Final report to Canaan Valley Institute on Results of Land Use Analysis for Water Quality Study Sites in the Cacapon River's Lost and North River Watersheds

Cacapon Institute, September 22, 2003

Introduction

In September 2000, Canaan Valley Institute provided financial support for Cacapon Institute to complete development and verification of GIS land use data for water quality study sites in the Lost and North rivers of the Cacapon watershed, and for production of a report describing land use influences on water quality observed in streams.

This report will focus on the methods used to develop land use data for the study watersheds and present the results for each study site. Detailed background information on the water quality study and water quality data analysis is presented in the attached "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." Data in the latter report covers the period from March 1997 to June 2002.

Project Overview

In March 1997, Cacapon Institute initiated an intensive study in the Cacapon River's Lost River watershed to determine land use influences on nutrient and bacteriological water quality. The intensely agricultural Lost River watershed was ranked first on the Potomac Headwaters Interagency Water Quality Office list of watersheds in need of agricultural Best Management Practice (BMP) implementation, primarily due to the density of integrated poultry and associated agriculture (cattle, crop) in this basin. The Cacapon's North River watershed was added to the study in June 1998 to establish nutrient water quality patterns in a relatively low intensity agricultural basin.

Sampling sites were selected with the help of knowledgeable personnel from the USDA-Natural Resources Conservation Service, West Virginia University, the US Fish and Wildlife Service and the Potomac Headwaters Resource Alliance. Each site provided different mixes of land use within its watershed, ranging from nearly 100% forested to heavily agricultural in the floodplain. Small watersheds were selected to serve as indicator sites for how different land uses effect water quality. Mainstem sites, with watersheds larger than 30 sq. mi., were selected to accumulate impacts from many sources.

Financial support for these water quality studies came from many different sources, including the U.S. Fish and Wildlife Service, WV Stream Partners, the Potomac Headwaters Resource Alliance, and the members of CI.

Over the years, a substantial data set accumulated, and clear patterns become apparent. Interpretation of that data, however, was hampered by the lack of accurate, quantitative data on land use in each study watershed. In the spring of 2000, CI began the process of

digitizing land cover information for the two study watersheds using NAPP photographs, with an emphasis on agricultural uses. USFWS, Canaan Valley Institute (CVI) and ESRI (for GIS software) provided funding for this phase of the project. Technical and in-kind support was provided by Paul Kinder, Corey Anderson and Matt Sherald of CVI, Ron Estep of the USDA-NRCS, and John Young of the USGS-BRD.

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, as 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.

CVI 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-SCS, 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.

Lost River watershed. NAPP photographs (April 1996, 1997) on loan from the USDA-NRCS were scanned at 150 dpi, saved as TIFF files, rectified, digitized, and the resulting land use coverage field verified where possible. Aerial photographs were rectified (linked) to topographic maps by a minimum of 6 points (usually 8 or more) using the ArcView Image Analysis extension. The topographic maps were produced as spatially referenced TIF files by the WVDNR. The resulting coverage was in 1927 North American Datum. These NAD27 files were later converted to NAD83 by CVI staff in September 2001 using ARC/Info.

It quickly became apparent that the parallax error inherent in NAPP photography would create problems. We had two somewhat conflicting requirements: the photographs needed to be accurately rectified and the borders of the many adjacent images had to match so that landscape features at the edges could be digitized. After consultation with our technical advisors, we elected to rectify so that photographs along the Lost River mainstem were closely linked to features on the topographic maps, and the other photographs were linked to them. Since we had many photographs to link, the spatial errors became increasingly large with increasing distance from the Lost River mainstem. These errors were later partially corrected by moving agricultural shape file elements to corresponding "open areas" on the topographic maps. However, we are confident that the land coverage percentages presented below provide an accurate representation of each sampling site's watershed.

North River watershed. CVI provided high-resolution DOQQs for Hampshire/Morgan counties (based on 1996/1997 NAPP) for use in this watershed. These DOQQs were projected in NAD83. NAPP photography, as described above for the Lost River watershed, was used to establish coverages for those portions of the North River watershed found in the Needmore and Baker quads; these were later corrected using DOQQs in NAD83 downloaded from the West Virginia State GIS Technical Center.

Cacapon River watershed. Thanks to an arrangement with the USDA-NRCS, NRCS interns digitized the remainder of the Cacapon River watershed during the summer of 2001 using 1996/1997 DOQQs (NAD83) provided by CVI and downloaded from the West Virginia State GIS Technical Center website.

Results

Table 1 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 view of water quality in a heavily forested basin for that project. The Lost River tributary Baker Run was not included as a regular site until early 2000.

Table 1. 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	21.8%	1.62%	7.43%	6.80%	69.50%	20.41%	42	1.85
LR at LostCity	68.09	19.2%	1.03%	5.42%	5.83%	64.19%	14.41%	85	1.25
LR at LostRiver	109.07	18.6%	0.97%	5.24%	5.86%	58.62%	12.67%	123	1.13
LR at HangingRock	157.42	19.5%	1.14%	5.88%	6.22%	60.39%	15.23%	188	1.19
LR at SquirrelGap	168.53	18.7%	1.07%	5.74%	5.97%	59.27%	14.82%	190	1.13
LOST R. TRIBUTARY									
Cullers Run	11.48	16.8%	0.61%	3.63%	6.69%	60.45%	9.08%	12	1.04
Upper Cove Run3	7.66	18.3%	0.00%	0.00%	1.95%	54.55%	0.00%	24	3.13
Upper Cove Run1	9.14	17.5%	0.19%	1.21%	3.70%	34.79%	3.67%	28	3.06
Mill Gap Run	2.59	15.9%	0.00%	0.00%	0.81%	58.22%	0.00%	0	0.00
Camp Branch Run South	5.70	8.9%	0.00%	0.00%	5.47%	16.98%	0.00%	3	0.53
Kimseys Run	18.44	14.5%	0.00%	0.00%	5.28%	39.91%	0.00%	15	0.81
No-Name Trib of Kimsey R.	1.48	16.4%	0.00%	0.00%	0.00%	0.00%	0.00%	0	0.00
Baker Run	22.81	20.7%	0.00%	0.00%	4.72%	43.90%	0.00%	36	1.58
Waites Run	16.80	3.9%	0.10%	2.59%	3.09%	19.50%	0.00%	5	0.30
NORTH RIVER MAINSTEM									
NR at Skaggs	10.93	16.4%	0.00%	0.00%	4.55%	20.45%	0.00%	3	0.27
NR at FH Rd.	38.72	18.1%	0.15%	0.84%	4.80%	33.76%	0.00%	16	0.41
NR at Rio	59.86	16.0%	0.11%	0.70%	4.61%	34.15%	0.00%	21	0.35
NR at Rt.50	112.78	16.0%	0.43%	2.69%	5.55%	45.78%	4.90%	22	0.20
NR at IM	183.93	22.4%	0.40%	1.78%	5.75%	45.47%	3.34%	40	0.22
NRat Rt. 127	204.35	20.9%	0.39%	1.89%	5.71%	42.02%	3.22%	40	0.20
NORTH R. TRIBUTARY									
Skaggs Run	7.61	21.6%	0.55%	2.54%	4.58%	24.39%	0.00%	11	1.44
CACAPON MAINSTEM									
CR at Arnolds Ford	327.37	13.6%	0.79%	5.77%	n.d.	n.d.	n.d.	210	0.64
CR at USGS Gage Site	675.09	15.3%	0.54%	3.53%	n.d.	n.d.	n.d.	251	0.37
Cacapon Watershed Overall	680.14	15.2%	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 Baker 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 (Upper Cove 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 was assumed for the purposes of this report that all but approximately one percent of the land not included in the above agricultural categories was forested. The remaining one percent consisted of water bodies (rivers, streams, ponds, one lake), roads, residential areas and small commercial facilities.

Discussion of Land Use Quantification

This GIS project had a number of goals. First and foremost was to accurately quantify agricultural land use in the watershed for each of Cacapon Institute's water quality study sites to facilitate meaningful analysis of data. While difficulties with the images used for the Lost River had an impact on the accuracy of spatial referencing of shape files, the overall land cover information is the most reliable to date. We also made a mistake by allowing the "suggestion" of our scanning software to convince us that a suitable resolution for the scanned photographs was 150 dpi; this resolution was too low and made on-screen interpretation of images more difficult than it should have been. We are in the process of using the improved imagery and spatial referencing of the DOQQ imagery to improve the Lost River coverages.

A secondary goal of this project was to determine how well objective data supported the subjective knowledge used to select sites as "indicators" of different land uses. A comparison of the initial rationale for selecting each indicator site and the results of land cover analysis follows:

- Lost River at Mathias. This site was selected because it was heavily agricultural in every category. This was verified by the land cover analysis. It has a high percentage of land in TAL, the highest percentage of land in row crop, the highest percentage of agriculture in the floodplain, the highest percentage row crop in the floodplain, and the third highest density of poultry houses.
- Cullers Run. This site was selected as the only tributary in the Lost River Study Area with a significant amount of cropland, as well as fairly high density of poultry houses. It does, in fact, have more cropland than any other tributary site (only three have any), and most of that row crop is located in the floodplain, where it is likely to have the greatest and most immediate impact on water quality. Poultry house density is fourth highest among the nine tributary sites.
- Upper Cove Run 3. This site was located slightly downstream of a large concentration of poultry houses, and was included in the study to assess the impacts of poultry houses themselves, in a watershed with minimal area for land application of poultry litter. It does have the highest density of poultry houses, but also has a fairly high percentage of land in the TAL category. No row crop was observed in this watershed, and a significant percentage of the TAL land appeared marginal.
- Upper Cove Run 1. This site was located at the confluence of Upper Cove Run with the Lost River. It was selected for the same reasons as Upper Cover Run 3, as well as its location downstream of the small town of Mathias. We were interested in "town" as well as poultry litter effects. Town effects would be difficult to detect however, as the "town" has, within its boundaries, pasture, feedlots and some row crop. This watershed has about 3.5% of its floodplain area planted in row crop, which was not known when we selected the site.
- Mill Gap Run. This site was selected because it had no poultry, no row crop and little pasture. It was perceived as mostly forested with moderate residential development on ridge tops. It, in fact, has no poultry or row crop, but has TAL in a percentage similar to most of the study watersheds. This is one of those watersheds with remote areas developed at low density on land that was once used for

- Camp Branch Run South. This site was selected to assess the direct impacts of poultry houses in a watershed otherwise covered in pasture and forested. Three poultry houses are located adjacent to the stream just upstream of the sampling site. An unexpected bonus for this site was the low percentage of land in TAL and the absence of row crop determined through land cover analysis.
- Kimseys Run. This site was selected as a tributary with a moderate number of poultry houses, no row crop and with pasture mostly located away from stream – to assess water quality impacts in a watershed with a substantial poultry litter resource and only grass to put it on. No surprises here.
- No-Name Tributary of Kimseys Run. This watershed was selected as 100% forested. It's not -- it has a substantial area of managed hayfields at its headwaters. The photographic images of these fields show clear signs of fertilization, which helps explain some unexpectedly high nitrogen concentrations we detected early in the study, which were very surprising at the time.
- Baker Run. This watershed was initially considered, and rejected, as a study area because it appeared to lack specific defining characteristics to make it suitable as an indicator site. However, we run occasional "spot checks" of nitrate-nitrogen levels in many Lost River tributary streams, and discovered that, following the drought of 1999, nitrate concentrations became unusually high in Baker Run for a considerable time. We decided to add it as a regular site. Land cover analysis shows this was a fortunate decision. Based on the land cover data presented here, Baker Run is a valuable "pair" to the Lost River at Mathias site, because their drainage area, percentage of land in agriculture and poultry house density are very similar. They differ in that agriculture in the Baker Run watershed lacks row crops, one of the defining features of agriculture in the Lost River at Mathias watershed.
- Waites Run. This site was selected due to its small number of poultry houses and limited agricultural land, all located well away from the riparian area, light residential development along a part of the stream, and heavily forested headwaters region in the George Washington National Forest. Land cover analysis confirms the basis for the selection and found this site to have by far the lowest percentage of TAL.
- North River at Skaggs Run. This site was selected as having relatively light agricultural land cover, and as a comparison to Skaggs Run (below), which was expected to show a greater agricultural influence.
- Skaggs Run at North River. This site was selected as a small, North River watershed having relatively heavy agricultural land cover. With among the highest percentage TAL of all study sites, the fourth highest poultry house density, and a moderate percentage of land in row crop, it fulfilled our expectations. Unlike Lost River study sites, row crop in this watershed is located on hilltops, not in the floodplain. Construction of a modern four-land highway began in the headwaters of Skaggs Run in late 2000, and attempts to grow grass for bank stabilization on rocky slopes may have contributed to elevated nitrate and phosphorus concentrations in this stream.

The final goal of this project was to determine how the quantified land uses relate to water quality. As a prelude to that report (see attached document titled "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."), Table 2 presents correlations of land use variables with one another on combined North and Lost River data (Table 2). Varying levels of covariance between land use variables are apparent. However, many of these relationships are weak, with coefficients of determination less than 30%. The strongest correlations were detected between the three measures of row crop land use -- percent total land in row crop, percent agricultural land in row crop, and percent of floodplain in row crop -- with coefficients of determination 90% or higher for these three variables, differentiating between their effects on water quality is problematic. Poultry house density was not correlated with any of the other land use variables.

Table 2. Multivariate Correlations: Land Use Variables on North and Lost River Land Use Data. The top half of the table provides significance levels (indicated as: n.s. for not significant; (*) p<=0.05; (**) p<=0.01; (***) p<=0.001) and coefficient of determination (expressed as a percent). The bottom half of the table provides the correlation coefficient.

	Overall Land Use					Floodplain Land Use		Poultry Houses	
	Drainage Area	Ag Land	% Rowcrop	Ag Land in Row Crop	Land in Floodplain	Ag in Floodplain	Row Crop in Floodplain	Number	No./ Sq.Mi.
Drainage Area	1.0000	n.s.	* 20%	* 19%	* 23%	n.s.	n.s.	** 43%	n.s.
Ag Land	0.4081	1.0000	* 21%	n.s.	n.s.	* 22%	n.s.	n.s.	n.s.
% Rowcrop	0.4422	0.4572	1.0000	*** 95%	** 40%	*** 46%	*** 93%	*** 50%	n.s.
Ag Land in Row Crop	0.4339	0.3041	0.9760	1.0000	** 37%	** 41%	*** 90%	*** 50%	n.s.
Land in Floodplain	0.4817	0.3022	0.6291	0.6103	1.0000	* 23%	** 36%	* 20%	n.s.
Ag in Floodplain	0.3644	0.4712	0.6771	0.6437	0.4770	1.0000	*** 53%	** 30%	n.s.
Row Crop in Floodplain	0.4074	0.3766	0.9661	0.9506	0.5954	0.7248	1.0000	*** 54%	n.s.
PH#	0.6526	0.3275	0.7043	0.7073	0.4445	0.5491	0.7325	1.0000	n.s.
PH/SQMI	-0.2308	0.2286	0.2242	0.1897	0.0549	0.3524	0.2571	0.1907	1.0000

Conclusion

Meaningful analysis of water quality data in relation to land-use was facilitated by the development of quantified land-use coverages using GIS tools, which was the ultimate goal of this and related projects.

Cacapon Institute has used the completed land-use product for analysis and reporting of chemical and biological water quality data, and in the effective presentation of those analyses in a number of public settings. For example, in February 2002, CI made a presentation before the WV Environmental Quality Board on the subject of developing nutrient criteria (see enclosed CD with PowerPoint presentation entitled "In-stream Nutrients and Landscape Setting: An Overview;" filename "EQB Nutrient Standards ver 2.ppt"). This presentation provided a view of the complexity of nutrient patterns in landscape settings where potential nutrient sources abound. It also provided a daunting vision of the complexity of the task undertaken by WV Nutrient Criteria Committee (CI is a member of that body) as it works to develop water quality criteria for nutrients in WV.

We are currently seeking funding to expand a pilot project we conducted with Shepherd College and WVDEP in 2000 exploring relationships between water quality chemistry, biological (periphyton and benthic macroinvertebrates) and land use parameters.

References

USDA-NRCS, 1998. Soil Survey Geographic (SSURGO) data base for Grant and Hardy counties West Virginia. USDA-NRCS.

USDA-SCS, 1978. Soil survey of Hampshire, Mineral, and Morgan counties West Virginia. National Cooperative Soil Survey. 131 p. plus maps.

USDA-SCS, 1989. Soil survey of Grant and Hardy counties West Virginia. National Cooperative Soil Survey. 246 p. plus maps.

West Virginia State GIS Technical Center
ftp://centauri.geo.wvu.edu/pub/Clearinghouse/DOQQ/NAD83/
Standard digital orthophotos, 3.75-minute coverage, are cast on the Universal Transverse Mercator (UTM) projection on the North American Datum of 1983 (NAD83) with coordinates in meters.