NC Division of Water Quality
Planning Section
Modeling and TMDL Unit

MEMORANDUM

To: Kathy Stecker, Modeling Unit Supervisor

From: Narayan Rajbhandari, Senior Env. Specialist

Date: December 17, 2010

Subject: Assessment of Natural Conditions for Dissolved Oxygen in Smith Creek, Roanoke River Basin, NC

Summary

Smith Creek (AU# 23-10a, 23-10b, 23-10c), is impaired for dissolved oxygen (DO) for approximately 10.7 miles. The watershed exhibits low velocity due to beaver impoundments and large areas of agricultural and forested lands. Decomposition of the large inputs of vegetation from areas of forested land and heavy tree canopy throughout the watershed create lower DO as they decay in the waterbodies. There is no discernable anthropogenic impact on the creek. Smith Creek exhibits low nutrient concentrations near or below national background levels from undeveloped areas. Based on the information, the water quality standards for Smith Creek and its tributaries have not been violated. A Total Maximum Daily Load (TMDL) is not required for DO for Smith Creek.

Introduction

Smith Creek has been listed as impaired since 1998 on the North Carolina 303(d) List due to violations of the State's water quality standard for DO. As reported in the list, the impaired segment is located from the source to the North Carolina-Virginia State line (Figure 1). The assessment unit numbers for the impaired section of the creek are 23-10a, 23-10b, and 23-10c. The total mileage of impaired section is 10.7 and is designated as Class C. The Division of Water Quality (DWQ) defines Class C as waters protected for secondary recreation, fishing, wildlife, fish, and aquatic life propagation and survival, agriculture and other uses suitable for Class C. This report evaluates the DO impairment by determining if natural conditions are the cause of the apparent impairment, thus obviating the need for a TMDL.

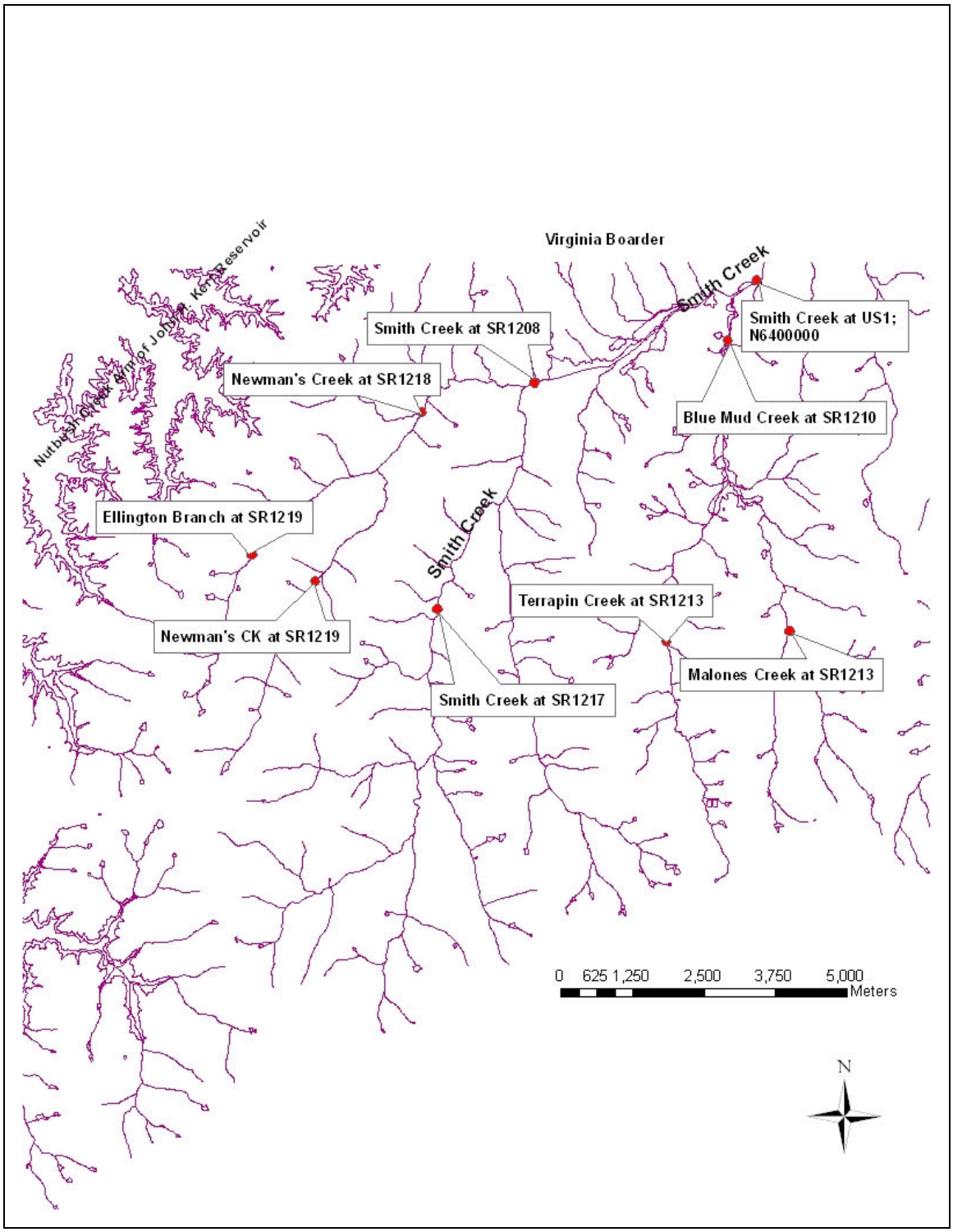

Figure 1. Smith Creek and its tributaries, showing field measurement sites

General Description of Watershed

Smith Creek, located in northwestern Warren County in North Carolina, is a tributary to the Roanoke River (Lake Gaston) in Virginia, approximately two and a half miles north of US1. The creek has three major arms; they are Newman's Creek, Terrapin Creek, and Blue Mud Creek (Figure 1). The watershed has an area of approximately 68.7 square miles. There is an ambient water quality station (N6400000) at US1 near Paschall. DWQ collects water samples monthly to measure physical and chemical constituents. Data collected at this ambient station was used for the purpose of this report. There are no USGS gage stations to measure flow in this watershed.

Geology and Soils

Smith Creek is in the Eastern and Central Piedmont Physiographic area in North Carolina. The geology consists mostly of felsic metaigneous, felsic gneiss, and schist rocks (Giese and Mason, 1993). Weathering from these rocks form Cecil soil. Therefore, the watershed comprises predominantly of Cecil soil series, which consists of very deep, well drained moderately permeable soils. (Source: http://urbanext.illinois.edu/soil/st_soils/nc_soil.htm.)

Climate

Climate data was acquired from a nearby weather station – John H. Kerr Dam (VA444414) located at Baydton, Virginia. Figure 2 shows monthly averaged temperature and total rainfall distribution in the watershed during 2004 through 2009. The average annual maximum and minimum temperatures (°F) are 71 and 48, respectively. The average annual precipitation is 40.31 inches.

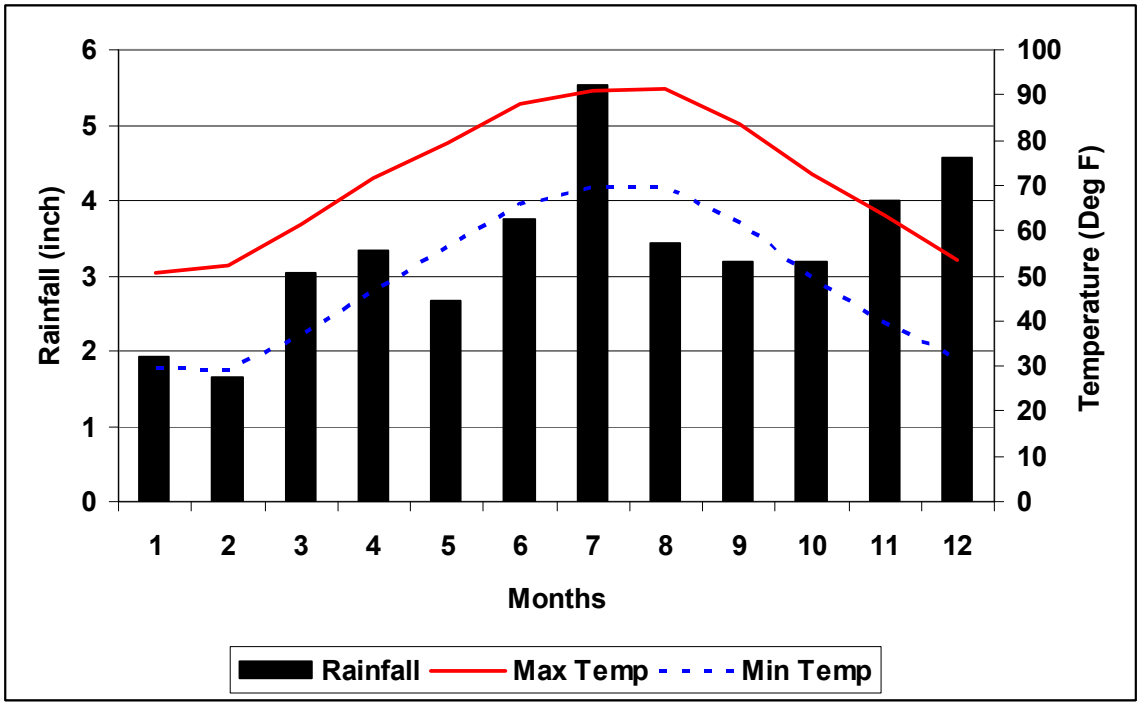

Figure 2. Air temperature and rainfall distribution in Smith Creek watershed.

Land Use

The Smith Creek watershed is approximately 68.7 square miles in size, and is predominantly forested (52%) and agricultural (35%) (USGS Landsat data, 2001). The forested area includes 24% deciduous forest, 18% evergreen forest, and 10% mix forest. The agricultural area includes 2% cultivated crops and 33% range/hay lands. Other uses are comprised of 4% woody wetlands, 7% urban lands, and 2% water area. The woody wetlands are largely concentrated along the creek.

Water Quality Standard

According to the North Carolina Water Quality Standards for Class C waters (15A NCAC 02B.0211), DO concentration shall not be less than 6.0 mg/l for trout waters; for non-trout waters, not less than a daily average of 5.0 mg/l with a minimum instantaneous value of not less than 4.0 mg/l; swamp waters, lake coves or backwaters, and lake bottom waters may have lower values if caused by natural conditions. When greater than 10% of water samples are below the standard, the corresponding water body is assessed as impaired for aquatic life.

Statement of Impairment

During the Basinwide assessment period, 2004-2008, DO concentration in 11 out of 51 water samples (21.6%) at Smith Creek at US 1 near Paschall (N6400000) demonstrated less than 4 mg/L. As a result, approximately 10.7 miles from the source of Smith Creek to the North Carolina-Virginia State line is listed as impaired waters for DO on the 2008 303(d) list.

Natural Condition Assessment

In a water body, oxygen is usually restored through aeration and photosynthesis processes, whereas oxygen is depleted through decomposition and respiration processes. Oxygen-depletion processes dominate oxygen-restoration processes in slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids, thereby reducing pH level. Because Smith Creek exhibits low flow, the following five steps are selected to identify natural conditions that result in low DO and to determine the likelihood of anthropogenic impacts that will exacerbate the natural condition in the creek: observation of low velocity, impact from point sources, impact from nonpoint sources, impact from seasonal fluctuation, and field observation.

Observation of Low Flow Velocity

Local topographic relief is approximately 2.3 feet per mile and maximum land surface altitude is about 100 ft above sea level. Based on the topography and rainfall distribution amount (Figure 2), flow velocity in Smith Creek is expected to be moderate. However, there is no gage station to calculate flow rate in the creek. Smith Creek flows through the Raleigh Belt hydrologic area, the median 7Q10 flow value is expected to be 0.065 ft^3/ sec/ mi^2 (Giese and Manson, 1993). Nevertheless, due to the presence of beaver impoundments throughout the watershed, flows stay low or stop flowing (Crouch, December 16, 2004).

The DWQ staff made a special trip to the creek to measure flow velocity on November 19, 2010. Flow results are discussed in detail in Field Observation Section, below.

Impact from Point Sources

There are no point sources in the Smith Creek watershed.

Impact from Nonpoint Sources

Excessive nutrient inputs from non-point sources such as forested land, agricultural land, wetland, and urban land can stimulate plant growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels in the waterbodies where flow is relatively slow and aeration is low. So as to understand the nutrient levels in Smith Creek, the ambient monitoring data collected at N6400000 from 1997 through 2007 was obtained from the EPA's Storet database (Source: http://www.epa.gov/storet/).

The non-detected values are replaced with half of the practical quantitation limit values specified by the DWQ (Source: http://h2o.enr.state.nc.us/lab/qa/pqlinorg.htm). Monthly averaged nutrient concentrations are given in Table 1.

Table 1. Averaged instream nutrient concentration (mg/L) in Smith Creek at the ambient station (N6400000) at US 1 near Paschall (1997-2007)

Months	No. of Observations	TKN	NOx	TN	TP
	(n)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	10	0.23	0.12	0.34	0.04
2	11	0.32	0.16	0.48	0.05
3	9	0.31	0.09	0.40	0.06
4	11	0.41	0.04	0.45	0.05
5	10	0.42	0.06	0.48	0.07
6	10	0.40	0.05	0.45	0.08
7	12	0.53	0.03	0.56	0.09
8	10	0.61	0.03	0.64	0.09
9	8	0.38	0.02	0.41	0.12
10	11	0.37	0.04	0.41	0.08
11	11	0.34	0.02	0.36	0.06
12	9	0.28	0.06	0.33	0.07

Note: Total number of observations = 122

On average TN and TP concentrations remained lower than 1.0 mg/L and 0.1 mg/L, respectively. These averaged nutrient concentrations are near or below the USGS national background averages (Source: http://pubs.usgs.gov/circ/ circ1225/ index.html). These averages are developed from nutrient concentrations in streams from undeveloped areas with typical concentrations of TN ≤ 1.0 mg/L and TP ≤ 0.1 mg/L. Overall, TN varies from 0.10 mg/L to 2.6 mg/L and TP varies from <0.01 mg/L to 0.2 mg/L in undeveloped stream basins in the USA (Clark et. al., August 2000).

Three of the selected streams for the USGS national background study were in NC. They were Cataloochee Creek in Western NC, Van Swamp in Eastern NC, and Coweeta Creek in Southern NC (Source: Personal communication with Greg Clark, USGS). Except on Cataloochee Creek, there are no active ambient data available. Table 2 demonstrates the monthly averaged concentrations of TN and TP during 1997 through 2008 at SR 1395 near Cataloochee (E6450000). The low nutrient concentration levels in Tables 1 and 2 indicate that Smith Creek is not significantly affected by anthropogenic inputs of nitrogen and phosphorus.

Table 2. Averaged instream nutrient concentration (mg/L) in Cataloochee Creek at the ambient station (E6450000) at SR1395 near Cataloochee (1997-2008). The USGS selected this creek as one of the background sources to estimate TN and TP concentrations from undeveloped areas.

Months	No. of Observations	TKN	NOx	TN	TP
	(n)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	6	0.18	0.21	0.39	0.02
2	5	0.18	0.20	0.38	0.02
3	8	0.19	0.16	0.35	0.02
4	8	0.20	0.16	0.36	0.02
5	9	0.27	0.15	0.42	0.04
6	10	0.18	0.15	0.33	0.03
7	10	0.37	0.15	0.52	0.05
8	9	0.25	0.13	0.37	0.04
9	9	0.17	0.11	0.28	0.02
10	9	0.19	0.07	0.26	0.02
11	10	0.16	0.07	0.23	0.02
12	8	0.18	0.14	0.31	0.02

Note: Total number of observations = 101

Impact from Seasonal Fluctuation

Figure 3 shows a relationship among averaged monthly DO concentrations and water temperature in Smith Creek. As temperature increases, DO decreases. This is indeed a natural phenomenon where flow velocity is lower, because still water is affected by air temperature more rapidly which facilitates decomposition of plant material. This process increases oxygen demand and lowers DO as plants decay. Therefore, summer periods seem to be critical for low DO in the creek.

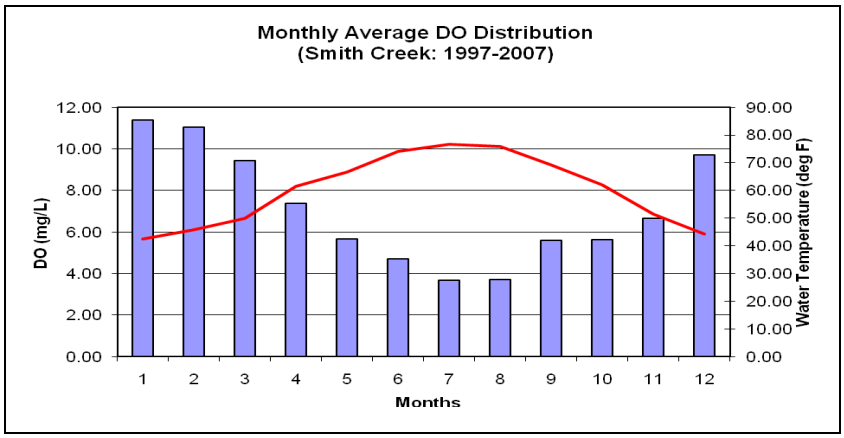

Figure 3. Monthly distribution of median DO and water temperature in Smith Creek at the ambient station (N6400000) at US 1 near Paschall (1997-2007)

Field Observation

On April 26, 2004, the DWQ staff visited Smith Creek Watershed to collect water samples for a stressor study. The staff reported that many tributaries carried very low flow due to presence of beaver dams throughout the watershed (Crouch, December 16, 2004). As a follow up to this study, the staff revisited the watershed to measure flow as well as some physical data on November 19, 2010. The measured data are respectively presented in Tables 3 and 4.

Table 3. Observed flow velocity on November 19, 2010 in Smith Creek and its tributary.

Locations	Flow Velocity (ft/sec)
Smith Creek at SR 1208	0.03
Smith Creek at US1	0.58
Blue Mud Creek at SR 1210	0.04

The DWQ staff observed water following through Smith Creek and its tributaries due to a rainfall event of 0.33 inch, two days prior to their visit (Source: South Hill, Mecklenburg-Brunswick Regional Airport). However, flows in Smith Creek at SR 1208 and Blue Mud Creek SR 1210 were much slower than Smith Creek at US 1 (Table 3). The slower flows were due to presence of beaver dams around the watershed. The DWQ staff found several beaver dams in Malones Creek at SR 1213 and Blue Mud Creek at SR1210 (Figures 4 to 7). The beaver dams had impounded water all over the creeks.

Normally, Smith Creek experiences low DO concentration during summer period when flow gets substantially lower due to beaver dams and when water temperature reaches higher. Low flow lacks aeration and higher water temperature enhances decomposition of vegetation inputs from surrounding lands, thereby increasing oxygen demand and lowering DO.

Figure 4. Beaver impoundment in Blue Mud Creek at SR1210, November 19, 2010. The DWQ staff in the background are Harold Quidley and Laura Spell.

Figure 5. Beaver dam blocking water in Blue Mud Creek at SR1210, November 19, 2010. The DWQ staff in the background is Laura Spell.

Figure 6. Upstream view of Beaver dam, blocking water in Blue Mud Creek at SR1210, November 19, 2010.

Figure 7. Upstream view of Malones Creek at SR1213, showing channelized water flow due to beaver activities, November 19, 2010.

Table 4. Observed water chemistry data during April 26, 2004 and November 19, 2010 in Smith Creek and its tributaries.

Locations	Temperature (deg C)		DO (mg/L)		Conductivity (µmhos/cm)		pH	
	Apr04	Nov10	Apr04	Nov10	Apr04	Nov10	Apr04	Nov10
Newman's Creek at SR 1218	19.0	NA	6.0	NA	84	NA	7.0	NA
Newman's Creek at SR 1219	16.0	NA	NA	NA	54	NA	NA	NA
Ellington Branch At SR 1219	16.0	NA	7.6	NA	75	NA	6.8	NA
Smith Creek at SR 1217	23.0	8.0	7.1	8.3	88	86	7.0	7.56
Smith Creek at SR 1208	21.0	7.9	7.3	10.85	89	85	7.2	7.94
Smith Creek at SR US1	20.0	8.7	3.6	7.47	95	88	6.8	7.50
Terrapin Creek at SR 1213	21.0	NA	7.5	NA	93	NA	7.2	NA
Malones Creek at SR 1213	NA	8.0	NA	6.31	NA	87	NA	7.6
Blue Mud Creek at SR 1210	NA	9.11	3.3	5.25	NA	94	NA	7.5

Table 4 suggests that Smith Creek receives a large portion of low DO from its major tributary, Blue Mud Creek, when beaver dams obstruct flow and water temperatures increase. On April 26, 2004, when there was low flow and high temperature (68 deg F or 20 deg C), the DWQ staff measured substantially low DO (< 5mg/L) in Blue Mud Creek at SR 1210 and Smith Creek at SR US1(Table 4). In contrast, on November 19, 2010, the staff measured higher DO (> 5mg/L) in the both creeks when there was modest flow and low temperature (48 deg F or 9 deg C). Furthermore, during the both visits, conductivity was measured less than 100 µmhos/cm and pH was measured in between 6 and 9 (Table 4), suggesting no anthropogenic impact on DO. (Source: http://water.epa.gov/type/rsl/monitoring/vms59.cfm.) These two field measurements, therefore, clearly demonstrate that the historical low DO at Smith Creek at US 1 was due to beaver impoundments and seasonal water temperature variations.

Conclusion

Smith Creek (AU# 23-10a, 23-10b, 23-10c), 10.7 miles, shows evidence of lacking aeration to store DO due to low flows. There are several beaver dams around the watershed. The dams are blocking natural movement of water in Smith Creek and its tributaries. In addition, the watershed comprises predominantly large areas of agricultural and forested lands and heavy tree canopy. Decomposition of the large inputs of vegetation from areas of forested heavy tree canopy throughout the watershed not only produce organic acids but also increase oxygen demand and lower DO as they decay in the creek. Decomposition of vegetation seems more critical during summer period when water temperature reaches 25 degrees C (77 degrees F). These are not considered anthropogenic impacts.

Smith Creek exhibits low nutrient concentrations near or below national background levels from undeveloped areas. The result suggests that agriculture is not contributing nutrients to lower DO concentration in the creek. The creek also exhibits lower conductivity and absolute pH values, suggesting no human impacts in the creek. Based on the information, it is concluded that the water quality in Smith Creek is due to natural conditions. Therefore, Smith Creek should be assessed as category 2: natural conditions, no TMDL needed for the next 305(b)/303(d) assessment.

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Cam McNutt
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Laura Spell

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