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16. Abstract

Procedures particularly applicable to Washington State have been developed to assist the highway designer in evaluating and minimizing the impacts of highway runoff on receiving waters. The guide provides computation procedures to estimate pollutant concentrations and annual loadings for three levels of analysis which depend on the watershed, the discharge system and traffic. It further provides means to judge the potential impacts of the runoff on receiving waters.

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EXECUTIVE SUMMARY

This guide presents stepwise procedures for assessing stormwater runoff impacts on receiving waters resulting from highway operations and maintenance. The methods were developed from the results of the Highway Runoff Water Quality research project, sponsored by the Washington State Department of Transportation (WSDOT) and conducted by the Department of Civil Engineering of the University of Washington. The assessment procedure is organized in three levels, ranging from a rapid screening method intended to identify those cases having a low probability of extensive impacts (Level I) to a detailed evaluation focusing on impact mitigation (Level III). Within each level the analysis is concerned with runoff quantity, pollutant concentrations, and cumulative contaminant loadings. In Levels II and III, runoff quantity is estimated according to the procedure specified by the WSDOT "Highway Hydraulic Manual" and compared to regulations placed on receiving stream peak flow increases. Highway runoff pollutant loadings are estimated using a model developed during the research and compared to existing receiving water loadings. A series of graphs is included to establish the probability of exceeding pollutant concentration criteria in any storm. The guide also presents methods for assessing water quality impacts of sanding, deicing, pesticide applications, woodwaste fill leachate, and accidental spills, as well as considerations where highway runoff affects groundwater.

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I. INTRODUCTION

Scope

This guide for assessment of water quality and aquatic ecological impacts of operating highways combines experience gained during conduct of the Washington State Department of Transportation (WSDOT)/University of Washington (UW) Highway Runoff Water Quality research project with relevant findings reported in the stormwater runoff literature. The basis for the recommended methods has been covered in the various reports previously issued during the project (Horner, et al., 1979; Clark and Mar, 1980; Asplund et al., 1980; Mar et al., 1981a, 1981b; Chui et al., 1981; Wang et al., 1982; Portele et al., 1982). The assessment approach is responsive to the Draft Guidelines for Review of Environmental Impact Statements, Volume I, Highway Projects, issued by the U.S. Environmental Protection Agency (1978), and is specifically oriented towards the operating requirements and conditions of Washington State highways.

The potential water quality impacts resulting from highway operations are: (1) possible increase of peak flows in receiving streams; (2) possible erosion and sediment transport into receiving waters; (3) degradation of receiving water quality, with possible impairment of beneficial uses and harm to aquatic biota, due to drainage of contaminants incidently deposited on the roadway; and (4) receiving water effects associated with maintenance procedures. The guide provides assessment techniques applicable to each of these impacts and recommends strategies for reducing the severity of the identified impacts. It also treats special problems in water quality impact assessment.

It is anticipated that this guide will be used by designers preparing environmental assessments for proposed transportation projects, with emphasis on commitments associated with mitigating measures carried out by construction and field maintenance and operations personnel. Routine maintenance and operations activities do not require environmental documentation except during the design phase.

most cases, receive runoff from a wide area. As few loading criteria exist, assessing the highway contribution usually involves comparing the loadings of various pollutants in highway runoff relative to those in drainage from the remainder of the watershed. Evaluating loading effects, therefore, requires placing the highway in the context of the surrounding land uses. This is the strategy recommended for impact analysis at Levels II and III.

The approach presented in this guide is representative of certain conditions prevalent in Washington State but not the nation as a whole. Research by the Municipality of Metropolitan Seattle (Farris et al., 1979) and WSDOT/UW (Asplund, 1980) has shown that there is a minimal "first-flush" of high pollutant concentrations in Western Washington, as opposed to findings in most other areas. The first-flush is a period at the onset of storm runoff, usually only a fraction of an hour in length, during which accumulated contaminants wash off in considerably greater concentrations than during the remainder of the storm. In Western Washington the frequent, low intensity storms continually clean surfaces and prevent heavy pollutant accumulations. In Eastern Washington the situation differs due to the combination of sparse vegetation, erosive soils and relatively high wind speeds. These factors result in the movement of considerable quantities of solids from surrounding lands to highway surfaces. First-flush concentrations would, in general, be higher in Eastern than Western Washington. Highway runoff in Eastern Washington, however, usually is distributed overland rather than directed to surface waters. In this situation cumulative contaminant loadings to any subsurface waters intercepted are of greater importance than concentrations.

The recommended impact assessment procedure omits an evaluation of dissolved oxygen depletion in receiving streams, which, in general, is a potential impact of highway runoff. This effect is not expected to occur in Washington State, since most runoff occurs in the winter, when low temperatures increase oxygen solubility and high flows provide high dilution ratios.

It has been observed during the WSDOT/UW research that the major sources of pollutants in highway runoff are deposition from vehicles, transport from adjacent lands, pavement wear, and certain maintenance procedures. The research demonstrated that vehicular deposition primarily results from the spray-washing of material adhering to the undercarriages of vehicles traveling on the wet roadway. This material is apparently impacted and retained during dry periods. Between storms, traffic also generates winds which transport a portion of the deposited material off the highway surface.

A pollutant loading model was formulated on the basis of the research data and the observation that highways serve as receptacles for contaminants transported from adjacent areas and washed from the undersides of vehicles traveling during storms (considered to be the period while the road remains wet). The model expresses cumulative runoff pollutant loadings as functions of highway geometry, drainage configuration, and vehicles during storms, as follows:

$$TSS = (K)\ (VDS)\ (C)$$

$$\text{Loading of Pollutant } i = (K_{p_i})\ (\text{TSS Loading})$$

where: TSS = loading of total suspended solids from runoff (lb/highway-mi)

K = loading constant (lb/1000 VDS/highway-mi)

VDS = vehicles during the storm (in thousands)

C = runoff coefficient (ratio of runoff volume to precipitation volume)

K_{p_i} = ratio of pollutant i to TSS

The loading relationships represent pollutants incidently deposited during normal highway operations. The impact of sand applied for winter traction must be analyzed separately, as outlined in Section IV.

The pollutant loadings estimated in this way are valid over the long-term (monthly or annually). However, little precision results if the equations are applied on a storm-by-storm basis. It is hypothesized that there is a cyclic accumulation and washoff of pollutants, the build-up being associated with small storms which wash the undersides of vehicles. Larger storms then periodically wash the road surface. Therefore, loadings in a given locale are highly variable in the short time frame but more constant in the longer span, when normalized for traffic and runoff coefficient.

In addition to assessing cumulative impacts by means of the loading model, it is necessary to evaluate acute effects on receiving waters. To do so, individual event concentrations and loadings must be expressed. Substantial variation occurs in all pollutant concentrations and loadings from storm-to-storm. Thus, the assessment of acute effects is based on a probability analysis indicating the chance of exceeding given concentration and loading values in any event. Curves have been derived from the data to illustrate the probability relationships for Eastern and Western Washington conditions at two traffic levels. Curves are also included on these plots to represent reductions of the contaminants by set amounts as a result of removal by treatment methods, dilution by receiving waters, or a combination of the two. In the case of some pollutants, established water quality criteria are indicated to provide a basis for evaluating impact.

The data indicated that the concentrations and loadings of many pollutants are proportional to those of total suspended solids. Loadings of these pollutants are modeled according to this relationship. An important consequence of this finding is that removing TSS from the runoff also reduces other contaminants. One specific result is that the most toxic organic contaminants, if detectable at all, are primarily adsorbed on solid particles. As one example, Zawlocki (1981) found that 59-98 percent of aromatic compounds occurring in Washington State highway runoff are associated with solids. That being the case, absence of an impact due to TSS is presently regarded as a valid indication that organics would likewise not impair the receiving water. The toxicity demonstrated in certain highway runoff samples (Portele et al., 1982) is thought to be caused chiefly by dissolved metals.

The most cost-effective means of removing solids and associated pollutants appears to be directing runoff over a vegetated drainage course. It was demonstrated that a grass-lined ditch 200 ft in length is capable of decreasing the total suspended solids, chemical oxygen demand, and total lead by approximately 80 percent. More soluble metals, such as zinc and copper, were reduced by approximately 60 percent (Wang et al., 1982). Unvegetated channels do not provide filtering action, and residues deposited in them are easily entrained by subsequent runoff.

Maintaining vegetated drainage systems may require modified cleaning procedures to achieve both acceptable hydraulic performance and runoff treatment. One possible strategy would be to clean only a portion of a ditch each year and hydroseed to promote regrowth if scraped bare. In the case of a highway adjacent to an ecologically sensitive receiving water in an arid area, it may be warranted to protect the water by cultivating and, if necessary, irrigating a vegetated drainage area.

General Highway Design and Operating Recommendations

Project design features and subsequent maintenance practices can frequently eliminate or greatly reduce runoff receiving water impacts, thus alleviating the need to employ more costly impact mitigation techniques. Several design strategies which would serve this purpose emerged during the course of the WSDOT/UW research; generally stated, they are:

1.) Highway corridors should be as distant as possible from potential receiving waters and should occupy a minimum proportion of the drainage area of a specific receiving water. This guideline is particularly important for ecologically sensitive waters.

2.) Avoid, if at all possible, direct discharge of highway runoff to receiving waters, especially via long pipes, concrete conduits or bare ditches, unless it will be immediately diluted to acceptable levels by natural waters (as determined by the Level II concentration analysis). It is recommended that runoff be channeled over vegetated drainage courses 200 ft or more in length. Vegetated drainage system design is especially recommended when ecologically sensitive receiving waters are involved.

3.) Minimize the use of fine sands and road salts in winter operations, since these materials greatly increase the suspended and dissolved solids loads, respectively, on receiving waters. Coarse particles are not nearly so effectively transported by runoff as are fine grains.

II. DATA REQUIREMENTS

A highway project environmental assessment should contain information concerning highway design features, drainage system details, physical and hydrologic characteristics of the receiving water, baseline water quality and biological data, anticipated impacts and proposed mitigating measures and their expected effectiveness. Table 1 lists the data that should be assembled for presentation and use in conducting the water quality assessment. Appendix A provides a listing of possible sources for the environmental data.

Additional detailed information must be presented when a highway impinges upon an EPA-designated sole-source aquifer. These requirements are listed under the topic "Involvement with Groundwater" in Section IV.

Table 1: Data for Assessing Water Quality Impacts of Highway Operations.

<u>Highway Design Features</u>
- Length
- Number of lanes and lane widths
- Type of access
- Access ramps or intersecting roads
- Paving material
- Type of section(s) involved (at grade, cut, fill)
- Slopes (longitudinal and side)
- Median characteristics (width, paving, barrier type)
- Shoulder characteristics (width, paving, barrier type)
- Characteristics of area outside the shoulders but within the right-of-way (dimensions, topography, vegetation)
- Total impervious surface area

<u>Operating Conditions</u>
- Design average daily traffic (ADT)
- Projected vehicle composition
- Expected daily, weekly and seasonal traffic patterns
- Anticipated average speeds and braking characteristics
- Summary of applicable accident and spill data (from records on similar highways; also see Eagen, 1980; Andrews et al., 1981)

<u>Drainage System Characteristics</u> (to the extent available during environmental assessment)
- Channel types (closed conduit, paved open channel, bare open channel, vegetated open channel, unchanneled overland flow, etc.)
- Channel dimensions and slopes
- Soils and vegetation characteristics in flow path
- Discharge points
- Collection systems (type, dimensions and spacings of drop boxes, etc.)
- Design flow rates

<u>Hydrologic Characteristics</u> (see Appendix A for information sources)
- Average annual precipitation (rain and snow) and monthly distribution of precipitation
- Receiving water and ground water data --
  - Streams (base flow, annual average flow, peak flow, flood plain maps)
  - Lakes and reservoirs (surface area, mean depth, water residence time); Reference: Washington State Department of Conservation, 1961a, b.
  - Wetlands (surface area)
  - Groundwater (locations of aquifers, recharge characteristics)
- Summary of available data on point and nonpoint source flows in the watershed

<u>Water Quality and Aquatic Biological Data</u> (see Appendix A for information sources)
- Summary of available receiving water and groundwater monitoring data (water quality; microflora; microfauna; aquatic plants; benthic macro-invertebrates; fish populations, migrations and spawning areas)
- Sensitive or unique habitats
- Threatened and endangered species
- Summary of available data on effluent quality of sources in the watershed
- Beneficial use classification
- Established water quality criteria

<u>Surrounding Land Use Characteristics</u>
- Total watershed area
- Percentage of total area in each land use category (organized as in Tables 3 and 4)

<u>Projected Highway Maintenance Characteristics</u>
- Sanding application (quantity, frequency, particle size description)
- Deicing agent application (type, quantity, frequency, additives used)
- Pesticide application (type, quantity, frequency, toxicity)
- Roadway maintenance (sweeping, washing)
- Right-of-way maintenance (mowing, ditch cleaning, fertilizing, irrigation)

<u>Description of Special Features</u>
- Construction on woodwaste fill
- Detention basins
- Oil and grease traps
- Other mitigative features

III. GENERAL IMPACT ASSESSMENT PROCEDURES

This section contains a stepwise guide to estimating and evaluating highway runoff impacts of stormwater constituents incidently deposited on most Washington State highways. Figure 1 presents a flow chart of the assessment procedure through the three levels of detail. Analysis of special cases and the effects of maintenance applications is covered in Section IV.

Level I

1.) If all runoff discharges via a vegetated drainage course at least 200 ft in length (1), go to step 3. Otherwise, proceed to step 2.
2.) If projected traffic volume is less than 10,000 ADT (2), proceed to step 3. Otherwise, perform Level II analysis.
3.) Determine the total area of the watershed located upstream from the highway runoff discharge point. If there are multiple discharge points, base the determination on the one located farthest downstream.
4.) Determine the total area of impervious roadway surface contributing runoff to the stream.
5.) If the ratio of impervious roadway surface/total watershed area is less than 0.01 (3), declare no impact from ordinary runoff and

(1) Length identified by Wang et al. (1982) as reliably providing 60-80 percent reduction of major pollutants in highway runoff.

(2) Traffic volume below which no toxic effects appeared in bioassays (Portele et al., 1982).

(3) The 0.01 factor was selected on the basis of the research data. It is assumed that the dilution ratio is approximately equal to the ratio of areas. Highway runoff can contain concentrations of toxicants comparable to LC_{50}'s (concentration lethal to 50 percent of the organisms in an acute bioassay). A common means of protecting aquatic life is to limit receiving water concentrations to 0.01 X LC_{50}. In addition, investigation of the concentration-probability distributions (Figures 4-7) indicates that dilution of the order 100:1 is generally required to insure only a slight probability (< 0.1 percent) that established water quality criteria will be exceeded. With a high dilution ratio and either low traffic volume or drainage over a vegetated drainage course, it can be stated with assurance that the impact would be insignificant, thus avoiding more detailed analysis.

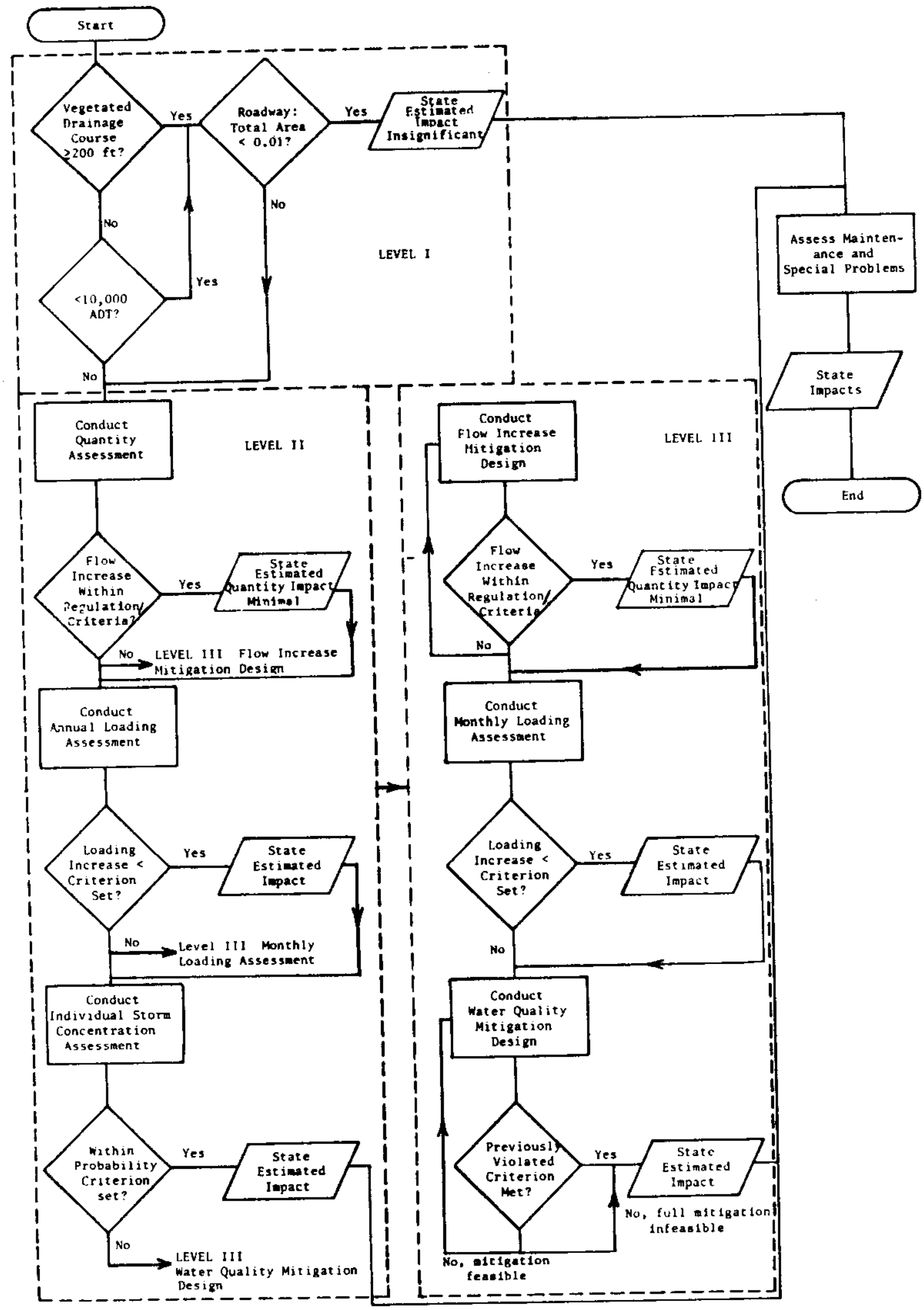

Figure 1: Flow Chart of Assessment Procedure

proceed to step 6. Otherwise, perform Level II analysis.

6.) Analyze impacts associated with the particular maintenance practices anticipated or any special problem areas (see Section IV).

Level II

1.) Runoff quantity assessment (when receiving water is a stream):

a.) Estimate runoff rate (Q, cfs) from the total area where normal permeability is expected to be modified by highway construction according to the Rational Method in the "Highway Hydraulic Manual" (Washington State Department of Highways, 1972):

$$Q = CIA$$

Where: C = runoff coefficient (ratio of runoff volume to precipitation volume)

I = design storm rainfall intensity (in/hr) (use storm of recurrence interval 25 yr and duration = time of concentration)

A = area where normal permeability is expected to be modified by highway construction (acre)

Note: In estimating time of concentration according to given procedure, use the average slope of the highway section. A value of 0.016 is typical for Manning's n for highway paving and storm sewers.

In addition to the guidance provided in the "Highway Hydraulic Manual" for selecting the runoff coefficient the following values were established during the research:

For right-of-ways constructed at grade and entirely paved and curbed, C = 0.75

For elevated sections, C = 0.70 (if leakage through expansion joints occurs, this value must be adjusted)

For other situations, C can be estimated from (after Hydrologic Engineering Center, 1974):

$$C = C_p + (C_I - C_p)(X)$$

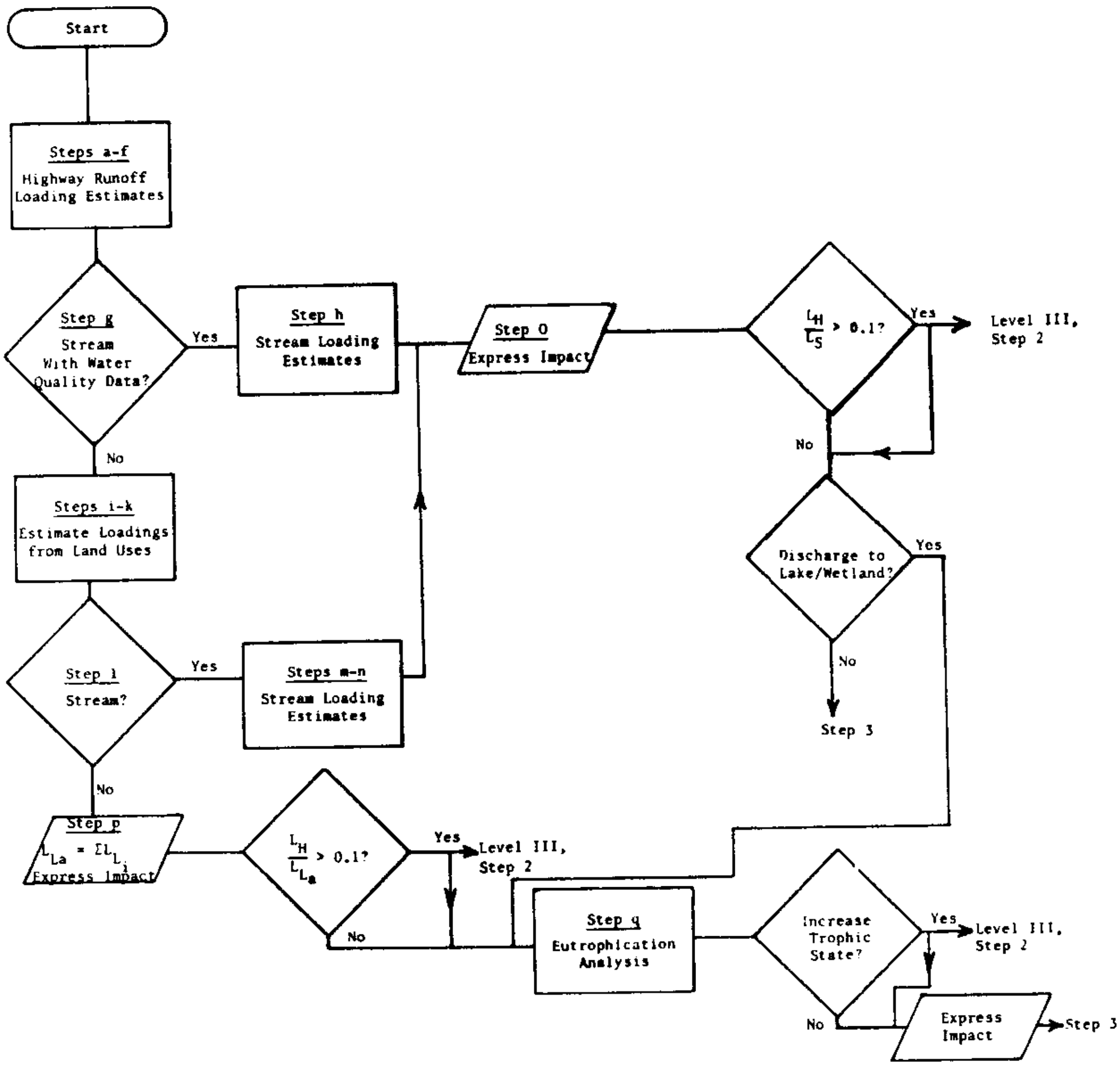

Figure 2: Flow Chart of Pollutant Loading Assessment Procedure

where: C_P = runoff factor for pervious surfaces (use 0.45 as default value)

C_I = runoff factor for impervious surfaces (use 0.70 as default value)

X = fraction of total right-of-way surface which is impervious

b.) If detention facilities will be provided, modify Q to the anticipated release rate during the design storm flow. If the facilities will not release water during periods of peak receiving streamflow, declare no impact on streamflow. Otherwise proceed to step 1.c.

c.) Determine peak flow rate (cfs) in the receiving stream for the design storm condition in one of the following ways:

(1) For streams having a gaging record, estimate the design peak streamflow rate according to the probability procedure in Appendix B.

(2) Consult "Magnitude and Frequency of Floods in Washington" (U.S. Geological Survey, 1975), using the appropriate equation for the 25-yr recurrence interval storm. (Note: Be sure to apply the equations only under the conditions stated. Use only the precipitation data in the manual).

(3) Apply the procedure described in step 1.a. to the entire watershed in its state prior to highway construction.

d.) Express the impact on streamflow in terms of the estimated increase due to highway runoff as a percentage of the original peak streamflow. If the estimated increase exceeds that permitted under the regulations existing at the location in question, reconsider detention facilities, as advised in Level III, step 1.

2.) Annual pollutant loading assessment:

The flow chart in Figure 2 provides a guide to the loading assessment.

a.) Estimate the hr/yr during which the roadway is expected to be wet as equal to the hr/yr of recorded precipitation [1], using data in Appendix C for the location closest to the proposed construction site.

b.) Estimate the total annual vehicles passing during storms (VDS/yr) as follows:

$$VDS/yr = ADT \left(\frac{\text{wet hr/yr}}{\text{24 hr/day}}\right)$$

where: ADT = projected average daily traffic on highway lanes draining to receiving water

c.) Estimate annual highway runoff TSS loading according to:

$$TSS(\text{lb/highway - mi/yr}) = (K)\left(\frac{VDS/yr}{1000}\right)(C)$$

where: K = 6.4 lb TSS/highway-mi/1000 VDS for Western Washington [2]

K = 26 lb TSS/highway-mi/1000 VDS for Eastern Washington [2]

C is from step 1.a.

Note: If the lanes in one direction only drain to the receiving water, adjusted ADT accordingly.[3]

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(1) The reported hr/yr of recorded precipitation ($\geq$ 0.01 inch) represents the mean of a number of years of data (1948-1964). Trace quantities are eliminated from consideration since they do not generally produce runoff. The tabulated data are recommended as an estimate of the hr/yr of wet roadway, recognizing that two counteracting factors are operating: (1) the highway remains wet for some time after precipitation stops; however (2) precipitation does not necessarily fall throughout a recorded hour.

(2) The loading constants given apply to new highways and existing highways where traffic increase is anticipated. On existing highways the constants apply whether or not additional lanes are constructed, up to a maximum of four lanes in a single direction, representing the cases contributing to the data base (Little, 1982). With greater widths, pollutants deposited on innermost lanes may be transported less effectively into shoulder drainage such that K would tend to decrease; however, there was no sampling to test this hypothesis.

(3) The research demonstrated that pollutant loadings were better correlated with highway-mi than highway surface area or lane-mi.

d.) Express total annual highway loading (L_H) by multiplying by number of highway-mi.

e.) If a mitigation device such as a detention basin is provided, reduce the TSS loading according to the solids removal capability of the device. If highway runoff is discharged to receiving water via a vegetated drainage course, multiply the estimated TSS loading by the appropriate fraction, as follows (after Wang, 1981). Interpolate as necessary.

Length of Vegetated Drainage Course (ft)	Fraction of Pollutant Remaining
$\leq$ 30	1
31- 60	0.50
61- 90	0.40
91-120	0.30
121-150	0.26
151-180	0.23
$\geq$ 180	0.20

Use the modified TSS loading in further calculations.

f.) Estimate annual highway loadings of other pollutants from:

$$\text{Loading (lb/yr)} = (K_p)(\text{TSS Loading})$$

where: K_p = ratio of pollutant P to TSS (Table 2)
TSS Loading is estimate from step 2.d. or 2.e.

g.) If the receiving water is a stream and if a comprehensive water quality record exists for the stream, proceed to step 2.h. Otherwise, go to step 2.i.

h.) Estimate the mean annual loading of each pollutant transported by the stream prior to the presence of the highway (L_S, lb/yr) according to:

$$L_S = 1965\ \bar{Q}_S\ \bar{C}_S$$

where: $\bar{Q}_S$ = average stream discharge (cfs)

$\bar{C}_S$ = average pollutant concentration (mg/l) (see Appendix A for potential data sources)

Table 2: K_P (Pollutant:TSS Ratios) for Various Contaminants in Highway Runoff.

Pollutant	Abbreviation	K_P
Chemical Oxygen Demand	COD	$K_{COD} = 0.4$
Lead (Western Washington)	Pb	$K_{Pb} = 1.5 \times 10^{-4} + (8.7 \times 10^{-8})(ADT)$
(Eastern Washington)		$K_{Pb} = 5.3 \times 10^{-4} + (2.8 \times 10^{-9})(ADT)$ (Note 1)
Zinc (Western Washington)	Zn	$K_{Zn} = 1.4 \times 10^{-4} + (3.0 \times 10^{-8})(ADT)$
(Eastern Washington)		$K_{Zn} = 2.0 \times 10^{-4} + (3.2 \times 10^{-7})(ADT)$
Copper	Cu	$K_{Cu} = 7.9 \times 10^{-5} + (2.7 \times 10^{-9})(ADT)$
Nitrate + Nitrite-Nitrogen	NO_3+NO_2-N	$K_N = 2.0 \times 10^{-3}$
Total Kjeldahl Nitrogen (Western Washington)	TKN	$K_{TKN} = 2.7 \times 10^{-3}$
(Eastern Washington)	-	$K_{TKN} = 1.2 \times 10^{-3}$
Total Phosphorus	TP	$K_{TP} = 2.1 \times 10^{-3}$

Note: (1) Base predicted lead loading on the lead concentration in gasoline at the time in proportion to that during the years of research. During those years, the concentration was 0.13 grams/liter. That concentration is scheduled to be reduced under U.S. Environmental Protection Agency regulations, and that agency can provide information on adherence to the schedule. For estimation purposes, it should be assumed that the proportion of vehicles using leaded gasoline remains constant.

If the stream is gaged, obtain $\overline{Q}_S$ in the U.S. Geological Survey Water Resources Data for Washington, Vol. 1 (Western Washington) or Vol. 2 (Eastern Washington) for a recent water year. If the stream is not gaged, estimate $\overline{Q}_S$ from the record of a nearby stream with similar watershed characteristics, as follows:

$$\overline{Q}_s = \overline{Q}'_s \frac{A_W}{A'_W}$$

where: $\overline{Q}_S$ = average discharge in runoff receiving stream (cfs)

$\overline{Q}'_S$ = average discharge in stream of record (cfs)

A_W = runoff receiving stream watershed area (any area units)

A'_W = stream of record watershed area (any area units)

Go to step 2.0.

i.) Determine annual areal loading (lb/acre/yr) of each contaminant from each land use in the receiving water basin from local data, if they exist, or Table 3. Where a range is given, use the lower value if a conservative estimate of highway contribution to total loading is desired; otherwise, use the midpoint of the range.

j.) Determine the areas (in acres) in General Urban, General Residential, General Agricultural and Forested or Open land uses in the watershed draining to the highway runoff discharge point located farthest downstream. If it is projected by the planning agency for the location that development will modify land uses substantially in coming years, conduct the analysis for both present and ultimate land uses.

k.) Multiply loadings in lb/acre/yr by the respective areas to obtain annual loadings from each land use (L_{L_i}). Then sum over all land uses for each pollutant (ΣL_{L_i}).

l.) If the receiving water is a stream, proceed to step 2.m. If the receiving water is a lake or wetland, go to step 2.p.

m.) Estimate point source loadings (L_P) of each pollutant as follows:

$$L_P \text{ (lb/yr)} = 1965\ Q_P\ C_P$$

where: Q_P = point source effluent flow rate (cfs) (average over year if not continuous)

C_P = average point source effluent pollutant concentration (mg/l)

See Appendix A for potential sources of effluent data.

n.) Estimate total stream loadings prior to the highway presence (L_S) as:

$$L_S = \Sigma L_{L_i} + L_P$$

Table 3: Storm Runoff Pollutant Loadings for General Land Use Categories

Land Use	Loading (lb/acre/yr)							
	TSS	COD	Pb	Zn	Cu	NO_3+NO_2-N	TKN	TP
General Urban	400	18-240	0.13-0.45	0.3-0.5	0.04-0.12	0.3-4.0	7.1	1.8
General Residential	375	27-270	0.05	0.02	0.03	0.3-3.4	5.4	1.6
General Agricultural	17,900-44,000	NA	0.002-0.07	0.004-0.3	0.002-0.08	0.3-7.1	0.3-30	0.1-8.0
Forested or Open	6-76	1.8	0.01-0.03	0.01-0.03	0.02-0.03	0.3-0.5	1.5-2.7	0.06-0.08

Notes: (1) Means given where available; otherwise ranges are reported. References include Wiebel et al., 1964; Avco Economic Systems Corporation, 1970; U.S. Army Corps of Engineers, 1974; Heany et al., 1976; Reese, 1976; Omernik, 1977; Wanielista, 1978; Browne and Grizzard, 1979.

(2) NA -- Not Available.

o.) Express the impact on stream pollutant loadings in terms of the estimated increase due to highway runoff (L_H) as a percentage of the original stream loadings (L_S). If the estimated increase exceeds ten percent for any pollutant, it is recommended that a Level III analysis be conducted for that contaminant to confirm the projected impact with a more exact procedure. If the stream eventually discharges to a lake or wetland, also evaluate the impact on that water body according to steps 2.p. and 2.q. Otherwise, go to step 3.

p.) If the immediate or eventual receiving water is a lake or wetland, estimate total annual loadings prior to the highway presence (L_{La}) as equal to ΣL_{L_i} plus any point source loading (1965 $Q_P C_P$). Express and evaluate the impact on lake or wetland pollutant loadings as in step 2.o.

q.) If the immediate or eventual receiving water is a lake, conduct a special analysis to assess the potential impact of phosphorus loading on trophic state as follows:

(1) Convert L_H and L_{La} to kg/yr by dividing by 2.2 lb/kg.

(2) Find the contributions of the highway and all other sources to the lake areal total phosphorus (TP) loading (Kg/ha/yr) by dividing L_H and L_{La} respectively, by the lake surface area (A_{La}, ha). (Note: 1 hectare, ha = 2.47 acres.)

(3) Divide lake mean depth (m) by water residence time (yr), where water residence time = lake volume (any volume units)/outflow rate (any consistent volume/yr units).

(4) Locate the lake on Figure 3, the trophic state graph (Vollenweider and Dillon, 1974) by using L_{La}/A_{La} as ordinate and the result of step 2.q.(3) as abscissa.

(5) Note the change in status that would be expected from the addition of highway runoff loading in the amount L_H/A_{La}.

(6) If the highway loading addition does not move the status point near or into a higher trophic category, declare minimal impact on lake eutrophication and go to step 3. Otherwise, reevaluate according to Level III, step 2.

3.) Individual storm event concentration assessment:

a.) Determine pollutant reduction factor due to mitigation measures according to step 2.d.

b.) Assume instantaneous mixing of runoff in receiving water. If the immediate receiving water is a stream, proceed to step 3.c. If the immediate receiving water is a lake or wetland, go to step 3.d.

c.) Approximate the mean dilution ratio as $Q/(Q + \overline{Q}_S)$, where $\overline{Q}_S$ is determined as in step 2.h.[1] For this calculation Q should be estimated from the Rational Method using for I the average intensity of the 25 yr recurrence interval, 24 hour duration storm. Consult NOAA, Atlas 2, Volume IX, Washington (U.S. Department of Commerce, 1973), which contains an isopluvial map for the given storm (divide quantity from map by 24 hours to get average intensity). Go to step 3.e.

d.) Approximate the dilution ratio as $QT/(QT + V)$, where Q is determined as described in step 3.c., T = 24 hr, the duration of the design storm (expressed as 86,400 seconds), and V = lake or wetland water volume (ft^3) (see footnote associated with step 3.c.). For lakes, V = mean depth x surface area.

e.) Determine the overall pollutant reduction factor as the product of the factor due to mitigation (step 3.a.) and the dilution ratio (step 3.c. or 3.d.)

---

(1) The exact mass balance relationships for stream and lake concentrations (C'_S and C'_{La}, mg/l), respectively are:

$$C'_S = (QC + \overline{Q}_S\overline{C}_S)/(Q + \overline{Q}_S) \text{ and } C'_{La} = (QTC + V\overline{C}_{La})/(QT + V)$$

where: C = pollutant concentration in highway runoff for a given event, which must be expressed probabilistically as in subsequent steps (mg/l)

$\overline{C}_{La}$ = mean lake concentration (mg/l)

Since the dilution ratio C'_S/C (or C'_{La}/C) cannot be exactly determined without a definite value of C, the approximation implicitly assume $\overline{C}_S$ (or $\overline{C}_{La}$) is negligible relative to C.

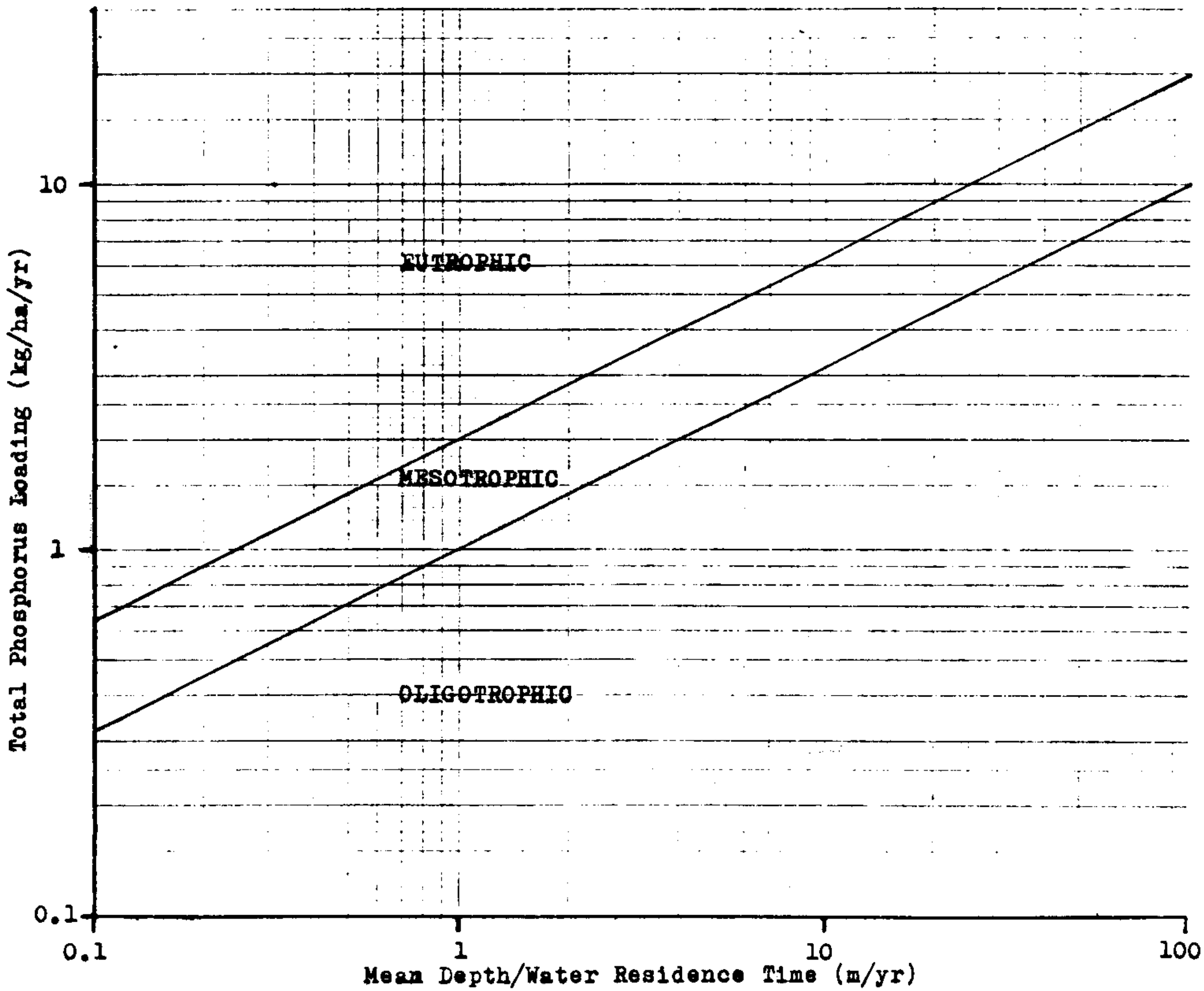


Figure 3: Lake Trophic State in Response to Phosphorus Loading (Vollenweider and Dillon, 1974).

f.) For the pollutant reduction factor, location, and traffic levels [1], determine for each pollutant the probability of exceeding a given concentration in any storm event by referring to Figure 4, 5, 6, or 7. The given concentration should be the water quality criterion if one has been set. If not, the given concentration should be referred to existing receiving water conditions to provide a basis for expressing impact (for example, equal to current mean concentration, maximum concentration, ten percent above current mean concentration, etc.). Express the impact on receiving water concentration in terms of the identified probability. An effective demonstration of minimal impact would be a low probability of exceeding a criterion or present contamination level.

g.) If a substantial probability exists for violating the selected concentration condition, reconsider mitigation measures, as described in Level III, step 3.

4.) Analyze impacts associated with the particular maintenance practices anticipated or any special problem areas (see Section IV).

---

(1) Traffic level breakdowns are based on data from sites having the following ADT:

Western Washington, High Traffic -- 42,000-53,000
Wastern Washington, Low Traffic -- 7,700-8,600
Eastern Washington, High Traffic -- 17,300
Eastern Washington, Low Traffic -- 2,000-2,500

At this stage of development of the methodology, linear interpolation is recommended to make estimates for intermediate traffic levels. The respective high traffic curves are recommended for traffic volumes greater than or equal to the ADT at the sites providing the data base. Except as noted, the source of aquatic life water quality criteria is the Federal Register, 45 FR 79318-79379, November 28, 1980.

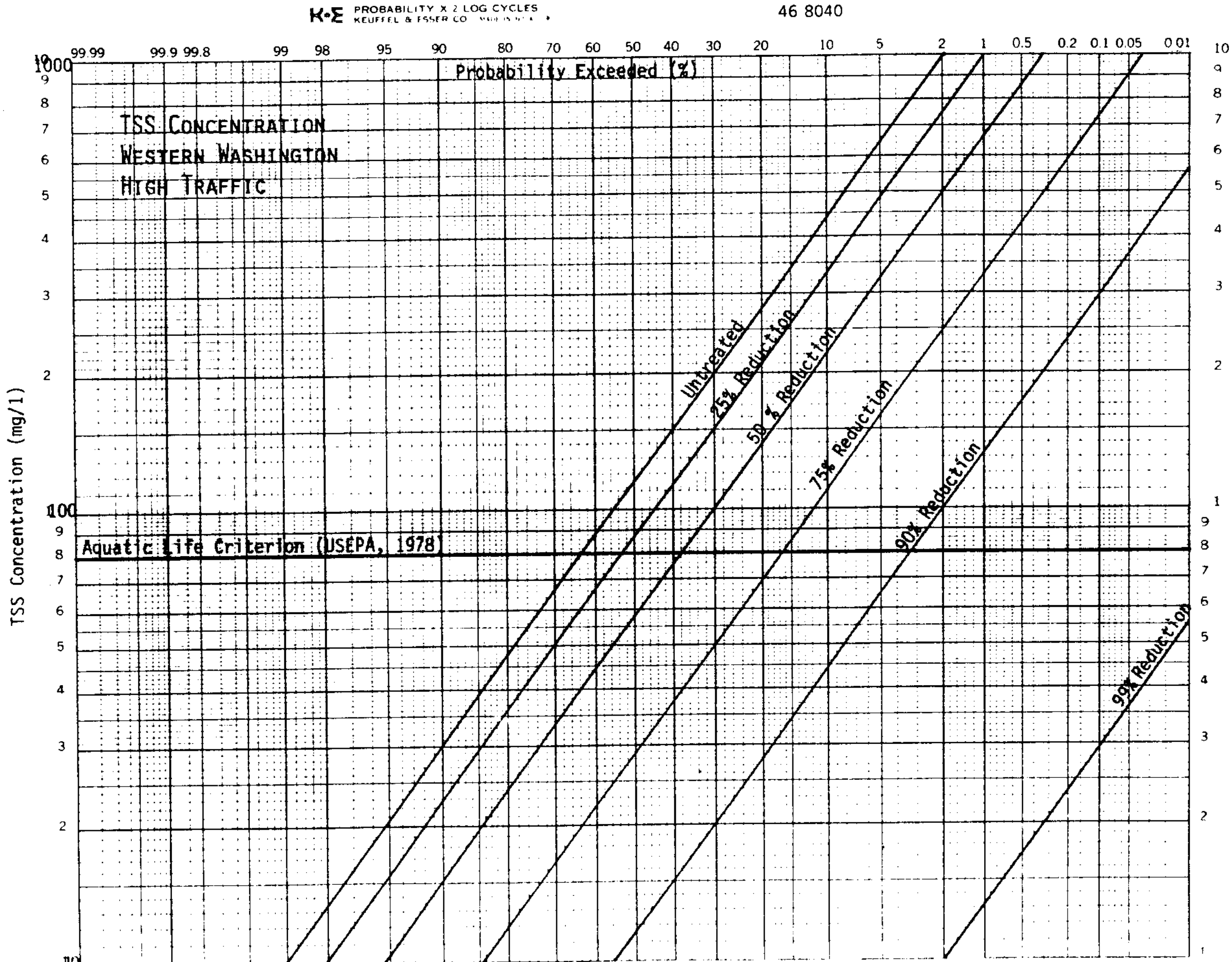
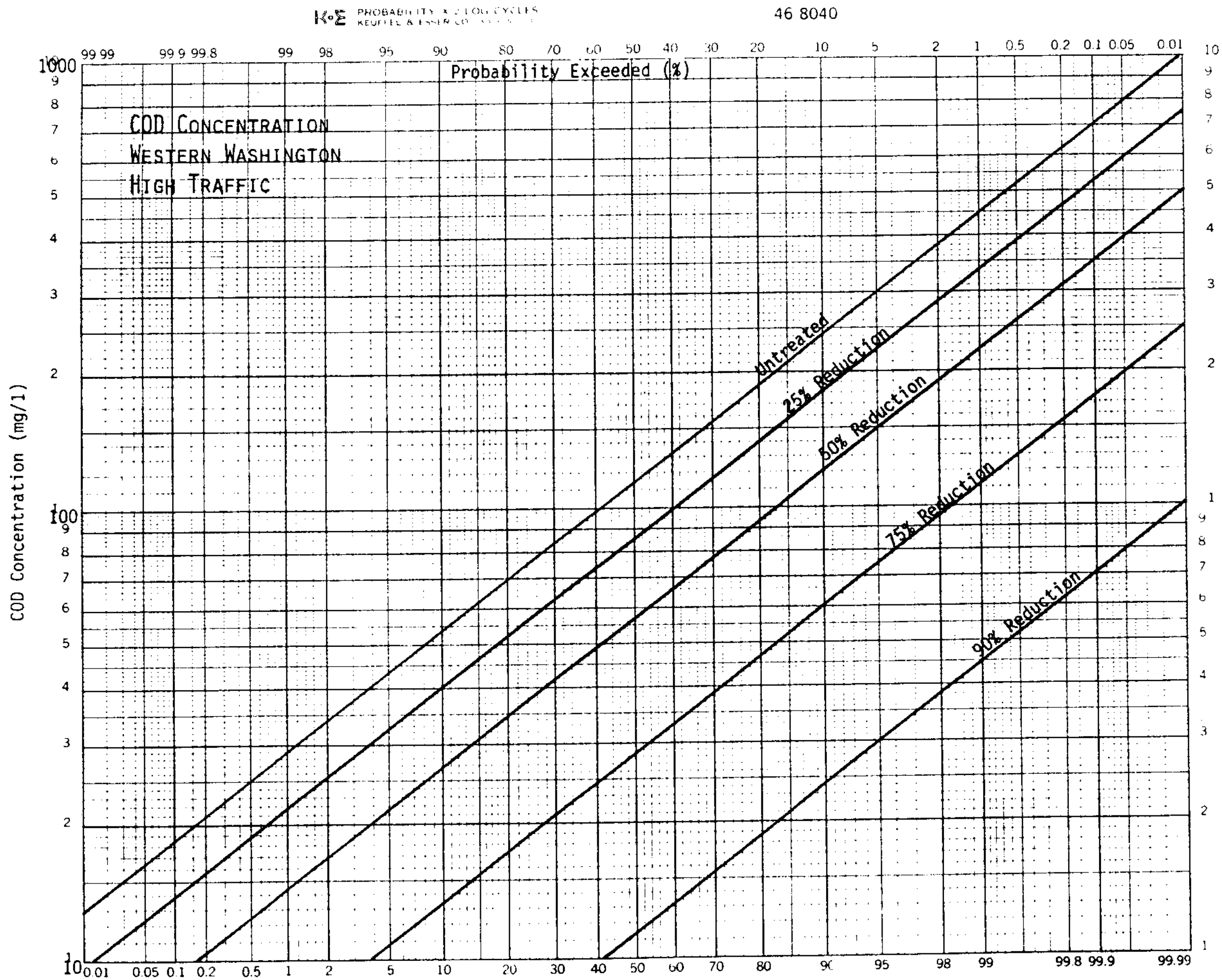
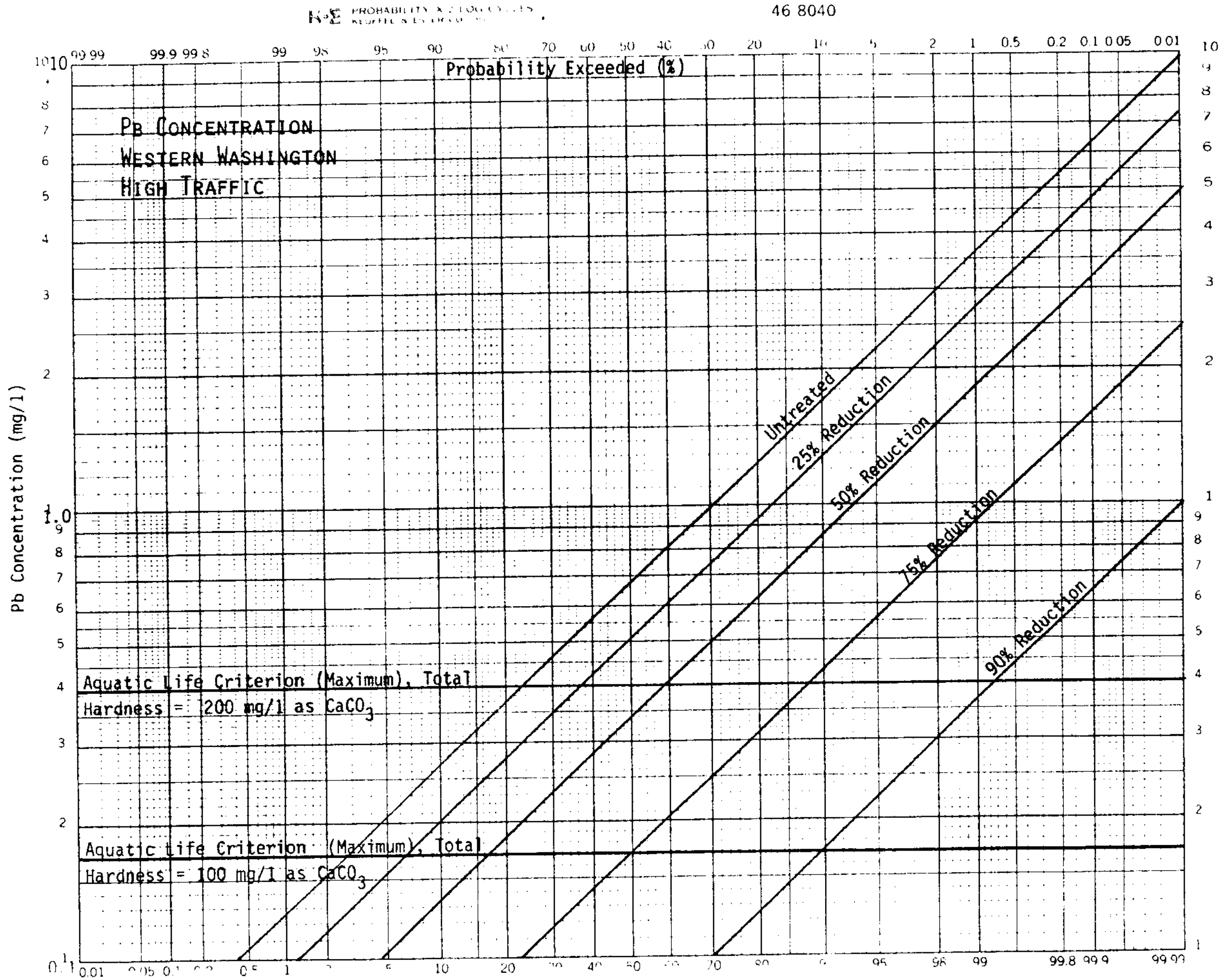
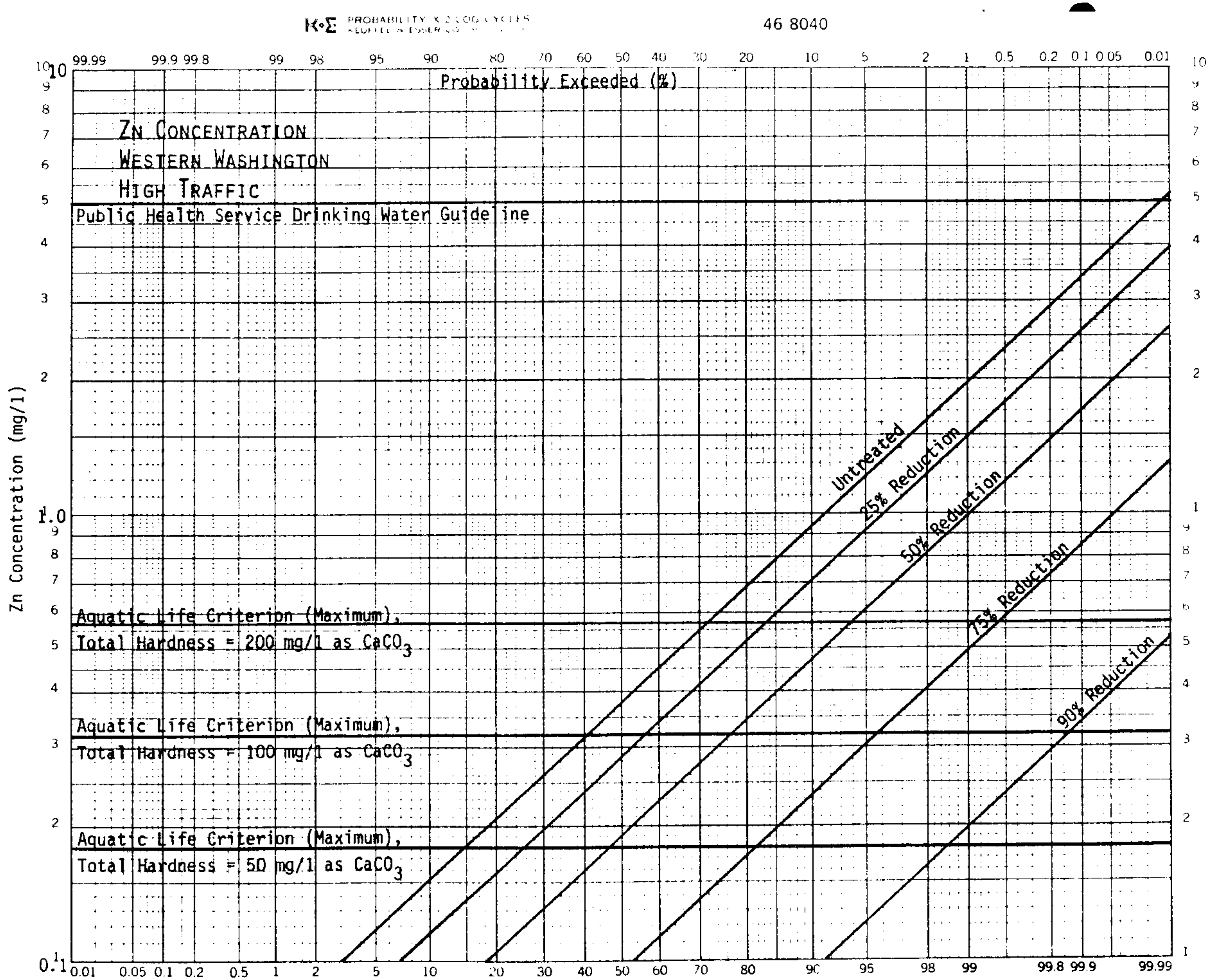


Figure 4 Concentration - Probability Distributions for Western Washington; High Traffic Volume (Continued next 6 pages)

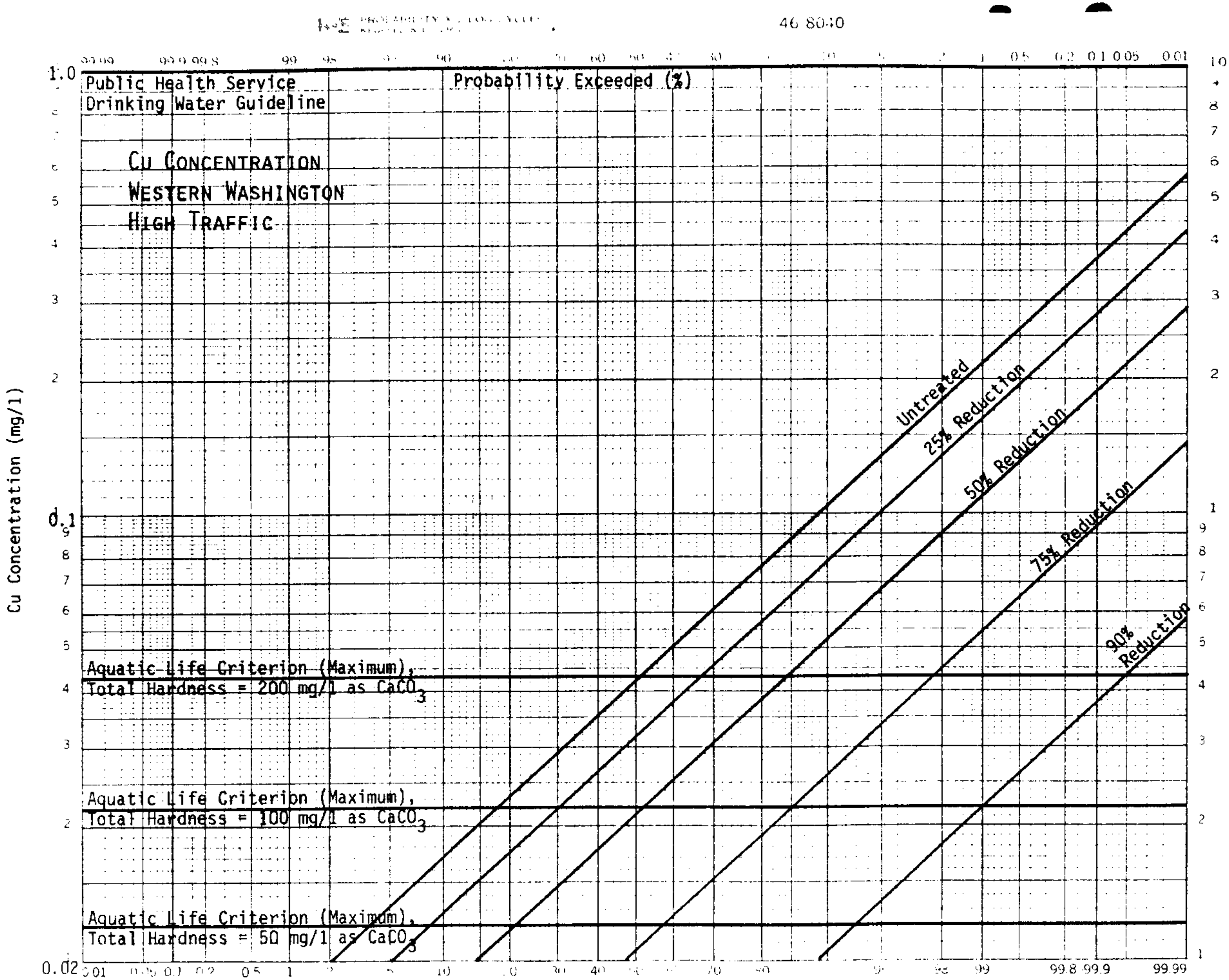


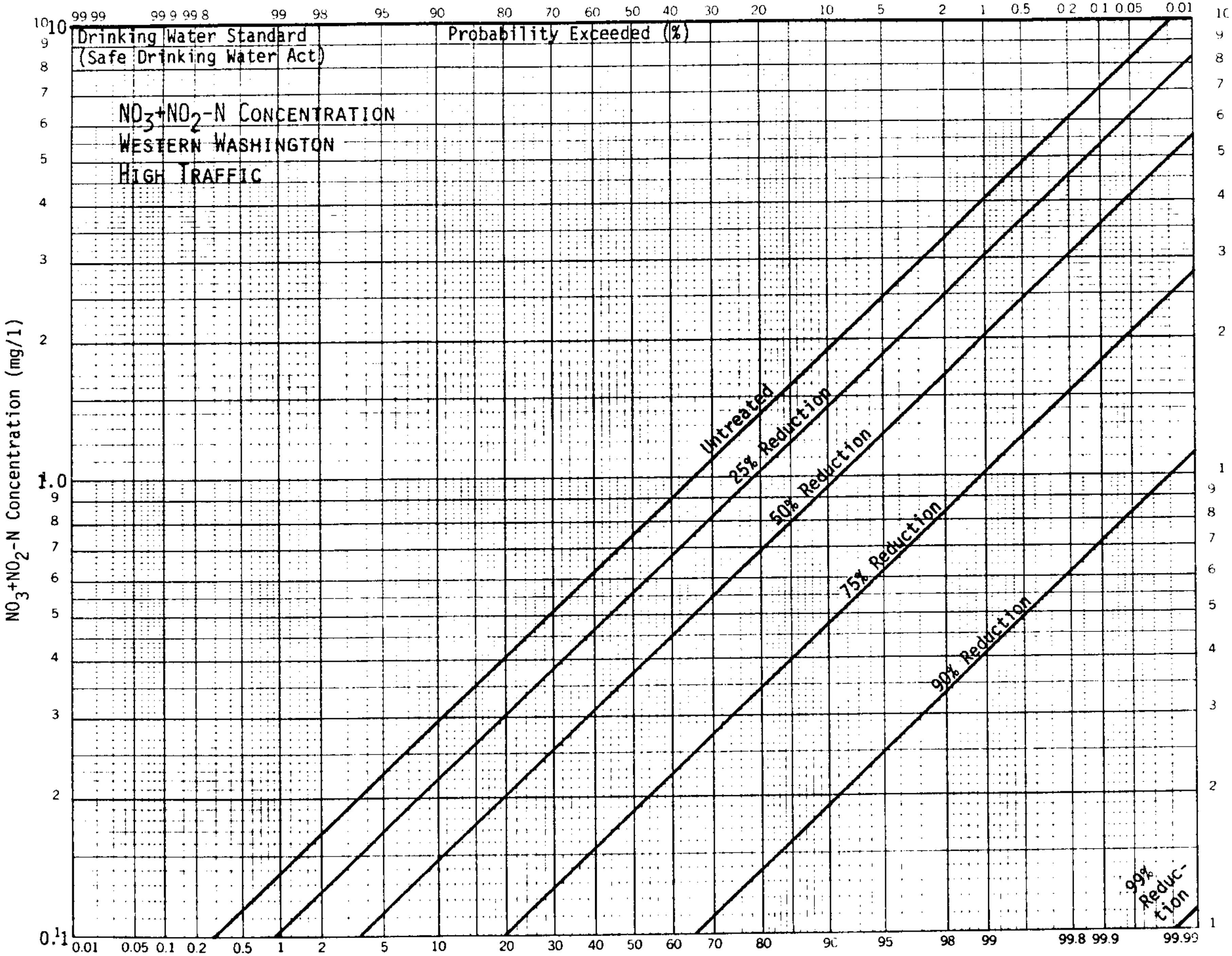
K•E PROBABILITY x 2 LOG CYCLES KEUFFEL & ESSER CO.
46 8040
Probability Exceeded (%)
COD CONCENTRATION
WESTERN WASHINGTON
HIGH TRAFFIC
COD Concentration (mg/l)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction


46 8040
Probability Exceeded (%)
Pb Concentration
Western Washington
High Traffic
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
Aquatic Life Criterion (Maximum), Total
Hardness = 200 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum), Total
Hardness = 100 mg/l as $CaCO_3$
Pb Concentration (mg/l)

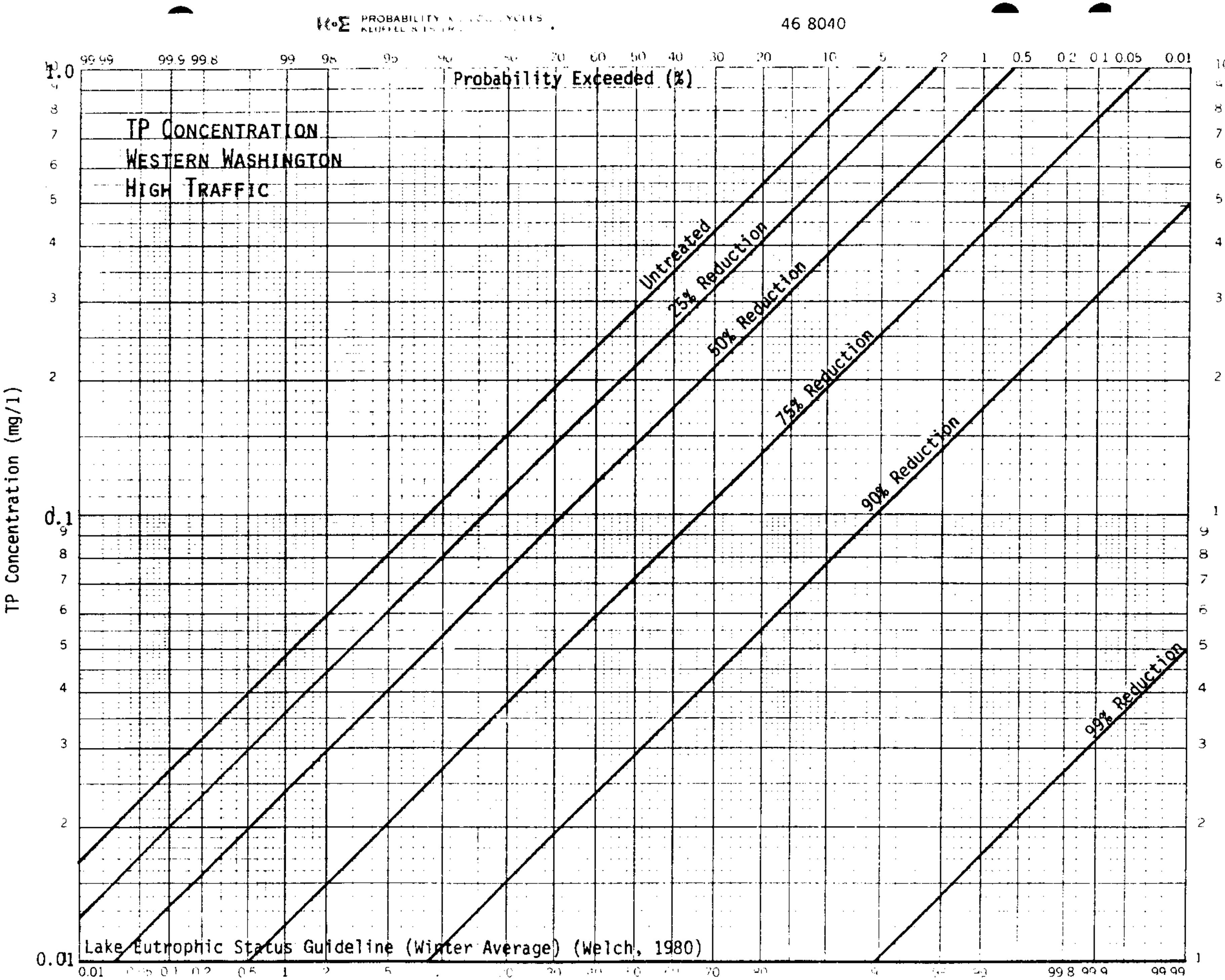


K·E PROBABILITY X 2 LOG CYCLES
46 8040
Probability Exceeded (%)
Zn Concentration
Western Washington
High Traffic
Public Health Service Drinking Water Guideline
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/l as $CaCO_3$
Zn Concentration (mg/l)

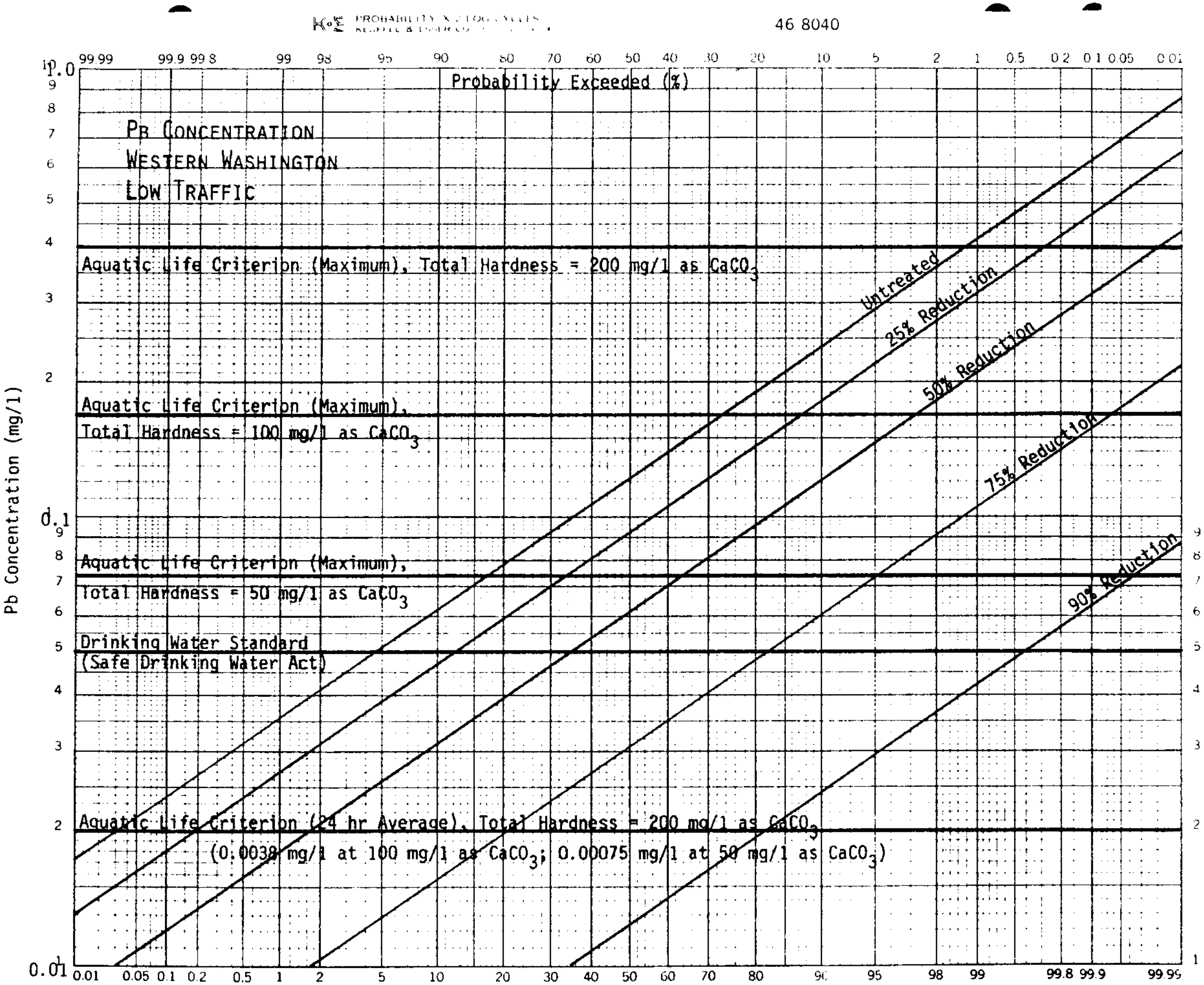

46 8040
Probability Exceeded (%)
Public Health Service
Drinking Water Guideline
Cu Concentration
Western Washington
High Traffic
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/l as $CaCO_3$
Cu Concentration (mg/l)
1.0
0.1
0.02



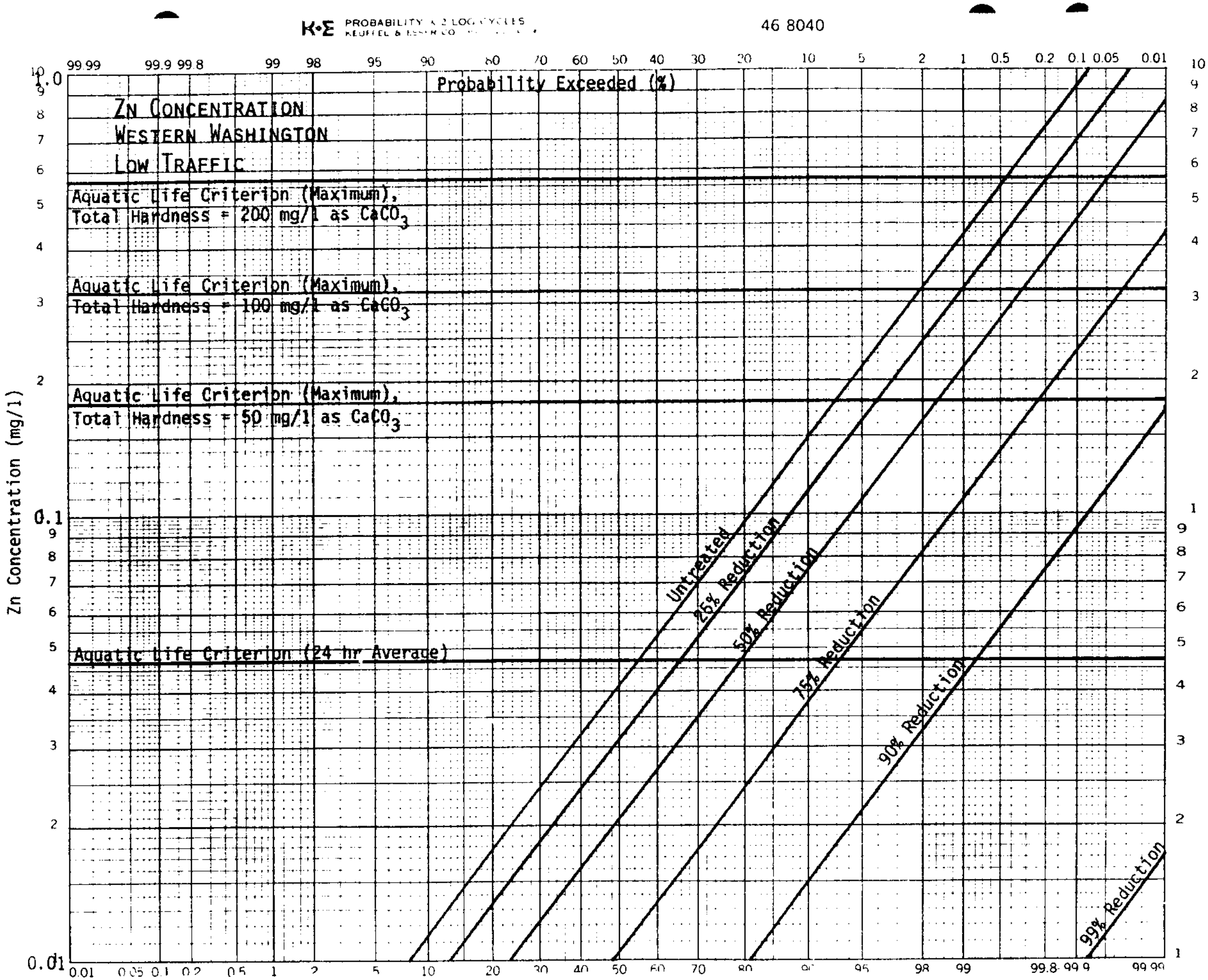
Drinking Water Standard
(Safe Drinking Water Act)
Probability Exceeded (%)
NO3+NO2-N CONCENTRATION
WESTERN WASHINGTON
HIGH TRAFFIC
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduc-tion
NO3+NO2-N Concentration (mg/l)



46 8040
Probability Exceeded (%)
TP CONCENTRATION
WESTERN WASHINGTON
HIGH TRAFFIC
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
TP Concentration (mg/l)
1.0
0.1
0.01
Lake Eutrophic Status Guideline (Winter Average) (Welch, 1980)



K&E PROBABILITY X 2 LOG CYCLES
Probability Exceeded (%)
PB CONCENTRATION
WESTERN WASHINGTON
LOW TRAFFIC
Aquatic Life Criterion (Maximum), Total Hardness = 200 mg/l as CaCO3
Aquatic Life Criterion (Maximum), Total Hardness = 100 mg/l as CaCO3
Aquatic Life Criterion (Maximum), Total Hardness = 50 mg/l as CaCO3
Drinking Water Standard (Safe Drinking Water Act)
Aquatic Life Criterion (24 hr Average), Total Hardness = 200 mg/l as CaCO3
(0.0038 mg/l at 100 mg/l as CaCO3; 0.00075 mg/l at 50 mg/l as CaCO3)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
Pb Concentration (mg/l)
1.0
0.1
0.01


K•E PROBABILITY X 2 LOG CYCLES
46 8040
Probability Exceeded (%)
ZN CONCENTRATION
WESTERN WASHINGTON
LOW TRAFFIC
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as CaCO3
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as CaCO3
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/l as CaCO3
Aquatic Life Criterion (24 hr Average)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Zn Concentration (mg/l)
1.0
0.1
0.01

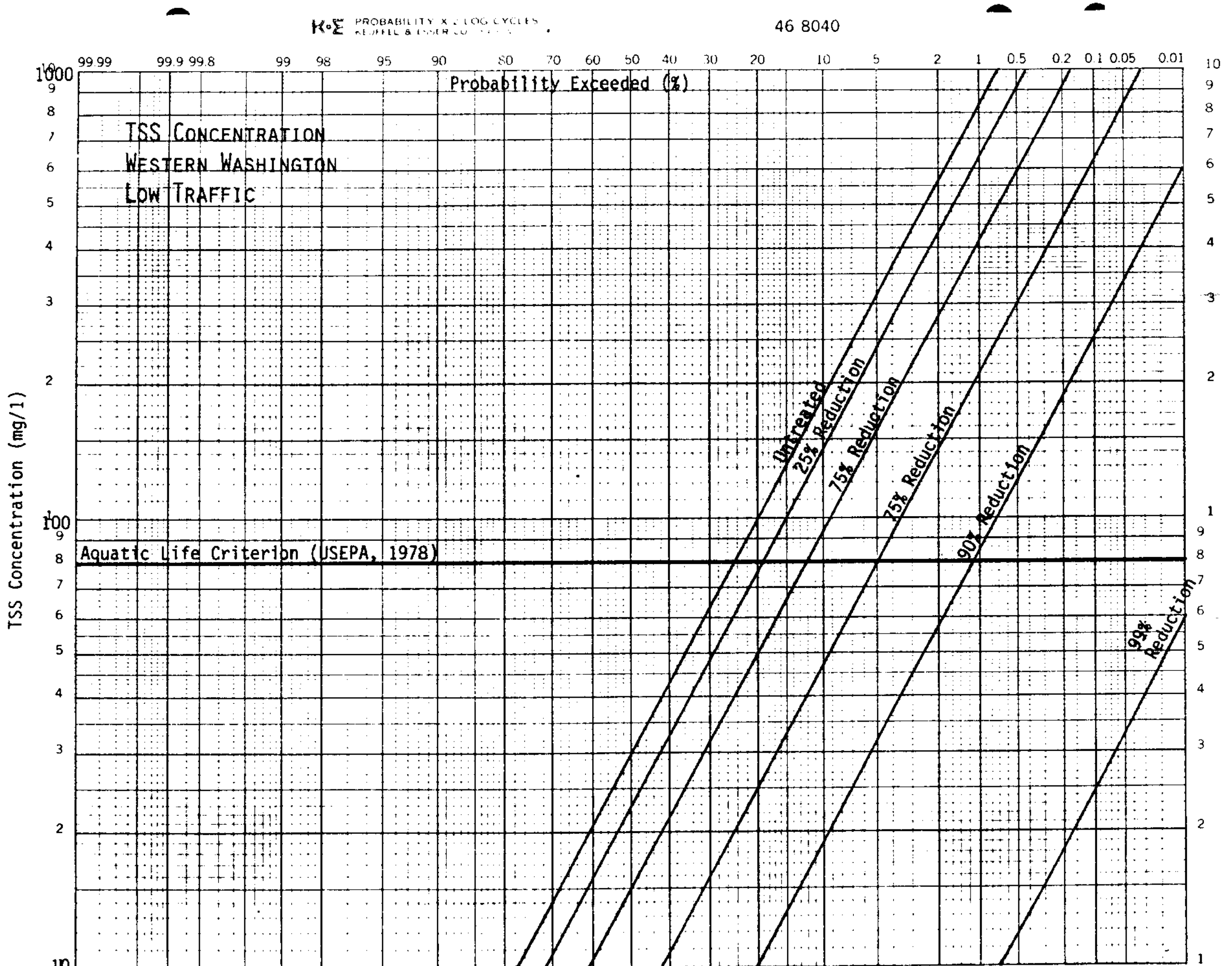
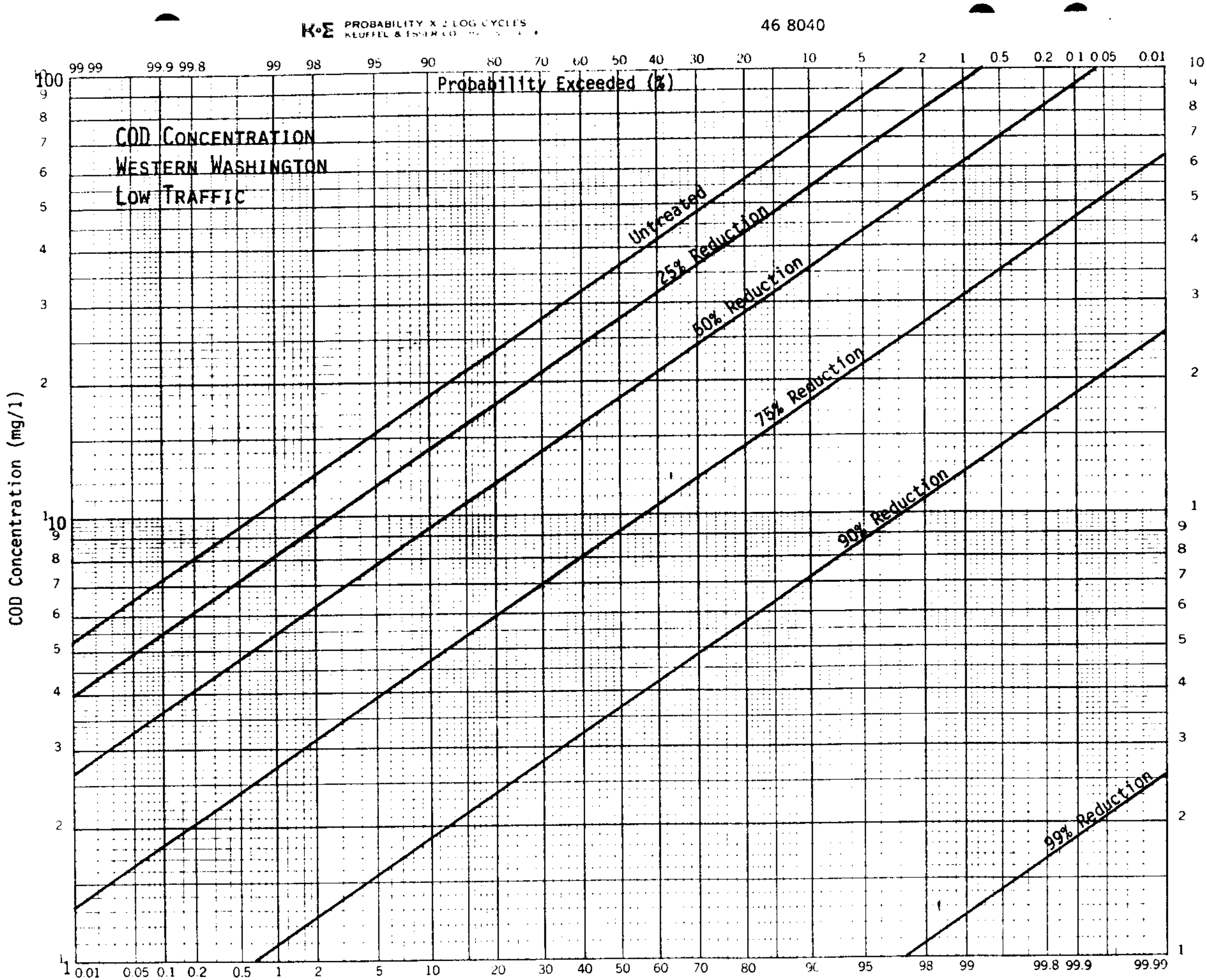
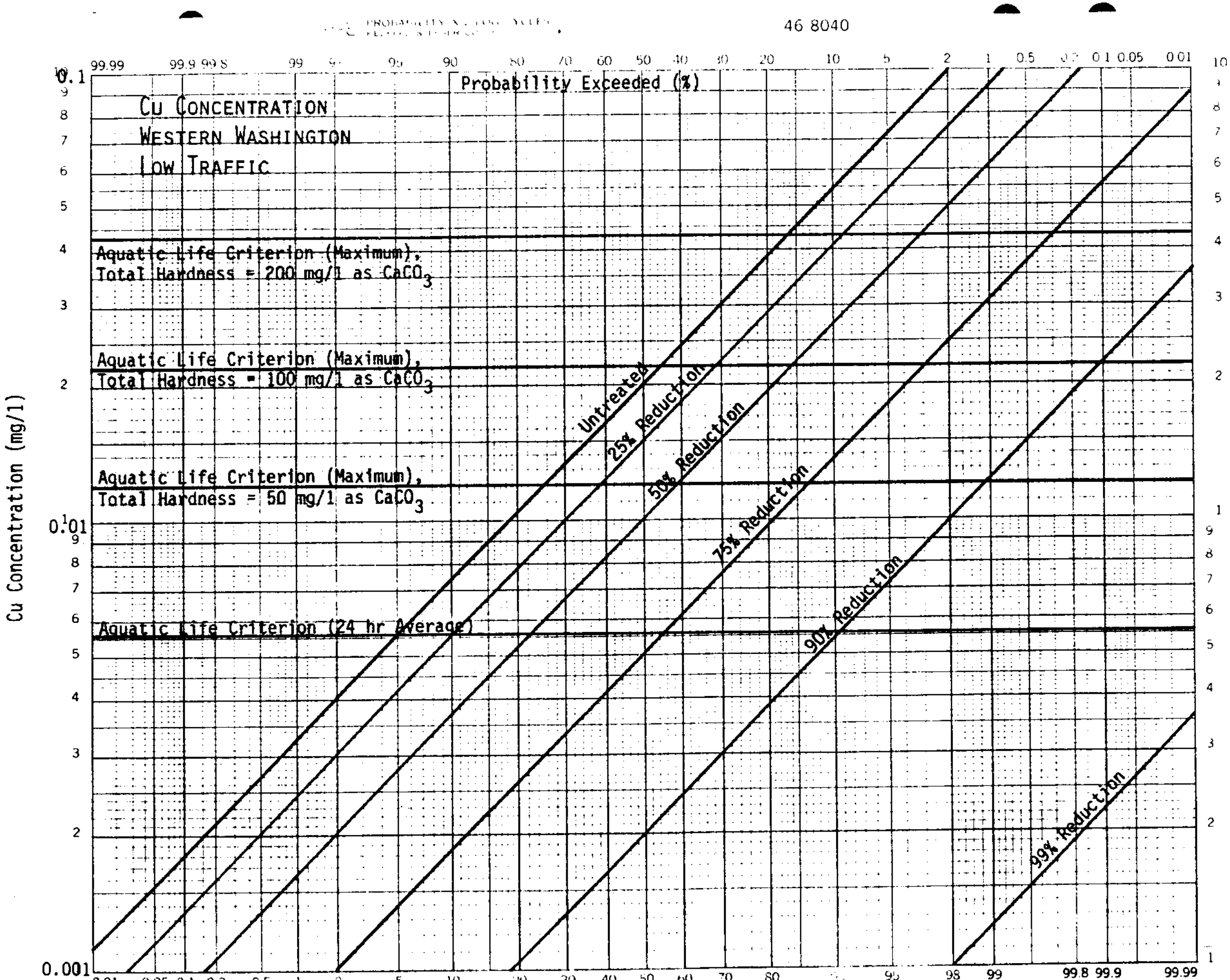
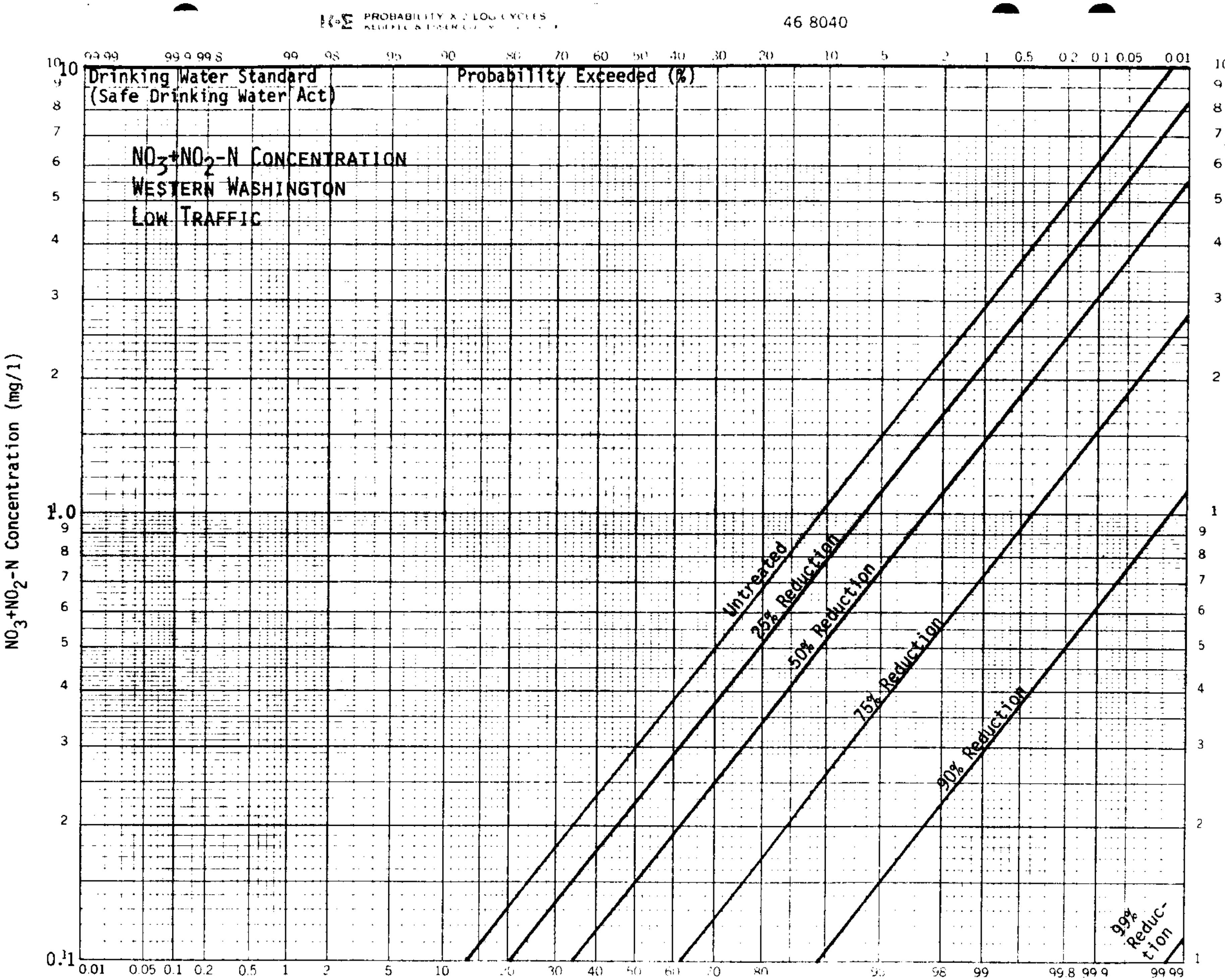
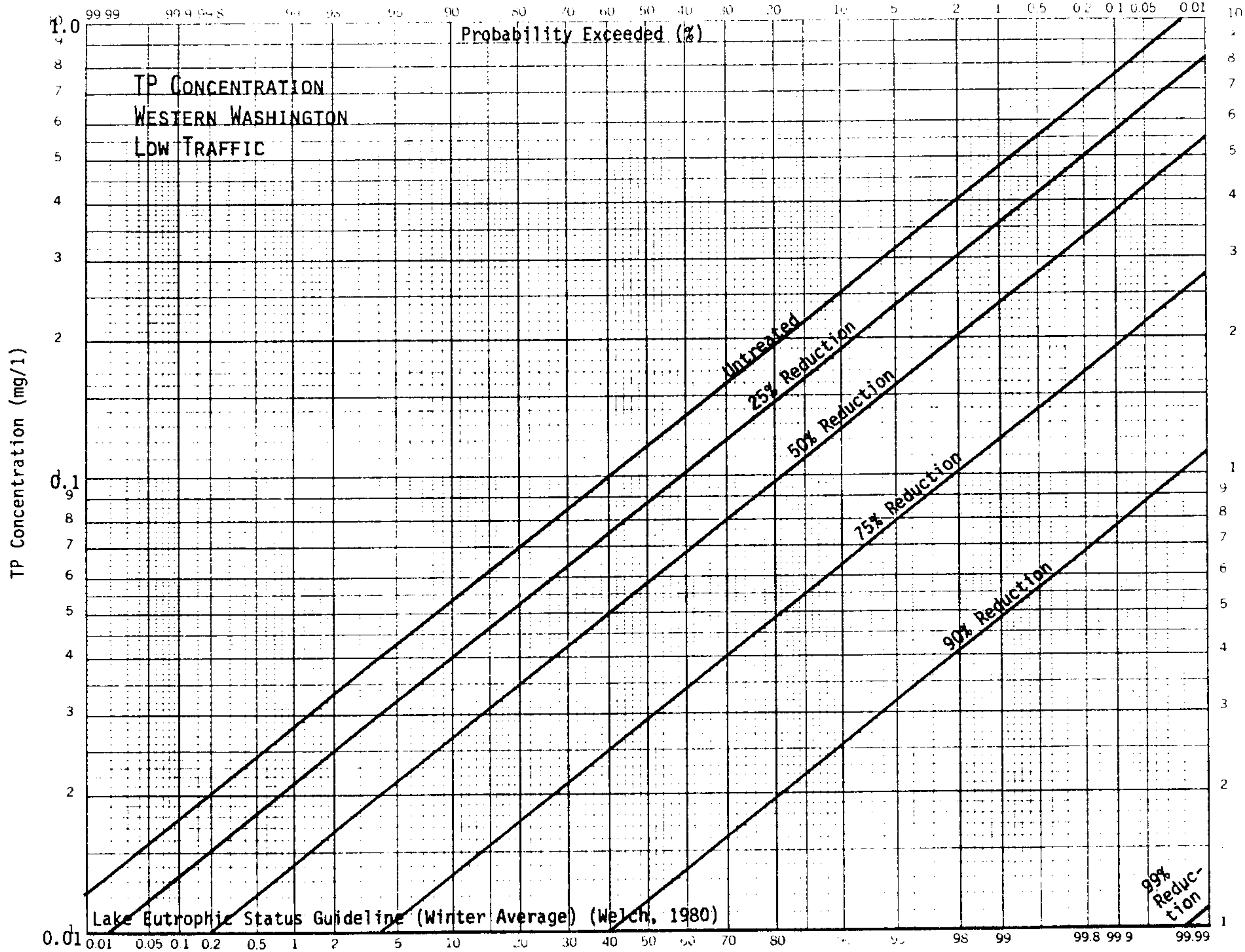


Figure 5. Concentration - Probability Distributions for Western Washington; Low Traffic Volume (Continued next 6 pages


K•E PROBABILITY X 2 LOG CYCLES
46 8040
Probability Exceeded (%)
COD CONCENTRATION
WESTERN WASHINGTON
LOW TRAFFIC
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
COD Concentration (mg/l)


46 8040
Probability Exceeded (%)
Cu CONCENTRATION
WESTERN WASHINGTON
LOW TRAFFIC
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/1 as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/1 as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/1 as $CaCO_3$
Aquatic Life Criterion (24 hr Average)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Cu Concentration (mg/1)
0.1
0.01
0.001


Drinking Water Standard
(Safe Drinking Water Act)
Probability Exceeded (%)
NO3+NO2-N CONCENTRATION
WESTERN WASHINGTON
LOW TRAFFIC
NO3+NO2-N Concentration (mg/l)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduc-tion
46 8040


TP CONCENTRATION
WESTERN WASHINGTON
LOW TRAFFIC
Probability Exceeded (%)
TP Concentration (mg/l)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduc-tion
Lake Eutrophic Status Guideline (Winter Average) (Welch, 1980)
1.0
0.1
0.01

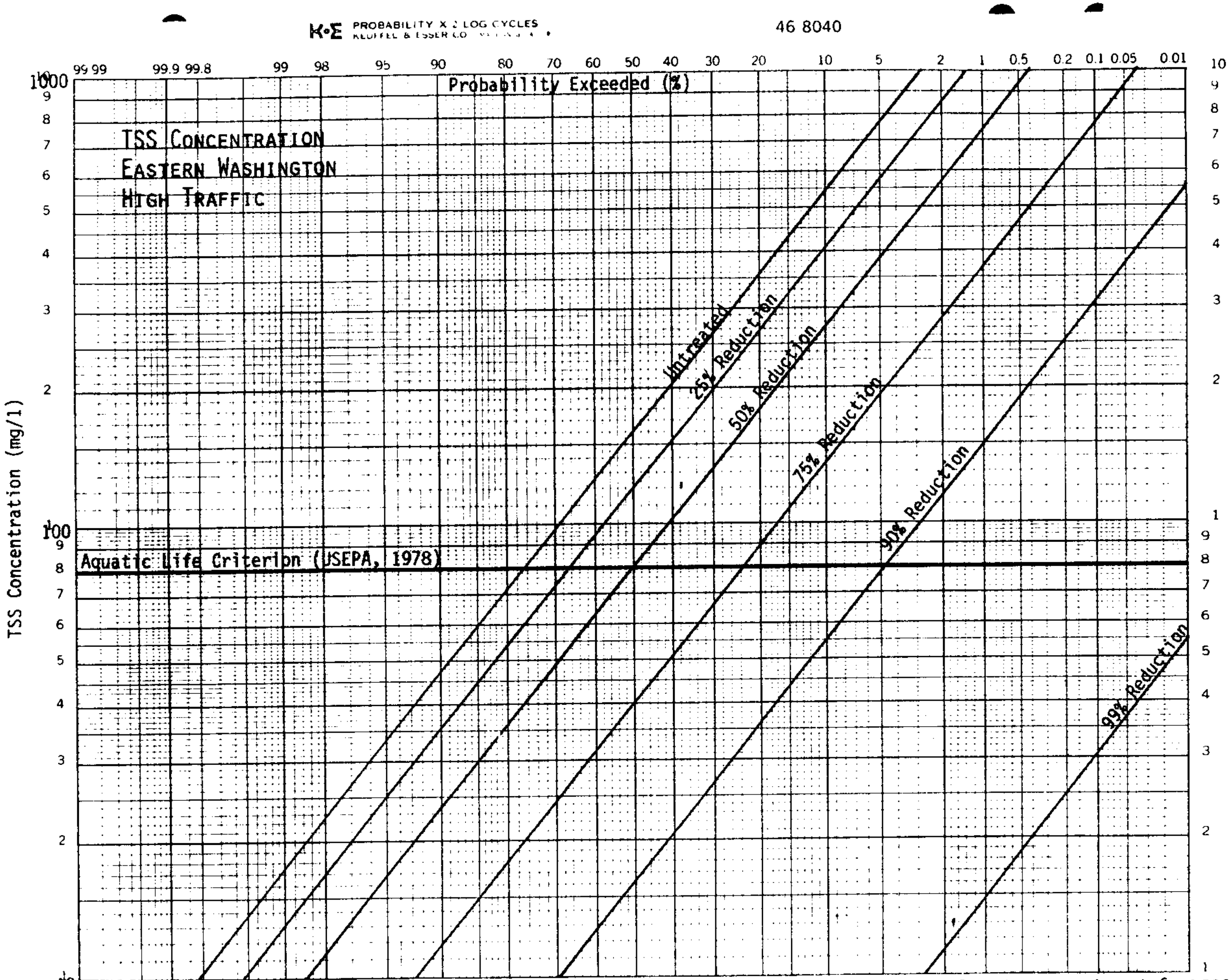
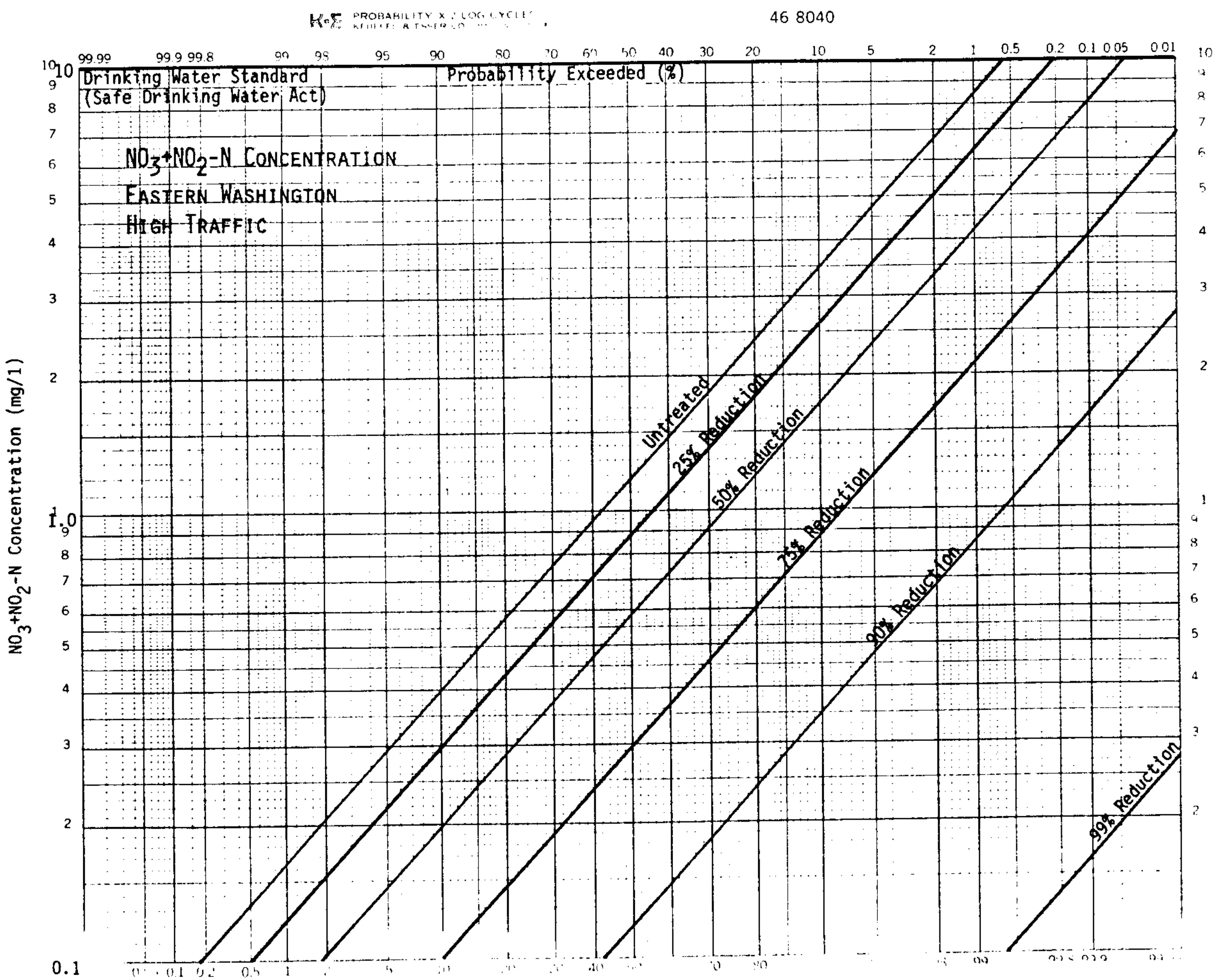
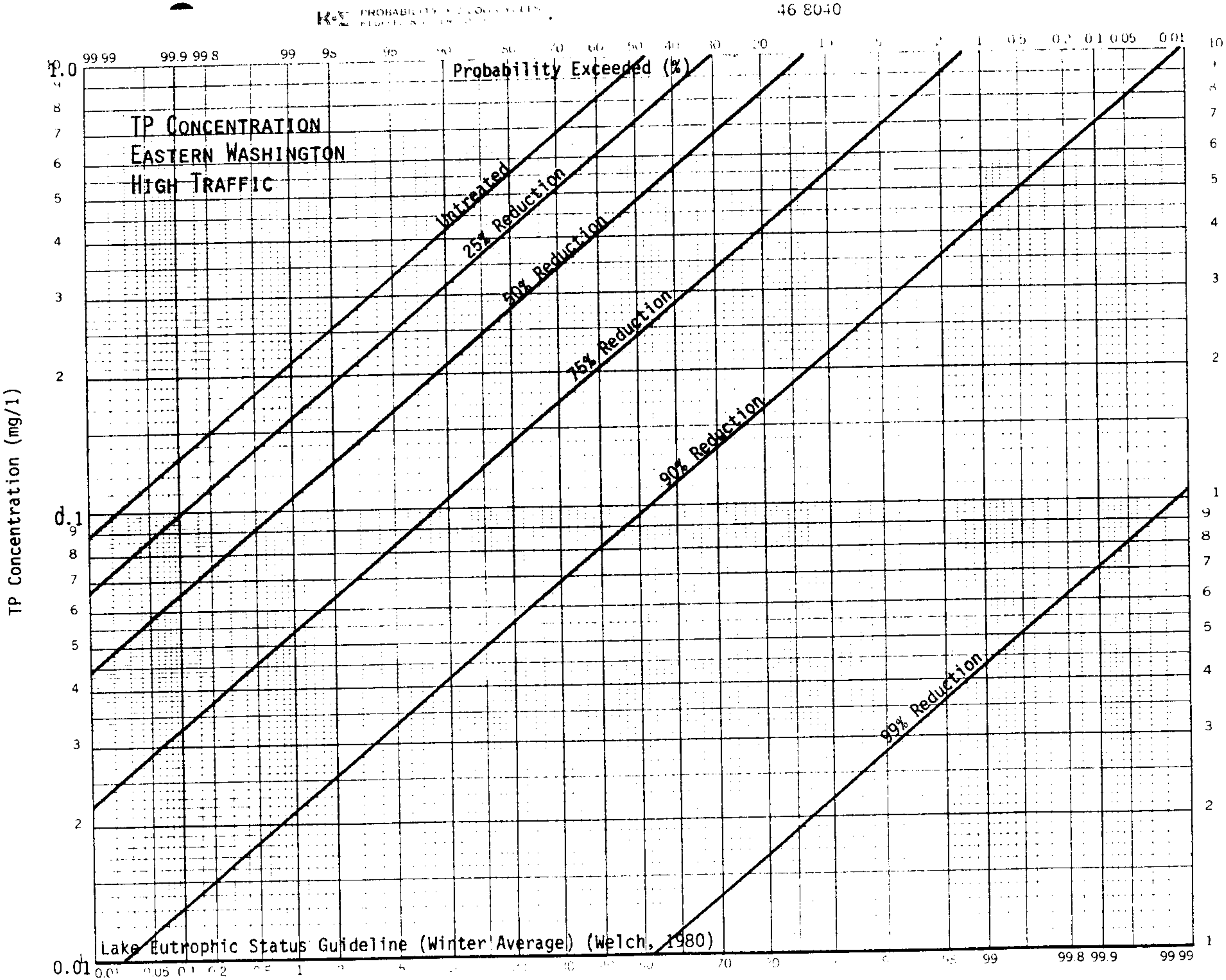
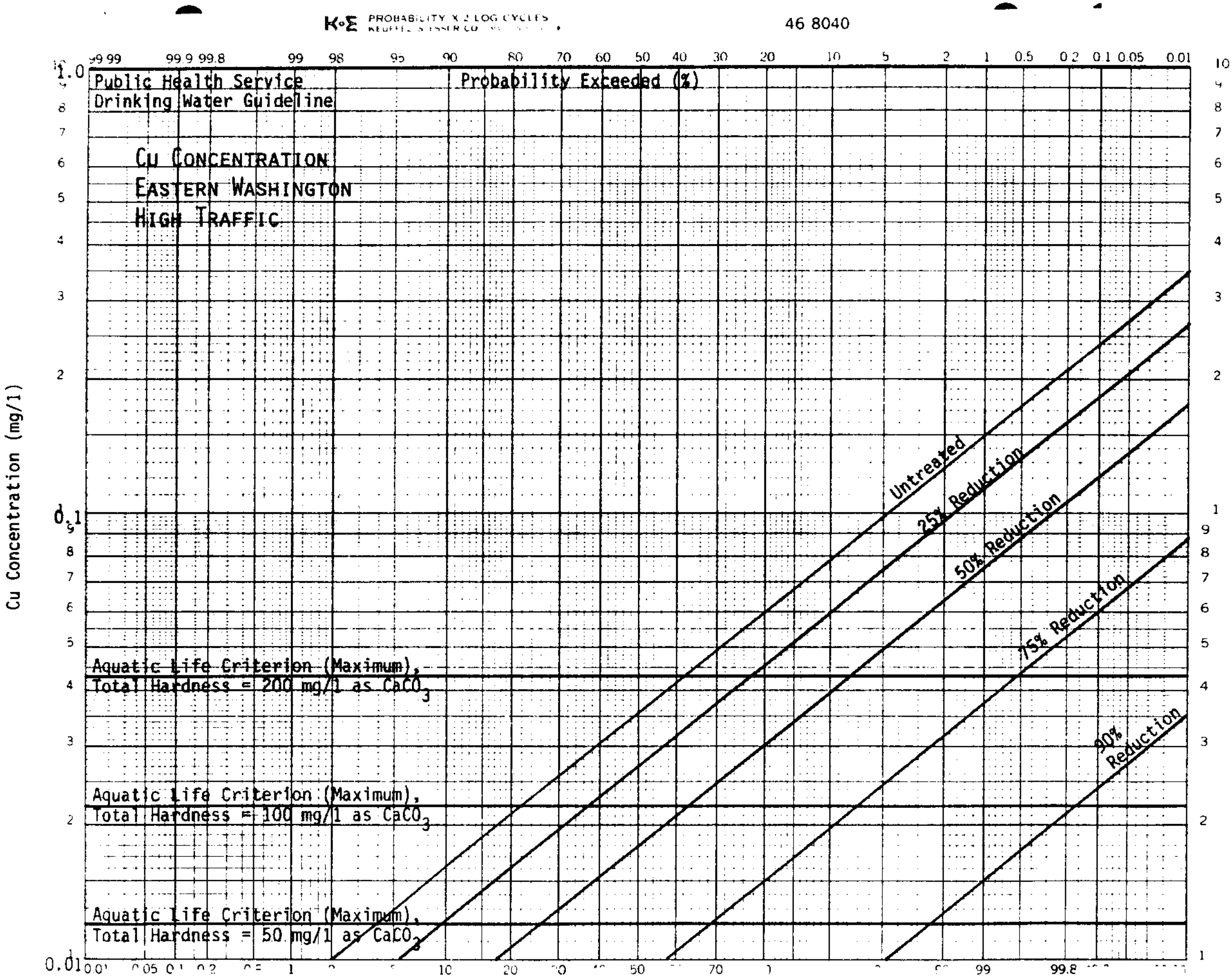


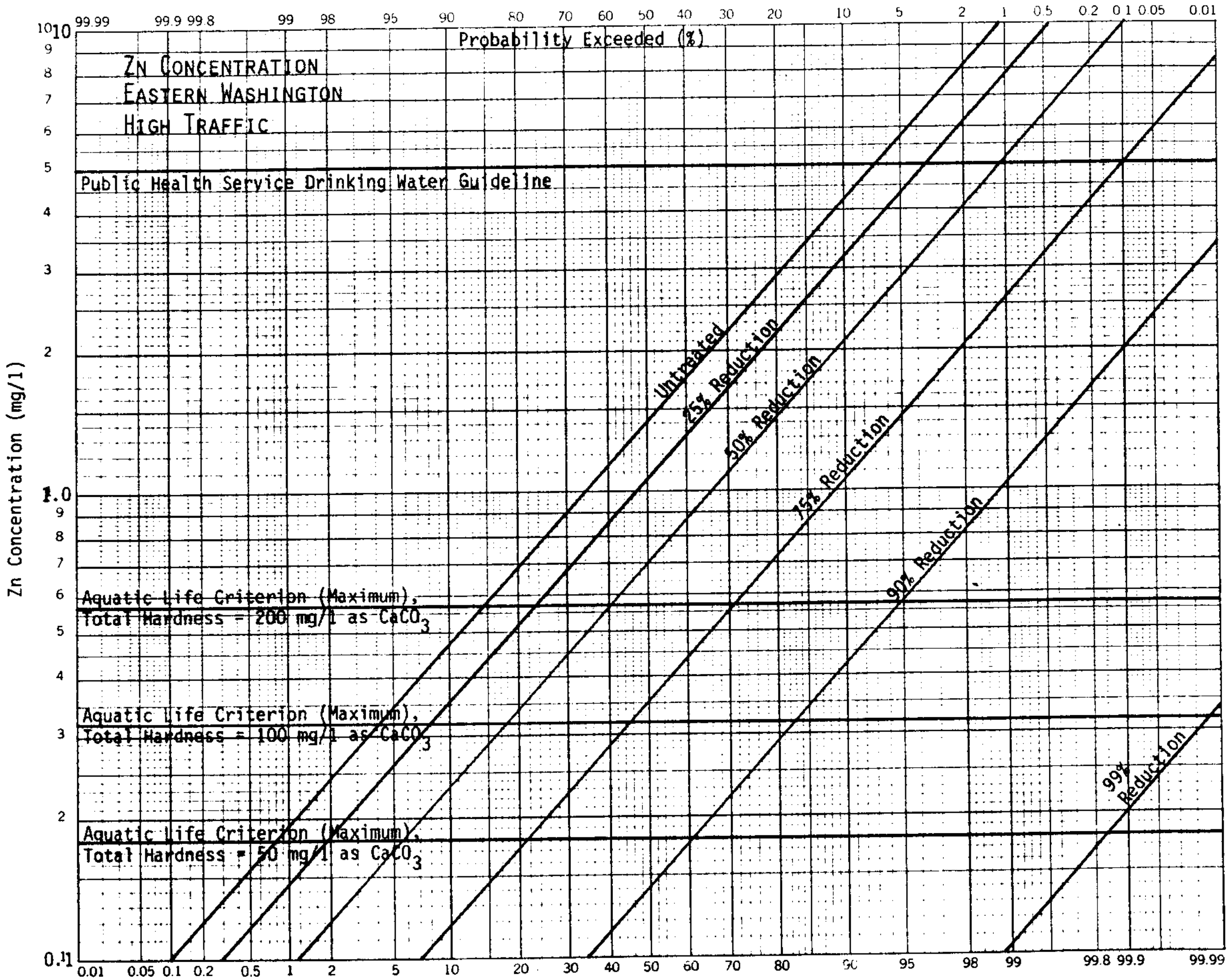
Figure . Concentration Probability Distribution for Eastern Washington; High Traffic Volume (Continued next 6 pages)

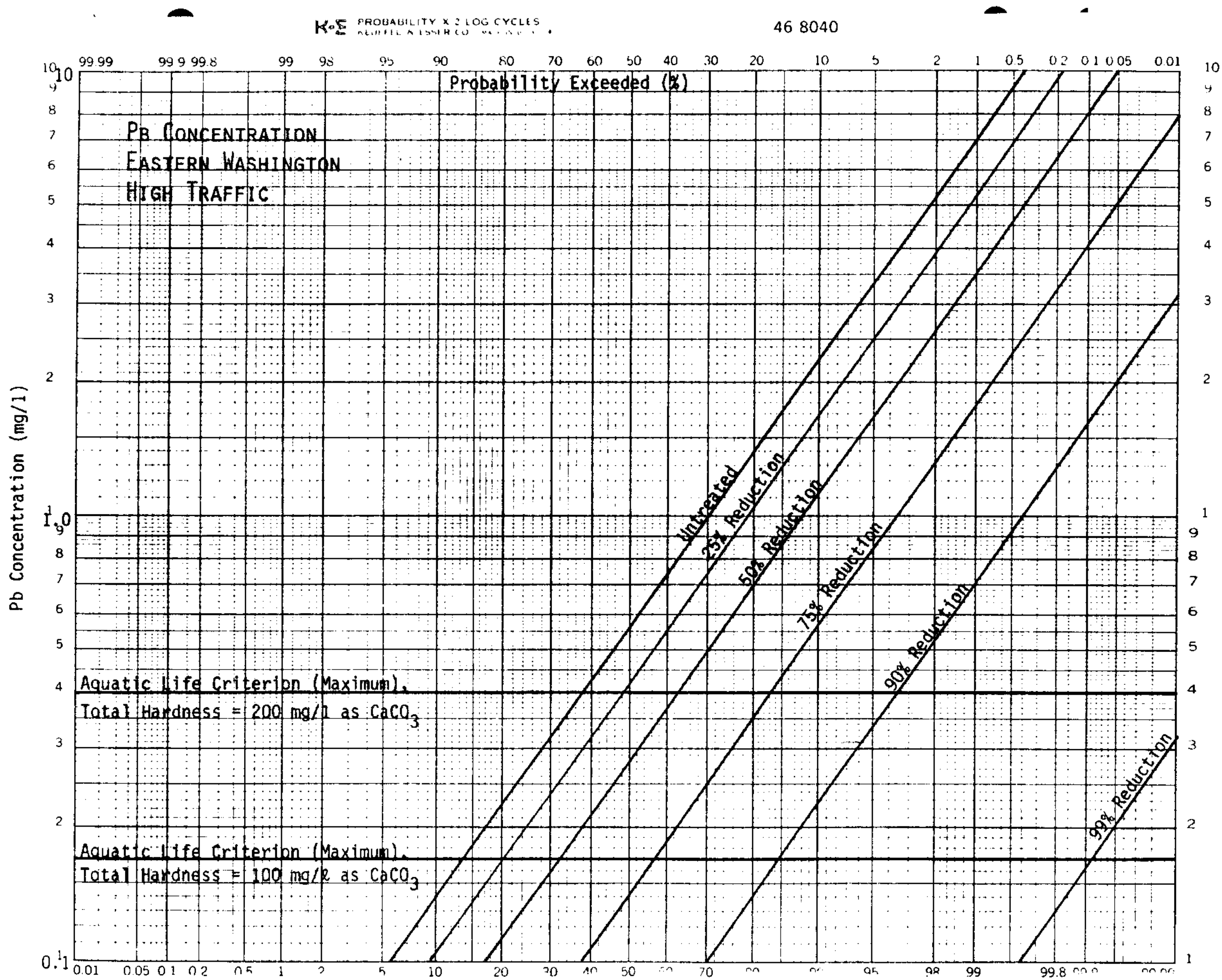

K+E PROBABILITY X 2 LOG CYCLES
46 8040
Drinking Water Standard
(Safe Drinking Water Act)
Probability Exceeded (%)
NO3+NO2-N CONCENTRATION
EASTERN WASHINGTON
HIGH TRAFFIC
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
NO3+NO2-N Concentration (mg/1)



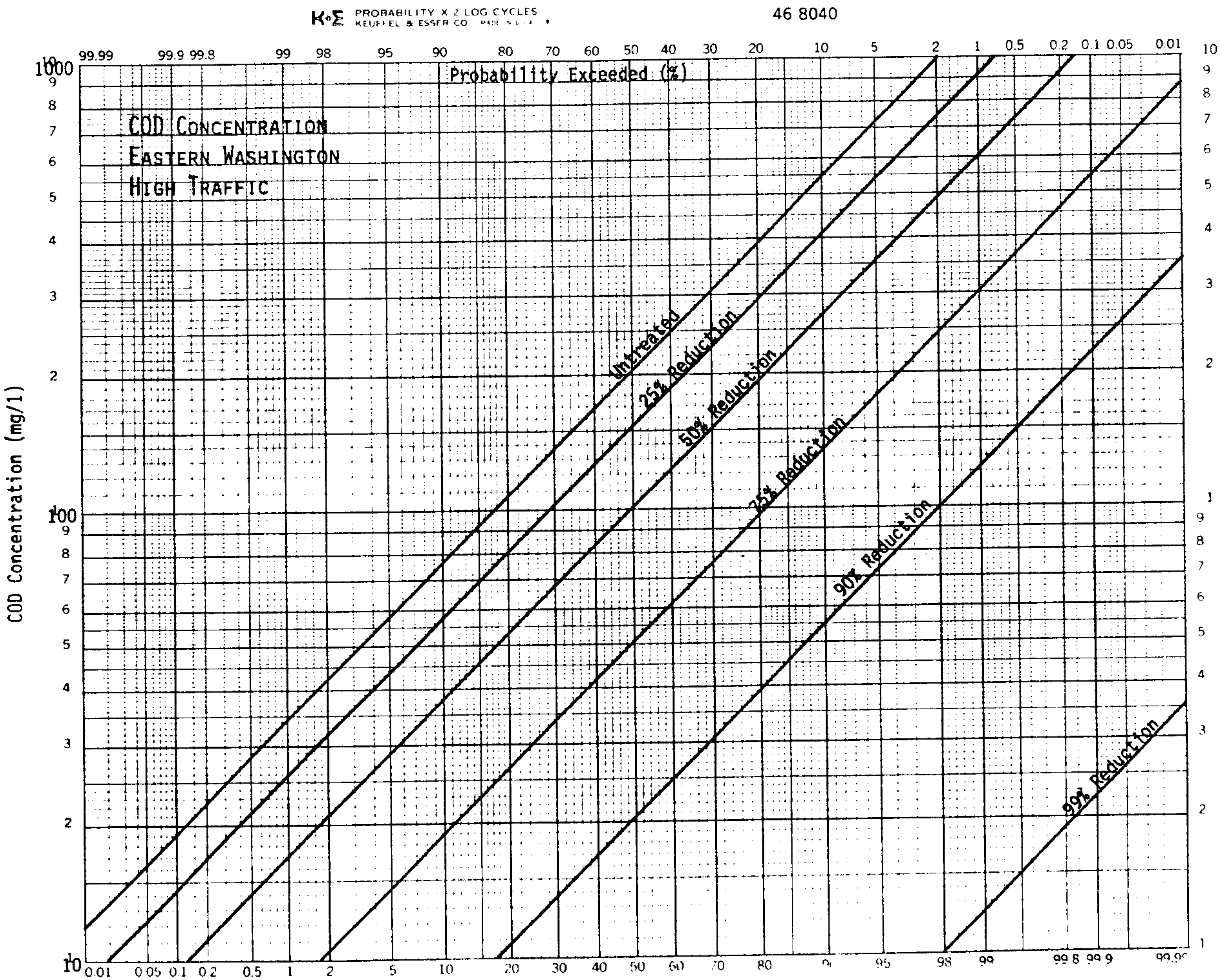
46 8040
Probability Exceeded (%)
TP CONCENTRATION
EASTERN WASHINGTON
HIGH TRAFFIC
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
TP Concentration (mg/l)
1.0
0.1
0.01
Lake Eutrophic Status Guideline (Winter Average) (Welch, 1980)

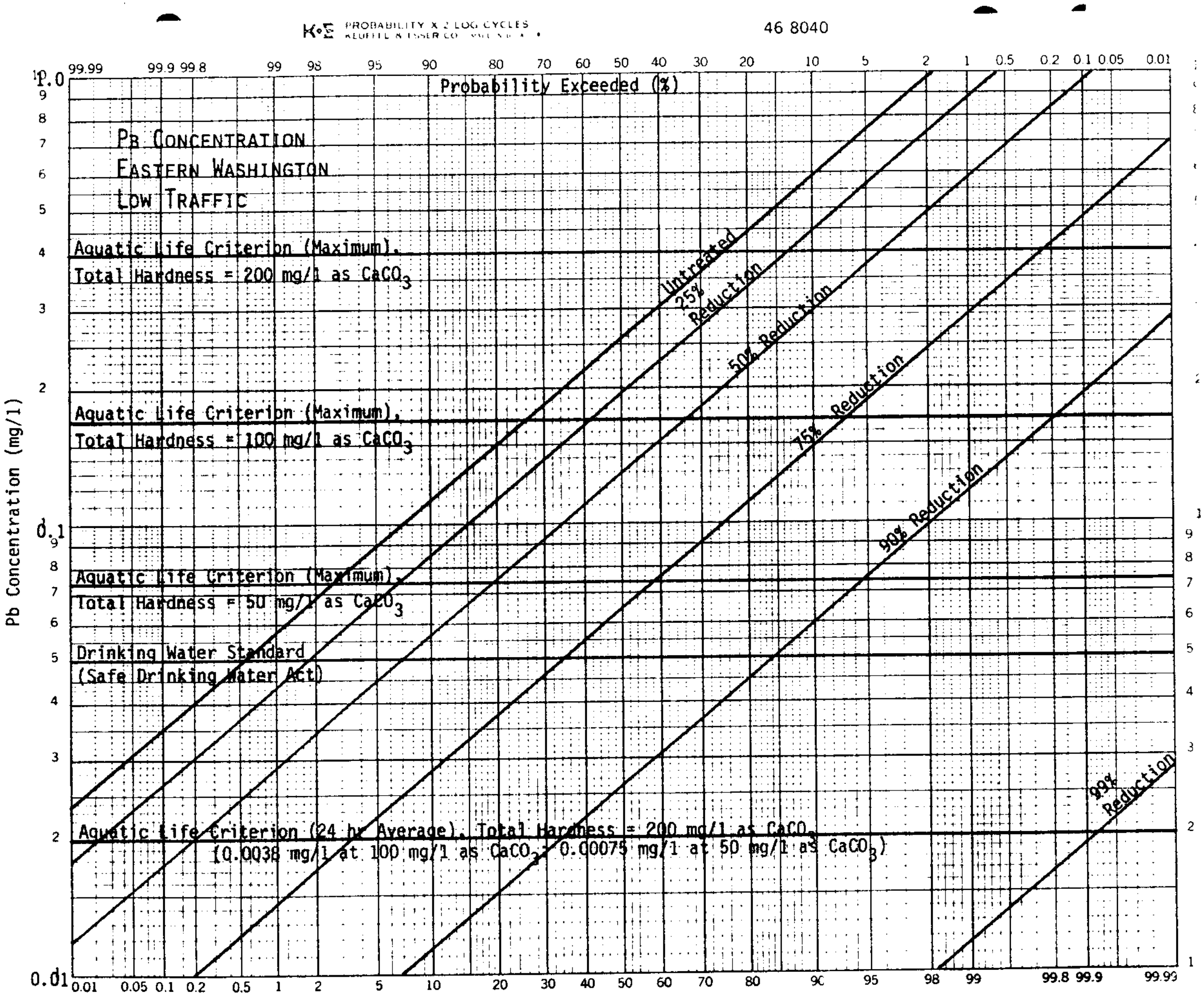

K&E PROBABILITY X 2 LOG CYCLES
46 8040
Probability Exceeded (%)
Cu Concentration (mg/l)
Public Health Service
Drinking Water Guideline
Cu Concentration
Eastern Washington
High Traffic
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/l as $CaCO_3$

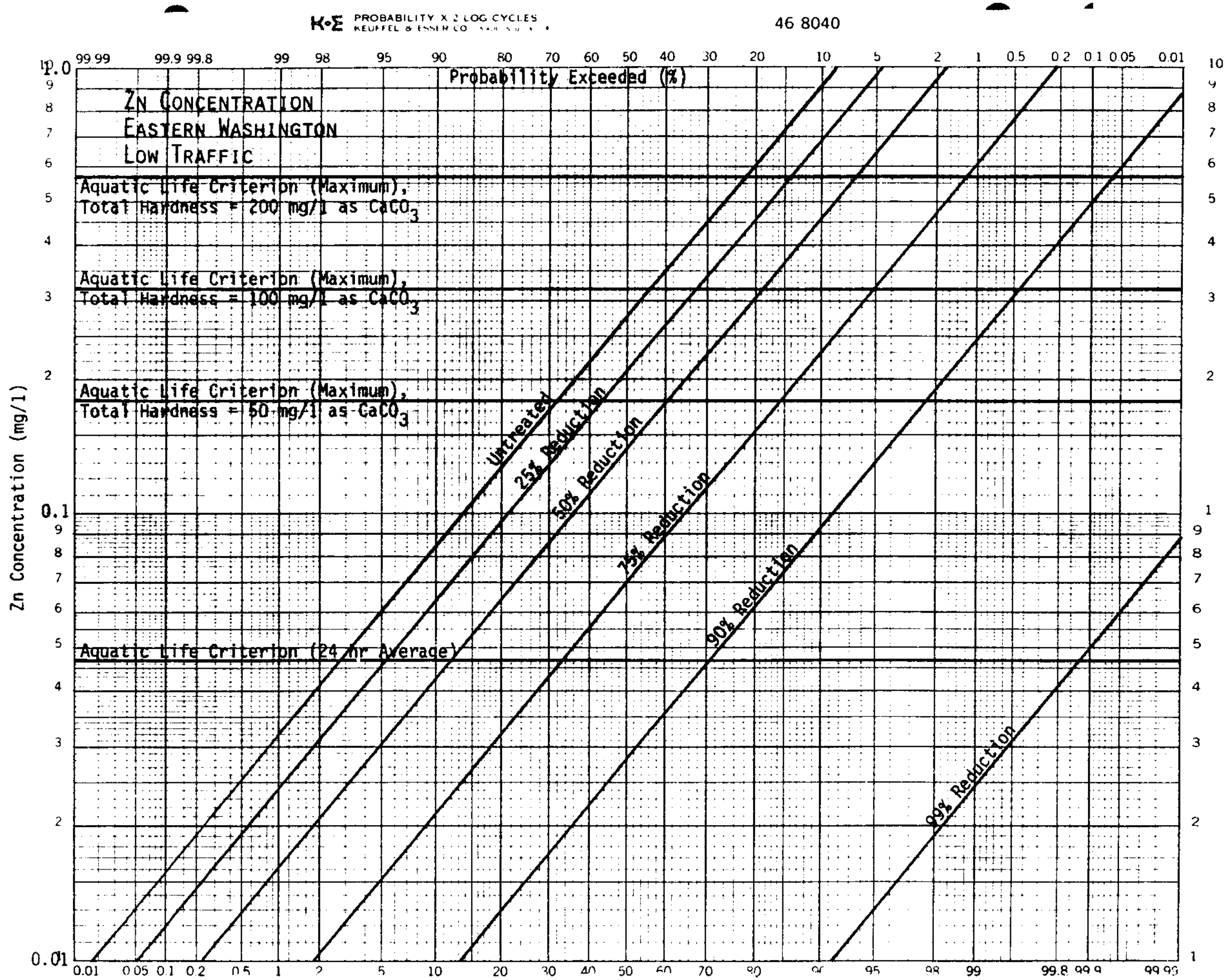

K•E PROBABILITY X LOG CYCLES
Probability Exceeded (%)
ZN CONCENTRATION
EASTERN WASHINGTON
HIGH TRAFFIC
Public Health Service Drinking Water Guideline
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as CaCO3
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as CaCO3
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/l as CaCO3
Zn Concentration (mg/l)

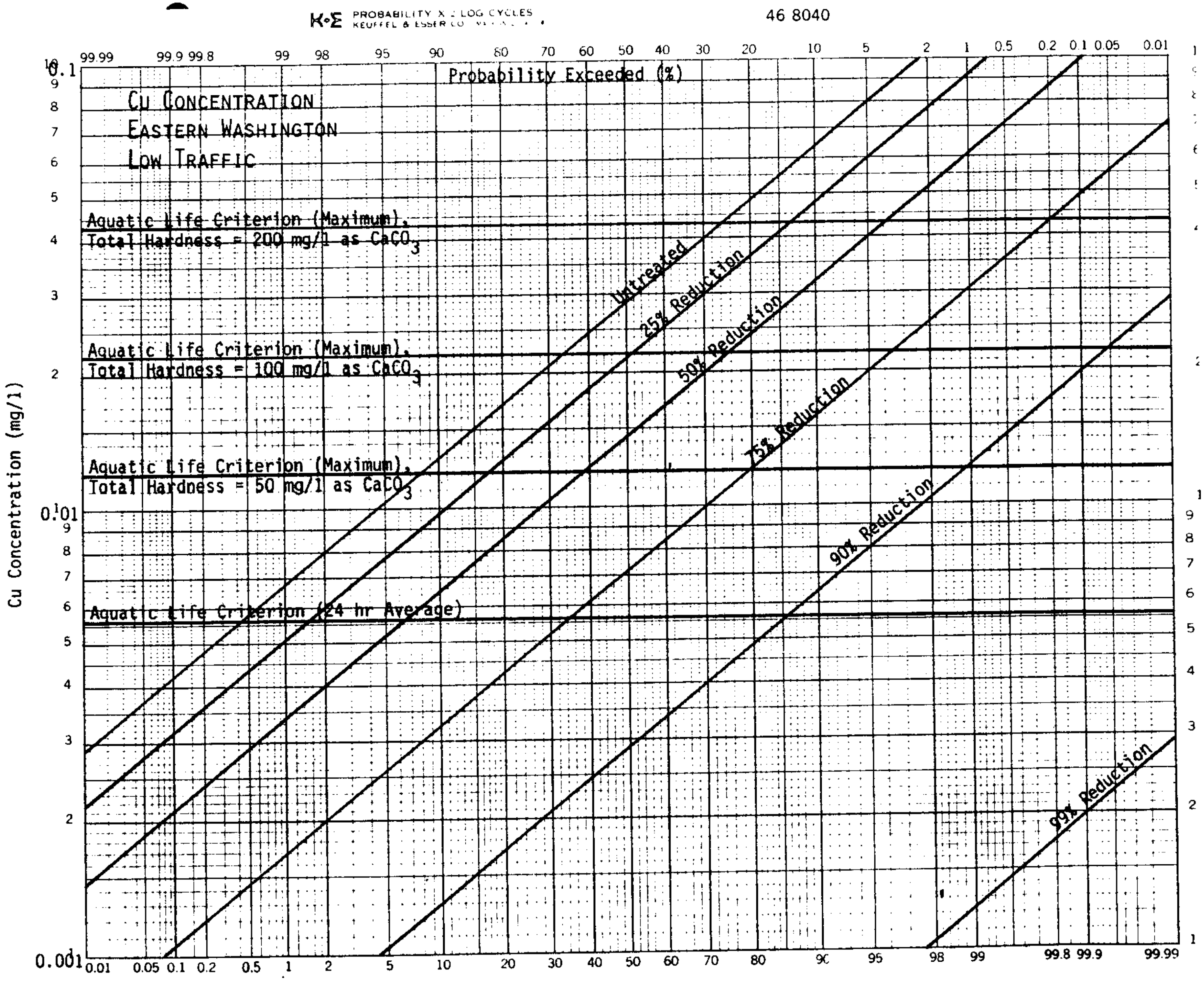


K+E PROBABILITY X 2 LOG CYCLES
46 8040
Probability Exceeded (%)
Pb CONCENTRATION
EASTERN WASHINGTON
HIGH TRAFFIC
Pb Concentration (mg/l)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as CaCO3
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as CaCO3

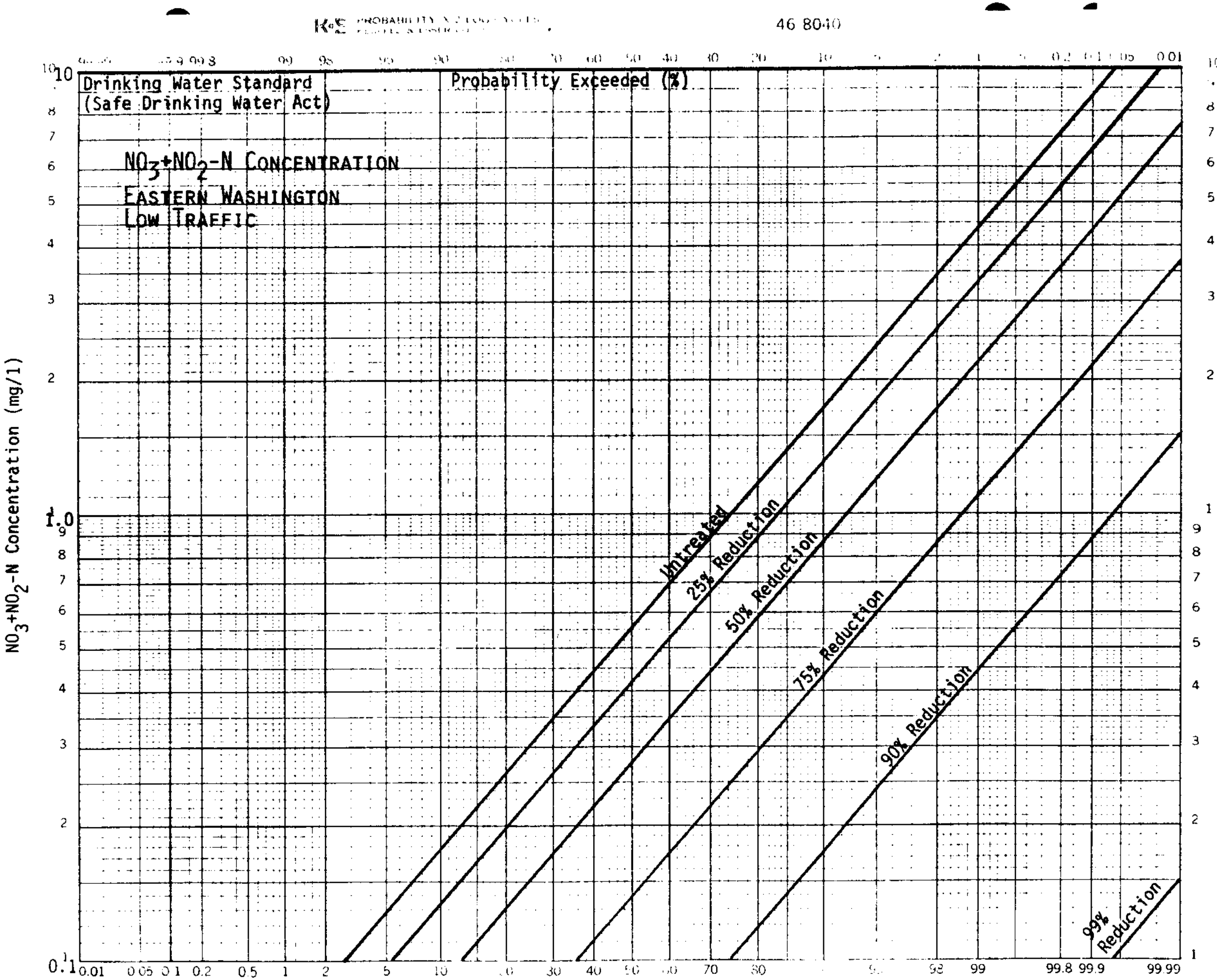

K+E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO.
46 8040
Probability Exceeded (%)
COD CONCENTRATION
EASTERN WASHINGTON
HIGH TRAFFIC
COD Concentration (mg/1)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction


K•E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO.
46 8040
Probability Exceeded (%)
PB CONCENTRATION
EASTERN WASHINGTON
LOW TRAFFIC
Aquatic Life Criterion (Maximum),
Total Hardness = 200 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 100 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum),
Total Hardness = 50 mg/l as $CaCO_3$
Drinking Water Standard
(Safe Drinking Water Act)
Aquatic Life Criterion (24 hr Average), Total Hardness = 200 mg/l as $CaCO_3$
(0.0038 mg/l at 100 mg/l as $CaCO_3$; 0.00075 mg/l at 50 mg/l as $CaCO_3$)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Pb Concentration (mg/l)
1.0
0.1
0.01


K•E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO.
46 8040
Probability Exceeded (%)
Zn CONCENTRATION
EASTERN WASHINGTON
LOW TRAFFIC
Aquatic Life Criterion (Maximum), Total Hardness = 200 mg/l as CaCO3
Aquatic Life Criterion (Maximum), Total Hardness = 100 mg/l as CaCO3
Aquatic Life Criterion (Maximum), Total Hardness = 50 mg/l as CaCO3
Aquatic Life Criterion (24 hr Average)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Zn Concentration (mg/l)

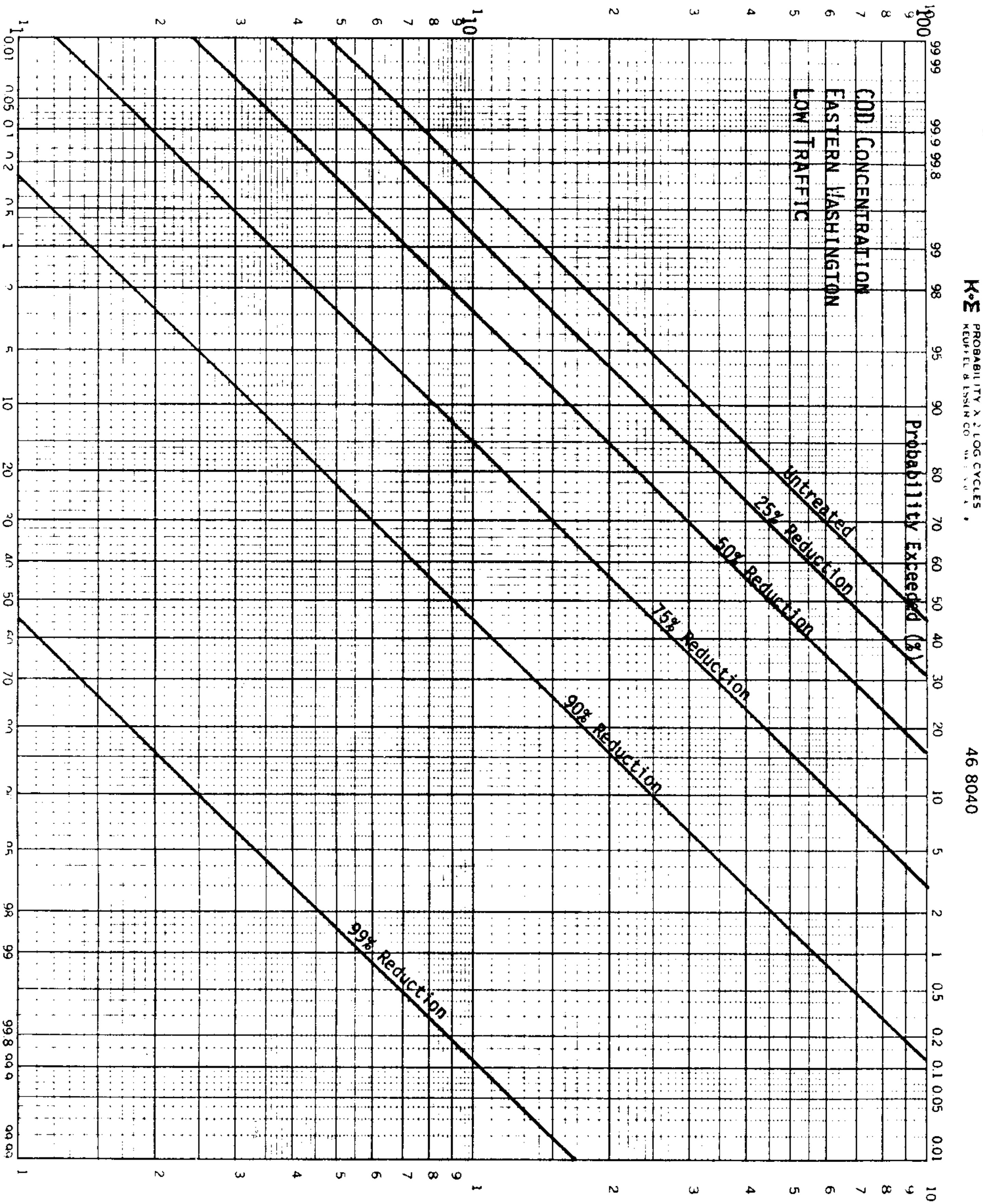


K•E PROBABILITY X 2 LOG CYCLES KEUFFEL & ESSER CO.
46 8040
Probability Exceeded (%)
Cu Concentration
Eastern Washington
Low Traffic
Aquatic Life Criterion (Maximum), Total Hardness = 200 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum), Total Hardness = 100 mg/l as $CaCO_3$
Aquatic Life Criterion (Maximum), Total Hardness = 50 mg/l as $CaCO_3$
Aquatic Life Criterion (24 hr Average)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Cu Concentration (mg/l)
0.1
0.01
0.001
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01



46 8040
Drinking Water Standard
(Safe Drinking Water Act)
Probability Exceeded (%)
NO_3+NO_2-N CONCENTRATION
EASTERN WASHINGTON
LOW TRAFFIC
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
NO_3+NO_2-N Concentration (mg/l)

COD Concentration (mg/l)



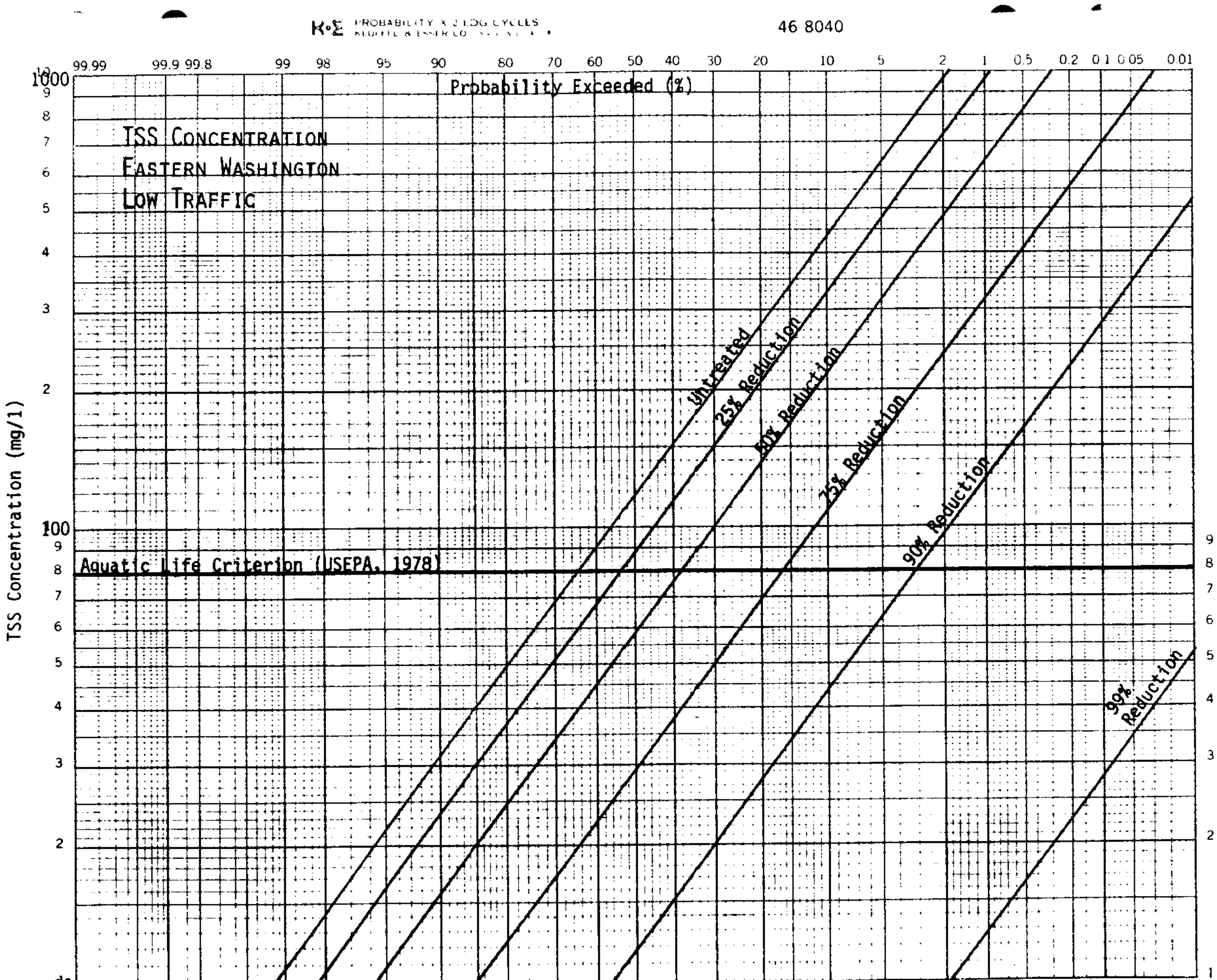
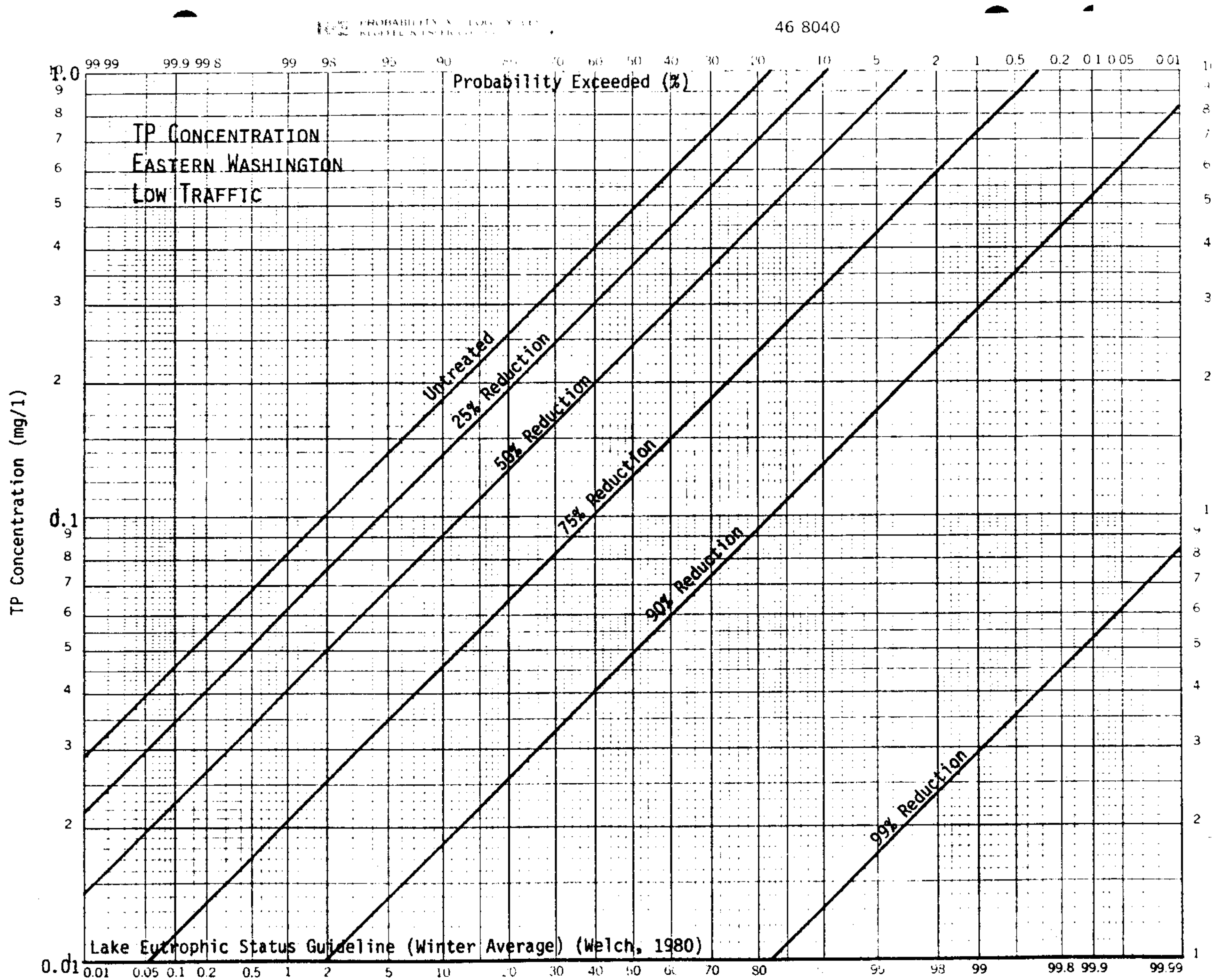


Figure 7. Concentration - Probability Distributions for Eastern Washington; Low Traffic Volume (Continued next 6 page


46 8040
Probability Exceeded (%)
TP CONCENTRATION
EASTERN WASHINGTON
LOW TRAFFIC
TP Concentration (mg/l)
Untreated
25% Reduction
50% Reduction
75% Reduction
90% Reduction
99% Reduction
Lake Eutrophic Status Guideline (Winter Average) (Welch, 1980)
1.0
0.1
0.01

Level III

Note: The purpose of Level III analysis is to reconsider cases identified by Level II analysis which may cause significant environmental impacts. It is recommended that these cases be reviewed using the more comprehensive and exact methods outlined and that mitigation measures be considered in more detail if the Level III analysis confirms the likelihood of significant impacts. Conduct a Level III assessment only for the specific problem(s) (quantity, loading or individual storm) identified by Level II analysis as potentially significant.

1.) Runoff quantity assessment (if receiving water is a stream):
   a.) Where Level II analysis has indicated a runoff quantity increase exceeding that permitted under the regulations existing at the location in question, design or redesign detention facilities, using customary departmental procedures. Repeat the assessment as in Level II, step 1, with the revised detention facilities.
2.) Monthly pollutant loading assessment:
   a.) For the month experiencing the greatest number of hr of precipitation, estimate the hours during which the roadway is expected to be wet as equal to the hours of recorded precipitation, using data in Appendix C for the location closest to the proposed construction site (see footnote associated with Level II, step 2.a.
   b.) Estimate the total vehicles passing during storms for the month in question (VDS/mo) as follows:

$$\text{VDS/mo} = \text{ADT}\left(\frac{\text{wet hr/mo}}{\text{24 hr/day}}\right)$$

   c.) Estimate highway runoff TSS loading for the month in question according to:

$$\text{TSS (lb/highway-mi/mo)} = (K)\left(\frac{\text{VDS/mo}}{1000}\right)(C)$$

   where: K and C are as defined in Level II, step 2.c.
   d.) Express highway loadings (L_H) for TSS in kg/mo for the month in question by multiplying by the number of highway-mi.

e.) If a mitigation device such as a detention basin is provided, reduce the TSS loading according to the solids removal capability of the device. If highway runoff is discharged to receiving water via a vegetated drainage course, multiply the estimated TSS loading by the appropriate fraction, as follows (after Wang, 1981). Interpolate as necessary.

Length of Vegetated Drainage Course (ft)	Fraction of Pollutant Remaining
< 30	1
31- 60	0.50
61- 90	0.40
91-120	0.30
121-150	0.26
151-180	0.23
≥ 180	0.20

Use the modified TSS loading in further calculations.

f.) Estimate annual highway loadings of other pollutants from:

$$\text{Loading (lb/yr)} = (K_p)(\text{TSS Loading})$$

where: K_p = ratio of pollutant P to TSS (Table 2)
TSS Loading is estimate from step 2.d. or 2.e.

g.) If the receiving water is a stream and if a comprehensive water quality record exists for the stream, proceed to step 2.h. Otherwise, go to step 2.i.

h.) Estimate the mean monthly loading for the month in question of each pollutant transported by the stream prior to the presence of the highway (L_S, lb/mo) according to:

$$L_{\overline{S}} = 1965\ \overline{Q}_S \overline{C}_S$$

where: $\overline{Q}_S$ and $\overline{C}_S$ are average quantities for the month in question (otherwise as in Level II, step 2.h.)
Go to step 2.p.

i.) Determine annual areal loading (lb/acre/yr) of each contaminant for each land use in the receiving water basin from local data, if they exist, or Table 4. Where a range is given, use the lower value if a conservative estimate of highway

Table 4: Storm Runoff Pollutant Loadings for Specific Land Use Categories

Land Use	Loading (lb/acre/yr)							
	TSS	COD	Pb	Zn	Cu	NO_3+NO_2-N	TKN	TP
Central Business District	964	955	6.3	2.7	1.9	4.0	13	2.5
Other Commercial	750	906	2.7	2.9	N/A	0.6	13	2.4
Industrial	50	56	1.8 - 6.3	3.1 - 11	0.3 - 1.0	0.4	2 - 13	0.8 - 3.6
Single-Family Residential	15	25	0.1	0.2	0.03	0.3	1 - 5	0.2 - 1.3
Multiple-Family Residential	390	297	0.6	0.3	0.3	3.4	3 - 4	1.2 - 1.4
Cropland	402	N/A	0.004 - 0.005	0.03 - 0.07	0.01 - 0.05	7.0	1.5	0.3
Pasture	306	N/A	0.003 - 0.013	0.02 - 0.15	0.02 - 0.04	0.3	0.6	0.06
Forested	76	N/A	0.01 - 0.03	0.01 - 0.03	0.02 - 0.03	0.5	2.6	0.08
Open	6	1.8	N/A	N/A	N/A	0.3	1.5	0.06

Notes: (1) Means given where available; otherwise ranges are reported. See Note 1 in Table 3 for references.

(2) N/A -- Not available.

contribution to total loading is desired; otherwise, use the midpoint of the range.

j.) Approximate the proportion of each annual areal loading delivered during the month in question according to:

$$\text{lb/acre/mo} = \left(\frac{\text{hr precipitation during the month}}{\text{annual hr precipitation}}\right)(\text{lb/acre/yr})$$

k.) Determine the areas (in acres) in Central Business District, Other Commercial, Industrial, Single-Family Residential, Multiple-Family Residential, Cropland, Pasture, Forested and Open land uses in the watershed draining to the highway runoff discharge point located farthest downstream. If it is projected by the planning agency for the location that development will modify land uses substantially in coming years, conduct the analysis for both present and ultimate land uses.

l.) Multiply loadings in lb/acre/mo by the respective areas to obtain loadings for the month in question for each land use (L_{L_i}). Then sum over all land uses for each pollutant (ΣL_{L_i}).

m.) If the receiving water is a stream, proceed to step 2.n. If the receiving water is a lake or wetland, go to step 2.q.

n.) Estimate point source loadings (L_p) of each pollutant as follows:

$$L_p \text{ (lb/mo)} = 1965\ Q_p C_p$$

where: Q_p and C_p are monthly quantities for the month in question (otherwise as in Level II, step 2.m.)

o.) Estimate total stream loadings prior to highway presence (L_S) as:

$$L_s = \Sigma L_{L_i} + L_p$$

p.) Express the impact on stream pollutant loadings in terms of the estimated increase due to highway runoff (L_H) as a percentage of the original stream loading (L_S). If in the judgment of the impact analyst the evidence accumulated through Level II and III analyses indicates the impact may be excessive, mitigation should be further considered. An individual storm event loading assessment procedure is included (Level III, step 3) to aid in designing pollution control facilities. If the stream eventually discharges to a lake or wetland, also evaluate the impact on that water body according to steps 2.q. and 2.r. Otherwise, go to step 3 (if necessary) or step 4.

q.) If the immediate or eventual receiving water is a lake or wetland, estimate total loadings for the month in question prior to the highway presence (L_{La}) as equal to ΣL_{Li} plus any point source loading (1965 Q_pC_p). Express and evaluate the impact on wetland pollutant loadings as in step 2.p.

r.) If the immediate or eventual receiving water is a lake, conduct a special analysis to assess the potential impact of phosphorus loading on trophic state as follows:

(1) Convert L_H and L_{La} to kg/mo by dividing by 2.2 lb/kg.

(2) Estimate annual loadings from the monthly loadings found previously by proportion (for both L_H and $\Sigma L_{L_i} + L_B$):

$$Kg/yr = \left(\frac{\text{annual hr precipitation}}{\text{hr precipitation during the month}}\right) (Kg/mo)$$

(3) Carry out steps (2) to (4) under Level II, step 2.q.

(4) If the highway loading addition does not move the status point near or into a higher trophic category, declare minimal impact on lake eutrophication and analyze impacts associated with maintenance or special problem areas (Section IV). If a substantial impact on trophic state appears likely, mitigation should be further considered (see step 3).

3.) Individual storm event loading assessment:

Note: The available data are not sufficient at this point to support a Level III individual storm event concentration assessment. The following loading assessment procedure is included to provide a basis for the design of detention and other mitigation devices. A specific probability of occurrence may be selected as a design basis and the associated loading used to select and design facilities.

a.) Select a probability on which to base design (for example, the control device should be designed for the loading exceeded in only ten percent of the storms).

b.) For the design probability, location, and traffic level, determine the design TSS loading (lb/highway-mi) by referring to Figure 8 or 9 (for definition of traffic levels, see footnote associated with Level II, step 3.f.).

c.) Multiply by highway-mi to obtain total mass loading.

d.) Calculate the design loadings of other pollutants by multiplying by the ratios from Table 2.

e.) Using the estimated loadings and design storm and customary departmental procedures, design the control device.

f.) With the control device included in the analysis, repeat the portion of the assessment which indicated an unacceptable water quality impact (Level II, step 3 for pollutant concentrations or Level III, step 2 for pollutant loadings) to insure that the impact will be reduced to an acceptable level.

4.) Analyze impacts associated with the particular maintenance practices anticipated or any special problem areas (see Section IV).

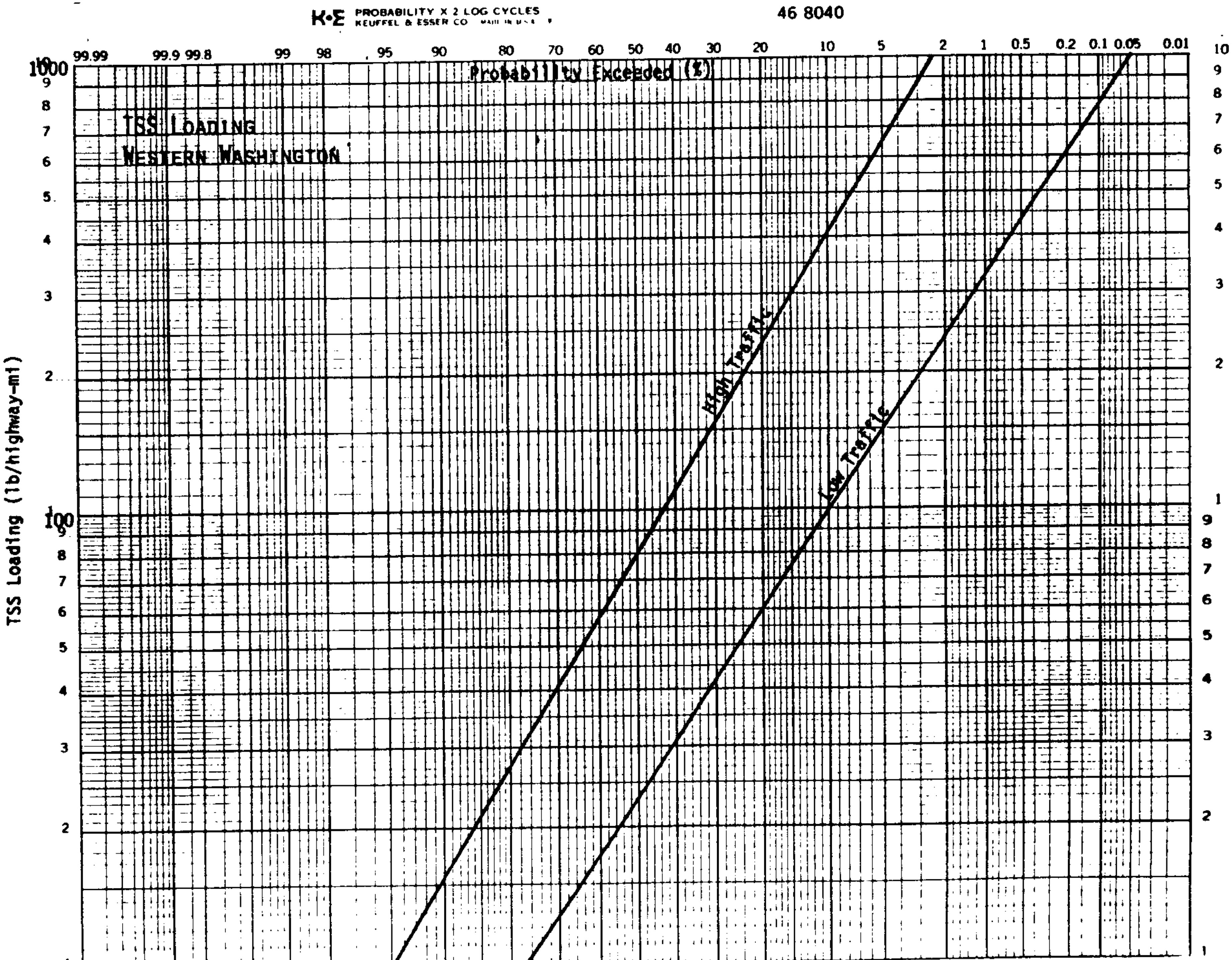


Figure 8. TSS Loading - Probability Distribution for Western Washington

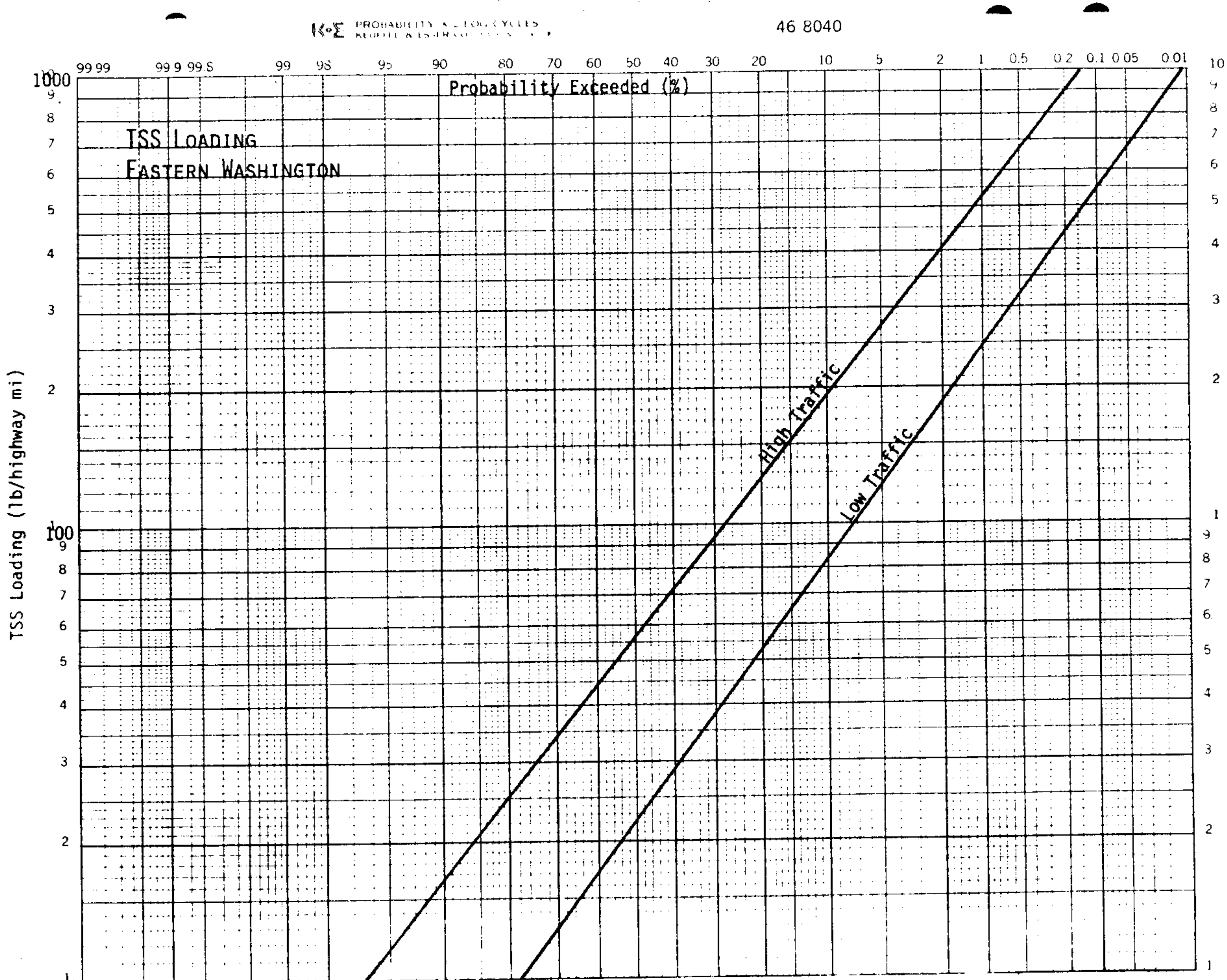


Figure 9. TSS Loading Probability Distributions for Eastern Washington

IV. ASSESSMENT OF IMPACTS ASSOCIATED WITH MAINTENANCE PRACTICES AND SPECIAL PROBLEMS

This section covers impact assessment under highway operating conditions which may differ from time-to-time or district-to-district within Washington State or which are somewhat out of the ordinary. In projects where they apply, these conditions must be evaluated in addition to the general case detailed in the preceding section and their expected impacts added to those previously estimated.

Sanding

Sand applied to the roadway for winter operations is biologically and chemically stable. The total amount applied may eventually contribute to the solids loading on the receiving water. Smaller particles can be transported by the runoff water as part of the suspended solids, and larger particles can be pulverized by traffic and then suspended in the runoff. The following factors reduce the fraction of applied sand entering the drainage system:

1.) Larger particle sizes and/or denser particles (if removed from the traffic lanes before pulverized).
2.) A period between application and the first extensive runoff, during which traffic-generated winds can remove particles from the highway.
3.) Plowing which throws sand particles to the side before melting and runoff occur.
4.) Sweeping which cleans the shoulder and avoids any chance of accumulated material in the larger size fractions being carried along with runoff from a heavy storm.

One approach to sanding impact assessment is to estimate a typical winter's usage (lb/yr) from the expected number of storms and prevailing lane-mile application rates and assume the entire quantity drains from the highway as TSS. If runoff discharges via a vegetated drainage course or other mitigation measures are provided, modify the loading as described in Section III. Then add the sanding TSS load to that from normal operations, as estimated by Level II or III methods. This total loading should then be evaluated in the context of TSS loads from all land uses, also as outlined in Section III.

Another approach would be to estimate the reduction in runoff loading likely to result from selection of particle size and density, plowing, and sweeping. Only the remaining sanding load would then be added to that from normal operations. Estimating the reduction due to the various factors would be difficult and subject to judgment but would be warranted when the sand characteristics and maintenance procedures are well-established. With plowing, it is likely that most of the sand will be removed prior to runoff. Therefore, when regular plowing is anticipated, the sanding contribution to TSS loading can be considered small and neglected. When sweeping is anticipated, it may be possible for maintenance personnel to estimate the quantity recovered by sweeping according to records on the number of truck loads removed. The TSS loading in runoff would then be estimated as the difference between application and removal.

The research demonstrated that the ratios of other pollutants to TSS associated with sanding were equal to those reported in Table 2 at the high traffic sites. With lower traffic, pollutant deposition failed to saturate the solids due to sanding, and the ratios were substantially lower on a cumulative basis (Asplund, 1980). It is thus recommended that the loadings of other pollutants be established according to the procedures given in Section III when ADT is projected to exceed 10,000. With lower traffic, the assessment should reflect the elevated TSS loading due to sanding but should not augment the loadings of other pollutants in proportion to the TSS resulting from sanding.

Deicing

Deicing salts have a number of potential environmental impacts, including degradation of drinking water supplies, stress on the aquatic ecosystem created by chlorides and anti-caking ingredients, density stratification of lakes, damage to roadside vegetation and corrosive damage to metals. Because of these effects, avoiding the use of salt is recommended whenever possible. WSDOT has followed this policy in recent years. Sand-salt mixtures are still used and vary considerably within the state. In District 1, for instance these mixtures contain 20-25 percent salt (WSDOT, 1982). On the other hand, many roads do not receive any salt.

The deicing material most frequently used in Washington State is sodium chloride. The average total application rate in recent winters on the Spokane viaduct has been 12.89 tons/lane-mi, whereas an average of 43.46 tons/lane-mi had been used in 1980-81 and previous winters on I-90 at Snoqualmie Pass (Wieman, personal communication). During the 1981-82 winter pelletized urea and isopropyl alcohol were used as deicing agents on I-90 in the Snoqualmie Pass area (WSDOT, 1982). Oxidation products of urea, principally ammonia and nitrate, could create water quality impacts.

Road salt purchased by WSDOT is treated by the supplier with sodium ferrocyanide at 200 ppm by weight to prevent caking (Forman, personal communication).

For the evaluation of water quality impacts where winter maintenance will employ salt, the EPA (1978) Draft Guidelines require the following:

> ...data on chloride concentrations in surface and groundwaters with analysis of the seasonal variation in levels. If data are available, the trends in chloride levels should be presented and correlated to trends in quantities of deicing salt used in the drainage basin. Sodium and chloride data on municipal and well water supplies in the vicinity of the proposed highway should be presented in the EIS if the maintenance program includes plans for significant salt application. The EIS should also summarize or include by reference the results of any published study on the salinity of the impacted receiving waters or the water quality effects of highway deicing in the drainage basin. Finally, the EIS should describe the extent to which the plans for highway deicing conform to state and local non-point source regulations and regional or local water quality plans.

As soluble but chemically and biologically stable compounds, sodium chloride and sodium ferrocyanide quantities must be regarded as likely to enter the runoff. Some would probably be sprayed from the highway by passing traffic, but the amount removed in this way is unpredictable.

No modeling of deicing salt runoff was undertaken during this project. The U.S. Geological Survey (Frost et al., 1981), in cooperation with the Massachusetts Department of Public Works, conducted a five-year investigation to develop methods of estimating annual mean and maximum chloride and sodium concentrations and loadings in streams receiving highway runoff. The data were analyzed using multiple and simple linear regression techniques. Table 5 summarizes the resulting relationships.

The estimates can be used to express deicing impacts and, when it appears necessary, to guide mitigation strategy. Specific chloride and sodium criteria have not been promulgated for public water supplies and aquatic life. It has been recommended (U.S. Environmental Protection Agency, 1973) that

Table 5: Regression Equations for Estimating Chloride and Sodium Concentrations and Loadings (from Frost et al., 1981)

$$MEAN\_CL = -0.94 + 1.22 \times \frac{SALT\_APP}{ANAVFLOW} + 0.06\ SLOPE$$

R = 0.91 SE 3.3 mg/L

$$MAX\_CL = 26.1 + 2.1 \times \frac{SALT\_APP}{ANAVFLOW} - 3.2 \times STORAGE$$

R = 0.76 SE = 12 mg/L

$$CL\_LOAD = -37.8 + 50.0\ STORAGE + 0.816\ SALT\_APP$$

R = 0.93 SE = 90 tons

$$MEAN\_NA = 5.13 + 0.483 \times CONCSALT$$

R = 0.90 SE = 1.9 mg/L

$$MAX\_NA = 11.0 + 1.02 \times CONCSALT$$

R = 0.90 SE = 4.0 mg/L

$$NA\_LOAD = -36.4 + 14.9\ STORAGE + 1.02\ SALT\_APP$$

R = 0.98 SE = 26 tons

where:

R	Multiple correlation coefficient.
SE	Standard error of estimate.
MEAN_CL	Annual average of daily mean chloride concentrations (mg/L).
MAX_CL	Annual maximum of daily mean chloride concentrations (mg/L).
CL_LOAD (tons/day)	Annual sum of daily values of chloride concentrations (mg/L) x discharge (ft^3/s) x 0.0027.
MEAN_NA	Annual average of daily mean sodium concentrations (mg/L).
MAX_NA	Annual maximum of daily mean sodium concentrations (mg/L).
NA_LOAD (tons/day)	Annual sum of daily values of sodium concentration (mg/L) x discharge (ft^3/s) x 0.0027.
SALT_APP	Annual sum of tons of NaCl applied to roadways in the basin.
SLOPE	Slope of main channel, in feet per mile, between points 10 percent and 85 percent along the stream from discharge point to the topographic divide.
STORAGE	Area of lakes and ponds expressed as a percentage of the drainage area plus 0.5 percent.
ANAVFLOW	Annual mean rate of water discharge (ft^3/s); flood with recurrence interval 2.33yr
CONCSALT	SALT_APP divided by ANAVFLOW.

chloride in drinking water not exceed 250 mg/l on the basis of taste considerations. McKee and Wolf (1963) reported that 95 percent of U.S. waters sustaining good fish life had less than 170 mg/l of chloride. Natural salinity is generally relatively low in Washington State waters, and aquatic life is adapted to such conditions. Thus, a large increase in chloride due to deicing salt runoff would be of special concern in ecologically sensitive waters of the state. The U.S. Environmental Protection Agency (1973) reported that individuals on sodium-restricted diets are permitted no more than 20 mg/l of sodium in drinking water but recommended no limit for public water supplies.

Pesticides

The application of pesticides to roadside vegetation must be selective because of their potential to adversely impact receiving water biota and beneficial uses and the possible destruction of vegetation which is capable of treating runoff water. Pesticides can impact aquatic life through acute toxicity and chronic effects resulting from bioaccumulation. The persistence of pesticides in the environment varies because of differing volatilities and rates of degradation.

The impact analyst should work closely with maintenance personnel to determine pesticide treatments anticipated at the site in question. The assessment should report pesticide types, quantities and application frequencies and provide data on LC_{50}'s and U.S. Department of Agriculture toxicity ratings if available. The assessment should also evaluate the potential for transport to receiving water. It should be kept in mind and pointed out if applicable that the organic compounds in question are effectively adsorbed by solids. Thus, vegetated drainage courses can remove pesticides, along with solids, as runoff passes through, unless a particular herbicide would destroy or prevent grass growth.

Highway Sections on Woodwaste Fill

As part of the WSDOT/UW research an extensive literature review, laboratory column studies and field observations on woodwaste fills were completed to establish the water quality impacts of this construction technique. Vause (1980) reported the details of these efforts, and Vause et al. (1980) summarized the findings.

The data indicated that pollutants were released by physical leaching of wood extracts and that microbial fermentation was of secondary importance. The ultimate pollutant releases measured were:

BOD -- 30 $\pm$ 8 lb/ton dry solids
COD -- 80 $\pm$ 20 lb/ton dry solids
TOC -- 20 $\pm$ 5 lb/ton dry solids

It was found that pollutants were released exponentially with time and that discharges were negligible after one year of soaking. The above values may thus be used as an approximation of maximum annual loadings for the first year after construction. Loadings to receiving waters would be reduced by any dilution or removal in the drainage system prior to entrance into the water body.

The total annual (or monthly for Level III) COD loading estimated from these results should be added to that computed for general operations and evaluated as indicated in Section III.

Pollutant concentrations were also determined during the research. Peak measured concentrations were:

	Leachate	Underdrain	Outfall	Seep
BOD (mg/l)		670		1590
COD (mg/l)		1830*		4220

*2920 in laboratory column simulating intermittent rainfall infiltration.

Underdrain BOD concentrations required approximately 180 days to decline to relatively stable low concentrations, while seep (slowly leaching) concentrations required about 100 days longer. Except in the intermittent rainfall experiment, outfall COD concentrations reached low, rather stable values in 60 to 180 days. As with BOD, seep COD concentrations required about 280 days to reach a low level. TSS concentrations were uniformly low, approximately 15 mg/l.

Receiving stream, lake, or wetland concentrations during the leaching period can be estimated according to a mass balance procedure in order to assess the leachate impact and, if necessary, guide the development of a mitigation strategy. The equations to make this estimate are:

$$\text{Stream -- } C_S' = \frac{QC + \overline{Q}_S\overline{C}_S}{Q + \overline{Q}_S}$$

where: All quantities are as defined in Level II, step 3, except Q and C apply to woodwaste fill leachate rather than highway runoff

$$\text{Lake or wetland -- } \overline{C}_{La} = \overline{C}_{in} + (\overline{C}_o - \overline{C}_{in})e^{-(\overline{Q}_{in}/V)t}$$

where: $\overline{C}_{La}$ = mean equilibrium lake or wetland pollutant concentration (mg/l)

$\overline{C}_{in}$ = mean inflow pollutant concentration (mg/l)

$$\overline{C}_{in} = (QC + \Sigma\,\overline{Q}_S\overline{C}_S\,/(Q + \Sigma\overline{Q}_S)$$

(Σ indicates summation of all tributary inflows)

$\overline{C}_o$ = mean lake or wetland pollutant concentration prior to discharge of woodwaste fill leachate (mg/l)

e = base of natural logarithms

$\overline{Q}_{in}$ = mean total surface inflow of water (any volume/unit time units consistent with volume units)

V = lake or wetland water volume (any consistent volume units)

t = time of leachate discharge (any consistent time units)

Note: The equation given is the solution of a differential equation for mixed reactor with flushing, $d\overline{C}_{La}/dt = \overline{Q}_{in}\ V(\overline{C}_{in} - \overline{C}_L)$, with an initial condition $\overline{C}_L = \overline{C}_o$ at $t = 0$.

Several steps may be taken to reduce water quality impacts of woodwaste fills. First, pre-soaking of the woodwaste prior to placement or the use of old, weathered material would reduce leachate pollution. Secondly, the fill should be designed to reduce the entrance of water which would become contaminated leachate. Further, discharge of leachate in high volumes of dilution water would reduce its environmental impact. Finally, leachate could be treated.

Accidental Spills

The assessment should develop projections of the number, types and volumes of spills, working from records on similar highways. It should further outline a hazardous spill management plan that will minimize accident-related water impacts. An important element of this plan should be consideration of the construction of holding basins where ecologically sensitive waters are proximate to the highway. The impact analyst should consult Eagen (1980) and Andrews et al. (1981) for data helpful in developing projections and a more complete discussion of spill management.

Involvement with Groundwater

A key recommendation arising from the WSDOT/UW research is drainage of highway runoff over vegetated drainage courses whenever possible. Studies have shown (Wang, 1981) that pollutants captured in such channels in Western Washington soils and vegetation are effectively held in the upper soil horizons. There is less assurance that treatment of the runoff and soil retention would be as complete with the more meager vegetation and more porous soils of Eastern Washington. There surface receiving waters are scarce, and most storm runoff is directed off the pavement where it percolates through the soil. Extensive aquifers underlie Eastern Washington and are the source of most potable water.

The federal Safe Drinking Water Act requires additional specific information when federally funded construction is to occur in an area overlying an EPA-designated sole-source aquifer (when the aquifer serves as the sole or principal drinking water source for the area). The Spokane Valley and Whidbey and Camano Islands have been so designated in Washington State. The environmental impact statement documenting a project in such a region must contain the information noted in Table 6, in addition to that assembled for general assessment purposes, as listed in Table 1. Table 7 stipulates the analysis that must be conducted in this case (U.S. Environmental Protection Agency, 1977).

In conducting this analysis, loading estimates can be made according to the procedures previously outlined for surface receiving waters. Much as before, these loadings should be assessed in the context of those from all land uses in the recharge area. With present knowledge, it is not possible to predict at all accurately the proportion of the total loadings which actually enters groundwater. It can be said that the soils should act like a sand filter and remove the majority of the solids and the pollutants associated with them, unless the water table is very close to the surface. Removal of

Table 6: Outline of Specific Information Required for Groundwater Impact Evaluations in Sole-Source Aquifer Regions (U.S. Environmental Protection Agency, 1977).

Geologic Characteristics

- Location and extent of aquifer recharge and streamflow source zones in relation to project site (maps and description)
- Dimensions of aquifer (area, thickness, and variations)
- Hydraulic boundaries, including discontinuities, location, and extent of horizontal and vertical confining materials, and perched water tables
- Description of water-bearing formations (consolidated or unconsolidated, general proportions of clay, silt, sand, and gravel)
- Permeability of aquifer materials in project area

Hydrologic Characteristics

- Average annual precipitation and average annual recharge estimates
- Depth to water table in project area (especially where excavations will be required), including seasonal variations, if significant
- Magnitude and direction of hydraulic gradient in sufficient detail to estimate general direction of ground-water movement at project site and adjacent areas

Physiographic Characteristics

- Topography of project area
- Drainage patterns, including location of perennial and/or ephemeral streams relative to project site

Soil Characteristics

- Soil types (SCS maps or unpublished data) in project area
- Soil classifications (textural characteristics, particularly silt and clay content)
- Infiltration and transmission capacity of soils in the project area (e.g., SCS hydrologic soil groups)

Land Use/Cultural Characteristics

- Location of major producing and known abandoned wells in the project area, and effects on hydraulic gradient
- Land uses, including type, development densities, and vegetative cover at project site and in project area
- Local and regional land use plans and regulations affecting development in project area or entire aquifer recharge zone

Project Characteristics

- Type, alignment, and size of improvement (number of lanes, corridor dimensions, and impervious surface area)
- Location and magnitude of excavation and fill areas
- Expected traffic volume and mix
- Description of highway drainage facilities and provisions
- Probable maintenance practices with respect to storage and use of deicing chemicals, petroleum products, pesticides, and other chemicals

dissolved substances, NO_3+NO_2-N being of most concern, would not be expected to be nearly as effective. Measured concentrations in highway runoff have remained below the 10 mg/l drinking water standard for NO_3-N, however (Asplund, 1980; Chui, 1981). Thus, even if untreated by the soil, nitrate in Washington State highway runoff should not endanger aquifers. Should a situation arise in which highway runoff would be drained over thin, porous soils in the recharge area of an EPA-designated sole-source aquifer, it would be possible to gain insurance by engineering a channel containing more adsorbent soils and more profuse vegetation than naturally present.

Table 7: Outline of Impact Analyses Required for Projects in Sole-Source Aquifer Regions (U.S. Environmental Protection Agency, 1977).

- Estimation of effect on ground-water recharge and ground-water levels caused by highway construction; estimation methodology is described in DOT's Notebook 4 (U.S. Department of Transportation, 1975).
- Existing chloride concentrations in ground-water and estimation of contributions due to application of deicing chemicals in aquifer recharge zone (cumulative effects over time in combination with other possible chloride sources must be considered).
- Description of quantity, quality, and fate of stormwater runoff from highway right-of-way, particularly if significant ground-water recharge is likely.
- Description of probable future land uses along the highway corridor and estimation of potential for adverse ground-water quality impacts (special attention should be given to effects of possible development over critical aquifer areas such as highly permeable recharge zones).
- Description of proposed maintenance practices involving pesticides and other potentially hazardous chemicals; application rates and frequency, and restrictions on use in sensitive areas should be specified.
- Description of responsibilities and methods for handling accidental spills, including reporting, remedial actions, and monitoring.

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APPENDICES

APPENDIX A

SOURCES OF WASHINGTON STATE ENVIRONMENTAL DATA FOR IMPACT ASSESSMENT

Federal Agencies

U.S. Geological Survey
1201 Pacific Avenue
Suite 600
Tacoma, WA 98402

(stream gaging records, stream and lake water quality data)

Tel. 206-593-6510

U.S. Geological Survey 7-day low flow studies:

1. Cummans, J.E. and E.G. Nassar, "Low-Flow Characteristics of Streams in the Grays Harbor Drainages, Washington," 1975.

2. Hidaka, F.T., "Low Flows and Temperatures of Streams in the Seattle-Tacoma Urban Complex and Adjacent Areas, Washington," 1972.

3. LaFrance, "Low-Flow Characteristics of Selected Streams in Northeast Washington." 1975.

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6. Haushild, W.L., "Low-Flow Characteristics of Streams on the Olympic Peninsula," Open-File Report 77-812, 1978.

7. Collins, M.R. and F.T. Hidaka, "Low-Flow Characteristics of Streams in the Willapa Bay Drainages, Washington," 1974.

U.S. Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101
(general information)
Water programs tel. 206-442-1014

U.S. Army Corps of Engineers
(hydrologic and water quality data)

Seattle District Office
P.O. Box C3755
Seattle, WA 98124
Water Quality tel. 206-764-3586

Portland District Office
P.O. Box 2946
Portland, OR 97208
Hydrology tel. 503-221-6470

Walla Walla District Office
Building 602
City-County Airport
Walla Walla, WA 99362
tel. 509-525-5308

National Oceanic and Atmospheric Administration
Environmental Data and Information Service
7600 Sand Point Way N.E.
Seattle, WA 98115
(meteorological data)
tel. 206-527-6241

State Agencies

Department of Ecology

National Pollutant Discharge Elimination System permit records (point source data) --
Lloyd Taylor
PV-11
Olympia, WA 98504
tel. 206-459-6039
SCAN 585-6039

Surface water quality data (headquarters)
Allen Moore
PV-11
Olympia, WA 98504
tel. 206-459-6063
SCAN 585-6063

Surface water quality data (regional) --
Southwest Regional Office
7272 Clean Water Lane
Olympia, WA 98504
tel. 206-753-2353
SCAN 243-2353

Northwest Regional Office
4350 150th Avenue N.E.
Redmond, WA 98052
tel. 206-885-1900
SCAN 241-2610

Eastern Regional Office
East 103 Indiana
Spokane, WA 99207 — tel. 509-456-2926 — SCAN 545-2926

Central Regional Office
3601 West Washington
Yakima, WA 98903 — tel. 509-575-2991 — SCAN 558-2491

Local Agencies

Municipality of Metropolitan Seattle (King County)
821 Second Avenue
Seattle, WA 98104

Surface water and nonpoint source data --
Janet Condon — tel. 206-447-6370
Sewage treatment plant data --
West Point Plant (Gordon Gabrielson) — tel. 206-447-6801
Renton Plant (Bill Burwell) — tel. 206-226-3680

Snohomish County Metropolitan Municipal Corporation
c/o Office of Community Planning
County Administration Building
Everett, WA 98102 — Water Quality (Steve Rice) tel. 206-259-9313

Local municipal wastewater utilities
(for point source data)

APPENDIX B
FLOOD PROBABILITY ANALYSIS

Reference: Linsley et al. (1975).

1.) For the entire gaging record, find the mean ($\bar{q}$) and standard deviation (σ_q) of the annual maximum discharges.

2.) Select K for the design storm recurrence interval and gaging record length from the table below. Use linear interpolation between table entries where necessary.

Values of K for the Extreme-Value (Type 1) Distribution

Return Period, Years	Proba-bility	Record Length, Years						
		20	30	40	50	100	200	
1.58	0.63	-0.492	-0.482	-0.476	-0.473	-0.464	-0.459	-0.450
2.00	0.50	-0.147	-0.152	-0.155	-0.156	-0.160	-0.162	-0.164
2.33	0.43	0.052	0.038	0.031	0.026	0.016	0.010	0.001
5	0.20	0.919	0.866	0.838	0.820	0.779	0.755	0.719
10	0.10	1.62	1.54	1.50	1.47	1.40	1.36	1.30
20	0.05	2.30	2.19	2.13	2.09	2.00	1.94	1.87
50	0.02	3.18	3.03	2.94	2.89	2.77	2.70	2.59
100	0.01	3.84	3.65	3.55	3.49	3.35	3.27	3.14
200	0.005	4.49	4.28	4.16	4.08	3.93	3.83	3.68
400	0.0025	5.15	4.91	4.78	4.56	4.51	4.40	4.23

3.) Compute streamflow for the design condition (q) according to:

$$q = \bar{q} + K\sigma_q$$

APPENDIX C
AGGREGATED HOURLY PRECIPITATION DATA[1]

Location	Hr/yr	Data for Month with Maximum Hr Precipitation (2)	
		Month	Hr in Month
Aberdeen	1973	December	297
Blaine	979	December	143
Castle Rock	1257	December	179
Clearwater	1833	December	269
Colville	537	January/November	79/65
Cougar	1758	December	267
Coulee Dam	363	December/November	55/46
Darrington	1601	January	223
Dayton	652	December	105
Diablo Dam	1375	December/November	225/190
Easton	1220	December/November	203/170
Electron	1569	December	202
Glenwood	835	January/November	138/125
Lind	300	December/November	42/37
Mazama	584	December/November	111/99
Methow	363	January/November	60/42
Mud Mtn. Dam	1251	December	165
Naches	286	January/November	44/42
Oroville	384	December/November	51/46
Palmer	1683	December	224
Port Angeles	624	December and January	92
Pullman	620	December/November	92/78
Rainier-Ohanapecosh	1398	November	204

Republic	496	January/November	62/54
Seattle (City)	911	January	139
Silverton	2109	December	287
Snoqualmie Pass	1864	December/March	253/226
Spokane	558	December/November	90/72
Stampede Pass	1976	December/March	282/230
Walla Walla	454	January/November	66/56
Wenatchee	322	December/November	54/47
Yakima	269	January/November	48/34
Portland (use for Southwest Washington)	997	January	174

Notes: (1) Source: Pacific Northwest River Basin Commission, 1968.

(2) Where data are given for two months, the first quantity represents the month with the maximum hr precipitation in the average year and the second represents the month outside of the anticipated period of an extended freeze (December-February). If it is expected that temperatures will remain consistently below freezing in the month with the maximum hr in most years, the second quantity should be used in the assessment.

(3) For locations other than those given, the quantities can be estimated according to the following regression equations:

$$Hr/yr = 20.7\ P + 158 \qquad r^2 = 0.990$$

$$hr/mo = 18.1\ P' + 34 \qquad r^2 = 0.970$$

Where: P = mean annual precipitation (inches)
P' = mean precipitation in month with most hr precipitation (inches)

APPENDIX D
UNIT CONVERSIONS

Multiply -------------->	By ---------------->	To Get
To Get <--------------	By <----------------	Divide
grams (g)	2.2×10^{-3}	pounds (lb)
hectares (ha)	2.47	acres (ac)
kilograms (kg)	2.2	pounds (lb)
kilograms/hectare (kg/ha)	0.89	pounds/acre (lb/ac)
liters (l)	0.035	cubic feet (ft^3)
liters (l)	0.264	gallons (gal.)
meters (m)	3.28	feet (ft)
milligrams (mg)	2.2×10^{-6}	pounds (lb)
acre (ac)	43,560	square feet (ft^2)
mile (mi)	5,280	feet (ft)
square mile (mi^2)	640	acre (ac)
ton	2,000	pound (lb)
day	86,400	second (sec)
hour (hr)	3,600	second (sec)
year (yr)	8,760	hour (hr)