The Importance of Headwater Wetlands and Water Quality in North Carolina

North Carolina Department of Environment and Natural Resources

Division of Water Quality

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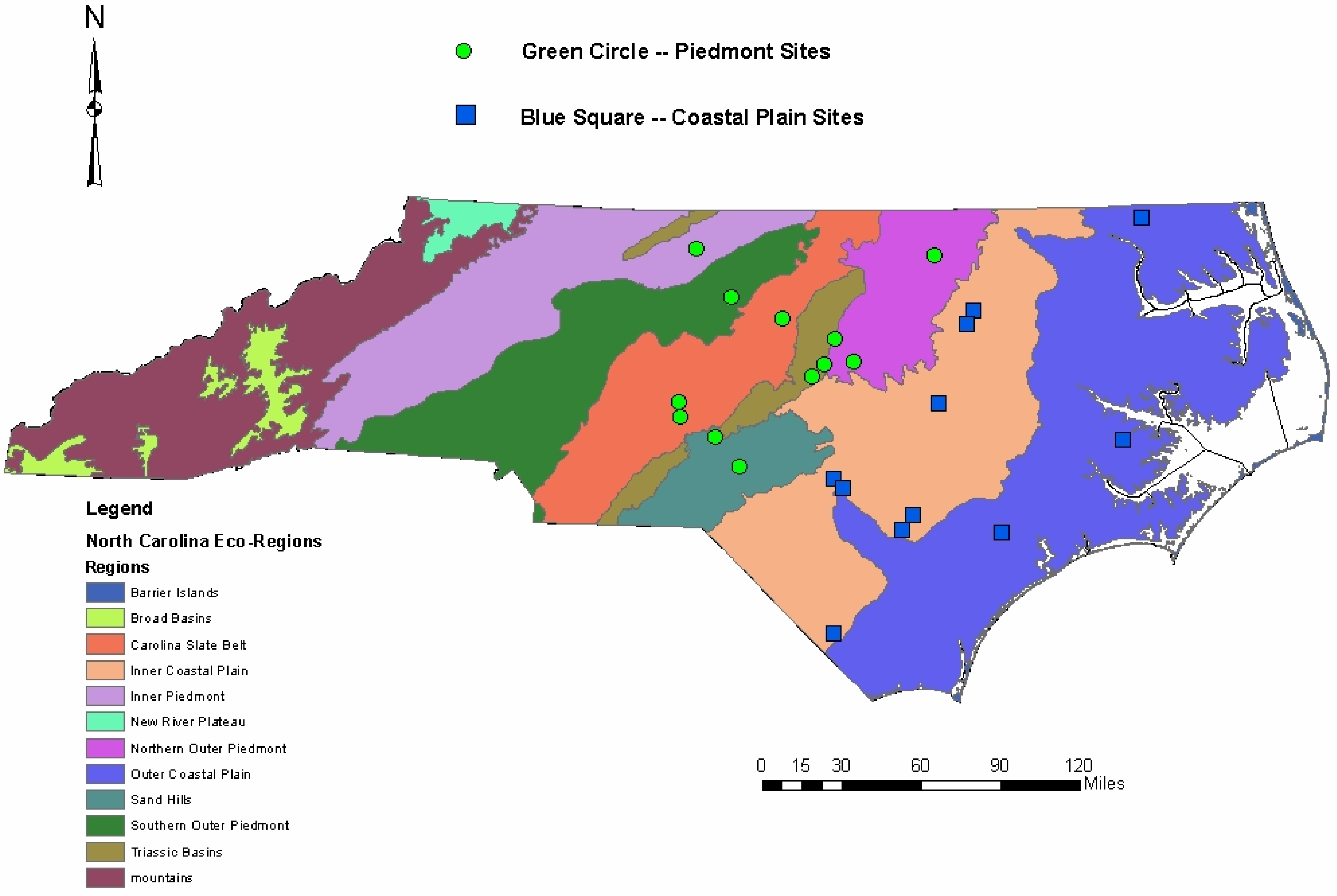
Headwater Wetlands

- Definition – Typically small bowl-shaped wetlands that grade into 1st order streams.
- Location - Upper reaches of watersheds in the Coastal Plain, Piedmont, and Mountain regions of NC.
- Importance – Protects downstream aquatic resources by acting as a natural filtering system for water quality.

Study Objectives

1. To determine whether headwater wetlands with more developed watersheds and buffers have lower water quality than wetlands with more natural watersheds and buffers.
2. To determine whether headwater wetlands have the capacity to affect pollutant levels by comparing upstream to downstream water quality results.
3. To determine whether headwater wetlands have a better filtering capacity in more natural watersheds than in more developed watersheds.

Headwater Wetland Monitoring Sites



Headwater Wetland Sites

Spring Garden

Kelly Road

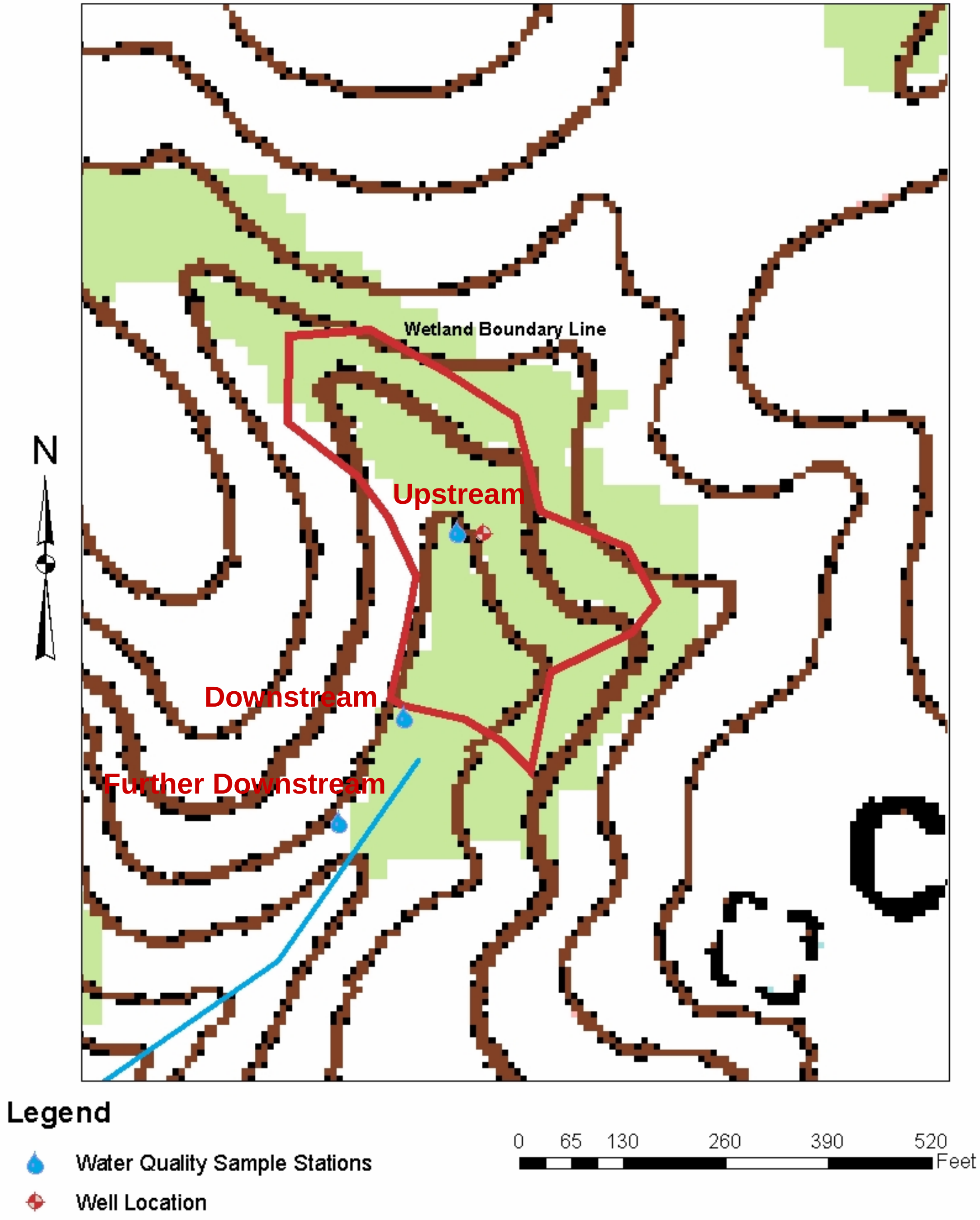
Nahunta

Batchelor

Water Quality Sampling Methods

- Six Quarterly water quality sampling times (2005-2006) at Upstream, Downstream, and Further Downstream stations
- Physical parameters – Temperature, DO, Specific Conductivity, pH, TSS, Turbidity
- Chemical parameters – Nutrients (Nitrate + Nitrite, TKN, Phosphorous, Ammonia), Heavy Metals (Ca, Mg, Zn, Cu, Pb), DOC, TOC, Fecal Coliform
- Samples obtained by direct grab (surface water only) or by digging (soil pore water).
- Separate Analysis for "All data" (surface and soil pore) and "no dug data" (surface water only).

Hog Farm Upper



Quarterly Water Sample Stations at Rough Rider

April 2005

July 2005

October 2005

January 2006

Objective 1-Watershed and Buffer Affect on Headwater Wetland Water Quality

Analysis Method

- Watershed Condition was determined by calculating the Land-Use Index (LUI, Brown and Vivas, 2003) score for each site's watershed and one-mile buffer.

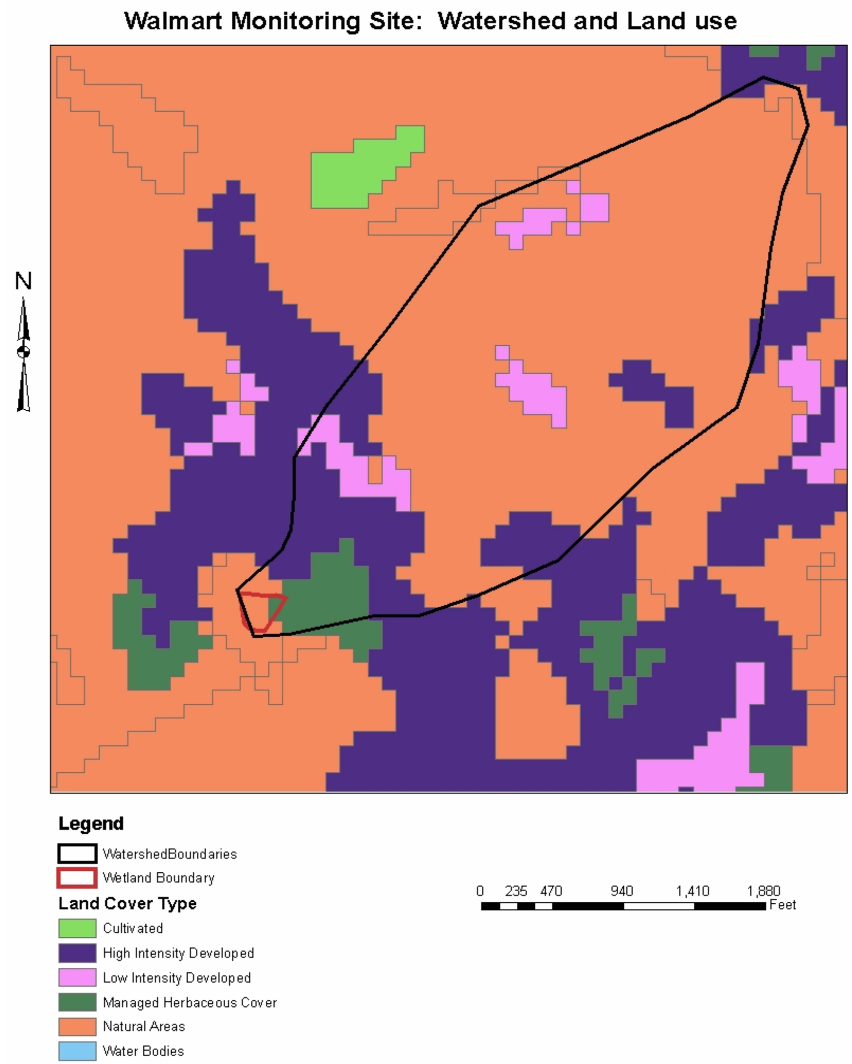
- Land-Use Index (LUI) - Summarized disturbance score for Land Cover Types in a given area were determined for wetland site watersheds.

- Correlation Analysis was run for each site's LUI score against each site's 19 different water quality parameter results.

Objective 1-Watershed Affect on Headwater Wetland Water Quality

$$LUI_{Total} = \sum \%Lu_i * LUI_i$$

- LUI_{Total} = LUI Ranking for landscape unit ***i***
- $\%Lu_i$= percent of the total area of influence in the land use ***i***
- land use i LUI_I=landscape development intensity coefficient for land use



Headwater Wetland Landcover Type and LUI Coefficient Values

Land Cover Type	*LUI Coefficient (*LUI_I)
Natural Areas	1
Water Bodies	1
Unmanaged Herbaceous Upland	2
Unmanaged Herbaceous Wetland	2
Managed Herbaceous Wetland	2
Cultivated	4
Unconsolidated Sediment	4
Low Intensity Development	5
High Intensity Development	8

Objective 1-To Determine the Watershed affect on Headwater Wetland Water Quality

Results

- Significant correlation between Watershed LUI scores and calcium, magnesium, Nitrite + Nitrate, specific conductivity, and pH (p-value<0.05) for all water quality samples (surface and pore water) and surface water quality samples.

- Significant correlation between Watershed LUI scores and Phosphorous and Zinc for surface water quality samples only.

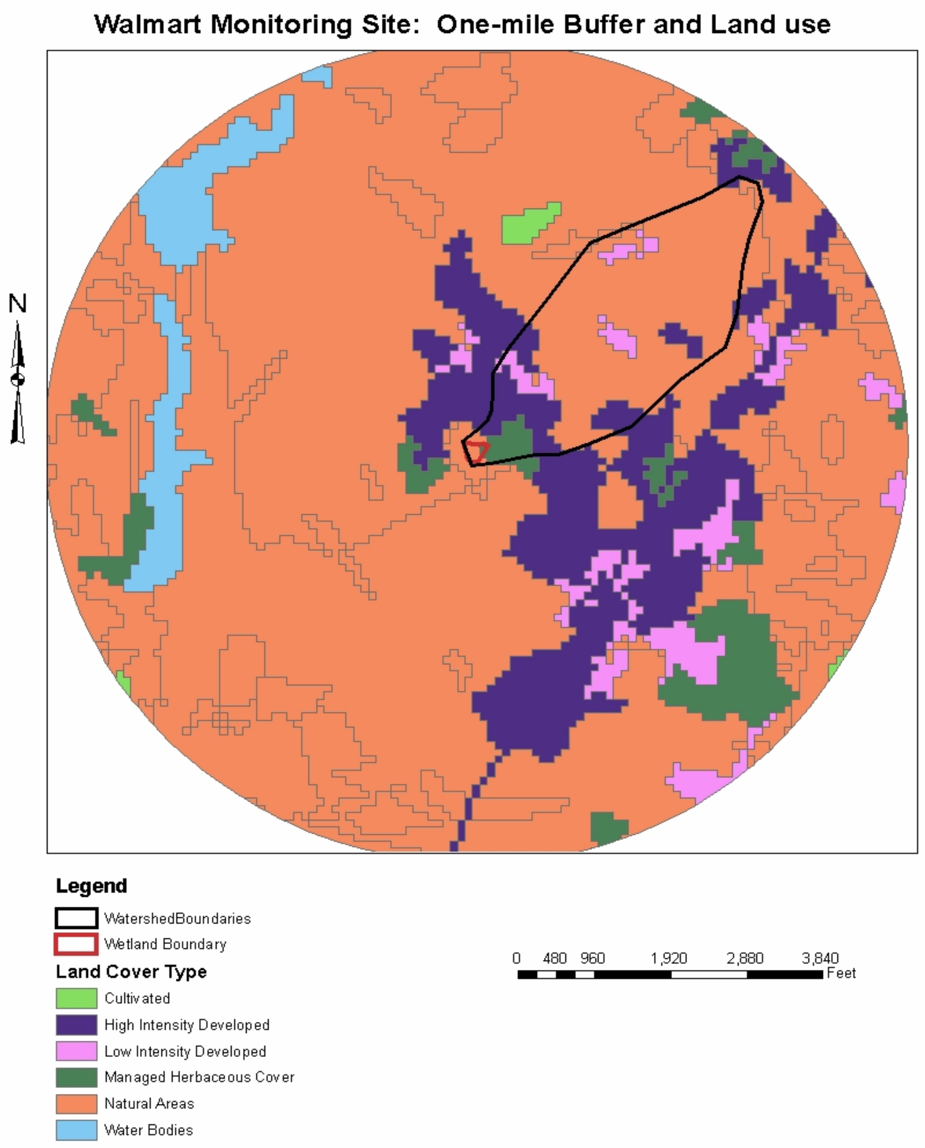
Conclusion

- There is a direct correlation between the headwater wetland water quality and the condition of the surrounding watershed.

Objective 1- One-Mile Buffer

Analysis Method and Results

- LUI scores for each site's one-mile buffer was calculated. Correlation Analysis was run for each site's one-mile buffer LUI value against each site's 19 different water quality parameter results.
- Significant correlation between one-mile buffer LUI scores and calcium, DOC, Dissolved Oxygen, Phosphorous, TOC, and Zinc (p-value<0.05) for all water quality samples (surface and pore water).
- Significant correlation between one-mile buffer LUI scores and DOC and Dissolved Oxygen for surface water quality samples only.



Objective 1 – ORAM

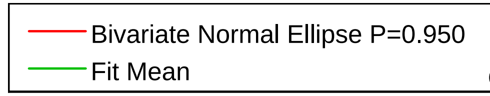
Analysis Method

- Ohio Rapid Assessment Method (ORAM v. 5.0, Ohio EPA 2001) was used to calculate a disturbance score for each site. ORAM assesses a site's size, 50m-buffer condition, hydrology, habitat, and plant community quality and interspersion, and microtopography.
- Correlation Analysis was run for each site's ORAM score against each site's 19 different water quality parameter results.

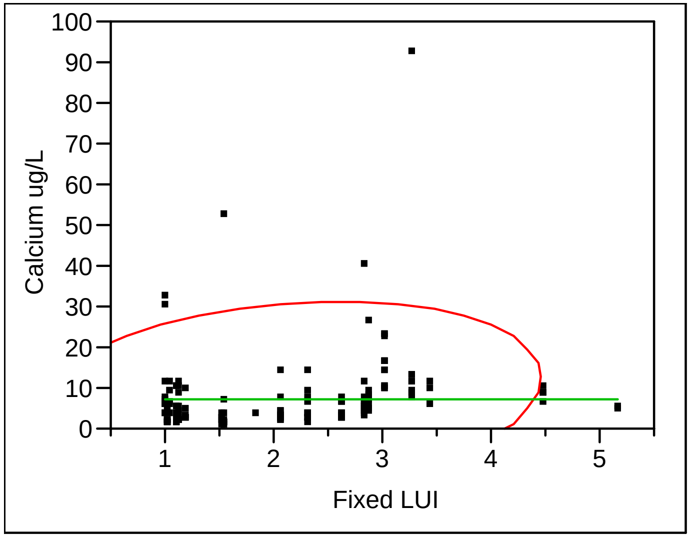
Results

- Significant correlation ($p<0.05$) between ORAM scores and calcium and magnesium for all water quality samples (surface and pore water).
- Significant correlation ($p<0.05$) between ORAM scores and magnesium, Nitrite + Nitrate, and specific conductivity for surface water quality samples only.

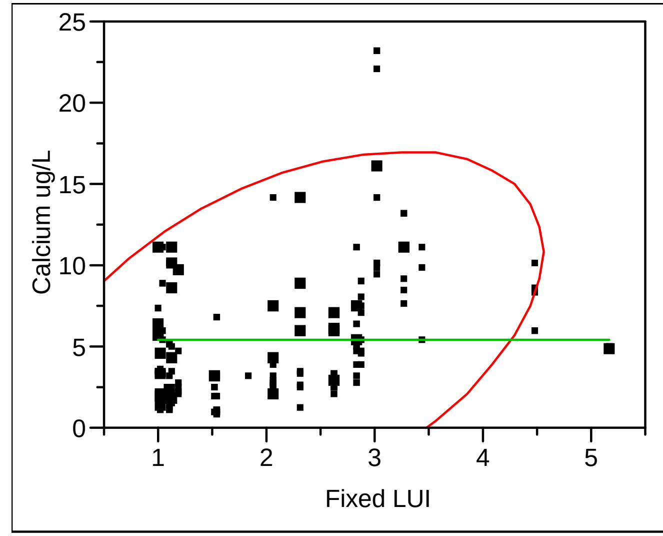
Objective 1 – Correlation Analysis Results



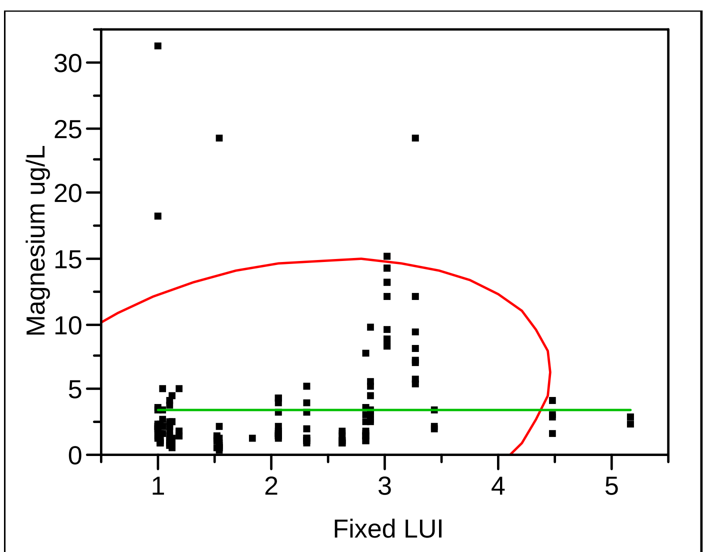
Correlation of LUI site watershed score and Calcium for All Water Quality Data



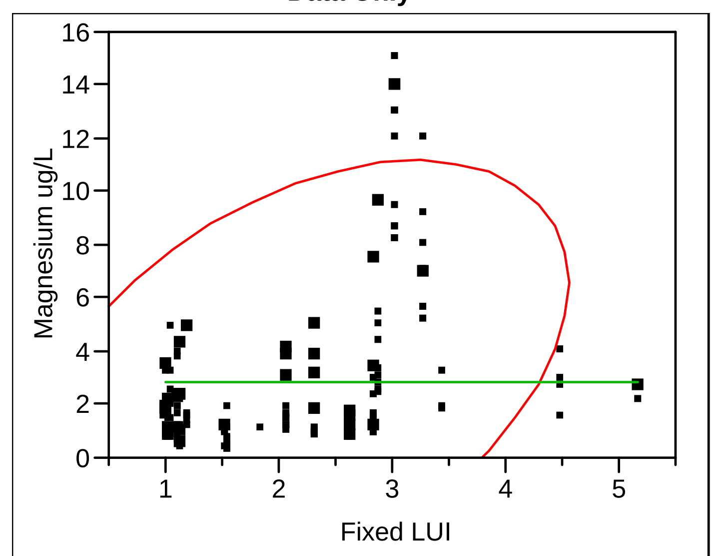
Correlation of LUI site watershed score and Calcium for Surface Water Quality Data Only



Correlation of LUI site watershed score and Magnesium for All Water Quality Data



Correlation of LUI site watershed score and Magnesium for Surface Water Quality Data Only



Objective 2-
Water Quality Station Comparisons to Determine Headwater Wetland Filtering Capacity

- Water Quality Sampling Stations
  - UP - Upstream
  - DN - Downstream (located 200 feet down stream from Upstream water quality station)
  - FD - Further Downstream - (located another 200 feet down stream from Downstream water quality station, 5 sites in Coastal Plain only, sampled last 2 quarters)
- Water Quality Station Comparisons
  - UP-DN – Upstream compared to Downstream
  - UP-FD – Upstream compared to Further Downstream
  - DN-FD – Downstream compared to Further Downstream

Objective 2-
Water Quality Station Comparisons to Determine Headwater Wetland Filtering Capacity

Methods Analysis

Coastal Plain and Piedmont Regional Station Comparison Analysis of Water Quality Parameters was completed for all data (surface and pore) and surface water data only.

- Overall regional comparisons of UP-DN, UP-FD, and DN-FD water quality parameter station means.
- ANOVA for the UP, DN, and FD water quality parameters results was run for each region to determine if there is a significant difference between stations.
- For Significant ANOVA results in the Coastal Plain, the Tukey Kramer Multiple Comparison test was used to determine which station comparison (UP-DN, UP-FD, DN-FD) were significantly different.

Piedmont Mean Comparison of Water Quality Parameter Results and ANOVA Results

Parameter		All Data					Surface Water Data			
		Upstream (UP)	Downstream (DN)	UP-DN Comparison	ANOVA Significant Results		Upstream (UP)	Downstream (DN)	UP-DN Comparison	ANOVA Significant Results
Ammonia mg/L		0.1	0.08	**0.01**			0.06	0.07	**-0.01**	
Calcium mg/L		5.16	6.17	**-1.01**			3.12	3.73	**-0.61**	
Copper ug/L		22.11	19.34	**2.77**			4.43	4.35	**0.08**	
Dissolved Oxygen (%)		33.39	41.51	**-8.13**	**p=0.05**		37.59	43.88	**-6.29**	
Dissolved Oxygen (mg/L)		3.18	4.09	**-0.91**	**p=0.02**		3.52	4.32	**-0.8**	
DOC mg/L		7.99	7.5	**0.49**			7.85	7.59	**0.25**	**p=0.07**
Fecal Colliform cfu/100 ml		1705.33	1367.18	**338.16**			1028.74	277.07	**751.68**	
Lead ug/L		34.67	60.95	**-26.27**			17.04	17.25	**-0.21**	
Magnesium mg/L		2.66	2.79	**-0.13**			1.29	1.59	**-0.3**	
NO2+NO3 mg/L		0.04	0.04	**0**			0.04	0.04	**0**	
Phosphorus mg/L		0.41	0.29	**0.11**			0.15	0.17	**-0.01**	
Specific Conductivity		49.98	56.89	**-6.9**			52.64	57.55	**-4.91**	
Total Kjeldahl (TKN) mg/L		3.1	2.03	**1.07**			1.12	0.75	**0.38**	**p=0.08**
TOC mg/L		40.77	37.16	**3.61**			18.36	16.2	**2.16**	
TSS mg/L		396.3	168.58	**227.72**			155.25	170.31	**-15.06**	
Turbidity NTU		114.82	67.85	**46.97**			110.89	72.84	**38.05**	
Water, Temperature C°		17.58	17.08	**0.5**			17.64	16.8	**0.84**	
Zinc mg/L		91.39	61.44	**29.95**			20.72	22.15	**-1.43**	
pH S.U.		5.38	5.48	**-0.1**			5.34	5.44	**-0.1**	

Blue - Water Quality **Improved**

Red - Water Quality showed **No Improvement** (stayed the same or became worse)

Significant Difference between Stations - P < 0.10 **Practical Significant Difference Between Stations - P < 0.15**

Coastal Plain Mean Comparison of Water Quality Parameter Results

Parameter		All Data					Surface Water Data			
		UP-DN Comparison	UP-FD Comparison	DN-FD Comparison	ANOVA Significant Results		UP-DN Comparison	UP-FD Comparison	DN-FD Comparison	ANOVA Significant Results
Ammonia mg/L		0.01	0.09	0.08			0	0.04	0.04	
Calcium mg/L		2.11	5.35	3.24			-0.84	2.44	3.28	
Copper ug/L		-0.68	12.35	13.02			-1.51	1.97	3.48	
Dissolved Oxygen (%)		-4.03	-14.56	-10.54	p=0.13 UP-FD & DN-FD		-3.59	-13.27	-9.68	
Dissolved Oxygen (mg/L)		-0.57	-1.02	-0.44			-0.57	-0.87	-0.3	
DOC mg/L		3.62	6.42	2.8			4.57	6.77	2.2	
Fecal Colliform cfu/100 ml		732.09	-13350.09	-14082.17	p=0.004 UP-FD		-288.71	-788.19	-499.48	
Lead ug/L		-10.36	29.15	39.52			-7.22	2.73	9.95	
Magnesium mg/L		0.78	2	1.22			-0.05	1.22	1.28	
NO2+NO3 mg/L		-0.29	0.26	0.55			-0.35	0.53	0.88	
Phosphorus mg/L		-0.11	0.3	0.41			-0.18	0.07	0.25	p=0.09 DN-FD
Specific Conductivity		-2.72	24.5	27.22			-8.67	19.31	27.98	
Total Kjeldahl (TKN) mg/L		5.55	9.19	3.63			-1.44	0.59	2.03	p=0.12 DN-FD
TOC mg/L		44.87	144.51	99.64			-16.61	8.23	24.84	p=0.11 DN-FD
TSS mg/L		-2.92	155.09	158.01			-55.79	77.26	133.05	
Turbidity NTU		-4.1	.	.			-4.1	.	.	
Water, Temperature C^{o}		0.64	-2.28	-2.92			0.15	-2.64	-2.8	
Zinc mg/L		-10.25	34.87	45.12			-6.15	10.39	16.54	
pH S.U.		-0.16	-0.26	-0.11			-0.25	-0.17	0.08	

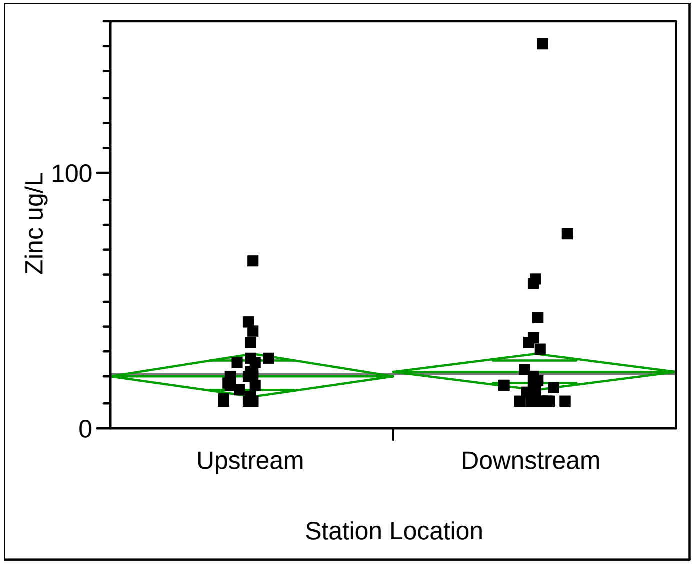
Blue - Water Quality **Improved**

Red - Water Quality showed **No Improvement** (stayed the same or became worse)

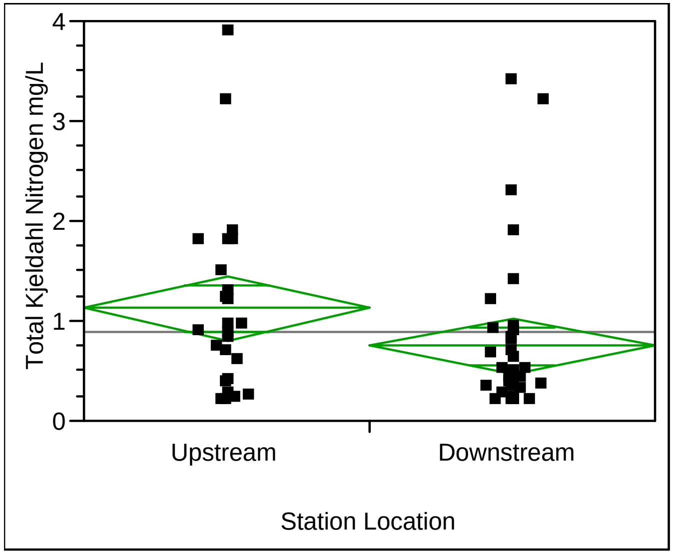
Significant Difference between Stations - P < 0.05 **Practical Significant Difference Between Stations - P < 0.10**

Objective 2 – Distribution of Water Quality Results

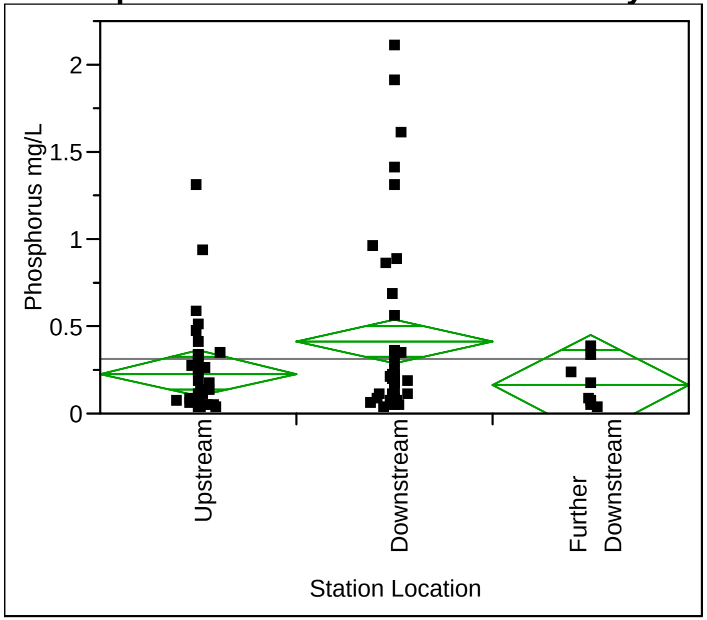
PIEDMONT
Zinc-Surface Water Data Only



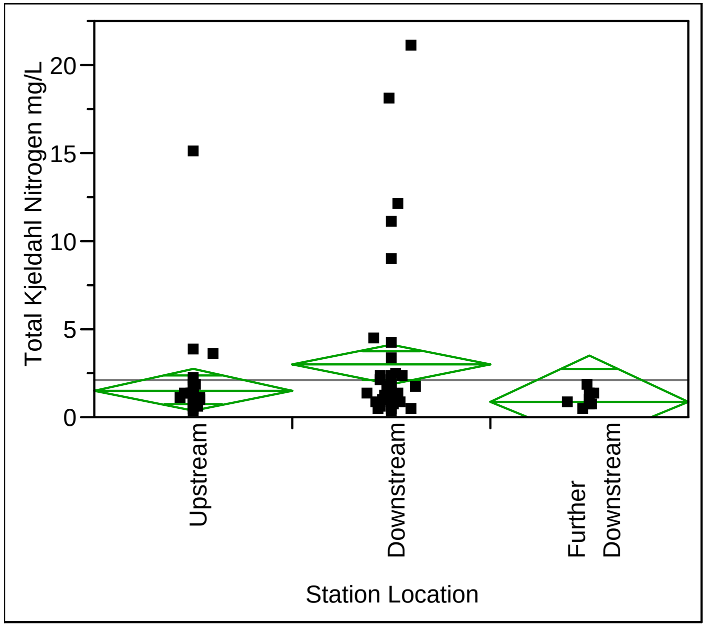
PIEDMONT
TKN - Surface Water Data Only



COASTAL PLAIN
Phosphorous –Surface Water Data Only



COASTAL PLAIN
TKN-Surface Water Data Only



Objective 2-
Water Quality Station Comparisons to Determine Headwater Wetland Filtering Capacity

<u>Methods Analysis</u>

Site Station Comparison Analysis of Water Quality Parameters was completed for all data (surface and pore) and surface water data only.

- Site Station comparisons of UP-DN, UP-FD, and DN-FD water quality parameter station means.
- The total number of mean station comparisons (UP-DN, UP-FD, and DN-FD) that showed "improvement" or "no improvement" for each parameter within each site was determined. A Chi-Square test was performed to determine if the number of site comparisons that "improved" was significantly different then the number of site comparisons that had "no improvement".

Regional Sample Station Location Comparison by Site of Water Quality Parameter Means

All Water Quality Results

Station Comparisons	Piedmont	Coastal Plain			Total Stations
	UP-DN	UP-DN	UP-FD	DN-FD	
Improvement	130	117	73	66	386
No Improvement	94	88	17	24	223
Total Stations	224	205	90	90	609
Chi Square Results	P=0.06	P=0.04	P<0.0001	P<0.0001	

Surface Water Quality Results

Station Comparisons	Piedmont	Coastal Plain			Total Stations
	UP-DN	UP-DN	UP-FD	DN-FD	
Improvement	104	104	55	66	329
No Improvement	91	101	35	24	251
Total Stations	195	205	90	90	580
Chi Square Results			P=0.03	P<0.0001	

Blue - Water Quality **Improved**

Red - Water Quality showed **No Improvement** (stayed the same or became worse)

Objective 3 – Watershed affect on Headwater Wetland Filtering Capacity

- Percent Improvement Capacity calculated for each site

$$= \frac{\text{Improved } (UP\text{-}DN)+(UP\text{-}FD)+(DN\text{-}FD)}{\text{All } \quad (UP\text{-}DN) + (UP\text{-}FD) + (DN\text{-}FD)}$$

- Correlation Analysis was run for each site's LUI value against each site's Improvement Capacity
- There was a positive significant correlation (P=0.089) for the analysis of all water quality data (surface and pore water) which indicates headwater wetland filtering capacity actually improved in more developed watersheds.
- The results of these correlations suggest that headwater wetlands are functioning properly by filtering out downstream pollutants which reinforces the importance of preserving these wetlands even in more developed watersheds.

Final Conclusions

- There is a direct correlation between the headwater wetland water quality and the condition of the surrounding watershed and buffer.
- Headwater wetlands affectively reduce the amount of pollutants entering downstream waters.
- Headwater wetlands in more urban and developed watersheds have a better capacity for filtering pollutants then headwater wetlands located in more watersheds.

Future Results to be Analyzed

- Other Headwater Wetland Physical, Chemical and Biotic Features to be studied.

Physical and Chemical Surveys

Water Quality

Hydrology

Soils

Biotic Communities Surveys

Amphibians

Macroinvertebrates

Plants

Individual Site Analysis

- 21 of 23 sites showed statistically significant improvement on at least one water quality measure.
- 10 of 23 sites showed statistically significant improvement on at two or more water quality measure.
- Only 2 sites had statistically significant results showing water quality measures degrading

Rapanos – in summary

- Three general themes:
  - Traditionally navigable waters – no change in jurisdiction
  - Relatively permanent water – no change in jurisdiction
    - Defined as flowing for at least three (3) months
  - Significant nexus test for all other waters
    - Various tests are suggested to show chemical, hydrologic or biologic connection

Results on “significant nexus” for small streams

- Biology – long term studies on aquatic macrobenthos for ephemeral, intermittent and small perennial streams in mountains, piedmont and (on-going) coastal plain.
- Compare biota to biota in downstream traditionally navigable water.
- Defined as intermittent or perennial using N.C. Division of Water Quality stream evaluation form (geomorphic, hydrologic and biologic variables).

Conclusions on “significant nexus” for small streams

- In all intermittent and small perennial streams, there is always at least one taxa also present in downstream traditionally navigable water.
- In half of ephemeral streams, this is also true.
- Therefore, all intermittent and small perennial streams have a significant nexus to downstream traditionally navigable water and the 404 jurisdiction should not change.

Headwater Wetlands

- Long-term (3 years) work on groundwater hydrology, water chemistry and biology (plants, aquatic macrobenthos and amphibians)
- Piedmont and Coastal Plain – 23 sites
- Headwater wetlands – occur across state at origins of streams in small watersheds.
- Small size – average about ½ acre in Piedmont, about 3 acres on Coastal Plain.

Headwater Wetlands – results to date

- Water Chemistry – significant improvement in water quality due to filtering effect of headwater wetlands.
- Aquatic macrobenthos – 207 taxa found at 58 stations. Of these, 103 taxa found in downstream traditionally navigable water.
- Therefore, headwater wetlands have significant nexus to downstream navigable water.

Other wetland types?

- Data in literature can show (not always) significant effect of wetlands on downstream water quality.
- Aquatic macrobenthos? – In NC, need to collect more data (underway).
- In my opinion, we can probably can safely extrapolate these results to other riparian wetlands – bottomland hardwood forests, riverine swamp forest, non-tidal freshwater marshes, etc.
- Non- riparian wetlands – less clear.

Overall conclusions from NC analysis

- Similar analyses from data from state water quality agencies can help the Corps and EPA minimize loss of 404 jurisdiction from Rapanos decision.
- In NC, can safely say that the Corps should lose no jurisdiction on streams and none on headwater wetlands.
- In my opinion, we can probably can safely extrapolate these results to other riparian wetland types. Non-riparian wetlands less clear.

Final report available soon

- DWQ staff are preparing a summary document for Corps and EPA staff
- Available soon (early Sept.) at our website at h2o.enr.state.nc.us/ncwetlands/rd_pub_not.html (under Public Notices section)

Questions?

North Carolina Division of Water Quality

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