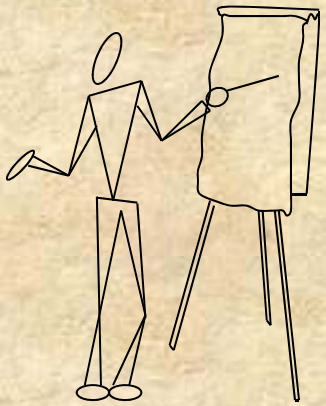
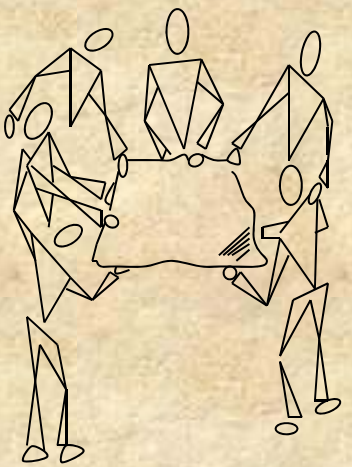
Developing Watershed Plans to Restore and Protect Our Waters





Setting Goals and Identifying Load Reductions Needed

Roger Miranda

Texas Commission on Environmental Quality

Texas Watershed Planning Short Course June 2-6, 2008
Bandera, Texas

TCEQ · Texas Water Resources Institute (make every drop count) · USDA ARS · River Systems Institute · Texas A&M AgriLIFE · TSSWCB (Soil Water) · TETRA TECH · Boise State University

WBP Guidance Review Chapters 4-8

- Define the Scope of the WBP
- Gather Existing Data
- Identify Data Gaps - Collect Additional Data
- Analyze Data – Characterize Pollutant Sources
- Estimate Pollutant Loads

What is needed to Develop and Implement a Watershed Management Strategy?

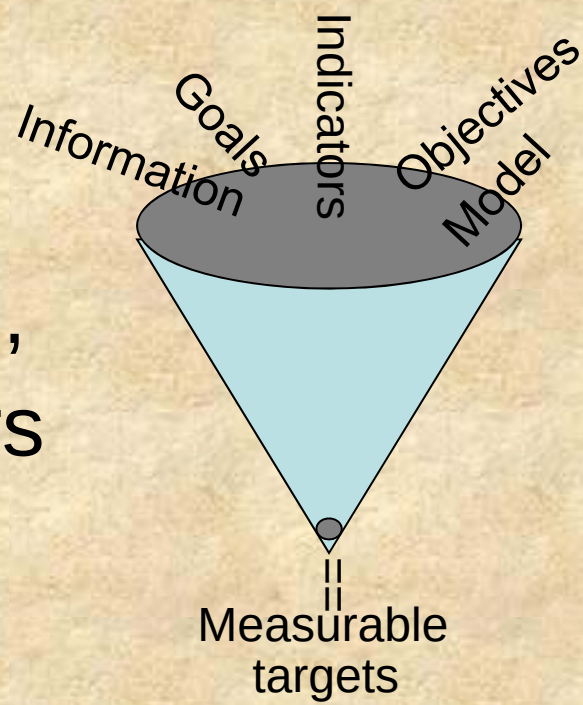
- Quantitative Characterization of Pollutant Sources
- Specific Management Goals with Associated Targets
- Means for Measuring Progress

From Watershed Goals to Management Objectives

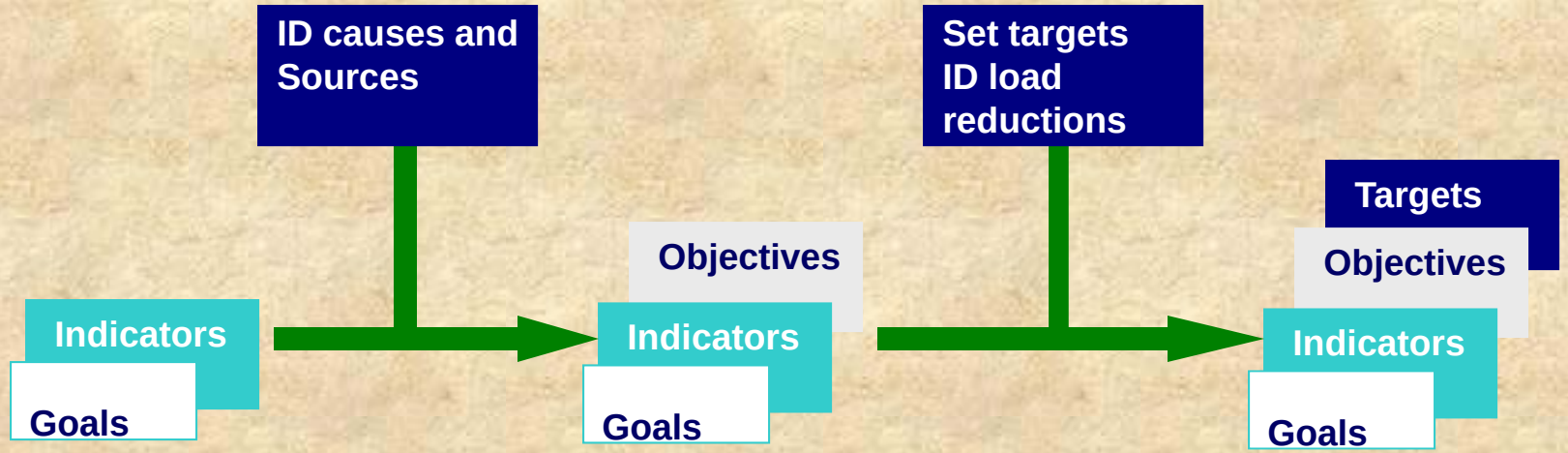
- Refinement (evolution) of watershed goals

  - Data analysis
    - Identify likely causes and sources affecting indicators

- Integration of goals, objectives, data/Information, and indicators to develop measurable targets



Process for Identifying Final Watershed Goals and Targets

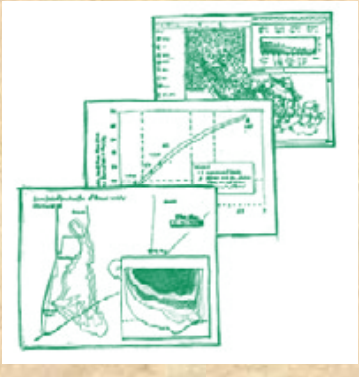


Sample Goals Linked to Sources and Impacts to Define Management Objectives

Preliminary Goal	Indicators	Cause or Source of Impact	Management Objective
Support designated uses for aquatic life; reduce fish kills	Dissolved oxygen Phosphorus Temperature	Elevated phosphorus causing increased algal growth and Decreased dissolved oxygen Cropland runoff	Reduce phosphorus loads from cropland runoff and fertilizer application
Reduce flood levels	Peak flow volume and velocity	Inadequate storm water controls, inadequate road culverts	Minimize flooding impacts by improving peak and volume controls on urban sources and retrofitting inadequate road culverts
Restore aquatic habitat	Riffle-to-pool ratio, percent fine sediment	Upland sediment erosion and delivery, stream bank erosion, near-stream land disturbance (e.g., livestock, construction)	Reduce sediment loads from upland sources; improve riparian vegetation and limit livestock access to stabilize stream banks
Meet water quality standards for bacteria to reduce beach closures	Fecal coliform bacteria	Runoff from livestock operations, waterfowl	Reduce bacteria loads from livestock operations
Improve aesthetics of lake to restore recreational use	Algal growth, chlorophyll a	Elevated nitrogen causing Increased algal growth	Reduce nitrogen loads to limit algal growth
Meet water quality standards for metals	Zinc, copper	Urban Runoff, Industrial discharges	Improve storm water controls to reduce metal loads from runoff

Selecting Environmental Indicators

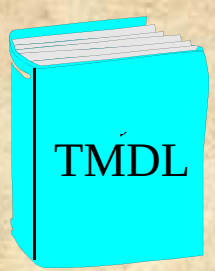
- If a TMDL exists, include TMDL targets as indicators (numeric or otherwise)
- If no TMDL exists, then rely on
  - data analysis
  - reference conditions
  - literature values
  - expert examination of water quality conditions



- Numeric targets are always preferable

Got TMDL?
Things to Consider

- How do the TMDL pollutants relate to your watershed goals?
- Have conditions changed since the TMDL?
- Can/should the TMDL be updated?
- What BMPs have been implemented since the TMDL?
- Is the level of detail in the TMDL sufficient?



Selecting Environmental Indicators (continued)

- It may be necessary to identify several indicators for the same impairment/concern
- Not all indicators have associated load reduction targets*
  - Link to other indicators, if possible
  - Identify other measurable mitigation outcomes

- Link between load reductions and environmental indicators
  - established through cause-and-effect relationships
  - documented through adaptive management

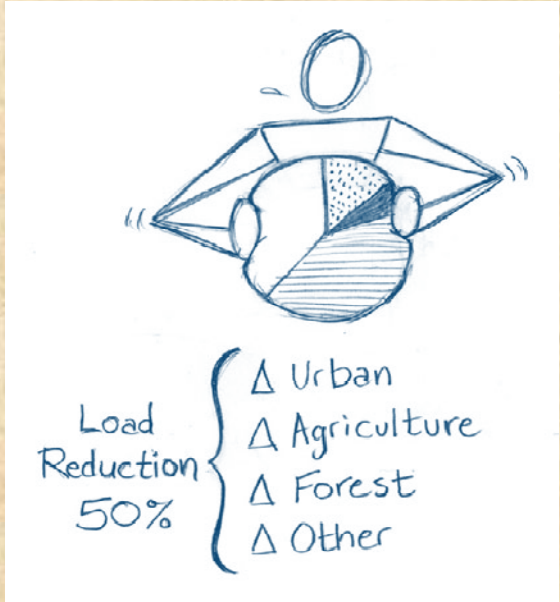
*Programmatic and Social Indicators are not discussed in this portion of the course

Examples of Indicators and Targets to Meet Management Objectives

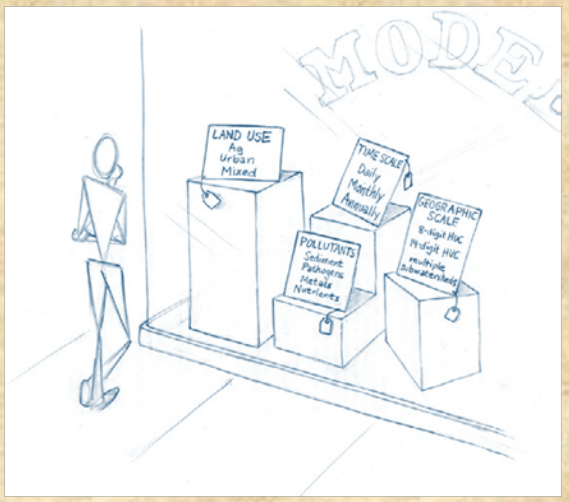
Management Objective	Indicator and Target Value
Reduce phosphorus loads from cropland runoff and fertilizer application	Dissolved oxygen: Daily average of 7 mg/L (from water quality standards) Phosphorus: Daily average of 25 µg/L (based on literature values)
Minimize flooding impacts by improving peak and volume controls on urban sources and retrofitting inadequate road culverts	Peak flow volume and velocity: Peak velocity for 1-yr, 24-hr storm of 400 cfs
Reduce sediment loads from upland sources; improve riparian vegetation and limit livestock access to stabilize stream banks	Riffle-to-pool ratio: 1:1 ratio (based on literature values) Percent fine sediment: <10 percent of particles <4 mm (based on reference conditions)
Reduce bacteria loads from livestock operations	Fecal coliform bacteria: Geometric mean of 200 cfu/100 mL (based on water quality standards)
Reduce nitrogen loads to limit algal growth	Algal growth: <10 percent coverage of algal growth (based on reference conditions) Chlorophyll a: <1 µg/L (based on literature values)
Improve storm water controls to reduce metal loads from runoff	Zinc: Maximum of 120 µg/L (based on water quality standards) Copper: Maximum of 13 µg/L (based on water quality standards)

Determining Load Reductions Needed

- Element *b* of the nine elements
- Pollutant/response cause-and-effect relationship(s) must be established
- Method for determining load reductions must be compatible with method used originally to quantify loads (Ch. 8)
- Method depends on:
  - Data availability
  - Type of stressor(s)
  - Water body type
  - Sources
  - Time frame
  - Spatial scale



Options for Determining Load Reductions

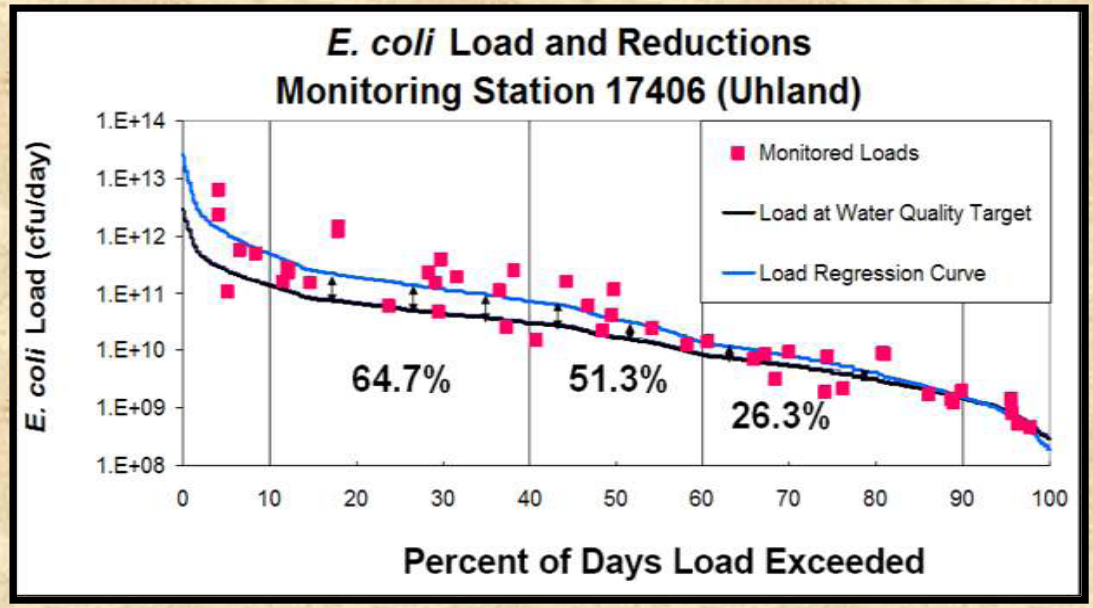


- Qualitative linkages
- Mass balance approach
- Empirical relationships
- Statistical or mathematical relationships
- Reference watershed approach
- Receiving water models

Qualitative Linkages

- Appropriate only when time is a factor and:
  - limited data or no data is available or…
  - watershed and pollutant sources are not well characterized or…
  - causes and/or cause-and-effect relationship(s) are not well established
- Linkages are typically based on theory or literature examples
- Should rely heavily on expert and/or local knowledge

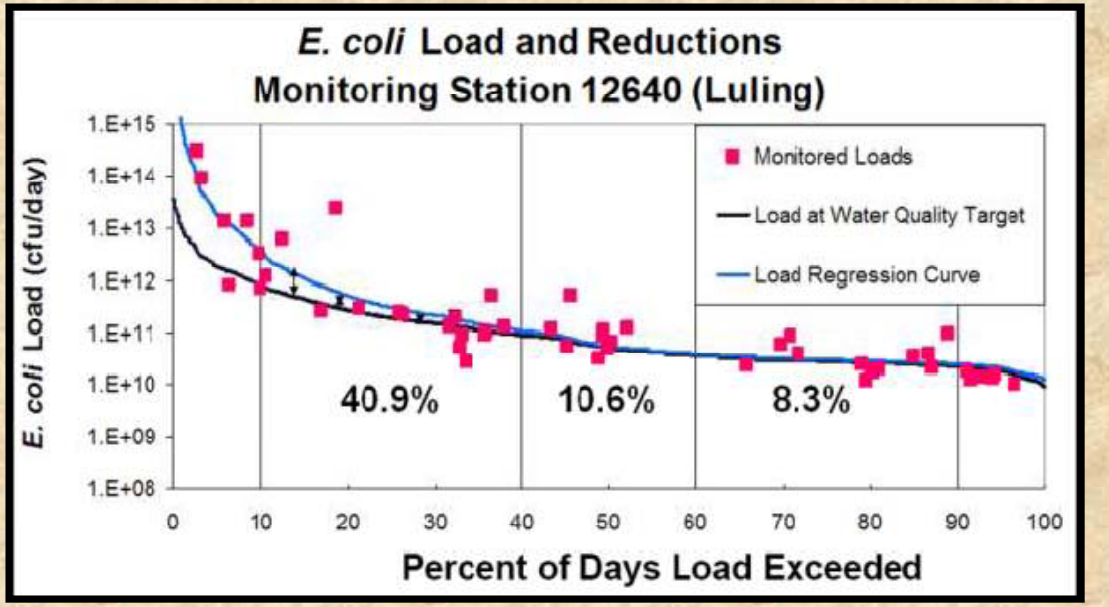
Qualitative Linkages (cont.)



Example from Plum Creek Watershed Protection Plan:

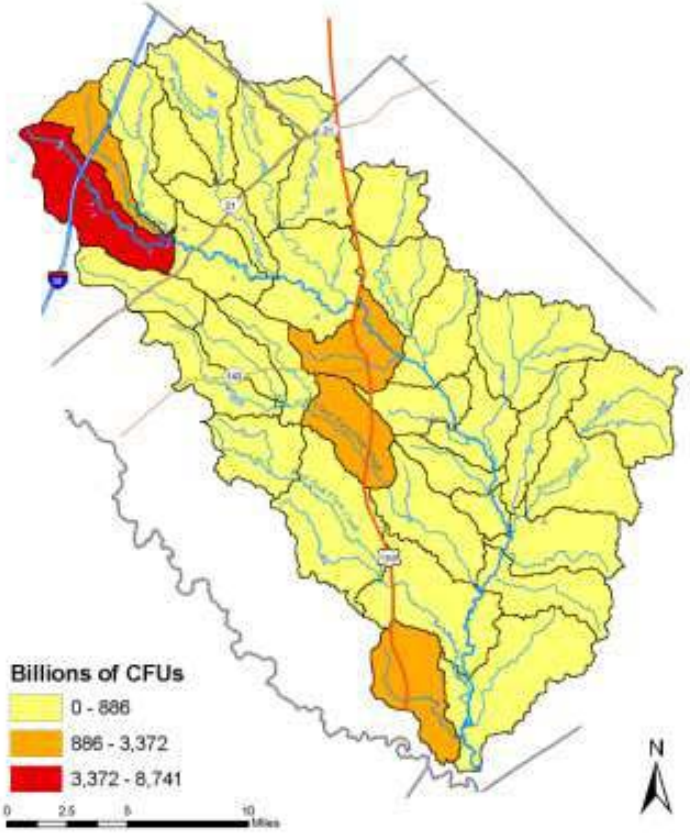
- >7 years of data (sufficient for analysis or model calibration)
- In-stream bacteria load reductions estimated using Load Duration Curves

Plum Creek Watershed Partnership

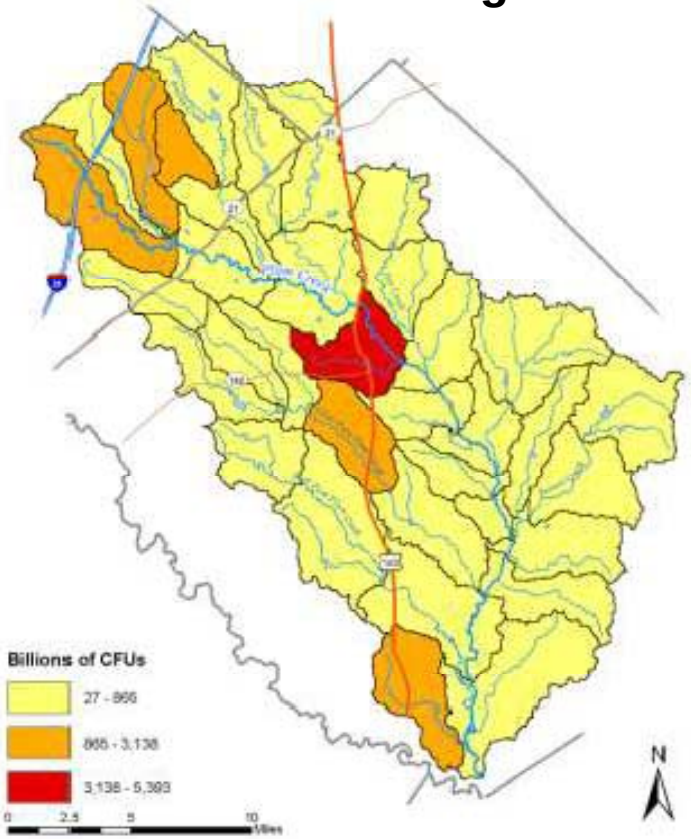


Qualitative Linkages (cont.)

Average Daily Potential *E. coli* Load from Urban Runoff



Average Daily Potential *E. coli* Load from Dogs



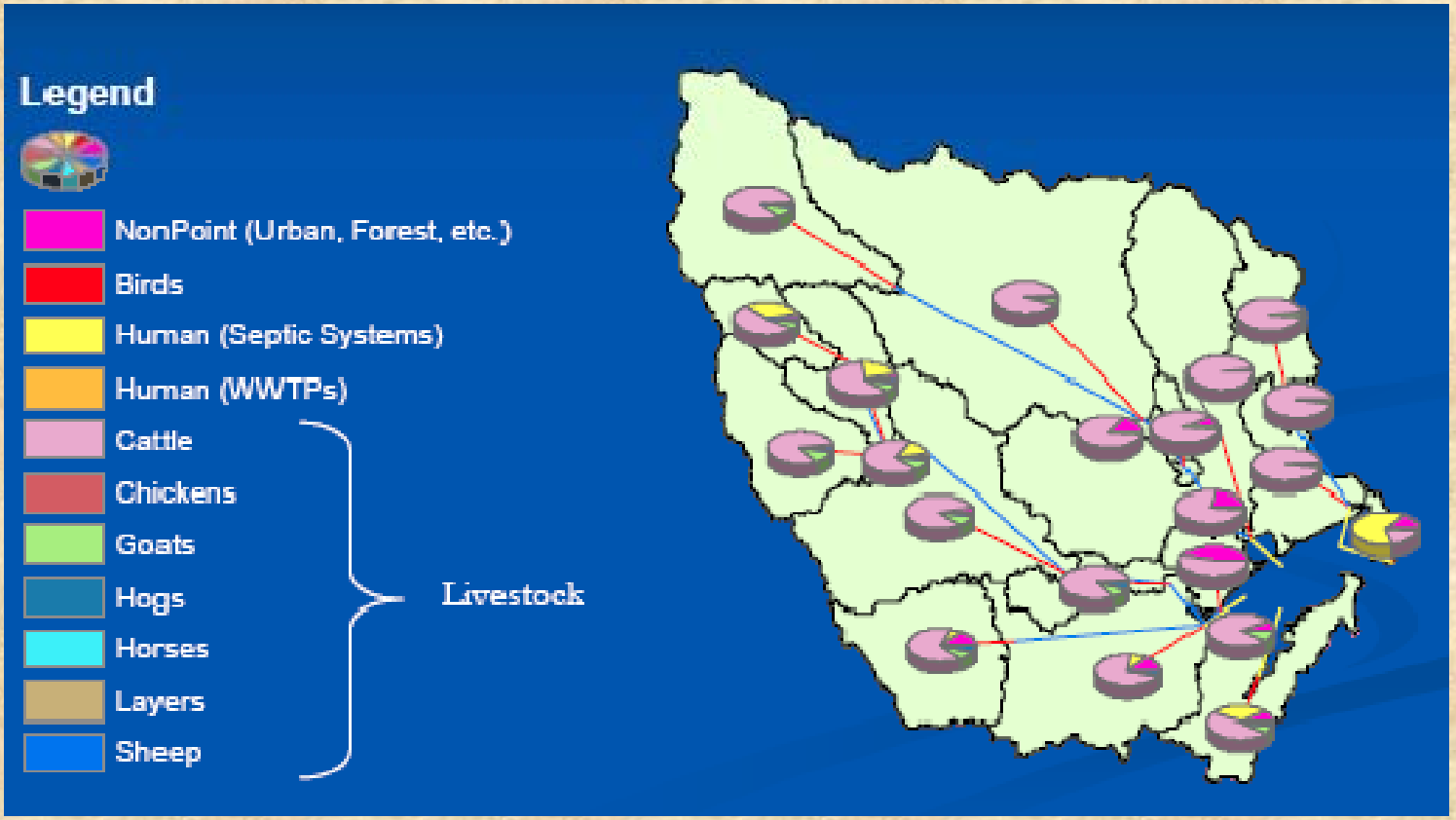
Select Model used to estimate watershed loadings from various sources

Mass Balance Approach

- It is an accounting of mass entering and exiting a natural system
- No attempt is made to simulate physical or biogeochemical systems in any detail
- Incorporates a general understanding of major watershed and in-stream processes including:
  - runoff
  - export
  - decay
  - settling
  - resuspension, etc.

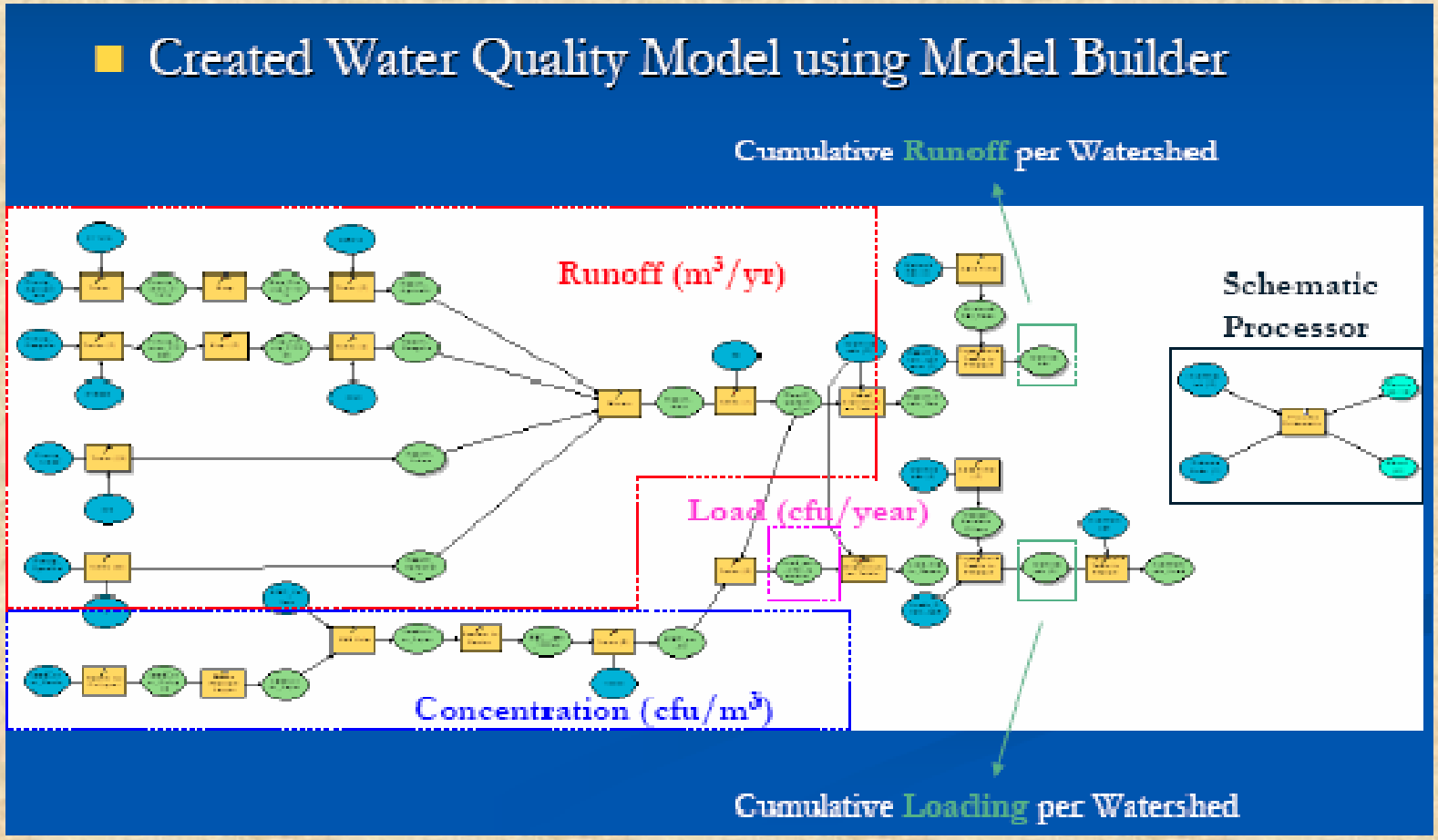
Mass Balance Approach (continued)

Example from Copano Bay TMDL



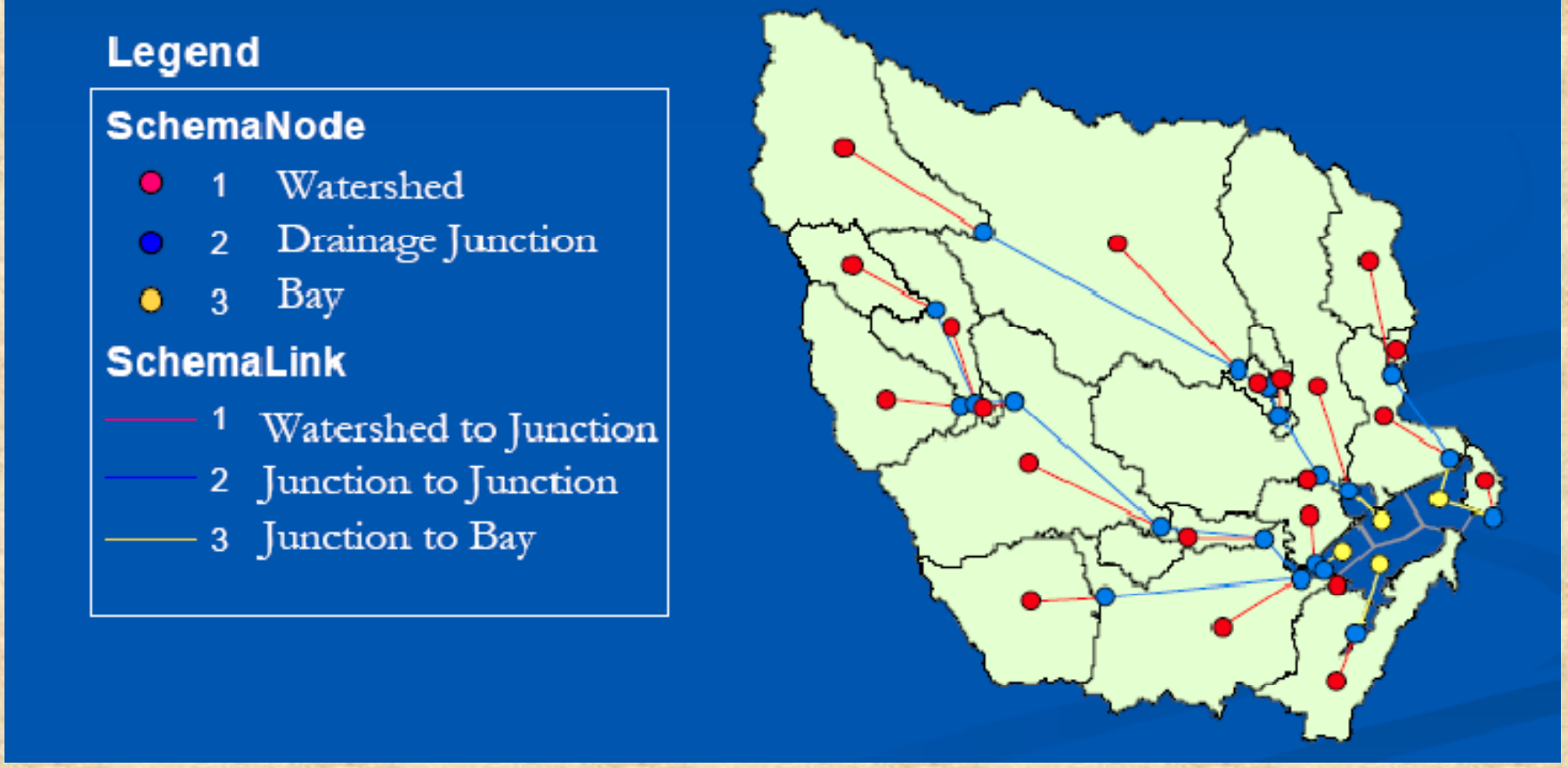
Mass Balance Approach (continued)

Example from Copano Bay TMDL



Mass Balance Approach
(continued)

- Creation of Schematic Network

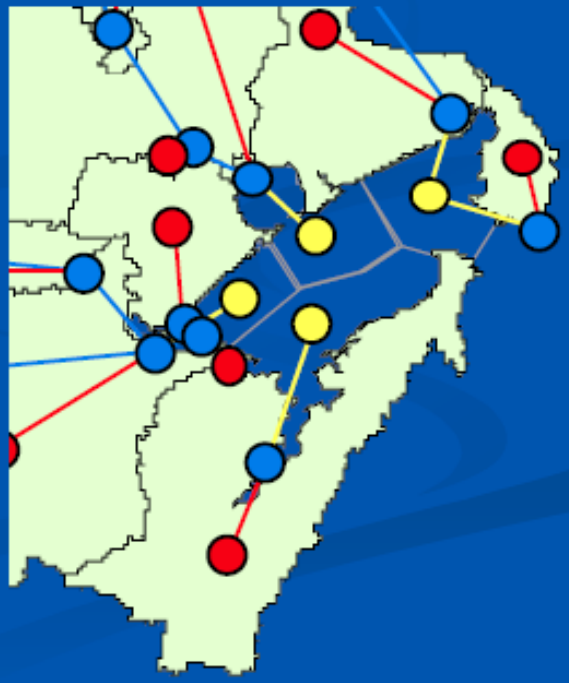


Mass Balance Approach
(continued)

- **First-order decay**
  - Simulates decay of bacteria along stream segments
    - Downstream Loading = Upstream Loading * $e^{-k\tau}$
      - **Decay Coefficient, k** ($days^{-1}$)
      - **Residence Time, τ** (days)

Mass Balance Approach (continued)

- **CFSTR**
- Bay is completely mixed and acts as four Continuous Flow, Stirred Tank Reactors (CFSTR)
  - Inflow = Outflow
  - c (cfu/100mL) = L/(Q+kV)
    - **Bacteria loading, L** entering bay (cfu/yr)
    - **Flow, Q** (m^3/yr)
    - **Decay Coefficient, k** (day^{-1})
    - **Volume, V** of Bay (m^3)

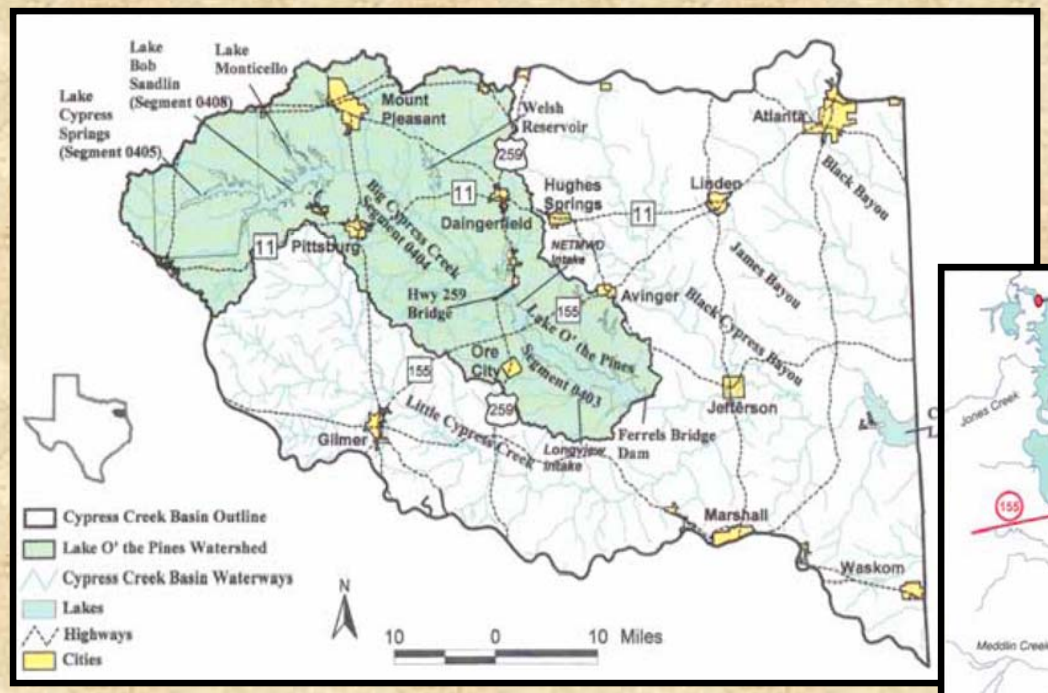


Empirical Relationships

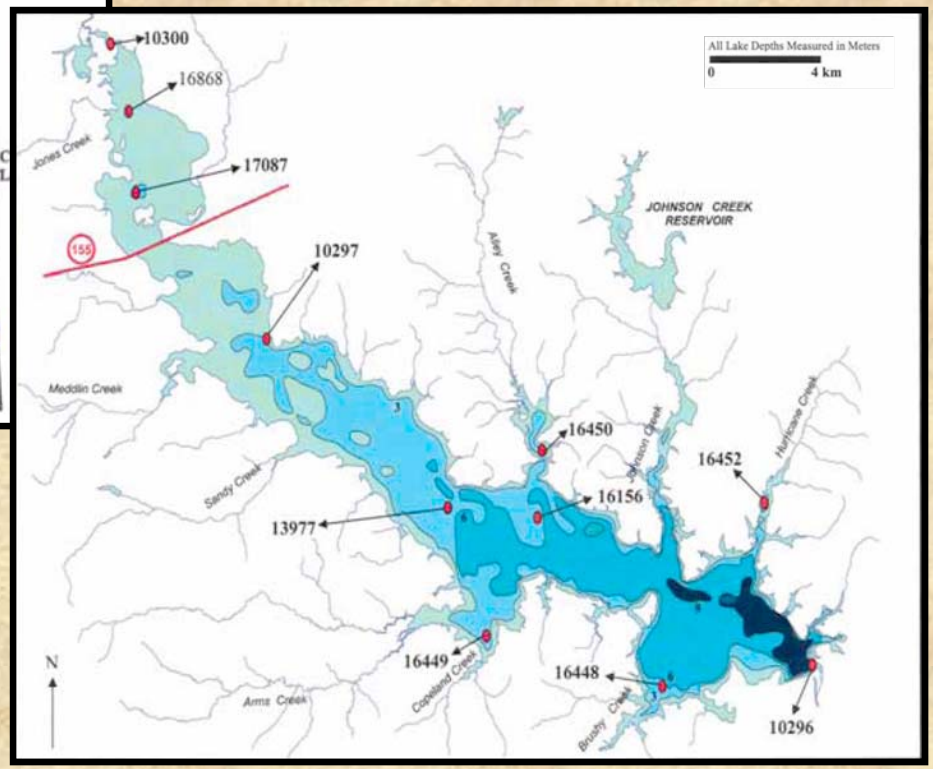
- Based strictly on observed data
- Use mathematical functions derived from analysis of historical data

- The functions (i.e., equations) are used to establish a relationship between pollutant loading rate and water body response
- Site-specific in nature, rarely applicable to (even slightly) dissimilar water bodies

Empirical Relationships (continued)



Lake O' the Pines TMDL Example



- Watershed TP loadings estimated using SWAT
- Vollenweider (empirical) model used to establish relationship between watershed loadings and in-lake TP concentrations
- Statistical relationship established between TP, chl*a*, and DO

Empirical Relationships (continued)

Lake O' the Pines TMDL Example

$$TP\ (mg/m3) = \frac{load\ (mgTP/m2*year)}{Z\ (r + s)}$$

where load refers to areal loading, or the mass of annual total phosphorus loading (from the SWAT simulation plus the point source load), divided by reservoir area:

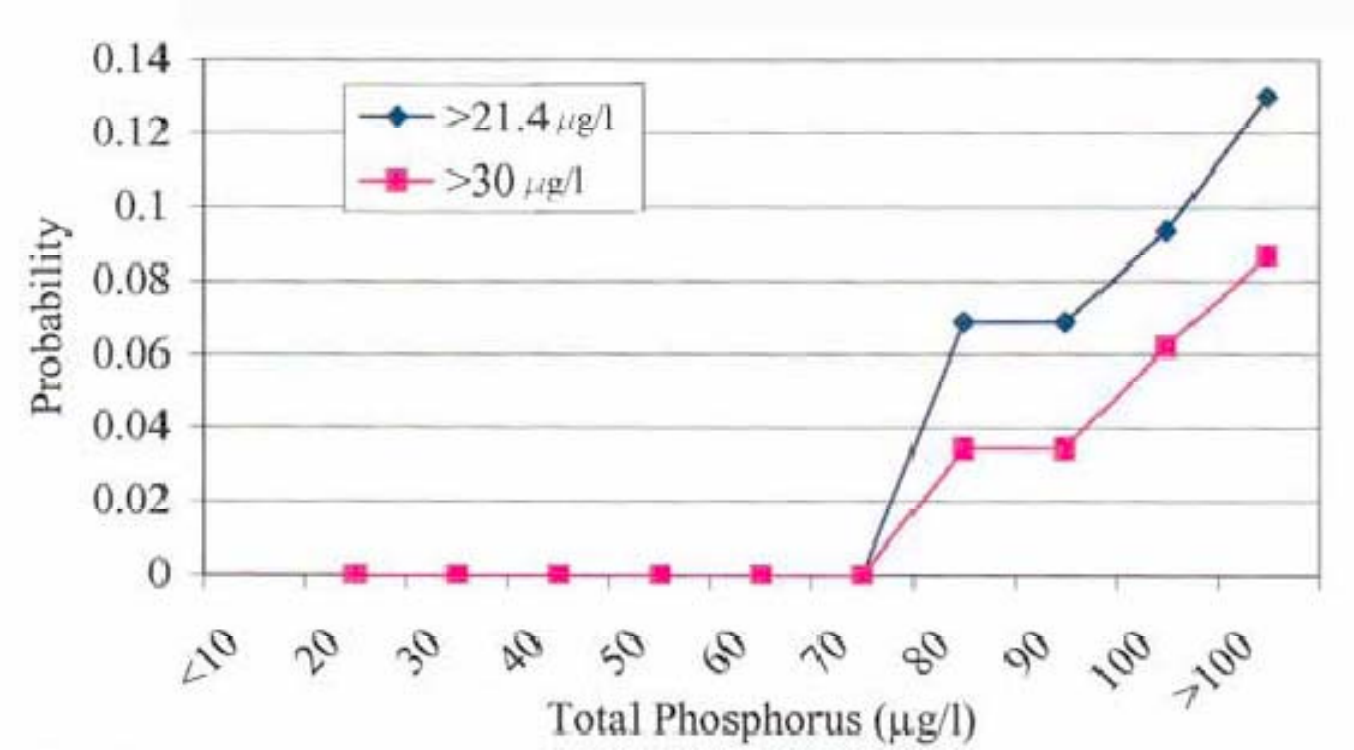
= (113,000 + 61,900 kgTP/year)*1,000,000/68,471,193 m2
= 2554 mgTP/m2*year

where
Z = average depth (reservoir volume/reservoir area, 4.34 m) (TWDB, 1999),
r = flushing rate (reservoir volume/annual inflow, 1.89), and
s = sedimentation coefficient (10/Z).

Statistical or Mathematical Relationships

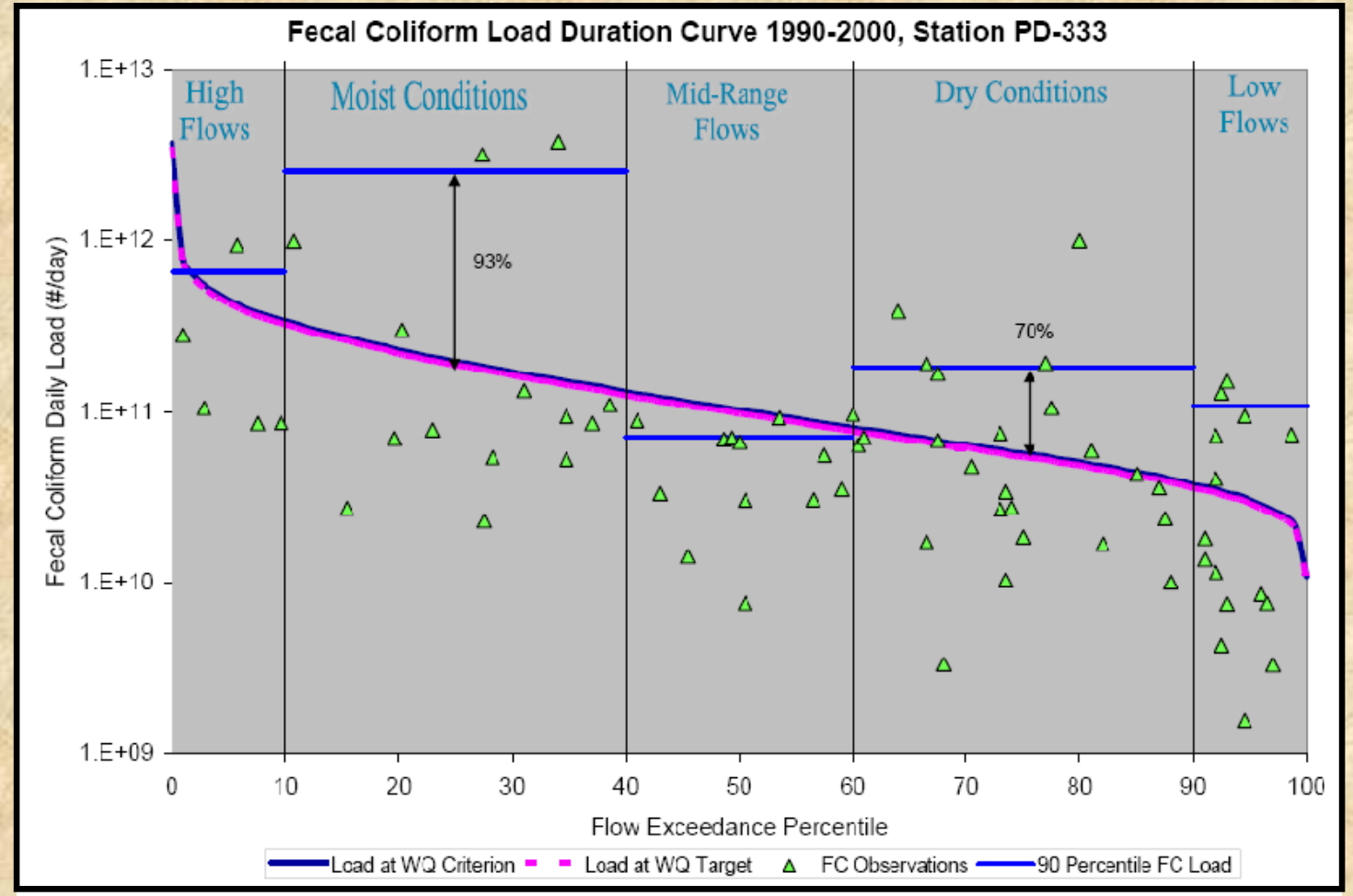
- Assumes some relationship between key factors in the watershed and in-stream conditions based on observed data
- Cannot, by itself, describe explicitly from where loadings originate
- Is an alternative to mechanistic (process-based) models when model input data is scarce or non-existent
- Does not identify load reductions by source type

Statistical or Mathematical Relationships

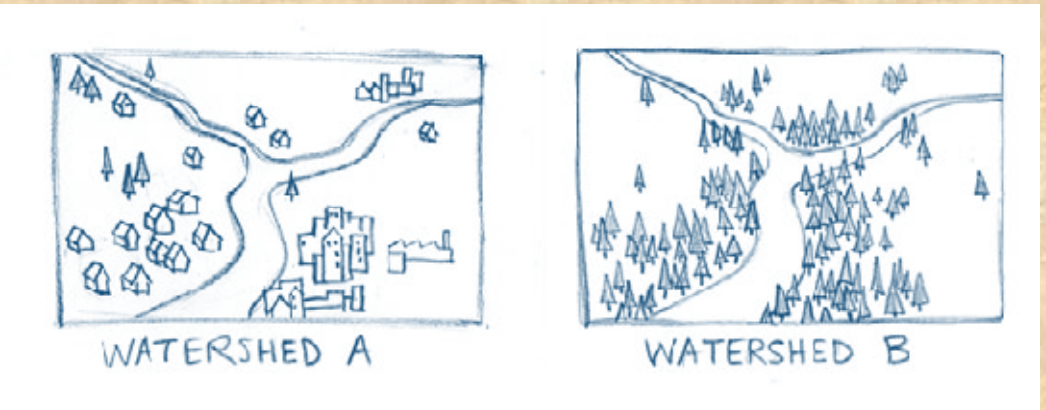


Threshold Frequencies of Chlorophyll-*a* Versus Total Phosphorus Concentrations

Statistical or Mathematical Relationships (cont.)



Reference Watershed Approach



- Used most frequently when no pollutant loading or water quality target is appropriate (i.e., biological and narrative criteria)
- Compares the subject watershed to a similar “healthy” reference watershed
- The paired watersheds must share similar ecoregion and geomorphological characteristics

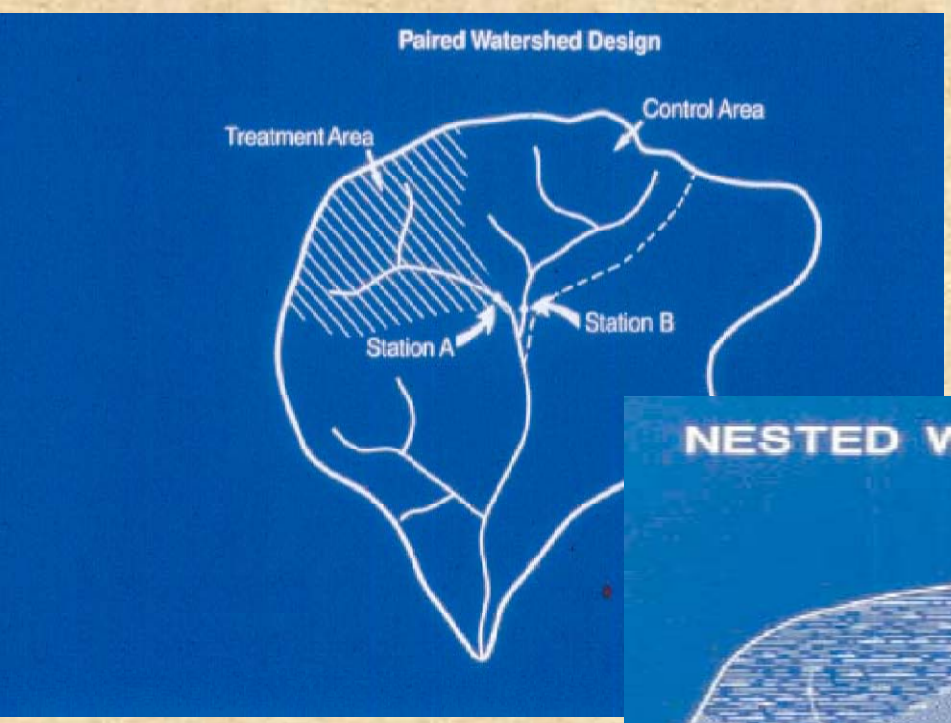
Reference Watershed Approach (continued)

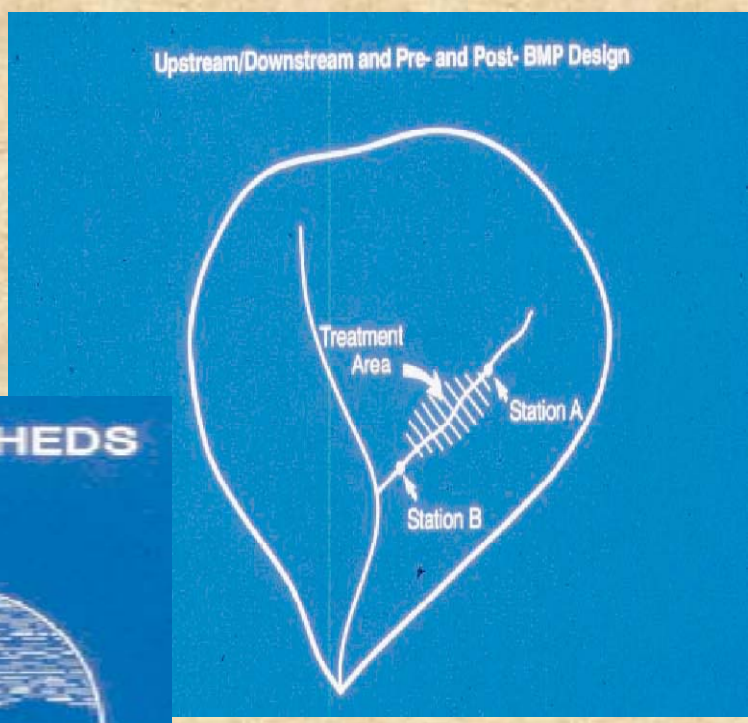
- Paired watershed conditions must be comparable:
  - size
  - soils
  - topography
  - geology, etc.

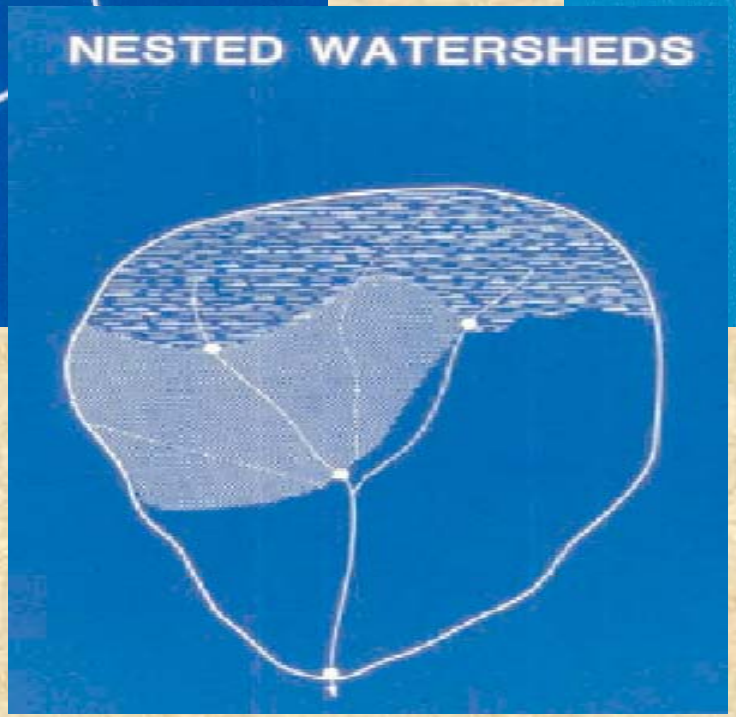
- Paired receiving water bodies must also be comparable (streams to streams, lake to lakes, etc.)

* From Jean Spooner – NC State, 2008

Reference Watershed Approach (continued)

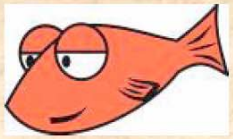






* From Jean Spooner – NC State, 2008

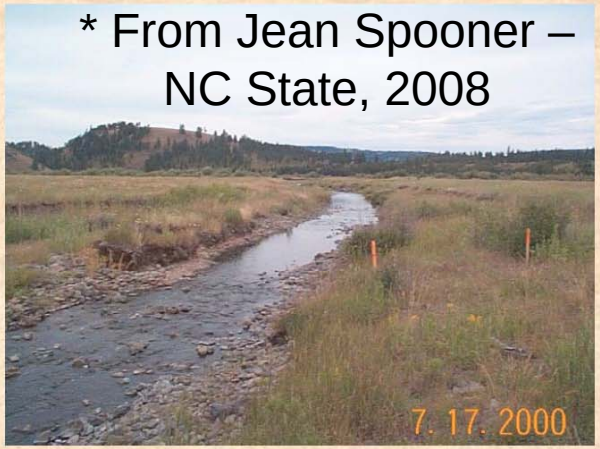
Reference Watershed Approach (continued)



Upper Grande Ronde River, OR
Channel Restoration, Cattle Exclusion/Fencing

- **Water Quality Impairment.** Rainbow trout: temperature-sensitive
- **Successes**
  - Improved slope, W/D ratios, sinuosity, pools, cool water habitat
  - Improved number of trout
- **Recommendations**
  - Livestock exclusion alone is not enough to recover sensitive aquatic life if stream channel & habitat remain degraded
  - Pool habitat provided critical temperature refugia

* From Jean Spooner – NC State, 2008



Receiving Water Models (continued)

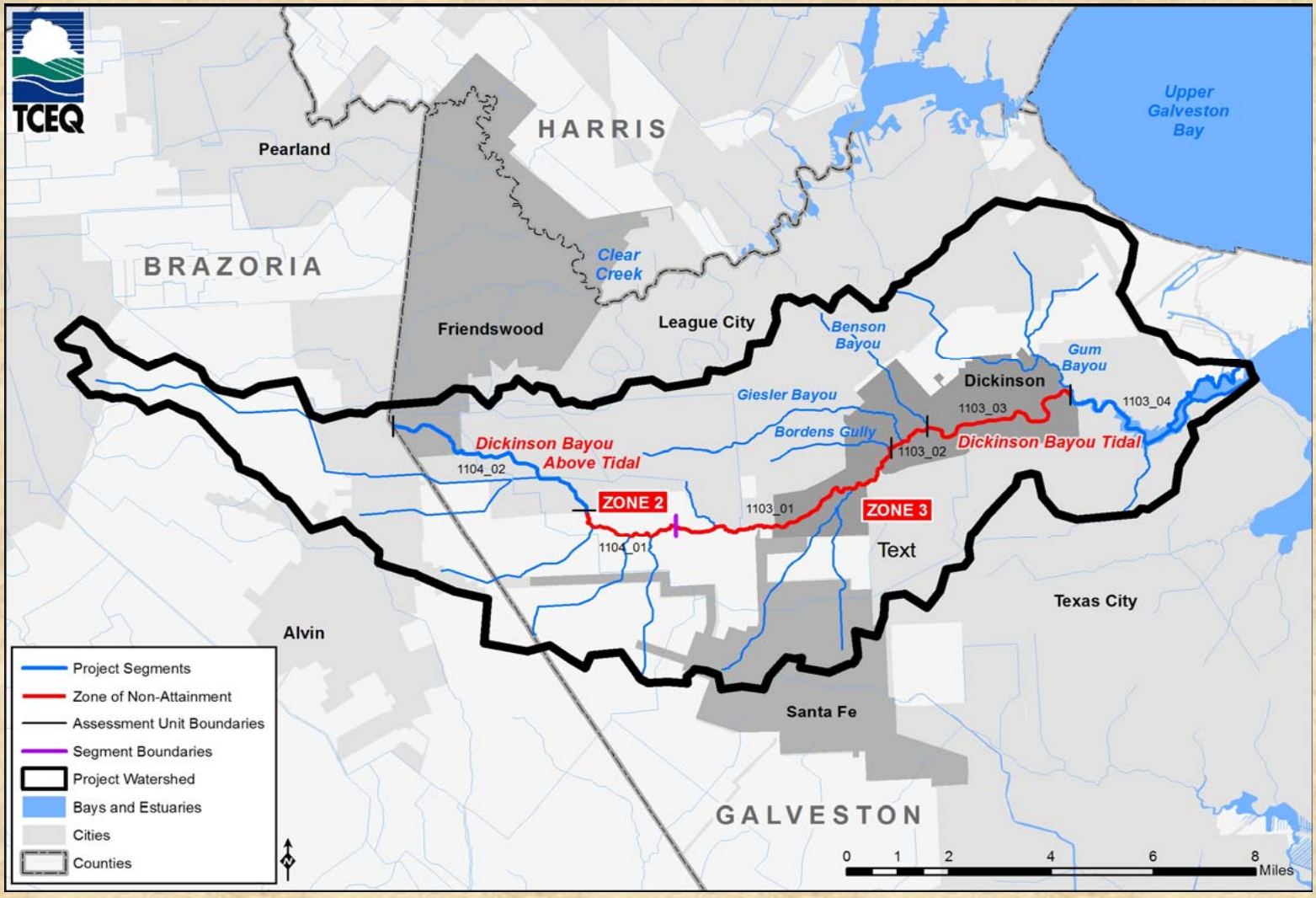
- They typically use specialized software designed to simulate natural processes
- A detailed “model” of the natural systems is constructed using linked mathematical algorithms
- They provide a quantitative link between pollutant loadings and conditions in the water body
- The use of a particular simulation software is dictated by the complexity of the water quality impairment
- Their use is sometimes inappropriate (i.e., bigger isn’t always better)

Receiving Water Models (continued)

- It is important to realize that models are always wrong! But, sometimes they are useful
- They require trained professionals with expertise and experience to run them
- They require substantial amounts of data
- They are typically expensive and time consuming

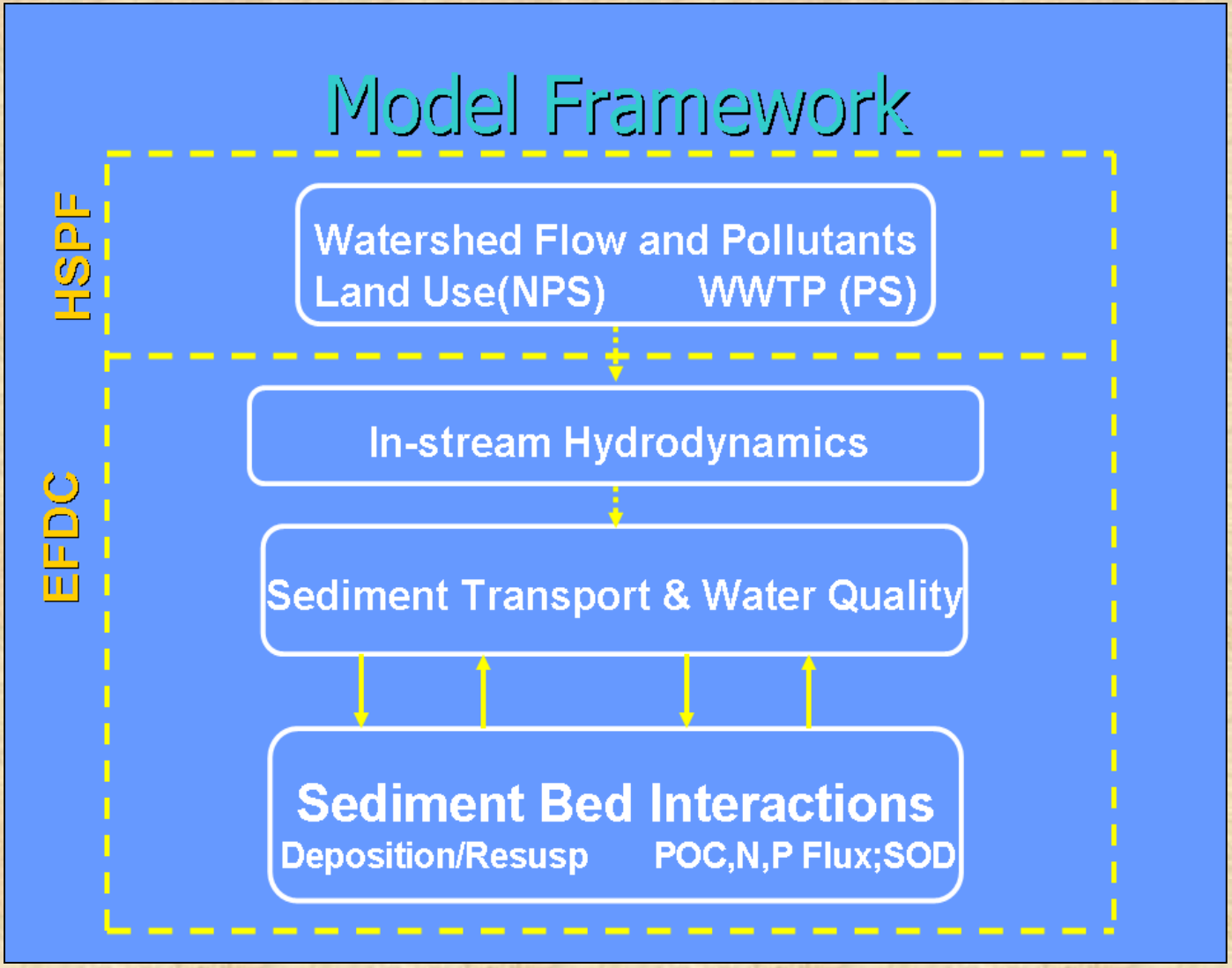
Receiving Water Models (cont.)

Dickinson Bayou Example



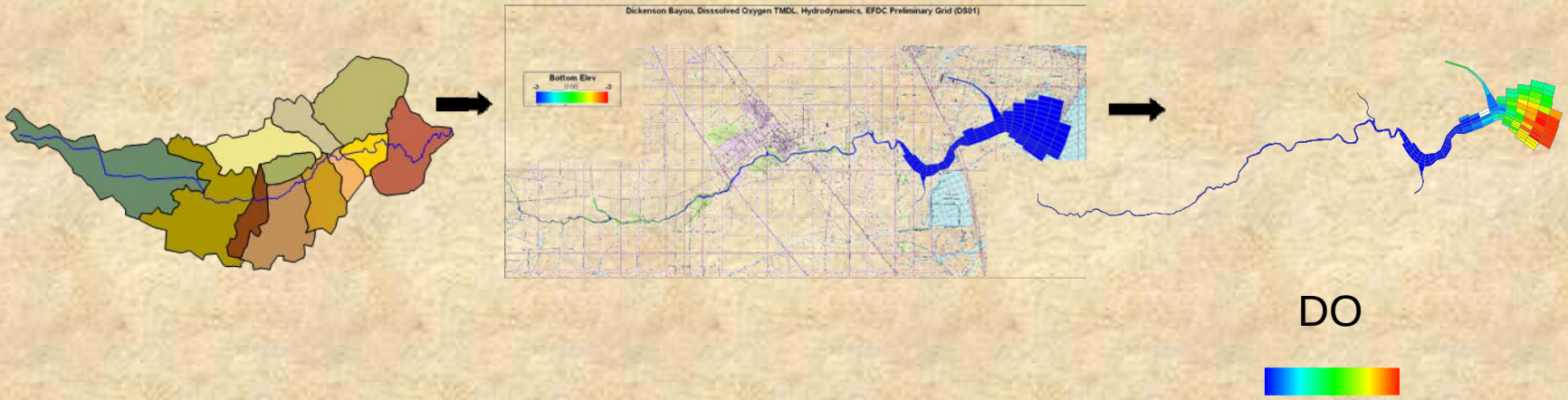
Receiving Water Models (cont.)

Dickinson Bayou Example

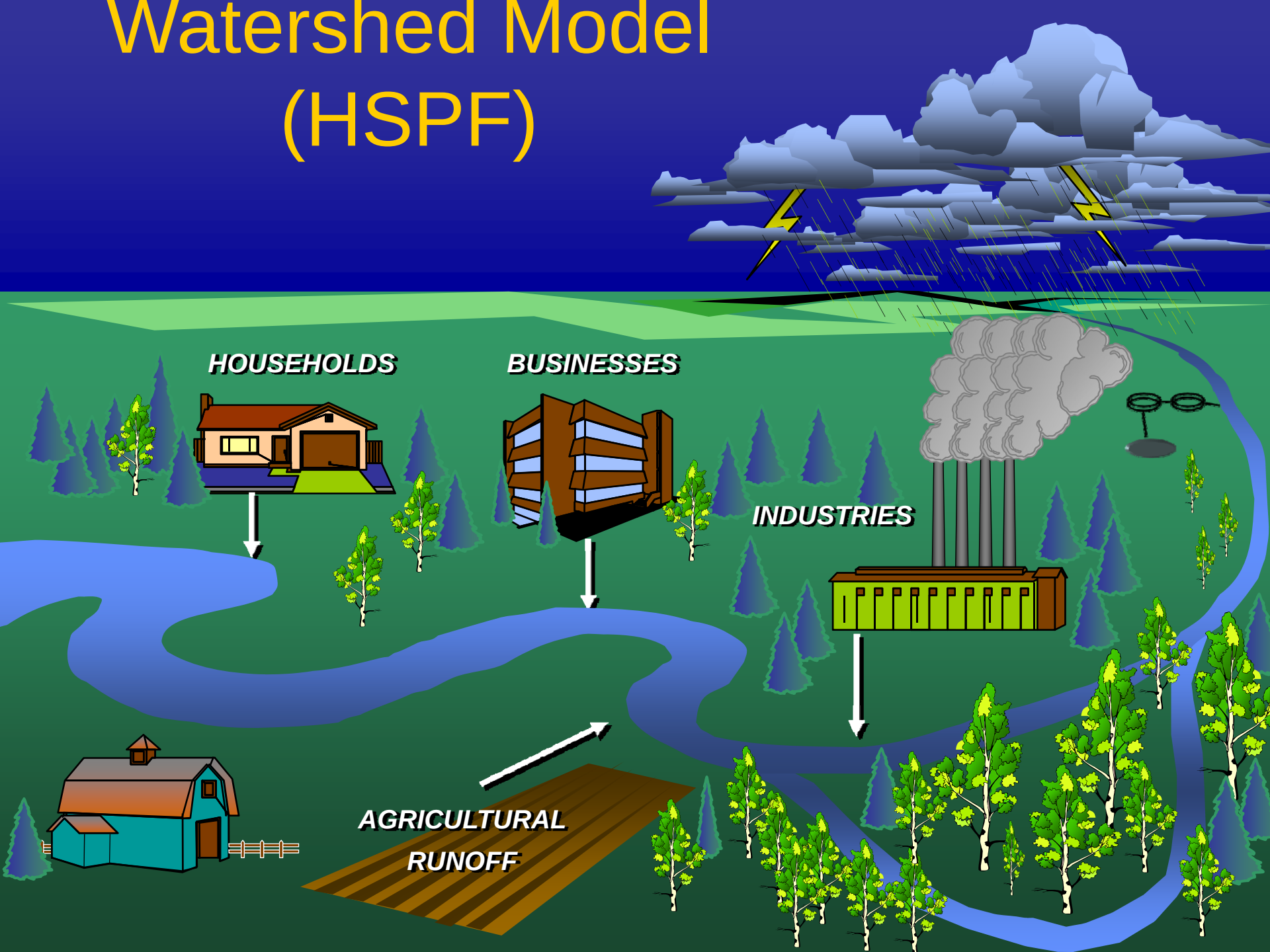


Receiving Water Models (continued)

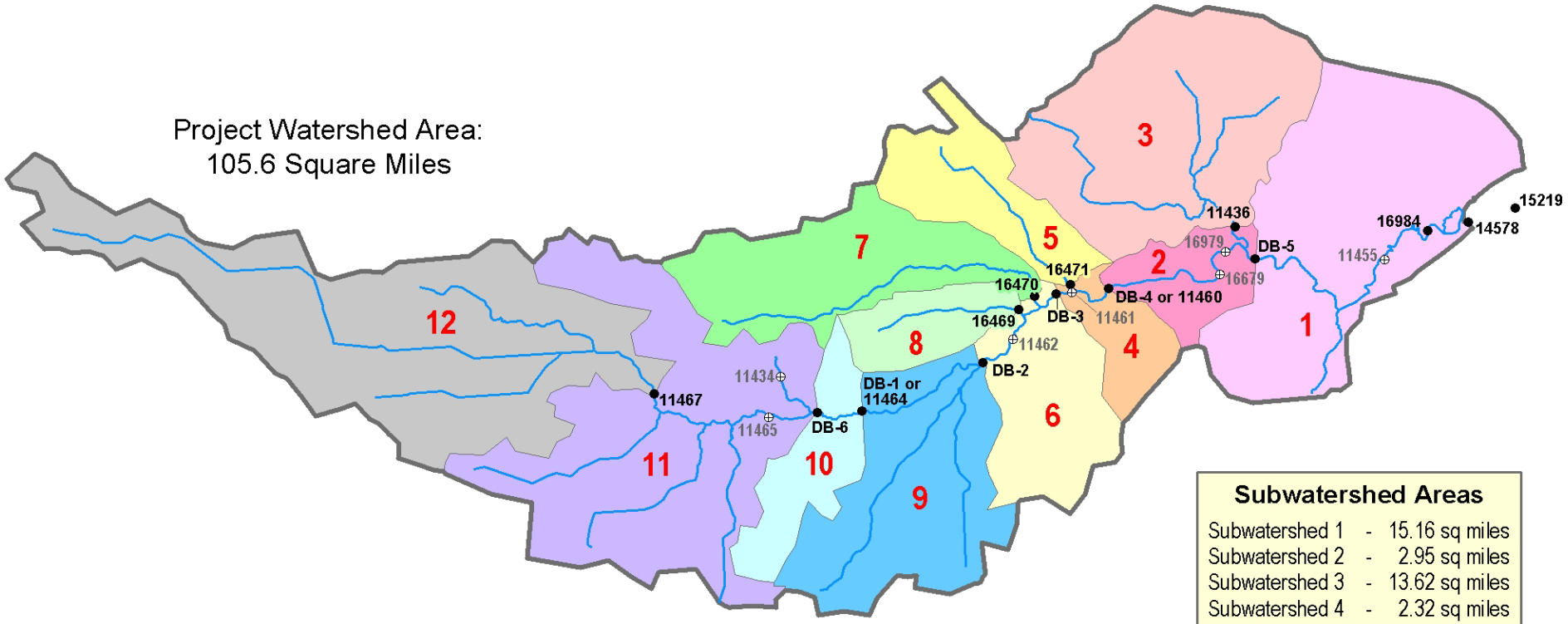
- Watershed Model (HSPF)
- Hydrodynamic Model (EFDC)
- In-stream Water Quality Model (EFDC)



Watershed Model (HSPF)



Monitoring Sites and Subwatersheds for Dickinson Bayou

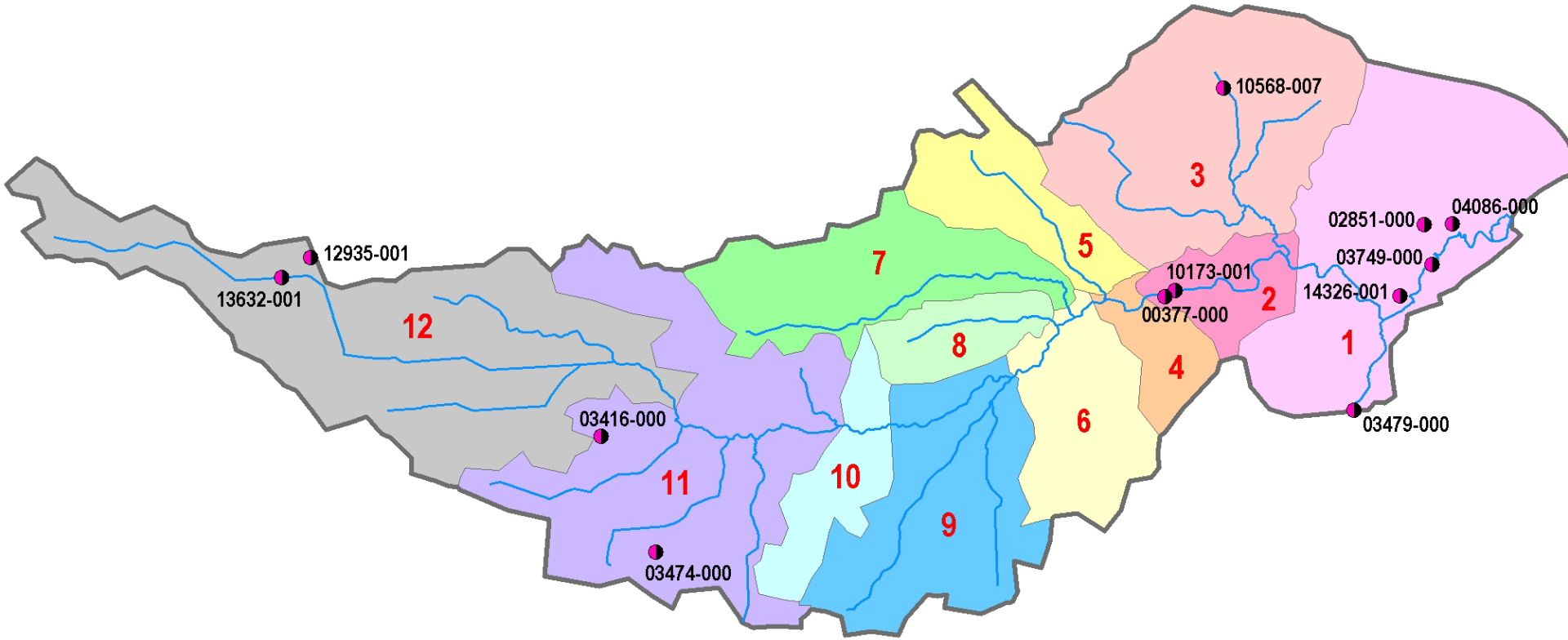


Subwatershed Areas

Subwatershed 1	-	15.16 sq miles
Subwatershed 2	-	2.95 sq miles
Subwatershed 3	-	13.62 sq miles
Subwatershed 4	-	2.32 sq miles
Subwatershed 5	-	4.87 sq miles
Subwatershed 6	-	5.78 sq miles
Subwatershed 7	-	7.89 sq miles
Subwatershed 8	-	2.79 sq miles
Subwatershed 9	-	9.76 sq miles
Subwatershed 10	-	3.75 sq miles
Subwatershed 11	-	16.96 sq miles
Subwatershed 12	-	19.78 sq miles

Revised 8/23/04

Outfall Locations for Dickinson Bayou

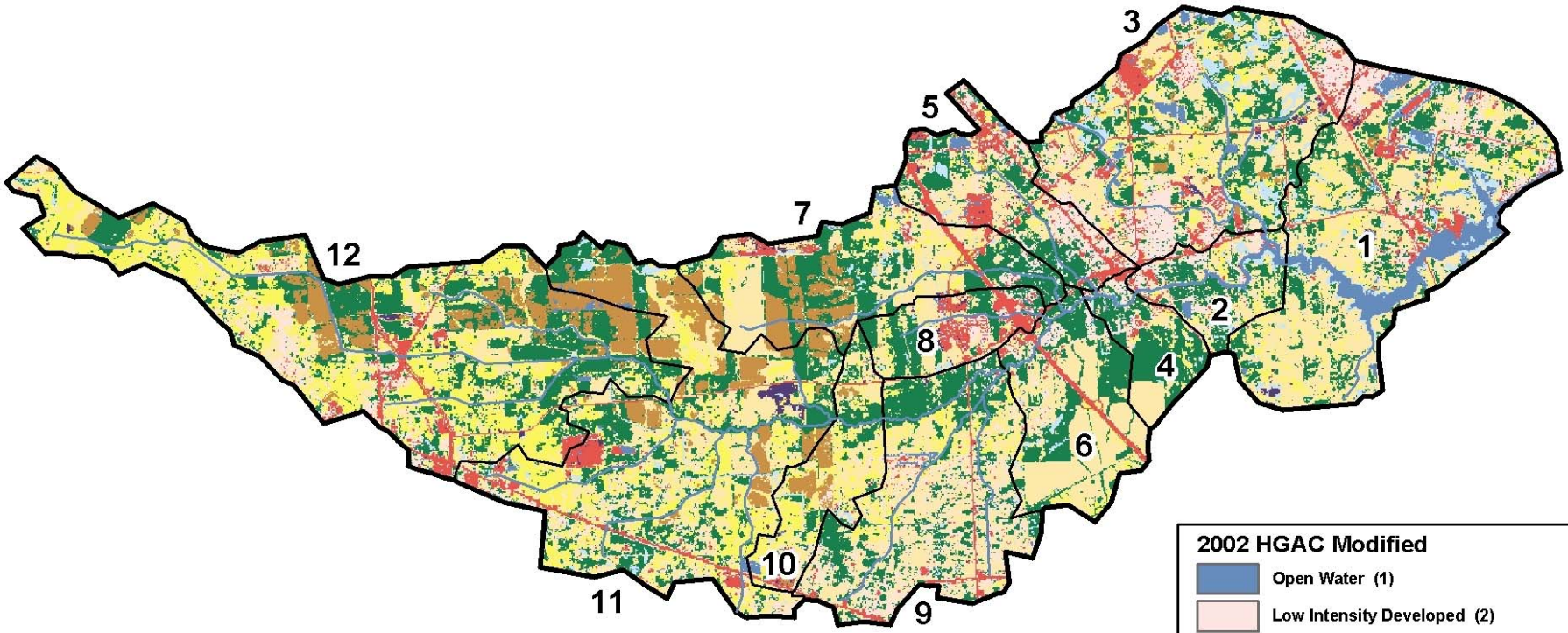


Miles

0 1 2 3 4 5

Revised 8/23/04

Land Use / Land Cover for Dickinson Bayou



2002 HGAC Modified

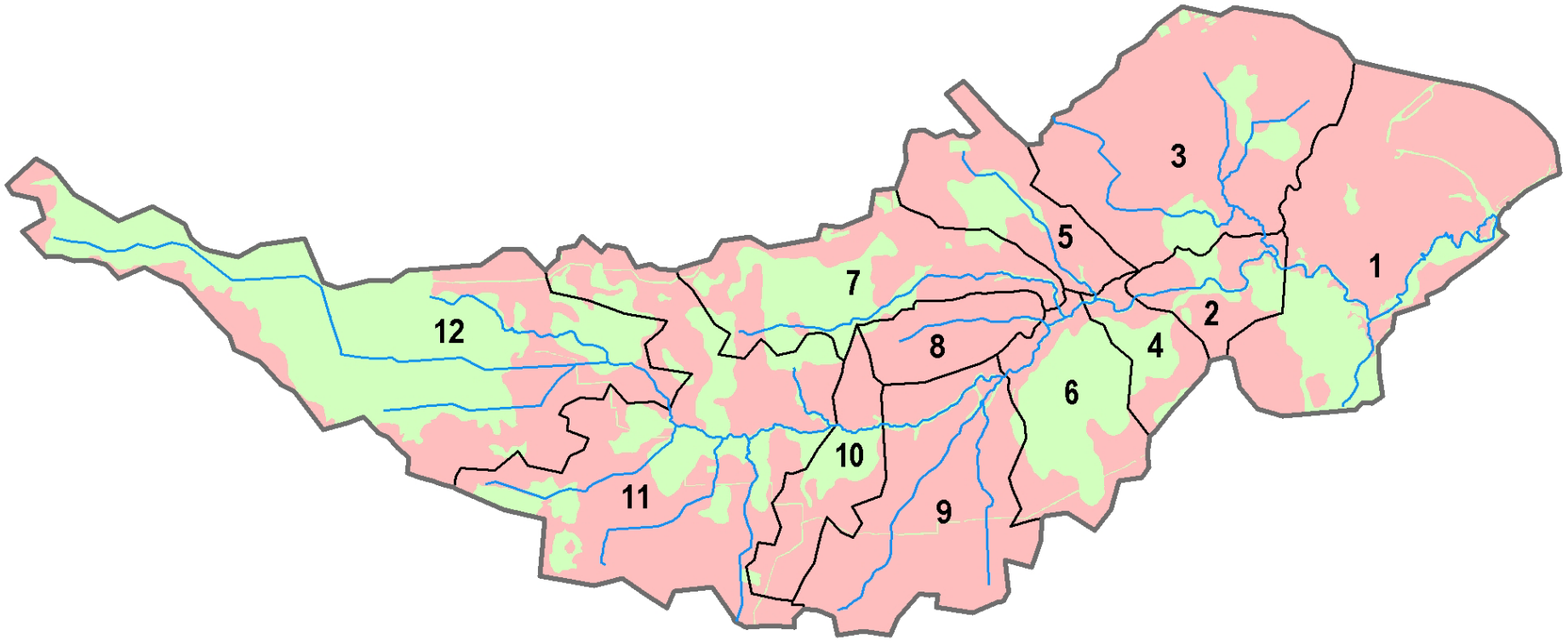
- Open Water (1)
- Low Intensity Developed (2)
- High Intensity Developed (3)
- Barren (4)
- Woody Land (5)
- Grassland (6)
- Cultivated Land (7)
- Pasture / Hay (8)
- Wetlands (9)

Miles

0 1 2 3 4 5

Revised 8/25/0

Soil Drainage for Dickinson Bayou



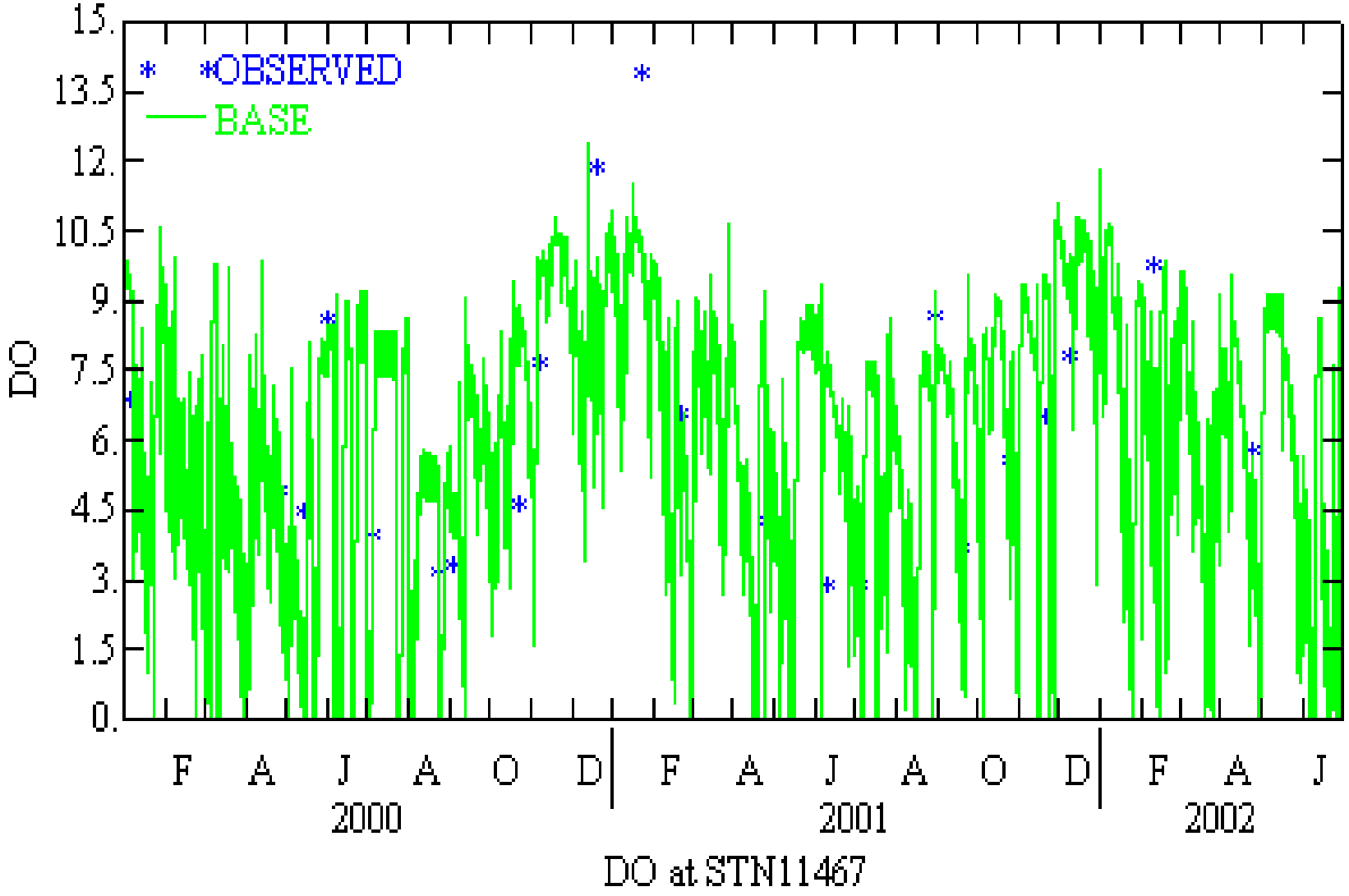
SSURGO Drainage Class

- 1 - Well & Moderately Well
- 2 - Somewhat Poorly, Poorly & Very Poorly

Miles

0 1 2 3 4 5

Revised 8/23/04


*OBSERVED
BASE
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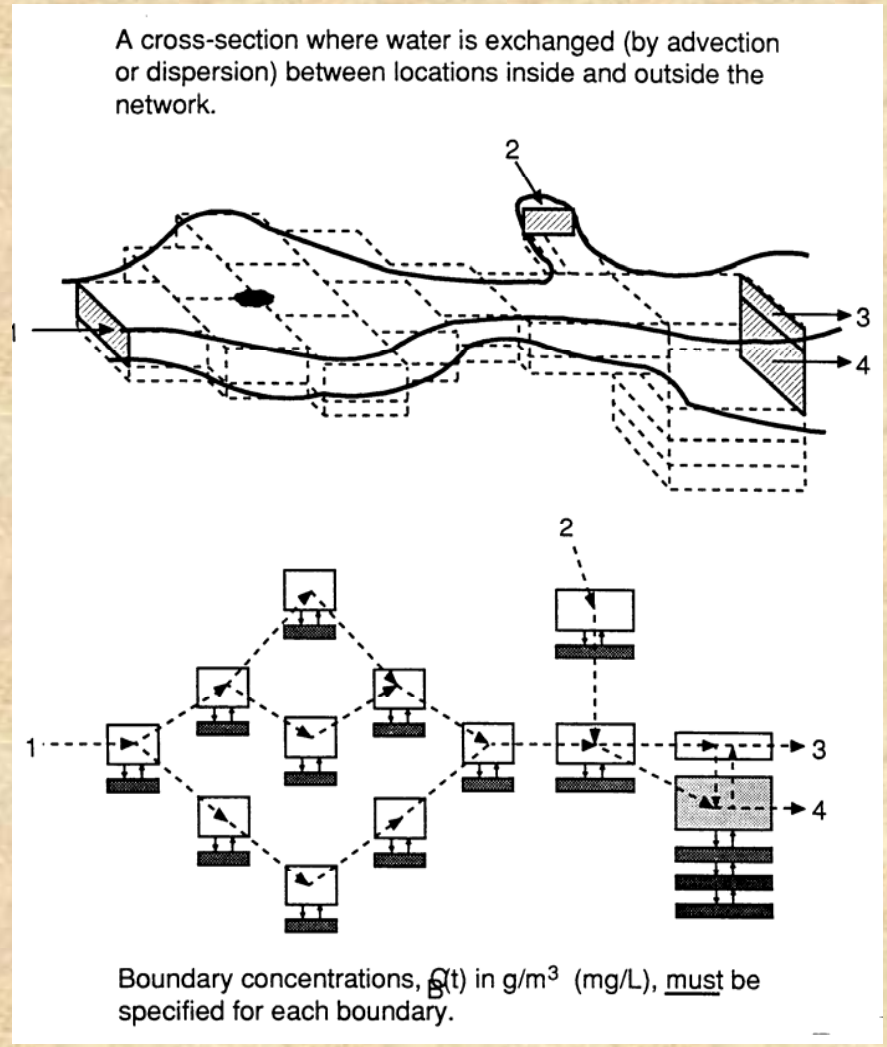
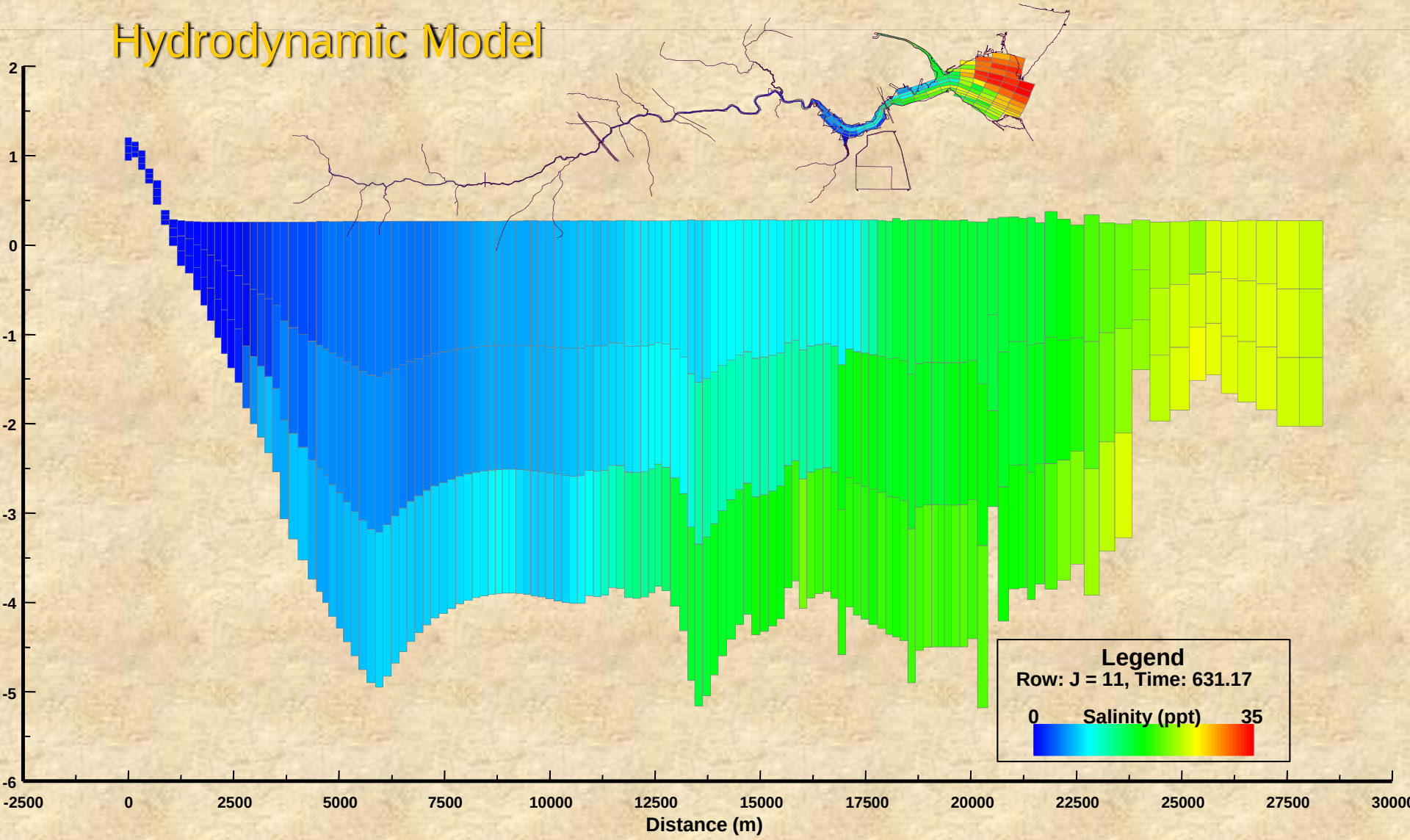
3-D Hydrodynamic and Water Quality Model

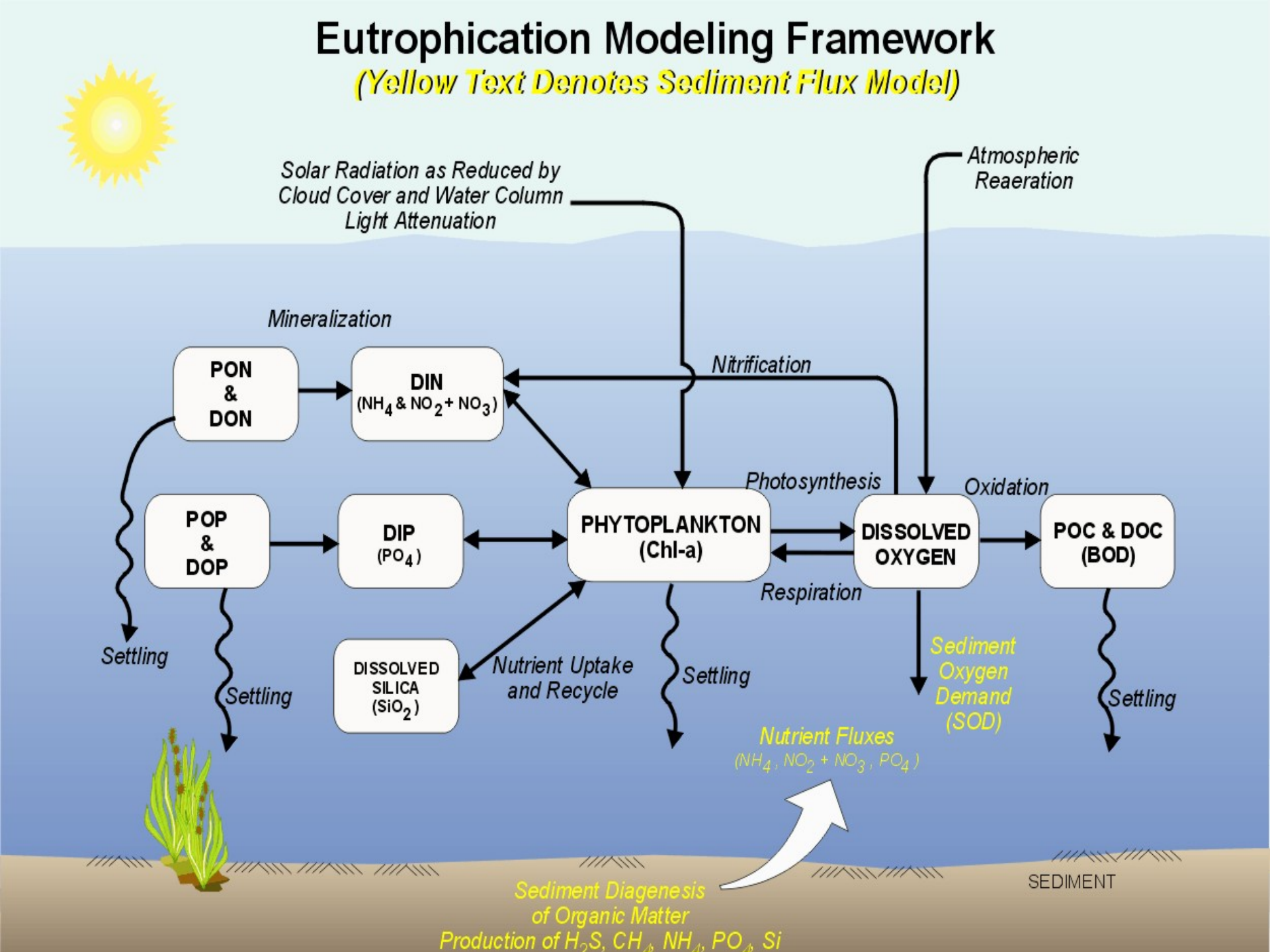


Hydrodynamic Model



Eutrophication Modeling Framework

(Yellow Text Denotes Sediment Flux Model)



Receiving Water Models (continued)

DO Simulation

Animation

(time permitting)

Focusing Load Reductions

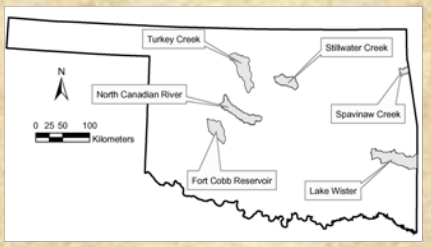
Why Focus Load Reductions?

- Many pollutant sources contribute disproportionately to impairments (magnitude)
- The location of certain pollutant sources makes them more critical than others (proximity)
- A more focused approach to load reductions is more cost effective (economics)

When using receiving water models, EPA recommends using a “top-down” approach

Focusing Load Reductions (cont.)

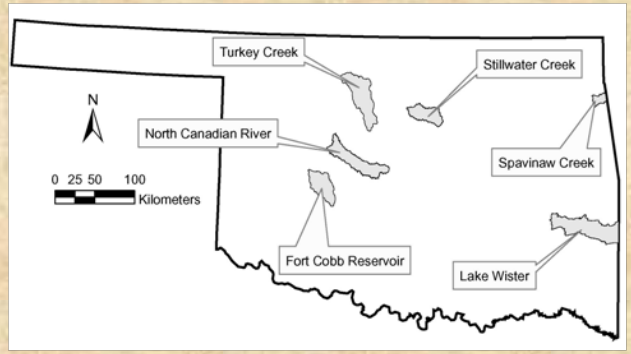
- An area that contributes a disproportionate pollutant amount compared to other areas of the watershed
  - Mass/unit area
  - kg/ha, lbs/ac
- Typically only portions of sub-watersheds

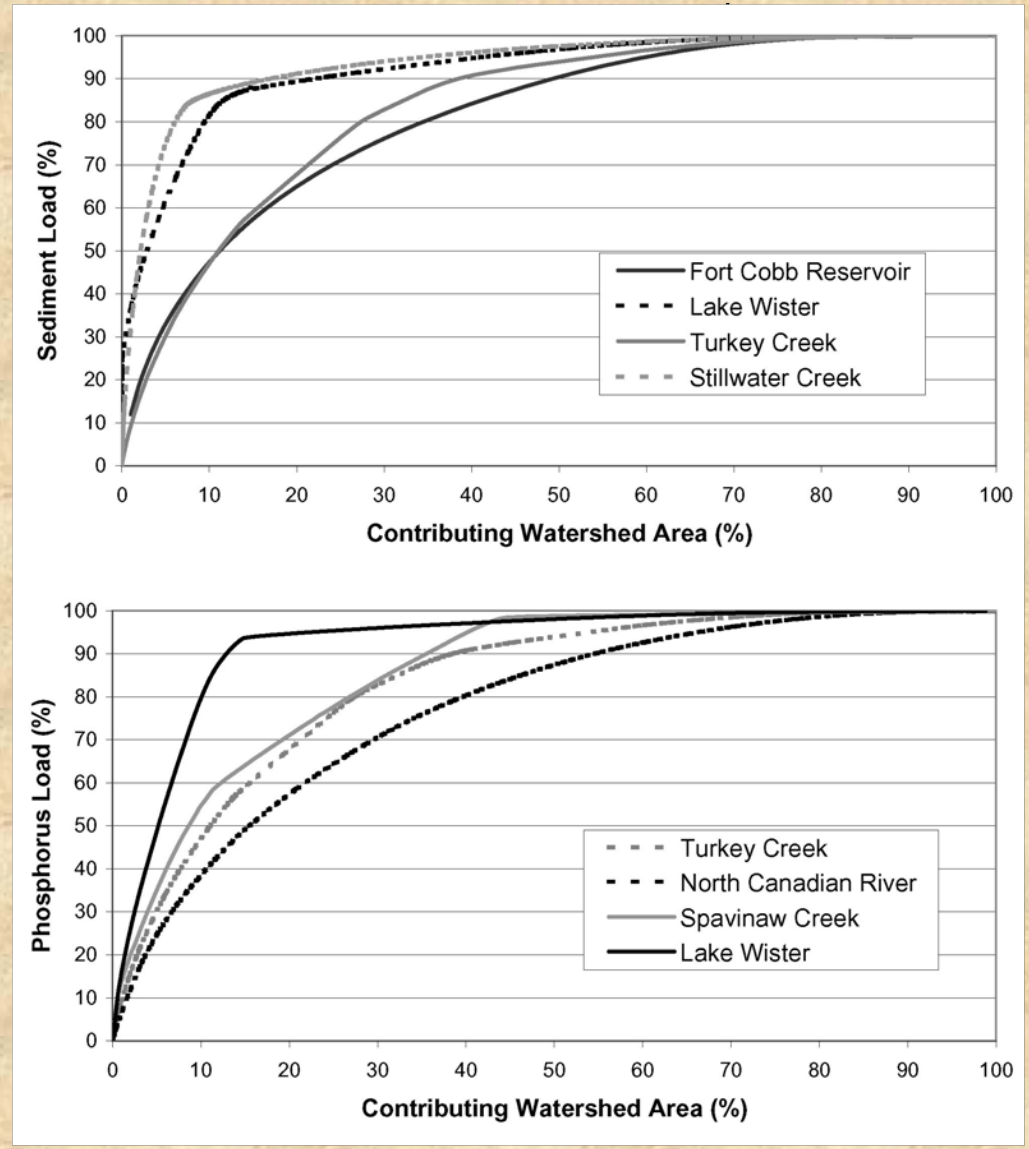


*From D. Storm – OSU, 2008

Focusing Load Reductions (cont.)

- Small areas can contribute the majority of pollutants
- 5% basin area
  - 36% Sediment
  - 21% Phosphorus





* From D. Storm – OSU, 2008

Summarizing Watershed Targets and Load Reductions Needed

- Load reductions should be calculated and presented at the same time and spatial scales as the source load estimations
- Include a summary of other watershed targets (i.e., pebble imbeddedness, percent fine sediment, etc.)
- Don’t forget programmatic and social indicators