Continuous Real-Time and Discrete Water-Quality Monitoring of Three Tributaries and Lake Houston, near Houston, Texas

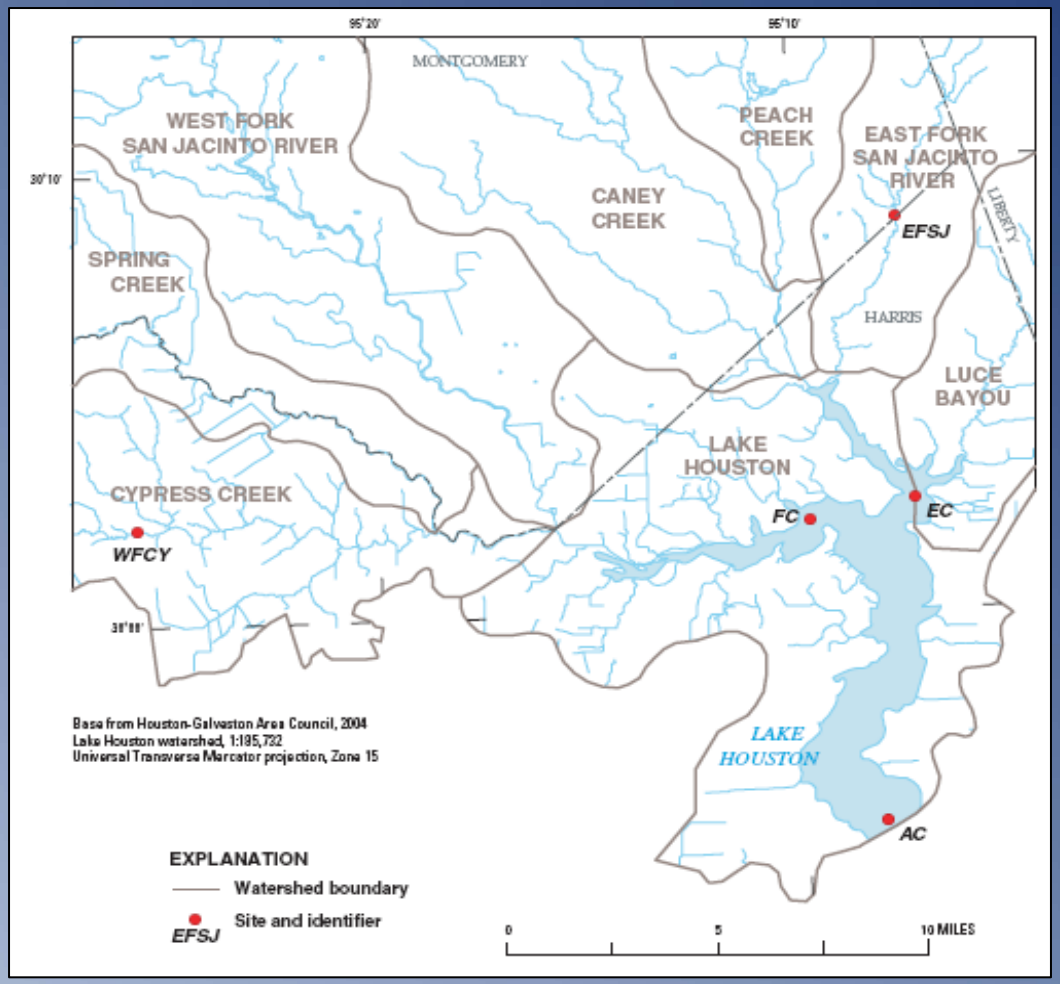
-by Amy Beussink, Jennifer Graham, Tim Oden, Mike Turco, and many others
USGS Texas Water Science Center

Prepared in Cooperation with the City of Houston

Trinity and San Jacinto Rivers and Galveston Basin and Bay Expert Science Team

Houston, TX June 10, 2009

Study Area

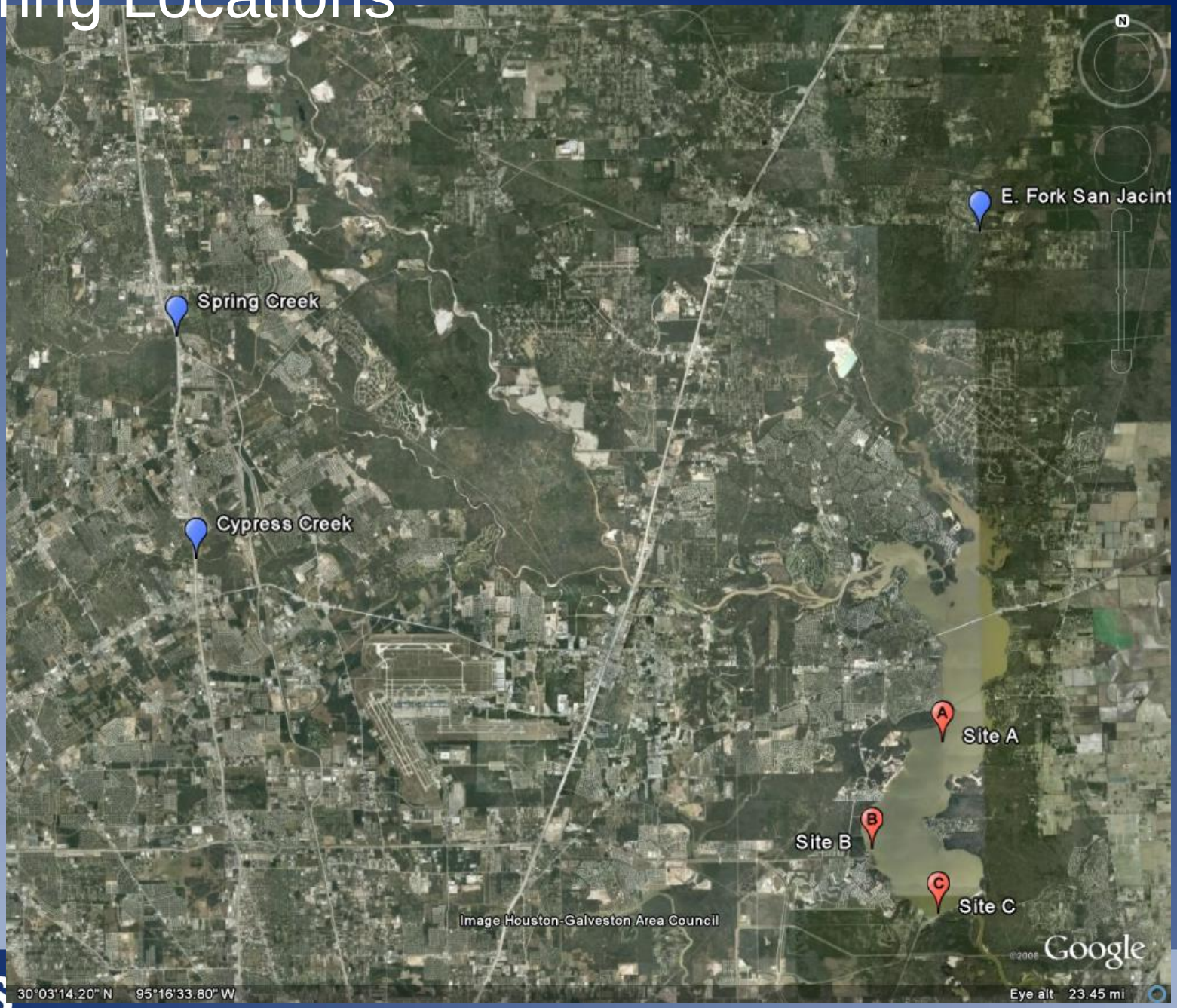


- Drainage area 2,835 mi^2
- Land use is rural, transitional and urban
- Western subbasin predominately urban
- Eastern subbasin predominately rural

Sneck-Fahrer and others, 2005

USGS

Monitoring Locations



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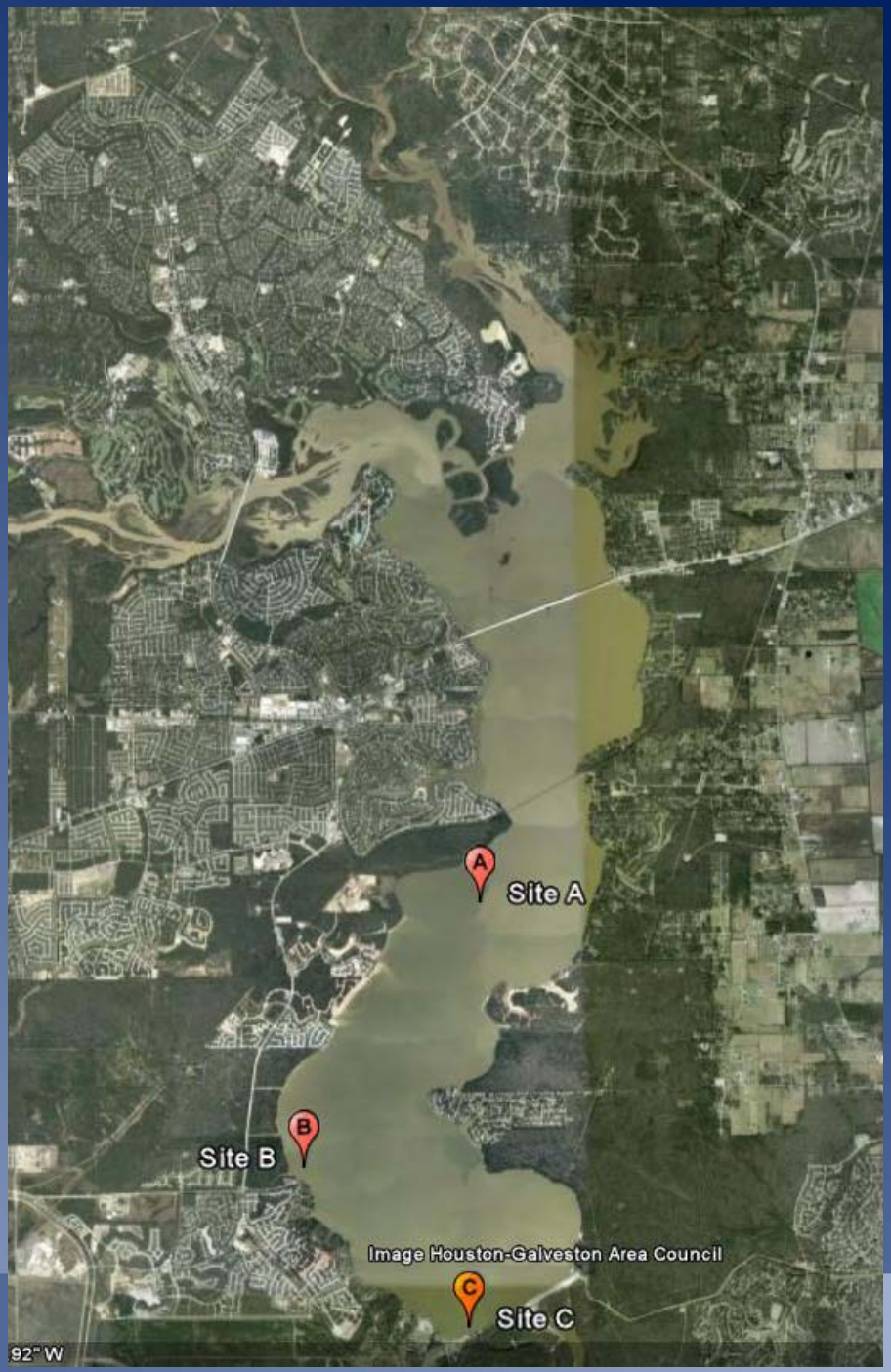
Lake Study Area

- Lake Houston located ~25 miles northeast of downtown Houston, TX
- Shallow reservoir, maximum depth ~40 feet
- Long and narrow, ~8 miles by <2 miles
- Impounded in 1954
- About 133,990 acre-feet of water
- Becoming significant source water for Houston (population 4.5 million)
  - New water treatment plant
  - Color, taste and odor complaints 2005 - 2006



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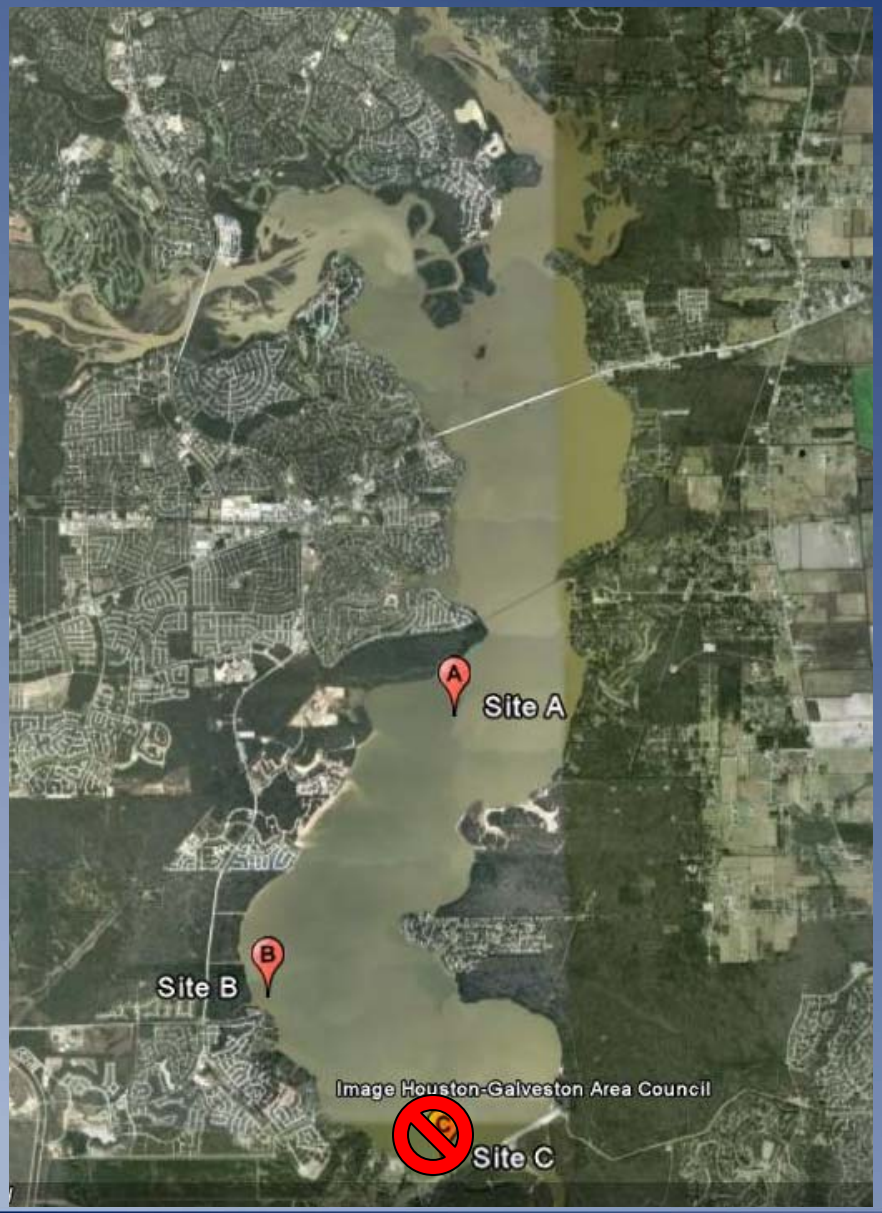
In-lake Monitoring



- Two locations in the lake
- Riverine lake (WRT ~12 hours to ~200 days)
- Site configuration provides information upstream and downstream from areas of source-water withdrawal
- Discrete sampling and continuous monitoring

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Continuous In-lake Monitoring

- Turbidity
- Dissolved Oxygen
- Water Temperature
- Specific Conductance
- pH
- Chlorophyll fluorescence
- Phycocyanin fluorescence

http://tx.usgs.gov/

USGS Real-Time Water Data for USGS 295826095082200 Lk Houston S Union Pacific

http://waterdata.usgs.gov/tx/nwis/uv/?site_no=295826095082200&PARAmeter_c

File Edit View Favorites Tools Help

USGS Real-Time Water Data for USGS 29...

---- Provisional Data Subject to Revision ----

Create presentation-quality graph

Parameter 0001

Specific conductance, Depth 1 ft, water, unfiltered, microsiemens per ce

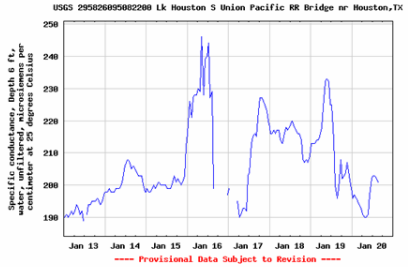
Most recent instantaneous value: 197 01-20-2009 15:15

Create presentation-quality graph

Parameter 0009

Specific conductance, Depth 6 ft, water, unfiltered, microsiemens per ce

Most recent instantaneous value: 201 01-20-2009 15:30



Create presentation-quality graph

Parameter 00095; DD 1L

Internet 75%

Start | Amy M Beussink - I... | Austin Water Utility... | NALMS08_Beussink | USGS Real-Time ... | 5:09 PM

USGS TX Water-Quality - Internal - Windows Internet Explorer

http://waterdata.usgs.gov/tx/nwis/current?type=intquality&group_key=office_cd#hst

File Edit View Favorites Tools Help

USGS TX Water-Quality - Internal

08068000	W Fk San Jacinto Rv nr Conroe, TX	06/08 16:30	28.7	747	10.0	7.7	--	--
08068275	Spring Ck nr Tomball, TX	06/08 15:30	24.4	288	6.9	7.2	--	--
08068400	Panther Br at Gosling Rd, The Woodlands, TX	06/08 16:00	28.8	916	4.6	7.9	--	--
08068500	Spring Ck nr Spring, TX	06/08 16:45	28.6	527	11.0	7.9	--	--
08069000	Cypress Ck nr Westfield, TX	06/08 16:00	29.5	825	10.8	9.1	--	--
08070200	E Fk San Jacinto Rv nr New Caney, TX	06/08 15:45	27.5	218	9.7	7.3	--	--
08076997	Clear Ck at Mykawa St nr Pearland, TX	06/08 16:00	31.4	779	--	--	--	--
08117300	Brazos Rv at GIWW Flood Gates nr Freeport, TX							
	Brazos River	06/08 16:00	--	--	--	--	--	0.56
	East Lock	06/08 15:00	--	--	--	--	--	15.8
	West Lock	06/08 16:00	--	--	--	--	--	-3.74
08162506	Colorado Rv Bypass Channel nr Matagorda, TX							
	Colorado River	06/08 15:30	--	--	--	--	--	-0.20
	Bypass Channel	06/08 15:30	--	--	--	--	--	0.06
294728095200103	LJ-65-14-738 (Northeast Piezometer No. 4)	06/08 15:00	22.4	--	--	--	--	--
295554095093401	Lk Houston at mouth of Jack's Ditch nr Houston, TX							
	Depth 1 ft	06/08 15:15	28.4	140	7.1	8.4	--	--
	Depth 6 ft	06/08 15:30	28.2	140	6.9	8.3	--	--
	Depth 12 ft	06/08 15:45	27.4	140	5.4	8.0	--	--
	Depth 16 ft	06/08 16:00	27.3	141	5.2	8.0	--	--
295826095082200	Lk Houston S Union Pacific RR Bridge nr Houston,TX							
	Depth 1 ft	06/08 15:15	28.5	144	8.8	8.0	--	--
	Depth 6 ft	06/08 15:30	28.4	144	8.7	7.8	--	--
	Depth 12 ft	06/08 15:45	28.1	145	7.8	7.5	--	--
	Depth 16 ft	06/08 16:00	27.8	150	6.7	7.3	--	--
300824095274701	TS-60-53-718 (Woodlands Piezometer No. 1-A)	06/08 16:00	21.6	--	--	--	--	--
300849095143301	TS-60-55-710 (New Caney Piezometer No. 7-A)	06/08 16:00	20.7	--	--	--	--	--
301228095272501	TS-60-53-516 (Needham Piezometer No. 4-A)	06/08 16:00	23.1	--	--	--	--	--
301505095343702	TS-60-44-805 (Lake Creek Piezometer No. 3-B)	06/08 16:00	20.8	--	--	--	--	--
301505095343704	TS-60-44-807 (Lake Creek Piezometer No. 3-D)	06/08 16:00	22.1					

Internet 100%

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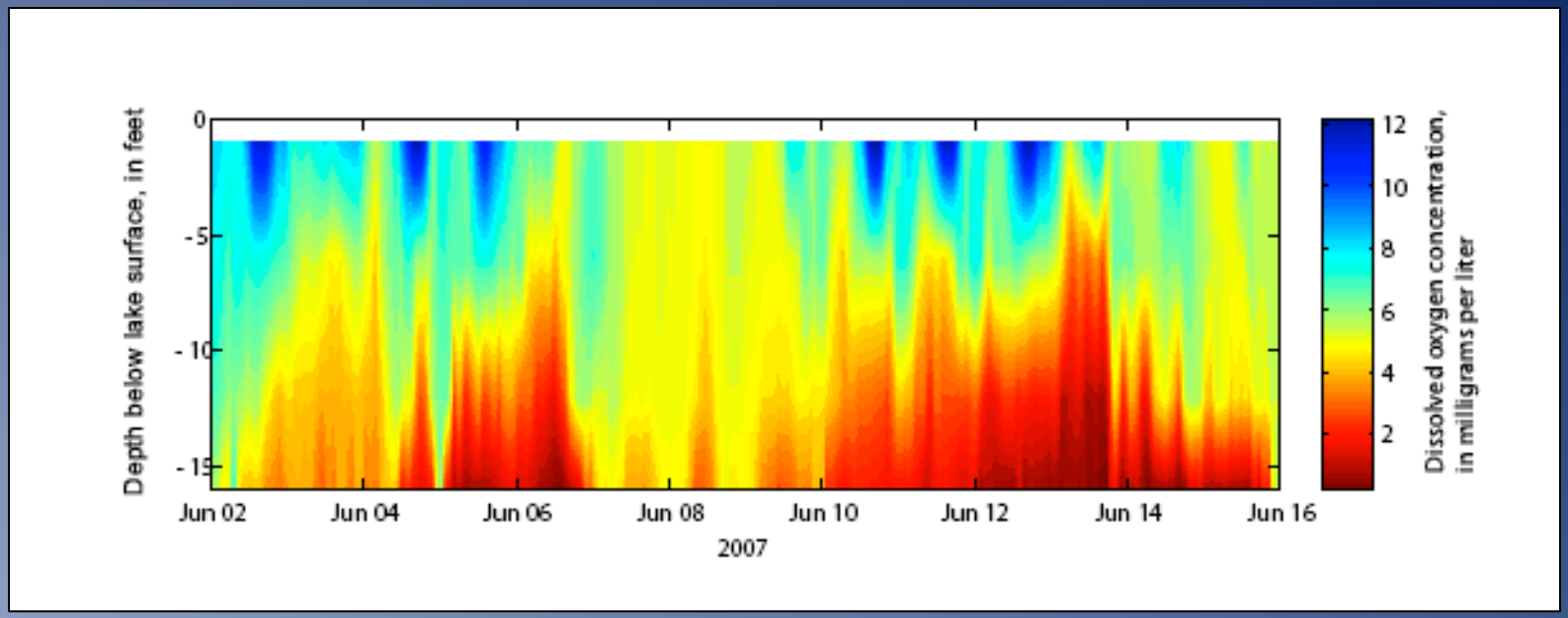
Continuous Data Profiles



Modified From Oden and Graham, 2008

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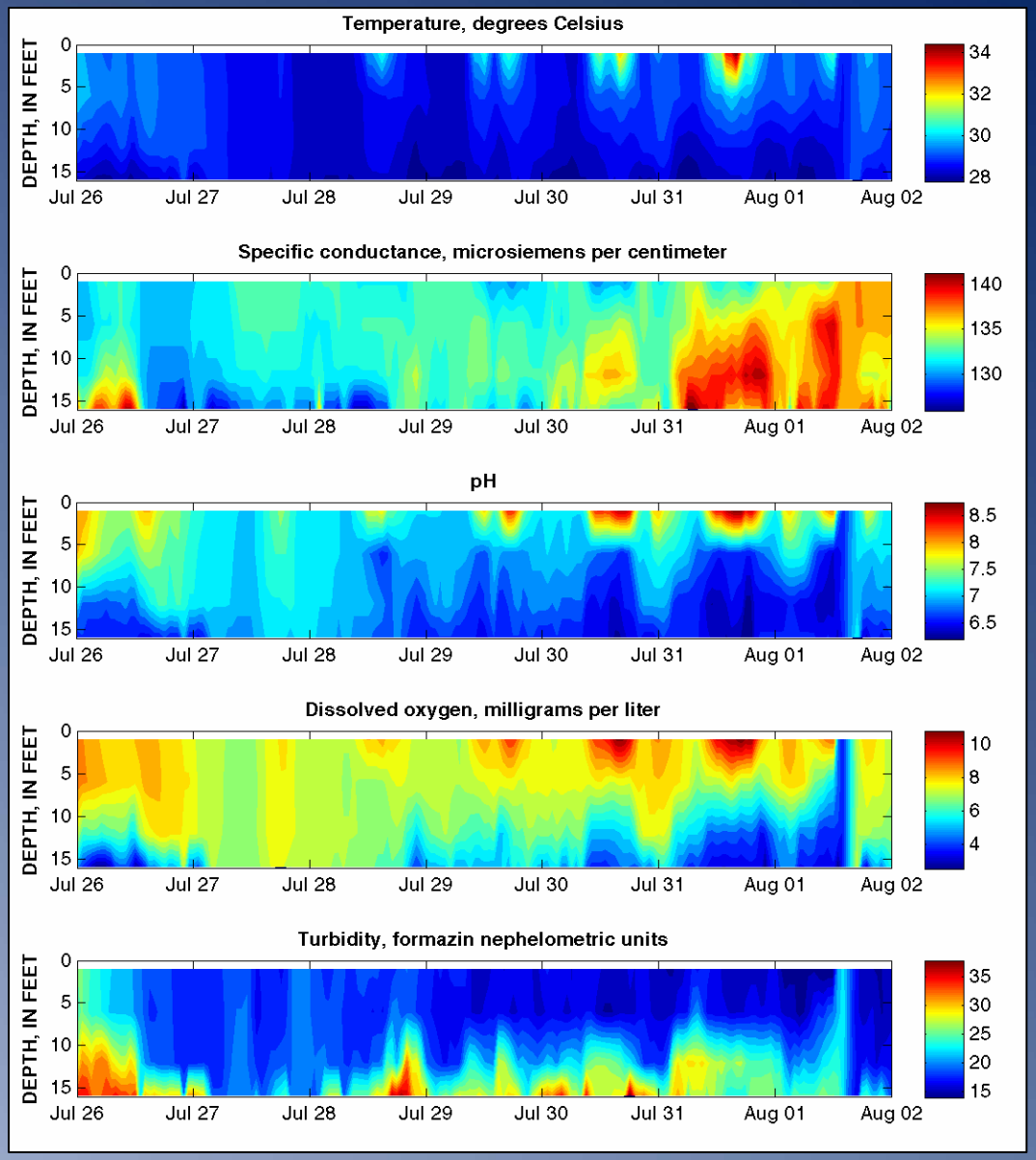
Continuous Data Profiles



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Continuous Tributary Monitoring

- Discharge
- Stage
- Turbidity
- Dissolved Oxygen
- Water Temperature
- Specific Conductance
- pH

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Tributary Monitoring

- Three sites selected above Lake Houston
  - 08068500 Spring Creek near Spring
    - Drainage area: 409 mi^2
    - Streamflow data: 1939-present
    - Water-quality data: 1999-present
  - 08070200 E. Fork San Jacinto River near New Caney
    - Drainage area: 388 mi^2
    - Streamflow data: 1984-present
    - Water-quality data: 1984-99; 2005-present
  - 08069000 Cypress Creek near Westfield
    - Drainage area: 285 mi^2
    - Streamflow data: 1944-present
    - Water-quality data: 1959-64; 1977-78; 1983-2004; 2008-present

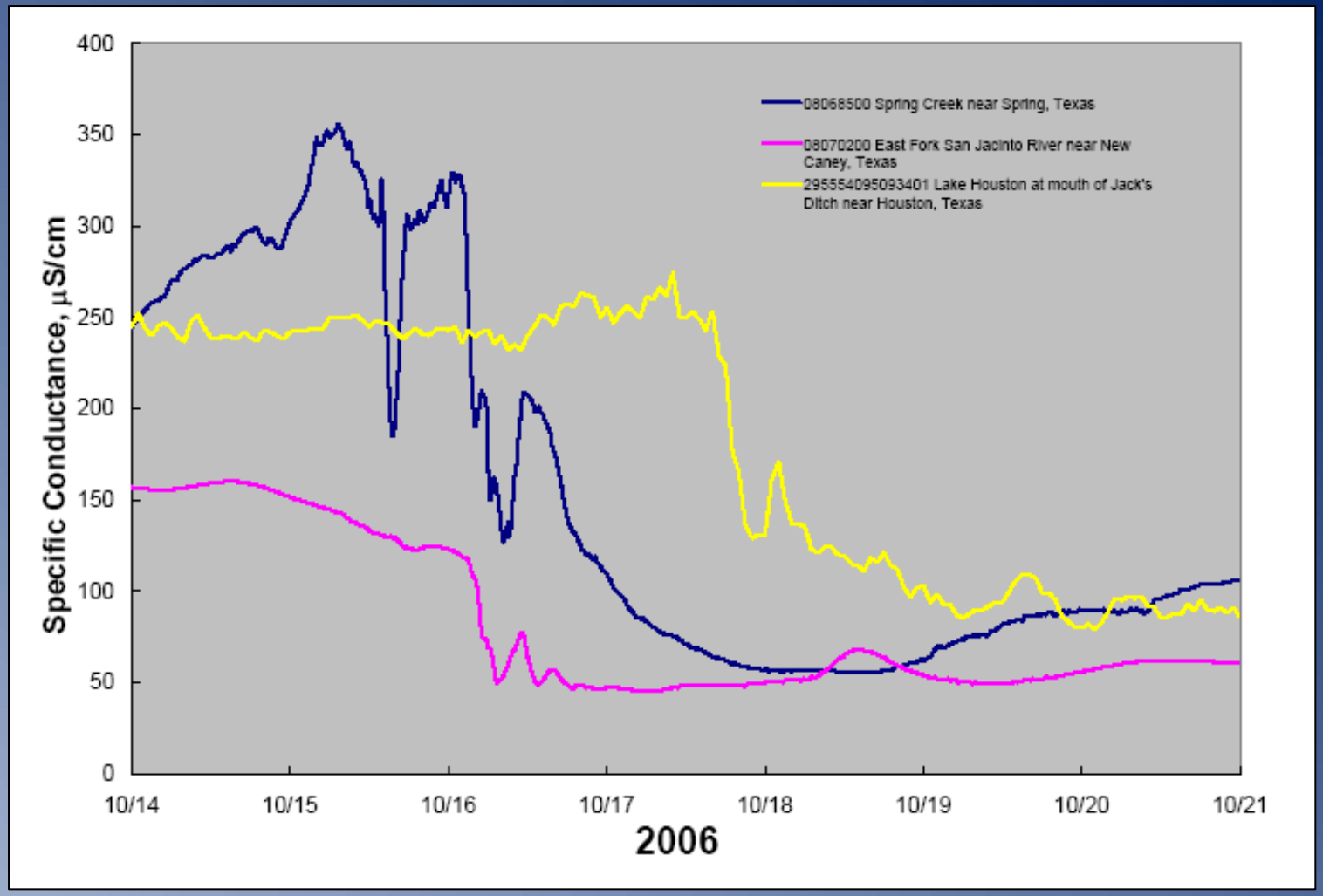
Tributary Monitoring

East Fork San Jacinto River near New Caney

Tributary Monitoring

Spring Creek near Spring

Time of Travel Estimation



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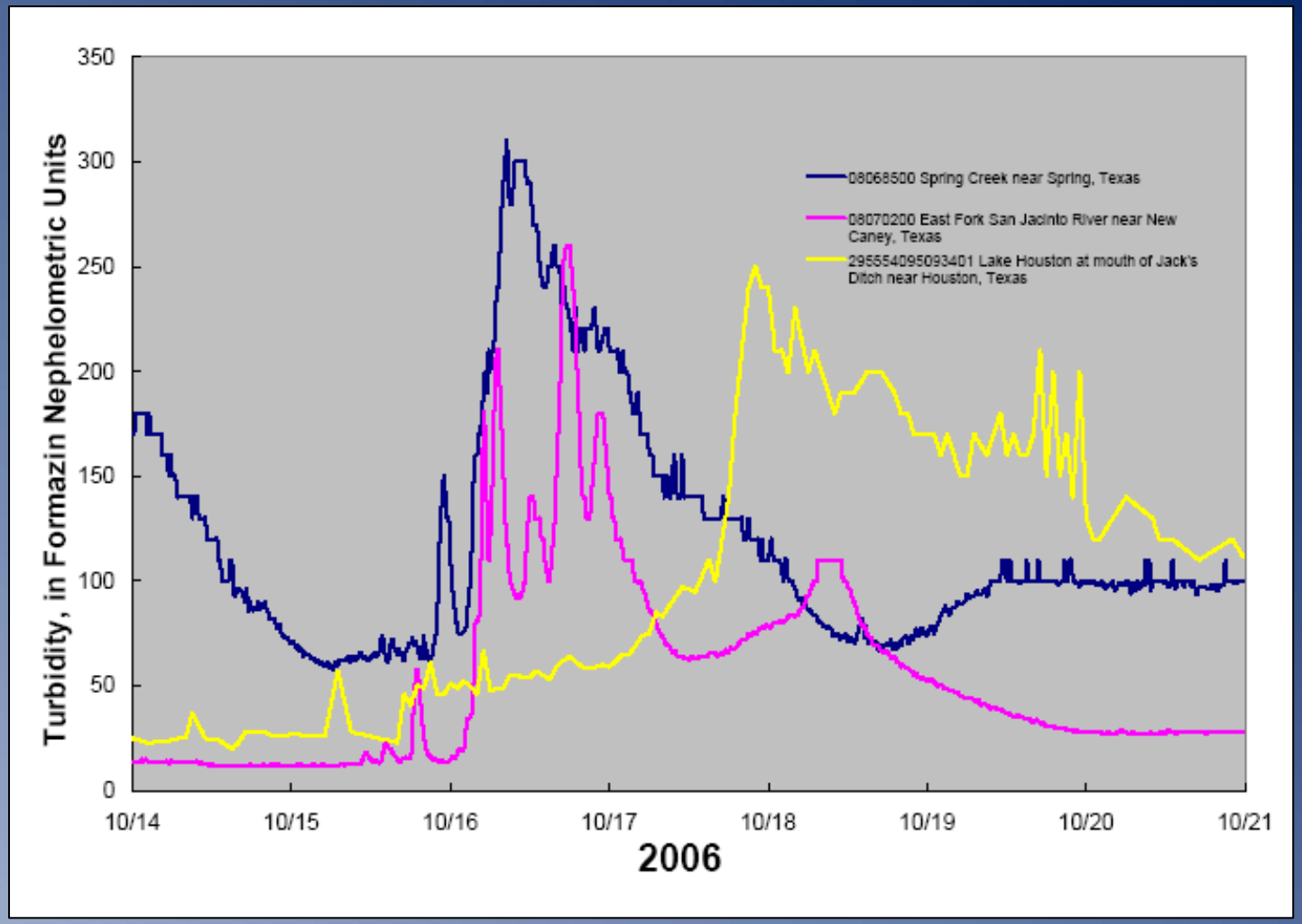
Modified From Oden and Graham, 2008

Time of Travel Estimation



Modified From Oden and Graham, 2008

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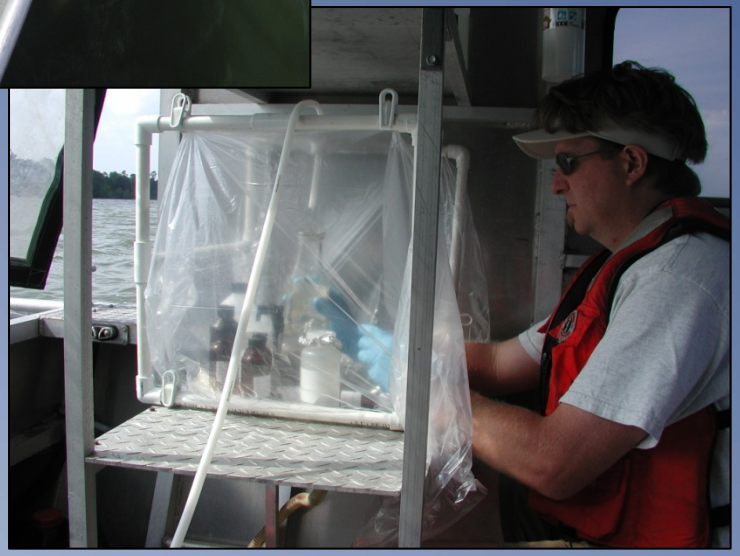
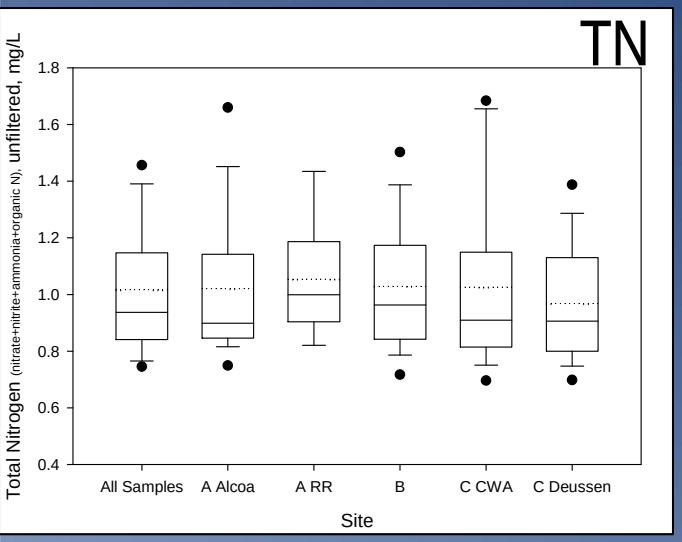
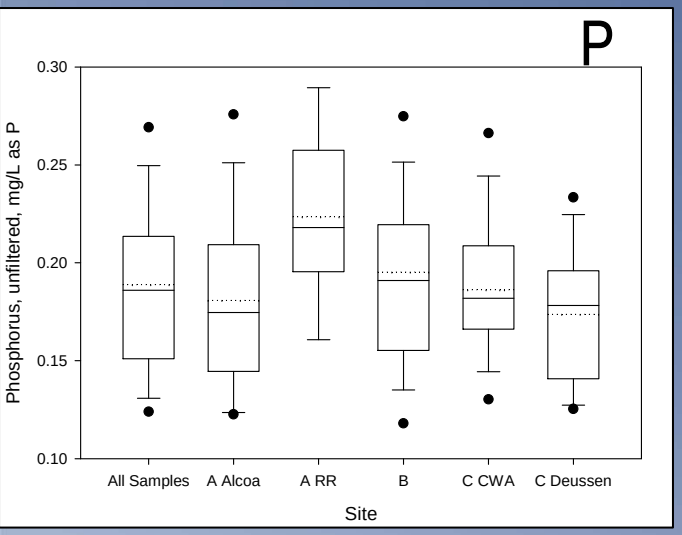
Discrete Sampling In-lake

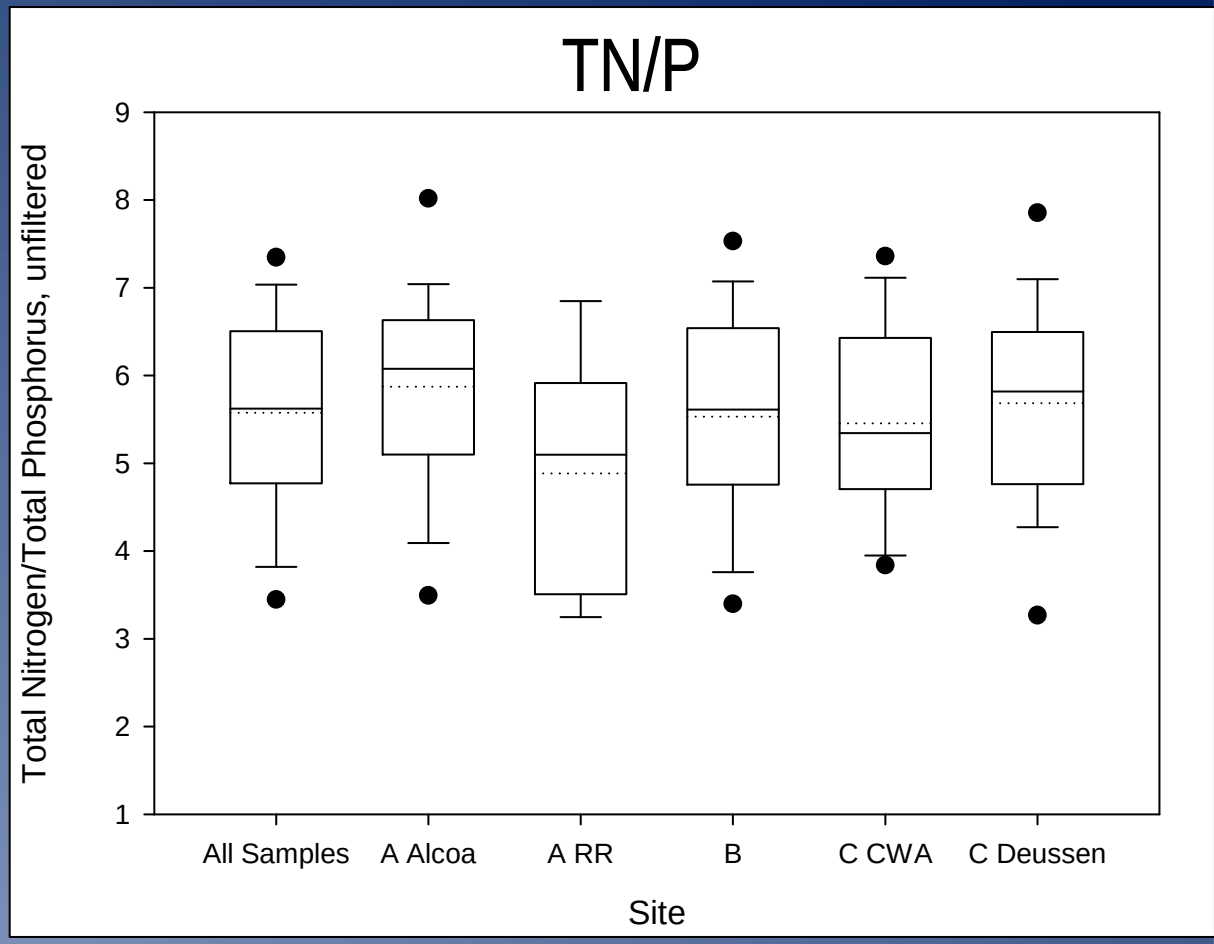


- Phytoplankton – Private MI lab
- Nutrients – COH lab & USGS NWQL CO
- Microcystin – USGS KS lab
- Geosmin and MIB – COH & USGS KS lab
- Actinomycetes – USGS OH lab
- Bacteria – USGS Houston lab
- Sediment – USGS KY lab
- Manganese – COH lab & USGS NWQL CO

Nutrients







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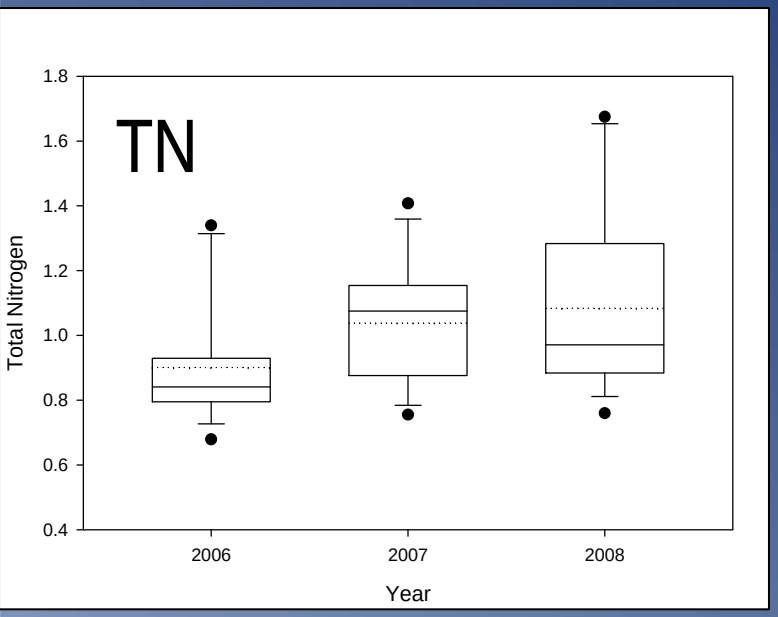
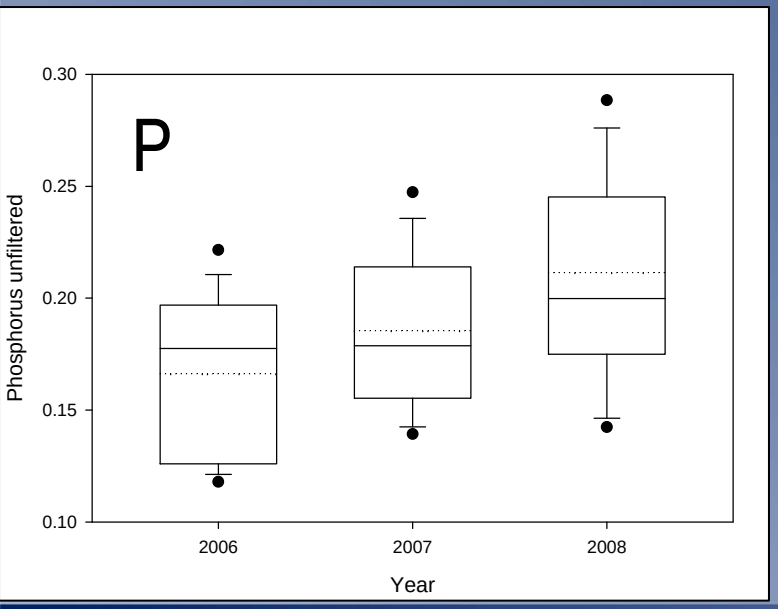
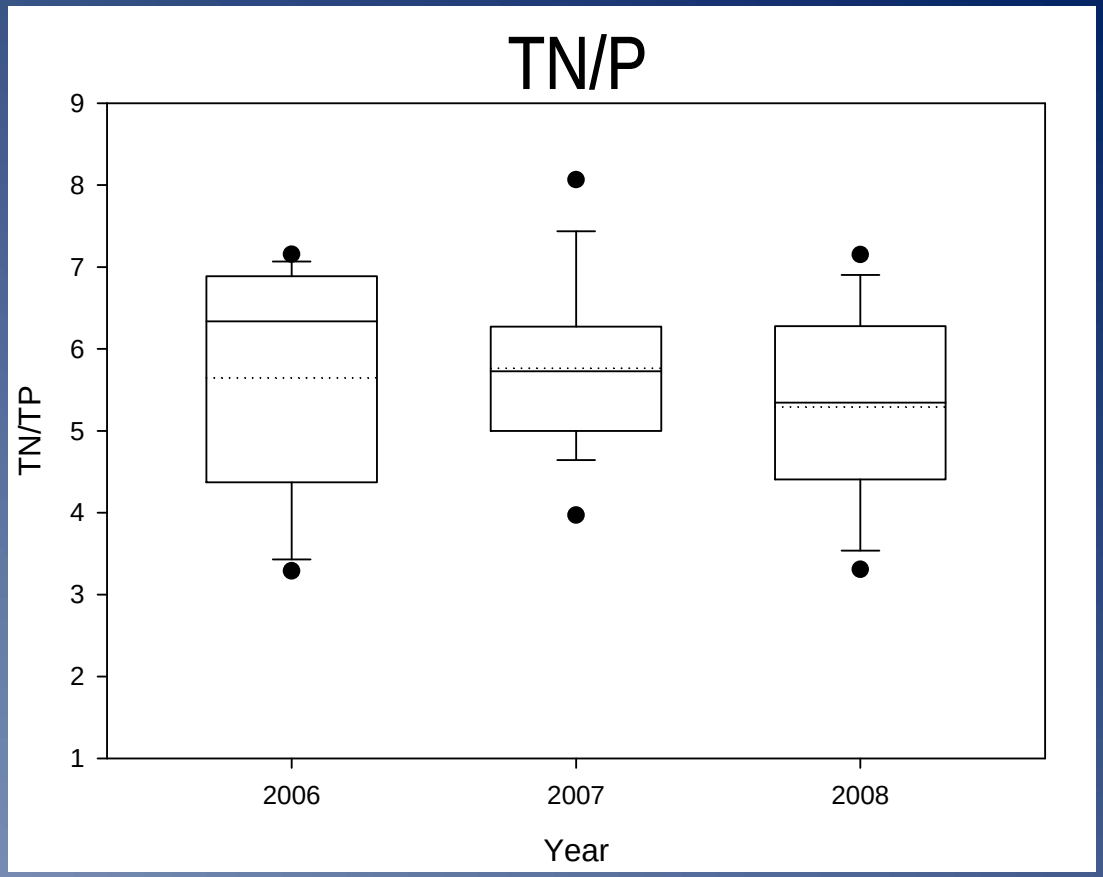
Provisional Data – Subject to Revision

Nutrients







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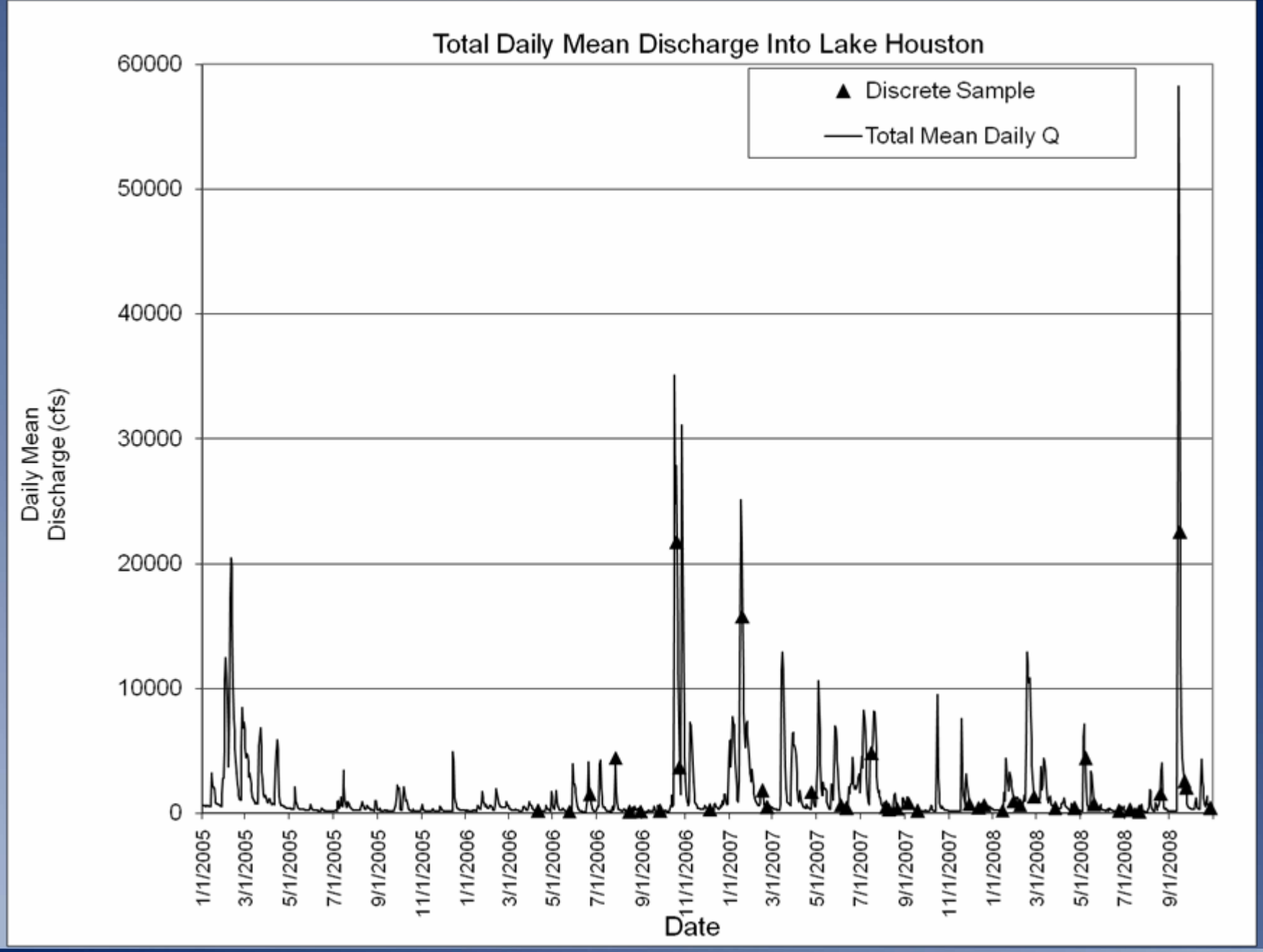
Provisional Data – Subject to Revision


Total Daily Mean Discharge Into Lake Houston
Discrete Sample
Total Mean Daily Q
Daily Mean Discharge (cfs)
60000
50000
40000
30000
20000
10000
0
1/1/2005
3/1/2005
5/1/2005
7/1/2005
9/1/2005
11/1/2005
1/1/2006
3/1/2006
5/1/2006
7/1/2006
9/1/2006
11/1/2006
1/1/2007
3/1/2007
5/1/2007
7/1/2007
9/1/2007
11/1/2007
1/1/2008
3/1/2008
5/1/2008
7/1/2008
9/1/2008
Date

USGS

Discrete Tributary Sampling

- Nutrients – USGS NWQL CO
- Bacteria – USGS Houston lab
- Suspended Sediment – USGS KY lab
- Atrazine – USGS Organic Geochemistry Research Lab

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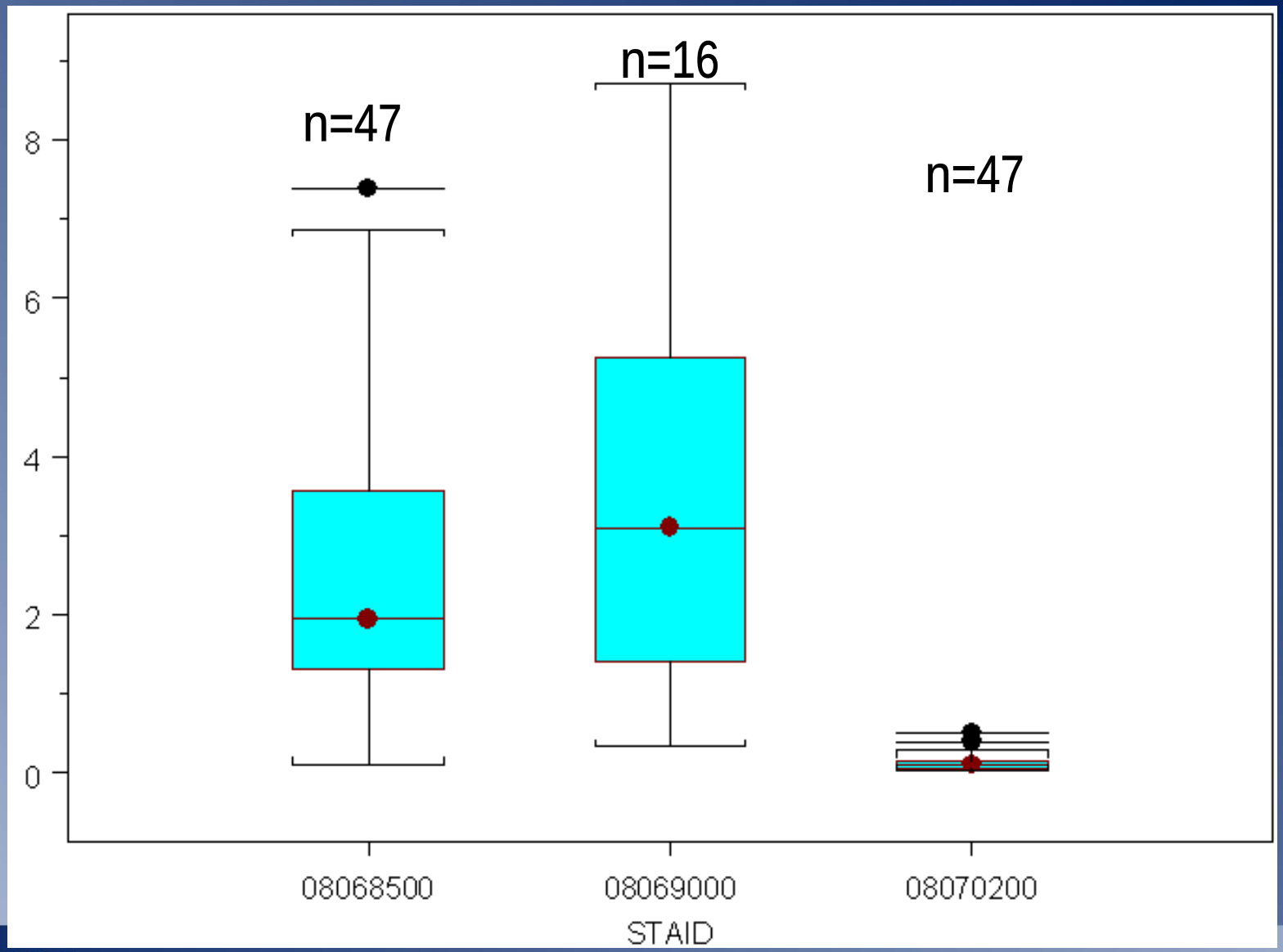
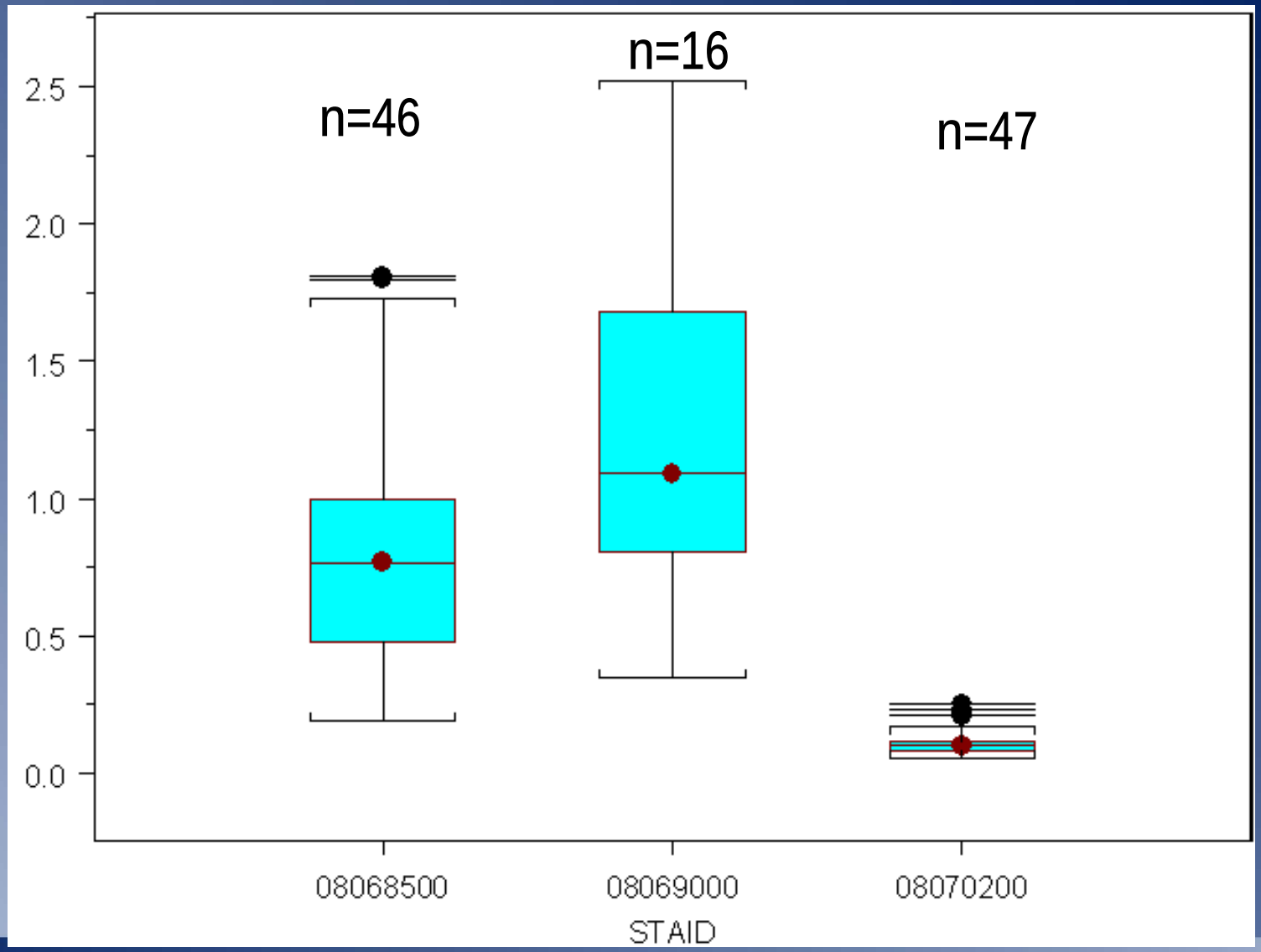
Nitrate + Nitrite as N



Total Phosphorus as P



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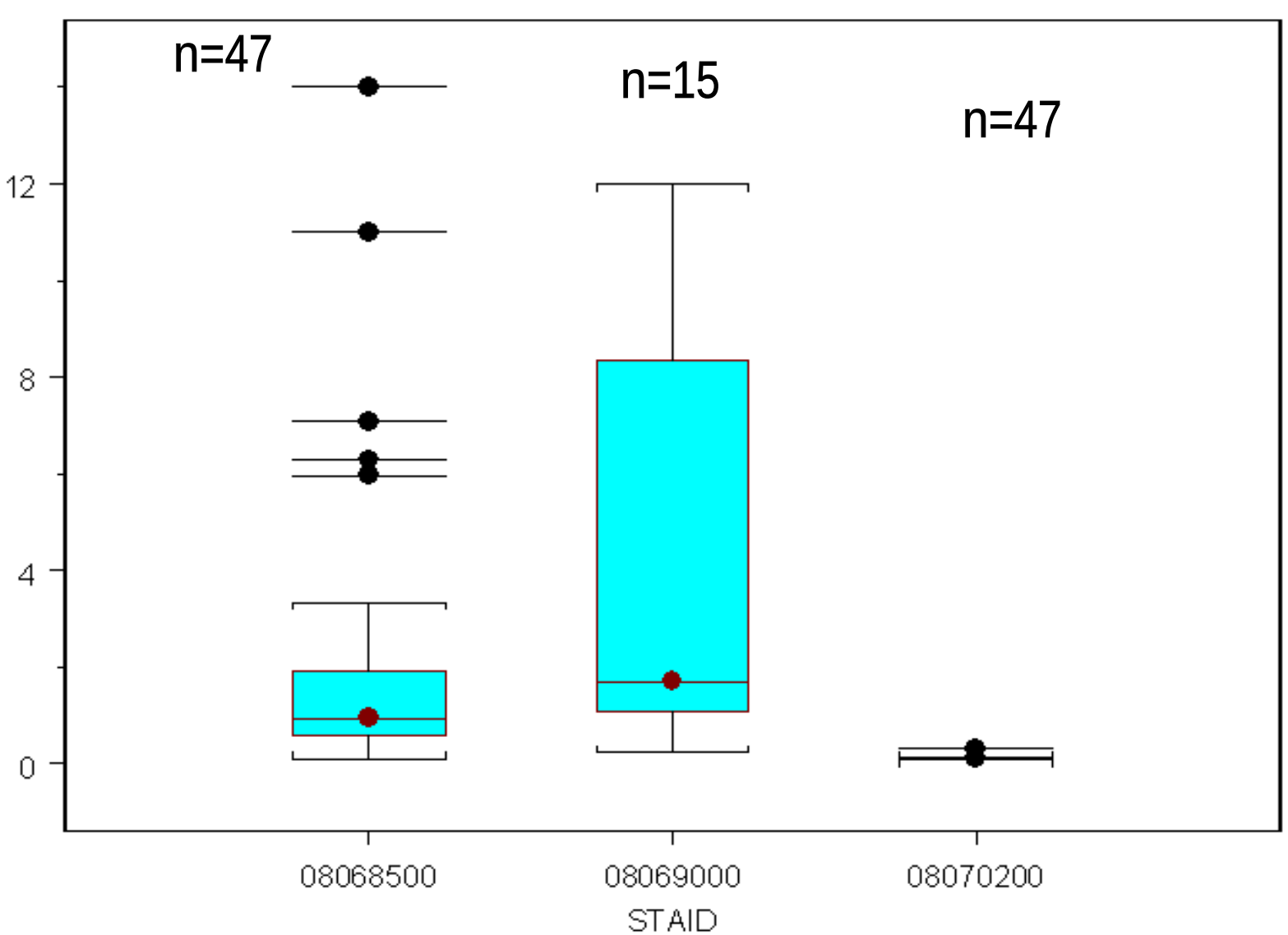
Provisional Data – Subject to Revision

Atrazine, µg/L



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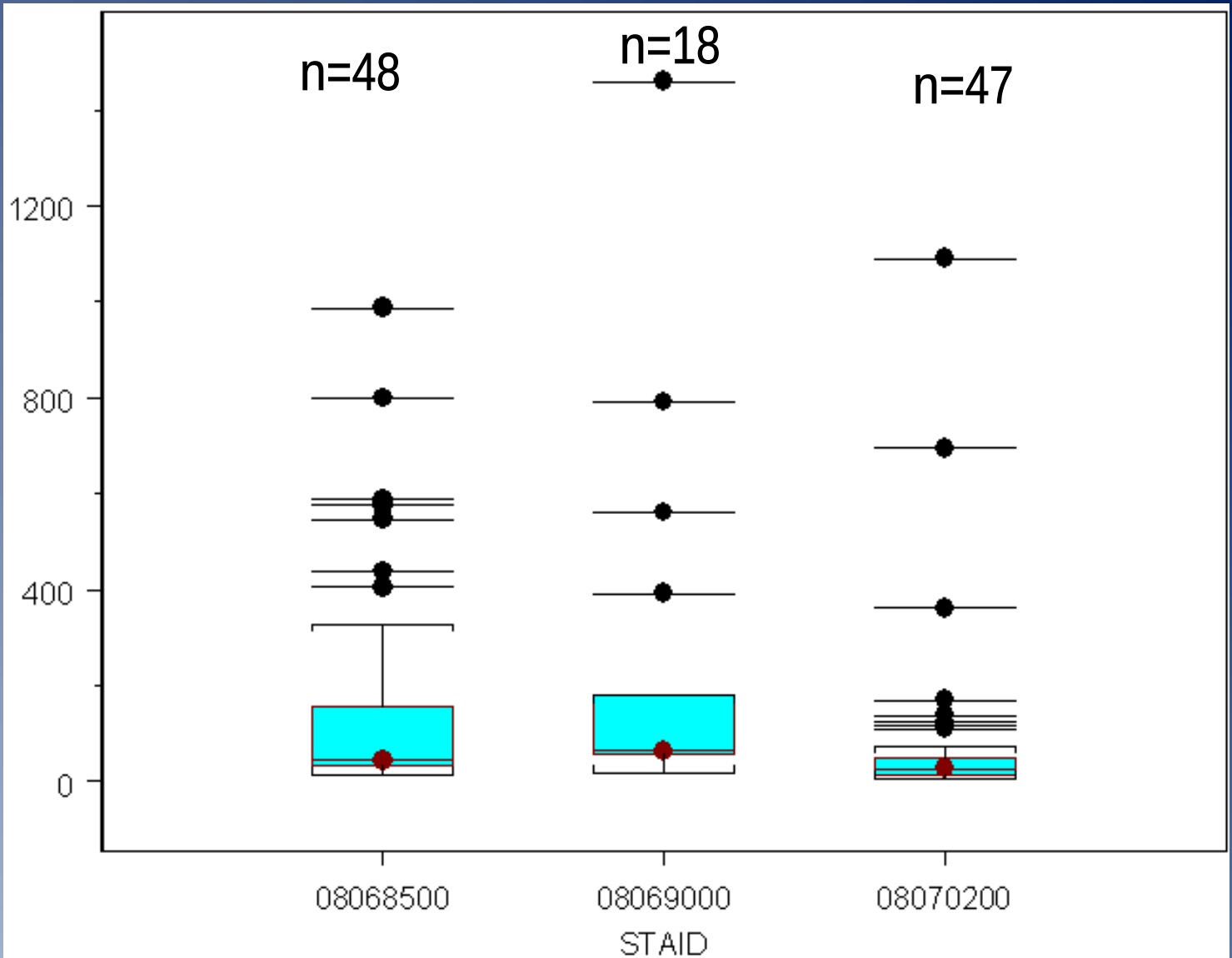
Suspended Sediment

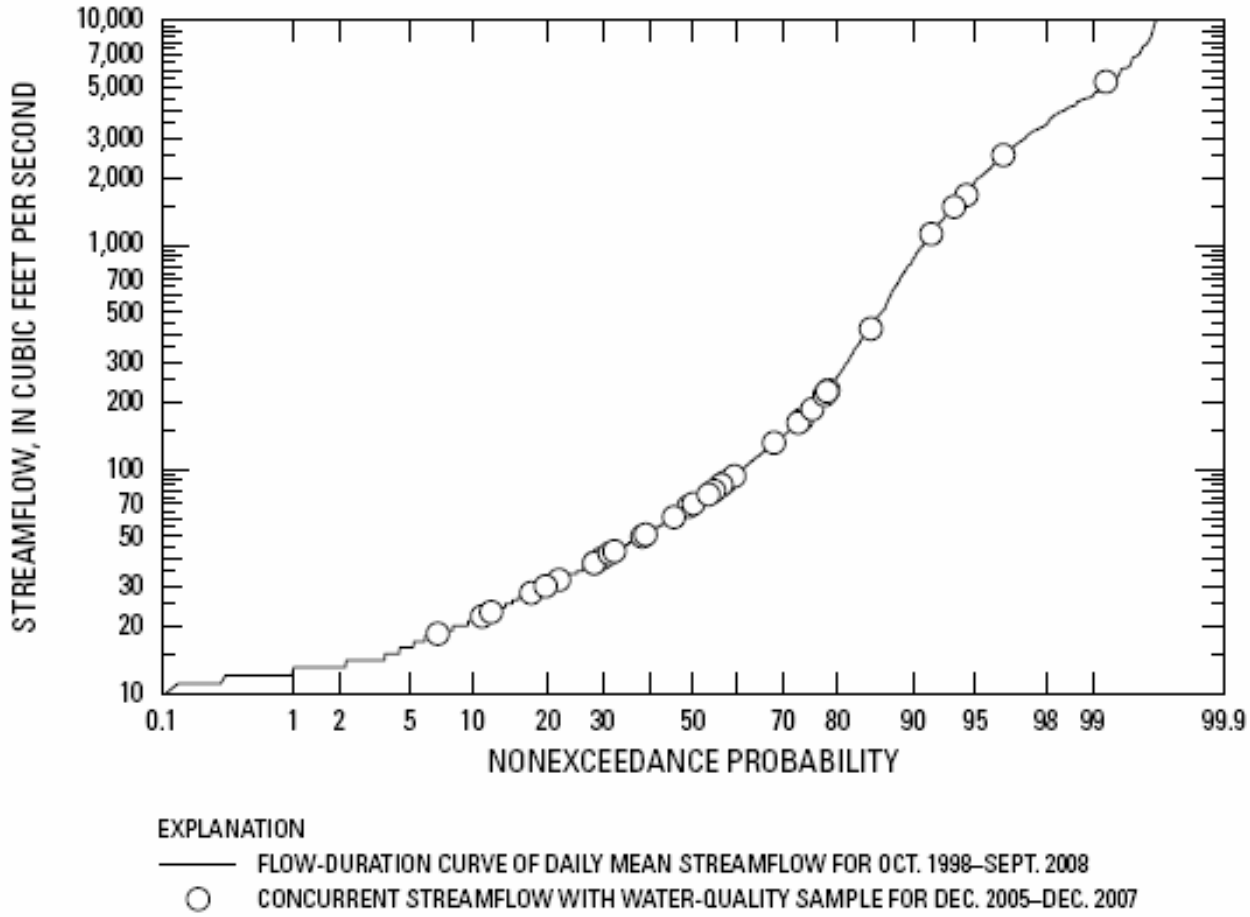


Provisional Data – Subject to Revision

Discrete Water-Quality **plus** Continuous Water-Quality = Real-time regression models

- Discrete Sample Strategy
  - Frequency
  - Flow duration
- Real-time Continuous Monitor
- Regression Analysis

Samples and Ten Year Flow-duration Curve – Spring Creek near Spring, Tex



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Suspended Sediment Regression Model – Spring Creek

Summary of Regression Analysis for the Constituent of:
Suspended Sediment (SS)

```
SUMMARY STATISTICS FOR SS, IN MILLIGRAMS PER LITER
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  15.00   34.25   44.50  152.90   81.50  987.00

REGRESSION EQUATION
Call:
ln(formula = log(SS) ~ log(Q) + poly(log(Turb), 2) + log(Temp))

Residuals:
      Min        1Q    Median        3Q       Max
-0.594926 -0.194488 -0.002587  0.241283  0.673800

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)             0.68026    0.67540   1.007 0.321167
log(Q)                  0.42009    0.06664   6.304 3.96e-07 ***
poly(log(Turb), 2)1     2.64107    0.60731   4.349 0.000124 ***
poly(log(Turb), 2)2     0.95660    0.35300   2.710 0.010592 *
log(Temp)               0.50494    0.19524   2.586 0.014303 *
---
Signif. codes:  0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1

Residual standard error: 0.3254 on 33 degrees of freedon
Multiple R-Squared: 0.9263,     Adjusted R-squared: 0.9174
F-statistic: 103.7 on 4 and 33 DF,  p-value: < 2.2e-16
```

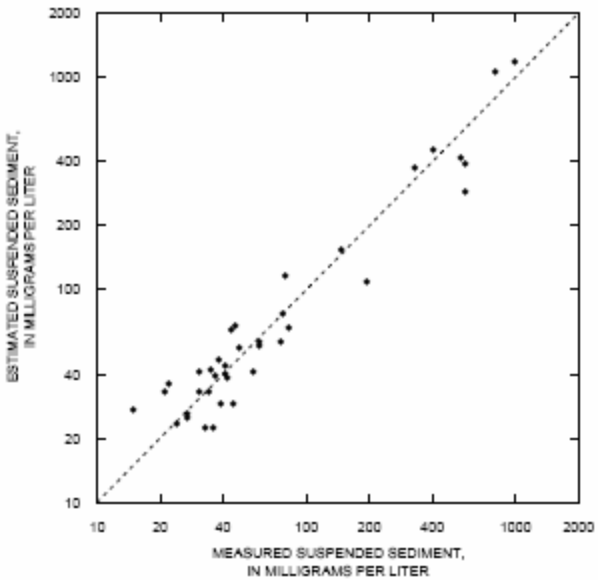
Nomenclature (all variables)

- Q is streamflow, in ft^3/s;
- pH is pH, in standard units;
- $Rain$ is rain, in inches;
- SC is specific conductance, in $\mu S/cm$;
- $Turb$ is turbidity in FNU;
- $Temp$ is water temperature, in °Celsius;
- $Date$ is Julian day t (days into year) divided by 365; and
- $\log(x)$ is natural log of x.

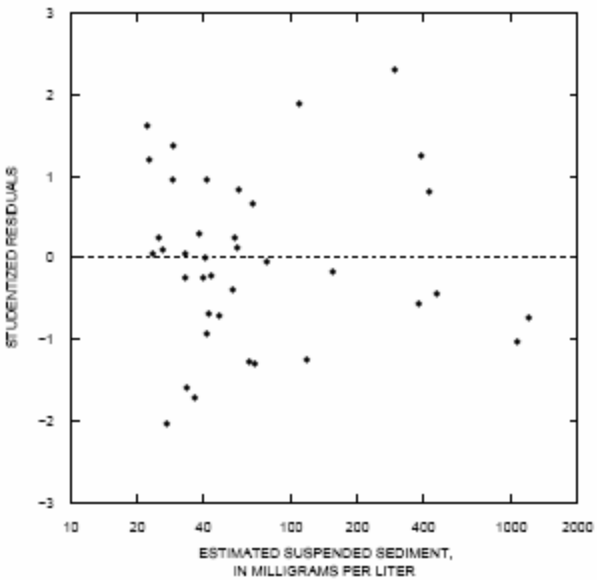
Algebraic Equation

$$\log(Y) = 0.680 + 0.420\log(Q) + 2.64\log(Turb) + 0.957\log(Turb)^2 + 0.505\log(Temp)$$

Measured verses Estimated Plot for Regression



Residual Plot for Regression



------ LINE OF EQUAL VALUE (left) OR ORIGIN (right)

● CONSTITUENT FOR STREAMFLOW-GAGING STATION-
18 Number, if present, indicates sequence number of station in input data file to statistical software identified by R software as a potential outlier.

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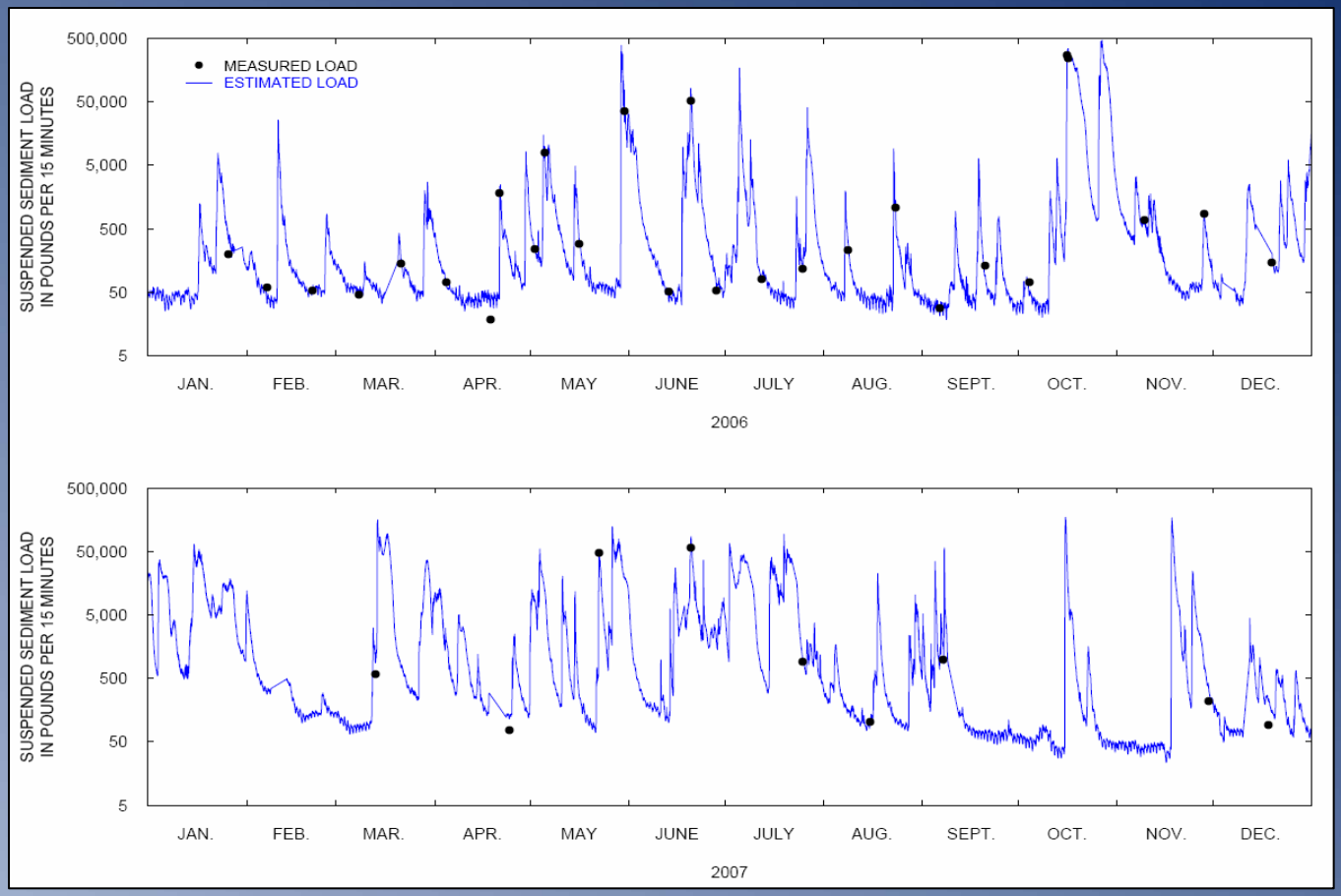
Estimated Loads



Provisional Data – Subject to Revision

Dependent variables:

- Sediment
- Nitrate + Nitrite
- Phosphorous
- Total Organic Carbon
- E. Coli
- Atrazine

Independent variables:

- Discharge
- Water Temperature
- SC
- pH
- Date
- Precipitation

USGS

Summary

- Mobile, multi-depth lake water-quality monitoring gages are a viable method for collecting and transmitting continuous data in real-time
- Combined with tributary water-quality information, the effects of watershed influences on water-quality in the lake can be observed
- Discrete sampling for ancillary constituents can be used to develop methods to estimate loads and frequency of occurrence
- Water-quality techniques developed through this project can be scaled and modified to fit most project needs

QUESTIONS ?

USGS Texas Water Science Center
Gulf Coast Program Office
The Woodlands, Texas

Amy Beussink – ambeussi@usgs.gov
Mike Turco – mjturco@usgs.gov
Jeannette Oden – jhoden@usgs.gov
Tim Oden – toden@usgs.gov

USGS Kansas Water Science Center
Jennifer Graham – jlgraham@usgs.gov

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