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MONITORING THE EFFECTS OF HIGHWAY CONSTRUCTION OVER THE LITTLE RIVER AND CRANE CREEK

Prepared By

Daniel E. Line, PE

NC State University
Biological and Agricultural Engineering Dept.
Box 7637, 909 Capability Dr., Suite 3200
Raleigh, NC 27695

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16. Abstract

This report summarizes the results of a two-year water quality monitoring project to document the effects of the construction of the Highway 1 bypass on the water quality of Crane (Crains) Creek and the Little River. Automated monitoring equipment were installed upstream and downstream of the highway corridor on both Crane Creek and the Little River. For Crane Creek, discharge was monitored and samples of creek water were collected on a flow-proportional basis throughout the project, while for the Little River samples were collected every 6-8 hours during the project. A recording raingage was also maintained for most of the study at Crane Creek and in-situ measurements of temperature, dissolved oxygen, conductivity, and pH were made at least monthly.

The mean suspended sediment concentration and turbidity for Crane Creek was 48 mg/L and 40 ntu upstream and 38 mg/L and 26 ntu downstream of the highway corridor. Statistical analysis of the bi-weekly sediment load data from both sites showed that the loads at the upstream site were not significantly different than the downstream site indicating that the construction had no effect on sediment loads of Crane Creek. The mean turbidity of samples was greater upstream compared to downstream, which also indicates no negative effect of highway construction. Means of temperature, dissolved oxygen, conductivity, and pH were nearly the same upstream and downstream indicating no effect on these water quality parameters.

Monitoring results for the Little River were similar to Crane Creek in that there were no significant differences between upstream and downstream sites according to paired t-tests conducted on the bi-weekly data. The mean suspended sediment concentration and turbidity upstream was 10 mg/L and 10 ntu upstream and downstream was 12 mg/L and 9 ntu.

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DISCLAIMER

SUMMARY

This report summarizes the results of a two-year water quality monitoring project to document the effects of the construction of the Highway 1 bypass on the water quality of Crane (Crains) Creek and the Little River. Automated monitoring equipment were installed upstream and downstream of the highway corridor on both Crane Creek and the Little River. For Crane Creek, discharge was monitored and samples of creek water were collected on a flow-proportional basis throughout the project, while for the Little River samples were collected every 6-8 hours during the project. A recording raingage was also maintained for most of the study at Crane Creek and in-situ measurements of temperature, dissolved oxygen, conductivity, and pH were made at least monthly.

The mean suspended sediment concentration and turbidity for Crane Creek was 48 mg/L and 40 ntu upstream and 38 mg/L and 26 ntu downstream of the highway corridor. Statistical analysis of the bi-weekly sediment load data from both sites showed that the loads at the upstream site were not significantly different than the downstream site indicating that the construction had no effect on sediment loads of Crane Creek. The mean turbidity of samples was greater upstream compared to downstream, which also indicates no negative effect of highway construction. Means of temperature, dissolved oxygen, conductivity, and pH were nearly the same upstream and downstream indicating no effect on these water quality parameters.

Monitoring results for the Little River were similar to Crane Creek in that there were no significant differences between upstream and downstream sites according to paired t-tests conducted on the bi-weekly sample analysis data. The mean suspended sediment concentration and turbidity upstream was 10 mg/L and 10 ntu upstream and downstream was 12 mg/L and 9 ntu.

The confidence in the no effect of construction finding for both water bodies is reduced by the realization that the monitoring began after the start of construction and the size of the upstream drainage area was much greater than that of the treatment or area of construction. These two as well as several other monitoring considerations are described in a monitoring guidance document included in the appendix.

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INTRODUCTION

Sediment is generally accepted as the most pervasive pollutant in rivers and streams of the United States in terms of volume (Clark et al., 1985). In response to the sediment pollution, billions of dollars have been spent on sediment control with most of the historic funding and effort focused on controlling erosion on agricultural land. However, relatively recently many states and municipalities have expanded their efforts to include controlling sediment export from urban related sources such as construction sites for highways and residential subdivisions (Mertes, 1989).

North Carolina has one of the strongest sediment and erosion control programs for construction sites in the U.S. in terms of its comprehensiveness, financing and staffing levels (Paterson et al., 1993). The program requires anyone who intends to disturb one acre or more of land to have an erosion and sediment control plan detailing the area to be disturbed and measures used to control sediment export from the site throughout the life of the project. Despite an ambitious program, sediment remains the primary pollutant affecting the quality of North Carolina's surface waters. Construction-related activities were cited by the state as a major source of degradation to lakes (NC DENR, 1992). Further, Burby et al. (1990) reported that one-third or more of urban construction sites in the state release sediment to neighboring property and nearby streams.

Sediment from urban areas received public notoriety in North Carolina in 1997 when a plume of red, muddy runoff, thought to be from construction sites, was photographed on its way down the Neuse River. Following this incident, the Governor called on the NC Department of Environment and Natural Resources (NC DENR) to begin stricter enforcement of erosion and sediment control regulations on construction sites. In addition, the Governor asked for a review of standards and needs for the erosion and sediment control program. One of the identified needs was to develop a better understanding of the limitations and efficiency of erosion and sediment control practices.

One of the few comprehensive field studies in NC on the limitations and efficiency of erosion and sediment control practices was conducted by Line and White (2001). Their study evaluated standard sediment traps on 2 residential construction sites over a nearly 2-yr. period of actual construction and rainfall activity. Results documented that 59 and 69% of incoming sediment from Piedmont and Coastal Plain construction sites was retained in the two traps. In addition, the study reported that 4.4 ton/ac-yr of sediment was exported from the Piedmont sites in spite of and approved erosion and sediment control plan. This study underscores the difficulty of controlling sediment export from most construction sites.

The NC Department of Transportation manages its own erosion and sediment control program within its Roadside Environmental Unit. Erosion and sediment control plans are written for every construction project and field personnel of the Roadside unit regularly inspect projects to ensure compliance with the provisions of the law. As stated in the above paragraph even when sites are following an approved erosion and sediment control plan some sediment may still leave a construction site and enter nearby waters. The effect of this sediment on the waters is dependent of the amount of sediment exported, the size and quality of the waters, and aquatic life in the waters. This study was designed to evaluate through water quality monitoring the effectiveness of the sediment control efforts on the Highway 1 bypass over Crane Creek and the Little River in Moore county.

METHODOLOGY AND PROCEDURES

Ideally evaluating the effects of construction in most watersheds would include a period (1.5-2 yr) of monitoring prior to the start of construction and then would continue through the completion of the project, which would be 1-3 years. The pre-construction monitoring is needed to adequately characterize the hydrology and sediment export of the area prior to disturbance and the rest of the monitoring data, during and hopefully some after construction, could be statistically compared to pre-construction to determine if significant changes had occurred. Two years of monitoring is recommended because climatic conditions affect discharge and sediment export to the extent that many different precipitation events are needed to make an adequate characterization. In some cases, monitoring an undisturbed drainage area upstream of the construction area can be substituted for pre-construction monitoring; however, this is generally risky because few areas are stable for very long. At both Crane Creek and Little River, construction began prior to the start of monitoring; however, both areas had upstream monitoring stations. The drainage area to the upstream station at Crane Creek was not stable. In fact, a considerable amount of the road construction was occurring in this area of 35,460 ac. For Little River, the drainage area to the upstream station (62,600 ac) was likely stable enough, given that relatively small changes in a large watershed would have minimal effects on water quality.

For Little River, the upstream monitoring station was located on the upstream side of the highway 1 bridge (fig. 1). The upstream side was selected to remove any of the localized effects of the bridge traffic. The end of the sampler's intake tube was attached to the bridge pillar about 1 ft from the river bottom. This depth was chosen so that the intake would be underwater even during low flow conditions, but would still be high enough above the river bed to not collect bedload sediment during high flow. The natural mixing of the river currents and the relatively low suspended sediment concentrations combine to cause consistent suspended sediment levels throughout the water column thereby providing a representative sample at this depth. The sampler was attached to the bridge deck to minimize the possibility of damage to the monitoring equipment from flooding (fig. 2), as the entire area around the bridge is flood prone.

For the first several months of operation, the sampler was equipped with a flow module that recorded the changes in the stage of the river. After determining that changes in upstream and downstream stages were indistinguishable, this flow module was removed. Development of a stage-discharge relationship for this site was not conducted due to the fact that the discharges at the upstream and downstream sites would be nearly the same given the large upstream area and the comparatively small drainage are between sites. In the absence of flow measurements, the samplers were programmed to collect samples on a timed basis-every 6 hours. The 6-hour interval was reasonable given that water quality in a river this size usually changes relatively slowly. Individual samples collected by the machine were then combined into 2 composite samples, one for each week, when they were recovered every 2 weeks.

The downstream station was the same as the upstream except that it had a flow module that continuously recorded stage height throughout the monitoring period. This was accomplished by mounting the pressure transducer from the flow module on a bridge pillar near the bed of the river. The transducer continuously recorded the height of the water above it.

For Crane Creek, monitoring stations were installed just upstream and downstream of the highway corridor on the creek (fig. 3). Staff gages were installed and stage-discharge relationships were developed for both stations. The smaller overall size of the Creek compared to the drainage area between the stations made measuring the differences in discharge between the two stations more likely. The stage-discharge relationship was developed by surveying the cross-section of the river to the top of the bank. A series of discharge measurements were made at various stages. Discharge for stages not measured were estimated based on the flow area computed from surveyed cross-sections and velocity values determined during discharge measurements at similar stages. Samplers were equipped with flow modules that had the stage-discharge relationship programmed into them so that they measured discharge continuously. Accurate measurement of discharge using this method requires that the cross-section of the creek remain relatively stable so that the stage-discharge relationship does not change. Unfortunately, this was not the case at Crane Creek. During site selection and equipment installation, the banks and creek bed looked relatively stable and were for a time, but as the monitoring progressed the creek bed at both the upstream and downstream stations filled in and scoured several times. How much this affected the discharge measurements is unknown.

Samplers were programmed to collect samples on a flow-proportional basis. Samplers were programmed to collect a sample after 4-16 million gallons of flow depending on the stage of the Creek. The frequency of sampling was continually evaluated to insure that enough samples were collected to adequately characterize the water, while making sure the capacity of the sampler was adequate to cover all the discharge during the 2-week period. Except for the very low flow period of the early summer of 1994, every 2-week period had at least 15 samples collected. Individual samples collected over the 2-week monitoring period were composited and analyzed. The low flow period presented many unanticipated difficulties in sampling including the problem that the flowing water was more than 50ft from the creek bank and thus the sampler, which meant that samplers were not collected for a period. During this period a grab sample was collected when the site was visited.

Additionally, a recording rainfall gage was installed near the downstream monitoring station. This gage recorded rainfall accumulation for 15-minute time intervals. Due to freezing conditions and problems with equipment, there were several gaps in the rainfall data. These gaps were filled by obtaining rainfall data from a nonrecording plastic raingage installed at the Little River downstream monitoring site or from a nearby weathernet raingage.

All samples were analyzed for total suspended solids (TSS), total solids (TS), and turbidity. Selected samples will also be analyzed for total Kjeldahl nitrogen (TKN), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3-N), and total phosphorus (TP) by the NC State University Biological and Agricultural Engineering Departmental laboratory. Samples were analyzed using standard methods (APHA, AWWA, WPCF. 1989). Selected samples were analyzed for TSS by two labs to assess the repeatability of the results.

In-situ monitoring of pH, dissolved oxygen (DO), conductivity, and temperature was conducted using a YSI multi-parameter meter on every other visit to the sites. Due to various equipment repairs, some of the planned measurements were missed. The meter was calibrated before each use. Typically the probe was thrown in an area of flowing water near the sampling point and allowed to equilibrate before the readings were made. For the Little River sites, the probe was lowered into the water from the highway bridge. At each site the probe settled to or near the bottom of the column of water.

Effective quality assurance and control procedures are essential to ensure the utility of monitoring data (U.S. DOT, 1996). Due to the remote locations of the monitoring sites refrigeration was not feasible; however, the four samples analyzed for nitrogen and phosphorus were collected during periods of relatively cool temperatures. The biweekly samples were analyzed for TSS, TS, and turbidity only; hence, keeping the sample in the dark was all that was needed to preserve the sample as additional measures to preserve solids and turbidity is only necessary in rare cases. All sampler tubing was new at installation and was not changed during the project, so no outside contamination was introduced into the samples.

SITE DESCRIPTIONS AND RESULTS

Descriptions of sites and monitoring results are presented by site in the following section. The extent, general topography, and land use of the drainage area to the monitoring stations were determined from maps and observation. Activities, construction phase, sediment control practices, and other hydrologic factors occurring on the construction sites were recorded when observed on the biweekly visits.

Crane Creek

Description of Site: The Crane Creek monitoring sites were located in Moore County on Crane Creek just upstream (N35’ 16.8”; W79’ 16.0”) and downstream (N35’ 16.3”; W79’ 15.9”) of the Highway 1 bypass corridor (figure 1). The upstream monitoring station (figure 2), located more than 100 yards upstream of the bridge crossing, had an estimated drainage area of 35,460 acres. This location was chosen because of the relatively straight and unimpeded channel reach and its close proximity to the construction activity nearest the creek. Just upstream of this location fallen trees across the channel and channel sinuosity make monitoring flow impractical. As shown in the figure, the site was subject to high water; thus, the sampler was put up on stilts after it was flooded in August 2003.

Ideally the upstream station would have been upstream of most, if not all, of the expected impact of the construction activity; however, this was not the case for this site. After installation, reconnaissance of the area revealed that a small stream that carried runoff from the construction corridor entered Crane Creek less than 50 yards upstream of the station. From an examination of topographic maps, it was evident that many other upstream tributaries to Little Crane creek also carried runoff from the construction corridor to the creek. In retrospect, it may have been more appropriate to establish monitoring stations on Crane Creek at Highway 1 and on Little Crane Creek at Crane Creek road; however, construction along Little Crane creek upstream would still have been an issue, additional monitoring equipment would have been required, another station could have introduced more error, and considerably more drainage area would have been added to the area between the monitoring stations, thereby introducing more unknowns.

The downstream station was located along a relatively straight and free flowing reach of the creek (figure 2) just downstream of where the outflow from a large sediment basin entered Crane Creek, which was several hundred yards downstream of the bridge being constructed for the bypass. The sediment basin (figure 3) had a design drainage area of 99 acres; however, it appeared that the actual drainage area was considerably less than that. The total drainage area between the monitoring stations was estimated from maps and ground reconnaissance to be 240 acres with about 13 acres of this being from the highway construction corridor. Soils on this land included Tetotum silt loam and Fuquay, Vauclose, Dothan and Ailey loamy sand. The topography of the land was mostly flat along the creek with slopes of 2 to 8% on the uplands.

A windshield survey of the nonhighway land indicated 40 acres of cropland, 50 acres of woodland and 30 acres of cleared noncropland. The cleared noncropland appeared to be cropland at one time but was now grown up in volunteer vegetation. Cropland was in a mixture of tobacco, soybeans, and wheat (figure 3). The average annual sediment yield from the nonhighway land was estimated to be 433 tons as shown in Table 1. This estimate was based on sediment yields from monitoring studies in the NC Piedmont (Hill, 1991). Because climatic conditions vary considerably between years, the actual amount of sediment contributed during the period of monitoring could differ greatly from those reported in Table 1.

Table 1. Estimated Sediment Contributions from Nonhighway Land.

Description	Area	Erosion	Sediment Delivery	Total Sediment to Crane Creek
	ac	ton/ac-yr	%	ton/yr
Tributary from NE				
Cropland	30	11	40	132
Wooded	50	0.1	40	2
Noncrop cleared	47	1	40	19
Land from West				
Cropland	60	11	40	264
Cleared	40	1	40	16
Total Nonhighway				433

Description of Monitoring: A stage-discharge relationship was developed for both monitoring stations to facilitate discharge measurement (figure 4). The upstream relationship was based on 8 discharge measurements at stages ranging from 0.59 to 2.8 ft and discharges from 0.83 to 73 cfs. The downstream relationship was based on 7 discharge measurements ranging from 0.65 to 2.67 ft and discharges from 10.4 to 73.1 cfs. Most of the discharge measurements were conducted within an hour of each other during nonstorm discharge periods when the measured discharge at the upstream site was very similar to the downstream. In order to estimate discharge for stages that were outside of the range of measurements, the cross section of the creek at both sites was surveyed. Cross sectional area for each stage was computed from the survey and an estimate of the velocity was obtained from the closest measurement available and used to compute the discharge. The stage-discharge relationship for moderate to low discharges at both monitoring sites had to be revised during the fall of 2003 due to shifting of formerly deposited sediment in the creek bottom after the high flows of August and September, 2003.

The stage-discharge relationship was programmed into the samplers so that discharge was estimated continuously. The samplers were programmed to collect a sample for every 4 to 16 million gallons depending on the current discharge rate. Individual samples were recovered from the machine every 2 weeks and composited into one sample for lab analysis. The upstream sampler was flooded in early August 2003, which damaged its flowmeter. The flowmeter was repaired and the sampler reactivated by 10/1/03 as is indicated by the gap in the data.

A tipping bucket raingage was installed at the request of DOT personnel near the downstream station in the fall of 2003. The raingage was connected to the automated sampler to store the data.

Results of Monitoring: At the request of Ted Sherrod, samples collected from 2 storms were analyzed individually to characterize the within storm variability of TSS and turbidity. Results of the sample analysis along with concurrent discharge are shown in figure 5 for storms occurring in March and April of 2004. Each bar represents 5 individual samples that were placed in one sample bottle and analyzed; therefore, the bar represents a longer period of the hydrograph than is indicated by its width. As seen in the figures, the highest turbidity occurs near the highest discharge rate. This also indicates that the highest TSS concentrations correspond to the highest discharge rate, which is consistent with other studies that show that most of the sediment is transported during storm flow. The turbidities of other samples varied, but those during the falling limb of the hydrograph were similarly moderately elevated from pre-storm levels.

Summary statistics for the monitoring data are shown in Tables 2 and 3. The mean, median, and range were computed from the 2-week composite or total for the periods when the samples were collected. The total was computed for the entire period of monitoring. Rainfall for the monitoring period totaled 64.5 inches or 35.4 inches/year, which is slightly less than the long-term annual rainfall for the area.

Discharge measured at the downstream site was greater than upstream; however, the difference was similar to the uncertainty of the measurements. In any monitoring data a certain amount of uncertainty or unexplained variability exists. This is particularly the case for a surface water body of the size of Crane Creek, because most of its discharges are too high for measurement with flow measuring devices such as weirs or flumes; hence, a stage-discharge relationship was developed. There are several sources of error in this method, the biggest being that it depends on the creek channel remaining relatively stable so that the stage-discharge relationship doesn't change over time. At Crane Creek both upstream and downstream stations have had shifting sediment bars during the monitoring, thereby creating the possibility of changing relationships, which would introduce error or uncertainty. In addition, there is error in the actual measurement of discharge at a given depth and error associated with not measuring discharge at every depth, especially at high discharges. The highest discharge measured was 73 cfs; however, much higher flows occurred, which could not be measured due to accessibility or time constraints. Often, the higher flows are measured off of a bridge over the creek, but there was no bridge available in this case. These factors combine to produce an estimated 15% uncertainty in discharge measurements at both sites, or 2,061 Mgal for upstream and 2,430 Mgal for downstream. Both of these uncertainty values are only slightly less than the difference indicating that the difference in total discharge is likely not significant from an uncertainty in monitoring standpoint.

The mean, median, and range for the bi-weekly discharge were greater at the downstream site (Table 2 column 3). Results of a paired t-test on the bi-weekly discharge data from both sites suggested that they were statistically different at the 0.05 level of significance. This test included periods for which both sites had discharge data with no apparent problems (39 of the 46 periods). The significant increased was expected given that 260 additional acres drained to the downstream site and that most of those acres were cleared. As shown in Table 2, the biweekly discharges had a considerable range reflecting both the wet and dry conditions experienced during the project.

Summaries of the bi-weekly TS and TSS concentration data are shown in columns 4 and 5 of Table 2. The mean and median TS and TSS concentrations were greater at the upstream as compared to the downstream site; however, the difference was not statistically significant according to a paired t-test performed on the bi-weekly TSS data. The TSS concentrations were much greater than those of the Little River indicating much poorer overall water quality in Crane Creek.

The total TSS load for the duration of monitoring was slightly greater upstream as compared to downstream (column 6 of Table 2). The mean and median of bi-weekly TSS loads was greater for the upstream site also. A paired t-test conducted on the bi-weekly TSS load data suggested that there was no significant difference between upstream and downstream TSS loads at the 0.05 level of significance. This result provides evidence that sediment from the highway construction occurring between the two sites had no significant effect on the TSS load in Crane Creek.

Like discharge the TSS load calculations have uncertainty associated with them. Because the load is computed using the discharge and the TSS concentration data, it includes the uncertainty from the discharge as well as the TSS concentrations. Two types of error enter into the TSS concentration: one is the representativeness of the sample to actual conditions and the other is error associated with measuring the actual TSS concentration of the sample. If both of these components of error can be assigned 5% for a total of 10%, then the total error of the TSS load is 25%, for which the uncertainty range in Table 3 column 6 originates. As shown in the Table the uncertainty is much greater than the difference between the two sites lending further evidence to the assertion that there was no discernable difference between the sites. The uncertainty values indicate, from a monitoring perspective, how much difference in the sites was needed to have reasonable confidence that there was a real difference and not one resulting from the chance uncertainties associated with monitoring this creek.

Table 2. Summary of Monitoring Data for Crane Creek.

	Rain	Discharge	TS	TSS	TSS	TSS export
	in	Mgal	mg/L		tons	ton/ac-yr
Upstream Site						
total	64.5	13,743			2,846 ±741	0.039
mean	1.34	292	153	48	61.8	
median	1.14	176	103	33	26.2	
range	0-6	2-1,020	17-253	5-218	0.2-437	
Downstream Site						
total	64.5	16,197			2,942 ±735	0.038
mean	1.34	345	89	38	61.3	
median	1.14	235	83	22	26.7	
range	0-6	3-1,200	11-317	4-223	0.2-381	

Table 3 includes summaries of the water quality parameters turbidity, temperature, conductivity, dissolved oxygen (DO), and pH. The mean and median of bi-weekly turbidity measurements were greater for the upstream site. A paired t-test of the bi-weekly values suggested that there was a significant difference in turbidities at the 0.05 level. Since the TSS concentrations were greater at the upstream site, it was expected that the turbidity would also be greater. A possible explanation for this would be that the runoff between the two sites contained less sediment and was less turbid thereby diluting the water from the upstream site. In addition, the upstream site continued to sample during the very low flows of June-August, 2004, while the water was too low to collect samples at the downstream site. This contributed to the greater upstream turbidity as excluding these seven samples reduced the mean turbidity from 40 to 33.6 ntu. While the mean turbidity of the water samples was much greater than that of Little River, it was still below the state standard of 50 ntu for receiving waters (NC DENR, 1997).

The mean temperature increased slightly from upstream to downstream. This was expected given that the Creek flowed from primarily a wooded area upstream through a more open area before it reached the downstream site. The mean conductivity, DO, and pH were basically the same for upstream and downstream sites. This was expected given that the highway construction activities should have little effect on these parameters unless there was an accident.

Table 3. Summary of Water Quality Data for Crane Creek.

	Turb. ntu	Temp. C	Conductivity mS/cm	DO mg/L	pH
Upstream Site					
mean	40	15.4	0.054	8.4	6.3
median	25	14.8	0.050	8.7	6.0
range	7-167	2-23	0.034-0.089	2.6-15.7	4.5-7.7
number	44	20	20	20	19
Downstream Site					
mean	26	15.9	0.054	8.3	6.2
median	19	15.1	0.049	8.1	6.3
range	7-56	2.3-23	0.037-0.089	3.1-15.5	5.2-7.9
number	43	21	21	21	23

The nitrogen and phosphorus concentrations in 4 upstream and downstream samples are shown in Table 4. While the concentrations for the individual samples vary slightly, the means for the upstream samples were nearly equal to the corresponding mean for the downstream samples. This was expected given that there were no apparent major inputs of nitrogen or phosphorus between the two monitoring sites.

Table 4. Summary of Nitrogen and Phosphorus Data for Crane Creek

Date	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L
Upstream					
10/31/2003	0.51	0.01	0.04	0.12	20
5/7/2004	0.90	0.01	0.11	0.14	11
11/5/2004	0.70	0.01	0.11	0.16	20
3/10/2005	0.71	0.01	0.32	0.12	44
Mean	0.71	0.01	0.15	0.14	24

Downstream					
10/31/2003	0.69	0.01	0.07	0.13	31
5/7/2004	1.24	0.01	0.16	0.16	23
11/5/2004	0.64	0.01	0.11	0.15	17
3/10/2005	0.24	0.01	0.27	0.11	22
Mean	0.70	0.01	0.15	0.14	23

Little River

Description of Monitoring Site: Upstream and downstream monitoring stations were installed on the Little River in July, 2003 at the request of DOT (figure 6). The upstream station was in an excellent location being just upstream of the construction corridor on the Highway 1 bridge over the river (figure 7). The monitoring equipment was attached to the bridge deck near the middle of the river due to the high probability of flooding in the area and the lack of high ground near the river. Locating the equipment near either bank of the river was unsuitable because this would put the sampler too far away from the water during low flow conditions. Ideally the downstream monitoring station would have been located 100-200 feet downstream of where the new bypass crossed the river; however, this was low-lying land with a somewhat undefined channel, which was subject to flooding and access to the main channel of flow was mostly by boat only. Hence, the downstream station was located further downstream at the Long Point Road bridge over the river. Like the upstream site, the sampler was attached to the bridge deck to get access to flowing water even during periods of low flow (figure 7).

There was approximately 2500 acres of drainage area between the two monitoring stations. Most of the land was rural with a few homes surrounded by large areas of woodland. The drainage area encompassed about 100 acres of a subdivision in the town of Vass and some small farming operations. The area of highway construction was on the order of 5 acres, which was 0.2% of the area between the monitoring stations. While the primary purpose of the monitoring is to document the effect of the construction on the water quality of the river, which necessitates monitoring stations on the river, realistically the only way to document sediment yield from highway construction would be to monitor runoff from the construction corridor itself.

Description of Monitoring: An automated sampler and integrated flowmeter were installed at each site. Because discharge was not being monitored, the flowmeter measured water height only. The water height was the measured from a reference point near the river channel bottom at each site, thus the measurements do not represent the depth of water in the river and only indicate relative changes in depth. The samplers were programmed to collect a sample every 6 hours. Sample times for the downstream sampler were several minutes after the upstream to attempt to synchronize the sampling. Individual samples were recovered every 2 weeks and composited into 2 samples (bottles 1-6 and bottles 7-12) for the lab analysis. Every sample was analyzed for TS, TSS, and turbidity using standards methods and four samples were analyzed for nitrogen, phosphorus, and suspended sediment. After several months it became apparent that changes in upstream and downstream water levels were the same (figure 8), so the upstream flowmeter was removed.

Results of Monitoring: Water depth measurements are shown in figure 8. Sections of the graph with straight dashed lines indicate periods when the flowmeter was not working. The absolute measurement indicated by the scale on the vertical axis has no real meaning since the readings were taken from an arbitrary depth, but the relative or changes in depth are meaningful as the datum did not change over the monitoring period. As the figure indicates an extended period of relatively high stages occurred from August, 2003 through April, 2004 followed by a period of low stages during June and July 2004. Hence, the monitoring period encompassed a range of flow conditions.

Summaries statistics for the monitoring data from the Little River are shown in Table 4. As seen in the table differences between upstream and downstream parameters are small, if any. Statistical analysis of the data using a paired t-test suggested no significant difference between upstream and downstream means for TS, TSS, and turbidity. These results indicate that there was no discernable effect of the highway construction on the water quality of the Little River between these two monitoring stations during the period of monitoring.

Results for samples analyzed for nitrogen and phosphorus are shown in Table 5. A paired t-test conducted on this data also indicated no significant differences at the 0.05 level of significance.

Table 4. Summary of Monitoring Data for Little River.

	TS	TSS	Turbidity	Temp	Conductivity	DO	pH
	mg/L		ntu	C	mS/cm	mg/L	
Upstream Site							
mean	54	9	9	17.5	0.034	8.3	6.1
median	50	8	8	18.5	0.035	7.9	6.0
range	15-205	1-30	4-35	3-25	0.03-0.04	5-11	5-8
count	84	84	84	17	17	17	18
Downstream Site							
mean	59	10	9	17.6	0.033	7.9	6.1
median	47	8	8	18.5	0.035	7.4	5.8
range	5-345	2-48	4-24	3-25	0.02-0.04	5-15	5-8
count	89	89	89	18	18	18	18

Table 5. Summary of Nitrogen and Phosphorus Data for Little River.

Date	TKN	NH_3-N	NO_3-N	TP	TSS
	mg/L	mg/L	mg/L	mg/L	mg/L
Upstream Site					
10/31/2003	0.64	0.03	0.10	0.11	12
5/7/2004	2.00	0.01	0.22	0.27	106
11/5/2004	0.60	0.01	0.12	0.12	3
3/10/2005	0.04	0.01	0.19	0.10	3
Mean	0.82	0.01	0.16	0.15	31
Downstream Site					

10/31/2003	0.49	0.04	0.11	0.10	17
5/7/2004	2.12	0.01	0.16	0.22	67
11/5/2004	0.58	0.01	0.12	0.11	2
3/10/2005	0.01	0.01	0.16	0.10	2
Mean	0.80	0.01	0.14	0.13	22

Relationship Between Turbidity and TSS

For many surface waters of NC, turbidity is directly related to TSS concentrations. Because, in general, turbidity can be measured more quickly and inexpensively than TSS, monitoring runoff for turbidity and then converting these values to TSS concentration would be cost and time effective. With this in mind the TSS and turbidity data were plotted and the strength of the relationship was quantified using linear regression as shown in figure 9. For Little River, the R^2 of 0.437 indicated a relatively weak relationship between turbidity and TSS data for the 190 samples collected from the two sites. The relatively weak relationship can be attributed to a combination of factors including the low TSS concentrations, which do not mask more subtle natural sources of turbidity and the large drainage area which could encompass many sources of turbidity other than sediment such as decaying organic matter or human derived sources. The two relatively high turbidities (24 and 35 ntu) on the graph were associated with high flows following 6+ inches of rain in August, 2003. The slope of the best fit regression equation was 0.41 indicating that TSS concentrations increased much more quickly that turbidity.

For Crane Creek (figure 9, right) the turbidity to TSS relationship was much stronger R^2= 0.78. This could be expected given that the TSS and turbidity values were generally much greater thereby masking more subtle effects of other sources of turbidity. The slope of the relationship was 0.51 indicating that, like the Little River data, the TSS concentrations increased more quickly than the turbidity.

Few studies have been conducted on sediment loss and turbidity of runoff from construction sites; however, two studies provide information for comparison purposes. A study by Line and White (2001) documented relatively strong linear correlations (R^2 of 0.96 and 0.64) between TSS and turbidity for two NC construction sites. The slope of the relationship for the two sites was 1.00 and 0.56. Yorke and Herb (1978) also reported a strong linear relationship (r^2=0.87) between TSS and turbidity for construction runoff from a Piedmont Maryland site. Therefore, data from these studies provide evidence that there is often a relationship between TSS and turbidity for construction site runoff; however, the strength of the relationship varies and the comparative rate of change between TSS and turbidity also varies. These variations and uncertainty indicate that a single relationship for the predicting TSS from turbidity does not exist; however, regional or within watershed relationships may be adequate.

CONCLUSIONS

The results from nearly two years of monitoring upstream and downstream of the Highway 1 bypass construction over Crane Creek and the Little River show that there was no significant effect of the construction activities on the water bodies. Given the relative size of the drainage areas of the upstream sites to the area of disturbed by construction and the fact that the monitoring was not started until well after construction had begun, it was likely that only a major input of sediment to the Creek or River over an extended period would have been detected by the monitoring effort.

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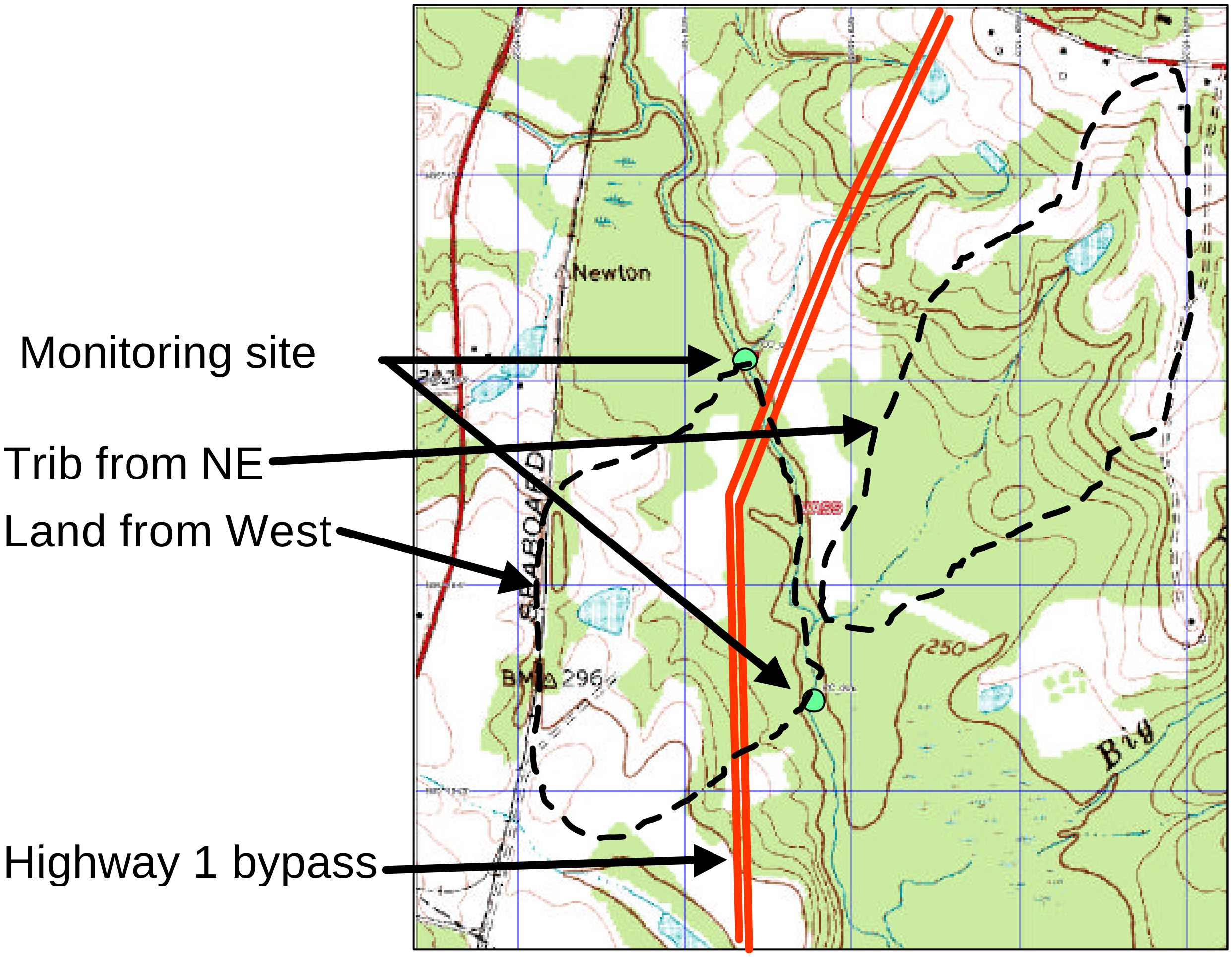

Figure 1. Crane Creek monitoring sites.

Figure 2. Upstream (left) and downstream (right) monitoring sites.

Figure 3. Sediment basin (left) and row crop (right).

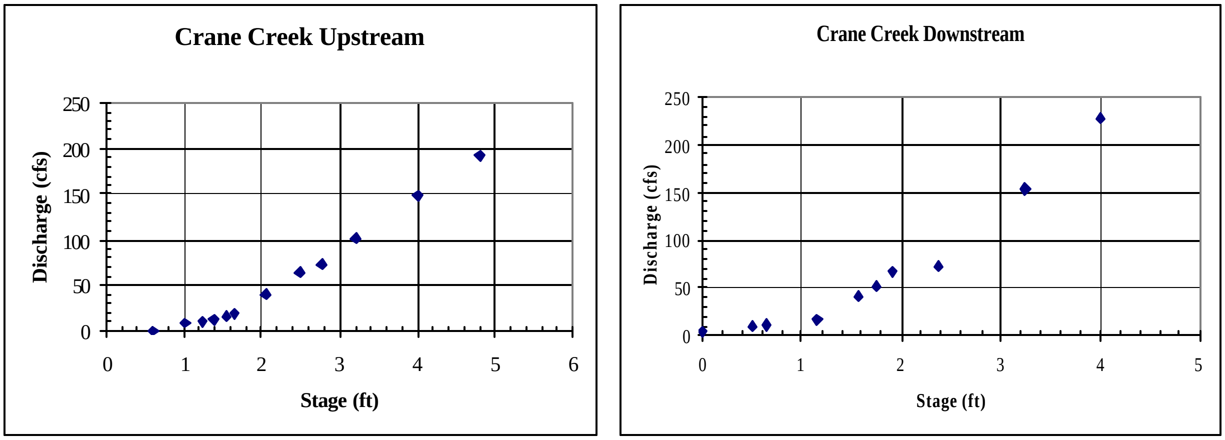

Figure 4. Upstream and downstream stage-discharge relationships for Crane Creek.

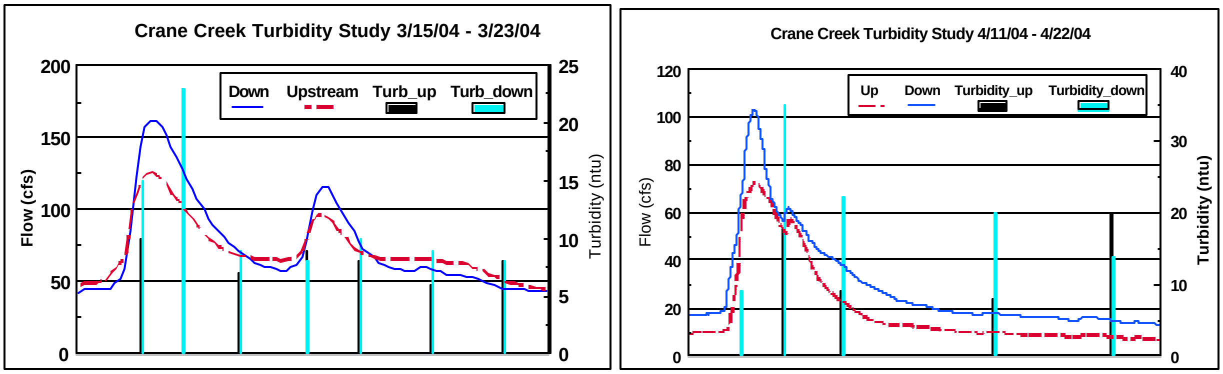

Figure 5. Results of individual sample analysis during two storm events.

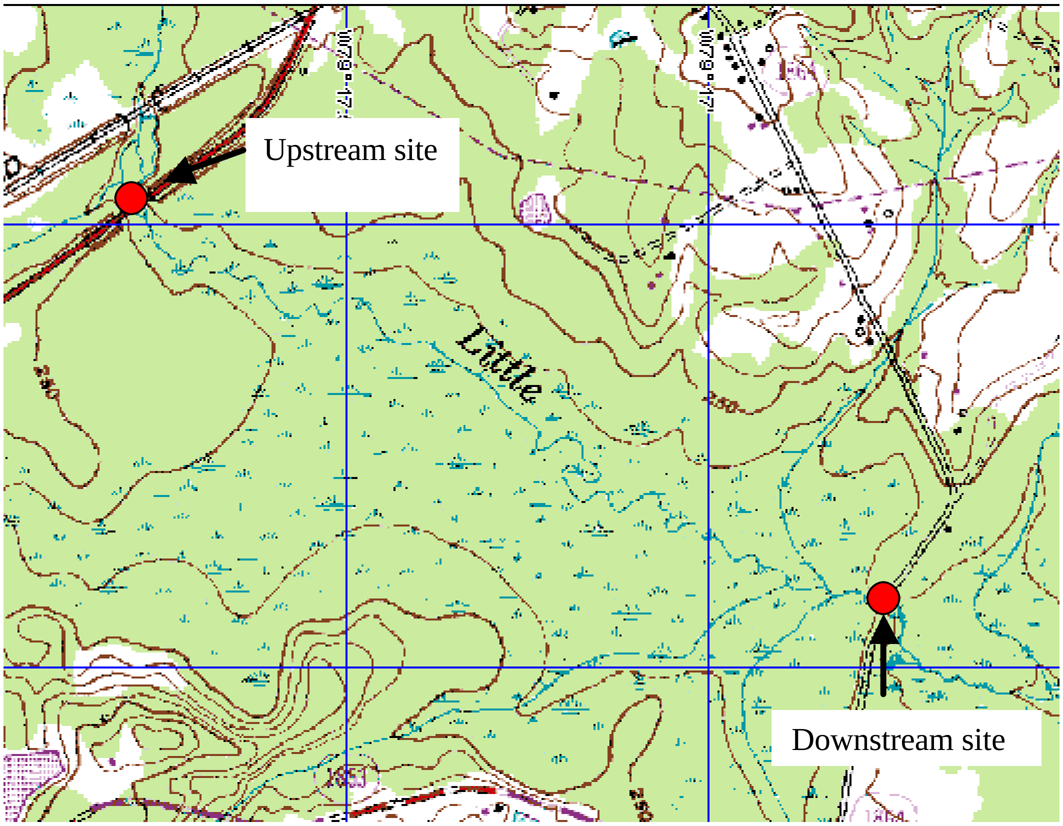

Figure 6. Map of Little River monitoring sites.

Figure 7. Picture of Little River upstream (left) and downstream (right) monitoring sites.

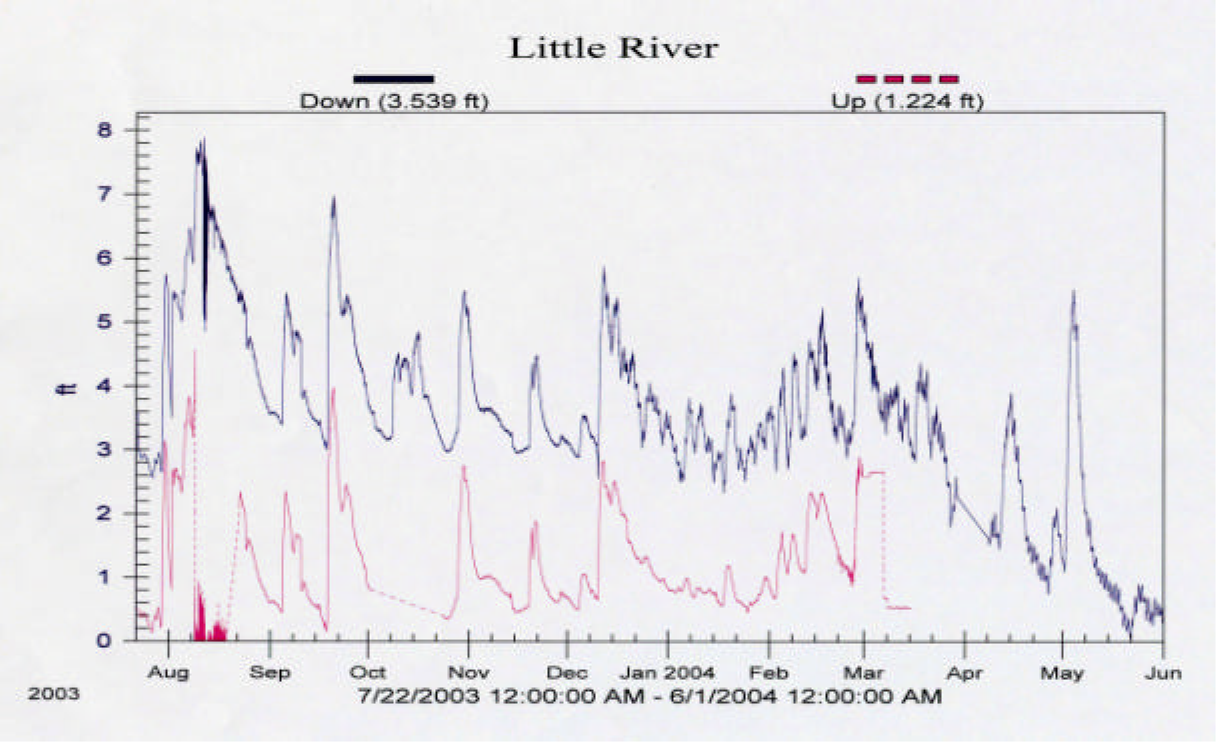

Figure 8. Water depth or stage for Little River.

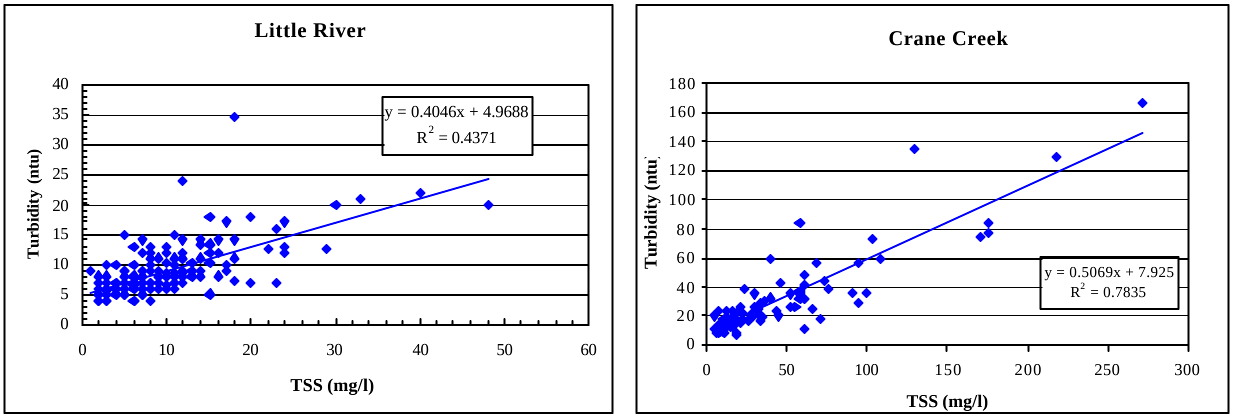

Figure 9. Graphs of TSS vs turbidity for Little River and Crane Creek.

APPENDICES

Exhibit 1. Guidelines for monitoring water quality for highway constructions sites:

The following report is only a very brief and not comprehensive description of monitoring guidelines and recommendations, but it does include the major considerations.

Criteria for Project Site Selection

While, any road construction project undertaken by NC DOT would be a candidate for a surface water monitoring program, those projects that involve a high quality or highly-valued water, an endangered species, and/or will likely effect significant wetlands will have higher priority. Another equally important factor is whether the hydraulics and hydrology of the project site are suitable for surface water monitoring. Sites where extensive flooding or backwater are probable, or where a poorly defined stream or river channel is present are not good candidates for monitoring as these sites present difficulties in monitoring and sampling all of the discharge. Also, sites where the area of highway construction activity is relatively (<20%) small compared to the overall drainage area being monitored are not good sites. This applies to locations where there is a large drainage area upstream of the highway construction corridor as compared to the corridor itself or where there is a large amount of land that is not part of the highway construction draining to the same monitoring station as the construction area of interest. Small changes in pollutant export or discharge from a large upstream drainage area and/or the inherent uncertainty in monitoring tend to mask changes in water quality resulting from the construction corridor. The presence of a significant area of land that was not part of the construction project adds uncertainty to the monitoring results, especially if the area is unstable with respect to sediment or other pollutant yield, in that sediment from this area often cannot be accurately estimated for the period of monitoring.

Another factor in overall site selection in some cases is the quality of the water resource involved. The effect of highway construction over a stream that carries a heavy sediment load already may be much more difficult to detect than the same effect on a stream that carries a relatively light sediment load. Monitoring equipment and laboratory analysis methods often have an optimum working range and when these are exceeded, their accuracy decreases. For instance, most turbidimeters are designed to measure from 1-1,000 ntu and when the upper limit is exceeded, uncertainty increase quickly.

The specific site of the monitoring station should ideally be in an easily accessible location with a stable stream channel that is straight and uniform. In addition, whether a flow control device is installed or a stage-discharge rating table is developed, water should flow unimpeded downstream from the site, thereby minimizing backwater conditions. Finally, the monitoring equipment should be housed above the flood stage and the instream probe(s), intake lines, or other accessories must be secured to avoid being washed downstream during high discharges.

Monitoring Station Configurations

There are basically three options for monitoring locations: single downstream station, paired watershed, and upstream/downstream (Spooner and Line, 1993). The single downstream station requires that the part of the drainage area that is not the highway construction corridor or treatment area be stable, preferably wooded, and less than 3-5 times the area of construction. Additionally, 2-3 years of monitoring prior to the start of the construction project should be conducted to adequately characterize the hydrology and sediment dynamics of the area. The pre-construction monitoring is especially important when the area outside the construction corridor is not wooded, because agricultural and developed drainage areas are highly variable and unpredictable in regard to hydrology and sediment dynamics. The pre-construction and during and post construction (1-3 years) monitoring data should then be statistically compared to determine the effect of the construction activity. This configuration of monitoring locations is generally only applicable to relatively small (<40 acres) drainage areas.

The paired watershed is similar to the single downstream station in that a single monitoring station just downstream of the highway construction corridor is needed. However, a second station installed at the outlet of a similar or paired drainage area that will be unchanged is also needed. The two stations should be installed 1-2 years before the start of construction so that their hydrology and sediment dynamics may be correlated. Monitoring at both stations must continue throughout the construction period (1-3 years). Monitoring during the construction period should continue until the highway corridor is stable. Monitoring data from both stations can then be statistically compared to determine the effect of the construction. This configuration of monitoring stations has proven to be the most powerful in documenting effects of nonpoint source pollution controls such as erosion and sediment controls.

The upstream/downstream configuration should be employed when there is a relatively large area upstream of the highway construction corridor. The upstream site should be located just above the primary area of construction activity and the downstream just below the area of greatest activity. The close proximity to the construction is necessary to isolate the runoff from the area of interest from the runoff from the surrounding area nontarget area. If the upstream area is similar in size and land use as the area between the stations and stays stable throughout the project, then this configuration is essentially the same as the paired configuration discussed above. Like the other configurations, 1-2 years of pre-construction monitoring is recommended to characterize the hydrology of each station. At sites where the entire area is consistently wooded, monitoring at the upstream station during the pre-construction period may not be necessary for the entire duration. However, the larger and/or more complex the drainage area, the longer the pre-construction monitoring that is required at both stations. As in the other configurations, the upstream area as well as the area between the stations should not be huge compared to the construction area. In general, monitoring discharge and sediment load from large areas has considerable uncertainty associated with it and if the area between the stations is relatively small, then the monitoring uncertainty may be greater than the effects of the construction activity. This would make the monitoring effort of little value.

For all three configurations, the duration of the pre-construction monitoring can vary depending on site conditions and the objective of the monitoring effort. However, the longer the pre-construction and construction monitoring periods, the greater the certainty in the data.

Hydrologic Monitoring and Sample Collection

Many monitoring studies have shown that most nonpoint source pollutants such as sediment are transported to streams during stormwater runoff. Therefore, the focus of monitoring efforts must be on storm event monitoring. Also, because the sediment has both immediate (clouds the water) and cumulative (fills voids in streams and impoundments) effects on surface water resources, it is necessary to characterize concentrations and mass loading or export. The most representative way to characterize both concentration and loading is to monitoring runoff or discharge continuously and collect flow-proportional samples for the entire storm event or continuously where there is continuous discharge. Collecting samples only on the rising limb of the hydrograph, such as with a single stage sediment sampler, does not adequately characterize the sediment dynamics of many storms. Additionally, collecting grab samples of nonstorm discharge or even storm discharge at a few times does not adequately characterize suspended sediment movement. In some cases, sampling of bedload may also be necessary to characterize the total sediment export.

Discharge monitoring is critical to the computation of sediment load or export and therefore should be conducted using the most accurate methods practical. Discharge monitoring may not be necessary for an upstream/downstream configuration for which the discharge between the two stations is not significantly different. There are a variety of appropriate methods depending on the site conditions, but only those involving a direct measurement of discharge whether via a flow control device or a stage-discharge rating table should be employed. The rating table should include at least 4 measurements of discharge encompassing at least 60% of the range of stages expected to be realized during the monitoring. Discharge monitoring should not be based on the use of the Manning's equation or another method of computing discharge as these methods are often inaccurate.

Discharge monitoring is needed for the collection of flow-proportional samples. Flow-proportional sampling involves collecting an equal volume of sample for every predetermined volume of discharge that passes the monitoring station. The predetermined volume of discharge should be small enough that for the median storm at least 5 individual samples are collected. Individual samples can then be composited into one sample per storm or 2-week period for laboratory analysis. If collecting flow-proportional samples is not possible, then timed- samples may be used. For the upstream-downstream station configuration where discharge does not change significantly between stations, timed-based sample collection would be appropriate. However, the interval between samples should be small enough to adequately characterize the runoff and sediment movement dynamics of the drainage area. Additionally, these dynamics, especially during storm events, render daily, weekly, or even a few storm event samples pretty much useless in characterizing sediment export.

The number of monitored storms required to accurately represent hydrologic and sediment export depends on site conditions, but a reasonable guideline is 75% of the events. Construction activity and variability of storm events makes estimating sediment export for many storms problematic; hence, planning to monitor every event is recommended. Equipment failure and other factors often result in some missed storm events, lending further credence to the recommendation to plan on monitoring every significant storm event during the duration of the monitoring program.

The collection of rainfall accumulation data is also important. A raingage that records rainfall amounts at 15 or 30-minute intervals is also recommended. The ability to document the intensity and total accumulation of rainfall for all events helps document the effectiveness of sediment controls for a variety of storm conditions. Detailed rainfall data can also be used to estimate runoff and sediment yield for storm events that have missing discharge or sample data.

Sample Variables

Since construction primarily affects sediment yield, the monitored variables must include total suspended solids (TSS), turbidity, and possibly total solids (TS). Total solids include TSS and dissolved solids. The dissolved solids are only a water quality problem in relatively rare cases. At very high TSS concentrations (>5,000 mg/L), the TSS and TS concentrations are nearly equal and given the problems with the TSS analysis method at these high concentrations, the TS analysis method should be substituted for the TSS. Other variables that could be considered include pH, conductivity, dissolved oxygen, and temperature; however, there is little evidence that these variables should change significantly as a result of construction. Clearing trees for highway construction may, in some cases, increase water temperature slightly, but usually the highway corridor is too narrow to have a big impact on temperature. While road construction should not significantly affect nutrients and heavy metals in streams, there may be instances where nutrient and/or metals analysis is warranted such as when vegetation requiring fertilizer must be established on a large area or when a highway beautification project involving mulch and fertilization are involved. In those cases, the nutrients sampled should include nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N), total Kjeldahl nitrogen (TKN) and total phosphorus (TP). Heavy metals sampling is not recommended unless there is a concern about metals contributions from traffic on the finished highway, then establishing background levels of metals such as lead, zinc, chromium, copper, and nickel during the construction period could be useful.

Quality Assurance/Quality Control

To insure that results from sampling are accurate and reproducible appropriate field and laboratory methods must be used. Field methods include thoroughly cleaning automated samplers prior to installation. During continued use at the same site, cleaning is not usually necessary after each sample recovery interval because the most important results are cumulative; hence any residue left from a previous storm will simply be added to a following storm. Cleaning of laboratory sample containers is important, especially if they have been used for sampling other sites. Disposable laboratory containers are often used to prevent contamination.

Sample preservation is a key element of quality assurance. Samples should always be analyzed as soon as possible after collection; however, in most cases preservation is necessary. For sediment or total suspended solids (TSS), refrigeration is recommended by U.S. EPA (1992); however, preservation is generally not needed as most sediment does not degrade appreciably over a several week period. When analyzing samples for nitrogen and phosphorus forms, preservation is required if the sample cannot be recovered within 48 hours. This preservation may include refrigeration (temp<4 deg C) or acidification (H_2SO_4 to pH<2) or both as recommended by U.S. EPA (1992). For some forms such as dissolved phosphorus, refrigeration is the only option. For automated sample collection in remote areas, acid may be added to sample containers prior to sample collection so that the sample is maintained at a pH<2 for the entire holding time.

Sample handling is also important in maintaining the integrity of the sample; therefore, a chain of custody record should be employed. At no time should the sample or any container part that might come in contact with the sample be touched by fingers or hands. Always hold sampler and laboratory containers as well as their lids by the outside. Always shake sampler and composite containers thoroughly and invert at least once immediately prior to pouring into laboratory container. Sediment often settles very quickly resulting in unrepresentative concentrations, if the sample is not transferred immediately after shaking. Cap laboratory containers immediately after filling and leave capped until in the laboratory.

Once in the laboratory standard laboratory procedures should be used which include the use of recovery standards, blanks, etc. Methods of analysis should follow those outlined in Standard Methods (i.e. APHA et al., 1995). For laboratories that are not state certified, it is advisable to have several duplicate samples analyzed by a different lab to compare results. This will add confidence to the analysis results.

In addition to maintaining the quality of samples, it is important to have accurate hydrologic data collected as well. Following the development of the initial stage-discharge rating table, discharge measurements should be made occasionally to check the continued validity of the relationship. Water stage readings collected by an automated sampler should be regularly checked against a permanent stream staff gage and adjustments made as necessary. Experience with automated samplers indicates that their depth measurements tend to drift with continued use and that regular adjustment is needed to maintain accurate stage readings.

Data Storage and Reporting and Data Analysis

Hydrologic and sample analysis data must be merged in a spreadsheet or database for any meaningful analysis to occur. Statistical analysis of data using parametric and/or nonparametric analysis methods should be used to compare sites or periods as the monitoring data often has considerable variability that must be accounted for. Parametric methods such as analysis of variance and/or covariance and nonparametric analysis such as the Wilcoxin signed rank test are commonly used. These tests are necessary because simple means or medians do not adequately account for the variability in the data.

References

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Exhibit 2. Crane Creek Data:

		Upstream Monitoring Site									Downstream Monitoring Site								
Date	Rain	Discharge	TS	TSS	TSS	Turb	Temp	Cond	DO	pH	Discharge	TS	TSS	TSS	Turb	Temp	Cond	DO	pH
	in	Mgal	mg/L	mg/L	kg	ntu	C		mg/L		Mgal	mg/L	mg/L	kg	ntu	C		mg/L	
22-Jul-03	1.00		na	na		na	na	na	na	na	na	75	27		30	na	na	na	na
29-Jul-03	0.90		75	11		16	23.7	NA	7.0	6.4		na	na		na	24.2	na	6.7	6.5
4-Aug-03	4.00	457	100	na		45	na	na	na	na	464	165	na		87	na	na	na	na
18-Aug-03	6.20	flood	na	na		na	na	na	na	na	na	na	175		83	na	na	na	na
22-Aug-03	na		na	na		na	23.9	NA	NA	6.4	3362	na	na		na	23.9	na	na	6.4
27-Aug-03	0.53		na	na		na	na	na	na	6.4	na	na	na		na	na	na	na	6.3
3-Sep-03	0.90	58	75	60	13,172	31	na	na	na	na	104	11	70	27,555	18	na	na	na	na
17-Sep-03	1.50	153	na	na	45,363	42	19.7	0.05	7.1	6.0	235	na	na	21,381	17	20.0	0.05	7.3	6.3
1-Oct-03	2.00	503	210	58	110,424	83	14.9	0.05	8.6	5.8	574	148	95	206,396	28	15.1	0.05	8.7	5.8
16-Oct-03	1.44	143	60	14	7,578	12	14.7	0.04	9.7	5.7	189	49	60	9,989	11	15.0	0.04	9.7	5.5
30-Oct-03	2.13	202	115	33	31,014	28	14.0	0.04	9.7	5.7	279	115	22	23,232	22	14.2	0.04	9.7	5.9
12-Nov-03	0.51	286	70	17	18,467	16	12.1	0.05	9.7	5.8	307	45	10	10,458	10	12.4	0.05	9.6	6.2
24-Nov-03	0.35	190	65	15	11,241	14					199	70	16	12,051	15	na	na	na	na
9-Dec-03	0.69	180	55	8	5,511	9					194	50	7	5,140	10	na	na	na	na
30-Dec-03	2.62	1024	85	40	155,034	32	7.3	0.05	13.3	6.0	1088	105	58	238,849	37	7.7	0.05	14.0	na
13-Jan-04	0.26	260		na	14,762						289	50	15	16,408	12	na	na	na	na
29-Jan-04	0.25	240	45	18	20,371	22	1.8	0.05	15.7	6.5	300	25	10	11,355	13	2.3	0.04	15.5	6.6
16-Feb-04	2.72	na	na	na	29,092	7					na	na	na	12,615	na	na	na	na	na
2-Mar-04	0.01	984	40	14	52,142	14	9.0	0.05	11.3	6.1	666	40	4	10,083	10	9.2	0.05	11.3	6.2
15-Mar-04	1.52	646	50	8	19,561	13					522	60	10	19,758	9	na	na	na	7.4
29-Mar-04	0.00	381	120	6	8,653	8	14.2	0.05	9.6	7.7	519	120	19	37,324	9	14.9	0.05	9.7	7.9
8-Apr-04	0.56	121	100	5	2,290	20					196	na	15	10,757	na	na	na	na	na
22-Apr-04	1.50	157	25	10	5,942	18	18.4	0.06	7.9	7.5	237	70	43	38,573	23	19.0	0.06	7.9	7.4
6-May-04	3.35	351	168	130	172,710	135					535	80	74	149,848	44	na	na	na	6.8
19-May-04	0.16	168	125	66	41,968	25	20.8	0.07	6.1	7.4	262	90	58	57,517	35	21.1	0.07	6.7	7.5

2-Jun-04	0.53	54	na	10	2,044						82	60	11	3,414	11	na	na	na	6.9
16-Jun-04	0.45	9	na	10	343		22.8	0.09	2.6	7.4	10	na	14	511	na	23.1	0.09	3.6	7.3
30-Jun-04	1.73	2	210	175	132	77					3	70	16	182	24				
14-Jul-04	1.96	12	203	170	532	74					15	57	12	607	19				7.2
28-Jul-04	1.50	4	17	12	170	23					5	110	20	379	26				
11-Aug-04	1.17	15	67	7	390	24	20.9	0.08	3.5	6.5	17	na	12	772		20.9	0.08	3.1	6.6
25-Aug-04	2.71	52	253	218	42,907	130					55	123	223	46,001	38				
9-Sep-04	6.16	540	127	103	210,522	73					852	40	103	332,156	19	23.0	0.06	6.1	5.6
22-Sep-04	1.46	511	na	73	140,225						555	83	60	126,041	48				
8-Oct-04	1.57	319	2070	45	54,334	20	15.4	0.06	8.3	6.4	369	110	52	72,627	35	15.2	0.06	8.1	5.5
21-Oct-04	0.08	99	90	33	12,366	17					129	317	30	14,648	35				
5-Nov-04	0.19	97	70	19	7,002	17	16.3	0.07	6.6		122	100	19	8,774	7	16.0	0.07	6.9	na
19-Nov-04	0.43	91	140	52	17,867	27					118	na		23,225					
2-Dec-04	0.90	133	120	50	25,170	36					165	150	55	34,349	26	no ysi avail			6.3
17-Dec-04	1.26	176	120	46	30,310	36					215	107	35	28,482	19				
30-Dec-04	0.69	128	53	20	9,690	15					155	90	61	35,787	31				
13-Jan-05	2.98	123	110	58	27,002	32	11.4	0.06	8.7	5.3	155	103	75	44,001	39	11.6	0.06	8.0	5.6
27-Jan-05	1.80	710	111	109	292,384	167					851	143	94	302,777	56				
10-Feb-05	1.05	468	40	15	26,571	19	10.3	0.04	9.7	6.2	542	40	17	34,875	14	10.1	0.04	9.6	5.2
25-Feb-05	1.07	369	113	33	46,090	20					428	70	17	27,540	15				
10-Mar-05	1.70	678	110	61	156,540	41					814	133	30	91,364	27				
24-Mar-05	2.14	893	150	40	135,140	60	13.1	0.03	10.5	na	1137	93	29	124,803	22	12.4	0.04	9.3	na
6-Apr-05	1.05	671	87	32	81,272	25					793	77	22	66,033	18				
21-Apr-05	2.01	931	167	108	380,574	59	16.1	0.04	4.5	5.9	1196	103	36	162,967	30	16.3	0.04	5.3	6.3
4-May-05	0.55	257	103	61	59,337	42					279	97	16	16,896	16				
18-May-05	0.26	103	83	26	10,136	17	17.9	0.05	6.8	5.9	131	80	8	3,967	11	17.8	0.05	7.0	5.8
1-Jun-05	0.62	65	90	9	2,214	14					75	60	13	3,690	15				
15-Jun-05	2.90	173	143	69	45,182	56					188	107	46	32,733	43				
29-Jun-05	1.11	13		10	492						46	83	23	4,005	21				
Total	64.5	13743			2,582,229						16,197			2,562,892					

Exhibit 3. Little River Data:

Upstream Monitoring Site								Downstream Monitoring Site						
Date	TS	TSS	Turb	Temp	Cond	DO	pH	TS	TSS	Turb	Temp	Cond	DO	pH
	mg/L	mg/L	NTU	C	ms/cm	mg/L		mg/L	mg/L	NTU	C	ms/cm	mg/L	
8-Jul-03	15	7	6					65	13	10.5				
8-Jul-03	65	9	8											
22-Jul-03	70	24	13					65	16	12				
22-Jul-03	50	15	11											
29-Jul-03														
4-Aug-03	45	18	35					5	8	7				
4-Aug-03	55	17	17					45	14	14				
18-Aug-03	60	5	9											
18-Aug-03	60	6	7				6.7	70	7	9				6.7
3-Sep-03	45	15	5											
3-Sep-03	65	20	7					50	12	24				
17-Sep-03	60	15	14	22.1	0.029	7.4	5.6	85	40	22	22.0	0.029	7.2	5.6
17-Sep-03	100	18	11					70	14	13.5				
1-Oct-03	55	3	6	18.7	0.028	7.9	5.3	60	18	7.5	18.6	0.024	7.8	5.4
1-Oct-03	65	12	11					55	12	9				
16-Oct-03	45	22	13	17.2	0.028	8.6	5.0	60	29	12.5	16.8	0.025	8.5	5.1
16-Oct-03	45	10	9					45	10	10.5				
30-Oct-03	50	12	11					75	24	17				
30-Oct-03	55	7	9					50	12	12				
12-Nov-03	50	11	7					40	12	8.5				
24-Nov-03	45	10	8					45	13	9				
24-Nov-03	45	11	9					35	6	6.5				
9-Dec-03	40	8	9					40	9	8				
9-Dec-03	45	6	7					40	8	7				

30-Dec-03	70	30	20					45	14	9				
30-Dec-03	125	6	7					40	2	7				
13-Jan-04	205	10	7					100	7	5				
13-Jan-04								30	8	6				
29-Jan-04	20	3	4	2.8	0.034	15.3	6.1	40	2	5	2.7	0.036	15.0	nd
29-Jan-04	35	2	5					40	2	4				
16-Feb-04	35	11	8					345	11	6				
16-Feb-04	30	7	6					345	10	6				
2-Mar-04	40	8	6	9.4	0.039	11.4	6.2	45	6	8	9.7	0.036	15.9	5.7
2-Mar-04								55	9	9				
15-Mar-04								40	5	6				
29-Mar-04	55	17	9	16.8	0.036	9.3	7.7	25	7	7	16.3	0.037	9.0	7.7
29-Mar-04	70	23	7					45	9	7				
8-Apr-04	20	11	15											
8-Apr-04	55	15	18											
22-Apr-04	60	10	12	21.7	0.036	7.3	7.4	85	48	20	21.6	0.036	6.8	7.3
22-Apr-04	50	12	11					80	14	8				
6-May-04	30	8	13					15	12	14				
6-May-04	15	8	12					12	5	15				
19-May-04	75	23	16	24.1	0.036	6.1	7.6	45	18	14	23.9	0.036	5.8	7.6
19-May-04								75	12	8				
2-Jun-04	15	4	7				6.7	30	24	12				7.2
2-Jun-04								15	7	7				
16-Jun-04	30	4	7	25.4	0.040	6.0	7.7	100	7	12	25.1	0.040	5.6	7.7
16-Jun-04								90	3	10				
30-Jun-04	15	7	9					10	7	8				
30-Jun-04	50	1	9					40	5	9				
14-Jul-04	57	7	8					30	15	12				
14-Jul-04	33	6	8					40	13	8				

28-Jul-04	67	7	14					110	8	11				
28-Jul-04	33	6	13					40	11	11				
11-Aug-04	57	20	18	24.3	0.038	6.5	6.0	53	17	10	24.3	0.036	5.3	6.3
11-Aug-04	57	6	10					43	12	8				
25-Aug-04	23	8	10					60	16	14				
25-Aug-04	180	9	8					67	10	8				
9-Sep-04	20	11	10	23.7	0.037	5.2		40	12	9	23.9	0.037	5.2	
9-Sep-04								13	4	10				
22-Sep-04	53	11	11					27	5	8				
22-Sep-04	37	11	10					10	5	8				
8-Oct-04	47	11	7	18.5	0.035	7.7	5.7	43	11	7	18.4	0.034	7.2	5.8
8-Oct-04	70	9	6					50	9	7				
21-Oct-04	100	7	5					47	8	4				
21-Oct-04	97	2	6					103	8	6				
5-Nov-04	50	4	6	17.7	0.040	8.2		73	5	5	17.7	0.040	7.6	
5-Nov-04	47	6	4					67	2	5				
19-Nov-04								57	5	9				
19-Nov-04								43	5	6				
2-Dec-04	40	5	9				5.8	40	9	8				5.7
2-Dec-04	57	5	6					73	6	8				
17-Dec-04	63	5	7					40	2	4				
17-Dec-04	93	3	6											
30-Dec-04	60	2	8					60	2	7				
30-Dec-04	47	3	7											
13-Jan-05	33	6	4	13.0	0.035	8.4	5.6	50	3	4	13.0	0.033	8.4	5.8
13-Jan-05	37	2	4					73	3	5				
27-Jan-05	50	10	13					37	3	8				
27-Jan-05	37	12	7					53	5	6				
10-Feb-05	30	4	6	10.1	0.025	10.5	4.6	90	6	6	10.1	0.025	9.1	4.8

10-Feb-05	30	10	6					103	5	5				
25-Feb-05	37	7	6					63	6	4				
25-Feb-05	107	16	8					13	7	7				
10-Mar-05	83	5	6					90	7	5				
24-Mar-05	63	6	6	13.4	0.026	9.9		53	3	4	13.7	0.027	7.9	
24-Mar-05	30	5	7					37	3	6				
6-Apr-05	50	3	6					53	2	4				
6-Apr-05	53	2	5					47	4	5				
21-Apr-05	30	5	5	18.6	0.028	5.2	6.0	40	9	6	18.7	0.028	5.4	6.1
21-Apr-05	30	5	6					27	7	6				
4-May-05	47	3	6					90	12	11				
4-May-05	47	3	6					107	33	21				
18-May-05								47	8	7	20.2	0.034	5.4	5.8
18-May-05								33	11	7				
1-Jun-05								67	6	7				
1-Jun-05								43	6	6				