Christina Basin Trends, 1995–2009

- **Population**
- **Land Use**
- **Water Quality**
- **Water Temperature**
- **Stream Flow**

Compiled by Andrew Homsey, Sarah Chatterson, Erin McVey, Stacey Mack, Martha Corrozi Narvaez, and Gerald Kauffman of IPA's Water Resources Agency

BRANDYWINE: A CREEK AT RISK AS PA. AND DEL. DEBATE WHAT TO DO, THE POLLUTION FLOWS ON.

Source: Rich Henson, INQUIRER STAFF WRITER

In a corner of Chester County, on either side of a tree-lined ridge that stretches out from the Welsh Hills, the East and West Branches of the Brandywine Creek gurgle from the ground as cold, pristine springs.

For the next 20 miles, the two branches meander south through one of the most picturesque and fastest-developing areas in the Philadelphia region - past forests, meadows, farmland, industrial sites, housing developments and small towns, finally converging just north of Chadds

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EPA Environmental News

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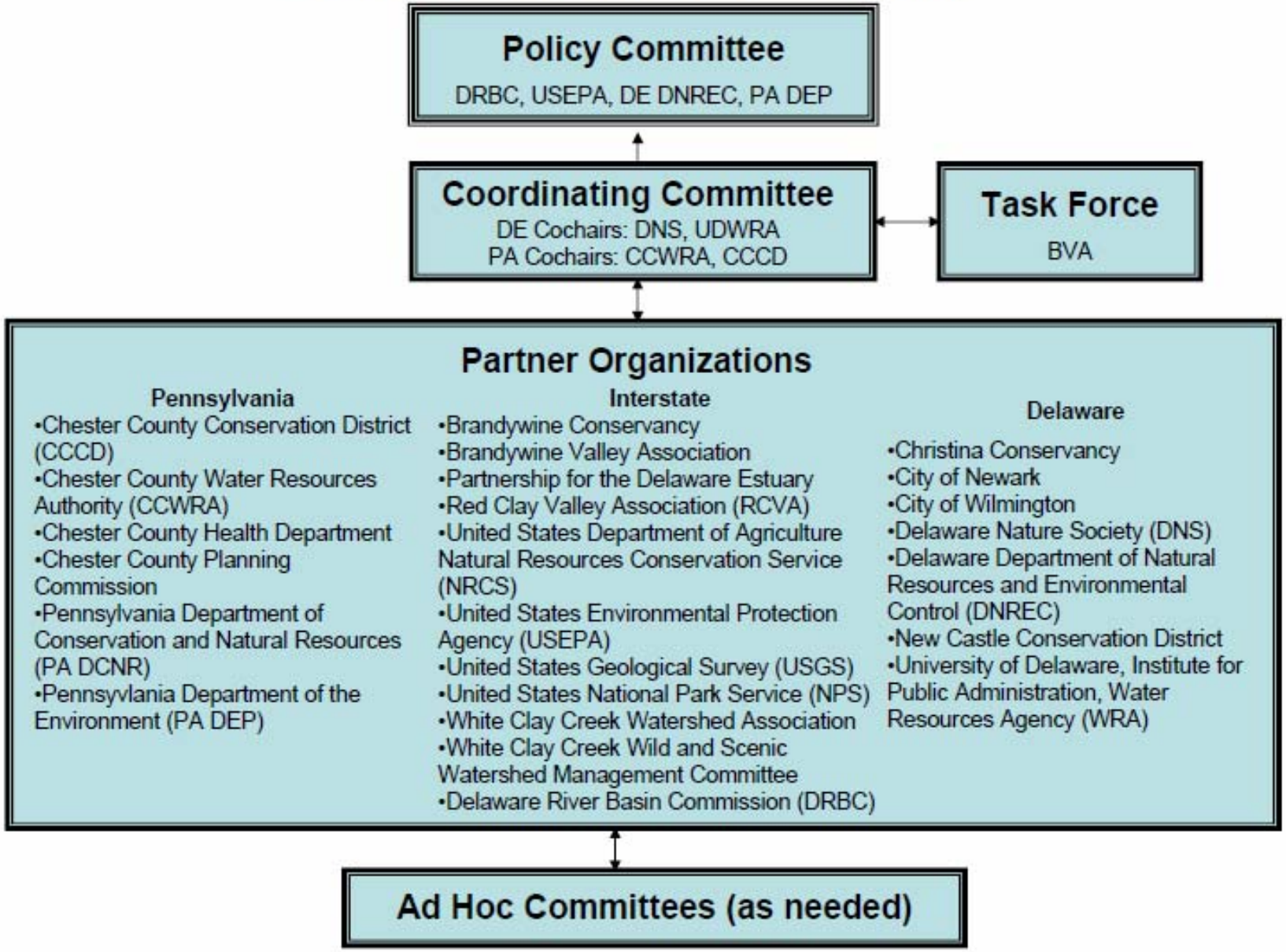
Report Shows Progress Exceeding Plans in Christina River Basin

(PHILADELPHIA, February 5, 2009) – The U.S. Environmental Protection Agency, announced today that the Christina River Basin Clean Water Partnership in Pennsylvania and Delaware has made significant progress in reducing pollution from storm water runoff to the Christina River basin.

A recent report by the University of Delaware and the Delaware River Basin Commission shows that, throughout the past four years, the Partnership, with the assistance of a $1 million EPA grant, has implemented numerous projects to reduce the harmful effects of stormwater runoff pollution on drinking water supplies, recreation, fisheries, and wildlife.

For every federal dollar invested in the project, the Partnership leveraged more than two dollars, allowing them to exceed the original goals, some by more than 50 percent.

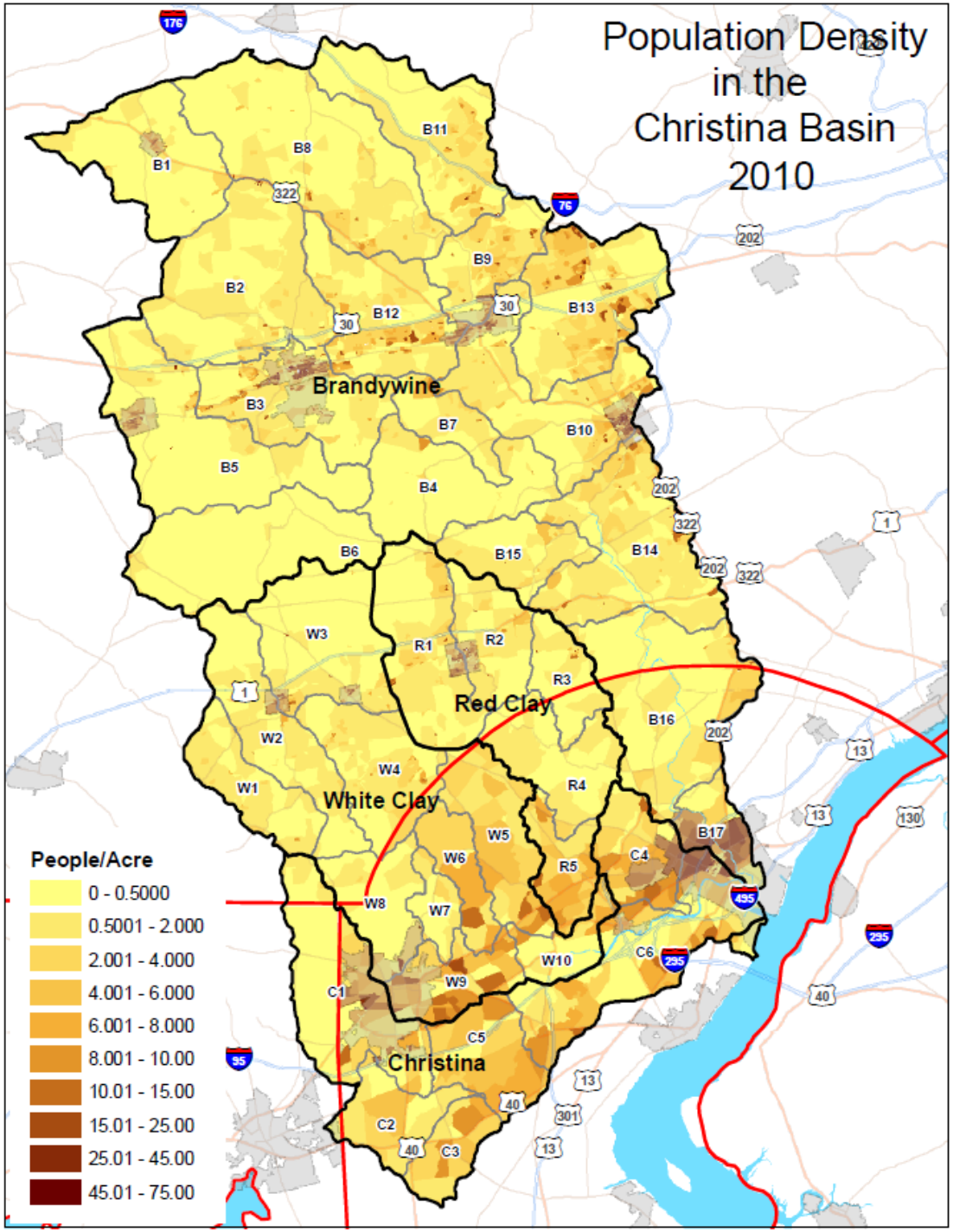
Christina Basin Clean Water Partnership



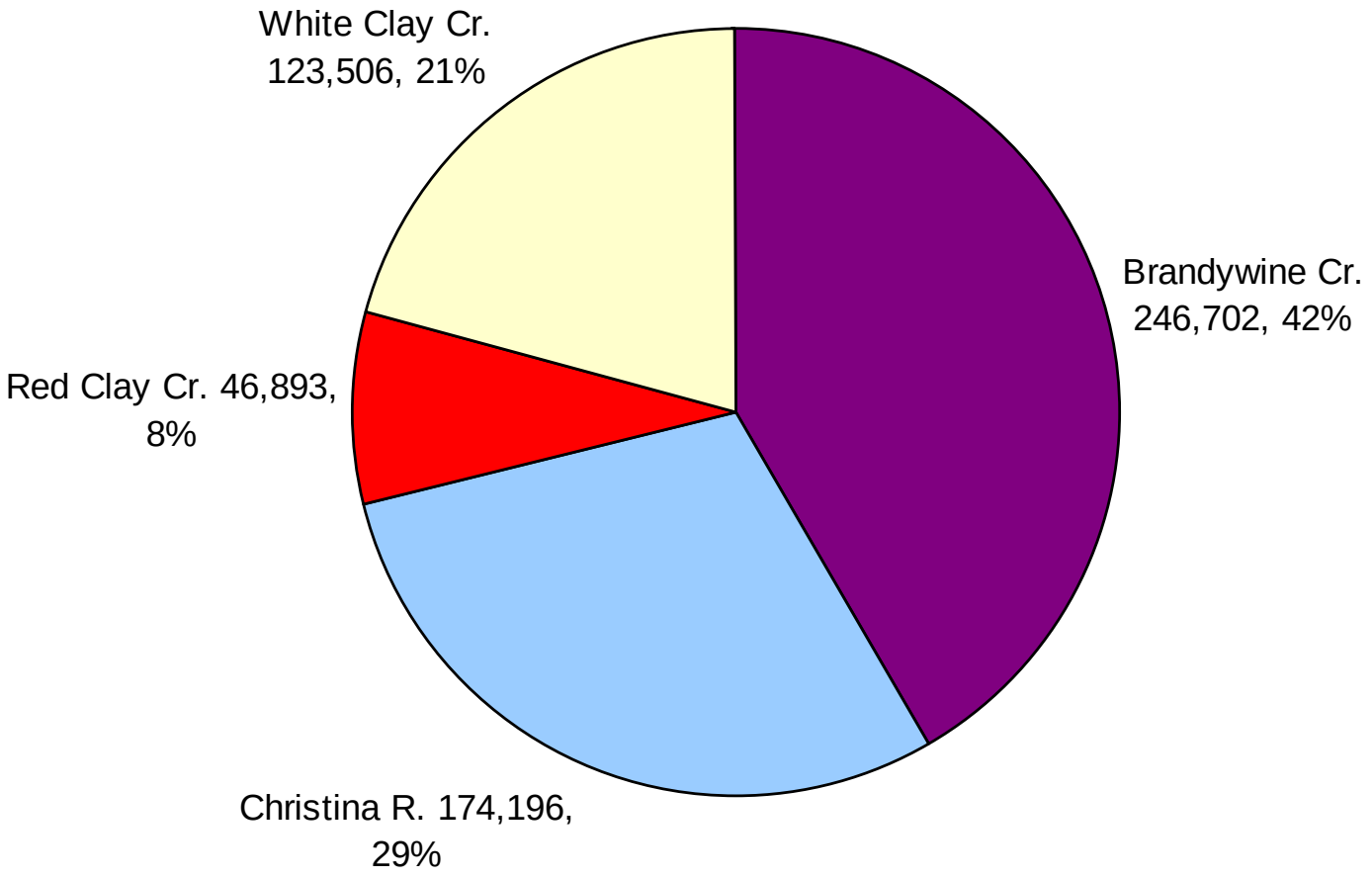
Christina Basin Population

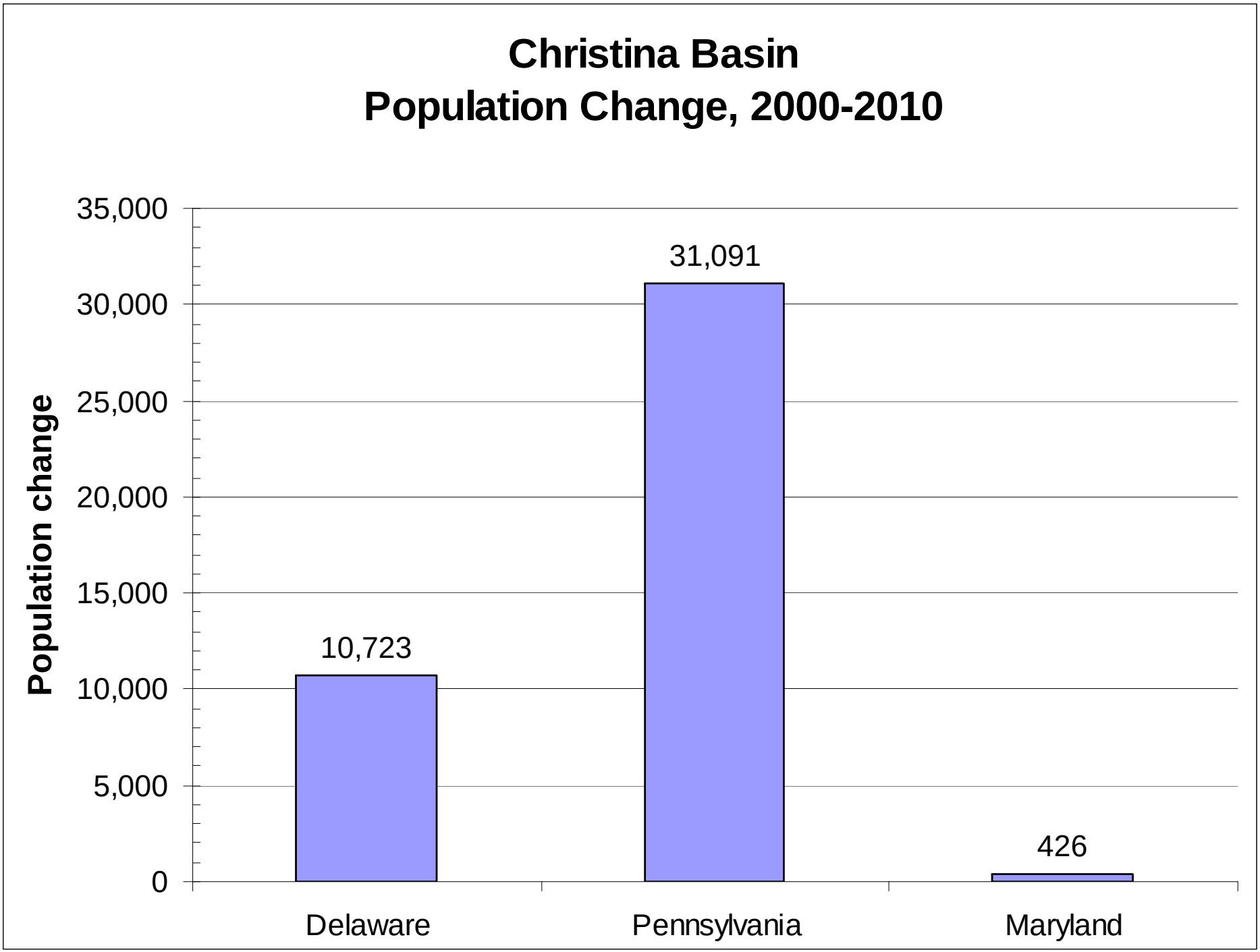
Watersheds	sq mi	2000 pop.	2010 pop.	Change	2000 p/sm	2010 p/sm
Brandywine Creek	326	221,413	246,702	25,289	679	757
Christina River	78	166,435	174,196	7,761	2,134	2,233
Red Clay Creek	54	42,630	46,893	4,263	789	868
White Clay Creek	107	118,579	123,506	4,927	1,109	1,155
Christina Basin	565	549,057	591,297	42,240	972	1,047

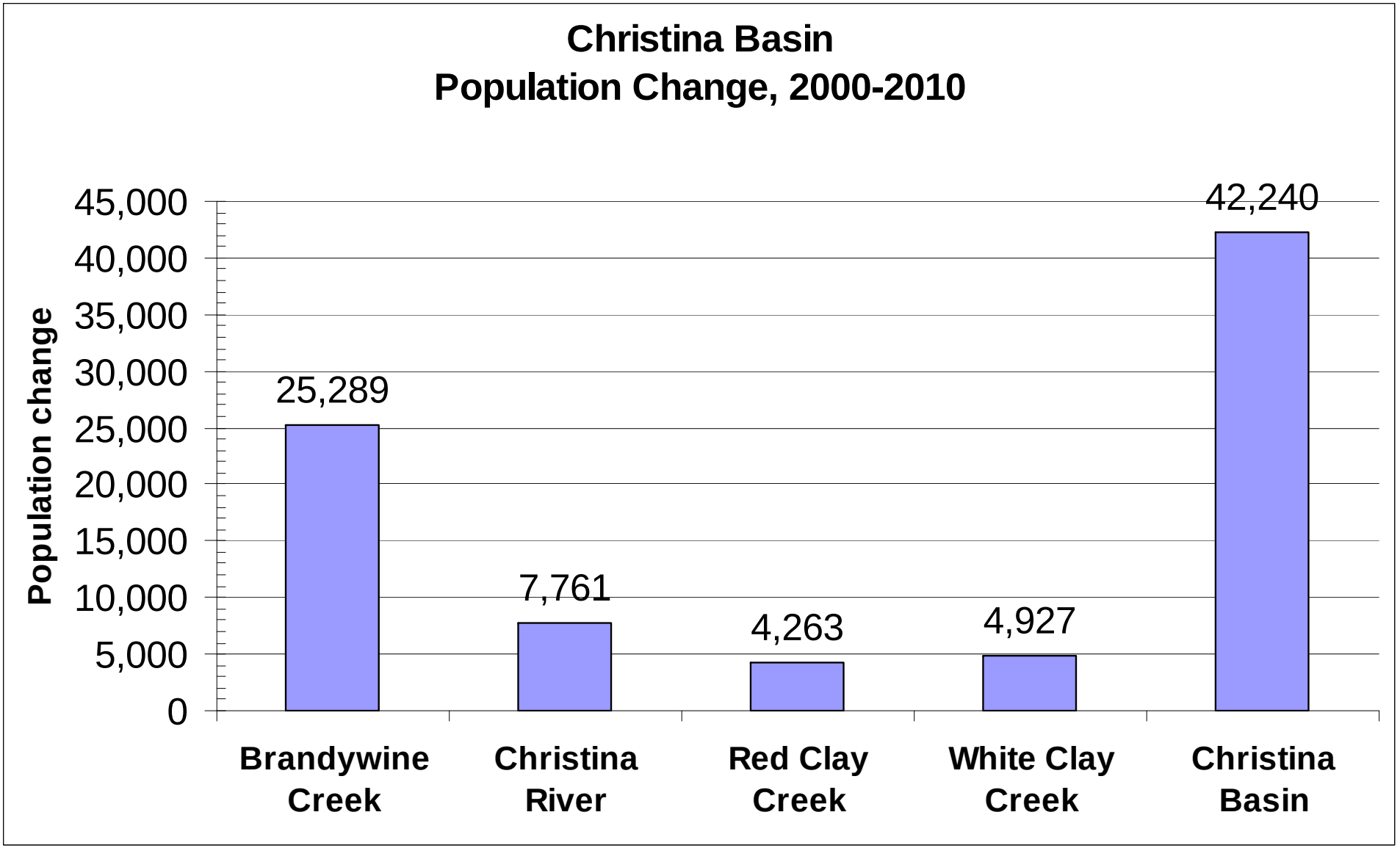
Source: U. S. Census

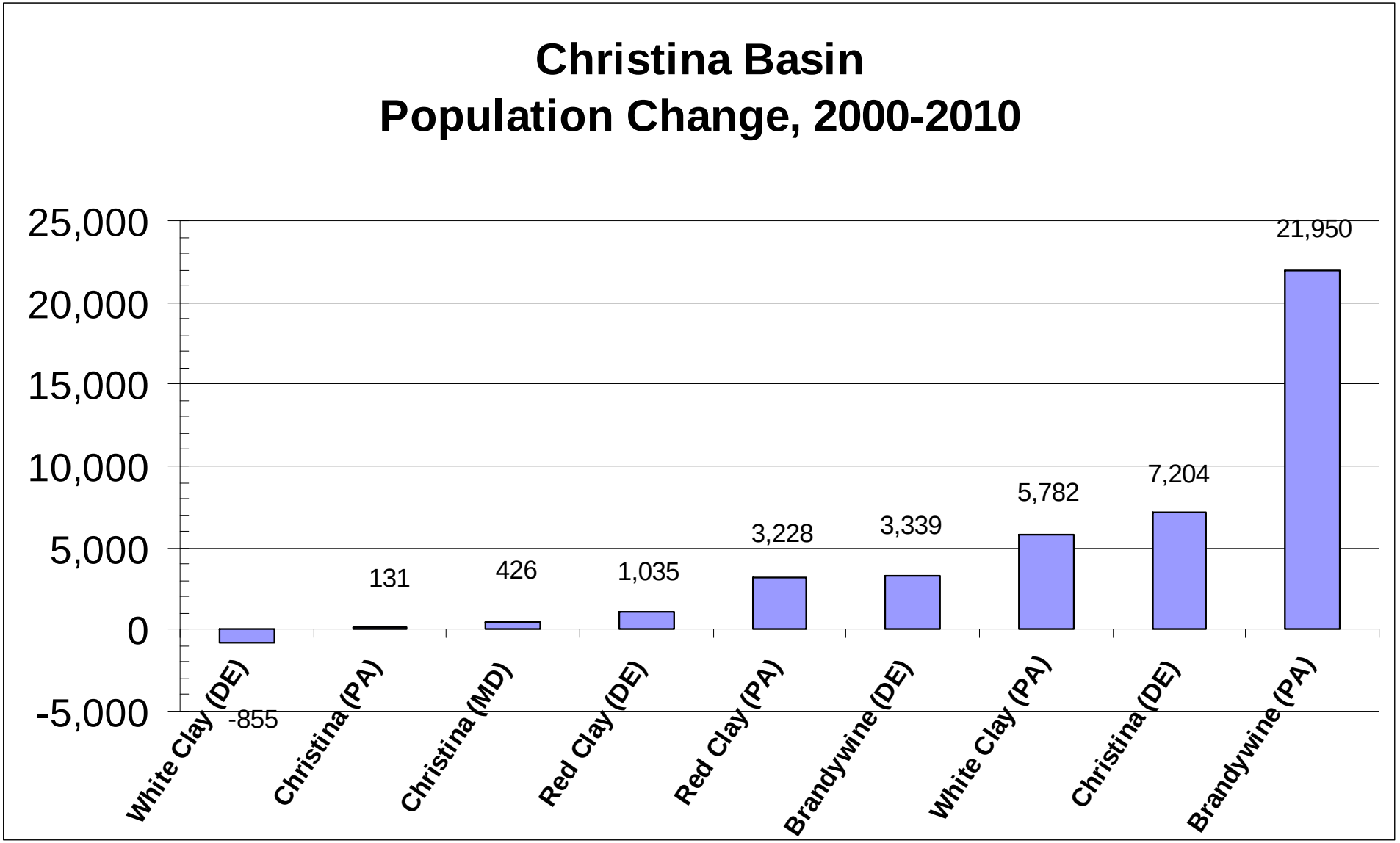

Population Density
in the
Christina Basin
2010
Brandywine
Red Clay
White Clay
Christina
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
B12
B13
B14
B15
B16
B17
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
R1
R2
R3
R4
R5
C1
C2
C3
C4
C5
C6
People/Acre
0 - 0.5000
0.5001 - 2.000
2.001 - 4.000
4.001 - 6.000
6.001 - 8.000
8.001 - 10.00
10.01 - 15.00
15.01 - 25.00
25.01 - 45.00
45.01 - 75.00

Christina Basin Population, 2010

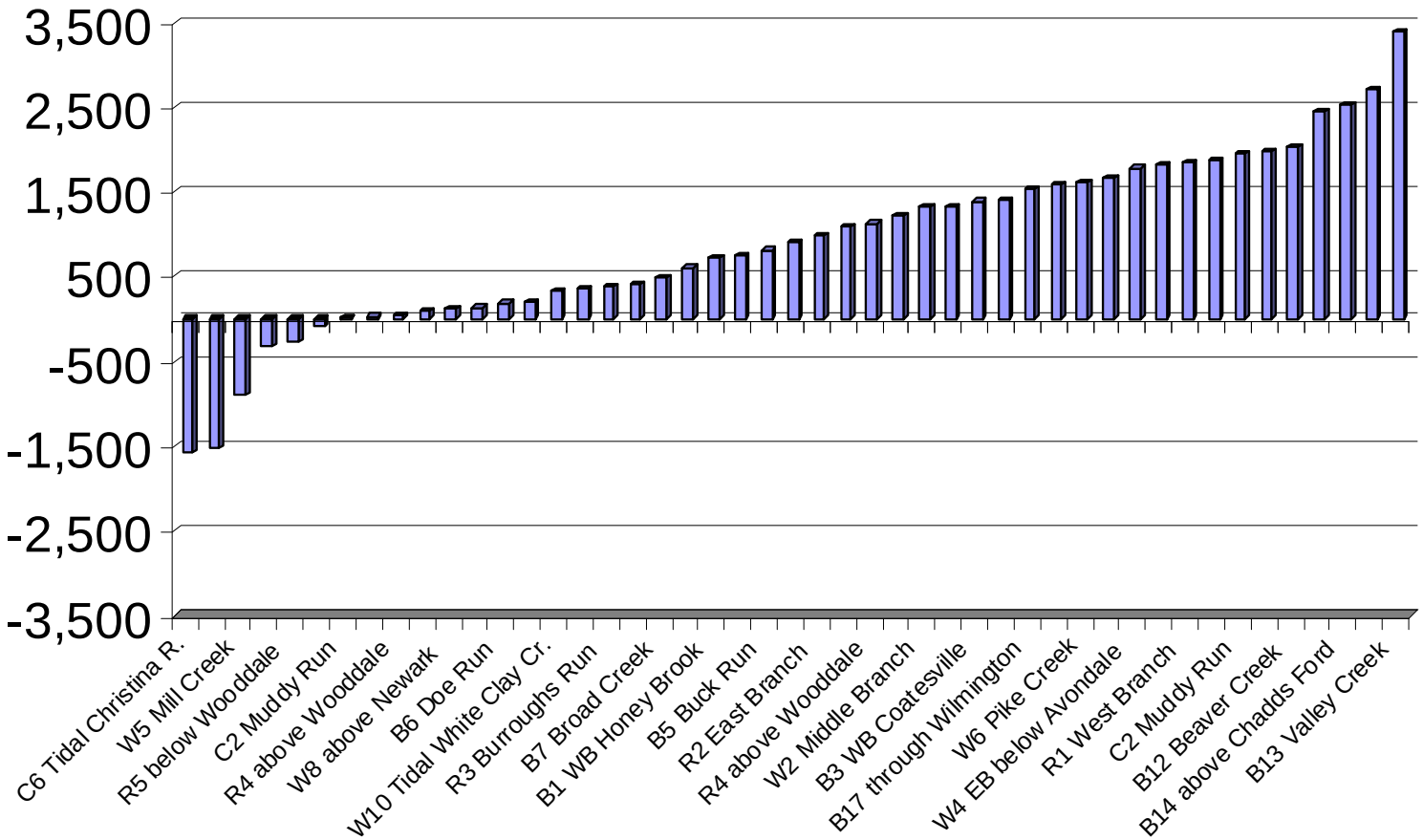



Christina Basin
Population Change, 2000-2010
Population change
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
10,723
31,091
426
Delaware
Pennsylvania
Maryland


Christina Basin
Population Change, 2000-2010
Population change
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
25,289
7,761
4,263
4,927
42,240
Brandywine Creek
Christina River
Red Clay Creek
White Clay Creek
Christina Basin


Christina Basin
Population Change, 2000-2010
25,000
20,000
15,000
10,000
5,000
0
-5,000
-855
131
426
1,035
3,228
3,339
5,782
7,204
21,950
White Clay (DE)
Christina (PA)
Christina (MD)
Red Clay (DE)
Red Clay (PA)
Brandywine (DE)
White Clay (PA)
Christina (DE)
Brandywine (PA)

Christina Basin
Population Change, 2000-2010

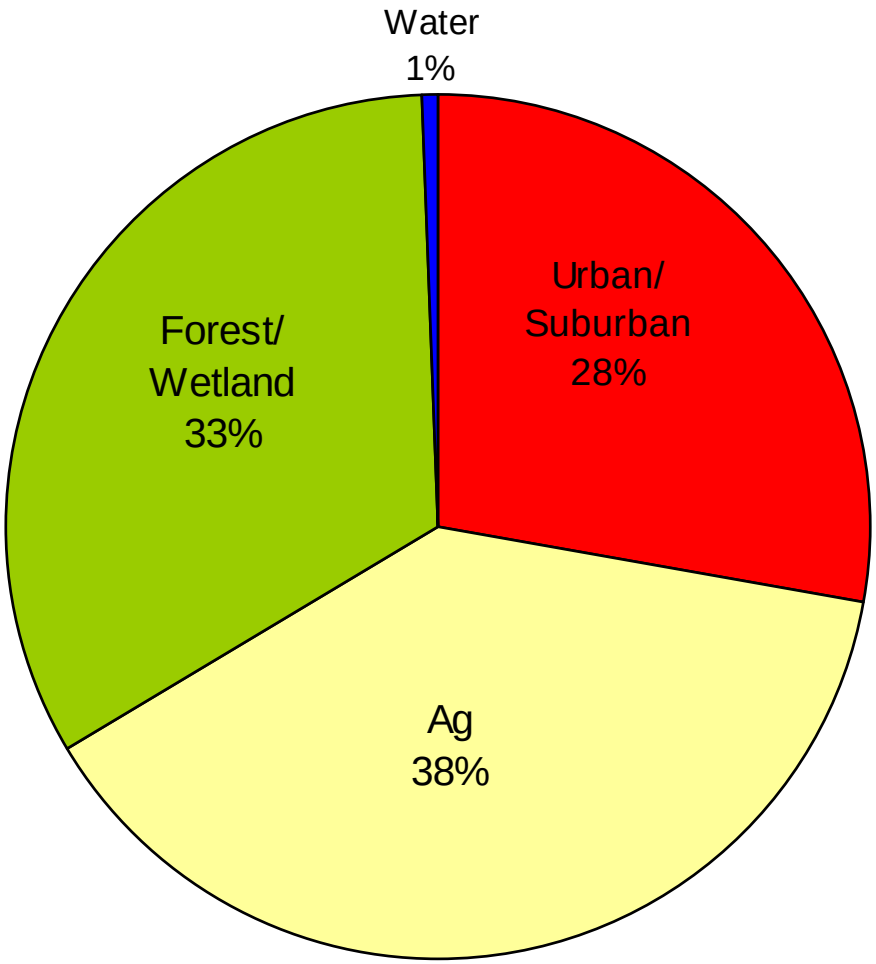


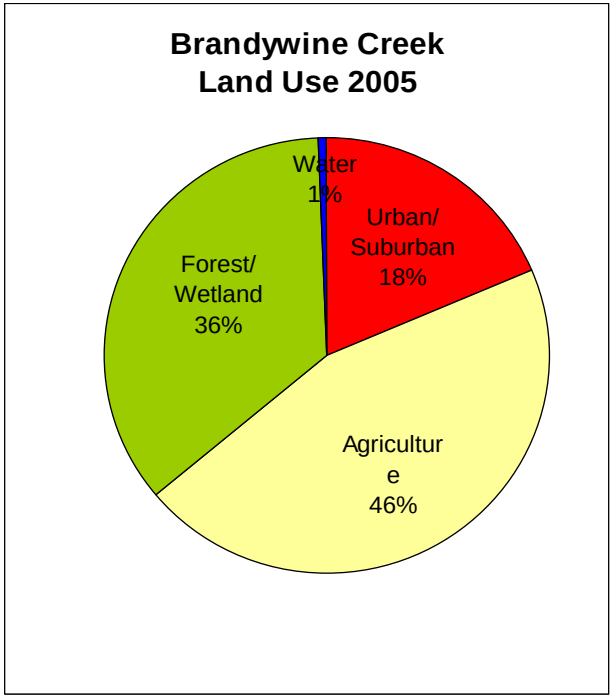
Christina Basin Land Use

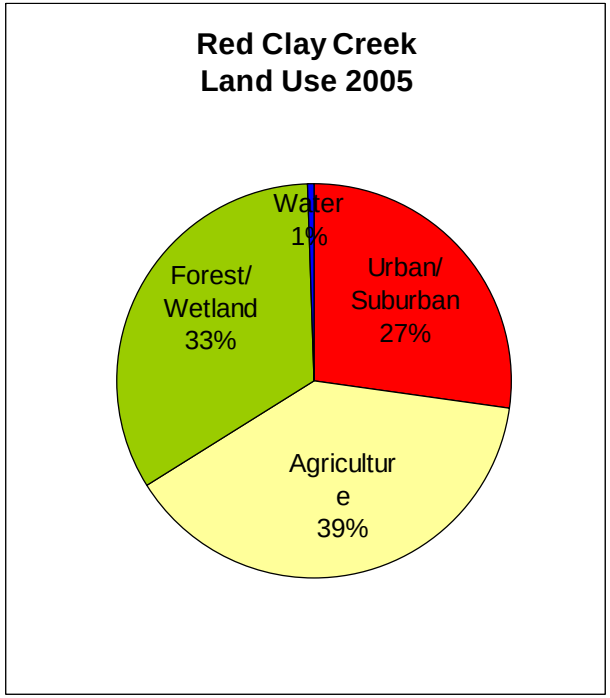
2005 Land Use									
Watershed	Urb/Sub	Ag	For/Wet	Water	Total	Urb/Sub	Ag	For/Wet	Water
Brandywine	60.1	147.7	115.9	1.6	325.4	18%	45%	36%	0%
Christina	45.2	11.2	19.9	0.8	77.1	59%	15%	26%	1%
Red Clay	14.7	20.9	18.1	0.3	54.1	27%	39%	33%	1%
White Clay	36.8	38.1	32.0	0.3	107.3	34%	36%	30%	0%
--	0.6	0.0	0.1	0.0	0.7	92%	0%	8%	0%
Total	156.8	218.0	185.9	3.1	563.8	28%	39%	33%	1%

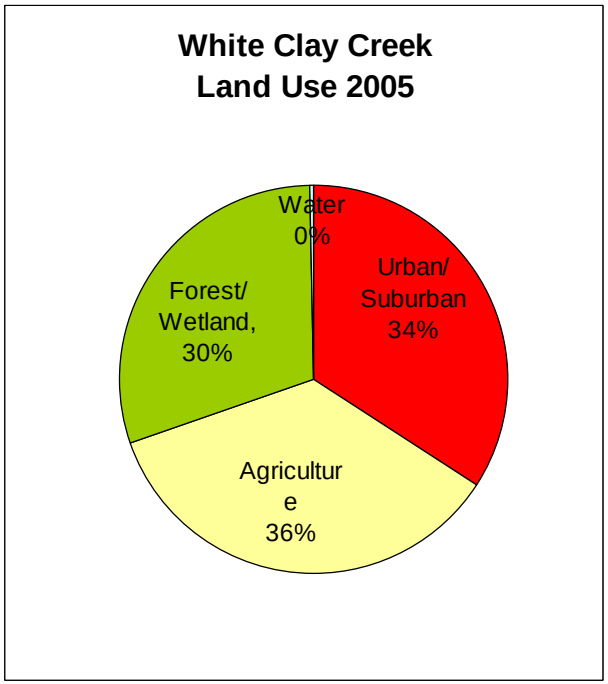
Source: NOAA CSC

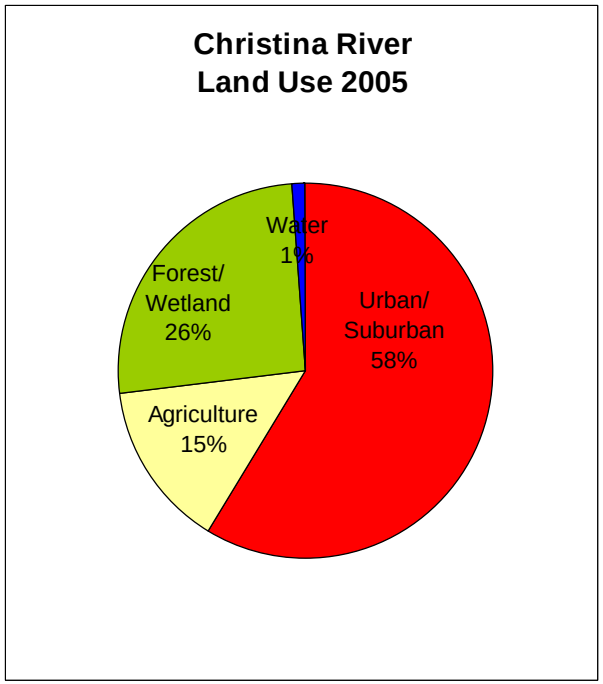
Christina Basin
Land Use, 2005



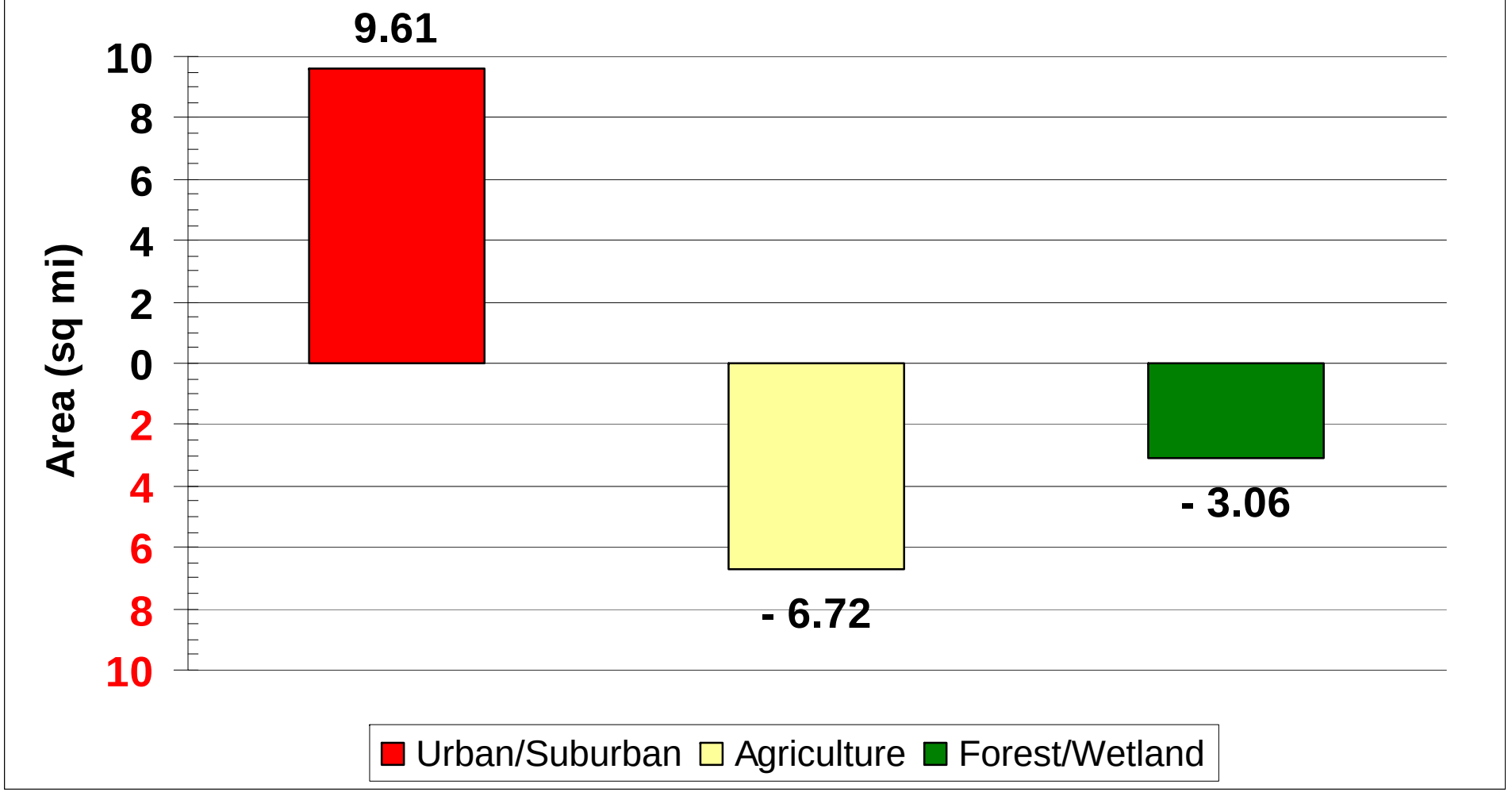

Brandywine Creek
Land Use 2005
Water
1%
Urban/
Suburban
18%
Forest/
Wetland
36%
Agricultur
e
46%

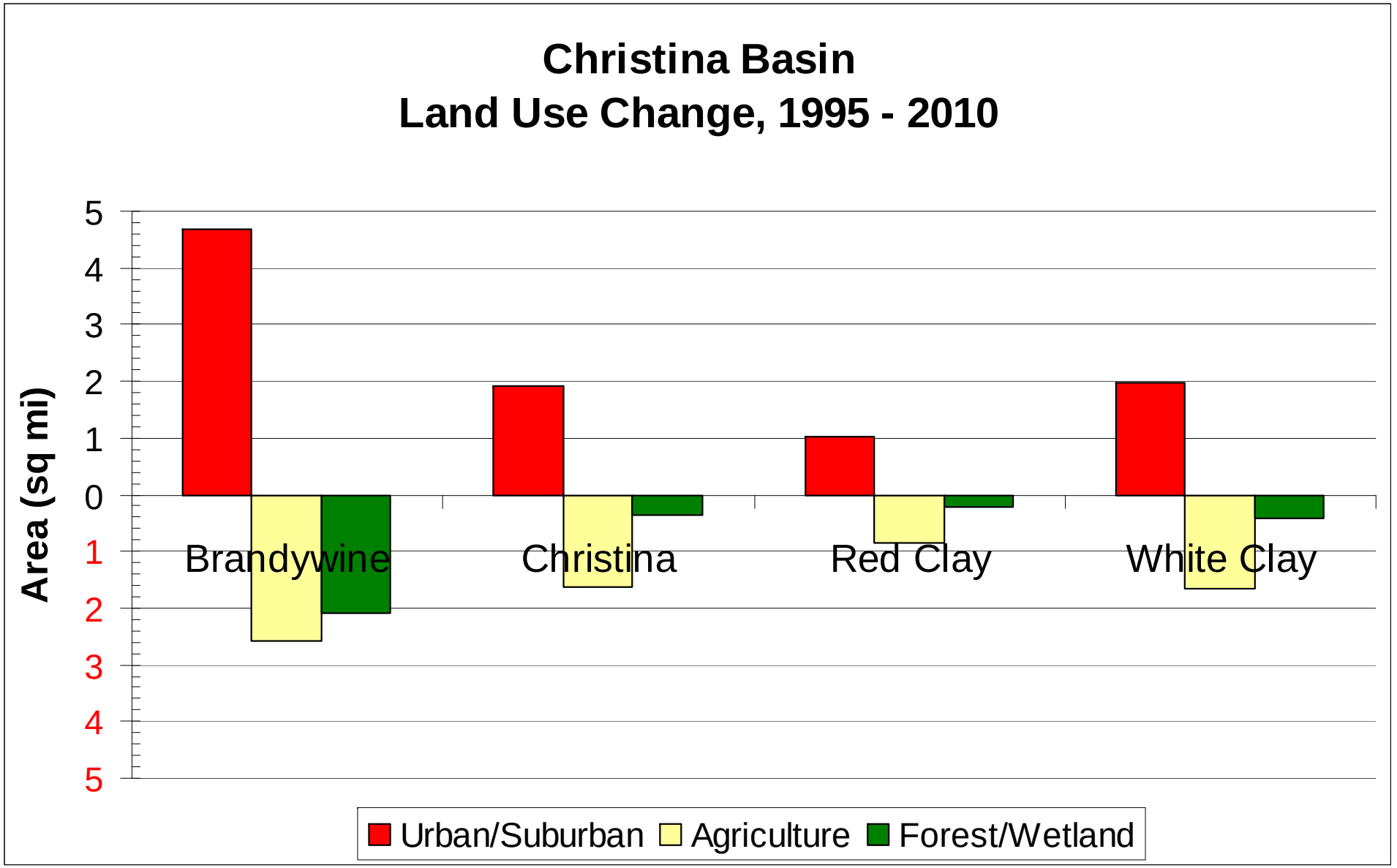

Red Clay Creek
Land Use 2005
Water
1%
Urban/
Suburban
27%
Forest/
Wetland
33%
Agricultur
e
39%


White Clay Creek
Land Use 2005
Water
0%
Urban/
Suburban
34%
Forest/
Wetland,
30%
Agricultur
e
36%

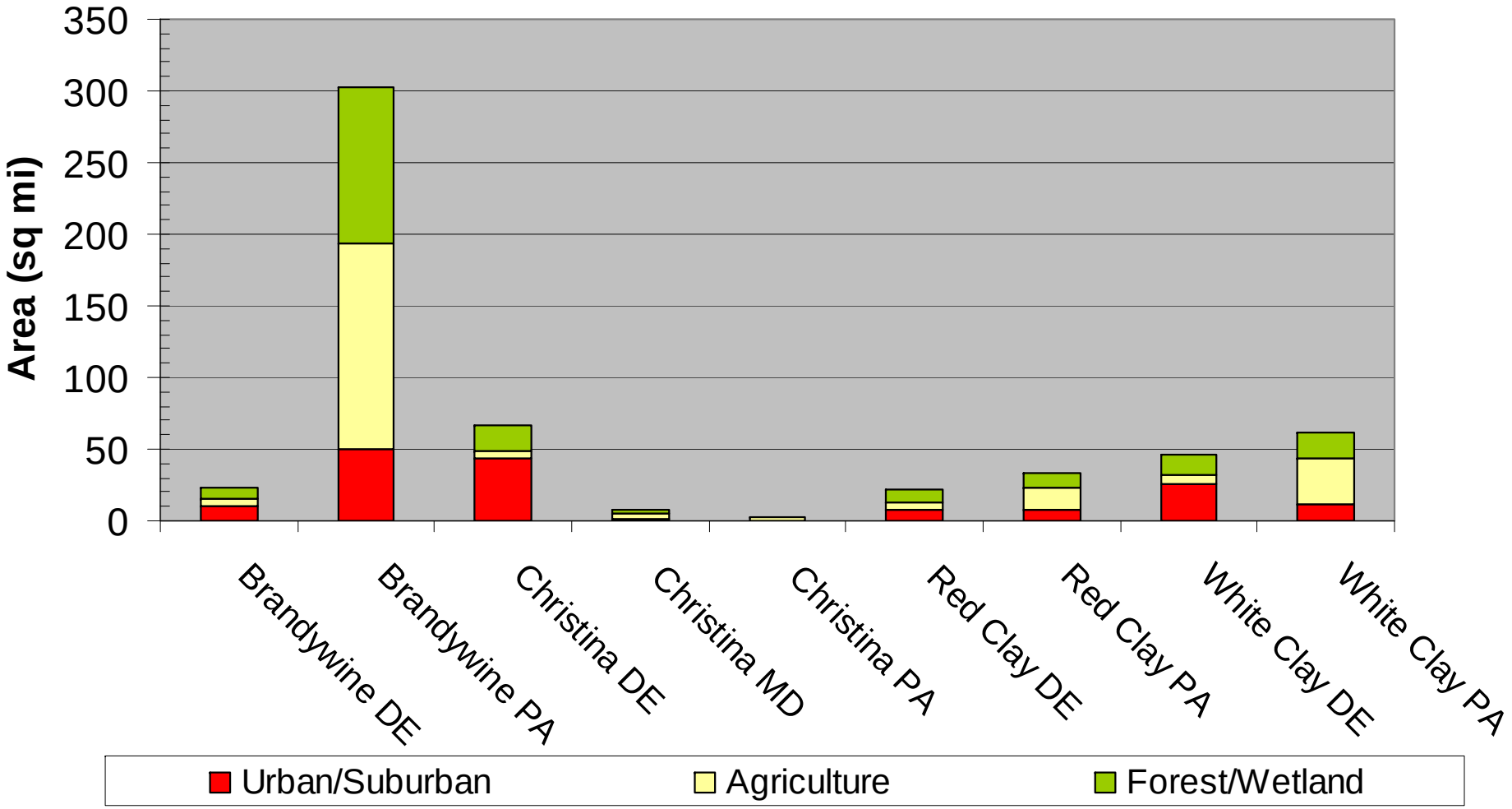

Christina River
Land Use 2005
Water
1%
Urban/
Suburban
58%
Forest/
Wetland
26%
Agriculture
15%

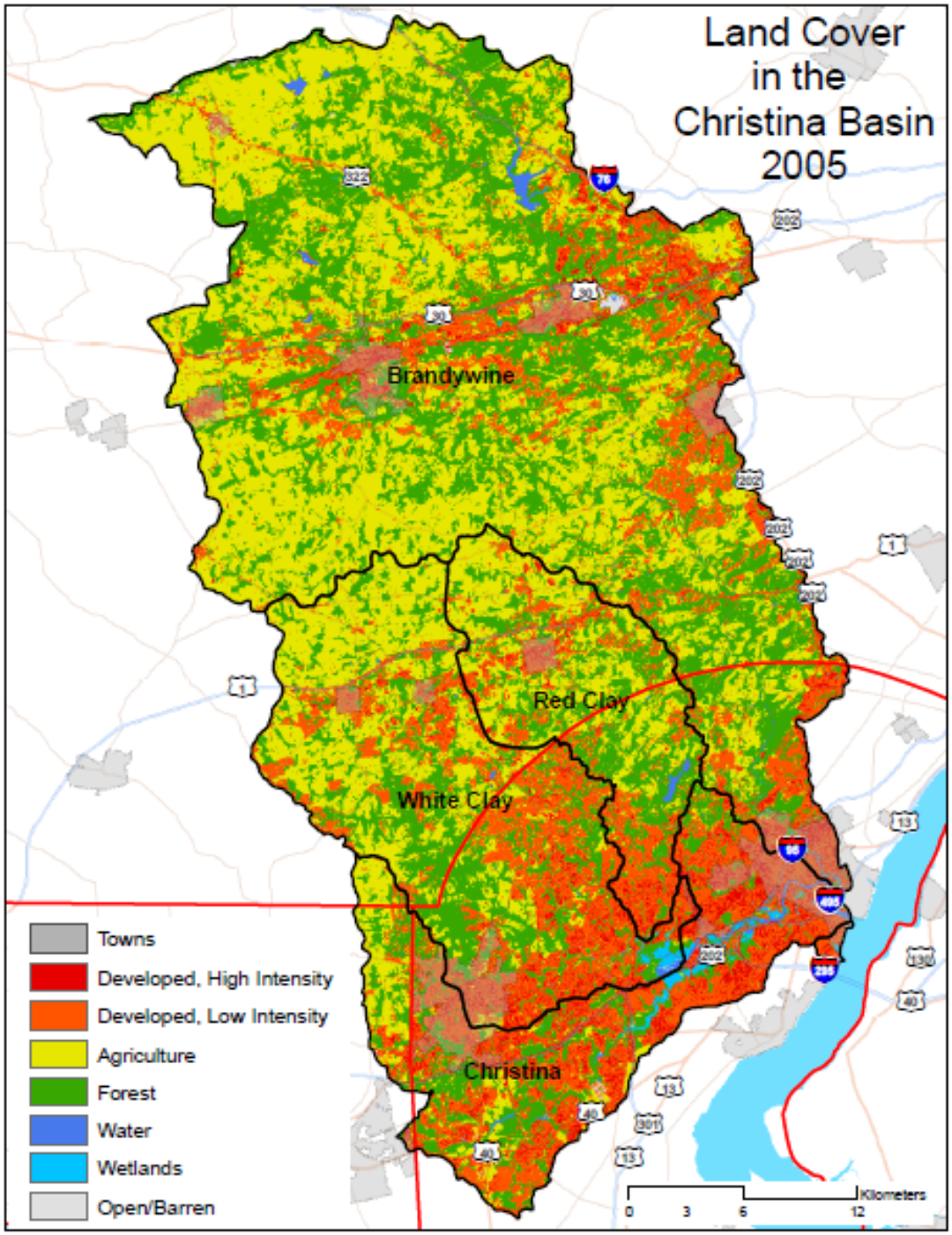
Christina Basin
Land Use Change, 1996 - 2005

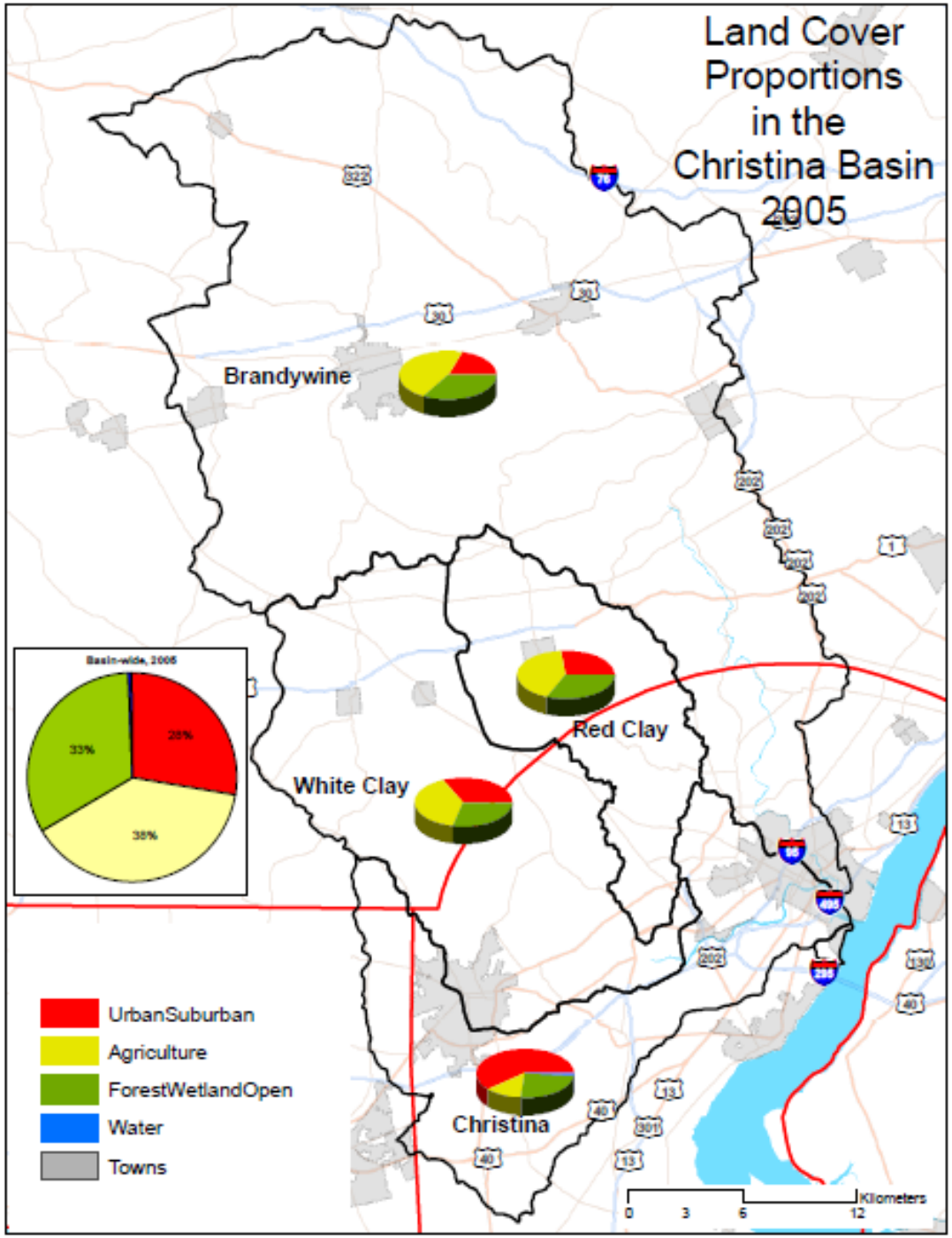


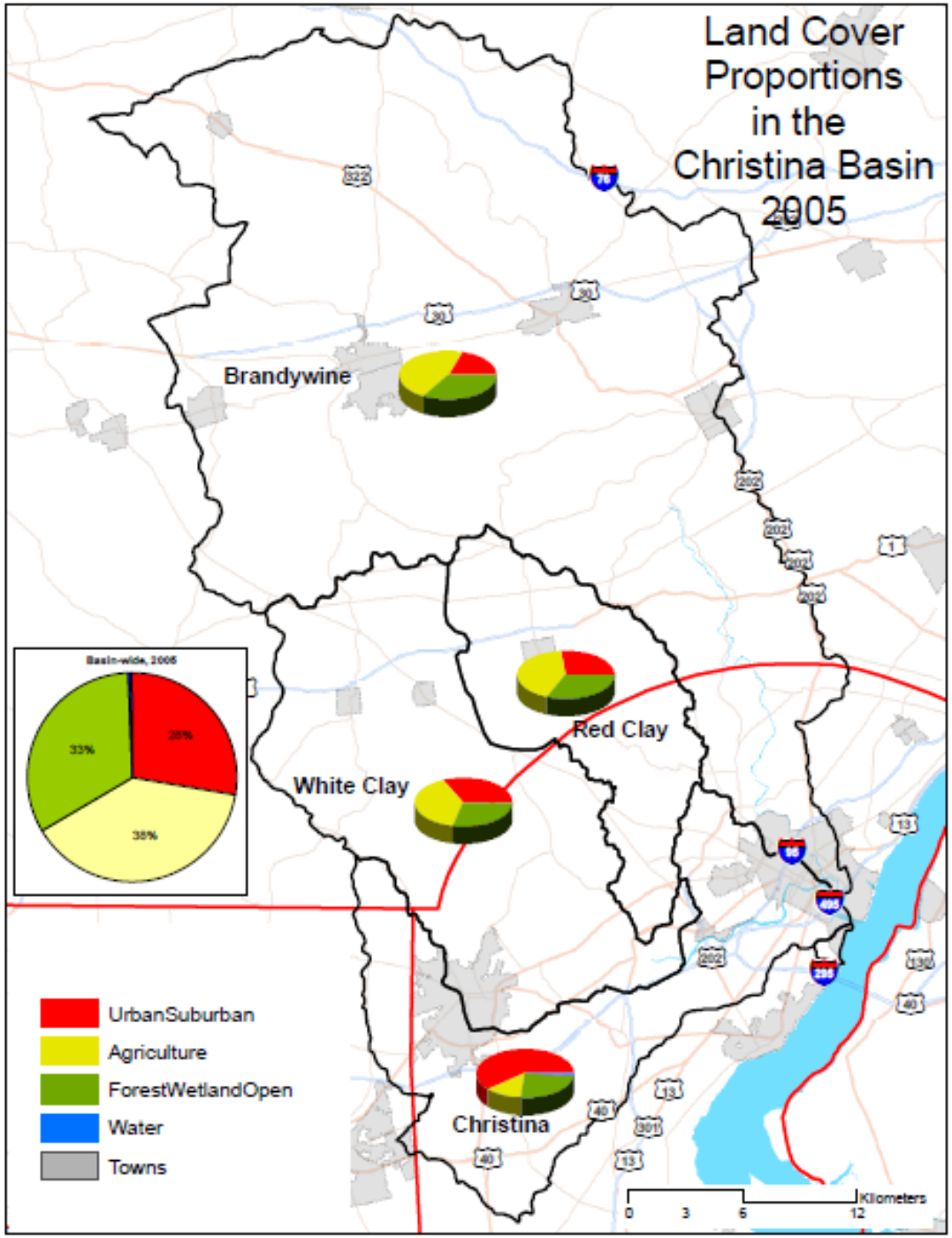

Christina Basin
Land Use Change, 1995 - 2010
Area (sq mi)
5
4
3
2
1
0
1
2
3
4
5
Brandywine
Christina
Red Clay
White Clay
Urban/Suburban
Agriculture
Forest/Wetland

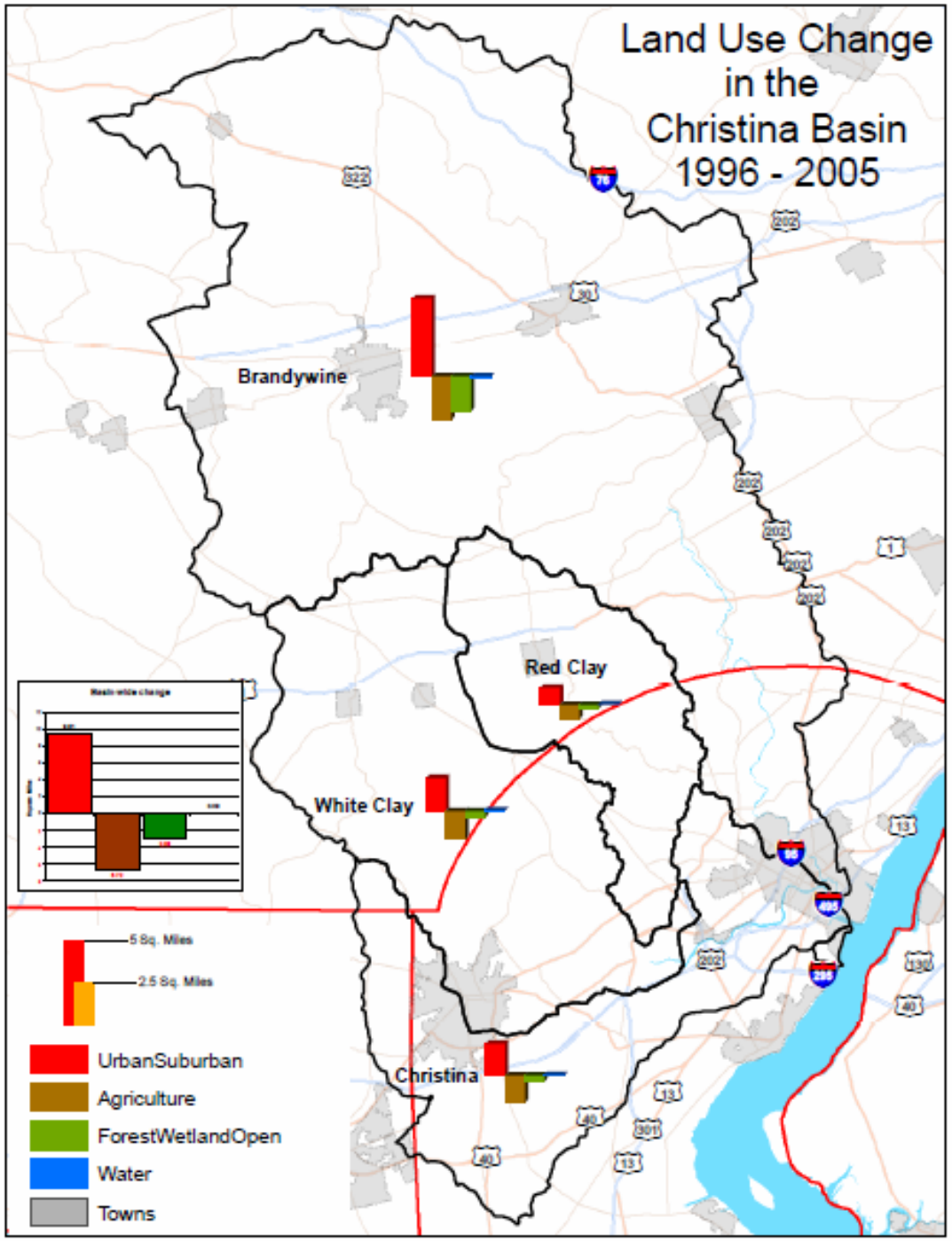
Christina Basin Land Use by State and Watershed, 2005

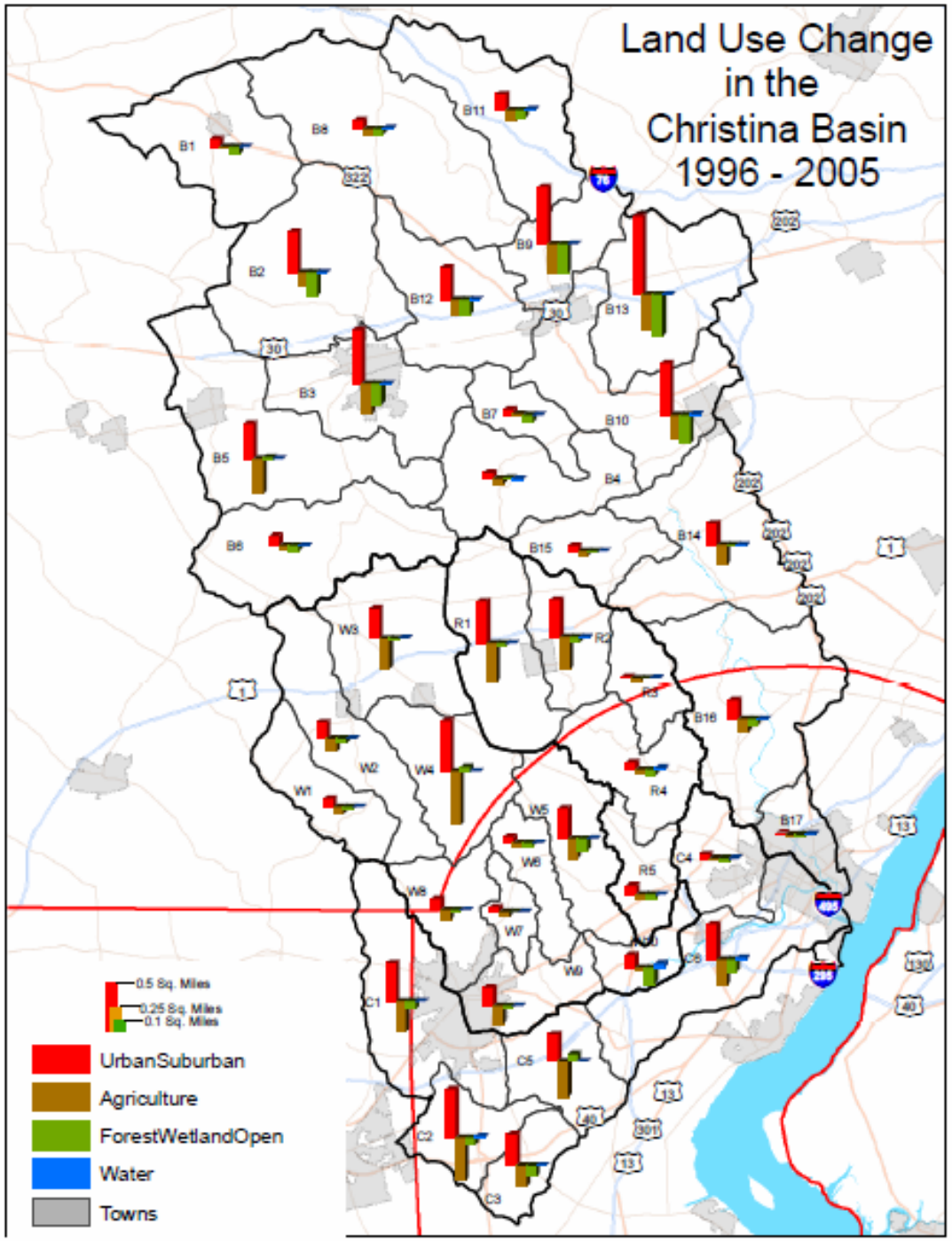



Land Cover
in the
Christina Basin
2005
Brandywine
Red Clay
White Clay
Christina
Towns
Developed, High Intensity
Developed, Low Intensity
Agriculture
Forest
Water
Wetlands
Open/Barren
Kilometers
0
3
6
12


Land Cover Proportions in the Christina Basin 2005
Brandywine
Red Clay
White Clay
Christina
Basin-wide, 2005
28%
33%
38%
UrbanSuburban
Agriculture
ForestWetlandOpen
Water
Towns
Kilometers
0
3
6
12


Land Cover Proportions in the Christina Basin 2005
Brandywine
Red Clay
White Clay
Christina
Basin-wide, 2005
28%
33%
38%
UrbanSuburban
Agriculture
ForestWetlandOpen
Water
Towns
Kilometers
0
3
6
12

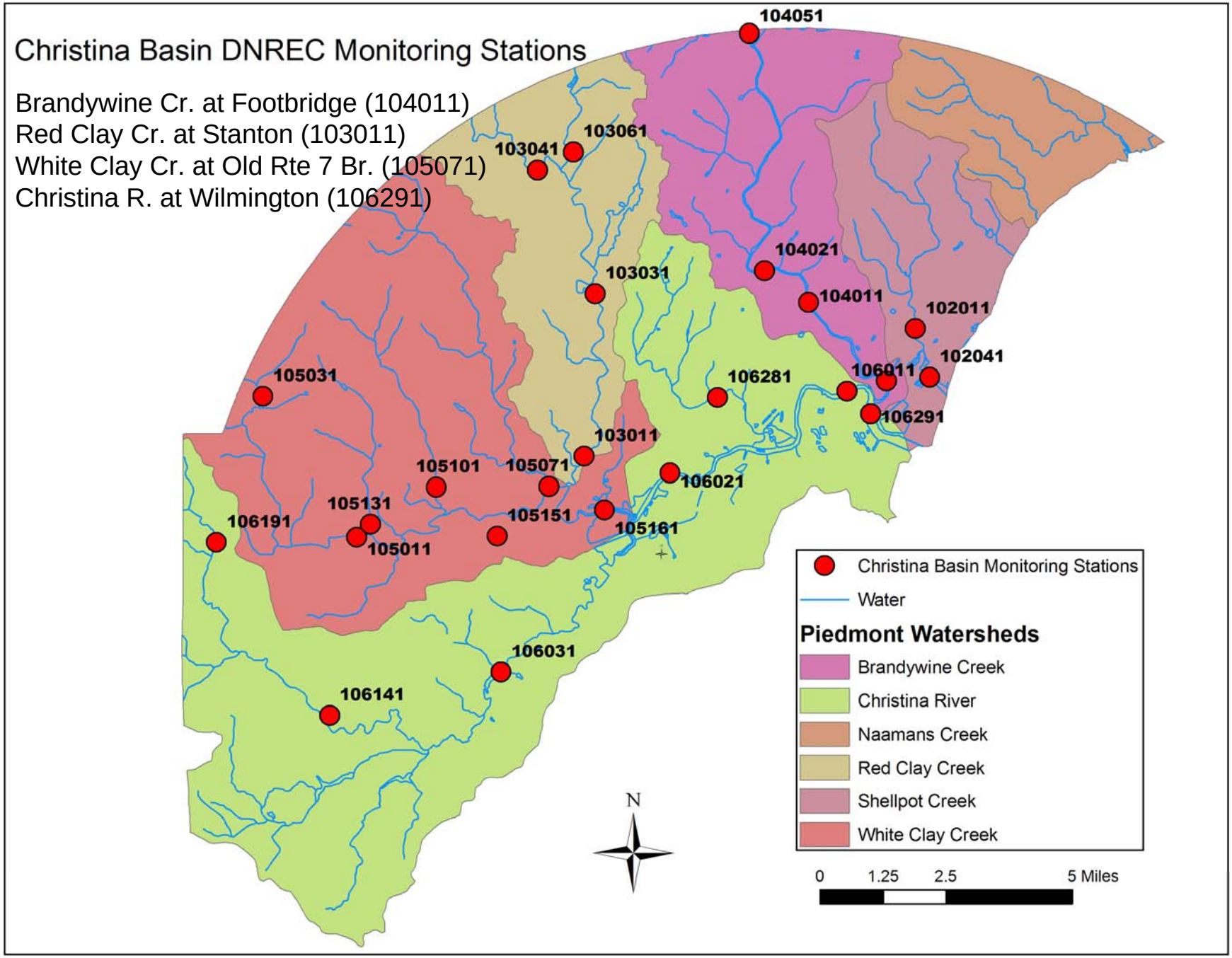

Land Use Change
in the
Christina Basin
1996 - 2005
Brandywine
Red Clay
White Clay
Christina
5 Sq. Miles
2.5 Sq. Miles
UrbanSuburban
Agriculture
ForestWetlandOpen
Water
Towns

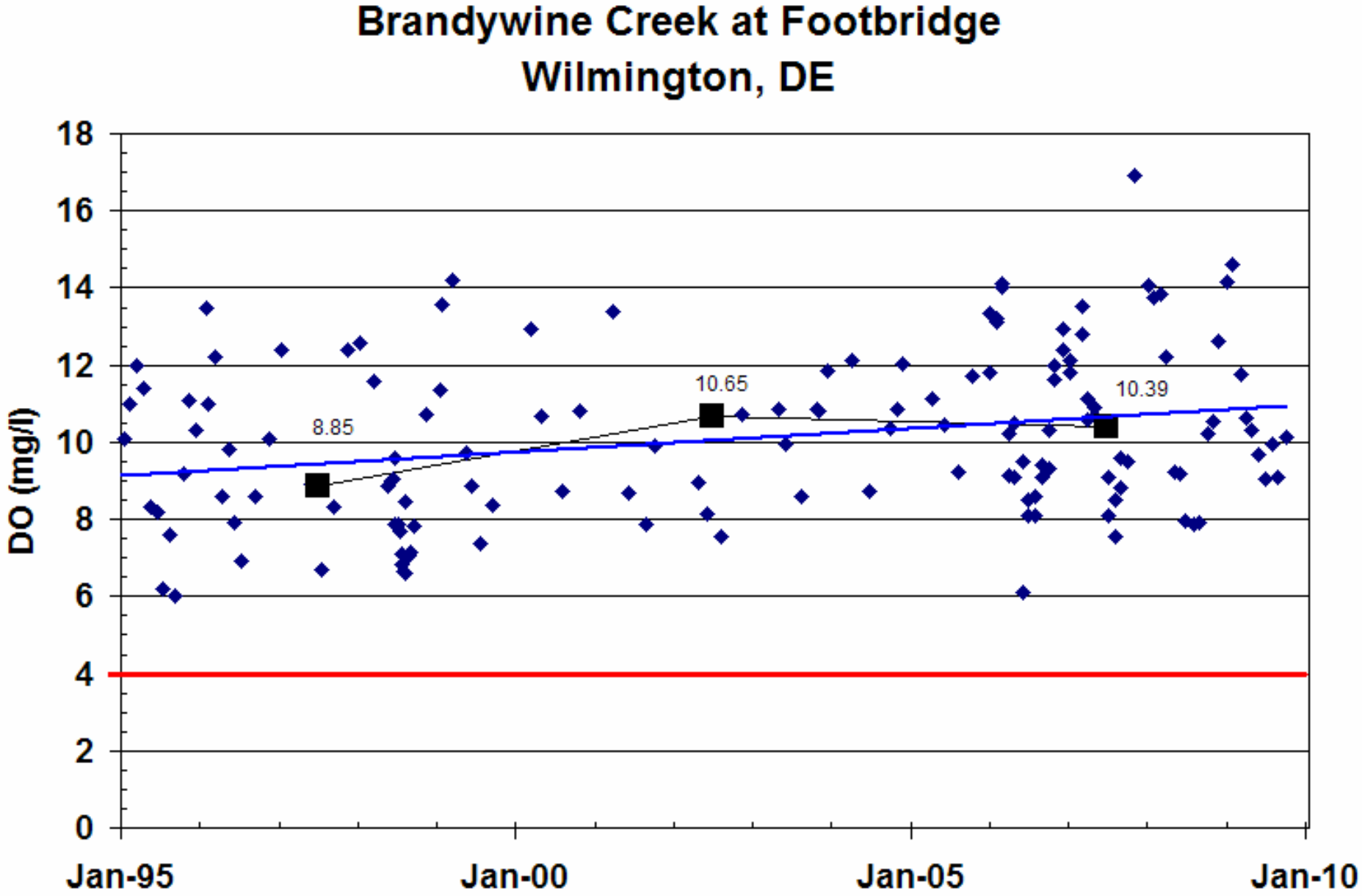

Land Use Change
in the
Christina Basin
1996 - 2005
0.5 Sq. Miles
0.25 Sq. Miles
0.1 Sq. Miles
UrbanSuburban
Agriculture
ForestWetlandOpen
Water
Towns

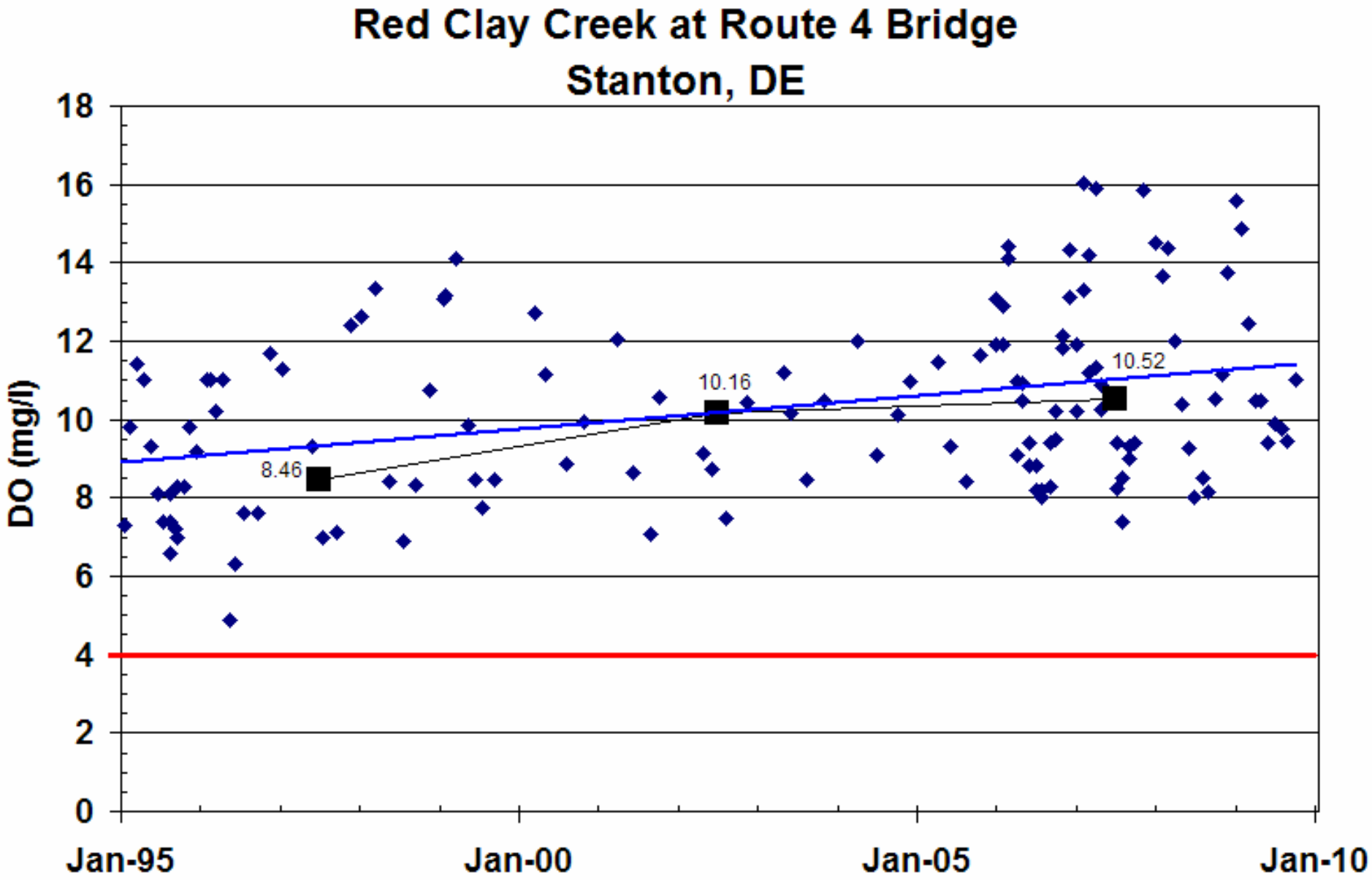
Christina Basin Water Quality

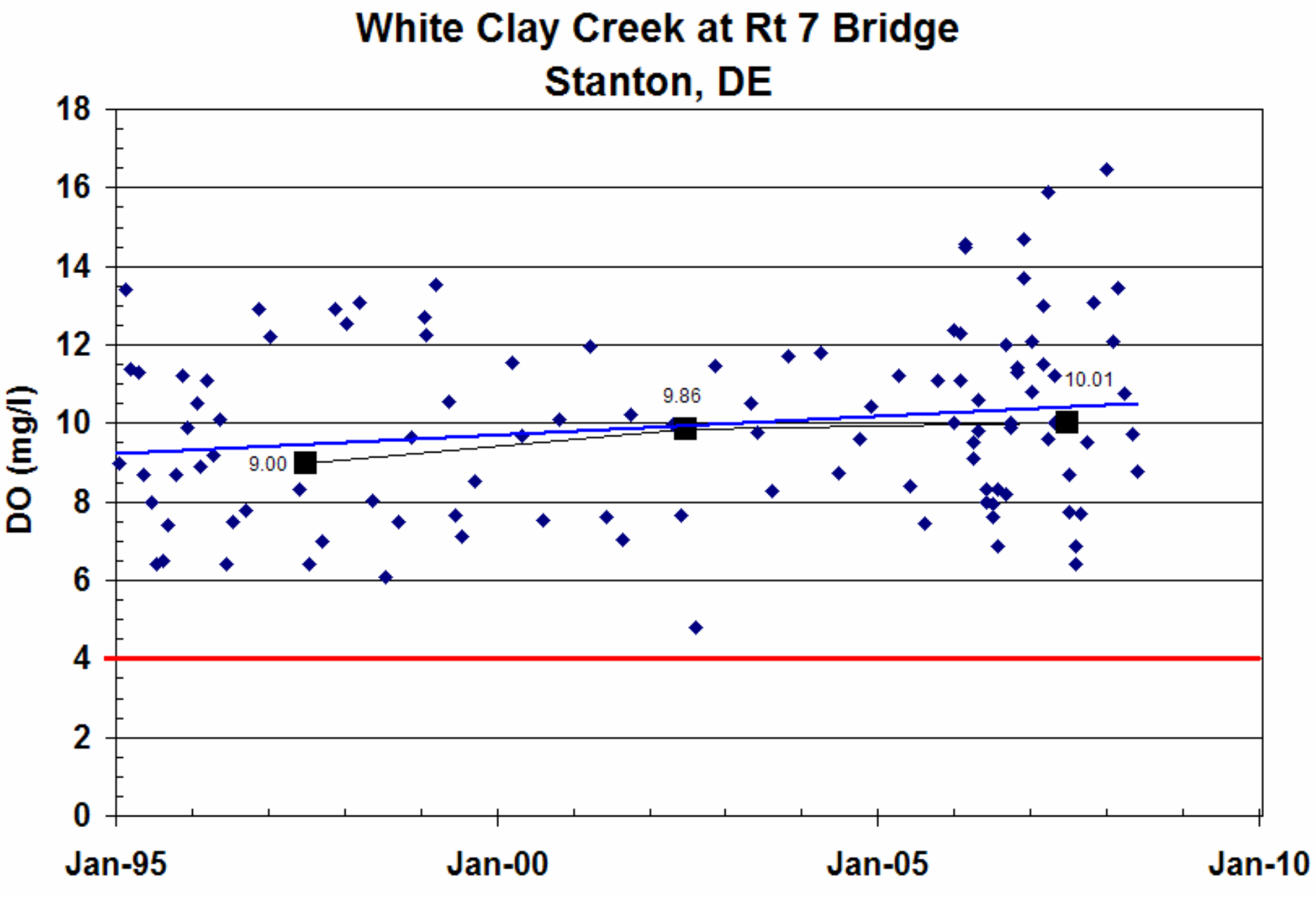
- Dissolved Oxygen
- Total Suspended Sediment
- Enterococcus Bacteria
- Nitrogen
- Phosphorus

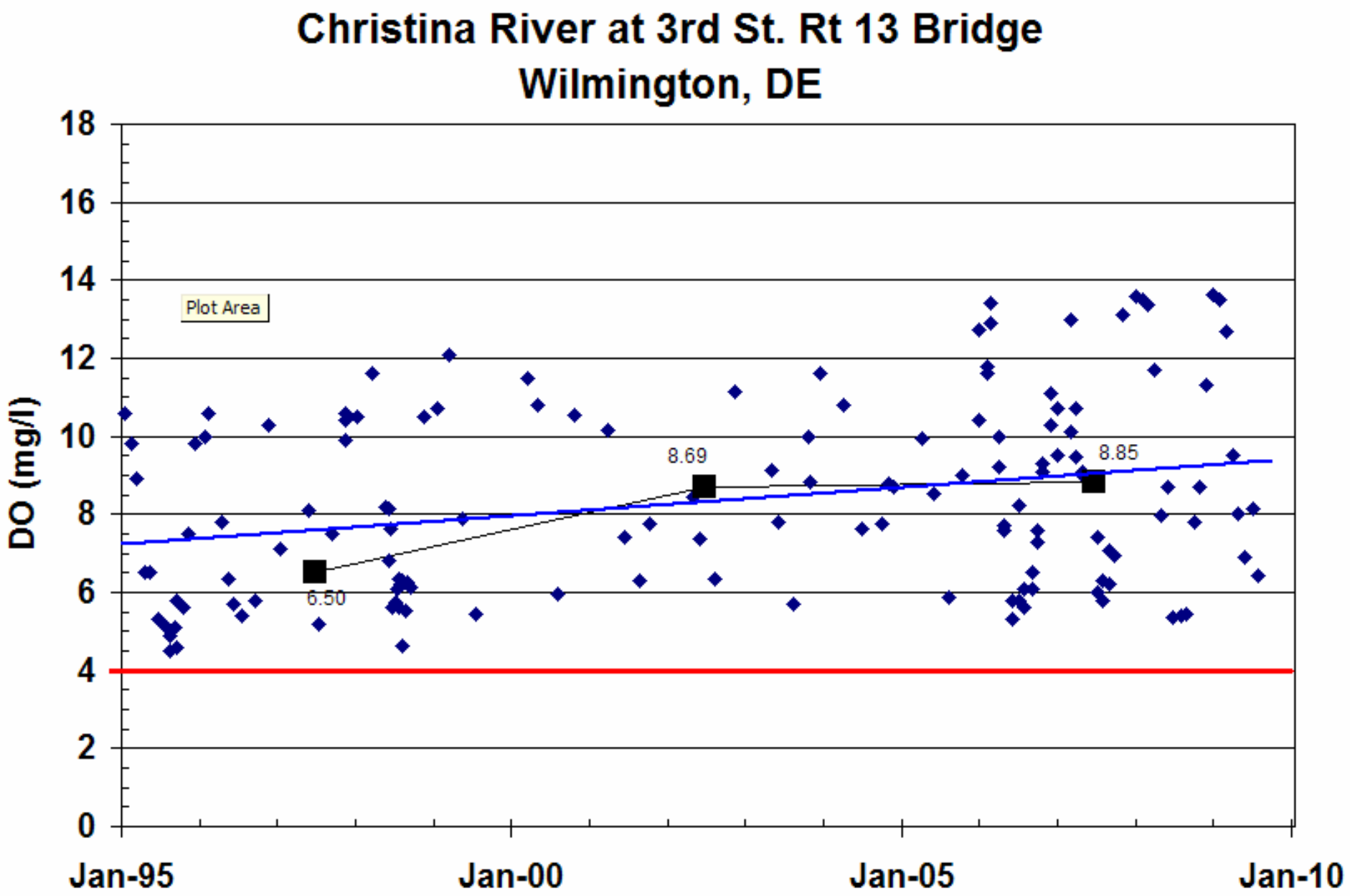
Source: DNREC STORET Monitoring Stations

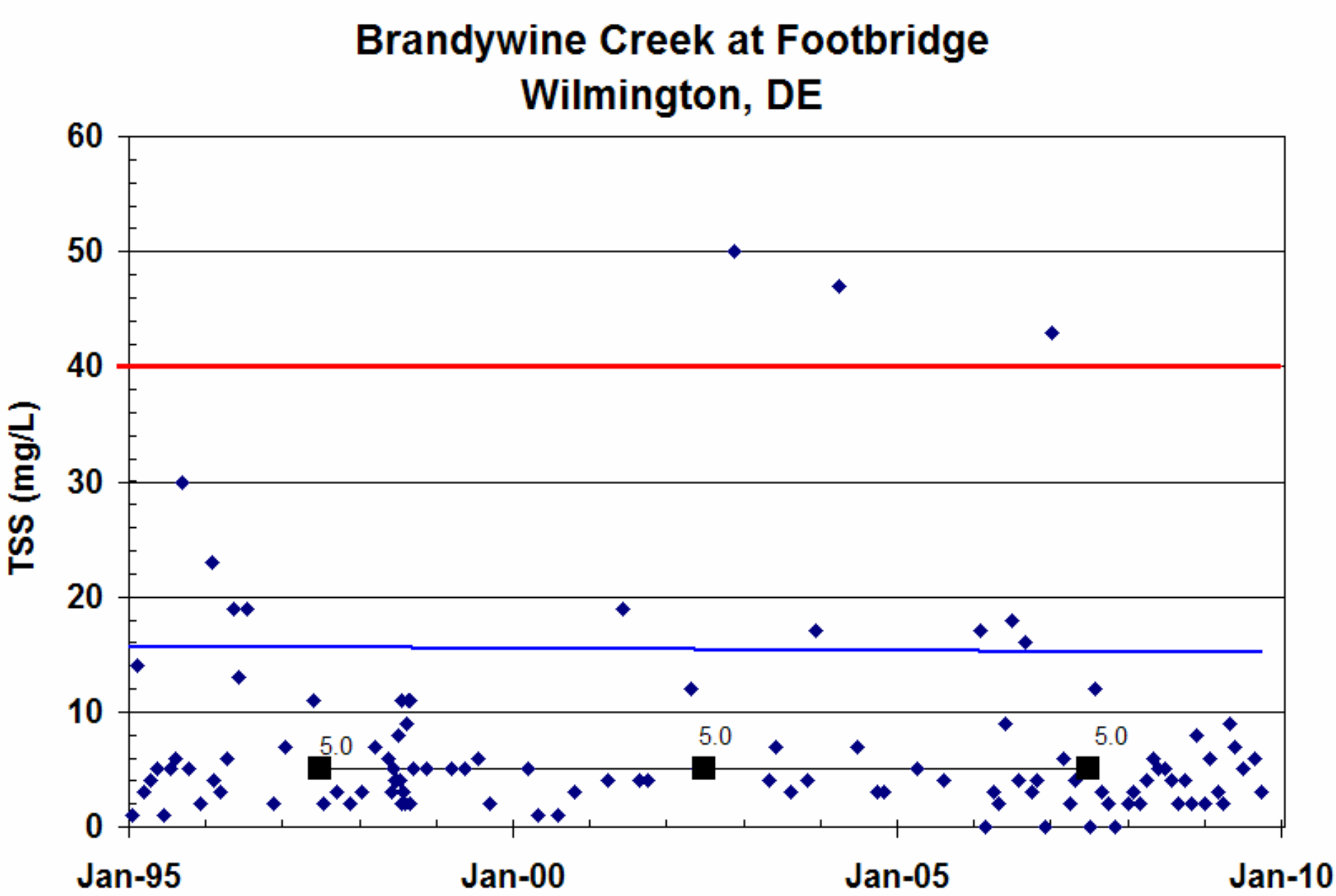

Christina Basin DNREC Monitoring Stations
Brandywine Cr. at Footbridge (104011)
Red Clay Cr. at Stanton (103011)
White Clay Cr. at Old Rte 7 Br. (105071)
Christina R. at Wilmington (106291)
104051
103061
103041
104021
103031
104011
102011
102041
106011
106281
105031
106291
103011
105101
105071
106021
105131
105151
106191
105161
105011
106031
106141
N
Christina Basin Monitoring Stations
Water
Piedmont Watersheds
Brandywine Creek
Christina River
Naamans Creek
Red Clay Creek
Shellpot Creek
White Clay Creek
0
1.25
2.5
5 Miles

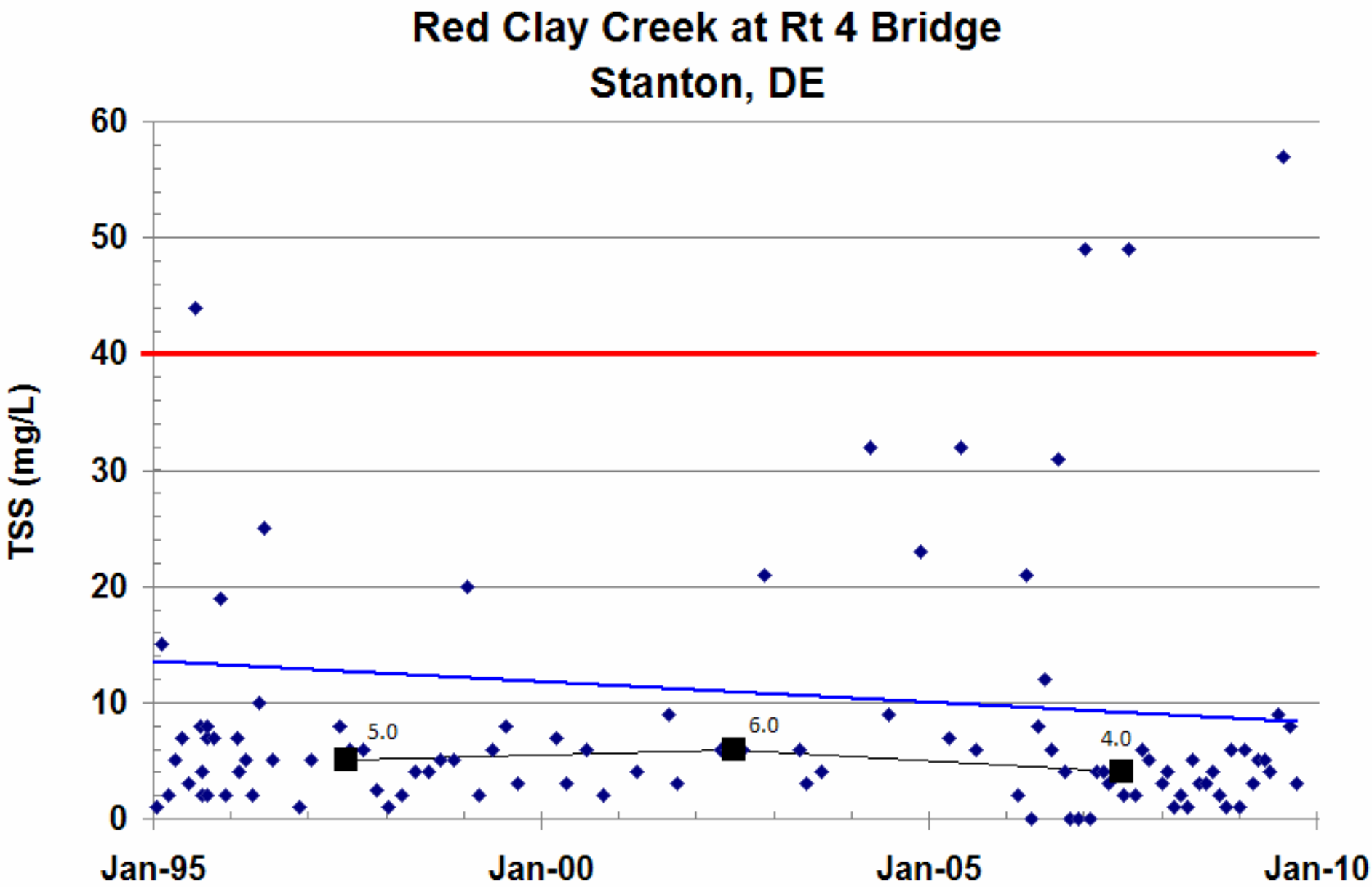

Brandywine Creek at Footbridge
Wilmington, DE
DO (mg/l)
18
16
14
12
10
8
6
4
2
0
8.85
10.65
10.39
Jan-95
Jan-00
Jan-05
Jan-10

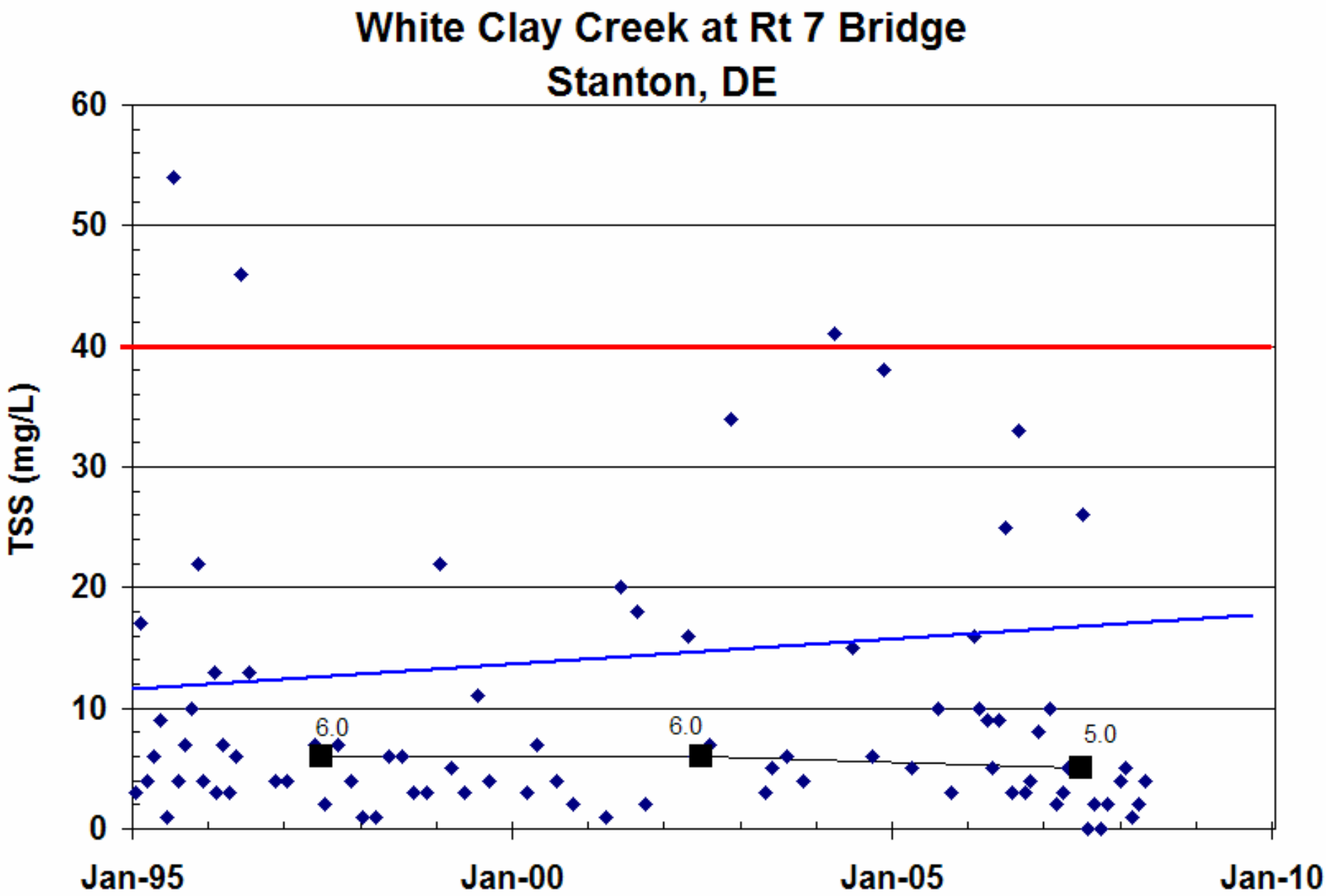

Red Clay Creek at Route 4 Bridge
Stanton, DE
DO (mg/l)
18
16
14
12
10
8
6
4
2
0
Jan-95
Jan-00
Jan-05
Jan-10
8.46
10.16
10.52

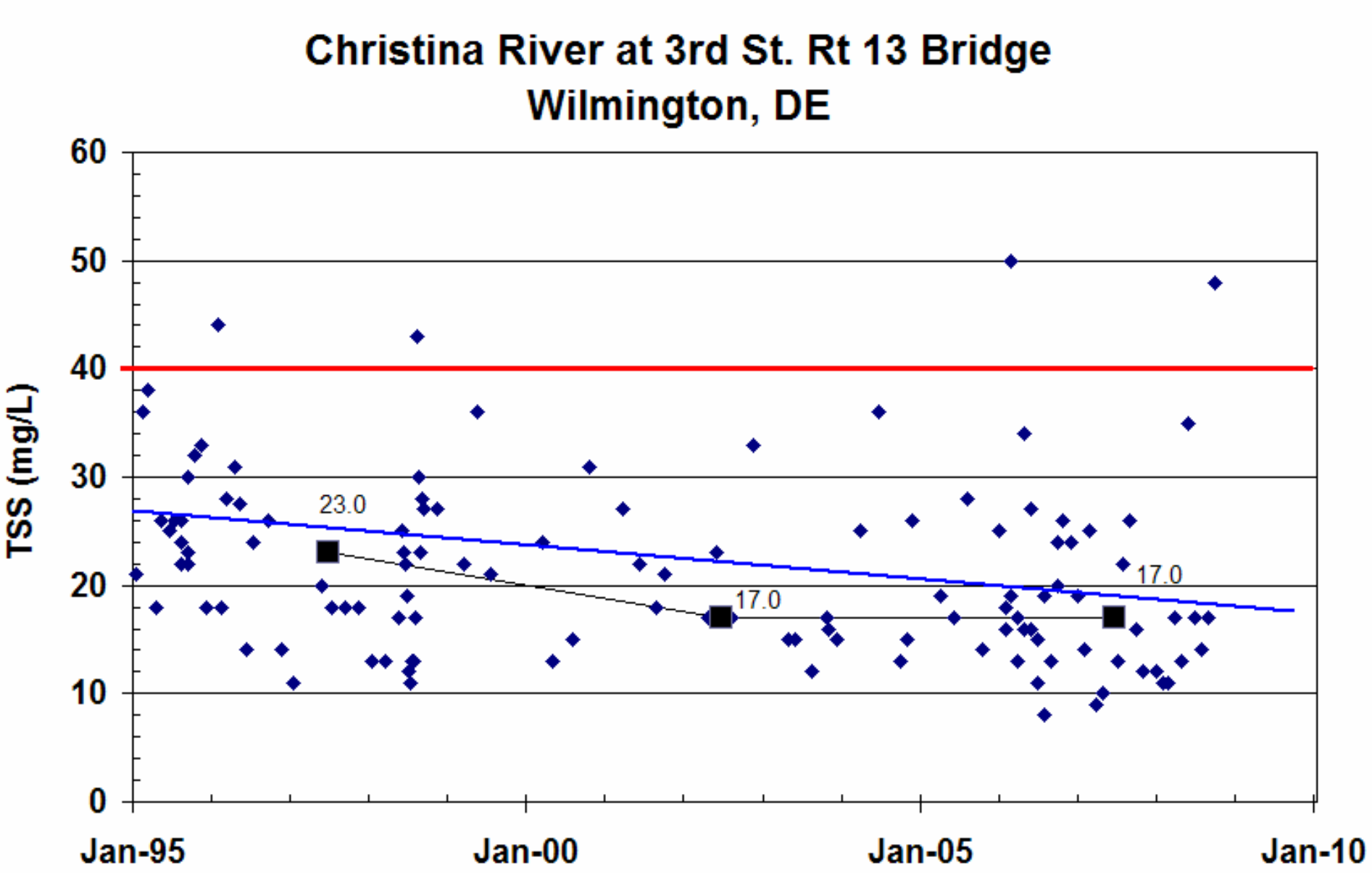

White Clay Creek at Rt 7 Bridge
Stanton, DE
DO (mg/l)
18
16
14
12
10
8
6
4
2
0
Jan-95
Jan-00
Jan-05
Jan-10
9.00
9.86
10.01

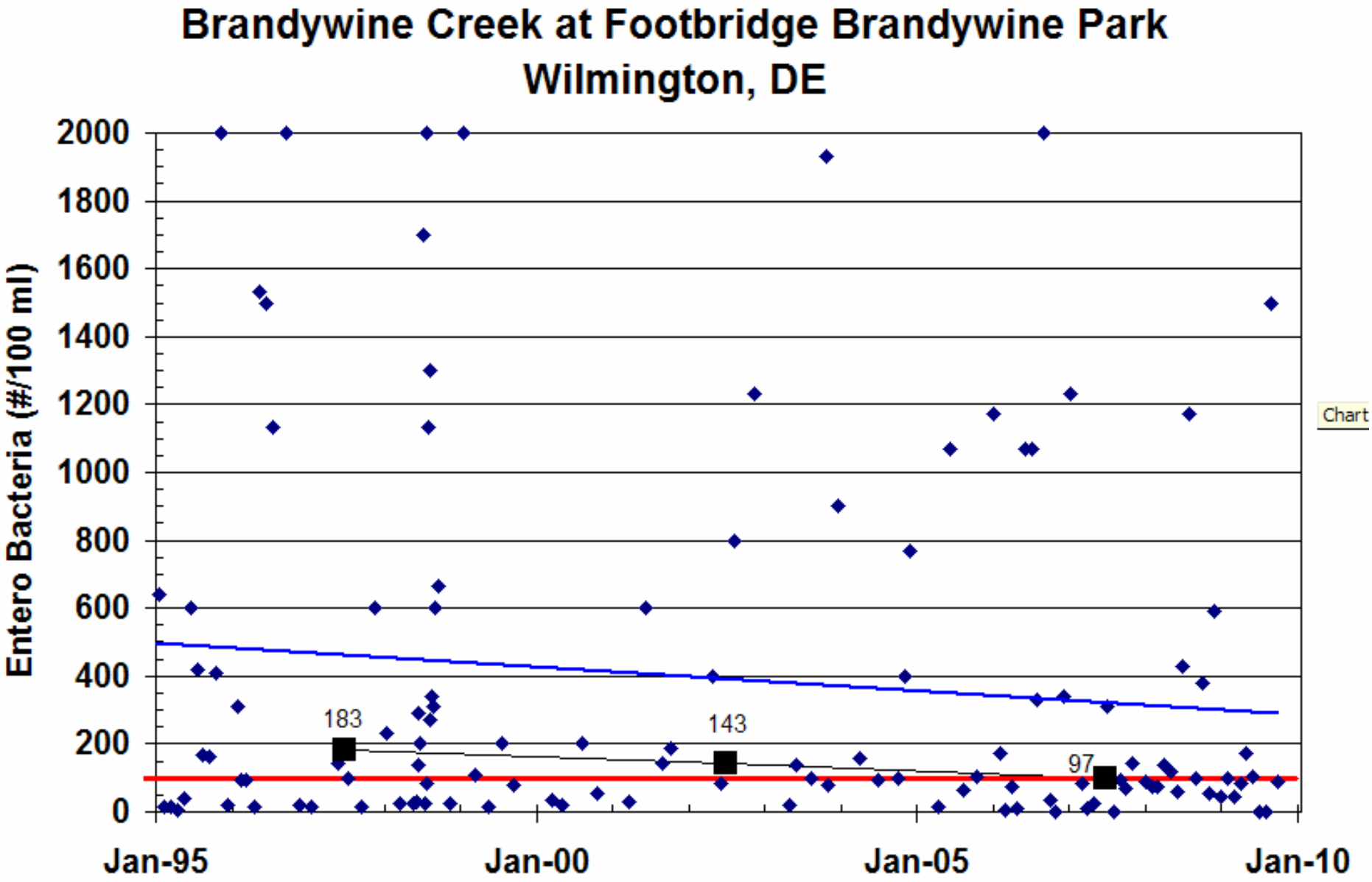

Christina River at 3rd St. Rt 13 Bridge
Wilmington, DE
DO (mg/l)
18
16
14
12
10
8
6
4
2
0
Plot Area
8.69
8.85
6.50
Jan-95
Jan-00
Jan-05
Jan-10

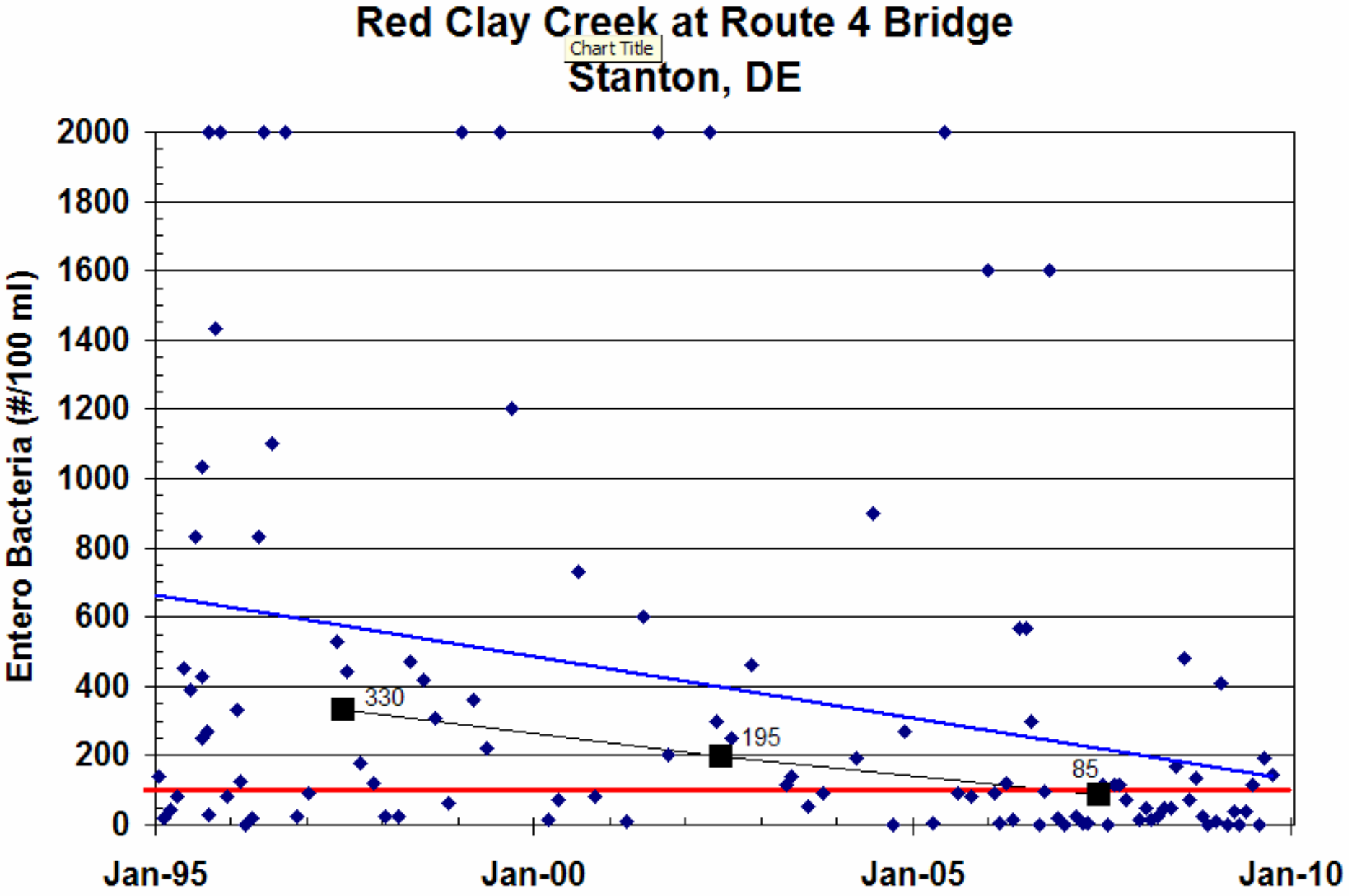

Brandywine Creek at Footbridge
Wilmington, DE
TSS (mg/L)
60
50
40
30
20
10
0
5.0
5.0
5.0
Jan-95
Jan-00
Jan-05
Jan-10

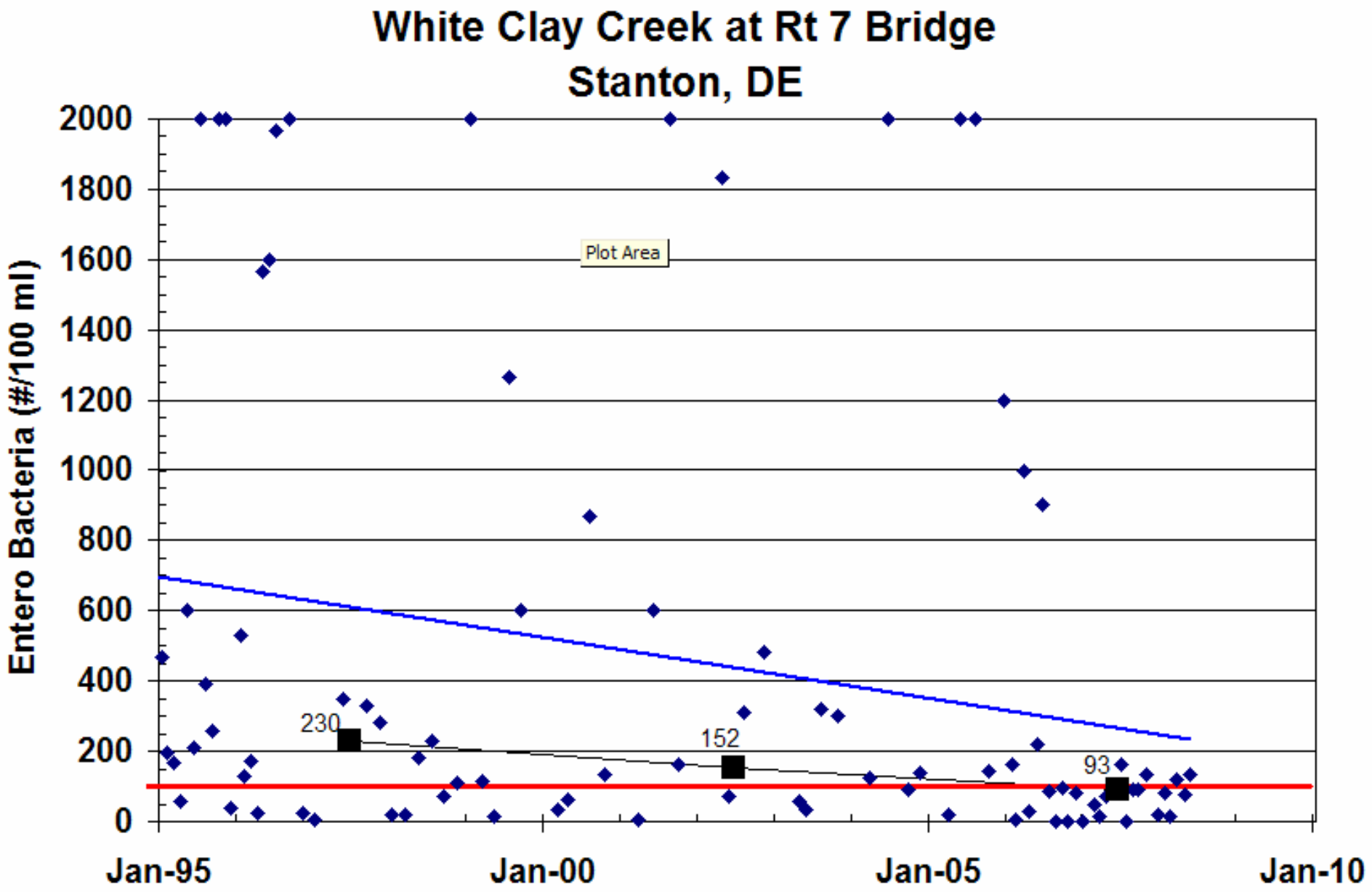

Red Clay Creek at Rt 4 Bridge
Stanton, DE
TSS (mg/L)
60
50
40
30
20
10
0
5.0
6.0
4.0
Jan-95
Jan-00
Jan-05
Jan-10

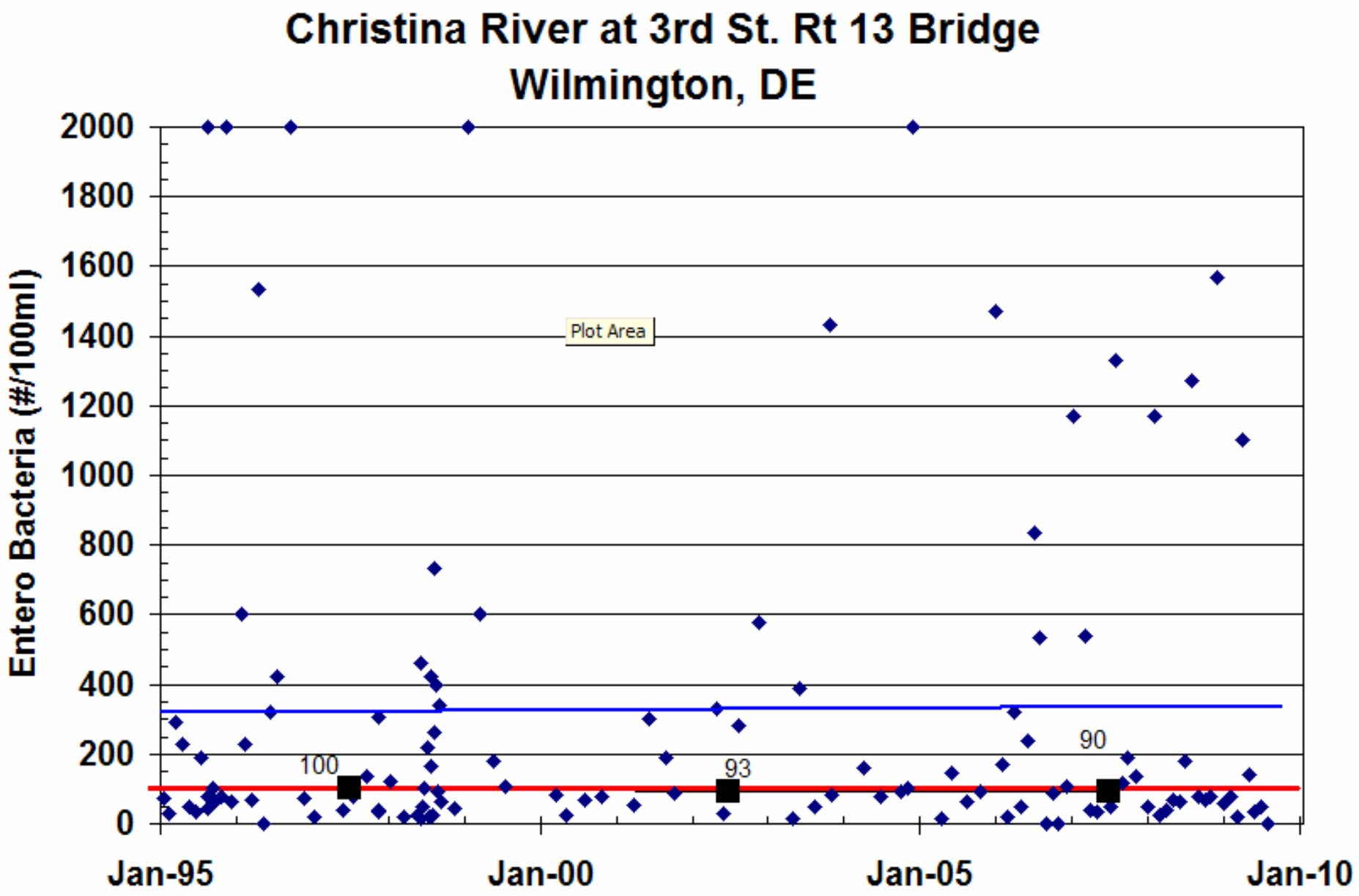

White Clay Creek at Rt 7 Bridge
Stanton, DE
TSS (mg/L)
60
50
40
30
20
10
0
6.0
6.0
5.0
Jan-95
Jan-00
Jan-05
Jan-10

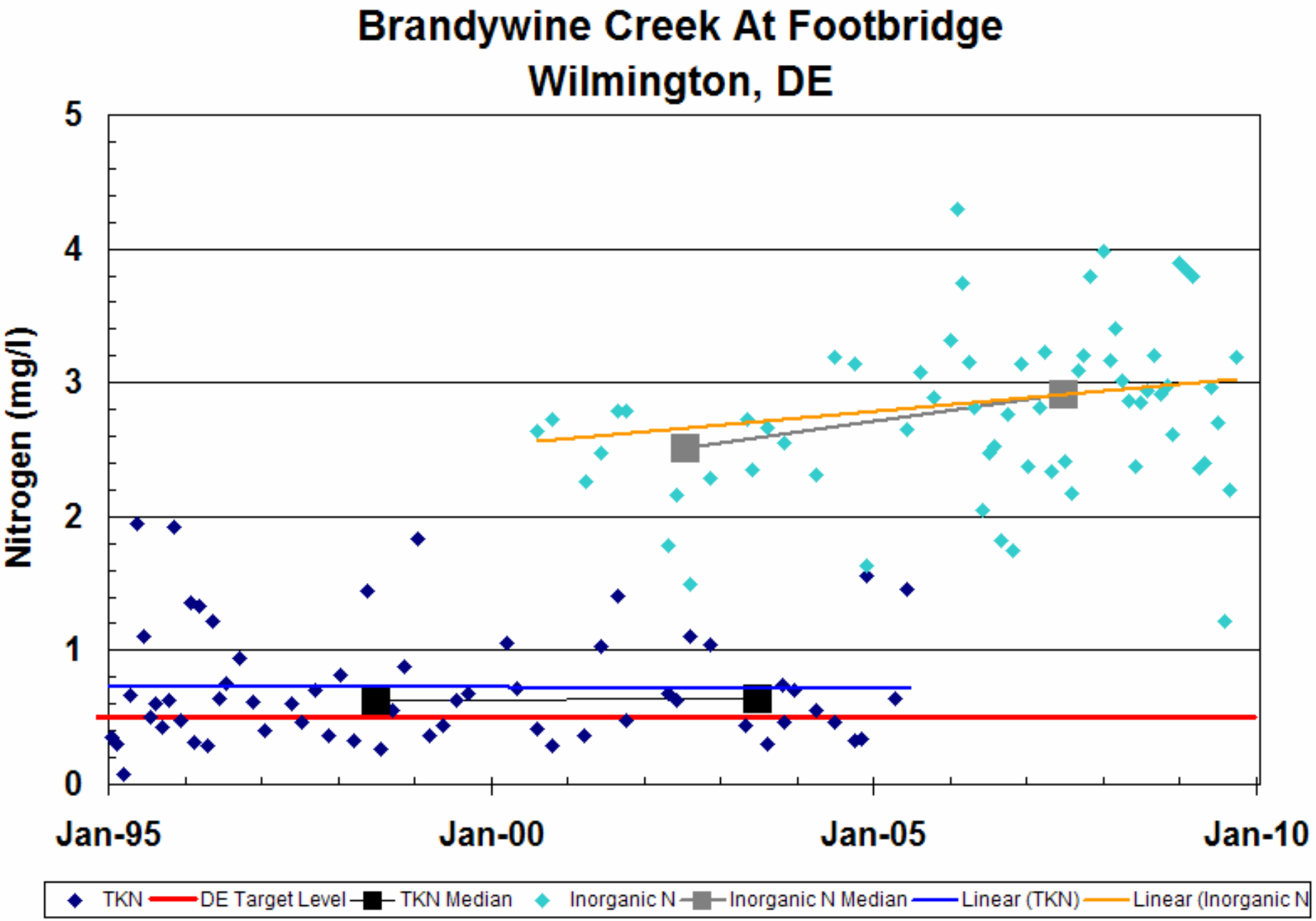

Christina River at 3rd St. Rt 13 Bridge
Wilmington, DE
TSS (mg/L)
60
50
40
30
20
10
0
23.0
17.0
17.0
Jan-95
Jan-00
Jan-05
Jan-10

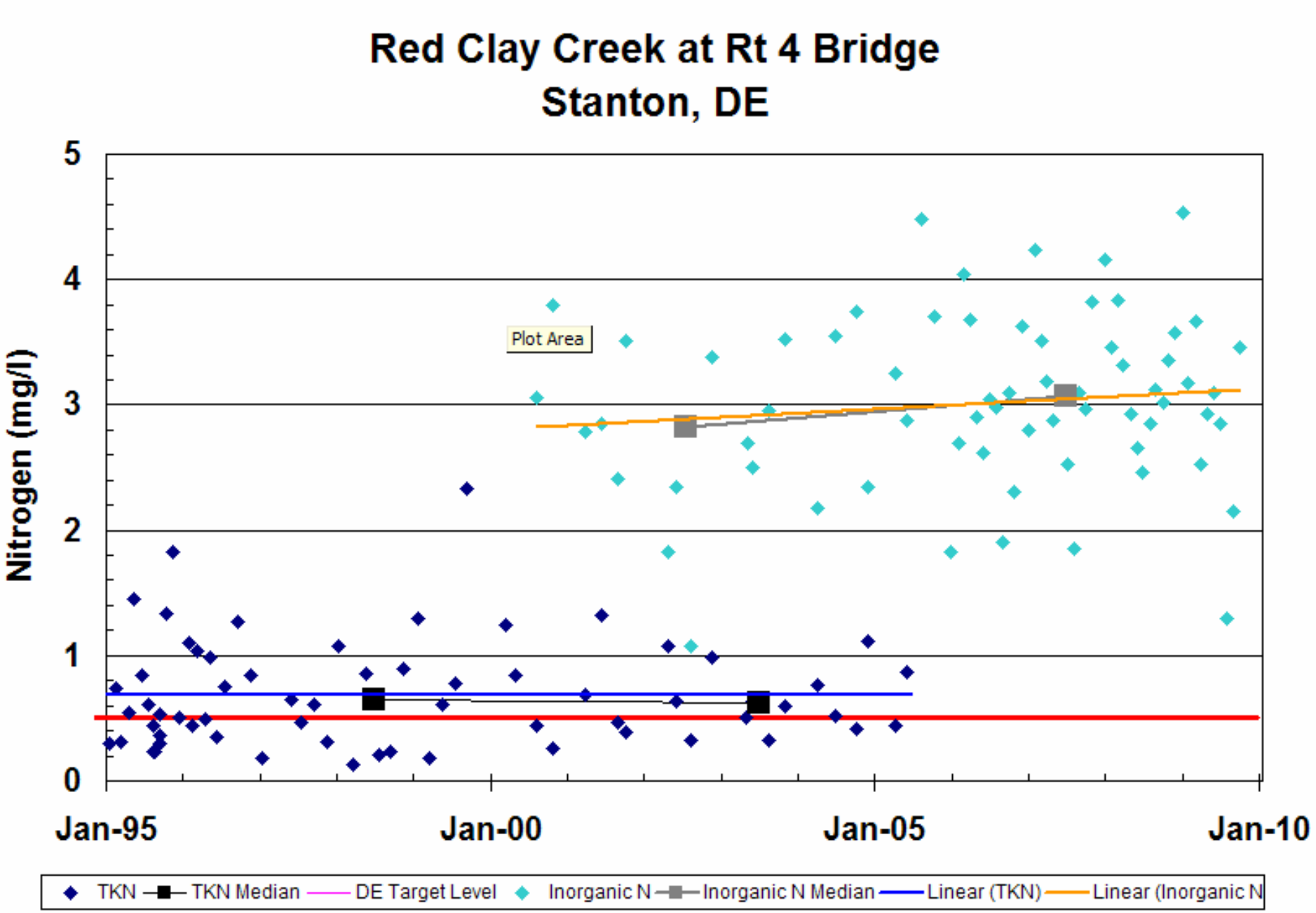

Brandywine Creek at Footbridge Brandywine Park
Wilmington, DE
Entero Bacteria (#/100 ml)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
183
143
97
Jan-95
Jan-00
Jan-05
Jan-10
Chart

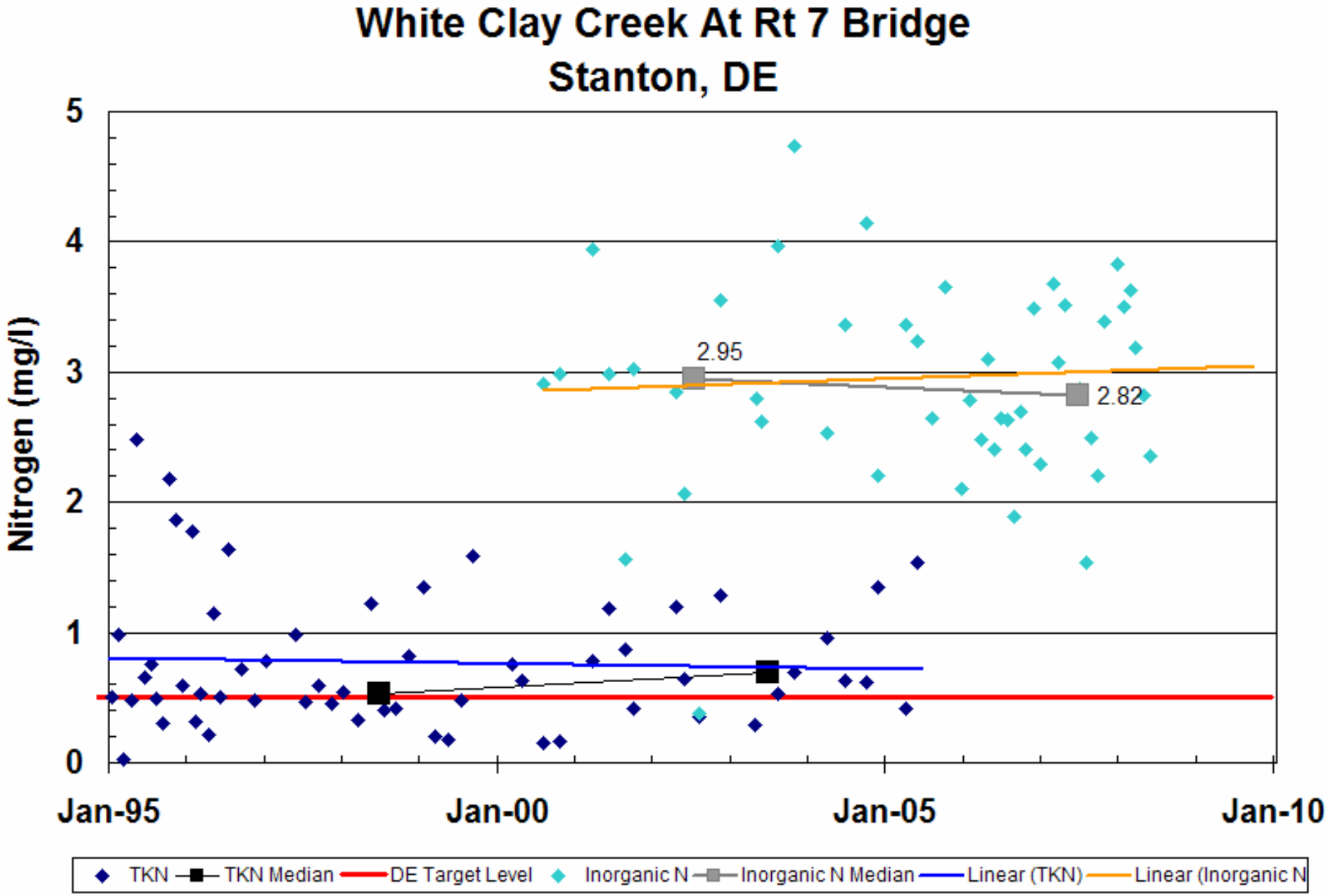

Red Clay Creek at Route 4 Bridge
Chart Title
Stanton, DE
Entero Bacteria (#/100 ml)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
330
195
85
Jan-95
Jan-00
Jan-05
Jan-10

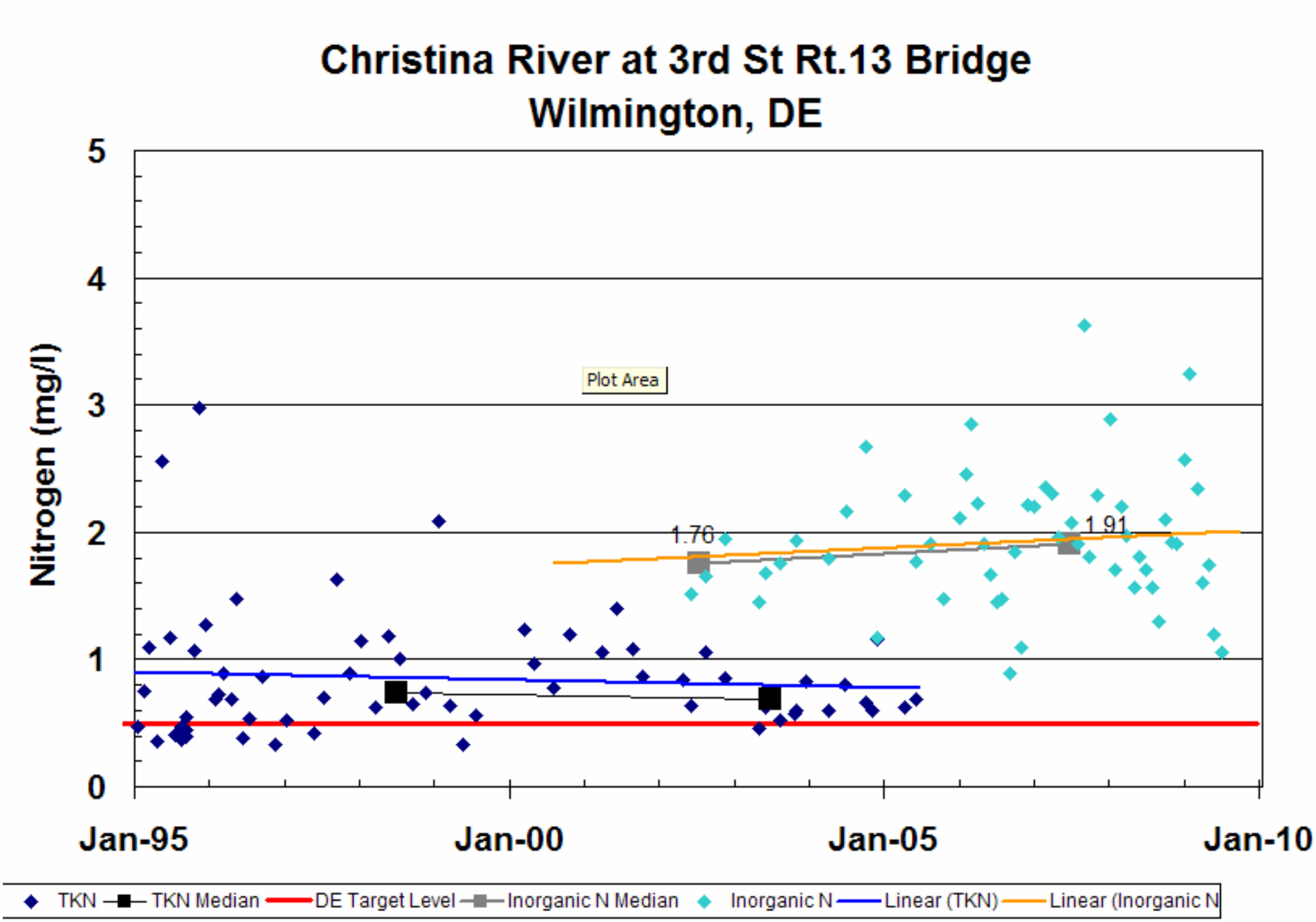

White Clay Creek at Rt 7 Bridge
Stanton, DE
Entero Bacteria (#/100 ml)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Plot Area
230
152
93
Jan-95
Jan-00
Jan-05
Jan-10

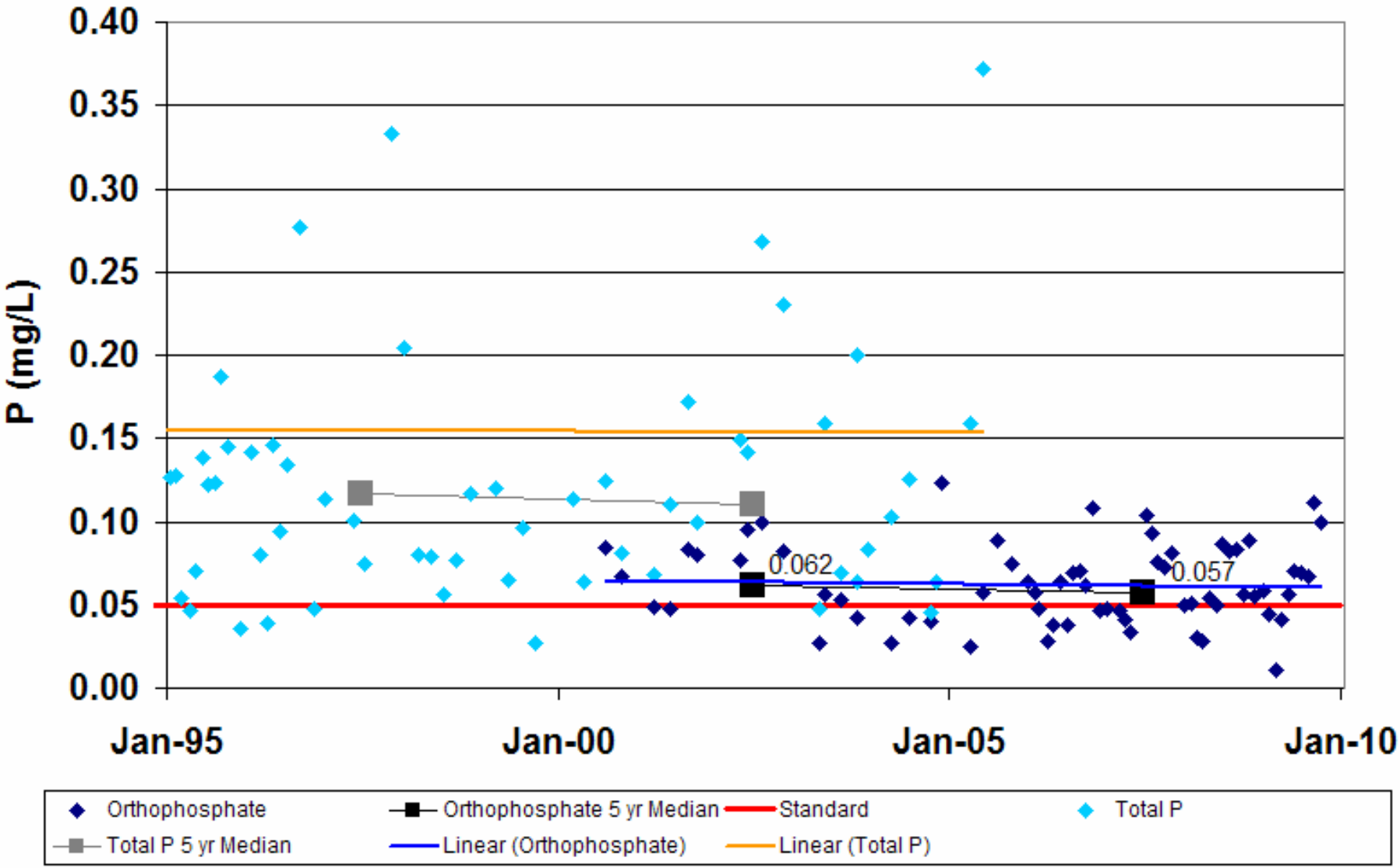

Christina River at 3rd St. Rt 13 Bridge
Wilmington, DE
Entero Bacteria (#/100ml)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Plot Area
100
93
90
Jan-95
Jan-00
Jan-05
Jan-10

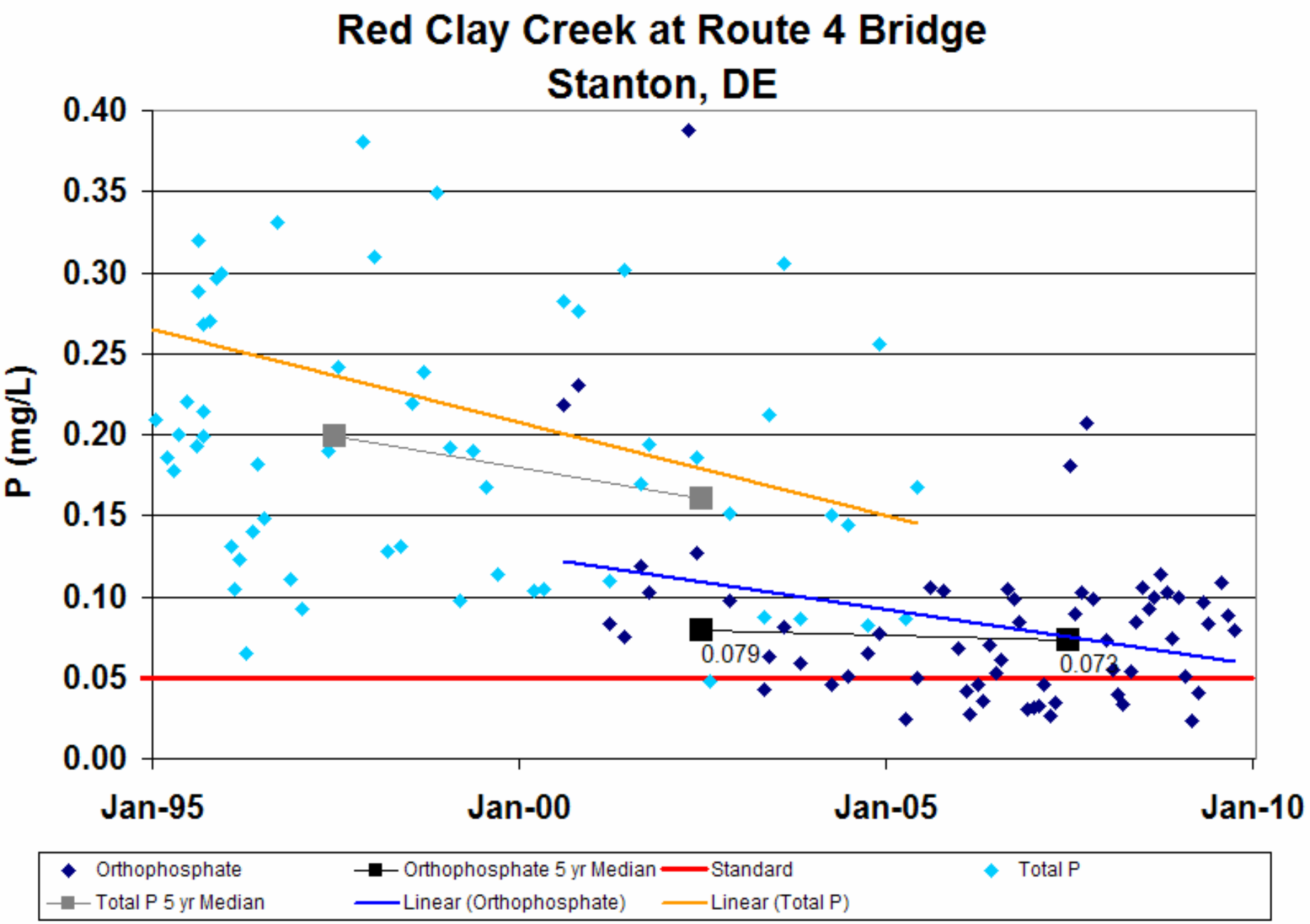

Brandywine Creek At Footbridge
Wilmington, DE
Nitrogen (mg/l)
5
4
3
2
1
0
Jan-95
Jan-00
Jan-05
Jan-10
TKN
DE Target Level
TKN Median
Inorganic N
Inorganic N Median
Linear (TKN)
Linear (Inorganic N

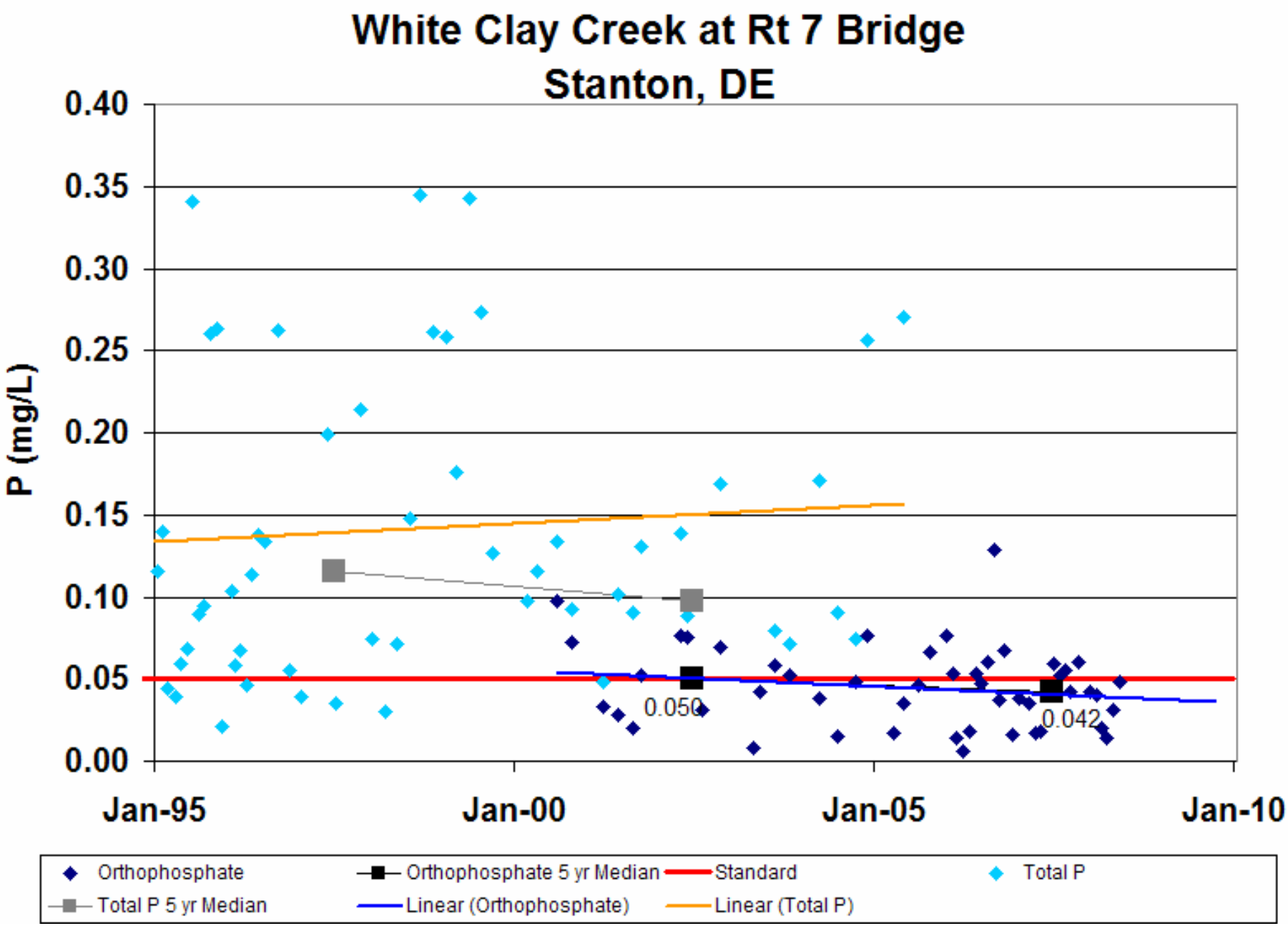

Red Clay Creek at Rt 4 Bridge
Stanton, DE
Nitrogen (mg/l)
5
4
3
2
1
0
Plot Area
Jan-95
Jan-00
Jan-05
Jan-10
TKN
TKN Median
DE Target Level
Inorganic N
Inorganic N Median
Linear (TKN)
Linear (Inorganic N

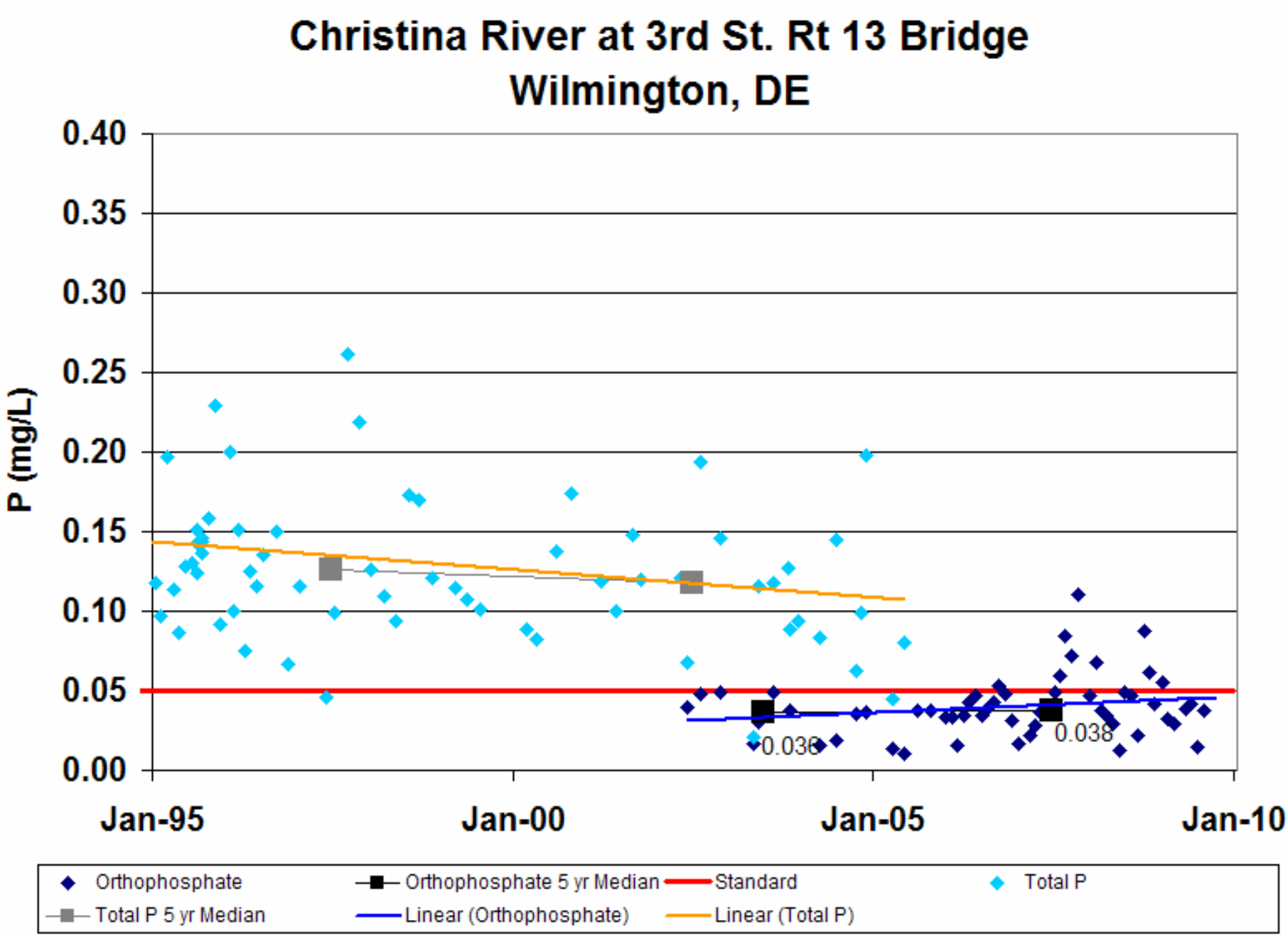

White Clay Creek At Rt 7 Bridge
Stanton, DE
Nitrogen (mg/l)
5
4
3
2
1
0
2.95
2.82
Jan-95
Jan-00
Jan-05
Jan-10
TKN
TKN Median
DE Target Level
Inorganic N
Inorganic N Median
Linear (TKN)
Linear (Inorganic N


Christina River at 3rd St Rt.13 Bridge
Wilmington, DE
Nitrogen (mg/l)
5
4
3
2
1
0
Plot Area
1.76
1.91
Jan-95
Jan-00
Jan-05
Jan-10
TKN
TKN Median
DE Target Level
Inorganic N Median
Inorganic N
Linear (TKN)
Linear (Inorganic N


Brandywine Creek at Footbridge
Wilmington, DE
P (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-95
Jan-00
Jan-05
Jan-10
0.062
0.057
Orthophosphate
Orthophosphate 5 yr Median
Standard
Total P
Total P 5 yr Median
Linear (Orthophosphate)
Linear (Total P)


Red Clay Creek at Route 4 Bridge
Stanton, DE
P (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-95
Jan-00
Jan-05
Jan-10
0.079
0.072
Orthophosphate
Orthophosphate 5 yr Median
Standard
Total P
Total P 5 yr Median
Linear (Orthophosphate)
Linear (Total P)


White Clay Creek at Rt 7 Bridge
Stanton, DE
P (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-95
Jan-00
Jan-05
Jan-10
0.050
0.042
Orthophosphate
Orthophosphate 5 yr Median
Standard
Total P
Total P 5 yr Median
Linear (Orthophosphate)
Linear (Total P)


Christina River at 3rd St. Rt 13 Bridge
Wilmington, DE
P (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-95
Jan-00
Jan-05
Jan-10
0.036
0.038
Orthophosphate
Orthophosphate 5 yr Median
Standard
Total P
Total P 5 yr Median
Linear (Orthophosphate)
Linear (Total P)

Seasonal Kendall Test for Dissolved Oxygen, 1995-2009

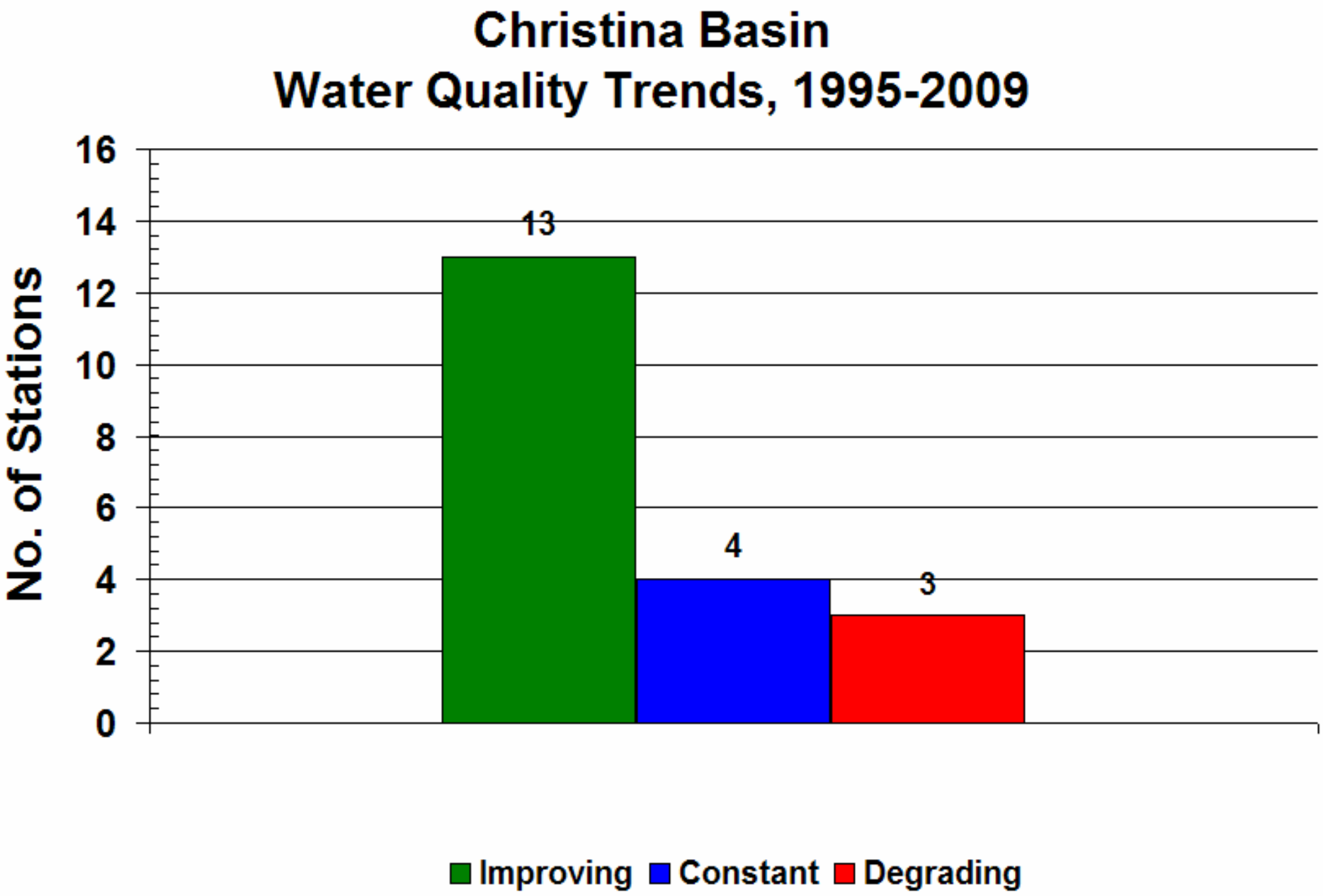
	Median Value	Variance	Z	P	P (adjusted)	Median Annual Sen slope	5% Confidence Limit	95% Confidence Limit
Red Clay Creek	10.0825	1128.0000	5.9847	0.0000	0.0000	0.3491	-99.9900	0.0000
Brandywine Creek	10.1000	1244.0000	4.2812	0.0000	0.0017	0.1861	-99.9900	0.0000
White Clay Creek	9.7500	718.3333	3.4699	0.0005	0.0044	0.0177	-99.9900	0.0000
Christina River	8.1675	1147.6667	4.0735	0.0000	0.0001	0.0983	-99.9900	0.0000

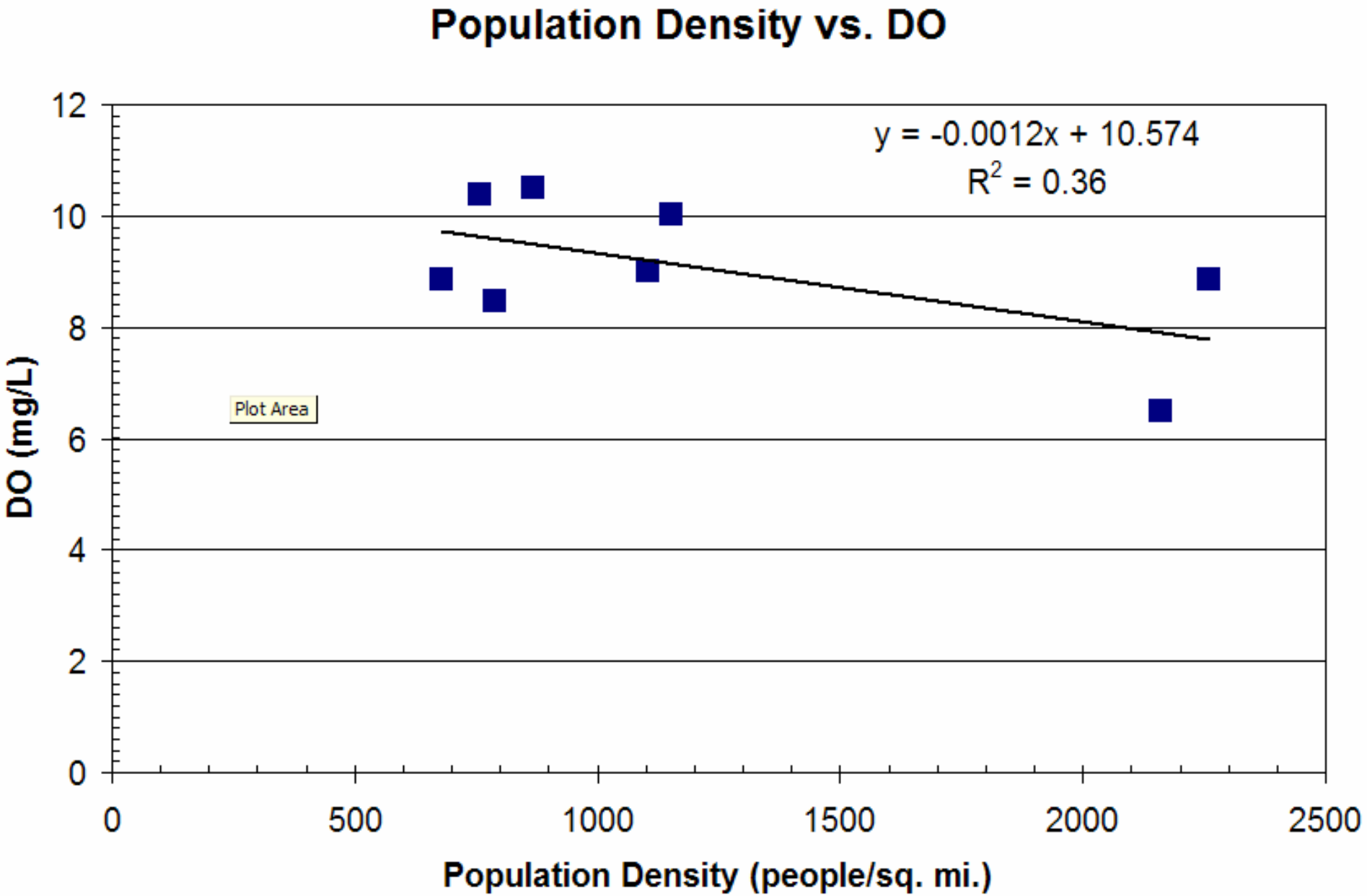
The Red Clay Creek, Brandywine Creek, White Clay Creek, and Christina River all had had statistically significant improvement in DO with a $p < .01$.

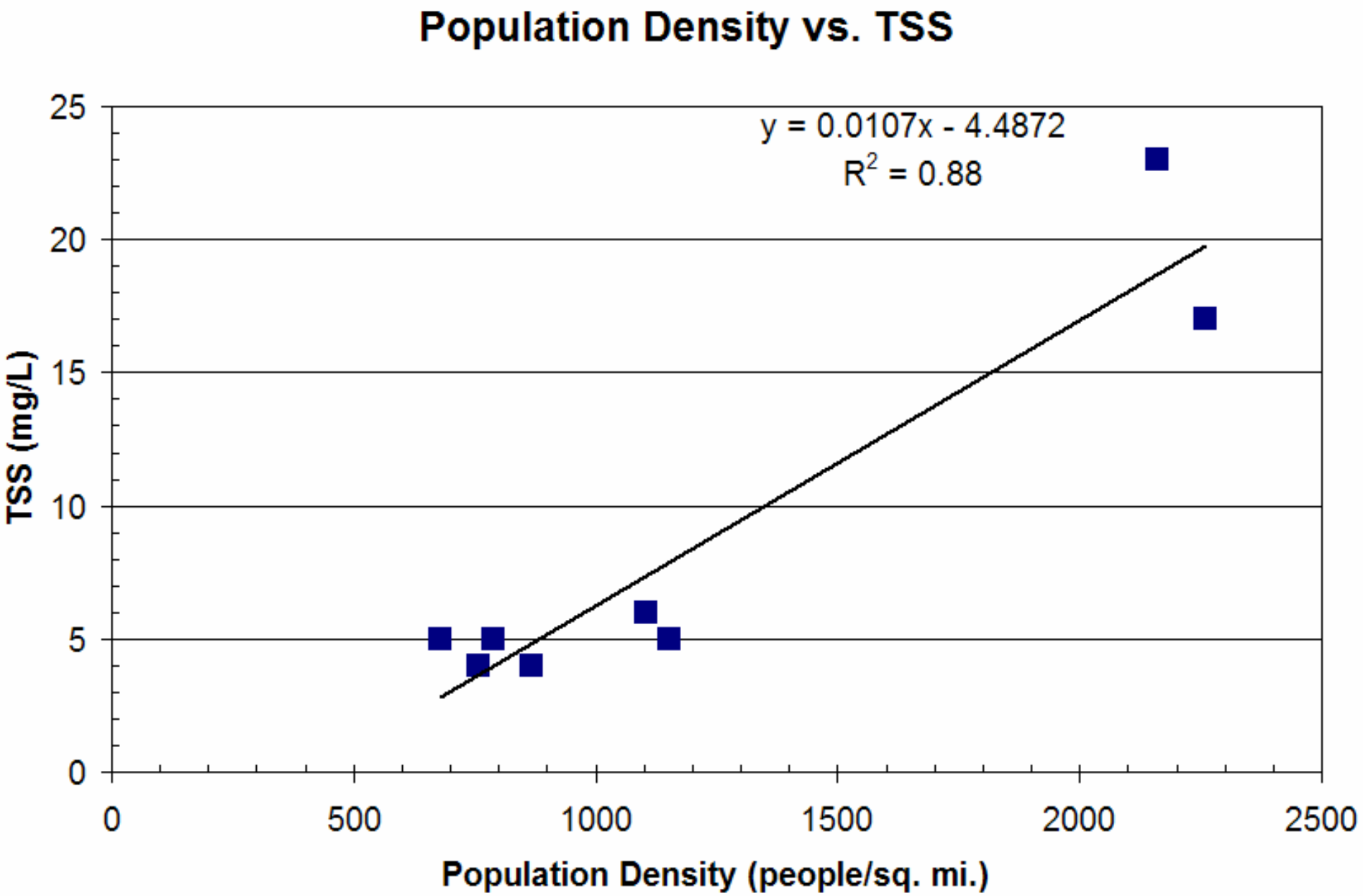
Christina Basin Water Quality Trends, 1995-2009

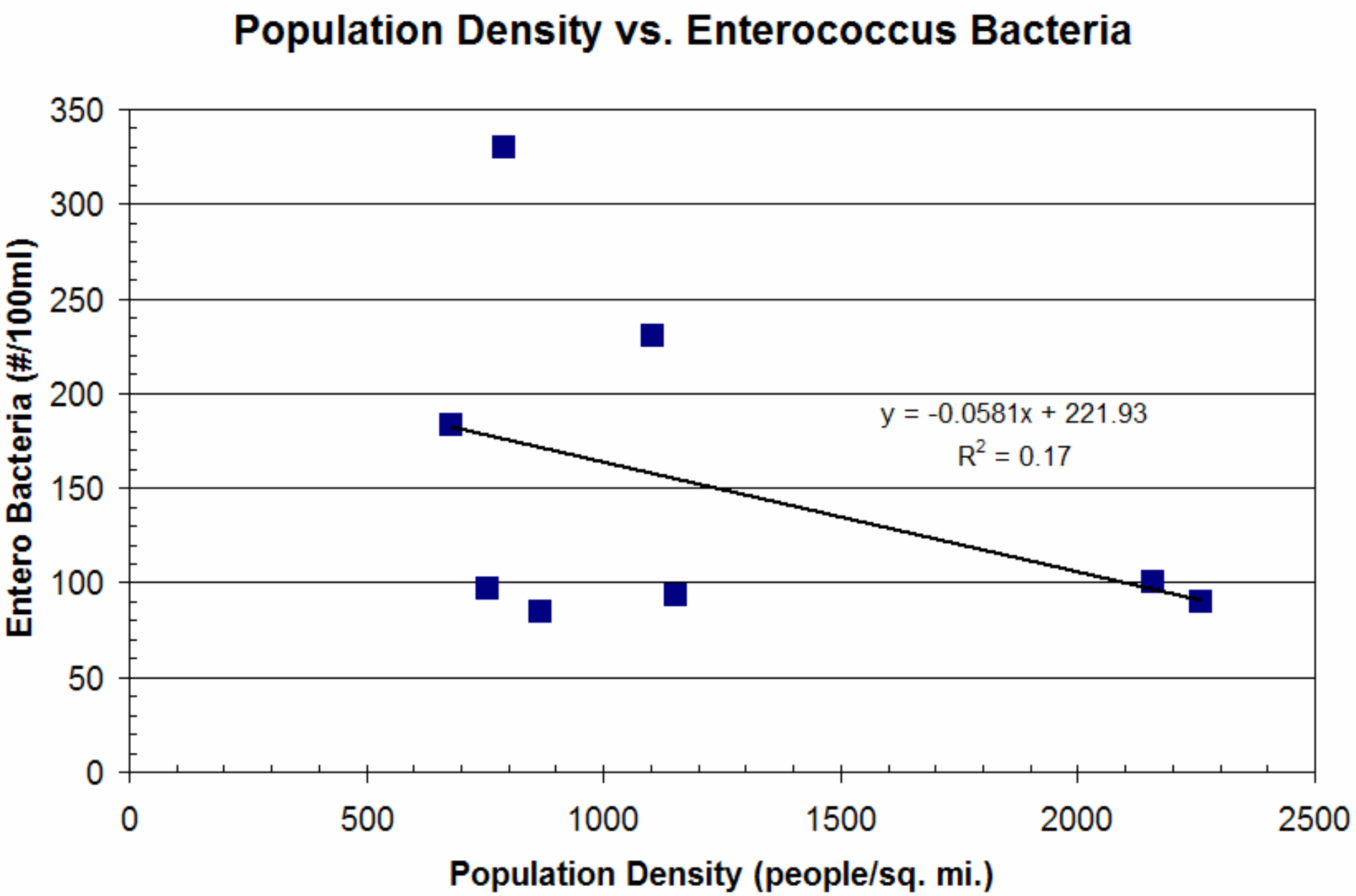
Watershed	DO (mg/L)		TSS (mg/L)		Bacteria (#/100ml)		Inorg. N (mg/L)		Ortho P (mg/L)	
Brandywine Creek	10.4	▲*	5	●	97	▲	2.90	▼	0.06	▲
Red Clay Creek	10.5	▲*	4	▲*	85	▲*	3.10	▼	0.07	●*
White Clay Creek	10.0	▲*	5	▲*	93	▲*	2.82	●	0.04	▲
Christina River	8.9	▲*	17	▲*	90	▲	1.91	▼	0.04	●*
▲ Improving	4/4 (100%)		3/4 (75%)		4/4 (100%)		0/4 (0%)		2/4 (50%)	
● Constant	0/4 (0%)		1/4 (25%)		0/4 (0%)		1/4 (25%)		2/4 (50%)	
▼ Degrading	0/4 (0%)		0/4 (0%)		0/4 (0%)		3/4 (75%)		0/4 (0%)	

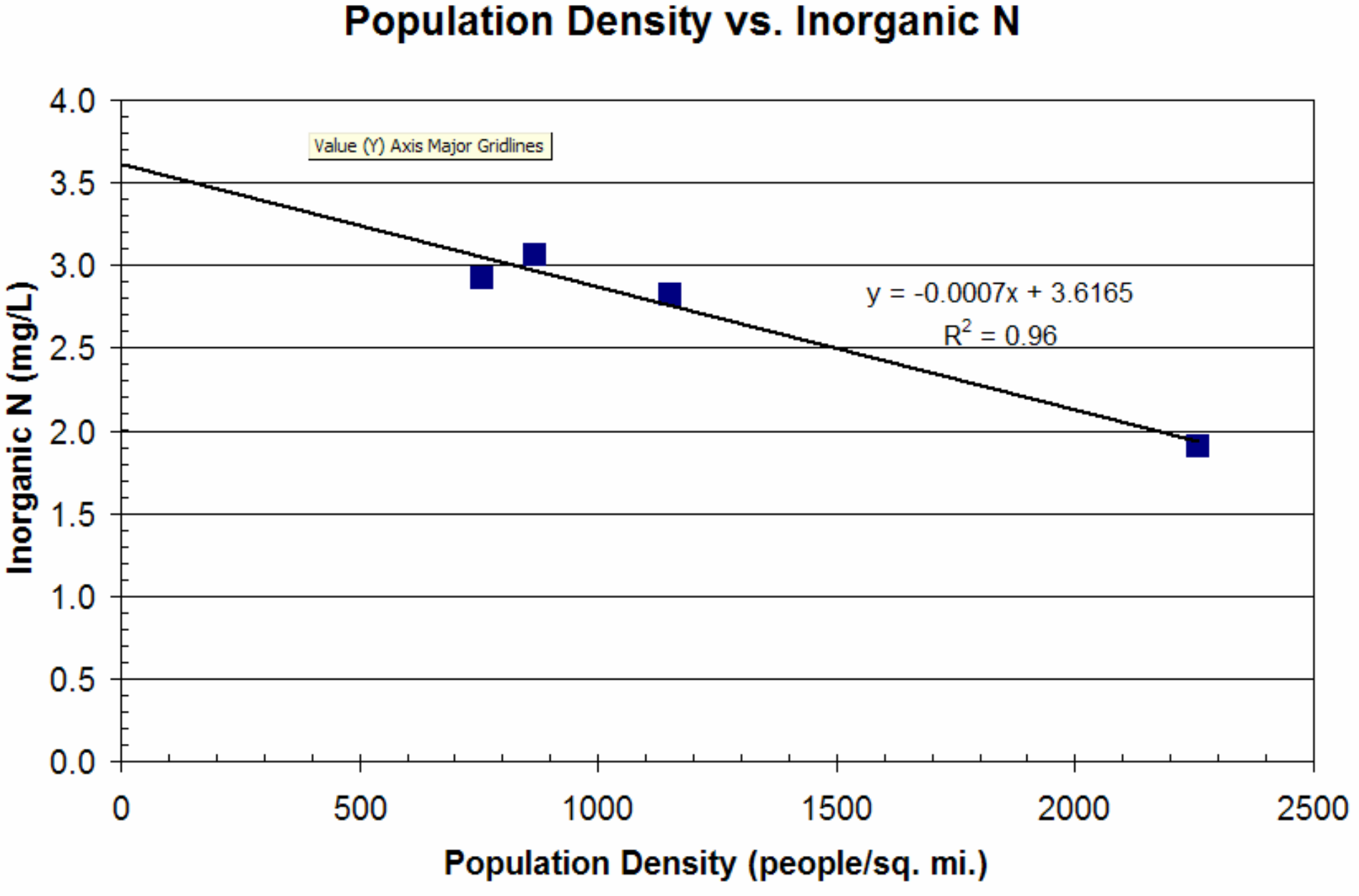
* statistically significant at $p \leq 0.10$

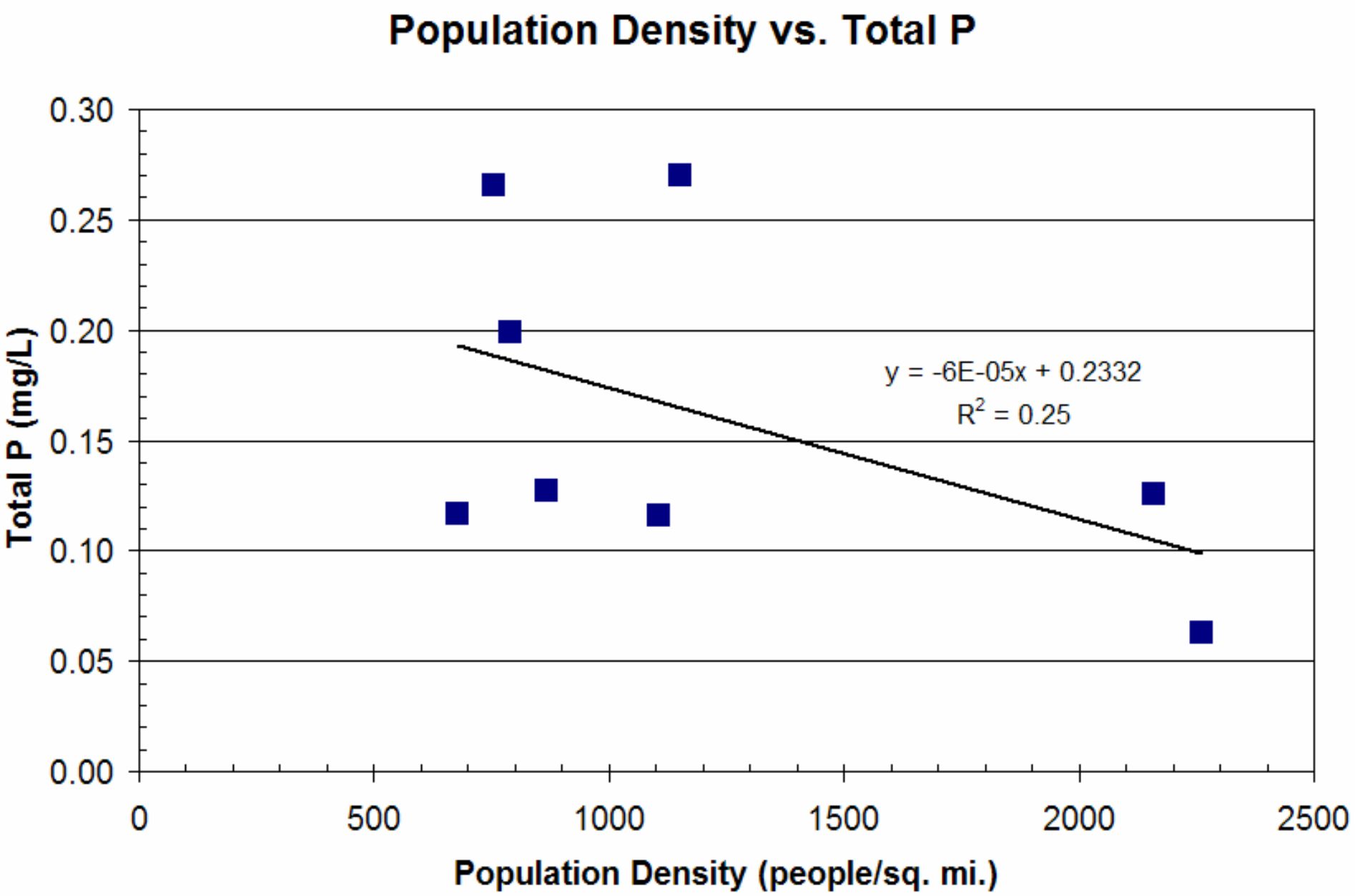

Christina Basin
Water Quality Trends, 1995-2009
No. of Stations
16
14
12
10
8
6
4
2
0
13
4
3
Improving
Constant
Degrading

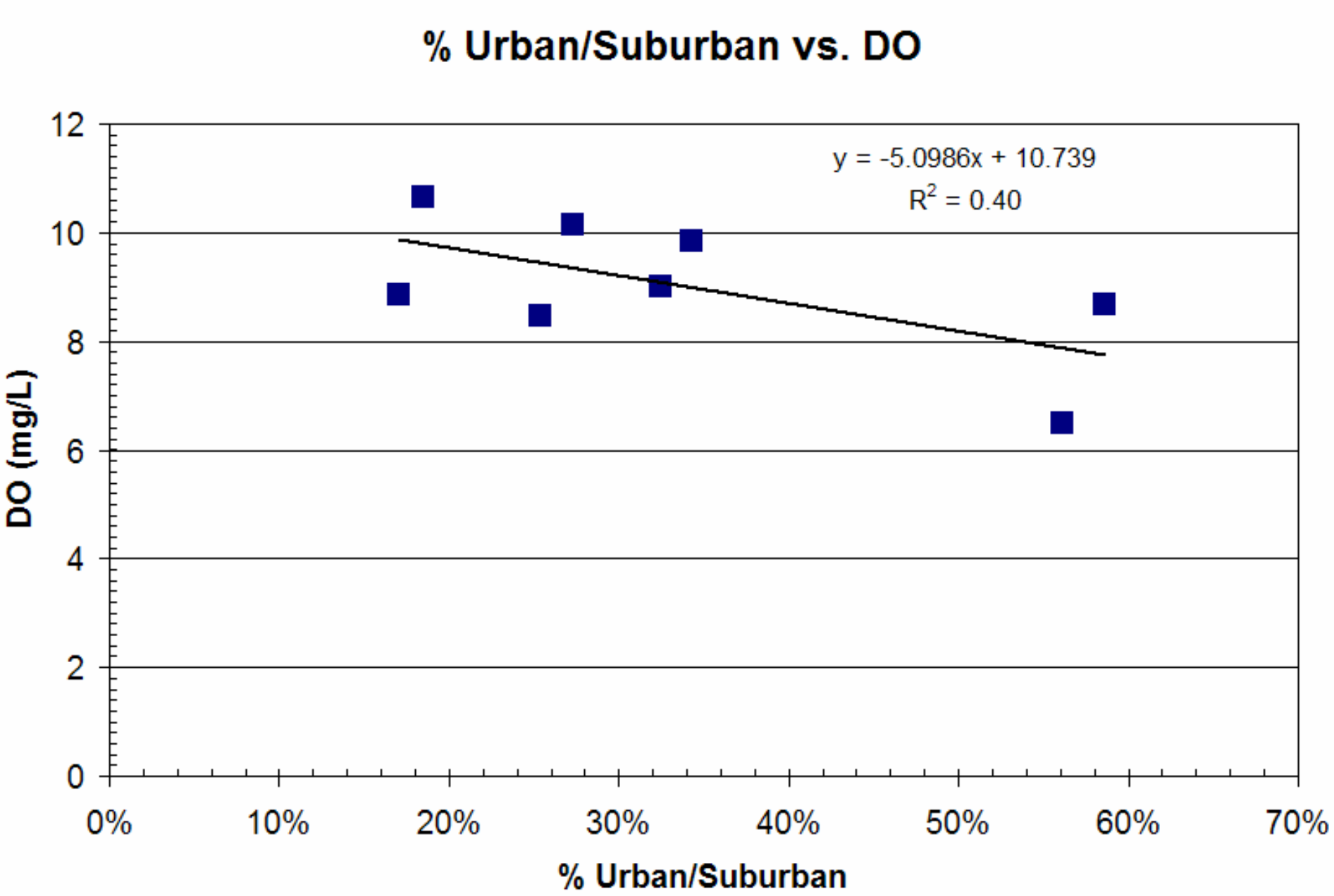

Population Density vs. DO
y = -0.0012x + 10.574
R2 = 0.36
Plot Area
DO (mg/L)
Population Density (people/sq. mi.)
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500

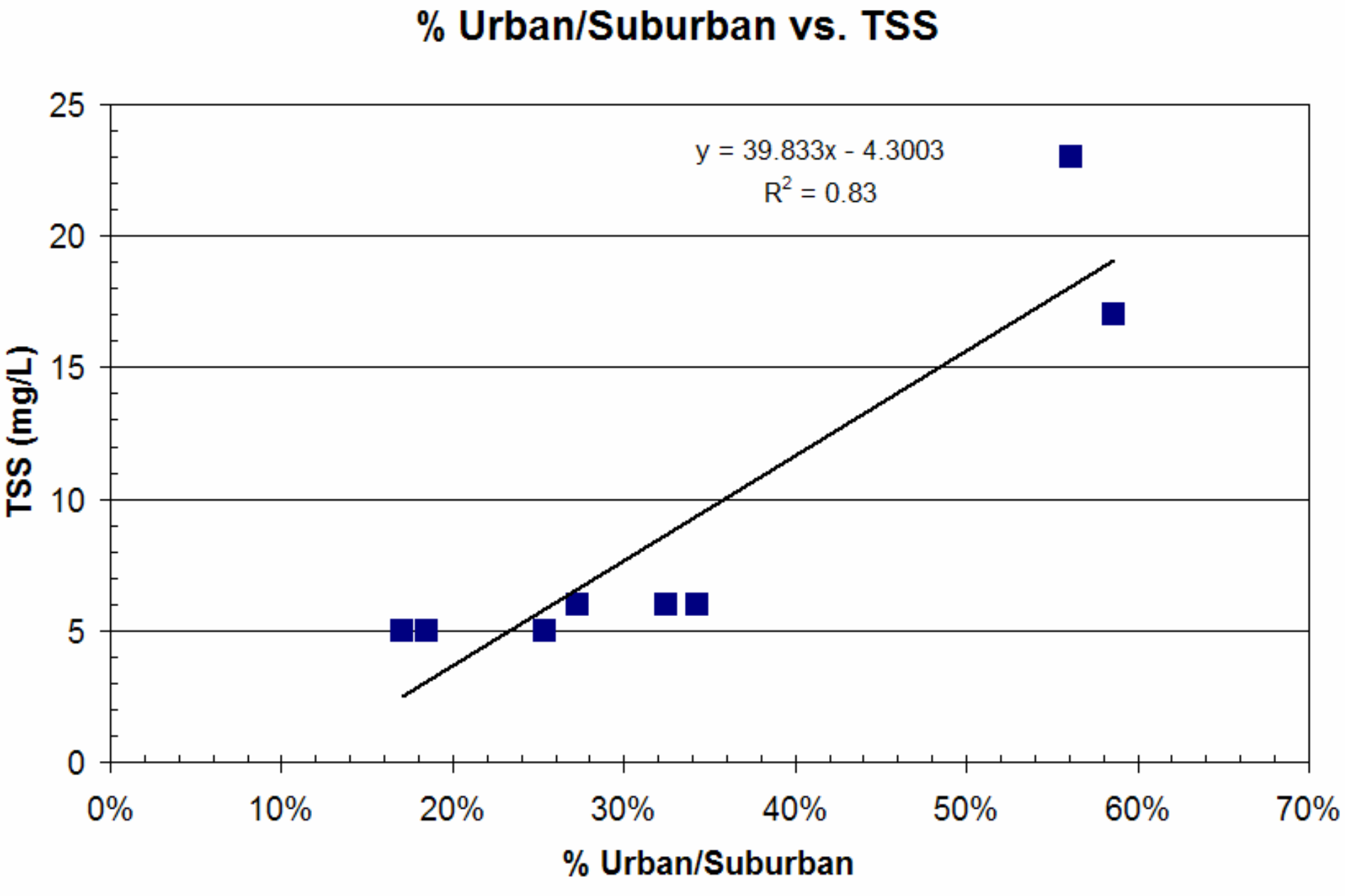

Population Density vs. TSS
y = 0.0107x - 4.4872
R2 = 0.88
TSS (mg/L)
25
20
15
10
5
0
0
500
1000
1500
2000
2500
Population Density (people/sq. mi.)

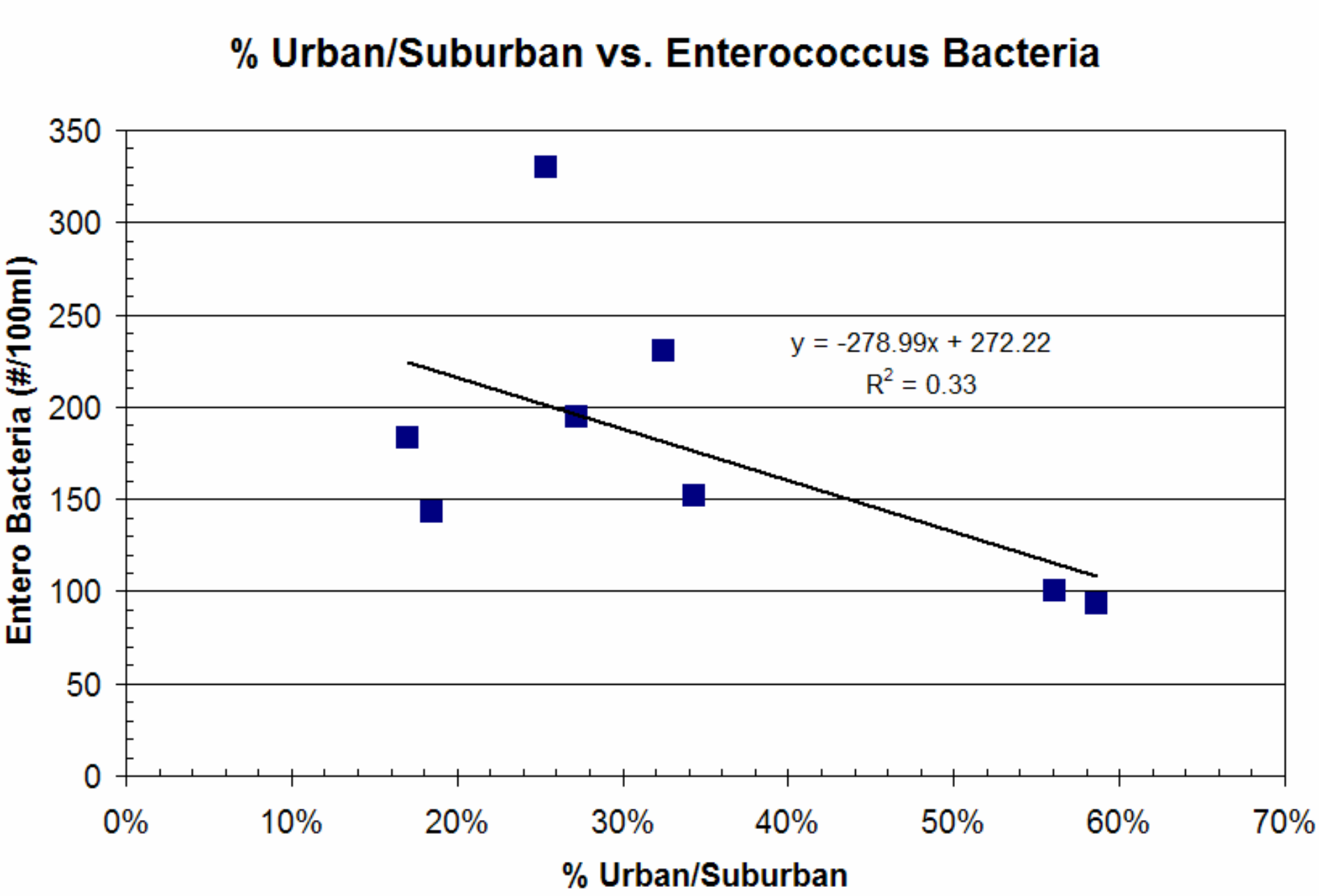

Population Density vs. Enterococcus Bacteria
Entero Bacteria (#/100ml)
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
Population Density (people/sq. mi.)
y = -0.0581x + 221.93
R2 = 0.17

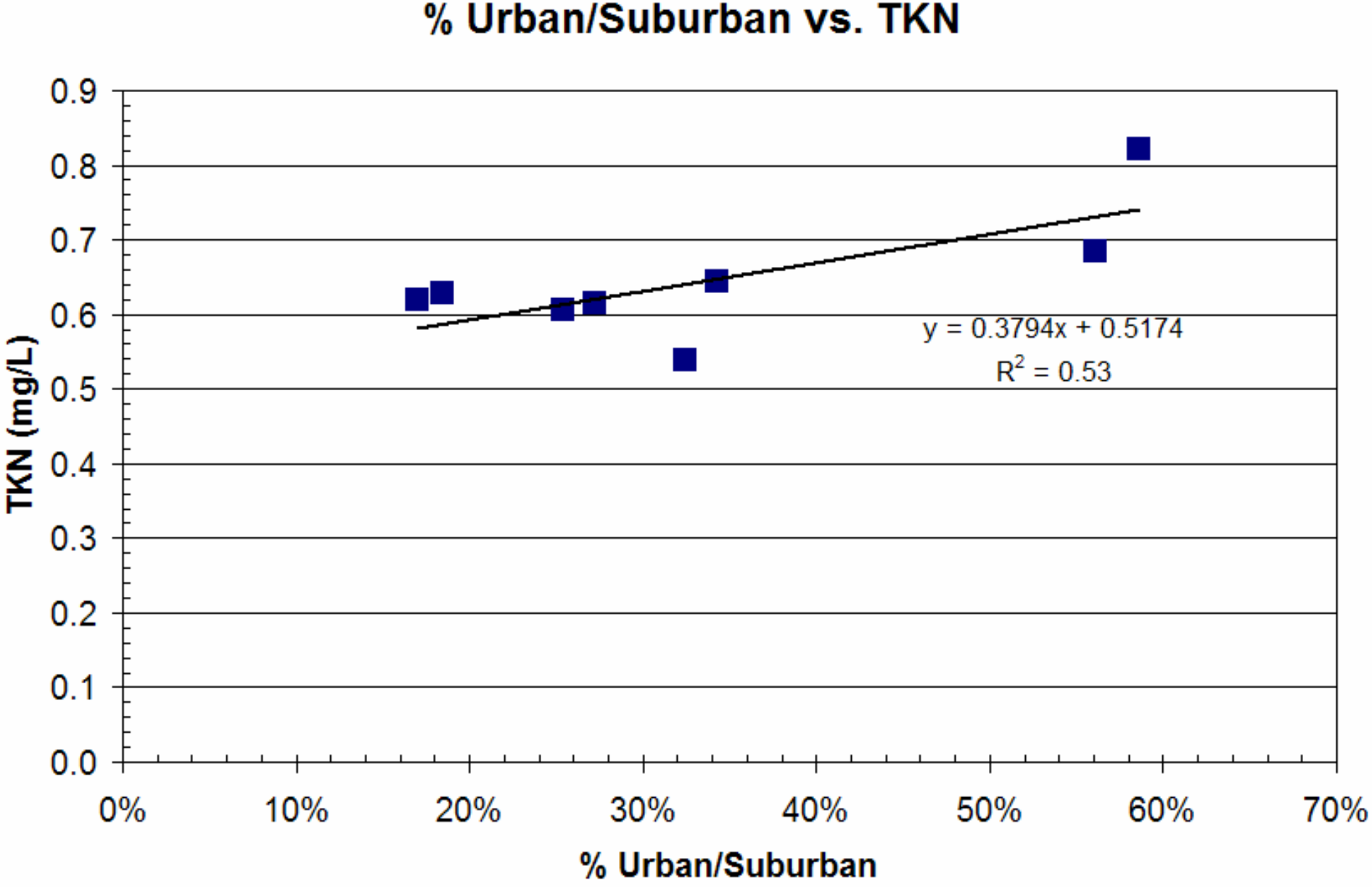

Population Density vs. Inorganic N
Value (Y) Axis Major Gridlines
y = -0.0007x + 3.6165
R2 = 0.96
Inorganic N (mg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
500
1000
1500
2000
2500
Population Density (people/sq. mi.)

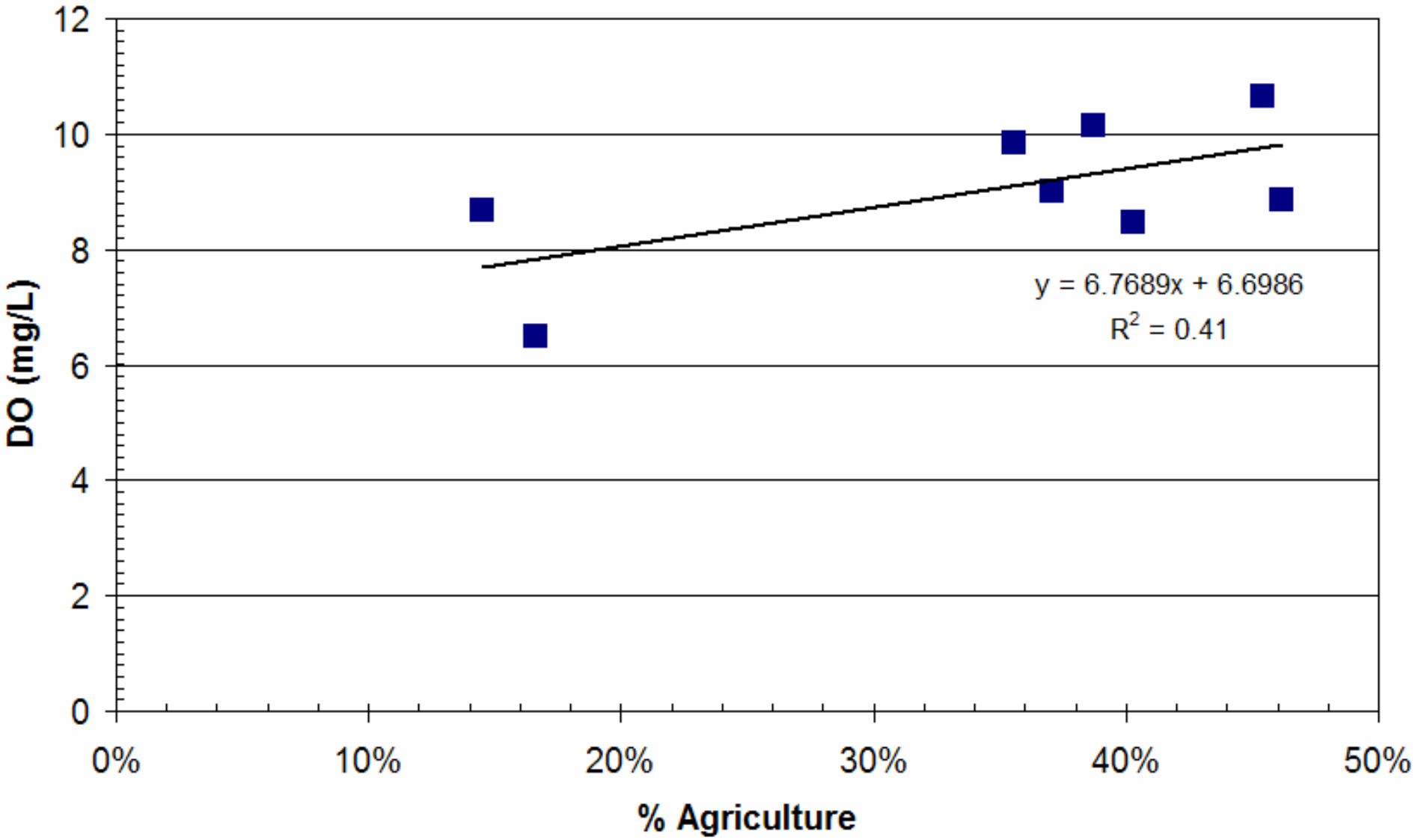

Population Density vs. Total P
Total P (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
500
1000
1500
2000
2500
Population Density (people/sq. mi.)
y = -6E-05x + 0.2332
R2 = 0.25

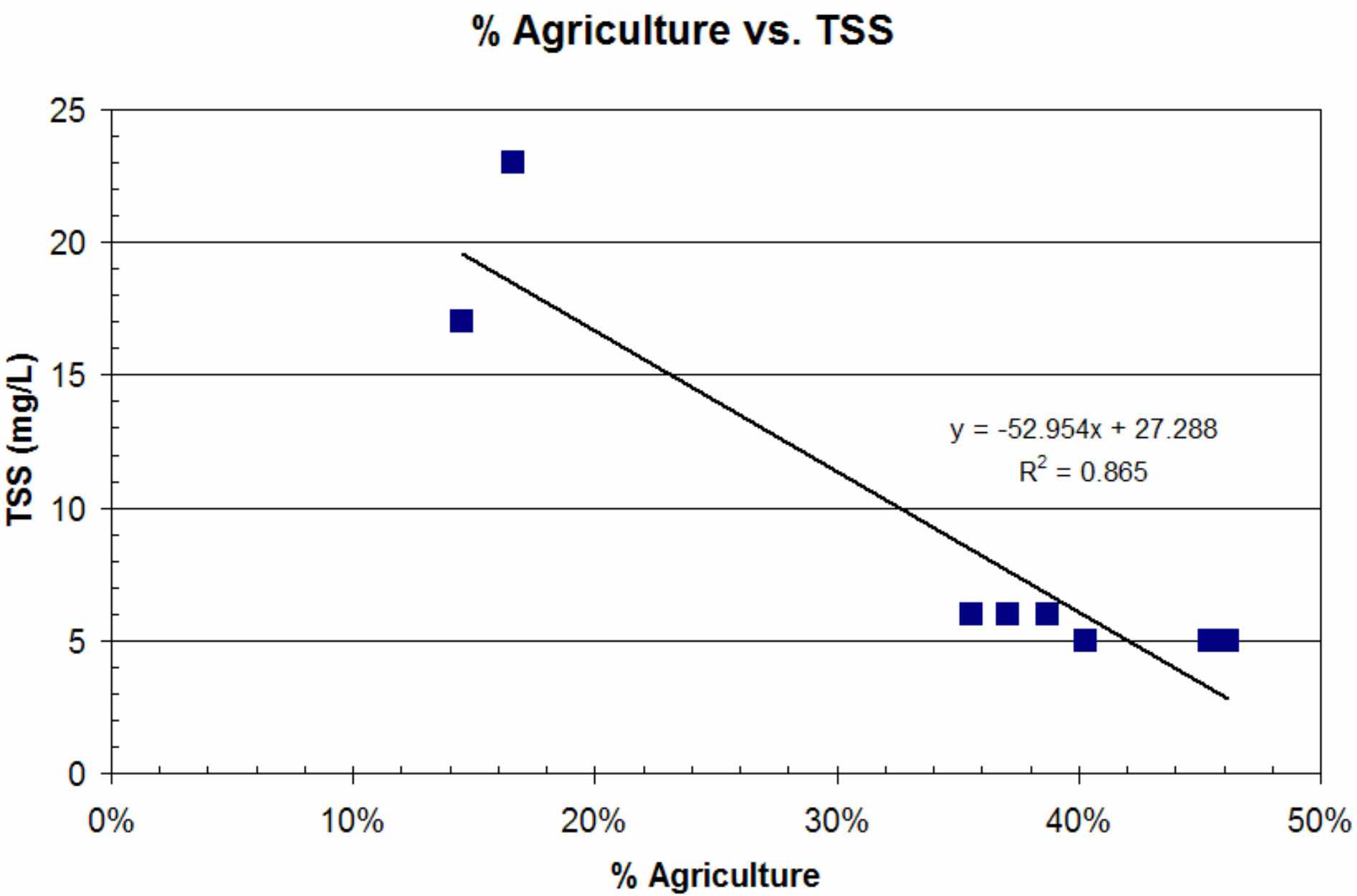

% Urban/Suburban vs. DO
y = -5.0986x + 10.739
R2 = 0.40
DO (mg/L)
12
10
8
6
4
2
0
0%
10%
20%
30%
40%
50%
60%
70%
% Urban/Suburban

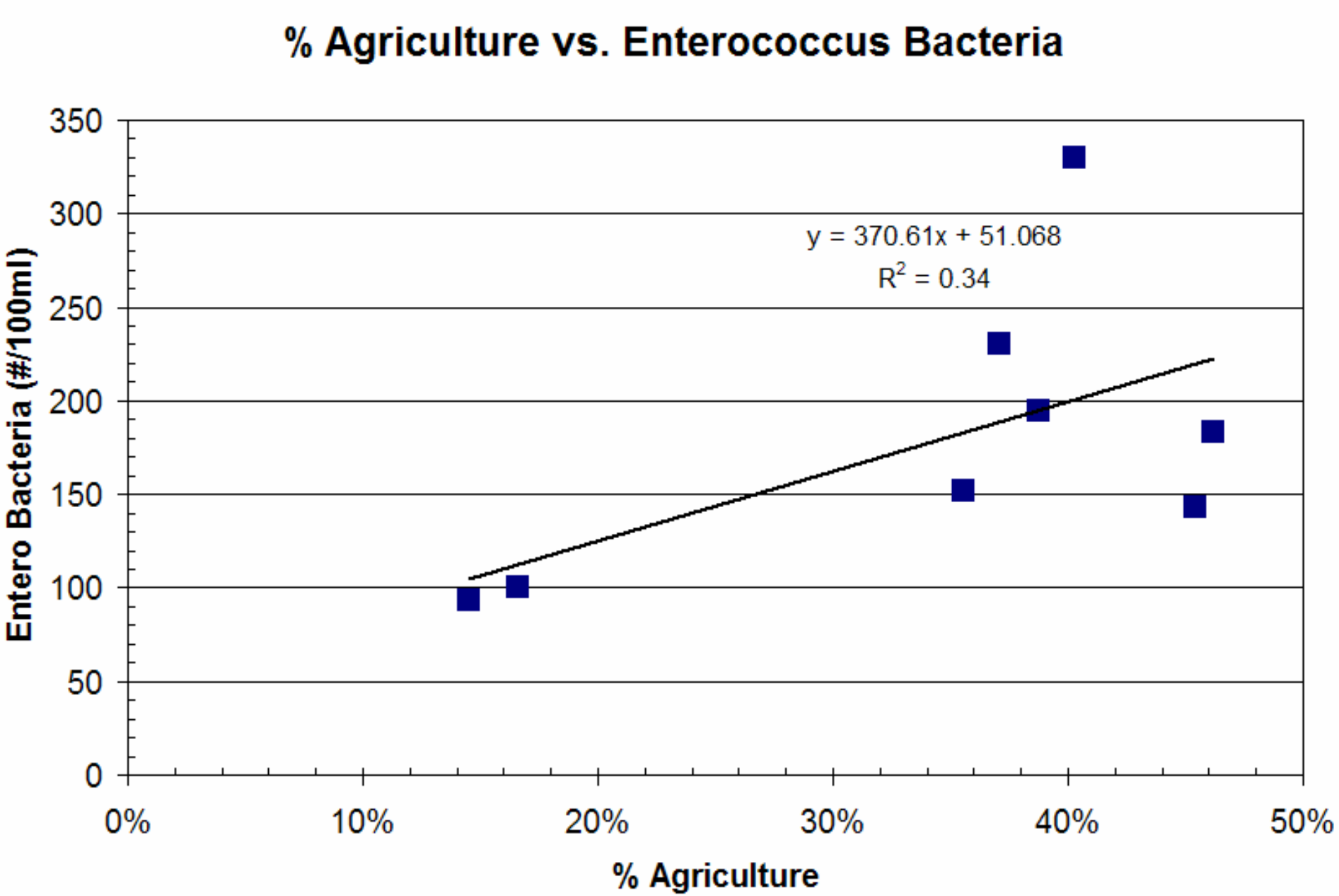

% Urban/Suburban vs. TSS
y = 39.833x - 4.3003
R2 = 0.83
TSS (mg/L)
25
20
15
10
5
0
0%
10%
20%
30%
40%
50%
60%
70%
% Urban/Suburban

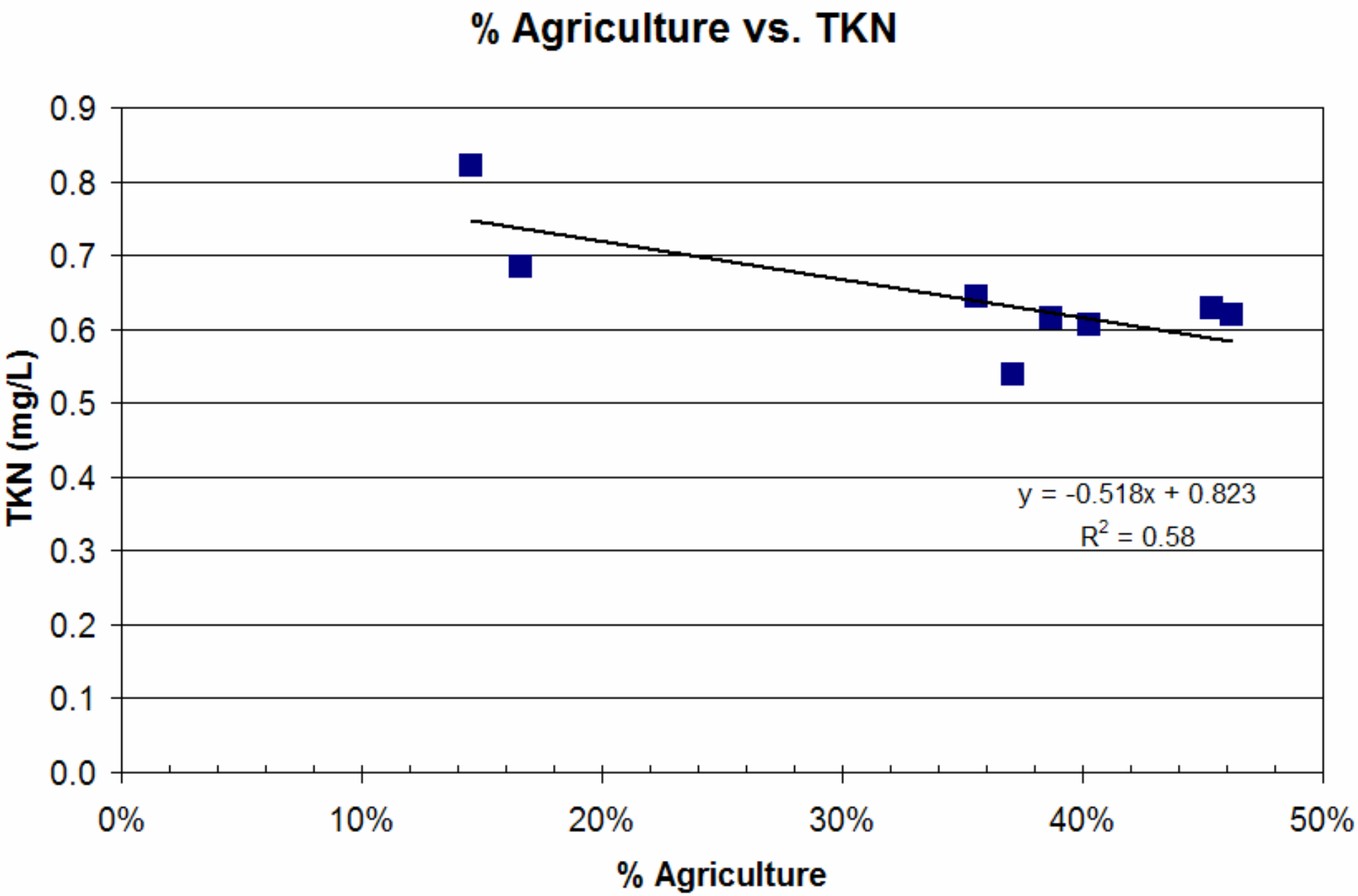

% Urban/Suburban vs. Enterococcus Bacteria
Entero Bacteria (#/100ml)
350
300
250
200
150
100
50
0
y = -278.99x + 272.22
R2 = 0.33
0%
10%
20%
30%
40%
50%
60%
70%
% Urban/Suburban

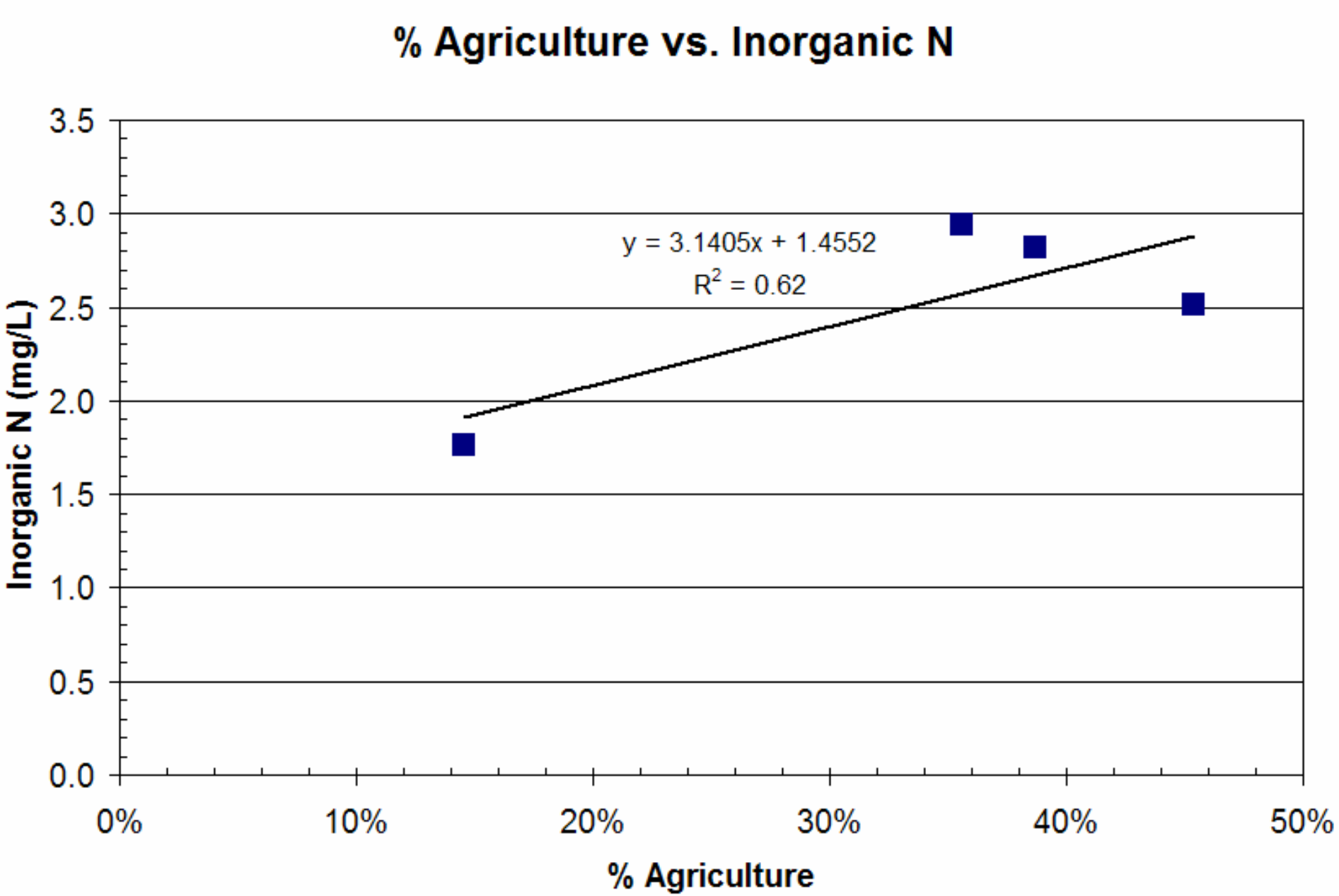

% Urban/Suburban vs. TKN
TKN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0%
10%
20%
30%
40%
50%
60%
70%
% Urban/Suburban
y = 0.3794x + 0.5174
R2 = 0.53

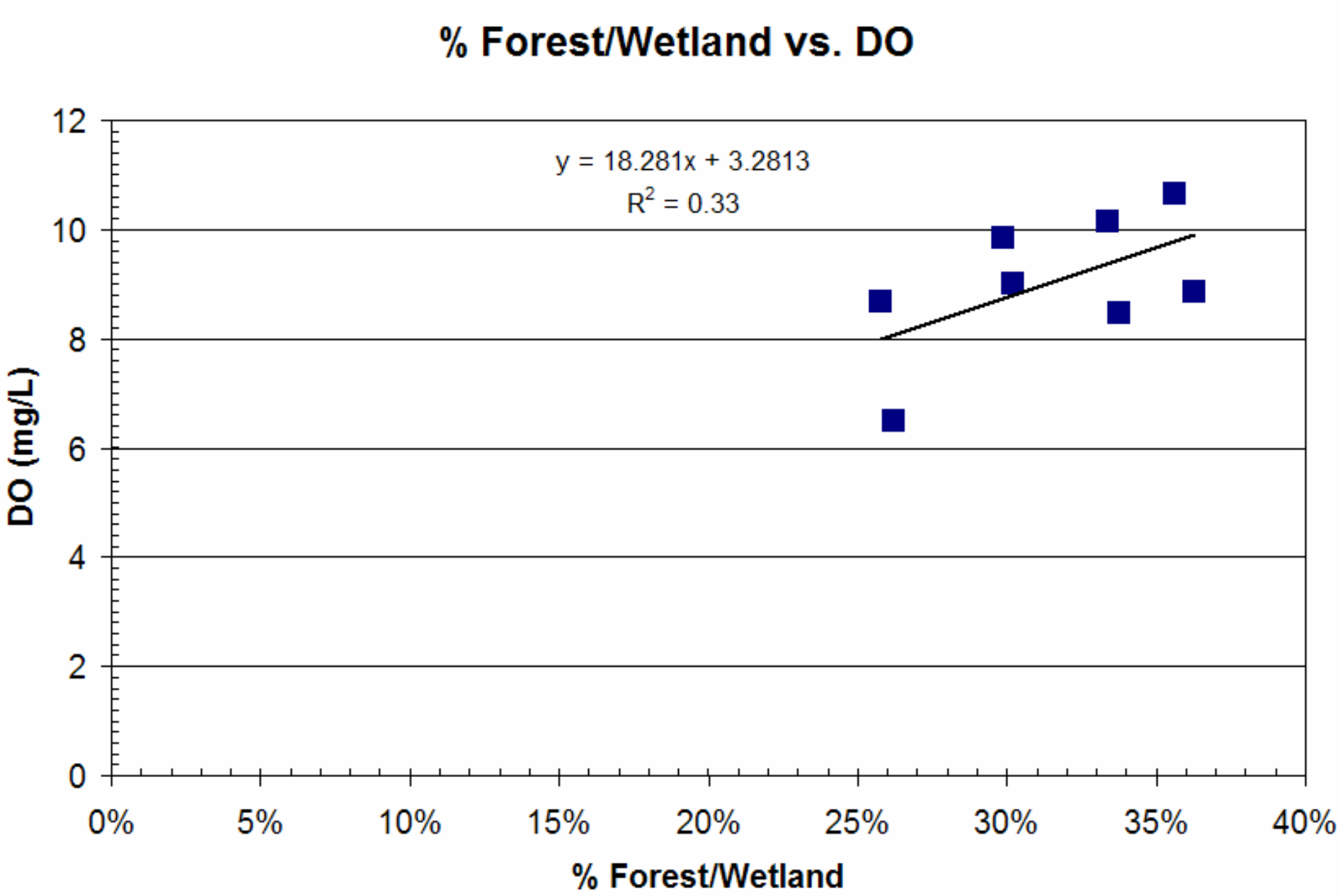

% Agriculture vs. DO
DO (mg/L)
12
10
8
6
4
2
0
0%
10%
20%
30%
40%
50%
% Agriculture
y = 6.7689x + 6.6986
R2 = 0.41

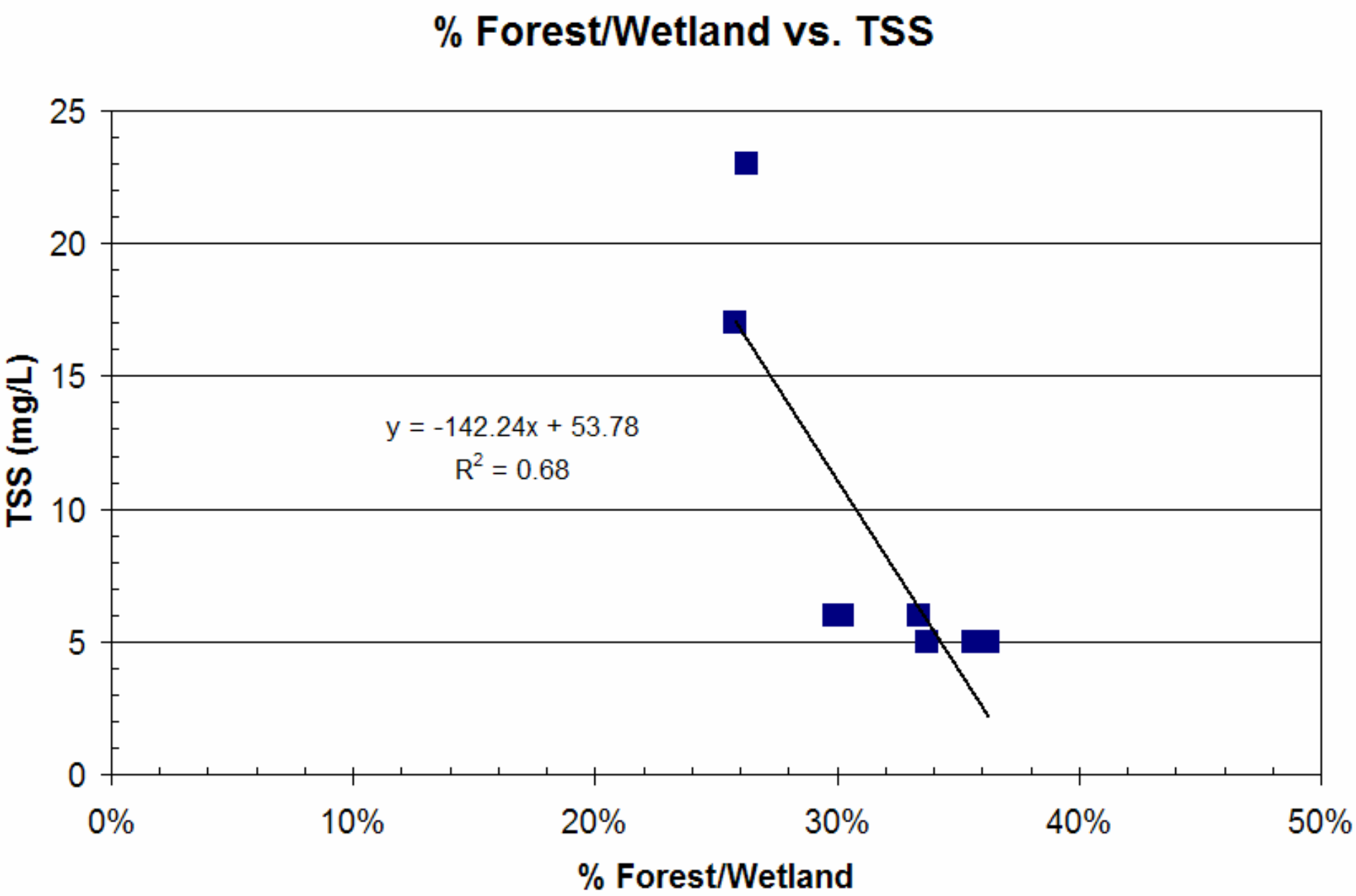

% Agriculture vs. TSS
TSS (mg/L)
25
20
15
10
5
0
0%
10%
20%
30%
40%
50%
% Agriculture
y = -52.954x + 27.288
R2 = 0.865

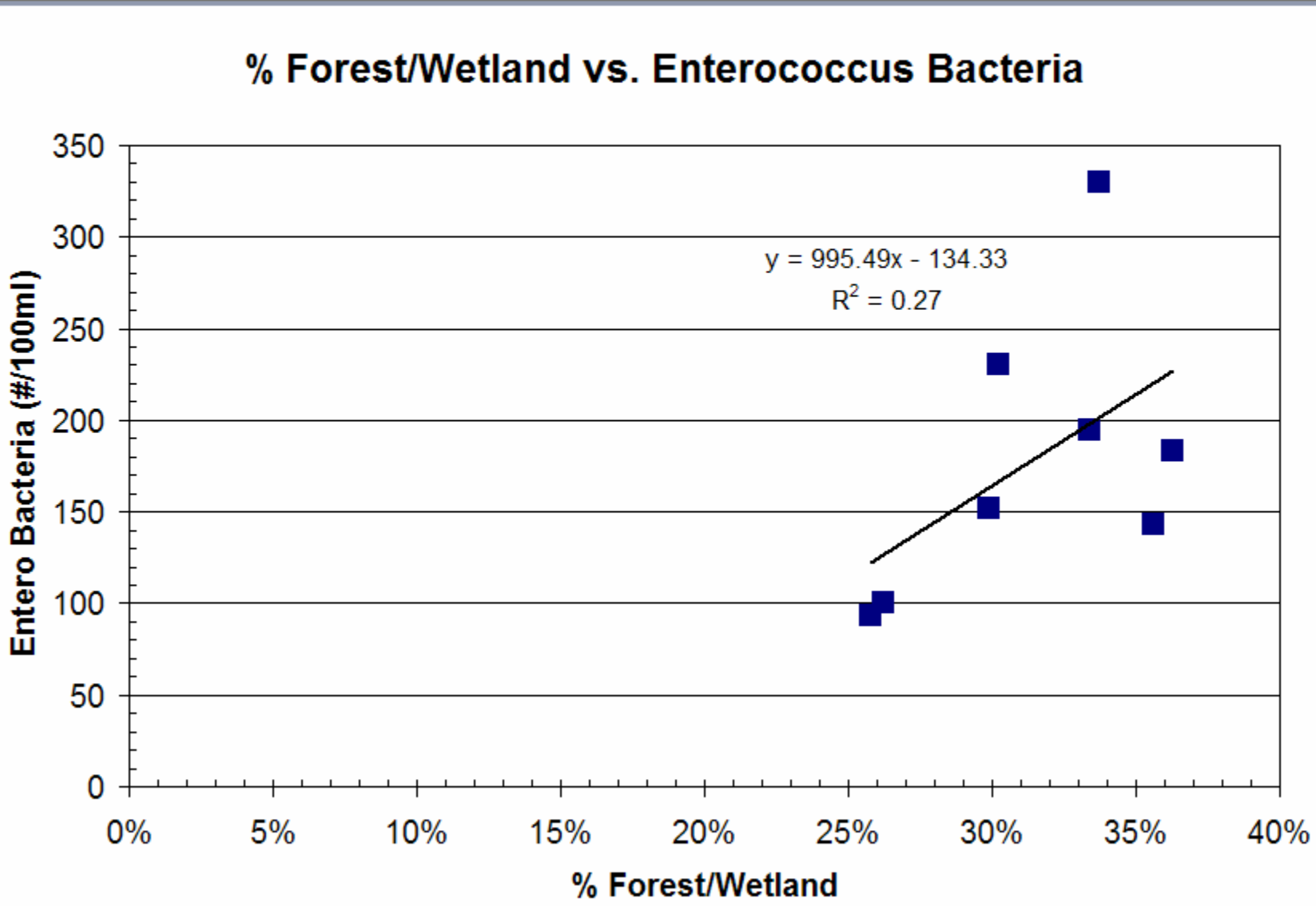

% Agriculture vs. Enterococcus Bacteria
y = 370.61x + 51.068
R2 = 0.34
Entero Bacteria (#/100ml)
350
300
250
200
150
100
50
0
0%
10%
20%
30%
40%
50%
% Agriculture

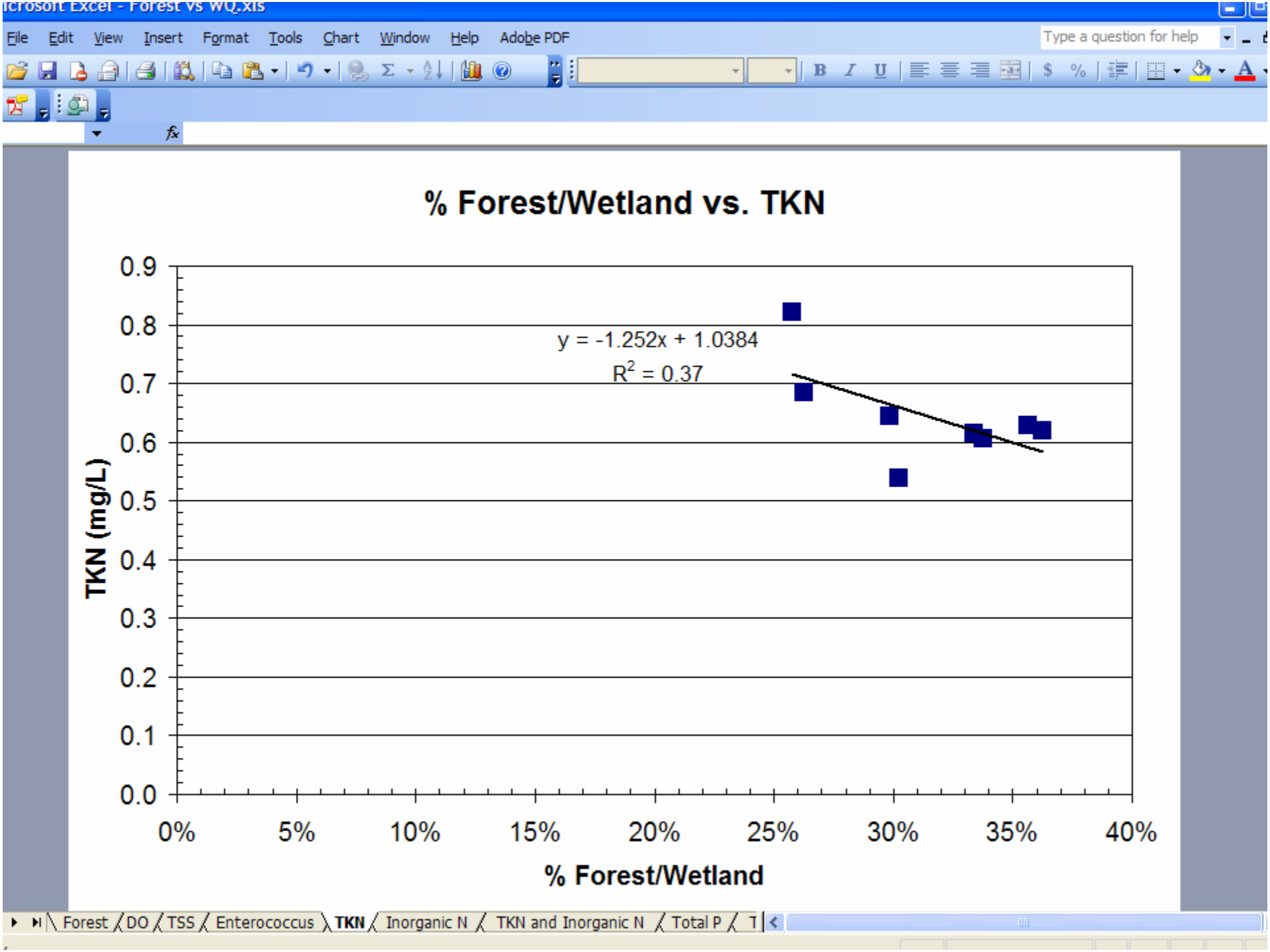

% Agriculture vs. TKN
TKN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0%
10%
20%
30%
40%
50%
% Agriculture
y = -0.518x + 0.823
R2 = 0.58


% Agriculture vs. Inorganic N
y = 3.1405x + 1.4552
R2 = 0.62
Inorganic N (mg/L)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0%
10%
20%
30%
40%
50%
% Agriculture


% Forest/Wetland vs. DO
y = 18.281x + 3.2813
R2 = 0.33
DO (mg/L)
12
10
8
6
4
2
0
0%
5%
10%
15%
20%
25%
30%
35%
40%
% Forest/Wetland

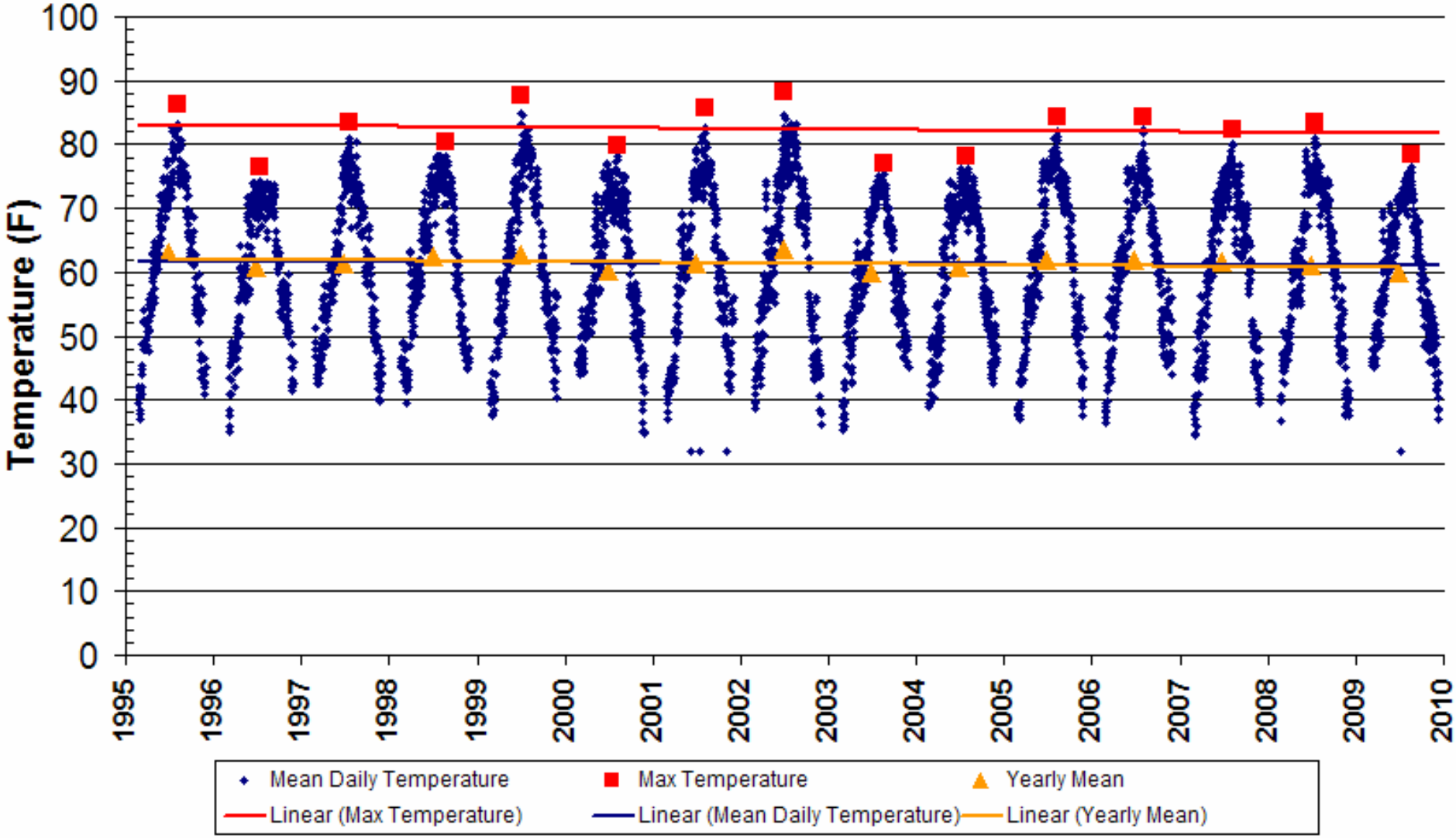

% Forest/Wetland vs. TSS
TSS (mg/L)
25
20
15
10
5
0
y = -142.24x + 53.78
R2 = 0.68
0%
10%
20%
30%
40%
50%
% Forest/Wetland




Microsoft Excel - Forest vs WQ.xls
File Edit View Insert Format Tools Chart Window Help Adobe PDF
Type a question for help
% Forest/Wetland vs. TKN
y = -1.252x + 1.0384
R2 = 0.37
TKN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0%
5%
10%
15%
20%
25%
30%
35%
40%
% Forest/Wetland
Forest DO TSS Enterococcus TKN Inorganic N TKN and Inorganic N Total P T

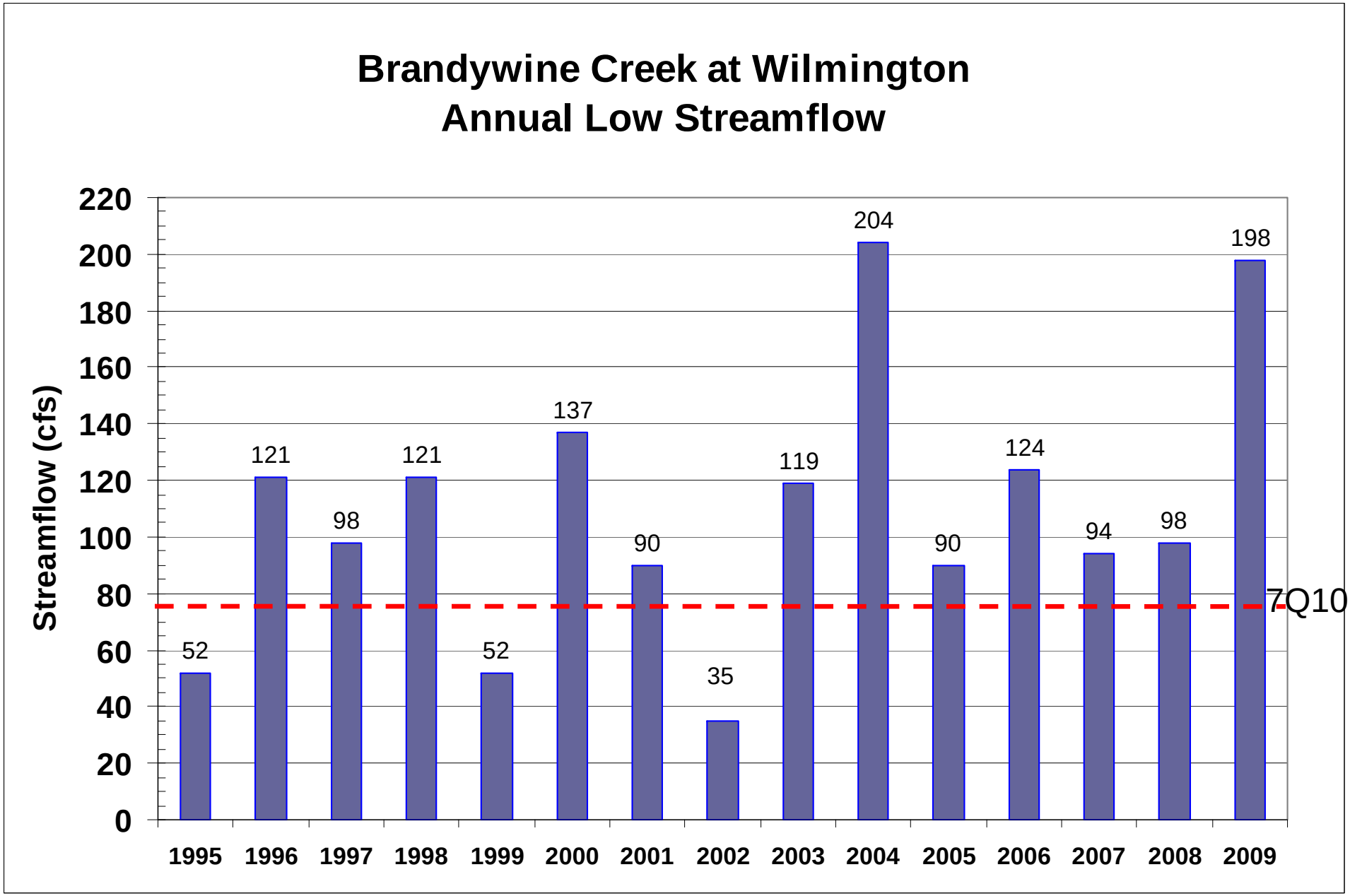
Water Temperature

Brandywine Creek at Chadds Ford
Water Temperature, 1995-2009

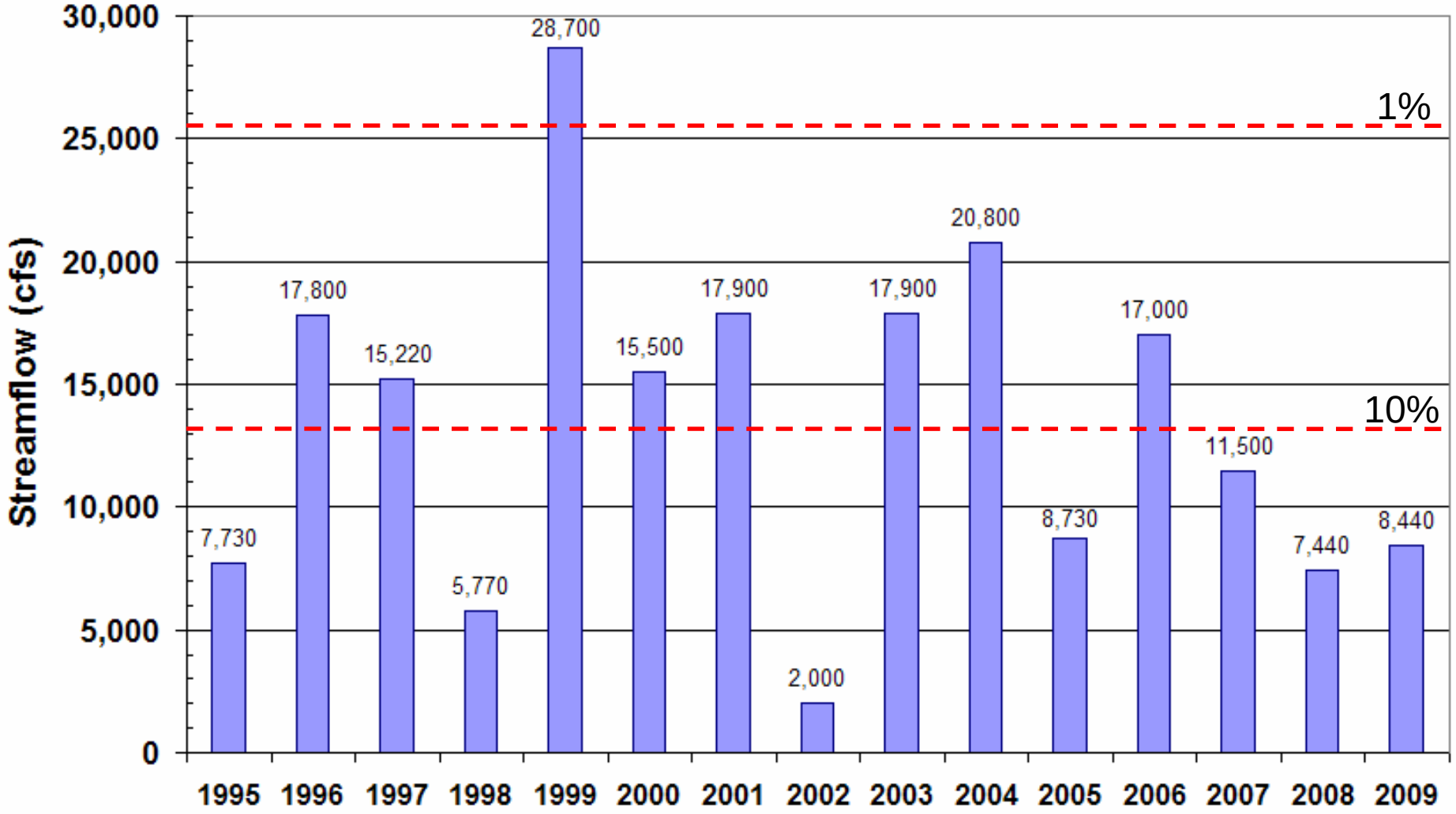


Streamflow

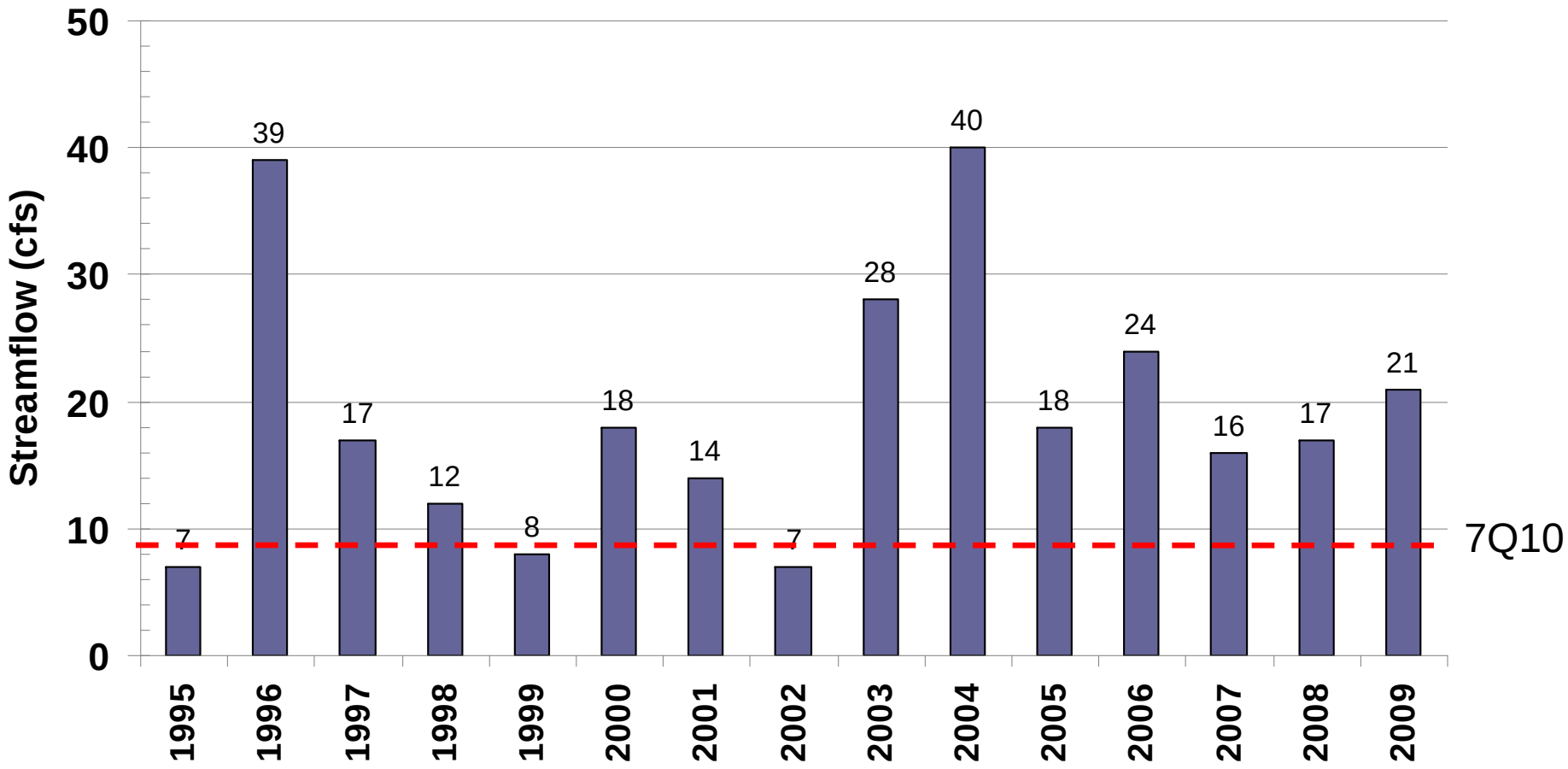
- Annual Low Flow (Drought)
- Annual Peak Flow (Flood)


Brandywine Creek at Wilmington
Annual Low Streamflow
Streamflow (cfs)
220
200
180
160
140
120
100
80
60
40
20
0
52
121
98
121
52
137
90
35
119
204
90
124
94
98
198
7Q10
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

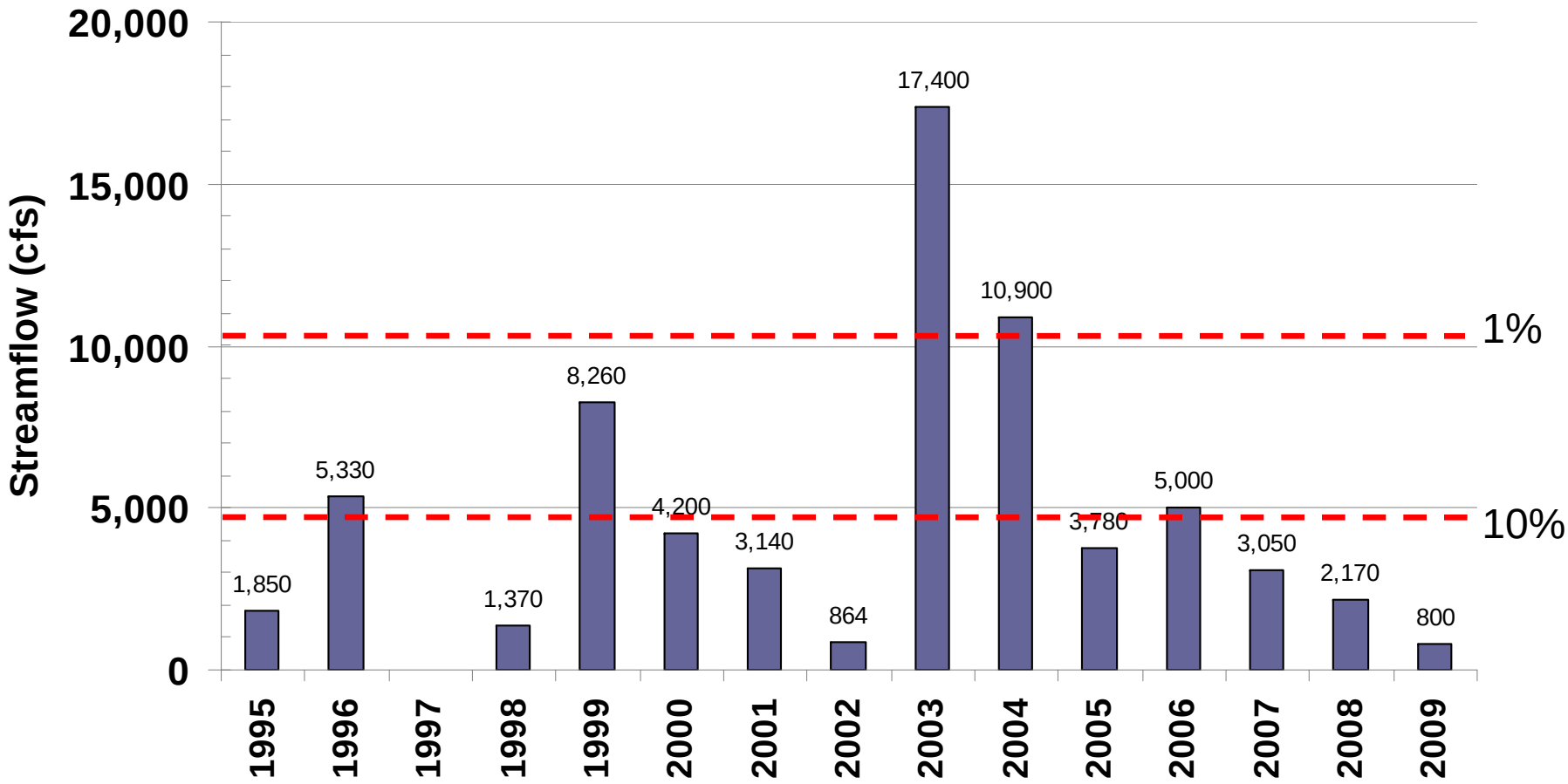
Brandywine Creek at Wilmington
Annual Peak Streamflow



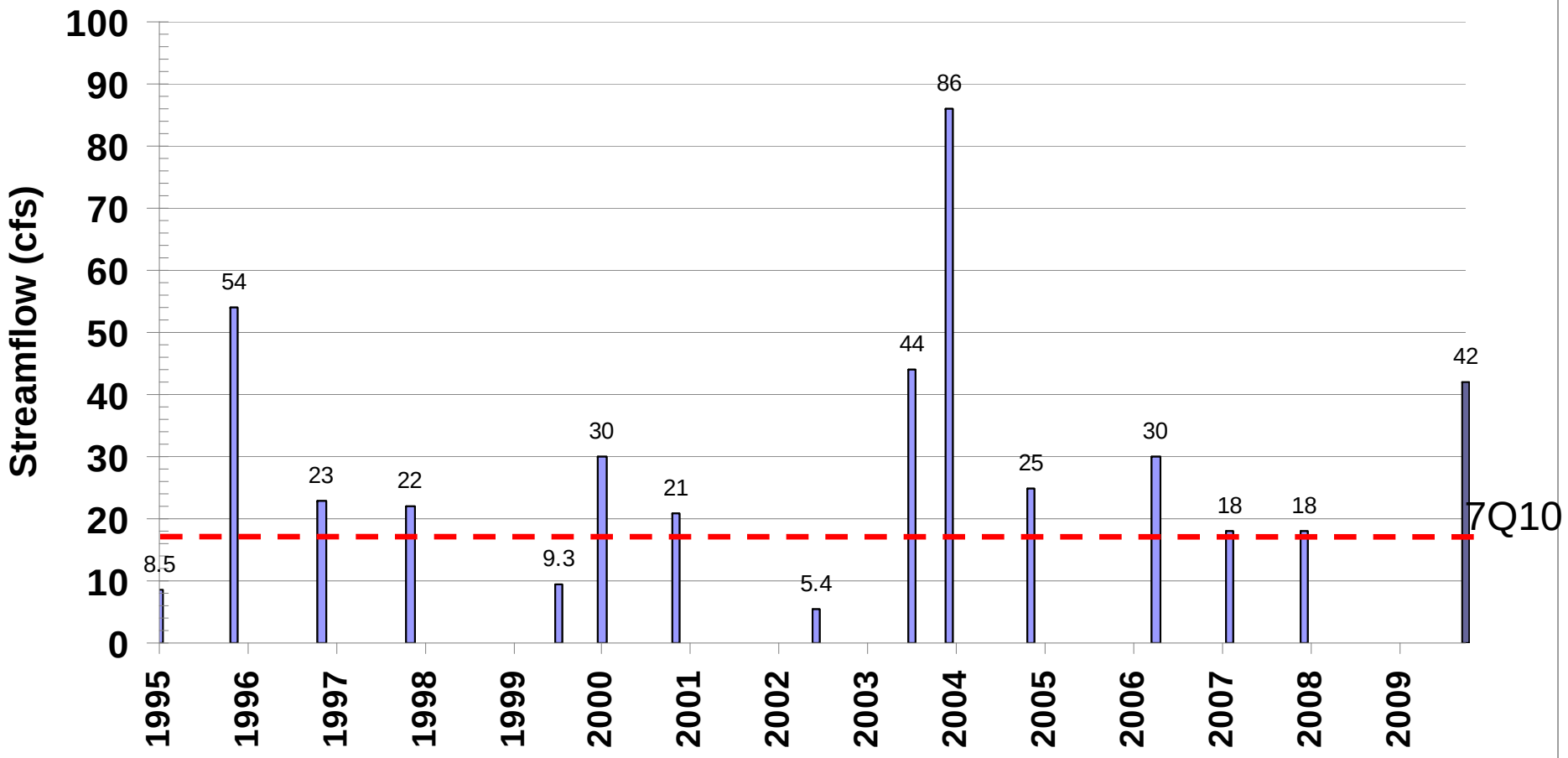
Red Clay Creek at Stanton
Annual Low Streamflow

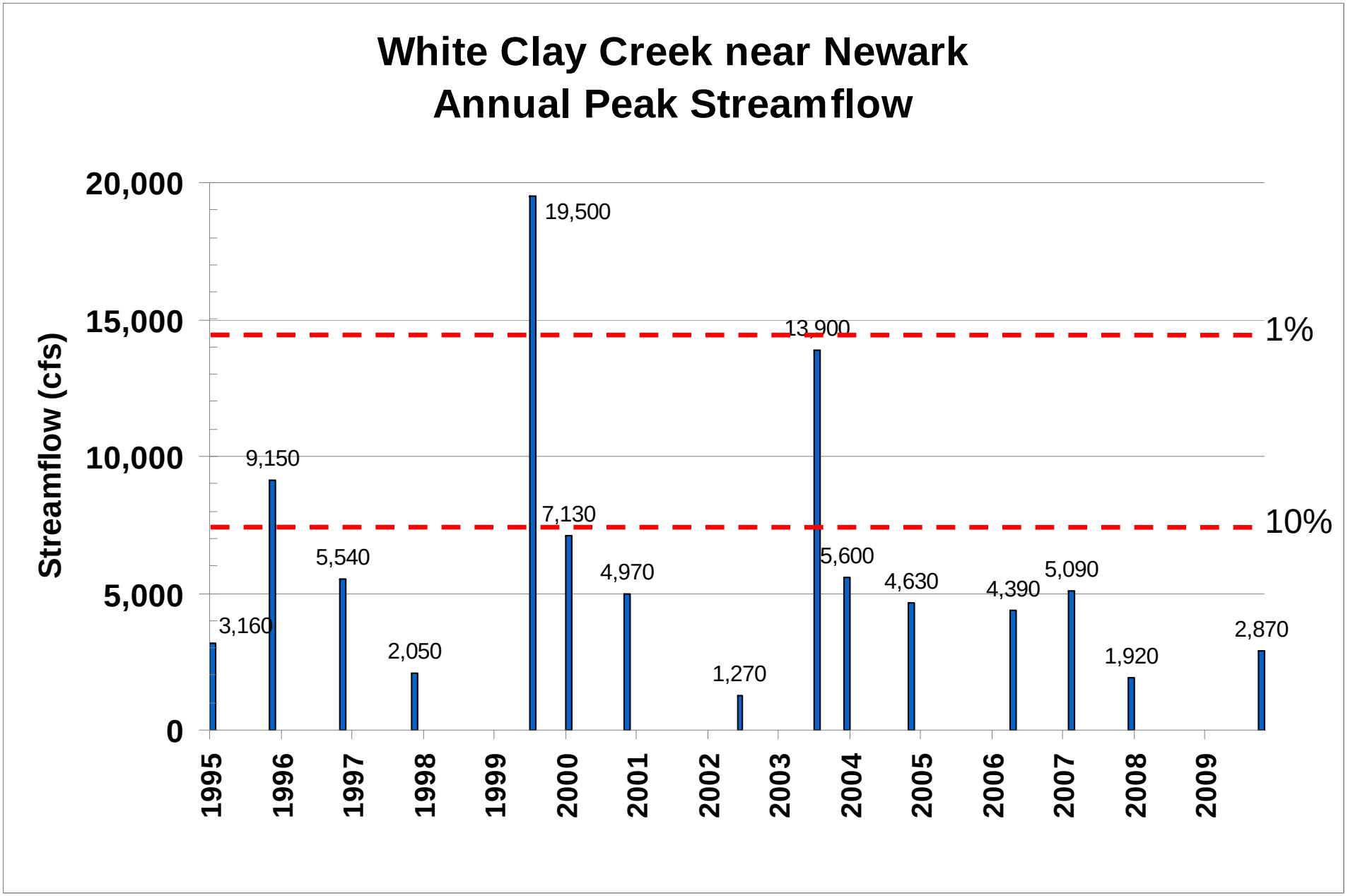


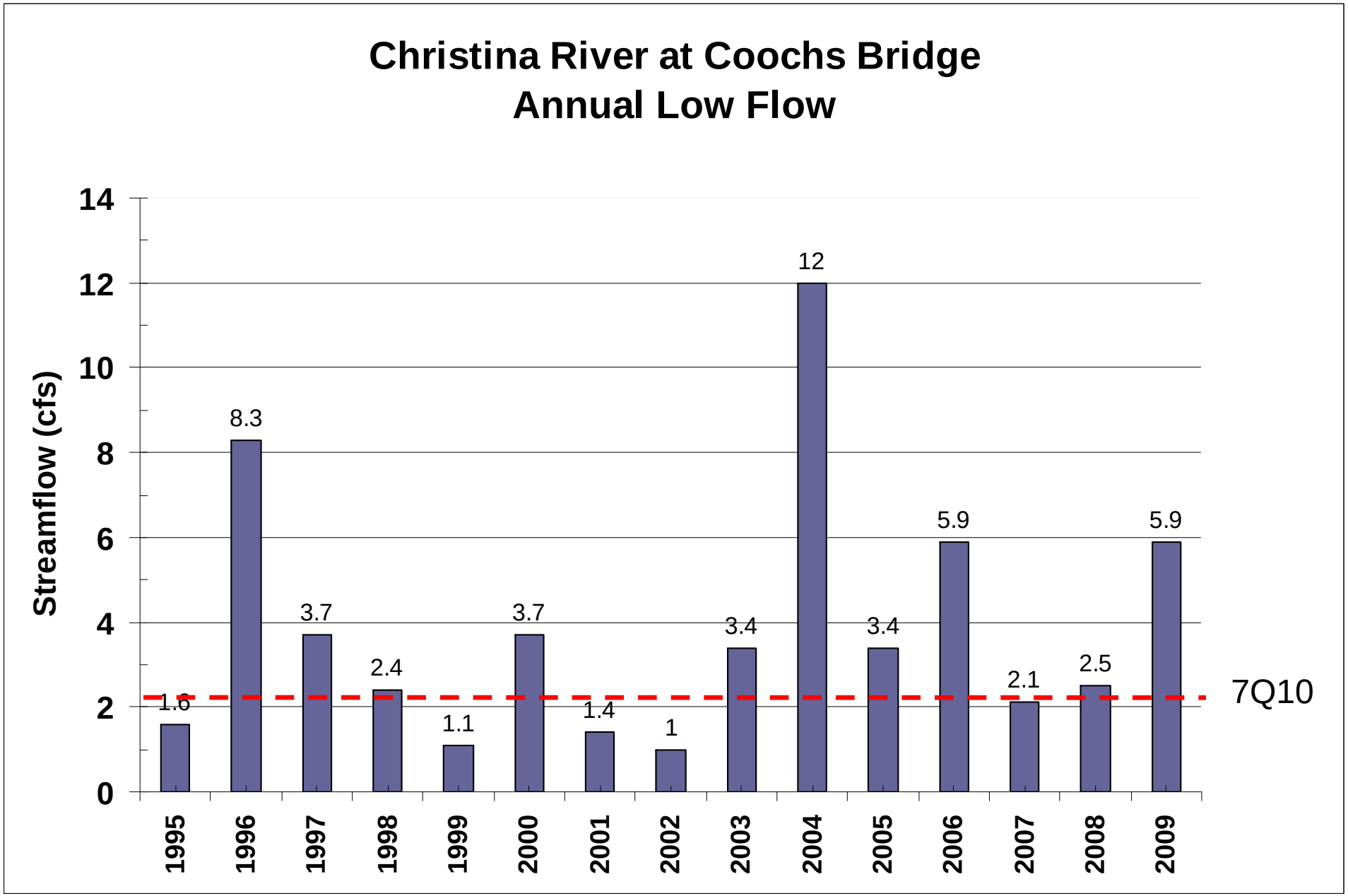
Red Clay Creek at Stanton
Annual Peak Streamflow



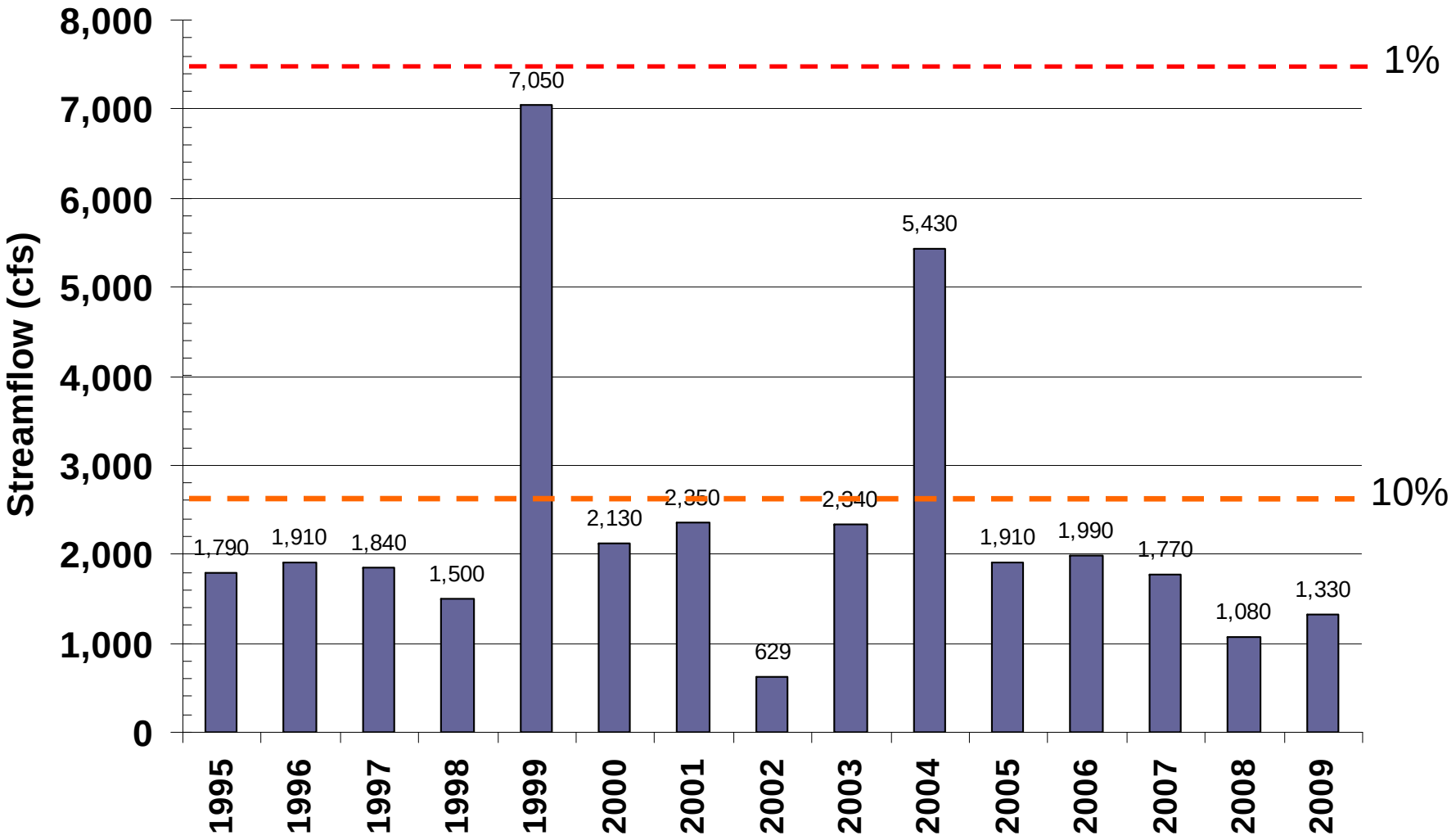
White Clay Creek near Newark
Annual Low Streamflow




White Clay Creek near Newark
Annual Peak Streamflow
Streamflow (cfs)
20,000
15,000
10,000
5,000
0
1%
10%
3,160
9,150
5,540
2,050
19,500
7,130
4,970
1,270
13,900
5,600
4,630
4,390
5,090
1,920
2,870
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009


Christina River at Coochs Bridge
Annual Low Flow
Streamflow (cfs)
14
12
10
8
6
4
2
0
1.6
8.3
3.7
2.4
1.1
3.7
1.4
1
3.4
12
3.4
5.9
2.1
2.5
5.9
7Q10
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

Christina River at Coochs Bridge
Annual Peak Streamflow



Summary

- Water quality improvements are congruent with 15-year contributions of CBCWP.
- Water quality has improved even with 42,000 increase in population (2000-2010) and 9 sq mi increase in urban/suburban land (1996-2005).
- Nitrogen levels are degrading for some reason(s).
- No low flows since drought of 2002.