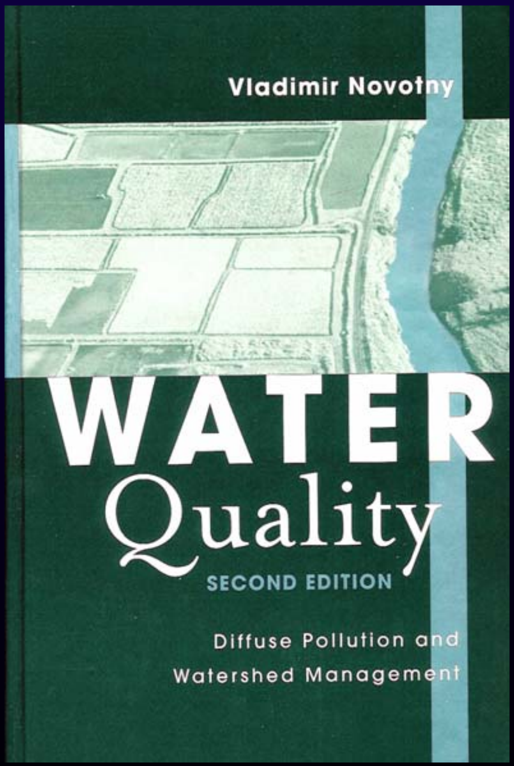
WATER BODY ASSESSMENT CONCEPTS AND DATA NEEDS



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Supplement to Chapter 12

- Water Body Assessment for 305(b) listing
  - 10-20 percent of data may exceed the water quality standard
- WBA for 303(d), TMDL and UAA
  - Strict adherence to water quality standards regulations (e.g., 99.8 percent compliance is required for priority pollutants)
  - Narrative standards should be "translated" to numeric valuer of the parameter and surrogates

STATISTICAL (PROBABILISTIC) NATURE OF TMDL

ALL TMDL COMPONENTS ARE STATISTICAL QUANTITIES AND CANNOT BE EXPRESSED AS A SIMPLE NUMBER

USING SO CALLED CRITICAL LOW FLOW IS ONLY APPROPRIATE FOR SOME BUT NOT ALL POINT SOURCE DISCHARGES

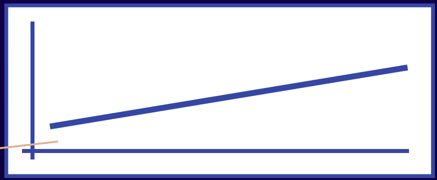
NONPOINT SOURCE LOADS ARE MOSTLY RANDOM INTERMITTENT EVENTS

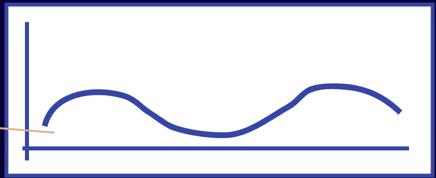
SIMPLE DETERMINISTIC MODELS ARE NOT CAPABLE TO CONSIDER RANDOM VARIABILITY

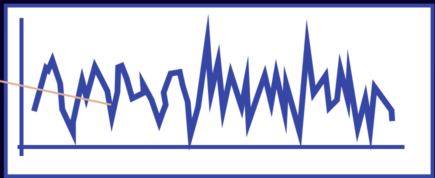
PROBABILISTIC NATURE OF WATER QUALITY

A series of monitored water quality and hydroloogical data is made of:

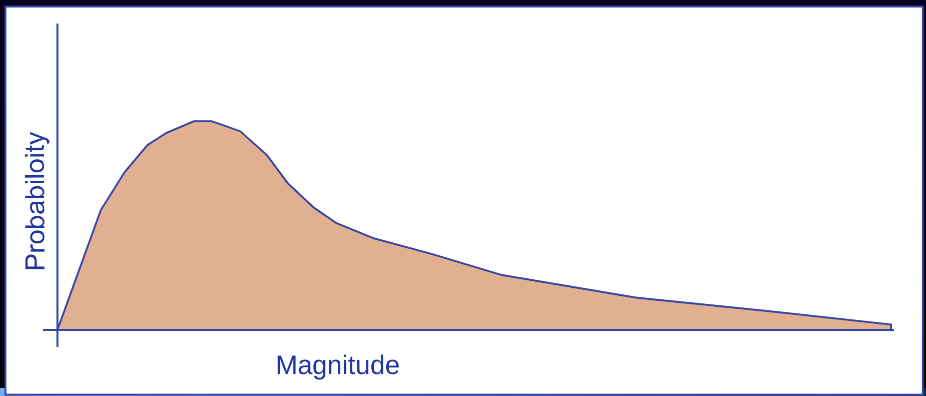
- A trend (that can be stationary)
- Periodicity (seasonality)
- A random component







THESE SERIES FOLLOW A LOG NORMAL OR LOG PEARSONTYPE III PROBABILISTIC DISTRIBUTION



DATA REQUIREMENTS

- For assessment of compliance
  - 3-5 years of data collected at least with monthly frequency
  - Parameters
    - pH, Temperature, DO, Nutrients, priority pollutants
- For development, Calibration and verification of Models
  - Several special surveys (when deterministic models are used)
  - Monitoring data as specified above can be used for development of statistical (stochastic) models

DATA NEEDS

I. Assessment of the physical integrity of the water body that includes habitat conditions, hydraulic and hydrologic conditions, substrate, slope, etc.

II. Assessment of the biological integrity. Biological surveys are needed to identify the composition of the biota living in water (fish, macroinvertebate, zooplankton, phytoplankton, and peryphyton) and in the benthic layer (benthic macroinvertebrate composition).

III. Assessment of chemical integrity. Routine monitoring and survey data are needed on key water quality parameters parameters that are generally divided into physical (e.g, temperature, turbidity or clarity, color, pH), biodegradable organics (BOD, COD, TOC), nutrients (organic and inorganic nitrogen compounds and phosphorus), and organic and inorganic priority pollutants. In some cases, information on radiological parameters is also being collected.

ROTATING BASIN APPROACH used by Florida

Phase I
Preliminary Basin Assessment

YEARS 1-2

Build basin management team
Prepare status report
- Document physical setting
- Preliminary water quality assessment and TMDL
- Inventory existing and proposed conditions
- Identify and prioritize management goals and objectives and issues of concern
- Develop plan of study

↓

Phase II
Strategic Monitoring

YEARS 1-3

Carry out strategic monitoring to collect additional data

↓

Phase III
Data analysis and TMDL Development

YEARS 2-4

Compile and evaluate new data
Finalize list of waters requiring TMDL
Develop TMDL
Identify additional data collection needs
Report new findings

↓

Phase IV
Management Action Plan

YEARS 2-4

Finalize management goals and objectives
Develop draft management action plan
Identify monitoring and management partnerships , needed rule changes, legislative actions and funding opportunities
Obtain participants' commitment to implement plan
Develop monitoring and evaluation plan

↓

Phase V
Implementation

YEAR 5+

Implement management action plan
Secure project funding
Carry out rule development/legislative action
Transfer information to public and other agencies
Conduct environmental education
Monitor and evaluate implementation plan

Use of Geographical Information System.

Geographical Information System (GIS) is a powerful mapping, presentation and analytical software that can be conveniently used for many purposes from which the following are important for diffuse pollution abatement planning and TMDLs:

A Storage and display of pertinent watershed characteristics
B Storage and display of meteorological, hydrological and water quality data
C Mapping of habitat, riparian corridors
D Development of input data for loading and water quality models and display of the model output
E Generation of simple one or two dimensional models for such processes erosion modeling, source modeling and identification.

Field Monitoring

A typical monitoring station has the following component:

1. Rain gauge.
2. Wet and dry atmospheric deposition collector.
3. Flow monitoring device.
4. Quality monitoring device.
5. Power source.
6. Telecommunication link or recorder of data.

SAMPLES AND DATA

- FLOW- daily mean flow
- Continuous- e.g., temperature, DO
- GRAB SAMPLES

$$C = \frac{\Sigma C_i Q_i}{\Sigma Q_i}$$

  - Periodically taken
  - Daily maximum and minimum
  - Random
- COMPOSITE
  - Time averaged
  - Flow averaged
    - Event Mean Concentration

$$C = \frac{\Sigma C_i Q_i}{\Sigma Q_i}$$

WATER QUALITY STANDARDS

Water quality standards regulation in the United States allows States to develop numerical criteria of their own or modify EPA's recommended criteria to account for site specificity or other scientifically defensible factors (US EPA, 1991a, 1994). The criteria may be based on chemical specific numeric values for the priority pollutants or on the whole effluent toxicity (the term effluent applies to point discharges regardless of whether these are of diffuse or traditional point origin). The ambient water quality standards are related to the designated use of the water body

Core Indicators

Fish	**Macroinvertebrates**	**Periphyton**	**Physical Habitat**	**Chemical quality**
• Use at least two assemblages			• Channel morphology • Flow regime • Substrate quality • Riparian condition	• pH • Temperature • Conductivity • Dissolved oxygen

For Specific Designated Uses, add the following:

	Aquatic Life	***Recreation***	***Water Supply***	***Human/Wildlife Consumption***
Base list	• Ionic strength • Nutrients, sediment	• Fecal bacteria • Ionic strength	• Fecal bacteria • Ionic strength • Nutrients, sediment	• Metals (in tissues) • Toxic organics (in tissues)
Supple-mental list	• Metals • Biodegradable organics • Toxics	• Other pathogens • Biodegradable organics	• Metals • Toxic organics • Other pathogens	

Appplication of Standards

Dimension of magnitude - that specifies the numeric magnitude of the standard expressed commonly as the limiting concentration

Dimension of frequency of allowable excursions - that is how often the standard can be exceeded. Typical frequency of allowable excursions may be once in three years.

Dimension of duration - that specifies for how long the standard can be exceeded. The dimension of duration is important for standards that are based on chronic long term exposure. The US standards recognize one day (instantaneous grab sample) duration for all acute toxicity standards, and consecutive four or thirty day average for chronic toxicity standards.

Some water quality standards are site specifric and are a function of other parameters

Toxic metals - function of hardness

Ammonium - function of temperature and pH

Dissolved Oxygen- early life forms present or absent

Define a parameter

$$f = \frac{concentration}{(criterion)}$$

STANDARDS USED

MASSACHUSETTS INCORPORATED FEDERAL AQUATIC LIFE PROTECTION AND CONTACT RECREATION

- Priority pollutants
  - Magnitude, frequency and duration
    - 99.8 percentile for acute toxicity (CMC)
    - 99.4 percentile for chronic toxicity (CCC)
- Non priority (e.g., temperature, DO)
  - Scientific judgement on frequency (probability) and duration
- Bacteria
  - Scientific judgement on frequency and probability based on the formulation of standards

NO NEVER TO BE EXCEEDED

DESIGNATED USES

In Massachusetts three classes are recognized

- CLASS A
  - Best stream segments with great aesthetic values and habitat, also used for drinking water supply
- CLASS B
  - Still suitable for water supply with treatment, good aesthetic quality and provide for secondary recreation
- CLASS C
  - Differ from B by the level of aesthetic quality

Frequency and Duration can be converted to probability

Probability of exceedance

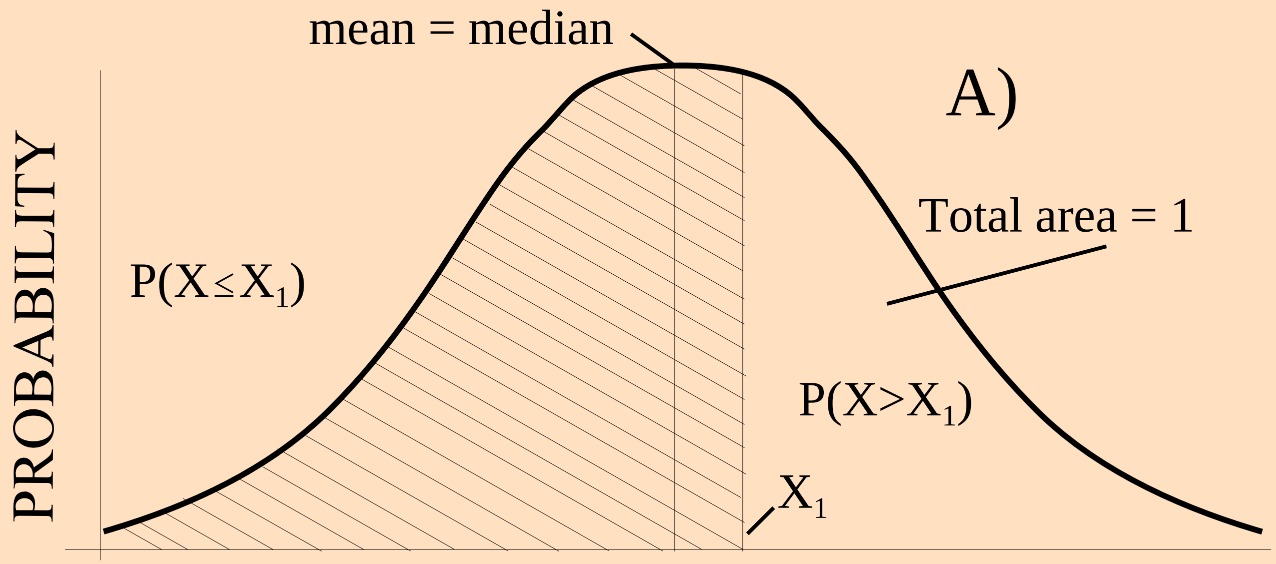
probability = frequencyx duration
e.g., once in three years daily grab exceedance

$p_{exceedence}=1/(3x365)\approx 0.001$

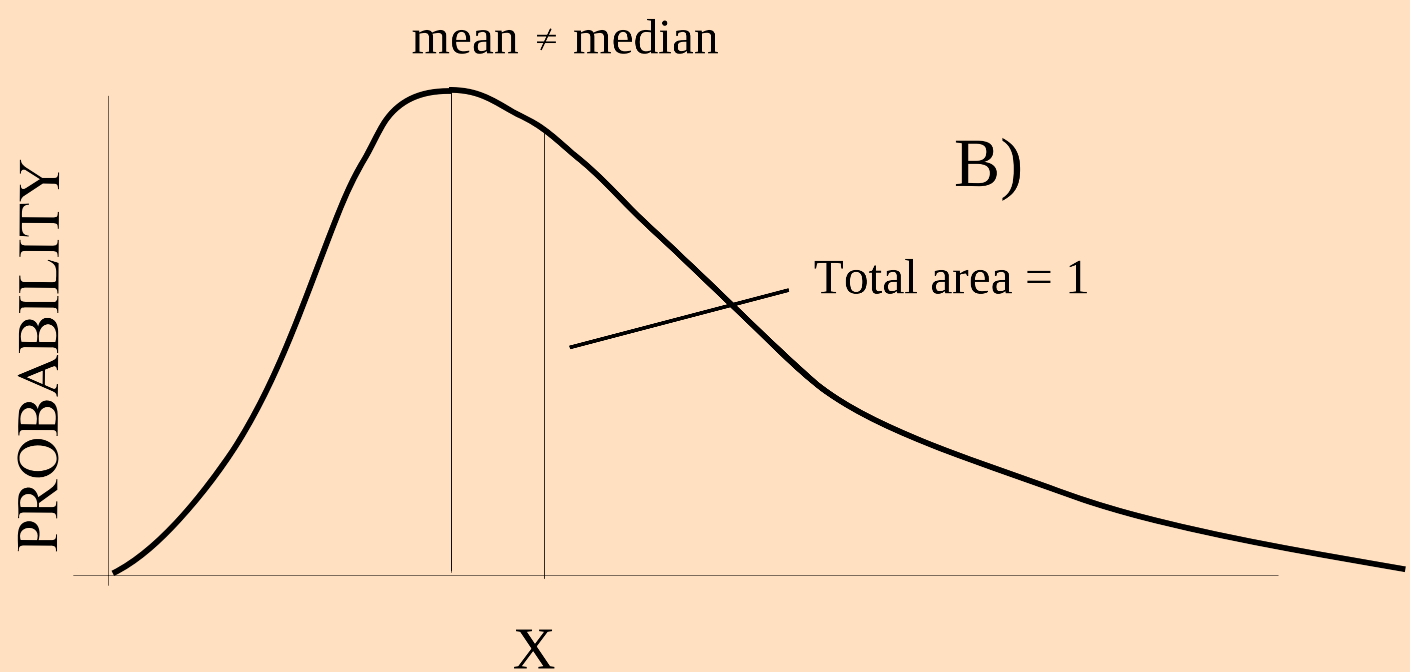
probability of compliance

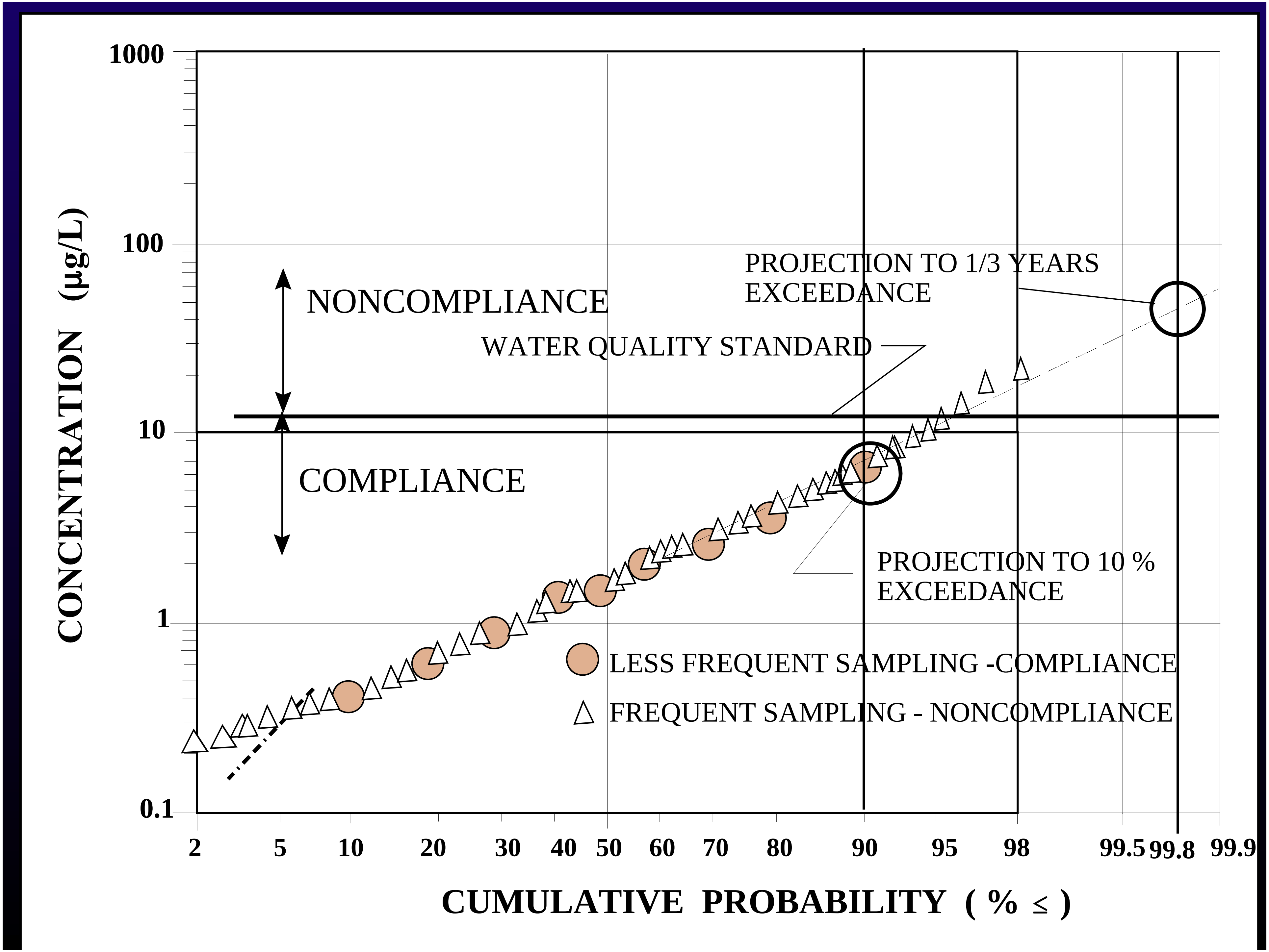
$p_{compliance}= 1 - p_c$

There is numerical magnitude of the standard, C(max), that has to be maintained in the water body with a probability of X of not being exceed.



$$Z = \frac{X - \mu}{\sigma}$$



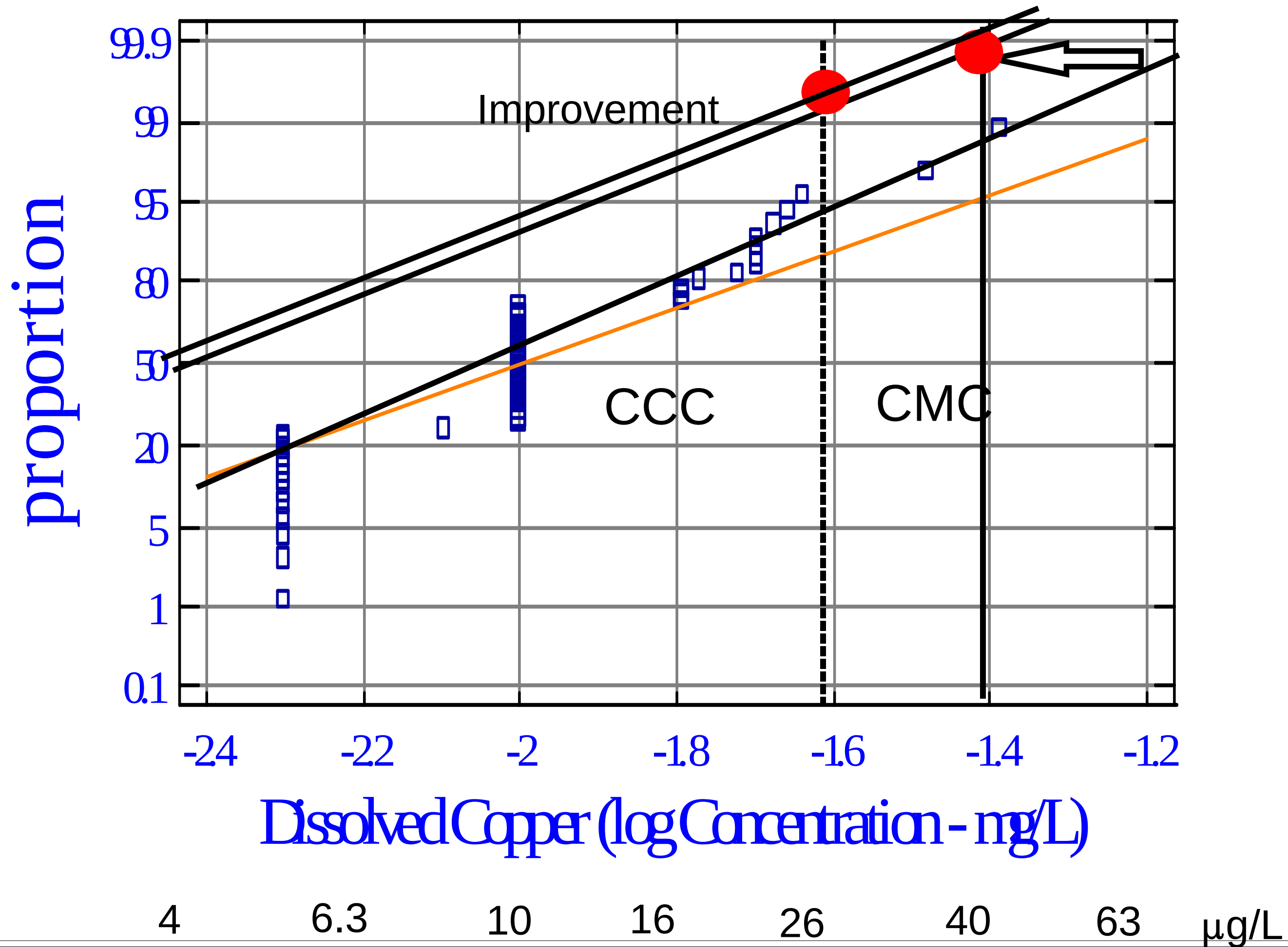


CONCENTRATION (µg/L)
1000
100
10
1
0.1
NONCOMPLIANCE
COMPLIANCE
WATER QUALITY STANDARD
PROJECTION TO 1/3 YEARS EXCEEDANCE
PROJECTION TO 10 % EXCEEDANCE
LESS FREQUENT SAMPLING -COMPLIANCE
FREQUENT SAMPLING - NONCOMPLIANCE
2
5
10
20
30
40
50
60
70
80
90
95
98
99.5
99.8
99.9
CUMULATIVE PROBABILITY (% ≤)

Water Effect Ratio (WER). Because of the complexity of metals (toxic organic compound) there is no chemical analytical method that can accurately determine the metal fraction (toxic organics) that are bioavailable and toxic. For implementing metals and many organic priority pollutants criteria established from laboratory toxicity tests, an adjustment of the criteria value can address this constraint. This involves measuring of a pollutant's water-effect ratio (WER) in the receiving water or effluent covered by the standard. The water-effect ratio compares the toxicity of a pollutant in the actual water site to its toxicity in laboratory water, for two or more aquatic species. Because the metal (toxic organic compound) toxicity in laboratory water is the basis for the national criterion, the water-effect ratio is used as an adjustment to obtain a site-specific value. The WER converts the concentration of a polutant to its toxic fraction then which is then compared with the CMC and CC standard or the standard is modified by WER.

$$CMC_{ss} = CMC \times WER$$

$$CCC_{ss} = CCC \times WER$$



Example of probability plot for copper at MWRD 94 including the Illinois CMC and CCC values corresponding to average hardness

Example 3.2: **Statistics and Probability Distribution of Measured Stormwater Concentrations**

Nine urban runoff events (N = 9) were measured at a storm water outlet location. The event mean concentrations (EMCs) pf lead measured by an automatic sampler are given in column 2 in the Table below. The probability plot of the data is presented on Figure 3.6 . Calculate the arithmetic and logarithmic mean and plot the data on the log-probability chart.

Date of sampling	X [EMC mg Pb/L]	log X	Order of Magnitude (M)	Plotting Position (%) p = 100 M/(N-1)	
3/5/2001	1.41	0.1492	6	60	
4/15/2001	2.24	0.3502	8	80	
5/2/2001	1.10	0.0414	4	40	
5/25/2001	0.90	-0.0458	3	30	
6/14/2001	1.27	0.1038	5	50	Median
7/12/2001	1.72	0.2355	7	70	
7/20/2001	3.20	0.5051	9	90	
9/17/2001	0.50	-0.3010	1	10	
10/4/2001	0.74	-0.1303	2	29	

$\sum X$ -= 13.08 $\sum \log X = 0.9081$

Arithmetic mean $\mu_A = \Sigma X/N = 13.8/9 = 1.53$ mg/L

Logarithmic mean $\mu_L = \Sigma(\log X)/N = 0.9081/9 = 0.1009$

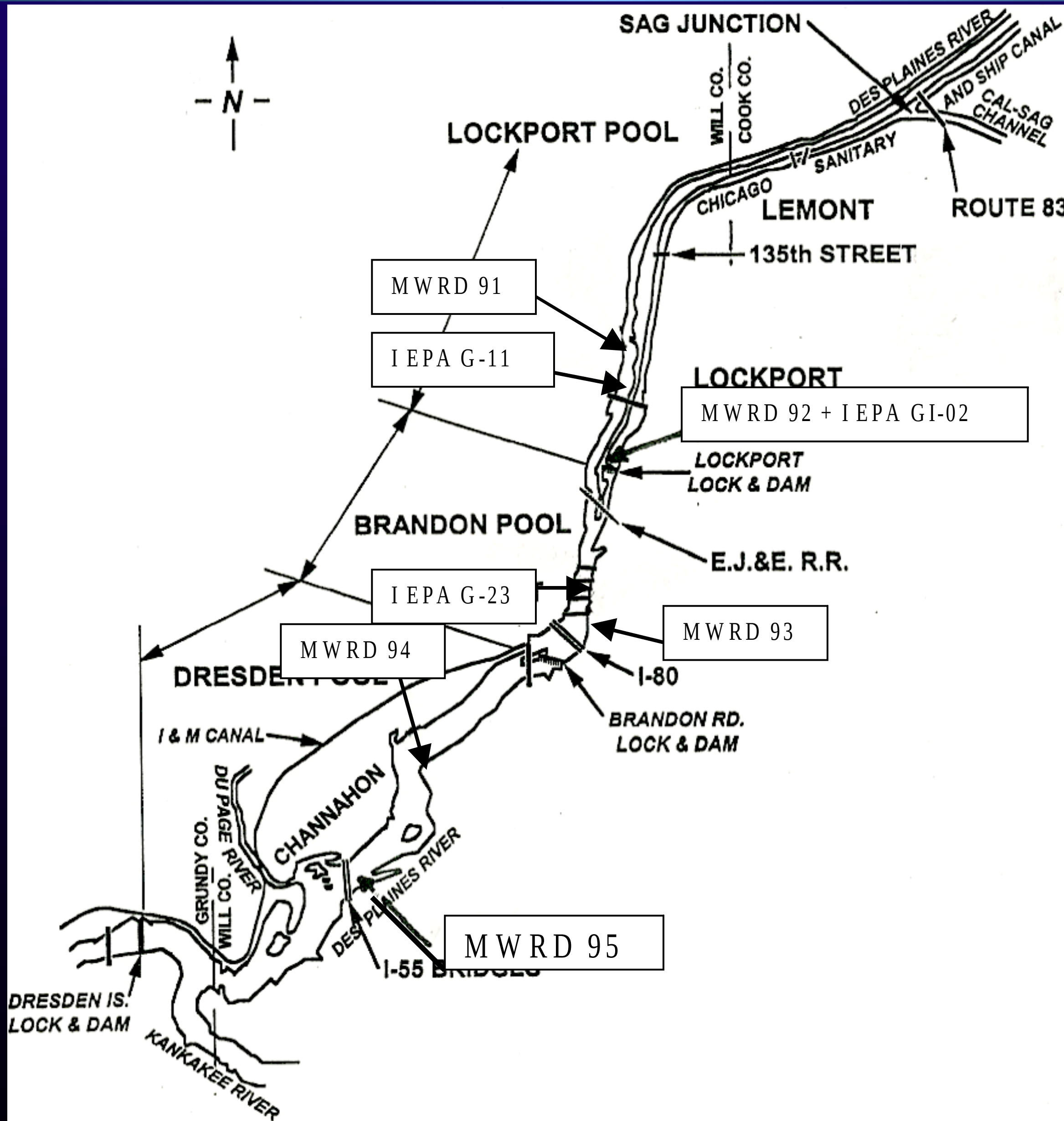
Note that the arithmetic mean, μ_A = 1.53 mg/L, does not equal $= 10^{0.1009} = 1.26$, because the data that would fit log-normal distribution are skewed on the arithmetic scale. Only for logarithmically transformed valued the mean would approximately equal its median(50%) value.

NURP Data on Urban Runoff - log Normal Distribution

Table 3.2 Overall Water Quality Characteristics of Urban Runoff from U.S. NURP sites.

Constituent	Mean EMC: Median Urban Site	Mean EMC: 90 Percentile Urban Site
TSS (mg/l)	141 - 234	424 - 671
BOD_5 (mg/l)	10 - 13	17 - 21
COD (mg/l)	73 - 92	157 - 198
Tot. Phosphorus (mg/l)	0.37 - 0.47	0.78 - 0.99
Sol. Phosphorus (mg/l)	0.13 - 0.17	0.23 - 0.30
TKN (mg/l)	1.68 - 2.12	3.69 - 4.67
NO_{2+3}-N (mg/l)	0.76 - 0.96	1.96 - 2.47
Total Cu (µg/l)	38 - 48	104 - 132
Total Pb* (µg/l)	161 - 204	391 - 495
Total Zn (µg/l)	179 - 226	559 - 707

* reflects partial control (ban) on leaded gasoline



N
SAG JUNCTION
DES PLAINES RIVER
AND SHIP CANAL
CAL-SAG CHANNEL
WILL CO.
COOK CO.
LOCKPORT POOL
SANITARY
CHICAGO
LEMONT
ROUTE 83
135th STREET
MWRD 91
IEPA G-11
LOCKPORT
MWRD 92 + IEPA GI-02
LOCKPORT LOCK & DAM
BRANDON POOL
E.J.&E. R.R.
IEPA G-23
MWRD 93
MWRD 94
I-80
DRESDEN POOL
BRANDON RD. LOCK & DAM
I & M CANAL
CHANNAHON
DU PAGE RIVER
GRUNDY CO.
WILL CO.
DES PLAINES RIVER
MWRD 95
I-55 BRIDGES
DRESDEN IS. LOCK & DAM
KANKAKEE RIVER

Compliance probability for copper
Total Cu concentrations

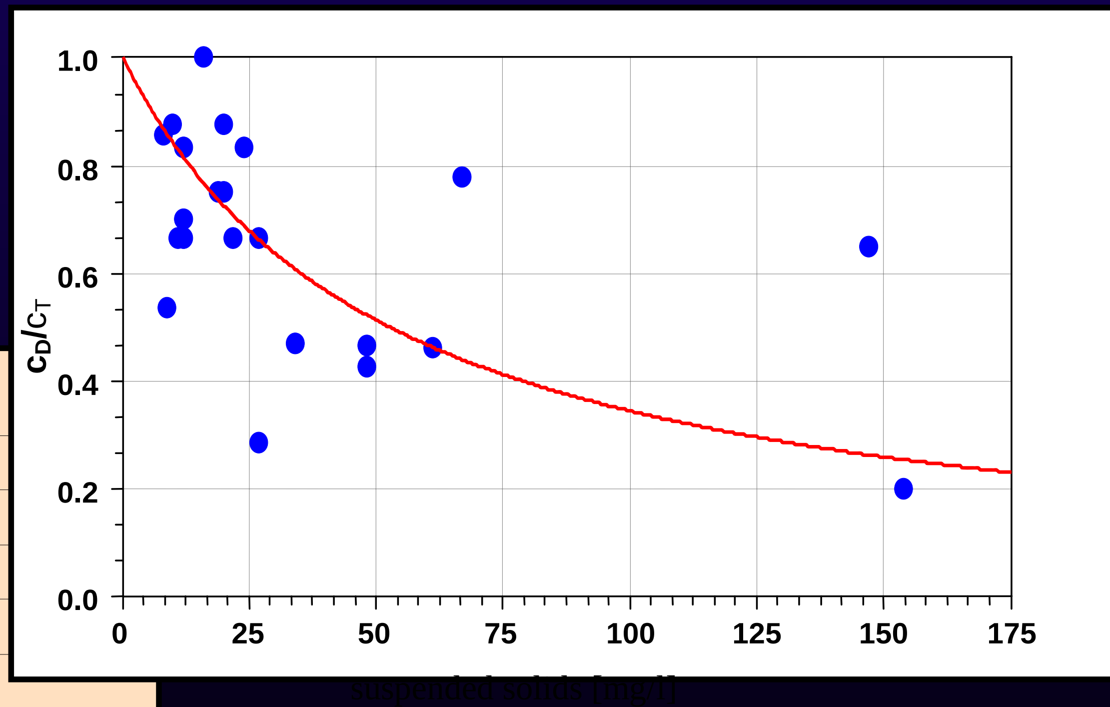
(Dissolved concentrations of IEPA site in Joliet was in compliance)

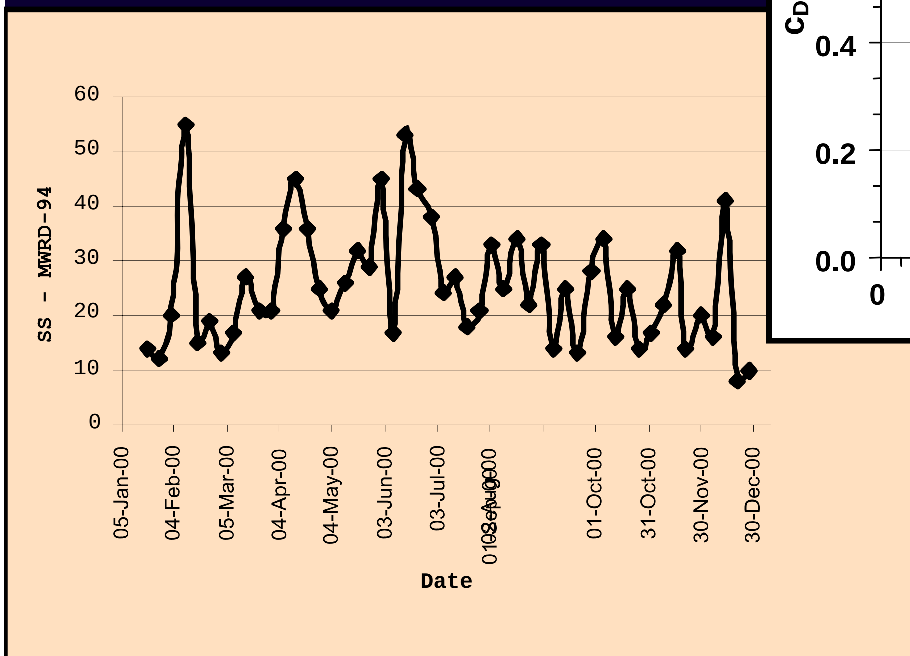
	CMC	CCC
MWRDGC 92 (Lockport)	99 %	95%
MWRD GC 93 (Joliet)	>99.8%	99.2%
MWRDGC 94(Upper Dresden Island Pool)	95	85%
MWRDGC 95 (Lower Dresden Island Pool, I55)	>99.8%	99%

The MWRDC 92 location is outside of the investigated reach

Estimation of dissolved fraction of copper by metal - sediment partitioning

$$\frac{c_D}{c_T} = \frac{1}{1 + \Pi_{SS}\, c_{SS}}$$





Sediment concentrations

BIOLOGICAL MONITORING

Fish - Index of Biotic Integrity

Macroinvertebrates

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes (1989) Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/444/4-89-001. United States Environmental Protection, Washington, DC.

Index of Biotic Integrity (Karr 1981)

12 Metrics

- Species richness
- #Darter species
- #Sunfish species
- #Sucker species
- %Intolerant species
- %Green sunfish
- %Omnivores
- %Insectivores
- %Top Carnivores
- %Hybrids
- %Diseased individuals
- Number of Fish

Community Composition

Environmental Tolerance

Community Function

Community Condition

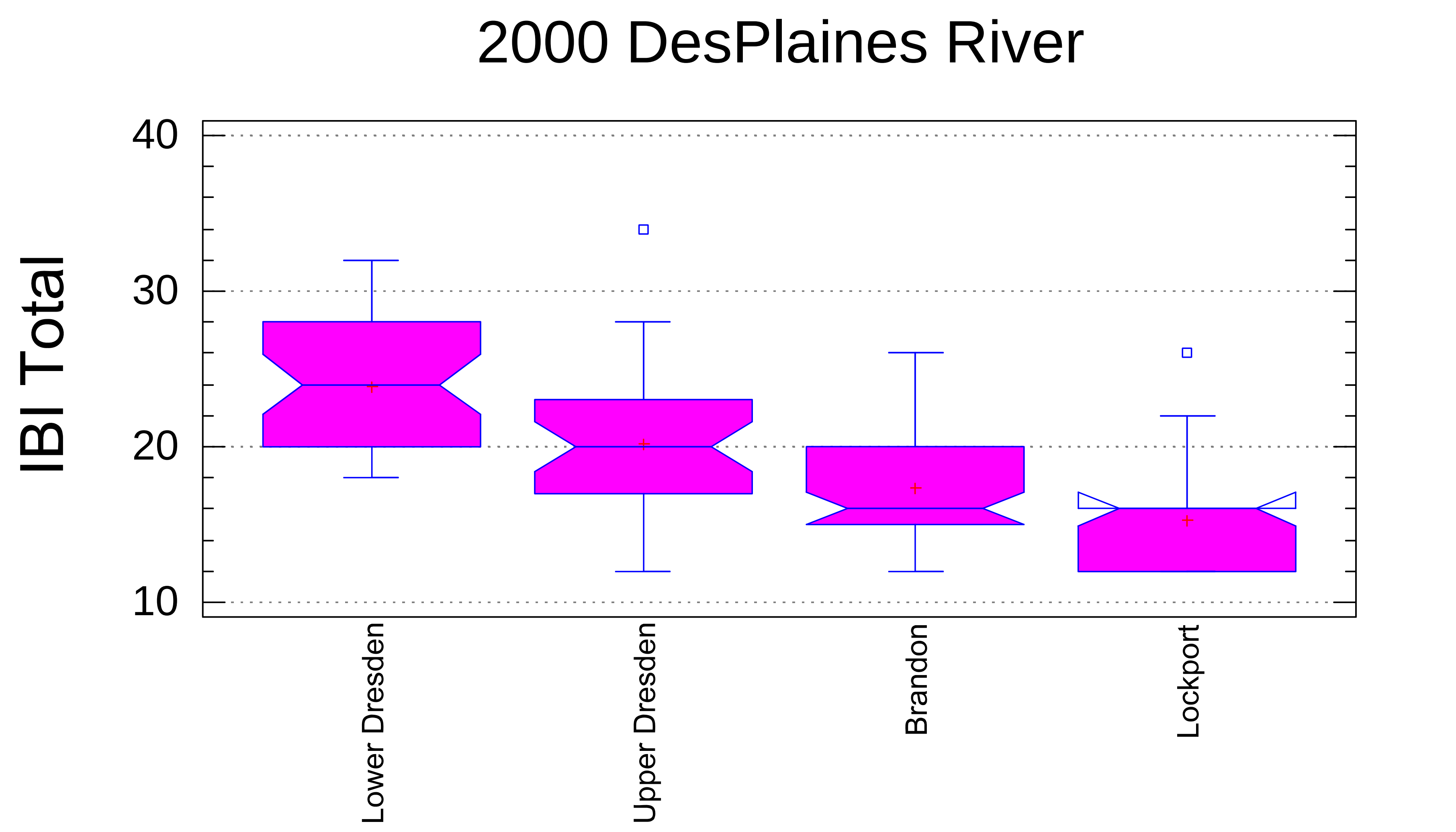
- 5,3,1 metric scoring categories.
- 12 to 60 scoring range.
- Calibrated on a regional basis.
- Scoring adjust-ments needed for very low numbers.

Basic Premise of IBI Type Measures

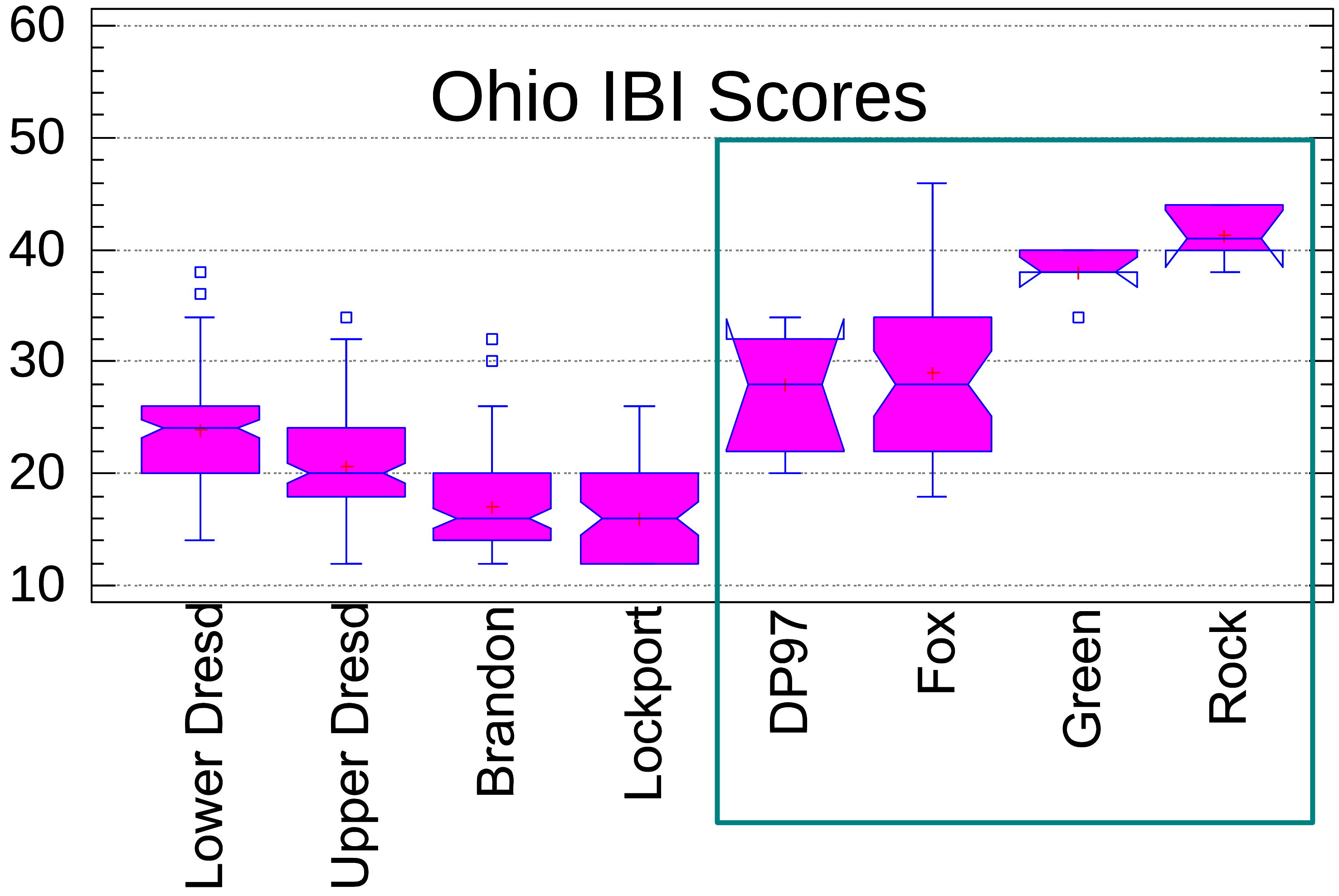
- Least impacted biological systems have distinctive structural and functional attributes.
- Some attributes can be measured in the field and aggregated into metrics.
- Departure of metrics from a reference condition is correlated with the degree (severity) of a perturbation.
- Synthesis of multiple, representative metrics reflects the overall integrity of the community.

Fish IBI for Des Plaines River

All 2000 Sample Dates Pooled by Reach



Des Plaines River IBI compared with Selected Illinois Rivers



REFERENCE SITES

Ecoregions

- The measured IBIs are often normalized by the IBIs measured at unimpacted water bodies of the same morphologic character located in the same ecoregion
- Such water bodies may not be available. Furthermore, impounded streams (such as the Illinois Waterway) can not be compared with wadeable small headwater streams that commonly serve as reference streams.

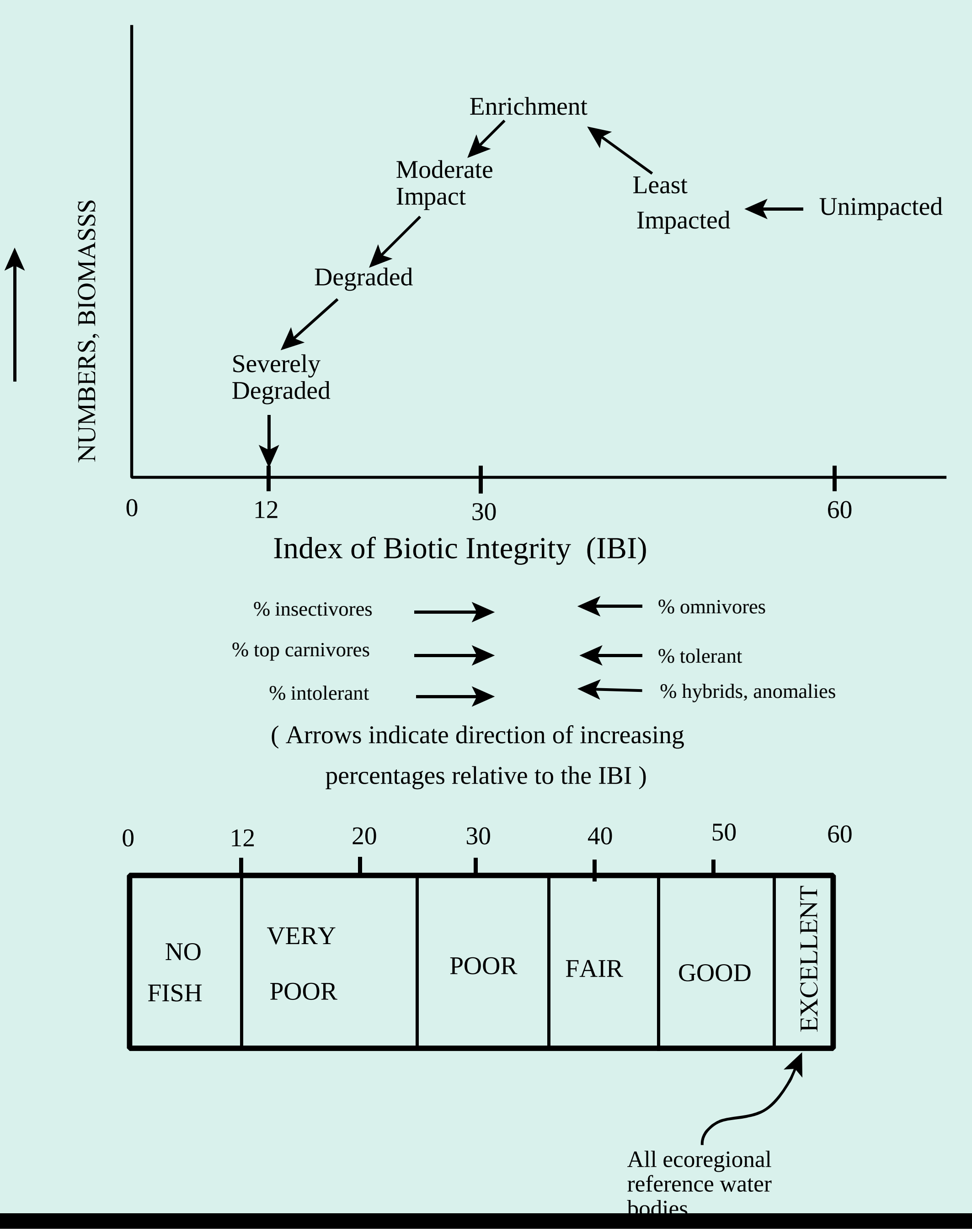
Establishing Reference Condition

Reference Sites

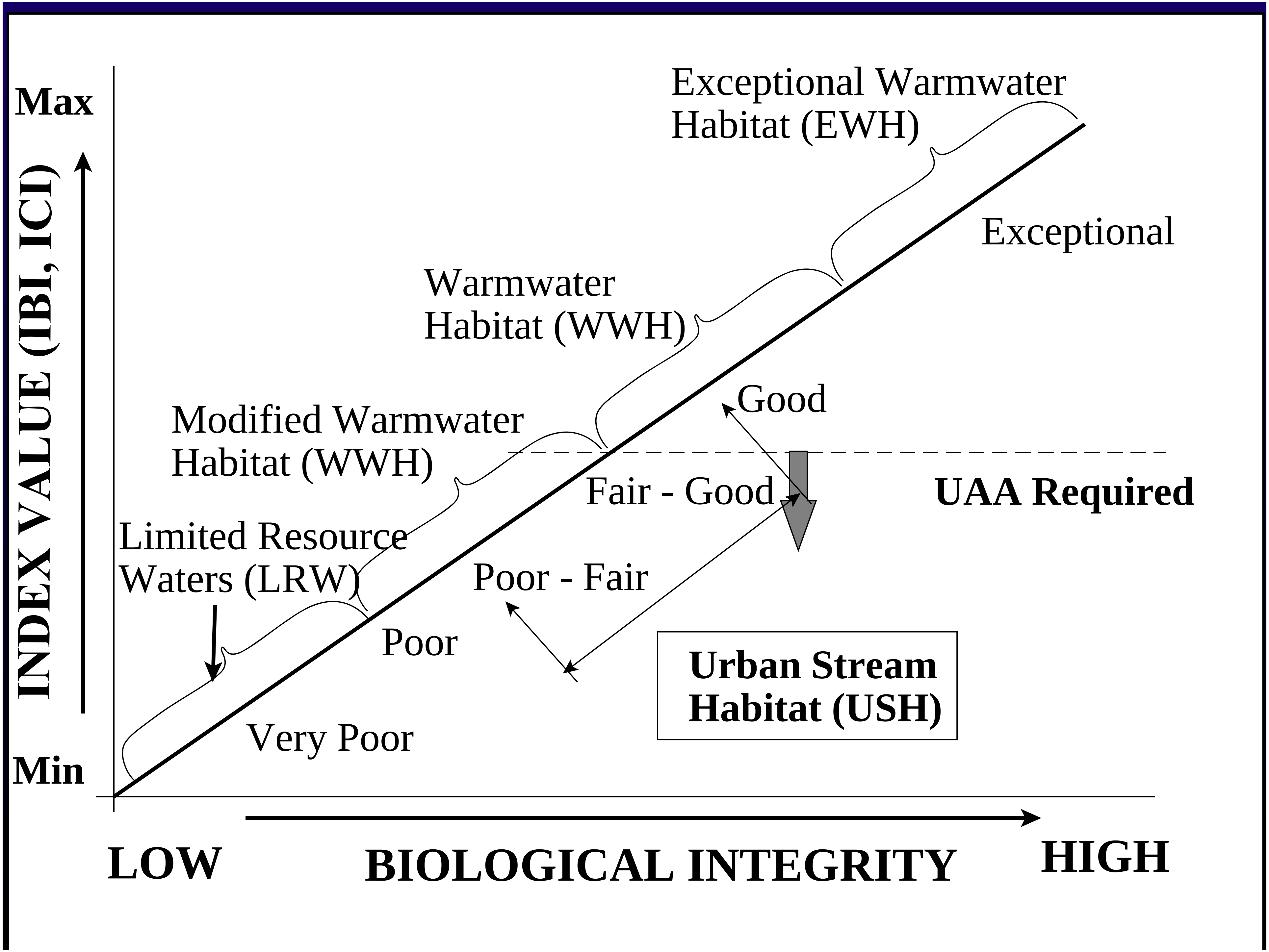
- A collection of sites within a **homogenous regional area** which represent the best attainable conditions (unimpaired) for all waters *with similar physical dimensions and attributes* for that particular region.

Control Sites

- A single site usually located on or adjacent to the waterbody under study which represents the *best or most appropriate condition for that waterbody* whether it is impaired or unimpaired.



NUMBERS, BIOMASSS
Enrichment
Moderate Impact
Degraded
Severely Degraded
Least Impacted
Unimpacted
0
12
30
60
Index of Biotic Integrity (IBI)
% insectivores
% top carnivores
% intolerant
% omnivores
% tolerant
% hybrids, anomalies
(Arrows indicate direction of increasing percentages relative to the IBI)
0
12
20
30
40
50
60
NO FISH
VERY POOR
POOR
FAIR
GOOD
EXCELLENT
All ecoregional reference water bodies


Max
Min
INDEX VALUE (IBI, ICI)
Exceptional Warmwater
Habitat (EWH)
Exceptional
Warmwater
Habitat (WWH)
Good
Modified Warmwater
Habitat (WWH)
Fair - Good
UAA Required
Limited Resource
Waters (LRW)
Poor - Fair
Poor
Urban Stream
Habitat (USH)
Very Poor
LOW
BIOLOGICAL INTEGRITY
HIGH

BIOTIC INDICEC CAN:

- ☐ Detect impairment of integrity
- ☐ Identify the problem
  - Physical impairment (impoundments, channelization, siltation)
  - Chemical long term effects
  - Invasion of foreign species
- ☐ Important for 305(b) and 303(d) listing
  - If IBIs consistently indicate no impairment the water bodt should not be listed a TMDL should not be performed

BIOTIC INDICES ALONE CANNOT:

- ☐ Lead to a load or waste load allocation
- ☐ Currently difficult for TMDLs

ADDRESSING THE DO

Developing a subuse designation

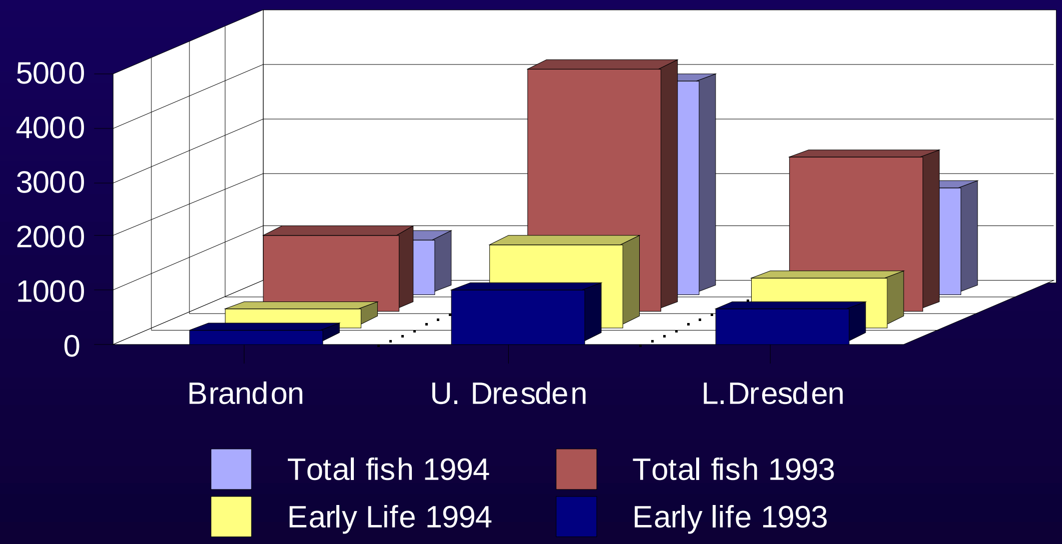
Water quality standards for dissolved oxygen

Standard or criterion	Illinois general use*	Secondary contact and indigenous aquatic life*	Federal warm water criteria**
Dissolved Oxygen mg/L All minima should be considered as instantaneous minima to be achieved at all times	Dissolved oxygen shall not be less than 6.0 mg/L at least 16 hours at any 24 hour period, nor less than 5.0 mg/L at any time	Dissolved oxygen shall not be less than 4.0 mg/L at any time.	Early life stages present: Lowest 7 day mean 6.0 mg/L 1 day minimum 5.0 mg/L Other life stages 30 day mean 5.5 mg/L 7 day minimum 4.0 mg/L 1 day minimum 3.0 mg/L

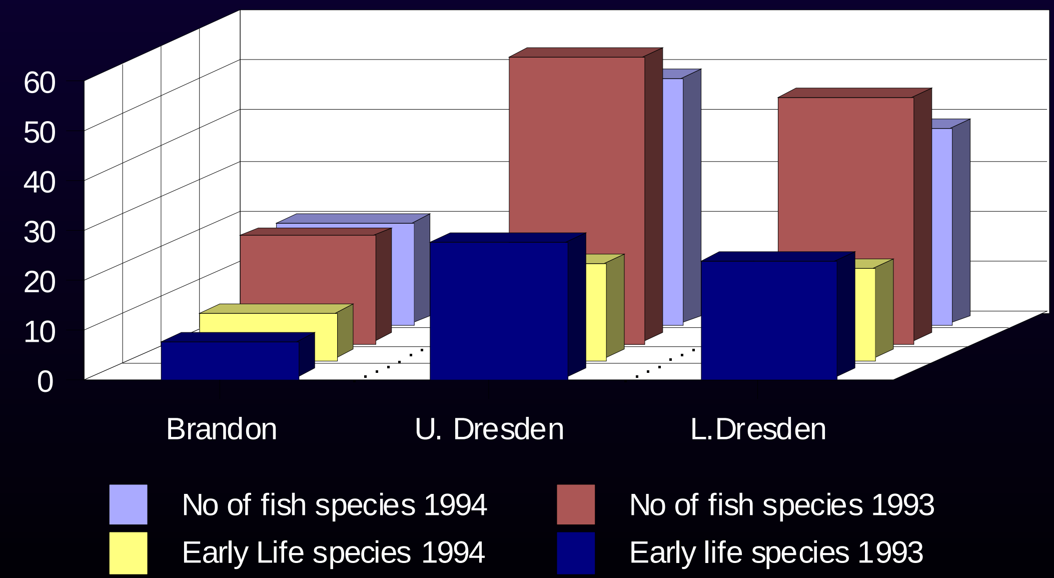
* Illinois Water Pollution Board, Section 35

** US EPA (1986)

Total Fish and Early Life



Number of Fish and Early Life Species

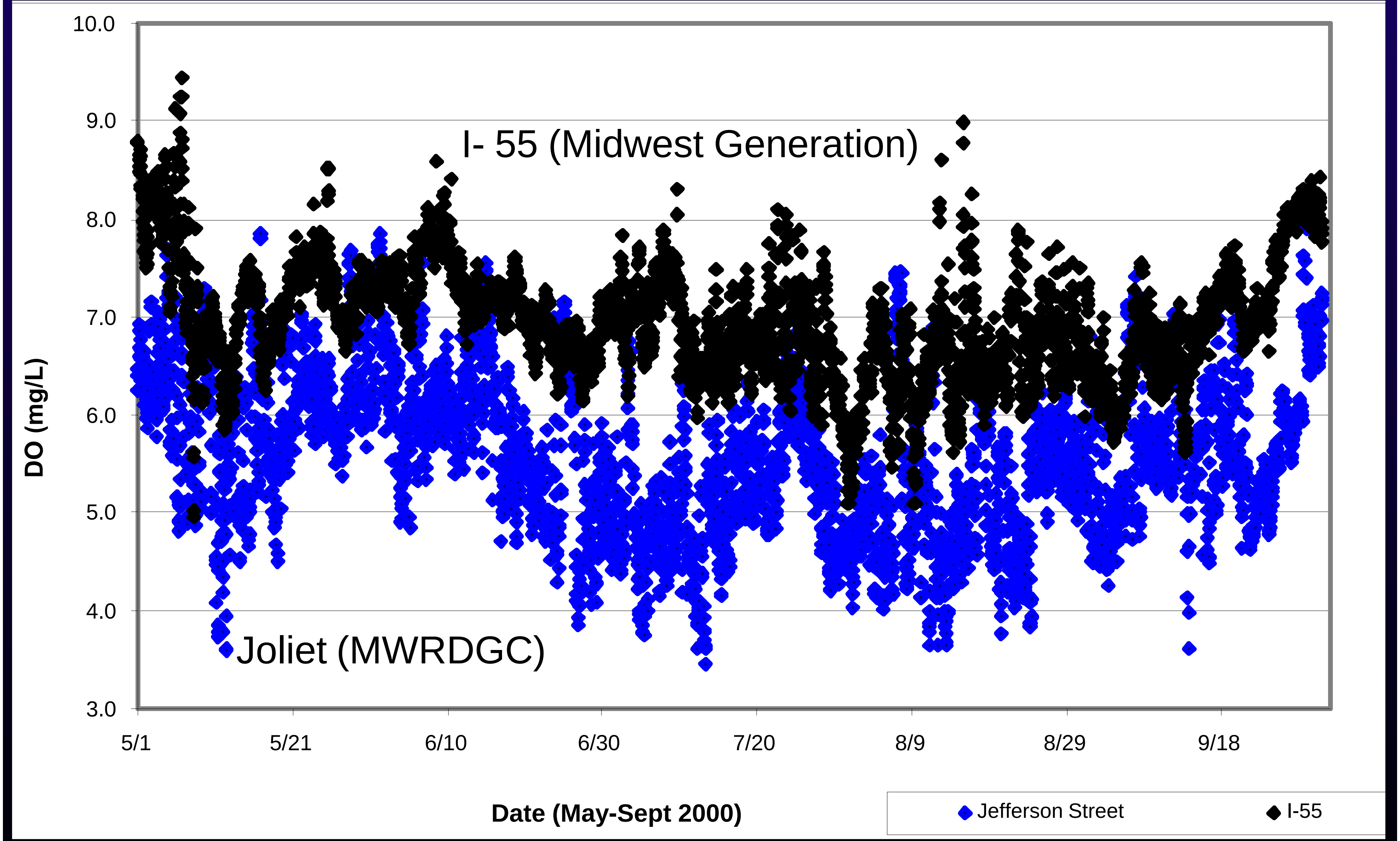


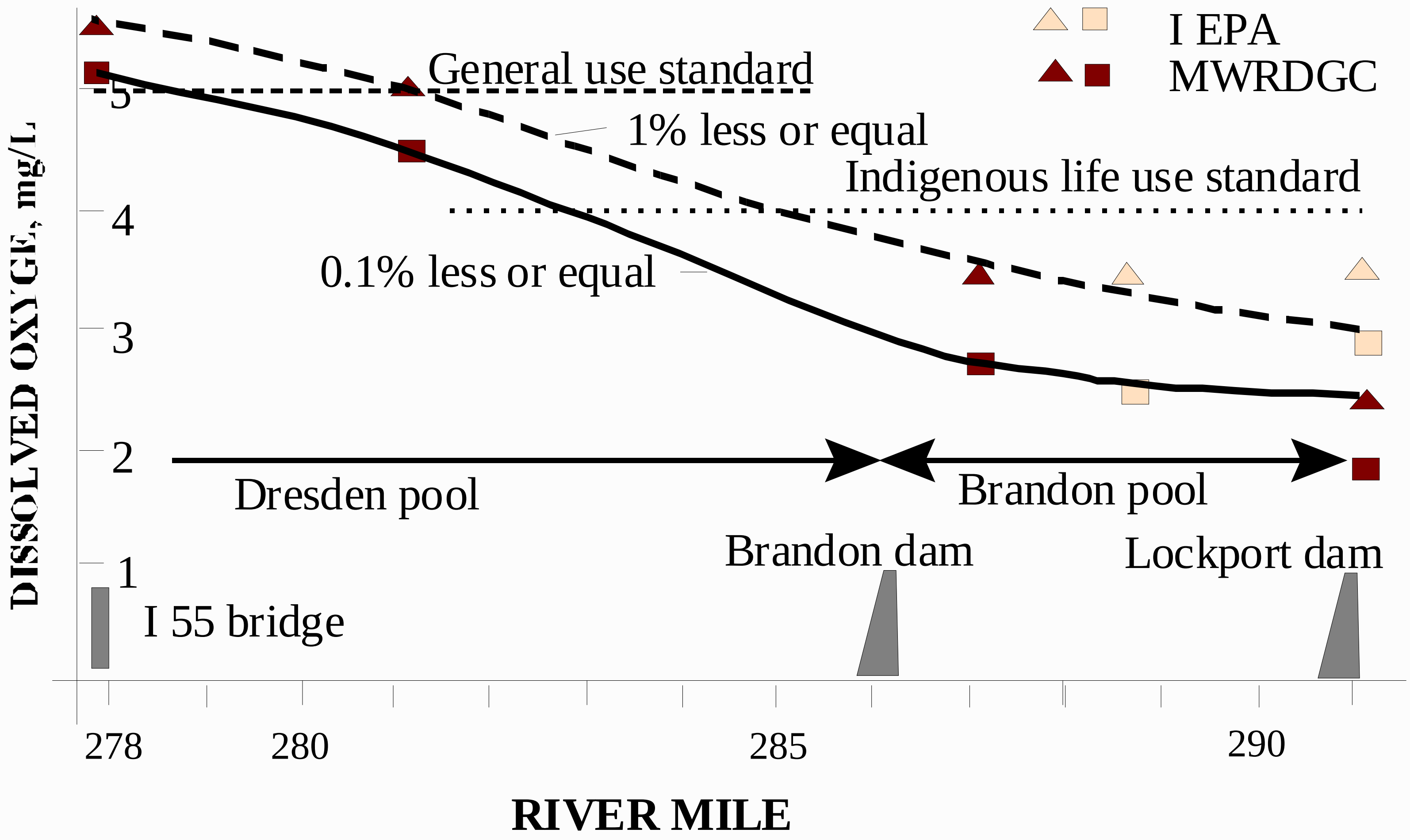
Data Courtesy Midwest Generation , EME, LLC

Brandon Pool does not appear suitable for early life forms. Early life forms exist in the pool but may be passing through from the upstream free flowing Des Plaines River that has very good habitat conditions.

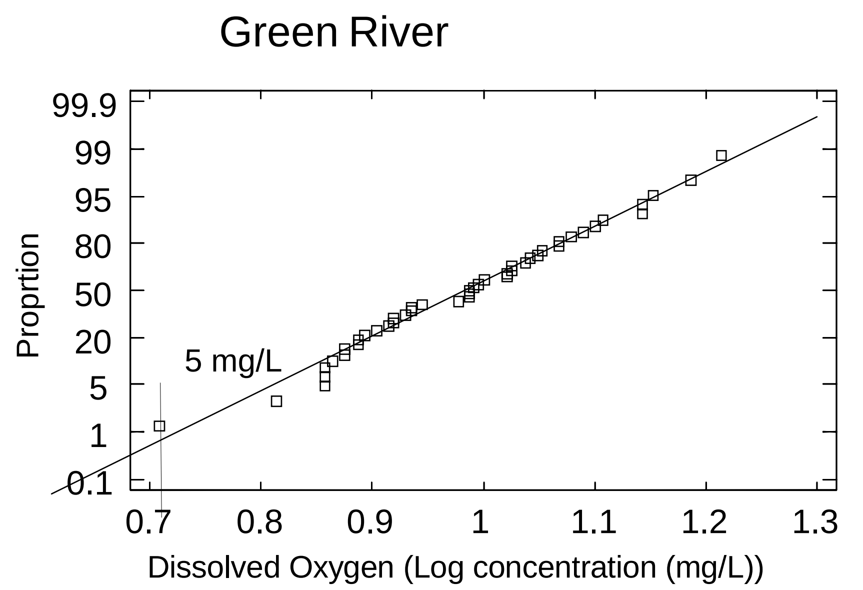
Physical Integrity Index (both Ohio and US EPA) indicate poor habitat condition in the Brandon Pool

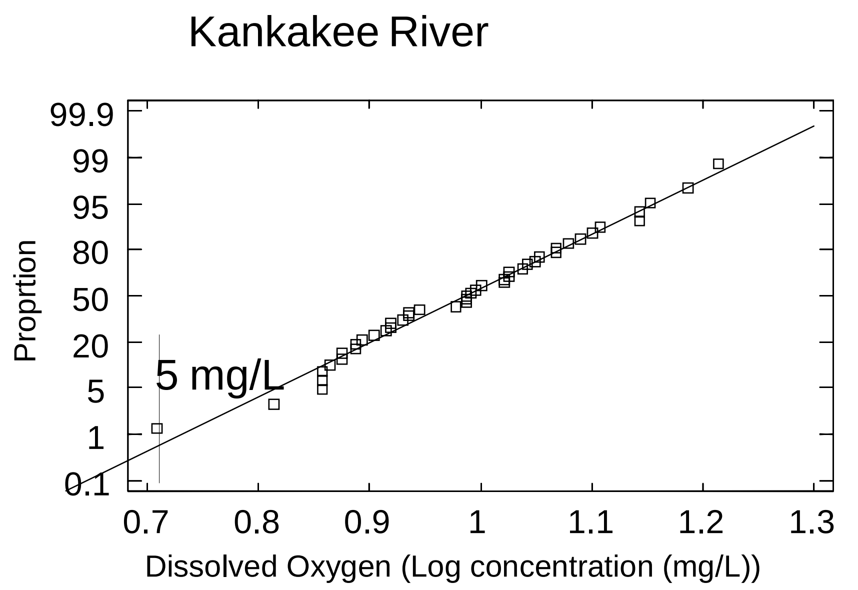
Comparison of I55 and Brandon Pool (Joliet) DO measurements





I EPA
MWRDGC
General use standard
1% less or equal
Indigenous life use standard
0.1% less or equal
Dresden pool
Brandon pool
Brandon dam
Lockport dam
I 55 bridge
DISSOLVED OXYGEN, mg/L
1
2
3
4
5
278
280
285
290
RIVER MILE





REFERENCE STREAMS

In these reference streams the natural DO that would have a probability of 99.8 % being greater or equal (0.1 % of being less) is 4.5 mg/L

These streams are not impounded, if they were the DO could be even smaller.