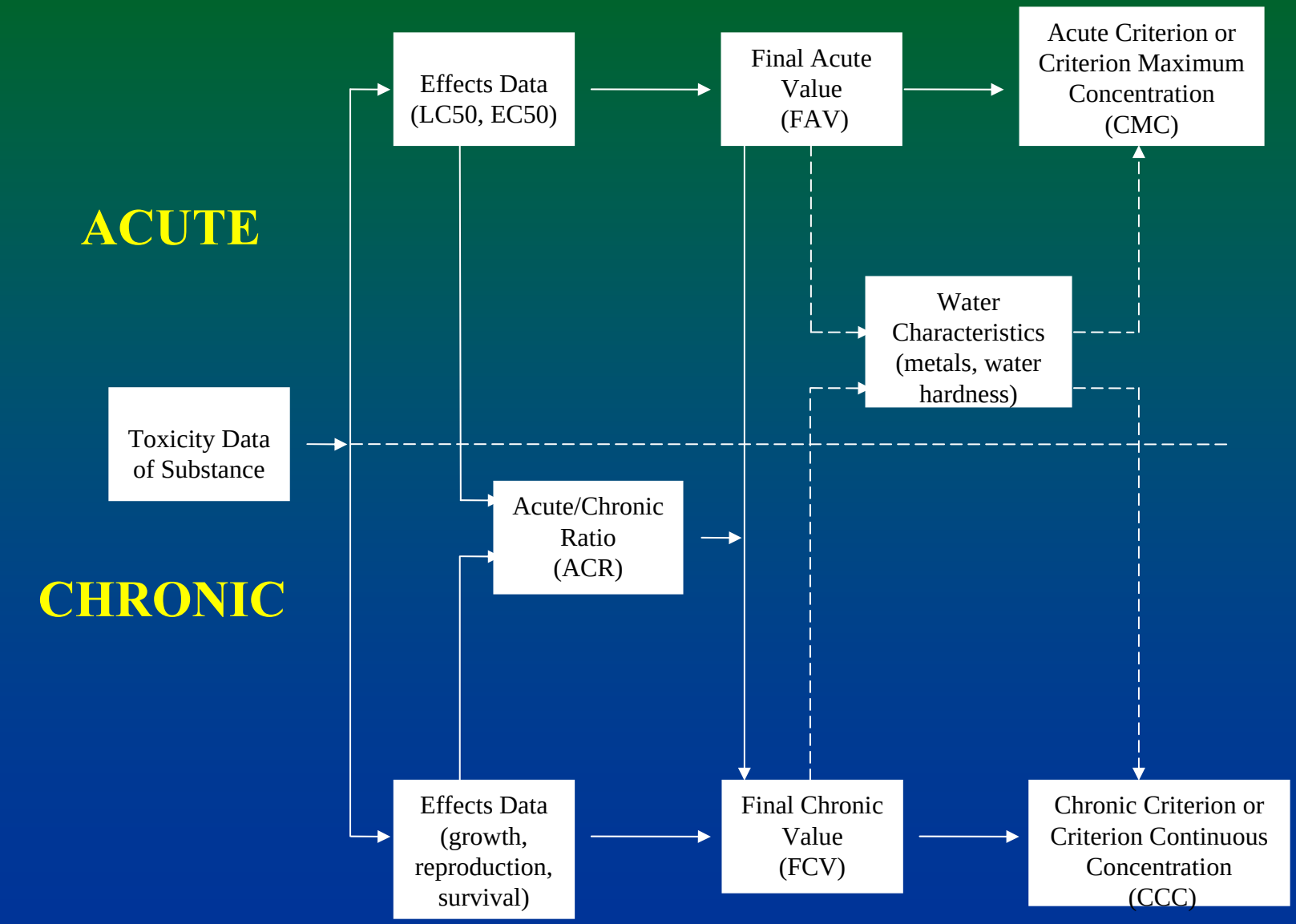
Module 9
Aquatic Life Criteria

Water Quality Standards Academy

Aquatic Life Criteria: Derivation Overview



Aquatic Life Criteria

Question: **What is an Aquatic Life Criterion?**

Answer: **The highest instream concentration of a toxicant to which organisms can be exposed for a period of time without causing an *unacceptable adverse effect.***

Q: **What is it intended to protect?**

A: **Aquatic animals (e.g., fish, invertebrates, crustaceans) and plants from acute and chronic exposure to a toxicant or condition.**

Aquatic Life Criteria: Components

Q: What are the three components of an Aquatic Life Criterion?

A: Magnitude (how much)

- µg/L

Duration (how long)

- four days

Frequency (how often)

- once every three years

Aquatic Life Criteria: Components

Q: Are there "defaults" for these components of an Aquatic Life Criterion?

A: Magnitude (how much):

- No. The concentration is based on toxicity testing.

Duration (how long):

- For acute exposure, 1-24 hour averaging period

- For chronic exposure, 4 day averaging period.

Frequency (how often):

- Once every 3 years, for both acute and chronic criteria.

Example of Aquatic Life Criterion Chlordane

Based on procedures in the "Guidelines" (Stephan et al. 1985) and except possibly where a locally important species is very sensitive Freshwater aquatic organisms and their uses should not be affected unacceptably if:

Chronic - the four-day average concentration of chlordane does not exceed 0.0043 µg/L more than once every three years on the average,

and

Acute - the short-term average concentration does not exceed 2.4 µg/L more than once every three years on the average

Example of Aquatic Life Criteria Copper

The available toxicity data, when evaluated using the procedures described in the ``Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses'' indicate that freshwater aquatic life should be protected if the 24-hour average and four-day average concentrations do not respectively exceed the acute and chronic criteria concentrations calculated by the Biotic Ligand Model.

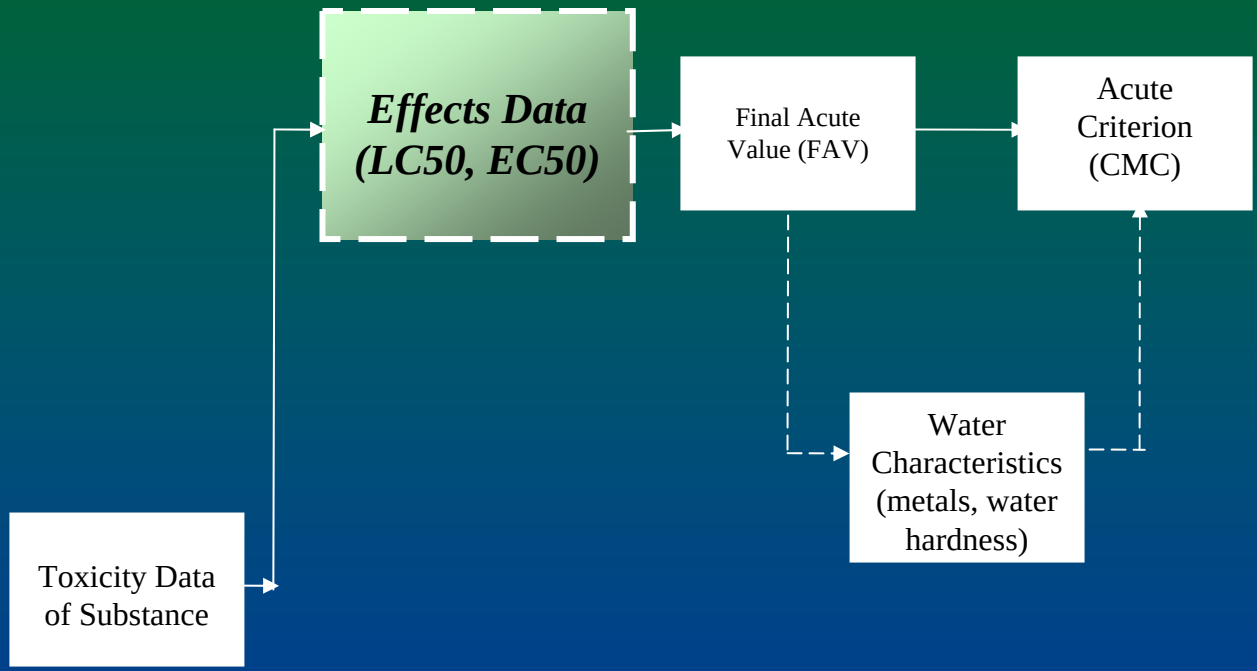
A return interval of 3 years between exceedances of the criterion continues to be EPA's general recommendation. However, the resilience of ecosystems and their ability to recover differ greatly. Therefore, scientific derivation of alternative frequencies for exceeding criteria may be appropriate.

Toxicity Test Data Endpoints

- **Acute: 48-hr or 96-hr LC50, EC50**
  - **lethal concentration/effects concentration of 50% tested organisms**

- **Chronic: growth, reproduction, survival**
  - **early life stage**

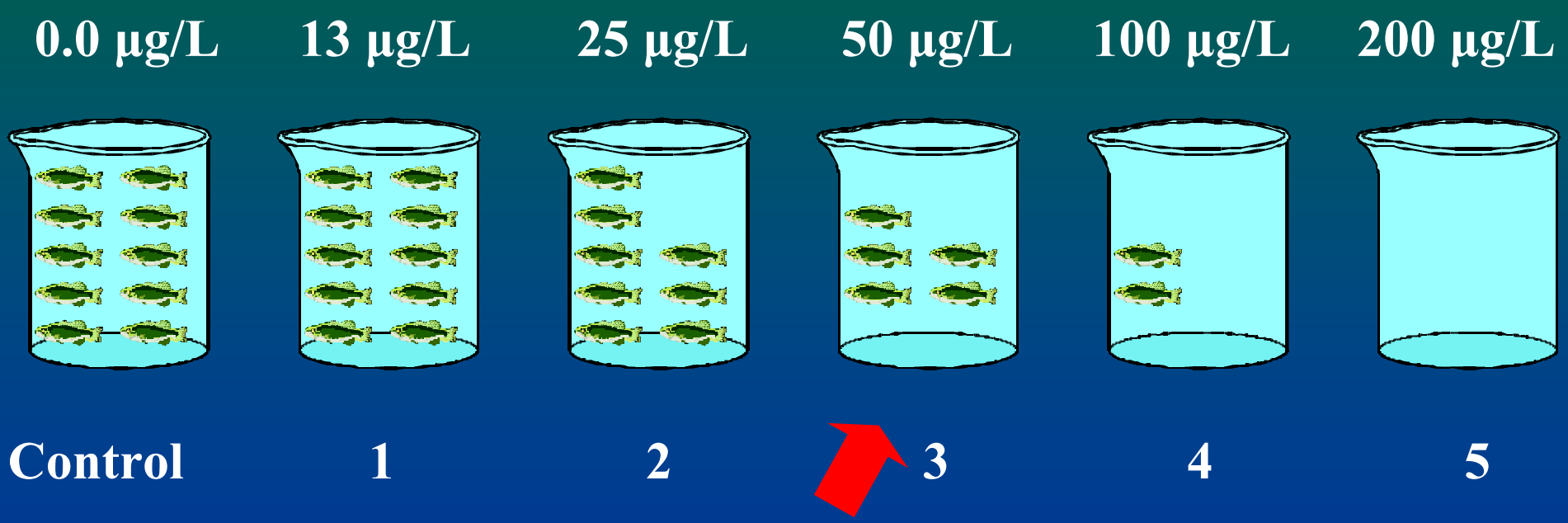
Acute Effects Data



ACUTE TOXICITY DATA

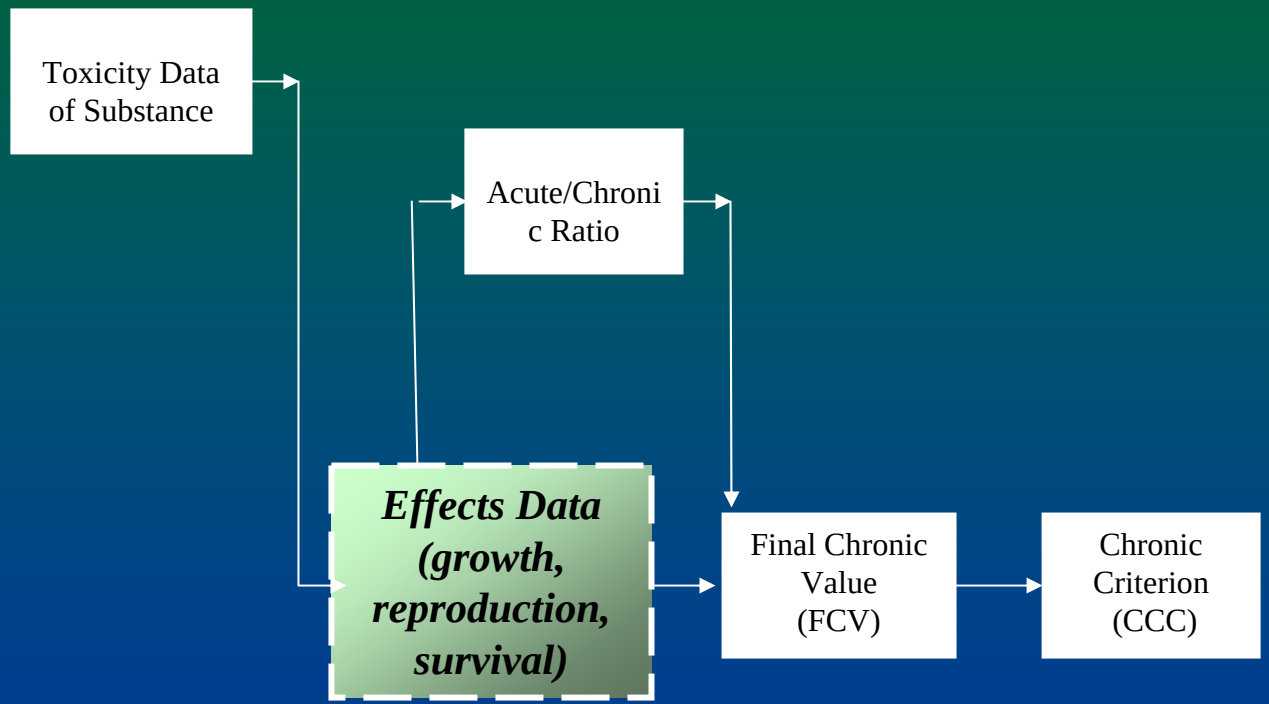
96-hour LC50

Concentration:



96-hr LC50 = 50 µg/L

Chronic Effects Data

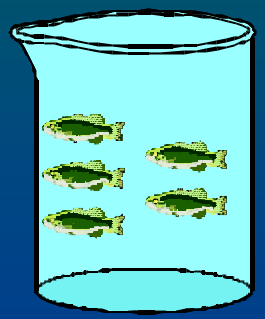
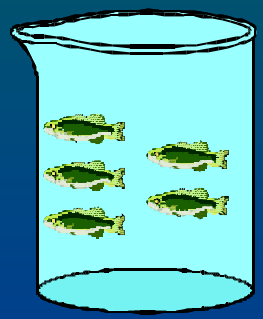
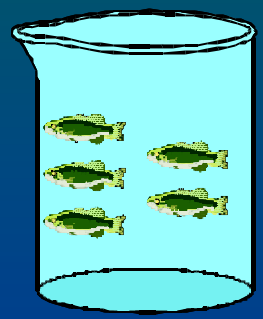
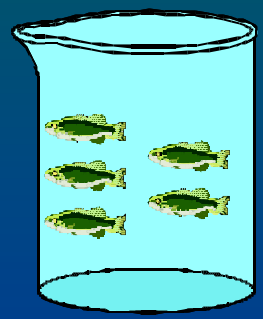
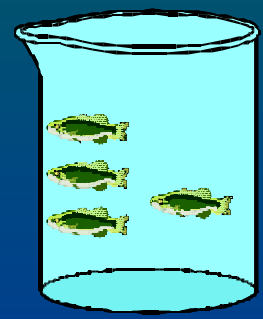
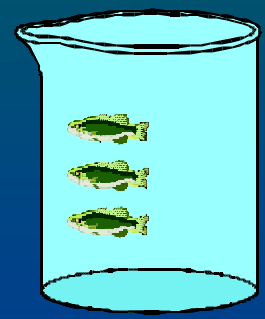


CHRONIC TOXICITY DATA

Fathead Minnow Early Life Stage Test
Growth Measured as Length

Concentration:

Control

0.0 µg/L	3.8 µg/L	7.5 µg/L	15 µg/L	30 µg/L	60 µg/L
					
Length:					
40 mm	41 mm	38 mm	37 mm	25 mm	5 mm

Chronic Value = 21.2 µg/L

Data Requirements

Q: What are the data requirements to calculate an Aquatic Life Criterion?

A: Acute and chronic test data from 8 taxonomically different families of organisms.

Data Requirements: Data from the most sensitive life stage

Egg

Larva

Most Sensitive

Adult

MINIMUM DATASET FOR FRESHWATER CRITERIA DERIVATION

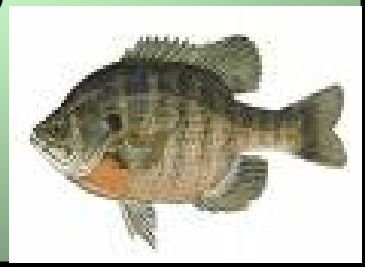
Eight families:

1. Salmonid
2. Second Fish Family
3. Chordata
4. Planktonic Crustacean
5. Benthic Crustacean
6. Insect
7. Rotifer, Annelida, Mollusca
8. Other Insect or Mollusca

MINIMUM DATASET FOR FRESHWATER CRITERIA DERIVATION

SALMONID

SECOND FISH FAMILY



CHORDATA

PLANKTONIC CRUSTACEAN

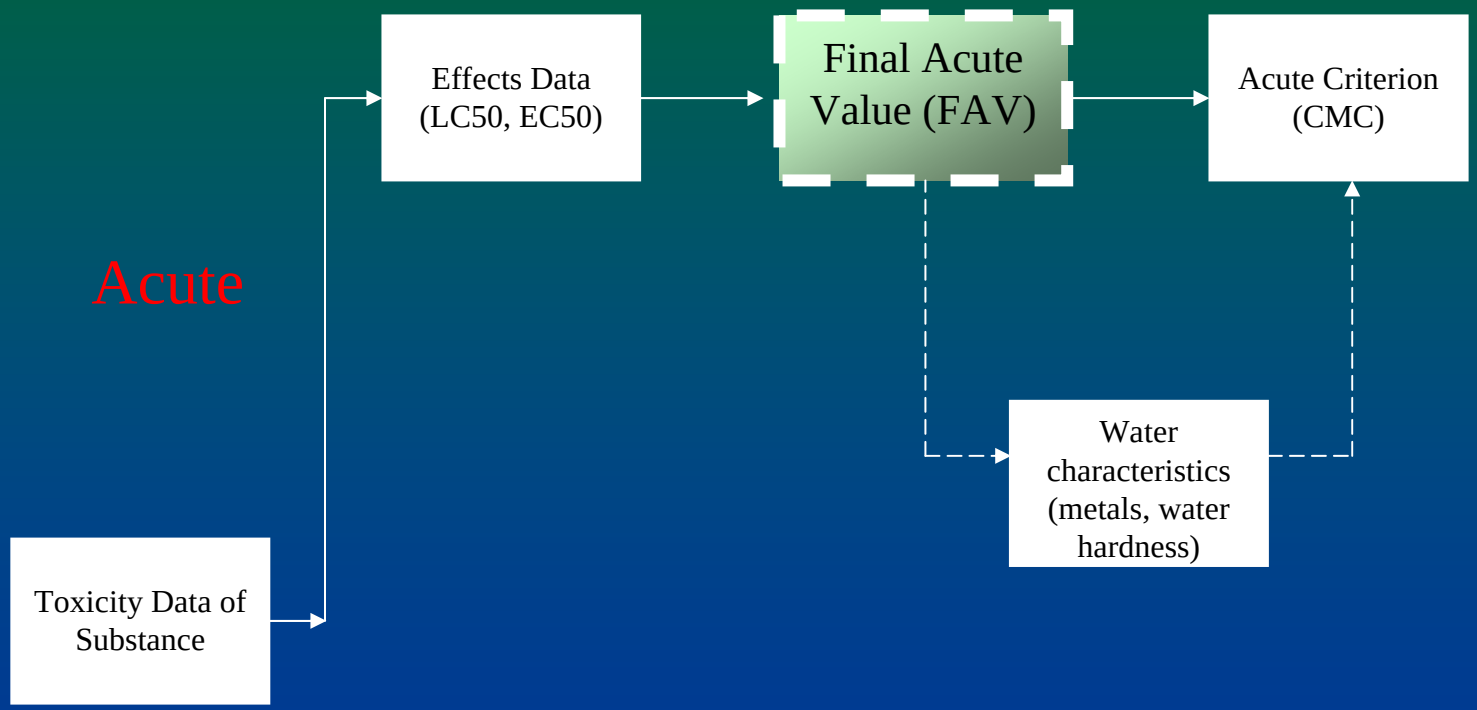
BENTHIC CRUSTACEAN

INSECT

ROTIFERA, ANNELIDA, MOLLUSCA

OTHER INSECT OR MOLLUSCA

Acute Criteria Derivation



FAV CALCULATION

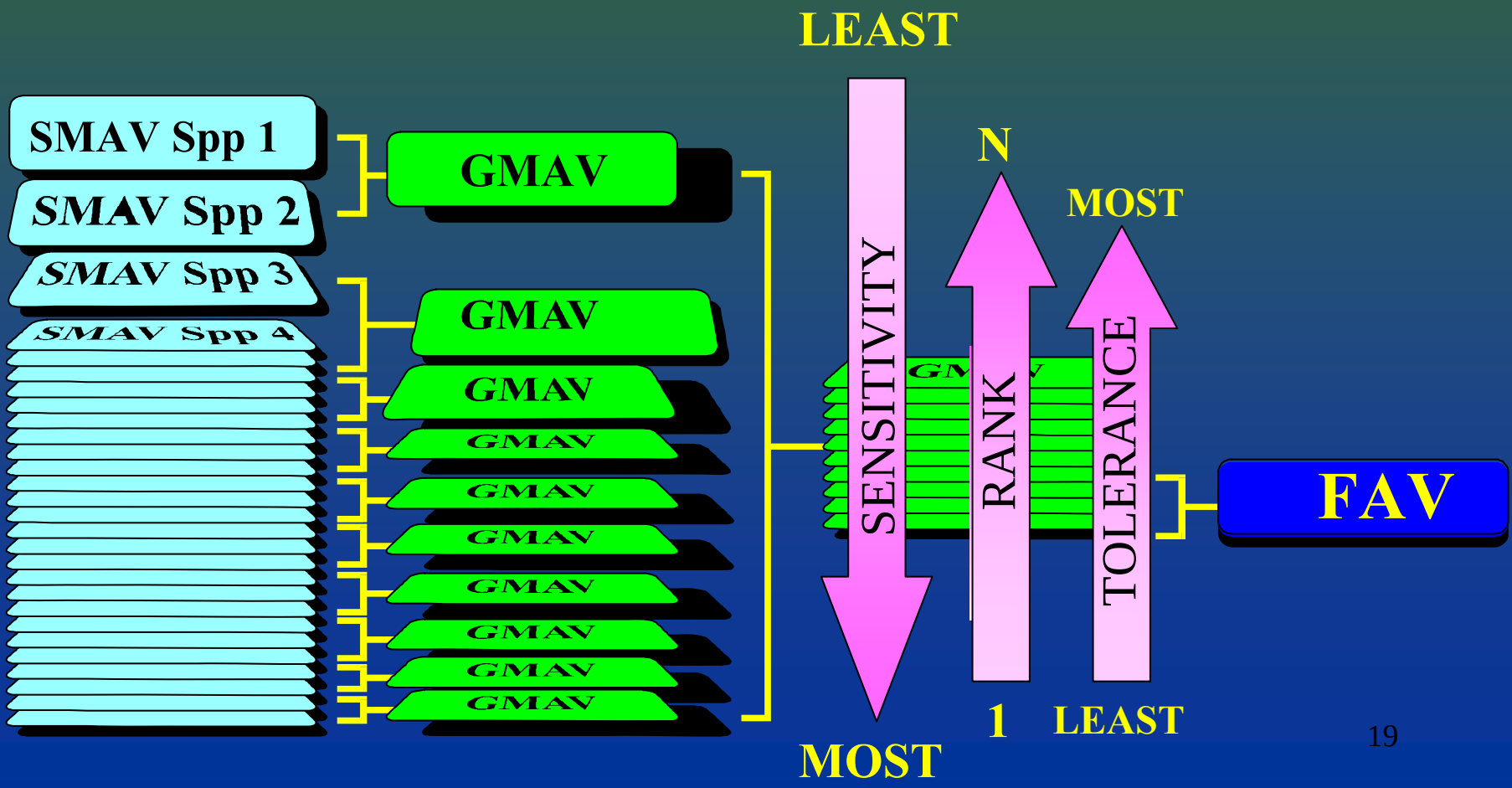
Step 1. Calculate Species Mean Acute Values (SMAVs)
- geometric mean of all acceptable acute values for species

Step 2. Calculate Genus Mean Acute Values (GMAVs)
- geometric mean of all SMAVs for genus

Step 3. Rank Genus Mean Acute Values
- from most sensitive (#1) to least sensitive (n)

Step 4. Calculate Final Acute Value Using 4 Lowest GMAVs

Aquatic Life Criteria Derivation



SPECIES MEAN ACUTE VALUE (SMAV)

Daphnia magna **EC50**	**25 µg/L**
Daphnia magna **EC50**	**30 µg/L**
Daphnia magna **EC50**	**35 µg/L**
Daphnia magna **EC50**	**28 µg/L**
SMAV =	**29.3 µg/L**

GENUS MEAN ACUTE VALUE (GMAV)

Daphnia magna	SMAV	29 µg/L
Daphnia pulex	SMAV	38 µg/L
Daphnia ambigua	SMAV	42 µg/L

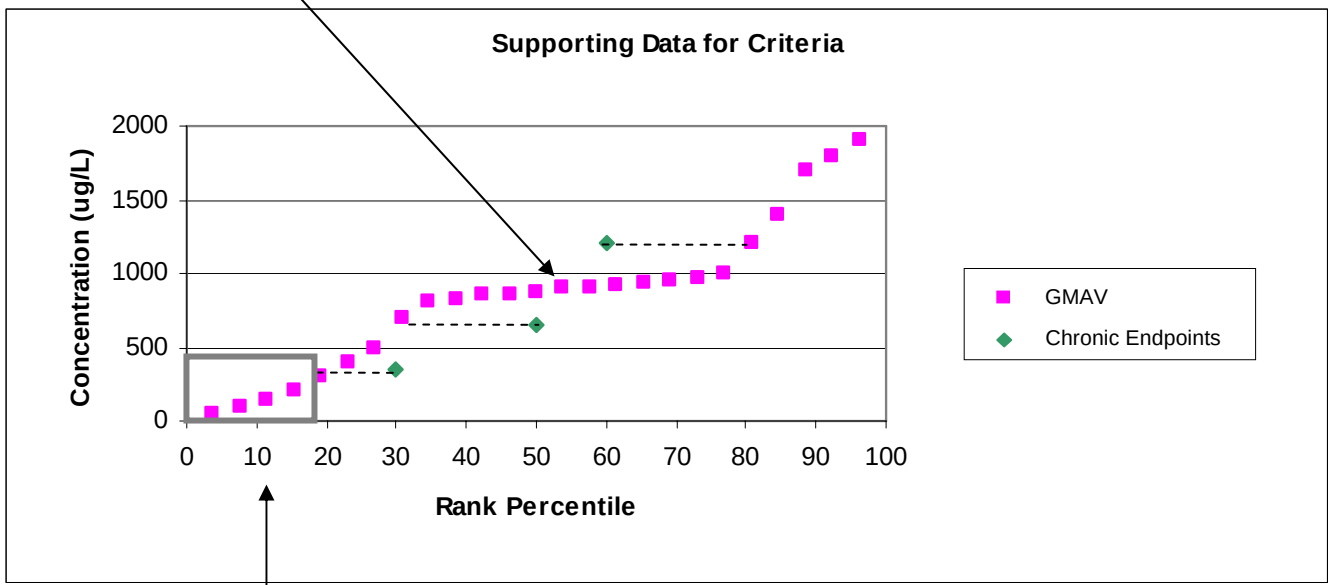
GMAV = 39.6 µg/L

TABLE 3 - RANK GMAVS

RANK	GMAV (µg/L)	Species	SMAV (µg/L)
4	100	Rainbow Trout, *Oncorhynchus mykiss*	100
3	36	Cladoceran, *Daphnia ambigua*	42
		Cladoceran, *Daphnia pulex*	38
		Cladoceran, *Daphnia magna*	29
2	25	Amphipod, *Gammarus pseudolimnaeus*	25
1	19	Amphipod, *Hyalella azteca*	19

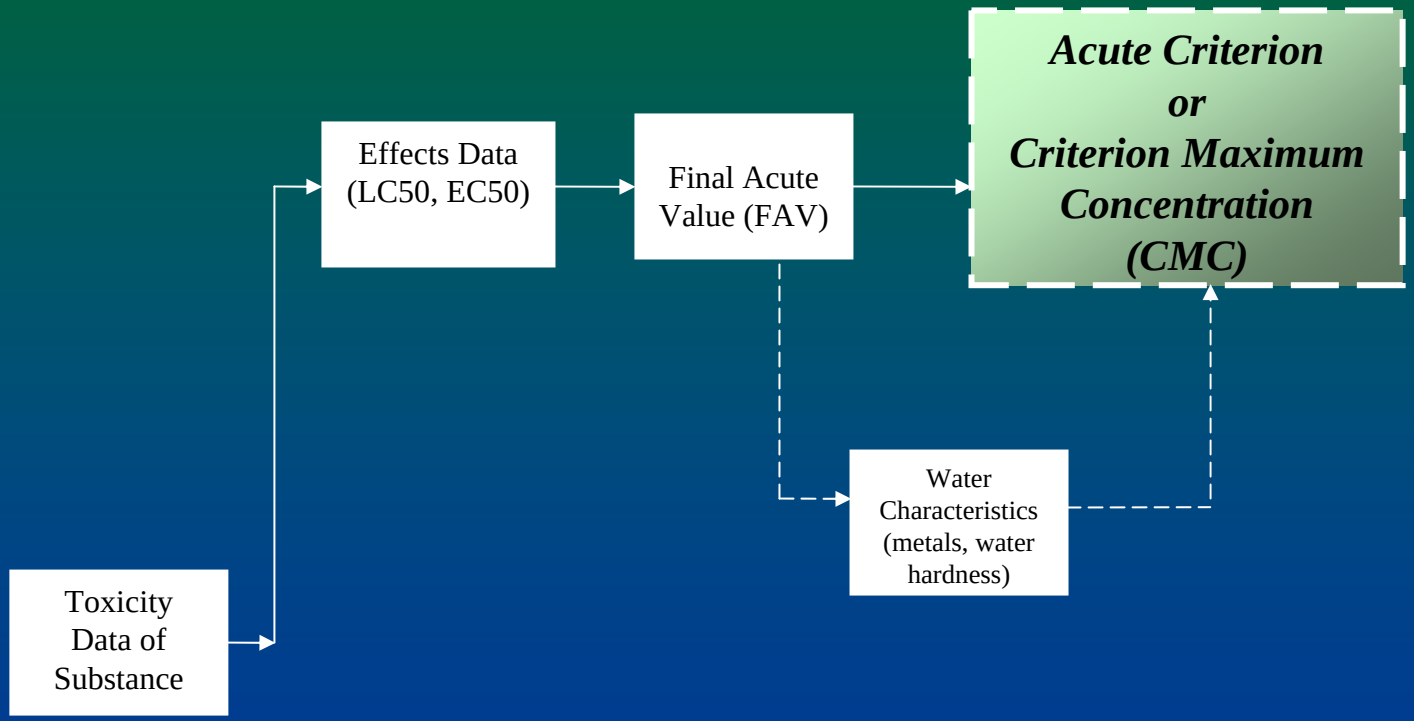
Aquatic Life WQC Calculation

Rank Genus Mean Acute Values (GMAV) and Calculate the Percentile of Each Rank (100 R/(N+1))

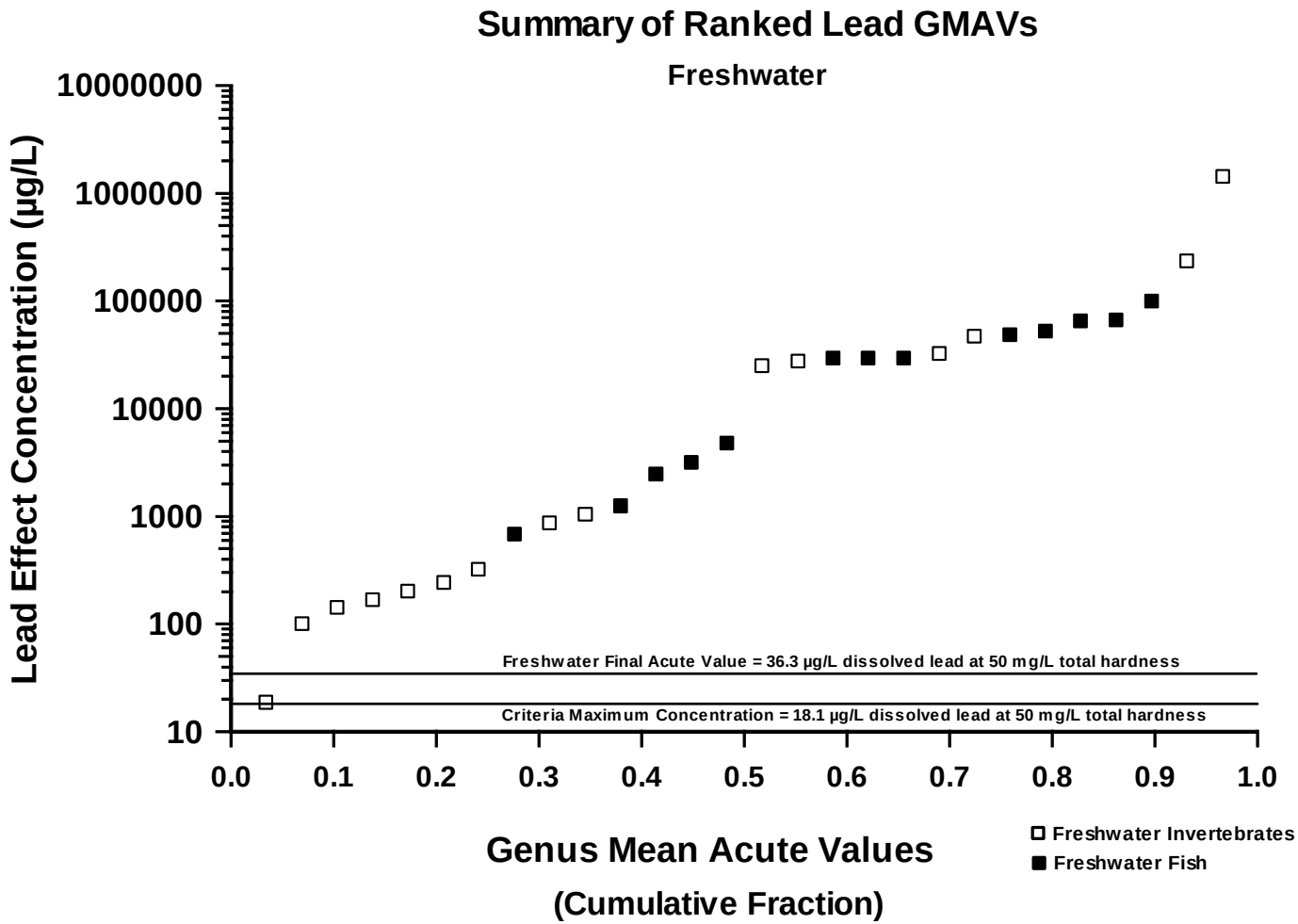


Using the 4 Most Sensitive Genera, Perform a Least Squares Regression of the $GMAV^2$ (log values) on the Percentile Ranks (square roots)

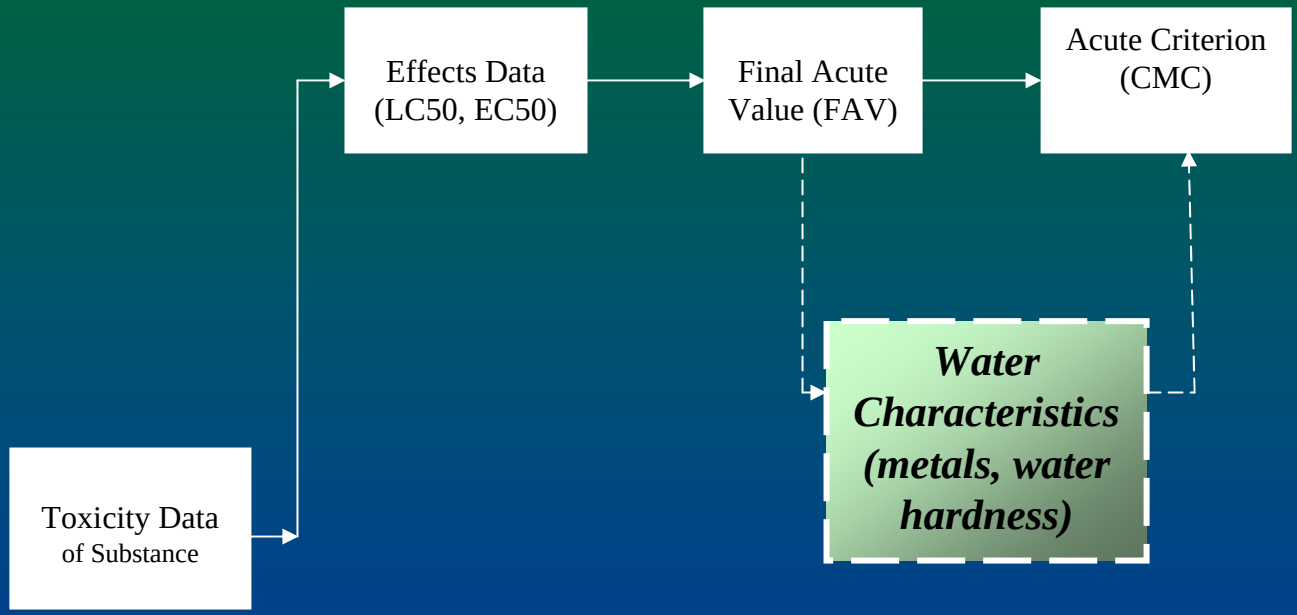
Acute Criterion (CMC)



Aquatic Life WQC Calculation



Water Characteristics (CMC)



CADMIUM FRESHWATER CRITERIA USING HARDNESS

Criteria Equation* = $e^{(1.0166\ (\ln \text{Hardness}) - 3.924)}$

Hardness (mg/L)	Equation	Criteria Value (µg/L)
50	$e^{(1.0166\ (\ln 50) - 3.924)}$	1.1
100	$e^{(1.0166\ (\ln 100) - 3.924)}$	2.1
200	$e^{(1.0166\ (\ln 200) - 3.924}$	4.3

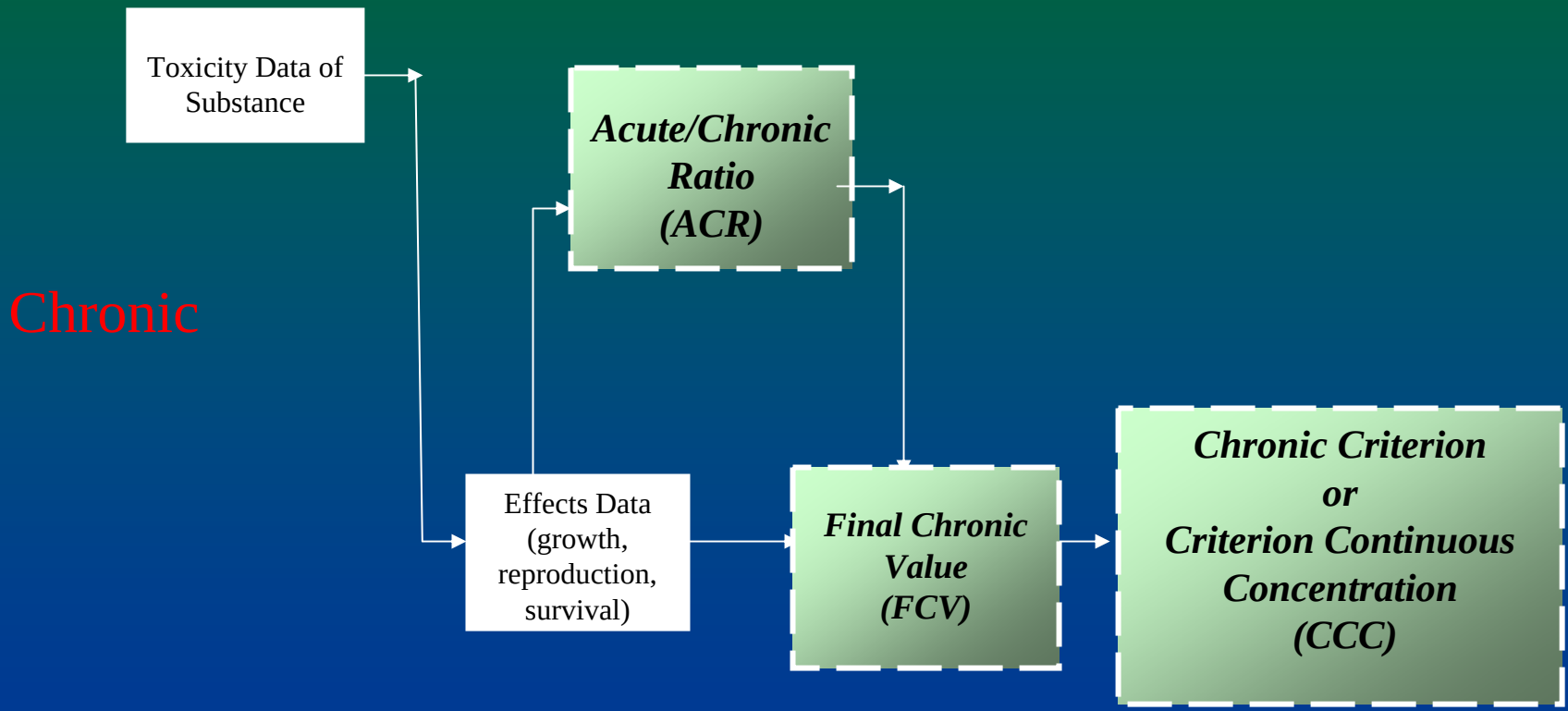
* Based on total recoverable metal

Example of Water Hardness Adjusted Aquatic Life Criteria - Cadmium

The available toxicity data, when evaluated using the procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that, except possibly where a locally important species is unusually sensitive, freshwater aquatic life should be protected at a total hardness of 50 mg/L as CaCO3 if the four-day average concentration (in µg/L) of dissolved cadmium does not exceed the numerical value given by $0.938\ [e^{(0.7409[\ln(\text{hardness})]-4.719)}]$ more than once every three years on the average, and if the 24-hour average dissolved concentration (in µg/L) does not exceed the numerical value given by $0.973\ [e^{(1.0166[\ln(\text{hardness})]-3.924)}]$ more than once every three years on the average.

For example, at hardness of 50, 100, and 200 mg/L as CaCO3 the four-day average dissolved concentrations of cadmium are 0.15, 0.25 and 0.40 µg/L, respectively, and the 24-hour average dissolved concentrations are 1.0, 2.0, and 4.1 µg/L.

Chronic Criterion Derivation



Acute to Chronic Ratio

Q: What is the Acute-Chronic Ratio?

A: The Acute-Chronic Ratio Is Used To Quantify the Difference in the Toxicities Observed in an Acute Test & a Chronic Test.

Q: Why use it?

A: In cases where there are only chronic toxicity data from 3 different families, and to calculate a Final Chronic Value.

CALCULATION OF FINAL CHRONIC VALUE FROM ACUTE-CHRONIC RATIO

1. Perform Acute & Chronic Testing Using Same Species in Same Dilution Water

2. Use Results to Calculate Acute-Chronic Ratios (ACR)

$$ACR = \frac{\text{Acute Value}}{\text{Chronic Value}}$$

3. Develop a Final Acute-Chronic Ratio (FACR) by taking a Geometric Mean of the appropriate Acute-Chronic Ratios

4. Calculate the Final Chronic Value (FCV) using the Final Acute-Chronic Ratio

$$FCV = \frac{\text{Final Acute Value}}{\text{FACR}}$$

Aquatic Life Criteria: Site-Specific Criterion
What is a Site?

What is a Site?

Aquatic Life Criteria: Site-Specific Criterion

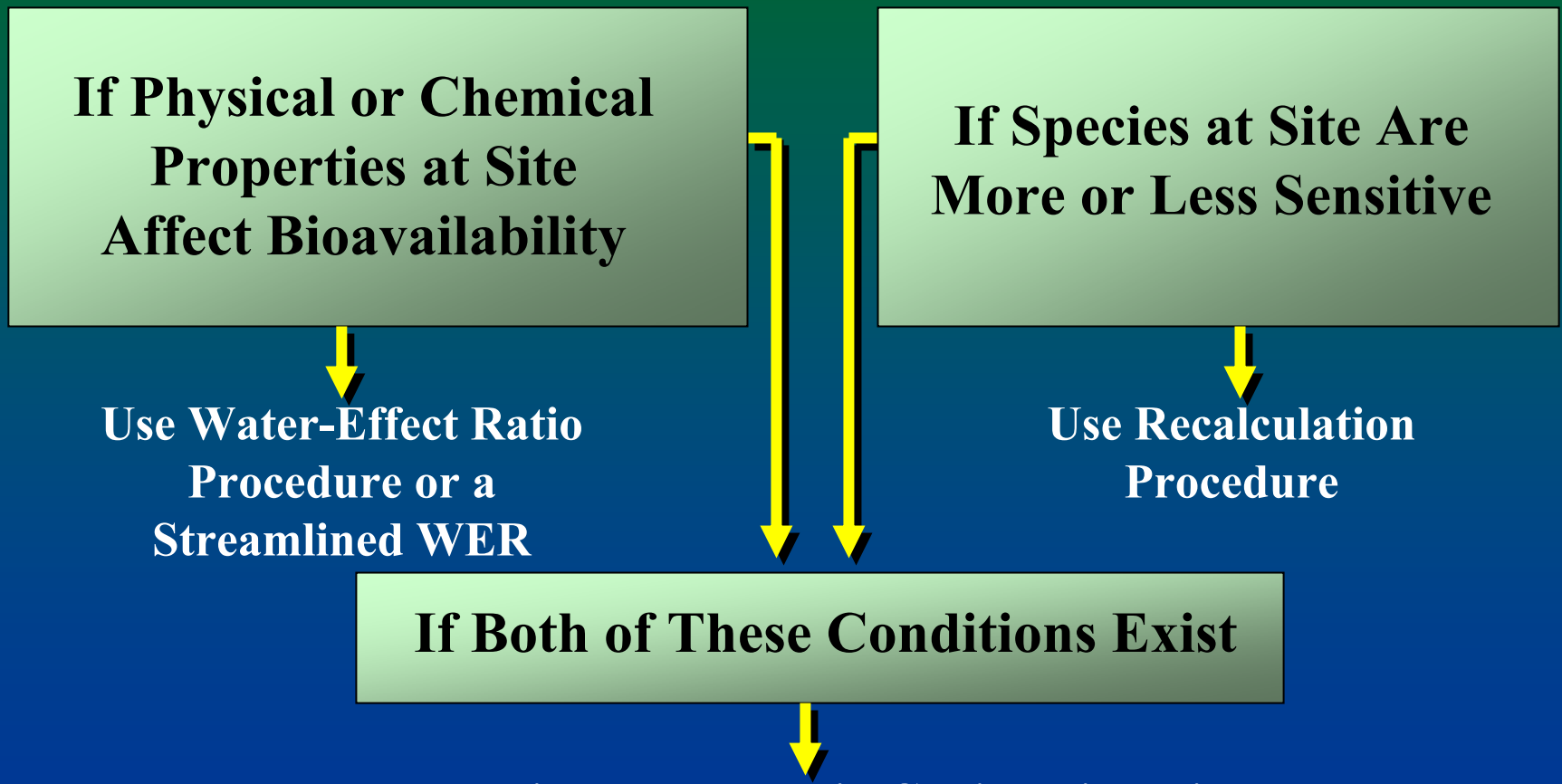
Q: Why would you develop a site-specific criterion?

A: The Sensitivities of the Site-Species Differ from the National Data Base

and/or

The Physical/Chemical Characteristics of the Site Alter the Bioavailability/Toxicity of the Pollutant

SITE-SPECIFIC CRITERIA PROCEDURES



WER Calculation Procedure

Quantification of the Difference in Toxicities of the Test Material in Site Water as Compared To Lab Water

$$\text{WER} = \frac{\text{Site Water Toxicity Concentration}}{\text{Lab Water Toxicity Concentration}}$$

Site-Specific Criteria = WER x National Criteria

WER Calculation Procedure

Quantification of the Difference in Toxicities of the Test Material in Site Water as Compared To Lab Water

Example:

$$\textbf{WER} = \frac{\text{Site Water LC50} = 66\ \mu g/L}{\text{Lab Water LC50} = 22\ \mu g/L}$$

WER = 66 ÷ 22 = 3.0

Site-Specific Criteria = WER x National Criteria

Site-Specific Criteria = 3.0 x National Criteria

Aquatic Life Criteria: Site-Specific Criterion

Q: What are the requirements for Deriving a Site-Specific Criterion?

A: Same minimum dataset (8 families)

1. Salmonid
2. Second Fish Family
3. Chordata
4. Planktonic Crustacean
5. Benthic Crustacean
6. Insect
7. Rotifer, Annelida, Mollusca
8. Other Insect or Mollusca

Site-Specific Criterion: Where can I get help?

Region 7 Species Recalculation Tool (SPRT):
http://www.epa.gov/region07/water/sprt.htm

Aquatic Life Criteria: Final Review

1. Is Toxicity related to WQ Characteristic?

Yes → Develop Equation & Adjust

No

2. Check Sensitive Life Stages (use most sensitive life stage)

3. Calculate Species Mean Acute Values (SMAVs)

4. Calculate Genus Mean Acute Values (GMAVs)

5. Rank GMAVs

6. Calculate Final Acute Value (FAV)

7. Calculate CMC (CMC = FAV/2 since LC50's are used)

Aquatic Life Criteria: Revisions to Guidelines

Near Term Products (2007):

- Kinetic modeling for addressing duration of exposure.
- Reevaluation of the allowable frequency recommendations.

Longer Term Efforts:

- Extract more information from available data.
- Address priority mechanisms of action (e. g., EDCs).
- Inject more realism into the evaluation of species sensitivity distributions composed of a diversity of species and life-stages.