EFFECTS OF TROPICAL DEPRESSIONS IVAN AND JEANNE ON WATER QUALITY OF THE UPPER OCONEE RIVER BASIN: RESULTS FROM A WATERSHED GROUP MONITORING PROGRAM

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Abstract. We measured storm water quality at 10 long-term monitoring sites in the Middle and North Oconee River basins near peak flow during Tropical Depressions (TD) Ivan and Jeanne and compared our results to the Upper Oconee Watershed Network low flow dataset. Maximum turbidity levels for the North Oconee River were 5-10 times lower than those in the Middle Oconee River (474 - 834 NTUs) during both storms. We found the lowest turbidity levels in small streams with vegetated buffers and an urban stream. Most of the fine particulate material transported in the 10 streams at low flow and peak flow during TD Jeanne was in the form of inorganic sediment. An estimated 4,039 kg of sediment moved downstream every minute in the Middle Oconee River just prior to peak flow during TD Ivan, while sediment in the North Oconee River was transported downstream at a rate of 88 kg/min. Fecal coliform bacteria concentrations were also greater during peak storm flow (<500 - 11,800 CFU/100 mL), while nitrate, pH, and conductivity values did not differ greatly from low flow conditions. Our results demonstrate the negative effects of high flows on sediment transport and fecal coliform concentrations in the upper Oconee River basin, particularly in the Middle Oconee River watershed.

INTRODUCTION

Recent studies have suggested that global warming may result in future increases in hurricane intensity and precipitation rates (e.g., Knutson and Tuleya 2004). Increases in storm intensities and precipitation in the southeastern U.S. could lead to increased water quality problems in Georgia. Hurricanes Frances, Ivan, and Jeanne, which were downgraded to tropical depressions (TDs) after reaching northern Georgia, resulted in 262 mm (10.3 in) of rainfall in the Upper Oconee River basin over a 4-wk period in September 2004 (USGS). During TDs Frances, Ivan, and Jeanne mean daily discharges for the Middle Oconee River were 8–15 times greater than mean daily values for those dates over 71 years of record by USGS (Figure 1).

The Upper Oconee Watershed Network (UOWN) has monitored baseline water quality conditions in the Middle and North Oconee River basins on a quarterly basis since 2000. Low flow (defined as discharge <14 m^3/sec at the Middle Oconee River USGS gauge) water quality ranges from poor to excellent in the basins (Conners et al. 2001, Wenner et al. 2003). The paths of Hurricanes Ivan and Jeanne over north Georgia and the Upper Oconee River basin provided a unique opportunity to collect water quality data during reoccurring storms.

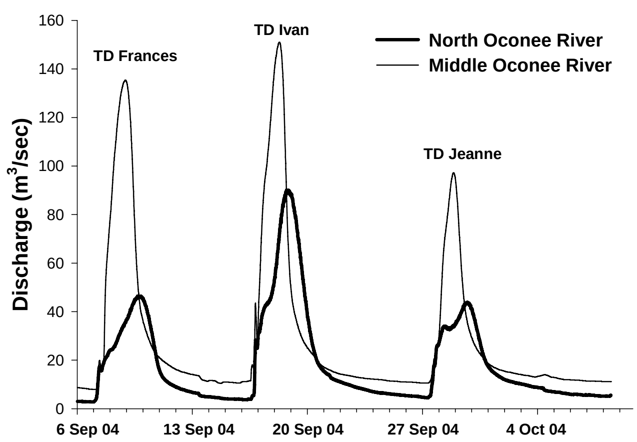

Figure 1. Hydrographs of North Oconee River at College Street (USGS station 02217770) and Middle Oconee River near Athens, GA (USGS station 02217500) during TDs Frances, Ivan, and Jeanne. Provisional data subject to revision from http://waterdata.usgs.gov.

Table 1. Water quality (mean ± SE) at UOWN sites during low flow (2000-2004), Tropical Depression (TD) Ivan (September 17, 2004) and TD Jeanne (September 27, 2004). ND = no data available. Site location indicated by latitude and longitude.

	Bear Creek Trib.	Orange Trail Creek	Brooklyn Creek	Hunni-cutt Creek	McNutt Creek	Middle Oconee River	Sandy Creek	Trail Creek	Carr Creek	North Oconee River
Location										
Latitude	33° 58'N	33° 54'N	33° 57'N	33° 57'N	33° 55'N	33° 57'N	33° 59'N	33° 57'N	33° 57'N	33° 58'N
Longitude	83° 29'W	83° 23'W	83° 24'W	83° 26'W	83° 26'W	83° 26'W	83° 23'W	83° 22'W	83° 21'W	83° 22'W
pH										
Low flow	6.6±0.2	6.4±0.1	6.7±0.1	6.5±0.4	6.5±0.2	7.1±0.3	6.4±0.3	6.7±0.1	6.1±0.1	ND
Ivan	6.4	ND	6.3	6.4	6.2	6.4	6.1	6.3	6.2	6.2
Jeanne	6.3	6.3	6.2	6.5	6.2	6.3	6.2	6.2	6.0	6.1
Conductivity (μS/cm)										
Low flow	45±2	75±12	113±5	79±5	57±3	75±4	56±3	71±3	656±25	ND
Ivan	45	ND	129	63	57	57	51	60	394	57
Jeanne	37	33	32	33	34	78	72	38	194	52
NO_3 (mg/L)										
Low flow	0.7±0.1	5.3±0.3	2.3±0.4	1.4±0.0	0.7±0.1	1.4±0.1	0.7±0.1	0.7±0.4	7.3±1.8	ND
Ivan	0.3	ND	1.8	0.9	0.2	0.9	0.2	0.5	2.2	0.4
PO_4 (μg/L)										
Low flow	5±5	77±17	50±34	25±15	50±50	63±33	65±65	137±102	133±109	ND
Ivan	30	ND	190	80	0	0	0	10	110	20
Turbidity (NTU)										
Low flow	7±1	5±1	6±2	7±2	10±2	21±4	12 ±2	21±7	11±2	ND
Ivan	30	ND	16	101	150	834	72	72	111	82
Jeanne	86	100	105	359	326	474	49	275	248	87
Fecal Coliform (CFU/100mL)										
Low flow	464 ±204	60 ±40	1354 ±380	601 ±159	1354 ±1007	190 ±42	132 ±40	2097 ±1094	72 ±18	ND
Jeanne	1000	7400	11800	4000	<500	7800	4650	600	11200	1800

METHODS

During TD Ivan, we collected turbidity, total suspended sediments (TSS), pH, conductivity, and nutrient data at the quarterly monitoring sites. We gathered extensive turbidity and TSS data at USGS gauged sites on the Middle and North Oconee Rivers, as well as fecal coliform data at each of the quarterly sites during TD Jeanne. During TD Ivan we sampled the tributaries at slightly past peak flow, while the Oconee River sites were sampled just prior to peak flow. We sampled the smaller streams at peak flow during TD Jeanne and sampled the larger sites from the beginning of the storm through the falling limb of the hydrograph. Discharge data were not available for the small, ungauged sites.

We measured pH and conductivity during low flow and storm flow with calibrated portable field meters. Turbidity was measured with a 2020 LaMotte turbidimeter. We analyzed nitrate and phosphate samples with an 890 Hach colorimeter. We measured fecal coliform concentrations by membrane filtration (APHA et al. 1992). TSS concentrations were measured by standard methods (APHA et al. 1992). We estimated total organic and inorganic export at the two gauged Oconee River sites by multiplying ash-free dry mass (AFDM) and ash concentrations by discharge for each interval and summing each for the storm duration.

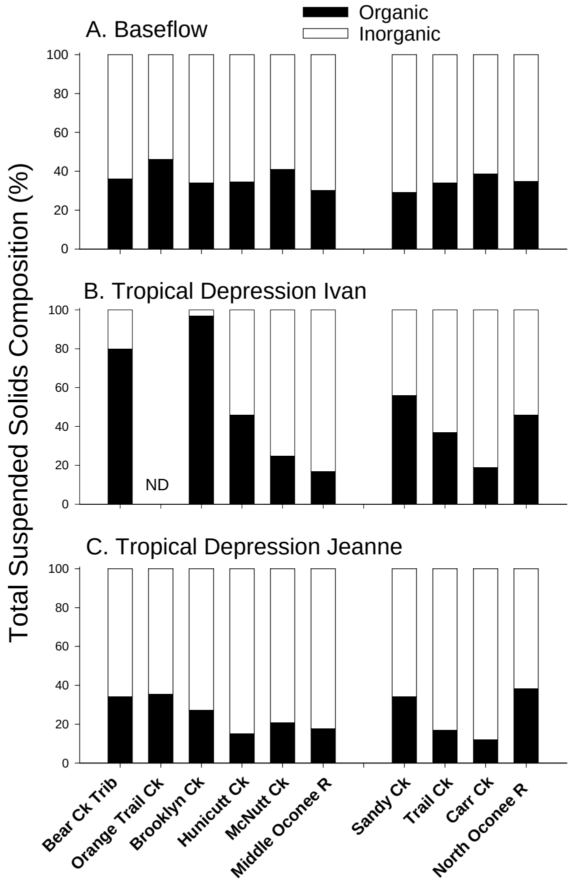

Figure 2. Percent organic and inorganic composition of total suspended solids collected during (A.) Low flow, (B.) TD Ivan, and (C.) TD Jeanne at UOWN sampling sites. ND = no data available.

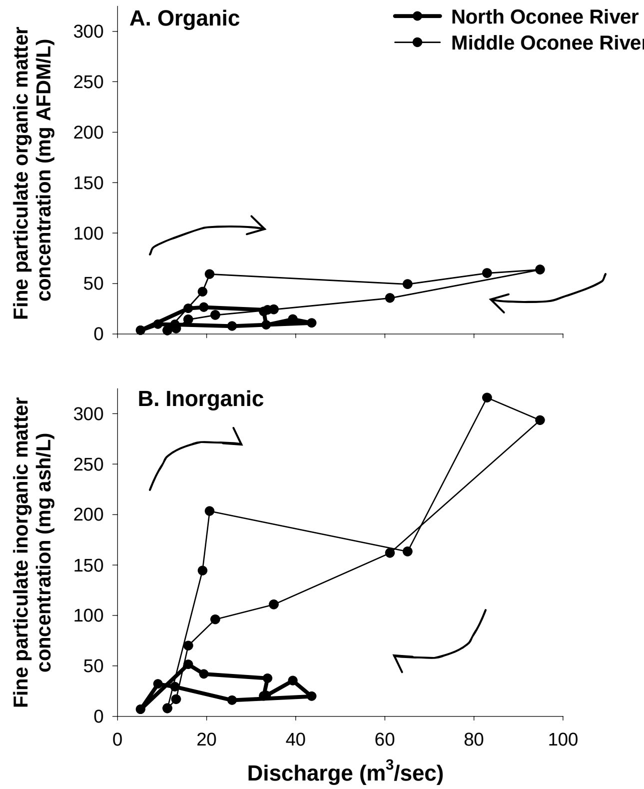

Figure 3. Relationship between fine particulate organic (A.) and inorganic (B.) matter concentrations and discharge during TD Jeanne at North and Middle Oconee River sites. Arrows indicate sequence of sample collection during storm.

RESULTS AND DISCUSSION

High turbidity levels were observed in the Middle Oconee River of during TDs Ivan (834 NTU) and Jeanne (474 NTU) (Table 1). Maximum turbidity levels recorded for the North Oconee River were lower than those in the Middle Oconee River; 82-87 NTUs near peak flow during both storms. Maximum turbidity and TSS values in the Oconee River during TD Ivan are conservative estimates, since we did not sample the entire rising limb of the hydrograph. We found the lowest turbidity levels in undisturbed streams with vegetated buffers (Orange Trail Creek, Bear Creek Tributary, Sandy Creek) and an urban stream (Brooklyn Creek). These results are not unexpected. Vegetated buffers trap sediment before it runs off to streams and urban streams such as Brooklyn Creek have few active construction sites that contribute to sediment runoff.

TSS measurements allowed us to examine the composition of fine particulate matter transported during the storms. TSS values were closely related to turbidity measurements made at the same time: TSS (mg/L) = 3.547 + 0.921 x NTU (r^2 = 0.96, n = 30, TSS range = 10.4 – 785.8 mg/L). The majority of low flow TSS at each site was inorganic material (Figure 2A). During the rising limb of TD Ivan, a greater proportion of fine particulate material transported in small streams was organic (Figure 2B). The majority of TSS during peak flow of TD Jeanne was in the form of inorganic sediment (Figure 2C). Suspended organic concentrations at both the North and Middle Oconee River sites increased most rapidly during early stages of TD Jeanne and leveled off until peak flow was reached (Figure 3A). In contrast, suspended inorganic sediment concentrations in the Middle Oconee didn't peak until peak flows were reached (Figure 3B). We estimated that 4,039 kg of sediment moved downstream every minute in the Middle Oconee River just prior to peak flow during TD Ivan. In contrast, sediment in the North Oconee River was transported downstream at a rate of 88 kg/min during TD Ivan. Total fine organic and inorganic yield were 2.5 and 5.1 times greater, respectively, in the Middle Oconee

Table 2. Total export of fine particulate organic matter (FPOM) and fine particulate inorganic (FPIM) during TD Jeanne (27 Sept 2004 - 8 Oct 2004) at North and Middle Oconee River sites.

	North Oconee River	Middle Oconee River
FPOM export (kg)	183,447	692,493
FPOM yield (kg/ha)	2.68	6.72
FPIM export (kg)	394,785	3,040,443
FPIM yield (kg/ha)	5.77	29.50

River compared to the North Oconee during TD Jeanne (Table 2).

Fecal coliform bacteria concentrations were 2-160 times greater during storm flow than during low flow, except for Trail and McNutt Creeks, which previously experienced sewage spills during 2000-2004 (Table 1). Nitrate, pH, and conductivity values measured in all streams during the two storms were similar to, or lower than low flow averages due to storm water dilution (Table 1). Phosphate concentrations in the smaller streams were slightly higher during storm flow, a pattern typically observed for compounds that adsorb to sediment (Richards and Baker 1993).

CONCLUSIONS

When compared to long-term low flow data, our results clearly demonstrate that high flows substantially increase sediment transport and fecal coliform concentrations in the Upper Oconee River basin. The high coliform counts represent a human health hazard (USEPA 1976) and increased sediment transport has serious negative consequences for aquatic life (e.g., Runde and Hellenthal 2000; Sutherland et al. 2002; Roy et al. 2003). Our data also showed that the storm sediment transport problem is considerably worse in the Middle Oconee River compared to the North Oconee River. It is unclear whether the source of the sediment input to the Middle Oconee River is related to historical sediment deposits being transported downstream, or recent inputs as a result of rapid development in the basin. Further sampling and an analysis of land use changes over time may help to determine the source of the problem and potential solutions for the prevention and management of sediment inputs.

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