Water Quality Group at NC State University

Draft Memorandum

To: Lick Creek Watershed Restoration Plan Partners and Stakeholders
Cc: Kimberly Nimmer, NC Division of Water Quality
From: Dan Line, Water Quality Group at NC State University
Date: March 12, 2009
Re: Draft Recommendations for Long Term Monitoring Of Lick Creek

Background

Lick Creek is listed as biologically impaired on the North Carolina 2006 303(d) list (NCDWQ 2006). It is also a tributary to Falls Lake, a state-designated nutrient-sensitive water and a water-supply reservoir for 600,000 Wake County residents. These two factors combine to underscore the importance of long-term monitoring in the watershed and guide the monitoring design described in this memorandum.

The geology of the watershed is predominantly of the Triassic Basin system, which is characterized by soils of low permeability and high erosion hazard. These characteristics translate into flashy streams with high sediment loading and low base flow, especially in developing areas. The topography of the watershed is gently to moderately steep sloping land.

Land use is mostly rural with homes along the roads and mostly woodland on the land between the roads. Relatively recently, a large development has been constructed in the southwestern headwaters area of the watershed and considerable development pressure still exists. According to the Upper Neuse River Basin Association (UNRBA) (2007a), Durham's Urban Growth Area (UGA) encompasses most of the southern portion of the watershed, and the watershed is expected to be developed to suburban densities similar to those of neighboring Little Lick Creek, with a majority of new housing on lots less than 0.5 acre.

<u>Biological Monitoring Data:</u> The Lick Creek watershed is in the Triassic Basin region of North Carolina, which is characterized by highly erodible soils with very low permeability. Therefore, once the landscape is disturbed, these factors are largely responsible for stream channels having a high sediment load and minimal summer base flows. For this reason, productive in-stream habitat for benthic insects is often limited to short reaches of sandy riffles and large woody debris or snag habitats. The minimal baseflow may itself result in fair to poor biological/benthic macroinvertebrate health, and when combined with sediment deposition, the two often result in poor bioclassifications.

Biological data from Lick Creek have been collected by biologists from NC Department of Environment and Natural Resources (NCDENR), the NC Division of Water Quality (NCDWQ), NC State University (NCSU), and the City of Durham's Stormwater Services (DSS). Surveys conducted by NCDWQ at SR1809 in 1995, 1998, and 2000 showed that the creek supported a Fair benthic community; however, during the 2000 assessment it was noted that habitat was poor resulting in the creek being added to the

2004 303(d) list for impaired biological integrity (NCDENR 2008). Hence, by statewide standards the watershed is impaired, but it is also important to recall that NCDWQ personnel have noted that because of the unique geology and its associated affect on stream flow, bioclassifications for streams within this ecoregion should be used with caution. In fact, the NCDWQ no longer assigns bioclassifications to streams in the Triassic Basin region.

Chemical and Physical Parameter Monitoring Data: The short-term monitoring (2 years), which occurred concurrently with the development of the Lick Creek Watershed Restoration Plan, consisted of collecting monthly grab samples (24 months from January 2007 through January 2008) at 5 sites (fig. 1), and flow-proportional samples from at least 2 storm events per site. Four of the monitoring sites (L2, L4, L5, L6) were located at the outlets of major tributaries or headwater contributing areas and the fifth (L1) was on Lick Creek near Falls Lake (fig. 1). Because the sites labeled “L1 and L3” on figure 1 were already being sampled monthly by DSS personnel, they were not initially included in the monitoring conducted by NCSU for the UNRBA Lick Creek Watershed Restoration Plan (WRP)); however, L1 was added in May, 2007 following a meeting with NCDWQ personnel.

Summaries of the grab sampling and in-situ physical parameter data are shown in Table 1. These data are from in-situ measurements of temperature (temp), dissolved oxygen (DO), conductivity (Cond), and pH and the analysis of grab samples collected on the indicated day. Table 2 contains analyses of flow proportional storm event samples collected for various storms during the project. Overall, the short-term monitoring (along with data from DSS) documented higher levels of turbidity, bacteria, nitrogen, and phosphorus in baseflow discharge from L3 and L6 as compared to the other 4 monitoring sites. These data indicate that the focus of restoration efforts should be in the subwatersheds (Subwatersheds 1 and 7, fig. 1) draining to these monitoring sites.

Long Term Monitoring Plan

The design of a long term monitoring plan depends, to a large extent, on the goal of the monitoring. Monitoring locations, monitoring frequencies, monitoring parameters, and monitoring duration all depend on the goal. For purposes of this plan, the goals of the long term monitoring were to (1) document the effects of development on water quality in a subwatershed, (2) document changes in pollutant inputs from the overall watershed to Falls Lake, and (3) document the effects of restoration efforts in a subwatershed. Each of these goals is relevant to the Lick Creek watershed and is seemingly important to a constituent group. One or more of the monitoring stations included in the long term monitoring may be employed to meet one or more of the goals. The long term monitoring may also be used to help determine the cause of the biological impairment, which is thought to be, at least partially, related to the effects of urban runoff from development in the watershed (NCDENR 2006).

Monitoring Sites: Monitoring of all 6 existing sites long term would provide valuable data; however, this may not be feasible, thus prioritizing sites is warranted. Continued monitoring at station L1, which is the downstream most location for monitoring the main stem of Lick Creek (fig. 1), is needed to document water quality trends for the watershed as a whole and pollutant export to Falls Lake. This monitoring site was located just upstream of Southview Road to coincide with the DSS monitoring; however, the site is upstream of the confluence with Rocky Branch. Because Rocky Branch enters Lick Creek downstream of L1 (fig. 1), a monitoring station such as L3 is needed on it to characterize the quality of its discharge to Falls Lake. These two stations together can be used to characterize pollutant inputs from the overall watershed to Falls Lake. In addition, mean pollutant concentrations in grab samples collected at L3 were greater than most other subwatersheds indicating a need for restoration efforts to be focused in this drainage area. Thus, this station (L3) could also be used to document the effectiveness of restoration efforts.

The goal of documenting the effect of development on water quality in the watershed requires monitoring a subwatershed with a significant portion of the land area where active development is either on-going or imminent (preferred). This is the case for the drainage area to the L6 monitoring site, because Subwatershed 1 is an actively developing subwatershed. Because development began prior to the start of monitoring, it is also recommended to concurrently monitor a comparison or paired subwatershed that is not experiencing, or expected to experience, development, such as L5 or possibly L4. Monitoring at L5 is preferred over L4 because it is similar in size, adjacent to L6, and relatively stable, but access to the monitoring site is limited and physically difficult. Monitoring of the two drainage areas simultaneously should facilitate a faster assessment of the effects of development compared to the conventional method of monitoring 2 years prior to, during, and following development.

Because the streams in this watershed tend to have naturally low and even intermittent baseflow and high sediment loading from erodible soils, the macroinvertebrate community can often be stressed from natural factors thereby making bioclassifications in this ecoregion somewhat questionable. So the usefulness of biological monitoring of the tributary streams in the watershed is questionable and is thus not recommended. Biological monitoring at SR1809 by NCDWQ will likely be continued on a rotating basis (once every 3-5 years). One site, L1, should be continued as part of long term biological monitoring, because this site tends to have the fewest periods of no discharge and has the longest history of biological assessment. However, even this site may be questionable given that bioclassifications for streams in this region will no longer be assigned by NCDWQ.

Thus, long term monitoring should include at least 4 monitoring sites (L1, L3, L5, and L6). Assessment of development in other subwatersheds will necessitate the establishment of additional sites.

Water Quality Indicators: The water quality indicators should include those used in the short-term monitoring conducted for the UNRBA Lick Creek WRP, namely total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_4-N), nitrate+nitrite nitrogen (NO_x-N), total phosphorus (TP), total suspended solids (TSS), turbidity, DO, temp, pH, Cond, and bacteria (e coli or fecal coliform [FC]). Furthermore, samples should be collected and in-situ measurement of these parameters should be made at the same locations and using the same sampling techniques for comparison. Although the DO, temp, pH, and Cond are a lower priority for assessing the effects of development as they are more important when point source discharges are present, they are nonetheless valuable as indicators of aquatic life and algal growth. Thus, continuing these measurements is recommended, especially for sites L1 and L3 (fig. 1), which are located on or near stream reaches that might support larger aquatic organisms such as fish.

Stream channel stability monitoring including annual surveys, bank pins, bank erosion assessments, etc. may also be conducted at monitoring sites. Stability monitoring at site L6 is particularly important because development tends to increase peak discharge rates, which often destabilize stream channels resulting in excessive stream bank and bed erosion. The fact that the stream channel at L6 is not incised, has a mature hardwood buffer, and appears to be stable makes this site a good candidate for assessing the long term effects of development on stream stability. Because the pattern and profile of the stream channel at L6 appears to still have 'natural stability', a before/after experimental monitoring design may be followed thereby negating the need for the stability monitoring at the paired/control site L5. In addition, the stream channel at L5 is already incised and appears to be unstable making it much different than that of L6 and not a good control site.

Several samples in the short-term monitoring conducted for the UNRBA Lick Creek WRP were analyzed for the metals copper (Cu), lead (Pb), and zinc (Zn) and DSS has analyzed many samples collected from L1 and L3 for Cu and Zn and found only low levels. Hence, heavy metals do not appear to be a concern and may be omitted from the list of indicators for long-term monitoring. There is no data for other pollutants such as pesticides, hydrocarbons, and pathogens, but these can be associated with some types of development.

A Quality Assurance Project Plan (QAPP) should be developed and approved by the NCDWQ to help insure acceptance of the data by all parties involved. Along with this sample, analyses should be conducted by a state certified lab to help ensure acceptance of the results. Obviously, groups experienced in water resource investigations on streams and in storm event monitoring should be employed to conduct the monitoring and interpret/analyze the data.

Covariates: Covariates or explanatory information should also be collected including rainfall and discharge. Adequate rainfall data may be obtained from nearby gages or monitored with manual gages that watershed residents maintain. Continuous discharge monitoring at the currently established monitoring sites can be accomplished relatively easily by installing a simple water level recorder, since the stage-discharge rating tables have been developed during this project. An increase in peak discharge, runoff temperature, and storm as compared to non-storm (baseflow) discharge volumes has been shown to occur as a result of development (Line and White 2007). These changes can result in streambank and bed degradation, which in turn affects macroinvertebrate communities. Land use variables that effect water quality should also be tracked for the monitored drainage areas such as impervious surfaces, riparian vegetation, active and completed development, etc.

Sampling Methods: Monthly grab sampling should continue, supplemented by flow-proportional storm sample collection for several storms per year. During the current short-term monitoring conducted for the UNRBA Lick Creek WRP, concentrations of NO_x-N, TP, and TSS in storm samples were considerably greater than those in non-storm grab samples (Tables 1 and 2). In addition, the discharge levels were much greater during storm flow; hence, the combined effect of increased discharge and concentration indicates that much of the pollutant export occurs during storm discharge. Hence, continued monitoring of storm event discharge is very important for accurately documenting pollutant export from the corresponding drainage areas. Continued measurement of physical parameters (temp, DO, Cond, pH, turbidity) monthly is also recommended.

<u>Experimental Monitoring Design:</u> To properly interpret and get the most out of the monitoring data, past experience has shown that an appropriate experimental design should be followed. In this plan, monitoring of outflow from a paired watershed (L5) with little to no development is recommended to compare to the monitoring data from the developed drainage area of (L6). Monitoring data from L5 will help account for natural variability associated with changes in rainfall and other factors which will make statistical analyses much more powerful, because it will help to isolate the effect of development. Monitoring data from station L5 will also help to document long term water quality of a relatively undeveloped drainage area which may provide a baseline for which to compare monitoring from other sites in the Triassic Basin.

Ideally, monitoring of these two watersheds would have begun at least 2 years prior to the start of development in the drainage area to L6. This pre-development period would have established the hydrologic relationship between the areas, which then could be compared to the post-development relationship. However, pre-development monitoring was not conducted, and an assumption of hydrologic similarity will need to be employed. Given their proximity and physical similarities, this is a reasonable assumption.

The design at the other recommended stations (L1 and L3) is basically a single downstream station. This simply means the sites are designed to document changes over time. If restoration efforts decrease pollutant levels significantly after several years, appropriate statistical analyses can be used to confirm the trend. It is also generally accepted that it takes 5-10 years of monitoring to adequately establish these trends.

The long term monitoring at each site should continue for at least 5 years. Climatic and other natural variability often mask relatively subtle changes in water quality resulting from changes in land treatment/management; thus, monitoring should continue for considerable time to collect the data needed to detect significant changes in monitoring parameters.

Table 1. Summary of long term monitoring recommendations.

Site	Location	Measurements	Frequency/ number
L1	Lick Creek near Southview Road	Field & laboratory grab sample[1]	monthly
		Laboratory storm sample[1] + discharge	2-4 storms/yr
		Benthic macroinvertebrates	2x/yr
		Discharge	monthly
L3	Rocky Branch at Kemp Road	Field & laboratory grab sample[1]	monthly
		Laboratory storm sample[1] + discharge	2-4 storms/yr
		Discharge	monthly
L5	Unnamed tributary	Field & laboratory grab sample[1]	monthly
		Laboratory storm sample[1] + discharge	2-4 storms/yr
		Discharge	monthly
L6	Lick Creek upstream of confluence with tributary of L5	Field & laboratory grab sample[1]	monthly
		Laboratory storm sample[1] + discharge	2-4 storms/yr
		Discharge	monthly

[1] Field & laboratory: field=DO, Cond, pH, and temp; lab= turbidity, TKN, NH_4-N, NO_x-N, TP, TSS, FC (e coli). Storm samples will likely not be analyzed for FC. For analysis methods refer to Quality Assurance Project Plan.

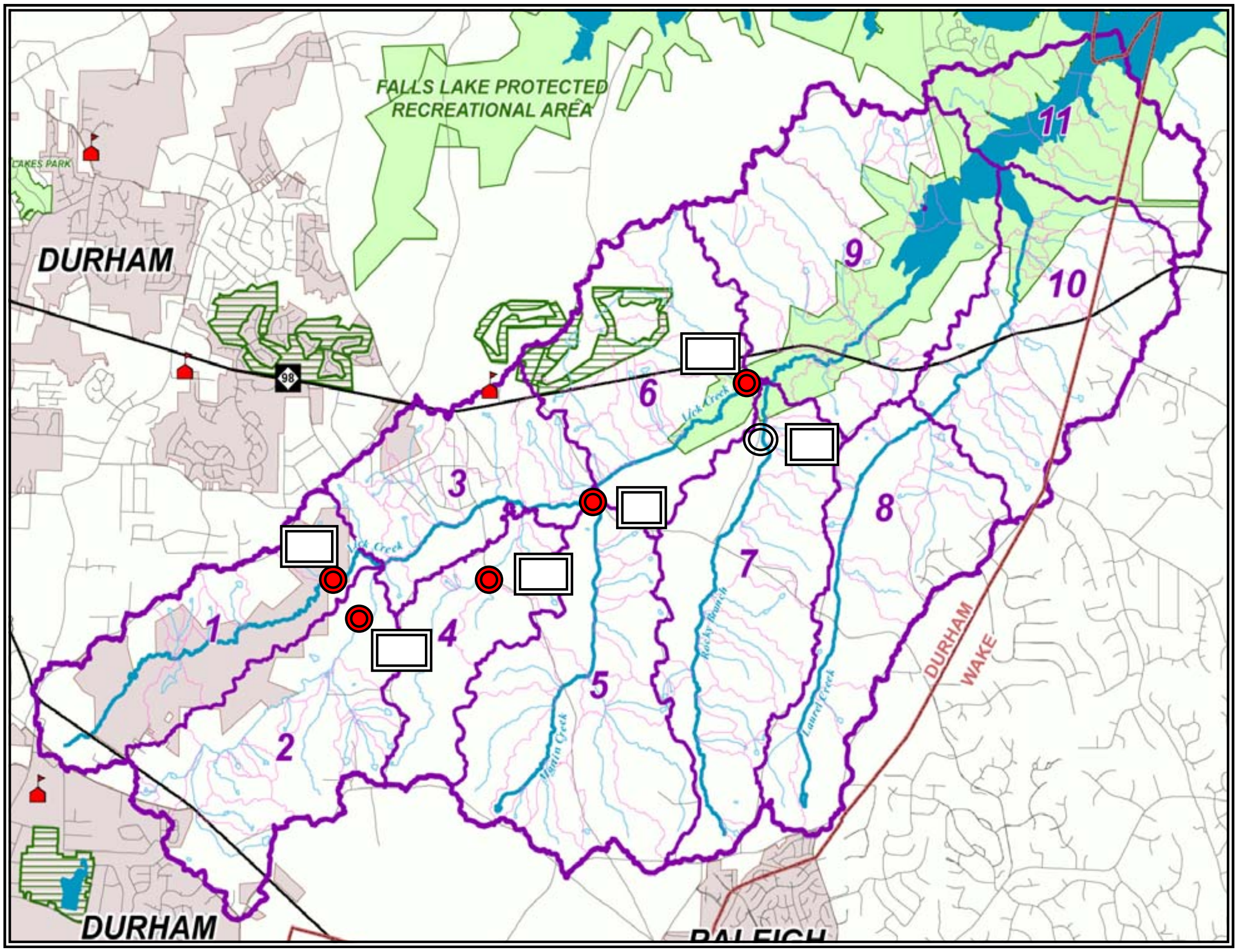

Figure 1. Map of watershed showing monitoring sites (solid red dots). L3 was monitored by the DSS and was not included in the short-term monitoring conducted for the UNRBA Lick Creek WRP project.

Table 2. Summary of Grab Sample and In-situ Data.

	Flow cfs	Turb ntu	e coli mpn/100ml	TKN mg/L	NOx mg/L	NH_4 mg/L	TN mg/L	TP mg/L	TSS mg/L	temp mg/L	Cond mg/L	DO mg/L	pH
L1 Lick Creek at Southview Road													
mean	2.5	34.7	476	0.53	0.06	0.08	0.59	0.09	12.6	17.7	0.135	3.9	6.2
median	1.6	29.1	100	0.50	0.05	0.05	0.59	0.08	10.0	18.3	0.131	3.7	6.5
count	19	16	19	16	16	16	16	16	16	8	8	8	8
L2 Martin Branch/Creek													
mean	1.0	18.7	209	0.47	0.10	0.04	0.57	0.05	13.6	16.1	0.095	5.4	6.8
median	0.3	17.0	122	0.49	0.04	0.04	0.60	0.05	13.5	18.4	0.096	4.5	6.8
count	22	14	14	12	12	12	12	12	12	8	8	8	8
L3 Rocky Branch[1]													
mean	na	78	2170[1]	1.19	0.09	0.39	1.28	0.09	148	15.4	0.174	5.6	7.3
median	na	31	490	0.90	0.10	0.11	0.98	0.08	16	17.4	0.170	5.0	7.4
count	na	18	20	20	20	20	20	20	20	16	16	16	16
L4 Unnamed Tributary at Olive Branch Road													
mean	0.2	21.2	149	0.55	0.04	0.06	0.59	0.06	7.5	13.9	0.118	5.3	6.3
median	0.0	18.5	93	0.47	0.02	0.04	0.54	0.05	7.0	17.7	0.097	4.7	6.6
count	20	12	11	11	11	11	11	11	11	7	7	7	7
L5 Unnamed Tributary in upper Lick Creek													
mean	0.6	24.2	287	0.41	0.06	0.05	0.47	0.08	7.2	15.7	0.218	5.5	6.7
median	0.2	20.0	122	0.32	0.04	0.04	0.39	0.07	5.0	17.2	0.149	4.8	6.8
count	16	15	14	13	13	13	13	13	13	8	8	8	8
L6 Lick Creek Headwaters													
mean	0.5	69.9	518	0.68	0.05	0.08	0.73	0.13	34.1	16.3	0.143	5.2	6.7
median	0.1	66.0	167	0.70	0.04	0.04	0.74	0.12	28.0	20.3	0.134	4.3	7.2
count	20	14	14	12	12	12	12	12	12	7	7	7	7

note: Yellow box indicates maximum of the tributaries (LC2-LC6) and blue indicates minimum.

[1] Sampling and analysis conducted by Durham Stormwater Services, Ecoli is really fecal coliform.

Table 3. Storm Event Mean Concentrations*.

Site	Rain in	TKN mg/L	NOx mg/L	NH_4 mg/L	TN mg/L	TP mg/L	TSS mg/L
LC1	1.37	1.49	0.13	0.25	1.63	0.56	319
	3	3	3	3	3	3	3
LC2	1.52	0.73	0.18	0.27	0.91	0.17	49
	3	3	3	3	3	3	3
LC4	2.15	1.09	0.14	0.11	1.23	0.23	38
	3	3	3	3	3	3	2
LC5	1.66	0.76	0.09	0.05	0.85	0.14	83
	2	2	2	2	2	2	2
LC6	0.76	0.85	0.13	0.12	0.98	0.29	116
	4	4	4	4	4	4	4

note: Yellow box indicates maximum of the tributaries (LC2-LC6) and blue indicates minimum.

References

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