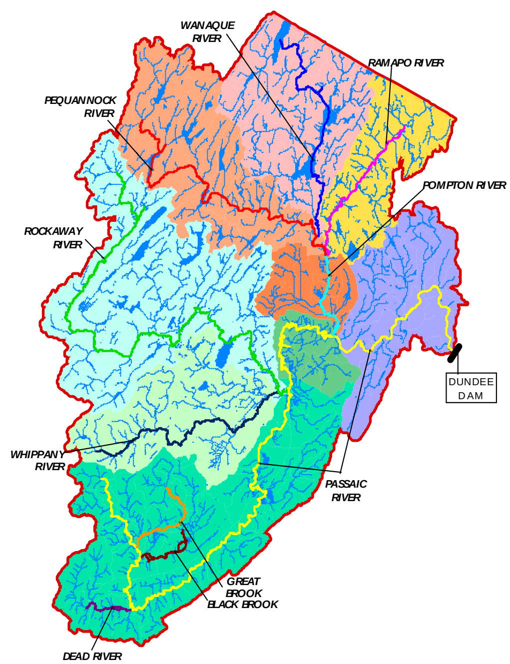
Omni Environmental

FINAL REPORT

The Non-Tidal Passaic River Basin Nutrient TMDL Study

Phase II Watershed Model and TMDL Calculations

Appendices



Prepared for:

Rutgers University
New Jersey EcoComplex
and
New Jersey Department of Environmental Protection
Division of Watershed Management

February 23, 2007

Research Park • 321 Wall Street • Princeton, NJ 08540
Tel: 609-924-8821 • Fax: 609-924-8831
www.Omni-Env.com

Table of Contents

APPENDIX A

Presentations to NJDEP and NJEC
October 7, 2005
April 28, 2006

Presentation to Public Stakeholders
May 19, 2006

Non-Tidal Passaic River Basin Nutrient TMDL
Review of Model Calibration and Results

Rutgers University
New Jersey EcoComplex

New Jersey Department of Environmental Protection
Division of Watershed Management

October 7, 2005

TRC Omni Environmental Corporation

TRC Omni Environmental Corporation

Purpose of Meeting

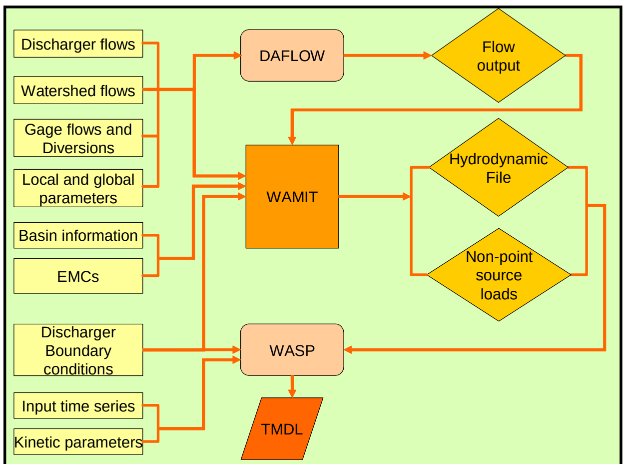
- Review calibration of watershed model
- Review preliminary results of future scenarios
- Obtain direction for TMDL

Modeled Segments of The Passaic Basin

TRC Omni Environmental Corporation

Model Overview

- Flow model
  - DA-FLOW one-dimensional flow model by USGS
  - modified to account for mixing at confluence
- Water quality model
  - one dimensional dynamic simulation using WASP 7
  - Large-scale unified system model
- Watershed Model Integration Tool (WAMIT)
  - Nonpoint source simulation using flow-weighted EMCs
  - DA-FLOW and WASP integration



TRC Omni Environmental Corporation

Model Limitations

- Boundary Condition Uncertainties
  - temperature estimated based on measurements at three locations
  - actual STP, NPS, and baseflow loadings
- Unified System Kinetics
  - global decay rates
  - global growth rates

TRC Omni Environmental Corporation

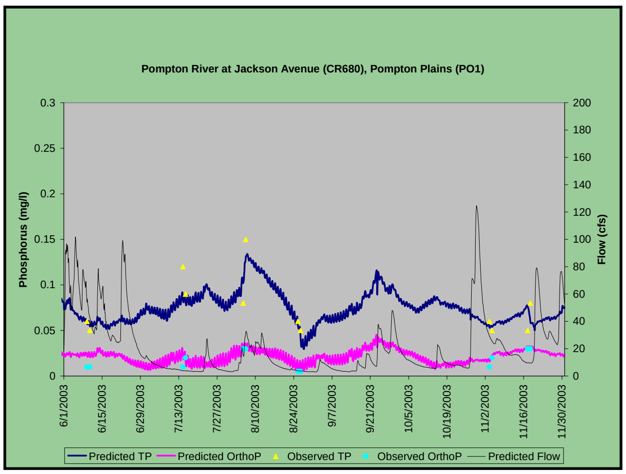
Calibration / Validation Review

- Stream Segments
  - Pompton River
  - Upper, Mid, and Lower Passaic River
  - Dead River
  - Whippany River
  - Rockaway River
  - Pequannock and Wanaque Rivers
  - Singac Brook
  - Peckman River
- Calibration and Validation Graphs
  - Nitrate and Total Phosphorus Calibration
  - Diurnal Dissolved Oxygen Calibration
  - Long-Term Validation

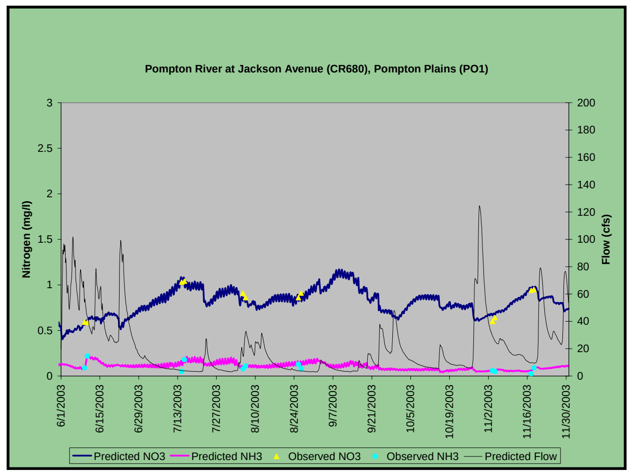
TRC Omni Environmental Corporation

Pompton River

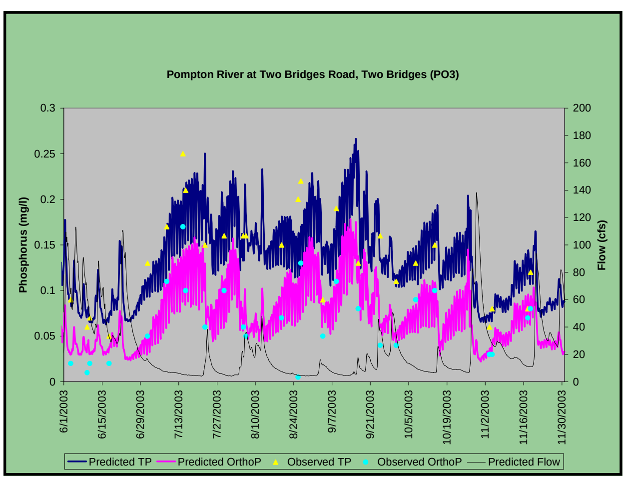
- 2003 Calibration – PO1
  - TP and Nitrate
- 2003 Calibration – PO3
  - TP and Nitrate
- Dissolved Oxygen
  - August 2003 – PO1
  - August 2003 – PO3
- Validation
  - Diurnal Dissolved Oxygen at PO1 in 1999 and 2002
  - Dissolved Oxygen, Phosphorus, and Nitrogen at PO1



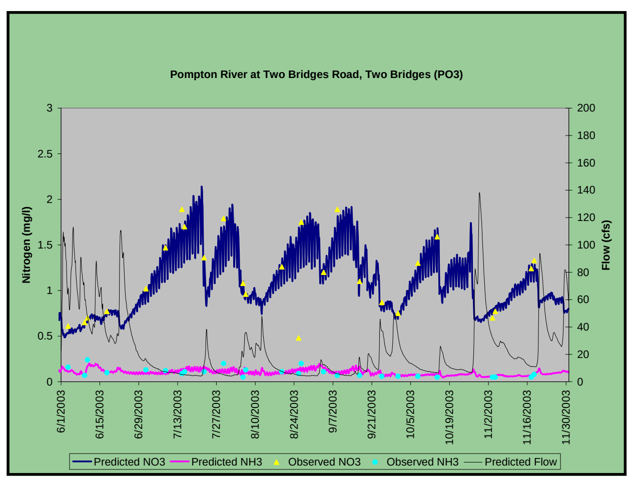
Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)



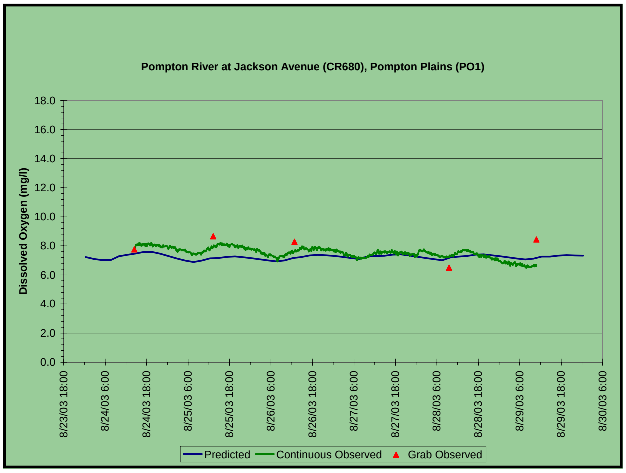
Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)

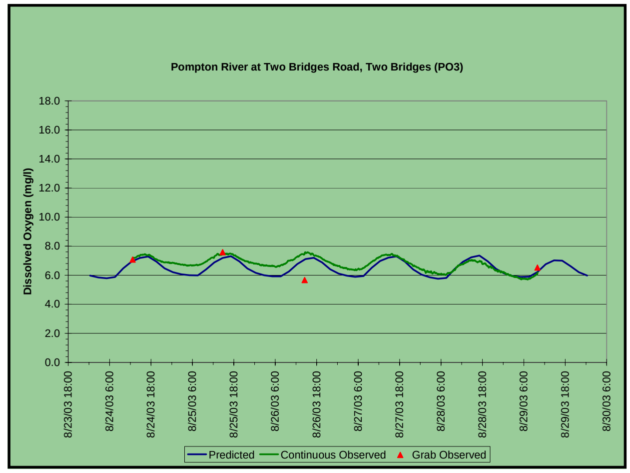


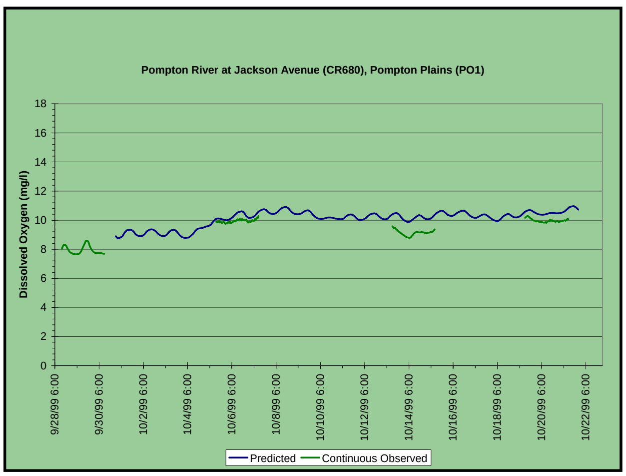
Pompton River at Two Bridges Road, Two Bridges (PO3)

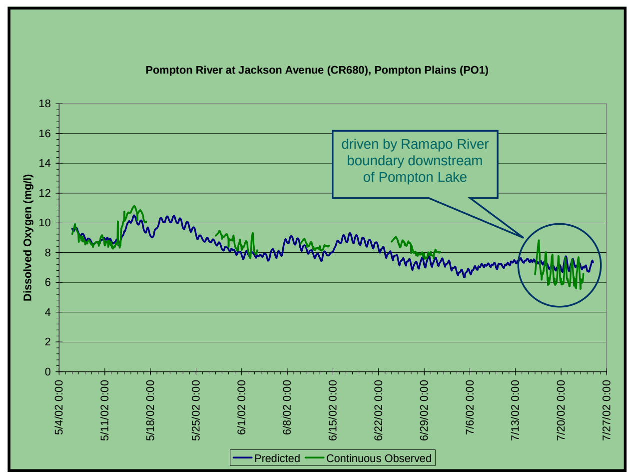


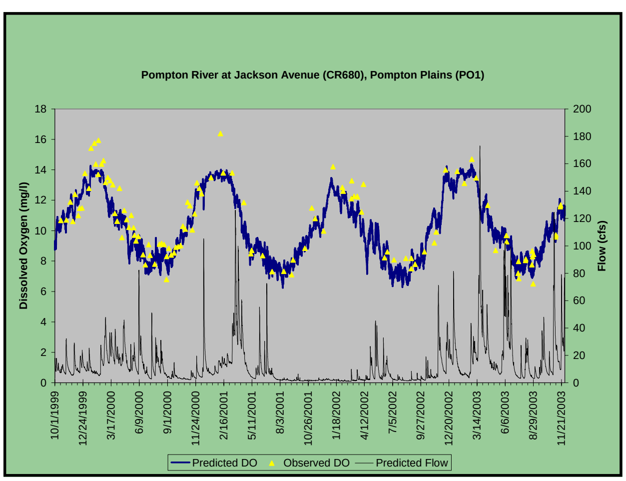
Pompton River at Two Bridges Road, Two Bridges (PO3)

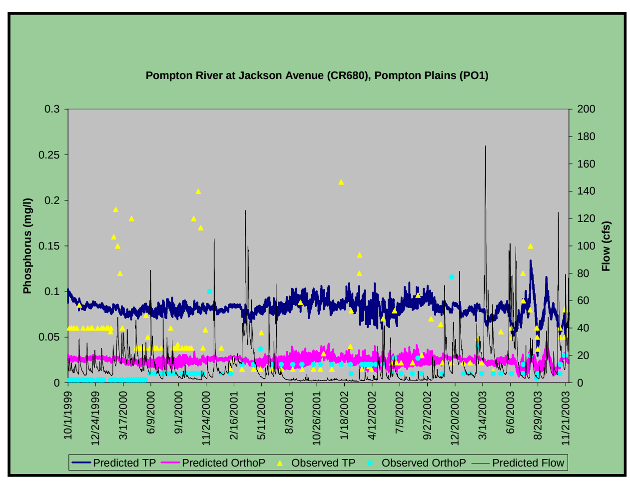

Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)
Dissolved Oxygen (mg/l)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
8/23/03 18:00
8/24/03 6:00
8/24/03 18:00
8/25/03 6:00
8/25/03 18:00
8/26/03 6:00
8/26/03 18:00
8/27/03 6:00
8/27/03 18:00
8/28/03 6:00
8/28/03 18:00
8/29/03 6:00
8/29/03 18:00
8/30/03 6:00
Predicted
Continuous Observed
Grab Observed

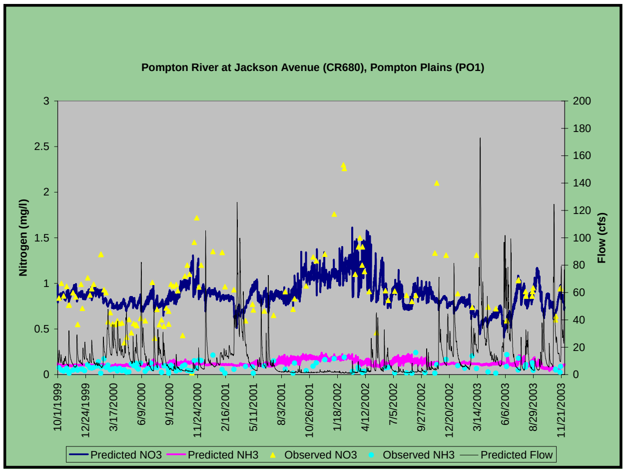

Pompton River at Two Bridges Road, Two Bridges (PO3)
Dissolved Oxygen (mg/l)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
8/23/03 18:00
8/24/03 6:00
8/24/03 18:00
8/25/03 6:00
8/25/03 18:00
8/26/03 6:00
8/26/03 18:00
8/27/03 6:00
8/27/03 18:00
8/28/03 6:00
8/28/03 18:00
8/29/03 6:00
8/29/03 18:00
8/30/03 6:00
Predicted
Continuous Observed
Grab Observed


Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)
Dissolved Oxygen (mg/l)
18
16
14
12
10
8
6
4
2
0
9/28/99 6:00
9/30/99 6:00
10/2/99 6:00
10/4/99 6:00
10/6/99 6:00
10/8/99 6:00
10/10/99 6:00
10/12/99 6:00
10/14/99 6:00
10/16/99 6:00
10/18/99 6:00
10/20/99 6:00
10/22/99 6:00
Predicted
Continuous Observed


Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)
driven by Ramapo River boundary downstream of Pompton Lake
Dissolved Oxygen (mg/l)
18
16
14
12
10
8
6
4
2
0
5/4/02 0:00
5/11/02 0:00
5/18/02 0:00
5/25/02 0:00
6/1/02 0:00
6/8/02 0:00
6/15/02 0:00
6/22/02 0:00
6/29/02 0:00
7/6/02 0:00
7/13/02 0:00
7/20/02 0:00
7/27/02 0:00
Predicted
Continuous Observed


Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)
Dissolved Oxygen (mg/l)
Flow (cfs)
18
16
14
12
10
8
6
4
2
0
200
180
160
140
120
100
80
60
40
20
0
10/1/1999
12/24/1999
3/17/2000
6/9/2000
9/1/2000
11/24/2000
2/16/2001
5/11/2001
8/3/2001
10/26/2001
1/18/2002
4/12/2002
7/5/2002
9/27/2002
12/20/2002
3/14/2003
6/6/2003
8/29/2003
11/21/2003
Predicted DO
Observed DO
Predicted Flow

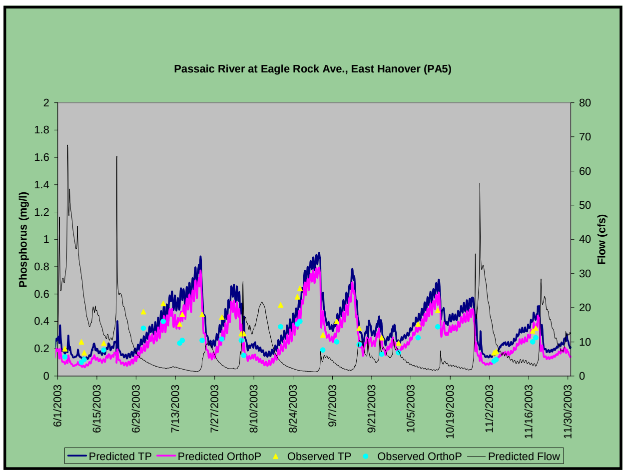

Pompton River at Jackson Avenue (CR680), Pompton Plains (PO1)
Phosphorus (mg/l)
Flow (cfs)
0.3
0.25
0.2
0.15
0.1
0.05
0
200
180
160
140
120
100
80
60
40
20
0
10/1/1999
12/24/1999
3/17/2000
6/9/2000
9/1/2000
11/24/2000
2/16/2001
5/11/2001
8/3/2001
10/26/2001
1/18/2002
4/12/2002
7/5/2002
9/27/2002
12/20/2002
3/14/2003
6/6/2003
8/29/2003
11/21/2003
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow

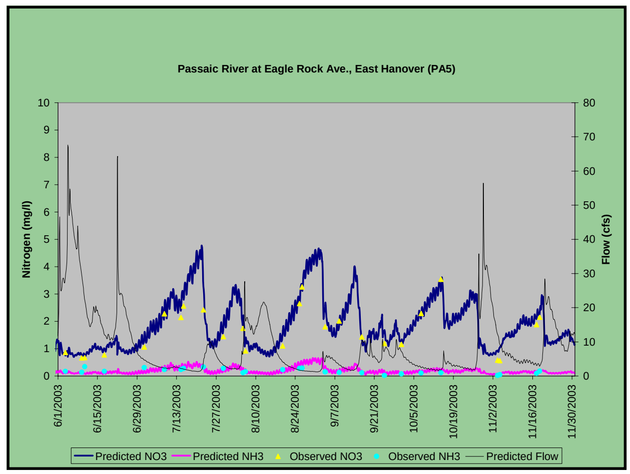


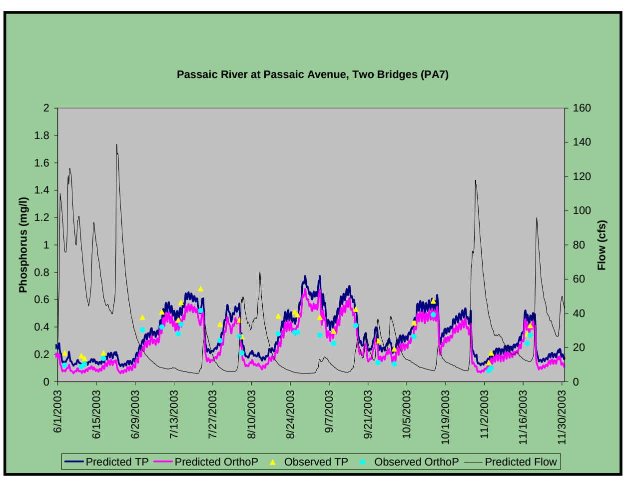
TRC Omni Environmental Corporation

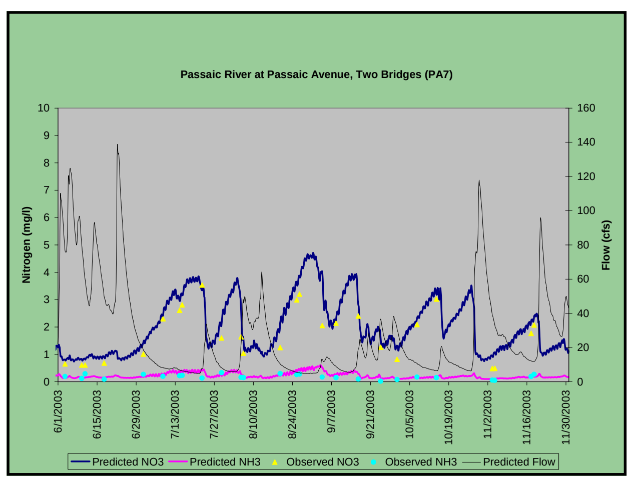
Passaic River Calibration

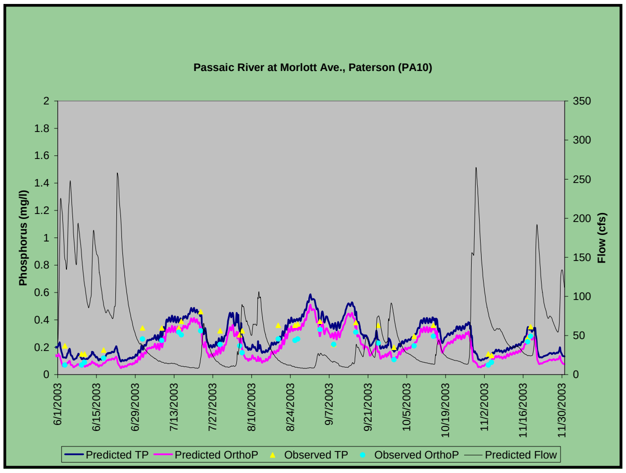
- 2003 Calibration – PA5
  - TP and Nitrate
- 2003 Calibration – PA7
  - TP and Nitrate
- 2003 Calibration – PA10
  - TP and Nitrate
- Dissolved Oxygen
  - August 2003 – PA5
  - August 2003 – PA8
  - August 2003 – PA10

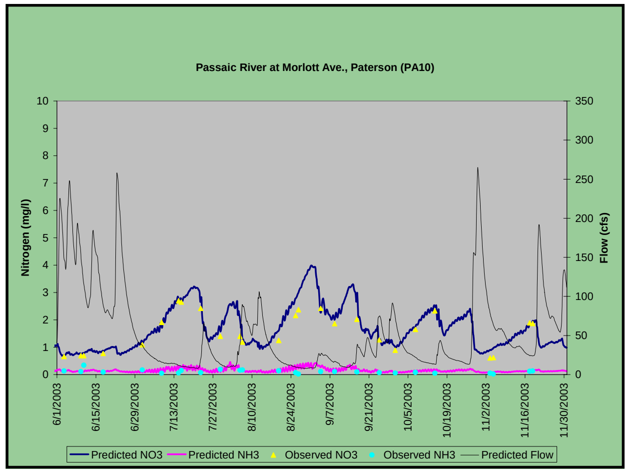


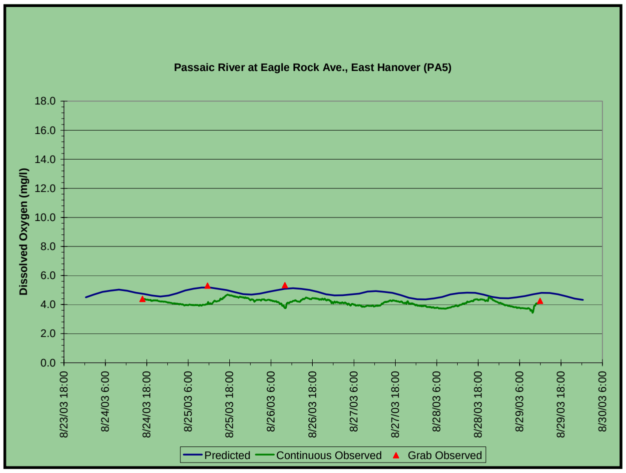


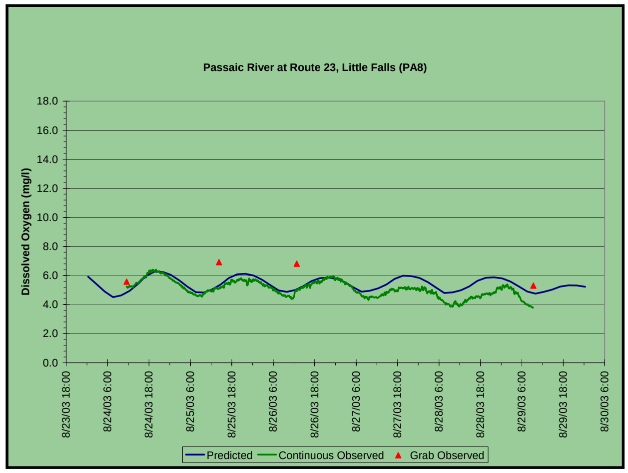


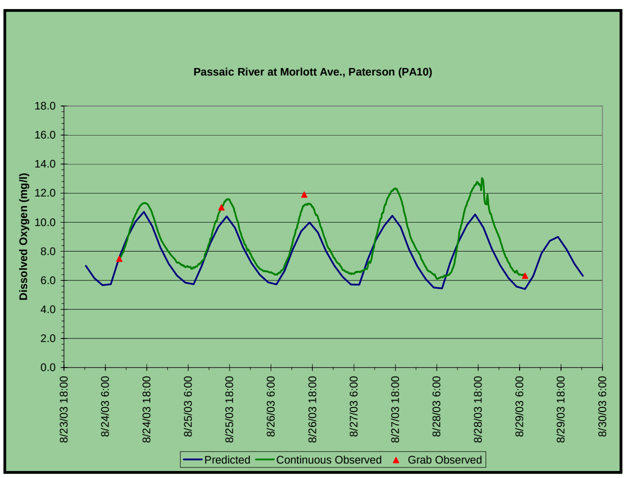








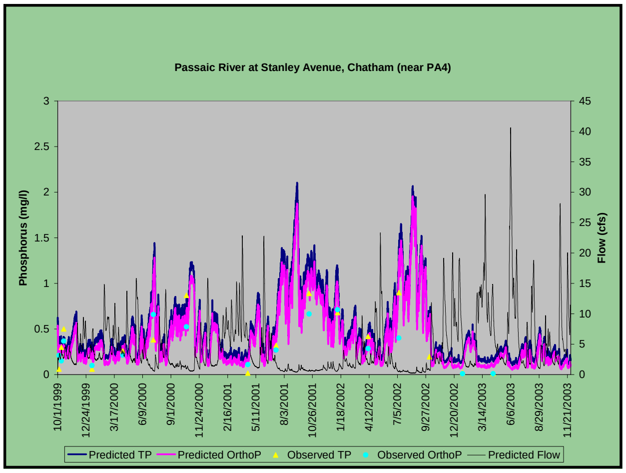


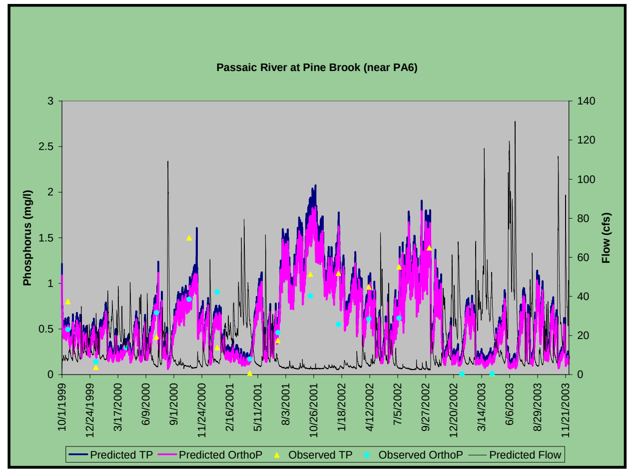


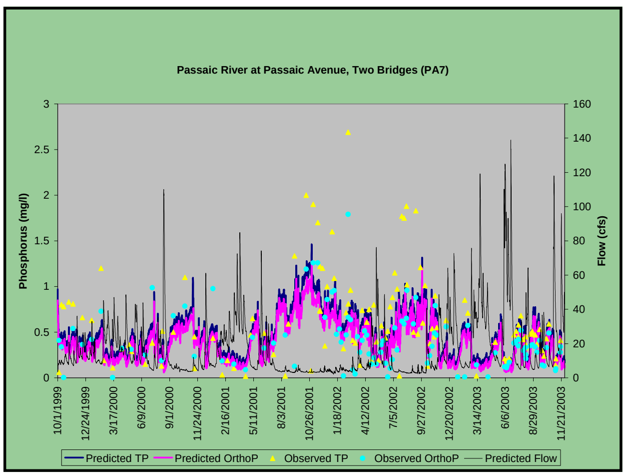
TRC Omni Environmental Corporation

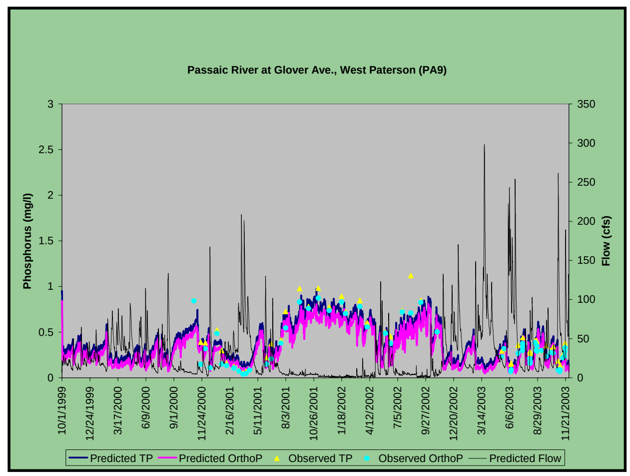
Passaic River Historical Validation Phosphorus and Nitrogen

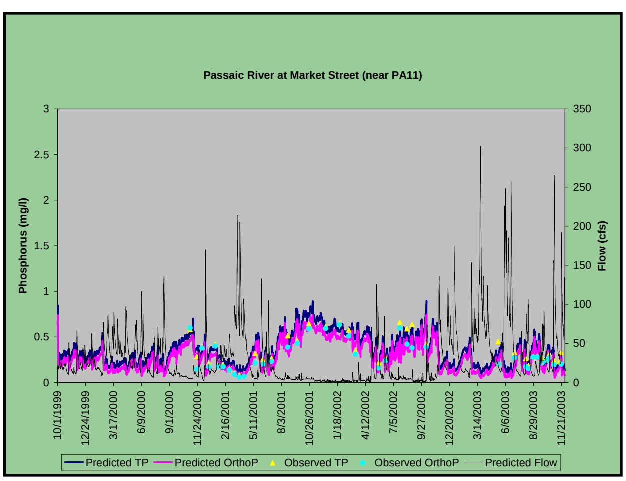
- Phosphorus
  - Passaic River at Stanley Avenue, Chatham
  - Passaic River at Pine Brook
  - Passaic River at Passaic Avenue, Two Bridges
  - Passaic River at Glover Avenue, West Paterson
  - Passaic River at Market Street, Paterson
- Nitrogen
  - Passaic River at Stanley Avenue, Chatham
  - Passaic River at Pine Brook
  - Passaic River at Passaic Avenue, Two Bridges
  - Passaic River at Glover Avenue, West Paterson

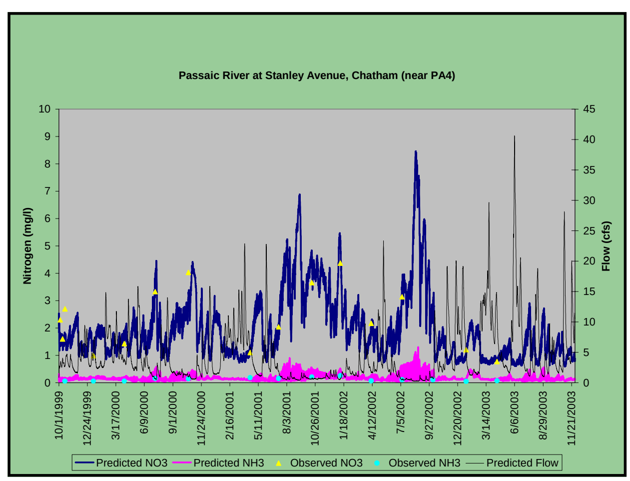

Passaic River at Stanley Avenue, Chatham (near PA4)
Phosphorus (mg/l)
Flow (cfs)
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow

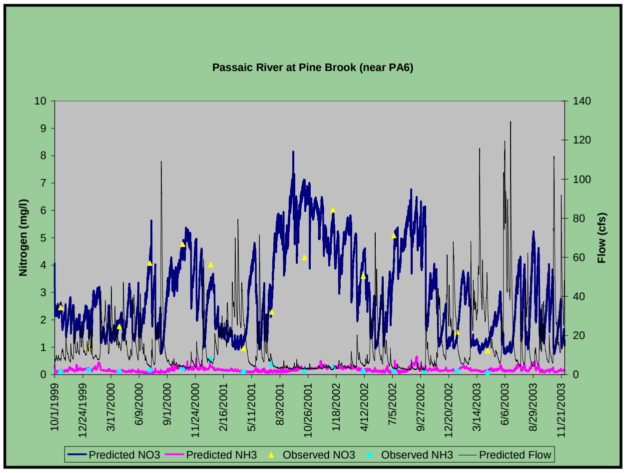

Passaic River at Pine Brook (near PA6)
Phosphorus (mg/l)
Flow (cfs)
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow

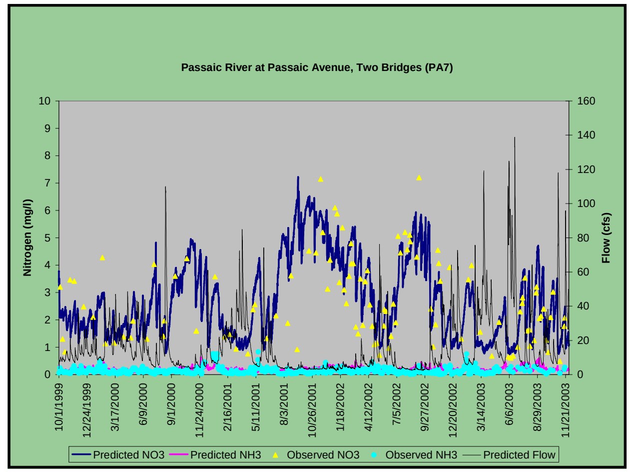

Passaic River at Passaic Avenue, Two Bridges (PA7)
Phosphorus (mg/l)
Flow (cfs)
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow

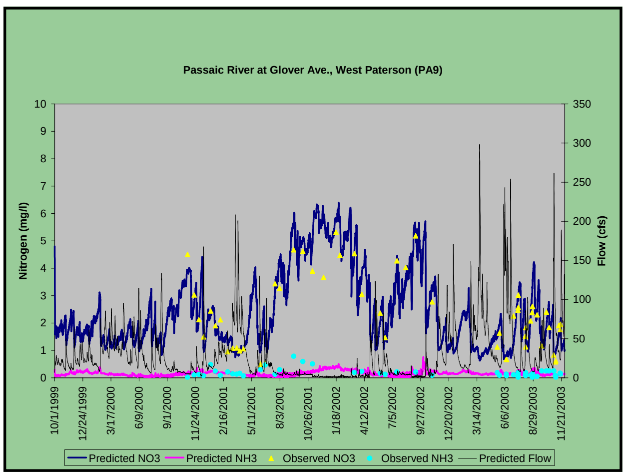

Passaic River at Glover Ave., West Paterson (PA9)
Phosphorus (mg/l)
Flow (cfs)
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow


Passaic River at Market Street (near PA11)
Phosphorus (mg/l)
Flow (cfs)
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow


Passaic River at Stanley Avenue, Chatham (near PA4)
Nitrogen (mg/l)
Flow (cfs)
Predicted NO3
Predicted NH3
Observed NO3
Observed NH3
Predicted Flow



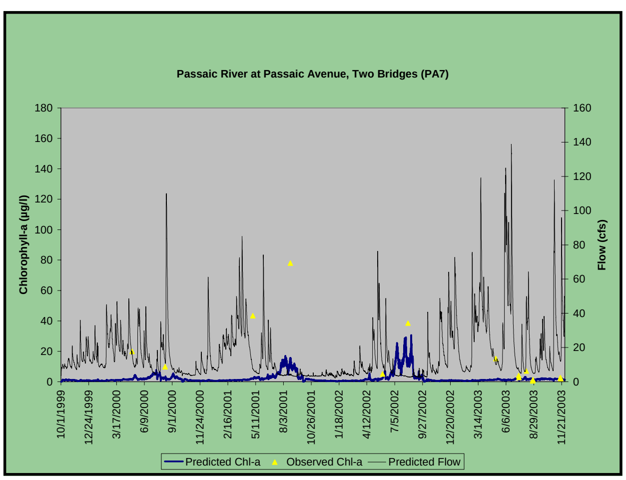


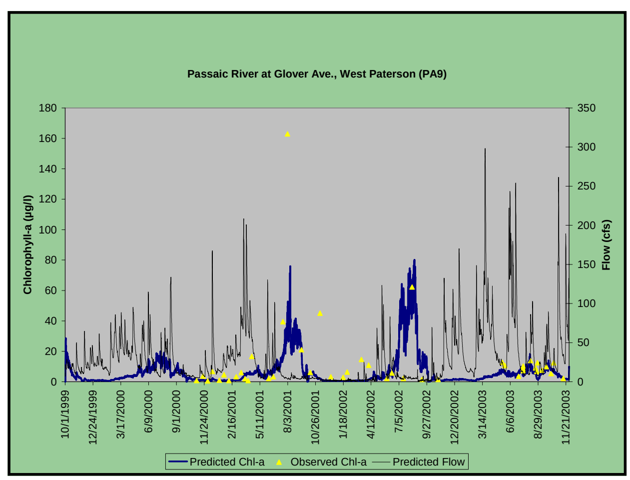


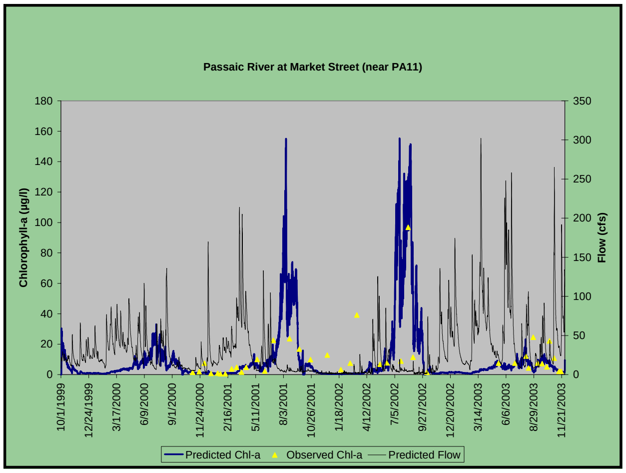
TRC Omni Environmental Corporation

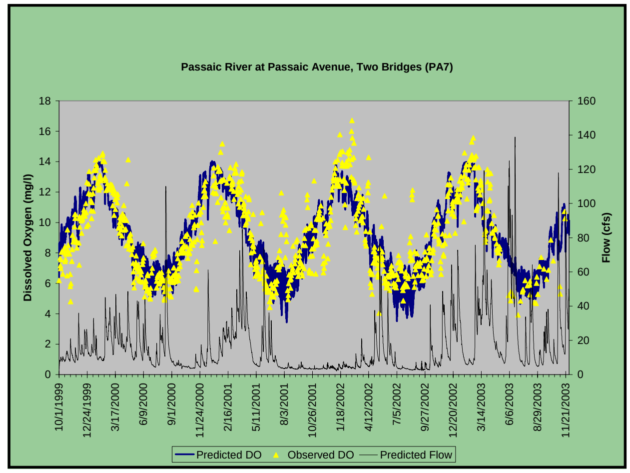
Passaic River Historical Validation Chlorophyll-a and Dissolved Oxygen

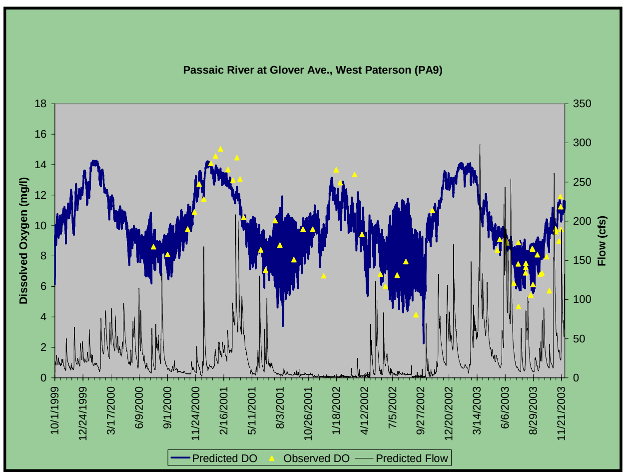
- Chlorophyll-a
  - Passaic River at Passaic Avenue, Two Bridges
  - Passaic River at Glover Avenue, West Paterson
  - Passaic River at Market Street, Paterson
- Dissolved Oxygen (Grab)
  - Passaic River at Passaic Avenue, Two Bridges
  - Passaic River at Glover Avenue, West Paterson
  - Passaic River at Market Street, Paterson
- Dissolved Oxygen (Diurnal) in 2002
  - Passaic River at Stanley Avenue, Chatham
  - Passaic River at Little Falls

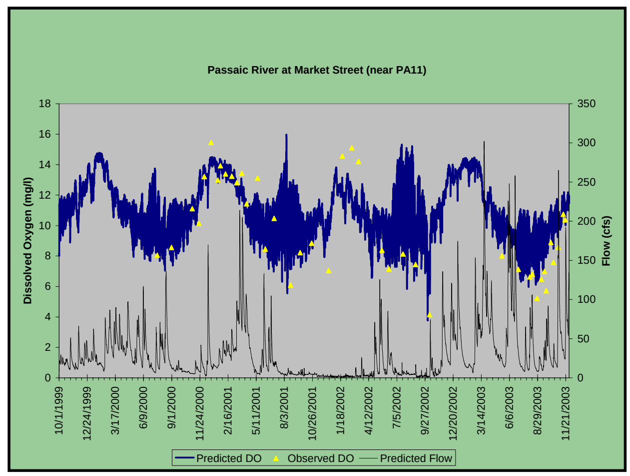


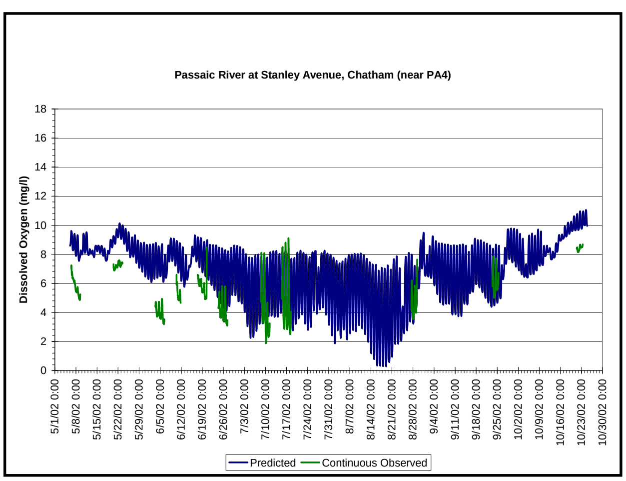


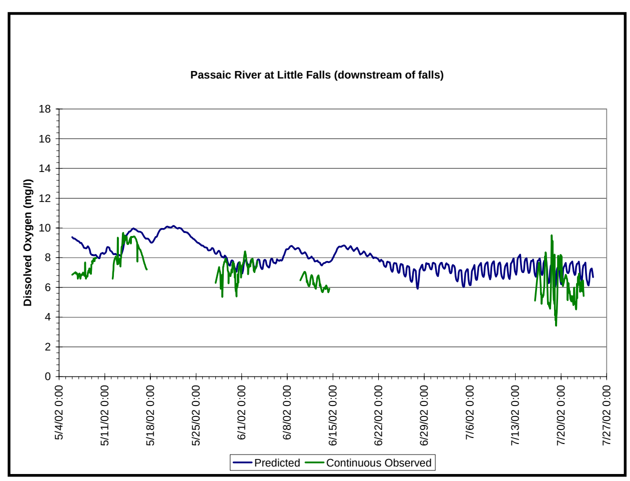

Passaic River at Market Street (near PA11)
Chlorophyll-a (µg/l)
Flow (cfs)
10/1/1999 12/24/1999 3/17/2000 6/9/2000 9/1/2000 11/24/2000 2/16/2001 5/11/2001 8/3/2001 10/26/2001 1/18/2002 4/12/2002 7/5/2002 9/27/2002 12/20/2002 3/14/2003 6/6/2003 8/29/2003 11/21/2003
Predicted Chl-a
Observed Chl-a
Predicted Flow


Passaic River at Passaic Avenue, Two Bridges (PA7)
Dissolved Oxygen (mg/l)
Flow (cfs)
10/1/1999 12/24/1999 3/17/2000 6/9/2000 9/1/2000 11/24/2000 2/16/2001 5/11/2001 8/3/2001 10/26/2001 1/18/2002 4/12/2002 7/5/2002 9/27/2002 12/20/2002 3/14/2003 6/6/2003 8/29/2003 11/21/2003
Predicted DO
Observed DO
Predicted Flow


Passaic River at Glover Ave., West Paterson (PA9)
Dissolved Oxygen (mg/l)
Flow (cfs)
10/1/1999 12/24/1999 3/17/2000 6/9/2000 9/1/2000 11/24/2000 2/16/2001 5/11/2001 8/3/2001 10/26/2001 1/18/2002 4/12/2002 7/5/2002 9/27/2002 12/20/2002 3/14/2003 6/6/2003 8/29/2003 11/21/2003
Predicted DO
Observed DO
Predicted Flow


Passaic River at Market Street (near PA11)
Dissolved Oxygen (mg/l)
Flow (cfs)
10/1/1999 12/24/1999 3/17/2000 6/9/2000 9/1/2000 11/24/2000 2/16/2001 5/11/2001 8/3/2001 10/26/2001 1/18/2002 4/12/2002 7/5/2002 9/27/2002 12/20/2002 3/14/2003 6/6/2003 8/29/2003 11/21/2003
Predicted DO
Observed DO
Predicted Flow

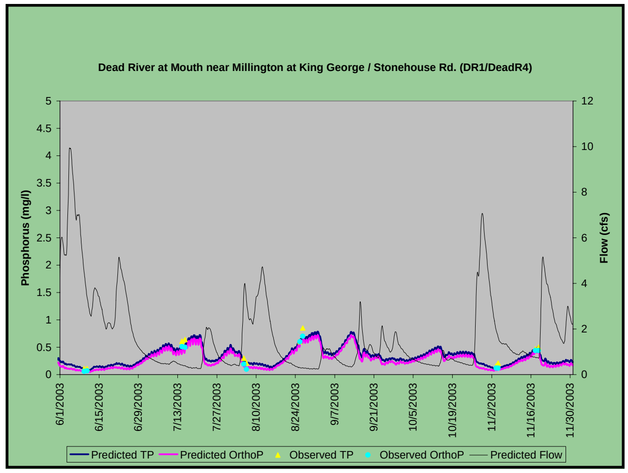

Passaic River at Stanley Avenue, Chatham (near PA4)
Dissolved Oxygen (mg/l)
5/1/02 0:00 5/8/02 0:00 5/15/02 0:00 5/22/02 0:00 5/29/02 0:00 6/5/02 0:00 6/12/02 0:00 6/19/02 0:00 6/26/02 0:00 7/3/02 0:00 7/10/02 0:00 7/17/02 0:00 7/24/02 0:00 7/31/02 0:00 8/7/02 0:00 8/14/02 0:00 8/21/02 0:00 8/28/02 0:00 9/4/02 0:00 9/11/02 0:00 9/18/02 0:00 9/25/02 0:00 10/2/02 0:00 10/9/02 0:00 10/16/02 0:00 10/23/02 0:00 10/30/02 0:00
Predicted
Continuous Observed

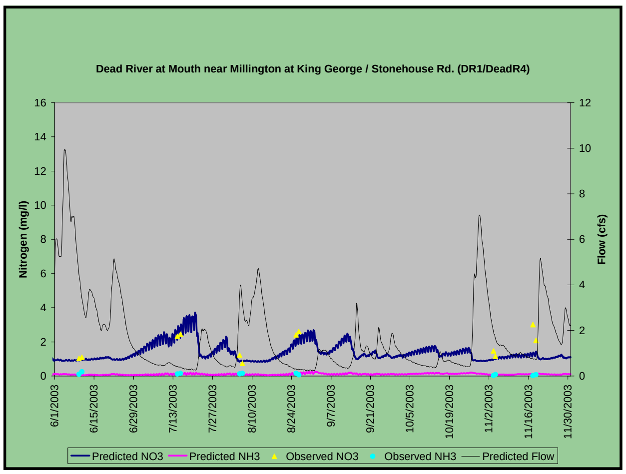

Passaic River at Little Falls (downstream of falls)
Dissolved Oxygen (mg/l)
5/4/02 0:00 5/11/02 0:00 5/18/02 0:00 5/25/02 0:00 6/1/02 0:00 6/8/02 0:00 6/15/02 0:00 6/22/02 0:00 6/29/02 0:00 7/6/02 0:00 7/13/02 0:00 7/20/02 0:00 7/27/02 0:00
Predicted
Continuous Observed

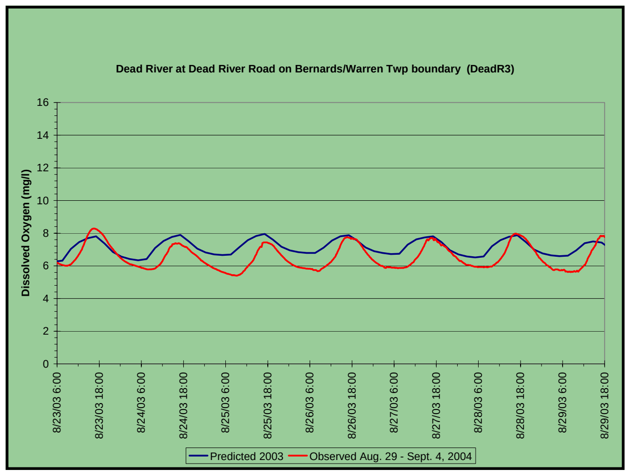
TRC Omni Environmental Corporation

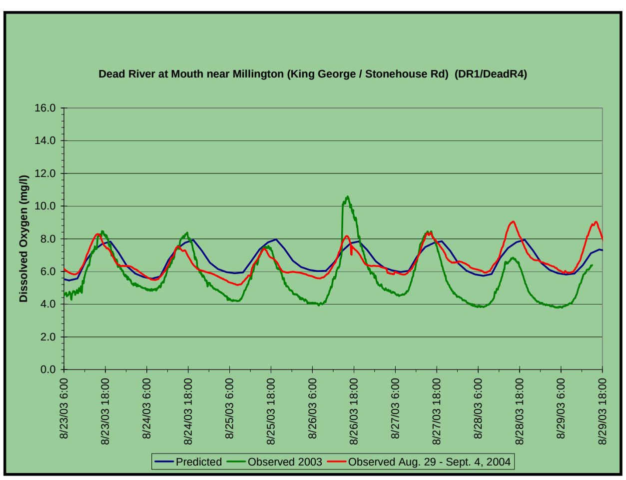
Dead River

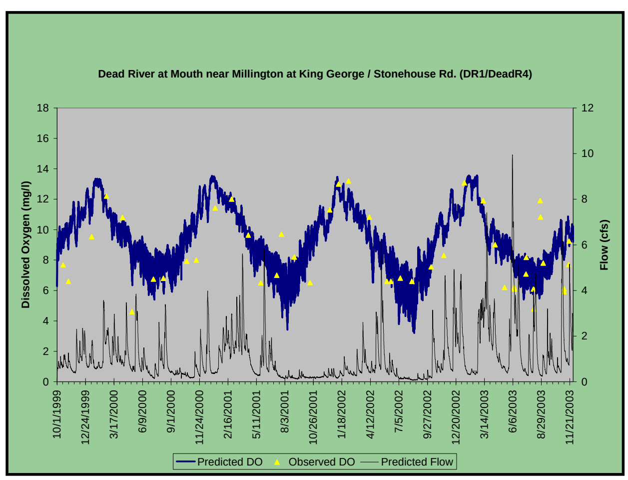
- 2003 Calibration – DR1
  - TP and Nitrate
- Dissolved Oxygen
  - 2004 Measurements Compared with 2003 Simulation
    - DeadR3
    - DeadR4 (DR1)
- Validation
  - Dissolved Oxygen, Phosphorus, and Nitrogen – DR1

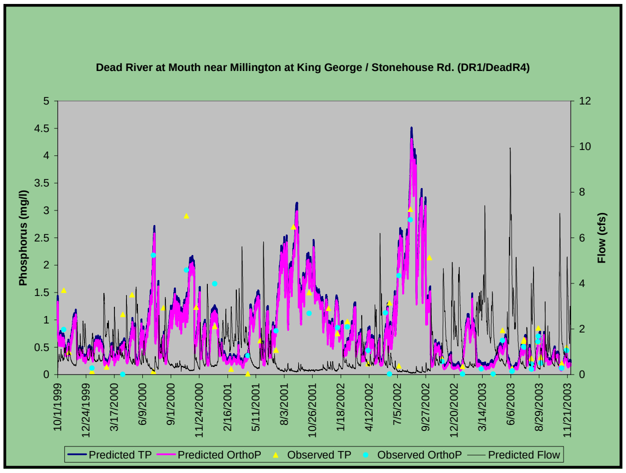


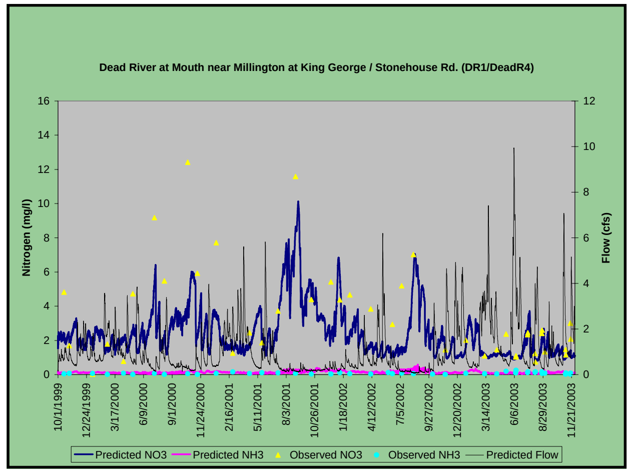








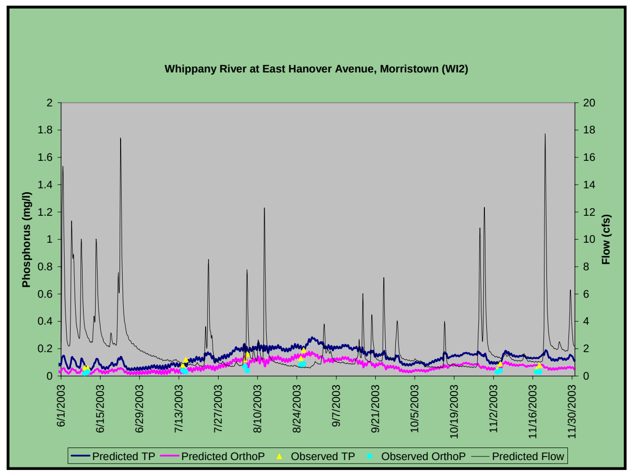


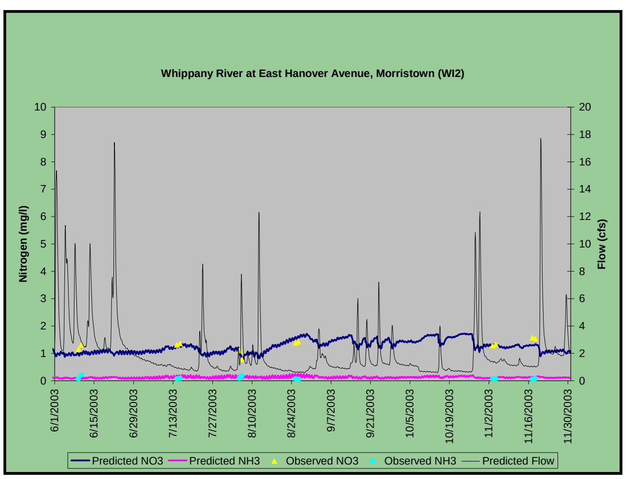


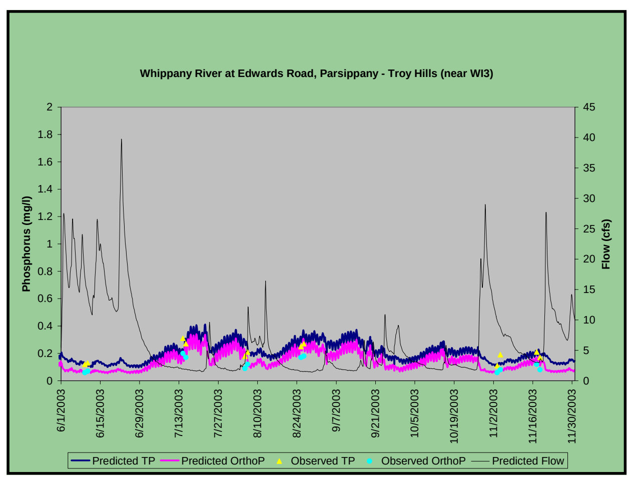
TRC Omni Environmental Corporation

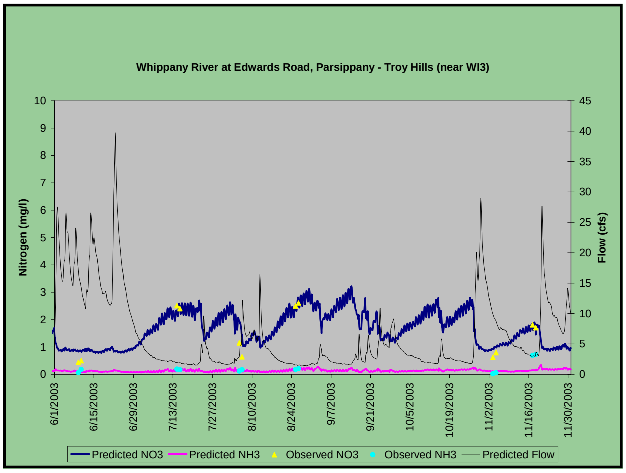
Whippany River

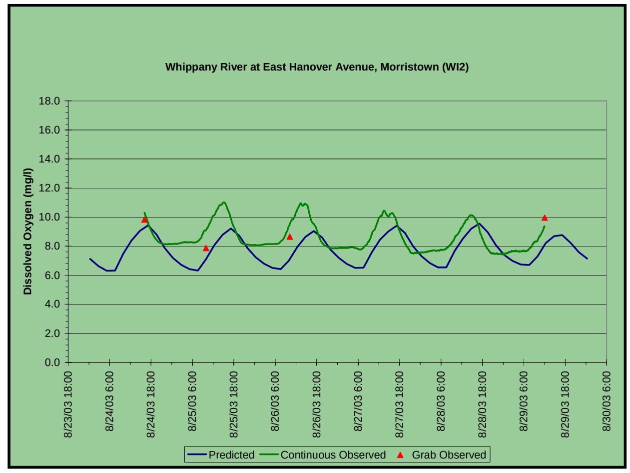
- 2003 Calibration – WI2
  - TP and Nitrate
- 2003 Calibration – WI3
  - TP and Nitrate
- Dissolved Oxygen
  - August 2003 – WI2
  - August 2003 – WI3
- Validation
  - Diurnal Dissolved Oxygen at WI3 in 1999
  - Phosphorus and Nitrogen near WI3 (Edward's Road)

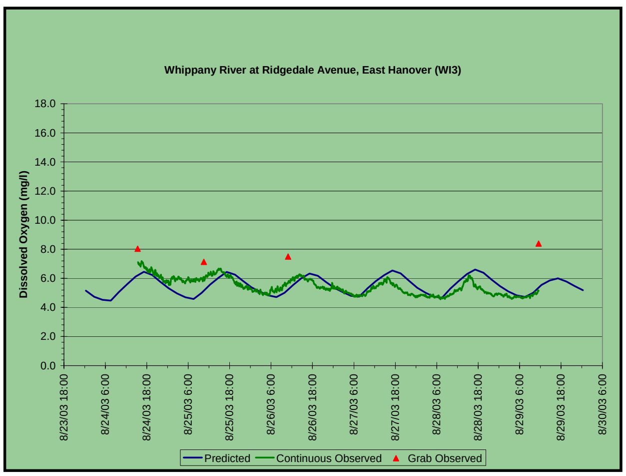


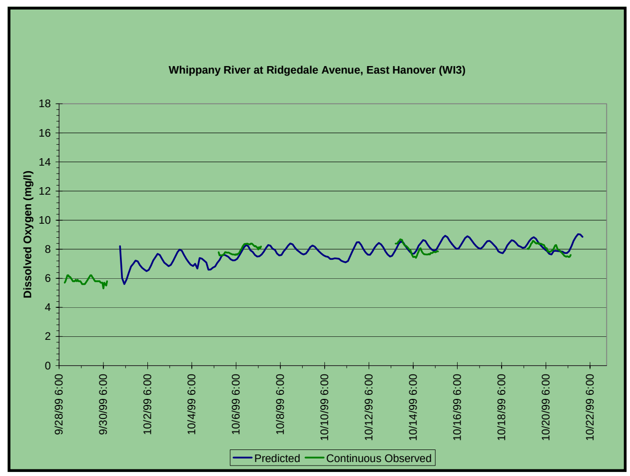


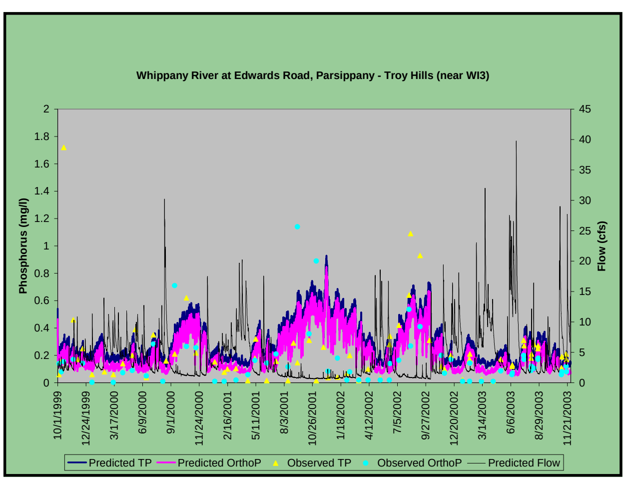


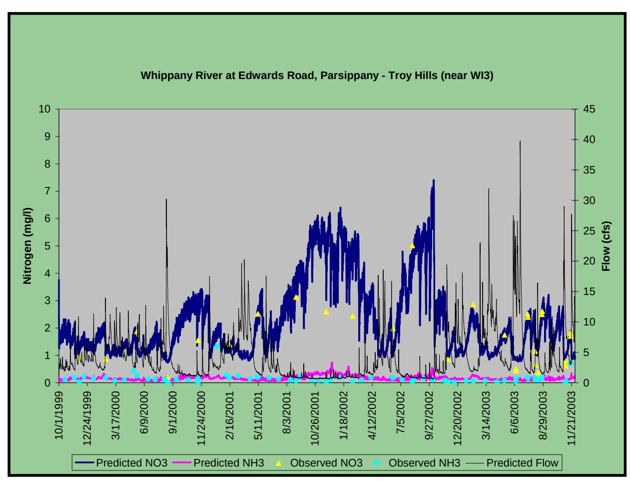

Whippany River at Edwards Road, Parsippany - Troy Hills (near WI3)
Nitrogen (mg/l)
Flow (cfs)
Predicted NO3
Predicted NH3
Observed NO3
Observed NH3
Predicted Flow


Whippany River at East Hanover Avenue, Morristown (WI2)
Dissolved Oxygen (mg/l)
Predicted
Continuous Observed
Grab Observed


Whippany River at Ridgedale Avenue, East Hanover (WI3)
Dissolved Oxygen (mg/l)
Predicted
Continuous Observed
Grab Observed


Whippany River at Ridgedale Avenue, East Hanover (WI3)
Dissolved Oxygen (mg/l)
Predicted
Continuous Observed

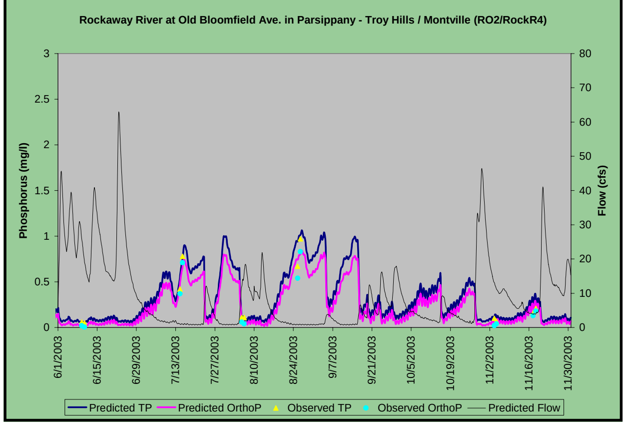

Whippany River at Edwards Road, Parsippany - Troy Hills (near WI3)
Phosphorus (mg/l)
Flow (cfs)
Predicted TP
Predicted OrthoP
Observed TP
Observed OrthoP
Predicted Flow

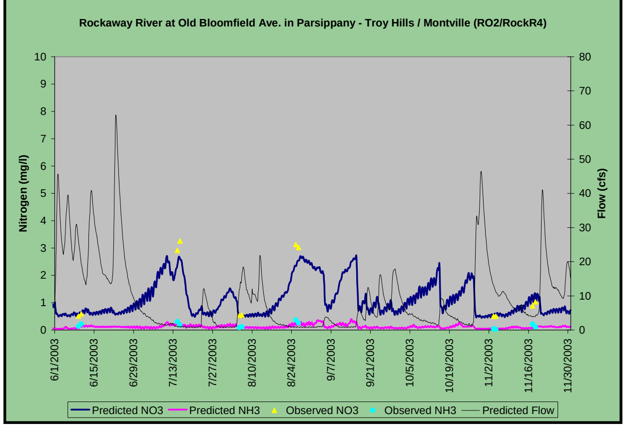

Whippany River at Edwards Road, Parsippany - Troy Hills (near WI3)
Nitrogen (mg/l)
Flow (cfs)
Predicted NO3
Predicted NH3
Observed NO3
Observed NH3
Predicted Flow

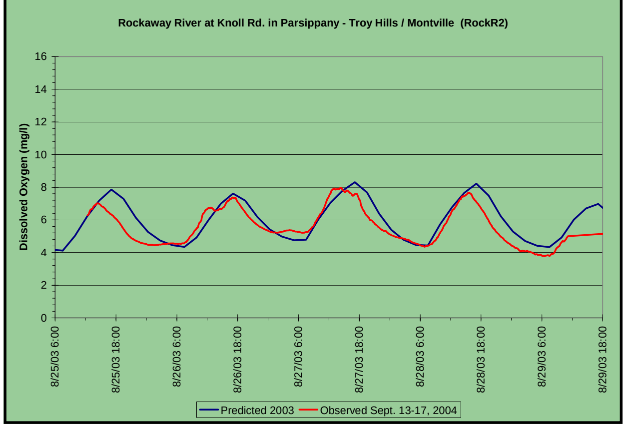
TRC Omni Environmental Corporation

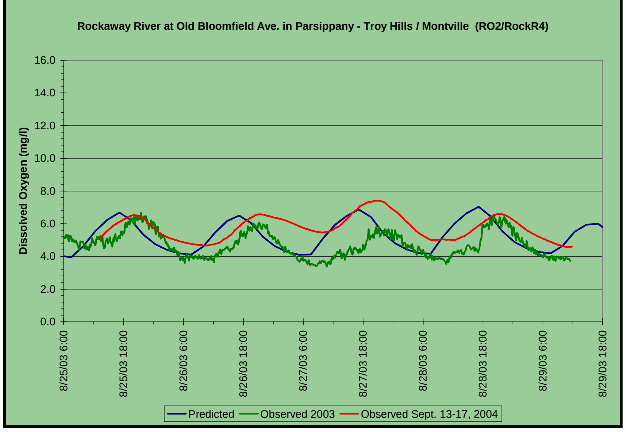
Rockaway River

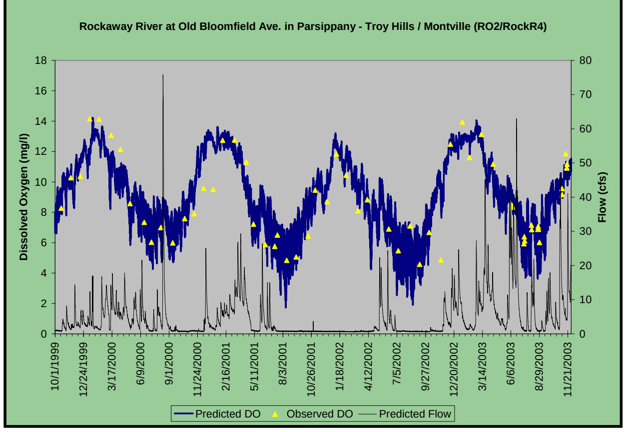
- 2003 Calibration – RO2
  - TP and Nitrate
- Dissolved Oxygen
  - 2004 Measurements Compared with 2003 Simulation
    - RockR2
    - RockR4 (RO2)
- Validation
  - Dissolved Oxygen, Phosphorus, and Nitrogen – RO2

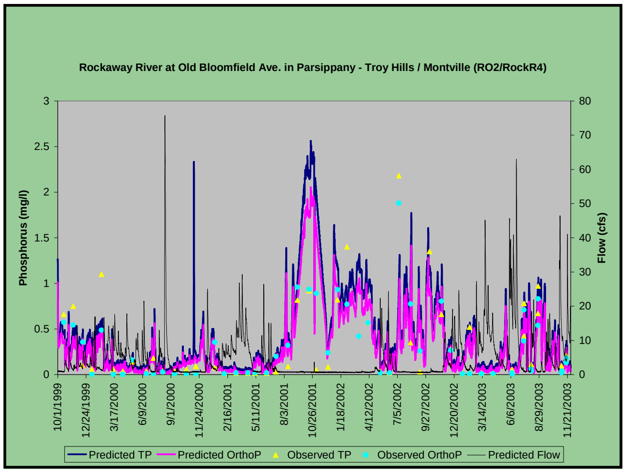


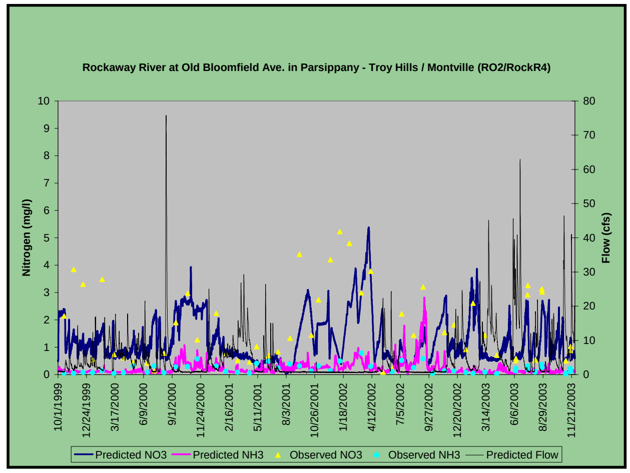






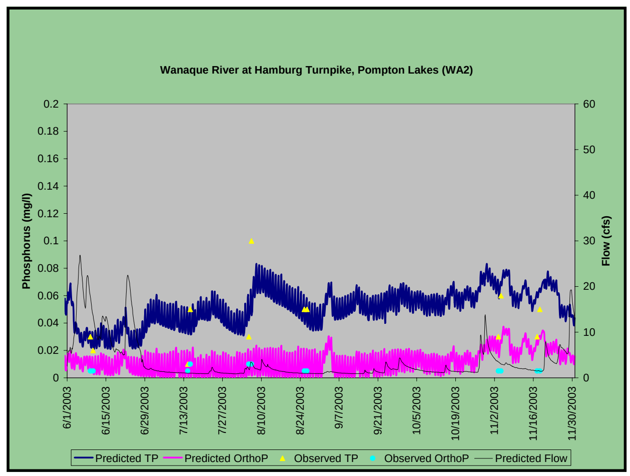


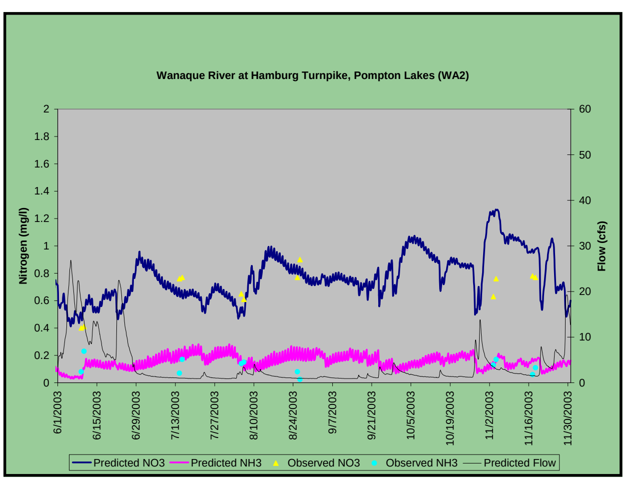


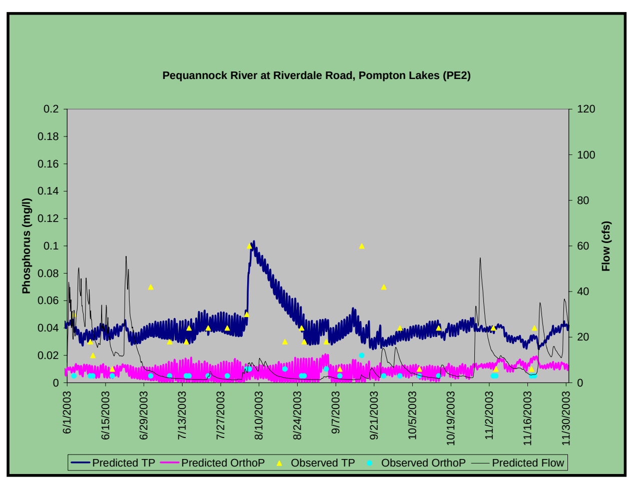


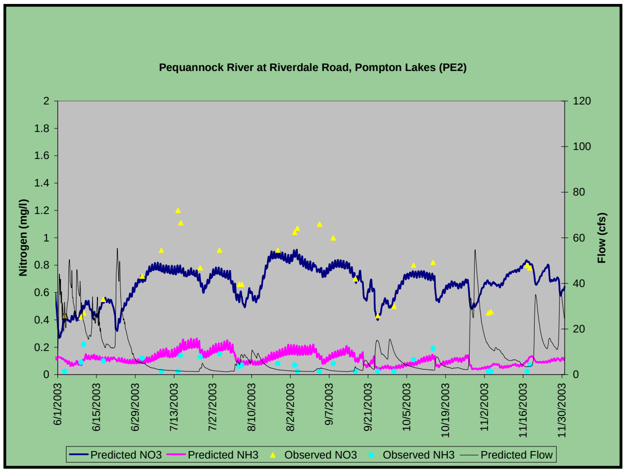
Pequannock and Wanaque Rivers

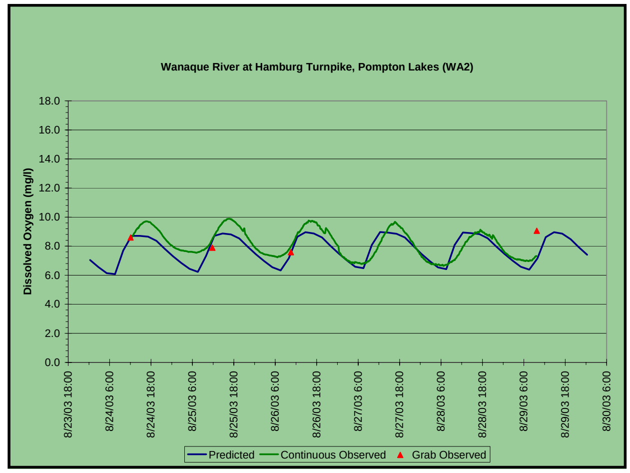
- 2003 Calibration – WA2
  - TP and Nitrate
- 2003 Calibration – PE2
  - TP and Nitrate
- Dissolved Oxygen
  - August 2003 – WA2
  - August 2003 – PE2
- Validation
  - Phosphorus and Nitrogen at WA2

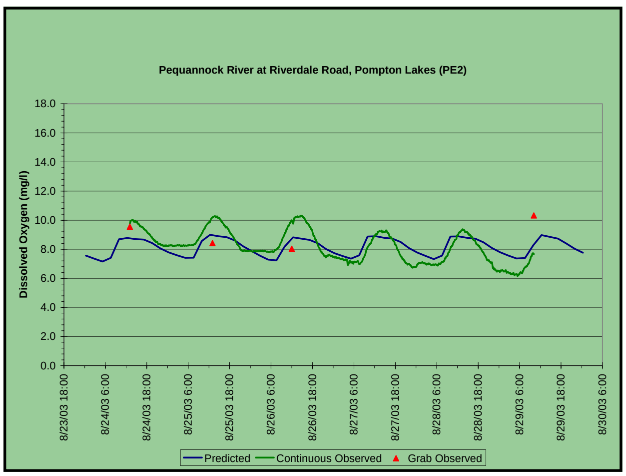


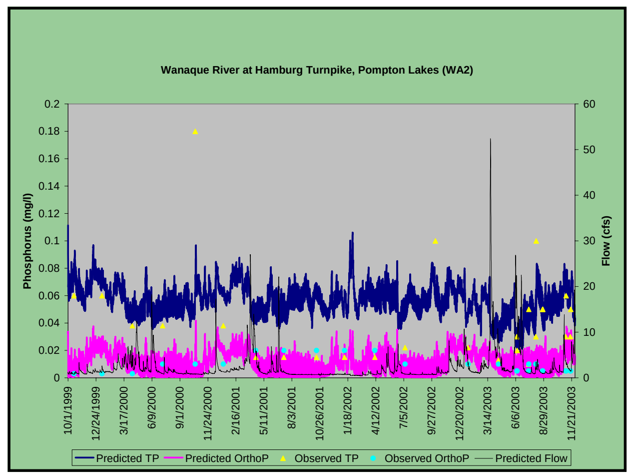


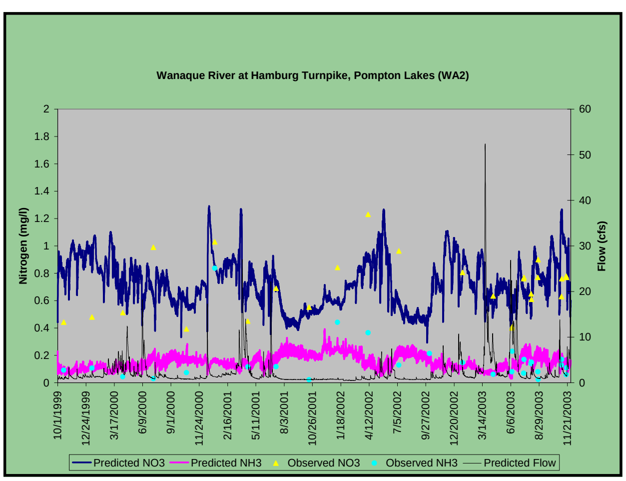








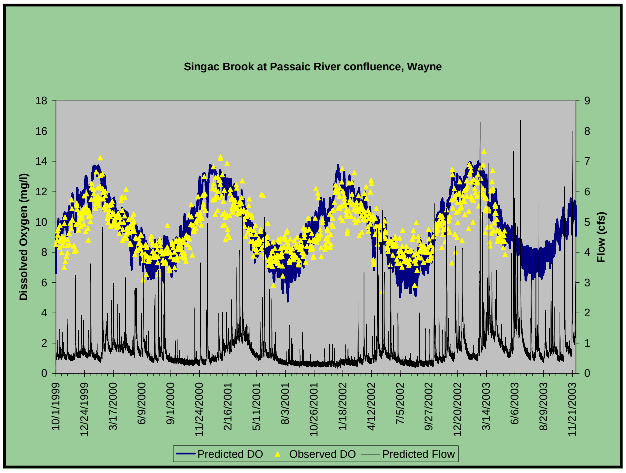


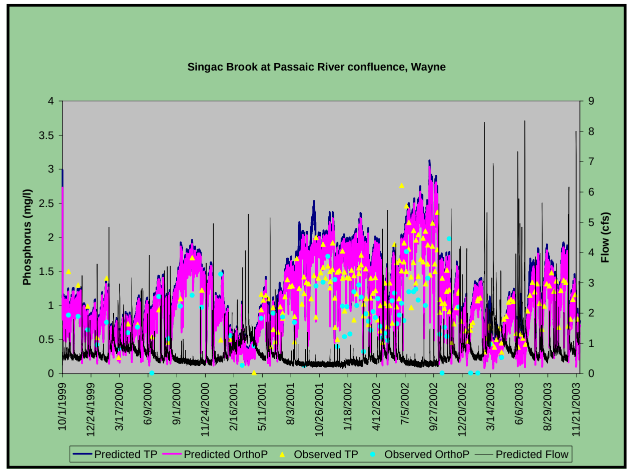


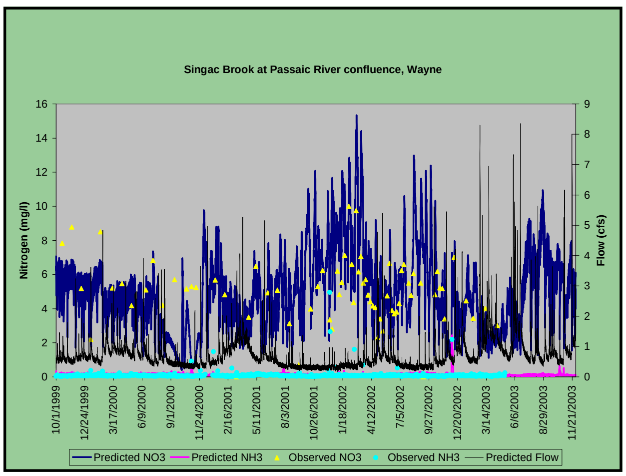
TRC Omni Environmental Corporation

Singac Brook

- Singac Brook at Passaic River confluence in Wayne
  - Dissolved Oxygen
  - Phosphorus
  - Nitrogen

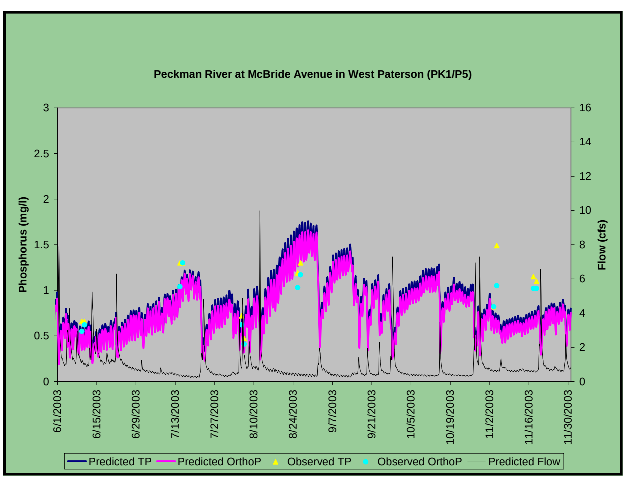


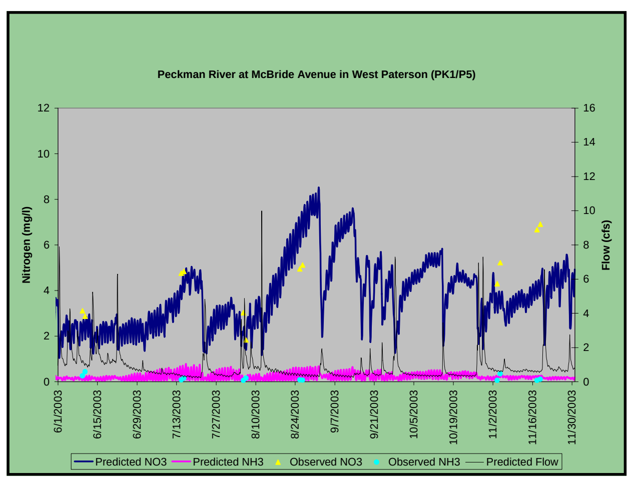


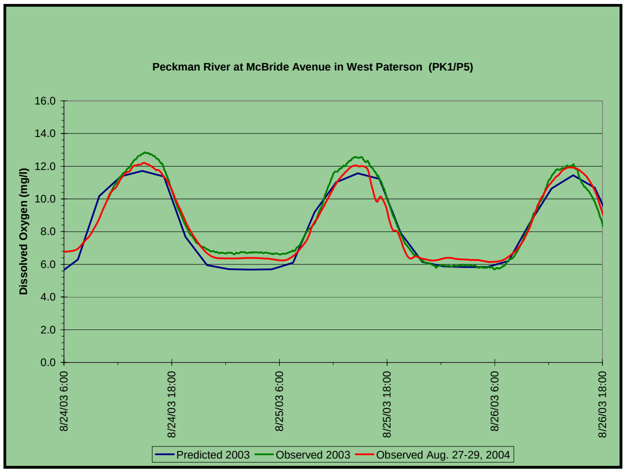


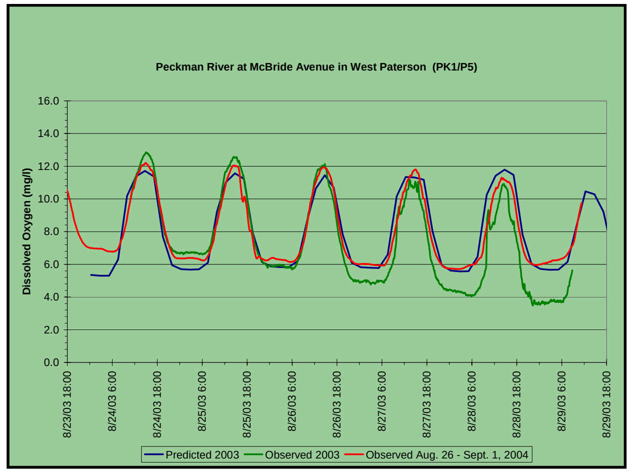
Peckman River

- 2003 Calibration – PK1
  - TP and Nitrate
- Dissolved Oxygen Calibration and Validation
  - 2004 Measurements Compared with 2003 Simulation
    - P5 (PK1) August 24 – 26, 2003
    - P5 (PK1) August 26 – September 1, 2003









Calibration and Validation Summary

- System-wide water quality model calibrated and validated for nutrients, dissolved oxygen, and chlorophyll-a
- Impact of point and nonpoint source reductions on dissolved oxygen, phosphorus concentrations, and chlorophyll-a can be calculated

Summary of Critical Locations

- Pompton River
  - Upstream TBSA: TP may control productivity
  - PO3: moderate productivity
- Passaic River
  - Stanley Avenue: low DO, substantial swings
  - Pine Brook: low DO
  - PA8 Little Falls: low DO and moderate Chl-a
  - Glover Avenue PA9: substantial DO swings and Chl-a
  - Morlott Avenue PA10: substantial DO swings and Chl-a
  - Dundee Dam: substantial DO swings and Chl-a
- Other Tributaries
  - Rockaway River at Knoll Rd: low DO, substantial swings
  - Dead River near Millington: substantial DO swings
  - Peckman River at McBride: very high DO swings with low minima

Future Scenarios

- Baseline Future Scenario
- P01NP80 – How Low Can You Go?
- P01NP20 – Most Reduction Feasible
- P02NP80 – Wanaque Reservoir TMDL
- Sensitivity Analyses
  - No Kinetics
  - No CSO
  - Baseflow and Headwater Concentration
  - Point and Nonpoint Reduction Combinations

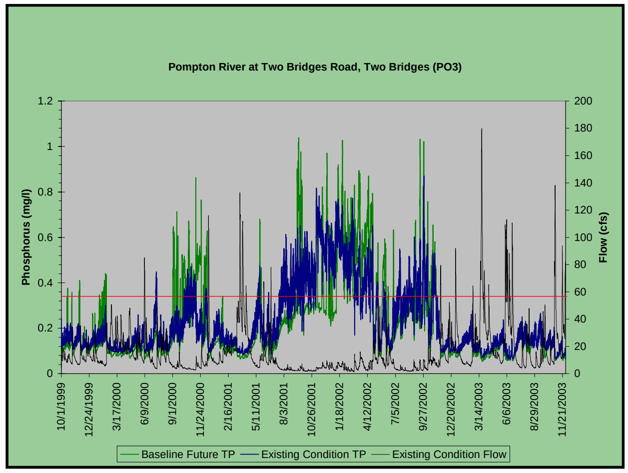
Future Scenario Graphs

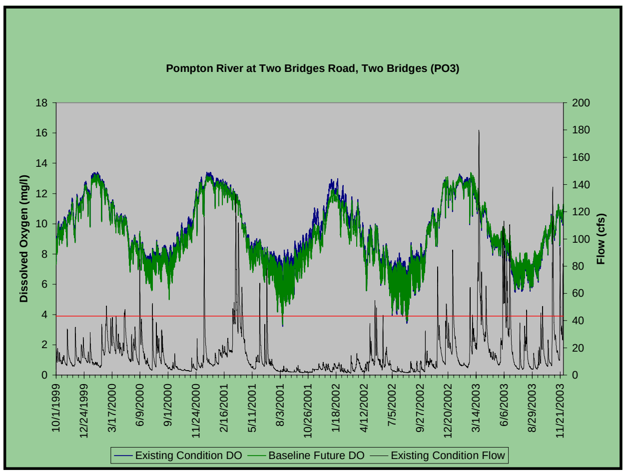
- Pompton River
  - PO3: TP, DO and Chl-a
- Passaic River
  - Stanley Avenue: DO
  - Pine Brook: DO
  - PA8 Little Falls: DO and Chl-a
  - Glover Avenue PA9: DO and Chl-a
  - Morlott Avenue PA10: DO and Chl-a
  - Dundee Dam: TP, DO and Chl-a
- Other Tributaries
  - Rockaway River at Knoll Rd: DO
  - Dead River near Millington: DO
  - Peckman River at McBride: DO

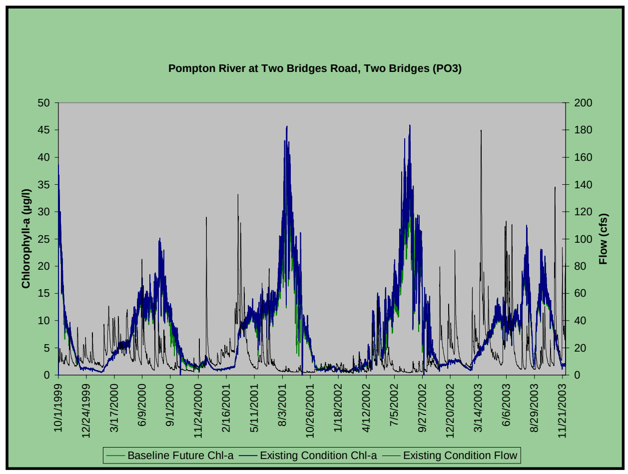
TRC Omni Environmental Corporation

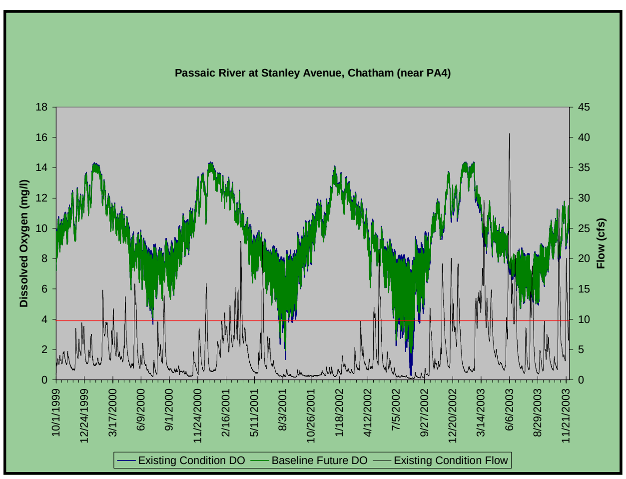
Baseline Future Scenario

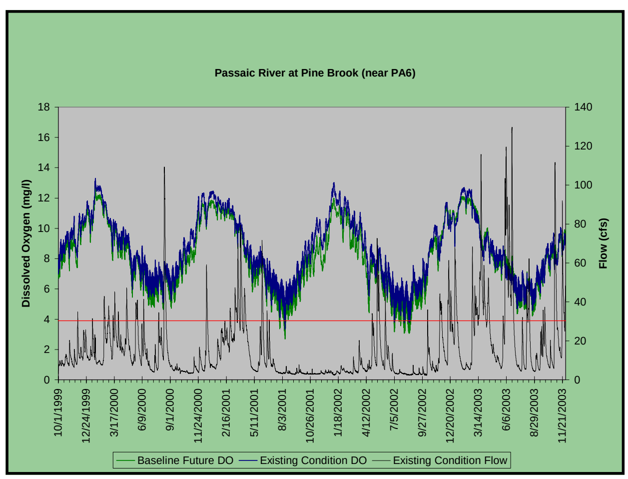
- Permitted flows and concentrations
- Headwater lakes with TMDLs set to 0.05 mg/l TP
- Future diversion scenario implemented for NJDWSC

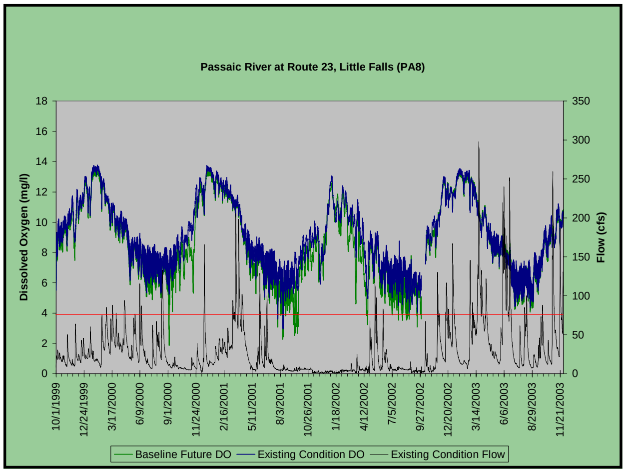


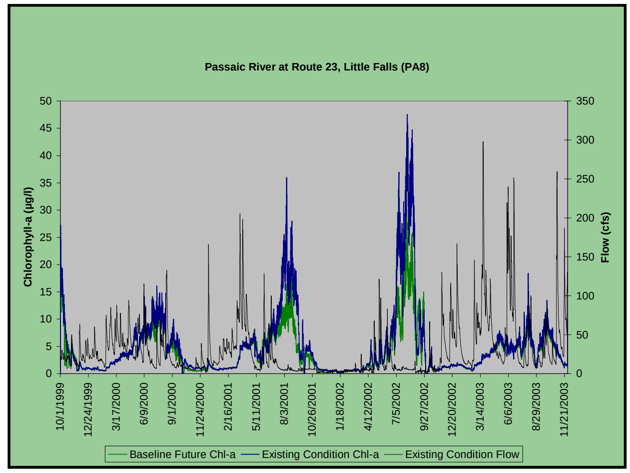


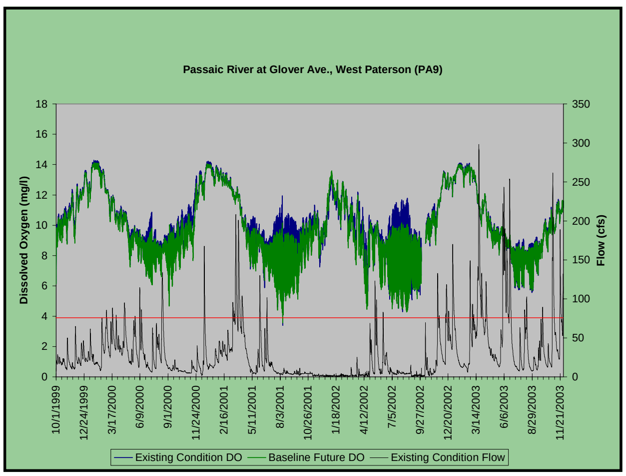


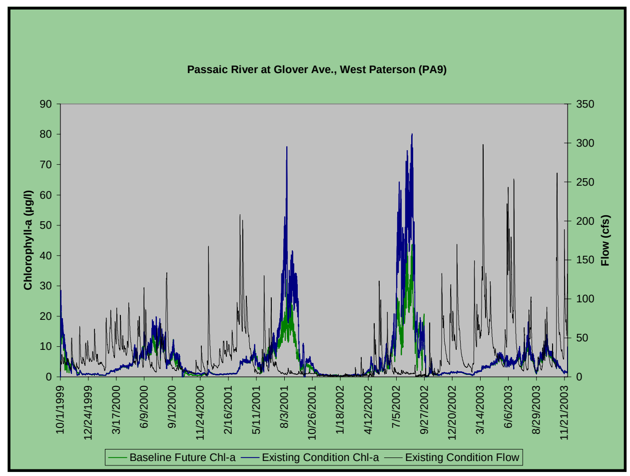


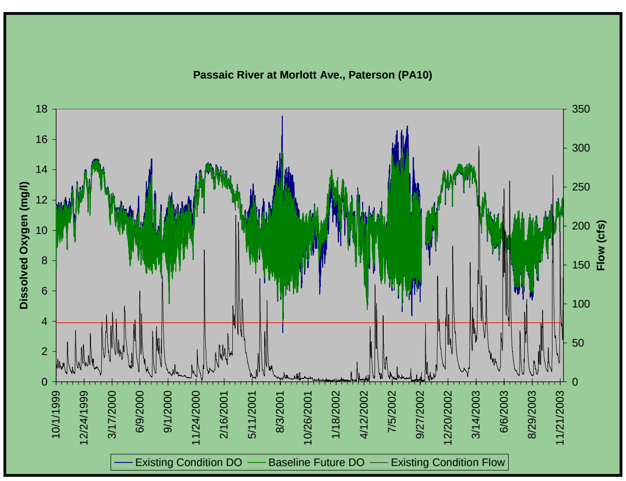


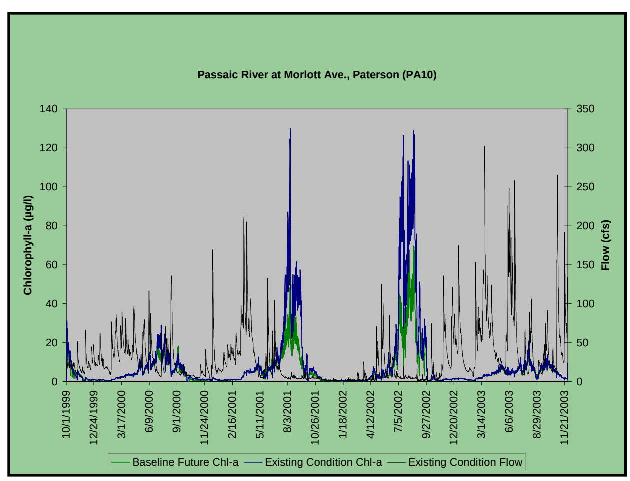

Passaic River at Route 23, Little Falls (PA8)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
Existing Condition DO
Existing Condition Flow

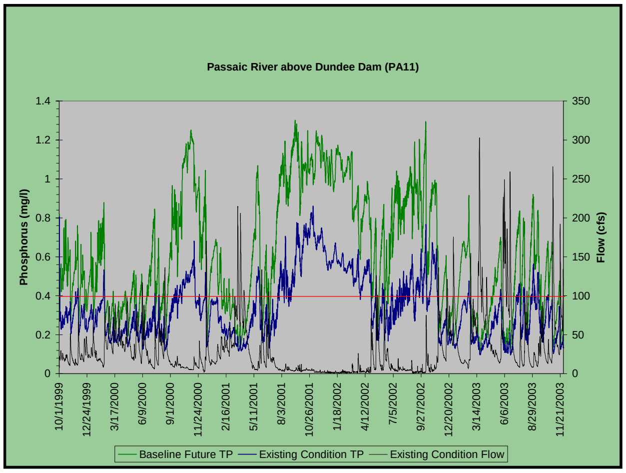

Passaic River at Route 23, Little Falls (PA8)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
Existing Condition Chl-a
Existing Condition Flow

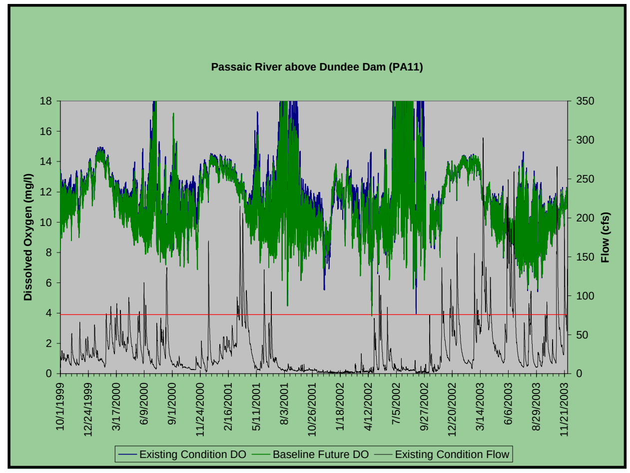

Passaic River at Glover Ave., West Paterson (PA9)
Dissolved Oxygen (mg/l)
Flow (cfs)
Existing Condition DO
Baseline Future DO
Existing Condition Flow

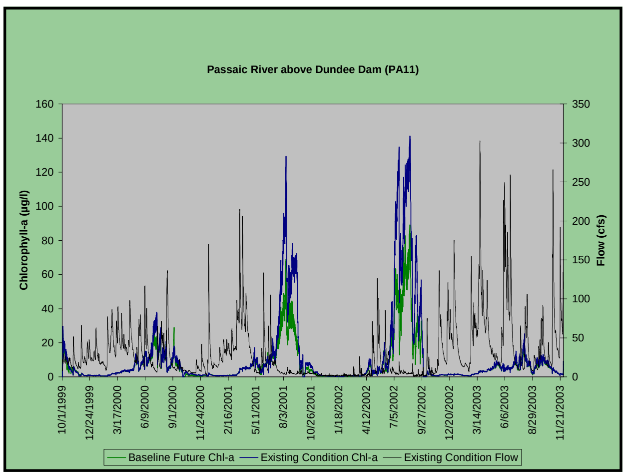

Passaic River at Glover Ave., West Paterson (PA9)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
Existing Condition Chl-a
Existing Condition Flow

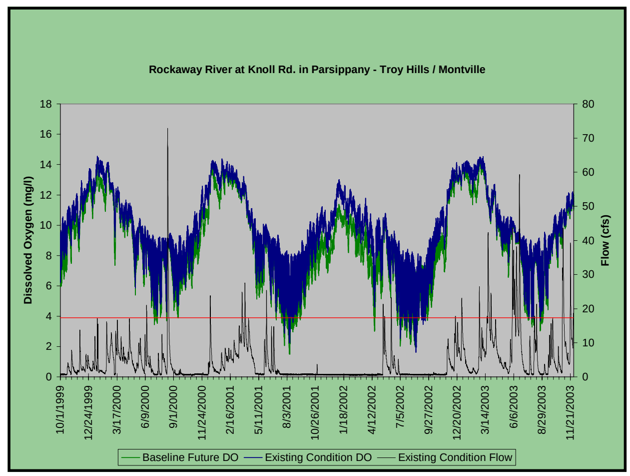

Passaic River at Morlott Ave., Paterson (PA10)
Dissolved Oxygen (mg/l)
Flow (cfs)
Existing Condition DO
Baseline Future DO
Existing Condition Flow

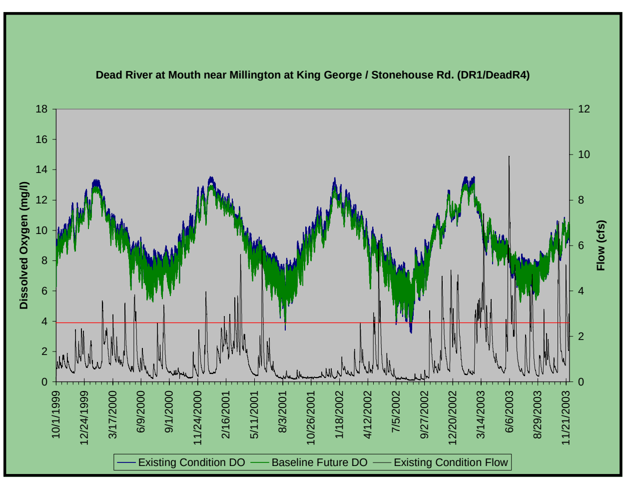

Passaic River at Morlott Ave., Paterson (PA10)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
Existing Condition Chl-a
Existing Condition Flow

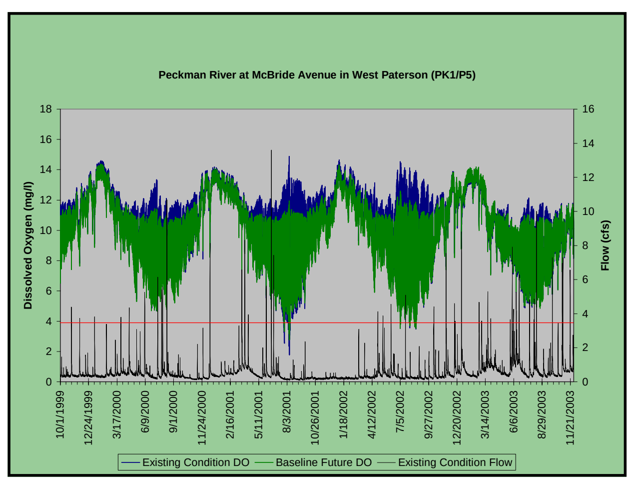

Passaic River above Dundee Dam (PA11)
Phosphorus (mg/l)
Flow (cfs)
Baseline Future TP
Existing Condition TP
Existing Condition Flow


Passaic River above Dundee Dam (PA11)
Dissolved Oxygen (mg/l)
Flow (cfs)
Existing Condition DO
Baseline Future DO
Existing Condition Flow


Passaic River above Dundee Dam (PA11)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
Existing Condition Chl-a
Existing Condition Flow


Rockaway River at Knoll Rd. in Parsippany - Troy Hills / Montville
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
Existing Condition DO
Existing Condition Flow


Dead River at Mouth near Millington at King George / Stonehouse Rd. (DR1/DeadR4)
Dissolved Oxygen (mg/l)
Flow (cfs)
Existing Condition DO
Baseline Future DO
Existing Condition Flow


Peckman River at McBride Avenue in West Paterson (PK1/P5)
Dissolved Oxygen (mg/l)
Flow (cfs)
Existing Condition DO
Baseline Future DO
Existing Condition Flow

TRC Omni Environmental Corporation

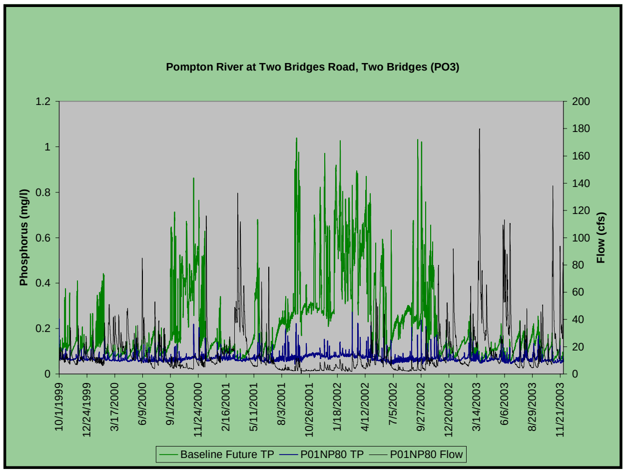
Baseline Future Scenario Summary of Results

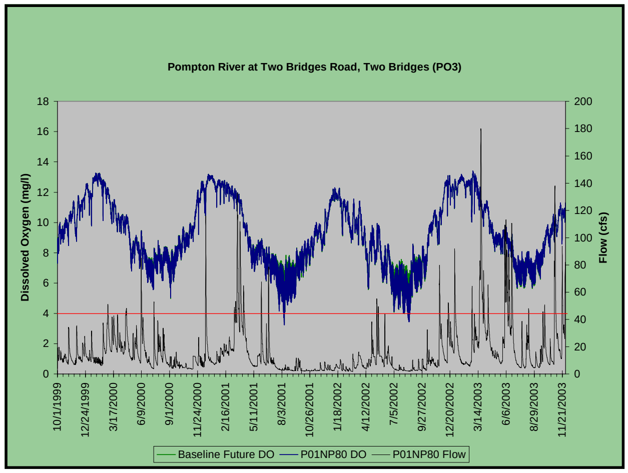
- Pompton River
  - no change in dissolved oxygen or chlorophyll-a
- Passaic River
  - Upstream of Pompton (Stanley Ave and Pine Brook)
    - slightly lower productivity, minimal change in dissolved oxygen
  - Little Falls
    - dissolved oxygen worse due to lower productivity
    - chlorophyll-a better
  - Great Falls to Dundee
    - no change in minimum dissolved oxygen
    - productivity lower (DO peaks lower, chlorophyll-a peaks reduced)
- Rockaway River
  - no substantial change
- Dead River
  - no substantial change
- Peckman River
  - no change in minimum dissolved oxygen ; DO peaks lower

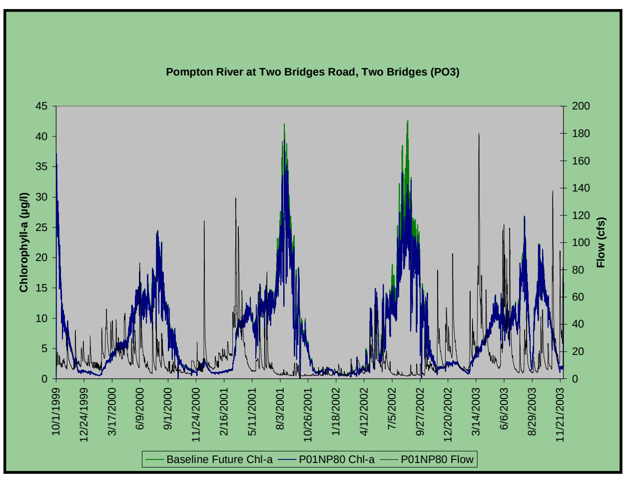
TRC Omni Environmental Corporation

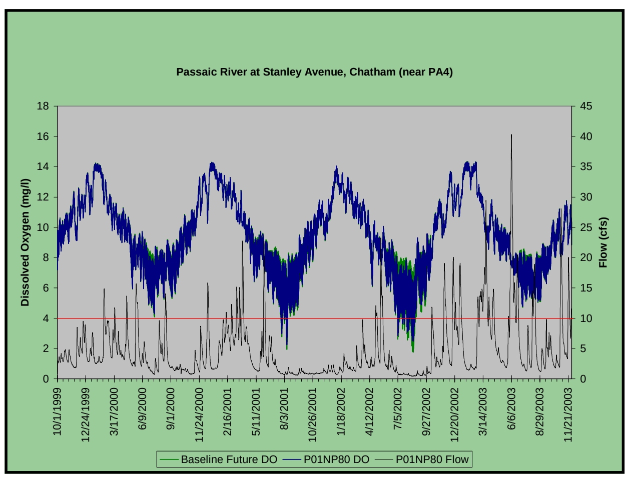
P01NP80 How Low Can You Go?

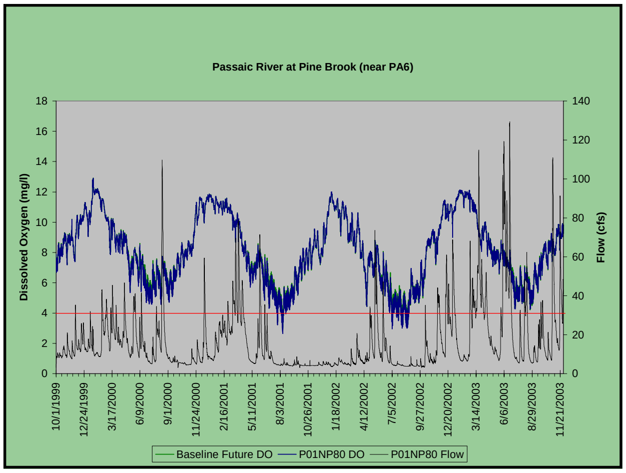
- Hypothetical scenario
- Permitted flows for point sources
- Point Sources set to 0.1 mg/l TP
- urban and agricultural land use EMCs for phosphorus reduced by 80%

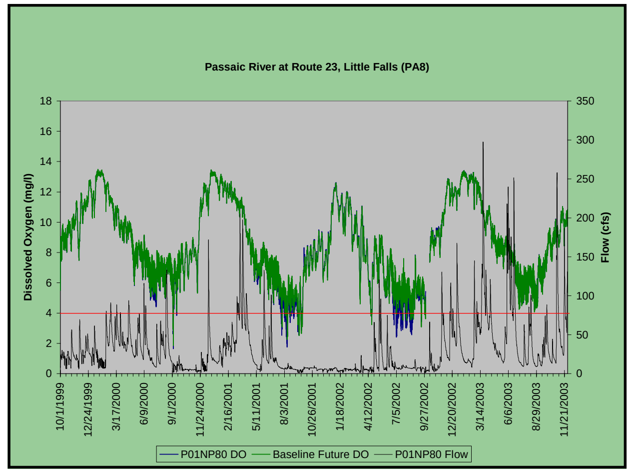


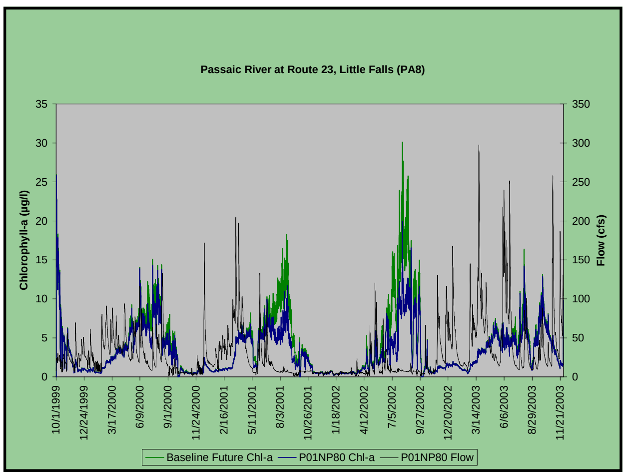


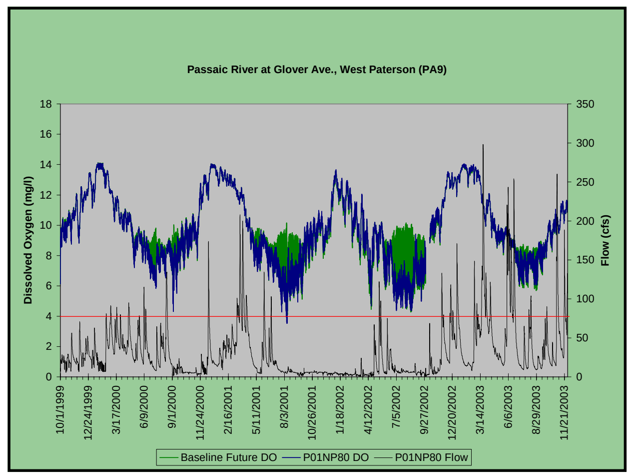


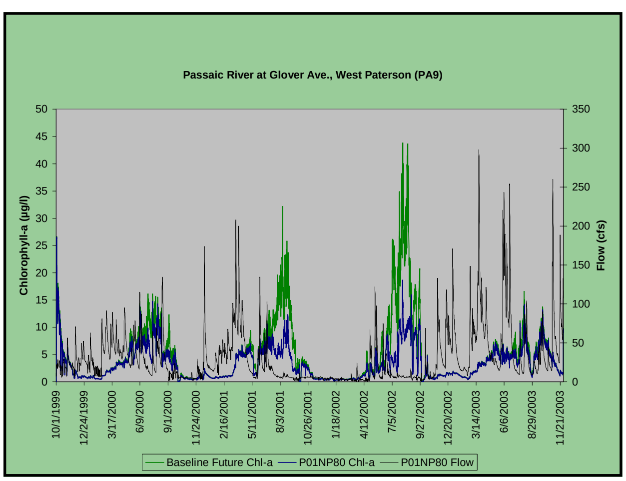


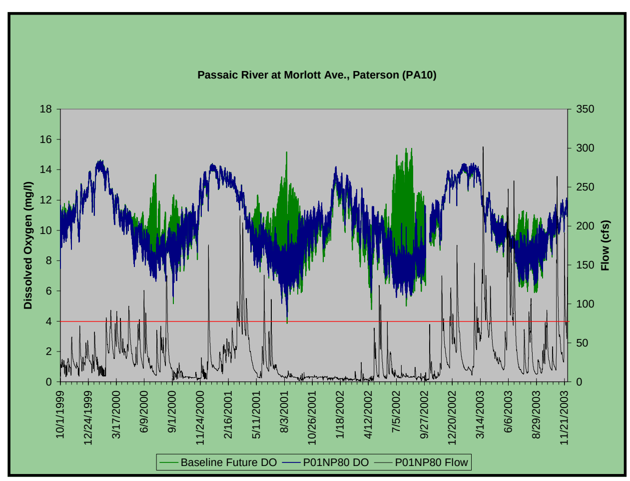

Passaic River at Pine Brook (near PA6)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P01NP80 DO
P01NP80 Flow

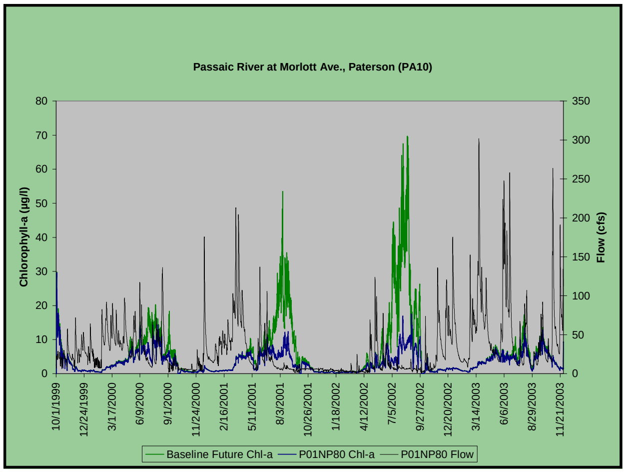

Passaic River at Route 23, Little Falls (PA8)
Dissolved Oxygen (mg/l)
Flow (cfs)
P01NP80 DO
Baseline Future DO
P01NP80 Flow

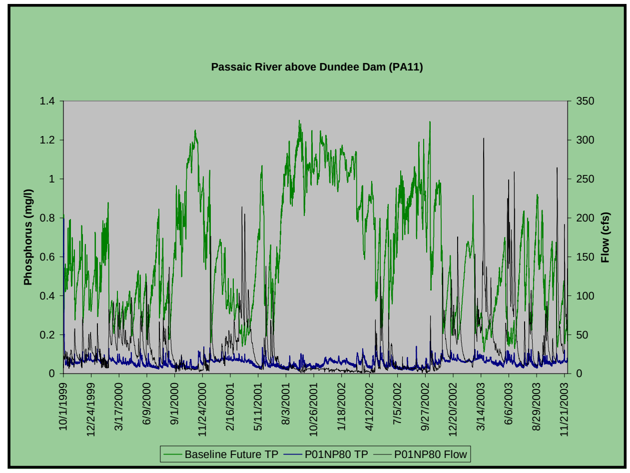

Passaic River at Route 23, Little Falls (PA8)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
P01NP80 Chl-a
P01NP80 Flow

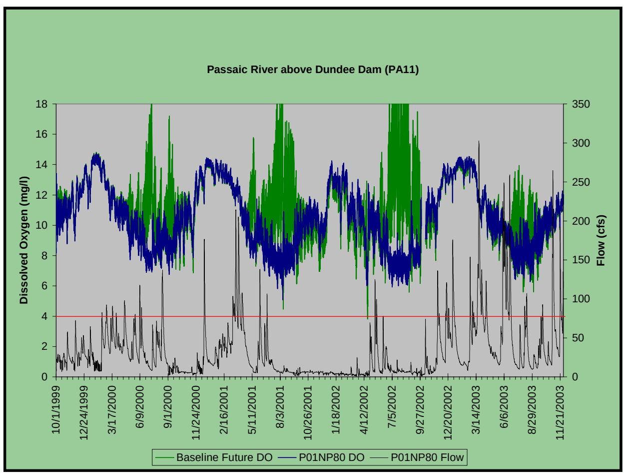

Passaic River at Glover Ave., West Paterson (PA9)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P01NP80 DO
P01NP80 Flow

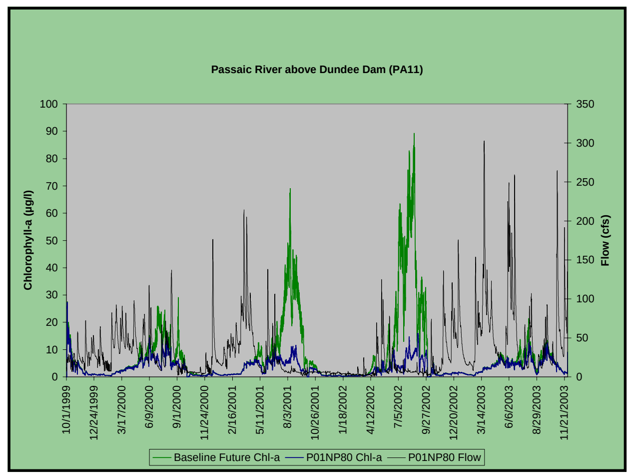

Passaic River at Glover Ave., West Paterson (PA9)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
P01NP80 Chl-a
P01NP80 Flow

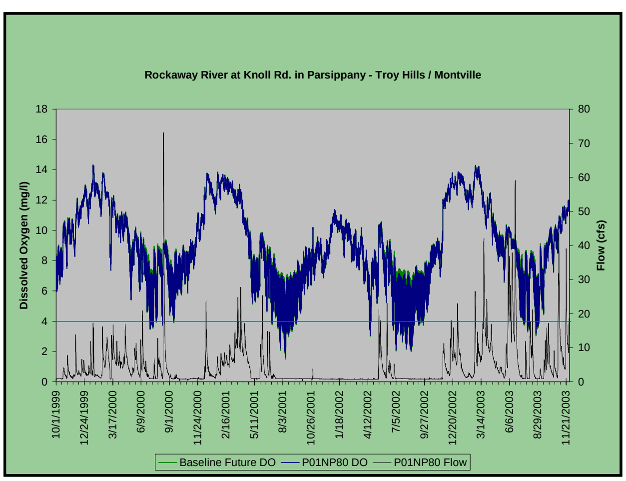

Passaic River at Morlott Ave., Paterson (PA10)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P01NP80 DO
P01NP80 Flow

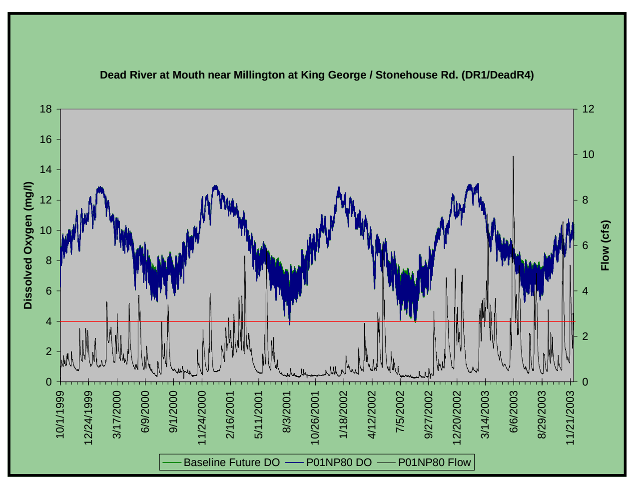

Passaic River at Morlott Ave., Paterson (PA10)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
P01NP80 Chl-a
P01NP80 Flow

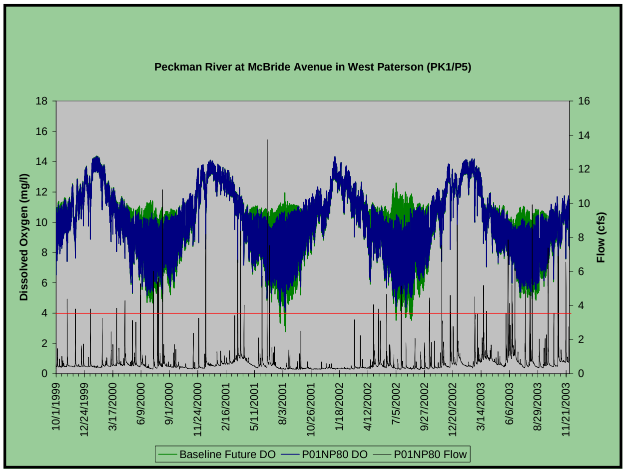

Passaic River above Dundee Dam (PA11)
Phosphorus (mg/l)
Flow (cfs)
Baseline Future TP
P01NP80 TP
P01NP80 Flow


Passaic River above Dundee Dam (PA11)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P01NP80 DO
P01NP80 Flow


Passaic River above Dundee Dam (PA11)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
P01NP80 Chl-a
P01NP80 Flow


Rockaway River at Knoll Rd. in Parsippany - Troy Hills / Montville
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P01NP80 DO
P01NP80 Flow


Dead River at Mouth near Millington at King George / Stonehouse Rd. (DR1/DeadR4)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P01NP80 DO
P01NP80 Flow



TRC Omni Environmental Corporation

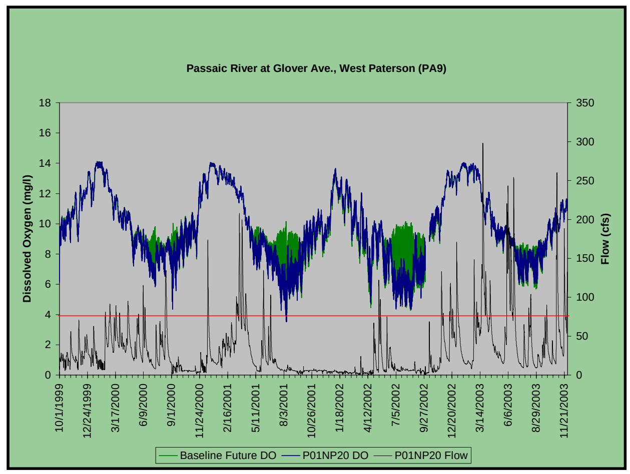
P01NP80 – How Low Can You Go? Summary of Results

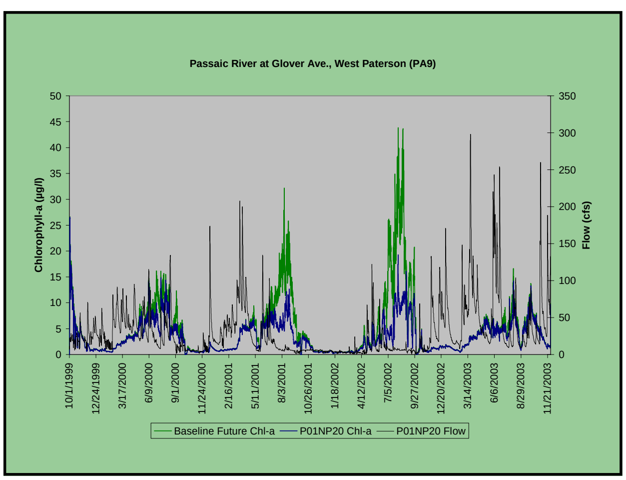
- Pompton River
  - no change in dissolved oxygen or chlorophyll-a
- Passaic River
  - Upstream of Pompton (Stanley Ave and Pine Brook)
    - minimal change in dissolved oxygen
  - Little Falls
    - dissolved oxygen slightly worse due to even lower productivity
    - chlorophyll-a better
  - Great Falls to Dundee
    - dissolved oxygen (minimum) no change or worse
    - productivity substantially lower (DO variation lower, chlorophyll-a peaks reduced)
- Rockaway River
  - no change
- Dead River
  - no change
- Peckman River
  - dissolved oxygen improved ; productivity still very high

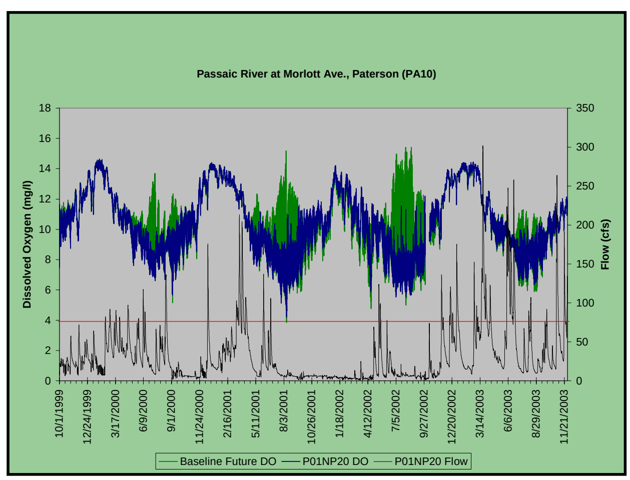
TRC Omni Environmental Corporation

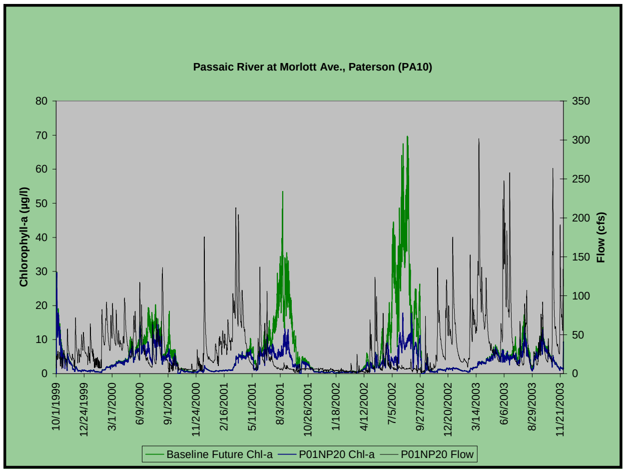
P01NP20 Most Reduction Feasible

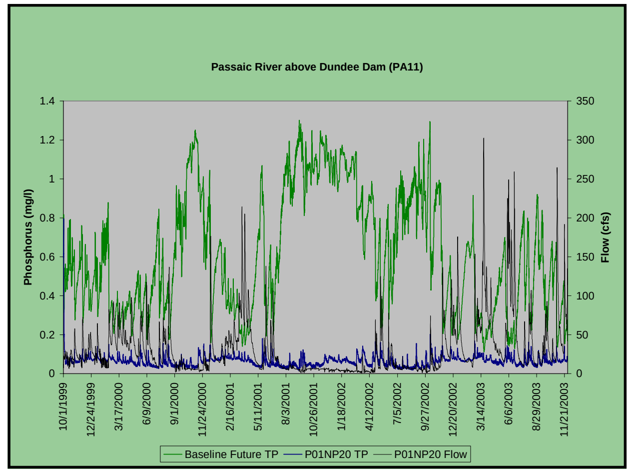
- Permitted flows for point sources
- Point Sources set to 0.1 mg/l TP
- urban and agricultural land use EMCs for phosphorus reduced by 20%

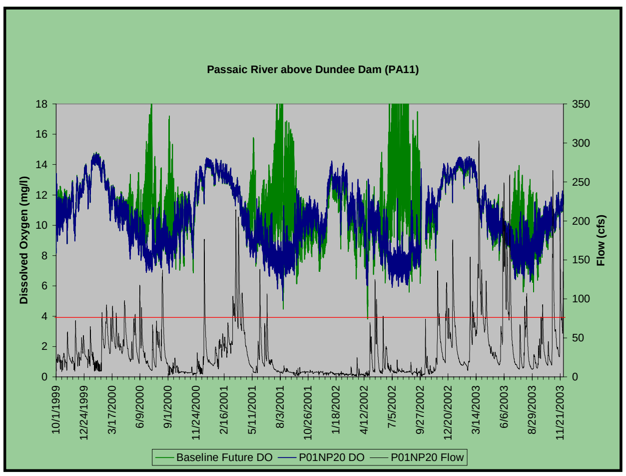


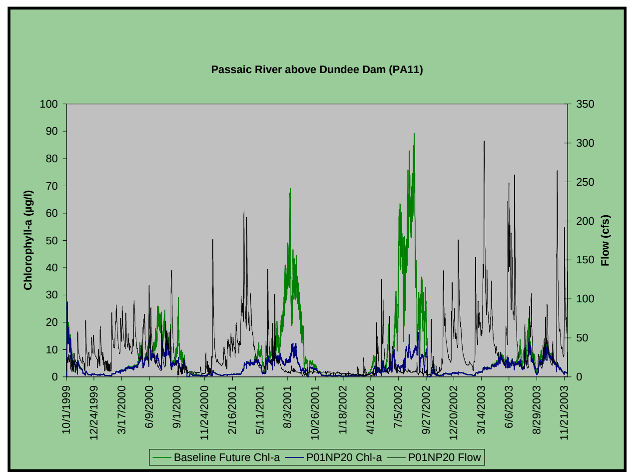


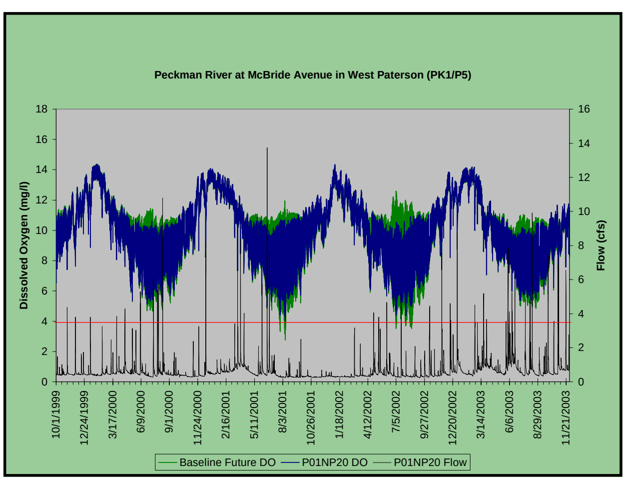












TRC Omni Environmental Corporation

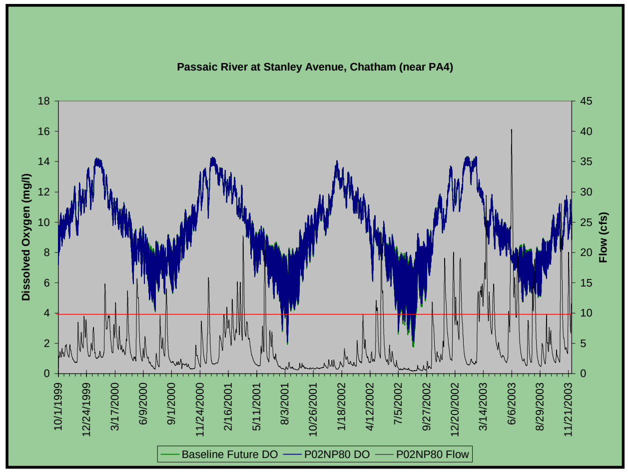
P01NP20 – Most Reduction Feasible Summary of Results

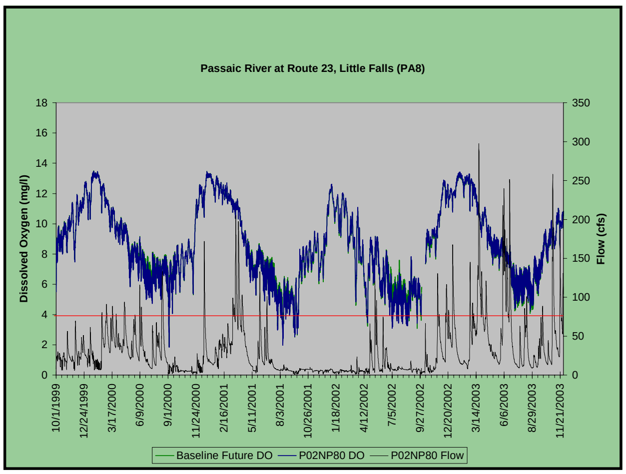
- Identical to P01NP80
- No discernible difference between 20% and 80% nonpoint source reduction WHEN point sources are reduced to 0.1 mg/l

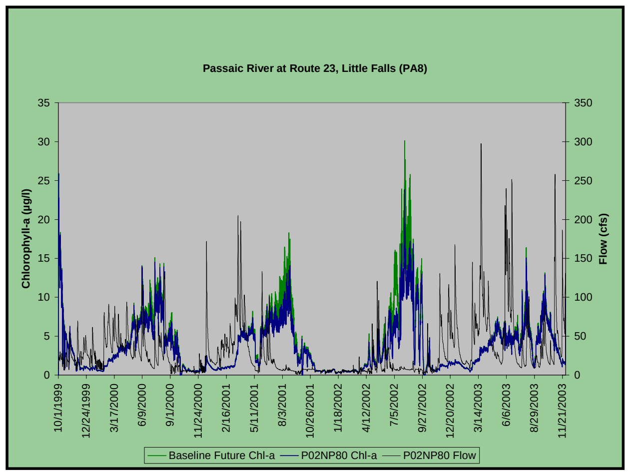
TRC Omni Environmental Corporation

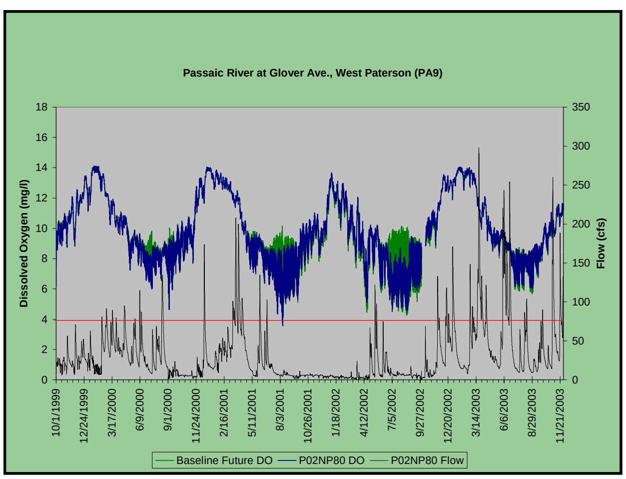
P02NP80
Wanaque Reservoir TMDL Scenario

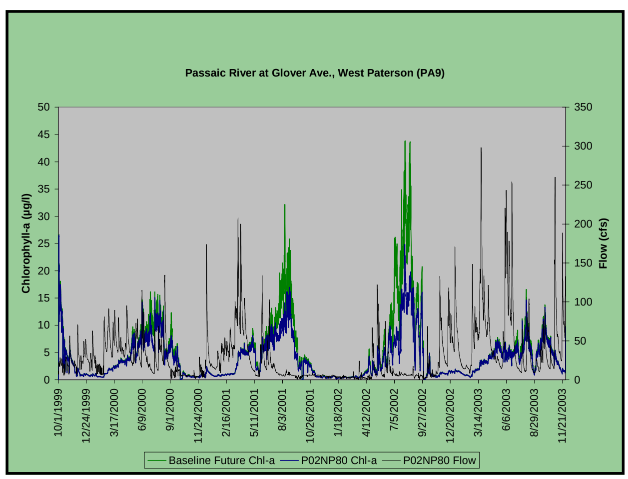
- Permitted flows for point sources
- Point Sources set to 0.2 mg/l TP
- urban and agricultural land use EMCs for phosphorus reduced by 80%

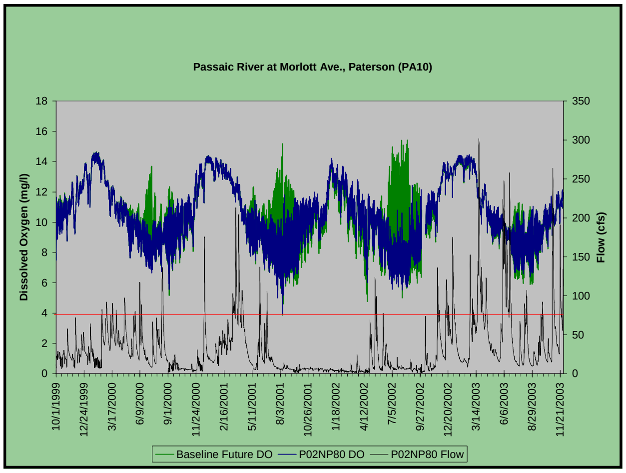


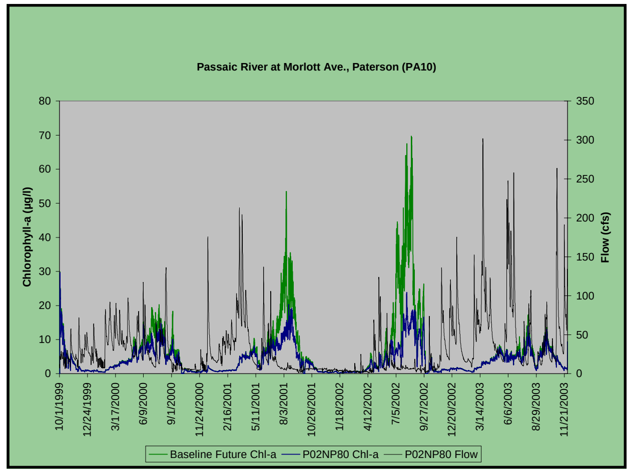


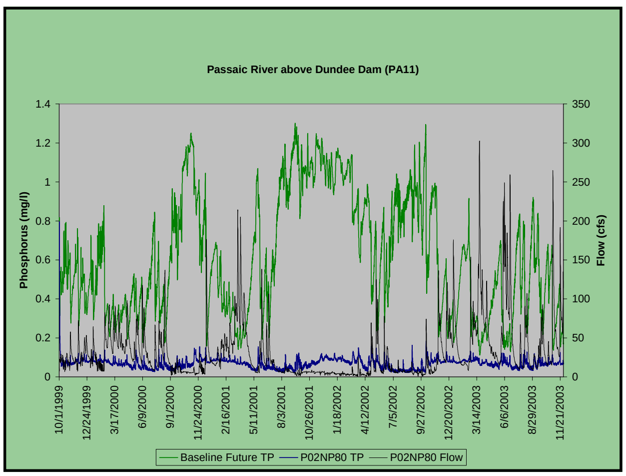


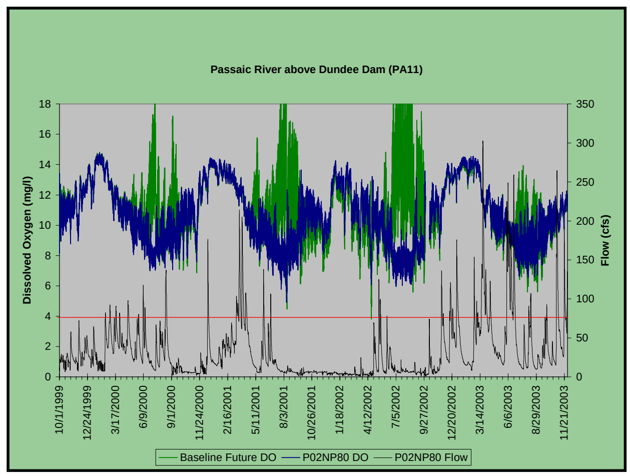


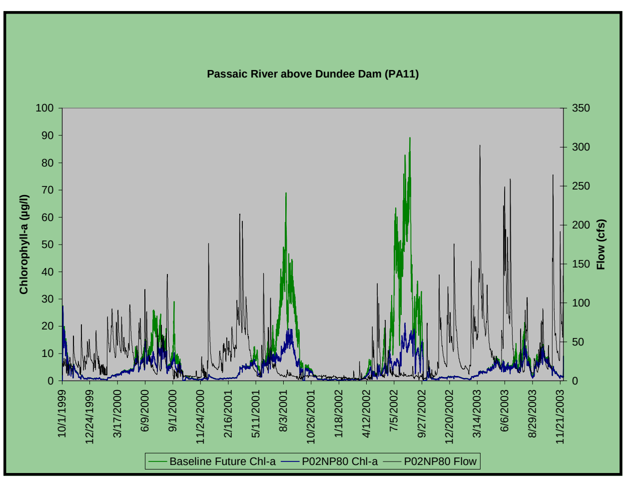


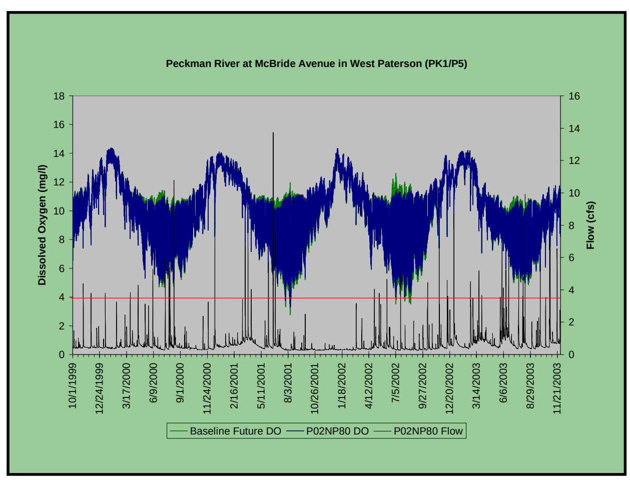

Passaic River at Morlott Ave., Paterson (PA10)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P02NP80 DO
P02NP80 Flow


Passaic River at Morlott Ave., Paterson (PA10)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
P02NP80 Chl-a
P02NP80 Flow


Passaic River above Dundee Dam (PA11)
Phosphorus (mg/l)
Flow (cfs)
Baseline Future TP
P02NP80 TP
P02NP80 Flow


Passaic River above Dundee Dam (PA11)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P02NP80 DO
P02NP80 Flow


Passaic River above Dundee Dam (PA11)
Chlorophyll-a (µg/l)
Flow (cfs)
Baseline Future Chl-a
P02NP80 Chl-a
P02NP80 Flow


Peckman River at McBride Avenue in West Paterson (PK1/P5)
Dissolved Oxygen (mg/l)
Flow (cfs)
Baseline Future DO
P02NP80 DO
P02NP80 Flow

TRC Omni Environmental Corporation

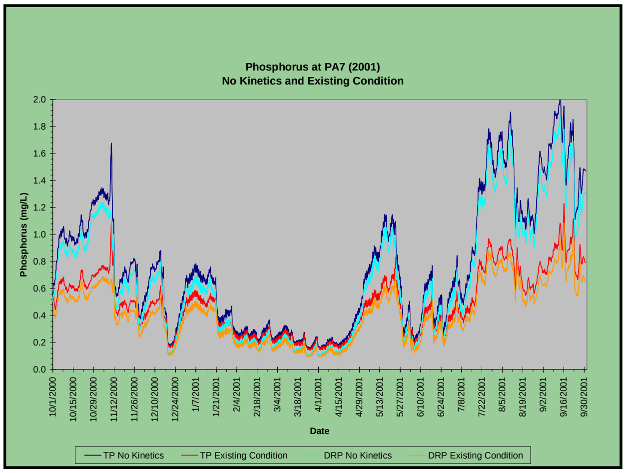
P02NP80 – Wanaque Reservoir TMDL Summary of Results

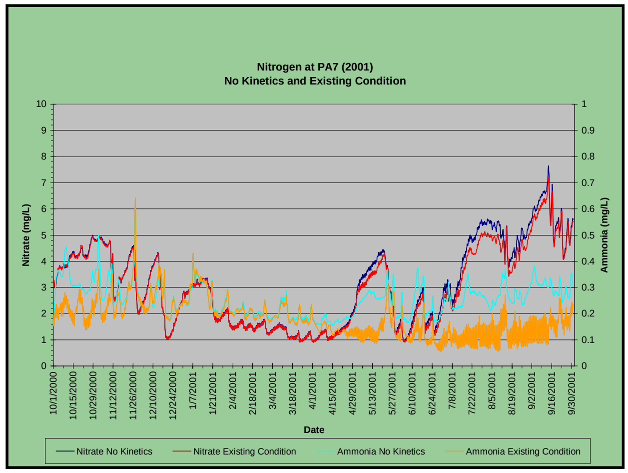
- Very similar to P01NP80
  - Passaic River slightly higher in productivity, which is better in most places
  - Downstream phytoplankton still very low
  - Peckman River does not improve as much
- No important difference between 0.1 mg/l and 0.2 mg/l point source concentrations WHEN nonpoint sources are reduced by 80%

TRC Omni Environmental Corporation

Sensitivity Analysis

- No Kinetics
  - Based on Existing Condition (Calibrated Model)
  - WY2001
  - Phosphorus and Nitrogen evaluated in Passaic River at Two Bridges
- Results
  - Kinetics affects phosphorus and ammonia by a factor of two
  - Kinetics not as important for nitrate

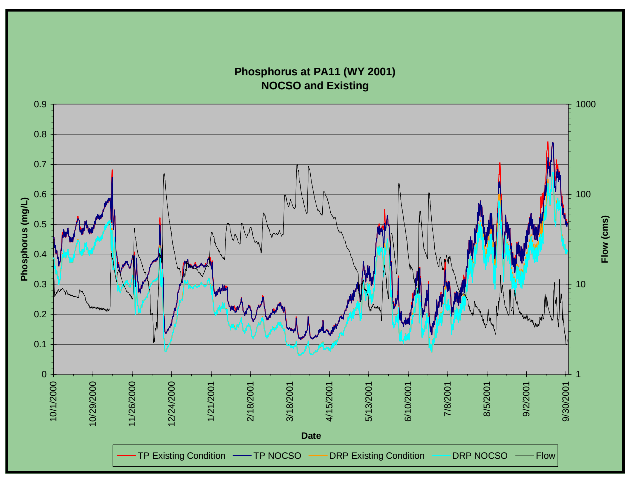


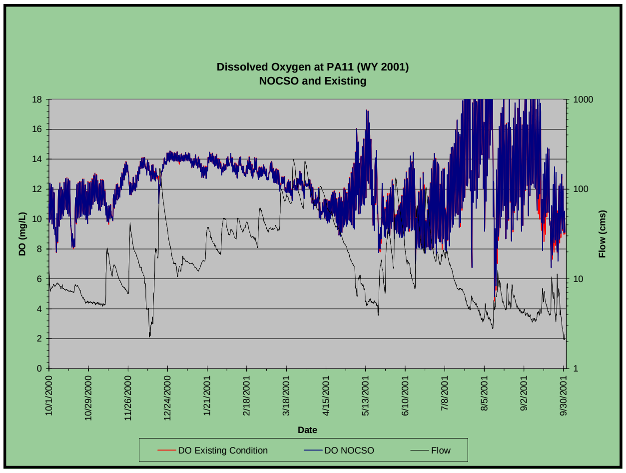


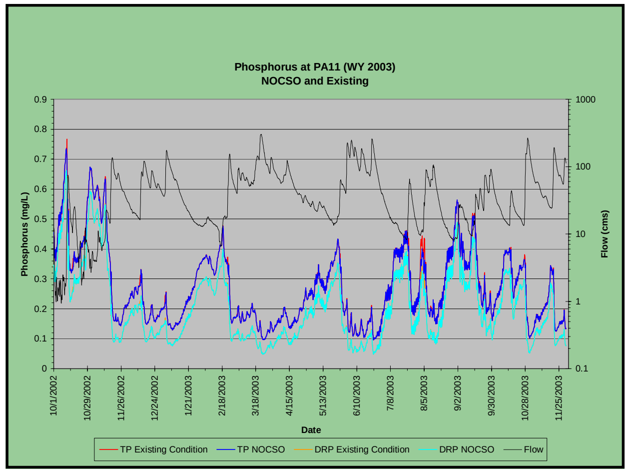
TRC Omni Environmental Corporation

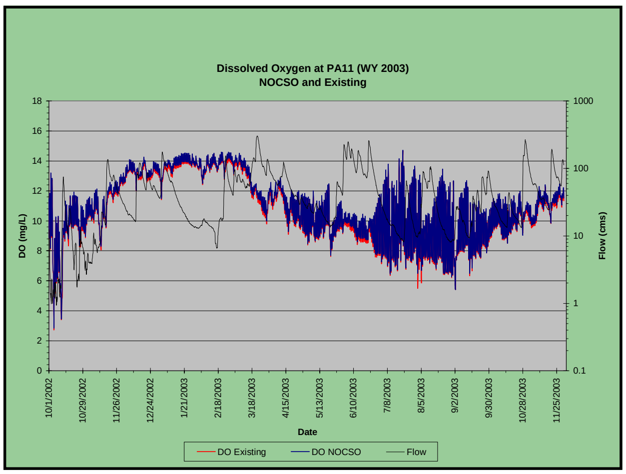
Sensitivity Analysis

- No Combined Sewer Overflow loading
  - Based on Existing Condition (Calibrated Model)
    - simulations performed in WY2001 and WY2003
    - phosphorus and dissolved oxygen compared in Passaic River at Dundee
  - Based on P01NP80 (How Low Can You Go?)
    - simulation performed in 2002
    - phosphorus, chlorophyll-a, and dissolved oxygen compared in Passaic River at Dundee
- Results
  - CSOs are not important contributions to either Existing Condition or low-phosphorus Future Condition

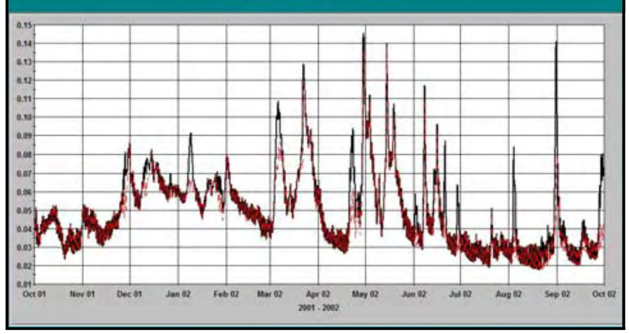




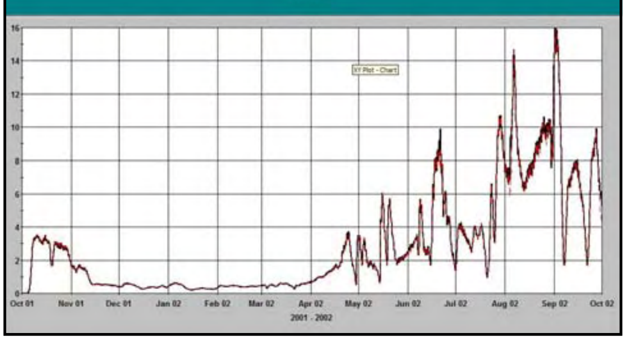




TP in Passaic River at Dundee (PA11) With and Without CSOs (Identical)



Chl-a in Passaic River at Dundee (PA11) with and without CSOs (Identical)

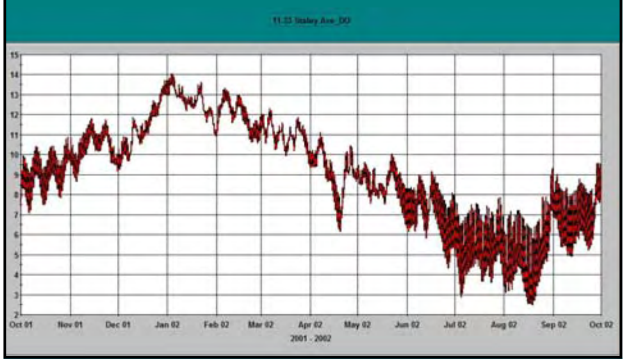


TRC Omni Environmental Corporation

Sensitivity Analyses

- Baseflow and Headwater Concentrations
  - Based on P01NP80 (How Low Can You Go?)
    - simulation performed in 2002
    - Baseflow TP reduced from 0.08 mg/l to 0.04 mg/l
    - Passaic headwater condition changed from 0.13 mg/l to 0.1 mg/l
    - Baseflow and headwater changed together
    - DO and chl-a evaluated at all critical locations
- Results
  - No effect on productivity

DO in Passaic River at Stanley Ave. (near Chatham)
Headwater and Baseflow Loads Reduced (Identical)

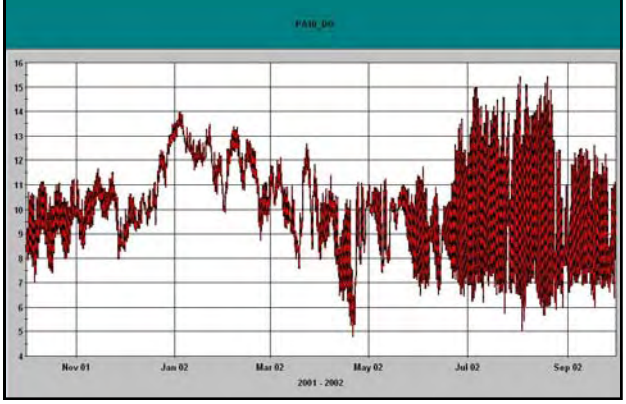


TRC Omni Environmental Corporation

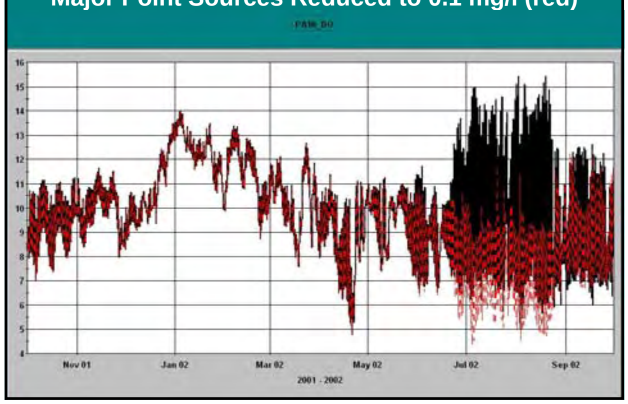
Sensitivity Analyses

- Point Source Reduction Combinations
  - Based on Baseline Future Condition
    - simulation performed in 2002
    - "Super-Majors" reduced to 0.1 mg/l (STPs > 5 MGD)
    - Majors reduced to 0.1 mg/l (STPs > 1 MGD)
    - DO and chl-a evaluated at all critical locations
- Results
  - Reduction of only "Super-Majors" produces no changes in productivity (it's not enough!)
  - Reduction of only Major Point Sources produces all the same changes as P01NP80 (minors do not matter)

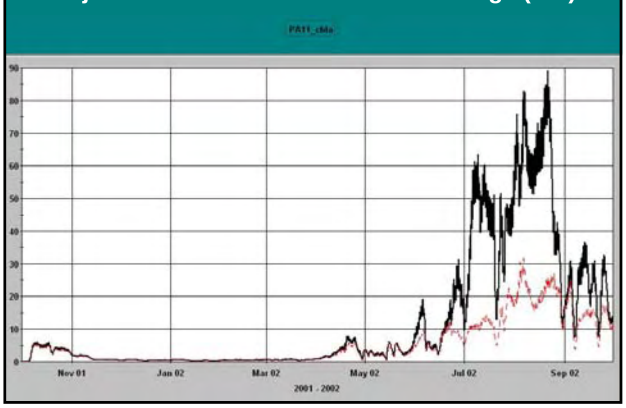
DO in Passaic River at Morlott Ave. (PA10)
Super-Major Point Sources Reduced to 0.1 mg/l (red)



DO in Passaic River at Morlott Ave. (PA10)
Major Point Sources Reduced to 0.1 mg/l (red)



Chl-a in Passaic River at Dundee (PA11)
Major Point Sources Reduced to 0.1 mg/l (red)

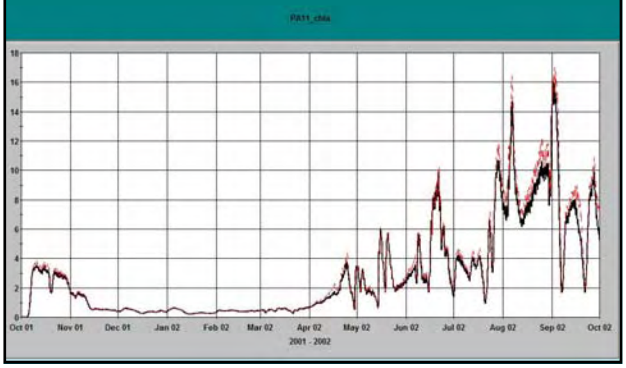


TRC Omni Environmental Corporation

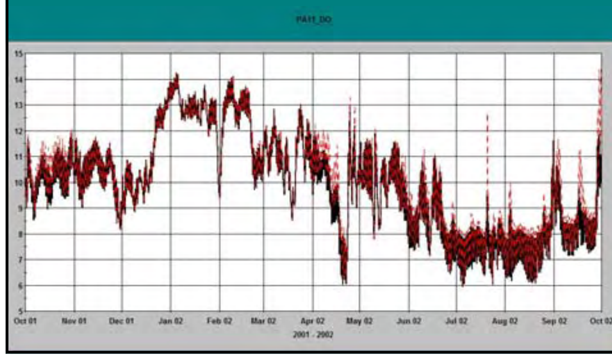
Sensitivity Analyses

- Nonpoint Source Reduction Combinations
  - Based on P01NP80 (How Low Can You Go?)
    - simulation performed in 2002
    - NPS reduced by only 40%
    - NPS not reduced at all
    - DO and chl-a evaluated at all critical locations
- Results
  - Reduction of NPS by only 40% produces the same result as reduction by 80%
  - No reduction of NPS produces meaningless difference in productivity

Chl-a in Passaic River at Dundee (PA11) Nonpoint Sources Not Reduced (red)



DO in in Passaic River at Dundee (PA11) Nonpoint Sources Not Reduced (red)



TRC Omni Environmental Corporation

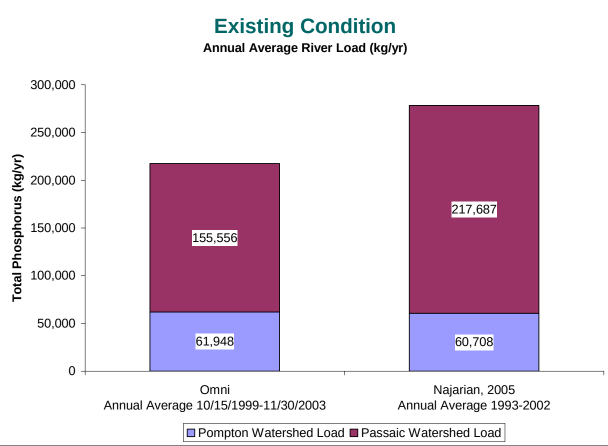
Conclusions from Future Scenario Simulations

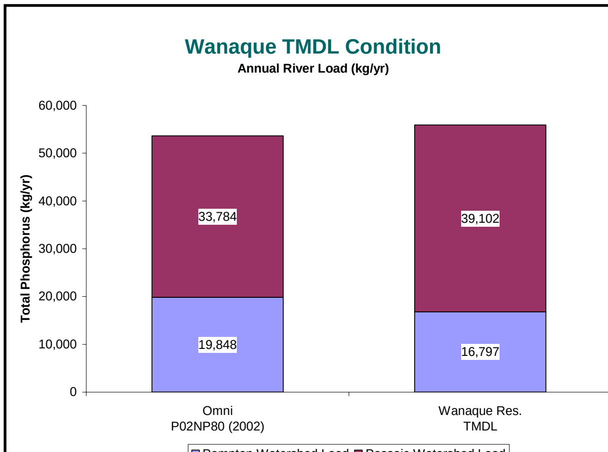
- Impact of Phosphorus Reductions in Passaic River Basin
  - Limited benefit due to substantial background sources, light limitation, and SOD
  - In many places where P reduction will decrease productivity, dissolved oxygen gets worse
  - Two areas where P reduction will decrease productivity and produce some benefit (reduced DO swing and Chl-a)
    - Passaic River from Great Falls to Dundee
    - Peckman River near mouth
- Nonpoint source reductions do not appear to produce a noticeable change in water quality
- Point source reductions below some threshold (to be defined) do not produce additional benefit

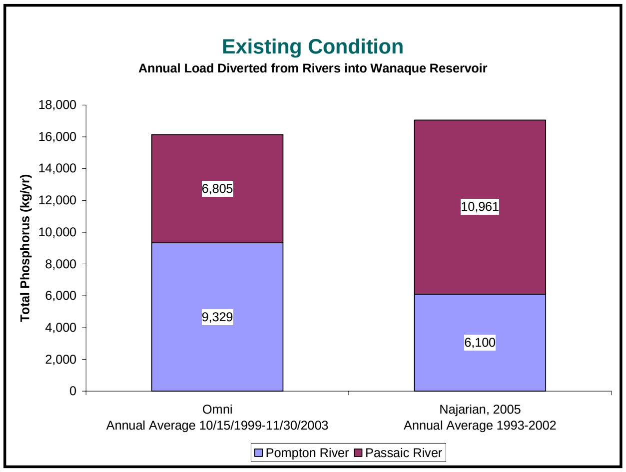
TRC Omni Environmental Corporation

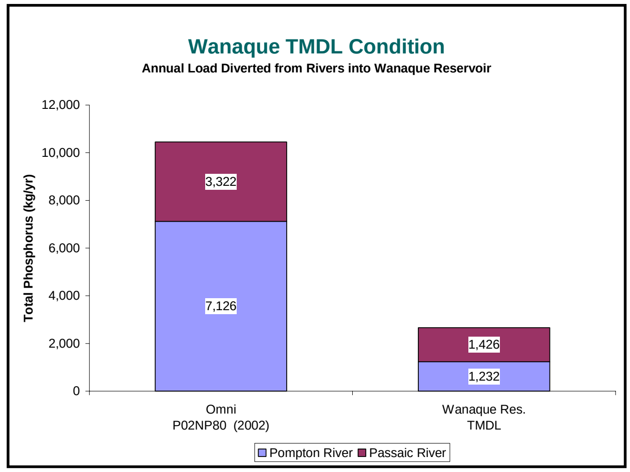
Implications for Wanaque Reservoir TMDL

- Comparison of River Loads
  - Annual Average Existing Condition
  - TMDL river allocations vs P02NP80 simulation
- Comparison of Reservoir Loads
  - Annual Average Existing Condition
  - TMDL allocations vs P02NP80 simulation









TRC Omni Environmental Corporation

Conclusions Regarding Wanaque Reservoir TMDL

- Instream predictions under existing conditions appear to be reasonably consistent
  - Passaic River predictions are lower, which is expected
  - Impossible to compare directly without year-to year information
- Appears to be discrepancy between TMDL reservoir load allocations and future diversion scenario

TRC Omni

Non-Tidal Passaic River Basin Nutrient TMDL Study

Performed on behalf of:
Rutgers University - New Jersey EcoComplex and
New Jersey Dept. of Environmental Protection

April 28, 2006

TRC Omni

Agenda

- Background
- Phase I – Watershed Monitoring
- Phase II – Watershed Modeling
- Impact of Flow on Productivity
- Impact of Phosphorus Reductions on Productivity
- Summary of Sensitivity Analyses
- Effluent TP Reduction Sensitivity
- Watershed-Specific Criteria
- Conclusion

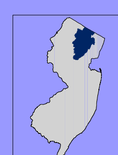
TRC Omni

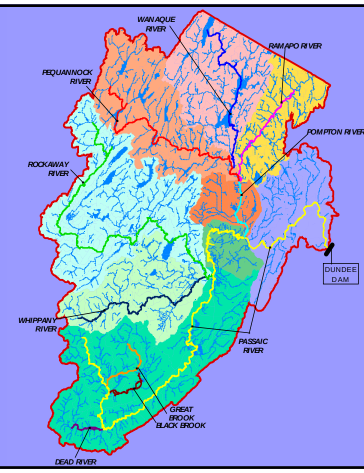
Purpose of Study

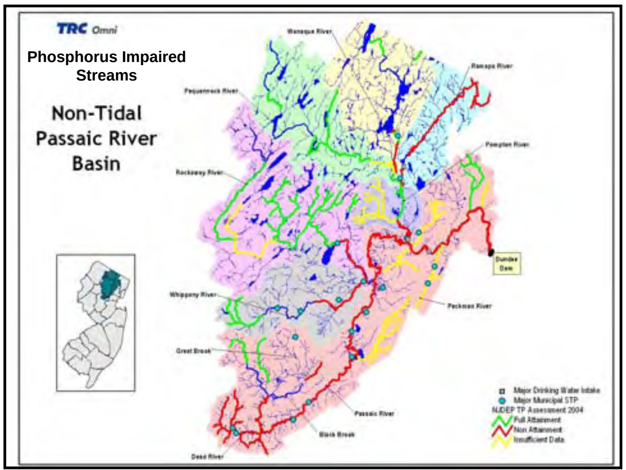
- To provide a scientifically defensible approach to establishing a nutrient Total Maximum Daily Load (TMDL) for the Non-Tidal Passaic River Basin
- To establish nutrient load reductions that will translate into environmental benefits

---

Non-Tidal Passaic River Basin







TRC Omni

Pollutants of Concern

- Total Phosphorus is primary Pollutant of Concern
  - Regulated due to potential to stimulate excessive plant and algal growth
  - Primary emphasis – impact of phosphorus on dissolved oxygen and algae
- Nitrate
  - Addressed through WQBELs
- Total Nitrogen
  - Need tool to translate load allocation from NY/NJ Harbor TMDL to load and wasteload allocations throughout the system

Phosphorus Criteria

- Stream Criterion
  - TP $\leq$ 0.1 mg/l **unless** it can be demonstrated that …
- Lake, Pond, and Reservoir Criterion
  - TP$\leq$0.05 mg/l
- Narrative Nutrient Policy
  - Nutrients shall not be allowed in concentrations that render the waters unsuitable for the designated uses
- Watershed or Site-Specific Criteria
  - This study provides a direct and quantitative linkage between phosphorus sources and productivity impacts
  - Strong technical basis to establish a watershed-specific criterion for phosphorus

Phase I Watershed Monitoring

- Monitoring Program
  - Data to Identify Impairment at Critical Locations
  - Data to Calibrate and Validate Watershed Model
  - Data to Characterize Nutrient Sources
- 11×17 Handout shows all sampling locations

Data to Identify Impairment at Critical Locations

- Diurnal DO, pH, temperature
  - 20 stream locations during 3 low-flow events (2-7 days continuous)
- Phytoplankton (chl-a)
  - 20 stream locations during 3 low-flow events (2 days)
  - 8 baseflow/reference locations during 3 low-flow events (1 day)
- Periphyton (chl-a)
  - 20 stream locations during 4 low-flow events
  - 8 baseflow/reference locations during 3 low-flow events

Data to Calibrate and Validate Watershed Model

- Algae and Diurnal DO (previous slide)
  - Phytoplankton, periphyton, and pH/temperature/DO
- Stream Chemistry
  - pH, temperature, DO, alkalinity, $CBOD_5$, P-series, N-series, iron, TDS, TSS, TOC, turbidity
    - 6 stream characterization stations
      - 20 weekly events
    - 30 stream intensive locations
      - 3 high-flow events and 3 low-flow events, 2 days each
    - 8 baseflow/reference locations
      - 3 low-flow events, 1 day each

Additional Field Data for Watershed Model Calibration / Verification

- Bank-to-bank cross sections at every sampling location
- SOD measurements at 6 locations in 2003 and 8 additional locations 2004
- Diurnal solar radiation (light intensity) taken during three diurnal events
- Underwater light intensity measured at each station to calculate light extinction

Additional Stream Sampling in 2004

- Purpose was to obtain data to be able to model each tributary explicitly rather than as a boundary condition
- Rockaway River
  - 4 stream locations plus one tributary location
  - one diurnal event
- Peckman River
  - 5 stream locations plus two tributary locations
  - one diurnal event
- Dead River
  - 4 stream locations plus one tributary location
  - one diurnal event

Data to Characterize Nutrient Sources

- Sewage Treatment Plants (24 STPs)
  - pH, temperature, DO, alkalinity, $CBOD_5$, P-series, N-series, TDS, TSS, TOC
    - 24-hour composites
    - 3 low-flow and 3 high-flow events (stream events)
- Stormwater Sources
  - alkalinity, $CBOD_5$,P-series, N-series, TDS, TSS, TOC
    - 8 stormwater stations for different land uses
    - 3 storm events, ~4 samples per storm

Other Calibration / Validation Data

- NJDEP Diurnal DO measurements
  - Passaic River at Chatham 2002
  - Passaic River at Little Falls 2002
  - Pompton River 1999 and 2002
- PVSC Historical Phytoplankton Chlorophyll-a
  - Passaic River from Great Falls to Dundee
- USGS Continuous DO and temperature measurements
  - Ramapo River at Pompton Lakes
  - Passaic River at Two Bridges

General Observations and Assessment

- Upper and Mid-Passaic River Watershed
  - Phosphorus is very high
  - Productivity is surprisingly low
    - Macrophytes
    - Diurnal DO swings are generally small to none
    - Naturally low DO – productivity generally increases average DO
- Pompton River Watershed
  - Phosphorus is generally low
  - Productivity is low to moderate
  - DO is higher than Passaic
- Lower Passaic River Watershed
  - Phosphorus is very high
  - Productivity is very high under critical conditions
  - Macrophytes and phytoplankton are important

Phase II Watershed Modeling

- Watershed Model Purpose and Overview
- Model Inputs
- Calibration and Validation Summary

Watershed Model Purpose

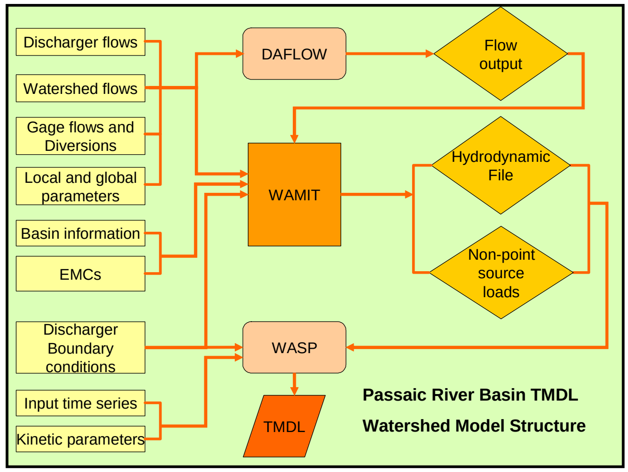
- Purpose
  - To relate point and nonpoint sources of phosphorus to water quality impacts under a variety of conditions, including critical conditions
- Critical Water Quality Indicators
  - Dissolved oxygen was identified as a primary water quality indicator
  - Phytoplankton (measured as water column chlorophyll-a), especially in the most downstream areas of the system prone to substantial growth
  - Phosphorus concentration and loads, especially for waters supply diversions
  - Nitrogen components (ammonia, nitrate, and organic nitrogen)

Model Overview

- Flow model
  - DA-FLOW one-dimensional flow model by USGS
  - modified to account for mixing at confluence
- Water quality model
  - one dimensional dynamic simulation using WASP 7 with EUTRO
  - large-scale unified system model
- Watershed Model Integration Tool (WAMIT)
  - Nonpoint source simulation using flow-weighted EMCs
  - DA-FLOW and WASP integration

Water Quality State Variables

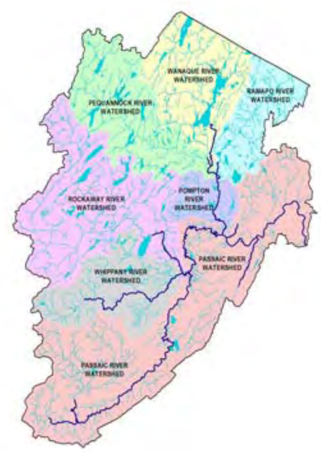
- ammonia
- nitrate
- organic nitrogen
- orthophosphate
- organic phosphorus
- ultimate biochemical oxygen demand
- dissolved oxygen
- chlorophyll
- benthic algae (or macrophytes)



Watershed Model Spatial and Temporal Extent

- Spatial extent (next slide)
  - Location of continuous streamflow gauges that drive the flow model
  - Inclusion of STP discharges that represent substantial phosphorus sources
  - Inclusion of streams designated by NJDEP as impaired by phosphorus
- Temporal Extent (October 1, 1999 – November 30, 2006)
  - WY2000 – "normal"
  - WY2001 – dry
  - WY2002 – extreme drought
  - WY2003 – wet

Modeled Segments of The Passaic Basin



Model Inputs

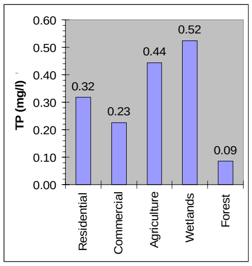
- Basin Information
- NPS Loads
- Boundary Conditions
  - Discharger flows and quality
  - Water supply diversions
  - Headwater boundaries
- Time series data
  - solar radiation
  - stream temperature
- Water quality kinetic parameters
  - Local and global

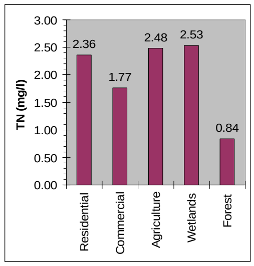
Nonpoint Source Loads

- Hydrograph Separation
  - Contributing runoff
  - Contributing baseflow
- Runoff Loads
  - Flow-weighted runoff EMC × contributing runoff
  - Curve number method only used to weight EMC
- Baseflow Loads
  - Baseflow concentration × contributing baseflow

TRC Omni

Runoff EMCs by Land Use Category



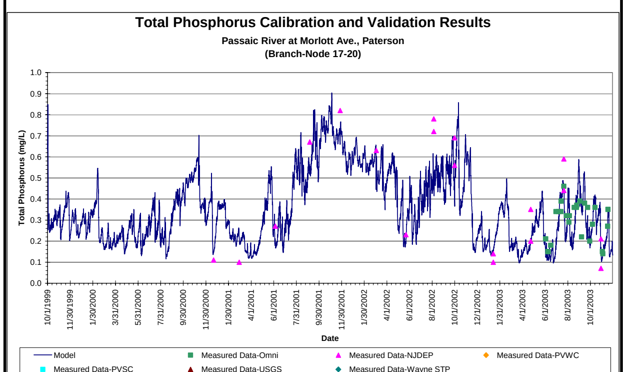


TRC Omni

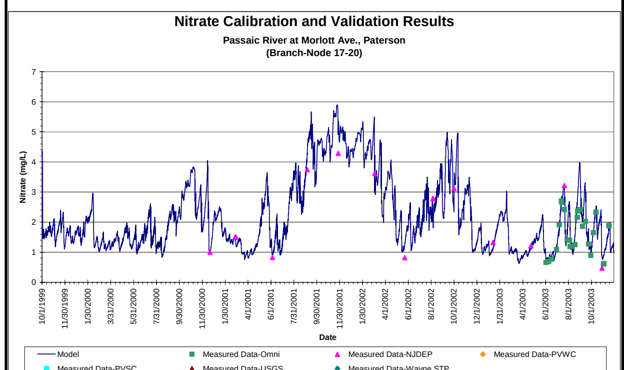
Calibration and Validation Data

- Calibration Data
  - 1/3 of TRC Omni data collected in 2003
  - NJDEP diurnal DO data collected 2002
  - PVSC chlorophyll-a data from 2001 and 2002
- Validation Data
  - TRC Omni, NJDEP, USGS, PVSC, PVWC data collected from 1999 to 2003

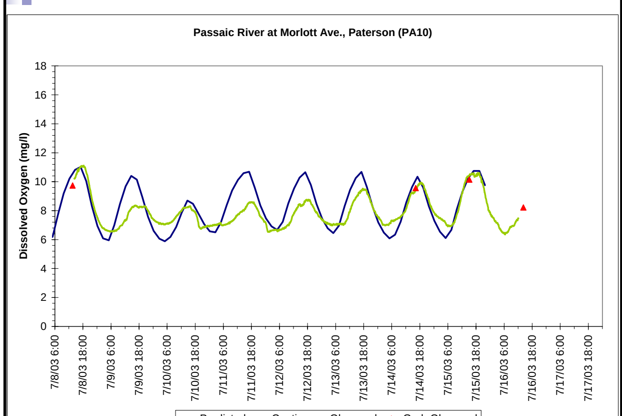
TRC Omni



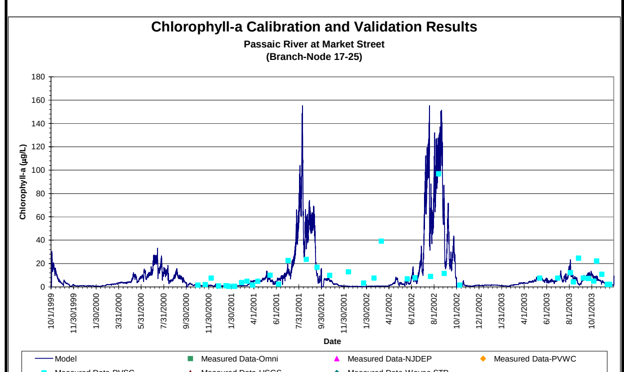
TRC Omni

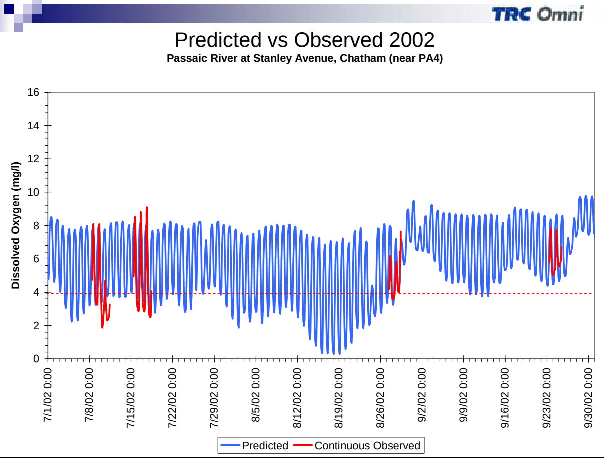


TRC Omni



TRC Omni



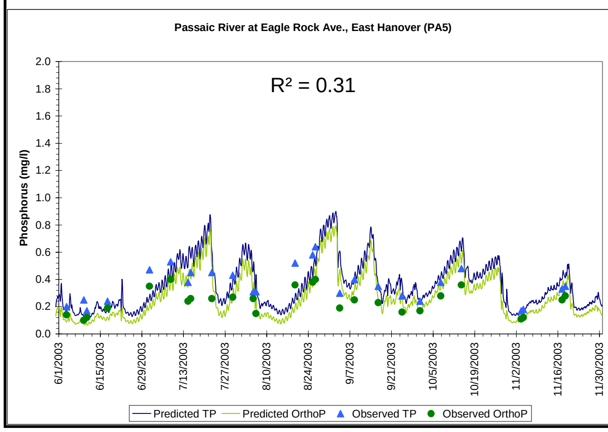


Calibration Statistics

- Mean error, predicted mean, observed mean, predicted standard deviation, observed standard deviation, and r^2
  - Provided in Final Report
  - Within range of stats obtained for other WASP applications
- Stats are good, especially for phosphorus, but they should not be relied upon too heavily
  - High number of random samples required to calculate really good stats
  - Sampling and calibration approach relied on synoptic sampling of specific events, resulting in small number of samples
  - Some locations affected by temporal variation of boundary conditions
  - Some stats affected by diurnal variation of DO and ammonia

Average TP Statistics

Mean Error	-0.01
Predicted Mean	0.26
Observed Mean	0.27
Predicted Standard Deviation	0.13
Observed Standard Deviation	0.11
R^2 (Correlation of Determination)	0.62



Calibration and Validation Summary

- System-wide water quality model calibrated and validated for:
  - nutrients
  - dissolved oxygen
  - chlorophyll-a
- Impact of point and nonpoint source reductions on dissolved oxygen, phosphorus, and chlorophyll-a can be calculated

Model Limitations

- Boundary Condition Uncertainties
  - temperature estimated based on measurements at three locations
  - actual STP, NPS, and baseflow loadings
- Unified System Kinetics
  - global decay rates
  - global growth rates

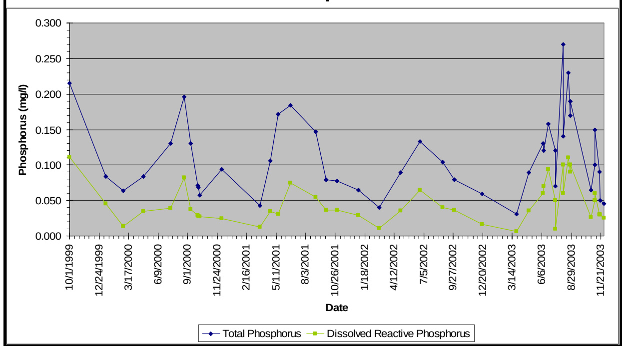
Model Enhancements

- Refined Baseflow Concentrations
  - Based on branch groupings
- Enhanced Passaic River Boundary Condition for Phosphorus
  - Based on outlet of Great Swamp
- Enhanced Ramapo River Boundary Condition for Chl-a and TP
  - Based on Pompton Lake TMDL

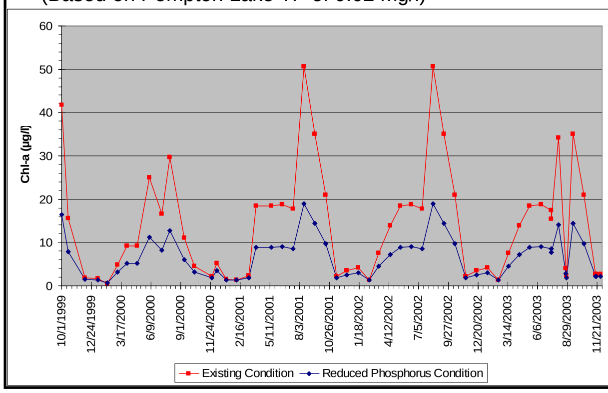
Refined Baseflow Concentrations

Branch Groupings	Basis	TP (mg/l)	OrthoP (mg/l)
Forest Dominated (Wanaque - 2)	RAB, HAB, PRB, PA1	0.045	0.021
Major Tribs(3,4,5,6,7,13)	WIB, TBB, CrookB1, WI1	0.054	0.023
Upper Passaic / Minor Tribs (8,9,10,11,12,14)	DRB, WIB, SBB, TBB	0.063	0.022
Lower Passaic (15,16,17)	SBB, P2	0.060	0.031

Enhanced Passaic River Boundary Condition for Phosphorus

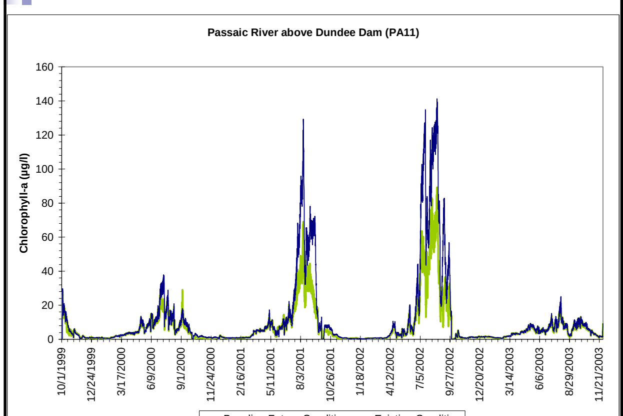


Enhanced Ramapo River Boundary Condition for Chl-a (Based on Pompton Lake TP of 0.02 mg/l)



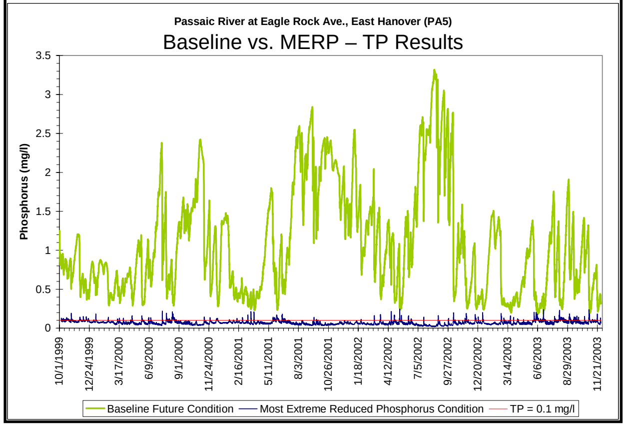
Impact of Flow on Productivity

- What happens when STPs discharge at permitted flows and concentrations?
  - Phosphorus concentration and load increases
  - Stream flows during critical conditions increase
  - Productivity decreases dramatically (see next slide)
- Increasing flows during critical summer periods would dramatically decrease productivity
  - Implications for water supply



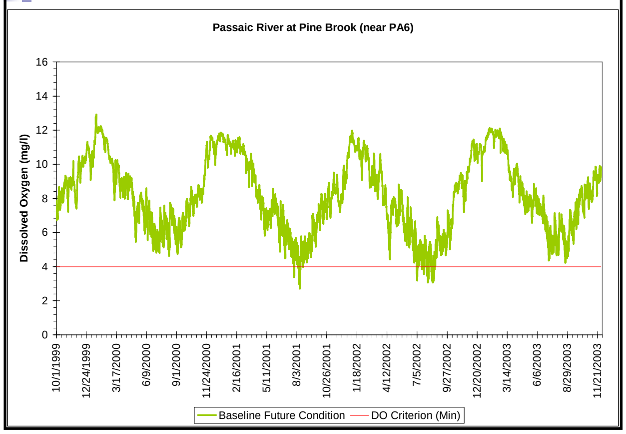
Impact of Phosphorus Reductions on Productivity

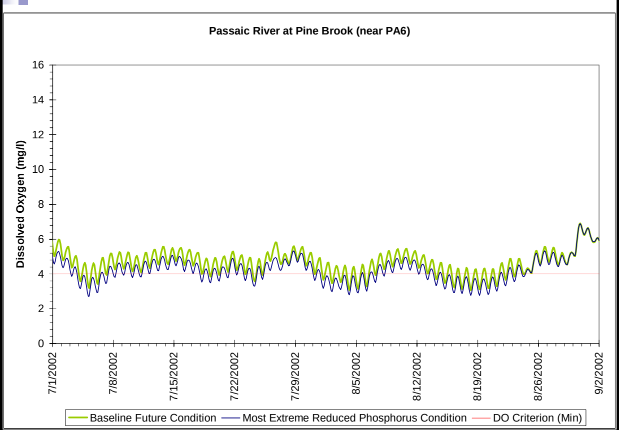
- Baseline Future Condition – Upper Bound
  - Permitted STP flows and concentrations
  - Headwater lakes with TMDLs set to 0.05 mg/l TP
  - Future diversion scenario implemented for NJDWSC
- Most Extreme Reduced Phosphorus Condition – Lower Bound
  - Permitted flows for point sources
  - Point Sources set to 0.05 mg/l TP
  - Phosphorus loads from urban and agricultural land uses reduced by 80%
  - Incorporated model enhancements

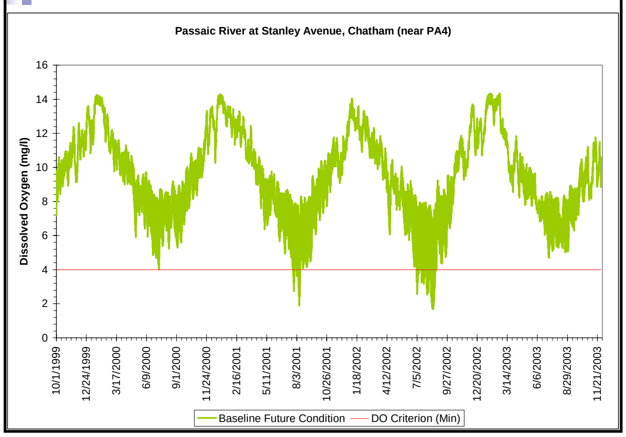


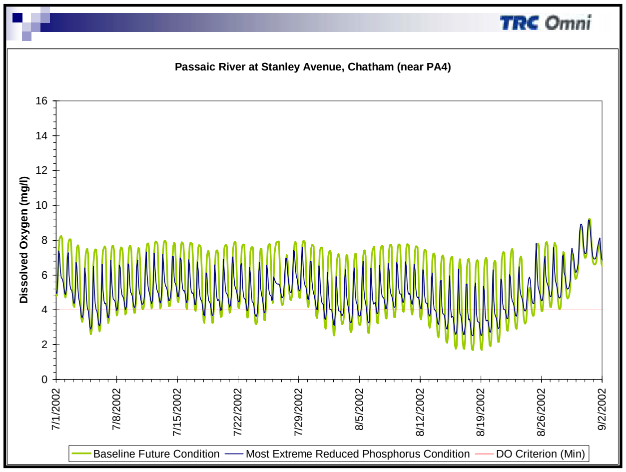
Passaic River Mainstem

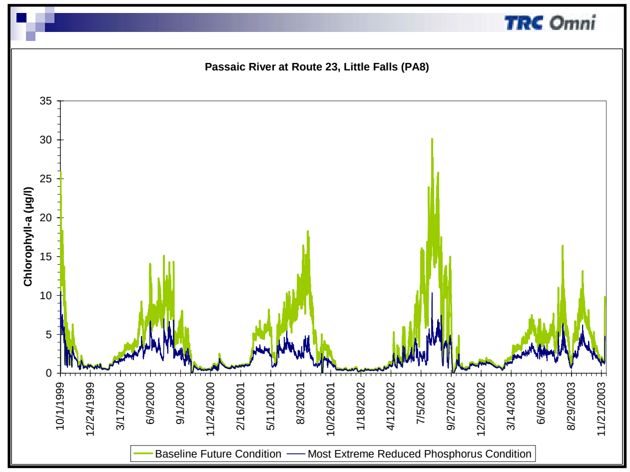
- Passaic Headwaters to Pompton Confluence
  - Passaic River at Pine Brook (most representative)
  - Passaic River at Stanley Avenue, Chatham (critical)
- Passaic River at Little Falls
- Downstream Passaic River (Great Falls to Dundee)
  - Passaic River at Dundee

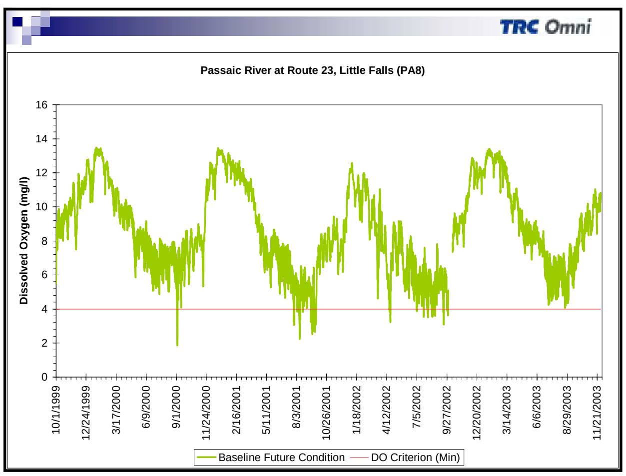


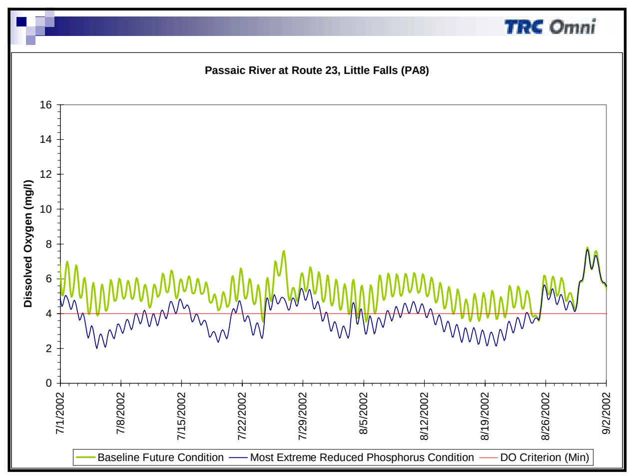


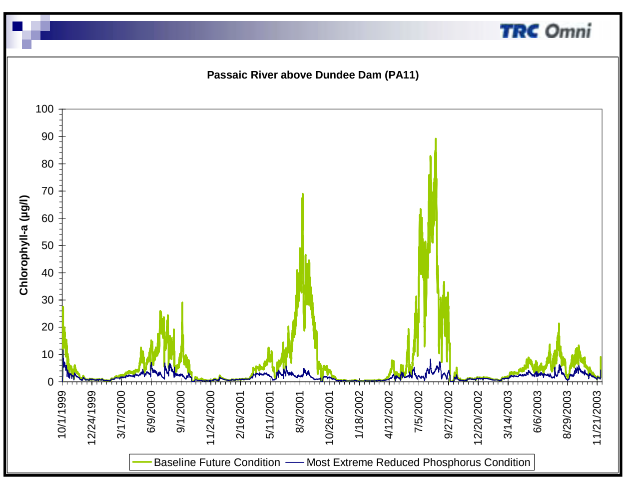


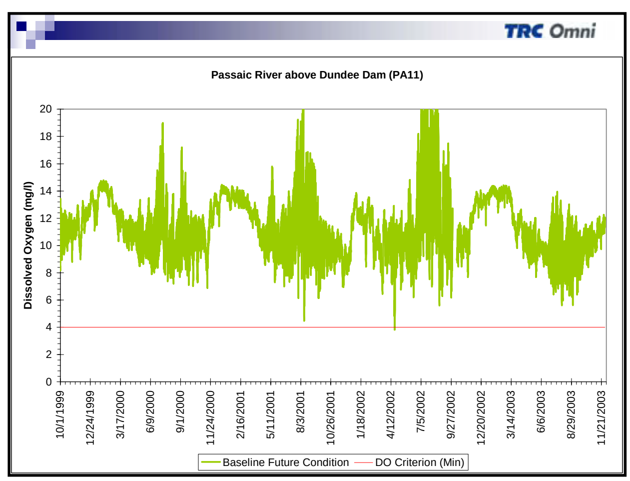

TRC Omni
Passaic River at Stanley Avenue, Chatham (near PA4)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)

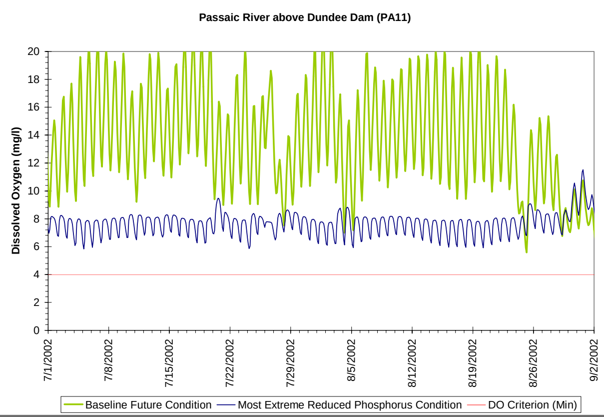

TRC Omni
Passaic River at Route 23, Little Falls (PA8)
Chlorophyll-a (µg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition


TRC Omni
Passaic River at Route 23, Little Falls (PA8)
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)


TRC Omni
Passaic River at Route 23, Little Falls (PA8)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)


TRC Omni
Passaic River above Dundee Dam (PA11)
Chlorophyll-a (µg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition


TRC Omni
Passaic River above Dundee Dam (PA11)
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)

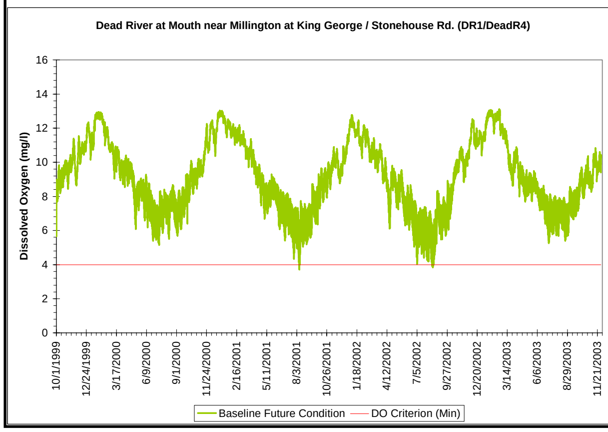


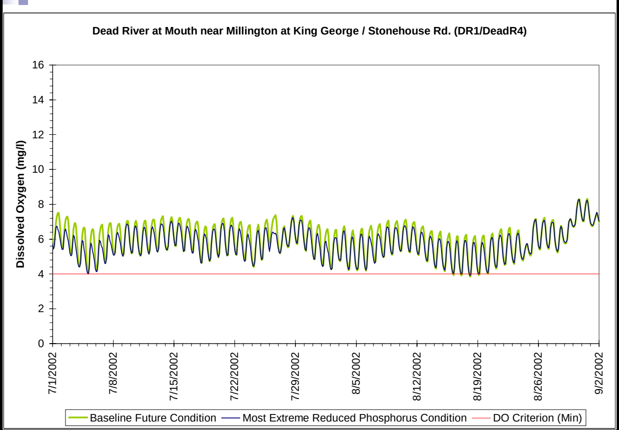
Impact of Phosphorus Reductions: Passaic River Mainstem

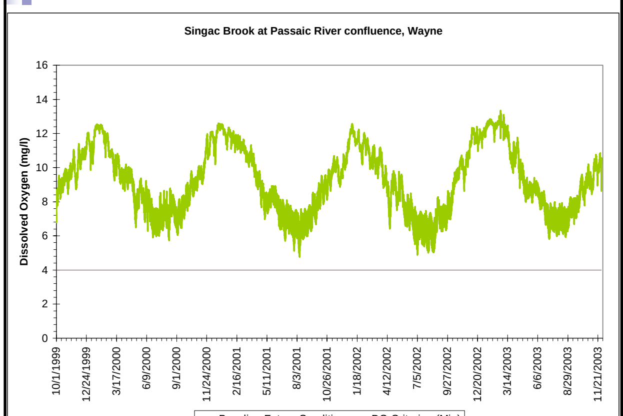
- Passaic Headwaters to Pompton Confluence
  - minimal change in dissolved oxygen
- Passaic River at Little Falls
  - chlorophyll-a better
  - dissolved oxygen worse due to even lower productivity
- Downstream Passaic River (Great Falls to Dundee)
  - chlorophyll-a peaks reduced substantially
  - diurnal DO variation reduced substantially
  - much more desirable DO and phytoplankton condition

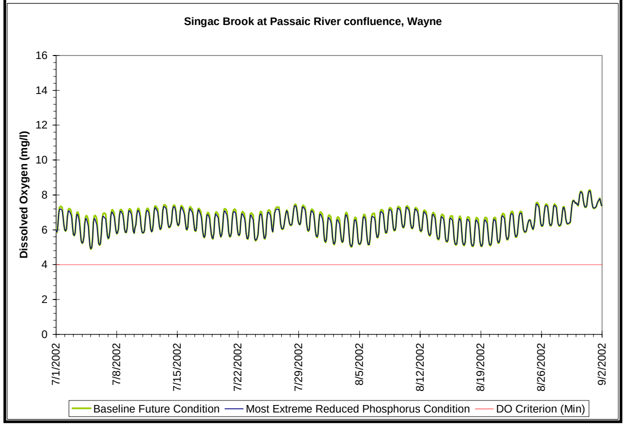
Dead River, Singac Brook, Peckman River

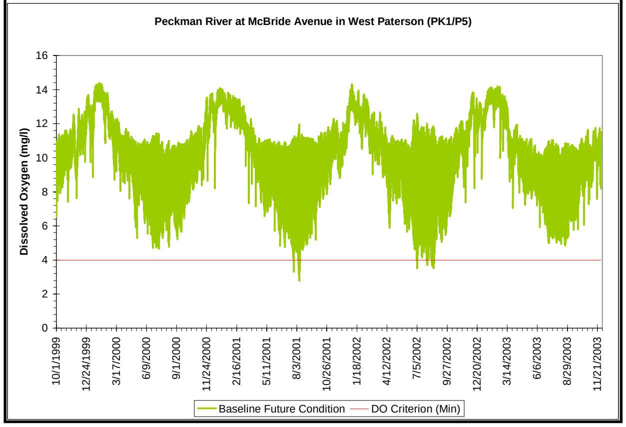
- Dead River near Millington
- Singac Brook at Wayne
- Peckman River in West Paterson

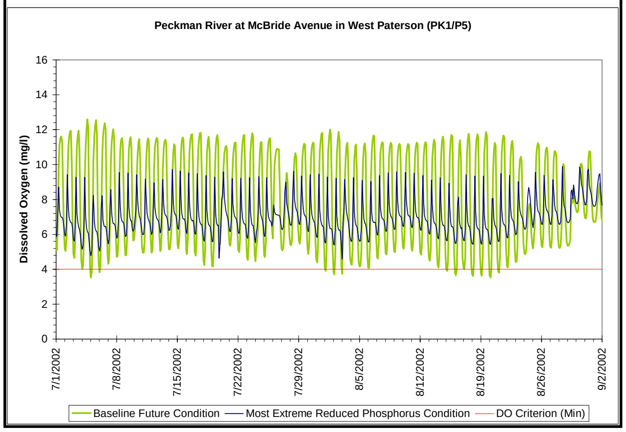










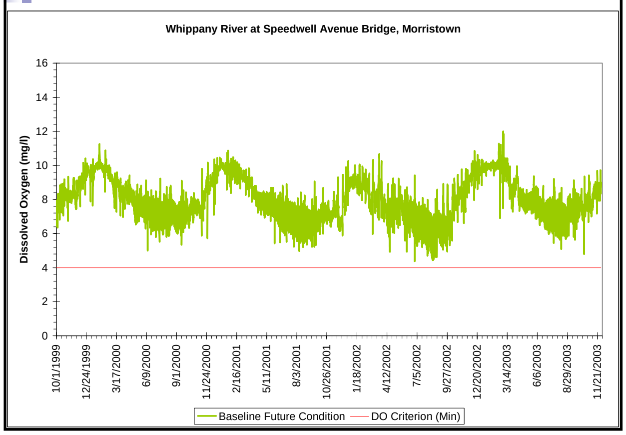


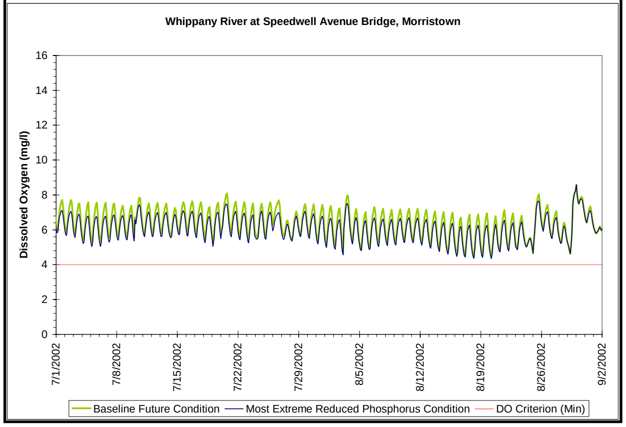
Impact of Phosphorus Reductions: Dead River, Singac Brook, Peckman River

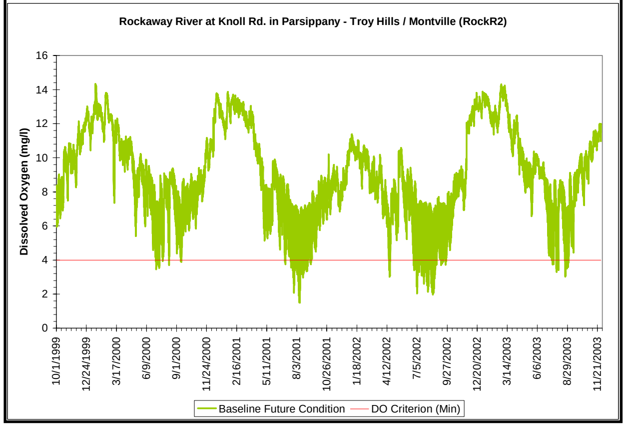
- Dead River
  - minimal change in dissolved oxygen
- Singac Brook
  - no discernible change in dissolved oxygen
- Peckman River
  - diurnal DO variation reduced substantially
  - minimum DO increased above DO criterion

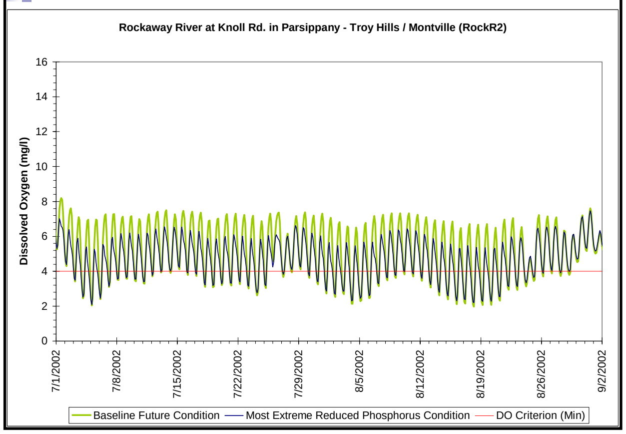
Whippany and Rockaway Rivers

- Whippany River at Speedwell Avenue Bridge in Morristown
- Rockaway River at Knoll Rd. in Parsippany – Troy Hills







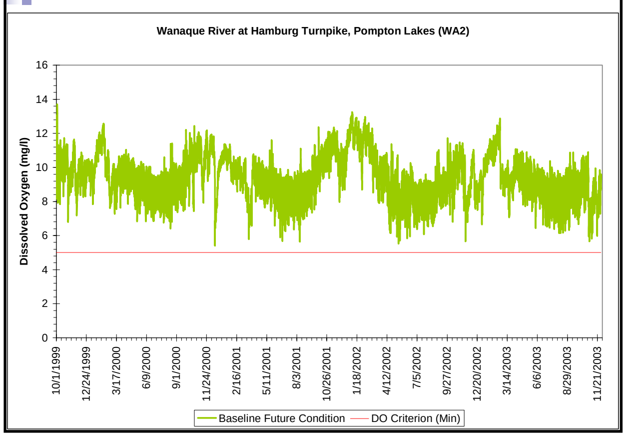


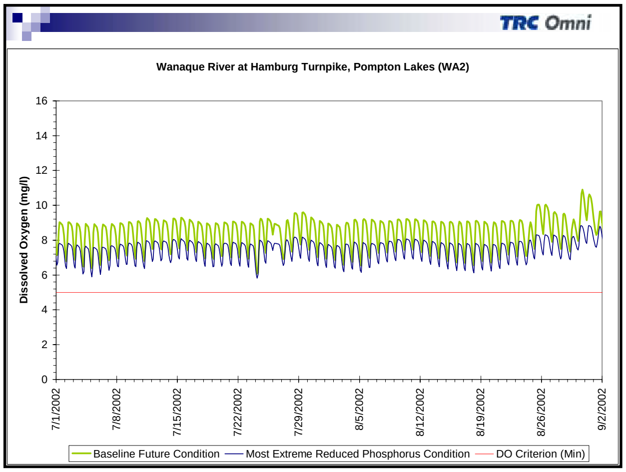
Impact of Phosphorus Reductions: Whippany and Rockaway Rivers

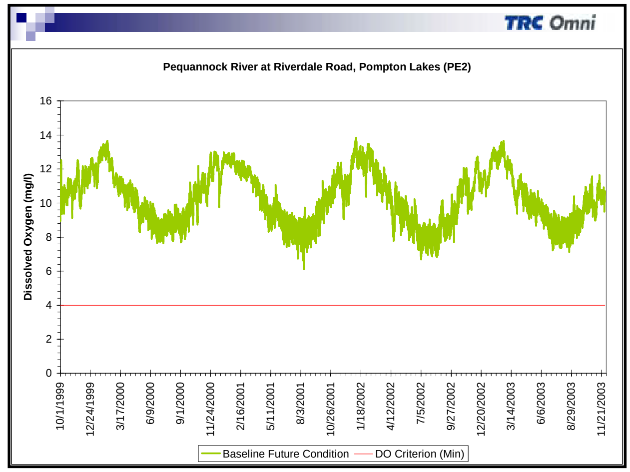
- Whippany River
  - minimal change in dissolved oxygen
- Rockaway River
  - minimal change in dissolved oxygen

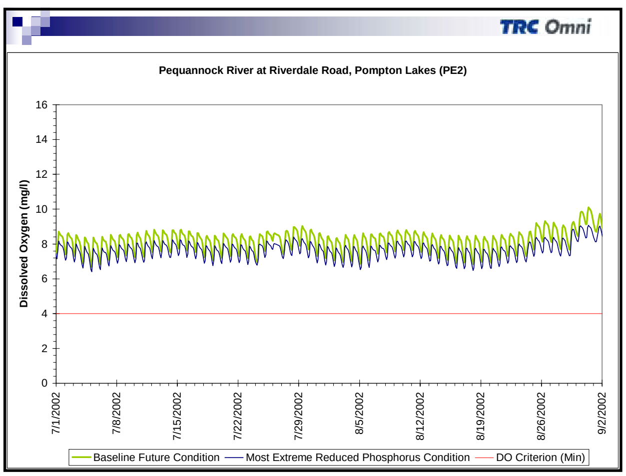
Wanaque, Pequannock, and Pompton Rivers

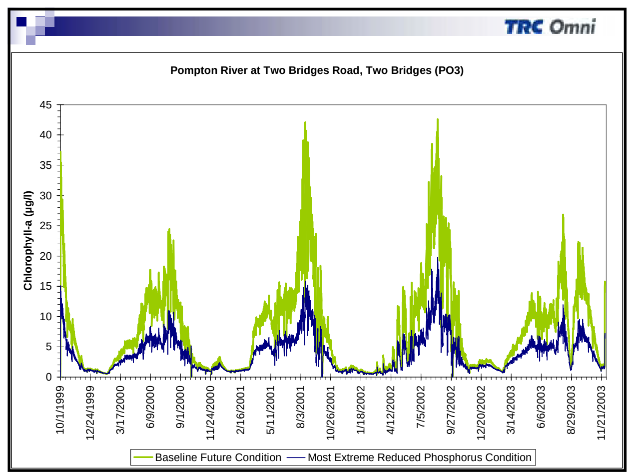
- Wanaque River at Pompton Lakes
- Pequannock River at Pompton Lakes
- Pompton River at Two Bridges

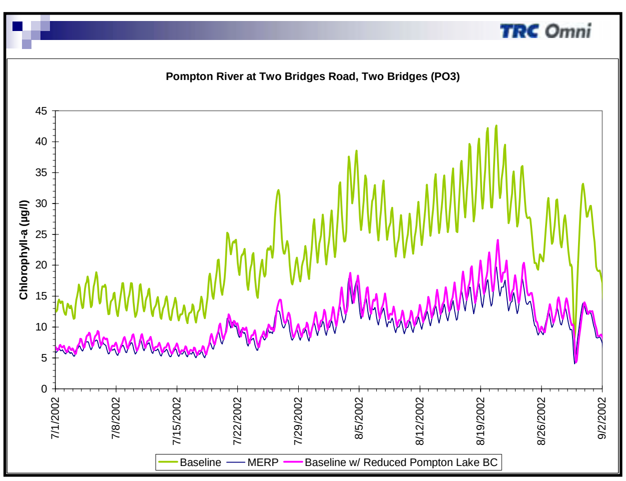


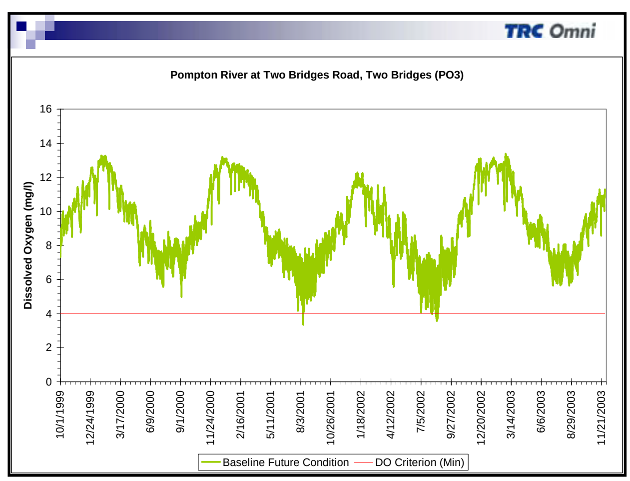

Wanaque River at Hamburg Turnpike, Pompton Lakes (WA2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)

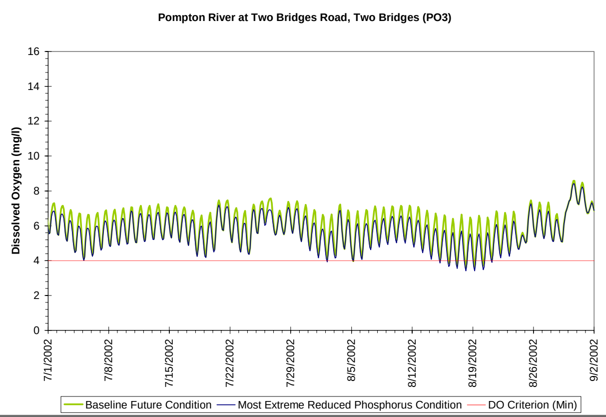

Pequannock River at Riverdale Road, Pompton Lakes (PE2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)


Pequannock River at Riverdale Road, Pompton Lakes (PE2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)


Pompton River at Two Bridges Road, Two Bridges (PO3)
Chlorophyll-a (µg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition


Pompton River at Two Bridges Road, Two Bridges (PO3)
Chlorophyll-a (µg/l)
Baseline
MERP
Baseline w/ Reduced Pompton Lake BC


Pompton River at Two Bridges Road, Two Bridges (PO3)
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)



Impact of Phosphorus Reductions:
Wanaque, Pequannock, and Pompton Rivers

- Wanaque and Pequannock Rivers
  - minimal change in dissolved oxygen
- Pompton River at Two Bridges
  - minimal change in dissolved oxygen
  - minor change in phytoplankton Chl-a
  - Phytoplankton in Pompton River driven by boundary condition in Ramapo River at Pompton Lake

Summary of Impact of Phosphorus Reductions on Water Quality

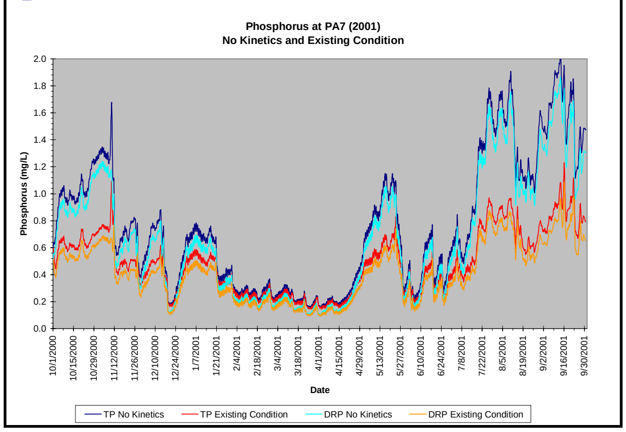
- Two locations where phosphorus reduction can improve water quality
  - Passaic River from Great Falls to Dundee Dam
    - Attenuated DO swing
    - Reduced phytoplankton peaks
  - Peckman River in West Paterson
    - Attenuated DO swing
    - minimum DO increased above DO criterion

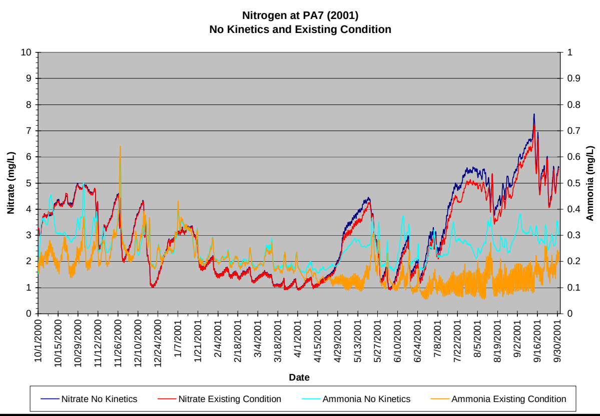
Sensitivity Analyses

- No Kinetics
- No Combined Sewer Overflow loading
- Baseflow and Headwater Concentrations
- Point Source Reduction Combinations
- Nonpoint Source Reduction Combinations

No Kinetics –
What happens if all kinetics are turned off?

- No Kinetics
  - Based on Existing Condition (Calibrated Model)
  - WY2001
  - Phosphorus and Nitrogen evaluated in Passaic River at Two Bridges
- Results
  - Kinetics affects phosphorus and ammonia by a factor of two
  - Kinetics not as important for nitrate

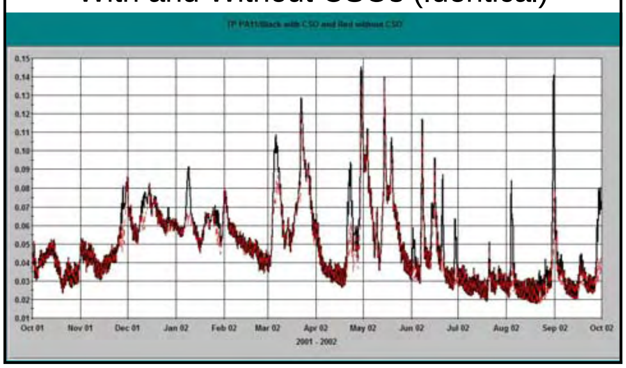




No CSOs – What happens if CSOs are removed?

- No Combined Sewer Overflow loading
  - Based on Existing Condition (Calibrated Model)
    - simulations performed in WY2001 and WY2003
    - phosphorus and dissolved oxygen compared in Passaic River at Dundee
  - Based on reduced phosphorus scenario (PS = 0.1 mg/l, NPS reduced 80%)
    - simulation performed in 2002
    - phosphorus, chlorophyll-a, and dissolved oxygen compared in Passaic River at Dundee
- Results
  - CSOs are not important contributions to either Existing Condition or low-phosphorus Future Condition

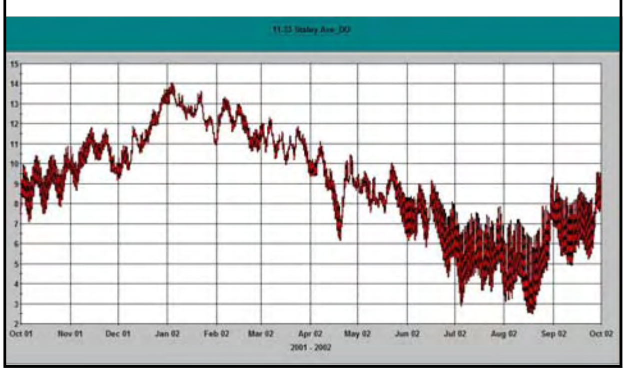
TP in Passaic River at Dundee (PA11) With and Without CSOs (Identical)



Baseflow and Passaic River Headwater – What happens if TP concentrations in both are reduced?

- Baseflow and Headwater Concentrations
  - Based on reduced phosphorus scenario (PS = 0.1 mg/l, NPS reduced 80%)
    - simulation performed in 2002
    - Baseflow TP reduced from 0.08 mg/l to 0.04 mg/l
    - Passaic headwater condition changed from 0.13 mg/l to 0.1 mg/l
    - Baseflow and headwater changed together
    - DO and chl-a evaluated at all critical locations (especially Passaic River at Chatham)
- Results
  - No effect on productivity (DO and Chl-a)
- Baseflow and Headwater concentrations refined for MERP condition

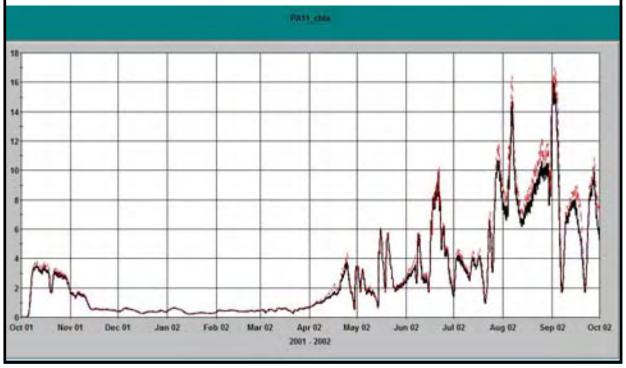
DO in Passaic River at Stanley Ave. (near Chatham) Headwater and Baseflow Loads Reduced (Identical)



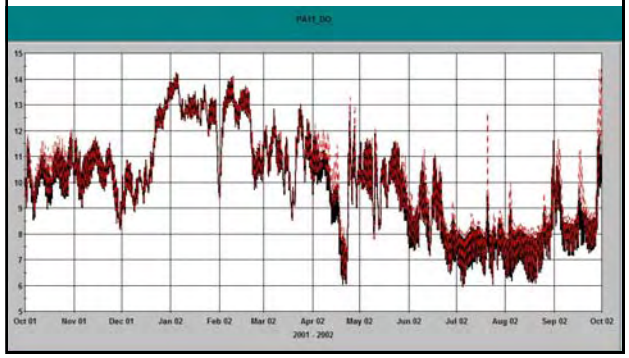
Nonpoint Source Reductions – How much do nonpoint sources affect productivity?

- Nonpoint Source Reduction Combinations
  - Based on reduced phosphorus scenario (PS = 0.1 mg/l, NPS reduced 80%)
    - simulation performed in 2002
    - NPS reduced by only 40%
    - NPS not reduced at all
    - DO and chl-a evaluated at all critical locations
- Results
  - Reduction of NPS by only 40% produces the same result as reduction by 80%
  - No reduction of NPS produces meaningless difference in productivity

Chl-a in Passaic River at Dundee (PA11) Nonpoint Sources Not Reduced (red)



DO in in Passaic River at Dundee (PA11) Nonpoint Sources Not Reduced (red)

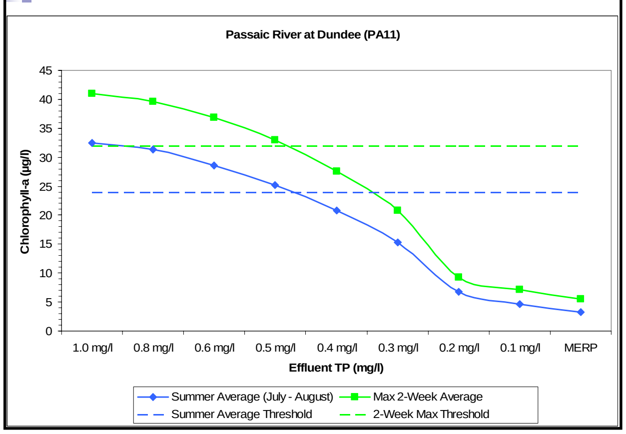


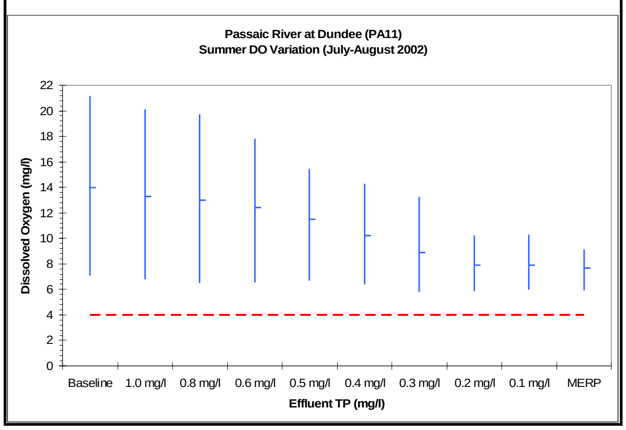
Summary of Sensitivity Analyses

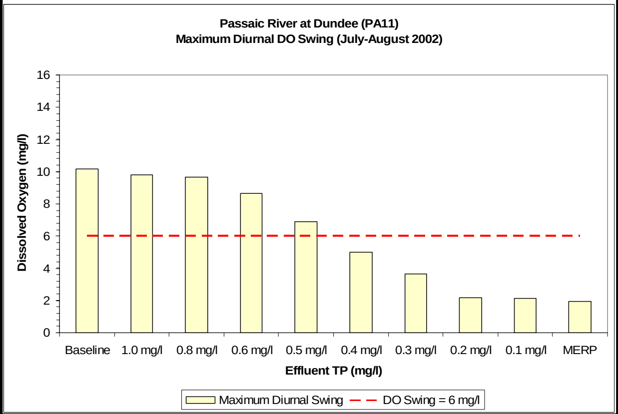
- Kinetics are important to overall nutrient balance
- Combined Sewer Overflows do not noticeably affect nutrient balances or associated productivity
  - also true for reduced phosphorus scenarios
- Variations in baseflow and headwater concentrations within realistic ranges will not affect productivity
- Nonpoint runoff sources have no noticeable impact on productivity

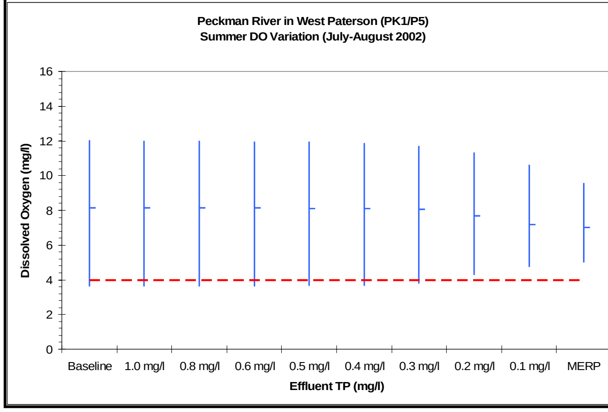
Effluent Phosphorus Reduction Sensitivity

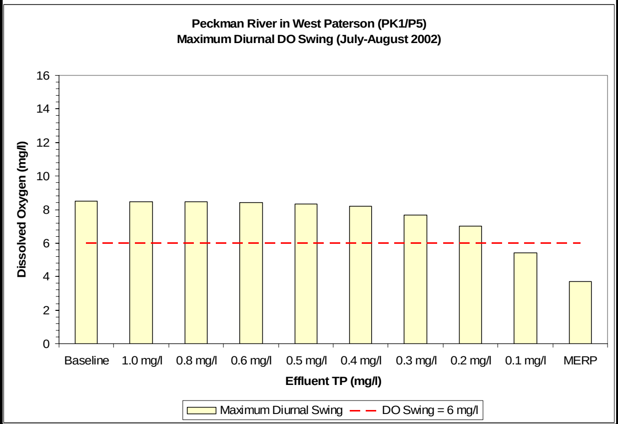
- Focus on areas where phosphorus reduction can improve water quality conditions
  - Passaic River above Dundee Dam
  - Peckman River near Confluence
- What level of effluent phosphorus reduction would result in acceptable water quality?
- Evaluation based on July and August 2002
  - Similar productivity observed in 2001







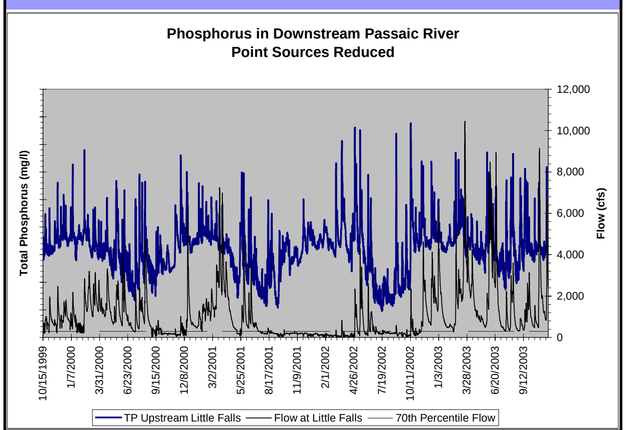




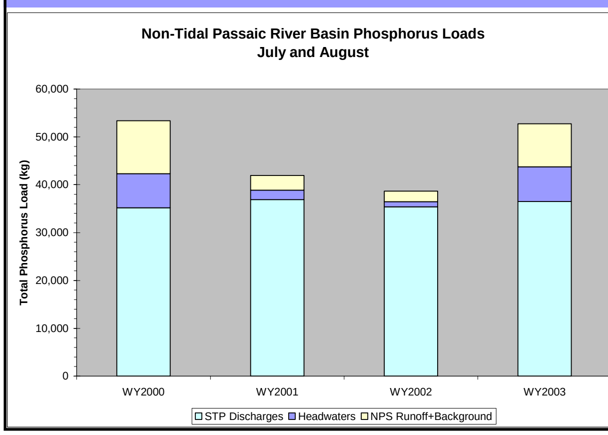
Why Develop Watershed-Specific Criteria?

- Disadvantages to applying existing criterion
  - Expensive point and nonpoint source reductions that do not result in water quality benefits
  - Most streams will always remain designated as impaired
- Advantages to Developing Watershed-Specific Criterion
  - Hard to imagine a stronger basis!
  - Allows for trading to optimize reductions
  - Provides basis for meaningful TMDL

Why it is not possible to set a meaningful phosphorus criterion in the stream



Why it is not possible to set meaningful phosphorus allocations based on load



A Path to Achieve Results

- Express criterion as a maximum diurnal DO variation
  - 6 mg/l maximum diurnal swing in Passaic River?
- Use TMDL to establish wasteload allocations for phosphorus
- Express TMDL and wasteload allocations as effluent concentration
  - 0.4 mg/l effluent TP concentration?
- Use seasonal wasteload allocations

Discussion

Non-Tidal Passaic River basin TMDL Process

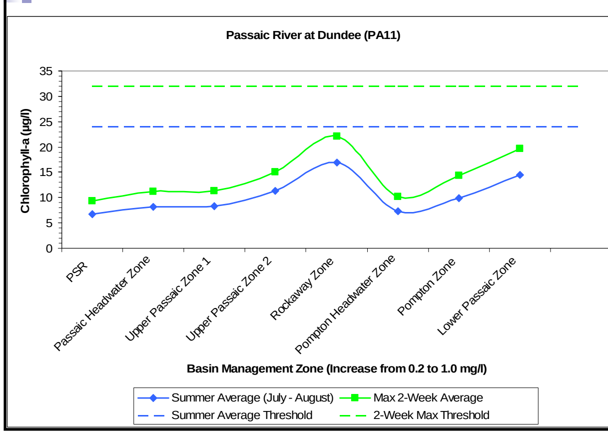
- Whippany River Watershed Process
  - Years of extensive technical work and public involvement
  - Interim Total Phosphorus Reduction Plan
    - Instream TP Criterion does not apply to Whippany River
- Statewide Watershed Management Planning
  - Passaic River TMDL Work Group
  - Technical Approaches document
    - Wanaque Reservoir TMDL Study
    - Pompton Lake TMDL Study
    - USGS Flow Model
  - Passaic River Basin Alliance
    - Work Plan

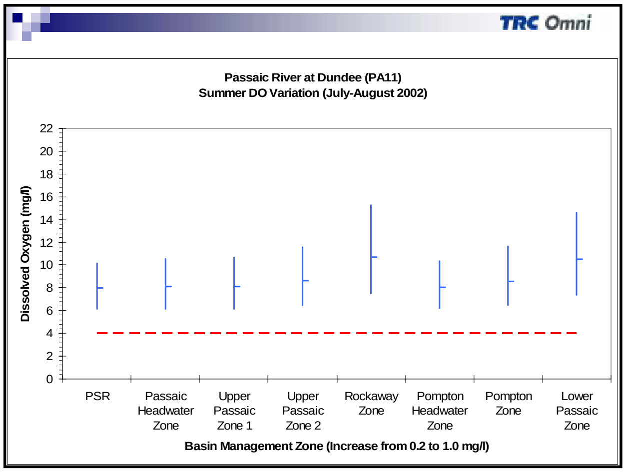
Basin TP Reduction Sensitivity

- Phosphorus Source Reduction Condition
  - Point sources set to 0.2 mg/l at permitted flows
  - Runoff NPS from developed land reduced by 40%
  - Other features same as MERP Condition
- Basin-Specific Impact Conditions
  - Effluent TP set to 1.0 mg/l in each of 7 zones
- WY2002 simulation
  - Impact to productivity at Passaic River at Dundee

"Management Zones"

- Passaic Headwater Zone
  - Bernards, Warren V, Warren IV
- Upper Passaic Zone 1
  - Long Hill, Warren I-II, Berkely Heights, Chatham Hill, Chatham-Glen
- Upper Passaic Zone 2
  - Madison-Chatham, Florham Park, Livingston, Caldwell
- Rockaway Zone
  - RVRSA, Morris-Butterworth, Morristown, Hanover, Par-Troy
- Pompton Headwater Zone
  - Wanaque Valley, Pompton Lakes
- Pompton Zone
  - Two Bridges
- Lower Passaic Zone
  - Wayne, Verona, Cedar Grove




TRC Omni
Passaic River at Dundee (PA11)
Summer DO Variation (July-August 2002)
Dissolved Oxygen (mg/l)
22
20
18
16
14
12
10
8
6
4
2
0
PSR
Passaic Headwater Zone
Upper Passaic Zone 1
Upper Passaic Zone 2
Rockaway Zone
Pompton Headwater Zone
Pompton Zone
Lower Passaic Zone
Basin Management Zone (Increase from 0.2 to 1.0 mg/l)

Non-Tidal Passaic River Basin Nutrient TMDL Study

Presented to:
Passaic River Basin Stakeholders

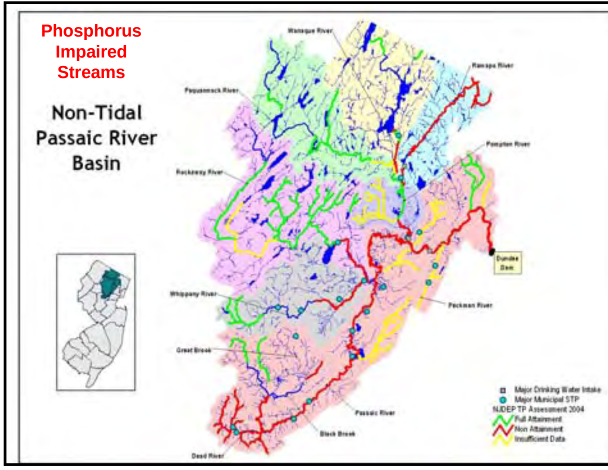
May 19, 2006

Agenda

- Purpose of Study
- Phase I – Watershed Monitoring
- Phase II – Watershed Modeling
  - Model Calibration
  - Impact of Phosphorus Reductions on Productivity
- Watershed-Specific Criteria
- Conclusion

Purpose of Study

- To provide a scientifically defensible approach to applying the nutrient criteria in the SWQS and establishing a nutrient Total Maximum Daily Load (TMDL) for the Non-Tidal Passaic River Basin
- To establish nutrient load reductions that will translate into environmental benefits as defined by either the SWQS or site specific criteria



Surface Water Quality Standards

- Lakes
  - Phosphorus as TP shall not exceed 0.05 mg/l in any lake, pond or reservoir, or in any tributary at the point where it enters such waterbody, except where site-specific criteria are developed where necessary to protect uses.
- Streams
  - Except as necessary to satisfy the Lakes criteria or where site specific criteria are developed, TP shall not exceed 0.1 mg/l in streams unless phosphorus is not limiting productivity and is not rendering waters unsuitable

Nutrient Policies 7:9B-1.5(g)

- Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation or otherwise render the waters unsuitable for the designated uses.
- The Department may establish site specific water quality criteria for nutrients in lakes, in addition to or more stringent, when necessary to protect designated uses.

Pollutants of Concern

- Total Phosphorus (Primary Pollutant of Concern)
  - Regulated due to potential to stimulate excessive plant and algal growth
    - Segment is listed where stream concentrations exceed 0.1 mg/l
    - SWQS also contain narrative criteria (evaluated after listing)
  - Phosphorus is a causal parameter
    - Response parameters include dissolved oxygen and plant/algal growth
- Total Nitrogen
  - Need tool to translate load allocation from NY/NJ Harbor TMDL to load and wasteload allocations throughout the system

Phase I: Watershed Monitoring

- Monitoring Program
  - Data to Verify Impairment and Establish Critical Locations
  - Data to Calibrate and Validate Watershed Model
  - Data to Characterize Nutrient Sources
    - point
    - nonpoint
- 11”×17” Handout shows all sampling locations
- Prior Presentations on monitoring results - April 27, 2004 and September 28, 2004

Water Quality Data (Collected in 2003)

- To identify impairments
  - Diurnal DO, pH, temperature; phytoplankton; periphyton
- To calibrate and validate model
  - Diurnal DO, pH, temperature; phytoplankton; periphyton
  - Grab Chemistry: pH, temperature, DO, alkalinity, $CBOD_5$, P-series, N-series, iron, TDS, TSS, TOC, turbidity
- To characterize nutrient sources
  - STPs: pH, temperature, DO, alkalinity, $CBOD_5$, P-series, N-series, TDS, TSS, TOC
  - Stormwater: alkalinity, $CBOD_5$, P-series, N-series, TDS, TSS, TOC
- Additional Data
  - Stream cross sections
  - SOD measurements
  - Diurnal solar radiation (light intensity)
  - Underwater light extinction

Water Quality Data (Collected in 2004)

- Additional data so could model each tributary explicitly rather than as a boundary condition
- Rockaway River
  - 4 stream locations plus one tributary location
  - one diurnal event
- Peckman River
  - 5 stream locations plus two tributary locations
  - one diurnal event
- Dead River
  - 4 stream locations plus one tributary location
  - one diurnal event

Other Calibration / Validation Data

- NJDEP Diurnal DO Measurements
  - Passaic River at Chatham 2002
  - Passaic River at Little Falls 2002
  - Pompton River 1999 and 2002
- PVSC Historical Phytoplankton Chlorophyll-a
  - Passaic River from Great Falls to Dundee
- USGS Continuous DO and Temperature Measurements
  - Ramapo River at Pompton Lakes
  - Passaic River at Two Bridges
- PVWC Historical Stream Chemistry Data
- Stream Chemistry Data from Dischargers

General Observations and Assessment

- Upper and Mid-Passaic River Watershed
  - Phosphorus is very high
  - Productivity is low
    - Few macrophytes
    - Diurnal DO swings are generally small to none
    - Naturally low DO – productivity generally increases average DO
    - Chatham is exception
- Pompton River Watershed
  - Phosphorus is generally low
  - Productivity is low to moderate
  - DO is higher than Passaic
- Lower Passaic River Watershed
  - Phosphorus is very high
  - Productivity is very high under critical conditions
  - Macrophytes and phytoplankton are important

Phase II: Watershed Modeling

- Watershed Model Purpose and Overview
- Calibration and Validation Summary

Watershed Model Purpose

- Purpose
  - To relate point and nonpoint sources of nutrients to water quality impacts under a variety of conditions, including critical conditions
- Critical Water Quality Indicators
  - Dissolved oxygen was identified as a primary water quality indicator
  - Phytoplankton (measured as water column chlorophyll-a)
  - Phosphorus concentration and loads
  - Nitrogen components (ammonia, nitrate, and organic nitrogen)

Nutrient Response Indicators

- Phosphorus
  - Impacts water quality by stimulating excessive plant and algae growth
- Dissolved oxygen (DO)
  - DO influenced by BOD and SOD in addition to photosynthesis
  - Excessive plant and algae growth results in diurnal swing due to photosynthesis/respiration cycle
- Phytoplankton (chlorophyll-a)
  - Excessive phytoplankton growth results in algal blooms
- Study emphasized impact of phosphorus on dissolved oxygen and phytoplankton Chl-a

Model Overview

- Flow model
  - DA-FLOW one-dimensional flow model by USGS
  - modified to account for mixing at confluence
- Water quality model
  - one dimensional dynamic simulation using WASP 7 with EUTRO
  - large-scale unified system model
- Watershed Model Integration Tool (WAMIT)
  - Nonpoint source simulation using flow-weighted EMCs
  - DA-FLOW and WASP integration

Model Inputs

- Basin Information
- NPS Loads
- Boundary Conditions
  - Discharger flows and quality
  - Water supply diversions
  - Headwater boundaries
- Time series data
  - solar radiation
  - stream temperature
- Water quality kinetic parameters
  - Local and global

Watershed Model Spatial and Temporal Extent

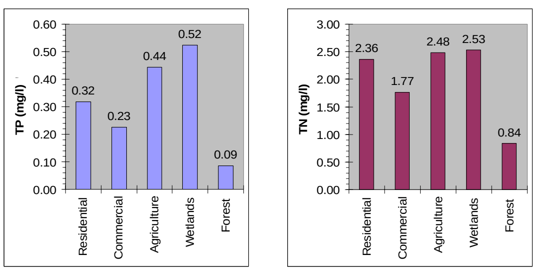
- Spatial Extent (next slide)
  - Location of continuous streamflow gauges that drive the flow model
  - Inclusion of STP discharges that represent substantial phosphorus sources
  - Inclusion of streams designated by NJDEP as impaired by phosphorus
- Temporal Extent (October 1, 1999 – November 30, 2003)
  - WY2000 – "normal"
  - WY2001 – dry
  - WY2002 – extreme drought
  - WY2003 – wet

Modeled Segments of The Passaic Basin

Nonpoint Source Loads

- Hydrograph Separation
  - Contributing runoff
  - Contributing baseflow
- Runoff Loads
  - Flow-weighted runoff EMC × contributing runoff
  - Curve number method only used to weight EMC
- Baseflow Loads
  - Baseflow concentration × contributing baseflow

Runoff EMCs

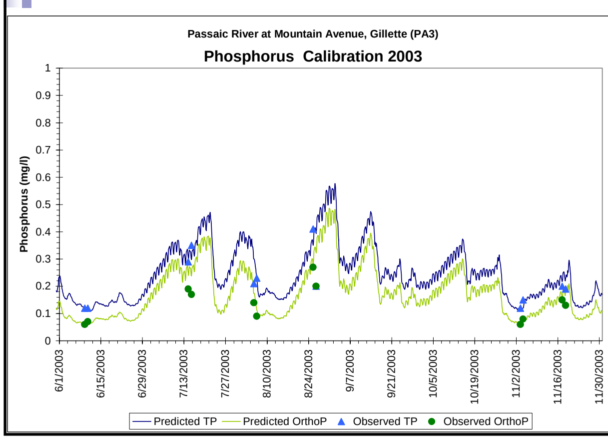


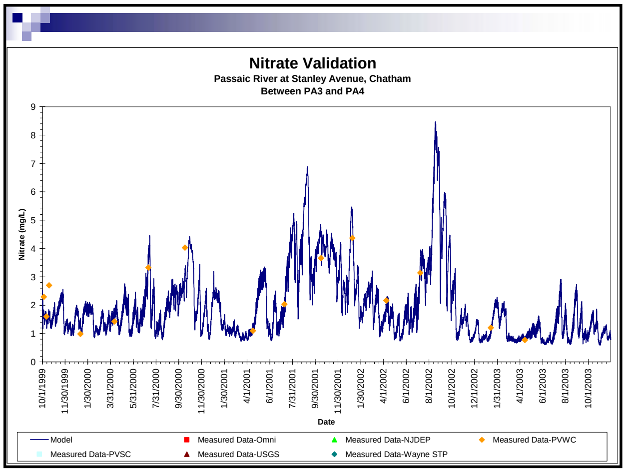
Baseflow Concentrations

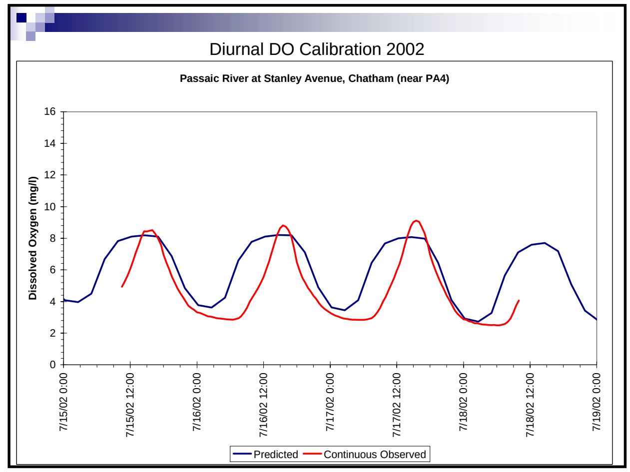
Branch Groupings	Basis	TP (mg/l)	OrthoP (mg/l)
Forest Dominated (Wanaque - 2)	RAB, HAB, PRB, PA1	0.045	0.021
Major Tribs(3,4,5,6,7,13)	WIB, TBB, CrookB1, WI1	0.054	0.023
Upper Passaic / Minor Tribs (8,9,10,11,12,14)	DRB, WIB, SBB, TBB	0.063	0.022
Lower Passaic (15,16,17)	SBB, P2	0.060	0.031

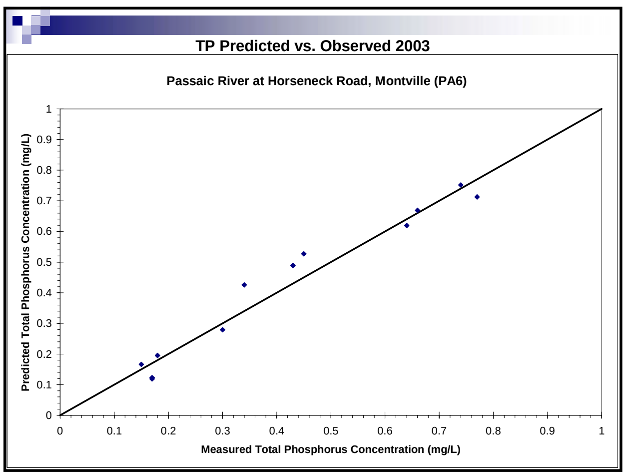
Calibration and Validation Data

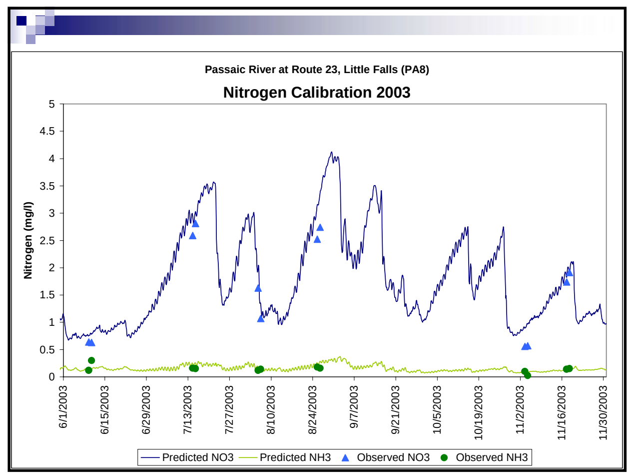
- Calibration Data
  - TRC Omni data collected in 2003
  - NJDEP diurnal DO data collected 2002
  - PVSC chlorophyll-a data from 2001 and 2002
- Validation Data
  - TRC Omni, NJDEP, USGS, PVSC, PVWC data collected from 1999 to 2003

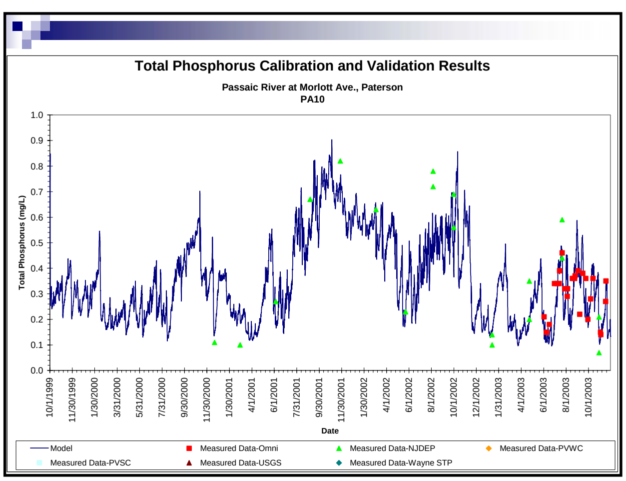


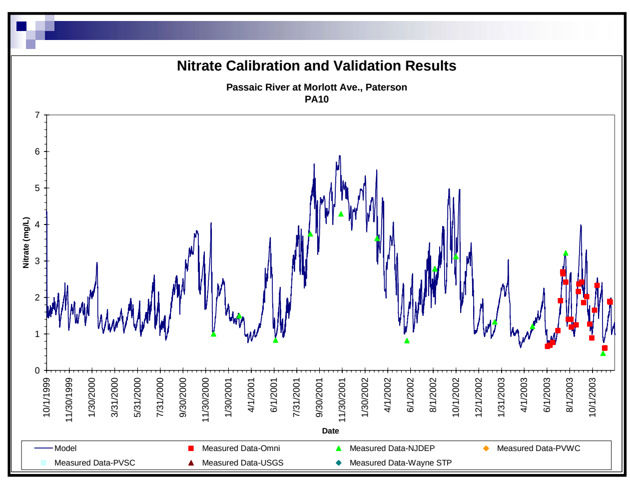

Nitrate Validation
Passaic River at Stanley Avenue, Chatham
Between PA3 and PA4
Nitrate (mg/L)
Date
Model
Measured Data-Omni
Measured Data-NJDEP
Measured Data-PVWC
Measured Data-PVSC
Measured Data-USGS
Measured Data-Wayne STP


Diurnal DO Calibration 2002
Passaic River at Stanley Avenue, Chatham (near PA4)
Dissolved Oxygen (mg/l)
Predicted
Continuous Observed

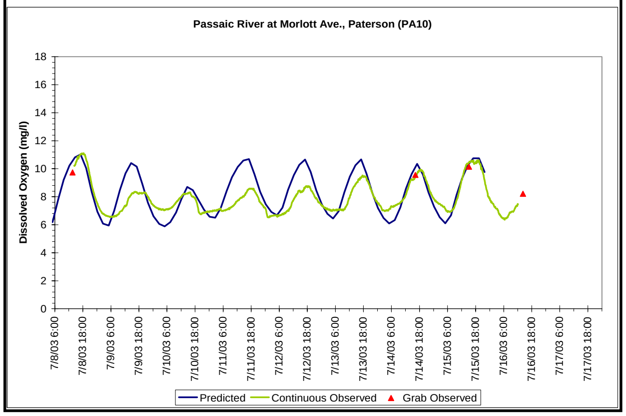

TP Predicted vs. Observed 2003
Passaic River at Horseneck Road, Montville (PA6)
Predicted Total Phosphorus Concentration (mg/L)
Measured Total Phosphorus Concentration (mg/L)

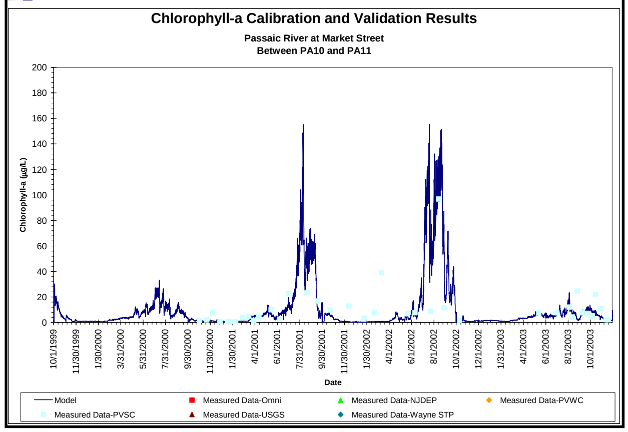

Passaic River at Route 23, Little Falls (PA8)
Nitrogen Calibration 2003
Nitrogen (mg/l)
Predicted NO3
Predicted NH3
Observed NO3
Observed NH3

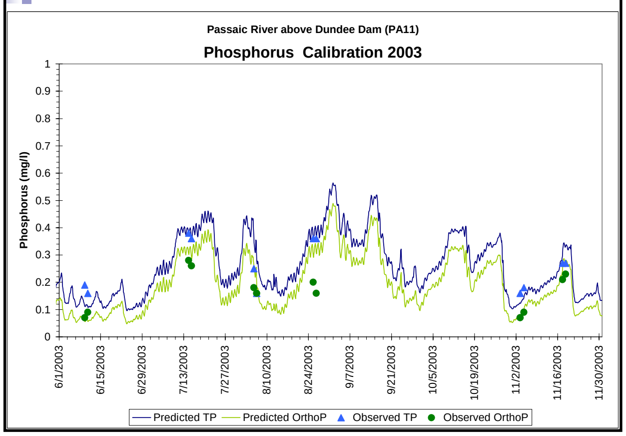

Total Phosphorus Calibration and Validation Results
Passaic River at Morlott Ave., Paterson
PA10
Total Phosphorus (mg/L)
Date
Model
Measured Data-Omni
Measured Data-NJDEP
Measured Data-PVWC
Measured Data-PVSC
Measured Data-USGS
Measured Data-Wayne STP

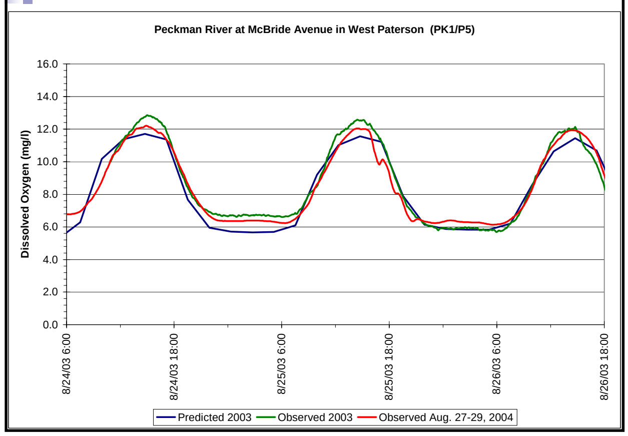

Nitrate Calibration and Validation Results
Passaic River at Morlott Ave., Paterson
PA10
Nitrate (mg/L)
Date
Model
Measured Data-Omni
Measured Data-NJDEP
Measured Data-PVWC
Measured Data-PVSC
Measured Data-USGS
Measured Data-Wayne STP

Diurnal DO Calibration Results







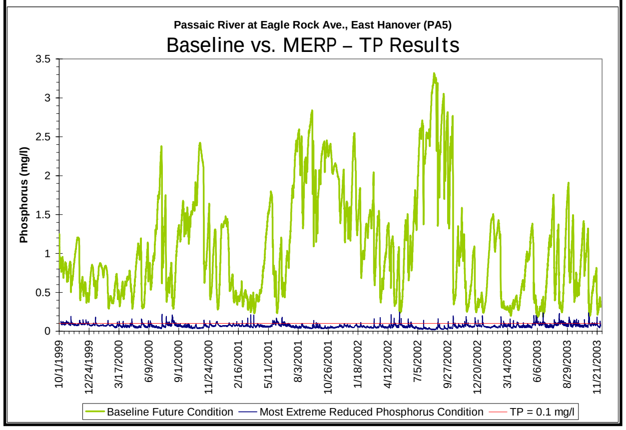


Calibration and Validation Summary

- System-wide water quality model calibrated and validated for:
  - nutrients
  - dissolved oxygen
  - chlorophyll-a
- Impact of point and nonpoint source reductions on dissolved oxygen, phosphorus, and chlorophyll-a can be calculated

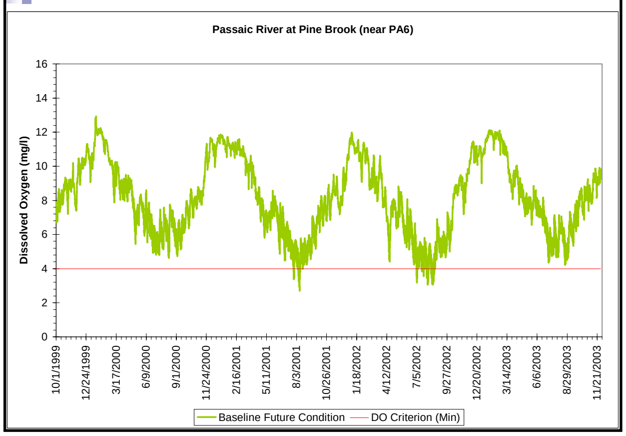
Impact of Phosphorus Reductions on Productivity

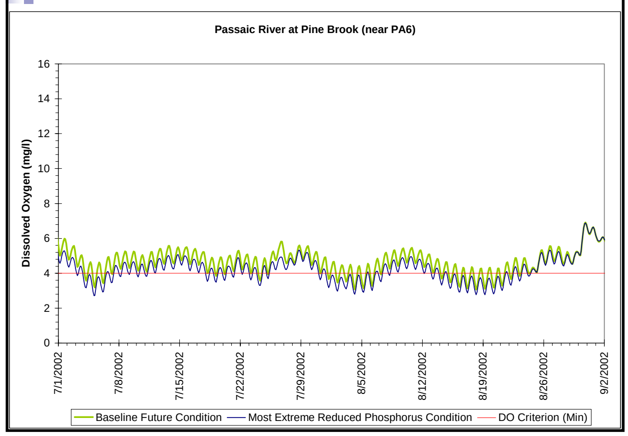
- Baseline Future Condition – Upper Bound
  - Permitted STP flows and concentrations
  - Headwater lakes with TMDLs set to 0.05 mg/l TP
  - Future diversion scenario at full allocation for NJDWSC
- Most Extreme Reduced Phosphorus Condition (MERP) – Lower Bound
  - Permitted flows for point sources
  - Point Sources set to 0.05 mg/l TP
  - Phosphorus loads from urban and agricultural land uses reduced by 80%
  - Incorporated model enhancements

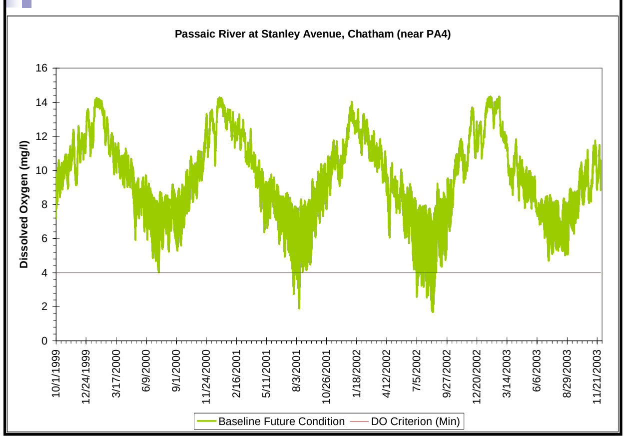


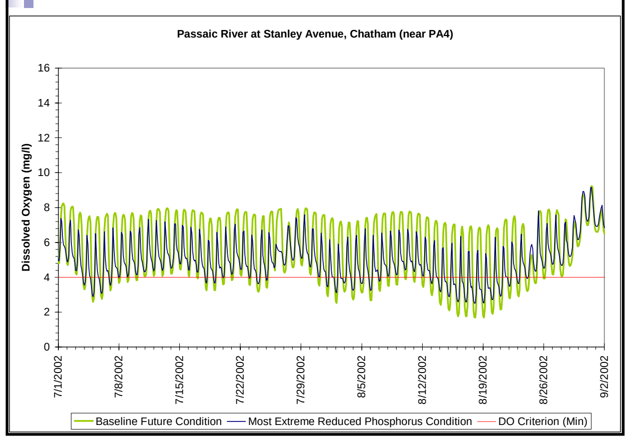
Passaic River Mainstem

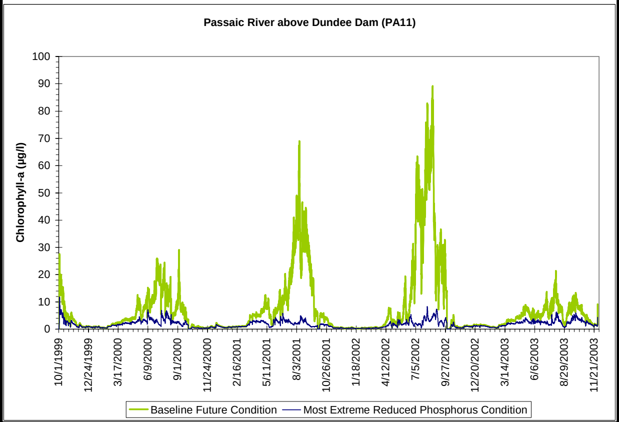
- Passaic Headwaters to Pompton Confluence
  - Passaic River at Pine Brook (most representative) [PA6]
  - Passaic River at Stanley Avenue, Chatham (higher productivity) [~ PA4]
- Downstream Passaic River (Little Falls to Dundee)
  - Passaic River at Dundee [PA11]

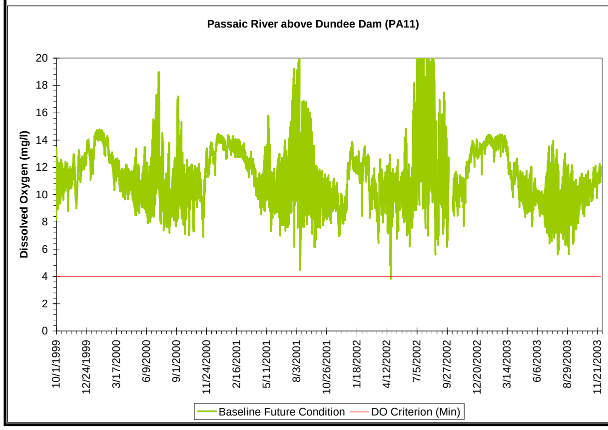


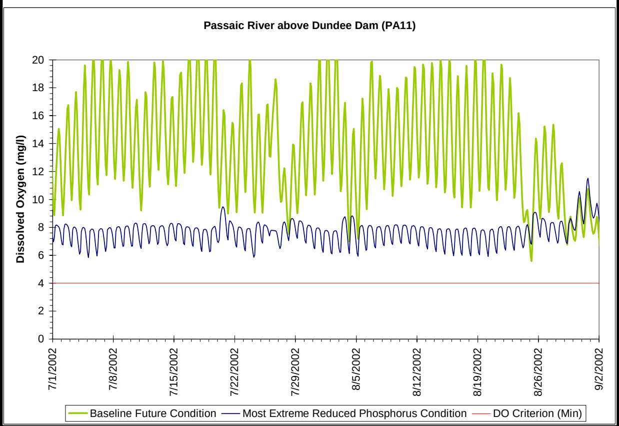










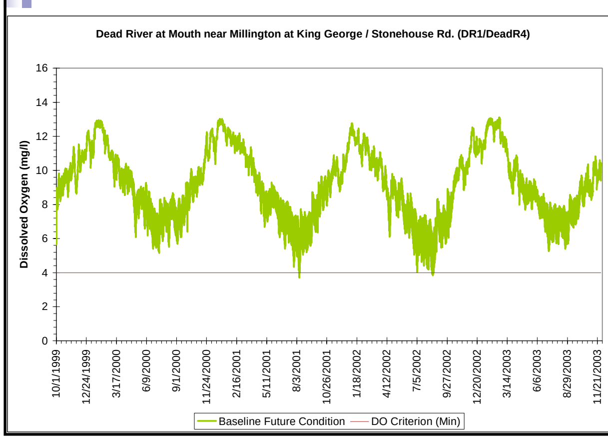


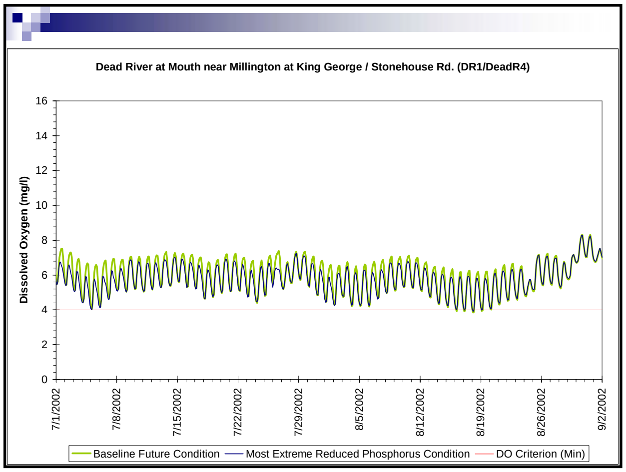
Phosphorus Reduction Impact Summary: Passaic River Mainstem

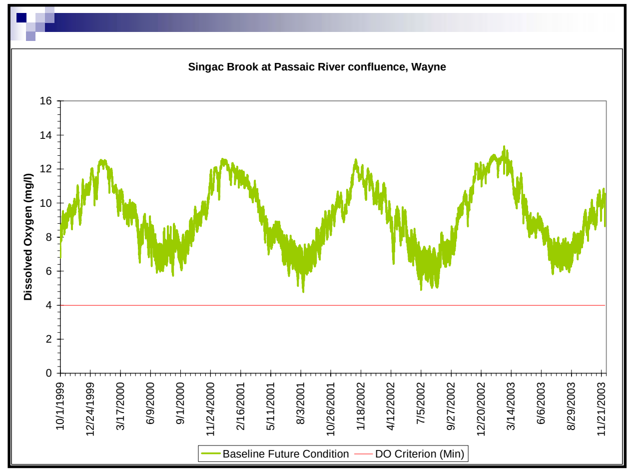
- Passaic Headwaters to Pompton Confluence
  - minimal change in dissolved oxygen
- Downstream Passaic River (Little Falls to Dundee)
  - chlorophyll-a peaks reduced substantially
  - diurnal DO variation reduced substantially
  - much more desirable DO and phytoplankton condition

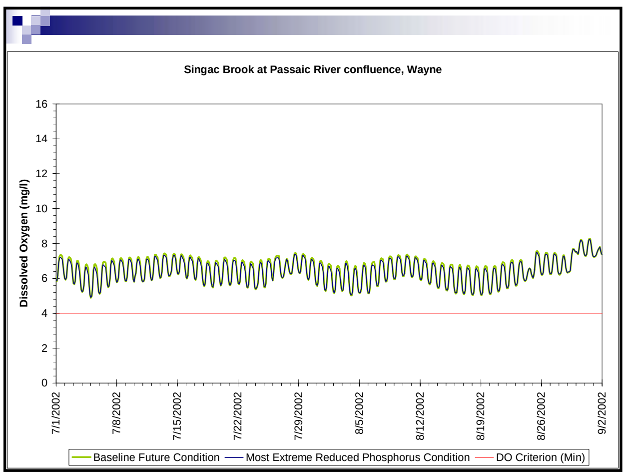
Dead River, Singac Brook, Peckman River

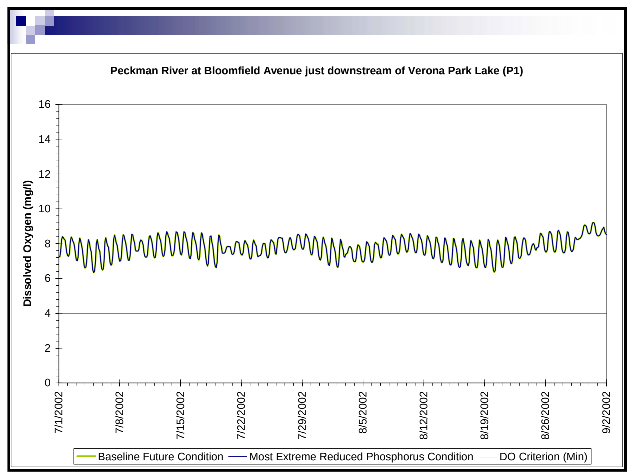
- Dead River near Millington
- Singac Brook at Wayne
- Peckman River
  - Representative Locations in Verona and Cedar Grove (P1, P2, P3, P4)
  - Peckman River in West Paterson (PK1/P5)

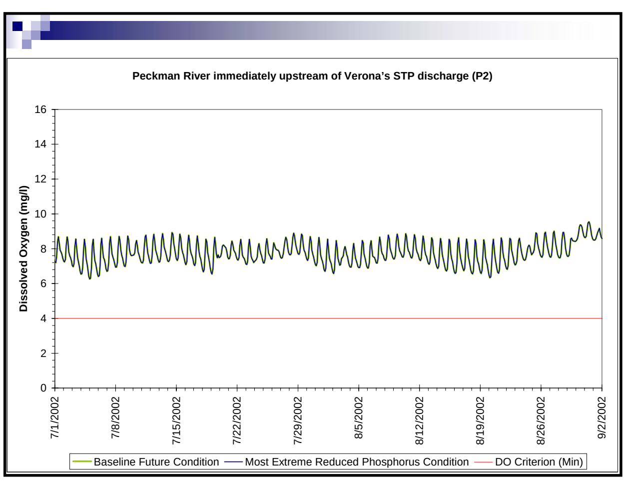


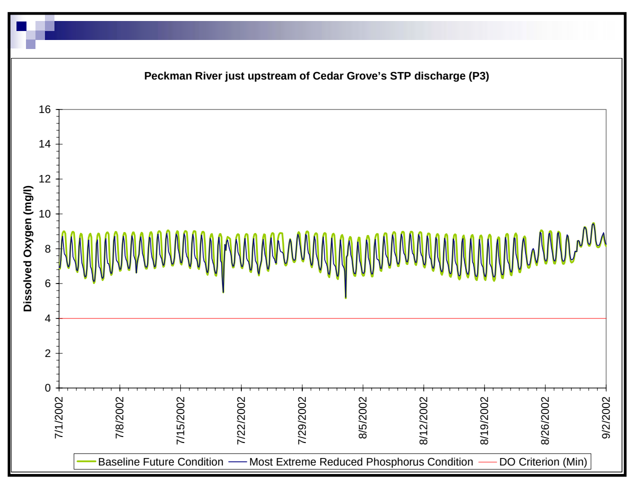

Dead River at Mouth near Millington at King George / Stonehouse Rd. (DR1/DeadR4)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)

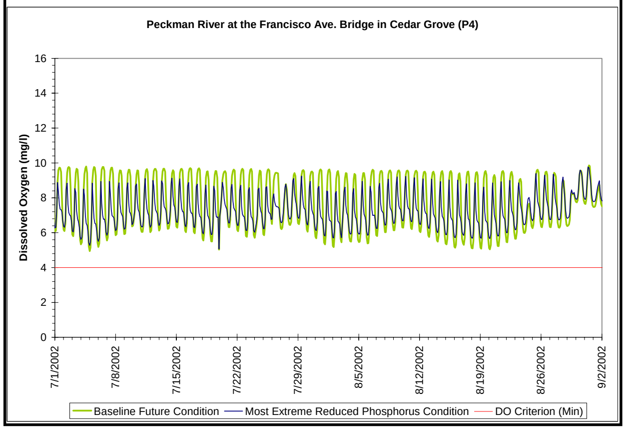

Singac Brook at Passaic River confluence, Wayne
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)

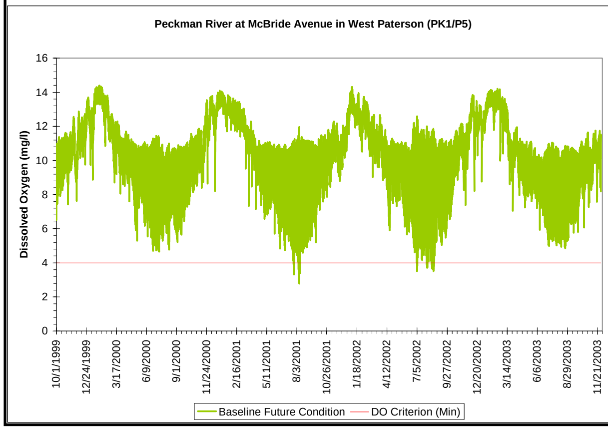

Singac Brook at Passaic River confluence, Wayne
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)

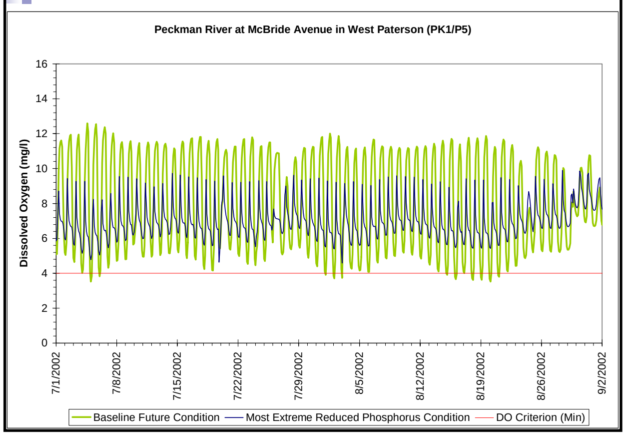

Peckman River at Bloomfield Avenue just downstream of Verona Park Lake (P1)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)

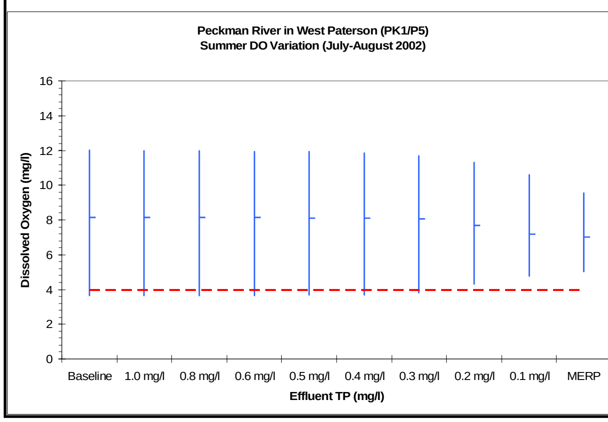

Peckman River immediately upstream of Verona's STP discharge (P2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)


Peckman River just upstream of Cedar Grove's STP discharge (P3)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)







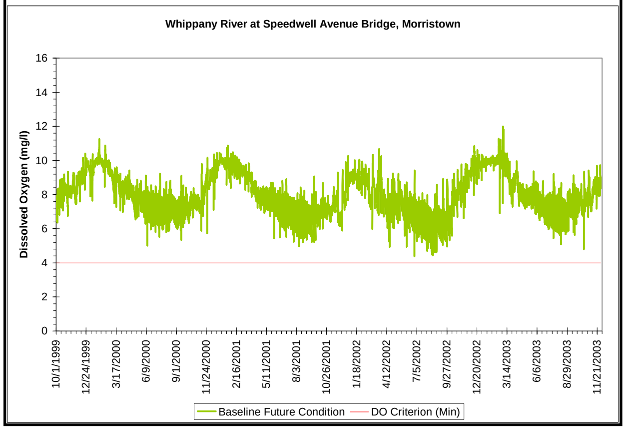


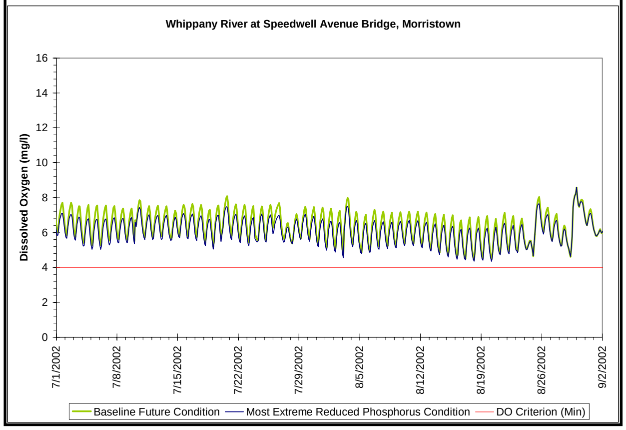
Phosphorus Reduction Impact Summary: Dead River, Singac Brook, Peckman River

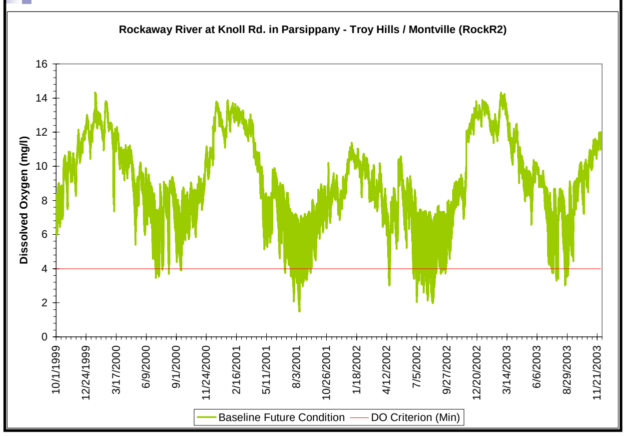
- Dead River
  - Minimal change in dissolved oxygen
- Singac Brook
  - No discernible change in dissolved oxygen
- Peckman River (Generally)
  - Little to no change in dissolved oxygen
  - Healthy dissolved oxygen levels
- Peckman River in West Paterson (less than ½ mile)
  - Substantial diurnal DO swings
  - Theoretical improvement with extremely high phosphorus reduction
    - Sensitivity to phosphorus reduction very low compared to model accuracy

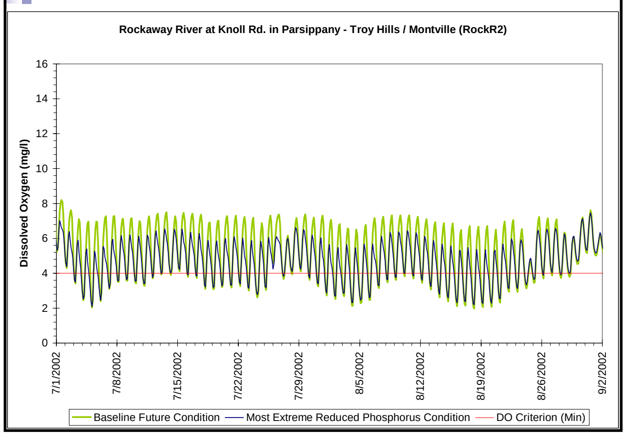
Whippany and Rockaway Rivers

- Whippany River at Speedwell Avenue Bridge in Morristown
- Rockaway River at Knoll Rd. in Parsippany – Troy Hills







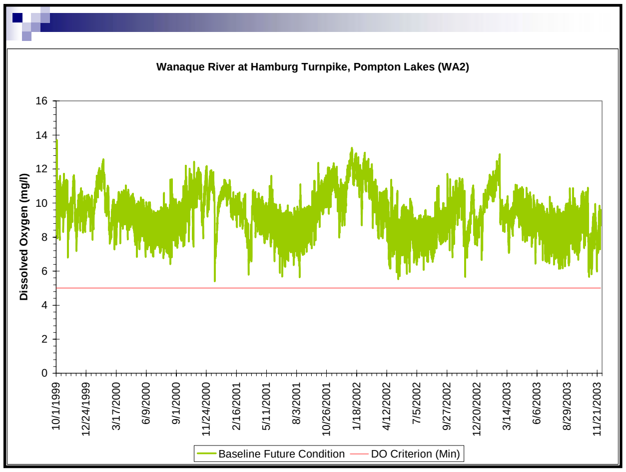


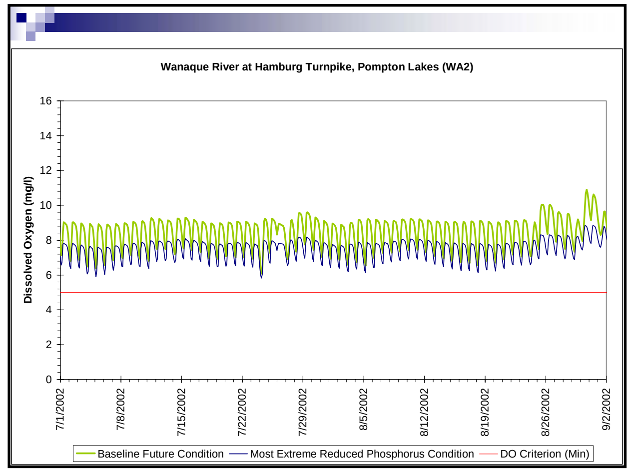
Phosphorus Reduction Impact Summary: Whippany and Rockaway Rivers

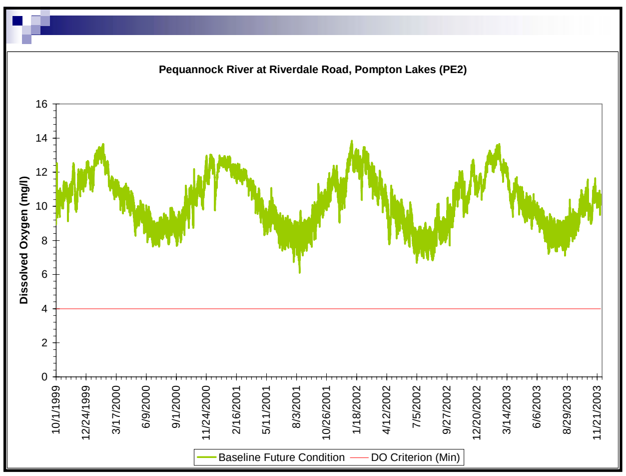
- Whippany River
  - minimal change in dissolved oxygen
- Rockaway River
  - minimal change in dissolved oxygen

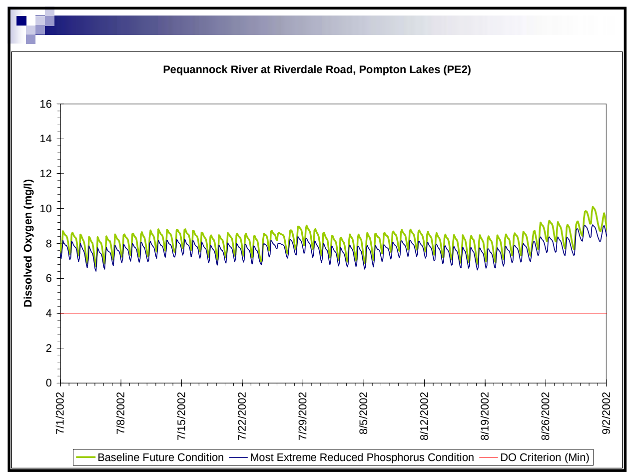
Wanaque, Pequannock, and Pompton Rivers

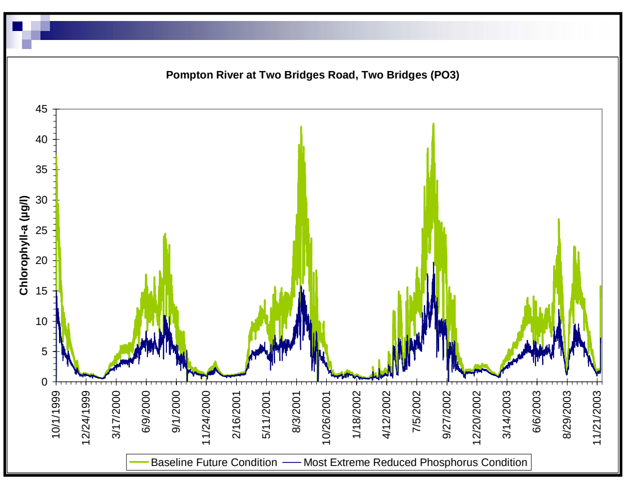
- Wanaque River at Pompton Lakes
- Pequannock River at Pompton Lakes
- Pompton River at Two Bridges

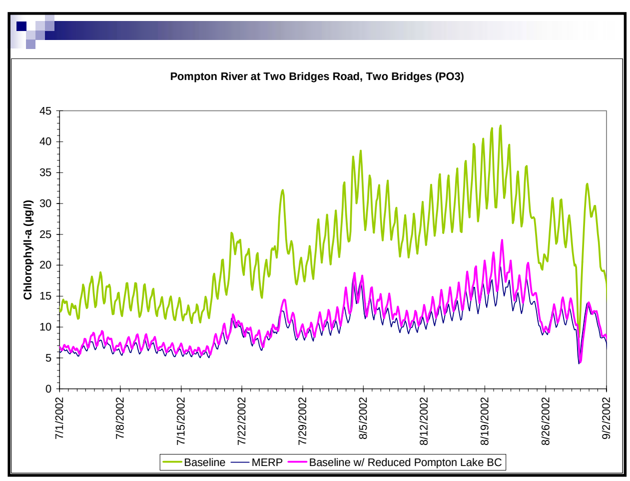

Wanaque River at Hamburg Turnpike, Pompton Lakes (WA2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)

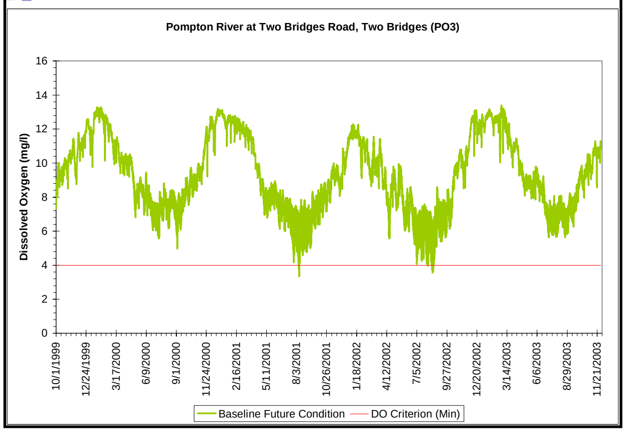

Wanaque River at Hamburg Turnpike, Pompton Lakes (WA2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)

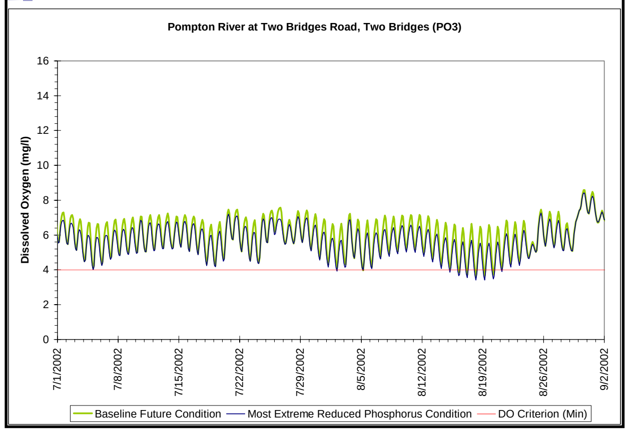

Pequannock River at Riverdale Road, Pompton Lakes (PE2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
DO Criterion (Min)


Pequannock River at Riverdale Road, Pompton Lakes (PE2)
Dissolved Oxygen (mg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition
DO Criterion (Min)


Pompton River at Two Bridges Road, Two Bridges (PO3)
Chlorophyll-a (µg/l)
Baseline Future Condition
Most Extreme Reduced Phosphorus Condition


Pompton River at Two Bridges Road, Two Bridges (PO3)
Chlorophyll-a (µg/l)
Baseline
MERP
Baseline w/ Reduced Pompton Lake BC





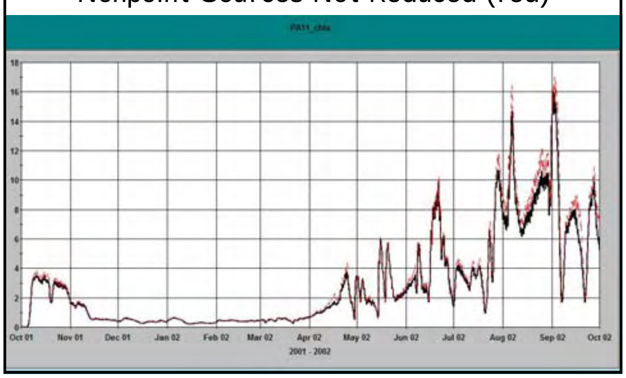
Phosphorus Reduction Impact Summary: Wanaque, Pequannock, and Pompton Rivers

- Wanaque and Pequannock Rivers
  - minimal change in dissolved oxygen
- Pompton River at Two Bridges
  - minimal change in dissolved oxygen
  - minor change in phytoplankton Chl-a
  - Phytoplankton in Pompton River driven by boundary condition in Ramapo River at Pompton Lake

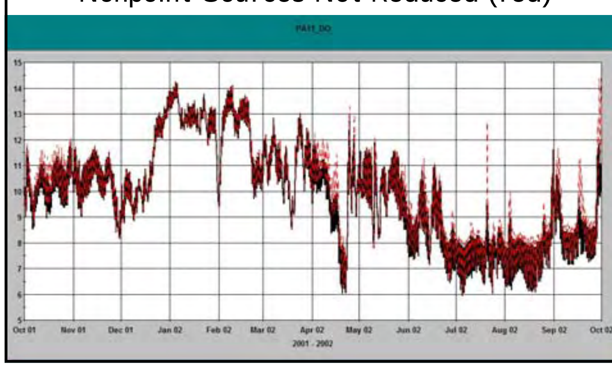
How do nonpoint sources affect productivity in the Passaic River?

- Nonpoint Source Reduction Combinations
  - Based on reduced phosphorus scenario
    (PS = 0.1 mg/l, NPS reduced 80%)
    - NPS reduced by 40%
    - NPS not reduced at all
    - DO and chl-a evaluated at all critical locations
  - Results
    - 40% NPS reduction produces the same productivity as 80% NPS reduction
    - 0% NPS reduction produces very minor difference in productivity compared with 80% NPS reduction
    - However, downstream loads are reduced with NPS reductions, which matters for the Wanaque Reservoir

Chl-a in Passaic River at Dundee (PA11) Nonpoint Sources Not Reduced (red)



DO in in Passaic River at Dundee (PA11) Nonpoint Sources Not Reduced (red)

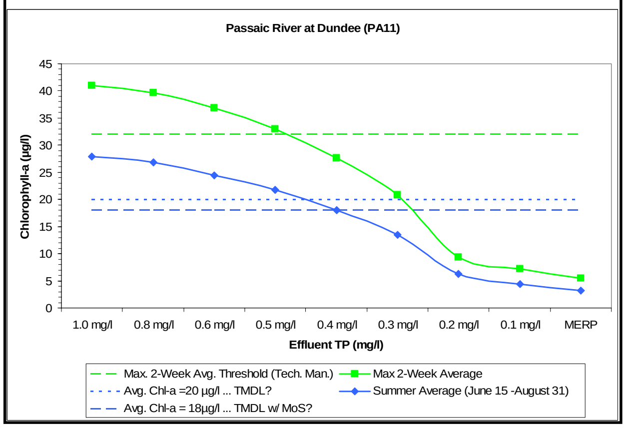


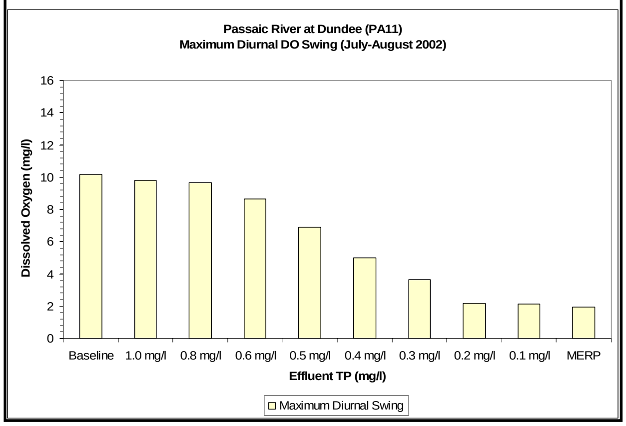
Critical Locations

- Based on assessment of stream response and the Wanaque Reservoir TMDL, critical locations have been identified as follows:
  - Wanaque Reservoir
  - Passaic River at Dundee
- Other areas of concern:
  - Passaic River at Chatham
  - Peckman River at mouth
- TP numeric criterion does not apply in the rest of the system based on the application of the narrative criteria

Endpoints

- Establishing endpoints based on the response indicators is proposed
- Chlorophyll-a selected:
  - Wanaque Reservoir – 10 µg/l seasonal average
  - Passaic at Dundee – 20 µg/l seasonal average





Allocation Scenarios

- Critical locations and proposed endpoints drive different load reduction requirements
- System kinetics suggest breaking down into management zones
- Load reductions can be achieved by a combination of wastewater treatment and treatment of water diverted to the reservoir
- Need to assess cost effectiveness of achieving load reductions, recognizing that the public pays

Next Steps

- Integrate with Wanaque Reservoir TMDL to determine final load reductions needed for each endpoint
- Propose TMDL with site specific criteria
- EPA must approve site specific criteria; TMDL approval would be contingent on adoption of criteria in rule
- Implementation through permit modifications and NPS reduction measures

Discussion

APPENDIX B

Supplemental Data Reports for Dead, Rockaway, and Peckman Rivers

TRC Omni Environmental Corporation

Research Park
321 Wall Street
Princeton, New Jersey 08540-1515
Telephone 609-924-8821
Facsimile 609-924-8831

February 21, 2005

VIA EMAIL AND USPS

Peter Messina, P.E., P.P.
Bernards Township Sewerage Authority Administrator
277 South Maple Avenue
Basking Ridge, New Jersey 07920

**RE: PASSAIC NUTRIENT TMDL STUDY
RESULTS OF ADDITIONAL DEAD RIVER MONITORING**

Dear Mr. Messina:

As you recall, the Bernards Township Sewerage Authority contracted with TRC Omni Environmental Corporation (TRC Omni) to complete supplemental sampling on the Dead River in 2004 to expand the database that had previously been developed by TRC Omni during 2003 on behalf of the New Jersey Department of Environmental Protection (NJDEP). This work is part of a Nutrient Total Maximum Daily Load (TMDL) Study on the Non-Tidal Passaic River Basin. The purpose of this letter is to summarize the results of the additional data collected on BTSA's behalf.

BACKGROUND

During the summer and fall of 2003, TRC Omni sampled the Dead River, the Bernards Township Wastewater Treatment Facility effluent, and numerous other STP and stream locations within the Passaic Basin. Sampling in the Dead River (near its confluence with the Passaic River at King George Road) showed very high total phosphorus concentrations and possible slight violations of the 4 mg/l minimum instream dissolved oxygen criterion. Because of those findings, the Dead River was identified as a critical location with respect to nutrient productivity in the Passaic Basin.

In order to determine whether phosphorus reductions in the Dead River Watershed would translate into an environmental benefit, we are developing a water quality model of the Dead River. That model will allow us to understand how phosphorus loading reductions will influence the river system. Samples collected during 2003 were obtained only near its confluence with the Passaic. Therefore, the data collected during 2004 with BTSA funding provides additional instream data at intermediate points within the system in order to develop a far stronger model and a better understanding of phosphorus dynamics and water quality impacts in the Dead River.

2004 SAMPLING PROGRAM OVERVIEW

A Quality Assurance Sampling Plan was prepared by TRC Omni and approved by NJDEP for the sampling performed for this project. We collected instream water quality and hydraulic data on two occasions at four locations on the Dead River (DeadR1 – DeadR4 on Figure 1) and at one location on Harrison Brook (HarrB1 on Figure 1). In addition, sampling was completed once on the Bernards and Warren (Stage IV) STP effluents. Although an effluent sample from the Warren Stage V plant was collected, data are not available for this facility, as the sample was lost by the laboratory. Fortunately, we have other data for that facility to adequately characterize its effluent quality

At each of the sampling locations, grab samples were collected with the following parameters analyzed in the laboratory: nitrogen series (ammonia, TKN, nitrate, and nitrite), phosphorus series (total phosphorus and dissolved reactive phosphorus), $CBOD_5$, total suspended solids (TSS), and total dissolved solids (TDS). Also, the following in-situ parameters were measured: pH, temperature, dissolved oxygen, and stream flow (based on cross-sectional depth and velocity measurements). At four of the stream sampling locations (DeadR2, DeadR3, DeadR4, and HarrB1), diurnal dissolved oxygen, pH, and temperature were measured with continuously recording meters.

Sampling was performed in 2004 during low flow, dry weather conditions. Diurnal meters were installed from August 23 to September 13, and grab samples at stream locations were obtained on August 31 and September 13. Composite samples from treatment plant effluents were obtained on September 2. While flows were measured at the stream locations during sampling, the Dead River watershed does not contain a flow gage to allow comparison with historical flows. Flow conditions during sampling were therefore assessed using the nearest continuous flow gage, the Passaic River near Millington, as shown in Figure 2. Note that flows were below the annual 70th percentile flow from September 1st to 8th and again from September 11th through the 13th.

2004 SAMPLING PROGRAM RESULTS

We have completed the additional sampling work and are now using the data and information to develop the Non-Tidal Passaic River Basin Nutrient TMDL on behalf of NJDEP. Analytical results for all the grab sampling are provided in the attached Table 1, along with graphs of the continuous monitoring of dissolved oxygen, pH, and temperature at each of the four stream locations where continuous monitoring was performed (Figure 3A – 3D). In addition, Figure 4 shows locations where stream cross-sections were obtained during the field survey we performed to better understand the hydrology of the system. Graphs of the cross-sections measured at these locations are provided in Figure 5.

COMPARISON OF 2003 AND 2004 RESULTS

One of the key parameters for this study is dissolved oxygen. In 2003, dissolved oxygen concentrations were measured below the minimum standard of 4 mg/l. However, in 2004, minimum dissolved oxygen concentrations were found to be slightly below 6 mg/l, with smaller diurnal swings than 2003. See Figure 6 for an inter-year comparison of dissolved oxygen near the mouth of the Dead River during periods of time when stream flows and temperatures were similar. A key question with which we are left is whether the DO data measured during 2003 are truly different than 2004 or whether there was a problem with the accuracy of the DO sensor in the Dead River during 2003. It is important to note that the continuous recording devices were not installed at exactly the same locations during both years. In fact, the monitoring device was installed just upstream of the Warren Stage IV STP discharge in 2003 in order to characterize the dissolved oxygen dynamics in the stream without the attenuation from the relatively constant STP effluent, and just downstream of the Warren Stage IV STP discharge during 2004 to better assess the conditions of the mouth of the river. It is likely that the dissolved oxygen pattern observed in 2003 accurately represented what was occurring in the stream at the location of the device. However, the possibility that the extremely low velocity in the Dead River confounded the dissolved oxygen readings during the 2003 diurnal event must be acknowledged. (A new sensor technology that better accommodates low velocity conditions was utilized in 2004.)

Given all these considerations, we will use the 2004 data to calibrate the Dead River portion of the TMDL model. The Dead River is a shallow stream with a mucky bottom and extremely low velocity, making sediment oxygen demand (SOD) a very important consideration. In order to adequately simulate the Dead River, we performed additional SOD measurements during 2004, which confirmed that SOD is very high. Once calibrated, we will run the model using a variety of critical conditions for the TMDL to determine whether in fact the current productivity in the Dead River causes violations of the dissolved oxygen criteria. Since 2003 is one of the years being used for future simulations, the model simulations will help us understand the validity of the diurnal dissolved oxygen observations in August of 2003.

CONCLUSIONS

The additional data we obtained allowed us to model the Dead River with much greater certainty. We are currently completing model calibration and will apply the model in the Dead River to determine the following:

1. Are current levels of productivity causing the Dead River to contravene dissolved oxygen criteria during critical conditions?
2. What impact would phosphorus reductions from point and nonpoint sources have on the dissolved oxygen dynamics?

As you recall, we had recommended in our proposal that Bernards Township complete its own instream grab sampling on a routine basis over the course of the summer in order to augment the sampling performed for this study. If you performed any additional sampling to provide data for the TMDL study, please transmit those data to us within the next two weeks so that we can integrate them into our modeling and assessment efforts in the Dead River.

Please do not hesitate to contact me with any questions via telephone at 609-924-8821 (ext. 11) or via email at *JCosgrove@TRCsolutions.com*.

Sincerely,

James F. Cosgrove, Jr., P.E.
President

c: John Belardo, Esq.
Roger Bowlby

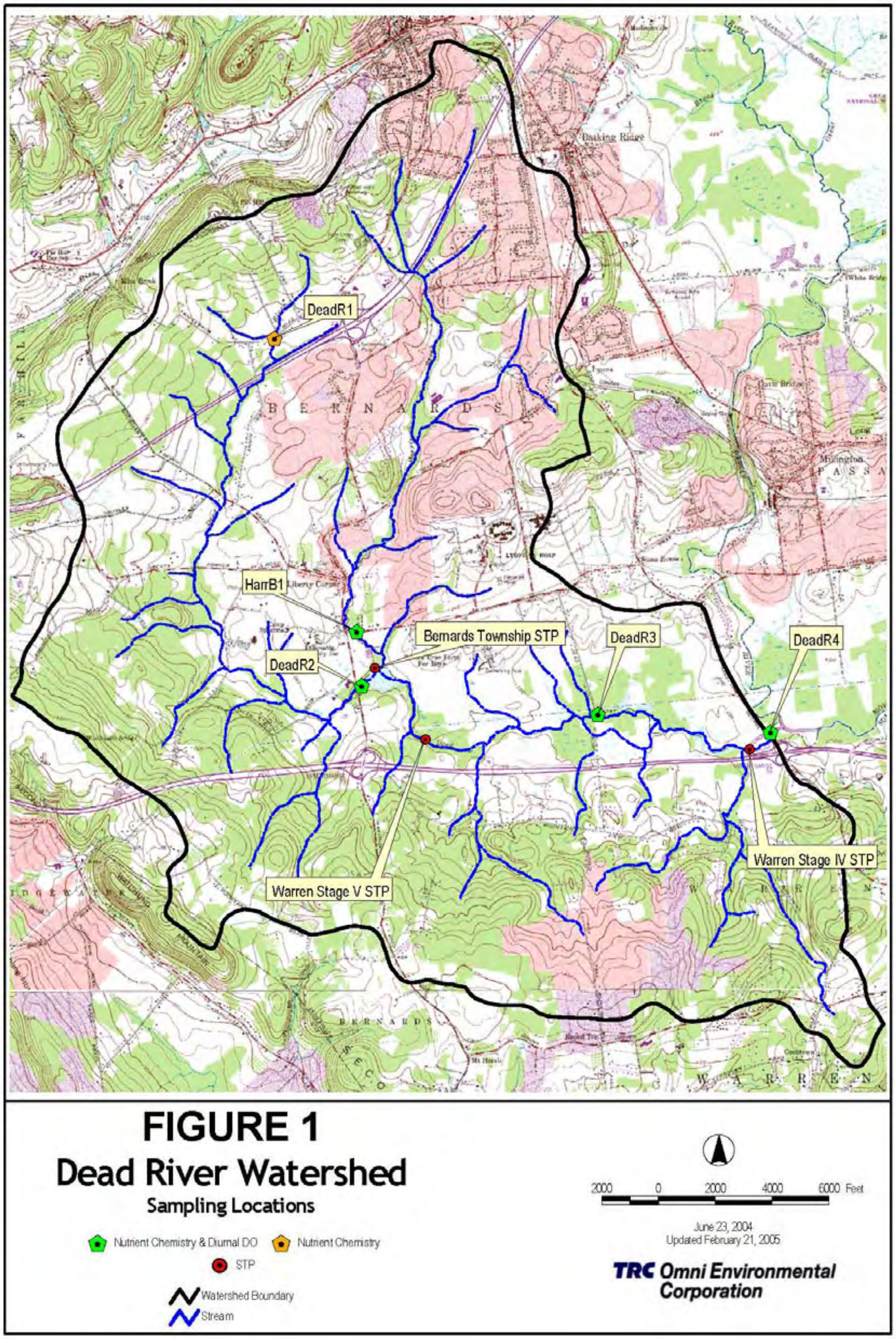


FIGURE 1
Dead River Watershed
Sampling Locations

Figure 2 Flow Conditions During Sampling

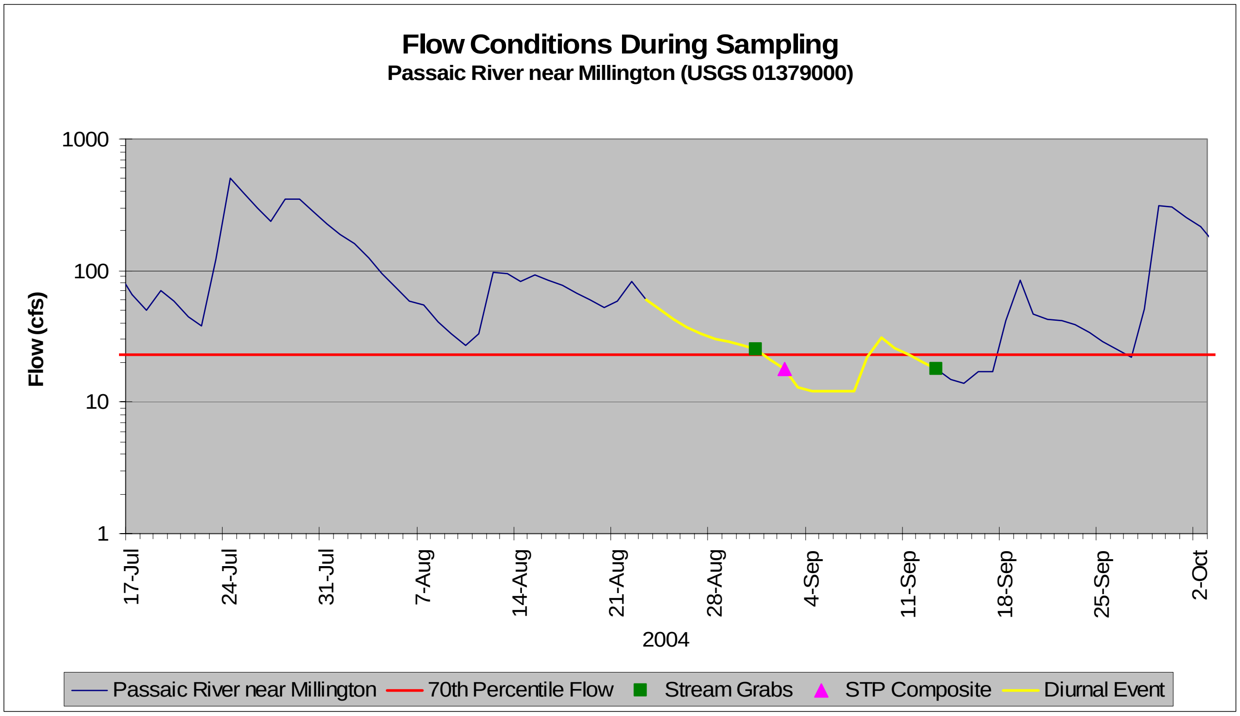


Figure 3A Continuous Monitoring Results at HarrB1

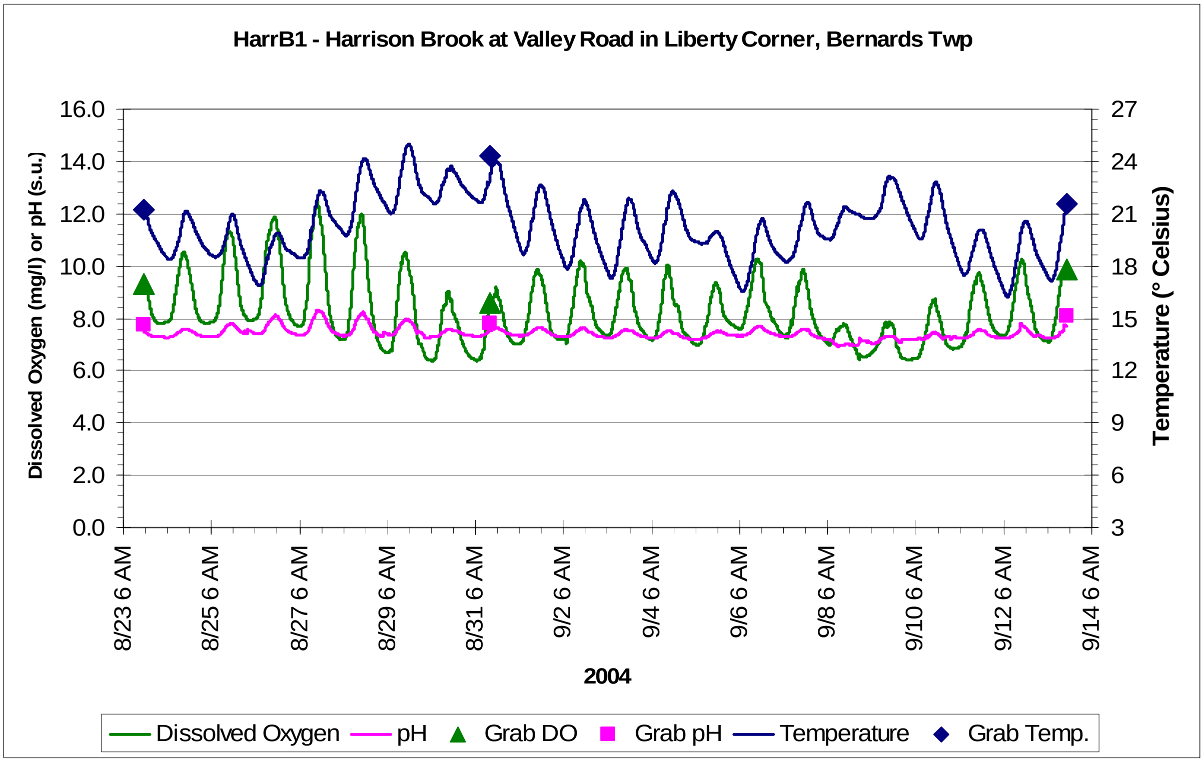


Figure 3B Continuous Monitoring Results at DeadR2

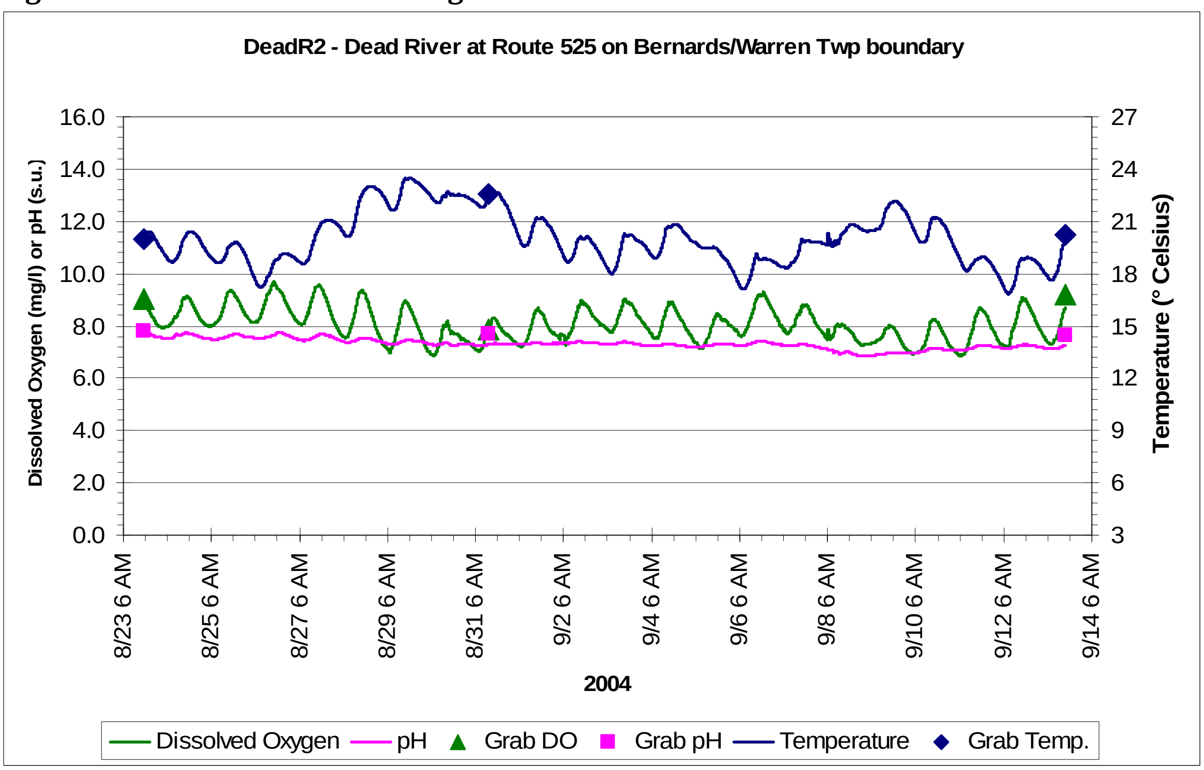


Figure 3C Continuous Monitoring Results at DeadR3

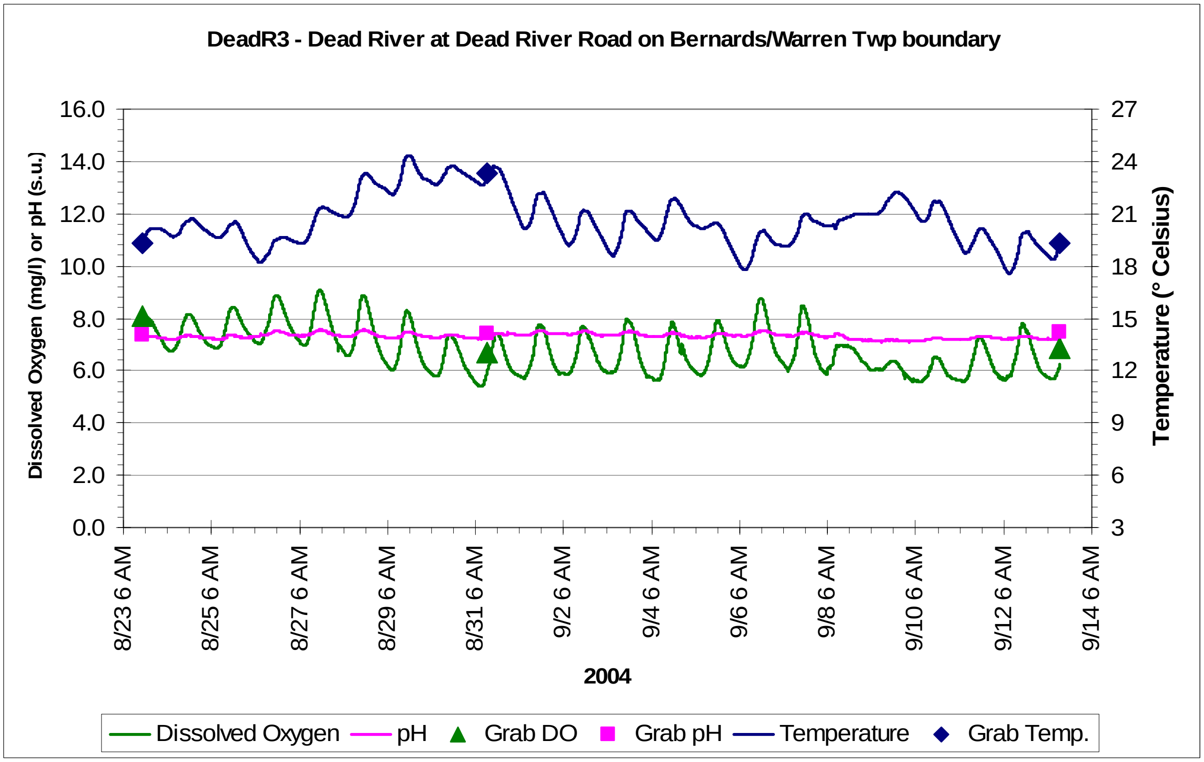
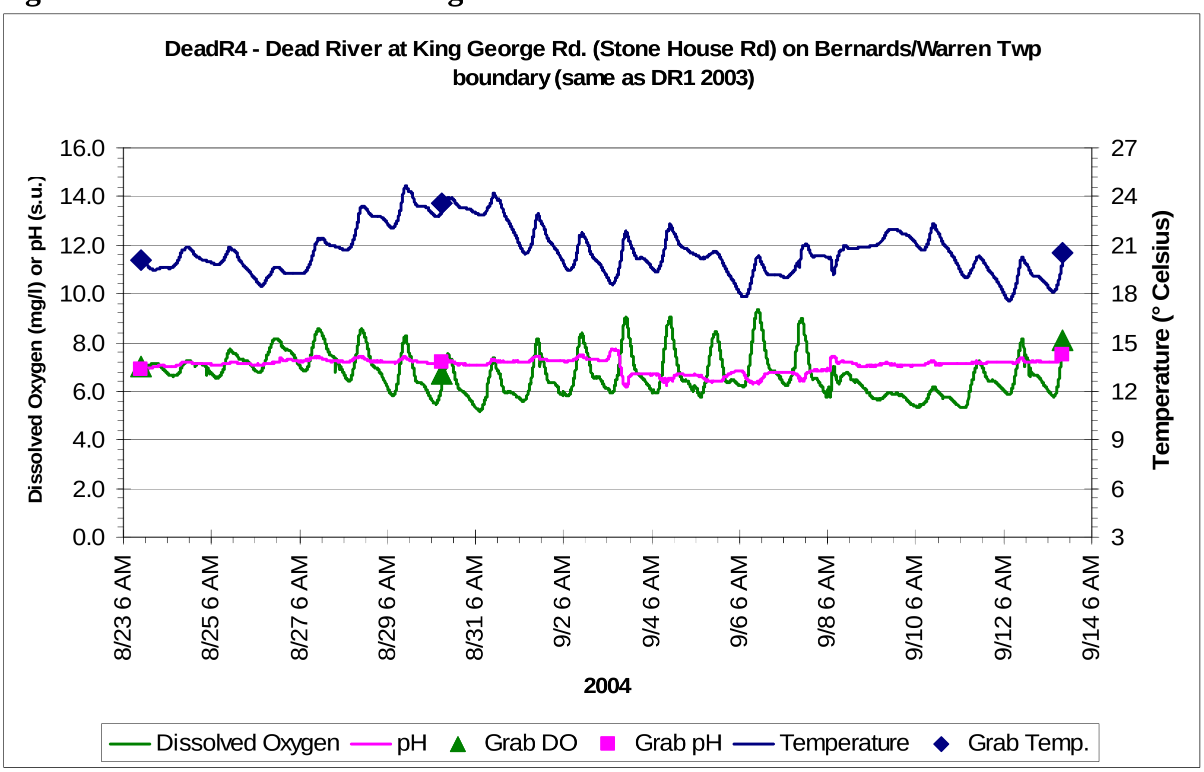


Figure 3D Continuous Monitoring Results at DeadR4



TRC Omni Environmental Corporation

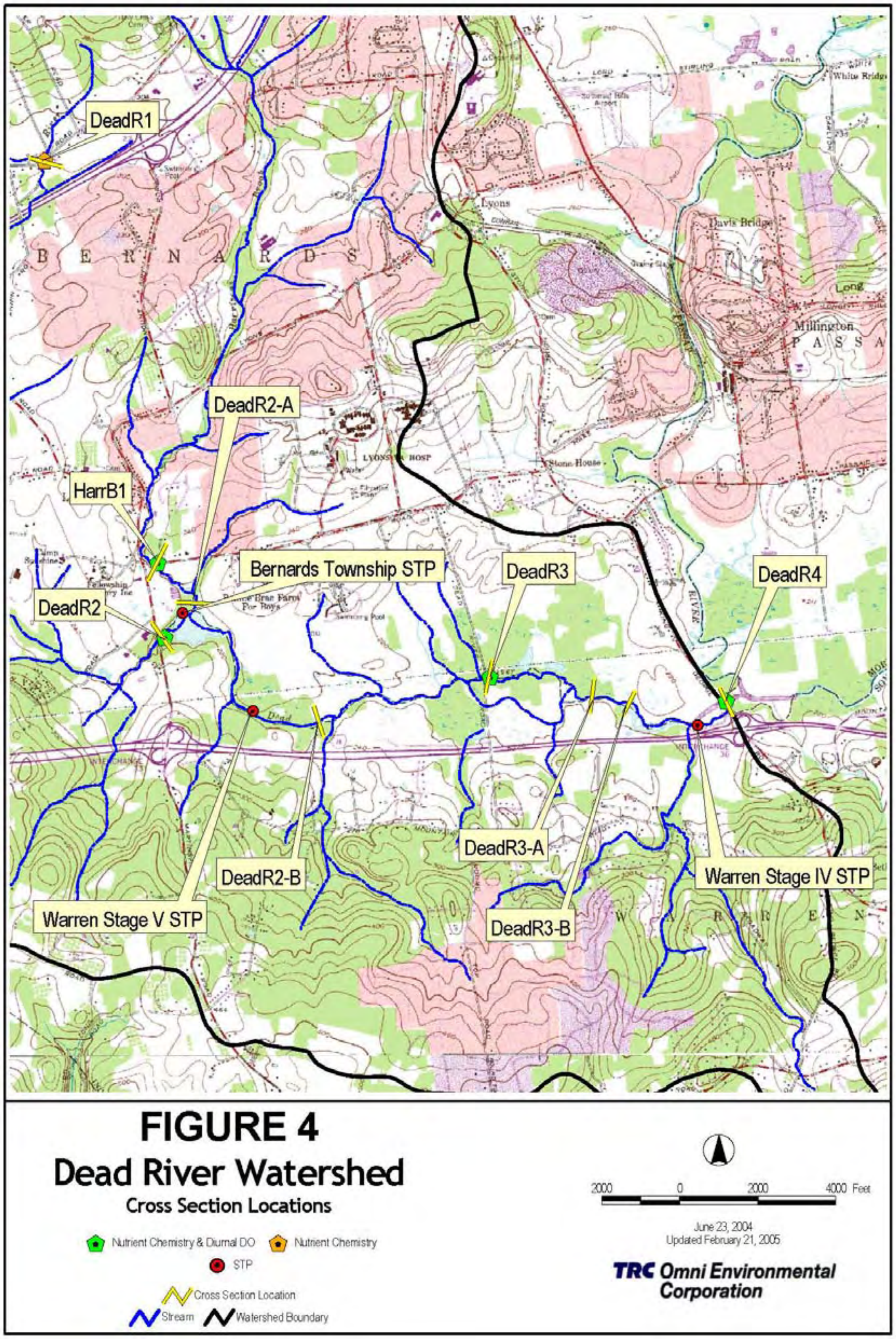


FIGURE 4
Dead River Watershed
Cross Section Locations

Figure 5
Dead River Cross-Sections

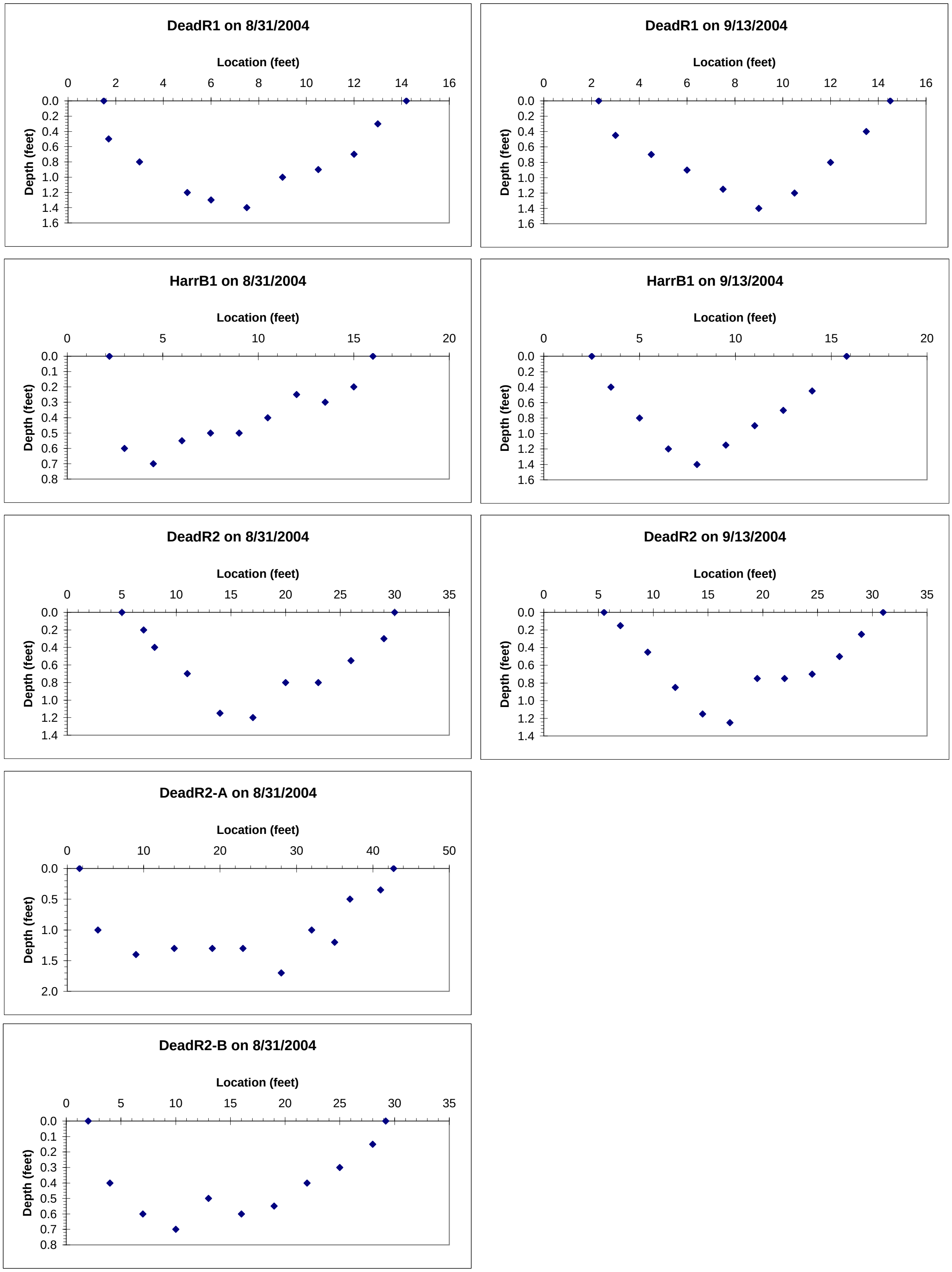
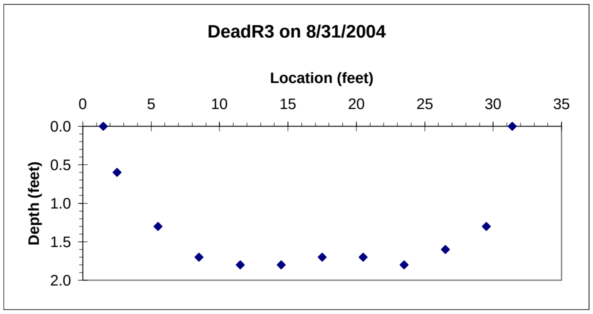
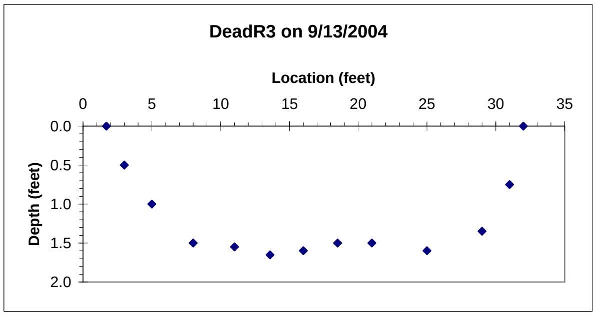
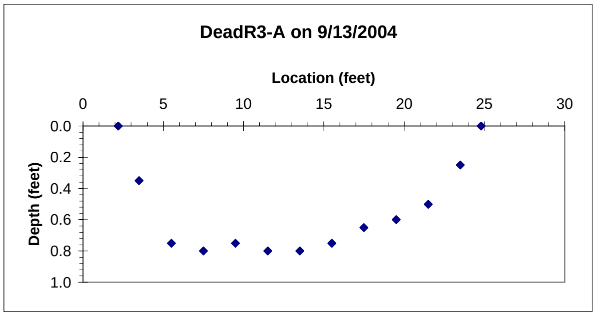
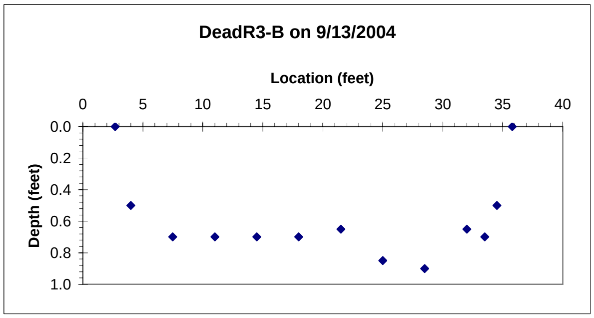


Figure 5
Dead River Cross-Sections









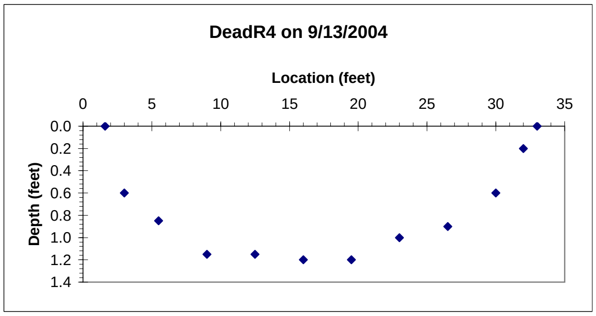


Figure 6 Inter-Year Comparison near Mouth of Dead River

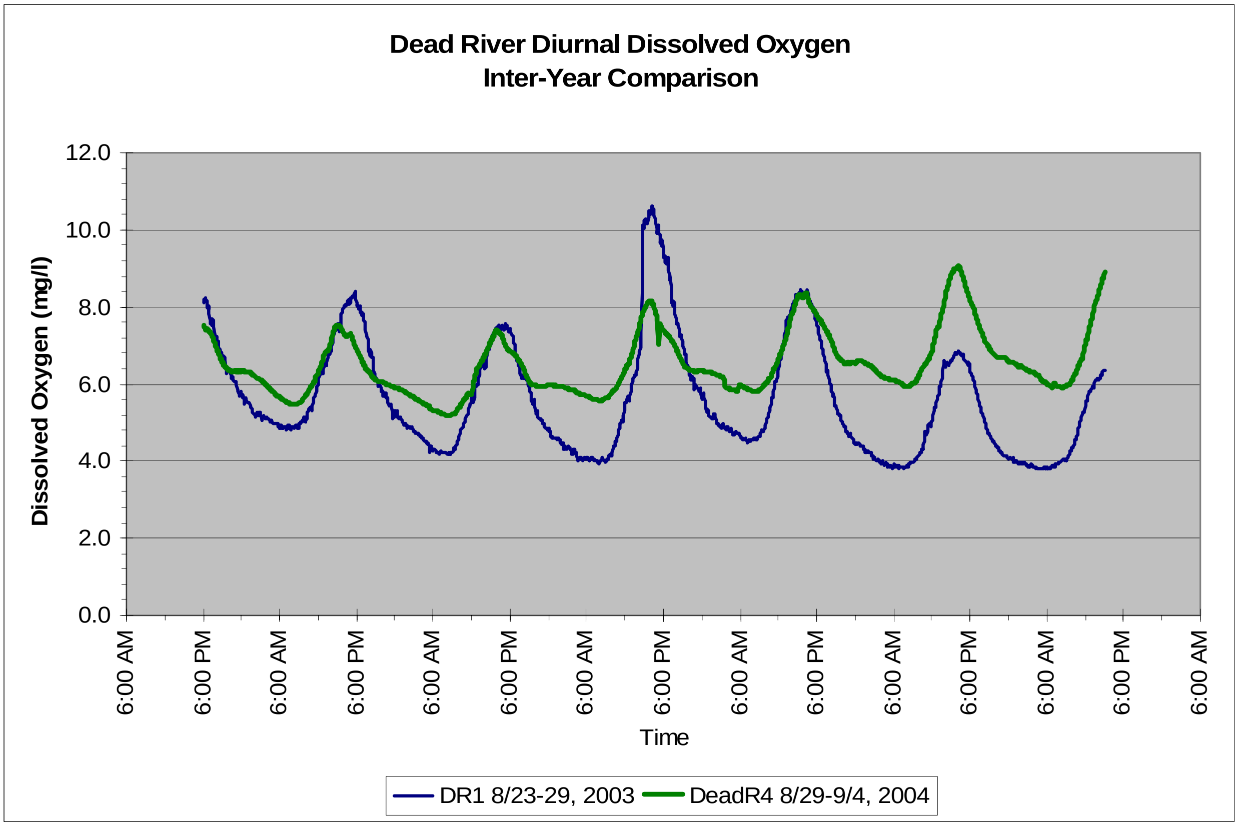


Table 1
Sampling Results

Station ID	Date	Time	Flow cfs	Dissolved Oxygen mg/l	Temperature Degrees C	pH s.u.	CBOD5 mg/l	Total Dissolved Solids (TDS) mg/l	Total Suspended Solids (TSS) mg/l
DeadR1	8/31/04	2:25:00 PM	0.2	9.06	24.6	7.88	< 2	170	2.5
	9/13/04	4:25:00 PM	0.01	8.90	22.8	7.85	< 2	230	4
DeadR2	8/31/04	1:30:00 PM	2.1	7.88	22.6	7.68	< 2	200	7
	9/13/04	3:20:00 PM	1.8	9.23	20.2	7.65	< 2	280	10
DeadR3	8/31/04	11:55:00 AM	7.8	6.68	23.3	7.41	< 2	190	10.5
	9/13/04	12:20:00 PM	7.3	7.00	19.4	7.41	< 2	350	10.5
DeadR4	8/31/04	11:35:00 AM		6.73	23.6	7.21	< 2	250	11.5
	9/13/04	11:50:00 AM	8.3	7.19	19.9	7.45	< 2	340	< 0.5
HarrB1	8/31/04	2:00:00 PM	1.9	8.61	24.3	7.82	< 2	280	6
	9/13/04	3:50:00 PM	2.8	9.78	21.7	7.92	< 2	300	5
STP-BernHB	9/1/04	8:30:00 AM	1.9	7.80	22.0	7.7	< 2	390	4
STP-WT4	9/2/04	8:22:00 AM		9.10	21.0	7	< 2	520	1.5

Table 1
Sampling Results

Station ID	Date	Time	Ammonia (NH3-N) mg/l	Diss. Nitrate (NO3-N) mg/l	Diss. Nitrite (NO2-N) mg/l	Kjeldahl Nitrogen (TKN) mg/l	Phosphorus, Diss. Reactive mg/l	Phosphorus, Total (TP) mg/l
DeadR1	8/31/04	2:25:00 PM	0.050	0.46	< 0.04	0.334	0.011	0.041
	9/13/04	4:25:00 PM	0.068	0.41	< 0.04	0.273	0.015	0.033
DeadR2	8/31/04	1:30:00 PM	< 0.050	0.75	< 0.04	0.418	0.013	0.033
	9/13/04	3:20:00 PM	0.059	0.85	< 0.04	0.563	0.020	0.048
DeadR3	8/31/04	11:55:00 AM	0.074	1.40	< 0.04	0.480	1.088	1.105
	9/13/04	12:20:00 PM	0.981	2.79	< 0.04	1.410	1.043	1.030
DeadR4	8/31/04	11:35:00 AM	0.086	2.53	< 0.04	0.842	0.976	1.116
	9/13/04	11:50:00 AM	0.623	2.50	< 0.04	1.307	0.854	0.893
HarrB1	8/31/04	2:00:00 PM	0.080	1.11	< 0.04	0.457	0.026	0.060
	9/13/04	3:50:00 PM	0.087	0.93	< 0.04	0.444	0.028	0.063
STP-BernHB	9/1/04	8:30:00 AM	0.297	1.10	< 0.04	0.837	4.203	4.426
STP-WT4	9/2/04	8:22:00 AM	0.099	19.28	< 0.04	0.911	2.575	2.975

TRC Omni Environmental Corporation

Research Park
321 Wall Street
Princeton, New Jersey 08540-1515
Telephone 609-924-8821
Facsimile 609-924-8831

February 24, 2005

Barbara Hirst, Chief
New Jersey Department of Environmental Protection
Bureau of Environmental Analysis and Restoration
401 E. State Street, 7th floor W
PO Box 418
Trenton, NJ 08625-0418

**RE: PASSAIC NUTRIENT TMDL STUDY
RESULTS OF 2004 MONITORING IN THE ROCKAWAY RIVER**

Dear Ms. Hirst:

As you know, the New Jersey Department of Environmental Protection (NJDEP), in partnership with the Rutgers EcoComplex, retained TRC Omni Environmental Corporation to complete a Nutrient Total Maximum Daily Load (TMDL) Study on the Non-Tidal Passaic River Basin. During the summer and fall of 2003, we sampled a great many streams and sewage treatment plant (STP) effluents throughout the Passaic River Basin, including the Rockaway River and effluent from Rockaway Valley Regional Sewerage Authority (RVRSA). Sampling in the Rockaway River (near its confluence with the Passaic River) showed mild dissolved oxygen variations and slight violations of both the 4 mg/l minimum instream and the 5 mg/l minimum 24-hour average dissolved oxygen criteria. While the diurnal variation was less than 3 mg/l, the peaks and troughs occurred about 4 hours later than would be expected from productivity impacts. The data suggested the possibility that the diurnal variation observed at Old Bloomfield Avenue represented an attenuation of a more substantial diurnal variation at some upstream location. The purpose of this letter is to summarize the results of the additional monitoring performed in the Rockaway River Watershed in 2004.

BACKGROUND

In order to better characterize and model the Rockaway River, additional data were collected. The purpose of the additional monitoring was twofold. First, diurnal dissolved oxygen monitoring at multiple strategic locations was performed to better understand the dissolved oxygen pattern observed in 2003 and to identify any critical locations around which the nutrient TMDL must be developed. Second, additional diurnal monitoring and chemistry sampling were performed to provide more detailed information to enhance the water quality model developed to support the nutrient TMDL for the non-tidal Passaic River Basin. The additional data obtained by TRC Omni have allowed us to develop a stronger model and a better understanding of phosphorus dynamics and water quality impacts in the Rockaway River.

2004 SAMPLING PROGRAM OVERVIEW

A Quality Assurance Sampling Plan was prepared by TRC Omni and approved by NJDEP for the sampling performed in the Rockaway River. We collected instream water quality and hydraulic data at four locations on the Rockaway River (RockR1 – RockR4) and at one location on Crooked Brook (CrookB1). In addition, samples were collected from the RVRSA STP effluent. These locations are identified on Figure 1.

At each of the sampling locations, grab samples were collected, and the following parameters were analyzed in the laboratory: nitrogen series (ammonia, TKN, nitrate, and nitrite), phosphorus series (total phosphorus and dissolved reactive phosphorus), $CBOD_5$, total suspended solids (TSS), and total dissolved solids (TDS). Also, the following in-situ parameters were measured: pH, temperature, dissolved oxygen, and stream flow (based on cross-sectional depth and velocity measurements). During the first diurnal event, diurnal dissolved oxygen, pH, and temperature were measured with continuously recording meters at four of the stream sampling locations (RockR2, RockR3, RockR4, and CrookB1). In order to rule out any unusual upstream dissolved oxygen patterns, a second diurnal event was performed at the three upstream locations (RockRO, RockR1, and RockR2), with a continuous recording device being placed in the RVRSA effluent (STP-RVRSA) at the same time.

Sampling was performed during low flow, dry weather conditions whenever possible. Diurnal meters were initially installed from August 19 to September 10. The meters at CrookB1 and RockR4 stopped functioning after only two days. In addition, the meter at RockR2 stopped functioning after the first week, and the meter at RockR3 only functioned during the second week. None of the meters showed any signs of tampering, and we had on other occasions deployed over 30 of these meters in the field simultaneously throughout New Jersey and experienced near zero failure rate. The cause of the failure of the meters in the Rockaway River was apparently due to a batch of faulty batteries that had been supplied to us by the meter manufacturer. The diurnal event was therefore repeated from September 13 to 17. Because the dissolved oxygen at the most upstream diurnal station (RockR2) was surprisingly low, an additional diurnal event was performed from September 23 to 27. During this second event, meters were installed at RockR2 again, RockR1, and RockR0 (upstream of RVRSA discharge), in addition to the RVRSA effluent itself. Grab samples from stream locations, as well as composite samples from RVRSA effluent, were obtained on September 3, September 10, and September 27. While flows were measured at many of the stream locations during sampling, the USGS flow gage in the Rockaway River just downstream of Boonton Reservoir was used to allow comparison with historical flows as well as to plan sampling events. Flow and precipitation conditions (using the gage just downstream of Lake Hopatcong) during sampling events are shown in the Figure 2. Note that while flows were never below the annual 70th percentile flow, the flows remained low and steady-state from August 31st through September 17th. It should be also noted that flows in the lower Rockaway River originate from the Boonton

Reservoir, and that releases from the reservoir almost never allow the flow to dip below the statistical 70^{th} percentile flow of 10 cfs.

2004 SAMPLING PROGRAM RESULTS

We have completed the additional sampling work and are now using the data and information to develop the Non-Tidal Passaic River Basin Nutrient TMDL. Analytical results for all the grab sampling are provided in the attached Table 1. Graphs of the continuous monitoring of dissolved oxygen, pH, and temperature from September 13-17 are shown in Figure 3. In addition, graphs of the continuous monitoring of dissolved oxygen, pH, and temperature from September 23-27 are shown in Figure 4. Locations are shown in stream order from upstream to downstream. Finally, graphs of the cross-sections measured at sampling locations are provided in Figure 5.

COMPARISON OF 2003 AND 2004 RESULTS

Figure 6 shows an inter-year comparison between the September 2004 diurnal data from RockR4 near the confluence with the Whippany River and the diurnal data taken at the same location (called RO2 in 2003) in August of 2003. In most respects, the 2004 diurnal data confirm the results from 2003. Observations from both years show a mild diurnal variation of less than 3 mg/l, with the peaks and troughs about four hours later than usual. Also, the overall dissolved oxygen is quite low, generally between 4 and 7 mg/l, apparently indicating a substantial sediment oxygen demand (SOD) and perhaps substantial groundwater influence. However, dissolved oxygen concentrations in 2003 were measured below the minimum standard of 4 mg/l, whereas minimum dissolved oxygen concentrations in 2004 were found to be slightly below 5 mg/l. Given that the stream temperatures were also higher during the 2003 event (secondary axis in Figure 6), it is very possible that increased SOD could explain the inter-year difference observed. However, the possibility that the extremely low velocity in the Rockaway River during critical low-flow periods confounded the dissolved oxygen readings during the 2003 diurnal event must be acknowledged. A new optical sensor technology that better accommodates low velocity conditions was utilized in 2004; Figures 3 and 4 demonstrate the extremely tight agreement between grab samples measured in the field and continuous data measured by the optical sensors during the 2004 event.

Given all these considerations, we are utilizing the 2004 data to calibrate the Rockaway River portion of the TMDL model. Once calibrated, we will run the model using a variety of critical conditions for the TMDL to determine whether in fact the current productivity in the Rockaway River causes violations of the dissolved oxygen criteria. The model simulations will also help us understand the diurnal dissolved oxygen observations in August of 2003 at RO2 (same location as RockR4).

CONCLUSIONS

The diurnal monitoring from Stations RockR2 and RockR3 indicate that these locations are critical locations that need to be simulated carefully. They show a moderate diurnal swing of

3 to 4 mg/l and minimum dissolved oxygen approaching the criterion of 4 mg/l. The additional data we obtained allowed us to model the Rockaway River with much greater certainty. We are currently completing model calibration and will apply the model in the Rockaway River to determine the following:

1. Are current levels of productivity causing the Rockaway River to contravene dissolved oxygen criteria during critical conditions?
2. What impact would phosphorus reductions from point and nonpoint sources have on the dissolved oxygen dynamics?

Please do not hesitate to contact me with any questions via telephone at 609-924-8821 (Ext. 11) or via email at *JCosgrove@TRCsolutions.com*.

Sincerely,

James F. Cosgrove, Jr., P.E.
President

c: Marzooq Alebus, NJDEP

Figure 1 Sampling Locations

Figure 2 Flow and Precipitation Conditions During Sampling

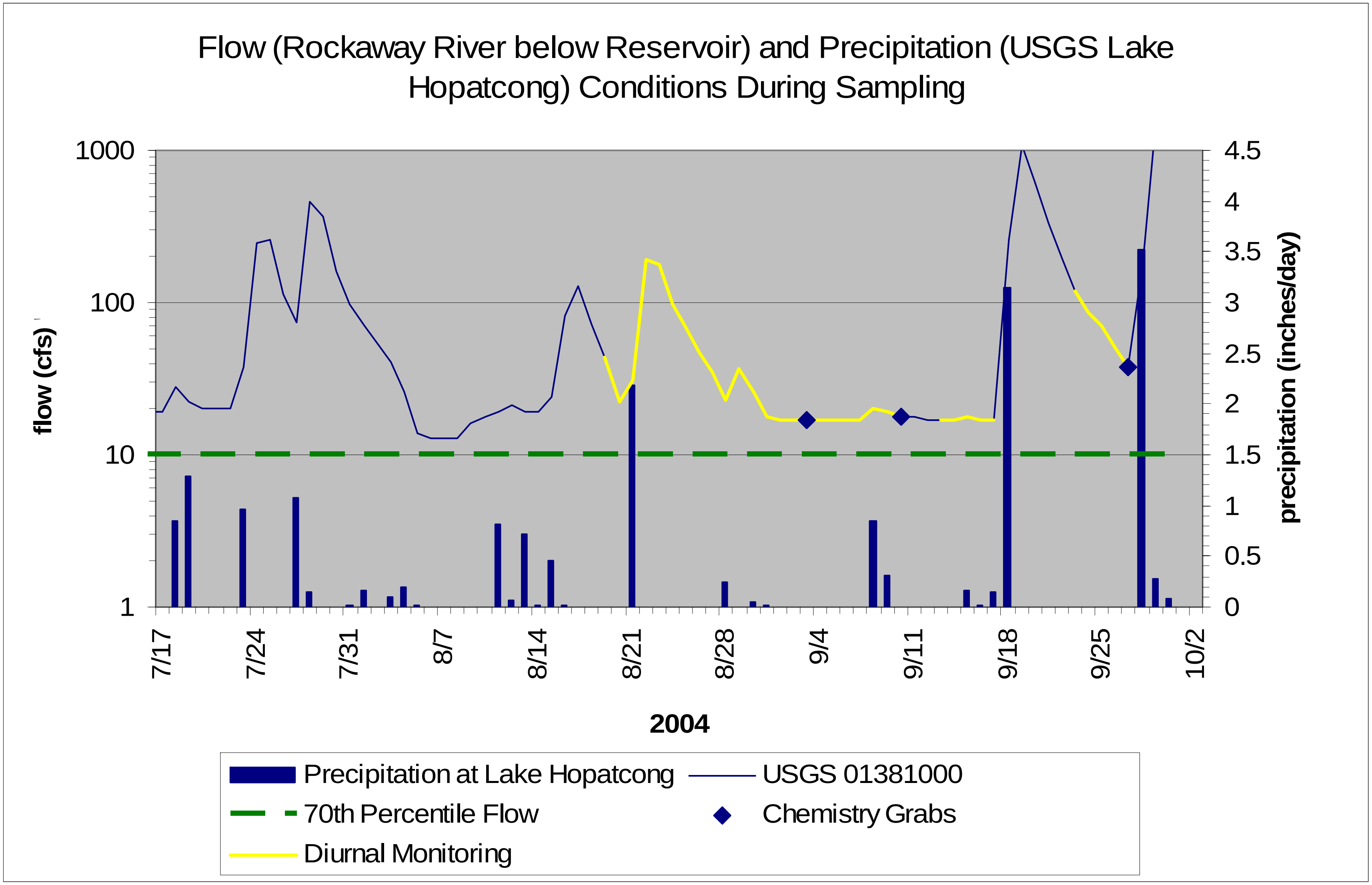
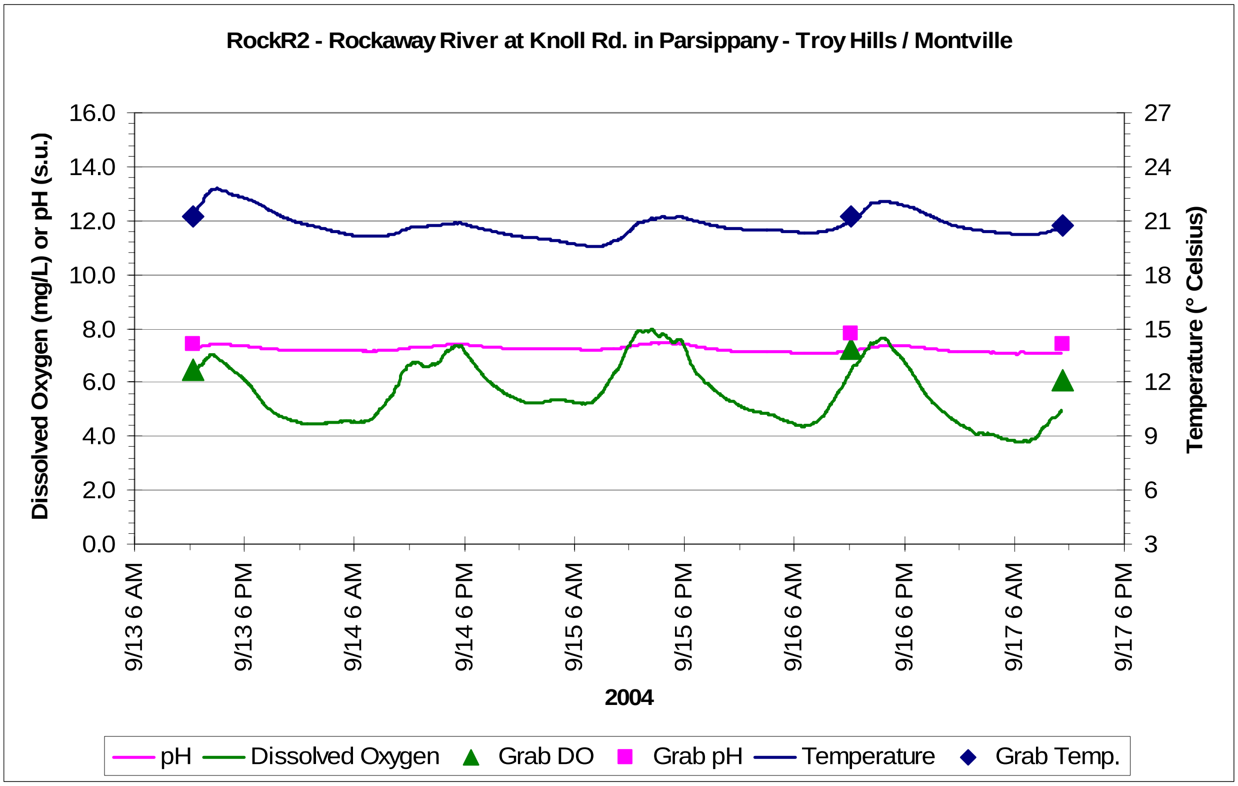


Figure 3 Diurnal Monitoring September 13-17, 2004



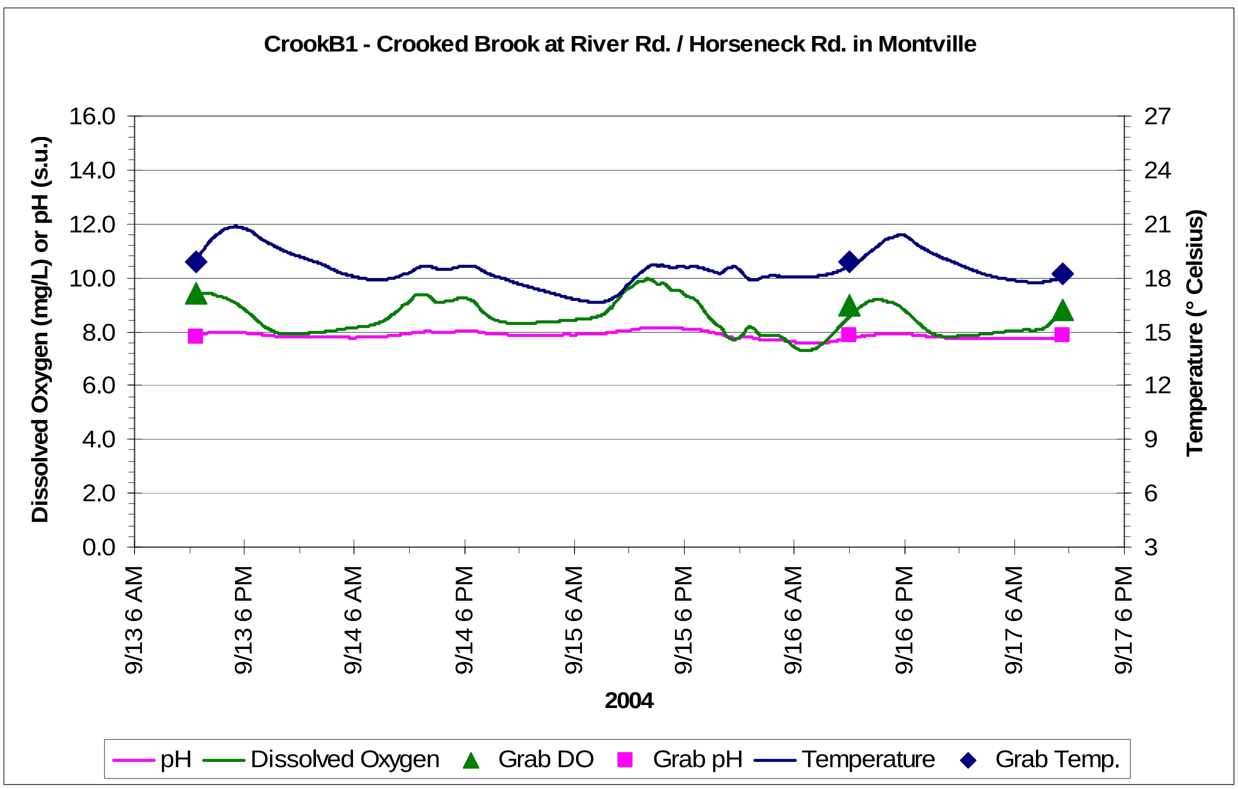
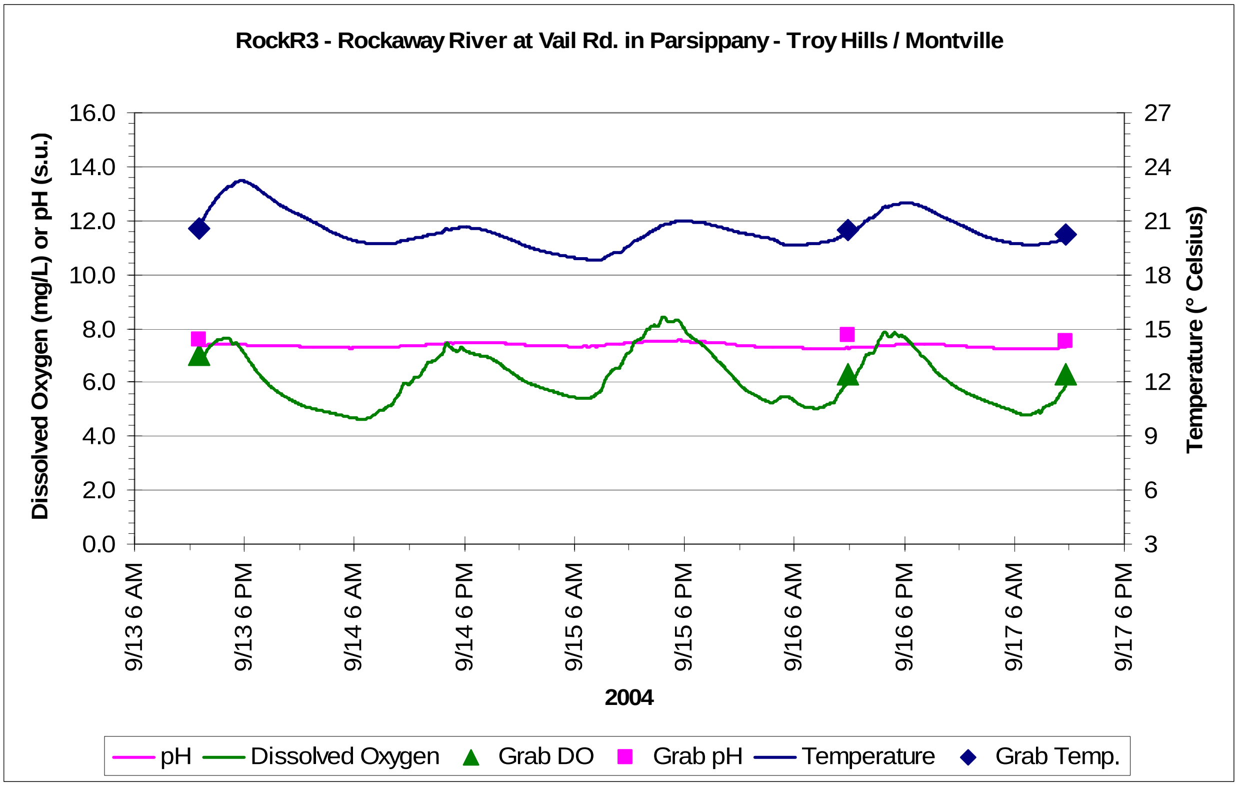


Figure 3 Diurnal Monitoring September 13-17, 2004



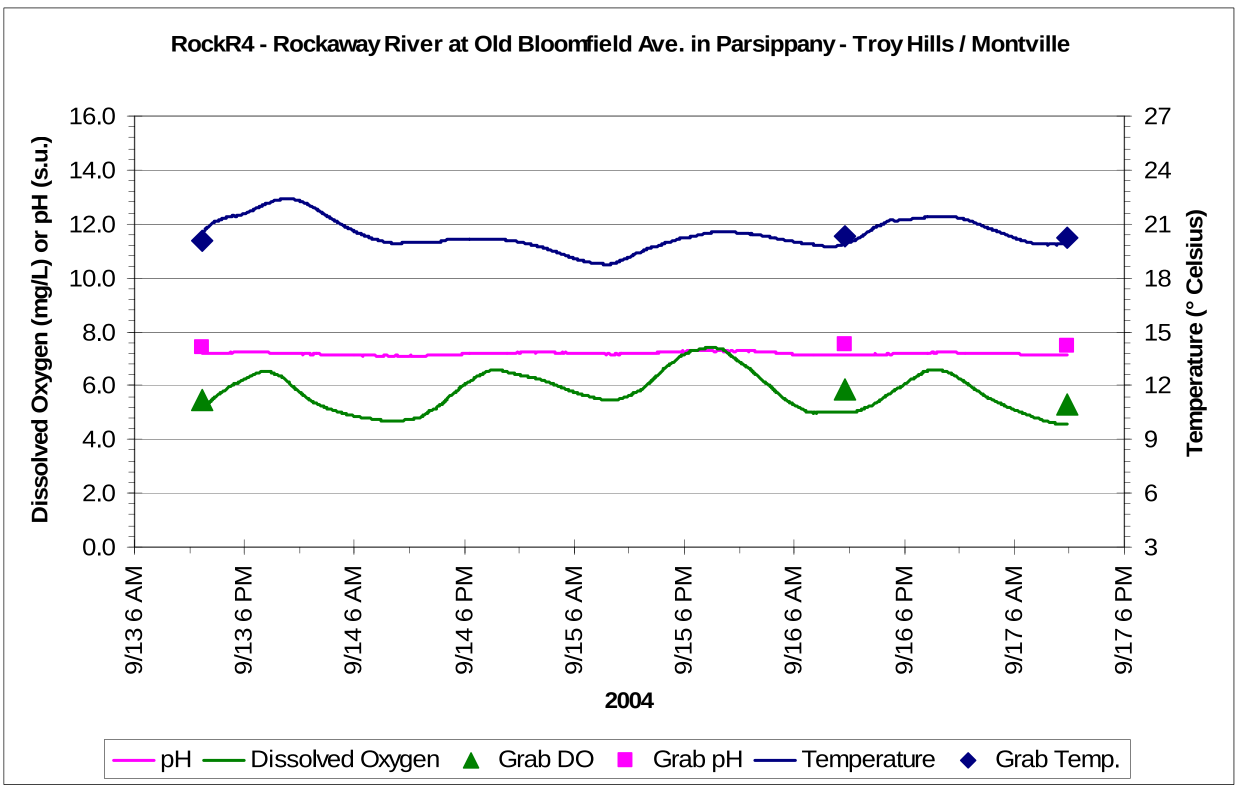
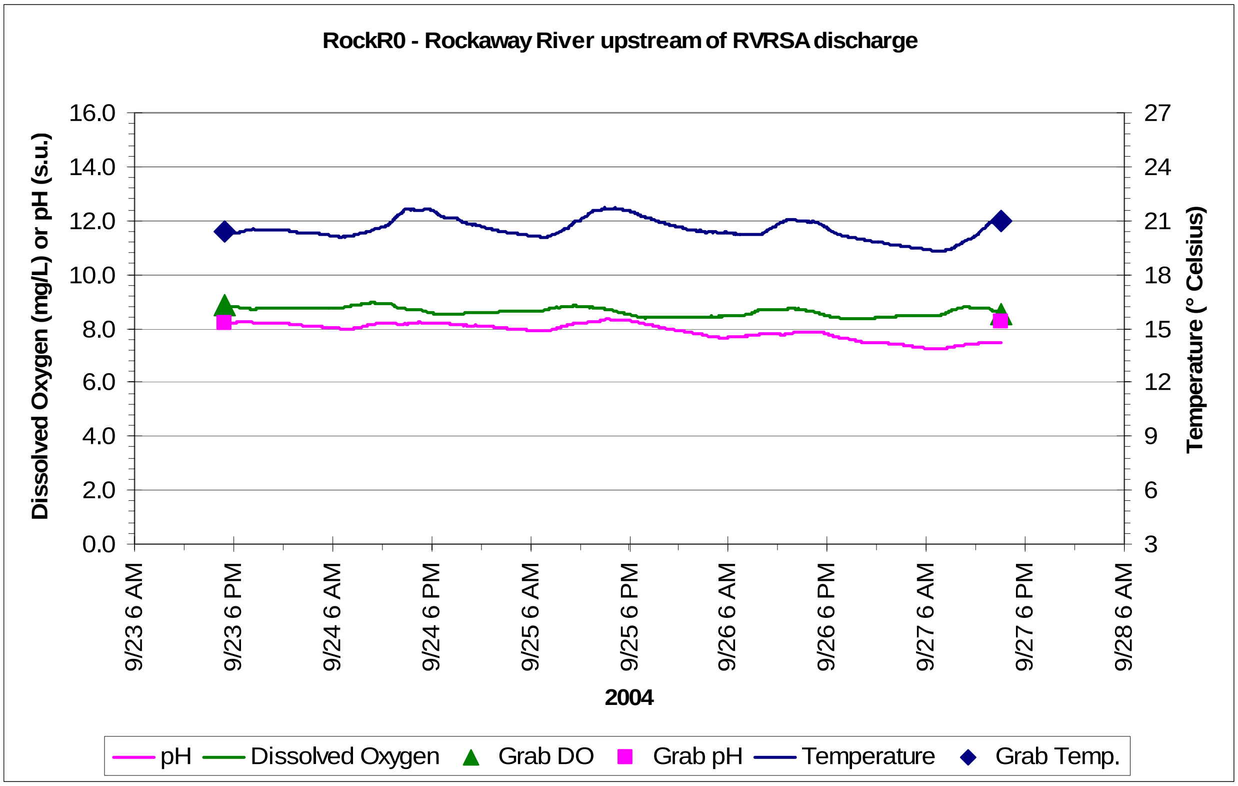


Figure 4 Diurnal Monitoring September 23-27, 2004



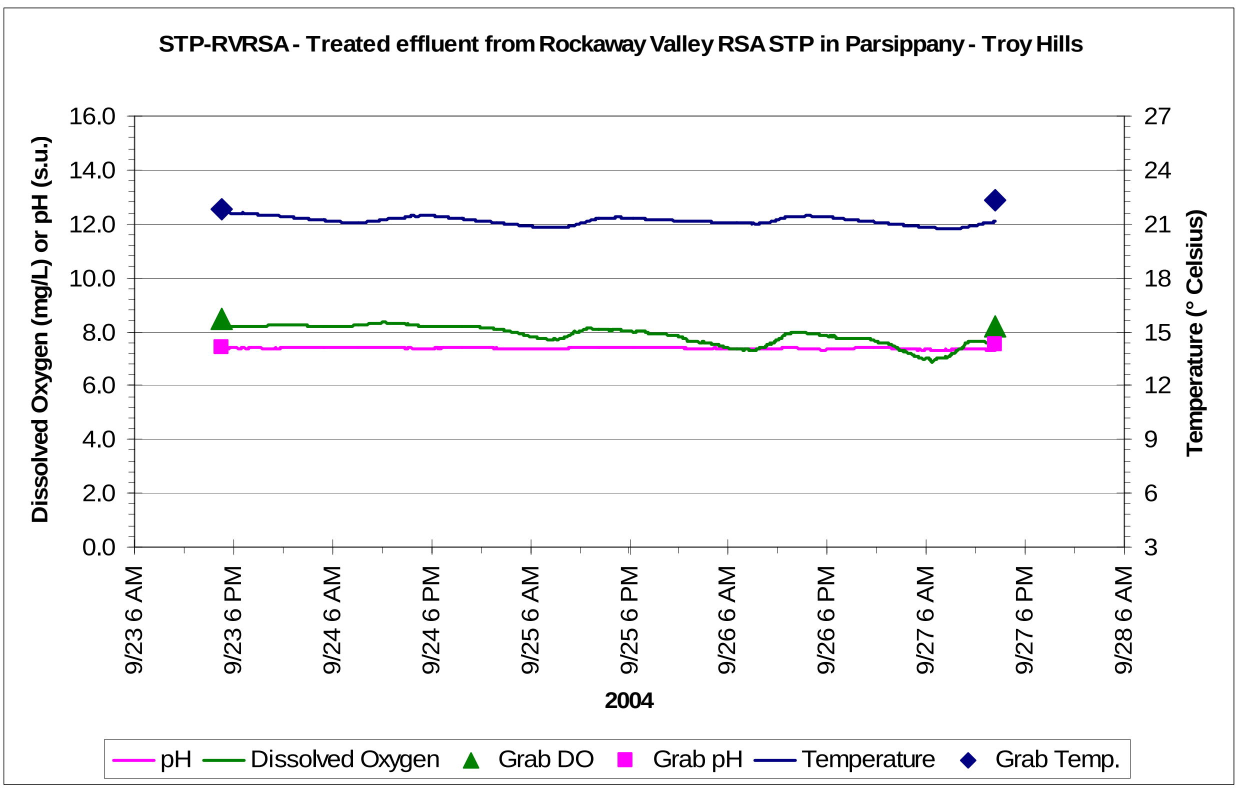
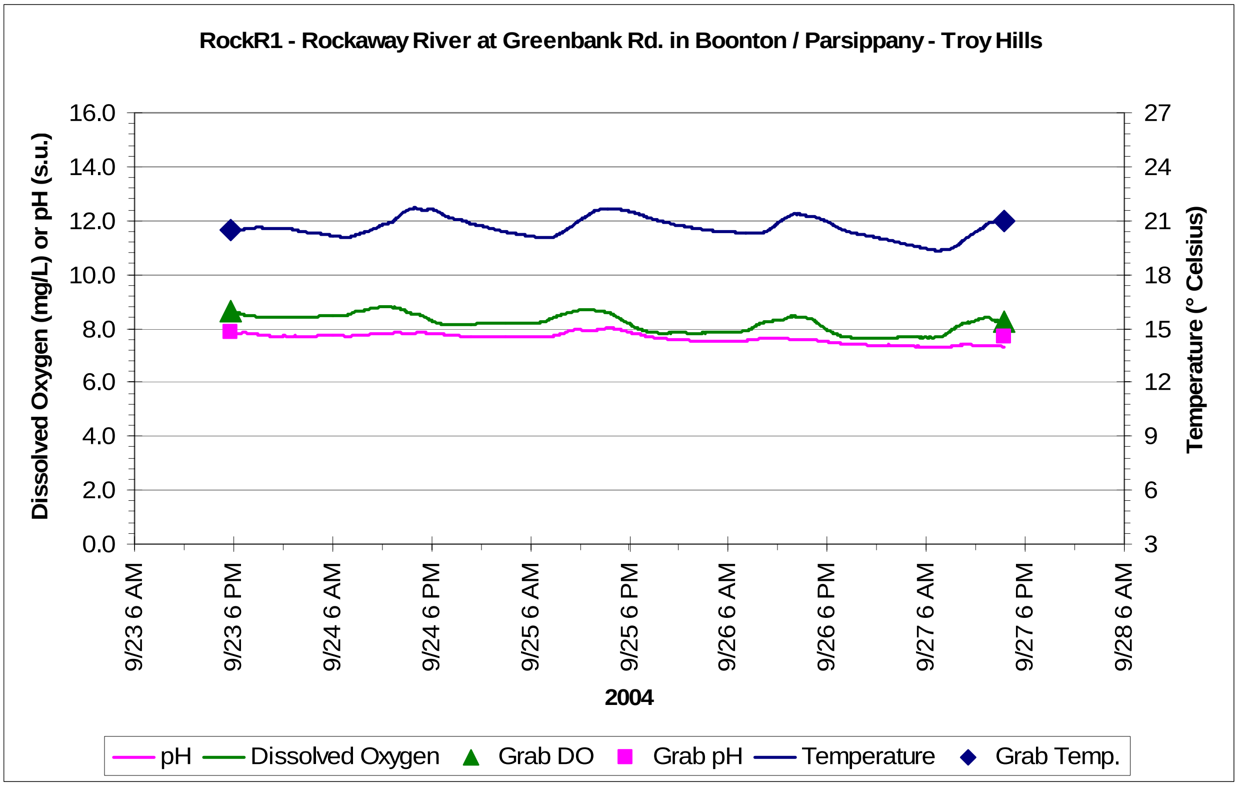


Figure 4 Diurnal Monitoring September 23-27, 2004



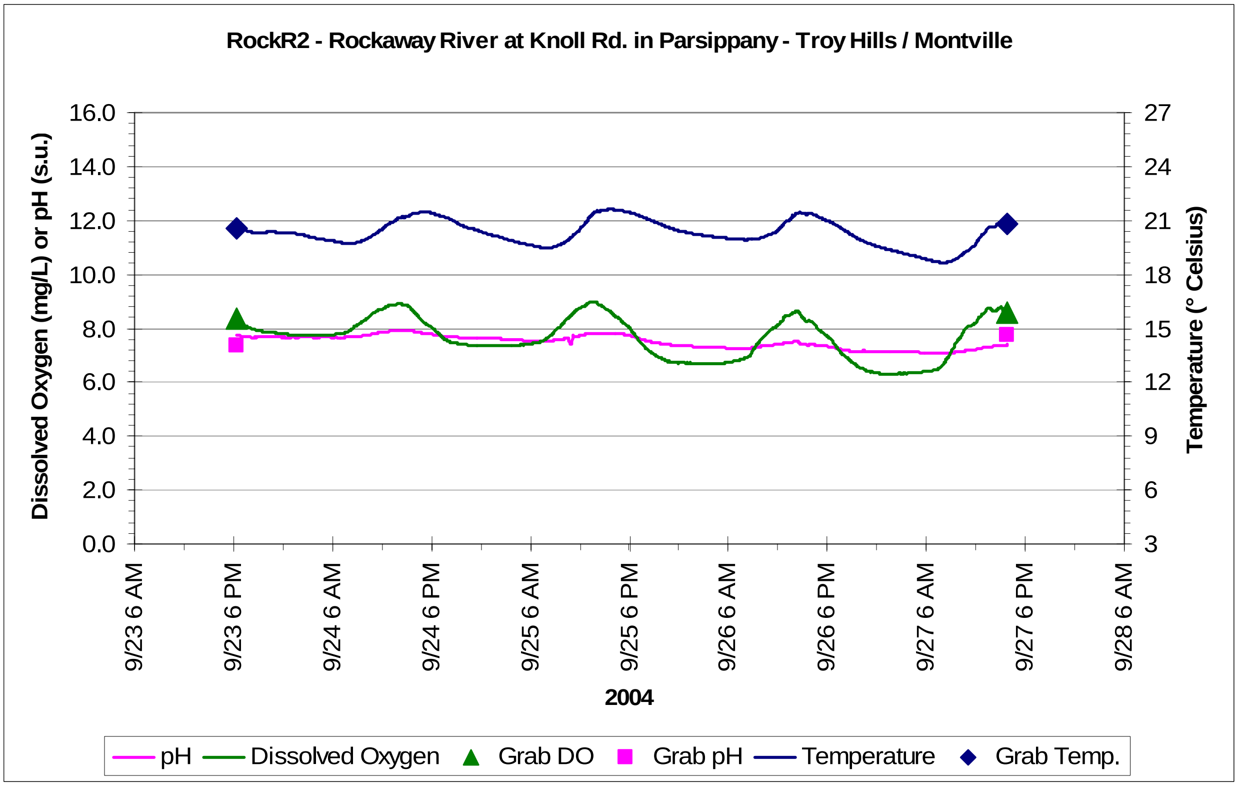


Figure 5 Stream Cross-Sections, page 1 of 2

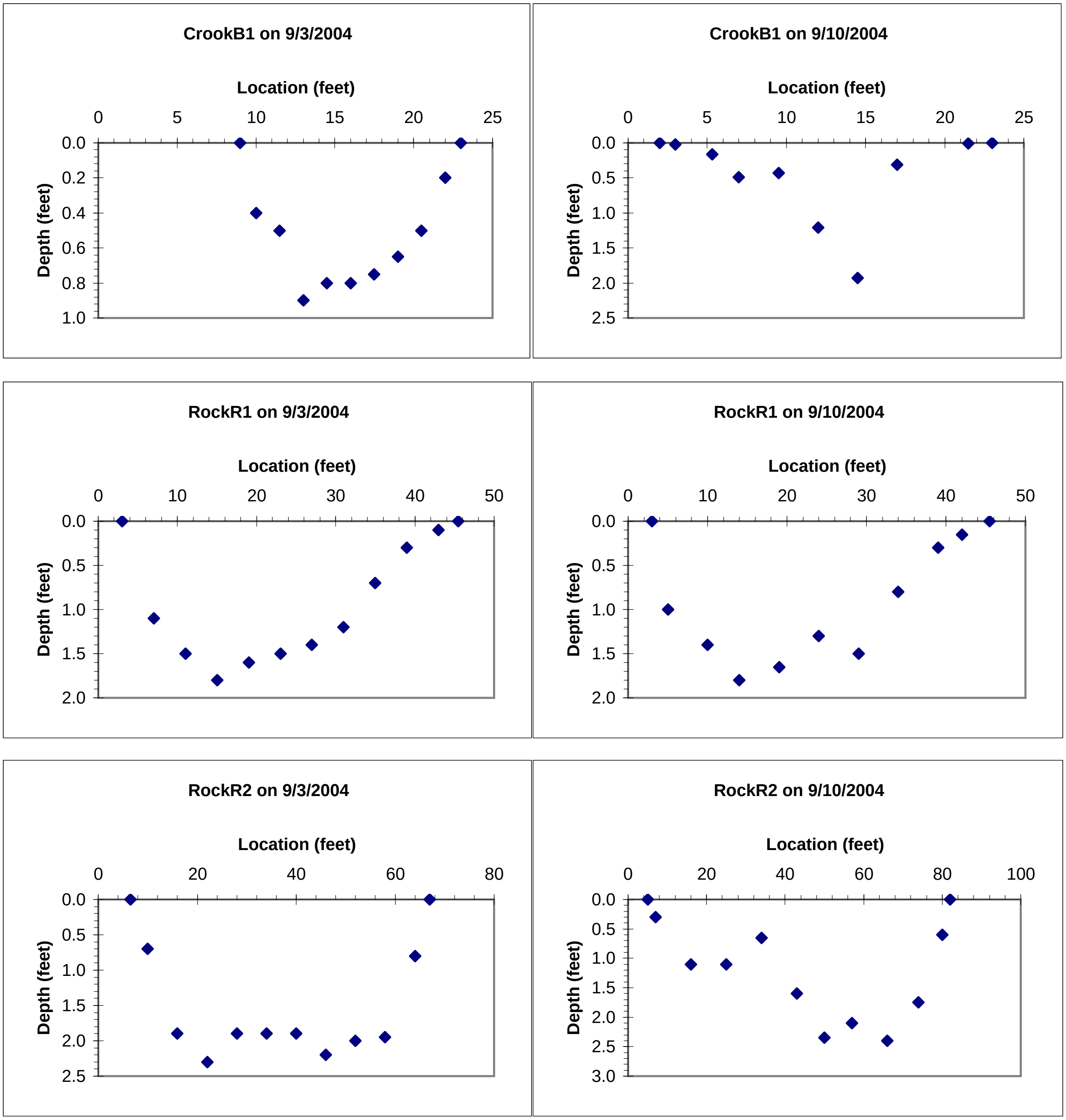


Figure 5 Stream Cross-Sections, page 2 of 2

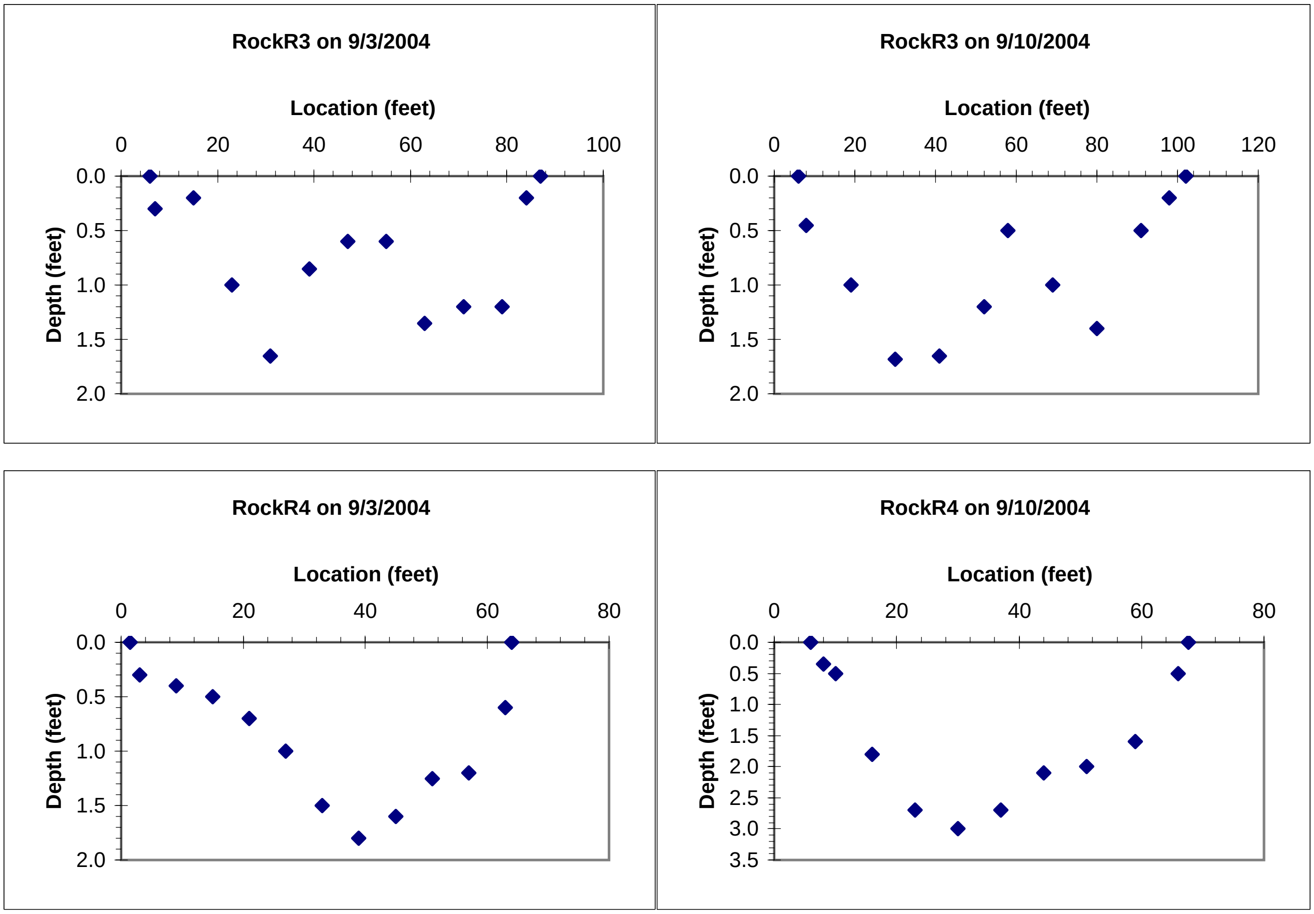


Figure 6 Comparison Between 2003 and 2004 Diurnal Data

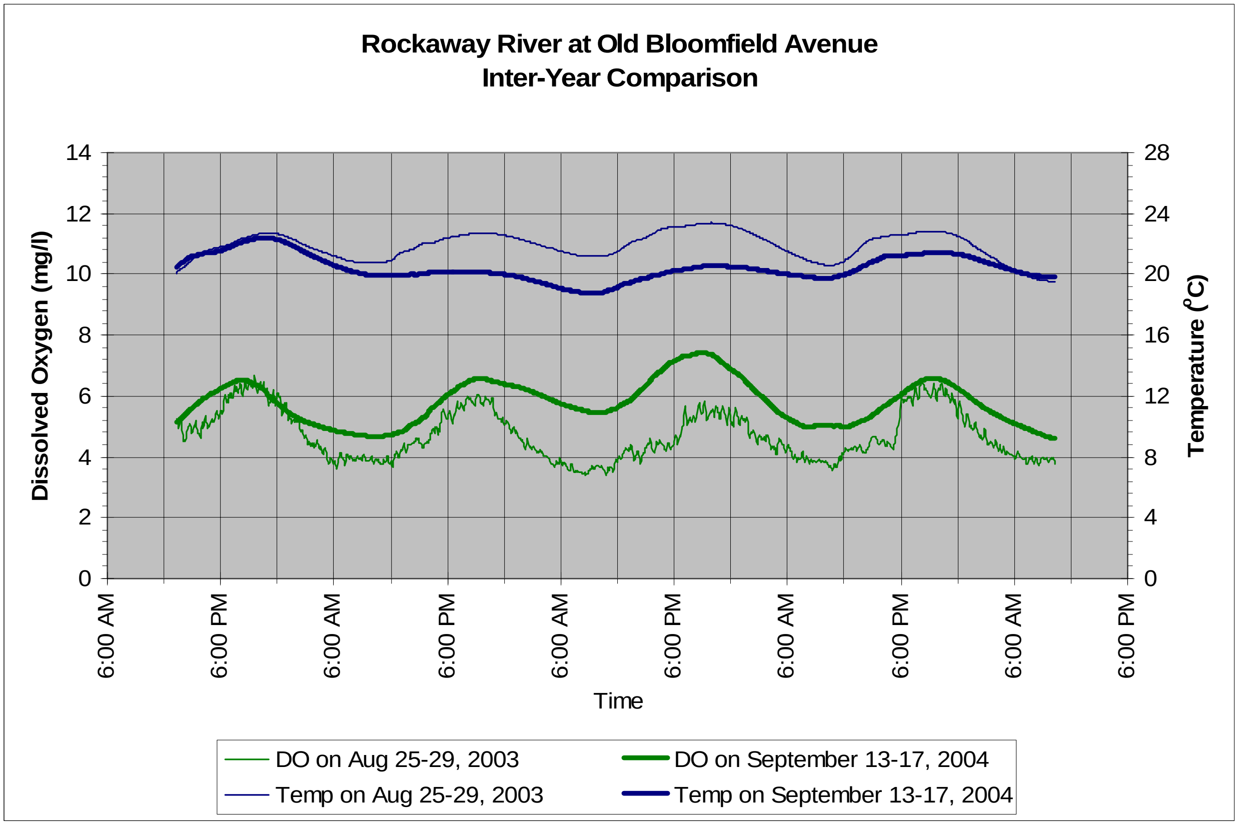


Table 1 Sampling Results, page 1 of 2

Station ID	Date	Time	Flow (cfs)	Temperature (°C)	pH (s.u.)	Dissolved Oxygen (mg/l)	CBOD5 (mg/l)	Total Dissolved Solids (mg/l)	Total Suspended Solids (mg/l)
CrookB1	9/3/2004	12:00:00 PM	3.8	19.5	8.05	9.6	< 2.0	340	3.5
	9/10/2004	12:50:00 PM	6.3	20.6	7.43	8.6	< 2.0	220	4.0
RockR0	9/27/2004	2:30:00 PM	38.0	21.7	8.19	8.5	< 2.0	220	5.5
RockR1	9/3/2004	11:00:00 AM	16.1	21.7	7.70	7.6	< 2.0	350	5.0
	9/10/2004	2:30:00 PM	13.9	22.5	7.65	7.7	< 2.0	380	2.0
	9/27/2004	3:15:00 AM	N/A	21.1	7.68	8.2	< 2.0	290	1.5
RockR2	9/3/2004	11:30:00 AM	14.7	21.0	7.68	7.7	< 2.0	340	3.0
	9/10/2004	1:24:00 PM	12.2	22.4	7.59	7.1	< 2.0	370	0.5
	9/27/2004	3:35:00 PM	N/A	20.8	7.23	8.6	< 2.0	290	4.5
RockR3	9/3/2004	1:00:00 PM	34.2	22.4	7.84	7.8	< 2.0	360	2.5
	9/10/2004	11:57:00 AM	40.0	20.9	7.53	6.6	< 2.0	340	3.0
RockR4	9/3/2004	1:30:00 PM	41.4	21.0	7.66	6.4	< 2.0	370	5.0
	9/10/2004	11:11:00 AM	38.3	20.7	7.43	5.4	< 2.0	310	5.0
STP-RVRSA	9/3/2004	10:00:00 AM	12.8	21.8	7.77	8.0	5.9	530	5.0
	9/10/2004	10:04:00 AM	13.5	22.0	7.76	5.5	6.9	520	6.5
	9/27/2004	2:40:00 PM	13.6	22.5	7.50	8.2	< 2.0	500	4.5

Table 1 Sampling Results, page 2 of 2

Station ID	Date	Ammonia Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)	Nitrite Nitrogen (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Total Phosphorus (mg/l)	Dissolved Reactive Phosphorus (mg/l)	Total Dissolved Phosphorus (mg/l)
CrookB1	9/3/2004	0.067	1.25	< 0.040	0.314	0.060	0.030	N/A
	9/10/2004	0.049	0.860	< 0.040	0.391	0.056	0.020	N/A
RockR0	9/27/2004	0.116	0.380	< 0.040	0.393	0.041	< 0.010	< 0.020
RockR1	9/3/2004	0.368	0.720	< 0.040	1.18	0.539	0.407	N/A
	9/10/2004	0.218	1.60	< 0.040	1.13	0.428	0.364	N/A
	9/27/2004	0.268	1.83	< 0.040	1.00	0.595	0.447	0.500
RockR2	9/3/2004	0.259	0.960	< 0.040	0.914	0.483	0.439	N/A
	9/10/2004	0.314	1.15	< 0.040	1.21	0.554	0.550	N/A
	9/27/2004	0.177	1.72	< 0.040	0.882	0.382	0.297	0.382
RockR3	9/3/2004	0.181	1.04	< 0.040	0.676	0.461	0.391	N/A
	9/10/2004	0.300	1.07	< 0.040	0.881	0.543	0.521	N/A
RockR4	9/3/2004	0.167	1.12	< 0.040	0.810	0.331	0.270	N/A
	9/10/2004	0.292	1.11	< 0.040	1.02	0.487	0.441	N/A
STP-RVRSA	9/3/2004	1.46	0.930	< 0.040	3.81	1.12	0.770	N/A
	9/10/2004	2.13	0.890	< 0.040	3.69	1.55	1.36	N/A
	9/27/2004	0.841	5.10	< 0.040	2.05	1.56	1.52	1.60

TRC Omni Environmental Corporation

Research Park
321 Wall Street
Princeton, New Jersey 08540-1515
Telephone 609-924-8821
Facsimile 609-924-8831

February 25, 2005

VIA EMAIL AND USPS

Barbara Hirst, Chief
New Jersey Department of Environmental Protection
Bureau of Environmental Analysis and Restoration
401 E. State Street, 7th floor W
PO Box 418
Trenton, NJ 08625-0418

RE: PASSAIC NUTRIENT TMDL STUDY
RESULTS OF 2004 MONITORING IN THE PECKMAN RIVER

Dear Ms. Hirst:

As you know, the New Jersey Department of Environmental Protection (NJDEP), in partnership with the Rutgers EcoComplex, retained TRC Omni Environmental Corporation to complete a Nutrient Total Maximum Daily Load (TMDL) Study on the Non-Tidal Passaic River Basin. During the summer and fall of 2003, we sampled a great many streams and sewage treatment plant (STP) effluents throughout the Passaic River Basin, including the Peckman River near its confluence with the Passaic River, and the STPs that discharge into the Peckman River, namely Verona and Cedar Grove. At that time, it was envisioned that the Peckman River would be characterized as a tributary that provides a load to the Passaic system. However, sampling in the Peckman River near its confluence with the Passaic River at McBride Avenue showed high total phosphorus concentrations and large dissolved oxygen variations, suggesting that the Peckman River itself may be a critical location where phosphorus can impact water quality. The purpose of this letter is to summarize the results of the additional monitoring performed in the Peckman River Watershed in 2004.

BACKGROUND

In order to better model the Peckman River, additional data were collected. The purpose of the additional monitoring was twofold. First, simultaneous diurnal dissolved oxygen monitoring at strategic locations was performed to either confirm the presence of critical locations around which the nutrient TMDL must be developed, or to demonstrate that the phosphorus stream criterion of 0.1 mg/l does not apply. Second, additional diurnal monitoring and chemistry sampling were performed to provide more detailed information to enhance the water quality model developed to support the nutrient TMDL for the non-tidal Passaic River Basin. The additional data obtained by TRC Omni have allowed us to develop a stronger model and a better understanding of phosphorus dynamics and water quality impacts in the Peckman River.

2004 SAMPLING PROGRAM OVERVIEW

A Quality Assurance Sampling Plan was prepared by TRC Omni and approved by NJDEP for the sampling performed in the Peckman River. We collected instream water quality and hydraulic data at five locations on the Peckman River (P1 – P5) and two tributaries to the Peckman (T1 and T2). The purpose of sampling the tributaries to the Peckman River was to better understand and quantify any possible nonpoint sources of phosphorus and other pollutants to the Peckman River mainstem. Note that location T1 is downstream of the outlet of Cedar Grove Reservoir. In addition, samples were collected from the Verona and Cedar Grove STP effluents. These locations are identified on Figure 1.

At each of the sampling locations, grab samples were collected, and the following parameters were analyzed in the laboratory: nitrogen series (ammonia, TKN, nitrate, and nitrite), phosphorus series (total phosphorus and dissolved reactive phosphorus), $CBOD_5$, total suspended solids (TSS), and total dissolved solids (TDS). Also, the following in-situ parameters were measured: pH, temperature, dissolved oxygen, and stream flow (based on cross-sectional depth and velocity measurements). Continuous recording meters were used to monitor diurnal dissolved oxygen, pH, and temperature at three of the stream sampling locations (P3, P4, P5).

Sampling was performed during low flow, dry weather conditions. Diurnal meters were installed from August 26 to September 1. Stream samples were obtained on August 26 and September 1, while 24-hour composite samples from STP effluents were obtained on September 1. While flows were measured at many of the stream locations during sampling, the USGS flow gage in the Saddle River at Ridgewood was used to allow comparison with historical flows as well as to plan sampling events. Flow and precipitation conditions (using the gage at Newark Airport) during sampling events are shown in the Figure 2. Note that flows were below the annual 70^{th} percentile flow from August 27 – 29, and again on September 1.

2004 SAMPLING PROGRAM RESULTS

We have completed the additional sampling work and are now using the data and information to develop the Non-Tidal Passaic River Basin Nutrient TMDL. Analytical results for all the grab sampling are provided in the attached Table 1. While the daytime dissolved oxygen and TSS at location T2 were very high, this tributary has an extremely low flow and exerts virtually no influence on the water quality in the Peckman River. It turns out that this “tributary” is nothing more than a small ditch with very little flow under low-flow conditions. Results from location T1 reveal that the flow from this tributary under low-flow conditions is similar to the headwater upstream of Verona STP, and that the dissolved phosphorus concentration is substantial (over 0.2 mg/l). While the load is low compared to the point source loads, it would represent an important load if point sources were reduced substantially. Also, the fact that virtually all the phosphorus is dissolved is unusual in a nonpoint source influenced stream and worth noting. The other observation worth noting is that both phosphorus and nitrate are quite high in the Peckman River. Nitrate was well over 5 mg/l in the mainstem Peckman River when we sampled; during more critical conditions approaching the 7Q10 flow, it is very possible that the nitrate criteria of 10 mg/l would be exceeded. Phosphorus was as high as 1.6 mg/l when we sampled; virtually all the phosphorus was dissolved reactive phosphorus, indicating that phosphorus is not even close to levels that could limit productivity in the Peckman River. Graphs of the continuous monitoring of dissolved oxygen, pH, and temperature from August 26 through September 1 are shown in Figure 3. Finally, graphs of the cross-sections measured at sampling locations are provided in Figure 4.

COMPARISON OF 2003 AND 2004 RESULTS

Figure 5 shows an inter-year comparison between the diurnal data in August 2004 from P5 near the confluence with the Passaic River and the diurnal data taken at the same location (called PK1 in 2003) in August of 2003. When the three days from each year that have the most similar flows and temperature are compared, as shown in Figure 5, the results are strikingly similar. Both years show substantial diurnal fluctuations with minimum dissolved oxygen around 6 mg/l. However, the daily minimums in 2003 declined more rapidly over the course of the event than was observed in 2004, eventually resulting in a minimum dissolved oxygen below the 4 mg/l criterion. Since flows were decreasing and temperatures were increasing during the 2003 event (and, to a lesser extent, the 2004 event), it is very possible that the decline observed was real. However, the possibility that the extremely low velocity in the Peckman River during critical low-flow periods confounded the dissolved oxygen readings during the 2003 diurnal event, resulting in downward drift of the meter, must be acknowledged. A new optical sensor technology that better accommodates low velocity conditions was utilized in 2004; Figure 3 demonstrates the extremely tight agreement between grab samples measured in the field and continuous data measured by the optical sensors during the 2004 event.

Given all these considerations, we are utilizing the 2004 data to calibrate the Peckman River portion of the TMDL model. Once calibrated, we will run the model using a variety of critical conditions for the TMDL to determine whether in fact the current productivity in the Peckman River causes violations of the dissolved oxygen criteria. The model simulations will also help us understand the diurnal dissolved oxygen observations in August of 2003 at PK1 (same location as P5).

CONCLUSIONS

The 2004 diurnal monitoring confirms that the location at McBride Avenue (PK1 in 2003 and P5 in 2004) is the critical location that needs to be simulated carefully. This locations experiences a substantial diurnal swing of about 6 mg/l and the minimum dissolved oxygen approaches the criterion of 4 mg/l during critical low-flow conditions. The additional data we obtained allowed us to model the Peckman River with much greater certainty. We are currently completing model calibration and will apply the model in the Peckman River to determine the following:

1. Are current levels of productivity causing the Peckman River to contravene dissolved oxygen criteria during critical conditions?
2. What impact would phosphorus reductions from point and nonpoint sources have on the dissolved oxygen dynamics?

In addition, we will apply the model to establish load and wasteload allocations as necessary for nitrate in order to prevent the Peckman River from exceeding the stream criterion for nitrate.

Please do not hesitate to contact me with any questions via telephone at 609-924-8821 (Ext. 11) or via email at *JCosgrove@TRCsolutions.com*.

Sincerely,

James F. Cosgrove, Jr., P.E.
President

c: Marzooq Alebus, NJDEP

Figure 1 Sampling Locations

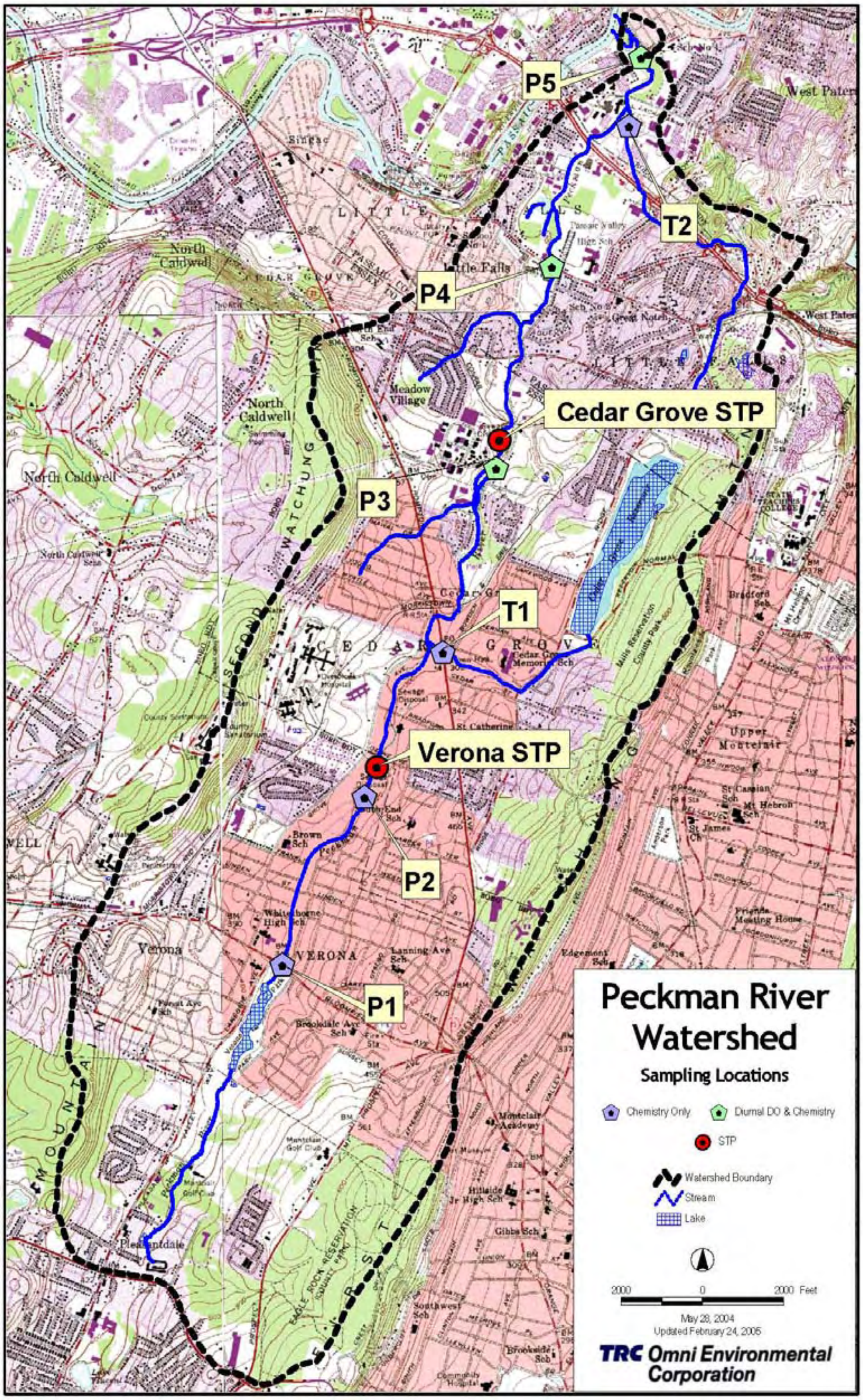


Figure 2 Flow and Precipitation Conditions During Sampling

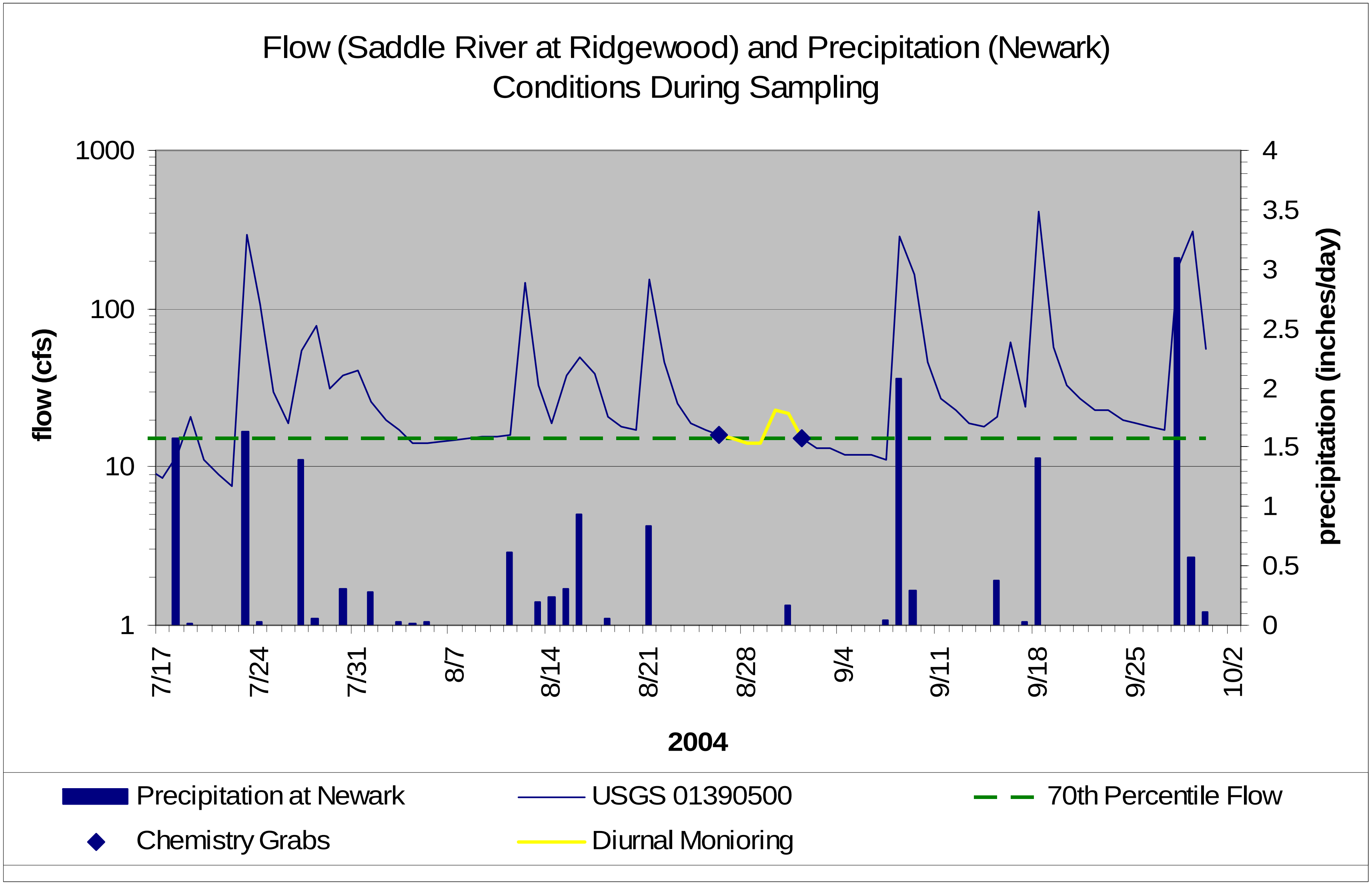
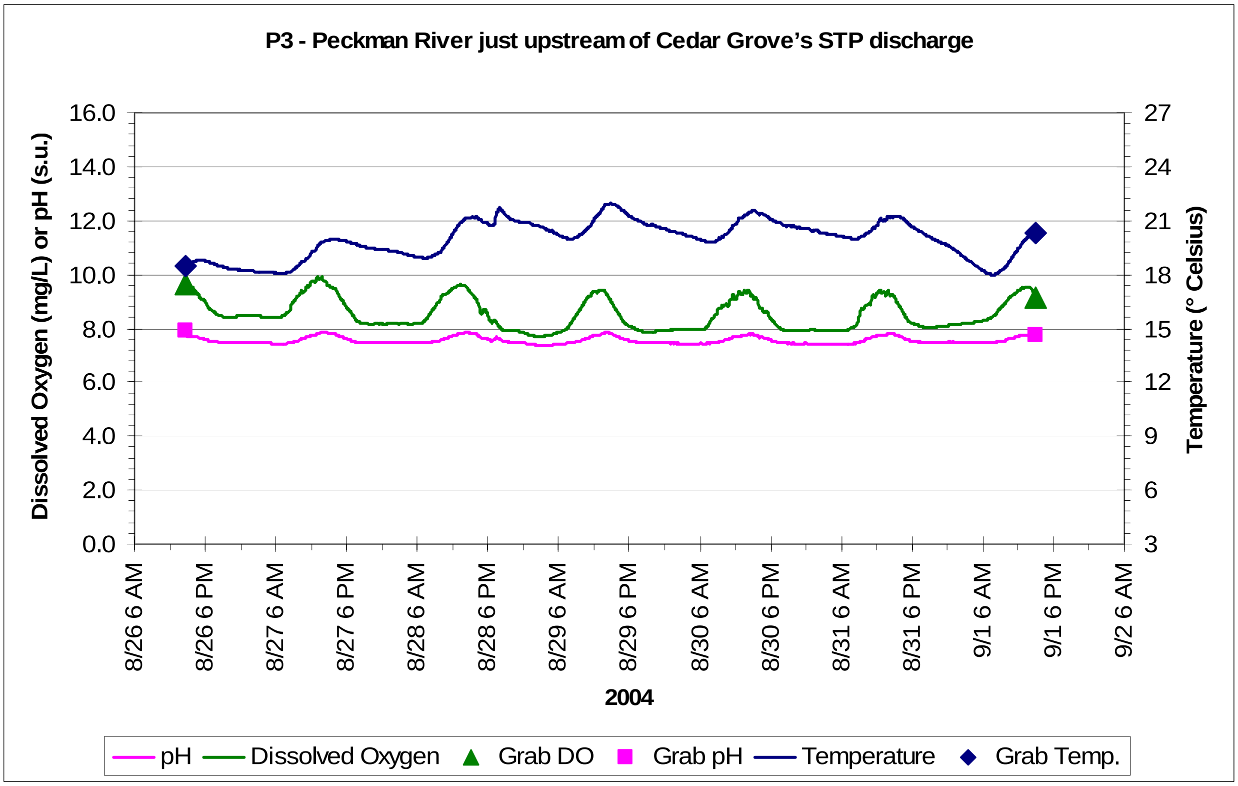


Figure 3 Diurnal Monitoring August 26 – September 1, 2004



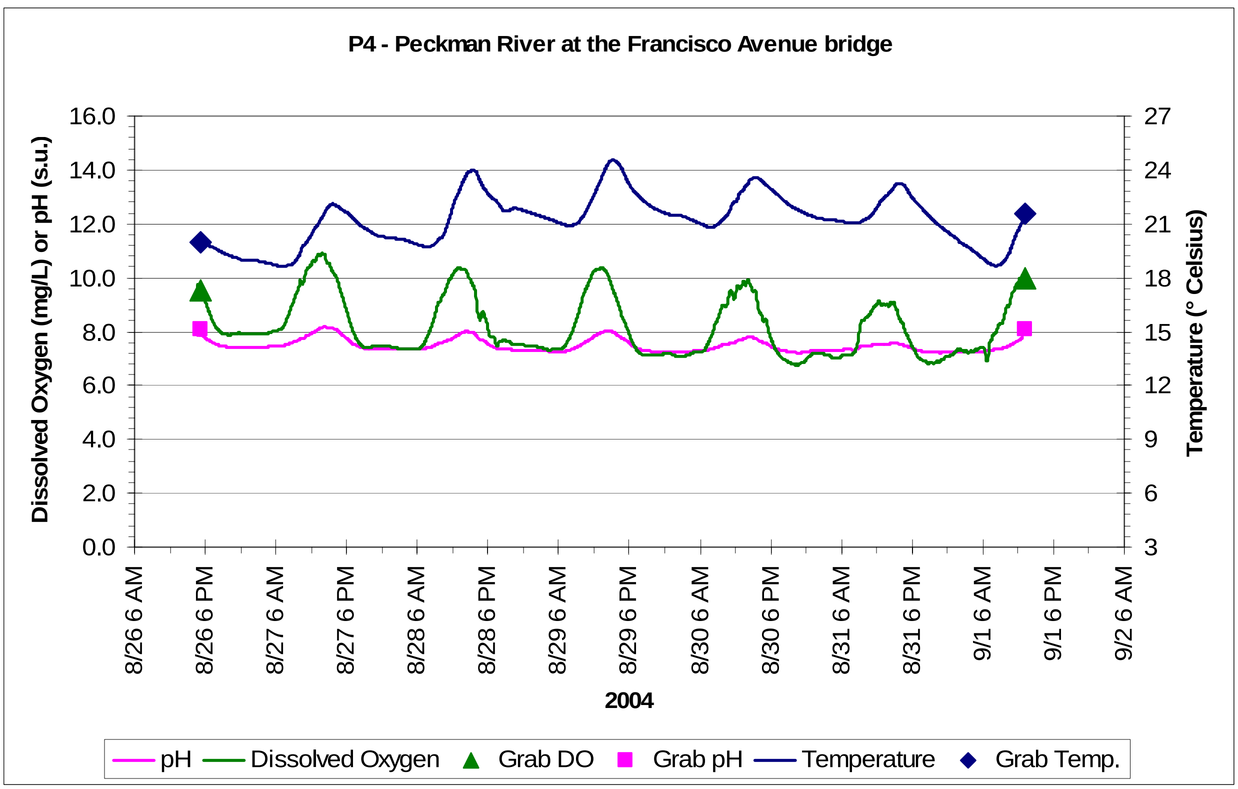


Figure 3 Diurnal Monitoring August 26 – September 1, 2004 (cont'd)

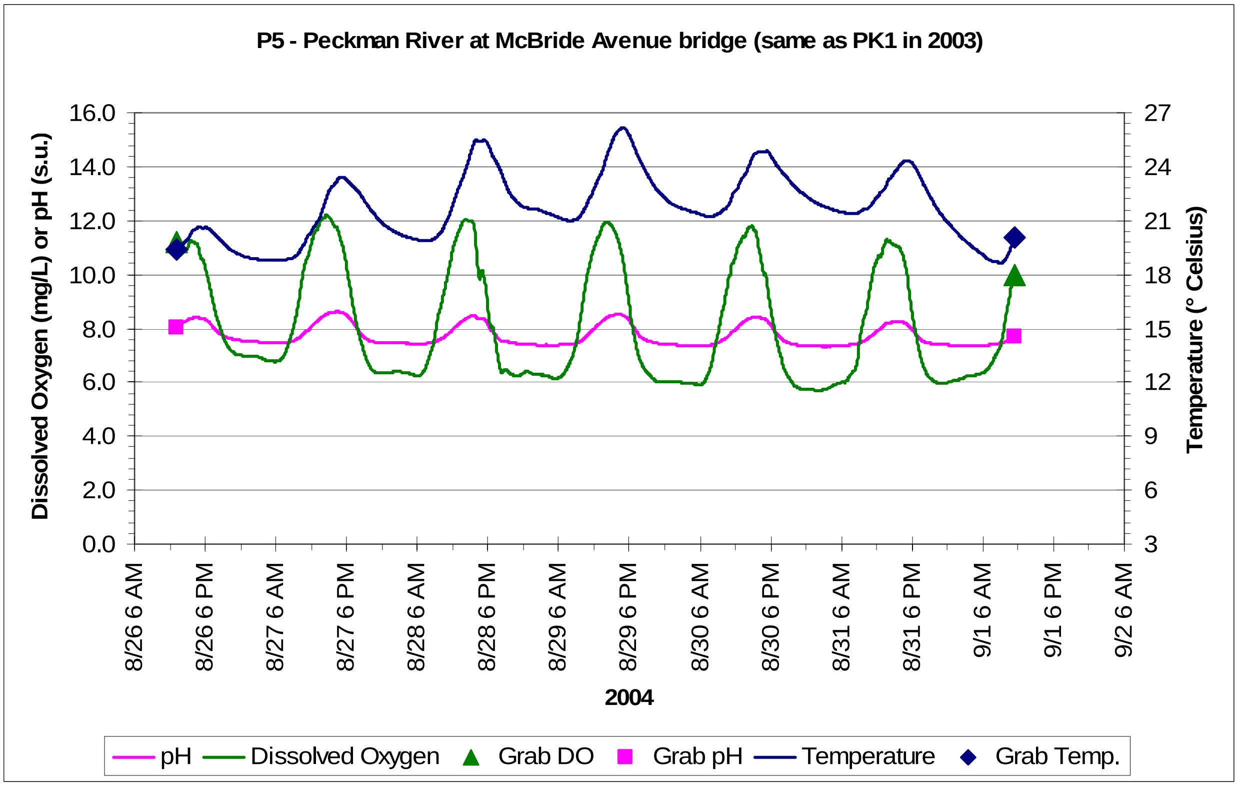


Figure 4 Stream Cross-Sections

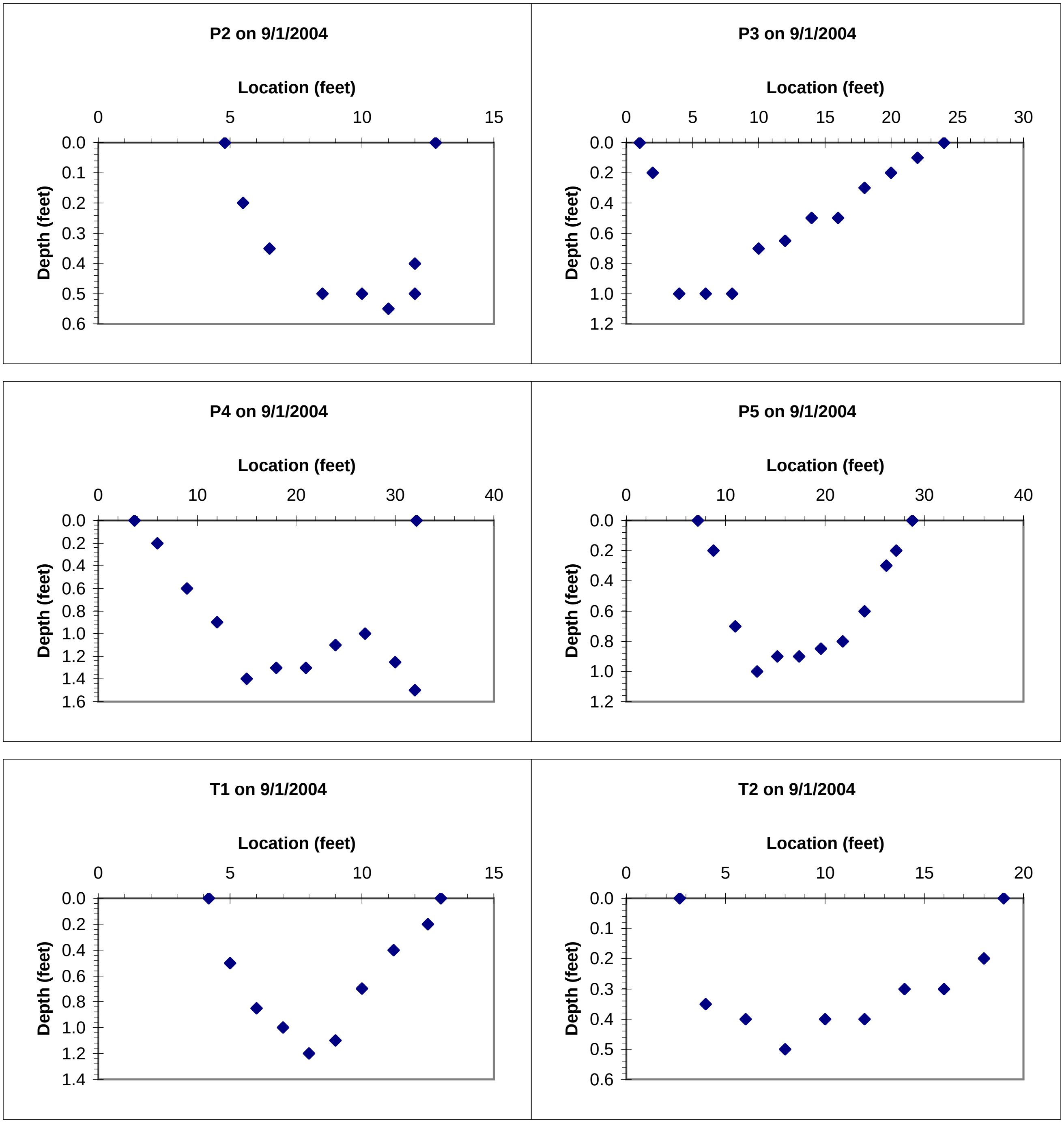


Figure 5 Comparison Between 2003 and 2004 Diurnal Data

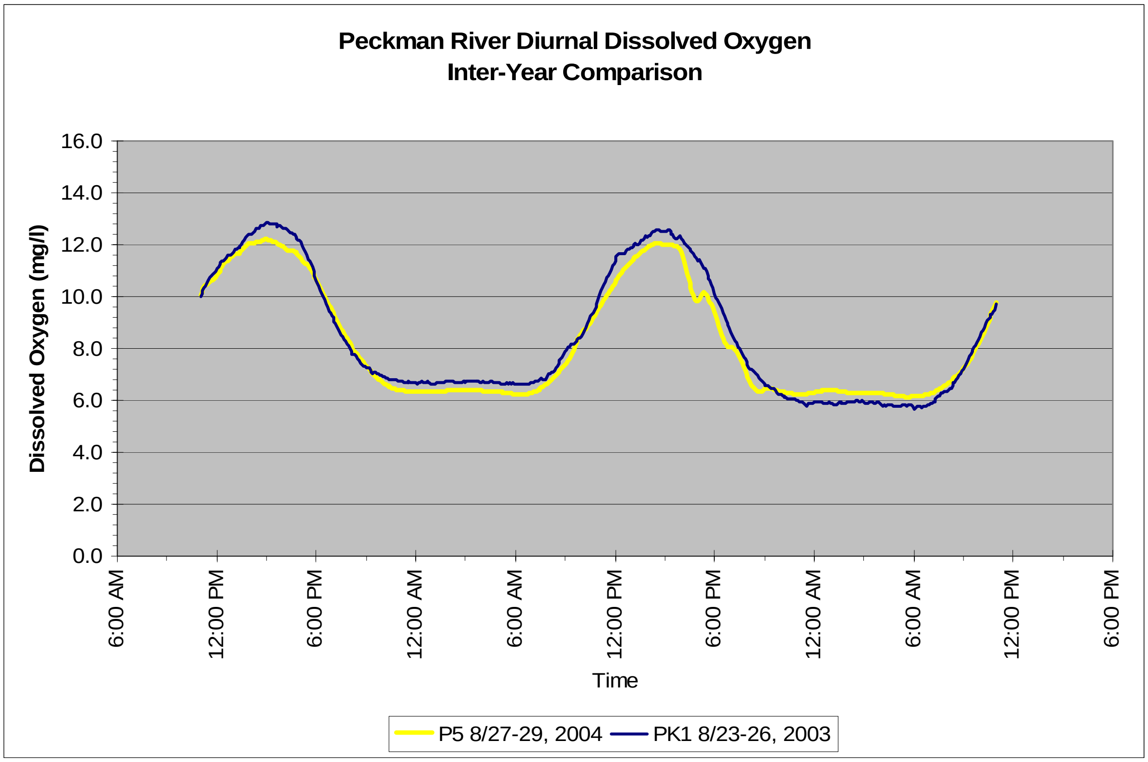


Table 1 Sampling Results, page 1 of 2

Station ID	Date	Time	Flow (cfs)	Temperature (°C)	pH (s.u.)	Dissolved Oxygen (mg/l)	CBOD5 (mg/l)	Total Dissolved Solids (mg/l)	Total Suspended Solids (mg/l)
P1	8/26/04	3:55 PM	N/A	23.3	7.9	8.5	2.3	380	7.0
	9/1/04	4:33 PM	N/A	26.1	7.8	7.3	< 2.0	360	5.0
P2	8/26/04	3:26 PM	N/A	19.6	8.1	9.1	< 2.0	380	1.5
	9/1/04	4:03 PM	0.9	21.0	7.8	8.5	< 2.0	410	2.0
P3	8/26/04	2:23 PM	N/A	19.0	7.9	9.6	< 2.0	390	0.5
	9/1/04	2:40 PM	6.7	20.5	7.8	9.3	< 2.0	380	3.5
P4	8/26/04	5:00 PM	N/A	20.3	8.1	9.4	< 2.0	480	3.5
	9/1/04	12:35 PM	9.6	21.6	8.0	9.6	< 2.0	480	5.0
P5	8/26/04	12:34 PM	11.9	19.3	7.5	10.6	< 2.0	450	2.5
	9/1/04	10:53 AM	8.4	19.7	7.6	9.4	< 2.0	480	4.0
T1	8/26/04	4:13 PM	N/A	19.7	8.4	10.0	< 2.0	400	2.5
	9/1/04	3:25 PM	0.6	20.9	8.1	8.8	< 2.0	480	2.5
T2	8/26/045	5:29 PM	N/A	22.9	8.4	14.7	< 2.0	510	3.5
	9/1/04	11:55 AM	0.1	23.6	8.3	18.0	2.9	520	51.5
STP-CG	9/1/04	8:30 AM	1.9	22.0	6.8	9.4	4.9	310	9.0
STP-Verona	9/1/04	7:30 AM	3.2	23.2	7.3	7.8	< 2.0	430	3.0

Table 1 Sampling Results, page 2 of 2

Station ID	Date	Time	Ammonia Nitrogen (mg/l)	Nitrate Nitrogen (mg/l)	Nitrite Nitrogen (mg/l)	Total Kjeldahl Nitrogen (mg/l)	Total Phosphorus (mg/l)	Dissolved Reactive Phosphorus (mg/l)
P1	8/26/04	3:55 PM	0.110	0.800	< 0.04	0.958	0.093	0.035
	9/1/04	4:33 PM	0.230	0.650	< 0.04	1.00	0.123	0.052
P2	8/26/04	3:26 PM	< 0.050	1.02	< 0.04	0.538	0.063	0.043
	9/1/04	4:03 PM	< 0.050	0.980	< 0.04	0.389	0.071	0.060
P3	8/26/04	2:23 PM	< 0.050	6.08	< 0.04	0.601	1.24	1.24
	9/1/04	2:40 PM	< 0.050	5.12	< 0.04	0.624	1.25	1.00
P4	8/26/04	5:00 PM	0.186	6.63	< 0.04	1.01	1.60	1.60
	9/1/04	12:35 PM	0.126	6.66	< 0.04	0.772	1.54	1.45
P5	8/26/04	12:34 PM	0.089	5.55	< 0.04	0.598	1.41	1.23
	9/1/04	10:53 AM	0.084	6.43	< 0.04	0.856	1.54	1.34
T1	8/26/04	4:13 PM	< 0.050	1.12	< 0.04	0.241	0.245	0.242
	9/1/04	3:25 PM	< 0.050	1.16	< 0.04	0.354	0.298	0.277
T2	8/26/045	5:29 PM	< 0.050	0.820	< 0.04	0.517	0.048	0.017
	9/1/04	11:55 AM	0.050	0.770	< 0.04	1.45	0.205	0.011
STP-CG	9/1/04	8:30 AM	3.63	9.75	< 0.04	5.46	3.40	2.98
STP-Verona	9/1/04	7:30 AM	0.126	17.1	< 0.04	2.43	4.04	3.45

APPENDIX C

Curve Numbers Used to Flow-Weight Runoff EMCs

**Summary of Curve Number* Values by
Land Use Type and Hydrologic Soil Group
(*Curve Numbers NOT Used to Calculate Flow)**

Land Cover Type	Hydrologic Soil Group			
	A	B	C	D
ALTERED LANDS	94	94	94	94
ATHLETIC FIELDS (SCHOOLS)	49	69	79	84
COMMERCIAL/SERVICES	89	92	94	95
CROPLAND AND PASTURELAND	67	77	83	87
DECIDUOUS BRUSH/SHRUBLAND	35	56	70	77
DECIDUOUS FOREST	36	60	73	79
EXTRACTIVE MINING	81	88	91	93
INDUSTRIAL	81	88	91	93
MIXED DECIDUOUS/CONIFEROUS BRUSH/SHRUBLAND	35	56	70	77
MIXED FOREST	36	60	73	79
OLD FIELD (< 25% BRUSH COVERED)	30	58	71	78
OTHER AGRICULTURE	57	73	82	86
OTHER URBAN OR BUILT-UP LAND	49	69	79	84
PLANTATION	43	65	76	82
RECREATIONAL LAND	49	69	79	84
RESIDENTIAL, HIGH DENSITY, MULTIPLE DWELLING	77	85	90	92
RESIDENTIAL, RURAL, SINGLE UNIT	46	68	79	84
RESIDENTIAL, SINGLE UNIT, LOW DENSITY	54	68	79	84
RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	57	72	81	86
TRANSITIONAL AREAS	76	85	89	91
TRANSPORTATION/COMMUNICATIONS/UTILITIES	89	92	94	95
WATER	98	98	98	98
WETLANDS	80	80	80	80

Values Consolidated From:
Soil Conservation Service. 1986. Urban hydrology for small watersheds. Technical Report 55. United States Department of Agriculture, Springfield, VA.

Composite Curve Numbers* Used to Flow-Weight Runoff EMCs for Each Subwatershed
(*Curve Numbers NOT Used to Calcuate Flow)

Contributing Subwatershed	Sum of Areas	Residential		Commercial		Agricultural		Forest		Wetlands		Barren Lands	
		CN	Area (%)	CN	Area (%)	CN	Area (%)	CN	Area (%)	CN	Area (%)	CN	Area (%)
2-12	296	79	6.3%	94	8.9%	0	0.0%	69	68.9%	80	15.5%	74	0.4%
2-13	5,035	76	15.5%	92	4.9%	82	0.4%	68	72.6%	80	6.3%	63	0.3%
2-14	97	75	59.4%	93	35.6%	0	0.0%	55	4.3%	80	0.8%	0	0.0%
2-15	292	72	72.0%	92	5.8%	0	0.0%	59	11.8%	80	10.3%	0	0.0%
2-2	4,062	80	31.6%	93	3.9%	83	0.1%	69	56.3%	80	7.3%	74	0.9%
2-7	514	81	1.7%	94	3.0%	0	0.0%	70	85.7%	80	9.6%	0	0.0%
3-2	30	72	19.6%	92	69.7%	0	0.0%	55	2.6%	80	8.1%	0	0.0%
3-6	1,689	72	33.6%	92	22.0%	77	1.2%	62	26.7%	80	13.7%	64	2.8%
4-6	698	75	42.7%	93	13.8%	77	4.2%	66	22.8%	80	15.6%	70	0.9%
5-13	8,122	75	34.9%	92	9.6%	78	1.8%	64	30.0%	80	23.0%	66	0.7%
5-19	4,226	79	53.3%	93	12.1%	77	0.9%	67	18.5%	80	13.5%	64	1.7%
5-20	611	74	42.2%	92	27.5%	0	0.0%	56	12.2%	80	18.2%	0	0.0%
5-3	167	72	49.0%	92	30.4%	77	0.3%	55	3.3%	80	12.2%	61	4.7%
5-7	1,362	74	66.5%	92	14.9%	83	0.7%	60	8.0%	80	9.9%	0	0.0%
5-9	455	72	60.6%	92	18.9%	0	0.0%	55	10.1%	80	10.4%	0	0.0%
6-10	677	80	64.2%	94	7.6%	82	0.7%	69	14.0%	80	13.4%	0	0.0%
6-15	2,347	80	61.2%	94	13.6%	80	0.5%	69	7.0%	80	17.3%	72	0.4%
6-16	166	80	11.1%	94	39.3%	80	0.0%	69	15.8%	80	33.8%	72	0.0%
6-17	334	81	11.3%	94	44.8%	0	0.0%	66	6.7%	80	22.8%	66	14.4%
6-8	5,813	78	31.8%	93	9.9%	78	1.5%	68	45.3%	80	10.0%	66	1.5%
6-9	270	81	58.1%	93	9.3%	0	0.0%	66	7.8%	80	24.6%	74	0.2%
7-15	2,473	75	46.1%	92	30.4%	83	2.1%	65	19.1%	80	1.2%	65	1.1%
7-16	79	72	2.9%	92	70.2%	0	0.0%	55	18.1%	80	8.8%	0	0.0%
7-22	1,348	75	37.3%	92	33.0%	0	0.0%	56	19.1%	80	10.6%	0	0.0%
7-23	204	78	28.5%	92	26.7%	0	0.0%	63	25.6%	80	19.3%	0	0.0%
7-26	3,355	77	34.3%	93	32.7%	0	0.0%	66	17.6%	80	13.6%	73	1.8%
7-33	8,083	79	32.6%	93	34.7%	82	0.2%	65	11.4%	80	20.5%	70	0.7%
7-41	727	76	23.5%	94	37.8%	0	0.0%	59	5.5%	80	33.1%	0	0.0%
7-46	10,620	79	36.4%	93	20.2%	83	0.5%	67	20.8%	80	21.8%	73	0.3%
7-47	597	78	23.1%	93	24.9%	0	0.0%	58	10.8%	80	40.0%	62	1.2%
7-6	6,170	79	43.2%	94	12.8%	83	3.2%	69	35.1%	80	4.9%	74	0.8%
7-8	520	72	34.0%	92	40.1%	0	0.0%	55	23.4%	80	2.6%	0	0.0%
8-3	334	75	5.7%	93	20.4%	0	0.0%	58	9.4%	80	64.6%	0	0.0%
9-6	1,509	75	47.5%	93	9.7%	80	1.6%	65	16.5%	80	19.3%	72	5.3%
10-13	88	81	2.0%	94	23.2%	83	4.1%	70	12.9%	80	51.8%	74	6.1%
10-8	4,792	80	31.8%	94	7.3%	83	2.6%	70	28.4%	80	28.9%	73	0.9%
11-13	591	81	54.3%	94	2.4%	83	0.7%	70	24.3%	80	18.3%	0	0.0%
11-14	34	80	33.5%	94	13.5%	83	0.4%	70	11.5%	80	41.2%	0	0.0%
11-17	2,484	80	51.2%	94	12.0%	83	0.4%	67	17.8%	80	18.5%	74	0.1%
11-27	4,726	81	65.9%	94	15.3%	83	0.0%	70	12.9%	80	5.8%	0	0.0%
11-33	537	81	57.8%	94	4.5%	83	1.7%	70	30.5%	80	2.8%	74	2.7%
11-38	1,405	81	63.4%	94	25.2%	0	0.0%	70	8.3%	80	3.0%	0	0.0%
11-39	545	81	38.2%	94	36.6%	0	0.0%	70	2.3%	80	22.7%	74	0.3%
11-42	7,468	81	54.1%	94	9.6%	83	0.5%	70	26.2%	80	8.8%	74	0.8%
11-48	6,734	79	48.4%	94	14.9%	83	0.3%	69	16.5%	80	19.7%	71	0.2%
11-58	3,449	79	43.2%	94	23.6%	83	0.0%	68	12.4%	80	20.4%	74	0.4%
11-6	5,246	78	26.7%	94	10.6%	83	3.2%	67	22.0%	80	37.2%	69	0.4%
11-65	528	76	38.0%	94	17.6%	79	1.0%	65	23.8%	80	19.3%	74	0.2%
11-66	192	81	52.8%	94	3.0%	0	0.0%	70	21.7%	80	22.5%	0	0.0%
11-69	3,966	78	41.9%	93	15.4%	78	0.7%	65	16.8%	80	24.8%	61	0.5%
12-13	1,438	78	27.5%	93	22.6%	83	0.2%	70	11.4%	80	36.6%	74	1.6%
12-14	51	81	44.9%	94	0.8%	0	0.0%	70	26.7%	80	27.4%	74	0.2%
12-20	1,116	81	24.4%	94	1.7%	0	0.0%	70	10.9%	80	62.5%	74	0.4%
12-27	1,243	81	14.9%	94	1.5%	0	0.0%	70	16.7%	80	66.8%	74	0.1%
12-33	1,833	79	9.8%	94	4.4%	83	0.4%	68	6.6%	80	78.6%	61	0.3%
12-37	898	72	52.1%	92	15.3%	77	1.6%	55	4.7%	80	25.6%	61	0.8%
12-38	358	73	30.3%	92	19.5%	77	0.9%	60	9.6%	80	39.7%	0	0.0%
12-5	7,434	78	48.6%	93	23.3%	78	0.4%	64	15.0%	80	12.4%	70	0.3%
13-2	72	72	40.9%	92	20.8%	0	0.0%	55	24.7%	80	13.7%	0	0.0%
14-7	540	72	8.0%	92	34.3%	0	0.0%	55	16.4%	80	41.2%	61	0.1%
15-11	81	72	39.9%	92	40.0%	0	0.0%	55	9.5%	80	8.4%	61	2.1%
15-12	559	79	27.4%	93	53.0%	0	0.0%	60	11.5%	80	6.9%	74	1.2%
15-2	1,152	73	9.1%	92	66.5%	77	0.0%	62	11.0%	80	13.1%	61	0.2%
15-5	619	77	54.1%	92	25.6%	0	0.0%	65	17.8%	80	2.5%	0	0.0%
15-6	446	78	57.0%	92	14.5%	83	0.5%	68	26.3%	80	1.5%	74	0.3%
15-9	1,220	75	34.6%	92	43.8%	83	0.1%	59	11.8%	80	9.0%	61	0.7%
16-16	622	81	52.0%	94	19.0%	0	0.0%	70	23.2%	80	2.9%	74	2.9%
16-19	924	79	53.0%	93	28.4%	0	0.0%	67	13.3%	80	4.0%	69	1.3%
16-8	2,006	81	45.4%	94	21.3%	0	0.0%	70	30.4%	80	2.3%	74	0.6%
17-14	7,301	77	64.1%	93	23.6%	83	0.1%	65	9.5%	80	2.1%	69	0.6%
17-17	3,465	78	70.1%	93	26.0%	0	0.0%	65	2.2%	80	1.7%	67	0.1%
17-20	317	75	60.2%	92	32.0%	0	0.0%	55	5.6%	80	1.5%	61	0.7%
17-21	671	80	67.0%	94	32.3%	0	0.0%	67	0.4%	80	0.3%	0	0.0%
17-28	2,836	75	57.4%	93	39.3%	0	0.0%	61	2.2%	80	0.7%	61	0.4%
17-29	855	80	58.3%	94	39.3%	0	0.0%	61	1.1%	80	0.5%	61	0.8%
17-5	1,657	79	62.4%	93	25.3%	0	0.0%	67	11.0%	80	1.2%	0	0.0%
17-6	70	72	43.9%	92	55.0%	0	0.0%	55	1.1%	80	0.0%	0	0.0%
17-8	5,922	78	53.9%	93	11.1%	83	0.2%	69	29.0%	80	3.2%	73	2.6%
17-9	79	72	61.6%	92	35.9%	0	0.0%	55	2.6%	80	0.0%	0	0.0%

APPENDIX D

Export of Phosphorus from Great Swamp to Passaic River

Export of Phosphorus from Great Swamp to Passaic River

I. Purpose and Background

The Passaic River at Millington Gorge (PA2) is the headwater boundary of the flow and water quality model developed for the Non-Tidal Passaic River Basin TMDL Study, and exhibits relatively high phosphorus concentrations. The Passaic River at Millington Gorge is also the outlet of the Great Swamp watershed in Morris and Somerset Counties. The average phosphorus concentration based on the sampling performed in 2003 by Omni Environmental (Omni) was 0.13 mg/l total phosphorus, which is consistent with earlier data collected by NJDEP in the 1990s when that station was included in the Ambient Surface Water Monitoring Network (ASMN). NJDEP requested this study in order to better characterize the Passaic River headwater phosphorus condition at the outlet of Great Swamp as well as the phosphorus inputs to the Great Swamp. In other words, how do tributary and point source phosphorus imports to Great Swamp compare with the export of phosphorus to the Passaic River? The study was not designed to quantify processes within the swamp itself, but rather to make use of existing data to quantify phosphorus loads entering and exiting the swamp through the Passaic River.

The Great Swamp Watershed Association (GSWA) and Ten Towns Great Swamp Watershed Management Committee (TTC) have a high quality long-term dataset, made available to Omni in January 2006, at the outlet of Great Swamp (the Passaic River at Millington Gorge). It reveals no relationship with flow that might indicate point source influence, but instead shows a strong seasonal trend. For this reason, bimonthly average concentrations for total phosphorus were used along with actual measured concentrations to develop a seasonally varying boundary condition for total phosphorus at the Passaic River headwater boundary. The predictive strength of this seasonal variation based on bimonthly average total phosphorus concentrations is remarkable, as discussed in Section IV. The strong seasonal trend, along with observations of very high nonpoint source concentrations in the Great Swamp in streams that are not downstream of any sewage treatment plant (STP) discharge, suggest that the Passaic River headwater quality may be dominated by wetland dynamics.

II. Great Swamp Watershed Characterization

Several datasets were combined to provide a characterization of the phosphorus conditions throughout the Great Swamp watershed. GSWA and TTC have collaborated to develop an extensive dataset that includes the major tributaries to Great Swamp as well as the export to Passaic River. These data were collected by trained volunteers using prescribed quality assurance procedures under the direction of a professional technical consultant, and samples were analyzed by a NJDEP-certified laboratory[1] for phosphorus and the other constituents. Further information on the GSWA and TTC stream monitoring program, as well as the data results, are available at http://www.greatswamp.org/StreamMon.htm). In addition to the GSWA dataset, Omni has data from the TMDL monitoring program as well as long term quarterly data from Black Brook that were collected on behalf of the Township of Chatham under a NJDEP-approved Quality Assurance Sampling Plan. Finally, monthly reporting data submitted to NJDEP from July 2000 through April 2005 from Morris-Woodland STP and Chatham-Main STP were assembled. All these data were compiled within a single database in order to perform this study, and are provided in Attachment 1 as well as electronically in Appendix M of the Phase II Final Report for the Non-Tidal Passaic River Basin TMDL Study. Figure GS-1 shows the sampling locations and point sources within the Great Swamp watershed.

There are five subwatersheds that drain to Great Swamp: the Passaic River headwaters, Primrose Brook, Great Brook, Loantaka Brook, and Black Brook. The Morris-Woodland STP discharges to Loantaka Brook well upstream of the point where it enters Great Swamp. The Chatham-Main STP discharges to a tributary to Black Brook at a location just outside the boundary of the National Wildlife Refuge. Black Brook and Great Brook combine to form the Passaic River within the Great Swamp.

A. Great Swamp

The area of the Great Swamp is not defined precisely. The heart of Great Swamp is the Great Swamp National Wildlife Refuge, shown on Figure GS-1. However, there are extensive wetlands that are part of the Great Swamp, but that lie outside the National

[1] Environmental Compliance Monitoring, Inc in Hillsborough, NJ (NJDEP Certification #18630)

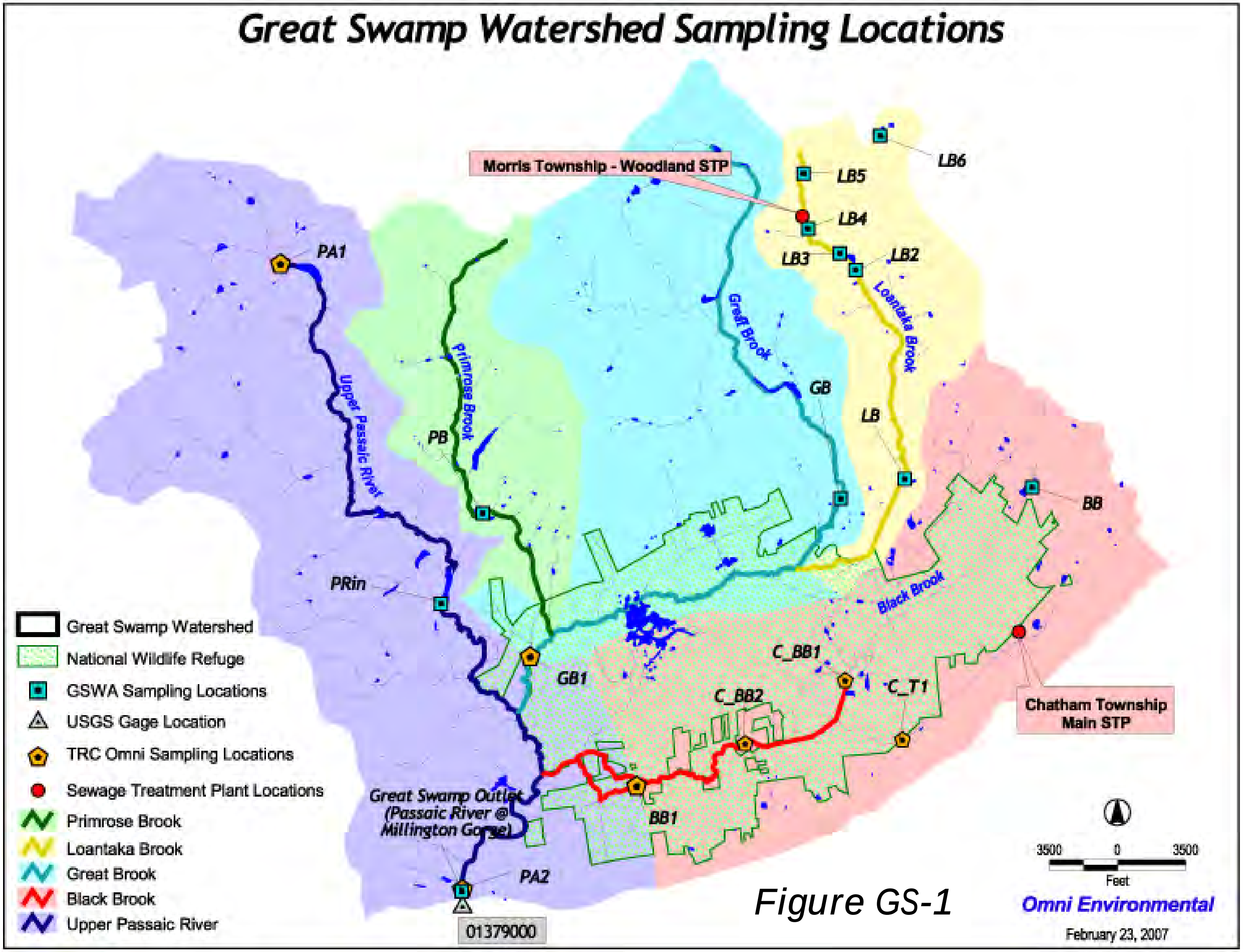

Great Swamp Watershed Sampling Locations
Morris Township - Woodland STP
LB6
LB5
LB4
LB3
LB2
PA1
Primrose Brook
Upper Passaic River
Greatt Brook
Loantaka Brook
GB
LB
PB
BB
PRin
Black Brook
C_BB1
C_T1
C_BB2
GB1
Chatham Township Main STP
Great Swamp Outlet (Passaic River @ Millington Gorge)
BB1
PA2
01379000
Great Swamp Watershed
National Wildlife Refuge
GSWA Sampling Locations
USGS Gage Location
TRC Omni Sampling Locations
Sewage Treatment Plant Locations
Primrose Brook
Loantaka Brook
Great Brook
Black Brook
Upper Passaic River
3500
0
3500
Feet
Omni Environmental
February 23, 2007

Figure GS-1

Wildlife Refuge. Furthermore, there is very little wetland area upstream of the GSWA[2] sampling stations (PRin, PB, GB, LB, and BB). Therefore, the Great Swamp can be considered the portion of the Great Swamp watershed downstream of the GSWA station locations on the Passaic River (PRin), Primrose Brook (PB), Great Brook (GB), Loantaka Brook (LB), and Black Brook (BB). Figure GS-2 provides an idealization of the Great Swamp watershed showing inlet subwatersheds, point sources, and the outlet location. Inlet subwatersheds were defined as the drainage areas of the GSWA sampling locations listed above.

Using this definition, the following stream sampling stations are located within the swamp itself: the Black Brook upstream of the tributary into which Chatham-Main STP discharges (C_BB1), the tributary into which Chatham-Main STP discharges (C_T1), the Black Brook downstream of the tributary into which Chatham-Main STP discharges (C_BB2), the mainstem Black Brook (BB1), and the mainstem Great Brook (GB1). Figure GS-3 shows the average total phosphorus concentrations at stations in the subwatersheds upstream of Great Swamp (LB2, LB3, LB4, LB5, LB6, PA1), the inlets to Great Swamp (PRin, PB, GB, LB, and BB), stations within Great Swamp (C_BB1, C_T1, C_BB2, BB1, GB1), and the outlet (PRout/PA2). Growing season was defined as May through September for this analysis.

Notice that very high phosphorus concentrations are going into Great Swamp, and that the inlet concentrations are higher during the growing season. The phosphorus conditions at the various inlets to the Great Swamp will be examined in more detail in the ensuing section. Within the Great Swamp, phosphorus concentrations are even higher than the inlet concentration during the growing season, and lower than the inlet concentration during the non-growing season. The fact that stream phosphorus concentrations within the Great Swamp are higher during the growing season is likely the cause of the seasonal pattern observed at the outlet, namely that phosphorus concentration is higher in the summer than the winter.

---

[2] These sites are referenced as GSWA sites because they are included in the dataset housed by GSWA. They are in fact TTC sites that are sampled by GSWA volunteers under the management of TTC's technical consultant.

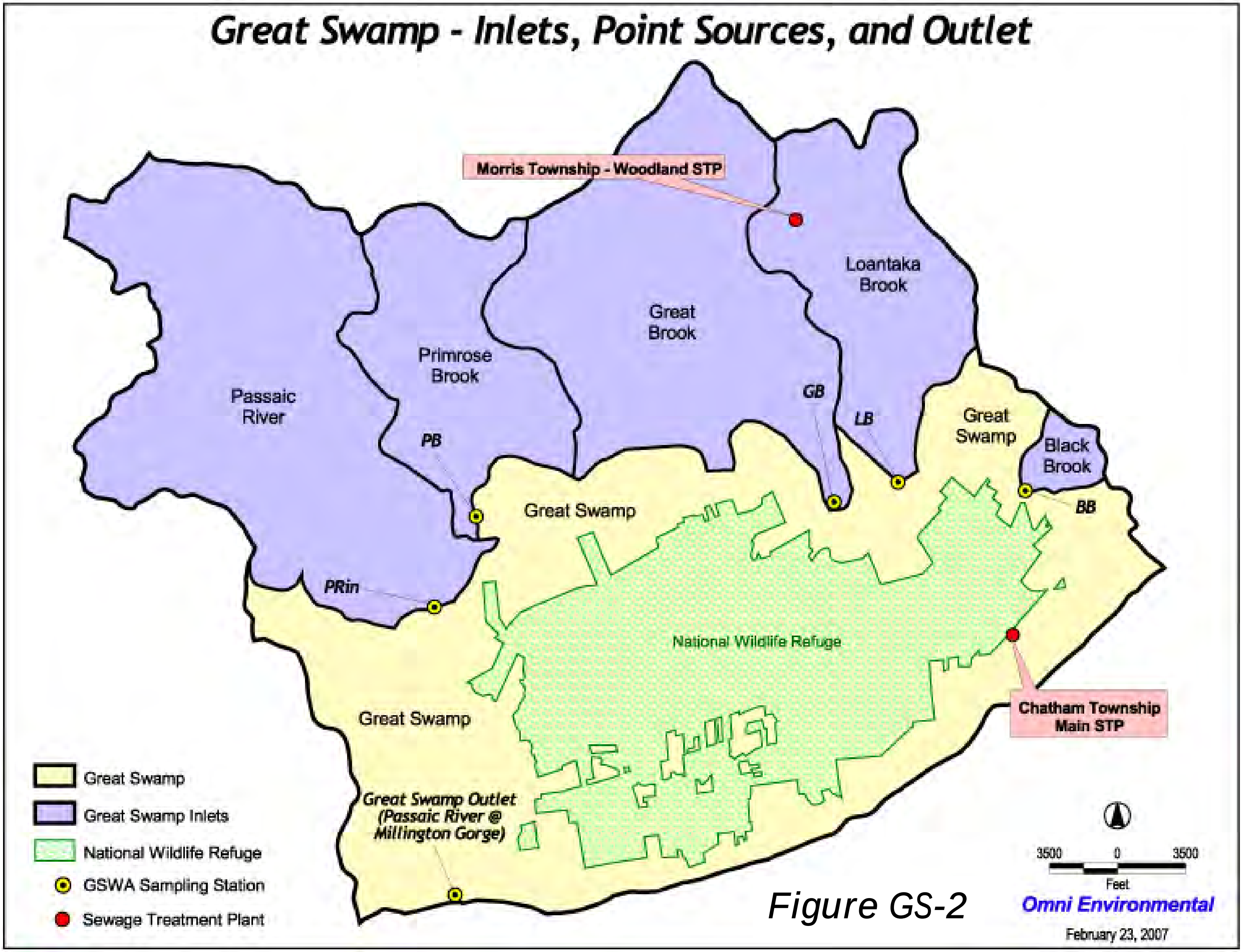
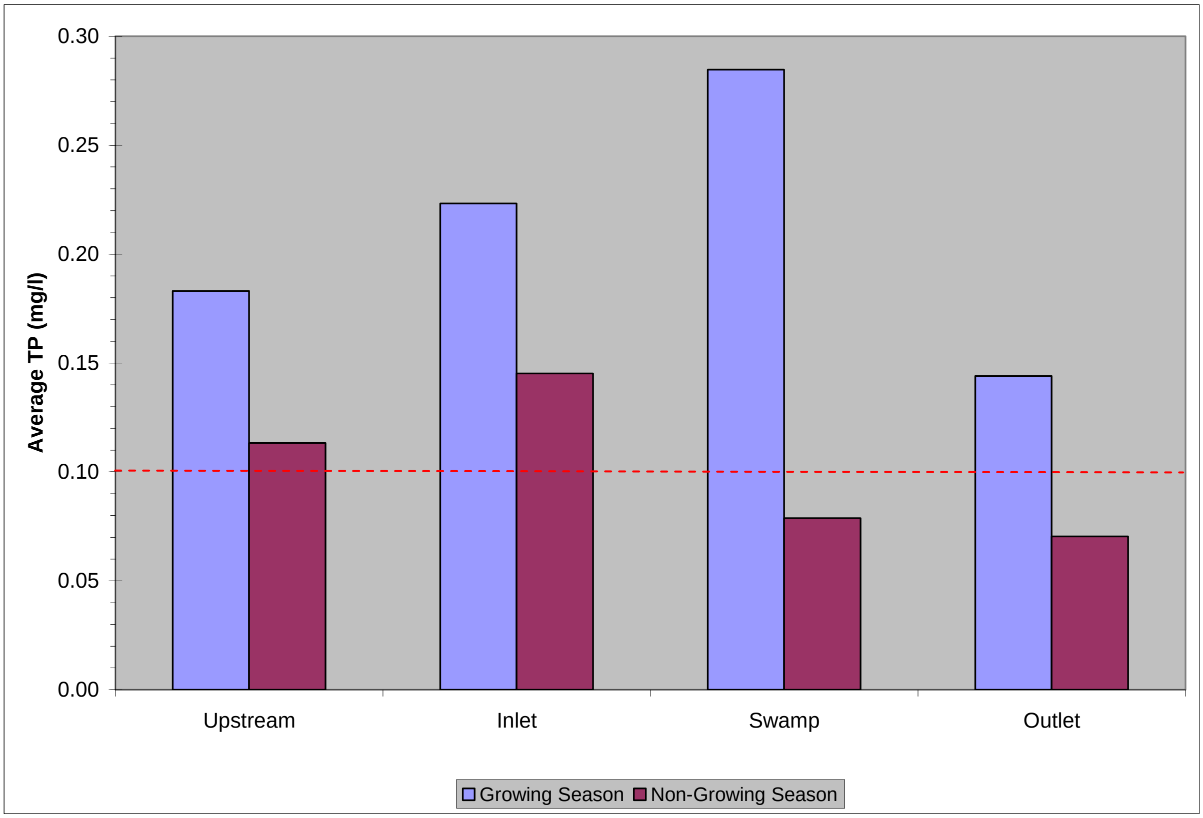

Great Swamp - Inlets, Point Sources, and Outlet
Morris Township - Woodland STP
Loantaka Brook
Great Brook
Primrose Brook
Passaic River
GB
LB
PB
Great Swamp
Black Brook
BB
Great Swamp
PRin
National Wildlife Refuge
Chatham Township Main STP
Great Swamp
Great Swamp
Great Swamp Inlets
National Wildlife Refuge
GSWA Sampling Station
Sewage Treatment Plant
Great Swamp Outlet (Passaic River @ Millington Gorge)
3500
0
3500
Feet
Omni Environmental
February 23, 2007
Figure GS-2

Figure GS-3: Average Phosphorus Concentrations in Great Swamp Watershed



One possible explanation for this pattern (i.e. higher phosphorus levels during the summer) is that natural levels of dissolved oxygen within the Great Swamp are extremely low during the summer (Phase I Report, TRC Omni, 2004). As a result, iron in the sediments will reduce to its ferrous form and release phosphorus into the water column. Iron levels in Great Brook and Black Brook within Great Swamp were generally high, varying from about 0.5 to 3.0 mg/l (Phase I Report, TRC Omni, 2004). Higher levels were observed in the summer than winter. Also, it should be noted that sediment interactions are very important within the Great Swamp. Based on experience of Omni staff who have sampled several locations in Great Swamp for many years, the substrates of streams in the Great Swamp are comprised of soft and deep black muck extending several feet down from the stream bottom, making sampling difficult and hazardous. This deep muck, a natural condition present throughout much of the Great Swamp, likely represents a major oxygen demand, phosphorus bank, and interflow connection.

Sediment interactions within the Great Swamp appear to be much more important to the overall phosphorus balance than plant uptake, since the Great Swamp is providing a source of phosphorus during the summer when uptake is highest (see Section IV). If productivity within the swamp were controlling phosphorus exports, then one would expect phosphorus leaving the swamp to be lowest during the growing season when uptake (and retention) within the swamp is highest. While investigating processes within the swamp is beyond the scope of this analysis, this discussion provides plausible contributing factors for the observed seasonal pattern of phosphorus in the Great Swamp.

Figure GS-4 shows the average phosphorus concentrations observed within Great Swamp itself. Stations C_BB1 and C_T1 were sampled 10 times from May to November of 2002. C_BB2 was sampled 22 times from May 2002 to August 2005. Stations BB1 and GB1 were sampled 12 times from June to November of 2003. Note that station C_BB1 is upstream of any point source influence, and exhibits phosphorus concentrations higher than the treated effluent from either of the STPs that discharge within the Great Swamp watershed. Extremely high concentrations (0.7 and 2.4 mg/l) were observed in August of 2002 at station C_BB1. Figure GS-4 also shows the very large contrast between phosphorus concentrations during the growing season versus the non-growing season. Both are high, but the concentrations are highest during the growing season. Again, this points to the sediment interactions overwhelming any impact from uptake (which would tend to decrease concentrations during the growing season). Stations BB1 and GB1 are remarkably similar to one another in phosphorus concentration, despite receiving inputs from completely different inlet subwatersheds; they are located in the Black Brook and Great Brook, respectively, near the point where each combines with the Passaic River within the Great Swamp. Given the myriad of interconnected streams within the Great Swamp (Figure GS-5), it is very likely that Black Brook and Great Brook not completely independent within the swamp itself. In fact, precise definitions of upstream and downstream may not have much meaning within the Great Swamp. The inlets and outlet of the swamp, however, are well-defined hydrologically, and each exhibits distinct water quality characteristics, as described below. The fact that the inlets and outlet are distinct, but locations within the swamp are not, supports the basic idealization shown in Figure GS-2 on which the loading analysis was based.

Figure GS-4: Average Phosphorus Concentrations within Great Swamp

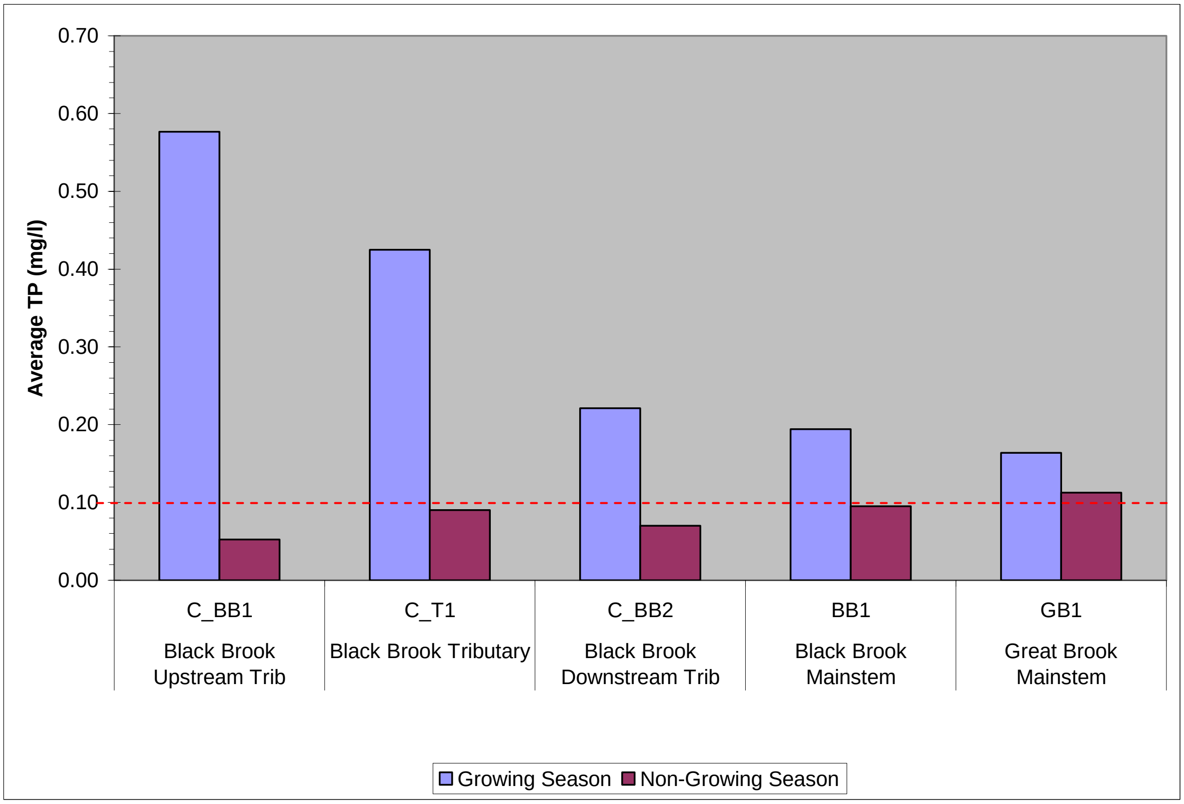
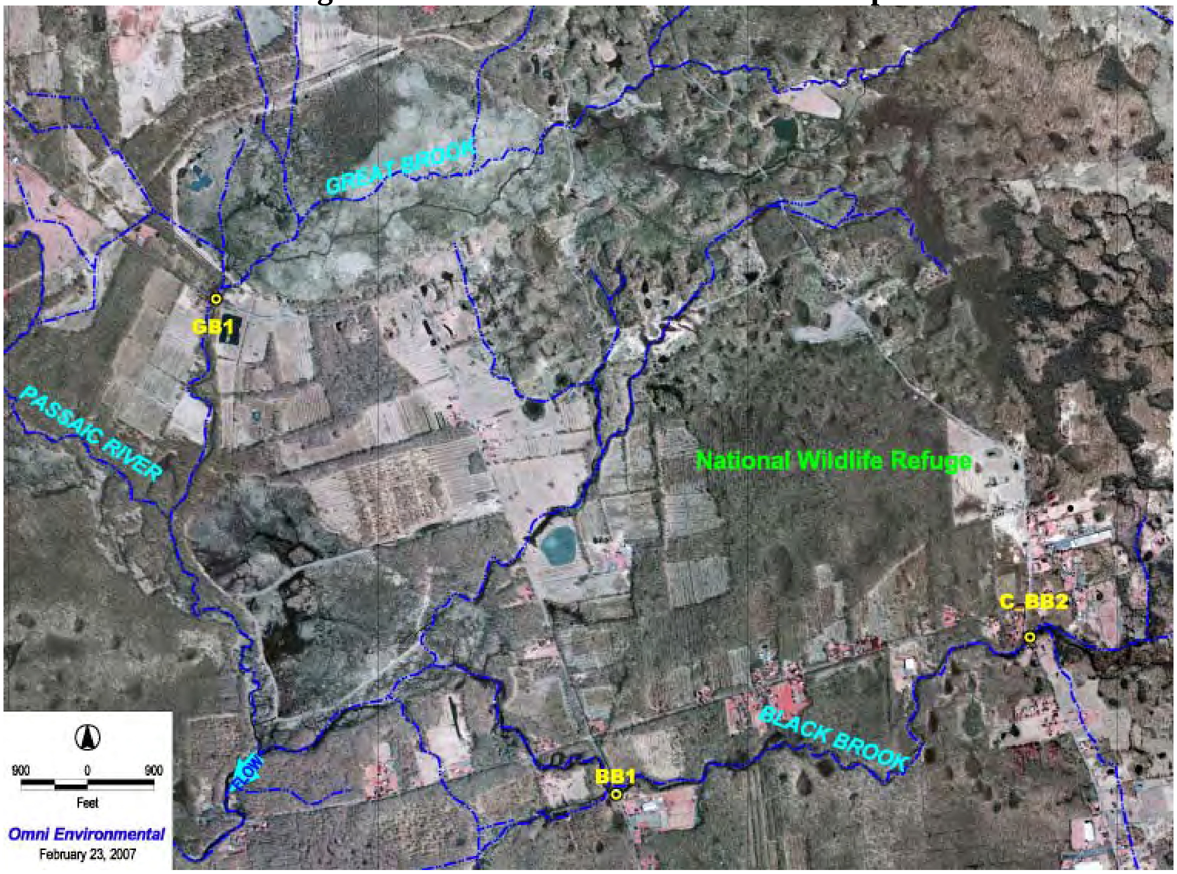


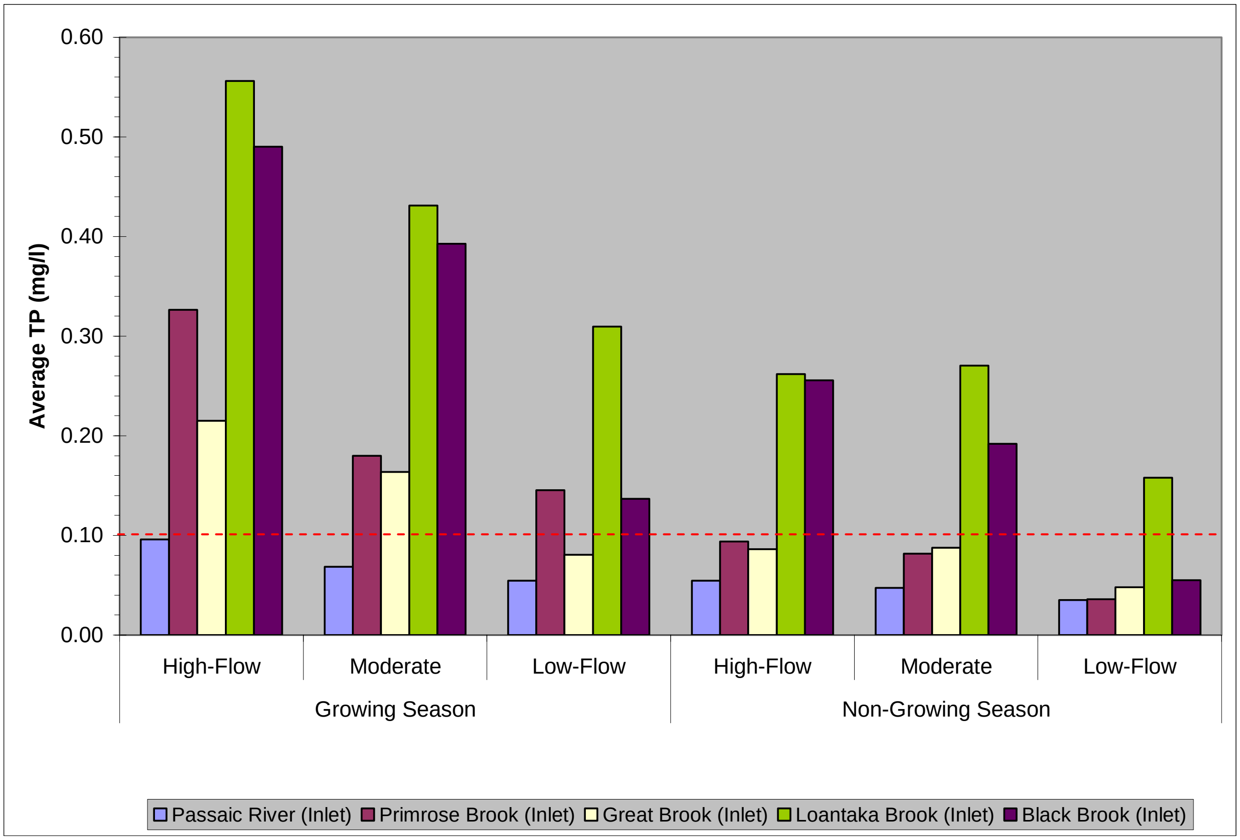
Figure GS-5: Aerial Photo of Great Swamp



B. Great Swamp Inlets

As shown in Figure GS-2, there are five subwatersheds that drain to the Great Swamp: Passaic River upstream of GSWA station PRin; Primrose Brook upstream of GSWA station PB; Great Brook upstream of GSWA station GB; Loantaka Brook upstream of GSWA station LB; and Black Brook upstream of GSWA station BB. Figure GS-6 shows the average phosphorus concentrations at the five inlets to the Great Swamp. General flow conditions were defined using the daily records from the USGS flow gage at the Passaic River at Millington (01379000), the outlet of the Great Swamp. Samples taken when flows at the gage were over the 25th Percentile flow (defined by USGS to be 113cfs) were designated High-Flow; samples taken when flows at the gage were below the 70th Percentile flow (defined by USGS to be 23cfs) were designated Low-Flow. Figure GS-6 reveals strong differences between growing season and non-growing season, among various flow conditions, and among the five inlets.

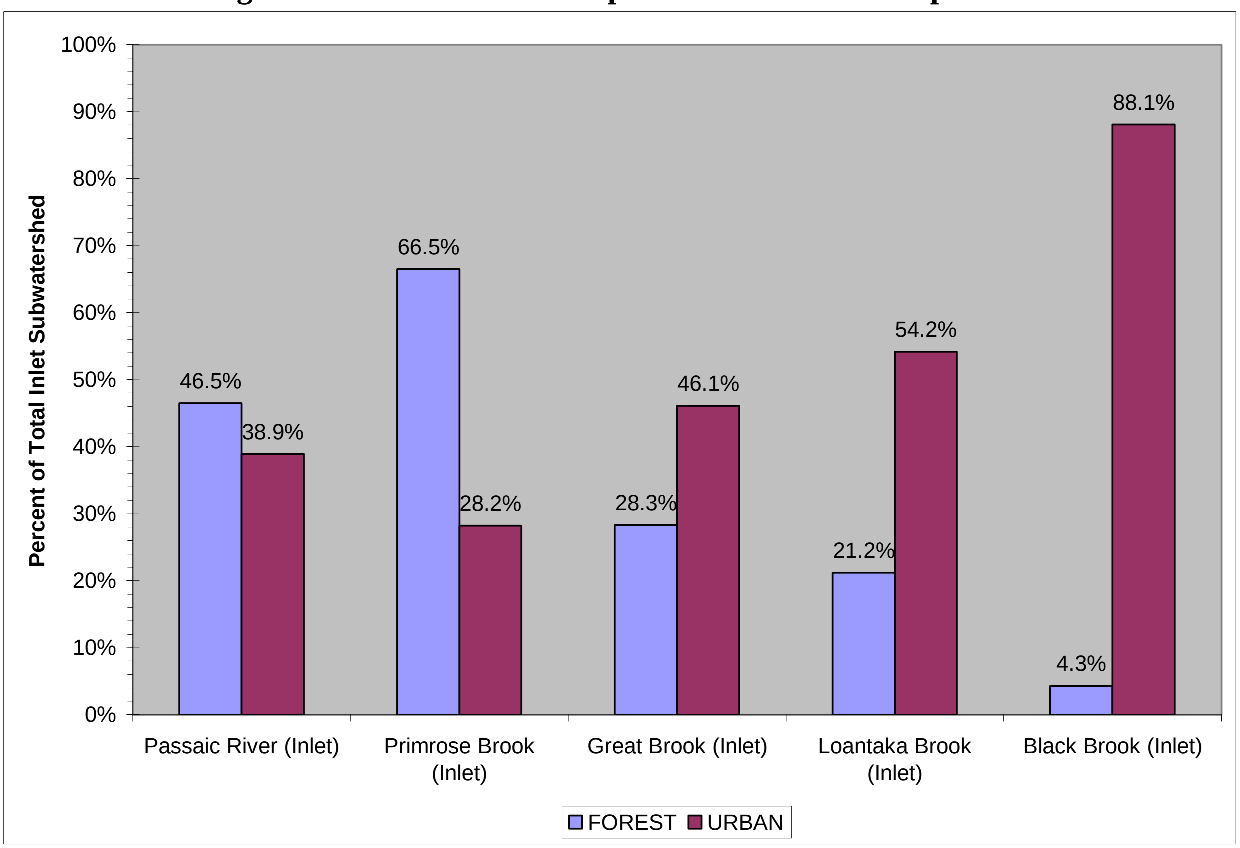
Figure GS-6: Average Phosphorus Concentrations at Inlets to Great Swamp



Distinguishing between natural and anthropogenic sources within the inlets to the Great Swamp is difficult. High-flow concentrations are higher in concentration than low-flow concentrations, even in Loantaka Brook, which includes the Morris-Woodland STP discharge. Growing season concentrations are higher than non-growing season concentrations; this may reflect seasonally varying baseflow concentrations, migratory waterfowl contributions, and/or seasonal urban sources such as lawn fertilization. However, lawn fertilization is not likely to explain all (or even most) of the difference, since lawn fertilization is also applied in the early Spring and late Fall during the non-growing season (as defined in this analysis). The fact that Loantaka Brook remains high in concentration during low flow periods can certainly be attributed to the fact that Morris-Woodland STP discharges to it. Furthermore, Black Brook drains Chatham and is highly urbanized. Figure GS-7 shows the percent forest and percent urban land use areas within the subwatersheds of the various inlets to the Great Swamp (according to

NJDEP's 1995 land use coverage). Urbanization can explain some of the high phosphorus sources, but an important component unrelated to urbanization remains. The Passaic River inlet, despite being 39% urban, is very low in phosphorus compared to the other inlets. Furthermore, Primrose Brook is over 66% forested and yet exhibits average phosphorus concentrations of 0.14 mg/l. Similarly, the Loantaka Brook headwater (GSWA station LB6) furthest upstream of Morris-Woodland STP exhibits an average phosphorus concentration of 0.17 mg/l, with a summer high reaching 0.38 mg/l. Clearly, there are very high sources of phosphorus being delivered to Great Swamp even upstream of point sources and unrelated to urbanized areas. Defining the exact nature of these sources and investigating the degree to which they are naturally occurring, is beyond the scope of this analysis.

Figure GS-7: Land Use Composition of Great Swamp Inlets



III. Hydrology of the Great Swamp

In order to characterize phosphorus loads into and out of the Great Swamp over time, flows must be estimated at all inlets and the outlet. Flow at the outlet is available from the USGS stream flow gage at that location (01379000). Flows at the inlets were often measured by GSWA during their sampling. In order to be able to predict flows at the inlets during days that were not sampled, attempts were made to relate flows at the inlets to gaged flow at the outlet. Traditional drainage area ratio methods could not be used, because the inlet flows as a percentage of the outlet flow varied greatly over time. In fact, the variation of inlet flows as a percentage of the outlet flow varies with the outlet flow; the lower the outlet flow, the higher the inlet flow as a percentage of the outlet flow. Individual inlet flows were frequently larger than the outlet flow during low-flow conditions.

This relationship between inlet flows as a percentage of outlet flow and the outlet flow turns out to be very strong when described using a power function for each inlet. Figures GS-8 to GS-12 show the power functions and strengths for each subwatershed inlet. These are remarkably strong flow correlations. During low-flow conditions, much more water is flowing into the Great Swamp than flowing out. In fact, each of the inlet flows alone is greater than the outlet flow during low-flow conditions. The Great Swamp during low-flow conditions is storing and/or losing (e.g., through evapotranspiration) vast quantities of water. As flow conditions increase, more and more of the inlet flow is being passed through to the outlet. Under high-flow conditions, there is much more water flowing out of the Great Swamp than is flowing in at that time. The additional water released during high flow periods, in addition to being the water stored during low flow periods, may also originate from water sources within the swamp such as groundwater discharge.

It is important to understand that this evaluation is not a water balance for the Great Swamp, nor is one required for the scope of the analysis. Recall from the idealization in Figure GS-2 that the Great Swamp is essentially being treated like a black box. The objective of the loading analysis is to quantify loads entering the Great Swamp at the inlets and exiting via the Passaic River at Millington. A water balance would attempt to account for the difference between the water entering and the water exiting the Great Swamp by quantifying water loads such as groundwater discharge and losses such as evapotranspiration. This analysis instead focused simply on quantifying the loads entering the swamp through its inlets and exiting through the outlet. Using the power functions shown in Figures GS-8 to GS-12, the flows at the inlets can be calculated directly from the flow at the outlet, which is measured continuously by USGS. Moreover, the strength of these relationships is excellent, providing an accurate empirical means of predicting flows at the five inlets as a function of gaged flow at the outlet. R-squared correlations vary from 0.53 to 0.96, with the weighted average (by mean flow) R-squared correlation for all inlets being 0.83.

Figure GS-8: Flow at Passaic River Inlet as a Percentage of Outlet Flow

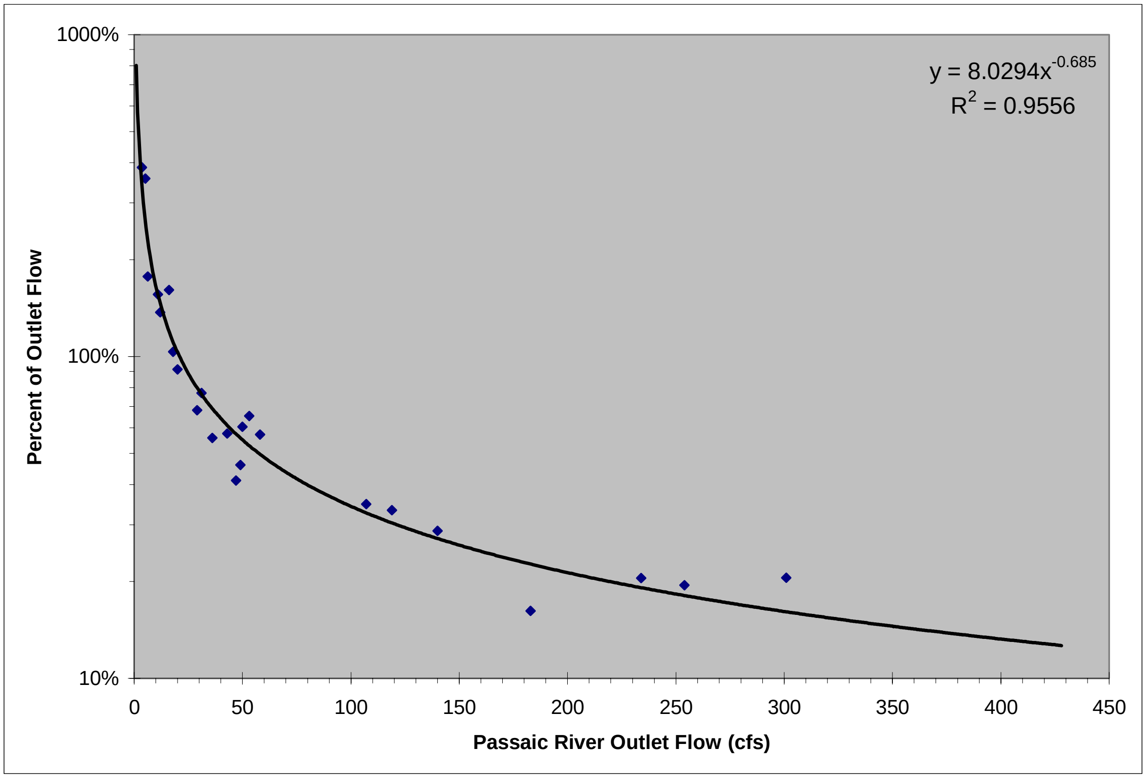


Figure GS-9: Flow at Primrose Brook Inlet as a Percentage of Outlet Flow

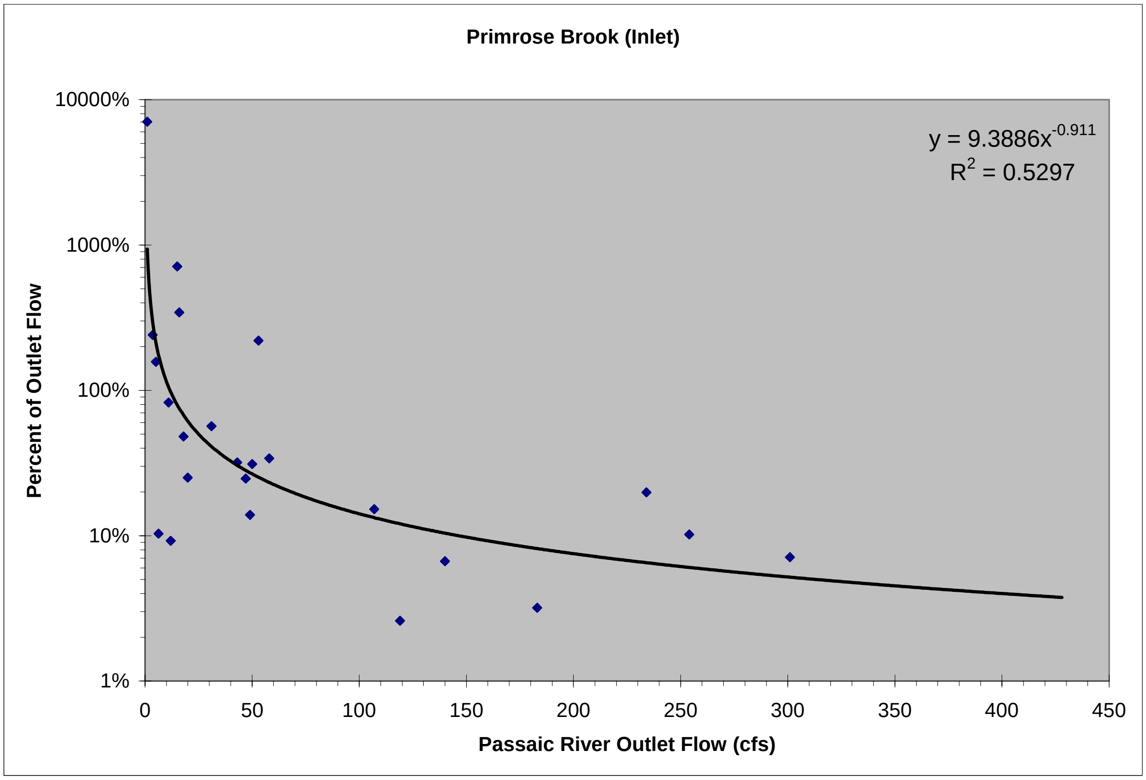


Figure GS-10: Flow at Great Brook Inlet as a Percentage of Outlet Flow

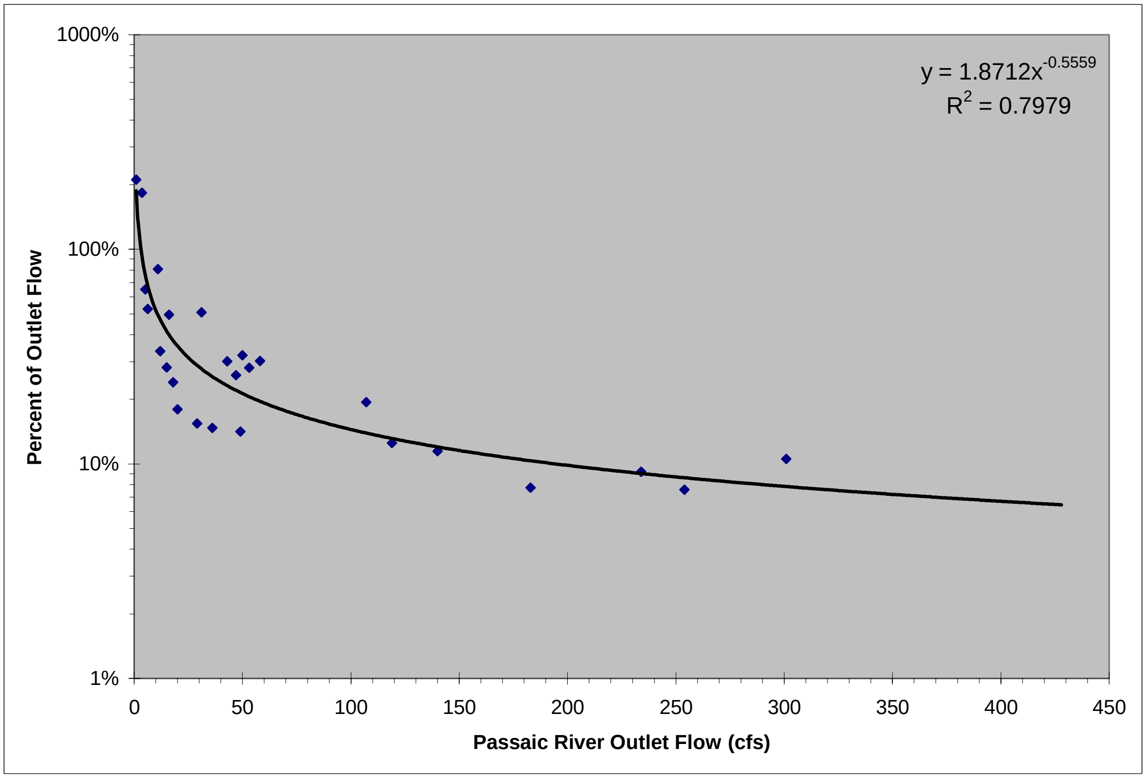


Figure GS-11: Flow at Loantaka Brook Inlet as a Percentage of Outlet Flow

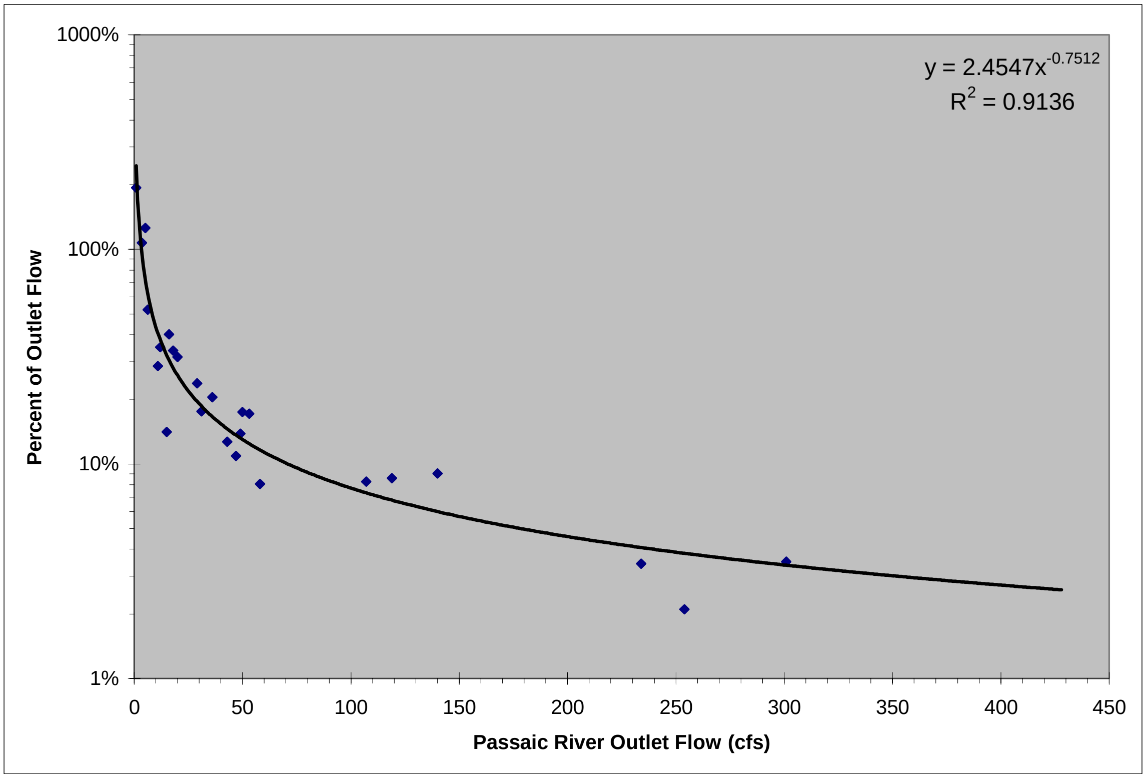
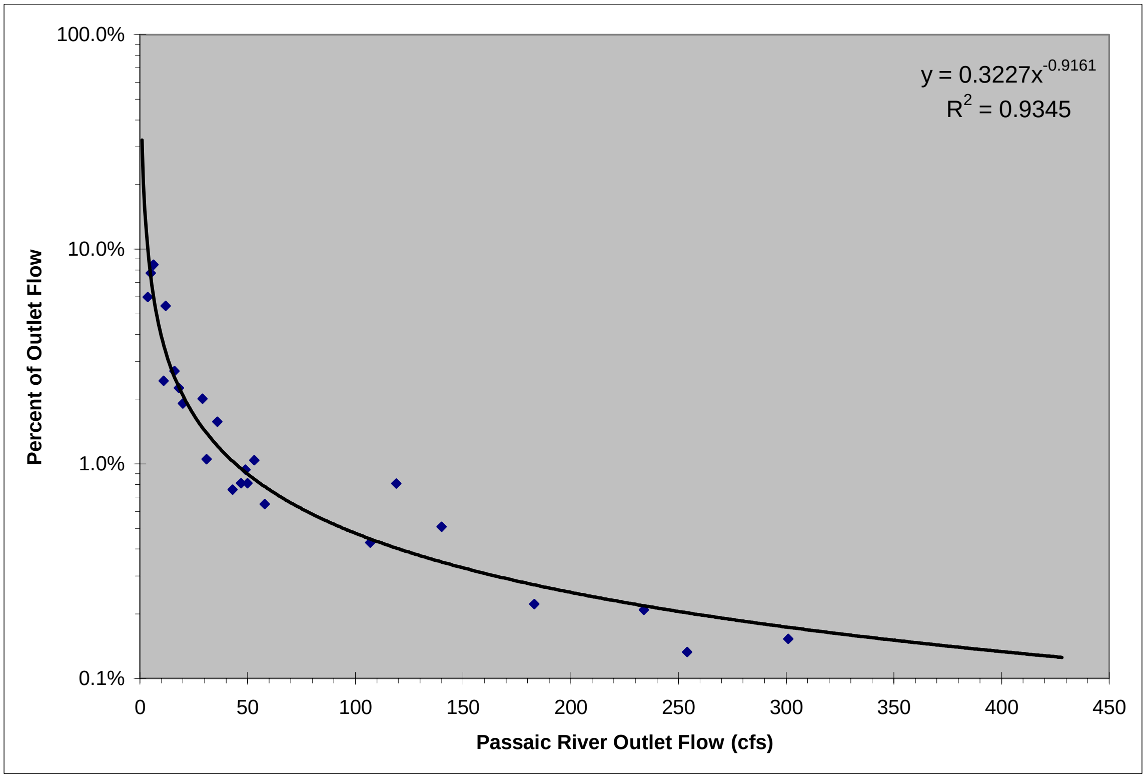


Figure GS-12: Flow at Black Brook Inlet as a Percentage of Outlet Flow



IV. Characterization of Loads

Given the hydrologic and pollutant loading characteristics of the Great Swamp, it makes sense to evaluate annual loads over multiple years. Looking at annual loads integrates the seasonal storage and release mechanism that are occurring and allows a direct comparison between the loads entering and exiting the Great Swamp. Loads for all subwatershed inlets and the two STP point sources were therefore calculated on a daily time scale for a seven-year period from 1999 through 2005, and then summed up annually.

Daily flows for each subwatershed inlet were calculated based on the outlet flow using the power functions described previously. Daily average flows for the Morris-Woodland STP and the Chatham-Main STP were based on the average of the flows available for each month. For most months, only monthly Discharge Monitoring Report (DMR) data were used. For months for which no flow data were available, the average flows of 2.066 cfs and 1.126 cfs were used for the Morris-Woodland and Chatham-Main STPs, respectively. Daily flow records at the USGS stream flow gage (01379000) were used to characterize flow at the Great Swamp outlet.

Total phosphorus concentrations for each day at the subwatershed inlets were assumed to vary by growing season and general flow condition as shown previously in Figure GS-6 and in Table GS-1 below. Daily total phosphorus concentrations of treated effluent from Morris-Woodland STP and Chatham-Main STP were based on the average of the effluent concentrations available for each month. For most months, monthly DMR data were used. For months for which no data were available, the average effluent phosphorus concentrations for summer and winter were used, as shown in Table GS-2 below. Total phosphorus concentrations at the Great Swamp outlet (Passaic River at Millington Gorge) were assumed to vary on a bi-monthly basis according to the averages shown in Table GS-3. Each of these assumptions was carefully selected based on the amount of data available and the trends observed.

Table GS-1: Average Inlet Phosphorus Concentrations

Season	Flow Condition	Passaic River Inlet	Primrose Brook Inlet	Great Brook Inlet	Loantaka Brook Inlet	Black Brook Inlet
Growing Season	High-Flow	0.096	0.327	0.215	0.556	0.490
	Moderate	0.069	0.180	0.164	0.431	0.393
	Low-Flow	0.055	0.145	0.081	0.309	0.137
Non-Growing Season	High-Flow	0.055	0.094	0.086	0.262	0.256
	Moderate	0.047	0.082	0.088	0.270	0.192
	Low-Flow	0.035	0.036	0.048	0.158	0.055

Table GS-2: Average Effluent Phosphorus Concentrations

Summer / Winter	Morris-Woodland STP	Chatham-Main STP
Summer	0.541	0.470
Winter	0.493	0.287

Table GS-3: Average Outlet Phosphorus Concentrations[3]

Bi-Month	Passaic River (Outlet)
Dec-Jan	0.064
Feb-March	0.040
April-May	0.090
June-July	0.141
Aug-Sept	0.166
Oct-Nov	0.078

In order to assess the performance of the resultant empirical model of daily total phosphorus concentrations at each of the five inlets as well as the outlet, model predictions were compared with actual measurements. The following goodness-of-fit statistics were calculated for each inlet and the outlet and are provided in Table GS-4:

Mean Error: the average residual (predicted minus observed);

[3] The average bi-monthly concentrations at the outlet were based on GSWA data; data collected by Omni during the TMDL monitoring program were used as an independent validation of the resultant model for the Great Swamp outlet (Passaic River headwater boundary).

% Mean Error: the Mean Error divided by the average observed concentration;

Mean Absolute Error: the average absolute residual (absolute value of predicted minus observed); and

Root Mean Squared Error: the square root of the average squared residual,

$$RMSE = \sqrt{\frac{\sum(Predicted - Observed)^2}{N}},$$

where N = the number of observations.

Since the main purpose of the model is to characterize loads in and out of the Great Swamp over time rather than daily concentrations, the Mean Error and Percent Mean Error are the most important statistics. If the Mean Error is zero, then overpredictions of daily concentrations are exactly balanced by underpredictions. This is important, since daily loads are summed up over time to characterize seasonal and annual loads. The Percent Mean Errors are under 2%. Statistics for the outlet were calculated separately for the GSWA data used to estimate the bimonthly concentration averages, and the Omni TMDL sampling data were used for model validation. These statistics show a remarkably good fit for each of the inlets as well as the outlet.

In order to determine whether the residual errors were skewed one way or another under different flow conditions, Figures GS-13 through GS-18 show the residual errors plotted against the gaged flow at the outlet. The Great Swamp inlets from the Passaic River and Great Brook comprise approximately two-thirds of the flow into the Great Swamp and exhibit very low residual errors (i.e., good fit), as does the Passaic River at the Great Swamp outlet. The higher residual values at the inlets from Black Brook and Primrose Brook reflect the greater variation in phosphorus concentrations observed at those locations, apparently the result of intermittent sources. Even those inlets with higher residual errors, however, exhibit no bias with respect to flow that would confound the load calculations. For instance, if the model were overpredicting phosphorus concentration during low stream flow conditions, but underpredicting phosphorus concentration during higher stream flow conditions, load predictions would be grossly in error even though the Mean Error might look very good. The fact that the residual errors are balanced positive and negative and are not skewed with respect to stream flow conditions reflects the overall fitness of the predicted concentrations for performing load calculations. The goodness-of-fit statistics and residual versus flow graphs clearly demonstrate that the empirical model of phosphorus concentrations is very strong across a full range of flow conditions.

Table GS-4: Goodness-of-Fit Statistics for Empirical TP Concentration Model

Great Swamp Boundary		Mean Error	% Mean Error	Mean Absolute Error	Root Mean Squared Error
Passaic River (Inlet)		0.000	0.00%	0.021	0.026
Primrose Brook (Inlet)		0.000	0.30%	0.113	0.155
Great Brook (Inlet)		-0.001	-1.22%	0.046	0.064
Loantaka Brook (Inlet)		0.003	1.04%	0.128	0.167
Black Brook (Inlet)		0.000	0.00%	0.147	0.180
Passaic River (Outlet)	Calibration (GSWA)	0.000	-0.29%	0.023	0.029
	Validation (Omni)	-0.005	-3.68%	0.035	0.046
	All Outlet Data	-0.001	-1.17%	0.025	0.033

Figure GS-13: Residual TP Error at Passaic River Inlet Versus Outlet Flow

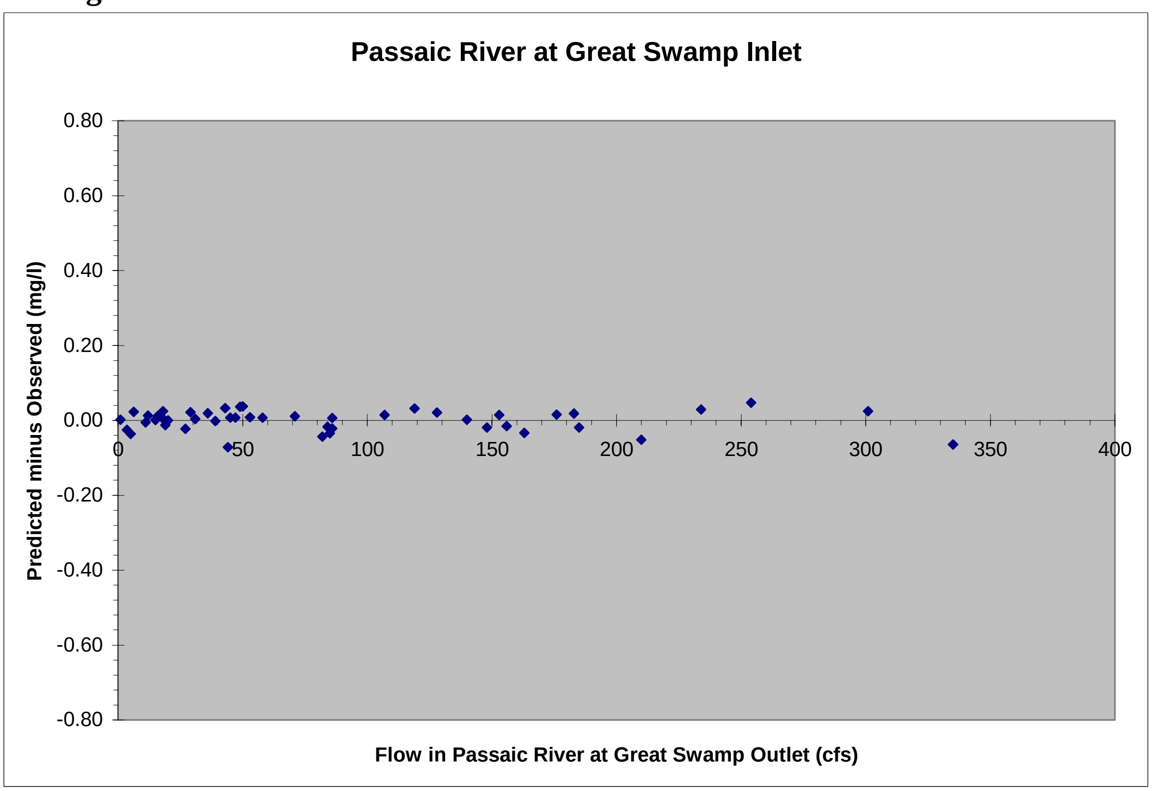


Figure GS-14: Residual TP Error at Primrose Brook Inlet Versus Outlet Flow

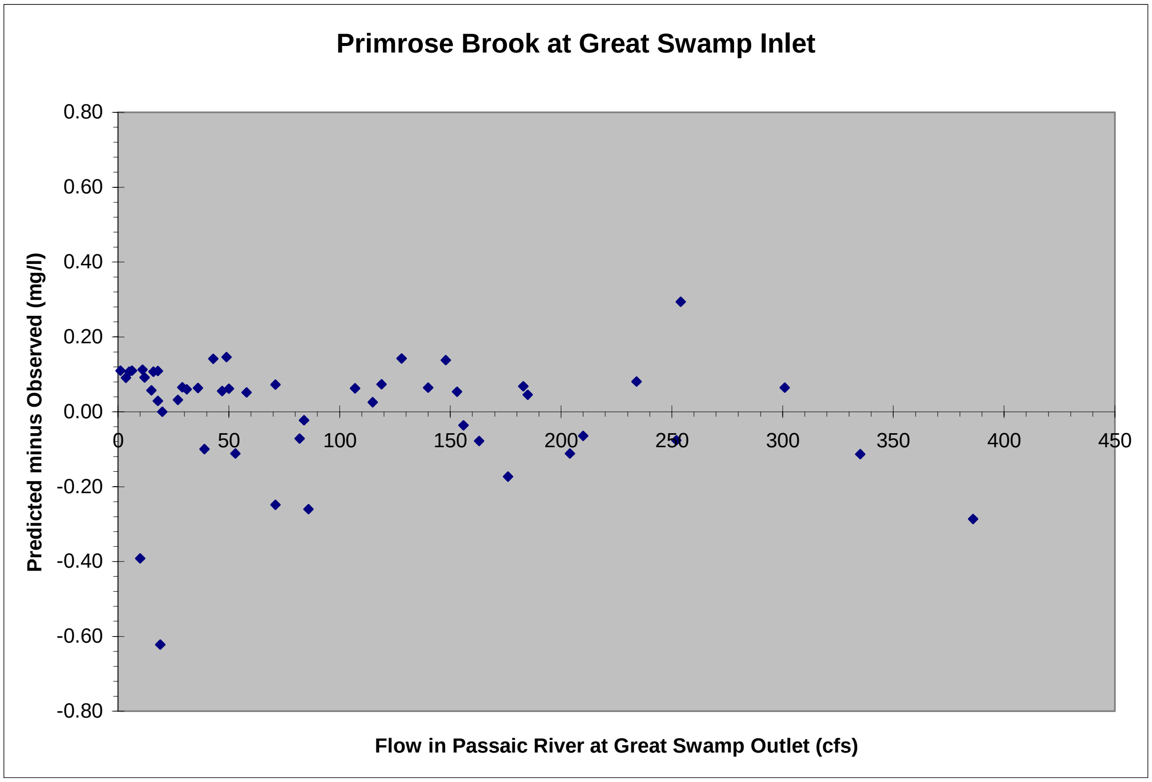


Figure GS-15: Residual TP Error at Great Brook Inlet Versus Outlet Flow

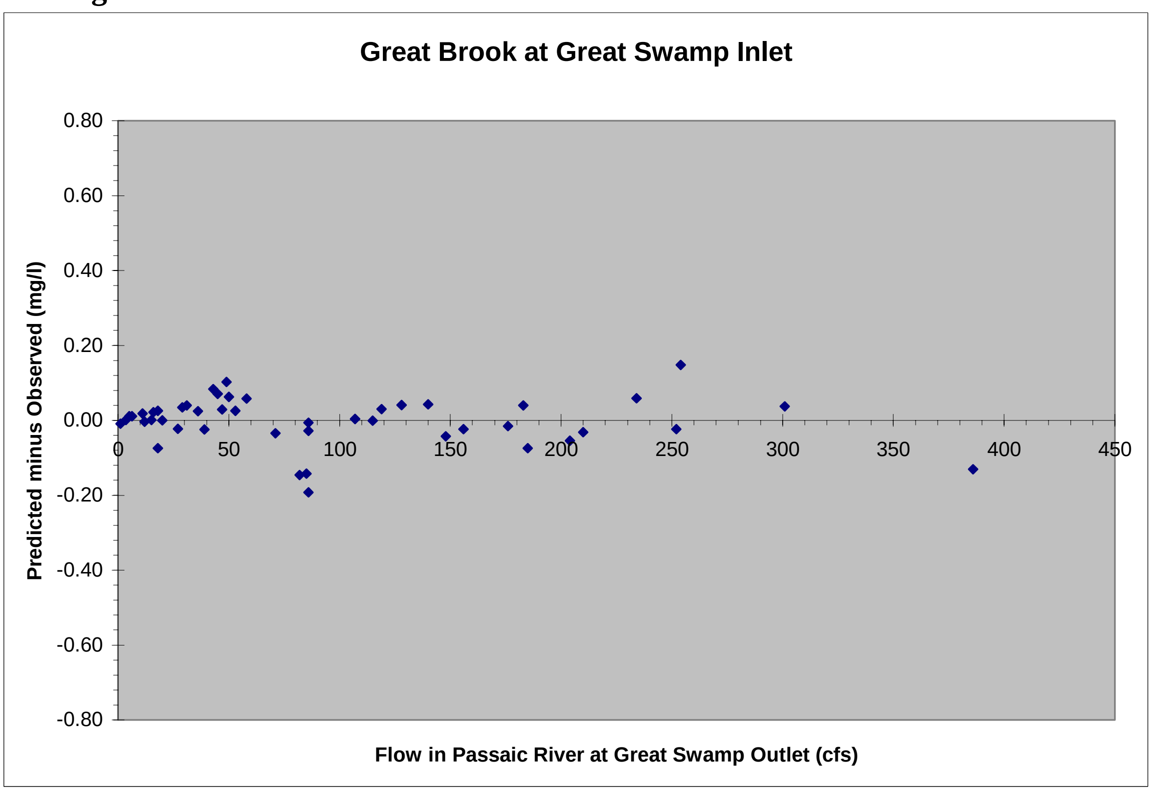


Figure GS-16: Residual TP Error at Loantaka Brook Inlet Versus Outlet Flow

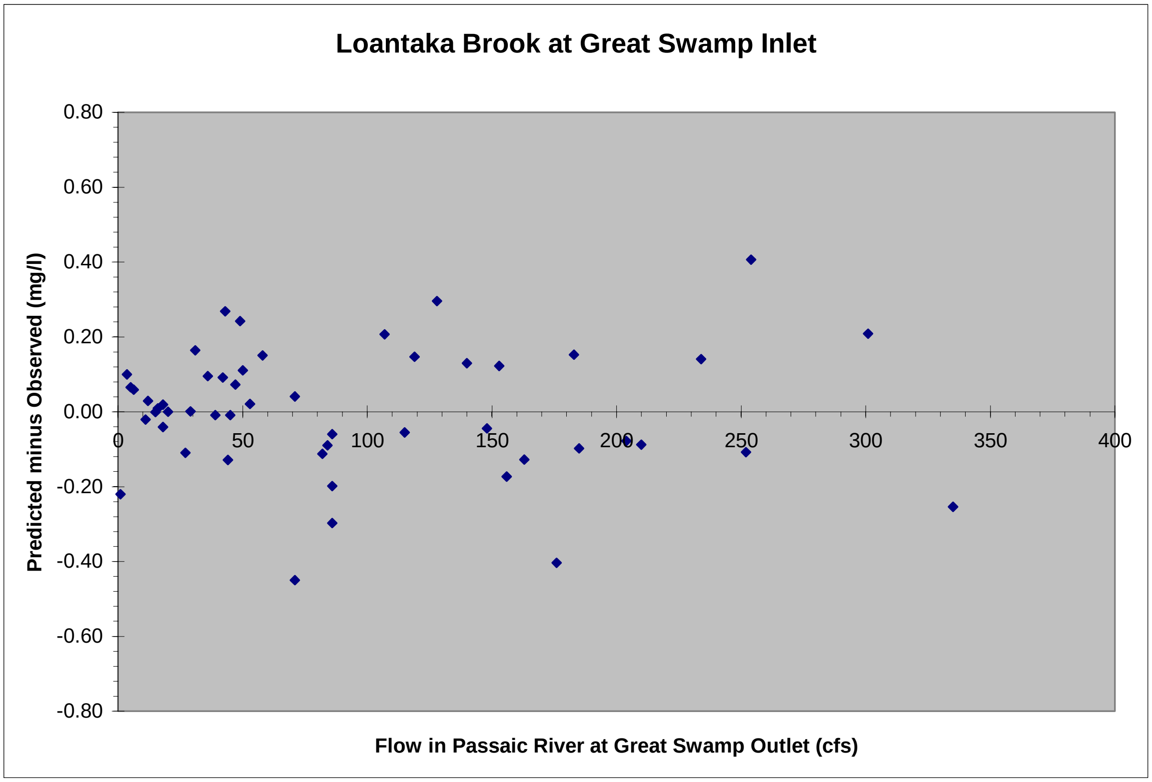


Figure GS-17: Residual TP Error at Black Brook Inlet Versus Outlet Flow

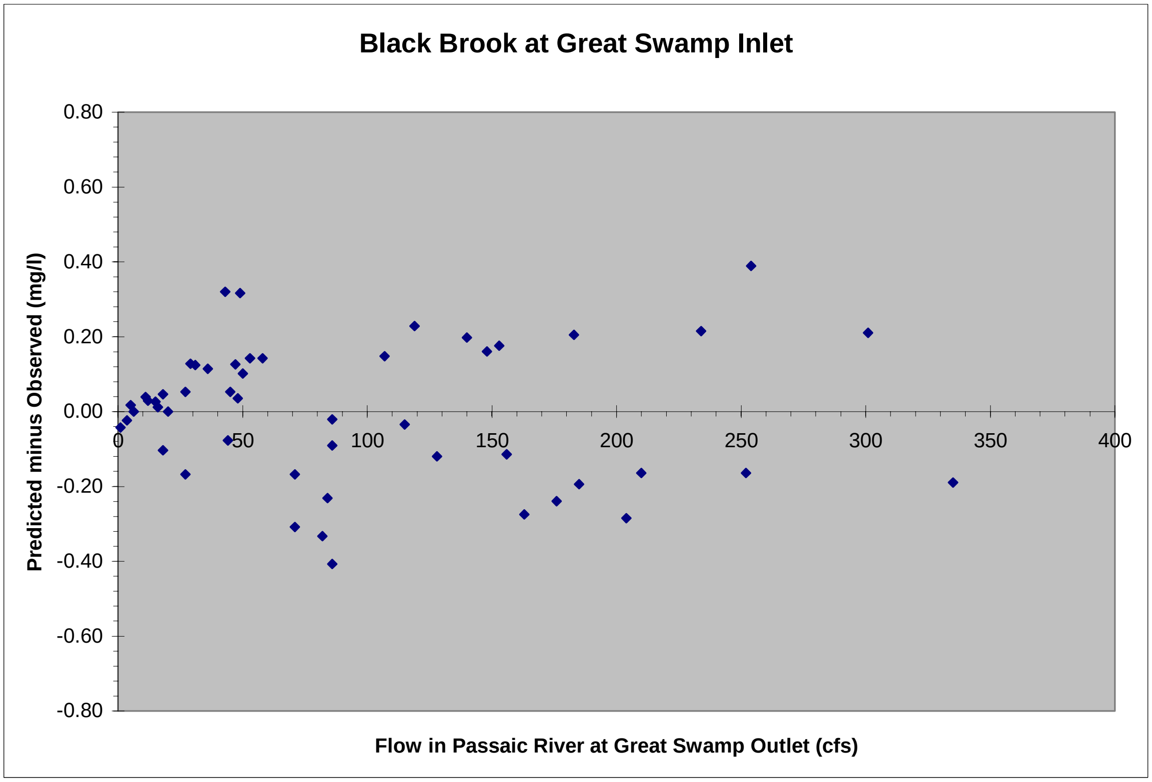
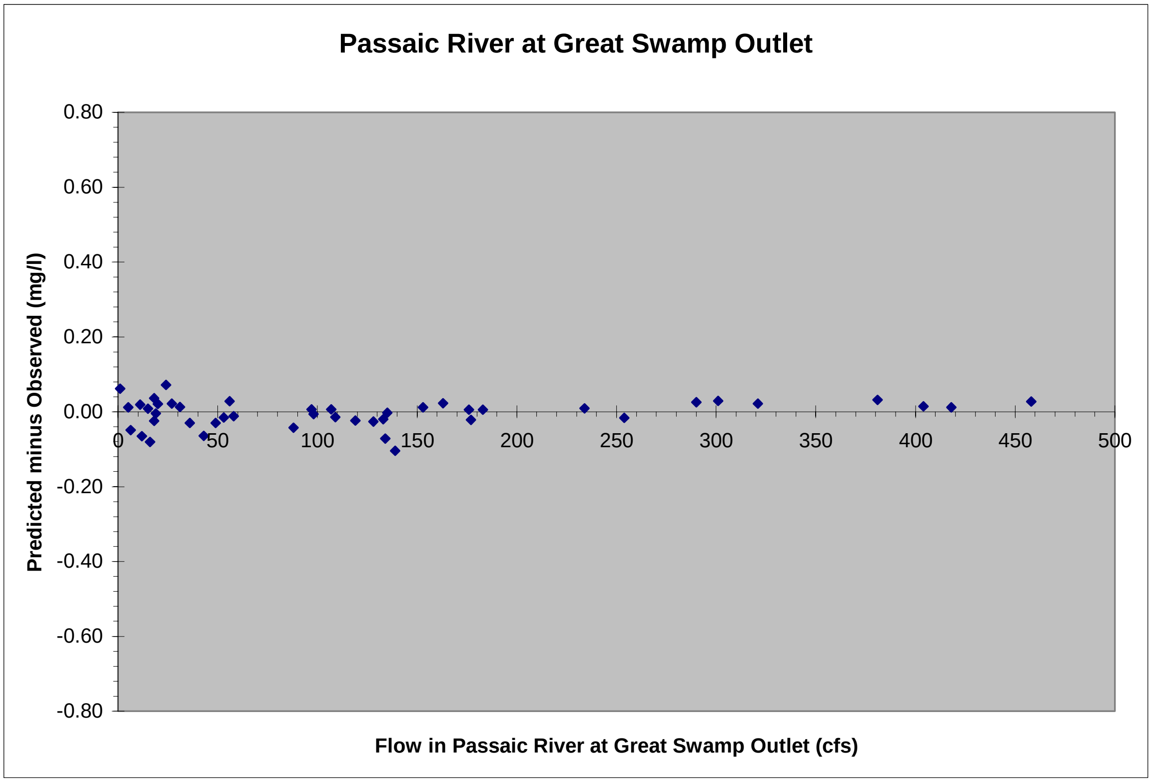
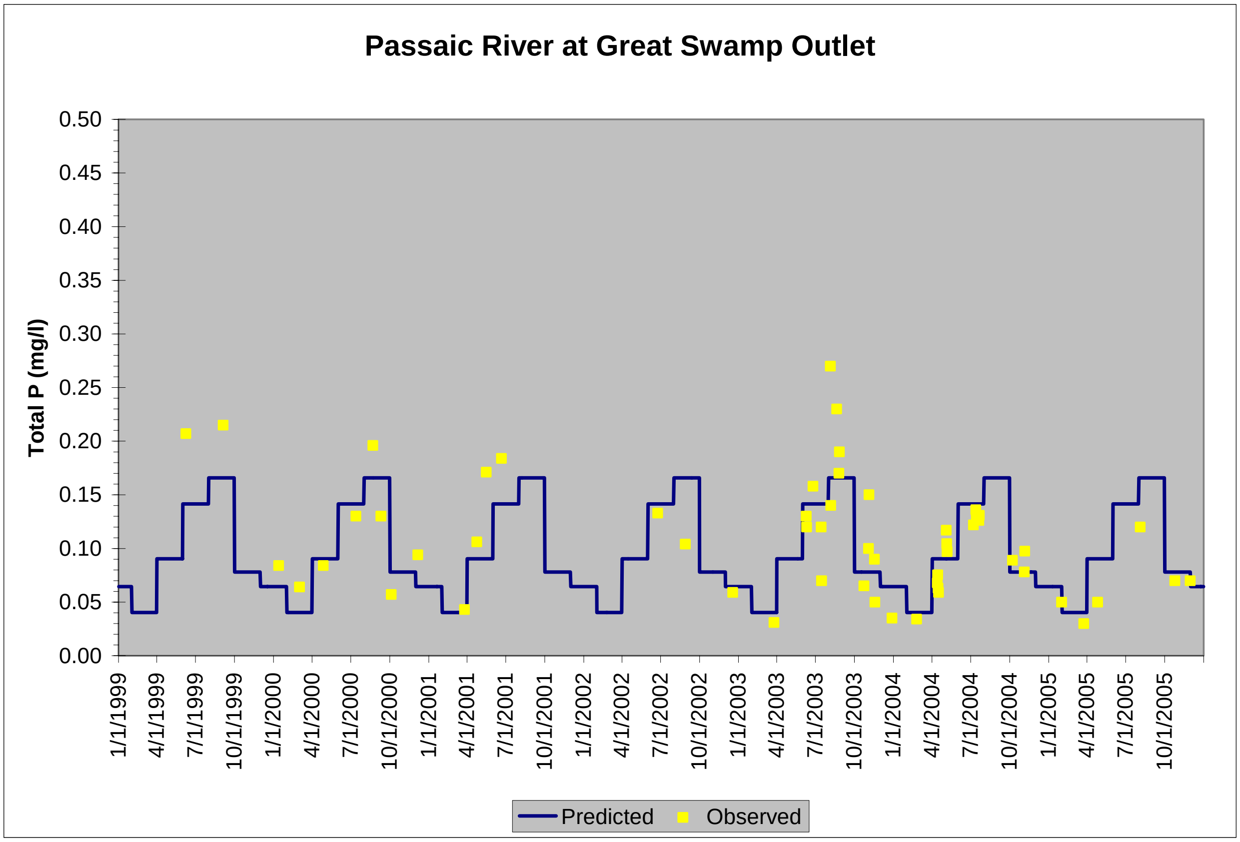


Figure GS-18: Residual TP Error at Passaic River Outlet Versus Flow



Since the Great Swamp outlet is also the Passaic River headwater boundary, the total phosphorus concentrations predicted using the empirical model described above at this location were also used to develop the headwater boundary condition for the Passaic TMDL model. Figure GS-19 shows the predicted and observed total phosphorus concentrations over time, demonstrating an excellent fit. The predicted seasonally varying total phosphorus concentrations based on bimonthly concentrations were used along with actual measured concentrations to develop a seasonally-varying boundary condition for total phosphorus at the Passaic River headwater boundary. The empirical model developed herein provides a very solid basis for the headwater boundary condition used for the Passaic TMDL model.

Figure GS-19: Predicted Versus Observed TP at Passaic River at Great Swamp Outlet



As described above, powerful empirical tools were developed to calculate both stream flow rates and total phosphorus concentrations at the inlets and outlet of the Great Swamp. The only inputs required include gaged flow rate at the outlet (Passaic River at Millington) and the month of the year. Based on these two inputs, flows and total phosphorus concentrations can be calculated at each of the five inlets as well as the outlet of Great Swamp. Given the strength of the empirical relationships observed in the system, this empirically based model calculates loads in and out of the Great Swamp with a relatively high degree of certainty.

Phosphorus loads in and out of Great Swamp were calculated on a daily time scale over a seven-year period from 1999 through 2005. The load from the Morris-Woodland STP was subtracted out of the load from the Loantaka Brook inlet in order to account for point and nonpoint source loads independently. No attenuation was assumed from Morris-Woodland STP to the Loantaka Brook inlet location (approximately 3.2 miles), making the estimation of load from Morris-Woodland STP conservative. However, the total load from both Morris-Woodland

STP and Loantaka Brook is based on measured data; only the portion of that load attributed to Morris-Woodland STP can be considered conservative. The Chatham-Main STP discharges within the Great Swamp as defined in this analysis; that load is calculated directly.

Figure GS-20 shows the composition of phosphorus loads to Great Swamp over the seven-year period analyzed. Figure GS-21 shows the annual loads in and out of the Great Swamp from 1999 to 2005, along with the average annual loads. During dry years like 2001 and 2002, Great Swamp functions like a sink; more phosphorus enters Great Swamp than leaves it. On the other hand, during wet years like 2003, Great Swamp acts like a source; much more phosphorus leaves the Great Swamp than enters it. It is important to recall that this analysis is not a water or phosphorus balance; it merely calculates loads entering and exiting the Great Swamp. There are important processes within the Swamp that very likely affect the balance of both water and phosphorus, such as groundwater discharge.

Figure GS-20: Composition of Phosphorus Loads to Great Swamp

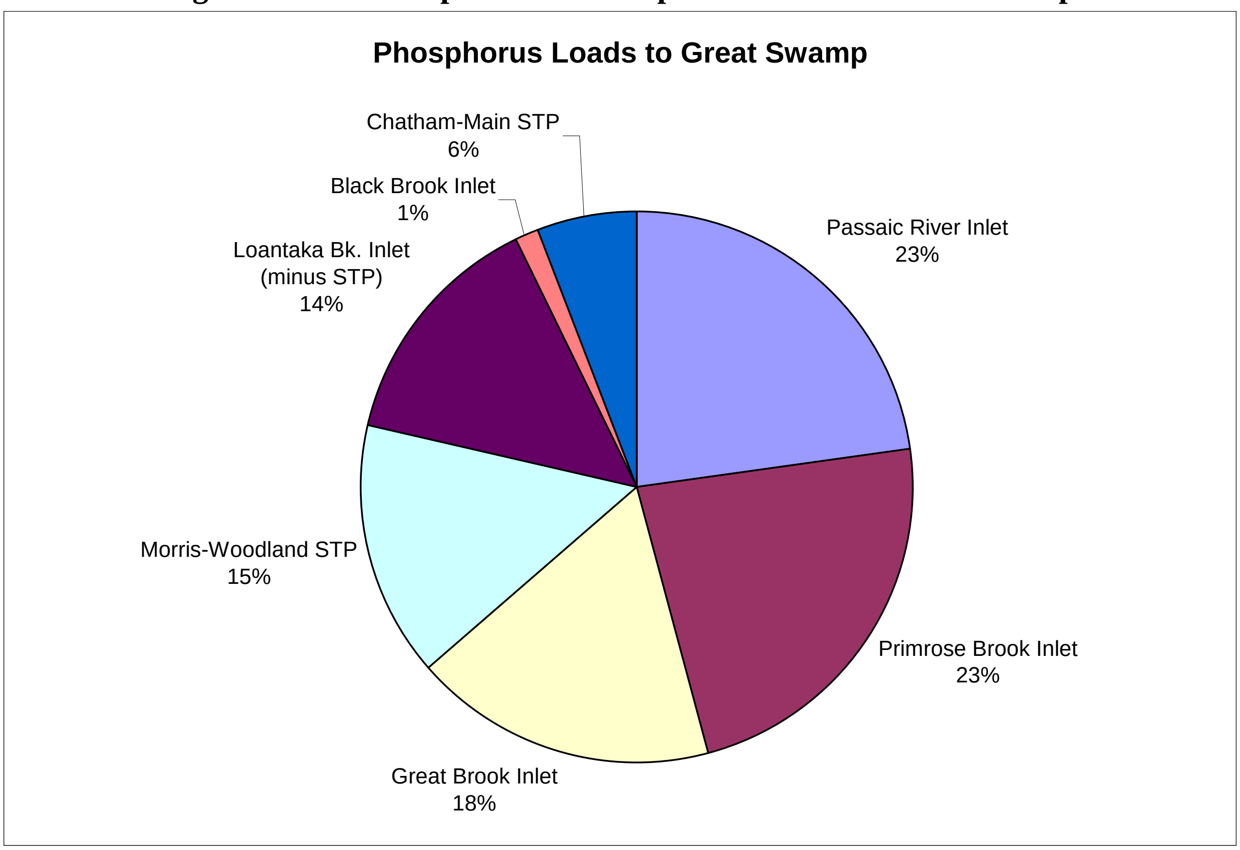
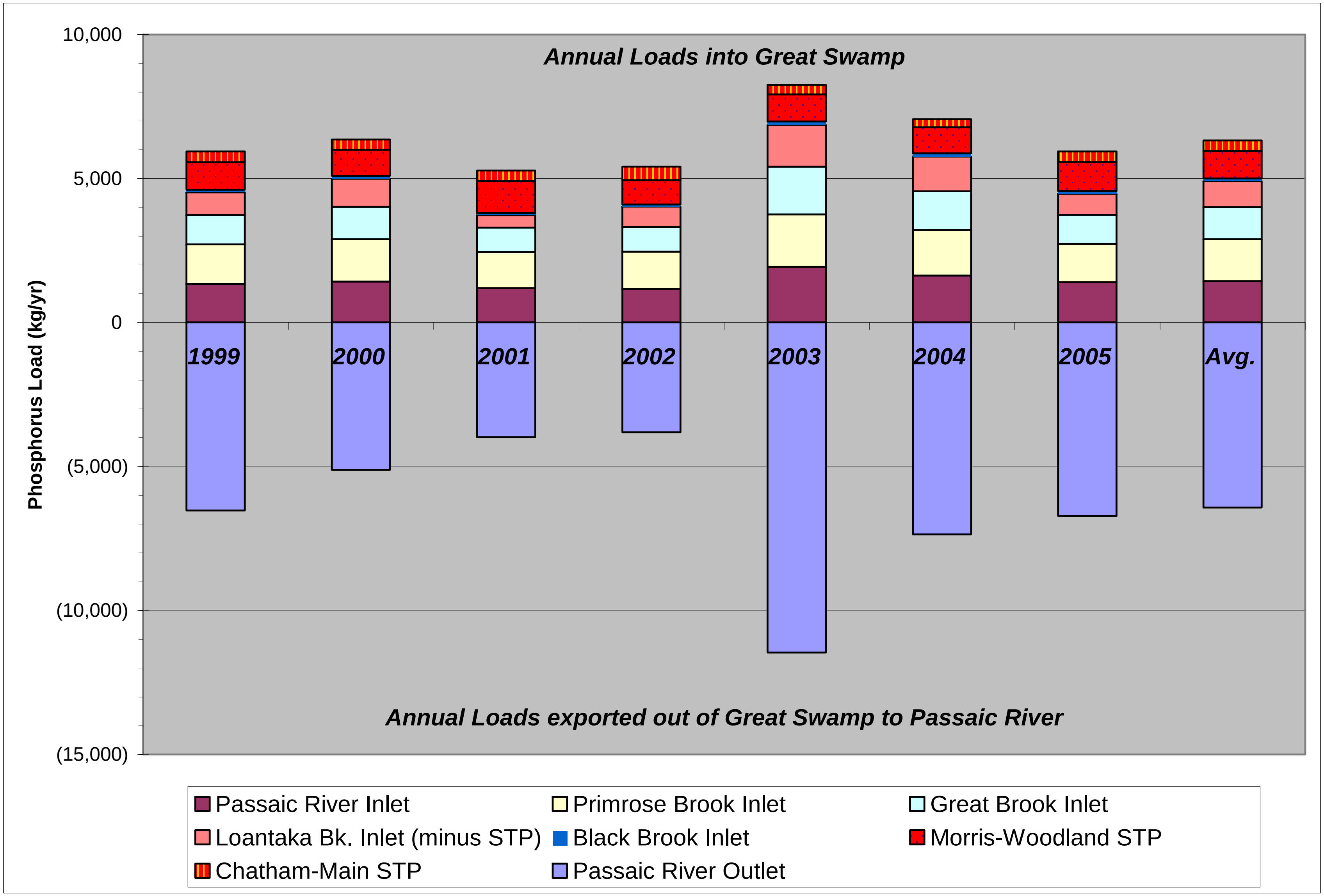


Figure GS-21: Annual Phosphorus Load Summary for Great Swamp (1999 – 2005)



V. STP Loads

It is not known whether decreases in phosphorus loads to Great Swamp would change the phosphorus condition at the outlet. Nevertheless, since the loads entering Great Swamp are similar in magnitude to the loads exported from Great Swamp to the Passaic River, it is justified to establish limits to prevent future loads from increasing.

Both the Morris-Woodland and Chatham-Main STPs remove phosphorus in order to satisfy effluent limitations of 1.0 mg/l total phosphorus. Table GS-5 provides average effluent phosphorus concentrations and flows for both STPs based on the effluent data analyzed (July 2000 to April 2005), along with permitted effluent phosphorus concentrations and flows.

Table GS-5: Actual and Permitted Effluent Phosphorus Concentrations and Flows

Actual / Permitted	Effluent Flow / Concentration	Morris-Woodland	Chatham-Main
Actual	Concentration (mg/l TP)	0.517	0.383
	Flow (cfs)	2.07	1.13
Permitted	Maximum Concentration (mg/l TP)	1.0	1.0
	LTA Concentration (mg/l TP)[1]	0.526	0.483
	Flow (cfs)	3.094 (2 MGD)	1.547 (1 MGD)

Figure GS-22 compares the average annual phosphorus loads from each of the STPs to the annual loads associated with two scenarios:

- 0.4 mg/l at Permitted Flow – effluent concentration of 0.4 mg/l discharging at the permitted effluent flow; and
- Permitted Flow and Concentration[4] – permitted effluent concentration (LTA based on monthly limit of 1.0 mg/l total phosphorus) discharging at the permitted effluent flow.

It is important to understand how the loads associated with these STP scenarios compare with the overall loads imported to the Great Swamp. Figure GS-23 shows the average annual phosphorus load imported to Great Swamp for each of the STP loading scenarios. Nonpoint

[4] For long-term loading calculations, the permitted average monthly effluent concentrations were translated into permitted long-term averages (LTA) based on assumed coefficient of variation of 0.6 and the number of samples per month at each facility.

source loads from the subwatershed inlets are distinguished from the point source loads in the graph. If one assumes that the incremental load associated with Permitted Flows and Concentrations is not attenuated at all from the point of discharge to the outlet of the Great Swamp, the load would translate into an average concentration increase of 0.01 mg/l in the Passaic River at the outlet of the Great Swamp. On the other hand, LTA effluent concentrations of 0.4 mg/l total phosphorus would hold the phosphorus loads imported to Great Swamp very near their current levels even when the treatment plants are discharging at their permitted flows. In fact, the average total phosphorus load imported to Great Swamp would remain less than 5% more than the average total phosphorus load currently exported from Great Swamp to the Passaic River. It is therefore technically justified to impose effluent limits of 0.4 mg/l LTA total phosphorus on the STPs in the Great Swamp watershed in order to prevent potential increases to the phosphorus loads and concentrations exported from the Great Swamp to the Passaic River.

Figure GS-22: Average Annual STP Loads Associated with Effluent Loading Scenarios

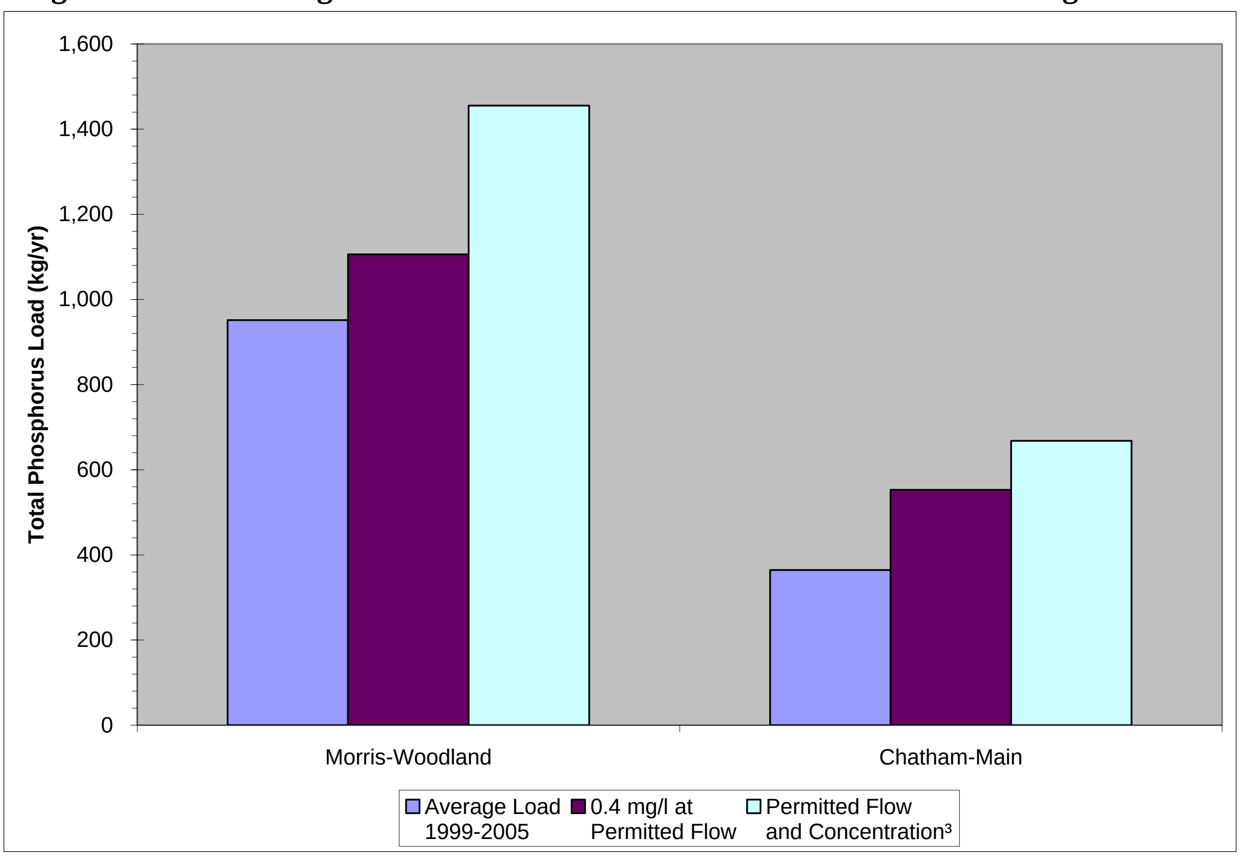
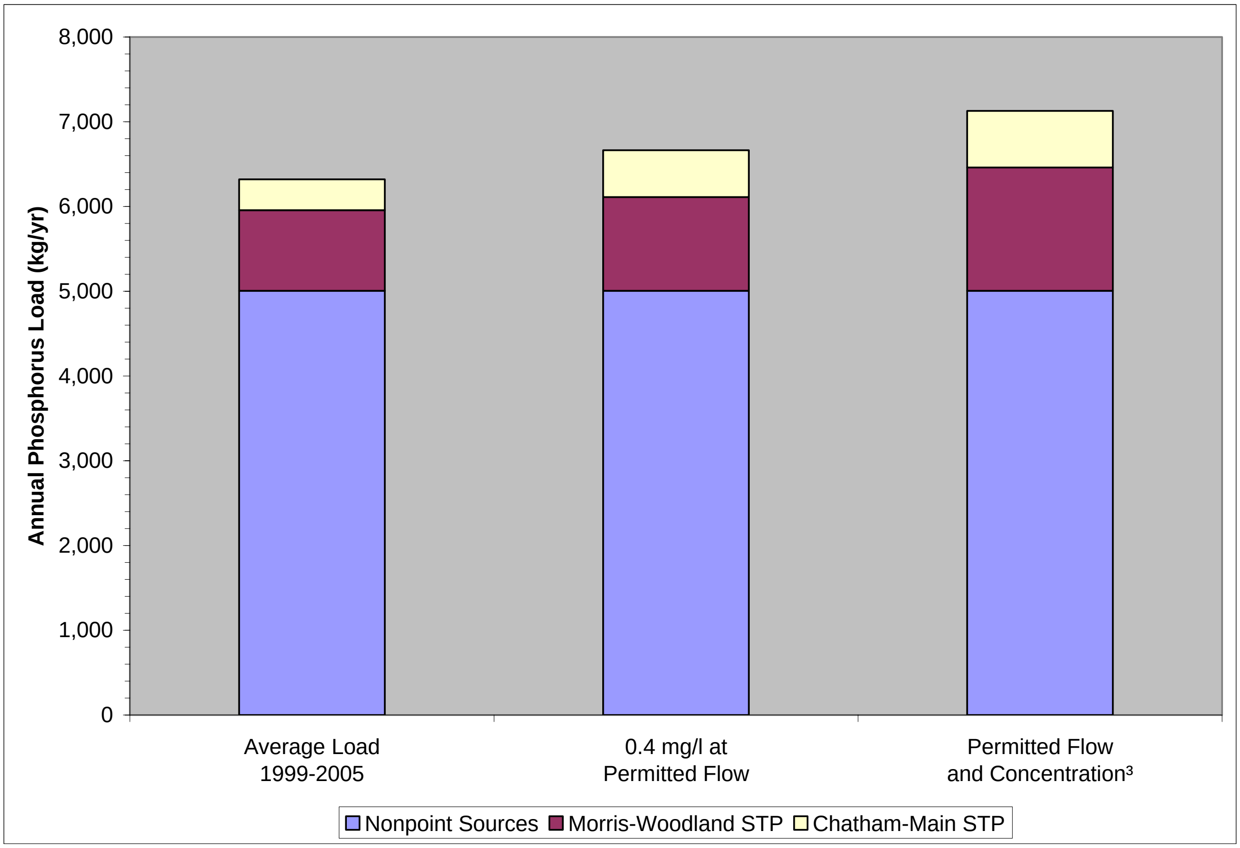


Figure GS-23: Overall Loads to Great Swamp Associated with Effluent Loading Scenarios



VI. Conclusion

Total phosphorus concentrations at the inlets to the Great Swamp vary by growing season and general flow condition, and total phosphorus concentrations at the Great Swamp outlet (Passaic River at Millington Gorge) vary on a seasonal basis. Furthermore, the relationships between flows at the inlets to the Great Swamp as a percentage of outlet flow and the outlet flow itself turn out to be very strong when described using a power function for each inlet. As a result, powerful empirical tools were developed to calculate both flow rates and total phosphorus concentrations at the inlets and outlet of the Great Swamp. The only inputs required include gaged flow rate at the outlet and the month of the year. Based on these two inputs, flows and total phosphorus concentrations were calculated at each of the five inlets as well as the outlet of Great Swamp.

Given the strength of the empirical relationships observed in the system, both the hydrology and phosphorus concentrations at the inlets and outlet of the Great Swamp are remarkably predictable, albeit in ways that are counterintuitive. Over the seven-year period analyzed, the total load leaving Great Swamp was almost the same as the load entering Great Swamp. The year-to-year pattern suggests that Great Swamp experiences substantial year-to-year variation in the degree to which it functions as a phosphorus source or a phosphorus sink according to hydrologic and seasonal patterns. The highest phosphorus loads are exported from Great Swamp during summer high flow events, when high phosphorus concentrations get flushed into the Passaic River. The fact that phosphorus concentrations within the swamp and exported from the swamp are highest during the summer when uptake is highest suggest that the sediment dynamics in the wetlands are driving the phosphorus conditions rather than plant uptake.

The outlet of Great Swamp (Passaic River at Millington Gorge) exhibits seasonally varying phosphorus concentrations, from a low of 0.04 mg/l in February to a high of 0.166 mg/l in August. During the summer when phosphorus concentrations at the outlet (and within the Great Swamp) are highest, especially during critical dry summers, the Great Swamp is functioning like a sink; more phosphorus is entering the swamp than leaving during those periods. Baseflow concentrations in the Passaic River, Primrose Brook, and Great Brook inlets can be estimated by averaging their concentrations during low-flow conditions when nonpoint sources would have minimal impact. The average low-flow phosphorus concentration at these three inlets is 0.097 mg/l during the growing season and 0.04 mg/l during the non-growing season. This can be considered a conservative estimate of background contribution; in reality, a portion of the phosphorus carried in stormwater is likely due to background sources as well. The sediment interactions within Great Swamp receive phosphorus load over time and deliver it to the outlet with higher concentrations during the growing season and lower concentrations during the non-growing season.

Since the loads entering Great Swamp are similar in magnitude to the loads exported from Great Swamp to the Passaic River, it is technically justified to impose effluent limits of 0.4 mg/l LTA total phosphorus on the STPs within the Great Swamp. While a direct link between loads imported and loads exported from Great Swamp could not be established based on existing information, 0.4 mg/l LTA effluent concentrations will prevent the phosphorus loads entering the Great Swamp from increasing such that the loads and concentrations exported to the Passaic River might potentially increase as well.

This research was limited by the available information and the scope of the analysis. The intent was to synthesize available datasets and to make the best possible characterization of loads based on existing data. The fact that the loads into and out of the Great Swamp can be empirically modeled with a reasonable degree of certainty was a surprising and helpful outcome. As a result, the study provided a seasonally varying boundary condition for phosphorus concentration at the Passaic River headwater (the outlet of Great Swamp) that was used to enhance the Non-Tidal Passaic River Basin TMDL Study. In addition, the study characterized the phosphorus loads from the two major treatment plants in the context of all the other loads into the Great Swamp as well as the load exported out of the Great swamp into the Passaic River, providing the technical basis to recommend effluent limits of 0.4 mg/l LTA total phosphorus for these facilities.

However, additional study is needed to better understand the sources of the phosphorus loads that are currently imported to the Great Swamp, as well as the processes within the Great Swamp that affect phosphorus storage and release. A detailed study of the sources of phosphorus currently imported to the Great Swamp through its inlets would isolate the natural background component from the anthropogenic sources, and provide a better determination of how much of the inlet phosphorus load can be reduced through phosphorus reduction measures. Furthermore, a detailed water budget and phosphorus budget would be necessary to better understand how phosphorus reductions at the inlets would translate into phosphorus reductions exported through the outlet to the Passaic River. Additional studies as described would require considerable additional data and information. This study provided a detailed characterization of phosphorus loads based solely on existing information.

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Black Brook (Inlet)	BB	GSWA	2/13/1999	0.9	0.213	0.048
Inlet	Black Brook (Inlet)	BB	GSWA	5/20/1999	0.8	0.483	0.037
Inlet	Black Brook (Inlet)	BB	GSWA	6/8/1999	0.7	0.108	0.048
Inlet	Black Brook (Inlet)	BB	GSWA	9/4/1999	0.5	0.137	0.082
Inlet	Black Brook (Inlet)	BB	GSWA	10/10/1999	0.6	0.157	0.080
Inlet	Black Brook (Inlet)	BB	GSWA	11/3/1999	0.9	0.525	0.254
Inlet	Black Brook (Inlet)	BB	GSWA	3/2/2000	1.0	0.027	0.007
Inlet	Black Brook (Inlet)	BB	GSWA	3/18/2000	1.0	0.420	0.039
Inlet	Black Brook (Inlet)	BB	GSWA	4/25/2000	0.7	0.058	0.033
Inlet	Black Brook (Inlet)	BB	GSWA	5/11/2000	0.7	0.470	0.108
Inlet	Black Brook (Inlet)	BB	GSWA	6/22/2000	0.6	0.340	0.060
Inlet	Black Brook (Inlet)	BB	GSWA	7/13/2000	0.4	0.119	0.072
Inlet	Black Brook (Inlet)	BB	GSWA	7/27/2000	2.6	0.330	0.095
Inlet	Black Brook (Inlet)	BB	GSWA	8/22/2000	0.5	0.076	0.044
Inlet	Black Brook (Inlet)	BB	GSWA	9/10/2000	0.4	0.090	0.040
Inlet	Black Brook (Inlet)	BB	GSWA	9/26/2000	1.5	0.340	0.058
Inlet	Black Brook (Inlet)	BB	GSWA	10/4/2000	0.4	0.055	0.032
Inlet	Black Brook (Inlet)	BB	GSWA	11/10/2000	1.3	0.500	0.198
Inlet	Black Brook (Inlet)	BB	GSWA	11/19/2000	0.6	0.064	0.045
Inlet	Black Brook (Inlet)	BB	GSWA	12/6/2000	0.6	0.078	0.025
Inlet	Black Brook (Inlet)	BB	GSWA	12/17/2000	9.1	0.450	0.081
Inlet	Black Brook (Inlet)	BB	GSWA	1/31/2001	1.3	0.290	0.043
Inlet	Black Brook (Inlet)	BB	GSWA	3/22/2001	1.5	0.420	0.049
Inlet	Black Brook (Inlet)	BB	GSWA	4/24/2001	0.5	0.050	0.019
Inlet	Black Brook (Inlet)	BB	GSWA	5/16/2001	0.4	0.125	0.017
Inlet	Black Brook (Inlet)	BB	GSWA	6/2/2001	5.5	0.680	0.090
Inlet	Black Brook (Inlet)	BB	GSWA	6/17/2001	1.9	0.800	0.144
Inlet	Black Brook (Inlet)	BB	GSWA	9/26/2001	0.4	0.240	0.054
Inlet	Black Brook (Inlet)	BB	GSWA	11/26/2001	0.4	0.360	0.168
Inlet	Black Brook (Inlet)	BB	GSWA	6/24/2002		0.110	0.061
Inlet	Black Brook (Inlet)	BB	GSWA	8/28/2002		0.179	0.122
Inlet	Black Brook (Inlet)	BB	GSWA	12/18/2002	0.4	0.051	0.020
Inlet	Black Brook (Inlet)	BB	GSWA	3/25/2003	0.5	0.041	0.009

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Black Brook (Inlet)	BB	GSWA	6/25/2003	0.3	0.101	0.064
Inlet	Black Brook (Inlet)	BB	GSWA	8/20/2003	0.3	0.072	0.001
Inlet	Black Brook (Inlet)	BB	GSWA	10/23/2003	0.3	0.068	0.040
Inlet	Black Brook (Inlet)	BB	GSWA	12/28/2003	0.5	0.045	0.022
Inlet	Black Brook (Inlet)	BB	GSWA	2/24/2004	0.5	0.044	0.012
Inlet	Black Brook (Inlet)	BB	GSWA	4/13/2004	1.0	0.530	0.080
Inlet	Black Brook (Inlet)	BB	GSWA	5/4/2004	0.5	0.610	0.037
Inlet	Black Brook (Inlet)	BB	GSWA	7/7/2004	0.3	0.098	0.057
Inlet	Black Brook (Inlet)	BB	GSWA	7/13/2004	0.9	0.730	0.104
Inlet	Black Brook (Inlet)	BB	GSWA	7/19/2004	0.7	0.560	0.082
Inlet	Black Brook (Inlet)	BB	GSWA	10/7/2004	0.4	0.066	0.001
Inlet	Black Brook (Inlet)	BB	GSWA	11/5/2004	0.6	0.423	0.235
Inlet	Black Brook (Inlet)	BB	GSWA	1/31/2005	0.4	0.090	0.045
Inlet	Black Brook (Inlet)	BB	GSWA	3/24/2005	0.9	0.080	0.001
Inlet	Black Brook (Inlet)	BB	GSWA	4/26/2005	0.4	0.050	0.027
Inlet	Black Brook (Inlet)	BB	GSWA	8/4/2005	0.2	0.160	0.090
Inlet	Black Brook (Inlet)	BB	GSWA	10/25/2005	1.5	0.370	0.110
Inlet	Black Brook (Inlet)	BB	GSWA	11/30/2005	2.2	0.540	0.078
Inlet	Great Brook (Inlet)	GB	GSWA	2/13/1999	14.0	0.116	0.024
Inlet	Great Brook (Inlet)	GB	GSWA	5/20/1999	7.5	0.356	0.011
Inlet	Great Brook (Inlet)	GB	GSWA	6/8/1999	4.0	0.084	0.032
Inlet	Great Brook (Inlet)	GB	GSWA	9/4/1999	3.3	0.070	0.025
Inlet	Great Brook (Inlet)	GB	GSWA	9/16/1999	112.5	0.346	0.060
Inlet	Great Brook (Inlet)	GB	GSWA	11/3/1999	47.2	0.234	0.061
Inlet	Great Brook (Inlet)	GB	GSWA	3/2/2000	14.9	0.056	0.008
Inlet	Great Brook (Inlet)	GB	GSWA	3/18/2000	25.1	0.118	0.020
Inlet	Great Brook (Inlet)	GB	GSWA	4/25/2000	16.0	0.043	0.023
Inlet	Great Brook (Inlet)	GB	GSWA	6/22/2000	10.6	0.093	0.010
Inlet	Great Brook (Inlet)	GB	GSWA	7/13/2000	3.3	0.070	0.020
Inlet	Great Brook (Inlet)	GB	GSWA	7/27/2000	135.0	0.258	0.040
Inlet	Great Brook (Inlet)	GB	GSWA	8/22/2000	6.9	0.061	0.025
Inlet	Great Brook (Inlet)	GB	GSWA	9/10/2000	4.3	0.055	0.031
Inlet	Great Brook (Inlet)	GB	GSWA	9/27/2000	6.9	0.188	0.026

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Great Brook (Inlet)	GB	GSWA	10/4/2000	3.6	0.048	0.022
Inlet	Great Brook (Inlet)	GB	GSWA	11/11/2000	11.6	0.230	0.062
Inlet	Great Brook (Inlet)	GB	GSWA	11/19/2000	4.5	0.053	0.035
Inlet	Great Brook (Inlet)	GB	GSWA	12/6/2000	5.3	0.063	0.030
Inlet	Great Brook (Inlet)	GB	GSWA	12/17/2000	212.7	0.160	0.053
Inlet	Great Brook (Inlet)	GB	GSWA	1/31/2001	37.5	0.087	0.024
Inlet	Great Brook (Inlet)	GB	GSWA	3/22/2001	55.7	0.110	0.019
Inlet	Great Brook (Inlet)	GB	GSWA	4/24/2001	14.9	0.062	0.011
Inlet	Great Brook (Inlet)	GB	GSWA	5/16/2001	7.9	0.059	0.029
Inlet	Great Brook (Inlet)	GB	GSWA	6/17/2001	111.7	0.170	0.034
Inlet	Great Brook (Inlet)	GB	GSWA	9/26/2001	7.7	0.155	0.004
Inlet	Great Brook (Inlet)	GB	GSWA	11/26/2001	6.6	0.110	0.007
Inlet	Great Brook (Inlet)	GB	GSWA	6/24/2002	4.2	0.080	0.045
Inlet	Great Brook (Inlet)	GB	GSWA	8/28/2002	2.1	0.090	0.026
Inlet	Great Brook (Inlet)	GB	GSWA	12/18/2002	14.2	0.046	0.022
Inlet	Great Brook (Inlet)	GB	GSWA	3/25/2003	21.5	0.027	0.006
Inlet	Great Brook (Inlet)	GB	GSWA	6/25/2003	19.3	0.067	0.040
Inlet	Great Brook (Inlet)	GB	GSWA	8/20/2003	12.9	0.080	0.005
Inlet	Great Brook (Inlet)	GB	GSWA	10/23/2003	15.8	0.048	0.026
Inlet	Great Brook (Inlet)	GB	GSWA	12/28/2003	31.7	0.049	0.026
Inlet	Great Brook (Inlet)	GB	GSWA	2/24/2004	20.8	0.084	0.012
Inlet	Great Brook (Inlet)	GB	GSWA	5/4/2004	27.4	0.174	0.032
Inlet	Great Brook (Inlet)	GB	GSWA	7/7/2004	8.9	0.062	0.033
Inlet	Great Brook (Inlet)	GB	GSWA	7/13/2004	139.7	0.230	0.044
Inlet	Great Brook (Inlet)	GB	GSWA	7/19/2004	22.8	0.198	0.037
Inlet	Great Brook (Inlet)	GB	GSWA	10/7/2004	12.2	0.059	0.001
Inlet	Great Brook (Inlet)	GB	GSWA	1/31/2005	16.0	0.020	0.016
Inlet	Great Brook (Inlet)	GB	GSWA	1/31/2005		0.030	0.017
Inlet	Great Brook (Inlet)	GB	GSWA	4/26/2005	17.5	0.030	0.019
Inlet	Great Brook (Inlet)	GB	GSWA	8/4/2005	6.6	0.080	0.037
Inlet	Great Brook (Inlet)	GB	GSWA	10/25/2005	76.0	0.110	0.035
Inlet	Great Brook (Inlet)	GB	GSWA	11/30/2005	221.8	0.140	0.019
Inlet	Loantaka Brook (Inlet)	LB	GSWA	2/13/1999	9.1	0.330	0.135

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Loantaka Brook (Inlet)	LB	GSWA	5/20/1999	8.9	0.729	0.057
Inlet	Loantaka Brook (Inlet)	LB	GSWA	6/8/1999	4.2	0.280	0.194
Inlet	Loantaka Brook (Inlet)	LB	GSWA	9/4/1999	3.3	0.250	0.206
Inlet	Loantaka Brook (Inlet)	LB	GSWA	9/30/1999	12.5	0.340	0.086
Inlet	Loantaka Brook (Inlet)	LB	GSWA	11/3/1999	18.6	0.383	0.115
Inlet	Loantaka Brook (Inlet)	LB	GSWA	3/2/2000	10.2	0.115	0.035
Inlet	Loantaka Brook (Inlet)	LB	GSWA	3/18/2000	14.3	0.350	0.046
Inlet	Loantaka Brook (Inlet)	LB	GSWA	4/25/2000	12.6	0.132	0.072
Inlet	Loantaka Brook (Inlet)	LB	GSWA	5/11/2000	8.9	0.560	0.210
Inlet	Loantaka Brook (Inlet)	LB	GSWA	6/22/2000	8.9	0.440	0.203
Inlet	Loantaka Brook (Inlet)	LB	GSWA	7/13/2000	6.4	0.244	0.226
Inlet	Loantaka Brook (Inlet)	LB	GSWA	7/27/2000	105.8	0.600	0.130
Inlet	Loantaka Brook (Inlet)	LB	GSWA	8/22/2000	6.8	0.189	0.068
Inlet	Loantaka Brook (Inlet)	LB	GSWA	9/10/2000	6.1	0.350	0.280
Inlet	Loantaka Brook (Inlet)	LB	GSWA	9/27/2000	7.4	0.440	0.078
Inlet	Loantaka Brook (Inlet)	LB	GSWA	10/4/2000	6.3	0.158	0.133
Inlet	Loantaka Brook (Inlet)	LB	GSWA	11/10/2000	34.9	0.720	0.218
Inlet	Loantaka Brook (Inlet)	LB	GSWA	11/19/2000	6.9	0.270	0.220
Inlet	Loantaka Brook (Inlet)	LB	GSWA	12/6/2000	7.4	0.175	0.092
Inlet	Loantaka Brook (Inlet)	LB	GSWA	12/17/2000	136.1	0.360	0.110
Inlet	Loantaka Brook (Inlet)	LB	GSWA	1/31/2001	26.4	0.317	0.071
Inlet	Loantaka Brook (Inlet)	LB	GSWA	3/22/2001	31.4	0.370	0.056
Inlet	Loantaka Brook (Inlet)	LB	GSWA	4/24/2001	9.1	0.250	0.102
Inlet	Loantaka Brook (Inlet)	LB	GSWA	5/16/2001	6.4	0.300	0.197
Inlet	Loantaka Brook (Inlet)	LB	GSWA	6/2/2001	119.4	0.810	0.090
Inlet	Loantaka Brook (Inlet)	LB	GSWA	6/17/2001	75.0	0.630	0.130
Inlet	Loantaka Brook (Inlet)	LB	GSWA	9/26/2001	7.4	0.290	0.131
Inlet	Loantaka Brook (Inlet)	LB	GSWA	11/26/2001	6.2	0.380	0.120
Inlet	Loantaka Brook (Inlet)	LB	GSWA	6/24/2002	2.1	0.310	0.260
Inlet	Loantaka Brook (Inlet)	LB	GSWA	8/28/2002	1.9	0.530	0.480
Inlet	Loantaka Brook (Inlet)	LB	GSWA	12/18/2002		0.110	0.049
Inlet	Loantaka Brook (Inlet)	LB	GSWA	3/25/2003	8.0	0.121	0.016
Inlet	Loantaka Brook (Inlet)	LB	GSWA	6/25/2003	5.3	0.150	0.102

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Loantaka Brook (Inlet)	LB	GSWA	8/20/2003	5.4	0.163	0.099
Inlet	Loantaka Brook (Inlet)	LB	GSWA	10/23/2003	5.4	0.106	0.071
Inlet	Loantaka Brook (Inlet)	LB	GSWA	12/28/2003	10.6	0.053	0.028
Inlet	Loantaka Brook (Inlet)	LB	GSWA	2/24/2004	8.9	0.064	0.018
Inlet	Loantaka Brook (Inlet)	LB	GSWA	4/13/2004	26.9	0.390	0.029
Inlet	Loantaka Brook (Inlet)	LB	GSWA	5/4/2004	9.8	0.260	0.036
Inlet	Loantaka Brook (Inlet)	LB	GSWA	7/7/2004	3.1	0.330	0.280
Inlet	Loantaka Brook (Inlet)	LB	GSWA	7/13/2004	29.9	0.960	0.101
Inlet	Loantaka Brook (Inlet)	LB	GSWA	7/19/2004	12.4	0.390	0.096
Inlet	Loantaka Brook (Inlet)	LB	GSWA	10/7/2004	5.1	0.198	0.164
Inlet	Loantaka Brook (Inlet)	LB	GSWA	11/5/2004	11.7	0.360	0.179
Inlet	Loantaka Brook (Inlet)	LB	GSWA	1/31/2005	8.7	0.160	0.081
Inlet	Loantaka Brook (Inlet)	LB	GSWA	3/24/2005	11.6	0.140	0.029
Inlet	Loantaka Brook (Inlet)	LB	GSWA	4/26/2005	4.7	0.120	0.098
Inlet	Loantaka Brook (Inlet)	LB	GSWA	8/4/2005	3.9	0.210	0.190
Inlet	Loantaka Brook (Inlet)	LB	GSWA	10/25/2005	60.1	0.420	0.046
Inlet	Loantaka Brook (Inlet)	LB	GSWA	10/25/2005		0.450	0.050
Inlet	Loantaka Brook (Inlet)	LB	GSWA	11/30/2005	53.8	0.340	0.043
Inlet	Passaic River (Inlet)	PRIN	GSWA	5/20/1999	35.3	0.062	0.009
Inlet	Passaic River (Inlet)	PRIN	GSWA	6/8/1999	16.5	0.042	0.015
Inlet	Passaic River (Inlet)	PRIN	GSWA	8/26/1999	18.2	0.067	0.006
Inlet	Passaic River (Inlet)	PRIN	GSWA	9/4/1999	11.2	0.032	0.012
Inlet	Passaic River (Inlet)	PRIN	GSWA	11/3/1999	44.3	0.091	0.009
Inlet	Passaic River (Inlet)	PRIN	GSWA	3/2/2000	39.6	0.023	0.007
Inlet	Passaic River (Inlet)	PRIN	GSWA	3/18/2000	47.9	0.106	0.013
Inlet	Passaic River (Inlet)	PRIN	GSWA	4/25/2000	40.2	0.053	0.011
Inlet	Passaic River (Inlet)	PRIN	GSWA	5/11/2000	36.5	0.140	0.017
Inlet	Passaic River (Inlet)	PRIN	GSWA	6/22/2000	37.1	0.061	0.014
Inlet	Passaic River (Inlet)	PRIN	GSWA	7/13/2000	18.2	0.091	0.027
Inlet	Passaic River (Inlet)	PRIN	GSWA	7/27/2000	179.6	0.115	0.020
Inlet	Passaic River (Inlet)	PRIN	GSWA	8/22/2000	22.6	0.032	0.015
Inlet	Passaic River (Inlet)	PRIN	GSWA	9/10/2000	18.6	0.030	0.010
Inlet	Passaic River (Inlet)	PRIN	GSWA	9/27/2000	29.7	0.070	0.012

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Passaic River (Inlet)	PRIN	GSWA	10/4/2000	18.2	0.035	0.011
Inlet	Passaic River (Inlet)	PRIN	GSWA	11/11/2000	32.4	0.082	0.015
Inlet	Passaic River (Inlet)	PRIN	GSWA	11/19/2000	19.7	0.026	0.016
Inlet	Passaic River (Inlet)	PRIN	GSWA	12/6/2000	20.1	0.028	0.014
Inlet	Passaic River (Inlet)	PRIN	GSWA	12/17/2000	290.8	0.074	0.016
Inlet	Passaic River (Inlet)	PRIN	GSWA	4/24/2001	34.7	0.039	0.011
Inlet	Passaic River (Inlet)	PRIN	GSWA	5/16/2001	25.7	0.043	0.011
Inlet	Passaic River (Inlet)	PRIN	GSWA	6/2/2001	401.6	0.160	0.021
Inlet	Passaic River (Inlet)	PRIN	GSWA	6/17/2001	110.1	0.090	0.050
Inlet	Passaic River (Inlet)	PRIN	GSWA	9/26/2001	20.9	0.050	0.005
Inlet	Passaic River (Inlet)	PRIN	GSWA	11/26/2001	19.6	0.070	0.005
Inlet	Passaic River (Inlet)	PRIN	GSWA	6/24/2002		0.054	0.015
Inlet	Passaic River (Inlet)	PRIN	GSWA	8/28/2002		0.053	0.012
Inlet	Passaic River (Inlet)	PRIN	GSWA	12/18/2002	29.7	0.037	0.009
Inlet	Passaic River (Inlet)	PRIN	GSWA	3/25/2003	47.9	0.026	0.003
Inlet	Passaic River (Inlet)	PRIN	GSWA	6/25/2003	49.4	0.049	0.023
Inlet	Passaic River (Inlet)	PRIN	GSWA	8/20/2003	24.8	0.036	0.007
Inlet	Passaic River (Inlet)	PRIN	GSWA	10/23/2003	23.9	0.044	0.011
Inlet	Passaic River (Inlet)	PRIN	GSWA	12/28/2003	61.8	0.030	0.015
Inlet	Passaic River (Inlet)	PRIN	GSWA	2/24/2004	37.3	0.033	0.010
Inlet	Passaic River (Inlet)	PRIN	GSWA	4/13/2004	76.4	0.088	0.015
Inlet	Passaic River (Inlet)	PRIN	GSWA	5/4/2004	56.6	0.075	0.018
Inlet	Passaic River (Inlet)	PRIN	GSWA	7/7/2004	17.2	0.060	0.023
Inlet	Passaic River (Inlet)	PRIN	GSWA	7/13/2004	93.3	0.080	0.021
Inlet	Passaic River (Inlet)	PRIN	GSWA	7/19/2004	49.4	0.058	0.025
Inlet	Passaic River (Inlet)	PRIN	GSWA	10/7/2004	19.4	0.040	0.001
Inlet	Passaic River (Inlet)	PRIN	GSWA	11/5/2004	41.6	0.065	0.001
Inlet	Passaic River (Inlet)	PRIN	GSWA	1/31/2005	30.2	0.010	0.008
Inlet	Passaic River (Inlet)	PRIN	GSWA	3/24/2005	45.0	0.040	0.001
Inlet	Passaic River (Inlet)	PRIN	GSWA	4/26/2005	33.2	0.040	0.032
Inlet	Passaic River (Inlet)	PRIN	GSWA	8/4/2005	13.9	0.080	0.019
Inlet	Passaic River (Inlet)	PRIN	GSWA	10/25/2005	77.7	0.070	0.011
Inlet	Primrose Brook (Inlet)	PB	GSWA	6/8/1999	1.1	0.054	0.025

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/14/1999	2.8	0.537	0.029
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/26/1999	2.0	0.768	0.021
Inlet	Primrose Brook (Inlet)	PB	GSWA	9/4/1999	0.6	0.036	0.020
Inlet	Primrose Brook (Inlet)	PB	GSWA	9/16/1999	929.1	0.613	0.028
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/3/1999	2.8	0.153	0.008
Inlet	Primrose Brook (Inlet)	PB	GSWA	3/2/2000	3.1	0.020	0.007
Inlet	Primrose Brook (Inlet)	PB	GSWA	3/18/2000	37.4	0.158	0.016
Inlet	Primrose Brook (Inlet)	PB	GSWA	4/25/2000	9.4	0.029	0.012
Inlet	Primrose Brook (Inlet)	PB	GSWA	7/13/2000	8.0	0.038	0.035
Inlet	Primrose Brook (Inlet)	PB	GSWA	7/27/2000	46.7	0.189	0.039
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/22/2000	6.8	0.034	0.023
Inlet	Primrose Brook (Inlet)	PB	GSWA	9/10/2000	8.7	0.037	0.026
Inlet	Primrose Brook (Inlet)	PB	GSWA	9/27/2000	1.5	0.280	0.053
Inlet	Primrose Brook (Inlet)	PB	GSWA	10/4/2000	5.0	0.036	0.021
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/10/2000	6.8	0.330	0.036
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/19/2000	0.0	0.016	0.014
Inlet	Primrose Brook (Inlet)	PB	GSWA	12/6/2000	6.3	0.018	0.014
Inlet	Primrose Brook (Inlet)	PB	GSWA	12/17/2000	144.1	0.048	0.015
Inlet	Primrose Brook (Inlet)	PB	GSWA	1/31/2001		0.068	0.011
Inlet	Primrose Brook (Inlet)	PB	GSWA	3/22/2001	42.4	0.170	0.012
Inlet	Primrose Brook (Inlet)	PB	GSWA	4/24/2001	116.5	0.193	0.003
Inlet	Primrose Brook (Inlet)	PB	GSWA	5/16/2001	54.9	0.038	0.019
Inlet	Primrose Brook (Inlet)	PB	GSWA	6/2/2001	1216.2	0.440	0.031
Inlet	Primrose Brook (Inlet)	PB	GSWA	6/17/2001	149.1	0.440	0.028
Inlet	Primrose Brook (Inlet)	PB	GSWA	9/26/2001	20.4	0.116	0.008
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/26/2001	1.5	0.050	0.002
Inlet	Primrose Brook (Inlet)	PB	GSWA	6/24/2002	106.7	0.088	0.074
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/28/2002	70.5	0.036	0.023
Inlet	Primrose Brook (Inlet)	PB	GSWA	12/18/2002	5.9	0.026	0.012
Inlet	Primrose Brook (Inlet)	PB	GSWA	3/25/2003	46.5	0.013	0.002
Inlet	Primrose Brook (Inlet)	PB	GSWA	6/25/2003	25.9	0.033	0.016
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/20/2003	13.7	0.038	0.004
Inlet	Primrose Brook (Inlet)	PB	GSWA	10/23/2003	17.6	0.022	0.014

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Inlet	Primrose Brook (Inlet)	PB	GSWA	12/28/2003	21.4	0.029	0.014
Inlet	Primrose Brook (Inlet)	PB	GSWA	2/24/2004	16.3	0.019	0.011
Inlet	Primrose Brook (Inlet)	PB	GSWA	4/13/2004	28.6	0.172	0.012
Inlet	Primrose Brook (Inlet)	PB	GSWA	5/4/2004	25.9	0.184	0.016
Inlet	Primrose Brook (Inlet)	PB	GSWA	7/7/2004	9.1	0.033	0.030
Inlet	Primrose Brook (Inlet)	PB	GSWA	7/13/2004	18.1	0.500	0.031
Inlet	Primrose Brook (Inlet)	PB	GSWA	7/19/2004	7.8	0.107	0.025
Inlet	Primrose Brook (Inlet)	PB	GSWA	10/7/2004	11.6	0.026	0.001
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/5/2004	16.0	0.104	0.001
Inlet	Primrose Brook (Inlet)	PB	GSWA	1/31/2005	15.6	0.020	0.012
Inlet	Primrose Brook (Inlet)	PB	GSWA	3/24/2005	21.4	0.040	0.001
Inlet	Primrose Brook (Inlet)	PB	GSWA	4/26/2005	19.8	0.030	0.026
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/4/2005	8.7	0.040	0.017
Inlet	Primrose Brook (Inlet)	PB	GSWA	8/4/2005		0.070	0.051
Inlet	Primrose Brook (Inlet)	PB	GSWA	10/25/2005	40.2	0.130	0.010
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/30/2005	30.9	0.200	0.005
Inlet	Primrose Brook (Inlet)	PB	GSWA	11/30/2005		0.210	0.004
Outlet	Passaic River (Outlet)	PROUT	GSWA	6/8/1999		0.207	0.042
Outlet	Passaic River (Outlet)	PROUT	GSWA	9/4/1999		0.215	0.111
Outlet	Passaic River (Outlet)	PROUT	GSWA	1/13/2000		0.084	
Outlet	Passaic River (Outlet)	PROUT	GSWA	3/2/2000		0.064	0.014
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/27/2000		0.084	0.035
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/13/2000		0.130	0.039
Outlet	Passaic River (Outlet)	PROUT	GSWA	8/22/2000		0.196	0.082
Outlet	Passaic River (Outlet)	PROUT	GSWA	9/10/2000		0.130	0.037
Outlet	Passaic River (Outlet)	PROUT	GSWA	10/4/2000		0.057	0.027
Outlet	Passaic River (Outlet)	PROUT	GSWA	12/6/2000		0.094	0.025
Outlet	Passaic River (Outlet)	PROUT	GSWA	3/26/2001		0.043	0.013
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/24/2001		0.106	0.035
Outlet	Passaic River (Outlet)	PROUT	GSWA	5/16/2001		0.171	0.031
Outlet	Passaic River (Outlet)	PROUT	GSWA	6/21/2001		0.184	0.075
Outlet	Passaic River (Outlet)	PROUT	GSWA	6/24/2002		0.133	0.065
Outlet	Passaic River (Outlet)	PROUT	GSWA	8/28/2002		0.104	0.040

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Outlet	Passaic River (Outlet)	PROUT	GSWA	12/18/2002		0.059	0.016
Outlet	Passaic River (Outlet)	PROUT	GSWA	3/25/2003		0.031	0.006
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	6/9/2003		0.130	0.060
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	6/10/2003		0.120	0.070
Outlet	Passaic River (Outlet)	PROUT	GSWA	6/25/2003		0.158	0.094
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	7/14/2003		0.120	0.050
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	7/15/2003		0.070	0.010
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	8/5/2003		0.270	0.100
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	8/6/2003		0.140	0.060
Outlet	Passaic River (Outlet)	PROUT	GSWA	8/20/2003		0.230	0.110
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	8/25/2003		0.170	0.090
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	8/26/2003		0.190	0.100
Outlet	Passaic River (Outlet)	PROUT	GSWA	10/23/2003		0.065	0.026
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	11/3/2003		0.100	0.050
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	11/4/2003		0.150	0.060
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	11/17/2003		0.090	0.030
Outlet	Passaic River (Outlet)	PA2	Omni - Phase I	11/18/2003		0.050	0.030
Outlet	Passaic River (Outlet)	PROUT	GSWA	12/28/2003		0.035	0.015
Outlet	Passaic River (Outlet)	PROUT	GSWA	2/24/2004		0.034	0.011
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/13/2004		0.068	0.018
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/14/2004		0.074	0.013
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/14/2004		0.077	0.020
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/15/2004		0.060	0.023
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/15/2004		0.066	0.023
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/16/2004		0.059	0.017
Outlet	Passaic River (Outlet)	PROUT	GSWA	5/4/2004		0.105	0.051
Outlet	Passaic River (Outlet)	PROUT	GSWA	5/4/2004		0.129	0.062
Outlet	Passaic River (Outlet)	PROUT	GSWA	5/5/2004		0.103	0.054
Outlet	Passaic River (Outlet)	PROUT	GSWA	5/5/2004		0.106	0.067
Outlet	Passaic River (Outlet)	PROUT	GSWA	5/6/2004		0.097	0.058
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/7/2004		0.122	0.061
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/13/2004		0.132	0.057
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/13/2004		0.140	0.052

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/14/2004		0.130	0.062
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/19/2004		0.123	0.061
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/19/2004		0.138	0.057
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/20/2004		0.122	0.062
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/20/2004		0.130	0.072
Outlet	Passaic River (Outlet)	PROUT	GSWA	7/21/2004		0.131	0.077
Outlet	Passaic River (Outlet)	PROUT	GSWA	10/7/2004		0.089	0.055
Outlet	Passaic River (Outlet)	PROUT	GSWA	11/4/2004		0.078	0.001
Outlet	Passaic River (Outlet)	PROUT	GSWA	11/5/2004		0.095	0.001
Outlet	Passaic River (Outlet)	PROUT	GSWA	11/5/2004		0.100	0.001
Outlet	Passaic River (Outlet)	PROUT	GSWA	1/31/2005		0.050	0.046
Outlet	Passaic River (Outlet)	PROUT	GSWA	3/24/2005		0.030	0.001
Outlet	Passaic River (Outlet)	PROUT	GSWA	4/26/2005		0.050	0.038
Outlet	Passaic River (Outlet)	PROUT	GSWA	8/4/2005		0.120	0.029
Outlet	Passaic River (Outlet)	PROUT	GSWA	10/25/2005		0.070	0.033
Outlet	Passaic River (Outlet)	PROUT	GSWA	11/30/2005		0.070	0.019
STP	Chatham-Main STP	Chatham Main	DMR	7/15/2000	1.0	0.500	
STP	Chatham-Main STP	Chatham Main	DMR	8/15/2000	1.0	0.500	
STP	Chatham-Main STP	Chatham Main	DMR	9/15/2000	1.0	0.400	
STP	Chatham-Main STP	Chatham Main	DMR	10/15/2000	1.0	0.400	
STP	Chatham-Main STP	Chatham Main	DMR	11/15/2000	1.1	0.300	
STP	Chatham-Main STP	Chatham Main	DMR	12/15/2000	1.1	0.200	
STP	Chatham-Main STP	Chatham Main	DMR	1/15/2001	1.2	0.240	
STP	Chatham-Main STP	Chatham Main	DMR	2/15/2001	1.3	0.190	
STP	Chatham-Main STP	Chatham Main	DMR	3/15/2001	1.3	0.190	
STP	Chatham-Main STP	Chatham Main	DMR	4/15/2001	1.2	0.270	
STP	Chatham-Main STP	Chatham Main	DMR	5/15/2001	1.1	0.400	
STP	Chatham-Main STP	Chatham Main	DMR	6/15/2001	1.2	0.330	
STP	Chatham-Main STP	Chatham Main	DMR	7/15/2001	1.0	0.460	
STP	Chatham-Main STP	Chatham Main	DMR	8/15/2001	0.9	0.560	
STP	Chatham-Main STP	Chatham Main	DMR	9/15/2001	1.0	0.660	
STP	Chatham-Main STP	Chatham Main	DMR	10/15/2001	1.0	0.570	
STP	Chatham-Main STP	Chatham Main	DMR	11/15/2001	1.0	0.290	

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
STP	Chatham-Main STP	Chatham Main	DMR	12/15/2001	1.0	0.520	
STP	Chatham-Main STP	Chatham Main	DMR	1/15/2002	1.0	0.620	
STP	Chatham-Main STP	Chatham Main	DMR	2/15/2002	1.0	0.420	
STP	Chatham-Main STP	Chatham Main	DMR	3/15/2002	0.9	0.560	
STP	Chatham-Main STP	Chatham Main	DMR	4/15/2002	0.9	0.640	
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	5/9/2002	1.0	0.900	0.680
STP	Chatham-Main STP	Chatham Main	DMR	5/15/2002	1.0	0.770	
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	5/16/2002	1.1	0.690	0.440
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	5/21/2002	1.1	0.720	0.290
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	5/28/2002	1.1	0.820	0.510
STP	Chatham-Main STP	Chatham Main	DMR	6/15/2002	1.0	0.810	
STP	Chatham-Main STP	Chatham Main	DMR	7/15/2002	0.9	0.790	
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	8/6/2002	0.8	0.760	0.690
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	8/13/2002	0.9	0.590	0.500
STP	Chatham-Main STP	Chatham Main	DMR	8/15/2002	0.9	0.570	
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	8/20/2002	0.8	0.440	0.360
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	8/27/2002	0.9	0.490	0.400
STP	Chatham-Main STP	Chatham Main	DMR	9/15/2002	1.0	0.420	
STP	Chatham-Main STP	Chatham Main	DMR	10/15/2002	1.1	0.410	
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	11/5/2002	1.1	0.150	0.090
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	11/12/2002	1.2	0.270	0.210
STP	Chatham-Main STP	Chatham Main	DMR	11/15/2002	1.2	0.210	
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	11/21/2002	1.3	0.190	0.160
STP	Chatham-Main STP	C_WWTP	Omni - Chatham	11/26/2002	1.3	0.250	0.190
STP	Chatham-Main STP	Chatham Main	DMR	12/15/2002	1.3	0.220	
STP	Chatham-Main STP	Chatham Main	DMR	1/15/2003	1.3	0.190	
STP	Chatham-Main STP	Chatham Main	DMR	2/15/2003	1.2	0.180	
STP	Chatham-Main STP	Chatham Main	DMR	3/15/2003	1.4	0.190	
STP	Chatham-Main STP	Chatham Main	DMR	4/15/2003	1.3	0.300	
STP	Chatham-Main STP	Chatham Main	DMR	5/15/2003	1.1	0.510	
STP	Chatham-Main STP	Chatham Main	Omni - Phase I	6/10/2003	1.5	0.450	0.360
STP	Chatham-Main STP	Chatham Main	DMR	6/15/2003	1.5	0.330	
STP	Chatham-Main STP	Chatham Main	Omni - Phase I	7/14/2003	1.1	0.360	0.250

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
STP	Chatham-Main STP	Chatham Main	DMR	7/15/2003	1.1	0.240	
STP	Chatham-Main STP	Chatham Main	Omni - Phase I	8/6/2003	1.2	0.340	0.260
STP	Chatham-Main STP	Chatham Main	DMR	8/15/2003	1.1	0.310	
STP	Chatham-Main STP	Chatham Main	Omni - Phase I	8/26/2003	1.0	0.370	0.180
STP	Chatham-Main STP	Chatham Main	DMR	9/15/2003	1.2	0.370	
STP	Chatham-Main STP	Chatham Main	DMR	10/15/2003	1.2	0.270	
STP	Chatham-Main STP	Chatham Main	Omni - Phase I	11/4/2003	1.2	0.360	0.270
STP	Chatham-Main STP	Chatham Main	DMR	11/15/2003	1.2	0.230	
STP	Chatham-Main STP	Chatham Main	Omni - Phase I	11/18/2003	1.1	0.230	0.160
STP	Chatham-Main STP	Chatham Main	DMR	12/15/2003	1.5	0.200	
STP	Chatham-Main STP	Chatham Main	DMR	1/15/2004	1.2	0.190	
STP	Chatham-Main STP	Chatham Main	DMR	2/15/2004	1.3	0.231	
STP	Chatham-Main STP	Chatham Main	DMR	3/15/2004	1.2	0.880	
STP	Chatham-Main STP	Chatham Main	DMR	4/15/2004	1.3	0.120	
STP	Chatham-Main STP	Chatham Main	DMR	5/15/2004	1.2	0.200	
STP	Chatham-Main STP	Chatham Main	DMR	6/15/2004	1.1	0.283	
STP	Chatham-Main STP	Chatham Main	DMR	7/15/2004	1.0	0.280	
STP	Chatham-Main STP	Chatham Main	DMR	8/15/2004	1.1	0.080	
STP	Chatham-Main STP	Chatham Main	DMR	9/15/2004	1.1	0.080	
STP	Chatham-Main STP	Chatham Main	DMR	10/15/2004	1.1	0.360	
STP	Chatham-Main STP	Chatham Main	DMR	11/15/2004	1.1	0.290	
STP	Chatham-Main STP	Chatham Main	DMR	12/15/2004	1.3	0.250	
STP	Chatham-Main STP	Chatham Main	DMR	1/15/2005	1.3	0.150	
STP	Chatham-Main STP	Chatham Main	DMR	2/15/2005	1.2	0.110	
STP	Chatham-Main STP	Chatham Main	DMR	3/15/2005	1.3	0.190	
STP	Chatham-Main STP	Chatham Main	DMR	4/15/2005	1.4	0.300	
STP	Morris-Woodland STP	Morris Woodland	DMR	7/15/2000	2.0	0.585	
STP	Morris-Woodland STP	Morris Woodland	DMR	8/15/2000	2.2	0.446	
STP	Morris-Woodland STP	Morris Woodland	DMR	9/15/2000	2.0	0.605	
STP	Morris-Woodland STP	Morris Woodland	DMR	10/15/2000	1.7	0.258	
STP	Morris-Woodland STP	Morris Woodland	DMR	11/15/2000	1.8	0.625	
STP	Morris-Woodland STP	Morris Woodland	DMR	12/15/2000	2.0	0.455	
STP	Morris-Woodland STP	Morris Woodland	DMR	1/15/2001	2.0	0.620	

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
STP	Morris-Woodland STP	Morris Woodland	DMR	2/15/2001	2.4	0.828	
STP	Morris-Woodland STP	Morris Woodland	DMR	3/15/2001	2.4	0.570	
STP	Morris-Woodland STP	Morris Woodland	DMR	4/15/2001	2.3	0.688	
STP	Morris-Woodland STP	Morris Woodland	DMR	5/15/2001	2.0	0.696	
STP	Morris-Woodland STP	Morris Woodland	DMR	6/15/2001	2.2	0.583	
STP	Morris-Woodland STP	Morris Woodland	DMR	7/15/2001	1.9	0.493	
STP	Morris-Woodland STP	Morris Woodland	DMR	8/15/2001	1.9	0.488	
STP	Morris-Woodland STP	Morris Woodland	DMR	9/15/2001	1.9	0.712	
STP	Morris-Woodland STP	Morris Woodland	DMR	10/15/2001	1.9	0.554	
STP	Morris-Woodland STP	Morris Woodland	DMR	11/15/2001	1.9	0.524	
STP	Morris-Woodland STP	Morris Woodland	DMR	12/15/2001	1.8	0.470	
STP	Morris-Woodland STP	Morris Woodland	DMR	1/15/2002	1.7	0.650	
STP	Morris-Woodland STP	Morris Woodland	DMR	2/15/2002	1.6	0.418	
STP	Morris-Woodland STP	Morris Woodland	DMR	3/15/2002	1.8	0.393	
STP	Morris-Woodland STP	Morris Woodland	DMR	4/15/2002	2.0	0.462	
STP	Morris-Woodland STP	Morris Woodland	DMR	5/15/2002	2.2	0.670	
STP	Morris-Woodland STP	Morris Woodland	DMR	6/15/2002	2.0	0.428	
STP	Morris-Woodland STP	Morris Woodland	DMR	7/15/2002	1.8	0.622	
STP	Morris-Woodland STP	Morris Woodland	DMR	8/15/2002	1.8	0.715	
STP	Morris-Woodland STP	Morris Woodland	DMR	9/15/2002	1.9	0.368	
STP	Morris-Woodland STP	Morris Woodland	DMR	10/15/2002	2.0	0.383	
STP	Morris-Woodland STP	Morris Woodland	DMR	11/15/2002	2.2	0.248	
STP	Morris-Woodland STP	Morris Woodland	DMR	12/15/2002	2.3	0.450	
STP	Morris-Woodland STP	Morris Woodland	DMR	1/15/2003	2.1	0.516	
STP	Morris-Woodland STP	Morris Woodland	DMR	2/15/2003	2.0	0.320	
STP	Morris-Woodland STP	Morris Woodland	DMR	3/15/2003	2.5	0.488	
STP	Morris-Woodland STP	Morris Woodland	DMR	4/15/2003	2.3	0.638	
STP	Morris-Woodland STP	Morris Woodland	DMR	5/15/2003	1.9	0.623	
STP	Morris-Woodland STP	Morris Woodland	Omni - Phase I	6/10/2003	3.6	0.500	0.370
STP	Morris-Woodland STP	Morris Woodland	DMR	6/15/2003	2.7	0.505	
STP	Morris-Woodland STP	Morris Woodland	Omni - Phase I	7/14/2003	3.0	0.550	0.410
STP	Morris-Woodland STP	Morris Woodland	DMR	7/15/2003	1.9	0.684	
STP	Morris-Woodland STP	Morris Woodland	Omni - Phase I	8/6/2003	2.8	0.410	0.290

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
STP	Morris-Woodland STP	Morris Woodland	DMR	8/15/2003	2.0	0.498	
STP	Morris-Woodland STP	Morris Woodland	Omni - Phase I	8/26/2003	1.9	0.420	0.300
STP	Morris-Woodland STP	Morris Woodland	DMR	9/15/2003	2.1	0.490	
STP	Morris-Woodland STP	Morris Woodland	DMR	10/15/2003	1.9	0.360	
STP	Morris-Woodland STP	Morris Woodland	Omni - Phase I	11/4/2003	2.9	0.120	0.070
STP	Morris-Woodland STP	Morris Woodland	DMR	11/15/2003	2.1	0.288	
STP	Morris-Woodland STP	Morris Woodland	Omni - Phase I	11/18/2003	2.9	0.230	0.190
STP	Morris-Woodland STP	Morris Woodland	DMR	12/15/2003	2.2	0.278	
STP	Morris-Woodland STP	Morris Woodland	DMR	1/15/2004	1.5	0.498	
STP	Morris-Woodland STP	Morris Woodland	DMR	2/15/2004	1.9	0.450	
STP	Morris-Woodland STP	Morris Woodland	DMR	3/15/2004	2.2	0.366	
STP	Morris-Woodland STP	Morris Woodland	DMR	4/15/2004	2.0	0.360	
STP	Morris-Woodland STP	Morris Woodland	DMR	5/15/2004	1.8	0.445	
STP	Morris-Woodland STP	Morris Woodland	DMR	6/15/2004	1.7	0.818	
STP	Morris-Woodland STP	Morris Woodland	DMR	7/15/2004	1.8	0.888	
STP	Morris-Woodland STP	Morris Woodland	DMR	8/15/2004	1.7	0.630	
STP	Morris-Woodland STP	Morris Woodland	DMR	9/15/2004	1.8	0.438	
STP	Morris-Woodland STP	Morris Woodland	DMR	10/15/2004	1.5	0.462	
STP	Morris-Woodland STP	Morris Woodland	DMR	11/15/2004	1.7	0.730	
STP	Morris-Woodland STP	Morris Woodland	DMR	12/15/2004	2.0	0.660	
STP	Morris-Woodland STP	Morris Woodland	DMR	1/15/2005	2.0	0.725	
STP	Morris-Woodland STP	Morris Woodland	DMR	2/15/2005	2.0	0.592	
STP	Morris-Woodland STP	Morris Woodland	DMR	3/15/2005	2.1	0.705	
STP	Morris-Woodland STP	Morris Woodland	DMR	4/15/2005	2.2	0.404	
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/9/2002	12.5	0.150	0.100
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/16/2002	67.4	0.130	0.020
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/21/2002	37.5	0.080	0.010
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/28/2002	8.1	0.210	0.110
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/6/2002	0.2	0.450	0.290
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/13/2002	0.1	0.390	0.280
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/20/2002	0.1	0.340	0.240
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/27/2002	0.2	0.370	0.270
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/5/2002	8.3	0.100	0.050

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/12/2002	8.7	0.060	0.020
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/21/2002	58.9	0.040	0.030
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/26/2002	29.2	0.080	0.050
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/13/2003	7.1	0.090	0.050
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/28/2003	2.6	0.190	0.120
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/18/2003	15.1	0.060	0.030
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	2/12/2004	57.8	0.060	0.010
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/4/2004	15.1	0.110	0.060
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/4/2004	16.1	0.340	0.190
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/9/2004	12.4	0.070	0.040
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	2/9/2005	10.8	0.030	0.020
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	5/10/2005	1.0	0.070	0.020
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	8/18/2005	0.3	0.350	0.100
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	11/14/2005	4.0	0.090	0.050
Swamp	Black Brook Downstream Trib	C_BB2	Omni - Chatham	1/4/2006	76.8	0.110	0.010
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	6/10/2003		0.100	0.060
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	7/14/2003		0.210	0.140
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	7/15/2003		0.230	0.140
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	8/5/2003		0.250	0.170
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	8/6/2003		0.100	0.100
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	8/25/2003		0.240	0.130
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	8/26/2003		0.230	0.130
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	11/3/2003		0.120	0.070
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	11/4/2003		0.140	0.080
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	11/17/2003		0.050	0.030
Swamp	Black Brook Mainstem	BB1	Omni - Phase I	11/18/2003		0.070	0.030
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	5/9/2002	2.3	0.420	0.180
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	5/16/2002	7.2	0.200	0.090
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	5/21/2002	4.7	0.230	0.040
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	5/28/2002	1.6	0.480	0.230
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	8/6/2002	0.6	0.640	0.550
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	8/13/2002	0.6	0.540	0.460
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	8/20/2002	1.2	0.430	0.330

Data Used for Great Swamp Analysis

Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	8/27/2002	0.5	0.460	0.410
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	11/5/2002	1.6	0.150	0.070
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	11/12/2002	3.0	0.120	0.080
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	11/21/2002	6.0	0.050	0.030
Swamp	Black Brook Tributary	C_T1	Omni - Chatham	11/26/2002	4.4	0.040	0.040
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	5/9/2002		0.090	0.030
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	5/16/2002		0.060	0.010
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	5/21/2002		0.060	0.010
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	5/28/2002		0.130	0.030
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	8/6/2002		0.720	0.440
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	8/13/2002		2.400	0.770
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	11/5/2002		0.070	0.010
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	11/12/2002		0.050	0.010
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	11/21/2002		0.030	0.010
Swamp	Black Brook Upstream Trib	C_BB1	Omni - Chatham	11/26/2002		0.060	0.020
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	6/9/2003		0.130	0.080
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	6/10/2003		0.130	0.090
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	7/14/2003		0.100	0.040
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	7/15/2003		0.120	0.050
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	8/5/2003		0.200	0.070
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	8/6/2003		0.220	0.090
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	8/25/2003		0.210	0.080
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	8/26/2003		0.200	0.070
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	11/3/2003		0.130	0.050
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	11/4/2003		0.130	0.060
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	11/17/2003		0.100	0.020
Swamp	Great Brook Mainstem	GB1	Omni - Phase I	11/18/2003		0.090	0.020
Upstream	Loantaka Brook (Downstream STP 1)	LB4	GSWA	2/7/2005		0.290	0.208
Upstream	Loantaka Brook (Downstream STP 1)	LB4	GSWA	5/9/2005		0.250	0.200
Upstream	Loantaka Brook (Downstream STP 1)	LB4	GSWA	8/9/2005		1.200	1.100
Upstream	Loantaka Brook (Downstream STP 1)	LB4	GSWA	11/6/2005		0.210	0.134
Upstream	Loantaka Brook (Downstream STP 3)	LB2	GSWA	2/7/2005		0.180	0.085
Upstream	Loantaka Brook (Downstream STP 3)	LB2	GSWA	5/9/2005		0.240	0.160

Data Used for Great Swamp Analysis

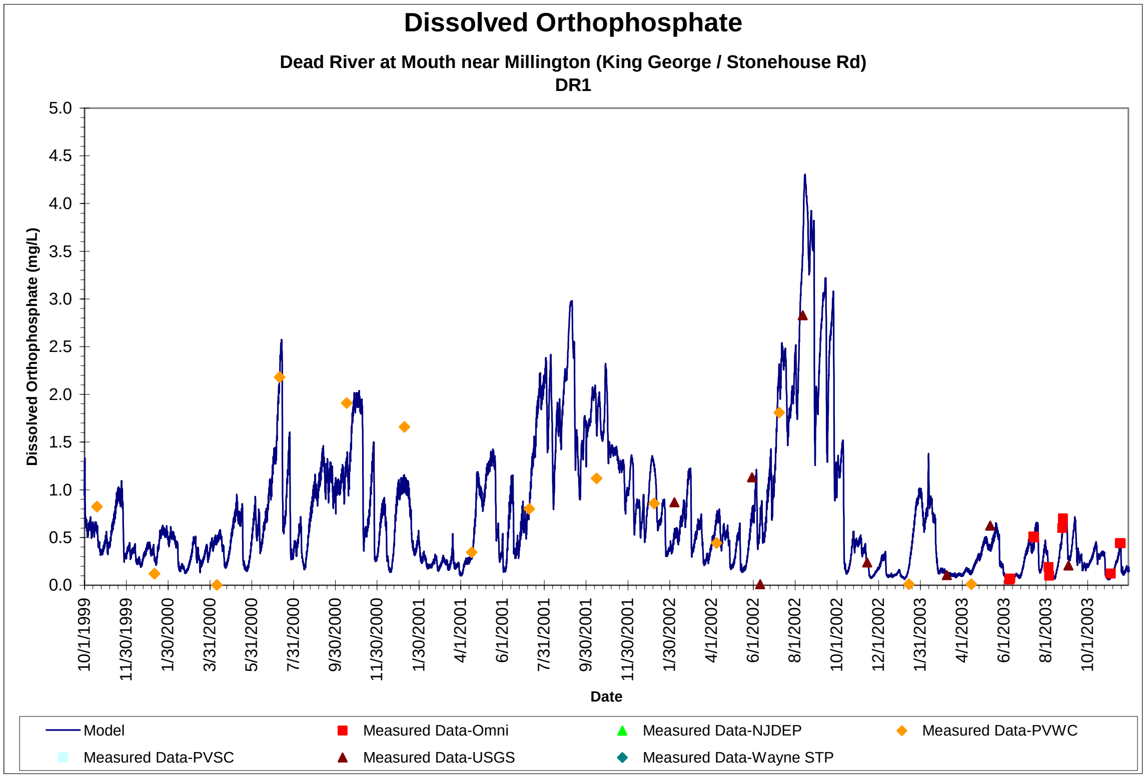
Station Type	Location	Site ID	Source	Date	Flow (cfs)	TP (mg/l)	DRP (mg/l)
Upstream	Loantaka Brook (Downstream STP 3)	LB2	GSWA	8/9/2005		0.280	0.200
Upstream	Loantaka Brook (Downstream STP 3)	LB2	GSWA	11/6/2005		0.130	0.090
Upstream	Loantaka Brook (Upstream STP 2)	LB6	GSWA	2/7/2005		0.060	0.003
Upstream	Loantaka Brook (Upstream STP 2)	LB6	GSWA	5/9/2005		0.060	0.003
Upstream	Loantaka Brook (Upstream STP 2)	LB6	GSWA	8/9/2005		0.380	0.006
Upstream	Loantaka Brook (Upstream STP 2)	LB6	GSWA	11/6/2005		0.190	0.002
Upstream	Loantaka Brook Upstream STP 1)	LB5	GSWA	2/7/2005		0.030	0.004
Upstream	Loantaka Brook Upstream STP 1)	LB5	GSWA	5/9/2005		0.010	0.003
Upstream	Loantaka Brook Upstream STP 1)	LB5	GSWA	8/9/2005		0.030	0.015
Upstream	Loantaka Brook Upstream STP 1)	LB5	GSWA	11/6/2005		0.010	0.008
Upstream	Passaic River Upstream	PA1	Omni - Phase I	6/9/2003		0.060	0.020
Upstream	Passaic River Upstream	PA1	Omni - Phase I	6/10/2003		0.060	0.020
Upstream	Passaic River Upstream	PA1	Omni - Phase I	7/14/2003		0.020	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	7/15/2003		0.050	0.050
Upstream	Passaic River Upstream	PA1	Omni - Phase I	8/5/2003		0.030	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	8/6/2003		0.120	0.020
Upstream	Passaic River Upstream	PA1	Omni - Phase I	8/25/2003		0.050	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	8/26/2003		0.090	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	11/3/2003		0.120	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	11/4/2003		0.080	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	11/17/2003		0.030	0.010
Upstream	Passaic River Upstream	PA1	Omni - Phase I	11/18/2003		0.030	0.010

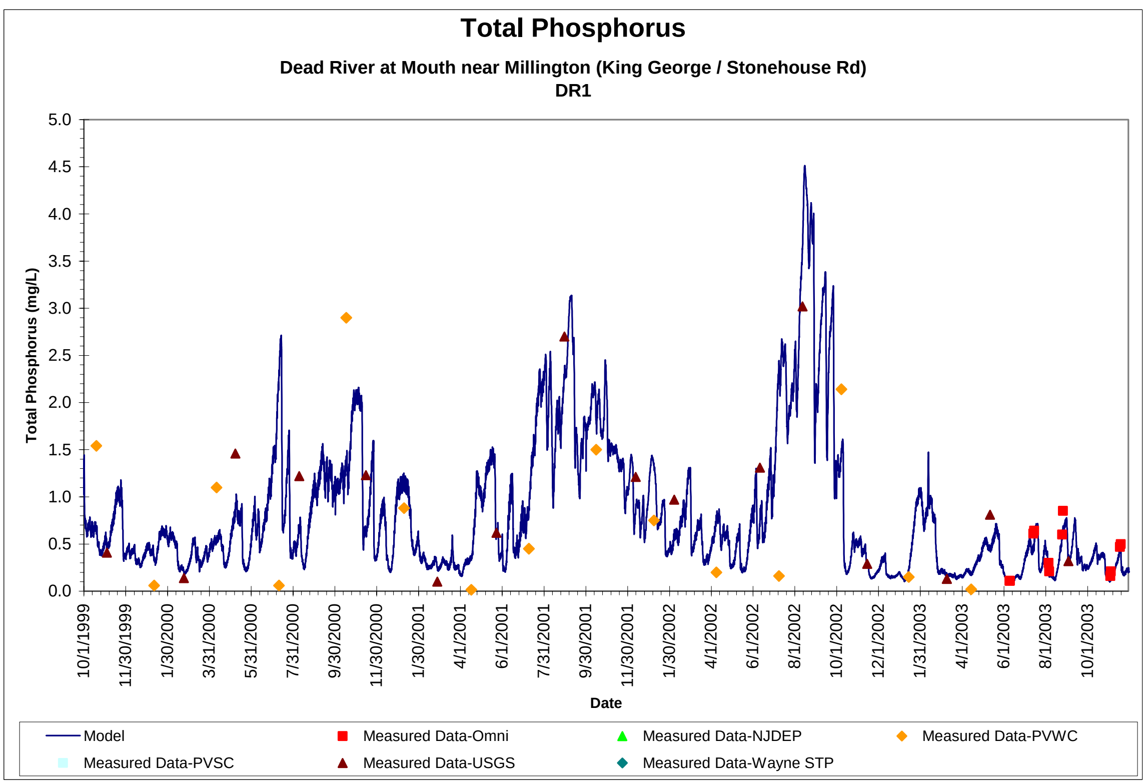
APPENDIX E

Grab Chemistry
Calibration and Validation Results

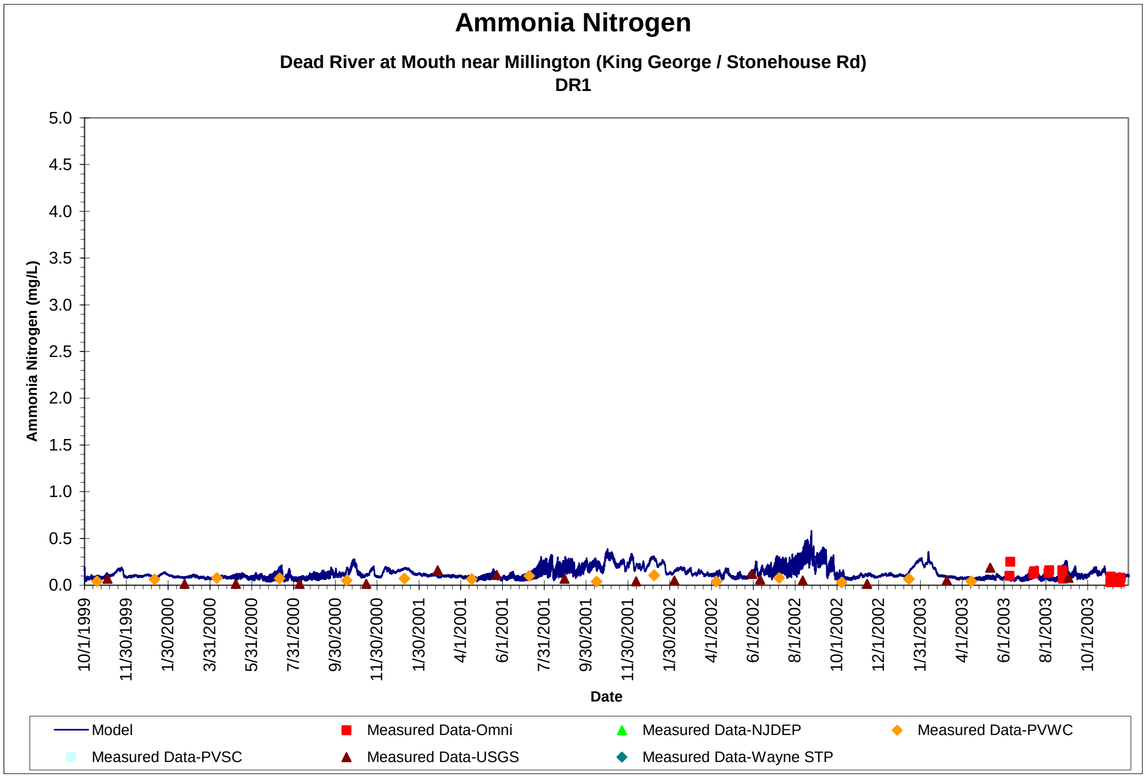
[Please note that the accuracy of grab samples collected by others is suspect in several instances. Therefore, greater emphasis should be placed on the red squares (data collected for this study) than other symbols that represent data sources not QA/QC'd by Omni. Much of the PVWC data is particularly questionable.

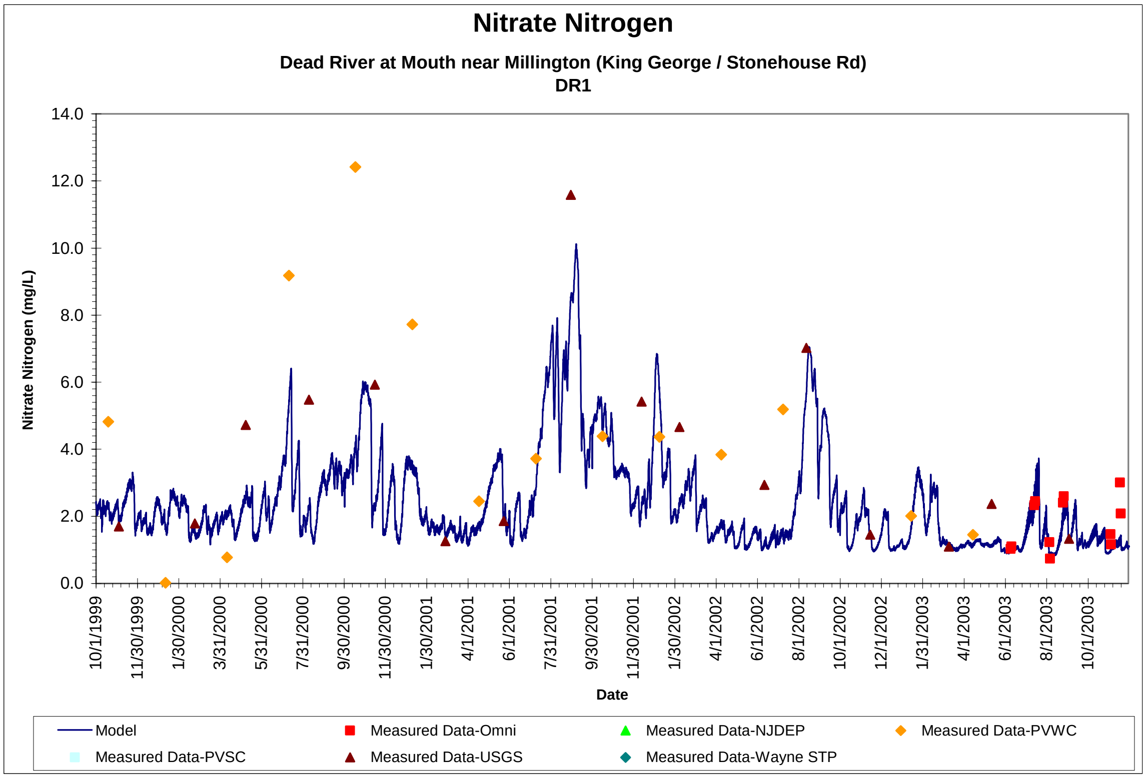
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



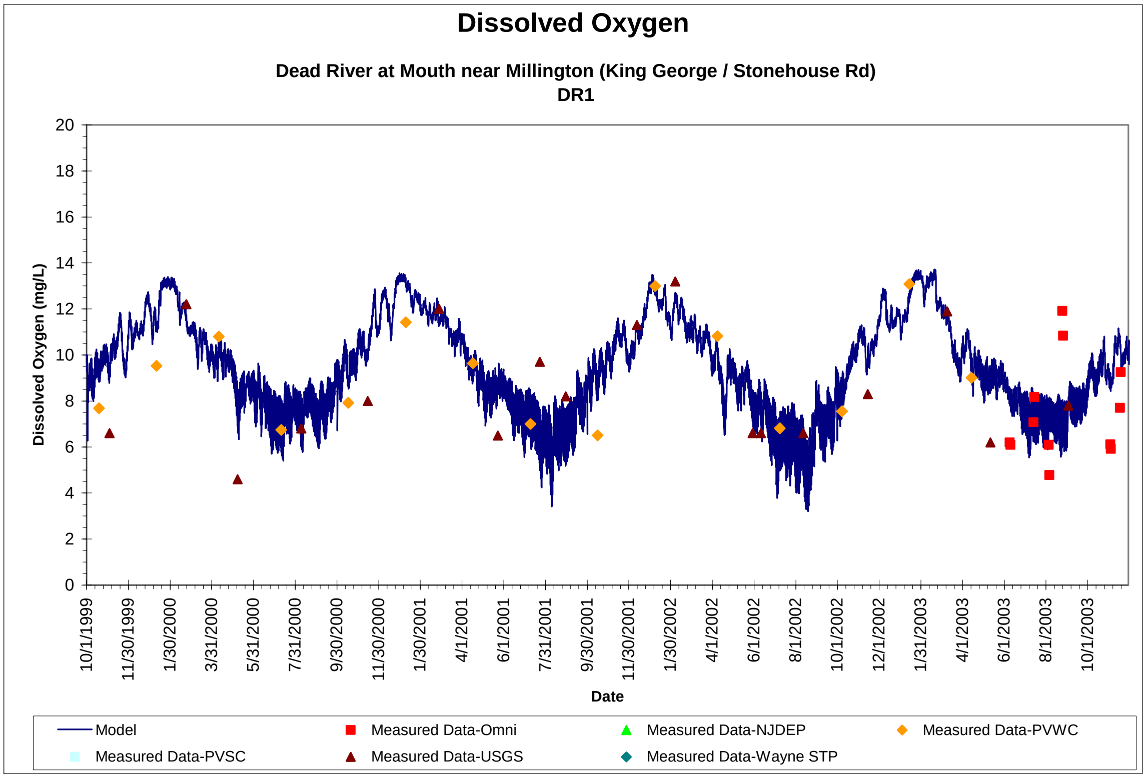


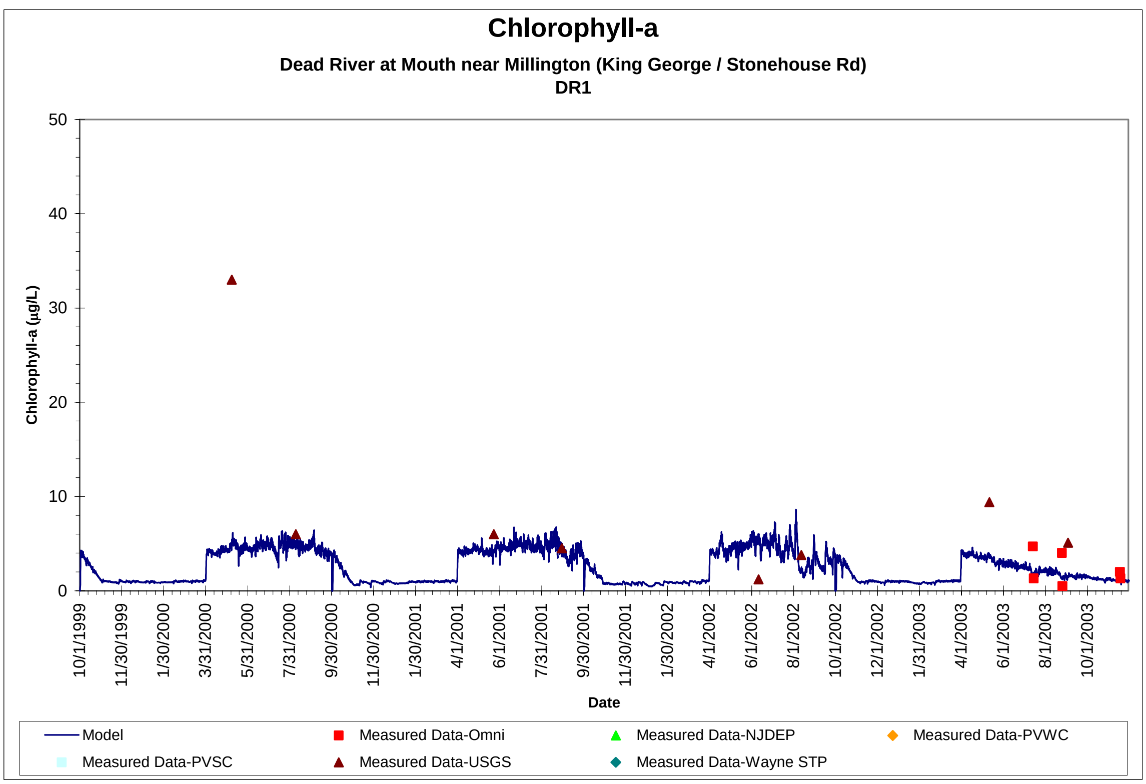
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



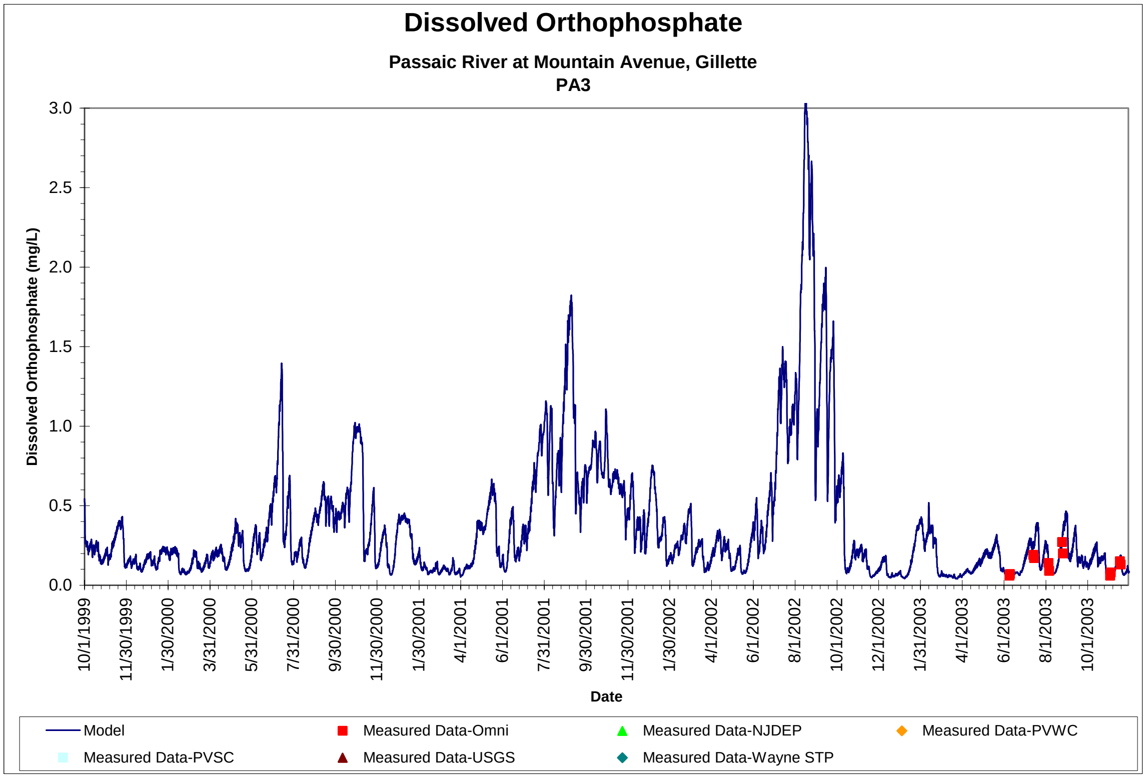


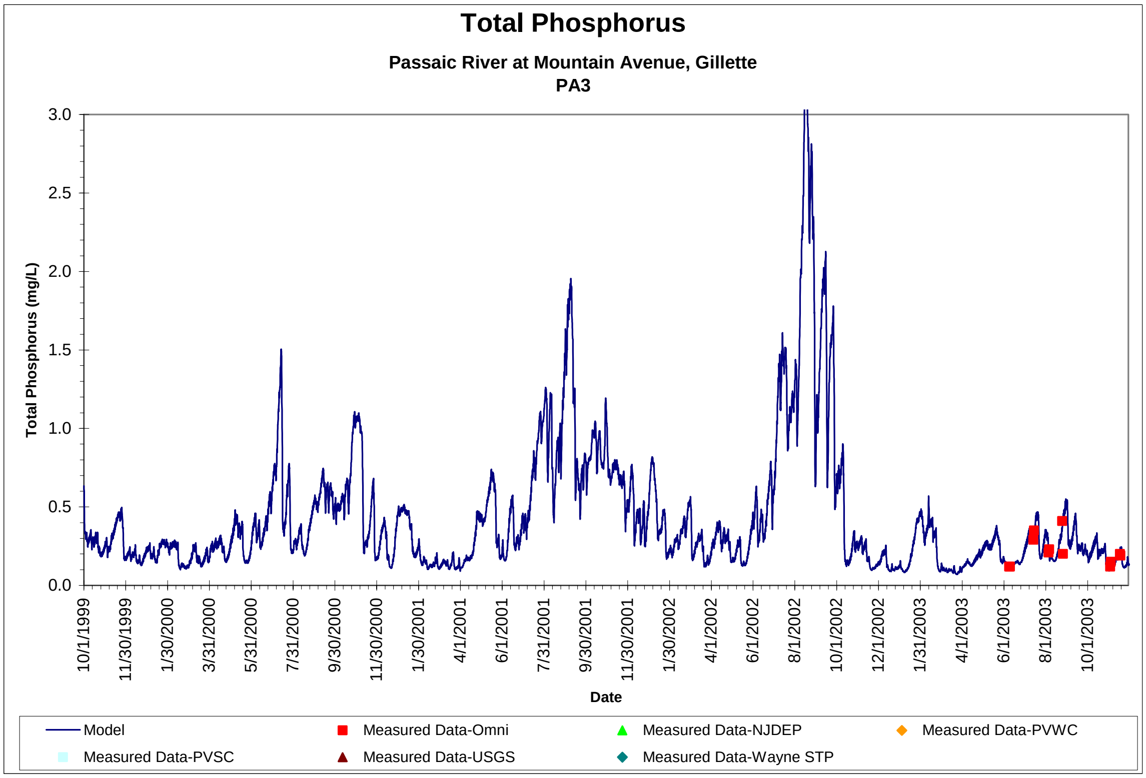
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



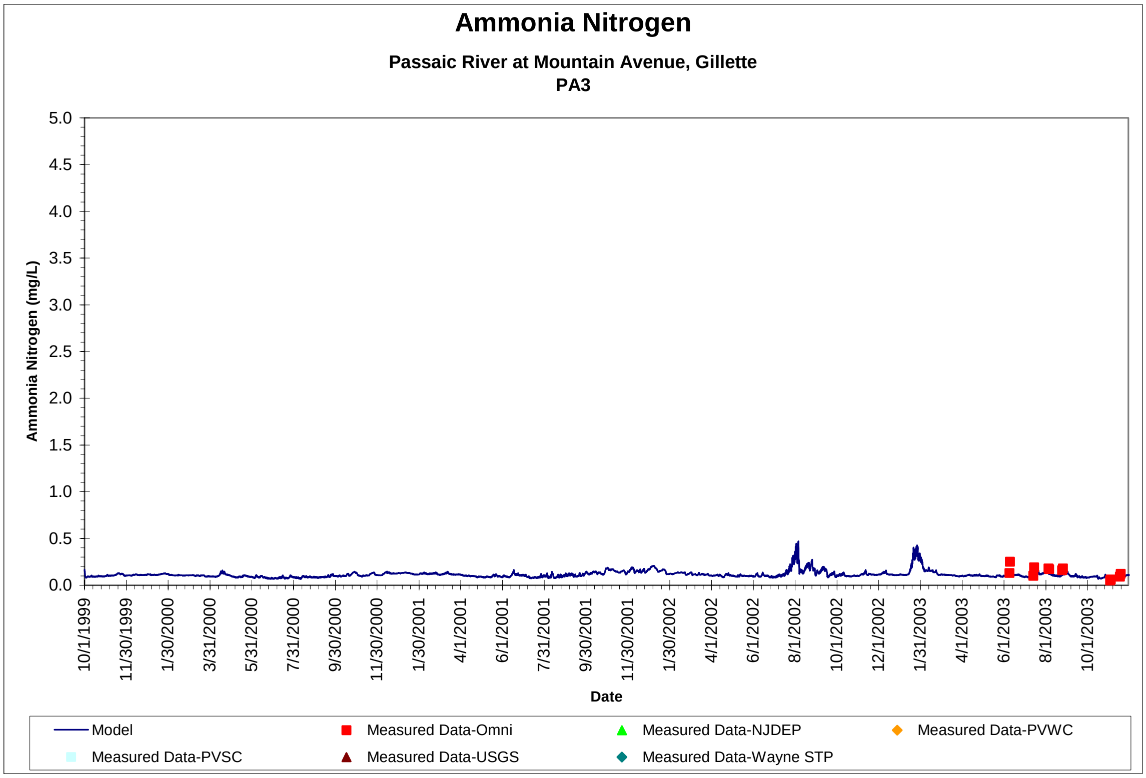


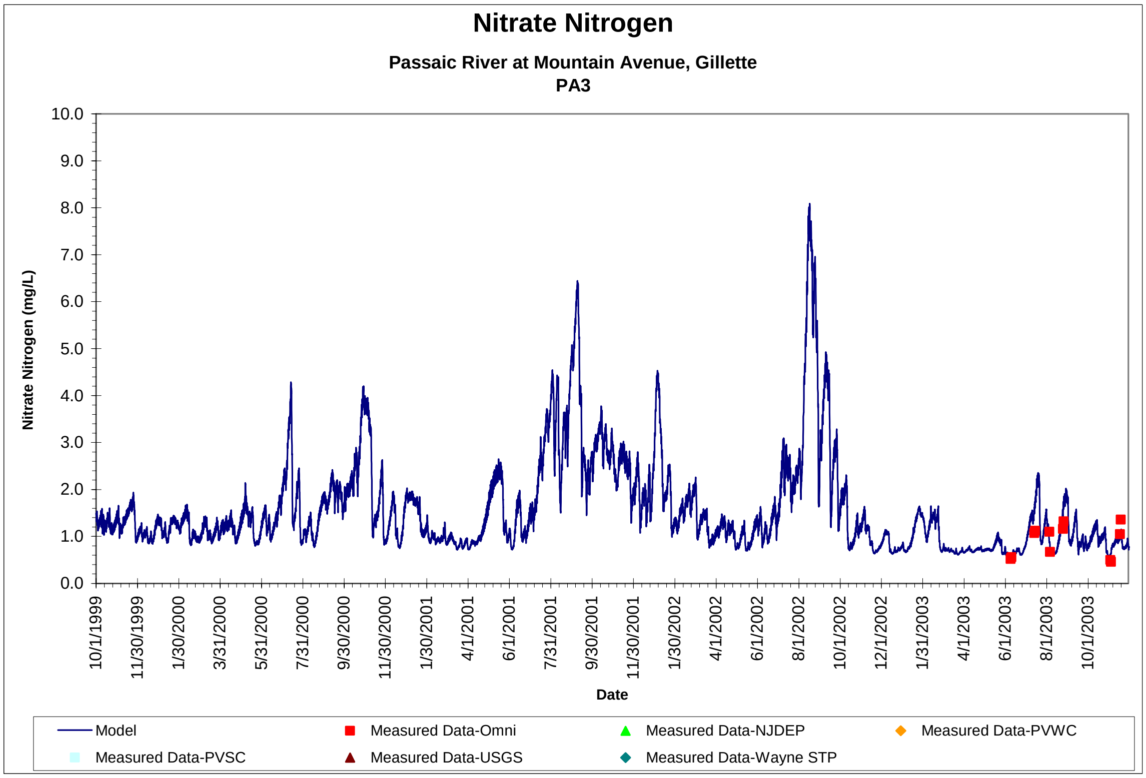
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



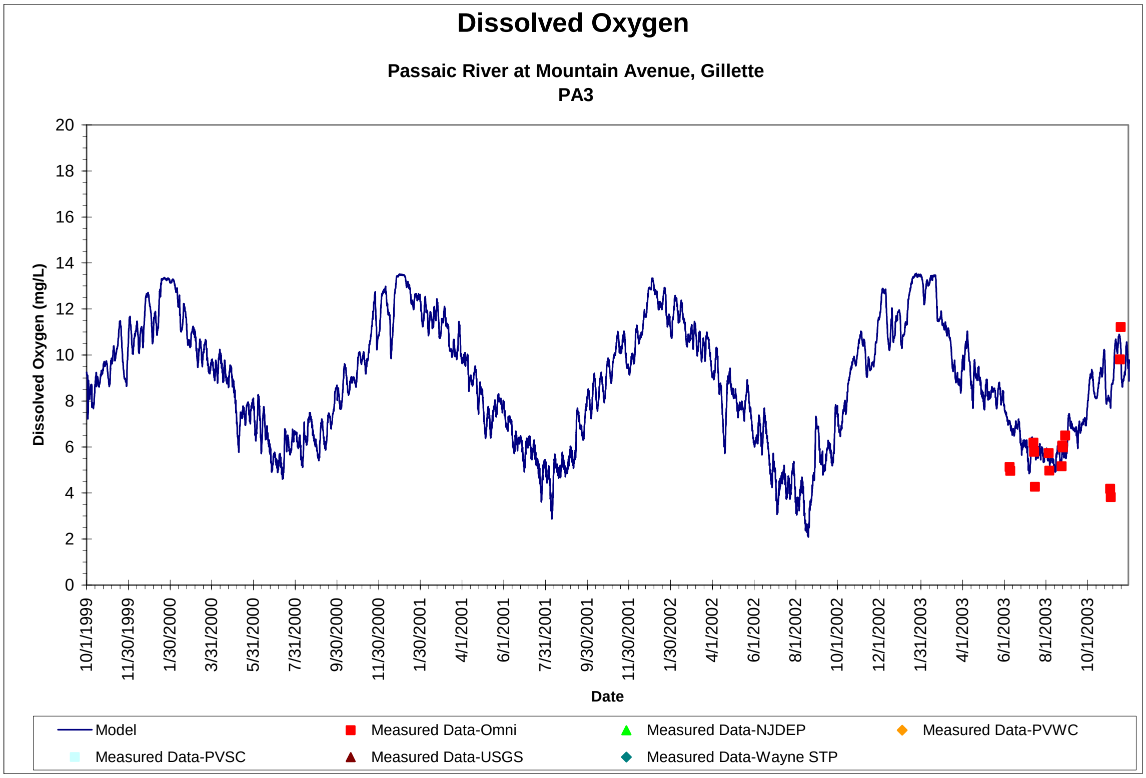


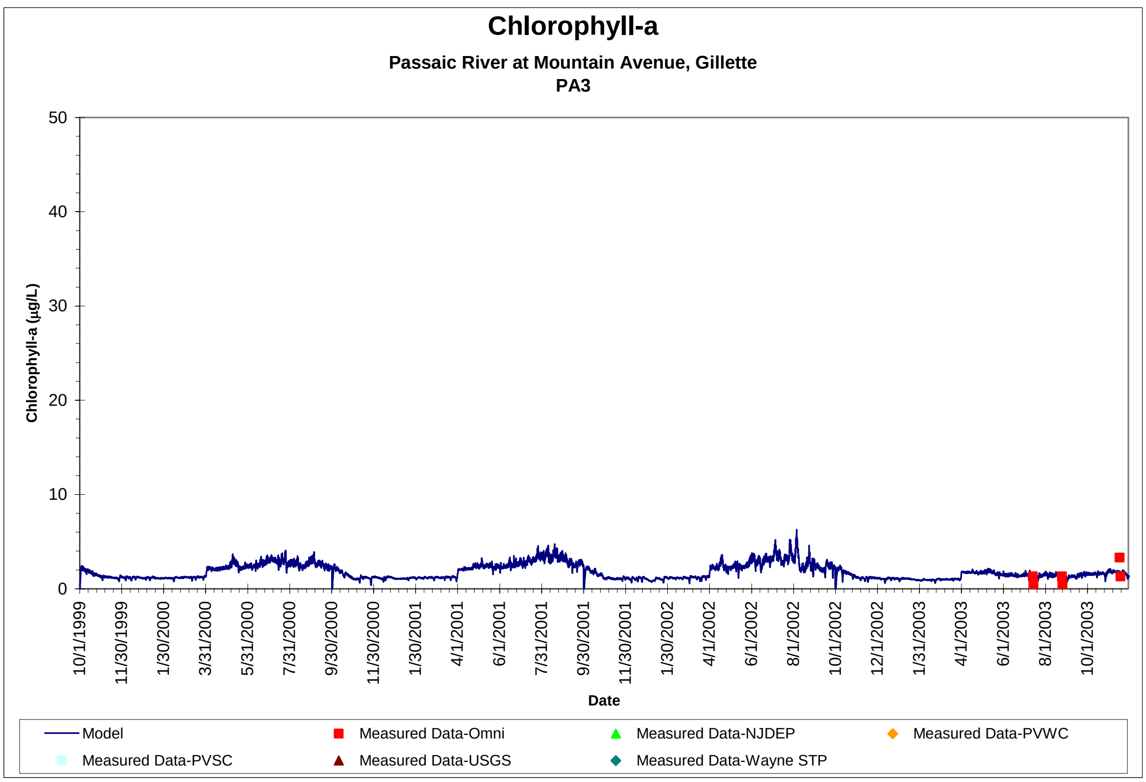
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



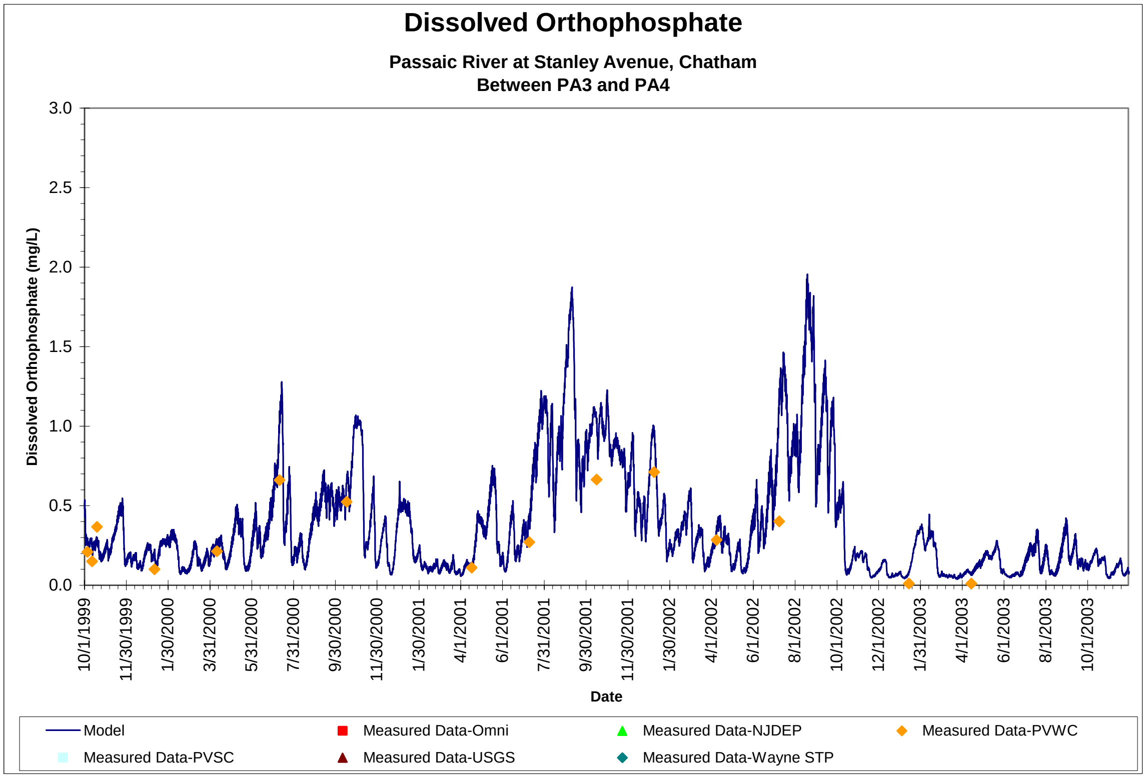


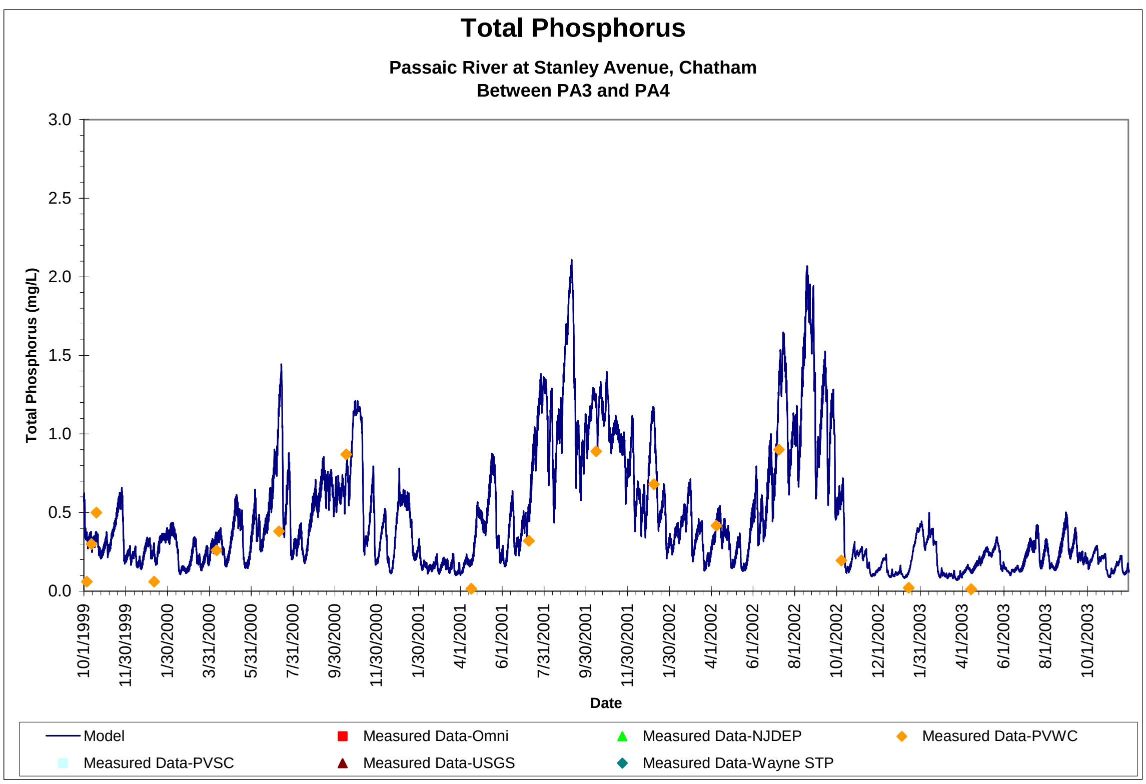
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



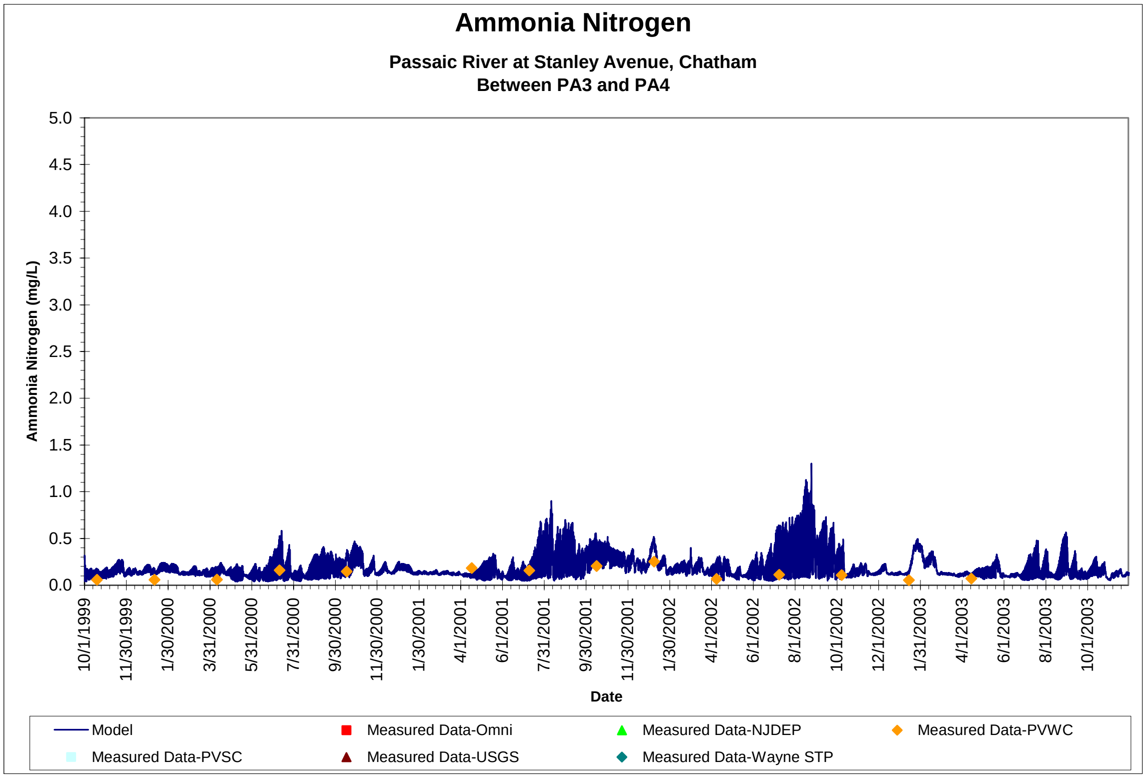


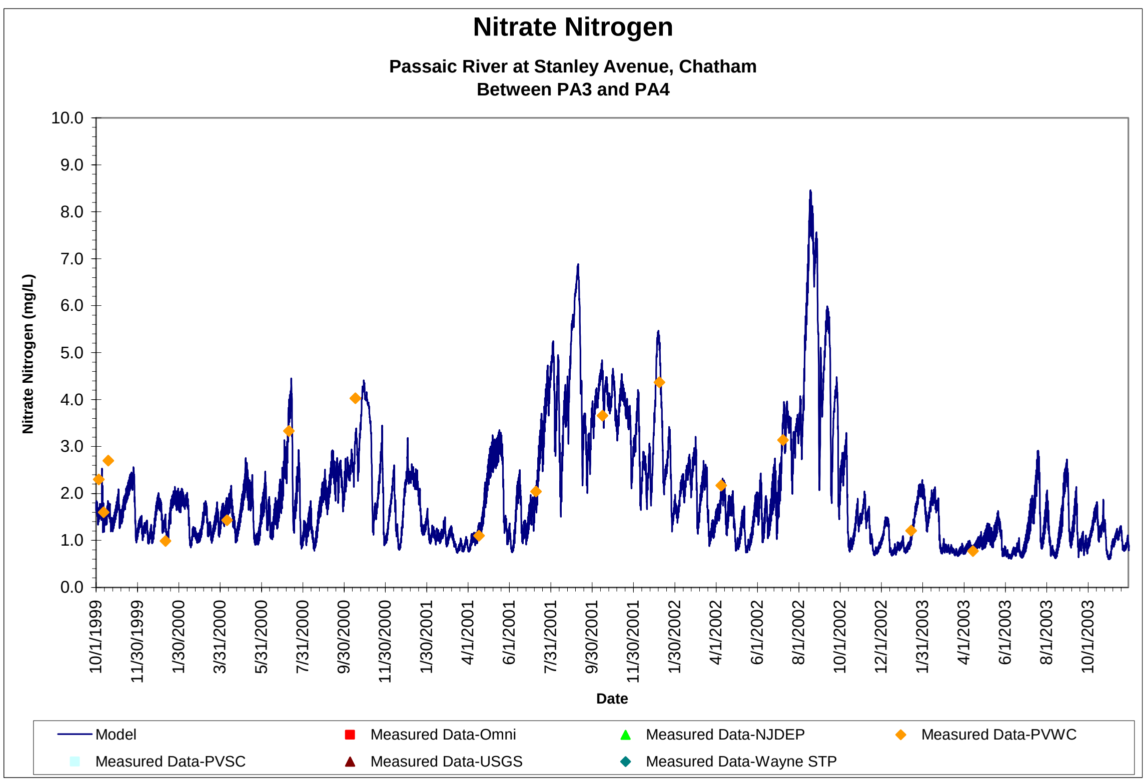
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



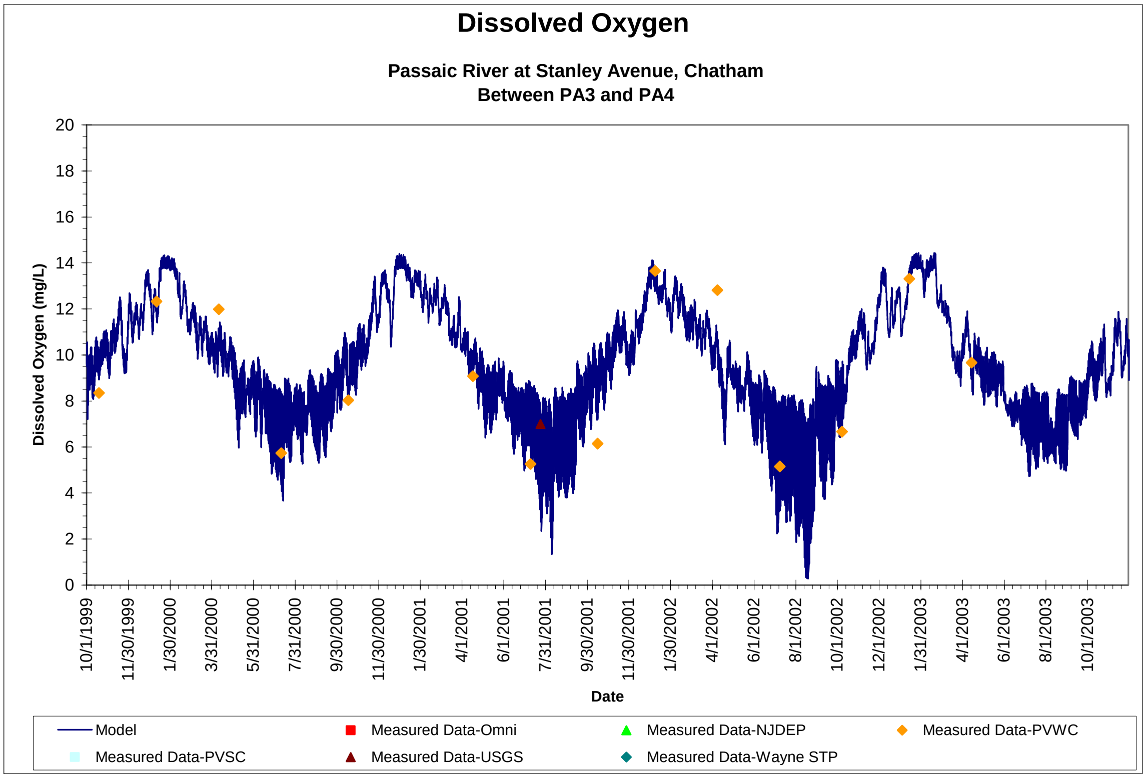


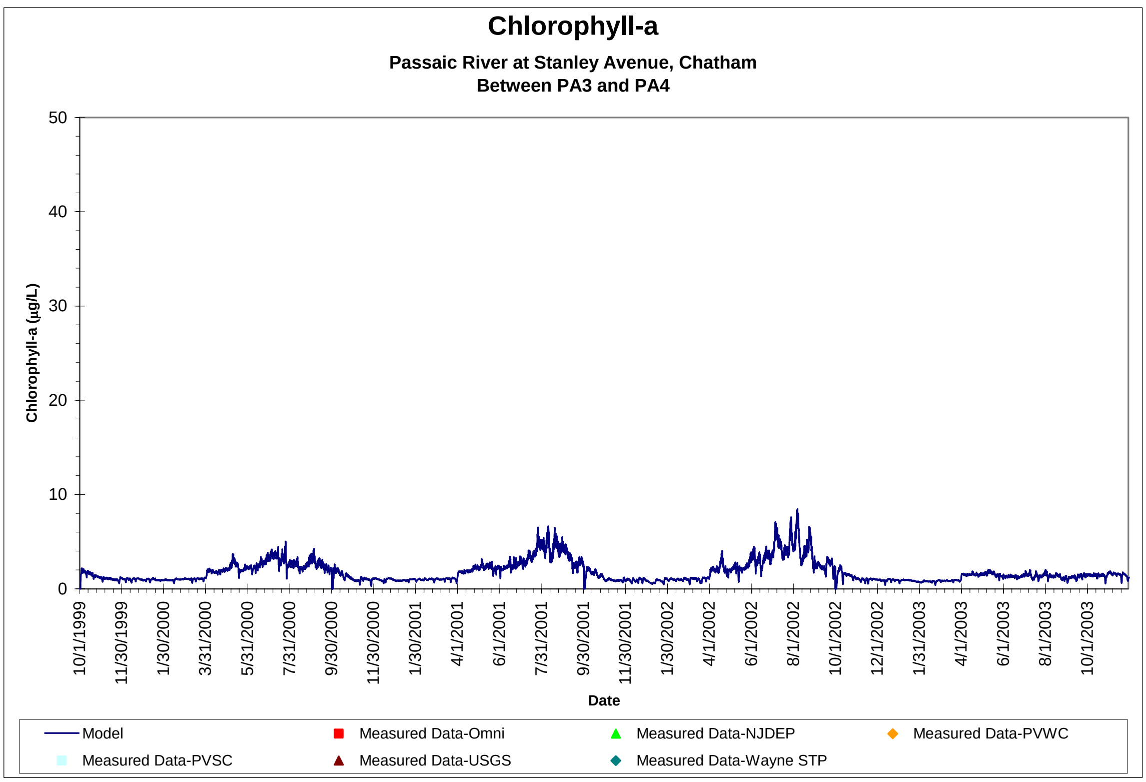
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



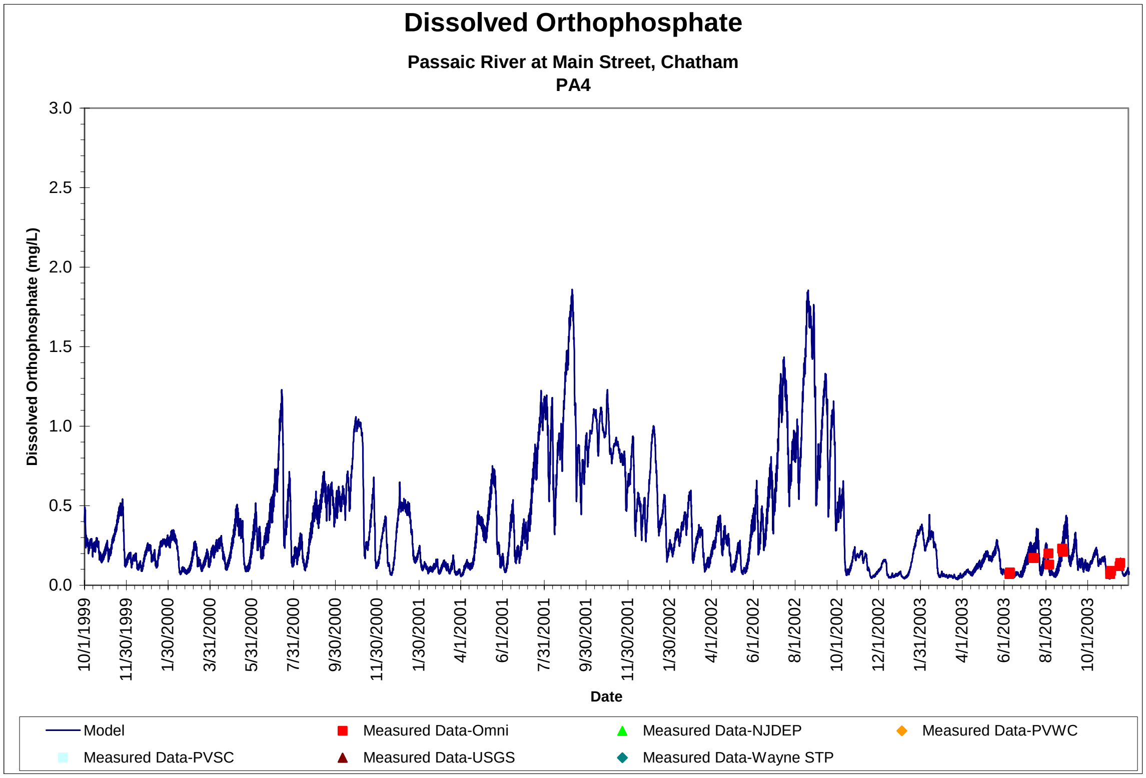


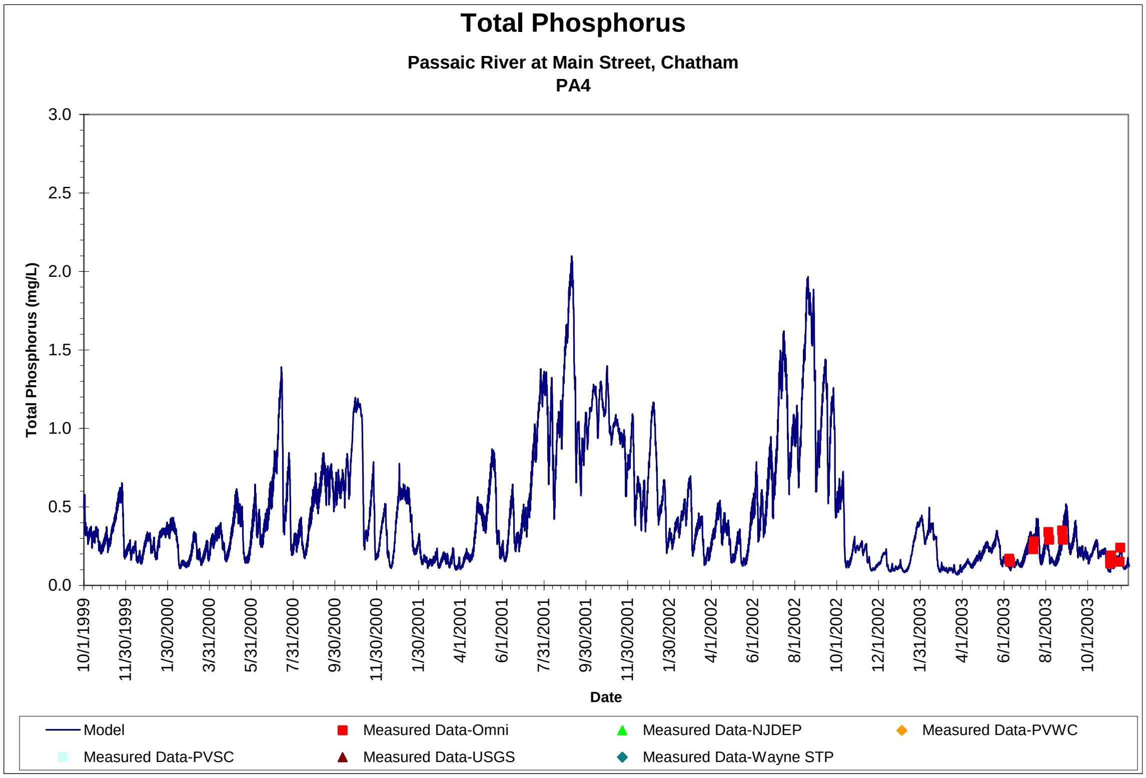
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



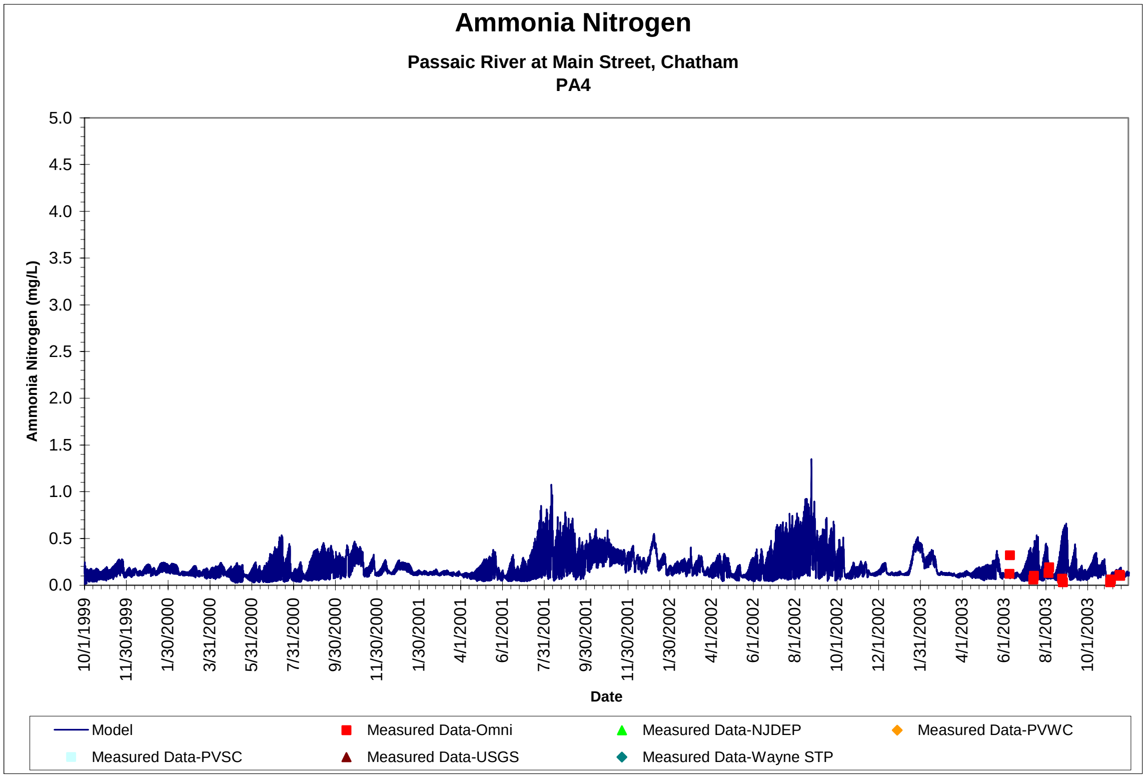


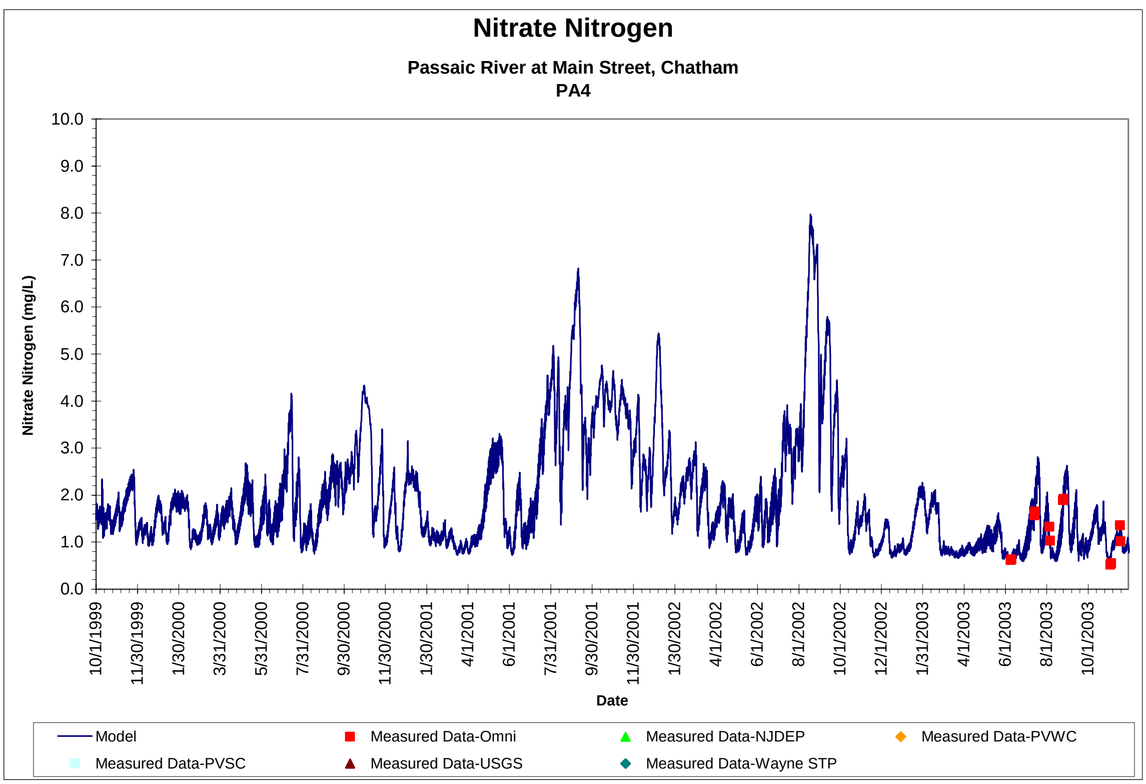
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



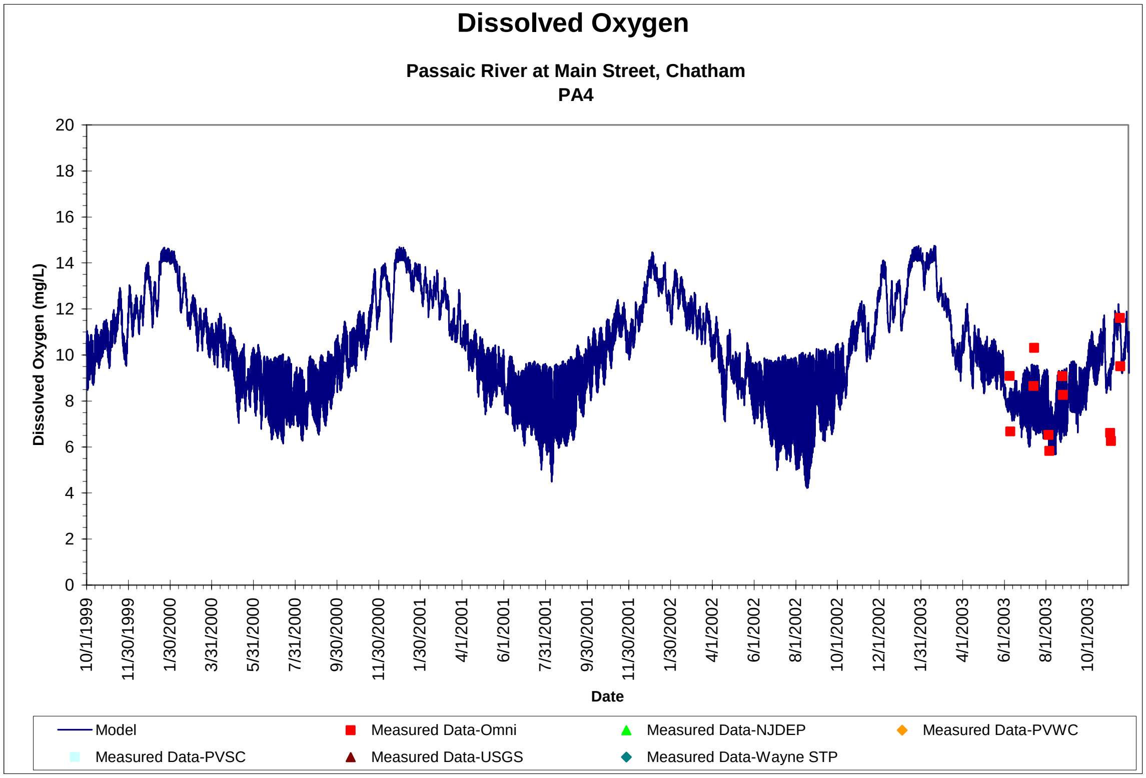


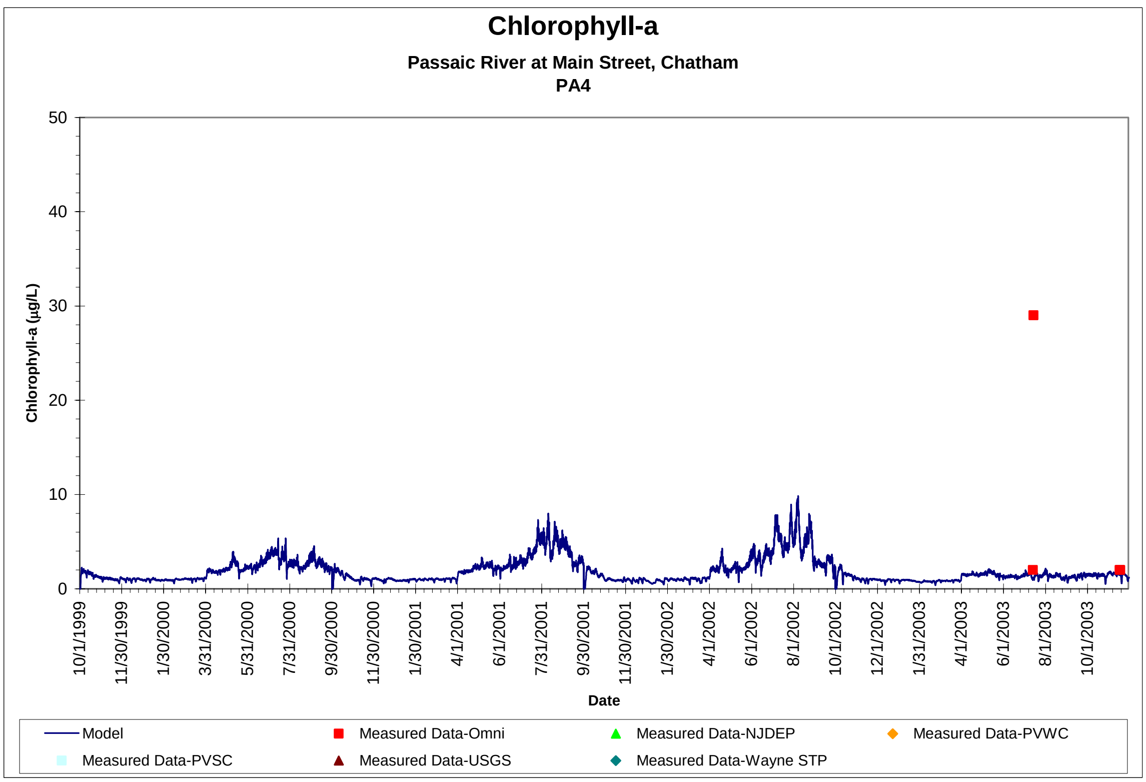
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



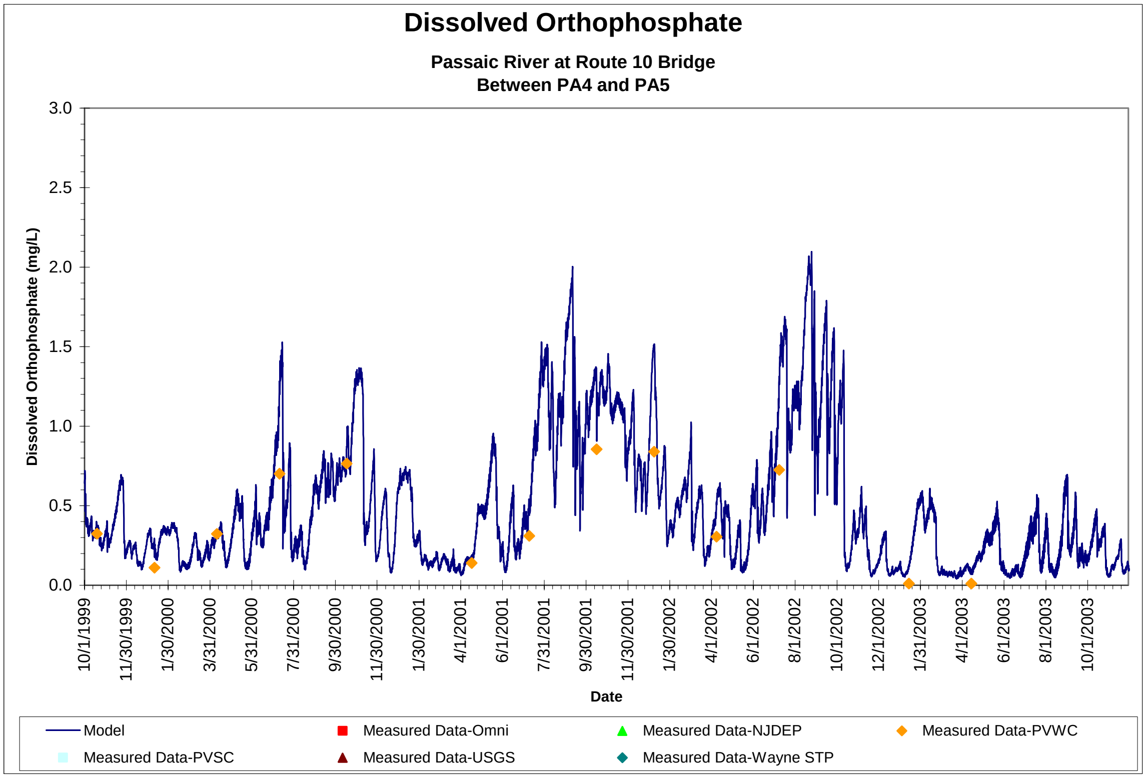


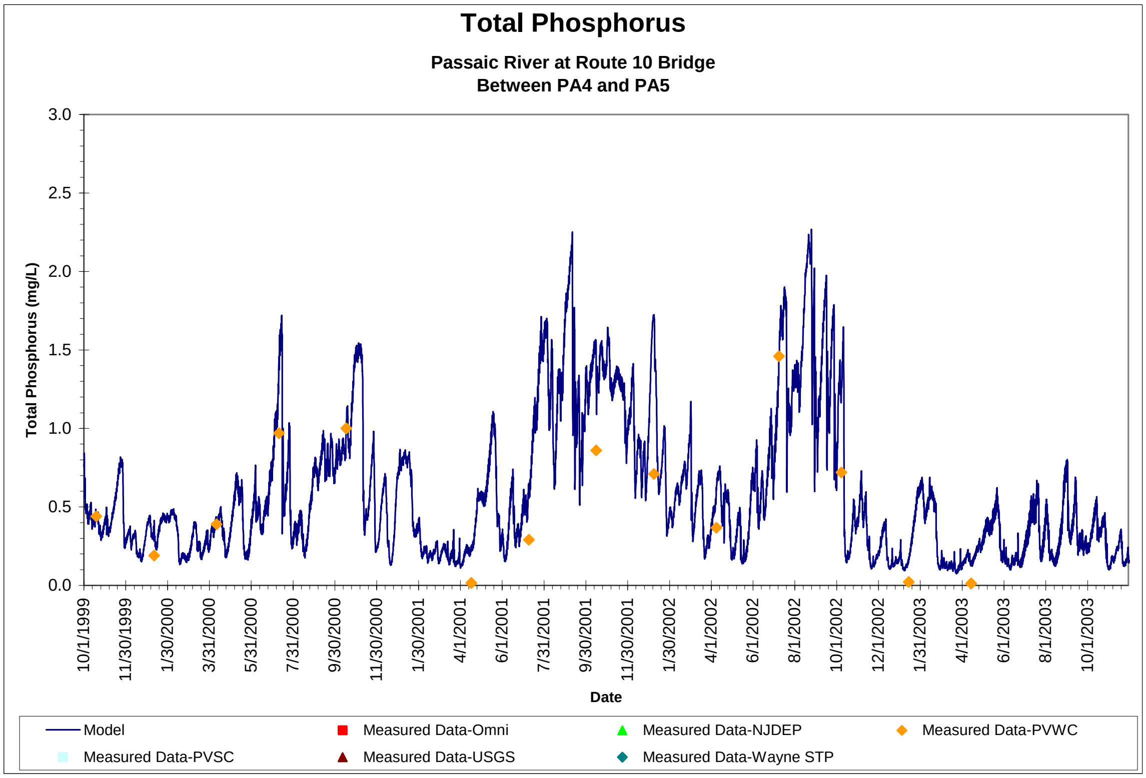
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



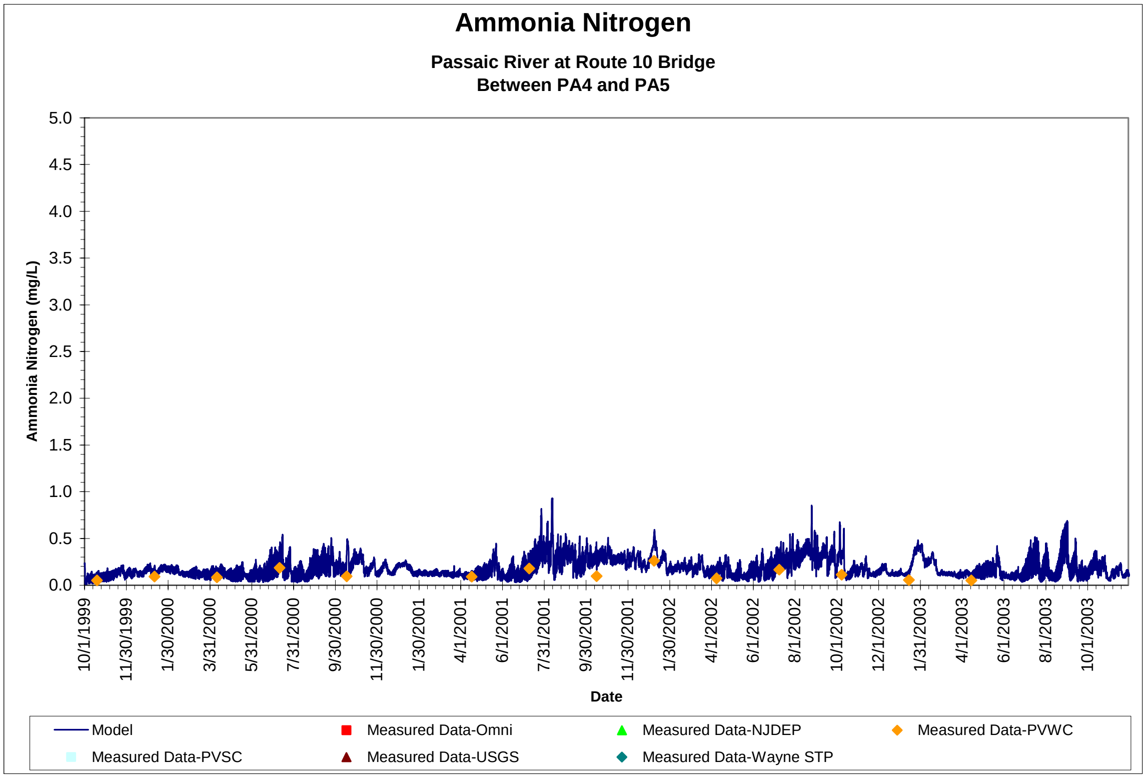


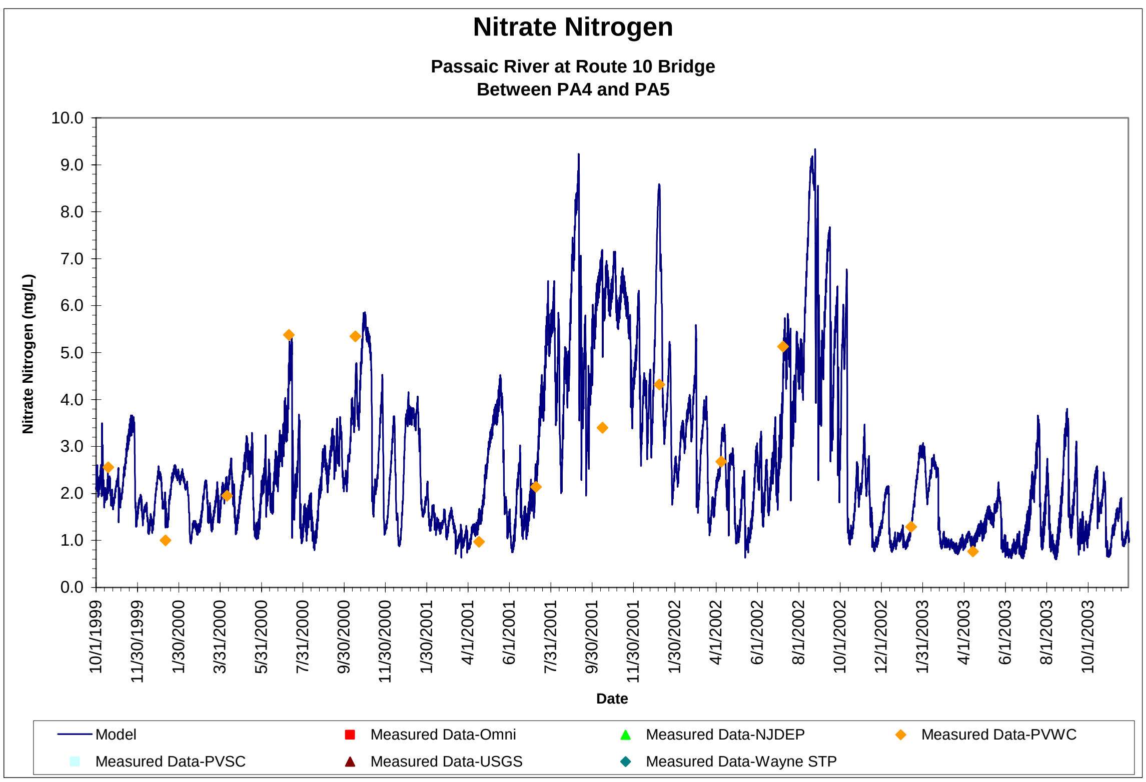
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



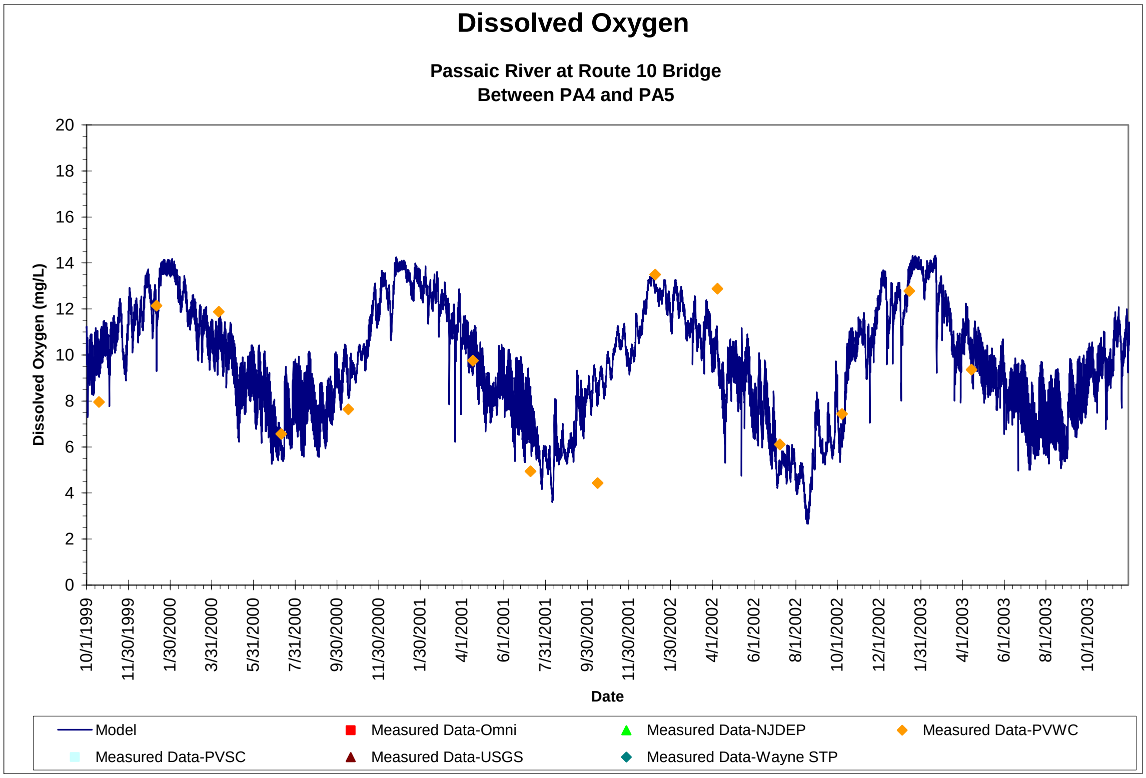


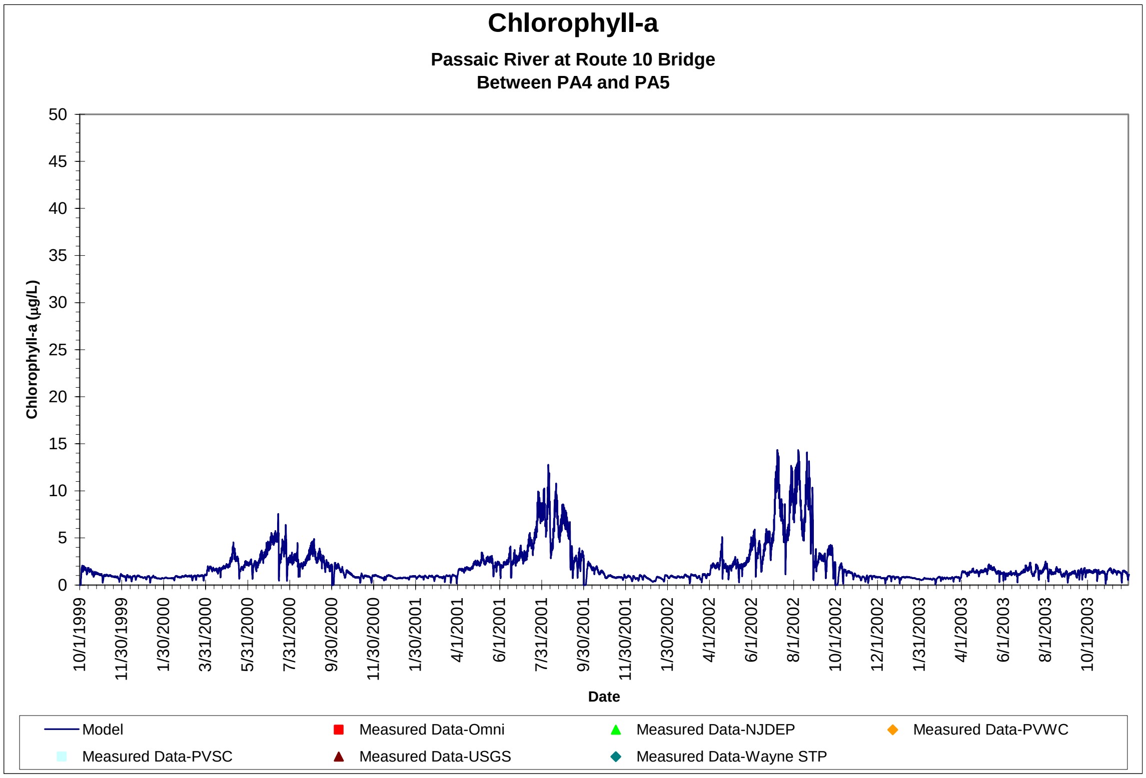
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



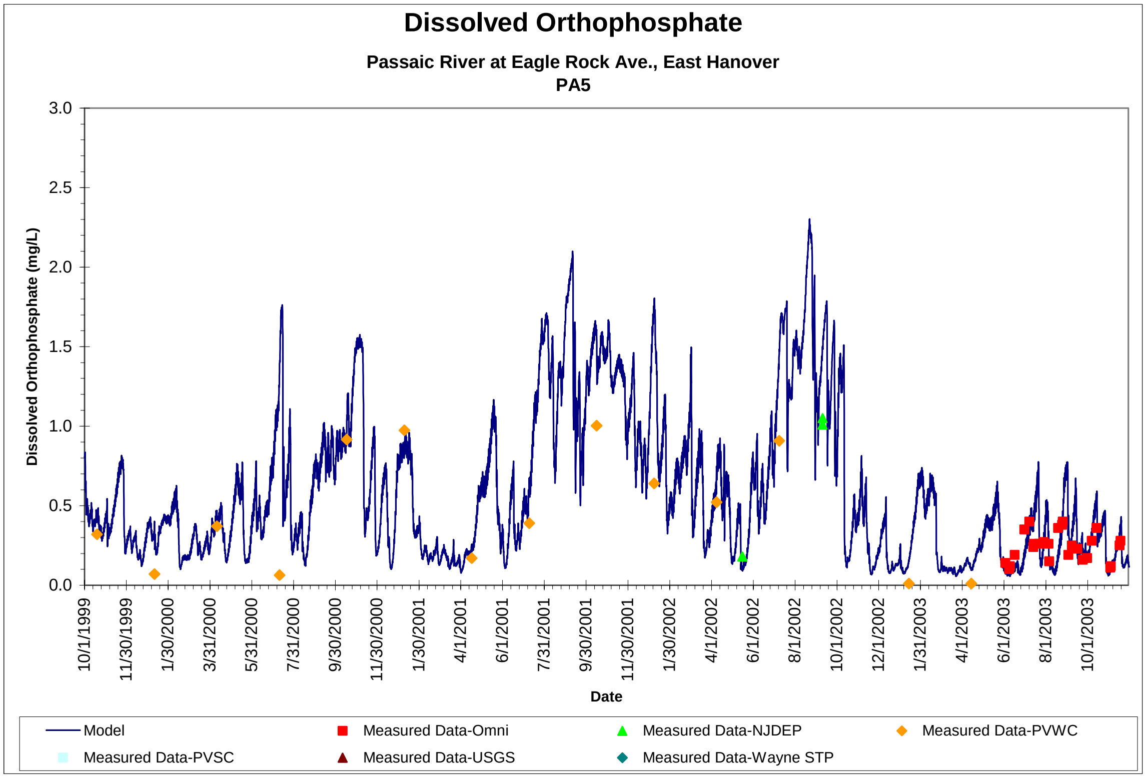


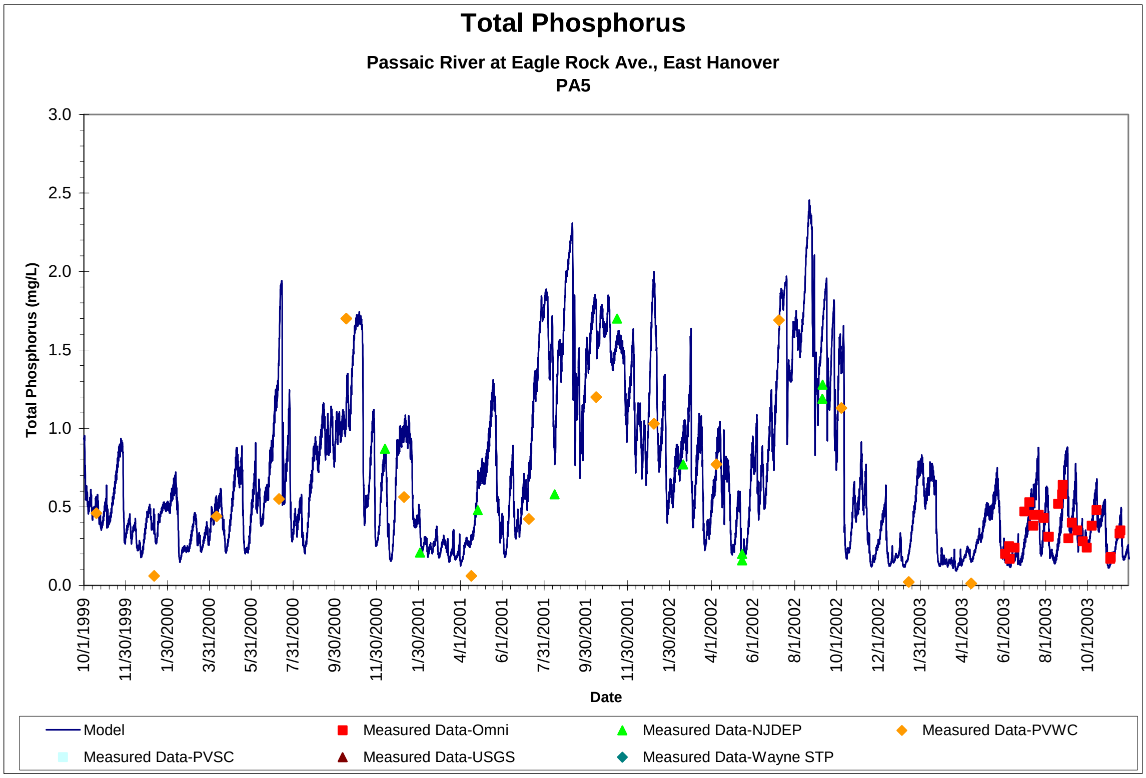
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



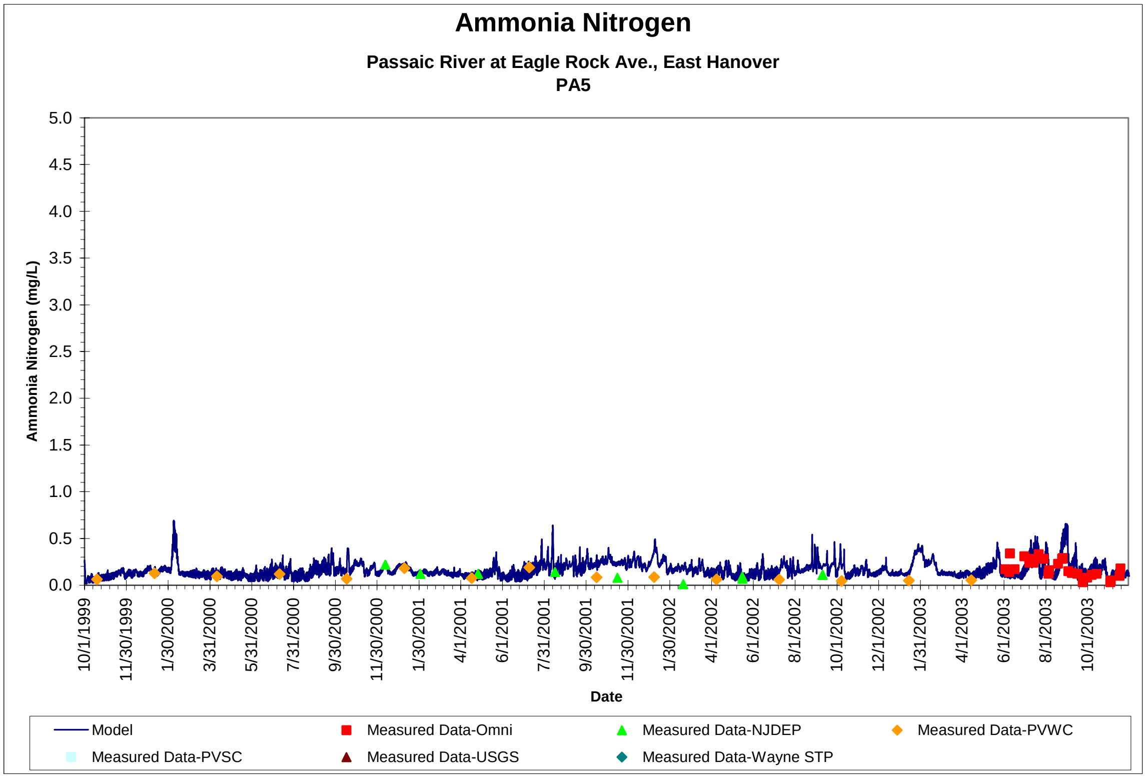


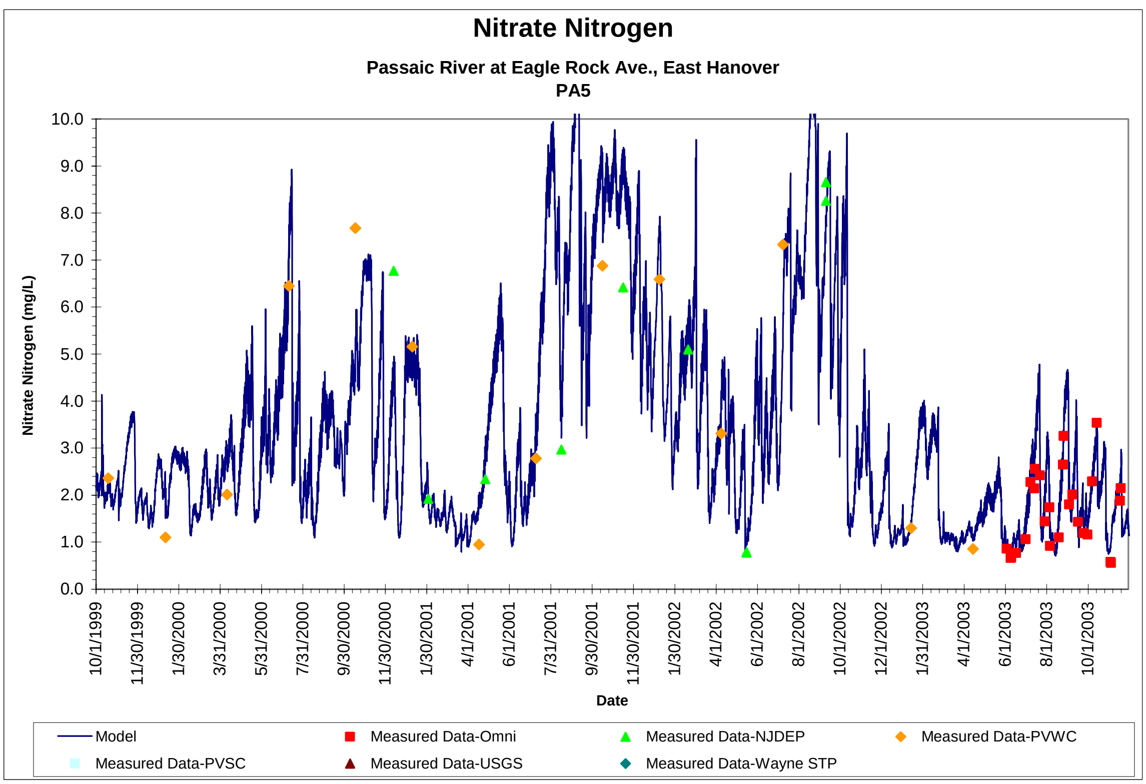
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



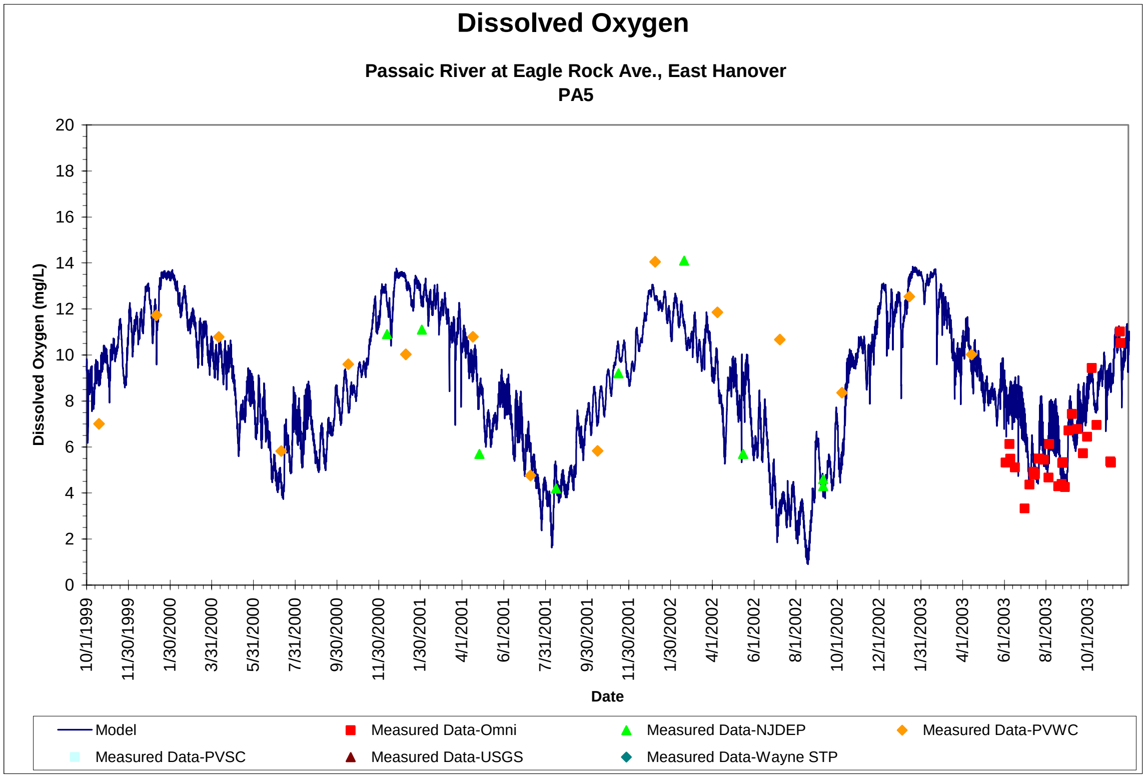


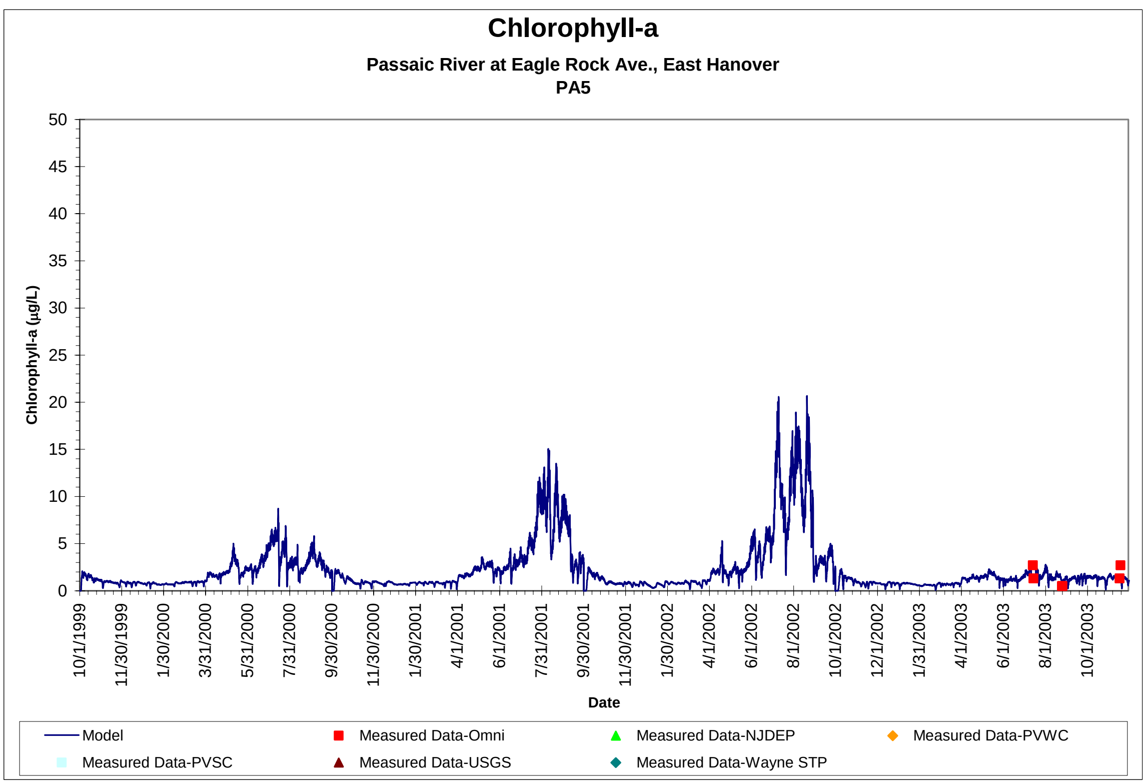
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



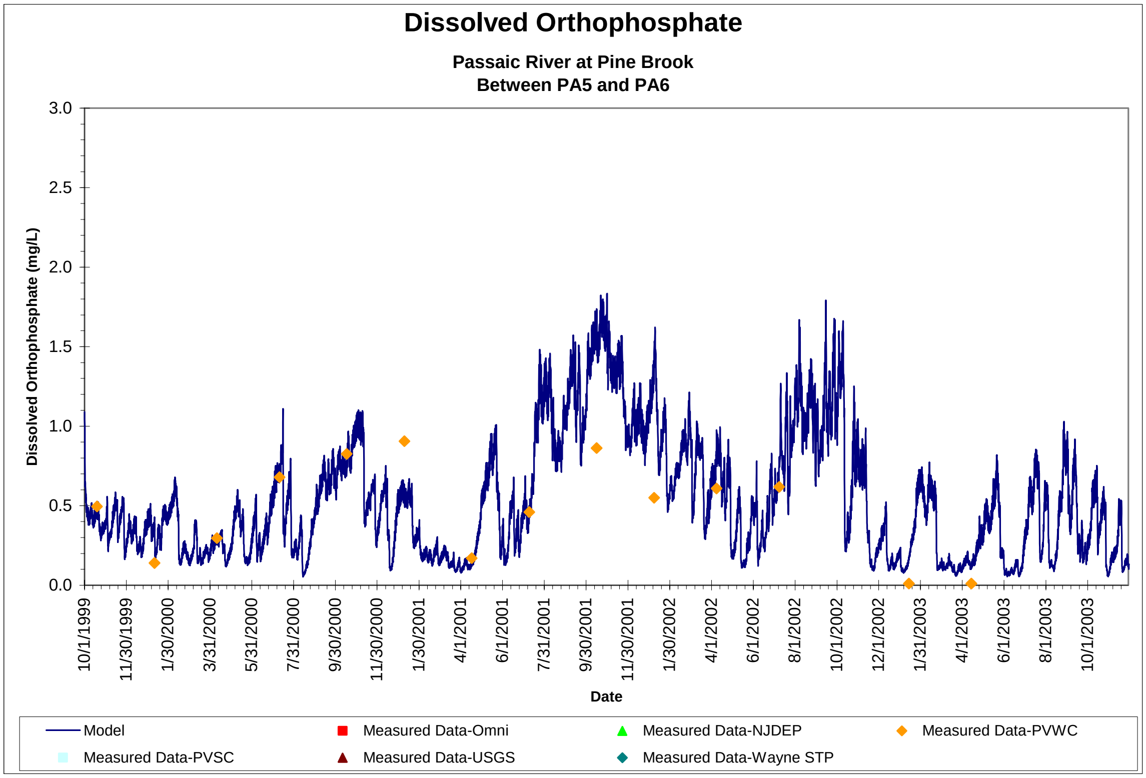


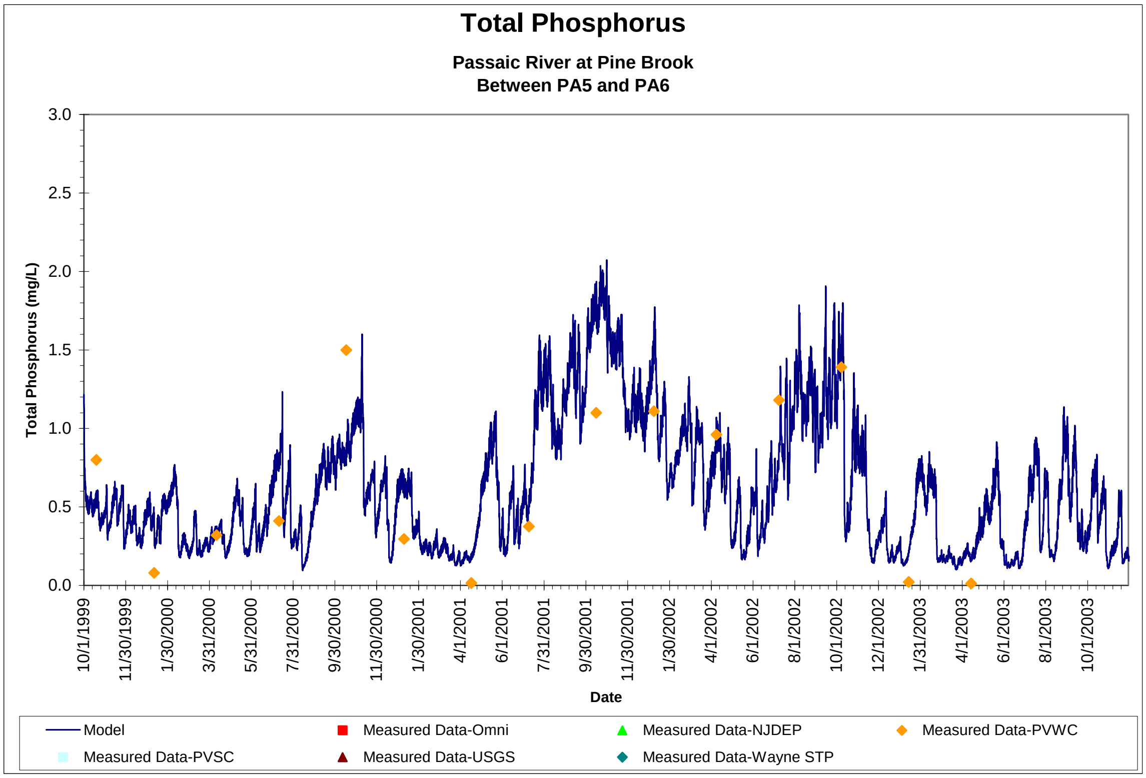
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



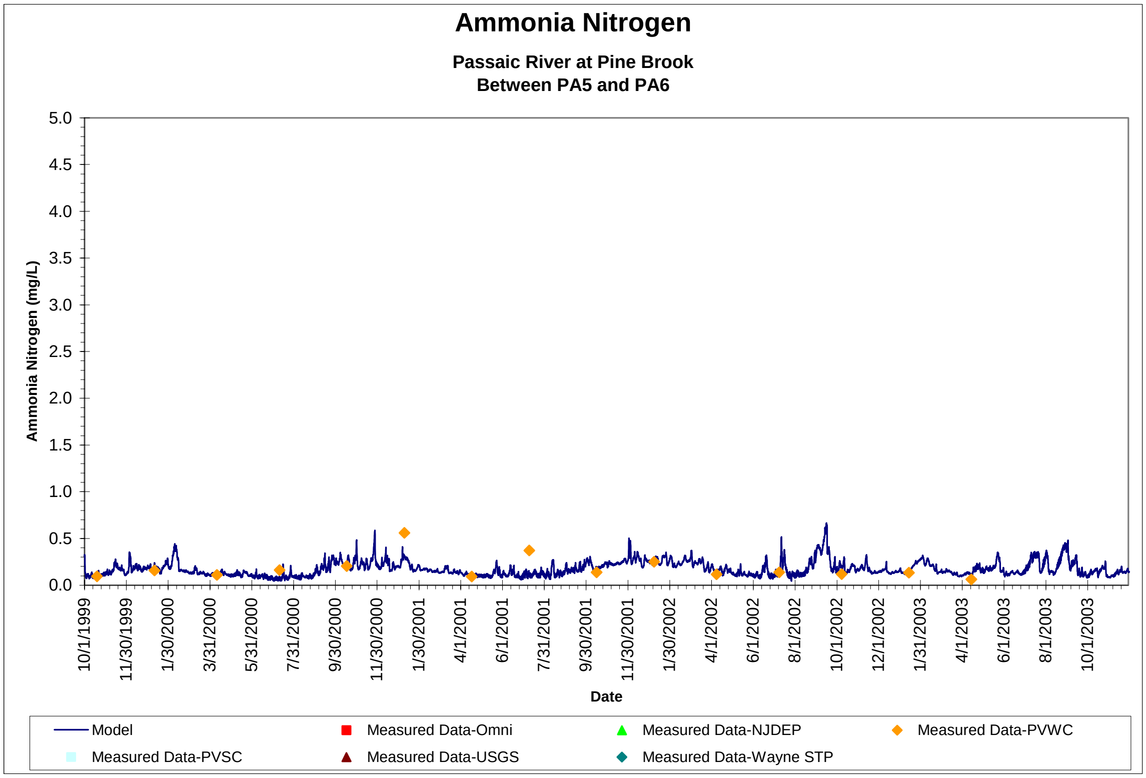


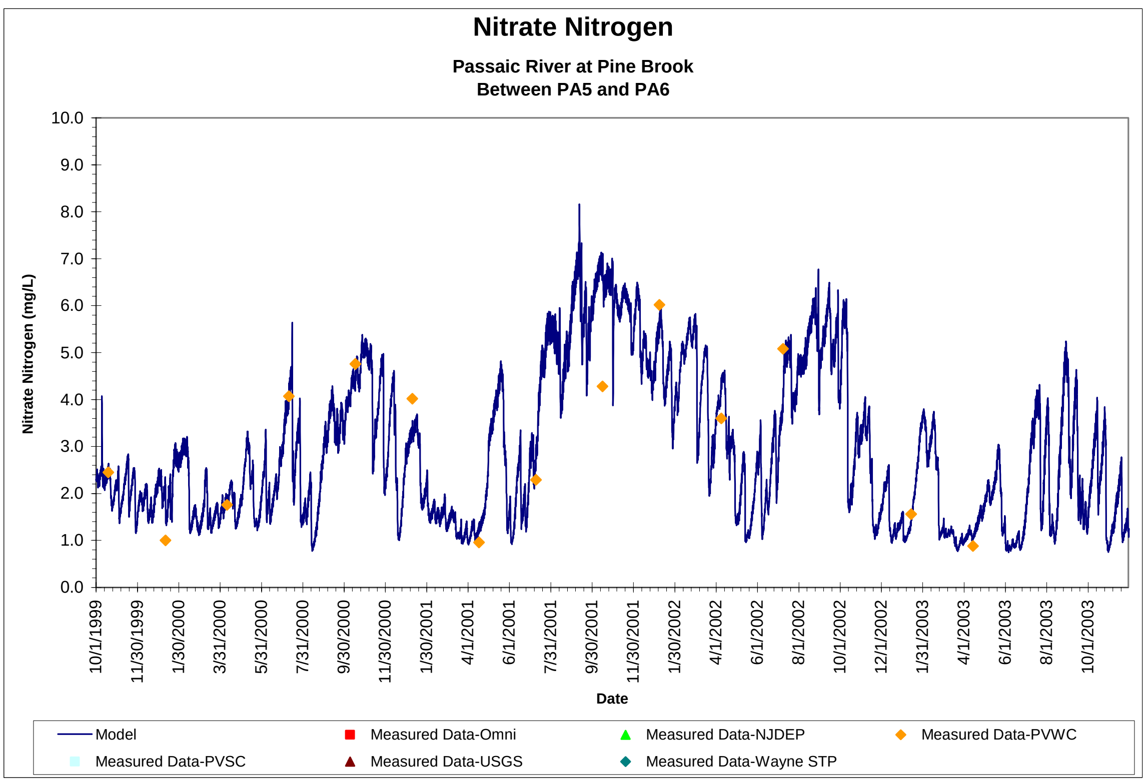
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



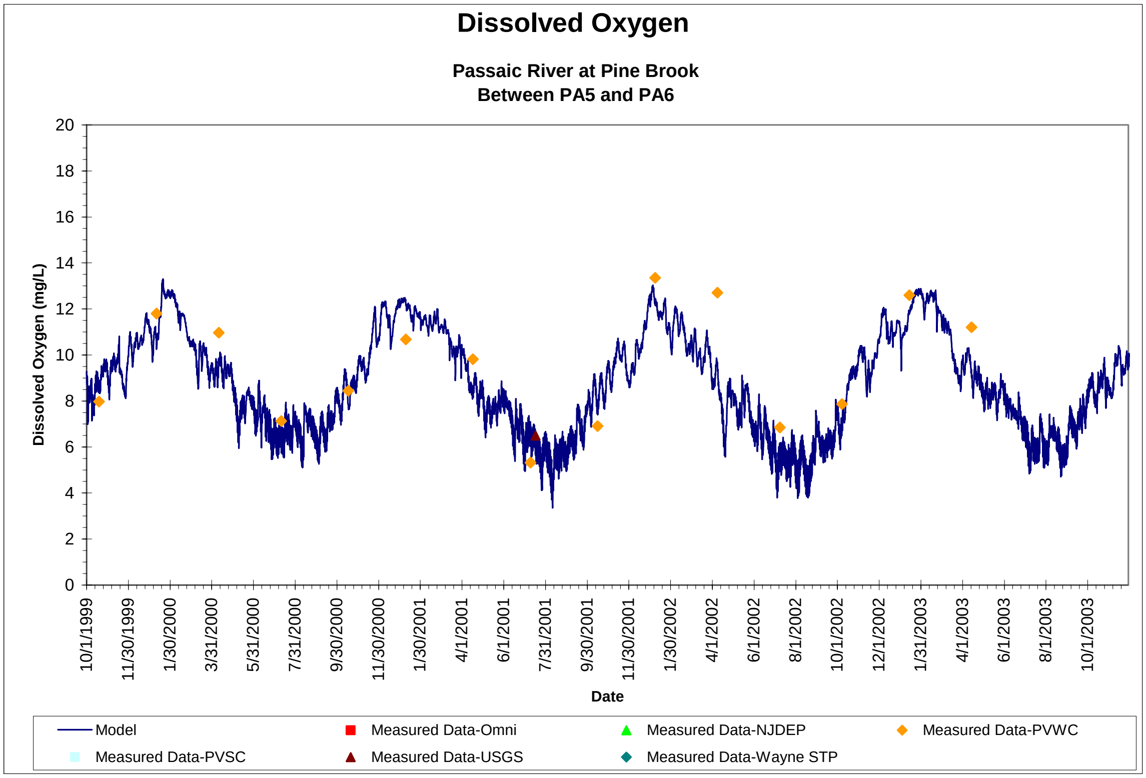


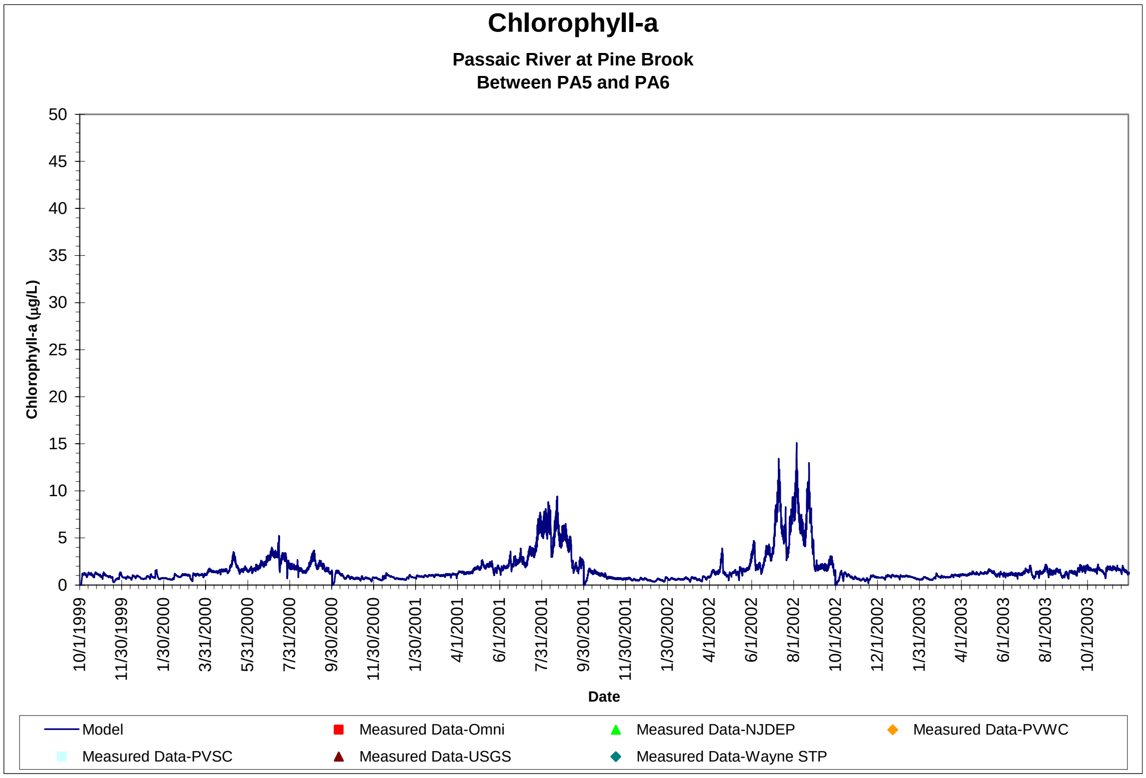
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



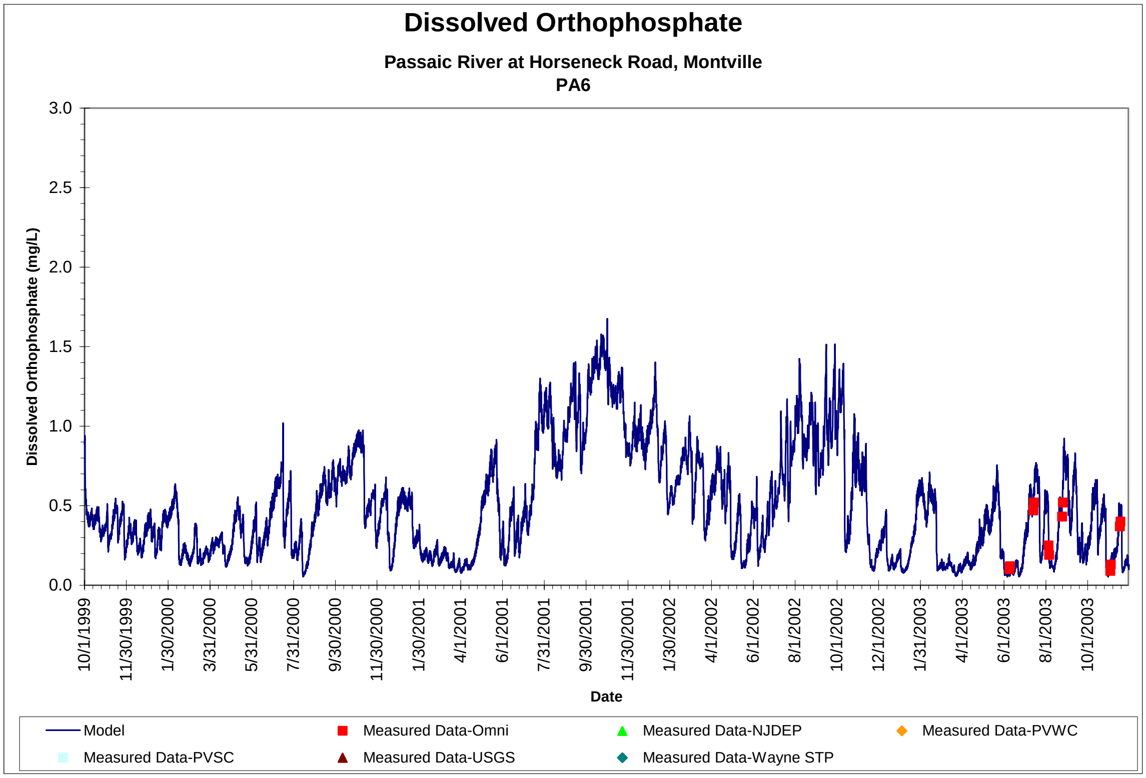


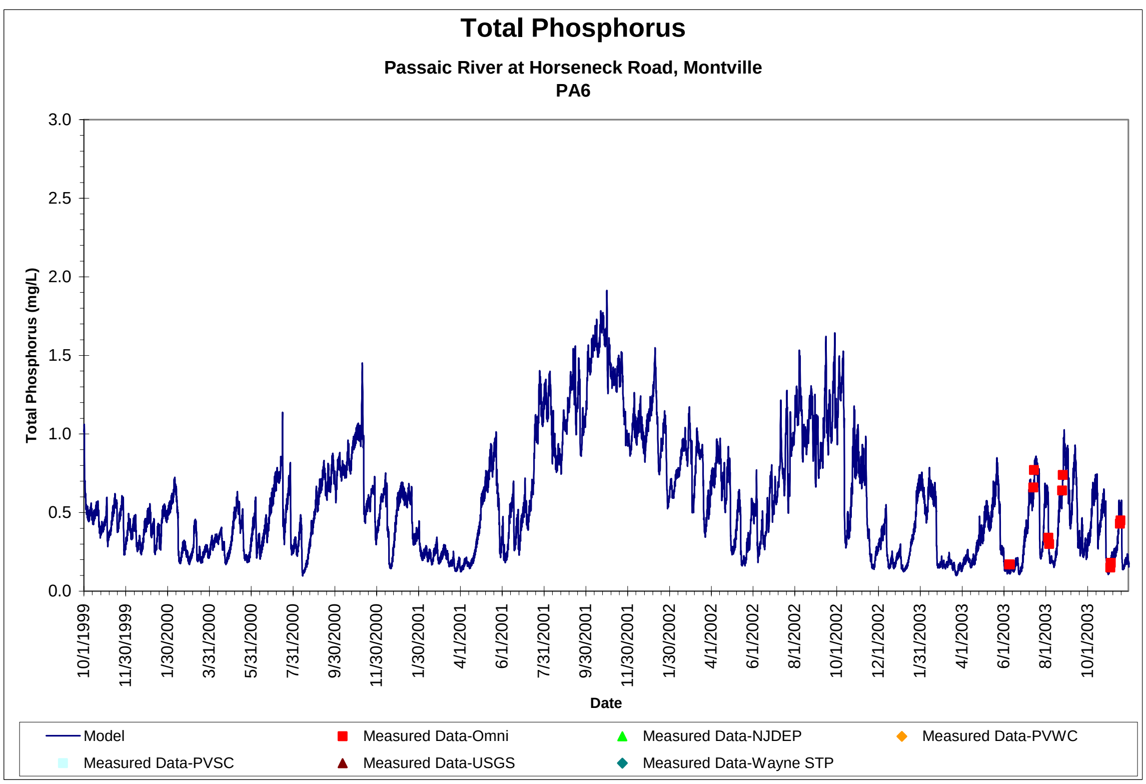
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



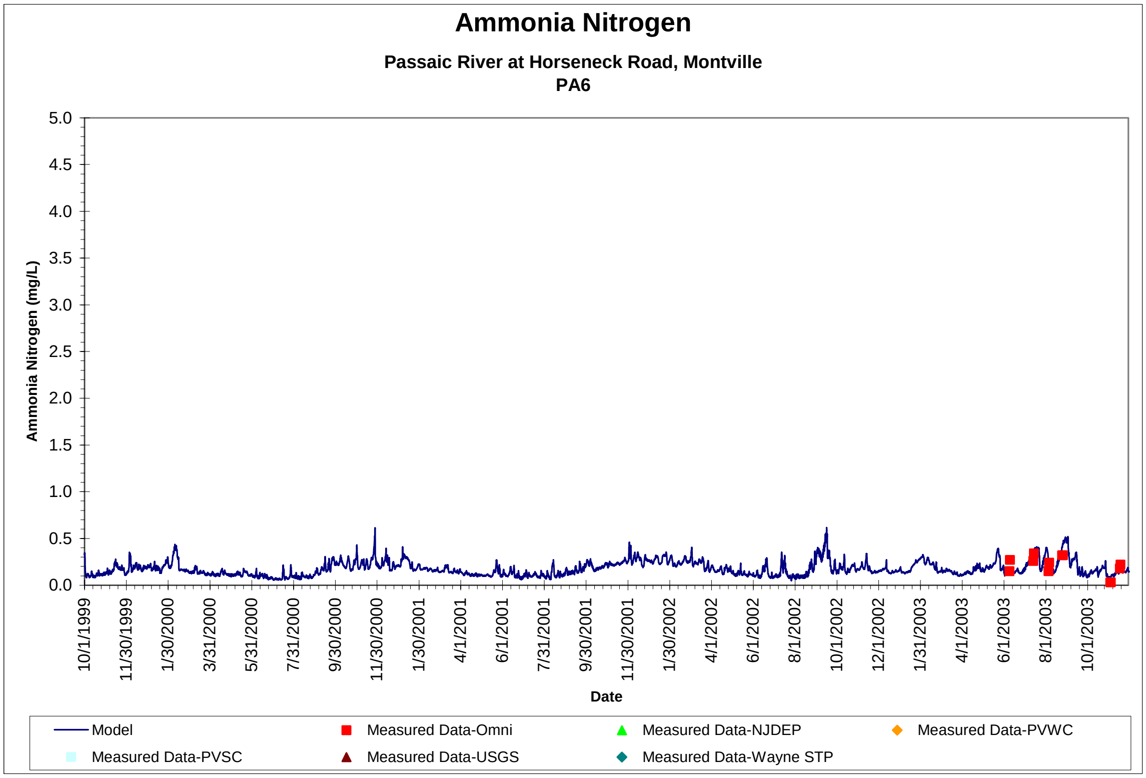


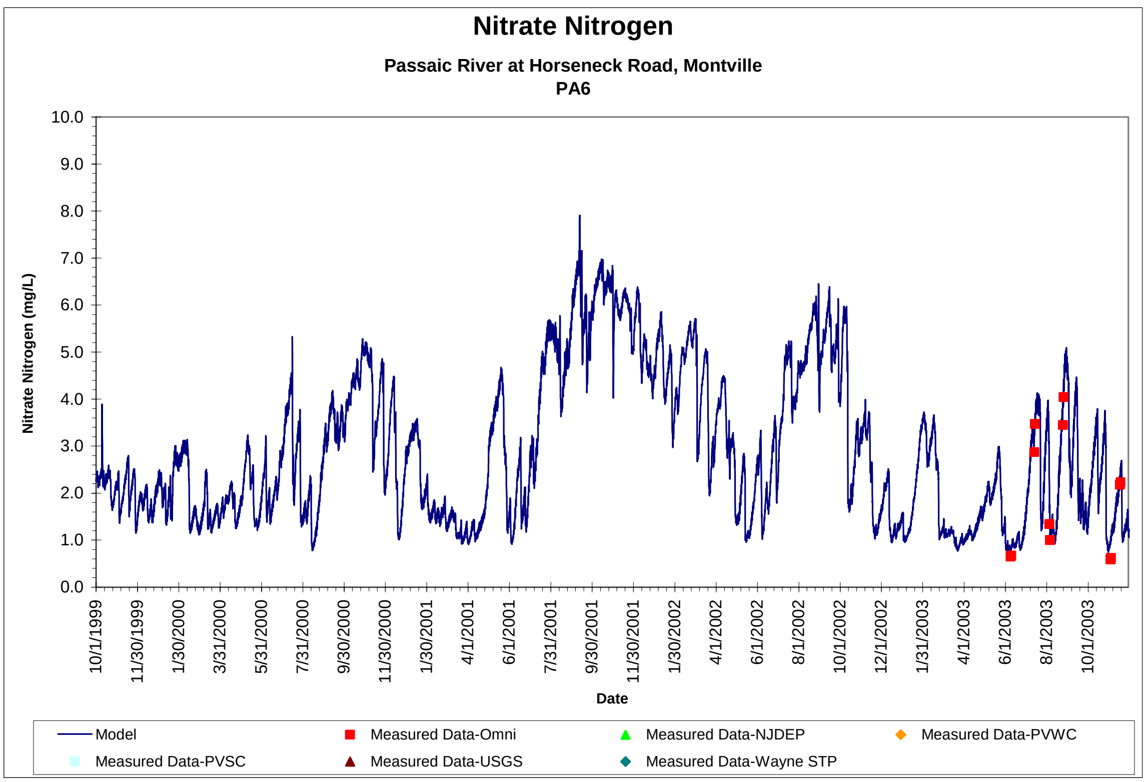
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



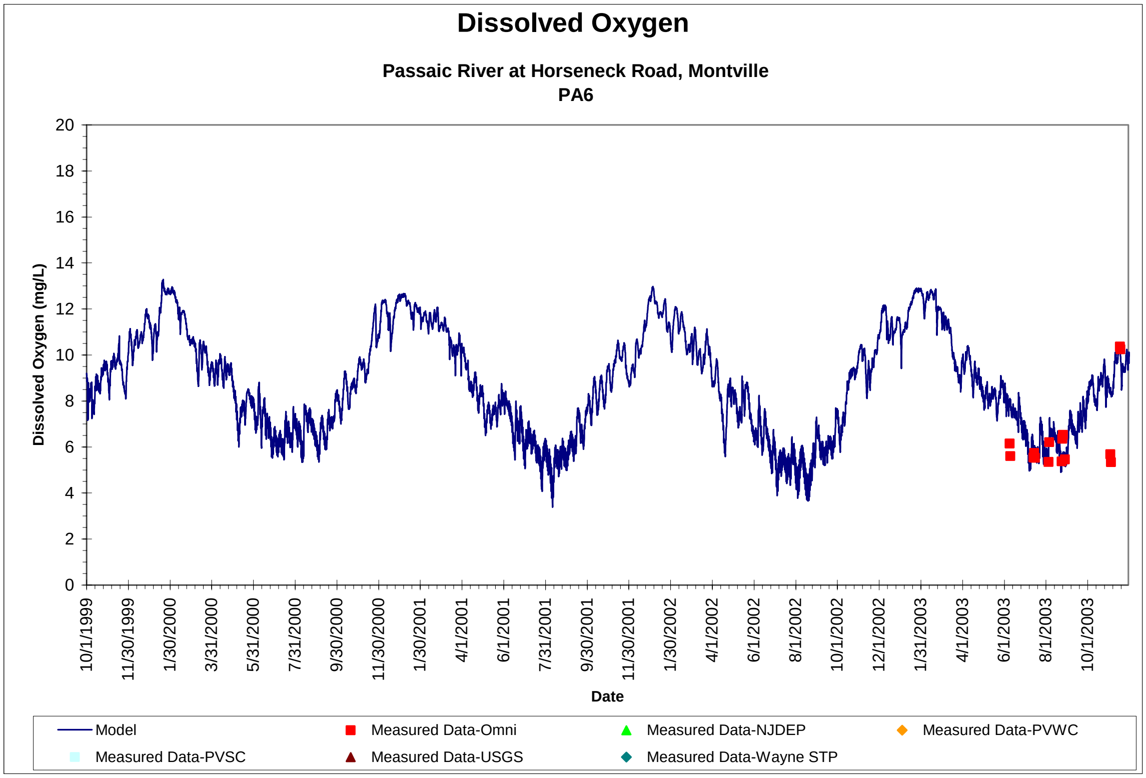


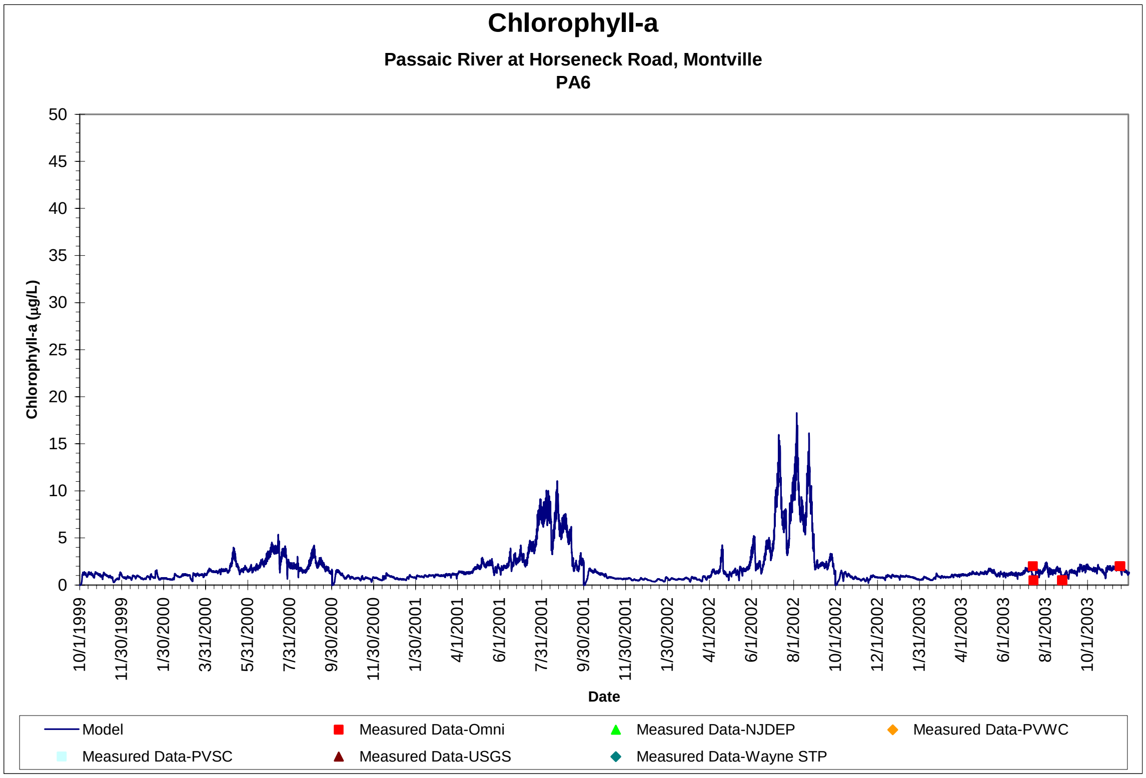
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



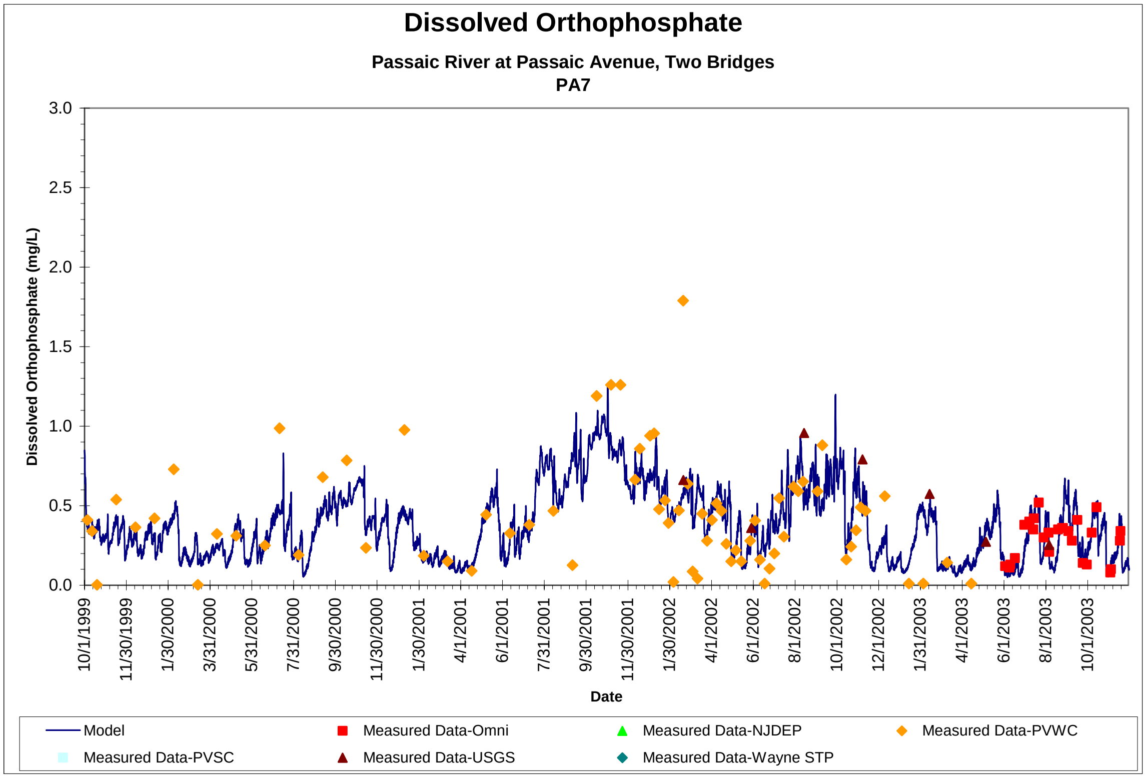


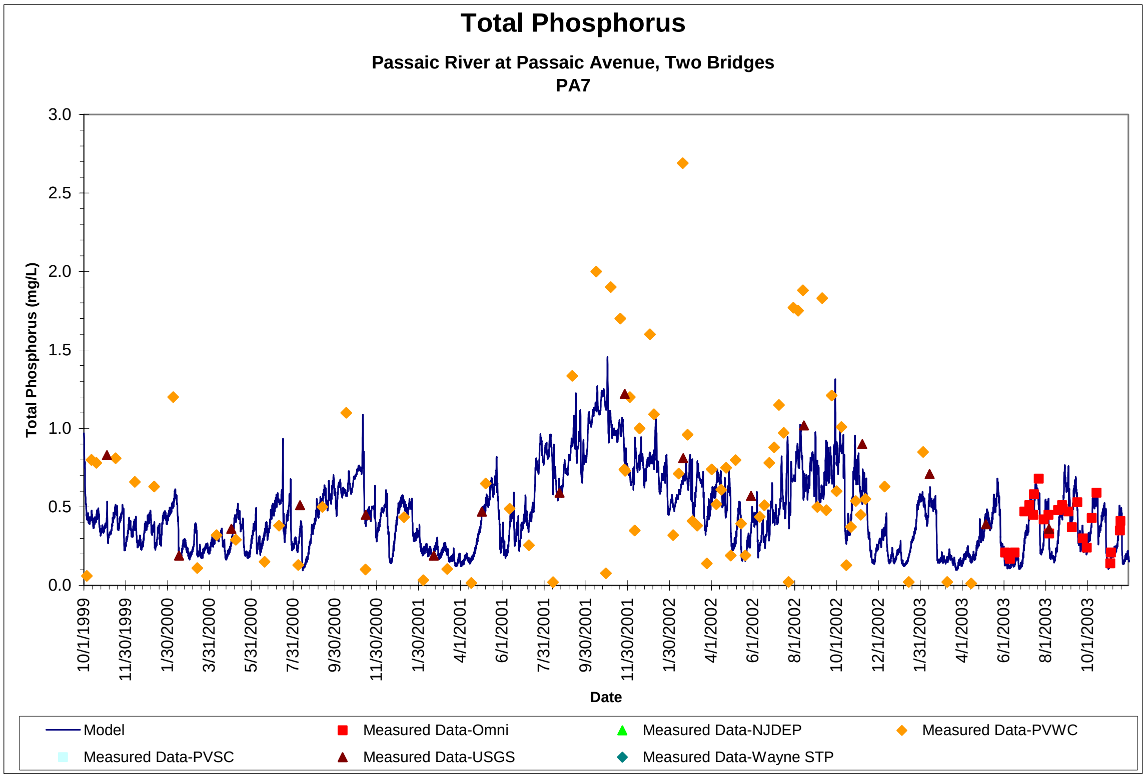
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



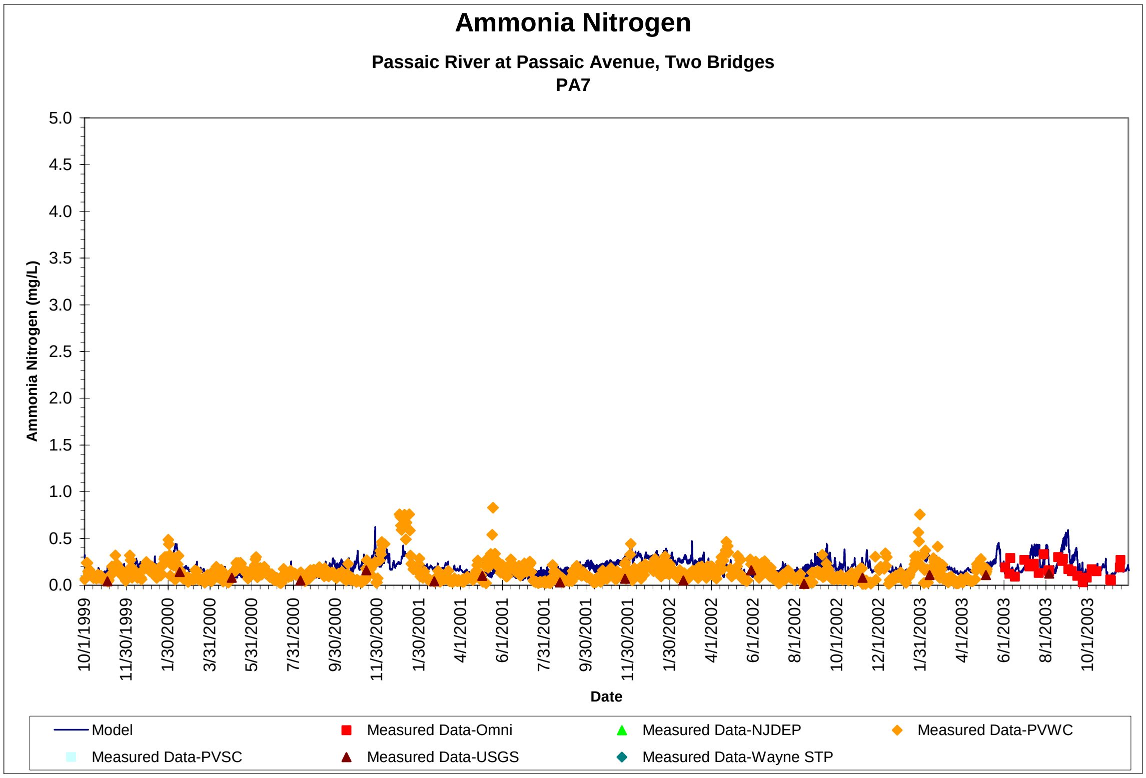


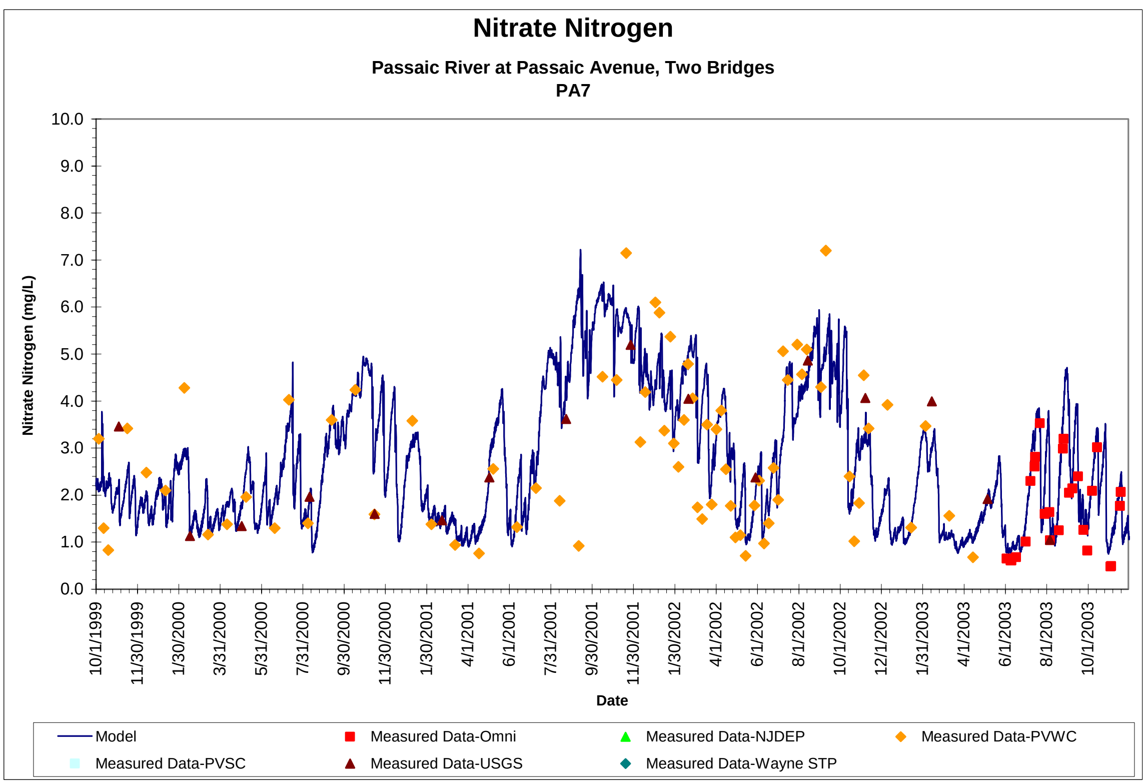
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



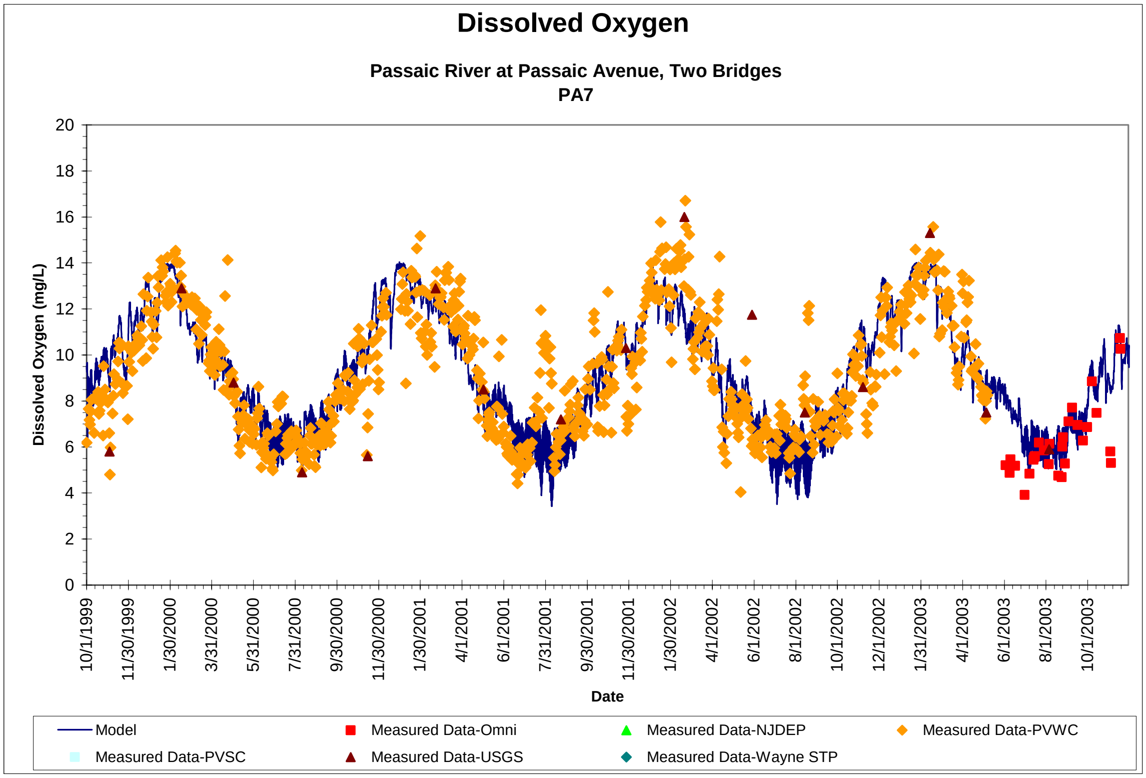


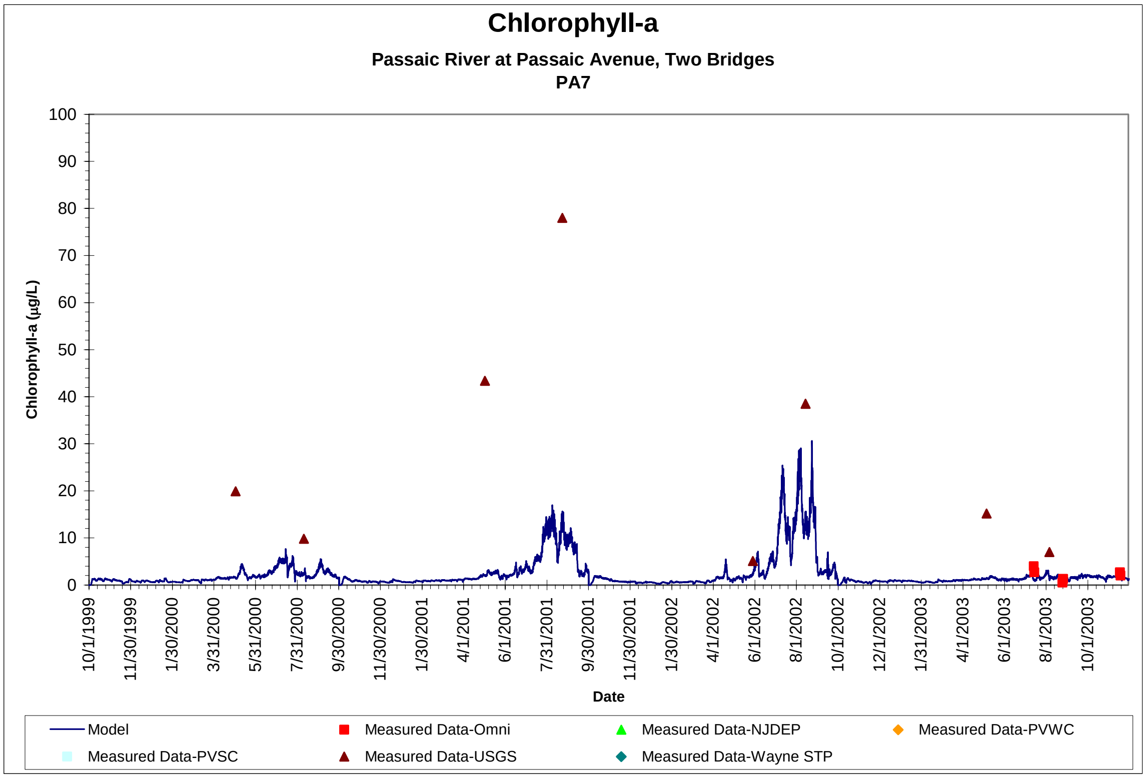
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



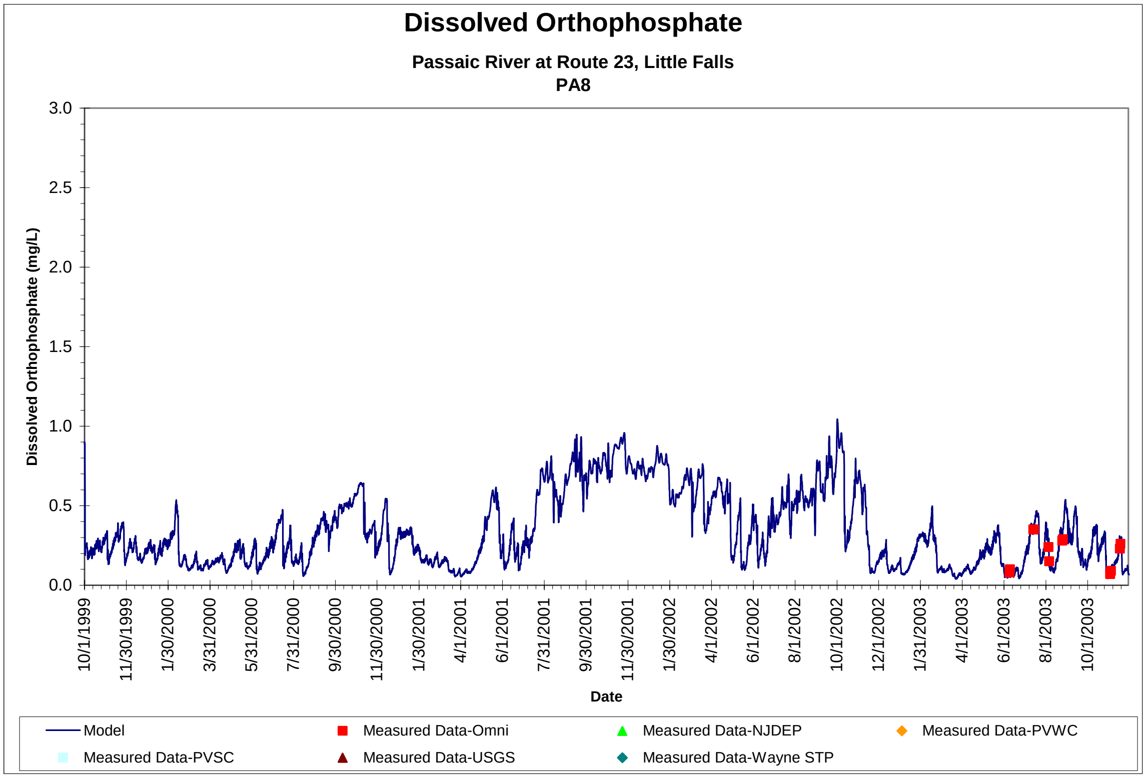


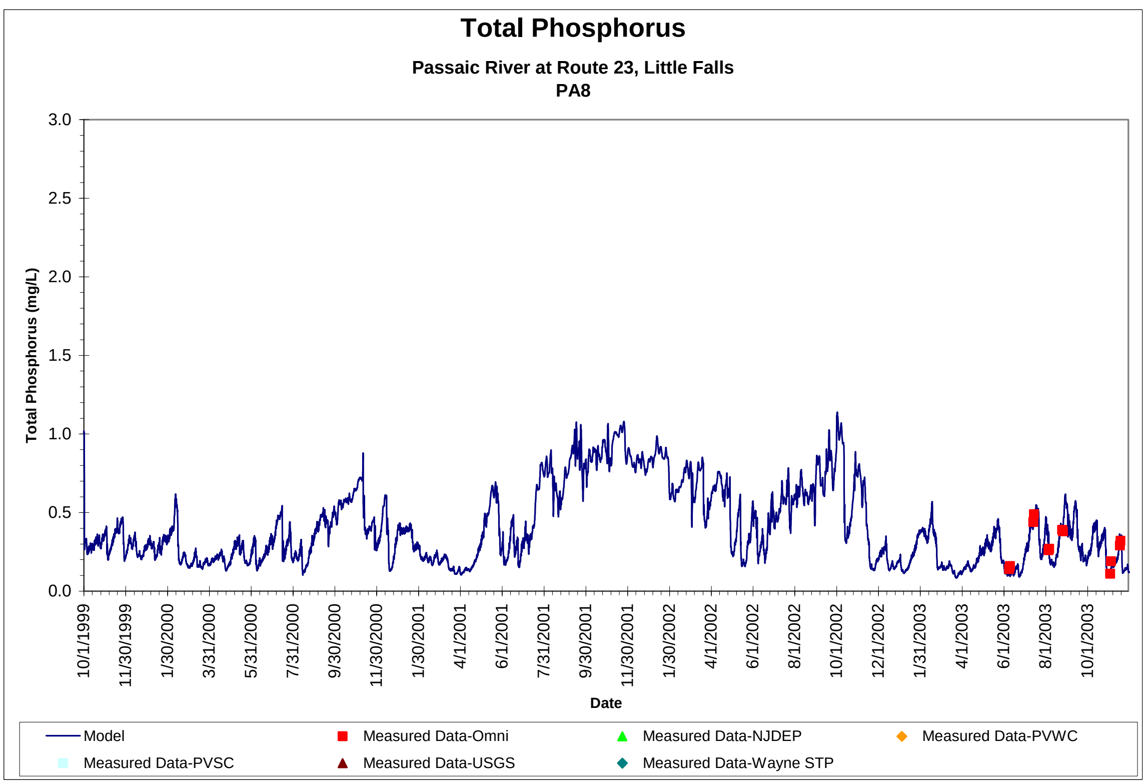
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



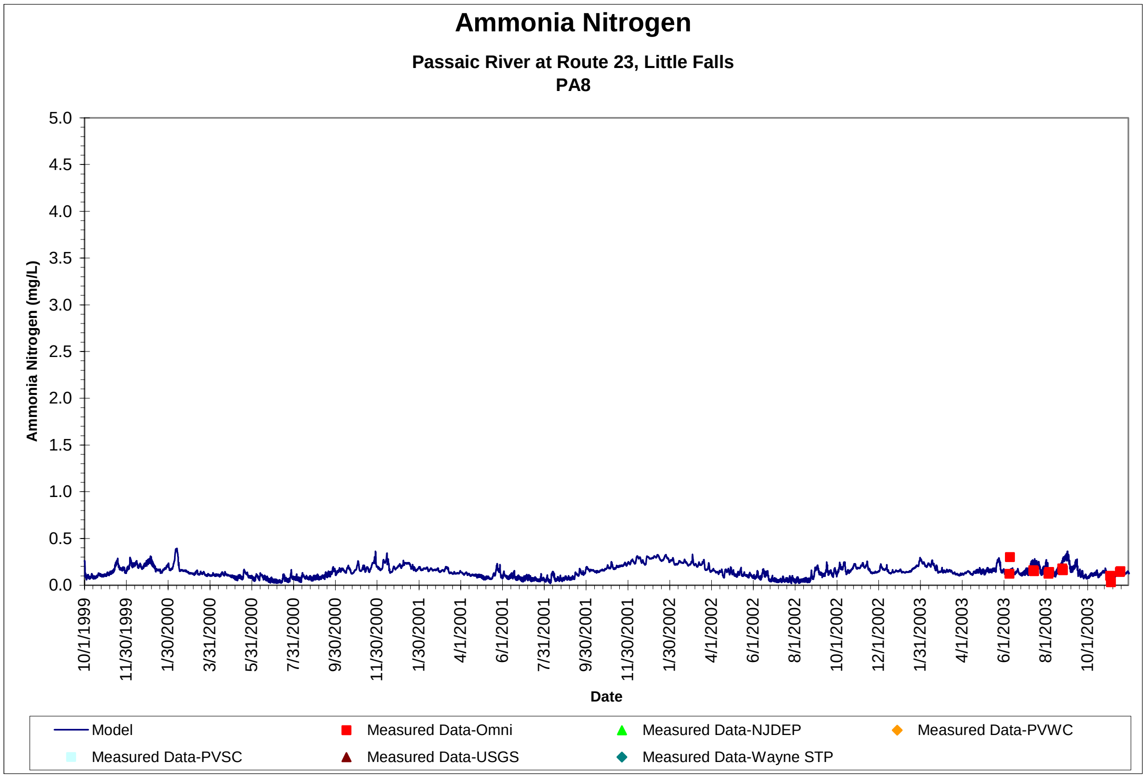


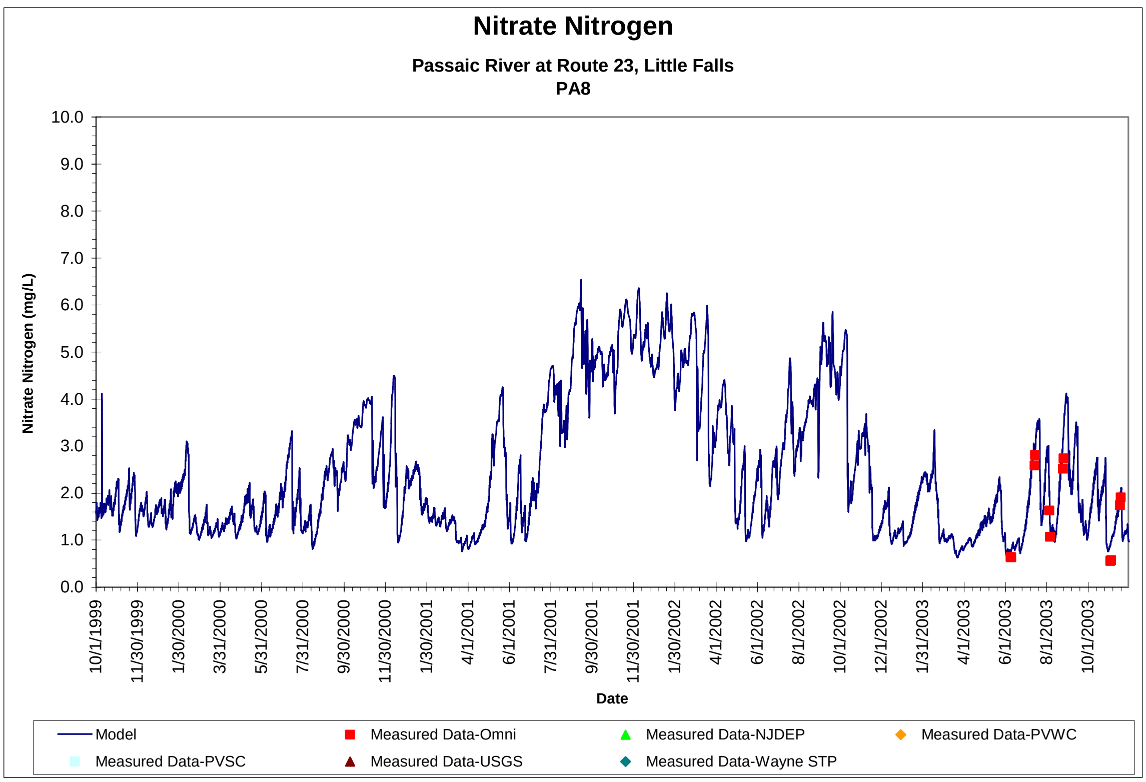
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



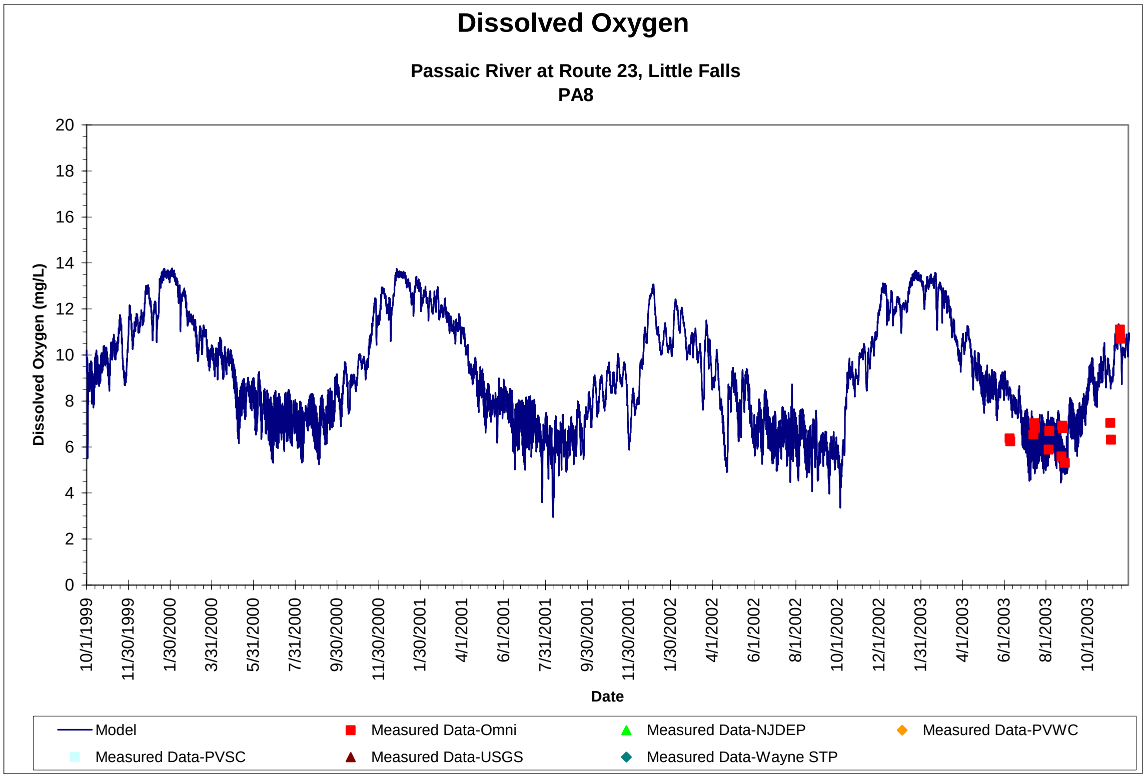


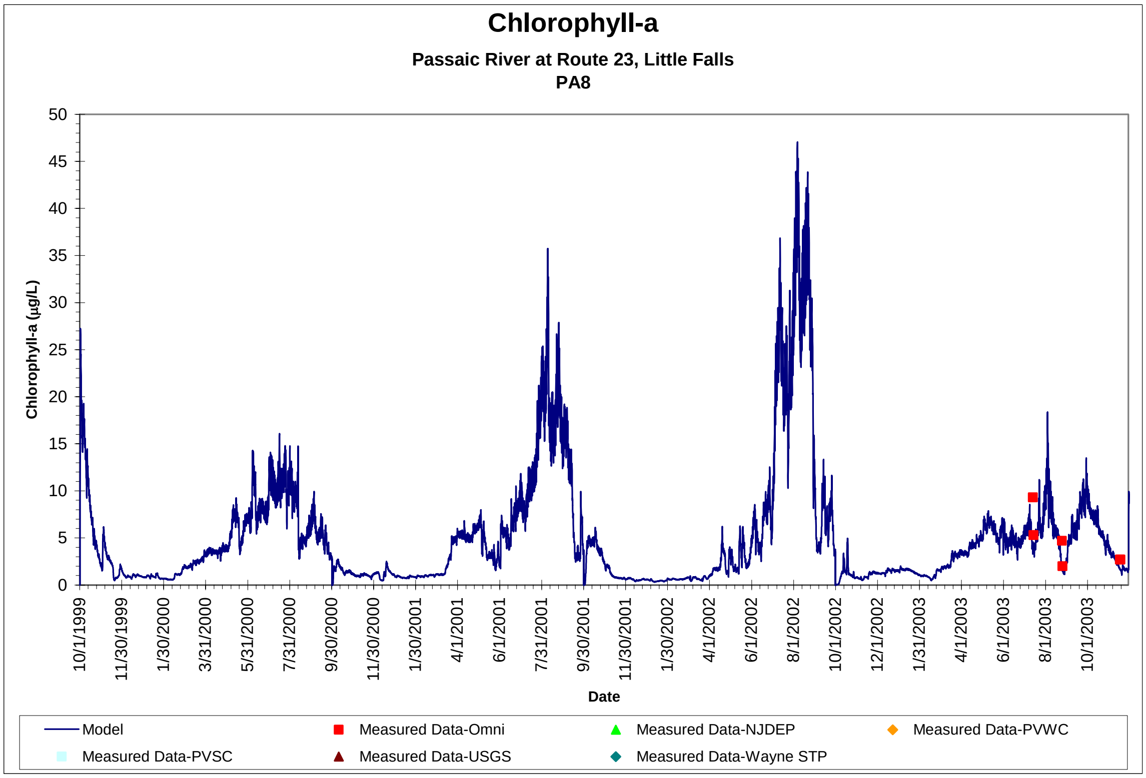
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



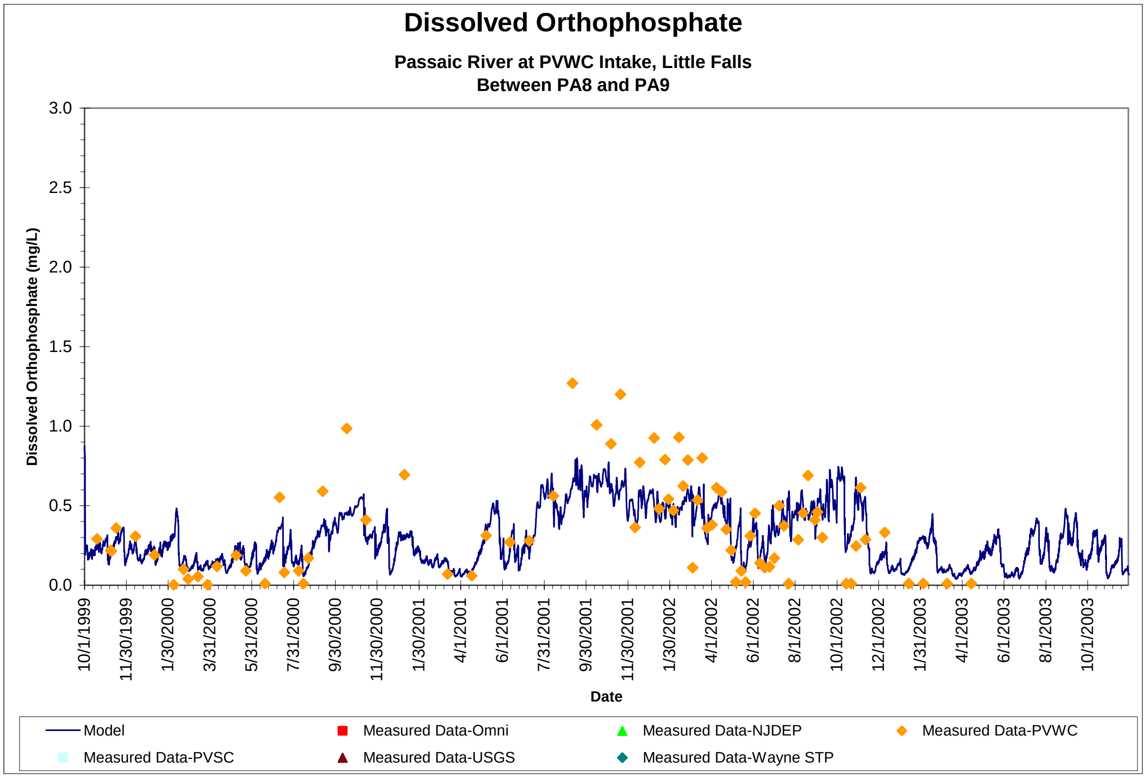


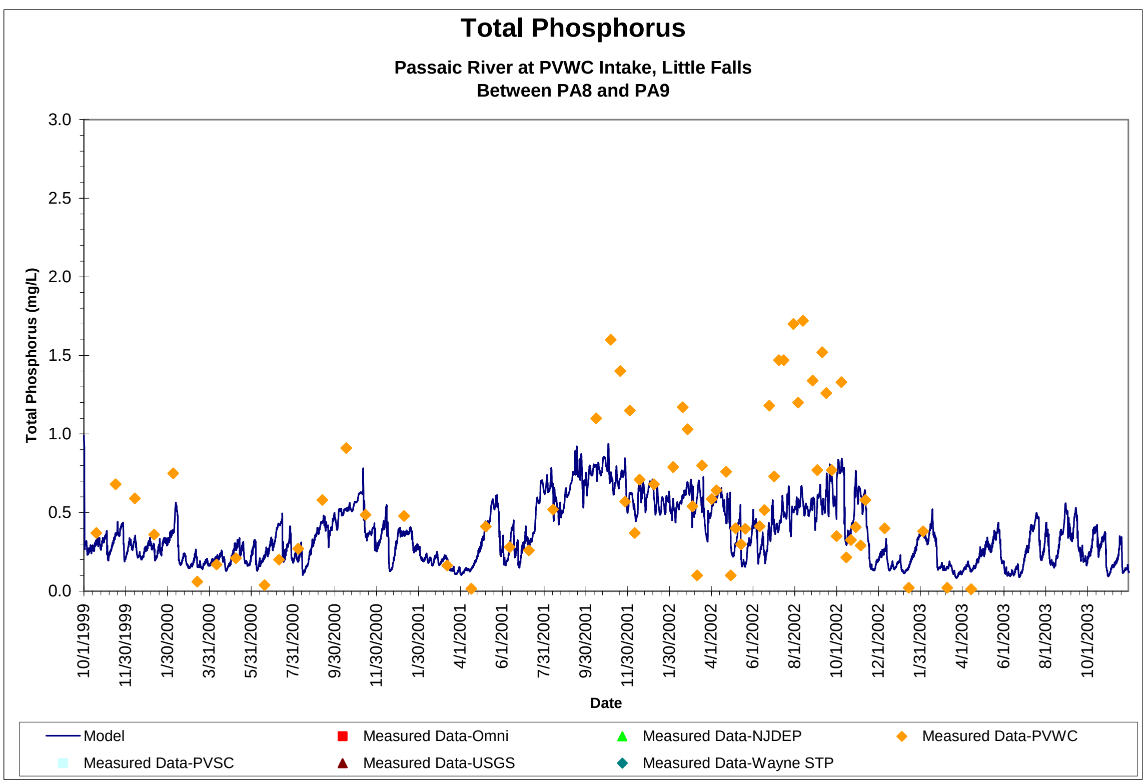
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



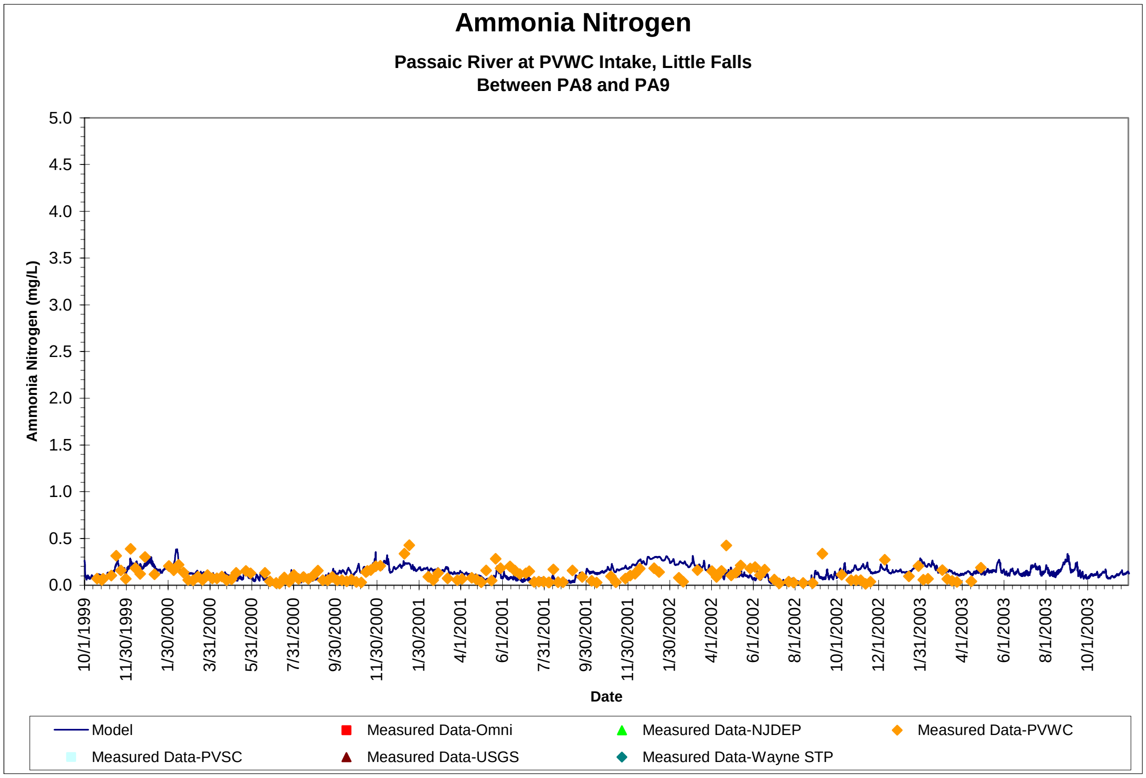


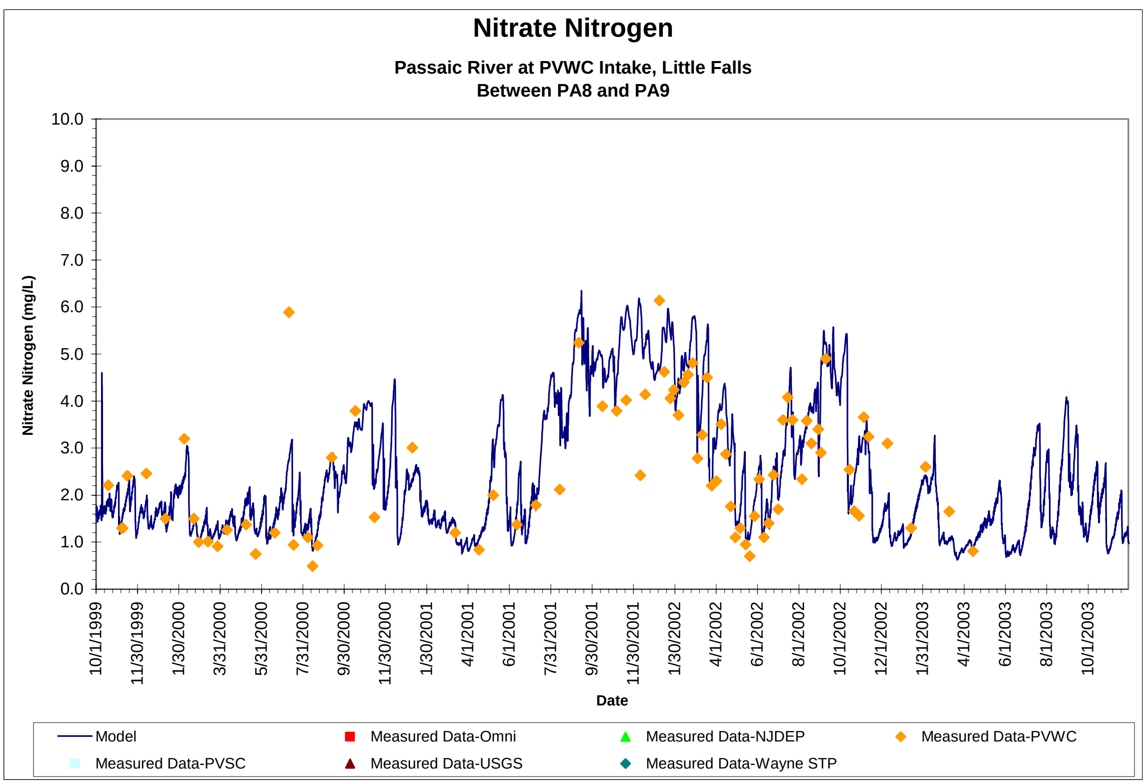
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



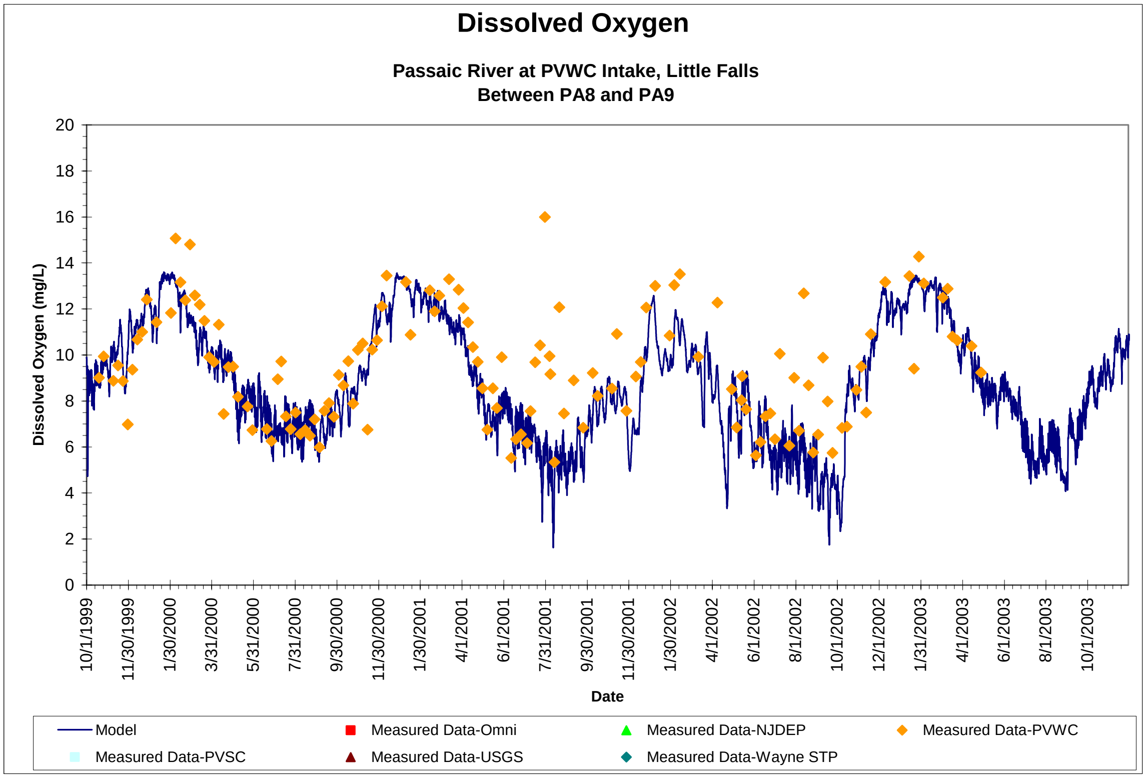


GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS

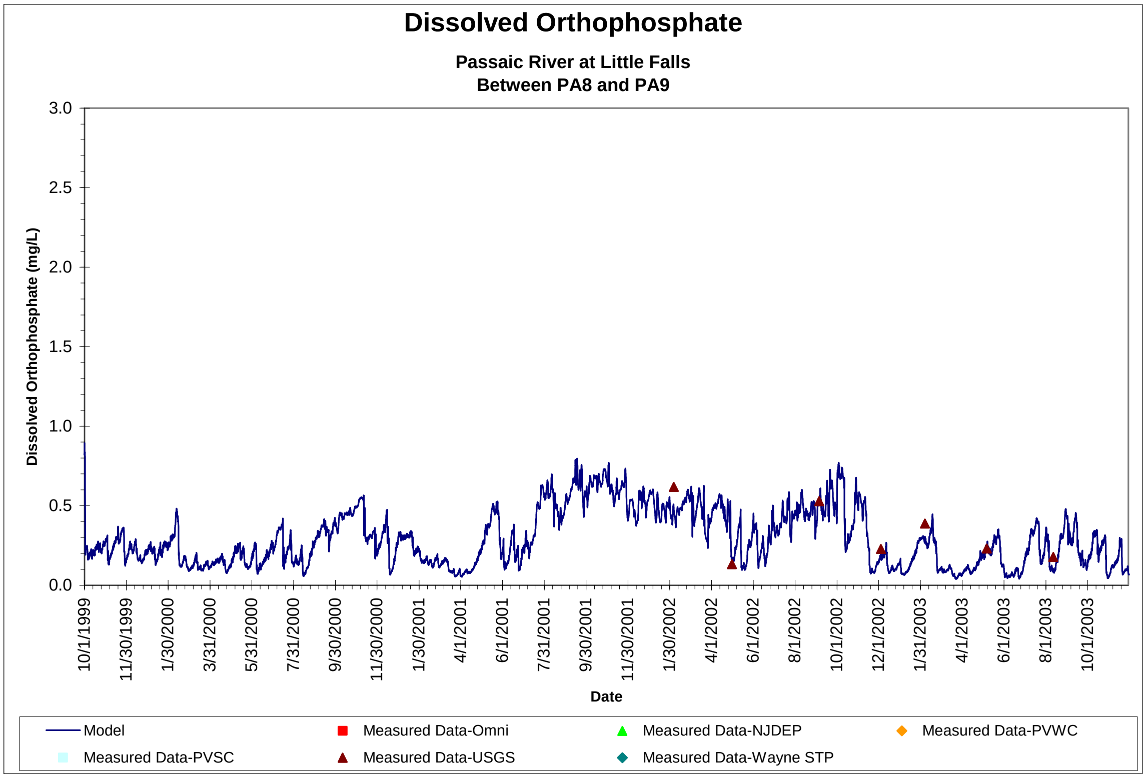


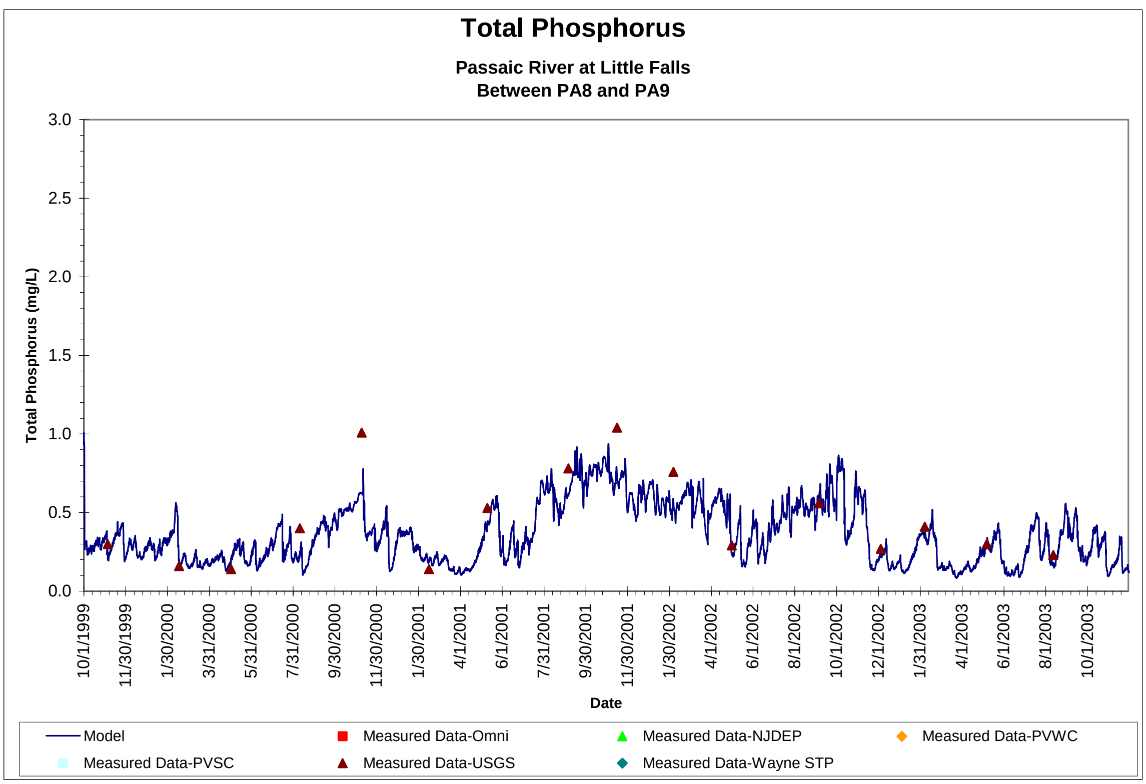


GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS

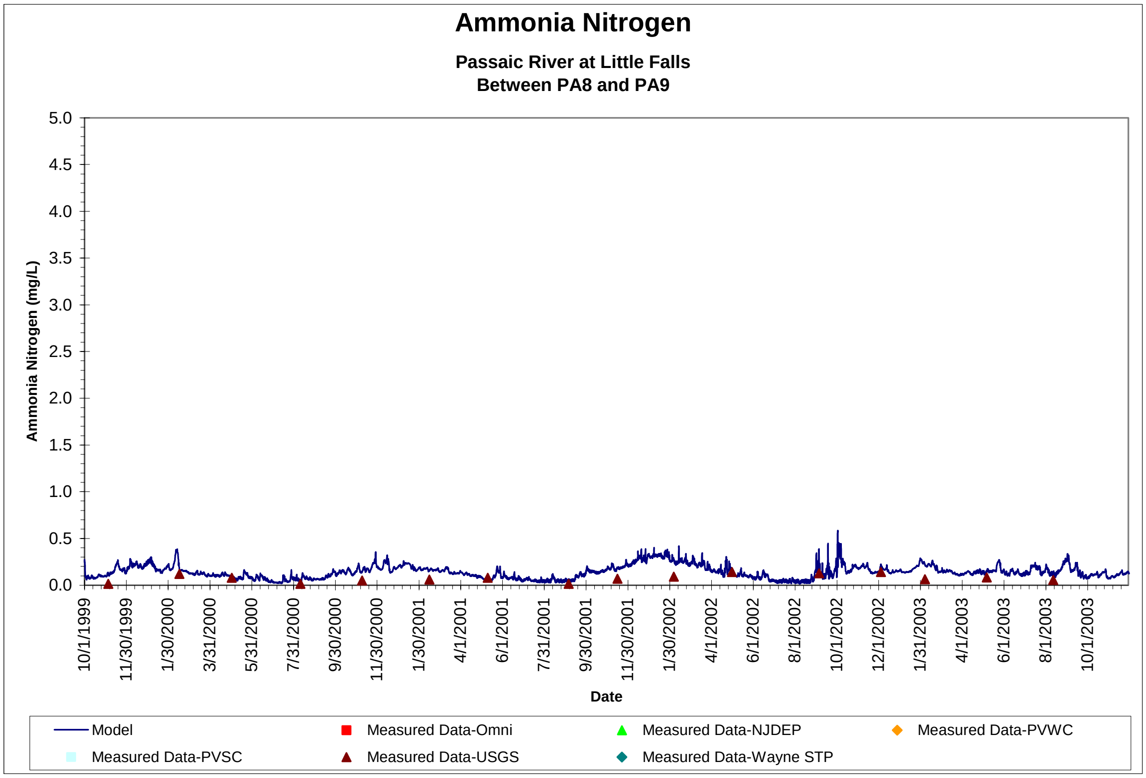


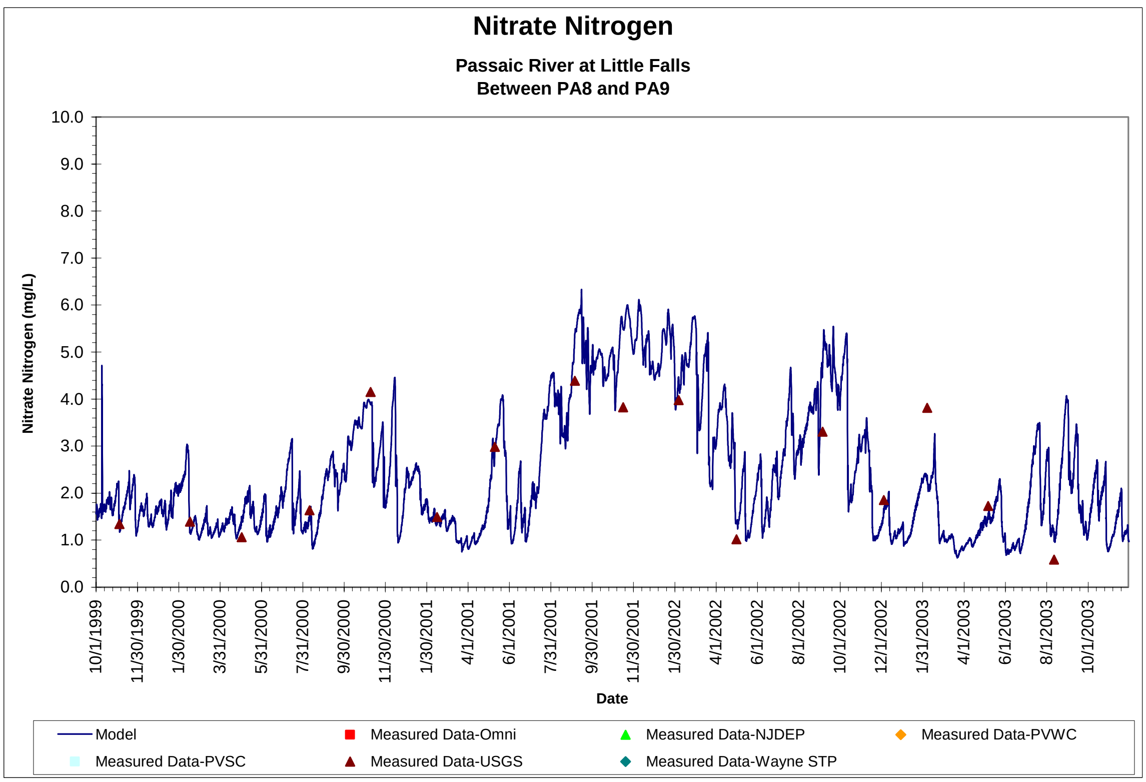
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



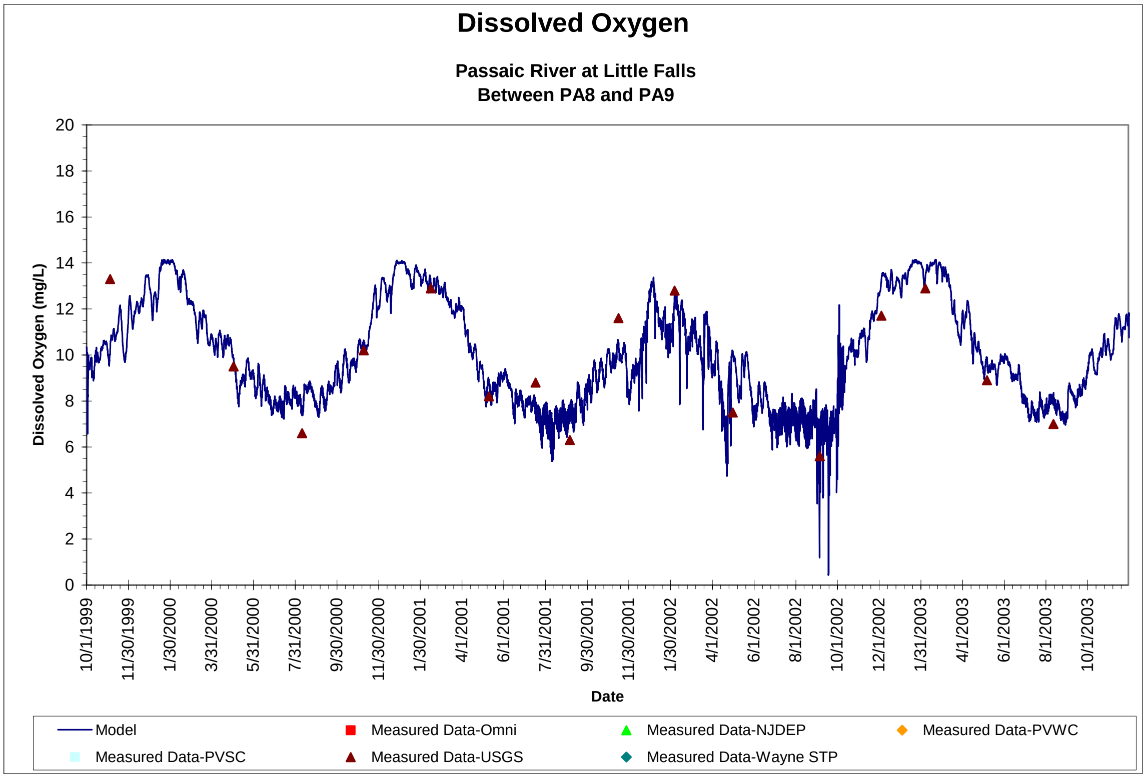


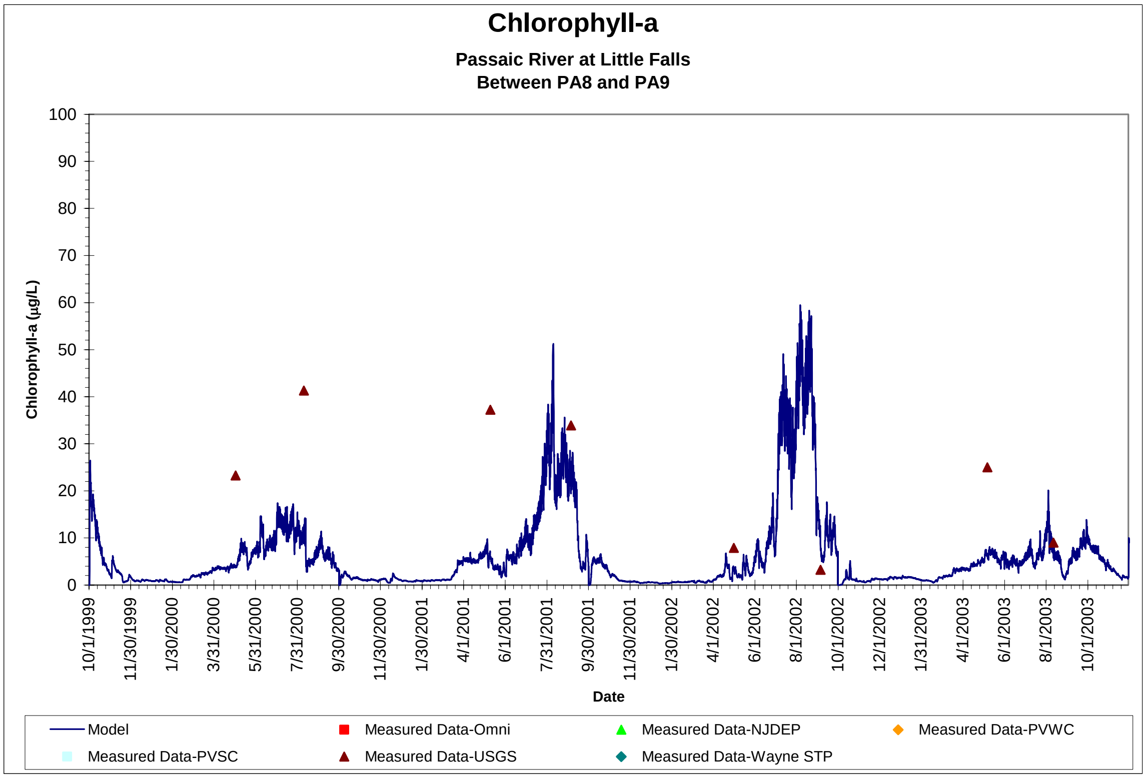
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



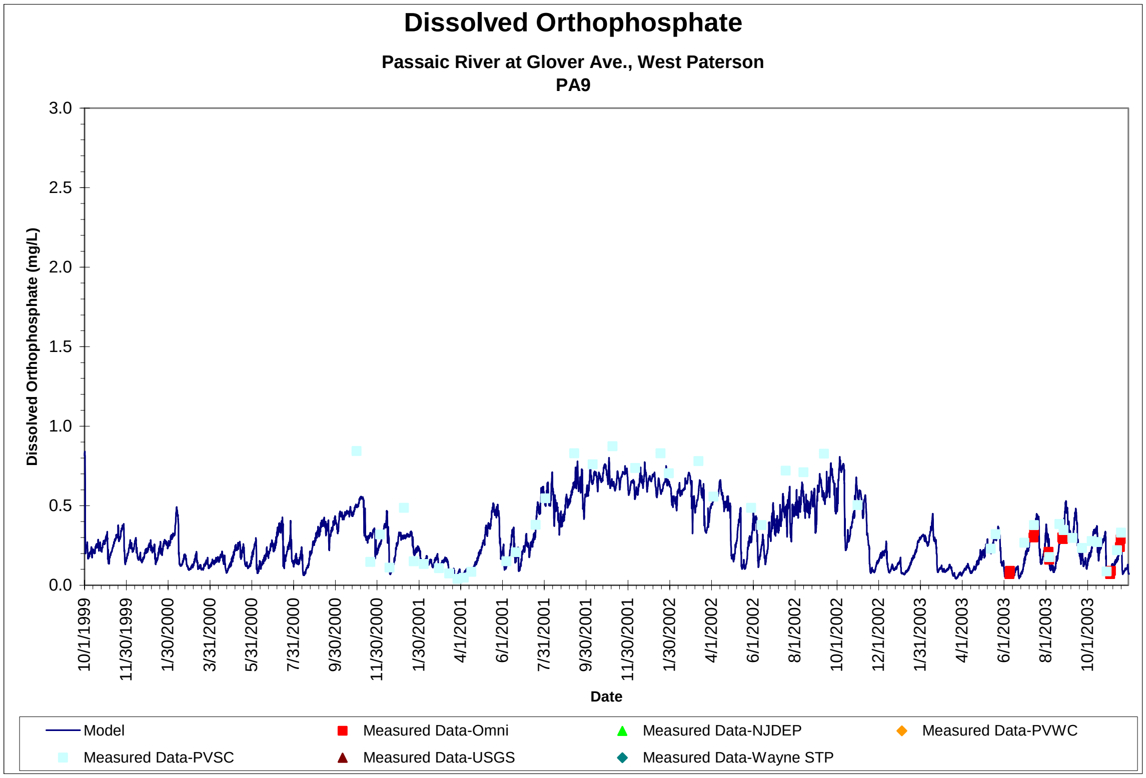


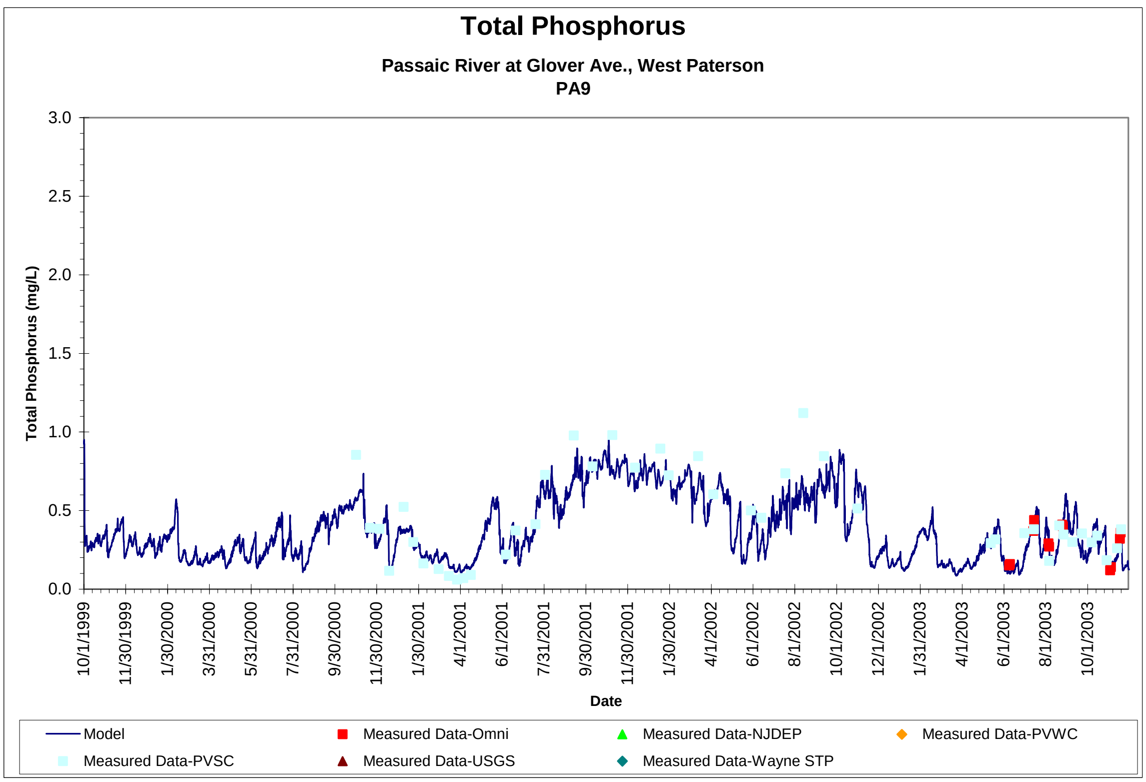
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



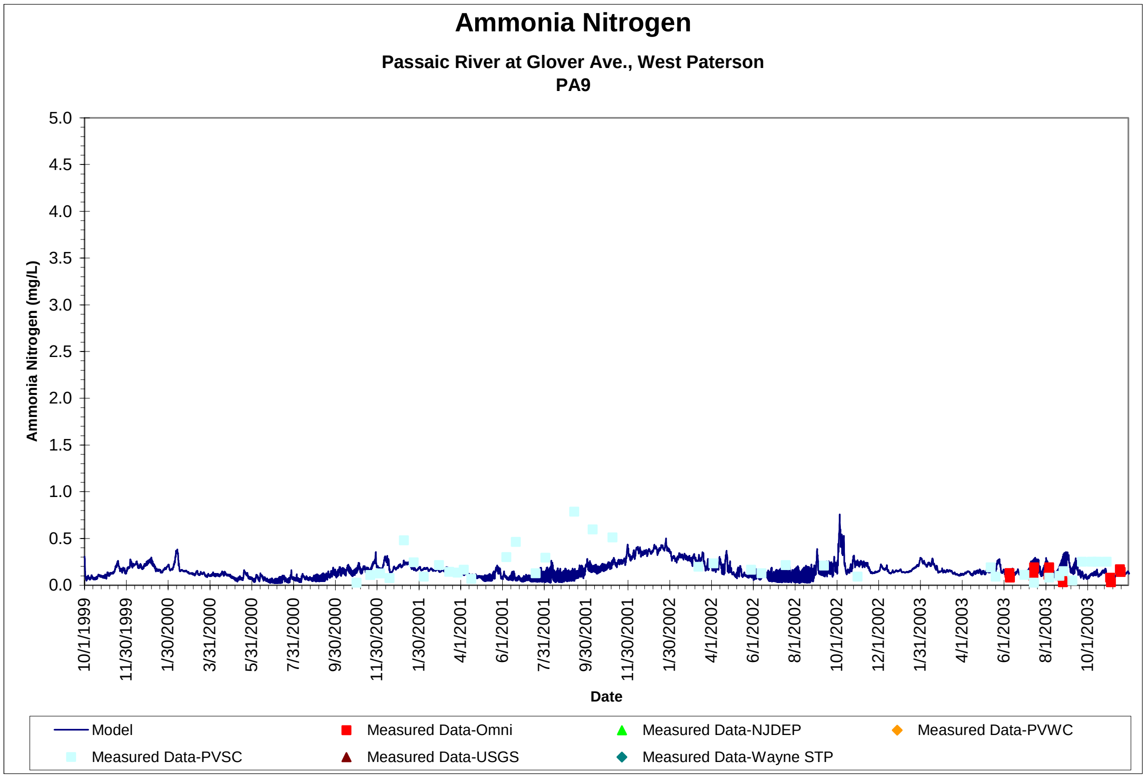


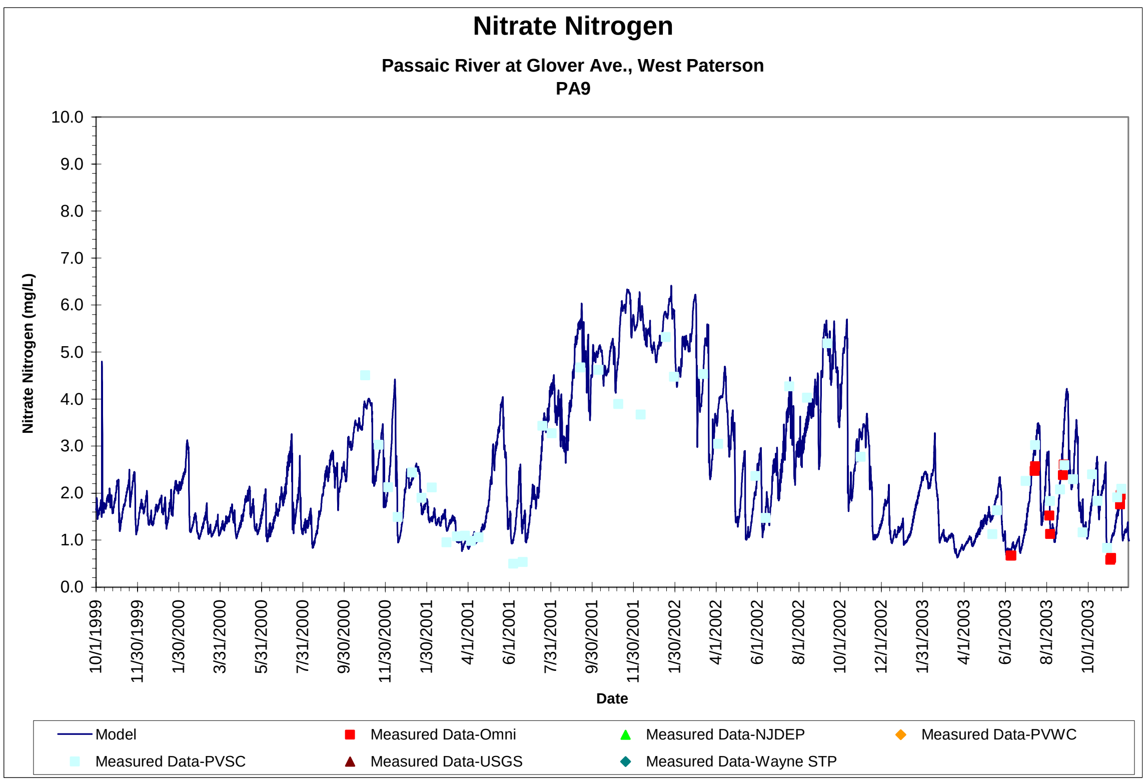
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



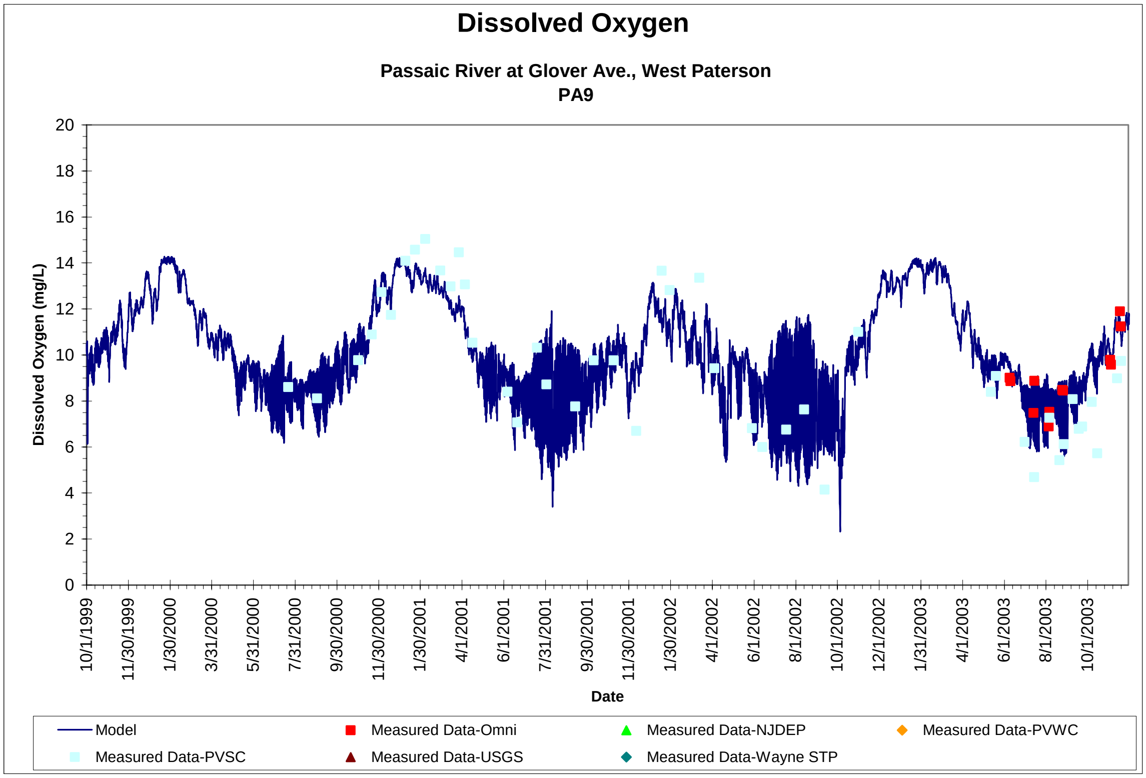


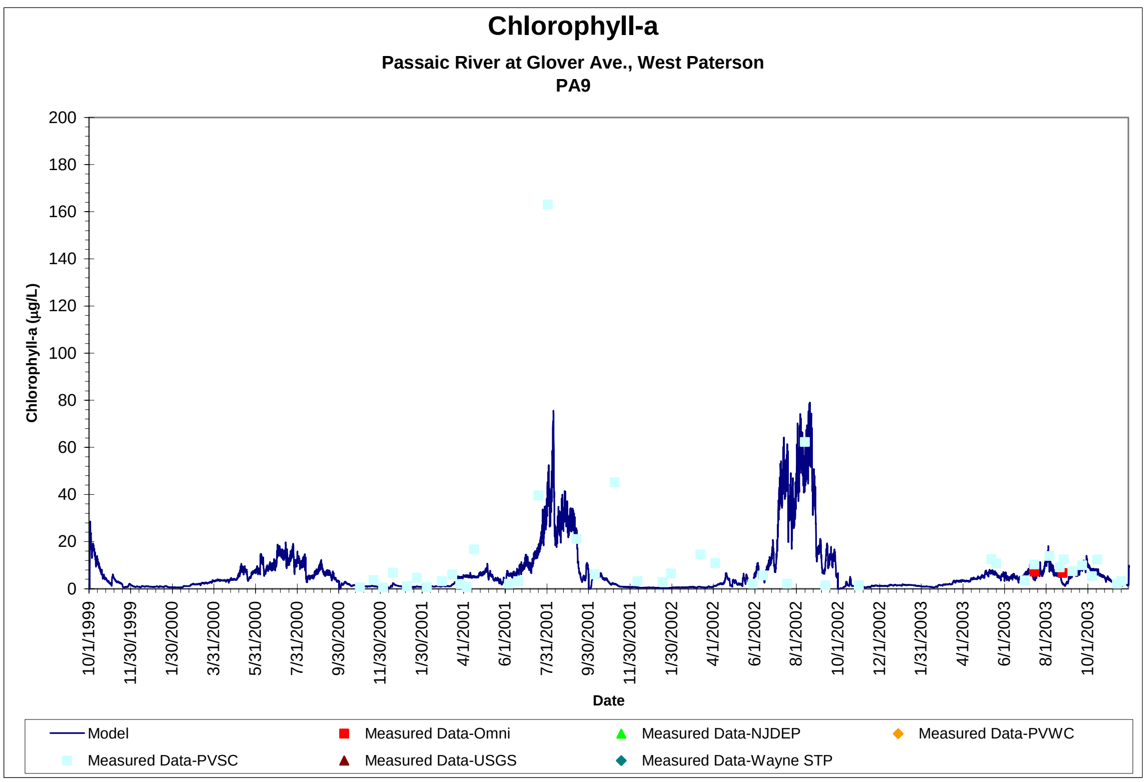
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



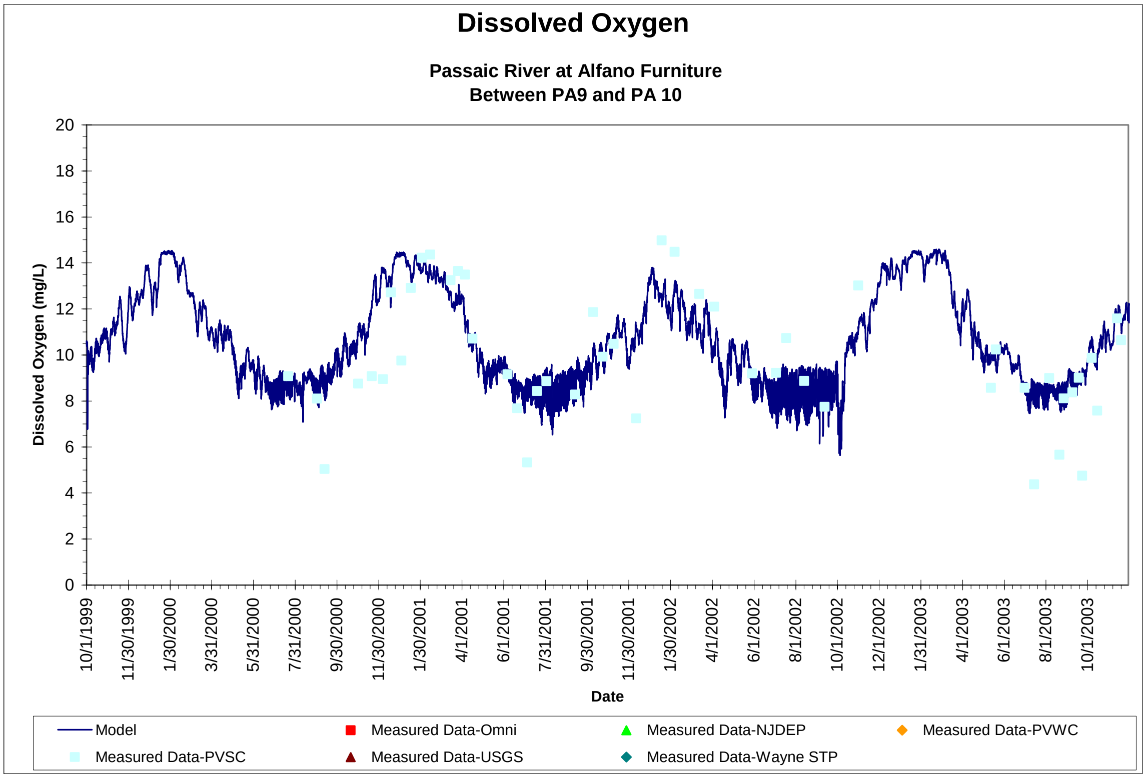


GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS

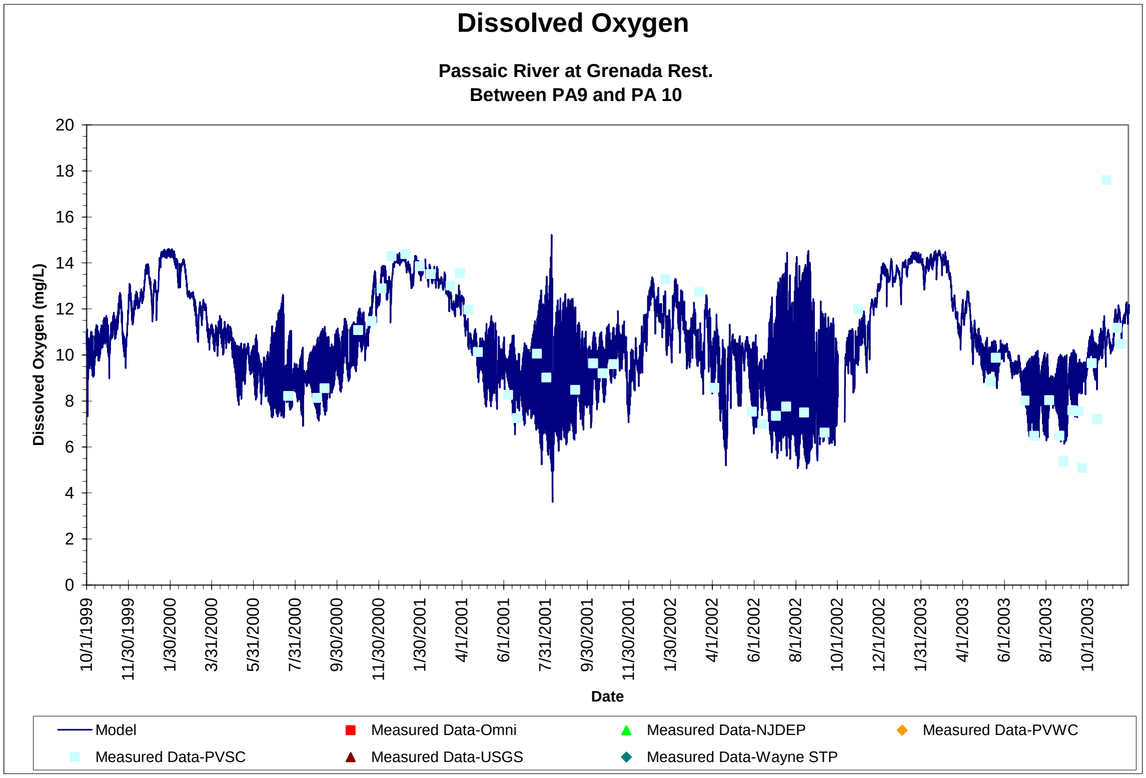




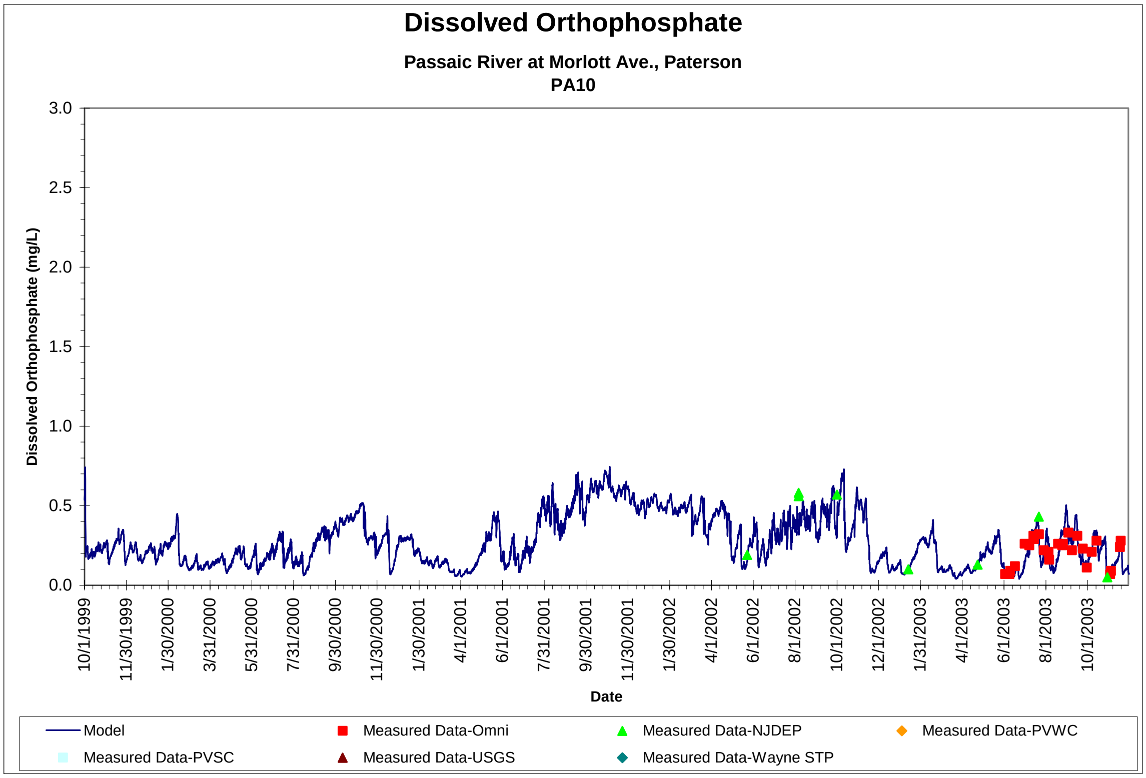
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS

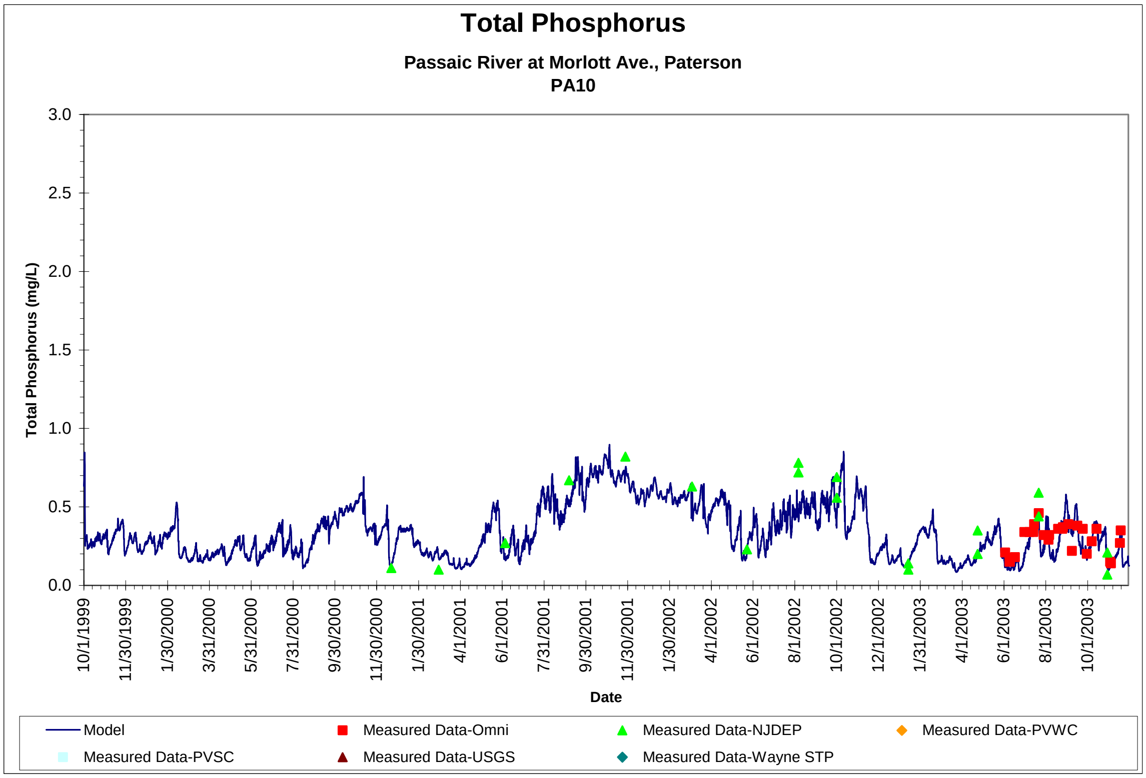


GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS

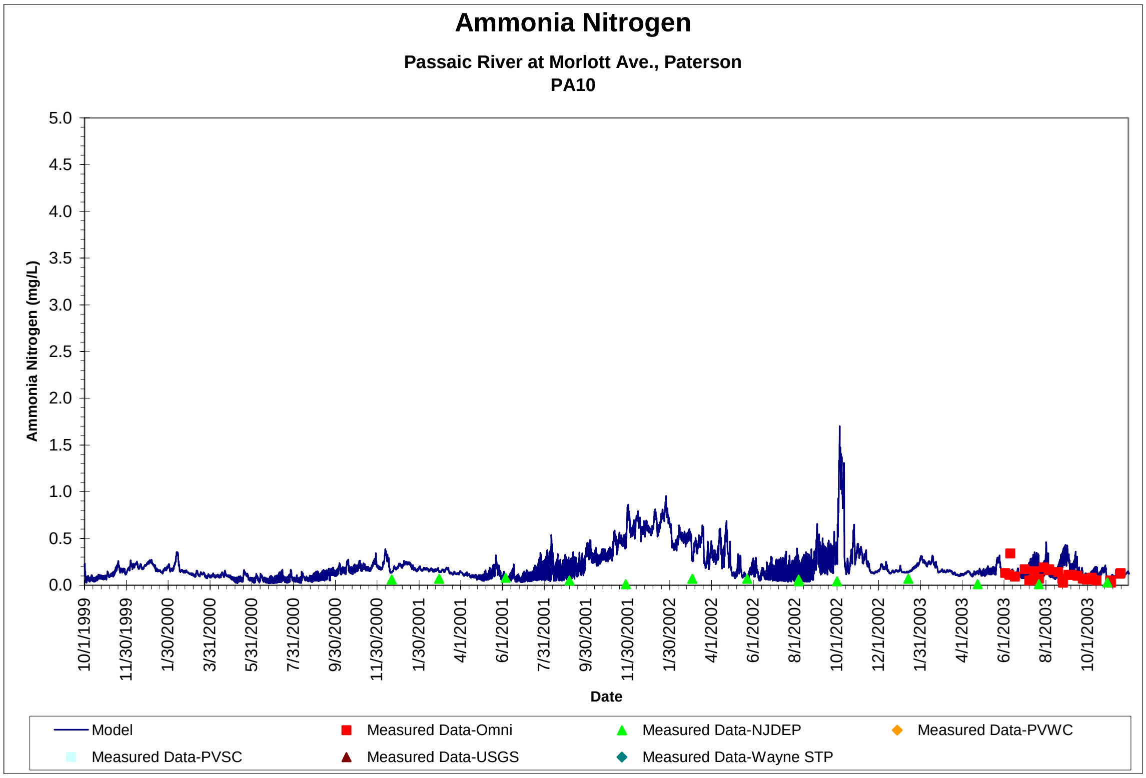


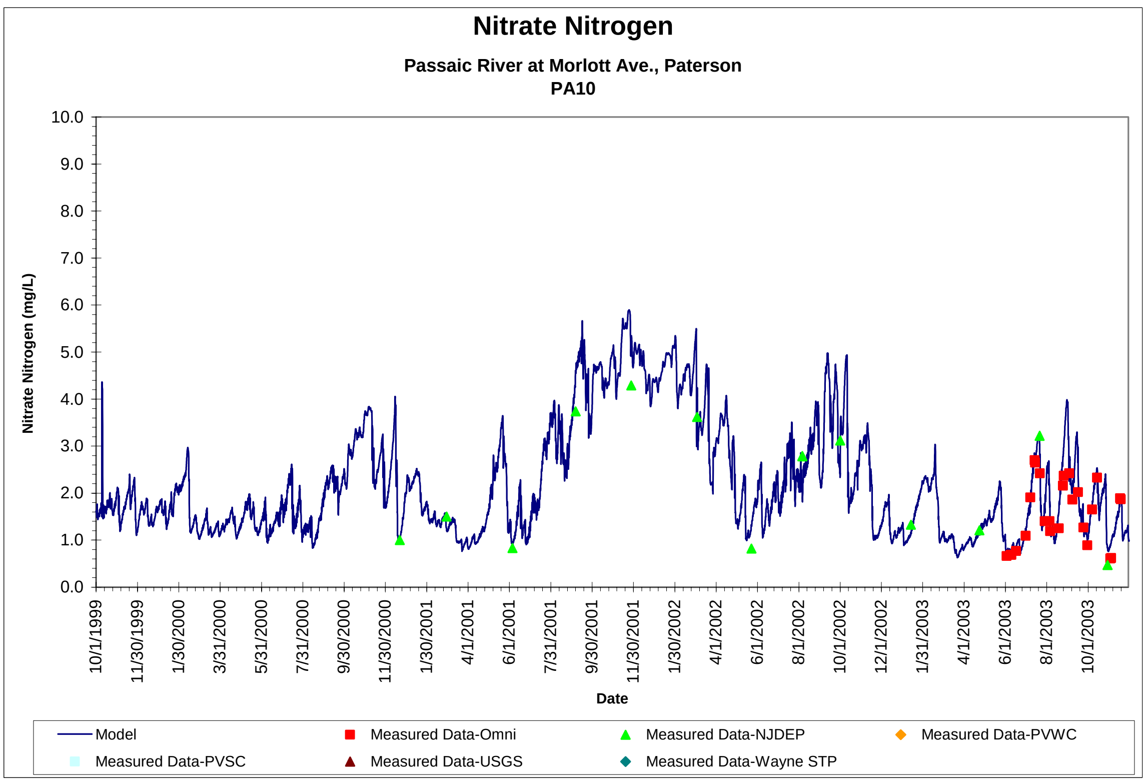
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



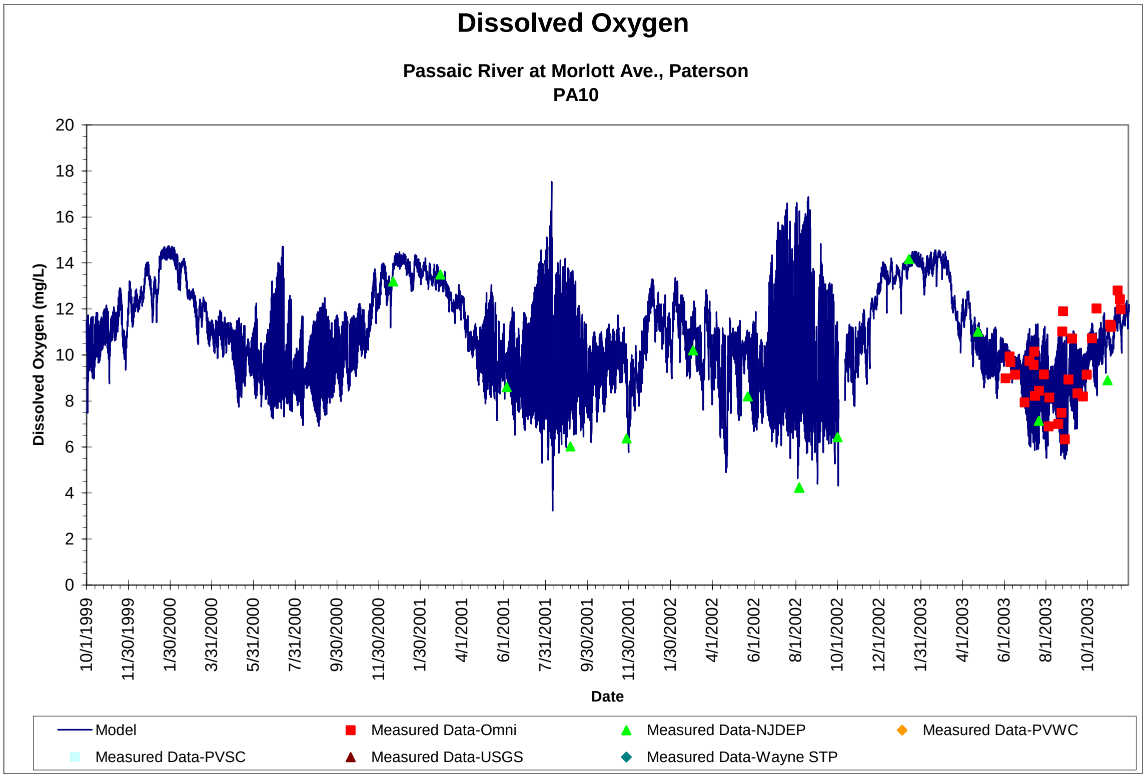


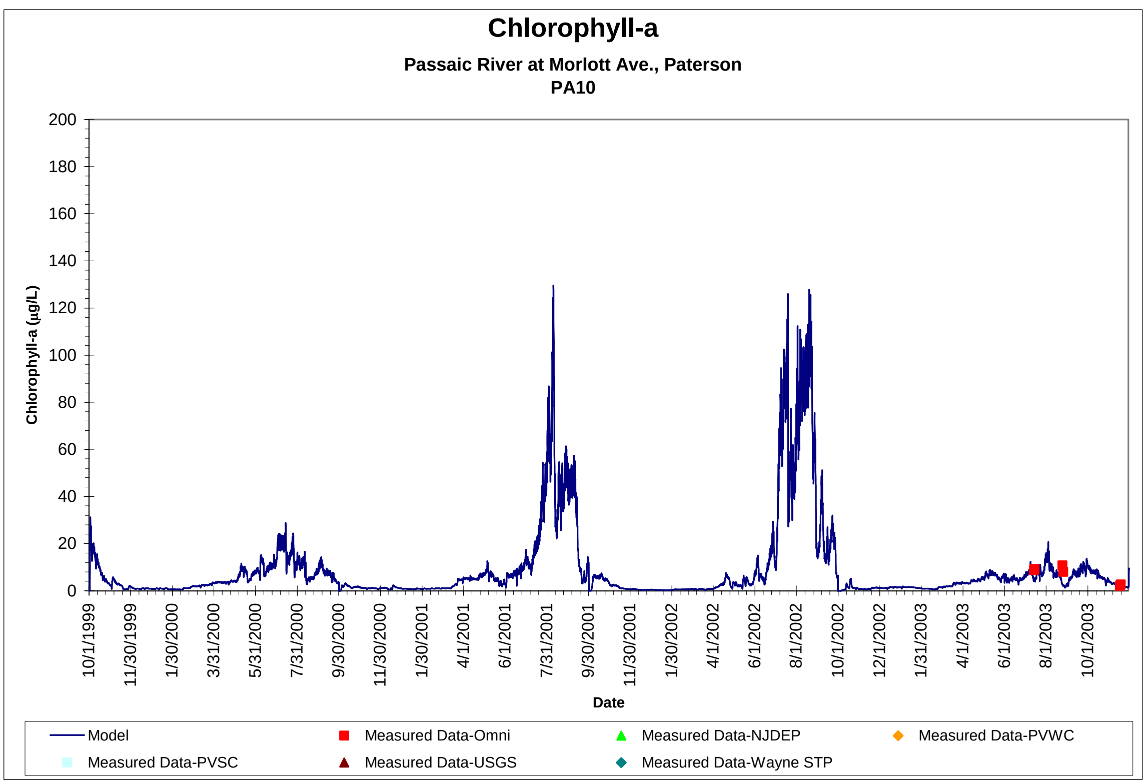
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



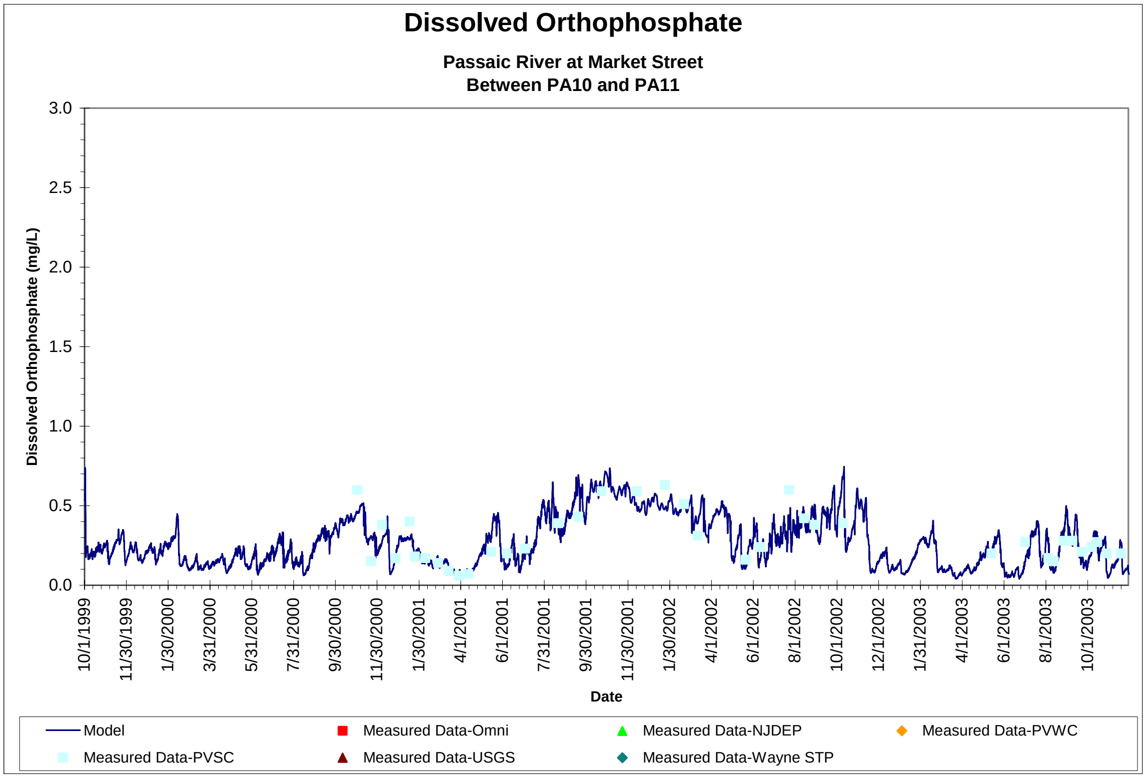


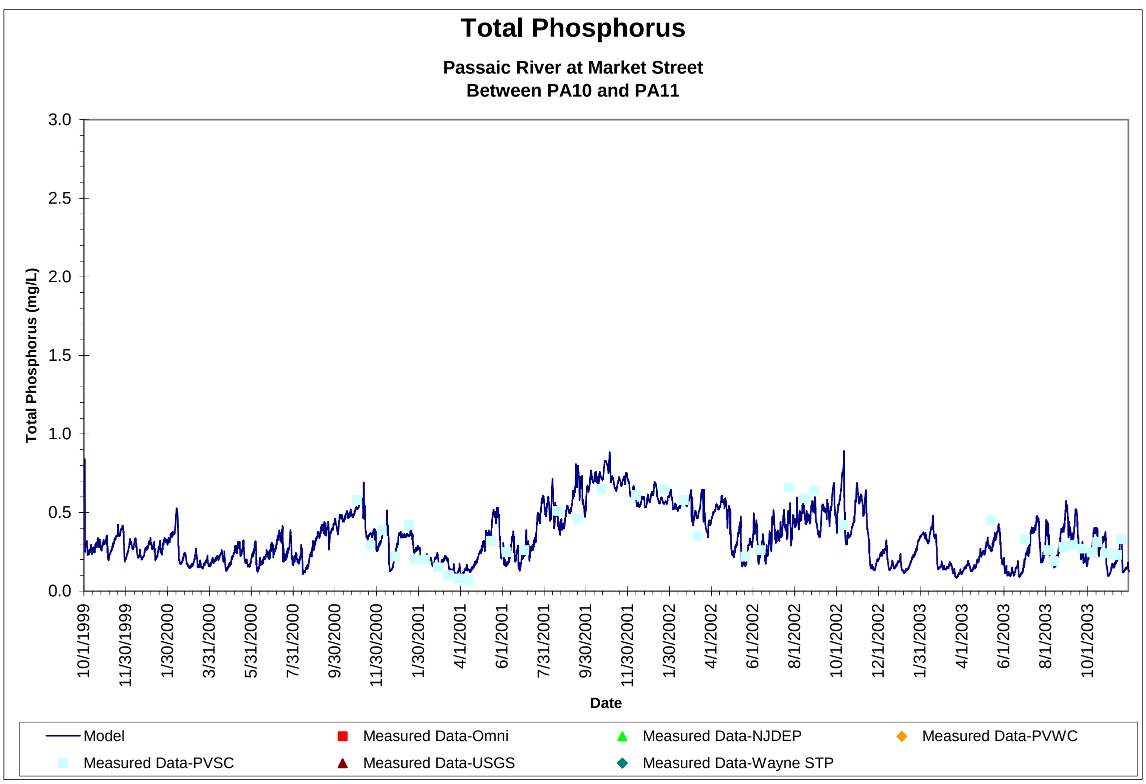
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



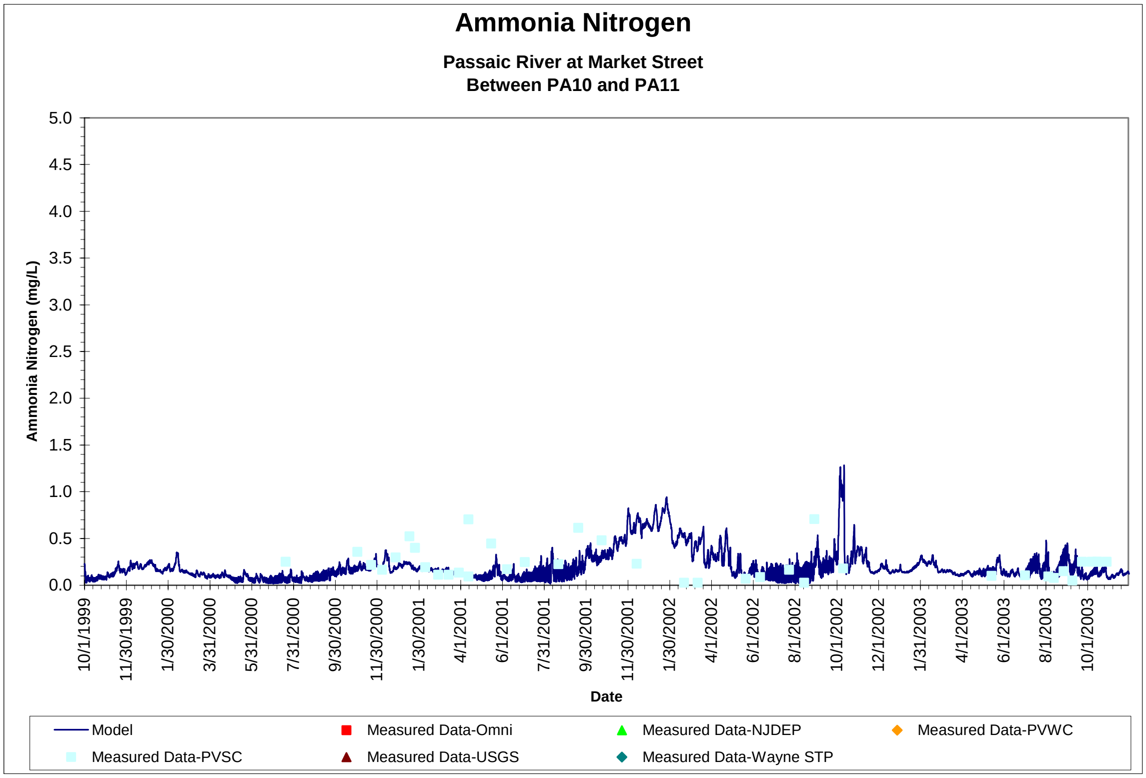


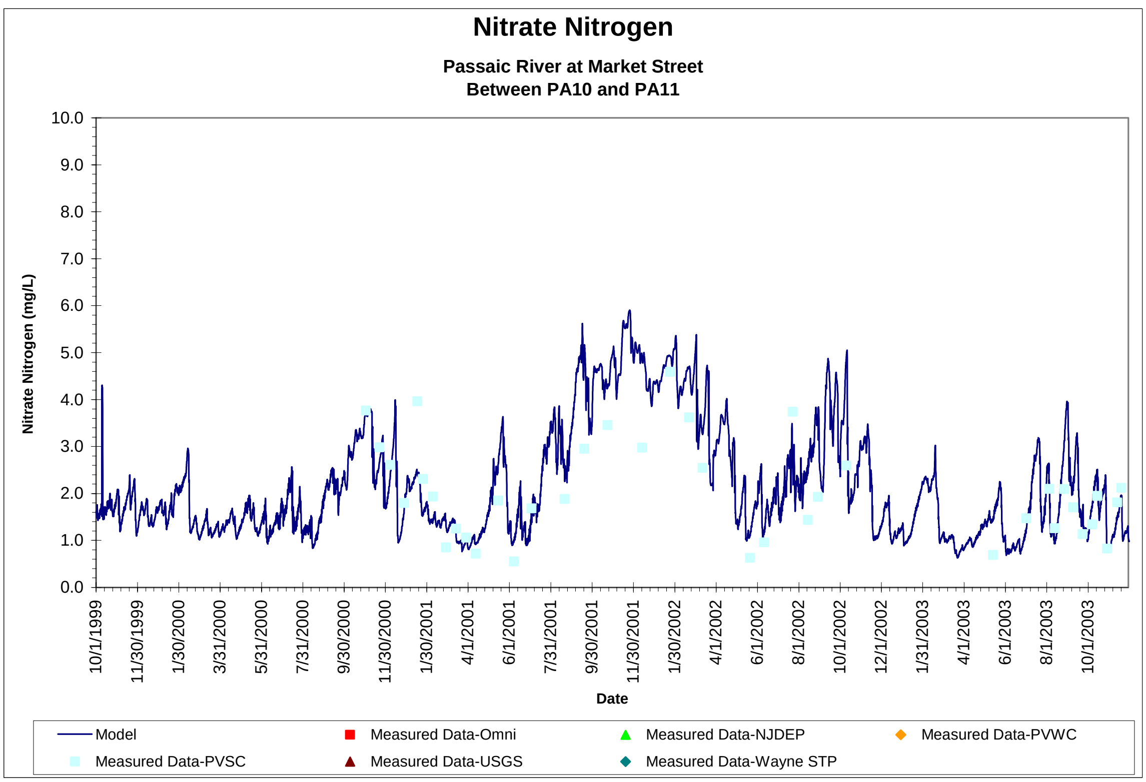
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



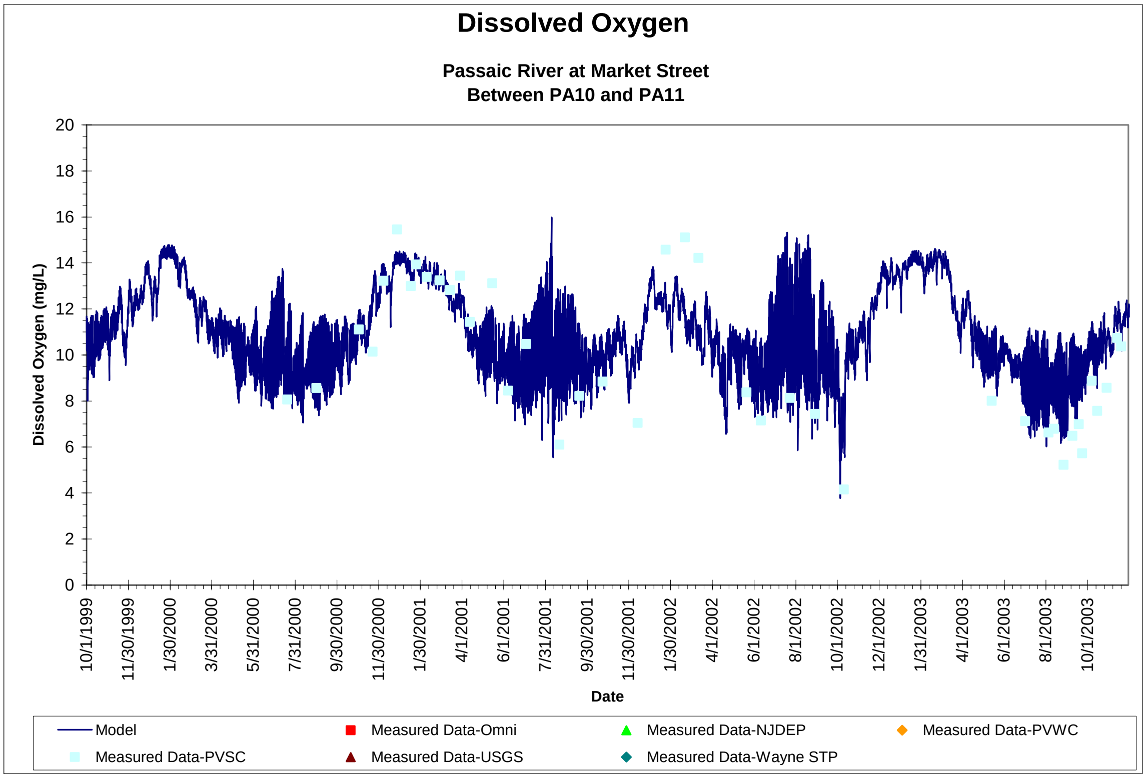


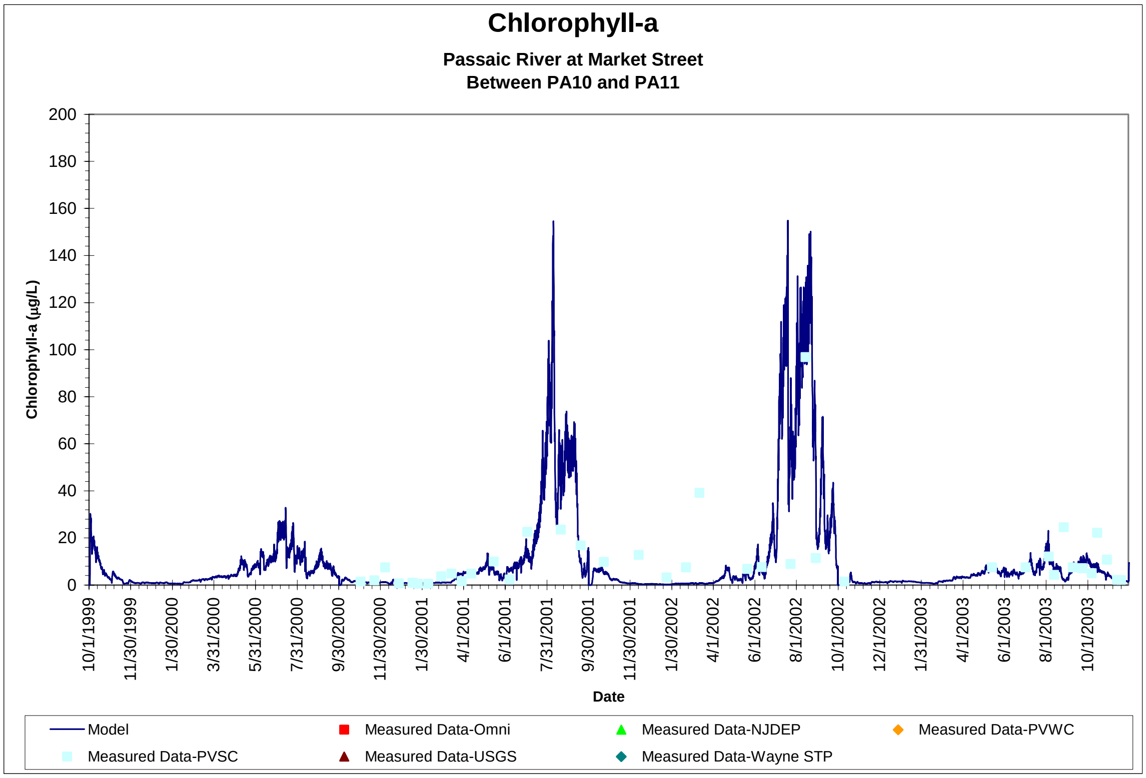
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



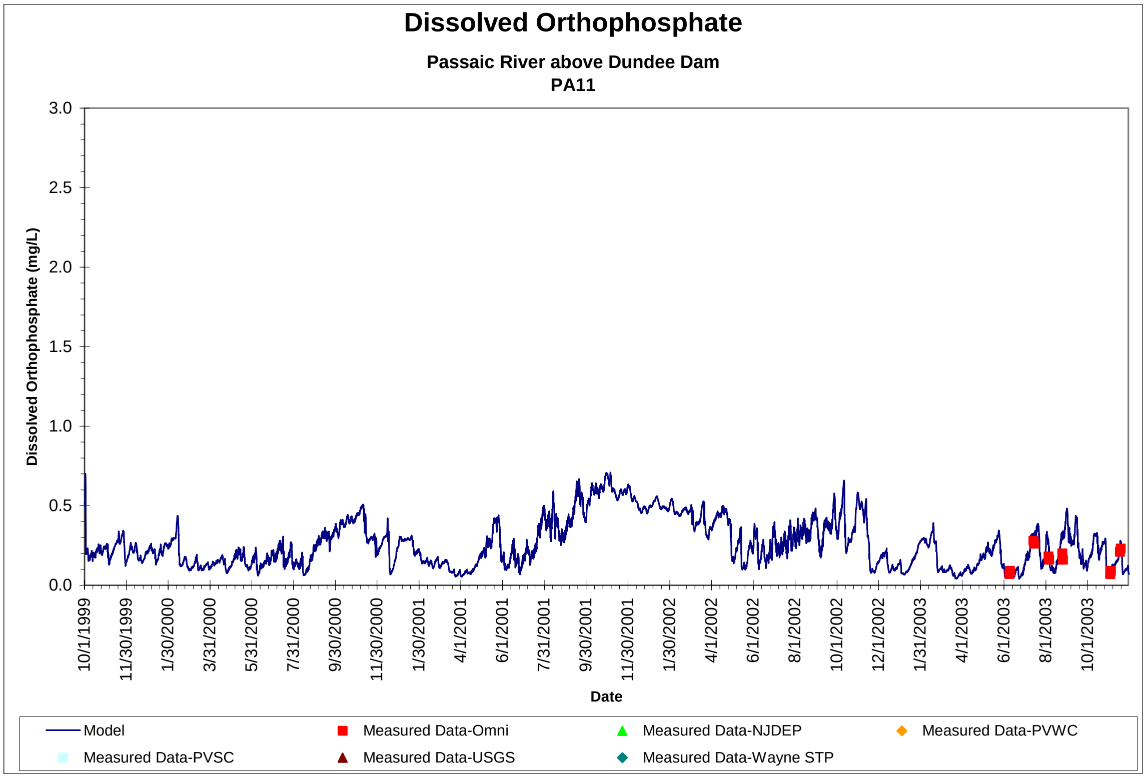


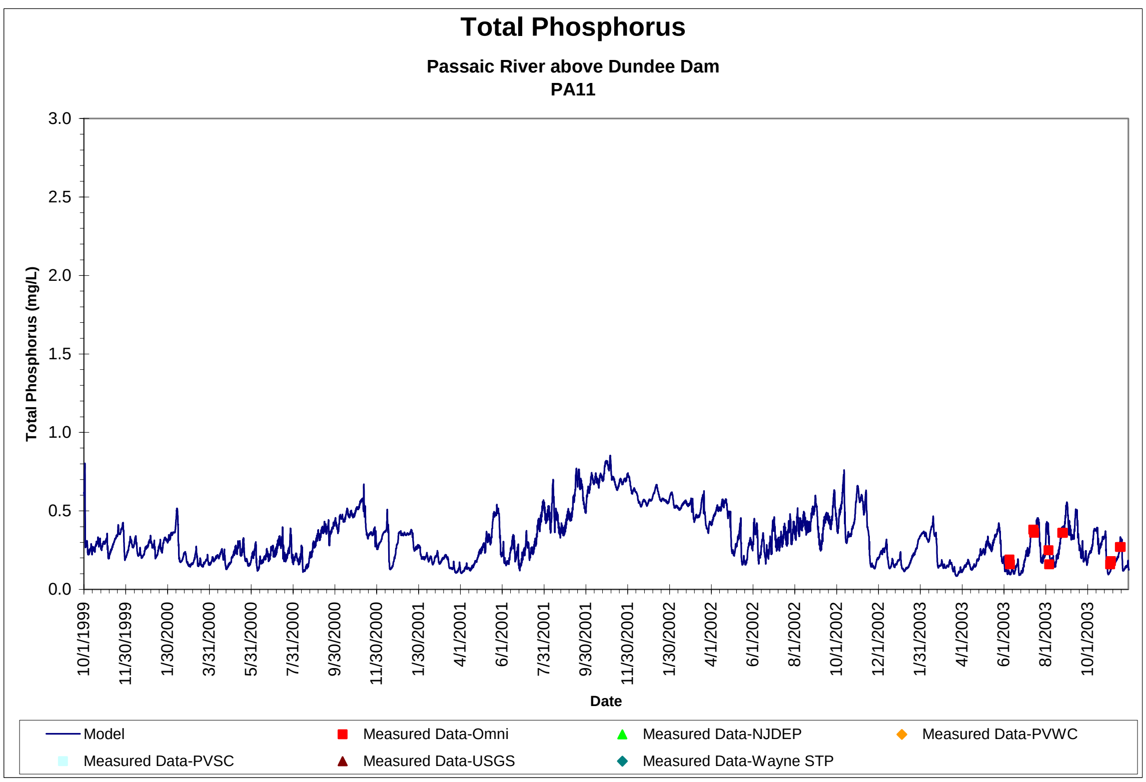
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



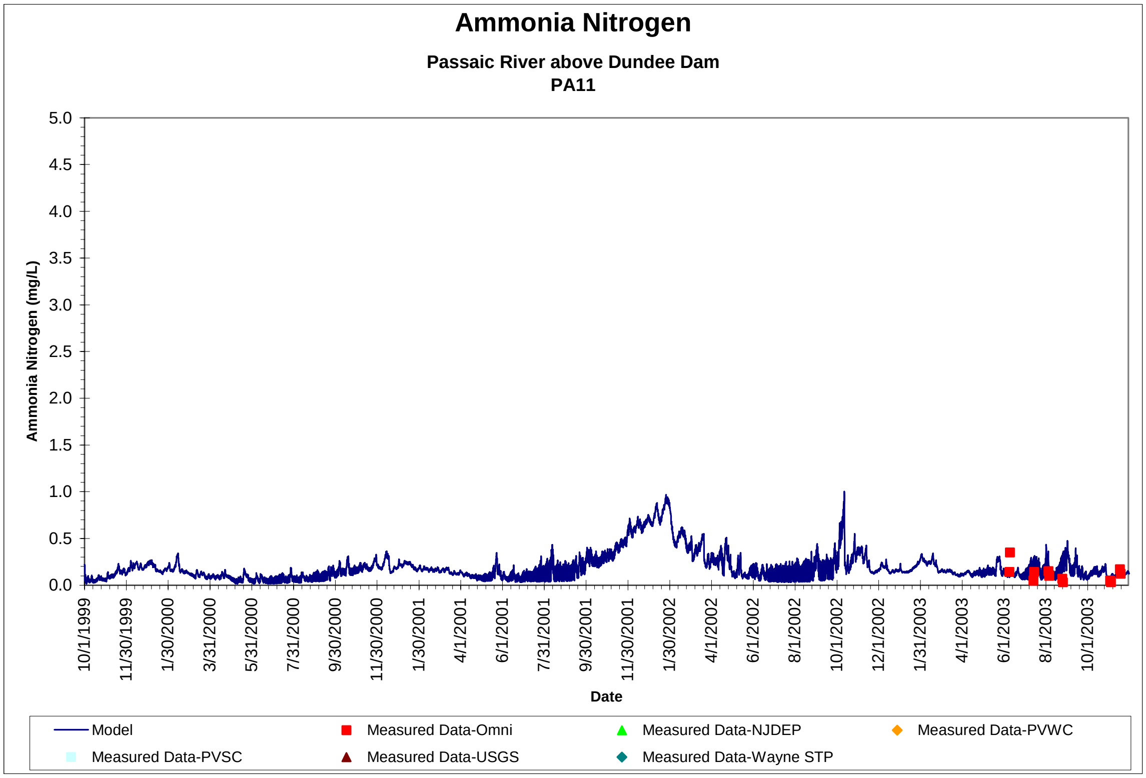


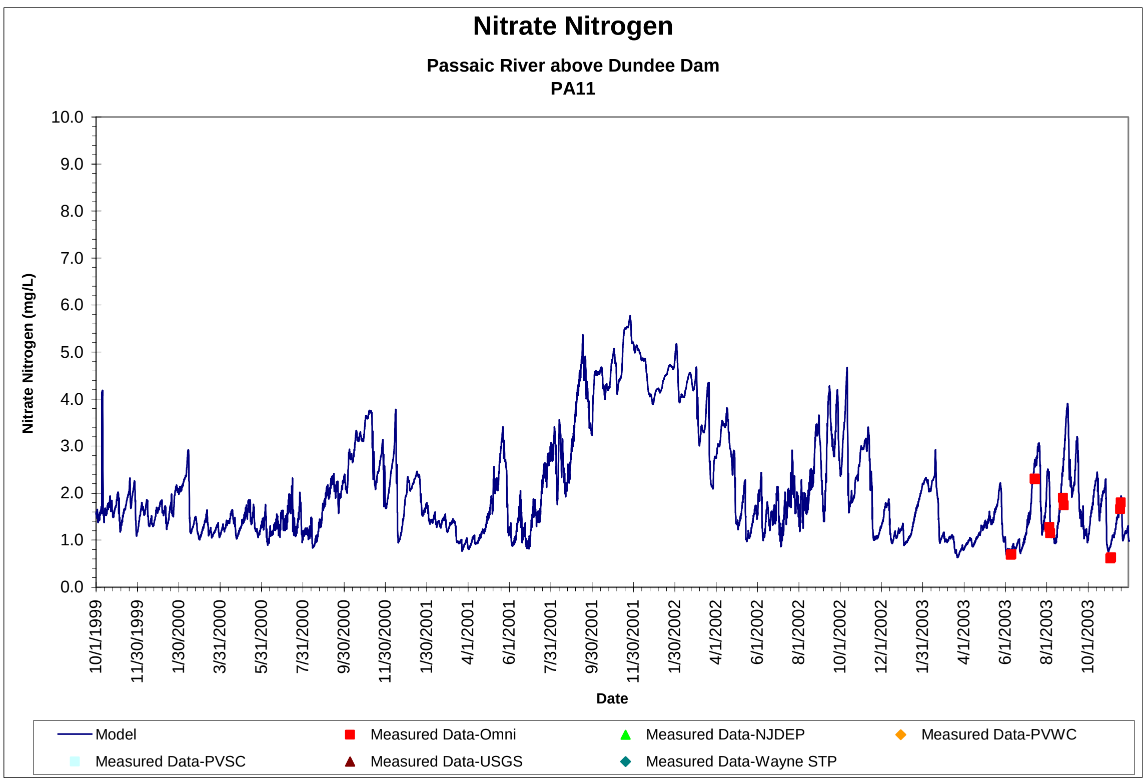
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



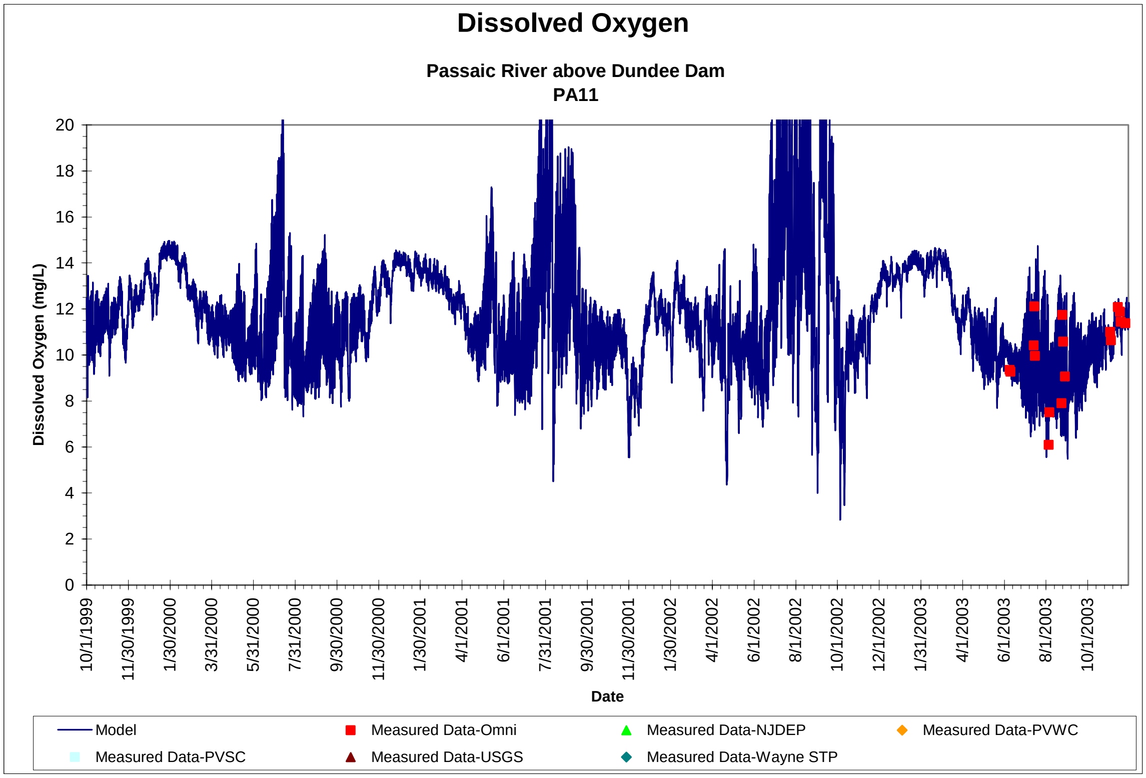


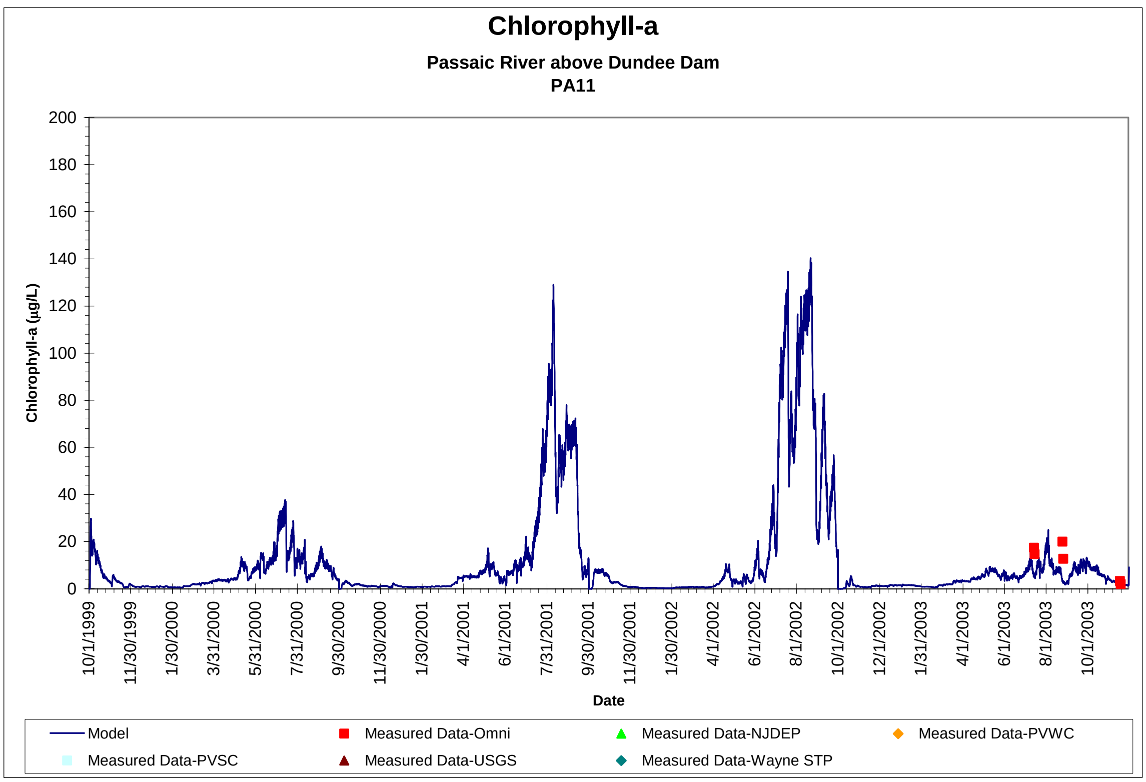
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



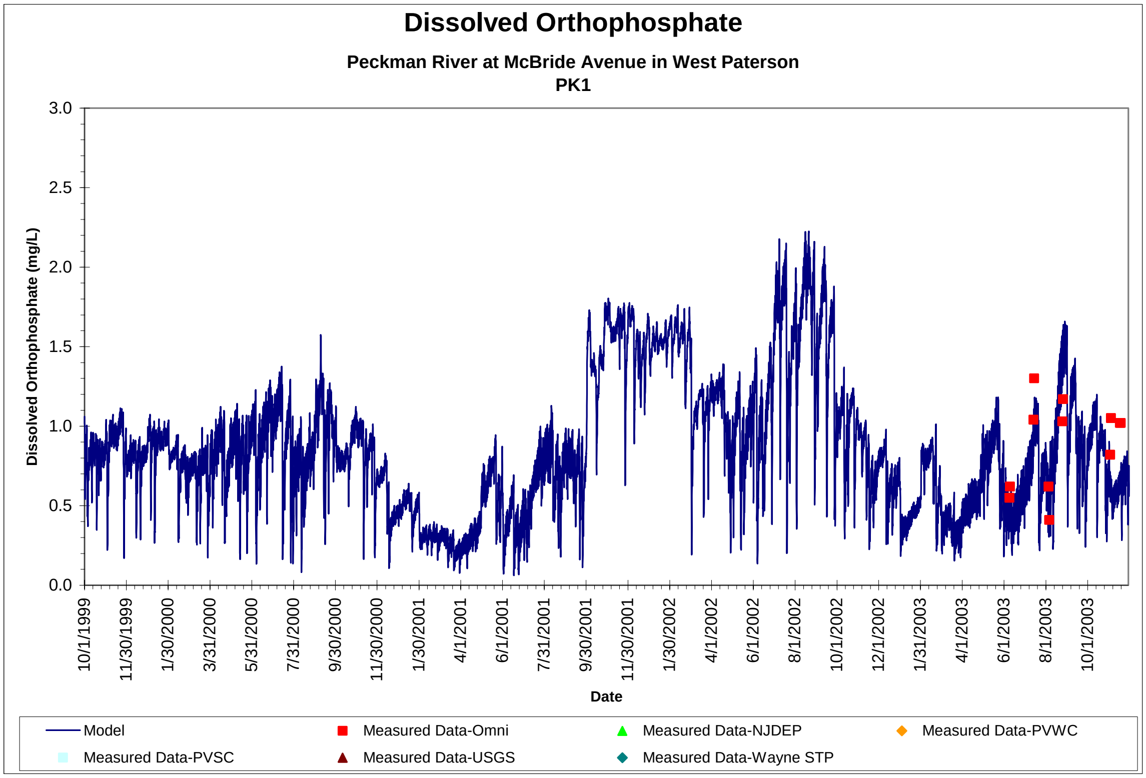


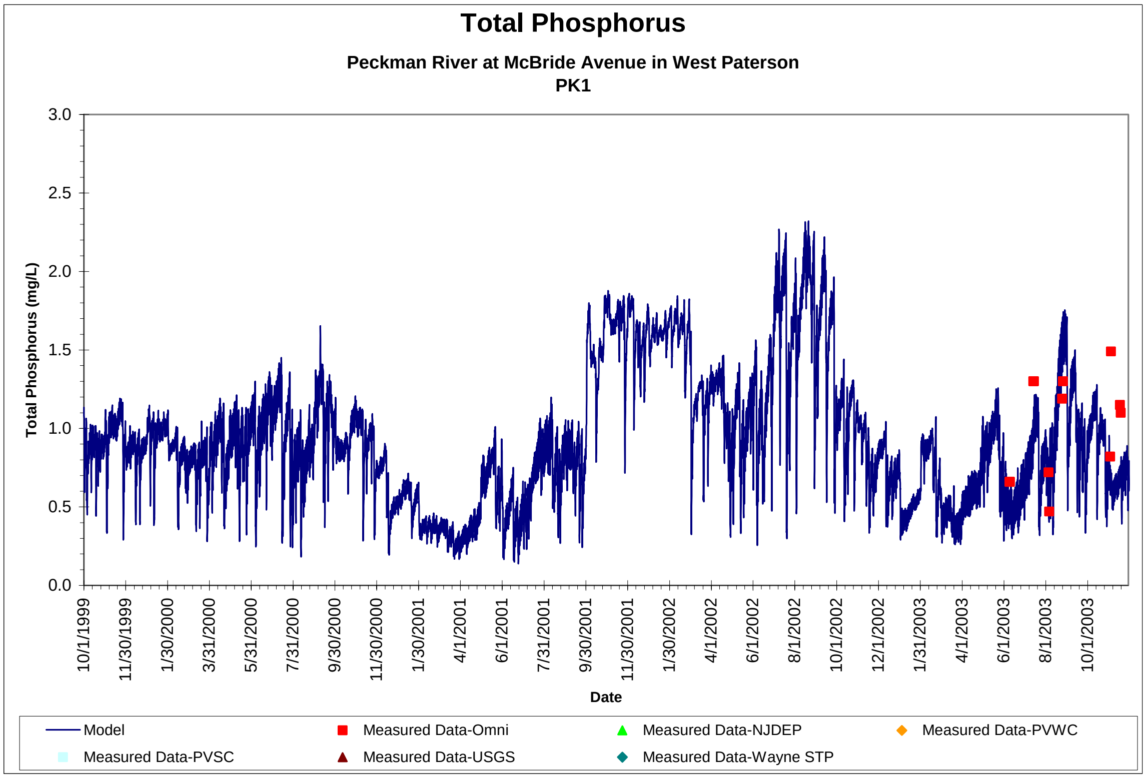
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



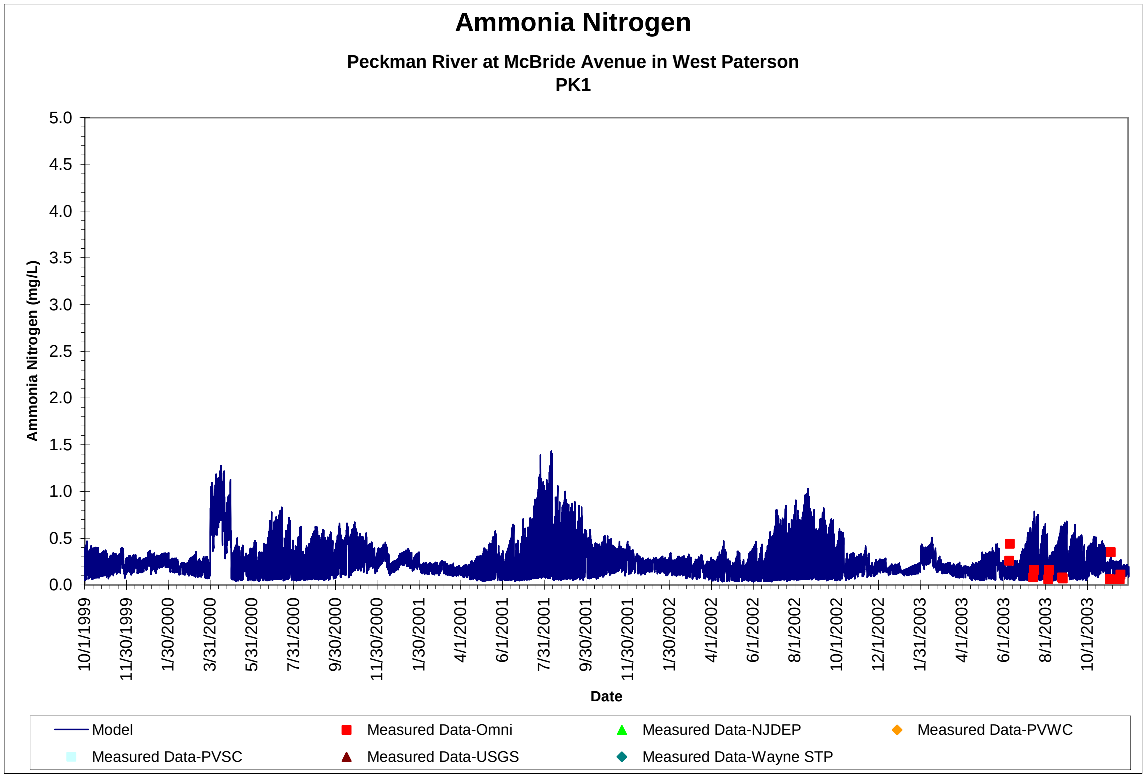


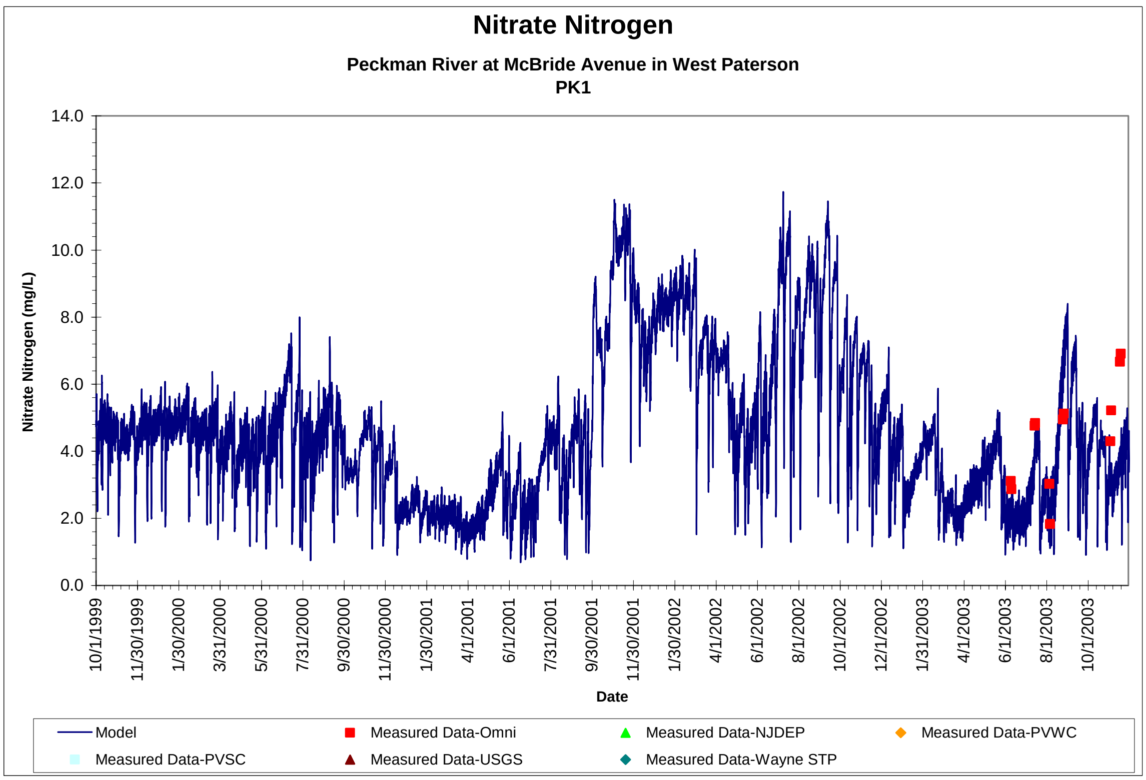
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



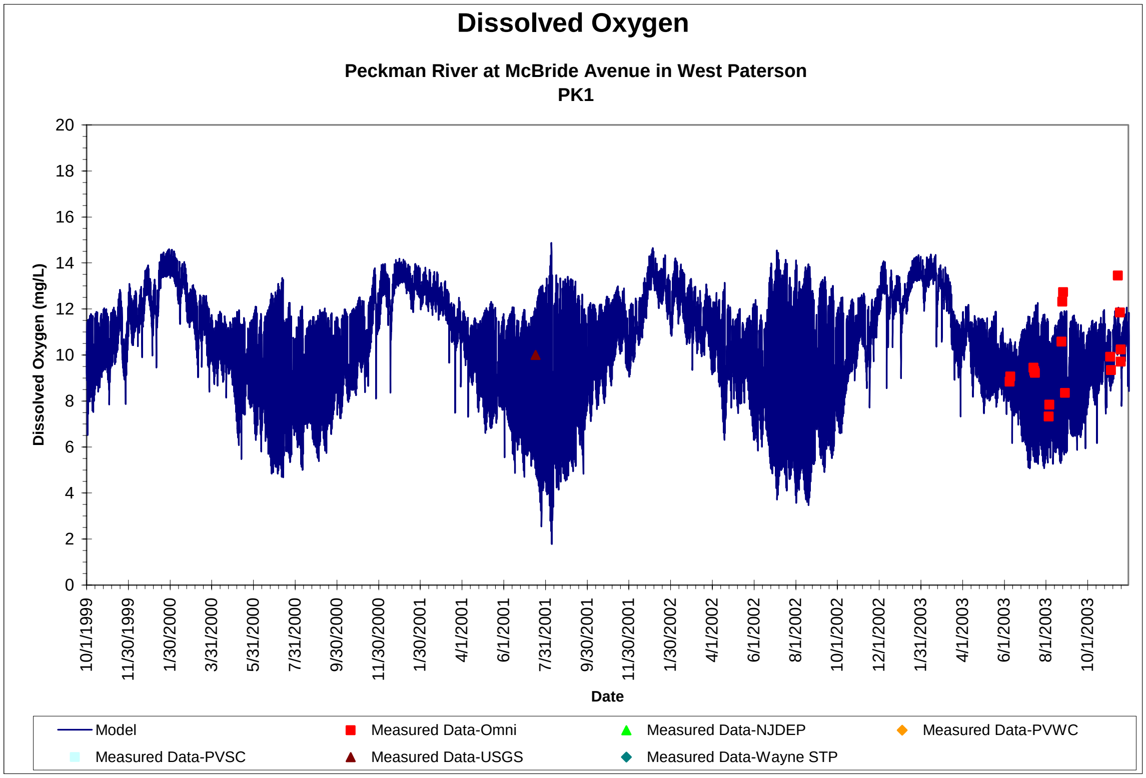


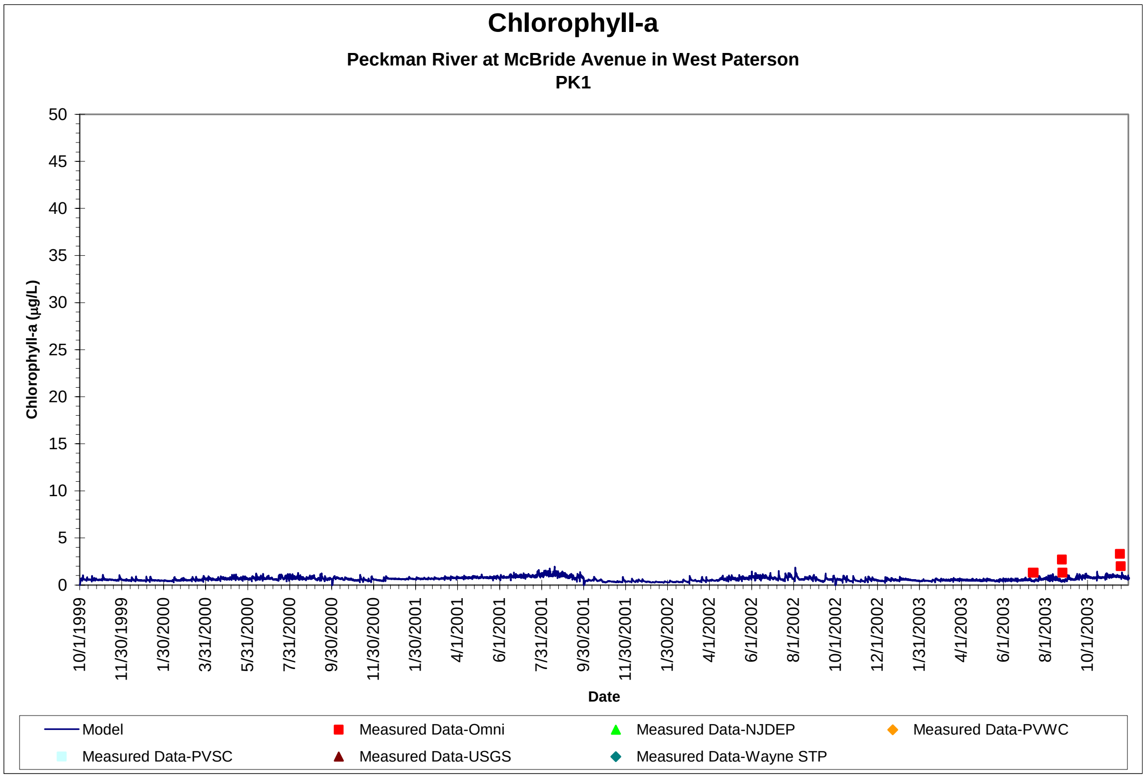
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



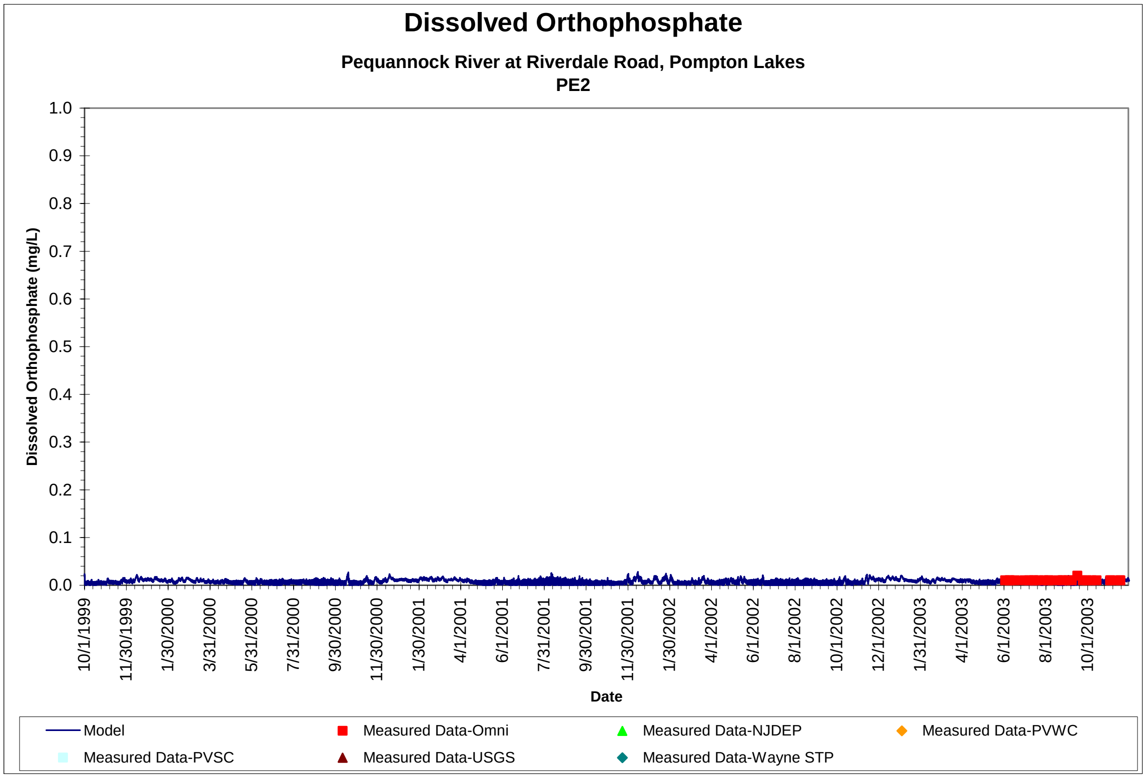


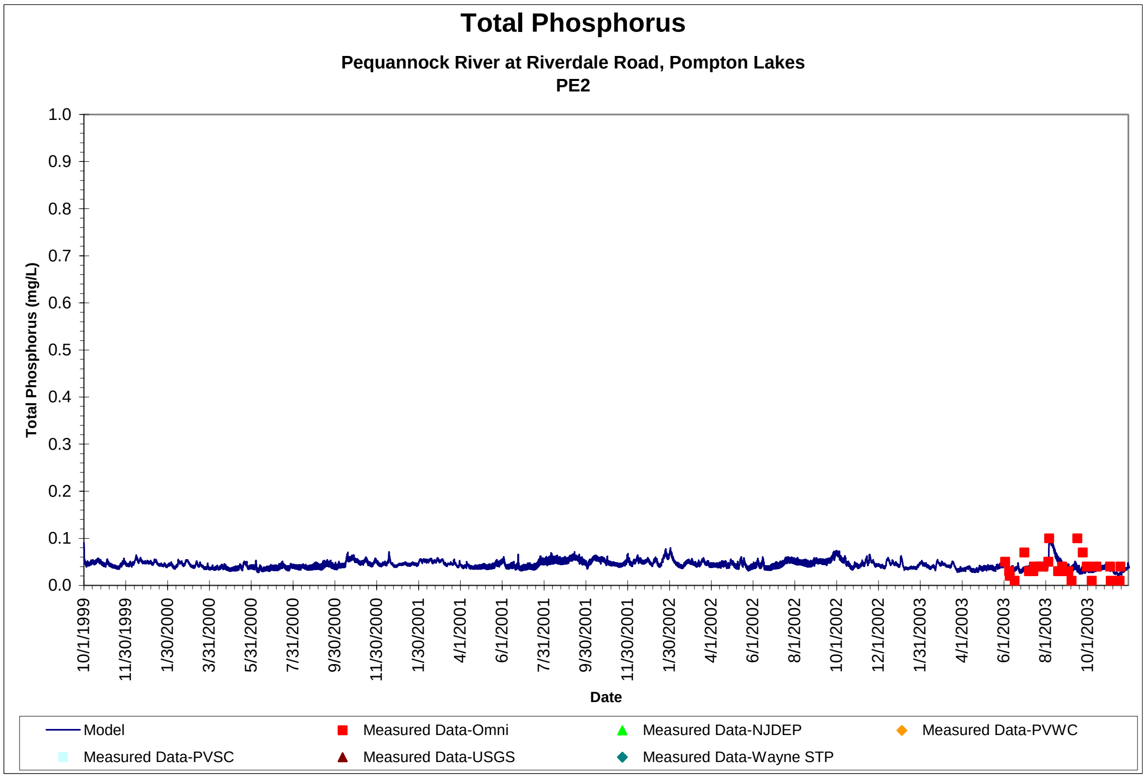
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



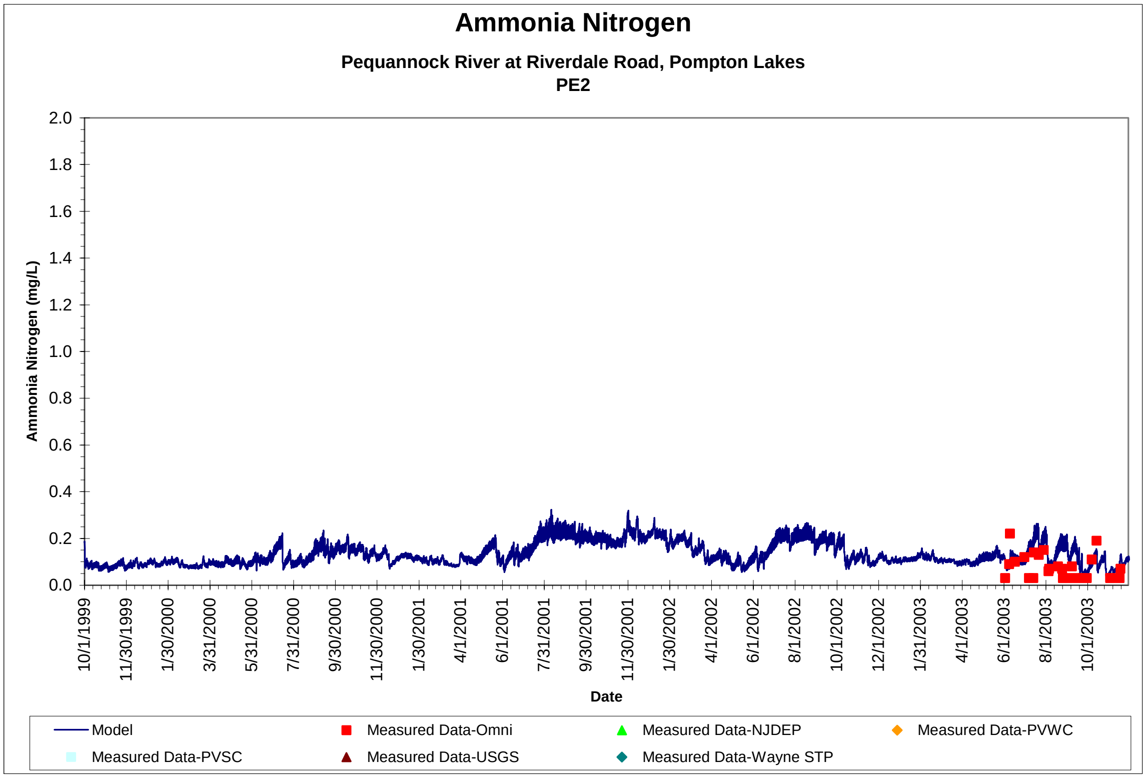


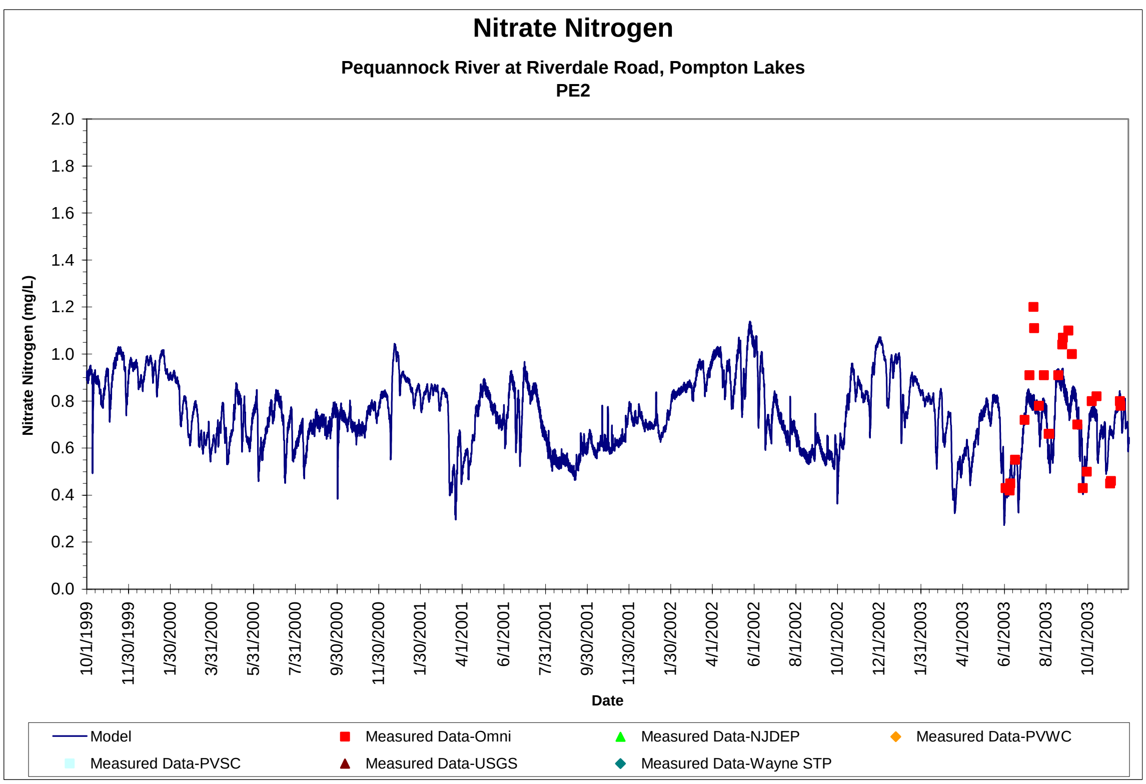
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



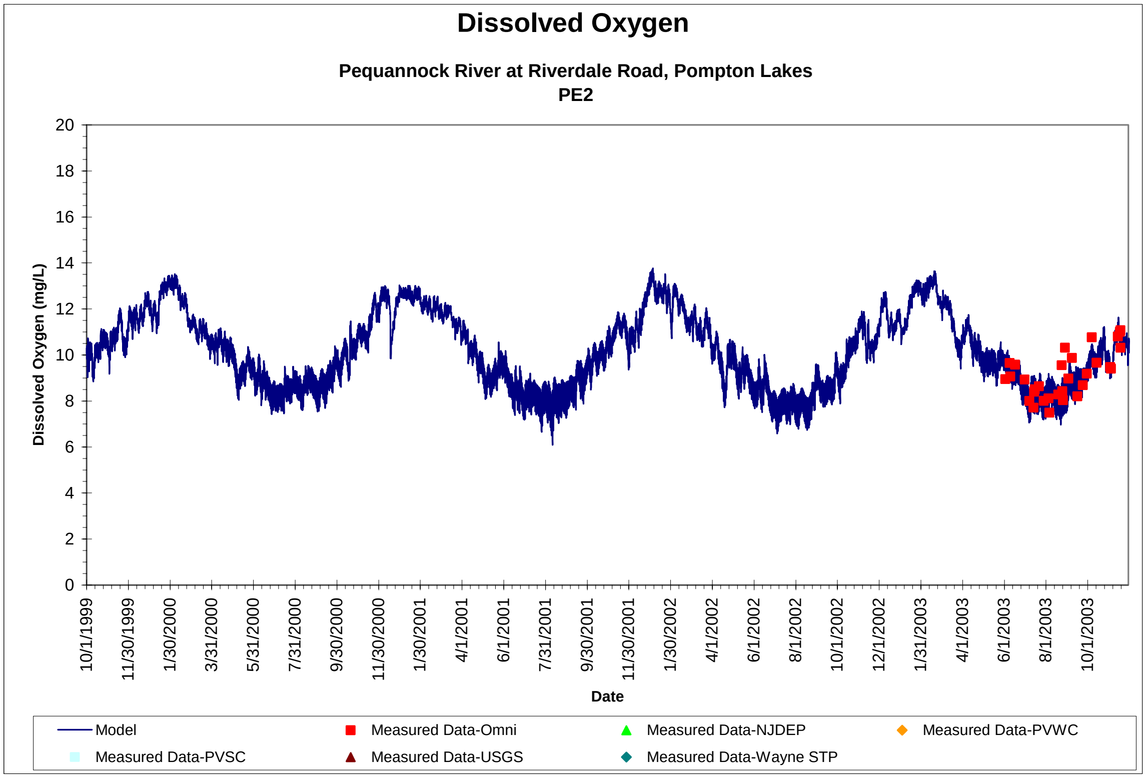


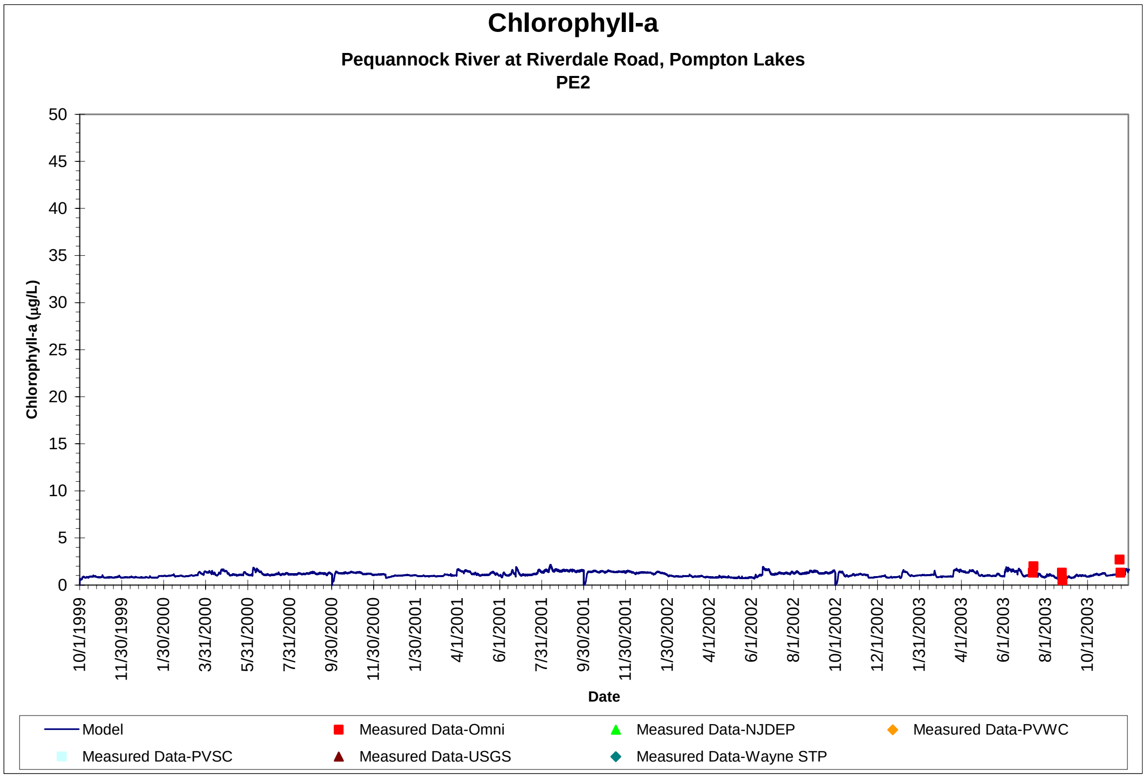
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



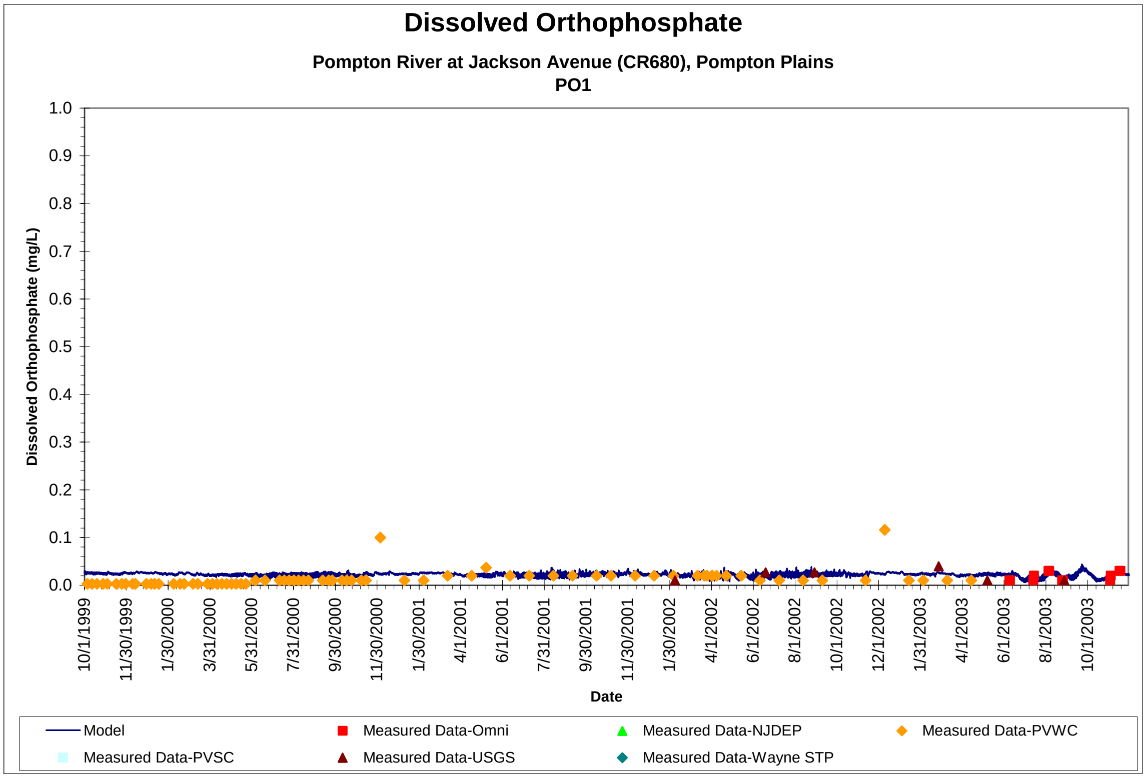


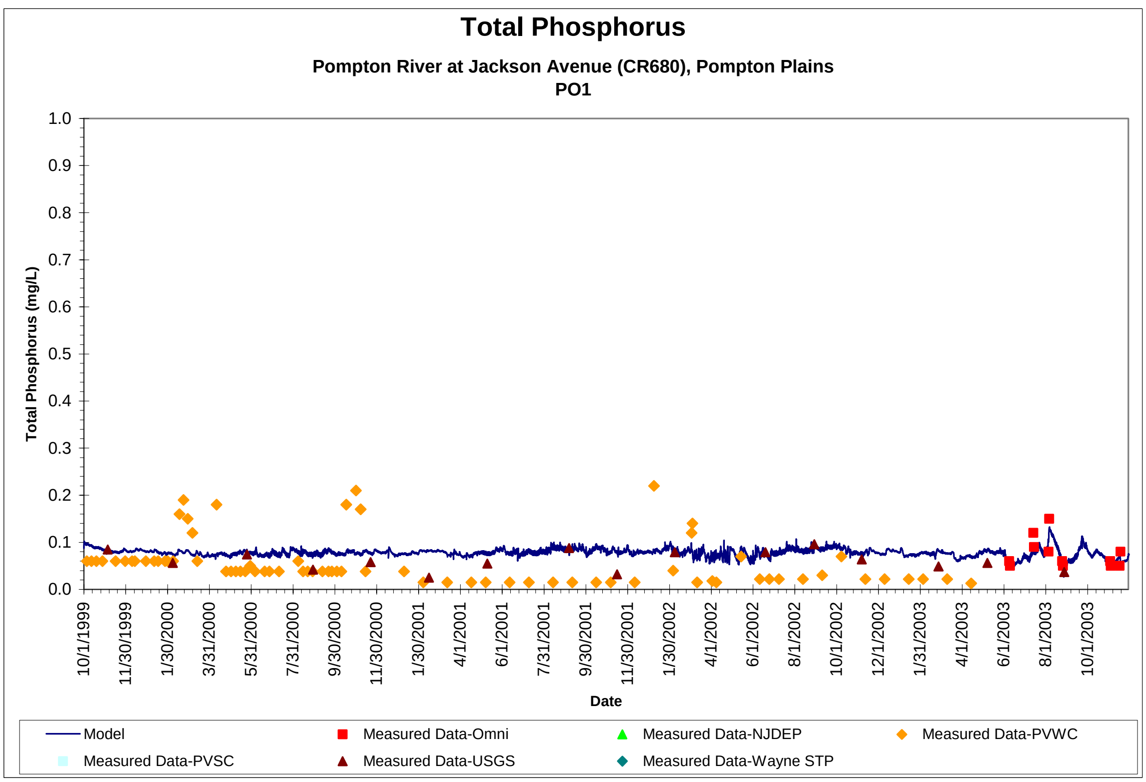
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



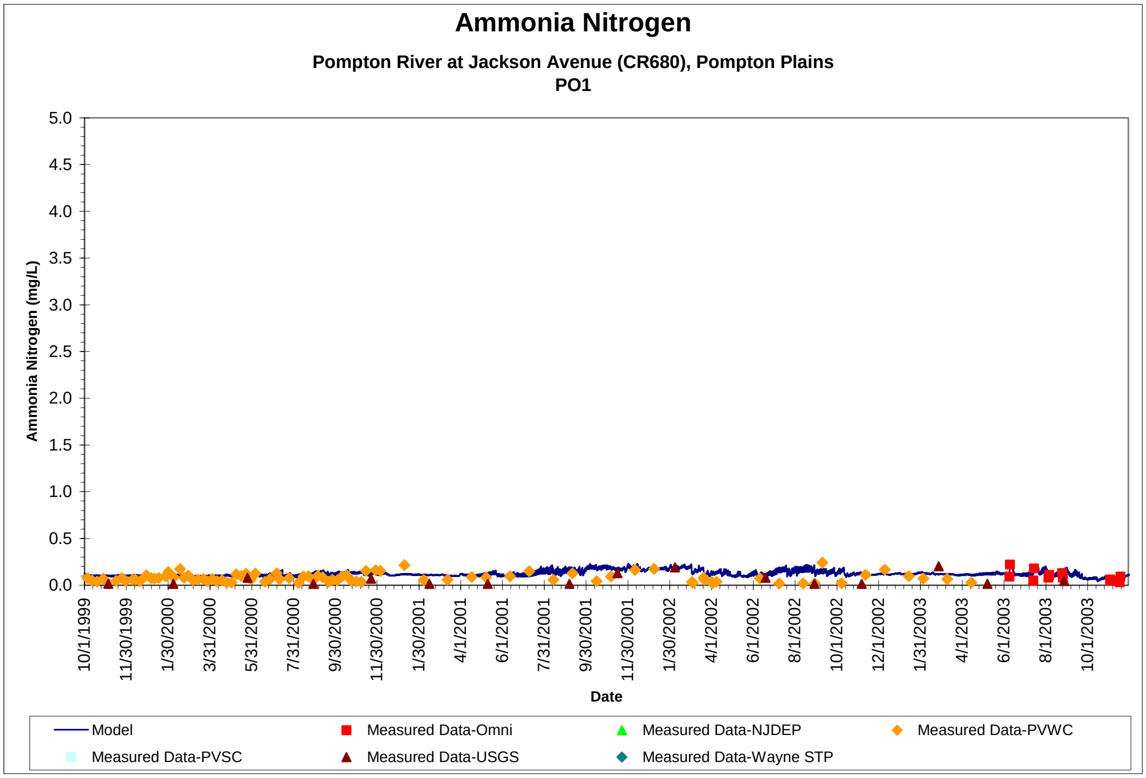


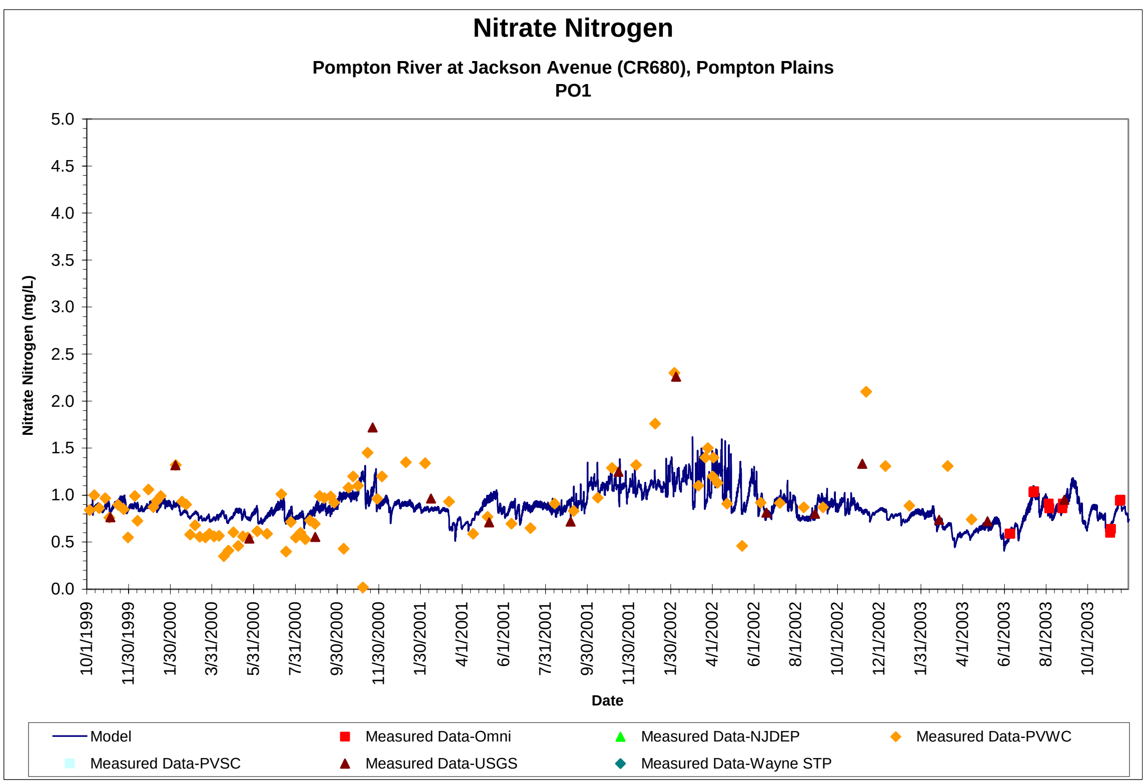
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



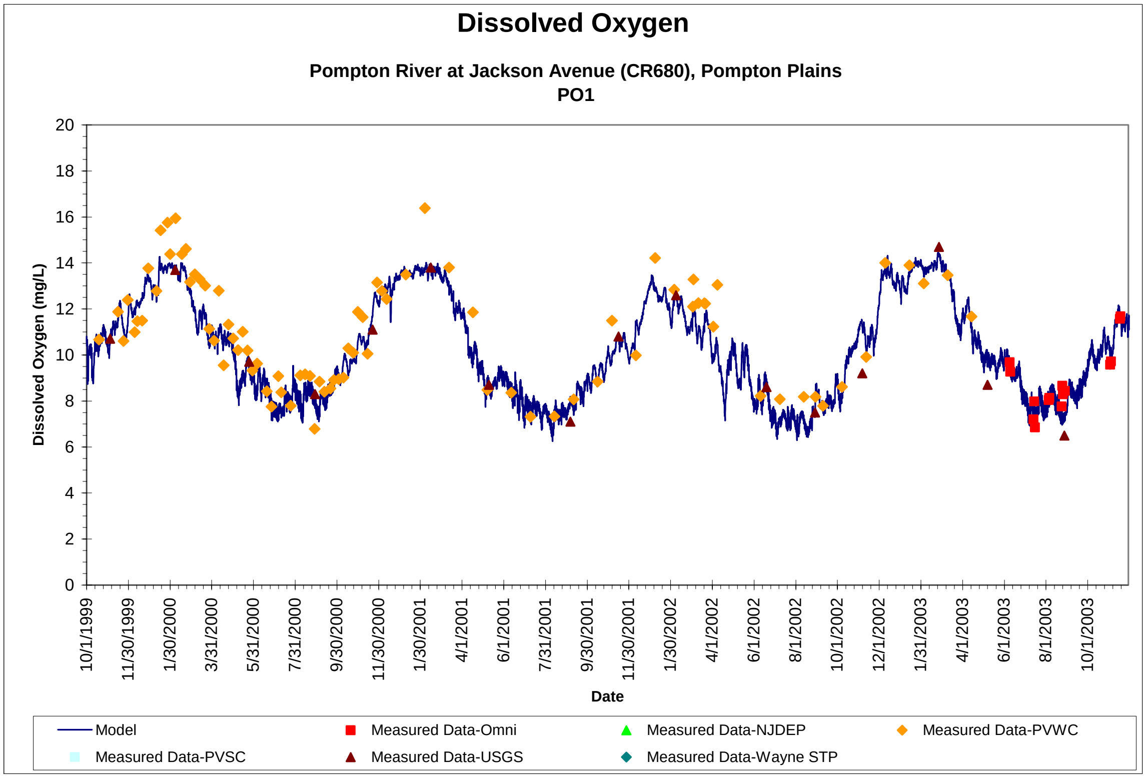


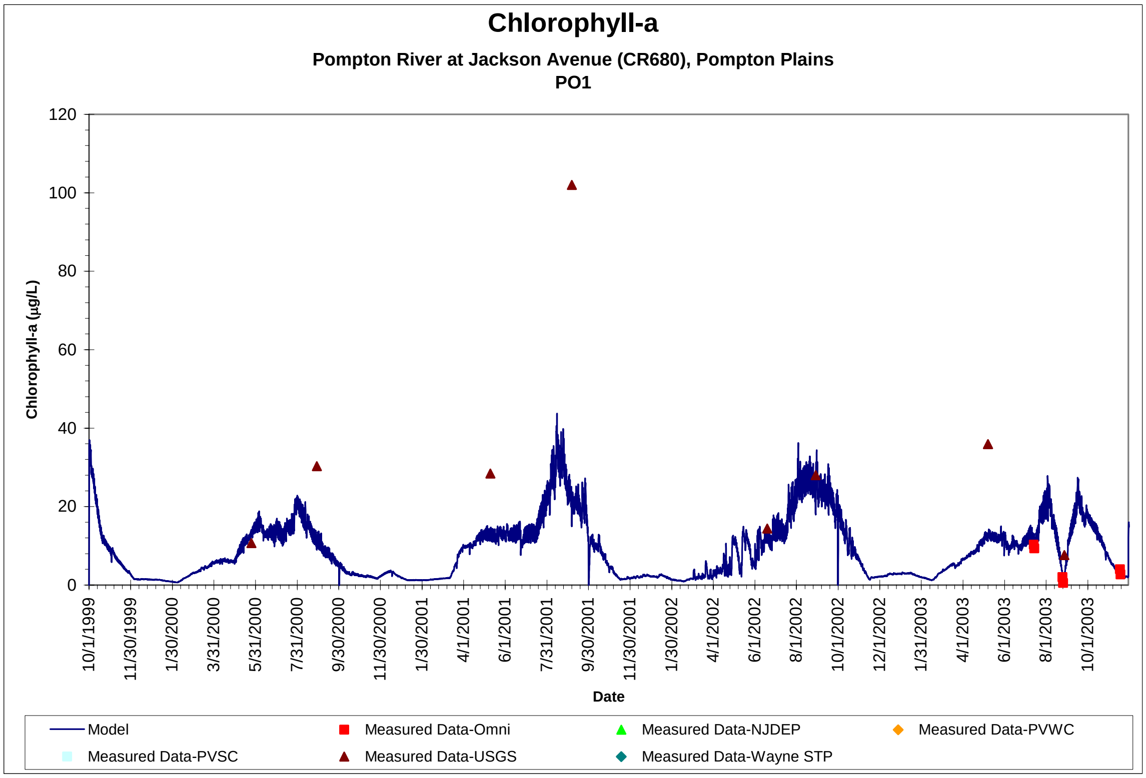
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



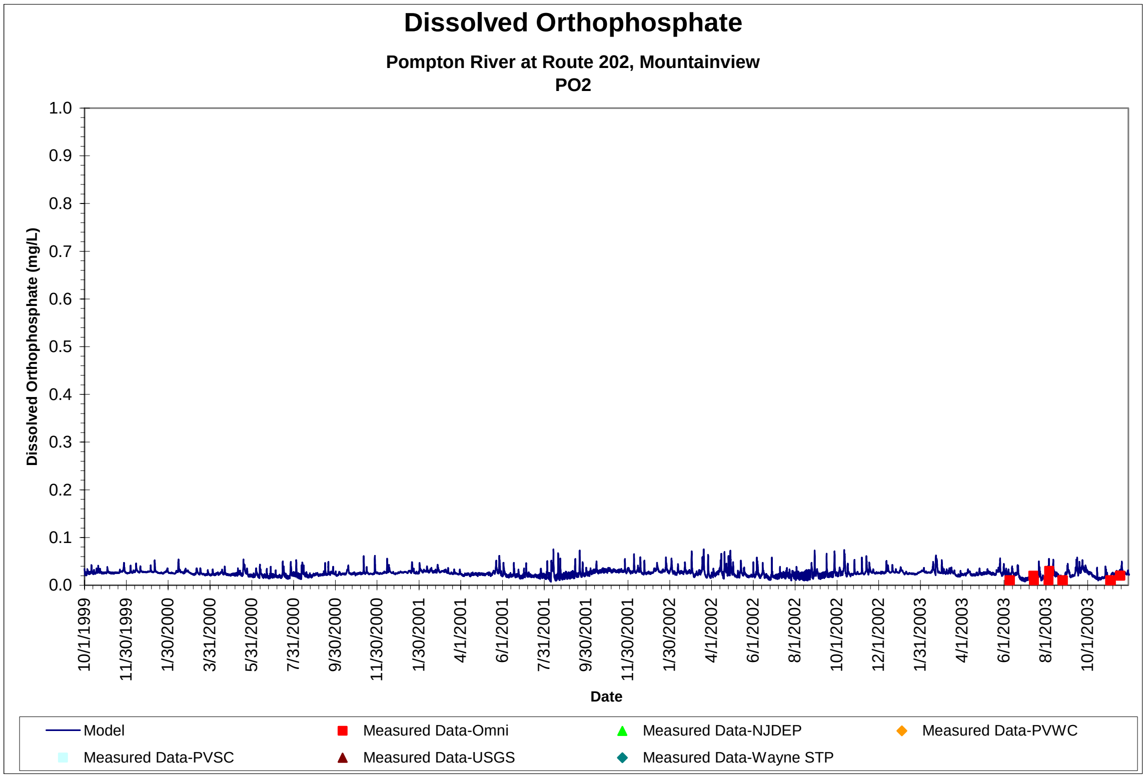


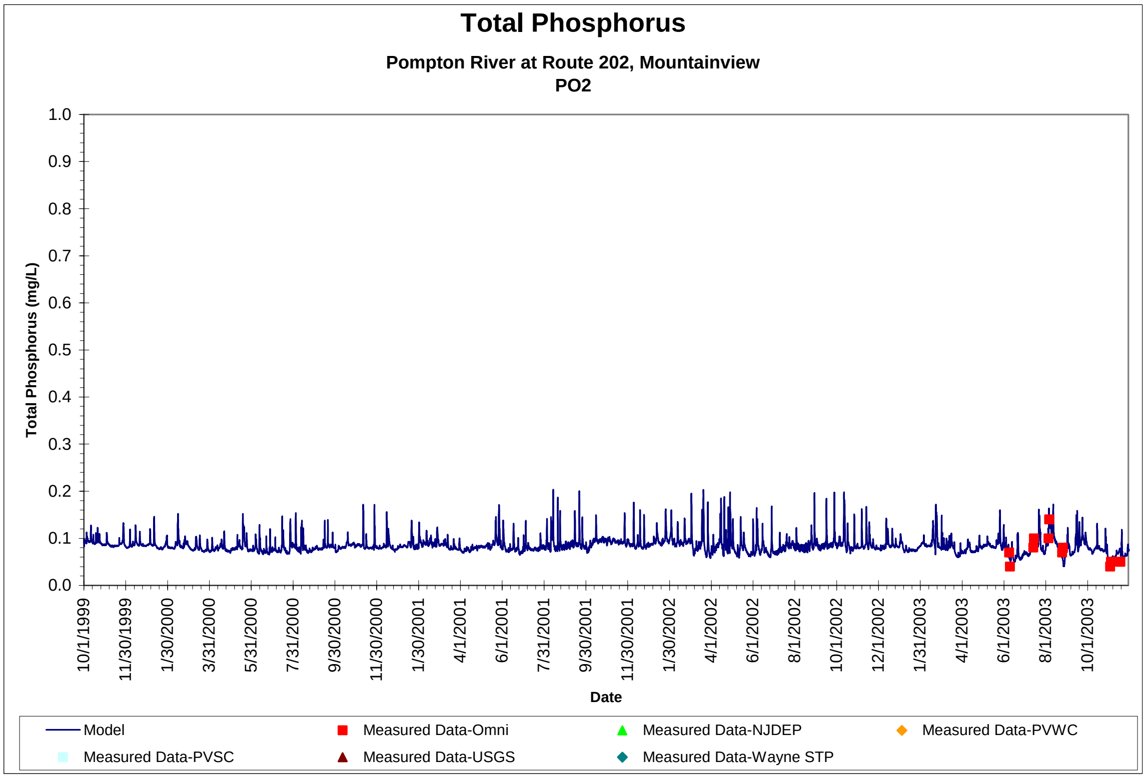
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



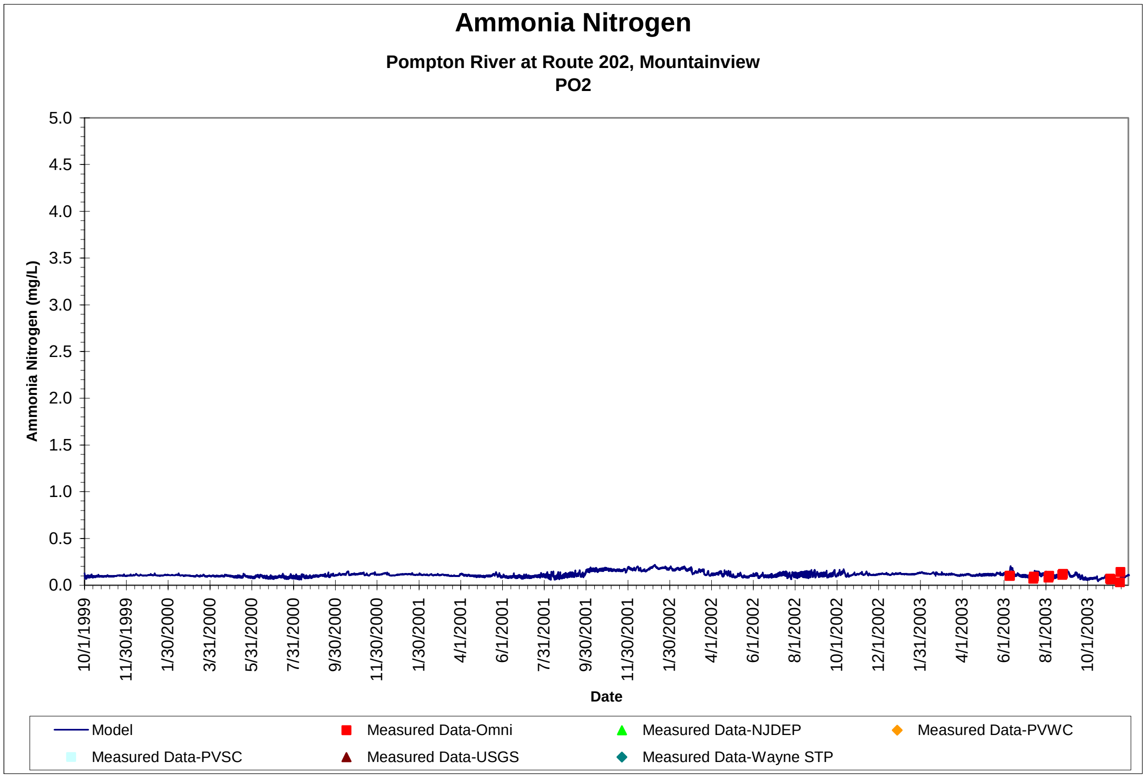


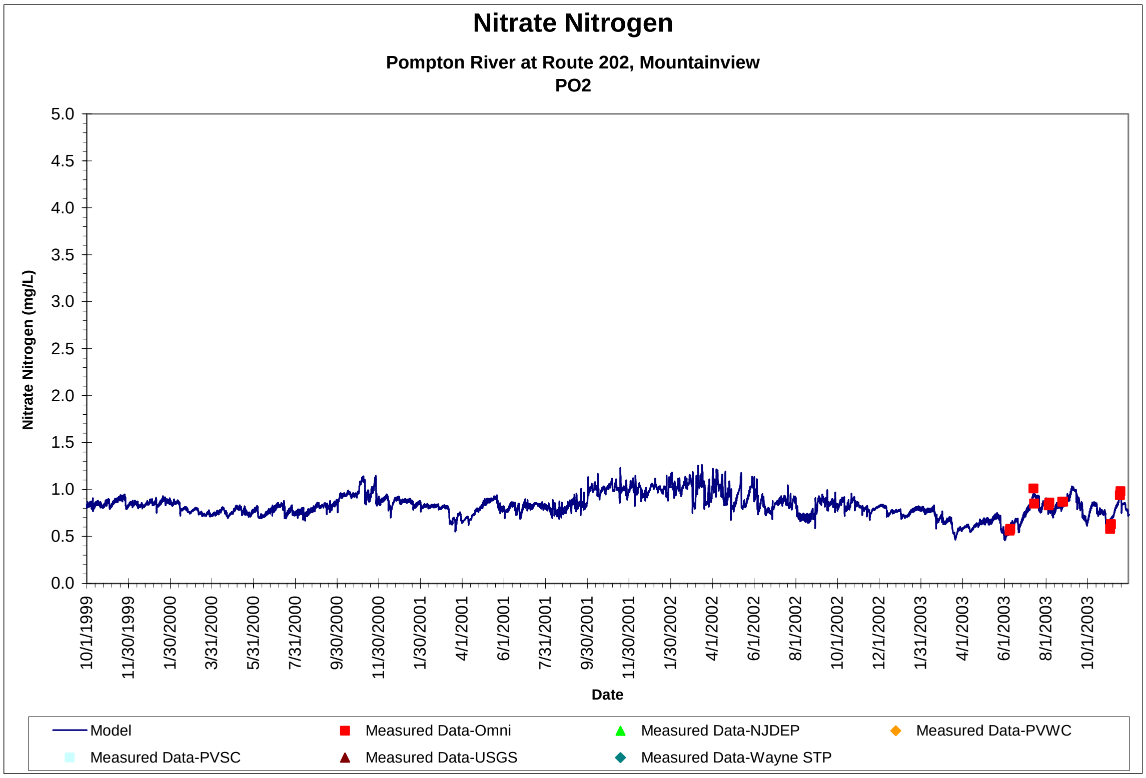
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



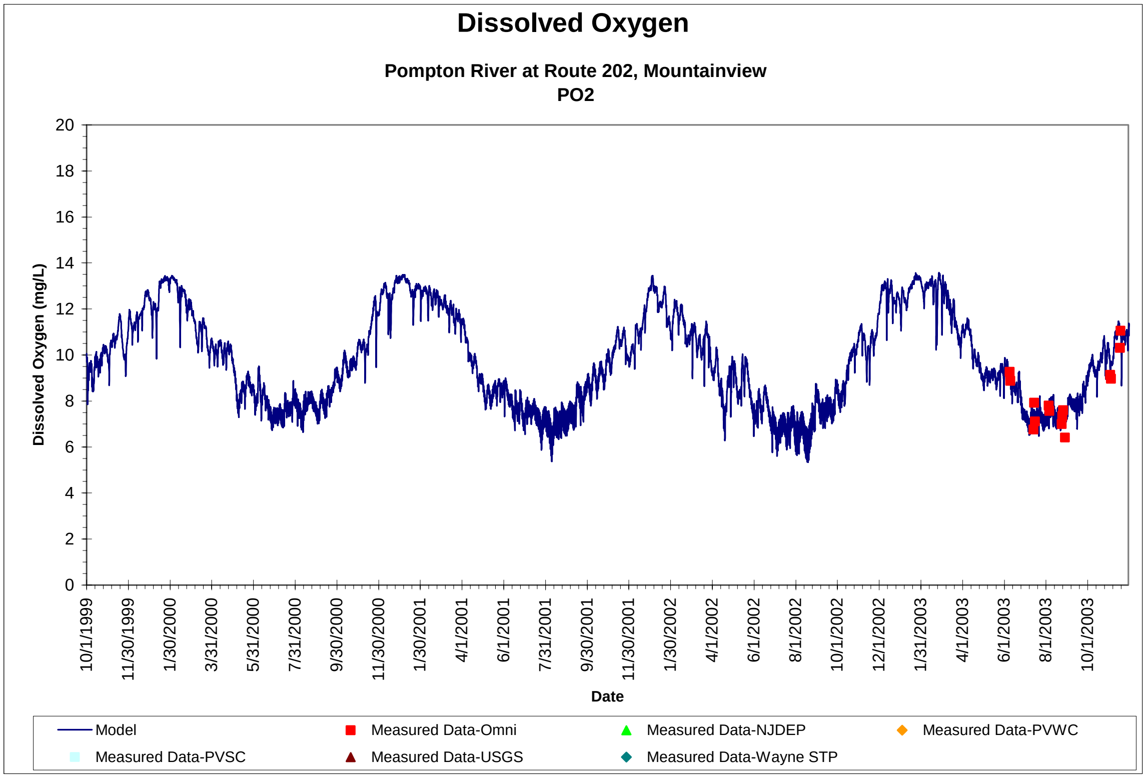


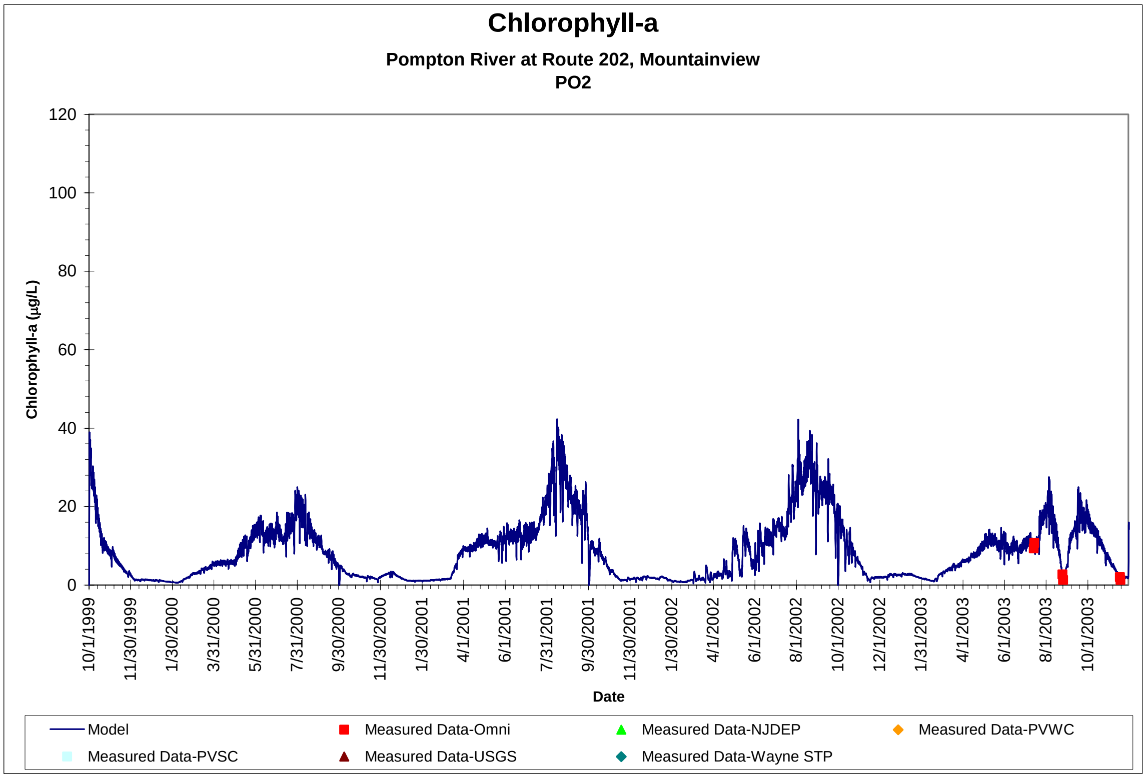
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



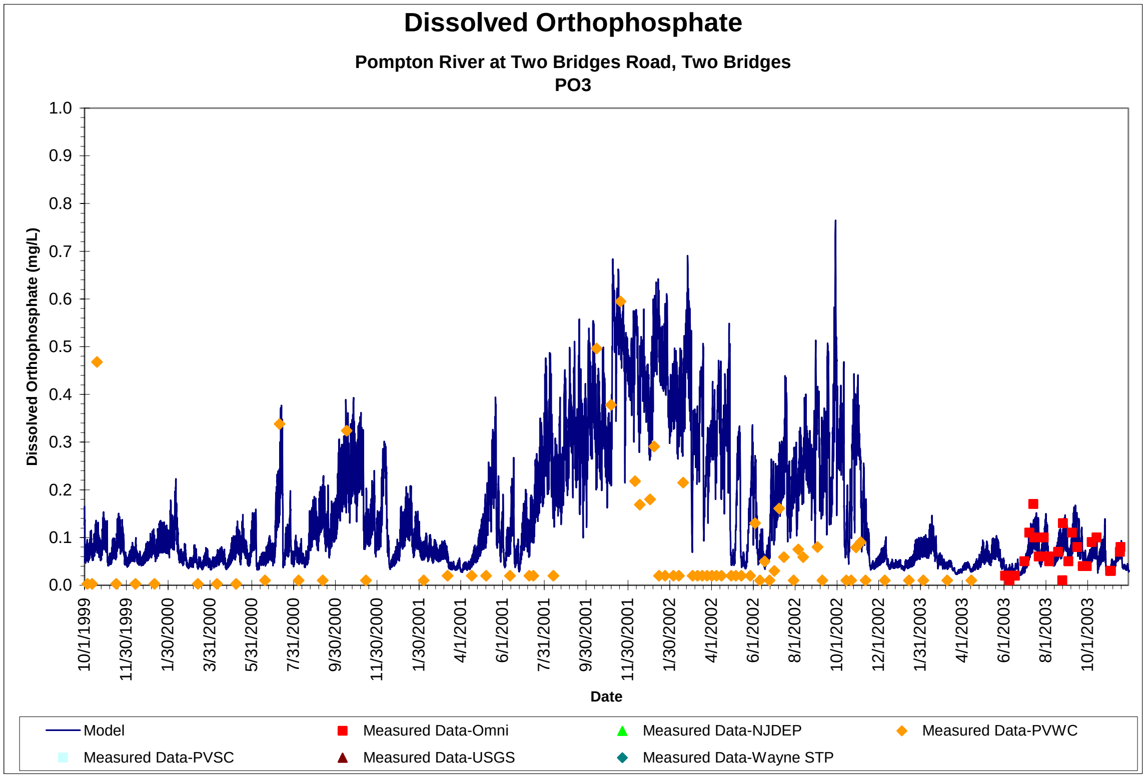


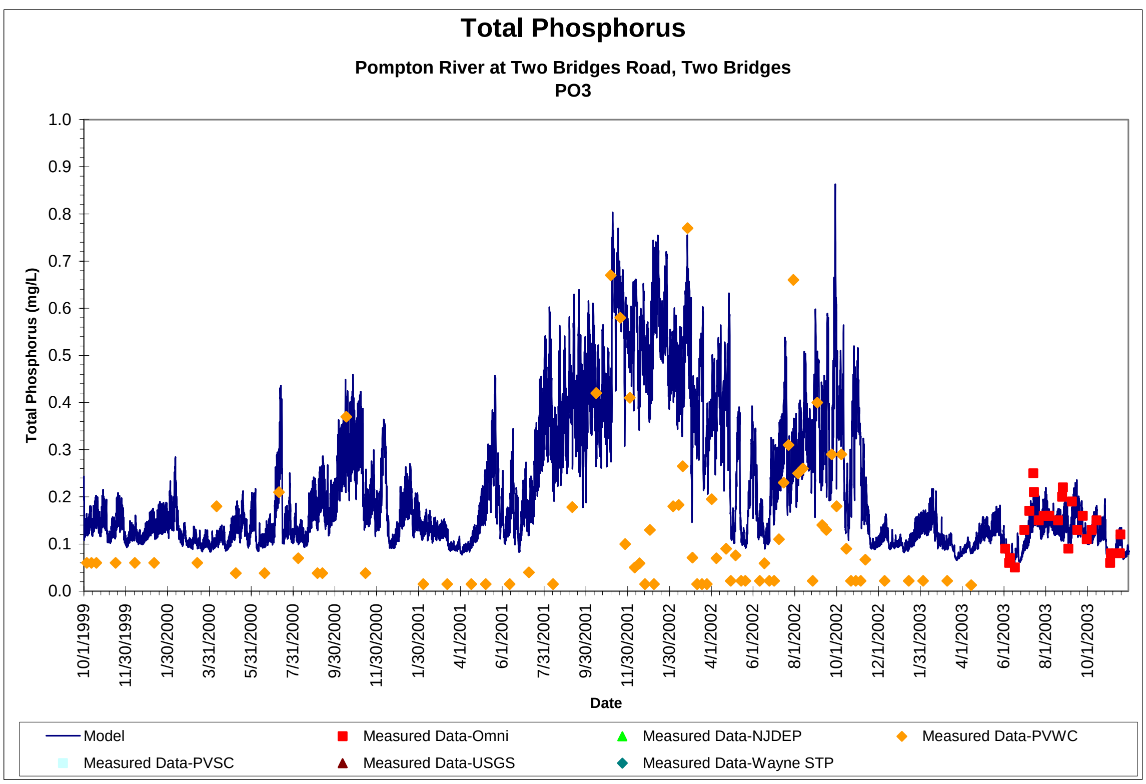
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



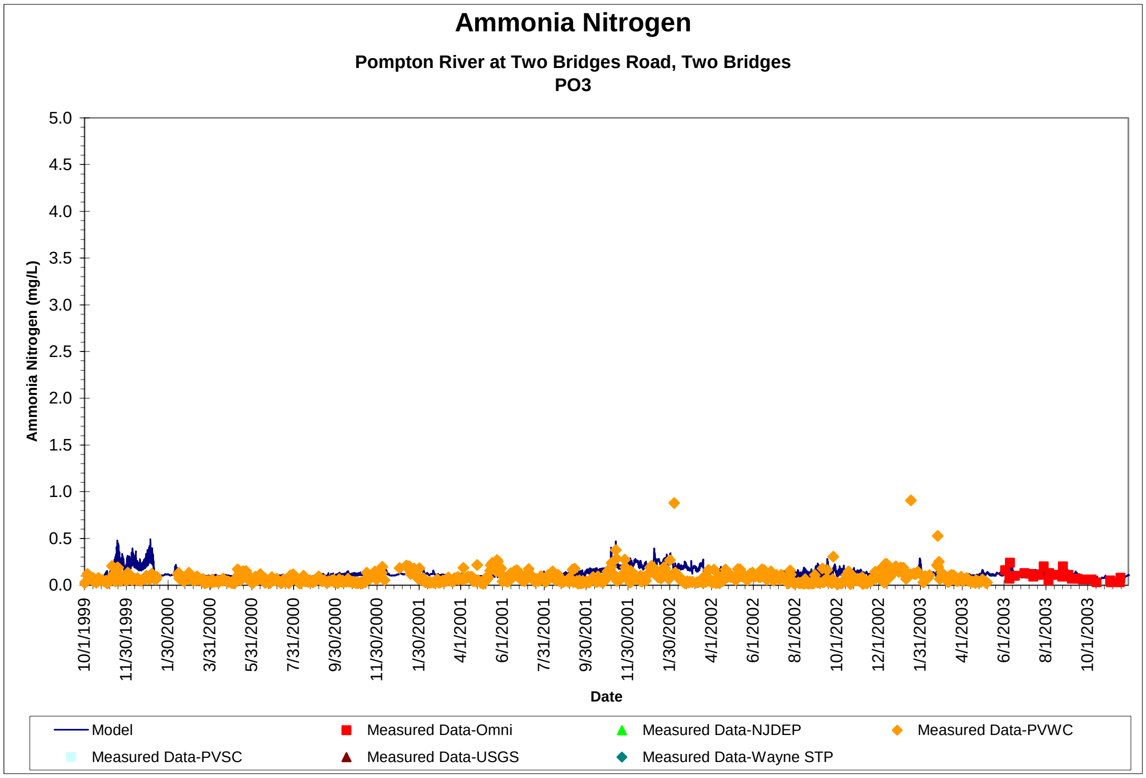


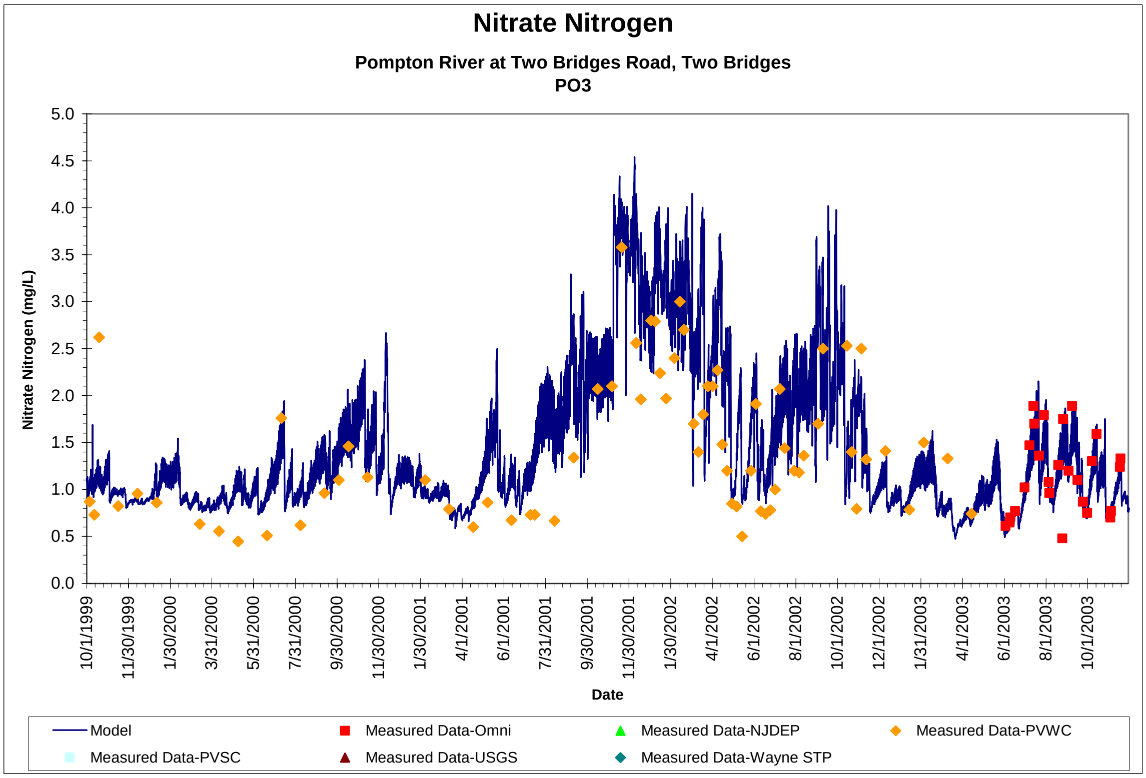
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



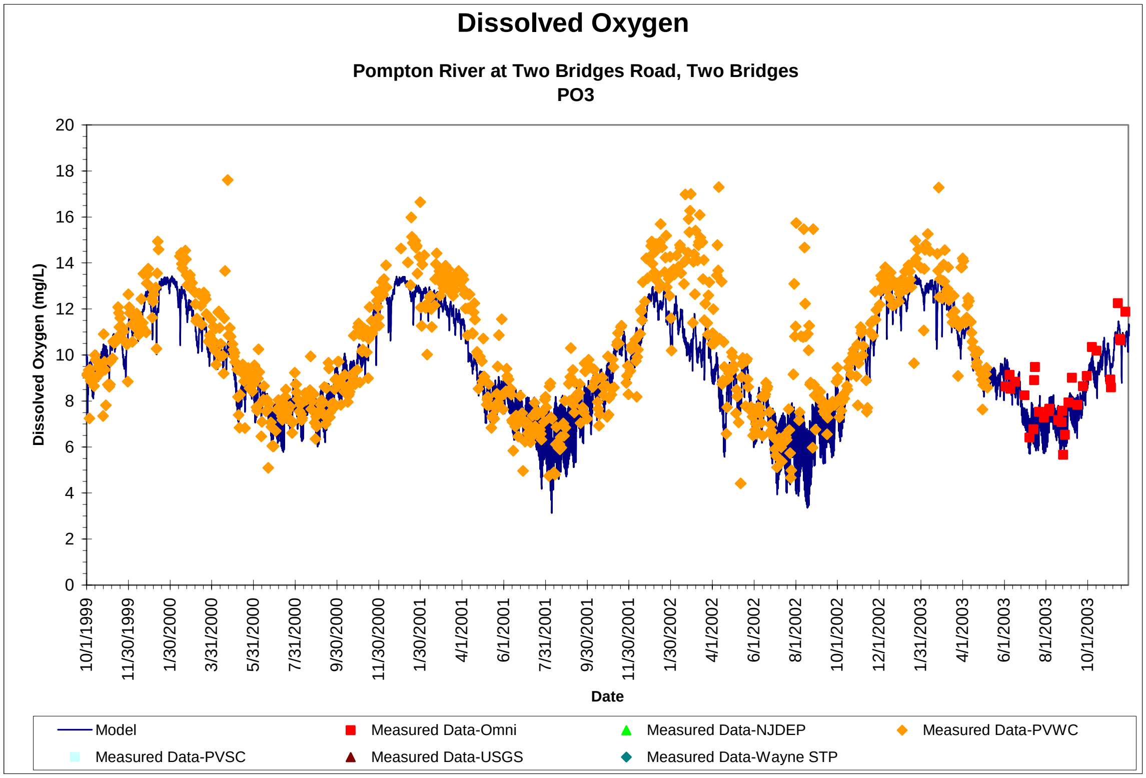


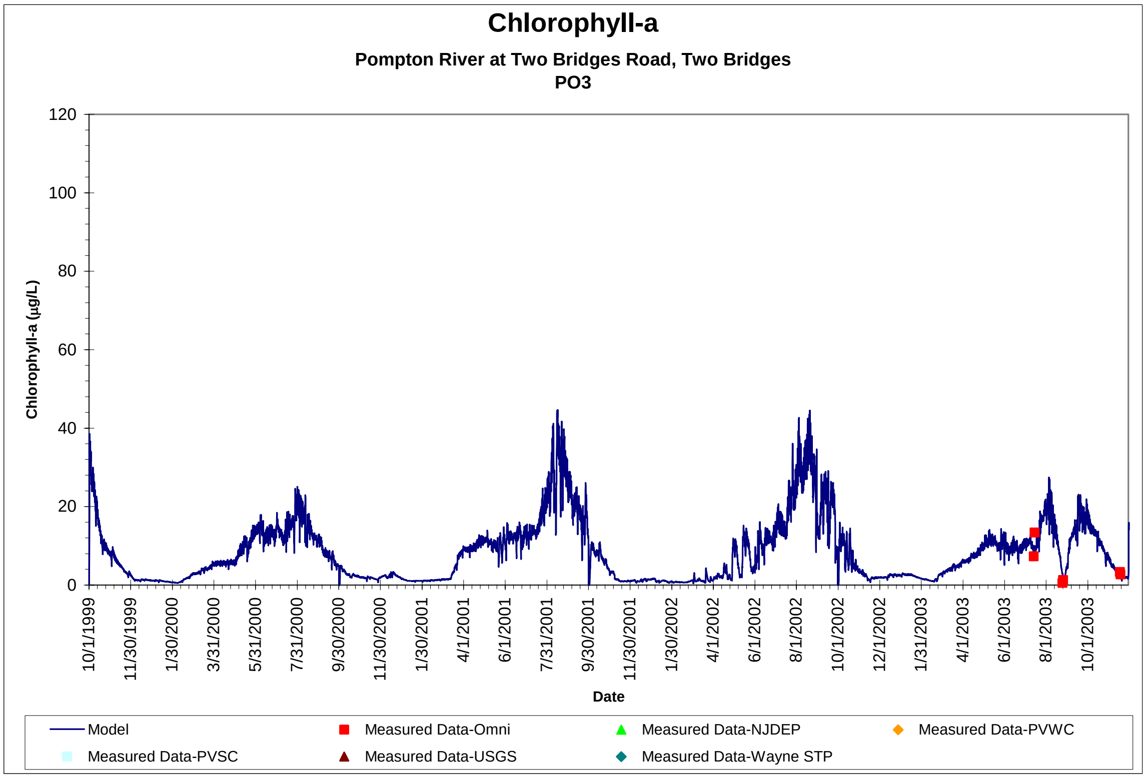
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



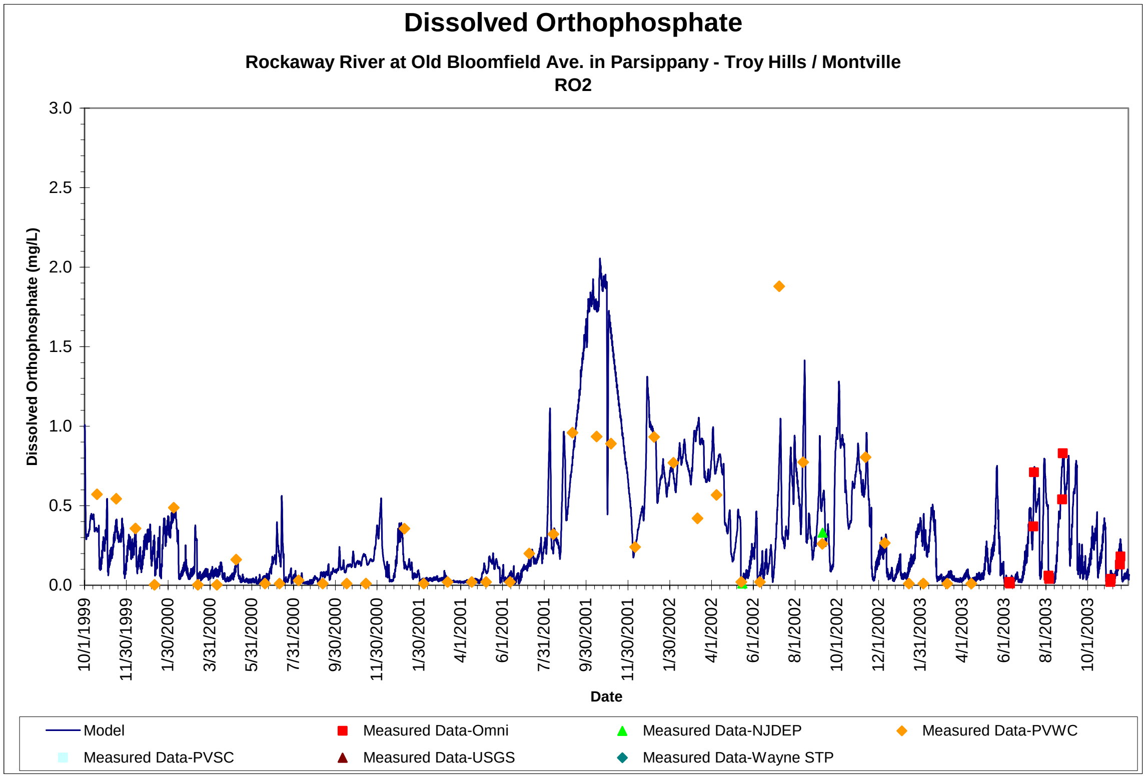


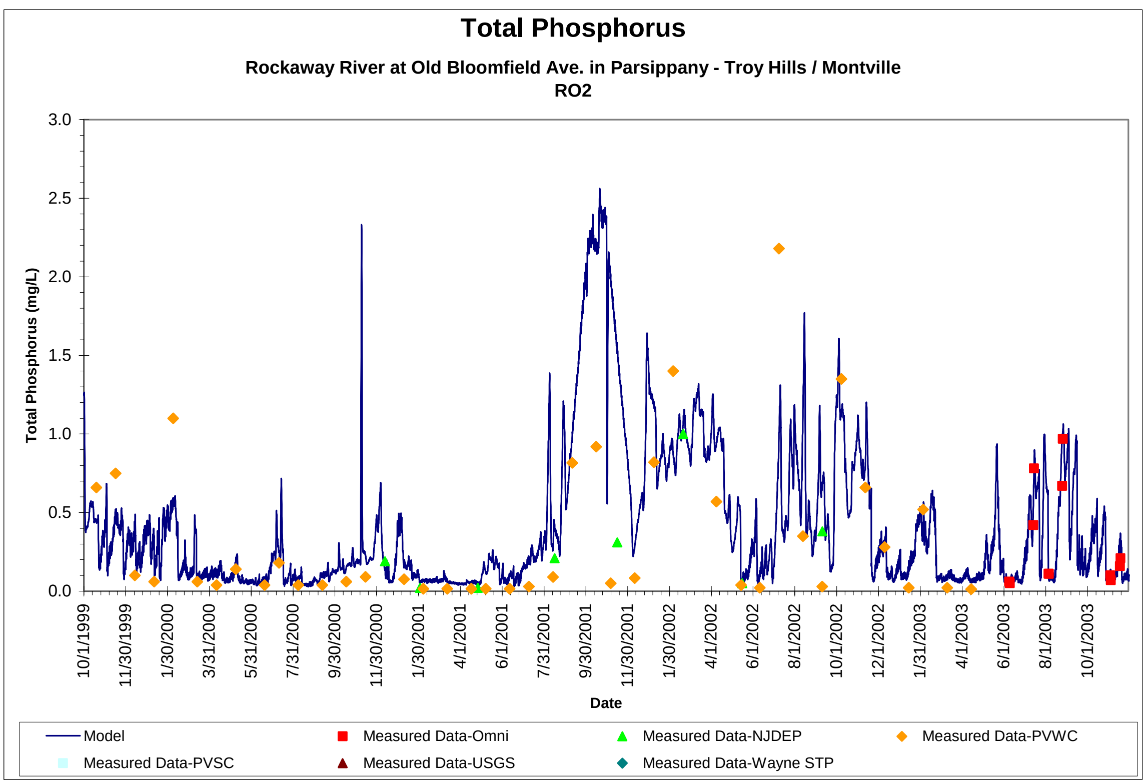
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



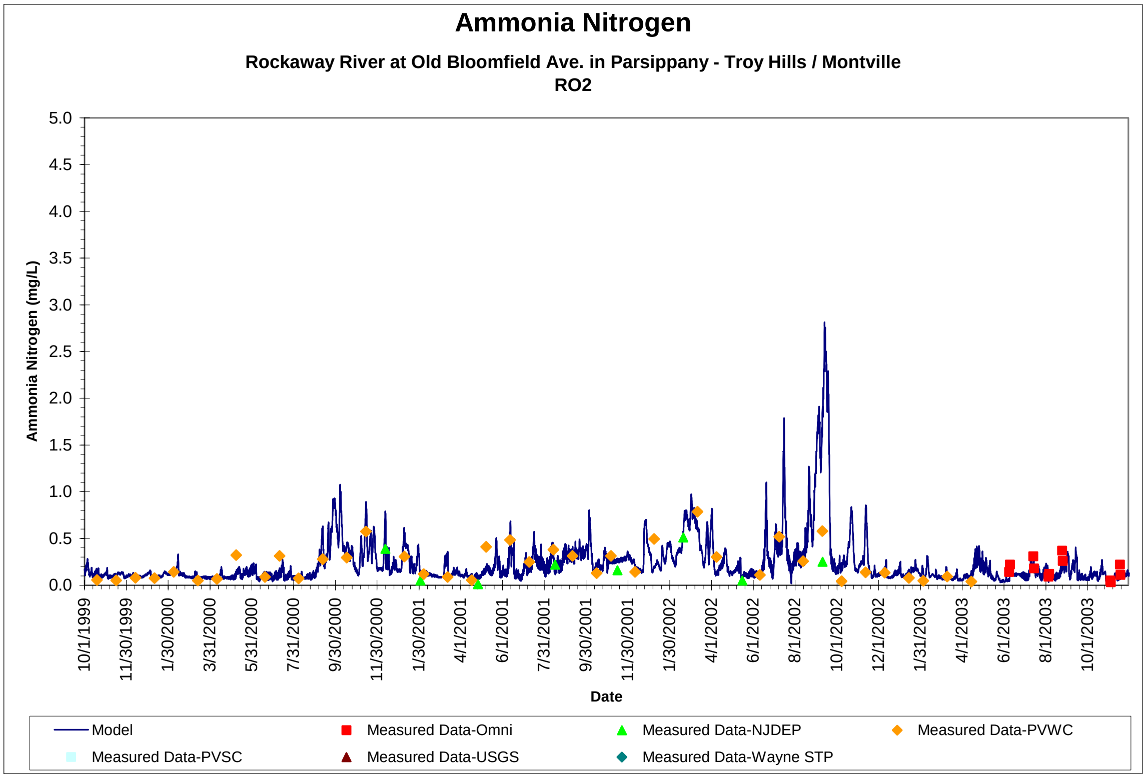


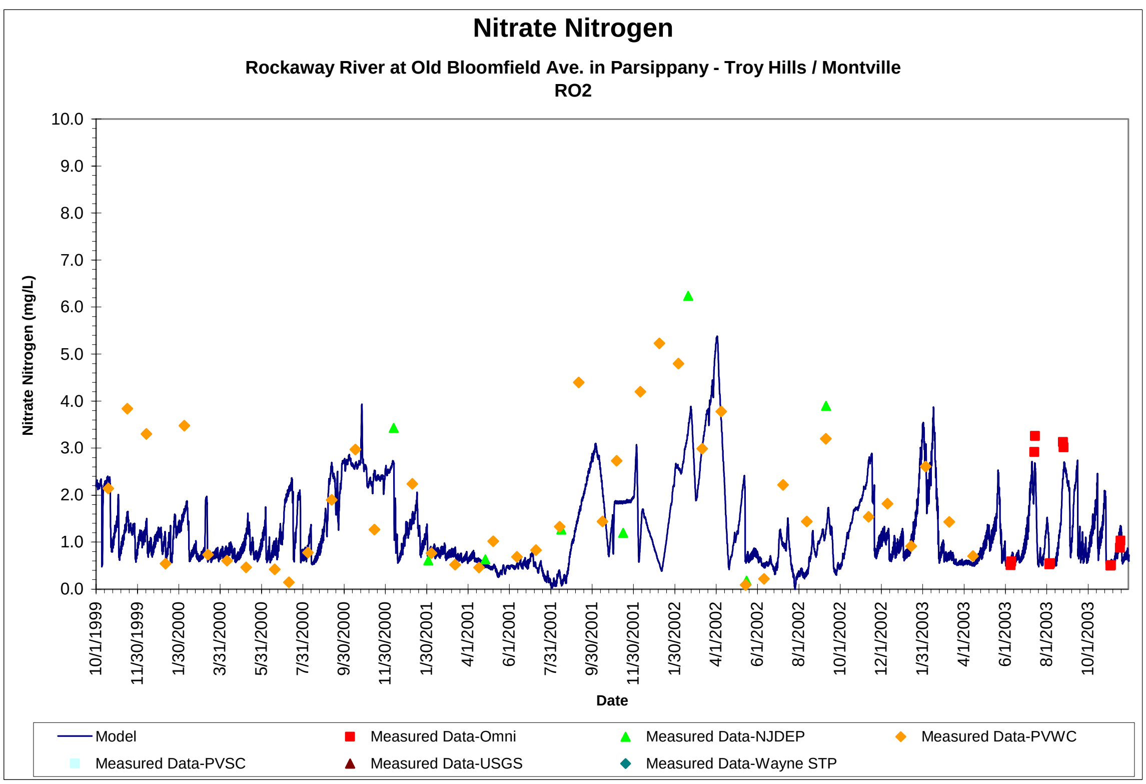
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



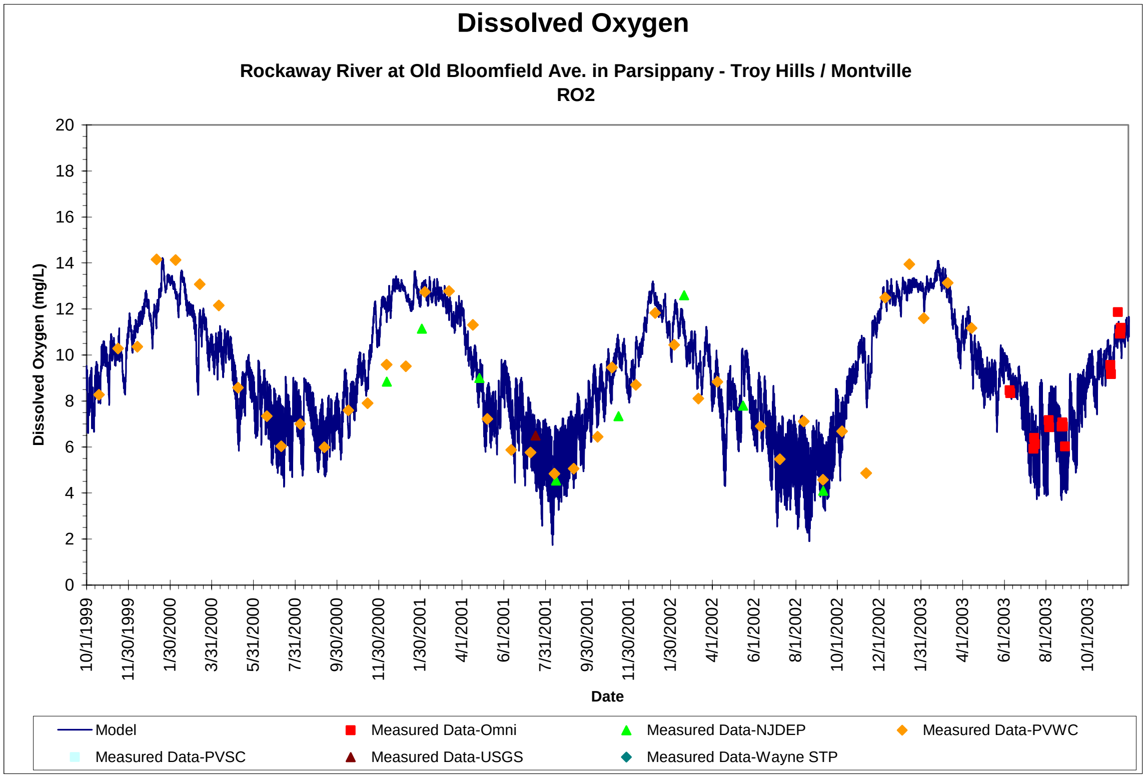


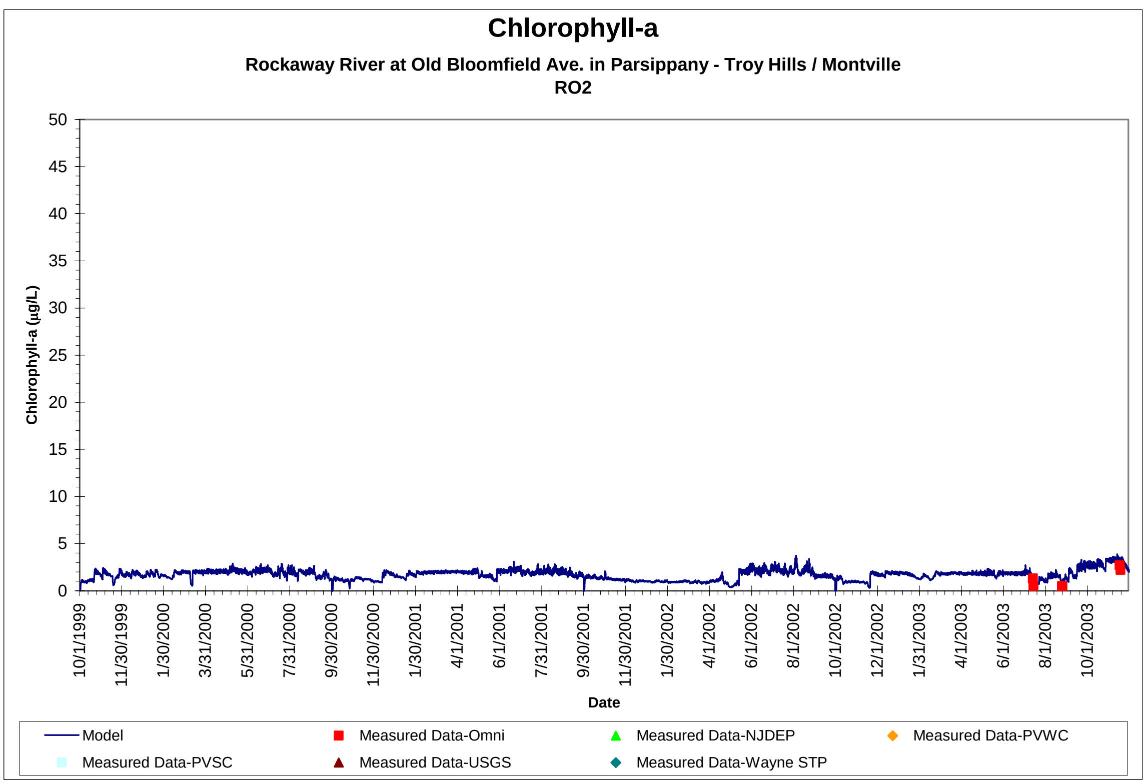
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



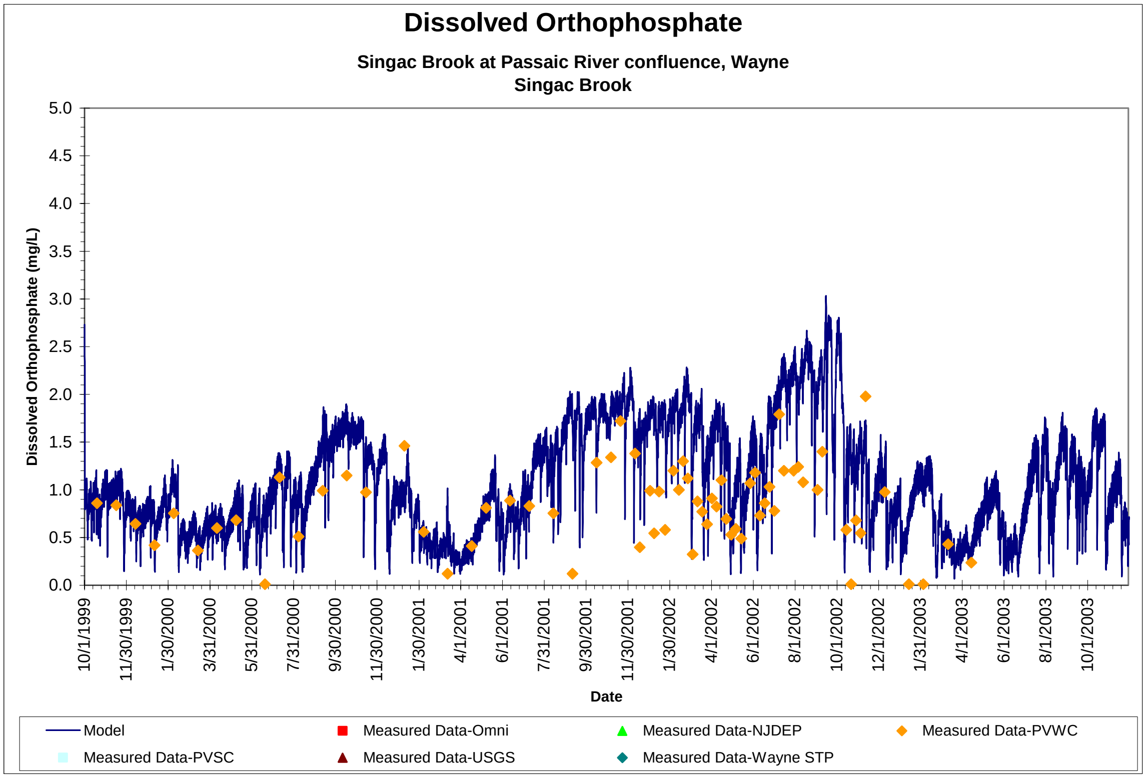


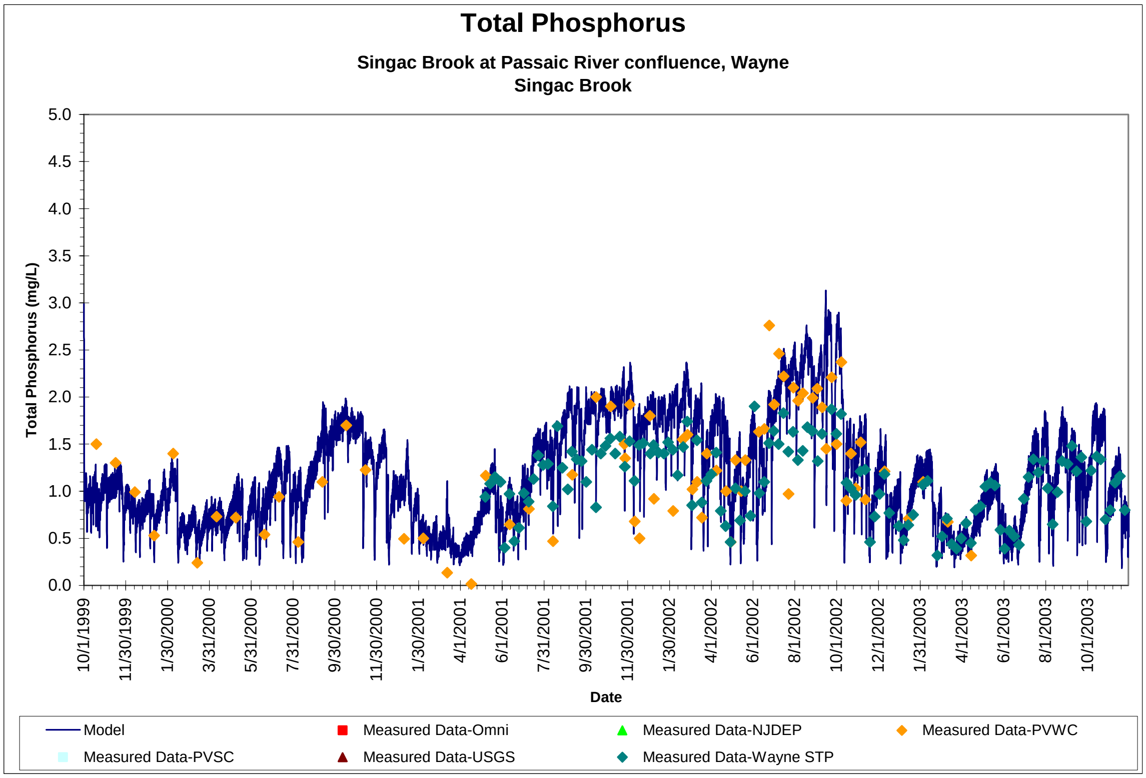
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



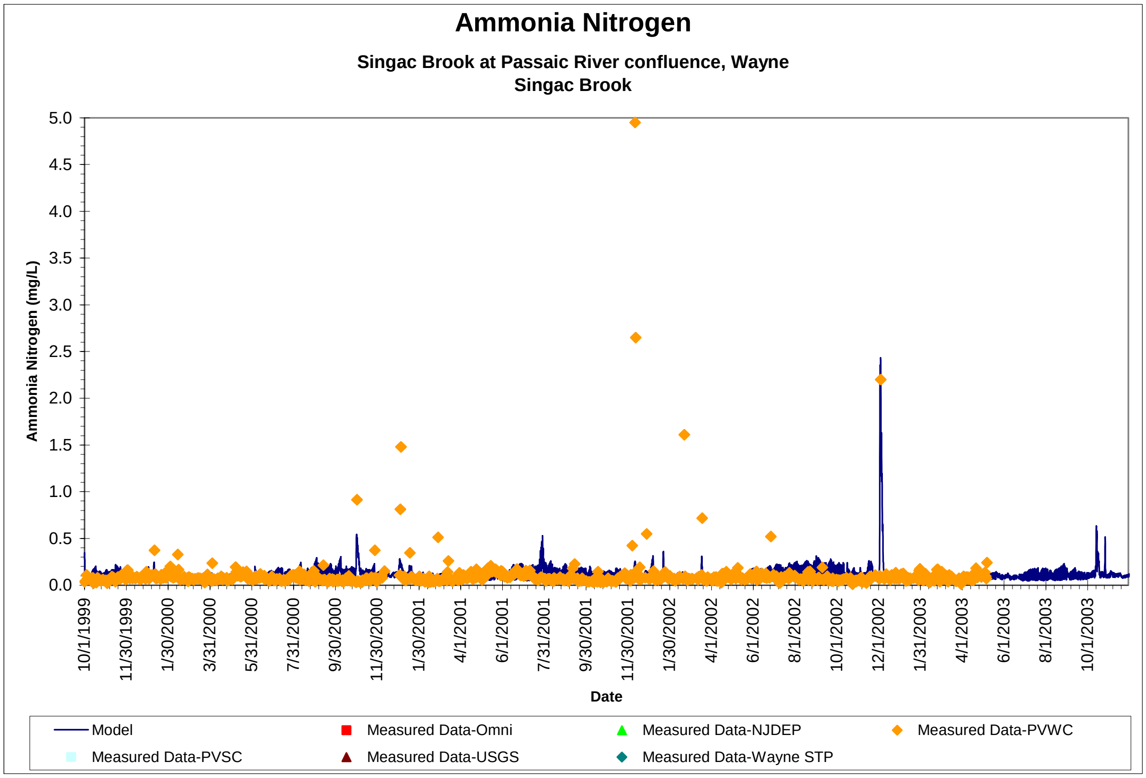


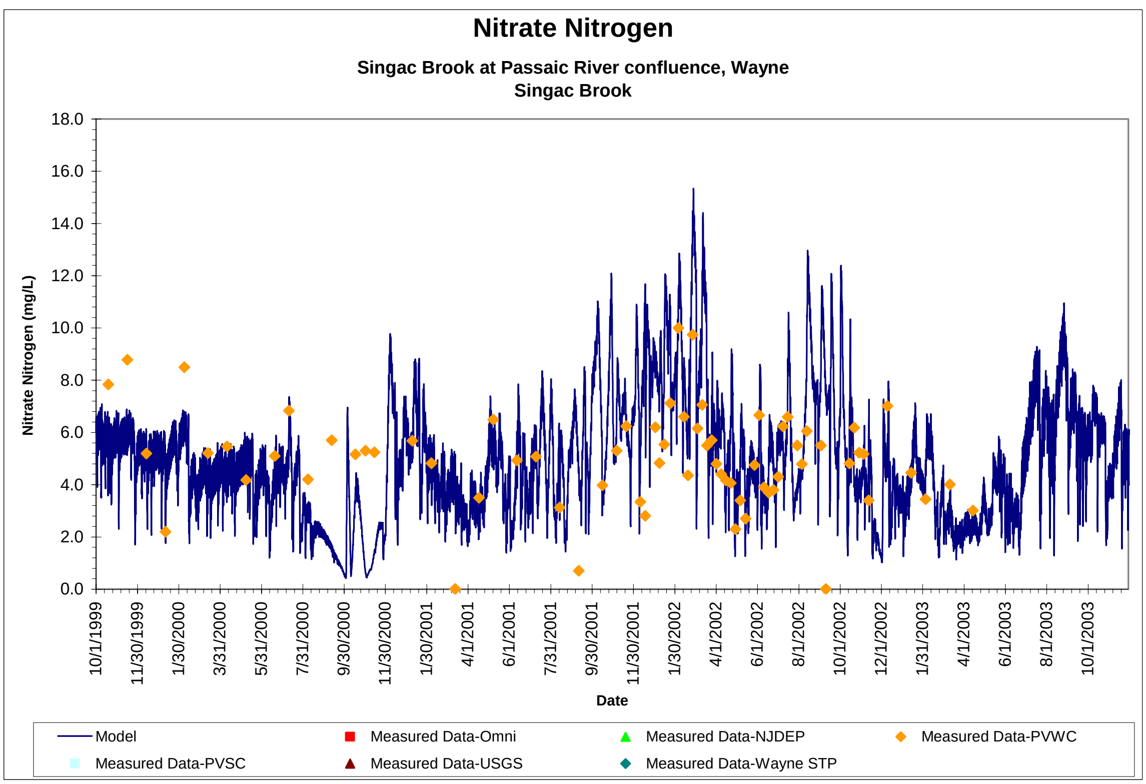
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



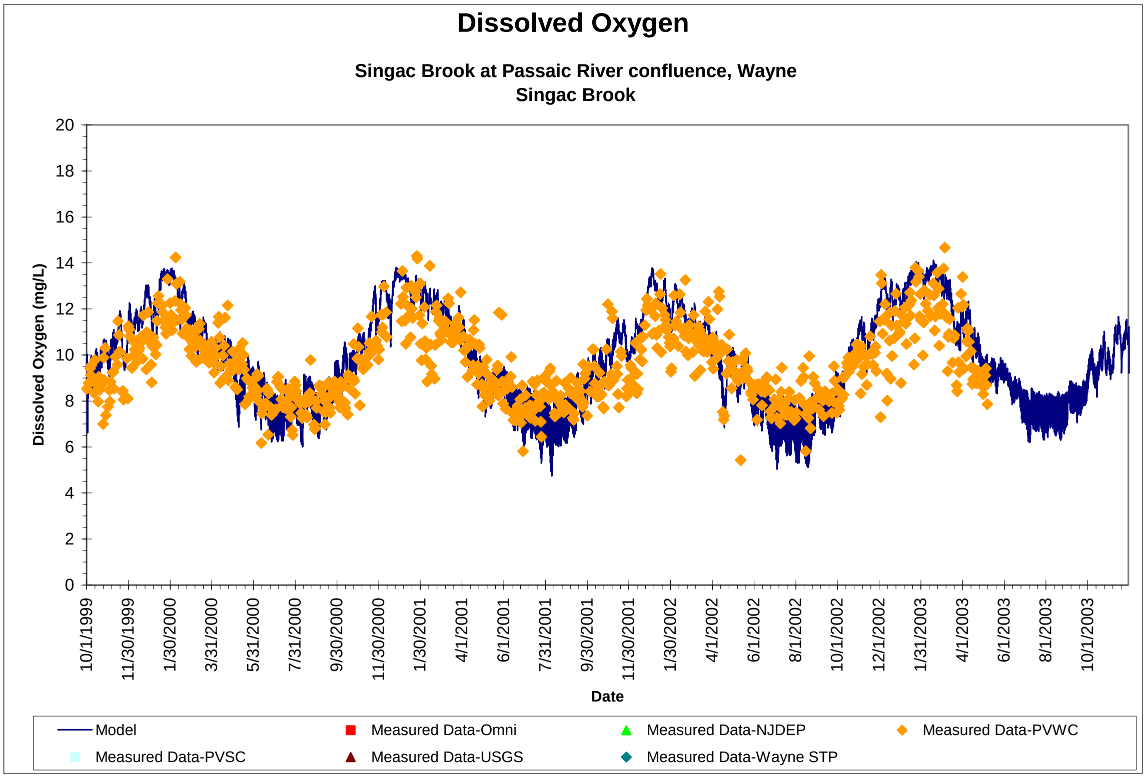


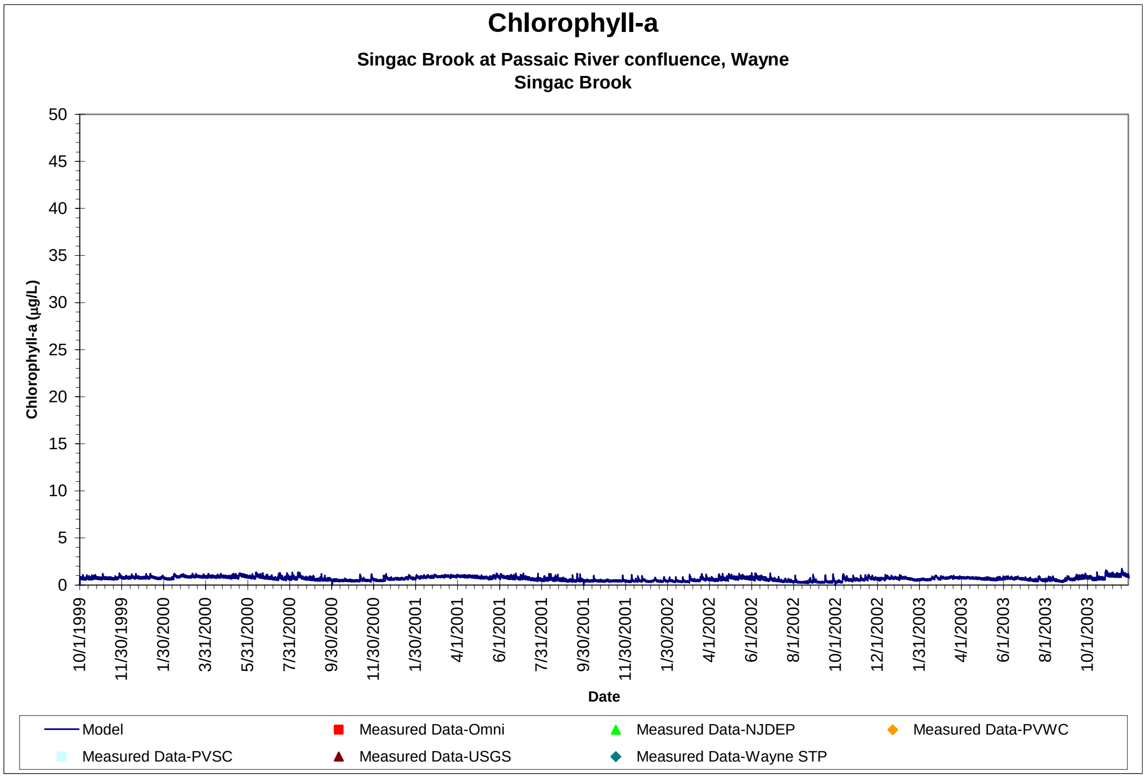
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



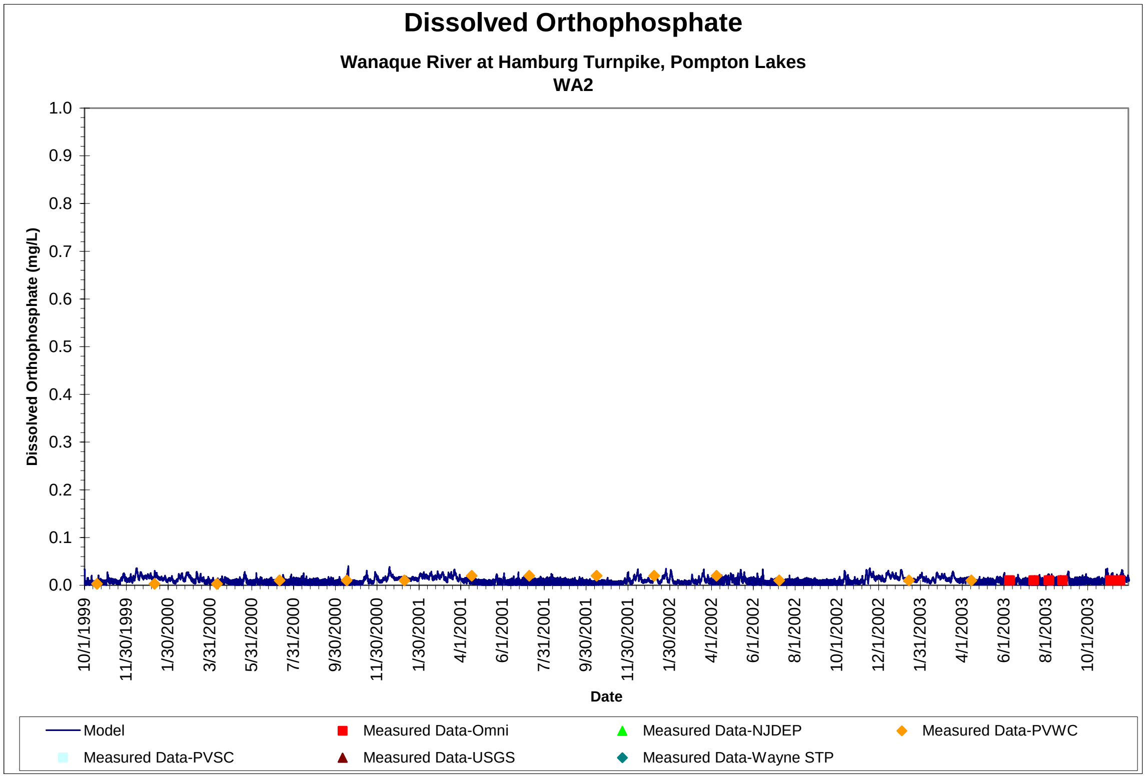


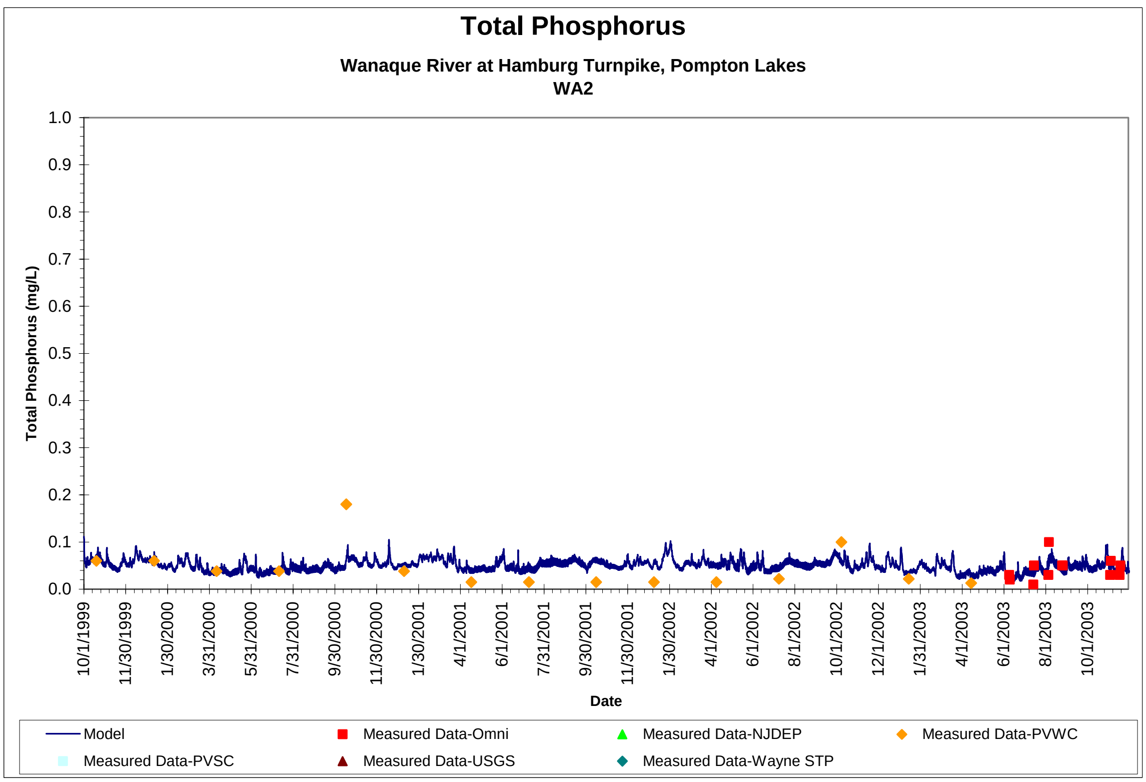
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



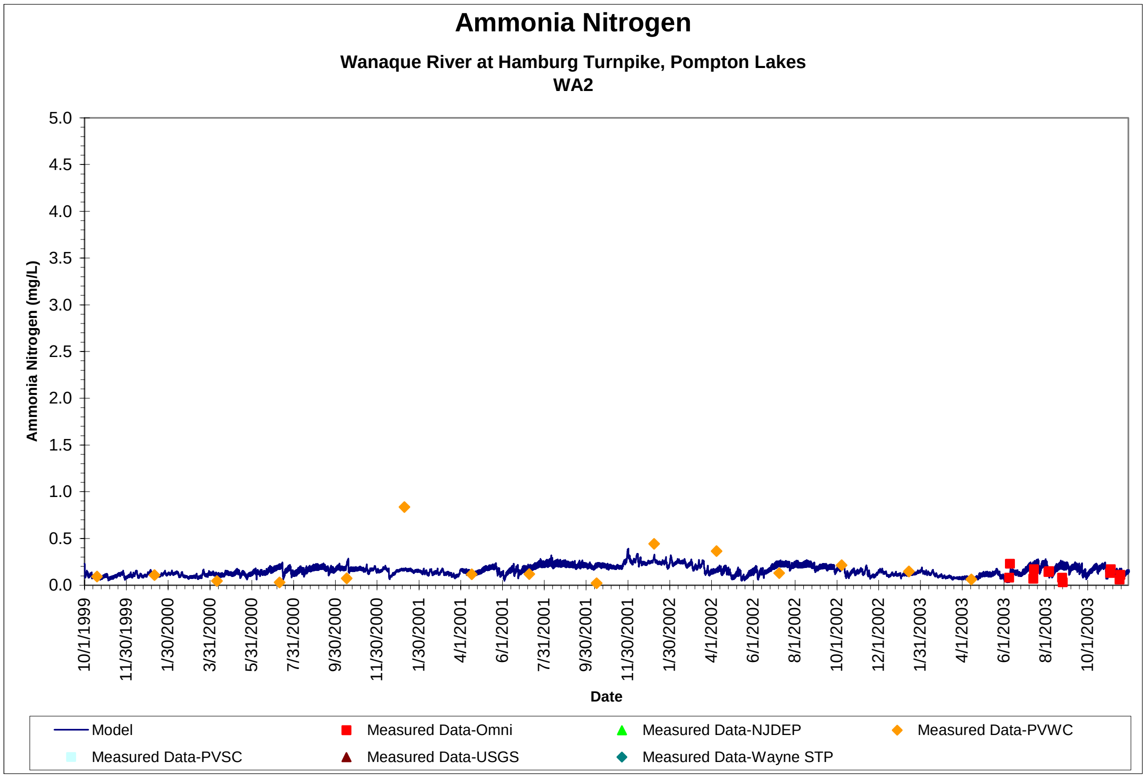


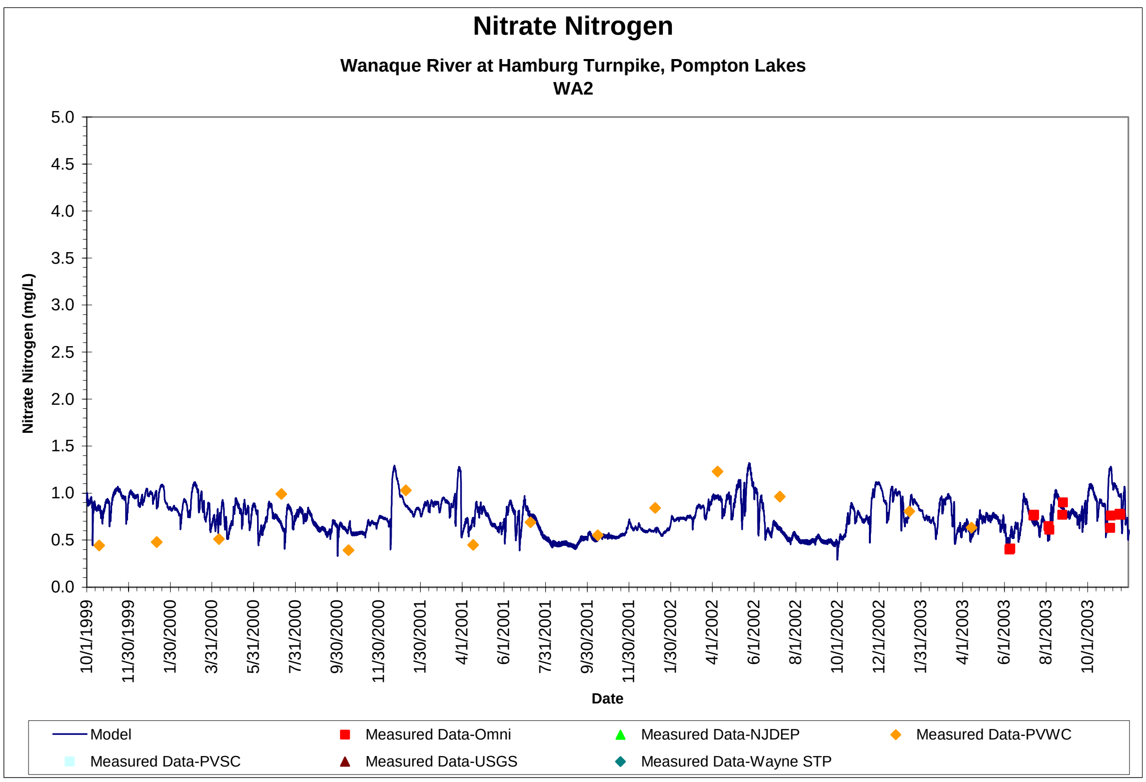
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



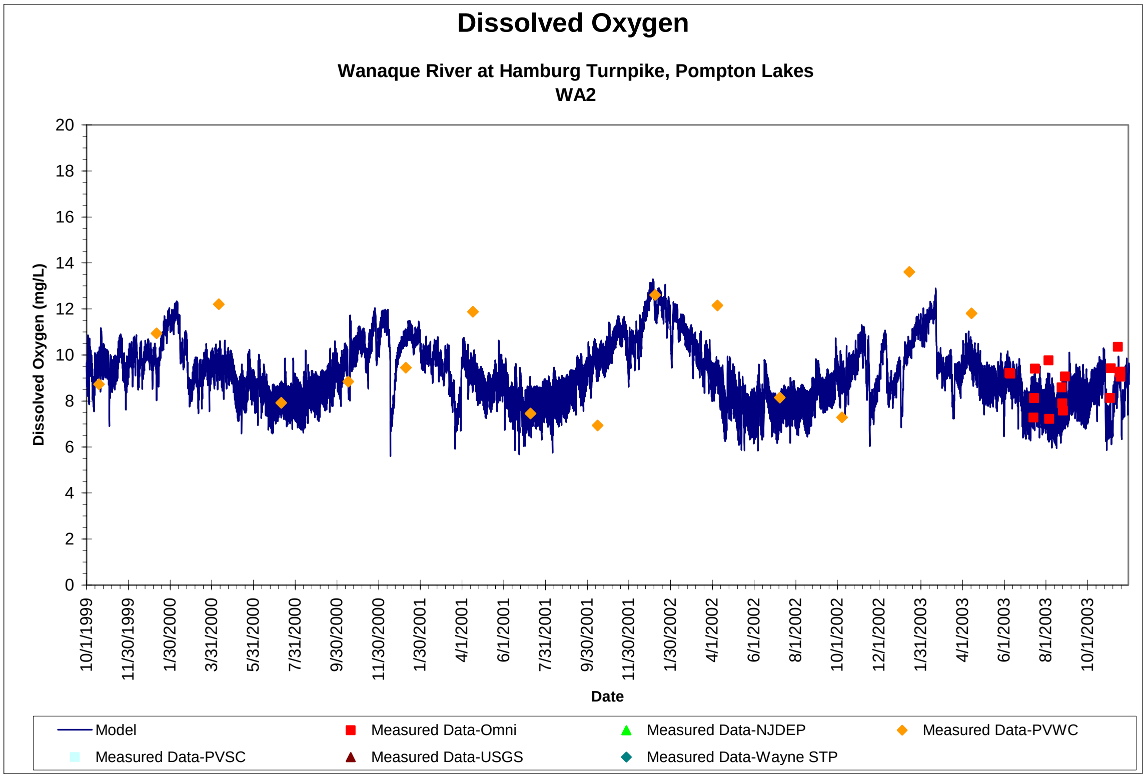


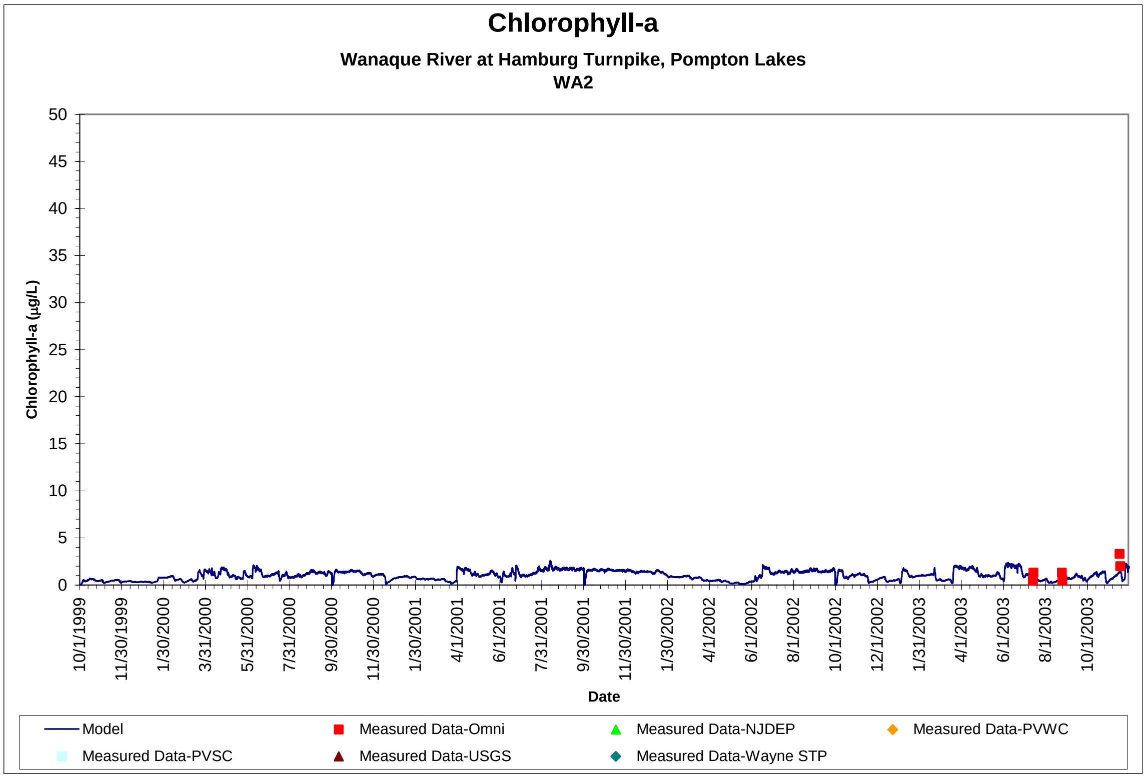
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



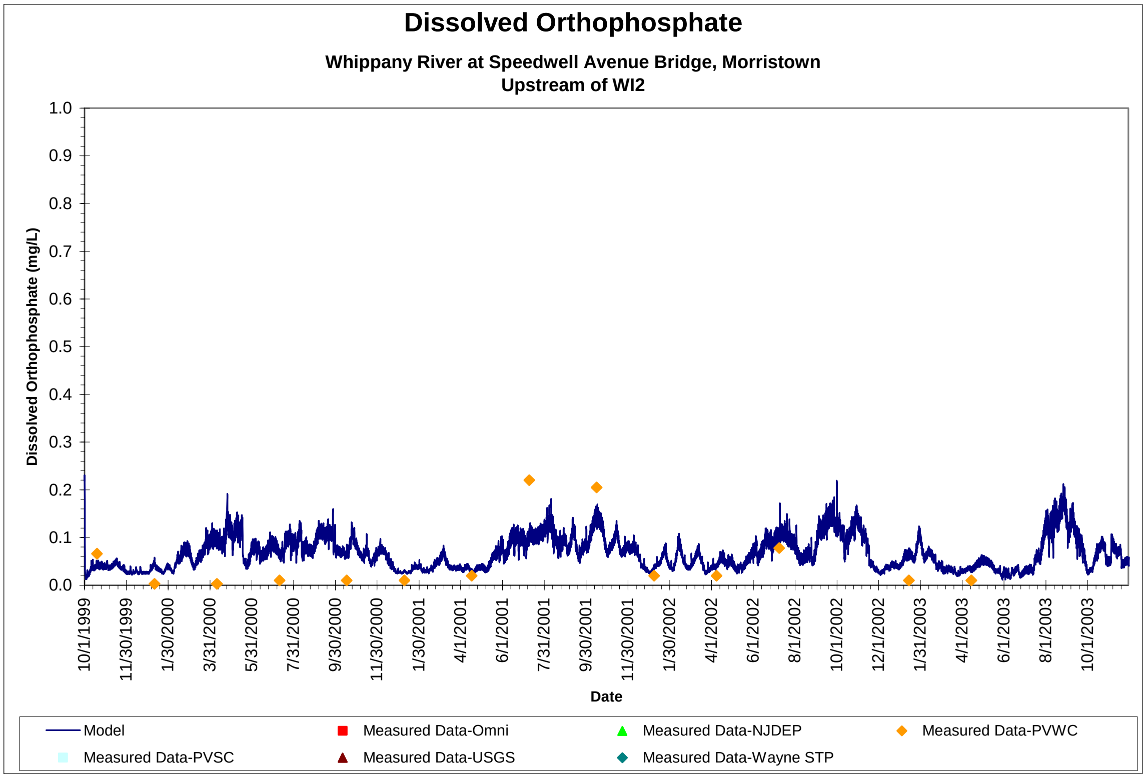


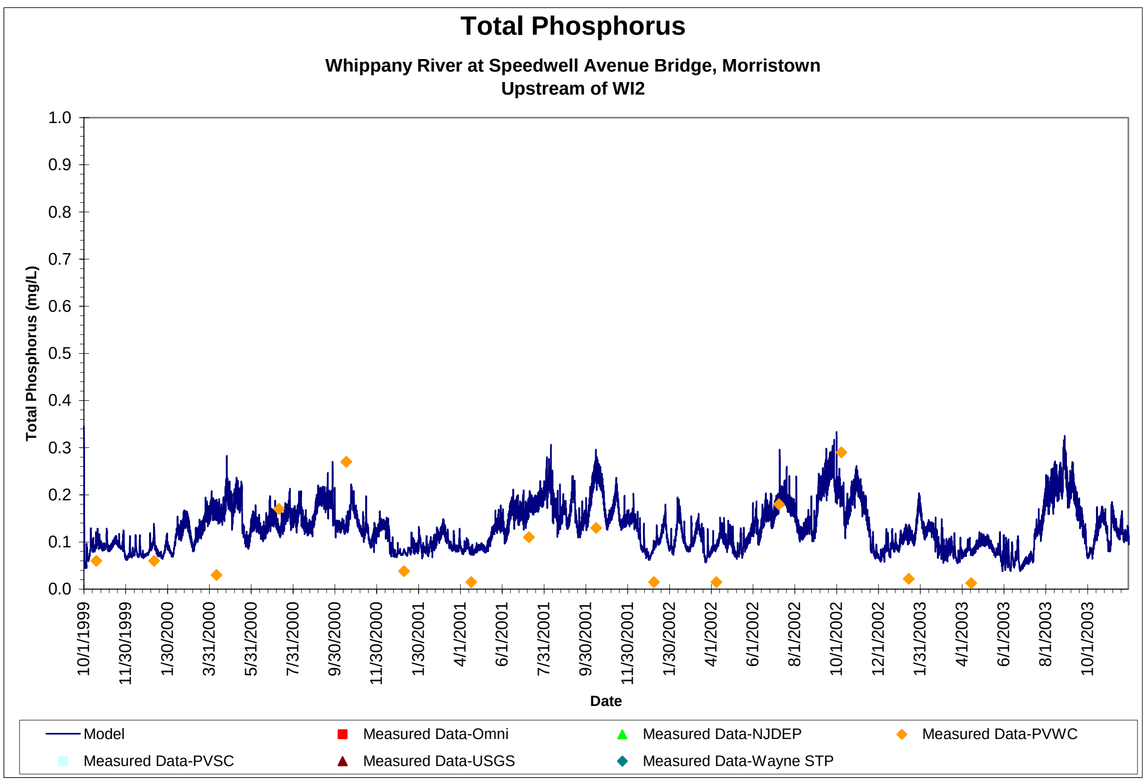
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



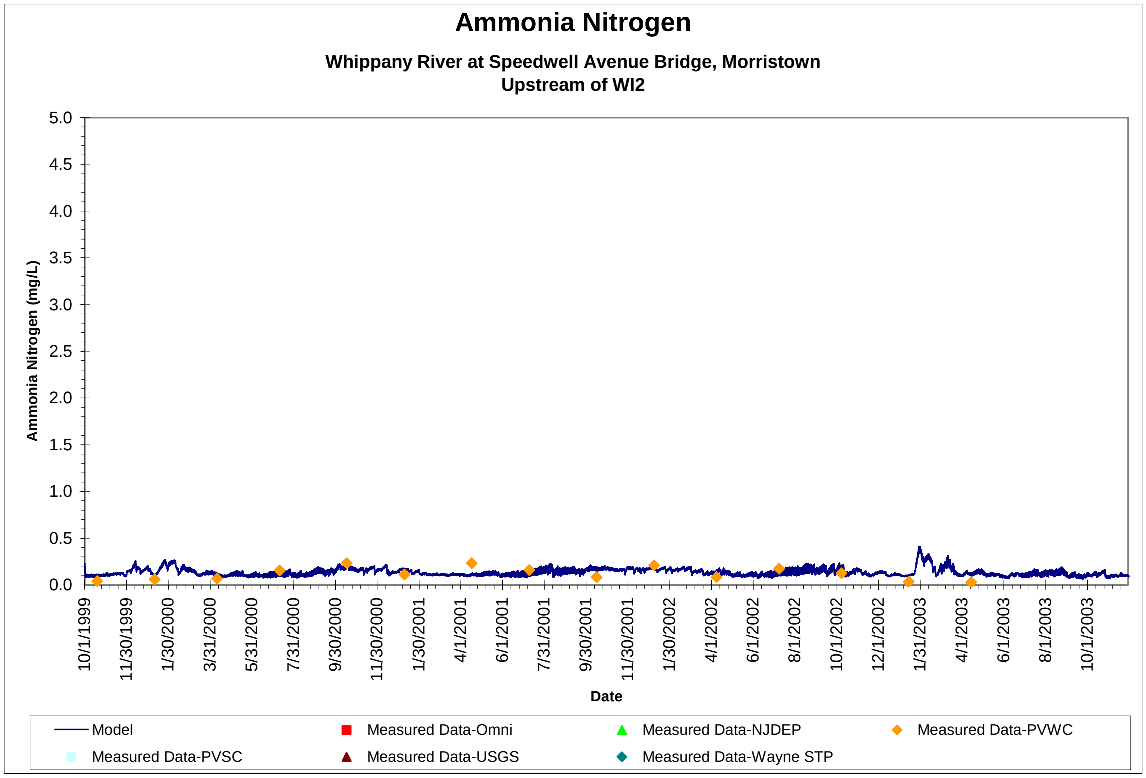


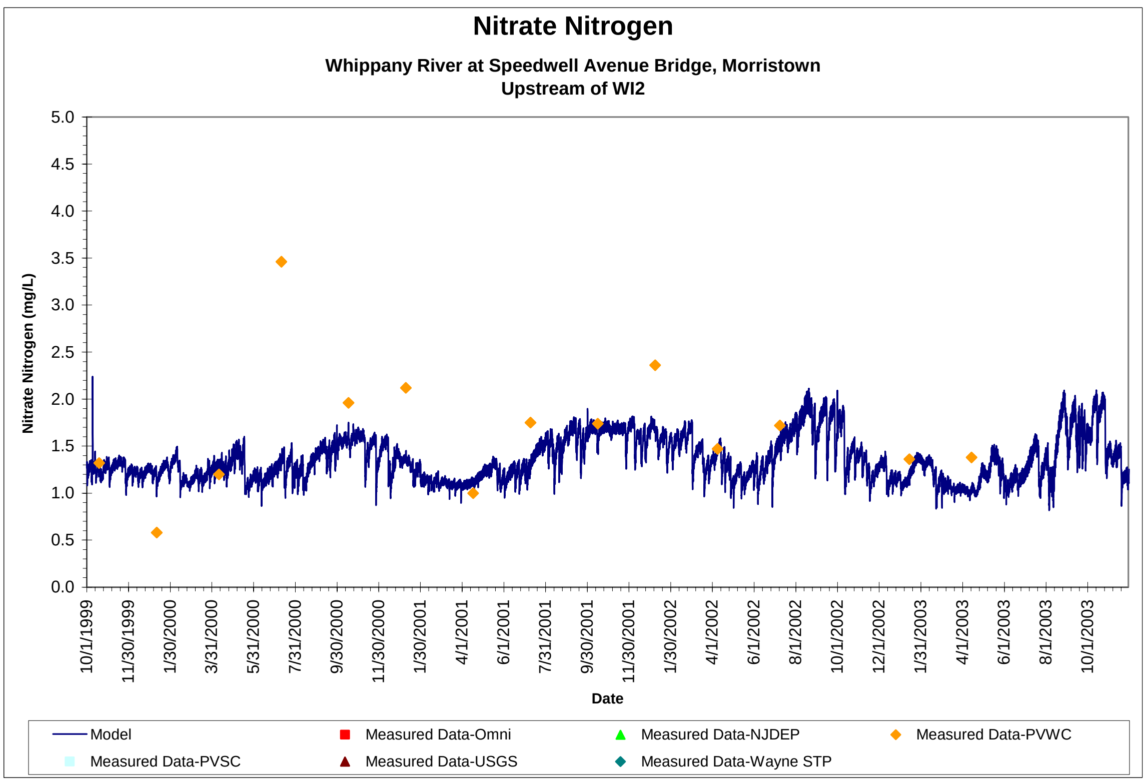
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



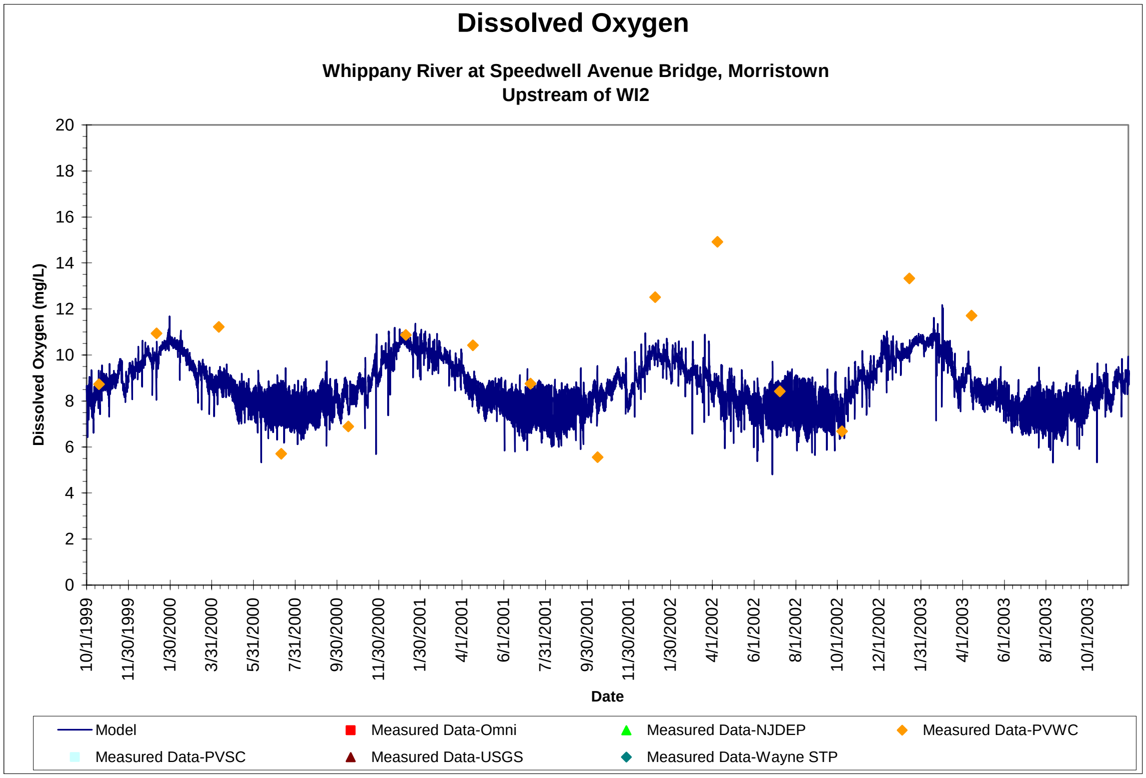


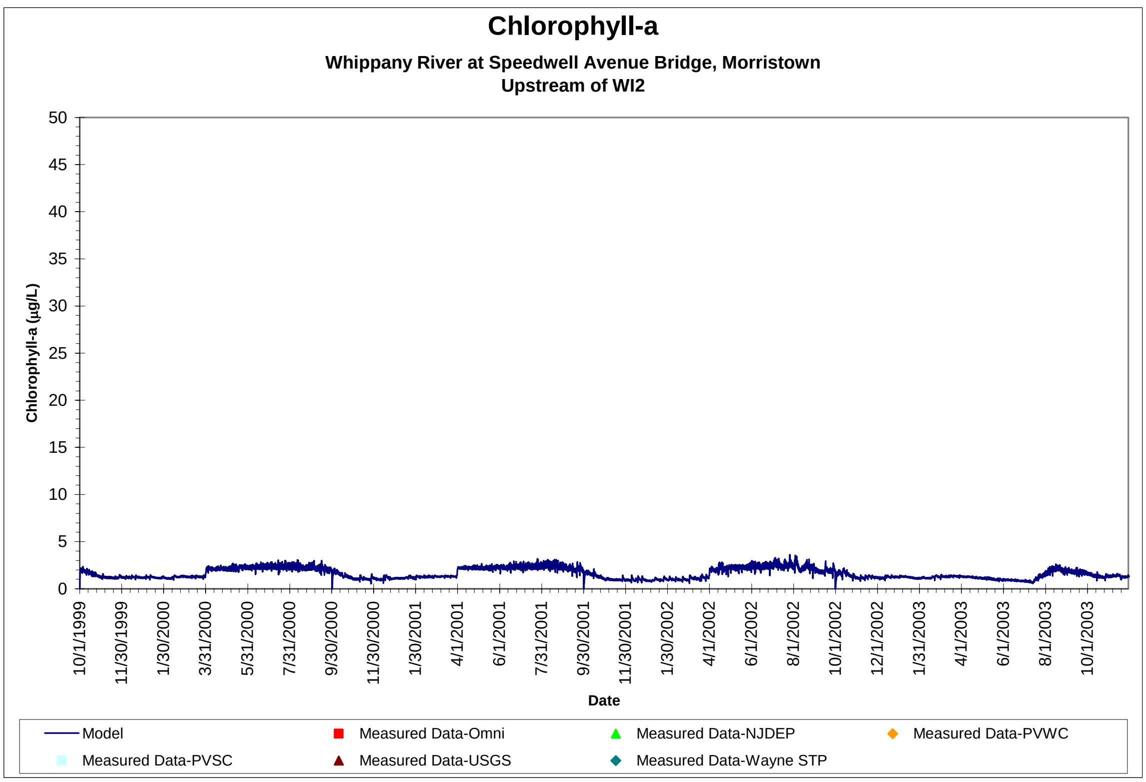
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



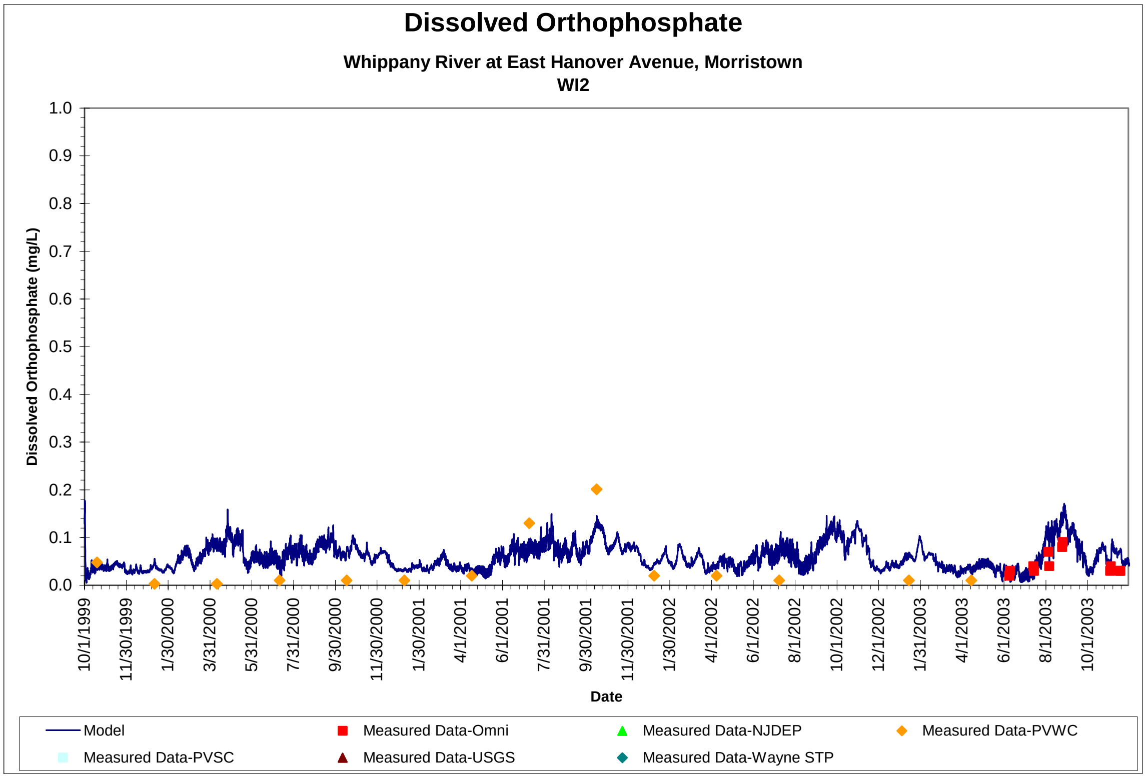


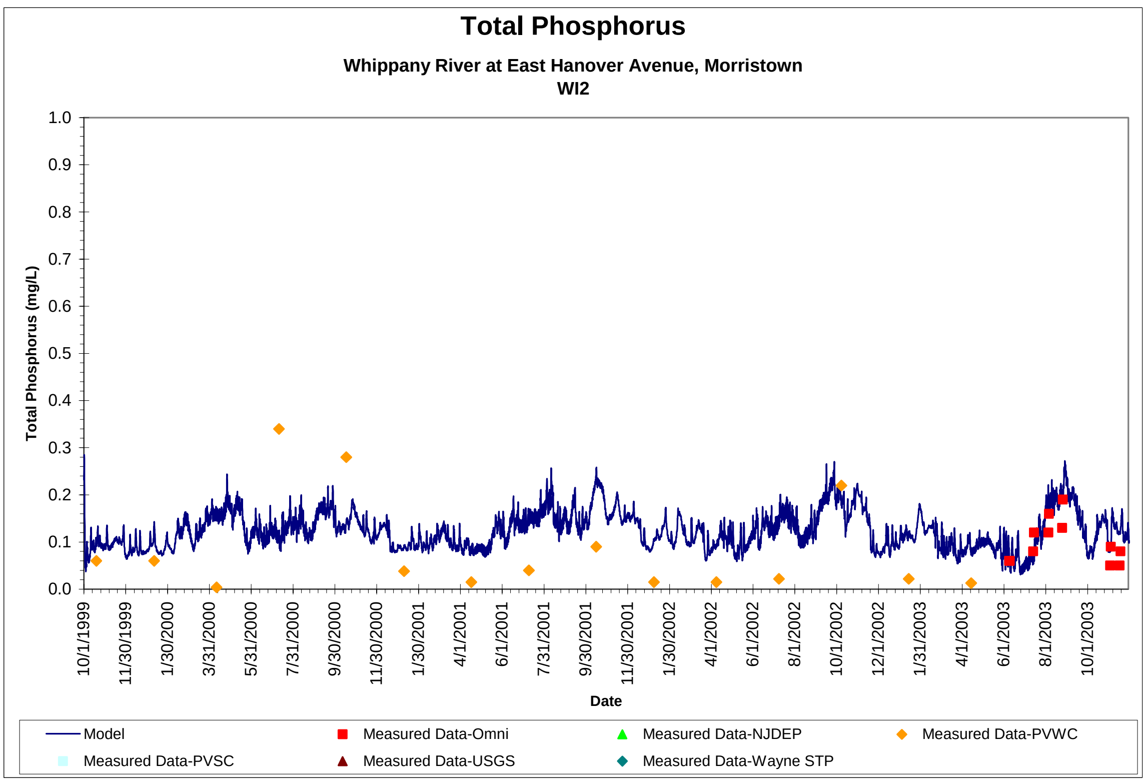
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



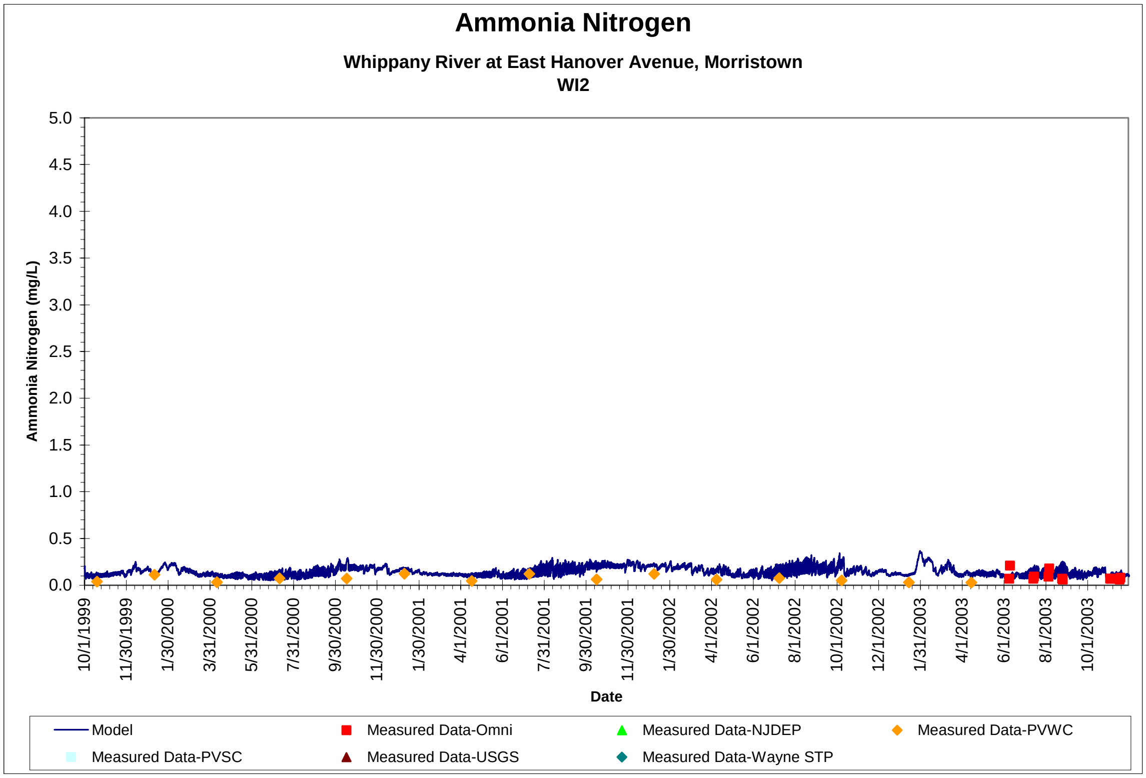


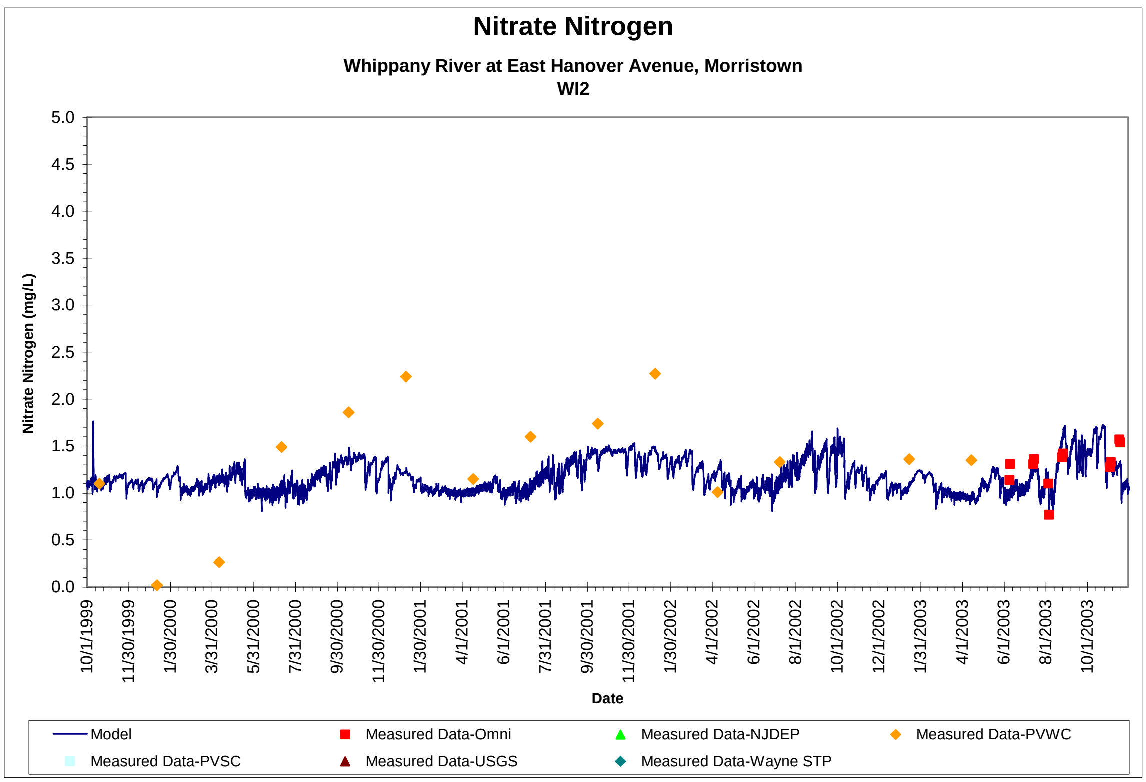
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



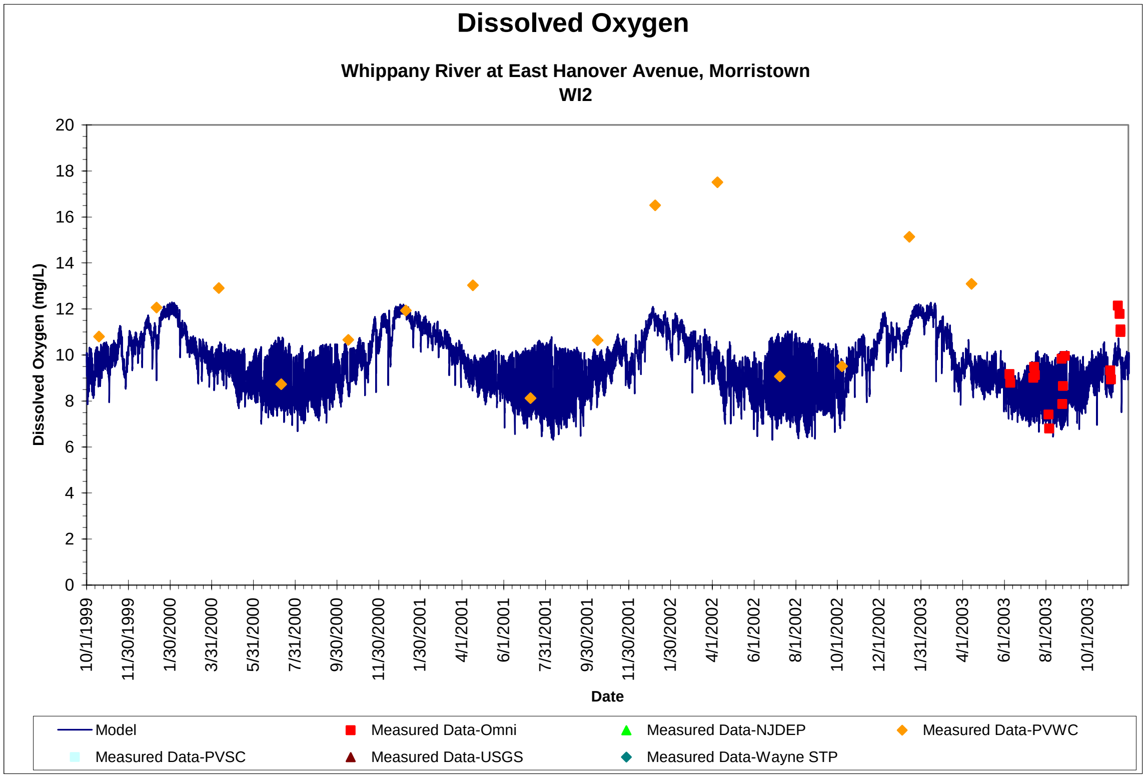


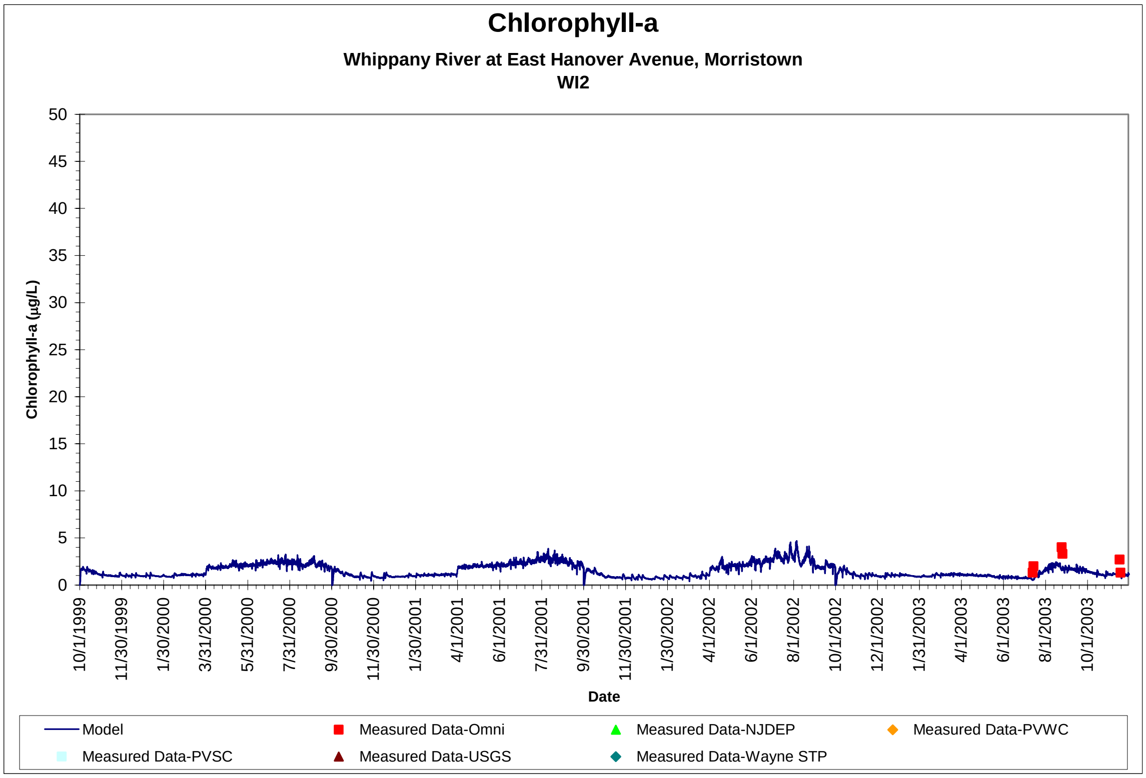
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



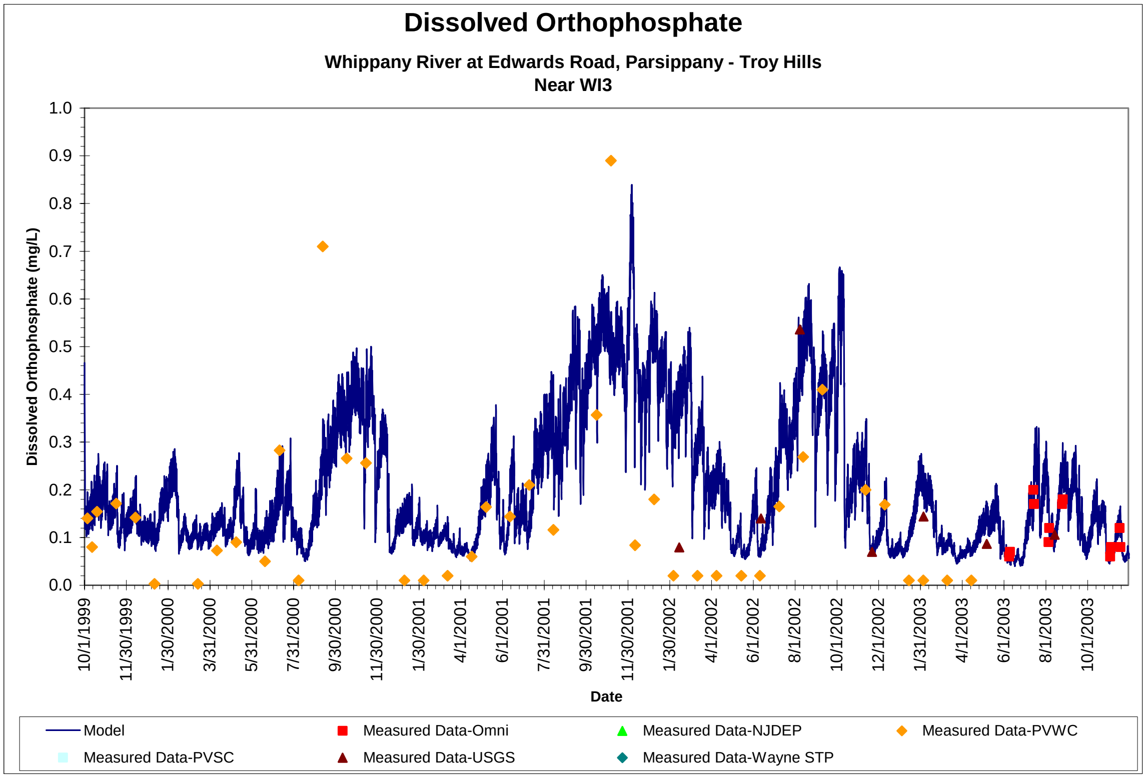


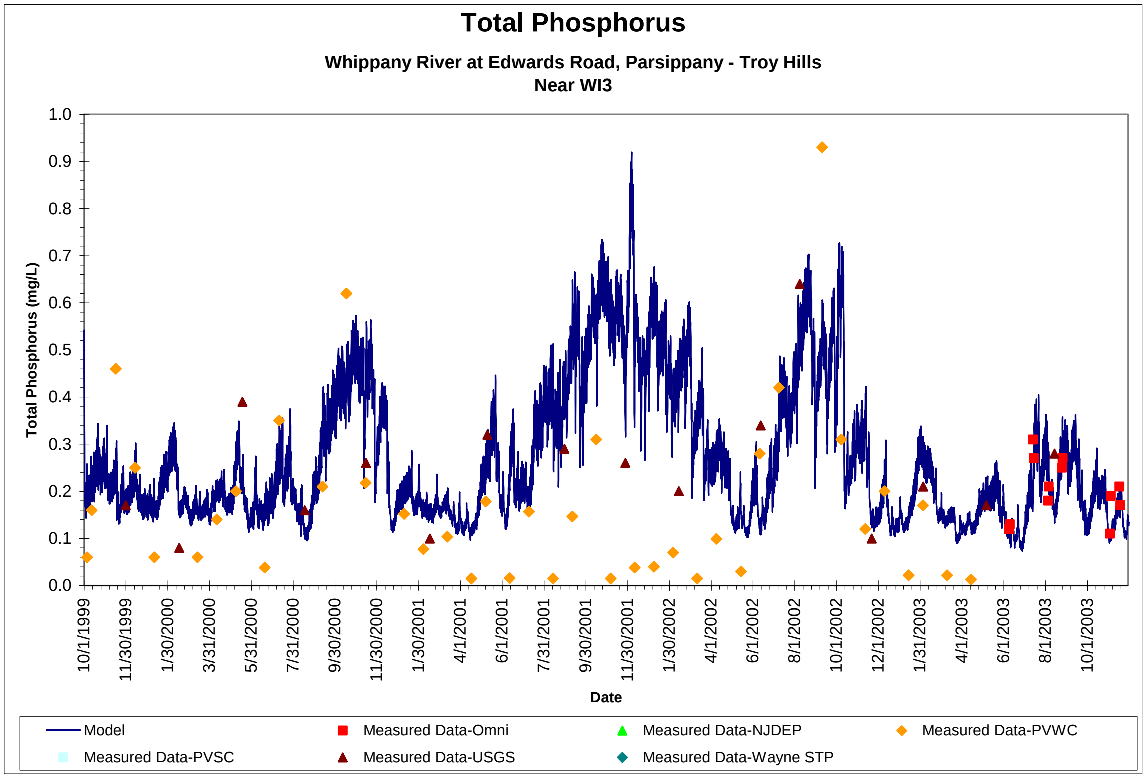
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



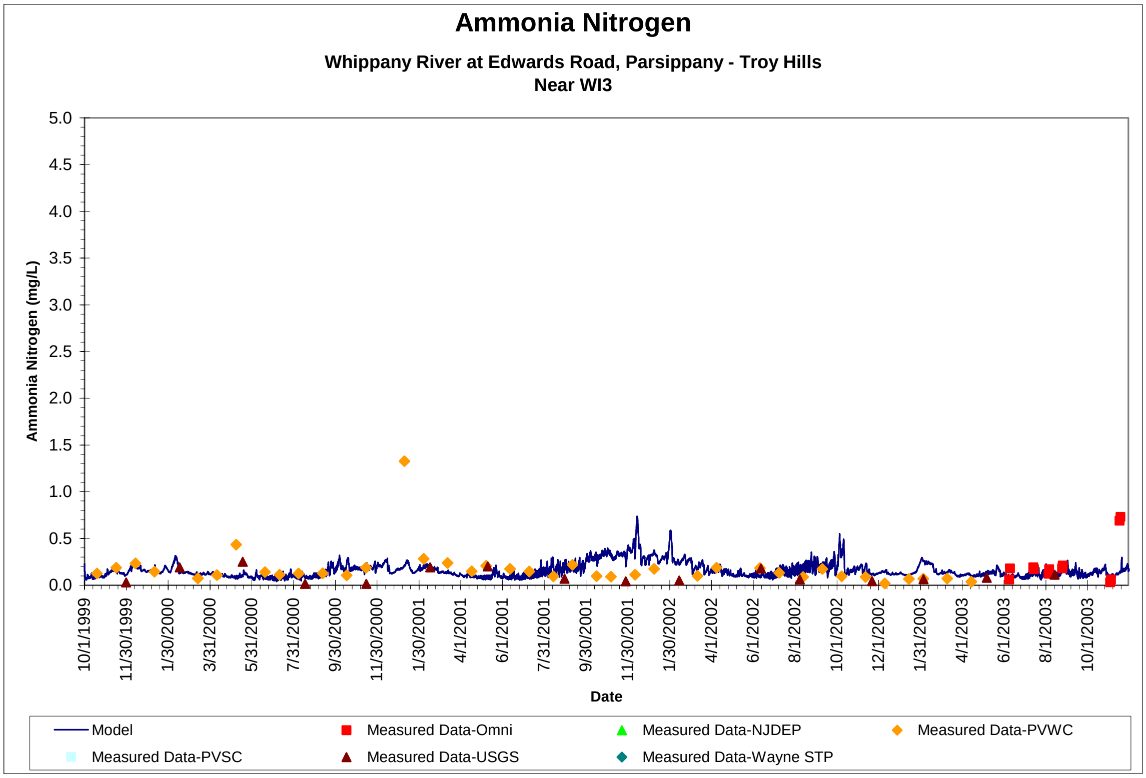


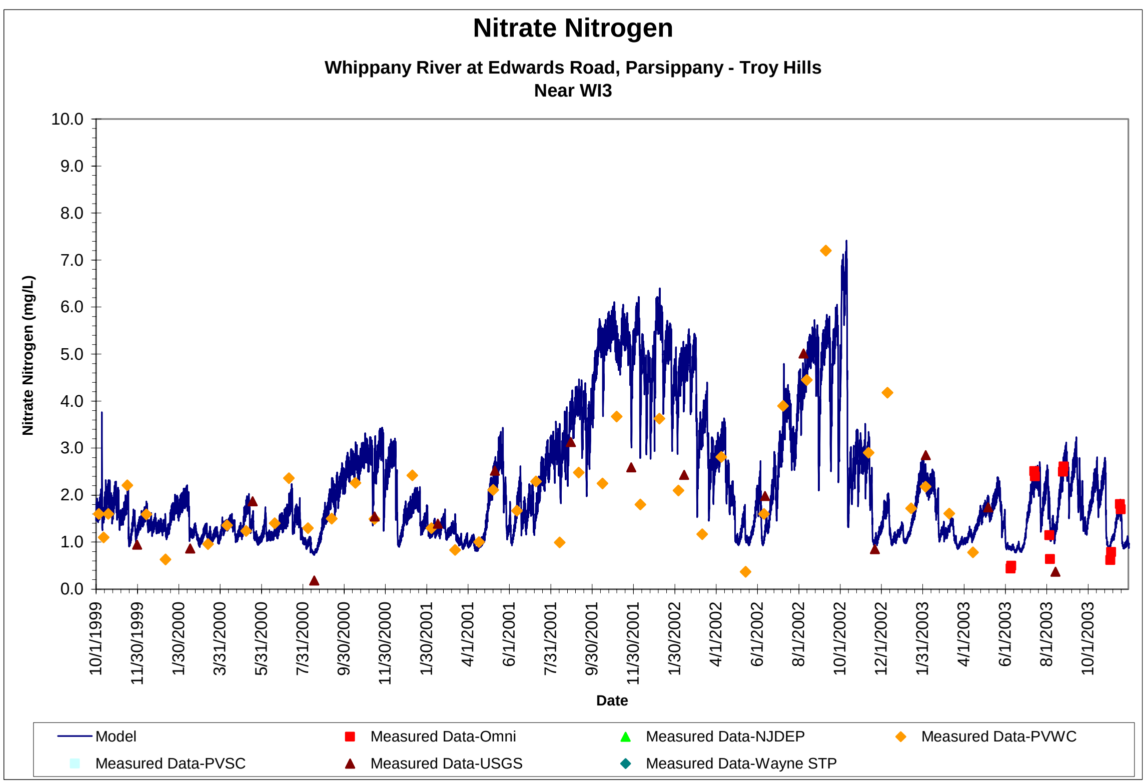
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



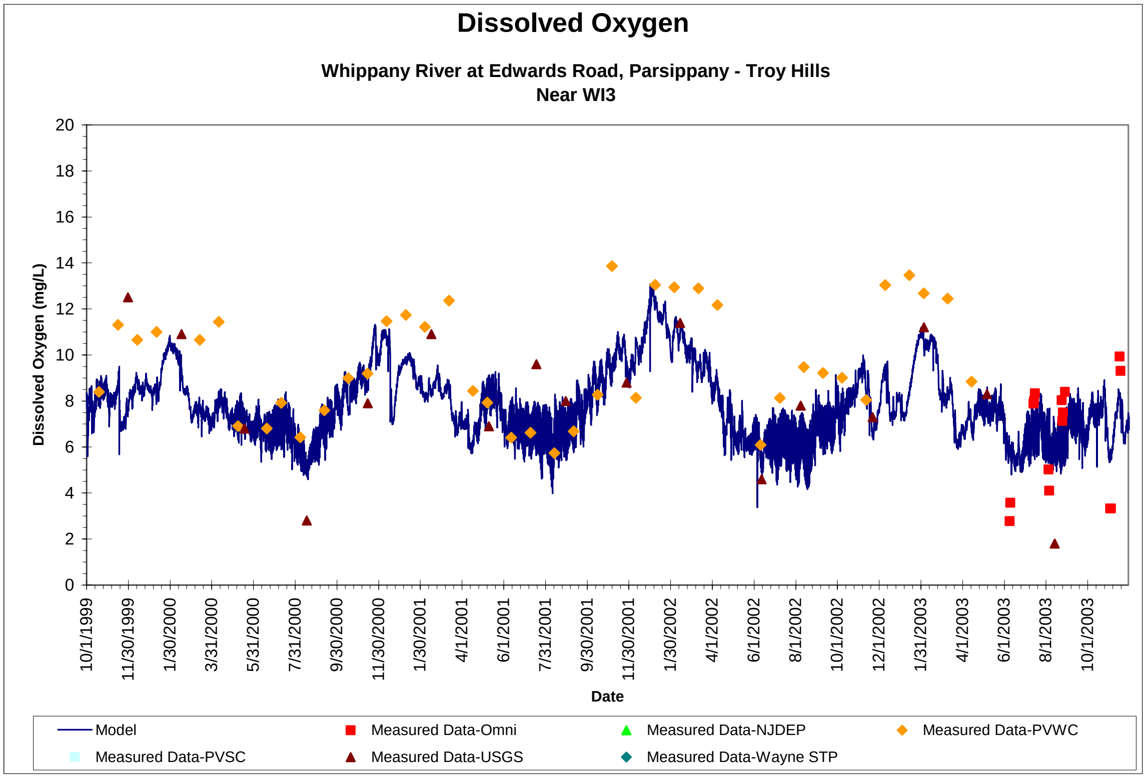


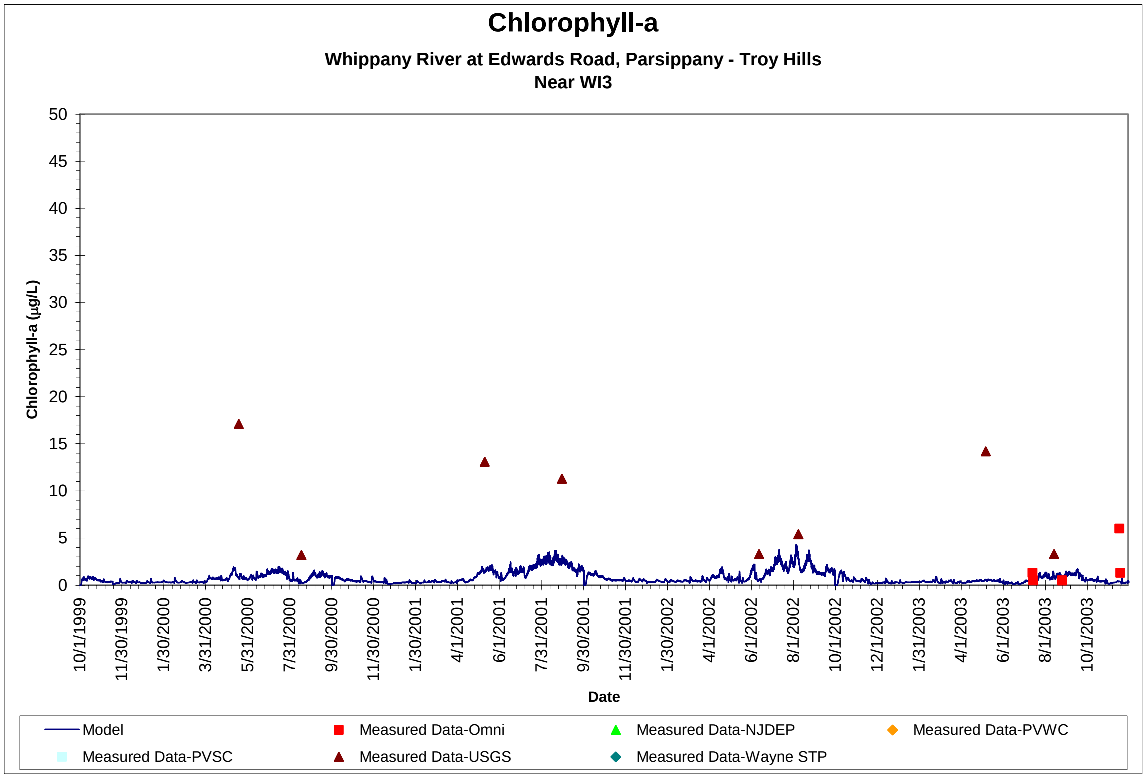
GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS





GRAB CHEMISTRY CALIBRATION AND VALIDATION RESULTS



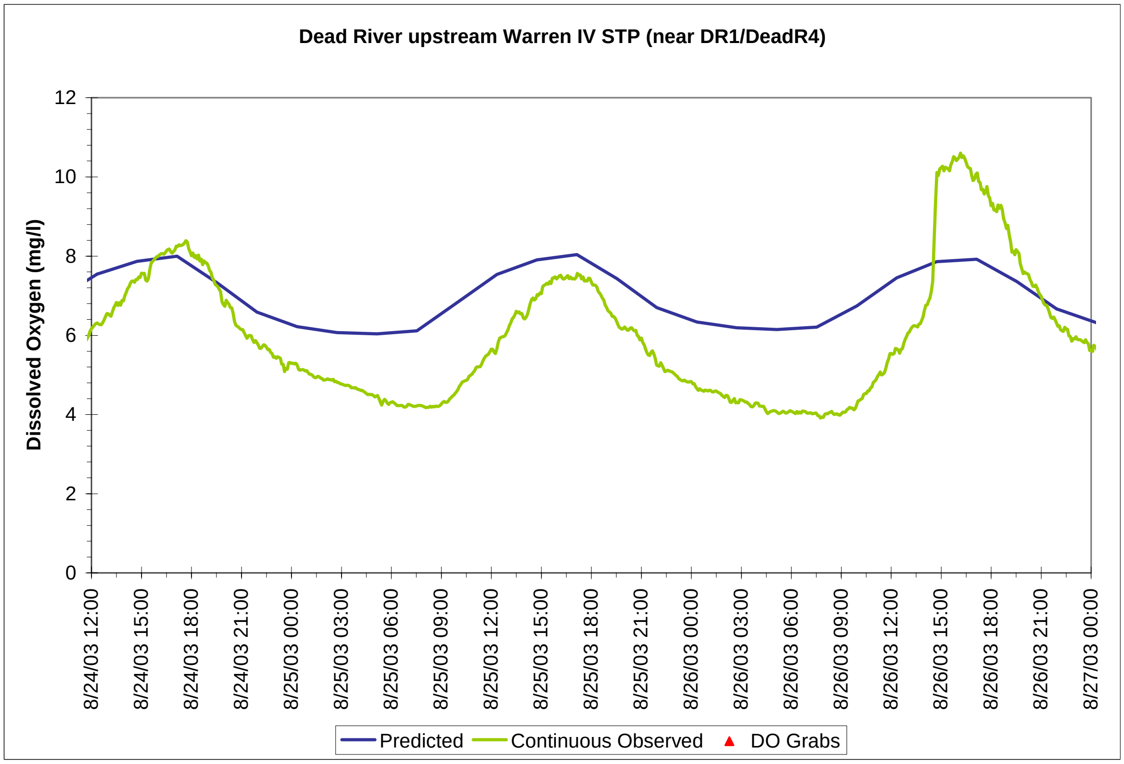


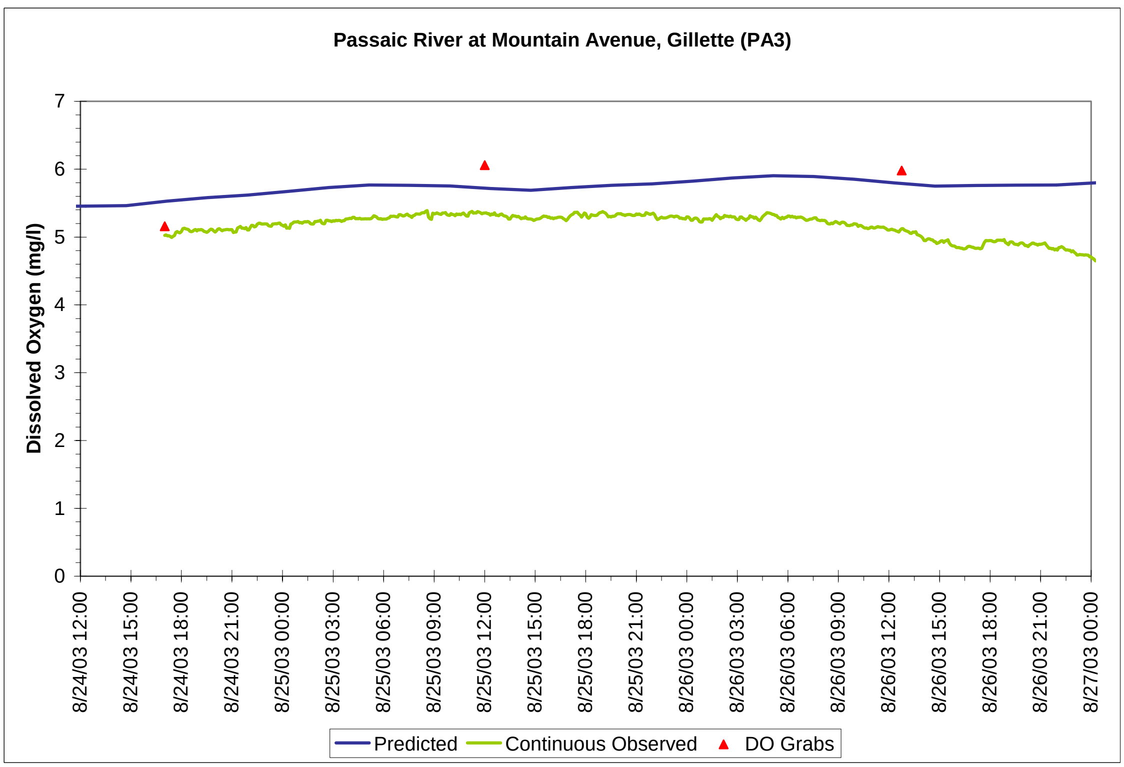
APPENDIX F

Diurnal Dissolved Oxygen
Calibration and Validation Results

DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

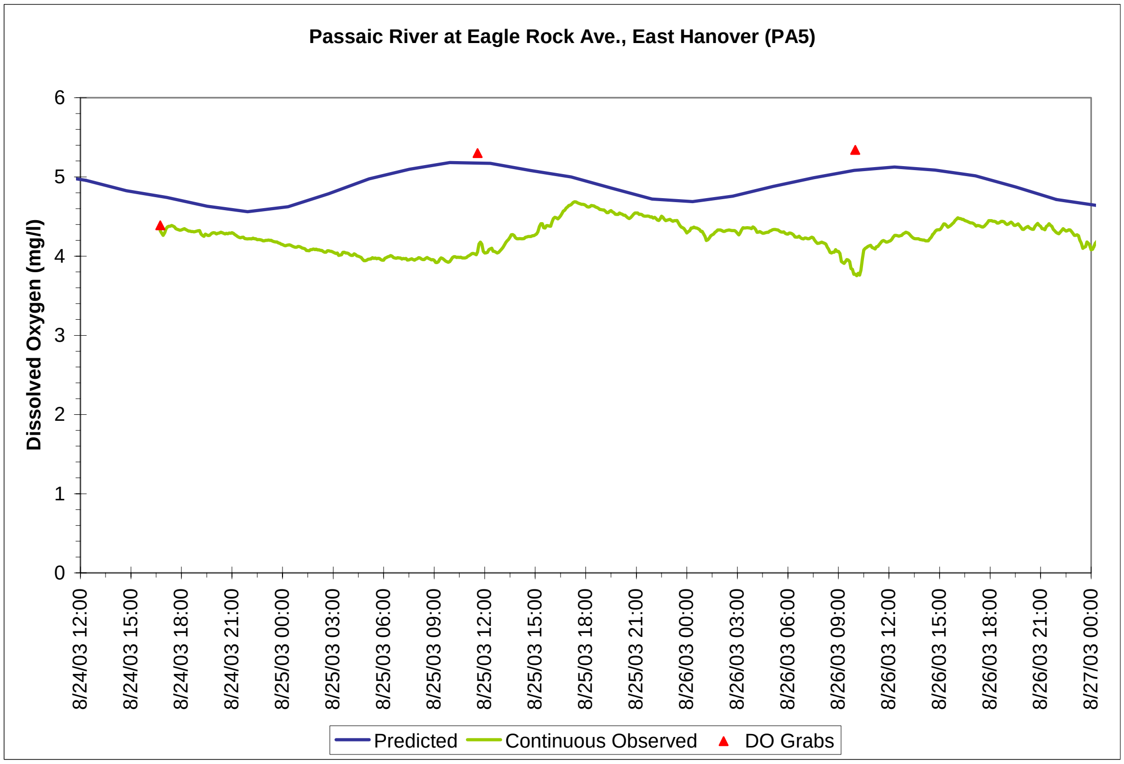
August 2003 Calibration

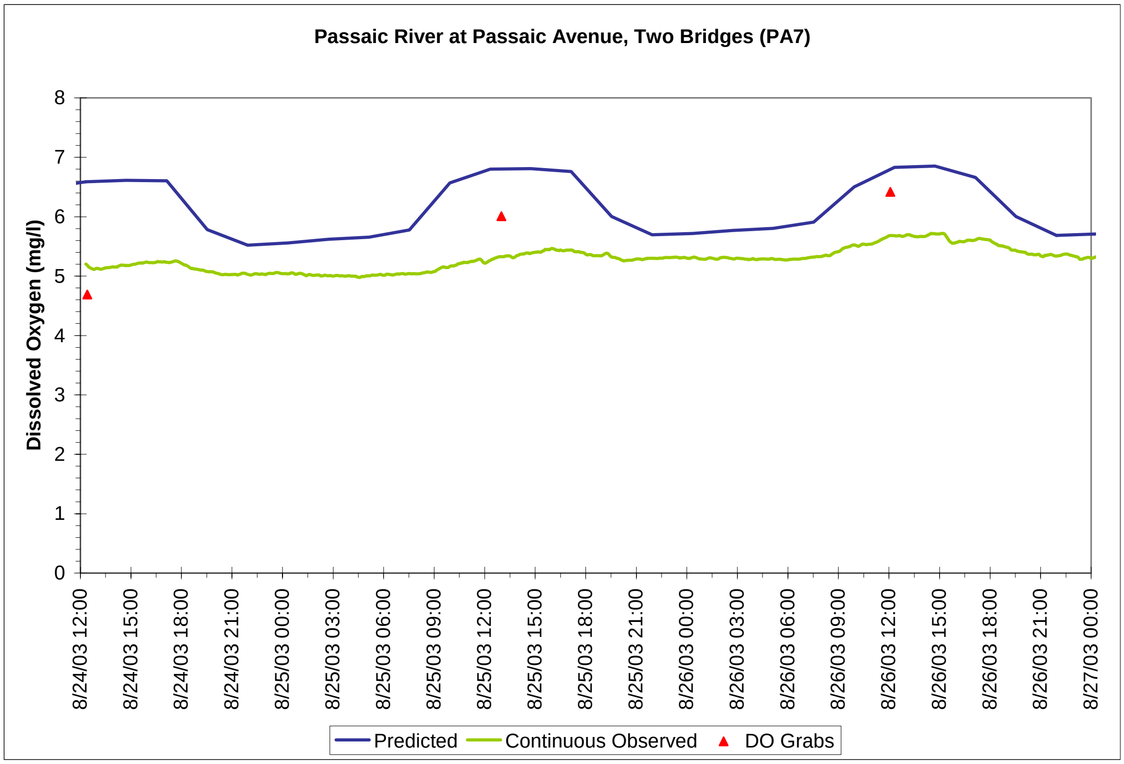




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

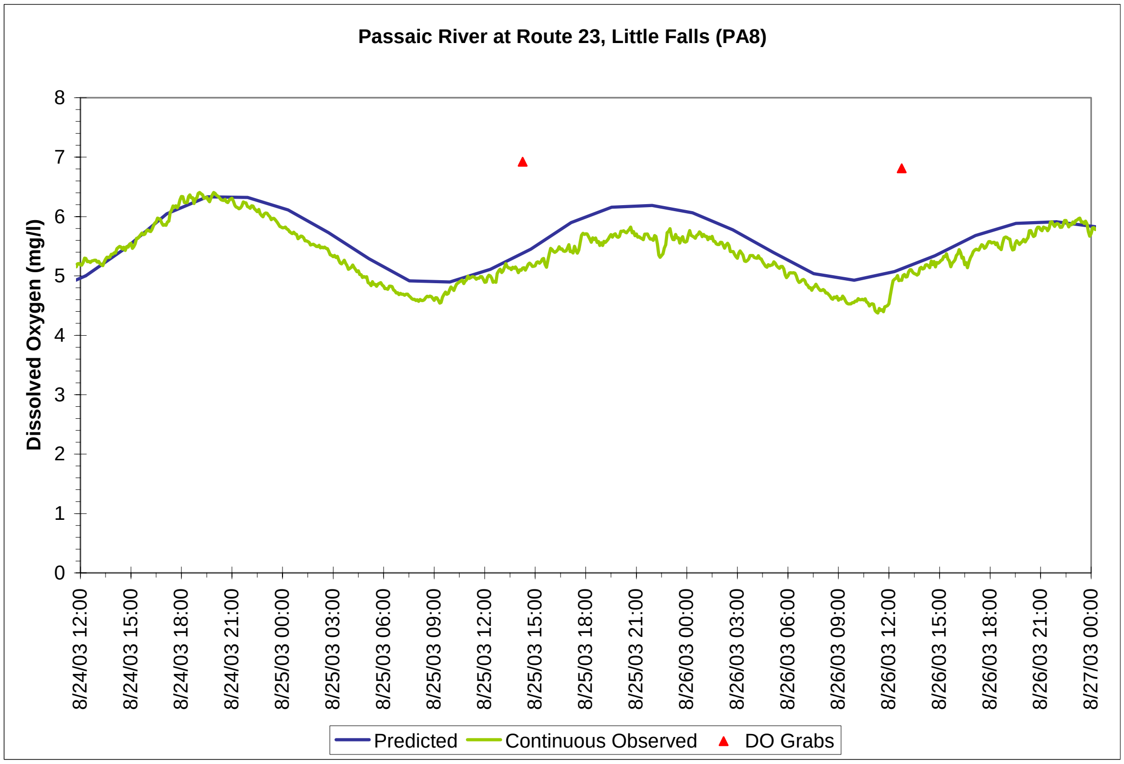
August 2003 Calibration

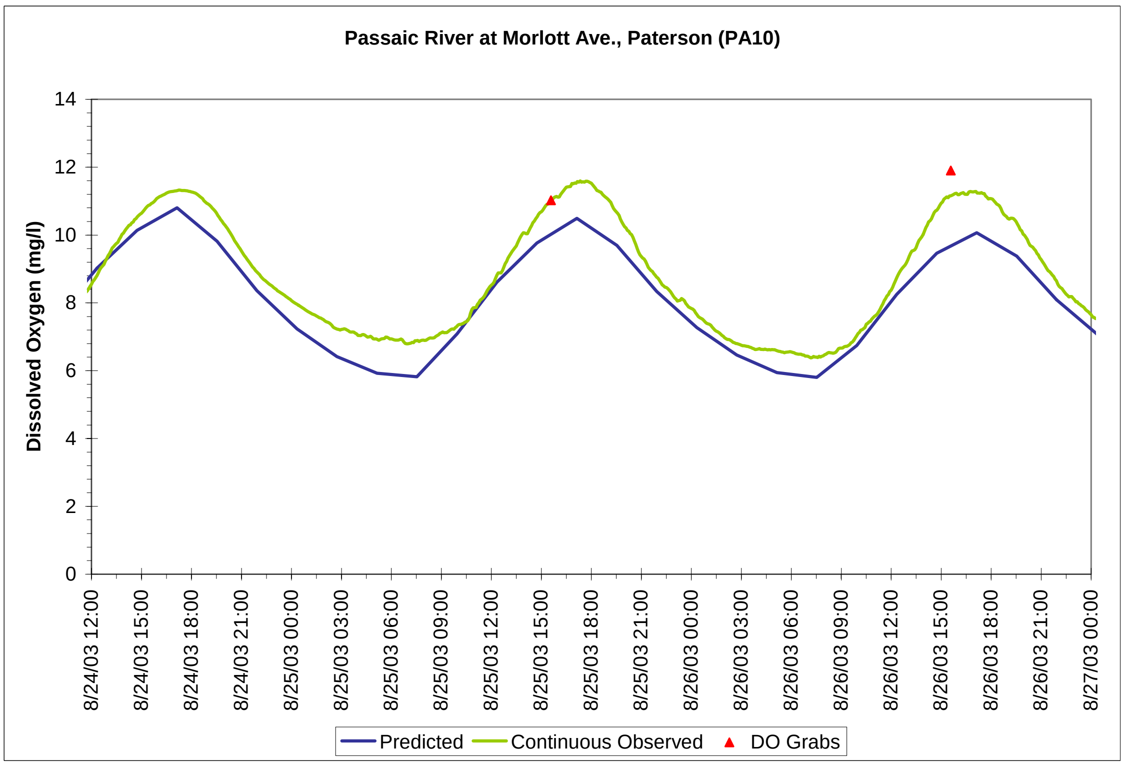




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

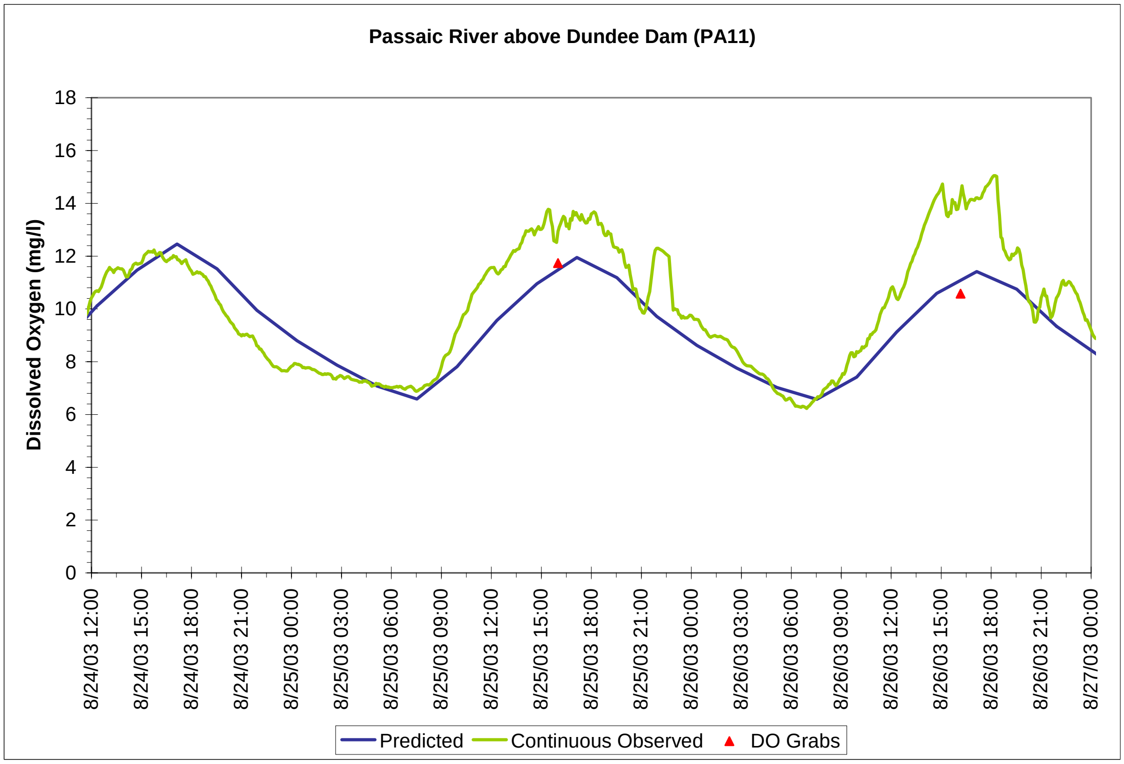
August 2003 Calibration

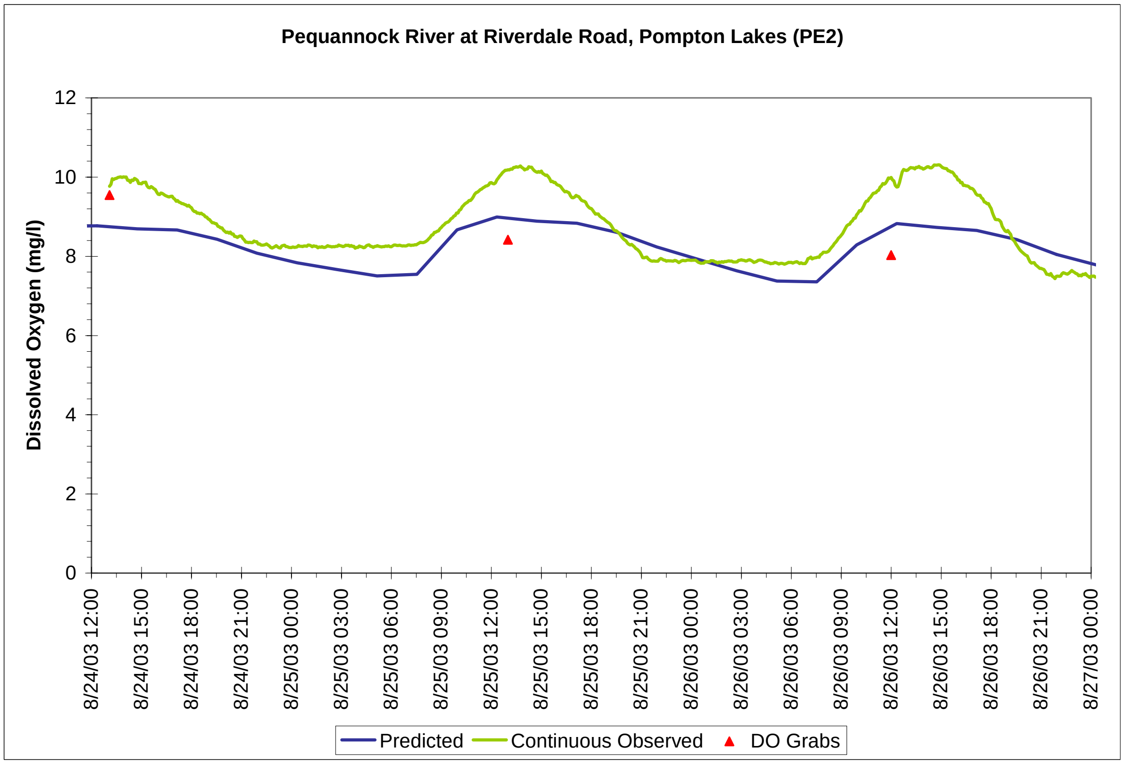




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

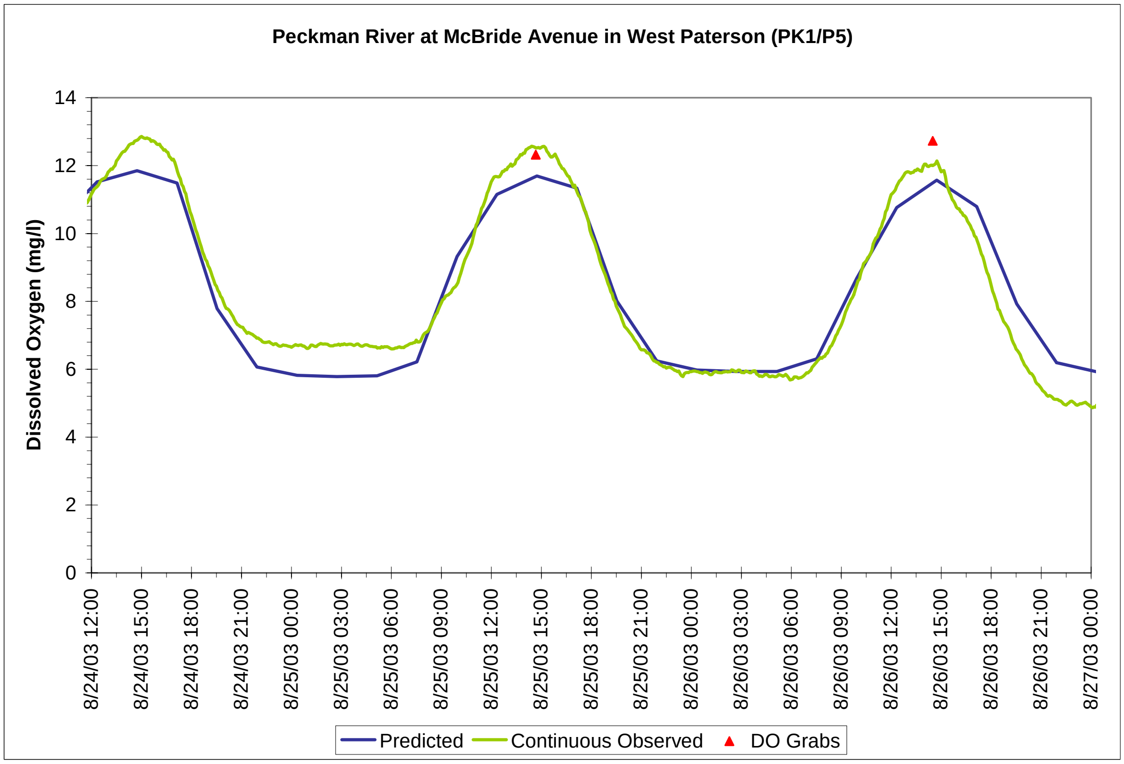
August 2003 Calibration

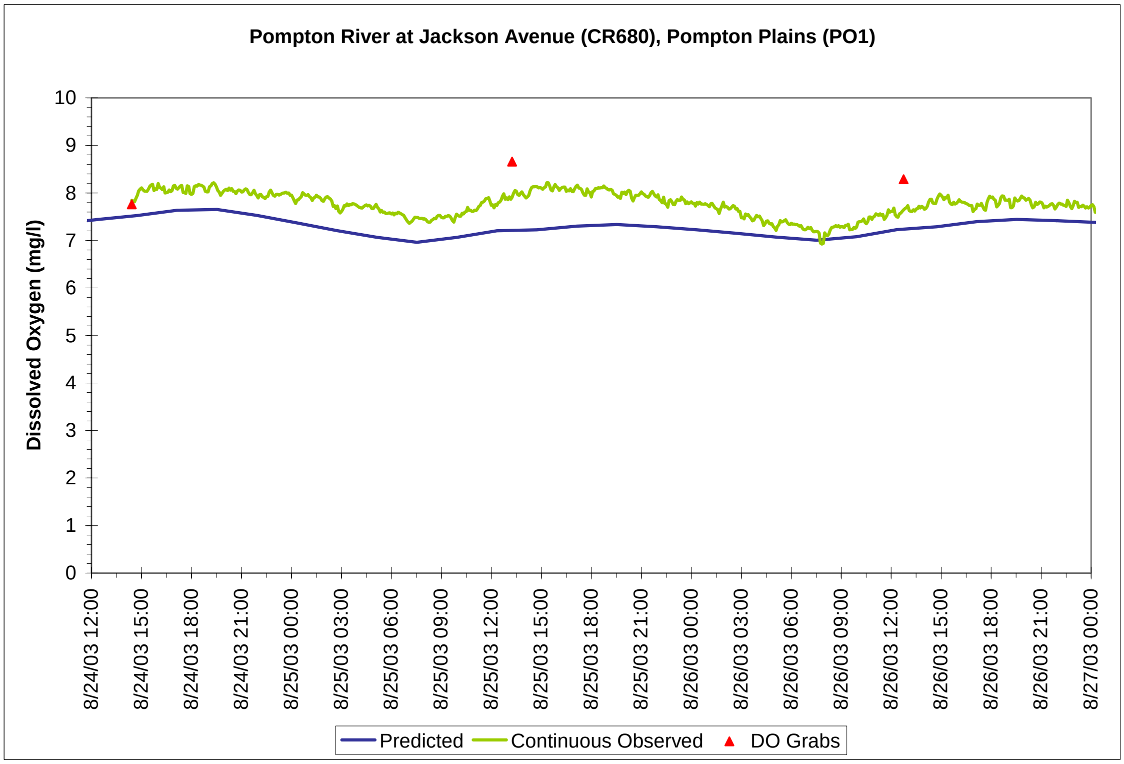




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

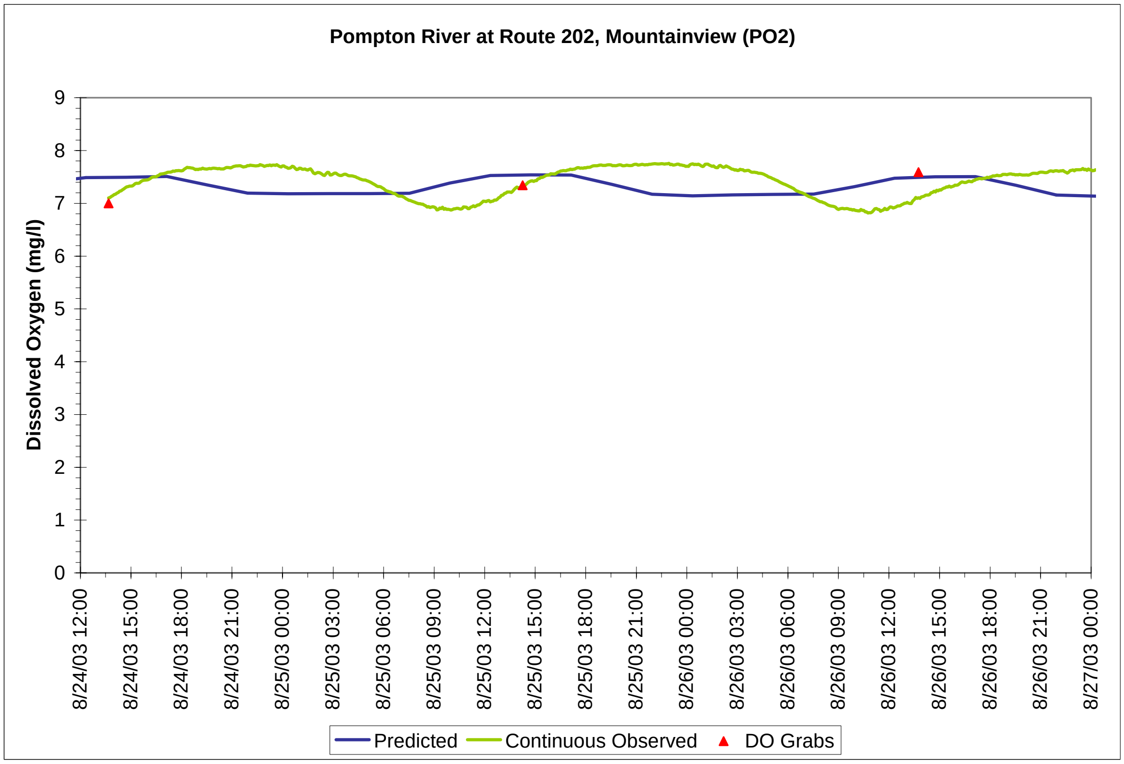
August 2003 Calibration

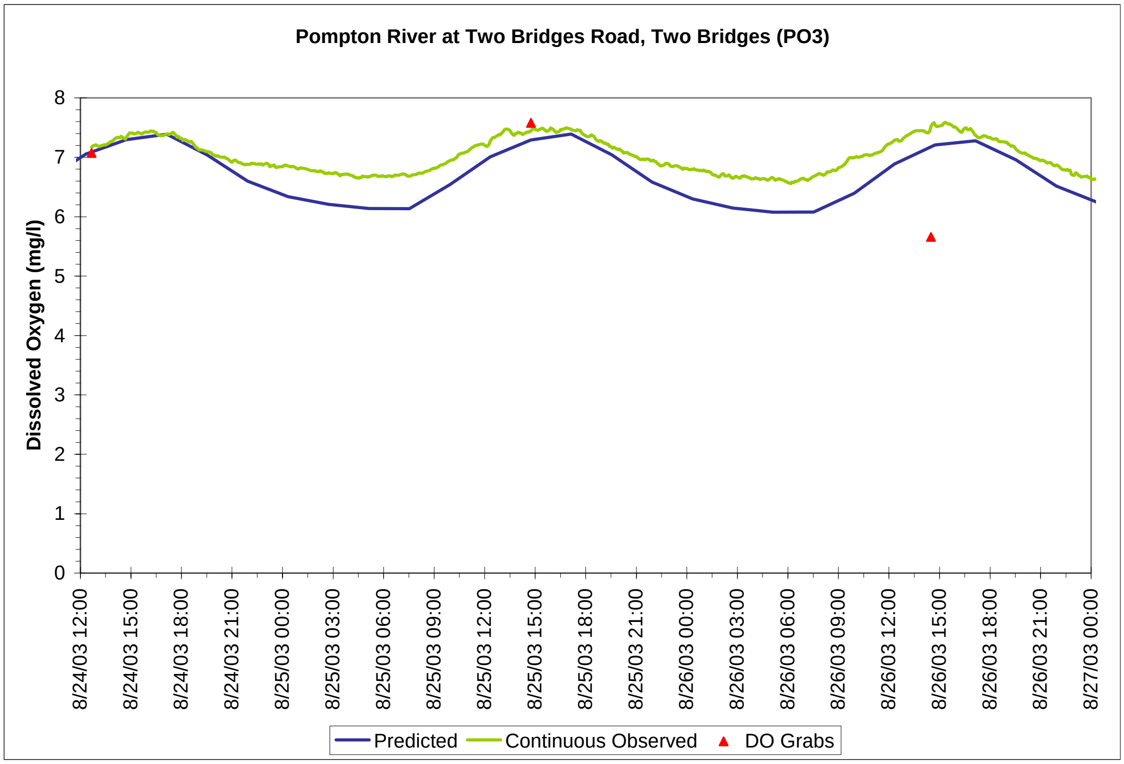




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

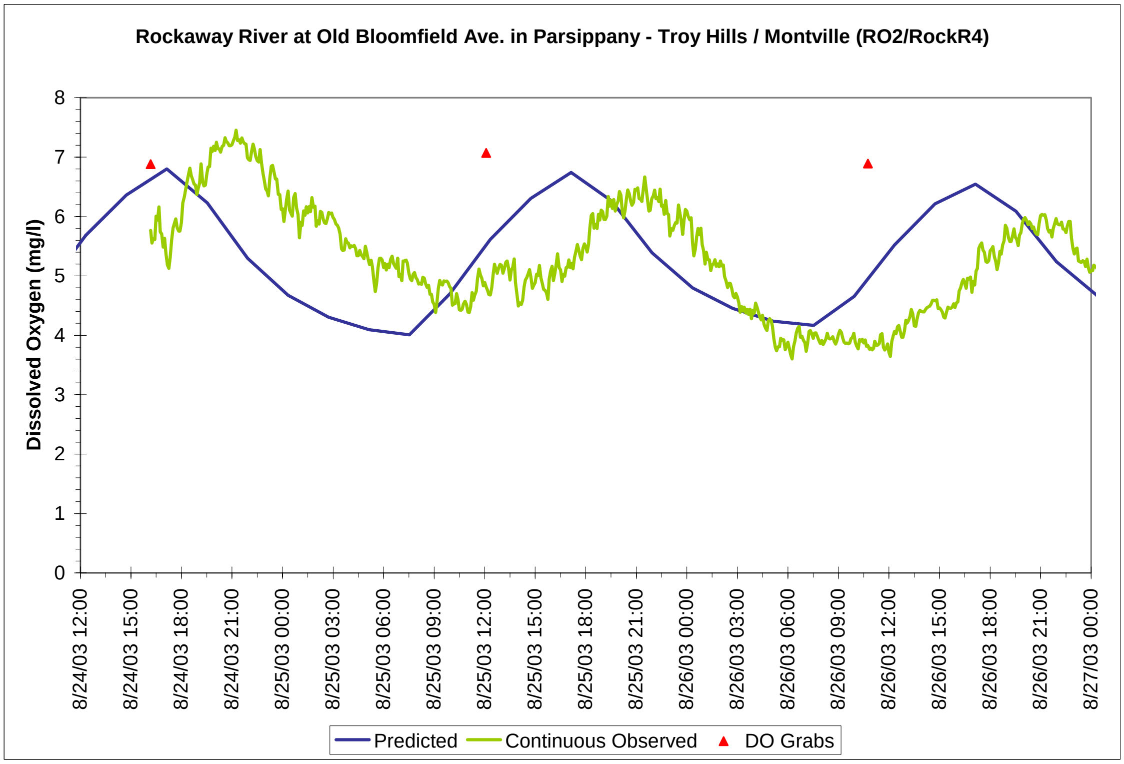
August 2003 Calibration

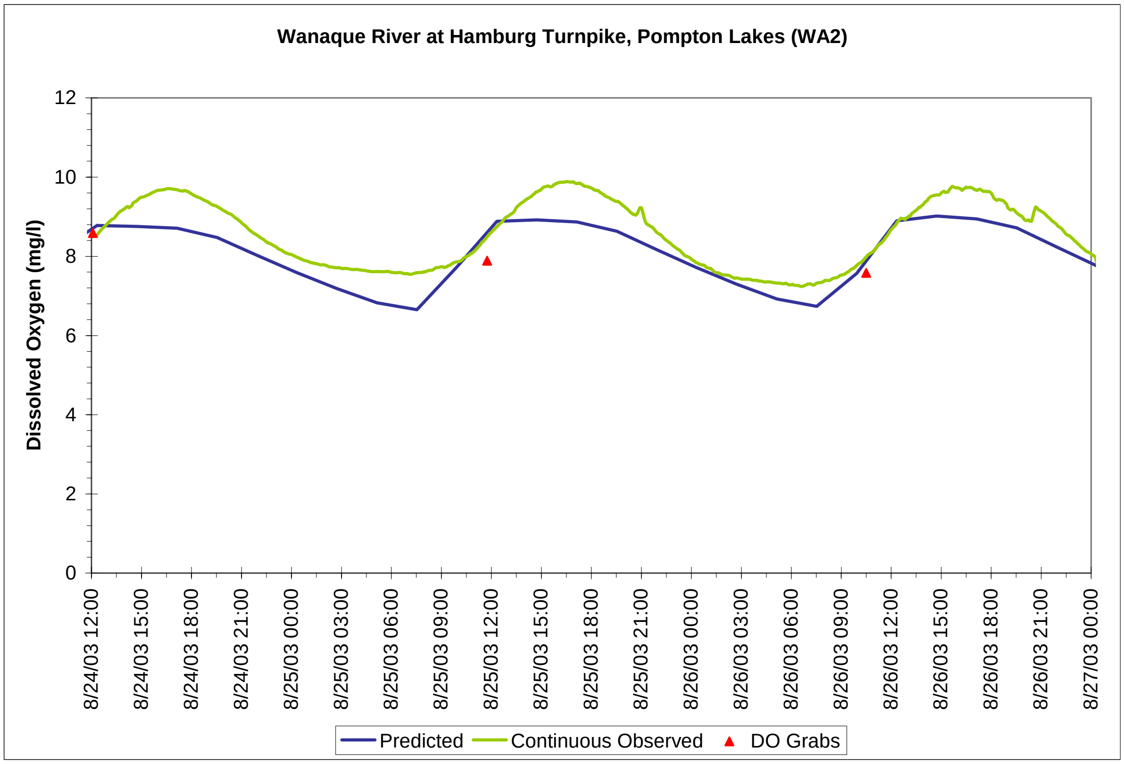




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

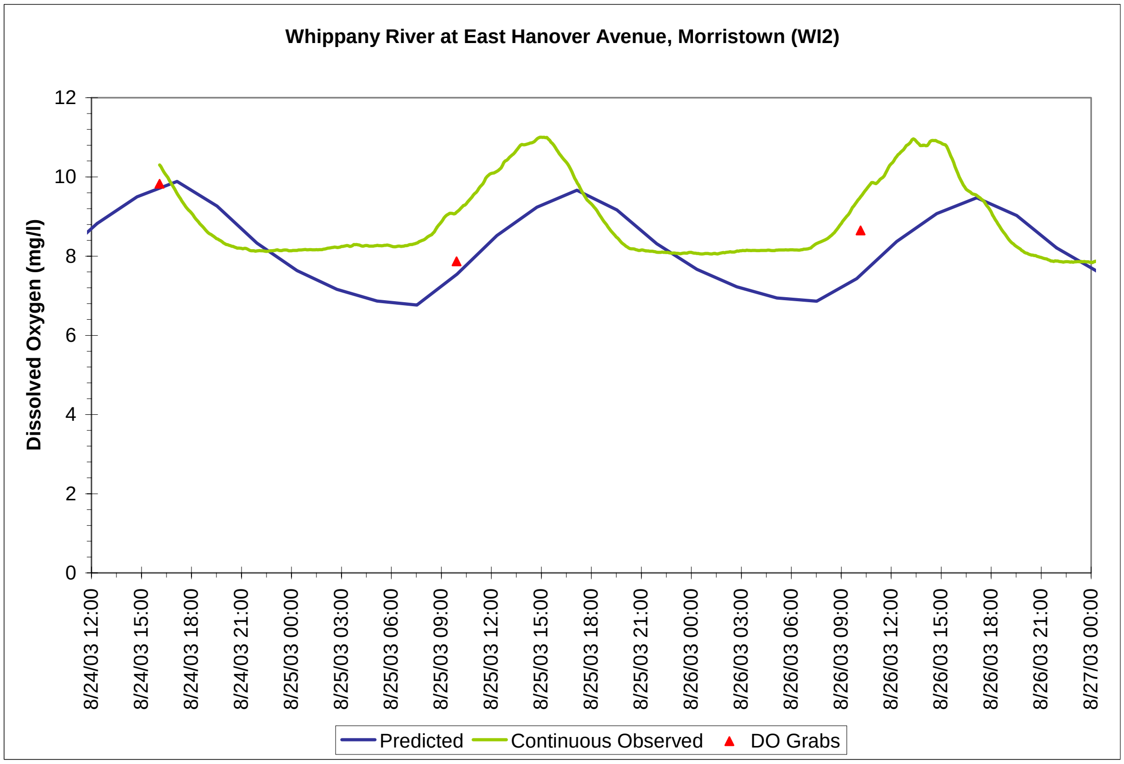
August 2003 Calibration

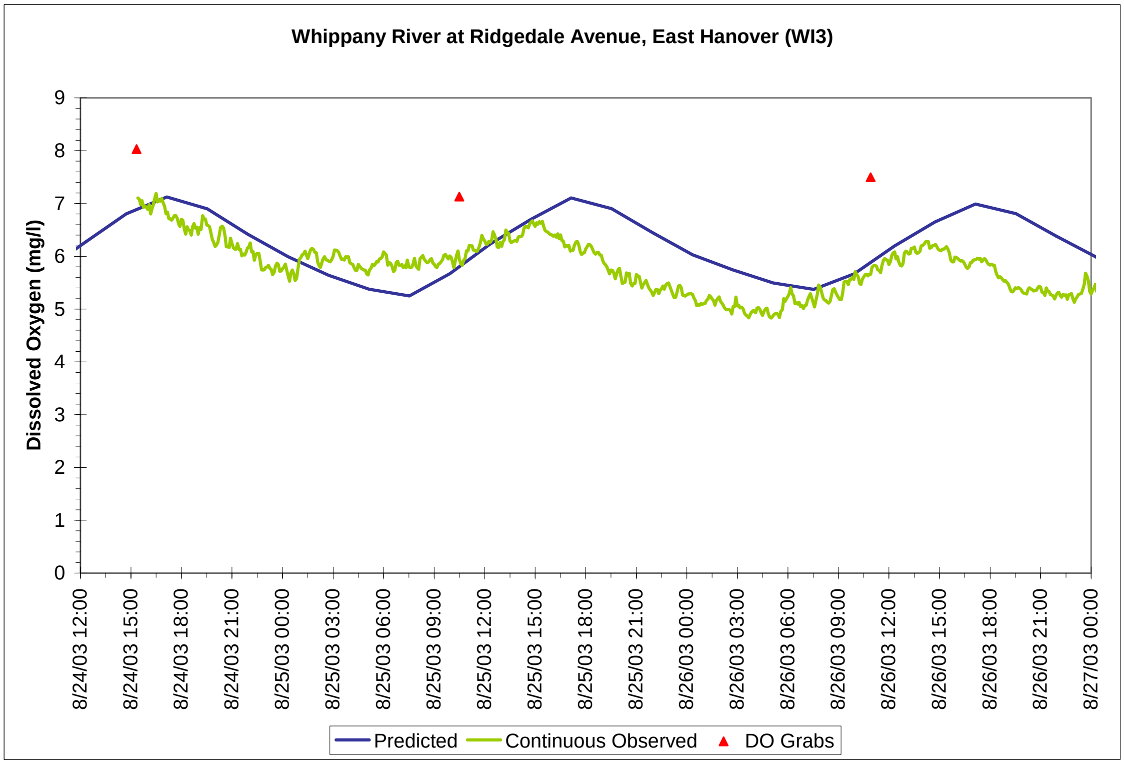




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

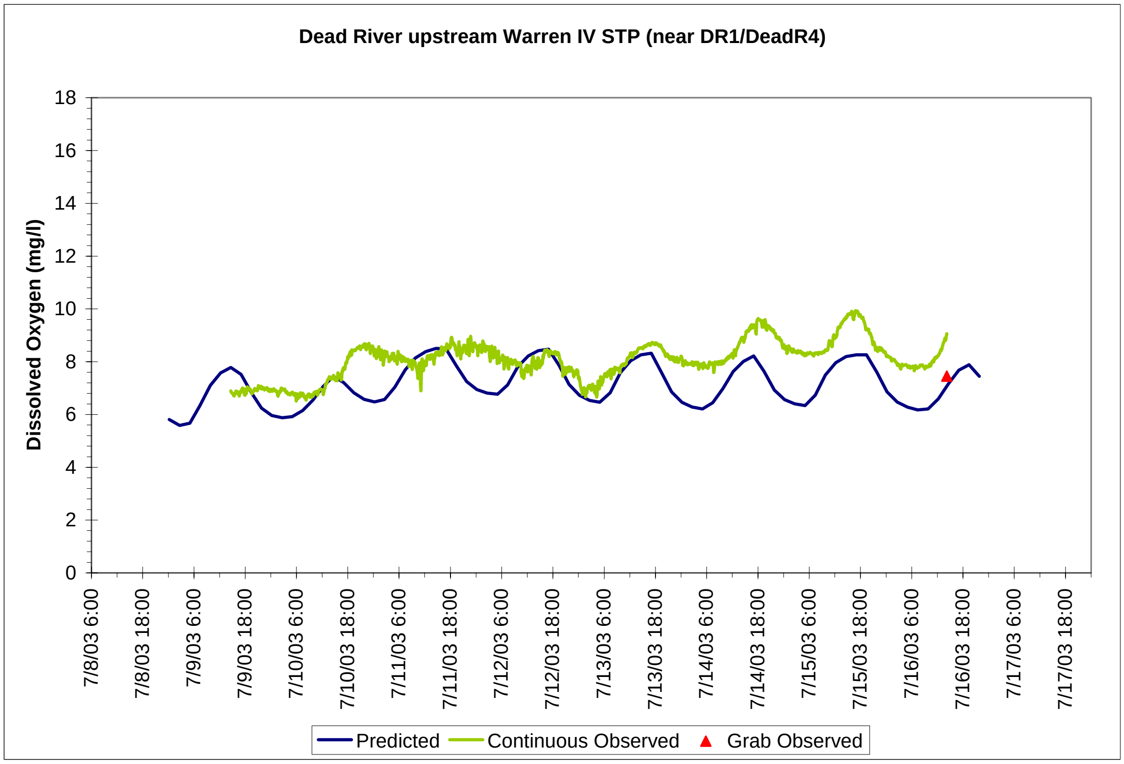
August 2003 Calibration

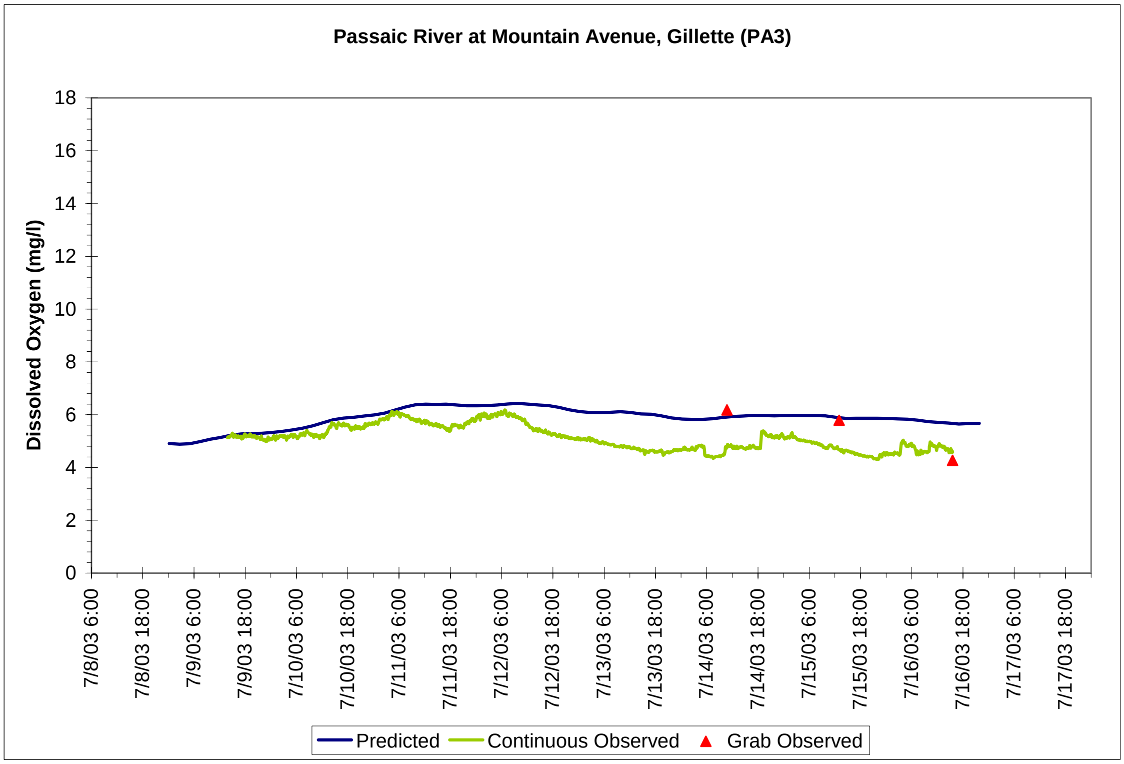




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

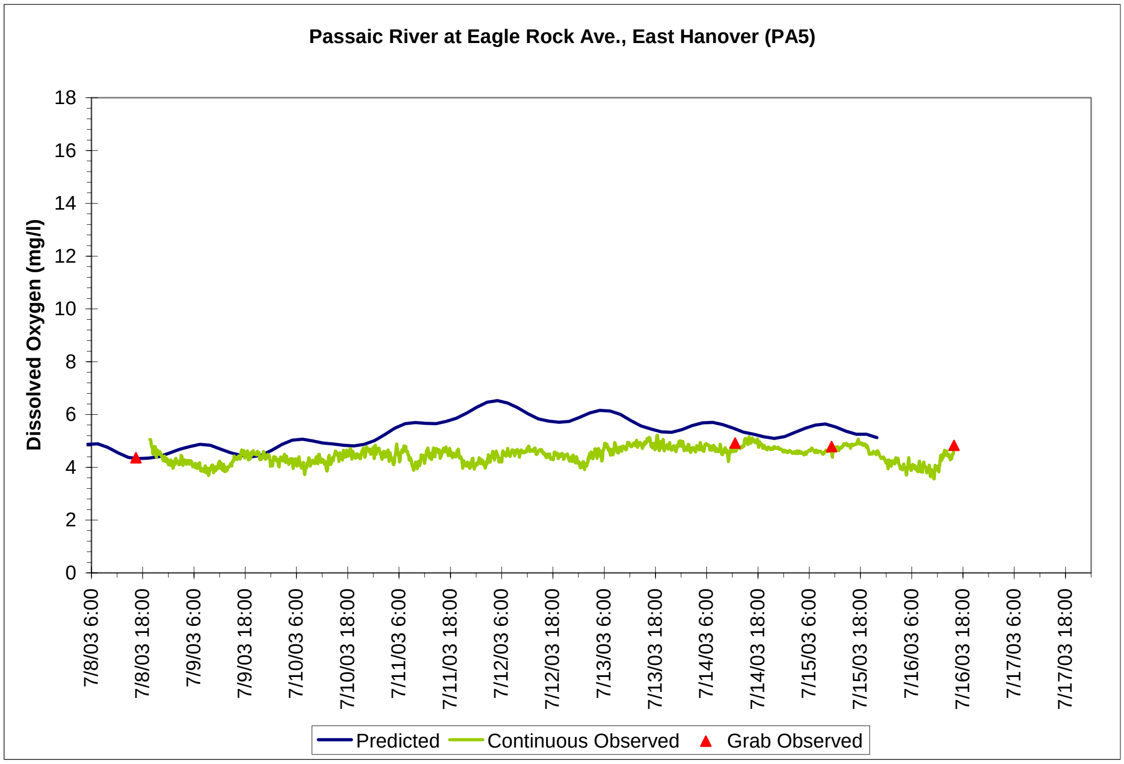
July 2003 Validation

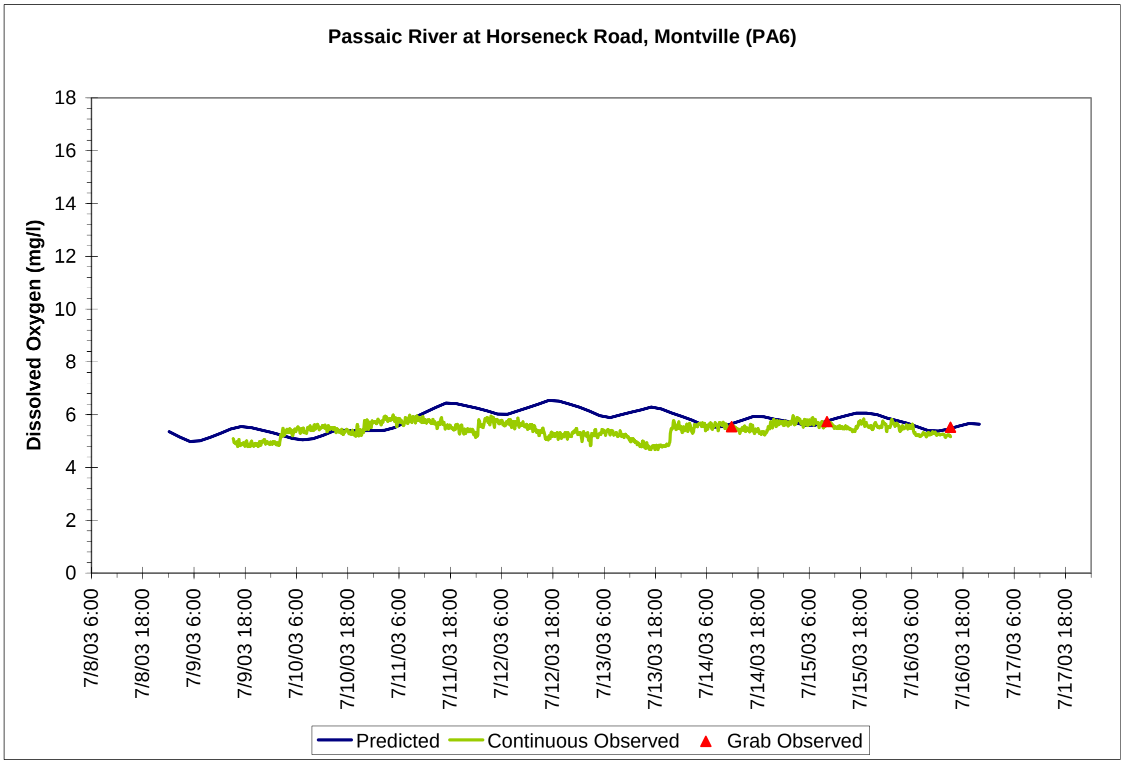




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

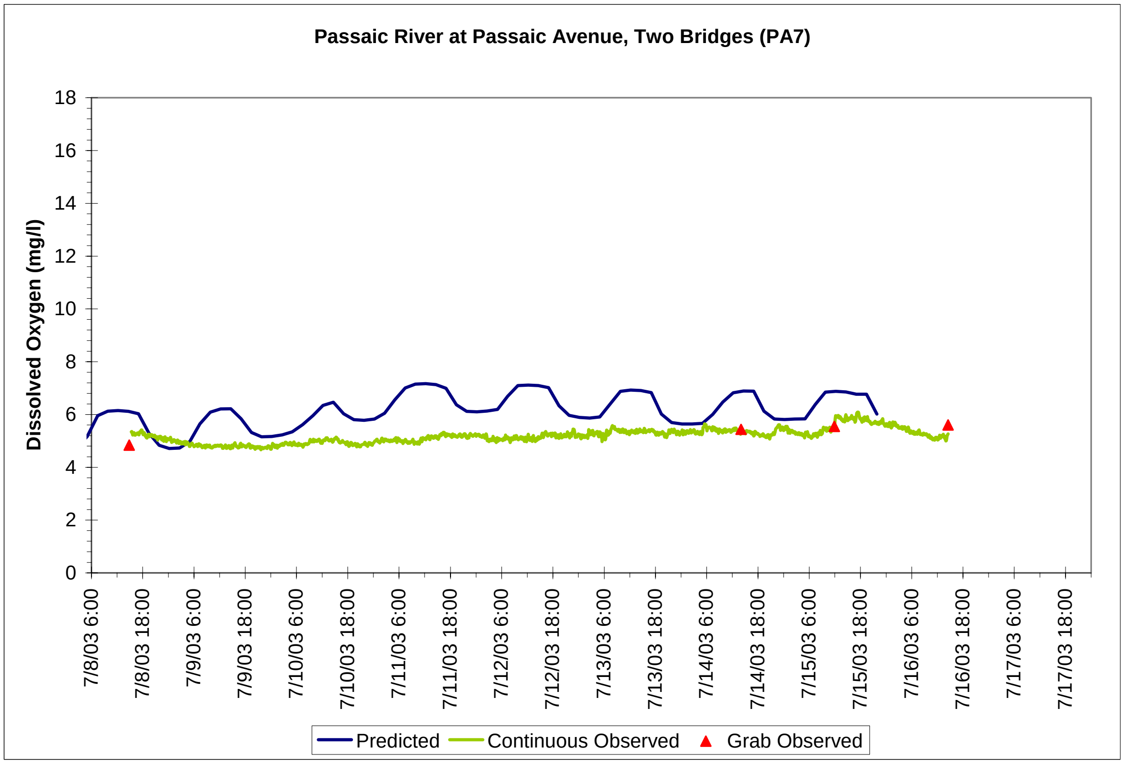
July 2003 Validation

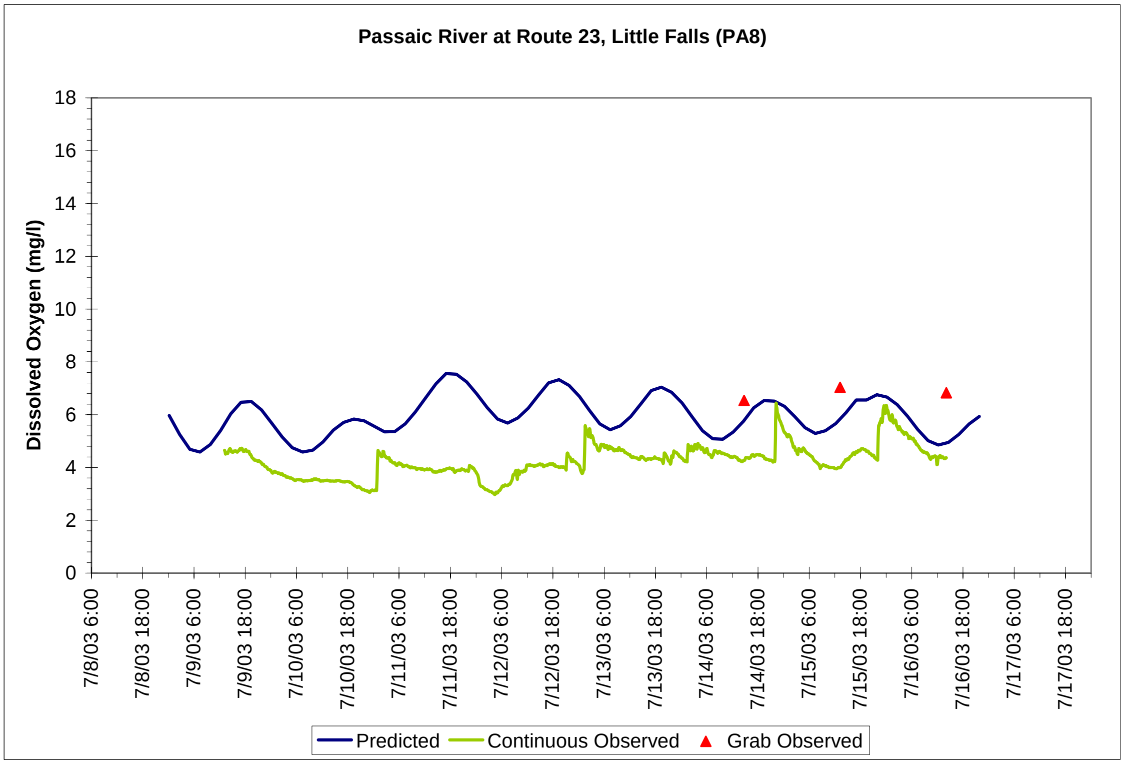




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

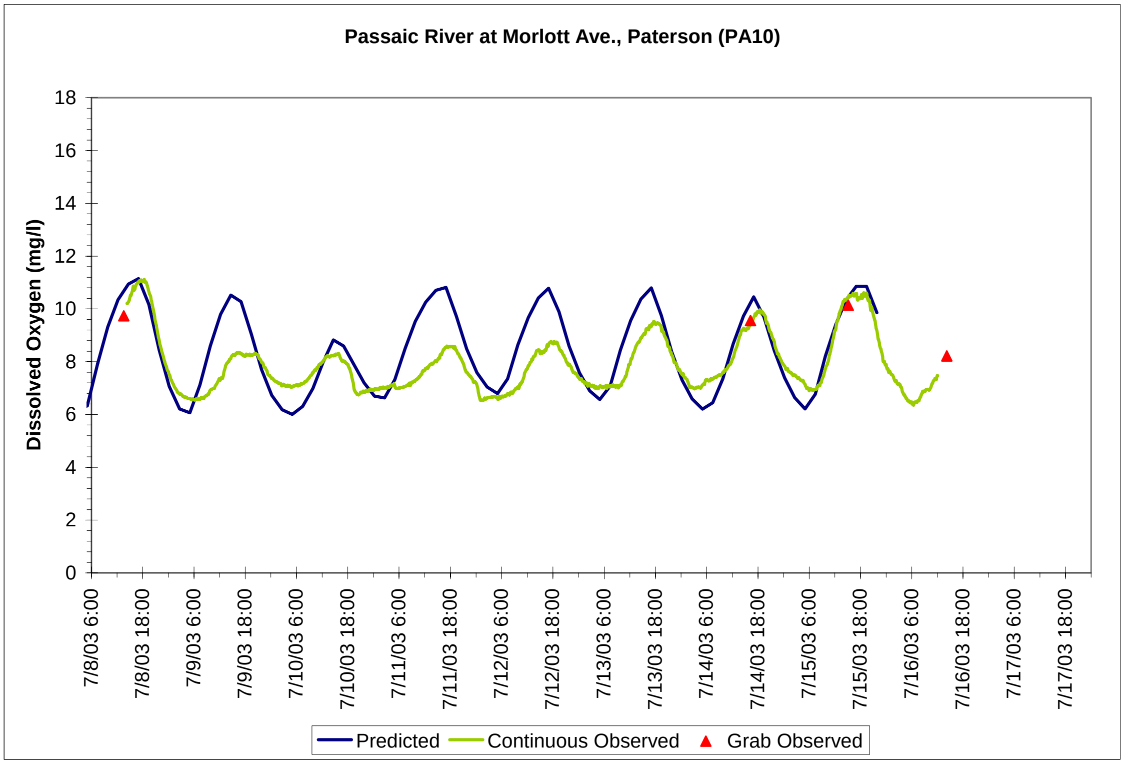
July 2003 Validation

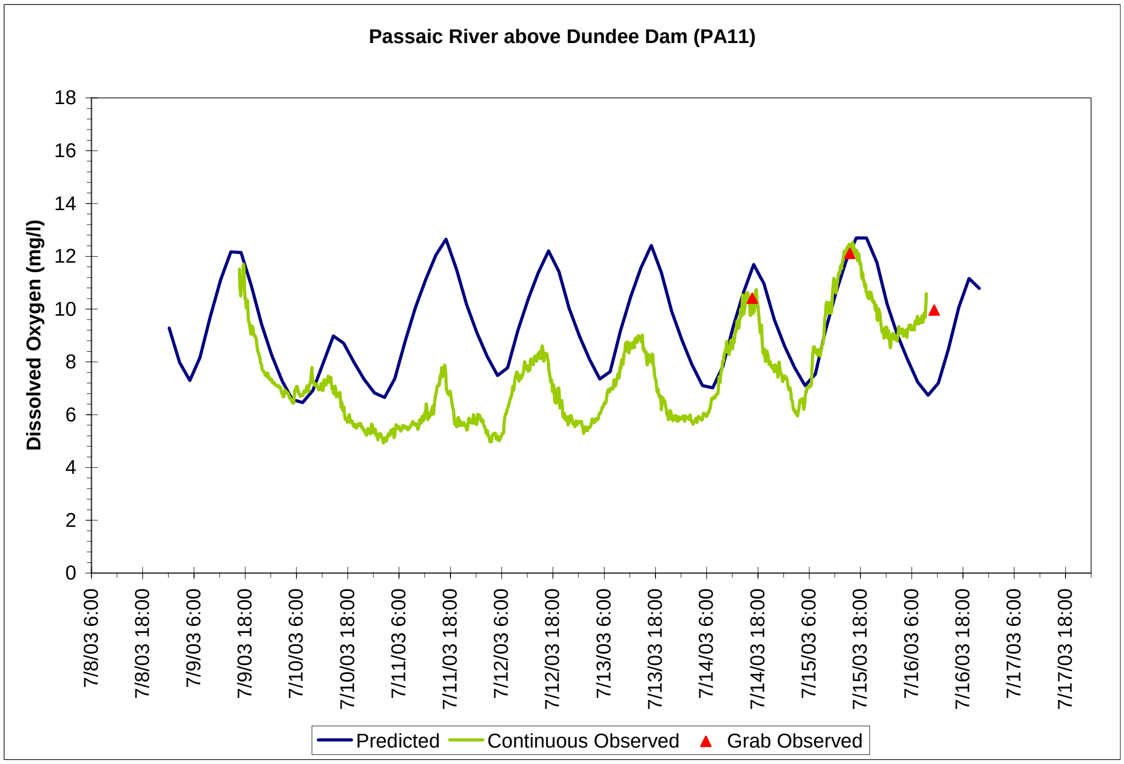




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

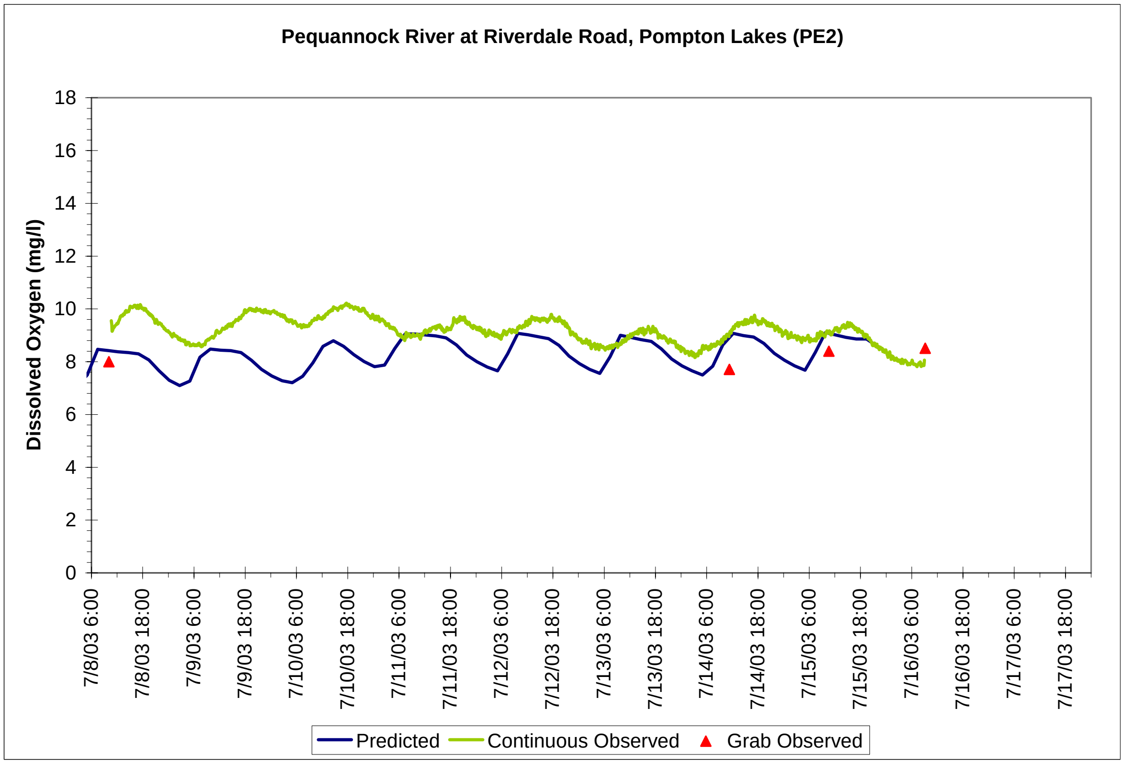
July 2003 Validation

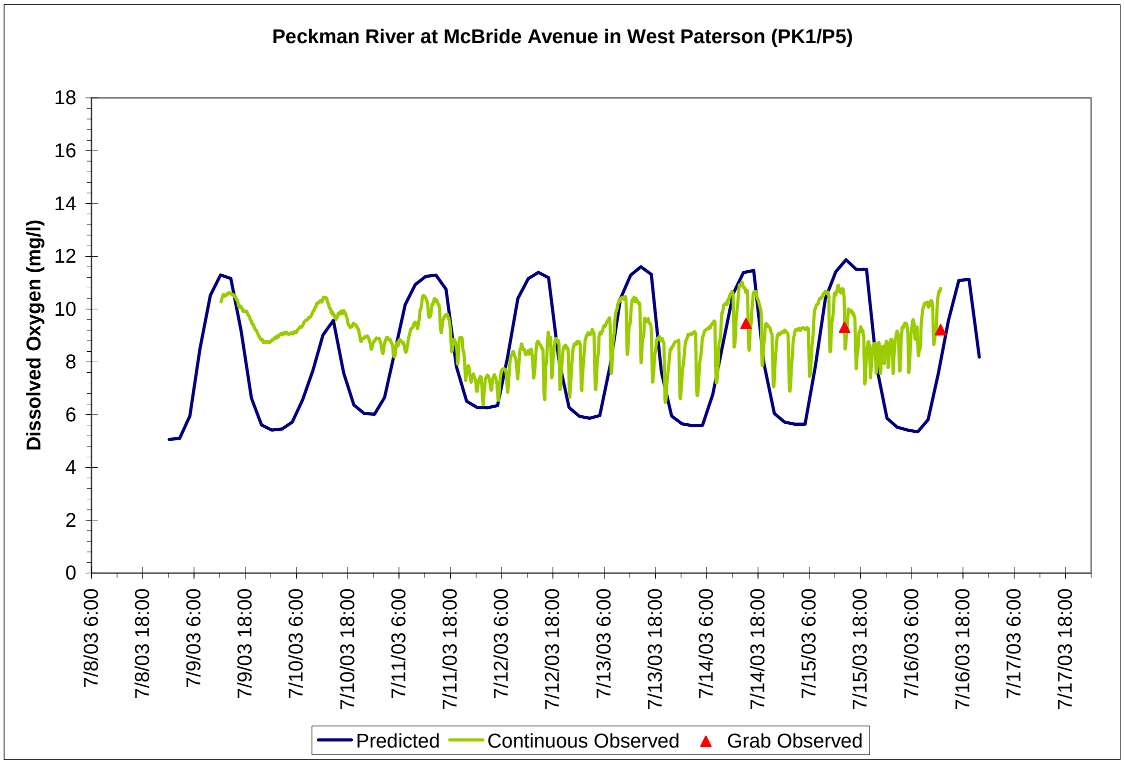




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

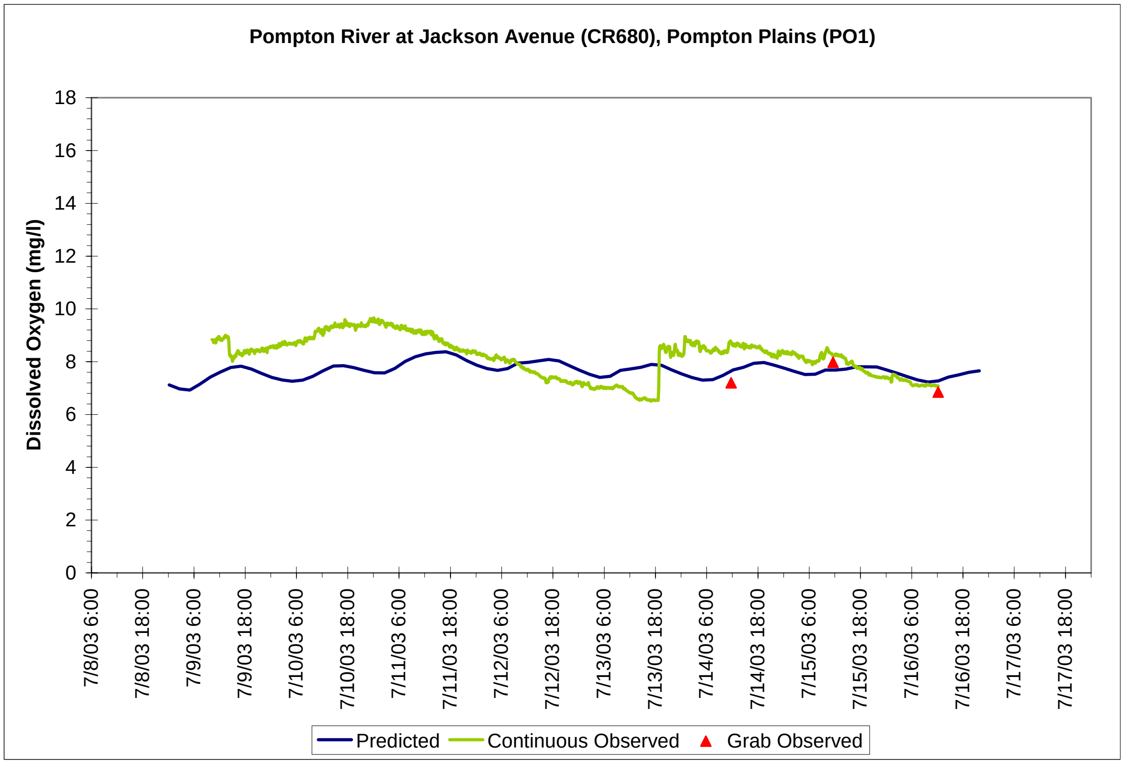
July 2003 Validation

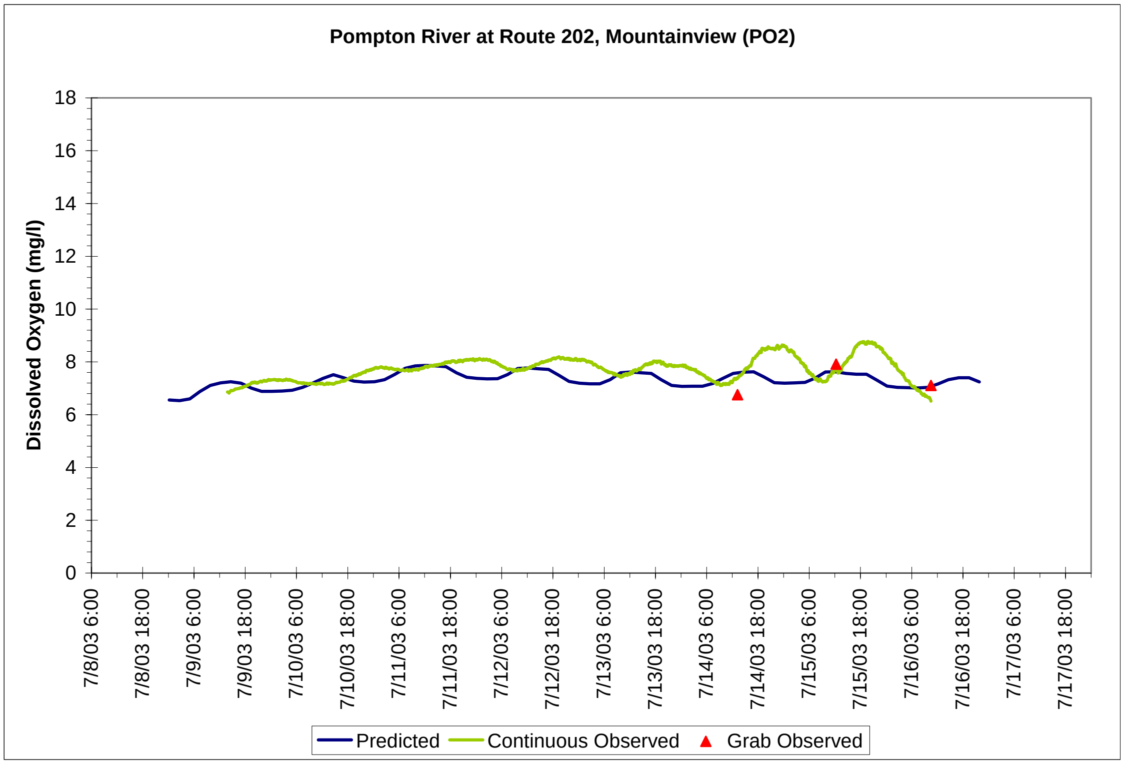




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

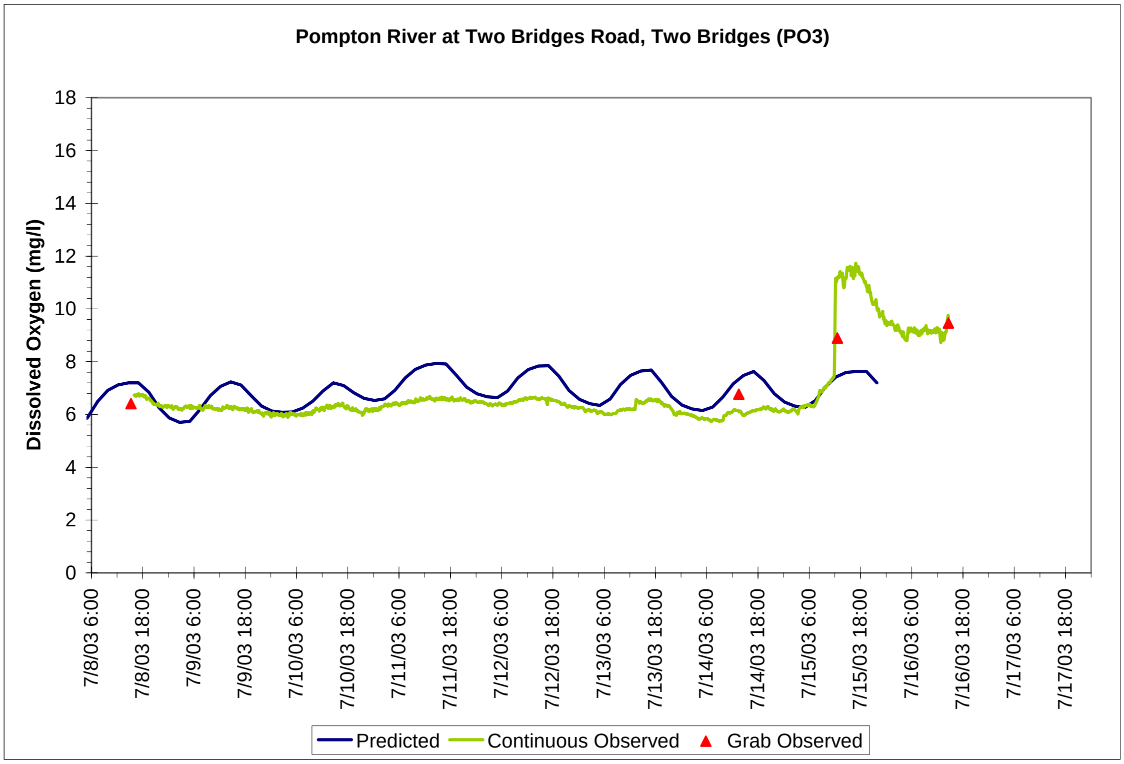
July 2003 Validation

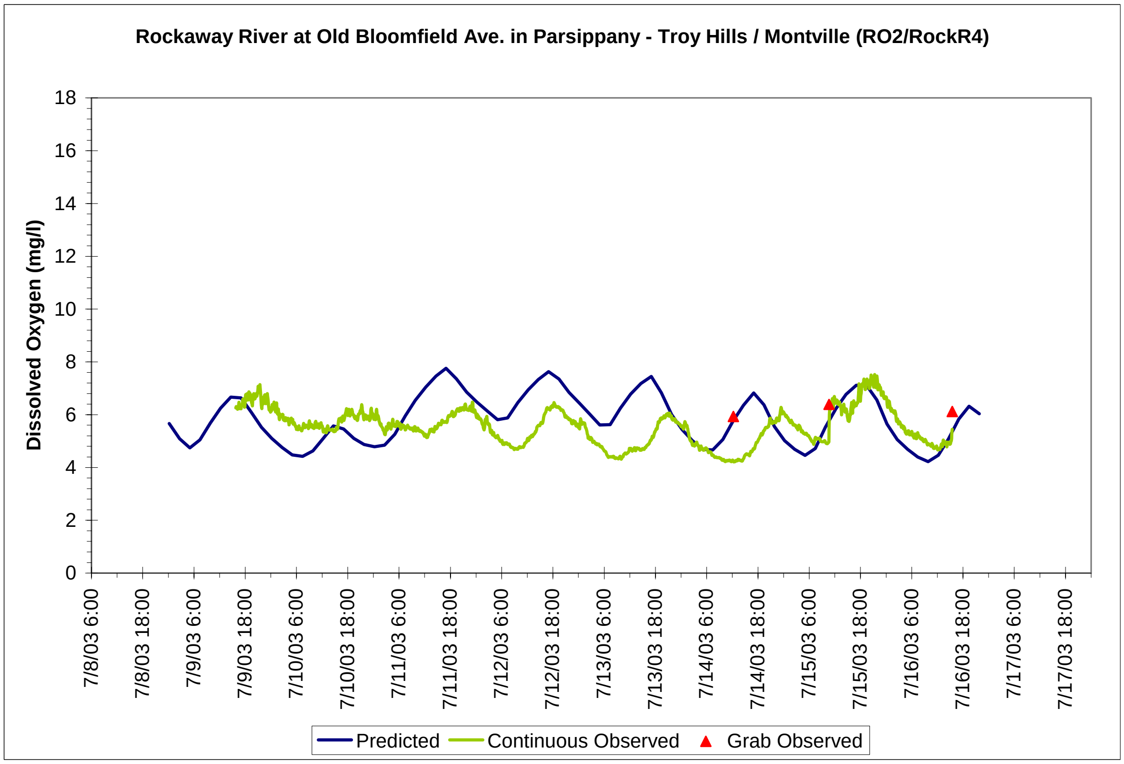




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

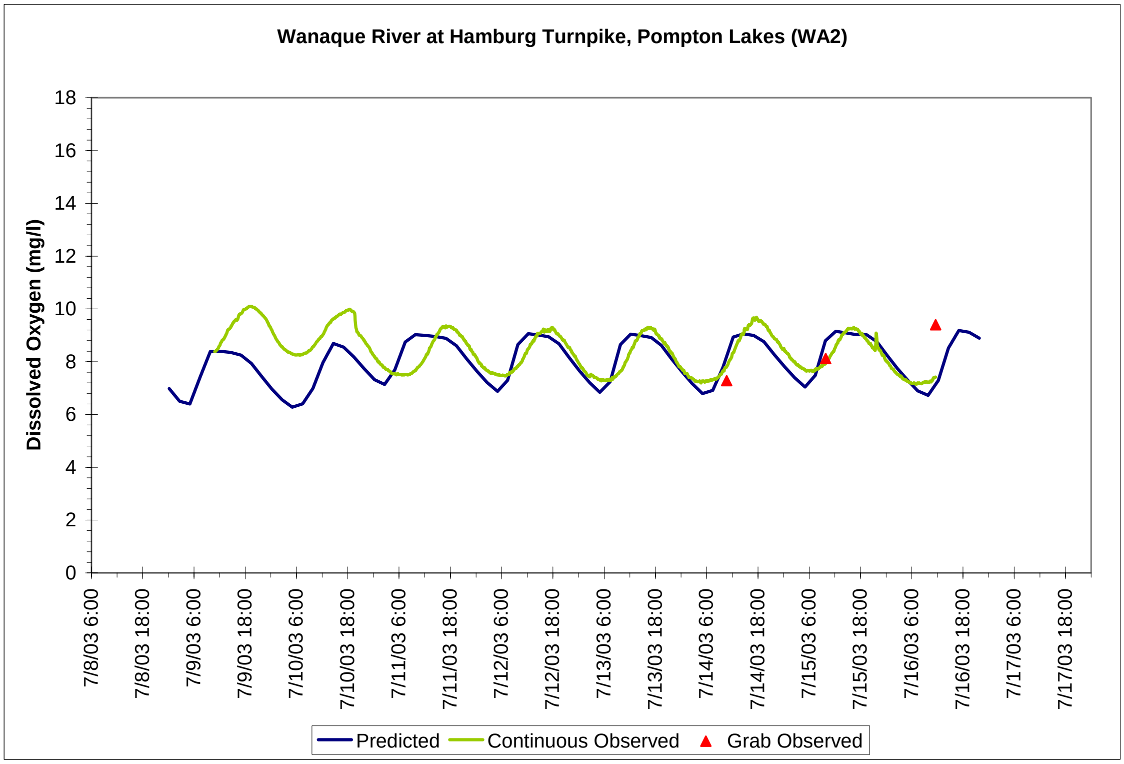
July 2003 Validation

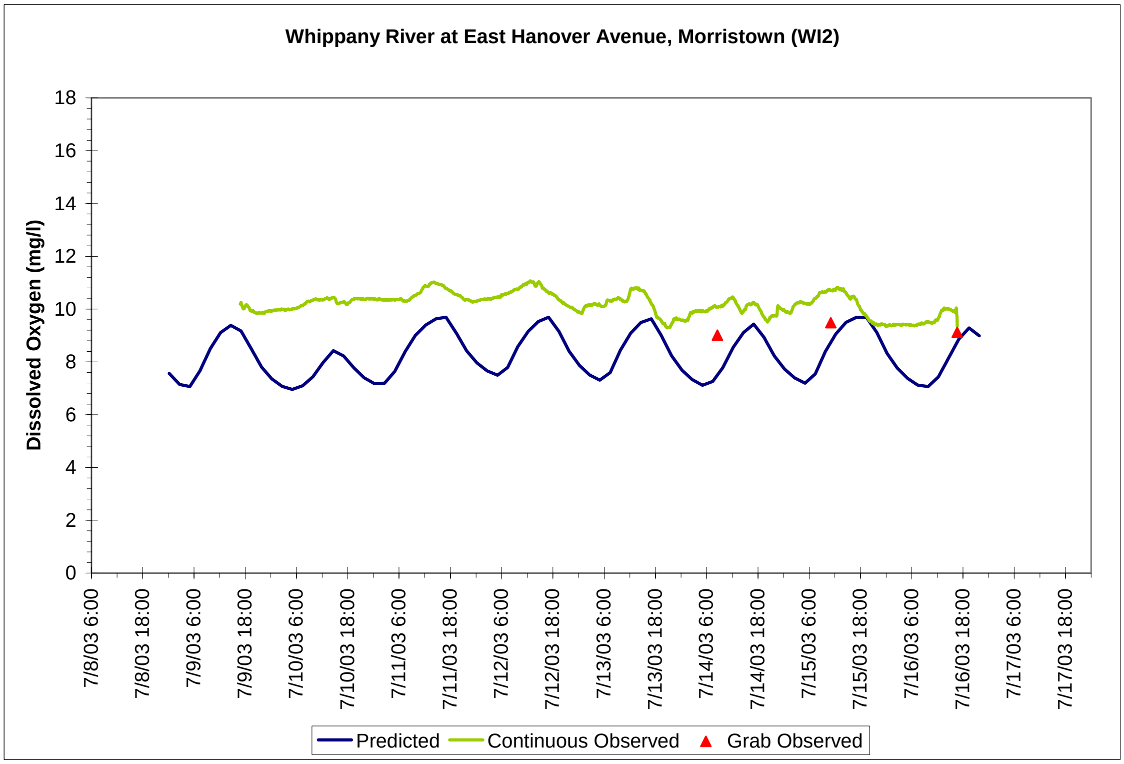




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

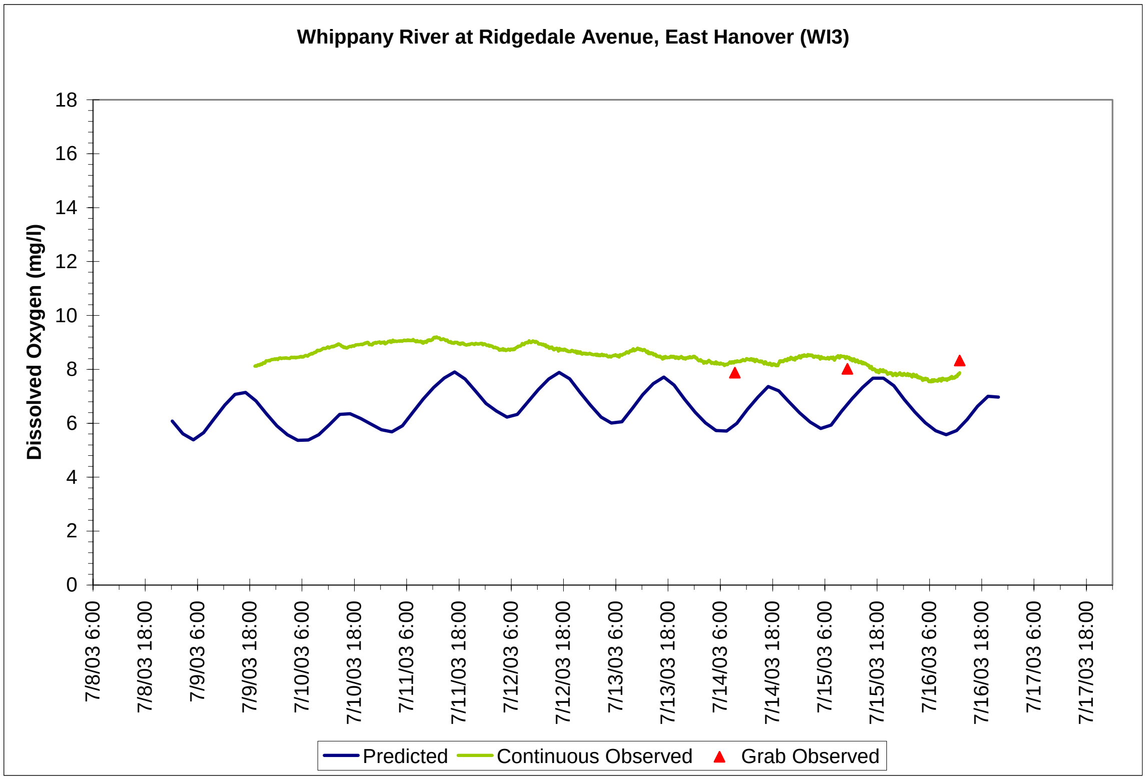
July 2003 Validation





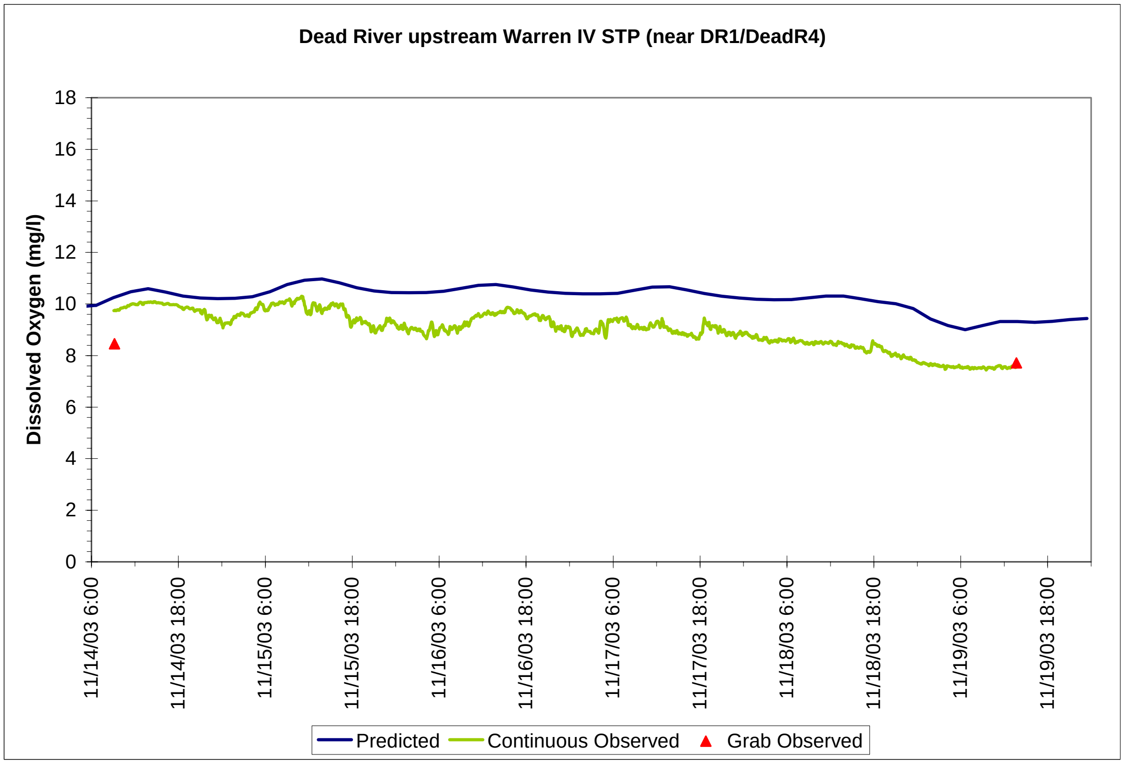
DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

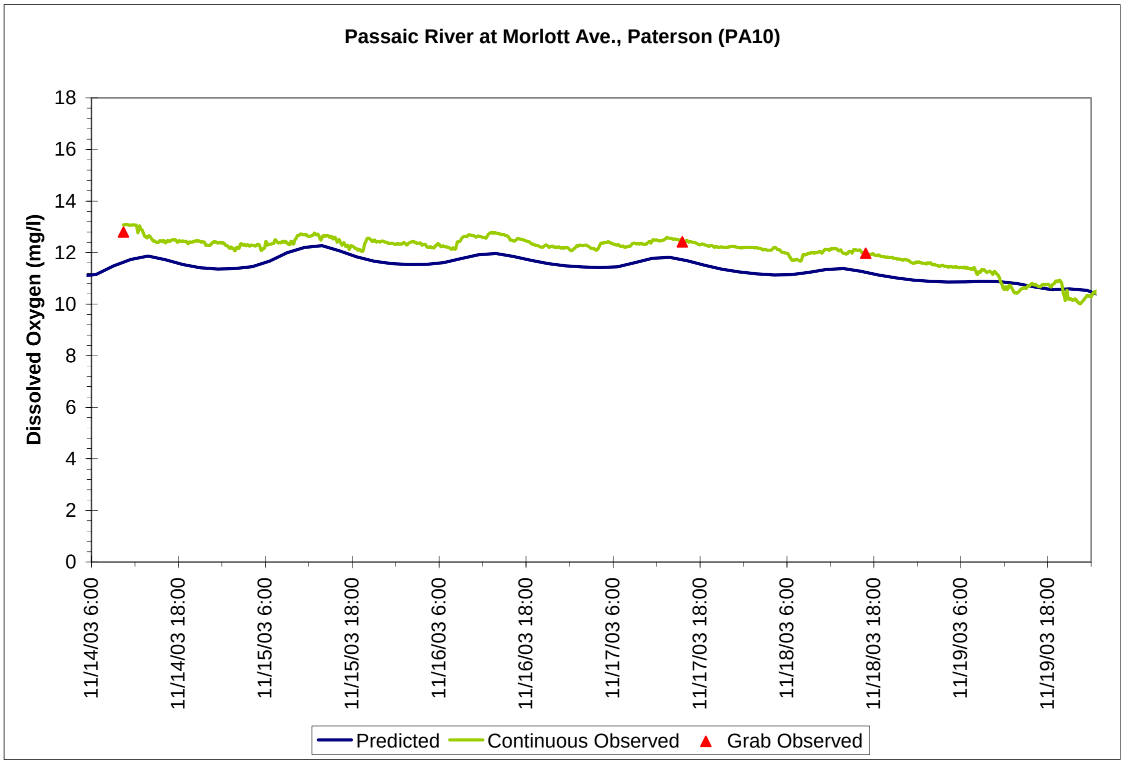
July 2003 Validation



DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

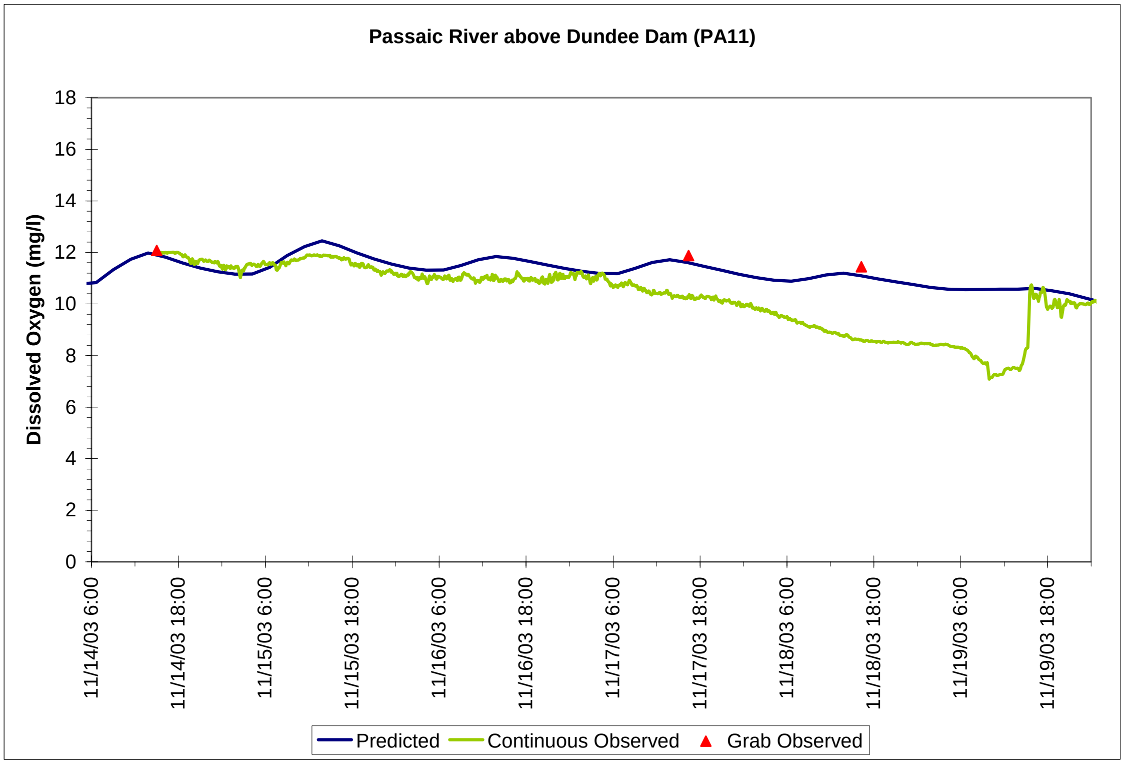
November 2003 Validation

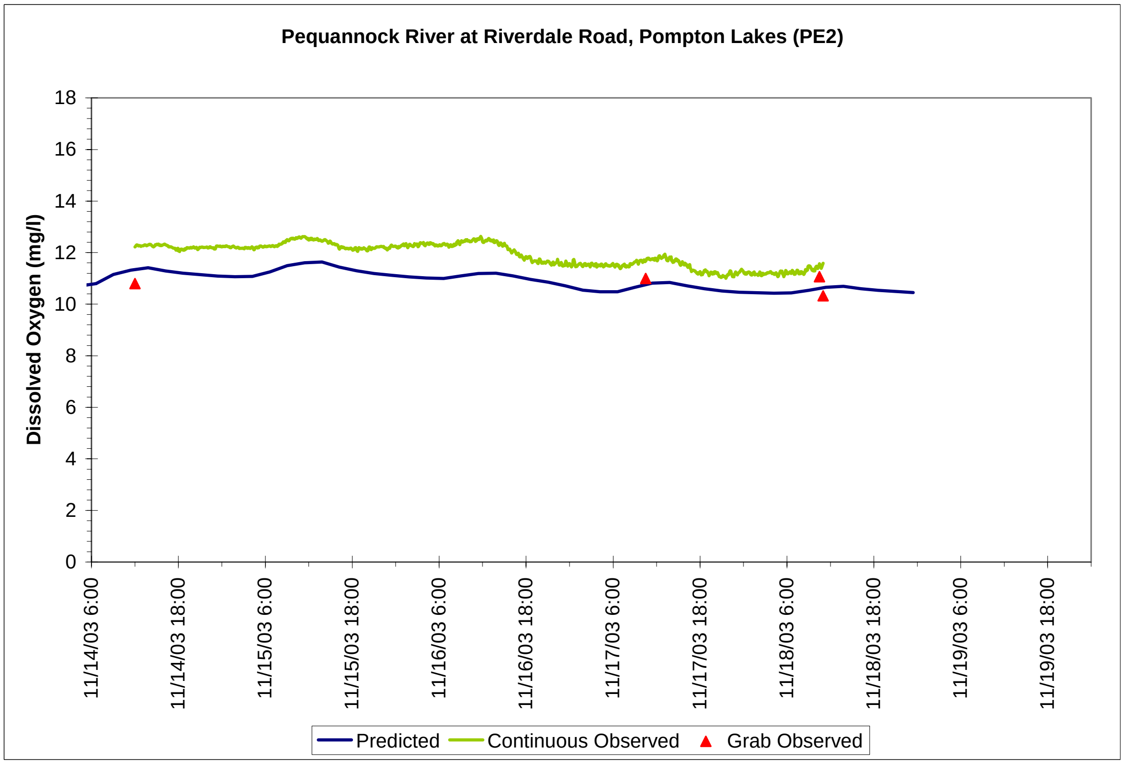




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

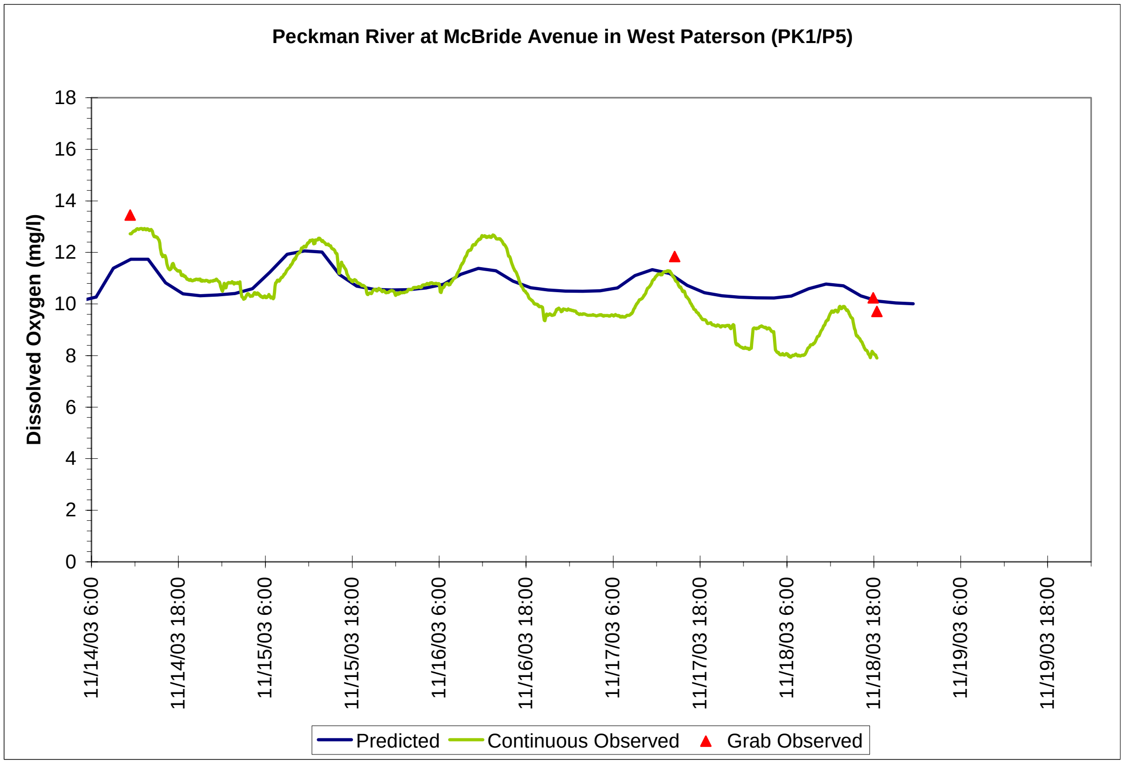
November 2003 Validation

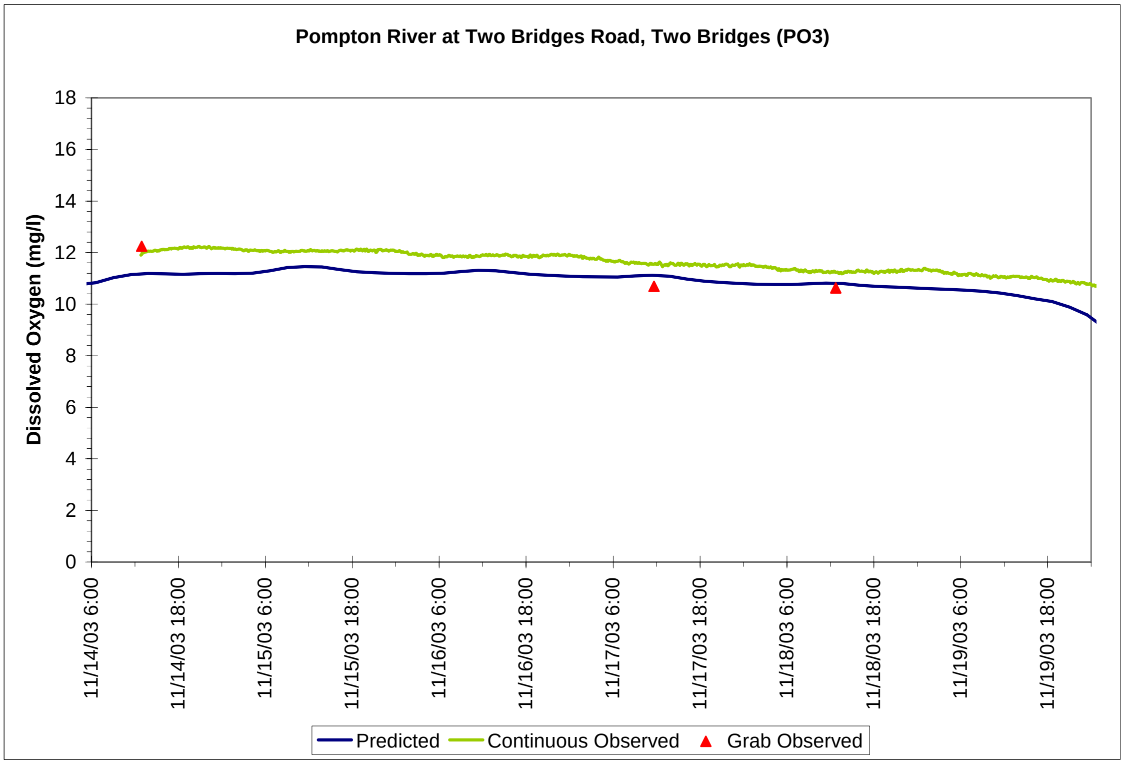




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

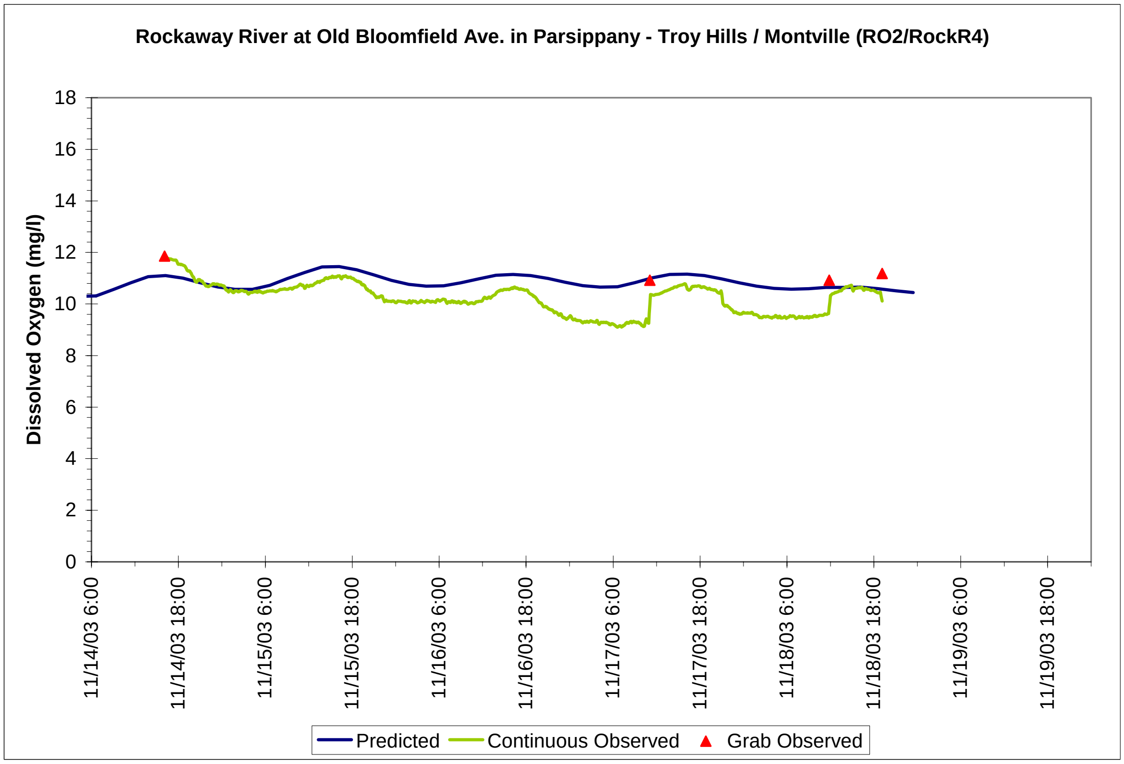
November 2003 Validation

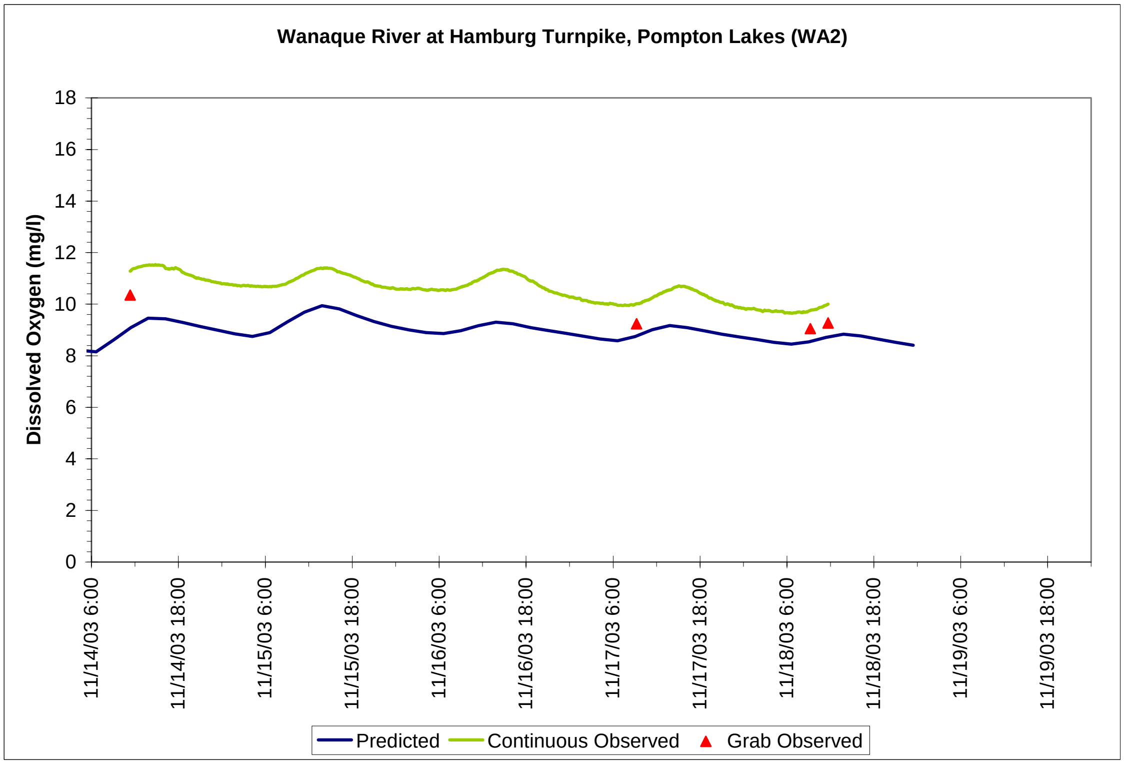




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

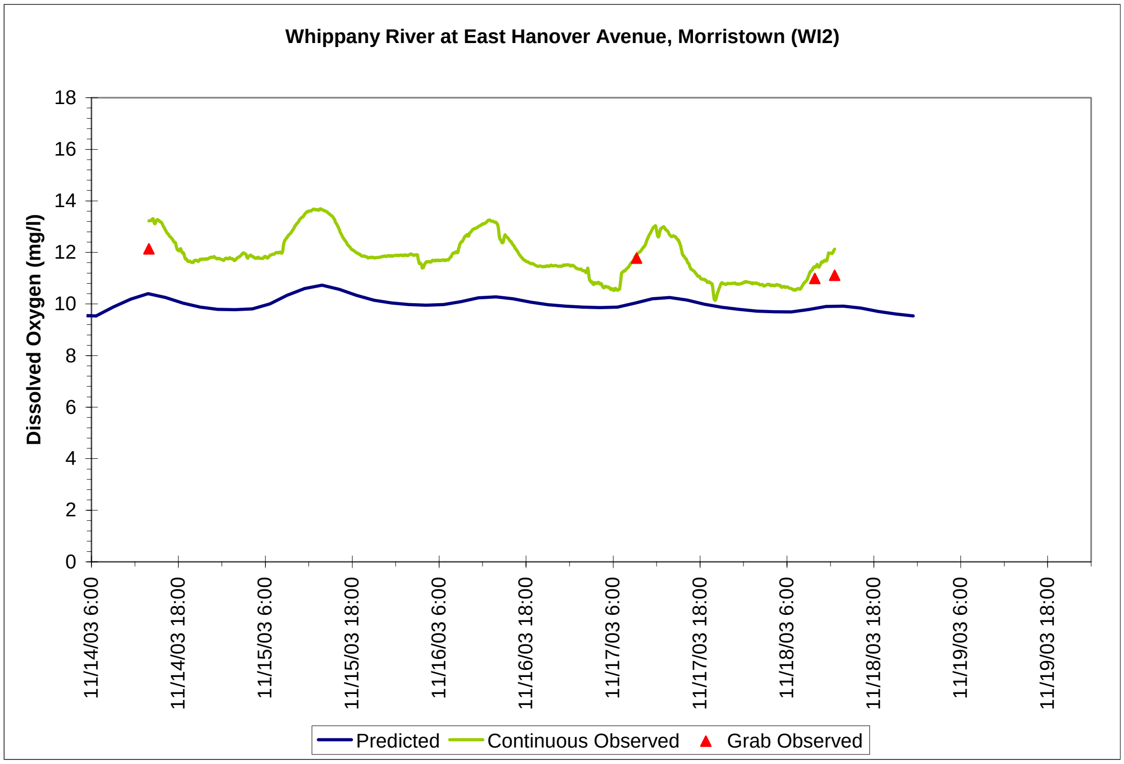
November 2003 Validation





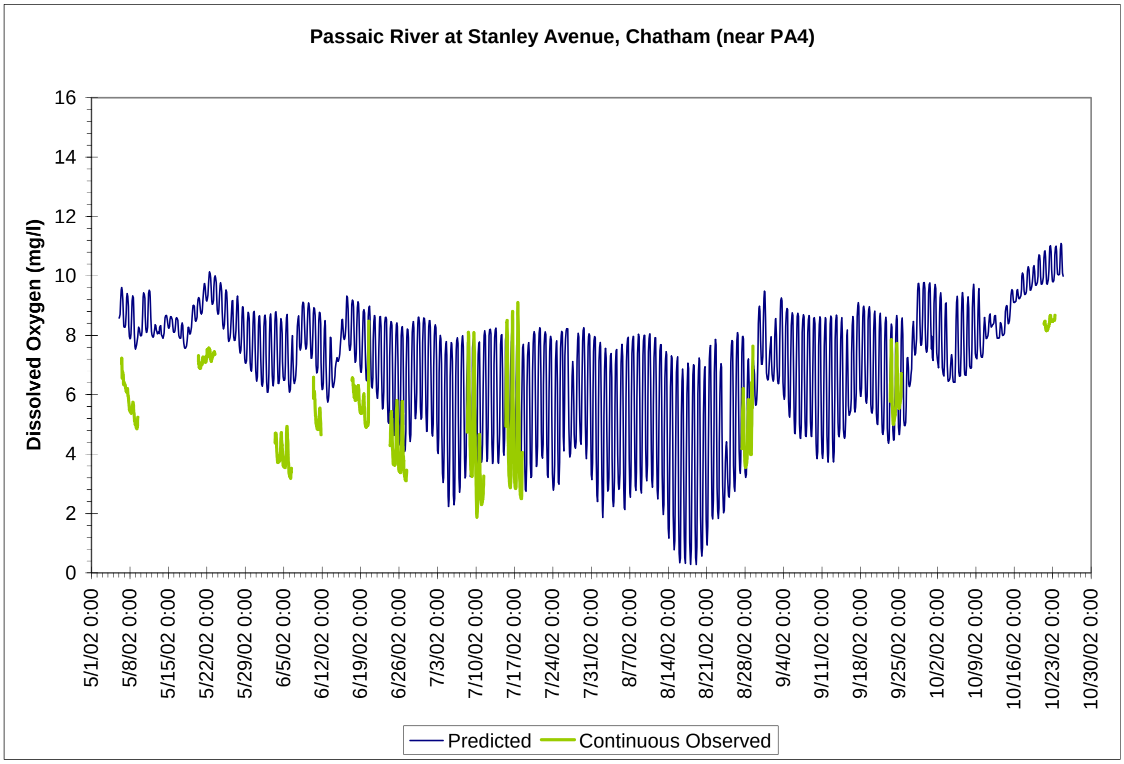
DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

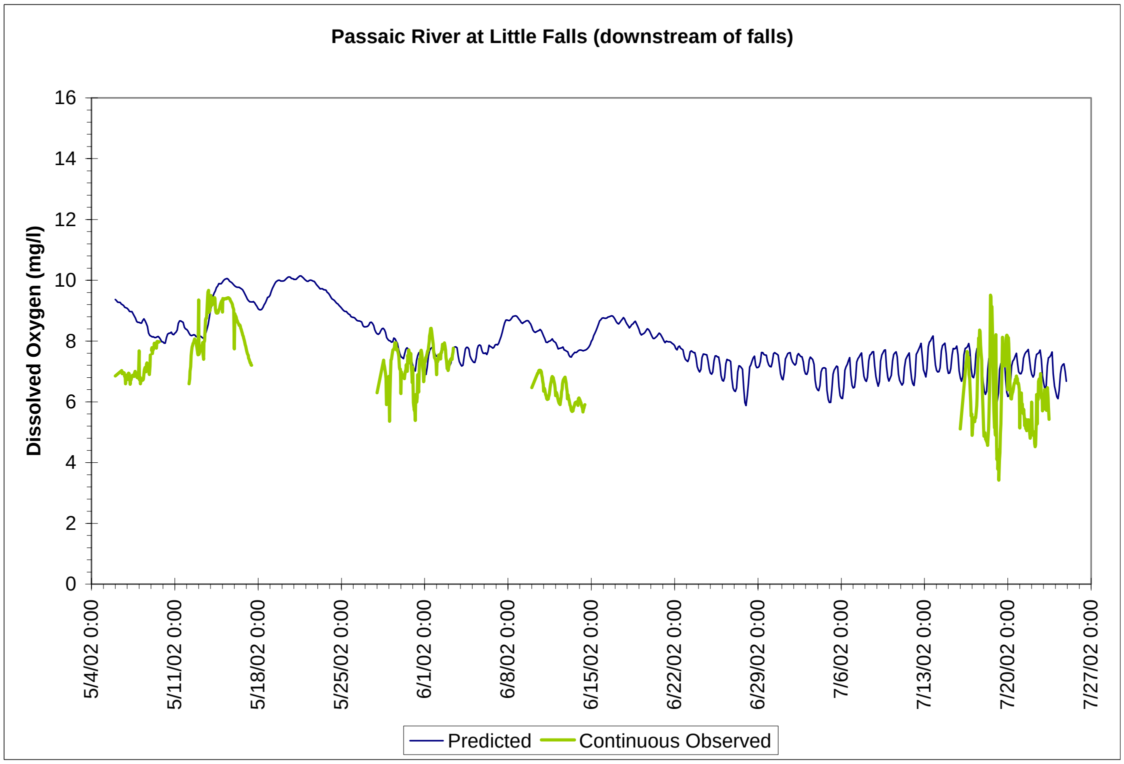
November 2003 Validation



DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

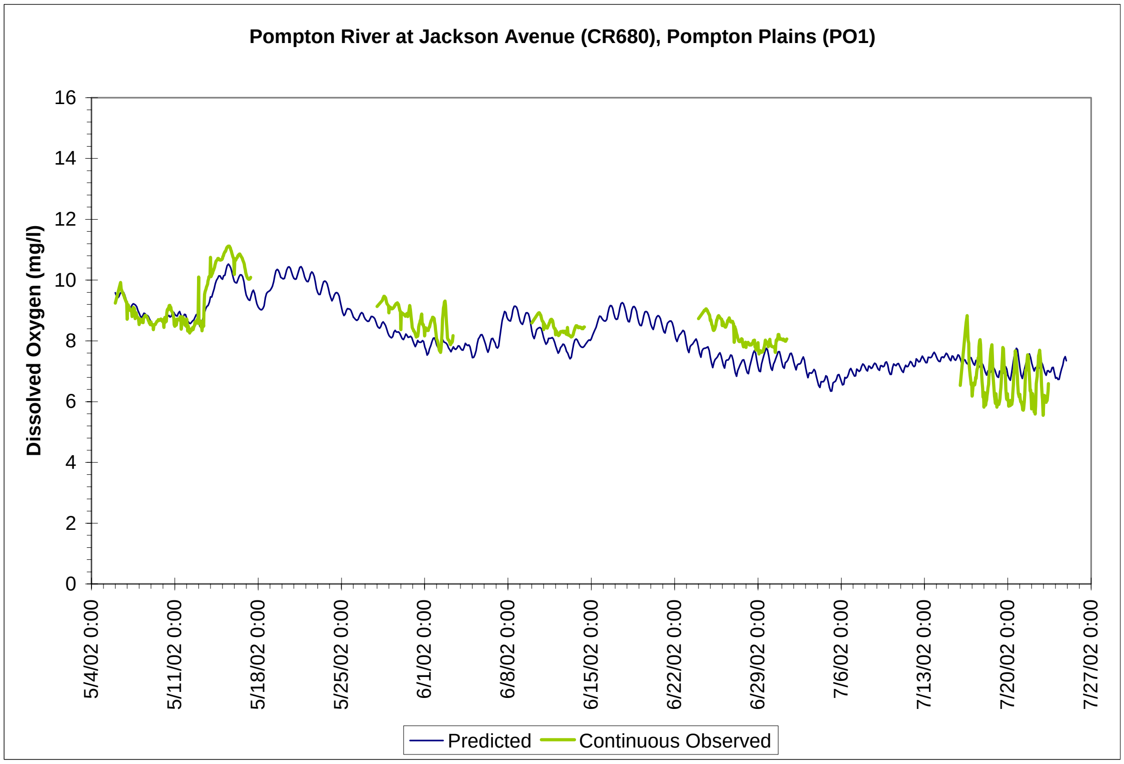
2002 DEP Calibration





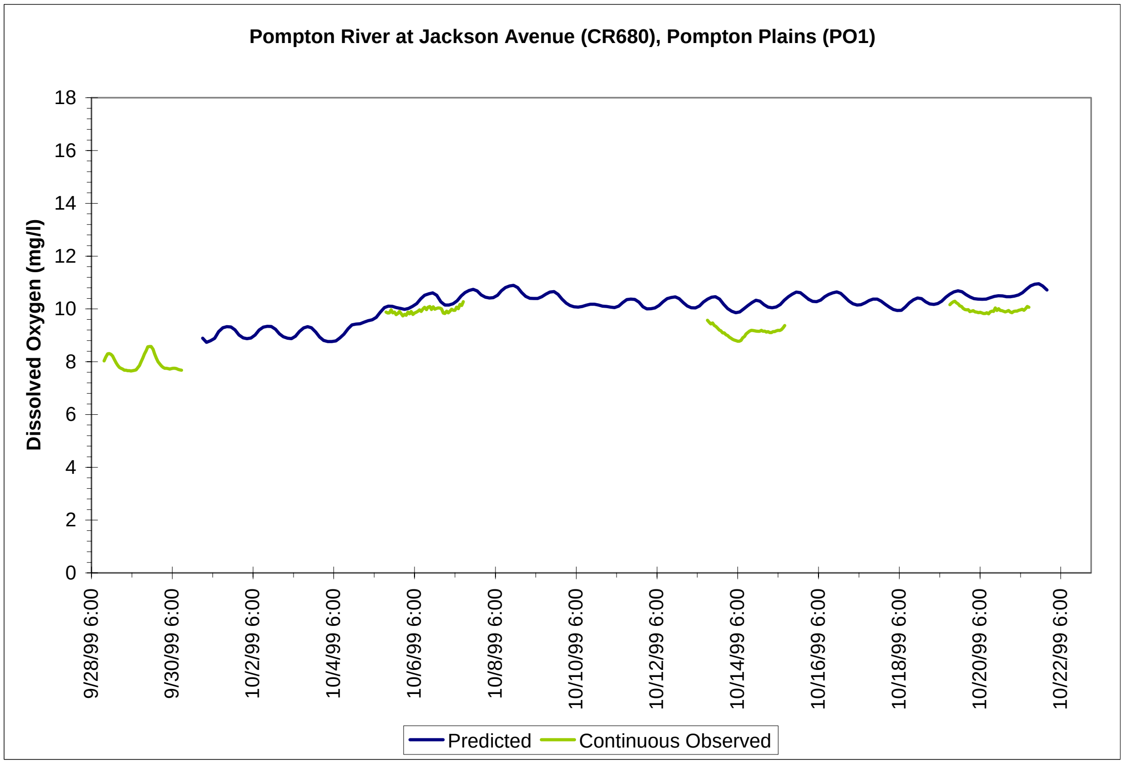
DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

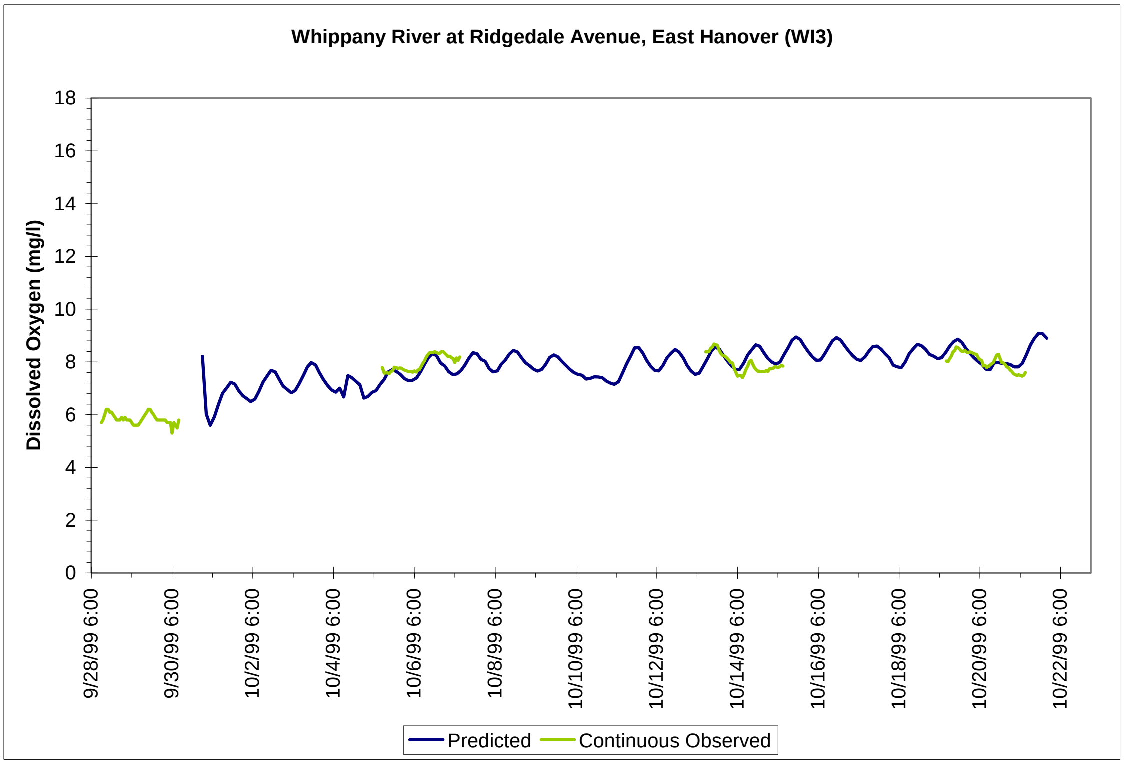
2002 DEP Calibration



DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

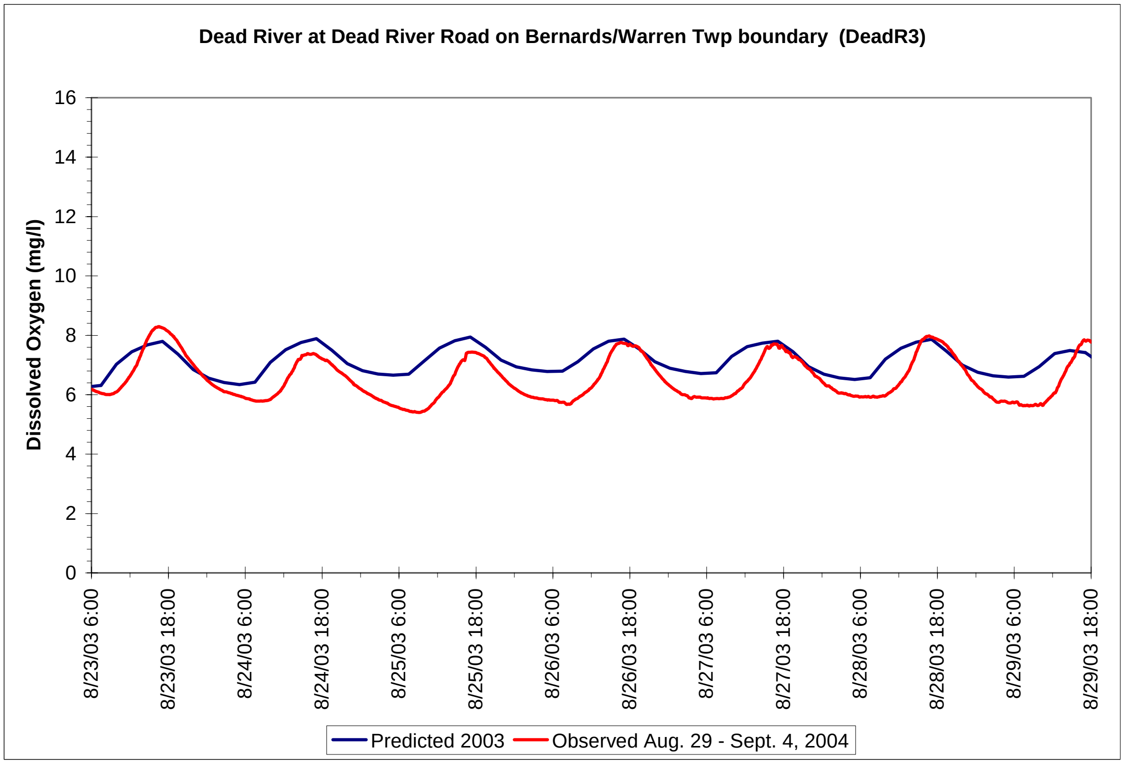
1999 DEP Validation

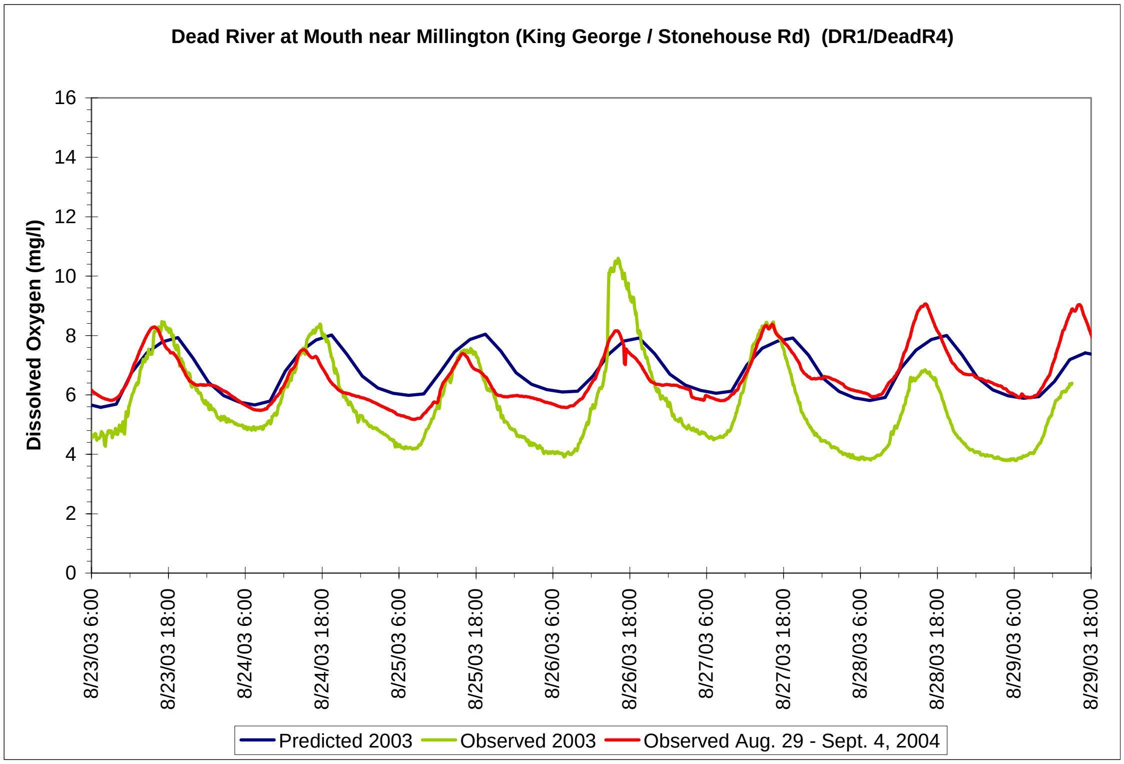




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

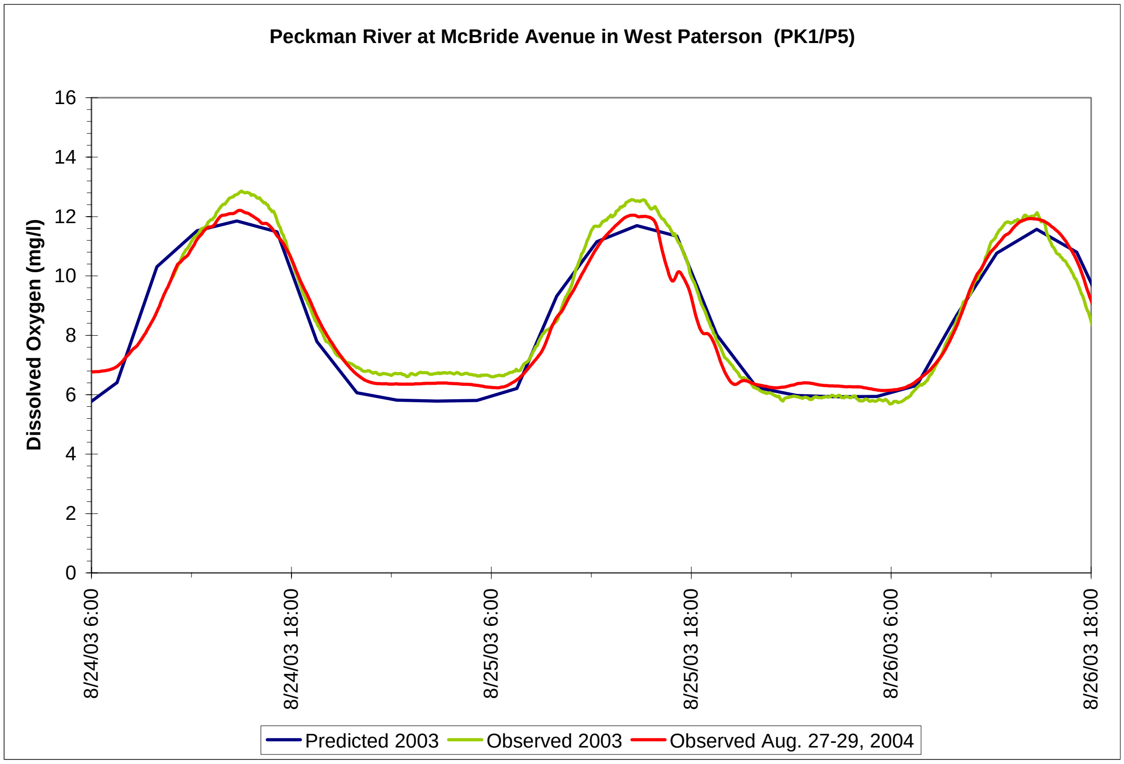
Calibration of 2004 Tributaries

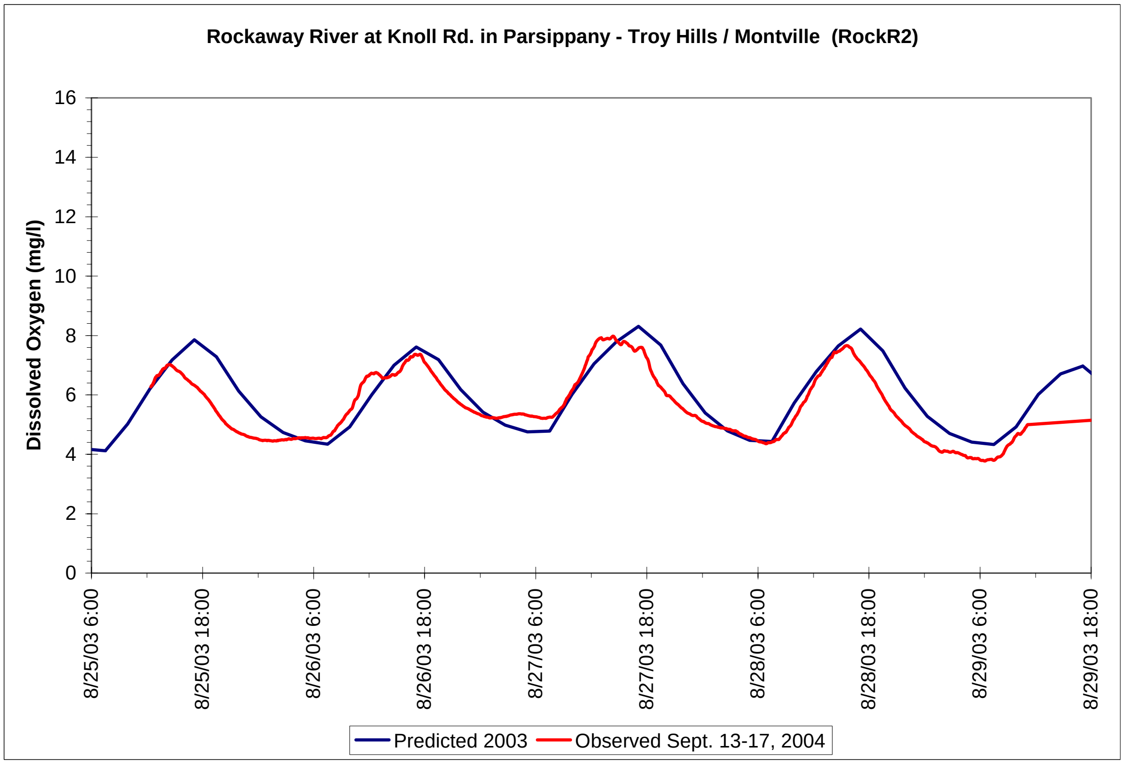




DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

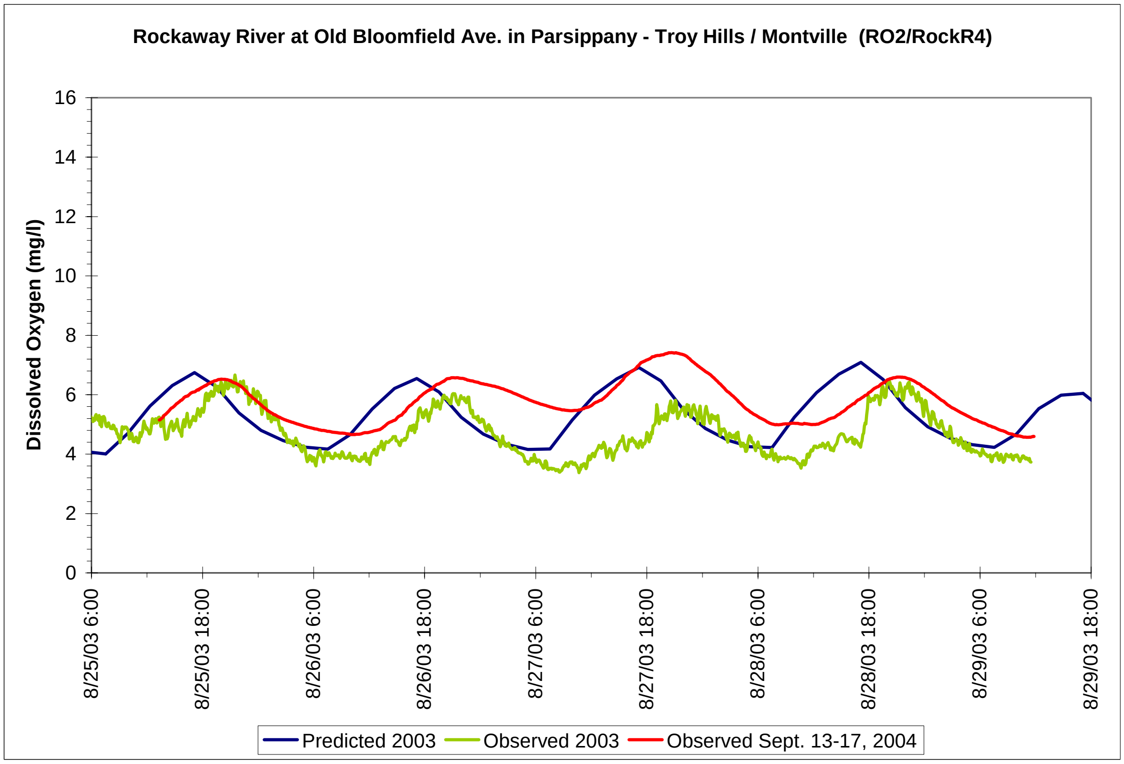
Calibration of 2004 Tributaries





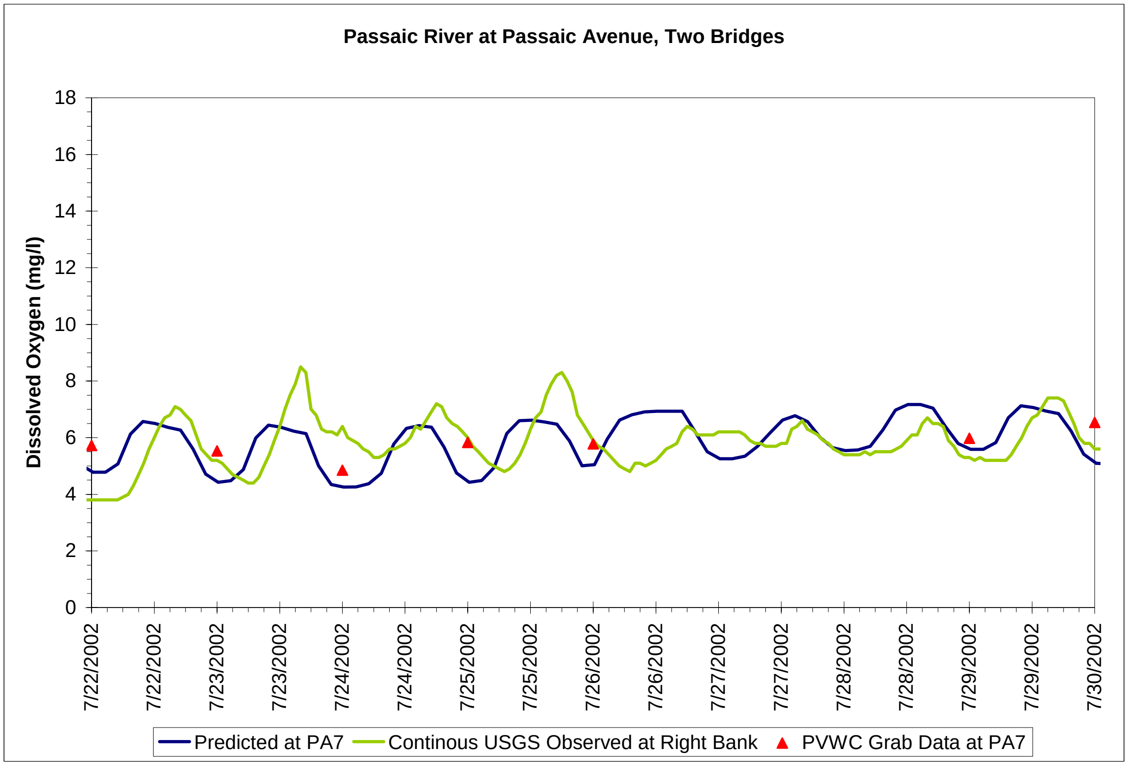
DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

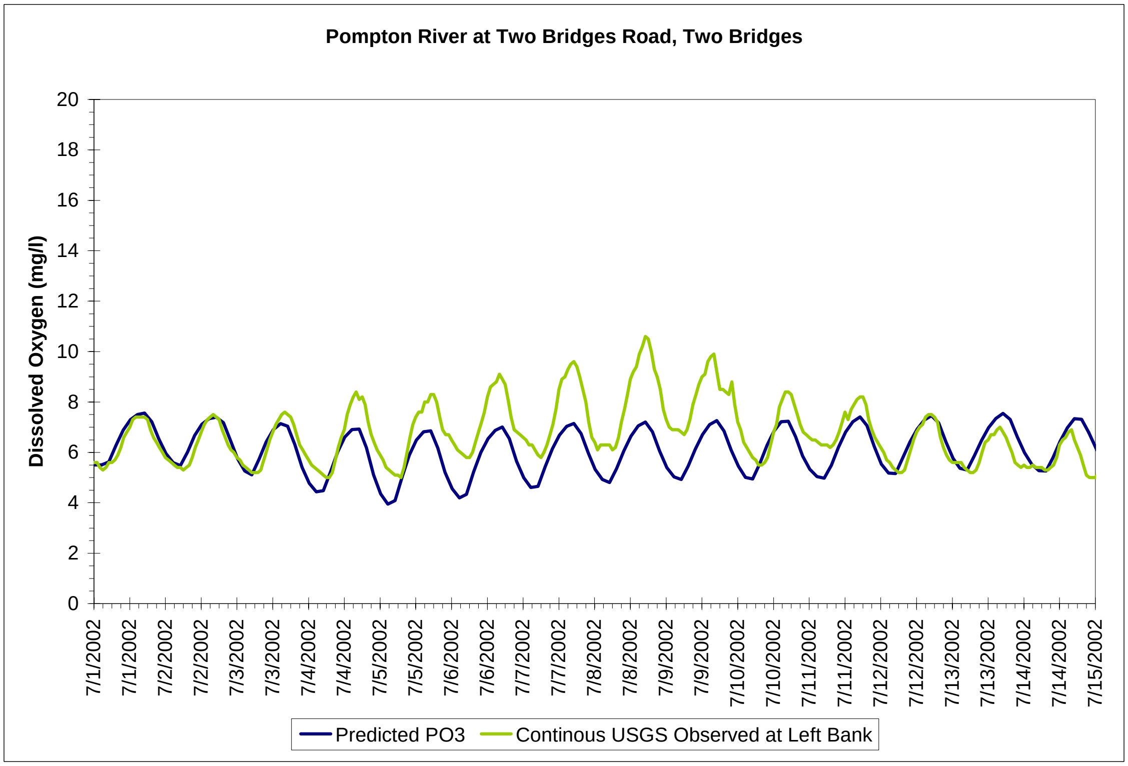
Calibration of 2004 Tributaries



DIURNAL DISSOLVED OXYGEN CALIBRATION AND VALIDATION RESULTS

Calibration of 2004 Tributaries

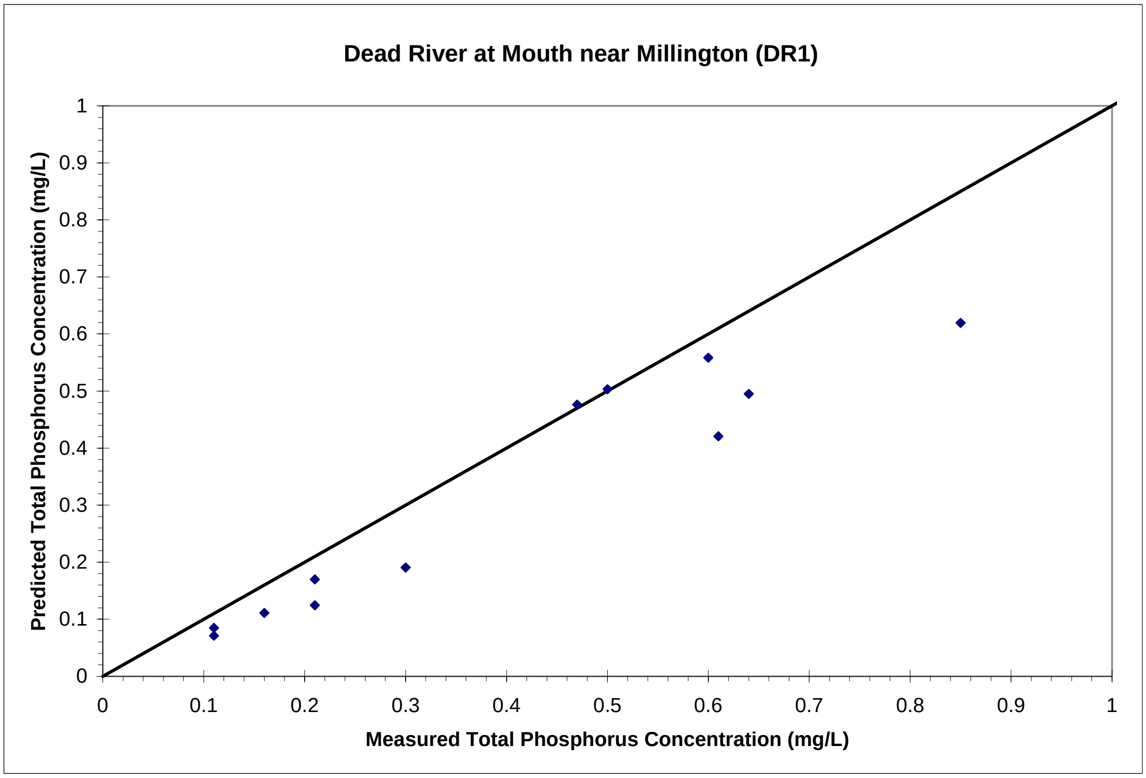


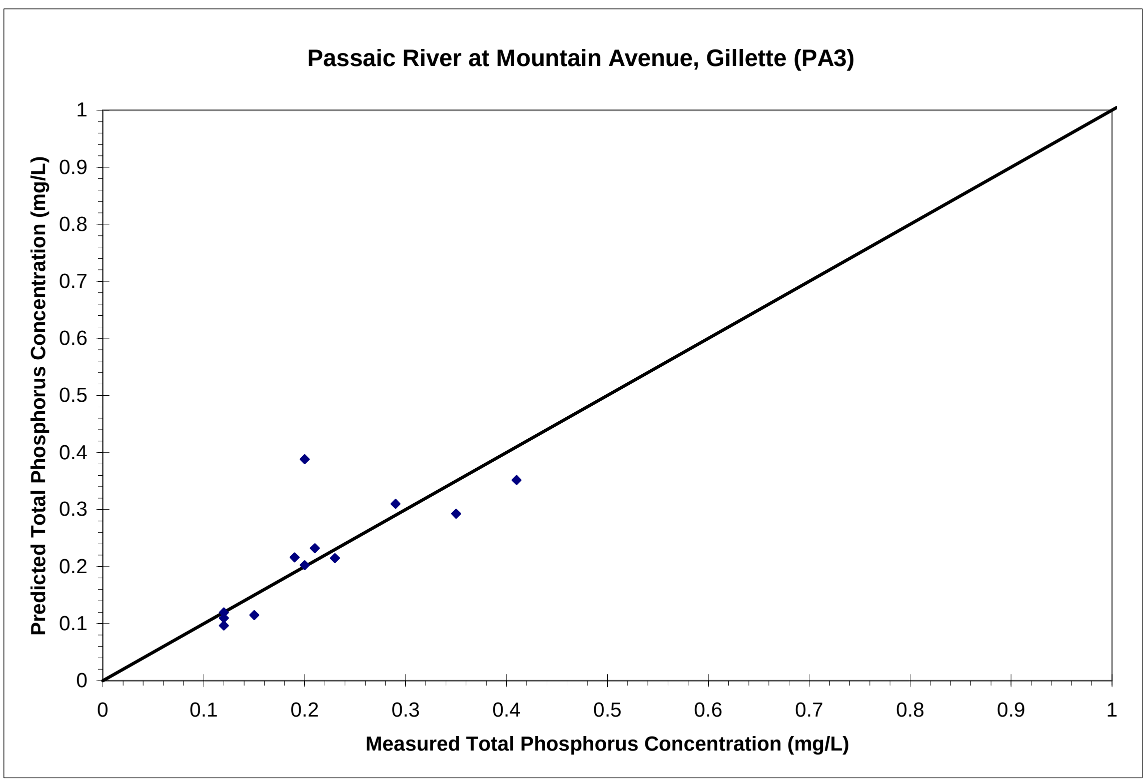


APPENDIX G

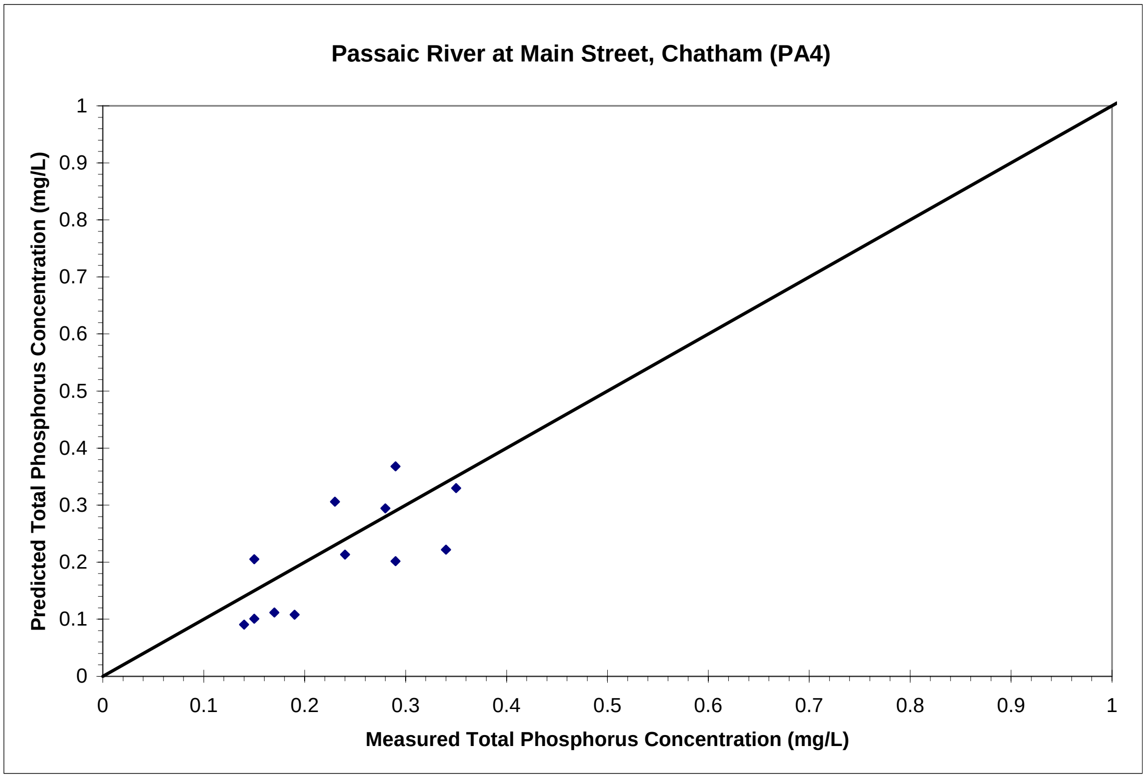
Relationship Between Predicted and Measured Total Phosphorus

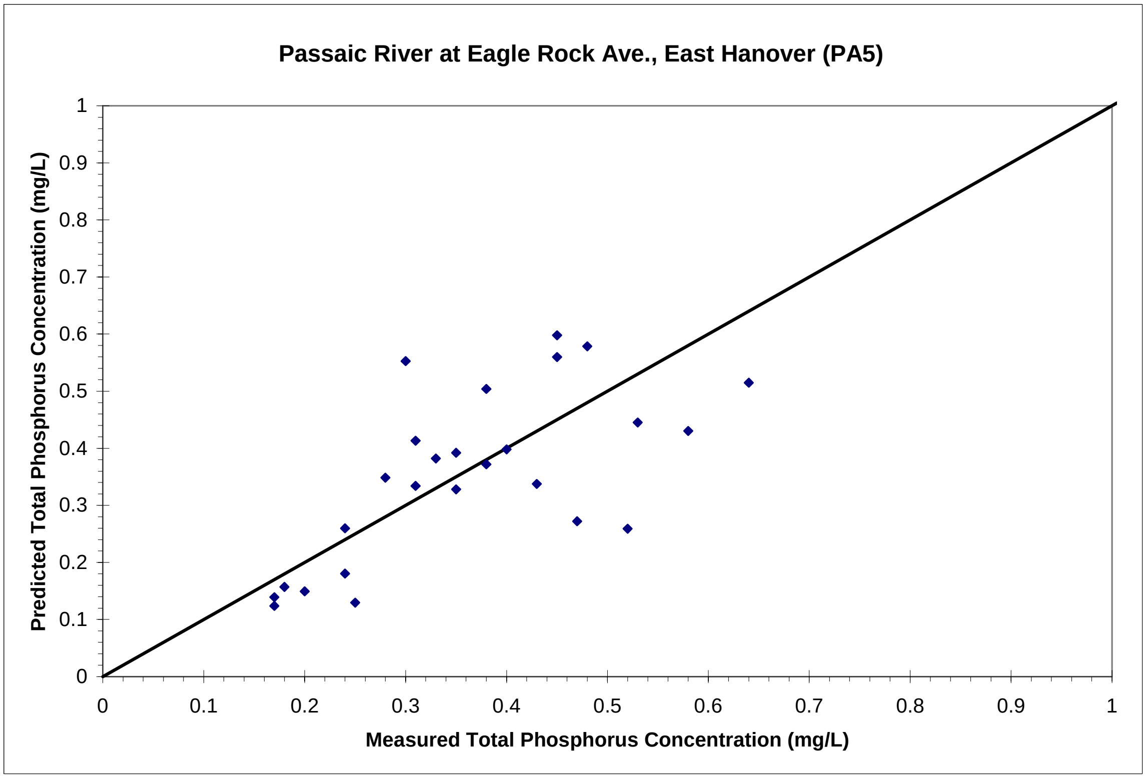
Comparison of Model Prediction with Measured Total Phosphorus



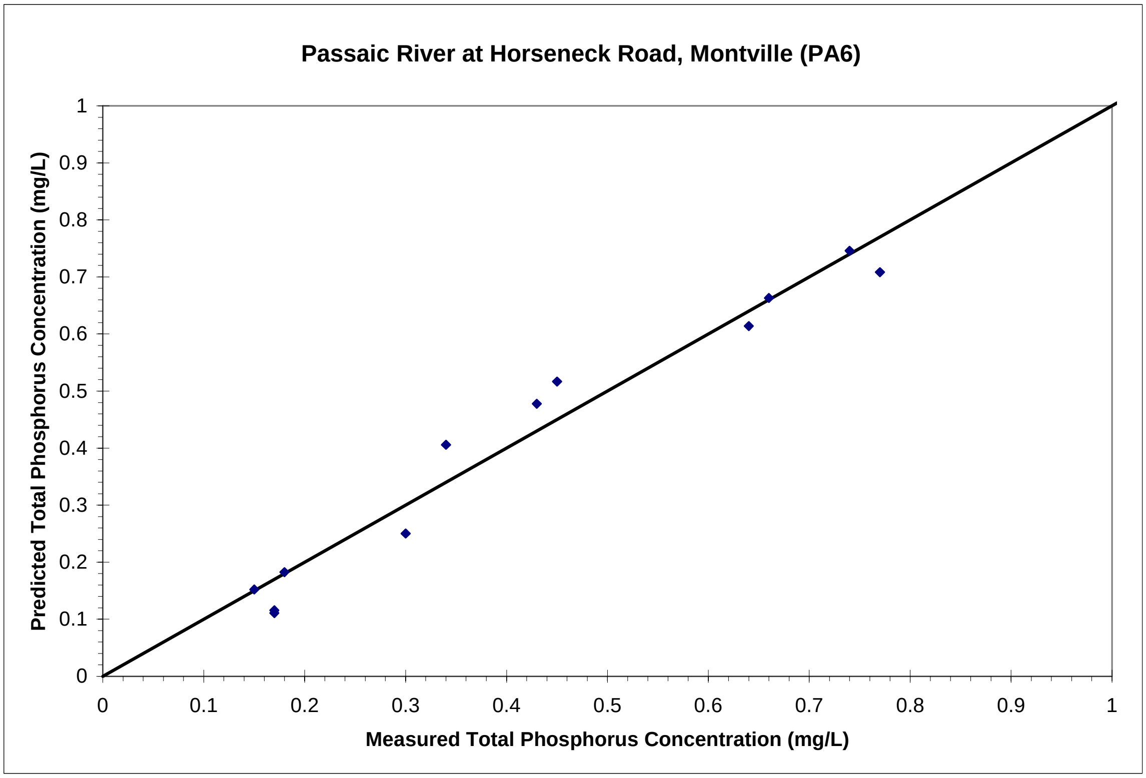


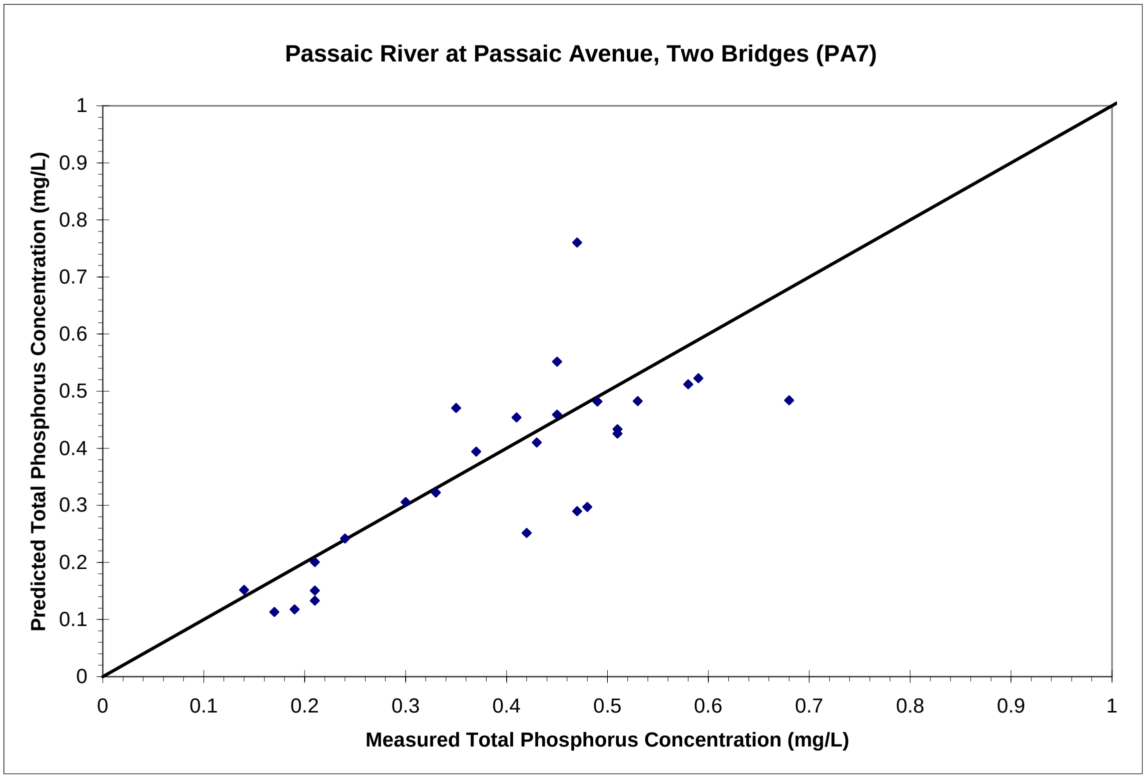
Comparison of Model Prediction with Measured Total Phosphorus



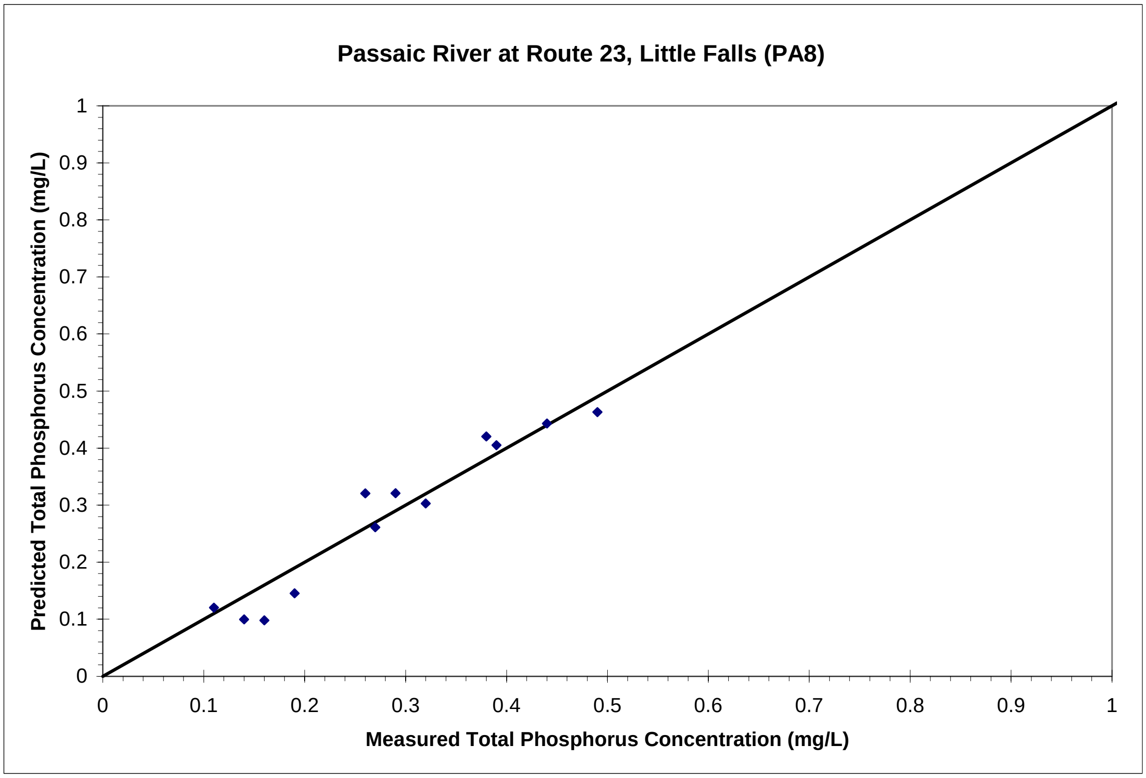


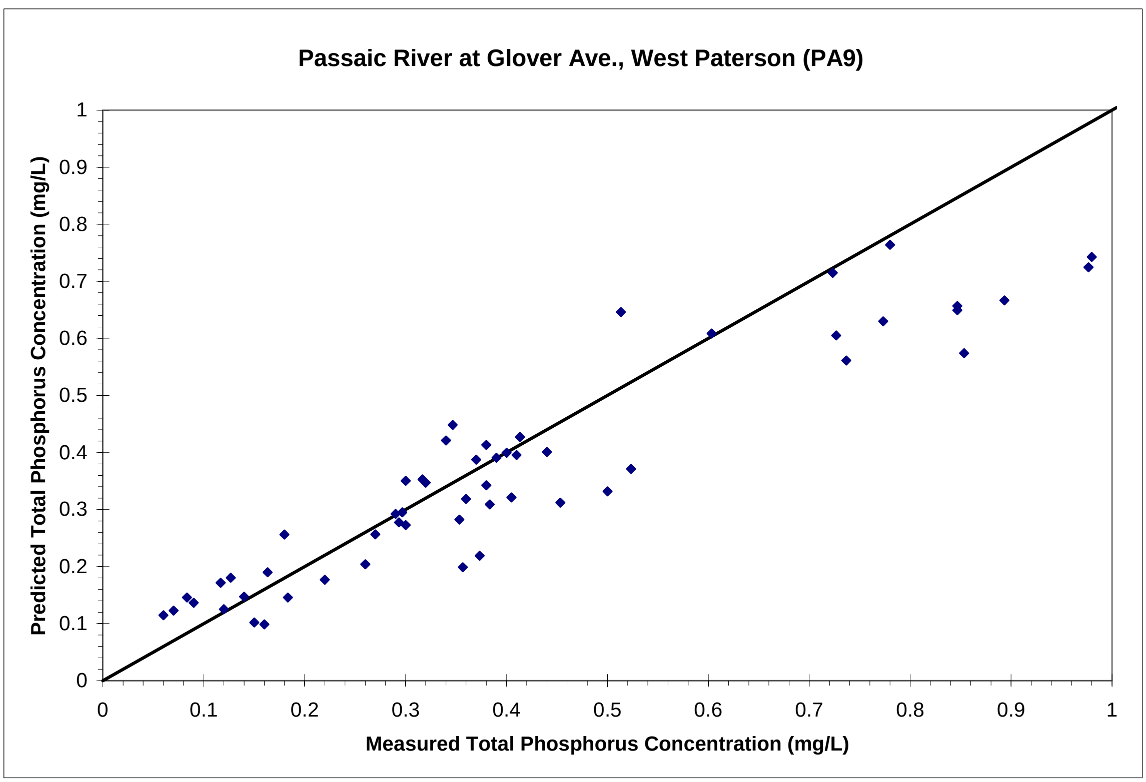
Comparison of Model Prediction with Measured Total Phosphorus



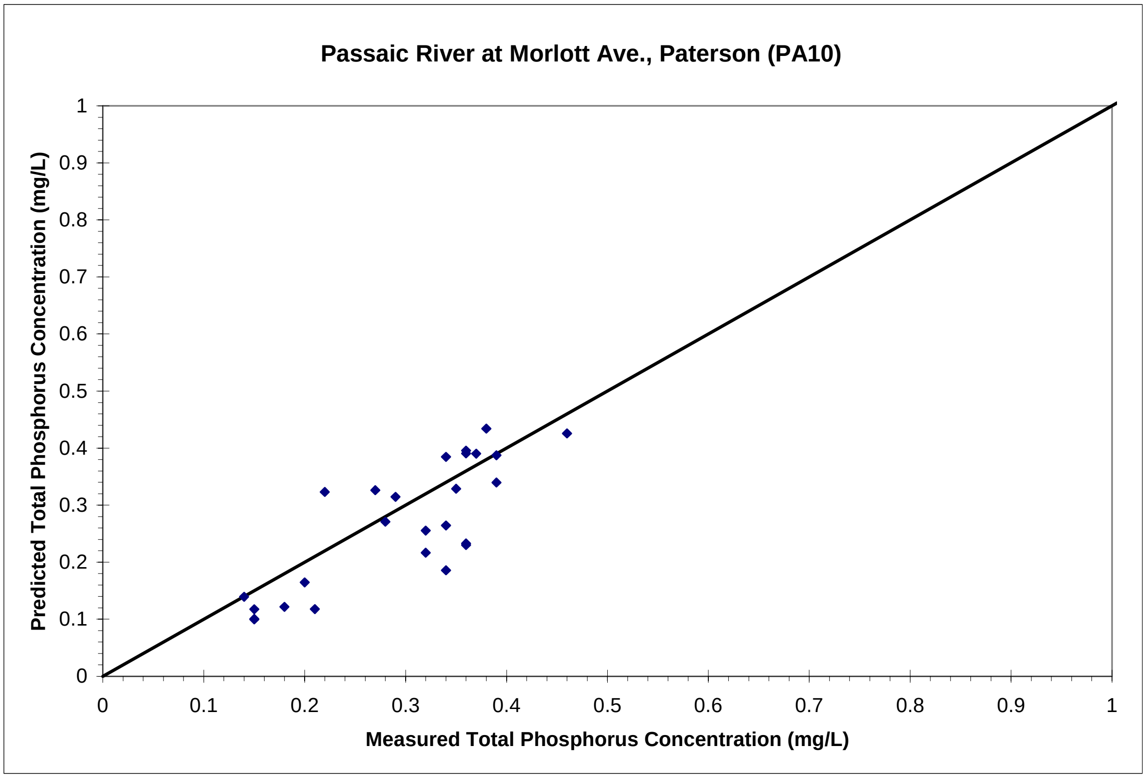


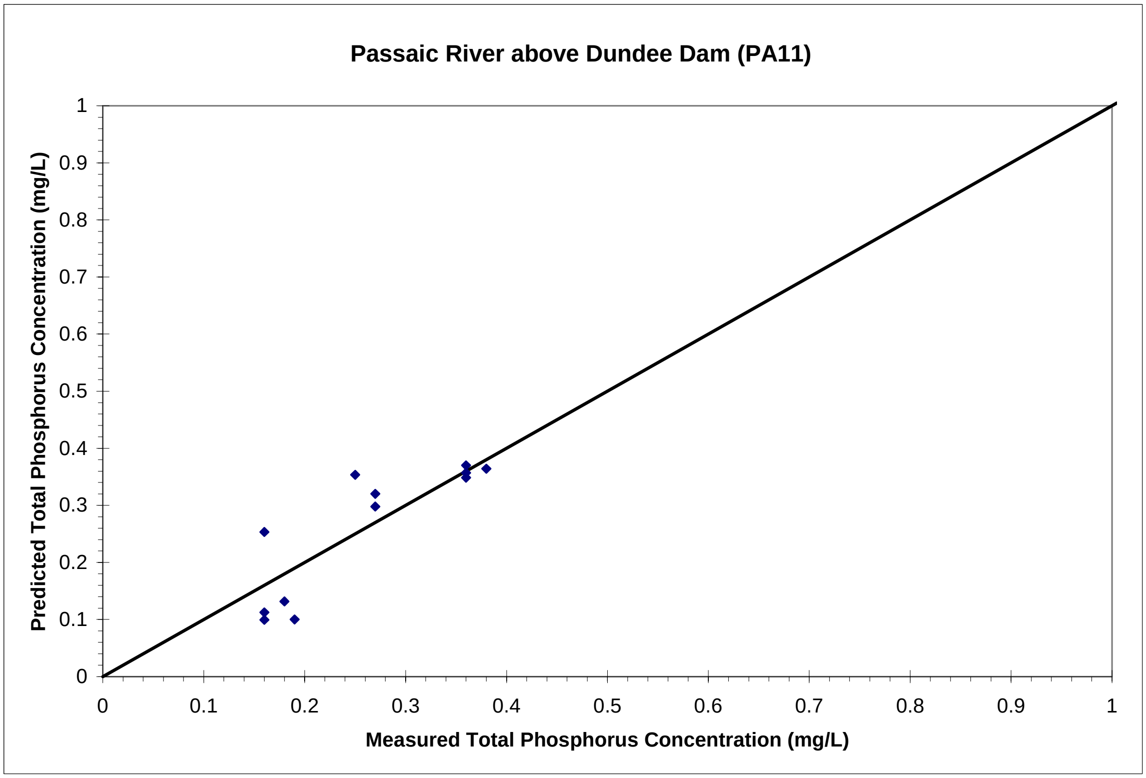
Comparison of Model Prediction with Measured Total Phosphorus



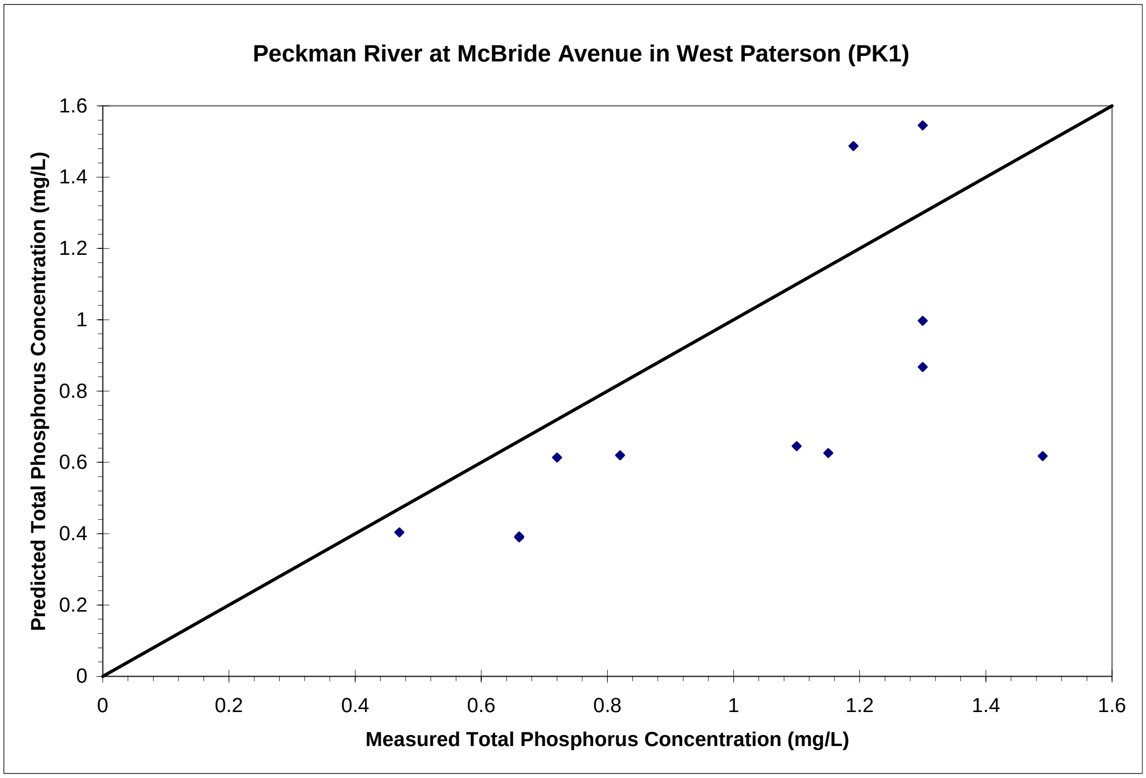


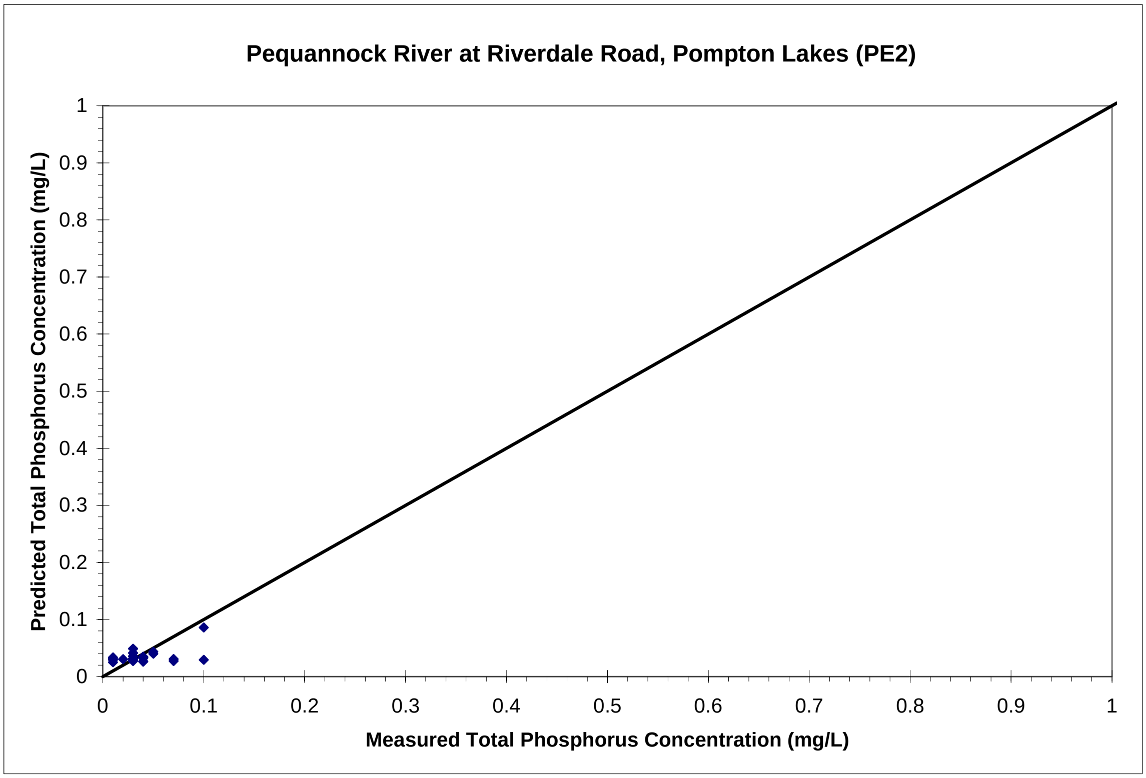
Comparison of Model Prediction with Measured Total Phosphorus



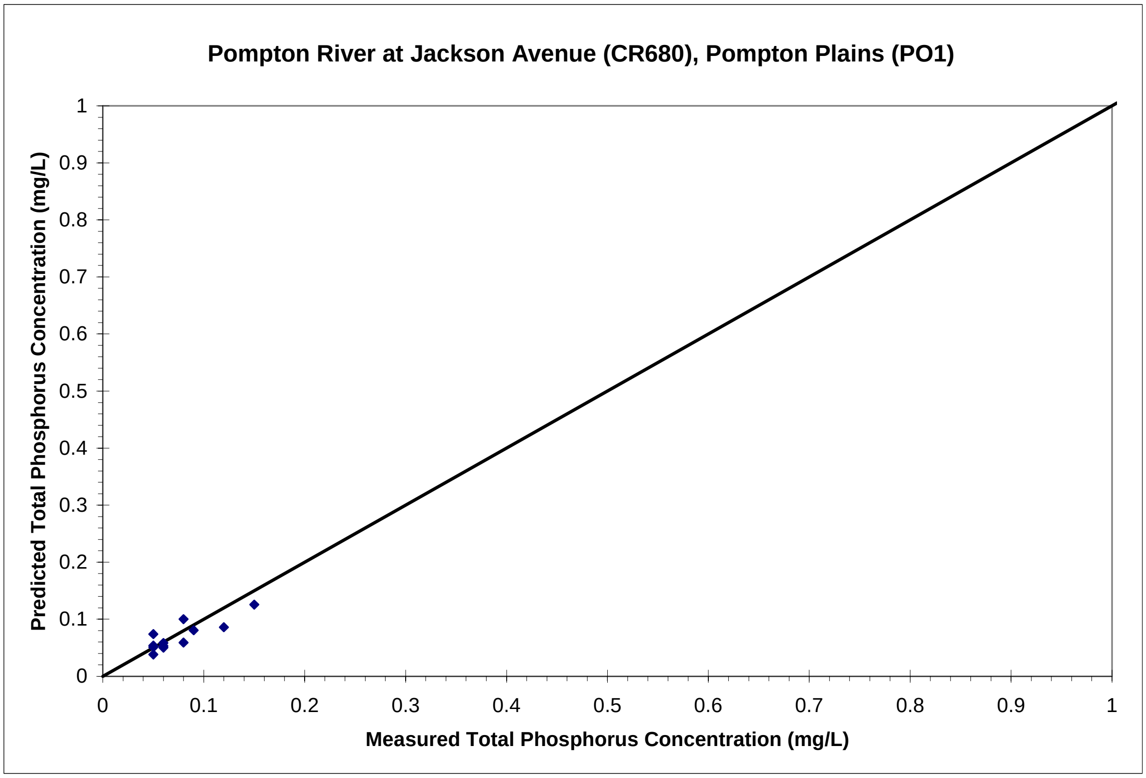


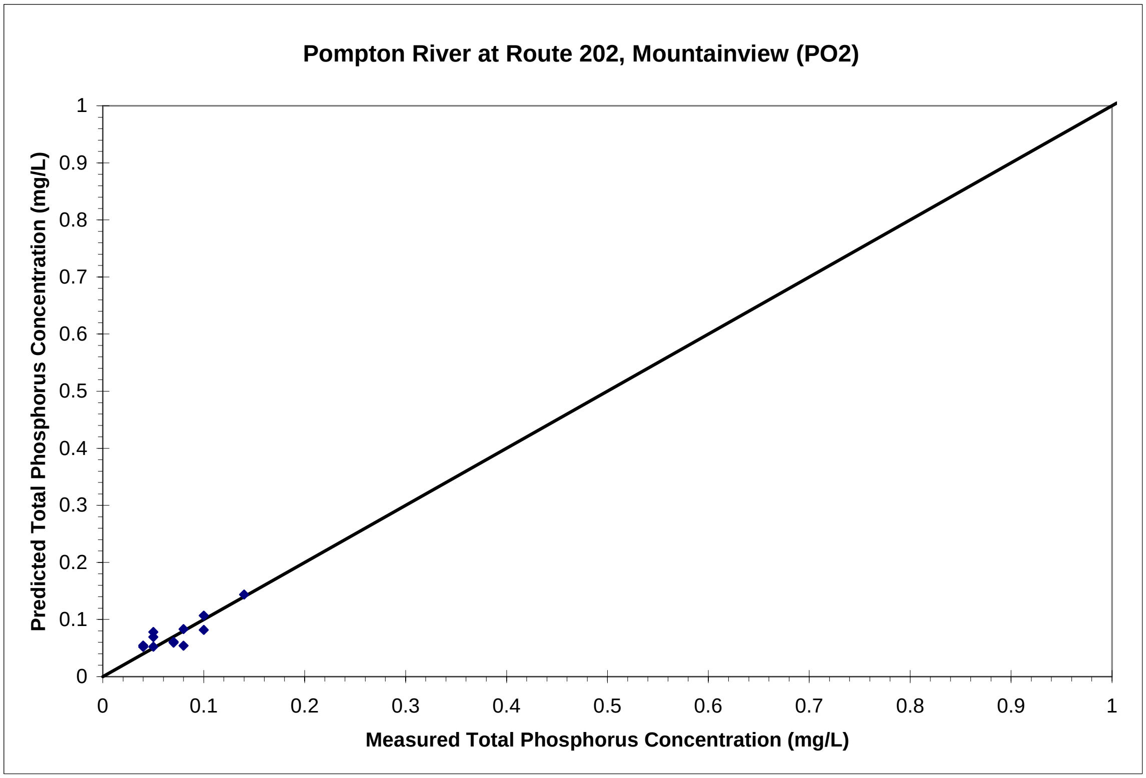
Comparison of Model Prediction with Measured Total Phosphorus



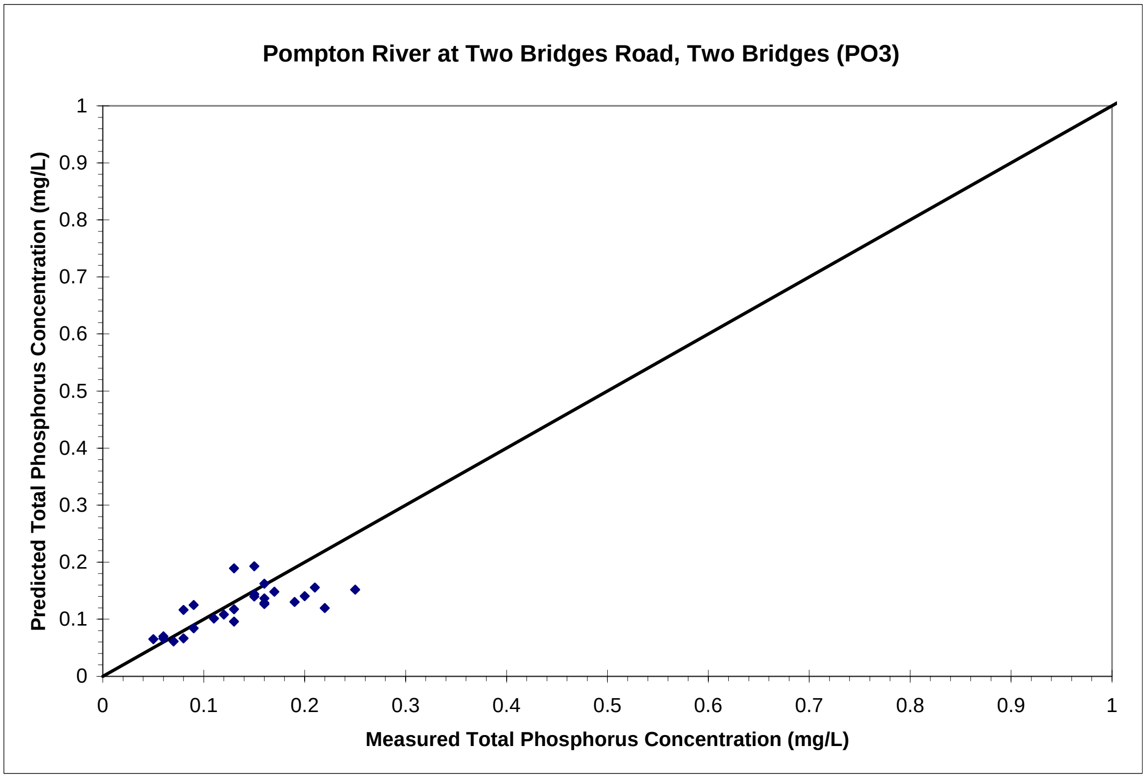


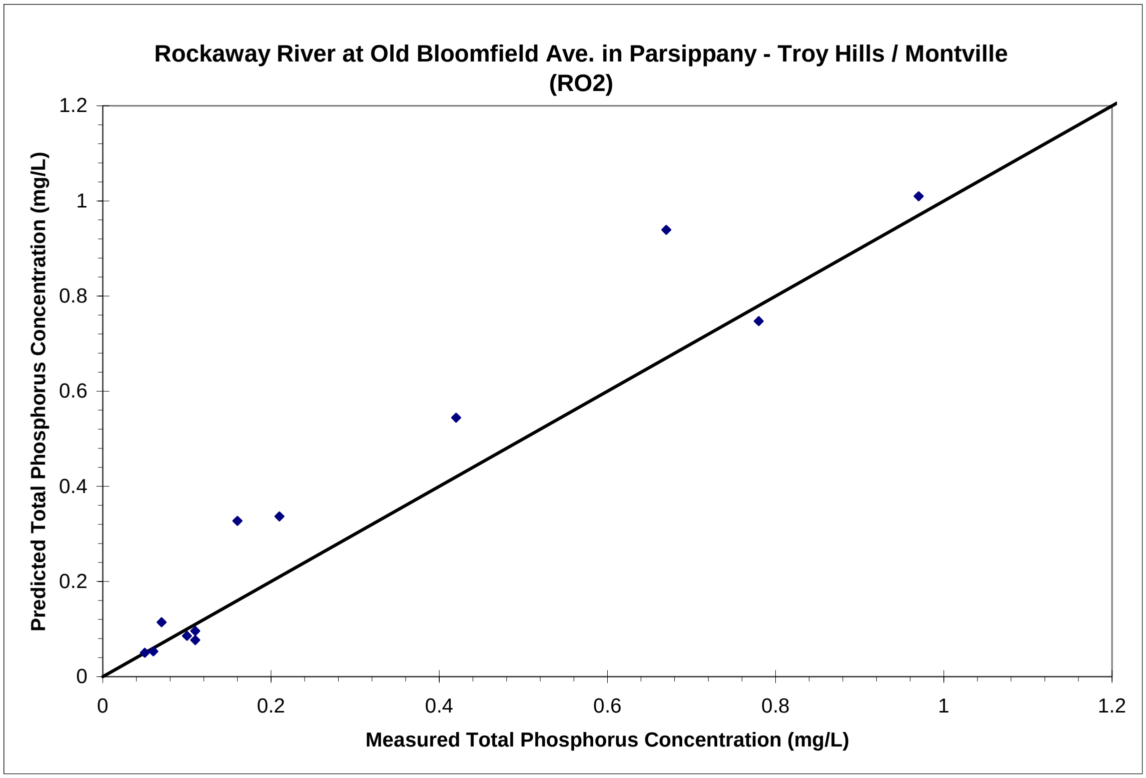
Comparison of Model Prediction with Measured Total Phosphorus



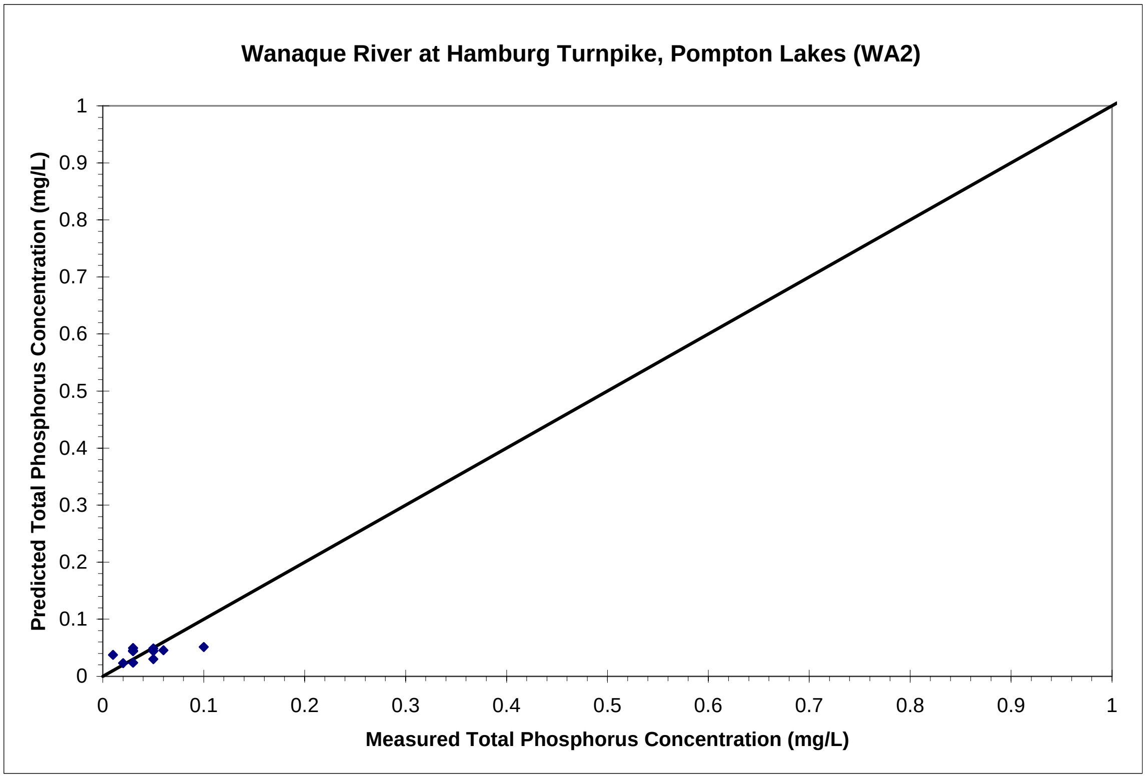


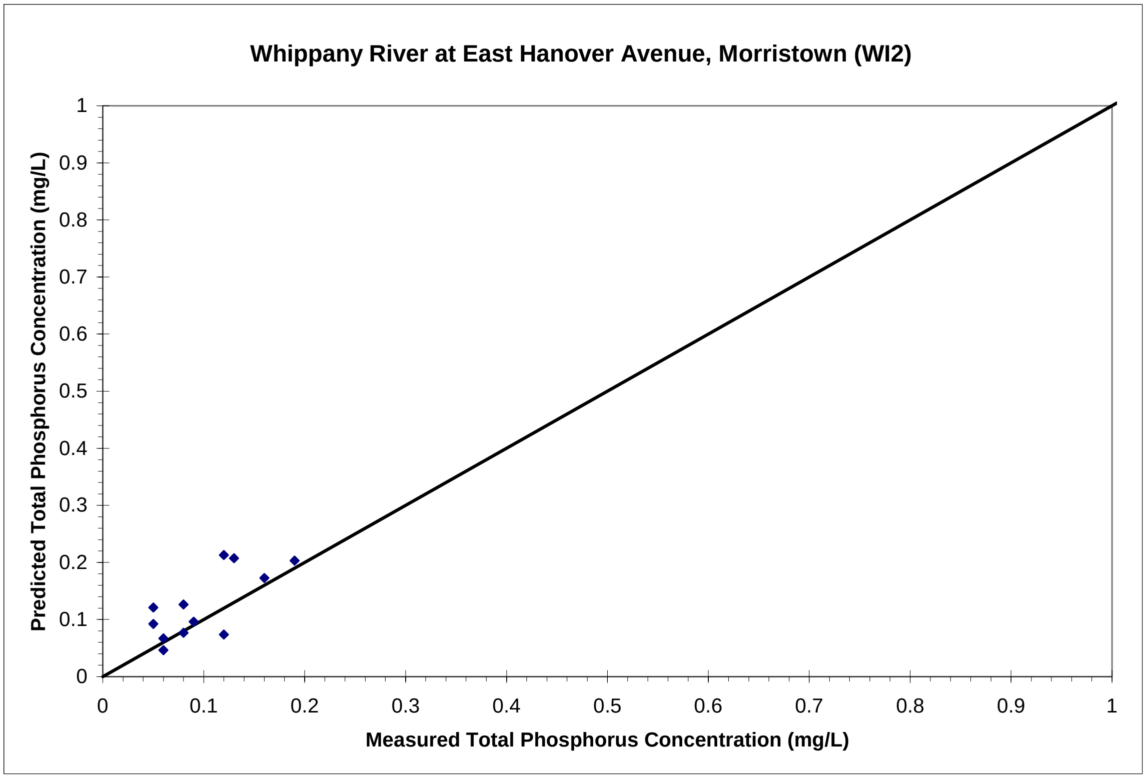
Comparison of Model Prediction with Measured Total Phosphorus



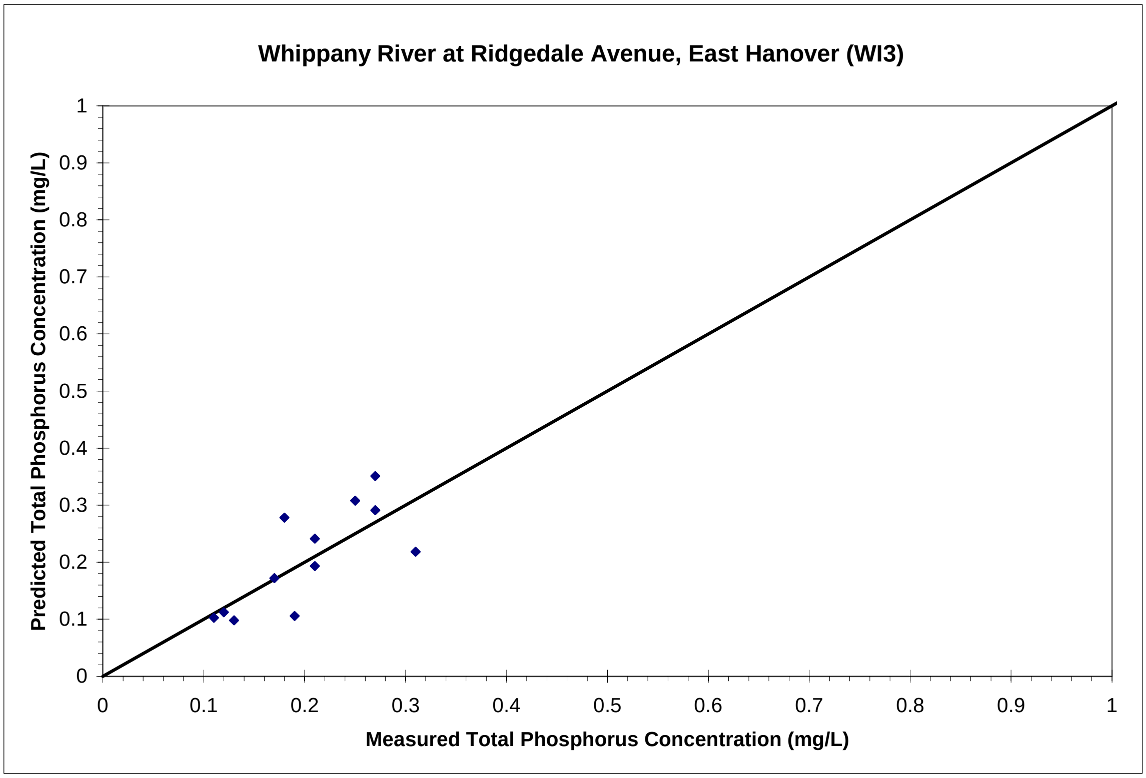


Comparison of Model Prediction with Measured Total Phosphorus





Comparison of Model Prediction with Measured Total Phosphorus



APPENDIX H

Uncertainty Analyses

Uncertainty Analysis Viewer

The Uncertainty Analysis Viewer is a tool that allows the user to graphically compare model output under different conditions. The concentrations of total phosphorus (TP), dissolved oxygen (DO) and chlorophyll-a (Chl-a) from the sensitivity analysis simulations were extracted at various locations. The outputs can be graphically compared in order to gain a better understanding of the variables affecting the transport and fate of phosphorus and its impact on productivity and dissolved oxygen. This document explains how to use the Uncertainty Analysis Viewer in order to graphically compare different sensitivity analyses.

The Uncertainty Analysis Viewer consists of different tabs. The first three tabs are the Data Viewer, Analysis Description and Individual Location Description, respectively. The rest of the tabs consist of the results of all the sensitivity analysis runs at different locations for total phosphorus, dissolved oxygen and chlorophyll-a.

In the Data Viewer tab, comparisons of different simulations at different locations for different parameters are performed. The Data Viewer consists of a graphic viewer (chart) and four different sets of buttons. The buttons are used to select a particular simulation for a parameter at a specific location displayed on the graphic viewer. The buttons located to the left of the graphic viewer are used to select the simulations; the buttons on the top of the graphic viewer are used to change/add the parameters being displayed; the buttons on the upper right side of the graphic viewer are used to change/add the location of the parameter being displayed; and the buttons on the lower right side of the graphic viewer are used to change the time period of the simulations.

The Analysis Description tab contains a detailed description of all the sensitivity analyses performed as part of the Passaic River TMDL. The Individual Location Description tab contains descriptions of locations from which the output is extracted from the sensitivity analyses performed.

The following steps must be followed to use the Uncertainty Analysis Viewer to view/compare the output for different simulations at various locations:

1. Open the Uncertainty Analysis Viewer.

2. Click on the Data Viewer tab.
3. By default, the series displayed on the graphic viewer is Total Phosphorus at location W2 for simulation “Base-M01.”

To add a new series to the existing series:

- Select the parameter of interest by clicking the buttons on the top of the graphic viewer (e.g. TP, DO, Chl-a).
- Select the location from which you want the results to be displayed by clicking the buttons under the “Add” column on the right side of the graphic viewer.
- Select the simulation of interest by clicking the button against the simulation name at the left side of the graphic viewer. This adds a new series to the existing series based on the selections made by the user.

To delete an existing series:

- Select the series to be deleted and hit “Delete” on the keyboard or right click and hit “Clear.” NOTE: There should always be at least one series on the graphic viewer. The series to be deleted can be selected by looking at the color of the series from the legend location on the graphic viewer.

To change the parameter, keeping the selected locations and simulations:

- Click the blank button next to the parameter of interest on the top of the graphic viewer.

To change the location, keeping the selected parameters and simulations:

- Click the button under the “Change” column next to the location of interest on the upper right side of the graphic viewer.

To change the period of interest for the simulations:

- Click the buttons on the lower right side of the graphic viewer.

APPENDIX I

Phosphorus End-Point for Passaic Valley Water Commission Intakes
Lawler, Matusky & Skelly Engineers LLP

Lawler, Matusky & Skelly Engineers LLP

Memo

To: James F. Cosgrove, P.E. (TRC-Omni Environmental)

From: Charles V. Beckers, Jr., P.E.

CC: Phil Roosa (Passaic Valley Water Commission)

Date: 08 August 2005 File Number: 1021-001

Re: Phosphorus End-point for Passaic Valley Water Commission Intakes

---

Overview

This memo summarizes the methods and results of our investigation of the effects of phosphorus in the Passaic and Pompton river source waters on the treatment process now used at the Passaic Valley Water Commission (PVWC) Little Falls Water Treatment Plant (LFWTP). The investigation considers both quantities of chemicals used in treatment and the cost of treatment.

Background

PVWC uses both the Passaic River and the Pompton River as source water for the drinking water it provides to its retail and wholesale customers. Water is withdrawn from the Passaic River at the LFWTP by gravity flow. Pompton River water is pumped to the LFWTP via the Two Bridges pump station on the Pompton River, where it is either withdrawn directly from the river or is supplied by gravity flow from Point View Reservoir. Because of its small watershed, water stored in Point View Reservoir is essentially all Pompton River water, which is pumped to the reservoir by the Jackson Avenue Pump Station.

While there is no Federal or state standard for the maximum concentration of phosphorus in finished drinking water, phosphorus does interact with the various physical and chemical processes used to treat the source waters. Because there is no standard threshold, unlike other organic and inorganic chemicals, it is not possible to set a maximum allowable concentration of phosphorus in the source waters based on the capacity of the filtration plant to reduce or remove the contaminant. It is necessary, instead, to trade-off the cost of treating source waters containing phosphorus in the filtration plant against the cost of reducing phosphorus concentrations in the source waters by other means, such as reduction of point or non-point source loads.

It should also be noted that phosphorus contributes to the growth of algae in fresh water, such as the Passaic and Pompton rivers. Algae can have their own impact on production of drinking water at the LFWTP, both directly and indirectly. The principal direct effect is the need to remove the algae through filtration to meet primary turbidity standards. The principal indirect effects are taste and odor issues associated with algae that must be addressed to meet consumer expectations.

Overall Goal

The goal of the study summarized in this memo is to identify the relationship between phosphorus in the source waters and the consumption of treatment chemicals in the LFWTP, as measured both by quantity used and by cost. The reason for considering both quantity and cost is that even small changes in usage of a higher-priced chemical can have important effects on the overall cost of treatment.

The study focuses on orthophosphate, a dissolved form of phosphorus, rather than total phosphorus. Orthophosphate was selected after a statistical review of the available phosphorus data (total and orthophosphorus) obtained from the watershed model developed by TRC-Omni Environmental indicated that the correlation between the two constituents was nearly equal to 1 (0.9986).

Overall Approach

The first step was to meet with PVWC staff. That meeting was hosted by Mr. Phil Roosa (PVWC) and was held on 11 August 2004 at the LFWTP. The purpose of the meeting was to explain our study to PVWC, to enlist the cooperation and assistance of PVWC, to gain an initial understanding of the unit processes used in the LFWTP, and to provide an opportunity for PVWC staff to present what they had learned about the relationship between source water phosphorus and chemical usage. The meeting included a tour of the facility. While PVWC staff were able to provide a number of insights on the issue, their experience was limited by the fact that the existing filtration plant had only been in operation since early 2003, following a major upgrade project, and many of the unit processes had not been used in the filtration plant before the upgrade.

Following that meeting, we developed a basic process diagram, which was critiqued by Mr. Roosa (PVWC) and went through several iterations of refinement. Ultimately, the process diagram presented later in this report and used in our study was prepared by Mr. Roosa.

Based on a review of the data provided by PVWC following the meeting, we decided the best approach would be to conduct a detailed in-plant sampling program to determine the influence of phosphorus on the LFWTP. We developed a draft study plan for in-plant sampling, which was presented to Mr. Roosa for comment. The study plan went through several cycles of review and improvement before we jointly settled on the final plan in mid-January 2005 (see Appendix A).

Based on their extensive data set on phosphorus concentrations in the rivers, PVWC expressed a general preference to delay the study until a period of lower river flows, when concentrations are typically higher. In addition, implementation of the study plan required final approval by PVWC Executive Director, Mr. Joseph A. Bella.

Unfortunately, before those conditions could be met and the in-plant sampling begun, PVWC experienced an incident in its filtration plant that led to the death of one of its employees. As a consequence, PVWC understandably decided it would be best not to pursue a non-essential study that would involve outside personnel in its facility, and the in-plant sampling program was abandoned. (Should an opportunity to pursue in-plant sampling present itself in the future, the sampling plan in Appendix A will provide a basis for that renewed effort.)

At that time, it was necessary to revise our approach to meeting the goals of the study and rely entirely on the available data set, which has a number of limitations from the viewpoint of this study. The remainder of our report presents the methodology and results of the revised study.

Analysis of Impacts of Phosphorus on LFWTP Chemical Usage and Costs

Purpose

Phosphorus is essential to the growth of algae and other biological organisms. The main sources of phosphorus in receiving water bodies include but are not limited to municipal and industrial wastewater discharges, and agriculture and farming practices. Other sources can include failed septic systems and runoff from landscaping. In the Passaic watershed, urban and suburban stormwater runoff acts as an important source, while agricultural sources are negligible. Although there are no drinking water standards that currently limit the amount of phosphorus in drinking waters, large quantities of phosphorus may act as a nuisance, resulting in use of larger quantities of chemicals for treatment and adding to a filtration plant's O&M costs.

Hence, the focus of this analysis was to develop and understand the relationship between the influent phosphorus at the LFWTP and the various chemicals used in the treatment of drinking water at the plant. This would, in turn, allow for quantification of the impacts of phosphorus on the chemical usage and associated costs.

Literature

A comprehensive literature search for impacts of phosphorus on drinking water treatment systems resulted in the finding that very few, if any, studies have been published. In contrast, several studies have been carried out on phosphorus removal from wastewater. T.K.Walsh et al. [1983].[1], in their review of biological phosphorus removal technology, point out that the quantity of chemicals required (thus the cost) for chemical phosphorus removal using metal salts is directly related to the quantity of phosphorus that must be removed. Boyko et al., [1976] in their work on a predictive methodology for phosphorus removal using jar tests on a pilot scale and full scale wastewater treatment plants, conclude that the complicated nature of the many competing reactions and their composition both make a stoichiometric assessment of phosphorus removal a virtual impossibility. This suggests that our original study approach, which called for in-plant sampling, would be the preferred approach.

Treatment Plan Schematic:

A detailed schematic of the Little Falls Water Treatment Plant System is shown below. The three main sources of raw water are the Passaic River, Pompton River and Point View Reservoir.[2]

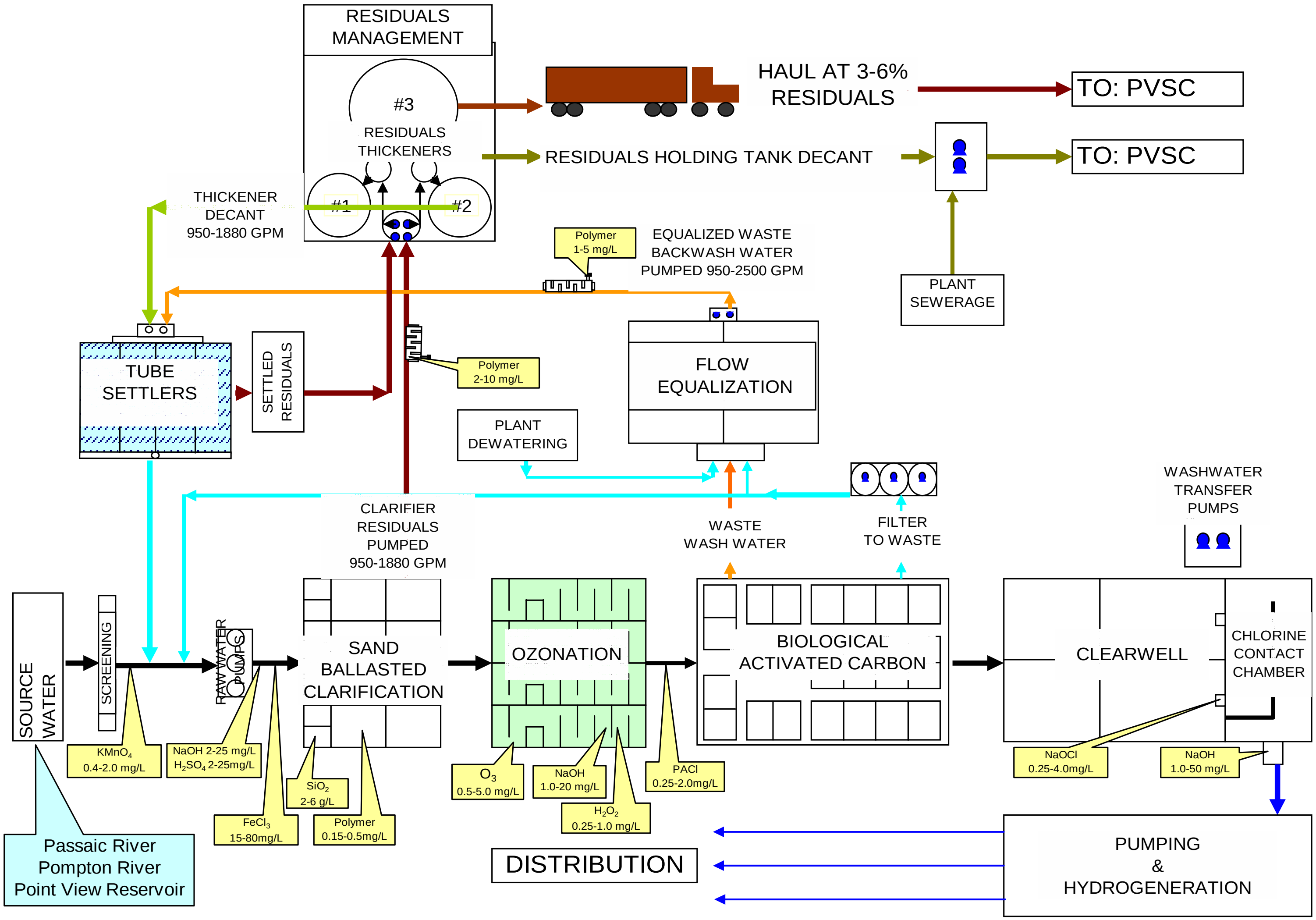
Screening of raw water is followed by addition of potassium permanganate to oxidize ferrous and manganese ions. The pH is adjusted by adding sodium hydroxide (NaOH) or sulfuric acid (H_2SO_4) for optimum coagulation for TOC reduction in the finished water. Coagulation is carried out using ferric chloride ($FeCl_3$) in a sand-ballasted clarification unit using microsand. A polymer (MagnaFloc) is used as a coagulant aid which reduces the settling time to minutes rather than hours. Residuals (solids) from the clarifiers are pumped to the sludge thickeners. Ozone (O_3) at 0.5-5.0 mg/L is currently used as the primary disinfectant, but sodium hypochlorite (NaOCl) has also been used at two points in the process (see next paragraph). Sodium hydroxide (NaOH) at 1-20 mg/L and hydrogen peroxide (H_2O_2) at 0.25 to 1 mg/L are added to the ozonation tank to quench ozone residual at the ozone contactor effluent and to oxidize geosmine and MIB (taste and odor compounds from algae), volatile organic compounds (VOCs) and other organic compounds. Addition of polyaluminum chloride (PACl) helps to re–coagulate colloidal particles before filtration. Residual organics and taste and odor removal occurs in the biological activated carbon unit. Thickened residuals flow to the residual holding tank prior to being hauled off-site for disposal at 3-6% solids. The residuals holding tank decant is also disposed of

---

[1] Full citations for documents referenced in the text may be found on Page 17.

[2] Even though virtually all water supplied by Point View Reservoir comes from the Pompton, we describe it as a separate source because water typically remains in the reservoir long enough for reservoir processes to modify its characteristics.

Passaic Valley Water Commission
Little Falls Water Treatment Plant



off-site along with the plant sewerage. The thickener decant water flows to the tube settlers where settled residuals are recycled back to the thickener and the supernatant flows to the head of the plant. Waste wash water and filter material from the biological activated carbon system are diverted to a flow equalization tank that also receives any plant dewatering flows and Filter to Waste. Alternatively, the Filter to Waste material can be recycled to the head of the plant. Polymer is added to the flow from equalization tank effluent before it is pumped to the tube settlers.

As noted above, both ozone and sodium hypochlorite are used for disinfection. During the period on which our regression modeling is based (see below), sodium hypochlorite was used at two points in the process train, just prior to the ozonation chamber[3] and in the chlorine contact chamber immediately following the clearwell. The sodium hypochlorite used in the chlorine contact chamber provides residual chlorine for the distribution system.

Data

The analytical approach for this study was to develop a simple spreadsheet mass balance model relating the major components of interest expected to contribute to the overall treatment costs:

- River flows
- Rainfall
- Influent phosphorus concentration (total phosphorus and orthophosphate)
- Finished water flow
- Coagulant (ferric chloride) dosage
- Polymer (MagnaFloc) dosage
- Chlorination (sodium hypochlorite) dosage
- Caustic soda (sodium hydroxide) dosage

Ozone was not included in the evaluation, because it is generated on site and PVWC did not provide usage or cost data. The two chlorination points were addressed separately as “intermediate chlorination” (just prior to the ozone tank) and “post-chlorination” (just after the clearwell), because it was unclear whether or not intermediate chlorination was expected to continue into the future. Should it be discontinued, that usage and cost element can be straightforwardly eliminated from the calculations.

The river flow and the rainfall components were included in the analysis due to the fact that the total phosphorus load delivered to the treatment plant intakes at any point in time depends on the available river flows and the time of the year (summer, winter etc). For example during a wet season, higher flows result in greater dilution of phosphorus and lesser concentrations of phosphorus being delivered to the treatment plant intakes. The opposite is true during low flow periods when higher concentrations of phosphorus are delivered to the treatment plant intakes. Rainfall was used to represent local effects in the immediate vicinity of the intakes, while river flow was used to represent basin-wide conditions.

PVWC’s yearly chemical usage and cost reports from 1995-2003 were screened for this purpose. Alum was used as a coagulant until February 2003, which is when the sand-ballasted clarification unit went on-line as part of the plant up-grade. At that time, alum was replaced by ferric chloride and MagnaFloc, as the coagulant and the polymer respectively. Therefore, any data before February 2003 is not reflective of the present day functioning of the plant and is not included in the analysis.

Unfortunately, the yearly reports do not have any influent phosphorus measurements. These data (total and orthophosphate) were generated for the PVWC intakes by a calibrated watershed model developed by TRC-Omni Environmental and provided to LMS for the period of October 1999 –

[3] The NaOCl addition just prior to the ozonation chamber is not shown on the diagram because it is expected to be a temporary measure during initiation of the new treatment processes.

November 2003. The influent phosphorus concentration was estimated as the flow weighted average of the Passaic and Pompton influent concentrations, based on influent flow data provided by PVWC.

The data covering the period of February – November 2003 (10 months) were selected to be used in a linear regression analysis to develop the relationships between independent and dependent variables. The absence of the sand ballasted clarification unit prior to February 2003 precluded the use of any data prior to that time. Subsequent hindcasts of chemical usage and costs make use of nearly the entire independent variable data set, because they are not constrained by the changes in the process train post-February 2003.

Monthly finished water flow data were provided by PVWC for the period.

River flow was represented as the summation of the monthly river flows at two USGS Stations (Pompton River at Pompton Plains, USGS01388500 and Passaic River at Pine Brook, USGS01381900) [USGS 2003].

Even though there is a rain gage at LFWTP and PVWC provided those data, the rainfall data used come from the rain gage at the Essex County Airport, approximately 4 miles west of the LFWTP. These data were provided by TRC-Omni Environmental and were used for consistency with the Passaic River water quality modeling done by TRC-Omni Environmental. Comparison of results using data from both sources disclosed no significant differences.

A statistical software package, NCSS 2001, [Hintze 2001] was used to develop linear relationships among the various usage components using the multiple regression technique.

The table (and key) below shows the data that were used in the regression analysis of chemical usage.

Date	NCSS Date	NCSS VARIABLES								
		RFLOW	FWFLOW	RAIN	ORTP	usgCOAGT	usgPLYMR	usgINCL2	usgPSCL2	usgCAUSTIC
Feb-03	2	913	246	2.66	0.290	159,878	3,673	43,825	552	-
Mar-03	3	3,561	1,179	4.47	0.101	182,628	4,382	39,194	3,910	174,509
Apr-03	4	2,004	1,496	3.11	0.126	296,747	2,487	45,571	12,151	224,272
May-03	5	827	1,614	4.1	0.260	356,239	2,625	46,011	16,704	301,802
Jun-03	6	3,949	1,607	6.47	0.091	349,839	2,608	52,267	19,120	264,424
Jul-03	7	608	1,733	3.09	0.312	389,513	3,978	59,508	23,182	500,810
Aug-03	8	1,245	1,704	7.73	0.264	417,127	5,181	57,214	23,266	471,429
Sep-03	9	1,134	1,217	7.67	0.302	241,491	4,372	39,142	16,732	326,141
Oct-03	10	1,427	1,111	3.87	0.251	217,199	3,981	30,035	14,592	270,653
Nov-03	11	2,399	1,090	6.17	0.142	204,104	4,013	32,532	14,194	210,431

KEY

(yellow)	Independent variables
(green)	Dependent variables

The table below presents a description of the NCSS chemical usage variables:

RFLOW	Summation of monthly river flows at USGS 01388500 (Pompton R @ Pompton Plains, NJ) & USGS 01388500 (Passaic R @ Pine Brook, NJ) in mgd
FWFLOW	Total Finished Water Flows (MG)
RAIN	Rainfall (in)
ORTP	Orthophosphorous Conc (mg/L) from TRC-Omni's watershed model
usgCOAGT	$FeCl_3$, coagulant dosage (lbs)
usgPLYMR	MagnaFloc, polymer dosage (lbs)
usgINCL2	NaOCl dosage (lbs) for intermediate chlorination
usgPSCL2	NaOCl dosage (lbs) for post-chlorination
usgCAUSTIC	NaOH dosage (lbs) for pH adjustment

A comparable set of cost variables was used in the regression analysis of chemical costs. In the case of cost, there are three ways to evaluate cost:

- One can simply multiply the unit cost of each chemical times the usage calculated with the linear regression equations for usage.
- One can develop a separate linear regression equation for the cost of each chemical.
- One can develop a single linear regression equation for the overall cost of treatment.

The data and variables used in the multiple regression analysis of chemical costs are shown in the next two tables. Note that these costs are expressed as dollars/million gallons finished water.

Date	NCSS Date	NCSS VARIABLES									
		RFLOW	FWFLOW	RAIN	ORTP	cstCOAGT	cstPLYMR	cstINCL2	cstPSCL2	cstCAUSTIC	cstTOTAL
Feb-03	2	913	246	2.66	0.290	$18.79	$2.59	$16.73	$0.21	$40.49	$78.82
Mar-03	3	3,561	1,179	4.47	0.101	$21.98	$3.16	$15.32	$1.53	$29.78	$71.77
Apr-03	4	2,004	1,496	3.11	0.126	$24.78	$2.50	$12.36	$3.30	$20.64	$63.58
May-03	5	827	1,614	4.1	0.260	$31.33	$1.38	$13.15	$4.77	$29.25	$79.88
Jun-03	6	3,949	1,607	6.47	0.091	$30.91	$1.38	$15.00	$5.49	$25.74	$78.51
Jul-03	7	608	1,733	3.09	0.312	$31.90	$1.37	$15.83	$6.17	$45.20	$100.47
Aug-03	8	1,245	1,704	7.73	0.264	$34.74	$2.58	$15.48	$6.29	$43.26	$102.36
Sep-03	9	1,134	1,217	7.67	0.302	$28.16	$3.05	$14.83	$6.34	$41.91	$94.28
Oct-03	10	1,427	1,111	3.87	0.251	$27.75	$3.05	$12.47	$6.06	$38.11	$87.43
Nov-03	11	2,399	1,090	6.17	0.142	$26.57	$3.13	$13.76	$6.00	$30.19	$79.65

KEY

Independent variables
Dependent variables

RFLOW	Summation of monthly river flows at USGS 01388500 (Pompton R @ Pompton Plains, NJ) & USGS 01388500 (Passaic R @ Pine Brook, NJ) in mgd
FWFLOW	Total Finished Water Flows (MG)
RAIN	Rainfall (in)
ORTP	Orthophosphorous Conc (mg/L) from TRC-Omni's watershed model
cstTOTAL	Unit chemicals cost ($/MG)
cstCOAGT	Unit coagulant cost ($/MG)
cstPLYMR	Unit polymer cost ($/MG)
cstINCL2	Unit intermediate chlorination cost ($/MG)
cstPSCL2	Unit post chlorination cost ($/MG)
cstCAUSTIC	Unit caustic soda cost ($/MG)

Usage Models

Five different models corresponding to the five dependent variables (chemicals), i.e., COAGT, PLYMR, INCL2, PSCL2 and CAUSTIC, were estimated by applying the multiple regression technique:

Variables		Equation (intercept EQUAL TO 0)	R^2
Dependent	**Independent**		
COAGT	RAIN RFLOW ORTP FWFLOW	**236774.117*ORTP - 303.556*RAIN - 4.669*RFLOW + 185.316*FWFLOW**	0.9846
PLYMR	RAIN RFLOW ORTP FWFLOW	**10391.287*ORTP + 192.397*RAIN + 0.517*RFLOW - 0.295*FWFLOW**	0.9711
INCL2	RAIN RFLOW ORTP FWFLOW	**99064.055*ORTP - 1368.734*RAIN + 5.686*RFLOW + 15.237*FWFLOW**	0.9765
PSCL2	RAIN RFLOW ORTP FWFLOW	**- 8944.061*ORTP + 1249.690*RAIN - 2.929*RFLOW + 11.974*FWFLOW**	0.9701
CAUSTIC	RAIN RFLOW ORTP FWFLOW	**360900.294*ORTP + 8841.934*RAIN - 33.351*RFLOW + 176.950*FWFLOW**	0.9799

It should be noted that, as orthophosphate concentration approaches zero in the influent, these equations may under estimate treatment dosage and cost. This approach was required by the sparseness of the data available at the time of the analysis, but it is consistent with the notion that chemical usage should approach zero as finished water flow approaches zero.

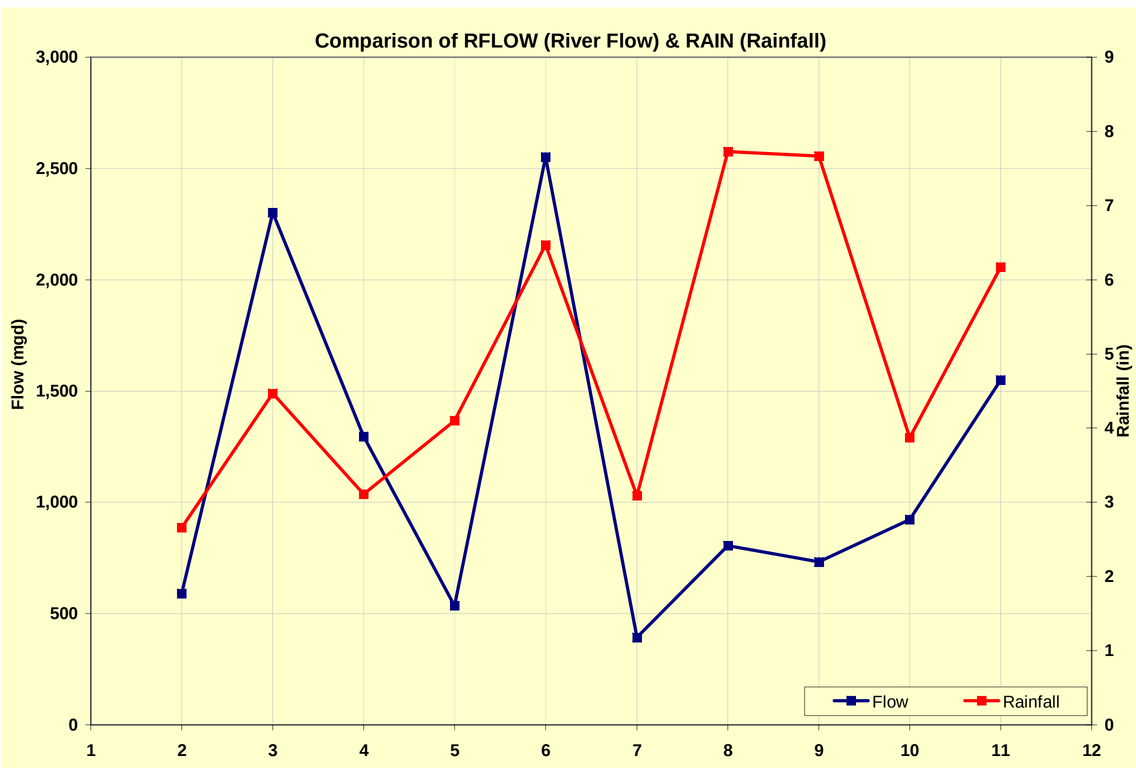
To confirm that use of the Essex County Airport rain data did not bias the resulting linear equations, we developed comparable equations using the LFWTP rain data. Comparison of the results of the two sets of equations shows nearly identical results. The airport data were used for consistency with the water quality modeling, which found the airport data to be representative of regional precipitation.

Usage Model Plots

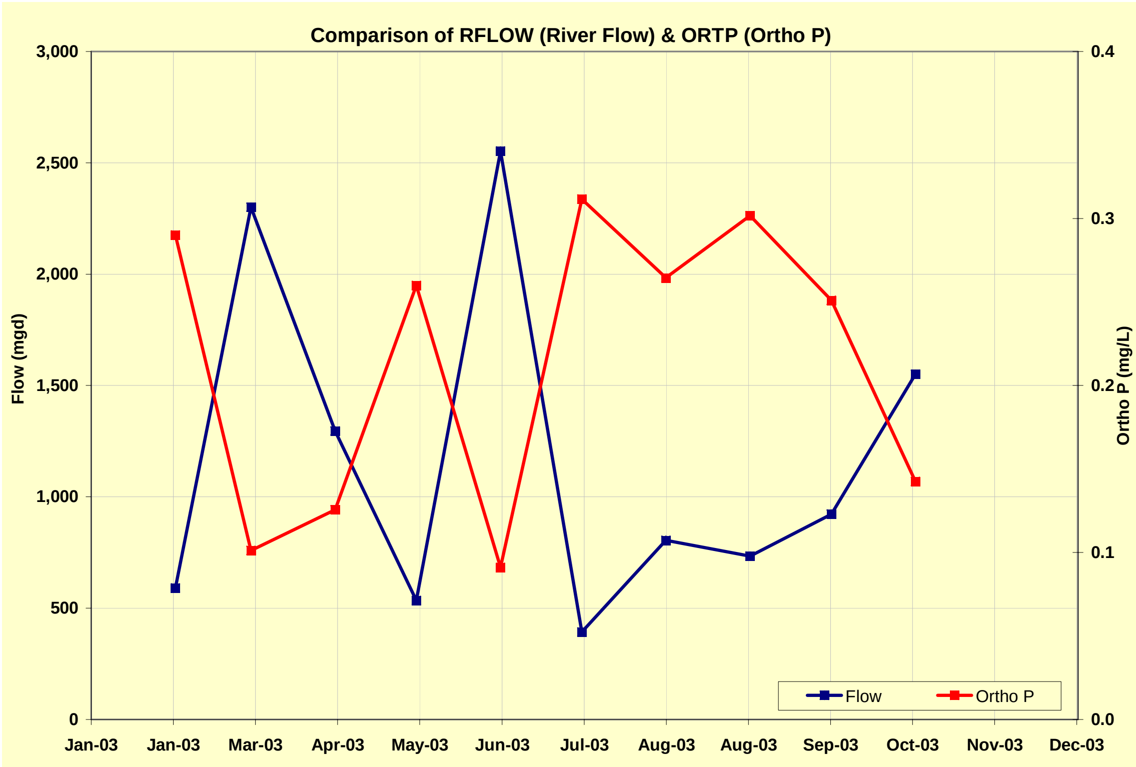
This section presents the data plots for the five regression models.

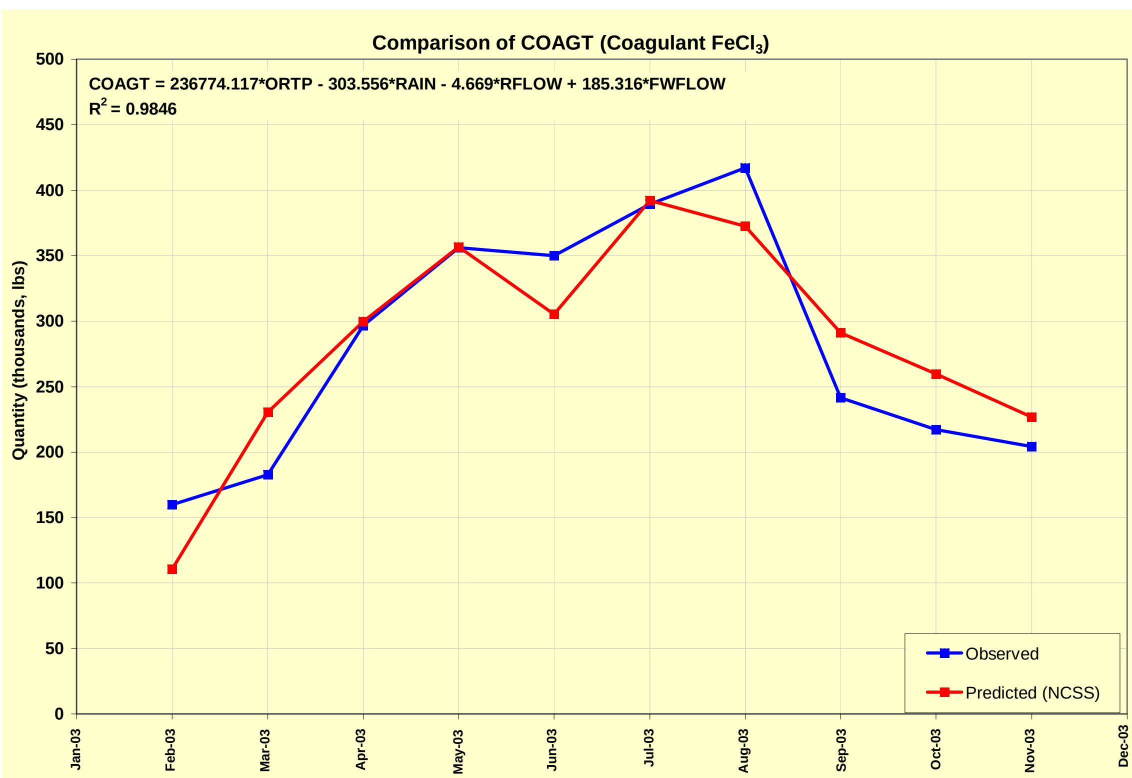
The first plot shows rainfall and stream flow, as recorded at the airport and the two upstream USGS gages, respectively. The trends look reasonable, except during the months of August, September and October, when the flow does not respond proportionately to the rainfall. This may be due to the fact that that the upstream reservoirs were below spillway level and refilling during that period [USGS 2003].

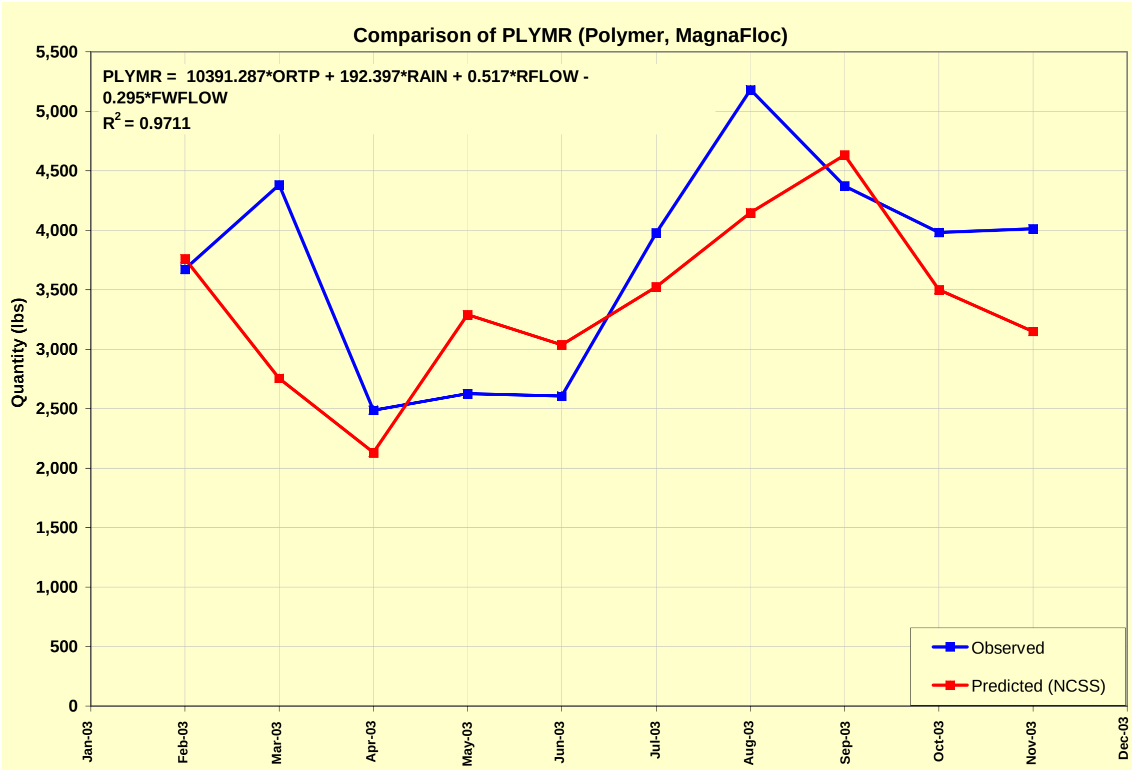
The second plot shows the relationship between the orthophosphate concentration hindcast by the river model and the observed total flow at the two upstream USGS gaging stations. The inverse relationship between river flow and orthophosphate concentration is clearly seen in this plot.

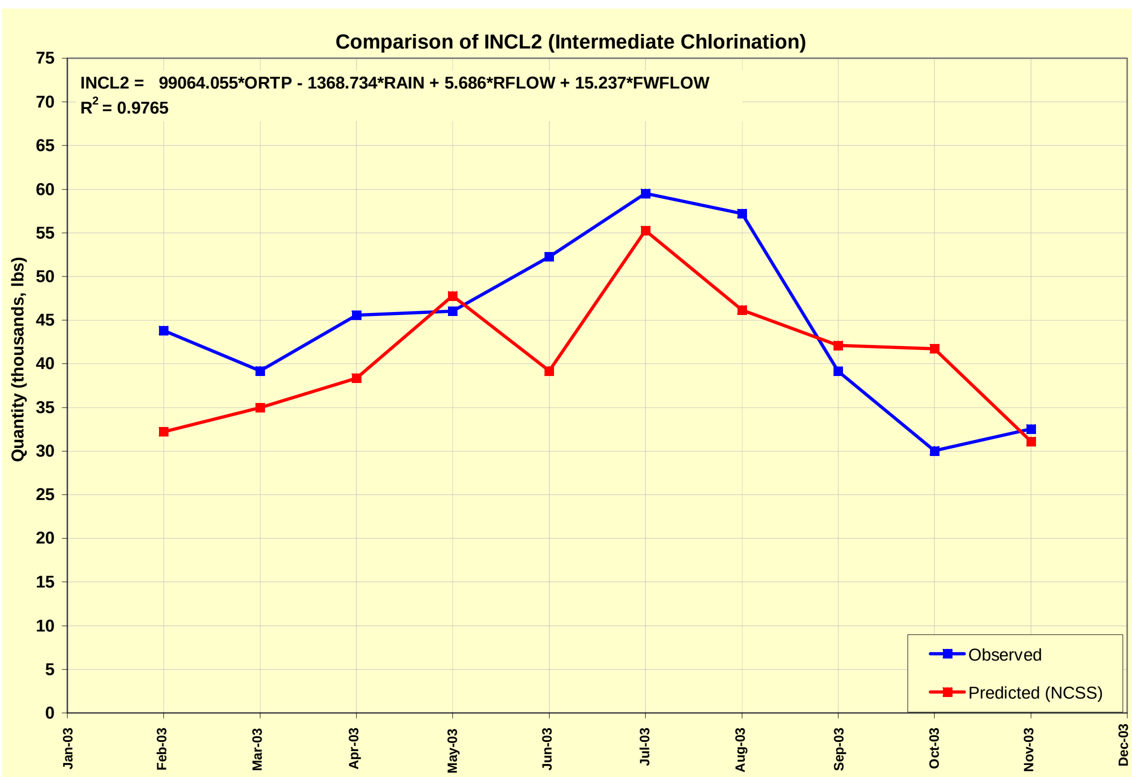


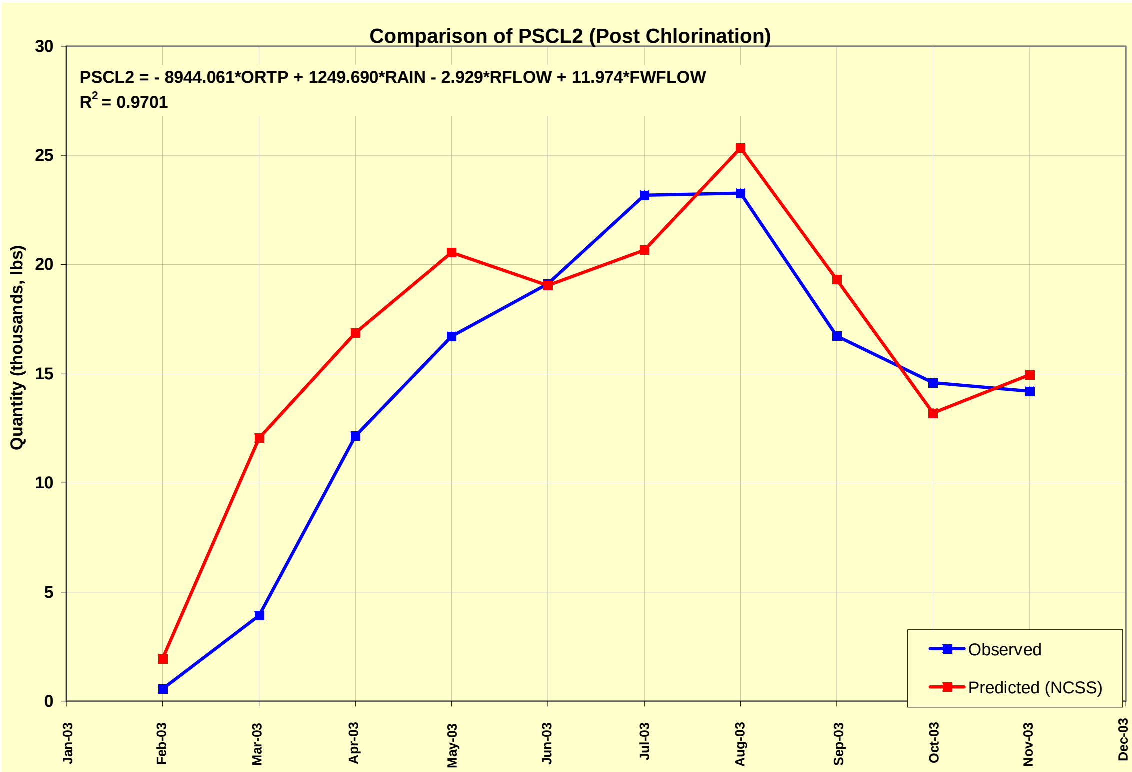
 Lawler, Matusky & Skelly Engineers LLP

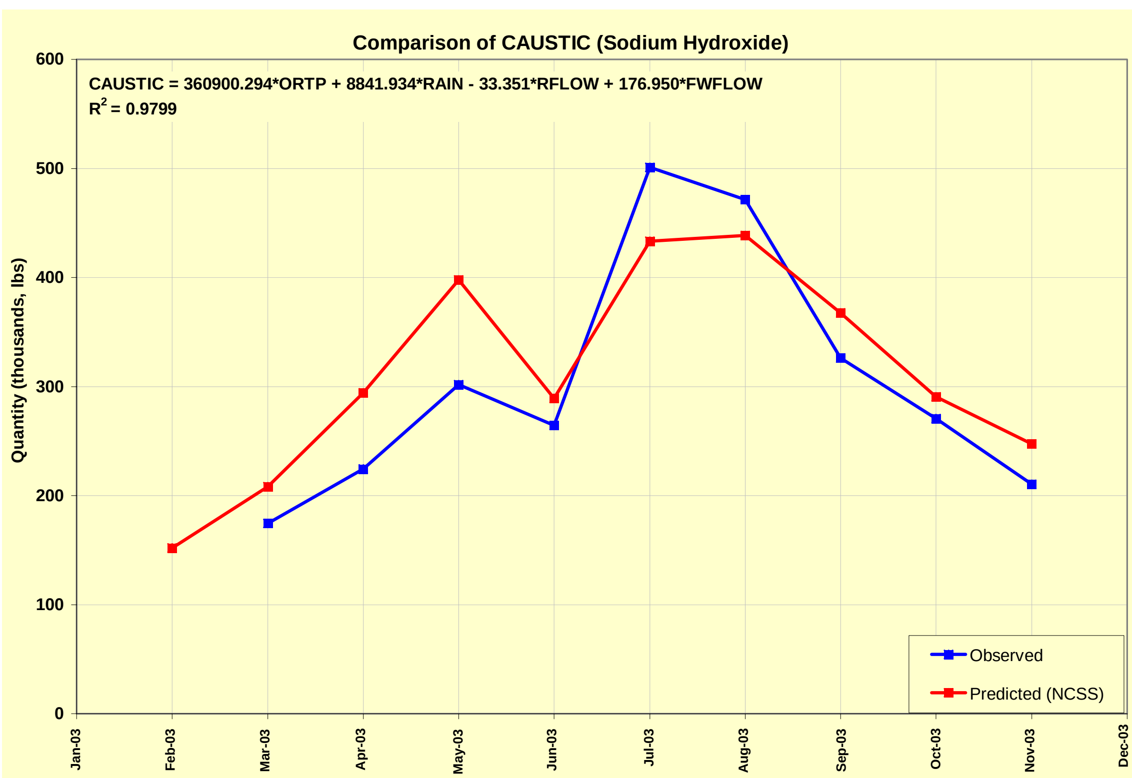

Comparison of RFLOW (River Flow) & ORTP (Ortho P)
Flow (mgd)
Ortho P (mg/L)
3,000
2,500
2,000
1,500
1,000
500
0
0.4
0.3
0.2
0.1
0.0
Jan-03 Jan-03 Mar-03 Apr-03 May-03 Jun-03 Jul-03 Aug-03 Aug-03 Sep-03 Oct-03 Nov-03 Dec-03
Flow
Ortho P


Comparison of COAGT (Coagulant $FeCl_3$)
COAGT = 236774.117*ORTP - 303.556*RAIN - 4.669*RFLOW + 185.316*FWFLOW
$R^2 = 0.9846$
Quantity (thousands, lbs)
500
450
400
350
300
250
200
150
100
50
0
Jan-03 Feb-03 Mar-03 Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03 Dec-03
Observed
Predicted (NCSS)


Comparison of PLYMR (Polymer, MagnaFloc)
PLYMR = 10391.287*ORTP + 192.397*RAIN + 0.517*RFLOW - 0.295*FWFLOW
R2 = 0.9711
Quantity (lbs)
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of INCL2 (Intermediate Chlorination)
INCL2 = 99064.055*ORTP - 1368.734*RAIN + 5.686*RFLOW + 15.237*FWFLOW
R2 = 0.9765
Quantity (thousands, lbs)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of PSCL2 (Post Chlorination)
PSCL2 = - 8944.061*ORTP + 1249.690*RAIN - 2.929*RFLOW + 11.974*FWFLOW
R2 = 0.9701
Quantity (thousands, lbs)
30
25
20
15
10
5
0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of CAUSTIC (Sodium Hydroxide)
CAUSTIC = 360900.294*ORTP + 8841.934*RAIN - 33.351*RFLOW + 176.950*FWFLOW
R2 = 0.9799
Quantity (thousands, lbs)
600
500
400
300
200
100
0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)

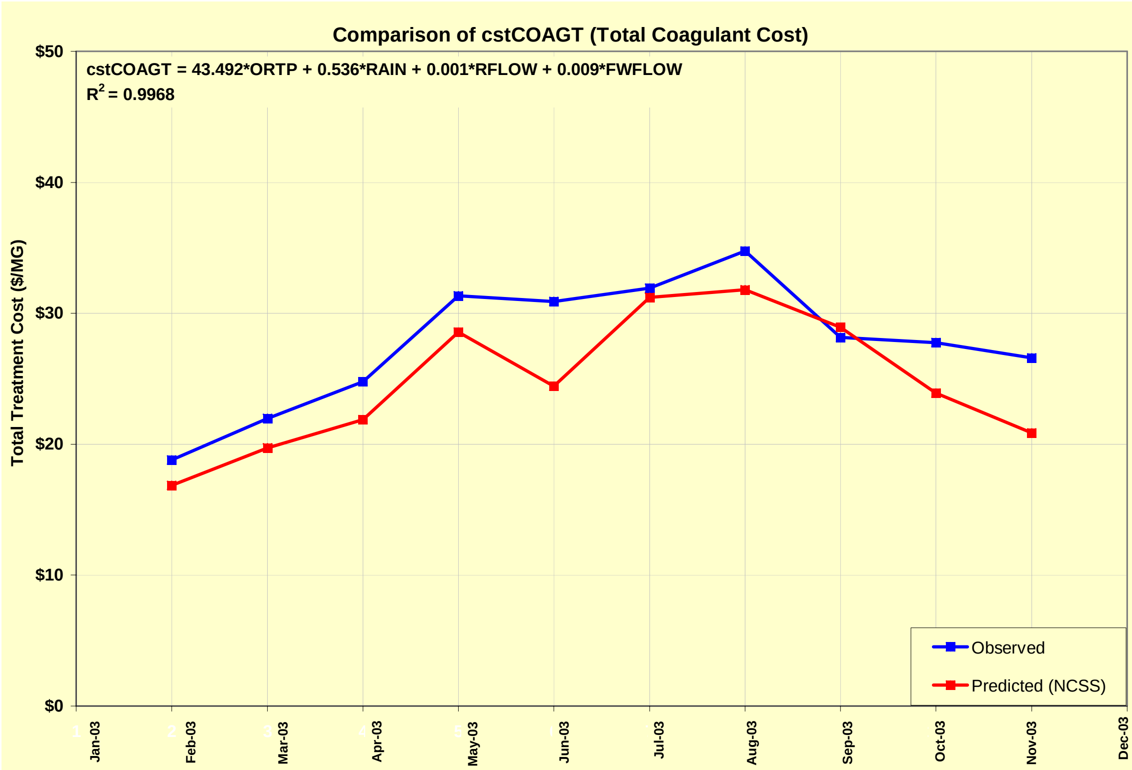
The remaining five plots compare the observed and hindcast chemical usage based on the linear regression models for the five dependent variables (treatment chemicals) studied.

Note that the R^2 values associated with each linear regression equation are consistently above 0.97, all well within the acceptable range for the purposes of this study.

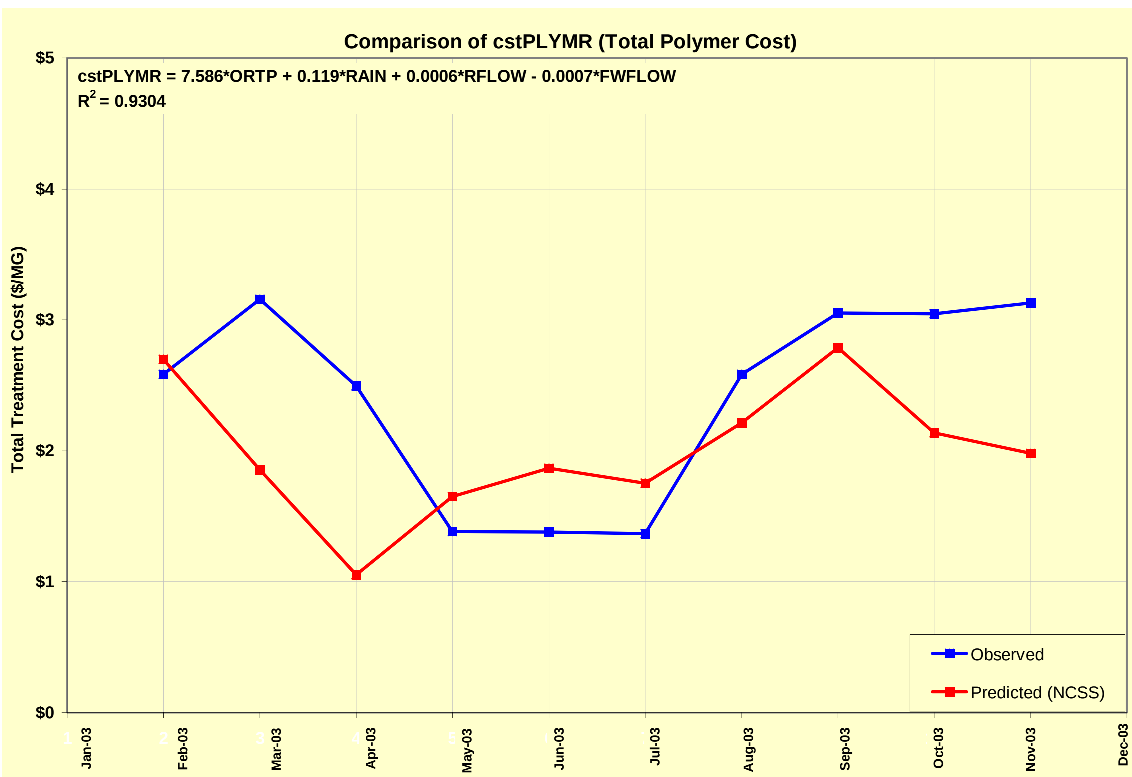
Cost Model and Plots

We developed linear regression equations for both individual costs and total cost, and compared them with calculations of cost developed by simply multiplying unit cost times the results of the usage model equations. We found that, while there are the small differences one would expect from doing the calculations in various ways, the total cost equation produces results that are comparable to the other methods. The following presents the resulting equations and comparison plots for each approach.

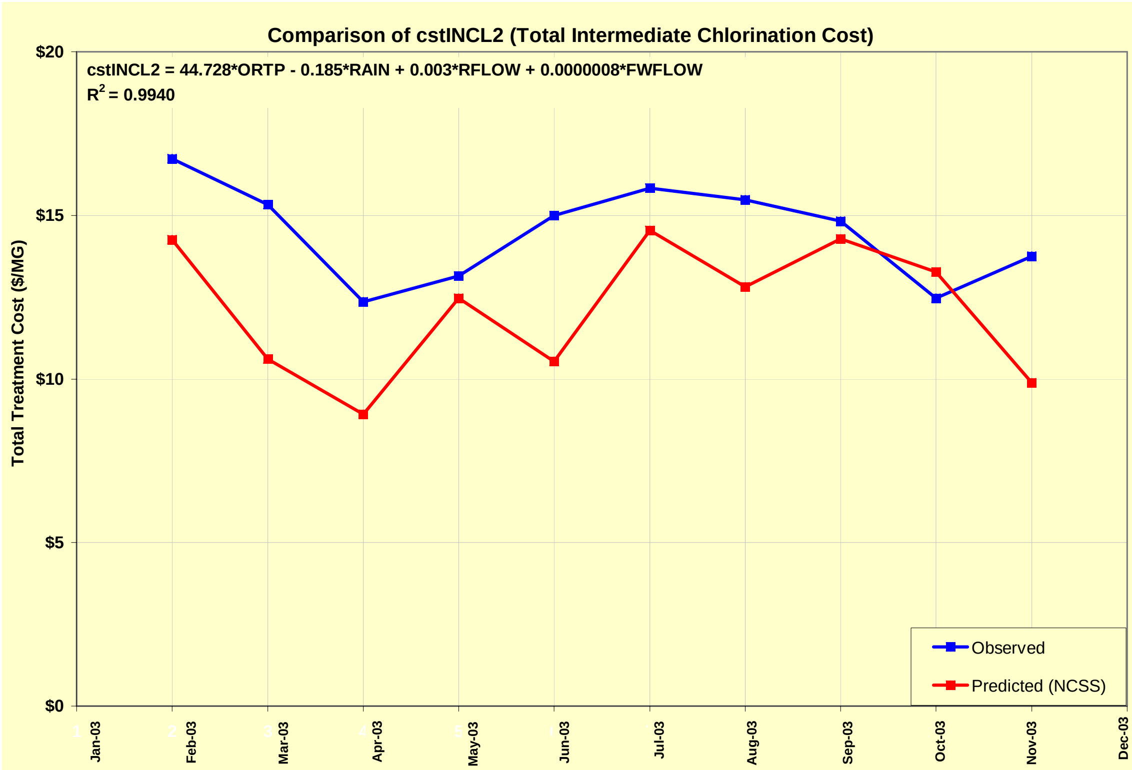
Variables		Equation (intercept EQUAL TO 0)	R^2
Dependent	Independent		
UNTCST1	RAIN RFLOW ORTP FWFLOW	221.832*ORTP + 1.514*RAIN + 0.008*RFLOW + 0.009*FWFLOW	0.9974
COAGT	RAIN RFLOW ORTP FWFLOW	43.492*ORTP + 0.536*RAIN + 0.001*RFLOW + 0.009*FWFLOW	0.9968
PLYMR	RAIN RFLOW ORTP FWFLOW	7.586*ORTP + 0.119*RAIN + 0.0006*RFLOW - 0.0007*FWFLOW	0.9304
INCL2	RAIN RFLOW ORTP FWFLOW	44.728*ORTP - 0.185*RAIN + 0.003*RFLOW + 0.0000008*FWFLOW	0.9940
PSCL2	RAIN RFLOW ORTP FWFLOW	- 0.820*ORTP + 0.563*RAIN - 0.0006*RFLOW + 0.002*FWFLOW	0.9439
CAUSTIC	RAIN RFLOW ORTP FWFLOW	126.830*ORTP + 0.480*RAIN + 0.003*RFLOW - 0.001*FWFLOW	0.9919

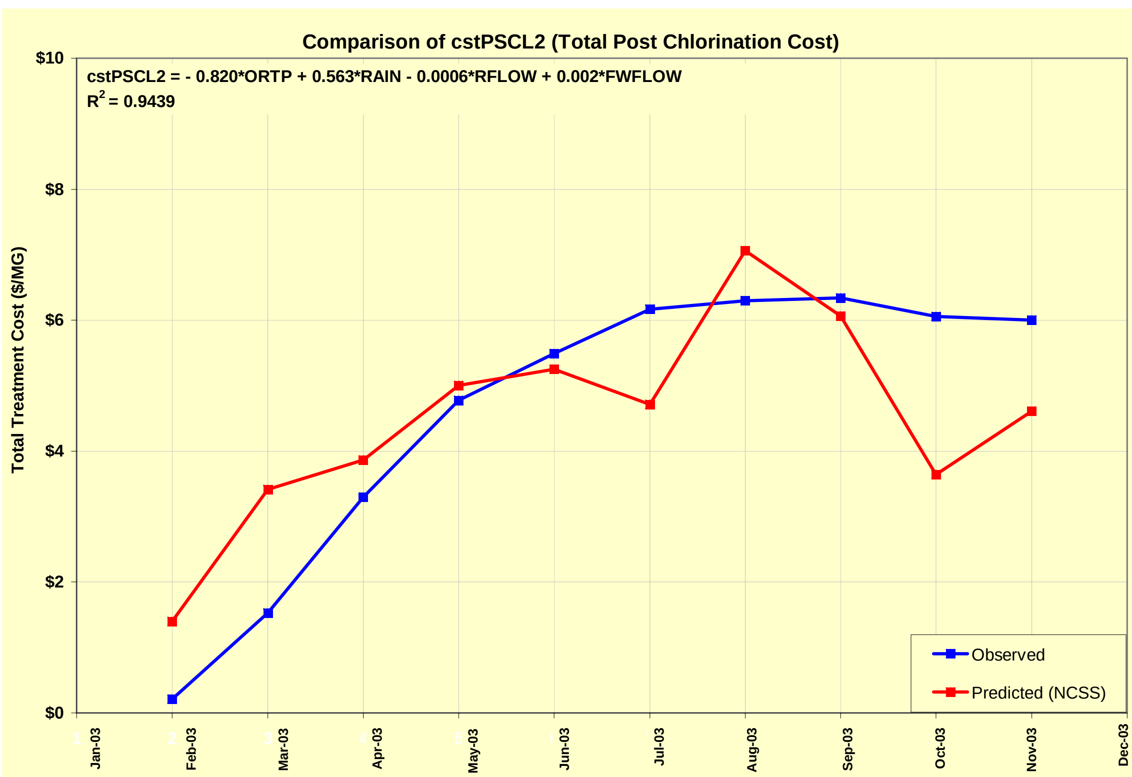


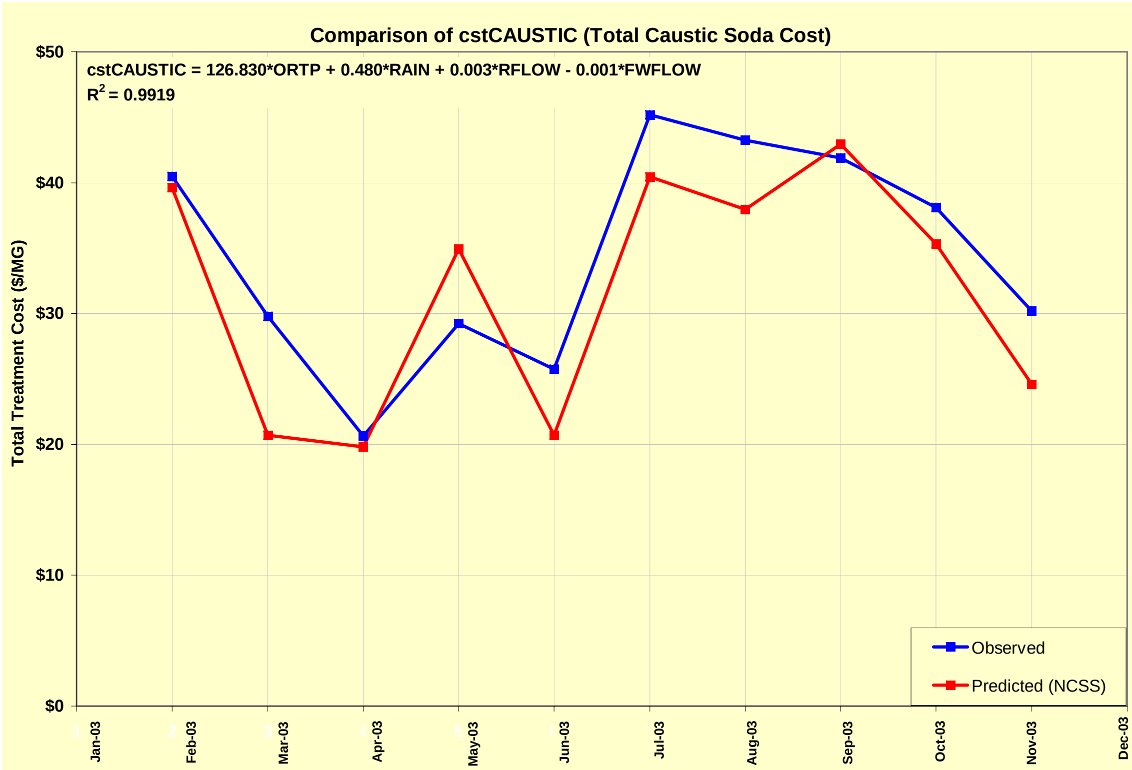
Comparison of cstCOAGT (Total Coagulant Cost)
cstCOAGT = 43.492*ORTP + 0.536*RAIN + 0.001*RFLOW + 0.009*FWFLOW
R2 = 0.9968
Total Treatment Cost ($/MG)
$50
$40
$30
$20
$10
$0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)

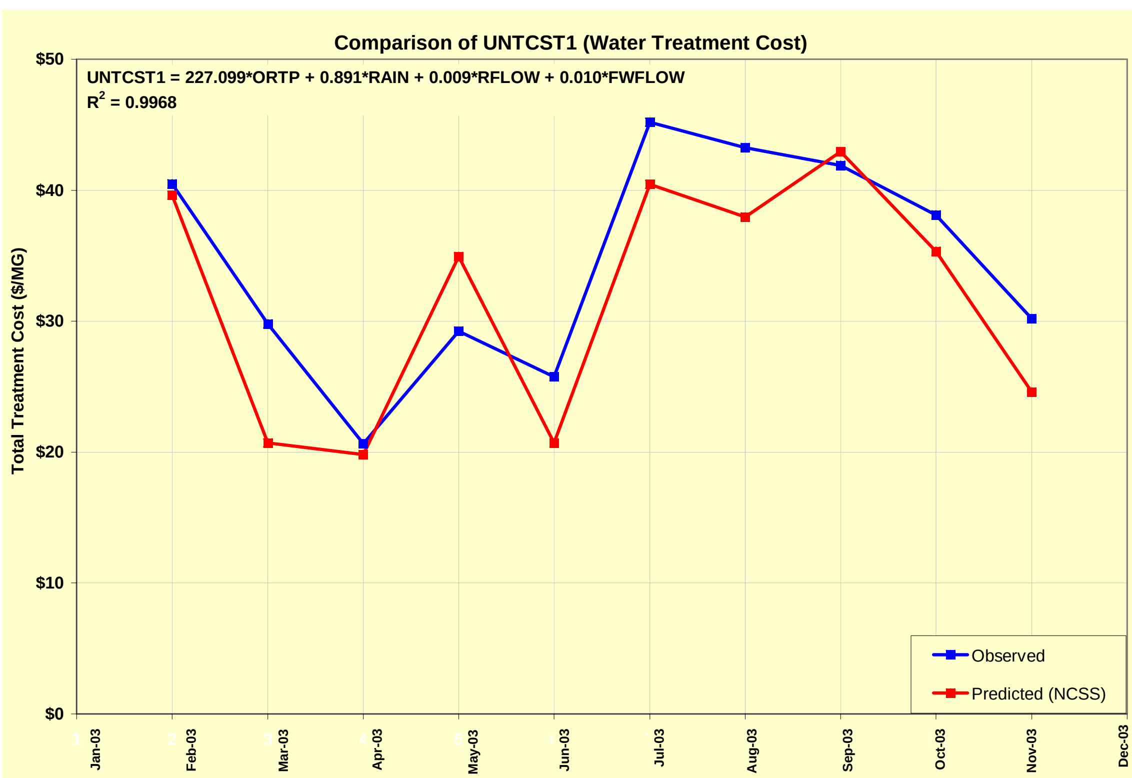


Comparison of cstPLYMR (Total Polymer Cost)
cstPLYMR = 7.586*ORTP + 0.119*RAIN + 0.0006*RFLOW - 0.0007*FWFLOW
R2 = 0.9304
Total Treatment Cost ($/MG)
$5
$4
$3
$2
$1
$0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of cstINCL2 (Total Intermediate Chlorination Cost)
cstINCL2 = 44.728*ORTP - 0.185*RAIN + 0.003*RFLOW + 0.0000008*FWFLOW
R2 = 0.9940
Total Treatment Cost ($/MG)
$20
$15
$10
$5
$0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of cstPSCL2 (Total Post Chlorination Cost)
cstPSCL2 = - 0.820*ORTP + 0.563*RAIN - 0.0006*RFLOW + 0.002*FWFLOW
R2 = 0.9439
Total Treatment Cost ($/MG)
$10
$8
$6
$4
$2
$0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of cstCAUSTIC (Total Caustic Soda Cost)
cstCAUSTIC = 126.830*ORTP + 0.480*RAIN + 0.003*RFLOW - 0.001*FWFLOW
R2 = 0.9919
Total Treatment Cost ($/MG)
$50
$40
$30
$20
$10
$0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)


Comparison of UNTCST1 (Water Treatment Cost)
UNTCST1 = 227.099*ORTP + 0.891*RAIN + 0.009*RFLOW + 0.010*FWFLOW
R2 = 0.9968
Total Treatment Cost ($/MG)
$50
$40
$30
$20
$10
$0
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Observed
Predicted (NCSS)

Conclusions and Recommendations — Analytical Study

The regression models developed using NCSS for usage and cost of the five major components – coagulant, polymer, intermediate chlorination, post-chlorination and caustic – serve as a reasonable starting point for a basic cost analysis of monthly chemical usage.

However, while using these models, their major limitations should be considered:

1. Short span of available data for development of the regression equations.

2. Use of influent phosphorus data from a calibrated watershed model rather than actual field measured data.

3. Intercept specified as 0.

Further, due to the complicated nature of phosphorus chemistry in water bodies and the various chemical reactions that can take place, it is highly recommended that experimental jar tests be carried out on a pilot scale to better understand the chemical usage as impacted by the influent phosphorus. Additionally, an intensive sampling program spanning a few weeks in spring, summer, fall and winter would capture the seasonal variations. The NCSS regression model can then be modified to include this newly acquired data, thus validating it to the point where it can be used as a predictive tool to evaluate the chemical costs of running the treatment plant under scenarios with varying influent phosphorus concentrations.

References for Analytical Study

Boyko, B.I. and Gerald Rupke, J.W. (1976), Phosphorus Removal within Existing Wastewater Treatment Plan Facilities, August 1976.

Hintze, J (2001). NCSS & PASS. Number Cruncher Statistical Systems, Kaysville, UTAH www.ncss.com.

USGS (2003), Water Resources Data for New Jersey, Water Year 2003, Water-Data Report NJ-03-1

Walsh, T.K., Behrman, B.W., Weil, G.W., Jones, E.R. (1983), A Review of Biological Phosphorus Removal Technology, Water Pollution Control Federation, 1983.

Additional Bibliography

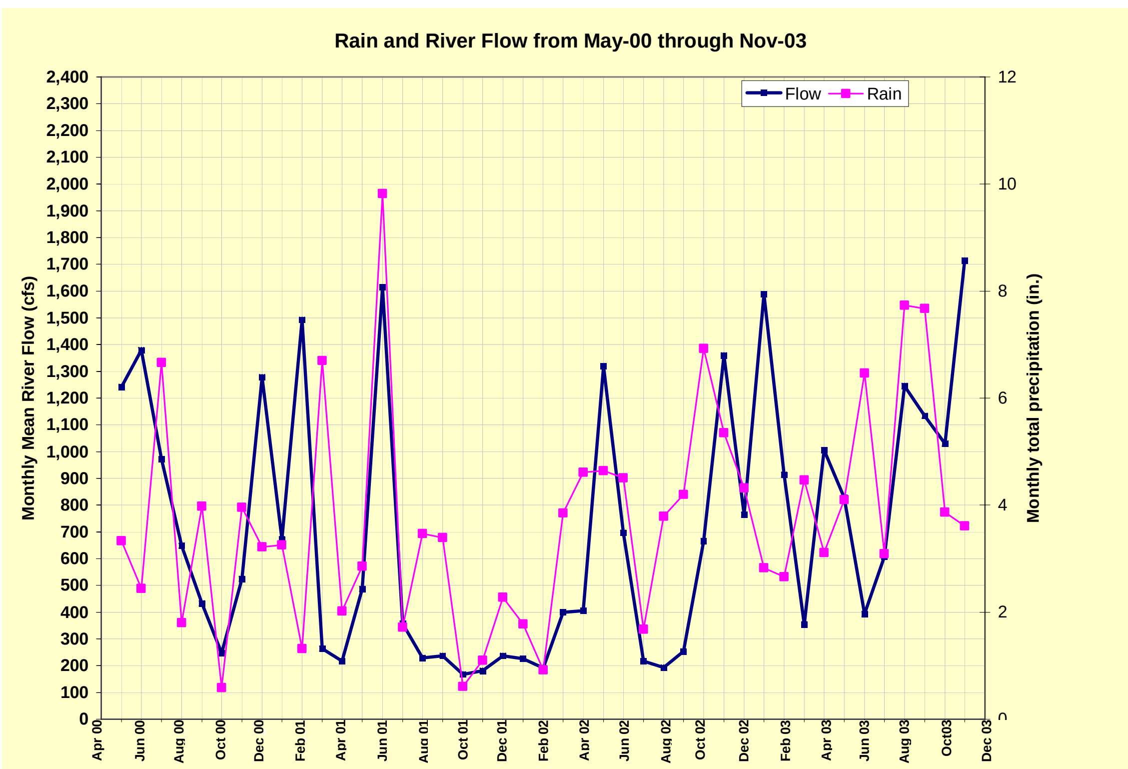
Metcalf and Eddy, Wastewater Engineering Treatment, Disposal and Reuse, Third Edition.

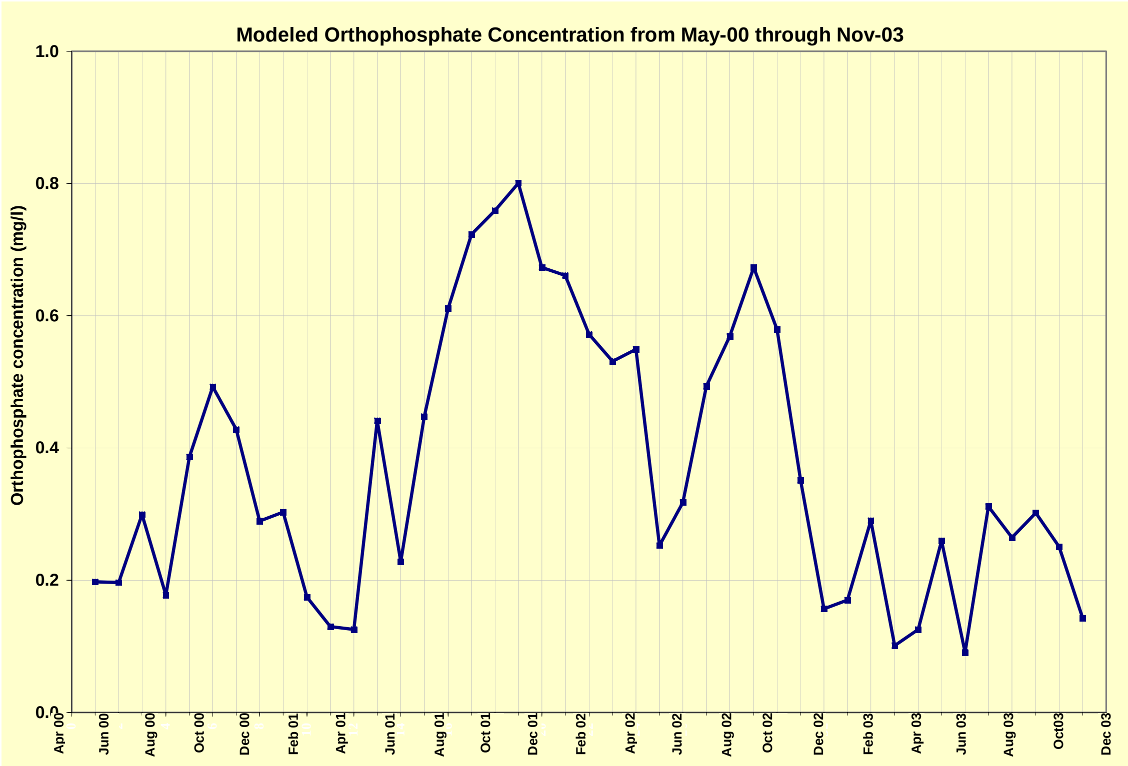
Snoeyink, Vernon L., and David Jenkins, Water Chemistry, 1980.

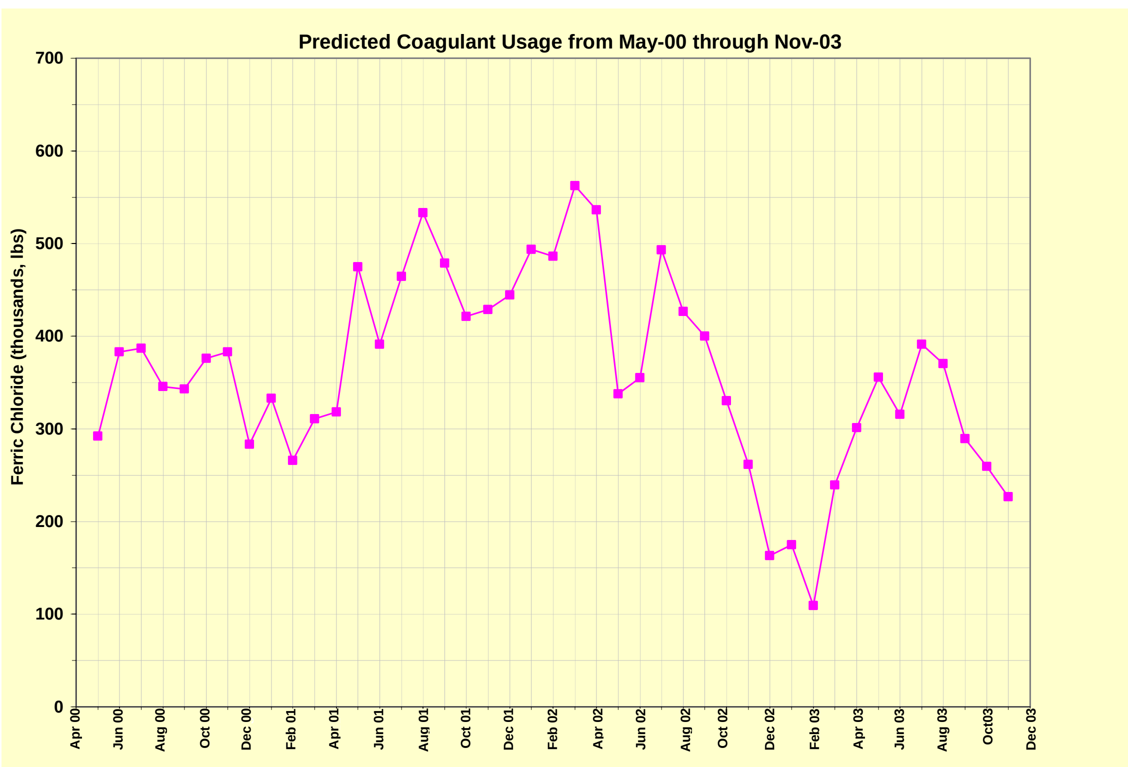
Use of Linear Regression Models in Hindcast Mode

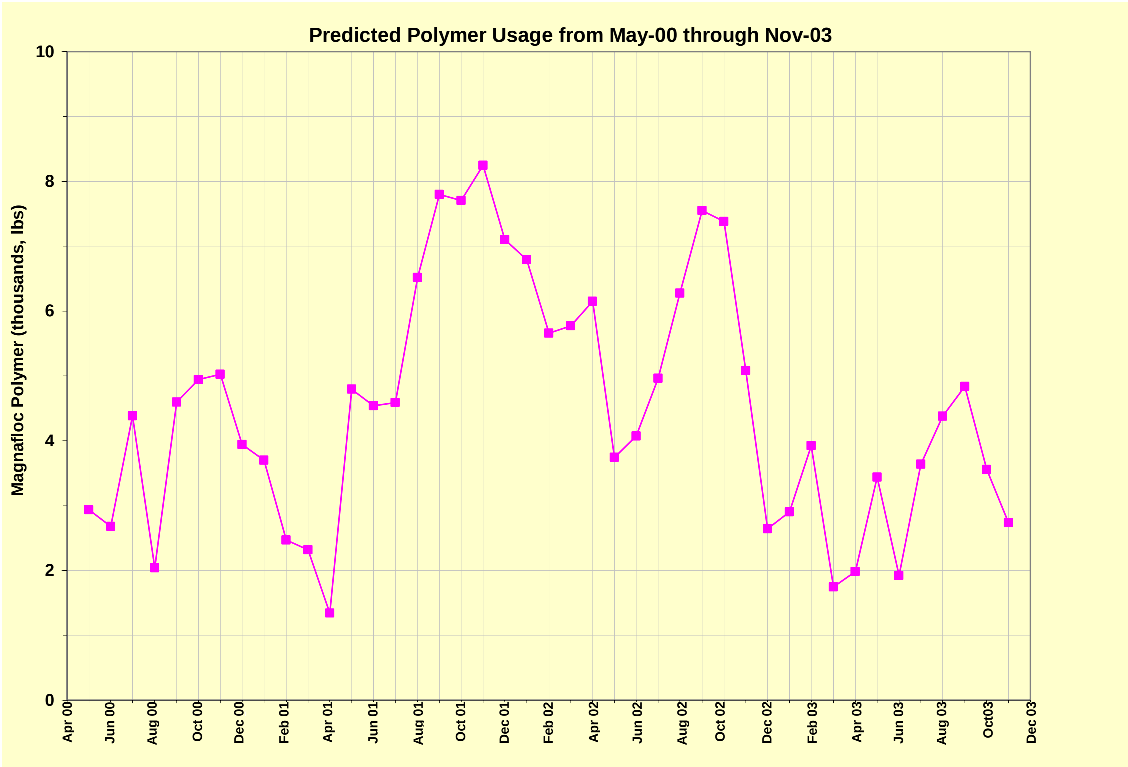
Because of the recent changes in the treatment processes used at LFWTP, it is instructive to look at what would have happened (a "hindcast") had these unit processes been in place over a longer span of time. In particular, the February through November 2003 time period used to develop the linear regression equations was a relatively "wet" period, and "dry" periods are known to result in higher phosphorus concentrations in the vicinity of the LFWTP intakes. In addition, during the 2001-2002 period, a drought emergency was declared in New Jersey, leading to reduced water usage.

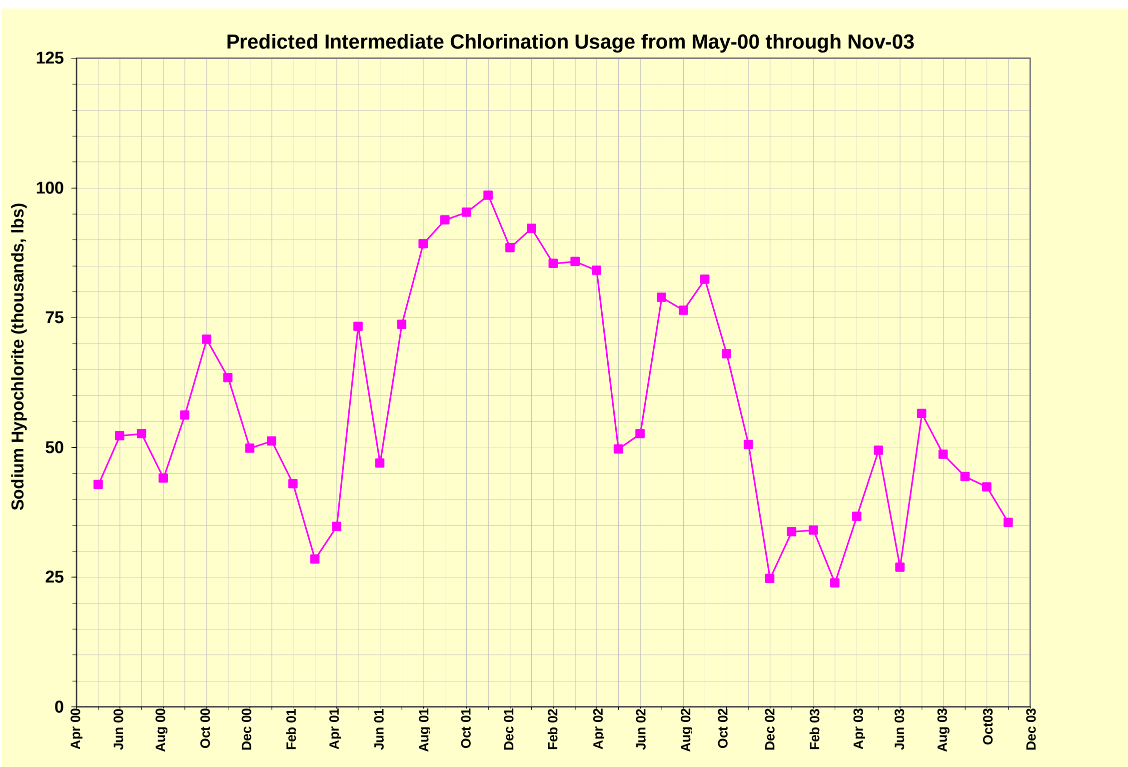
The following plots show the results of applying the linear regression equations over the period May 2000 through November 2003, the longest span of available data for all inputs. The river flows are the sum of actual observed flows at the two USGS gaging stations, as used in the model development. Rainfall is actual observed rainfall at the Essex County Airport over that span of time. Orthophosphate concentrations are those hindcast by the TRC-Omni Environmental model for that timespan.

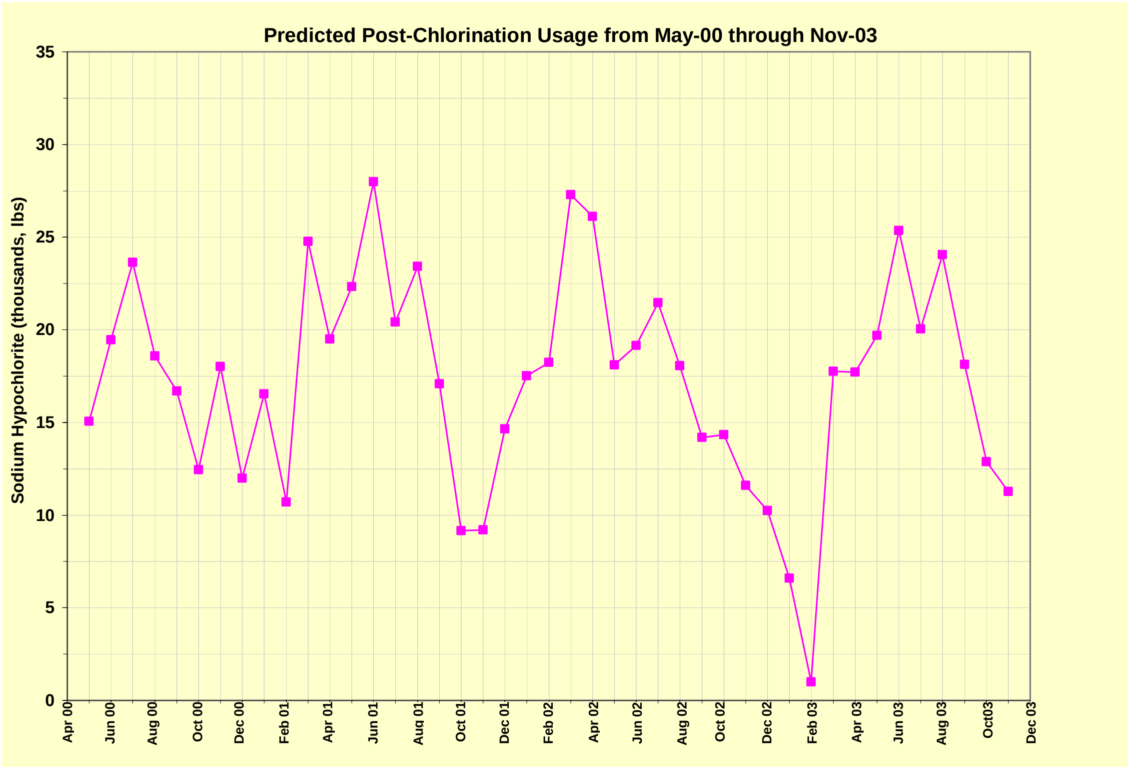


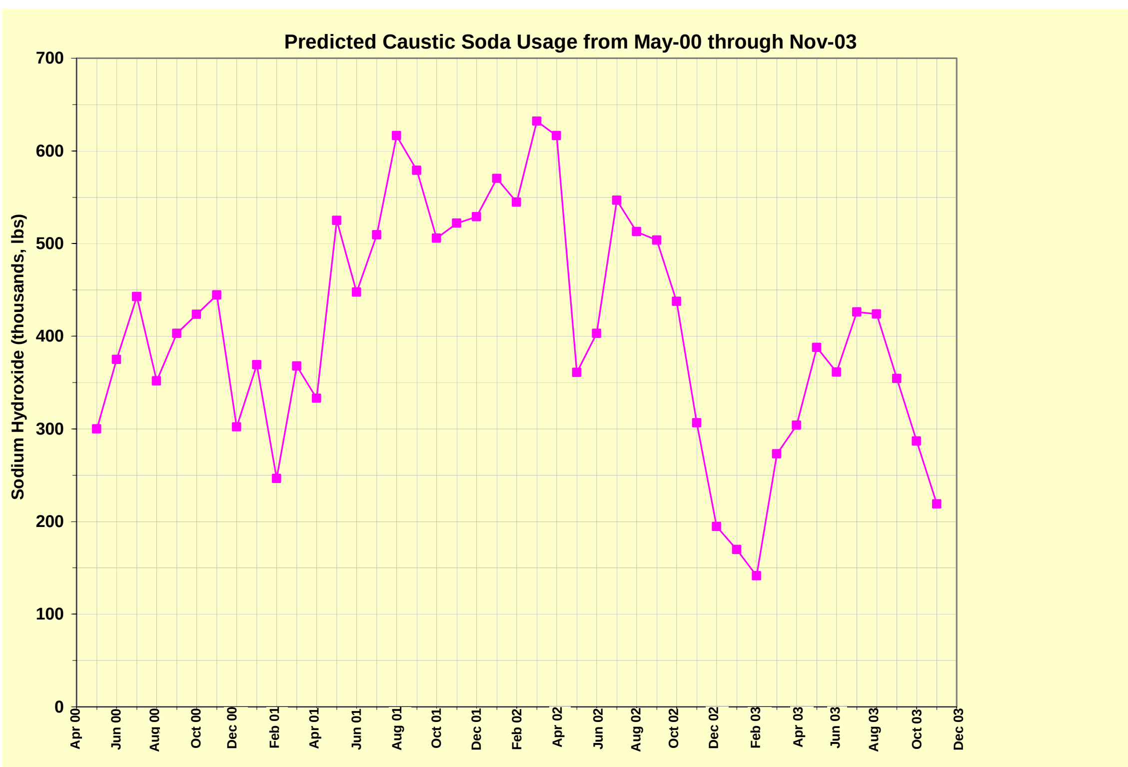

Modeled Orthophosphate Concentration from May-00 through Nov-03
Orthophosphate concentration (mg/l)
1.0
0.8
0.6
0.4
0.2
0.0
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03

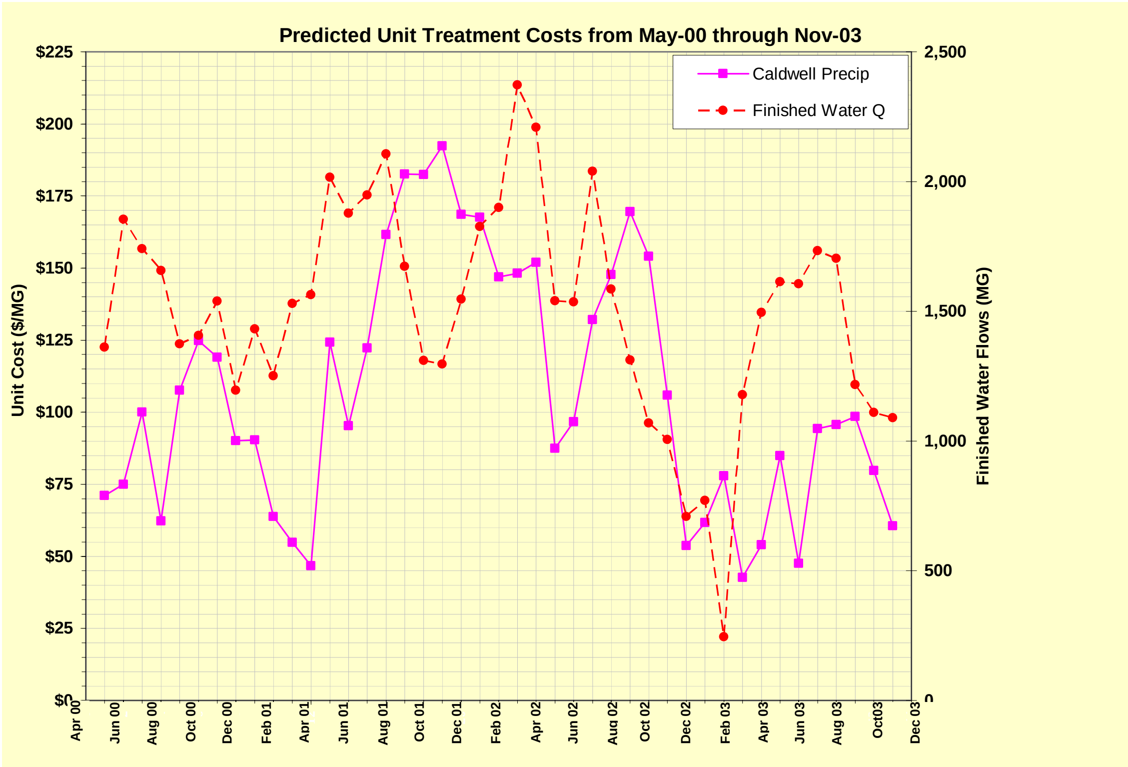

Predicted Coagulant Usage from May-00 through Nov-03
Ferric Chloride (thousands, lbs)
700
600
500
400
300
200
100
0
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03

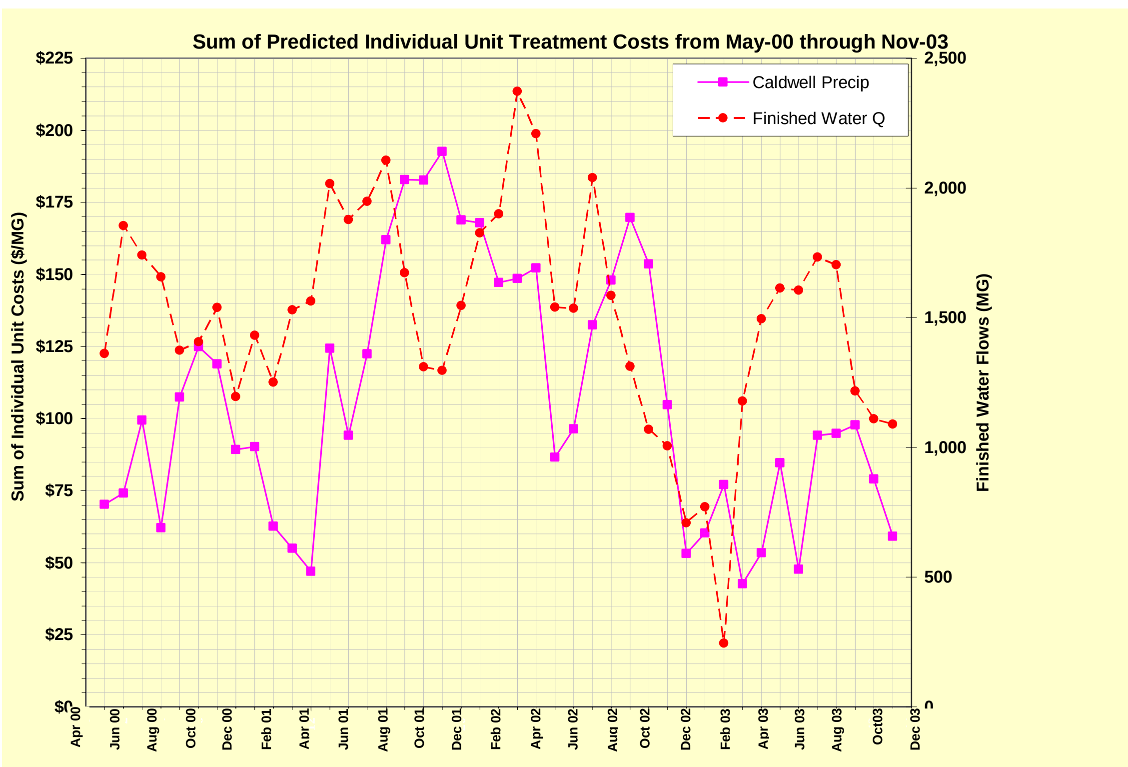

Predicted Polymer Usage from May-00 through Nov-03
Magnafloc Polymer (thousands, lbs)
0
2
4
6
8
10
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03

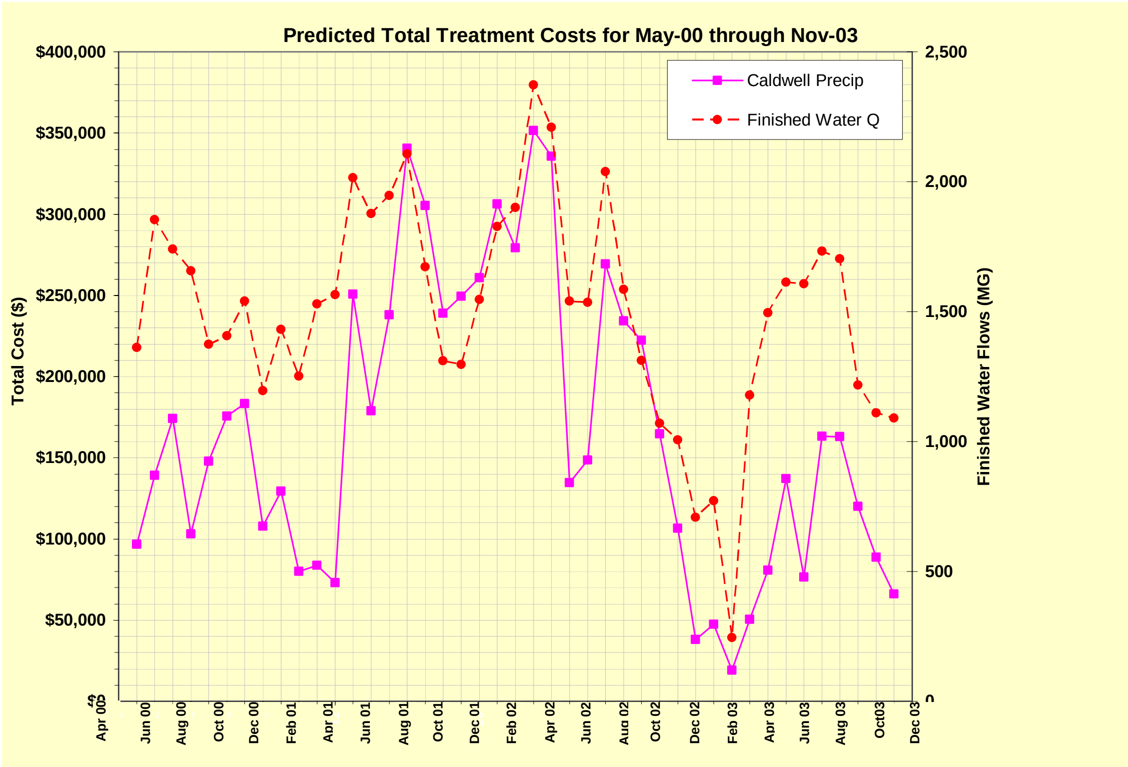

Predicted Intermediate Chlorination Usage from May-00 through Nov-03
Sodium Hypochlorite (thousands, lbs)
0
25
50
75
100
125
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03


Predicted Post-Chlorination Usage from May-00 through Nov-03
Sodium Hypochlorite (thousands, lbs)
35
30
25
20
15
10
5
0
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03


Predicted Caustic Soda Usage from May-00 through Nov-03
Sodium Hydroxide (thousands, lbs)
700
600
500
400
300
200
100
0
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct 03
Dec 03


Predicted Unit Treatment Costs from May-00 through Nov-03
Unit Cost ($/MG)
Finished Water Flows (MG)
Caldwell Precip
Finished Water Q
$225
$200
$175
$150
$125
$100
$75
$50
$25
$0
2,500
2,000
1,500
1,000
500
0
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03


Sum of Predicted Individual Unit Treatment Costs from May-00 through Nov-03
Sum of Individual Unit Costs ($/MG)
Finished Water Flows (MG)
Caldwell Precip
Finished Water Q
$225
$200
$175
$150
$125
$100
$75
$50
$25
$0
2,500
2,000
1,500
1,000
500
0
Apr 00
Jun 00
Aug 00
Oct 00
Dec 00
Feb 01
Apr 01
Jun 01
Aug 01
Oct 01
Dec 01
Feb 02
Apr 02
Jun 02
Aug 02
Oct 02
Dec 02
Feb 03
Apr 03
Jun 03
Aug 03
Oct03
Dec 03



Examination of the foregoing plots discloses the inter-relationship between wet/dry conditions and the costs to treat at LFWTP. During dry conditions, such as occurred in 2001, the unit cost to treat increases, as does water demand, leading to increased total costs for treatment. Once drought emergency regulations take effect, the unit cost to treat remains high, but the total cost is reduced due to lower demand. This, however, is not a benefit to PVWC, because reduced demand equates to reduced revenues; the important relationship during a drought emergency is the unit cost to treat compared with the unit price of water. In this case, the reduced demand imposed by the drought emergency compounds the effect of the increased unit cost to treat.

During wet conditions, such as occurred in 2002 and 2003, both the unit cost and the total cost to treat are reduced, as is the demand (presumably due primarily to lower landscaping usage). Because the total cost and revenue are responding to the same driving variables in this case, the impact on PVWC is limited to absorption of fixed costs, such as labor and debt service.

Overall Discussion, Conclusion and Recommendations

While the foregoing analysis provides a basis for evaluation of the impacts of phosphorus on raw water treatment chemical usage and cost at the LFWTP in the context of a TMDL study, it has a number of limitations:

- The underlying data set for chemical usage in the LFWTP are for the first year of operation of the newly upgraded facility, a time when plant personnel were still “getting the feel” of the new processes, and may not be representative of the long-term usage.

- The results are expressed as linear equations, so they do not display any strong inflection points that could be used to establish a single end-point value for phosphorus concentrations in the raw water supply. There were insufficient data to explore alternative formulations, but the success of the linear regression, as measured by the R-squared values, suggests that the relationships may be fundamentally linear.

- The analysis results must be used in the context of a cost-effectiveness analysis, weighing the cost to treat drinking water against the cost to limit phosphorus concentrations in the raw source waters.

- There were insufficient data to evaluate the influence of phosphorus recycling in the initial settling process (sand ballasted clarification). The effect of any such recycling would be to "average out" the influence of short-term variability in influent phosphorus concentrations. There is insufficient information to characterize what "short term" means in this context, because the fundamental data used in the analysis are monthly.

- The analysis does not differentiate between the Passaic and Pompton rivers as sources of raw water, because the two sources are blended before being treated. The differential cost to control phosphorus concentrations in the two rivers must be considered in any subsequent cost-effectiveness analysis.

- The analysis does not explore the potential for correlated effects, such as the potential relationship between algae as a source of demand for water treatment chemicals and orthophosphate concentration.

Nonetheless, the results of this study provide a reasonable basis for the evaluation of costs associated with alternative nutrient control approaches in the Passaic watershed, as they relate to impacts on the PVWC LFWTP.

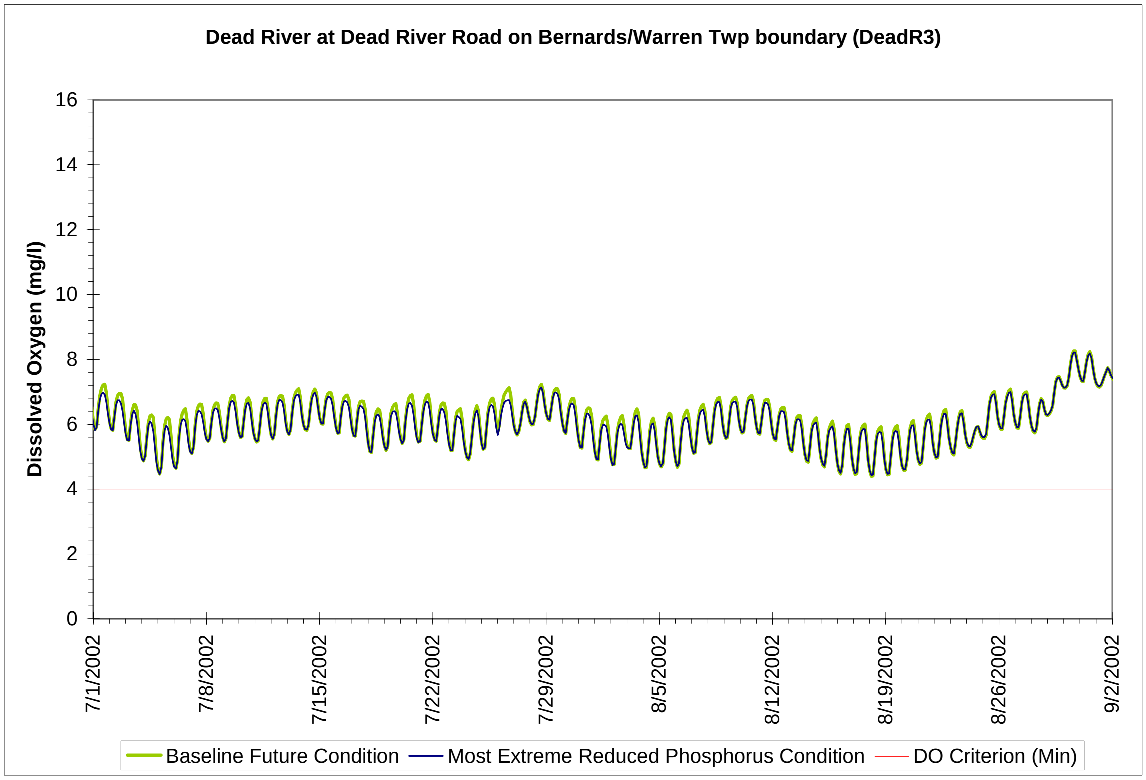
We recommend that the originally planned in-plant sampling program be carried out at the earliest date that safety concerns and funding allow.

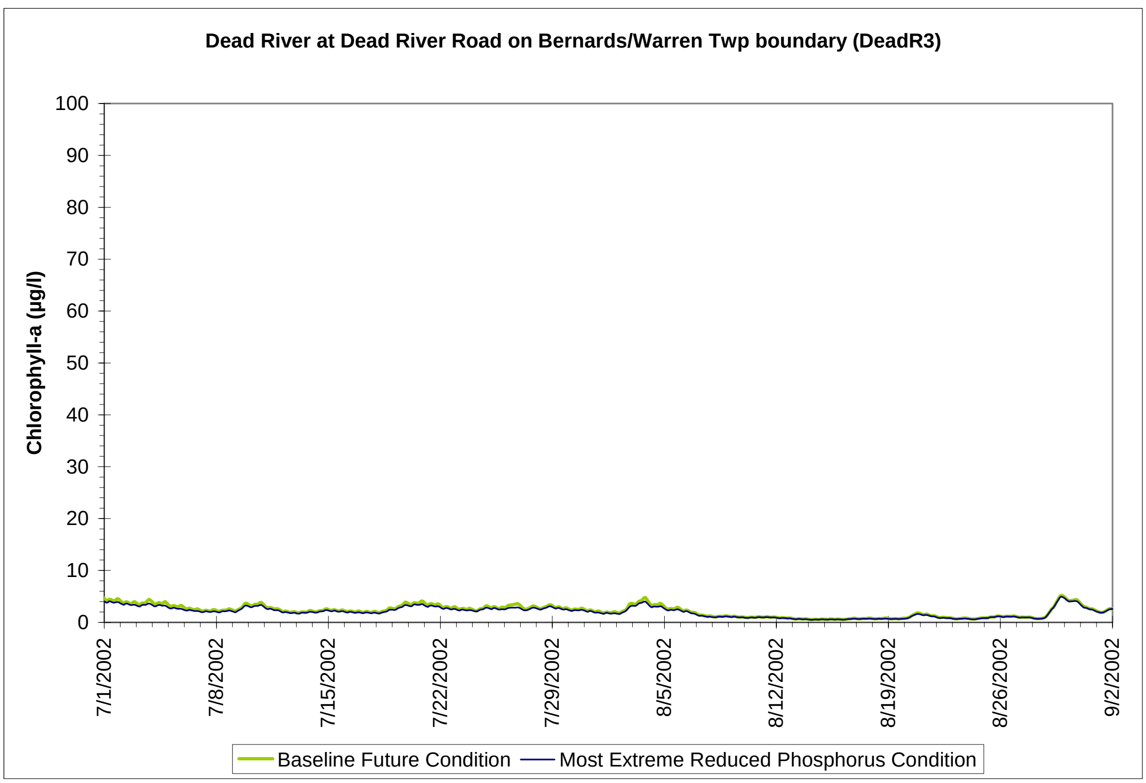
We suggest that PVWC may find it useful to institute routine monitoring of phosphorus concentrations in the influent raw water and clarifier effluent before ozonation (at a minimum) as part of their extensive data acquisition program.

APPENDIX J

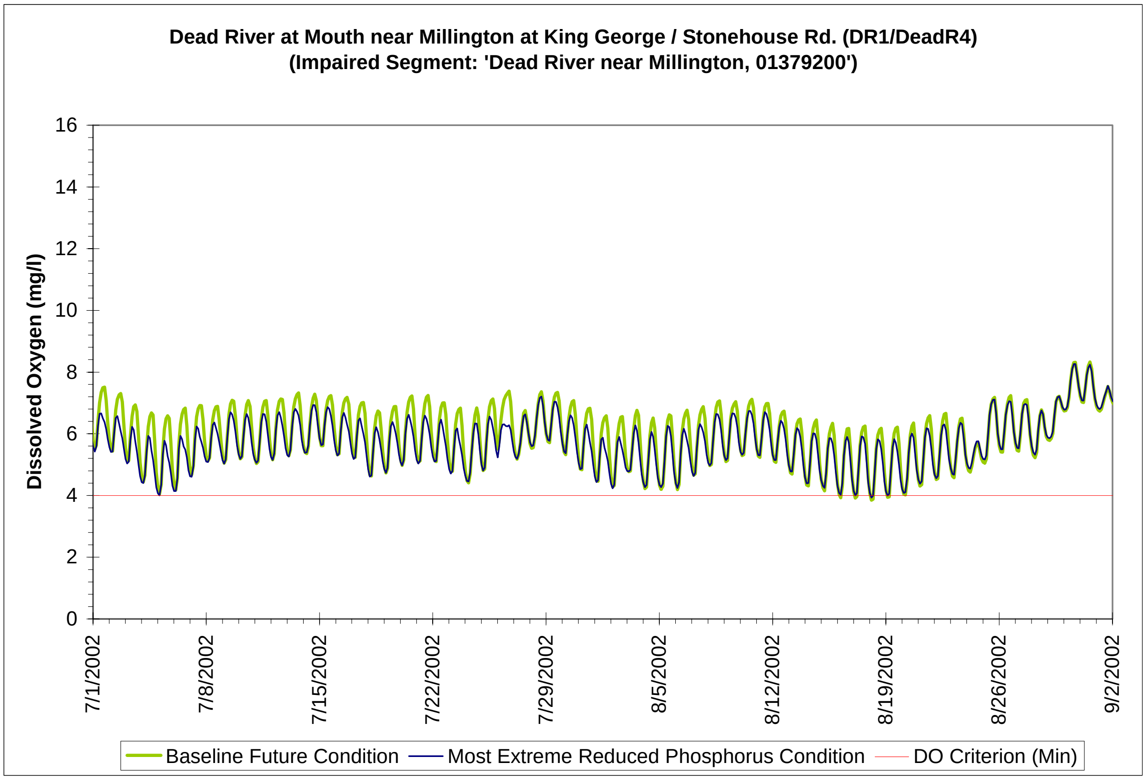
Impact of Extreme Phosphorus Reductions:
MERP vs. Baseline

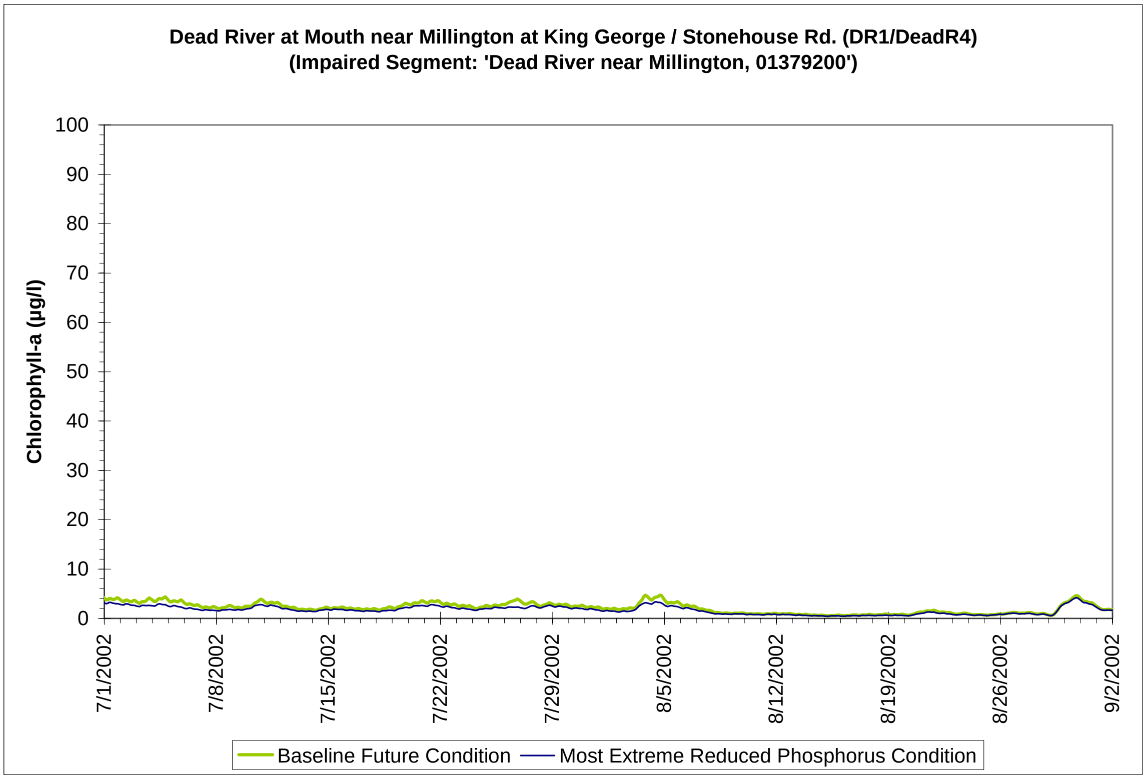
The Impact of Reducing Phosphorus on the Passaic River Basin



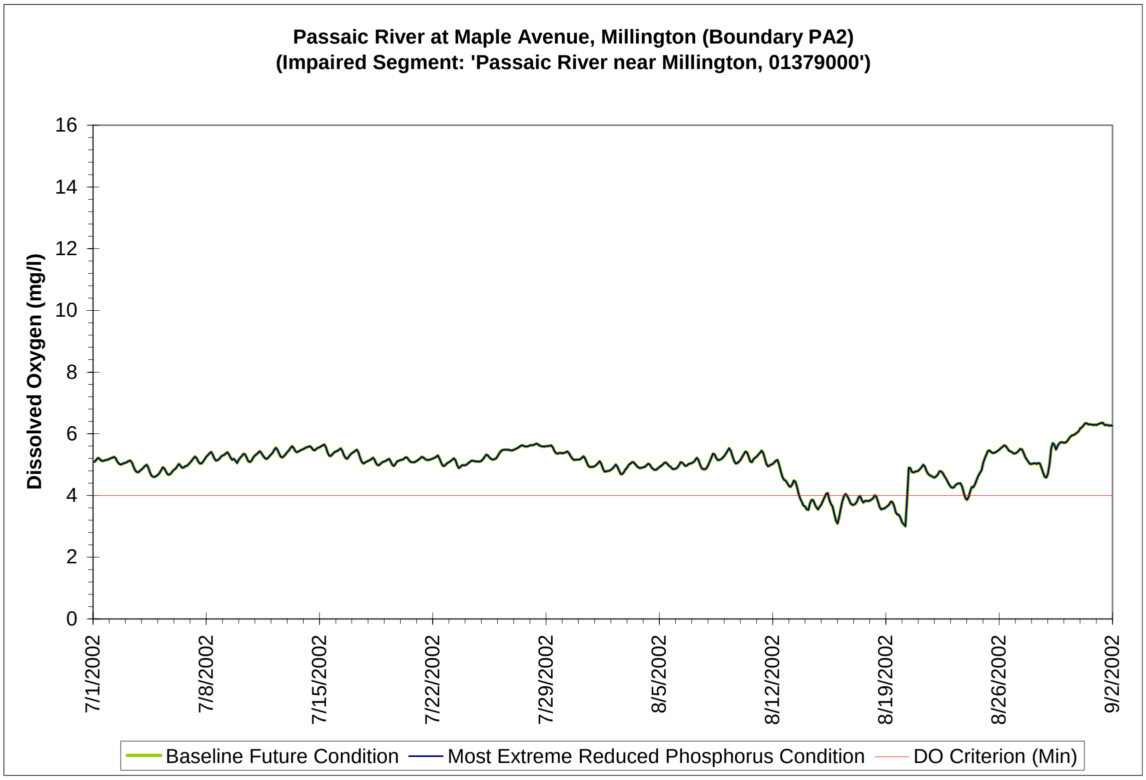


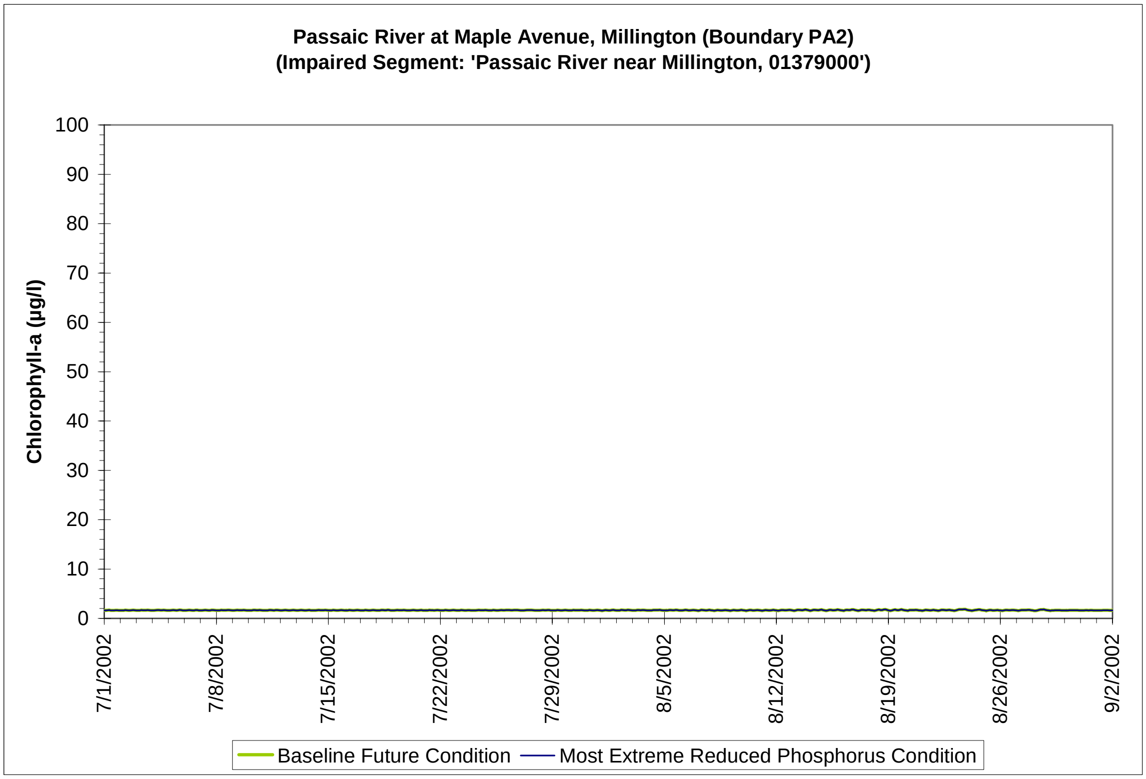
The Impact of Reducing Phosphorus on the Passaic River Basin



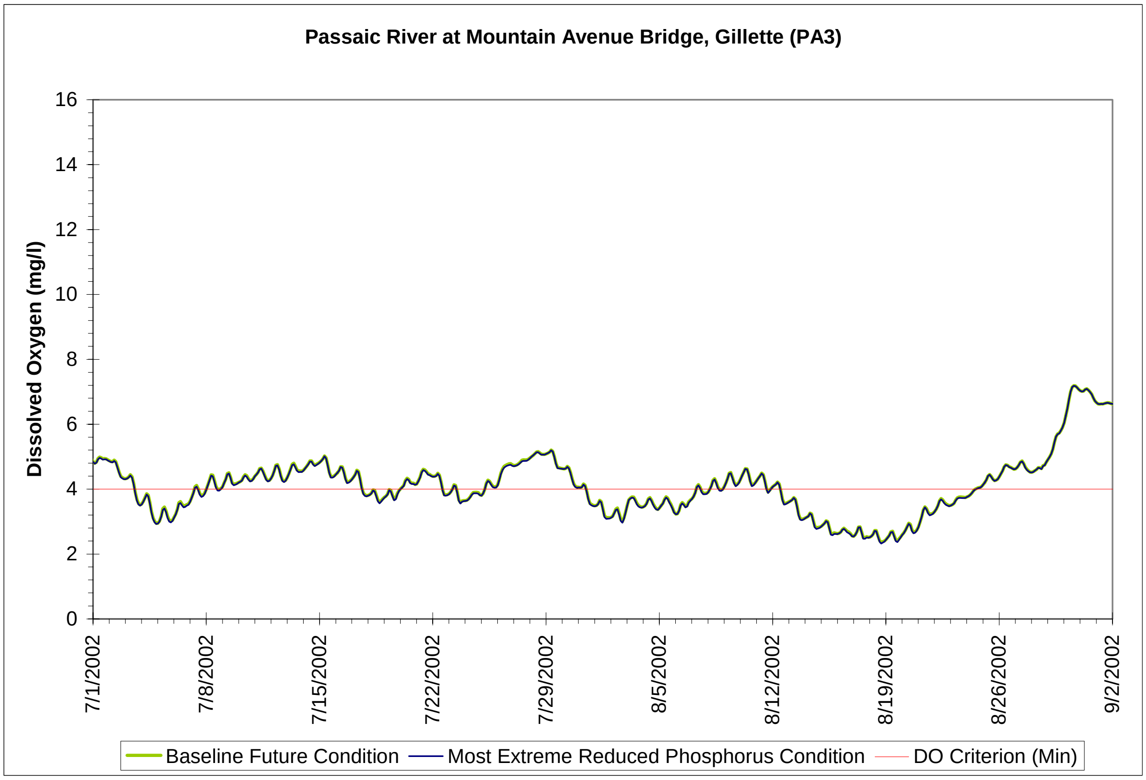


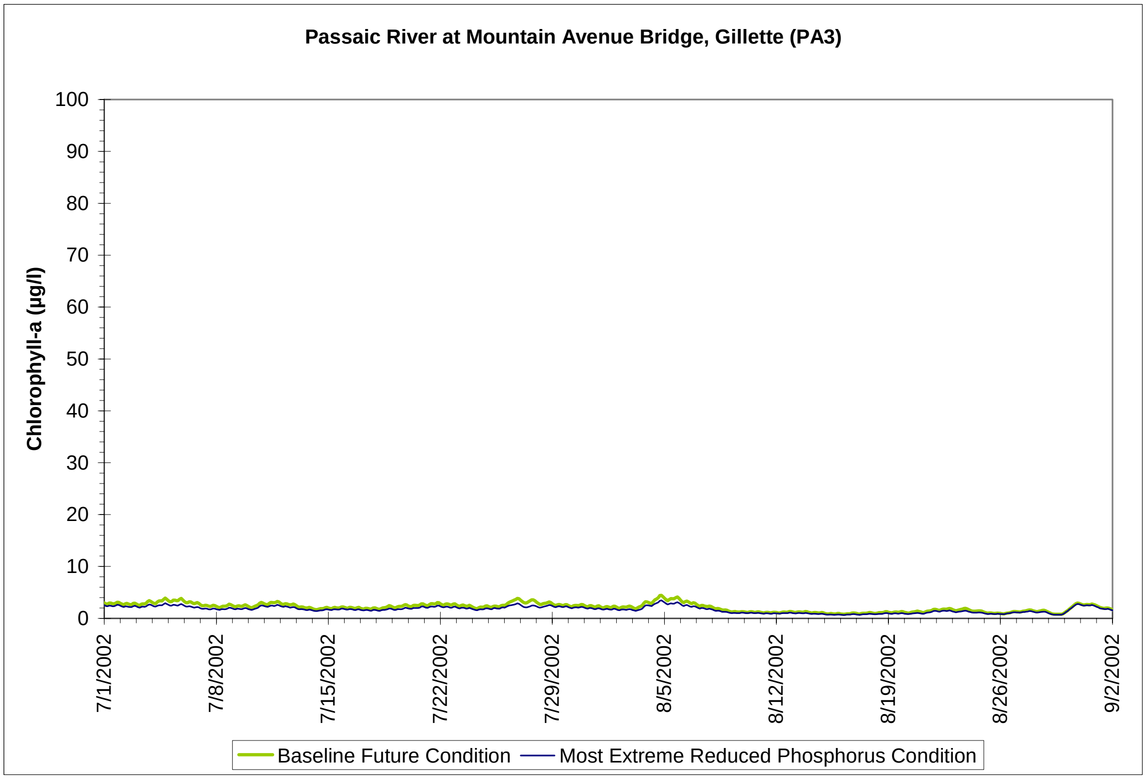
The Impact of Reducing Phosphorus on the Passaic River Basin



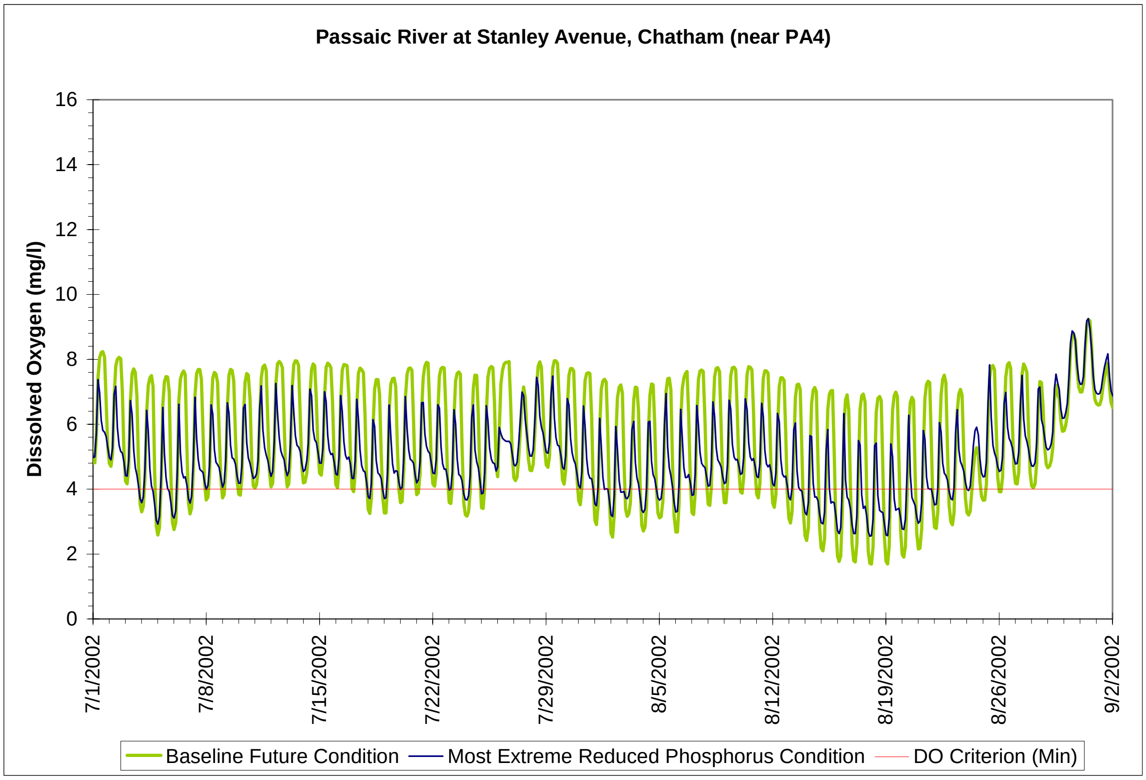


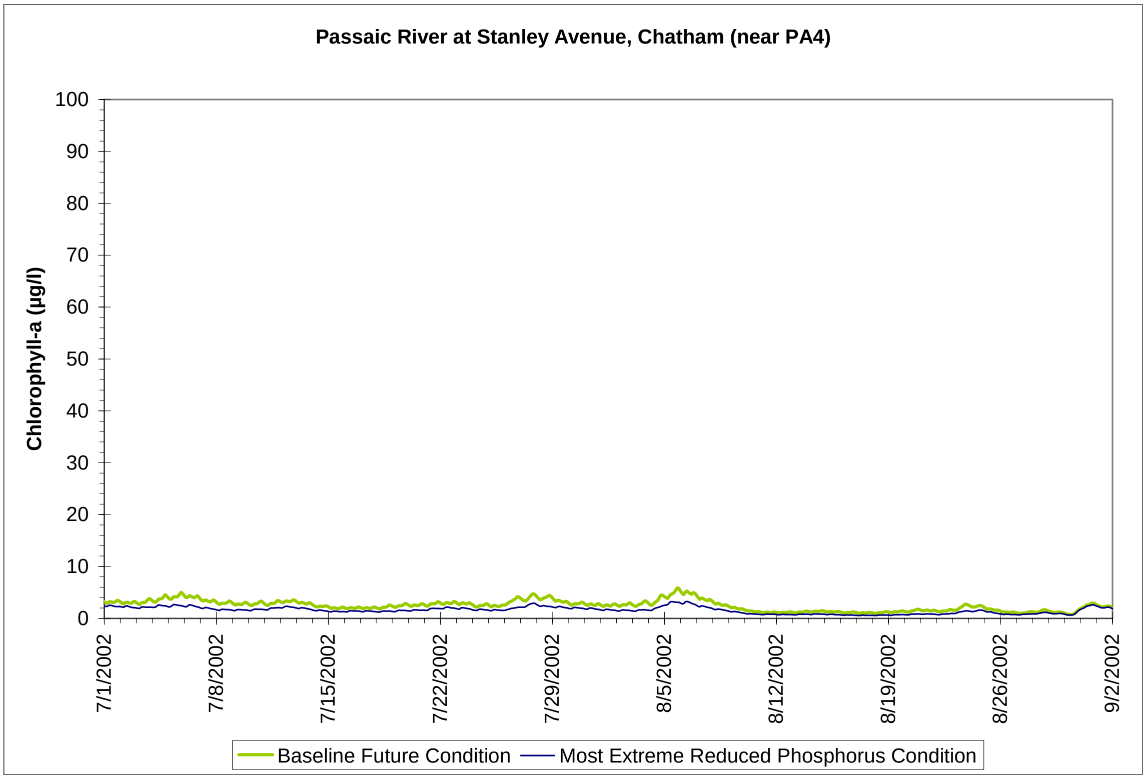
The Impact of Reducing Phosphorus on the Passaic River Basin



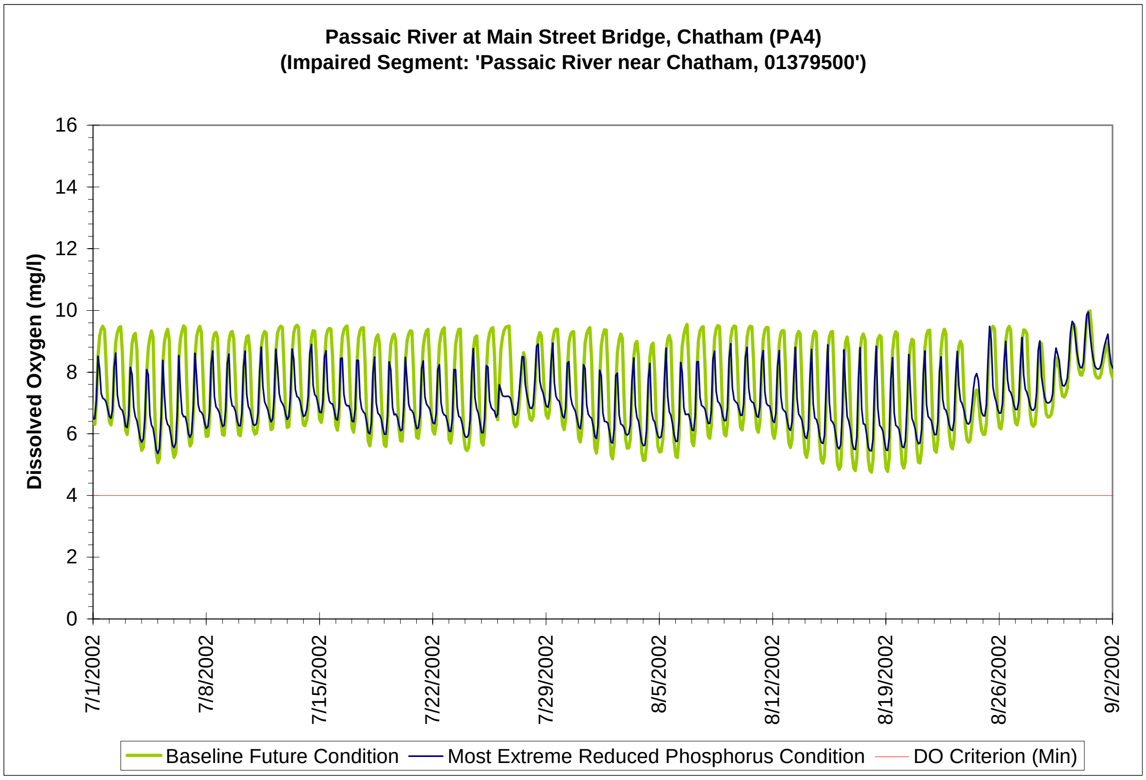


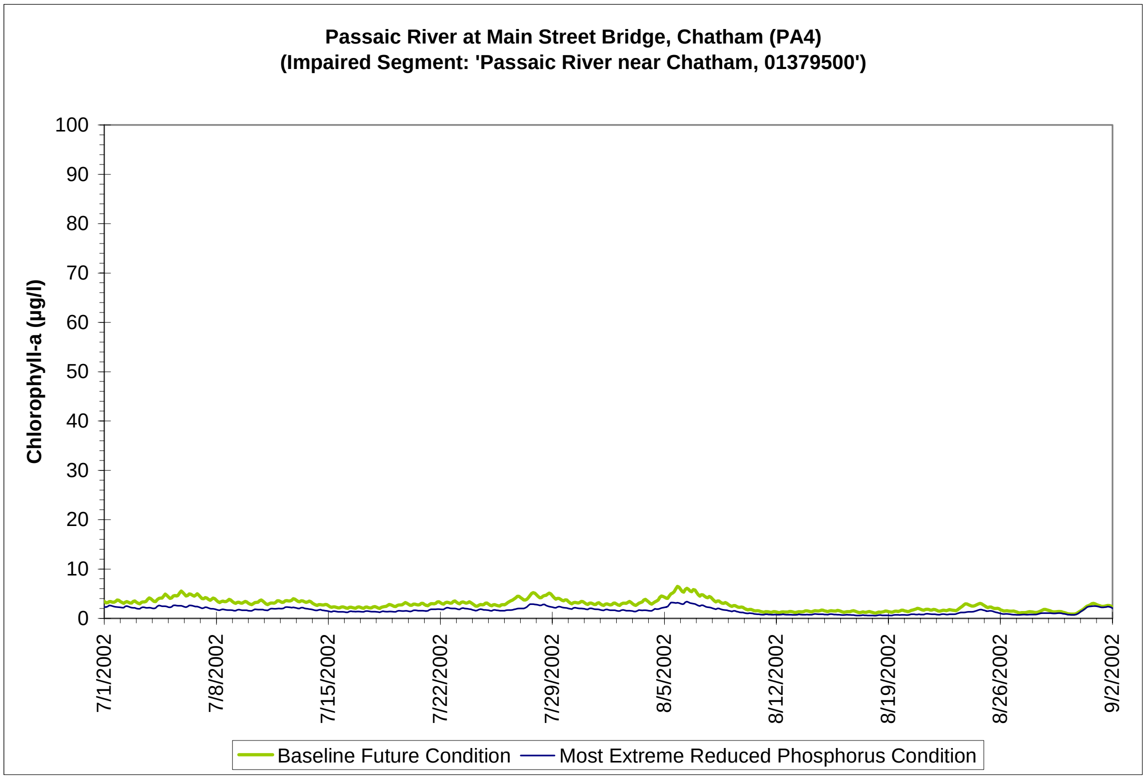
The Impact of Reducing Phosphorus on the Passaic River Basin



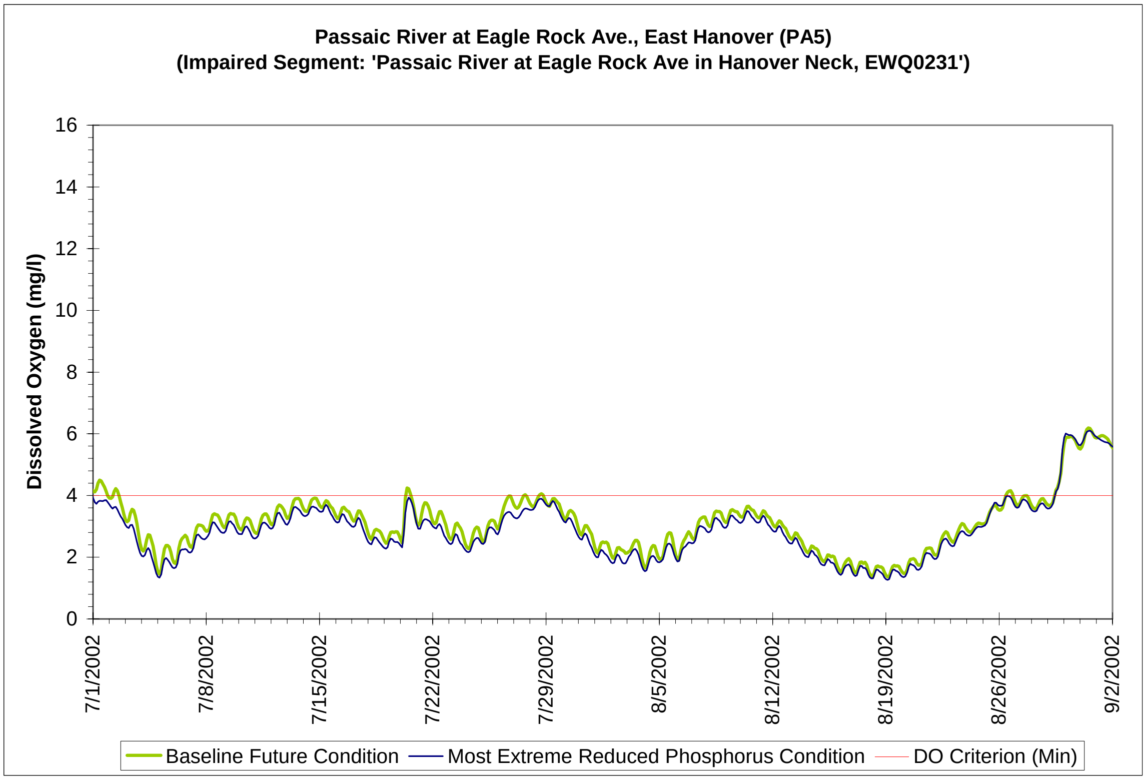


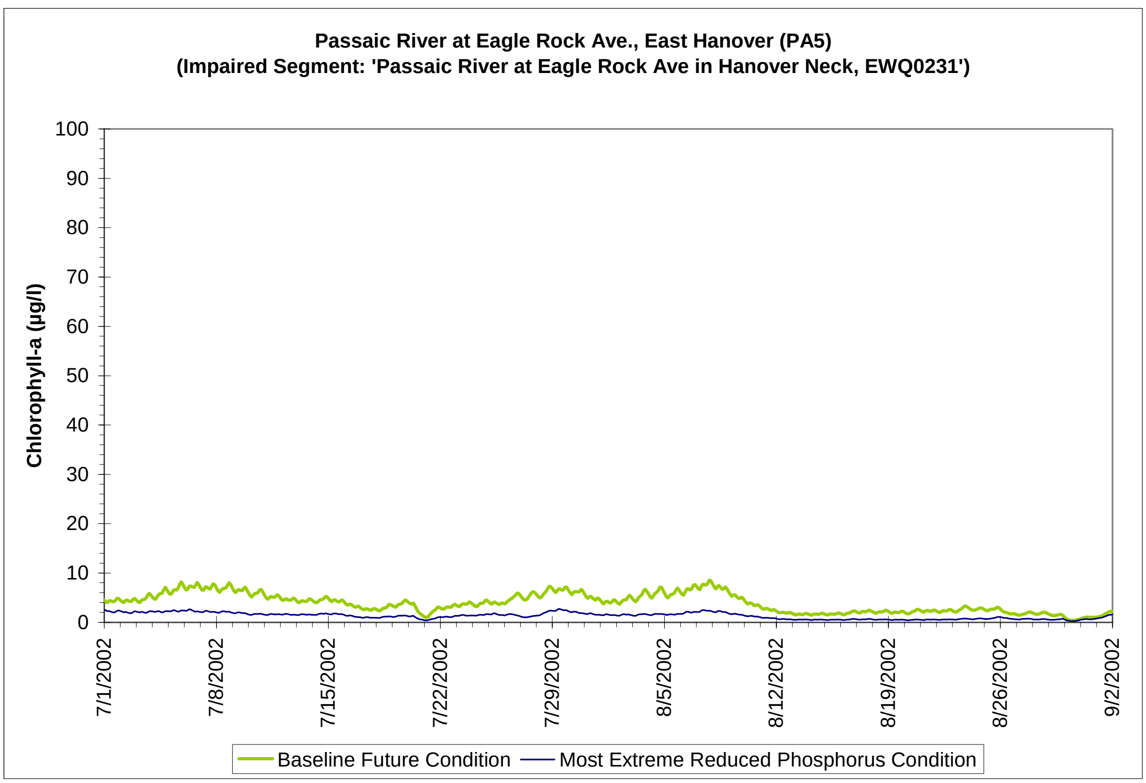
The Impact of Reducing Phosphorus on the Passaic River Basin



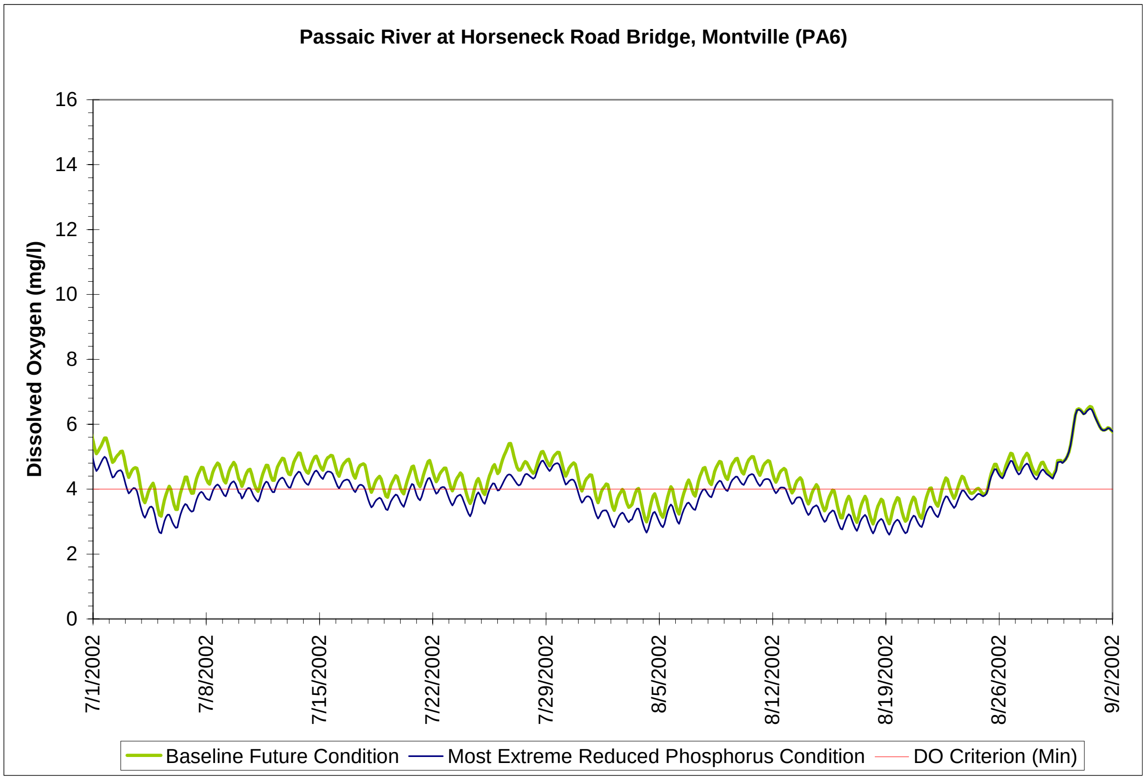


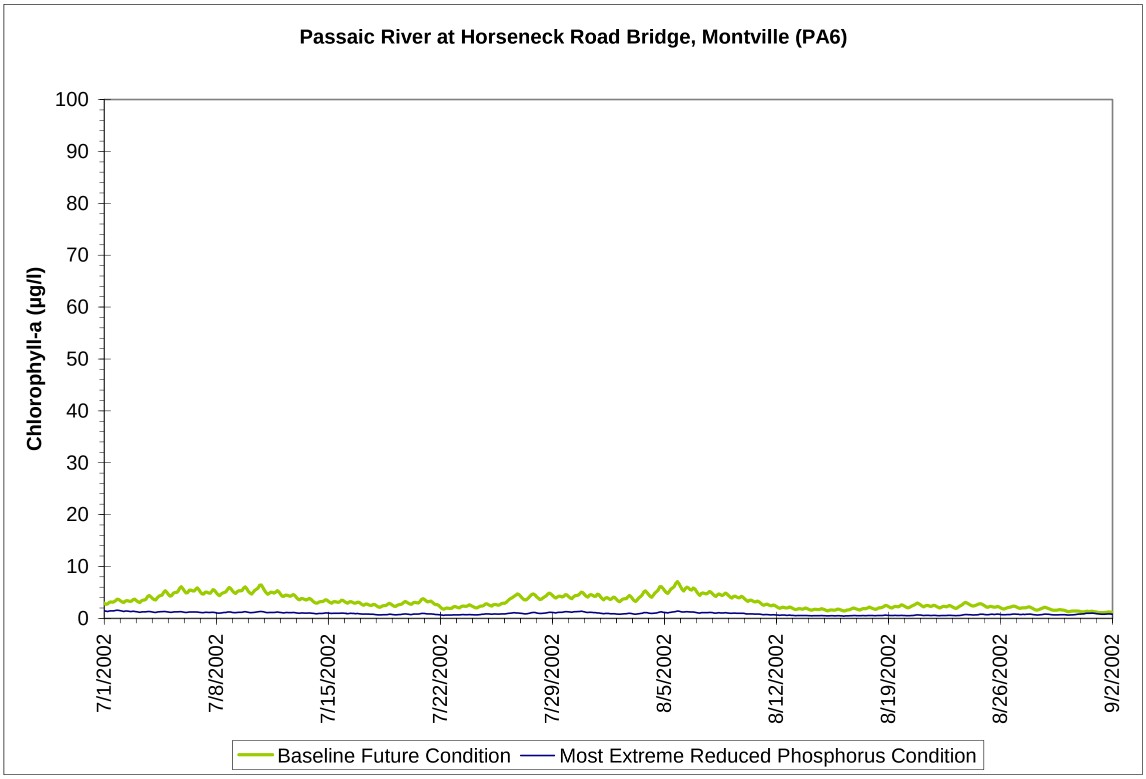
The Impact of Reducing Phosphorus on the Passaic River Basin



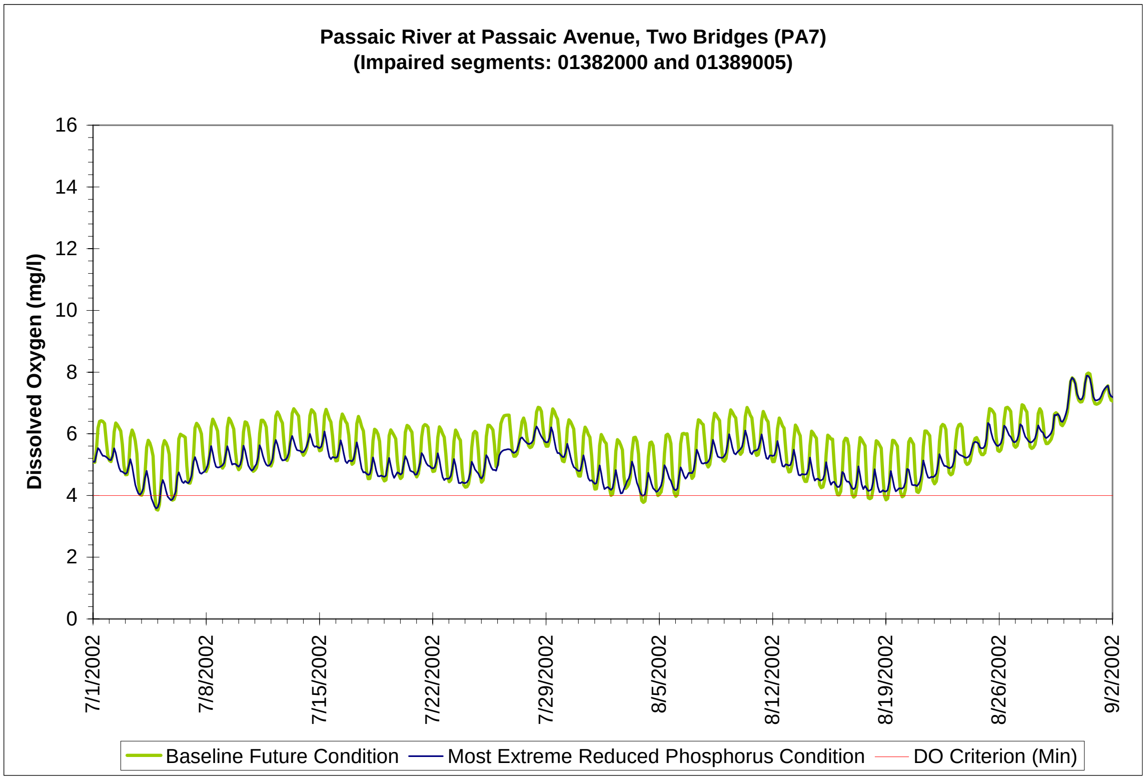


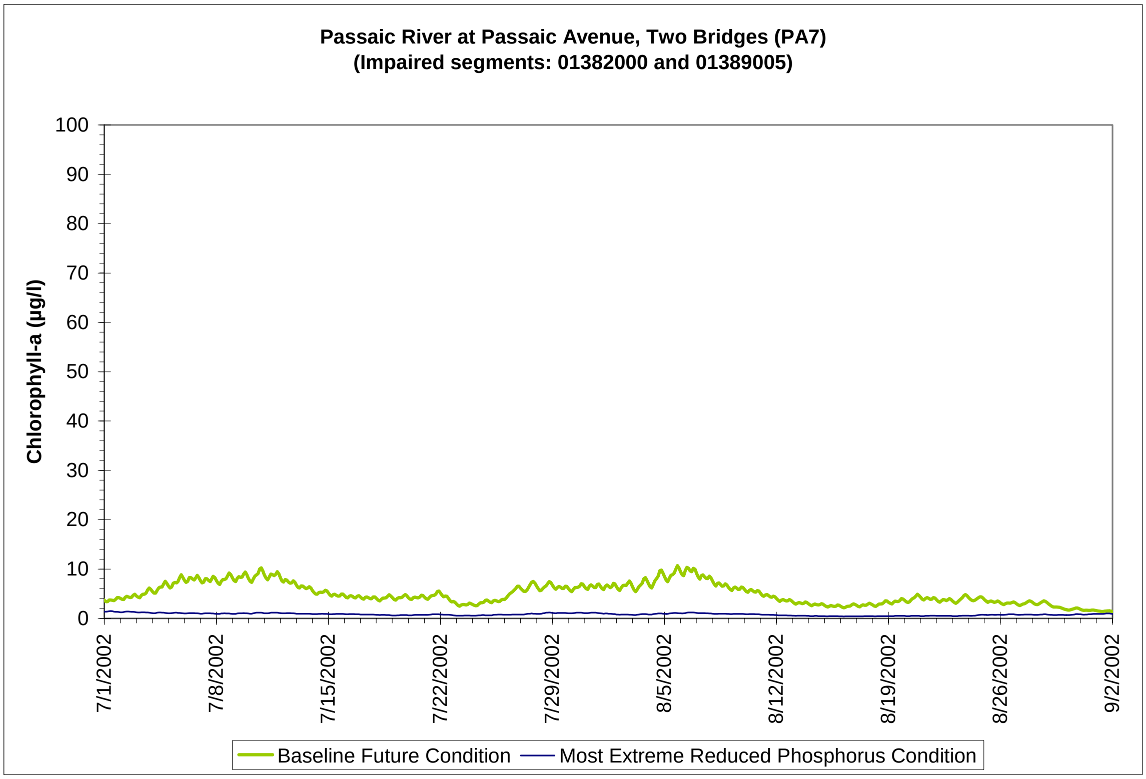
The Impact of Reducing Phosphorus on the Passaic River Basin



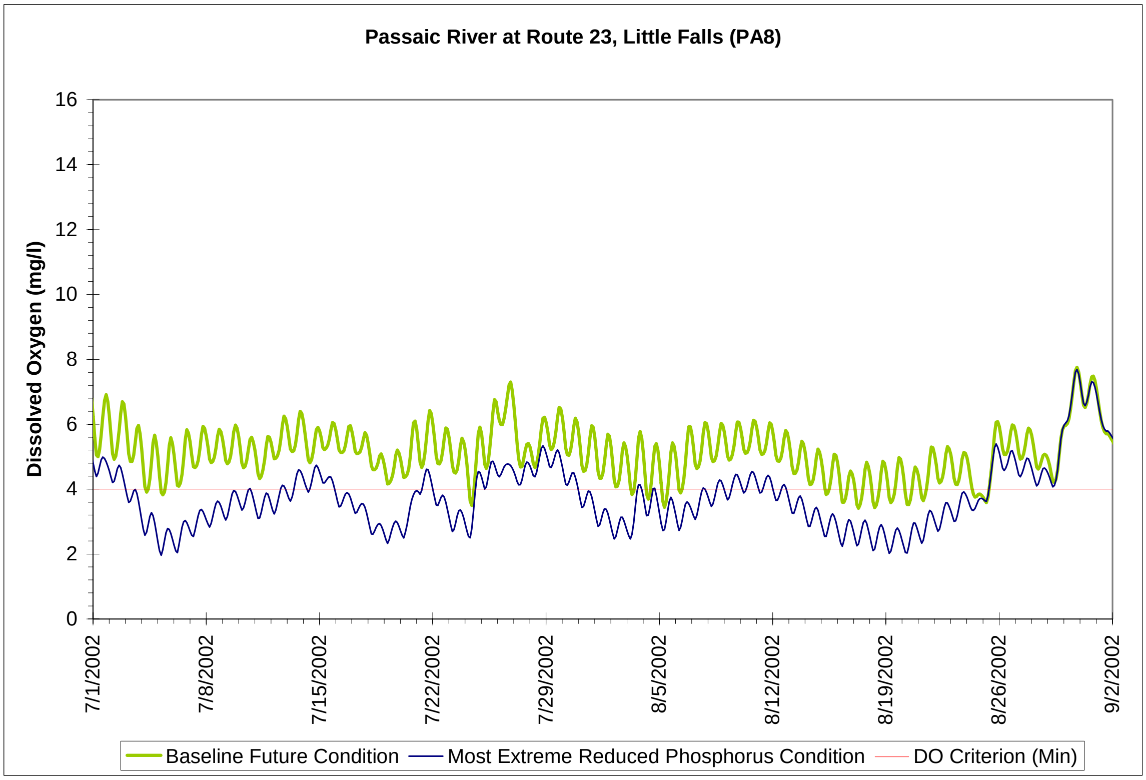


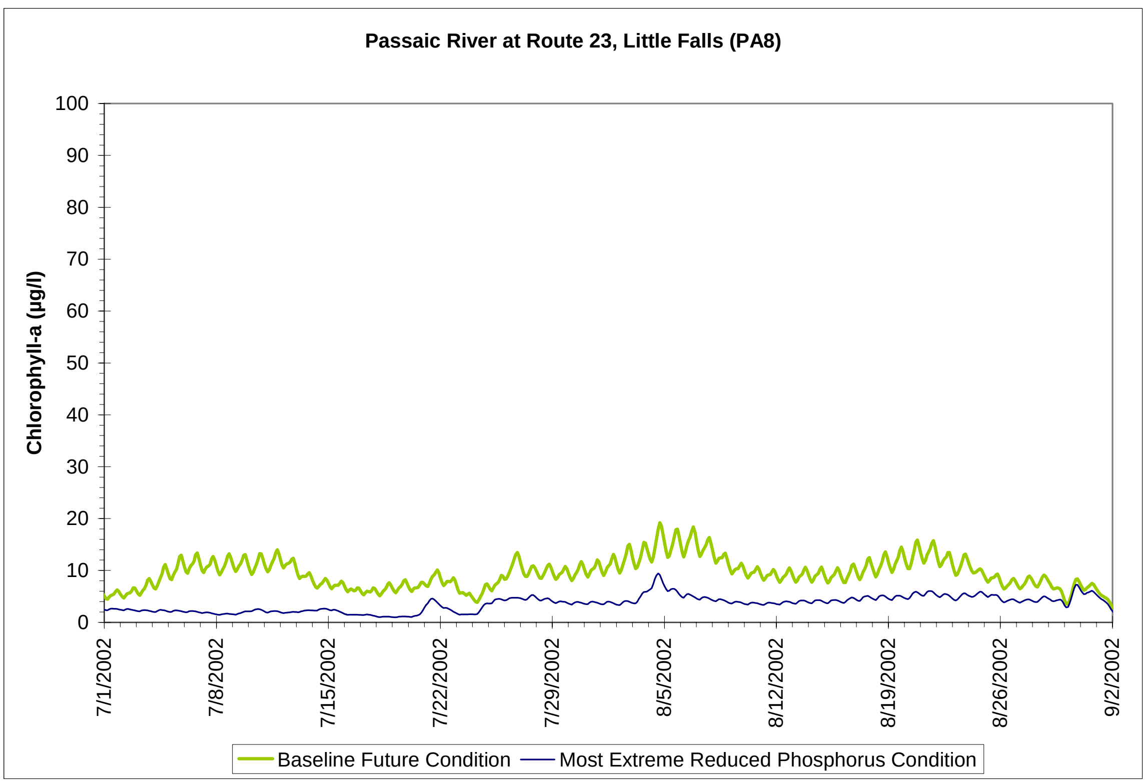
The Impact of Reducing Phosphorus on the Passaic River Basin



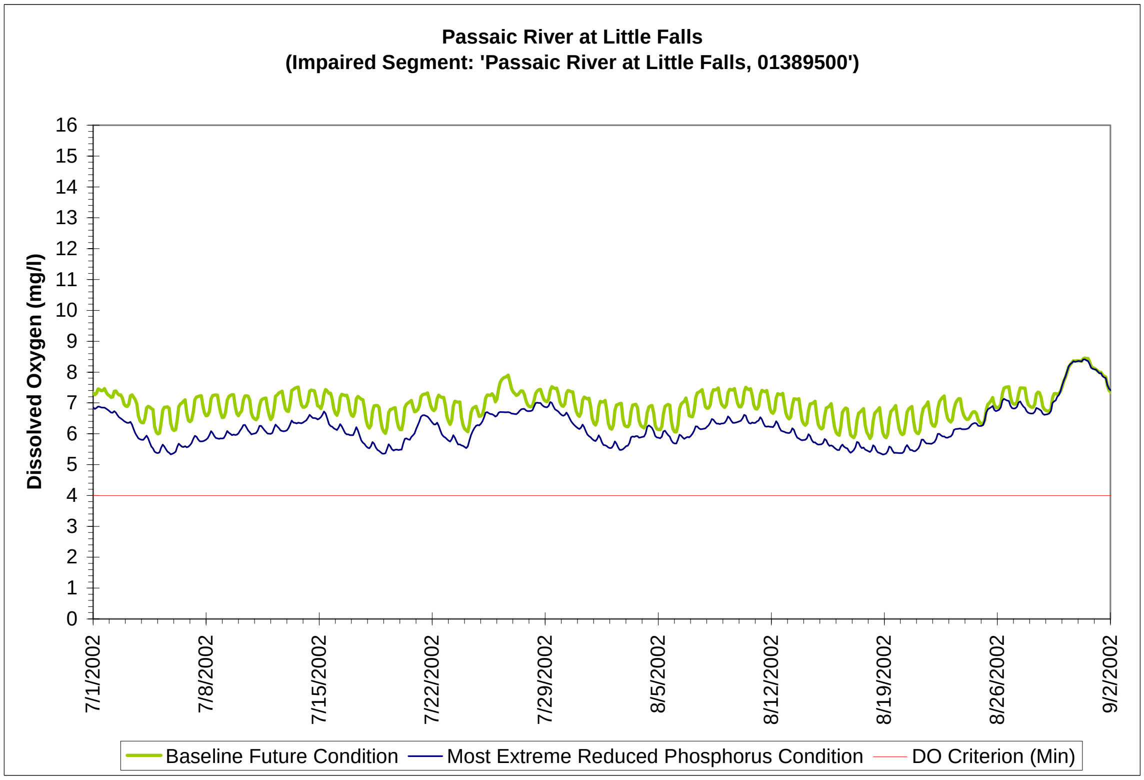


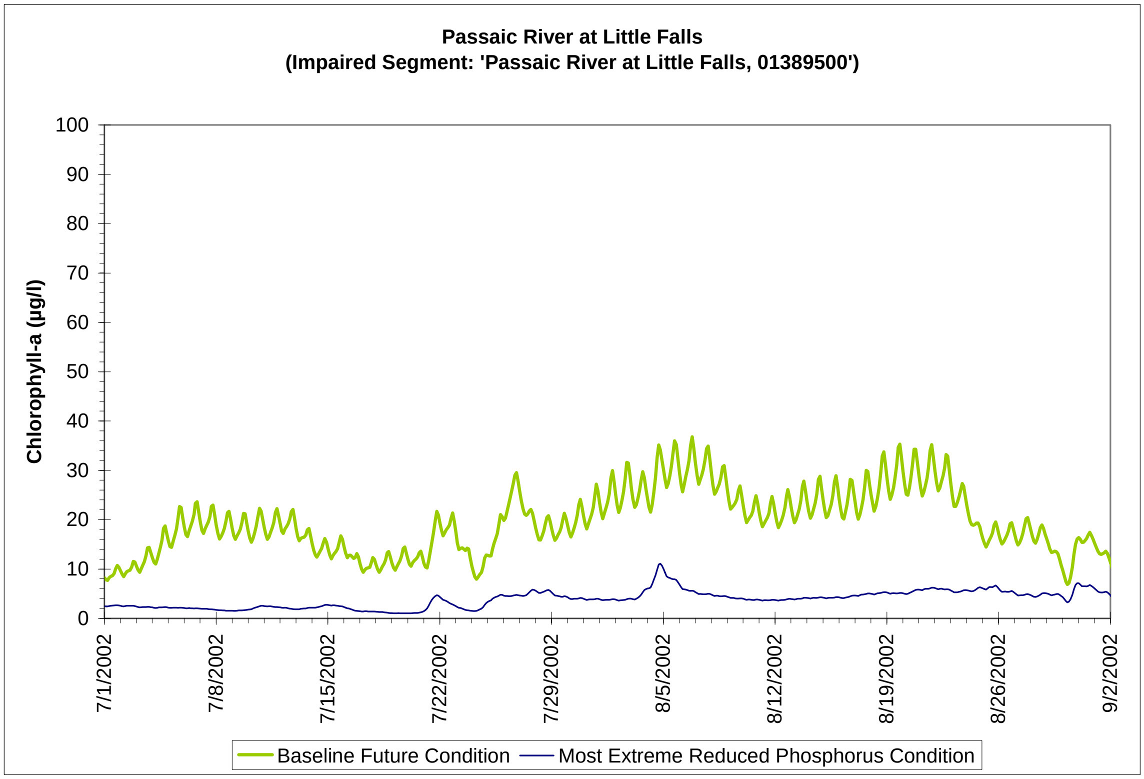
The Impact of Reducing Phosphorus on the Passaic River Basin



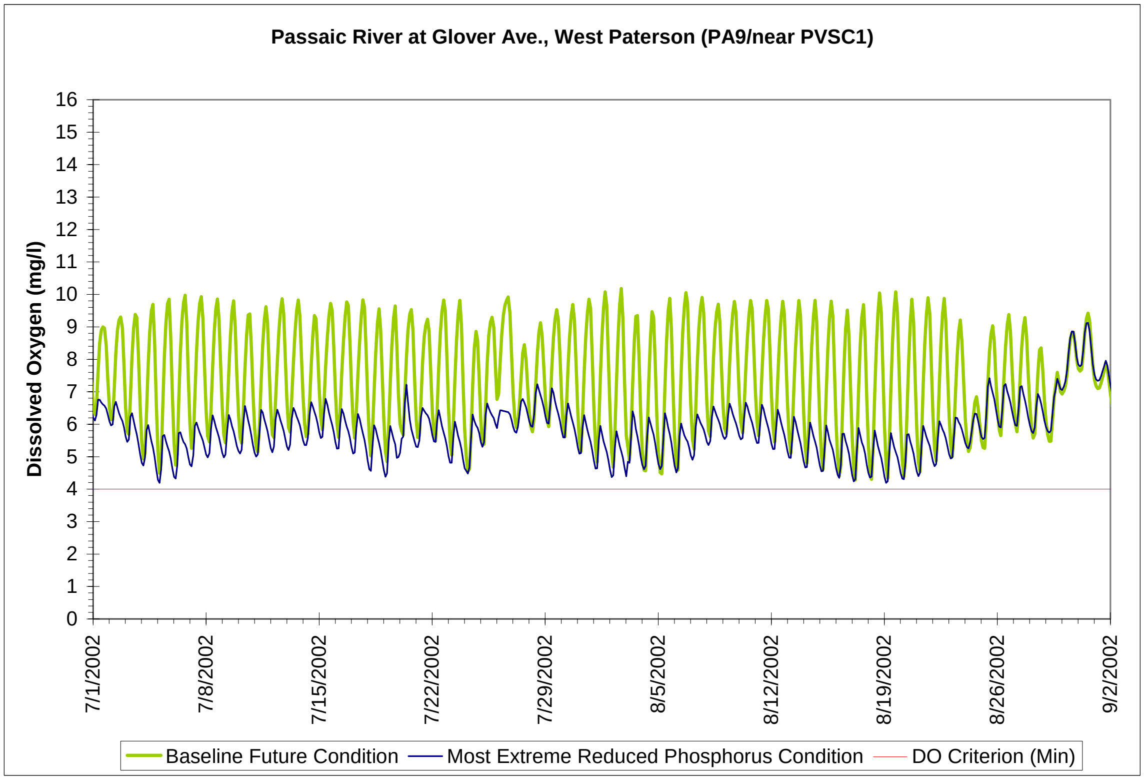


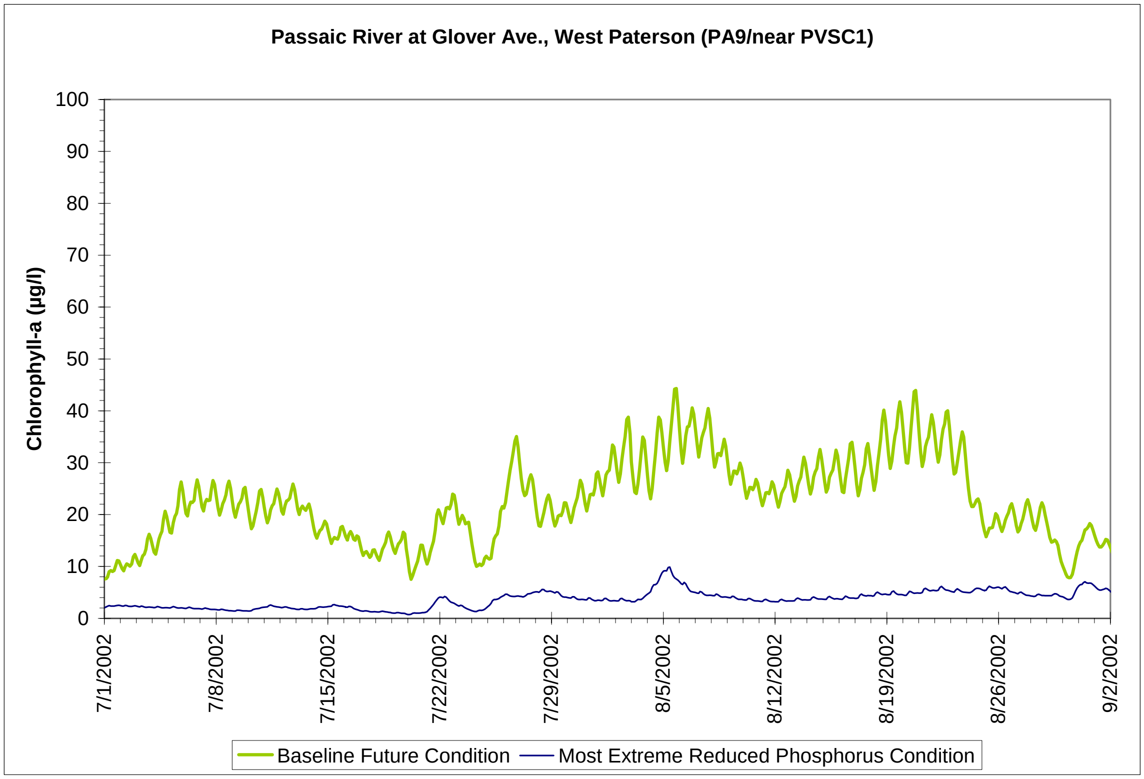
The Impact of Reducing Phosphorus on the Passaic River Basin



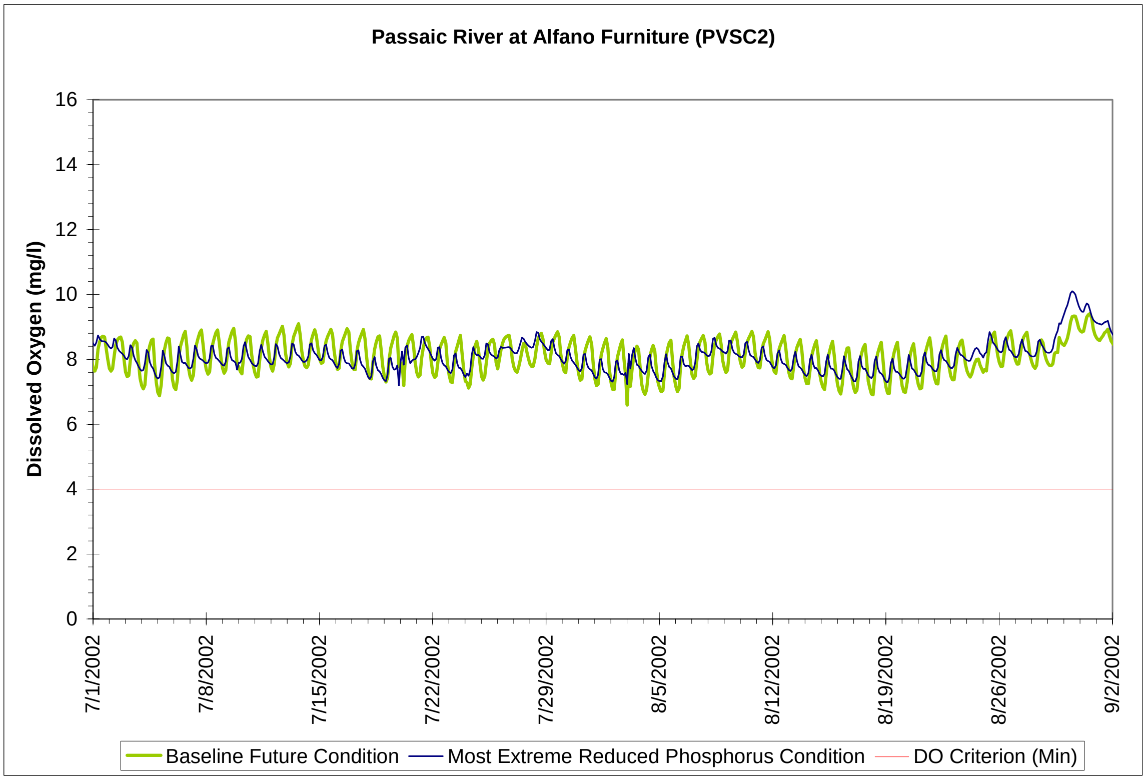


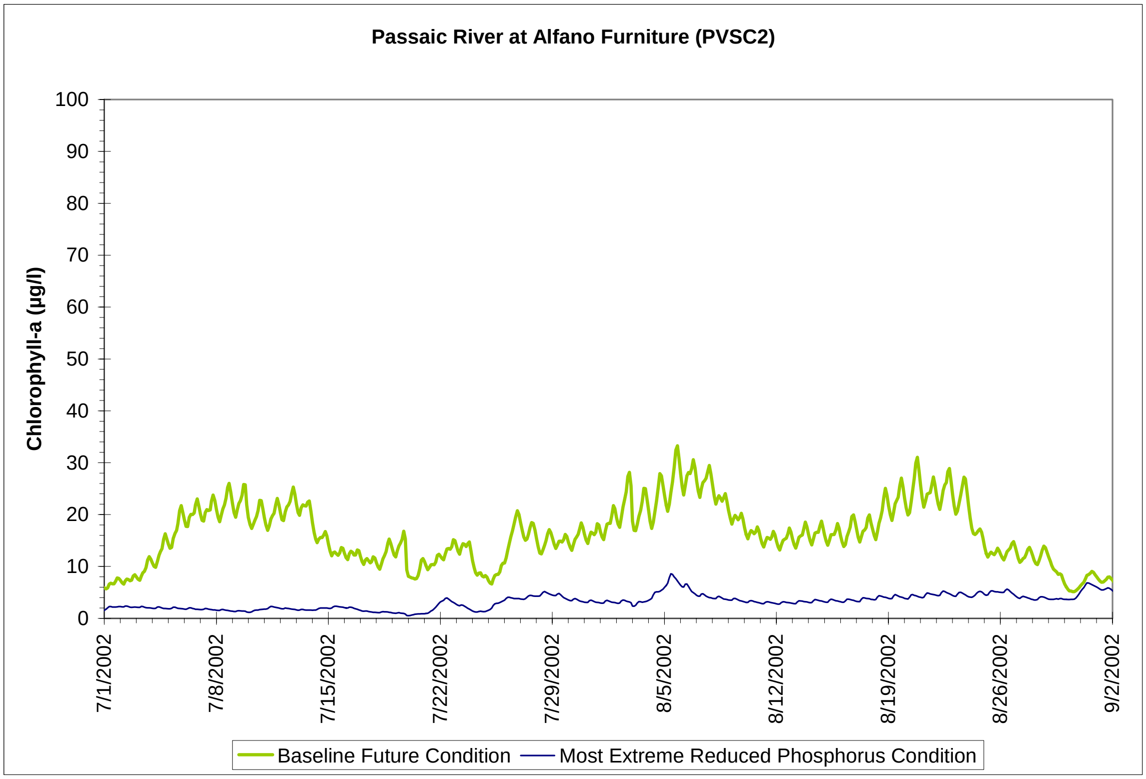
The Impact of Reducing Phosphorus on the Passaic River Basin



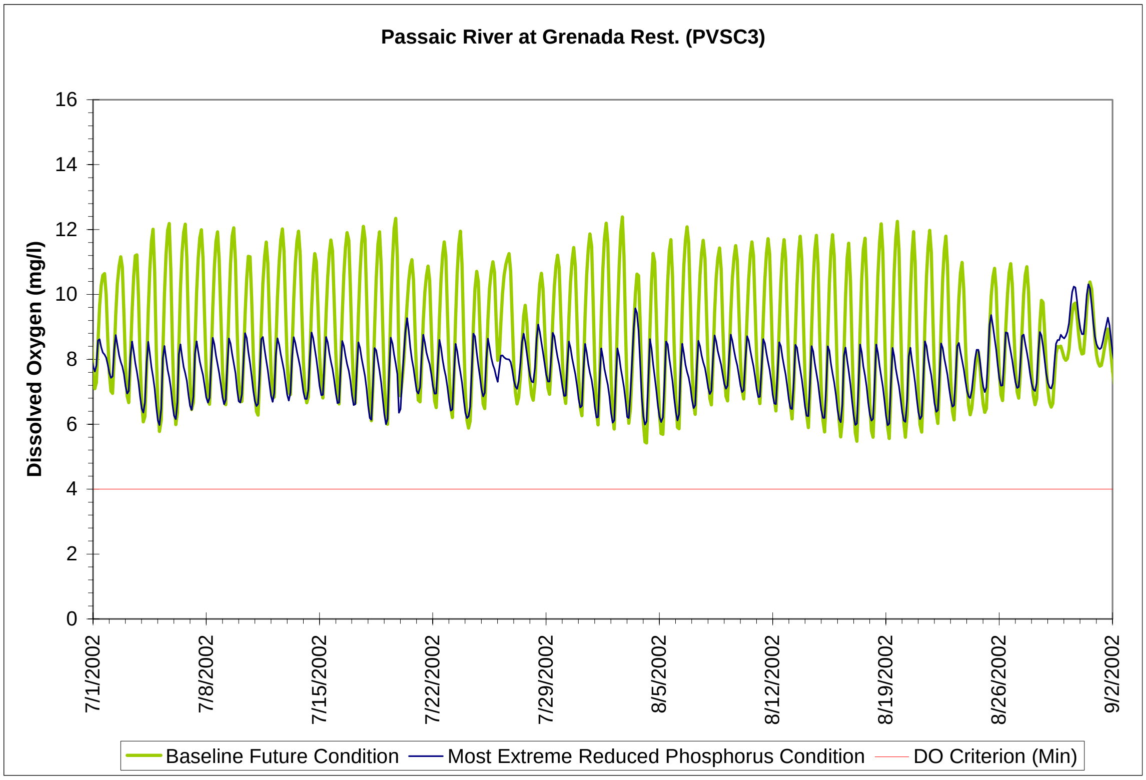


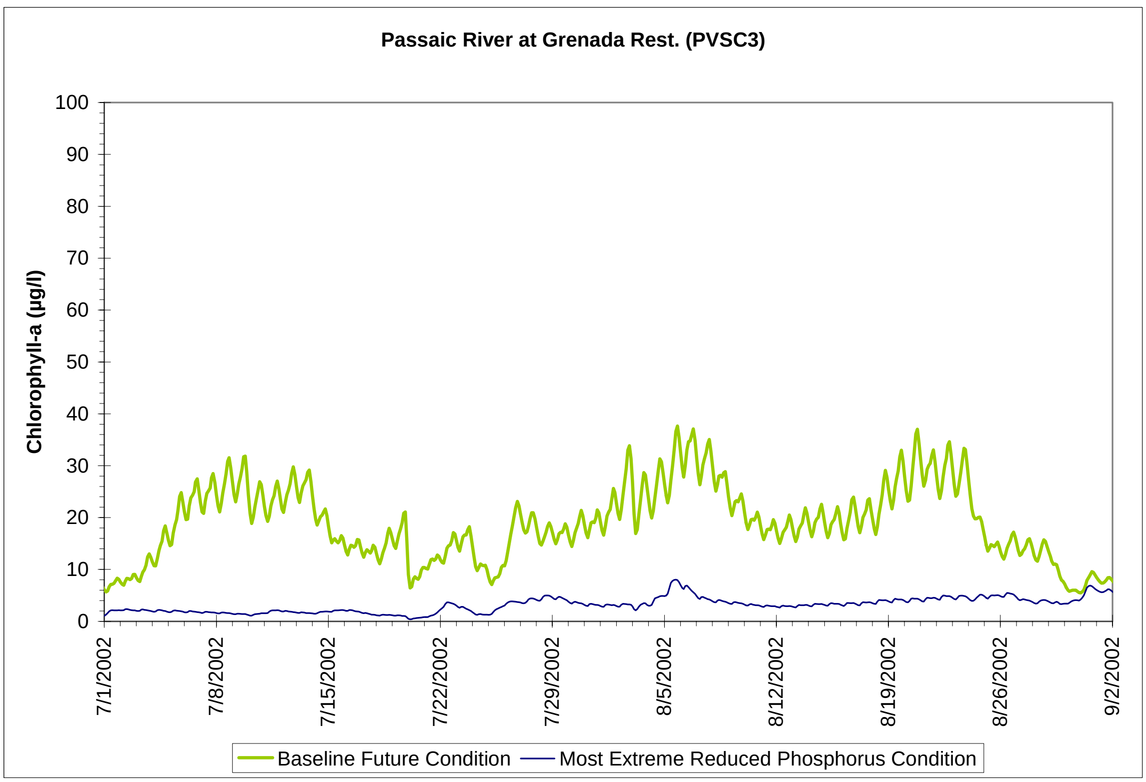
The Impact of Reducing Phosphorus on the Passaic River Basin



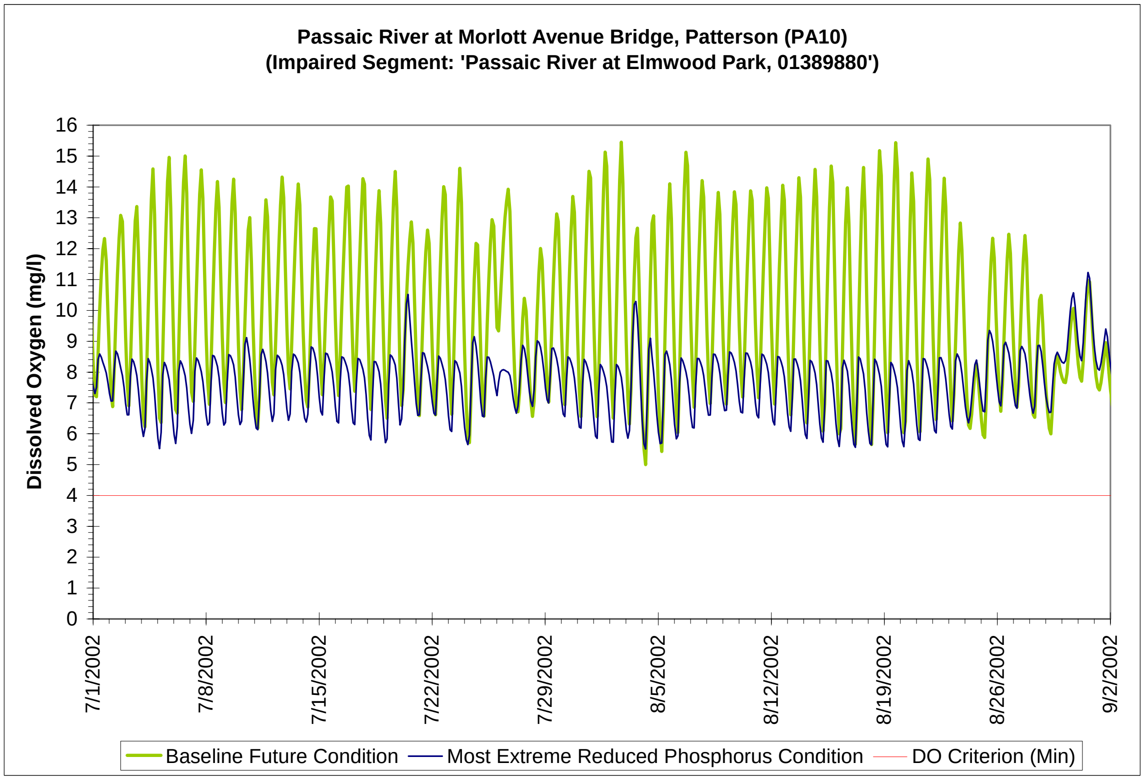


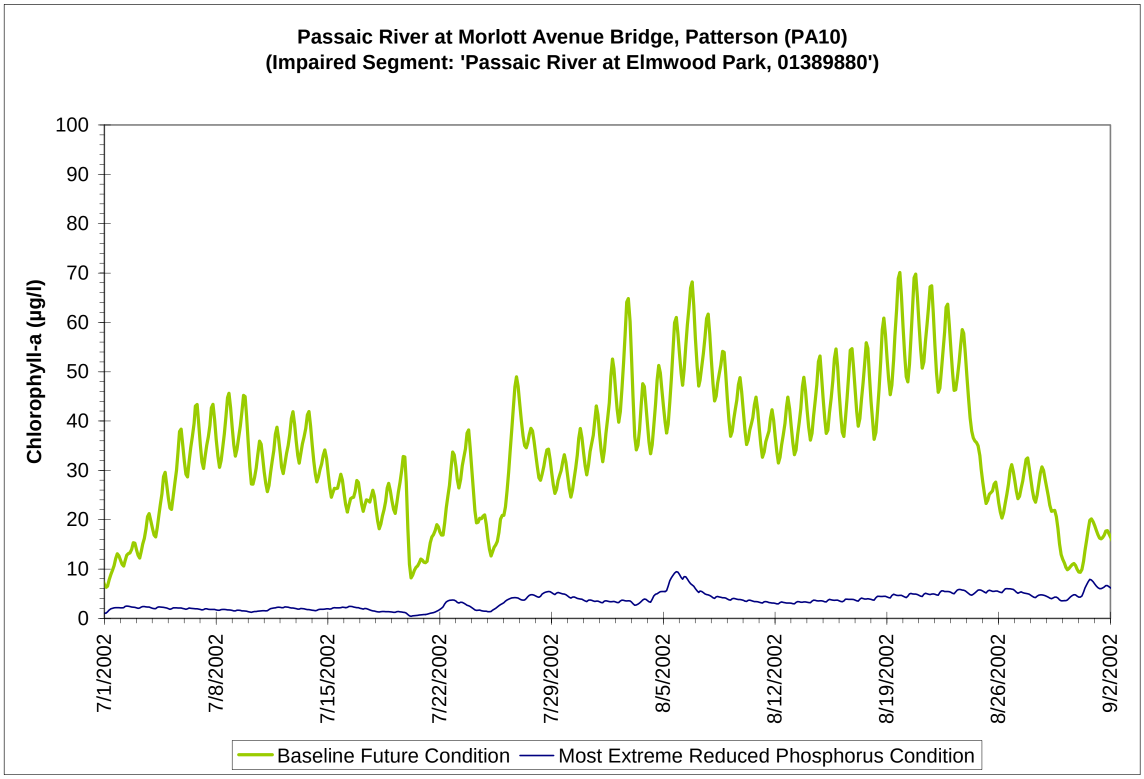
The Impact of Reducing Phosphorus on the Passaic River Basin



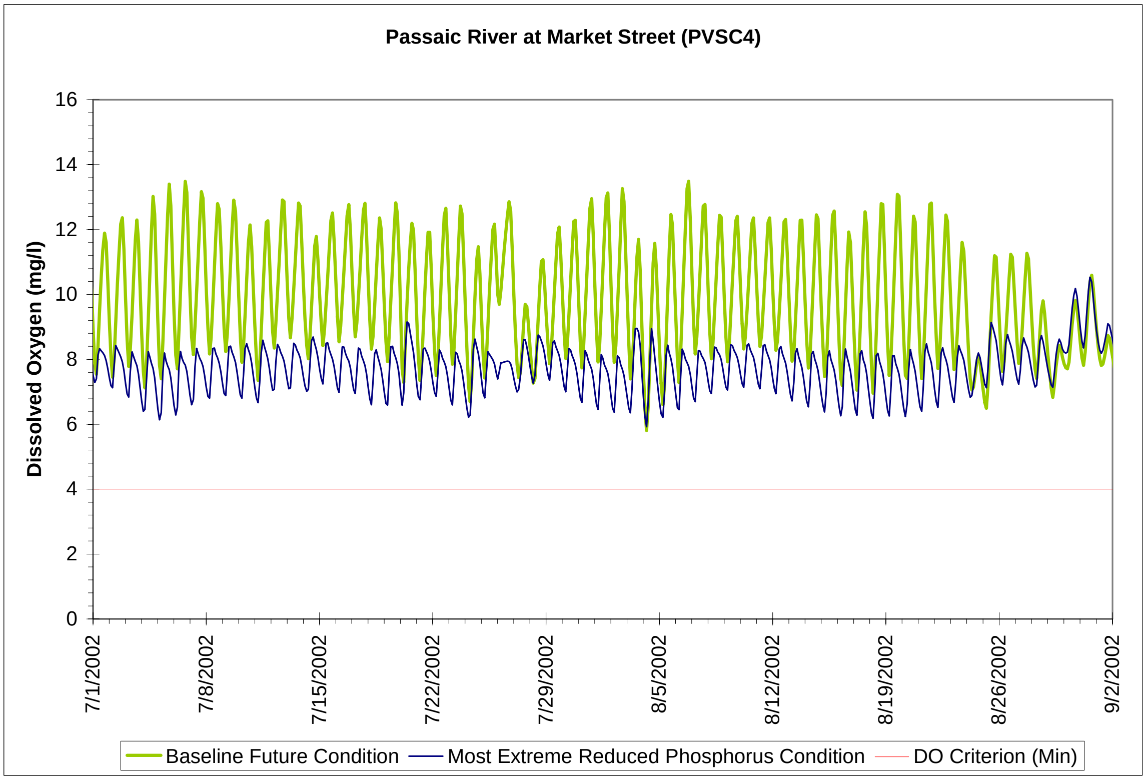


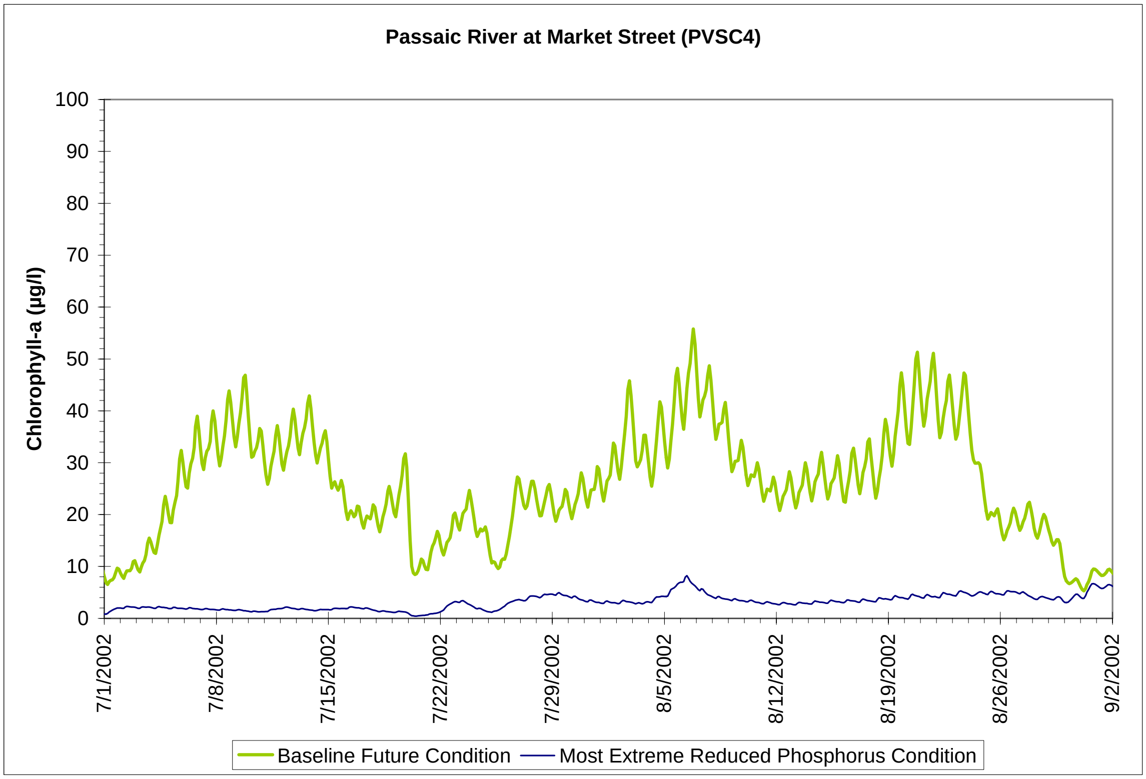
The Impact of Reducing Phosphorus on the Passaic River Basin



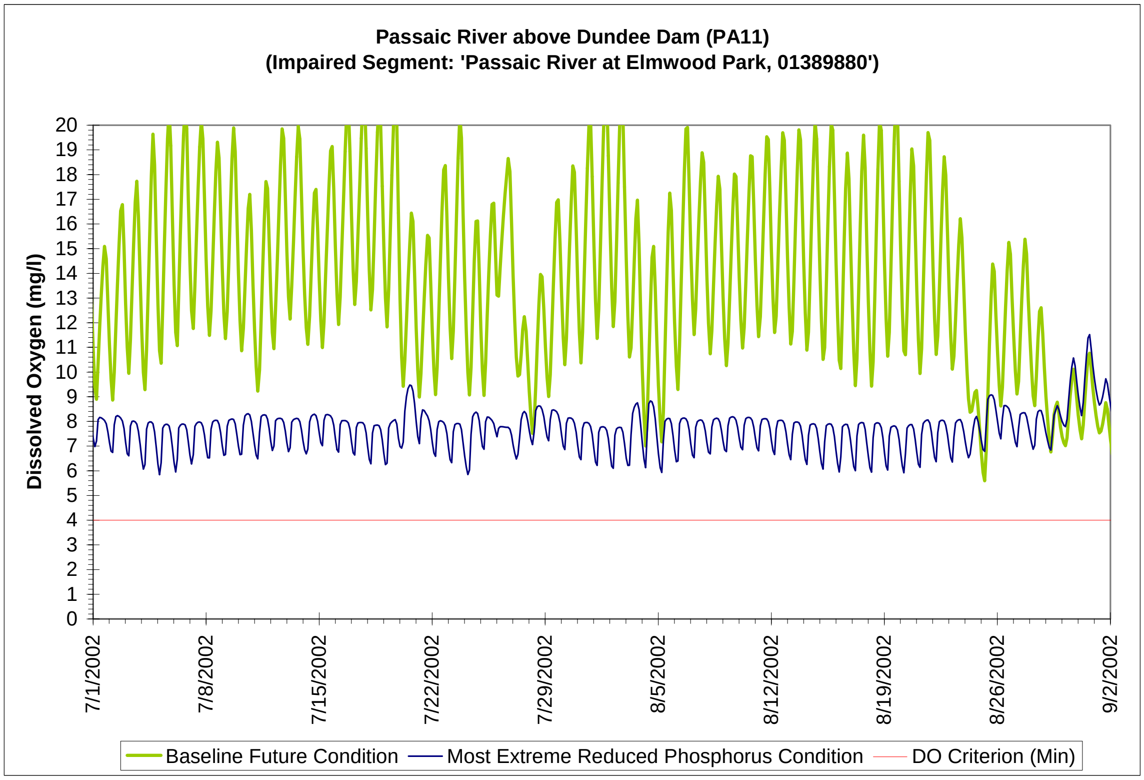


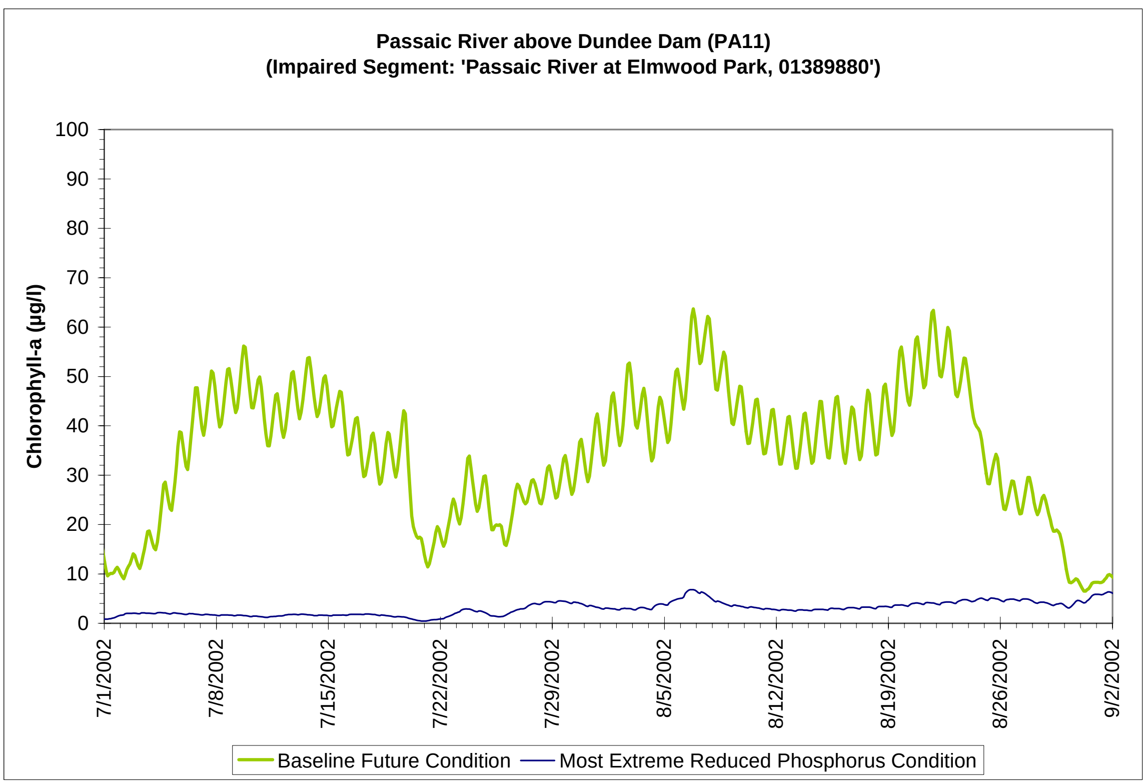
The Impact of Reducing Phosphorus on the Passaic River Basin



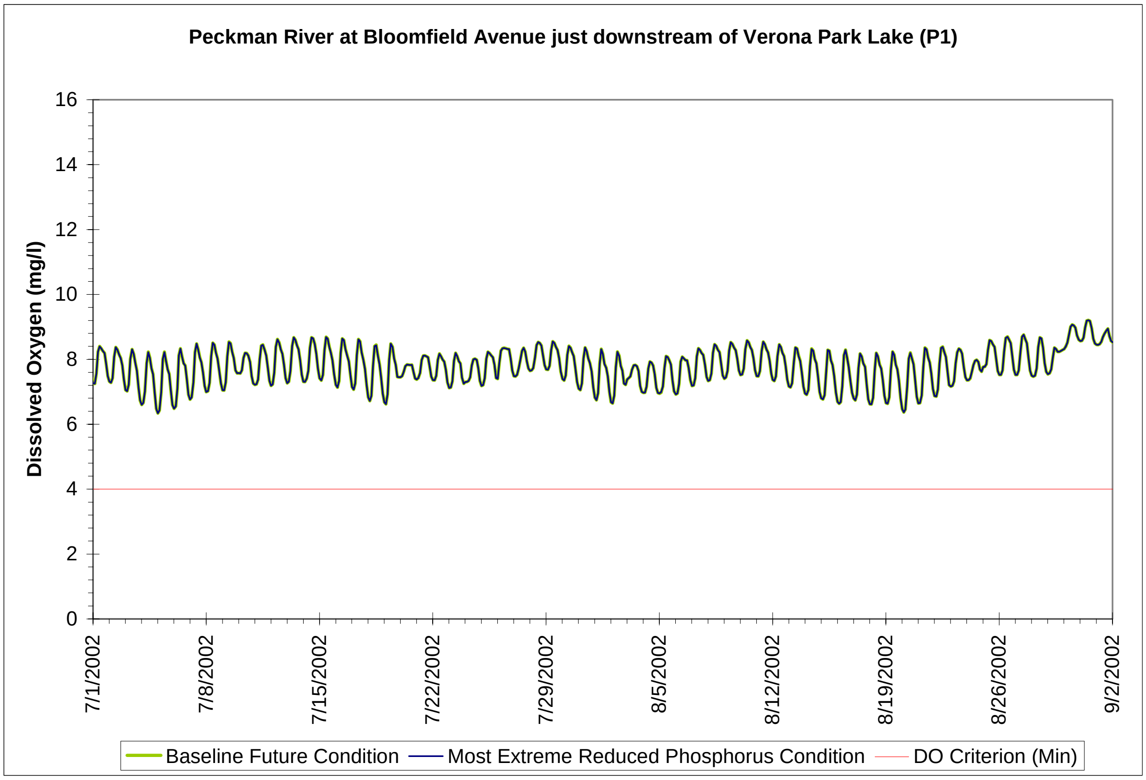


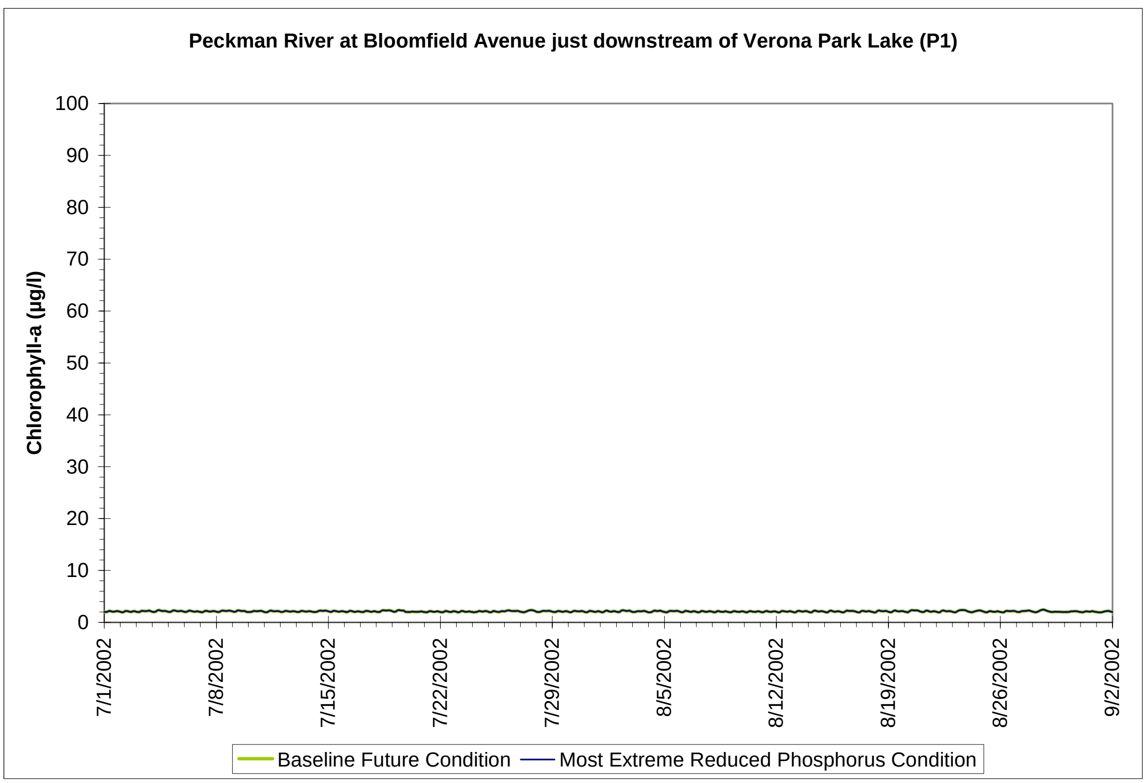
The Impact of Reducing Phosphorus on the Passaic River Basin



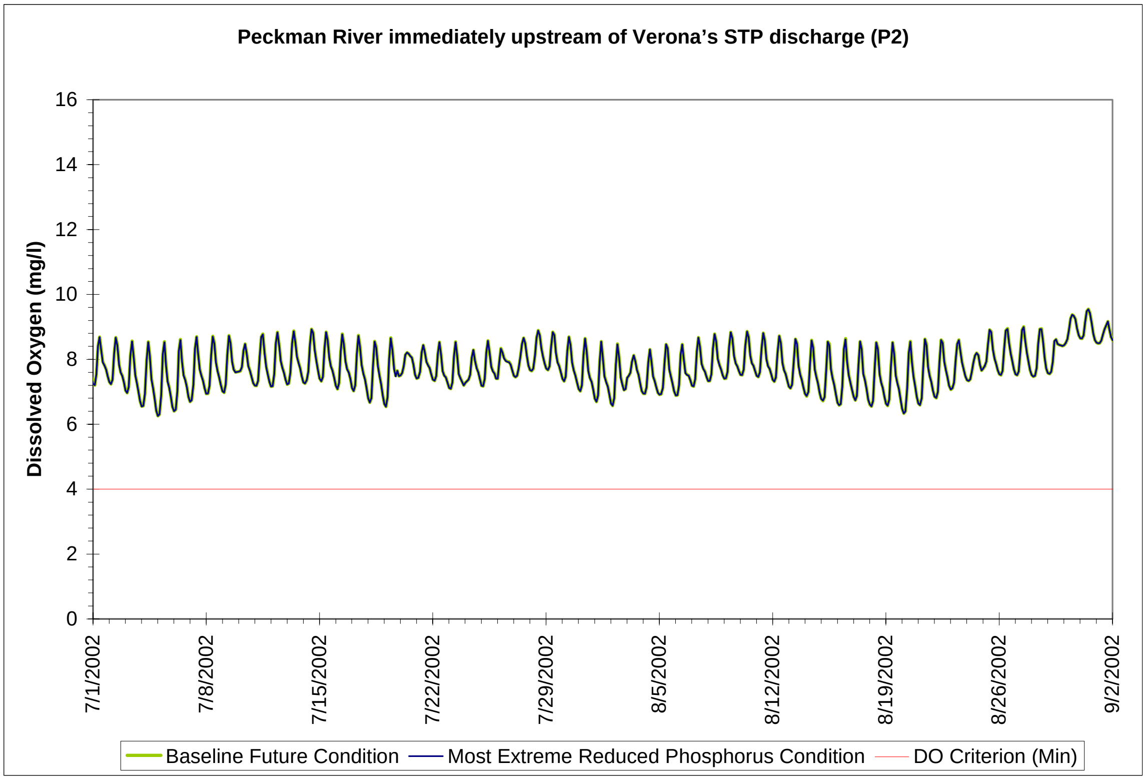


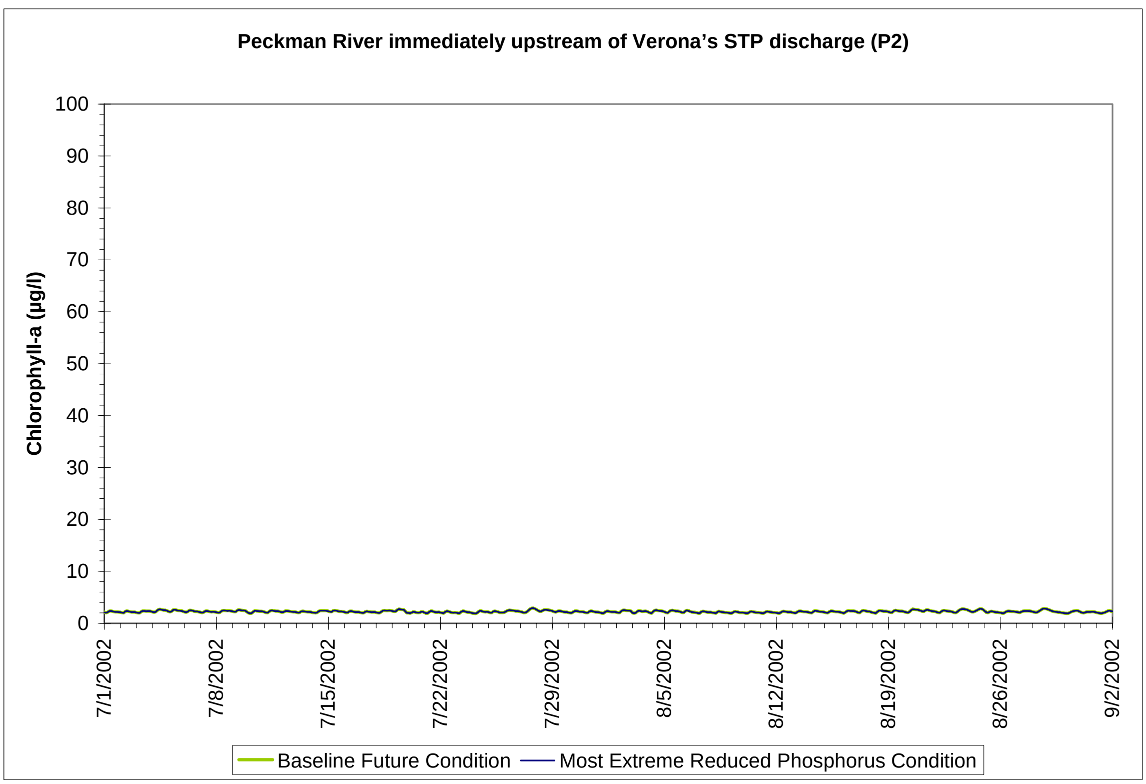
The Impact of Reducing Phosphorus on the Passaic River Basin



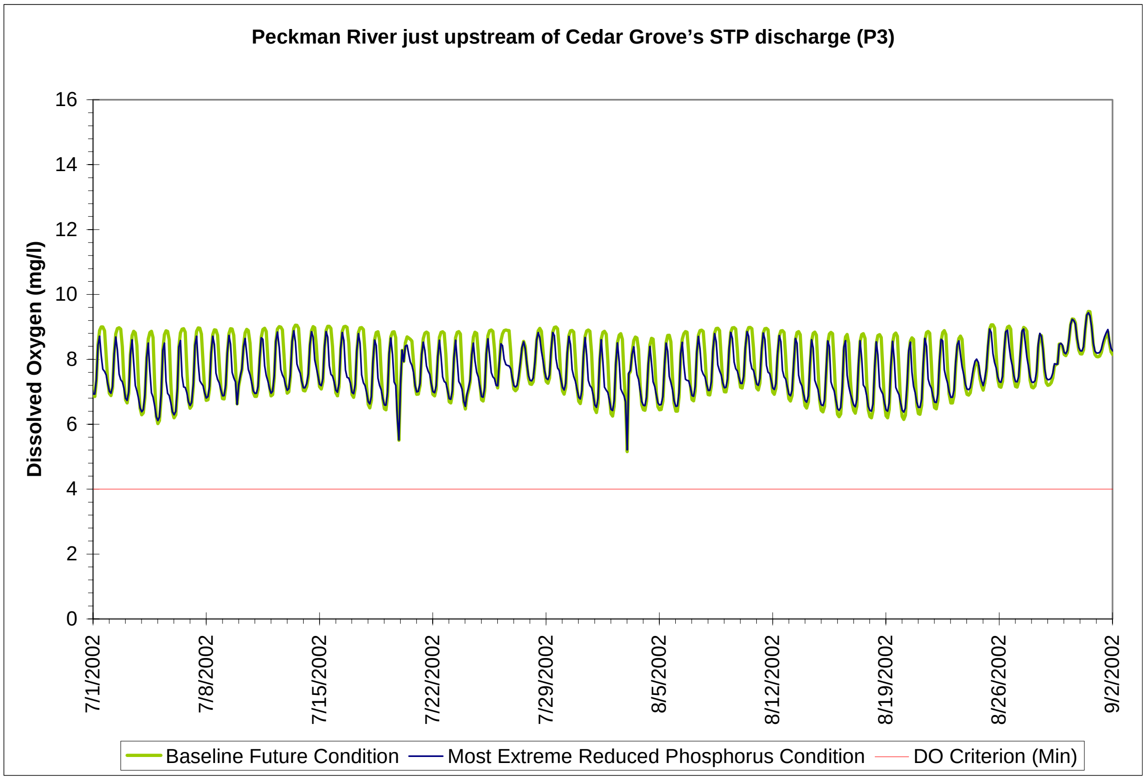


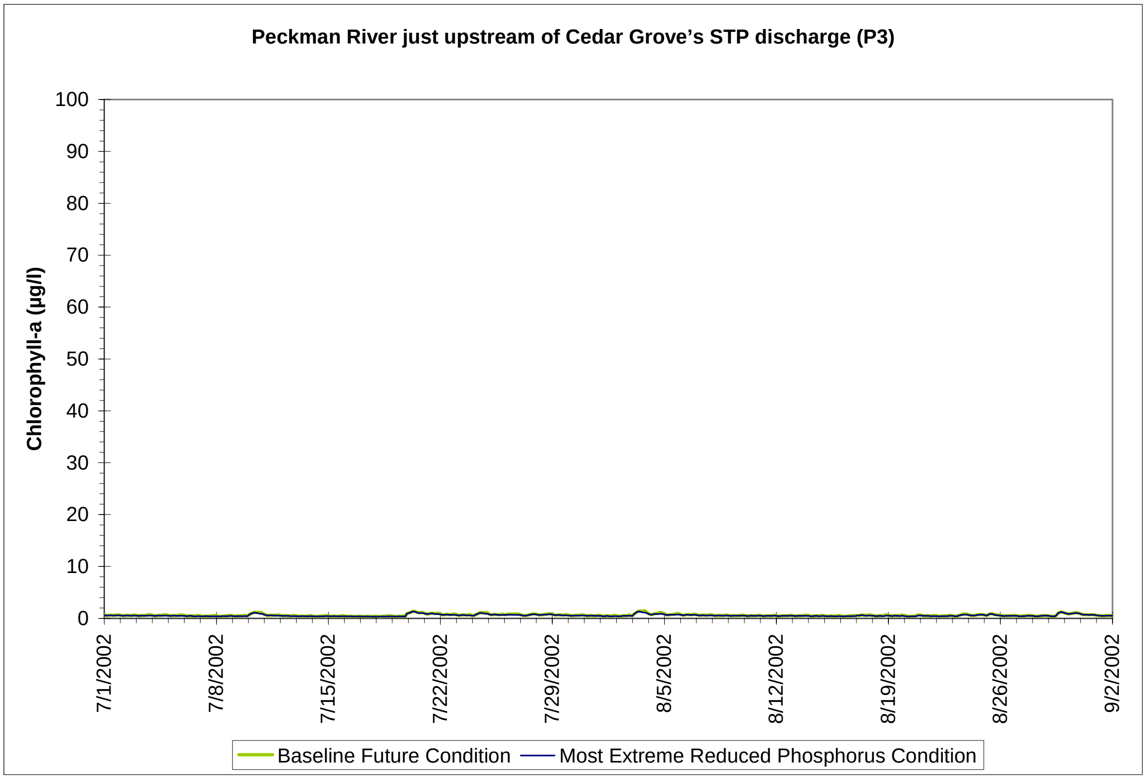
The Impact of Reducing Phosphorus on the Passaic River Basin



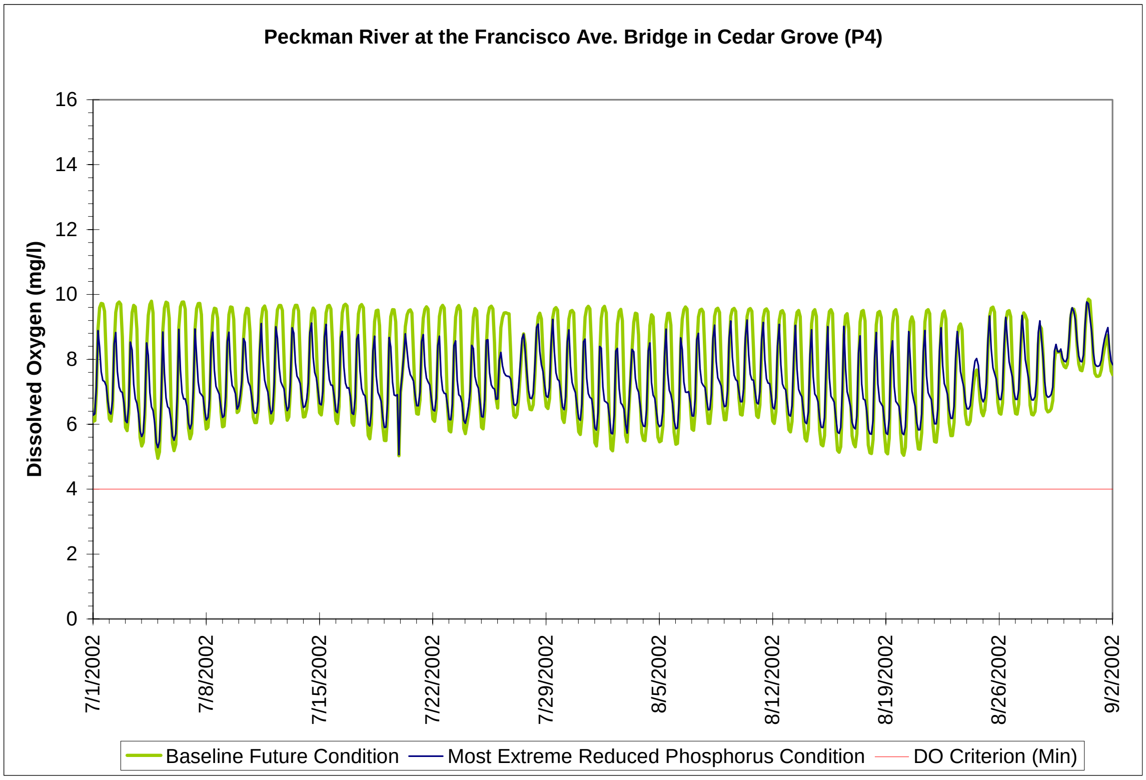


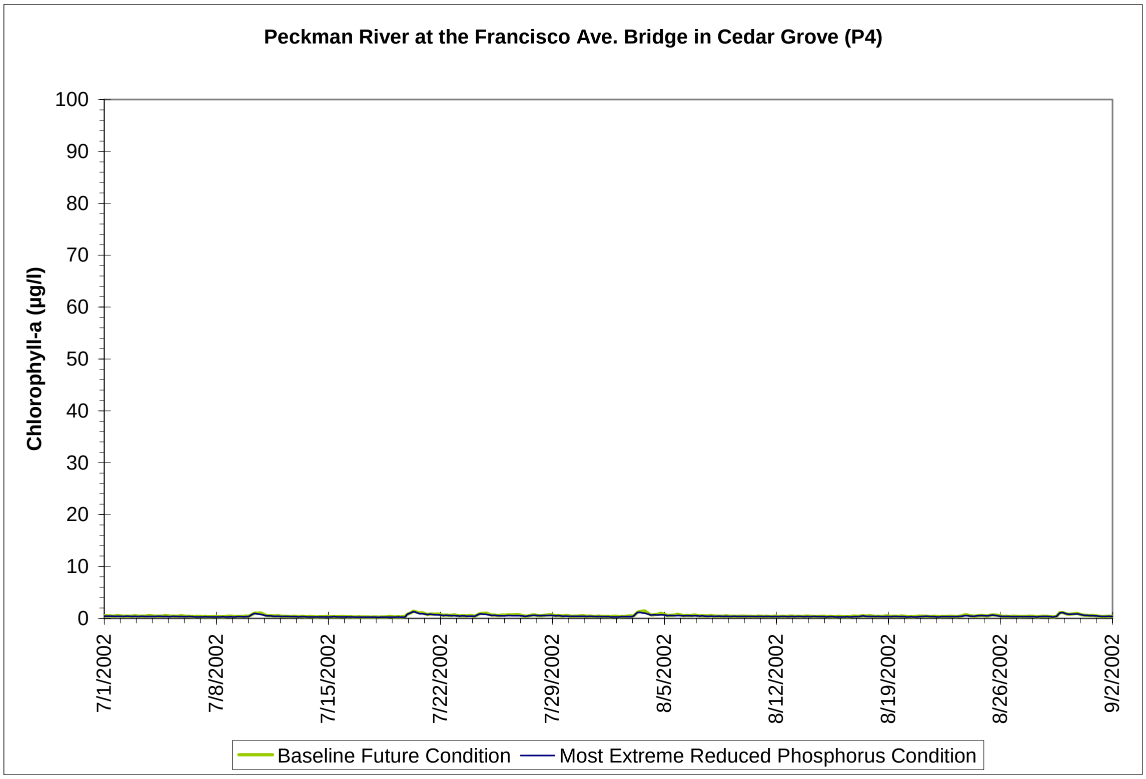
The Impact of Reducing Phosphorus on the Passaic River Basin



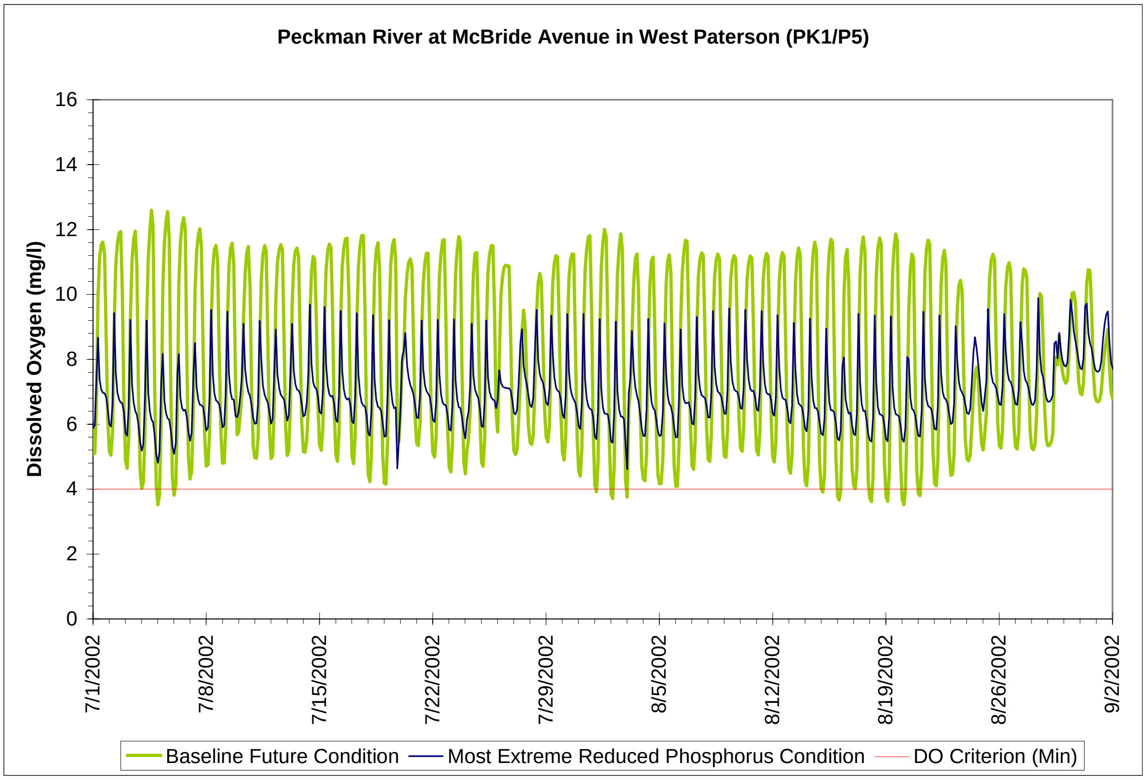


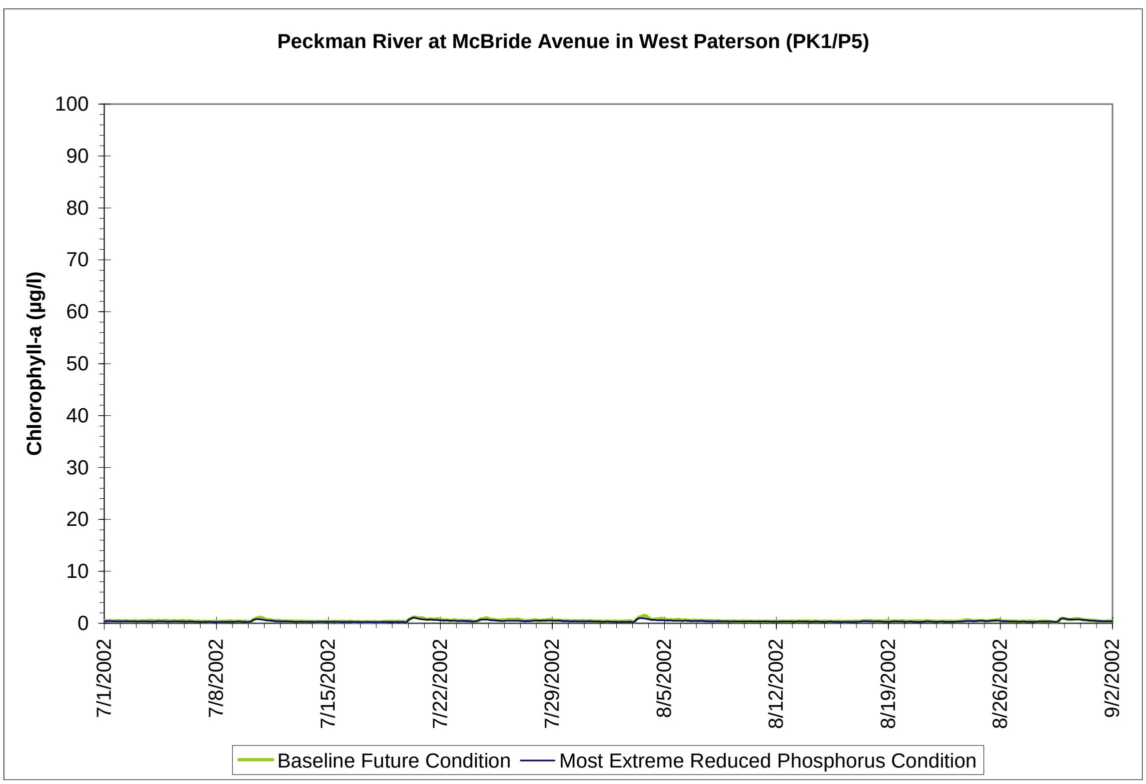
The Impact of Reducing Phosphorus on the Passaic River Basin



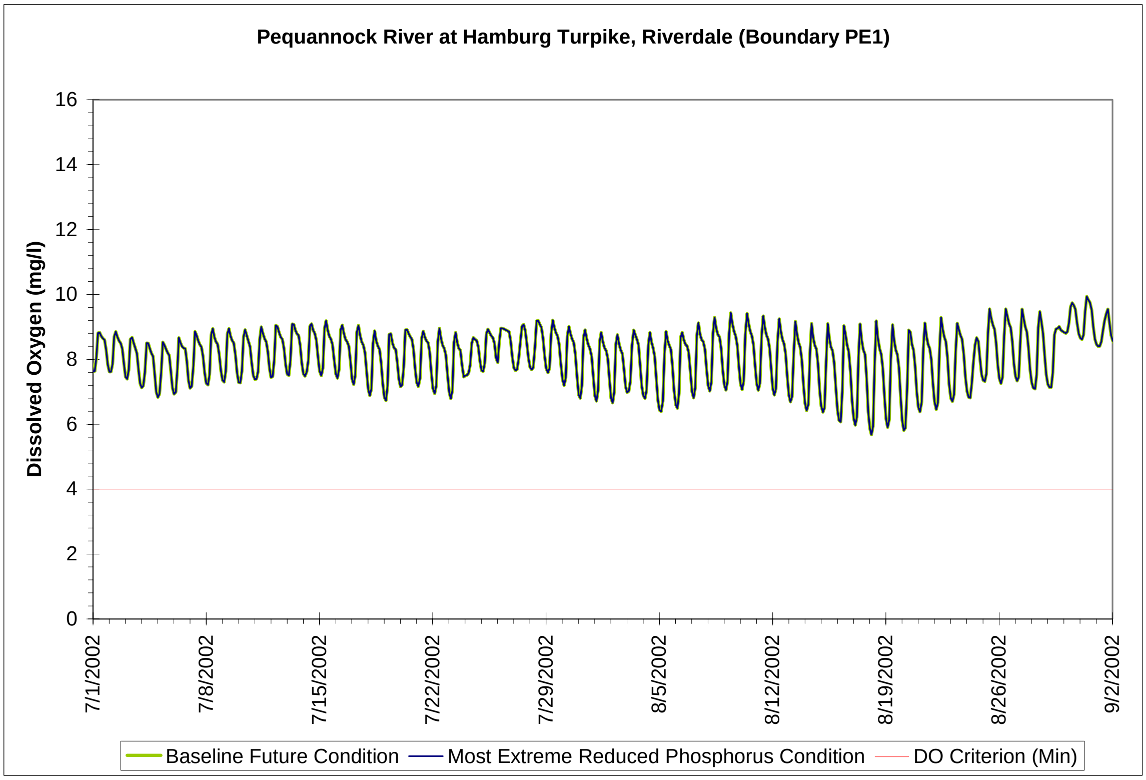


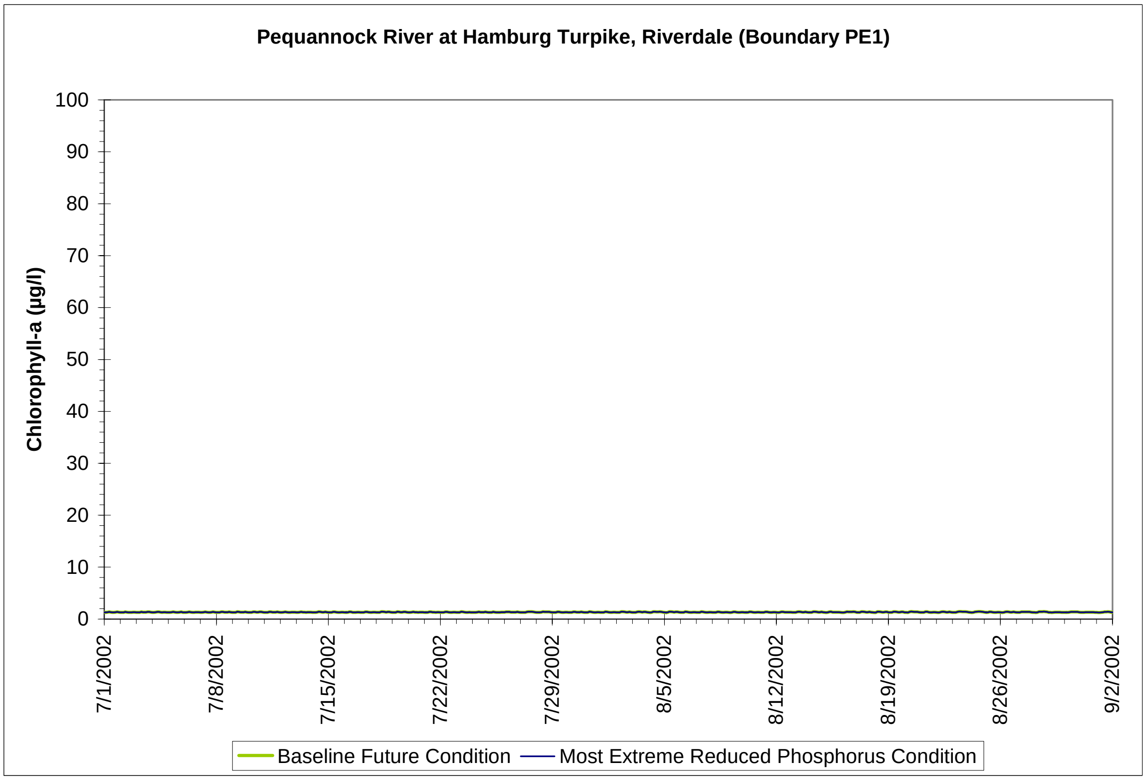
The Impact of Reducing Phosphorus on the Passaic River Basin



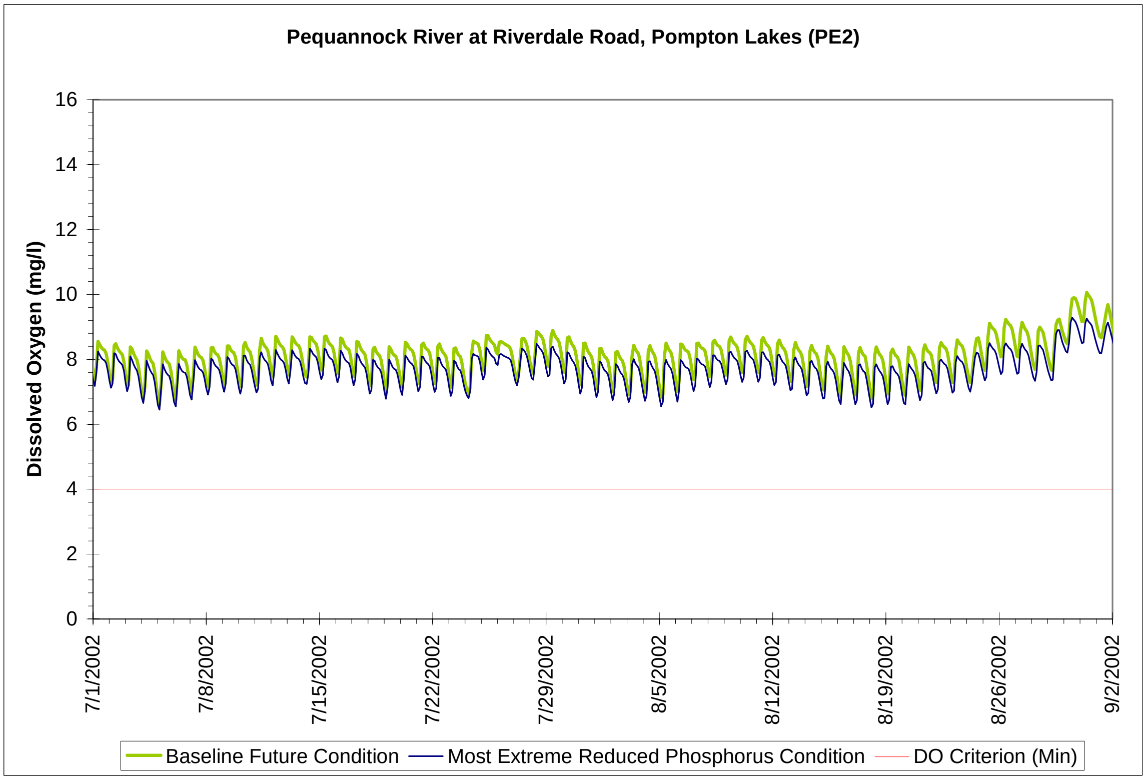


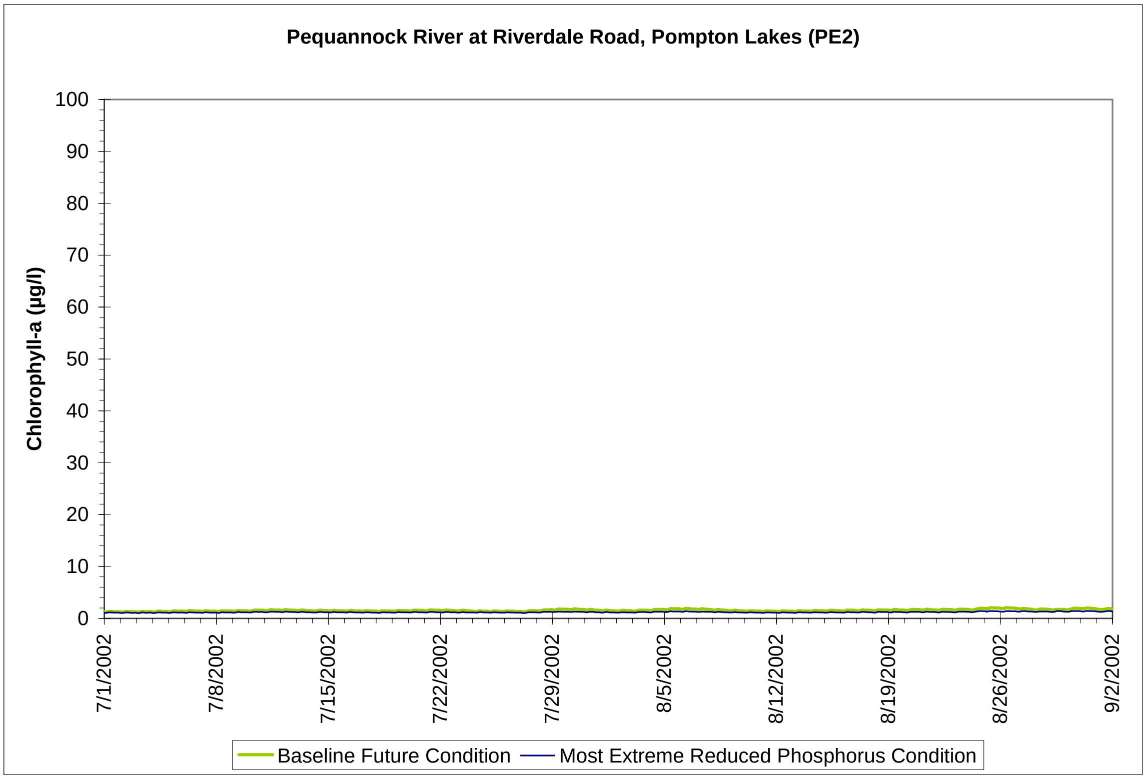
The Impact of Reducing Phosphorus on the Passaic River Basin



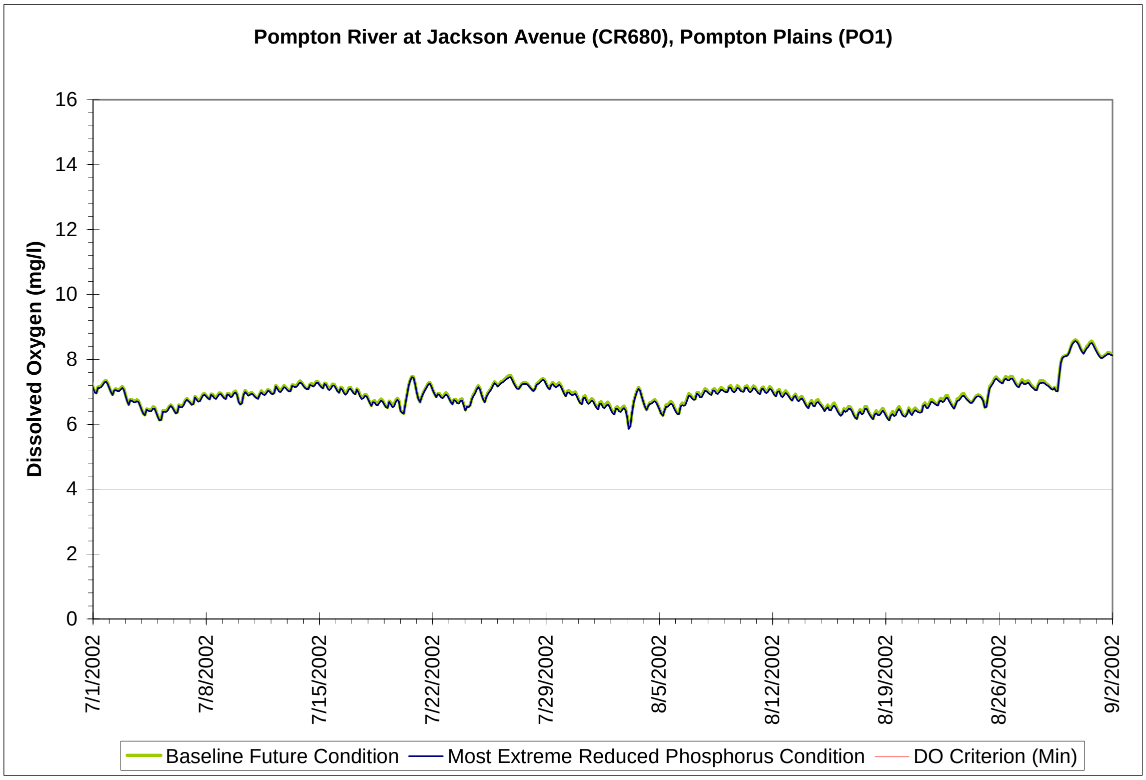


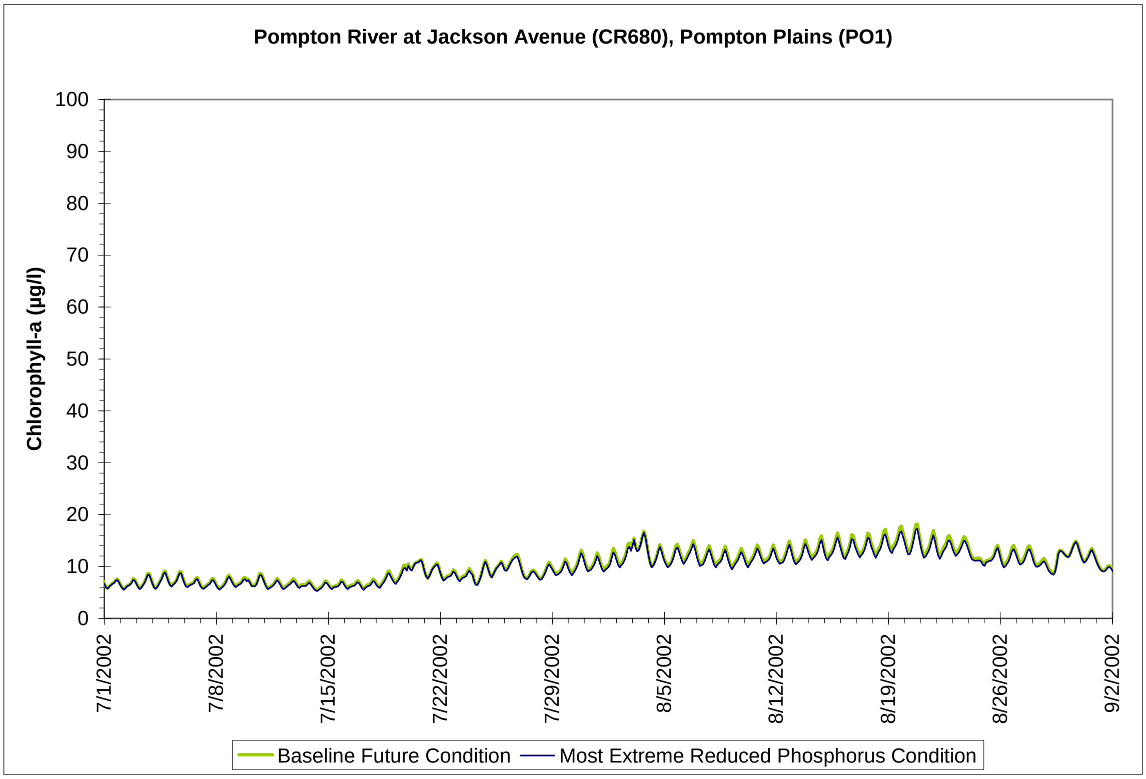
The Impact of Reducing Phosphorus on the Passaic River Basin



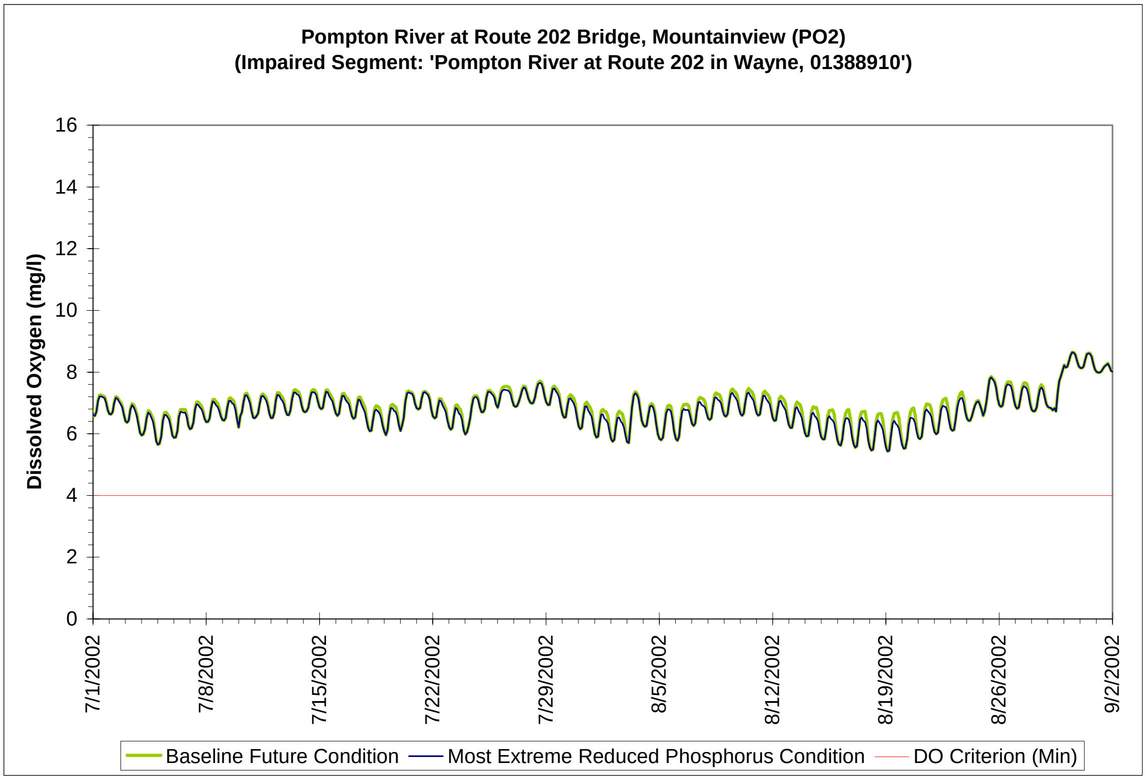


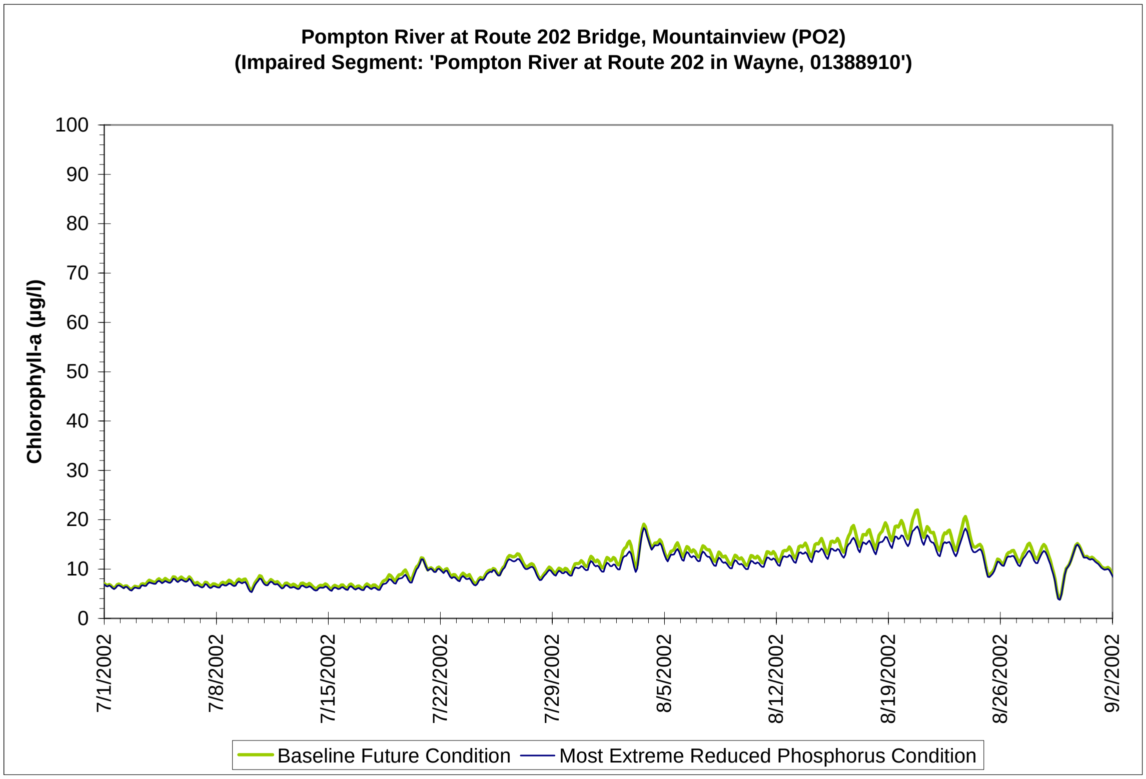
The Impact of Reducing Phosphorus on the Passaic River Basin



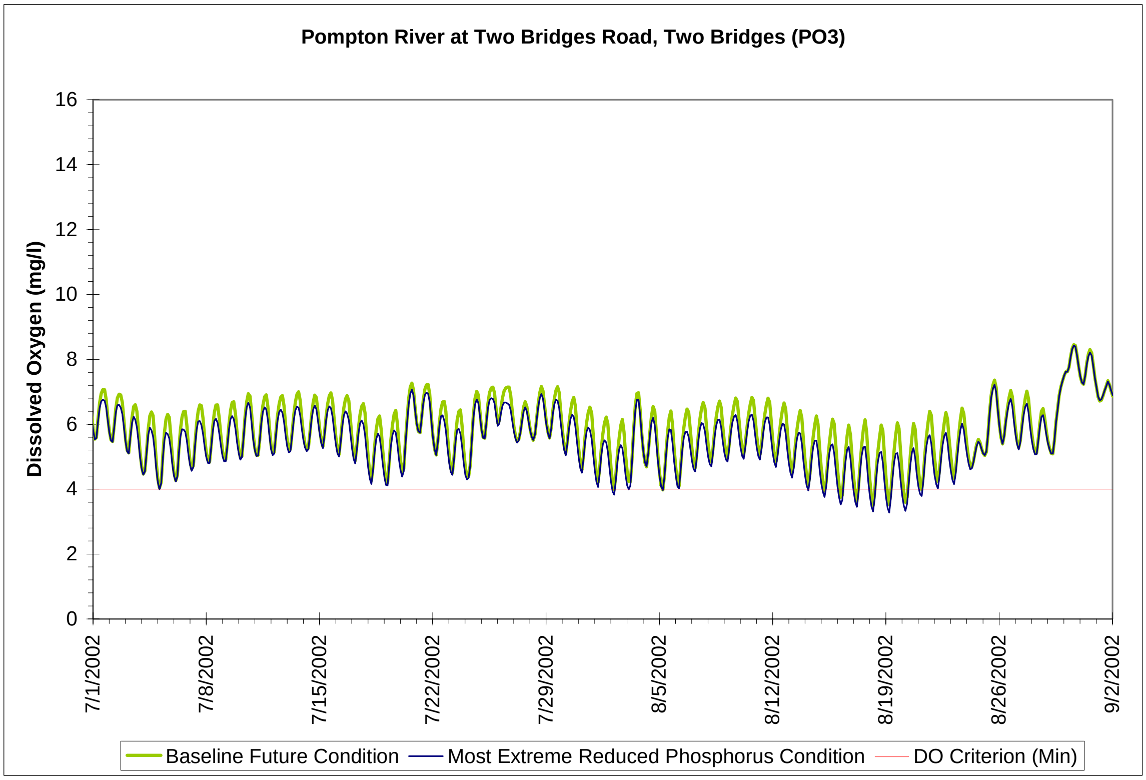


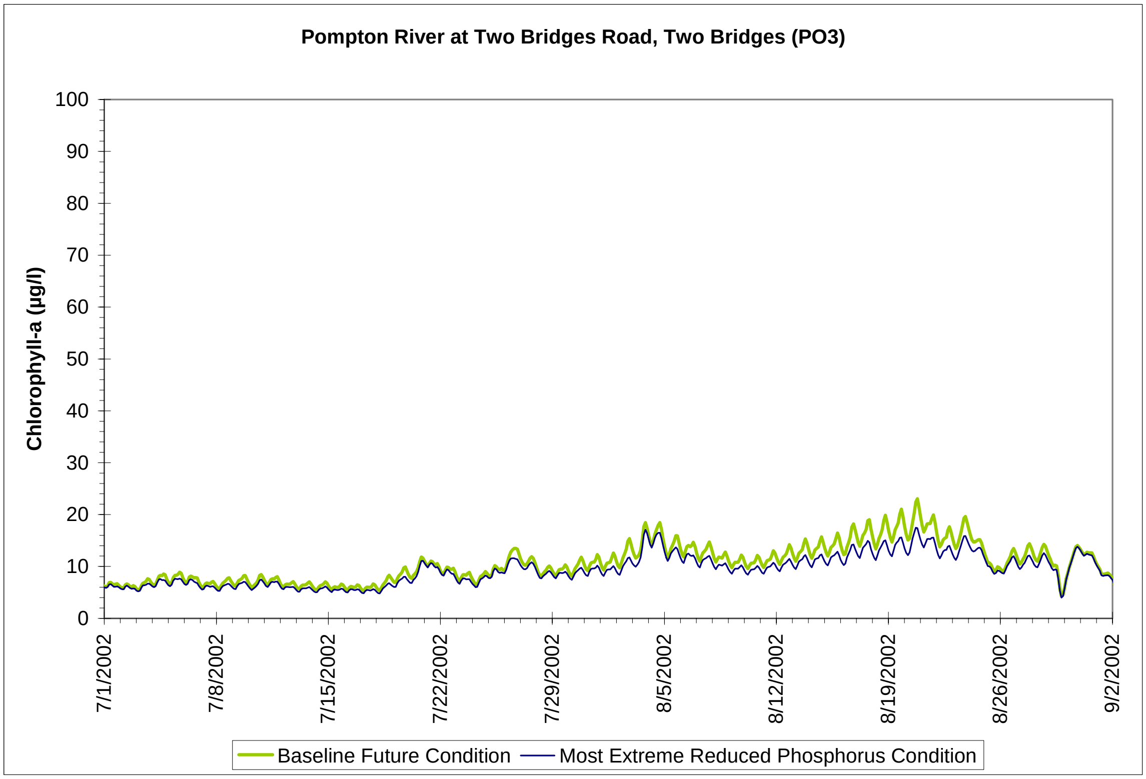
The Impact of Reducing Phosphorus on the Passaic River Basin



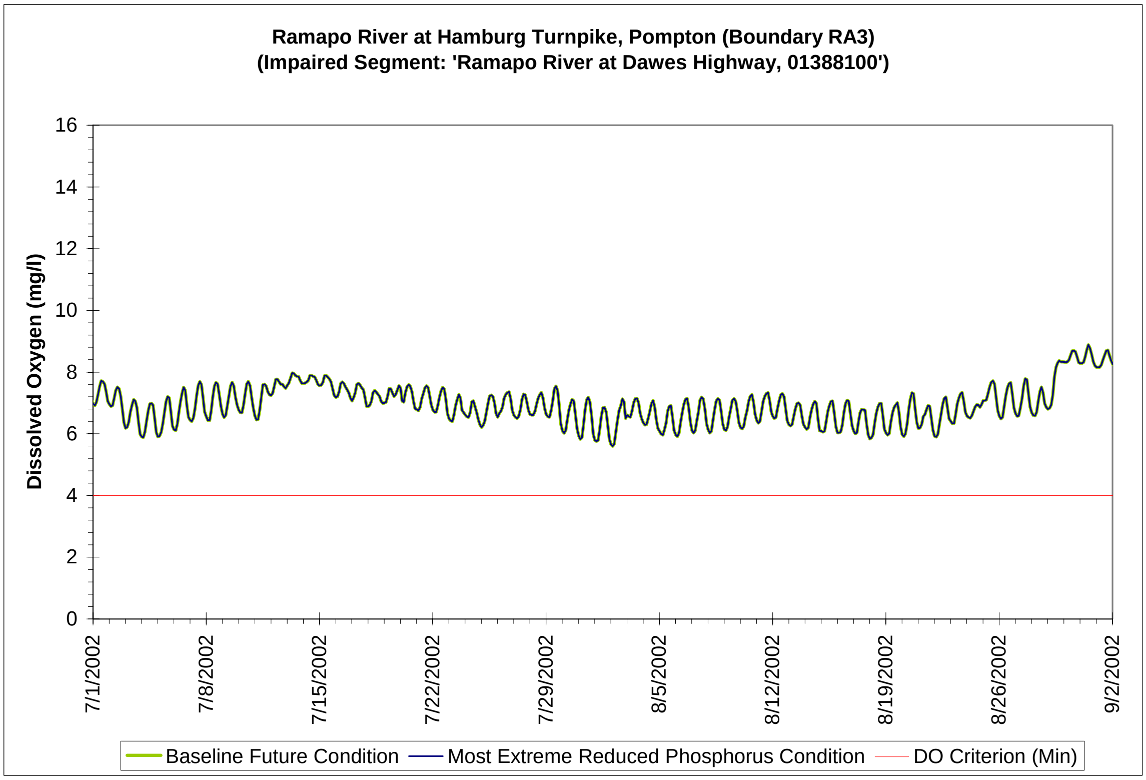


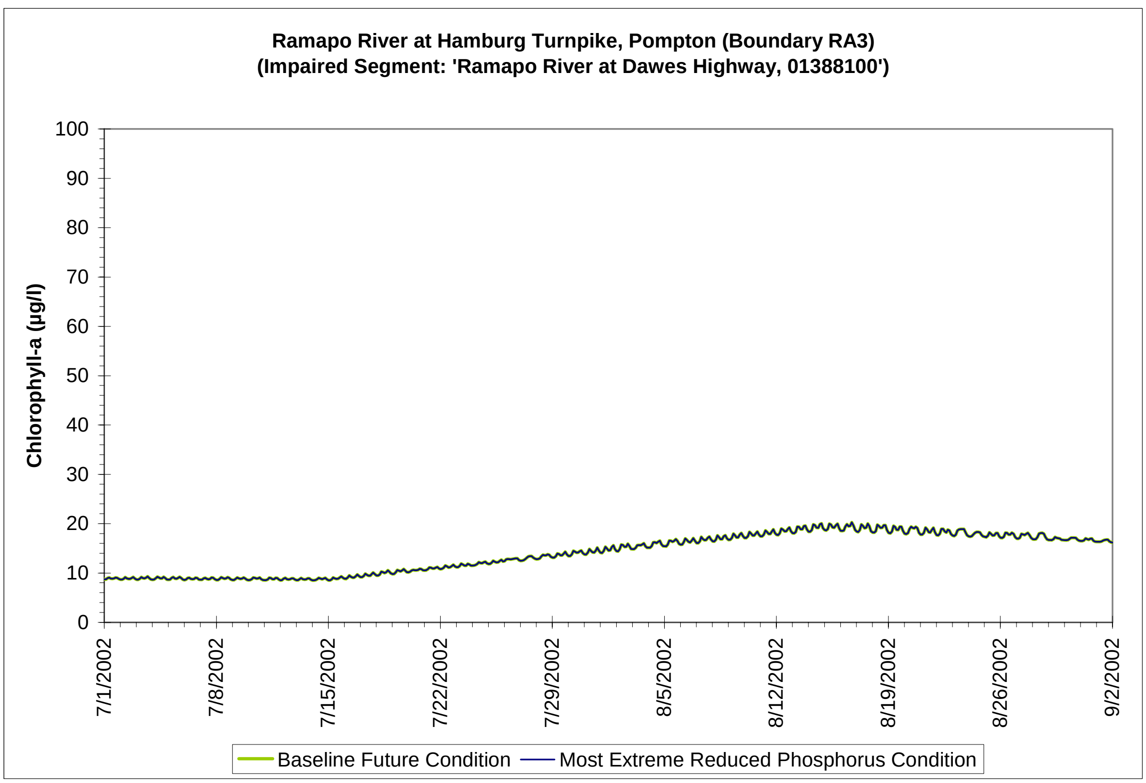
The Impact of Reducing Phosphorus on the Passaic River Basin



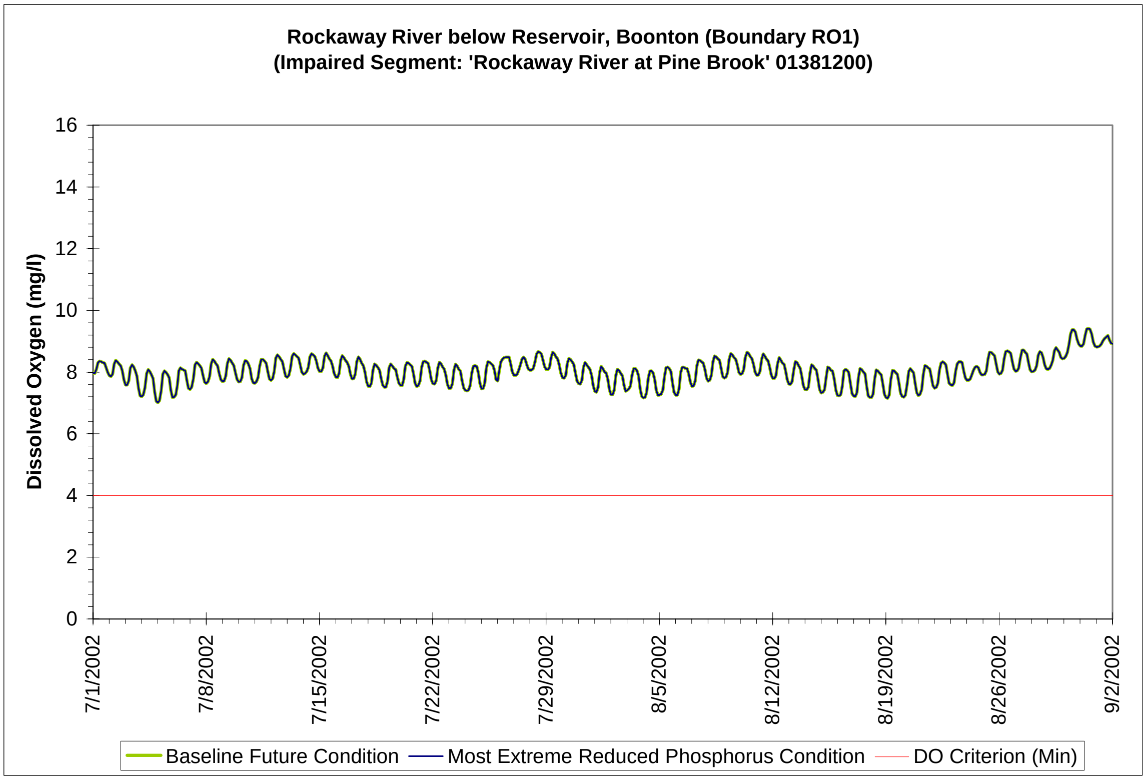


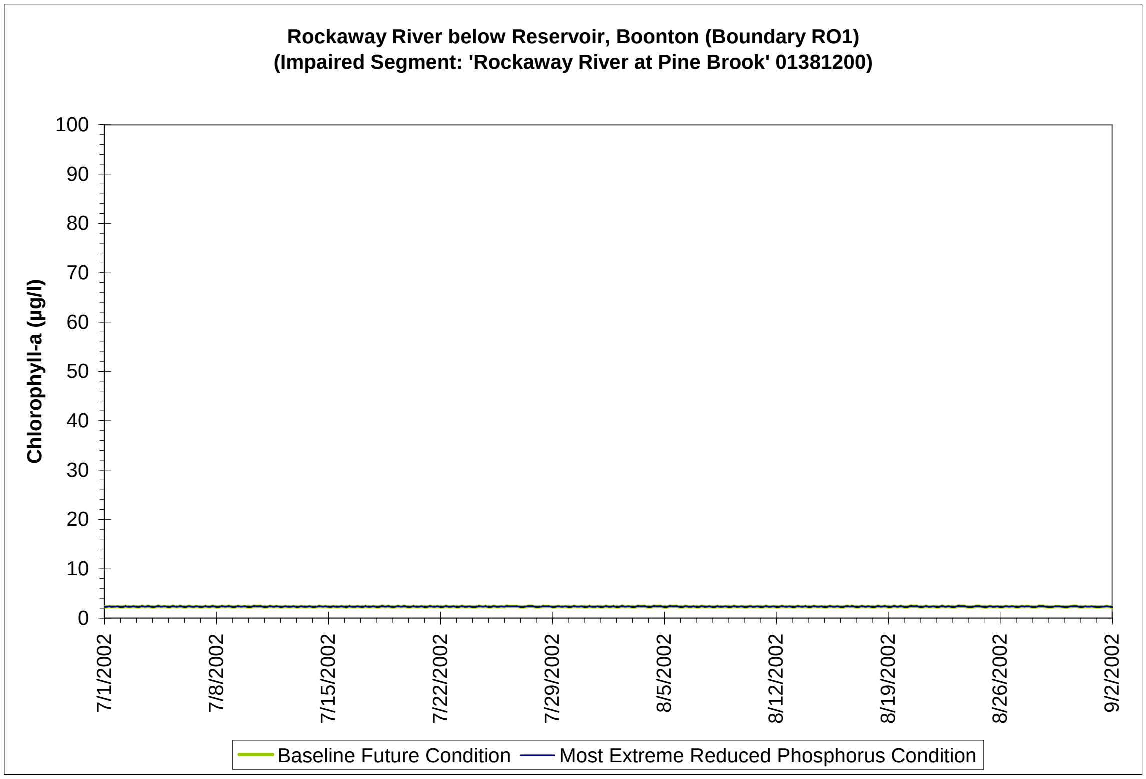
The Impact of Reducing Phosphorus on the Passaic River Basin



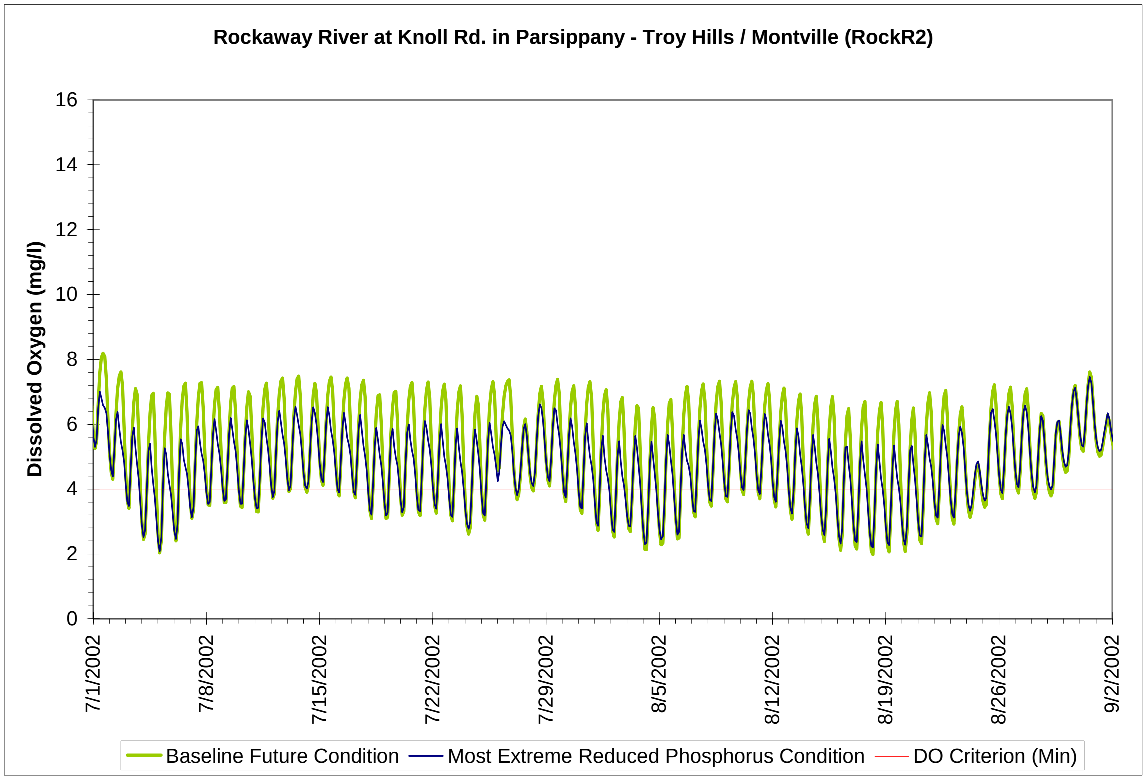


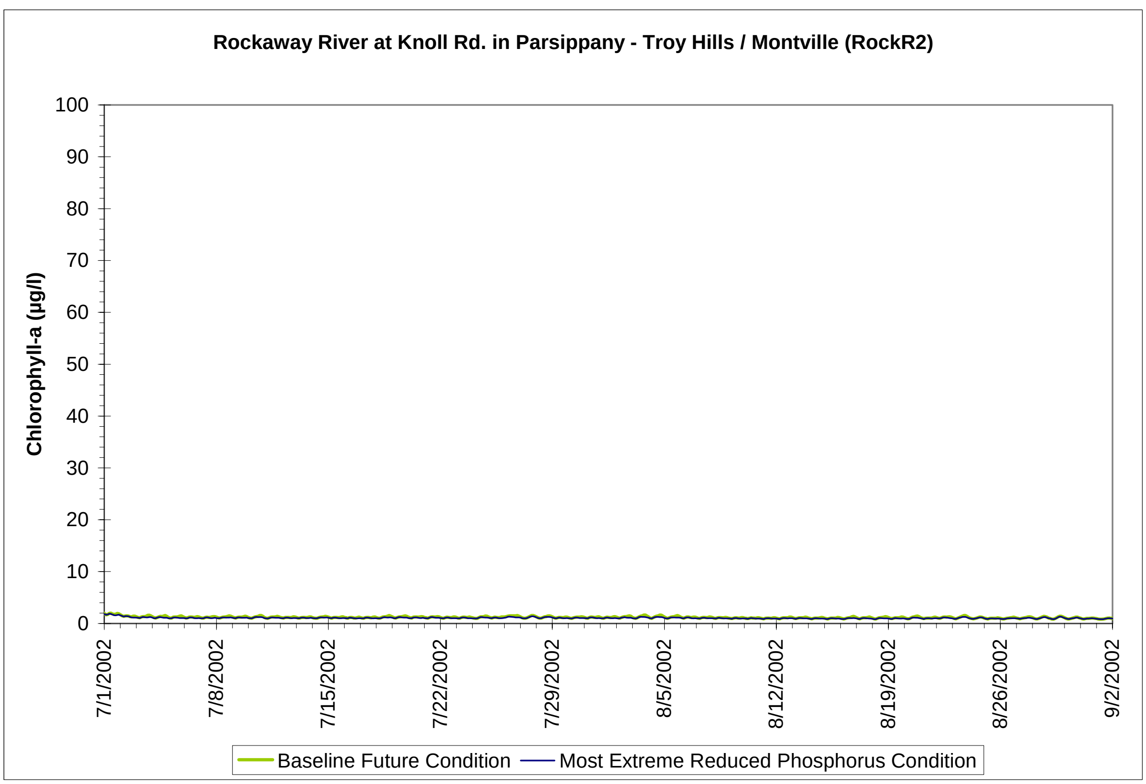
The Impact of Reducing Phosphorus on the Passaic River Basin



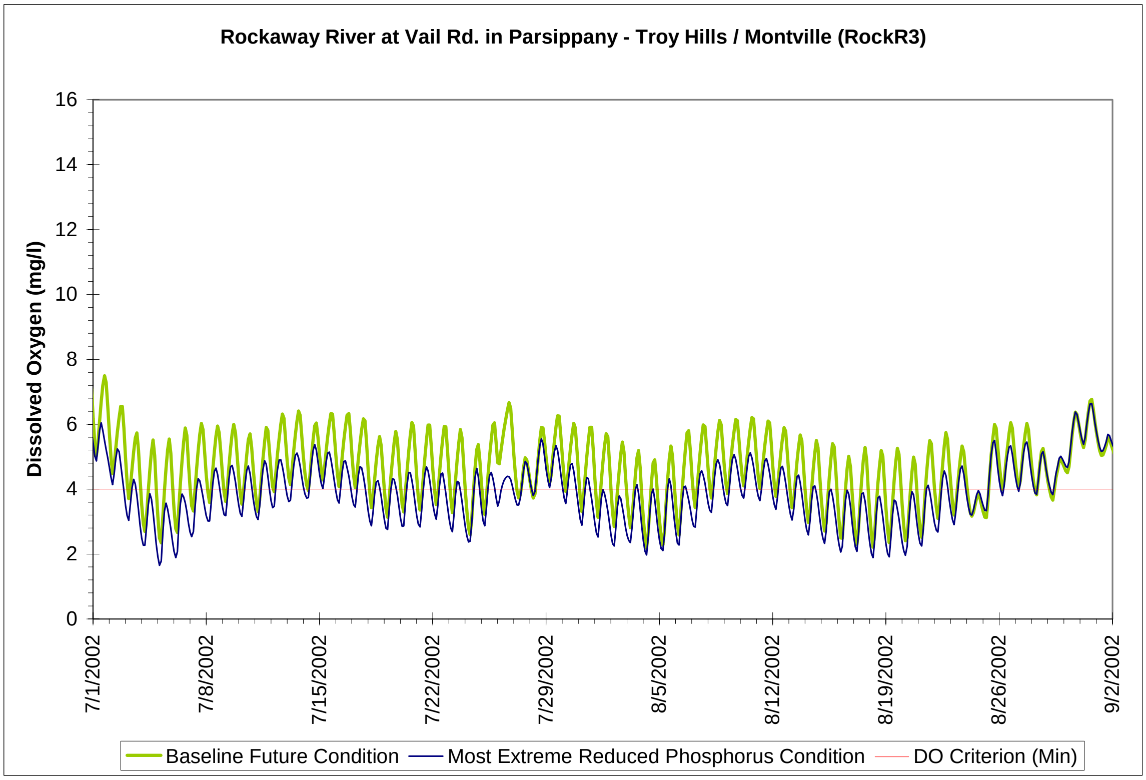


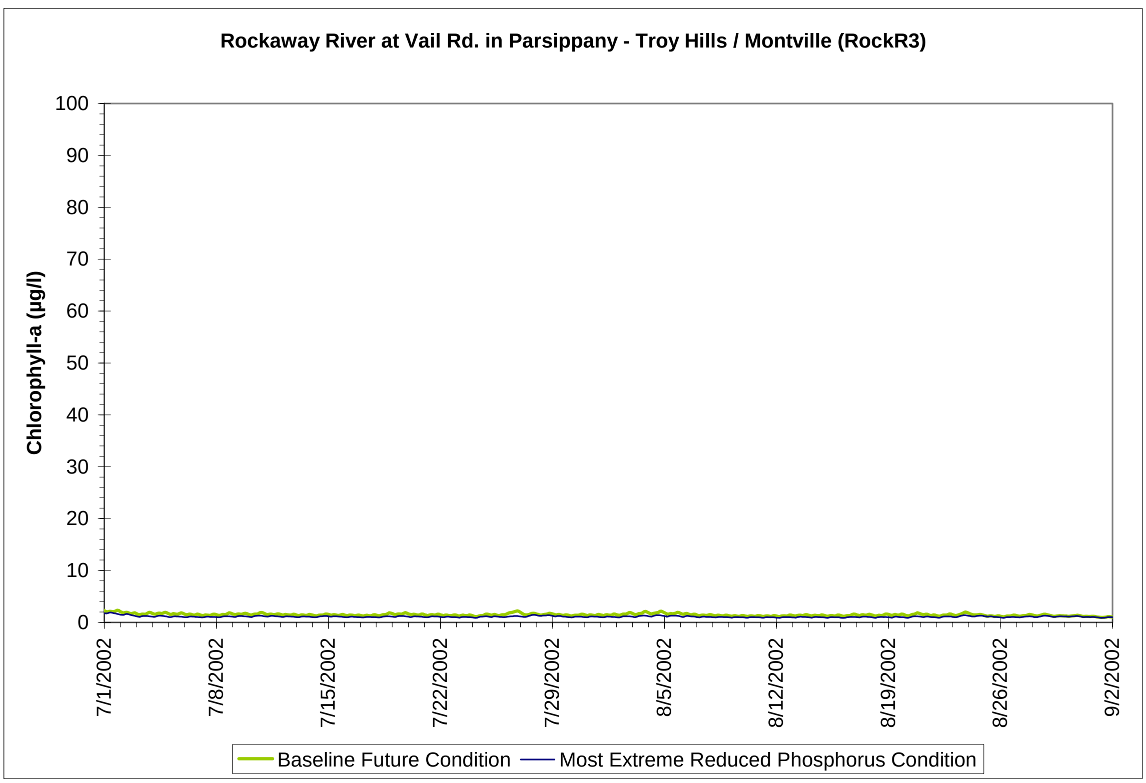
The Impact of Reducing Phosphorus on the Passaic River Basin



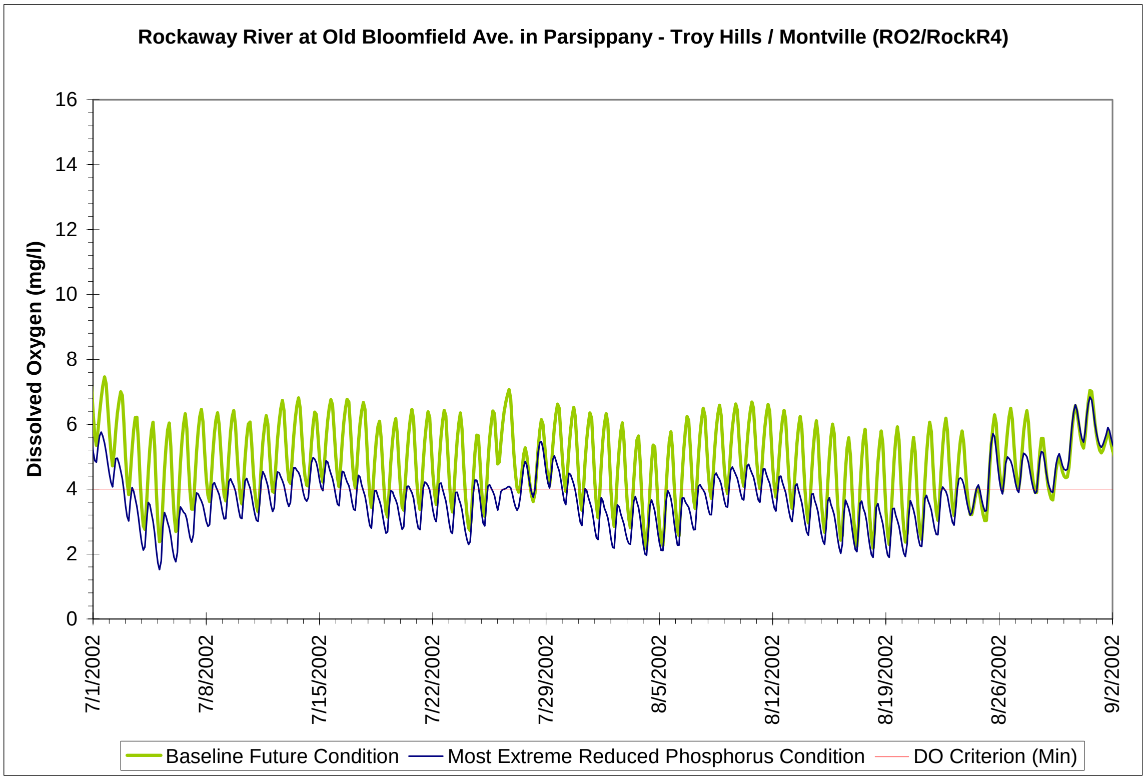


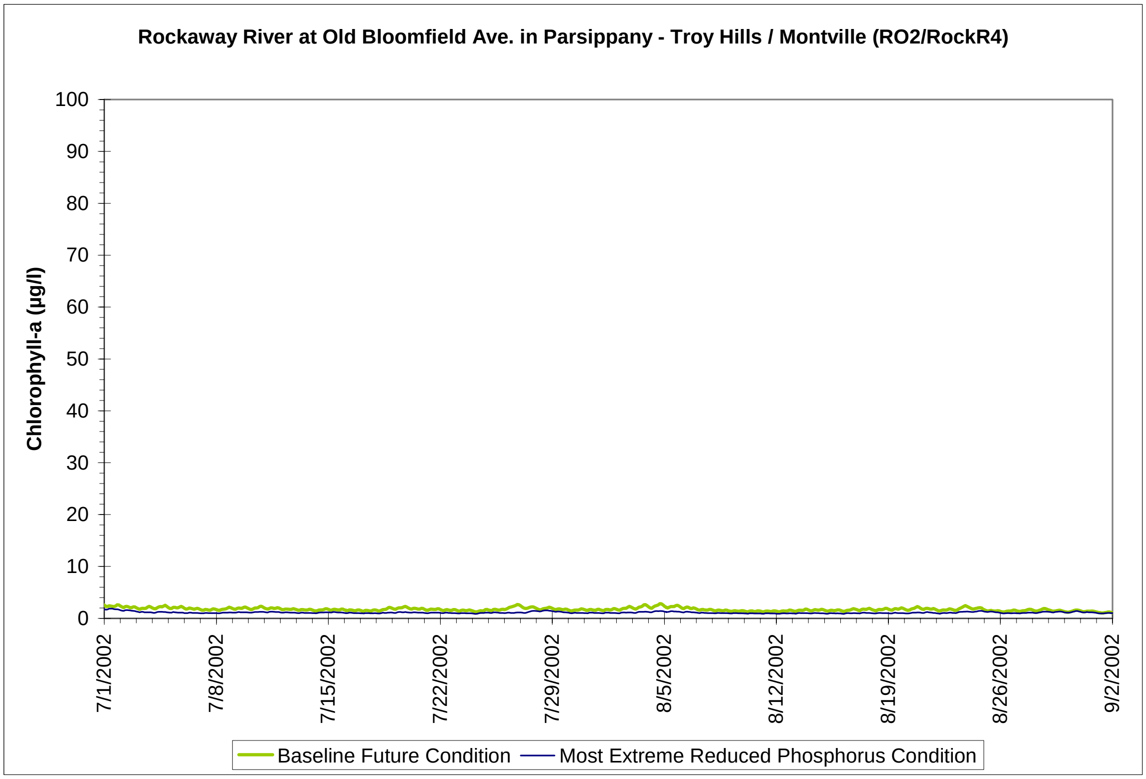
The Impact of Reducing Phosphorus on the Passaic River Basin



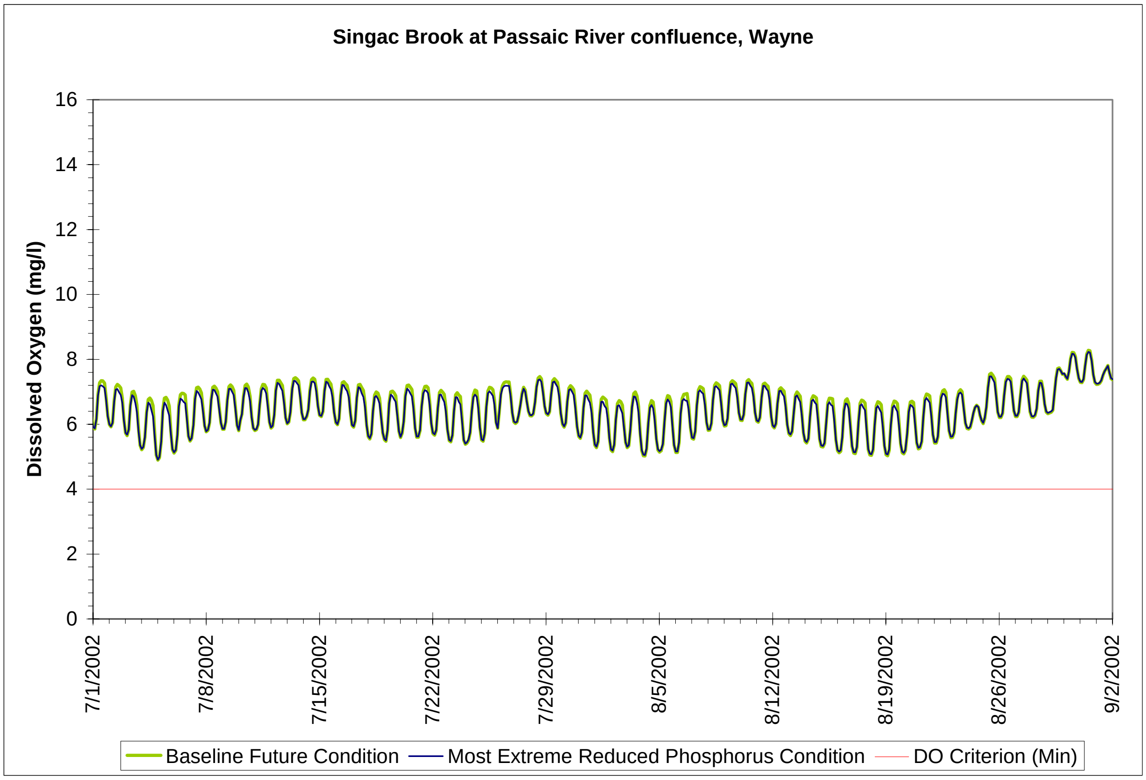


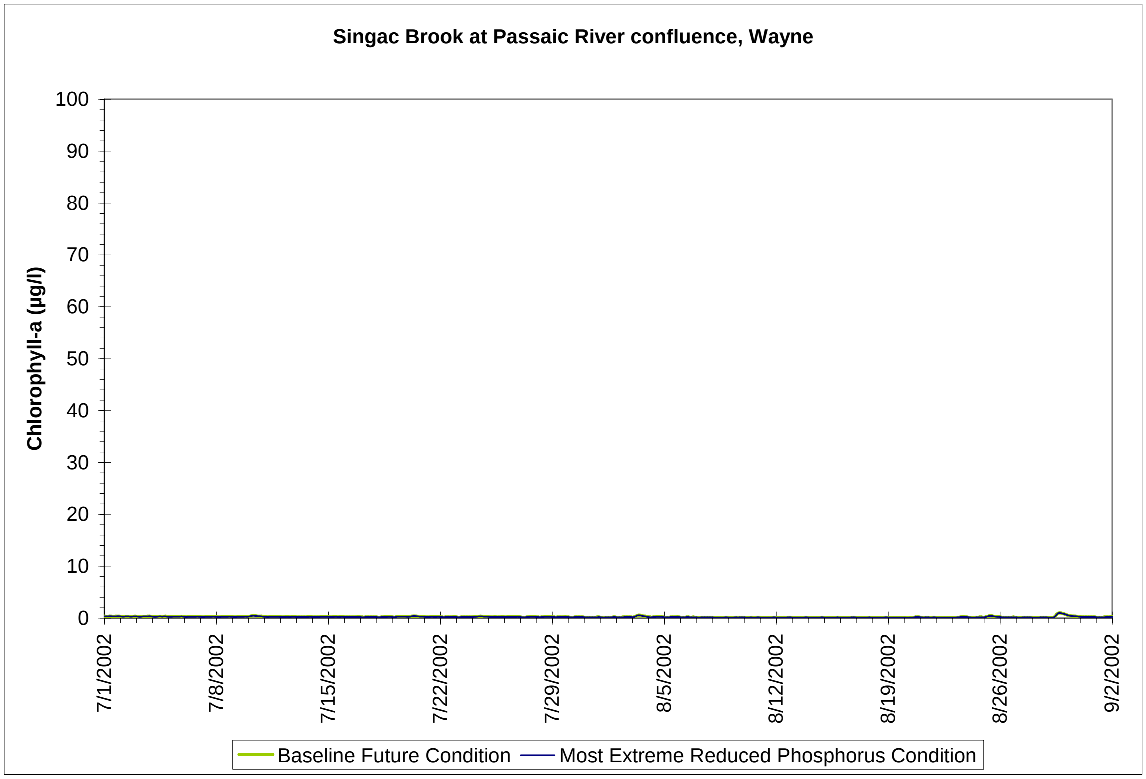
The Impact of Reducing Phosphorus on the Passaic River Basin



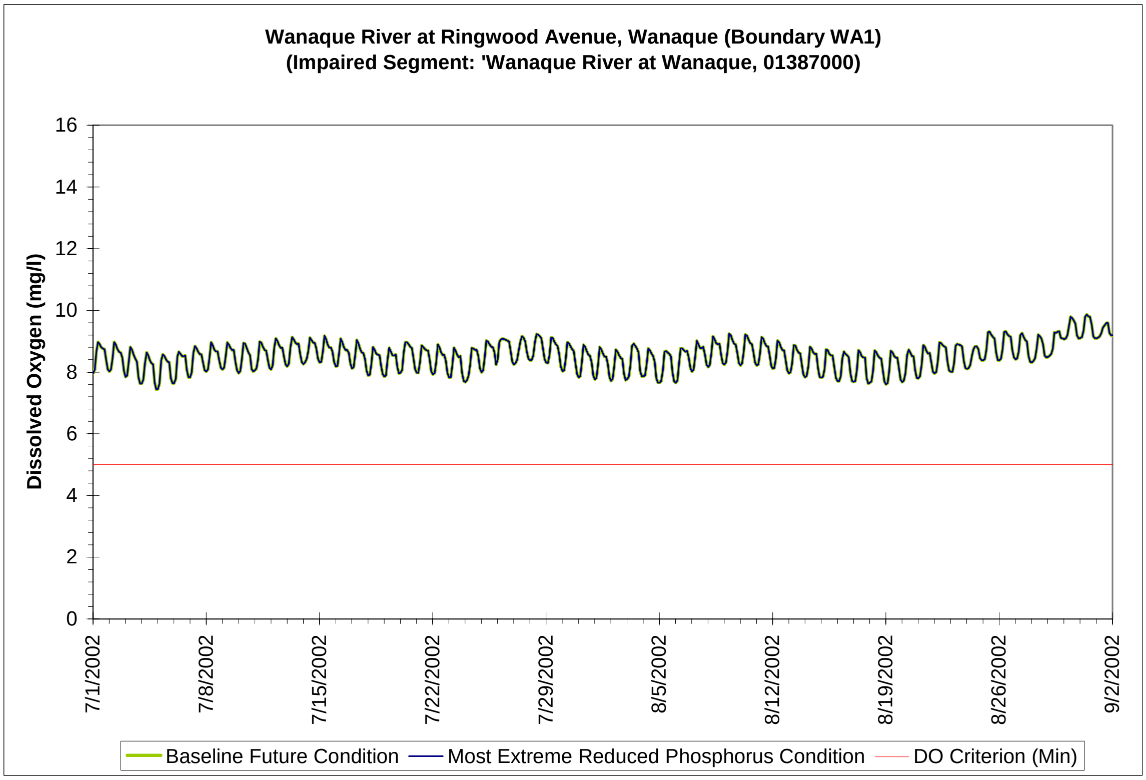


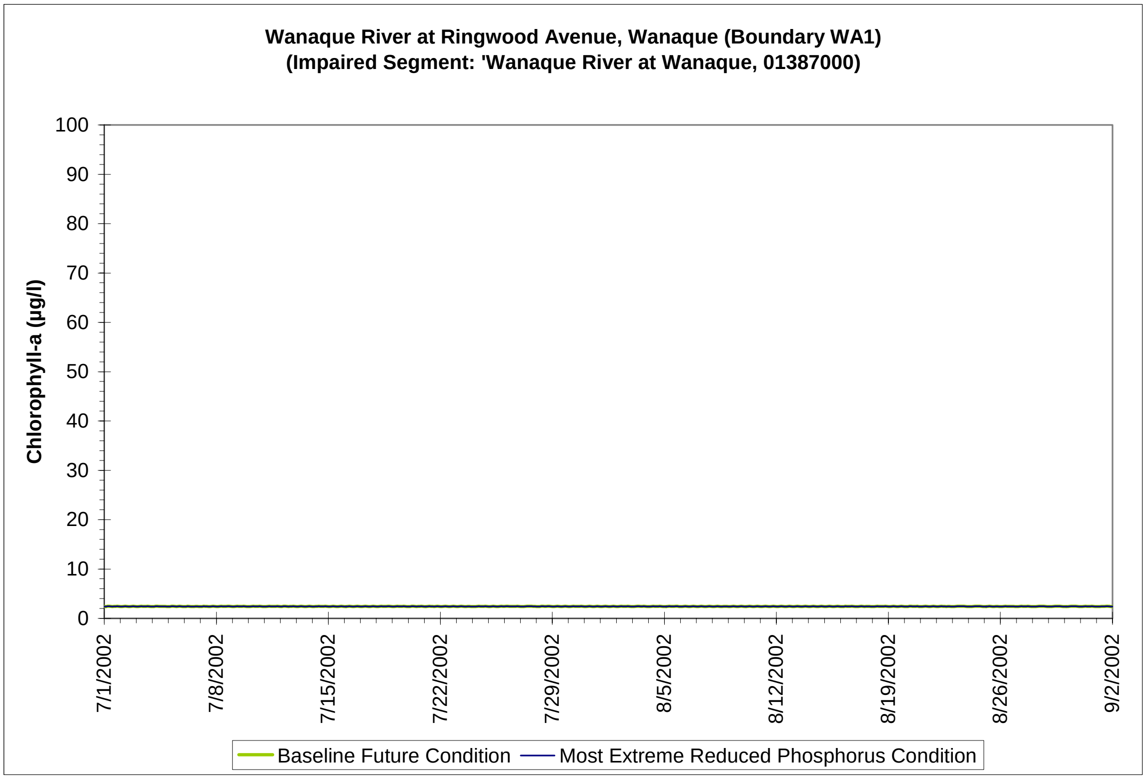
The Impact of Reducing Phosphorus on the Passaic River Basin



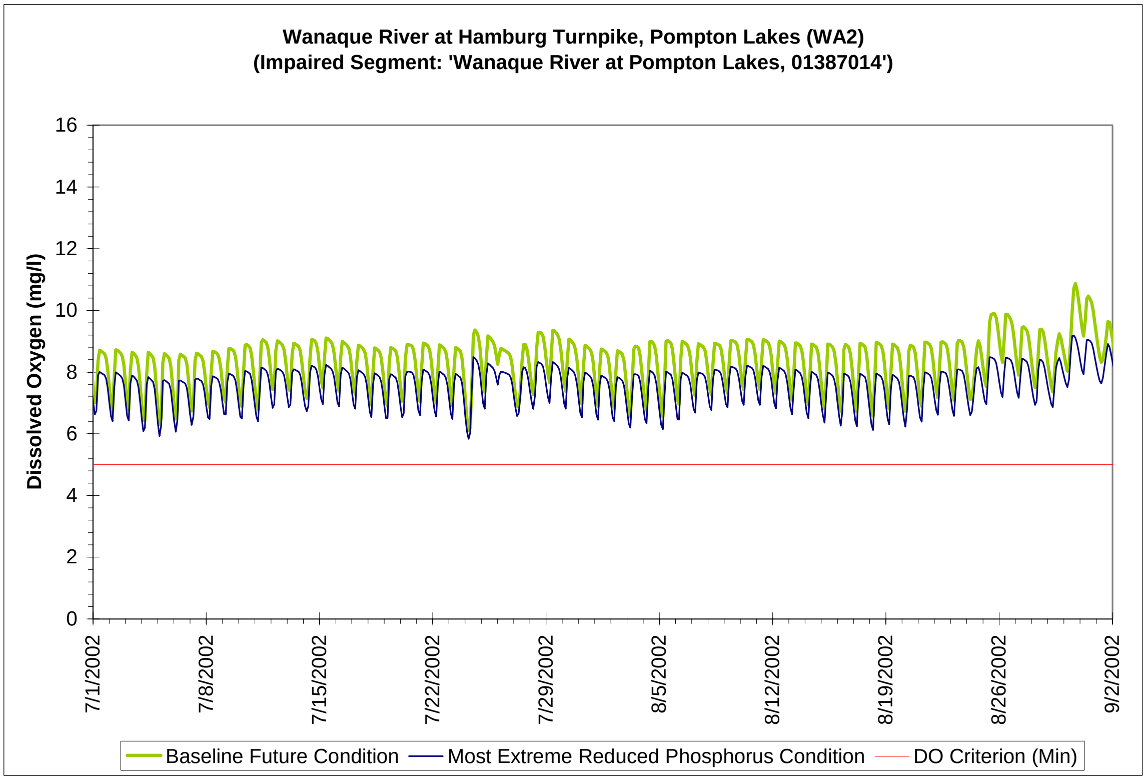


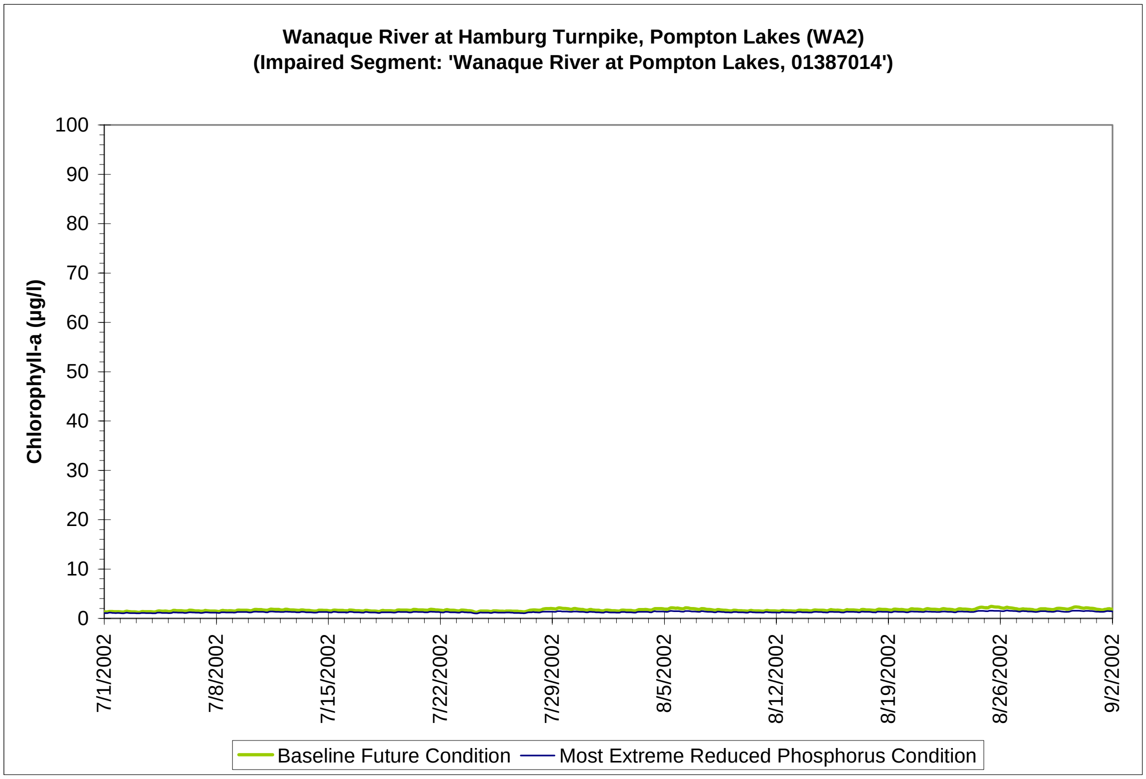
The Impact of Reducing Phosphorus on the Passaic River Basin



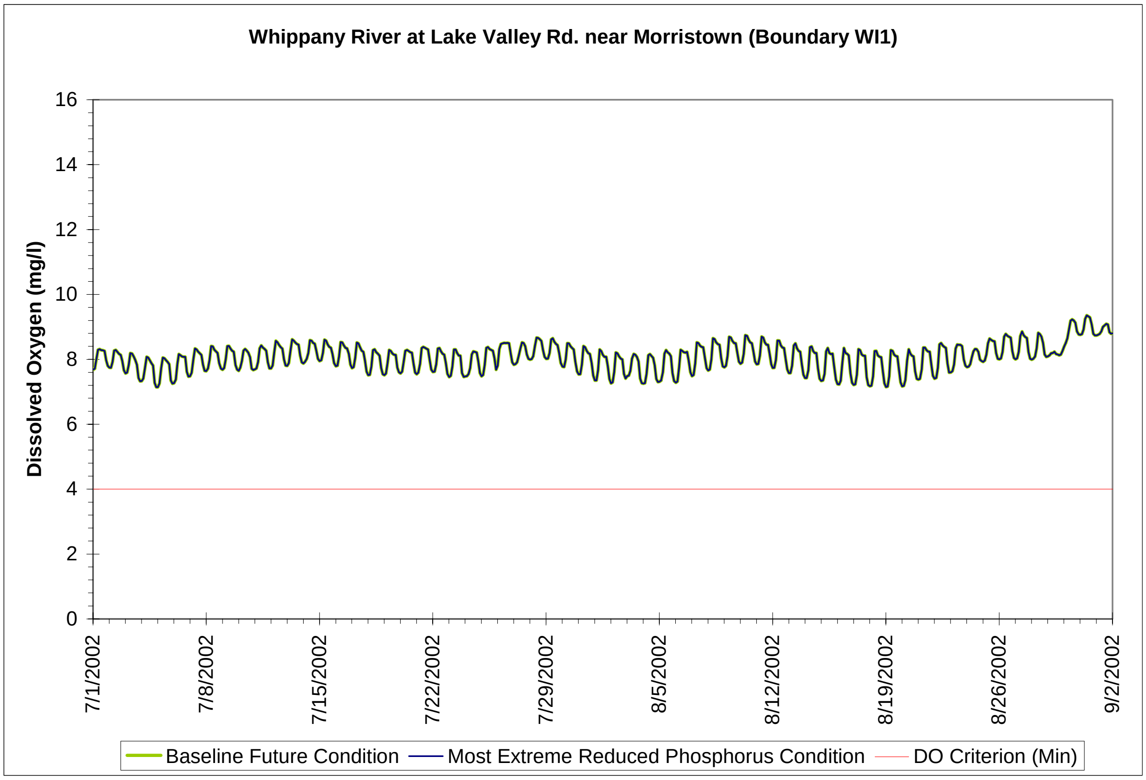


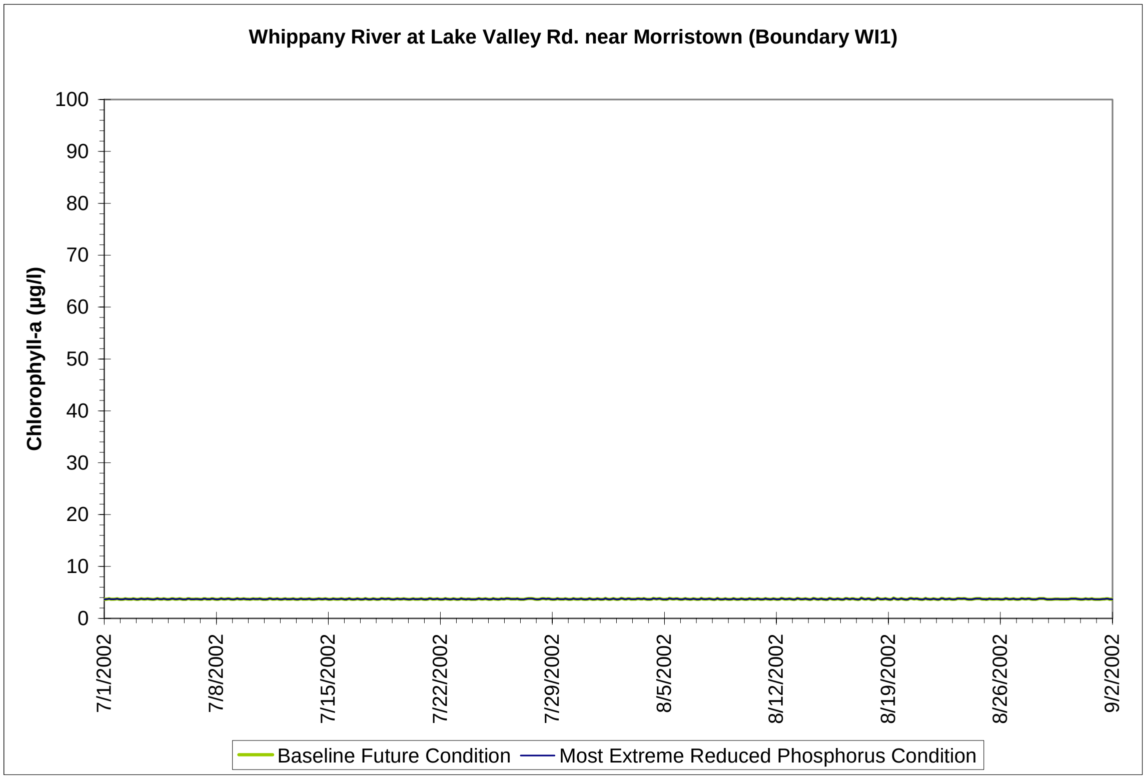
The Impact of Reducing Phosphorus on the Passaic River Basin



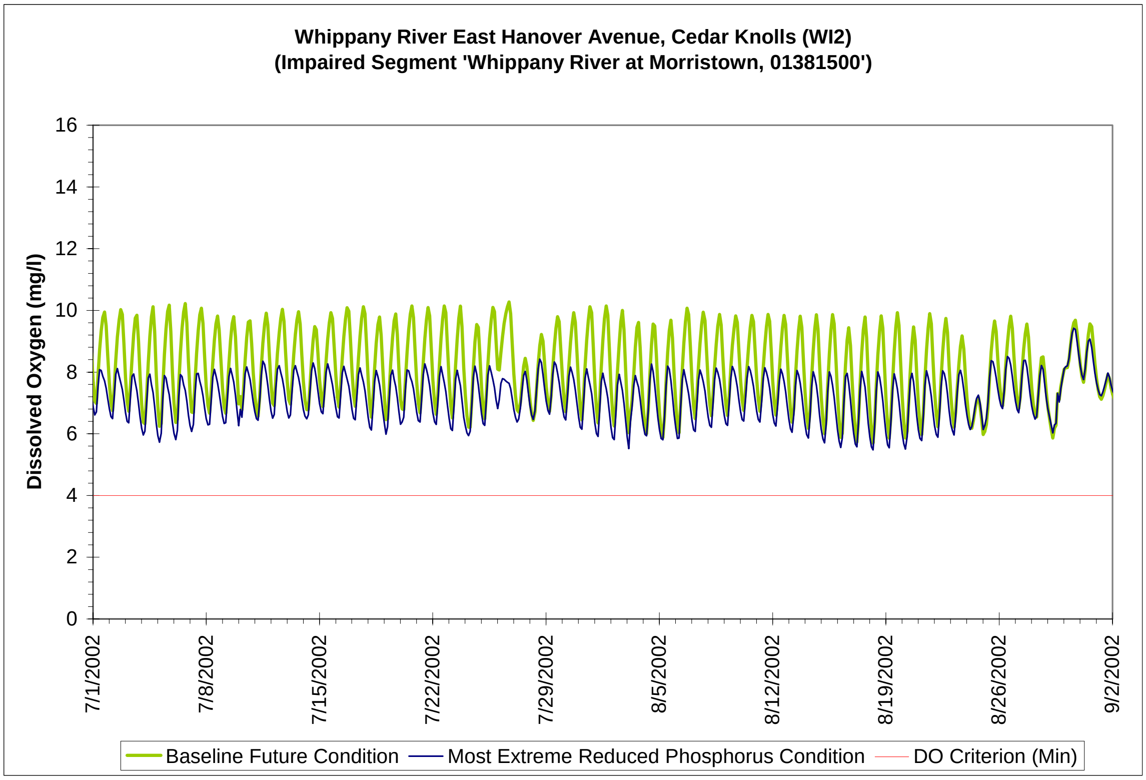


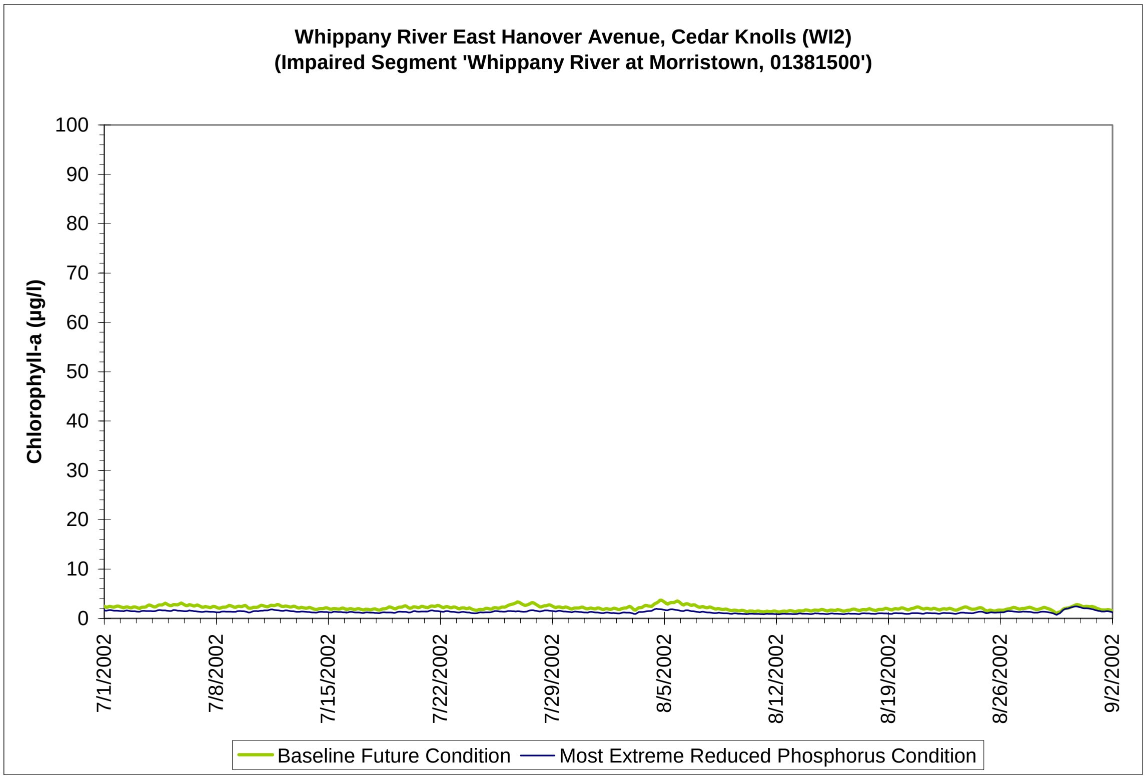
The Impact of Reducing Phosphorus on the Passaic River Basin



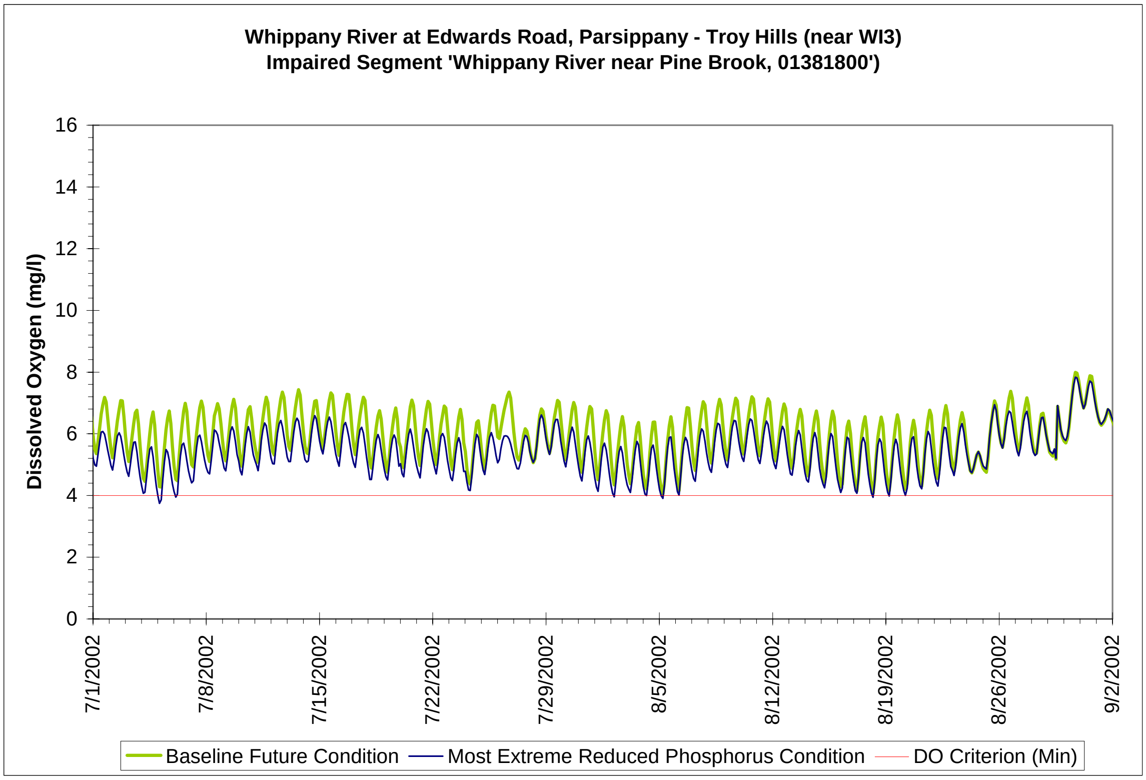


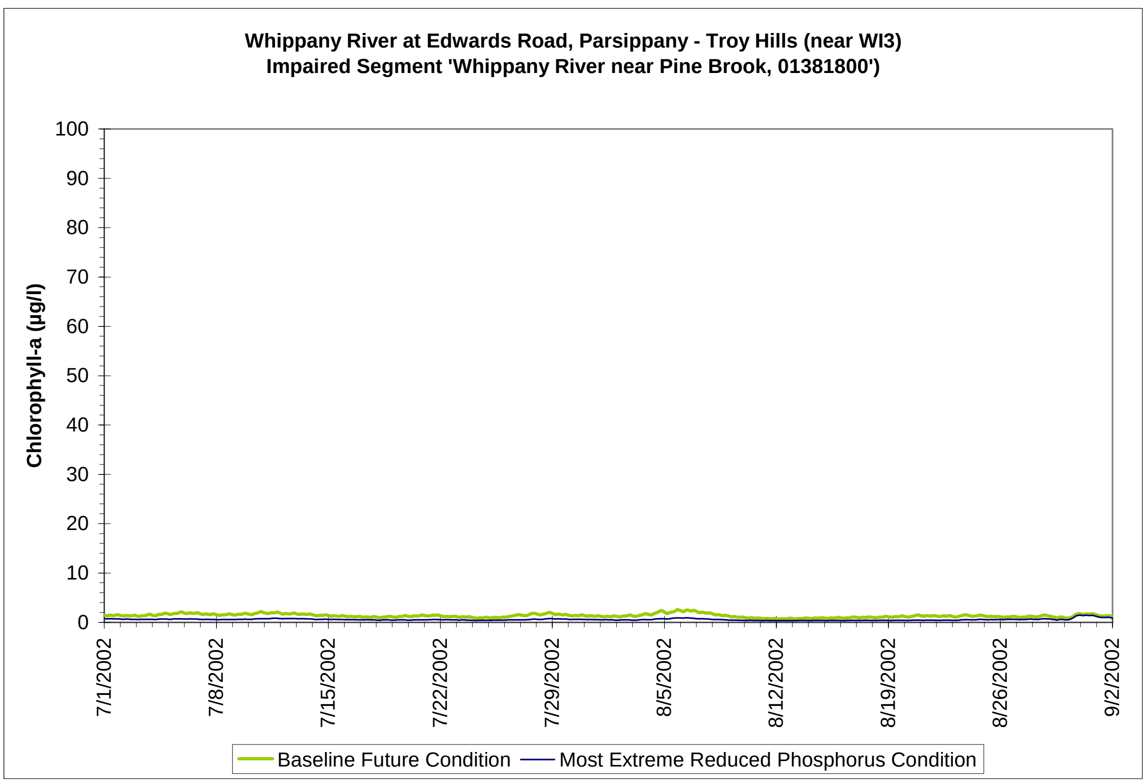
The Impact of Reducing Phosphorus on the Passaic River Basin





The Impact of Reducing Phosphorus on the Passaic River Basin

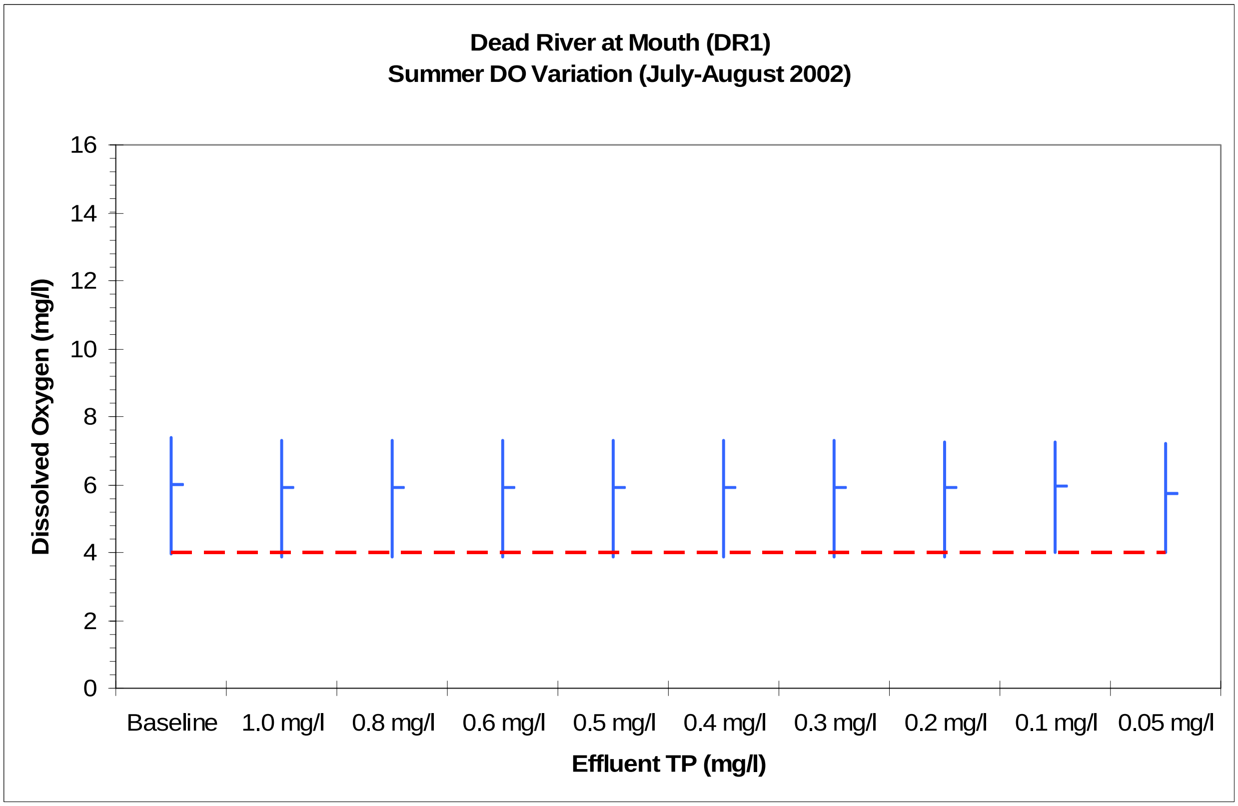


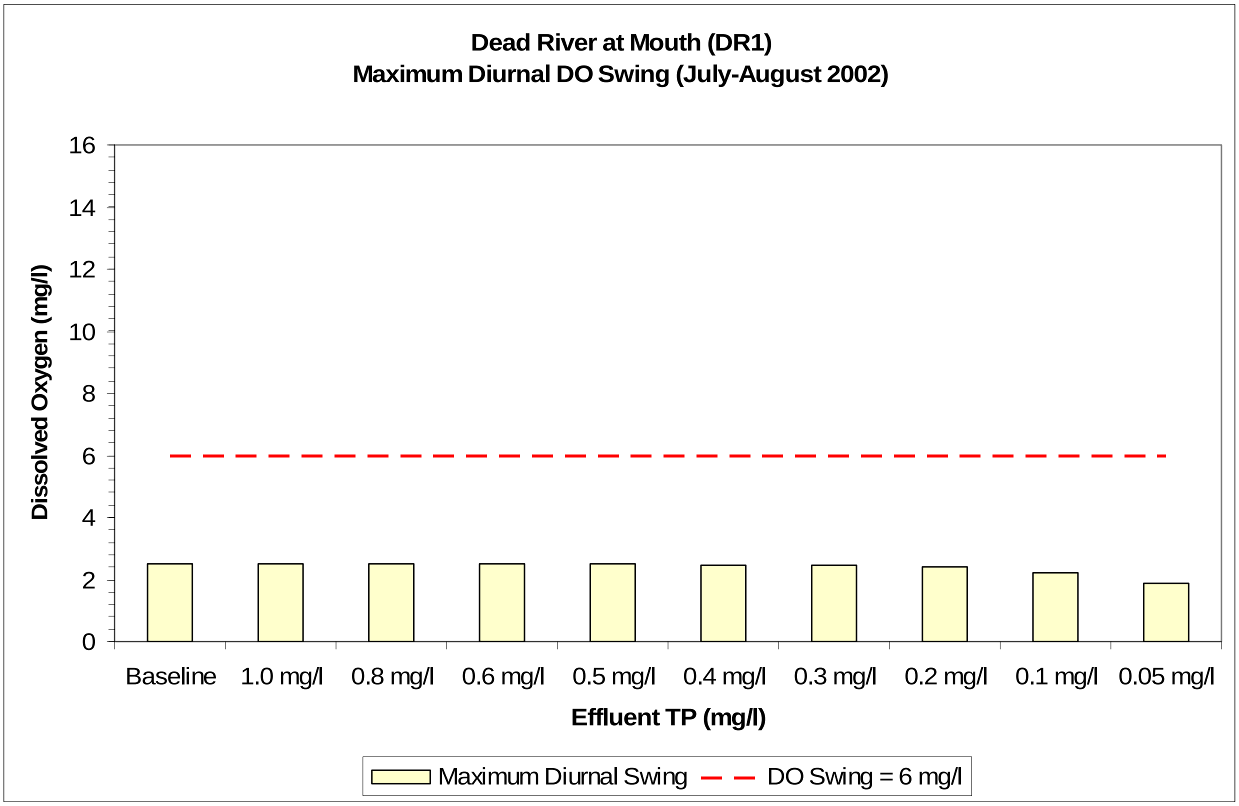


APPENDIX K

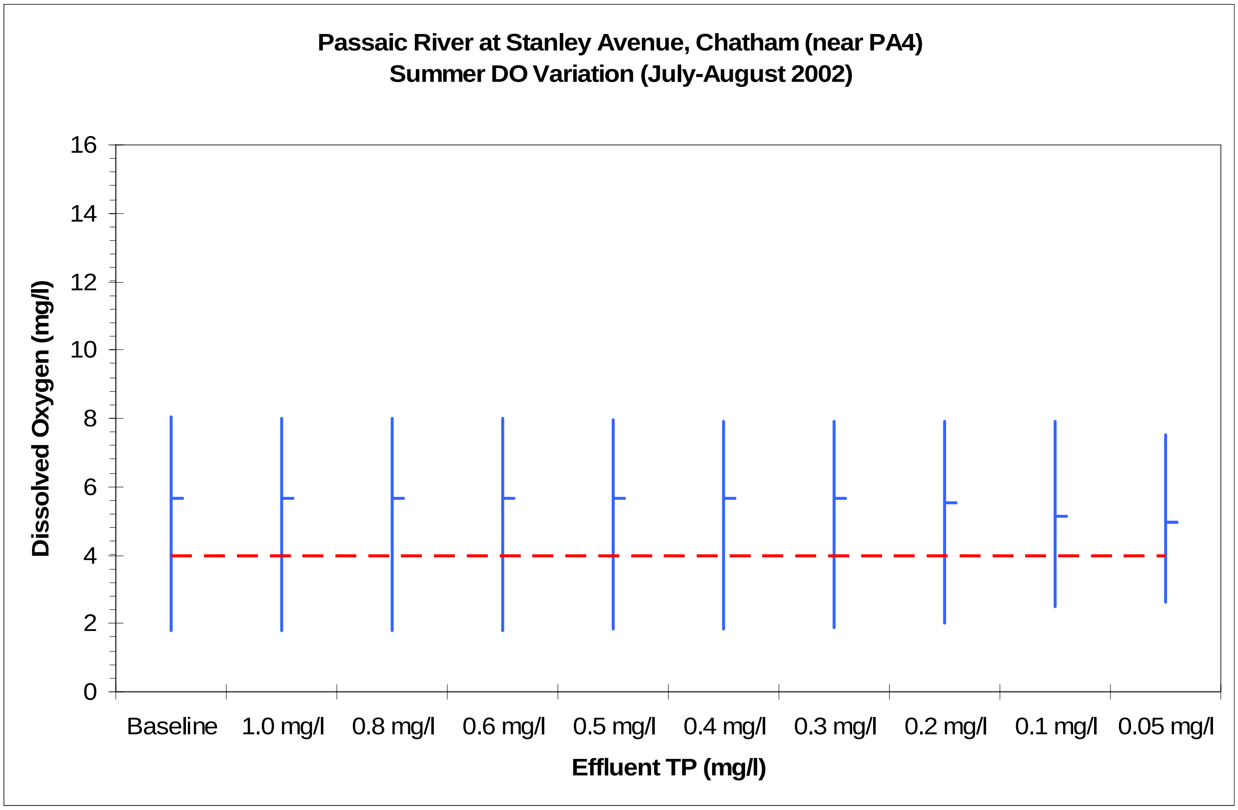
Sensitivity of Productivity Indicators to Effluent Phosphorus Concentration

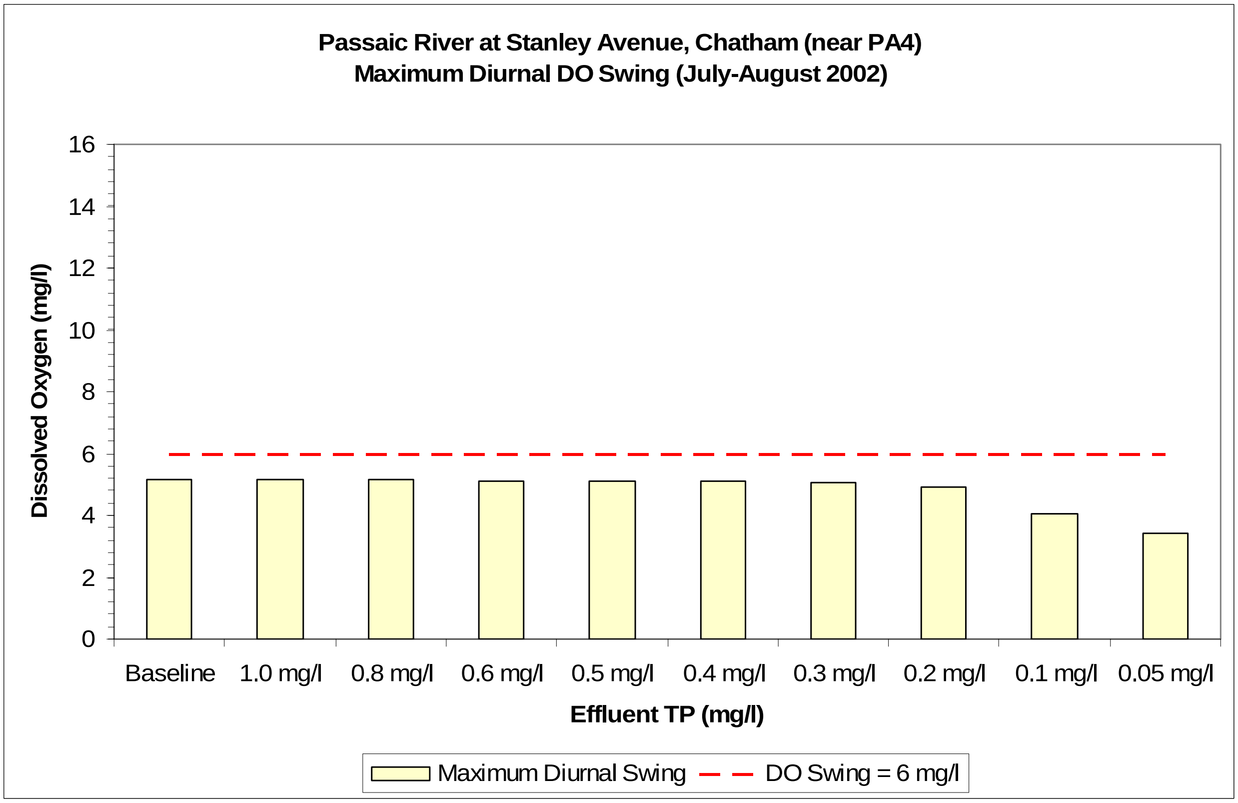
Sensitivity of Productivity Indicators to Effluent Concentration



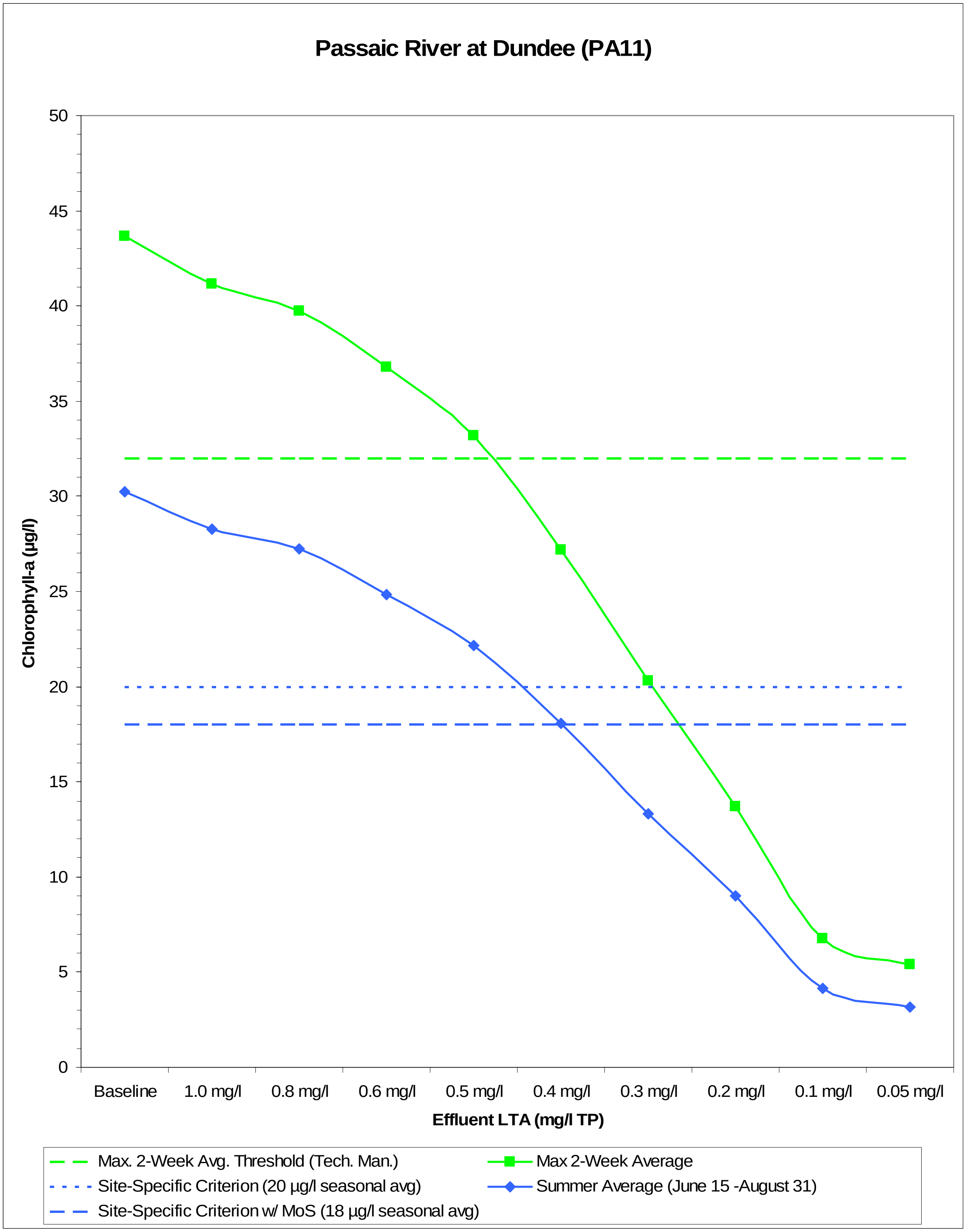


Sensitivity of Productivity Indicators to Effluent Concentration

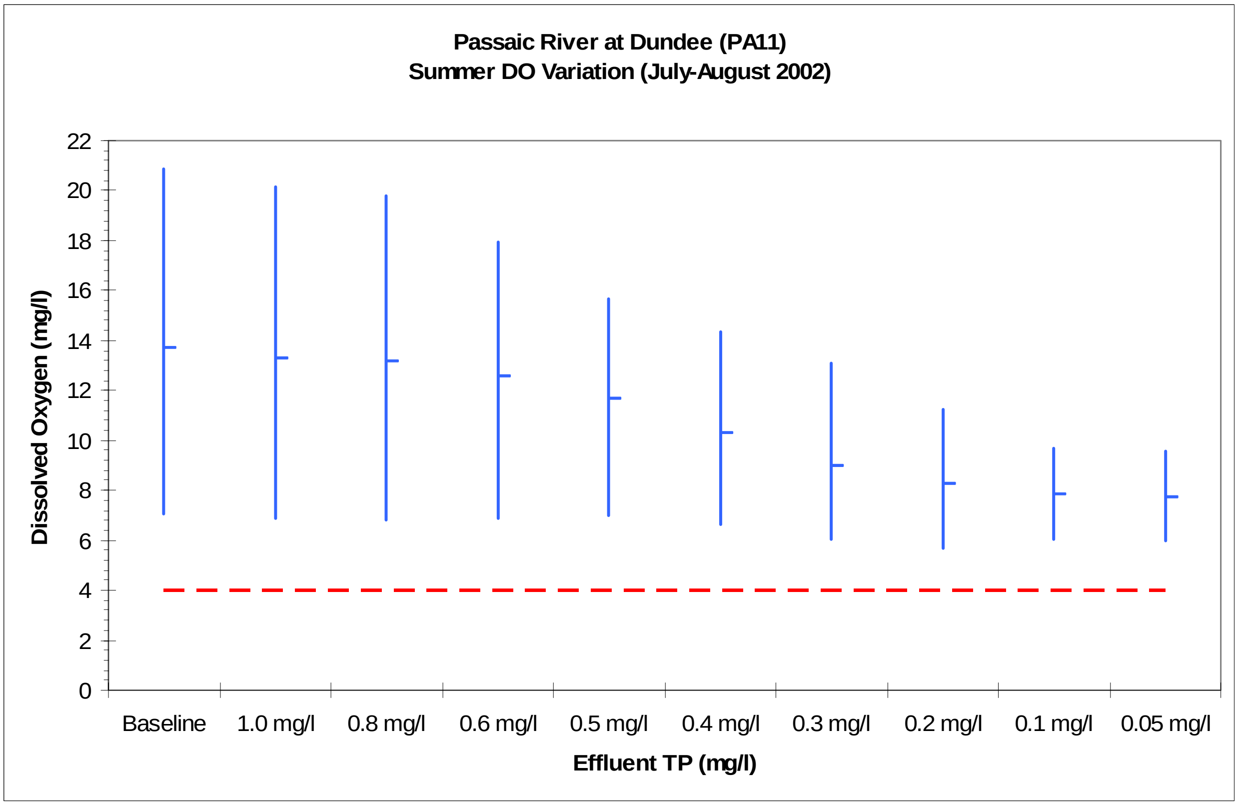


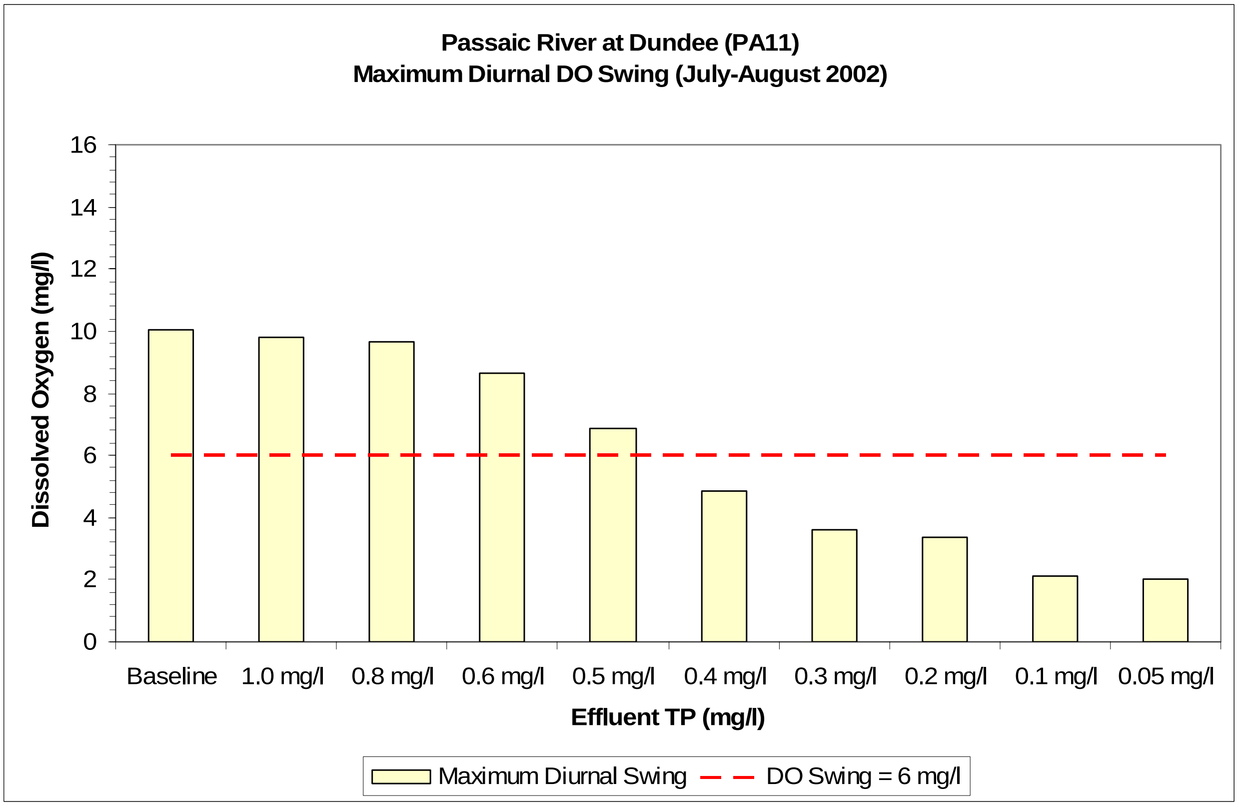


Sensitivity of Productivity Indicators to Effluent Concentration

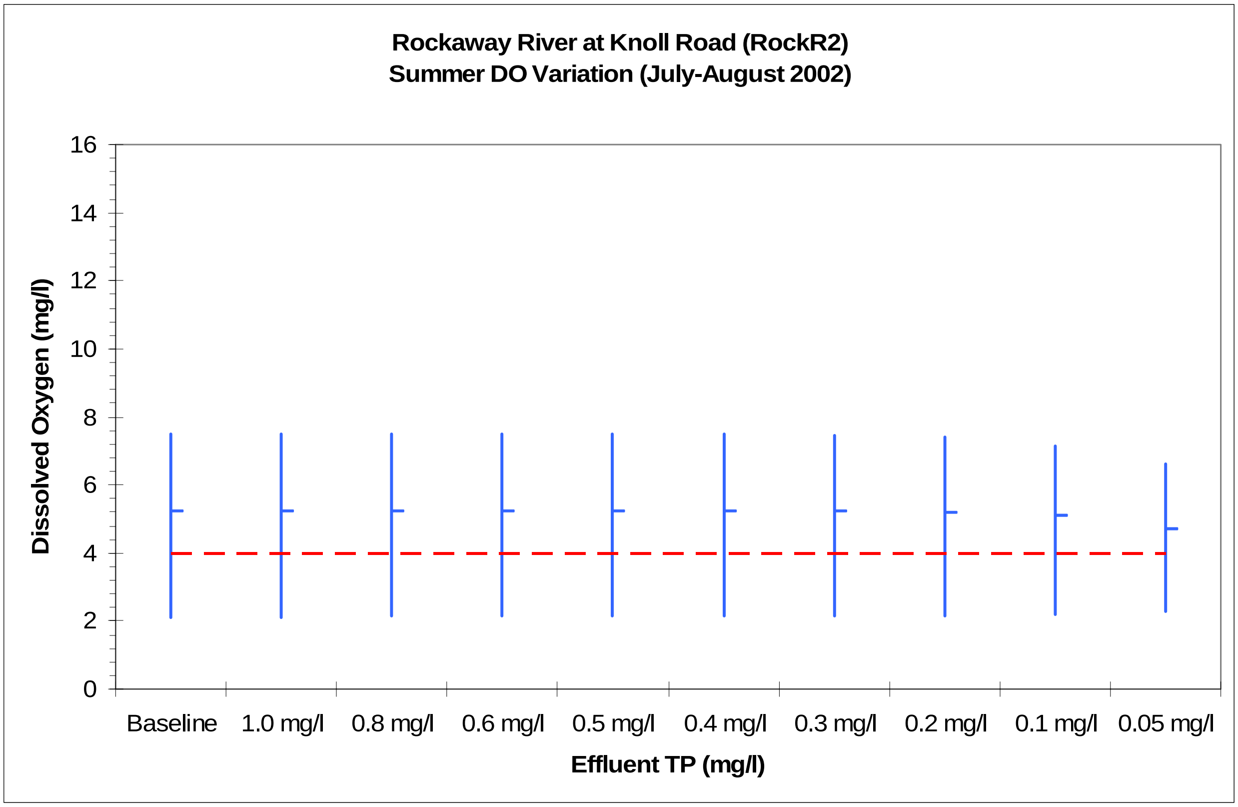


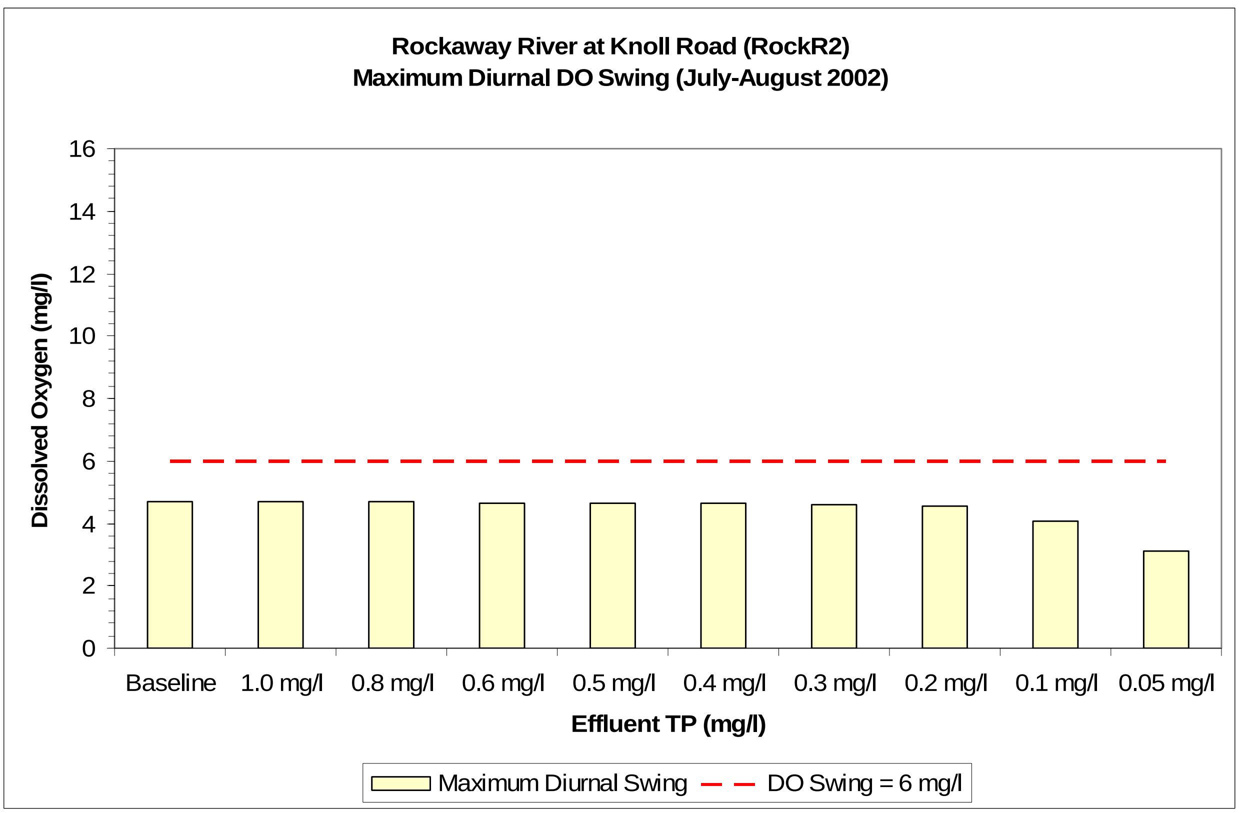
Sensitivity of Productivity Indicators to Effluent Concentration



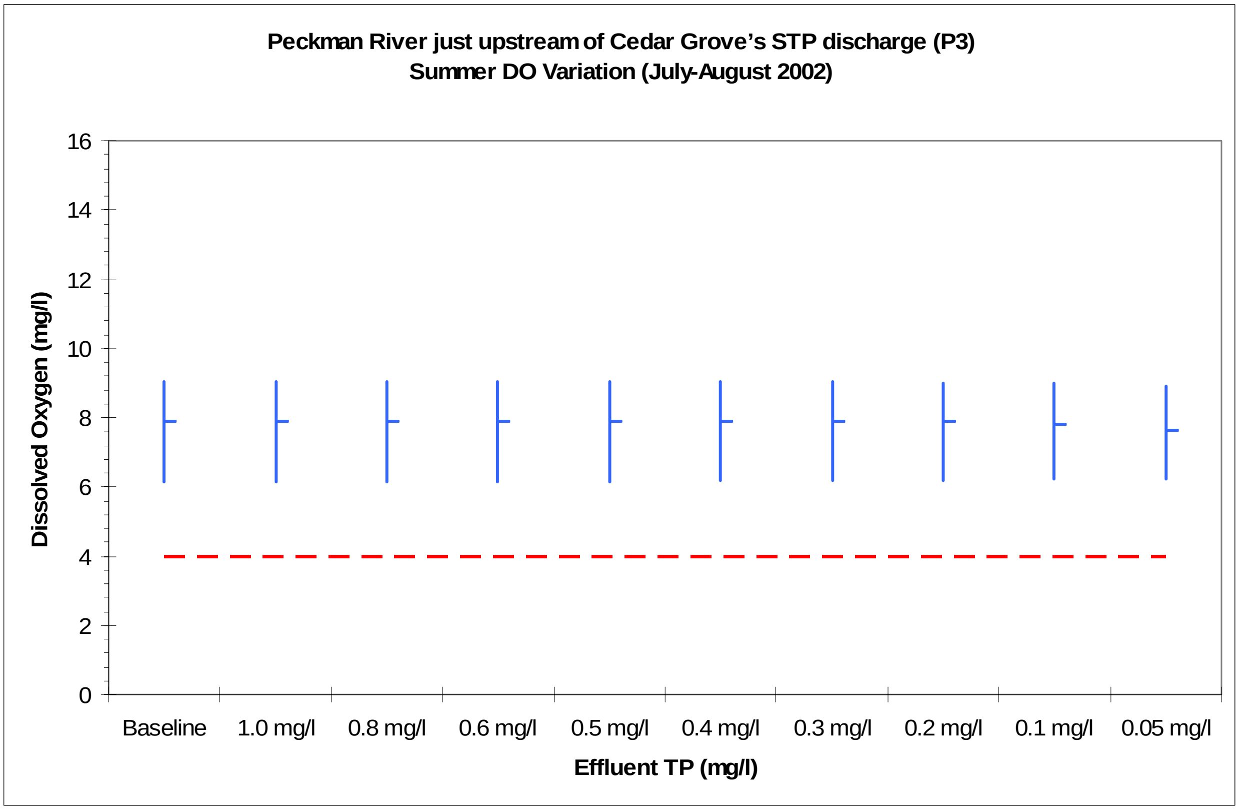


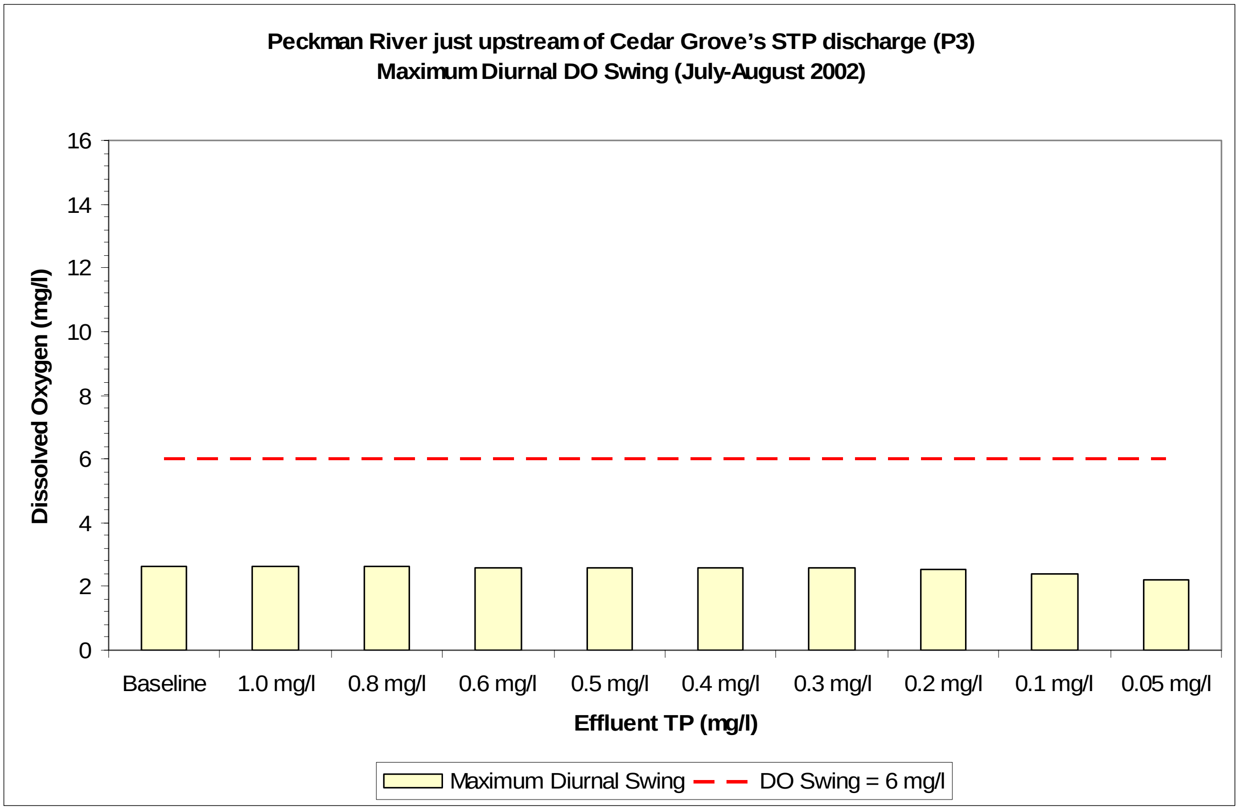
Sensitivity of Productivity Indicators to Effluent Concentration



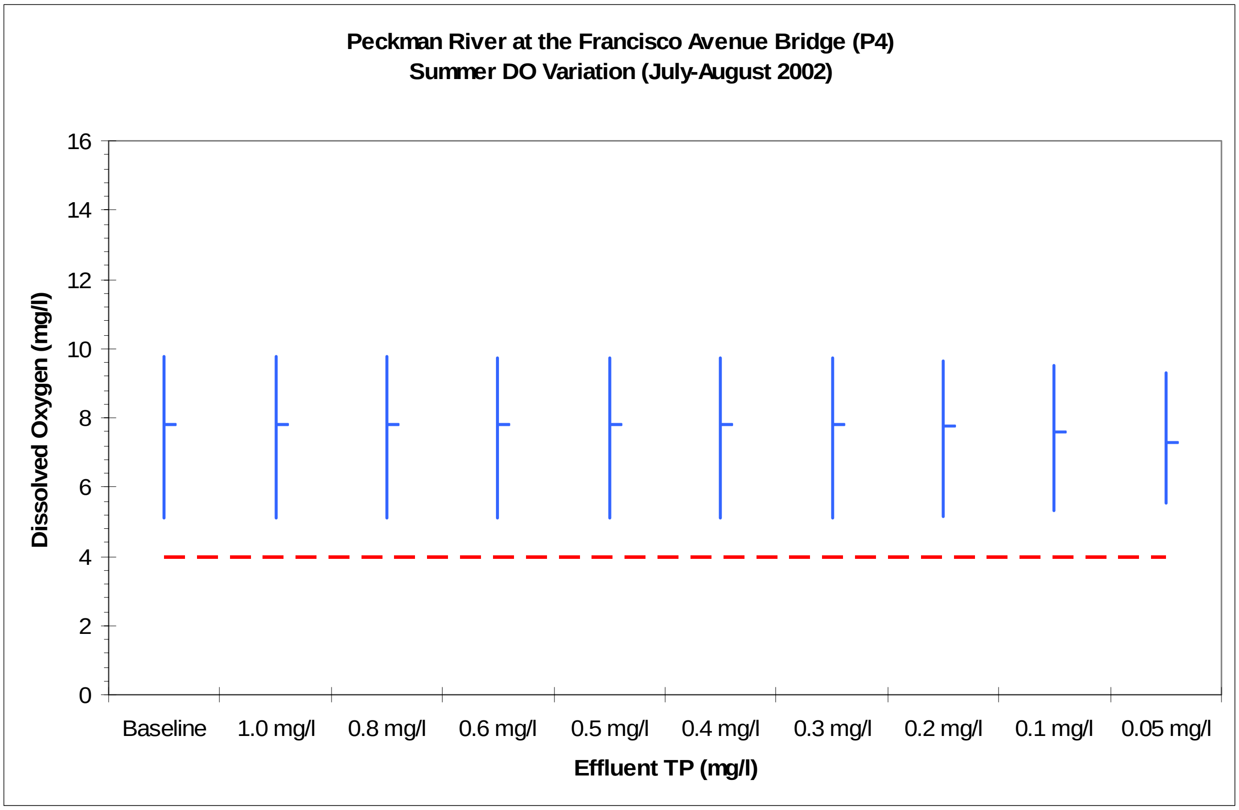


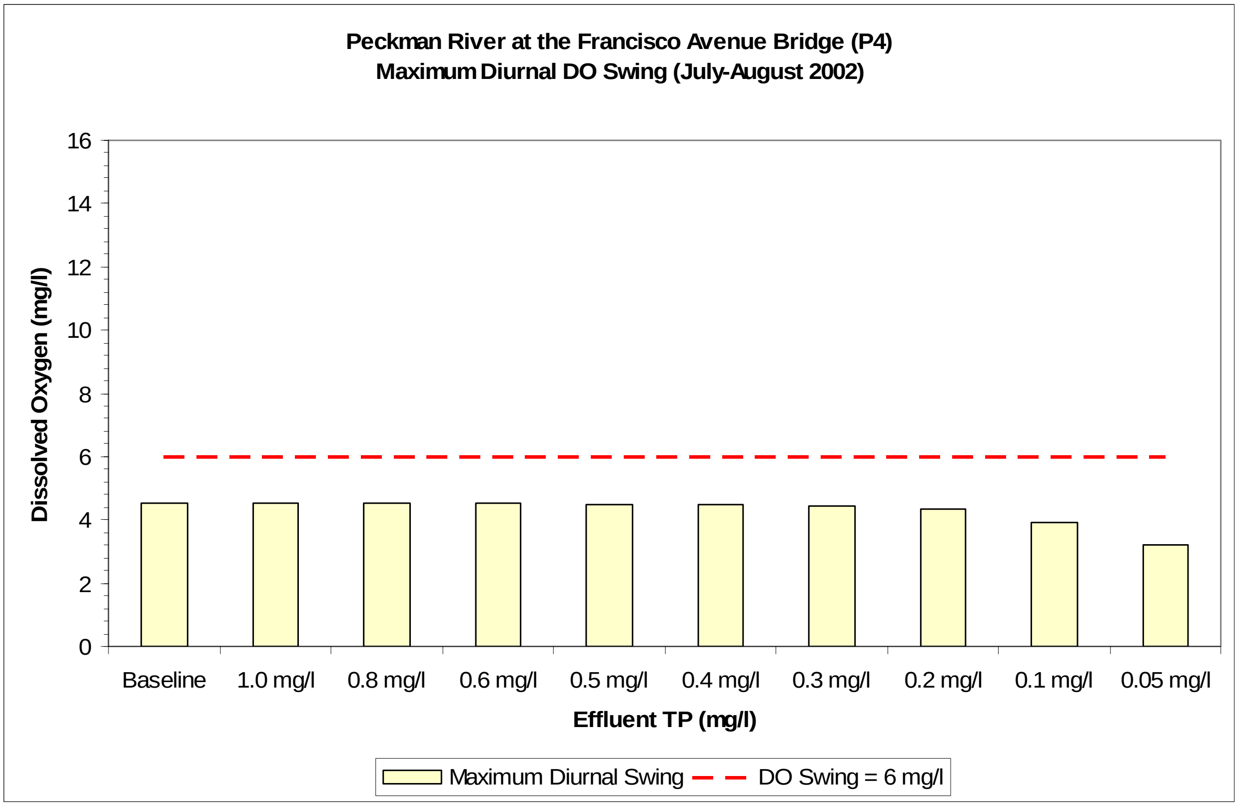
Sensitivity of Productivity Indicators to Effluent Concentration



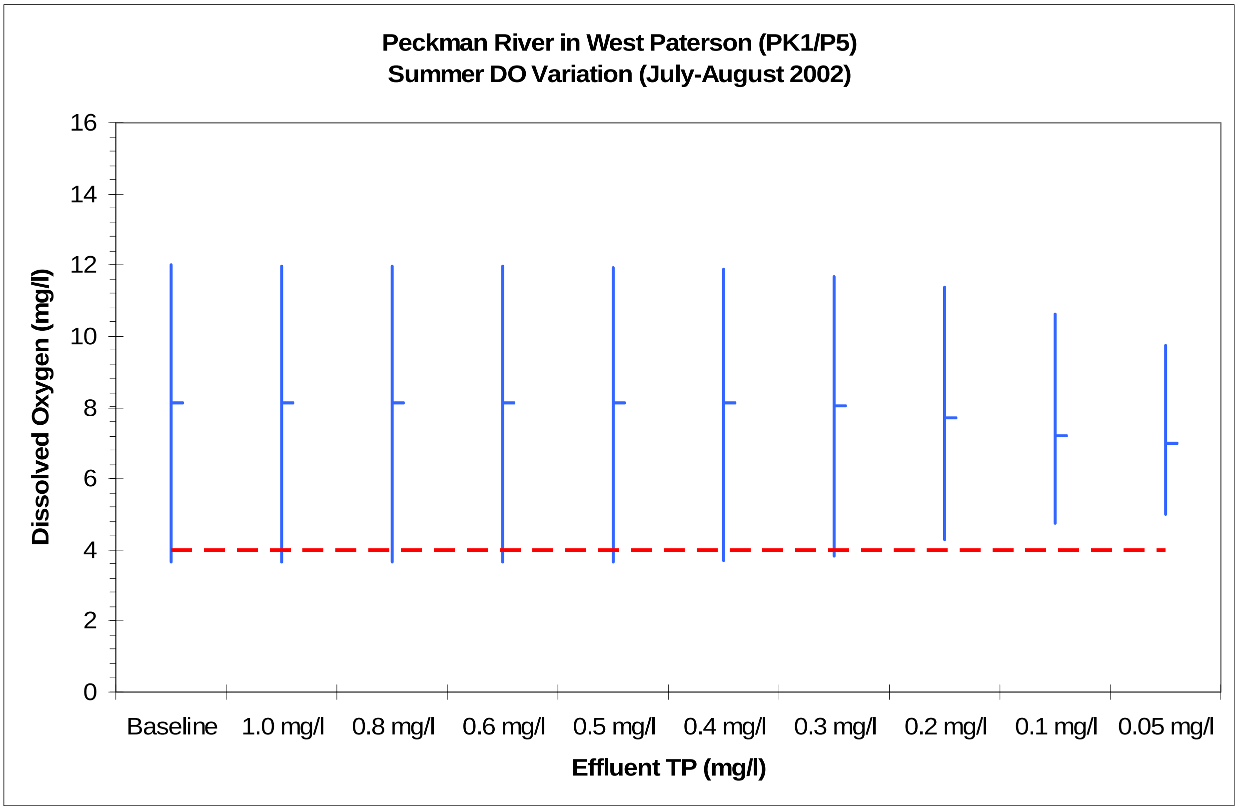


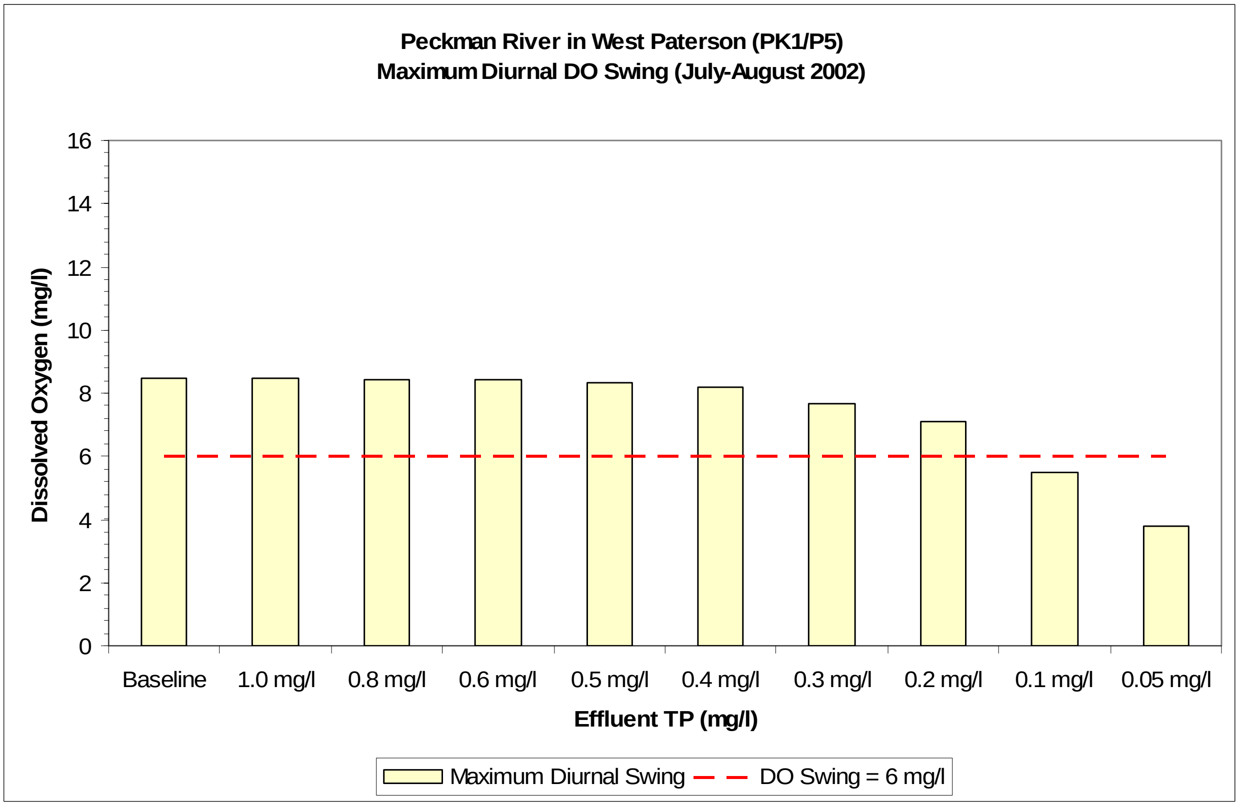
Sensitivity of Productivity Indicators to Effluent Concentration





Sensitivity of Productivity Indicators to Effluent Concentration

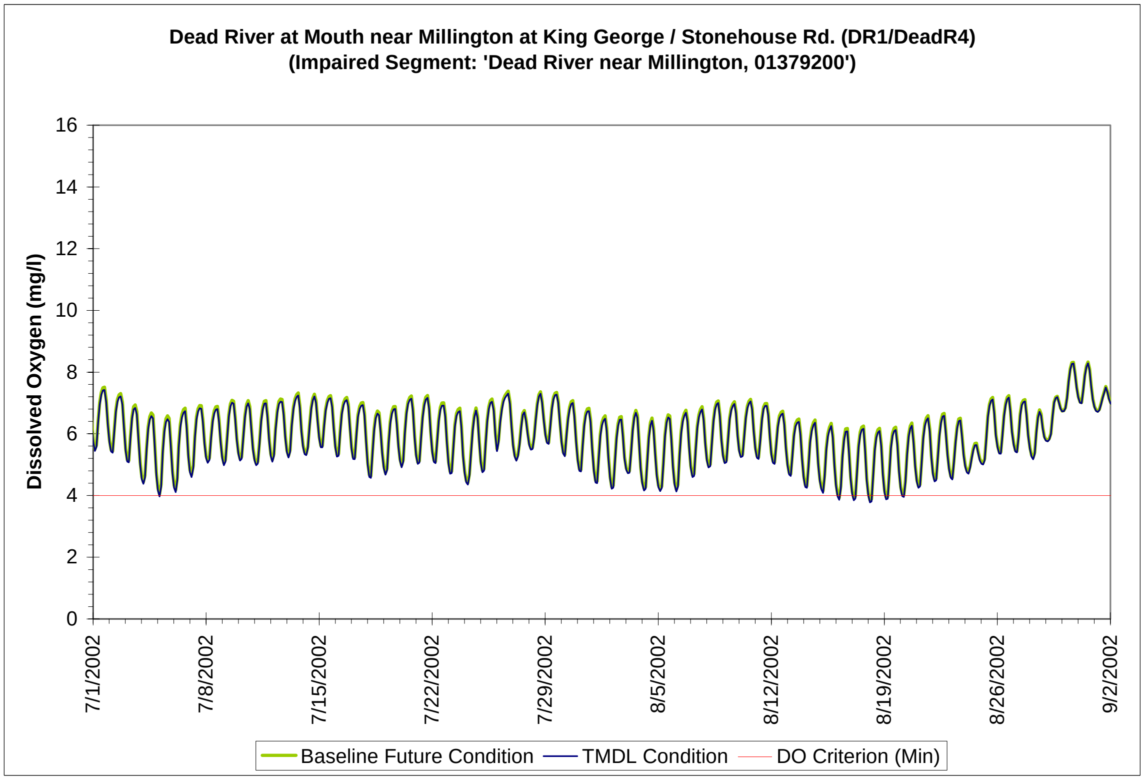




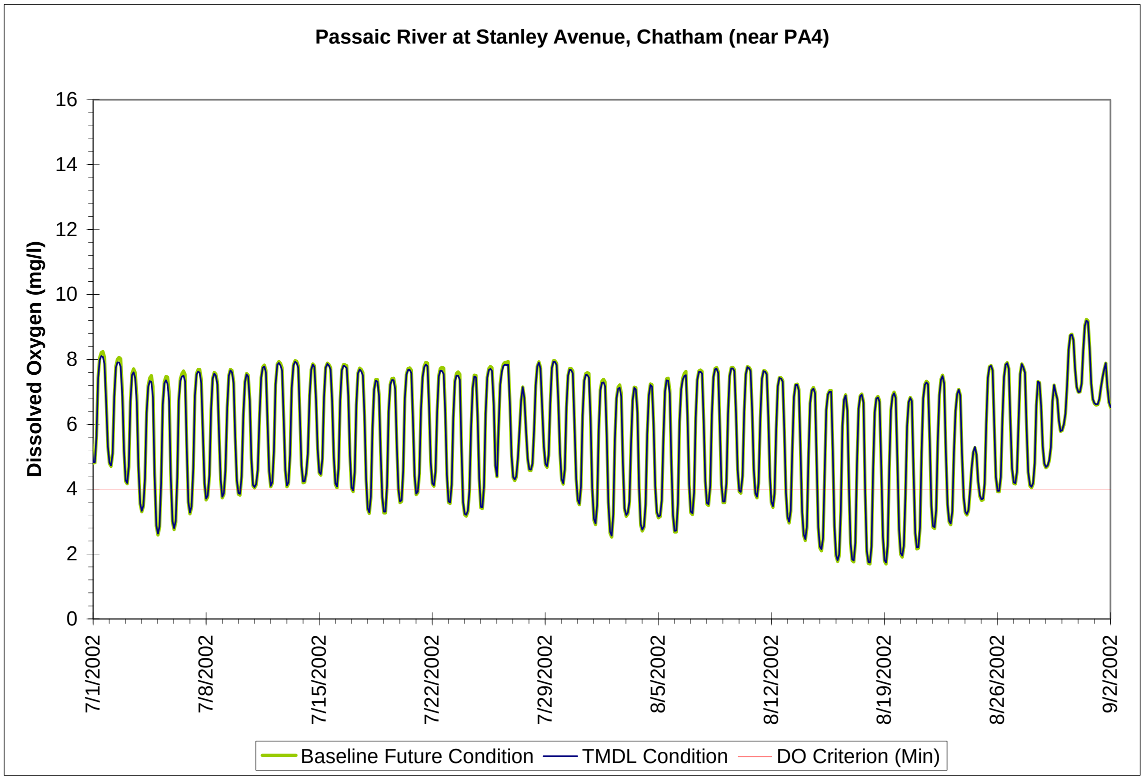
APPENDIX L

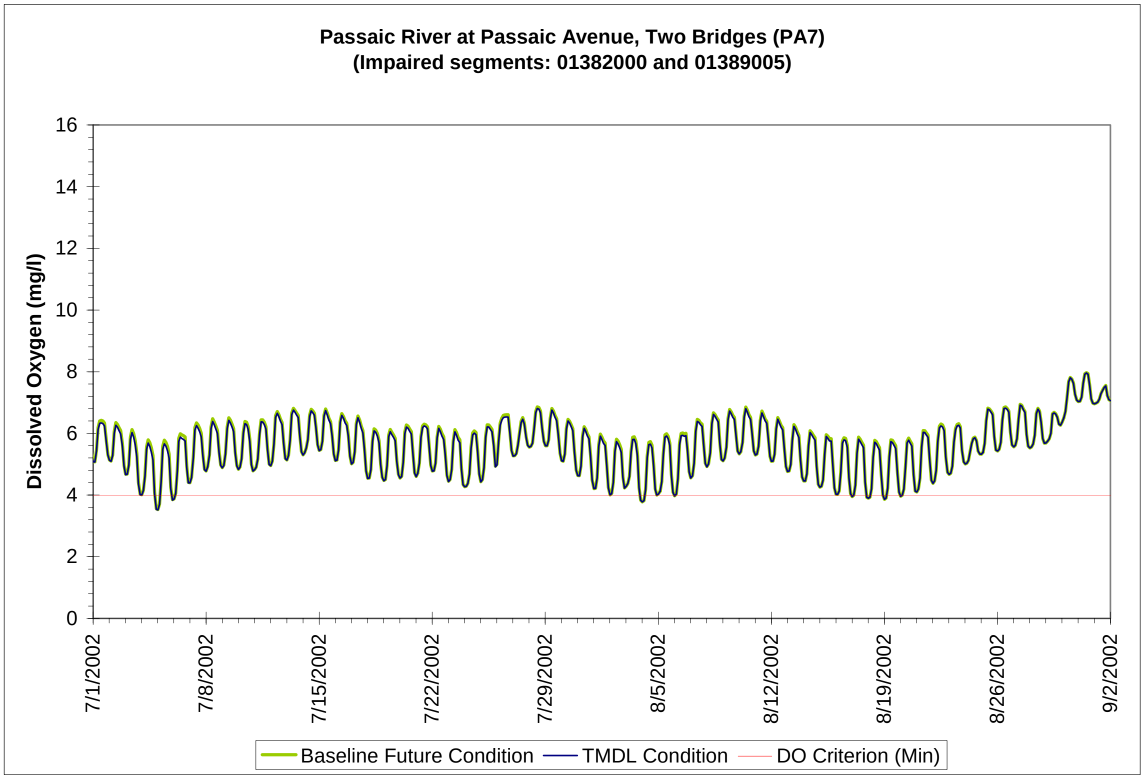
Impact of TMDL Condition:
TMDL vs. Baseline

The Impact of the TMDL Condition on the Passaic River Basin

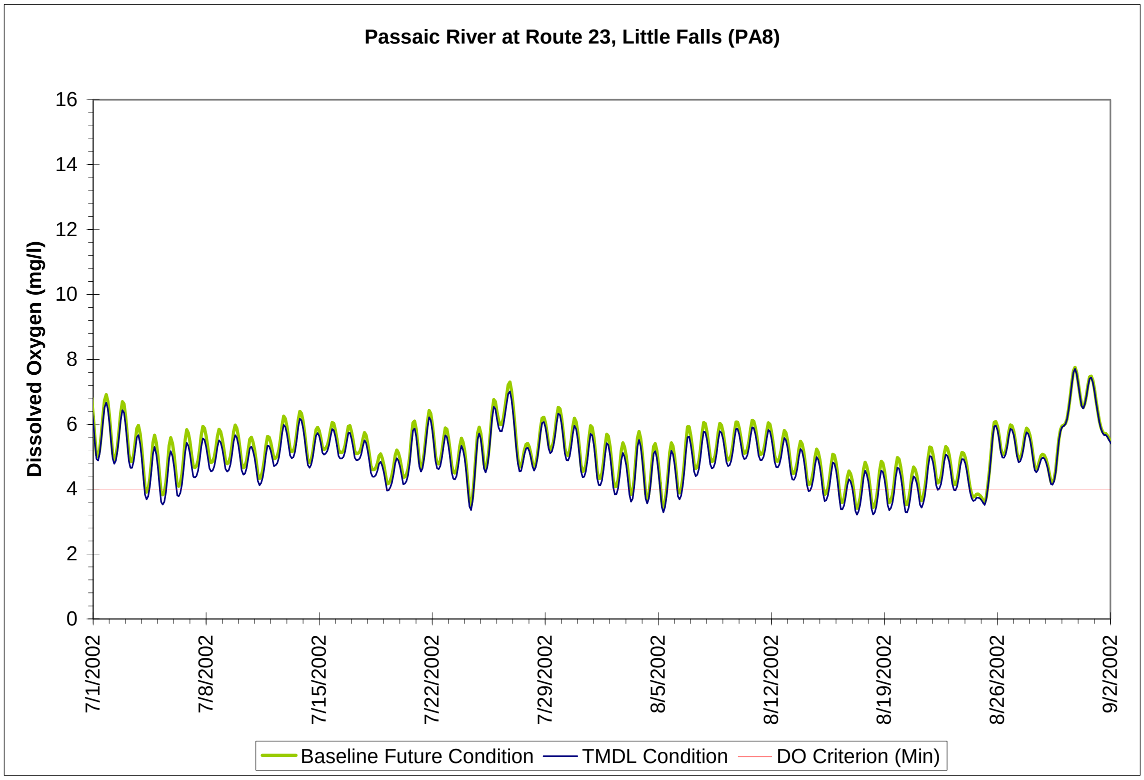


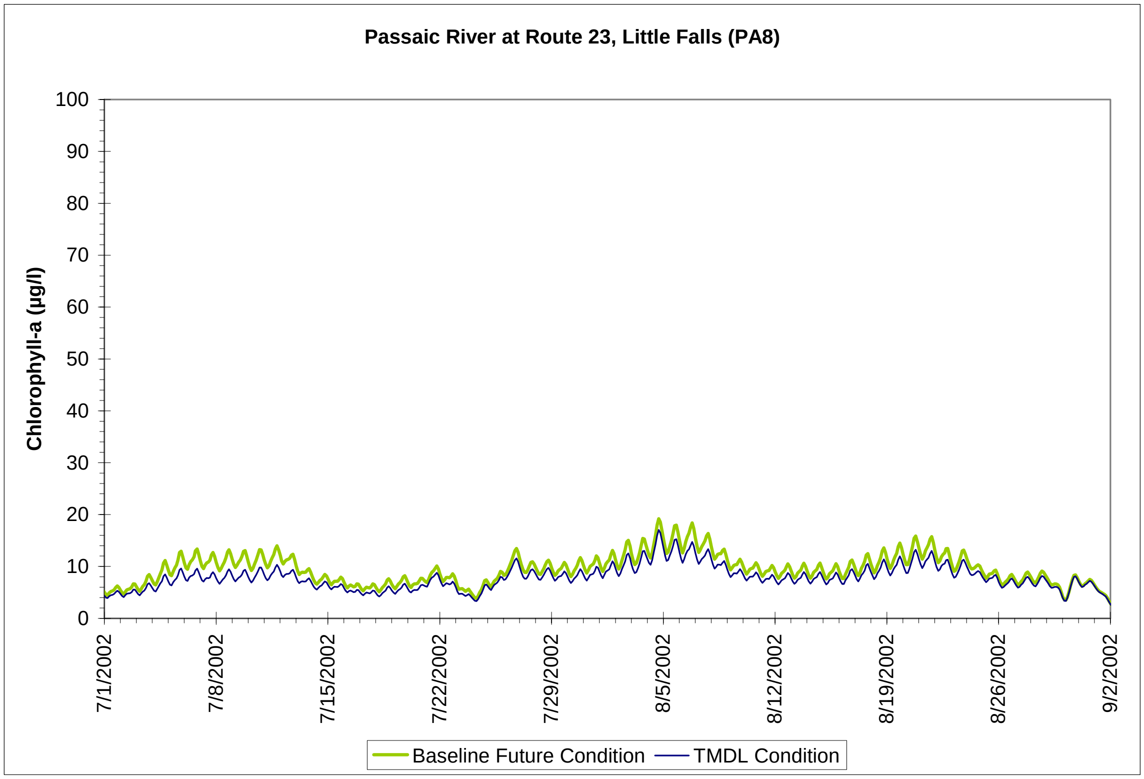
The Impact of the TMDL Condition on the Passaic River Basin



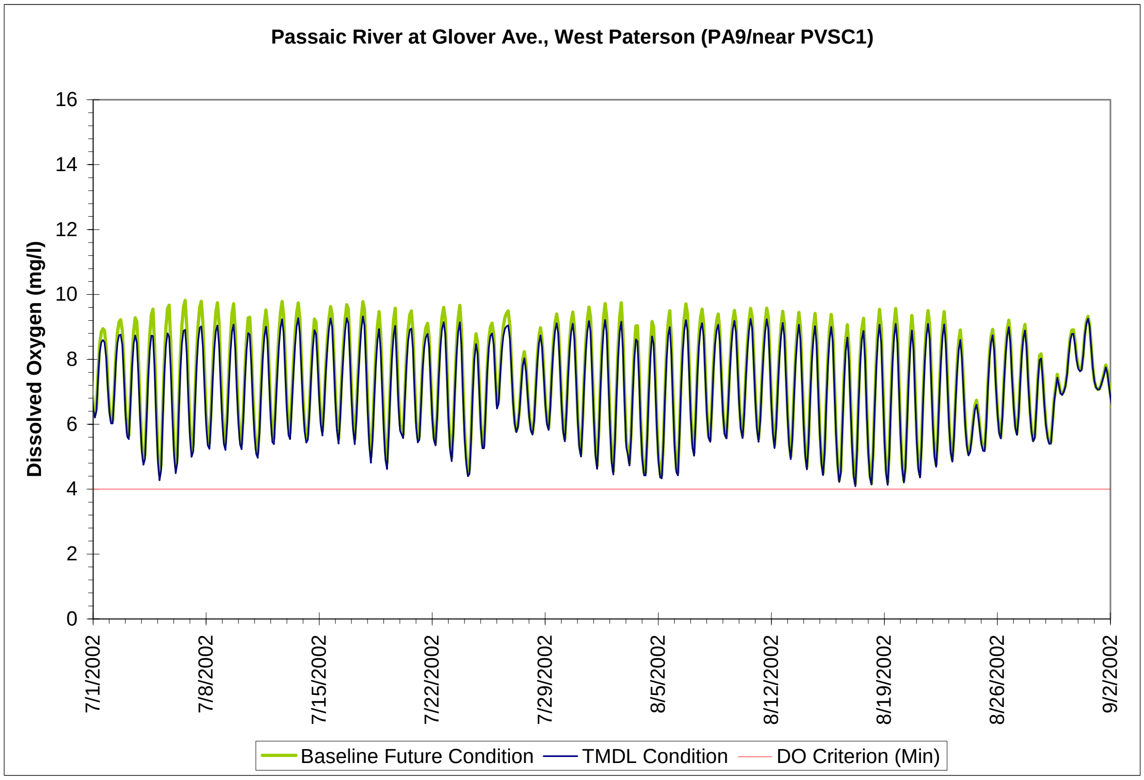


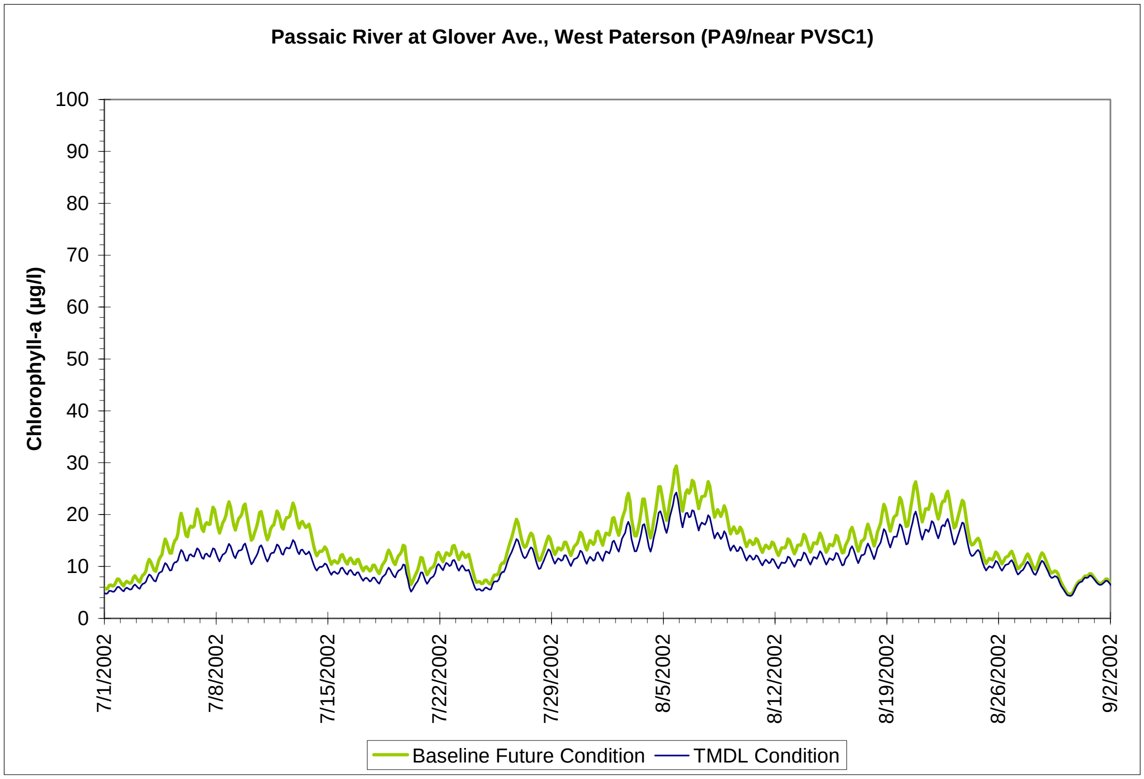
The Impact of the TMDL Condition on the Passaic River Basin



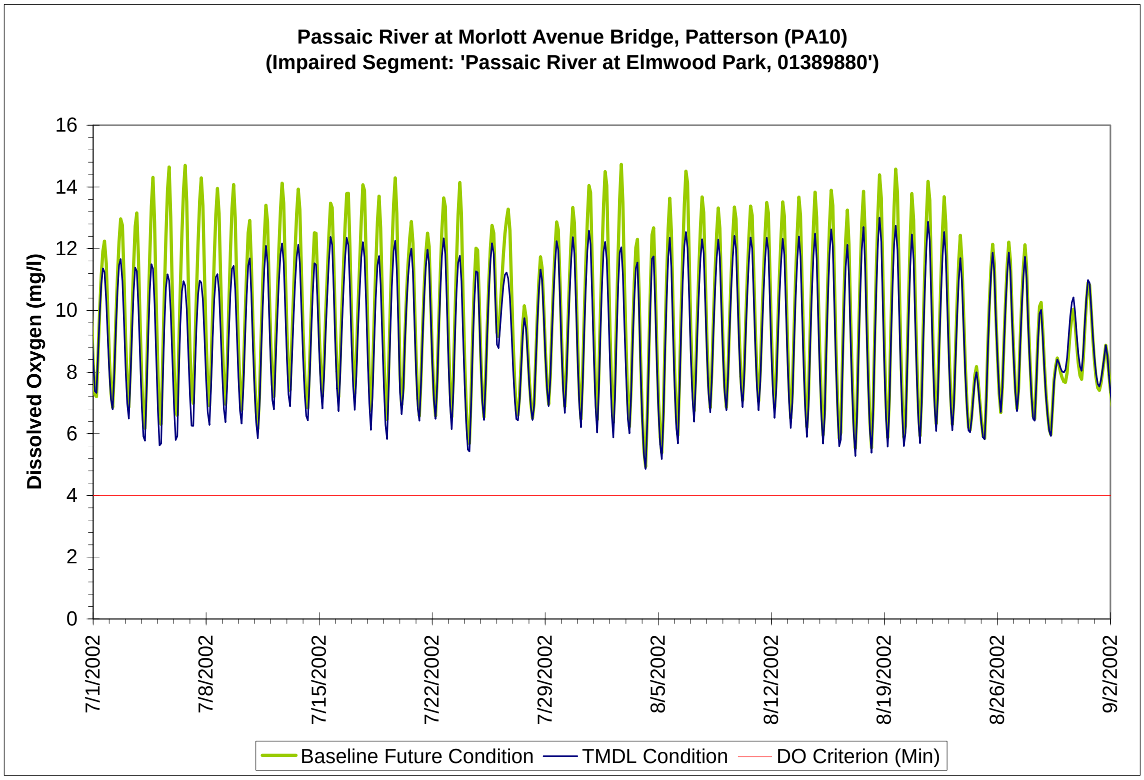


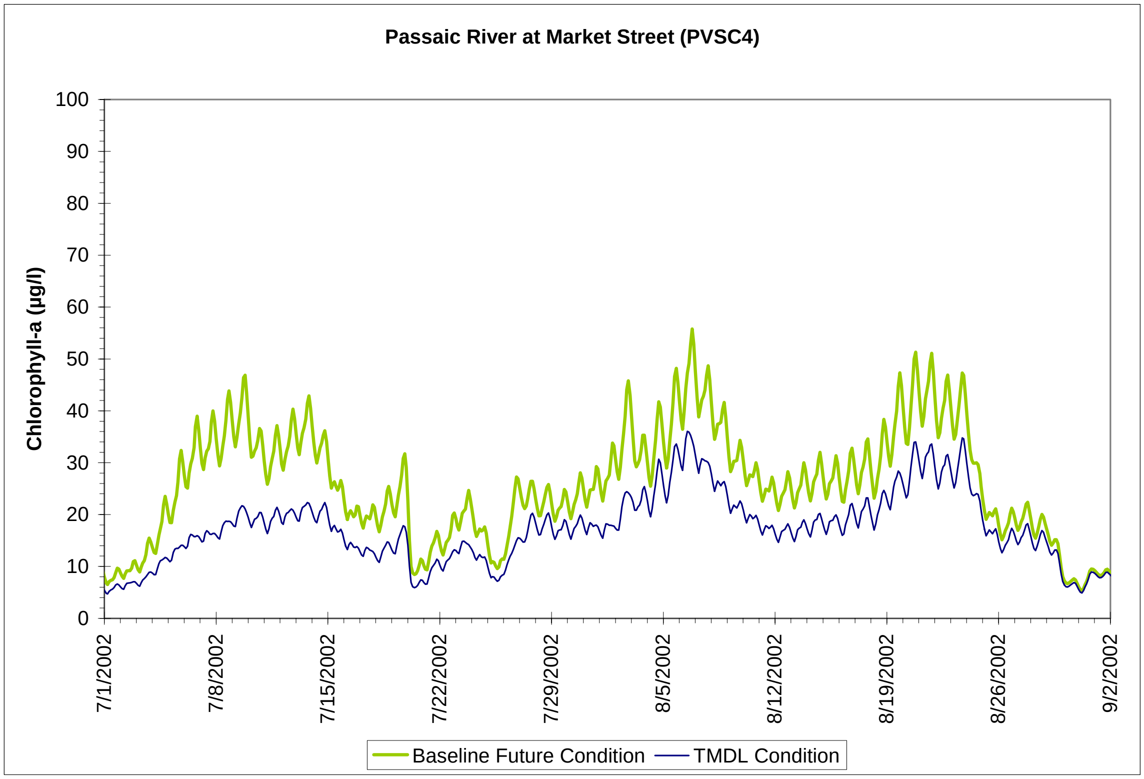
The Impact of the TMDL Condition on the Passaic River Basin



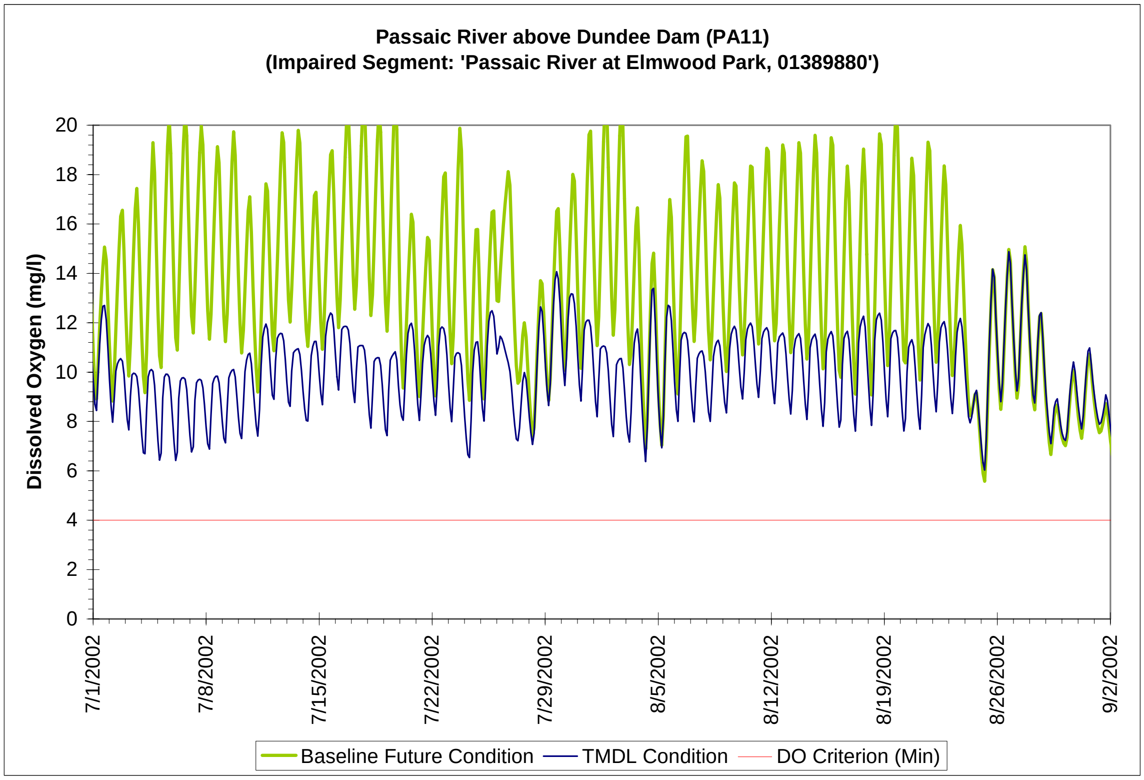


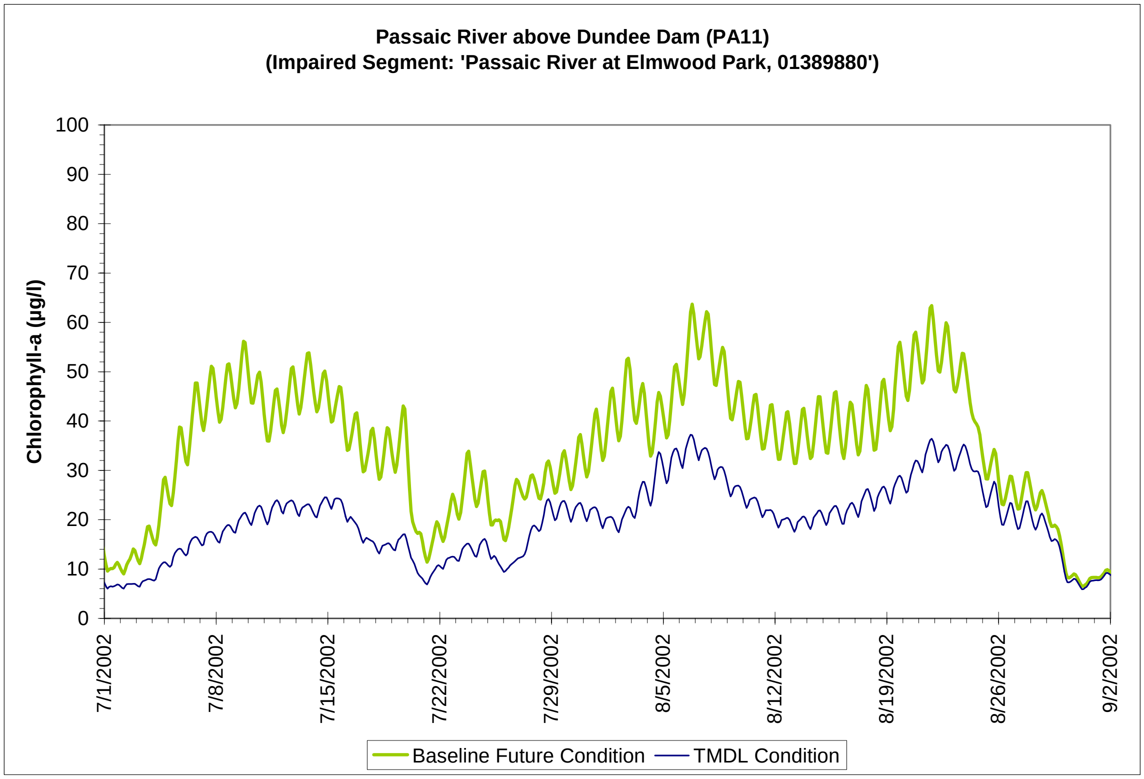
The Impact of the TMDL Condition on the Passaic River Basin



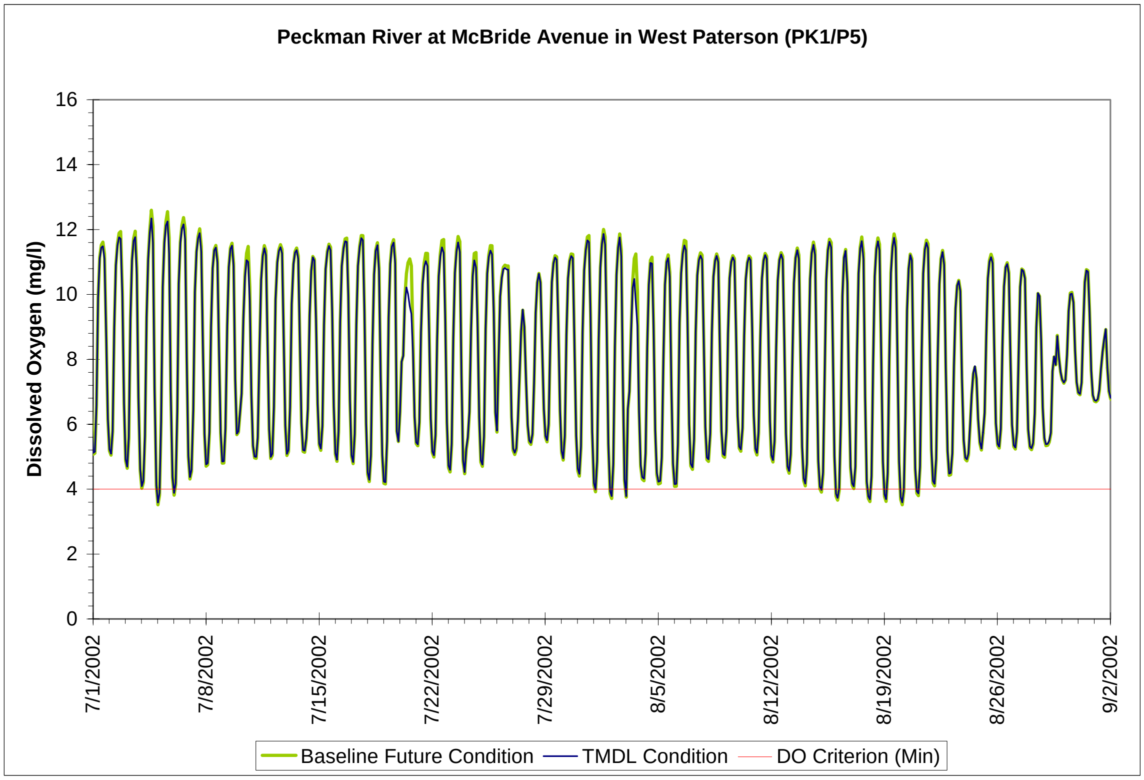


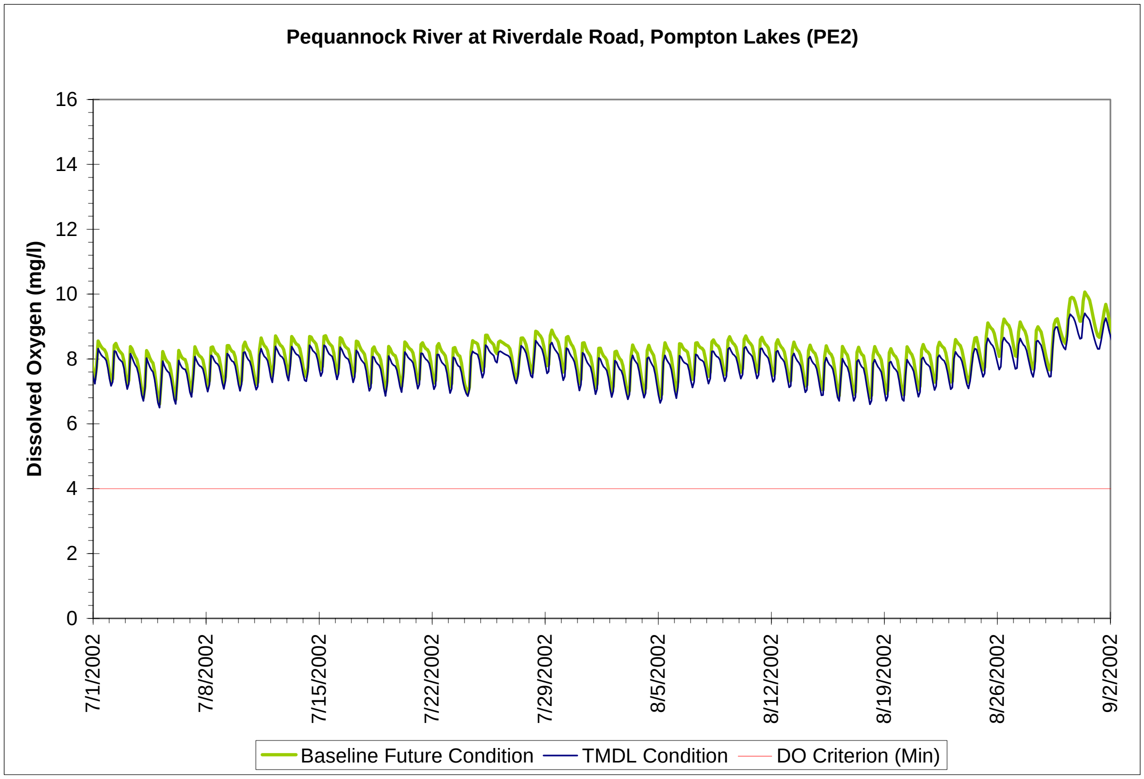
The Impact of the TMDL Condition on the Passaic River Basin



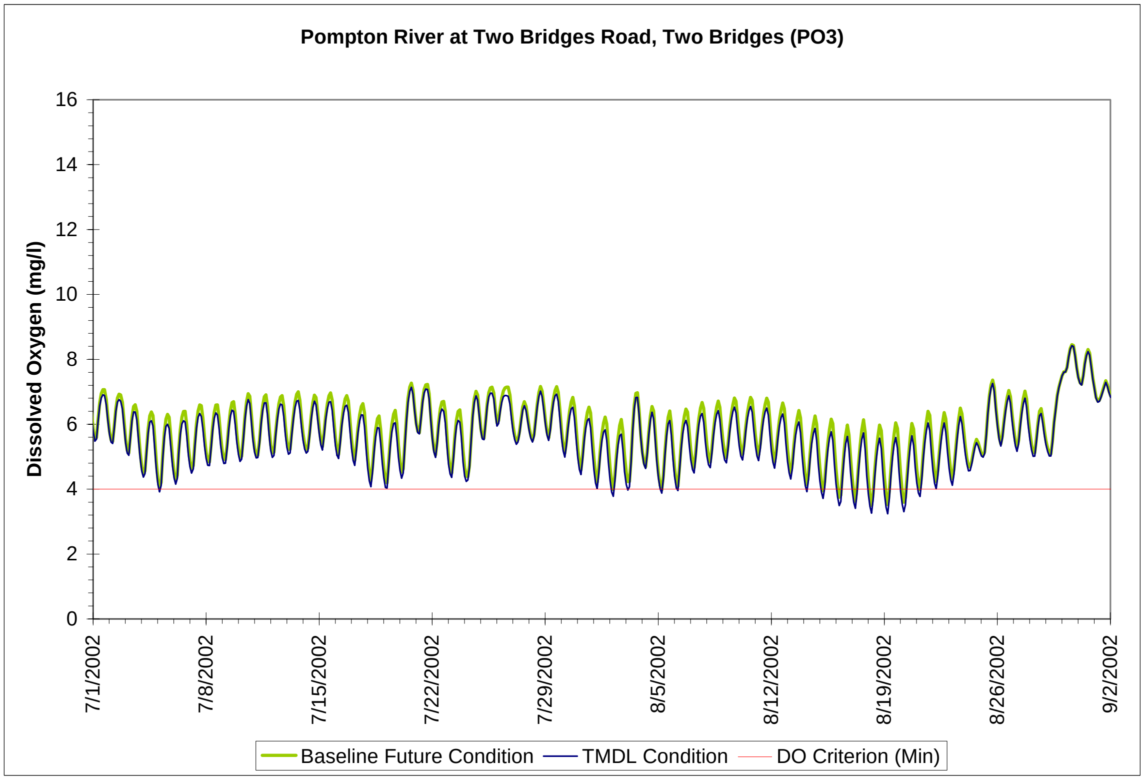


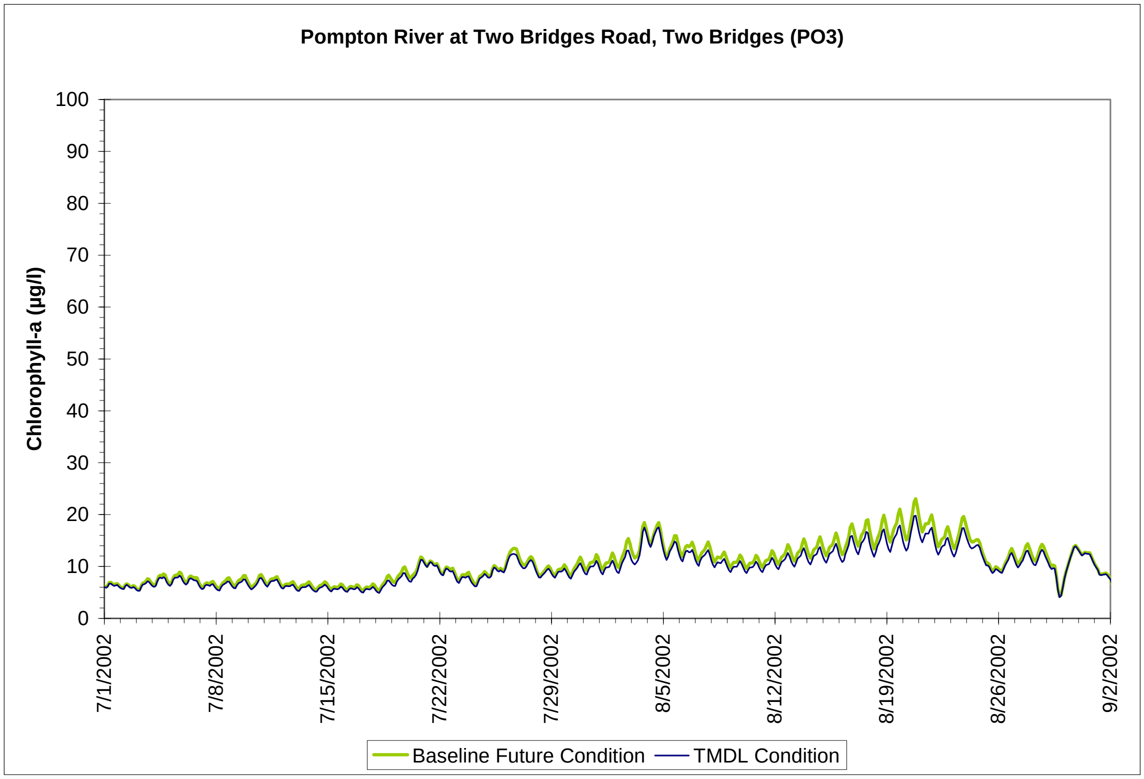
The Impact of the TMDL Condition on the Passaic River Basin



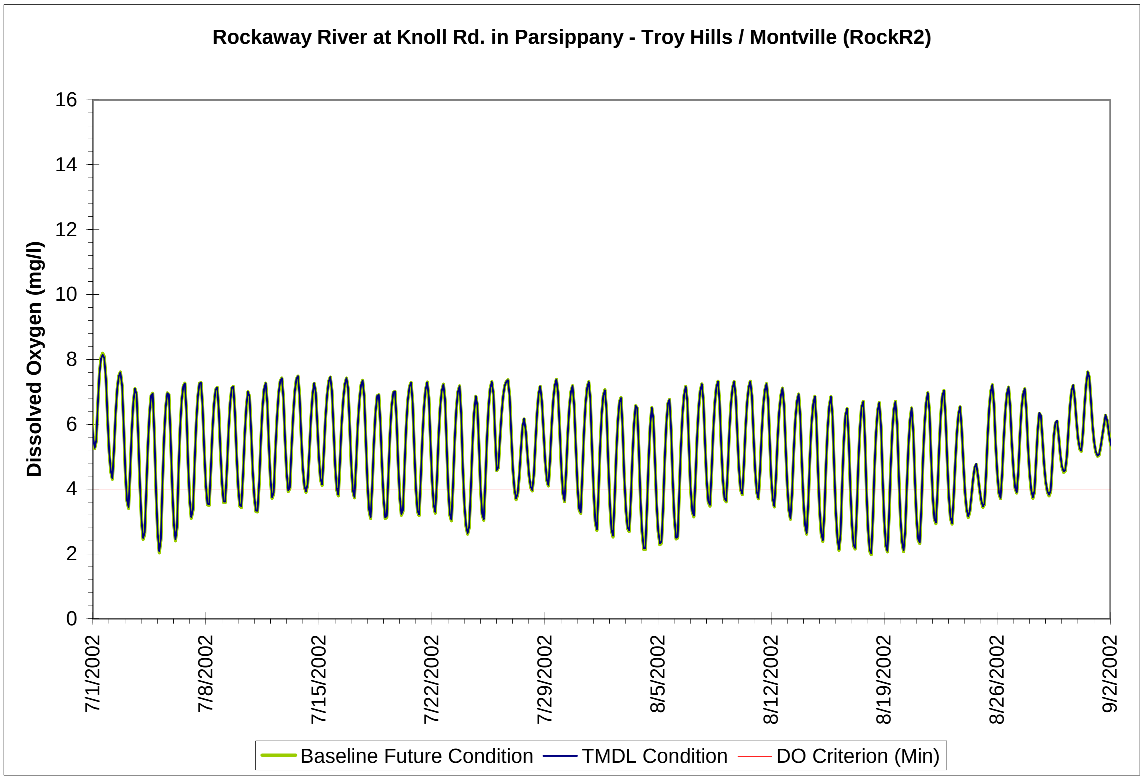


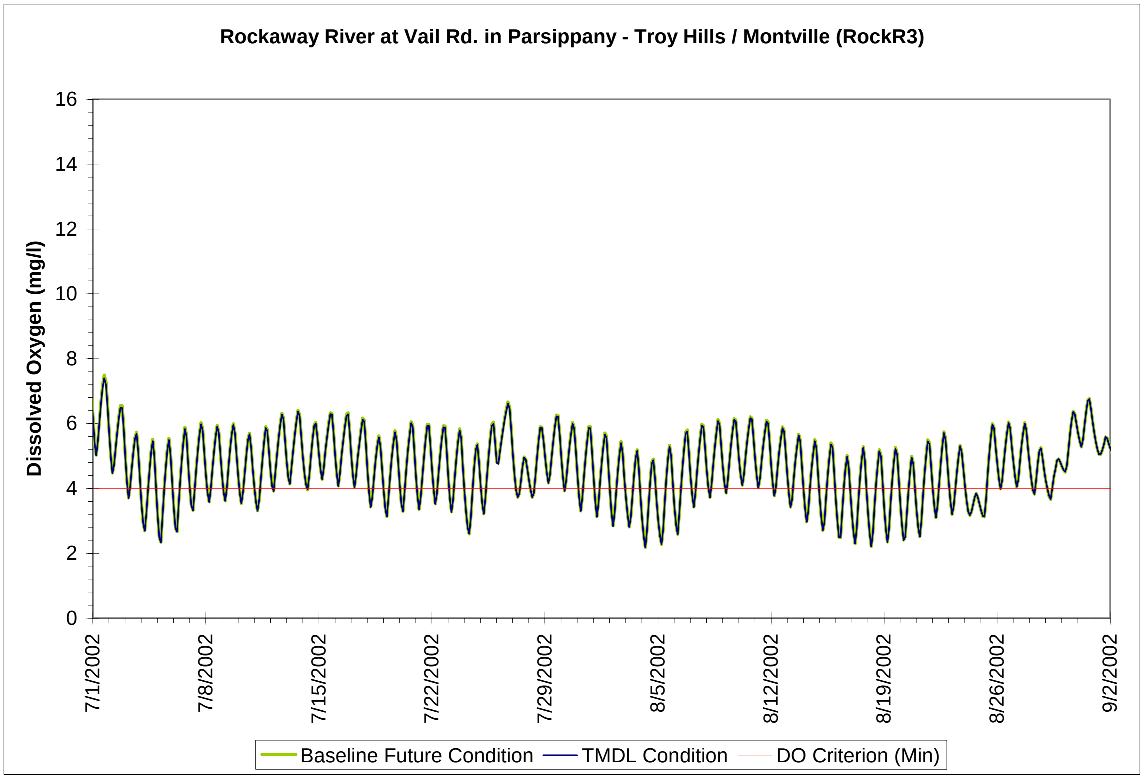
The Impact of the TMDL Condition on the Passaic River Basin



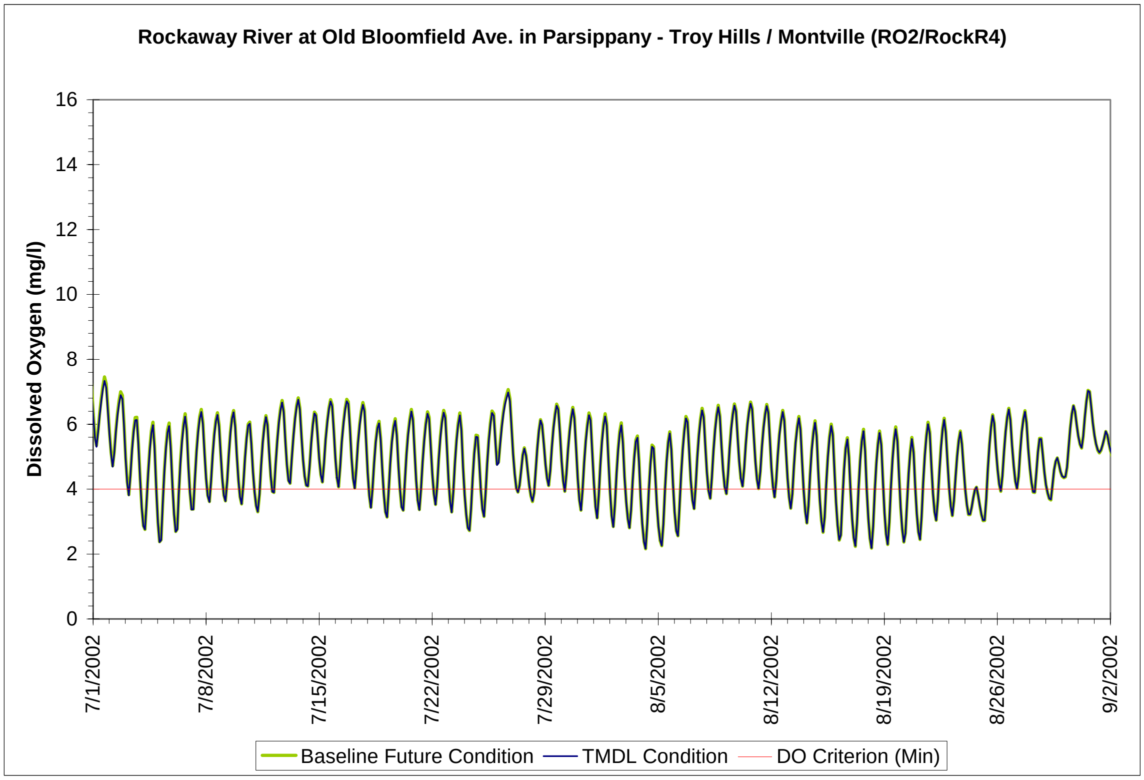


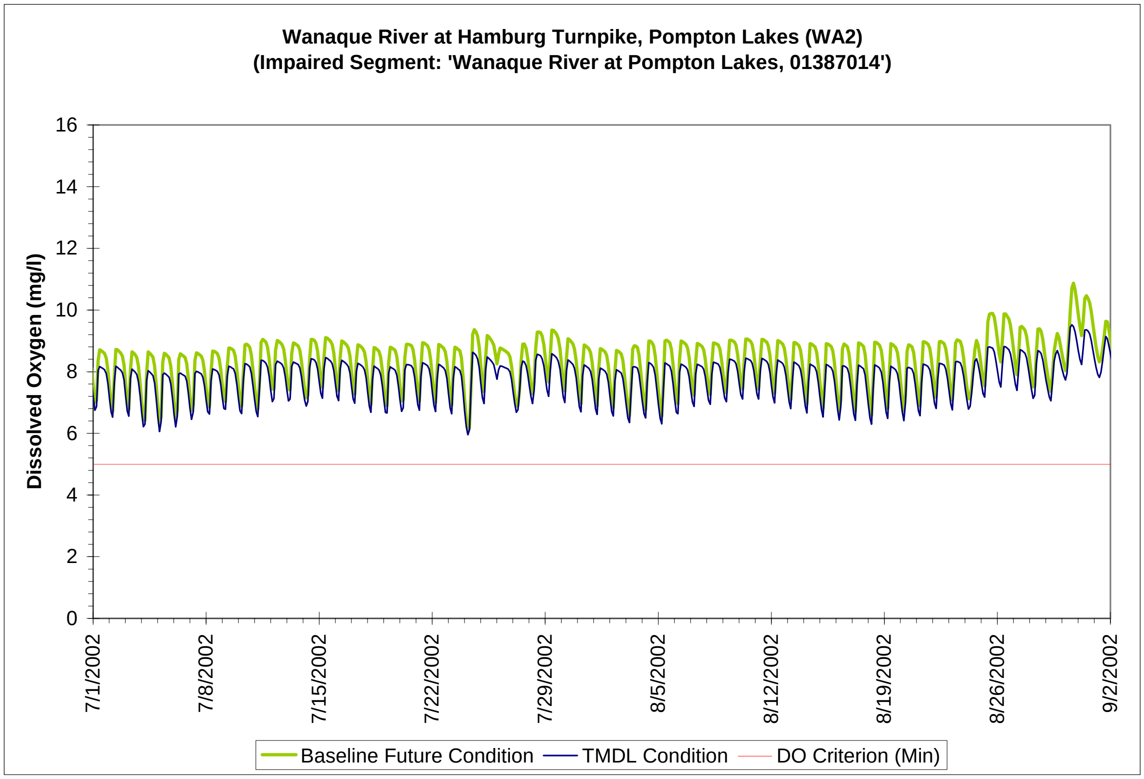
The Impact of the TMDL Condition on the Passaic River Basin



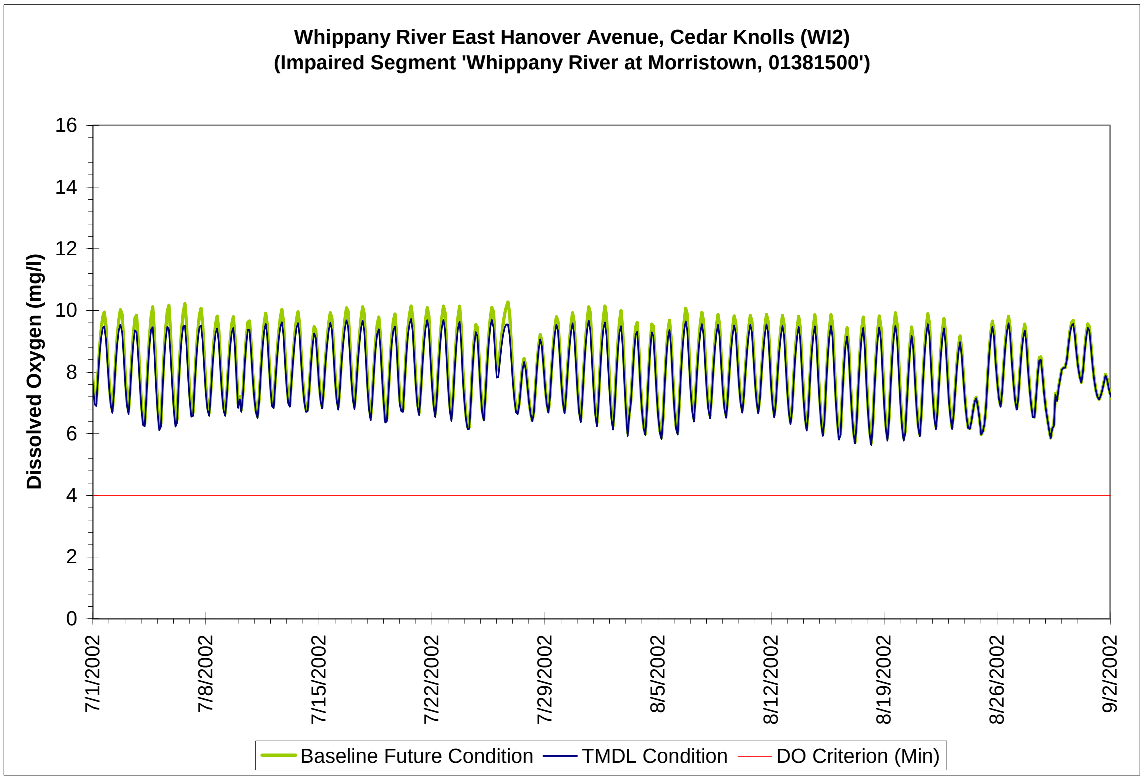


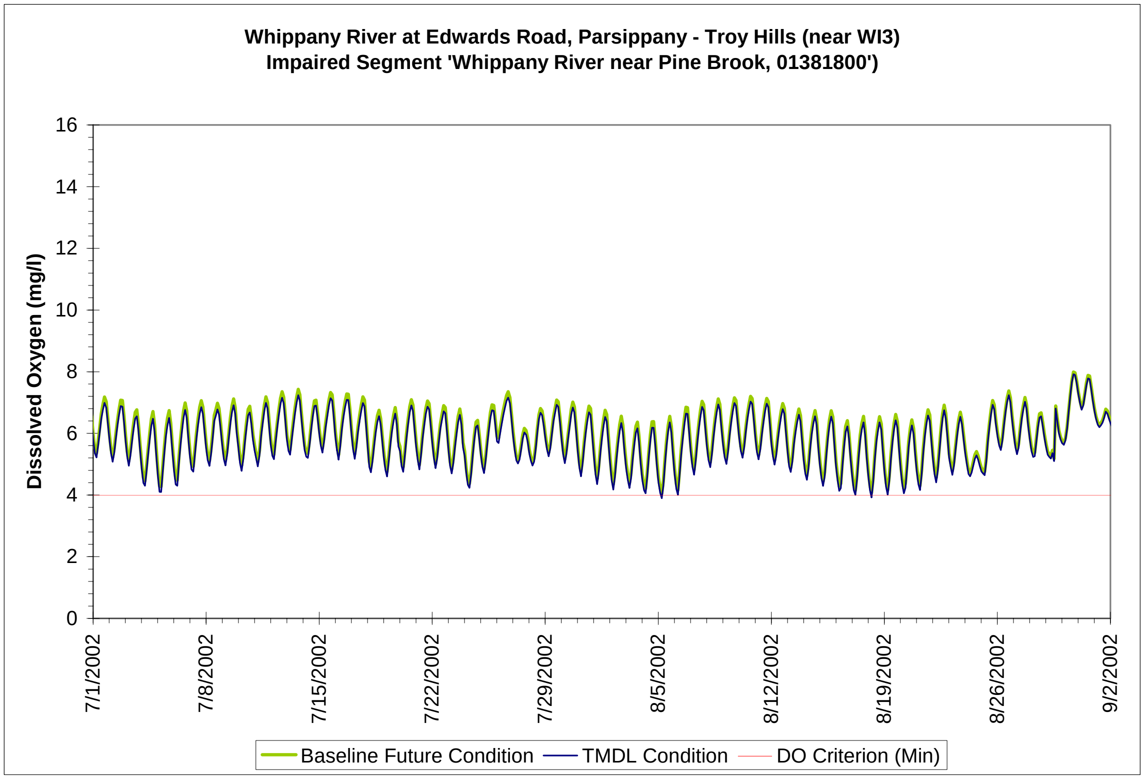
The Impact of the TMDL Condition on the Passaic River Basin





The Impact of the TMDL Condition on the Passaic River Basin





APPENDIX M

Electronic Data