Tea Creek

Coldwater Conservation Plan

A Coldwater Heritage Partnership and American Rivers funded Project

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May 2007

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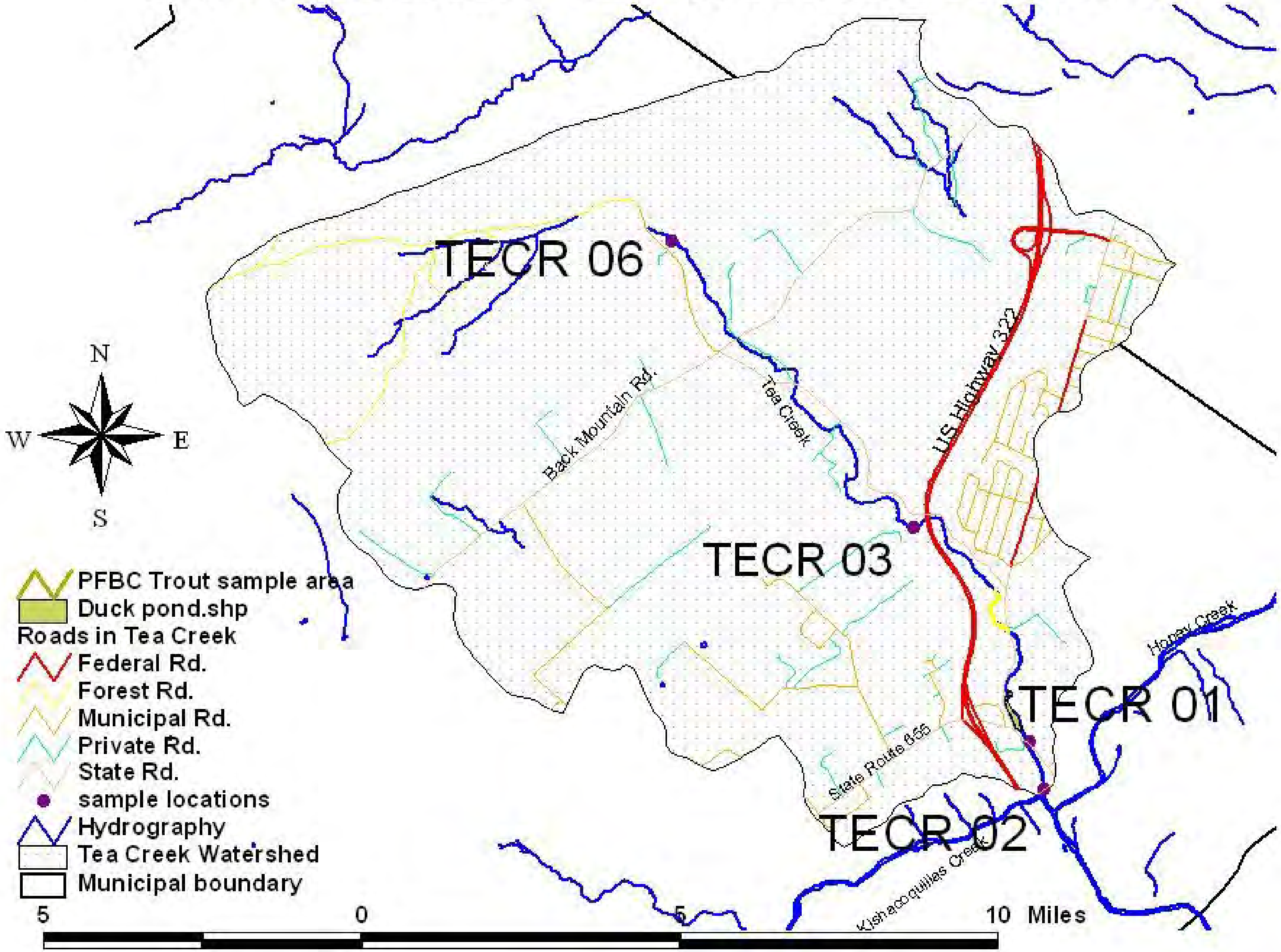


Background and Interest In Tea Creek:

In the 1870's the Reedsville Milling Company built a 14 foot high, 47 foot long dam on Tea Creek which created a 2 acre pond. The pond was locally referred to as the "duck pond" because of a large population of ducks, mostly domestic hybrids that lived there. Over the years the dam was not maintained properly and to keep its permit, was going to require a lot of costly repairs. The current owner of the dam decided to allow it to be removed and in September 2004 American Rivers and the Pennsylvania Fish and Boat Commission removed this dam.

One of Tea Creek's attributes is that it is classified High Quality Cold Water Fisheries (HQ-CWF) and a 1.1 mile section is designated Class A Wild Trout Stream because it supports a wild population of Brown Trout (*Salmo trutta).* It was unknown how the dam removal was going to impact this wild population because the dam, an obstruction preventing fish movement, was located approximately one mile from the confluence of Tea Creek and Kishacoquillas Creek. Although the vast majority of Kishacoquillas Creek is designated Cold Water Fisheries (CWF), the section adjacent to the confluence with Tea Creek is designated Trout Stocked Fisheries (TSF). The impact that stocked trout may have on wild brown trout is unclear.

Watershed Location and Description:

Tea Creek, a tributary to Kishacoquillas Creek, is located within the Kishacoquillas Valley, in Mifflin County, Pennsylvania. The Kishacoquillas Valley, bounded by Stone Mountain to the north, and Jacks Mountain to the south, makes up the whole northern portion of Mifflin County. As a tributary to Kishacoquillas creek, Tea Creek is a sub-watershed of the larger Kishacoquillas Creek watershed. Tea Creek is located in the center of Kishacoquillas Valley (Figure 1). The headwaters of Tea Creek begin in Rothrock State Forest and it joins Kishacoquillas Creek at the point where this main stream takes a 90 degree turn to flow through Mann's Narrows, a natural occurring gap in Jacks' Mountain caused by Kish Creek. Honey Creek, following from the east, joins Kishacoquillas Creek about 20 feet below the confluence with Tea Creek. The Tea Creek subwatershed is 11 square miles, or 6953 acres. Most (90%) of the Tea Creek watershed is within Brown Township with the remaining 10% in Armagh Township.

The town of Reedsville is currently the main urbanized area within this watershed. Reedsville is located at the southern most point of the watershed where Tea Creek joins Kishacoquillas Creek.

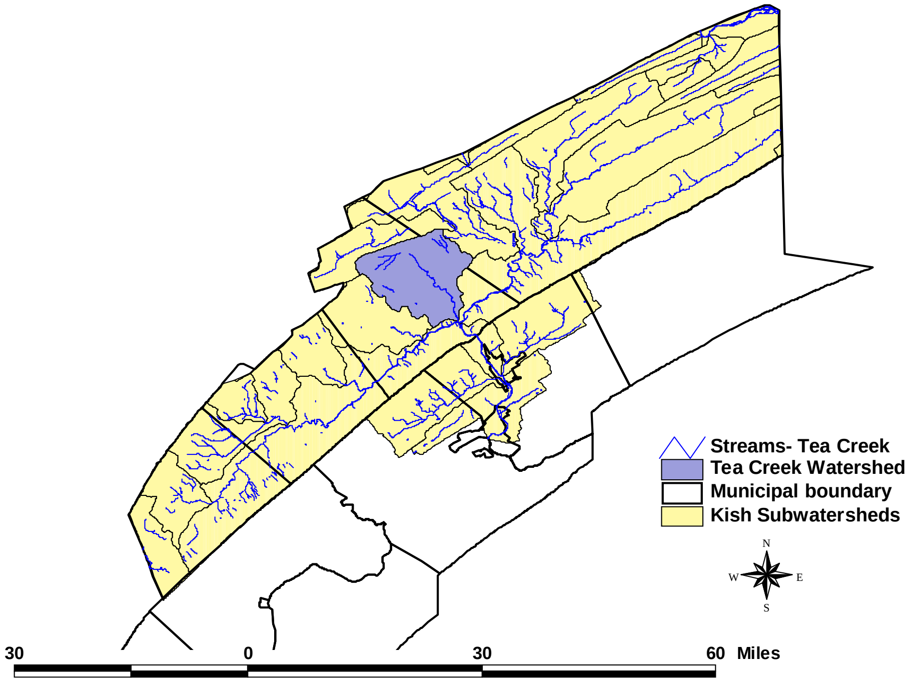


Figure 1. Tea Creek Subwatershed as viewed in the entire Kishacoquillas Creek Watershed

Topography, Geology, and Soils:

Tea Creek is situated in the "Ridge and Valley" physiographic province. Elevation in this small watershed ranges from 1555 feet to 700 feet above sea level. Kishacoquillas Valley is formed on an anticlinal (upward) fold in the sequence of Cambrian and Ordovician age limestone and dolomite formations that exceed 8,000 feet in thickness. The valleys occur in the central part of the fold, and in this physiographic setting they overturn slightly to the northwest. The ridges are primarily sandstone of the Tuscarora, Juniata and Bald Eagle Formations.

The soils in the Tea Creek watershed are productive due to the high percentage of Hagerstown soils which makes up 44% of all of the soils in the watershed. Other soils in the watershed include Brinkerton, Buchanan, Murrill and Opequon. Ease of farming is generally good but the erosion potential can be significant in this watershed with 37 percent of the acres having 0-8% slope, 34 percent of the acres having 8 -15 % slope and 29 percent of the acres in the watershed having a slope greater than 15% slope (Table 1.).

Table 1. Number of acres and percent slope in the Tea Creek Watershed

	0 to 8 % slope (acres)	8 to 15 % slope (acres)	Over 15% slope (acres)
	2607	2360	1986
% of Tea Creek Watershed	37%	34%	29%

Land Use:

The two largest land uses in the Tea Creek watershed are agriculture (44% or 3050 acres) and forest (41% or 2830 acres) (Figure 2). The Amish community farms 35% (1067.5 acres) of the agricultural land in this watershed, while the majority of the forest is part of the Rothrock State Forest. Residential housing, light industry/commercial , and vacant land make up the remainder of the land use in the watershed.

Land use in this watershed is rapidly changing. State Route 322 transects this watershed and contains a prominent exit in Milroy on the eastern edge of the Tea Creek watershed. The area surrounding this exit is zoned commercial and has been developing fairly rapidly. Additionally, this watershed has received a lot of proposals for residential subdivisions. From the years 1996 to 2003 subdivisions consumed 1394 acres (20% of the watershed).

According to Paths and Bridges to the 21st Century: Mifflin County Comprehensive Plan 2000, most of the watershed is projected to be "Rural Development" areas, or "Natural Resource" areas (Table 2). The purpose of Rural Development Areas are to help preserve the existing agricultural and natural resource production economies, and also to protect the quality of the groundwater supply, the open space and the rural character presently found in these areas. Natural Resource areas delineate those areas unsuitable for development and protect the county's environmentally sensitive resources. Currently developed areas and areas with improved infrastructure, specifically roads, public water and/or sewer, facilitate higher density development. However, portions of Reedsville and Milroy are projected as "Unzoned High Growth (Industrial & Commercial)" with "Village Centers" in the villages themselves. Portions of Reedsville and Milroy are also "Zoned High Growth Area (Residential)". These areas of high growth could potentially harm the resources of Tea Creek if the approved Act 167 Kishacoquillas Creek Stormwater Plan is not followed. Currently this plan states that post-construction stormwater runoff cannot exceed 75% of pre-construction run-off rates in area zoned for high-growth.

Table 2. Mifflin County's Future Land Use Plan Classifications

Rural Development Area	To help preserve the existing agricultural and natural resource production economies, and rural character, as well as protect the culture that is unique to the County's Plain Sect population.
Natural Resource Protection Area	To delineate those areas unsuitable for development and to protect the County's environmentally sensitive resources.
High Growth (residential) (Industrial & Commercial)	Encourage the development of this urban fringe area by designating appropriate areas for medium and high density residential development as well as commercial and industrial uses.
Village Centers	Delineates developed areas such as Allensville, Belleville, Milroy, and Reedsville. These areas have mixed residential, commercial, industrial and public uses, and generally do not have zoning. Furthermore, they have lot sizes equaling one acre or less, may have access to water or sewer, and are within ½ mile of a state highway.
Limited Growth Areas	Encourage the development of livable, planned communities that promote a variety of residential opportunities, provide public facilities, goods and services, adequate open space and recreational opportunities, and employment at a neighborhood scale.

Source: Paths and Bridges to the 21st Century: Mifflin County Comprehensive Plan 2000

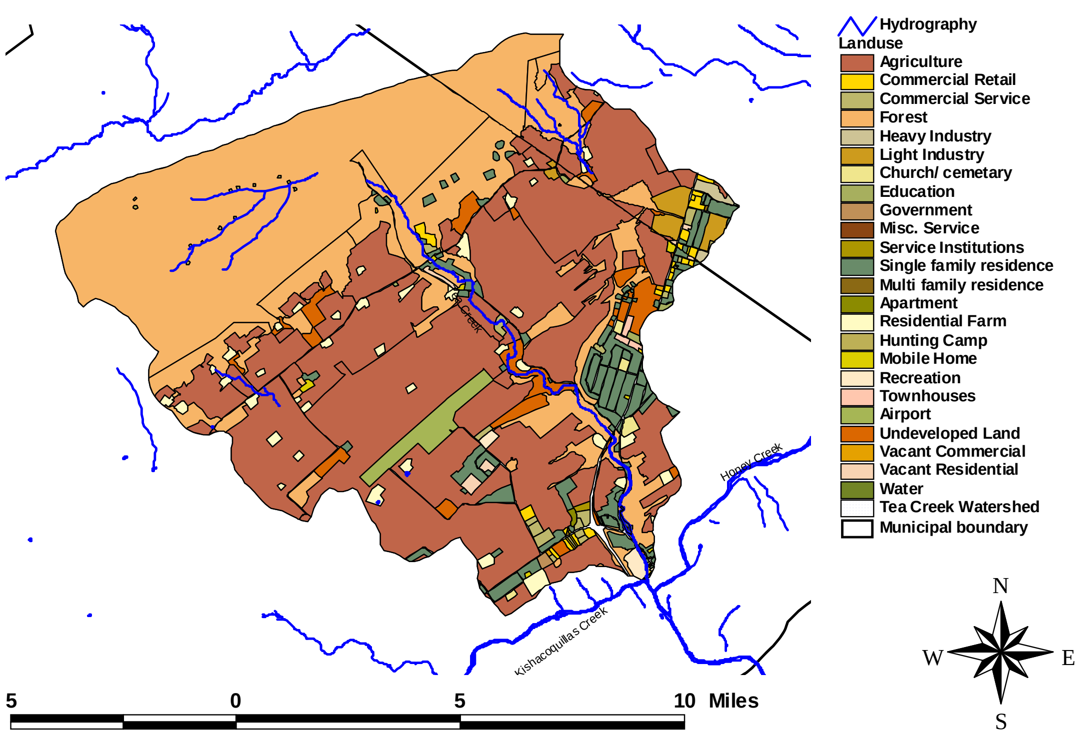


Figure 2. Landuse in the Tea Creek Watershed

Water Quality Standards:

Designated uses and the standards for water quality can be found in the Commonwealth of Pennsylvania, Pennsylvania Code, Title 25, Environmental Protection, Chapter 93, Water Quality Standards (Chapter 93). Chapter 93 outlines protected water uses, statewide water uses, and the water quality standards that protected water uses must meet. Tea Creek is classified HQ-CWF (High Quality Cold Water Fishes) (Figure 3). For standards specific to CWF refer to Tables 3 & 4. According to the PA Fish and Boat Commission (PFBC), a 1.1 mile stretch of Tea Creek from a spring located near the Rt. 322 bridge to the stream's mouth is also classified as a Class A Wild Trout Waters. This classification is given to "Streams that support a population of naturally produced trout of sufficient size and abundance to support a long-term and rewarding sport fishery." (PFBC Definition of Class A Waters). No stocking occurs on Class A Wild Trout Waters because there is sufficient natural reproduction.

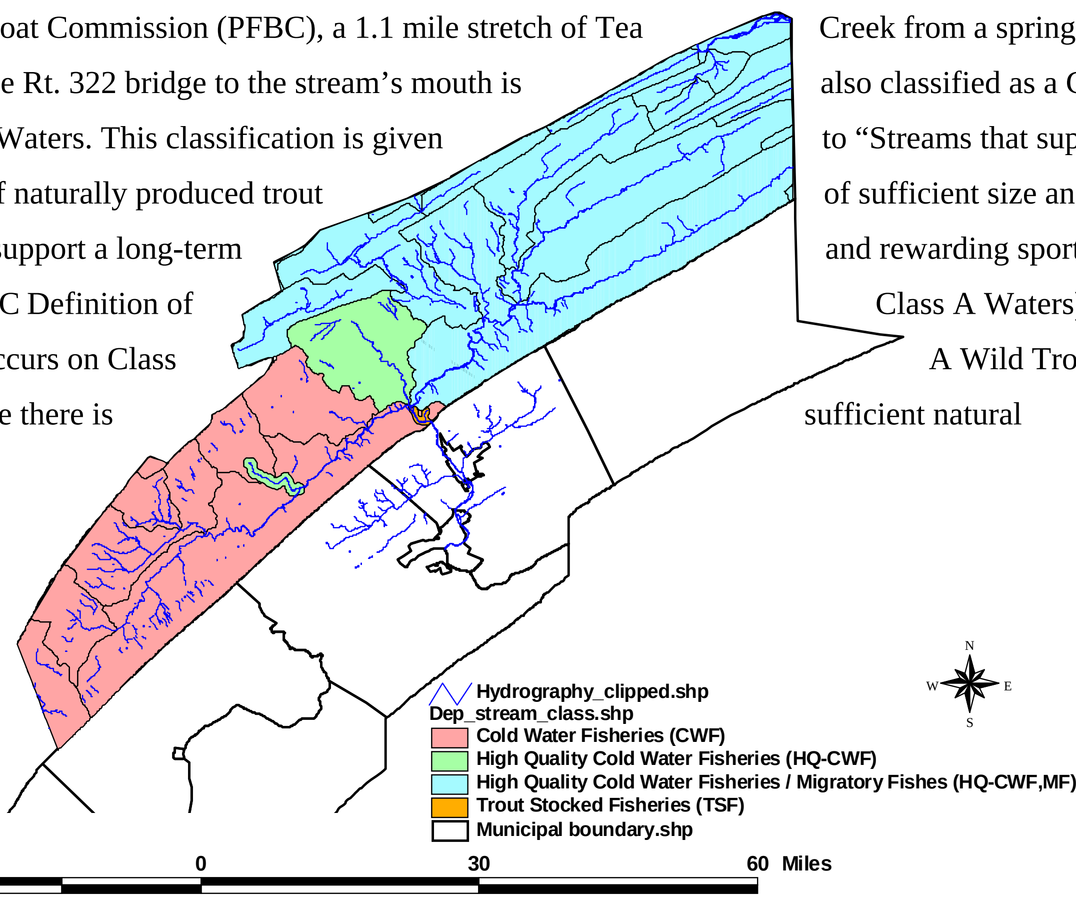


Figure 3. DEP Stream Classifications for the subwatersheds of Kishacoquillas Creek Watershed showing Tea Creek as a High Quality Cold Water Fishery.

Table 3. Temperature for an HQ-CWF stream

Critical Use Period	Temperature (^oF)
January 1-31	38
February 1-29	38
March 1-31	42
April 1-15	48
April 16-30	52
May 1-15	54
May 16-31	58
June 1-15	60
June 16-30	64
July 1-31	66
August 1-15	66
August 16-30	66
September 1-15	64
September 16-30	60
October 1-15	54
October 16-31	50
November 1-15	46
November 16-30	42
December 1-31	40

Table 4. Water Quality Standards for an HQ-CWF stream

Parameter	***Criteria***
Dissolved Oxygen (DO)	AVG 6.0 mg/L daily; minimum 5.0 mg/L daily
Iron (Fe)	30 day AVG of 1.5 mg/L as total recoverable
pH	6.0 to 9.0 inclusive
Alkalinity	Minimum 20 mg/L as $CaCO_3$ (except where natural conditions are less)
Total Dissolved Solids (TDS)	500 mg/L as a monthly AVG value; maximum 750 mg/L

(Reference: Commonwealth of PA)

Assessment of Water Quality:

In accordance with The Clean Water Act (CWA), the primary federal law that protects our nation's waters, all states must identify and report on water quality. The Pennsylvania Department of Environmental Protection (PA DEP) conducted a statewide survey of unassessed waters to determine if the waters were meeting their Chapter 93 designated uses. In this survey the PA DEP sampled macroinvertebrates throughout the state and classified streams as either attaining the designated use, or not attaining the designated use thereby being "impaired". According to PA DEP, Tea Creek was found to be "attaining".

The Pennsylvania Fish and Boat Commission have historically surveyed a 360 meter stretch of Tea Creek to determine brown trout biomass and reproduction (Appendix A). For a stream to be classified as Class A, a minimum biomass for wild brown trout is 40 kg/ha (PFBC). Tea Creek has far

exceeded this threshold every time it has been surveyed with the exception of a survey following the August 5, 1997 concrete incident in which concrete was poured into a sinkhole during construction of SR 322. This incident caused a dramatic fish kill from which Tea Creek has apparently recovered (Table 5).

Table 5. Estimated Biomass of Brown Trout in Tea Creek at a historic Pennsylvania Fish and Boat Commission sample location (912A),

Survey Month & Year	August 1985	August 1989	August 1994	August 1998	August 2000	June 2005
Kilograms/ Hectare (kg/ha)	**142.08**	**105.10**	**112.86**	**28.02**	**90.91**	**249.93**

Source: Data from the PFBC Area 7 Fish Management Field Report and personal communication

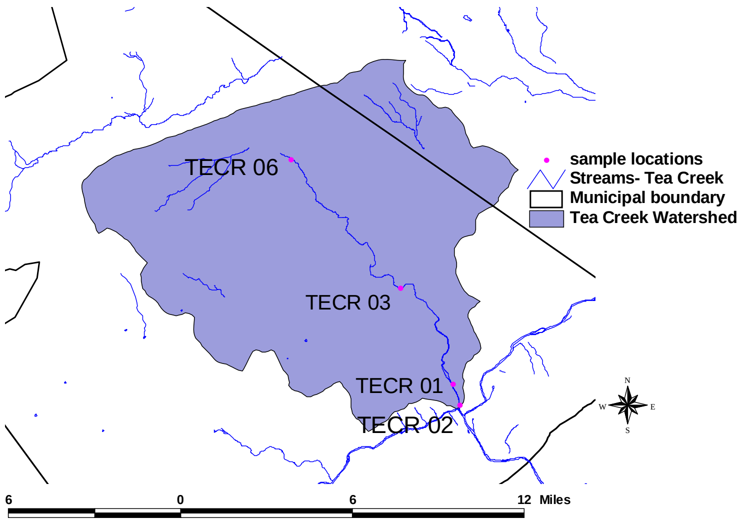
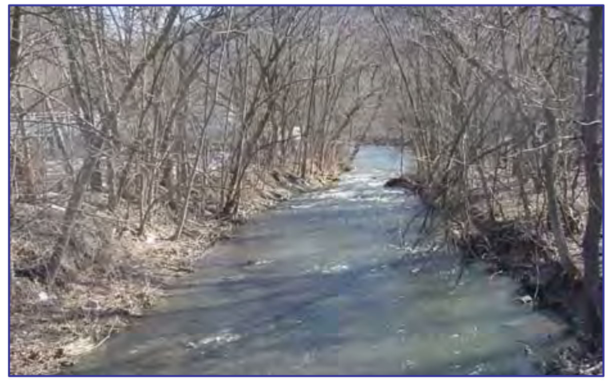


Figure 4. Sample sites in the Tea Creek watershed



TECR 02 at Confluence of Tea Creek and Kishacoquillas Creek

An in-depth assessment was conducted by the Mifflin County Conservation District from 2001-2002 for the Kishacoquillas watershed which included Tea Creek. This assessment was conducted prior to the removal of the dam on Tea Creek at the "Duck Pond" in Reedsville. The in-depth assessment included testing water chemistry, evaluating the riparian and in-stream habitat, and sampling macroinvertebrates. The assessment sampled water chemistry for 12 consecutive months. In the Tea Creek watershed only sites TECR06, TECR03 and TECR02 were sampled during the full assessment. Sample Location TECR01, immediately downstream of the dam in Reedsville, was sampled one time during our in-depth study and then was sampled again post dam removal (Figure 4). Only one location, TECR 02, was within the stretch classified as Class A Wild Trout and it was below the dam in Reedsville at the confluence with Kishacoquillas Creek. Sample location TECR03 was upstream of the spring that marks the beginning of that PFBC designation and therefore outside of the designated area.

TECR 01 between Reedsville Fire Hall and the Youth Park

Water chemistry results during this assessment indicated that temperature was a threat to the trout (Table 6). Twenty-two (55%) of the temperature readings at the three sample locations exceeded specific water quality criteria. TECR03, a spring fed site, was the warmest. Ten (83%) of the temperature readings at TECR03 exceeded specific water quality criteria. Winter temperatures at TECR03 were consistently higher than the air temperature, a common occurrence in streams fed by ground water. One (2.5%) pH reading was outside specific water quality criterion. All dissolved oxygen readings were within specific water quality criteria. Only TECR06 had alkalinity readings less than 20mg/L, however, this is the natural condition of this site which is along the ridge in Coopers Gap. Alkalinity readings at TECR02 and TECR03 were consistently greater than 140mg/L, signifying that these are true limestone sites. Eleven (83%) of the fecal coliform readings exceeded the criterion. Site TECR03 exceeded the criterion five out of six times tested. Fecal Coliform results at TECR03 were high, and were the highest in December (8050 col/100ml). Our tests on this stream never found nitrogen levels to exceed 10mg/L, a "critical use" for drinking water.

TECR06 in Coopers Gap

Stabilized crossina at TECR 03

Table 6 - Summary Water Chemistry Statistics for Tea Creek from May 2001 – April 2002

Category	Avg	Max	Min
Air Temp in F	55	81.5	28
pH	7.556	8.300	5.800
Stream Temp in F	52.5	68	34
Conductivity (mS)	291.769	541.000	26.000
Alkalinity (mg/L CaCO3)	133.205	360.000	10.000
Dissolved O2 (mg/L)	10.500	16.000	7.000
Nitrate (mg/L)	2.028	5.000	0.000
Sulfate (mg/L)	53.649	85.000	49.000
Nitrate-N (mg/L)	3.563	5.000	2.000
Total Phosphorus 0.000	---	---	---
Total Coliform (col/100m)	202.000	202.000	202.000
Fecal Coliform (col/100m)	1936.143	8050.000	1.000
Total Suspended Solids mg/L	20.000	48.000	8.000

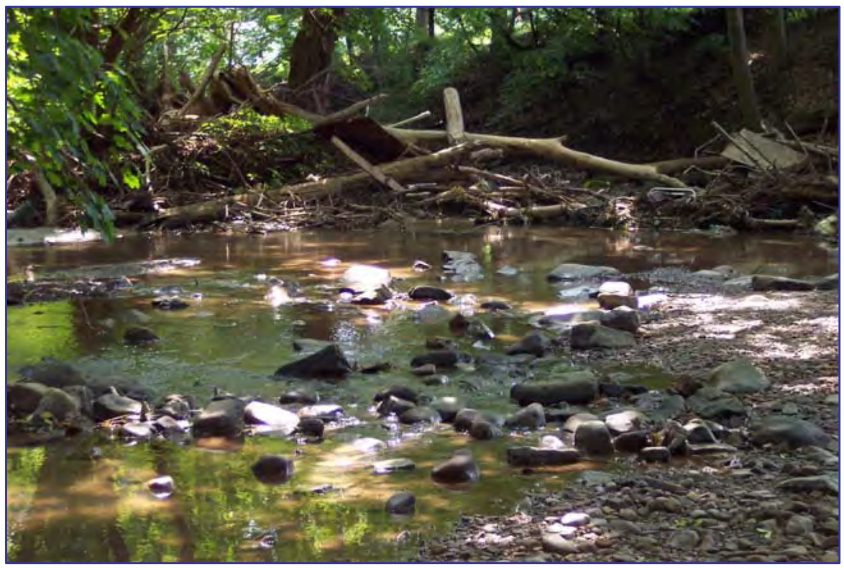
Source: Kishacoquillas Valley Watershed Assessment and Restoration Plan.

Assessment of Habitat:

The Environmental Protection Agency established a protocol for the assessment of stream habitats based upon twelve physical parameters important to the survival and reproduction of fish and macroinvertebrates in lotic (flowing-water) environments. This protocol outlines the twelve parameters and provides descriptions of what features to address a rating of poor, marginal, suboptimal, or optimal for a particular parameter. These twelve parameters and their descriptions are as follows.

Definitions for the Twelve Habitat Parameters (from Barbour et al. 1999)**:**

1. *Instream Cover (fish)*: A measure of the relative quantity and variety of natural structures in the stream, such as cobble (riffles), fallen trees, logs, and undercut banks, available as refugia for feeding, spawning, and nursery functions. A wide variety of structures provides aquatic organisms a large number of niches and increases habitat diversity. A lack of structural diversity reduces the potential for recovery following disturbance.



2. *Epifaunal Substrate*: Epifaunal substrate is essentially the amount of niche space or hard substrates (rocks, snags) available for insects, snails, fish, and other aquatic species. Numerous types of insect larvae attach themselves to rocks, logs, branches, or other submerged substrates. The greater the variety and number of available niches or attachment sites, the greater the variety of insects in the stream. Rocky-bottom areas are critical for maintaining a healthy variety of insects. Snags and submerged logs provide additional areas for macroinvertebrate colonization, increase diversity, and provide important areas for fish.

3. *Embeddedness*: Embeddedness refers to the extent that rocks (gravel, cobble, and boulders) are surrounded by, covered, or sunken into the silt, sand, or mud of the stream bottom. As rocks become embedded, fewer living spaces are available to macroinvertebrates and fish for shelter, spawning, and egg incubation. To estimate the percent of embeddedness, observe the amount of silt or finer sediments overlying and surrounding the rocks. If kicking does not dislodge the rocks or cobble, they may be greatly embedded. It may be useful to lift a few rocks and observe the extent of the dark area on their underside.

4. *Velocity/Depth Regimes*: Fast water increases the amount of dissolved oxygen in the water, keeps pools from being filled with sediment, and helps food items like leaves, twigs, and algae move more quickly through the aquatic system. Slow water provides spawning areas for fish and shelters macroinvertebrates that might be washed downstream in high stream velocities. Similarly, shallow water tends to be more easily aerated, but deeper water stays cooler longer.

The best stream habitat includes all four habitat categories of slow, deep; slow, shallow; fast, deep; and fast, shallow.

5. *Channel Alteration*: A measure of large-scale changes in the shape of the stream channel. Channel alteration includes concrete channels, artificial embankments, straightening of the natural channel, riprap, or other structures, as well as recent sediment bar development.

6. *Sediment Deposition*: This parameter measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result. Sediment bars typically form on the inside of bends, below channel constrictions, and where stream gradient decreases. Bars tend to increase in depth and length with continued watershed disturbance. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.

7. *Frequency of Riffles*: Riffles are a source of high-quality habitat and diverse fauna. An increased frequency of riffle occurrence greatly enhances the abundance and diversity of the stream community. Riffles are important because they serve as spawning and feeding areas for fish, increase the amount of dissolved oxygen, and the essential habitat required for many macroinvertebrates.

8. *Channel Flow Status*: The degree to which the channel is filled with water. The flow status will change as the channel enlarges, or as flow decreases as a result of drought or diversions for irrigation. When water does not cover much of the streambed, the amount of suitable substrate for aquatic organisms is limited.

9. *Condition of Banks*: A measurement of whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to suffer from erosion than are gently sloping banks and are therefore considered unstable. Eroded banks indicate a problem of sediment movement and deposition. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Assessments of both the upper and lower banks should be done concurrently. The upper bank is the land area from the break in the general slope of the surrounding land to the top of the bankfull channel. The lower bank is the intermittently submerged portion of the stream cross section from the top of the bankfull channel to the existing waterline.

10. *Bank Vegetative Protection*: Measures the amount of vegetative protection afforded to the stream bank. The root systems of plants growing on stream banks help hold soil in place. This

parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap.

11. *Grazing or Other Disruptive Pressure*: This is a measure of disruptive changes to the riparian zone because of grazing or human interference (e.g., mowing). In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded. Residential developments, urban centers, golf courses, and rangeland are the common causes of anthropogenic pressure on the riparian.

12. *Riparian Vegetative Zone Width*: Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. A vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input to the stream. A relatively undisturbed riparian zone supports a robust stream system.

Two individuals evaluated all twelve habitat parameters at each sample location using the modified EPA Rapid Bioassessment Index score sheet also used by PADEP biologists during the state-wide "unassessed waters" survey. Site specific Habitat Assessment Scores were calculated using the individual scores for each category (Table 7).

The habitat along Tea Creek has areas that are wonderful and areas that need to be improved. Our sample locations were not located in the middle of a farmer's active pasture because we did not get permission to be there, but instead, our sample locations tended to be in areas where the habitat was improved. Two of the three locations scored "optimal" (240-187) for the overall habitat assessment score. The third location scored "suboptimal" (186-127). Individual habitat parameters looked very good for these locations. The only individual parameter scores that were not 100% in the "optimal" range (20-16), or "suboptimal" range (15-11) were for embeddedness, sediment deposition and condition of banks which scored in the marginal range (10-6) or poor range (5-0) (Table 7).

Table 7- Habitat Scores for three sample locations on Tea Creek using 12 individual parameters

Sample Location	**TECR02**	**TECR03**	**TECR06**
Instream Cover (Fish)	18	16	20
Epifaunal Substrate	20	16	15
Embeddedness	13	13	9
Velocity/Depth Regimes	15	18	15.5
Channel Alteration	15	19	20
Sediment Deposition	9	15	7.5
Score Side one	90	97	87
Frequency of Riffles	19	19	20
Channel Flow Status	17	19	20
Condition of Banks	5	17	20
Bank Vegetative Protection	18	20	20
Grazing or Other Disruptive	18	19	20
Riparian Vegetative width	11	18	20
Totals (side 2)	88	112	120
Totals (side 1)	90	97	87
Station Score	**178**	**209**	**207**
NOTES			
Alpha code	S	O	O
Optimal - 240-187		X	X
Suboptimal - 186-127	X		
Marginal - 126-68			
Poor - 67-0			

Source: Kishacoquillas Valley Watershed Assessment and Restoration Plan.

We sampled one site on an unnamed tributary to Tea Creek. It scored "suboptimal" for the overall habitat assessment score. The only scores that were not in the "optimal" or "suboptimal" range were for embeddedness and sediment deposition, both of which scored in the "marginal" range.

A look at the section of Tea Creek designated "Class A Wild Trout" also shows an area of exceptional habitat. This 1.1 mile stretch has overhanging branches, vegetation right up to the edge of the stream, and a buffer that was un-measured, but has thick mature vegetation. The stream has a few very deep pools, shallow riffles, and the sediment is transported through this section because of the stream flow.

This series of photos shows more than just impressive fish. It shows impressive habitat as well. Notice how deep the water is in places and the healthy fast-flowing riffles. Notice how much vegetation is along the banks in all of the pictures. Also notice also the branches and other natural items in the stream.

Permission was not obtained to survey the habitat in areas where the stream flowed through pasture. Due to the topography, it is easy to visually assess the condition of banks, bank vegetative protection, grazing or other disruptive pressure, and the riparian vegetative width. The vast majority of Tea Creek would not score in the Optimal or subobtimal range based on these observations. It is also doubtful that fishing would be as productive in these areas as it is in the section of "Class A Wild Trout" waters.

Assessment of Macroinvertebrates:

In October, 2001, as part of the Kishacoquillas Creek Watershed Assessment, benthic macroinvertebrates were sampled at all three sites on Tea Creek using in-depth sampling techniques that identified macroinvertebrates to the genus level to evaluate the relative pollution tolerance of biological communities. This in-depth procedure was repeated at each of the sample locations on Tea Creek in October 2004, May 2005 and October 2005.

We followed the procedure outlined in Hilsenhoff's article, "An Improved Biotic Index of Organic Stream Pollution" (Hilsenhoff 1987) and in the EPA's Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Bentic Macroinvertebrates, and Fish *Second Edition*.

Benthic macroinvertebrates were collected from riffle habitats using a 1 meter x 1 meter kick seine held downstream with the lower edge in the bottom substrate of a riffle. An individual upstream disturbed the stream bottom by vigorously shuffling their feet as they walked toward the seine. An area only as wide as the seine was disturbed. Bottom disturbance occurred for approximately one minute. Rocks in the sample area were rubbed by hand to collect additional organisms potentially not found in the bottom substrate. This procedure (referred to as a "kick") was done twice at each sample location in two separate riffles.

The net was rinsed into a bucket and then poured through a No. 30 standard testing sieve. All large debris items were washed off into the bucket and then discarded prior to straining the sample. Samples were then bagged and preserved with enough 90% ethanol to produce a concentration of about 70% ethanol when combined with the water in the debris. The samples were taken back to the office where the liquid mixture was replaced with 70% ethanol. A flat pan marked with a 5 cm numbered grid was used to select macroinvertebrates for identification. Four grid squares were randomly chosen for sampling and all arthropods in those four squares were selected. The target sample was 300 macroinvertebrates. If four squares did not yield this number, additional grids were chosen at random until the sample target was met. All chosen grids were sampled completely. If greater than 360 were "picked", then the sample was sub-sampled to achieve the target. Sorted macroinvertebrates were identified to genus using a dissecting scope and toxemic keys and were recorded on a data form.

Biotic Indexes

Using biotic indexes provides for the evaluation of sites by assigning numerical scores to specific organisms at a particular taxonomic level and then calculating the percentage or actual number of each organism in the sample. Biotic Indexes also take into account different aspects of the macroinvertebrate community such as richness, tolerance and composition and therefore are able to asses the picture more completely. Organisms that have specific requirements in terms of physical and chemical conditions are considered “indicator species”. Their presence or absence, change in numbers, morphology, physiology or behavior can indicate that the physical and/or chemical conditions are outside their preferred limits. The presence of numerous families of highly tolerant organisms usually indicates poor water quality.

There are many different biotic indexes. We used Taxa Richness, Hilsenhoff Biotic Index, Modified EPT Index, Shannon Diversity, % Modified Mayflies, % Modified EPT, and % Intolerant taxa to develop a specific score used in the evaluation of TECR01, TECR02, and TECR06. At site TECR03, a “true limestone” site, % Tolerant taxa was added and EPT was not “modified”. The following Indexes were not used to develop a score at this site: % Modified Mayflies, and % EPT. Ideally, sampling occurs on a “reference reach” of a similar type stream that is undisturbed. In the case of this study, TECR06 served as our “reference reach” for our “freestone” and “limestone influenced” sites as it is free of most disturbances. We did not have a reference site for TECR03, but rather this data will serve as a baseline for future sampling.

Taxa Richness - the number of distinct taxa. It represents the diversity within a sample. An increased diversity suggests that habitat and food sources are adequate to support survival and propagation of many different species.

Hilsenhoff Biotic Index - Uses tolerance values ranging from 1-10, increasing as water quality decreases, to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution

$$HBI = \Sigma \, {}^{xi*ti}/n$$

Where *xi* is the number of individuals within a taxon, *ti* the tolerance value of that taxon, and *n* the total number of organisms in the sample

Modified EPT Index - Number of taxa in the insect orders Ephemeroptera (mayflies)- excluding the families Baetidea, Caenidae, Siphlonuridae; Plecoptera (Stoneflies); and Trichoptera (caddisflies)- excluding the families Hydropsychidae and Polycentropodidae.

Shannon Diversity - A species diversity index that takes into account the numbers of organisms of each species present in a given sample.

$$D.I. = -\Sigma \, {}^{ni}/N \log_e {}^{ni}/N$$

Where D.I. is the species diversity index, *ni* the number of organisms of species *i*, and *N* the total number of organisms in the sample

% Modified Mayflies - Percent of mayfly nymphs in a sample, excluding the families Baetidae, Caenidae, Siphlonuridae.

% Modified EPT - Percent of the composite of mayfly, stonefly and caddisfly larvae in a sample excluding the families mentioned above in the Modified EPT Index.

% Intolerant taxa - Percent of macroinvertebrate families in a sample considered to be tolerant of various types of pollution.

% Tolerant taxa - Percent of macroinvertebrate families in a sample considered to be intolerant of various types of pollution (we used this only for the "true limestone" sample).

Bentic macroinvertebrates sampling completed in October 2001 demonstrated impairment (Table 8). TECR03 was not evaluated properly during this initial study, but instead was evaluated as a "limestone influenced" stream, hence the score of "poor". As seen in Table 15, the data from October 2001 was reevaluated and TECR03 scored "good". TECR02, a site located on Tea Creek just before it enters Kish Creek, scored "Very Poor". This site was approximately ¼ mile downstream from the duck ponds on Tea Creek in Reedsville.

Table 8. Biotic Index Site Scores of sample locations on Tea Creek in October 2001

Site Name	Taxa Richness	Modified EPT Index (HBI <5)	Modified Hilsenhoff Index	% Intolerant Taxa (HBI <4)	Shannon Diversity	% Modified Mayflies (HBI <5)	% Modified EPT (HBI <5)	Total Score	Classification
TECR06	6	6	4	2	6	0	2	**26**	**Good**
TECR03	4	2	4	0	4	0	0	**14**	**Poor**
TECR02	2	2	2	0	2	0	0	**8**	**Very Poor**

Source: Kishacoquillas Valley Watershed Assessment and Restoration Plan.

In our original Kish Watershed assessment the following conclusion was drawn,

> "All of the sample locations that scored "Very Poor" have been negatively influenced by a continuous concentration of waste from ducks, fish, and cows. Sample location TECR02 is located below the duck ponds in Reedsville, sample location ALSP03 is located below a fish hatchery, sample locations SORU01 and LKCR06 are both located below a concentration of farms that pasture their cows along the stream, don't have conservation plans, manure storage structures, roof gutters, concrete barnyards, or other conservation practices that help filter excessive nutrients and prevent erosion. High concentrations of organic nutrients negatively affect water quality and aquatic life. Any area of concentrated, untreated waste will have the same effect. The effects of the duck ponds may have also contributed to the score of "Fair" at site KICR25." *(Kishacoquillas Valley Watershed Assessment and Restoration Plan)*

The following tables used only data collected from October 2004- October 2005. Table 9 shows the number of species, percentage of species, or result of the equation, meeting the criteria each of the metrics described above. This same table calculates the 5th and 95th percentiles, which are used in Table 10 to develop the scoring criteria used to calculate a total score and the classification for the site as shown in Table 11.

Table 9. Results of the metrics used to calculate the Biotic Index Score (IBI) for each sample location and the calculations for the 95th and 5th Percentile for samples taken on Tea Creek from October 2004, May 2005 and October 2005

	Taxa Richness	Modified EPT Index (HBI <5)	Hilsenhoff Index	% Intolerant Taxa (HBI <4)	Shannon Diversity	% Modified Mayflies (HBI <5)	% Modified EPT (HBI <5)
TECR01 10/2004	12	4	5.13	9.8	2.53	8.2	9.8
TECR01 5/2005	16	7	5.49	7.7	2.21	9.3	10.9
TECR01 10/2005	17	7	5.2	6.7	2.77	2.5	5.3
TECR02 10/2001	11	4	5.53	1.9	1.76	2.5	3.1
TECR02 10/2004	16	7	4.61	26.0	2.87	25.3	26.3
TECR02 5/2005	15	8	5.54	11.7	2.62	9.9	14.5
TECR02 10/2005	17	8	5.11	5.6	2.75	3.8	5.6
TECR06 10/2001	23	13	4.38	26.4	3.01	8.1	25.4
TECR06 10/2004	27	14	3.78	41.8	3.44	4.9	33.2
TECR06 5/2005	23	11	3.55	48.1	3.62	21.3	37.5
TECR06 10/2005	30	17	3.54	38.7	3.50	4.4	37.8
5th Percentile			3.54				
Median	17.0	8.0	5.11	11.7	2.77	8.1	14.5
95th Percentile	28.5	15.5		45.0	3.56	23.3	37.7

Table 10. Scoring Criteria for the Biotic Index

Metric	Percentile	5th or 95th	Scoring Criteria			
			6	4	2	0
Taxa Richness	95th	28	>21	21-15	14-8	<8
Modified EPT Index (HBI <5)	95th	15	>11	11-8	7-4	<4
*** Modified Hilsenhoff Index**	5th	3.54	<4.66	4.67-5.77	5.78-6.89	>6.90
% Intolerant Taxa (HBI <4)	95th	45	>33.75	33.75-22.5	22.4-11.25	<11.25
Shannon Diversity	95th	3.56	>2.70	2.69 - 1.80	1.79 - 0.90	<0.89
% Modified Mayflies (HBI <5)	95th	23.3	>17.49	17.48 - 11.66	11.65 - 5.83	<5.82
% Modified EPT (HBI <5)	95th	38	>28.8	28.7- 19.2	19.1 - 9.6	<9.5

* 8.0 was used for top range of HBI

Classification	Very Good	Good	Fair	Poor	Very Poor
Total Score	**>34**	**34-26**	**25-18**	**17-9**	**<9**

Table 11. Biotic Index Scores from all four sample locations on Tea Creek from 2004-2005. Samples in gray were taken in May, samples in white were taken in October.

	Taxa Richness	Modified EPT Index (HBI <5)	Modified Hilsenhoff Index	% Intolerant Taxa (HBI <4)	Shannon Diversity	% Modified Mayflies (HBI <5)	% Modified EPT (HBI <5)	Total Score	Classification
TECR01 10/2004	2	2	4	0	4	2	2	16	**Poor**
TECR01 5/2005	4	2	4	0	4	2	2	18	**Fair**
TECR01 10/2005	4	2	4	0	6	0	0	16	**Poor**
TECR02 10/2004	4	2	6	4	6	6	4	32	**Good**
TECR02 5/2005	4	4	4	2	4	2	2	22	**Good**
TECR02 10/2005	4	4	4	0	6	0	0	18	**Fair**
TECR06 10/2004	6	6	6	6	6	0	6	36	**Very Good**
TECR06 5/2005	6	4	6	6	6	6	6	40	**Very Good**
TECR06 10/2005	6	6	6	6	6	0	6	36	**Very Good**

Interestingly enough, TECR02 did show improvement from “very poor” in October 2001 (Table 8) to a score of “Good” in October 2004 and May 2005 (Table 11). This site has not stabilized yet as it was back to “Fair” in October 2005. On September 17, 2004 Hurricane Ivan flooded the region (Figure 5 and Figure 6.). Large and widescale events such as hurricanes redistribute organisms. When newly deposited organisms meet with favorable habitat conditions they populate the area. If organisms meet with unfavorable habitat conditions they do not establish new populations. One explanation for a classification of “good” at TECR02 in October 2004 following the September flooding may be that macroinvertebrates had been redistributed to this downstream most site at the confluence of Kishacoquillas Creek and Tea Creek and were detected during the sampling one month after the event. A review of Table 11 shows that many of these macroinvertebrates were “intolerant species” and many of them were tolerant mayflies, but by October 2005, these newly deposited macroinvertebrates were no longer detected at this site. As mentioned above, this would indicate that the physical and/or chemical conditions were outside their preferred limits. Despite the “fair” and “poor” macroinvertebrate scores, the fish sampling showed dramatic improvement.


Figure 5. Pavilion in Mifflin County Youth Park, Reedsville, PA following the September 2004 flood (left) and during a dry summer (right).


Figure 6. Recreation Park, Lewistown, PA located along Kishacoquillas Creek following the September 2004 flood (left) and during a dry summer (right)

This dramatic improvement in fish biomass, like the fluctuating macroinvertebrate communities, may not be the final result. The removal of the dam has opened up new areas for the trout as well and additional monitoring may prove that this population has not stabilized yet. It did demonstrate that additional habitat is available for the trout, and they are utilizing it en mass at the moment- certainly a good sign.

One explanation of the discrepancy between the macroinvertebrate sampling and the fish biomass sampling may be the fact that the 360 meter fish sampling area is in the best section of Tea Creek. This sampling area is well buffered with mature vegetation, no pressure from livestock or nearby houses or roads. The area has all of the habitat components, is well shaded, and really is an example of what all of Tea Creek should look like (see photographs in the habitat section of this stretch of stream). None of the sample locations for macroinvertebrates were located within this ideal stretch of Tea Creek. Two of our three sample areas (TECR03 & TECR01) directly experience the pressures of agriculture or urbanization and TECR02 reflects the total effects of the watershed. Should these areas improve, the existing fish community will be able to take advantage of the improvements. It is also apparent that macroinvertebrates will also be able to respond to favorable changes in water chemistry and habitat improvements as there are favorable macroinvertebrates within the watershed that would be able to repopulate the new favorable locations.

Large storm events such as Hurricanes are not the only means macroinvertebrates have for recolonizing areas, but it is a fast and effective way. As macroinvertebrates go through the life cycles many emerge from the water and take flight. Tea Creek is in such close proximity to Honey Creek and Kishacoquillas Creek that it is certain that macroinvertebrates in the last stages of life looking for places to lay eggs will end up in Tea Creek if there is favorable habitat.

"True Limestone" streams

Tea Creek is a unique stream in many ways. The headwaters begin in Rothrock State Forest along Sand Hole Ridge. As the name of the ridge implies, the geological base is sandstone. In the classification of macroinvertebrates, this portion of the stream is a "freestone" habitat type. As Tea Creek travels into the limestone valley, true limestone springs come up and a portion of the stream is classified as "true limestone" and favors fewer species of macroinvertebrates than are found at "freestone locations". As the stream travels away from the springs towards Kishacoquillas Creek it is classified as "limestone influenced" thus making sampling along this one stream the equivalent of sampling in three separate streams.

A Spring House on Tea Creek. The landowner reports that this spring stays at a constant flow year round.

Because the valley is limestone, it would seem that all of the sample locations in the valley would be "true limestone" locations, but according to studies done by PA DEP on limestone streams, the criteria for "true limestone" classification is actually very specific. The two most important characteristics in the classification of "true limestone" are temperature and alkalinity. Groundwater temperatures are approximately 50 to 55 degrees Fahrenheit (F) and streams originating from large alkaline springs will maintain temperatures near 50 degrees F year-round. Alkalinity should be greater than 140 mg/l through out the year as well. Because the criteria is based on consistency year round, streams need to be examined carefully to determine if they are “true limestone” or “limestone influenced”.

One reason for this splitting in the classification is that most macroinvertebrates require temperature fluctuations to complete their life cycle so in areas where the temperatures do not fluctuate, those macroinvertebrates will not be found. This greatly reduces the diversity found at “true limestone” sites, but they should not be penalized for this unique feature. The process of using biological indexes weighs the various differences between “freestone” streams and “limestone influenced” streams so they can be compared to one another easily. Table 12 demonstrates how using the same criteria used for the limestone influenced and the freestone sites would classify TECR03 as “Poor”. Instead, “true limestone” streams should be evaluated using a different set of criteria.

Table 12. Biotic Index Scores for TECR03 using the scoring methods appropriate for “limestone influenced and Freestone streams” but not appropriate for “true limestone” streams

	Taxa Richness	Modified EPT Index (HBI <5)	Modified Hilsenhoff Index	% Intolerant Taxa (HBI <4)	Shannon Diversity	% Modified Mayflies (HBI <5)	% Modified EPT (HBI <5)	Total Score	Classification
TECR03 10/2004	2	0	4	0	4	0	0	10	**Poor**
TECR03 5/2005	2	0	4	0	6	0	0	12	**Poor**
TECR03 10/2005	4	0	6	0	4	0	0	14	**Poor**

A slightly different set of Indexes is used to evaluate “true limestone” streams. These indexes can be found in Table 13 along with the number of species, percentage of species, or result of the equation, meeting the criteria each of the metrics described above. This same table calculates the 5th and 95th percentiles, which are used in Table 14 to develop the scoring criteria used to calculate a total score for the site as shown in Table 15. Using the appropriate set of criteria, TECR03 actually is not as “poor” as it may seem, but is really doing “good” (Table 15).

Table 13. Biotic Indexes Scores for TECR03 – a "True" limestone Stream.

	Taxa Richness	EPT Index	Hilsenhoff Index	% Intolerant Taxa (HBI <4)	% Tolerant Taxa (HBI>6)	Shannon Diversity
TECR03 10/2001	17	6	4.52	1.6	24.4	2.20
TECR03 10/2004	11	4	5.23	2.5	62.0	2.47
TECR03 5/2005	14	5	5.20	4.0	63.1	2.86
TECR03 10/2005	17	6	4.55	3.0	20.9	2.60
5th Percentile			4.52		21.43	
Median	15.5	5.5	4.9	2.8	43.2	2.5
95th Percentile	17.0	6.0		3.9		2.8

Table 14. Scoring Criteria for the Biotic Index for TECR03

Metric	Percentile	5th or 95th	Scoring Criteria			
			6	4	2	0
Taxa Richness	95th	17	17-13	12 - 9	8 - 5	<4
EPT Index	95th	6	>6	5 - 4	3 - 2	<1
*** Modified Hilsenhoff Index**	5th	4.52	<5.39	5.40 - 6.27	6.28 - 7.15	>7.16
% Intolerant Taxa (HBI <4)	95th	3.9	>2.97	2.96- 1.99	1.98 - 1.01	<1
% Tolerant Taxa (HBI>6)	5th	21.43	< 41.07	41.08-60.62	60.63-80.36	>80.37
Shannon Diversity	95th	2.8	>3.54	3.53 - 1.42	1.41 - .71	<.7

* 8.0 was used for top range of HBI

Classification	Very Good	Good	Fair	Poor	Very Poor
Total Score	**>36**	**35 - 27**	**26 - 18**	**17 - 9**	**<8**

Table 15. Classification of TECR03 using the correct Biotic Indexes for a "true limestone" stream.

	Taxa Richness	EPT Index	Hilsenhoff Index	% Intolerant Taxa (HBI <4)	% Tolerant Taxa (HBI>6)	Shannon Diversity	Total Score	Classification
TECR03 10/2001	6	6	6	2	6	4	30	**Good**
TECR03 10/2004	4	4	6	4	2	4	24	**Fair**
TECR03 5/2005	6	4	6	6	2	4	28	**Good**
TECR03 10/2005	6	6	6	6	6	4	34	**Good**

In May 2002 aquatic biologists from PA DEP sampled Tea Creek as part of the sampling efforts to develop specific criteria for "true" limestone streams and resulted in *An Index of Biological Integrity (IBI) for "True" Limestone Streams*. The same sub-sampling procedure was used by both PA DEP and the Mifflin County Conservation District. This PA DEP study was used during the preparation of this report to determine which criteria to use for "True" limestone streams. Because the same methods were used, it was easy to evaluate the data gathered during this study, to the data gathered during the PA DEP study.

The 5th and 9th percentile were calculated for each of the biotic indexes chosen (Table 14), but instead of dividing into quartiles, the percentile value was scored proportionally from 0 to 100 (Table 16).

For Biotitic indices that ***decrease*** with greater impairment, such as Taxa Richness, EPT Index, % Intolerant Taxa (HBI <4) and Shannon Diversity, the following formula is used:

$$\text{Score} = (X) / (X_{95} - X_{min}) \times 100$$

Where:

X = index value
X_{95} = 95th percentile value
X_{min} = minimum possible value, usually 0

For Biotic indices that ***increase*** with greater impairment, such as the Hilsenhoff index and % Tolerant Taxa (HBI >6), the 5th percentile is used along with the following formula:

$$\text{Score} = (X_{max} - X) / (X_{max} - X_5) \times 100$$

Where:

X = index value
X_5 = 5th percentile value
X_{max} = maximum possible value, 100% for percentage metrics, 10 for HBI*

Table 16. Example of formula use and Index of Biological Integrity Score generated for TECR03 10/2001

Biotic Index	Raw Index score	95th or 5th percentile	Standardization Formula	Standardized Score
Taxa Richness	17	17	Score = (17/17) x 100	100
EPT Index	6	6	Score = (6/6) x 100	100
Modified Hilsenhoff Index*	4.52	4.52	Score = (8-4.52) / (8-4.52) x 100	100
% Intolerant Taxa (HBI <4)	1.6	3.9	Score = (1.6/3.9) x 100	41
% Tolerant Taxa (HBI>6)	24.4	21.43	Score = (100- 24.4) / (100- 21.43) x 100	96
Shannon Diversity	2.2	2.8	Score = (2.20/2.8) x 100	79
IBI Score				**86**

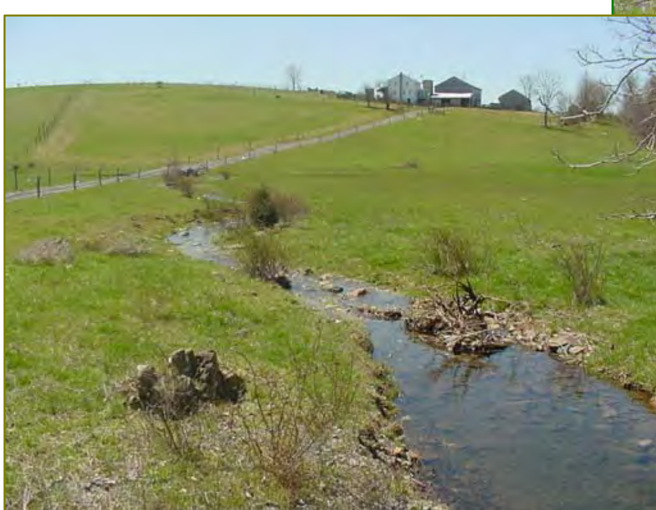
*8.0 was used for top range of HBI

Table 17. Index of Biological Integrity Scores generated for each sample location and compared to the sample taken by PA DEP in 2002

	IBI Score
TECR03 **10/2001**	86
TECR03 **10/2004**	68
TECR03 **5/2005**	83
TECR03 **10/2005**	95
DEP Tea Creek 5/2002	84

October 2004 showed the biggest variance (Table 15. and Table 17). Again, Hurricane Ivan had just affected the area one month prior to this sample period. It is unclear why this site went from "good" to "fair", but it appears to have recovered.

Good baseline data has been collected for this stream. As efforts to preserve this unique aquatic community continues, additional monitoring can be used to determine the effects of these efforts.



What Became of the Duck Pond?

The dam was constructed of concrete that forced the water to flow to the center where a water wheel was located to generate power for the Reedsville Milling Company. When this form of power was no longer needed, the water wheel was removed and the opening in which it had been located was replaced by wooden boards. The dam remained in this condition until removal in August 2003.

Photo by Mark Embeck- courtesy of PA DEP and located in the report: Aquatic Biological Investigation Reedsville Milling Company Dam Draw-down Tea Creek (Appendix B).

A draw-down permit was obtained by the Reedsville Milling Company from the Pennsylvania Fish & Boat Commission to begin removing the boards and lower the level of the Duck Pond prior to the full removal of the dam. In a report issued by PA DEP (Appendix B) the draw-down resulted in a "catastrophic" release of sediment.

Photo by Mark Embeck - courtesy of PA DEP and located in the report: Aquatic Biological Investigation Reedsville Milling Company Dam Draw-down Tea Creek (Appendix B).

Following such a release of sediment, PA DEP Water Pollution Biologists conducted macroinvertebrate sampling and found, "The macroinvertebrate community downstream of the dam was depauperate." Only four *Gammarus* (Scuds) were found at the sample area. The conclusion of the PA DEP report was that "the Release of sediment from the draw down of the Reedsville Milling Company Dam had a catastrophic effect on the stream habitat and organisms living below the dam."

The influence of Hurricane Ivan in 2004 on this vulnerable site may have sped the sediment transport up by years. The excessive flushing effect of such a storm removed the deposited sediment from the draw-down and removed all of the sediment still on the banks that had not been stabilized. Luckily this storm did not occur in September 2003 or more damage than good would have resulted. As it was, efforts had already gotten underway to restore the site. Grass was growing on the banks and a few structures had been installed.

Once the dam had been removed, restoration efforts got underway. Under the guidance of the Pennsylvania Fish & Boat Commission, Gleim Environmental Group installed a rock vane, and the Penns Creek chapter of Trout Unlimited installed several multiple log vanes, a rock cross vane and a modified mud sill. These structures help stabilize the stream by channeling the direction of stream flow towards the center of the stream and reduce erosion by taking the pressure off of the stream banks and also provide in-stream fish habitat. The Penns Creek Trout Unlimited Chapter also planted the area with native vegetation. As this vegetation matures, it will shade the stream, keeping it cool, and it will also provide important food and structural components for macroinvertebrates and trout.

Recent macroinvertebrate sampling has demonstrated a rebound with the results even showing a slightly favorable response.

Looking upstream. Tea Creek following restoration efforts. A portion of the concrete dam is still intact and visible on the left hand side of the picture.

Looking downstream. Tea Creek during the restoration efforts. If you look carefully, you can see a portion of the concrete dam on the right next on the building.

The edges of the former 2 acre pond can still clearly be seen. The edge of mature trees was the edge of the pond, locally referred to as the "duck pond".

Other Habitat Improvement Projects on Tea Creek

As mitigation for work on State Route 322, Pennsylvania Department of Transportation relocated a portion of Tea Creek and created a riparian area on Roger Park's farm. This section of the stream is a perfect example of how farmland and natural stream habitat can co-exist. Although Tea Creek runs in the middle of the pasture, there is a livestock crossing to allow the animals both sides of the stream to graze. The picture below shows that the pastures have not been over utilized, and the pasture grasses also serve as a filter and an additional buffer before soil and nutrients reach the stream.

The Pennsylvania Fish & Boat Commission and students and teachers from Indian Valley High School continued the work on the Park's farm to increase the length of stream that was protected with vegetated buffers and to improve the fish habitat within that reach of stream. The students, staff, and Fish Commission personnel installed fish habitat and worked hard to improve the conditions in the stream itself for trout to thrive.

Park's farm showing lightly used pastures and vegetated stream buffers

Problem Identification:

Sedimentation and Nutrient Loading

The results of our habitat and in stream work demonstrated that sedimentation is an issue in this watershed. Our study determined that there are three main causes for this accelerated sedimentation; 1. agricultural practices such as fall plowing, no use of cover crops to protect the soil, in a few cases no use of contour strips, and pasturing animals with full access to the streams, 2. Logging practices that did not fully protect the streams and 3. urban runoff.

Few of the farms in this watershed follow an approved Conservation Plan outlining practices that protect soil and water. In the majority of the cases it is because the farmer is not aware that the methods of farming they practice have such a negative impact on soil and water quality, and because they are farming in the traditional way, assistance is not sought nor readily accepted.

The acceptance of a few different practices would benefit this watershed by preventing or slowing down soil erosion and stream sedimentation. Fencing the livestock out of the stream and planting shrubs, grasses and trees in this riparian area would go a long way to slowing overland sediment and nutrients from reaching the stream. This planted vegetation would also utilize much of the nutrient load. Fencing protects stream banks from sloughing into the streams as animals walk too close to the edge, or enter the streams. Farming on the contour and planting various crops such as corn alternating with hay also prevents

excessive soil loss and helps to keep the soil in the fields and not in the streams.

Along with contour strip cropping, the best way to protect the soil and prevent excessive sedimentation in the streams is to plant a covercrop following harvest in the fall. Covercrops keep the

soil in place and are one of the best practices to reduce erosion. If cover crops were planted and farmers no longer plowed their fields in the fall and winter, this would go a long way to protecting Tea Creek.

Agriculture is not the only source of sediment to Tea Creek. Logging practices that took place in Rothrock State Forest are still evident by the amount of sediment we observed at TECR06. This sample location

was in the State Forest and we were amazed at the level of sedimentation. This excessive soil loss comes from the dirt roads in the Forest, and also by past logging practices that did not have adequate control measures for the silt. Sediment and erosion control practices must be in place during logging and a Sediment and Erosion Control Plan must have been written for the site, but these standards are not always followed and damage does occur. Similar plans must be

written and followed during housing construction.

Earth disturbance activities are regulated under PA DEP's Chapter 102 Erosion and Sediment Control Regulations, which requires anyone proposing or conducting earth disturbance to develop, implement and maintain Erosion and Sediment Control Best Management Practices (BMP's) to minimize erosion and the potential for pollution to water resources. Still, construction disturbs a lot of soil and is a potential source of sediment to the streams, but more importantly, development permanently changes the hydrography of an area and must be accounted for during the subdivision process.

Land Use

The rate of development in this watershed is significant. While the county planning office has designated portions of this watershed as "Unzoned High Growth (Industrial & Commercial)", "Zoned High Growth Area (Residential)", and "Rural Development" areas, there are no Ag Security areas within this watershed. Without Ag Security areas, farms are not eligible for the Pennsylvania Agland Preservation program. According to Paths and Bridges to the 21st Century: Mifflin County Comprehensive Plan 2000 the stated purpose of "Rural Development" areas is to preserve farmland, yet subdivisions outside of the areas designated "High Growth" are not turned down by the subdivision review committee, and farmers do not currently have the option of preserving their farms and receiving financial compensation for such a decision. Figure 7. demonstrates that not all of the subdivsions are within the areas that have been identified by the County Comprehensive Plan to be High Growth, but many in fact are within areas projected to be "Rural Development".

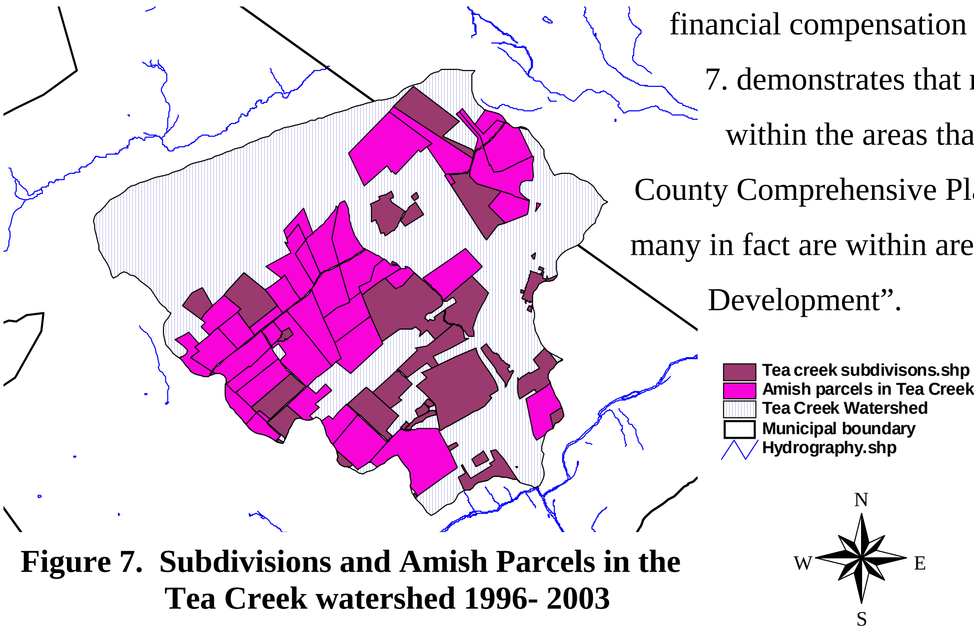


Figure 7. Subdivisions and Amish Parcels in the Tea Creek watershed 1996- 2003

Stream research has shown there is a direct correlation between the amount of impervious cover (cover that prevents water from infiltrating into the ground) in a watershed and water quality in the watershed (See Appendix C). Streams first start to degrade when 10% of the watershed is impacted by impervious surfaces and then a second threshold appears between 25-30% impervious (Figure 8) (*The Stormwater Manager's Resource Center*). Practices such as ponds, wetlands, filtering systems, infiltration and open channels help mitigate the loss of open space that previously filtrated the water naturally.

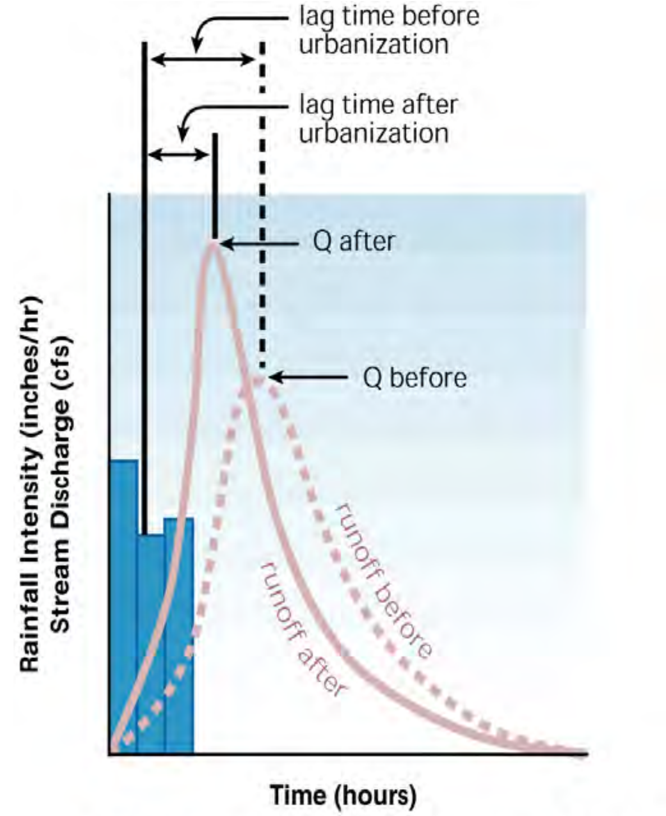
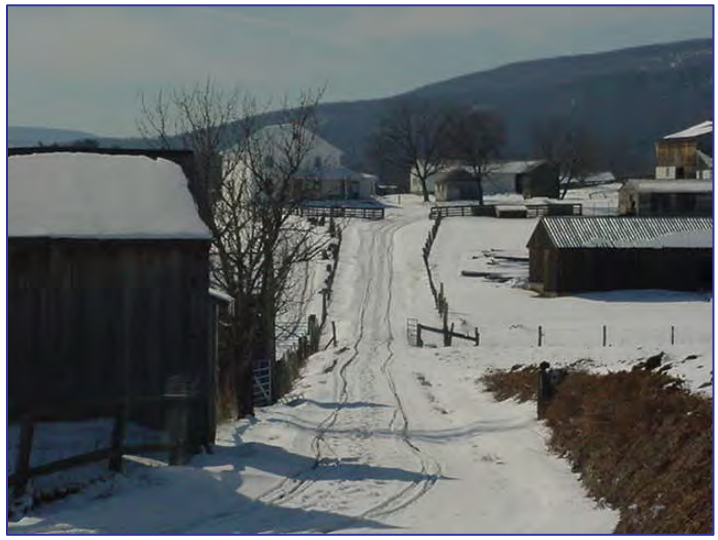


Figure 8. Comparisons of Hydrographs before and after urbanization

Mifflin County formally adopted an Act 167 Stormwater Management Plan for all of the Kish Creek Watershed, including Tea Creek. The goal of Act 167 is to foster the development of a consistent set of local rules and regulations that will protect and improve the capacity of natural stream channels throughout the state *(Kishacoquillas Creek Watershed:Act 167 Storm Water Management Study Final Report)* This Act acknowledges the fact that stormwater runoff threatens the health of a watershed by reducing groundwater recharge, increasing flood flows and velocities, increasing erosion and sedimentation and overtaxing the carrying capacity of existing streams, potentially causing damage to landowners downstream. It attempts to mitigate stormwater effects by requiring developers to account for an increase in impervious surfaces through accepted stormwater practices. This ordinance regulates the stormwater runoff based on pre-development and post-development condition. In some areas, post-development run-off or release rates are required to be 75% of pre-development release rates.

Tea Creek behind Reedsville in the Youth Park

If these requirements are met by all of the proposed subdivisions, it will go a long way to maintaining natural levels in the stream and reduce the flash flooding effects of runoff during storm events. Stormwater practices that improve water quality are important as well. *Home*A*Syst: An Environmental Risk-Assessment Guide for the Home* claims that on average homeowners apply ten times more chemical fertilizers and pesticides per acre than farmers use on farmland. In a watershed that is impaired by nutrients (and sediment), this figure is alarming given the amount of residential growth.



Unpaved Roads

The majority of the unpaved roads found in this watershed occur in Rothrock State Forest. There are a tremendous number of dirt farm lanes in this watershed, and although they are not public roads, they receive heavy use and are often traveled by horse and buggy.

These travel areas develop ruts and are subject to loosening due to the types of travel that are occurring on them. They are not maintained to the high standards that the Center for Dirt and Gravel Roads at Penn State University suggest and in many cases, are not maintained in a regular and consistent manner at all. Many of these unpaved roads are continual sources of sediment to Tea Creek.

Sewage

The Brown Township Municipal Authority serves the Reedsville, Lumber City, Church Hill, and Taylor Park areas of the township as well as providing treatment for sewage from Armagh Township. Currently this facility uses approximately 50 to 60 percent of its 600,000 gallon per day capacity depending on the time of year (Mifflin County Planning Commission).

Areas that are zoned for growth will receive sewage hookups. Farms and other subdivision outside of the “Zoned High Growth Area (Residential)” do not currently have public sewer, nor are they projected to receive public sewer. Some existing residents have outdated or failing septic systems, or untreated outhouses.

Leaching is a serious concern to the watershed and to human health and should be addressed by the Townships (Appendix D). On-lot systems depend upon a very sensitive system of physical, chemical, and biological processes in the soil and groundwater to renovate and dispose of sewage. The Pennsylvania Sewage Facilities Act (Act 537) was written to addresses all of the wastewater needs including on-lot systems and help Townships evaluate alternatives to address those needs. Each Township was encouraged to write and formally adopt an Act 537 Plan. This adopted plan would then be the official sewage facilities plan for the Township and future Township planning would take into consideration the findings of the Plan. According to a map located on PA DEP's website, Brown Township has not updated their Act 537 plan within the last 20 years.

Nitrate Nitrogen loading of groundwater is more critical than loading of surface water because nitrate nitrogen in surface water is available for use by aquatic plants and dilution and mixing occur in surface waters. While an abundance of aquatic plants is not desirable for many reasons, they do at least utilize nitrate nitrogen. Nitrate nitrogen does not break down in groundwater and flushing of groundwater is a slow process. Untreated effluent can cause nitrate nitrogen concentrations to exceed 10ppm, the established upper limit for drinking water. Nitrites change hemoglobin to methomoglobin thus reducing the amount of oxygen in the blood stream. In infants and those with weak immune systems, severer oxygen deprivation can occur and even cause death. A goal of every watershed plan should be to reduce nitrate nitrogen, therefore, addressing on-lot septic systems is an important step.

Stakeholders

Educating everyone so that there is a level of understanding: understanding how clean water directly affects each of us, understanding the importance of clean surface and ground water, understanding the big picture, understanding how each of us fit into both the problems and the solutions, and understanding how this affects our future ability to utilize our resources- is the most difficult task of all.

Community Residents:

Tea Creek is a developing watershed. While farmers are the major stake holders currently, this balance will shift in the near future to residents and business owners. An informed community is more likely to make decisions that will least likely impact the health of the stream and our ground water. To help develop a more informed public, activities such as:

1. Community Water Awareness Day- Having an organized "event" with different stations/booths. Taking a page out of the education standards and using many of the educational activities that kids participate in, but doing if for adults and kids alike in the community might be a great way to help bring kids, parents, and the community together, not to mention help educate. This type of event would be fun because kids would already know much of the information and how to do the activities and they could help teach their parents.
2. Continuing Education of Adults is important and various ways to reach out to adults must be attempted. All levels of outreach are needed
    a. Newspaper articles
    b. TV shows/ commercials
    c. Websites
    d. Family activities
    e. Public Displays
    f. Brochures for Realtors to give to homebuyers

Look carefully at the center of this picture. You will see a fence line, boulders, and shrubs. This is Tea Creek in the middle of a pasture. This farmer is to be commended for fencing the cows out of the stream and for allowing vegetation to grow, however, this is not enough to protect Tea Creek from the sediment and nutrients coming down the hill and across this pasture. More education is needed so that the people who are willing to do the right thing, will truly benefit the stream, and the health of the community.

Farmers

Currently farmers are having the largest impact on Tea Creek. The majority of the stream is in the middle of pasture land. Just two farms have allowed the stream to be fenced and are protecting the stream from livestock. Priorities for farmers include:

1. Outreach to discuss the importance of stream buffers and fencing livestock away from streams
2. Outreach to discuss other Farming Best Management Practices that would help reduce soil erosion and nutrients from getting into the streams and groundwater. A Conservation Plan can be obtained at the local NRCS (Natural Resource Conservation Service) office or by contacting the Conservation District. Recommended BMP's include, but are not limited to:

a. Streambank fencing
b. Pasture water systems to provide fresh drinking water for livestock
c. No-till method of planting crops
d. Planting cover crops in the winter to reduce soil exposure to the elements
e. Farming on the contour
f. Crop rotation for better soil health
g. Managing storm water around barnyards
h. Having a nutrient management plan

3. Providing educational opportunities that are short in duration and close in location. These opportunities include:
    a. Demonstrating the Enviroscape Non-point source model.
    b. Field days to functional buffers to discuss the importance
    c. Organized fishing days for farmers

Municipal Officials

Brown Township and Armagh Township have both adopted the Stormwater Management Act of Pennsylvania (Act 167) plan that was written for the Kishacoquillas Creek watershed, including Tea Creek. This is a positive step toward improving the stormwater generated by development. Enforcement will be an important step to ensure that the benefits are actualized. Municipal Officials should also be aware of the County Comprehensive Plan. Proposed development that is outside of the areas designated within the Comprehensive Plan should be scrutinized more carefully. One tool that was developed during the Comprehensive Plan process was an ArcView GIS layer mapping the future land use layers in the county. Every Municipality, not just Brown Township and Armagh Township, should be using ArcView and this layer in particular to guide the growth in the Township. This action alone would go a long way to a planned community that can support its growth. Development proposed outside of areas targeted for public water and public sewer should also be scrutinized carefully.

Brown Township should update their Act 537 plan as an additional means to provide a healthy place to live. Pubic health depends on clean drinking water. Drinking water wells depend on clean, healthy ground water, which depends on healthy land practices. An updated Act 537 plan would continue to insure appropriate land use practices in the area of sewage disposal.

Prioritization:

The top recommended priorities for this watershed and potential leaders

1. Develop 102/ Act 38 compliant conservation plans for all agricultural acres in the watershed. *Mifflin County Conservation District (MCCD)*

2. Facilitate the creation of an Ag Security Area in Brown Township so that farms can qualify for the County Agland Preservation program. *Farmers in Brown Township, Mifflin County Agland Preservation Board, Farm Bureau, Brown Township, PSU Cooperative Extension, MCCD*

   a. This could potentially slowdown the rapid development of prime farmland and help reserve the rural character of the Tea Creek Watershed.

3. Promote sediment and nutrient saving agronomic practices such as *NRCS, MCCD, FSA*
   a. No-till farming
   b. Planting cover crops
4. Fence livestock out of Tea Creek *farmers, MCCD, NRCS, TU*
   a. Provide alternative water source for livestock
5. Plant vegetation along the streambanks *TU, farmers, MCCD, NRCS*
6. Continue habitat improvement projects like the one recently completed at the "old duck pond" *PFBC, TU,*
7. Update Brown Township Act 537 Plan *Brown Township*
8. Enforce compliance with Act 537 standards for existing and proposed on-lot septic systems *Brown Twp.*
9. Review proposed subdivsions carefully *Mifflin County Planning Office, Brown Township*
   a. to determine that they are compliance with the Act 167 Stormwater plan
   b. To determine that they are in compliance with the Act 537 plan.
   c. To determine that they are within the proposed identified county use areas
      i. If they are not, determine if the groundwater levels are healthy for drinking water wells.
10. Implement environmentally sensitive maintenance practices including Bureau of Forestry roads in Rothrock State Forest and private lanes and farm access roads, to reduce sediment impacts. *BoF*

11. Develop a Community Water Awareness day at the Mifflin County Youth Fair grounds to provide needed community education and outreach *TU, MCCD, PFBC*

12. Develop a sense of "local community ownership" of Tea Creek. *TU, MCCD, PFBC*
    a. Organizations such as Trout Unlimited would be a valuable asset to this accomplishing this goal.
    b. Programs such as Pennsylvania Fish and Boat Commission's "Adopt-A-Stream" could also facilitate this effort.

13. Continue to monitor the trout and macroinvertebrate populations. *PADEP*

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Appendix A::

Fisheries Management Field Report: Tea Creek

Tea Creek

RECOVERY OF A WILD BROWN TROUT STREAM

Tea Creek, a tributary to Kishacoquillas Creek at Reedsville in Mifflin County, maintained a Pennsylvania Fish and Boat Commission (PFBC) Class A wild brown trout fishery managed under conventional statewide angling regulations for fifteen years after cessation of hatchery stocking. Commission biologists reported wild brown trout biomass at 142.08 kg/ha for the August 1985 survey, 105.10 kg/ha for the August 1989 survey and 112.86 kg/ha for the August 1994 survey. PFBC minimum for wild brown trout management is 40 kg/ha.

Concrete poured into a sinkhole during construction on US 322 on August 5, 1997 caused a drastic chemical alteration resulting in a severe fish kill that largely destroyed the wild brown trout fishery of Tea Creek. Commission biologists reported that the August 1998 survey with a single pass conservative estimate of 28.02 kg/ha documented the early recovery of the fishery through reproduction by the few surviving adult brown trout and the high survival of fingerlings from that 1998 cohort.

Tea Creek was examined on August 7-8, 2000 to assess the condition of the wild brown trout fishery three years after the August 1997 pollution. The historical 360 meter electrofishing station was sampled using a Direct Current (DC) electrofishing generator.

Brown trout were captured in lengths from 2 to 13 in. Tea Creek has continued its recovery from the pollution of August 1997 to Class A status with an August 2000 biomass of 90.91 kg/ha well exceeding the Pennsylvania Fish and Boat Commission's minimum criteria of 40 kg/ha for wild brown trout management. Biomass for brown trout less than 150 mm total length was 15.87 kg/ha, exceeding the 0.1 kg/ha minimum.

Total brown trout biomass in August 2000 was 90.91 kg/ha, significantly higher than the conservative single pass estimate derived in August 1998 of 28.02 kg/ha only one year after the 1997 pollution and approaching pre-pollution biomass ranges of 105.10 kg/ha in 1989 to 142.08 kg/ha in 1985.

The 2000 survey of this small stream estimated 996 brown trout per mile in size groups from 2 to 13 in. with 24% of that total estimate exceeding the legal harvest length of 7 in. The 1998 survey estimated 812 brown trout per mile ranging in size groups from 2.0 to 10.8 in.; however, only 5.5% of that total brown trout estimate exceeded 7 in. The 1994 survey estimate of 726 brown trout per mile ranging in size groups from 2.0 to 15.7 in reported 43% of the total brown trout estimate exceeded 7 inches. The 1989 survey estimated 731 brown trout per mile ranging in size groups from 2.0 to 14.7 in. and reported 33% of the total brown trout estimate exceeded 7 inches. A mature wild brown trout population made up of more big trout very likely will have fewer trout per stream mile as seen in 1994 with a comparatively low 726 brown trout per mile, but recording a high 43% of that population at 7 inches and longer.

The August 1997 pollution and resulting fishkill severely damaged the reproducing brown trout population of Tea Creek. Fortunately, unlike with sedimentation or channel alteration, the stream habitat and spawning areas remained undamaged in the Tea Creek pollution. Increased reproduction and high survival of the 1998 and 1999 year classes combined with the excellent growth rates of a limestone stream and the reduced predation by a lower numbers of larger brown trout population following the fishkill have restored the reproducing brown trout fishery in Tea Creek to near historic wild brown trout abundance.

-- Area 7

Appendix B:

Aquatic Biological Investigation

Reedsville Milling Company Dam Draw-down

COMMONWEALTH OF PENNSYLVANIA
Department of Environmental Protection
September 9, 2003

Stream Code: 12533
Stream File: 2.23.5

SUBJECT: Aquatic Biological Investigation
Reedsville Milling Company Dam Draw-down
Tea Creek
Brown Township, Mifflin County

TO: Leon M. Oberdick
Environmental Program Manager
Water Management Program

FROM: Mark S. Embeck MSE
Water Pollution Biologist 2
Water Management Program

THROUGH: Robert J. Schott
Water Pollution Biologist 3
Water Management Program

EXECUTIVE SUMMARY

The Reedsville Milling Company owns a dam situated on Tea Creek in Mifflin County. Tea Creek is protected as a High Quality Cold Water Fishery under 25 PA Code § 93.9n. In addition, the Pennsylvania Fish and Boat Commission (PFBC) list Tea Creek as a Class A wild trout stream.

The Milling Company received a draw-down permit from the PFBC. According to the mill owner, he started removing boards in the end of June and removed the last board about August 29th. As the water level was lowered to the height of the sediment layer, pulling additional boards allowed large volumes of sediment to flow into the stream below. He indicated he had not seen or spoken to anyone from the PFBC since board removal was initiated. The pace of board removal was initially the subject of controversy, as Mr. Scott Carney indicated, "apparently all the boards (30 or so) in the dam were removed in short order contrary to advice given by the regulatory agencies (DEP, PFBC)". Subsequently, it appears that the advice of the regulatory agencies was indeed followed: the boards having been removed over a several month period. However, other than staged draw-down, it does not appear that the guidance document, "Minimizing Sediment Pollution to Downstream Channels During Impoundment Dewatering (September 8, 2001)" was followed. No sediment control structures were constructed. No existing sediment was excavated.

Pictures are attached which indicate the volume of sediment released and the condition of the stream following board removal. The effects of the sediment release were nothing short of catastrophic. It was not difficult to find areas containing 38 cm (15 in) or more of accumulated sediment. Sediment laden water continued to discharge from the millpond area. The macroinvertebrate community downstream of the dam was depauperate. Only four scuds were found in 4 m^2 of sampled area. This is without question the largest and most damaging sediment release I have seen in my twenty-one year career with the Department.

Since this is not the first time a permitted dam draw-down or breaching episode has severely impacted downstream aquatic life, it is recommended that the Regional Water Quality Management staff be notified prior to any future dam removals or draw-downs in the Southcentral Region. In addition, it is recommended that the BMPs outlined in the guidance document be instituted in future draw-downs. Better inspection and monitoring of these activities is also warranted.

METHODS AND MATERIALS

Macroinvertebrates were collected at the upstream and downstream stations (Figure 1). Stations were chosen to be as similar as possible and sampling was standardized to riffle areas. Sampling proceeded from downstream to upstream.

Four kickscreen (600 X 600µm mesh) samples were collected. For each, an area of approximately 1 m x 1 m was vigorously disturbed allowing organisms to flow downstream into the net. The relative abundance of various taxa was noted in the field. Representative organisms were collected from the net and placed in 70% ethyl alcohol for verification and further identification. An equal amount of sampling effort was expended at each station.

In the laboratory, the organisms were identified to the lowest practicable taxonomic level using a Bausch and Lomb StereoZoom® 7 with 10 - 140X magnifications. The following principal taxonomic references were used: Peckarsky *et al.* (1990), Wiggins (1977), Thorp and Covich (1991) and Merritt and Cummins (1996).

RESULTS

Results of the macroinvertebrate sampling are given in Table 1. The results for each station are summarized below:

Station 1: Approximately 200 m upstream of Reedsville Milling Company Dam.

The stream is located is a mostly shaded, forested area. Riffle substrate was largely cobble interspersed with gravel and finer textured material. Substrate embeddedness was light to moderate. The flow was clear.

Eighteen taxa were collected. The station had a modified EPT index of 5. The modified EPT index represents the number of taxa in the mayfly, stonefly and caddisfly orders (Ephemeroptera, Plecoptera and Tricoptera) having a Hilsenhoff Tolerance Value of 4 or lower. Hilsenhoff values reflect the tolerance of organisms to organic pollutants. The scores range from 0 to 10, with lower values indicative of increased sensitivity. The stream is not atypical of a heavily limestone influenced stream suffering some agricultural impacts. It contains an abundance of crustaceans and a moderate, seasonally reflective diversity including sensitive taxa.

Station 2: Approximately 50 m downstream of Reedsville Milling Company Dam.

The stream is partly shaded. The substrate consisted of sediment filled cobbles with deeper (38 cm and greater) areas of sediment in pools and along the sides of the channel. The water was excessively turbid. Disturbing the substrate released darkened organic material.

One taxon was collected represented by a total of four organisms.. Previous sampling conducted by the Mifflin County Conservation district in 2001 revealed similar taxa at this location as were found in this study at Station 1, above. These additional organisms were presumably buried, suffocated and/or ground apart by the heavy releases of sediment during the draw-down process.

CONCLUSIONS

The release of sediment from the draw down of the Reedsville Milling Company Dam had a catastrophic effect on the stream habitat and organisms living below the dam.

RECOMMENDATIONS

Since this is not the first time a dam draw-down or breaching episode has severely impacted aquatic life, it is recommended that the Regional Water Quality staff be notified prior to any future dam removals or draw-downs. It is recommended that the BMPs be instituted in future draw-downs. Better inspection and monitoring of these activities is also warranted.

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Cc: Robert Fry
Larry Jackson, Area PFBC Fisheries Manager
Stream File
T

Table 1
Qualitative Macroinvertebrate Data
Tea Creek - Reedsville Milling Company Dam Sediment Release
Brown Township, Mifflin County
September 4, 2003

TAXA		STATION 1				STATION 2			
	H	1	2	3	4	1	2	3	4
TURBELLARIA (Flatworms)	9		R		R				
NEMATODA (Roundworms)					R				
OLIGOCHAETA (Aquatic Worms)	10		R	R	P				
EPHEMEROPTERA (Mayflies)									
Baetidae									
Baetis	6	P	P	P	P				
Ephemerellidae									
Drunella	1			R	R				
Heptageniidae									
Heptagenia	4			R	R				
Leptophlebiidae									
Paraleptophlebia	1			R					
TRICOPTERA (Caddisflies)									
Hydropsychidae									
Hydropsyche	5		P	P	P				
Rhyacophilidae									
Rhyacophila	1		P	R					
Uenoidae									
Neophylax	3	R							
COLEOPTERA (Beetles)									
Elmidae									
Optioservus	4	P_F	P	P	P				
Promoresia	2	P_F							
DIPTERA (True Flies)									
Chironomidae	6	R	P	P	P				
Simulidae									
Simulium	6		R						
Tipulidae									
Hexatoma	2			R					
AMPHIPODA (Scuds)									
Gammaridae									
Gammarus	6	A	VA	VA	VA	R		R	R
ISOPODA (Sowbugs)									
Ascellidae									
Lirceus	8		R						
DECAPODA (Crayfish)									
Cambaridae									
Cambarus	6			R					
Total Screen Taxa		6	10	12	10	1	0	1	1
Total Screen Modified EPT Taxa		1	1	4	2	0	0	0	0
Total Station Taxa		18				1			
Total Station Modified EPT Taxa		5				0			

R = Rare (<3), P = Present (3-9), C = Common (10-24), A = Abundant (25-99), R_F = Rare at Family Level, P = Present at Family Level, C_F = Common at Family Level, A_F = Abundant at Family Level

Photo 1: Sediment laden water below Reedsville Milling Company Dam discharge.


Photo 2: Sediment laden water being released from Reedsville Milling Company Dam with all boards removed

Photo 3: Sediment deposition below Reedsville Milling Company Dam.

Photo 4: Newly eroded channel upstream of Reedsville Milling Company Dam.

Photo 5: Nickpoint showing continuing upstream erosion above Reedsville Milling Company Dam.

Appendix C:

The Impervious Cover Model

The Stormwater Manager's Resource Center

The Impervious Cover Model

** For updated information on how impervious cover impacts aquatic systems, you might want to check out Impacts of Impervious Cover on Aquatic Systems, available from the Center for Watershed Protection at* http://www.cwp.org.

Stream research generally indicates that certain zones of stream quality exist, most notably at about 10% impervious cover, where sensitive stream elements are lost from the system. A second threshold appears to exist at around 25 to 30% impervious cover, where most indicators of stream quality consistently shift to a poor condition (e.g., diminished aquatic diversity, water quality, and habitat scores). Table 1 reviews the key findings of recent research regarding the impacts of urbanization on aquatic systems.

Table 1. Review of Key Findings of Recent Research Examining the Relationship of Urbanization on Aquatic Systems

Watershed Indicator	***Key Finding***	***Reference***	***Year***	***Location***
Aquatic insects	Negative relationship between number of insect species and urbanization in 21 streams.	Benke, *et al*.	1981	Atlanta
Aquatic habitat	There is a decrease in the quantity of large woody debris (LWD) found in urban streams at around 10% impervious cover.	Booth, *et al*.	1996	Washington
Fish, habitat & channel stability	Channel stability and fish habitat quality declined rapidly after 10% impervious area.	Booth	1991	Seattle
Fish, habitat	As watershed population density increased, there was a negative impact on urban fish and habitat	Couch, *et al*.	1997	Atlanta
Aquatic insects and fish	A comparison of three stream types found urban streams had lowest diversity and richness	Crawford & Lenat	1989	North Carolina
Stream temperature	Stream temperature increased directly with subwatershed impervious cover.	Galli	1991	Maryland
Aquatic insects	A significant decline in various indicators of wetland aquatic macroinvertebrate community health was observed as impervious cover increased to levels of 8-9%.	Hicks & Larson	1997	Connecticut
Insects, fish, habitat water quality, riparian zone	Steepest decline of biological functioning after 6% imperviousness. There was a steady decline, with approx 50% of initial biotic integrity at 45% impervious area.	Horner, *et al*.	1996	Puget Sound Washington
Aquatic insects and fish	Unable to show improvements at 8 sites downstream of BMPs as compared to reference conditions.	Jones, *et al*.	1996	Northern Virginia
Aquatic insects	Urban streams had sharply lower insect diversity with human population above 4/acre. (About 10%)	Jones & Clark	1987	Northern Virginia
Aquatic insects & fish	Macroinvertebrate and fish diversity decline significantly beyond 10-12% impervious area.	Klein	1979	Maryland
Aquatic insects	Drop in insect taxa from 13 to 4 noted in urban streams.	Garie and McIntosh	1986	New Jersey
Fish spawning	Resident and anadromous fish eggs & larvae declined in 16 streams with > 10% impervious area.	Limburg & Schmidt	1990	New York
Fish	Shift from less tolerant coho salmon to more tolerant cutthroat trout pop.-between 10-15% impervious area at 9 sites.	Luchetti & Fuersteburg	1993	Seattle
Stream channel stability	Urban stream channels often enlarge their cross-sectional area by a factor of 2 to 5. Enlargement	MacRae	1996	British Columbia

	begins at relatively low levels of impervious cover.			
Aquatic insects & stream habitat	No significant difference in biological and physical metrics for 8 BMP sites versus 31 sites without BMPs (with varying impervious area).	Maxted and Shaver	1996	Delaware
Insects, fish, habitat, water quality, riparian zone	Physical and biological stream indicators declined most rapidly during the initial phase of the urbanization process as the percentage of total impervious area exceeded the 5-10% range.	May, *et al*.	1997	Washington
Aquatic insects and fish	There was significant decline in the diversity of aquatic insects and fish at 10% impervious cover.	MWCOG	1992	Washington, DC
Aquatic insects	As watershed development levels increased, the macroinvertebrate community diversity decreased.	Richards, *et al.*	1993	Minnesota
Aquatic insects	Biotic integrity decreases with increasing urbanization in study involving 209 sites, with a sharp decline at 10% I. Riparian condition helps mitigate effects.	Steedmen	1988	Ontario
Wetland plants, amphibians	Mean annual water fluctuation inversely correlated to plant & amphibian density in urban wetlands. Declines noted beyond 10% impervious area.	Taylor	1993	Seattle
Wetland water quality	There is a significant increase in water level fluctuation, conductivity, fecal coliform bacteria, and total phosphorus in urban wetlands as impervious cover exceeds 3.5%.	Taylor, *et al.*	1995	Washington
Sediment loads	About 2/3 of sediment delivered into urban streams comes from channel erosion.	Trimble	1997	California
Water quality-pollutant conc.	Annual P, N, COD, & metal loads increased in direct proportion with increasing impervious area.	US EPA	1983	National
Fish	As watershed development increased to about 10%, fish communities simplified to more habitat and trophic generalists.	Weaver	1991	Virginia
Aquatic insects & fish	All 40 urban sites sampled had fair to very poor index of biotic integrity (IBI) scores, compared to undeveloped reference sites.	Yoder	1991	Ohio

Taking all the research together, it is possible to construct a simple urban stream classification scheme based on impervious cover and stream quality. This simple classification system contains three stream categories, based on the percentage of impervious cover. **Figure 1** illustrates this simple, yet powerful model that predicts the existing and future quality of streams based on the measurable change in impervious cover.

The model classifies streams into one of three categories: sensitive, impacted, and non-supporting. Each stream category can be expected to have unique characteristics as follows:

Sensitive Streams. These streams typically have a watershed impervious cover of zero to 10 percent. Consequently, sensitive streams are of high quality, and are typified by stable channels, excellent habitat structure, good to excellent water quality, and diverse communities of both fish and aquatic insects. Since impervious cover is so low, they do not experience frequent flooding and other hydrological changes that accompany urbanization. It should be noted that some sensitive streams located in rural areas may have been impacted by prior poor grazing and cropping practices that may have severely altered the riparian zone, and consequently, may not have all the properties of a sensitive stream. Once riparian management improves, however these streams are often expected to recover.

Impacted Streams. Streams in this category possess a watershed impervious cover ranging from 11 to 25 percent, and show clear signs of degradation due to watershed urbanization. The elevated storm flows begin to alter stream geometry. Both erosion and channel widening are clearly evident. Streams banks become unstable, and physical habitat in the stream declines noticeably. Stream water quality shifts into the fair/good category during both storms and dry weather periods. Stream biodiversity declines to fair levels, with most sensitive fish and aquatic insects disappearing from the stream.

Non-Supporting Streams. Once watershed impervious cover exceeds 25%, stream quality crosses a second threshold. Streams in this category essentially become conduits for conveying stormwater flows, and can no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and streambank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Water quality is consistently rated as fair to poor, and water recreation is no longer possible due to the presence of high bacterial levels. Subwatersheds in the non-supporting category will generally display increases in nutrient loads to downstream receiving waters, even if effective urban BMPs are installed and maintained. The biological quality of non-supporting streams is generally considered poor, and is dominated by pollution tolerant insects and fish.

Although the impervious cover model is supported by research, its assumptions and limitations need to be clearly understood. There are some technical issues involved in its development which are discussed below:

Limitations of the Impervious Cover Model

1. Scale effect. The impervious cover model should generally only be applied to smaller urban streams from first to third order. This limitation reflects the fact that most of the research has been conducted at the catchment or subwatershed level (0.2 to 10 square mile area), and that the influence of impervious cover is strongest at these spatial scales. In larger watersheds and basins, other land uses, pollution sources and disturbances often dominate the quality and dynamics of streams and rivers.

2. Reference condition. The simple model predicts **potential** rather than **actual** stream quality. Thus, the reference condition for a sensitive stream is a high quality, non-impacted stream within a given ecoregion or sub-ecoregion. It can and should be expected that some individual stream reaches or segments will depart from the predictions of the impervious cover model. For example, physical and biological monitoring may find poor quality in a stream classified as sensitive, or good diversity in a non-supporting one. Rather than being a shortcoming, these "outliers" may help watershed managers better understand local watershed and stream dynamics. For example, an "outlier" stream may be a result of past human disturbance, such as grazing, channelization, acid mine drainage, agricultural drainage, poor forestry practices, or irrigation return flows.

3. Statistical variability. Individual impervious cover/stream quality indicator relationships tend to exhibit a considerable amount of scatter, although they do show a general trend downward as impervious cover increases. Thus, the impervious cover model is not intended to predict the precise score of an individual stream quality indicator for a given level of impervious cover. Instead, the model attempts to predict the average behavior of a group of stream indicators over a range of impervious cover. In addition, the impervious cover thresholds defined by the model are not sharp breakpoints, but instead reflect the expected transition of a composite of individual stream indicators.

4. Measuring and projecting impervious cover. Given the central importance of impervious cover to the model, it is very important that it be accurately measured and projected. Yet comparatively relatively little attention has been paid to standardizing techniques for measuring existing impervious cover, or forecasting future impervious cover. Some investigators define impervious cover as "effective impervious area" (i.e., impervious area not directly connected to a stream or drainage system) which may be lower than total impervious cover under certain suburban or exurban development patterns (Sutherland, 1995).

5. Regional adaptability. To date, much research used to develop the model has been performed in the mid-Atlantic and Puget Sound eco-regions. In particular, very little research has been conducted in western, midwestern, or mountainous streams. Further research is needed to determine if the impervious cover model applies in these ecoregions and terrains.

6. Defining thresholds for non-supporting streams. Most research has focused on the transition from sensitive streams to impacted ones. Much less is known about the the nature of the transition from impacted streams to non-supporting ones. The impervious cover model projects the transition occurs around 25% impervious cover for small urban streams, but more sampling is needed to firmly establish this threshold.

7. Influence of BMPs in extending thresholds. Urban BMPs may be able to shift the impervious cover thresholds higher. The ability of the current generation of urban BMPs to shift these thresholds however, appears to be very modest according to several lines of evidence. First, a handful of the impervious cover/stream indicator research studies were conducted in localities that had some kind of requirements for urban best management practices; yet no significant improvement in stream quality was detected. Second, Maxted and Shaver (1996) and Jones, *et al.* (1996) could not detect an improvement in bioassessment scores in streams served by stormwater ponds.

8. Influence of riparian cover in extending thresholds. Conserving or restoring an intact and forested riparian zone along urban streams appears to extend the impervious cover threshold to a modest degree. For example, Steedman (1988) found that forested riparian stream zones in Ontario had higher habitat and diversity scores for the same degree of urbanization than streams that lacked an intact riparian zone. Horner, *et al.* (1996) also found evidence of a similar relationship. This is not surprising, given the integral role the riparian zone plays in the ecology and morphology of headwater streams. Indeed, the value of conserving and restoring riparian forests to protect stream ecosystems is increasingly being recognized as a critical management tool in rural and agricultural landscapes as well (CBP, 1995).

9. Potential for stream restoration. Streams classified by their potential for restoration (also known as restorable streams) offer opportunities for real improvement in water quality, stability, or biodiversity and hydrologic regimes through the use of stream restoration, urban retrofit and other restoration techniques.

10. Pervious areas. An implicit assumption of the impervious cover model is that pervious areas in the urban landscape do not matter much, and have little direct influence on stream quality. Yet urban pervious areas are highly disturbed, and possess few of the qualities associated with similar pervious cover types situated in non-urban areas. For example, it has recently been estimated that high input turf can comprise up to half the total pervious area in suburban areas (Schueler, 1995a). These lawns receive high inputs of fertilizers, pesticides and irrigation, and their surface soils are highly compacted.

Although strong links between high input turf and stream quality have yet to be convincingly demonstrated, watershed planners should not neglect the management of pervious areas. Pervious areas also provide opportunities to capture and store runoff generated from impervious areas. Examples include directing rooftop runoff over yards, the use of swales and filter strips, and grading impervious areas to pockets of pervious area. When pervious and impervious areas are integrated closely together, it is possible to sharply reduce the "effective" impervious area in the landscape (Southerland, 1995).

While there are some limitations to the application of the urban stream impervious cover model, impervious cover still provides us with one of the best tools for evaluating the health of a subwatershed. Impervious cover serves not only as an indicator of urban stream quality but also as a valuable management tool in reducing the cumulative impacts of development within subwatersheds.

Source: The Stormwater Manager's Resource Center
http://www.stormwatercenter.net/

obtained 3/2/07

Appendix D:

Impact of the Use of Subsurface Disposal Systems on Groundwater Nitrate Nitrogen Levels

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Water Supply and Wastewater Management

DOCUMENT ID:	362-2207-004
TITLE:	Impact of the Use of Subsurface Disposal Systems on Groundwater Nitrate Nitrogen Levels
EFFECTIVE DATE:	December 29, 1997 Minor edits were made throughout (August 27, 2002) Minor edits were made on pages i, 6, 8, and 9 (March 31, 2003)
AUTHORITY:	Pennsylvania Sewage Facilities Act, Section 3(6) and Section 10(6) 35 P.S. §§705.3(6) and 750.10(6)
POLICY:	The Department of Environmental Protection (DEP) shall publish technical guidance and cooperate in studying and evaluating new methods of sewage disposal in continuing support of the policy goals set by the Pennsylvania Sewage Facilities Act 537.
PURPOSE:	The Department of Environmental Protection (DEP) shall supplement the information incorporated into Title 25 Pennsylvania Code Chapter 71, as needed.
APPLICABILITY:	This guidance applies to consideration of onlot wastewater disposal systems and consideration of the use of denitrifying technologies, as and where they apply.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not an adjudication or regulation. There is no intent on the part of DEP to give these rules that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
PAGE LENGTH:	15 pages
LOCATION:	Volume 33 Tab 26

I. GENERAL

A. Use of onlot subsurface disposal systems and community onlot subsurface disposal systems requires extensive site evaluation. These systems are dependent upon a very sensitive system of physical, chemical and biological processes in the soil and groundwater to renovate and dispose of sewage.

A number of onlot system proposals anticipate flows in excess of 10,000 gallons per day or have a density of more than one EDU per acre. These proposals may be located in areas where existing groundwater contamination levels or the geology would preclude the use of such systems. Additional planning information relating to siting these systems may be required including:

1. site specific soil profiles and percolation testing;

2. additional permeability testing; and

3. hydrogeologic studies

B. The use of high individual onlot system density or high volume community onlot occurs in Pennsylvania because these systems may be more cost-effective than other conventional treatment technologies in many situations. Additionally, the cost of operating and maintaining these systems can be lower and less energy demanding than conventional sewered collection and treatment systems.

C. This use has caused continued concern about a problem inherent in these systems. The systems release high volumes of treated effluent to local groundwater. This effluent can cause nitrate nitrogen (NO_3-N) concentrations in groundwater which exceed the upper limit of 10 ppm established for drinking water supplies.

D. This fact limits the use of subsurface system technology unless specific procedures are understood and implemented. The purpose of this paper is to discuss the nitrate nitrogen problem and the DEP policies and procedures which have been developed to protect water supplies from the potentially detrimental groundwater effects generated by subsurface disposal systems. Supporting documents pertaining to specific issues in this paper are listed in the bibliography.

II. PUBLIC HEALTH SIGNIFICANCE OF NITRATES IN DRINKING WATER

A. The U.S. Public Health Service first proposed nitrate limitations as part of drinking water standards in 1962. The EPA's National Primary Drinking Water Regulations, published in 1997, continues to set 10 parts per million (ppm)[1] nitrate nitrogen as the upper limit for drinking water. The documents base this limit on studies conducted from 1945 through 1975, as well as later confirming studies, in which infant cyanosis caused by methemoglobinemia was linked with high concentrations of nitrate nitrogen in potable water supplies.

B. Three factors make infants less than 6 months of age more susceptible to cyanosis than adults:

1. Liquid intake is three times higher than adults per unit of body weight.

2. Gastric pH is 5-7. This is a range at which nitrate reducing bacteria thrive.

[1] For purposes of this discussion, 1 ppm is equivalent to 1 milligram per liter (mg/l)

3. Fetal hemoglobin F is more susceptible to the formation of methemoglobin than is adult hemoglobin A.

C. In infants drinking water having greater than 10 ppm nitrate nitrogen, the nitrate reducing bacteria in the intestine can convert nitrates to nitrites. These nitrites change the hemoglobin in the infant's blood stream to methemoglobin. Hemoglobin carries oxygen to the cells of the infant's body. Methemoglobin cannot carry oxygen. If enough hemoglobin is converted to methemoglobin, cyanosis and oxygen deprivation occurs. Death has been attributed to nitrate concentration in water of less than 40 ppm. The existence of this process is supported by studies that have shown elevated levels of methemoglobin in the blood stream of infants experiencing cyanosis after consuming water containing high nitrate levels (10 ppm).

D. As a result of this potential public health problem, the EPA has retained the limit of 10 ppm for nitrate nitrogen in drinking water. Public water supplies having concentrations in excess of this amount may be required to seek alternative water sources, treat water to remove excess nitrates and notify the public of the health hazards associated with such nitrate levels. These National Primary Drinking Water Regulations do, however, allow noncommunity water supplies to be used with up to 20 ppm nitrate nitrogen if the state provides control measures (notification of physicians and public notice).

III. SUBSURFACE DISPOSAL SYSTEMS AND NITRATE GENERATION

A. The sequence of events that releases nitrates in a subsurface disposal system is shown in figure 1. It is as follows:

1. Toilet wastes which contribute 78 to 90 percent of the nitrogen generated by a household, enter the septic tank as urea, uric acid, ammonia, proteinaceious food stuff, and bacterial cells. In the septic tank, these materials undergo anoxic microbial decomposition with the aid of enzymes such as protease and urease. As a result, these materials are broken down to more basic products. About 75% becomes dissolved ammonia (NH_3) and ammonium (NH_4^+) and 25% becomes dissolved organic nitrogen. The effluent liquid leaves the septic tank to enter the subsurface absorption area

2. Upon entering the soil the remaining organic nitrogen is converted to ammonia. Some of the ammonia and ammonium, in a water solution, undergoes adsorption on soil particles through anion/cation exchange until equilibrium occurs. Excess ammonium ions remain in an available form for continued aerobic nitrification as these leach through the soil. Through the action of bacterial agents, such as Nitrosomonas, the ammonium ion is broken down to nitrite nitrogen:

$$2\ NH_4^+ + 3\ O_22 \rightarrow 2\ NO_2 + 4H^+ + 2H_2O$$

Nitrite nitrogen is further broken down through the action of Nitrobacter bacterium to nitrate nitrogen:

$$2\ NO_2 + O_2 \rightarrow 2\ NO_3$$

3. If the soil and groundwater have the normal presence of oxygen this nitrate nitrogen remains unchanged in the groundwater aquifer.

B. Nitrate nitrogen loading of groundwater is more critical than such loading for surface water for several reasons:

1. Rapid dilution and mixing occurs in surface waters. Dilution and mixing of groundwater occurs more slower. The rate of this mixing is more difficult to estimate.

2. Use of nitrates as food by aquatic plants occurs rapidly in surface waters. Assimilation of nitrates does not occur in groundwater.

3. Essentially all nitrogenous materials entering subsurface disposal systems ultimately converts into nitrate nitrogen. This nitrate nitrogen does not break down in normal groundwater.

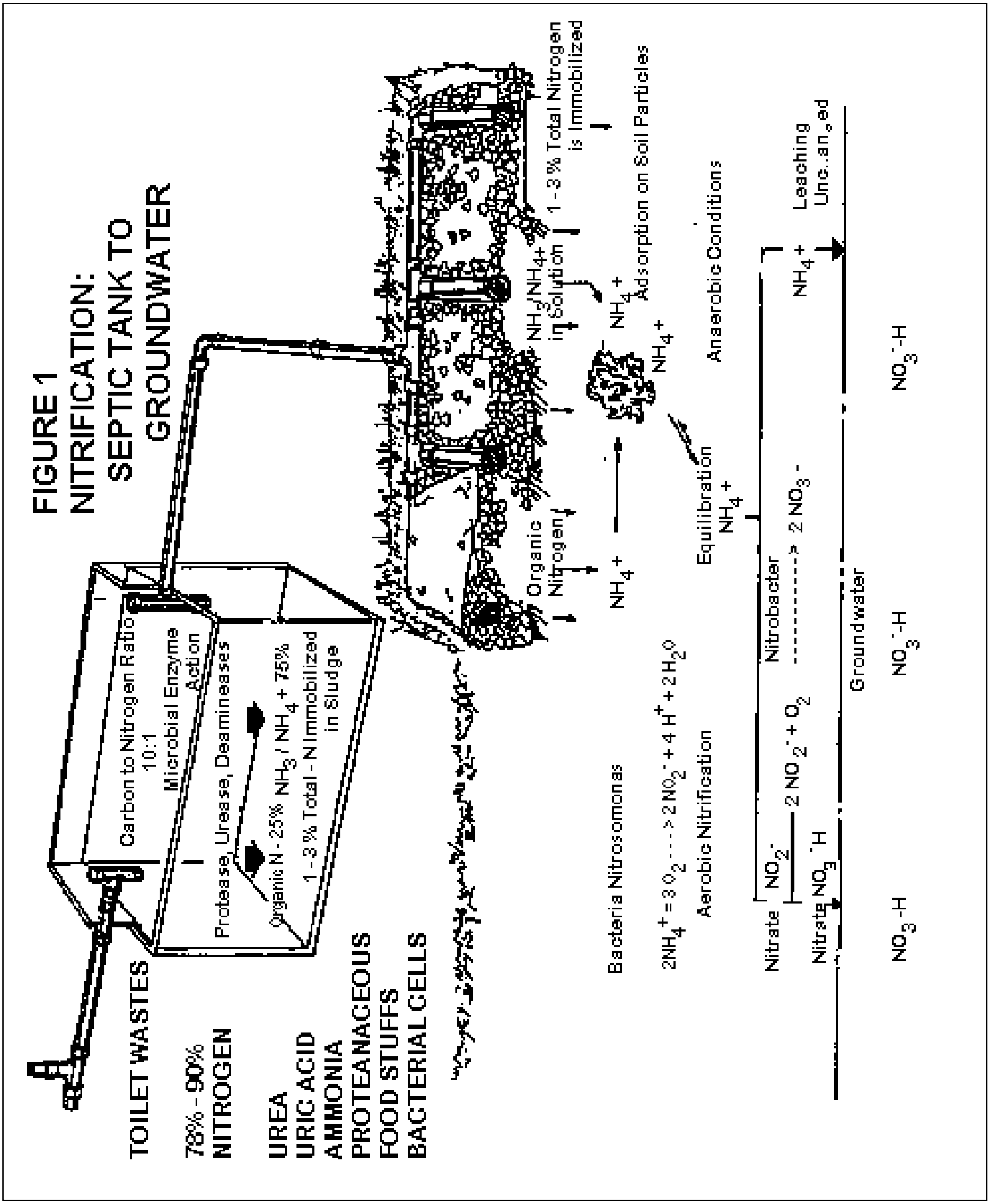
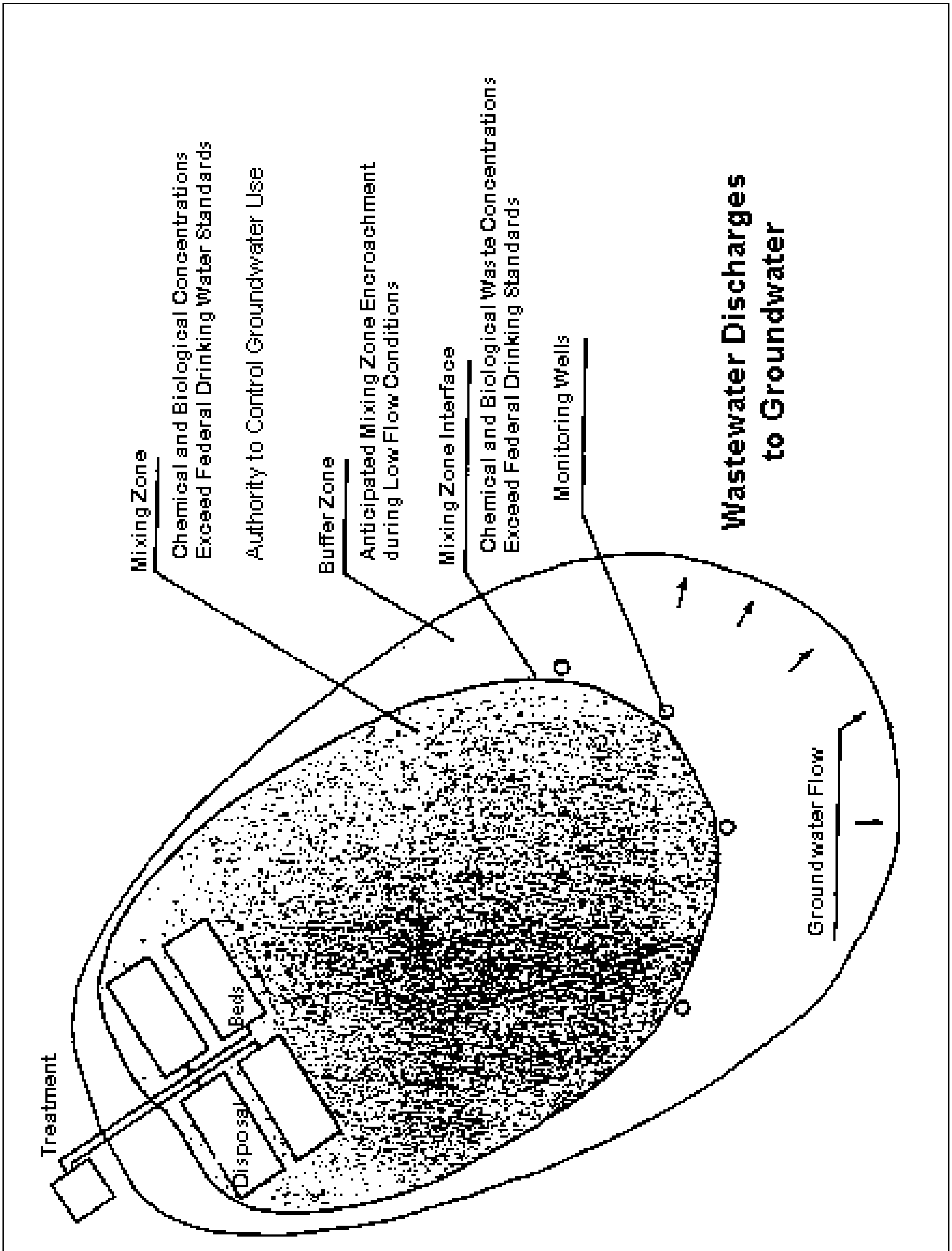


FIGURE 1
NITRIFICATION:
SEPTIC TANK TO
GROUNDWATER
TOILET WASTES
78% - 90%
NITROGEN
UREA
URIC ACID
AMMONIA
PROTEANACEOUS
FOOD STUFFS
BACTERIAL CELLS
Carbon to Nitrogen Ratio
10:1
Microbial Enzyme
Action
Protease, Urease, Deamineases
Organic N - 25% NH3 / NH4 + 75%
1 - 3 % Total - N Immobilized
in Sludge
Organic
Nitrogen
NH4 +
NH3/NH4+
in Solution
1 - 3 % Total Nitrogen
is Immobilized
Adsorption on Soil Particles
Anaerobic Conditions
Equilibration
NH4 +
Bacteria Nitrosomonas
2NH4+ = 3 O2 - - -> 2 NO2- + 4 H+ + 2 H2O
Aerobic Nitrification
Nitrobacter
Nitrate NO2-
2 NO2- + O2 ---------> 2 NO3 -
Nitrate NO3 H
Groundwater
NO3 -H
Leaching



Wastewater Discharges
to Groundwater
Mixing Zone
Chemical and Biological Concentrations
Exceed Federal Drinking Water Standards
Authority to Control Groundwater Use
Buffer Zone
Anticipated Mixing Zone Encroachment
during Low Flow Conditions
Mixing Zone Interface
Chemical and Biological Waste Concentrations
Exceed Federal Drinking Standards
Monitoring Wells
Groundwater Flow
Treatment
Disposal
Beds

IV. TREATMENT TO REDUCE NITRATE NITROGEN CONCENTRATIONS

A. Biological Denitrification

Water can be treated to reduce concentrations of nitrate nitrogen. The process is called denitrification. Denitrification involves the biological reduction of nitrate to nitrite and finally to nitrogen gas. Such biological denitrification requires:

1. Bacteria - Pseudomonas, Micrococcus, Bacillus and Acomobacter;

2. No available oxygen (anoxic conditions) and,

3. A source of organic carbon compounds

Biological denitrification occurs as the bacteria use nitrate to oxidize organic carbon to obtain energy. This can only occur if oxygen is not present (anoxic conditions).

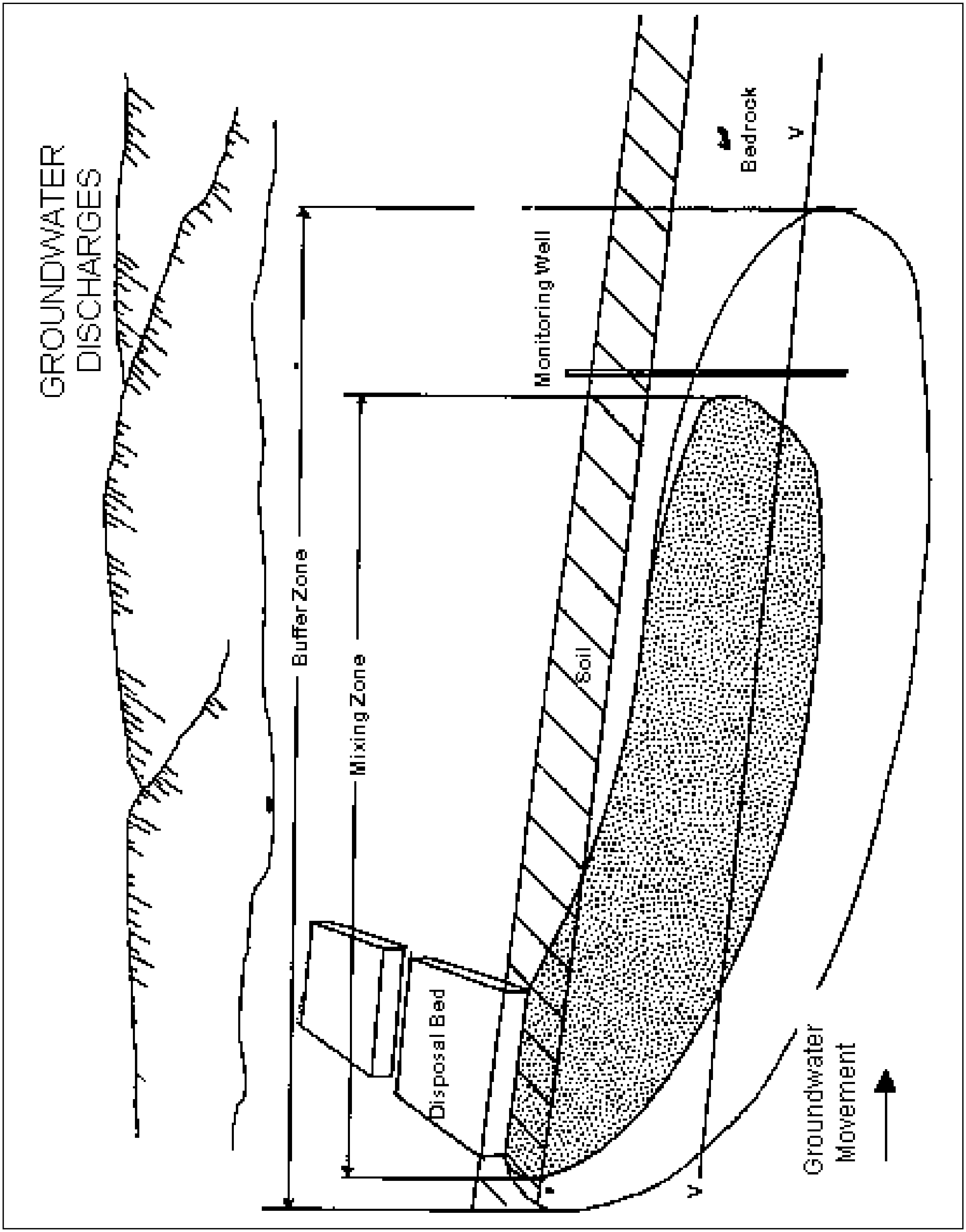
B. Denitrification by System Components

A number of treatment methods based on the denitrification process have been developed. These eliminate nitrates from sewage prior to disposal by subsurface absorption systems. Most treatment methods require operation and maintenance activities. Most methods which have been utilized and evaluated are components of treatment plant systems. Such systems have been utilized to provide necessary nitrate removal before a subsurface discharge proposed to recharge groundwater in areas where maintaining groundwater supply is critical.

C. Dilution and Dispersion of Contaminants in Groundwater

Subsurface disposal systems depend upon soil activity for proper treatment of sewage. They depend on groundwater for dispersion and dilution of contaminants that have not been completely treated. Nitrates generated in subsurface disposal systems enter the groundwater at levels of approximately 45 ppm directly under the absorption field. The groundwater concentration is reduced through dilution and dispersion in a zone of attenuation (mixing zone).

1. The water supply for a single family dwelling served by an onlot subsurface disposal system is protected by nitrate concentration reduction through regulatory control of isolation distances (100 feet) between the sewage system and well. Dilution and dispersion reduce the nitrate nitrogen concentration from sewage effluent as groundwater travels through the soil. The 100 foot distance, however, may not provide sufficient isolation to allow for nitrate nitrogen dilution to less than 10 ppm before reaching a water supply due to the presence of additional systems in the area. These systems also release nitrate nitrogen to the local groundwater. Theoretically, approximately 1.4 acres is necessary to isolate each sewage system serving a single family dwelling in a subdivision so that sufficient dilution of nitrate can occur. The existing 100 foot well/sewage system isolation distance requirement can be met on 1/4 acre lots. The potential for nitrate nitrogen contamination increases as the density of the subdivision (number of single family dwellings/acre) increases.


GROUNDWATER
DISCHARGES
Buffer Zone
Mixing Zone
Monitoring Well
Soil
Bedrock
Disposal Bed
Groundwater
Movement

2. A significant concern about nitrate nitrogen loading of groundwater arises with single large volume effluent discharges or high density discharges from multiple subsurface disposal systems. Because of the large volume of effluent being discharged in relation to the area for disposal, nitrate nitrogen loading is increased relative to the dilution/dispersion capabilities of the groundwater system. Therefore, the capability of the local groundwater system to dilute and disperse these increased nitrate loads must be determined before the approval of these discharges.

V. DETERMINATION OF THE IMPACT OF NITRATES ON DRINKING WATER SUPPLIES

A hydrogeologic study evaluates the existing and proposed nitrate loading of the groundwater. It estimates the velocity and direction of groundwater movement. It projects the area of potential contamination above 10 ppm that can be anticipated in the local aquifer and its impact on water uses in the local area.

A. Hydrogeologic studies are site specific. Final determination as to the final content of such studies should be made by groundwater geologists working for the Department. Their judgment rests on an evaluation of specific geological characteristics of the area proposed for subsurface disposal systems.

B. Hydrogeologic studies should delineate a:

1. Dispersion Plume - Volume of effluent and groundwater flowing away from a treatment disposal site.

2. Mixing Zone - Portion of the dispersion plume in which groundwater quality does not meet Federal Drinking Water Standards.

3. Buffer Zone - The groundwater surrounding the mixing zone. It is provided for containment and restoration activities should groundwater which exceeds Federal Drinking Water Standards leave the mixing zone.

C. General guidelines for such studies are included in DEP Policy, and Procedures and Modules.

VI. USE OF ACT 537 PLANNING TO CONTROL THE IMPACT OF NITRATES ON DRINKING WATER

A. DEP does not approve or disapprove permits for onlot or small community onlot subsurface disposal systems (treating less than 10,000 gal/day). This approval or disapproval power is given to the individual municipalities administering the provisions of Section 7 of the Pennsylvania Sewage Facilities Act. Any requirements for such safeguards as hydrogeologic studies must, therefore, be required as part of the Act 537 planning process over which DEP has approval power.

B. Pennsylvania does have principles to guide groundwater protection and remediation. DEP currently does not require any discharge limitations where subsurface sewage disposal systems are discharging to groundwater and groundwater nitrate concentrations are less than 5 ppm. Existing DEP regulations on subsurface disposal systems do not establish effluent limitations for specific types of sewage disposal systems. Effluent limitations for surface waters do not apply to subsurface discharges to groundwater.

C. The Environmental Protection Agency's drinking water regulations define the concentrations and chemical characteristic parameters that are harmful to public health. These regulations state that water containing nitrate nitrogen levels in excess of 10 ppm should not be used for drinking water. Further, nitrite nitrogen may not exceed 1 ppm. This regulation, when linked with the language of the Clean Streams Law which defines pollution in part as "contamination…that renders…waters harmful…to public health," thereby provides the basis for requiring hydrogeologic studies.

D The Act 537 planning process can be used to require site specific testing and hydrogeologic studies to determine the extent of groundwater contamination expected from subsurface systems. Such studies can also identify existing and potential water supplies that will be affected by nitrate nitrogen levels in excess of 10 ppm. The Act 537 Plan can require that the methods of preventing use of this water for drinking water purposes be evaluated. A method can be chosen and implemented, as part of the plan, to prevent creation of a public health hazard.

E. Evaluations of possible methods of prohibiting the present and potential use of contaminated groundwater within the mixing and buffer zones for drinking water purposes include:

1. Sewage Facilities Planning that limits the installation of treatment facilities in high nitrate nitrogen zones.

2. Land use zoning established by local government agencies which prohibits development using on-site wells in high nitrate nitrogen zones (this would eliminate drinking water use).

3. Use of alternative water supplies.

4. Deed restrictions, easements, or other legal mechanism limiting use of affected groundwater areas.

5. Ownership of all property impacted.

F. Act 537 Planning can also be used to require evaluation and implementation of groundwater monitoring activities which will detect nitrate nitrogen levels and movement outside the mixing zone defined by the hydrogeologic study. Such monitoring can be used to initiate action to stop nitrate nitrogen from reaching 10 ppm in drinking water supplies. The planning can require an evaluation of contingencies to stop such unpredicted contamination including:

1. Abandonment of the onlot system (replacement with another type of system, connection to public sewers).

2. Adding Nitrate Nitrogen treatment components to the onlot system.

3. Groundwater diversion.

4. Temporary water supply treatment in conjunction with 1, 2, or 3 above.

VII. SUMMARY OF ISSUES

The following summary identifies major issues discussed in this paper and provides DEP's position on each issue along with support for each position:

Issue No. 1

Subsurface sewage disposal systems can cause nitrate nitrogen pollution of groundwater. Large volume or high density discharges from subsurface systems increase the potential impact of nitrate nitrogen introduction into potable water supplies.

Position

DEP recognizes the fact that subsurface sewage disposal systems rely upon the soil and hydrogeologic treatment systems to renovate sewage and that dilution and dispersion through the groundwater flow system reduces the concentration of nitrate nitrogen generated from subsurface systems. Such systems can only be allowed if the concentration of nitrate nitrogen reaches safe levels prior to use of the groundwater as a potable water supply source

Support

Chapter 73 of DEP's Rules and Regulations

Clean Stream Law Sec. 5(a)(2) & Sec. 402(a)

Issue No. 2

Opinion varies as to the public health significance of nitrate nitrogen and the concentration which poses a public health hazard in drinking water.

Position

DEP accepts 10 ppm as the maximum allowable level of nitrate nitrogen in drinking water systems. The siting of subsurface sewage disposal systems must protect existing and potential potable water supplies from nitrate nitrogen loadings in excess of this limit. Scientific opinion seems solidified that the 10 ppm limit for nitrate in drinking water is valid. National Primary Drinking Water Regulations, 40 CFR 141.11(d), were finalized in 1997 using this limit.

Support

Bibliography References #1, #2, #3, #7, #8, and #9.

PA Sewage Facilities Act 537 Sec. 5(d)(3) and (5).

Clean Streams Law Sec. 5(a)(2)

Eagles View Lake Inc. v. DER Environmental Hearing Board Docket No. 76-086-W, April 4, 1978

Issue No. 3

The level of nitrate nitrogen leaving a subsurface sewage disposal system is important in determining the impact of this effluent on the groundwater. The treatment capabilities of subsurface disposal systems have been claimed to be from 0% to 44% removal of nitrate nitrogen.

Position

Unless DEP accepted components of a subsurface sewage disposal system have been demonstrated to consistently reduce nitrate nitrogen loading of the groundwater directly under the subsurface absorption area, all nitrogen entering the system will be assumed to be converted to nitrate nitrogen and loaded to the groundwater. The accepted figure for this loading from household waste is 45 ppm nitrate nitrogen.

Support

References #10, #11, #12, #13, #14,#15

Issue No. 4

A number of treatment methods are now available that claim to reduce nitrate nitrogen levels prior to treatment in the subsurface sewage disposal system components.

Position

Only treatment facilities shown to have a consistent nitrogen removal capability, as documented by in-field testing, can be employed as a means of reducing nitrogen loading levels prior to sewage disposal by a subsurface system.

Support

References #14, #15

Issue No. 5

The permitting of subsurface sewage disposal systems is controlled by Chapter 73 of DEP's regulations. The 100 foot isolation distance between subsurface systems and drinking water supplies established by these regulations may not be adequate to provide for nitrate concentration reductions in effluent from large systems before reaching a water supply.

Position

Act 537 planning for community onlot disposal systems utilizing subsurface disposal for wastewater flows in excess of 10,000 gallons per day; high density developments (lot less than 1 acre in size) utilizing individual onlot systems for a subdivision of more than 50 lots; onlot system proposed in areas documented by DEP as having existing nitrate nitrogen levels in excess of 5 ppm, or areas with critical geology must evaluate the impact of nitrate nitrogen on the groundwater. A preliminary hydrogeologic study will estimate the extent of the potential problems. A detailed hydrogeologic study will be required where DEP concludes there is a need for more detailed information. This information is included as supporting documentation to sewage facilities planning module components. Permit exempt systems must be installed 200 feet horizontal distance from potential water supplies of all types.

Support

Chapter 71, Sec. 71.62(c)

Chapter 72, Sec. 71.23(g)

Clean Streams Law, Sec. 5(a)(2), 5(b)(2), 402(a)

Eagles View Lake Inc. v. DER Environmental Hearing Board Docket No. 7 6-086-W, April 4, 1978

Issue No. 6

Once a hydrogeologic study delineates a mixing zone and it has been established that the water in that zone will be in excess of 10 parts per million, the water in that zone cannot be used for drinking water purposes. Sufficient measures must be taken to prevent a public health hazard (consumption of the water) from occurring in such cases.

Position

Act 537 planning must evaluate and establish the legal or institutional measures to control both present and potential water usages within the mixing and buffer zones. Usage controls must prevent human consumption of water with nitrate concentrations in excess of levels associated with specific health hazards. Adverse impacts on existing or potential public or private water supplies that may be caused by a proposed sewage disposal system must be mitigated to the satisfaction of DEP by measures approved through the Act 537 planning process. Act 537 planning proposals must also establish groundwater monitoring requirements to confirm the validity of the original hydrogeologic study. Measures to prevent hazardous groundwater nitrate-nitrogen levels in the mixing zone from migrating beyond the buffer zone must be evaluated. Plans must evaluate and establish remedial actions that can be taken before hazardous concentrations of nitrate-nitrogen leave control of the established zone of attenuation.

Support

Ref. 1, 2, 12

Chapter 71, Sec. 71.3, 71.62(c)(2)-(4)

Clean Streams Law Sec. 4 and Sec. 5

Eagles View Lake Inc., v. DER Environmental Hearing Board Docket No. 76-086-W, April 4, 1978

Sewage Facilities Act Sec. 5

DEP Document Number 383-0800-001, December 1, 1996, Principles for Groundwater Pollution Prevention and Remediation.

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1. U.S. Department of Health, Education and Welfare, Public Health Services, 1962, *Public Health Service Drinking Water Standards*, Page 47-57. Establishes 10 ppm nitrate limit for potable water supplies based upon support from ten studies showing the public health impact of nitrogen. Replaced by 40 CFR 141.11(d).

2. Code of Federal Regulations, 1997, *National Primary Drinking Water Regulations*, 40 CFR 141.11(d). Continues the use of 10 ppm nitrate nitrogen limit for potable water supplies based upon nine more recent studies showing the public health impact of nitrogen.

3. National Academy of Sciences, 1977, *Drinking Water and Health*, pages 411-439. This report supports the 10 ppm nitrate nitrogen limit stating that: "Epidemiological investigation on the occurrence of methemoglobinemia in infants tends to confirm the value near 10 mg/L nitrate as nitrogen as a maximum concentration level for water with no adverse health effect, but there is little margin of safety in the value." The same report questions the 10 ppm limit stating that; "The highly sporadic incidence of methemoglobinemia when drinking water that contains much greater concentration of nitrate is used suggested, however, that factors other than nitrate intake are important in connection with development of the disease."

4. Parsons, M. L., 1977, Current Research Suggests the Nitrate Standard in Drinking Water is Too Low. *Journal of Environmental Health*, (November-December, 1977), Volume 40, No. 3, page 140. Parsons proposed raising the 10 ppm limit on nitrate nitrogen to 100 ppm based on evidence that both high nitrate nitrogen levels and bacterial contamination of water supply are needed to cause methemoglobinemia. In addition, he points out the lack of recent documentation of public health problems resulting from nitrates in spite of the high concentrations begin injected in water and food.

5. Craun, Gunther F., 1981, An Alternative for Meeting the Nitrate Standard for Public Water Supplies. *Journal of Environmental Health*, (July-August, 1981), Volume 44, No. 1, pages 20-24. Craun supports directing enforcement activities to the specific population that is susceptible to methemoglobinemia (infants less than 3 months of age). He proposes requiring alternative water supplies for this population along with an education program. Support for this proposal follows that provided in reference 4 above, and a review of capabilities States and Health Agencies to carry out such an approach. This proposal is intended to be a substitute for EPA's requirements to treat for nitrates in public water supplies.

   No cases were found in two studies where concentrations were as much as 20 mg/l nitrate nitrogen.

6. EPA letter of March 19, 1979, from Bernie Sarnoski, Chief, State Program Section, Water Supply Branch to J. Stephen Schmidt, Pennsylvania DEP. Mr. Sarnoski discussed the nitrate nitrogen problem stating that "the U.S. Environmental Protection Agency's draft of the amendments to the National Interim Primary Drinking Water Regulations relating to non-municipal water systems under the Safe Drinking Water Act has expanded Section 141.11 to give discretionary authority to the States with respect to the maximum contaminant level (MCLs) for nitrates. This amendment provides that the nitrate levels up to 20 mg/L (as N) may be allowed in a non-community water system only if it has been demonstrated to the State that whenever the nitrate level exceeds 10 mg/L (as N) a number of control measures, such as informing local physicians and providing continuous public notification to parents not to feed such water to infants under six months of age, will be implemented."

7. Winton E. F.; Tardiff, R. G.; and McCabe, L. J., 1971, Nitrate in Drinking Water, *Journal of American Waterworks Association*, (February 1971), Volume 63, pages 95-98. This paper studies the validity of the 10 ppm nitrate nitrogen limit placed on public water supplies. A review of the causative factors of a study of 111 infants exposed to nitrates in formulas under controlled conditions lead the authors to conclude in the 10 ppm nitrate nitrogen (45 mg/L nitrate) limit on water supplies is valid.

8. Environmental Protection Agency, 1985, *Occurrence of Nitrate in Drinking Water, Food, and Air*. Supports 10 mg/L standard.

9. Bouchard, Dermont C;. Williams, Mark K.; Surampalli Rao Y., 1992. Nitrate Contamination of Groundwater: Sources and Potential Health Effects. *Journal of the American Water Works Association*, (September 1992), Volume 84, Number 9, page 85-90. This is an overview of health concerns of nitrate-nitrite exposure. Concludes that information to date supports the current drinking water standard.

10. Jenkins, P. F. and Paluzzo, A. J., 1991. Wastewater Treatment by a Prototype Slow Rate Land Treatment System, *CRREL Report 81-14*. A six year study was conducted of six disposal systems in sandy loam and silt loam receiving either primary or secondary effluents sprayed under controlled conditions. The study revealed that denitrification and other nitrate nitrogen removal mechanisms other than plant uptake and leaching account for only about 9% removal of the total nitrogen applied.

11. Kristinsen, Roly, 1981. Sand-Filter Trenches for Purification of Septic Tank Effluent: II. The Fate of Nitrogen, *Journal of Environmental Quality*, (July-September, 1981), Volume 10, Number 3, Page 358. A study of sand filters was conducted to determine what occurred in such systems with regard to nitrate nitrogen. The study determined that insignificant amounts of nitrogen were removed during renovation in the sand filter due to the aerobic conditions in the sand and subsequent nitrification. Uptake of nitrogen by microbial biomass, cation exchange complexes and dead organic matter accounted for only three months of nitrogen loading from households. The report recommended intermittent loading as a possible means of increasing denitrification in subsurface systems.

12. Aulenbach, D. B. 1974. Recharge of Treated Sewage into Sand -- Nutrient Transport Through the Sand. *Ground Water*, (September-October 1974), Volume 12, Number 5, page 301. An extensive study of the disposal of secondary sewage onto sandbeds revealed that nitrate nitrogen levels in excess of 10 ppm generated in the beds traveled downgradient in the groundwater system. The study also indicated that nitrification occurs under aerobic conditions in such filters and that dilution and dispersion is responsible for natural attenuation of nitrate nitrogen in the groundwater system.

13. Bouma, J., Keney, D. R., Magdoff, F. R., and Walker, W. B., 1973. Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluent in Sands: Soil Transformation. *Journal of Environmental Quality*, (October-December 1973), Volume 2, Number 4, page 475. This article studies several subsurface sewage disposal systems to determine the changes taking place in relation to nitrogen as sewage passes through the soil under the drain field. Nitrogen in the form of NH_4-N and organic nitrogen in the septic tank was nitrified to nitrate nitrogen under aerobic conditions in most of the systems. Nitrification did not occur in one drain field that was completely saturated and had anaerobic conditions present. No significant denitrification occurred in these systems and concentrations of nitrate nitrification in the water below the system averaged between 43 and 110 mg/L. A second study, II. Ground Water Quality, showed concentrations of as much as 40 mg/L nitrate nitrogen under drain fields. Dilution and dispersion of these concentrations to an acceptable 10 ppm nitrate nitrogen level did not occur until a distance of 231 feet from the disposal system.

14. United States Environmental Protection Agency, 1980. *Design Manual, On Site Wastewater Treatment and Disposal Systems*. Provides data on nitrate nitrogen in relation to onlot disposal and provides a discussion of denitrification treatment methods.

15. United States Environmental Protection Agency, 1975. *Process Design Manual for Nitrogen Control*. Provides information as to nitrification/denitrification and treatment systems available for denitrification.

16. Robertson, W. D. and Chorry, J. A., 1995. In situ Denitrification of Septic-System Nitrate Using Reactive Porous Media Barriers: Field Trails. *Ground Water*, (January-February 1995) Vol. 33, No. 1, page 99. A study of saturated silt/sawdust/sand layered porous media barriers.