Manasquan River Non-Point Source Identification Project

Presentation Before the Manasquan Watershed Source Water Protection Plan Project Committee

NJWSA Manasquan Water Supply System Conference Room
Allenwood, NJ
April 22, 2009

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John-Paul Do
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NEW JERSEY WATER SUPPLY AUTHORITY

Watershed Characteristics

Manasquan Watershed

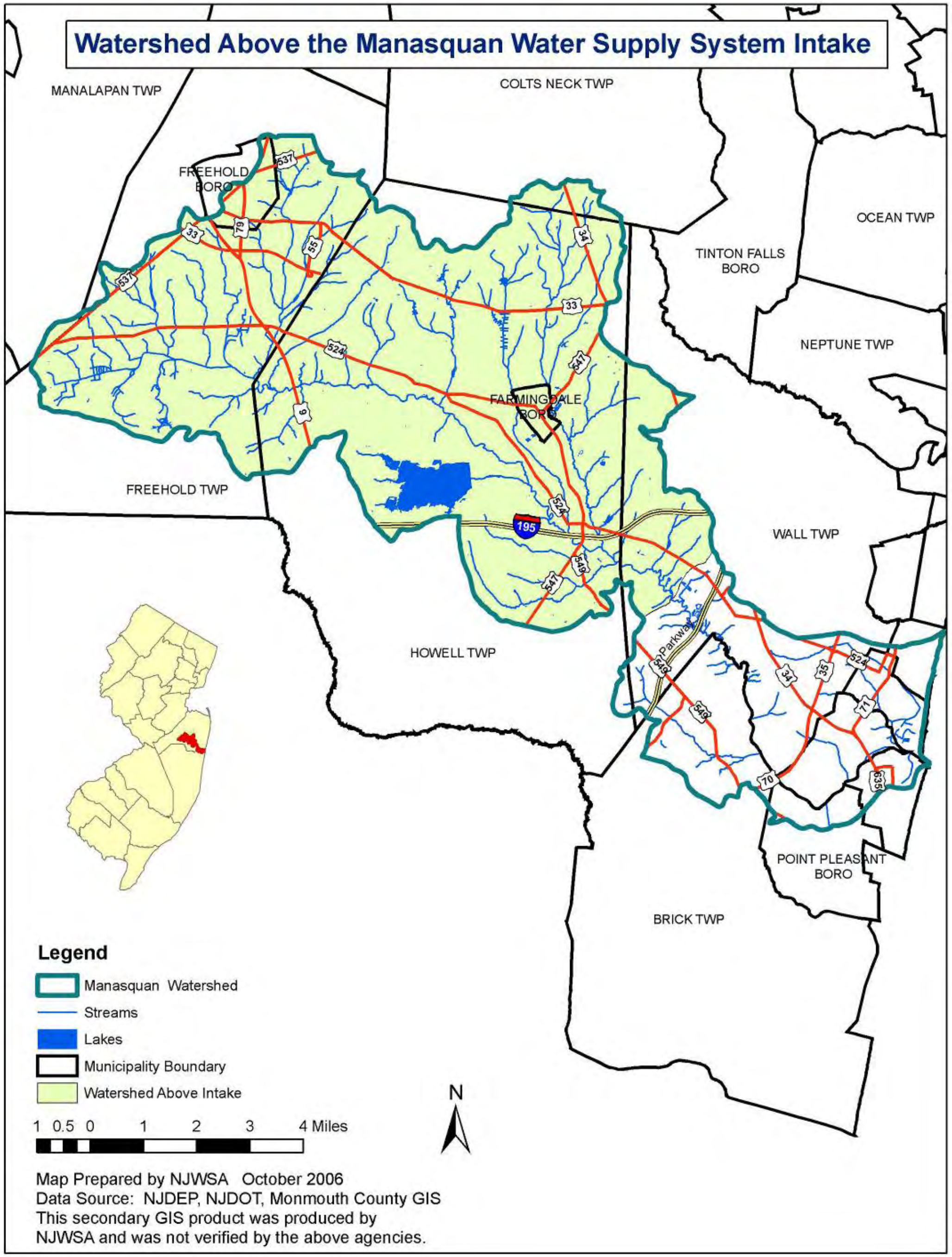
- 82 square miles
- 13 municipalities

Area Upstream of Manasquan Water Supply System

- 64 square miles
- 7 municipalities (Manalapan, Freehold, Colts Neck, Howell, and Wall Townships; and Freehold and Farmingdale Boroughs)

Land Characteristics

- Significant land-use changes from agriculture and wetlands to suburban/urban
- Low-pH soils with high iron content



Watershed Above the Manasquan Water Supply System Intake
MANALAPAN TWP
COLTS NECK TWP
FREEHOLD BORO
OCEAN TWP
TINTON FALLS BORO
NEPTUNE TWP
FARMINGDALE BORO
FREEHOLD TWP
WALL TWP
HOWELL TWP
POINT PLEASANT BORO
BRICK TWP
Parkway
Legend
Manasquan Watershed
Streams
Lakes
Municipality Boundary
Watershed Above Intake
1 0.5 0 1 2 3 4 Miles
N
Map Prepared by NJWSA October 2006
Data Source: NJDEP, NJDOT, Monmouth County GIS
This secondary GIS product was produced by
NJWSA and was not verified by the above agencies.

Background

Turbidity and Color

- Monitoring-data for turbidity and color show increased levels in the Manasquan River.
- Records of turbidity and color in the Manasquan River have been collected at the Manasquan Water Supply System (MWSS) since 1991. An increasing trend exists.
- Sections of the Manasquan River channel are very unstable and erodible, adding turbidity and color (mostly from iron) during higher baseflows and stormwater runoff flows.

Background

Total Phosphorus

- NJDEP developed a TMDL for total phosphorus in May 2005 for sections of the Manasquan River and Long Brook.
- As part of the project, the Authority is assisting the NJDEP in tracking total phosphorus loads for portions of the Manasquan River and its tributaries.

Program Goal:

Eliminate or reduce baseflow and stormwater turbidity, and sources of sediment loads

Project Objectives:

- Determine levels of turbidity and its interactions with flow, pH, total suspended solids (TSS), total phosphorus (TP), color, and iron
- Provide land-use management and stream-channel stabilization strategies to watershed municipalities and Monmouth County for reducing, or eliminating, sediment loads and the associated increase in turbidity, suspended solids, and nutrients

Manasquan Non-Point Source Identification Project Tasks

– Assess existing water quality data to determine effectiveness of using turbidity as a surrogate for total phosphorus and total suspended solids.
– Use WinSLAMM modeling to compare sediment loadings from sub-watershed land uses.
– Develop GIS technique to determine “at-risk” stream channels for erosion.
– Perform stream visual assessments on a sample of identified “at-risk” stream channels

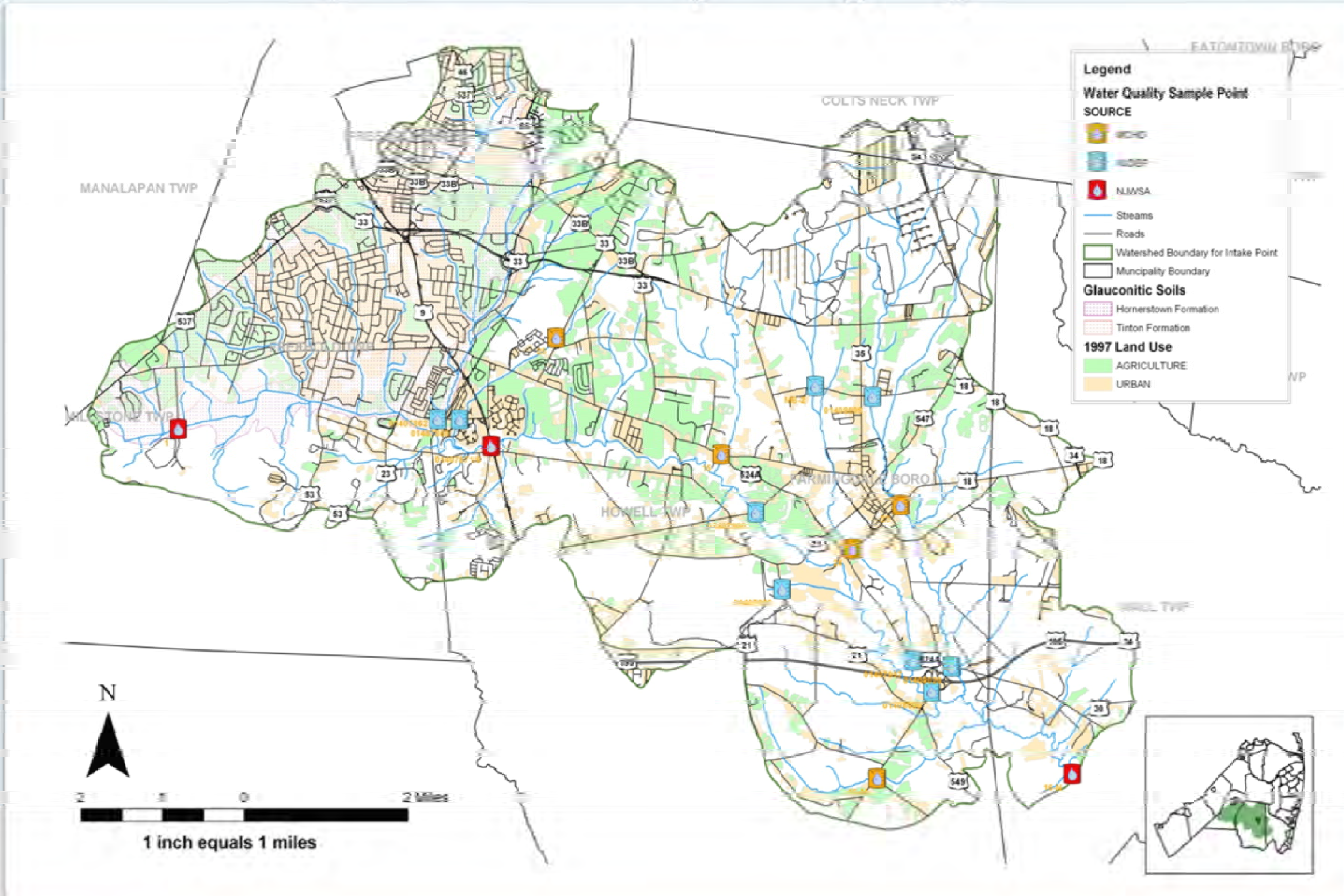
Manasquan Non-Point Source Identification Project Tasks

- Perform baseflow and storm flow grab sampling and water quality analysis for turbidity, total phosphorus, and TSS.
- Perform automated turbidity monitoring with periodic pH, total and ferrous iron sampling.
- Use statistical and trend analyses of datasets from all tasks.
- Determine priority list of potential sources of turbidity and sediment
- Present recommendations for mitigation and management

Existing Water Quality Data

- Ambient water quality data – total suspended solids (TSS), turbidity, fecal coliform and total phosphorus
- Data obtained from:
  - Monmouth County Health Department (MCHD)
  - New Jersey Water Supply Authority (NJWSA)
  - New Jersey Department of Environmental Protection (NJDEP)

Existing Water Quality Sampling Locations



Data summary

Site Name/number	SummarySite Location	Number of Observations (N) Fecal Coliform	TP	TSS	Turbidity
1	Manasquan River @ Burke Rd., Freehold	38	82	0	0
1407862	Debois Creek @ Strickland Rd, Freehold	0	3	3	0
1407868	Killtime Brook @ Wyckoff Mills, Howell	0	3	0	0
6 (1407871)	Manasquan River @ Route 9 and Ford Rd, Howell	36	93	11	0
1407900	Manasquan River @ West Farms Rd, Farmingdale	0	3	3	0
1407970	Timber Swamp Brook @ Manassa Rd, Farmingdale	0	3	3	0
1407997	Marshes Bog Brook @ Yellow Brook Rd, Squankum		3	3	0
1408000	Manasquan River @ Lakewood Farmingdale Rd, Squankum	0	5	0	0
1408009	Mingamahone Brook @ Cranberry Rd, Farmingdale	0	7	0	0
1408020	Mingamahone Brook @ Route 524 Bridge	0	3	0	0
15	Yellow Brook @ Elton Adelphia Rd, Farmingdale	25	13	19	14
16-M	Squankum Brook @ Easy St, Howell	25	13	19	14
16-N	Manasquan River @ NJWSA Intake, Wall	39	82	0	0
23	Mingamahone Brook @ Belmar Blvd, Farmingdale	25	13	19	14
24	Marshes Bog Brook @ Preventorium Rd, Howell	25	13	19	14
25	Long Brook @ Howell Rd, Jerseyville	22	11	16	13
MB-2	Marshes Bog Brook @ , Farmingdale	0	3	3	0
	All Sites	235	353	118	69

Existing Water Quality Data Analysis – Conclusions & Recommendations

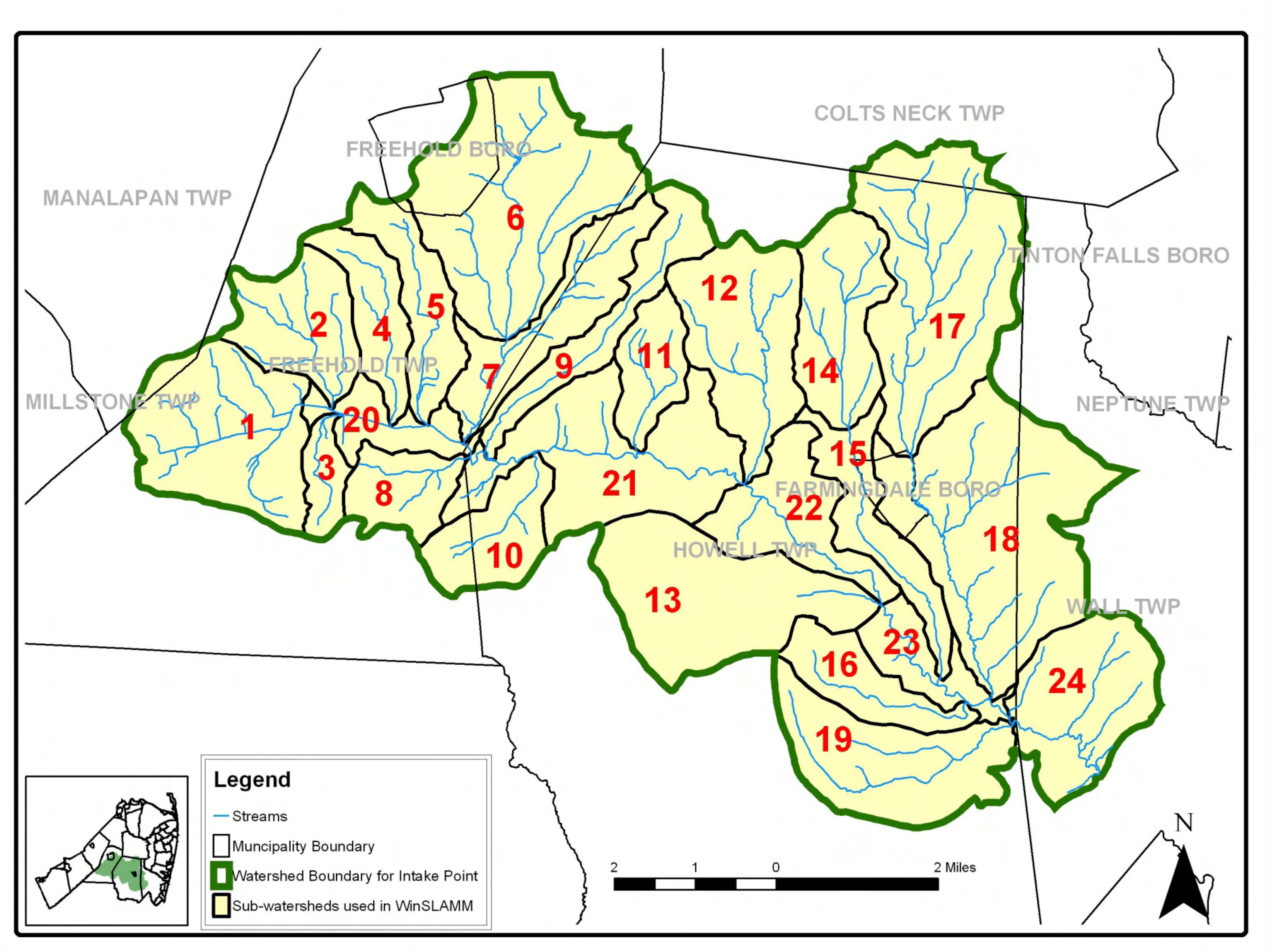
- Turbidity may be adequate surrogate for TSS
- Location of sampling sites has significant affect on water quality
- Seasonal variation significantly affects water quality; water quality monitoring should extend across multiple seasons.
- Conclusions are limited by:
  - unknown flow conditions at the time of sampling
  - variability in the methods of analyses used among the datasets

WinSLAMM

Source Loading And Management Model for Windows

This model was developed as a planning tool to better understand the relationships between sources of urban runoff pollutants and runoff quality. The model is strongly based on actual field observations.

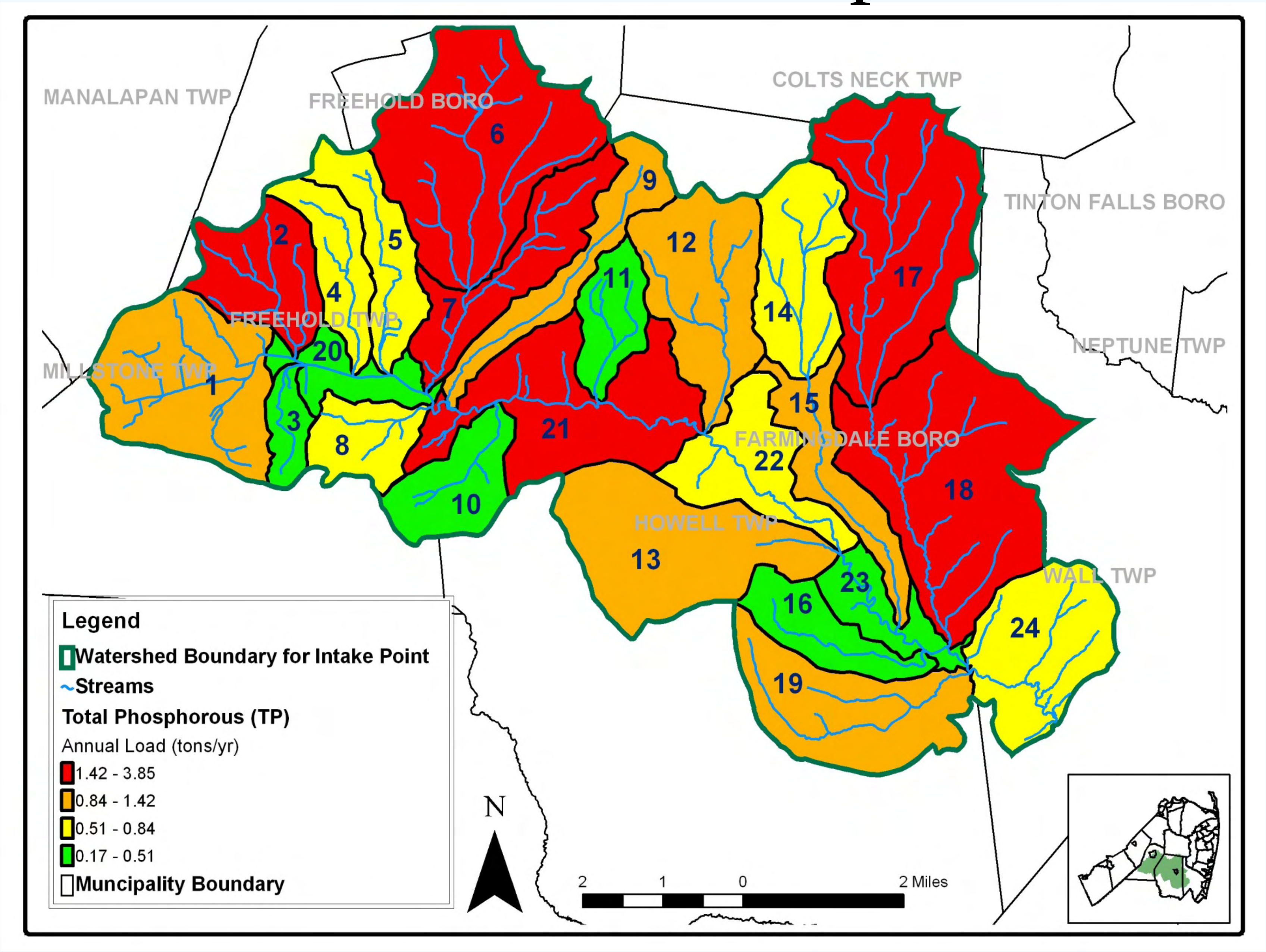
WinSLAMM Subwatersheds



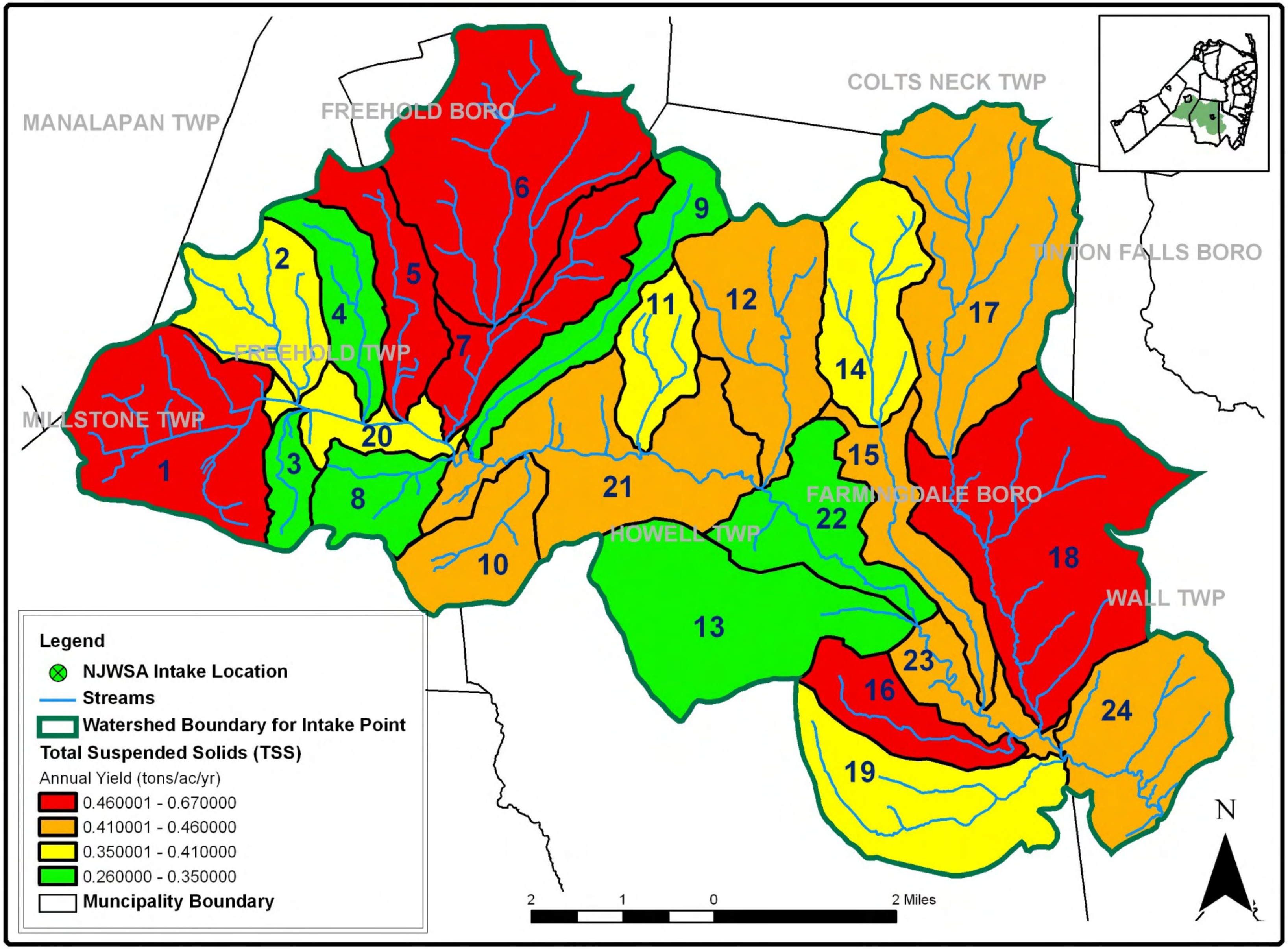
WinSLAMM– Total Phosphorus & TSS Results

- TP and TSS loads were highest in:
  - Transition areas (subwatersheds 2, 6 and 7)
    - Agr/undeveloped land transitioning to suburban
  - Rapid suburban development (subwatershed 21)
  - Large impervious surfaces (Earle Naval Base - subwatershed 17 and a regional airfield – subwatershed 18)
  - Transitional subwatersheds (6, 7 and 18) had the highest values

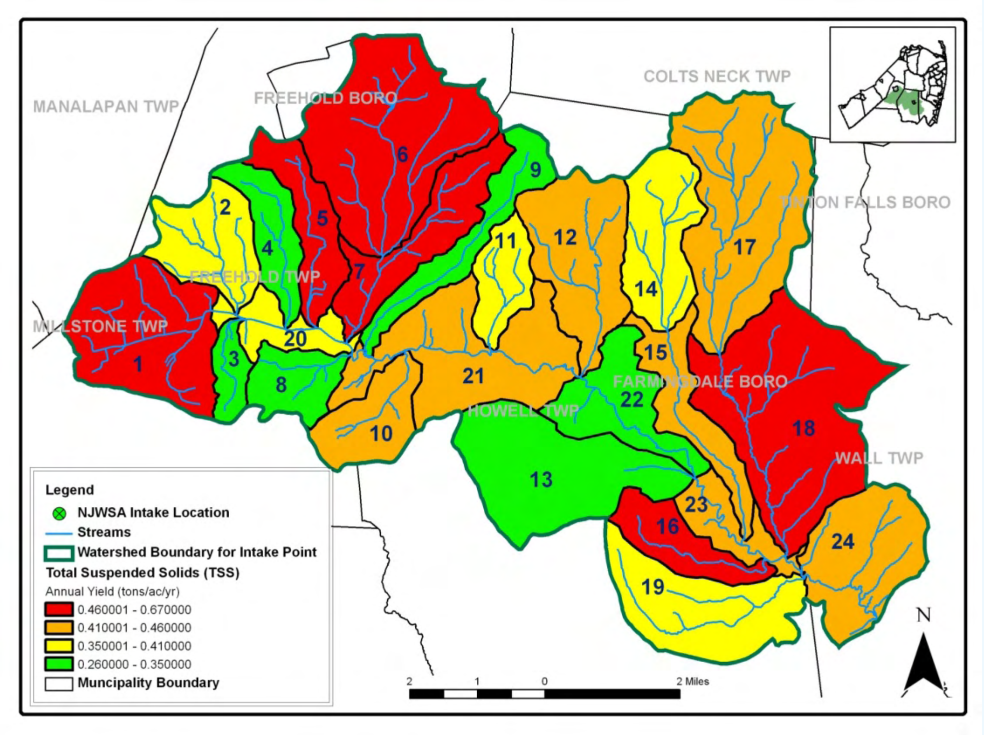
WinSLAMM Total Phosphorus Loads



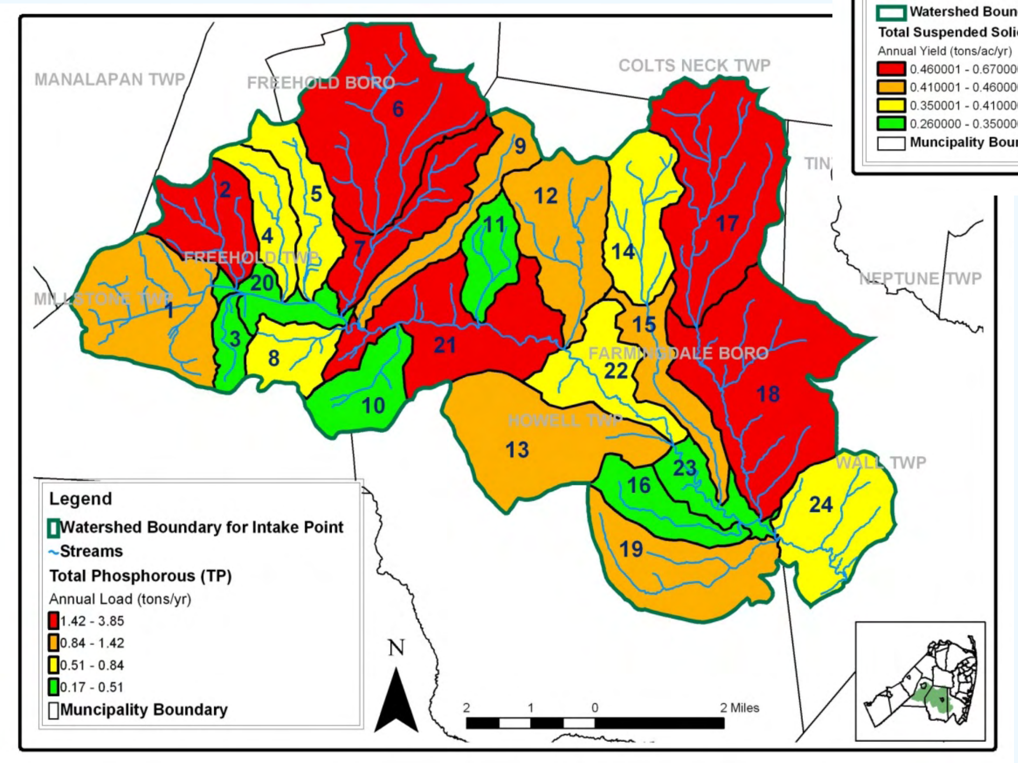
WinSLAMM Total Suspended Solids Loads



TSS



MANALAPAN TWP
FREEHOLD BORO
COLTS NECK TWP
FREEHOLD TWP
MILLSTONE TWP
FARMINGDALE BORO
HOWELL TWP
WALL TWP
Legend
NJWSA Intake Location
Streams
Watershed Boundary for Intake Point
Total Suspended Solids (TSS)
Annual Yield (tons/ac/yr)
0.460001 - 0.670000
0.410001 - 0.460000
0.350001 - 0.410000
0.260000 - 0.350000
Muncipality Boundary
2 1 0 2 Miles
N



MANALAPAN TWP
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HOWELL TWP
WALL TWP
Legend
Watershed Boundary for Intake Point
Streams
Total Phosphorous (TP)
Annual Load (tons/yr)
1.42 - 3.85
0.84 - 1.42
0.51 - 0.84
0.17 - 0.51
Muncipality Boundary
2 1 0 2 Miles
N

TP

Remote Sensing Sediment-Loading Risk Analysis

Quantified five risk factors for sediment loading from channel processes such as streambank erosion and streambed incision:

1. Riparian land use
2. Highly erodible soils adjacent to the stream banks
3. Channel slope
4. Changes in upstream land uses
5. Percent of upstream impervious area

Remote Sensing Index Scores

- Delineated 391 stream segments (300-2500 ft in length)
- Quantified the five risk factors for each stream segment
- Normalized values to a sub index score (0-10)
- Total index score from sum of all sub-index scores
- Using natural breaks, segments ranked as shown in next slide.

Land-Use Changes
1986 thru 2002

Land Use Change – 1986 thru 1995:

Urban +18.1% (increase of 5,153 acres)

Agriculture -22.6% (decrease of 3,907 acres)

Wetlands -6.1% (decrease of 2,083 acres)

Land Use Change – 1995 thru 2002:

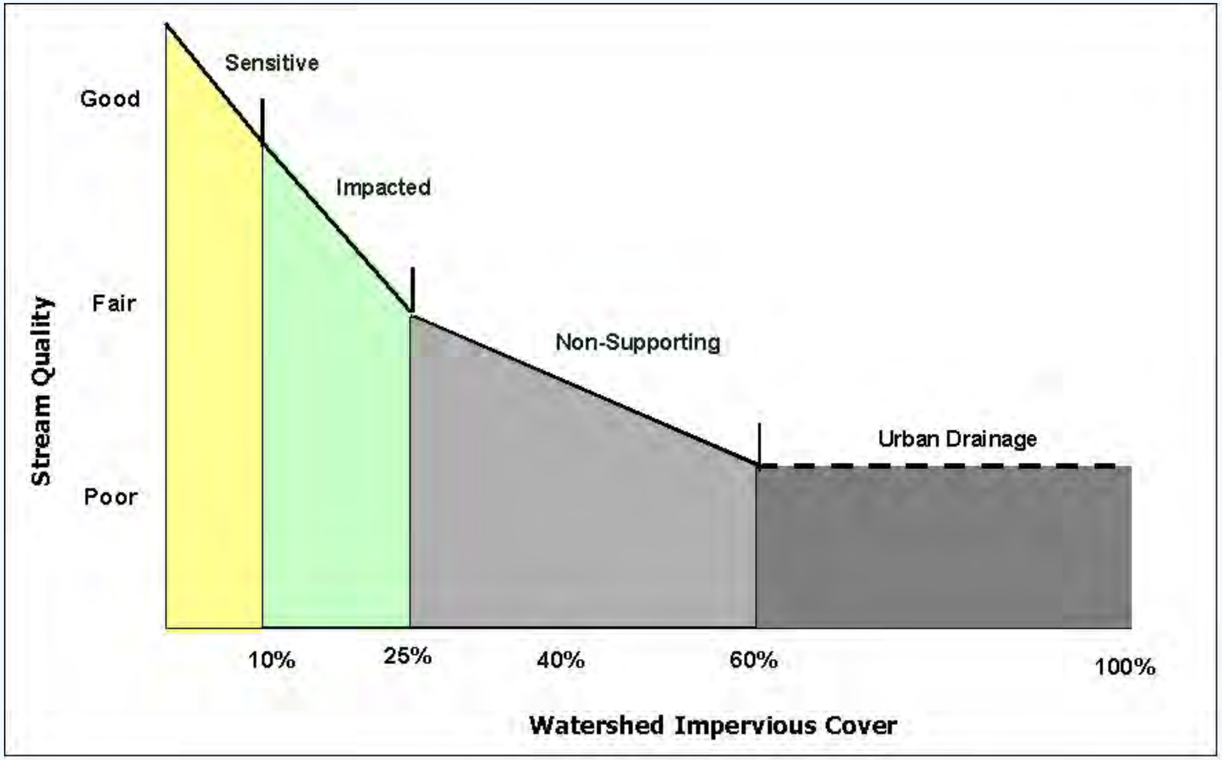
Urban +14.7% (increase of 4,892 acres)

Agriculture –31.7% (decrease of 4,234 acres)

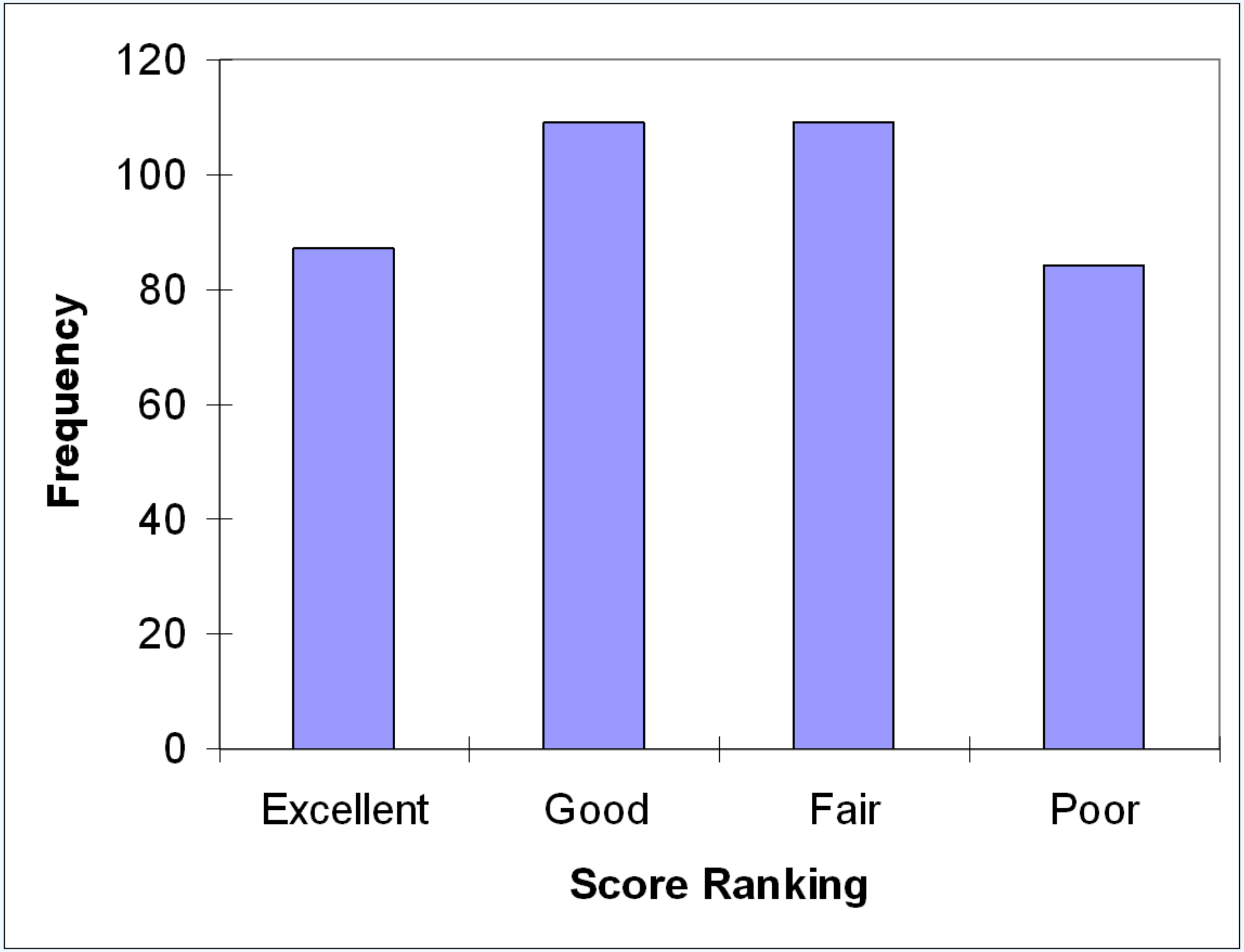
Wetlands -4.4% (decrease of 661 acres)

Remote Sensing Index Scores

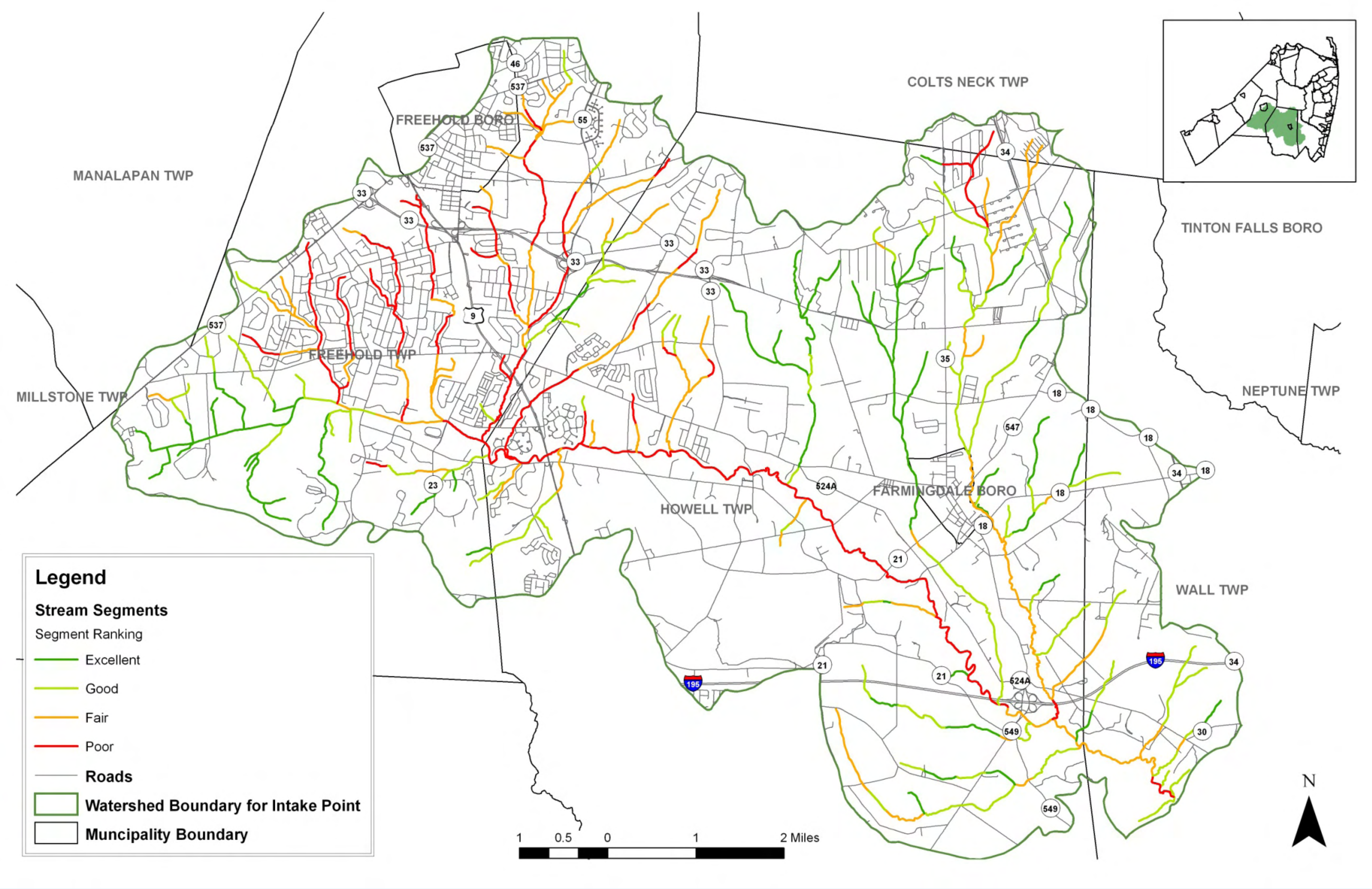
- Evaluated change in land use from 1986-1997 and change in urban land use 1997-2002
- Adjusted these values to account for exponential effect of land use change on stream health.



Remote Sensing Index Scores



Remote Sensing Rankings

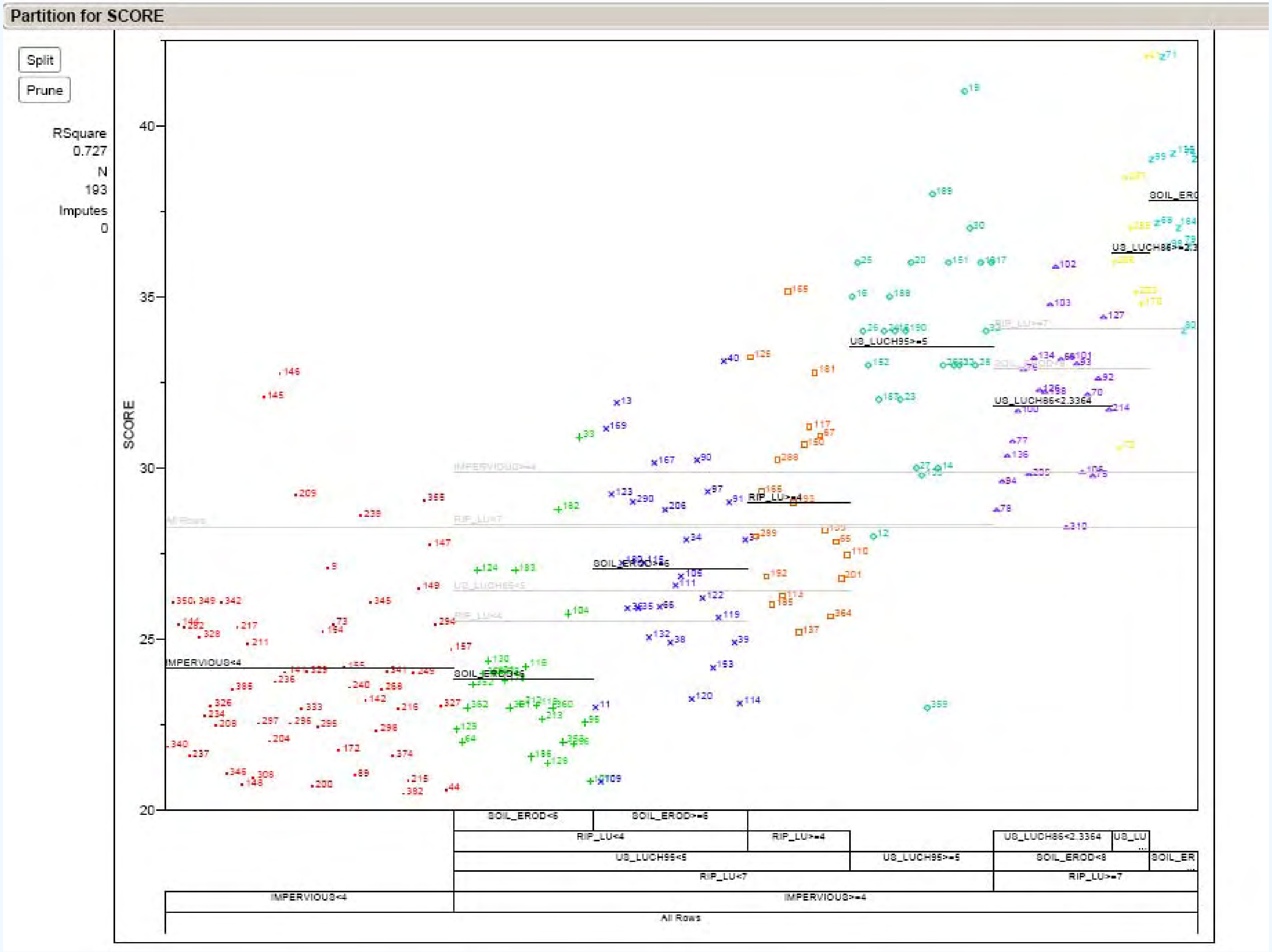


Stream-Channel Visual Assessments

- A reference reach was selected from among the “Excellent” stream segments identified by remote sensing and from windshield survey of the watershed.

- “Poor” and “Fair” Segments from the remote sensing rankings were partitioned into eight groups with similar features (based on remote sensing sub index scores).

Remote Sensing Partitions



Stream-Channel Visual Assessments

- From each of these remote sensing partitions, two to three segments were selected for visual assessments.

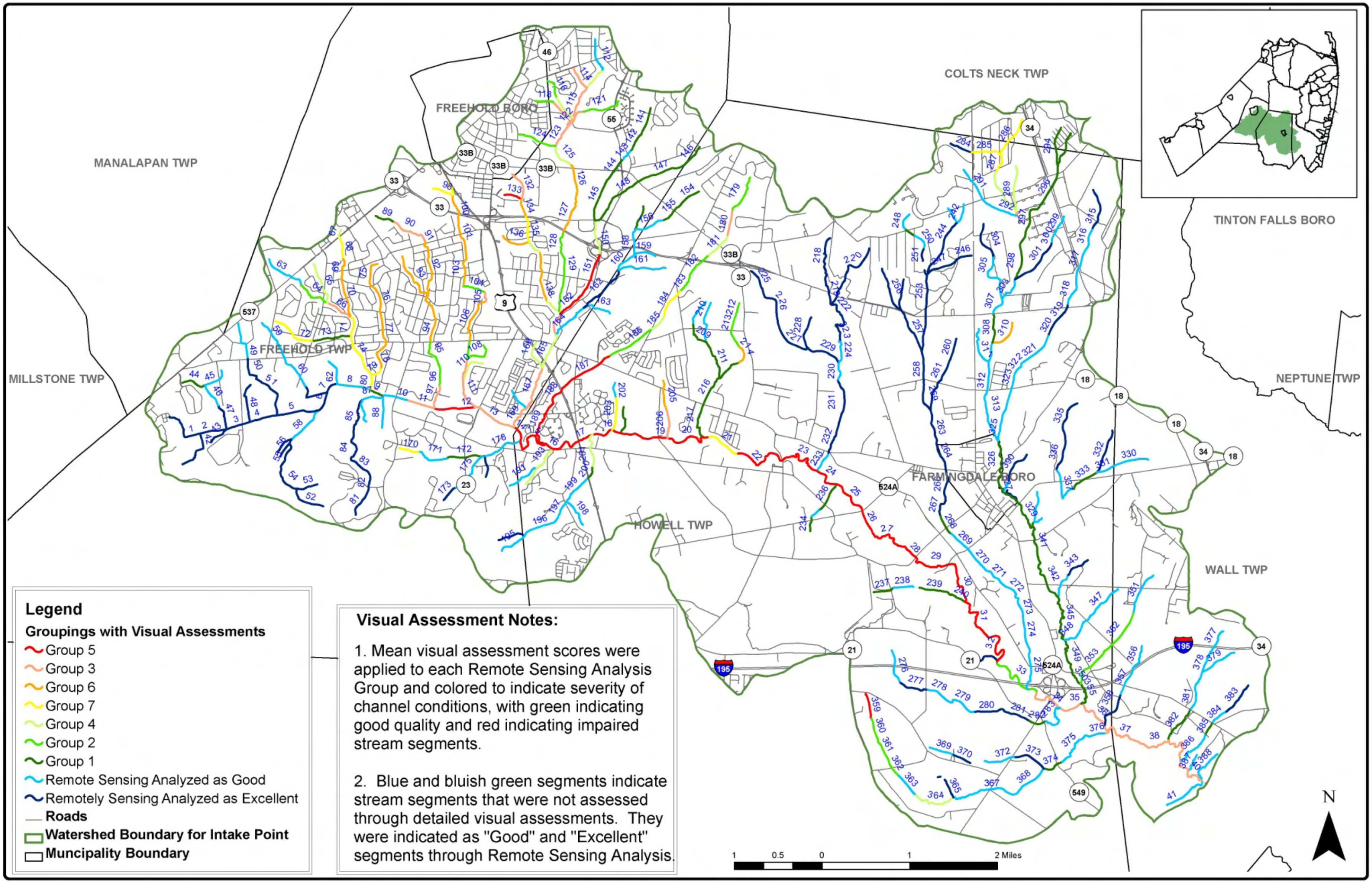
- Three field methods were used to score stream segments: Vermont Rapid Geomorphic Assessment for Unconfined Streams, Pfankuch Channel Stability Rating and the Rosgen Bank Erodibility Hazard Index (BEHI)

Stream Visual Assessment, Reference Reach

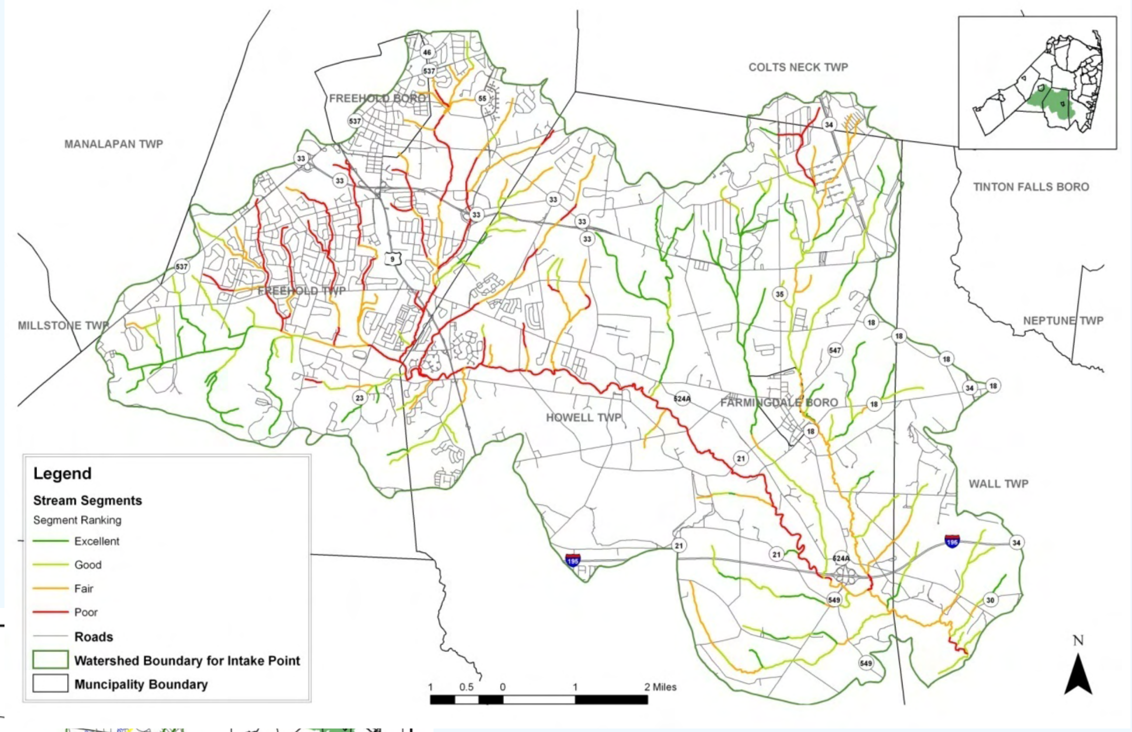
Stream Visual Assessment, Fair Condition

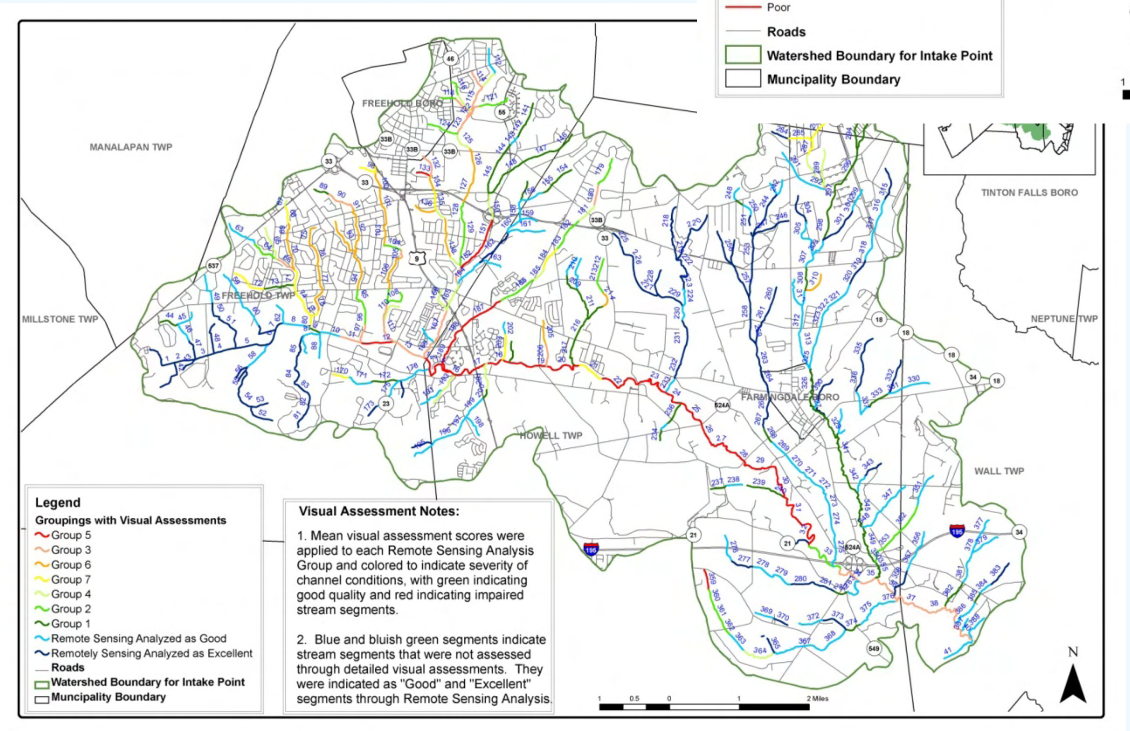
Stream Visual Assessment, Poor Condition

Stream-Channel Visual Assessment



Remote





Visual

Storm and Baseflow Grab Sampling

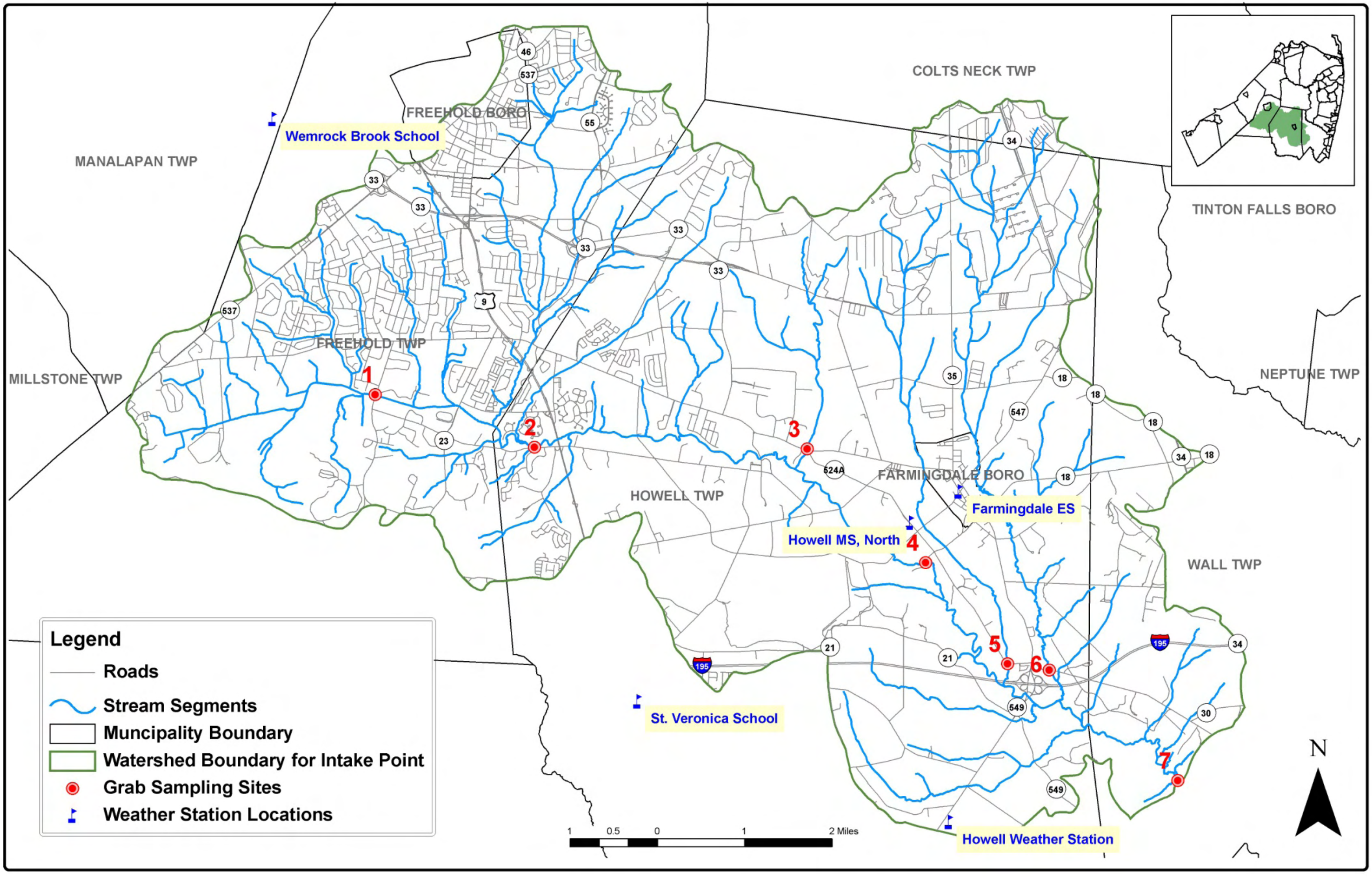
- Samples were analyzed for total suspended solids, total phosphorus, and turbidity
- 10 samples per site were collected during storm flows and 2 samples per site were collected during baseflow conditions

Grab Sampling Sites

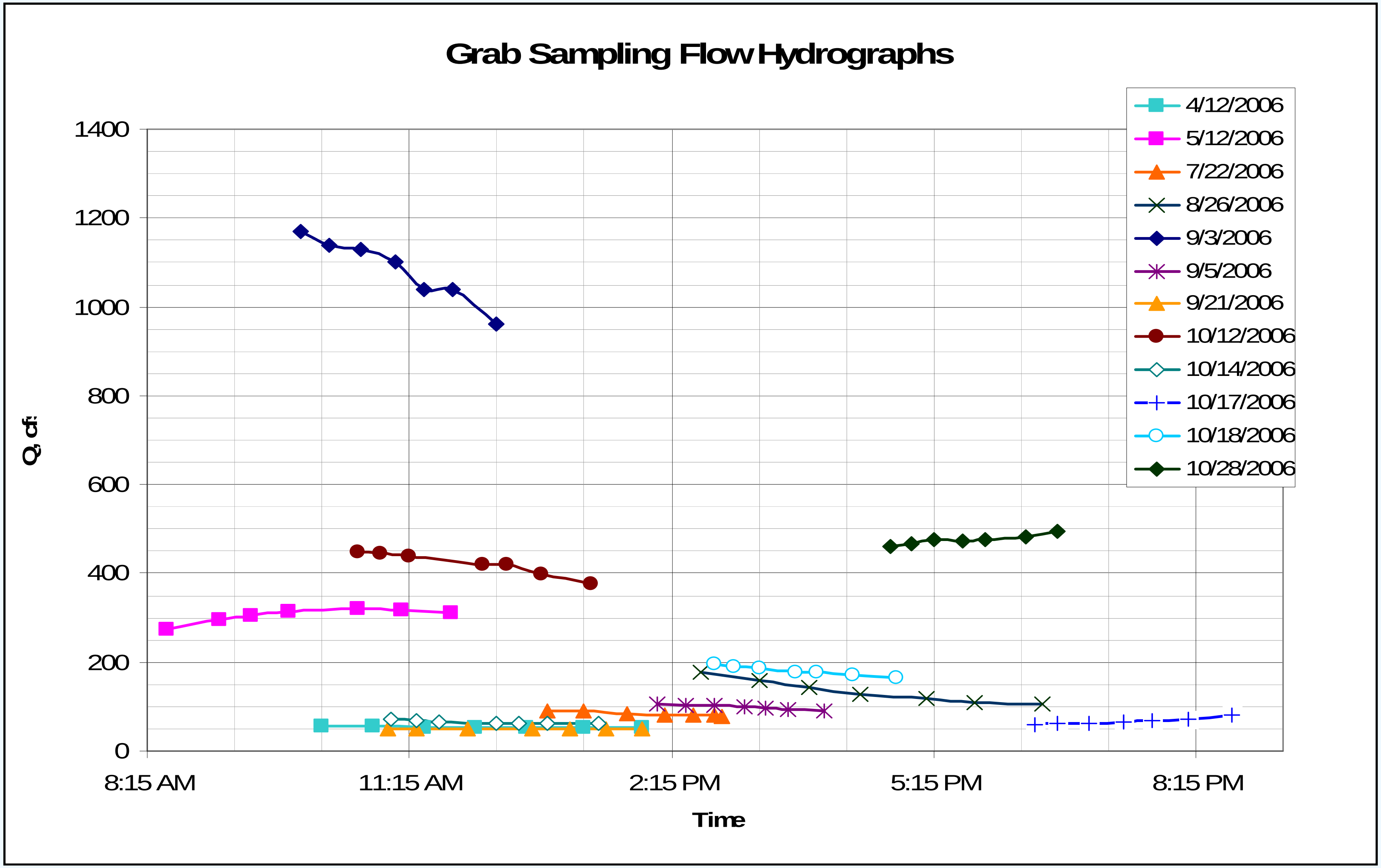
- 1) Manasquan River at Georgia Road
- 2) Manasquan River at Point of Woods Drive
- 3) Yellow Brook at Adelphia-Farmingdale Road
- 4) Manasquan River at Preventorium Road
- 5) Marsh Bog Brook at Yellow Brook Road
- 6) Mingamahone Brook at Allaire Road
- 7) Manasquan River at Hospital Road (MWSS intake)

Red-highlight represents highest loadings

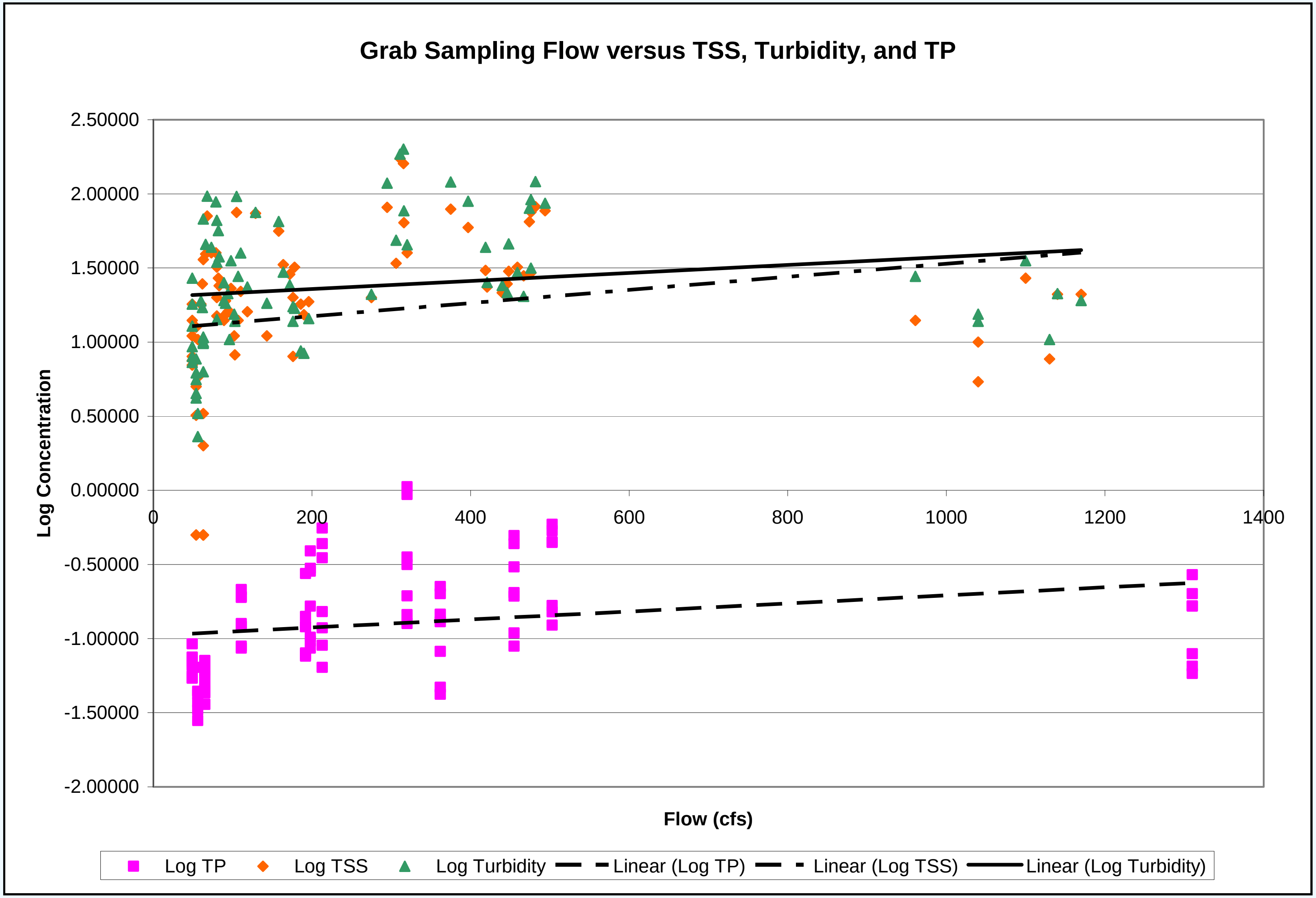
Grab Sampling Sites



Grab Sampling Flows (Q vs. Time)



TSS, Turbidity and TP versus Flow (Log(Concentration) vs. Q)



Grab Sampling - Turbidity

Site	Sampling Location	Turbidity (NTU)			
		Min	**Max**	**Mean**	**St. Dev**
1	Manasquan River @ Georgia Rd.	3.3	80.0	23.4	20.7
2	Manasquan River @ Pointe of Woods Dr & Bergerville Rd.	2.3	118.0	43.4	39.5
3	Yellow Brook @ Adelphia-Farmingdale Rd.	4.5	67.7	24.2	19.0
4	Manasquan River @ Preventorium Rd.	4.2	200.0	59.0	56.3
5	Marshes Bog Brook @ Yellow Brook Rd.	6.2	45.3	18.5	11.9
6	Mingamahone Brook @ Allaire Rd.	7.7	88.2	32.1	26.4
7	Manasquan River @ Hospital Rd.	5.6	185.0	56.8	55.5
Overall		**2.3**	**200.0**	**36.8**	**38.6**

Grab Sampling - TSS

Site	Sampling Location	Total Suspended Solids (mg/L)			
		Min	Max	Mean	St. Dev
1	Manasquan River @ Georgia Rd.	3.3	64.7	22.5	16.6
2	Manasquan River @ Pointe of Woods Dr & Bergerville Rd.	0.5	81.0	33.2	29.3
3	Yellow Brook @ Adelphia-Farmingdale Rd.	2.0	36.0	19.2	10.4
4	Manasquan River @ Preventorium Rd.	0.5	160.0	44.4	44.9
5	Marshes Bog Brook @ Yellow Brook Rd.	0.5	40.0	16.5	11.1
6	Mingamahone Brook @ Allaire Rd.	0.5	64.0	20.5	18.8
7	Manasquan River @ Hospital Rd.	0.5	173.0	44.3	49.7
Overall		**0.5**	**173.0**	**28.7**	**30.8**

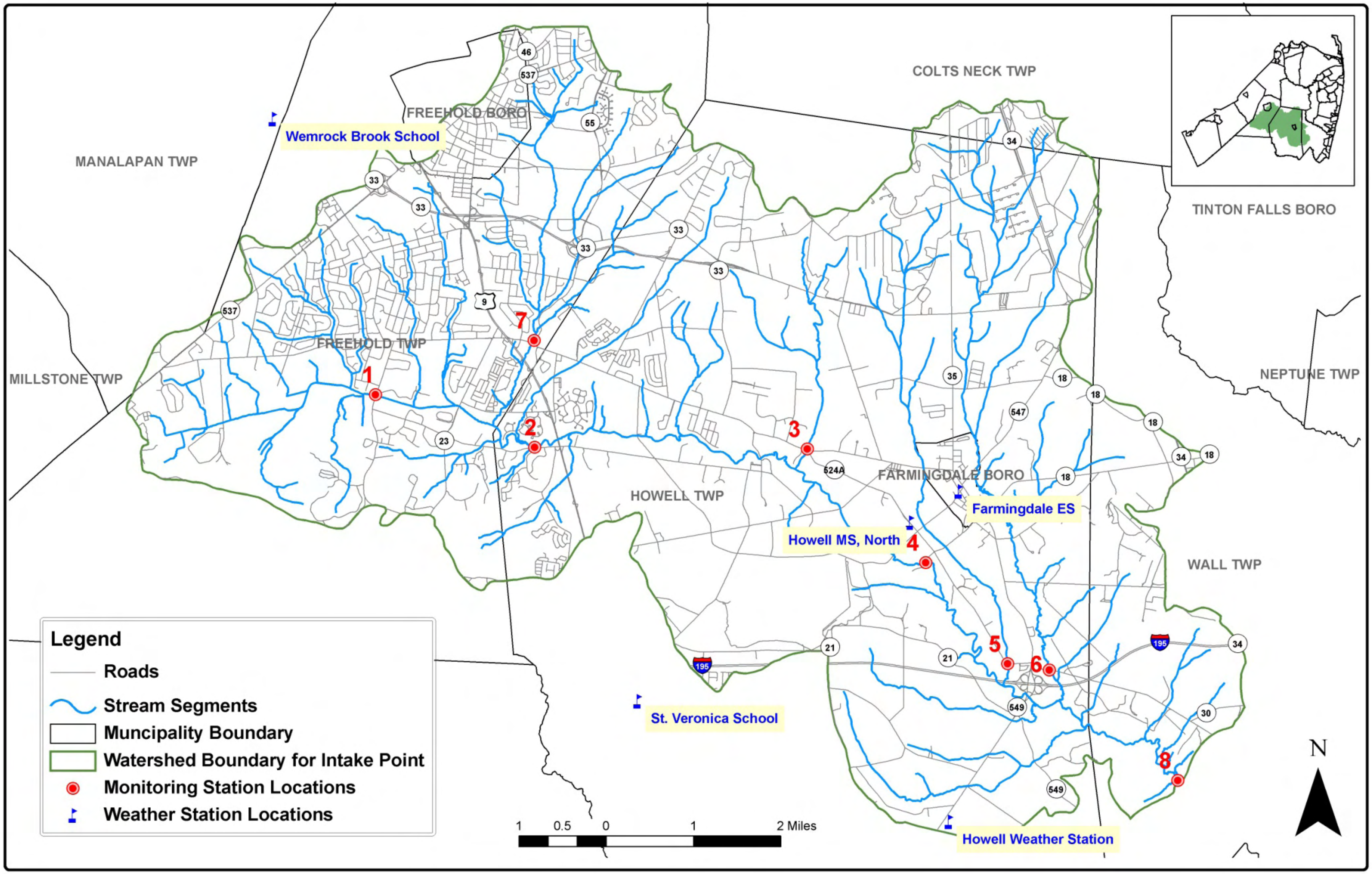
Grab Sampling - TP

Site	Sampling Location	Total Phosphorus (mg/L)			
		Min	Max	Mean	St. Dev
1	Manasquan River @ Georgia Rd.	0.064	0.444	0.169	0.107
2	Manasquan River @ Pointe of Woods Dr & Bergerville Rd.	0.043	0.449	0.204	0.139
3	Yellow Brook @ Adelphia-Farmingdale Rd.	0.042	0.165	0.084	0.041
4	Manasquan River @ Preventorium Rd.	0.028	0.935	0.316	0.258
5	Marshes Bog Brook @ Yellow Brook Rd.	0.036	0.354	0.101	0.086
6	Mingamahone Brook @ Allaire Rd.	0.037	0.315	0.119	0.078
7	Manasquan River @ Hospital Rd.	0.033	1.056	0.299	0.305
Overall		**0.028**	**1.056**	**0.185**	**0.187**

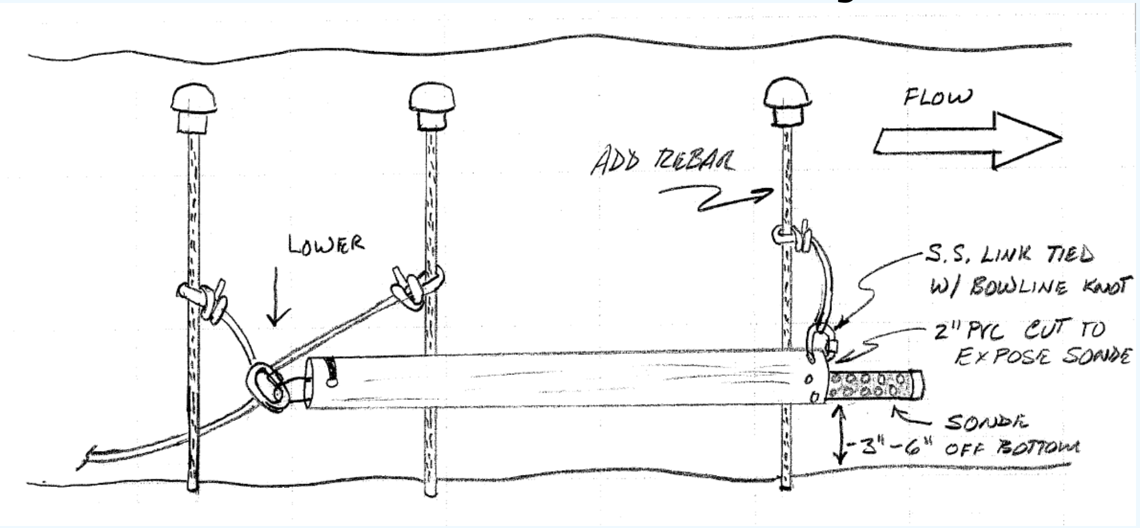
Continuous Water Quality Monitoring

- Automated water quality monitoring stations were set up at seven sampling sites.
- YSI Inc. 600-OMS multiparameter sondes took measurements continuously at ten minute intervals
- Parameters measured: water temperature, turbidity, depth and specific conductance.

Automated Water Quality Monitoring Stations



Continuous Water Quality Monitoring



- Sondes were recalibrated, had their batteries changed and water samples were collected at the locations of the automated water quality monitoring stations biweekly.

- Grab samples taken to labs for turbidity, total iron, pH, and apparent and true color analyses.

- Water temperature, pH and ferrous iron were measured in the field.

Automated Water Quality Monitoring - Month

Results from Automated Water Quality Monitoring Stations by Month												
	Temperature, degrees C			Conductivity, mS/cm			Depth, meters			Turbidity, NTU		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
April	9.13	18.49	13.72	0.074	0.354	0.188	0.059	1.777	0.583	N/A	N/A	N/A
May	8.74	21.72	15.34	0.092	0.517	0.215	0.039	1.225	0.461	N/A	N/A	N/A
June	12.76	23.65	18.31	0.085	1.008	0.225	0.039	1.543	0.371	N/A	N/A	N/A
July	13.72	24.65	19.91	0.054	0.525	0.227	0.032	1.956	0.344	4.5	579.4	31.2
August	15.74	25.43	19.81	0.065	0.582	0.228	0.027	1.000	0.266	5.6	346.6	24.7
September	11.47	23.69	17.45	0.084	0.317	0.242	0.021	0.579	0.200	3.6	420.1	20.5
October	7.12	21.33	15.39	0.103	0.557	0.247	0.025	0.871	0.321	2.0	420.1	20.1
November	2.26	13.99	8.20	0.100	0.340	0.222	0.001	0.738	0.354	2.5	268.9	14.9

Automated Water Quality Monitoring - Sites

Results from Automated Water Quality Monitoring Stations by Site												
	Temperature, degrees C			Conductivity, mS/cm			Depth, meters			Turbidity, NTU		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Site 1	2.26	24.65	15.39	0.054	0.525	0.219	0.001	0.857	0.208	2.50	284.60	22.01
Site 2	3.88	25.15	16.43	0.075	0.401	0.267	0.027	1.956	0.545	3.20	579.40	19.89
Site 3	7.27	22.33	15.85	0.119	0.216	0.180	0.025	0.633	0.372	n/a	n/a	n/a
Site 4	5.41	23.39	15.73	0.120	0.582	0.274	0.037	1.576	0.411	2.00	449.70	29.60
Site 5	3.27	24.57	16.12	0.065	0.277	0.162	0.021	0.714	0.308	n/a	n/a	n/a
Site 6	3.69	23.91	16.14	0.086	0.371	0.173	0.219	1.264	0.603	4.50	192.50	33.77
Site 7	3.23	25.43	16.73	0.062	1.008	0.295	0.039	1.468	0.513	3.40	325.40	22.03
Overall	**2.26**	**25.43**	**16.02**	**0.054**	**1.008**	**0.224**	**0.001**	**1.956**	**0.479**	**2.00**	**579.40**	**25.46**

pH and Ferrous Iron Field Measurements by Month

	pH			# of Samples	Ferrous Iron, ppm			# of Samples
	Min	Max	Mean		Min	Max	Mean	
May	5.46	7.04	6.42	3	1.17	6.98	3.31	2
June	5.96	7.13	6.73	2	2.00	6.16	3.80	2
July	6.32	7.22	6.77	2	1.16	6.26	3.07	2
August	6.43	7.28	6.83	2	0.83	5.16	3.27	2
September	-	-	7.04	1	-	-	2.14	1
October	6.52	7.47	7.04	2	-	-	2.57	1
November	6.54	7.70	7.13	4	0.99	6.60	2.90	4

pH and Ferrous Iron Field Measurements by Site

	pH			# of Samples	Ferrous Iron, ppm			# of Samples
	Min	Max	Mean		Min	Max	Mean	
Site 1	5.46	7.70	6.73	16	2.14	5.14	3.11	14
Site 2	6.42	7.41	6.97	16	0.83	2.80	1.62	14
Site 3	6.23	7.01	6.75	16	3.87	9.64	5.30	14
Site 4	6.67	7.47	7.16	16	1.80	3.76	2.47	14
Site 5	5.53	6.92	6.38	16	1.63	6.16	3.29	14
Site 6	6.72	7.40	6.99	16	1.91	5.40	3.71	14
Site 7	6.33	7.39	6.98	16	0.90	2.42	1.56	14

Upstream Land Use

Upstream Land Use/Land Cover to Monitoring Stations				
Site Number	**Site Name**	**% Ag**	**% Urban**	**%Ag+Urban**
1	Manasquan River @ Georgia Rd.	16.8%	32.3%	49.1%
2	Manasquan River @ Pointe of Woods Dr. & Bergerville Rd.	18.3%	49.6%	67.9%
3	Yellow Brook @ Adelphia-Farmingdale Rd.	11.7%	17.1%	28.8%
4	Manasquan River @ Southard Ave.	18.9%	42.6%	61.5%
5	Marshes Bog Brook @ Yellow Brook Rd.	3.8%	16.9%	20.7%
6	Mingamahone Brook @ Allaire Rd.	6.3%	21.7%	28.0%
7	Debois Creek @ Halls Mill Rd.	11.3%	13.7%	24.9%
8	Manasquan River @ Hospital Rd.	12.5%	32.3%	44.8%

Automated Water Quality Data – Results & Conclusions

Temporal Variations:

- Average values of Specific Conductance and Turbidity highest during Summer.
- Maximum specific conductance and depth of flow peaked in Spring.
- Values for all parameters were lowest during the Fall.

Automated Water Quality Data – Results & Conclusions

Spatial Variations:

- Turbidity and specific conductance increased going downstream on Main Stem Manasquan River (Sites 1, 2 and 4).
- All tributary sites (3, 5 and 7) had lower parameter values than main stem sites.
- Highest values of turbidity and specific conductance were measured at sites 2 and 7, the two most urbanized monitoring locations.

Turbidity Analysis Statistics (NTU)			
	Existing Water Quality Data	**Grab Sampling Data**	**Automated Monitoring Data**
Min	2.9	2.3	2.0
Max	75	200	579
Mean	15.6	37	26
St. Dev	15.8	39	45

TSS Analysis Statistics (mg/L)

	Existing Water Quality Data	Grab Sampling Data
Min	1.0	0.5
Max	32.0	173
Mean	9.29	28.7
St. Dev	6.90	30.8

TP Analysis Statistics (mg/L)

	Existing Water Quality Data	Grab Sampling Data
Min	0.010	0.028
Max	1.810	1.056
Mean	0.203	0.185
St. Dev	0.281	0.187

Existing Water Quality Data

Significant Predictor (X):	Response (Y):	Regression Type	Modifications	Adjusted R^2	Probability (ά)
log(TURB), site, season, discharge	log(TSS)	Stepwise	outliers excluded	0.590	<0.0001
site, season, site*season, discharge	log(TSS)	Stepwise	outliers excluded	0.395	<0.0001
site, season, discharge	log(TURB)	Stepwise	outliers excluded	0.444	<0.0001
site, season, discharge	log(FECAL)	Stepwise	outliers excluded	0.414	<0.0001
site, discharge	log(TP)	Stepwise	outliers excluded	0.349	<0.0001

Grab Sampling Data					
Significant Predictor (X):	**Response (Y):**	**Regression Type**	**Modifications**	**Adjusted R^2**	**Probability (ά)**
log(TURB), season	log(TSS)	Stepwise	outliers excluded	0.787	<0.0001
season, discharge, discharge*season	log(TSS)	Stepwise	outliers excluded	0.355	<0.0001
season, discharge	log(TURB)	Stepwise	outliers excluded	0.341	<0.0001
log(TURB), site, log(TURB)*discharge	log(TP)	Stepwise	outliers excluded	0.865	<0.0001
site, season, discharge, discharge*season	log(TP)	Stepwise	outliers excluded	0.431	<0.0001

Upstream Land Use Regressions			
		Adjusted R^2	
Significant Predictor (X):	**Response (Y):**	**Existing Water Quality Data**	**Grab Sampling Data**
% Agriculture	TSS	0.036	0.051
% Urban	TSS	0.083	0.074
% Agriculture	TP	0.135	0.106
% Urban	TP	0.016	0.147

Bivariate Regressions:
TSS as a function of Turbidity

Existing Water Quality Data				
Site	**Site Name**	**Observations (n)**	**R^2**	**Probability (ά)**
15	Yellow Brook @ Elton-Adelphia Rd.	14	0.794	< 0.0001
16-M	Squankum Brook @ Easy St.	14	0.028	> 0.05
Site 23	Mingamahone Brook @ Belmar Blvd.	14	0.030	> 0.05
Site 24	Marshes Bog Brook @ Preventorium Rd.	14	0.191	> 0.05
Site 25	Long Brook @ Howell Rd.	13	0.165	> 0.05
Overall		**69**	**0.559**	**< 0.0001**

Bivariate Regressions: TSS as a function of Turbidity

Grab Sampling Data				
Site	**Site Name**	**Observations (n)**	**R^2**	**Probability (ά)**
1	Manasquan River @ Georgia Rd.	12	0.861	<0.0001
2	Manasquan River @ Pointe of Woods Dr & Bergerville Rd.	12	0.964	<0.0001
3	Yellow Brook @ Adelphia-Farmingdale Rd.	11*	0.779	0.0002
4	Manasquan River @ Preventorium Rd.	12	0.951	<0.0001
5	Marshes Bog Brook @ Yellow Brook Rd.	11*	0.733	0.0005
6	Mingamahone Brook @ Allaire Rd.	11*	0.831	<0.0001
7	Manasquan River @ Hospital Rd.	12	0.935	<0.0001
Overall		**81****	**0.933**	**<0.0001**

* one (1) outlier excluded from analysis

** three (3) outliers excluded from analysis

Bivariate Regressions: TP as a function of Turbidity

Existing Water Quality Data				
Site	**Site Name**	**Observations (n)**	**R^2**	**Probability (ά)**
15	Yellow Brook @ Elton-Adelphia Rd.	6	0.00364	> 0.05
16-M	Squankum Brook @ Easy St.	5	0.00014	> 0.05
Site 23	Mingamahone Brook @ Belmar Blvd.	5	0.00004	> 0.05
Site 24	Marshes Bog Brook @ Preventorium Rd.	5	0.27616	> 0.05
Site 25	Long Brook @ Howell Rd.	5	0.75654	> 0.05
Overall		**26**	**0.06975**	> 0.05

Bivariate Regressions: TP as a function of Turbidity

Grab Sampling Data				
Site Number	**Site Name**	**Observations (n)**	**R^2**	**Probability (ά)**
1	Manasquan River @ Georgia Rd.	12	0.924	<0.0001
2	Manasquan River @ Pointe of Woods Dr & Bergerville Rd.	11*	0.900	<0.0001
3	Yellow Brook @ Adelphia-Farmingdale Rd.	12	0.877	<0.0001
4	Manasquan River @ Preventorium Rd.	12	0.951	<0.0001
5	Marshes Bog Brook @ Yellow Brook Rd.	11*	0.881	<0.0001
6	Mingamahone Brook @ Allaire Rd.	11*	0.931	<0.0001
7	Manasquan River @ Hospital Rd.	12	0.929	<0.0001
Overall		**81****	**0.913**	**<0.0001**

* one (1) outlier excluded from analysis

** three (3) outliers excluded from analysis

Project Assessment & Results

- Grab sampling and continuous water quality monitoring data confirm observations made in watershed modeling and visual assessments.

- Seasonal variation and discharge are the two most significant influences on the values of TSS, TP and Turbidity.

Project Assessment & Results

- Baseflow…related to site locations
- Stormflow…related to:
  - seasonal variation
  - discharge (flow)

- Bivariate regressions and linear regression models show strong and statistically significant correlations between Turbidity and TSS, and Turbidity and TP.

Conclusions & Recommendations

- Significant channel and watershed processes are contributing sediment into the surface waters of the Manasquan Watershed.

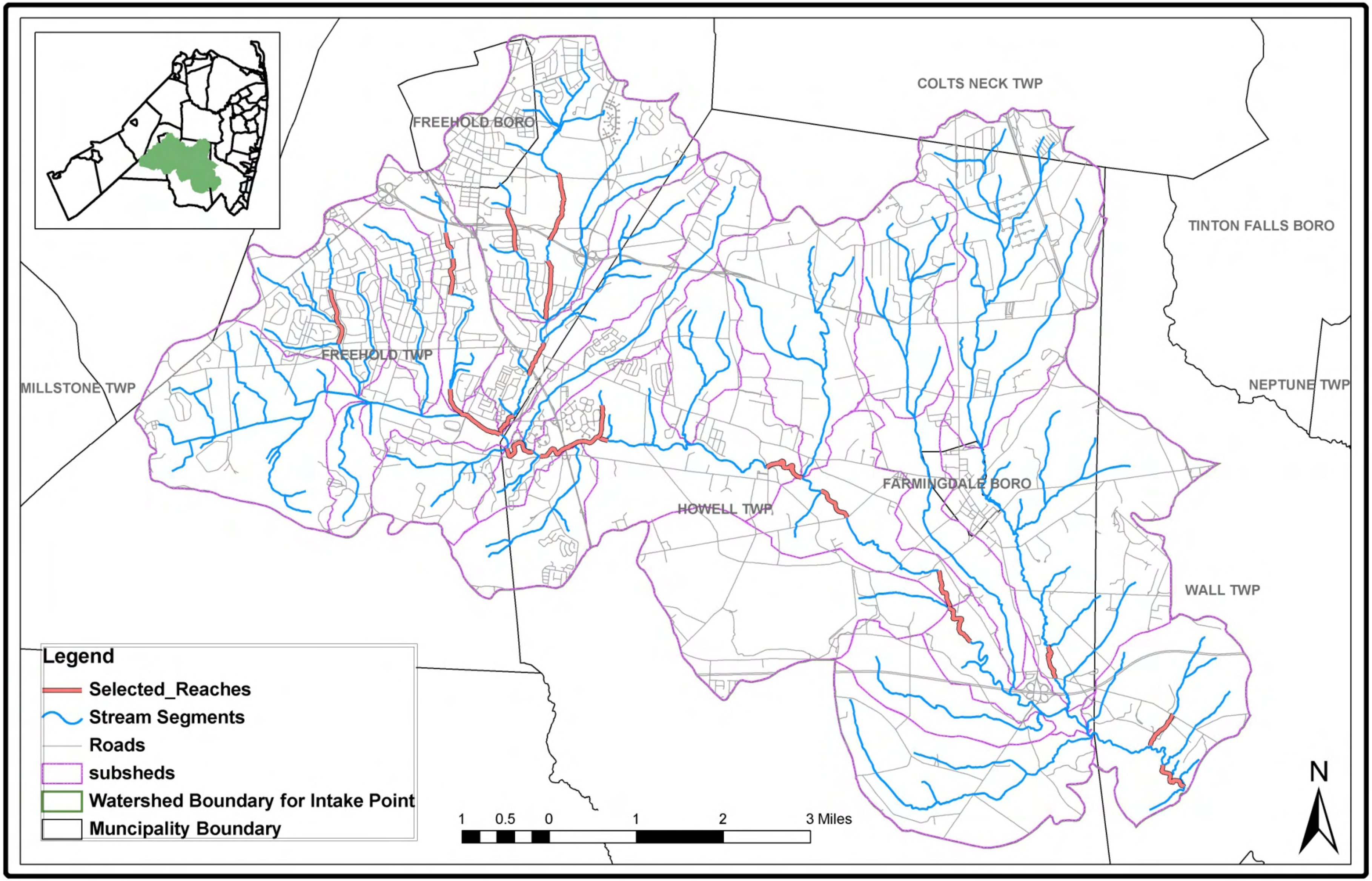
- Major causes of increased sediment loading include:
  - debris blockages of stream channel restricting flow and degrading banks,
  - lack of outlet structure control entering stream,
  - highly erodible soils that are easily transferable.

Conclusions & Recommendations

- The outcome of this degradation has resulted in:
  - bank erosion, undercutting, lack of channel definition,
  - increased turbidity and nutrient levels.

- 20 stream reaches have been identified as:
  - sites with the most severe deposition of silt
  - highest likelihood of success in lowering the levels of TSS, Turbidity and TP through proposed mitigation and management strategies.

Proposed Mitigation Sites



Proposed Mitigation & Management Strategies

- Debris should be cleared from stream channels, especially where flow is being constricted.

- Boulder toe revetments should be used to protect stream banks with moderate to severe bank erosion

- Stream banks should be stabilized and revegetated using biologs, fascines, fiber rolls or willow wattles.

Proposed Mitigation & Management Strategies

- Exposed outfall pipes and utility lines and scoured footings of bridges/culverts should be stabilized and repaired

- Homeowners adjacent to streams should be educated about non-point source pollution and stormwater runoff

- At the most severely impacted sites, channel restoration may be needed to redefine channels and reestablish floodplains

Next Steps

- Additional studies:
  - to identify the source of the yellow coloration that appears in the surface waters of the watershed during the summer.
  - to determine the effects of sediment resuspension on nutrient and trace metal loadings in the watershed
  - to examine remediation strategies for subwatersheds with nutrient, solids and turbidity contributions but do not have a severe potential for channel destabilization