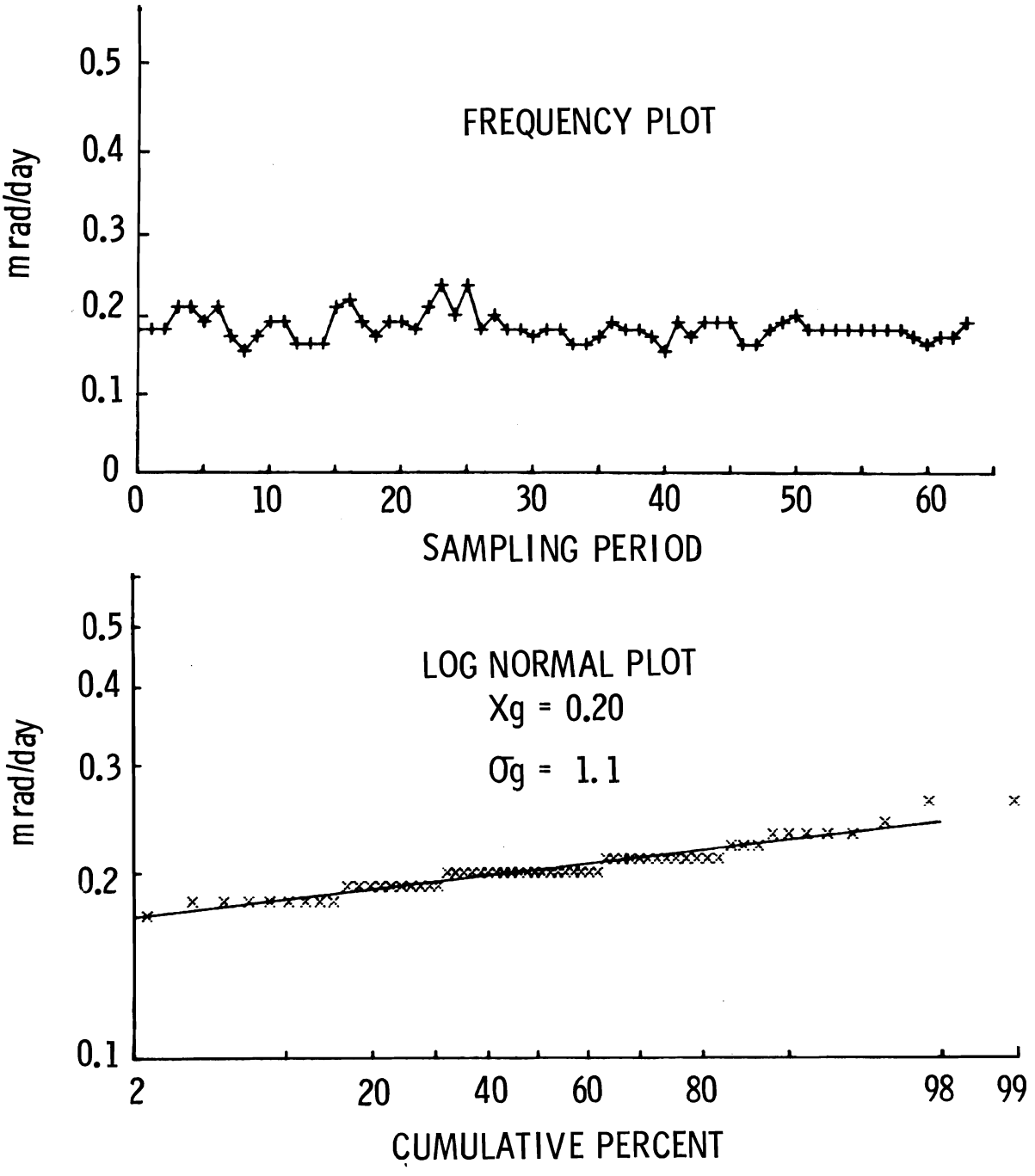
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0
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SAMPLING PERIOD
LOG NORMAL PLOT
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mrad/day
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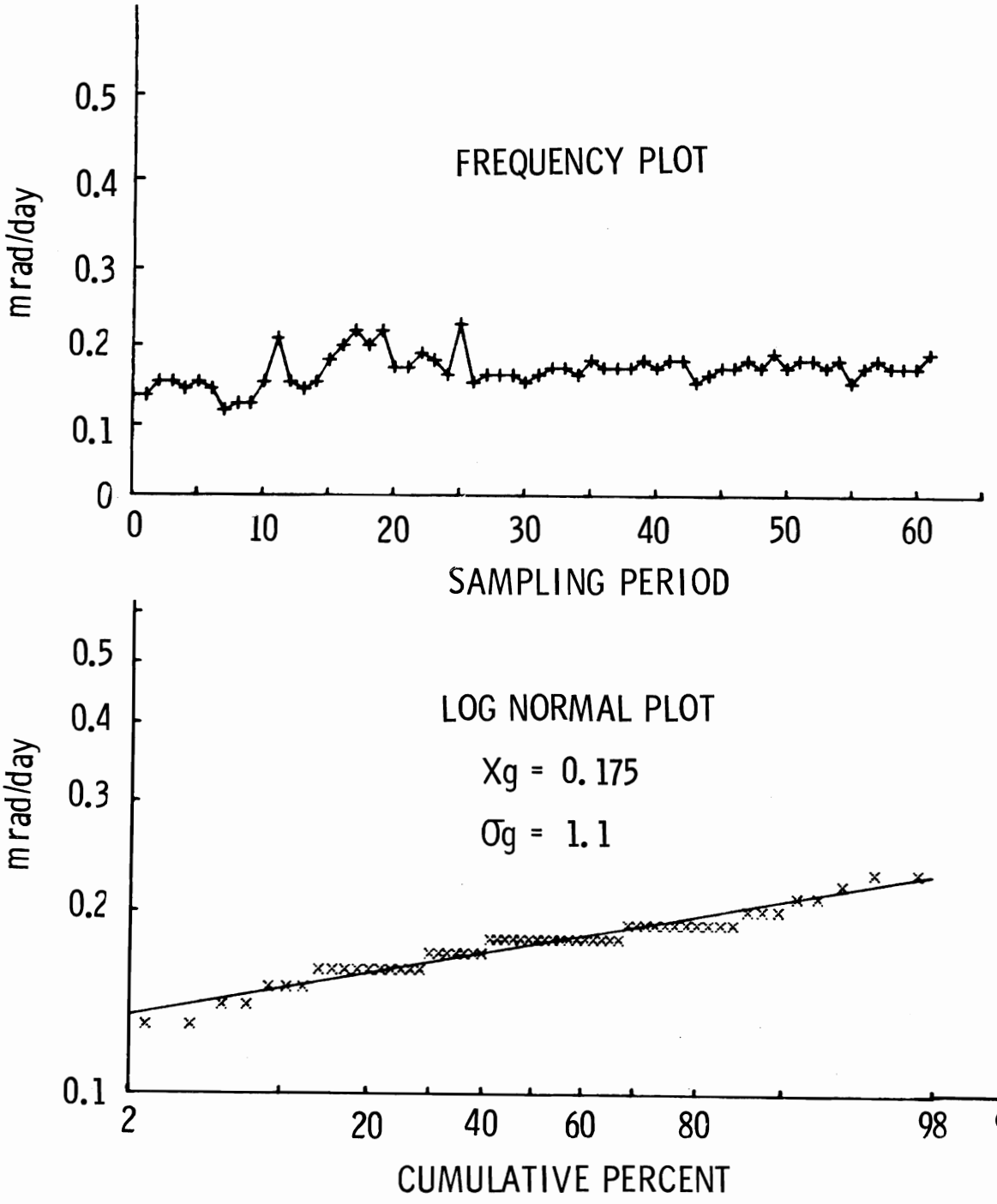
98
99
CUMULATIVE PERCENT

MOSES LAKE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0.1
0
0
10
20
30
40
50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.175
σg = 1.1
mrad/day
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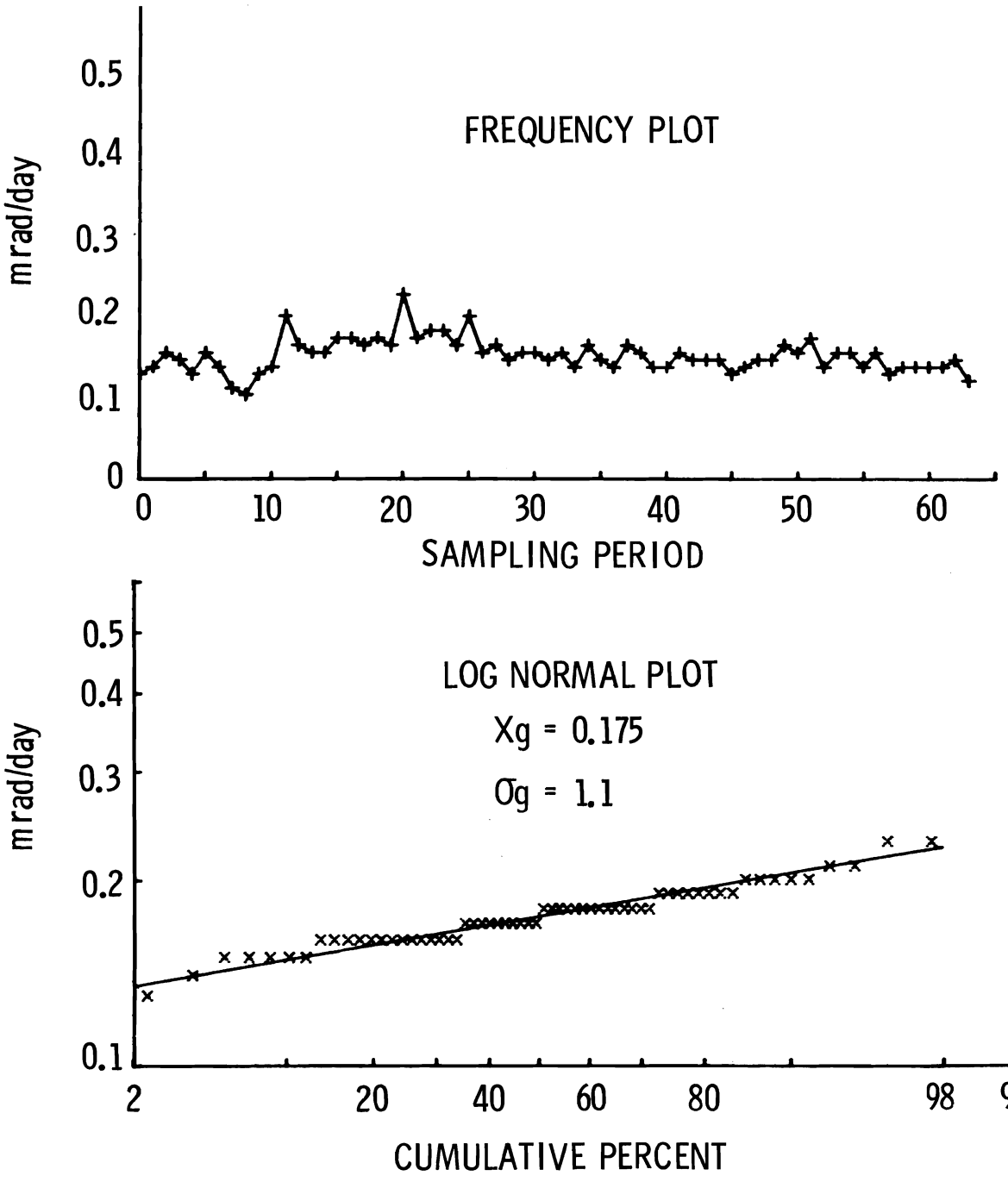
0.2
0.1
2
20
40
60
80
98
99
CUMULATIVE PERCENT

OTHELLO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0.2
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20
30
40
50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.175
Og = 1.1
mrad/day
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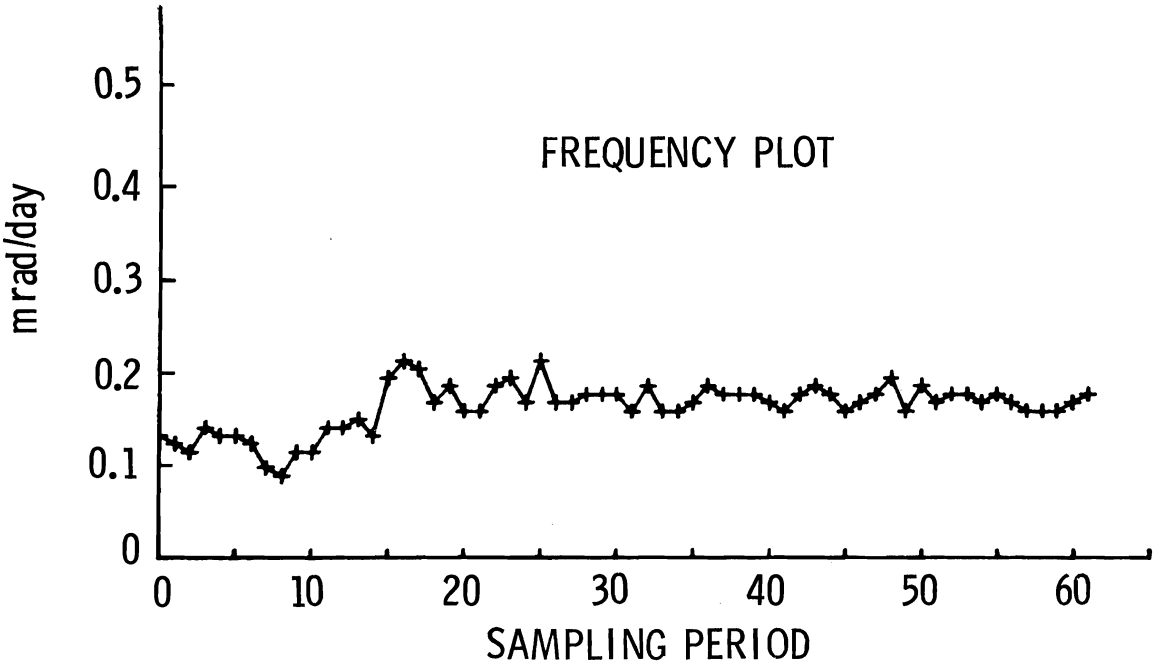
0.4
0.3
0.2
0.1
2
20
40
60
80
98
99
CUMULATIVE PERCENT

PASCO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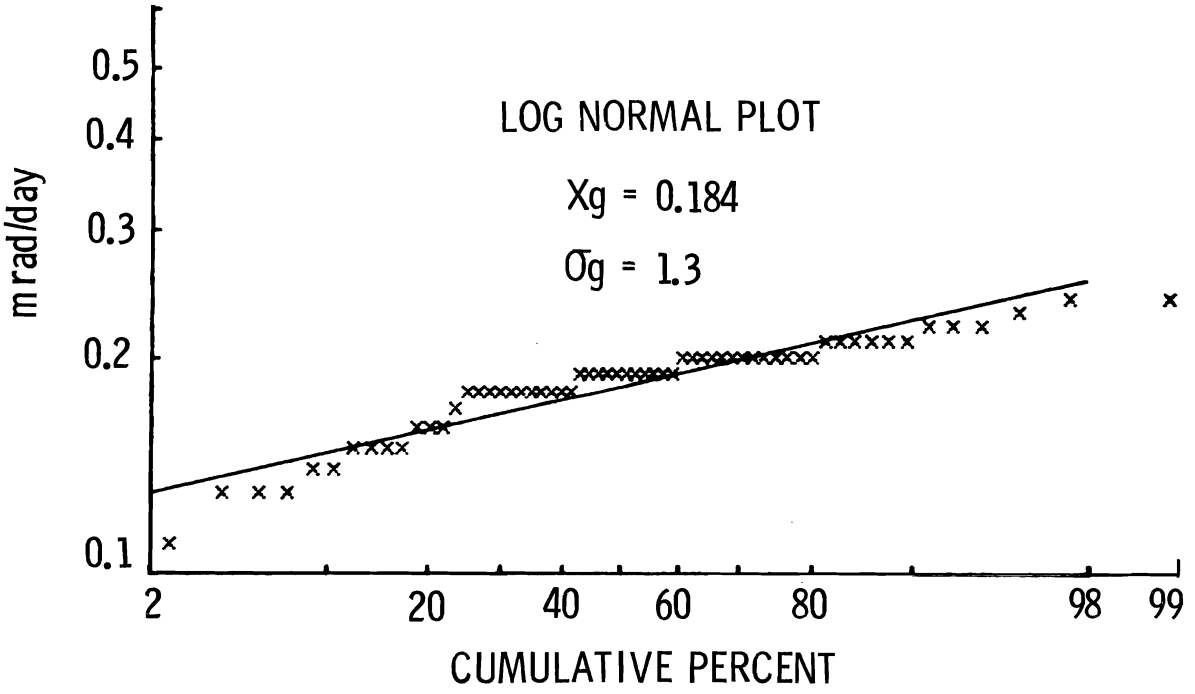
60
SAMPLING PERIOD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CUMULATIVE PERCENT

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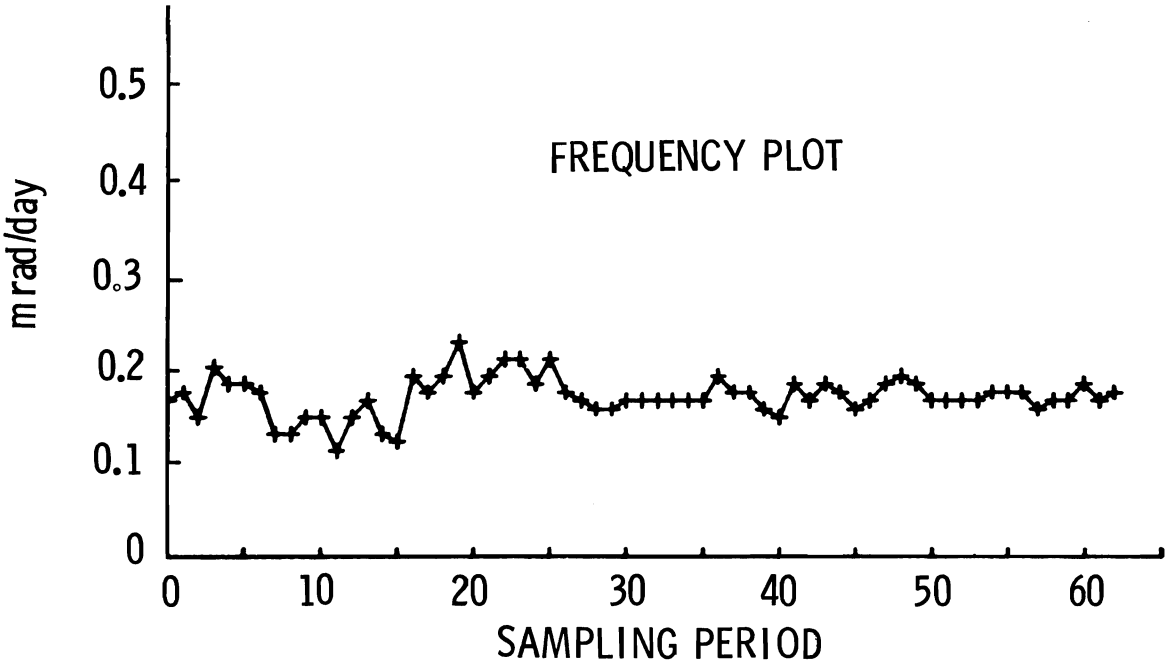
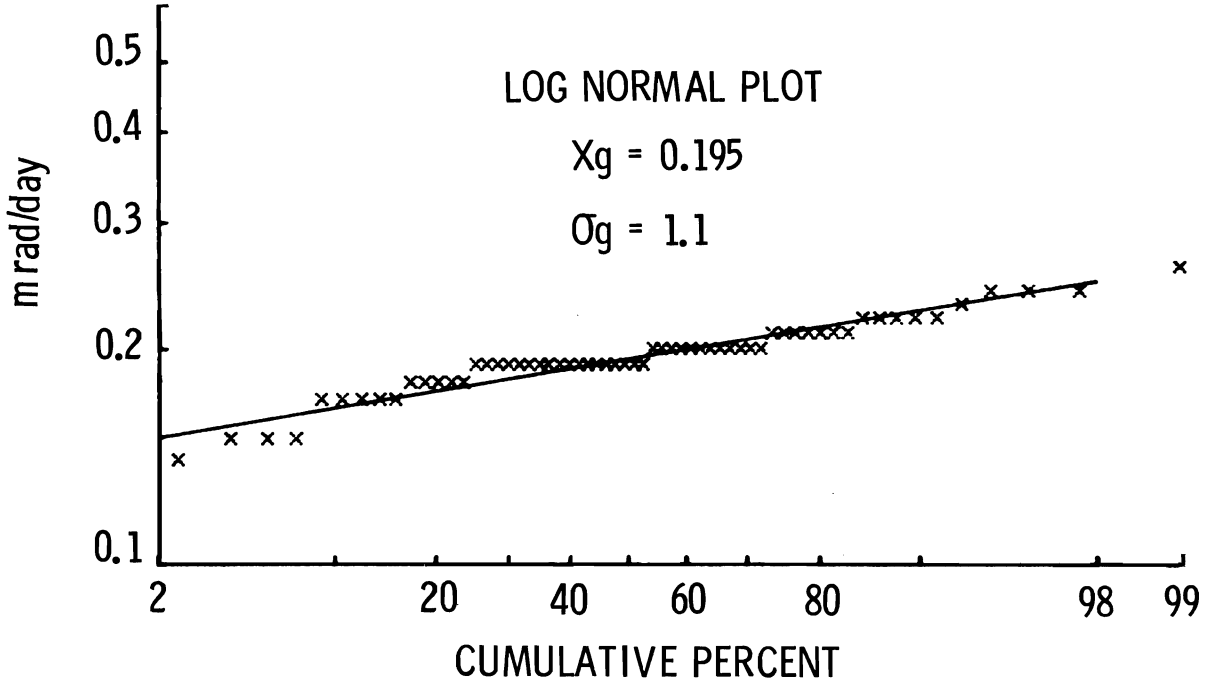
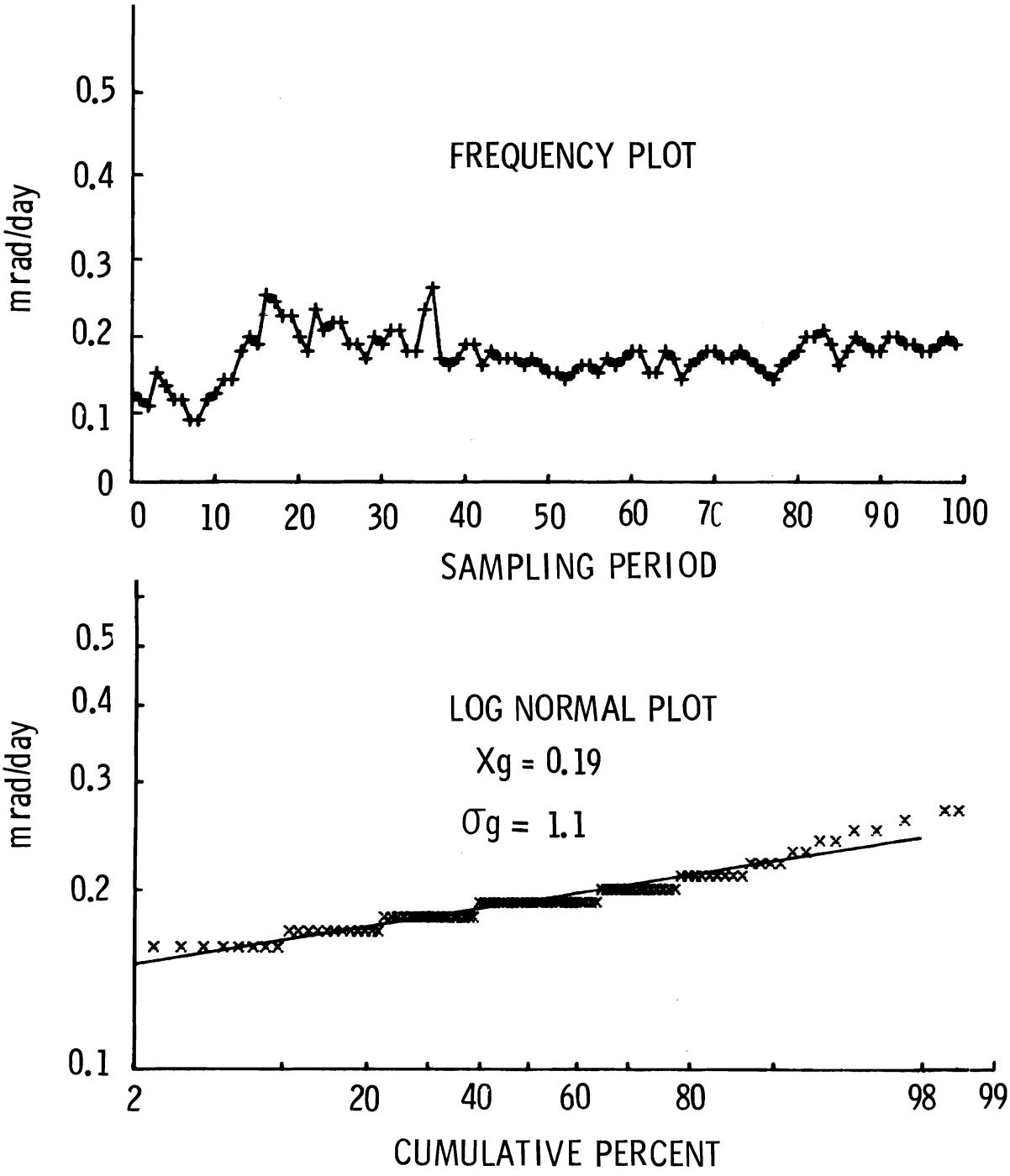




RICHLAND


FREQUENCY PLOT
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0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.19
σg = 1.1
mrad/day
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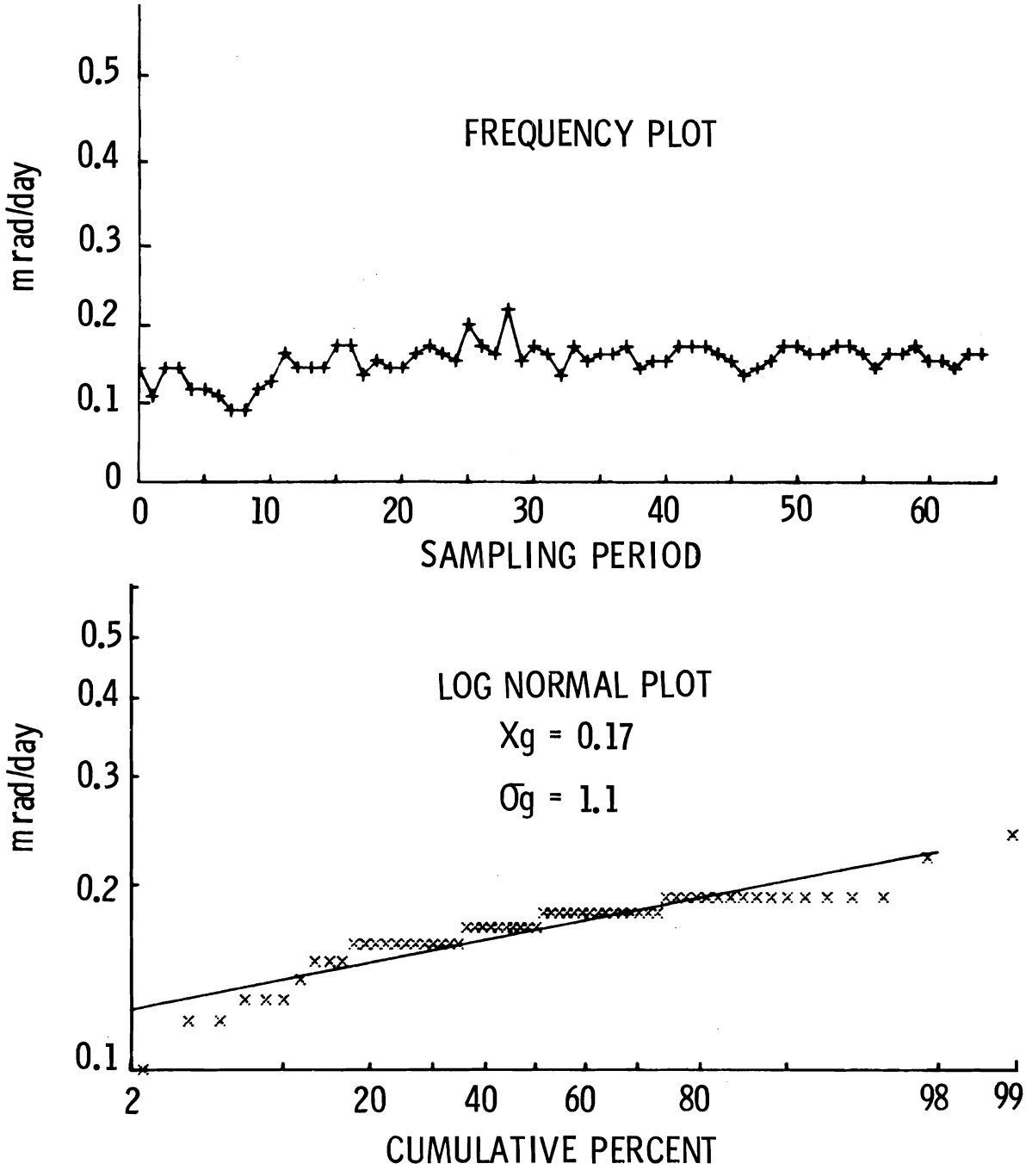
0.4
0.3
0.2
0.1
2 20 40 60 80 98 99
CUMULATIVE PERCENT

SUNNYSIDE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50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.17
σg = 1.1
mrad/day
0.5
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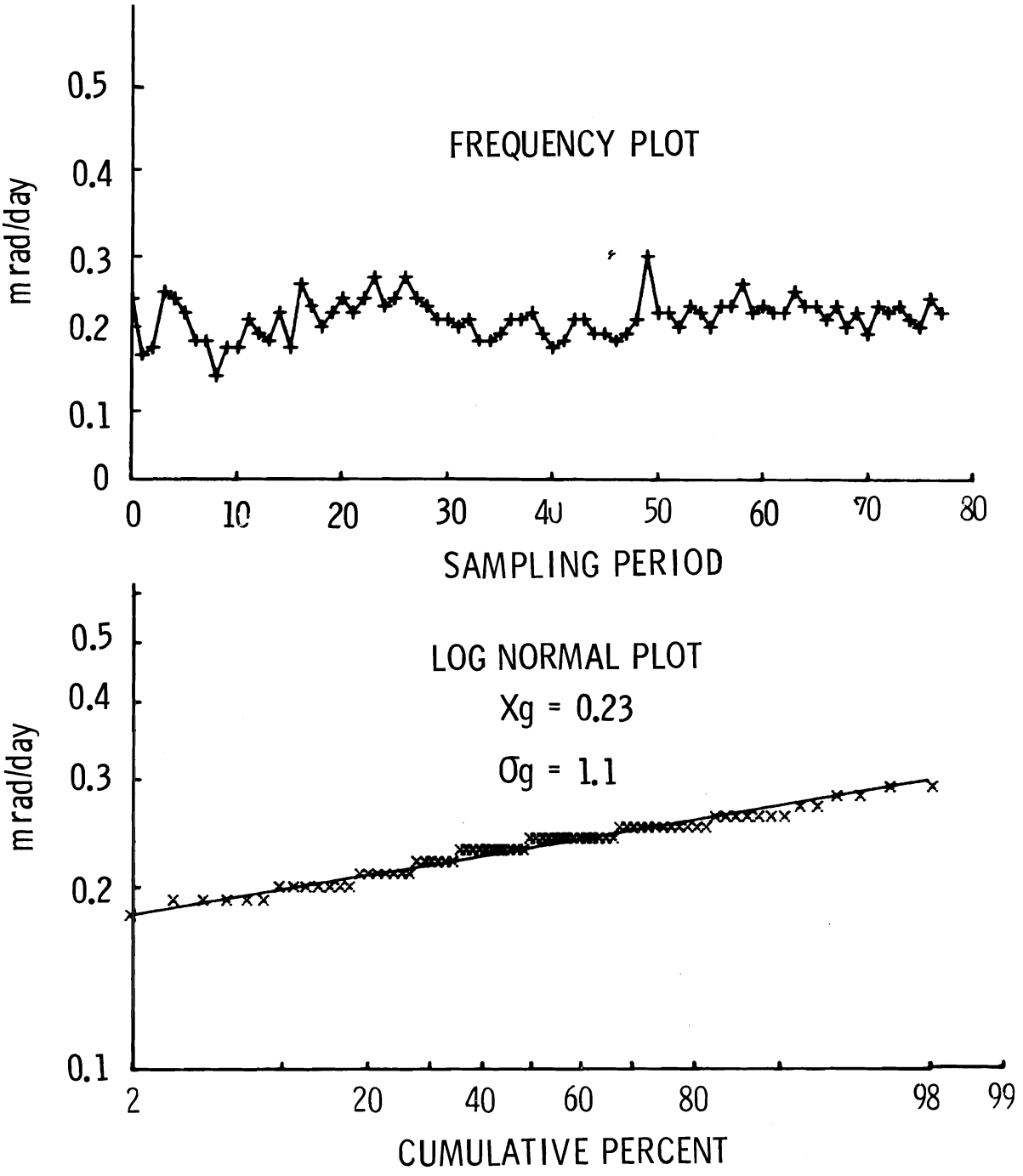
2
20
40
60
80
98
99
CUMULATIVE PERCENT

VERNITA BRIDGE



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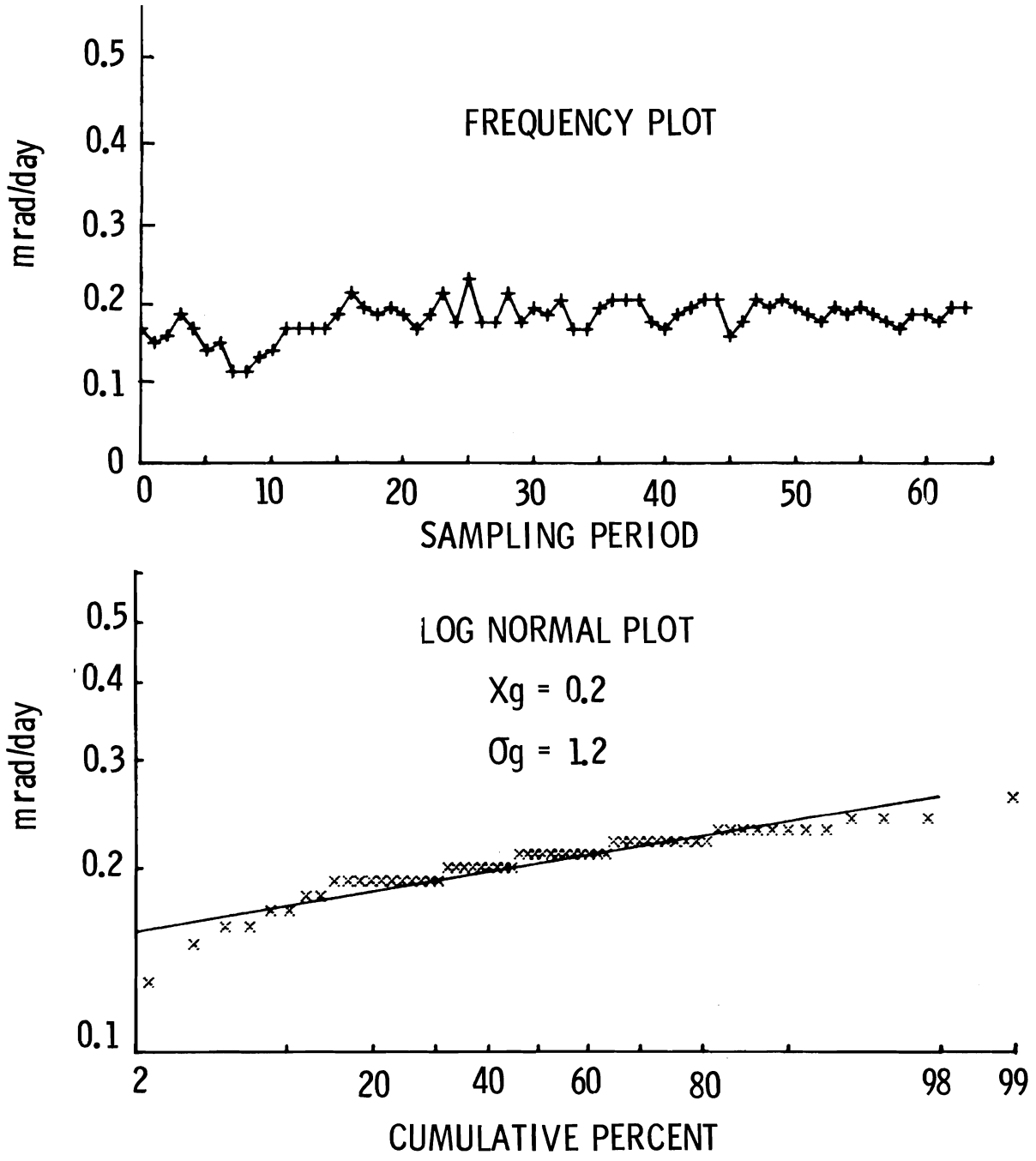
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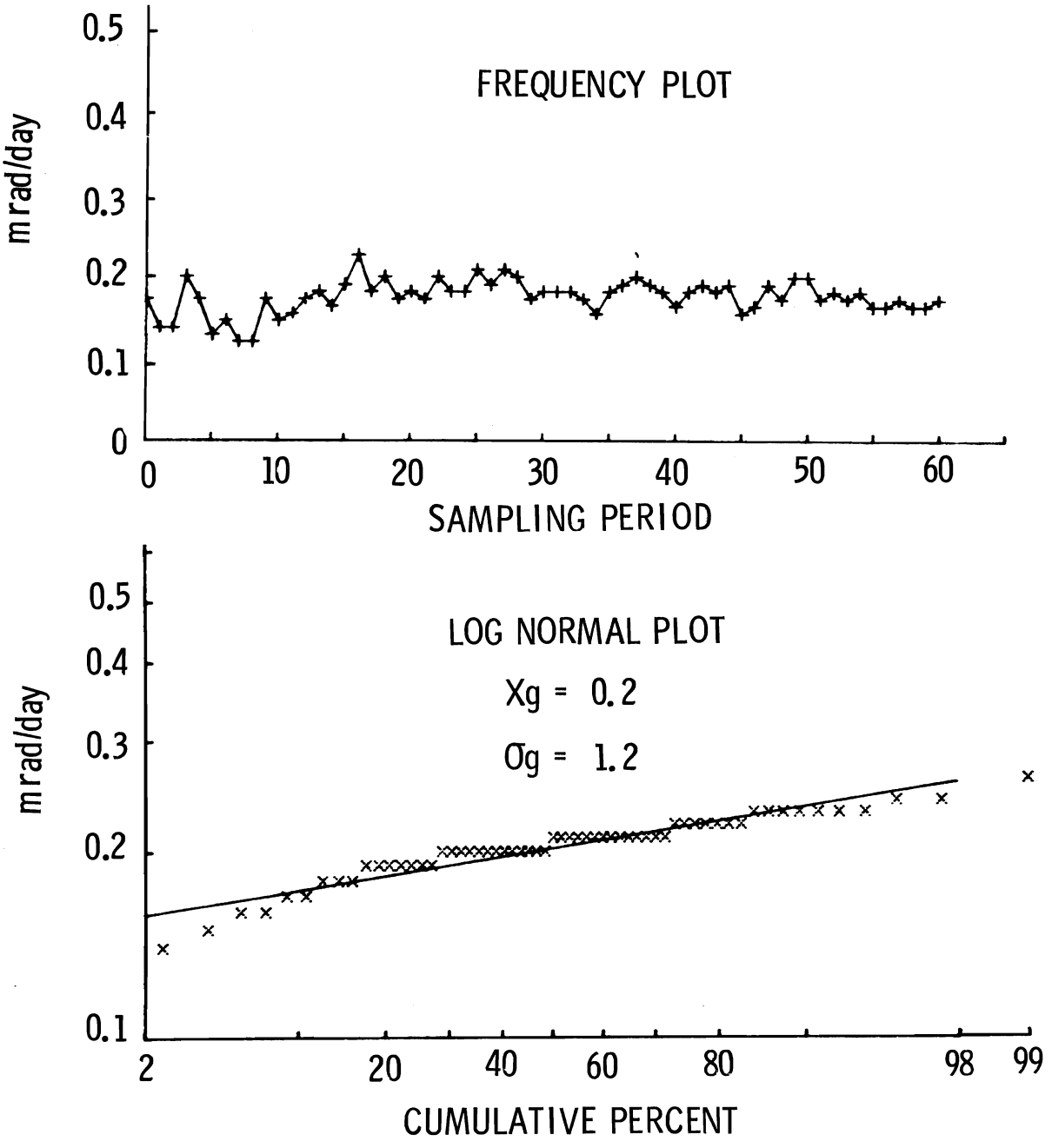
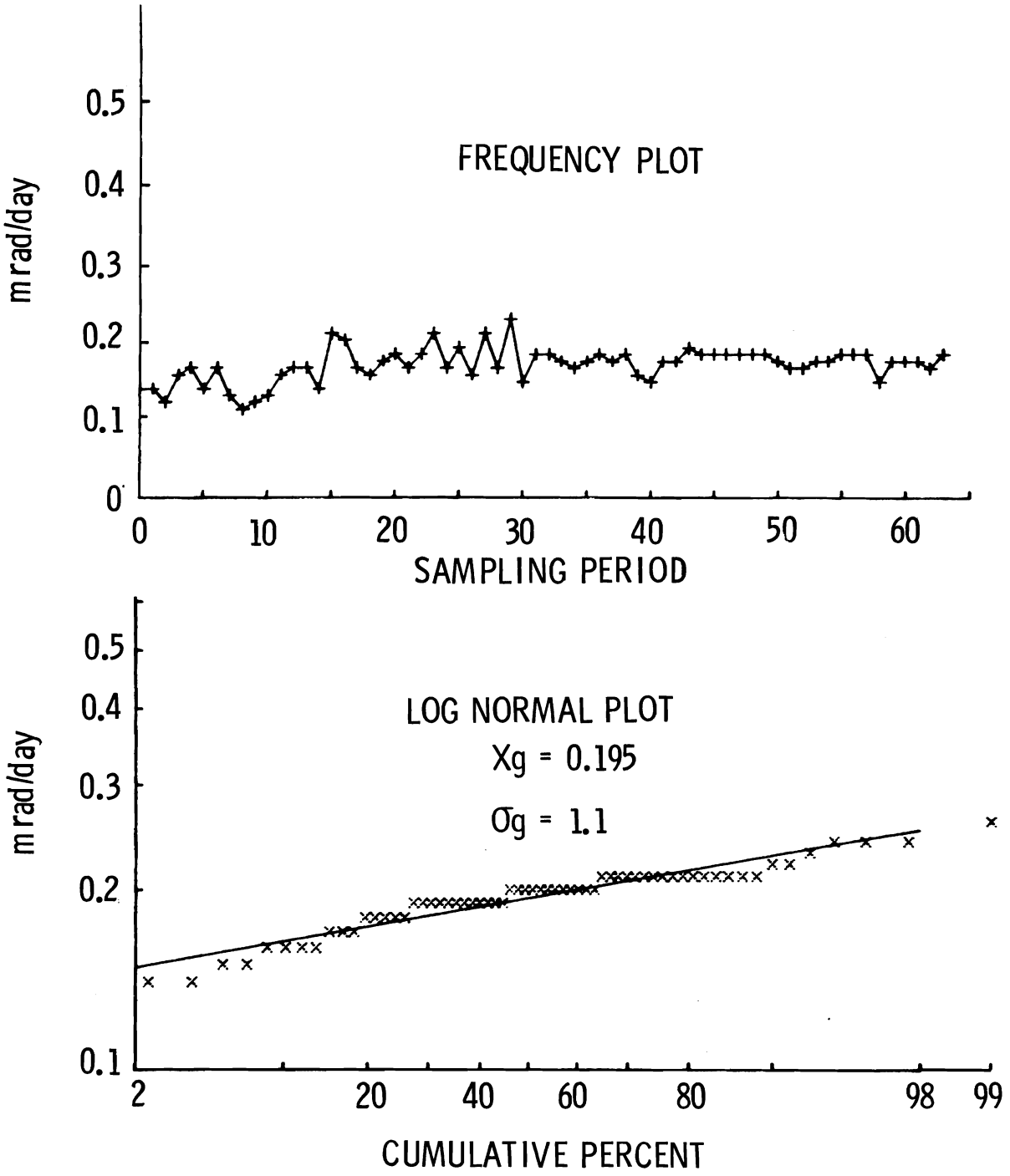
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.2
Og = 1.2
mrad/day
0.5
0.4
0.3
0.2
0.1
2
20
40
60
80
98
99
CUMULATIVE PERCENT

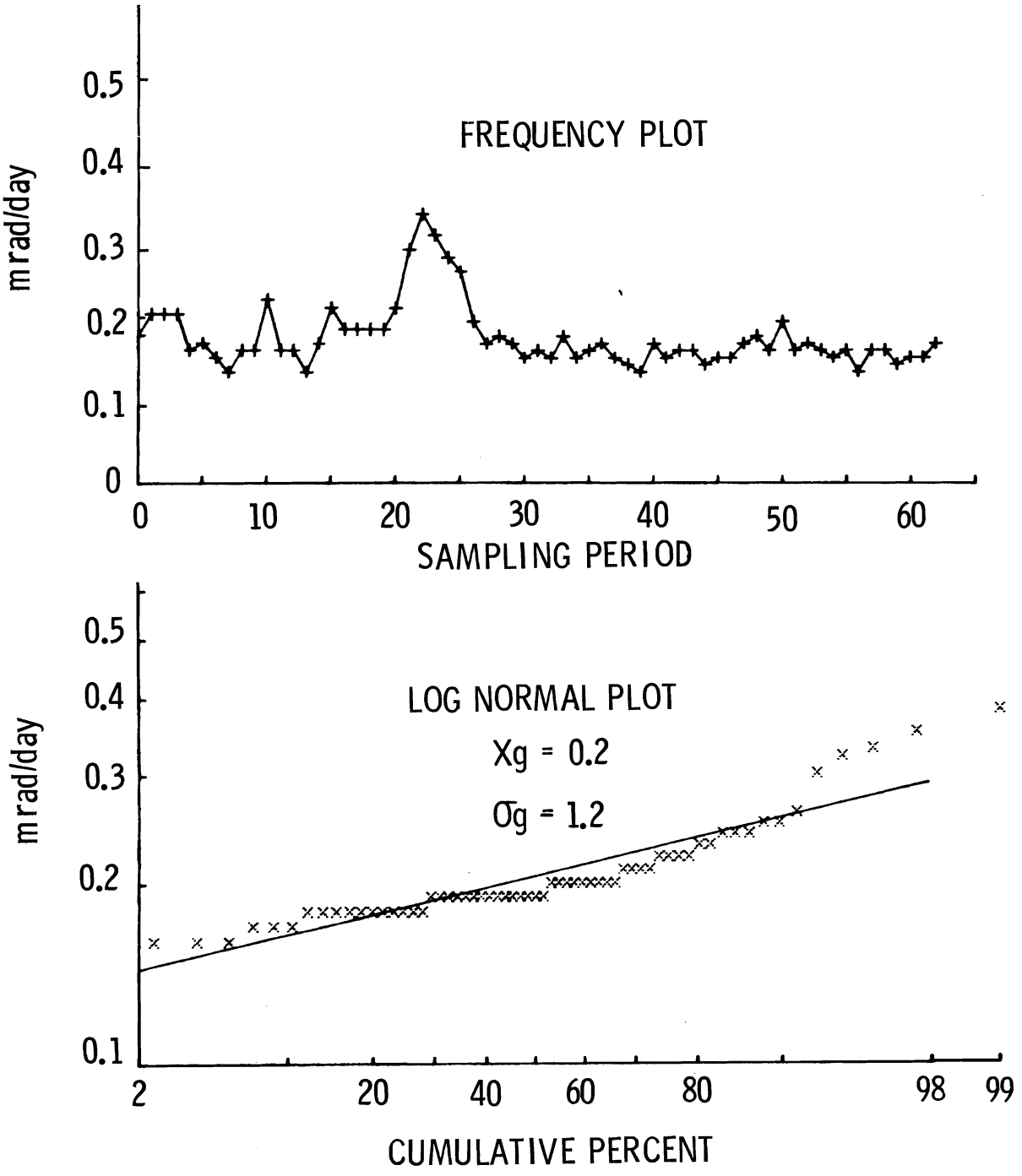
WAHLUKE WATERMASTER



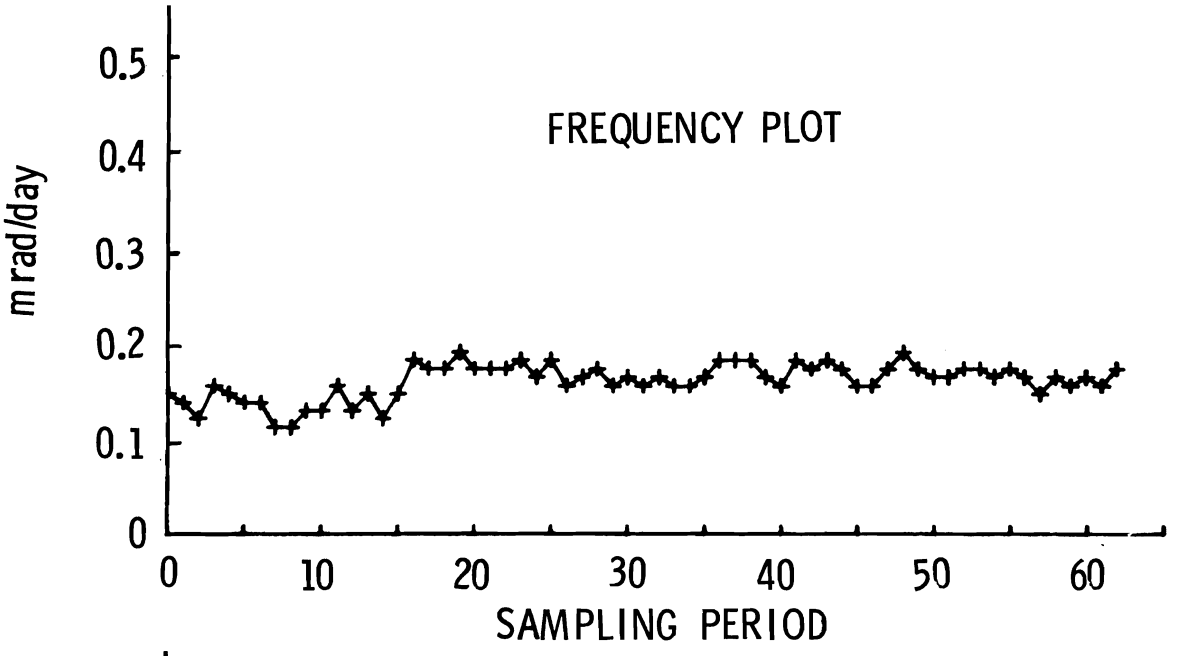
WALLA WALLA

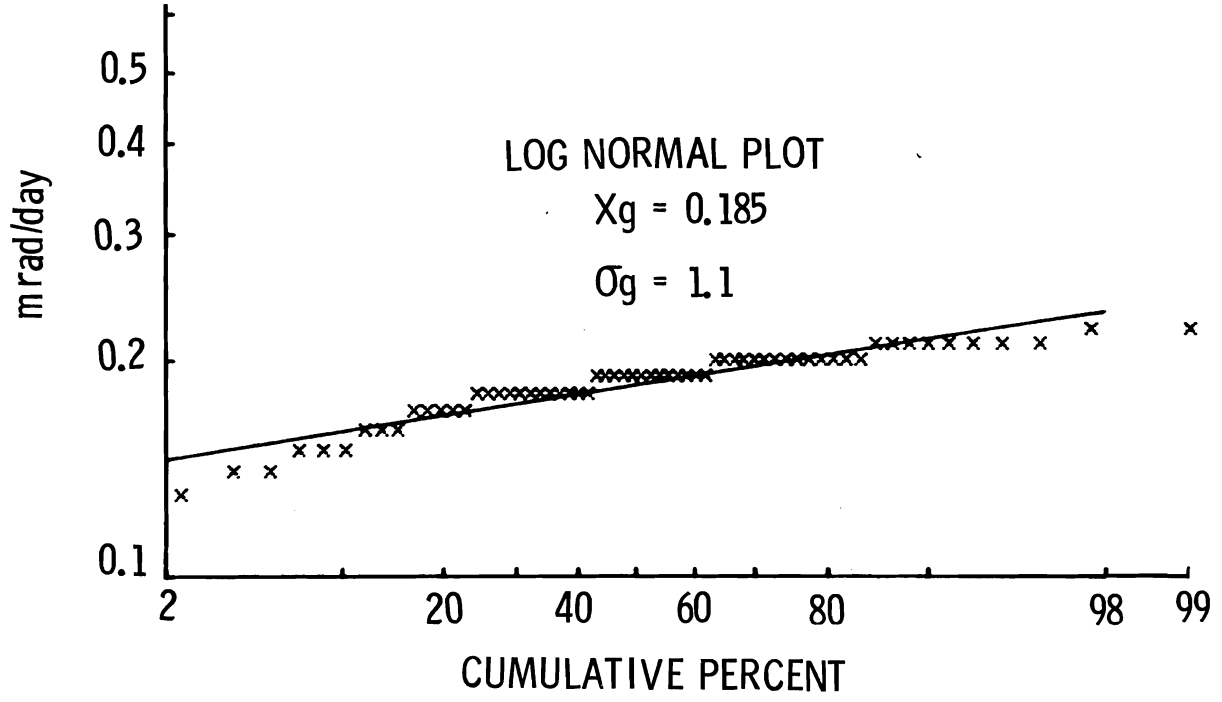

FREQUENCY PLOT
mrad/day
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.195
σg = 1.1
mrad/day
0.5
0.4
0.3
0.2
0.1
2
20
40
60
80
98
99
CUMULATIVE PERCENT

WASHTUCNA

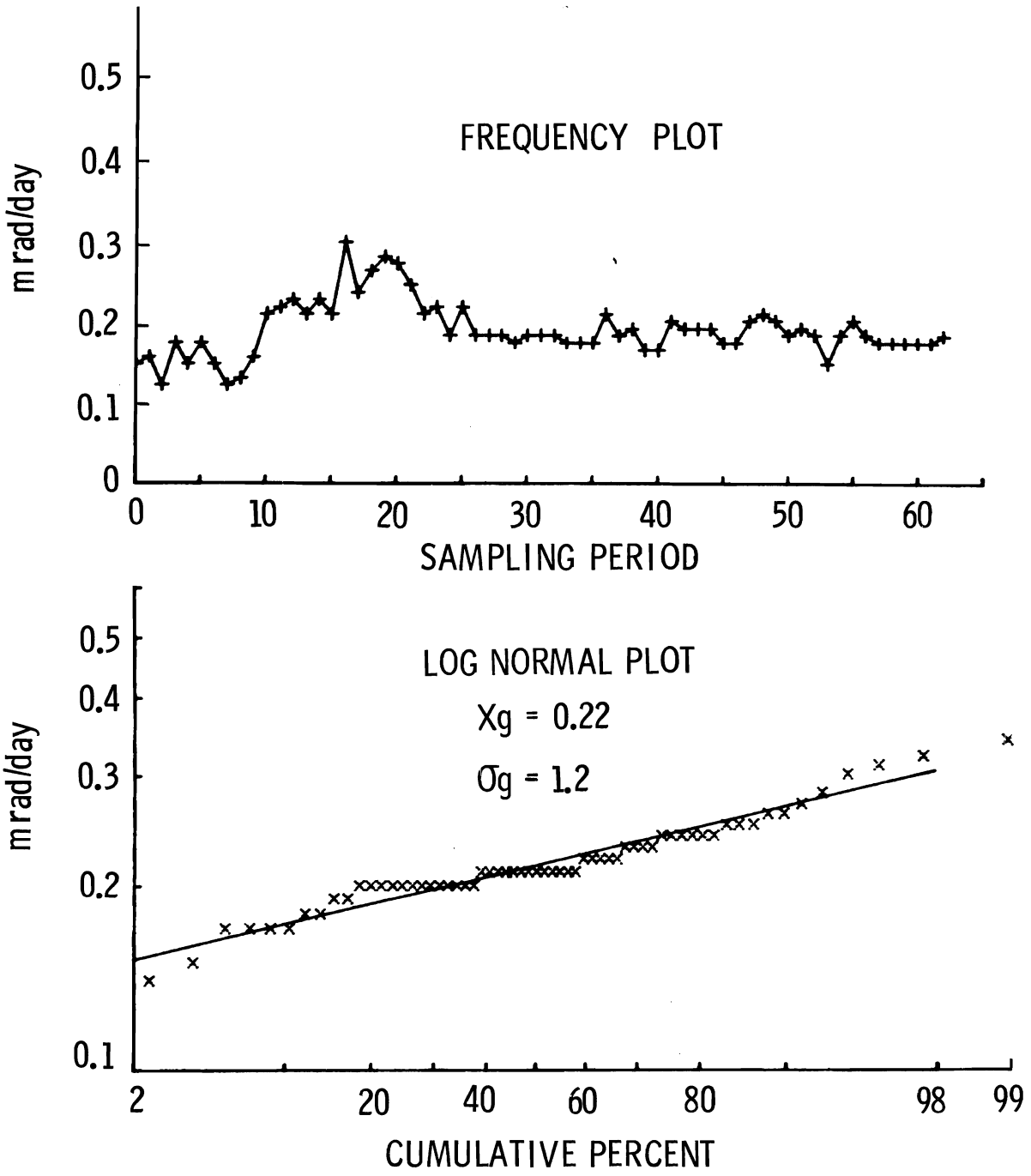

FREQUENCY PLOT
mrad/day
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
SAMPLING PERIOD
LOG NORMAL PLOT
Xg = 0.2
σg = 1.2
mrad/day
0.5
0.4
0.3
0.2
0.1
2
20
40
60
80
98
99
CUMULATIVE PERCENT

WYE BARRICADE





YAKIMA BARRICADE



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