Final Report
to the
U.S. Fish and Wildlife Service
on
Water Quality Studies in the Cacapon River's Lost and North River Watersheds in West Virginia.

Cacapon Institute, High View, WV

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Introduction and Purpose

Poultry production in the Potomac Headwaters region of WV has more than doubled since the early 1990s. The waste byproducts of this industry are typically land applied and concerns over potential water quality impacts are widespread. The report will provide a summary of data collected during Cacapon Institute's multi- year study of land use influences on nutrient and bacteria concentrations in the Lost and North River subwatersheds in the Cacapon River Basin of West Virginia; these watersheds have varying densities of integrated poultry agriculture.

Background.

The Potomac Headwaters region of West Virginia is located in the state's eastern panhandle and contains Hampshire, Hardy, Grant, Mineral and Pendleton counties. Agriculture is a key element in the region's economy, led by the integrated poultry industry and beef cattle production. The rapid expansion of the Headwater's poultry industry beginning in the early 1990s fueled concerns over the potential for water quality problems caused by this industry (Constantz et al, 1993; Ramsey, 1997).

In 1992, due in large part to the Headwater's rapidly expanding poultry industry, state and federal agencies recognized the need for a coordinated and comprehensive approach to protecting and enhancing ground and surface water quality in the area. In 1993, co-operating local, state and federal agencies formed the Potomac Headwaters Interagency Water Quality Office (PHIWQO), which was charged with protecting the waters of the Potomac while maintaining a strong agricultural industry. The cooperating agencies agreed to provide financial and technical assistance to area farmers to reduce and prevent water quality degradation arising from agricultural and urban lands. To identify areas most in need of this assistance, the PHIWQO ranked twenty one subwatersheds in the categories of number of poultry houses/feedlots and litter production versus treatable agricultural land (Table 1).

As part of the PHIWQO effort, the USDA-Natural Resources Conservation Service contracted with the U.S. Geological Survey (USGS) to conduct a surveillance level water quality study in 1994 and 1995 to assess the condition of the watershed's rivers. (PHIWQO, 1996). Nineteen sites in the South Branch drainage and four in the Lost River (headwaters of the Cacapon) drainage were sampled monthly for varying periods of time (Mathes, 1996). Their study "did not indicate high nutrient concentrations at any site." However, they noted significant algal growth at many sites during the summertime and suggested this might be related to nutrient loading to the streams. They found fecal coliform bacteria in excess of 200 colony forming units per 100 ml in one third of their samples. Nitrate and fecal coliform concentrations were positively correlated with numbers of feedlots and poultry houses. In conclusion, they suggested that "future water quality sampling could include a network of several small tributary basins with varying degrees of agricultural land use, where samples collected during the same time period might provide statistical verification of suggested or apparent relations seen in this reconnaissance study."

The USGS study and studies in the Cacapon River by Pine Cabin Run Ecological Laboratory (now Cacapon Institute, Constantz et al, 1993; Gillies 1997a) did not detect particularly high concentrations of nutrients in the area's streams, particularly in comparison to levels reported from agricultural areas in the Great Valley a few miles to the east (Ator et. al. 1998). Considering the high density of agriculture in some of the Headwater watersheds studied, this was unexpected and suggested further investigation was warranted.

Table 1. Priority ranking of subwatersheds for agricultural best management practice implementation in the Potomac Headwaters Watershed, West Virginia. Adapted from "Potomac Headwaters Land Treatment Watershed Project: Hardy, Hampshire, Mineral, Grant, and Pendleton Counties, West Virginia" (NRCS, 1996).

Subwatershed	Ranked No. Poultry Houses/Feedlots[1]	Ranked litter production versus agricultural land	Overall Rank
Lost River	4	1	1[2]
South Fork (of the S. Branch)	3	2	2[2]
South Branch (below Petersburg)	1	8	3[2]
South Branch (above Upper Tract)	2	7	4
N. & S. Mill Creek	6	3	5[2]
Lunice Creek	7	4	6[2]
North Fork	5	9	7
South Branch (Upper Tract to Petersburg)	10	5	8
Patterson Creek	8	10	9
North River	9	13	10[2]

Note 1: Ranked number of poultry houses/feedlots based on actual number of facilities, not number per square mile.
Note 2: Watersheds included in Cacapon Institute water quality studies.

In March of 1997, Cacapon Institute started an intensive study of land use influences on water quality in the Lost River watershed with a focus on nutrients. Storm sampling was included as an integral component of the study design, an important element lacking in previous studies. The Lost River was selected because it ranked first on the PHIWQO list of watersheds in need of best management practice implementation (Table 1). This basin produced twice as much poultry litter, or manure, as the available agricultural land could use as a fertilizer for corn, hay and pasture land (NRCS, 1996). While containing only 2% of the Potomac Headwaters drainage area, the Lost River watershed contained 21% (appx. 185) of the region's poultry houses — at more than one poultry house per sq. mile, the highest density in the Potomac Headwaters.

The North River was added to the study in June 1998 to compare to the Lost River basin. The North River is similar in characteristics and size to the Lost River, but has much less integrated poultry and associated agriculture (ranked #10, Table 1); it was included to establish nutrient water quality patterns in a relatively low intensity agricultural basin.

This report will provide a summary with brief discussions of data collected during sampling between March 1997 and June 2002 addressing two of the key questions addressed by the study: 1- are nutrients applied to the basin's agricultural soils entering the river; and 2- do streams with different land use characteristics have different nutrient and bacterial concentrations. (For reviews of early results, refer to Gillies, 1998a, 1998c., 1999a, 1999b.) In conclusion we will provide a brief sumary.

Study Area

The study area lies within the Valley and Ridge physiographic province in West Virginia, a mountainous region which consists of long, parallel valleys and ridges that run from the northeast to the southwest. Resistant sandstones form the ridges while less resistant limestones and shales form valleys. Major rivers flow down the main valleys and their tributaries flow down the mountainsides in a perpendicular branching pattern known as a trellised drainage system. Major rivers in this area are the North and South Branches of the Potomac and the Cacapon (including the Lost and North rivers). All of these rivers flow by way of the Potomac to the Chesapeake Bay.

Soils are formed from materials weathered from siltstone, sandstone, shale and limestone. The deep alluvial soils in the flood plain may be any combination of sand/loam/clay and range from well drained and coarse near the river to poorly drained and fine away from the river. Typically, river terrace soils are moderately well drained and upland soils are well drained. (Kesecker, personal communication)

Agriculture is forced by topography to remain largely confined to the narrow valleys and gentle slopes, and from 65-85% of these basins remain forested (Matthes, 1996). Most of the region's cropland and prime hay land is found in flood plains and river terraces. Cropland receives the most intensive nutrient application of animal wastes and fertilizer (NRCS, 1996). Hayfields, poultry houses and feedlots are located where the land's slope allows equipment access. Most pasture also occurs on gentle slopes; however, some is located on steep, often eroding, shale hillsides.

The integrated poultry industry dominates agriculture in many of the study area's watersheds. However, the presence of poultry houses within a tributary watershed does not necessarily mean that the litter produced will be utilized there. Many poultry houses are sited in areas with insufficient land available nearby for spreading litter. This litter is transported to other areas; much presumably to flood plain and river terrace land in the area. Litter is applied green or composted throughout the year. Unfortunately, quantitative data on these agricultural practices are not available.

The 178 km long Cacapon River, a tributary of the Potomac River, has a drainage area of

680 sq miles, about 7% of the Potomac drainage upstream of Virginia. The entire watershed contains only two incorporated communities and no heavy industry. Seventy-nine percent of the land in the Cacapon watershed is forested, while 19% is agricultural; the remaining 2% consists of residential development, barren lands and water (Constantz et. al., 1993).

The Cacapon's Lost River headwaters, in Hardy County, drains 179 square miles - 26% of the total Cacapon drainage area. This region contains the most intensive agricultural operations in the Cacapon watershed, dominated by the integrated poultry industry. A woody riparian corridor exists along much of each Lost River's tributaries. This is not the case along the Lost River's mainstem, where most trees were removed many years ago and crops, hay and pastureland typically extend to the river's edge.

The North River, the largest tributary of the Cacapon River, is slightly larger than the Lost; it drains 205 square miles - 30% of the total Cacapon drainage area. Agriculture in this watershed is less intense than in the Lost River basin and mostly consists of pasture/hayland and cattle. Poultry houses and feedlots are located in the headwaters area upstream of Rio and below Rt. 50 at low density; many of the poultry houses are located on ridges well away from the floodplain. A woody riparian corridor, ranging from a narrow band of trees to hundreds of feet wide, exists along much of this river's length in contrast to the mostly denuded banks observed along the upper 2/3's of the Lost River mainstem's .

Residences are scattered at low density throughout these watersheds. No municipal water and sewer facilities, large industrial point sources or large towns exist in the Lost and North river basins, although three small package sewage treatment plants serve two schools and one continuous care facility at the lower end of the Lost River watershed.

Field and Laboratory Methods

Tributary and mainstem sites were selected with the aid of local representatives of the USDA-NRCS, West Virginia University, the US Fish and Wildlife Service and the Potomac Headwaters Resource Alliance. Each site represents a different mix of land uses (Table 2 below). Sites with drainage areas of 25 square miles or less are considered "indicator sites" — sites sufficiently close to potential sources of pollution to "indicate" the impacts. Larger sites are considered "integrator sites" — sites that integrate the pollution impacts from many sources.

Samples were collected under two different protocols: regularly scheduled synoptic sampling and opportunistic storm event sampling. The synoptic sampling regime was used to create a data base of samples collected at all sites under nearly the same hydrologic conditions on each sampling day. The scheduled synoptic sampling regime, in which samples were collected at all sites within a three hour interval, occurred weekly from March through August 1997 in the Lost River, bimonthly thereafter until December 2001, when the frequency dropped again to monthly due to drought conditions.. Regular sampling in the North River watershed occurred monthly from July 1998 to February 2001, and December 2001 to June 2002, and twice monthly from March 2001 through November 2001. Storm sampling focused on either one or a few streams per event, and samples were collected repeatedly during and after storms.

Water samples were collected midstream 10-15 cm below the surface. When water levels precluded wading into the river, samples were collected from shore or bridges using a 12 ft. extension sampler. Sample containers were rinsed three times with river water at the sampling site prior to collecting a sample. Sampling containers, storage conditions and holding times followed APHA (APHA, 1992).

Rain measurements were collected daily at one site in the North River watershed (at Skaggs Run) using rain gages built to U.S. Weather Bureau specifications. In addition, precipitation data was obtained from NOAA Cooperative Weather Stations in Mathias (Hardy County, Lost River watershed, Station #465739) until this station was unexpectedly shut down in March 1999. Daily (24 hour) precipitation totals were collected at all sites prior to 8:00 a.m.

Study Parameters

Phosphorus (P). Two phosphorus parameters were included in this study, total orthophosphate (OP) and total phosphorus (TP). OP, the most common form of dissolved phosphorus, is readily available to plants as a nutrient. OP is only moderately soluble and readily adsorbs to sediments. TP is the sum of all forms of phosphorus: organic and inorganic, suspended and dissolved. While neither OP or TP move readily though ground water, erosion can transport large amounts of sediment-bound P to surface waters (Mueller et al, 1995). While OP is the form of P most readily available to plants, experimental evidence indicates that TP is the better indicator of potential for periphyton and plankton growth (Morris & Lewis, 1988; Dodds et. al., 1997). However, the ratio of OP to TP can be a useful indicator of source and, therefore, both parameters were included in this study.

Turbidity. Turbidity is a measure of water clarity and an indirect measure of the amount of sediment suspended in the water. It was included in this study as an indicator of sediment load. Since most P is attached to sediment, turbidity is a valuable indirect indicator of the potential for high P concentrations and of erosion producing storms.

Nitrate (NO_3-N). Nitrate readily dissolves in water, is chemically stable over a broad range of environmental conditions and moves easily through ground and surface waters (Mueller et al, 1995) Correll et al (1994) compared the concentrations of aqueous species of nitrogen (N) between different environmental settings in the Chesapeake Bay watershed. They found nitrate was the major dissolved form of nitrogen detected, with concentrations 10 to 20 fold higher than dissolved ammonium and organic nitrogen. Data collected by Cacapon Institute over several years also indicated that nitrate was the dominant form of nitrogen found in the Cacapon River (Gillies, 1997a; 1998c). For these reasons, we selected nitrate-nitrogen (NO_3-N) as the best quantitative indicator of nitrogen losses into the river. This parameter was added to the study in November 1997.

Fecal Coliform Bacteria. Fecal coliform bacteria thrive in the intestines of warm blooded animals and enter the environment when animals defecate. While fecal coliforms themselves are usually not harmful, they are often associated with other human pathogens carried in feces. Researchers use the presence of fecal coliforms as an indication that water is contaminated with fecal matter. This parameter is the one most commonly used to determine if a river is suitable for water contact recreation. The Lost River is currently on the USEPA's 303(d) list for water bodies not meeting their designated use due to fecal contamination based on studies by the USGS and Cacapon Institute. Fecal coliform bacteria sampling began regularly at most Lost River sites in January 1998, and at all Lost River sites in April 1998. It was not included in the North River study routinely until March 2001.

Algal cover. Algal cover at each site is estimated subjectively, on a scale ranging from very light to very heavy.

Laboratory Methods

Turbidity was measured using a Ratio Turbidimeter (Hach model 18900) calibrated with formazin primary standards (Hach #2461) and verified against Gelex secondary standards (Hach #22526-00) (EPA method 180.1). Total phosphorus (TP), and total reactive, or ortho, phosphorus (PO4 as P, OP) were determined colorimetrically using a Hach 2000 Spectrophotometer as follows: TP - ascorbic acid method preceded by acid persulfate digestion (EPA method 365.2); OP - ascorbic acid method (EPA method 365.2).

Nitrate-N (NO_3-N) has been determined by a series of methods over the life of this project. Initially, the Hach cadmium reduction Method 8171 was used, followed by the traditional cadmium reduction method using glass columns. Some interference problems, of unknown cause, occasionally impacted the accuracy of both cadmium methods (yielding a result somewhat lower than expected), and we began using a nitrate electrode with good success. The electrode method, however, was less than ideal due to a long electrode preparation and calibration period (24 hours) and a short life of electrode stability for analysis. Based on information from the WV Department of Agriculture, we began testing the direct read ultraviolet method on a Hach DR4000 spectrophotometer, and found this method to be reliable, accurate and stable.

The cadmium methods used to enumerate nitrate also includes nitrite. However, nitrite occurs in significant concentrations only in the immediate vicinity of sewage, industrial food processing and organic waste disposal (Mueller et. al., 1995) and, in rivers, is quickly converted by natural processes to nitrate. In addition, the USGS study in this region only rarely found detectable concentrations of nitrite in their samples and, when detected, it constituted less than 4% of the NO_3-N + NO_2-N total (Mathes, 1996). Values reported here for NO_3-N are those obtained for NO_3-N + NO_2-N, on the assumption that NO_2-N concentrations throughout the study have been negligible.

Fecal coliform bacteria were enumerated using the membrane filtration technique. QA/QC procedures followed EPA standards.

Statistical methods

The methods used to analyze data were graphical and statistical. Data distributions were displayed in tables of summary statistics and simple linear correlations. Box plot, line and area graphs were used using bar graphs for simplicity. Descriptive statistics and correlation matrices (based on pairwise correlations) were calculated using JMP Statistical Discovery Software (version 4). An alpha value of 0.05 was used to determine the significance of test results.

Development of Land Use Coverage's

Overview. Aerial photographs, in the form of NAPP photographs, that required scanning and rectification, and DOQQ imagery, fully rectified and spatially corrected by the USGS, were the primary data sources used to develop land use coverages for this project. Features were digitized from these images using ArcView. The digitizing effort focused on defining agricultural features, specifically poultry houses, row crop, and "Total Agricultural Land." Row crops and total agricultural land data were stored in Arc shape files as polygon themes, and poultry houses as line themes. Total Agricultural Land was defined rather broadly for the purposes of this analysis, and may more properly be described as mostly open land lacking a significant number of residential or commercial/industrial structures. No attempt was made to distinguish between pasture and hayfields for several reasons. First is that hay is made on many fields that are rather marginal for this purpose. Second, many fields from which prime hay is harvested are also used as pasture. Finally, within areas developed at low density on land that was once primarily agricultural, substantial portions of the open land may continue to be utilized for hay production, so the boundaries of towns and subdivisions do not necessarily provide a meaningful boundary between residential and agricultural land-use. It is likely that we erred on the side of including some open land in the agricultural category when in fact it no longer has an agricultural use; if so, this would be a small percentage of the total land area.

Poultry houses were counted from aerial NAPP and DOQQ photography. Several types of poultry houses exist in the study watersheds, including modern broiler, layer and turkey houses, and older single and double-decker poultry houses that are still in production. No attempt was made to distinguish between different types of poultry houses. Where poultry houses were known from field surveys to be abandoned, they were not included in the coverage.

No quantitative data on cattle production is available on a watershed basis.

Field verification of digitized data was widespread but not exhaustive. Many areas on private land are simply inaccessible. Interpretation of the photographic data for such areas depended on experience gained for those areas where coverage could be verified.

Canaan Valley Institute provided shape files outlining the watershed area for each of our sampling sites using ARC/Info.

Floodplain area was generated by identifying soils indicative of floodplain in the Soil Survey Geographic (SSURGO) database (USDA-NRCS,1998); this was done with the assistance of NRCS soil scientist Ron Estepp. The SSURGO data is based on Geodetic Reference System of 1980, and generated using Soil Map Units referenced in Soil Survey of Hampshire, Mineral, and Morgan Counties, West Virginia (USDA-SCS, 1978) and in Soil Survey of Grant and Hardy Counties, West Virginia (USDA-SCS,1989). The data used for developing the floodplain was projected in 1927 North American Datum.

Results: Land Use.

Table 2 provides the results of land coverage analysis of the 23 long-term study sites in the Cacapon watershed. These are presented by area: the Lost River mainstem (5 sites); Lost River tributaries (9 sites); North River mainstem (6 sites), North River tributaries (1 site); and Cacapon River mainstem (2 sites). Before continuing, the following comments are necessary. Waites Run, listed as a Lost River tributary, actually drains directly into the Cacapon River downstream of the Lost River; it was included in the Lost River Project Area because it drains the same general surface geology as tributary sites along the eastern side of the Lost River watershed and provides a look at water quality in a heavily forested basin. The Lost River tributary Baker Run was not included as a regular site until September 1999. Additional sites along the Cacapon River mainstem, Cullers Run and Upper Cove Run were added to the study in 2001 for nutrient gradient analysis, but will not be discussed in this report.

Table 2. Results of land coverage analysis of the 23 long-term study sites in the Cacapon watershed.									
Sampling Sites	Drainage Area (sq.mi.)	**Overall Land Use %**			**Floodplain Land Use %**			**Poultry Houses**	
		Ag Land	Rowcrop	% Ag Land in Row Crop	Land in Floodplain	Ag in Floodplain	Row Crop in Floodplain	Number	No. /Sq.Mi.
LOST RIVER MAINSTEM									
LR at Mathias	22.73	21.80%	1.62%	7.43%	6.80%	69.50%	20.41%	42	1.85
LR at LostCity	68.09	19.20%	1.03%	5.42%	5.83%	64.19%	14.41%	85	1.25
LR at LostRiver	109.07	18.60%	0.97%	5.24%	5.86%	58.62%	12.67%	123	1.13
LR at HangingRock	157.42	19.50%	1.14%	5.88%	6.22%	60.39%	15.23%	188	1.19
LR at SquirrelGap	168.53	18.70%	1.07%	5.74%	5.97%	59.27%	14.82%	190	1.13
LOST R. TRIBUTARY									
Cullers Run	11.48	16.80%	0.61%	3.63%	6.69%	60.45%	9.08%	12	1.04
Upper Cove Run3	7.66	18.30%	0.00%	0.00%	1.95%	54.55%	0.00%	24	3.13
Upper Cove Run1	9.14	17.50%	0.19%	1.21%	3.70%	34.79%	3.67%	28	3.06
Mill Gap Run	2.59	15.90%	0.00%	0.00%	0.81%	58.22%	0.00%	0	0
Camp Branch Run South	5.7	8.90%	0.00%	0.00%	5.47%	16.98%	0.00%	3	0.53
Kimseys Run	18.44	14.50%	0.00%	0.00%	5.28%	39.91%	0.00%	15	0.81
No-Name Trib of Kimsey R.	1.48	16.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0	0
Baker Run	22.81	20.70%	0.00%	0.00%	4.72%	43.90%	0.00%	36	1.58
Waites Run	16.8	3.90%	0.10%	2.59%	3.09%	19.50%	0.00%	5	0.3
NORTH RIVER MAINSTEM									
NR at Skaggs	10.93	16.40%	0.00%	0.00%	4.55%	20.45%	0.00%	3	0.27
NR at Ford Hill Rd.	38.72	18.10%	0.15%	0.84%	4.80%	33.76%	0.00%	16	0.41
NR at Rio	59.86	16.00%	0.11%	0.70%	4.61%	34.15%	0.00%	21	0.35
NR at Rt.50	112.78	16.00%	0.43%	2.69%	5.55%	45.78%	4.90%	22	0.2
NR at Ice Mtn.	183.93	22.40%	0.40%	1.78%	5.75%	45.47%	3.34%	40	0.22
NRat Rt. 127	204.35	20.90%	0.39%	1.89%	5.71%	42.02%	3.22%	40	0.2
NORTH R. TRIBUTARY									
Skaggs Run	7.61	21.60%	0.55%	2.54%	4.58%	24.39%	0.00%	11	1.44
CACAPON MAINSTEM									
CR at Arnolds Ford	327.37	13.60%	0.79%	5.77%	n.d.	n.d.	n.d.	210	0.64
CR at USGS Gage Site	675.09	15.30%	0.54%	3.53%	n.d.	n.d.	n.d.	251	0.37
Cacapon Watershed Overall	680.14	15.20%	0.54%	3.54%	n.d.	n.d.	n.d.	251	0.37

Drainage Area. Drainage area of mainstem sampling sites ranged from 22.7 to 168.5 sq. mi. in the Lost River, and from 10.9 to 204.4 along the North River. Tributary sites in the Lost River ranged from 1.5 to 22.8 sq. mi. The sole North River tributary drains a land area of 7.6 sq. mi.

Total Agricultural Land (TAL). The percentage of land categorized as TAL ranged broadly, from 3.9 to 22.4%. However, with the exception of two Lost River tributary sites (Waites Run - 3.9% and Camp Branch Run - 8.9%), TAL ranged narrowly from 14.5 to 22.4% among North and Lost River sites, and offered little in the way of a TAL land use gradient. In Lost River mainstem sites, TAL ranged from 18.4 to 21.8% of the total land area. In North River mainstem sites, TAL ranged from 16.0 to 22.4%.

Crop Land. Table 1 provides data on land area in row crops in three ways: percentage of total land area in row crop; percentage of agricultural land in row crop, and percentage of floodplain land in row crop. The percentage of agricultural land used for row crops varied widely among sites, ranging from zero to 7.4%. Lost River mainstem sites had the highest percentage of TAL in row crop, ranging from 5.24 to 7.43%. Much less of the TAL was planted in row crop in the North River mainstem site watersheds, ranging from zero to 2.69%. Only three of the nine Lost River tributary sites had any row crop, these were Cullers Run (3.63%), Waites Run (2.59%) and Upper Cove Run 1 (1.21%).

Floodplain Land Use. Floodplain land in the region provides the best agricultural soils. Proximity of floodplain land to streams also makes this land of particular importance to surface water quality. The Lost and North River watersheds have similar proportions of their total land area in the floodplain, 5.97% (LR at Squirrel Gap) and 5.71% (NR at RT.127), respectively. In the watersheds of Lost River mainstem sites, 58.62 to 69.50% of this floodplain land is used for agriculture, 12.67 to 20.41% for row crops. A lower proportion of the floodplain land was used for agriculture in North River mainstem sites, ranging from 20.45 to 45.78%, zero to 4.9% for row crops.

Poultry Houses. Counts of poultry houses are, of course, cumulative as one progresses downstream, but total numbers are of some interest so they are provided in Table 1. Of greater importance for potential water quality impacts is the density of poultry houses in each watershed, here expressed as number of houses per square mile. The density of poultry houses varied widely between sites, ranging from zero to 3.13/sq.mi. In the watersheds of Lost River mainstem sites, poultry house density ranged from 1.13 to 1.85/sq.mi, substantially higher than North River mainstem sites, which ranged from 0.20 to 0.41/sq.mi. Lost River tributaries had poultry house density ranging from zero (No-Name Tributary and Mill Gap Run) to over three (UpperCove Run sites 1 and 3). The single North River tributary site had 1.44 poultry houses/sq.mi., a high density in comparison to most sampling sites.

Other Land. It is assumed for the purposes of this report that all but approximately one percent of the land not included in the above agricultural categories is forested. The remaining one percent consists of water bodies (rivers, streams, ponds, one lake), roads, residential areas and small commercial facilities.

Results: Water Quality

Reactive phosphorus (OP), total phosphorus (TP), turbidity, nitrate-nitrogen (NO_3-N) and fecal coliform bacteria were present at detectable levels at all sampling sites. Summary statistics for each parameter by site are presented in Tables 3 through 8 below. Significant differences were detected between some of the sites for all constituents measured.

Table 3. Summary statistics for pH at the 21 long-term study sites.

	pH					
SAMPLING SITE [drainage area mi^2]	**N**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Median**
LOST RIVER MAINSTEM						
LR at Mathias [22.7]	67	6.2	8.0	7.2	0.4	7.2
LR at Lost City [68.1]	66	7.0	8.9	8.0	0.4	8.1
LR at Lost River [109.1]	64	6.7	10.0	8.0	0.5	8.0
LR at Hanging Rock [157.4]	65	6.9	9.4	8.0	0.4	8.0
LR at Squirrel Gap [168.5]	42	7.0	8.7	8.0	0.3	8.0
LOST R. TRIBUTARY						
Cullers Run [11.5]	52	6.5	8.3	7.4	0.4	7.4
Upper Cove Run 3 [7.7]	51	7.3	9.0	8.0	0.3	8.1
Upper Cove Run 1 [9.1]	51	7.4	9.4	8.3	0.4	8.4
Mill Gap Run [2.6]	50	7.5	8.5	8.0	0.2	8.0
Camp Branch South [5.7]	50	6.7	8.5	7.8	0.3	7.8
Kimseys Run [18.4]	49	6.8	9.2	7.8	0.4	7.8
No-Name Trib of Kimsey R. [1.5]	45	6.3	9.1	7.5	0.5	7.6
Baker Run [22.8]	25	6.9	9.4	8.4	0.7	8.5
Waites Run [16.8]	51	6.7	8.3	7.6	0.3	7.6
NORTH RIVER MAINSTEM						
NR at Skaggs [10.9]	37	6.2	8.4	7.2	0.4	7.2
NR at Ford Hill Rd. [38.7]	38	6.4	7.9	7.2	0.4	7.2
NR at Rio [59.9]	40	6.3	7.8	7.3	0.4	7.4
NR at Rt.50 [112.8]	40	6.4	7.8	7.2	0.4	7.3
NR at Ice Mtn. [183.9]	43	6.9	8.2	7.7	0.3	7.7
NRat Rt. 127 [204.4]	43	6.7	7.9	7.5	0.3	7.6
NORTH R. TRIBUTARY						
Skaggs Run [7.6]	37	6.4	7.8	7.3	0.3	7.4

All sampling sites had median pH in the slightly to moderately alkaline range (Table 3). Sites in the Lost River mainstem w as generally more alkaline than the North River mainstem sites. The Lost River at Mathias and Cullers Run had low er pH than other Lost River sampling sites, w ith medians of 7.2 and 7.4, respectively. pH at other sites ranged from 7.6 at NoName Tributary to a high of 8.2 at Lost River at Lost River. pH readings in excess of the state standard of 9.0 w ere detected at Lost River at Lost River, Lost River at Hanging Rock, Upper Cove Run 1 and 3, Kimsey Run, NoName Tributary, and Baker Run; these high levels w ere typically associated w ith moderately heavy to heavy grow th of algae.

Table 4. Summary statistics for orthophosphate at the 21 long-term study sites.

	PO_4-P mg/L					
SAMPLING SITE [drainage area mi²]	**N**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Median**
LOST RIVER MAINSTEM						
LR at Mathias [22.7]	178	n.d.	0.502	0.030	0.053	0.020
LR at Lost City [68.1]	162	n.d.	0.179	0.012	0.017	0.010
LR at Lost River [109.1]	168	n.d.	0.225	0.017	0.030	0.010
LR at Hanging Rock [157.4]	196	n.d.	0.635	0.021	0.054	0.008
LR at Squirrel Gap [168.5]	79	n.d.	0.186	0.011	0.023	0.007
LOST R. TRIBUTARY						
Cullers Run [11.5]	147	n.d.	0.033	0.010	0.005	0.010
Upper Cove Run 3 [7.7]	113	n.d.	1.954	0.036	0.192	0.010
Upper Cove Run 1 [9.1]	149	n.d.	0.195	0.017	0.023	0.013
Mill Gap Run [2.6]	139	n.d.	0.023	0.010	0.005	0.010
Camp Branch South [5.7]	140	n.d.	1.251	0.020	0.107	0.008
Kimseys Run [18.4]	133	n.d.	0.078	0.010	0.008	0.008
No-Name Trib of Kimsey R. [1.5]	116	n.d.	0.033	0.009	0.005	0.007
Baker Run [22.8]	53	0.003	0.081	0.014	0.012	0.010
Waites Run [16.8]	142	n.d.	0.042	0.013	0.008	0.010
NORTH RIVER MAINSTEM						
NR at Skaggs [10.9]	76	n.d.	0.036	0.008	0.005	0.007
NR at Ford Hill Rd. [38.7]	81	n.d.	0.085	0.009	0.010	0.007
NR at Rio [59.9]	77	n.d.	0.072	0.008	0.009	0.007
NR at Rt.50 [112.8]	80	n.d.	0.016	0.005	0.004	0.005
NR at Ice Mtn. [183.9]	69	n.d.	0.067	0.007	0.008	0.005
NRat Rt. 127 [204.4]	71	n.d.	0.020	0.007	0.005	0.007
NORTH R. TRIBUTARY						
Skaggs Run [7.6]	74	n.d.	0.107	0.010	0.014	0.008

Despite widely varying land use conditions, median reactive phosphorus concentrations were low and ranged narrowly from a low of 0.005 mg/L at the North River at Rt. 50 site to a high of 0.020 mg/L at the Lost River at Mathias site (Table 4). Mean values varied more widely and tended to be higher than median values, skewed by a few high values recorded during active runoff events; for example, the high mean of 0.036 mg/L at Upper Cove Run 3 was generated by two very high numbers (out of 113 samples) recorded during the summer of 1997 and caused by phosphorus laden runoff from a construction site — this has not been observed since that time. For that reason, the median is the preferred "measure of central tendency" for this parameter, while the mean and maximum values are more reflective of the tendency of certain sites towards high concentrations during extreme runoff events.

Table 5. Summary statistics for total phosphorus at the 21 long-term study sites.

	Total P mg/L					
SAMPLING SITE [drainage area mi^2]	**N**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Median**
LOST RIVER MAINSTEM						
LR at Mathias [22.7]	182	n.d.	1.96	0.08	0.20	0.04
LR at Lost City [68.1]	163	n.d.	0.63	0.03	0.06	0.02
LR at Lost River [109.1]	170	n.d.	1.00	0.05	0.11	0.03
LR at Hanging Rock [157.4]	202	n.d.	0.87	0.07	0.13	0.04
LR at Squirrel Gap [168.5]	76	n.d.	1.18	0.05	0.15	0.02
LOST R. TRIBUTARY						
Cullers Run [11.5]	151	n.d.	0.29	0.03	0.03	0.02
Upper Cove Run 3 [7.7]	116	n.d.	19.75	0.38	2.55	0.02
Upper Cove Run 1 [9.1]	151	n.d.	4.60	0.10	0.41	0.03
Mill Gap Run [2.6]	140	n.d.	0.19	0.03	0.03	0.03
Camp Branch South [5.7]	140	n.d.	2.20	0.04	0.19	0.02
Kimseys Run [18.4]	136	n.d.	0.23	0.02	0.03	0.02
No-Name Trib of Kimsey R. [1.5]	120	n.d.	0.15	0.02	0.02	0.02
Baker Run [22.8]	53	n.d.	0.58	0.04	0.08	0.02
Waites Run [16.8]	141	n.d.	0.28	0.03	0.03	0.02
NORTH RIVER MAINSTEM						
NR at Skaggs [10.9]	76	n.d.	0.18	0.02	0.03	0.01
NR at Ford Hill Rd. [38.7]	81	n.d.	0.38	0.03	0.06	0.01
NR at Rio [59.9]	76	n.d.	0.38	0.02	0.05	0.01
NR at Rt.50 [112.8]	80	n.d.	0.34	0.03	0.05	0.02
NR at Ice Mtn. [183.9]	68	n.d.	0.21	0.03	0.03	0.02
NRat Rt. 127 [204.4]	71	n.d.	0.11	0.03	0.02	0.02
NORTH R. TRIBUTARY						
Skaggs Run [7.6]	73	n.d.	0.45	0.03	0.06	0.02

As with orthophoshorus, median total phosphorus (TP) concentrations were low, and ranged narrowly from a detected low of 0.01 mg/L at three North River mainstem sites to a high of 0.04 mg/L at the Lost River at Mathias and Hanging Rock sites (Table 5). Like orthophoshorus, mean values varied much more widely and tended to be higher than median values, skewed by a few high values recorded during active runoff events. As with orthophoshorus, the high mean of 0.38 mg/L at Upper Cove Run 3 was generated by two very high numbers (out of 116 samples) recorded during the summer of 1997 and caused by phosphorus laden runoff from a construction site — this has not been observed since that time. For that reason, the median is the preferred "measure of central tendency" for this parameter, while the mean and maximum values are more reflective of the tendency of each site towards high concentrations during runoff events. TP mean and median concentrations tended to be higher in the Lost River than the North River mainstems, more so than observed for reactive phosphorus.

Table 6. Summary statistics for turbidity at the 21 long-term study sites.

SAMPLING SITE [drainage area mi²]	Turbidity ntu N	Min	Max	Mean	Std. Dev.	Median
LOST RIVER MAINSTEM						
LR at Mathias [22.7]	184	0.16	1680	19.4	131.4	1.5
LR at Lost City [68.1]	163	0.27	279	6.2	25.2	1.9
LR at Lost River [109.1]	170	0.52	470	12.8	48.6	2.5
LR at Hanging Rock [157.4]	206	0.59	1630	36.5	139.6	4.5
LR at Squirrel Gap [168.5]	79	0.45	950	22.0	113.5	2.9
LOST R. TRIBUTARY						
Cullers Run [11.5]	153	0.08	280	4.4	24.7	0.6
Upper Cove Run 3 [7.7]	116	0.2	28334	490.2	3578.3	2.3
Upper Cove Run 1 [9.1]	152	0.11	1920	50.2	238.9	2.0
Mill Gap Run [2.6]	143	0.36	132	7.2	16.1	4.0
Camp Branch South [5.7]	142	0.19	260	4.4	22.2	1.1
Kimseys Run [18.4]	139	0.19	96.6	4.6	13.6	1.0
No-Name Trib of Kimsey R. [1.5]	121	0.29	99	2.6	9.0	1.3
Baker Run [22.8]	53	0.28	846	23.8	118.2	2.0
Waites Run [16.8]	145	0.17	201	3.8	17.1	1.3
NORTH RIVER MAINSTEM						
NR at Skaggs [10.9]	76	0.22	85.5	5.1	14.0	1.8
NR at Ford Hill Rd. [38.7]	81	0.23	219	10.1	35.7	1.5
NR at Rio [59.9]	77	0.14	184.5	6.0	23.3	1.1
NR at Rt.50 [112.8]	80	0.59	255	10.8	35.5	2.3
NR at Ice Mtn. [183.9]	69	0.62	118.2	7.4	16.9	2.9
NRat Rt. 127 [204.4]	71	0.61	28.5	4.9	5.6	3.1
NORTH R. TRIBUTARY						
Skaggs Run [7.6]	74	0.18	1560	29.8	183.8	1.7

Turbidity is a measure of water clarity and an indirect measure of sediment suspended in the water column. Moderately high turbidity levels can also be caused by phytoplankton. Median turbidity levels ranged much more widely than the two phosphorus measures, from a “clear” low 0.60 NTU at Cullers Run to a “cloudy” high of 4.5 NTU at the Lost River at Hanging Rock site (Table 6); we believe the relatively high levels at the latter site are due to biological causes, but have no direct evidence of this. The relatively high median turbidity at Mill Gap Run appears related to logging and development activities. Mean values varied much more widely and tended to be higher, sometimes much higher, than median values, skewed by a few high values recorded during active runoff events. High mean and maximum turbidity values at Upper Cove Run 1&3 were associated with the same summer 1997 event as with the two measures of phosphorus. For that reason, the median is the preferred "measure of central tendency" for this parameter, while the mean and maximum values are more reflective of the tendency of each site towards high concentrations during runoff events.

Table 7. Summary statistics for nitrate-nitrogen at the 21 long-term study sites.

SAMPLING SITE [drainage area mi²]	NO_3-N mg/L N	Min	Max	Mean	Std. Dev.	Median
LOST RIVER MAINSTEM						
LR at Mathias [22.7]	155	0.1	7.8	2.4	1.7	2.2
LR at Lost City [68.1]	143	0.0	3.4	0.9	0.7	0.8
LR at Lost River [109.1]	144	0.0	3.2	1.0	0.6	0.9
LR at Hanging Rock [157.4]	182	0.0	3.5	1.2	0.7	1.2
LR at Squirrel Gap [168.5]	80	0.0	3.6	0.9	0.7	0.9
LOST R. TRIBUTARY						
Cullers Run [11.5]	126	0.4	3.9	1.6	0.8	1.4
Upper Cove Run 3 [7.7]	111	0.2	2.6	0.8	0.4	0.8
Upper Cove Run 1 [9.1]	123	0.0	3.2	0.8	0.6	0.7
Mill Gap Run [2.6]	115	0.0	1.1	0.4	0.2	0.3
Camp Branch South [5.7]	114	0.0	1.3	0.4	0.3	0.4
Kimseys Run [18.4]	111	0.1	3.7	0.9	0.6	0.8
No-Name Trib of Kimsey R. [1.5]	105	0.0	2.5	0.6	0.5	0.4
Baker Run [22.8]	53	0.0	4.8	1.2	1.1	1.1
Waites Run [16.8]	120	0.0	2.0	0.2	0.2	0.1
NORTH RIVER MAINSTEM						
NR at Skaggs [10.9]	73	0.0	3.3	0.6	0.5	0.5
NR at Ford Hill Rd. [38.7]	77	0.0	2.7	0.7	0.5	0.6
NR at Rio [59.9]	75	0.0	2.3	0.6	0.4	0.5
NR at Rt.50 [112.8]	77	0.0	1.8	0.4	0.4	0.4
NR at Ice Mtn. [183.9]	67	0.0	1.9	0.4	0.4	0.2
NRat Rt. 127 [204.4]	69	0.0	1.8	0.3	0.4	0.2
NORTH R. TRIBUTARY						
Skaggs Run [7.6]	71	0.0	4.8	1.6	1.1	1.5

Median nitrate-nitrogen concentrations ranged w idely from a low of 0.1 mg/L at Waites Run to a high of 2.2 mg/L at the Lost River at Mathias site (Table 7). Median nitrate concentrations w ere typically higher at Lost River Mainstem sites than the North River mainstem; at Lost and North river sites of about the same drainage area (such as the Lost River at Lost River and the North River at Rt 50), median nitrate concentrations w ere at least tw ice as high in the Lost River w ith the difference betw een the tw o basins increasing in the dow nstream direction. Mean values w ere only marginally different than the median values, and standard deviations w ere relatively low w hen compared to reactive and total phosphorus, and turbidity. For that reason, either the median or the mean provide a reasonable "measure of central tendency" for this parameter.

Nitrate concentrations w ere substantially higher in the Lost River than the North River mainstems. How ever, the lone North River tributary, Skaggs Run, has the second highest median nitrate concentration overall. Regression analysis show s nitrate concentrations at this site increased significantly through the study period (r^2=0.28), the reason for this apparent increase is not clear. Possible sources include the addition of four poultry houses in the w atershed and application of fertilizer associated w ith the construction of a four line highw ay.

Table 8. Summary statistics for fecal coliform bacteria at the 21 long-term study sites.

SAMPLING SITE [drainage area mi^2]	Fecal Coliform Bacteria cfu/100ml N	Min	Max	Mean	Std. Dev.	Median
LOST RIVER MAINSTEM						
LR at Mathias [22.7]	118	3	54500	1624.6	5909.7	131
LR at Lost City [68.1]	121	3	27800	588.7	2644.1	60
LR at Lost River [109.1]	119	3	94000	1669.0	9668.4	67
LR at Hanging Rock [157.4]	124	3	52000	1181.1	5176.5	37
LR at Squirrel Gap [168.5]	68	3	6500	178.9	816.7	6
LOST R. TRIBUTARY						
Cullers Run [11.5]	81	3	9333	213.1	1060.7	27
Upper Cove Run3 [7.7]	77	3	28900	493.9	3287.3	37
Upper Cove Run1 [9.1]	86	3	7500	341.1	962.2	45
Mill Gap Run [2.6]	85	3	1250	97.4	223.6	22
Camp Branch South [5.7]	80	3	2700	105.8	366.8	7
Kimseys Run [18.4]	71	3	1933	59.6	232.6	10
No-Name Trib of Kimsey R. [1.5]	68	0	1633	72.9	246.2	7
Baker Run [22.8]	29	3	247	20.3	47.9	3
Waites Run [16.8]	81	2	400	32.4	65.4	7
NORTH RIVER MAINSTEM						
NR at Skaggs [10.9]	20	3	133	30.3	36.7	20
NR at Ford Hill Rd. [38.7]	21	3	633	69.6	138.2	23
NR at Rio [59.9]	21	3	133	37.0	38.8	33
NR at Rt.50 [112.8]	21	3	1133	106.2	242.3	37
NR at Ice Mtn. [183.9]	45	3	420	81.3	110.8	20
NRat Rt. 127 [204.4]	21	3	187	38.3	42.4	30
NORTH R. TRIBUTARY						
Skaggs Run [7.6]	20	3	336	89.0	102.4	52.5

Median fecal coliform bacteria concentrations ranged from a low of 3 cfu/100ml at Baker Run to a high of 156 cfu/100ml at the Lost River at Mathias site (Table 8). Mean values varied much more widely and tended to be substantially higher than medians, sometimes much higher, than median values, skewed by the relatively few very high values recorded during active runoff events. For that reason, the median is the preferred "measure of central tendency" for this parameter, while the mean and maximum values are more reflective of the tendency towards higher bacteria concentrations during runoff events.

Comparisons between fecal coliform bacteria concentrations in the North and Lost River are somewhat problematic, as we didn't begin routine collection of bacteria samples in the North River until March 2001 (with the exception of "NR at Ice Mtn", which is also included in a separate long-term monitoring program). Nonetheless, it is reasonable to note that all of the Lost River sites has recorded at least one bacterial count in excess of 200 cfu/100ml, a threshold amount that indicates possible bacterial contamination, while half of the North River mainstem sites have not. Extended periods of drought-like conditions occurred during the study (see Water Quality and Precipitation below), during which bacterial counts were consistently very low at all sites. These dry intervals produced lower median bacterial counts than we would have anticipated, based on results during a six-month wet period, if more normal rainfall had occurred.

Overall, the Lost River at Mathias mainstem indicator site stands out as distinct from all other sampling sites, with the highest median concentrations for reactive and total phosphorus, nitrate nitrogen and fecal coliform bacteria.

Correlations of Water Quality Parameters and Land Use

Non-point source pollution in our streams is moved off the land by precipitation, either as particulate matter that travels across the surface of the land or in dissolved form; dissolved pollutants may move either overland or, in some cases, through the ground. Sediment suspended in the water column is a good indicator of storms strong enough to mobilize sediment that flows overland land into streams. It requires substantial energy to mobilize these sediments and substantial energy to keep all but the finest particulate matter in suspension in the water column. Turbidity is an indirect measure of sediment and other particulate matter in the water and, as such, is our best indicator of active storm flows. In order to determine which parameters are most dependent on storm flow conditions, we calculated simple linear correlations on summary statistics of turbidity against the other water quality parameters (Table 9).

Table 9. Correlations of turbidity with other water quality parameters. The table provides significant correlation coefficients and significance levels (indicated as: n.s. - not significant; (*) p<=0.05; (**) p<=0.01; (***) p<=0.001).

		TURBIDITY		
		Median	Mean	Maximum
TURBIDITY	Median	1	n.s.	n.s.
	Mean	0.0707	1	***
	Max	0.0536	0.9987	1
REACTIVE PHOSPHORUS	Median	n.s.	n.s.	n.s.
	Mean	n.s.	0.8033 ***	0.7174 ***
	Max	n.s.	0.7042 ***	0.8131 ***
TOTAL PHOSPHORUS	Median	0.4684 *	n.s.	n.s.
	Mean	n.s.	0.981 ***	0.9799 ***
	Max	n.s.	0.9817 ***	0.981 ***
NITRATE-NITROGEN	Median	n.s.	n.s.	n.s.
	Mean	n.s.	n.s.	n.s.
	Max	n.s.	n.s.	n.s.
FECAL COLIFORM BACTERIA	Median	n.s.	n.s.	n.s.
	Mean	n.s.	n.s.	n.s.
	Max	n.s.	n.s.	n.s.

It is clear from these results that high concentrations of total phosphorus are very closely linked to high turbidity and, therefore, storm flows. Reactive phosphorus concentrations are also correlated, to a somewhat lesser extent, with turbidity. Similar results were obtained with correlations on raw data. This makes sense, as much of the phosphorus found in a stream is bound to particulate matter that mostly occurs in the water column during storm flow conditions. Neither nitrate nor fecal coliform bacteria were significantly correlated with turbidity. Although high concentrations of both nitrate and fecal coliforms do occur during storm events, they also occur at many other times - which explains the lack of a strong correlation between these parameters and turbidity. (Weak correlations were detected between turbidity and nitrate - r=0.1632 - and fecal coliform bacteria - r=0.3292 - on correlations using raw data.)

Table 10 provides simple linear correlations of summary statistics (mean, median, maximum) for reactive phosphorus, total phosphorus, and turbidity with land use parameters. Correlations are provided for all sites combined, and for indicator sites. As noted above in the section on summary statistics, the median is the best "measure of central tendency" for these parameters, while the mean and maximum values are more reflective of high concentrations during runoff events. Median reactive phosphorus at indicator sites was positively correlated with the three measures of percentage of land in row crop and to the amount of agricultural land in the floodplain; correlation analysis finds these land use categories to be relatively strong covariates. Median reactive phosphorus at all sites combined was positively correlated with the percentage of row crop in the flood plain and with poultry house density. Mean and maximum values for each parameter (with the exception of maximum reactive phosphorus for indicator sites) are positively correlated with poultry house density. Otherwise, the mean/maximum statistics for these parameters show no correlation to the land use variables measured.

Median total phosphorus at indicator sites was positively correlated with the three measures of percentage of land in row crop. Median total phosphorus at all sites combined was positively correlated with the percentage of row crop in the flood plain, of agricultural land in row crop, and of floodplain in agriculture.

These patterns may be instructive. Since peak phosphorus concentrations, as indicated by mean and maximum values, seem to be related to storm flow conditions (see Table 9 above), the correlations between poultry house density and these statistics may indicate that poultry houses, or their proximity (Gillies, unpublished report), are important contributors of phosphorus during runoff events. That peak phosphorus concentrations rather conspicuously are not correlated with any of the agricultural lands on which poultry litter and other fertilizers are likely to be applied may indicate that relatively little phosphorus is flowing from these lands during runoff events; it could also be an artifact of unequal sampling effort during storm sampling.

Unlike phosphorus and turbidity, nitrate and fecal coliform bacteria were significantly correlated with many of the selected land use variables (Table 11); this indicates that nitrate and fecal bacteria are more easily “mobilized” than the former parameters. Correlations tended to be stronger for indicator sites alone than all sites together -- which is reasonable. Indicator sites are closer to potential sources of pollution and the relationships are less likely to be obscured in the background noise caused by dilution and downstream processes (chemical, biological, physical) that remove pollutants from the water column and thus from our

Table 10. Results of correlations of land use parameters and summary statistics for reactive and total phosphorus, and turbidity. The table provides significant correlation coefficients and significance levels (indicated as: n.s. - not significant; (*) p<=0.05; (**) p<=0.01; (***) p<=0.001).

		Overall Land Use			Floodplain land Use		Poultry Houses
		% Ag Land	% Rowcrop	% Ag Land in Row Crop	% Ag in Floodplain	% Row Crop in Floodplain	No./Sq.Mi.
REACTIVE PHOSPHORUS							
All Sites	**Median**	n.s.	n.s.	n.s.	n.s.	0.4635 *	0.5692 **
	Mean	n.s.	n.s.	n.s.	n.s.	n.s.	0.7547 ***
	Max	n.s.	n.s.	n.s.	n.s.	n.s.	0.5515 **
Indicator Sites	**Median**	n.s.	0.8007 **	0.7722 **	0.6539 *	0.8738 ***	n.s.
	Mean	n.s.	n.s.	n.s.	n.s.	n.s.	0.7084 **
	Max	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
TOTAL PHOSPHORUS							
All Sites	**Median**	n.s.	n.s.	0.5424 **	0.5312 *	0.6851 ***	n.s.
	Mean	n.s.	n.s.	n.s.	n.s.	n.s.	0.729 ***
	Max	n.s.	n.s.	n.s.	n.s.	n.s.	0.7 ***
Indicator Sites	**Median**	n.s.	0.7069 **	0.6262 *	n.s.	0.7545 **	n.s.
	Mean	n.s.	n.s.	n.s.	n.s.	n.s.	0.7251 **
	Max	n.s.	n.s.	n.s.	n.s.	n.s.	0.7037 **
TURBIDITY							
All Sites	**Median**	n.s.	n.s.	n.s.	0.4414 *	n.s.	n.s.
	Mean	n.s.	n.s.	n.s.	n.s.	n.s.	0.6364 **
	Max	n.s.	n.s.	n.s.	n.s.	n.s.	0.6264 **
Indicator Sites	**Median**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Mean	n.s.	n.s.	n.s.	n.s.	n.s.	0.6449 *
	Max	n.s.	n.s.	n.s.	n.s.	n.s.	0.6303 *

ability to quantify them. Median and mean nitrate concentrations were most strongly correlated (r > 0.700) at indicator sites with % Row crop, % Row crop in Floodplain, % Agricultural land, %

Agricultural Land in Row Crop, and, interestingly, Number of Poultry Houses but not poultry house density — indicative of a cumulative impact. This makes intuitive sense, since the major source of nutrients in the watershed is poultry litter, that litter is most abundantly applied to row crops, which are primarily situated on well drained flood plain soils with fairly direct connections to area streams via surface runoff and via interflow underground.

Median and mean fecal coliform bacteria counts are also correlated, very strongly, with the three measures of percent row crop -- and to little else. This may indicate that bacteria from poultry litter used to fertilize row crops are running off into the streams. The areas with substantial row crop are also used intensively for many agricultural purposes, including pasture for cattle, so a link to a specific "cause" is more obscure than for nitrate.

Table 11. Results of correlations of land use parameters and summary statistics for nitrate nitrogen and fecal coliform bacteria. The table provides significant correlation coefficients and significance levels (indicated as: n.s. - not significant; (*) p<=0.05; (**) p<=0.01; (***) p<=0.001).

		Overall Land Use				**Floodplain land Use**		**Poultry Houses**	
		% Ag Land	% Rowcrop	% Ag Land in Row Crop	% Land in Floodplain	% Ag in Floodplain	% Row Crop in Floodplain	Number	No./Sq.Mi.
NITRATE-NITROGEN									
All Sites	**Median**	0.495 *	0.5633 **	0.4425 *	n.s.	0.4744 *	0.5908 **	n.s.	0.5416 **
	Mean	0.5091 *	0.5366 **	0.412 *	n.s.	0.4403 *	0.5602 **	n.s.	0.5069 *
	Max	0.4807 *	0.5157 *	n.s.	n.s.	n.s.	0.5453 *	n.s.	0.5033 *
Indicator Sites	**Median**	0.7413 **	0.8341 ***	0.7311 **	0.6456 *	0.5807 *	0.7612 **	0.704 **	n.s.
	Mean	0.7465 **	0.8385 ***	0.7337 **	0.642 *	n.s.	0.7789 **	0.7106 **	n.s.
	Max	0.6836 *	0.8179 **	0.7327 **	0.6111 *	n.s.	0.7481 **	0.7599 **	n.s.
FECAL COLIFORM BACTERIA									
All Sites	**Median**	0.4867 *	0.6024 **	0.4857 *	n.s.	n.s.	0.5491 **	n.s.	n.s.
	Mean	n.s.	0.7373 ***	0.6579 ***	n.s.	0.5811 **	0.777 ***	n.s.	n.s.
	Max	n.s.	0.6468 ***	0.5836 **	n.s.	0.5519 **	0.6982 ***	n.s.	n.s.
Indicator Sites	**Median**	n.s.	0.8804 ***	0.7937 **	n.s.		0.7419 **	n.s.	n.s.
	Mean	n.s.	0.8725 ***	0.7884 **	n.s.	0.5846 *	0.8939 ***	0.6726 *	n.s.
	Max	n.s.	0.7848 **	0.7046 **	n.s.	0.6258 *	0.8253 ***	0.6647 *	n.s.

Water Quality and Precipitation

Non-point source pollution is moved off the land into our streams mostly by precipitation, either directly as runoff or, in some cases, less obviously through groundwater pathways. A record of precipitation is therefore essential to interpret water quality results. Table 12 provides summary precipitation data for the study period from our rain gage at Skaggs Run; data is presented as 10 day and 30 day cumulative rainfall "regimes," in one inch increments, for the entire study period and for days on which samples were collected in the Lost and North River study areas.

Table 12. Summary precipitation data for the study period from the Skaggs Run rain gage. Data are presented as 10 day and 30 day cumulative rainfall "regimes," in one inch intervals, for the entire study period and for days on which river samples were collected.

10 day Cumulative Rainfall (1" groupings)						
Inches	**Study Period**		**Lost River Sampling**		**North River Sampling**	
	Days	**% of Total**	**Days**	**% of Total**	**Days**	**% of Total**
0-0.50" = 0" interval	765	40.76%	66	30.84%	24	27.59%
0.51-1.50" = 1"	666	35.48%	63	29.44%	30	34.48%
1.51-2.50" = 2"	317	16.89%	58	27.10%	23	26.44%
2.51-3.50" = 3"	89	4.74%	14	6.54%	9	10.34%
3.51-4.50" = 4"	32	1.70%	10	4.67%	1	1.15%
4.51-5.50" = 5"	8	0.43%	3	1.40%		0.00%
TOTAL DAYS	**1877**		**214**		**87**	

30 day Cumulative Rainfall (1" groupings)						
Inches	**Study Period**		**Lost River Sampling**		**North River Sampling**	
	Days	**% of Total**	**Days**	**% of Total**	**Days**	**% of Total**
0-0.50" = 0" interval	75	4.04%	7	3.47%	4	4.60%
0.51-1.50" = 1"	435	23.42%	33	16.34%	11	12.64%
1.51-2.50" = 2"	401	21.59%	39	19.31%	16	18.39%
2.51-3.50" = 3"	342	18.42%	56	27.72%	29	33.33%
3.51-4.50" = 4"	222	11.95%	27	13.37%	9	10.34%
4.51-5.50" = 5"	172	9.26%	12	5.94%	8	9.20%
5.51-6.50" = 6"	134	7.22%	15	7.43%	4	4.60%
6.51-7.50" = 7"	65	3.50%	10	4.95%	5	5.75%
7.51-8.50" = 8"	11	0.59%	3	1.49%	1	1.15%
TOTAL DAYS	**1857**		**202**		**87**	

Table 12 shows that the sampling distributions in relation to rainfall in the two primary study basins were reasonably similar to one another and to the overall rainfall pattern during the study period, indicating no strong bias towards sampling either the low or high end of the precipitation spectrum in either basin. There actually appears to be a moderate, random bias towards sampling the middle of the range: 1.51-2.50" for 10 day cumulative rainfall; and 2.51-3.50" for 30 day cumulative rainfall. Heavy rainfall is a relatively rare event, which means that water quality sample sizes at these extremes are also small.

Average rainfall In these watersheds is about 35 inches per year, per long term data collected at the NOAA Cooperative Weather Stations in Mathias (Hardy County, Lost River watershed, Station #465739). Fifty percent of the overall 30 day cumulative rainfall pattern falls in the low rainfall range (less than 2.5" per 30 days); this weighting demonstrates that many prolonged periods of low rainfall occurred during the period of study. Of particular note were unusually dry conditions from the middle of June 1998 through December 1998, May through August 1999, September 2001 through the middle of March 2002. On the other end of the scale, a major rainfall event in early November 1997 led into an abnormally wet winter and spring of 1998 — before sampling in the North River watershed began in earnest.

The following section provides graphs and brief discussions for the response of water quality parameters to precipitation in each study basin. The parameters most dependant on active runoff conditions — turbidity, ortho- and total phosphorus — are discussed in relation to 10 day cumulative rainfall regimes (see Table 12 above). Graphics for the more mobile nitrate and fecal coliform bacteria constituents are presented for both 10 and 30 day precipitation regimes. Graphics use box plots to present the data (Figure 1); only median and the 10th, 25th, 75th and 90th percentile values are provided in these graphs because of difficulties associated with graphing extremes.

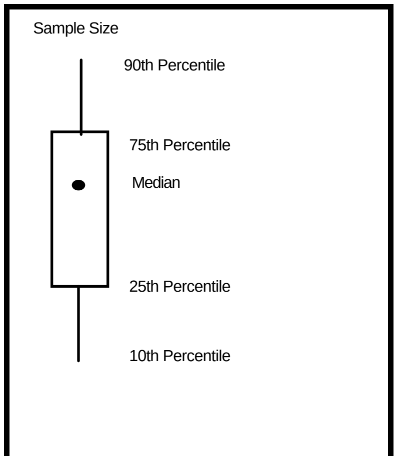

Figure 1. Example diagram and explanation of a boxplot.

Median **orthophosphate** concentrations showed little response to periods of increased rainfall in either the Lost River (Figure 2) or North River (Figure 3) watersheds. However, the range around the median increased substantially in the Lost River as the amount of precipitation in the ten days preceding sampling increased; this response did not occur in the North River study area.

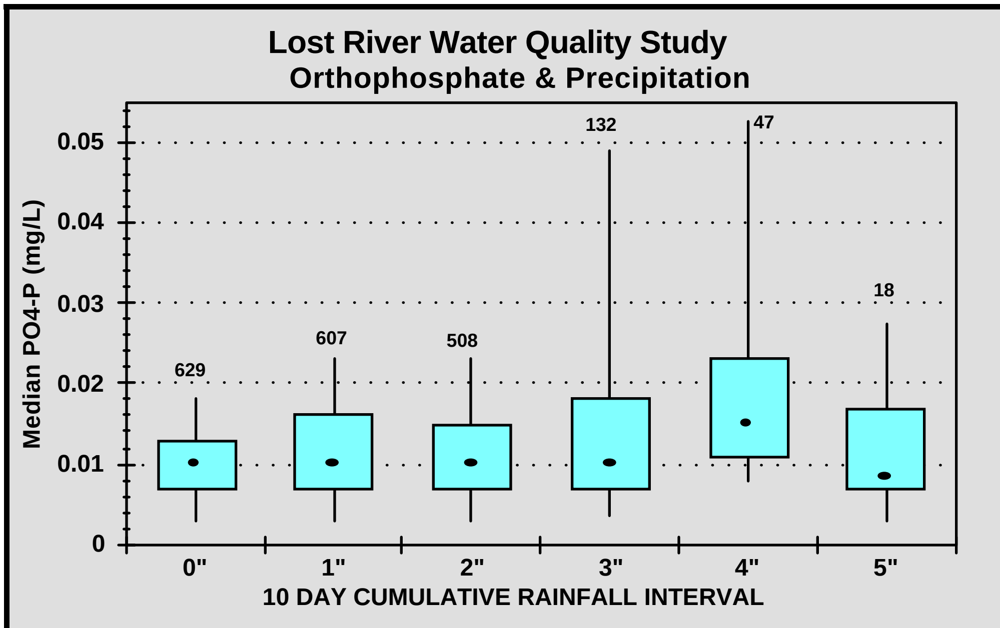

Figure 2. Overall response of orthophosphate to different precipitation “regimes” (10 day cumulative rainfall) at 13 Lost River sampling sites.

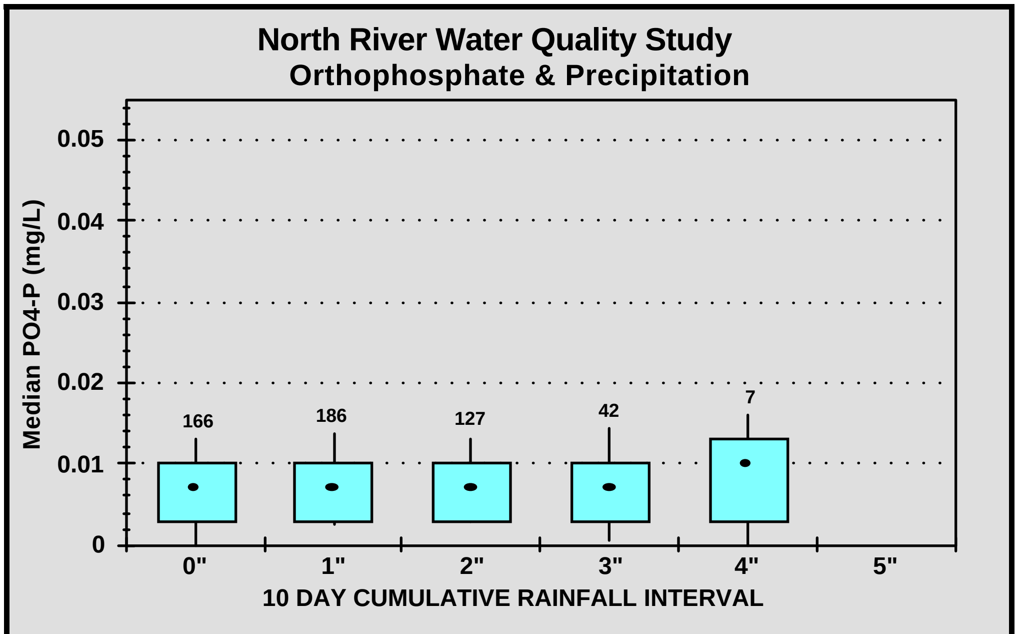

Figure 3. Overall response of orthophosphate to different 10 day cumulative rainfall regimes at 7 North River sampling sites.

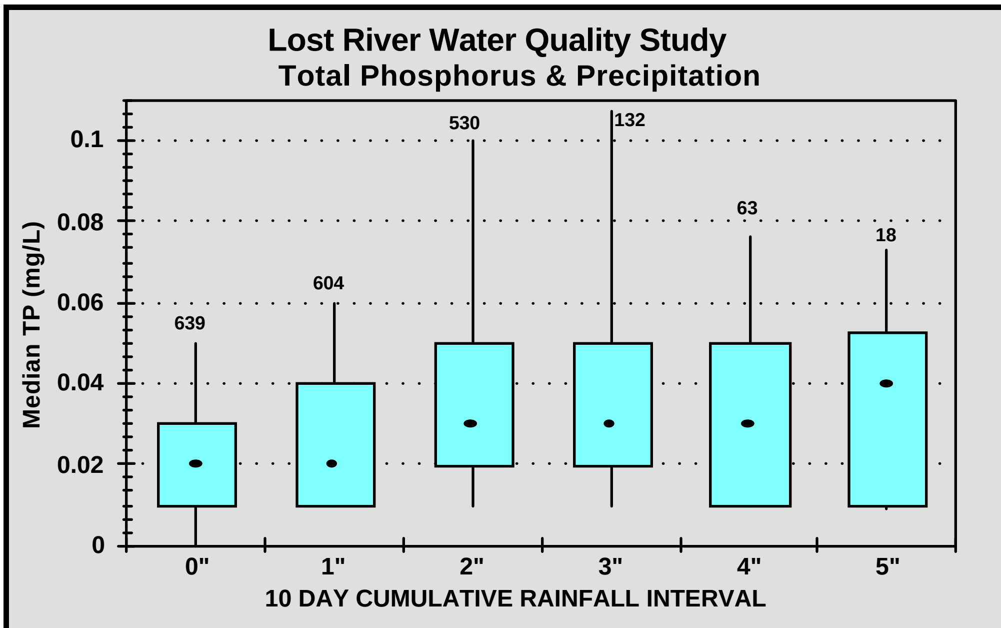

Figure 4 Overall response of total phosphorus to different 10 day cumulative rainfall regimes at 13 Lost River sampling sites.

Median **total phosphorus** concentrations increased in both watersheds in response to periods of increased rainfall. In the Lost River (Figure 4), median TP increased from the low 0.02 mg/L observed during the driest periods to 0.03 mg/L and then 0.04 mg/L during the wettest periods. Likewise, in the North River (Figure 5) basin, median TP increased from a low of 0.01 mg/L to a high of 0.04 along with increasing rainfall. The range around the median also increased as precipitation increased in both study areas, indicating a varied response among sampling sites.

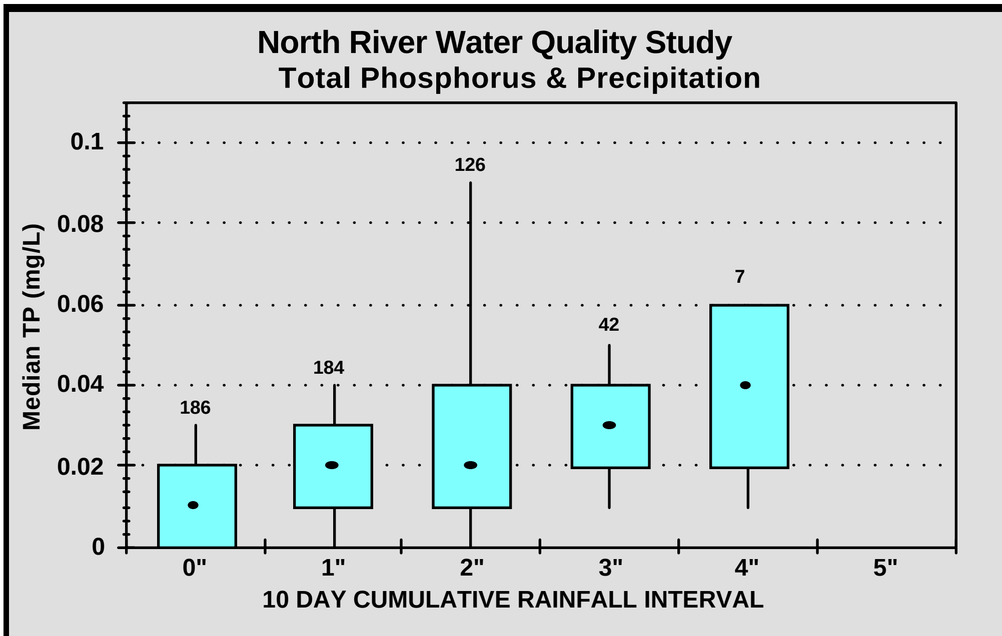

Figure 5. Overall response of total phosphorus to different 10 day cumulative rainfall regimes at 7 North River sampling sites.

Turbidity responded much like total phosphorus, with median "cloudiness" increasing in both watersheds in response to periods of increased rainfall. Both basins had uniformly low turbidity during the driest periods, which increased moderately as rainfall became more frequent. In the Lost River (Figure 6), median turbidity increased from a very low 1.01 ntu observed during the driest periods to 3.2 and then 3.8 ntu during the wettest periods. Likewise, in the North River (Figure 7) basin, median turbidity increased from a very low 0.96 ntu to a high of 5.6 ntu when 3" of rain had fallen within the previous 10 days. The range around the median also increased very substantially as precipitation increased in both study areas, indicating much greater variability.

Intensive storm sampling early in the project found that total phosphorus, orthophosphate and turbidity levels rapidly peak during a storm, then fall nearly as rapidly (Gillies, 1998c). During one storm, total phosphorus levels were reduced by 50 percent six hours after the peak was reached, 65% after 12 hours. Thirty eight hours after the storm, TP concentrations had dropped to pre-storm levels.

The literature indicates that over 75 percent of annual watershed runoff can occur during a small number of severe events (Edwards and Owens, 1991). Because P primarily moves in runoff, Sharpley (1995) estimates that over 90% of the annual P load can be delivered by these few events.

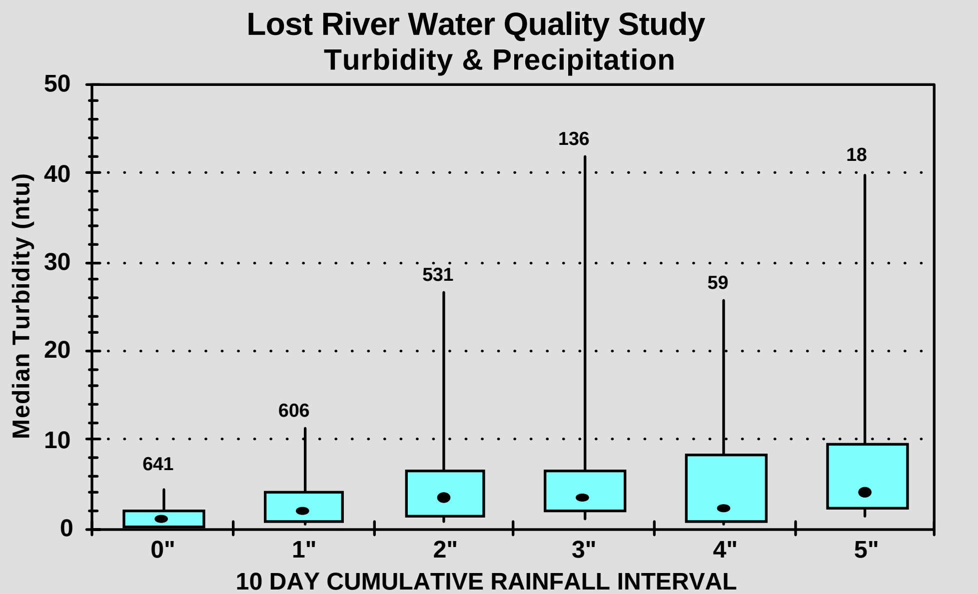

Figure 6. Overall response of turbidity to different 10 day cumulative rainfall regimes at 13 Lost River sampling sites.

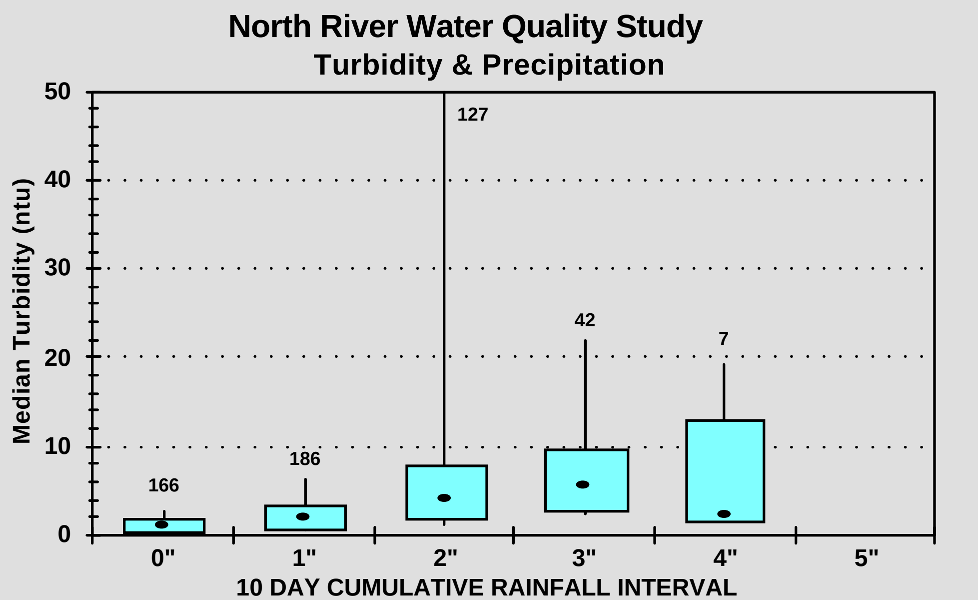

Figure 7. Overall response of total phosphorus to different 10 day cumulative rainfall regimes at 7 North River sampling sites.

Median nitrate-N concentrations increased in both watersheds in response to periods of increased rainfall. In the Lost River (Figure 8), median nitrate increased from the low 0.4 mg/L observed during the driest periods to about 1.0 mg/L when 2-3" of rain had fallen in the previous 10 days, up to 1.6 and 1.75 mg/L — a four fold increase -- during the wettest periods.

Nitrate levels also increased substantially with increasing rainfall in the North River basin (Figure 9). Median nitrate increased from a low of 0.2 mg/L to 0.4 to 0.8 to 0.6 mg/L along with increasing rainfall, typically about half the levels observed in the Lost. The North River data for the 4" cumulative rainfall interval reflects a single day of sampling, and the median of 2.3 mg/L may or may not represent the norm for that basin --more data will be necessary to answer that question. The range around the median also increased as precipitation increased in both study areas, indicating a varied response among sampling sites.

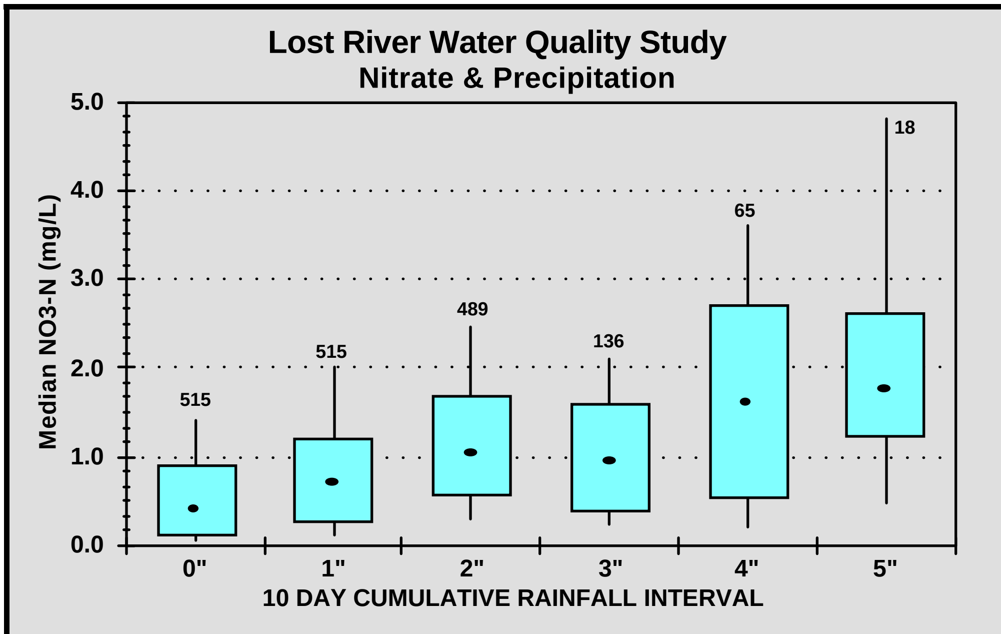

Figure 8. Overall response of nitrate-nitrogen to different 10 day cumulative rainfall regimes at 13 Lost River sampling sites.

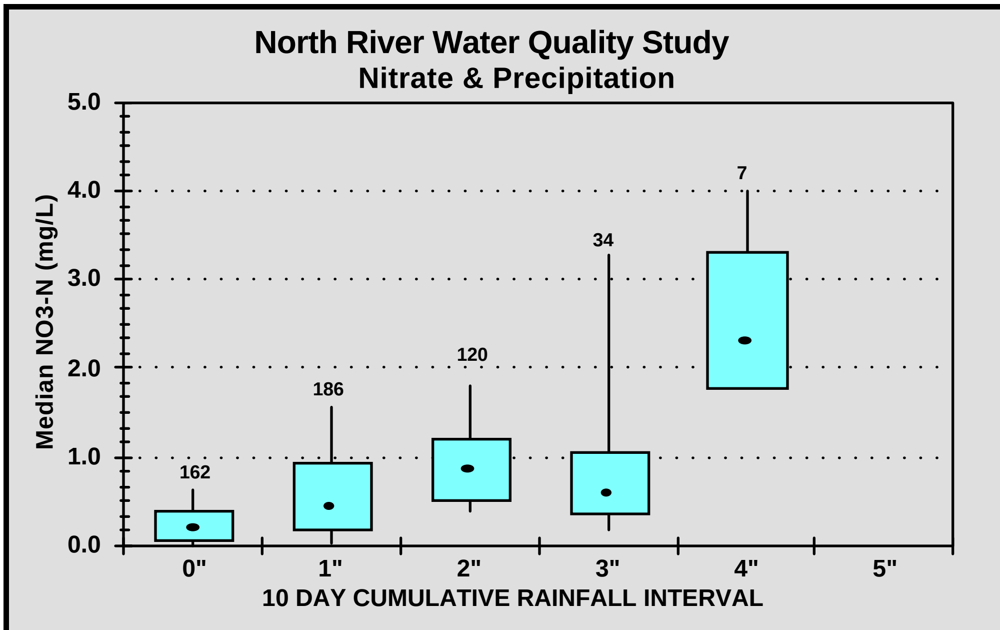

Figure 9. Overall response of nitrate-nitrogen to different 10 day cumulative rainfall regimes at 7 North River sampling sites.

The headwater tributary of the North River, Skaggs Run, appears to be uniquely high in nitrate for this basin (see Table 7 and following notes), and these elevated levels impact the North River mainstem for a considerable distance downstream.

The same storm sampling that highlighted the rapid, storm-related, peak and fall of total phosphorus, orthophosphate and turbidity levels (Gillies, 1998c) found nitrate to have quite a different pattern. Concentrations, once elevated, tended to remain elevated for a considerable time due to the ability of nitrate to move both via surface runoff and through groundwater pathways, and its relatively stable nature. Figures 10 and 11 (for the Lost River and North River, respectively) look at nitrate concentrations in relation to longer, 30 day cumulative rainfall patterns than discussed above.

Both the Lost and North river watersheds followed a similar median nitrate-N concentration pattern in relation to 30 day cumulative precipitation "regimes." When less than 1.5" fell in thirty days, median nitrate was low — 0.3 mg/L in the Lost and 0.1 mg/L in the North — and variability was minimal. At a still less than average rainfall rate of 1.51-2.50" in 30 days, median nitrate in the Lost River doubled to 0.6 mg/L, and quadrupled in the North River to 0.4 mg/L, and variability increases. At roughly average rainfall levels, 2.51 - 3.50" in 30 days, median nitrate levels increased again, to 0.9 mg/L in the Lost and 0.8 mg/L in the North River, with variability among samples increasing further.

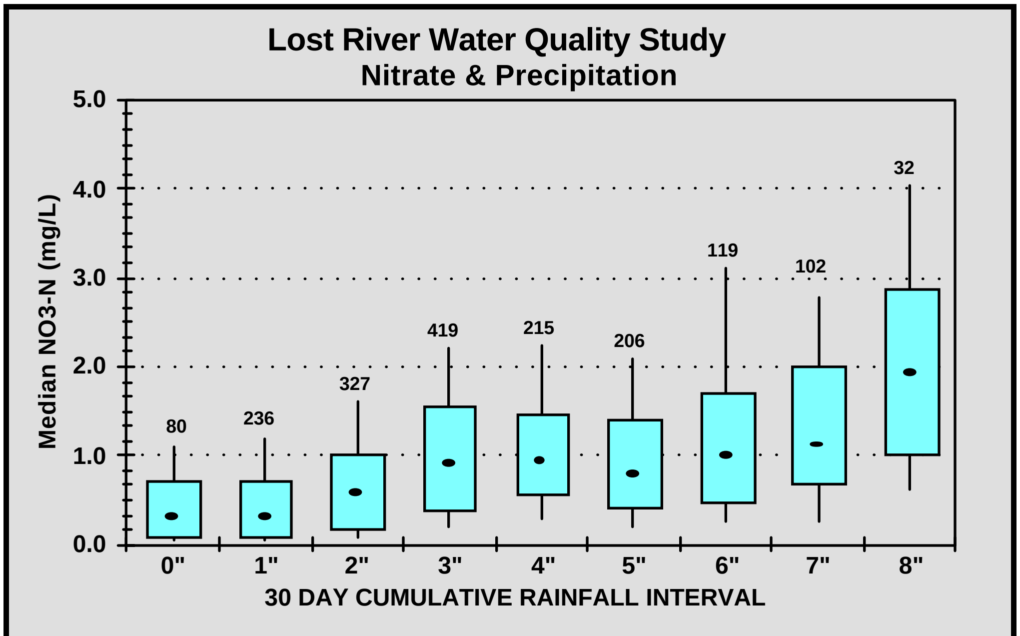

Figure 10. Overall response of nitrate-nitrogen to different 30 day cumulative rainfall regimes at 13 Lost River sampling sites.

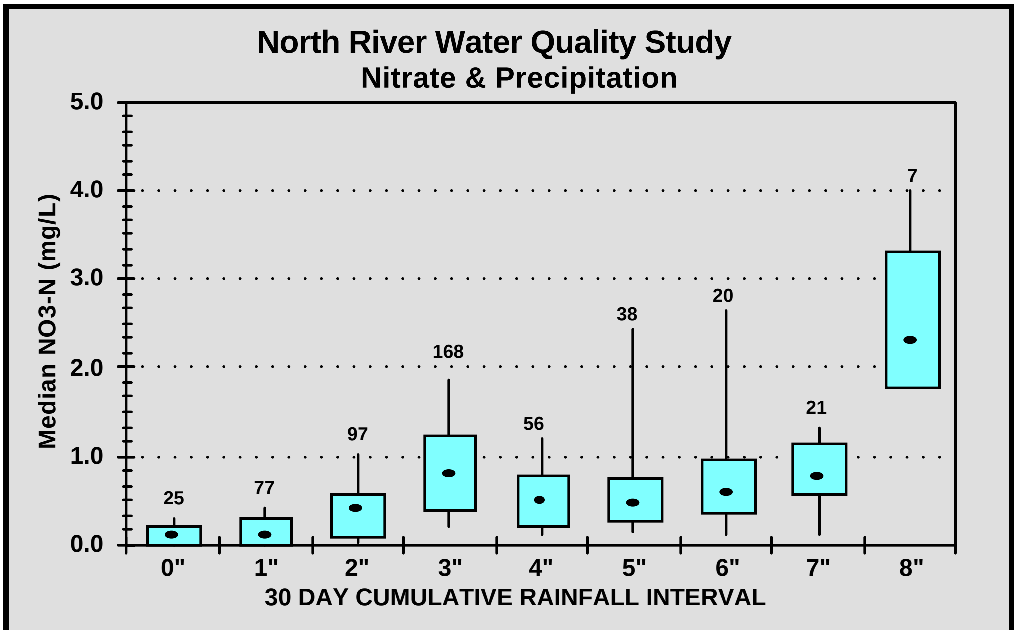

Figure 11. Overall response of nitrate-nitrogen to different 30 day cumulative rainfall regimes at 7 North River sampling sites.

At this point, the behavior of the two study areas diverged. Median nitrate levels in the Lost hovered between 0.9 and 1.1 mg/L from the 3" to the 7" in 30 day intervals, with variability among samples increasing only at the high end of the rainfall range. For the relatively rare 8 inch in 30 day condition, the median nitrate concentration nearly doubled to 1.9 mg/L from the previous interval.

Median nitrate levels in the North River were actually lower in the 4" to 6" 30 day interval than in the 3" interval. Levels increased again in the 7" interval and, as in the Lost River, rose sharply in the 8" interval. However, the North River data for the 8" cumulative rainfall interval reflects a single day of sampling, and the median of 2.3 mg/L may or may not represent the norm for that basin.

Median fecal coliform bacteria (fcb) concentrations increased in both watersheds in response to periods of increased rainfall. In the Lost River (Figure 12), median fcb increased steadily from the low 13 cfu/100ml observed during the driest periods to about 133 cfu/100ml when 4" of rain had fallen in the previous 10 days; the 5" interval is shown for information only, insufficient data makes this suspect. Bacteria in the North River followed a similar pattern and had similar concentrations for the 0 to 2" interval -- insufficient data was collected above that level and no North River graph is provided.

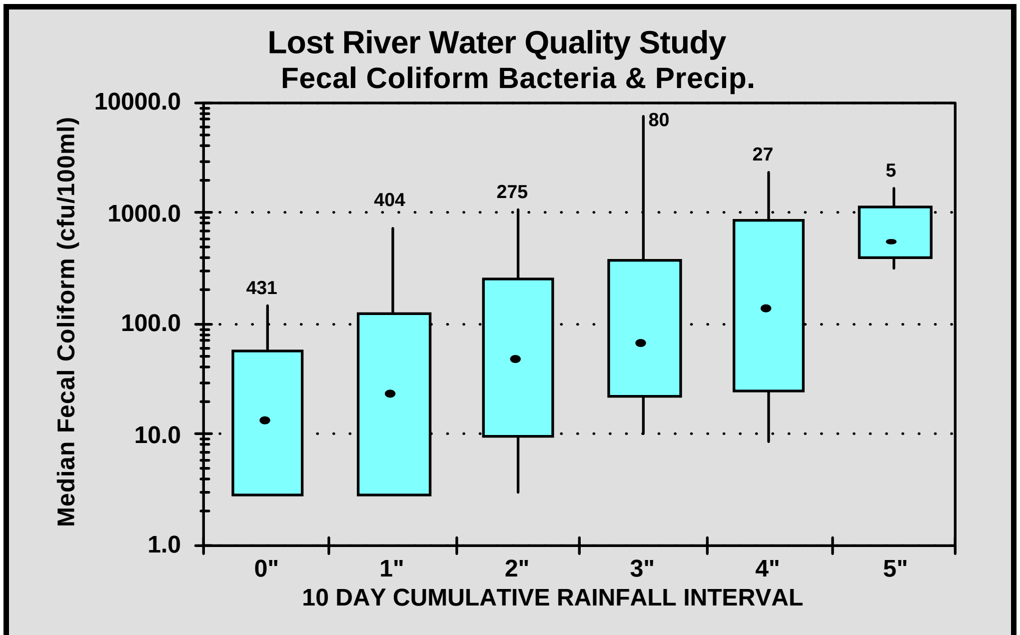

Figure 12. Overall response of fecal coliform bacteria to different 10 day cumulative rainfall regimes at 13 Lost River sampling sites.

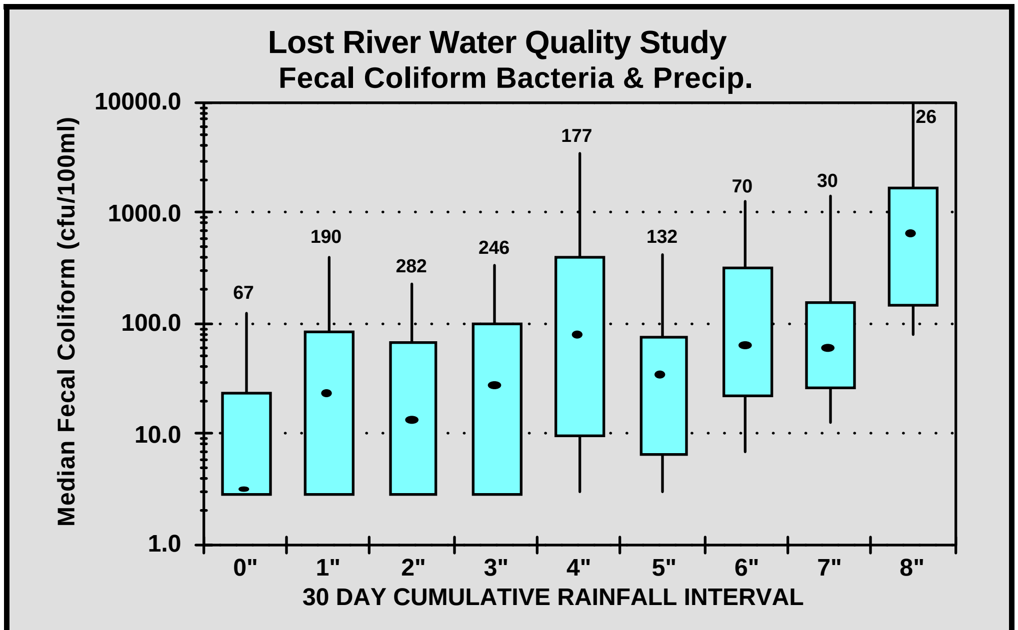

Figure 13. Overall response of fecal coliform bacteria to different 30 day cumulative rainfall regimes at 13 Lost River sampling sites.

Figure 13 provides fecal coliform data for the 30 day cumulative rainfall interval. Bacteria counts were routinely low (100 cfu/100 ml or less) at average and below average rainfall amounts (3" and less) and were mostly low at all intervals except the highest - 8" in 30 days.

Nitrate at Lost River Indicator Sites. Figures 8 and 10 (pages 26 and 27, respectively) indicated considerable variability in nitrate-nitrogen concentration in the Lost River overall, variability that increased in response to periods of increased rainfall. Table 7 (page 15) showed considerable variability among Lost River sampling sites. Figure 14 provides a look at how nitrate concentrations at Lost River indicator sites (sites of less than 25 mi^2) responded to different rainfall regimes. Each of these sites has different land use characteristics (Table 2, page 9), ranging from the intensely agricultural Lost River at Mathias site (with the highest percentages of land in agriculture [21.8%], flood plain land in row crop [20.4%] and one of the highest poultry house densities [1.85/$mi.^2$]) to Waites Run (with by far the lowest amount of land in agriculture [3.9%], no row crop in the floodplain and a low poultry house density [0.3/$mi.^2$]). These two sites represent the extremes in agricultural land use for the Lost River, and also demonstrate the extremes in nitrate response to precipitation. Median nitrate-N concentrations

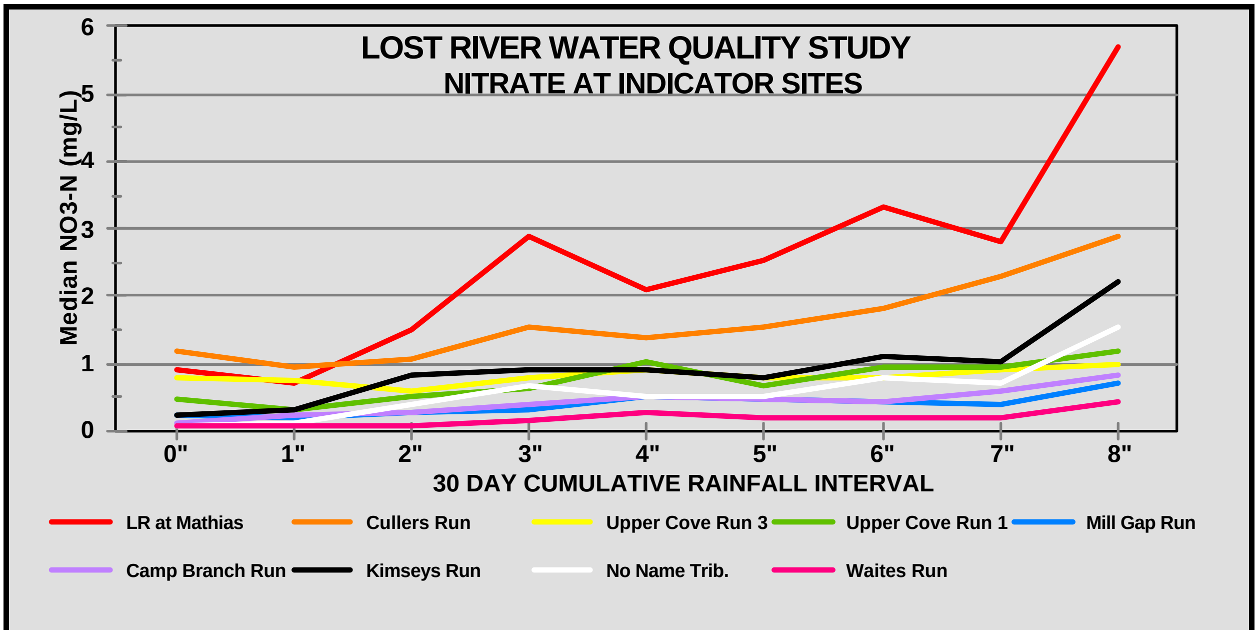

Figure 14. Response of nitrate-nitrogen to different 30 day cumulative rainfall regimes at 9 Lost River "indicator" sampling sites.

at Waites Run were the lowest of all study sites, and varied narrowly from a low of 0.1 mg/L during the driest period to 0.5 mg/L at the wettest; response to precipitation at this site was minimal. Median nitrate-N concentrations at Lost River at Mathias ranged broadly from a low of 0.7 to 0.9 mg/L during the driest period, increased rapidly to 1.5 mg/L even at below average precipitation in the 2" interval, and varied between 2.1 and 3.3 mg/L during periods of average to above average rainfall.

Other sites that clearly reinforce the relationship between nitrogen in streams and agricultural intensity as indicated in the correlation tables (page 20) include Cullers Run, Mill Map Run and Camp Branch Run. Cullers Run was second in nitrate levels and in nitrate increases related to precipitation — this site had the highest % row crop in its floodplain area of any of the tributary sites. Mill Gap Run and Camp Branch Run have the two lowest median nitrate concentrations, following Waites Run. Mill Gap has agricultural land in its watershed, but it is minimally used with few livestock, mainly horses, and no poultry houses. Camp Branch Run has the second lowest % of land in agriculture (8.9%), no row crop, and three poultry houses with litter that is probably applied to grass, if used in the watershed at all.

Time Series for Nitrate-N at Three Lost River Indicator Sites. As noted earlier, Baker Run was added as a regular Lost River sampling site in December 1999. Originally not included because the watershed appeared too generalized to serve as a meaningful indicator site, it was added after widespread tributary sampling for nutrients detected a stunning increase in nitrate levels in the weeks following a large rainstorm that relieved a drought. The site was added to follow these patterns through time It was not until later that GIS analysis determined the Baker Run site to be a near twin for the Lost River at Mathias, by then identified as our "signature" intensive agriculture site (Table 13). With very similar drainage area, % land in agriculture and poultry house density, they differ markedly in the lack of row crop in the Baker Run watershed. Figure 15 provides a time-series graph for nitrate at these two sites, along with Waites Run as a relatively "pristine" site.

Table 13. Results of land coverage analysis of the 3 Lost River watershed indicator study sites.

Sampling Sites	Drainage Area (sq.mi.)	Overall Land Use %			Floodplain Land Use %			Poultry Houses	
		Ag Land	Rowcrop	% Ag Land in Row Crop	Land in Floodplain	Ag in Floodplain	Row Crop in Floodplain	Number	No. /Sq.Mi.
LR at Mathias	22.73	21.80%	1.62%	7.43%	6.80%	69.50%	20.41%	42	1.85
Baker Run	22.81	20.70%	0.00%	0.00%	4.72%	43.90%	0.00%	36	1.58
Waites Run	16.8	3.90%	0.10%	2.59%	3.09%	19.50%	0.00%	5	0.3

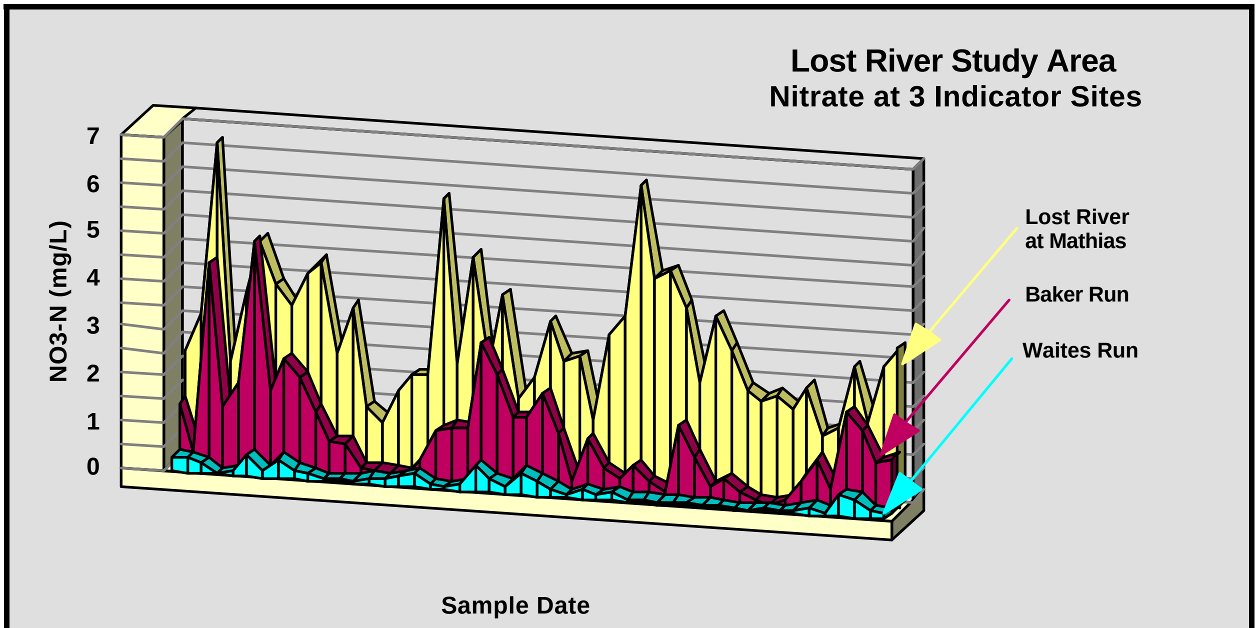

Figure 15. Time series of nitrate-N at three Lost River indicator sites.

As always, it is not possible to determine how much of the poultry litter produced in a watershed is utilized as fertilizer in that watershed. However, NAPP photography indicated many pastures and hayfields in the Baker Run watershed to be fertilized and it is reasonable to assume poultry litter was the fertilizer of choice. Figure 15 illustrates the magnitude of difference in nitrate contributions from watersheds with different land uses. Despite their overall similarity in land use, Baker Run and the Lost River at Mathias contributed markedly different nitrate concentrations in their streams; we suspect this is due to the difference in row cropping levels.

Discussion and Summary

Certain conclusions are inescapable from the data presented above. First, almost every site has a unique set of water quality and land use characteristics and responses to precipitation. However, in general, phosphorus and turbidity are low except during active runoff events at all sample sites, despite the presence of sites with presumed high phosphorus levels in the soils following many years of poultry litter application. The Lost River at Mathias, the "signature" intensive agricultural indicator site, had the highest median orthophosphate-P concentration, a relatively low 0.02 mg/L but higher than other sites. In addition to the obvious source of fertilized lands, phosphorus has been found associated with naturally phosphorus rich soils at a construction site (Gillies, 1998c) and in springs feeding Waites Run, Trout Run (another stream that flows into the Cacapon at Wardensville) and Lower Cove Run in the Lost River watershed; none of these phosphorus bearing springs had appreciable nitrate.

Nitrate is much more variable. Many sites show an extended increase in nitrate concentration following periods of substantial precipitation: paramount among these are the Lost River's mainstem and Cullers Run; correlation analysis suggests the likely source to be nitrogen leaching from crop lands. Some sites never or very rarely have elevated nitrate concentrations (the Lost River's Waites Run, Mill Gap Run, Camp Branch Run, all North River mainstem sites). Other sites have persistent sources of nitrate that appear to be associated with groundwater (Upper Cove Run 3 and possibly Cullers Run) with the ultimate source uncertain. Mill Gap Run also has at least one small spring with appreciable nitrate. None of the springs identified with elevated nitrate have appreciable phosphorus concentrations.

Fecal coliform bacteria were uniformly low during dry periods. High levels were generally associated with periods of above average rainfall, and then at a relatively small number of sites. Bacteria counts above the water quality standards for fecal coliforms in recreational waters were observed most frequently in the Lost River mainstem during the wet winter and spring of 1998. Fecal coliform bacteria levels correlated most strongly with land in row crop. This may indicate that bacteria from poultry litter used to fertilize row crops are washed into the streams. However, the areas with substantial row crop are also used intensively for many agricultural purposes, including pasture for cattle, so a link to a specific "cause" is more obscure than for nitrate.

Extended periods of abnormally dry weather occurred during the study period and reduced our ability to detect differences among sites, particularly for parameters that respond to periods of precipitation such as nitrate and fecal coliform bacteria.

The Lost River at Mathias stands out among all sites in all basins as having distinctly elevated nitrate, phosphorus and fecal coliform bacteria. It also has the greatest nitrate response to precipitation, reaching a concentration of 6.8 mg/L for several days following a saturating storm in November 1997 (Gillies, 1998c). This stream flows almost continuously through lands used for crops, hay, pasture and feedlots. Its only major tributary influence comes from Cullers Run, which has similar land uses in its lower third but has rarely been observed to contribute high bacteria and phosphorus concentrations; it does have persistently elevated nitrate levels.

Acknowledgments.

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