Water-Quality Monitoring– An Overview of Select Projects from the USGS Texas Water Science Center

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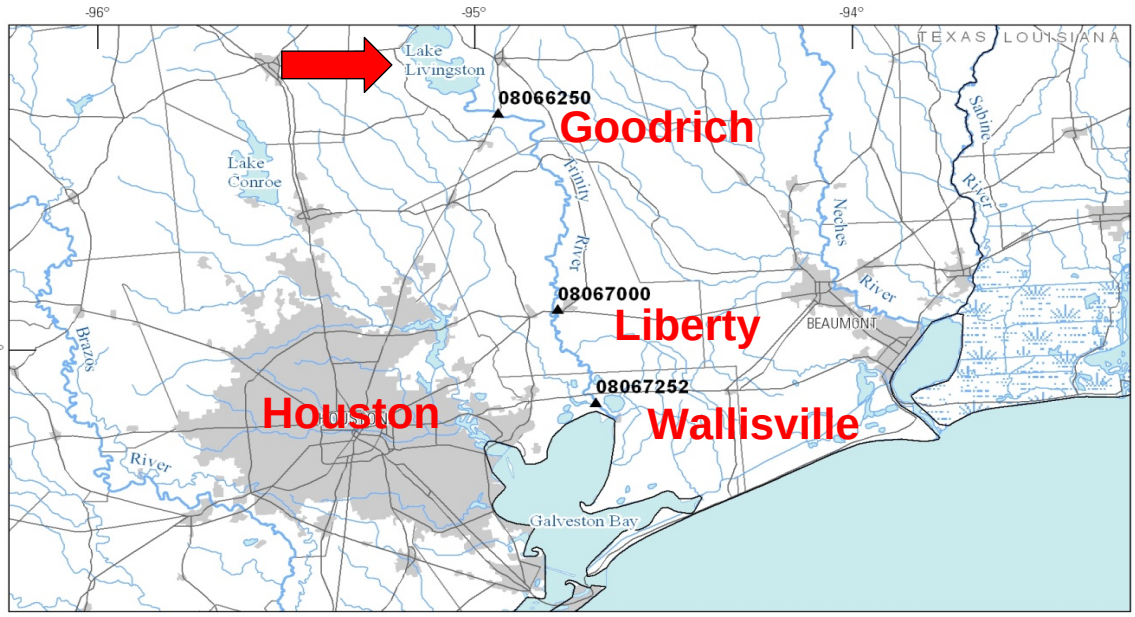
U.S. Department of the Interior
U.S. Geological Survey

TSSWCB

March, 2011

OVERVIEW

- Coastal Loads Evaluation
- Lake Houston and Inflow Monitoring



Base from:
U.S. Geological Survey,
The National Atlas of the
United States 1:2,000,000

Texas Centric Mapping System
Projection: Albers Equal Area
Linear Unit: Meter
Datum: North American Datum of 1983

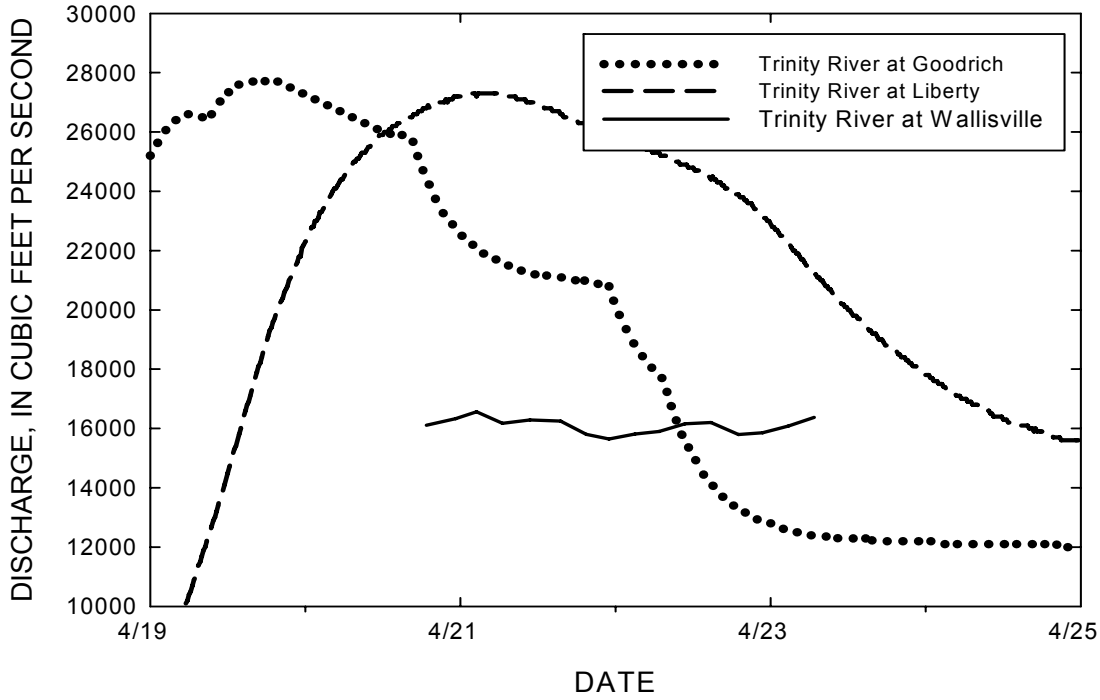
0 30 60 Miles

0 30 60 Kilometers

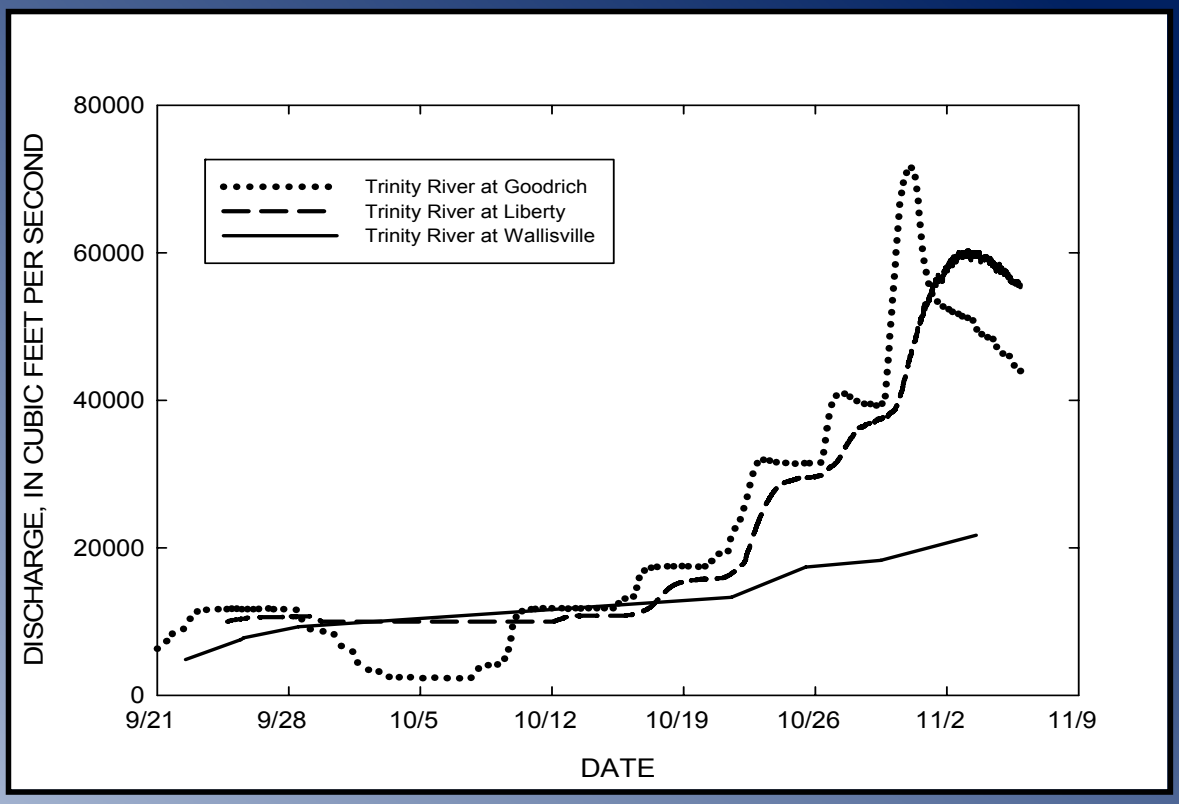
EXPLANATION

▲ Stream gage

USGS


DISCHARGE, IN CUBIC FEET PER SECOND
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
4/19
4/21
4/23
4/25
DATE
Trinity River at Goodrich
Trinity River at Liberty
Trinity River at Wallisville

USGS


80000
60000
40000
20000
0
DISCHARGE, IN CUBIC FEET PER SECOND
Trinity River at Goodrich
Trinity River at Liberty
Trinity River at Wallisville
9/21
9/28
10/5
10/12
10/19
10/26
11/2
11/9
DATE

USGS

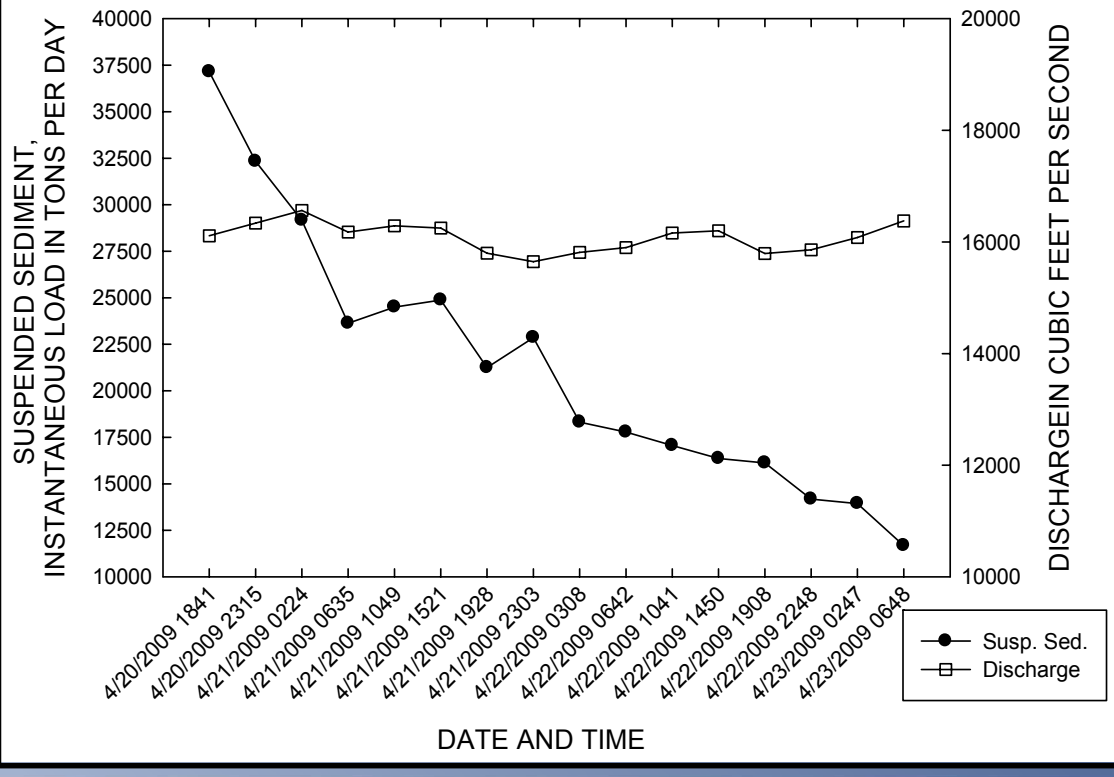
Liberty County
Chambers County
Mac Bayou
Lake Charlotte
H L & P Cooling Pond

USGS

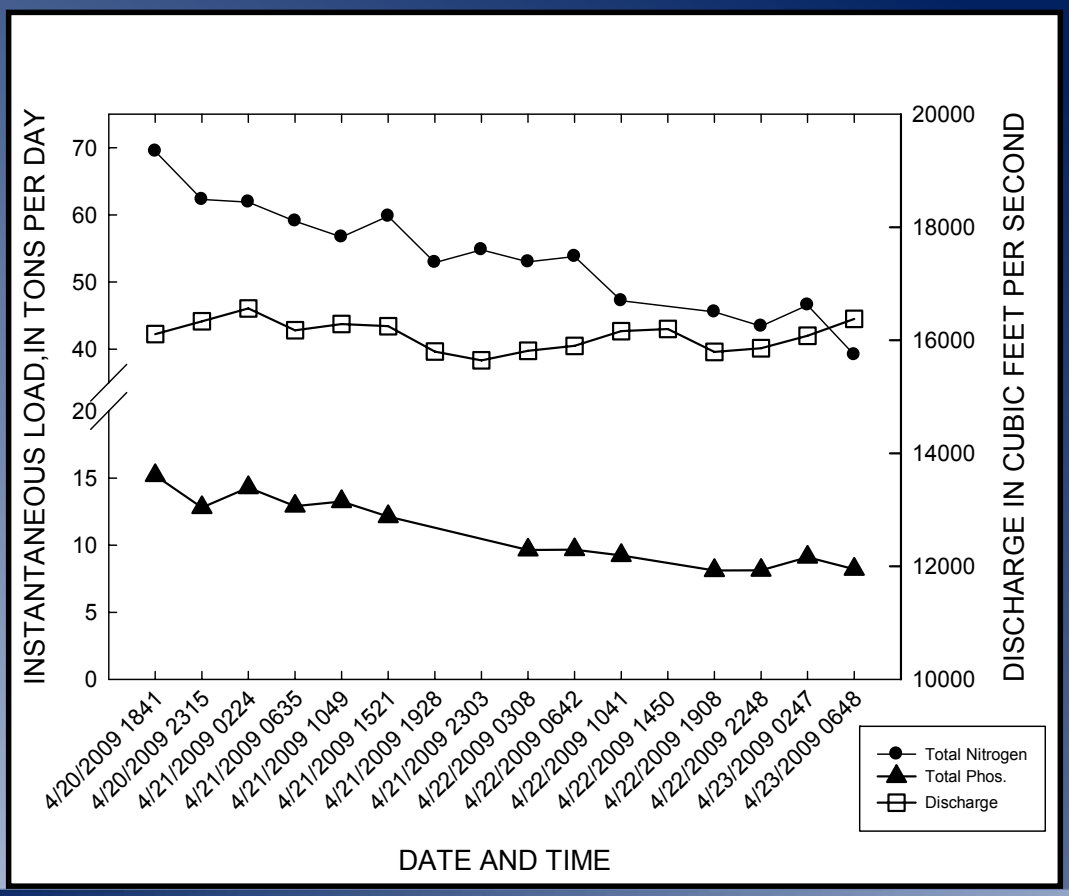
USGS

- Physical Water Properties
  Water Temperature, pH, Specific Conductance, Dissolved Oxygen Concentration, Turbidity
- Nutrients – Total and Filtered Components
  Ammonia, Nitrite, Nitrite+Nitrate, Orthophosphate
- Sediment - Suspended Sediment Concentration and Sand/Fine Break
- Discharge

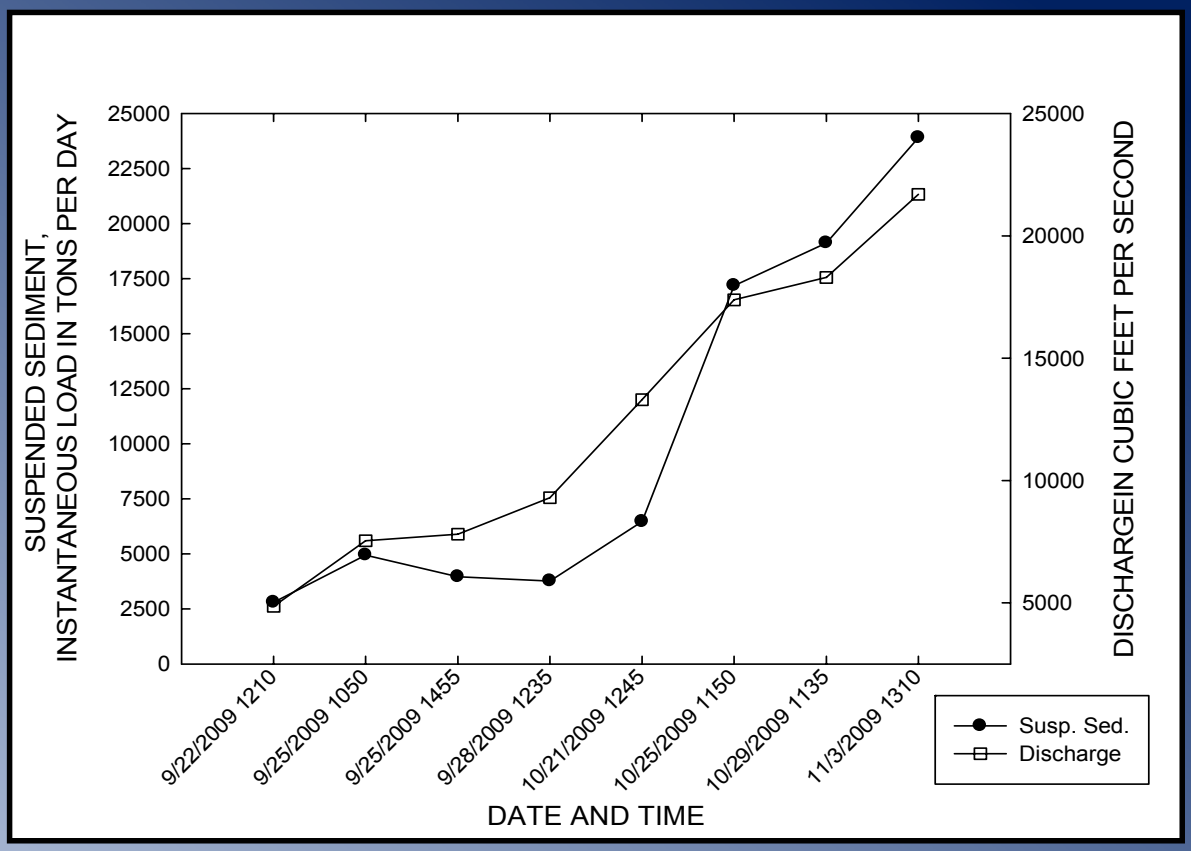
USGS


SUSPENDED SEDIMENT,
INSTANTANEOUS LOAD IN TONS PER DAY
40000
37500
35000
32500
30000
27500
25000
22500
20000
17500
15000
12500
10000
20000
18000
16000
14000
12000
10000
DISCHARGEIN CUBIC FEET PER SECOND
4/20/2009 1841
4/20/2009 2315
4/21/2009 0224
4/21/2009 0635
4/21/2009 1049
4/21/2009 1521
4/21/2009 1928
4/21/2009 2303
4/22/2009 0308
4/22/2009 0642
4/22/2009 1041
4/22/2009 1450
4/22/2009 1908
4/22/2009 2248
4/23/2009 0247
4/23/2009 0648
Susp. Sed.
Discharge
DATE AND TIME

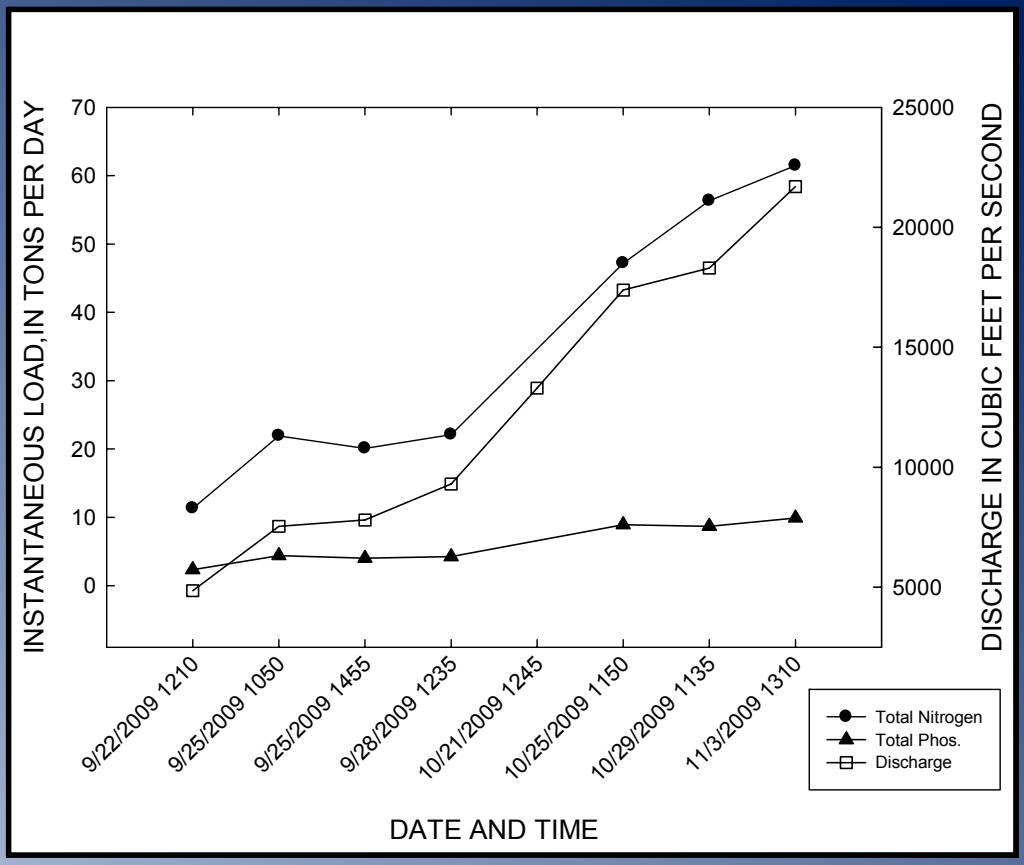
USGS


INSTANTANEOUS LOAD,IN TONS PER DAY
70
60
50
40
20
15
10
5
0
20000
18000
16000
14000
12000
10000
DISCHARGE IN CUBIC FEET PER SECOND
4/20/2009 1841
4/20/2009 2315
4/21/2009 0224
4/21/2009 0635
4/21/2009 1049
4/21/2009 1521
4/21/2009 1928
4/21/2009 2303
4/22/2009 0308
4/22/2009 0642
4/22/2009 1041
4/22/2009 1450
4/22/2009 1908
4/22/2009 2248
4/23/2009 0247
4/23/2009 0648
DATE AND TIME
Total Nitrogen
Total Phos.
Discharge

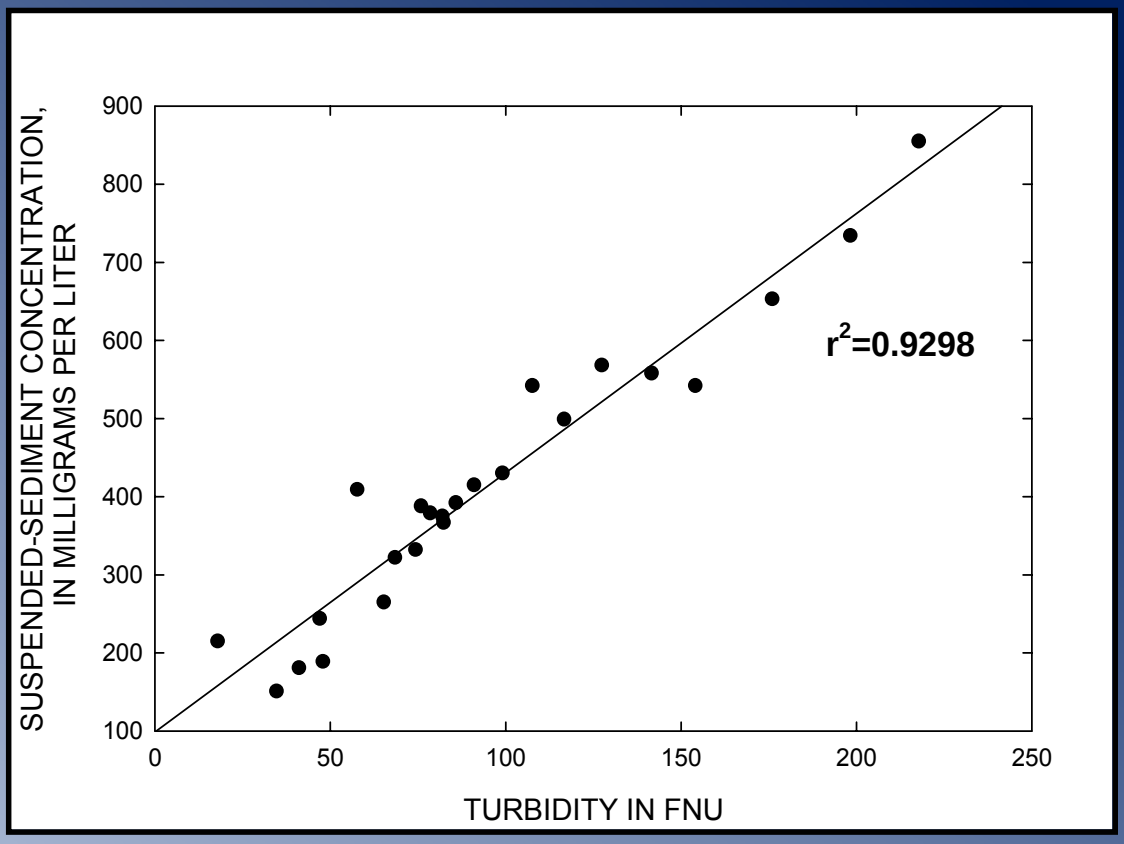
USGS


SUSPENDED SEDIMENT,
INSTANTANEOUS LOAD IN TONS PER DAY
25000
22500
20000
17500
15000
12500
10000
7500
5000
2500
0
DISCHARGEIN CUBIC FEET PER SECOND
25000
20000
15000
10000
5000
9/22/2009 1210
9/25/2009 1050
9/25/2009 1455
9/28/2009 1235
10/21/2009 1245
10/25/2009 1150
10/29/2009 1135
11/3/2009 1310
DATE AND TIME
Susp. Sed.
Discharge

USGS


INSTANTANEOUS LOAD,IN TONS PER DAY
70
60
50
40
30
20
10
0
25000
20000
15000
10000
5000
DISCHARGE IN CUBIC FEET PER SECOND
9/22/2009 1210
9/25/2009 1050
9/25/2009 1455
9/28/2009 1235
10/21/2009 1245
10/25/2009 1150
10/29/2009 1135
11/3/2009 1310
Total Nitrogen
Total Phos.
Discharge
DATE AND TIME

USGS

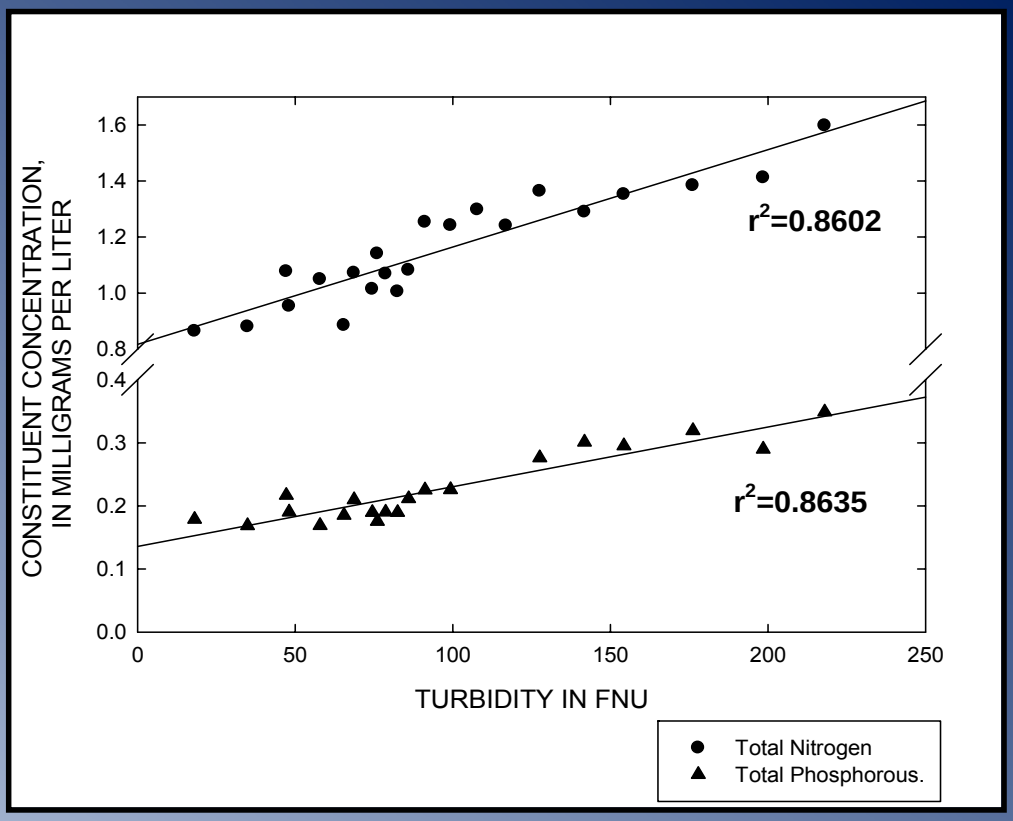

SUSPENDED-SEDIMENT CONCENTRATION, IN MILLIGRAMS PER LITER
900
800
700
600
500
400
300
200
100
0
50
100
150
200
250
TURBIDITY IN FNU
r2=0.9298

USGS

Ranges of percentages of filtered component concentrations in total nutrient constituents

Constituent	April 20–23, 2009	September 22–November 3, 2009
Filtered ammonia (NH_3)	<LRL – 8.9%	<LRL – 7.6%
Filtered nitrite (NO_2)	0.5% – 1.5%	<LRL – 3.3%
Filtered nitrite + nitrate ($NO_2 + NO_3$)	11.0% – 13.8%	<LRL – 37.8%
Orthophosphate (*o*-PO_4)	<LRL – 6.6%	11.4% – 24.8%

USGS


CONSTITUENT CONCENTRATION, IN MILLIGRAMS PER LITER
1.6
1.4
1.2
1.0
0.8
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
TURBIDITY IN FNU
r2=0.8602
r2=0.8635
Total Nitrogen
Total Phosphorous.

USGS

Conclusions

- Suspended sediment transport in the lower reaches of the Trinity can show considerable variability based on high-flow event origin and magnitude. Timing and magnitude very difficult to predict.
- Because of the surrounding wetlands, discharge and sediment response does not appear to follow typical patterns and demonstrate their importance in the processing of excessive sediment entering the system.

USGS

Conclusions

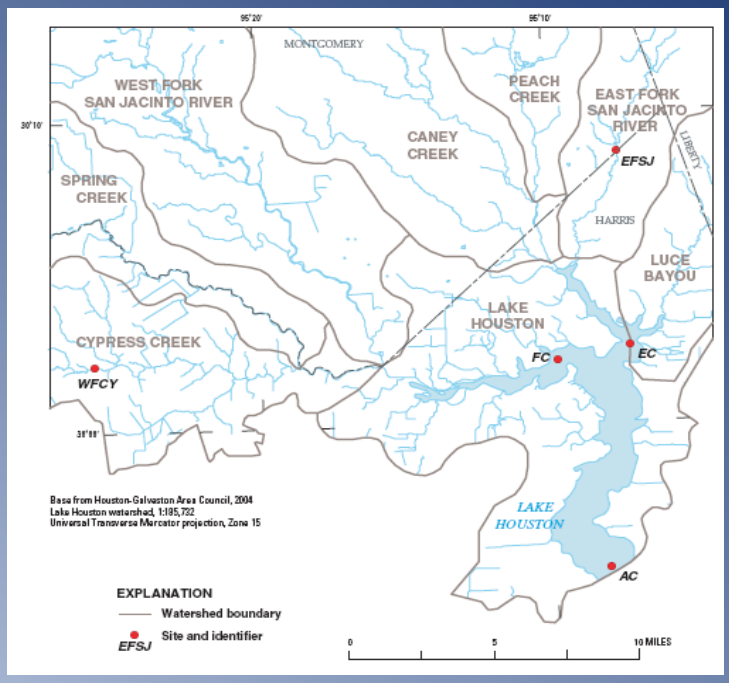
- The extent of nutrient loads during high-flow events from the Trinity appear to be correlated to the suspended sediment load demonstrating the importance sediment monitoring may be in water quality assessments.
- Preliminary data suggests continuous turbidity measurements may prove to be a successful surrogate to estimate suspended sediment concentrations AND nutrients entering Galveston Bay

OVERVIEW

- Coastal Loads Evaluation

- Lake Houston and Inflow Monitoring

Study Area

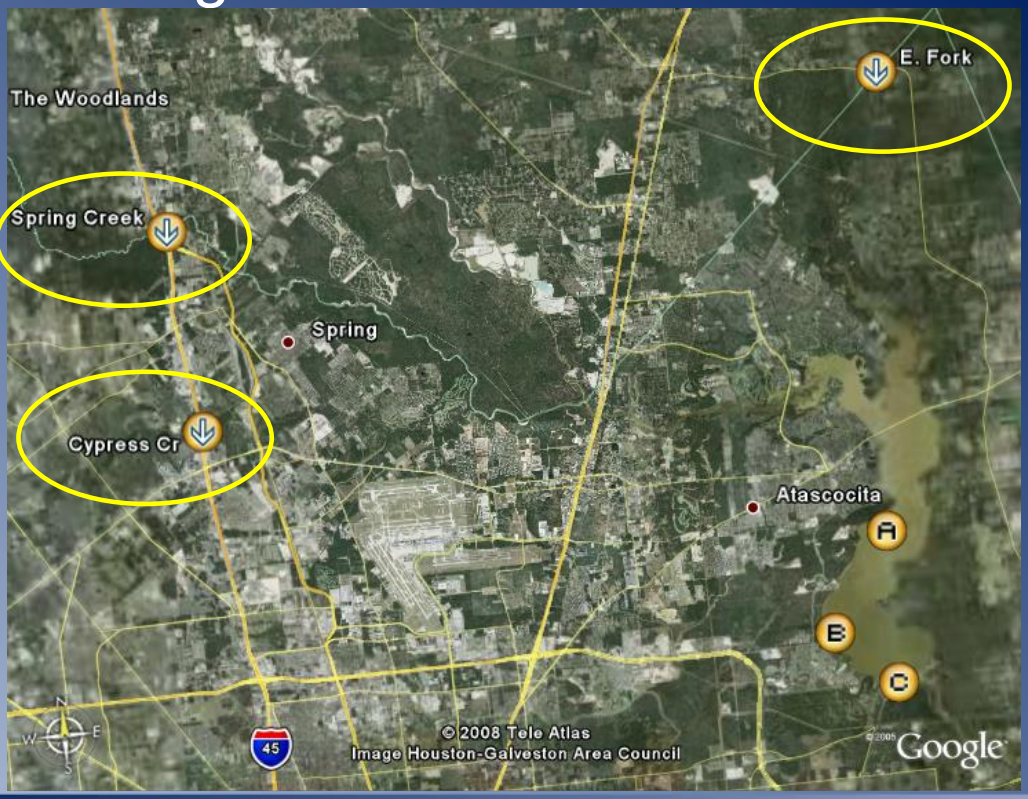


- Drainage area 2,835 mi^2
- Land use is rural, transitional, and urban
- Western subbasin predominately urban
- Eastern subbasin predominately rural

USGS

Figures from Sneck-Fahrer and others, 2005, USGS SIR 2005-5241

Monitoring Sites



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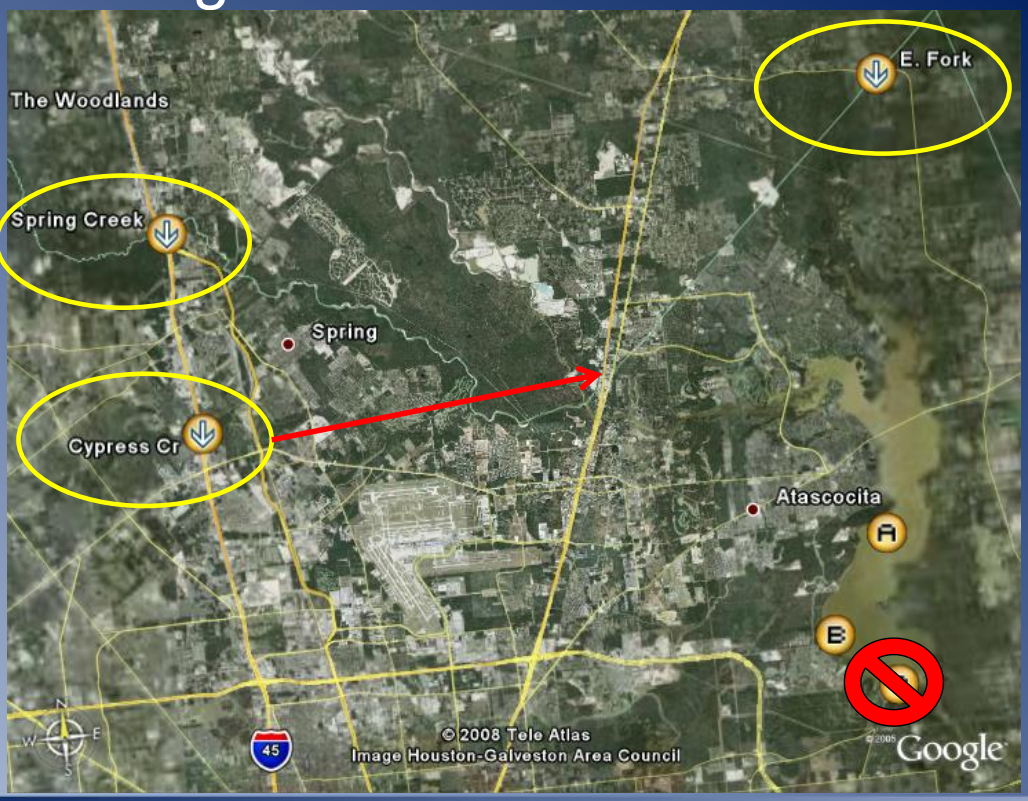
Monitoring Sites



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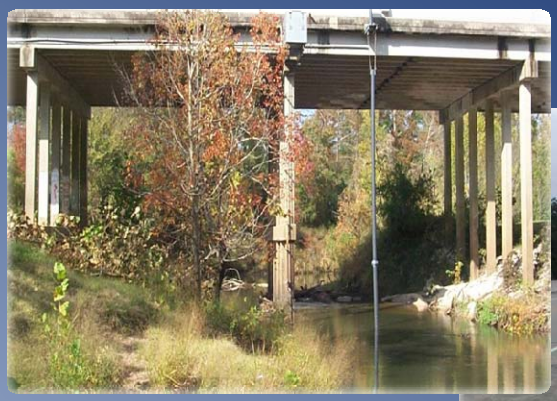
Watershed Monitoring

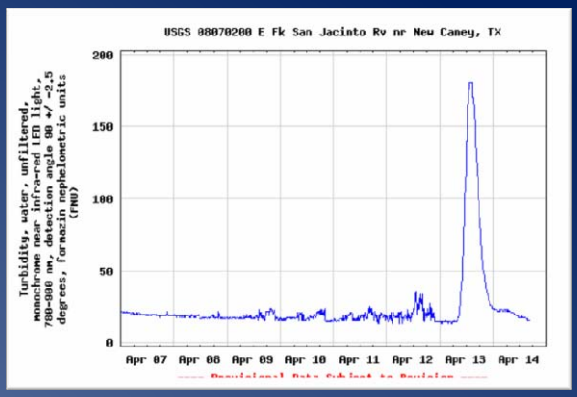


East Fork San Jacinto River near New Caney

In-Lake Monitoring

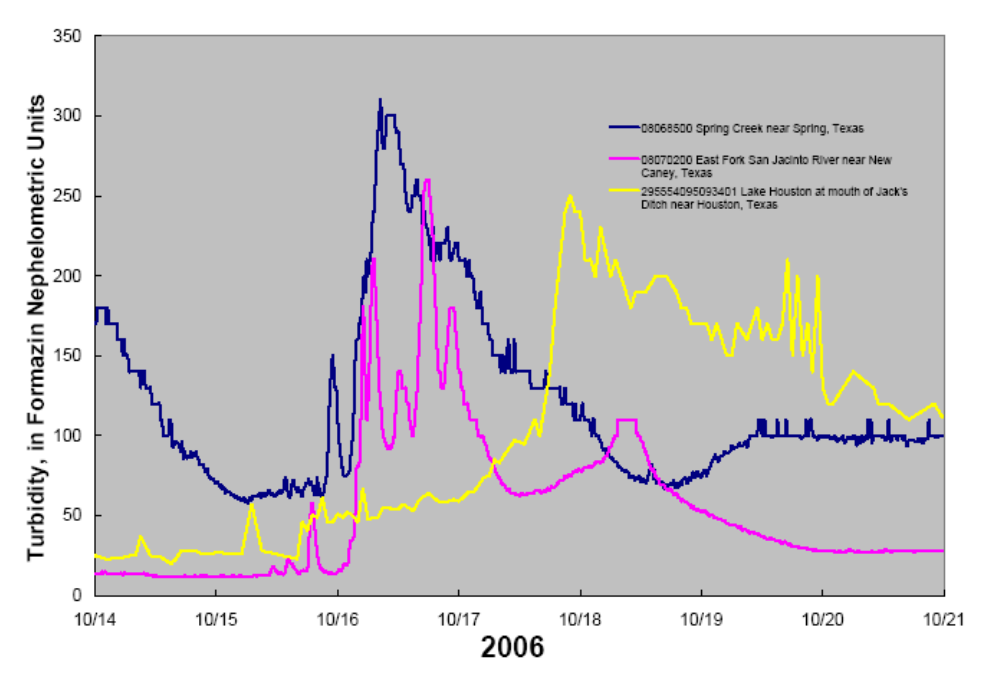
Monitoring Approach

- Continuous water-quality monitoring
  - Turbidity, dissolved oxygen, water temperature, specific conductance, and pH

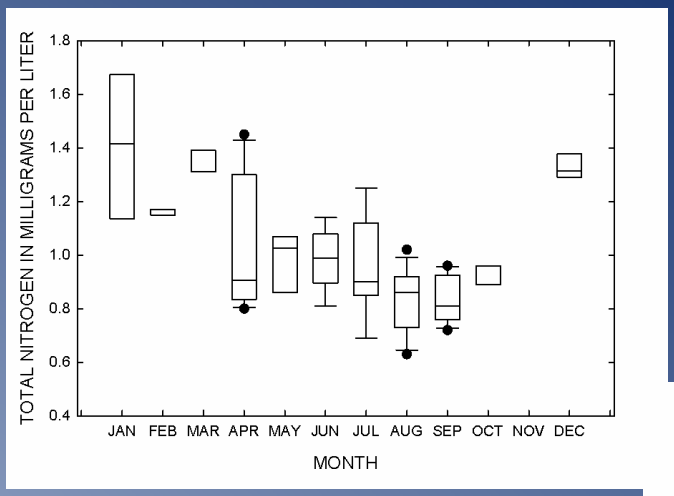


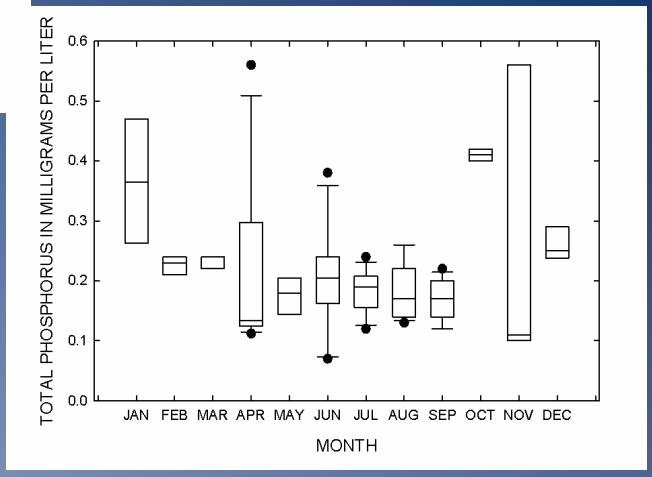
- Discrete sampling
  - Nutrients, sediment, and others

Time of Travel Estimation



Lake Houston at Mouth of Jack's Ditch and inflow turbidity data (zoom)





Data set from 2005 plus historical data from previous projects

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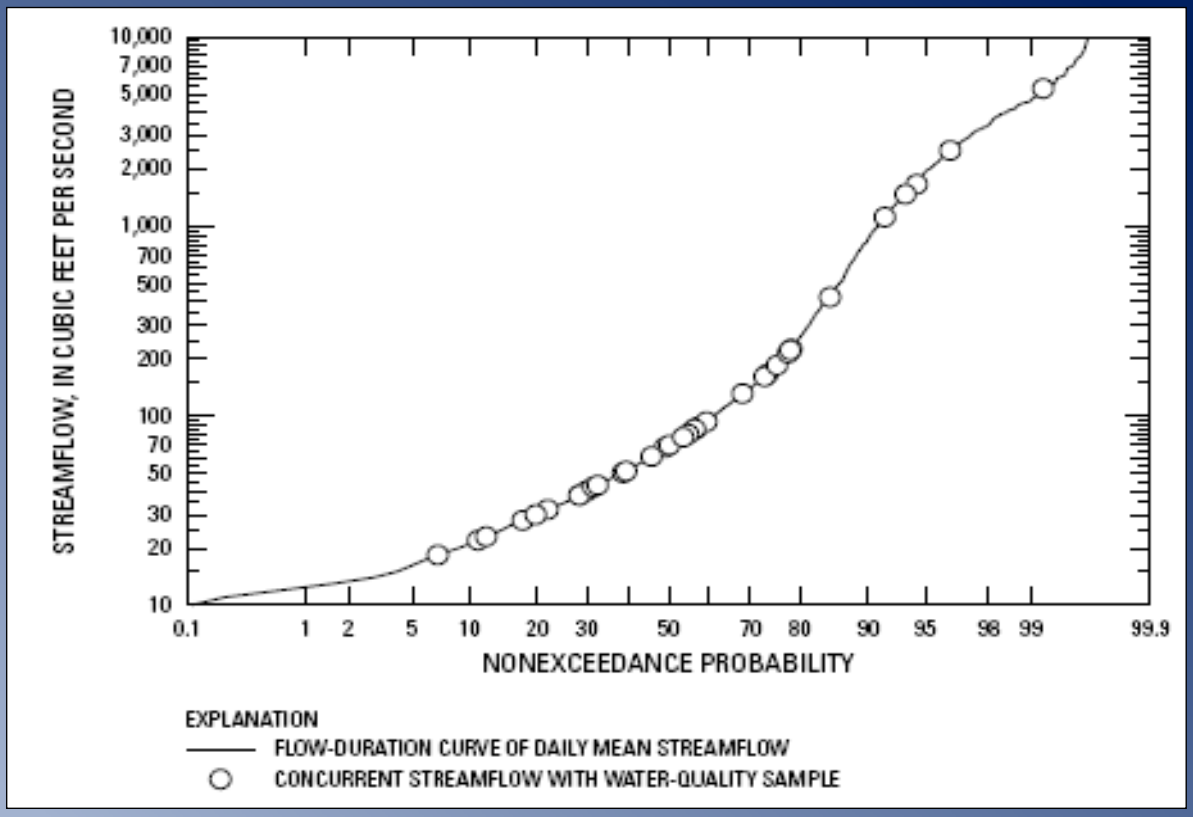
Sampled Range of Discharge



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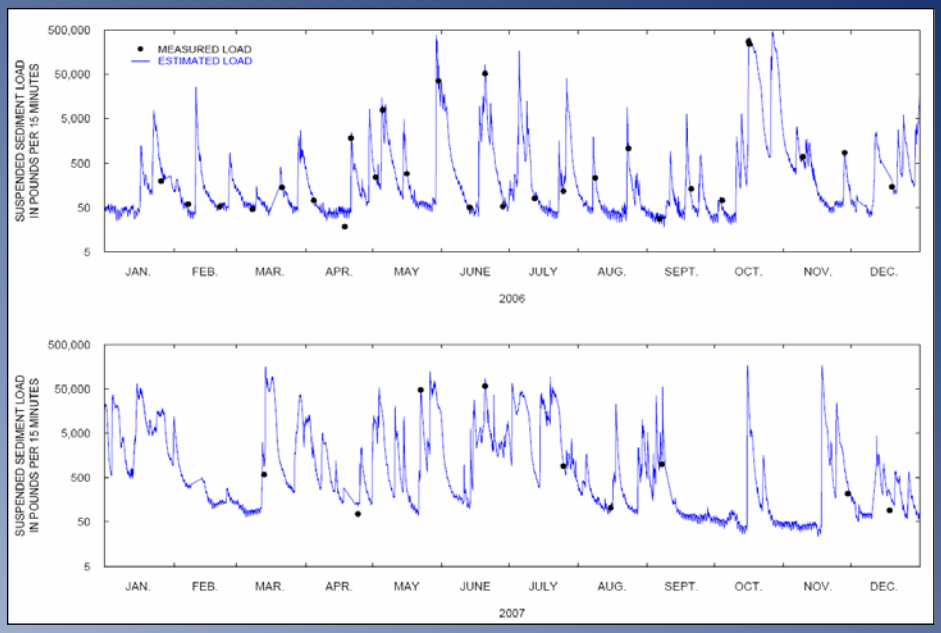
Dr. William Asquith

Estimated Loads



Independent variables:

- Discharge
- Temperature
- SC
- pH
- Date

Dependent variables:

- Sediment (TSS)
- Nitrate + Nitrite
- Phosphorous
- Organic Carbon
- E. Coli
- Atrazine

USGS

Inflow Statistics of Applicable Explanatory Variables: [Min., minimum, Qu., quartile, Max., maximum]

```
EXPLANATORY VARIABLE SUMMARY STATISTICS
   log10(SC)      I(log10(SC)^2)   log10(Turb)      cos(2 * pi * Date)
 Min.   :1.806   Min.   :3.262   Min.   :0.9966   Min.   :-0.9976
 1st Qu.:2.422   1st Qu.:5.864   1st Qu.:1.2670   1st Qu.:-0.7080
 Median :2.568   Median :6.596   Median :1.5682   Median :-0.2582
 Mean   :2.531   Mean   :6.455   Mean   :1.6277   Mean   :-0.1202
 3rd Qu.:2.687   3rd Qu.:7.223   3rd Qu.:1.9191   3rd Qu.: 0.4784
 Max.   :2.847   Max.   :8.105   Max.   :2.4771   Max.   : 0.9839
```

Summary of Regression Analysis for the Constituent of:
Total Phosphorous (Phos)

```
SUMMARY STATISTICS FOR PHOS, IN MILLIGRAMS PER LITER
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-0.82390 -0.29870 -0.06048 -0.11450  0.05489  0.35980

REGRESSION EQUATION
Call:
lm(formula = log10(PHOS) ~ log10(SC) + log10(SC)^2     + log10(Turb)
    +
    cos(2 * pi * Date), data = the.data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.15642 -0.04175 -0.01048  0.03778  0.21190

Coefficients:
                 Estimate Std.Error t-value Pr(>|t|)
(Intercept)       1.31807    0.86149   1.530 0.132323
log10(SC)        -3.18679    0.75534  -4.219 0.000103 ***
log10(SC)^2       0.95494    0.16106   5.929 2.82e-07 ***
log10(Turb)       0.28285    0.04081   6.931 7.68e-09 ***
cos(2 * pi * Date) -0.05983    0.01574  -3.802 0.000391 ***
---
Signif.codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1

Residual standard error: 0.07513 on 50 degrees of freedom
Multiple R-squared: 0.9245,     Adjusted R-squared: 0.9185
F-statistic: 153.2 on 4 and 50 DF,  p-value: < 2.2e-16

Duan (1983) Smearing Factor 1.0141
 (Detransformed estimates from equation are to be multiplied this
      factor.)
```

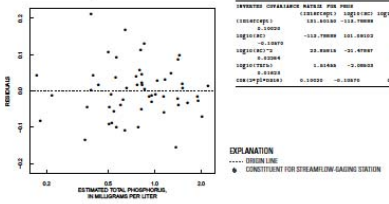
Nomenclature (all potential variables)

- Q is streamflow, in cubic feet per second;
- pH is pH, in standard units;
- SC is specific conductance, in micros per centimeter at 25°Celsius;
- $Turb$ is turbidity in Formazine Na ric Units;
- $Temp$ is water temperature, in °
- $Date$ is Julian day d (days into by 365.25; and
- $\log_{10}(x)$ is base-10 log of x.

Algebraic Equation

$$\log_{10}(Phos) = 1.32 - 3.19\log(SC) + 0.955\log_{10}(SC)^2 + 0.283\log_{10}(Turb) - 0.060\cos[2\pi(Date)]$$

Residual Plot for Regression



X-transpose X-inverse Matrix for Regression

```
INVERTED COVARIANCE MATRIX FOR PHOS
                  (Intercept)  log10(SC) log10(SC)^2   log10(Turb) cos(2*pi*Date)
(Intercept)        121.60130 -112.79899     26.84916     1.01484
    0.10020
log10(SC)         -112.79899  101.28102    -31.47987    -2.08603
   -0.10870
log10(SC)^2         26.84916  -31.47987      4.89617     0.60888
    0.02364
log10(Turb)          1.01484   -2.08603      0.60888     0.28606
    0.01603
cos(2*pi*Date)       0.10020   -0.10870      0.02364     0.01603          0.04288
```

Figure 1. Summary of regression analysis for Total Phosphorous (Phos) for 08068500 Spring Creek near Spring, Tex. based on data as described in text for period 2005–09.

Log10 (Phos) =
1.32 − 3.19 log (SC) +
0.955 log10 (SC)^2 +
0.283 log10 (Turb) −
0.060 cos [2π(Date)]

Adjusted R- squared : 0.9185

USGS

PUBLIC DISTRIBUTION

- TEXAS WATER SCIENCE CENTER

  http://tx.usgs.gov/

- NATIONAL REAL-TIME WATER QUALITY

  http://nrtwq.usgs.gov/

Lake Houston Model

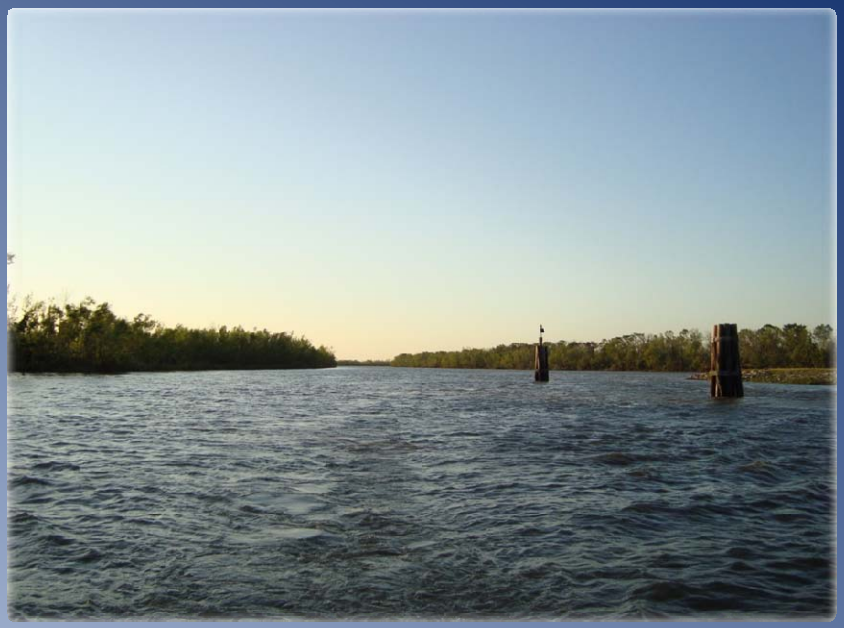
- EFDC Model Completed 2010

- Currently being tested and documented

- Will provide a way to run/test scenarios of constituent loading on Lake Houston

USGS

Contact Information



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19241 David Memorial Drive, Suite 180
Conroe, TX, 77385

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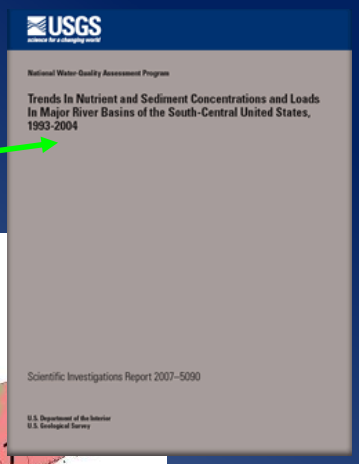
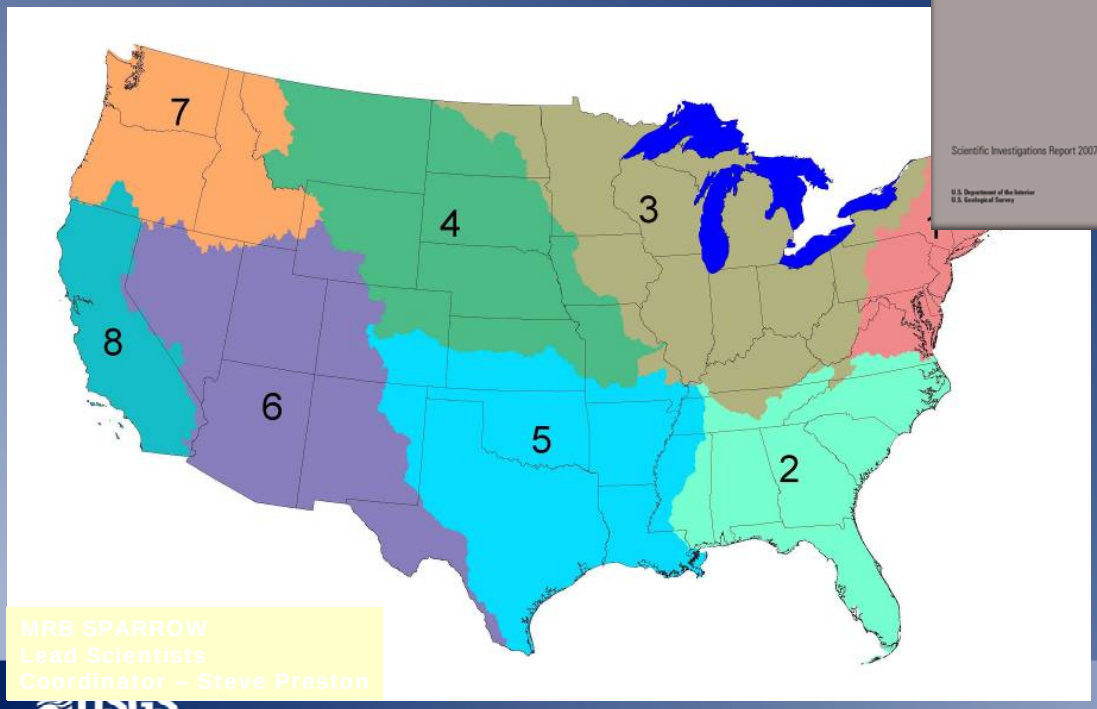
OVERVIEW

- Coastal Loads Evaluation
- Lake Houston and Inflow Monitoring
- Modeling Efforts
  - Richard Rebich – Mississippi Water Science Center, USGS

Regional Assessments

Regional assessments funded through the USGS NAWQA Program
Task 1 – Trend reports; completed in 2007; USGS SIR 2007-5090
Task 2 – SPARROW models; began in 2008; completed in 2010



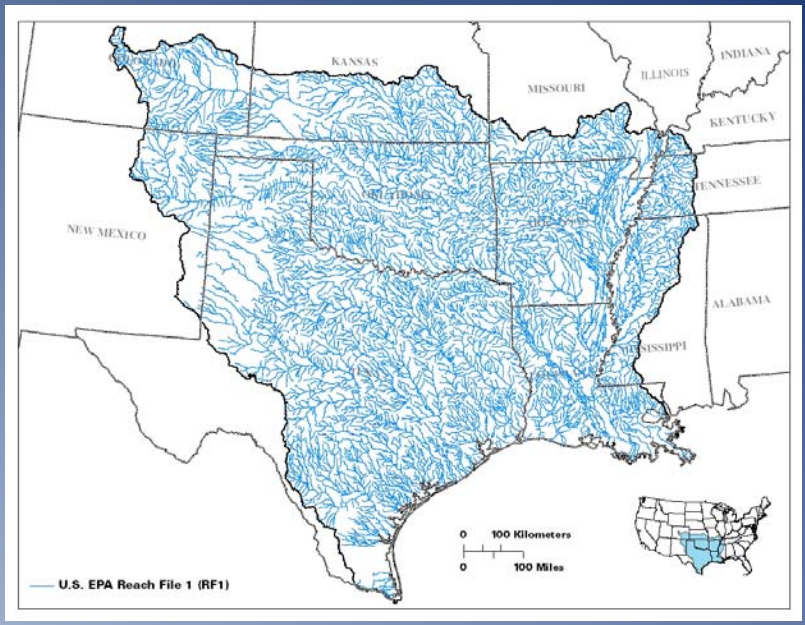


MRB SPARROW
Lead Scientists
Coordinator – Steve Preston

What is SPARROW?

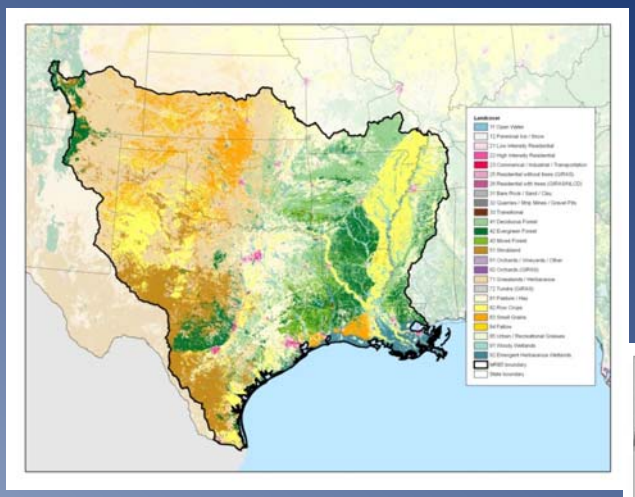
- SPAtially Referenced Regression on Watershed Attributes (Smith et al., Water Resour. Res., 1997)
- Regression-based model - model is calibrated and adjusted to monitored loads
- Hybrid mechanistic – includes transport, loss, mass-balance, etc.
- Static model - centered on a specific target year (2002); typically a year where spatial data have been assembled

Starts with reach network



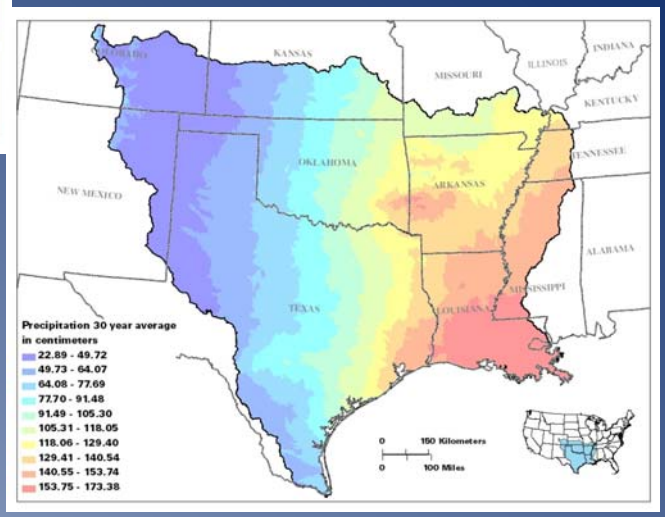
The E2RF1 digital stream network from the U.S. Environmental Protection Agency was used for this study

There were 8,375 stream reaches and catchments in the study area



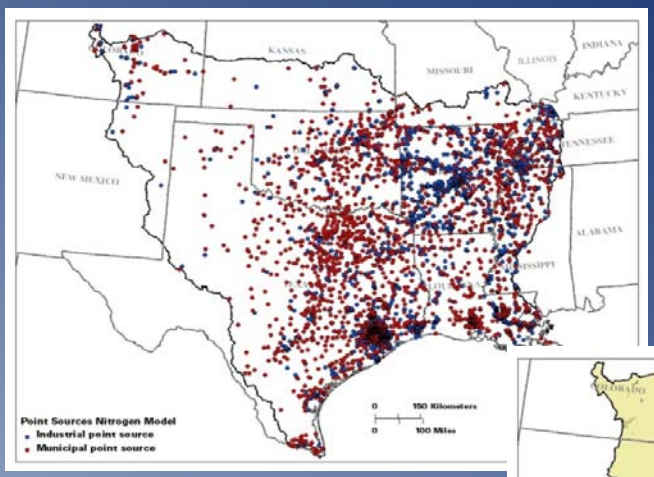
Land Use

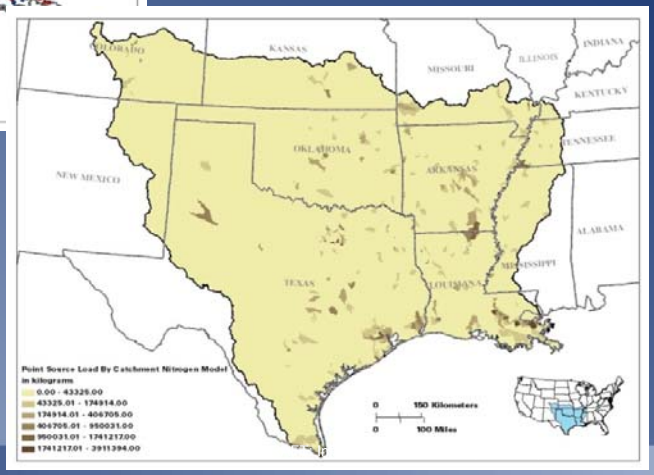
Rainfall



USGS

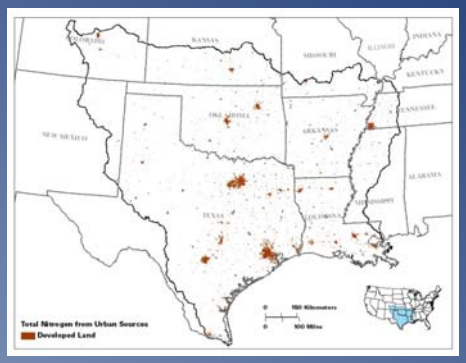
Point Sources



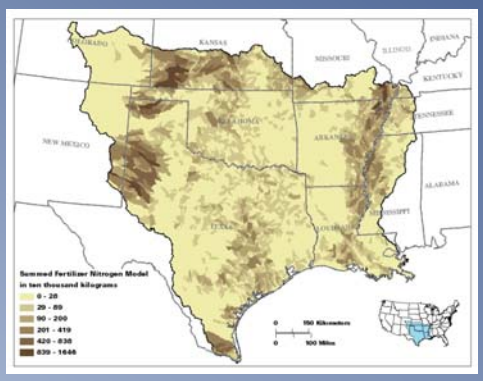


USGS

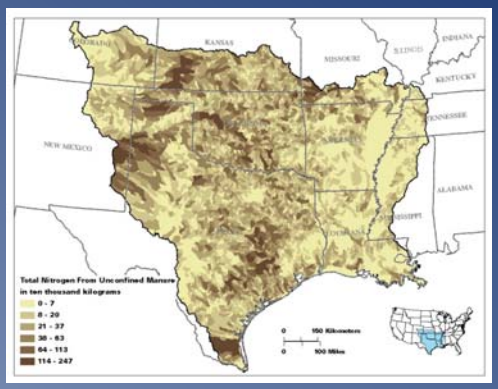
Developed Land



Atmospheric Deposition



Fertilizer

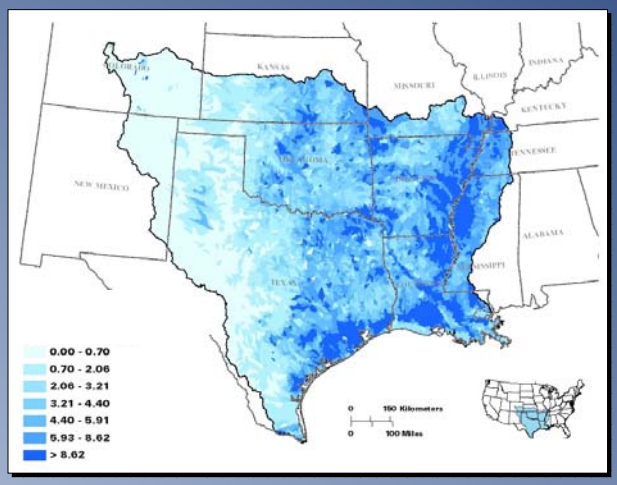


Livestock Manure

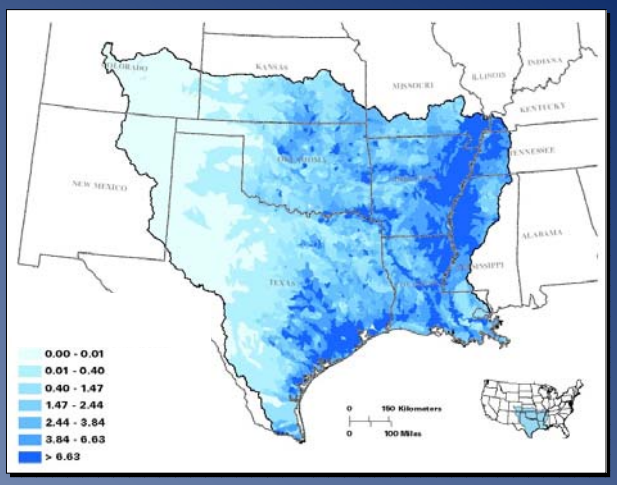
USGS

Total Nitrogen Yield Results

Delivered to local streams

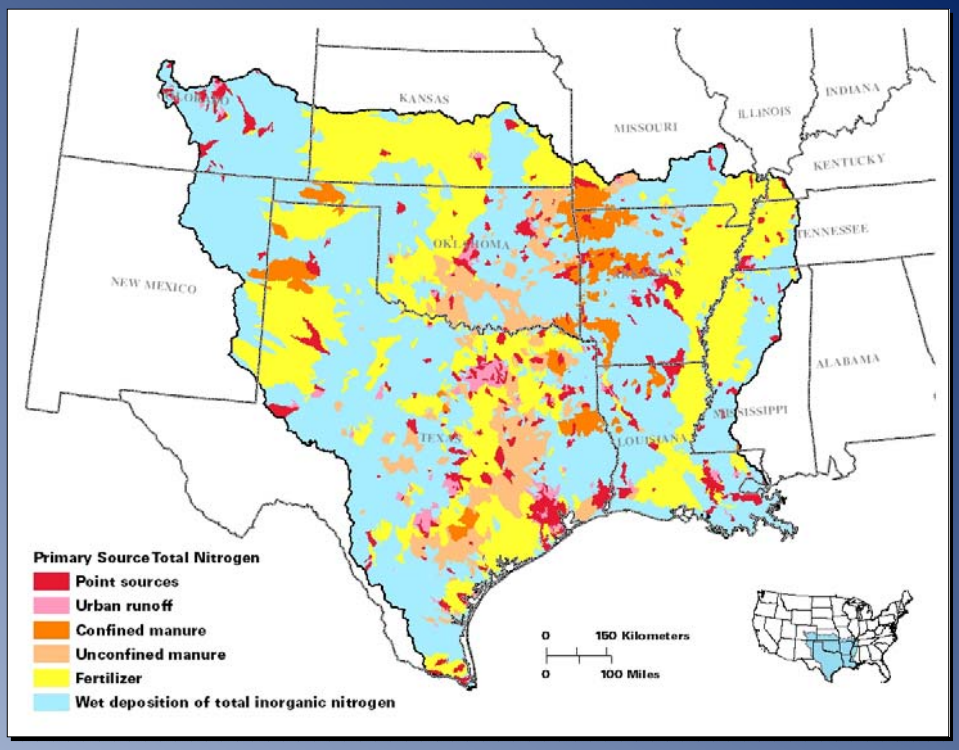


Delivered to the Gulf of Mexico



USGS

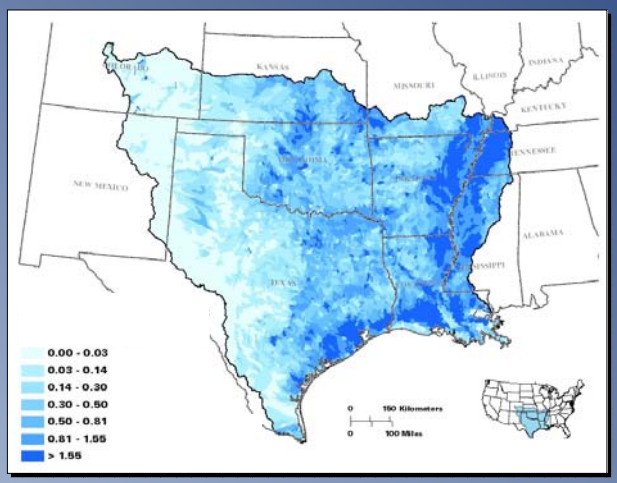
Primary Sources of Nitrogen



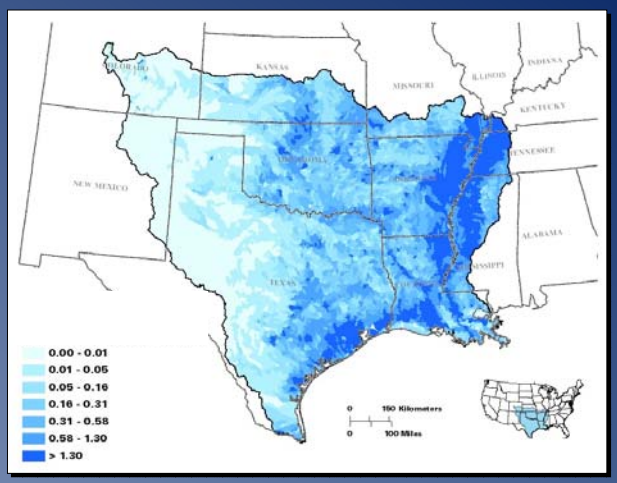
USGS

Total phosphorus yield results

Delivered to local streams

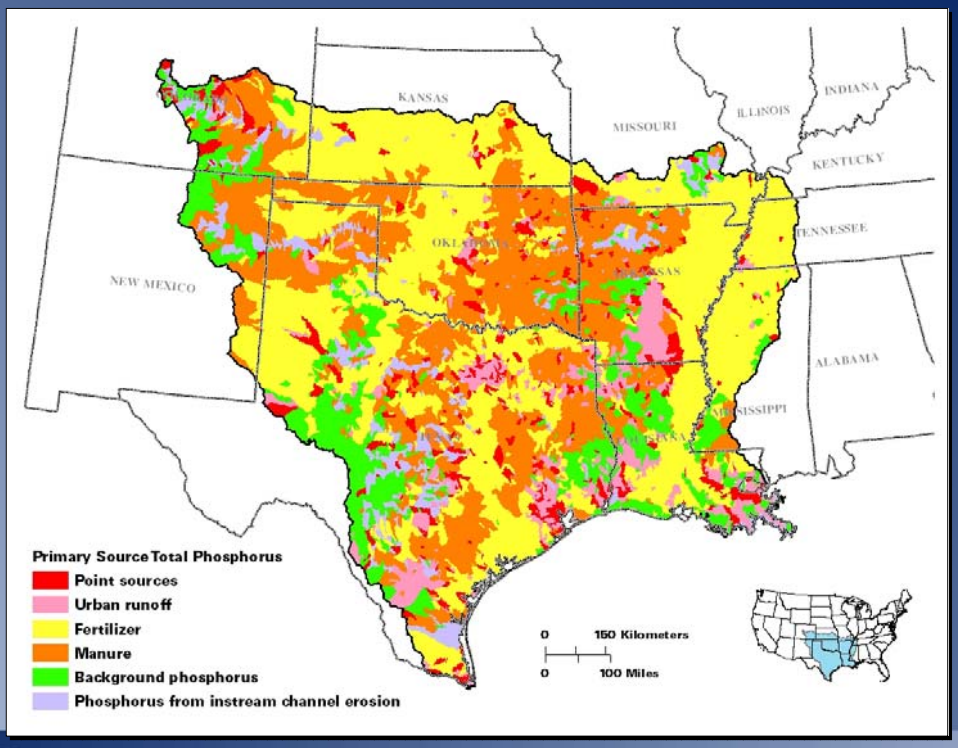


Delivered to the Gulf of Mexico



USGS

Sources of phosphorus

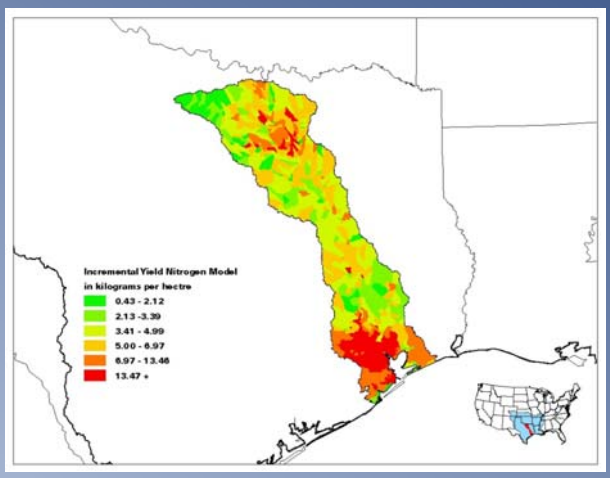


USGS

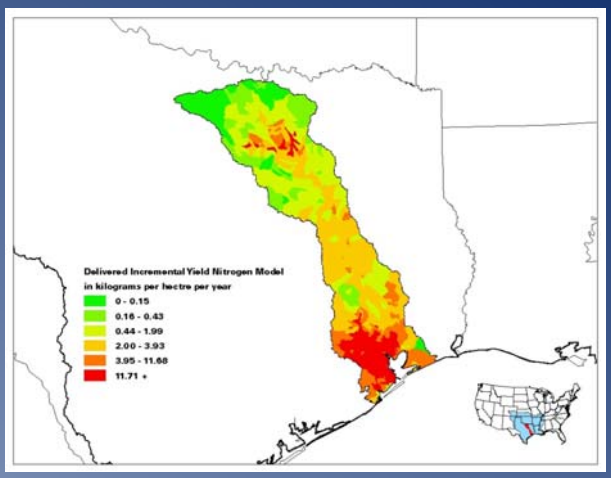
Other watershed-specific examples …

Yield plots

Catchment yield

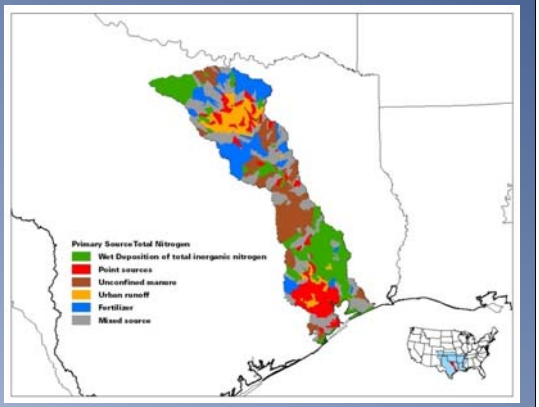


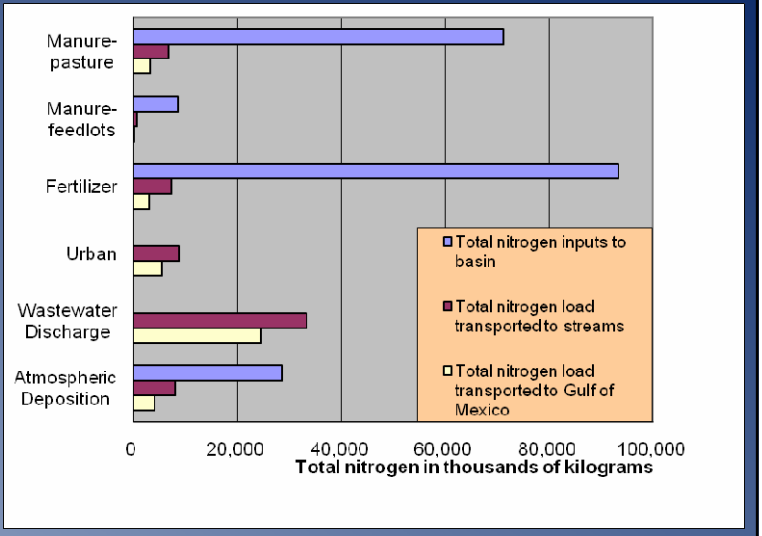
Catchment yield delivered to estuary



Other watershed-specific examples …

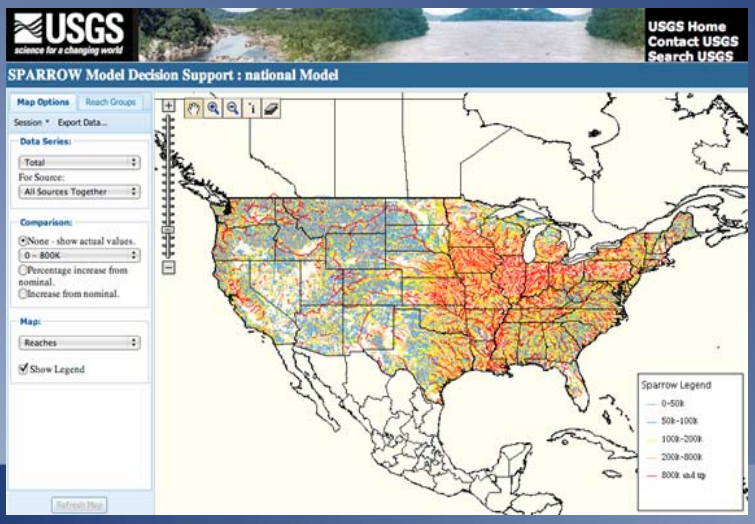
Source plots and bar charts



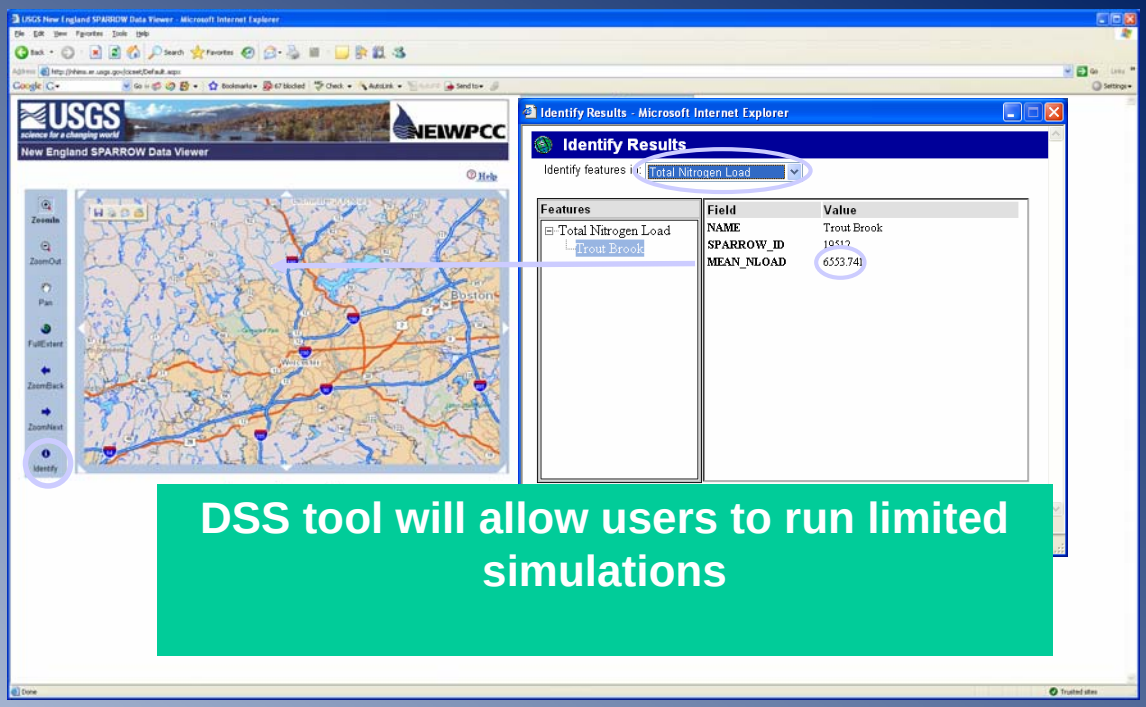


Nutrient Models—Decision Support Tools

Modeling decision support tools is being developed to enable managers to evaluate management scenarios and the associated environmental response and also incorporate economic aspects into the scenarios.



Decision Support Tool …



DSS tool will allow users to run limited simulations

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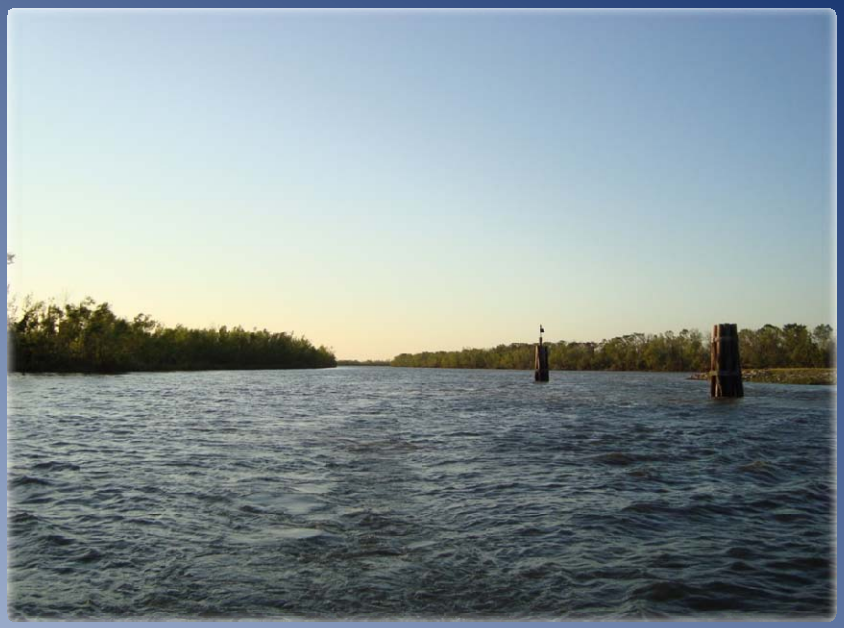
Contact Information



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