EXECUTIVE SUMMARY

Background. The Octoraro Watershed covers 208 square miles, of which 176 square miles are in southeastern Pennsylvania in both Chester and Lancaster Counties. The watershed includes portions of 18 municipalities and 25 major tributaries. Thirty-six miles of stream have been designated as scenic or pastoral river segments under Pennsylvania's Scenic River Program.

Despite the pressures of development from the surrounding metropolitan areas, the Pennsylvania portion of the watershed has an astounding 96% land use that is either farmland or woodland. The pastoral landscape is a vital part of making the region both a desirable living area and tourist attraction. Zoning regulations vary between the municipalities, although new regional planning initiatives are under way in two different parts of the watershed.

With its rural makeup, the watershed is host to very little major industry, with farming being the primary source of revenue for the area. Consequently, the population centers are clustered around the areas zoned for industry and commercial development. The watershed's population has grown approximately 18.5% since 1990.

Issues and concerns. Sprawl development, non-point source pollution and storm water management are the primary problems facing the watershed and its inhabitants. Thanks to education efforts from federal, state local and non-profit agencies, these issues are in the public consciousness far more than they were during the 1980's, when the Octoraro Watershed Association (OWA) participated in the publication of the document *Octoraro Creek: Management Options and Recommendations* (1986).

Land Resources. The soils of the Octoraro watershed are highly suitable for both agriculture and development. Consequently, most of the non-developable land in the watershed is contingent upon its slope rather than its geology.

The largest body of water is the Octoraro reservoir which is administered by the Chester Water Authority (CWA). This reservoir provides about 36 million gallons of water per day to CWA's customers in southeastern Pennsylvania and northern Delaware. There are a total of seven point source areas in the watershed that directly affect the Octoraro, but these account for only 6% of pollution loading in the Octoraro reservoir. The presence of non-point source pollution is far greater. Of all the municipalities in the watershed, only three have any sort of limited public water system, with the rest relying solely upon private wells for water supply.

Biological Resources. Many animals in the watershed area have been designated with various classifications of concern by the Pennsylvania Department of Conservation and Natural Resources (DCNR). In addition the invertebrate population contains many rare, endangered, and threatened species. Aside from the Serpentine Barrons, plant life is typical of vegetation found elsewhere in the state.

Cultural Resources. Recreational opportunities in the watershed include fishing, hunting, boating, and hiking. Three major parks provide areas of relatively undisturbed natural settings for the region: Nottingham and Octoraro Parks in Chester County and the Theodore Parker III Nature Area in Lancaster County. Local municipalities also have extensive land holdings that offer numerous recreational facilities for local residents and visitors.

Management Options.

1. Improve Water Quality in the Octoraro Creek and its Tributaries.
2. Encourage Environmentally Sound Municipal Planning
3. Promote Recreation Opportunities for Watershed Residents and visitors.
4. Protect and Maintain the Bridges of the Watershed

In addition, secondary options include:

- Enforcement of existing regulations
- Employ land management techniques for corridor preservation
- Build forums for future discussion of corridor concerns
- Adopt water withdrawal regulations in local municipalities.

Octoraro Watershed River Conservation Plan

PROJECT AREA CHARACTERISTICS

Location

The Octoraro Watershed includes fourteen townships and four boroughs in Chester and Lancaster Counties, Pennsylvania and Cecil County, Maryland (see map). This scenic region is surprisingly rural, considering its close proximity to the major population centers of Philadelphia, Baltimore and Lancaster. The area drains into the Octoraro Creek. The creek has two branches (East and West) that flow into a mainstem at the Octoraro reservoir. The mainstem continues into Maryland, where it empties into the Susquehanna River downstream of the Conowingo Dam. The Octoraro Watershed covers an area of 208 square miles, 176 of which are in Pennsylvania. The Watershed drains into the 60-mile long Octoraro Creek.

The entire Watershed constitutes a small portion of the 64,000 square mile Chesapeake Bay watershed. This valuable watershed and estuary basin is host to thousands of unique features, plant life and wildlife, as well a large human population and its accompanying cultural and historical heritage.

Chester County Townships & Boroughs In The Octoraro Watershed

Atglen Borough
East Nottingham Township
Highland Township
Lower Oxford Township
Oxford Borough
Parkesburg Borough
Upper Oxford Township
West Fallowfield Township
West Nottingham Township
West Sadsbury Township

Lancaster County Townships & Boroughs In the Octoraro Watershed

Bart Township
Christiana Borough
Colerain Township
East Drumore Township
Eden Township
Fulton Township
Little Britain Township
Sadsbury Township

Topography

The Piedmont range along the east coast of the United States runs directly through the Octoraro Watershed, creating a geologic and aesthetic "compromise" between the flat shore plains of the Atlantic coast and the august mountains of the Appalachian chain.Rolling hills are the prominent feature of the Octoraro Watershed's topography. The various tributaries have cut valleys ranging from a 1% grade to over 25% in the Atglen area. The steep slopes along the creek were key factors in helping to receive the Scenic River Designation in 1983 (Octoraro Creek Scenic River Study [SRS], 1983; Pennsylvania Department of Environmental Protection Watershed Restoration Action Strategy [WRAS] Report, unpublished).

Major Tributaries

There are 25 major tributaries in the Pennsylvania portion of the Watershed (see map). Three portions have been designated Exceptional Value (EV) streams: an unnamed tributary at River Mile 13.6; Black Run; and an unnamed tributary in West Nottingham Township just north of the Maryland boarder. Those receiving the High Quality (HQ) rating include Knott Run, Annan Run, McCreary Run, Reynolds Run, and the Octoraro west branch (WRAS Report, unpublished).

Table 1: Major Tributaries in the Octoraro Watershed

Annan Run	Leech Run
Ball Run	McCreary Run
Bells Run	Meetinghouse Creek
Black Run	Muddy Run
Blackburn Run	Nickel Mines Run
Bowery Run	Officers Run
Buck Run	Rattlesnake Run
Coopers Run	Stewart Run
Gables Run	Tweed Creek
Hog Run	Valley Run
Kings Run	Valley Creek
Knight Run	Williams Run
Knott Run	

In addition, 36.5 miles of stream have been designated as scenic or pastoral river segments in the Scenic River Designated area. These stream miles include the following.

Stream Segment	Classification	Length
Stewart Run		
1) 2 miles upstream of the West Branch confluence	Scenic	2.0 miles
West Branch		
1) Meetinghouse Creek to Bowery Run	Scenic	4.0 miles
2) Octoraro Water Company Dam to LR 36010 (Puseyville Road)	Scenic	2.75 miles
3) LR 36010 to (Puseyville Road) to backwaters of Octoraro Lake	Pastoral	3.75 miles

East Branch

1) Township Route 414 (Chester County) and Township Route 455 (Lancaster County) and associated bridge to LR 15058 (Steelville Road)	Scenic	3.5 miles
2) LR 15058 (Steelville Road) to LR 15025 (Eden Road)	Pastoral	8.25 miles
Main Stem		
1) Pine Grove Covered Bridge to Pennsylvania-Maryland line, including the 0.4 mile horseshoe bend at the Pennsylvania-Maryland line in West Nottingham Township, Chester County	Pastoral	12.25 miles
	TOTAL	**36.5 miles**

Land Use

Despite the pressures of development from the surrounding metropolitan areas, the Octoraro Watershed remains quite rural in its makeup. In the Watershed's Pennsylvania portion, 24% of the land is forested and 72% farmland, adding up to an astounding 96% of forested or agricultural land (see map). Corn, soybeans, hay, wheat and tobacco are the main agricultural crops grown in the Watershed, with numerous dairy farms also present. Most of the forested land can be found on steep slopes or rocky terrain that discourages its use for cultivation or development.

The presence of agricultural land on 72% of the Octoraro drainage basin has advantages and disadvantages for the ecology, aesthetics and resources of the Watershed. The pastoral landscape is a vital part of making the area both a desirable living area and tourist attraction, particularly in light of the large Amish population in the watershed (Octoraro Watershed Association [OWA] Survey, 1998). The presence of a single landowner over a given geographical area presents an easier opportunity to enlist allies in the implementation of Best Management Practices (BMPs) than one hundred landowners covering the same area. Open space also provides a greater freedom of movement and habitat for the local wildlife, allowing the opportunity for greater diversity than a residential area could allow. Disadvantages include high concentrations of non-point source pollution from fertilizer, manure and pesticide runoff and a lack of substantial buffers along the tributaries of the Octoraro. These contaminants also can and have infiltrated the groundwater supplies in the watershed.

This ratio of land use distribution is under relentless building pressure. Many proposed developments are under consideration or moving ahead in the Watershed area.

Zoning

As with all of Pennsylvania, the zoning regulations vary between municipalities (see chart below). While some natural resource areas such as floodplains are almost universally adressed, others are not. Due to the new "Pennsylvania Municipalities Code" revisions, townships and boroughs may now adopt regional comprehensive plans while retaining their individual zoning. Four Octoraro watershed municipalities in Lancaster County (Bart, Colerain, Sadsbury and Christiana) and six in Chester County (Atglen, Parkesburg, Highland, West Fallowfield, West Sadsbury and Londonderry, along with the Regional Park Commission) are now working on regional comprehensive plans. Early indications of both regional planning commissions are the emphasis on preservation of prime agricultural soils, the protection of the agricultual industry, and the protection of natural resources.

Table 2:Zoning Provisions and Protections by Municipality

Municipality (year of latest Comprehensive Plan)	**Zoning Provisions and Protections**												
	OS	**CD**	**GW**	**WW**	**F**	**W**	**SC**	**SS**	**WL**	**TR**	**AL**	**HW**	**R**
Atglen (1995)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Bart (1983)	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Christiana (1994)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	N/A	Yes	
Colerain (1987)	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No
East Drumore (1998)	Yes	No	Prp.	Prp.	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
East Nottingham													
Eden (1994)	Yes	Yes	Yes	Prp.	Yes	Yes	N/A	Yes	N/A	N/A	Yes	N/A	N/A
Fulton (1993)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Highland	Prp.	Prp.	Prp.	Prp.	Yes	Yes		Yes			yes		
Little Britain (1999)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Lower Oxford (1969)	No	No	No	No	Yes	Yes	No	Yes	No	No	No	Yes	No
Oxford (none)	yes	yes	no	no	yes	yes	no	yes	yes	no	no	yes	yes
Parkesburg													

Municipality (year of latest Comprehensive Plan)	Zoning Provisions and Protections												
	OS	CD	GW	WW	F	W	SC	SS	WL	TR	AL	HW	R
Sadsbury (1993)	N/A	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No
Upper Oxford (1982)	No	Prp.	No	No	Yes	Yes	No	Yes	No	No	Prp.	No	No
West Fallowfield (1997)	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
West Nottingham (1982)	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
West Sadsbury (2000)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Abbreviations:
OS – Open Space
CD – Cluster Development
GW – Ground water protection
WW – Water Withdrawal Regulations
F – Floodplains
W – Wetlands
SC – Stream Corridors
SS – Steep Slopes
WL - Woodlands
TR – Tree/Hedge Rows
AL – Agricultural Land
HW – Hazardous Waste
R - Runoff
Prp. – Proposed

Social/Economic Profile

Population Centers
The highest concentration of residents in the Watershed can be found on its northern and eastern borders. The boroughs of Christiana, Atglen and Parkesburg have a high concentration of people near the headwaters of the east branch. The town of Oxford and its surrounding area straddles the boundary of Octoraro and Elk Creek watersheds. The dense population of Quarryville Borough is located just northwest of the watershed's boundary.

Table 3: Population Changes 1990-2000
(Source: US Census Bureau)

Municipality	2000 Population	1990 Population	Population Change	Percent Change
Atglen	1,217	825	392	47.5
Bart	3,003	2,774	229	8.3
Christiana	1,124	1,045	79	7.6
Colerain	3,261	2,867	394	13.7
East Drumore	3,535	3,225	310	9.6
East Nottingham	5,516	3,841	1,675	43.6
Eden	1,856	1,857	-1	-0.1
Highland	1,125	1,199	-74	-6.2
Little Britain	3,514	2,701	813	30.1
Lower Oxford	4,319	3,264	1,055	32.3
Oxford	4,315	3,769	546	14.5
Sadsbury	3,025	2,712	313	11.5
Upper Oxford	2,095	1,615	480	29.7
West Fallowfield	2,485	2,342	143	6.1
West Nottingham	2,634	2,183	451	20.7
West Sadsbury	2,444	2,160	284	13.1
Totals	**45,468**	**38,379**	**7,089**	**18.5**

Transportation Facilities

Roads: Several major state thoroughfares transect the Watershed (see map). In the eastern portion of the Watershed, State Route 372 serves as a connection between Coatesville to the east and Quarryville to the west. State Route 10 and State Route 41 run from north to south along the east boundary. State Route 41, in particular, has history of tremendous traffic problems, with both congestion and safety concerns.

In the north of the Watershed, State Route 30 is a large source of population growth, with new housing and retail centers opening just outside the Watershed boundaries. The southern area of the Octoraro Watershed includes US Route 1, another major source of population growth, and State Route 222, which connects the Pennsylvania portion of the Octoraro Watershed to its Maryland counterpart.

Trains: One train line goes through Parkesburg, Christiana and Atglen Boroughs from Philadelphia to Harrisburg. This line carries freight and passenger trains, including a commuter stop in Parkesburg. The Parkesburg station is the only public transportation stop in the Watershed.

Airports and Bus Service: Neither of these entities is present in the Octoraro Watershed.

Overall, there are very few public transportation options in the Octoraro Watershed, leaving the region in a Catch-22 situation. With no public transportation, cars, trucks and Amish horse-drawn vehicles remain the only viable options for residents to use. This makes demand for roadways higher, thus increasing the runoff into the stream. On the other hand, there is a lack of any major business "hub" in the Watershed, making the advent of any sort of public transportation in the region unlikely.

Major Sources of Employment

The Octoraro Watershed's primary source of employment is agriculture. The only industrial area is located within the Atglen-Christiana-Parkesburg corridor, and this constitutes only 0.22% of the Watershed's land use. Data from the 1997 Economic Census confirms this. Even this data is somewhat deceiving because many of the non-farming businesses are located outside of the Watershed's borders.

Table 4: Number of Business Establishments and Farms Located In ZIP Codes of the Octoraro Watershed

ZIP Code	Manufacturing	Retail Trade	Professional, Scientific and technical services	Administrative & support & waste management & remediation services	Educational Services	Health care & Social Assistance	Arts, Entertainment & Recreation	Accommodation & Foodservices	Other services	*Farms*
17509 (Christiana)*	11	14	2	2	0	9	1	2	5	*141*
17527 (Gap)	9	22	6	0	0	4	0	17	12	*121*
17536 (Colerain)*	5	1	0	2	0	1	0	0	1	*77*
17563 (Drumore)	7	5	0	2	0	0	2	2	3	*102*
17566 (Quarryville)	23	46	7	4	2	17	2	17	23	*251*
19310* (Atglen)	5	4	2	3	0	0	1	1	2	*40*
19330 (Cochranville)	4	8	3	0	0	0	1	1	3	*86*
19362 (Nottingham)	3	7	1	2	0	0	0	3	5	*63*

19363 (Oxford)	15	54	14	7	0	14	2	15	18	*171*
19365 (Parkesburg)	8	27	4	6	0	12	0	8	9	*50*
TOTALS	**90**	**188**	**39**	**28**	**2**	**57**	**9**	**66**	**81**	***1102***

(Sources: US Census Bureau; National Agricultural Statistics Service)
*Entire ZIP Code area is located within watershed boundaries

Outstanding or Unique Features

One very important result of the geologic development of the region was the creation of a large band of serpentine rock throughout southwestern Chester and southeastern Lancaster Counties. Serpentine and the soil associated with it do not comprise an ideal environment for plant growth. Consequently, only a limited number of flora and fauna adapted to life in this area. The result is an extremely unique ecology not just to the region, but to the eastern United States as well.

Today, less than 1000 of the original 2000 acres of the "serpentine barrens" remain. The other areas have been destroyed by development or by some other action of man. Goat Hill, the most intact portion of the barrens, provides a habitat for a rare combination of plants and animals not found elsewhere in Pennsylvania. The long hairy-field chickweed and the serpentine aster are foremost among the more unusual species of plants. This unusual mixture of plant and animal life is reflective of the kinds of vegetation found in the area during the last glacial age of 25,000 years ago. As this age came to an end and the climate began to change, the plants on the barrens survived because the geology was not suitable for most of the forest species that became dominant elsewhere. This makes the barrens a living remnant of the Ice Age (SRS, 1983).

The Chester County Parks Department, in conjunction with the Nature Conservancy, has recently preserved 300 acres adjoining Nottingham Park that encompasses the Serpentine Barrens. The Nature Conservancy, under a Unified Management Plan with the Chester County Parks Department, will hold this land. The Nature Conservancy also holds the 340-acre Chrome Serpentine Barren Preserve, a unique area with self-guided nature trails (Chester County Parks Department).

The Octoraro Valley contains numerous other geological formations. The Mine Ridge anticline is part of the complex Honeybrook uplift. It is a double fold that is oriented in a southwesterly direction. The Peach Bottom syncline is a downfold in the rock formation. This syncline is composed of bluish black slate and is located between the West Branch and Kings Run in Colerain Township. Another outstanding scenic/geological feature is Black Rock (a massive outcrop of albite-chlorite schist), located on the West Branch of the Octoraro Creek about 1.9 miles northwest of Kirkwood. It is scenically situated in a narrow gorge and is marked by a public spring. (Scenic River Study, 1983)

Farmland preservation is one of the primary concerns of both Chester and Lancaster County officials. Agriculture is of tremendous economic importance to the watershed residents (OWA Survey, 1998). One if the principal reasons for this is the favorable nature of the soils. In the area of the West Branch, classes I-III soils, which comprise the best agricultural soils, are found intensively in two areas; one near Puseyville and the State Game Lands, and the other north of White Rock. While classes I-III soils may be the best for crops, classes IV and V also play an agricultural role in that they provide good pastureland for the many dairy farms in the region. Along the East Branch of the Octoraro, there are several areas of prime farmland. West Fallowfield and Upper Oxford Townships are primarily agricultural communities and encompass large tracts of classes I-III soils. Lower Oxford also has some good crop soil, and there is a limited amount in West Nottingham. (SRS, 1983)

ISSUES, CONCERNS, CONSTRAINTS, AND OPPORTUNITIES

Sprawl Development - Given the rapid growth of southeastern Pennsylvania, it is no surprise that sprawl development is a primary concern for the Watershed. Both Chester and Lancaster Counties have become hotbeds for communities whose occupants travel to other nearby regions for employment. According to a 2000 study commissioned by 10,000 Friends of Pennsylvania, unfettered sprawl:

- Increases the costs of roads, housing, school and utilities;
- Increases the cost of transportation;
- Consumes agricultural lands, natural areas and open spaces;
- Concentrates poverty and accelerates socio-economic decline in cities, towns and older suburbs; and
- Increases polution and stress.

The Octoraro Watershed contains all the elements necessary for sprawl: excellent soils, open space, a growing population, increased road infrastructure and varried zoning regulations.

Table 5: PROPOSED HOUSING IN THE OCTORARO WATERSHED

Municipality	Proposed Development	Estimated Number of Units
Atglen Borough	Newport Circle	26
Atglen Borough	Ridgeview	10
Parkesburg Borough	Parkesburg Knoll, Phase II	27
Parkesburg Borough	McGrail Sub	44
Parkesburg Borough	Crystal Springs	200
Highland Township	Single Family	7
Sadsbury Township	Simmontown Ridge	39
Sadsbury Township	Auntie Anne's	200
West Fallowfield	Burkhart Subdivision	7
West Fallowfield	Moccasin Woods	6

Non-point source pollution (NPS) – Contamination from agricultural runoff has reached serious levels in the Watershed. A study by the Cadmus Group, Inc., prepared for the US Environmental Protection Agency in 1998, indicates that nitrates and phosphorus contamination are well above the desired limits. These wash into water bodies from agricultural land, small and medium-sized animal feeding operations, construction sites, and other areas of disturbance. Other common NPS pollutants include pesticides, pathogens (bacteria and viruses), salts, oil, grease, toxic chemicals, and heavy metals. Destroyed habitat, unsafe drinking water, fish kills, and many other severe environmental and human health problems result from NPS pollutants. The pollutants also ruin the beauty of healthy, clean water habitats. (US EPA, 1996; Cadmus Group, 1998).

Stormwater Management – Strongly associated with NPS pollution is storm water runoff and its consequences. With the abundance of the Watershed's agricultual land and an increase in impervious surfaces due to develop and its infrastructure, runoff continues to be an accelerating problem. The Pennsylvania Stormwater Management Act itemizes many of the problems associated with runoff, including erosion and sedimentation; the overtaxing the carrying capacity of streams and sewers; a substantial increase in the cost to public facilities to carry and control stormwater; the undermining of flood control efforts in downstream communities; severe reductions in ground water recharge; and threats to public health and safety.

Thanks to education efforts from federal, state, local and non-profit agencies, stormwater management is far more in the public consciousness than it used to be. Once again, strong government participation by the municipalities has had a significant impact. Each municipality in the watershed uses a subdivision/land development plan that provides for stormwater management.

LAND RESOURCES

Soil Characteristics

As stated earlier on page 9, soil characteristics are very favorable for farming, which contributes to the importance of agriculture in the watrershed.Soil characteristics in the Octoraro Creek watershed are generally suited for cultivated crops and pasture land, although the soils are erosion prone due to poor farming practices and overgrazing. Soil series in the Watershed are predominantly Manor, Chester, Glenelg and are formed from mica, schist, granitized schist, quartzite and gneiss. These soils are generally very well drained deep soils that comprise the best agricultural soil in the State. The soils also tend to be strongly acidic by nature. They are considered Class I, II, and III soils, or prime crop land, while Classes IV and V represent pastureland.

Specific soil series found near the East Branch include Chester, Glenelg, and Elk soils, which tend to be deep and well drained. Along the parts of the East Branch with steep streambanks, the usually stony manor silt loam is found. This soil is very deep and very well drained, sometimes excessively drained. The steep slopes in this area make the land unsuitable for anything but forest cover. In the vicinity of the West Branch, prime agricultural soils (Classes I-III) are found intensively near Puseyville, the State Game Lands, and north of the White Rock. Other areas of prime farmland are found throughout Chester and Lancaster Counties.

Riparian soils along the East Branch are mostly Newark silt loam. Other Riparian soils include Glennville, Comus, Holly, and Baile, which are all poorly drained, and slightly to moderately acidic. Both Newark and Holly soil series are subject to frequent flooding. These soils are rarely used for agricultural or development purposes. Other soils found in the watershed are Neshaminy-Chrome-Conowingo, and are moderately deep, and deep silty or serpentine soils (Cadmus, 1998).

The characteristics that make these soils suitable for agriculture are the same characteristics that make the soils favorable for development. Since the best soil for development is traditionally the best soil for agriculture, there are numerous tracts of very developable land in the Octoraro Valley. West Nottingham Township, due to the influence of the serpentine Barrens, has the largest tract of unsuitable soil. Otherwise the suitability of the land is contingent upon its slope rather than its geology. Consequently, most of the non-developable land in the study area follows the Octoraro itself or one of its many tributaries. As noted in the presentation of topography, the extent to which this is true is dependent upon the location of the tract relative to the study region. The further south and east one goes, the less suitable is the land for development (Scenic River Study, 1983).

Critical Areas

Nickel ore was mined at the Gap Nickel Mine near the headwaters of the Octoraro Creek on Mine Road 3.5 miles south of Kinzers in Lancaster County. The ore body occurs on the edge of a gabbro mass that has intruded the Wissahickon Schist. The nickel ore minerals are pentlandite (iron-nickel sulphide) and millerite (nickel sulphide).

The mine was first opened for the extraction of copper (circa 1730). Copper was mined intermittently for 80 to 90 years, however, the operation proved unsuccessful and the mine remained idle for 30 years. In 1849 it was reopened, again as a copper mine. Up to this time nickel ore was being discarded as refuse because the miners did not distinguish it from pyritic material. In 1852 the refuse from the dump was analyzed and found to contain nickel at a concentration of between 1 to 30 percent. A smelter was opened a mile to the north of the mine. The Gap Nickel Mine closed in 1893.

In the past, chrome ore was mined from chromiferous serpentine along the Octoraro Creek in southern Lancaster and Chester Counties. At least a dozen mines and pits were operated here between the late 1820's and the mid 1870's. Prior to and during World War I some of the mines were reworked. At least 40 tons of chrome ore were removed from the Carter (Texas) mine in Lancaster County in 1915, probably from the existing dumps. There was also some geophysical work done during World War II when foreign supplies were threatened, but no mining took place. (SRS, 1983).

The only mineral activity in the study area today is at the County Line Quarry (formerly Cedar Hill) 1 ¾ miles south of Wrightsdale on the Octoraro Creek. This operation is a source of crushed rock (serpentine) and is located between the abandoned Tyson Reynolds mine (1830-1860) and the abandoned Geiger pits (1844-?).

No known sinkholes exist within the watershed boundaries at the present time. However, the limestone belt that runs along the Route 30 corridor on the northern part of the watershed boundary has had an enormous amount of construction over top of it. With the porous, unstable nature of limestone, this stretch of land should be monitored carefully for the beginnings of sinkholes.

There are no regional landfills currently in the Watershed area, nor do any hazardous waste sites currently exist in the Pennsylvania portion of the Octoraro Watershed.

WATER RESOURCES

The water resources of the Octoraro watershed are diverse (see maps, as well as above). Despite the abundance of surface water, however, a scant 0.9% of the land use in the watershed is designated as wetlands. The largest body of water is the Octoraro Reservoir, which is administered by the Chester Water Authority (CWA). This reservoir provides about 36 million gallons of water per day to CWA's customers in southeastern Pennsylvania and northern Delaware.

Table 6: Water Quality of Octoraro Lake

Parameter	Concentration
Alkalinity	43 mg/l
Conductivity	202 umhos/cm at 25 C
Dissolved Oxygen	8.6 mg/l
% Dissolved Oxygen Saturation	78%
Ammonia	0.19 mg/l
Nitrate	5.5 mg/l
pH	7.8
Total Phosphorous	0.046 mg/l
Total Solids	150 mg/l
Suspended Solids	10.2 mg/l
Turbidity	9 NTU
Total Coli forms	93/100 ml

Source: Cadmus Report, 1998

Water Quality

There are a total of seven point source areas in the watershed that directly affect the Octoraro (see chart). The Cadmus Report demonstrated that point source pollution has accounted for only 6% of pollution loading in the Octoraro Reservoir (Cadmus Report, 1998). The presence of non-point source pollution is of far greater concern. The Millersville Study demonstrated the amount and apparent effect of the nutrients, sedimentation and pesticides in four different monitoring sites. This confirmed conclusions of the Cadmus report, as well as data from both CWA and the US Geological Survey (USGS).

Table 7: Point Source Discharges in the Octoraro Watershed

Discharge Source	Receiving Stream	Flow in MGD (Design/Existing)	Discharge Type	NPDES Permit Number
Christiana Sewage Treatment Plant	Buck Run/East Branch Octoraro Creek	0.13/0.25	Sewage	0025399
Atglen Sewage Treatment Plant	Valley Creek	0.09/0.062	Sewage	0024651
Solanco School District (Bart Colerain)	Cooper Run	0.005/NA	Sewage	0081124
Solanco School District (Solanco High School)	Stewarts Run	0.02/NA	Sewage	0081116
Octoraro Area School	Knights Run	0.03/0.017	Sewage	0042889
Sadsbury Sewage Treatment Plant	Williams Run	0.023/NA	Sewage	008338
Bart Township Board of Supervisors	Nickel Mines Run	NA	Sewage	0083933

Source: Cadmus Report, 1998

Table 8: Octoraro Watershed Water Quality Data

Stream	Stream Code	Drainage Area Square Miles	Miles Impaired	Miles Attained	Sources/ Causes/ Comments
Octoraro Creek (9 UNTs)	6,947	176		21.2	
East Branch Octoraro Creek	7,070	90.6	16.29 Main stem	10.78 10 UNTs	AG-Organic enrichment/ low DO, nutrients, siltation, high

Stream	Stream Code	Drainage Area Square Miles	Miles Impaired	Miles Attained	Sources/ Causes/ Comments
					nitrates
Buck Run (3 UNTs)	7,144	18.1	7.44		AG-Organic enrichment/ low DO, nutrients, siltation
Williams Run (1 UNT)	7,143	4.89	4.46		AG-Organic enrichment/ low DO, nutrients, siltation
Pine Creek (1 UNT)	7,150	2.73	3.43		AG- Organic enrichment/ low DO, nutrients, siltation
Valley Run	7,141	10.6	2.98		AG- Organic enrichment/ low DO, nutrients, siltation
Glen Run	7,139	1.01			TSF-MF
Officers Run	7,133	5.83			TSF-MF
Knott Run	7,127	1.81		2.58	HQ_CWF
Annan Run	7,125	1/14		2.01	HQ-CWF
Knight Run UNT	7,111	9.04		0.96	TSF-MF
Ball Run	7,108	3.58		4.75	
Bells Run	7,104	4.17	2.16		AG- Organic Enrichment/ low DO, nutrients, siltation
Muddy Run near Cream	7,086	14.7			TSF-MF
Rattlesnake Run	7,095	2.62			TSF-MF
Coopers Run (3 UNTs)	7,081	6.33		10.57	
Leech Run	7,071	5.22			TSF-MF
West Branch Octoraro Creek	7,033	48.1	1.12 Main stem: .076, 1 UNT	10.36 Main stem; 15.5, 9 UNTs	AG-Organic enrichment/ low DO, nutrients, siltation HQ-CWF
Nickel Mines Run	7,066	4.63	7		AG-Organic enrichment/ low

Stream	Stream Code	Drainage Area Square Miles	Miles Impaired	Miles Attained	Sources/ Causes/ Comments
(3 UNTs)					DO, nutrients, siltation HQ-CWF
Meetinghouse Creek (1 UNT)	7,064	5.26	6.38		AG-Organic enrichment/ low DO, nutrients, siltation HQ-CWF
Bowery Run (5 UNTs)	7,056	7/83		10.82	HQ-CWF
Stewart Run (4 UNTs)	7,050	5.87		8.95	HQ-CWF
Kings Run	7,045	1.25		2.6	HQ-CWF
Gables Run (2 UNTs)	7,034	2.38		4.19	HQ-CWF
Tweed Creek (2 UNTs)	7,026	6.12		5.64	TSF-MF
McCreary Run (6 UNTs)	7,016	4.38		8.47	
Blackburn Run (2 UNTs)	7,012	2.52		3.23	TSF-MF
Black Run	7,004	4.31		1.78	EV-MF TSF-MV
Hog Run	7,003	1.15		3.23	TSF-MV
"Reynolds Run"					HQ-CWF
Stone Run	6,979	1.01			EV-MF

UNT = Unnamed Tributary
WWF = Warm Water Fish
MF = Migratory Fish

CWF = Cold Water Fish
TSF = Trout Stocking
EV = Exceptional Value
HQ = High Quality

(Source: WRAS Report, unpublished)

Water Supply
The Chester County Water Resources Authority reports that Chester County receives an average of about 45 inches of rain per year. This rainfall is the source of both surface water and groundwater recharge in the Octoraro watershed.

Of the 18 municipalities in the watershed, only three have any sort of limited public water system. All other municipalities rely solely upon private wells for water supply. Oxford

Borough gets some of its water from a well that draws about 28,000 gallons per day. Atglen Borough uses public water facilities drawn from wells and springs, with an average withdrawal of 80,000 gallons per day. The adjoining borough of Christiana also draws public water from two wells and ten springs in Sadsbury Township, with an average withdrawal of 110,000 gallons per day. Christiana Borough and Sadsbury Township have established a wellhead protection area in Sadsbury for Christiana's source wells and springs. The US Environmental Protection Agency recently recognized Christiana for its efforts in this area.

BIOLOGICAL RESOURCES

Wildlife

A presentation of the vegetation and animal life in the watershed must be included in any discussion of natural resources, since they are important to the overall ecology of the area. The wildlife of the area includes various species of birds, reptiles, fishes, and mammals. Numerous ducks, vultures, hawks, thrushes, orioles, finches plus many other types of birds are evident in the region. Snakes include garter and black snake. Besides the stocked trout, the Creek contains bass, carp, sunfish, and other aquatic life. Small mammals include rabbits, groundhogs, squirrels, opossums, moles, and other game animals. In addition there are numerous animal slides and burrows plus evidence of beaver (SRS, 1983).

Many animals in the watershed area have been designated with various classifications of concern by the Pennsylvania Department of Conservation and Natural Resources. Perhaps the most famous of these is the bald eagle, which has been seen more and more often in the watershed area. There are currently two pairs of nesting bald eagles within the watershed boundary. Other less lofty creatures, however, are of equal or greater value to the ecosystem and are also designated as vertebrates of concern. Some of these include the redbelly turtle, the broadhead skink and the Allegheny woodrat (Pennsylvania Natural Diversity Index [PNDI], 2002). The bog turtle *(clemmys muhlenbergii)* can be found in small numbers in the Serpentine Barrens and surrounding areas, and is a key indicator of the general health of the local environment.

The invertebrate population in the area contains many rare, endangered and threatened species (PNDI Index, 2002). In 1998, OWA commissioned a study of macro invertebrates at four sites along the Octoraro. The report demonstrated the relationship between high nitrate levels and low biodiversity ratios. (The entire report can be found later in this document.)

Vegetation

Plant life in the region is typical of vegetation found elsewhere in the State. (The Serpentine Barrens, a small part of the Octoraro Valley is not typical and is describes earlier in this section.) The watershed contains stands of walnut, hemlock, and sycamore. Other trees include oak, poplar, birch, ash, maple, beech, hickory, dogwood, spruce, and pine. A variety of smaller (understory) vegetation also exists. This consists of ferns, mosses, grasses, and shrubs.

The problem of noxious and invasive plants is one that the Octoraro watershed shares with the rest of Pennsylvania. Indeed, each of the entries listed by the Pennsylvania Biological survey can be found in the watershed region.

Table 9: Pennsylvania Noxious Weeds
(based on Noxious Weed Control Committee recommendations, 1994)

COMMON NAME	SCIENTIFIC NAME	DISTRIBUTION IN PA
nodding thistle	*Carduus nutans*	central & SE PA
Canada thistle	*Cirsium arvense*	common throughout state
bull thistle	*Cirsium vulgare*	common throughout state
jimsonweed	*Datura stramonium*	mostly S half of state
purple loosestrife of state	*Lythrum salicaria*	wetlands in many parts
mile-a-minute weed	*Polygonum perfoliatum*	mainly southeastern PA
kudzu	*Pueraria lobata*	documented from SE PA & Allegheny Co.
multiflora rose	*Rosa multiflora*	throughout state, often planted
shattercane	*Sorghum bicolor*	scattered, mainly eastern ssp. drummondii PA
Johnson grass	*Sorghum*	primarily eastern PA

(Source: Pennsylvania Biological Survey)

Plants, vertebrates, and invertebrates of concern are listed in Appendix B.

CULTURAL RESOURCES

Recreational

The underdeveloped, scenic character of the Octoraro watershed makes it ideal for a variety of outdoor recreational activities. The major uses are fishing and hunting, but there are also a number of other uses, such as boating, hiking, and nature observation. These activities are enjoyed by a large number of people who usually enjoy these activities without harm to the environment or local property owners. OWA's 1998 survey of watershed residents demonstrated that many people choose to recreate right in the watershed itself (see Appendix A).

Fishing- The Pennsylvania Fish Commission considers the Octoraro Creek a high-pressure trout stream. The Fish Commission stocks the East and West Branches several times a year primarily with brown and rainbow trout but- also with some brook trout. In addition to the trout stocking done by the Fish Commission, the Southern Lancaster County Farmers-Sportsmen Association maintains a trout hatchery in Colerain Township from which approximately 2,500 trout per year are stocked in the West Branch, Stewart Run, and Bowery Run.

The Fish Commission has designated a 1.25 mile stretch of the West Branch between Pennsylvania Route 472 and the southern end of the State Game Land Number 136 as an area for flying fishing only. In this area, fishing may only be done with artificial flies and conventional fly fishing tackle.

Access to the Octoraro Creek for fishing is very good. Most of the property owners along the stream allow fisherman access to the stream. Parking is usually not a problem except on opening day of the trout season when the area is very crowded.

Hunting- The woodland and agricultural land in the area provide for good hunting. There are deer in the woods all along the Octoraro Creek. Hunting for squirrels, rabbits, pheasants, ducks, and other small game also is common in the area.

State Game Land Number 136, containing 91 acres, is located along the West Branch in Colerain Township. This land provides a good habitat for deer, squirrel, and other game and non-game species. The amount of hunting in the Game Land depends upon the season and the weather. The Chester Water authority has recently begun permitting some limited hunting within their property. The Cheaster County Parks Department conducts deer hunts for two days in January by special permit in the new Octoraro Park on the East Branch.

Fox chasing is also popular in the Octoraro. There are a number of large horse stables in the study area whose owners participate in the sport. Chases are held primarily from November to March, providing a good workout for the foxes, hounds, and horses, as well as the chase organizers. Unlike other forms of hunting, the object is to merely chase the fox and not to kill it.

Boating- Due to low water levels, canoeing is possible only on the main branch of the Octoraro Creek below Octoraro Lake. Canoes can be put in just below the Lake at Pine Grove Covered Bridge in Ashville Road and can be taken out at road crossings, such as Sleepy Hollow Road, or the stream can be canoed into Maryland. While canoeing itself presents no problems to property owners, there have been instances where canoeists have stopped on private land during their trip without seeking approval from the property owner. In some cases, the canoeists have built fires for cooking, have left litter, and have taken crops from the farmers' fields. These problems need to be corrected if canoeing is to continue to be a desired recreational activity on the Octoraro Creek (SRS, 1983). Canoe outfitters conduct trips on Octoraro Creek from Octoraro Lake downstream when stream flows are sufficient. Recent droughts have made this form of recreation nearly impossible for the last few years.

The Chester Water Authority permits kayaks, canoes, row boats and boats with electric motors on Octoraro Lake; gasoline motors are not permitted. Boats can be launched or docked at the fishing station along Spruce Grove Road.

Hiking - Theodore Parker Park and Nottingham Park offer extensive trails along their repective streams. When Octoraro Park is open to the public, there will be five new miles of hiking trails in the watershed.

Other Recreational Uses- A number of other recreational activities are enjoyed in the study area. During the winter, snowmobilers can be seen riding throughout the area when there is sufficient snow. Activities such as photography, bird watching, and general nature observation are common. (Scenic River Study, 1983)

Three major county parks provide areas of relatively undisturbed natural settings for the residents of Pennsylvania and their visitors: Nottingham Park and the new Octoraro County Park in Chester County and The Theodore Parker III Natural Area in Lancaster County. A variety of complementing municipal facilities are also available (see chart below). Chester Water Authority, in cooperation with OWA, created and maintains the John Evans Park. This park has interactive trails, fishing and access to the East Branch. These parks, however, are not generally connected to one another. Greenway trails would provide an opportunity for both residents and wildlife to have access to the maximum mount of open space possible. Atglen Borough's township property and the Chester Water Authority's land near the reservoir are two areas with excellent greenway potential.

Table 10: Municipal-owned Recreational Facilities in the Watershed by Municipality

Municipality	Recreational Facility												
	BF	FF	SF	VC	PG	TC	PF	WP	BT	WA	P	EP	Total Acres
Atglen	Yes	No	No	No	Yes	Yes	Yes	No	No	No	No	No	18
Bart	No	No	No	No	No	No	No	No	No	No	No	No	0
Christiana	No	No	No	No	No	No	No	Yes	No	No	No	No	2.5
Colerain	Yes				Yes	Yes	Yes	Yes		Yes	No		
East Drumore	No	No	No	No	No	No	No	No	No	No	No	No	0
East Nottingham													
Eden	No	No	No	No	No	No	No	No	No	No	No	No	0
Fulton	No	No	No	No	No	No	No	No	No	No	No	No	0
Highland	Yes												2
Little Britain	Yes	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No	8
Lower Oxford	Prp.	No	No	No	Yes	No	Yes	No	No	No	No	No	N/A
Oxford	no	no	no	no	yes	no	yes	Prp.	no	no	no	no	N/A
Parkesburg													
Sadsbury	No	No	No	No	No	No	No	No	No	No	No	No	0

Municipality	Recreational Facility											
	BF	**FF**	**SF**	**VC**	**PG**	**TC**	**PF**	**WP**	**BT**	**WA**	**P**	**EP**	**Total Acres**
Upper Oxford	Yes	No	No	Yes	Yes	No	Yes	No	No	Yes	No	No	3.2
West Fallowfield	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	8.1
West Nottingham	No	No	No	No	No	No	No	No	No	No	No	No	0
West Sadsbury	Yes	No	No	No	Yes	No	Yes	No	No	No	No	No	N/A

Abbreviations:

BF – Baseball Field
FF – Football Field
SF – Soccer Field
VC – Volleyball Court
PG – Playgrounds
TC – Tennis Courts
PF – Picnic Facilities
WP – Walking Paths
BT – Bike Trails
WA – Wooded Areas
P - Pools
EP – Equestrian Paths

ARCHAEOLOGICAL/HISTORICAL RESOURCES

The Indians called it "Octoraro" or "rushing waters". Early settlers referred to it as "Ottararo", "Auchteraroe", "Ocktoraro, "Octoraro", and "Octorara". Engineers for the Pennsylvania Railroad said that the Octoraro was the "purest large stream of water" in the Commonwealth, and recommended using it in the boilers of their locomotives. From such high praise and early references came the name of the Octoraro Watershed.

Indian Life

Delaware and Shawnee Indian settlements were common throughout the Octoraro Watershed. The wooded river valleys were an abundant source of food and water with the streams providing not only fine fishing but a transportation corridor to the Susquehanna River and the Chesapeake Bay. Archeological artifacts found in all parts of the watershed offer evidence of numerous Indian settlements and intense use by Indian hunters, fishermen, and travelers. As the Indians were to discover, it was the very characteristics of the watershed that they found so appealing that would also prove attractive to Colonial pioneers.

European Settlement

By the late 17th Century, settlers from England, Ireland, Scotland, and the low countries of Europe were moving into the Octoraro area. Because of the rapid increase of these settlers, William Penn sought a meeting with King Opessah of the Shawnee tribe to discuss the safety of the new pioneers at a site near the present town of Gap. The success of these talks was instrumental to the creation of many small villages and settlements in the watershed and along the streams. These early settlers were joined in the early 18th Century by Mennonites and Amish from southern Germany and Switzerland who were seeking religious tolerance as part of William Penn's "Holy Experiment." The Southeastern part of Pennsylvania not only suited their religious needs but also was, and still is, eminently suitable for their agrarian life. These areas of Chester and Lancaster Counties have some of the richest soils in the United States.

Early Industry and Commerce

Waterpower served grist, saw and fueling mills. The upper portions of the East Branch of the Octoraro provided power for more than twenty mills which produced lumber, paper, strip iron, grist, flour seed, casks, barrels, flat irons, pottery, bricks, castings and small machines and farm implements.

Mining was also a prominent industry. Copper near Steelville, chrome in the Serpentine Barrens area of Nottingham, and nickel near the headwaters of the West Branch of the Octoraro Creek. Iron forges were also found in abundance. Four iron forges operated between Christiana and Steelville on the East Branch in the 'Forge Hills." Iron forges were also located near Black Rock on the West Branch.

Towns, Villages, and the Railroad

As the English and Scotch-Irish settlers rapidly increased in the region, numerous villages and towns appeared throughout the watershed. Villages such as Andrews' Bridge, Bellbank, and Steelville employed a fair number of persons in the milling operations discussed earlier as well as the many small businesses in operation throughout the area. Andrews' Bridge had its own hotel, country store, black smith and wheel rights shop. Bellbank boasted a prosperous creamery and Steeleville contained numerous small businesses including Buckley's Grist Mill which still stands today. Mount Vernon (Lower Oxford Township, Chester County) was the most populous town in the region at the time of the Civil War. Cotton factories and paper mills made Mount Vernon one of the thriving employment centers in the area. Hopewell, which was designated a Pennsylvania Historic District in 1996, and Lower Hopewell are both located in the valley of Tweed Creek in East Nottingham and Lower Oxford Townships, Chester County. Samuel Dickey (1769-1835) was an agricultural innovator who established Hopewell in 1815. He and his family developed this valley into a laboratory for progressive farming, milling and educational practices, while establishing many area schools. Hopewell was an early borough from 1853 to 1914 and the valley prospered until the 1870's. Much of the 19th Century character endures in the land and its' buildings today.

The largest towns in the watershed owe their development to the construction of a series of railroads. Atglen, Christiana, and Parkesburg are located on the Pennsylvania Railroads mainline to Chicago and Oxford is located on a spur of what were the Philadelphia, Wilmington, and Baltimore Railroads. Supplementing these standard gauge railroads was the Narrow Gauge Lancaster, Oxford, and Southern (fondly called L.O.& S or "Little", "Old" and "Slow") and the Peach Bottom Railroad (fondly called "the Peachy"). The Narrow Gauge line followed West from Oxford to Hopewell and

Tweedale and then along the West Branch of the Octoraro Creek to Spruce Grove, White Rock, and Kings' Bridge where it headed West to Peach Bottom on the Susquehanna Rover. This line carried passengers and freight until it fell victim to the two giants of the industry, the Pennsylvania Railroad and the Baltimore and Ohio in 1910.

The town of Christiana in Lancaster County may be best remembered for what is referred to as the "Riot of 1851." The disturbance began when a Maryland farmer and a U.S. Marshall entered the town to claim a band of four runaway slaves. Several of the townspeople rose on behalf of the slaves and a "riot" ensued. The slave owner, Edward Gorsuch was killed and several others were injured. It may be that some of the first shots of the Civil War were fired along the Octoraro. A new museum was opened recently in Christiana Borough (in conjunction with the More Memorial Library) to commemorate the event, as well as house important documents and related artifacts.

The Watershed Today

The industries of the late 18th and early 19th centuries evolved into the predominately agricultural industry that gives the watershed its rural character of today. Rolling farmland, dense woodlands, and picturesque villages are familiar sites. Although many of the settlements previously noted have evaporated or have assumed diminished roles, there are still numerous sites and structures remaining which are reminiscent of those bygone eras. Perhaps the most prominent are the four covered bridges which span the Octoraro.

At one time, virtually all the bridges crossing the Octoraro were covered. Time, fire, and vandalism have taken quite a toll. Of the four which remain, White Rock Bridge, which crosses the West Branch in Colerain Township, Lancaster County is the oldest, (1847). Jacksons Saw Mill Bridge in Bart Township was built in 1878. The Mercers Ford Bridge which crosses the East Branch north of Steelville was built in 1880. The Pine Grove Bridge at the southern tip of the Octoraro Lake was constructed in 1884. A fifth bridge, "Newcomers" at Bellbank, was destroyed by vandals a few years ago. Stone supports to the trestles of the Peach Bottom Railroad can still be seen.

Other historic sites in the area range from the remains of the Sadsbury Iron Forge along the East Branch to the numerous homes and mills of the areas, which are lovingly restored and maintained by the present owners. Included in this last category is the Pennsylvania Railroad Freight Station in Christiana which was recently restored by the Lancaster County Pennsylvania Charter Chapter of the National Railroad Historical Society and used as the headquarters of the Lancaster County Chapter.

Several organizations in the region document, preserve and provide information about the various historical sites in the Octoraro watershed. These include the Octoraro Area Historical Society, the Lancaster County Historical Society, and the Pennsylvania Railroad Historical Society. These organizations are the primary resources in any matter dealing with these issues.

Management Options

Goal I- Improve Water Quality in the Octoraro Creek and its Tributaries.

Objectives:

1) Increase the use of best management practices throughout the watershed through our partnership with the county conservation districts and watershed property owners to reduce erosion, sediment and nutrient turn-off problems.

2) Continue to increase land management projects with the Chesapeake Bay Foundation, Conservation Districts, Brandywine Conservancy, Ducks Unlimited, and U.S. Fish and Wildlife, including stream bank fencing, riparian buffers, wet land restoration and reforestation.

3) Expand our cooperation with the Chester County Water Resources Authority to reduce the high level of nitrates found in the Octoraro Watershed by USGS testing in 2001. Since most of the nitrates are from non point sources, community and property owner education will be a primary OWA objective in the next two years.

4) Request through Chester and Lancaster County Conservation Districts and Chester County Water Resources Authority to Pennsylvania Department of Environmental Protection that the PA Department of Environmental Protection include the Octoraro Watershed in their assessed waters research and map.

Goal II- Encourage Environmentally Sound Municipal Planning

Objectives-

1) Propose to the watershed that their future local and regional land use plans include the protection of prime agricultural soils, steep slopes, wood lands, flood plains and wet lands.

2) Encourage and try to find funding for groundwater recharge studies for the protection of these areas from future development. Atglen Borough, West Fallowfield Township, Sadsbury Township and West Nottingham have specifically listed these studies on their municipal questionnaires.

3) Help Atglen Borough and Sadsbury Townships establish a wellhead protection area for the wellsand springs that are the source of Atglen's public water system and are located in Sadsbury Township.

4) Encourage municipalities to uphold their storm water management plans to reduce runoff, erosion and sedimentation by aggressively controlling storm water runoff and flood control to increase ground water recharge. Specific areas of concern listed in the municipal survey are a) Little Britain Township- runoff problems on Blue Gill Road, b) Fulton Township- stream meandering causing erosion at the base of the bridges.

5) Write and adopt sub basin water withdrawal zoning ordinances through USGS, Susquehanna River Basin Authority, and Chester County Water Resources Authority based on current and projected water balances in the watershed.

6) Write and encourage adoption of a single set of guidelines for the protection of the scenic river corridor by the participating municipalities in the 1983 study and 1986 issue and management recommendations.

Goal III- Promote Recreation Opportunities for Watershed Residents and Visitors

1) Create a public park and walking trail on 14 acres of Atglen Borough land in the west end of Atglen.
2) Assist Oxford Borough in the location and creation of additional recreational areas in the borough, including a possible rail-trail along the old Lancaster/Oxford Southern Railroad line.
3) Identify sites in the watershed to promote recreational opportunities for public fishing, bird watching, hiking trails, and natural study areas.
4) Partnership with Lancaster County Parks and Recreation and the Chester County Parks and Recreational Departments to encourage use of Stuarts Run Park, Nottingham Park, and the proposed Octoraro Park along the east branch of the Octoraro Creek.

Goal IV- Protect and Maintain the Bridges of the Watershed

1) There are 40 bridges in the scenic river corridor or alone, 4 of which are historic covered bridges and one, an iron bridge, listed on the national register. These bridges are vital for transportation purposes, but many, particularly the covered bridges, also serve to enhance the aesthetic quality of the region and give residents a connection to the proud past of southeastern Pennsylvania. Sine the 1986 report, the maintenance of bridges in the Octoraro watershed has greatly improved. Much of this can be attributed to the proactive approach taken by both the residents and public officials of the various municipalities. By keeping the lines of communication open with Penn DOT, action has been taken to repair and restore the region's crossings in a timely and thorough fashion. Perhaps the most significant restoration came with the rebuilding of the Mercer covered bridge in 1996.

2) Over the past 15 years, flood plain regulations have been updated in the watershed municipalities. These regulations have helped slow erosion that undermines the bridges foundations. However, there are current specific needs for the protection of several bridges in the watershed. (a)In Atglen Borough- The bridge over Valley Creek (Old Newport Pike) is in need of repair due to erosion. (b) Colerain Township- the bridge over Cooper Run (Sproul Road) is in need of repair. The bridge over the Octoraro along Route 472 near Black Rock Retreat also is being compromised due to erosion. (c) West Fallowfield/Sadsbury Townships- Steelville bridge over the East Branch of the Octoraro Creek (Steelville Road) is being undermined by creek flow moving to the east side of the stream corridor. (d) Eden Township- Cherry Hill Bridge and Drywells Bridge are both in need of structural repair due to erosion. (e) Bart Township – King's Bridge has erosion problems.

3) OWA will continue to encourage municipalities to adopt ordinances that protect flood plains, and slow erosion that undermine the bridges' foundations.

4) OWA will continue to serve as a "watchdog" to report the need for bridge repairs, stream meandering, erosion, and hazards to the appropriate agencies.

More Details on Goals and Objectives. In 1986, the Octoraro Creek Task Force generated an *Issues and Recommendations* document for the Octoraro Scenic Corridor. This section updates and modifies the 1986 Report by revisiting those recommendations, assessing their effectiveness, and revising them to fit in with today's issues and needs. In addition, other recommendations can be found in the Knight's Run subwatershed section of this report. Those recommendations can be applied to all subwatersheds in the Octoraro.

1) <u>Enforcement of Existing Regulations</u>

   Many laws and regulations currently exist at the federal, state, county and municipal levels that provide needed protection for the Octoraro Watershed. However, the effectiveness and degree of protection provided by these laws depends on their proper enforcement. Enforcement in turn depends on monitoring for violations.

   The past 15 years have seen a better rapport develop between enforcement agencies and our community. Indeed, many people who live here in the Watershed and have been involved with OWA and its activities now work directly with the agencies and that can help. This familiarity with the region and its issues has proven invaluable to promoting the cleanliness and safety of the Octoraro watershed to partnering agencies.

   A partnership of municipal officials and citizens is crucial for reporting and acting on violations. In 2000, OWA, with funding from the National Fish and Wildlife Foundation (NFWF), began organizing semi-autonomous "satellite" watershed groups within each municipality. These groups work to talk about and find solutions to issues before they become problems that require intervention from regulating bodies. New funding from NFWF in 2001-2 will allow this program to continue and expand.

2) <u>Recreational Activities</u>

   Recreation remains an important part of life in the Octoraro Watershed. OWA's 1998 telephone survey showed that 41% of Watershed residents engaged in some sort of recreational activity at their local stream or reservoir.

   Since the 1986 Report, over 650 acres of land within the watershed has been set-aside as parkland. In Chester County, the new Octoraro Park covers 550 acres along the East Branch. This vital area not only preserves woodlands, but allows for a unique opportunity to demonstrate the effectiveness of forested buffers along the stream bank. An additional 100 acres was set aside along Stewart's Run near the west branch, where Theodore A. Parker Natural Area now provides walking trails and fishing access to Stewart's Run. This natural area is serving as the lynchpin to a concerted effort from the Growing Greener program to invest over $250,000 in BMP implementation s along Stewart's Run.

   OWA also partners with the Chester Water Authority on the 3.5 acre John Evans Memorial Park. This park serves as both a recreational area and a demonstration site for streambank fencing, forested buffers and reintroduction of native plants. The park includes an interpretive walking trail that describes the techniques and results of these practices.

Responses to municipal questionnaires demonstrate that, while many recreational facilities exist in the watershed, there is little connection between them. The establishment of parks without the context of regional planning can actually lead to more sprawl development rather than the desired result of "open space". Coordination between municipalities and the County Parks Departments is essential for the best utilization of our current recreation facilities. Investigation into the establishment of greenways that connect these facilities should be a top priority. The west end of Atglen borough and the main stem corridor on Chester Water Authority property north of the reservoir are areas worthy of greenway feasibility studies.

Suggestions that may help to minimize the adverse impacts of recreation along the Octoraro corridors include increased patrols, education and involvement, clean-up campaigns and trash pick-up days, and management of creek access points.

4) Land Management Techniques for Corridor Preservation

Once again, the fifteen years since the 1986 Report have seen a marked improvement in BMP information and implementation. Groups that are currently active in the watershed promoting BMPs include the County Conservation districts, the Chesapeake Bay Foundation, OWA, the Brandywine Conservancy and Ducks Unlimited. Proper land management is essential to preserve the scenic and pastoral qualities of the Octoraro for the future.

Existing township zoning ordinances offer many protective measures and are to some extent responsible for the current scenic and pastoral attributes of the Octoraro. Suggestions which offer additional protection and deserve consideration by municipal officials include community development objectives which recognize the Octoraro Scenic River Corridor and the need to protect it, steep slope conservation ordinances, agricultural preservation techniques, natural buffer areas and filter strips, lot averaging and clustering provisions. As demonstrated earlier, many of these suggestions from the 1986 Report have been effectively implemented by the municipalities (see Table 2 above).

Voluntary land management techniques for corridor preservation that landowners may wish to consider include establishment and maintenance of natural buffer areas and filter strips, conservation easements and deed restrictions, farm audits, agricultural security areas, and agricultural preserves. "Ag pres" has been particularly successful in the watershed, where the demand for easements is currently outweighing the number of easements allotted. Lancaster Farm Trust, Brandywine Conservancy, and the County

Conservation Districts are all working with OWA to assist landowners with applications and land management plans. OWA's grant from the National fish and Wildlife Foundation is helping OWA to identify landowners who may be interested in land preservation, and afterward facilitate the implementation of easements.

5) <u>Protection of Water Quality</u>

One thing the Octoraro does not suffer from is lack of data. The United States Geological Survey (USGS), and the Chester Water Authority are continually collecting data on both surface and groundwater. Other studies, such as the ones conducted by Millersville University, the Cadmus Group and the Chester County Water Resources Authority add to the growing wealth of information about the watershed. With greater and more precise information, the evidence clearly shows the problems created by non-point source pollution and stormwater runoff.

All recommendations regarding water quality inevitably return to smart development and agricultural BMPs. In addition to previous suggestions addressing other issues, additional measures recommended to protect water quality include, improved management practices for utilization of farm animal wastes, implementation of Chesapeake Bay Project nutrient management practices, design and construction of animal waste storage facilities and controlling stream access points for livestock. Several of these practices are being implemented through grants form Pennsylvania Department of Environmental Protection (DEP), the US Environmental Protection Agency (EPA), and private non-profits such as Ducks Unlimited and Trout Unlimited. Through the cooperation of OWA, the municipalities and the Conservation Districts, many successful grants have been awarded and completed. Municipalities are encouraged to call these entities for consultation on potential projects.

6) <u>Forum for Future Discussion of Corridor Concerns</u>

In the area of communication, the watershed is in excellent shape. The cooperation among the municipalities for the generation of this report is just one example of how the Watershed residents are utilizing each other as effective resources to protect and preserve the Octoraro Watershed. Regional plans are being developed for township clusters in Lancaster (Christiana-Sadsbury-Bart-Colerain) and Chester (West Fallowfield-Atglen-West Sadsbuy-Parkesburg-Highland-Londonderry) Counties.

In addition to the satellite groups discussed under Recommendation #3, OWA is organizing a seminar for all municipal officials of the watershed. The topics (selected by the officials themselves through an OWA survey) will include agricultural law, stormwater management and smart growth practices. Partners in this seminar include the US EPA, the National Fish and Wildlife Foundation, the Oxford Foundation, Philip Morris, Inc. and the Strawbridge Foundation.

OWA staffs a booth each year at the Southern Lancaster County Agricultural Fair. The booth provides citizens with an opportunity to learn about the Watershed, as well as submit questions and acquire information on watershed preservation programs applicable to them.

7) Adoption of water withdrawal regulations

One area that is of primary concern is the lack of water withdrawal regulations in the Watershed's municipalities. While the Scenic river designation may offer some protection, the exceptional value and high quality tributaries present in the Watershed will be an enticing lure to private water bottling companies. Other areas in Pennsylvania have had success in stopping these withdrawals, but only after lengthy and costly legislation.

I. APPENDICES AND FIGURES

Appendix A – Watershed Wide Telephone Survey

In 1998, OWA began work on conducting a series of surveys of Watershed residents. The surveys, partially financed by a grant from the National Association of Counties (NACo) and the US Environmental Protection Agency (EPA), collected and analyzed data from different target groups in the watershed.

The main survey was a random sample survey to be conducted via telephone. OWA staff wrote the survey questions, with assistance from US EPA, The Alliance for The Chesapeake Bay (ACB), Millersville University and the University of Delaware.

In July of 1998, OWA commissioned the Office of Media Research at Millersville University (PA) to administer the random sample survey to 400 watershed residents. Millersville constructed a survey frame that included telephone numbers that were located within the Octoraro Watershed. The 32 - question survey covered a wide range of issues, from personal stewardship practices to knowledge about environmental issues.

OCTORARO WATERSHED COMMUNITY SURVEY (n=423)
July 1998 (Results in bold)

1. What do you like most about where you live?

rural, open space	***47.5%***
peaceful, quiet	***14.9%***
private, secluded	***7.4%***

2. Please tell me whether you feel the following possible problems are very serious, serious, not very serious, or not at all serious problems for your area.

	very serious	***serious***	***not very***	***not at all***
1. environmental pollution	***6.3%***	***21.9%***	***44.0%***	***27.9%***
2. rapid residential development	***24.3%***	***38.0%***	***26.1%***	***11.6%***
3. lack of recreational opportunities	***20.0%***	***27.7%***	***29.2%***	***23.1%***
4. unemployment	***3.8%***	***18.5%***	***48.7%***	***29.0%***
5. poor roads	***18.4%***	***30.5%***	***29.6%***	***21.5%***
6. crime	***4.3%***	***20.8%***	***51.1%***	***23.9%***
7. lack of open space	***4.5%***	***17.3%***	***37.0%***	***41.2%***

3. Now thinking about the environment, what do you think is the most serious problem facing your area today?

air/water pollution	***26.5%***
overdevelopment	***24.1%***
"other"	***16.9%***
nothing	***7.9%***

farm runoff/pollution *7.4%*

4. How long have you lived at your current address?

spread very evenly

5. Is your property used as a residence only, meaning that it is not used as a farm or home business?

residence only *87.7%*

6. If not, for what else is it used?

farming	*54.0% (6.4%)*
home business	*32.0% (3.8%)*

7. Do you rent or own your residence?

rent	*15.1%*
own	*84.2%*
don't know	*0.2%*

8. On approximately how many acres is your residence located?

spread very evenly

9. Does your household water come from a private well, a municipal/public service, or are you not certain?

1. well	*78.0%*
2. municipal	*21.0%*
3. uncertain	*0.9%*

10. Are you concerned about the current quality of your drinking water?

yes	*35.7%*
no	*64.3%*

11. [IF YES] Why are you concerned about the current quality of your drinking water?

contamination from farms/runoff	*16.6% (5.7%)*
brown, discolored	*14.5% (5.0%)*
general pollution	*13.8% (4.7%)*
other	*12.4% (4.3%)*
chlorine taste, smell	*11.0% (3.8%)*

12. I'm going to read you several statements about how you like your property to look and I'd like you to tell me if you agree strongly agree, somewhat agree, somewhat disagree, or strongly disagree with the statement.

1. I think it is important to have a neat and well-kept property.
   strongly agree 64.8% agree 33.3% disagree 1.9%
   strongly disagree 0%
2. I like to have as much lawn as possible.
   strongly agree 29.0% agree 42.4% disagree 21.6%
   strongly disagree 7.0%
3. I really don't like to mow grass, but I don't know what else to do with my lawn.
   strongly agree 10.5% agree 26.2% disagree 43.1%
   strongly disagree 20.2%

13. How many creeks are on your property?

none	***80.8%***
one	***16.4%***
two	***2.6%***

14. Which best describes your use of land immediately surrounding the (largest) creek?

1. leave wild	***42.5% (8.0%)***
2. mow once or twice a year	***7.5% (1.4%)***
3. mow more than twice a year	***13.8% (2.6%)***
4. use as part of animal pasture	***20.0% (3.8%)***
5. grow crops	***2.5% (0.5%)***
6. mixed pasture/cultivation	***13.8% (2.6%)***

15. Would you say the water quality in the flowing streams in your general area is:

1. very good	***19.8%***
2. good	***38.4%***
3. fair	***34.0%***
4. bad	***5.9%***
5. very bad	***1.8%***
6. don't know	***0%***

16. Do you strongly agree, agree, disagree or strongly disagree with the following statement? **When working on my land, I do things a certain way, because I know what I do affects those who live downstream from me."**

strongly agree 51.0% ***agree 39.6%*** ***disagree 6.0%***
strongly disagree 3.4%

17. How great a role does each of the following play in polluting rivers and streams? Use a scale of one to ten where one means it plays no role at all and ten means it plays a major role.

1. Discharge from industrial facilities
   1-3=62% 4-6=14.4% 7-10=23.6%
2. Discharge from sewage and treatment plants
   1-3=58.7% 4-6=15.1% 7-10=24.1%
3. Fertilizer from lawns
   1-3=39.6% 4-6=32.5% 7-10=27.9%
4. pesticides and herbicides from farms
   1-3=23.8% 4-6=26.9% 7-10=49.6%
5. Animal manure
   1-3=32.1% 4-6=26.3% 7-10=41.6%
6. Soil erosion
   1-3=39.3% 4-6=31.3% 7-10=28.5%

18. Since January of this year, did you engage in outdoor activities such as walking, hunting, fishing or gardening...

1. on your own property	***89.8%***
2. at a local river or reservoir	***41.0%***
3. at a county park	***45.9%***
4. at a state park	***34.5%***
5. at some other place we haven't mentioned	***29.2% (answers varied)***

19. Now I'm going to ask you several questions about "Open Space". First, what does the phrase "Open Space" mean to you?

undeveloped, no commercial land	***48.2%***
green land, trees, farmland	***22.8%***
room to move around	***10.2%***

20. Would you like to see more or less of each of the following landscapes in your area?

1. undeveloped wooded areas, streams and meadows	***more=87.4%***
2. natural areas with developed trails and public access	***more=75.6%***
3. developed park land and recreational facilities	***more=68.4%***
4. farmland	***more=66.8%***
5. large residential lots	***more=23.2%***

21. Now we'd like to ask you some questions about the role of farming in your community. I will read a series of statements to you, and I'd like you to tell me whether you strongly agree , agree, disagree or strongly disagree with the statement.

1. Farmers should receive government support to help maintain their way of life.
strongly agree 29.4% agree 41.0% disagree 22.6% strongly disagree 7.0%
2. Farms are an irreplaceable characteristic of our area.
strongly agree 63.2% agree 33.5% disagree 1.7% strongly disagree 1.7%
3. On the whole, farmers care about the environment.
strongly agree 37.4% agree 54.7% disagree 6.4% strongly disagree 1.5%
4. If agriculture/farming is a major source of water pollution, it should be dealt with just like pollution from any other industry or business.
strongly agree 34.4% agree 44.7% disagree 16.7% strongly disagree 4.2%

22. Please state whether you strongly agree, agree, disagree or strongly disagree with the statement:

1. The oceans are gradually dying from oil pollution and dumping of waste.
strongly agree 39.3% agree 49.9% disagree 7.8% strongly disagree 3.0%
2. The problems of the environment are not as bad as most people think.
strongly agree 9.4% agree 14.4% disagree 53.1% strongly disagree 23.1%
3. We are quickly using up the world's natural resources.
strongly agree 42.6% agree 45.0% disagree 9.4% strongly disagree 2.9%
4. People worry too much about human progress harming the environment.
strongly agree 12.3% agree 21.7% disagree 47.7% strongly disagree 18.3%
5. The world would be a more peaceful place if its wealth were divided more equally among nations.
strongly agree 17.2% agree 36.4% disagree 32.7% strongly disagree 13.7%
6. We need to dramatically reduce inequalities between the rich and the poor, whites and people of color, and men and women.
strongly agree 33.0% agree 49.5% disagree 12.9% strongly disagree 4.6%
7. The free market is almost always the best way to supply people with the things they need.
strongly agree 22.6% agree 54.0% disagree 19.0%

strongly disagree 4.4%

8. People who are successful in business have a right to enjoy their wealth as they see fit.
   strongly agree 27.2% agree 52.6% disagree 16.1%
   strongly disagree 4.0%
9. If people volunteer to conserve their land, government should assist them with both money and resources.
   strongly agree 25.3% agree 50.4% disagree 20.8%
   strongly disagree 3.5%
10. Current laws and regulations designed to protect public health and the environment are too strict.
    strongly agree 8.5% agree 18.1% disagree 59.4%
    strongly disagree 14.0%

23. How far do you typically travel (one-way) to shop for:

    1. Food
    2. Clothing
    3. to get to work

24. What was your age on your last birthday?

25. What is the last grade level of schooling that you have completed?
    1. non-high school graduate ***10.9%***
    2. high school diploma ***45.8%***
    3. some college ***13.5%***
    4. two year or tech degree ***9.3%***
    5. four year college degree ***12.6%***
    6. graduate or postgraduate degree ***7.8%***

26. In which township or municipality do you live?

27. Are you currently working full-time, part-time, going to school, keeping house or something else?

full-time	***56.3%***
retired	***15.0%***
part-time	***13.3%***
keeping house	***9.5%***

28. What is the name of your job?

clerical	***15.9%***
service	***13.7%***
professional	***12.2%***
technical	***11.8%***

farming, forestry, fishing *5.2%*

29. Is your total family income above or below $30,000 per year?

    above ***73.1%***

30. [IF ABOVE] Is it $30-$40, $40-$50, $50-$75, or over $75,000 per year?

    $30-$40=20.8% ***$40-$50=18.6%*** ***$50-$75=20.8%*** ***over $75=10.9%***

31. [IF BELOW] Is it under $15,000 or $15-$30 per year?

    under $15=4.2% ***$15-30=18.3%***

32. Are you male or female?

    male ***39.0%***
    female ***61.0%***

Appendix B – Species of Concern in the Octoraro Watershed

Pennsylvania Invertebrate Species of Concern in Chester and Lancaster Counties

ANISOTA STIGMA - SPINY OAKWORM MOTH
ANOMOGYNA ELIMATA - SOUTHERN VARIABLE DART MOTH
APODREPANULATRIX LIBERARIA - A GEOMETER MOTH
ATRYTONOPSIS HIANNA - DUSTED SKIPPER
CAECIDOTEA PRICEI - PRICE'S CAVE ISOPOD
CALYCOPIS CECROPS - RED-BANDED HAIRSTREAK
CARIPETA ARETARIA - SOUTHERN PINE LOOPER MOTH
CRAMBIDIA PURA - PURE LICHEN MOTH
LAMPSILIS CARIOSA - YELLOW LAMPMUSSEL
LAMPSILIS RADIATA - EASTERN LAMPMUSSEL
ELAPHRIA FESTIVOIDES - A NOCTUID MOTH
ERASTRIA COLORARIA - BROAD-LINED ERASTRIA MOTH
HEMILEUCA MAIA - BARRENS BUCKMOTH
HESPERIA LEONARDUS - LEONARD'S SKIPPER
HESPERIA METEA - COBWEB SKIPPER
HOLOMELINA LAETA - JOYFUL HOLOMELINA MOTH
HYPAGYRTIS ESTHER - ESTHER MOTH
INCISALIA IRUS - FROSTED ELFIN
LAGOA CRISPATA - BLACK-WAVED FLANNEL MOTH
LYCAENA HYLLUS - BRONZE COPPER
MITOURA GRYNEA - OLIVE HAIRSTREAK
PAPAIPEMA MARGINIDENS - A BORER MOTH
POANES MASSASOIT - MULBERRY WING
SPHALLOPLANA PRICEI - REFTON CAVE PLANARIAN
STAPHYLUS HAYHURSTII - SCALLOPED SOOTYWING
STYGOBROMUS PIZZINII - PIZZINI'S CAVE AMPHIPOD
TOLYPE NOTIALIS - TOLYPE MOTH
ZALE CUREMA - A ZALE MOTH
ZALE OBLIQUA - OBLIQUE ZALE MOTH
ZALE SUBMEDIANA - A ZALE MOTH
ZANCLOGNATHA MARTHA - PINE BARRENS ZANCLOGNATHA

Pennsylvania Plant Species of Concern in Chester and Lancaster Counties

Proposed Endangered

ALETRIS FARINOSA - COLIC-ROOT
ARNICA ACAULIS - LEOPARD'S-BANE
ASCLEPIAS VARIEGATA - WHITE MILKWEED
ASPLENIUM BRADLEYI - BRADLEY'S SPLEENWORT
ASTER SOLIDAGINEUS - NARROW-LEAVED WHITE-TOPPED ASTER
BOLTONIA ASTEROIDES - ASTER-LIKE BOLTONIA
CAREX BICKNELLII - BICKNELL'S SEDGE
CAREX BULLATA - BULL SEDGE
CAREX MEADII - MEAD'S SEDGE
CAREX RICHARDSONII - RICHARDSON'S SEDGE
CAREX TYPHINA - CATTAIL SEDGE
CERASTIUM ARVENSE VAR VILLOSISSIMUM - SERPENTINE CHICKWEED
CHASMANTHIUM LATIFOLIUM - WILD OAT
CHRYSOPSIS MARIANA - MARYLAND GOLDEN-ASTER
CIRSIUM HORRIDULUM - HORRIBLE THISTLE
CLADIUM MARISCOIDES - TWIG RUSH
CORALLORHIZA WISTERIANA - SPRING CORAL-ROOT
CYNANCHUM LAEVE - SMOOTH SWALLOW-WORT
CYPERUS REFRACTUS - REFLEXED FLATSEDGE
DRYOPTERIS CELSA - LOG FERN
ELEOCHARIS COMPRESSA - FLAT-STEMMED SPIKE-RUSH
ELEPHANTOPUS CAROLINIANUS - ELEPHANT'S FOOT
EQUISETUM X FERRISSII - SCOURING-RUSH
EUPHORBIA PURPUREA - GLADE SPURGE
FESTUCA PARADOXA - CLUSTER FESCUE
GENTIANA SAPONARIA - SOAPWORT GENTIAN
GENTIANA VILLOSA - STRIPED GENTIAN
HELIANTHEMUM BICKNELLII - BICKNELL'S HOARY ROCKROSE
IRIS PRISMATICA - SLENDER BLUE IRIS
ISOTRIA MEDEOLOIDES - SMALL-WHORLED POGONIA
JUNCUS DICHOTOMUS - FORKED RUSH
JUNCUS TORREYI - TORREY'S RUSH
LINUM INTERCURSUM - SANDPLAIN WILD FLAX
LINUM SULCATUM - GROOVED YELLOW FLAX
LOBELIA PUBERULA - DOWNY LOBELIA
LUDWIGIA DECURRENS - UPRIGHT PRIMROSE-WILLOW

LYONIA MARIANA - STAGGER-BUSH
MATELEA OBLIQUA - OBLIQUE MILKVINE
PANICUM LUCIDUM - SHINING PANIC-GRASS
PANICUM SCOPARIUM - VELVETY PANIC-GRASS
PARONYCHIA FASTIGIATA VAR NUTTALLII - FORKED-CHICKWEED
PEDICULARIS LANCEOLATA - SWAMP LOUSEWORT
PHYSALIS VIRGINIANA - VIRGINIA GROUND-CHERRY
POA AUTUMNALIS - AUTUMN BLUEGRASS
POLYGALA CRUCIATA - CROSS-LEAVED MILKWORT
POLYGALA CURTISSII - CURTIS'S MILKWORT
QUERCUS FALCATA - SOUTHERN RED OAK
RANUNCULUS FASCICULARIS - TUFTED BUTTERCUP
RANUNCULUS PUSILLUS - SPEARWORT
RUBUS CUNEIFOLIUS - SAND BLACKBERRY
SISYRINCHIUM ATLANTICUM - EASTERN BLUE-EYED GRASS
SOLIDAGO RIGIDA - HARD-LEAVED GOLDENROD
SPIRANTHES VERNALIS - SPRING LADIES'-TRESSES
SPOROBOLUS CLANDESTINUS - ROUGH DROPSEED
SPOROBOLUS HETEROLEPIS - PRAIRIE DROPSEED
STYLOSANTHES BIFLORA - PENCILFLOWER
TRIOSTEUM ANGUSTIFOLIUM - HORSE-GENTIAN
TRIPSACUM DACTYLOIDES - EASTERN GAMMA-GRASS
VERNONIA GLAUCA - TAWNY IRONWEED
VIBURNUM NUDUM - POSSUM-HAW

Proposed Rare

APLECTRUM HYEMALE - PUTTYROOT
ASPLENIUM PINNATIFIDUM - LOBED SPLEENWORT
CAREX BUXBAUMII - BROWN SEDGE
CAREX SHORTIANA - SEDGE
LUPINUS PERENNIS - LUPINE
MAGNOLIA TRIPETALA - UMBRELLA MAGNOLIA
OPUNTIA HUMIFUSA - PRICKLY-PEAR CACTUS
ORONTIUM AQUATICUM - GOLDEN CLUB
PHYLA LANCEOLATA - LANCE FOG-FRUIT
ROTALA RAMOSIOR - TOOTH-CUP
SENECIO ANONYMUS - PLAIN RAGWORT
TIPULARIA DISCOLOR - CRANEFLY ORCHID
ZIZANIA AQUATICA - INDIAN WILD RICE

Proposed Threatened

AMMANNIA COCCINEA - SCARLET AMMANNIA
ARISTIDA PURPURASCENS - ARROW-FEATHERED THREE AWNED
ASTER DEPAUPERATUS - SERPENTINE ASTER
ASTER RADULA - ROUGH-LEAVED ASTER
BOUTELOUA CURTIPENDULA - TALL GRAMMA
CAREX TETANICA - A SEDGE
CHIONANTHUS VIRGINICUS - FRINGE-TREE
DRYOPTERIS CLINTONIANA - CLINTON'S WOOD FERN
ELLISIA NYCTELEA - ELLISIA
ERIGENIA BULBOSA - HARBINGER-OF-SPRING
FIMBRISTYLIS ANNUA - ANNUAL FIMBRY
ILEX OPACA - AMERICAN HOLLY
JUNCUS BIFLORUS - GRASS-LEAVED RUSH
LEUCOTHOE RACEMOSA - SWAMP DOG-HOBBLE
MAGNOLIA VIRGINIANA - SWEET BAY MAGNOLIA
PANICUM ANNULUM - SERPENTINE PANIC-GRASS
POA PALUDIGENA - BOG BLUEGRASS
RUELLIA STREPENS - LIMESTONE PETUNIA
SCLERIA PAUCIFLORA - FEW FLOWERED NUTRUSH
TALINUM TERETIFOLIUM - ROUND-LEAVED FAME-FLOWER
VITTARIA APPALACHIANA - APPALACHIAN GAMETOPHYTE FERN
WOODWARDIA AREOLATA - NETTED CHAINFERN
XYRIS TORTA - TWISTED YELLOW-EYED GRASS

Believed Extirpated from Pennsylvania

ILEX GLABRA - INK-BERRY
LUDWIGIA POLYCARPA - FALSE LOOSESTRIFE SEEDBOX
PIPTOCHAETIUM AVENACEUM - BLACKSEED NEEDLEGRASS

Tentatively Undetermined

ALOPECURUS AEQUALIS - SHORT-AWN FOXTAIL
ANDROPOGON GLOMERATUS - BUSHY BLUESTEM
ANDROPOGON GYRANS - ELLIOTT'S BEARDGRASS
ARABIS PATENS - SPREADING ROCKCRESS
ASTER DUMOSUS - BUSHY ASTER
ASTER ERICOIDES - WHITE HEATH ASTER

BARTONIA PANICULATA - SCREW-STEM
CAREX LUPULIFORMIS - FALSE HOP SEDGE
CUSCUTA CAMPESTRIS - DODDER
CUSCUTA PENTAGONA - FIELD DODDER
CYSTOPTERIS TENNESSEENSIS - BLADDER FERN
DESCHAMPSIA CESPITOSA - TUFTED HAIRGRASS
DESMODIUM LAEVIGATUM - SMOOTH TICK-TREFOIL
DESMODIUM NUTTALLII - NUTTALLS' TICK-TREFOIL
EUPATORIUM AROMATICUM - SMALL WHITE-SNAKEROOT
EUPATORIUM COELESTINUM - MISTFLOWER
EUPATORIUM ROTUNDIFOLIUM - A EUPATORIUM
HELIANTHEMUM PROPINQUUM - LOW ROCKROSE
ISOETES VALIDA - QUILLWORT
JUNIPERUS COMMUNIS - COMMON JUNIPER
LEMNA PERPUSILLA - MINUTE DUCKWEED
MELANTHIUM VIRGINICUM - VIRGINIA BUNCHFLOWER
OXYPOLIS RIGIDIOR - STIFF COWBANE
PANICUM FLEXILE - WIRY WITCHGRASS
PENSTEMON LAEVIGATUS - BEARD-TONGUE
PHASEOLUS POLYSTACHIOS - WILD KIDNEY BEAN
POLYGALA NUTTALLII - NUTTALL'S MILKWORT
PRENANTHES SERPENTARIA - LION'S-FOOT
RUDBECKIA FULGIDA - EASTERN CONEFLOWER
SPIRANTHES LUCIDA - SHINING LADIES'-TRESSES
STROPHOSTYLES UMBELLATA - WILD BEAN
TRILLIUM FLEXIPES - DECLINED TRILLIUM

Pennsylvania Vertebrate Species of Concern in Chester and Lancaster Counties

Proposed At Risk

ARDEA HERODIAS - GREAT BLUE HERON
ARTACE CRIBRARIA - DOT-LINED WHITE MOTH
NYCTICORAX NYCTICORAX - BLACK-CROWNED NIGHT-HERON
PSEUDEMYS RUBRIVENTRIS - REDBELLY TURTLE

Proposed Rare

CISTOTHORUS PALUSTRIS - MARSH WREN
EUMECES LATICEPS - BROADHEAD SKINK
PROTONOTARIA CITREA - PROTHONOTARY WARBLER
ASIO OTUS - LONG-EARED OWL

Proposed Endangered

ASIO FLAMMEUS - SHORT-EARED OWL
CLEMMYS MUHLENBERGII - BOG TURTLE
CRYPTOTIS PARVA - LEAST SHREW
HALIAEETUS LEUCOCEPHALUS - BALD EAGLE
NYCTANASSA VIOLACEA - YELLOW-CROWNED NIGHT-HERON
RALLUS ELEGANS - KING RAIL

Proposed Threatened

CISTOTHORUS PLATENSIS - SEDGE WREN
NEOTOMA MAGISTER - ALLEGHENY WOODRAT
OPHEODRYS AESTIVUS - ROUGH GREEN SNAKE
PANDION HALIAETUS - OSPREY

Sources: PA DCNR Pennsylvania Biological Survey and Pennsylvania Natural Diversity Inventory (2002)

II. Benthic Macroinvertebrate Water Quality Study

Seasonal Study of Benthic Macroinvertebrates as Water Quality Indicators in Four Headwater Stream Sites in the West Branch of Octoraro Creek, PA

Prepared For:
The Octoraro Watershed Association

Prepared By:
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Date:
November, 1998

ABSTRACT

Three headwater streams in the West Branch of Octoraro Creek were sampled during October, December, February and April of 1997-1998. Four sites were sampled: Bowery Run Headwaters (BRH), Bowery Run (BR), Meetinghouse Creek (MH), and Nickel Mines Run (NMR). All sampling sites were in third order streams except Nickel Mines Run that was a fourth order stream. Stream macroinvertebrates were sampled in riffles and pools with kick nets, and water samples were analyzed for nitrate, pH, hardness, alkalinity, dissolved oxygen, and temperature. Abundance of animals per kick net sample was higher in the riffle samples than in the pool samples. Highest abundance values in riffles were observed from Meetinghouse Creek (804 B 1572 animals/kick net sample), and the highest abundance values in pool samples were from Nickel Mines Run (215 B 273 animals/kick net). Most of the organisms found in riffle samples were insect larvae from the caddisfly family Hydropsychidae, and two mayfly familes, Oligoneuriidae and Heptageniidae. Chironomids, midge larvae, were the most abundant organisms found in pool samples. In Bowery Run Headwaters, Bowery Run, and Meetinghouse Creek, most of the organisms belonged to the Hydropsychid family with smaller number of other taxa such as Planarian flatworms, Elmid beetles, Simullid black fly larvae, and Tipulid crane fly larvae. The seasonal pattern in Nickel Mines Run was very different from the other three stream sites, since Chironomid midge larvae were the most abundant organisms in all months except October.

The Arelative health@ of the streams was analyzed with Rapid Bioassessment Protocol II developed by the Environmental Protection Agency (EPA). Six numerical indicators (metrics) were calculated: 1) taxa richness, 2) family biotic index, 3) ratio of scrapers to filtering collectors, 4) EPT Index with EPT representing the familes Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), 5) ratio of abundance of EPT taxa to abundance of Chironomids, and 6) percent contribution of dominant family. Rapid Bioassessment Numbers for 17 riffle samples were standardized to the most pristine sample, which was Bowery Run in October. Bioassessment Numbers did not change significantly during the seasons, but were significantly different between stream sites. Bioassessment Numbers for

the Bowery Run sites (MRH and MR) were significantly different from the other two sites (MH and NMR), which were also significantly
different from one another. Values for Family Biotic Index followed the same trends as the Bioassessment Numbers.

The highest nitrate concentrations occurred at the stream sites with the lowest Bioassessment Numbers. Nitrate concentrations were lowest at Bowery Run during all months During December and February, nitrate concentrations were usually less than 10 ppm at all sites. Nitrate concentrations in April increased at all sites due to high runoff, and at Meetinghouse Creek and Nickel Mines Run ranged from 22 to 30 ppm, over twice the drinking water limit of 10 ppm.

In summary, the least disturbed site was Bowery Run which had the highest Bioassessment Numbers, and the lowest nitrate concentrations. The most disturbed site was Nickel Mines Run which had the lowest Bioassessment Numbers and was also most strongly affected by runoff in April. Meetinghouse Creek consistently produced the highest number of macroinvertebrates for either riffle or pool samples, but had next to the lowest Bioassessment Numbers and was strongly impacted by runoff in April.

INTRODUCTION

Octoraro Creek, located in Lancaster and Chester Counties of southeastern Pennsylvania, drains into the Susquehanna River which is the major freshwater source for the Chesapeake Bay (Figure 1). The watershed of Octoraro Creek has been predominantly agricultural and at present 85% of the land is in agriculture (OWA 1996). In 1983, the General Assembly of Pennsylvania passed the Octoraro Scenic Rivers Act which designated 12.25 miles in the Scenic and 24.25 miles as Pastoral categories (OTF 1986). This act protected 4947 acres of stream with corridors, which are mostly (77%) floodplains and steep slopes. Although the Octoraro Scenic Rivers Act required that State agencies follow certain guidelines for managing state owned lands, the act also recommended that a local organization of private landowners, local governments and conservation groups work on guidelines to implement the act. The local organization became the Octoraro Task Force, which included the Octoraro Watershed Association, township and county planning commission representatives, and staff from the Department of Environmental Resources. The Octoraro Task Force prepared a management plan entitled "Octoraro Creek Corridors, Issues and Management Recommendations" in 1986.

In 1996, the Octoraro Watershed Association with support from all 18 townships in the Octoraro watershed (Fig. 2), and Chester and Lancaster Counties submitted and received a state grant from the Keystone Recreation, Park and Conservation Fund to analyze watershed resources and update the 1986 management plan (OWA 1996). Included in the analysis of watershed resources is the goal to study headwater streams, especially along the West Branch of Octoraro Creek. Several studies by the U.S. Geological Survey have included three sites along the East Branch of Octoraro Creek, which forms the border between Lancaster and Chester Counties (USGS 1987, 1989, 1995). Our study focuses on the water quality of three headwater streams of the West Branch of the Octoraro. We sampled benthic macroinvertebrates, and physical-chemical parameters (temperature, pH, hardness, nitrate, and dissolved oxygen) between October 1997 and April 1998 when macroinvertebrates are most abundant.

One of the main goals of the Octoraro Task Force plan in 1986 and the present plan for the Octoraro Watershed Association is to maintain or improve the water quality of streams. Since the Octoraro watershed is predominantly agricultural, 95% of the pollution in terms of sediment and inorganic nutrients is from nonpoint sources (OWA 1996). Poor farming practices lower water quality and the value of farmland through loss of topsoil and inorganic nutrients such as nitrate to the streams. These disturbances decrease the value of fisheries by decreasing dissolved oxygen concentrations and increasing temperature, and contribute to the eutrophication of Chesapeake Bay. Cold temperatures, high dissolved oxygen, and low nitrate concentrations indicate high water quality. Although these parameters can be measured rapidly, they are affected by weather conditions. Nitrate concentrations increase dramatically during a rainstorm due to land runoff and upstream loads.

Stream macroinvertebrates, which are primarily insect larvae, hatch from eggs laid in the summer and grow all year in the streams until they emerge the following summer. Thus these animals are affected by water quality conditions throughout the year and their presence and abundance indicates water quality conditions throughout the year. Hilsenhoff (1988) developed the Family Biotic Index (FBI), which was based on the response of macroinvertebrates to organic enrichment from sewage and agricultural runoff. Rapid Bioassessment Protocols include Hilsenhoff's Family Biotic Index, but also include other types of measurements or metrics that reflect sensitivity to pollution from heavy metals and increased nitrate concentrations. These protocols were developed for managers and the public to understand the results of stream monitoring. Resh and Jackson (1993) statistically compared the accuracy of several metrics in impacted and non-impacted streams, and found that metrics based on taxa richness (number of families, for example) and the Family Biotic Index were the best indicators. They cautioned that Rapid Bioassessment Protocols must be calibrated for local areas and that more than one metric should be employed. Rapid Bioassessment Protocols are currently used by the Pennsylvania Department of Natural Resources, U.S. Environmental Protection Agency and the U.S. Geological Survey to compare water quality of different streams. We use a Rapid Bioassessment

Protocol developed by the EPA for insect families, provide statistical comparisons of community composition and metrics, and compare the macroinvertebrate data to physical-chemical parameters. Our sampling includes the months during which stream macroinvertebrates are most abundant: October, December, February, and April.

BACKGROUND ON FOUR HEADWATER STREAM SITES

Three headwater streams of the West Branch of the Octoraro were sampled (Fig. 3): Bowery Run Headwaters (BRH) - Bowery Run north of PA 372 , Bowery Run (BR) - Bowery Run south of PA 372 downstream of junction with an unnamed stream, Meetinghouse Creek (MH) - Meetinghouse Creek north of PA 372 at the Bart Township Municipal Building, and Nickel Mines Run (NMR) - Nickel Mines Run near the Green Tree Inn. All stream sites were in third order streams except the Nickel Mines Run site which was a fourth order stream as determined from maps in the Soil Survey of Lancaster County (Custer 1985).

The Gap Nickel mine was located in the headwaters of our site on Nickel Mines Run (DER 1983). Copper was the first mineral mined commercially but not very successfully between 1730 and 1849. Nickel was discarded in a dump until an analysis of the dump materials in 1852 revealed that nickel was present in commercial quantities. By 1877 the Gap mine was producing one sixth of the world's nickel each year. The mine was closed in 1893 with the discovery of nickel at Sudbury, Ontario.

Almost all of the West Branch Octoraro is either classified as Scenic, 6.75 miles, or Pastoral, 3.75 miles (Fig. 3). Nickel Mines Run and Meetinghouse Creek join to form the West Branch which is designated as a 4.0 mile Scenic Corridor from its origin to the junction with Bowery Run (OTF 1986). Bowery Run and the upstream portion of the West Branch contribute water to the next scenic corridor (2.75 miles) which extends just downstream from Bowery Run at the Octoraro Water Company Dam to the Puseyville Bridge (OTF 1986). Therefore, the water quality of the three streams in our study affects the water quality in the West Branch Scenic Corridors.

All stream sites were bordered by forested areas and were near agricultural lands, except the Nickel Mines Run site which was in a fenced pasture with few trees bordering the stream. The dominant soil type along the creek corridors was Newark Silt Loam, which is a somewhat poorly drained alluvial soil from a variety of sources: mica schist, mica gneiss, limestone, siltstone, and sandstone (Custer 1985). Small areas of noncalcareous Holly silt loam and Baile silt loam also occur along these stream corridors, and are more poorly drained than the Newark silt loam. The slopes surrounding the creek corridors are composed of well drained soil types composed from mica schist and quartzite.

METHODS

Field Collections

At each sample location during each sampling month, water samples were collected for analysis of temperature, pH, hardness, nitrate, and dissolved oxygen. The pH was measured with either a LaMotte titrimetric kit or a pH probe in the field or laboratory at Millersville University. Water hardness (ppm Ca) and Nitrate (ppm, Cadmium reduction method) were measured in the field with LaMotte colorimetric kits. Dissolved oxygen (ppm) was measured with either a HACH Winkler titration kit or a YSI polarographic dissolved oxygen probe.

Stream macroinvertebrates were sampled with a kick net from a riffle and a pool at each site during each sampling month. The kick net was 30@ across and 24@ deep, and was made from 1mm window screen cloth. The kick net was placed in the water by one person, while upstream a second person picked up rocks and gently scrubbed them by hand to remove attached organisms. Then, for one minute, the second person moved small rocks and sediment with their feet to stir up bottom dwellers. The kick net was removed from the water, and the sample was washed into a white enamel pan. Debris in the enamel pan was removed and the sample was consolidated into a sampling jar. All organisms that remained on the screen were picked off by hand and added to the sampling jar. Seventy percent ethyl alcohol was added to preserve the specimens.

During each sampling month, two replicate samples were taken at one of the stream sites in riffle and pool habitats as follows: Bowery Run Headwaters in October, Bowery Run in December, Meetinghouse Creek in February, and Nickel Mines Run in April.

Laboratory Analysis

Approximately 100 animals were counted from each sample if possible. If the sample contained more than 100 animals, a subsample was counted. The whole sample was placed in a round petri dish with 38 squares, and at least 100 animals were picked from a known number of squares. The ratio of the subsample to the total sample was used to calculate the total abundance of the sample. Since the same sampling technique was used for each sample, the sample abundance per kick net can be compared.

The macroinvertebrates were sorted to family or the lowest taxa possible above family. Identifications were confirmed from Peckarsky et al. (1990). Identified specimens were placed into individual glass vials for permanent storage.

Statistical Analysis

Nonparametric statistical tests were performed with the data, because the number of samples was small, and biological abundance data tend to be aggregated so that the assumptions of normal distributions and homogeneity of variances could be violated. Although nonparametric tests compare relative ranks rather than the actual numerical values, these tests permit the same comparisons as parametric Student=s t tests and analysis of variance (McClave and Dietrich II, 1988). In this report the following nonparametric tests were used: Wilcoxon Rank Sum Test, Kruskal-Wallis H Test for completely randomized design, and the Friedman=s Fr-Test for a randomized block design. For all tests, the level of significance was 0.05.

PHYSICAL AND CHEMICAL PARAMETERS

Seasonal trends were similar at all three streams for temperature, pH, and dissolved oxygen (Table 1). The Bowery Run sites tended to have lower hardness, less calcium, than Meetinghouse Creek and Nickel Mines Run. Values of pH and alkalinity were within ranges commonly associated with limestone streams where pH ranges from 7.5 to 8.0 and alkalinity ranges from 75 to 150 ppm. Alkalinity is comparable to hardness values for limestone streams.

The lowest nitrate concentrations occurred at the Bowery Run site during all sampling months (Figure 4). During December and February, the other three sites had similar concentrations which were usually less than those for the drinking water standard of 10 ppm. In April, samples were taken 5 days after a heavy rain and the nitrate values were over 20 ppm at Meetinghouse Creek and Nickel Mines Run. Lower pH values in April also reflected heavy rains, since rainwater has slightly acidic pH values.

STREAM MACROINVERTEBRATE COMMUNITIES

The seasonal abundance of macroinvertebrates per kick net sample is shown for the four stream sites in Figure 5. Stream macroinvertebrates were much more abundant in riffle than pool samples. The highest abundance, 804 - 1572 animals per kick net, were found at riffle sites in Meetinghouse Creek, even after the heavy rains in April. The highest abundance for pool sites, 215 - 273 animals per kick net, were found in Nickel Mines Run. Although macroinvertebrates occurred in similar numbers every month in the riffle samples, pool samples were much more variable and may reflect sampling of different size pools.

The twenty different taxa found during our study were mostly insect larvae (Table 2, Appendix 1). The most abundant organisms found in riffle samples were insect larvae from the caddisfly family Hydropsychidae, and two mayfly familes, Oligoneuriidae and Heptageniidae. Chironomidae, midge larvae, was the most abundant family found in pool samples. Elmid beetles and Planarian flatworms were the next most abundant taxa for all samples.

The relative abundance of these taxa are shown in Figure 6 for the four sampling months. In general, each stream had a characteristic composition of macroinvertebrates. At the Bowery Run Headwaters and Bowery Run sites, the most abundant organisms were caddisflies from the family Hydropsychidae, and mayflies from the families Oligoneuriidae and Heptageniidae. In Meetinghouse Creek, the most abundant organisms were from the caddisfly family Hydropsychidae, with Planarian flatworms, Elmid beetles, and organisms from the "Other" category, Simullid black fly larvae and Tipulid crane fly larvae, also present. The seasonal pattern in Nickel Mines Run was very different from the other three streams, since Chironomids were the most abundant organisms in all months except October. The "Other" category in December at Nickel Mines Run included Oligocheates, which are segmented annelid worms.

A nonparametric Friedman Fr-Test was employed to test whether the relative abundance distribution of the macroinvertebrate families was the same at a particular site during the four sampling months. For Bowery Run and Meetinghouse Creek, the relative abundance of the macroinvertebrate community did not show seasonal changes. This consistency is seen in Figure 6 which shows that Hydropsychid caddisfly larvae dominated during every sampling period. The relative abundance distributions were significantly different between seasons for Bowery Run Headwaters and Nickel Mines Run (3 months compared instead of four because the April sample had <30 animals). The April sample for Bowery Run Headwaters and the October sample for Nickel Mines Run were dramatically different from the other seasons (Figure 6).

Although replicate samples were collected at one pool and riffle site every sampling month, only two riffle samples at two sites had similar abundance values: Bowery Run Headwaters (108 and 325 animals/kick net) and Meetinghouse Creek (1095 and 1128 animals/kick net). The composition of the two replicates for Meetinghouse Creek in February were similar with both samples dominated by Hydropsychids (Figure 7). Chironomids, Elmids, and the AOther@ category which included Simulids, Tipulids, and Oligocheates were found in lower abundances at this site. The replicate pair sampled at Bowery Run Headwaters in October was dominated by the same taxa, but the proportions of the families varied between the two replicates. All three families were found in replicate one, but only two families were found in replicate two. Abundance values for replicate riffle samples at Bowery Run in December were not comparable, 362 and 11 animals/kick net, and for Nickel Mines Run in April were very low, 3 and 18 animals per kick net. In general, if sufficient samples were collected, replicates showed similar composition of macroinvertebrates.

Comparisons of riffle and pool samples at the same stream and month were possible for three sampling times (Figure 8). Hydropsychid caddisfly larvae dominated in riffle samples and Chironomid midge larvae dominated in pool samples. Taxa found in the "Other" category included Tipulids in the Bowery Run Riffle in December; gastropods, isopods and tipulids in Bowery Run Pool in December; Simullids and Tipulids in Nickel Mines Run Riffle in February; and Oligocheates in Nickel Mines Run Pool in February.

RAPID BIOASSESSMENT ANALYSIS OF RIFFLE SAMPLES

Rapid Bioassessment Analysis was developed by the Environmental Protection Agency (EPA) to produce a management tool to assess the "health" of streams by sampling macroinvertebrate communities. The protocol assigns a Rapid Bioassessment Number based on several community parameters, and standardizes the Bioassessment Number to a percentage based on 100% for a reference site. Then each site is placed in one of three categories: non-impaired (79 B 100%), moderately impaired (29 B 79%), and severely impaired (< 21%). The reference site should be "the best situation to be expected within an ecoregion" (Plafkin et al. 1989). The overall procedure for Protocol II is shown in Figure 9, which is a flow diagram from Plafkin et al. (1989).

Choice of Metrics

The first step is to analyze the macroinvertebrate data in terms of several metrics, which describe the degree of environmental stress: exposure to organic pollution which includes sewage and manure, high nitrate concentrations which promote algal growth, heavy metal pollution, and lack of riparian forested buffers. For the present study, six of the eight metrics in Rapid Bioassessment Protocol II were chosen:

1. Taxa Richness: number of taxa usually at the family level of identification. Generally, the more taxa that are present, the less disturbed the site. Table 2 lists the taxa collected in our study.

2. Family Biotic Index: The Family Biotic Index developed by Hilsenhoff (1988)

assigns tolerance values to macroinvertebrate families in order to calculate a weighted mean or Biotic Index, which is related to stream water quality from very poor to excellent in terms of the degree of organic pollution. Table 2 includes tolerance values from Plafkin et al. (1989) for the taxa we sampled.

3. Ratio of Scrapers to Filtering Collectors: This index depends on the abundance of functional feeding groups (Allen 1995). Scrapers are macroinvertebrates which feed on diatoms attached to rocks. Diatoms are indicators of cold water, well shaded streams which have low impacts from organic enrichment. Filtering collectors are macroinvertebrates which use various methods to filter small particles from the water. These animals can use filamentous algae as attachment sites. Since filamentous algae are indicators of stream with more organic enrichment and less shading, an abundance of scrapers compared to the abundance of filtering collectors indicates a more pristine, less enriched stream. Functional groups were assigned from Cummins and Wilzbach (1985).

4. Ratio of EPT and Chironomid abundances: EPT represents the three macroinvertebrate orders that are most sensitive to organic pollution, metal discharges, and lack of forested riparian buffers: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Chironomids (midges) are more tolerant of environmental stress, and thus their presence indicates a less pristine site. This metric is a ratio of the abundances of EPT taxa to that of chironomids.

5. Percent Contribution of the Dominant Family: The rationale for this metric is that more stressed sites will be dominated by the abundance of one family. This metric can provide the same information as community similarity indices (Plafkin et al. 1989), but is much easier to calculate.

6. EPT Index: The EPT Index measures the number of families in the Ephemeroptera, Plecoptera and Trichoptera. More pristine, forested streams will have higher numbers of EPT families.

Choice of Reference Site

The EPA Rapid Bioassessment requires reference sites, so that the protocols can be adapted to different geographic areas, and areas with different land uses. Streams in areas with urban development and farms may never become as pristine as streams in undisturbed forested watersheds. Therefore the choice of a reference site is important and the results of Rapid Bioassessment should be considered in terms of the reference site chosen. For the present study, the reference site was Bowery Run during October, which had metric values representing the least impaired site. For future studies, another reference site within the West Branch of Octoraro Creek might be identified as a more pristine site.

Rapid Bioassessment results for the riffles of the four headwater stream sites in the West Branch of Octoraro Creek are shown in Table 3. For each sample, the metrics were analyzed in three ways: numerical value of metric, standardization with reference site on a scale from 0 to 100 percent, and a Rapid Bioassessment value of 0, 3 or 6 with 6 representing the least impaired value. These values of 0, 3 or 6 were assigned according to Protocol II (see Figure 9), and were summed for a maximum value of 36. The final calculation compared these summed values to 36 as a percentage, and is shown as the Bioassessment Numbers in the double lined boxes in Table 3. The reference site by definition will be 100. Seventeen of the 20 riffle samples had adequate numbers of animals (>30) to calculate Rapid Bioassessment Numbers.

Rapid Bioassessment Numbers were compared for effects of season and stream site by employing a Kruskal Wallis Test. There was no significant effect of season when all sites were combined, which says that the average rank of the Bioassessment Numbers was not different between seasons. However, there was a significant effect for stream site, which says that at least one of the stream sites was different from the others. To determine which streams were different, pairwise comparisons were made with the Wilcoxon Rank Sum Test. The two Bowery Run Sites were significantly different from the other two sites: Meetinghouse Creek and Nickel Mines Run. These latter two sites were also significantly different from one another.

Similar trends between the four streams were observed when Rapid Bioassessment categories were assigned (see Figure 9). Of the 17 riffle samples, 5 were in the "non-impaired" category, 11 were in the "moderately impaired" category, and 1 sample was in the "severely impaired category" (Table 4). Bowery Run Headwaters and Bowery Run sites were the least impaired overall. Meetinghouse Creek had all samples in the "moderately impaired" category, and Nickel Mines Run was the most impaired in this analysis.

Although the Rapid Bioassessment Protocol includes several metrics, the most commonly used metric is the Family Biotic Index. The number of samples in Hilsenhoff's (1988) categories based on the Family Biotic Index is shown in Table 5. The four streams were ranked in the same order as the Rapid Bioassessment Numbers. The two Bowery Run sites had "good to excellent" water quality, Meetinghouse Creek had "very good to good" water quality, and Nickel Mines Run had "good to very poor" water quality.

The relative impairment of the stream macroinvertebrate analyses were consistent with the nitrate concentrations observed during the four sampling months. The lowest nitrate concentrations occurred at the Bowery Run site, which was also the reference site. The April rains affected the most impaired sites, Meetinghouse Creek and Nickel Mines Run, more severely than the Bowery Run sites. Nitrate concentrations were usually < 10 ppm, the drinking water standard, during December and February, but increased to over 20 ppm in April at Meetinghouse Creek and Nickel Mines Run (Figure 4).

COMPARISON OF WEST AND EAST BRANCH SITES OF OCTORARO CREEK

Stream macroinvertebrate communities from three streams in the East Branch of Octoraro Creek were compared with the reference site at stream, Bowery Run. Original data for stream macroinvertebrates for Sites 33 (Christiana), 34 (Valley Creek at Atglen), and 35 (Steelville) in the East Branch of Octoraro Creek (USGS 1989) were analyzed by Rapid Bioassessment Protocol II for eight Fall collections from 1970 to 1980 (Appendix 2). These 24 samples from the East Branch were analyzed with the same metrics that were used for Rapid Bioassessment Protocol II for the four West Branch stream sites (Tables 3 and 6). The Bioassessment Numbers for the East Branch had means " standard deviations of 63 " 13 for site 33, 66 " 12 for site 34, and 68 " 12 for site 35. These means were closer to those for the Bowery Run sites, 73 " 12 for BRH and 77 " 6 for BR than the means from Meetinghouse Creek (45 " 10) and Nickel Mines Run (31 " 13).

CONCLUSIONS AND RECOMMENDATIONS

The Rapid Bioassessment Protocol II and the Family Biotic Index produced similar trends for the four headwater stream sites in the West Branch of Octoraro Creek. The streams were ordered from least to most impaired in the following pattern: Bowery Run, Bowery Run Headwaters, Meetinghouse Creek, and Nickel Mines Run. At least 2-3 replicates should be taken for each site and sampling date, since abundance values between two replicates could differ by an order of magnitude. However, this number of samples may be too many to process. Since our data demonstrated that macroinvertebrate composition was similar throughout the year (Figure 5), replicate samples could be taken at different sites during one sampling date.

Another indicator of stream water quality is the macroinvertebrate shredder community, which is collected in leaf pack samples. Future monitoring should include replicate samples from riffles as well as leaf packs, especially where riparian forests border streams.

Differences in nitrate concentrations before and after substantial rains indicate the magnitude of nitrate sources from fertilizers or cow manure, and the capacity of the soil and plants in the watershed to absorb nitrate before runoff flows into the stream. Therefore seasonal samples for nitrate concentration will indicate the capacity of the watershed to absorb nitrate as well as the magnitude of the nitrate sources. Nitrate concentrations dramatically increased in April after substantial storms increased runoff. Nitrate concentrations may also be higher this time of year, because plants are breaking their winter dormancy and crops are just beginning to develop their roots so that nitrate uptake from the soil is not occurring at maximal rates.

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FIGURES

Table 1. Physical and chemical parameters at the riffle and pool sites of the four headwater streams of the West Branch of Octoraro Creek during five months. Nitrate samples were not taken during Sept. and Oct. sampling.

Date	Time	Site	Riffle/Pool (R/P)	pH	DO (ppm)	Temperature (oC)	Hardness (ppm)	Nitrate (ppm)
09-Sep-97	9:35	BRH	R	7.8	12.1	14.2	124	
09-Sep-97	11:08	BR	R	7.8	9.1	15.0	78	
09-Sep-97	11:53	MH	R	7.8	7.8	17.2	120	
09-Sep-97	12:42	NMR	R	7.8	8.1	18.4	140	
26-Oct-97	8:45	BRH	R	7.6	11.0	9.4	140	
26-Oct-97	8:45	BRH	P	7.6	10.8	9.3		
26-Oct-97	11:53	BR	R	7.5	9.1	9.2	120	
26-Oct-97	11:53	BR	P	7.6	9.5	9.2		
26-Oct-97	10:19	MH	R	7.4	9.8	9.0	130	
26-Oct-97	10:19	MH	P	7.4	11.3	8.9		
26-Oct-97	11:06	NMR	R	7.4	9.1	8.9	160	
26-Oct-97	11:06	NMR	P	7.5	8.9	8.9		
13-Dec-97	9:29	BRH	R	7.6	14.9	3.1	103	9.8
13-Dec-97	9:29	BRH	P	7.5	14.4	3.2		9.4
13-Dec-97	12:25	BR	R	7.8	14.8	4.8	100	2.9
13-Dec-97	12:25	BR	P	7.8	14.1	4.6		3.6
13-Dec-97	10:45	MH	R	7.5	15.0	3.1	142	9.2
13-Dec-97	10:45	MH	P	7.5	14.7	3.0		8.5
13-Dec-97	11:40	NMR	R	7.6	14.5	4.0	146	6.3
13-Dec-97	11:40	NMR	P	7.5	14.0	4.0		7.7
17-Feb-98	9:01	BRH	R	6.7	13.6	5.4	100	11.7
17-Feb-98	9:01	BRH	P	6.7	13.1	5.6	86	9.0
17-Feb-98	12:57	BR	R	7.1	13.2	7.8	107	3.3
17-Feb-98	12:57	BR	P	7.1	12.5	7.8	92	2.6
17-Feb-98	10:23	MH	R	7.1	14.3	5.3	118	8.3
17-Feb-98	10:23	MH	P	7.1	13.8	5.3	126	7.5
17-Feb-98	12:07	NMR	R	7.1	14.2	6.8	130	5.1
17-Feb-98	12:07	NMR	P	7.1	14.3	6.8	137	8.0
10-Apr-98	8:00	BRH	R	6.3	12.4	7.6	104	14.2
10-Apr-98	8:00	BRH	P	6.3	12.7	7.5		19.8
10-Apr-98	8:42	BR	R	6.0	13.2	8.7	98	13.8
10-Apr-98	8:42	BR	P	6.0	12.9	8.7		13.0
10-Apr-98	9:30	MH	R	6.2	13.2	8.6	144	24.7
10-Apr-98	9:30	MH	P	6.2	12.8	8.6		29.8
10-Apr-98	10:15	NMR	R	6.2	13.3	8.8	135	22.3
10-Apr-98	10:15	NMR	P	6.2	12.3	9.2		20.0

Table 2. Taxa collected at the riffle and pool sites in the four headwater stream sites of the West Branch of the Octoraro during four different months. Family was lowest taxa identified. Tolerance values are from Plafkin et al. 1989, and Functional Group category is based on Cummins and Wilzbach (1985). S = scraper. FC = filtering collector.

Phylum	Order	Family	Tolerance Value	Functional Group	Symbol
Arthropoda, Insecta	Coleoptera	Elmidae	4	Gath. Coll.	
	Coleoptera	Psephenidae	4	Scraper	S
	Diptera	Chironomidae	8	Filt. Coll.	FC
	Diptera	Simullidae	6	Filt. Coll.	FC
	Diptera	Tipulidae	3	Shredder, Predator	
	Ephemeroptera	Baetidae	4	Gath. Coll.	
	Ephemeroptera	Ephemerellidae	1	Scraper, Gath. Coll.	S
	Ephemeroptera	Heptageniidae	4	Scrapers	S
	Ephemeroptera	Oligoneuriidae	2		
	Plecoptera	Capniidae	1	Shredder, Predator	
	Plecoptera	Perlidae	1	Shredder, Predator	
	Trichoptera	Glossosomatidae	0	Scraper	S
	Trichoptera	Hydropsychidae	4	Filt. Coll.	FC
	Trichoptera	Philopotomidae	3	Filt. Coll.	FC
Arthropoda,Crustacea	Isopoda	Asellidae	8	Shredder	
	Mollusca	Gastropoda	7	Scraper	S
Annelida	Oligocheate	Oligocheate	8		
Platyhelminthes	Turbellaria	Planaria type	4		

Table 3. Rapid Bioassessment for riffle samples for the four headwater stream sites of the West Branch of Octoraro Creek during four different months. For each sampling date, one replicate was done which is listed to the right of all the other sites and is labelled with the site abbreviation and -2. The Bowery Run sample from October was used as the reference site and is shaded gray. For each sampling site and date, there are three columns: 1) numerical values of metrics, 2) metric values standardized to the reference site as a percentage, and 3) numerical values of 0, 3, or 6 which are assigned from the rapid bioassessment protocol. The sum of these numbers is to the right of "sum," and the sums are then shown as percentages of the reference site sum and shown in double lined boxes. Rapid bioassessment summary numbers were only performed for samples with 30 or more total animals.

OCT	R-BRH1			R-BR			R-MH			RNMR			R-BRH2		
Total numb	108			168	Reference		804			118			325		
Taxa Richr	8	100	6	8	100	6	6	75	3	6	75	3	8	100	6
Family Bio	3.5	109	6	3.8	100	6	4.1	93	6	4.3	88	6	4.2	90	6
Ratio Scra	0.39	57	6	0.69	100	6	0.01	1	0	0.01	1	0	0.16	23	0
Ratio of EF	33.67	45	3	74.50	100	6	49.84	67	3	11.56	16	0	13.86	19	0
% Contrib.	44	100	6	44	100	6	79	56	6	83	53	6	75	59	6
EPT Index	4	100	6	4	100	6	1	25	0	2	50	0	4	100	6
			33			36			18			15			24
			92			100			50			41.66667			67
DEC	R-BRH			R-BR-1			R-MH			RNMR			R-BR-2		
Total numb	158			362			1110			210			11		
Taxa Richr	11	138	6	8	100	6	4	50	3	3	38	0	5		
Family Bio	4.7	81	3	4.2	90	6	4.2	90	6	7.7	49	0	3.7		
Ratio Scra	0.38	56	6	0.00	0	0	0.00	0	0	0.00	0	0	4.00		
Ratio of EF	3.41	5	0	6.50	9	0	18.78	25	3	0.07	0	0	7.00		
% Contrib.	42	105	6	71	62	6	91	48	3	78	56	6	36		
EPT Index	6	150	6	3	75	3	1	25	0	1	25	0	2		
			27			21			15			6			
			75			58			42			16.66667			
FEB	R-BRH			R-BR			R-MH-1			RNMR			R-MH-2		
Total numb	428			229			1095			223			1128		
Taxa Richr	8	100	6	12	150	6	8	100	6	6	75	3	6	75	3
Family Bio	4.8	79	3	4.6	83	3	4.5	84	3	6.2	61	3	4.7	81	3
Ratio Scra	0.09	13	0	0.11	16	0	0.00	0	0	0.00	0	0	0.00	0	0
Ratio of EF	3.52	5	0	2.96	4	0	7.13	10	0	0.69	1	0	4.24	6	0
% Contrib.	64	68.75	6	52	86	6	75	59	6	55	80	6	75	59	6
EPT Index	4	100	6	6	150	6	1	25	0	1	25	0	1	25	0
			21			21			15			12			12
			58			58			42			33.33333			33
APR	R-BRH			R-BR			R-MH			RNMR-1			R-NMR-2		
Total numb	33			131			1572			3			18		
Taxa Richr	5	63	3	9	113	6	7	88	6	1			2		
Family Bio	3.9	97	6	3.3	115	6	4.4	86	6	4			5.8		
Ratio Scra	5.75	833	6	0.60	87	6	0.00	0	0	0.00			0.00		
Ratio of EF	26.00	35	3	50.00	67	3	19.20	26	3	2.00			1.25		
% Contrib.	67	65.67164	6	33	133	6	68	65	6	33			44		
EPT Index	3	75	3	4	100	6	1	25	0	1			1		
			27			33			21						
			75			92			58						

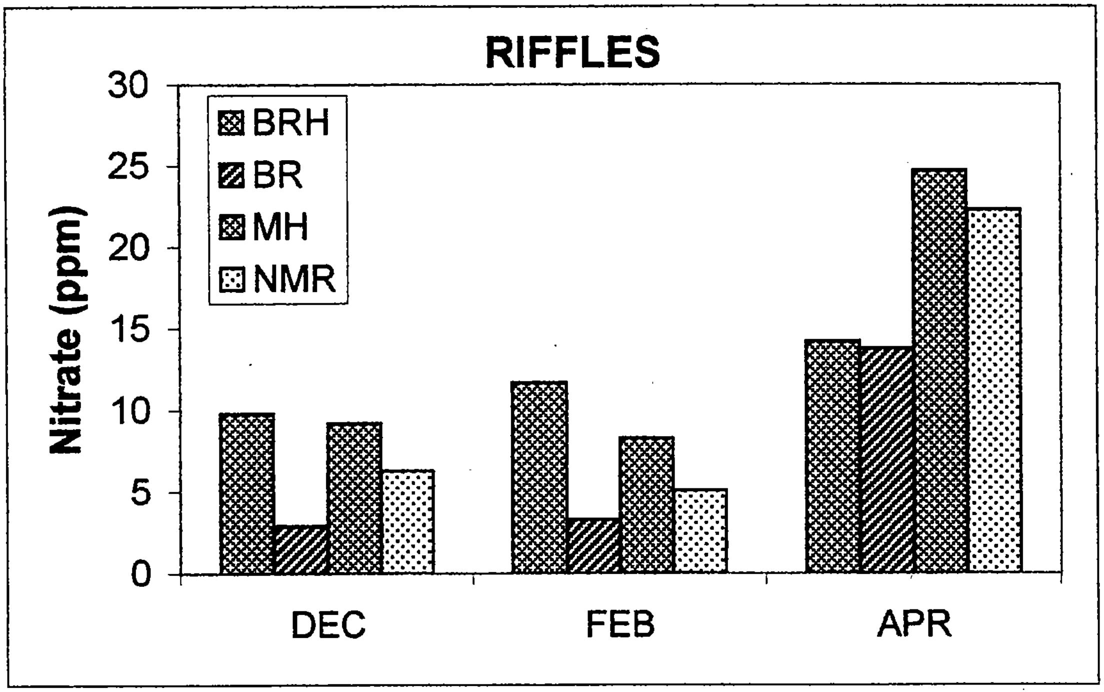
Table 4. Number of samples from the West Branch of Octoraro Creek in the three categories of Rapid Bioassessment from Table 4. The Reference Site was Bowery Run in October, and the number of samples in categories could be different if another reference site were used. Relative order of Octoraro amples would be the same with another reference site.

	BRH	BR	MH	NMR	Total
Total No. S	5	4	5	3	17
Non-Impair	3	2	0	0	5
Moderately	2	2	5	2	11
Severely In	0	0	0	1	1

Table 5. Number of samples from the West Branch Octoraro Creek in categories assigned by Hilsenhoff (1988) for values of the Family Biotic Index (FBI). Hilsenhoff's FBI was developed to detect organic pollution, and his interpretation of the categories is listed in column two. A direct comparison with Hilsenhoff's data is probably not valid, since he worked with Wisconsin streams, although his index is used for all streams in EPA protocols developed by Plafkin et al. (1989). The relative ordering of streams for the West Branch of Octoraro Creek shows the same trends as the overall Rapid Bioassessment percentage shown in Tables 3 and 5.

Category	Degree o	FBI values	BRH	BR	MH	NMR	Total
Excellent	Organic po	0.00-3.75	1	1	0	0	2
Very Good	Possible sl	3.76-4.25	2	2	2	0	6
Good	Some orga	4.26-5.00	3	1	3	1	8
Fair	Fairly subs	5.01-5.75	0	0	0	0	0
Fairly Poor	Substantial	5.76-6.50	0	0	0	1	1
Poor	Very subst	6.51-7.25	0	0	0	0	0
Very Poor	Severe org	7.26-10.00	0	0	0	1	1

Figure 4. Seasonal values of nitrate from the riffle and pool samples in the four headwater streans if the West Branch of Octoraro Creek. Drinking water standards for nitrate are 10 ppm. The April samples were taken several days after heavy rains.



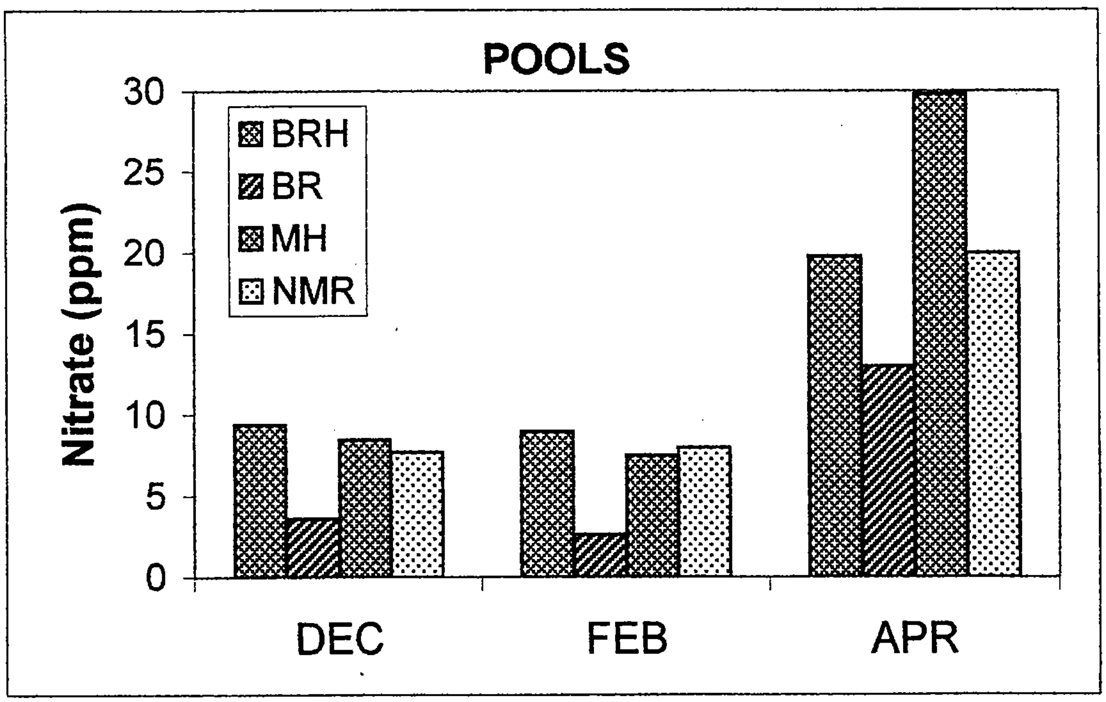
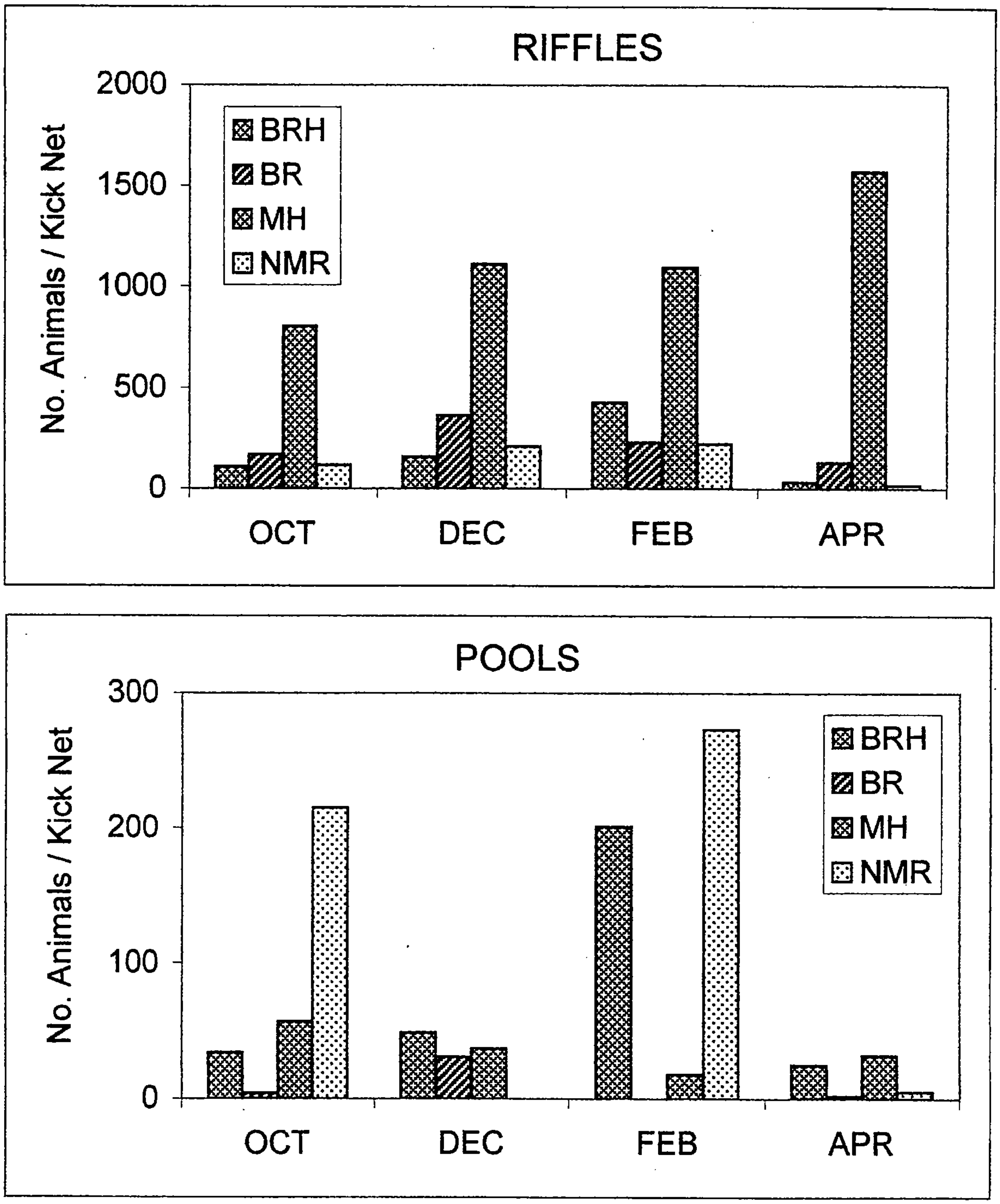
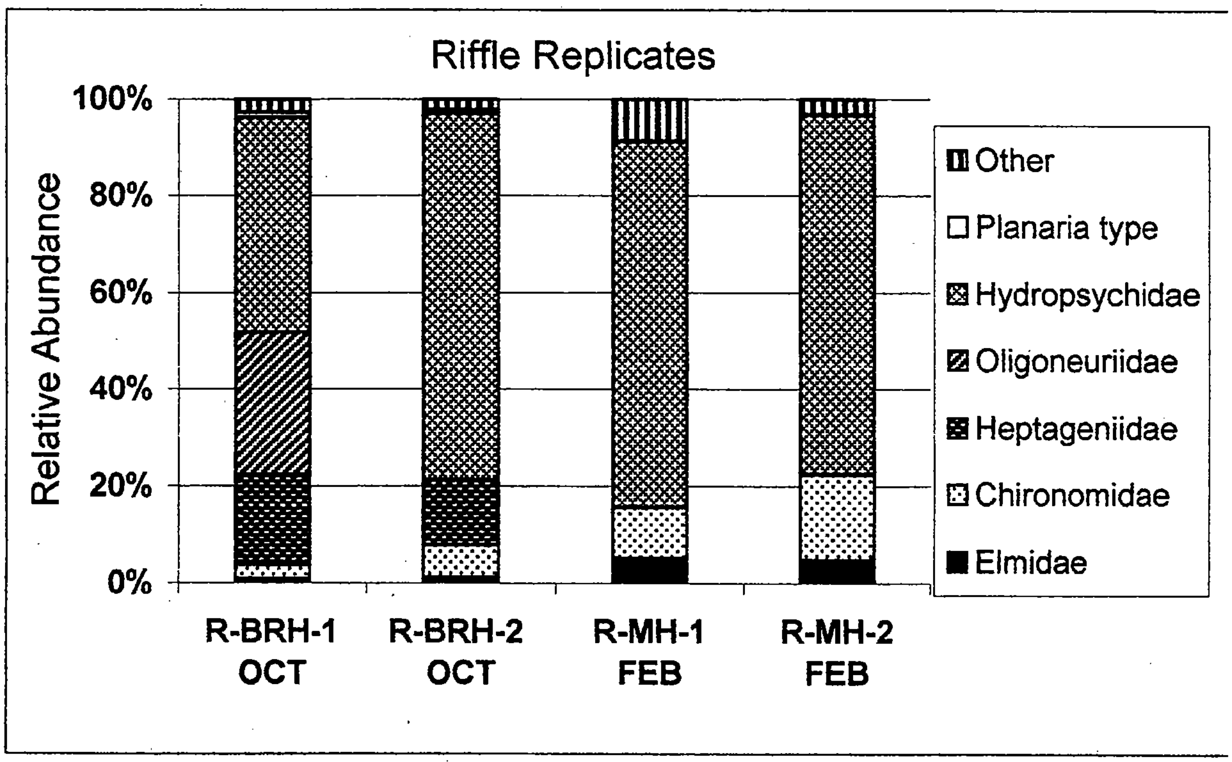


Figure 5. Seasonal changes in macroinvertebrate abundance sampled in riffles and pools in the four headwater streams of the West Branch of Octoraro Creek. Note difference in scale between riffle and pool samples.



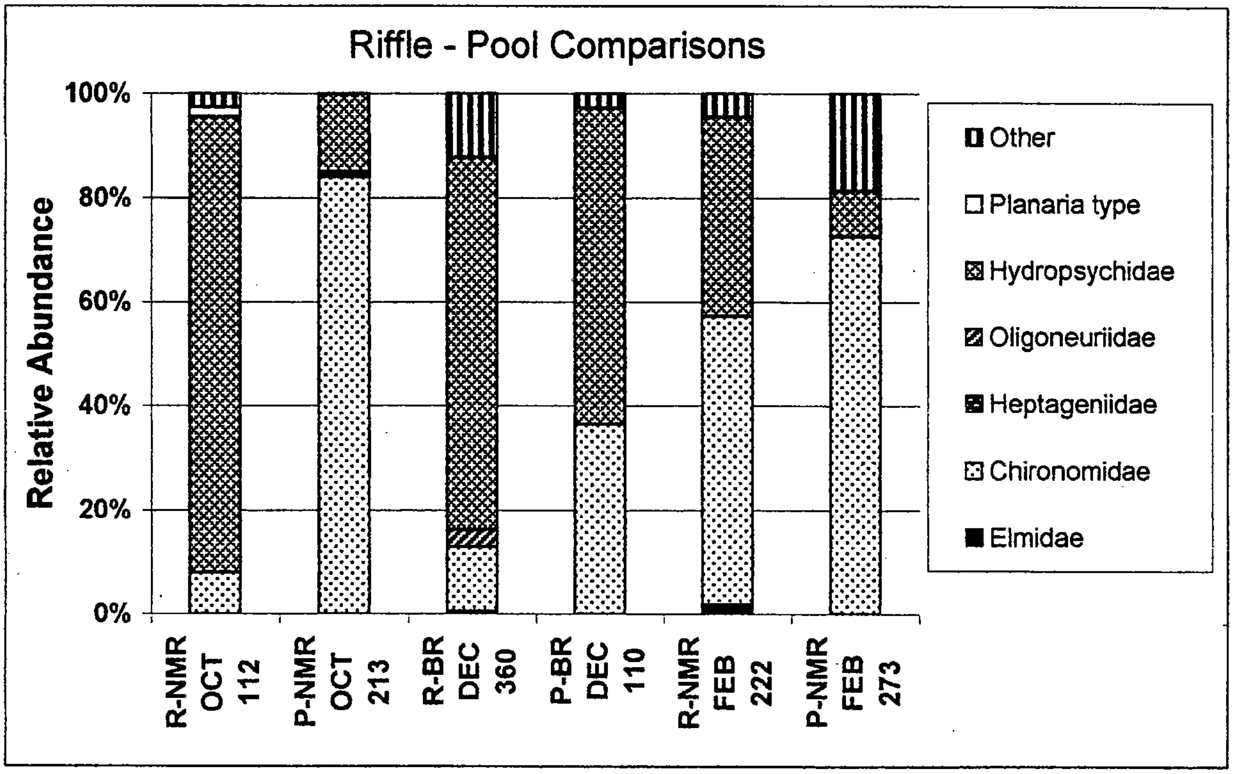
		OCT R-BRH-1	OCT R-BRH-2	FEB R-MH-1	FEB R-MH-2
Coleoptera	Elmidae	1	4	55	54
Diptera	Chironomic	3	21	115	198
Ephemerop	Heptagenii	20	43	0	0
Ephemerop	Oligoneurii	32	0	0	0
Trichoptera	Hydropsycl	48	243	820	840
Turbellaria	Planaria ty|	1	2	0	0
	Other	3	7	95	36
	TOTAL	108	320	1085	1128

Figure 7. Comparisons of replicates for riffle samples from Bowery Run Headwaters in October and Meetinghouse Creek in February. Total number of animals collected listed below month.



		OCT R-NMR	OCT P-NMR	DEC R-BR	DEC P-BR	FEB R-NMR	FEB P-NMR
Coleoptera	Elmidae	0	0	2	0	4	0
Diptera	Chironomid	9	179	44	40	123	198
Ephemero|	Heptagenii	0	2.2	0	0	0	0
Ephemero|	Oligoneurii	0	0	12	0	0	0
Trichopter	Hydropsycl	98	31.3	258	67	85	24
Turbellaria	Planaria ty|	2	0	0	0	0	0
	Other	3	0.5	44	3	10	51
	TOTAL	112	213	360	110	222	273

Figure 8. Comparisons of riffle and pool samples from Nickel Mines Run in October and February, and Bowery Run in December. Total number of animals in each sample is listed below the month of collection.



Appendix 1. Abundances of all taxa collected in Bowery Run Headwaters (BRH), Bowery Run (BR), Meetinghouse Run (MH), and Nickel Mines Run (NMR) during October, December, February, a nd April. R = riffle samples. P= pool samples For each sample the following metrics are listed: abundance ratio of scrapers to filtering collectors, number of EPT taxa, abundance ratio of EPT to chironomids, and percent of the dominant family which was usually either Hydropsychidae or Chironomidae.

OCTOBER		Group	R-BRH1	R-BR	R-MH	RNMR	R-BRH2	P-BRH1	P-BR	P-MH	P-NMR	P-BRH2	TOTALS
Coleopteran	Elmidae	O	1	10	13	0	4	0	0	0	0	1	28.7
Coleopteran	Psephenid	S	0	0	0	0	0	0	0	0	0	0	0.0
Diptera	Chironomi	FC	3	2	13	9	21	13	3	49	179	4	295.7
Diptera	Simulidae	FC	0	0	6	0	0	0	0	0	0	0	6.3
Diptera	Tipulidae	O	2	4	0	2	7	1	0	1	0	0	17.0
Ephemero	Baetidae	O	0	0	0	6	1	0	0	0	0	0	7.0
Ephemero	Ephemere	S	0	0	0	0	0	0	0	0	0	0	0.0
Ephemero	Heptageni	S	20	52	0	0	43	5	0	0	2	3	125.2
Ephemero	Oligoneuri	O	32	22	0	0	0	0	0	0	0	1	55.0
Megalopte	Sialidae	O	0	0	0	0	0	0	0	0	2	0	2.2
Plecopteri	Capniidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Plecopteri	Perlidae	O	1	2	0	0	0	0	0	0	0	0	3.0
Trichopten	Glossosor	S	0	0	0	0	0	0	0	0	0	0	0.0
Trichopten	Hydropsyc	FC	48	73	633	98	243	11	1	4	31	18	1160.3
Trichopten	Philopotan	FC	0	0	0	0	4	0	0	0	0	0	4.0
Isopoda	Asellidae	O	0	0	0	0	0	3	0	0	0	5	8.0
Mollusc	Gastropod	S	0	0	6	1	0	0	0	0	0	0	7.3
Mollusc	Bivalvia	FC	0	0	0	0	0	0	0	0	0	0	0.0
Oligochaet	earthworm	O	0	3	0	0	0	1	0	3	0	0	7.0
Turbellaria	Planaria tvi	O	1	0	133	2	2	0	0	0	0	0	138.0
	TOTAL		108	168	804	118	325	34	4	67	215	32	
	Scrapers		20	52	6	1	43	5	0	0	2	3	
	Filtering Collectors		61	76	652	107	268	24	4	53	210	22	
	Scrapers/Flt. Coll.		0.39	0.69	0.01	0.01	0.16	0.21	0.00	0.00	0.01	0.14	
	EPT No. taxa)		4	4	1	2	4	2	1	1	2	3	
	EPT/Chiro		1.33	2.00	0.08	0.22	0.19	0.15	0.33	0.02	0.01	0.75	
	% Hydro		44	43	79	83	75	32	25	7	15	56	
	%Chiro		3	1	2	8	6	38	75	86	83	13	

Appendix 1 cont'd. Abundance of taxa and metrics.

DECEMBER			R-BRH	R-BR1	R-MH	RNMR	R-BR2	P-BRH	P-BR1	P-MH	P-NMR	P-BR2	TOTALS
Coleopteran	Elmidae	O	5	2	24	0	2	1	0	0	0	0	34.0
Coleopteran	Psephenid	S	0	0	0	0	0	0	0	0	0	0	0.0
Diptera	Chironomi	FC	34	44	54	184	1	14	29	29	0	40	409.0
Diptera	Simulidae	FC	0	0	18	1	0	0	0	1	0	0	20.0
Diptera	Tipulidae	O	1	28	0	1	1	8	0	1	0	1	39.0
Ephemero	Baetidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Ephemero	Ephemere	S	1	0	0	0	0	0	0	0	0	0	1.0
Ephemero	Heptageni	S	36	0	0	0	4	7	1	0	0	0	48.0
Ephemero	Oligoneuri	O	11	12	0	0	3	0	0	0	0	0	26.0
Megalopte	Sialidae	O	0	2	0	0	0	0	0	0	0	0	2.0
Plecopteri	Capniidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Plecopteri	Perlidae	O	1	16	0	0	0	0	0	0	0	0	17.0
Trichopten	Glossosor	S	1	0	0	0	0	0	0	0	0	0	1.0
Trichopten	Hydropsyc	FC	66	258	1014	12	0	10	0	3	0	67	1430.0
Trichopten	Philopotan	FC	0	0	0	0	0	0	0	0	0	0	0.0
Isopoda	Asellidae	O	1	0	0	0	0	9	0	1	0	0	11.0
Mollusc	Gastropod	S	0	0	0	0	0	0	0	2	0	0	2.0
Mollusc	Bivalvia	FC	0	0	0	0	0	0	0	0	0	0	0.0
Oligochaet	earthworm	O	0	2	0	32	0	0	1	0	0	2	37.0
Turbellaria	Planaria tvi	O	1	0	0	0	0	0	0	0	0	0	1.0
	TOTAL		158	362	1110	210	11	49	31	37	0	110	2078
	Scrapers		38	0	0	0	4	7	1	2	0	0	52
	Filtering Collectors		100	302	1086	177	1	24	29	33	0	107	1869
	Scrapers/Flt. Coll.		0.38	0.00	0.00	0.00	4.00	0.29	0.03	0.06		0.00	0.03
	EPT (No. taxa)		8	3	1	1	2	2	1	1	0	1	1523
	EPT/Chiro		0.18	0.07	0.02	0.01	2.00	0.14	0.03	0.03		0.03	3.72
	% Hydro		42	71	91	6	0	20	0	8		61	68.8
	%Chiro		22	12	5	78	9	29	94	78		36	19.7
	%Heptagenidae						36						

Appendix 1 cont'd. Abundance of taxa and metrics.

FEBRUARY			R-BRH	R-BR	R-MH 1	RNMR	R-MH2	P-BRH	P-BR	P-MH1	P-NMR	P-MH2	TOTALS
Coleopteran	Elmidae	O	6	1	55	4	54	0	0	4	0	1	125.0
Coleopteran	Psephenid	S	0	0	0	0	0	0	0	0	0	0	0.0
Diptera	Chironomi	FC	92	54	115	123	198	152	0	12	198	56	1000.0
Diptera	Simulidae	FC	2	5	30	6	6	0	0	0	0	0	49.0
Diptera	Tipulidae	O	4	7	40	4	18	1	0	0	3	0	77.0
Ephemero	Baetidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Ephemero	Ephemere	S	0	6	0	0	0	0	0	0	0	0	6.0
Ephemero	Heptageni	S	34	12	0	0	0	22	0	0	0	0	68.0
Ephemero	Oligoneuri	O	14	5	0	0	0	3	0	0	0	0	22.0
Megalopte	Sialidae	O	0	1	5	1	0	0	0	0	0	0	7.0
Plecopteri	Capniidae	O	2	0	0	0	0	1	0	0	0	0	3.0
Plecopteri	Perlidae	O	0	17	0	0	0	0	0	0	0	0	17.0
Trichopten	Glossosor	S	0	1	0	0	0	0	0	0	0	0	1.0
Trichopten	Hydropsyc	FC	274	118	820	65	840	13	0	2	24	0	2177.0
Trichopten	Philopotan	FC	0	0	0	0	0	0	0	0	0	0	0.0
Isopoda	Asellidae	O	0	0	25	0	0	9	0	0	0	1	35.0
Mollusc	Gastropod	S	0	0	0	0	0	0	0	0	0	0	0.0
Mollusc	Bivalvia	FC	0	1	5	0	0	0	0	0	0	0	6.0
Oligochaet	earthworm	O	0	0	0	0	12	0	0	0	48	2	62.0
Turbellaria	Planaria tvi	O	0	0	0	0	0	0	0	0	0	0	0.0
	TOTAL		428	229	1096	223	1128	201	0	18	273	60	3656
	Scrapers		34	19	0	0	0	22	0	0	0	0	75
	Filtering Collectors		368	179	970	214	1044	165	0	14	222	56	3232
	Scrapers/Flt. Coll.		0.09	0.11	0.00	0.00	0.00	0.13		0.06	0.00	0.00	0.02
	EPT (No. taxa)		4	6	1	1	1	4		1	1	0	2294
	EPT/Chiro		0.04	0.11	0.01	0.01	0.01	0.03		0.08	0.01	0.00	2.28
	% Hydro		64	52	75	38	74	6		11	9	0	59.6
	%Chiro		21	24	11	55	18	76		67	73	93	27.4

Appendix 1 cont'd. Abundance of taxa and metrics.

APRIL			R-BRH	R-BR	R-MH	RNMR1	R-NMR2	P-BRH	P-BR	P-MH	P-NMR1	P-NMR2	TOTALS
Coleopteran	Elmidae	O	6	24	154	0	0	0	0	6	0	0	189.0
Coleopteran	Psephenid	S	1	3	0	0	0	0	0	0	0	0	4.0
Diptera	Chironomi	FC	1	2	56	1	8	1	2	7	3	1	79.0
Diptera	Simulidae	FC	0	0	0	0	0	0	0	0	0	0	0.0
Diptera	Tipulidae	O	0	0	25	0	0	0	0	0	0	0	24.5
Ephemero	Baetidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Ephemero	Ephemere	S	0	13	0	0	0	0	0	0	0	0	13.0
Ephemero	Heptageni	S	22	11	0	0	0	20	0	1	0	0	54.0
Ephemero	Oligoneuri	O	1	32	0	0	0	1	0	0	0	0	34.0
Megalopte	Sialidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Plecopteri	Capniidae	O	0	0	0	0	0	0	0	0	0	0	0.0
Plecopteri	Perlidae	O	0	1	0	0	0	0	0	0	0	0	1.0
Trichopten	Glossosor	S	0	0	0	0	0	0	0	0	0	0	0.0
Trichopten	Hydropsyc	FC	3	43	1076	2	10	3	0	2	0	0	1138.0
Trichopten	Philopotan	FC	0	0	0	0	0	0	0	0	0	0	0.0
Isopoda	Asellidae	O	0	0	105	0	0	0	0	4	0	0	109.0
Mollusc	Gastropod	S	0	0	0	0	0	0	0	0	0	0	0.0
Mollusc	Bivalvia	FC	0	0	0	0	0	0	0	0	0	0	0.0
Oligochaet	earthworm	O	0	2	4	0	0	0	0	12	1	0	18.5
Turbellaria	Planaria tvi	O	0	0	154	0	0	0	0	0	1	0	155.0
	TOTAL		33	131	1572	3	18	25	2	32	5	1	
	Scrapers		23	27	0	0	0	20	0	1	0	0	
	Filtering Collectors		4	45	1131	3	18	4	2	9	3	1	
	Scrapers/Flt. Coll.		5.8	0.6	0.0	0.0	0.0	5.0	0.0	0.1	0.0	0.0	
	EPT (No. taxa)		3	4	1	1	1	3	0	2	0	0	
	EPT/Chiro		3.00	2.00	0.02	1.00	0.13	3.00	0.00	0.29	0.00	0.00	
	% Hydro		9	33	68	67	56	12	0	6	0	0	
	%Chiro		3	2	4	33	44	4	100	22	60	100	
	% Heptagenidae		67					80					
	% Oligocheate									38			

Appendix 2. Abundances of taxa collected at three sites on the East Branch of Octoraro Creek in the fall from 1970 to 1980. Data published in USGS 85-686, and put in same format at Appendix 1 for the four headwater streams in the West Branch of Octoraro Creek.

Site 33 East Branch Octoraro Creek at Christiana, PA

Phylum to Or	Family	Functional Group	3-Nov-70	18-Oct-71	23-Oct-72	9-Oct-73	30-Oct-74	2-Nov-77	7-Nov-79	13-Nov-80
Coleoptera	Elmidae	O	0	0	2	8	1	8	4	12
Coleoptera	Psephenid	S	0	0	0	0	0	2	0	0
Diptera	Chironomid	FC	9	0	122	5	9	179	0	140
Diptera	Simuliidae	FC	0	0	0	1	1	7	0	0
Diptera	Tipulidae	O	0	0	17	2	3	28	0	16
Ephemeroptera	Baetidae	O	0	0	1	2	0	2	1	0
Ephemeroptera	Ephemerel	S	32	1	0	0	0	9	0	0
Ephemeroptera	Heptageni	S	13	33	29	7	1	7	0	0
Ephemeroptera	Oligoneuri	O								
Ephemeroptera	Siphlonuric	FC	0	0	1	5	8	2	0	0
Megaloptera	Sialidae	O								
Plecoptera	Capniidae	O								
Plecoptera	Perlidae	O								
Trichoptera	Glossosom	S	0	0	1	0	0	0	0	0
Trichoptera	Hydropsyc	FC	22	28	471	329	98	820	128	148
Trichoptera	Hydroptilidae		0	0	4	11	0	31	0	120
Trichoptera	Philopotam	FC	0	0	58	9	43	20	4	20
Isopoda	Asellidae	O	0	0	0	0	0	1	4	4
Mollusc	Gastropod	S	0	0	0	0	4	1	0	4
Mollusc	Bivalvia	FC	0	0	0	0	0	0	0	0
Oligochaet	earthworm	O								
Turbellaria	Planaria ty	O	0	0	0	6	6	0	0	0
	sum		76	62	704	385	172	1117	141	464
	Other		0	1	1	0	0	8	0	12
	TOTAL		76	63	705	385	172	1125	141	476
	Scrapers		45	34	30	7	5	19	0	4
	Filtering Collectors		31	28	650	349	157	1028	132	308
	EPT abundance		67	62	563	363	148	891	133	288
	% Hydro		29	44	67	85	56	73	91	31
	%Chiro		12	0	17	1	5	16	0	29
site 33	Taxa Richness No. t.		3	4	8	11	10	14	5	9
	Family Biotic Index									
	Scrapers/Filt. Coll.		1.45	1.21	0.05	0.02	0.03	0.02	0.00	0.01
	EPT/Chiro		7.44	62.00	4.61	72.00	16.44	4.98	133.00	2.00
	% dom		42	52	67	85	56	73	91	31
	EPT Index (No. taxa)		3	3	6	5	3	6	3	3

Appendix 2 cont'd.

Site 34 Valley Creek at Atglen

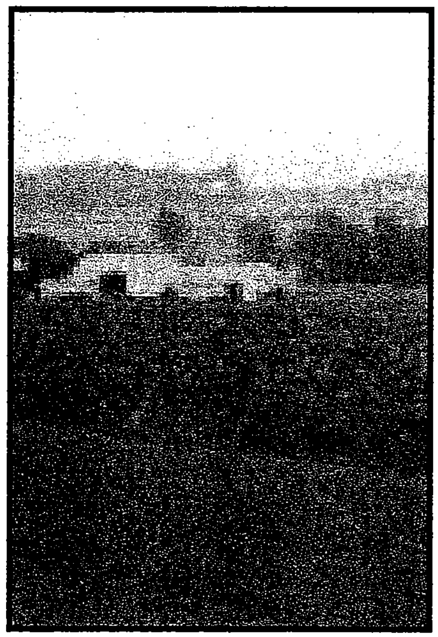
		Functional Group	3-Nov-70	18-Oct-71	23-Oct-72	9-Oct-73	30-Oct-74	2-Nov-77	7-Nov-79	13-Nov-80
Coleoptera	Elmidae	O	0	0	2	0	2	29	0	0
Coleoptera	Psephenid	S	0	0	0	0	0	0	1	0
Diptera	Chironomid	FC	18	0	24	1	16	118	0	296
Diptera	Simuliidae	FC	0	0	7	5	2	19	0	88
Diptera	Tipulidae	O	0	0	2	0	2	45	2	32
Ephemeroptera	Baetidae	O	10	0	10	1	0	9	0	0
Ephemeroptera	Ephemerel	S	27	0	0	0	0	5	0	0
Ephemeroptera	Heptageni	S	6	3	38	1	0	29	0	24
Ephemeroptera	Oligoneuri	O								
Ephemeroptera	Siphlonuridae		0	0	30	26	0	8	0	8
Megaloptera	Sialidae	O								
Plecoptera	Capniidae	O								
Plecoptera	Perlidae	O								
Trichoptera	Glossosom	S	0	0	4	0	0	7	0	0
Trichoptera	Hydropsyc	FC	16	2	215	102	107	384	9	648
Trichoptera	Hydroptilidae		0	0	0	0	0	9	0	160
Trichoptera	Philopotam	FC	0	0	0	0	0	29	0	8
Isopoda	Asellidae	O	0	0	0	0	1	0	0	0
Mollusc	Gastropod	S	0	0	0	0	0	22	0	0
Mollusc	Bivalvia	FC								
Oligochaet	earthworm	O								
Turbellaria	Planaria ty	O	0	0	0	0	0	0	0	0
	sum		77	5	332	136	130	711	12	1264
	Other		0	0	2	0	0	57	1	24
Site 34	TOTAL		77	5	334	136	130	768	13	1288
	Scrapers		33	3	42	1	0	63	1	24
	Filtering Collectors		34	2	276	134	125	556	9	1048
	EPT abundance		59	5	297	130	107	478	9	848
	% Hydro		21	40	64	75	82	50	69	50
	%Chiro		23	0	7	1	12	16	0	23
	Taxa Richness No. t.		5	2	9	6	6	13	2	8
	Family Biotic Index									
	Scrapers/Filt. Coll.		0.97	1.50	0.15	0.01	0.00	0.11	0.11	0.02
	EPT/Chiro		3.28	5.00	12.38	130.00	6.69	4.05	9.00	2.86
	% dom		35	80	64	75	82	50	69	50
	EPT Index (No. taxa)		4	2	4	4	1	9	1	5
Trichoptera	Psychomyiidae						0	53	1	0

Appendix 2 cont'd.

Site 35 East Branch Octoraro Creek at Steelville

		Functional Group	3-Nov-70	18-Oct-71	23-Oct-72	9-Oct-73	30-Oct-74	2-Nov-77	7-Nov-79	13-Nov-80
Coleoptera	Elmidae	O	0	0	0	0	0	5	0	0
Coleoptera	Psephenid	S	0	0	0	0	1	1	0	0
Diptera	Chironomid	FC	0	0	593	1	6	639	3	320
Diptera	Simuliidae	FC	0	0	9	0	0	0	0	0
Diptera	Tipulidae	O	0	0	7	0	1	16	0	72
Ephemeroptera	Baetidae	O	10	0	2	0	2	0	0	8
Ephemeroptera	Ephemerel	S	52	3	2	0	2	65	1	40
Ephemeroptera	Heptageni	S	6	12	114	8	6	82	15	80
Ephemeroptera	Oligoneuri	O								
Ephemeroptera	Siphlonuridae		0	0	19	26	13	6	0	0
Megaloptera	Sialidae	O	0	0	0	0	0	1	0	0
Plecoptera	Capniidae	O								
Plecoptera	Perlidae	O								
Trichoptera	Glossosom	S								
Trichoptera	Hydropsyc	FC	23	28	108	100	99	228	65	320
Trichoptera	Hydroptilidae		0	0	2	0	0	0	0	72
Trichoptera	Philopotam	FC	0	0	0	0	6	109	3	128
Isopoda	Asellidae	O	0	0	0	0	1	0	0	0
Mollusc	Gastropod	S	0	0	0	0	0	4	0	0
Mollusc	Bivalvia	FC								
Oligochaet	earthworm	O								
Turbellaria	Planaria ty	O	0	0	0	0	0	0	0	8
	sum		91	43	856	137	139	1156	77	1048
	Other		11	0	2	1	1	18	2	0
Site 35	TOTAL		102	43	858	138	140	1174	79	1048
	Scrapers		58	15	116	8	11	152	16	120
	Filtering Collectors		23	28	720	129	124	982	61	768
	EPT abundance		91	43	247	136	130	486	74	648
	% Hydro		23	65	13	72	71	19	70	31
	%Chiro		0	0	69	1	4	54	4	31
	Taxa Richness No. t.		4	3	8	4	10	11	5	9
	Family Biotic Index									
	Scrapers/Filt. Coll.		2.52	0.54	0.16	0.06	0.09	0.15	0.26	0.16
	EPT/Chiro		91.00	43.00	0.42	136.00	21.67	0.77	24.67	2.03
	% dom		57	65	69	72	71	54	78	31
	EPT Index (No. taxa)		4	3	8	3	8	5	4	8

III. Knight Run Subwatershed Study



Knight Run Subwatershed Study

Prepared For: **The Octoraro Watershed Association**

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INTRODUCTION

A comprehensive approach to water resource management is needed to address the wide range of water quality problems that exist today from non-point and point sources as well as from habitat degradation. Watershed- based planning and resource management is a strategy for more effective protection and restoration of aquatic ecosystems and for the protection of human health. Watershed-based planning emphasizes all aspects of water quality, including chemical water quality (e.g., toxins and conventional pollutants), physical water quality (e.g., temperature, flow, and circulation), habitat quality (e.g., stream channel morphology, substrate composition, and riparian zone characteristics), and biological health and biodiversity (e.g., species abundance, diversity and range) (METRO 1994).

A watershed should be managed as a single unit. Each small piece of the landscape has an important role in the overall health of the watershed. Paying attention primarily to the riparian zone, an area critical to a watershed's release function, will not make up for lack of attention to the watershed's uplands. Only a seamless management of the entire watershed and an understanding of the hydrologic process will ensure watershed health (METRO 1994).

The Knight Run Watershed

Knight Run has been selected as a representative watershed of the Octoraro Creek, and is the focus of this study. The Knight Run Watershed Study will identify the major issues affecting the water quality of the watershed. The recommendations and proposed interventions in the Watershed Plan will have application throughout the Octoraro Watershed.

Divided into three sections, the Knight Run Watershed Study includes a Watershed Inventory, a Watershed Analysis, and a Watershed Plan.

The Knight Run Watershed Inventory will further include the following categories:

- Landscape Ecology
- Historical Ecology
- Geology and Soils
- Water Resources
- Vegetation and Wildlife
- Land Use

After the completion of the Inventory, a Watershed Analysis will identify watershed stressors.
The final section of the report, the watershed plan, will include recommendations for Best Management Practices to target these stressors throughout the watershed.

I. WATERSHED INVENTORY

LANDSCAPE ECOLOGY

Introduction

The term landscape, as defined by Forman and Godron (1986) is "... a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout." The landscape-level scale for our location in the Piedmont geographic region translates into areas drained by major streams, within which climatic regime, geomorphic processes, and natural vegetation patterns are fairly uniform.

Three major components in understanding ecological systems exist: structures, functions, and the interactions among them. The structures are the physical elements that make up any system and are things you can touch, see, and feel. These structural elements can be either living or non-living, mobile or fixed.

Landscapes are commonly described as having three kinds of structures which are referred to collectively as 'landscape elements.' These landscape elements are: matrix, corridors, and patches. The matrix is a landscape element that includes the most connected portion of the landscape. Patches are areas on the landscape that are relatively homogeneous internally and that differ from what surrounds them (the matrix or other patches). Corridors are landscape elements that connect similar patches through a dissimilar matrix or aggregation of patches. Patches connected by corridors are often called nodes. Corridor effectiveness in providing connectivity often depends on how wide it is, and how frequently a person encounters breaks, or discontinuities. Since the spatial arrangements of these elements determines the function of a landscape as an ecological system, the pattern of the matrix, patches, and corridors in the landscape is of primary interest.

Defined as the ability of an ecological system to maintain its functions in the face of change or disturbance, ecosystem resilience is an important concept in land planning and natural resource management. Since ecosystem functions are dependent on the structures that perform them, changes which eliminate certain structural features can cause loss of function in the system. Proper natural resource management attempts to sustain ecological resilience by identifying and protecting individual types of structural, functional, and interactive relationships, with the objective of maintaining the overall function of the whole (Diaz and Apostol 1992).

After accepting the premise that ecosystem resilience derives in part from diversity, the next task is to characterize elements of diverse landscape. Characterized as having three components, diversity can either be compositional, structural, or process. At the landscape level compositional diversity refers to the variation in types of landscape elements or vegetation types, their relative proportions within the landscape, and their degree of rarity or commonness. Structural diversity describes the variation in sizes and shapes of landscape elements, as well as diversity of pattern (heterogeneity) (Noss 1990). Finally, process diversity relates to the variety of landscape flows, functions, and processes present. All three types are thought to be important in sustaining resilient landscapes.

Landscape Ecology of the Knight Run Watershed

Specific to the Knight Run Watershed, the landscape pattern has changed dramatically since European settlement of the area. In presettlement time, a forest matrix with patches of Native American villages and agricultural fields, and corridors of trails and streams existed in the Knight Run Watershed.

Due to the mild climate and excellent soils typical of this area, settlers to the region cleared the native forest to convert the land to agriculture. After settlement, the matrix of the watershed became agricultural fields, with patches of small settlements and farmsteads with corridors of roads, streams, and hedgerows. Forest land occurred as patches (woodlots) and corridors (in steep valleys) within the watershed.

The Knight Run watershed remains primarily agricultural in nature, but with major roads such as route 41 and route 10 occurring within the boundary of the watershed, and the watersheds proximity to major metropolitan areas, development pressures are beginning to impact the area.

Testing the resilience of the system, the modification of the landscape structure likely cause significant changes to the landscape function. We need to understand the effect of this forest to agricultural land conversion to understand the ecology of the watershed today, and to better predict how our actions will affect the watershed in the future.

HISTORICAL ECOLOGY

"An endless feedback loop:
Past functioning has produced today's structure;
today's structure produces today's functioning;
today's functioning will produce future structure."
(Forman and Godron 1986).

Introduction

To understand the structure, function, and interactions of today's ecological systems, you need to understand the history of the site. Settlement and land use practices of the past greatly influence the sites current condition and future potential. Historical ecology seeks to explain many enigmatic features of present ecosystems and landscapes by deciphering the legacies of past human activities (Bilsky 1980).

The Native Forests

In general, the Piedmont region and the State of Pennsylvania as a whole was well characterized when it was called 'Penn's Woods.' Best estimates are that only about 2 or 3 percent of Pennsylvania was not forest (Schein and Miller 1995).

A native northern temperate zone woodland has a six-layer stratification: a canopy of largest
trees (which name the forest), an understory of spreading, shorter trees (such as dogwoods and witch hazels), a shrub and sapling layer, an herb layer, a moss or ground layer, and a subterranean layer of roots and microflora. None of these layers is continuous, except perhaps the subterranean layer. The richness of the herb layer is greatest in the Piedmont because of the superior soils and milder winters (Schein and Miller 1995).

Native American Utilization of the Land

Native Americans are thought to have had an impact on the pre-European forest, particularly through their use of fire and their agriculture (Spur and Barnes 1980; MacCleery 1992; Williams 1992). Most Native Americans lived in villages throughout the northeastern United States. Each village included at least several acres of clearings that contained home sites.

The Native Americans expanded these clearings to obtain timber in the vicinity of homesites for building materials for homes, utensils, canoes, and other items, particularly for use as a fuel. The Iroquois and other tribes relied greatly on agriculture to provide foodstuffs, such as beans, maize, squash, and sunflowers, grown in clearings of the forest created by fires that were deliberately set or that occurred naturally. Fires were also used selectively by Native Americans to create forest edges and openings for deer, turkey and other wildlife, which were important as food.

GEOLOGY AND SOILS

Chester County Geology
Over 90% of the Knight Run Watershed is composed of Peters Creek Schist, a chlorite-sericite schist with quartzite. This formation is moderately resistant to weathering and highly weathered to a moderate depth and has good surface drainage. The topography of this formation is characterized by undulating hills of medium relief with natural slopes that are moderately steep and stable. Ground water yields of 75 gpm or more should be realized from 150' deep wells in the chlorite phase, whereas in the muskovite phase wells should be 300' deep for maximum production. This formation generally provides good quality foundations for heavy structures (Chester County Geology 1973).

A small percentage of the watershed, at the northern edge, is located in the Wissahickon Formation. Composed of albite-chlorite schist which is typically a phyllite made chiefly of quartz, feldspar, muscovite, and chlorite, the Wissahickon Formation is similar to the Peters Creek Schist in weathering, drainage, topography, ground water yield and foundation stability (Chester County Geology 1973).

Bedrock geology and soils have been important factors in the formation of natural vegetation and land-use patterns of Chester County. Also, geology is a primary determinant of groundwater quality and quantity.

Soils of the Knight Run Watershed
The soil types found in the Knight Run Watershed are Chester silt loam (CdA, CdB,) Chewacla loam (Ch,) Glenelg channery silt loam (GeA, GeA2, GeB, GeB2, GeB3, GeC2, GeC3, GeD, GeD3,) Glenelg silt loam (GgA3,) Glenville silt loam (GnA, GnB, GnB2,) Manor loam (MgA2, MgB, MgB2, MgC, MgC2, MgC3, MgD, MgD2, MgD3,) Manor loam and channery loam (MhE, MhE3,) Manor soils (MkF,) Manor very stony loam (MmD,) Worsham silt loam (WoA, WoB, WoB2,) and Wehadkee silt loam (We). Of these soils, Chester silt loam, Glenelg silt loam, Glenville silt loam and Manor silt loam are considered Prime Agricultural Soils by the NRCS. Approximately 75% of the Knight Run Watershed is covered by Prime Agricultural Soils. Many of the soils not classified as Prime Agricultural Soils, are designated as State Significant Soils by the Pennsylvania Department of Agriculture (Soil Conservation Service 1963).

WATER RESOURCES

As population increases, the need for water will also rise. What is often forgotten is that population increases along with changes in land use can have a detrimental effect on the quality and quantity of water. Suburban sprawl, with its increase in impervious surfaces (buildings, parking lots, roads, etc.), reduces the ability of area aquifers to replenish themselves to meet the growing demand for water. Water quality can also negatively affect surface and ground water by increased erosion and sedimentation and contamination due to runoff from roadways / parking lots and on-lot septic systems.

Agricultural production involves many activities and practices that can adversely affect the quality of surface and groundwater. Sediment from eroding land can negatively affect surface water, while nutrients from fertilizers, manure, and pesticides can contaminate both surface water and groundwater (USDA 1997). The application of fertilizers and / or manure to agricultural land increases the chance that nutrients will run off into surface waters or leach into groundwater. The two primary agricultural nutrients that play a role in water quality are nitrogen and phosphorus. Primarily found in the soil as nitrate, nitrogen is soluble and is easily transported by surface runoff or by leachate. Phosphorus, primarily in the form of phosphate, is only moderately soluble and, relative to nitrate, is not very mobile in soils or groundwater. An excessive amount of nitrogen or phosphorus in surface waters can cause algae to grow at an accelerated rate. An abundance of algae results in cloudy water, which prevents aquatic plants from receiving sunlight for photosynthesis. When the algae die, bacteria decomposes them which results is a depletion of the oxygen dissolved in the water. This is the process of eutrophication which can result in clogged pipelines, fish kills, and reduced recreational opportunities. According to EPA, nutrient pollution is the leading cause of water quality impairment in lakes and estuaries and the third leading cause in rivers (USDA 1997).

Surface Water Quality
Tilling the soil and / or leaving it without vegetation cover for some period of time results in accelerated soil erosion. Sediment harms water bodies when present in excessive amounts by clouding the water and coating the leaves of plants, both of which deprive them of sunlight needed for growth. The deposition of sediment reduces the useful life of reservoirs, clogs ditches and irrigation canals, and blocks navigation channels, resulting in increased dredging costs. By raising stream beds and burying stream side wetlands, sediment can increase the likelihood and severity of floods. Suspended sediment can increase the cost of water treatment for municipal and industrial water users. According to the EPA, siltation is one of the leading pollution problems in U.S. rivers and streams and is among the top four problems in lakes and estuaries (USDA 1997).

Studies have reported that as much as 70% of all water pollution comes from non-point source pollutants. Streambank and cropland erosion together accounted for an estimated 92-93% of all soil losses.

Acid rain also represents a problem for local surface water quality. Airborne nitrogen and sulfur, created by cars, trucks, power plants, and industries, cause acid rain and excess nutrients in streams and groundwater. Approximately one-third of nitrogen pollution may come from airborne pollutants. Pennsylvania has one of the highest levels of acid rain in the country. Ozone is a pollutant which is formed in the air by chemical reactions primarily involving volatile organic compounds, nitrogen oxides, and carbon monoxide.

Groundwater Quality

While the status of groundwater quality in the U.S. is not well known, of 38 States reporting overall groundwater quality, 29 judged their groundwater quality to be good or excellent. When degradation of groundwater quality does occur, it is typically a localized problem often caused by agriculture. Of the 49 States reporting sources of groundwater contamination, agriculture was cited as a source in 44 States (USDA 1997).

A public survey from the mid-1980's found that residents in Knight Run Watershed reported the highest percent of wells with nitrate problems (West Fallowfield Township 1993). Above a certain concentration, nitrate is a concern for drinking water. Based on the human health effects of nitrate and nitrite, EPA has established a maximum contaminant level (MCL) of 10 mg/L for nitrate, and 1 mg/L for nitrite in public drinking systems. Nitrates or nitrites above the MCL can be a factor in causing methemoglobinemia ("blue-baby syndrome"), which prevents the transport of oxygen in the bloodstream of infants, and may be a cancer risk to humans due to nitrosamine formation. In its 1988-90 national survey of drinking water wells, EPA found nitrate in more than half of the 94,600 community water system wells and almost 60 percent of the 10.5 million rural domestic wells, making nitrate the most frequently detected chemical in well water (USDA 1997).

Water quality problems caused by urban-suburban runoff are extremely difficult to control after development has occurred. Stormwater management regulations which apply to new development can greatly reduce storm water flows, thereby reducing water quality problems created by urban and suburban runoff.

Pesticide use by homeowners, businesses, institutions, and farmers can, even in small concentrations, be a public health concern when they enter area groundwater and streams. Major transportation routes, such as routes 10 and 41, pose a threat to the watershed's surface and groundwater / wellheads due to the potential for accidental spills.

Because property rights to the environment are not clearly defined, no market price associated with using water resources as a receptor for eroding soil, excess nutrients, pesticide residues, etc. exists. Consequently, farmers and other residents do not feel compelled to factor the offsite costs of erosion or chemical runoff and leaching into their daily decisions. These costs are "external" to their operation and economists refer to these effects as "externalities". In addition, individuals are often unaware of the offsite effects their decisions cause.

Knight Run Watershed
The Knight Run is made up of the flow from surface runoff and spring seeps from groundwater sources. The Knight Run channel has a total length of 6.8 miles, in which the stream falls 209 feet. The Knight Run Watershed drains an 5800 acre (9 square mile) basin. Eight tributaries and 11 stream channels comprise a total stream length of 15.9 miles. Approximately 70% of the total stream length is represented by first order streams. Flow data **(average, high, low, record level, etc.)**

The high-point within the watershed (elevation = 703) is at the northern edge of the watershed near the Highland / West Fallowfield Township borders on Highland Road. The low-point of the watershed is the confluence of Knight Run with the East Branch Octoraro Creek (elevation = 396).

The aquatic habitat provided by the Knight Run is considered fair to poor. Sediment and nutrient loading and a lack of forested riparian buffers is one of the main reasons for the poor habitat values this important open space corridor. The Knight Run and its adjacent terrestrial habitat provide very little habitat for nesting, rearing, resting, feeding, and cover due to the lack of vegetation structure. Knight Run and many of its tributaries are down cut in areas, so that they no longer have access to their historic floodplain. Dominating the existing floodplains are pasture grasses which provides poor food value, marginal habitat, and extremely low diversity. Nutrients and sediment, entering the stream by surface and groundwater sources, has a direct negative impact on the aquatic habitat of Knight Run.

VEGETATION AND WILDLIFE

Historic Vegetation of the Region

When European Colonists first arrived, approximately 95% of the Chesapeake Bay watershed was forested. By the mid 1800's, over half of the forest land had been converted to other uses. Forests have recovered somewhat from their historic lows, with about 60% of the Chesapeake Bay watershed being forested today (Chesapeake Bay Program 1995).

The Knight Run Watershed is located in the original Oak-Chestnut Forest Region, Piedmont Section (Braun 1950). The Oak-Chestnut forest extended from southern New England to northern Georgia. Oaks, and formerly chestnuts, are the tree species used to characterize the forest. Nothing remains of the original primary vegetation because of the demise of the chestnut from the chestnut blight caused by the parasitic fungus (*Endothia parasitica*) introduced to America in 1904. To underscore the enormity of the loss of the chestnut, estimates show that chestnuts accounted for one tree in five in the Pennsylvania woods (Schein and Miller 1995).

The transformation of the land from forest to agriculture at the time of settlement likely increased stream flow due to the removal of the transpiring native trees and shrubs. Increased flow, and the loss of the forests extensive root systems, would have increased erosion potential of upland areas causing sedimentation of streams and rivers. Sedimentation likely caused streams or rivers to aggrade, or to fill, raising the level of the bed of a stream by deposition of sediment.

The tree species that most benefited from the opening of the canopy were the Tulip poplar (*Liriodendron tulipifera*), which was a minor component of the original Oak-Chestnut Forest (Braun 1950). The Tulip-Oak forest type now forms the majority of the woodland in the region.

The resurgence of once nearly extinct native fauna like the white-tailed deer (*Odocoileus virginianus*) has had major impacts on forest regeneration. Heavy deer browsing in some areas in Pennsylvania has been blamed for the failure of many species from regenerating (Hough 1965). Forest regeneration due to deer browse is not considered a major concern in the watershed as deer populations are fairly stable due to lack of prime habitat due to forest fragmentation.

Vegetation of the Knight Run Watershed

In the Knight Run Watershed approximatley 13%, or 760 acres, of the land area is wooded. The remainder of the land is mostly in agricultural production, and pasture. The existing woodland varies greatly. Some areas are dominated by early successional tree species, while other areas are dominated by mature tree species such as walnut and oak.

The tornado that passed through this area in May / June 1998 caused areas of serious damage to the wateshed's forests. There are numerous stands with downed trees and there is cutting and clean up well underway.

Historic Changes in Wildlife

The effect of hunting on wildlife in Pennsylvania has been significant. Throughout the seventeenth and eighteenth centuries, hunting practices led to the extermination of the wolf and beaver in eastern North America. Although people may have substituted for predators in controlling the prey populations, the role of such species as beavers in damming creeks and cutting trees has been left unfilled. The dislocations caused by the loss of these animals most likely still affect forest structure (Russell 1997) and watershed functions.

When converting an area from a natural to a man-made state, we often disrupt the delicate balance of the local ecosystem. This imbalance degrades or strains the environment's ability to support varied forms of plant and animal species. In turn, local species become threatened or endangered. The key to protecting wildlife diversity is the protection of local natural habitats. The protection of habitats can also serve other equally important functions, like the control of erosion, the recharge of of groundwaters, the attenuation of pollutants, and providing passive recreational opportunities.

Wildlife and Habitat

Contiguous forest areas often provide the best biodiversity. Because of the cutting of the original forests, highly fragmented nature of existing woodlands, the growing of monocultures in the agricultural fields, biodiversity has decreased significantly within the watershed. Biodiversity is further reduced due to the degraded conditions of the watershed's riparian corridor.

Existing riparian corridors offer little habitat for nesting, rearing, resting, or feeding. Located throughout the watershed are riparian floodplains. These floodplains are rarely forested and are often dominated by pasture grasses, which provide very poor food value, marginal habitat, and extremely low diversity. Due to the lack of vegetation diversity and lack of quality habitats, the value of most terrestrial habitat along the Knight Run is marginal. Despite the marginal habitat, the watershed is still home to important wildlife species such as blue heron. The Knight Run Watershed is also home to several bald eagle nesting sites.

While the current state of the watershed's wildlife habitat is marginal, there are excellent opportunities for improvement. The proposed Octoraro County Park Site is proposed for a site north of the Knight Run watershed. The proposed Octoraro Park features a combination of wetlands, upland forested slopes, and 2.5 linear miles of Octoraro Creek floodplain. The site offers plant diversity that is rare in this portion of the state. The Octoraro County Park site contains three rare and endangered species which are present because of the unfragmented condition of the site's wooded slopes (Chester County 1996).

The proposed Octoraro County Park could act as a biodiversity reserve for the region. Future restoration efforts within the Knight Run Watershed should attempt to establish natural corridors that link to this reserve area. The establishment of these natural corridors are important for wildlife habitat and for maintaining viable wild plant and animal populations.

LAND USE

Introduction

The uniqueness of Chester County with its rich scenic, natural, and historical resources, has continued to attract people as a place to visit, live, and work. Increased development pressure brought on by increasing population is contributing to the loss of the scenic and natural features that initially attracted people to the area. If the Knight Run Watershed is to maintain or improve its natural resources and rural character, wise planning is required.

A survey of West Fallowfield Township residents showed that 84% of the respondents choose to live there because of the rural nature of the community. In the same survey, 94% of the residence believed that development and growth needed to be guided.

If current trends continue, the watershed area would experience a 66% increase in developed land from 9% developed land in 1990 to 14% in 2020 (Chester County Planning Commission 1996). Since the construction of Route 41 in the 1950's, an increase in development along that corridor brought businesses and industry to the area adjacent to Cochranville.

Currently, the Knight Run Watershed has approximately 5,220 acres (88% of the watershed area) in agricultural land, and 350 acres (6%) are in low-density residential areas and farmsteads. Other types of land uses (commercial, industrial, transportation, and institutional) occupy approximately 348 acres, or 6%, of the watershed. Commercial, industrial and residential land uses will likely increase as a result of the proposed improvements to Route 41, and the desire of many people to live in a rural environment.

Current planning needs to ensure that the pattern of future development preserves prime farmland, and protects or enhances the watershed's natural resources.

Chester County is endowed with a remarkably favorable natural, cultural, and economic environment for farming. Of the elements of natural environment, topography presents few handicaps to farming except in the steep hillslopes in the western portion of the county.
Approximately 740 acres are committed to Agricultural Security Areas in the Knight Run Watershed.

Cultural Resources

Identifying cultural resources is important in preserving the watershed's heritage for future generations. Early settlement of the township was concentrated in the villages of Cochranville, Glenville, and Steelville; all three of which surround the watershed (West Fallowfield Township 1993). In 1982, the Chester County Preservation Office surveyed West Fallowfield Township for historic sites and structures. According to that survey, the County Historic Preservation Office used historical atlases to identify over 160 sites and structures that were historically significant within the township (West Fallowfield Township 1993).

While historic preservation often addresses structures, historic preservation of cultural resources also includes landscape features. Because the township is full of cultural resources ranging from farm houses and barns to remnants of mills and hedgerows, preserving the township's heritage through preservation of the agricultural landscape is important. Within the West Fallowfield Township's Comprehensive Plan of 1993, suggestions for protecting these historic resources include addressing historic preservation and establishing a Township Historical Commission.
The proposed Octoraro County Park is to include cultural heritage interpretation and will specifically address the region's rich iron and steel heritage.

II. WATERSHED ANALYSIS

Introduction
Using data gathered for the Watershed Inventory, we can perform an analysis of the Knight Run Watershed. This Watershed Analysis will identify problem areas, or watershed stressors. This section will also identify land areas that are important for conservation, and areas that are best suited for future development.

Watershed Stressors
There are many factors that negatively impact water quality and overall quality of life within the Knight Run Watershed. These problem areas need to be identified, the watershed community needs to be educated about these problems, and together the citizens need to develop an action plan to solve these problems. The identification of, and education of the watershed community about these problems, is the first step to taking action to mitigate their negative effects. The watershed stressors can be categorized as either agricultural or urban / suburban problems.

Agriculture
With the vast majority of the watershed in agricultural production, water quality problems associated with agriculture are a major concern. The following are the major agricultural stressors on the watershed:

Soil Erosion - - Improper soil management and the use of conventional tillage methods have made soil erosion a major contributor to water quality problems.

Fertilizer - -The over use of manure and fertilizer is a problem for both surface and ground water.
Barnyard Management - - Runoff from barnyard areas often find their way to local ponds and streams.

Herbicides and Pesticides - - Herbicide and Pesticides entering surface and groundwater is detrimental to aquatic life and human health.

Stream Protection - - Cattle and other livestock often have direct access to Knight Run and its tributaries, polluting the stream directly with their waste, and indirectly by erosion of the streambanks.

Thermal Pollution - - With numerous farm ponds and lack of forested buffers, thermal pollution of Knight Run is a problem. As water temperatures increase it reduces the ability of the stream to support the wide range of aquatic life typically found in a healthy stream.

Forest Regeneration - - There are numerous opportunities to better manage farm woodlot regeneration. Control of competitive exotic species and periodic thinning are important and often overlooked management tools.

Urban / Suburban
With increased population growth projected for the area, urban and suburban issues will have an increased importance in maintaining the health of the Knight Run Watershed. The primary watershed stressors relating to urban and suburban areas are:

Sprawl - - We are using land inefficiently and unsustainably. The rate at which land is developed far out paces the growth of the population. Studies predict a 38% increase in population for this area between 1990 and 2020 (Chester County Planning Commission 1996). Chester County has experienced a decrease in the number of people per household from 3.53 in 1960 to 2.73 in 1990 (Chester County Planning Commission 1996). With an increased population and the current trend of fewer persons living within a household, the issue of sprawl development needs to be addressed. Sprawl harms the environment, increases the cost of infrastructure, and often results in the abandonment of downtown urban areas (Pennsylvania 21st Century Environment Commission 1998).

Loss of Aquifers - - The impervious surfaces associated with suburban and urban development can dramatically reduce the amount of water percolating down to the groundwater. Water storage in aquifers is critical to maintaining habitat for fish and a host of stream life during summer months when little rain falls. Public water sources are also negatively affected.

Urban / Rural Conflict - - Odors, dust and noise associated with normal farming practices often are the cause of conflict with new adjacent residential subdivisions.

Stormwater Runoff - - Because of increased impervious surfaces in urbanized areas, not only does water run faster, the water also contains many automobile contaminants from roads and parking areas.

Naturalized Landscaping - - Traditional residential and commercial landscapes, with their emphasis on the use of turf grasses, provide little habitat value and many ornamental plant species require the use of irrigation, fertilizers and pesticides.

Thermal Pollution - - Stormwater runoff from buildings and paving that directly flows or is piped to the stream can significantly increase the water's temperature. This problem is especially severe during summer months.

Air pollution and Acid Rain - - Between 1990 and 1996 total vehicle miles traveled (VMT) in Pennsylvania increased from about 263 million miles per day to 294 million miles per day demonstrating that we are spending more time in our cars (Pennsylvania 21st Century Environment Commission). Our region has one of the highest rates of acid rain precipitation in the United States with the pH of the rainfall ranging from 4.2 to 4.4 (Miller 1995). Air pollution and acid rain has many negative effects on the environment including the impoverishment of soil fertility, decreasing the pH of streams and prevention or slowing of the regeneration of woodlands.

Spills and Chemical Disposal - - The improper disposal of motor oil and household chemicals represents a serious threat to water quality. The threat of spills is also an ever present danger on major roadways, and in industrial areas.

Woodland / Forest Loss - - Home sites are often located in or near the watershed's forested areas. As suburban development expands, woodlands are being lost and / or further fragmented within the watershed.

III. WATERSHED PLAN

Introduction
The goal of the Watershed Plan is to make specific recommendations to improve water quality of the Knight Run watershed. This section will also identify sites for best management practices. All the proposed interventions discussed in this section will be applicable throughout the Octoraro Watershed.

Recommendations
Agriculture
Soil Erosion - - No till methods and leaving crop residues on the field are two alternatives that will alleviate the problem. The upland agriculture areas are well managed with the use of contour plowing, and grass swales and waterways throughout the watershed.

Fertilizer - - Fertilizer use should be directed by a nutrient management plan that will assess the crops fertilizer needs to eliminate the over application of fertilizer.

Barnyard Management - - A gutter and downspout system should be installed to separate clean rainwater from entering the barnyard. Runoff from the barnyard should be held in a storage tank, or run through a grassed swale and basin system to filter out solids and nutrients.

Herbicides and Pesticides - - Farmers should be given incentives to reduce the use of herbicides and pesticides, and to develop alternative methods such as Integrated Pest Management (IPM). Biodiversity of vegetation should also be encouraged on farmlands, with this diversity helping to create the habitat needed by beneficial insect that form the basis of IPM.

Stream Protection - - There are state and federal programs that financially assist farmers to install fencing to protect streams from grazing animals, and to plant stream buffers and grass swales to reduce soil loss.

Stream Corridor Restoration - - A systematic assessment of the stream channel should be conducted to both stabilize streambanks, re-establish the streams access to its floodplain and a healthy geometry with a diversity of aquatic habitat types.

Forest Management - - Areas damaged by the tornado, with newly opened canopies, will need to be properly managed to minimize the potential for the invasion of species such as multiflora rose and bittersweet. Damaged woodlands should be reforested with native trees such as oak and tulip poplar, and maintained with periodic removal of exotic plants. Mature woodlands should have stand delineations, appraisals and management plans which prescribed light and intermediate commercial thinnings. Younger forests would benefit from basic stand improvements such as thinning and invasive control.

Forested Riparian Buffers - - Stream fencing in conjunction with the planting and proper maintenance of a forested riparian buffer would likely be the most cost effective method of improving water quality in the Knight Run Watershed. Farmers and other landowners should be given tax incentives on all land dedicated to forested riparian buffers.

Urban and Suburban Areas

Sprawl and Urban / Rural Conflict - - Zoning ordinances should encourage the preservation of prime farmland and important habitat areas. Agricultural areas need to be preserved by protective zoning, and a buffer zone should be established between agriculture and residential areas. The Knight Run area should be categorized as a rural landscape that includes farms, farm-related businesses, and villages with some scattered housing sites (Chester County Planning Commission 1996).

Loss of Aquifers - - Aquifer recharge areas need to mapped and protected by zoning.

Stormwater Runoff - - Municipalities should require stormwater controls to reduce the rate of runoff, and regulate the quality of stormwater runoff, by advocating 'first flush' stormwater treatment devices such as filter strips or bio-filtration swales.

Naturalized Landscaping - - Naturalized landscaping, using native plants, should be encouraged on all residential landscapes. Native plant are adapted to local conditions so they will require little or no inputs. By replacing lawn areas with plantings of native grasses and wildflower, there will be a great reduction in the amount of time and money spent on maintenance, while improving wildlife habitat.

Thermal Pollution - - Industrial, commercial and residential areas should encourage the planting of street trees, and the development of water gardens to increase infiltration of water from building downspouts.

Spills and Chemical Disposal - - The public needs to be educated about the importance of proper disposal of oil and hazardous household chemicals, and needs to be given convenient disposal sites. Land planning needs to be done to prevent the building of industrial operations, in environmentally sensitive areas.

Conservation Areas
Woodlands - - Existing woodlands should be preserved. Wooded areas are often popular places for new residential development within the watershed. The character of these areas need to be maintained. Reforestation efforts should be encouraged within the watershed.

Wetlands - - While wetlands are regulated by law, there are numerous opportunities to improve degraded wetlands throughout the Knight Run watershed. Many wetlands, found in floodplain pastures, are degraded by grazing pressure. Fencing and supplemental plantings could greatly improve the functional values of these wetlands.

Steep Slopes - - Steep slopes throughout the watershed should be protected by zoning ordinances.

Areas for Development
Land that is best suited for development should have access to existing roads, public sewer and water. Residential development should occur adjacent to existing villages, or in cluster developments. Industrial and Commercial land uses should be located away from important resource areas such as aquifer recharge areas and streams.

Proposed Projects
Working in collaboration with the Chester County Conservation District and the NRCS, Ag-BMPs should be implemented on farms throughout the watershed. These BMPs could address any of the following areas:

- Barnyard Runoff Management
- Stream Fencing
- Alternative Livestock Watering Methods / Spring Development
- Forested Riparian Buffers
- Field Terracing and Contour Plowing
- No-Till and Conservation Tillage Practices
- Streambank Stabilization
- Rotational Grazing Systems
- Warm-Season Grass Pastures
- Wetland / Habitat Creation Projects
- Reforestation / Hedgerow Establishment
- Integrated Pest Management Systems
- Nutrient Management Planning

Urban and Suburban BMPs should be advocated by local zoning ordinances, the Chester County Planning Commission and articles in such publications as the Octoraro Watershed Association Newsletter. These Urban and Suburban BMPs may include:

Naturalistic Landscaping (Bay-scaping Methods)
Encourage Use of Pervious Surfaces for Drives, Parking Areas, Patios, etc.)
Treat Parking Lot and Roadway Runoff with Filter Strips, Wetlands and Bio-Swales
Regional Water Quality Facility
Wetland / Habitat Creation Projects
Streambank Stabilization
Forested Riparian Buffers
Reforestation- Street and Shade Trees
Stormwater Management BMPs - Wet Ponds and Rain Gardens

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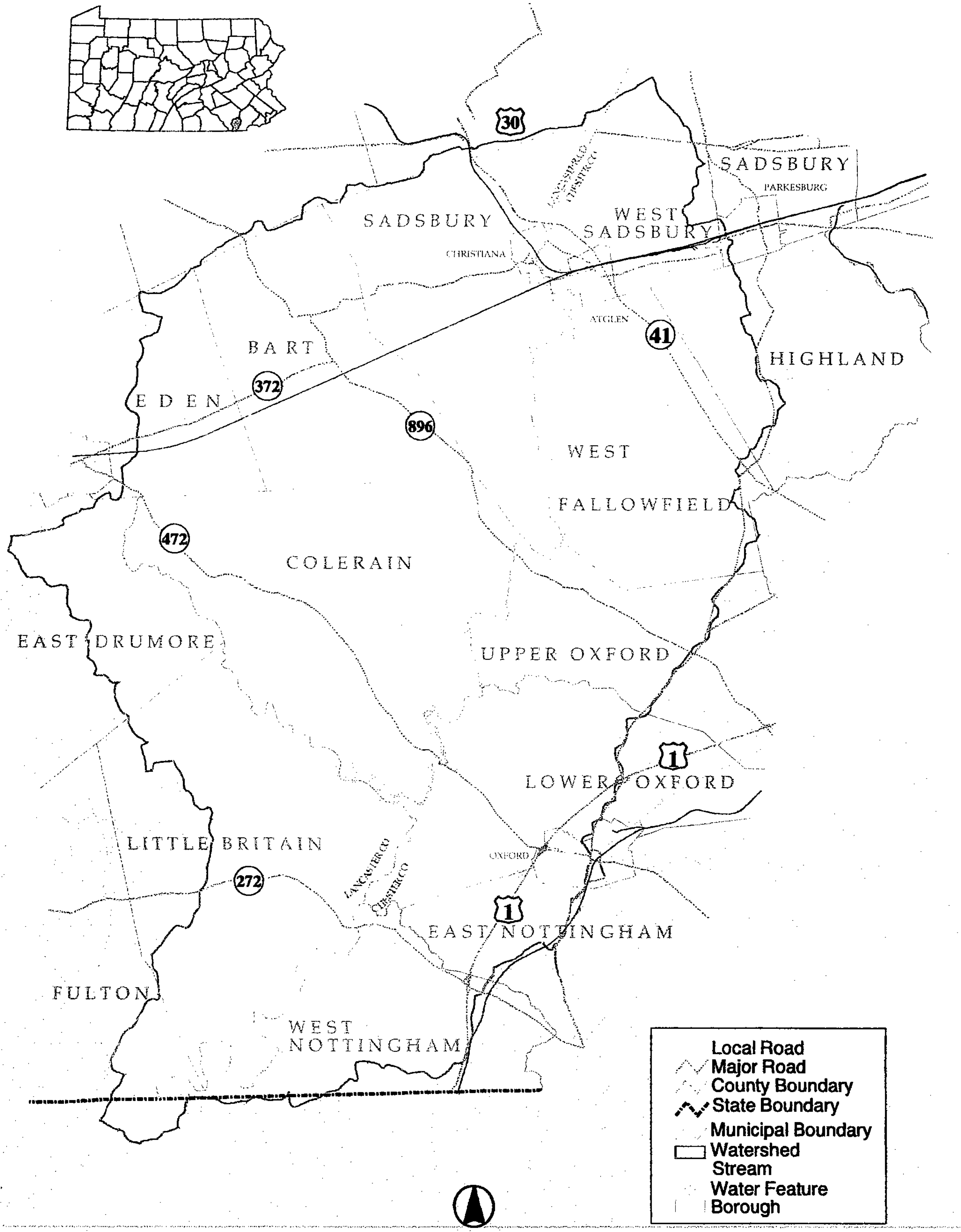
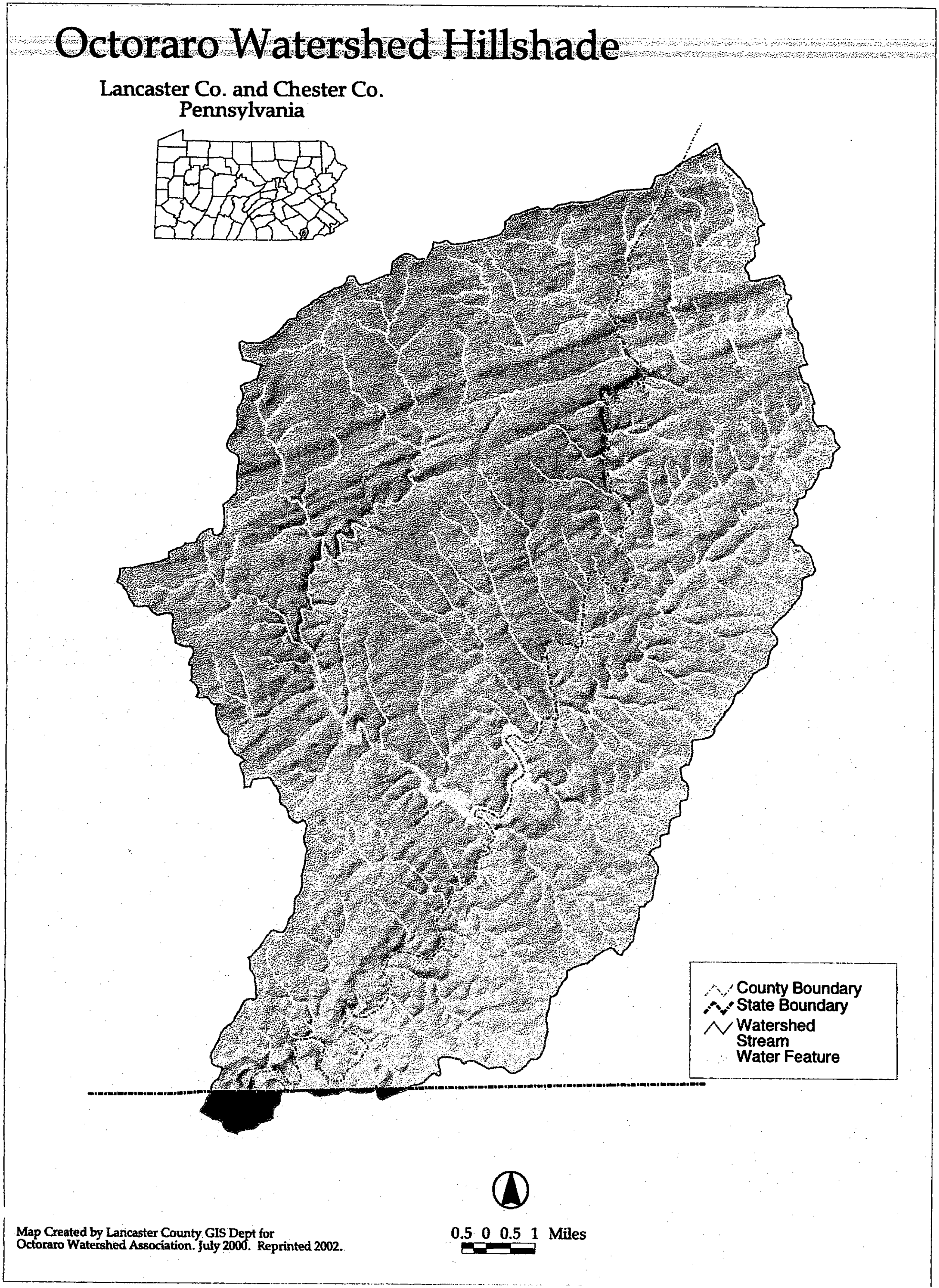
Octoraro Watershed

Lancaster Co. and Chester Co.
Pennsylvania

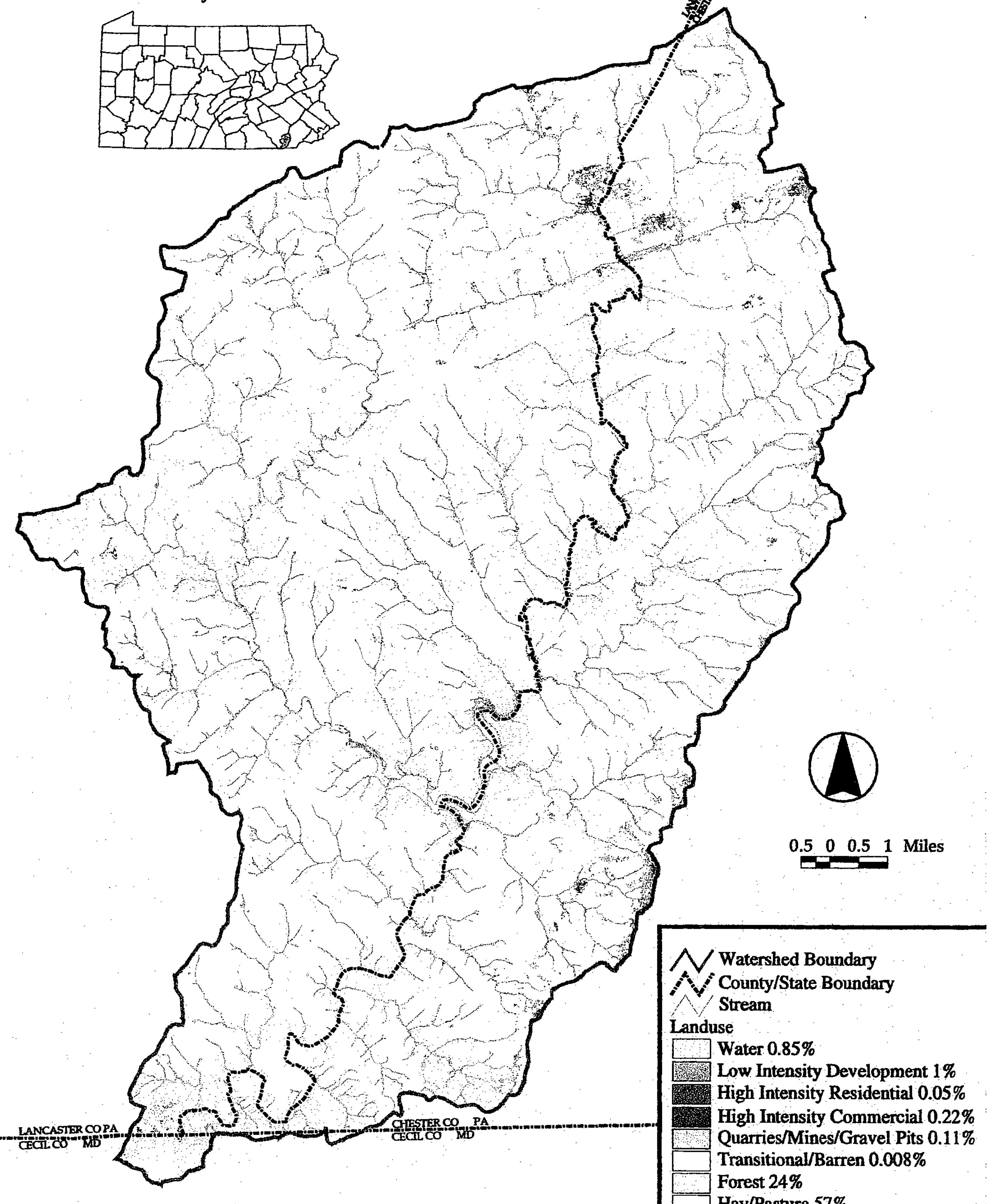


Map Created by Lancaster County GIS Dept for Octoraro Watershed Association. July 2000. Reprinted 2002.


Octoraro Watershed Hillshade
Lancaster Co. and Chester Co.
Pennsylvania
County Boundary
State Boundary
Watershed
Stream
Water Feature
0.5 0 0.5 1 Miles
Map Created by Lancaster County GIS Dept for
Octoraro Watershed Association. July 2000. Reprinted 2002.

Octoraro Watershed Land Cover

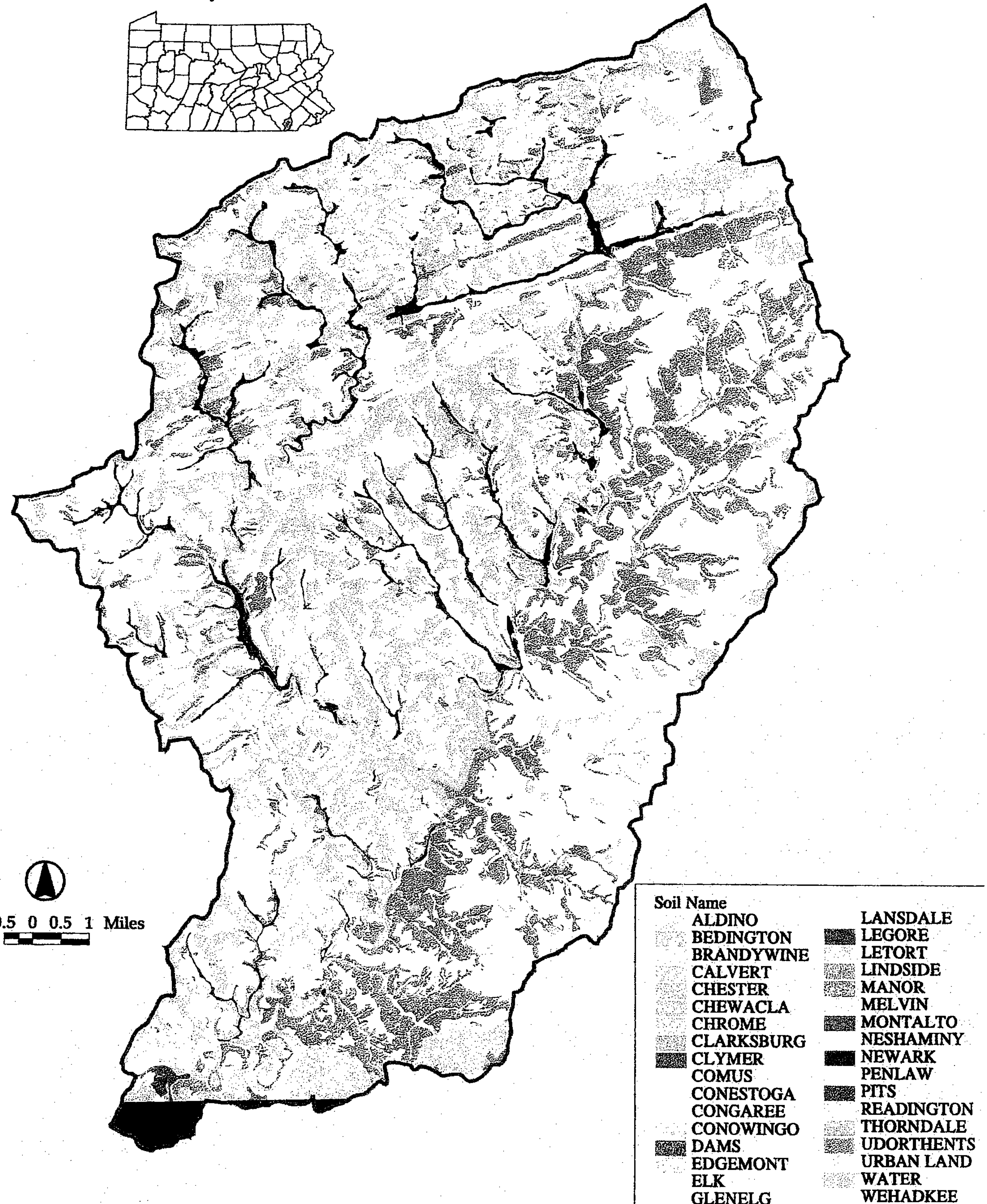
Lancaster Co. and Chester Co.
Pennsylvania



Landuse Data: EPA Region III 30m Land Cover Dataset. 1998
Map Created by Linda McCawley, Lancaster County GIS Dept for Octoraro Watershed Association. July 2000. Reprinted 2002.

Octoraro Watershed Soils

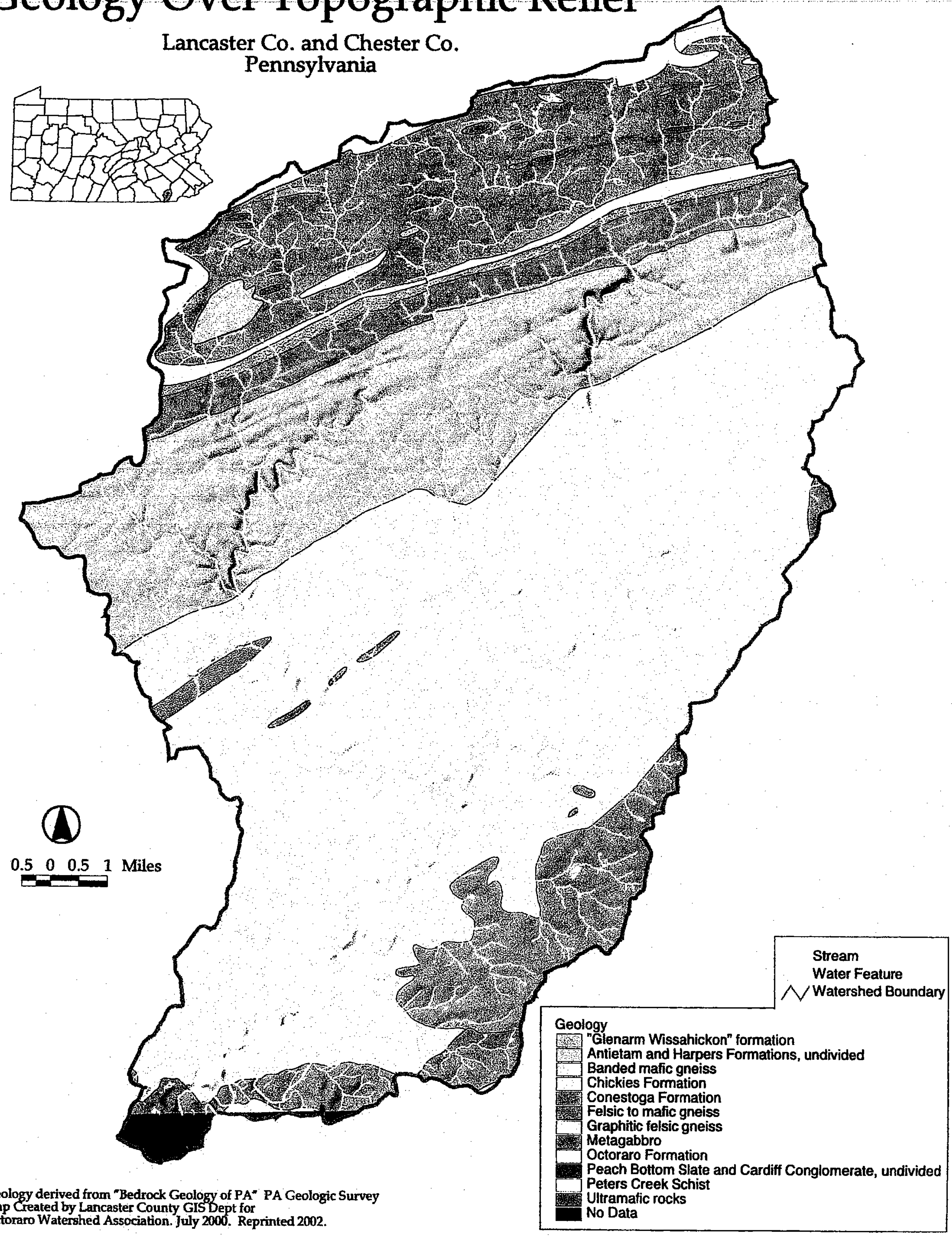
Lancaster Co. and Chester Co.
Pennsylvania



Soils Data derived from SSURGO data for Lancaster Co. and Chester Co.
Map Created by Lancaster County GIS Dept for
Octoraro Watershed Association, July 2000. Reprinted 2002.

Octoraro Watershed
Geology Over Topographic Relief

Lancaster Co. and Chester Co.
Pennsylvania



Geology derived from "Bedrock Geology of PA" PA Geologic Survey
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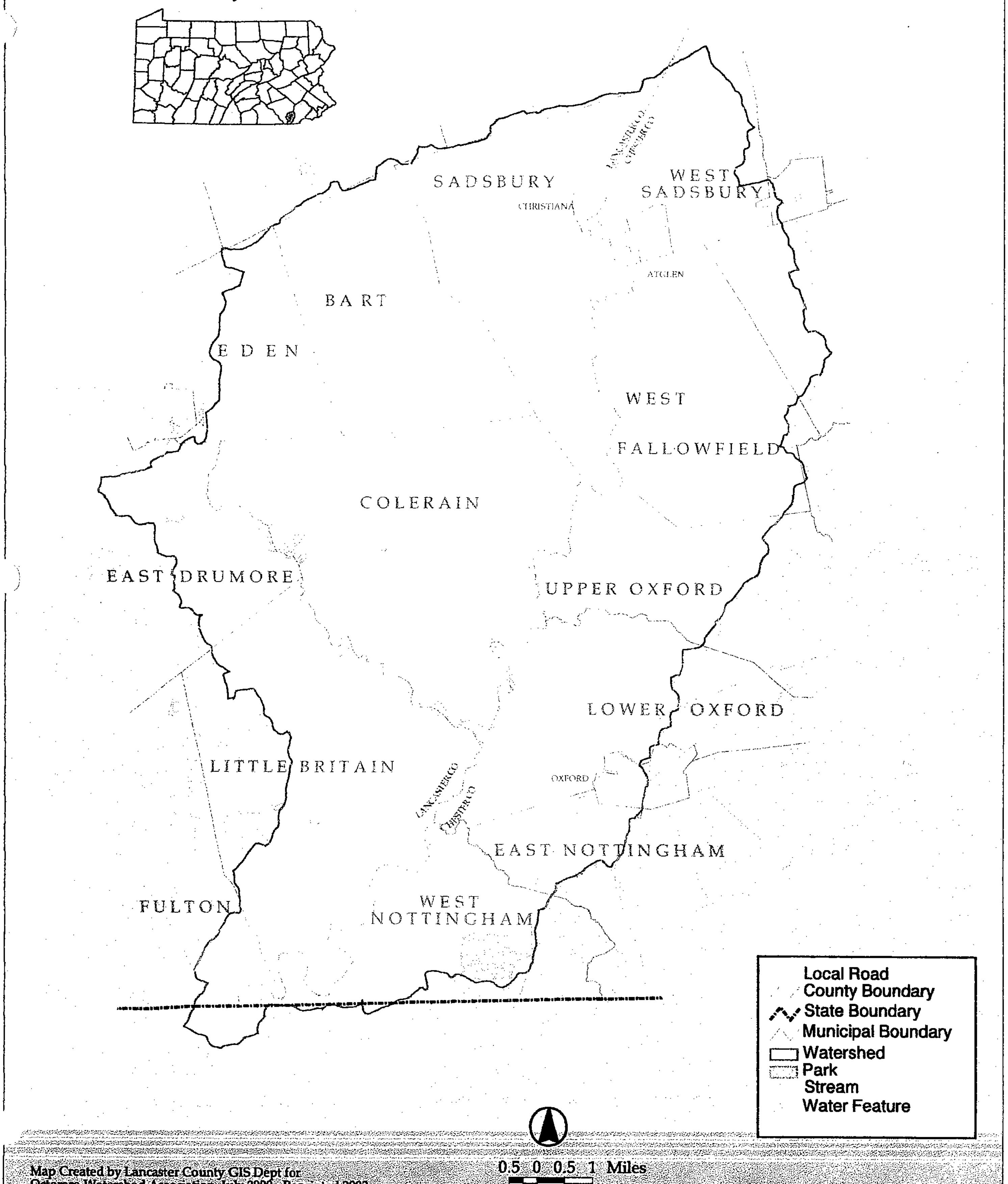
Octoraro Watershed Parks

Lancaster Co. and Chester Co.
Pennsylvania



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