

MONITORING STRATEGY AND SOURCE ASSESSMENT FOR TMDL DEVELOPMENT IN KARST GEOLOGY

Joseph L. Taraba Biosystems and Agricultural Engineering University of Kentucky 40546-0276 859-257-3000	Alex W. Fogle Kentucky Geological Survey University of Kentucky 40506-0107 859-257-3000
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The University of Kentucky Animal Research Center (ARC) is located in a karst-dominated terrain in Woodford County, Kentucky. Soils are high in native P as a result of the weathering of the underlying high P limestone. A water quality monitoring network was established to assess the surface water and ground-water resources associated with the ARC. Water quality monitoring stations were constructed at several sites on surface streams to determine the influence of the ARC land use on several water quality constituents that include ammonia-N, nitrate+nitrite-N, Total-N, organic-N, Total-P, phosphate-P, TOC, TSS, and metolachlor and triazine pesticides. A water quality monitoring strategy was based on bi-weekly grab sampling and automated storm water sampling. Continuous surface water flow monitoring occurred at seven weirs. These sites were below watersheds that had different levels of agricultural land use.

The collected water quality data was utilized to determine whether the guidance on the TMDL development process for waterbodies, that are impaired due to nutrients, are applicable to karst geology watersheds in the Kentucky Bluegrass Region. The USEPA *Protocol for Developing Nutrient TMDLs* (www.epa.gov/owow/tmdl/nutrient) recommends strategies to estimate source loads for TMDL development. Tables in the protocol present literature stream flow values for the nutrient concentrations of the total dissolved inorganic N and ortho-P, and typical total P and N loading (kg/ha-yr) ranges for various agricultural land uses. These values are recommended to be used when no data is available. Tables 1 and 2 present total dissolved inorganic N and ortho-P concentrations and total P and N loading from the ARC monitored watersheds.

The ARC watershed and subwatersheds are > 90% agriculture. The subwatersheds vary in the intensity of the row crop agriculture (wheat, corn, soybeans, and tobacco) with the subwatershed above ST-8 having -0% row crop, the subwatershed above ST-1 with -20% row crop, and the subwatershed above ST-11 with -60% row crop. The stream flow concentrations for Total inorganic N and Total ortho-P are not significantly different for ST-1 and ST-8 but are significantly lower than ST-11. The EPA values for pasture watersheds are 1/3 the values found for the ARC pasture watershed. The stream flow nutrient loads (kg/ha-yr) for Total N and ortho-P for the ARC watersheds with row crops exceed the maximum USEPA guidance values. For the pasture watershed, the ortho-P nutrient load exceeds the EPA maximum guidance value while the Total N load is slightly above the EPA median guidance value.

The USEPA *Protocol for Developing Nutrient TMDLs* does not provide guidance for a stream sampling strategy to obtain stream nutrient loads. Our study compared two sampling strategies to the continuous monitoring of stream flow and nitrate-N concentration. The first is a grab water sample with stream flow determined at time of sampling using stage and a flow rating curve. The second is a grab water sample with continuous stream stage monitoring. The data record covered a four-year period. Table 3 presents the results with sampling periods of 1, 2, and 4 weeks for the

ratio of grab sampling of stream flow nitrate-N load to continuous sampling of stream flow nitrate-N load. Grab sampling with continuous stage monitoring was nearing equal to continuous monitoring of concentration and flow. The four- week sampling period was comparable to the shorter periods; both in terms of the ratio and the standard deviation.

Table 1. ARC Watershed Stream Flow Nutrient Concentrations (10/1996-6/2000) Compared to USEPA Guidance Values

Watershed Land Use		ARC Watershed Mean (mg/l)		USEPA -- Central USA Mean (mg/l)	
ARC	EPA	Total Inorganic N	Total Ortho-P	Total Inorganic N	Total Ortho-P
> 90% Agriculture with -20% Row Crop (ST-1)		2.88 ^{A*}	0.21 ^A		
> 90% Agriculture with -0% Row Crop (ST-8)		2.86 ^A	0.21 ^A		
> 90% Agriculture with -60% Row Crop (ST-11)		9.56 ^B	0.38 ^B		
	> 90% Agriculture			0.77	0.085

* Medians in row with different superscript letters are significantly different at ($\alpha < 0.05$)

Table 2. ARC Watershed Stream Flow Nutrient Loads Compared to EPA Guidance Values

Watershed Land Use	Nutrient	ARC Watershed (kg/ha-yr)	USEPA (kg/ha-yr)		
			Minimum	Maximum	Median
> 90% Agriculture with -20% Row Crop (ST-1) - (10/1996-6/2000)	Total N	13.01			

(10/1996-6/2000)	Ortho-P	0.85			
> 90% Agriculture with -60% Row Crop (ST-11) - (4/1999-6/2000)	Total N	18.06			
	Ortho-P	0.59			
> 90% Agriculture with -0% Row Crop (ST-8) - (4/1999-6/2000)	Total N	4.52			
	Ortho-P	0.28			
Pasture	Total N		1.2	7.1	4.2
	Ortho-P		0.01	0.25	0.13

Table 3. Ratio of Grab Sampling of Stream Flow Nitrate-N Load (kg/ha-yr) to Continuous Sampling of Stream Flow Nitrate-N Load (kg/ha-yr)

Sample	(Grab Conc.)/((Grab Flow)/(Time))			(Grab Conc.)/((Total Flow Vol))		
	4 Week	2 Week	1 Week	4 Week	2 Week	1 Week
Mean	1.137	0.796	0.838	0.941	0.896	0.989
Median	1.032	0.622	0.820	1.005	0.999	0.995
Std Dev	1.141	0.635	0.449	0.314	0.330	0.186
Count	14	21	21	14	21	21
Conf. Limits (0.95)	∇0.598	∇0.272	∇0.192	∇0.165	∇0.141	∇0.080