Assessment Report: Biological Impairment in the Clayroot Swamp Watershed

Neuse River Basin
Pitt County, NC

North Carolina Division of Water Quality
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Collaborative Assessment for Watersheds and Streams (CAWS) Project
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I. Study Purpose

The Clayroot Swamp assessment is part of the Collaborative Assessment of Watersheds and Streams (CAWS) project, a study of 4 watersheds across the state being conducted by DWQ between 2001 and 2003. The goal of the project is to provide the foundation for future water quality restoration activities in each watershed by:

1. Identifying the most likely **causes** of biological impairment. Examples of such causes include degraded habitat or specific pollutants;
2. Identifying the major watershed activities and **sources** of pollution contributing to those causes. Examples of sources include streambank erosion or stormwater runoff from a particular location;
3. Outlining a watershed **strategy** that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

II. Study Approach

The general conceptual approach used to determine the causes of impairment in Clayroot Swamp was as follows:

1. Identify the most plausible potential causes of impairment in the watershed, based on existing data and initial watershed reconnaissance activities;
2. Collect a wide range of data bearing on the nature and impacts of those potential causes; and
3. Characterize the causes of impairment by evaluating all available information using strength of evidence approach. The strength of evidence approach involves a logical evaluation of multiple lines (types) of evidence to assess what information supports or does not support the likelihood that each candidate stressor is actually a contributor to impairment.

III. Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not enough to fully address the causes of the impairment. Extensive data collection was needed to develop a sufficient base of information. The types of data collected during this study included:

1. Macroinvertebrate sampling;
2. Assessment of stream habitat, morphology, and riparian zone condition;
3. Stream surveys that entailed walking the stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition;
4. Chemical sampling of stream water quality;
5. Chemical analyses of stream sediment;
6. Bioassays to assess water column toxicity, and, to a lesser degree, sediment toxicity; and
7. Watershed characterization that included evaluation of hydrologic conditions, land use, land management activities, and potential pollution sources.

IV. Description of the Clayroot Swamp Watershed

The Setting.
The Clayroot Swamp Watershed is located in the southeastern part of Pitt County. It is a tributary of the Swift Creek, which is a major tributary of the Neuse River. The total length of Clayroot Swamp is 12.6 miles. The watershed is primarily undeveloped with only a few small municipalities, including Clayroot, Stokestown, and Shmelerdine. Upper reaches of the Clayroot Swamp are located within the Voice of America Complex, where high proportion of impervious surfaces might contribute to the water quality impairment.

Topography and Land Use
Clayroot Swamp is located on the Coastal Plain of North Carolina, which is characterized by a very flat topography. Slopes generally do not exceed 4 percent. Change in elevation from the source of the Clayroot Swamp to its confluence with Swift Creek is only 12 feet over 12.6 miles of the stream. The eastern part of the Pitt County has elevation near sea level. Land use in the watershed is primarily agricultural. There are 12 registered hog production facilities in the Clayroot Swamp watershed.

Hydrology
Pitt County receives a relatively high amount of rainfall; average total rainfall is 47.5 inches. Precipitation is not evenly distributed throughout the year. Most rainfall occurs during summer months. Thunderstorms account for a large part of the rainfall received during the growing season. Rainfall in winter is usually associated with large low-pressure storms passing over eastern United States or Atlantic Ocean.

Clayroot Swamp is not gauged and long term monitoring data is not available. Due to flat topography, most streams in the area exhibit no flow during summer months. However, extensive ditching and artificial channelization of Clayroot Swamp provide additional discharge, maintaining streamflow during the summer.

Soils
The Clayroot Swamp consists of two soil associations. Soils adjacent to the stream on flood plain and stream terraces belong to Bibb-Portsmouth association. These soils are poorly drained to very poorly drained, and are underlain by very friable fine sandy loam, or that have a subsoil of friable sandy loam and sandy clay loam. Soils on the upland belong to the Lenoir-Bladen-Craven association, they are moderately well drained to poorly drained and have a subsoil of very firm and firm sandy clay to clay. Soils of both associations have low pH and fertility, and relatively low organic matter content. Most of the soils of the watershed are dominated by secondary minerals such as kaolinite, goethite, lepidocrocite, and gibbsite. These minerals have low surface area and low surface charge. Most of the charge on the surface of the colloids is pH dependent and might fluctuate widely depending on the use of lime and fertilizers by farmers. Due to low charge, these soils have low ability to adsorb nutrients and prevent them from leaching to the ground or surface waters.

V. Water Quality Data

Division of Water Quality collected benthic invertebrate samples in 1991, 1995, 2000, and 2001. Macroinvertebrates were collected using DWQ's EPT sampling procedure. The bioclassifications assigned to the stream were Poor and Fair for all sampling events. During the years 1991, 1995 and 2000 samples were collected at the SR1941 site. The 2001 sample was collected upstream of the previous site at the NC102 bridge crossing in Pitt County. Summer sampling identified significant algal growth, which might be an indication of high nutrient content. This conclusion is supported by conductivity data. Conductivity levels measured during summer were substantially higher than during winter. Dissolved oxygen levels appeared to be higher than state standard of 5.0 mg/L with an exception of one measurement in August 2000, when it was recorded at 4.7 mg/L.

Limited watershed assessments were conducted during invertebrate sampling in 1991, 1995, 2000, 2001 and 2003. Results are presented in Table 1. On October 11, 2000 DWQ staff conducted a reconnaissance survey of Clayroot Swamp and its watershed in Pitt County near Greenville. The survey included visual observations of land use activities in the twelve square mile drainage area upstream from Clayroot Swamp at SR1941. In addition, bridge-site evaluations consisting of physical parameters and habitat assessments were conducted at twelve locations on Clayroot Swamp and its major tributaries. All sites observed during surveys exhibited signs of channelization. It should be noted that Clayroot Swamp and its major tributaries are essentially agricultural drainage ditches. Evidence of active ongoing maintenance dredging could be observed in many locations.

Land use in the watershed was predominantly agricultural with an estimated 80% cotton fields, and the remaining 20% in soybean and corn. Although agriculture is the dominant land use, most farms in the area appeared to practice good environmental management. Communication with David Hardy of the local Soil and Water Conservation District confirmed that conclusion. Although water levels in the upper watershed of Clayroot Swamp, and its major tributary Indian Swamp, did not appear to be low, very little flow was observed in either system prior to their confluence. Staff of the DWQ involved in the sampling indicated that water appeared to be turbid and nutrient enriched with bottom substrate heavily covered with algae at most sites in the upper watershed. The lower reach of Clayroot Swamp exhibited severe erosion of the sandy banks and increased flow. Presence of the sandy soils in the watershed in combination with existing land use practices resulted in severe erosion and significant sedimentation.

Surveys conducted in 2000 and 2001 resulted in a very low habitat score due to channelization, eroding banks, lack of riparian vegetation, and lack of riffles and pools. Sediment also covered most of the channel producing very uniform habitat without much diversity. As a result of the deficiency in riparian vegetation, water temperature during summer months exceeded 30^{o} C.

Biological sampling has been conducted in the lower watershed five times since 1991, as part of the Basinwide Assessment Program. Benthic microhabitat here is practically nonexistent: no riffles, snags, or root mats. The low microhabitat scores in the 2000 surveys reflect this.

Fish sampling was conducted in Clayroot Swamp at SR1941 to evaluate fish community structure in 1991, 1995, and 2000. Clayroot Swamp received ratings of Good-Excellent during all these fish sampling events. The community was very diverse and the fish were abundant with over thirty species collected at the site.

Table 1. Watershed Characterization. Clayroot Swamp. SR 1941.

Collection Date	7/91	8/95	2/00	8/00	09/03
Width (m)	5	3	8	6	3
Average Depth (m)	0.1	0.1	0.5	0.1	0.2
Canopy	5	10	10	5	5
Aufwuchs	Abundant	Abundant	None	Abundant	Abundant
Bank Erosion	Moderate	Mod-Severe	Severe	Moderate	Severe
Substrate (%)					
Boulder	0	0	0	-	0
Rubble	0	0	0	-	0
Gravel	0	5	0	-	10
Sand	85	75	100	-	75
Silt	15	20	0	-	10
Habitat Score (100 max)	-	-	32	49	35
Microhabitat (20 max)	-	-	6	8	-
Embeddedness (15 max)	-	-	7	7	-
Conductivity (μmhos/cm)*	-	330	127	276	84
Temperature (^{o}C)	31	33	12	25	19
DO (mg/L)	-	13	-	4.7	9.4

<u>Bioassays</u>.

DWQ performed three chronic bioassays using water collected from Clayroot Swamp at SR1941 (total of six) between May 2002 and March 2003. We preferred the more sensitive chronic test because it is considered to be more representative of the pollutant exposure (longer duration and two samples) that local benthos experience. Clearly, it does not approach constant, in-situ exposure, but it is the more telling option. All tests have passed. These results were expected since macroinvertebrate sampling did not indicate any toxicity problems. Occasional toxic events are possible during pesticide application. However, we did not find any evidence suggesting their long-term effect.

Ambient Sampling

Ambient sampling was conducted at one sampling station near the bridge of SR1941. This station was used as an integrator station near the confluence of Clayroot Swamp with the larger stream. Between September 2001and September 2003 eight ambient samples and one sediment sample were collected. Ambient parameters are presented in Table 2, metals concentrations are presented in Table 3, and sediment analysis results are presented in Tables 4 and 5.

Table 2. Water Quality Characterization, Clayroot Swamp at SR1941.

Field Parameters	Date							
	9/21/01	10/3/01	10/30/01	1/10/02	2/25/02	5/17/02	1/14/03	7/28/03
Dissolved Oxygen, mg/L	7.72	5.31	9.47	6.87	10.38	9.3	8.76	6.82
Water Temperature, C^o	24.6	22.9	18.9	16.7	9.8	17.9	-	26.7
Specific Conductance	30.2	79.3	83.7	124.3	50	-	17.5	17.1
pH	7.0	6.17	-	7.13	7.4	6.95	6.43	6.81
Turbidity	-	30	4.4	10	2.7	10	9.6	27
Total Dissolved Solids, mg/L	130	140	150	190	200	150	170	230
Total Suspended Solids, mg/L	3.3	21	2.5	6	2	3	15	45
Hardness, mg/L	30	21	100	840	100	-	-	-
Total Phosphorus, mg/L	0.07	0.22	0.07	0.08	0.03	0.08	0.26	0.12
Ammonia-N, mg/L	0.42	0.11	0.11	<0.05	<0.05	0.4	0.06	0.02
Nitrate/Nitrite-N, mg/L	0.28	0.34	0.10	<0.05	<0.05	0.32	0.94	<0.02
Total Kjeldahl Nitrogen, mg/L	0.53	0.74	0.48	0.27	0.39	1.2	0.92	0.68
Total Nitrogen, mg/L	0.81	1.08	0.58	0.27	0.39	1.52	1.86	0.68
Calcium, mg/L	-	-	-	38	-	25	21	55
Magnesium, mg/L	-	-	-	3.8	-	2.7	3.4	3.6

Table 3. Clayroot Swamp at SR1941: Total Metals Concentrations and NAWQC Values.

Metal (µg/L)	CHRONIC BENCH-MARK [1]	ACUTE BENCH-MARK [2]	9/21/01	10/30/01	1/10/02	2/25/02	5/17/02	1/14/03	7/28/03
Aluminum	87	750	710	310	160	82	510	1200	1100
Arsenic	150	340	<10	<10	<10	<10	<10	<10	<10
Cadmium	1.3	1.8	<2	<2	<2	<2	<2	<2	<2
Chromium	11	16	<25	<25	<25	<25	<25	<25	<25
Copper	4.6	6.5	<2	4.6	<2	<2	2.6	2	<2
Iron	1000	N/A	780	830	760	490	1100	4600	180
Lead	1.1	28.7	<10	<10	<10	<10	<10	<10	<10
Manganese	120 [2]	2300 [2]	-	<10	24	<10	21	130	24
Nickel	26	234	<10	<10	<10	<10	<10	<10	<10
Silver	0.36 [2]	0.99	<5	-	<5	<5	<5	<5	<5
Zinc	60	60	<10	110	<10	<10	<10	21	<10

[1] Benchmark values are adjusted according to average hardness except for aluminum, iron and manganese for which no conversions are available.
[2] Tier II benchmark value; NAWQC not available.

Table 4. Organic Pollutants Collected in Depositional Sediment, Clayroot Swamp at SR1941.

Detected analytes	Level (µg/Kg)	Benchmarks Exceeded	Remark
Bis (2-ethilhexyl) phtalate	3300	NA	
alkane	120	NA	N1
hexadecenoic acid C16.H30.O2	240	NA	N1
hexadecenoic acid C16.H32.O2	150	NA	N1
phytol C20.H40.O	350	NA	N1

N1: the component has been tentatively identified based on mass spectral library search and has an estimated value.
NA: no benchmark available

Table 5. Metals Collected in Depositional Sediment, Clayroot Swamp at SR1941.

Analyte	Level (mg/Kg)	Benchmarks Exceeded
Cd	<0.20	none
Cr	0.55	none
Cu	<0.20	none
Ni	<0.20	none
Pb	<0.20	none
Zn	4.4	none
Al	380	NA
Fe	420	NA
Mg	24	NA
As	<0.20	NA
Hg	<0.02	none

NA: no benchmark available

VI. Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the Clayroot Swamp watershed using both biological assessment and watershed-based approaches. An evaluation of the aquatic macroinvertebrate community data, and data on stream and sediment chemistry, as well as habitat and land use activities, can point to the general types of impacts that may impact the stream's biological integrity. These stressors were flagged for further investigation, which DWQ conducted in this study.

Key Stressors Evaluated in the Clayroot Swamp Watershed

1. *Toxicity*. The watershed is predominantly rural and only potential toxic impact may come from agricultural and sylvicultural operations.

2. *Habitat degradation—sedimentation*. Sedimentation impacts habitat through loss of pools, burial or embedding of riffles, and high levels of substrate instability.

3. *Habitat degradation—lack of key microhabitat*. Preliminary watershed investigations indicated that habitat in Clayroot Swamp lacks diversity. Important microhabitats for benthic organisms, such as woody debris, leaf packs, and root mats are present in only limited amounts in some areas.

4. *Hydromodification—scour due to the dredging operations and stormflows*. Although Clayroot Swamp watershed has no urban development, the entire area is drained by the network of channels that quickly deliver stormwater to the stream channel. In addition, frequent dredging and channel straightening activities increase flow velocity, which result in bed scour. Two results of scouring stormflow are incised stream channels, and streambank habitat lost through erosion.

5. *Nutrient/organic enrichment*. Organic enrichment can affect stream biota in two ways. First, it can deplete dissolved oxygen to harmful levels. Second, it can favor pollution tolerant species that filter their food from the water column. Agricultural activity in the area contributes to nutrient enrichment.

Results of our investigation indicate that there is no evidence to suggest that toxicity has a long-term negative impact on the biological community of the Clayroot Swamp. It is reasonable to suggest that toxic flushes resulting from pesticide applications occur periodically. However, it appears that their effect is not significant.

Watershed evaluations conducted over the past 10 years indicate that sedimentation has a serious negative impact in macroinvertebrates of Clayroot Swamp. Constant influx of sand from erosion, and dredging operations covers stream bottom with a layer of sand and fills in pools and riffles. In addition, sand substrate is constantly shifting, which negatively affects recolonization and reproduction of aquatic organisms.

Lack of microhabitat that is apparent in all sections of Clayroot Swamp is directly related to sedimentation and continuous dredging operations. Shifting sand covers boulders, roots, cobble, wooden debris, and gravel. As a consequence, the number of ecological niches decreases and only the most resistant organisms are able to inhabit the stream.

Observation of several reaches of Clayroot Swamp showed that scour is very pervasive, especially in the lower reaches. Networks of ditches quickly deliver stormwater to the stream, which creates conditions that cause pronounced channel incision.

Chemical analyses of the samples collected from Clayroot Swamp provide strong evidence of nutrient enrichment. Concentration of nitrogen and phosphorus is frequently high. Biological indicators such as significant algal growth support this conclusion. Poorly drained sandy soils that dominate the watershed in combination with a network of drainage channels provide ideal conditions for fast delivery of nutrients from agricultural fields to the stream.

It appears that stressors 2, 3, 4 and 5 play an important role in impairment of Clayroot Swamp. Clayroot Swamp is located in a relatively flat region where ditching and channelization are necessary to prevent flooding during wet periods. Through the years, ditching has been a common practice to make land viable for agricultural and general development. Although agricultural BMPs appear to be in place in the watershed, continual nutrient loading, dredging operations and erosion of sandy soils are the key factors impacting water quality in Clayroot Swamp. Lack of habitat is likely the main cause of biological impairment with nutrient enrichment being a contributing factor.

VII. Mitigation Measures

It is unlikely that improvements in existing BMPs would lead to measurable improvements in water quality in Clayroot Swamp. Nutrient enrichment is not the most important cause of biological impairment. In order to improve water quality, significant stream restoration efforts have to be undertaken. Such measures would include creating natural stream channel that has appropriate sinuosity, and reconnecting the stream with the floodplain. Dredging operations have to be curtailed to decrease the inflow of sand and provide conditions for restoration of microhabitat. These measures are likely to create flooding and significantly complicate agricultural operation and living conditions for local residents. Therefore, it is reasonable to expect substantial resistance from local community. Historically, swamps and slow moving black water streams dominated eastern part of North Carolina. In order, to create conditions conducive for agricultural production and acceptable living conditions, streams were straightened and dredged. In addition, network of channels was created. Restoration efforts would have to reverse effect of these operations and are not likely to receive local support that is essential for success of the restoration program.

Appendix A.

Fig. 1. Clayroot Swamp near headwaters showing channelized streambed.

Fig. 2. Clayroot Swamp, upper watershed, channelized, nutrient enriched.

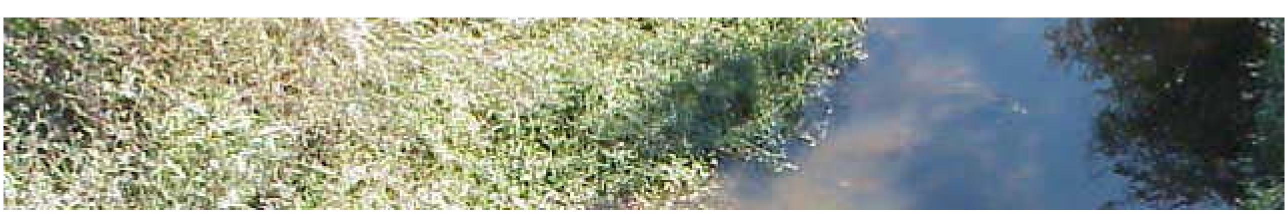

Fig. 3. Clayroot Swamp, middle watershed, algal mats.

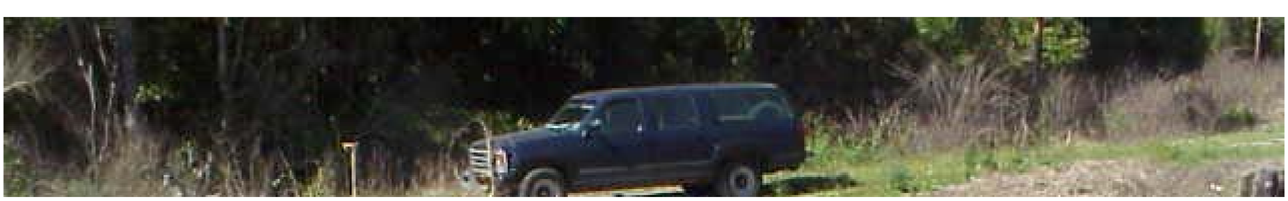

Fig. 4. Clayroot Swamp, lower watershed, sandy bank erosion.

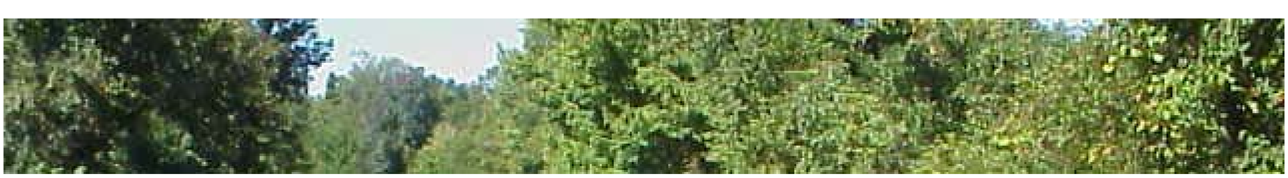

Fig. 5. Clayroot Swamp near mouth, SR1941, benthos site, sedimentation.

Fig. 6. Clayroot Swamp, lower reach, sedimentation.

Fig. 7. Clayroot Swamp, lower reach, incision.