Simplified Data Based TMDL

The world is log-normal

- TMDL is designed for **water quality limited water bodies**
  - Water body is either impaired or threatened and the water quality goals cannot be achieved by application of BATEA for point source (Sections 301, 306, and 307 of CWA) and implementable economical best management practices for nonpoint sources
  - Impaired water bodies are those where the water quality goals are not met; threatened water bodies are those that are not impaired now but could be impaired in the near future

TMDL FUNDAMENTAL CONCEPT

$$TMDL = \sum WLA + \sum LA + FG = LC - MOS$$

where TMDL is the allocation of the Loading Capacity , LC, among the individual point sources, WLA, nonpoint and background (natural sources), LA, and future growth, FG

MOS is a margin of safety

The most common units are mass/time

This equation explains the concept but it practical utility is small

Loading Capacity is determined by models from Water Quality Standards

$$LC = F^{-1}(WQS)$$

Current regulations in most states allow excursions of the standards at low design flows

- 1Q10 for acute toxicity (CMC) - aquatic biota
- 7Q10 for chronic toxicity (CCC) - aquatic biota
- 30Q5 for noncarcinogenic compounds - human health
- harmonic mean flow for carcinogenic compounds

With exception of the harmonic mean flow none of the above "design flows" allow consideration of diffuse wet weather sources

Commonly used water quality models are deterministic

- BASINS (includes HSP-F, QUAL 2-e, dilution model)
- SWMM
- Several others

Long tradition and wide spread availability lead TMDL preparers to selecting these models. Deterministic models are typically calibrated and verified to fit the average values of the water quality data

SEASONALITY REQUIREMENT

Water quaqlity goals should be met during all seasons of the year

- Wet and dry seasons
- Warm and cold seasons
- Growing and dormant seasons
- Spawning and non-spawning seasons

Deterministic approach to modeling wet weather events may require a definition of a design storm

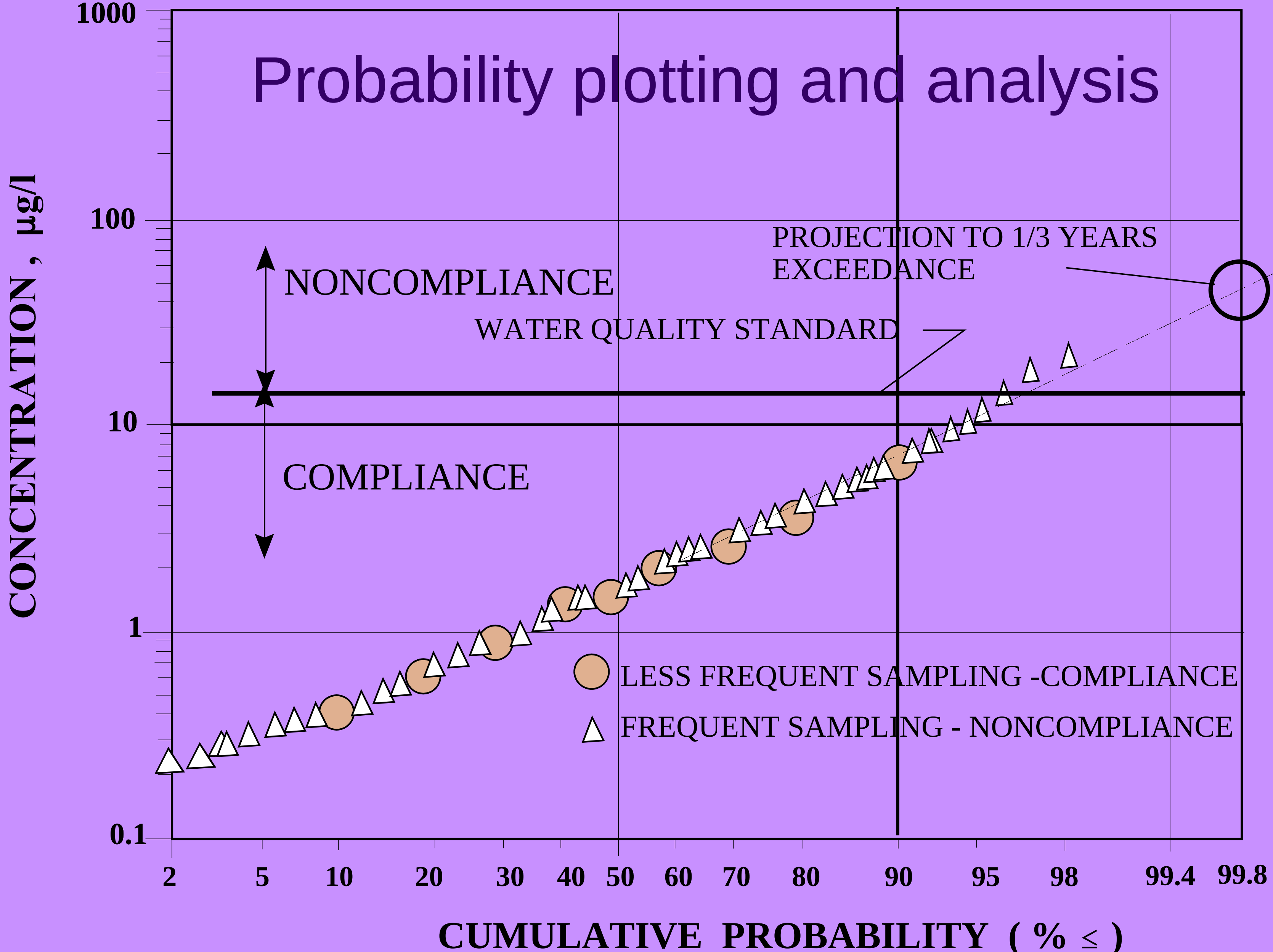
- Consultants and agencies typically select rare storms, e.g., 25 to 100 year storms.
- Water quality problems are caused by more frequent wet weather events such as frequent rainfalls causing CSOs.
- Considering seasonality in TMDL makes it difficult to define a single representative storm for the design and TMDL assessment

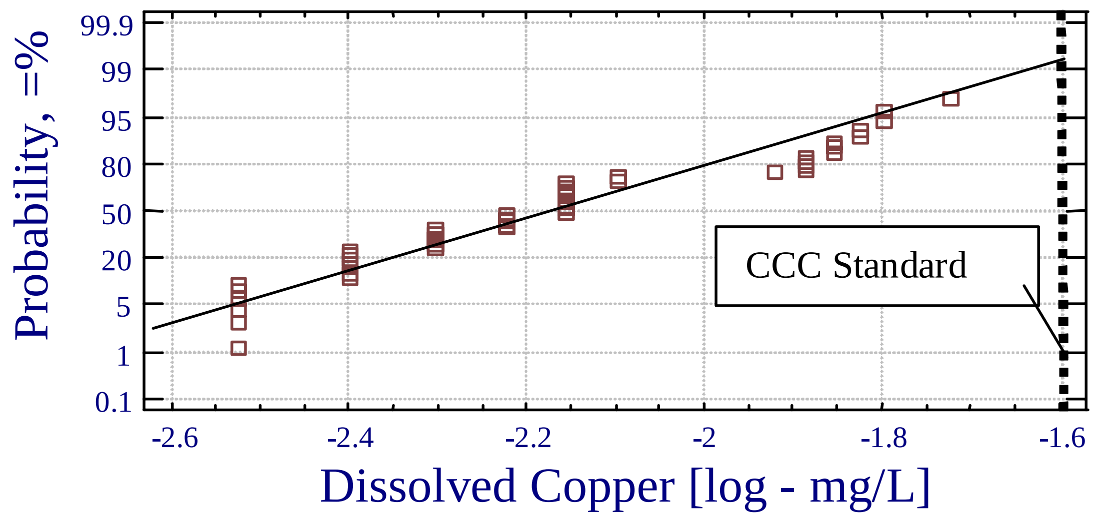
Statistical (Stochastic) Nature of TMDL Components

Statistically defined federal criteria (some states still require that standards should be met at all times)

- **Magnitude** - What is the allowed level of a pollutant
- **Duration -** The period of time (averaging period) over which the in-stream concentration is averaged.
- **Frequency -** How often the concentration averaged during duration can exceeded the water quality standard

Probability plotting and analysis





Example of dissolved copper concentration analysis of the Des Plaines River (Illinois)

StatGraphic software

Grab samples taken 2/month

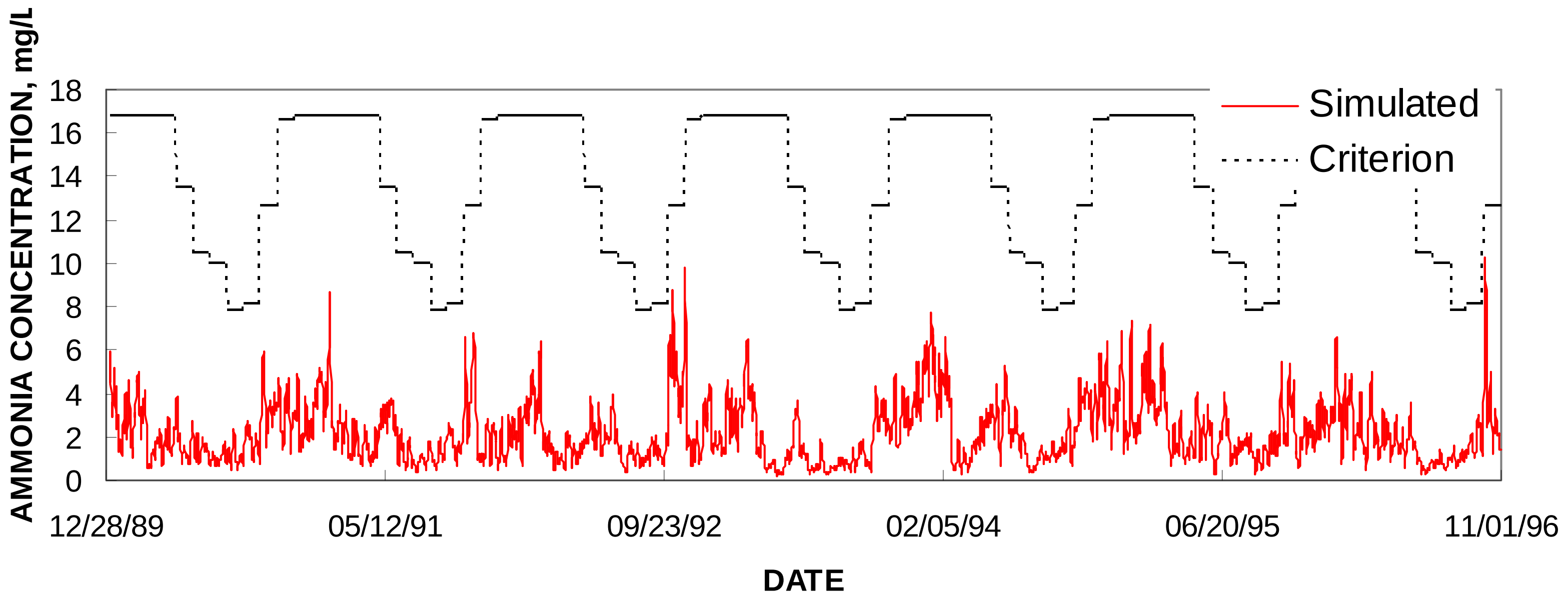
Some standards require daily data for averaging

- Ammonium (30 day averaging)
- All chronic (CCC) standards (4 day or 30 day averaging)
- Dissolved oxygen (4 or 7 day averaging)

- Continuous data gathering is rarely available
- Stochastic modeling, e.g. Monte Carlo or ARMA-TF, can substitute missing data with the same statistical characteristics as the original sample

Monte Carlo generated series of ammonium data

Comparison of 30 day average ammonia concentrations calculated by the Monte Carlo methodology and 30 days moving window averaging and site specific chronic toxicity criterion in the Milwaukee Outer Harbor.



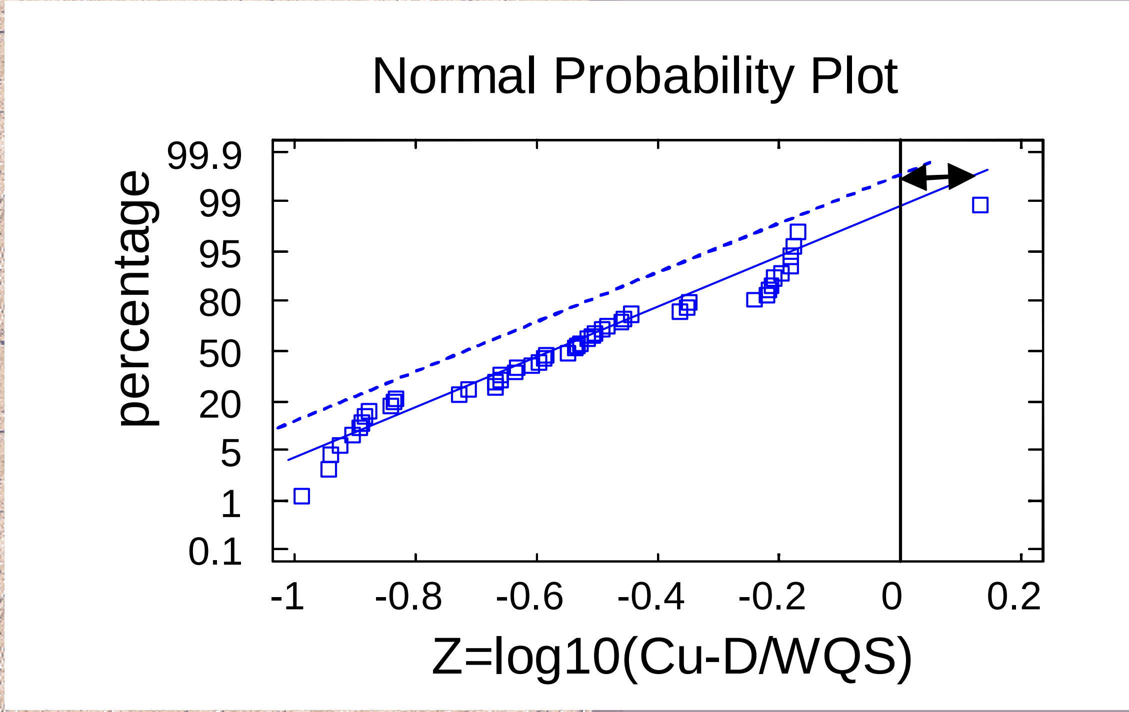
Statistical TMDL

Two step approach:

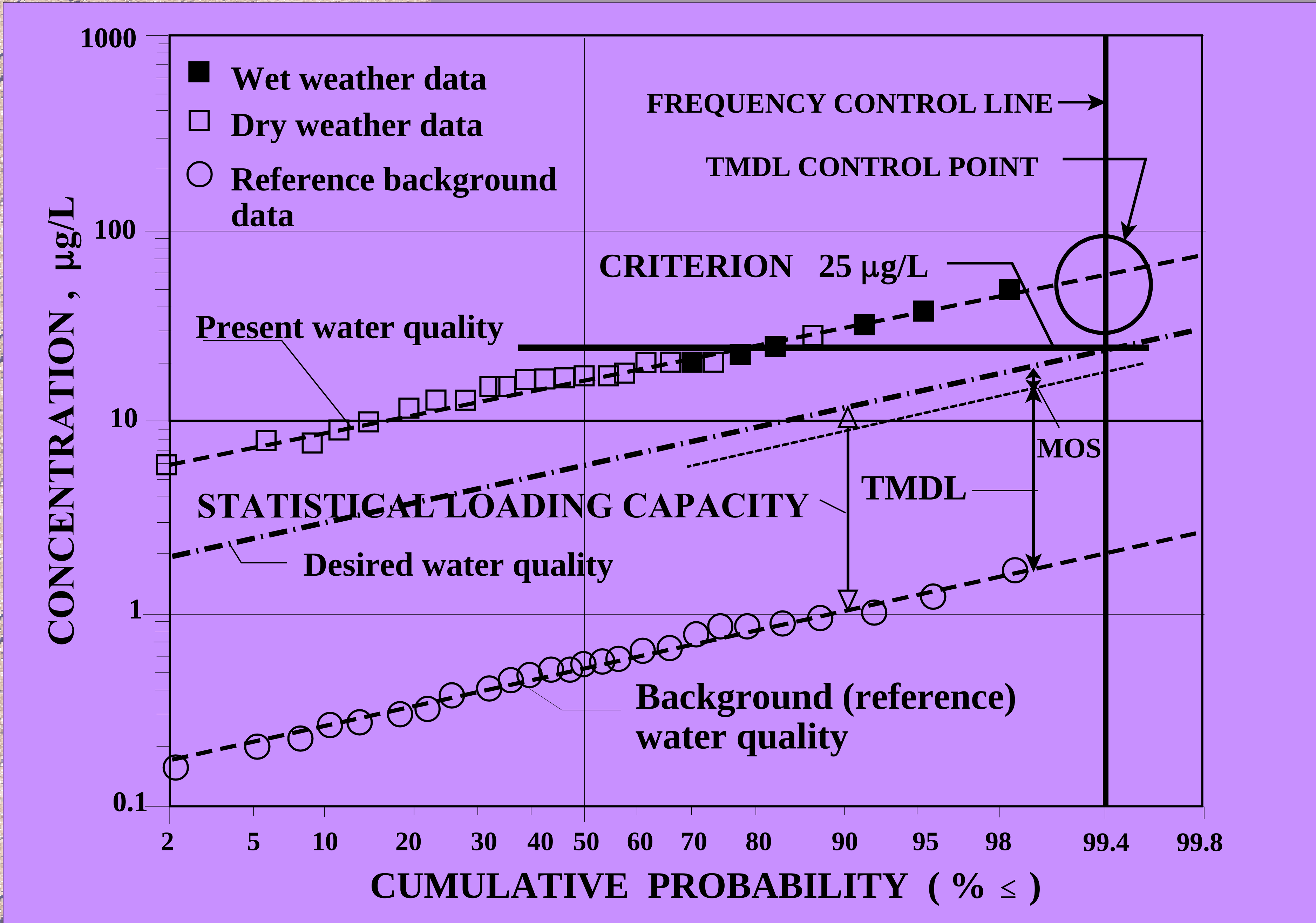
- Tier I - Screening
- Tier II - Monte Carlo Simulation with a model
  - Monte Carlo simulation is a hybrid between purely stochastic (e.g., ARMA) and purely deterministic modeling

Tier I - Probabilistic TMDL

Assumption: Event Mean Concentrations of pollutants are not autocorrelated and follow the arithmetic or log-normal distribution



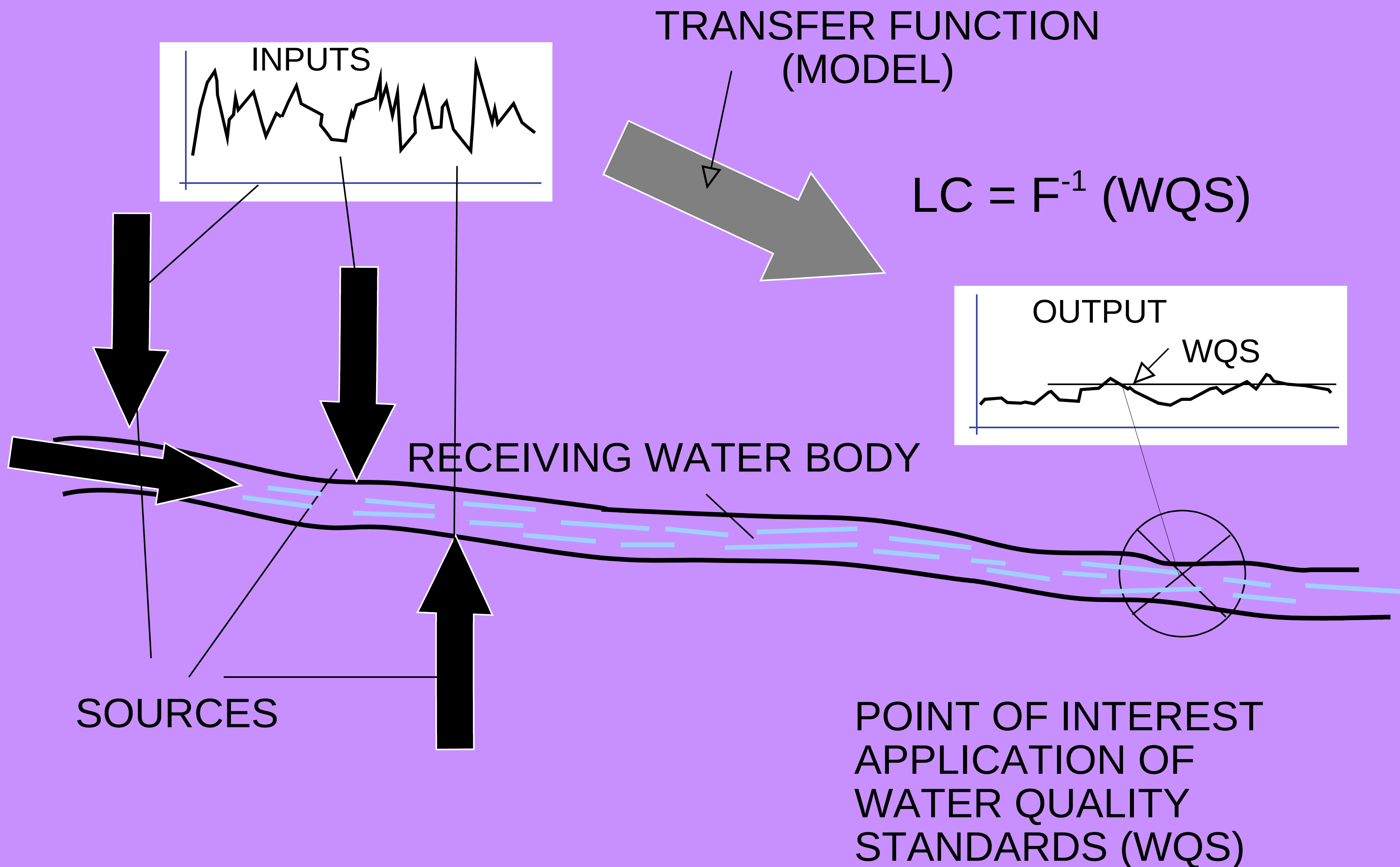
A standard is calulated from hardness for each measurement and a new v variable Z= C/WQS is calculated
The standard is then
ZS= log(1)
To meet the WQS at 99.8% probability of compliance the line of best fit has to be shifted to the left by a distance that corresponds to 15 % reduction.
Hence, TMDL=0.85 original load

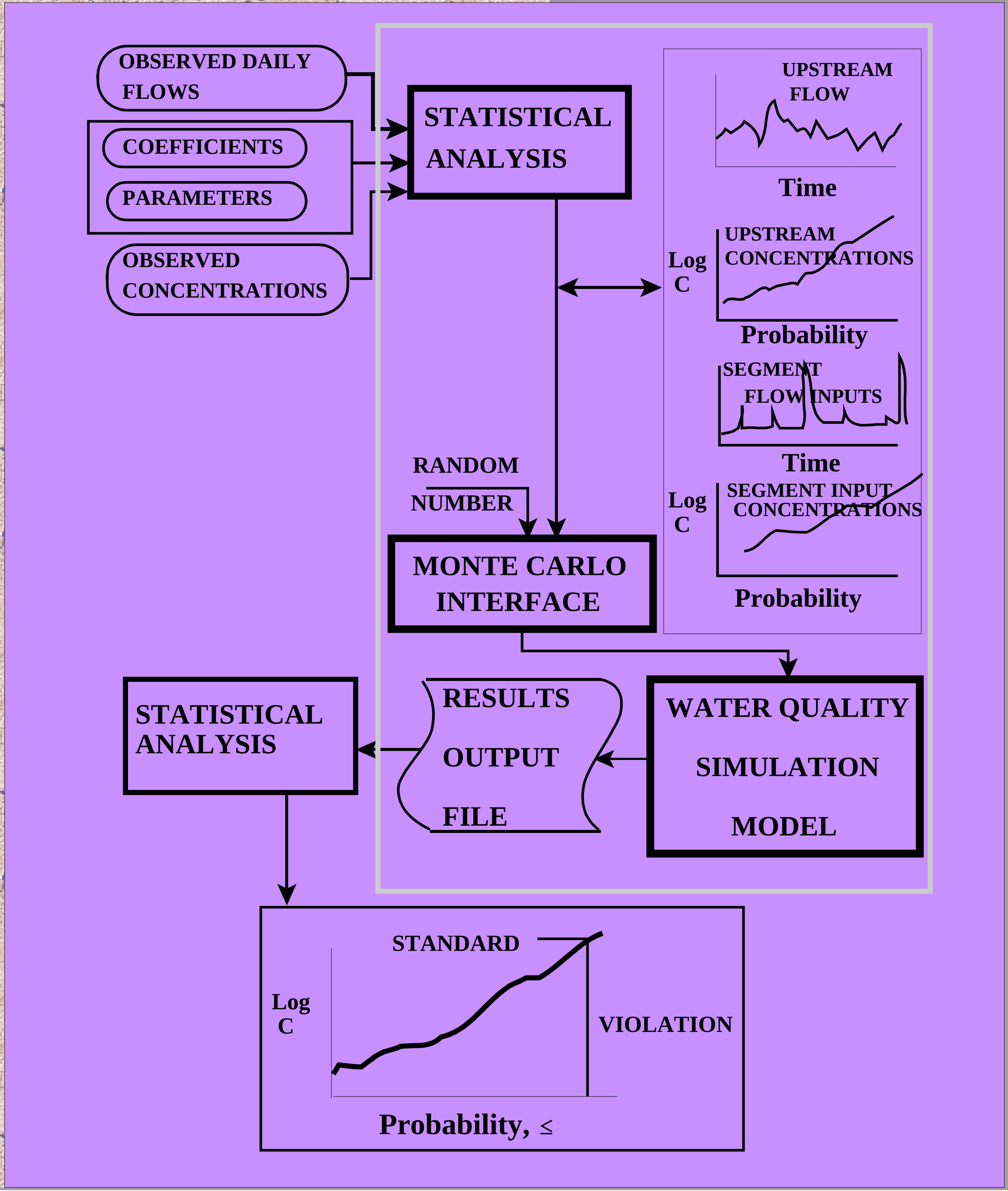

Wet weather data
Dry weather data
Reference background data
FREQUENCY CONTROL LINE
TMDL CONTROL POINT
CRITERION 25 µg/L
Present water quality
MOS
TMDL
STATISTICAL LOADING CAPACITY
Desired water quality
Background (reference) water quality
CONCENTRATION , µg/L
1000
100
10
1
0.1
2
5
10
20
30
40
50
60
70
80
90
95
98
99.4
99.8
CUMULATIVE PROBABILITY (% ≤)

Tier II - Stochastic (MC) Modeling

- MC modeling is not new and has been included in one version of QUAL-2E model
- DYNTOX model is a dilution model that also works on MC principle
- In MC simulation, a model (deterministic or any other acceptable model calculates concentrations. The key parameters of the model as well as all inputs are considered statistical quantities.

POLLUTION LOAD VS. WATER QUALITY RESPONSE - LOADING CAPACITY





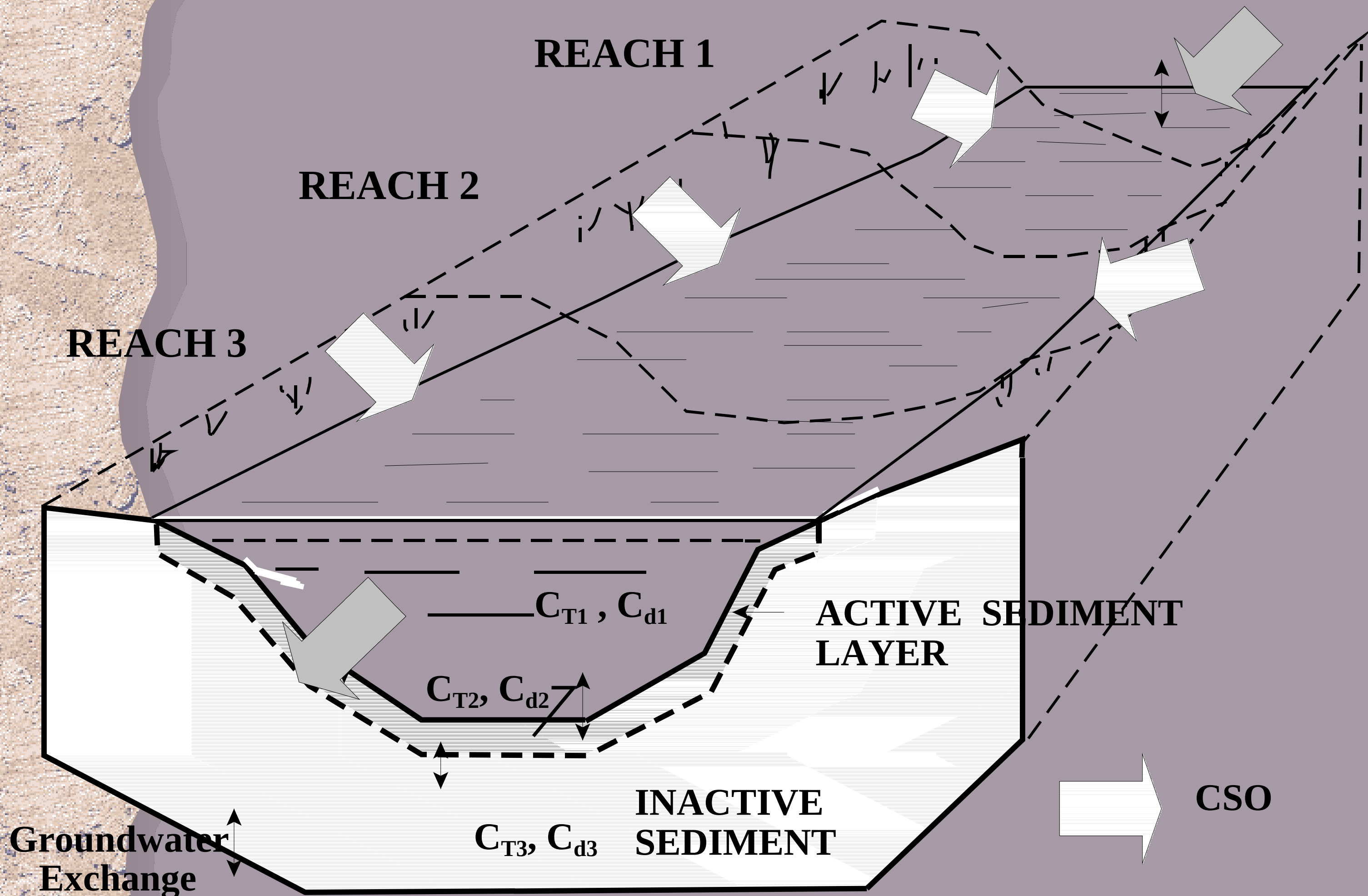
In each simulation (thousands) a random number is generated by the computer with a range from 0 to 1. This number is converted base on the Gaussian probability distribution to a probability multiplier K , so that a value of the parameter is then calculated as

$$X_i = \mu + K\,\sigma$$

where μ is the mean of the parameter and σ is its standard deviation

For log normal distribution μ and σ are calculated from log transformed data

Milwaukee River MC modeling of toxic compounds



Variables

INPUTS STOCHASTIC (MC Generated)

- Upstream concentrations of the pollutant in water column
- Concentrations of the pollutant in CSOs
- Upstream suspended solids concentrations in the water column
- Suspended solids concentrations in CSOs

DETERMINISTIC (MEASURED) INPUTS

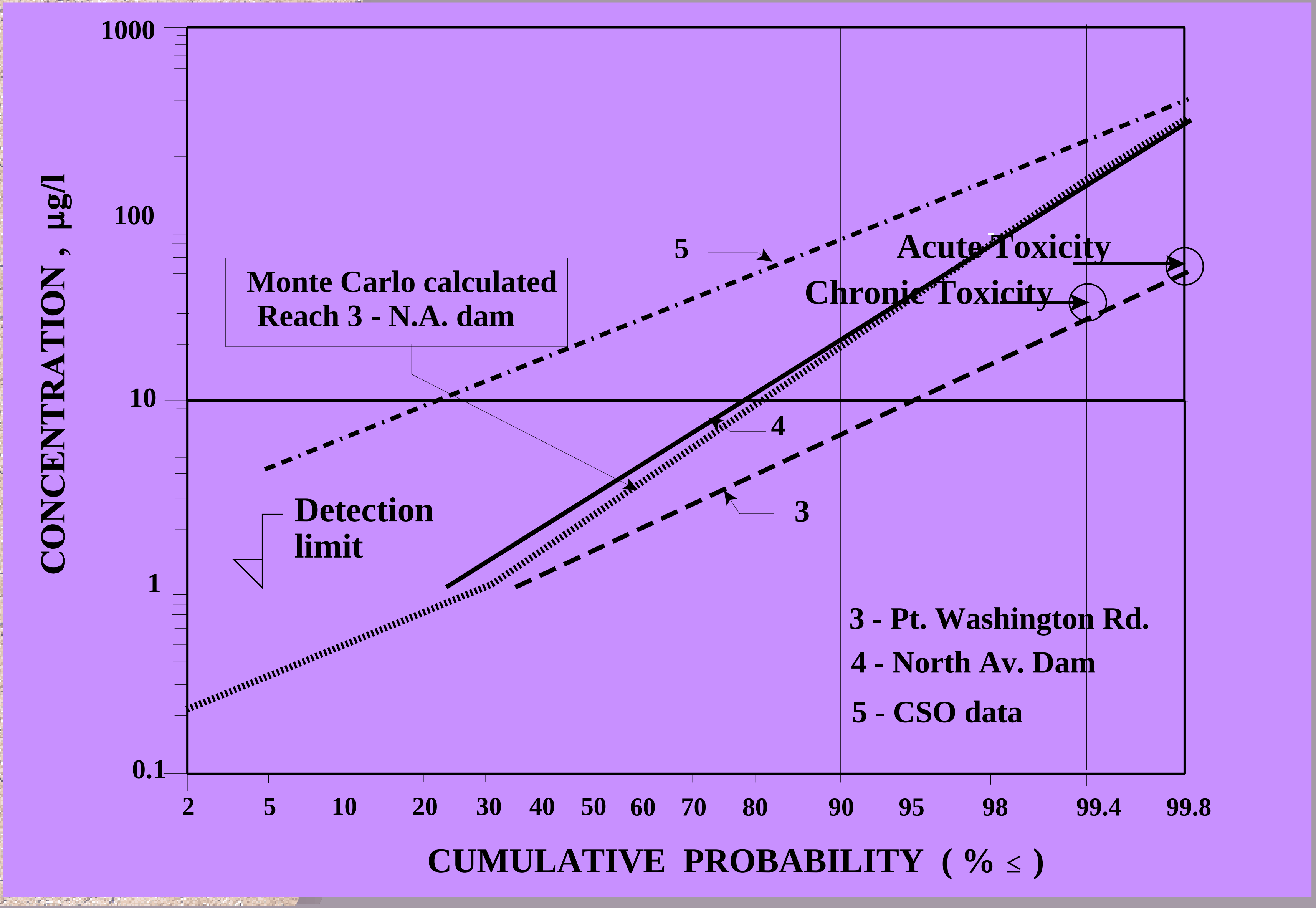
- Time series of upstrem flows
- Time series of precipitation

CSO FLOWS ARE CALCULATED FROM

$$Q_{cso} = r\,(P - \alpha)\,A$$

r = runoff coeffcient
P = precipitation
A= contributing area
α = rainfall subtraction diverted to treatment plant

Results


1000
100
10
1
0.1
CONCENTRATION , µg/l
2
5
10
20
30
40
50
60
70
80
90
95
98
99.4
99.8
CUMULATIVE PROBABILITY (% ≤)
Monte Carlo calculated
Reach 3 - N.A. dam
5
4
3
Acute Toxicity
Chronic Toxicity
Detection
limit
3 - Pt. Washington Rd.
4 - North Av. Dam
5 - CSO data