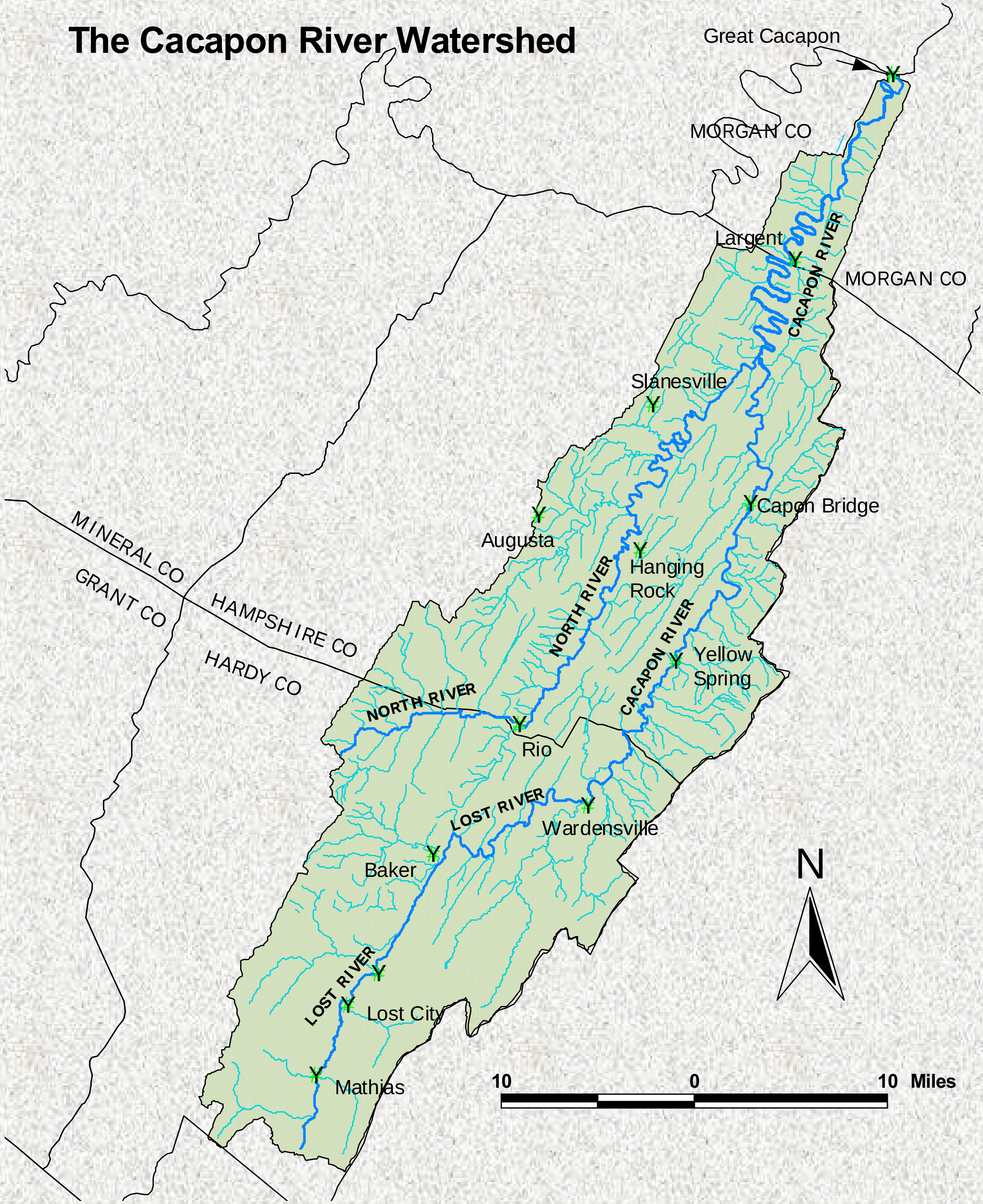
Portrait of a River

The Ecological Baseline of the Cacapon River

Pine Cabin Run Ecological Laboratory
High View, WV

The Cacapon River Watershed



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Portrait Of A River: The Ecological Baseline of the Cacapon River by
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LEFT: New road and bridge service recreational subdivision along the Cacapon River. At the Lab's request, developer included a 90-foot riparian conservation easement on all riverfront lots, protecting 4.5 miles.

ON THE FRONT COVER: Aerial view of the Cacapon River watershed at Caudy's Castle. Hampshire County, WV.

ON THE BACK COVER: Aerial view of the Cacapon River at the community of Forks of the Cacapon, Hampshire County, WV. Photo illustrates the two major land uses in the basin — forest and farms.

Summary

In 1989, the Pine Cabin Run Ecological Laboratory began an intensive, four-year effort to assemble an ecological baseline of the Cacapon River.

The baseline — a detailed scientific picture of the river's current ecological health — is part of a citizen-based effort[14] to protect the Cacapon (pronounced *Kuh-kay-pun).* The river, located about 80 miles west of Washington, B.C., faces an uncertain future. Increasing population, the growth of new industries, and the proposed construction of dams and a major highway have the potential to damage the river basin's environmental health.

Like a medical chart, the baseline is part of an early warning system, allowing future changes in the river's health to be diagnosed quickly.

Like a medical chart, the baseline is part of an early warning system, allowing future changes in the river's health to be diagnosed quickly and, it is hoped, treated before problems become too serious.

To the best of our knowledge, this baseline is the most comprehensive ever assembled for an entire river continuum. It is more than a dry scientific document, however. It is a conservation tool that can be used to trigger enforcement of environmental laws, to help develop new policies, and to involve the public in the process of learning about and protecting rivers. It is also meant to serve as a model — all of the nation's rivers could benefit from a baseline.

Except for one parameter, this baseline was assembled using research methods approved by the U.S. Environmental Protection Agency. Data produced by these methods can be used in courts of law and regulatory hearings. In many states, including West Virginia, this is important since state governments often lack the data needed to enforce environmental laws.

The four-year process of assembling the baseline (1989 through 1992) included 149 trips to 106 study sites and involved many hands-on volunteers, school groups, and extensive interactions with government, business, and community leaders.

Baseline findings

The baseline reveals a Cacapon River that is relatively healthy, but burdened by pollution created by certain land uses. It shows that the river's health varies significantly, depending on location and water level:

> **Location** — We divided the Cacapon into four reaches: Lower Cacapon, Middle Cacapon, Lost River, and North River. Two upstream reaches — Lost River and Middle Cacapon — are more polluted than the others, in part because cattle have free access to these reaches. As cattle access sites increase, so do pollution levels.

> **Water level** — The river is more polluted at high water lev-

els (after storms) than at low water. During high flow, pollution levels often exceed water quality standards established to protect human health.

These water quality changes are consistent with "nonpoint source" pollution. Unlike "point source" pollution, which comes from an easily located source such as a factory outlet pipe, nonpoint source pollutants wash off the landscape from a broad array of hard-to-control sources. Rivers suffering from point source pollution are often more polluted in downstream reaches and during low water. In contrast, the Cacapon suffers from pollution in upstream areas and at high water. A primary source of this nonpoint pollution is run-off from farms, particularly areas used by livestock.

The river's nonpoint pollution problem has public health implications:

> *First,* pollutants are transported downstream into areas used for recreation and include hundreds of riverside homes, six children's camps, and five public access sites.

> *Second,* many boaters use the Cacapon during times of high water, when unhealthy pollution levels occur.

The Cacapon's pollution problems are aggravated by damage to the river's riparia — the riverside corridors of vegetation that defend the river against many threats. For example, a healthy riparian corridor can block pollutants from entering a river, soak up storm waters, and reduce erosion.

CONFLUENCE
The meandering Cacapon joins the Potomac at the town of Great Cacapon, WV.

Photo taken September 2005

Restoring the Cacapon's damaged riparia — by planting trees and shrubs, stabilizing banks, or limiting cattle access to the river — will be an important first step toward improving the ecological health of the Cacapon. Other needed steps include:

> Preventing future riparian damage.

> Continued monitoring of the Cacapon's health. Without periodic check-ups, the baseline's early warning value will be lost.

> More study. For example, we need to know if the Cacapon harbors other serious pollutants, such as pesticides or heavy metals.

Protecting the Cacapon will take cooperation — from state and federal government officials, business owners and civic leaders, and landowners and parents. The time to act is now.

Prologue

Climb atop Caudy's Castle, a dramatic sandstone tower that pierces the sky in northeastern West Virginia, and you are greeted by a stunning sight. Emerald ridges march to the horizon and a slender azure ribbon glitters in the valley below: the Cacapon River. It is a sight that few—especially those who love to fish, paddle, or just enjoy rivers — will ever forget.

But as population and economic growth bring change to this rural corner of the nation, the Cacapon is flowing inexorably toward an uncertain future.

As population and economic growth bring change to this rural corner of the nation, the Cacapon is flowing inexorably toward an uncertain future.

Portrait of a River: The Ecological Baseline of the Cacapon River is part of an effort to shape that future, to ensure that the Cacapon's ecological health is permanently protected and, where necessary, improved. It presents the findings of an intensive, four-year effort to assemble the river's ecological baseline — a scientific picture of the river's current health. Like a medical chart, this baseline will allow future changes in the river's health to be quickly diagnosed and, we hope, treated before the river becomes too sick.

This baseline may be the most comprehensive ever assembled for an entire river. It is a popular, expanded version of a technical paper to be published in a scientific journal. No information has been left out; rather, the findings are presented in a way that may be clearer to those unfamiliar with the science of ecology.

In order to put the Cacapon's current health in context, we have divided this report into four major parts:

> *The Past* briefly reminds us of changes that have already visited the watershed.

> *The Present* provides a detailed look at the current health of the Cacapon River. This section is the heart of the baseline.

> *The Future* identifies solutions to the Cacapon's environmental problems.

> An *Epilogue* touches on a few ways the baseline fits into the big, even global, environmental picture.

This information is offered in the belief that, provided with facts, concerned citizens will act to protect the Cacapon. The publication also reflects our confidence in the ability of people from all walks of life to work together to protect a river that, in one way or another, touches us all.

We hope you enjoy — and learn from — this document. Now let's get to work solving the problems clouding the Cacapon's future.

George Constantz
Nancy Ailes
David Malakoff

The Past

It is easy to imagine that the waters of the Cacapon River have always meandered their way northward, forever taken the 112-mile journey from the river's headwaters in Hardy County, through the sharp-edged Appalachian ridges of Hampshire County, to their final mingling with the Potomac River in Morgan County.

But the sharp-eyed observer might notice a few signs along the way indicating that the watershed has not always looked the way it does today. A seashell fossil far from the ocean, a thick layer of sandstone balanced vertically on edge... these are clues that the Cacapon River basin has a rich geologic history spanning hundreds of millions of years *(see "Geologic Origins" box).* Similarly, the abandoned railway and the lonely log cabin hint at the valley's shorter, but no less significant, human history.[61]

No one knows exactly when humans first set foot in the Cacapon River basin. Most anthropologists believe we have been in Appalachia since the last ice age, about 12,000 years ago, and a few even believe we were here 100,000 years ago. We do know that by the late 1600s, human tribes populated the area and left their mark on the land. They used fire, for example, to maintain clearings that attracted game animals.

The next wave of human immigrants, from Europe, changed the basin in ways we can still see today. European settlers arrived in the early 1700s. Seeking good soil and water, they followed the river valleys, erecting cabins at promising sites. Sometimes, it was quick work: A one-room log cabin — like the Lab's headquarters — could be erected bv four men in a dav. Valleys with the best soil and sunlight — such as those along the Cacapon — were occupied first.

Settlers found themselves in one of the richest environments on earth. Flocks of passenger pigeons darkened the sky. Heavily forested mountains sheltered woodland buffalo, elk, and timber wolves.

In less than 200 years these and other species were gone, hunted to extinction or displaced by habitat changes. By the 1920s, the thick forests were also only a memory. With the coming of the railroad, virtually every major tract of Appalachian forest was logged — cleared for agriculture or cut for fuel, turpentine, and ship masts.

Geologic Origins

Weathered outcrops and boulder-strewn mountainsides of the Cacapon River basin offer clues to a geologic history hundreds of millions of years old.

About 250 to 300 million years ago, Appalachia underwent its last phase of mountain building. Peaks were thrust four to six miles above sea level, then slowly eroded into the rounded shapes we see today.

This period of mountain building — known as the Alleghenian orogeny — also left massive folds and fractures in rocks of the Cacapon River basin.

Today, the area is part of the Ridge and Valley Province. From the air or on a map you can see why: accordion-like folds have forced the Cacapon and other rivers into a series of straight, parallel drainages divided by ridges.

Most Cacapon rocks are sedimentary — made of tiny grains of rock that collected in water and then were compressed and cemented together. The presence of sedimentary rocks — and the occasional trilobite fossil — tell us that an ocean once covered the basin.

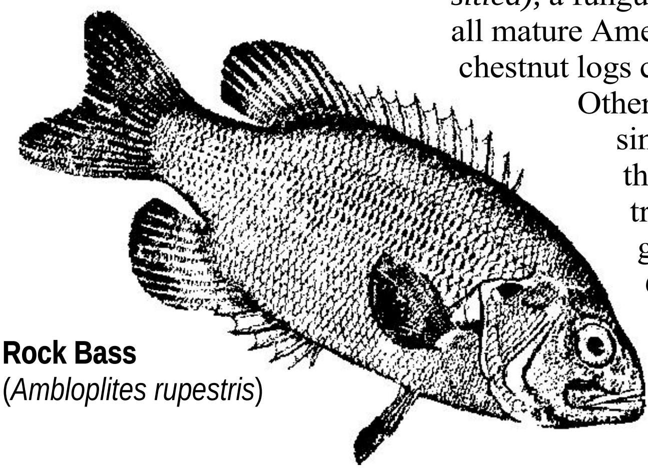
The oldest rocks in the basin are over 500 million years old. Much younger, however, are some of the landscape features. Only 20,000 years ago huge landslides occurred. Look carefully along the east side of Lost River, just north of the town of Lost River, and you can find the remains of one of these prehistoric landslides. Approximately one million cubic feet of sandstone fell from the hillside and spilled into the valley.

(See "The Geology of the Cacapon River Basin" in the Summer 1992 issue ot *Cacapon*, the Lab's river journal.)

In the Cacapon watershed, you can still find relics from industries that relied on logging. For example, along Waites Run — a tributary near Wardensville - are several large wood-fired furnaces that once forged pig iron. Similarly, abandoned rail lines that once carried timber and passengers can be spotted in the basin, though they are largely hidden by second-growth trees.

Deforestation surely had an impact on the Cacapon. Tons of soil eroded from denuded mountain slopes. Silt muddied the water, destroying fish spawning areas and blocking sunlight that powered aquatic plants. Settlers along the Cacapon's banks could have experienced frightening flash floods, as vegetation no longer soaked up and then slowly released *run-off* *(see "Floods,"page 7).*

Settlers not only *removed* organisms from the basin, they also *introduced* new species. One, the chestnut blight *(Cryphonectria parasitica),* a fungus accidentally introduced about 1900, eventually killed all mature American chestnut trees *(Castanea dentata).* Today, rotting chestnut logs can still be found in the forest.



Rock Bass
(*Ambloplites rupestris*)

Other exotic species that have degraded the Cacapon River basin include the gypsy moth *(Lymantria dispar),* an insect that can defoliate mountainsides and eventually kill the trees, and honeysuckle *(Lonicera japonica),* a fast-growing vine that shades out native plants. *(See *On Gypsy Moths and Pesticides" in the Winter 1991 issue of* Cacapon, *the Lab's river journal)*

But not all introduced species are seen as a threat. Most people aren't aware that the rock bass *(Ambloplites rupestris)* and the smallmouth bass *(Micropterus dolomieui)* — two popular sportfishes of the Cacapon — are not native to the river *(see "Fishes," page 7).*

Human settlement continues today. Along the river, numerous recreational cabins have been built by people from nearby cities. The permanent population of the three counties that include the Cacapon has also grown, from 35,608 in 1980 to 39,603 in 1990, an increase of 11 percent.[34]

Change in the basin will continue. To protect the Cacapon, we need a tool that will help us evaluate how changes will affect the river. The baseline is that tool.

The Lost River

A remarkable characteristic of the Cacapon River is that it disappears.

At the Route 55 bridge crossing the Lost River west of Wardensville, you'll find that a once robust river suddenly dries up. At 'The Sinks," you can sometimes hear the water disappear with a reverberating suck.

Where does the water go? It probably flows into cracks in the underlying rock. The area is underlaid with an unusually high amount of carbonated rock", such as limestone. As these rocks were uplifted millions of years ago, they were bent and fractured. Water began flowing through the cracks, dissolving the rock and enlarging the channels.

Today, as a result of this geologic history, the Lost River literally loses its water into the ground. For much of the year, no surface water can be seen for 2.5 miles.

No one knows how much water actually flows underground through the channels versus how much percolates through the riverbed. Whatever the answer, when the river reappears just above Wardensville, it has a new name: Cacapon.

Fishes

The Cacapon has long been known as one of the best places to fish in the region. Most anglers seek the smallmouth bass, a hard-fighting member of the sunfish family.

But the smallmouth is just one of 39 fish species inhabiting the river. The most abundant is the redbreast sunfish *(Lepomis auritus)*. Other species include:

- 3 trouts (which do not reproduce in the river);
- 4 suckers;
- 13 minnows;
- 5 catfishes;
- 8 sunfishes (including bass);
- 3 darters; and
- 1 sculpin.

The Cacapon ranks first in number of fish caught per cast (compared to the nearby Shenandoah River and South Branch of the Potomac). The river has yielded excellent numbers of trophy-sized smallmouth bass (3 pounds or greater). Between 1986 and 1988, 32 trophy bass from the Cacapon were registered with the state Department of Natural Resources.

While the smallmouth is the Cacapon's high-profile fish, the rock bass *(Ambloplites rupestris)* may actually tell us more about the river's health. This fish — known locally as the "redeye" or "goggleye" — needs rocky, silt-free river bottoms to prosper. It is abundant in Cacapon reaches with relatively silt-free waters.

Because they meet the criterion of being "over five miles in length with desirable fish populations and public utilization thereof," the state has listed the Lost, North, and Cacapon rivers as "high quality streams."[20] For everyone who likes to fish, the challenge will be to keep them that way.

(See "Fishes of the Cncopon River" in the Summer 1989 issue of *Cocopon.)*

The Present

Look at a map (see inside front cover) and you'll see that three major river segments — Lost, North, and Cacapon rivers — drain the Cacapon River basin.

The Lost and Cacapon are the same river. The two names arose because the Lost flows underground at "the Sinks," where Sandy Ridge blocks its path in Hardy County (*see "The Lost River, * page* 6). The river emerges a few miles downstream.

North River, the major tributary, meets the Cacapon at the small community aptly named Forks of Cacapon (*see photo, page 13*). The confluence is located about three-fourths of the way down the Cacapon's journey to the Potomac.

Together, these rivers drain 680 square miles (229,376 hectares) — or about 47 percent of the combined area of Hardy, Hampshire, and Morgan counties. Excluding the North River, the Lost/Cacapon River drains 475 square miles (177,152 hectares),22 while the North River drains 205 square miles (52,224 hectares).[52]

The majority of the basin is forested — 79 percent is covered by trees, primarily a mix of coniferous and deciduous species, including white pine and chestnut oak. Agricultural lands cover 19 percent of the basin, while residential development, barren lands, and water cover the remaining two percent.[43]

Farming is concentrated in the upstream half of the watershed — in the wide valleys of the Lost and North rivers and the upper half of Cacapon. Upriver of Capon Bridge, pasture and crops often edge up to the riverbanks.

In contrast, the narrow valleys downstream of Capon Bridge are more remote. In 1982, this wildness led the National Park Service to identify the lower 80 miles of the Lost and Cacapon rivers as eligible for the federal Wild & Scenic Rivers System.[43] Lack of local support, however, prevented the rivers from being added to the system.

The basin has a distinctly rural quality. It includes only two incor-

Floods

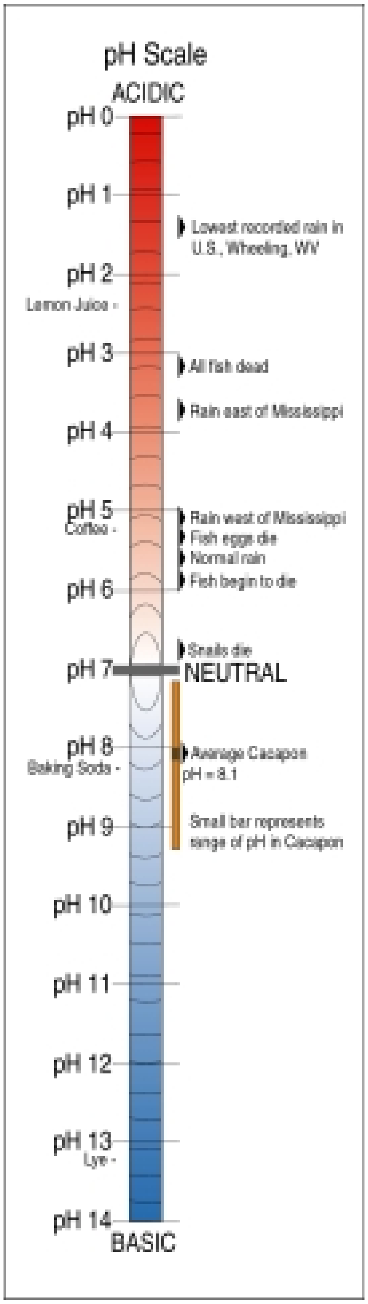
Many who remember the 1985 flood on the Cacapon wonder: "Was it the biggest ever?"

No. According to a list of the top ten Cacapon floods compiled by the Lab, it was only the seventh largest on record. The data suggest that floods equal to the 1985 event occur every 14 years.

THE TOP 10

Date	Peak Flow (cfs)	Height (ft)
Mar 18, 1936	87,600	30.1
May 1889	57,500	24.7
Aug19,1955	55,500	24.3
Aug16, 1942	52,600	23.7
Apr 26, 1937	47,400	22.6
Jun22,1972	45,500	22.2
Nov5,1985	44,500	22.0
May 12, 1924	38,000	19.3
Apr 17, 1929	36,000	20.0

(See "Floods" in the Spring 1991 issue of *Cacapon.)* cfs = cubic feet per second; ft=feet



porated communities — Wardensville in Hardy County, with a 1990 population of 140; and Capon Bridge in Hampshire County, with 192 people. There is no heavy industry in the basin.

Designing the Baseline

Researchers who studied the Cacapon River in the recent past concluded that it had good water quality.21 In one study, 19 water samples collected on a quarterly basis between May 1976 and October 1980 averaged 99 percent saturation of dissolved oxygen — a figure indicating good water quality.[43] Other studies found no dangerous levels of heavy metals, pesticides, or solvents.

The Lab's baseline research took place between 1989 and 1992. We collected water samples and aquatic organisms, and recorded observations of plant life and other conditions along the Cacapon (*see "Do Bottom-dwelling Animals Indicate Water Quality?" below*). A total of 149 visits were made to 106 sites along the river: 20 sites were studied twice, seven were studied three times, and three sites were visited during all four years. All visits took place between May 29 and October 6. (*For more technical information on materials and methods, see the Appendix on page 29.)* We studied eight parameters:

Subjective Impression	Turbidity (NTU)
Crystal clear	1
Clear	1-2
Slightly milky	2-4
Fairly muddy	4-7
Muddy	8

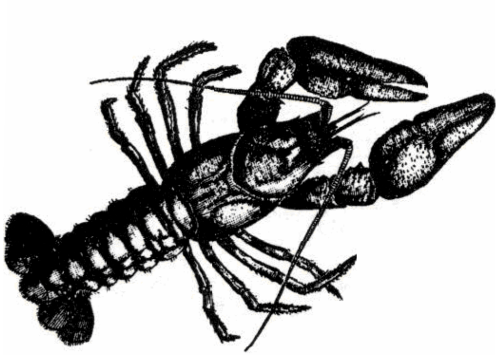
•**Water temperature**, which influences the kinds of plants and animals that can survive in the river;

•**Turbidity**, a measure of water clarity. Turbidity is measured in Nephelometric Turbidity Units (NTU). The lower the NTU, the clearer the water (*see box*). Turbidity is an indirect measure of the amount of sediment in the water column. In excess, sediment can smother fish eggs and block sunlight needed by aquatic plants;

•**pH**, a measure of the concentration of hydrogen ions in a solution. The denser the hydrogen ions, the more acidic the solution and the lower the pH; the higher the pH, the more basic the solution is (see pH scale). Water that is too acidic cannot support aquatic life. For example, below a pH of 6, fish begin to die;

Do Bottom-dwelling Animals Indicate Water Quality?

During the process of assembling the baseline, Lab staff collected 143 samples of the Cacapon's benthic macroinvertebrates — small animals without backbones that live on the bottom of the river. They include snails and clams, insects, crayfish, and worms, collected mostly from the river's shallow riffles.



On many rivers, these invertebrates are important indicators of water quality. Many species, for example, cannot live in polluted water, so their absence serves as a warning signal that toxic chemicals may be present.

On the Cacapon, however, early analyses suggest that benthic macroinvertebrates may not be a good indicator of some of the river's water quality problems. In part, this may be because the primary nonpoint pollutants found in the basin — silt and fecal residues — do not harm many of the benthic organisms in riffles, even though these pollutants can still degrade other parts of the river and threaten human health.

•**Alkalinity**, a measure of water's resistance to acidification;

•**Ammonia**, a by-product of animal farming that can poison aquatic organisms;

•**Phosphate**, a nutrient. High levels of phosphate would suggest that fertilizers applied to surrounding lands are washing into the river. Excess phosphate can stimulate the growth of nuisance aquatic plants;

TABLE 1
Summary statistics for water quality data collected on the Lost, North, and Cacapon rivers, 1989—1992.

Parameter	WV Standard	Nat'l Median	Mean	Standard Deviation	Range	Number of Observations
Temperature	30.6	—	23.7	2.34	18.4-30.7	117
Turbidity	*	—	10.5	48.90	0.7-512	117
pH	6.0—9.0	7.8	8.1	0.43	7.2-9.3	118
Alkalinity	—	104.3	60.5	19.8	20-107	97
Ammonia	0.05	—	0.02	0.03	0-0.20	95
Phosphate	—	0.13	0.03	0.02	0-0.14	99
Fecal Coliforms	400	355	302	609.00	0-2,400	139

Notes: temperature (degrees C), turbidity (NTU), pH (units), total alkalinity (mg/l), phosphate (mg/l), fecal coliforms (MPN/100ml); WV Standard = acceptable limits in West Virginia[57], Nat'l Median=median for America's rivers[54]; — = none available, * = 10 NTUs above background level.
October 2005 Note: See Appendix 2 for discussion and revised version of this table.

•**Fecal coliforms**, bacteria that live in the intestines of birds and mammals and are released in feces. While fecal coliforms themselves do not cause disease, their presence indicates fecal contamination of the river and, possibly, the occurrence of pathogens — organisms that threaten human health; and

•**Mean daily discharge**, a measure of the average daily volume of flow. Changing water level alters a river's water quality.

Four Perspectives On the Data

To get a balanced picture of the Cacapon, we analyzed the data from four perspectives:

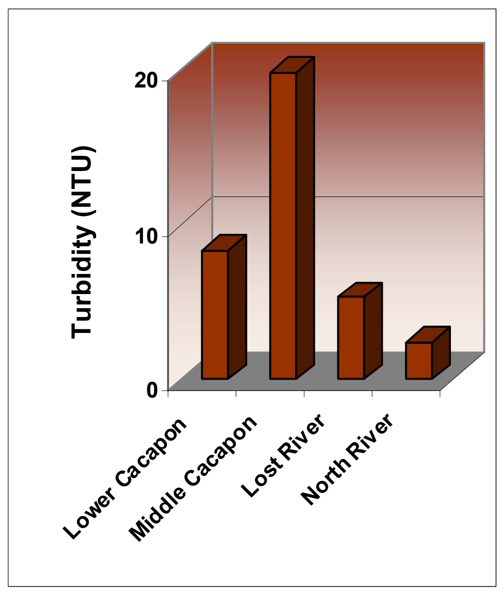
→ First, we took an "entire basin" view, which gives a broad, general overview of the entire river's health.
→ Second, we took a "river reach" perspective, which reveals the condition of each river segment.
→ A third approach shows how the health of the Cacapon changed as the river's discharge rose and fell.
→ Finally, a fourth perspective combined the river reach and discharge approaches. It reveals that water quality in the four reaches responded differently to changing discharge.

1. Entire Basin

TABLE 1 gives a statistical summary of all measurements made throughout the Cacapon River basin. Taken together, the figures suggest that the Cacapon is a healthy ecosystem that, on average, meets state water quality standards.

The figures found in the columns marked "Mean" and "Range" indicate that the waters of the Cacapon are:

→ warm enough to support a warm-water fishery,
→ muddy,



TURBIDITY
Middle Cacapon was, on average, muddier than the other reaches.

TABLE 2

Summary statistics for water quality data collected in the four river reaches

Reach	Mean	Std. Dev.	Range	# Obs.
Temperature (°C)				
Lower Cacapon	24.2	2	20.4 - 29.1	39
Middle Cacapon	23.2	1.8	19.1-26.7	39
Lost River	23.5	2.9	18.7-29.0	19
North River	23.8	3.1	18.4-30.7	20
Turbidity (NTU)				
Lower Cacapon	8.3	18.5	0.9-87.0	38
Middle Cacapon	19.8	83.4	0.8-512.0	38
Lost River	5.3	9	0.9-40.0	20
North River	2.4	3.7	0.7-18.4	21
pH				
lower Cacapon	8.1	0.4	7.2-8.8	39
Middle Cacapon	8.1	0.4	7.4-8.9	39
Lost River	8.4	0.6	7.4-9.3	19
North River	8	0.4	7.2-8.8	21
Alkalinity (mg/l)				
Lower Cacapon	66.4	14.1	30-90	27
Middle Cacapon	65.9	14.9	28-86	26
Lost River	68.3	24	24-107	18
North River	43.7	16.6	20-84	26
Ammonia (mg/l)				
Lower Cacapon	0.014	0.019	0-0.07	26
Middle Cacapon	0.016	0.025	0-0.12	28
Lost River	0.025	0.047	0-0.20	17
North River	0.01	0.008	0-0.02	24
Phosphate (mg/l)				
Lower Cacapon	0.026	0.019	0-0.10	27
Middle Cacapon	0.033	0.028	0.01-0.14	29
Lost River	0.034	0.028	0.01-0.12	17
North River	0.019	0.014	0-0.06	26
Fecal Coliform Bacteria (MPN/100 ml)				
Lower Cacapon	206.8	523.6	5-2,400	41
Middle Cacapon	263.7	608.2	8-2,400	42
Lost River	540.1	783.3	0-2,400	26
North River	279	516.9	13-2,400	30

Notes: Std. Dev. = standard deviation; # Obs. = number of observations.

→ decidedly basic and buffered by moderate alkalinity,
→ occasionally degraded by ammonia and feces, and
→ not enriched by phosphate.

How do the basin-wide figures for the Cacapon compare to other U.S. rivers? According to the column marked "Nat'1 Median" (TABLE 1), the Cacapon is slightly more basic, and carries 42 percent less alkalinity, 79 percent less phosphate, and 15 percent fewer fecal coliforms than the average U.S. river.[54]
This generally good picture of the Cacapon's health is not complete, however, because it masks the fact that the river's water quality varies in different reaches and can change with water level.

2. River Reaches

Based on the Cacapon's topography and land uses, we divided the river into four reaches (see map, inside front cover):

→ Lost River — 32.4 miles (54 kilometers) from headwaters to Wardensville,
→ Middle Cacapon — 24.6 miles (41 kilometers) from Wardensville to Capon Bridge,
→ Lower Cacapon — 46.2 miles (77 kilometers) from Capon Bridge to the Potomac River, and
→ North River — a 47.4-mile (79 kilometer) tributary.

TABLE 2 summarizes the data for each reach. These average figures indicate that, for some parameters, the water quality in the four river segments was very different.

Water temperature ranged from 23.2 to 24.2 C (73.8 to 75.6'F), suggesting no obvious differences among reaches.

Middle Cacapon was, on average, more **turbid** than the other river reaches. It averaged 19.8 NTU, which indicated muddy water, while Lost River averaged 5.3, and Lower Cacapon averaged 8.3. In contrast, North River — the clearest reach — averaged 2.4. Put another way, Middle Cacapon was 8.3 times more turbid than North River (*see bar graph, page* 9).

All four reaches were in the basic range of the **pH** scale. Lost River (8.4) was most basic, while North River (8.0) was least basic. Lower and Middle Cacapon (8.1) were intermediate. Water with the lowest pH had a 60 percent greater hydrogen ion concentration than water with the highest.

North River carried less **alkalinity** (43.7 mg/1) than the other three reaches (which ranged from 66 to 68).

Lost River carried the highest concentration of **am-**

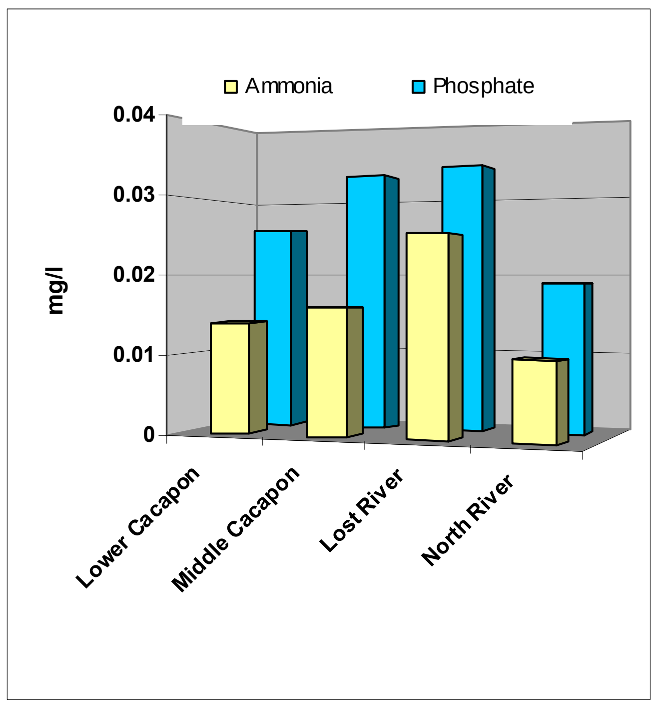
TABLE 3				
Fecal coliform measurements that met (<200 ceils/100 ml), were marginal (201 -400), or exceeded (>400) the state standard for water-contact recreation.				
Reach	**≤200**	**201-400**	**>400**	**#**
Lower Cacapon	33 (81%)	3 (7%)	5 (12%)	41
Middle Cacapon	34 (80%)	4 (10%)	4 (10%)	42
Lost River	14 (54%)	5 (19%)	7 (27%)	26
North River	21 (70%)	5 (17%)	4 (13%)	30
TOTAL	102 (73%)	17 (12%)	20 (15%)	139

monia (0.025 mg/1) while North River contained the least (0.010). Lower (0.014) and Middle Cacapon (0.016) were intermediate. The mean concentration in Lost River was 1.6 times greater than in Middle Cacapon, with the second highest concentration (*see bar graph, page 11*).

Lost River (0.034 mg/1) and Middle Cacapon (0.033) carried the highest levels of **phosphate**. North River carried the least (0.019), while Lower Cacapon was intermediate (0.026). The mean concentration in Lost River was 31 percent greater than in Lower Cacapon (*see bar graph, below*).

Lost River carried the highest level of **fecal coliforms**, an average of 540 cells (MPN)/100 ml, well above healthy limits and more than twice the average (207) found in Lower Cacapon. North River (279) and Lower Cacapon (264) fell between these two extremes.

TABLE 3 reveals that at least 10 percent of samples taken from all four river reaches exceeded the state's water-contact recreation standard (400 fecal coliform cells (MPN)/100 ml). Above this standard, water-contact recreation such as swimming and boating is considered unsafe. Lost River yielded the highest percentage of water samples exceeding the state's standard: 27 percent. In contrast, 10 to 13 percent of the samples from the other three reaches exceeded the standard.



AMMONIA AND PHOSPHATE
Lost River had the highest average levels of ammonia and phosphate.

3. Effects of Discharge

A river at high water is very different from one at low flow. On the Cacapon, water quality was quite different at low and high flows.

Discrete Water Levels — We first examined the river's water quality at three water levels (*see Appendix, page 29*):

→ baseflow averaged 96 cubic feet per second (cfs) (74 observations ranged from 61 to 132 cfs),

→ intermediate flow averaged 168 cfs (25 observations ranged from 133 to 199 cfs), and

TABLE 4

Summary statistics for water quality data collected during baseflow, intermediate and high flows.

Reach	Mean	Std. Dev.	Range	# Obs.
Temperature (°C)				
baseflow	24.4	2.5	19.1-30.7	52
intermediate	24.2	1.9	21.1-27.3	21
High flow	22.6	1.9	18.4-26.8	44
Turbidity (NTU)				
baseflow	3.2	5.8	0.7-40	54
intermediate	2.6	1.3	0.8-4.9	22
High flow	24.3	81.1	0.9-512	41
pH				
baseflow	8.3	0.4	7.4-8.9	53
intermediate	8.1	0.3	7.6-8.8	21
High flow	8.0	0.5	7.2-9.3	44
Alkalinity (mg/l)				
baseflow	70.2	16.5	29-107	52
intermediate	54.9	17.7	26-100	16
High flow	46.2	16.5	20-74	29
Ammonia (mg/l)				
baseflow	0.013	0.020	0-0.12	49
intermediate	0.023	0.047	0-0.020	17
High flow	0.016	0.019	0-0.07	29
Phosphate (mg/l)				
baseflow	0.023	0.016	0-0.08	52
intermediate	0.027	0.018	0.01-0.09	18
High flow	0.036	0.033	0.01-0.14	29
Fecal Coliform Bacteria (MPN/100 ml)				
baseflow	278	601	0-2,400	70
intermediate	98	80	14-350	23
High flow	441	733	11-2,400	46

Notes: Std. Dev. = standard deviation; # Obs. = number of observations.

→ high flow averaged 473 cfs (49 observations ranged from 203 to 1,750 cfs).

TABLE 4 summarizes the water quality data at the three flows.

Generally, the river was:

- slightly warmer at low flow. Water temperature was higher at baseflow — 24.4°C (75.9°F) — than at high flow — 22.6°C (72.7°F).
- muddier at high flow. Turbidity was 7.6 times greater in high water (24.3 NTU) than at baseflow (3.2).
- less basic at high flow. The river's pH fell from 8.3 at baseflow to 8.0 at high flow. At baseflow, the river carried 50 percent fewer hydrogen ions per unit volume than at high flow.
- less alkaline at high flow. High flow (46.2 mg/1) carried 34 percent less alkalinity per unit volume than baseflow (70.2).

Ammonia concentrations were lowest at baseflow and highest at intermediate flow. Ammonia concentration was 43 percent greater at intermediate (0.023 mg/1) flow than at baseflow (0.013).

Phosphate levels were highest at high flow. Compared to baseflow (0.023 mg/1), high water (0.036) carried 57 percent more phosphate per unit volume.

Fecal coliform counts were highest at high flow and lowest at intermediate flow. At baseflow (278 cells (MPN)/100 ml), fecal coliform counts were 2.8 times greater than at intermediate flows (98) and 63 percent of the count found at high flows (441).

Continuous Variation — The same data lead to additional conclusions if they are analyzed differently. Instead of using three discrete water levels — baseflow, intermediate, and high flow — the data can be correlated on continuous scales. This approach better represents the dynamic, rising and falling nature of a river.

According to the dictionary, the verb "to correlate" means to bear reciprocal or mutual relations. Less formally, it means to figure out how closely the behavior of one thing is associated with the behavior of another. For example, on the Cacapon, higher phosphate concentrations are found at higher water levels.

On the graphs in this baseline (*see pages 15 and 16*), the symbol r is the correlation coefficient, and n is the number of observations. An r of 0.75, for example, shows a high positive correlation — both variables increase together in strong association. In con-

MIDDLE CACAPON
The broad agricultural valleys of the Middle Cacapon are on display on the outskirts of Wardensville, WV.

trast, an r of -0.25 shows a low negative correlation: when one variable is high, another is low, but the association is weak.

A high r does not necessarily mean that a cause-and-effect relationship exists. While two variables may be closely associated to one another, their changes may reflect the action of a third variable. For example, in the Cacapon, ammonia and fecal coliform concentrations are positively correlated — when one rises, so does the other. But a rise in ammonia does not cause a rise in fecal coliforms; rather, a third variable, discharge, is responsible for the increase in both ammonia and fecal coliforms.

Using such continuous scaling, water level is revealed as a factor that drives ecosystem change. In essence, at low flows, the Cacapon is a diverse river — for example, on the same day, water quality can be good in one place but poor in another. In contrast, at very high flows water quality is pushed to one extreme or the other — along virtually the entire river, water quality is either good or bad (depending on the parameter).

Analysis of the correlations reveals:

→ At low flows, **water temperature** varied between 18.4 and 30.7°C (65.1 and 87.3F), but at high water, temperature ranged between 18.4 and 26.8°C (66.2 and 69.8°F) (not graphed).

→ As water level rose, **turbidity** increased by one or two orders of magnitude, from 1-9 to 50-500 NTU (*see graph, page 15*).

TABLE 5

Correlations between discharge (cfs) and water quality measurements in the four river reaches. For each correlation, the top number is correlation coefficient (r) and the bottom number is sample size (n). The asterisks indicate the probability that the observed correlation coefficient was due to chance. A probability (p) of .05 means that there were 5 chances in 100 {1 in 20) that the coefficent resulted from chance. (* = p.<05, ** = p.<01, *** = p<OOl, no asterisk = not significant)

Parameter	Lower Cacapon	Middle Cacapon	Lost River	North River
Temperature	***-0.53	**-0.49	*-0.46	-0.42
	39	39	19	20
Turbidity	***0.75	***0.74	-0.03	-0.6
	38	38	20	21
pH	**-0.42	"-0.44	-0.37	-0.33
	39	39	19	21
Alkalinity	***-0.69	***-0.67	*-0.45	***-0.61
	27	26	18	26
Ammonia	***0.63	0.23	-0.15	0.01
	26	28	17	24
Phosphate	***0.83	*«0.74	-0.69	0.28
	27	29	17	26
Fecal coliforms	+**0.61	***0.82	-0.06	0
	41	42	26	30

→ At low flows, **pH** varied between 7.2 and 9.3, but at high water ranged only from 7.2 to 7.4 (*see graph, page 15*).

→ At baseflow, **alkalinity** varied from 20 to 107 mg/1, but in high water varied from 20 to 30 mg/1 (*see graph, page 15*).

→ Because **ammonia** concentrations were uniformly low, a significant correlation was not evident (not graphed).

→ **Phosphate** levels increased with discharge by an order of magnitude, from 0.01 to 0.14 mg/1 (*see graph, page 15*).

→ At low flows, **fecal coliform** concentrations Were usually low, in single and double digit values, and occasionally high (2,400). At high water, however, only high concentrations were observed (*see graph, page 16*).

4. Interaction of reach and discharge

The results outlined above show that the Cacapon's water quality changes with location and with water level. These findings raise another question: Does water quality in all river reaches change the same way in response to changing water level?

TABLE 5 provides the data to answer this question.

In all four reaches, **water temperature** was cooler at high water levels. These negative correlations were statistically significant in all reaches but North River, where the trend nevertheless was present.

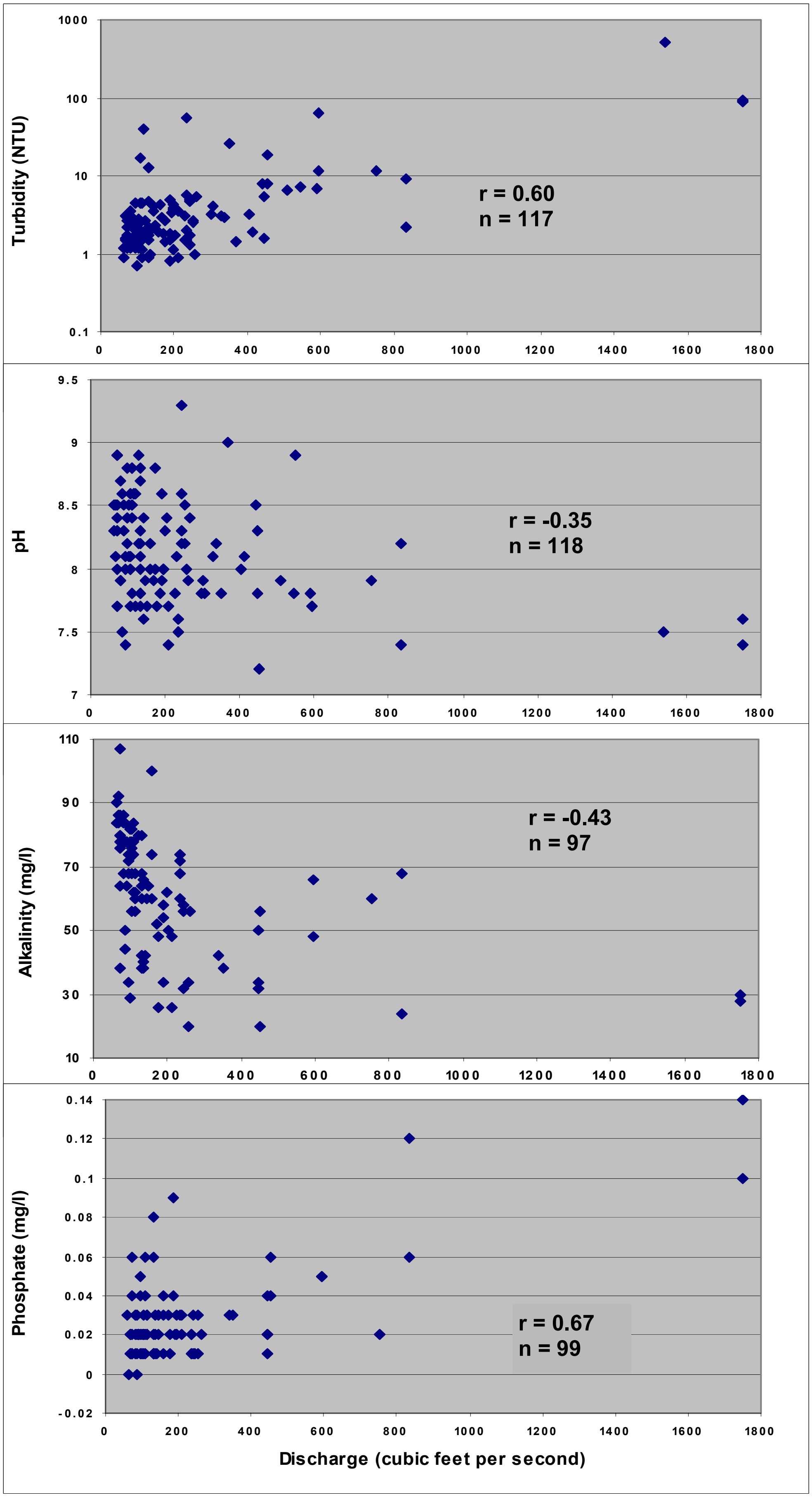
In all reaches except Lost River, water was more **turbid** at high water levels. Why did turbidity in Lost River behave differently? Perhaps because cattle herds have free access to this reach. At low water, cattle walk in the river and disturb sediment, keeping the water relatively turbid. At high water, the river is also turbid due to siltation from eroding banks. Thus, Lost River's turbidity may not respond to changing water level, precluding significant correlation.

In all four reaches, **pH** was lower when water levels were higher. While negative correlations were present in all four reaches, they were not statistically significant in Lost and North rivers.

In all four reaches, **alkalinity** was lower at higher water levels. These negative correlations suggest that two things happened: As water rose, (1) alkalinity was diluted and (2) chemical reactions "used up" the alkalinity, neutralizing acid and resulting in a less-depressed (higher) pH.

Only in Lower Cacapon was an increase in **ammonia** linked to higher water levels. This correlation was not significant in the other three reaches (where ammonia fluctuated independently of water level). It is possible that, because the banks of Lower Cacapon sup-

DISCHARGE AND WATER QUALITY



At higher water levels . . .

- **turbidity is higher**
- **pH is lower**
- **alkalinity is lower**
- **phosphate is higher**

port few cattle, any ammonia found there is imported from upriver by storm waters, yielding a positive correlation with water level.

Phosphate levels were higher at higher water levels in all river reaches. Positive correlations were significant in all reaches but North River, suggesting that rains washed phosphate off fields along Lost/Cacapon River, but to a lesser degree along North River. This finding could be the result of North River's low turbidity. Phosphate is bound to sediment; when turbidity is low, there are few soil particles to carry the phosphate.

In Lower and Middle Cacapon, **fecal coliform** levels were higher at high water levels; in the other two river reaches, we found no correlation. High fecal coliform levels in Lost and North rivers at low water may be due to the presence of in-stream cattle. Thus, there was little change as water level fluctuated.

Reviewing these findings, it appears that in Middle and Lower Cacapon water quality was strongly correlated to water level. In the other two reaches, this link may be stronger than our data indicate. A limitation of our study—the use of a single discharge gauge located near the river's mouth—may understate the association because the gauge can not accurately measure discharge in distant upstream reaches.

What Do the Data Mean?

Why hasn't acid rain damaged the Cacapon? Why does the river carry more pollution after a rainstorm? Why is the upper half of the river more polluted than downstream?

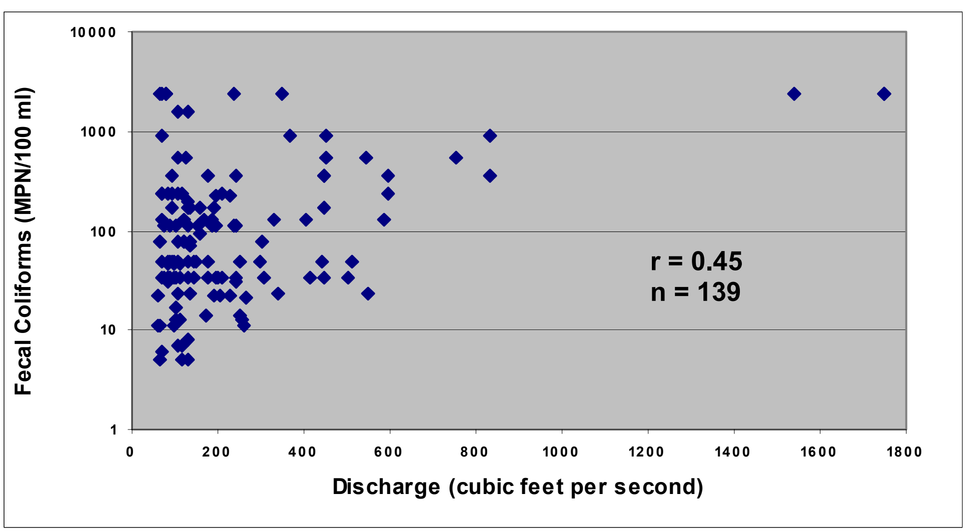
The answers to these questions can be found in the rocks of the basin, how land uses generate pollution, and an hypothesis of how the river transports and traps pollutants.

Basin's Alkalinity Neutralizes Acid Rain

The Cacapon River basin lies within a region of severe acid deposition.[7] The U.S. Environmental Protection Agency estimates that the average pH of precipitation in the region is 4.3.[25] Nonetheless, the Cacapon remains basic, with an average pH of 8.1.

At higher water levels ...

- **Fecal coliform counts are higher**



What protects the river from acid rain? The basin's rocks provide at least three sources of alkalinity that buffer the river's pH.

First, the basin has a few outcrops of limestone, a rock rich in calcium carbonate (lime), an alkaline substance that buffers water — gives it the ability to resist acidification. On Lower Cacapon, a waterfall cascades over one such limestone outcrop, adding buffered water to the river. In the Lost River basin, several outcrops have even supported commercial quarrying.

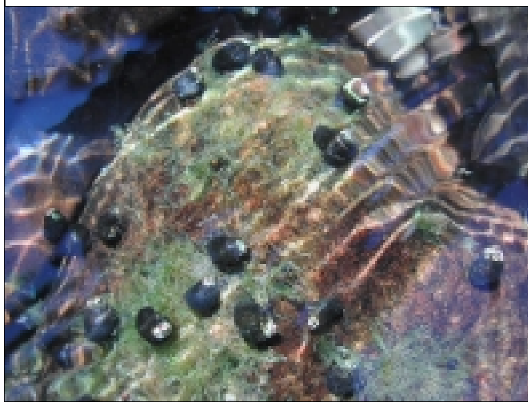
Second, underlying the basin are several strata (layers) of limestone.[56] Groundwater flowing through these strata and into the Cacapon could be another source of the rivers' alkalinity.

Third, the surface sandstones and shales found throughout the basin have a calcareous matrix — a natural, calcium carbonate-rich cement that holds the grains of these sedimentary rocks together.[59] Surface run-off dissolves alkalinity from this matrix and carries it to the river (*see "Crunch" box, right*).

"Crunch, crunch, crunch"

Every time Lab staff walk through the Cacapon, they cringe because of the snails that crunch under each step.

Compared to other nearby rivers, the Cacapon is blessed, even overwhelmed, with snails. The river bottom supports up to hundreds of snails per square foot — it's almost impossible to avoid stepping on them.



The vast majority of snails carpeting the Cacapon's bottom belong to a single species — *Leptoxis carinata.* Why are there so many?

Part of the answer lies in the Cacapon's pH. As the Lab's data reveal, the Cacapon is basic (high pH), even though local precipitation is quite acidic.

Acidic water (below pH 6.8) dissolves calcium carbonate, a major component of snail shells *(see pH scale, page 8).*

Stripped of calcium carbonate, shells become weak and disintegrate, killing the snails.

Nonpoint Sources Pollute the Cacapon

When it comes to pollution, the Cacapon appears to be degraded by nonpoint sources. Unlike point source pollution, which comes from an easily identifiable source, such as a pipe from a factory, nonpoint source pollution comes from a broad array of hard-to-control sources.[19,58] These sources include storm runoff from farm fields, streets and highways, construction sites, and logging areas. Another source of nonpoint pollution is malfunctioning septic systems that leach pollutants to the surface.

The pollutants from these sources come in many forms. They may be bacteria, nutrients, sediment, or ammonia. In other cases, such as runoff from farm fields treated with pesticides or herbicides, the pollution may include toxic chemicals.

The Cacapon isn't the only river degraded by nonpoint source pollution. Across the nation, nonpoint sources have emerged as the leading threat to rivers/According to one recent study, nonpoint sources degrade the water quality of 22 percent of the nation's river miles. Sediment is the leading nonpoint pollutant, degrading about half of the affected river miles.[10]

According to the U.S. Environmental Protection Agency, nonpoint sources contribute 65 percent of all pollution entering the country's streams. By far the leading cause of this pollution is agriculture (almost 70 percent), followed by municipal waste, resource extraction, and habitat modification (10 to 20 percent each).[64]

In the Cacapon River basin, the presence of nonpoint source pollution explains many of our findings. For example, pollution levels rise with water level because contaminants are washed off the landscape into the river by rainstorms. As the rain and water subside, the

Mean fecal coliform counts (gray bars) track the frequency of cattle access sites (brown line).

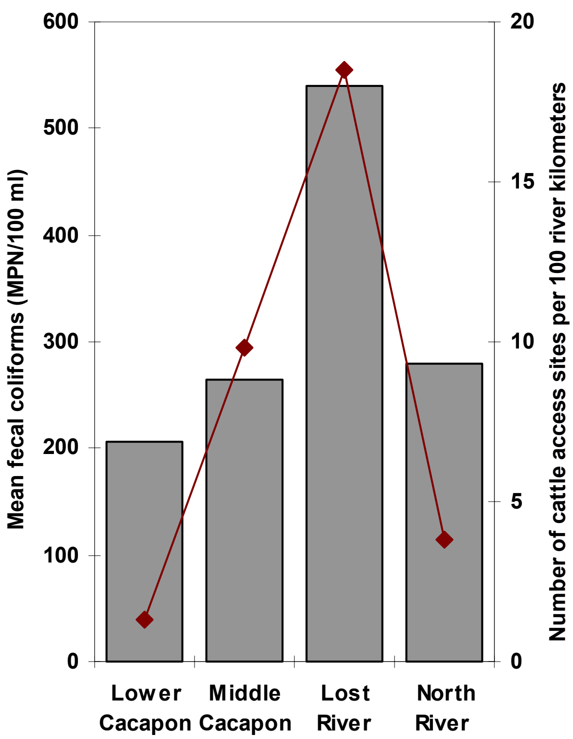


TABLE 6 Distribution of cattle along the four river sections.				
Reach	**A**	**B**	**C**	**D**
Lower Cacapon	**3/77**	**3.9**	**1/77**	**1.3**
Middle Cacapon	**15/41**	**36.6**	**4/41**	**9.8**
Lost River	**18/54**	**33.3**	**10/54**	**18.5**
North River	**8/79**	**10.1**	**3/79**	**3.8**

notes: A=number of sites with cattle/number of river kilometers, B=number of sites with tattle/l 00 river kilometers, C=number of sites offering cattle free access to river/number of river kilometers, D=number of sites offering cattle free access to river/100 river kilometers.

amount of pollution entering the river is reduced — a pattern consistent with nonpoint sources. (In contrast, rivers with point sources of pollution often carry a lower concentration of pollutants at high water levels because the pollutants become diluted.[32])

What land-use practices in the Cacapon River basin could be generating these nonpoint source pollutants?

Of all current land uses, farming practices—particularly allowing cattle unrestricted access to the river and plowing too close to the riverbank — appear to be the major causes of nonpoint source pollution (*see Cattle and Feces," page 18*). Cattle degrade water quality in at least two ways:

→ their manure — deposited directly in or washed into the river — increase fecal contamination and

→ their grazing and trampling kill riparian plants — vegetation that prevents sediment and other pollutants from entering the water (*see "Riparia," page 19*).

Along the Cacapon, the link between cattle and fecal coliform contamination is obvious. Reaches with the greatest number of cattle access sites also yield the highest average fecal coliform counts (*see graph and table 6, both left*).

Lost River had the most cattle access sites and also yielded the highest average fecal coliform count. In contrast, Lower Cacapon had the lowest number of cattle access sites and the lowest fecal coliform count.

Reaches showing the lowest water quality also have the most degraded riparian areas. Compared to other river reaches, Lost River's riparium is thin and sparse, and hosts few riparian trees. The upper Middle Cacapon's riparium is similarly degraded.

In contrast, Lower Cacapon is lined with dense corridors of native riparian plants such as silver maple, river birch, and paw paw (*see "Diversity Gradients" box, page 21*).

One of the main reasons riparia have not recovered

Cattle and Feces

Scientists have long known that livestock can elevate fecal coliform levels in rivers.[27,62]
Here are examples of how cattle pollute the river — and how the stream cleans itself:

• August 1, 1990 — On North River, Lab staff took two water samples. The first was taken from an unfarmed stretch upriver of 18 head of cattle with free access to the river. The second sample was taken downstream of the cattle. The upriver sample produced a fecal coliform measurement of 49 cells (MPN)/100 ml, well within acceptable limits. The sample taken below the cattle produced a measurement of 1,600 — four times the state's safe standard. In this case, cattle in the river caused the fecal coliform concentration to increase by two orders of magnitude.

• July 20, 1990 — Also on North River, Lab staff took three water samples (at river miles 11.8, 10.7. and 8.4) downstream of a cattle access site. The river's flow was stable, precluding the possibility that a slug of pollutants was moving downstream during sampling. The sample taken closest to the access site yielded a fecal coliform count of 350; the next two, taken in a forested basin several miles downstream, produced measurements of 170 and 33. The data show that the fecal coliform concentration decreased by an order of magnitude as the river flowed through about 3 miles of forested, non-agricultural landscape.

Riparia

The riparian corridor — what we call the "riparium" — is vital to the Cacapon's health.[11]

What is a riparium (the plural is "riparia")? In essence, it is the entire riverside ecosystem: the soil, plants, and animals that are influenced by the nearby river. The riparium, which should be at least 100 feet wide, can protect a river from many threats.[39] For example, it can prevent the erosion of sediment, which can smother fish eggs and destroy river-bottom habitat, in two crucial ways:

- the leaves of riparian trees — both those on branches and those that have fallen to the ground — protect soil by sheltering it from the force of falling rain; and
- roots hold the soil in place, preventing streambank erosion. Healthy riparia also:
- trap sediment, nutrients, and other pollutants — including pesticides attached to soil particles — before they reach the river;
- reduce the force of floods by soaking up water and releasing it slowly;
- keep river water cool in the summer by providing shade* which is important for fish;
- supply leaves and other organic material important in the river's food chain;
- and contribute woody debris that fish need for cover and feeding areas.

Some observers — such as a Nature Conservancy scientist — believe that the Lower Cacapon's riparium is one of the healthiest in the state. However, as the baseline indicates, it is severely degraded in other areas.

Cattle and Riparia

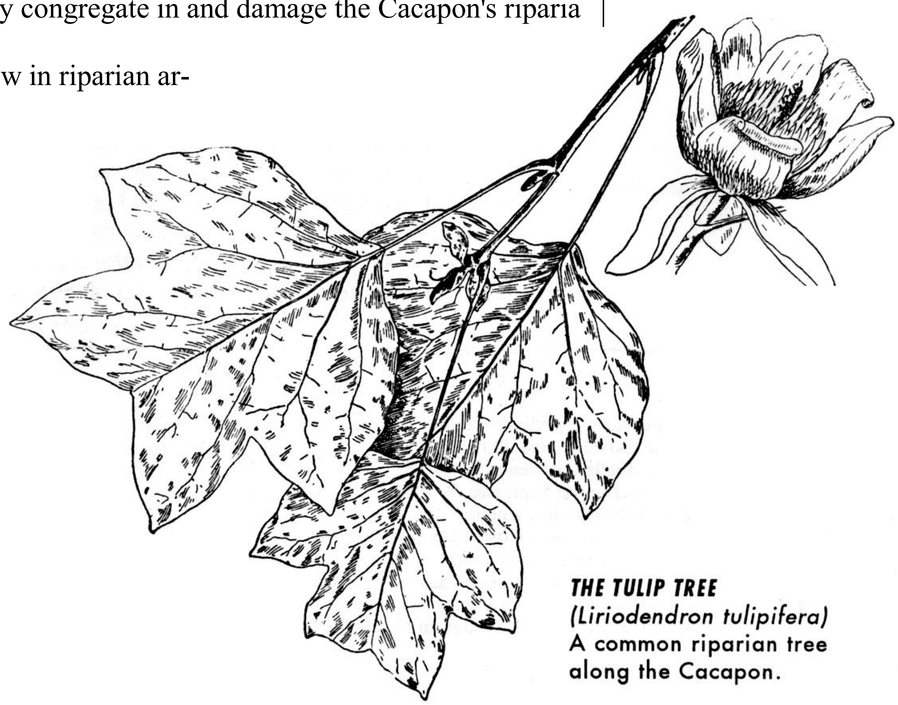
One cause of riparian degradation is farming that allows cattle free access to the river. Like humans, cows seek water. They congregate in and damage the Cacapon's riparia by:

- trampling plants that grow in riparian areas;[4,41,48] and
- loosening streambank soil.[8,17,50]

These insults, in turn, harm fish populations,[5,35,49] wildlife populations (by removing vegetation used for cover and food),[18,26,55] and groundwater quality.[40]

In addition to cattle defecating directly in the river, pollutants wash off sites where livestock gather. A healthy riparium can slow this flow of pollutants; a degraded riparium, however, allows unimpeded flow of pollutants into a river.[16,29,37,38,40,42,45,47]

The Cacapon's degraded riparium is not unique. Researchers estimate that of the nation's 123 million riparian acres, only about 23 million now remain in a semi-natural condition.[36]



THE TULIP TREE
(Liriodendron tulipifera)
A common riparian tree along the Cacapon.

(See "Riparia* in the Summer 1990 issue of Cacapon.)

The Case of the Clearing Pools

The long, slow pools of the Middle Cacapon appear to act as "pollution traps" — trapping and holding sediment.

Two field observations support this idea:

- On June 29, 1992, Lab staff measured the turbidity of water entering and leaving a long, slow pool at river mile 57. Water entering the pool averaged 6.35 NTU; in contrast, water leaving the pool averaged 5.75 NTU.
- In a more extensive study on July 17, 1992, Lab staff measured turbidity in a series of 14 pools over 11.5 miles of the Middle Cacapon. In the downstream direction, the pools' turbidity declined steadily, from 4.2 to 2.0 NTU.

along Lost River and upper Middle Cacapon is that cattle continue to have free access to the riyerbanks.

Pollutants Flow Downstream

Once in the river, pollutants are carried downstream. Suspended sediment and fecal coliforms are flushed from Lost River into Middle Cacapon and from Middle Cacapon into Lower Cacapon (*see "Going With the Flow," below*)

This transport pattern suggests that Lower Cacapon — which receives pollutants from all upstream reaches — should be the most polluted. But this lowest reach has good water quality. What explains this?

The first part of the answer is clear: this river segment has only a few cattle access sites and healthy riparia.

The rest of the answer? "Pollutant traps" — long, slow pools in Middle Cacapon that collect sediment and other pollutants and yield cleaner water that flows downstream.

In Middle Cacapon, some pools are visibly filling with silt. Water entering these pools is more turbid than water leaving the pools — evidence that suspended particles are settling in these quiet pools (*see "The Case of the Clearing Pools," left*).

Particles trapped in these pools may not stay forever on the bottom, however. Natural turbulence and human recreational users — such as boaters or people wading in the river — stir up the sediment. These kinds of disturbances may contribute to the high turbidity in Middle Cacapon (*see bar graph, page 9*).

Pathogens (disease-causing organisms) may also be resuspended. One study found that disturbing a stream bottom increased the mean concentration of fecal coliforms in the water by 1.7 times.[27]

Fecal Coliforms Exceed Safe Levels

Fecal coliform counts that exceed state standards in Lower and Middle Cacapon at high water — and in the other river reaches at all water levels — concern us (at times, these levels were six times the maximum acceptable level). The Cacapon's status as a popular recreational river means that many swimmers, boaters, and anglers run the risk of becoming ill.

Of particular concern is the fact that fecal contamination is flush-

Going With The Flow

Two field observations are consistent with the idea that pollutants flush down the Cacapon River:

- On July 22, 1989, Mathias and other areas of the Lost River basin experienced an intense rainstorm; Middle Cacapon received no rain. The next day, Middle Cacapon at Yellow Spring carried 512 NTU and greater than 2,400 fecal coliforms (MPNJ/100 ml. In contrast, at baseflow on September 7, 1989, the same spot yielded 2.5 NTU and 49 MPN. Therefore, pollutants were transported from Lost River to Middle Cacapon.
- On September 6 and 7, 1992, Lab staff followed a polluted silt slug as it moved from Middle through Lower Cacapon. In contrast to Lower Cacapon, which received no precipitation, an intense storm had struck the Middle Cacapon basin. On September 6, 1992, before high water arrived. Lower Cacapon carried 1.5 NTU and 110 fecal coliforms (MPN)/100ml. On September 7, after high water had arrived. Lower Cacapon contained 55 NTU and more than 2,400 fecal coliforms. Therefore, Lower Cacapon was degraded by pollutants imported from Middle Cacapon.

ing into high-use areas. These reaches host five children's summer camps, hundreds of riverside homes, and five public access sites (*see "The Month of May," page 22; map, inside back cover*).

As noted previously, fecal coliforms themselves are not harmful to humans. However, they are often accompanied by human pathogens.[28] The same animal wastes that carry fecal coliforms also carry microbes responsible for "zoonoses" — diseases such as dysentery and leptospirosis that are shared by humans and other animals.[6]

How serious is the Cacapon's fecal contamination? To answer this question, it's useful to estimate the river's natural level of fecal coliforms.[53] In areas devoid of obvious sources of fecal contamination (no nearby cattle access sites, for example), the average concentration of fecal coliforms at baseflow was 33.l cells (MPN)/100 ml (24 observations ranging from 5 to 49 MPN), In contrast, the average for the whole basin at baseflow was 278 (*TABLE 4, page 12*); at all flows the average was 302 (*TABLE 1, page 9*).

According to West Virginia law, these averages place the Cacapon's water quality in the acceptable range of fecal contamination.[57] According to the state, fecal coliform levels above 400 are unsafe for water contact recreation, such as swimming. For purposes of this study, the Lab defined fecal coliform levels of:

- → **33 as the natural background level,**
- → **0 to 200 as acceptable,**
- → **201 to 400 as marginal, and**
- → **over 400 as unacceptable.**

TABLE 3 (page 11) summarizes how water samples from the Cacapon's four river reaches compared to these standards. The figures show that, overall, 102 of 139 water samples (73 percent) were acceptable. In contrast, 37 samples (27 percent) were marginal or unacceptable. Water from Lost River was more than twice as likely to exceed the state standard of 400 than samples from other reaches.

These findings are at odds with previous reports. From 1982 to 1988, for example, only 2 of 40 (5 percent) samples from Great Cacapon violated the state standard for fecal coliforms.[21] Another study, based on five sites sampled monthly between November 1988 and September 1989, concluded that, "While localized degradation may be occurring, the overall water quality of the Cacapon River is very good."[63]

Similarly, only 7 percent of West Virginia's stream miles reportedly failed the federal Clean Water Act's standards of being fishable and swimmable.[23] In contrast, a higher percentage of the Cacapon's river miles appear to fail clean water standards. For example, we conclude that Lost River — which accounts for more than 20 percent of the Cacapon's river miles — fails clean water standards.

Taken together, our findings portray a sick, but treatable, patient.

Diversity Gradients

Though the cause is mysterious, ecologists have found that the number of species increases as you move down a river.

On the Cacapon, increasing downstream diversity is illustrated by riparian trees. On the lowest reach, near the Potomac, there are nine species of riparian trees, including river birch and paw paw.

In the middle third of the river, however, only seven riparian tree species are commonly found. The river birch is absent, and the paw paw is rare.

In the headwaters, the birch and paw paw are absent from the riverbanks.

Increasing diversity in the downriver direction is also exhibited by fishes and aquatic insects.

We conclude that Lost River — which accounts for more than 20 percent of the Cacapon's river miles — fails clean water standards.

The Month of May — Not So Merry

The next time you paddle the Middle Cacapon in May, don't fall in! That rule of thumb emerges from the Lab's finding that at high water levels, which are common in May, the river is more likely to carry health-threatening levels of fecal contamination.

High Water
Discharges above 650 cfs, 1988 through 1 992

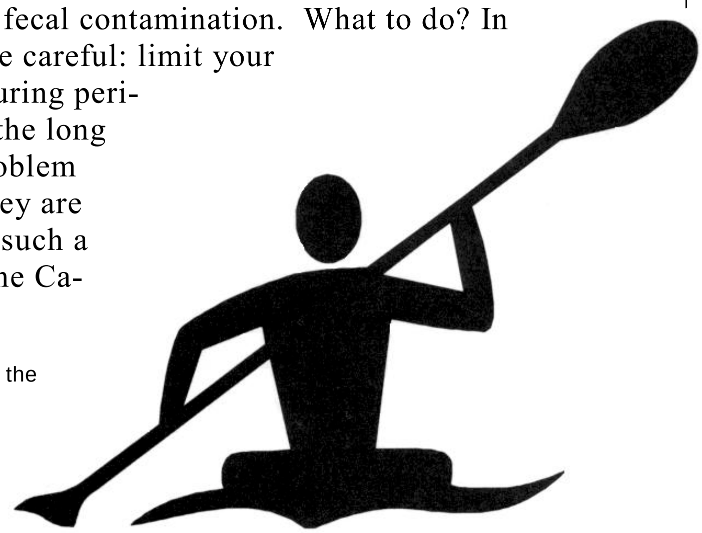
Month	# events	#days	Avg. # days per event	%
January	5	51	10.2	33
February	3	25	8.3	18
March	8	66	8.3	43
April	7	48	6.9	32
May	5	73	14.6	47
June	3	13	4.3	9
July	5	11	2.2	7
August	0	0	—	0
September	1	1	1.0	1
October	4	16	4.0	10
November	2	7	3.5	5
December	5	16	3.2	10
TOTALS	49	327	5.3	18

The Lab's data reveal that when the river's discharge rises above 650 cubic feet per second (cfs), fecal coliform levels are more likely to exceed the state's standard for safe water-contact recreation (see graph, page 16). Fecal coliform bacteria are associated with organisms that cause human diseases such as dysentery.

The table at left shows that the river ran above 650 cfs about 18 percent of the time during the five years of 1988 through 1992. In January through May, the river discharged at that level for 35 percent of the time. May had the most high-discharge days (47 percent); August had the least (0 percent).

This finding creates a dilemma. Because of the combination of adequate flows and warm weather, May is one of the best months to paddle the Cacapon. But it is also the month that features the most contaminated water — on almost half the days, a paddler could expect to find health-threatening levels of fecal contamination. What to do? In the short term, just be careful: limit your contact with water during periods of high flow. In the long run, causes of the problem must addressed. If they are not, May will not be such a merry month along the Cacapon.

(For information on paddling the Cacapon, see “Whitewater Ahead!” in the Spring 1992 issue of *Cacapon*.)



The Future

The Cacapon River flows toward an uncertain future. Dramatic change — which has swept the basin in the past— appears ready to revisit the area. Population growth, new industries, the construction of dams, and a major highway — these and other developments will bring change *(see "Change Is Coming/'page 24).*

In the face of certain change, the question we face is *how* to protect — and improve — the ecological health of the Cacapon River.

As a society, we have agreed to protect our rivers *(but see "Tragedy of the Commons?", below).* According to West Virginia state law, surface waters — which include rivers — must be maintained at "existing quality."[60] The State Water Resources Board has adopted an Anti-degradation Policy,[57] which states that "the level of water quality necessary to protect existing uses shall be maintained." On the Cacapon, this means that water quality must support water-contact recreation, such as swimming, boating, and fishing.

In theory, these laws should be adequate. In practice, however, they sometimes fall short because West Virginia lacks the funds necessary to document subtle water quality changes.

This baseline is an effort to provide the data needed for conserving one river. Public officials and private citizens now know that the water quality of the Cacapon River is degraded, particularly in several reaches affected by certain farming practices.

But scientific findings alone do not bring action. They are only the first step towards the goal of a healthy Cacapon River. Everyone — state and federal government officials, business owners and civic leaders, landowners and parents — must play a role in the river's recovery. It will take leadership, cooperation, sensitivity, and a willingness to compromise.

The changes needed to protect the Cacapon are clear:

> **First and foremost, the Cacapon's riparia — the riverbank corridors of vegetation that defend the river against a wide range of threats — must be restored.** In places, this will mean planting trees and shrubs, ideally in a 100-foot wide buffer-strip on both banks. In others, it will mean rebuilding or stabilizing eroded banks with rip-rap. In still others, it will mean limiting cattle access to the river. Some sites will need all of these actions.

> **Second, further riparian damage must be prevented.** Whether by voluntary agreement or law, those who use riverfront lands should act with the health of the river and downstream users in

In the face of certain change, the question we face is *how* to protect — and improve — the ecological health of the Cacapon River.

Tragedy of the Commons?

Is the Cacapon an example of the "tragedy of the commons"? In the late 1960s, ecologist Garrett Hardin coined that phrase to describe the abuse of public resources for private gain.31 According to West Virginia law, the Cacapon's water is a public resource — it has no single owner and many users. But the land along the river is in private hands. Riverside activities can degrade the water commons.

Though these activities may be legal, they are unethical, for they strip the rights of downstream and recreational users to enjoy a healthy river. Only when law fully reflects the moral obligation of private parties to protect public resources will a healthy commons remain for our grandchildren.

Change Is Coming

Big changes are coming to the Cacapon River basin. Some developments on the horizon include:

• **Population growth** — While only 39,603 people live in the three counties that include the Cacapon River basin, over seven million live within an easy two-hour drive.

This proximity to the Baltimore-Washington megalopolis has made some parts of the basin popular for building second homes. It has also stimulated the region's population growth. For example, from 1965 to 1987, the area around Capon Bridge grew 4.8 percent per year.[15] At this rate, population doubles every 14 to 16 years.

While West Virginia is losing population as a whole, the eastern panhandle — where the Cacapon River basin is located — continues to grow. For example, the combined population of Hardy, Hampshire, and Morgan counties grew by 11 percent between 1980 and 1990.[64]

Efforts to develop comprehensive land-use plans in Morgan and Hampshire Counties could help channel the growth and protect the river.[44] To be truly effective, however, land-use planning should occur in all three counties along the river.

• **Growth of the poultry industry** — The poultry industry is expanding in eastern West Virginia.12 Wampler-Longacre, the dominant chicken processor in the region, plans to double the capacity of its plant in Moorefield, Hardy County. Within the Cacapon River basin, hundreds of new poultry houses have been built since the early 1990s.

The industry brings with it several potential environmental problems:

- floodplain disruption from the construction of poultry houses,
- excessive silt and fecal contamination from the improper disposal of chicken manure, and
- contamination from the improper disposal of dead chickens.

With proper planning, these problems could be avoided.

• **Highway construction** — Plans are moving ahead to build Corridor H, a 100-mile long, four-lane highway across West Virginia.2,13 The Lab has opposed the highway because of its predicted ecological impacts on the Cacapon watershed. Plans call for the highway to travel across 22 miles of the Cacapon watershed in Hardy County. The new road would generally follow Route 55.
Environmental studies predict construction would directly impact 2.1 miles of the Cacapon watershed's rivers and streams, four acres of flood hazard zone, 508 feet of riparian buffers, and 2.4 acres of wetlands. The highway is predicted to spur development that, by the year 2013, will impact 1,784 acres of forest and 673 acres of farmland (a total of 2,457 acres or 3.8 square miles). The construction of residential housing is predicted to cause most of the impacts (2,412 acres).13

•**Dam construction** — The U.S. Natural Resources Conservation Service (formerly the Soil Conservation Service) has prepared plans to build five flood-control dams in the Lost River section of the basin.1,24 The Lab unsuccessfully opposed construction of the first of these dams — known as the Kimsey Run dam — on ecological grounds and because the agency's cost-benefit analysis was inadequate. The Lab has taken no position on a second dam planned for Upper Cove Run.

Lab staff and others have suggested spending the millions of dollars it will cost to build the dams on alternative methods of flood control. For example, the money could be used to restore riparian areas and to obtain voluntary conservation easements along the river.

(See the following articles in Cacapon: "What Will Happen To All The Chicken Manure?" Autumn 1992 • "Will Corridor H Help Our Economy?" Autumn 1992 • "Corridor H: Northern Route Less Damaging to River/ Winter 1993 • "Corridor H & The Cacapon Watershed," Winter 1994-95 • "A Dam for the Cacapon River Basin?" Autumn 1989 • "The Kimsey Run Dam Decision; Autumn 1991 • "Court Overturns Kimsey Run Decision," Winter 1993.)

mind. This does not mean the riparium must remain untouched. Numerous examples show that several uses — such as cattle farming and timber harvesting — can take place in harmony with ecological protection and water recreation.

> **Third, the Cacapon's health must be monitored.** Without periodic check-ups, this baseline's early warning value will be lost. We will not be able to tell if the river's health is getting better or worse.

> **Finally, more study is needed.** For example, we need to know if the Cacapon harbors other serious pollutants, such as pesticides, herbicides, and heavy metals. To safeguard public health, we need to know whether pathogens concentrate in sediments. We also need better tools -— such as computerized land-use analyses — to determine how large-scale changes in the basin affect the river's health.[46]

A lucky river

In many ways, the Cacapon is a lucky river. While it has borne some insults, and is far different today than it was 200 years ago, it has escaped the fate of many rivers: toxic pollution and ecological sterility.

In part, the river's luck is an accident of geography. To the east, urban growth and industry have severely damaged many rivers; to the west, coal mining has left a legacy of lifeless streams.

How long will the Cacapon's luck hold? Rather than waiting to find out, like a gambler, we should act now to protect this special river.

"When we try to pick out anything by itself, we find it hitched to everything else in the universe."
— John Muir

Epilogue: The Big Picture

John Muir, founder of the Sierra Club in the 1890's and one of the nation's pioneer environmentalists, once observed: "When we try to pick out anything by itself, we find it hitched to everything else in the universe."

Similarly, this project is the study of a single river system — yet the baseline fits into the bigger picture of learning about, and addressing, changes in the regional and global environment.

The baseline, for example, reminds us that the Cacapon is linked to the fate of a place far downstream — the Chesapeake Bay *(see "Links to Chesapeake Bay," page 25).* To put it simply, one of the best ways to solve

Links to Chesapeake Bay

Though 100 miles apart, the Cacapon River and Chesapeake Bay are inextricably linked. As part of the Bay's extensive network of feeder rivers, the Cacapon plays a small but important role in the health of the Bay, one of the world's most productive ecosystems.

West Virginia includes only a small part of the Bay's watershed (5.5 percent of the total). Still, the state contributes as much nutrient pollution to the Bay as Maryland or Virginia, states with much larger shares of the Bay watershed.

According to scientists at the Interstate Commission on the Potomac River Basin, West Virginia contributes 14 percent each of the nitrogen and phosphorous loads reaching the Bay via the Potomac River (one of the Chesapeake's major tributaries). Reducing these loads will be a key step toward meeting the federal government's goal of reducing nutrient pollution by 40 percent.

As the fourth largest tributary of the Potomac, cleaning up the Cacapon will contribute to the Bay's health. By helping to restore the Cacapon's riparia and reduce its nutrient loads, West Virginians — even those who have never seen the Chesapeake Bay — can say they are doing their part to restore this natural wonder.

the Bay's environmental problems is to restore the health of its tributaries. Why not start with the Cacapon?

The Lab's Cacapon project is also linked to distant tropical forests of South America, where "our" birds — the cherished riverside warblers and flycatchers of summer — spend the winter. But deforestation is fragmenting the winter homes of these migrants. Will they continue returning to the Cacapon? The Lab's annual bird counts will help answer this question *(see "Birds," page 27).*

Finally, the baseline study links the Lab to the frontiers of scientific discovery. For every question the baseline answered it raised new ones. For example, what animals remain to be discovered in the river's underground hyporheic zone *(see "Hyporheos," below)?* What causes the downstream increase in species diversity? How will global climate change affect the Cacapon River ecosystem? With more study, the answers to these questions will be revealed.

The Cacapon is only a single river. But, like a thread of blue, it connects the Lab to the global web of life.

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Thanks to all.

Hyporheos

There is more to a river than meets the eye. The Cacapon and other rivers hide a vast underground arena called the "hyporheic" zone. The zone is defined as the space among gravel and boulders below and alongside the channel penetrated by animals dependent on the river.

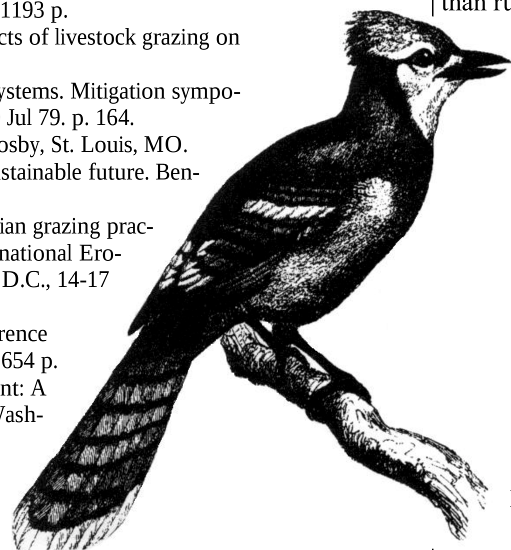
This underground world was once thought to extend only a few feet into the riverbank. Today, however, we know that it can run laterally for a mile or more. On the Flathead River in Montana, for example, aquatic insects have been collected over one mile from the river. How deep they descend into the riverbed remains a mystery.

The hyporheos supports animals that live part of their lives in the river's channel, and a group of specialized animals — such as blind shrimp and primitive worms — that never leave. At least a dozen new species have been discovered living in these hidden waters. What exotic creatures await discovery in the Cacapon's hyporheos?

(See "Hyporheos" in the Autumn 1990 issue of Cacapon.)

References

1. Ailes, J. 1991. The Kimsey Run dam decision. Cacapon 3 (4): 3.
2. Ailes, N. 1990. Basin environmental news. Cacapon 2 (4): 6.
3. APHA. 1976. Standard methods for the examination of water and wastewater, 14th ed. American Public Health Association, Washington, D.C. 1193 p.
4. Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16: 7.
5. Behnke, R.J. 1979. Values and protection of riparian ecosystems. Mitigation symposium, American Fisheries Society, Ft. Collins, CO, 16-20 Jul 79. p. 164.
6. Boyd, R.F. 1984. General microbiology. Times Mirror/Mosby, St. Louis, MO.
7. Chiras, D.D. 1991. Environmental science: action for a sustainable future. Benjamin/Cummings Publ. Co., Redwood City, CA. 549 p.
8. Clary, W.P., and B.F. Webster. 1990. Recommended riparian grazing practices. In: Erosion control: technology in transition, International Erosion Control Association, 21st conference, Washington, D.C., 14-17 Feb 90. p. 75.
9. Computing Resource Center. 1989. STATA release 2 reference manual. Computing Resource Center, Los Angeles, CA. 654 p.
10. Conservation Foundation, 1987. State of the Environment: A View Toward the Nineties. Conservation Foundation, Washington, D.C. 614 p.
11. Constants, G. 1990. Riparia. Cacapon 2(3): 1.
12. Constantz, G. 1992. What will happen to all the chicken manure? Cacapon 4(4):
13. Constantz, G. 1991. Where will the interstate go? Cacapon 3 (3): 4 and Malakoff, D. 1995. Corridor H and the Cacapon Basin. Cacapon 6 (4): 1.
14. Constantz, G., and J. Matheson. 1989. Science, grass roots, and the Cacapon River. Wonderful West Virginia 53 (8): 7.
15. Constantz, G., et al. 1987. Water and sewerage needs of the Capon Bridge community. Unpublished report. 4 p.
16. Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987, Riparian areas as filters for agricultural sediment. Soil Science ' Society of America Journal 51: 416,
17. Dahlem, E.A. 1978. The Mahogany Creek watershed—with and without grazing. In: Trout Unlimited grazing and riparian/stream ecosystems symposium, Denver, CO, 3-4 Nov 78. p. 31.
18. Dickson, J.G. 1989. Streamside zones and wildlife in southern U.S. forests. In: Practical approaches to riparian resource management workshop, Billings, MT, 8-11 May 89. U.S. Fish & Wildlife Service, p. 131.
19. Dijkhuis, A.H., N.K. Hoekstra, L. Lijklema, and S.E.A.T.M. van der Zee. 1992. Origin of peak concentrations of phosphate during high discharges in a rural watershed. Hydrobiologia 235/236: 257.
20. DNR. 1979. West Virginia high quality streams, 4th ed. Division of Wildlife Resources, WV Department of Natural Resources, Charleston, WV. 44 p.
21. DNR. 1988. Water quality status report of the Cacapon River. Division of Water Resources, WV Department of Natural Resources, Charleston, WV. 4 p. + appendices A-C.
22. DNR. 1989. Potomac River basin plan. WV Department of Natural Resources, Charleston, WV. 124 p.
23. Division of Water Resources, undated. West Virginia water quality status assessment, 1987 -1989, 305(b) report. WV Department of Natural Resources, Charleston, WV. 131 p.
24. Ensor, R. 1989. A flood-control dam for the Lost River area. Cacapon 1 (4): 1.
25. Environmental Protection Agency. 1988. Environmental Progress and Challenges: EPA's Update. EPA-230-07-88-033, Office of Policy Planning and Evaluation, Washington D.C. 140p.
26. Doyle, A.T. 1990. Use of riparian and upland habitats by small mammals. Journal of Mammalogy 71:14.
27. Gary, H.L., and J.C. Adams. 1985. Indicator bacteria in water and stream sediments near the Snowy Range in southern Wyoming. Water, Air and Soil Pollution 25:133.
28. Geldreich, E.E. 1966. Sanitary significance of fecal coliforms in the environment. Federal Water Pollution Control Administration, U.S. Department of the Interior. 110 p. + refs.
29. Green, D.M., and J. Kauffman. 1989. Nutrient cycling at the land-water interface: the importance of the riparian zone. In: Practical approaches to riparian resource management workshop, workshop at Billings, MT, 8-11 May 89, U.S. Fish & Wildlife Service, p, 61.
30. Hach. 1990. DR/2000 spectrophotometer procedures manual, 44879-00. Hach Co., Loveland, CO. 438 p.
31. Hardin, G. 1968. The tragedy of the commons. Science 162:1243.
32. Hiraishi, A., K. Saheki, and S. Hurie. 1984. Relationships of total coliform, fecal coliform, and organic pollution levels in the Tamagawa River. Bulletin of the Japanese Society of Scientific Fisheries 50: 991.
33. Hobba, W.A., Jr. 1985. Water in Hardy, Hampshire, and western Morgan counties, West Virginia.



Birds

"No two sounds harmonize better than running water and singing birds," wrote one unknown explorer about a South American river. The thought applies to the Cacapon as well. Throughout the year, the river corridor is alive with birds.

The Lab is involved in two efforts to monitor the health of bird populations in the basin. The first is an annual bird census float trip that surveys species nesting along the river in May. The second is the annual Hampshire County Christmas Bird Count, which has taken place since 1969.

Both counts usually tally about 60 species. But the two seasons produce a very different list of the ten most common birds:

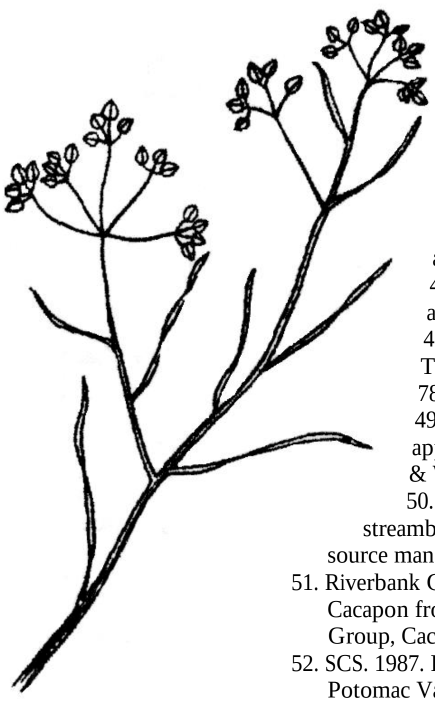
Top 10

Spring	**Winter**
Red-eyed Vireo	European Starling
Song Sparrow	Slate-colored Junco
Indigo Bunting	Chickadee species
Scarlet Tanager	American Crow
Eastern Phoebe	House Sparrow
Tufted Titmouse	Blue Jay
Acadian Flycatcher	Northern Cardinal
Great-crested Flycatcher	Tufted Titmouse
Wood Pewee	Tree Sparrow
Chipping Sparrow	White-breasted Nuthatch

The spring list is rich in neotropical migrants — birds that spend their winters in the tropics, but return here to breed. In contrast, the winter list is rich in resident birds that live here year-round.

(See these articles in Cacapon: "Hampshire County Christmas Bird Count A Success," Winter 1993 • "Winter Birds," Winter 1991* "Birds of the Cacapon River," Spring 1990 • "Rivers end Birds," Spring 1989.)

West Virginia Geological and Economic Survey, Environmental Geology Bulletin EGB-19.91p.
34. Hoffinan, Mark S. The World Almanac and Book of Facts: 1992. World Almanac, NY, NY. 960 p.
35. Howard, R.J. 1988. Streamside habitats in southern forested wetlands: their role and implications for management. In: Forested wetlands of the southern U.S., symposium, Orlando, FL, 12-14 Jul 88. p. 97.
36. Hunt, C.E. 1988. Down by the river. Island Press, Washington, D.C. 266 p.
37. Kesner, B.T., and V. Meentemeyer. 1989. A regional analysis of total nitrogen in an agricultural landscape. Landscape Ecology 2: 151.
38. Kuenzler, E.J. 1988. Value of forested wetlands as filters for sediments and nutrients. In: Forested wetlands of the southern U.S., symposium, Orlando, FL, 12-14 Jul 88. p. 85.
39. Lowrance, R., R. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint pollution. Journal of Soil and Water Conservation 40: 87.
40. Lowrance, R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. Bioscience 34: 374.
41. Martin, S.C. 1978. Evaluating the impacts of cattle grazing on riparian habitats in the national forests of Arizona and New Mexico. In: Trout Unlimited grazing and riparian/stream ecosystems symposium, Denver, CO, 3-4 Nov 78. p. 35.
42. McColl, R.H.S. 1978. Chemical runoff from pasture: the influence of fertilizer and riparian zones. New Zealand Journal of Marine and Freshwater Research 12: 371.
43. NPS. 1982. Draft wild and scenic river study: Cacapon River, West Virginia. National Park Service, U.S. Department of Interior. 50 p.
44. PCREL. 1992. Atlas of the Cacapon River basin within Hampshire County, WV. Pine Cabin Run Ecological Laboratory, High View, WV. Unpublished report submitted to the Cacapon River Committee, Yellow Spring, WV. 20 p.
45. Peterjohn, W.T., and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65: 1466.
46. Petersen, R.C., B.L. Madsen, M.A. Wilzbach, C.H. Magadza, A. Paarlberg, A. Kullberg, and K.W. Cummins. 1987. Stream management: emerging global similarities. Ambio 16: 166.
47. Phillips, J.D. 1989. Nonpoint source pollution control: effectiveness of riparian forests along a coastal plain river. Journal of Hydrology 110: 221.
48. Platts, W.S. 1978. Livestock grazing and riparian/stream ecosystems—an overview. In: Trout Unlimited grazing and riparian/stream ecosystems symposium, Denver, CO, 3-4 Nov 78. p. 39.
49. Platts, W.S. 1989. Compatibility of livestock grazing strategies with fisheries. In: Practical approaches to riparian resource management, workshop, Billings, MT, 8-11 May 89, U.S. Fish & Wildlife Service, p. 103.
50. Platts, W.S., and R.L. Nelson. 1989. Characteristics of riparian plant communities and streambanks with respect to grazing in northeastern Utah. In: Practical approaches to riparian resource management, a workshop, Billings, MT, 8-11 May 89, U.S. Fish & Wildlife Service, p. 73.
51. Riverbank Group. 1992. The Cacapon River: bank erosion and the riparian forest, vol. I: the Upper Cacapon from Cold Stream to the Lost River Sinks. Unpublished report prepared by the Riverbank Group, Cacapon River Committee. 21 p. + appendices 1 -3.
52. SCS. 1987. Preapplication report: North River watershed, Hampshire and Hardy counties, West Virginia. Potomac Valley Soil Conservation District, Soil Conservation Service (USDA) and Forest Service (USDA). 16 p.
53. Silsbee, D.G., and G.L. Larson. 1982. Water quality of streams in the Great/Smoky Mountains National Park. Hydrobiologia 89: 97.
54. Smith, R.A., et al 1987. Analysis and interpretation of water-quality trends in major U.S. rivers, 1974-81. U.S. Geological Survey Water-supply Paper 2307. 25 p.
55. Strassmann, B.I. 1987. Effects of cattle grazing and haying on wildlife conservation at national wildlife refuges in the United States. Environmental Management 11: 35.
56. Tilton, J.L. 1926. Map II, Hampshire County showing general and economic geology. WV Geological Survey, Morgantown, WV.
57. Water Resources Board. 1990. Title 46, Emergency legislative rules, Requirements governing water quality standards, Series I. State Water Resources Board, Charleston, WV. 20 p. + appendices A-E.
58. Weaks, A. 1991. Non-point source pollution: an introduction. Cacapon 3 (3): 1.
59. Werner, E. 1992. Geology of the Cacapon River basin. Cacapon 4 (3): 1.
60. West Virginia Code. 1985. Laws, Department of Natural Resources, Chapter 20, Article 5A, Section 1. The Michie Co., Charlottesville, VA.
61. Wirtz, W. 1990. Capon Valley Sampler. Bartleby Press, Silver Spring, MD. 204 p.
62. Wood, D.M. undated. Monitoring branch survey report: Anthony Creek watershed, fecal coliform bacteria pollution, Greenbrier County, West Virginia, November 1984-November 1986. Monitoring Branch, Water Resources Division, WV Department of Natural Resources, Charleston, WV. 21 p.
63. Wood, D.M. undated. Summary report of the West Virginia ambient water quality monitoring mini-network, 1988-1989. Monitoring Branch, Water Resources Division, WV Department of Natural Resources, Charleston, WV. 6 p.
64. World Resources Institute, 1991. The 1992 Information Please Environmental Almanac. Houghton Mifflin Company, Boston, MA. 606 p.



HARPERELLA (*Ptilimnium fluviatile*) A globally rare member of the carrot family that grows in the Cacapon's riparium. There are only two known populations in West Virginia. The Latin name means "rose of a river."

Appendix: Materials and Methods

Temperature - We measured water temperature (°C) in the field with the temperature function of a Hach One pH meter (model 43800), checked monthly against a mercury glass-bulb thermometer traceable to the National Bureau of Standards.

Turbidity - We twice rinsed clean turbidimeter sample cells (Hach number 20849) in the river immediately before collecting samples. Turbidity (NTU) was measured in the laboratory with a ratio turbidimeter (Hach model 18900), calibrated monthly with formazin primary (Hach number 2461) and weekly with Gelex secondary (Hach number 22526-00) standards.

pH - We measured pH in the field using the Hach One pH meter, calibrated every third measurement with standard solutions (pH 7.0 and 10.0, Biopharm BB4040 and BB4035, respectively).

Alkalinity - We measured total alkalinity by buret titration (APHA method 403).[3] Sample aliquots of 50 ml were titrated with 0.02N sulfuric acid to a pH end-point of 4.6 as indicated by bromcresol green-methyl red.

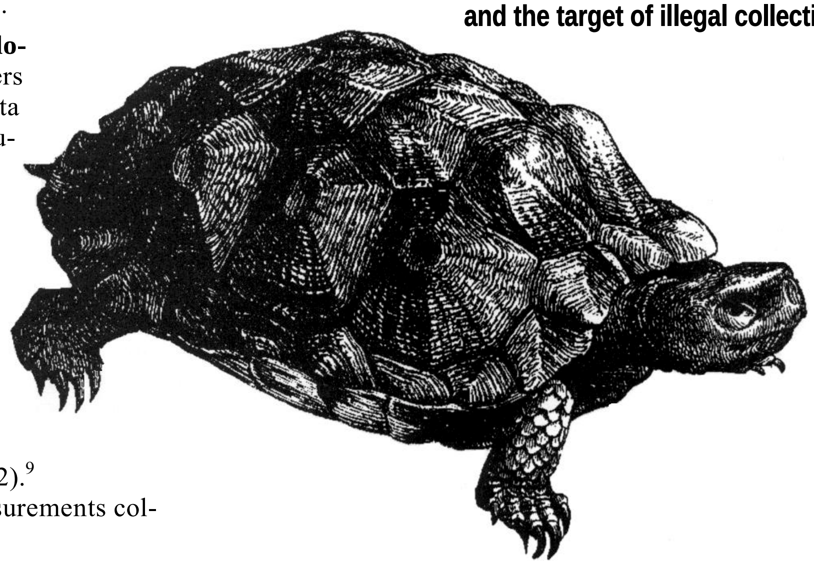
Ammonia - We measured the concentration of ammonia-nitrogen by the salicylate method[30] using a Hach DR/2000 spectrophotometer (Hach model 44800-00).

Phosphate - We measured the concentration of reactive phosphorus, or orthophosphate, by the ascorbic acid method[30] (based on APHA method 425F) using the Hach DR/2000 spectrophotometer.

Fecal coliforms - We measured the concentration of fecal coliform bacteria by the multiple-tube fermentation technique (APHA method 908).[3] Tubes scored positive in the presumptive test with lauryl tryptose medium (Hach number 21014) were confirmed with EC medium (Hach number 14104). Presumptive and confirmed MPN tubes were incubated (Hach bacterial incubator model 45900-00) at 35.0 ± 0.5 and 44.5 ± 0.2°C, respectively. Incubator temperatures were recorded twice per day. In statistical analyses, MPNs greater than or equal to 2,400 were treated simply as 2,400. During this study, the Lab's coliform analysis process was certified by the WV Department of Health.

Mean daily discharge (cfs) was recorded by the USGS gage (01611500) at River mile 6.0. We defined baseflow as water level that exposed the stem bases of water willow *(Justicia americana),* a common emergent herbaceous plant. Using this criterion, baseflow averaged 96 cfs (range=61-132, n=74). Intermediate flow averaged 168 cfe (range=133-199, n=25). High flow, which immersed terrestrial riparian plants, averaged 473 cfs (range=203-l,750, n=49).

WOOD TURTLE
(*Clemmys insculpta*)
A semi-aquatic reptile native to the lower two-thirds of the Cacapon. A Lab study, funded by the West Virginia non-game wildlife program, found that the turtles spend about half of their time on land, and half of their time in rivers. The study, which involved attaching radio transmitters to three turtles, was aimed at learning more about the habitat requirements of this species, which is designated as "of special concern" in West Virginia. The wood turtle has become a popular pet, and the target of illegal collecting.



Using a measuring wheel, we marked **river kilometers** (rkm) from the rivers' mouth to headwaters on USGS 7.5 minute quadrangle maps. Field data were keyed to the nearest 0.1 rkm. For this document, kilometers were converted to miles.

Sampling sites were selected according to a stratified randomized design: We cycled sequentially among reaches, within which we randomly chose specific sampling locations.

Water samples were collected in midstream - 15 cm below the surface. Sampling containers, storage conditions, and holding times followed APHA.

Statistics were calculated with STATA (release 2).[9] Correlation coefficients were calculated for measurements collected simultaneously.

Cattle access sites were identified in the field, by collating reports from knowledgeable boaters[51] and by surveying the river from small aircraft.

APPENDIX 2: October 2005 revisions to 1995 Edition

1. Contact information updated. However, original contact information was also included for historical purposes.
2. Because we did not have access to high resolution copies of the original high-altitude aerial photographs in *Portrait*, all photographs are new and were taken in September 2005. Captions modified to fit new images.
3. Drainage area of the Cacapon Watershed on page 7 corrected to 680 square miles. Paragraph reworked to correct associated facts.
4. The comparison of national median water quality statistics with means (averages) from the Cacapon baseline (TABLE 1 page 9, associated text pages 9 and 10) of the text was statistically inappropriate. TABLE 1 is revised below to include medians calculated using the Cacapon data. However, the document itself was not changed other than a note in the table referencing this appendix.

TABLE 1 (revised October 2005)
Summary statistics for water quality data collected on the Lost, North, and Cacapon rivers, 1989—1992.

			Cacapon Baseline Data				
Parameter	**WV Standard**	**Nat'l Median**	**Median**	**Mean**	**Standard Deviation**	**Range**	**Number of Observations**
Temperature	30.6	—	23.7	23.7	2.34	18.4-30.7	117
Turbidity	*	—	2.2	10.5	48.90	0.7-512	117
pH	6.0—9.0	7.8	8.1	8.1	0.43	7.2-9.3	118
Alkalinity	—	104.3	62	60.5	19.8	20-107	97
Ammonia	0.05	—	0.01	0.02	0.03	0-0.20	95
Phosphate	—	0.13	0.02	0.03	0.02	0-0.14	99
Fecal Coliforms	400	355	49	302	609.00	0-2,400	139

Notes: temperature (degrees C), turbidity (NTU), pH (units), total alkalinity (mg/l), phosphate (mg/l), fecal coliforms (MPN/100ml); WV Standard = acceptable limits in West Virginia[57], Nat'l Median=median for America's rivers[54]; — = none available, * = 10 NTUs above background level.
October 2005 Note: See Appendix 2 for discussion and revised version of this table.

5. About Pine Cabin Run Ecological Laboratory updated to include information on name change and current status of founders and organization. (Page 32)

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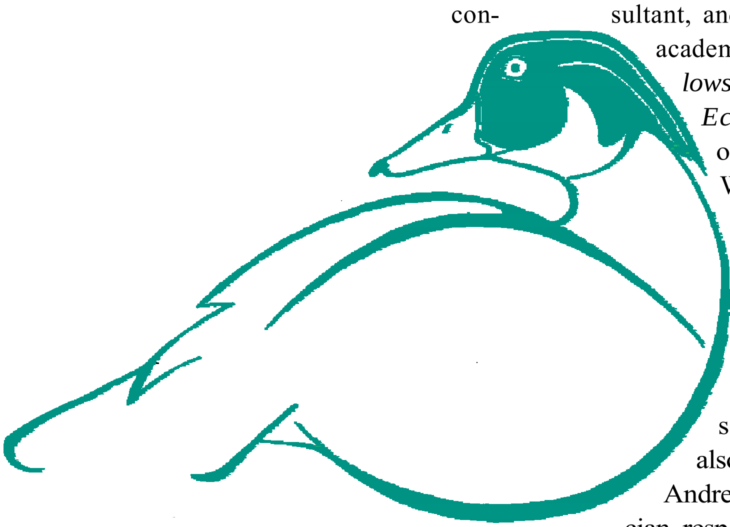
About Pine Cabin Run Ecological Laboratory

Nestled in a hollow off the Cacapon River in West Virginia's eastern panhandle, the Pine Cabin Run Ecological Laboratory is a nonprofit institution dedicated to using scientific research and education to help people protect and enjoy Appalachian rivers.

At the heart of the Lab's work are multi-year, large-scale ecological baseline studies. These detailed pictures of an ecosystem's health act as early warning systems—in the future, researchers and citizen monitors will be able to tell if an ecosystem's health is getting better or worse, and take action before the problem becomes too serious.

The Lab is applying its science-based conservation approach to several other river systems, including the Greenbrier River in southeastern West Virginia.

The Lab was founded in 1985 by the husband-and-wife team of Dr. George Constantz and Nancy Ailes. George, an ecologist, has worked as a university professor, researcher, consultant, and high school biology teacher. He is the author of numerous academic papers and a critically-acclaimed collection of essays, *Hollows, Peepers, and Highlanders: An Appalachian Mountain Ecology* (Mountain Press 1994). In 1993, George took a leave of absence from the Lab to serve as the first Coordinator of West Virginia's Watershed Conservation and Management Program. George has served as a board member of or advisor to a wide range of organizations, including The Nature Conservancy, the West Virginia Rivers Coalition, and the West Virginia Water Quality Advisory Committee.



Nancy, a Hampshire County native trained as a biologist and equine anesthetist, is the Lab's Administrator. She splits her time between research and administration. She also is Editor *of Cacapon,* the Lab's quarterly river journal.

Andrew Rogers, a Hampshire County native, is the Lab's Technician, responsible for a wide range of field and laboratory tasks.

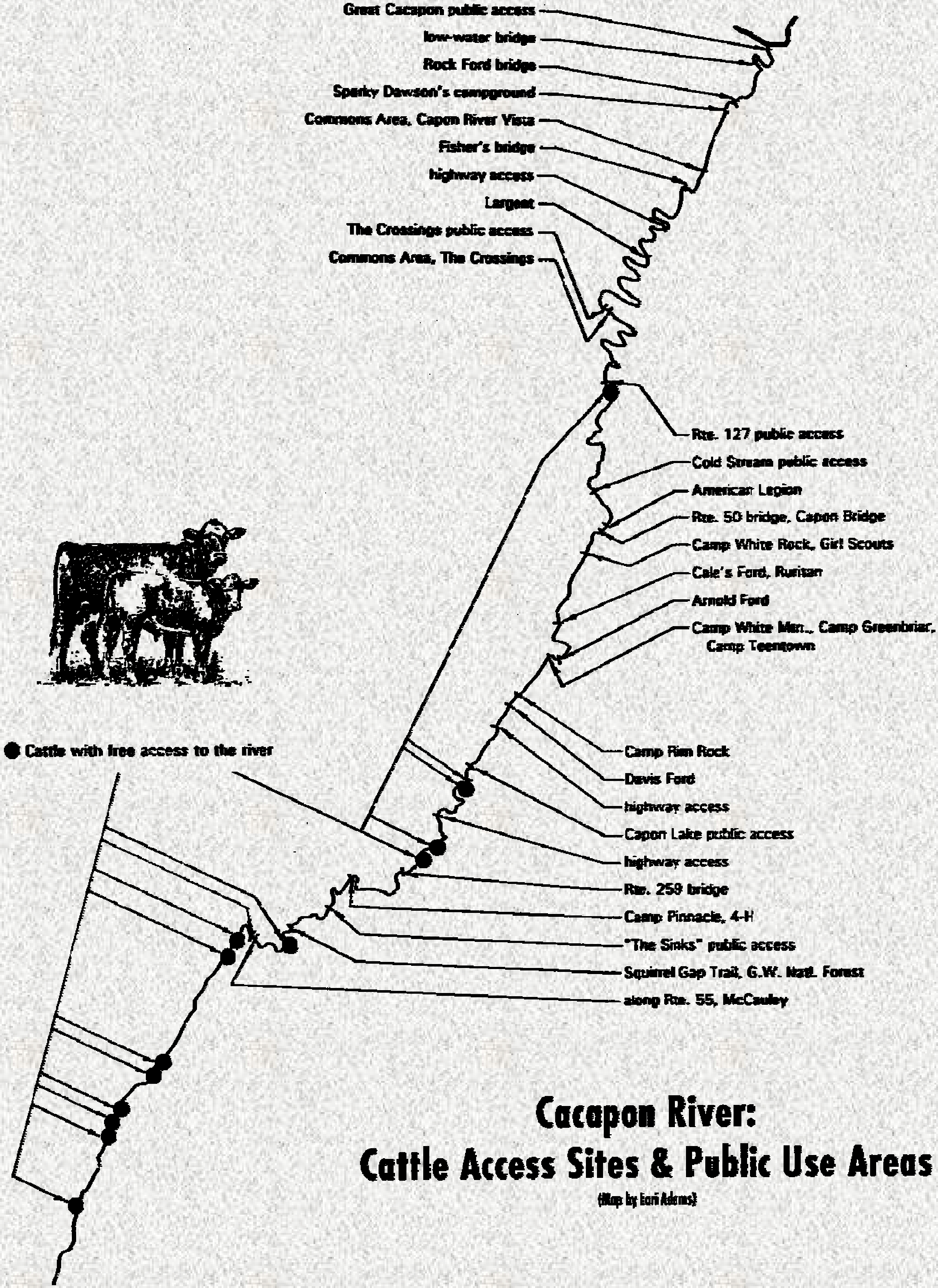
While the Lab's goals are ambitious, its facilities and budget are modest. A small, pre-Civil War log cabin serves both as the Ailes-Constantz home and the Lab's administrative center. The loft of a nearby barn houses the Lab's scientific equipment and research library. Both buildings sit beside Pine Cabin Run, a small mountain stream that lent its name to the Lab.

October 2005: updated information

In 1997, the Lab moved to a modern facility. In 1998, our name changed Cacapon Institute and the mission statement was changed to: *dedicated to using science and education to help concerned citizens protect and enjoy the Cacapon, Potomac, and other Appalachian watersheds.*

George Constantz is the Research and Development Manager at Canaan Valley Institute, Nancy Ailes is Director of the Cacapon and Lost Rivers Land Trust, and David Malakoff is a science journalist at National Public Radio.

Cacapon Institute
W . Neil Gillies, Director
Route 1 Box 326 ▪ High View, WV 26808 ▪ (304) 856-1385
pcrel@mountain.net ▪ www.cacaponinstitute.org



Cacapon River: Cattle Access Sites & Public Use Areas

(Map by Earl Adams)

Pine Cabin Run Ecological Laboratory

Founded in 1985, the Pine Cabin Run Ecological Laboratory is a nonprofit institution dedicated to using scientific research and public education to protect and restore Appalachian rivers.

Route 1 ● Box 326 ● High View, WV 26808