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Juniata River Subbasin Small Watershed Study: Morrison Cove

A Water Quality and Biological Assessment, April 2005 - February 2006

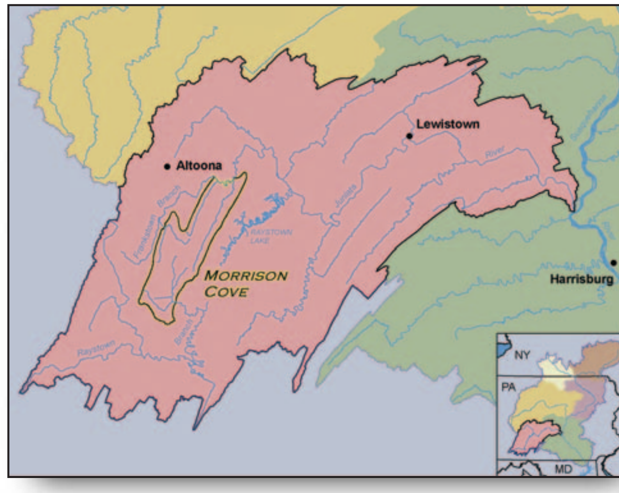


Figure 1. *Morrison Cove Location in the Juniata River Subbasin*

The Susquehanna River Basin Commission (SRBC) completed a water quality survey in the Morrison Cove (Cove) region from April 2005 through February 2006 as part of the Year-2 small watershed study in the Juniata River Subbasin (Figure 1). The Year-1 survey of the entire Juniata Subbasin was conducted from June to November 2004 (LeFevre, 2005). SRBC selected the Morrison Cove region for the more intensive Year-2 study based on the data collected in the Year-1 survey, and the fact that SRBC identified the Roaring Spring area in Morrison Cove as a Potentially Stressed Area in 2005.

Two primary goals were established for this Year-2 study. The first goal was to provide chemical, biological, and habitat data to state and local government entities, watershed organizations, local citizens, and other interested parties. The second goal was to characterize the hydrology of this area using chemical information, which can be used as a baseline for future groundwater studies and assist SRBC staff with project review activities. The Year-2 survey included quarterly water chemistry sample collection, discharge measurements, and a macroinvertebrate community and habitat assessment. This report was partially funded by a grant from the U.S. Environmental Protection Agency (USEPA).

For more information on SRBC's Subbasin Survey Program, see reports by LeFevre (2003), LeFevre (2004), and LeFevre (2005). These reports are posted on SRBC's website at *http://www.srbc.net/docs/Publications/techreports.htm.*

Waterfalls near the mouth of Cabbage Creek.

Description of the Morrison Cove Valley

Morrison Cove is a 186-square-mile valley surrounded on all sides by distinct ridges and located in Bedford and Blair Counties in central Pennsylvania (Figure 1). Morrison Cove is located within Ecoregion 67 - the Central Appalachian Ridges and Valleys, which is characterized by almost parallel ridges and valleys formed by folding and faulting events. The predominant geologic materials include limestone, dolomite, sandstone, shale, and siltstone. Within Ecoregion 67, the Morrison Cove valley is in subecoregion 67a - Northern Limestone/ Dolomite Valleys, while the ridges that surround the Cove are in subecoregion 67c - Northern Sandstone Ridges.

The underlying geology of Morrison Cove is folded bedrock that primarily consists of Cambrian and Ordovician age limestone and dolomite. The ridges around the valley consist of sandstones, siltstones, and shale (Figure 2). The limestone and dolomite in the valley are easily weathered, and the elemental compositions of those rock types, calcium and magnesium, often are found in the water. Because carbonate rocks are soluble in water, underground rock is dissolved, leaving channels and conduits that allow for high yielding aquifers. Groundwater in carbonate areas also augments stream flow, which enables relatively stable surface flow even during dry periods.

The Morrison Cove valley contains a number of large subwatersheds: Halter, Yellow, Clover, and Piney Creeks. The Halter Creek Watershed, which includes Plum and Cabbage Creeks, empties into the Frankstown Branch of the Juniata River. Piney and Clover Creeks also flow north, and both empty directly into the Frankstown Branch. Yellow Creek flows south and empties into the Raystown Branch of the Juniata River. Most of the Halter Creek Watershed is contained in the Morrison Cove valley, along with all of Piney and Clover Creeks. The upstream half of Yellow Creek also is included in the Cove.

Figure 2. *Geology and Sampling Site Locations in Morrison Cove*

The largest population centers in Morrison Cove are Roaring Spring, in the downstream reaches of Halter Creek Watershed, and Martinsburg, in the headwaters of Plum Creek. Yellow Creek flows through the small towns of Woodbury and Waterside, and then exits the Cove just east of Loysburg. The dominant land use in the Morrison Cove valley is agriculture, which accounts for about 55 percent of the Cove by area, followed by forested land at approximately 40 percent. Developed areas make up slightly more than one percent of the entire valley. State game lands encompass more than 2,000 acres in the middle of the Cove, in the headwaters of Potter and Yellow Creeks (Figure 3).

Other Studies

Beginning in early 2000, numerous studies have been done on smaller scales within the Morrison Cove region. The U.S. Geological Survey (USGS) published a report in 2004 on a study completed in the Martinsburg area. The purpose of the USGS study was to define the sources of water and contaminants, specifically nitrates, to the wells that serve as Martinsburg's public water supply. The results showed that animal manure was a possible primary source of nitrate in most groundwater, although there was some evidence that chemical fertilizers also were a possible source (Lindsey and Koch 2004).

A preliminary assessment on Potter Creek, sponsored by the Coldwater Heritage Partnership, was prepared by the Southern Alleghenies Conservancy and released in early 2005. The issues and concerns raised in that report include: erosion and sedimentation; possible sewage leaks; lack of adequate riparian buffers; habitat fragmentation; and development.

Blair County Conservation District currently is assessing Piney Creek through a Coldwater Heritage Grant. Results from that assessment project were not yet available at the time SRBC produced this publication. The initial Piney Creek Assessment and Conservation Plan, which identified sedimentation, nutrients, bacteria, and illegal trash dumping as the main concerns and threats to water quality in Piney Creek Watershed can be found at *www.blairconservationdistrict.org/Piney%20Creek%20 Watershed.htm*. Only one small reach of Piney Creek is currently listed as impaired, due to siltation, in accordance with the Pennsylvania Department of Environmental Protection's (PADEP) 2004 Integrated List of All Waters.

SRBC also sampled eight sites in Morrison Cove during the Juniata Year-1 Subbasin Survey project (see LeFevre, 2005 for more details). As would be expected, the water quality data were quite similar to what was found for this Year-2 study. There were no additional parameters exceeding water quality standards, although elevated nitrate concentrations were found in both the Year-1 and this Year-2 studies.

Figure 3. *Land Use and Sampling Site Locations in Morrison Cove*

View of agricultural land in Clover Creek Watershed.

Methods

DATA COLLECTION

Between April 2005 and February 2006, SRBC collected quarterly water chemistry samples and measured flow at 23 stream sites and 10 springs. Macroinvertebrate samples were collected, and habitat assessments were completed at the stream sites in April 2005. Appendix A contains a list of station names, sampling location descriptions, drainage areas, and latitude and longitude coordinates. Spring sites are listed below the stream sites and are in red. The sampling sites were selected so that biological, water quality, and habitat data from specific stream segments could be collected as well as water quality information for several spring sources throughout the Cove. Greater emphasis was placed on Halter Creek Watershed because it is located in the potentially stressed groundwater area of Roaring Spring. Ten stream sites and five springs were located in the Halter Creek Watershed. The information collected from the stream segments allowed for the determination of lengths and severity of impacted streams.

Taking a flow measurement in Plum Creek.

Water chemistry samples were collected in April 2005, July 2005, October 2005 and January/February 2006 and analyzed for field and laboratory parameters (Table 1). Water was collected using a hand-held depth integrated sampler at six verticals across the stream channel. The water was put into a churn splitter, mixed thoroughly, and split into a 125-ml bottle acidified with nitric acid for metals and a 500-ml bottle for all additional parameters. The remaining water was used to complete the field chemistry analyses. Temperature was measured in degrees Celsius with a field thermometer. A Cole-Parmer Model 5996 meter was used to measure pH. Conductivity was measured with a Cole-Parmer Model 1481 meter, and dissolved oxygen was measured with a YSI 55 meter. Field alkalinity was determined by titration of a known volume of sample water to pH 4.5 with 0.02N H_2SO_4.

Table 1. *Water Quality Parameters Sampled in Morrison Cove*

FIELD PARAMETERS	
Flow, instantaneous cfs[a]	Conductivity, µmhos/cm[b]
Temperature, °C	Alkalinity, mg/l
Dissolved Oxygen, mg/l[c]	
pH	
LABORATORY ANALYSIS PARAMETERS	
Total Nitrate, mg/l	Total Sulfate, mg/l
Total Hardness, mg/l	Total Potassium, mg/l
Total Magnesium, mg/l	Total Calcium, mg/l
Total Sodium, mg/l	Total Silica, mg/l
Total Chloride, mg/l	Alkalinity, mg/l

[a] cfs = cubic feet per second
[b] µmhos/cm = micromhos per centimeter
[c] mg/l = milligram per liter

Flow at stream locations and in tributaries from large springs was measured using a Scientific Instruments pygmy or AA meter according to the USGS methods (Buchanan and Somers, 1969). At smaller springs and tributaries, where it was impossible to use a flow meter, a bucket with a known volume and a stopwatch were used to estimate flow. Numerous tributaries and springs were dry at different times during the sampling period due to below normal precipitation during the summer and fall.

In April 2005, staff sampled 22 stations in Morrison Cove for benthic macroinvertebrates (organisms that live on the stream bottom, including aquatic insects, crayfish, clams, snails, and worms), using a modified version of Rapid Bioassessment Protocol III (Barbour and others, 1999). Two kick-screen samples were obtained at each station by disturbing the substrate of representative riffle/run areas and collecting dislodged material with a one-meter-square 600-micron mesh screen. Each sample was preserved in 95 percent denatured ethyl alcohol and returned to SRBC's lab, where the entire sample was picked and sorted into a subsample of at least 200 organisms. The remainder of the sample was examined for additional taxa that were not in the 200-count subsample. This enumeration of additional taxa was performed due to low diversity in the samples, which is characteristic of limestone streams. Organisms were identified to genus, except for midges and aquatic worms, which were identified to family.

Habitat conditions were rated using a modified version of RBP III (Plafkin and others 1989; Barbour and others, 1999). Stream sites were evaluated based on physical characteristics relating to pool and riffle composition, substrate, conditions of banks, and the extent of the riparian zone. Each habitat parameter was assessed on a scale of 0-20, with 20 being optimal; and all parameter scores were added together to generate the total habitat score for each site. Other field observations also were recorded regarding weather, land use, and substrate composition, as well as any other relevant watershed features.

DATA ANALYSIS

Water quality at stream sites was assessed by examining field and laboratory parameters, including major ions and nutrients. The data were compared to water chemistry values at a level of concern based on current state and federal regulations or references for reported tolerances of aquatic life (Table 2). When both laboratory and field values existed for the same parameter, the laboratory value was used in the analysis. The difference between the yearly average value for each parameter and the level of concern for that parameter was calculated for each site. If the value did exceed the level of concern, the difference was listed; if not, then the site was given a score of zero. For each site, the sum of all the exceeded values was calculated and averaged by the number of parameters.

Sites with a water quality score between 0-0.40 were classified as "higher" quality. Sites between 0.41-0.70 were classified as "middle" quality. Water quality scores between 0.71-1.0 were given the ranking of "lower" quality. Any site with a value more than 1.0 was classified as "poor" quality. Although there are aquatic life standards for magnesium and total hardness, these two parameters were not included in the water quality analysis due to the naturally high hardness of the streams, resulting from the underlying geology of Morrison Cove. For the water quality calculations, an average of the seasonal values for each parameter at each location was used.

Benthic macroinvertebrate samples were analyzed using six metrics mainly derived from RBP III (Plafkin and others, 1989; Barbour and others, 1999): (1) taxonomic richness; (2) modified Hilsenhoff Biotic Index; (3) percent Ephemeroptera; (4) number of Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa; (5) percent Chironomidae; and (6) Shannon-Wiener Diversity Index. Four reference categories were developed for the macroinvertebrate data analysis based on drainage size and origin. Two of the sites had drainage areas less than 1-square-mile and were separated from the others not only for size, but also because they originated on forested ridges while the other sites were in the valley area. Eight of the sites had a drainage area less than 10 square miles, seven of the sites had a drainage area from 10 to 20 square miles, and five sites had a drainage area greater than 20 square miles.

Reference sites were determined for each reference category, primarily based on the results of the macroinvertebrate metrics and secondarily based on habitat and water quality scores, to represent the best combination of conditions. The reference sites were T2 (tributary to Halter Creek) for the forested ridge tributaries, Y1 (Hickory Bottom Creek) for less than a 10-square-mile drainage, Y3 (Potter Creek) for 10 to 20 square miles, and C1 (Clover Creek) for greater than 20 square miles.

The metric scores for each site were compared to the reference scores, and a biological condition category was assigned based on RBP III methods (Plafkin and others, 1989; Barbour and others, 1999). The same reference sites were used in the analysis for the habitat scores. The ratings for each habitat parameter were totaled, and a percentage of the reference site was calculated. The percentages were used to assign a habitat condition category to each stream site (Plafkin and others, 1989; Barbour and others, 1999).

Table 2. *Water Quality Levels of Concern and References*

PARAMETER	LIMIT	REFERENCE CODE
Temperature	> 25 °C	a,e
Dissolved Oxygen	< 4 mg/l	a,g
Conductivity	> 800 µmhos/cm	c
pH	< 5.0	b,e
Alkalinity	< 20 mg/l	a,f
Total Nitrate	> 1.0 mg/l	d
Total Hardness	> 300 mg/l	d
Total Magnesium	> 35 mg/l	g
Total Sodium	> 20 mg/l	g
Total Chloride	> 150 mg/l	a
Total Sulfate	> 250 mg/l	a
Total Potassium	None	
Total Calcium	None	
Total Silica	None	

REFERENCE CODE & REFERENCES

a http://www.pacode.com/secure/data/025/chapter93/s93.7.html
b Gagen and Sharpe (1987) and Baker and Schofield (1982)
c http://www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm
d http://www.uky.edu/WaterResources/Watershed/KRB_AR/krww_parameters.htm
e http://www.hach.com/h2ou/h2wtrqual.htm
f http://sites.state.pa.us/PA_Exec/Fish_Boat/education/catalog/pondstream.pdf
g http://www.dec.state.ny.us/website/regs/part703.html

TAXONOMIC RICHNESS: Total number of taxa in the sample. Number decreases with increasing stress.

HILSENHOFF BIOTIC INDEX: A measure of organic pollution tolerance. Index value increases with increasing stress.

PERCENT EPHEMEROPTERA: Percentage of the number of Ephemeroptera (mayflies) in the sample divided by the total number of macroinvertebrates in the sample. Percentage decreases with increasing stress.

PERCENT CONTRIBUTION OF DOMINANT TAXA: Percentage of the taxon with the largest number of individuals out of the total number of macroinvertebrates in the sample. Percentage increases with increasing stress.

EPT INDEX: Total number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies) taxa present in a sample. Number decreases with increasing stress.

PERCENT CHIRONOMIDAE: Percentage of number of Chironomidae individuals out of total number of macroinvertebrates in the sample. Percentage increases with increasing stress.

SHANNON-WIENER DIVERSITY INDEX: A measure of taxonomic diversity of the community. Index value decreases with increasing stress.

Water quality at the spring sites was evaluated by comparing the data to state drinking water standards or Maximum Contaminant Loads (MCLs) (Table 3). (Not all drinking water parameters were analyzed in this study, but of those that were analyzed the only one that exceeded the standards in any of the springs was nitrate). Spring sites were ranked in order of their average concentrations of nitrate. Water quality data from springs also were used for water typing analysis.

Water typing was performed using a variety of methods to determine the origination of water for each of these springs. Sites were ranked based on calcium/magnesium (Ca^{+2}/Mg^{+2}) ratios, as well as concentrations of major ions, in order to group stream sites and springs by their water chemistry signatures. Additionally, a ternary plot was used to group sites with similar concentrations of major ions together. By using this information and comparing the data to previous studies done on the characteristics of groundwater in carbonate aquifers, some conclusions were made as to which streams and springs have water from a similar origin.

Table 3. *Pennsylvania Drinking Water Standards*

PARAMETERS	LIMITS	REFERENCE CODE
Nitrate	10 mg/L	a
Chloride	250 mg/L	a
Sulfate	250 mg/L	a
pH	6.5 - 8.5	a

REFERENCE CODE & REFERENCE

a www.depweb.state.pa.us/watersupply/lib/watersupply/pa-mcls_05.pdf

Results and Discussion

Water quality, macroinvertebrate, and habitat conditions for each stream sampling site in the Morrison Cove region are depicted in Figure 4. Two sites demonstrated the best overall conditions in each category with "higher" water quality, non-impaired macroinvertebrates and excellent habitat. Four sites did not exceed water quality levels of concern and were considered as "higher" water quality sites. Thirteen sites slightly exceeded levels of concern and received a "middle" water quality designation, while four sites considerably exceeded levels of concern and were given a "lower" water quality designation. The remaining two sites were classified as "poor" water quality, as they were considerably worse than the "lower" designation. Habitat conditions throughout Morrison Cove were rated highly overall. Fifteen sites were rated as excellent (68 percent), supporting habitat was found at five sites (23 percent), one site (4.5 percent) was rated as partially supporting, and one site (4.5 percent) was non-supporting. Of all the individual samples that were collected, 80 percent of the values exceeding water quality levels of concern were of nitrate. Another 12 percent of the exceedances were of sodium, while conductivity, alkalinity, and chloride accounted for the remaining few exceeding values (Figure 5).

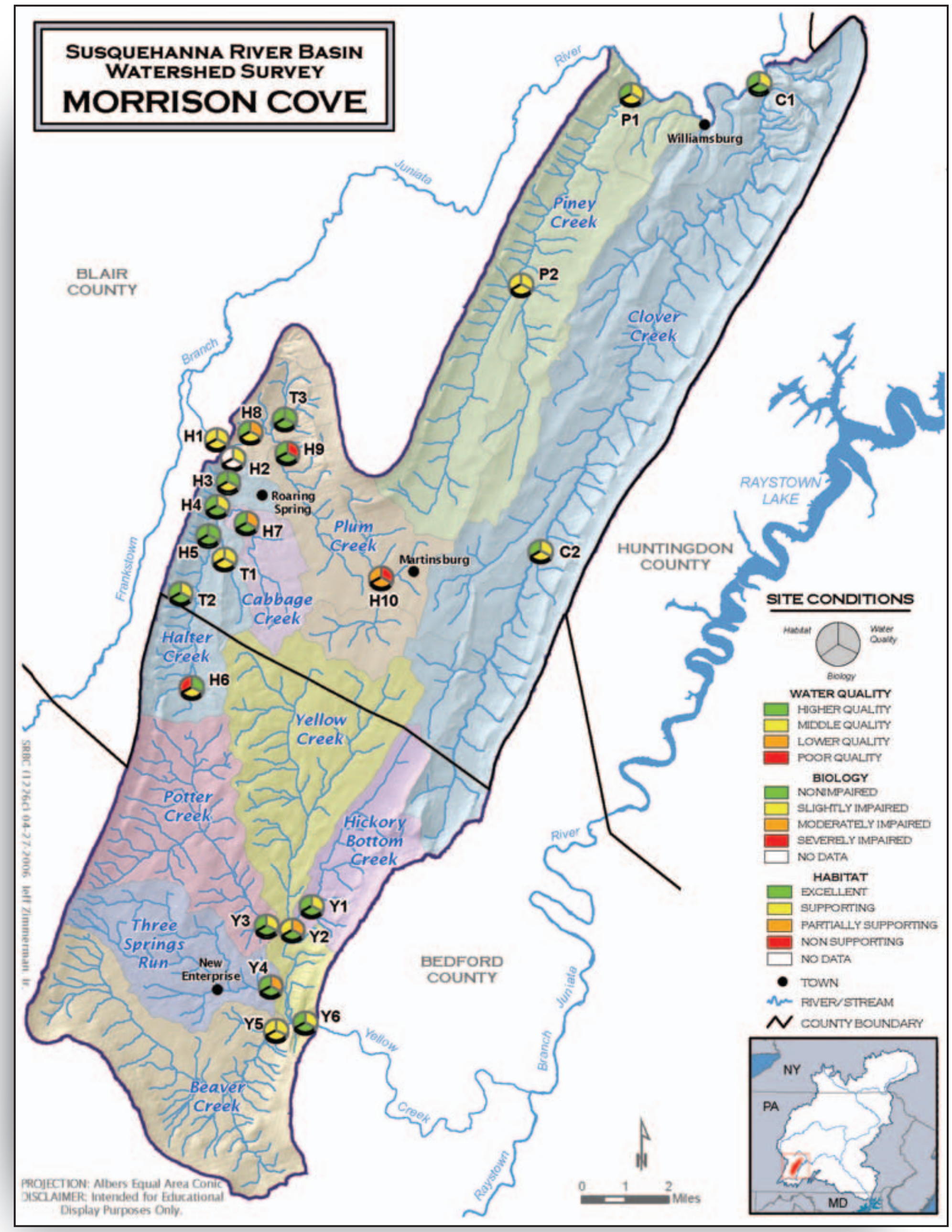


Figure 4. *Subwatersheds and Site Conditions at Each Sampling Site in Morrison Cove*

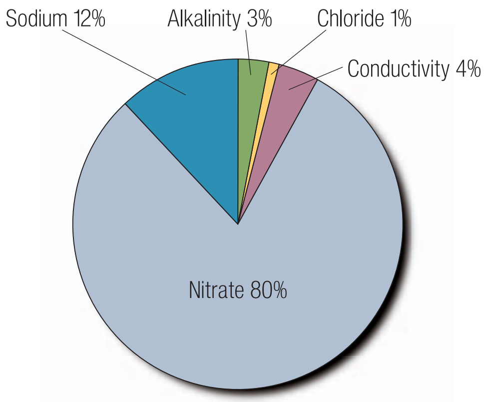


Figure 5. *Percentage of Water Quality Parameters Exceeding Levels of Concern in Morrison Cove Streams*

MACROINVERTEBRATES

The macroinvertebrate populations that commonly are found in limestone streams or limestone influenced streams have unique characteristics. These populations are often abundant, dominated by a few taxa such as *Ephemerella* (mayfly), Amphipoda (freshwater crustacean), Isopoda (freshwater crustacean), and Chironomidae (midges), but do not usually have many stonefly taxa. Limestone streams tend to be low gradient and are characterized by constant temperatures, high alkalinity, and an abundance of aquatic plants. The limestone streams in Morrison Cove tended to be dominated by *Ephemerella*, *Gammarus* (Amphipoda), *Baetis* (mayfly), and Chironomidae. Stoneflies were sparse in the limestone sections of the streams, although healthy populations of stoneflies existed in the tributaries that originated on the ridges. Due to the slope and rockiness of the ridges, these streams had more riffles and aeration of the water, which is a habitat characteristic favorable to stoneflies. Due to the low diversity and dominance by a few taxa in these streams, all the taxa were accounted for in each sample in order to discriminate further between streams.

By comparing the stream sites in Morrison Cove to the reference stations chosen within the watershed, there were 12 nonimpaired stations (54.5 percent), nine slightly impaired stations (41 percent), one (4.5 percent) moderately impaired station, and no severely impaired stations. A comparison to the sampling results from the Year-1 study (LeFevre, 2005) indicated that six of the eight sites sampled for that report were different in their biological conditions categories. Furthermore, these differences were consistently showing better conditions during this Year-2 study period than noted by LeFevre (2005). This phenomenon was likely due to the inclusion of additional taxa in the sub-sampling of the April 2005 samples and may also be due to comparison to reference sites only within the Morrison Cove area. Another potential factor that may have caused differences between the results of the Year-1 and Year-2 study was a dramatic difference in flow. The six stream locations that were sampled both years had an average of 40 percent less flow in 2005 than they did in 2004 during the same season.

Since many of the streams sampled were limestone or limestone-influenced and had similar macroinvertebrate composition, the number of mayfly and stonefly taxa present were used to differentiate between similar sites. The sites with six or seven mayfly taxa included one of the unnamed tributaries to Halter Creek (T2), the tributary to Plum Creek (T3), the mouth of Clover Creek (C1), a middle reach site on Halter Creek (H5), and three sites in the Yellow Creek basin: the downstream site on Yellow Creek, Potter Creek and Hickory Bottom Creek (Y6, Y3, and Y1, respectively). All these sites also had stoneflies present. Although, stoneflies are generally either present in low numbers or absent from limestone streams, the tributaries from the forested ridges that surround Morrison Cove served as sources of stoneflies for these streams. Both tributaries coming from the ridge to Halter and Plum Creeks (T2 and T3) had three or more stonefly taxa, as did the mouth of Clover Creek (C1), a middle reach of Halter Creek (H4) and the downstream site on Yellow Creek (Y6).

WATER QUALITY

Excess nitrates can reach groundwater or surface water by leaching through the soil and running off the land surface. The rate at which the nitrates leach is affected by factors including the type of soil, the amount of rainfall, and type of plant cover. Excess nitrates in groundwater and surface water are undesirable because of their adverse impacts on the environment, as well as their potential to be detrimental to human health (Grossman, 2000). The environmental effects of excess nitrate include eutrophication, which is an overabundance of nutrients that results in increased algal growth, depleted oxygen levels, and a decline in aquatic life. In this study, total nitrate-n exceeded the level of concern 101 times, which accounted for 80 percent of the total exceedances. The values set for nitrate-n (1.0 mg/l) are based on natural background conditions as opposed to aquatic life tolerances. Therefore, values greater than 1.0 mg/l suggest the presence of anthropogenic nitrate sources such as agriculture, fertilizers, or failing septic tanks. Nutrient standards or levels of concerns for aquatic life have not yet been developed in Pennsylvania.

There are also significant human health effects associated with drinking water that contains high levels of nitrate, especially for children and pregnant women. The current USEPA standard for nitrate concentration in drinking water is 10 mg/l. Morrison Cove, specifically the Martinsburg area, currently is facing some of the problems and complications that stem from excess nitrates in the local groundwater system (for more information, see Lindsey and Koch, 2004). The entire Morrison Cove region is primarily made up of agriculture and low-density residential land uses. As a result, fertilizers, animal manure and on-lot septic systems are all potential

"A study by the Pennsylvania Department of Agriculture reported that about 35 percent of the wells sampled in the Morrison Cove valley had nitrate levels exceeding the MCL of 10 mg/l."

sources of nitrate that cause concentrations to be elevated and approach or exceed the 10 mg/l MCL (Lindsey and Koch, 2004). A study by the Pennsylvania Department of Agriculture reported that about 35 percent of the wells sampled in the Morrison Cove valley had nitrate levels exceeding the MCL of 10 mg/l (Lindsey and Koch, 2004).

HABITAT

The habitat assessment in Morrison Cove showed some general trends among many of the streams. The biggest habitat problems throughout the Cove were channel alteration, sedimentation, and a lack of riparian zone and vegetative bank cover. The upstream sites on both Halter and Plum Creeks had the poorest habitat rating, while the middle reaches on both these streams tended to have higher habitat scores. In Yellow Creek Watershed, habitat scores varied greatly due to differences in riparian buffers, severity of sedimentation, and availability of epifaunal substrate. Piney and Clover Creeks generally had good habitat assessments, although riparian buffers were lacking at both upstream sites.

Halter Creek

The Halter Creek Watershed accounts for about 30 percent of the Morrison Cove region. The entire watershed currently is designated as Warm Water Fishes (WWF) by the Commonwealth of Pennsylvania (PA Code, Chapter 93.9n). The land use in the upper reaches of Halter Creek is primarily agricultural crop land. The land use surrounding the lower reaches of Halter Creek is mainly developed land: residential, commercial, and industrial. This includes a paper mill, a wastewater treatment plant, a water bottling company, and a quarrying operation. The town of Roaring Spring is the largest municipality in the Halter Creek Subbasin. The middle reaches of Halter Creek are the most protected sections of the stream with more extensive forested riparian buffers.

Within the boundaries of Morrison Cove, the downstream two miles of Halter Creek are impaired due to urban and industrial runoff and storm sewer problems. Halter Creek was placed on the Section 303(d) list of impaired waters in 1998 (PADEP 2004). The water chemistry in upstream reaches of Halter Creek was different than that in downstream reaches due to differences in adjacent and upstream geology and land use. Of the macroinvertebrate communities sampled in the Halter Creek Watershed, six were nonimpaired sites, five were slightly impaired sites, and one was moderately impaired.

The water quality in the headwaters (H6) of Halter Creek was greatly influenced by the tributaries coming off of the western sandstone ridge. This water was characterized by low alkalinity, low hardness, and low conductivity. Among the parameters that were analyzed for this project, H6 had no values exceeding water quality standards and was classified as "higher" water quality. However, the habitat condition was determined to be non-supporting with a biological condition of slightly impaired. This site was highly dominated by Chironomidae and had a very low percentage of Ephemeroptera. The land use in the area was predominantly agriculture, and there was no protective vegetative riparian zone surrounding the stream. The lack of suitable habitat had a negative effect on the macroinvertebrate community despite suitable water quality.

Numerous tributaries come into Halter Creek off the western ridge. One of these tributaries (T2) was sampled, and biological and habitat conditions were both ranked at the highest level, nonimpaired and excellent, respectively. The biological community had a high diversity with an excellent representation of mayflies and stoneflies. The water quality was classified as "middle" quality, due primarily to low alkalinity. However, this is not unusual for streams coming off sandstone ridges.

Confluence of Plum Creek with Halter Creek.

An unnamed tributary (T1) comes into Halter Creek above H5 and flows from the carbonate valley that makes up the center part of Morrison Cove. The water chemistry at T1 was "middle" quality and was generally representative of the dolomite geology from which it originated, specifically having high hardness and high magnesium concentrations. Nitrates also were elevated at this site. The habitat was rated as supporting with a slightly impaired biological condition. T1 is a limestone stream and was highly dominated (71.7 percent) by *Gammarus*. This tributary is quite small and its streambed is comprised mostly of sand. The riparian buffer around the sampling site was good, but upstream it flowed through multiple residential lawns.

The next downstream site on the mainstem of Halter Creek was H5, which was upstream of the confluence of Cabbage Creek with Halter Creek. The water chemistry at this site was rated as "higher" quality. There was also excellent habitat and a nonimpaired macroinvertebrate community. This site had six taxa of mayflies with *Baetis* being the dominant taxa in the sample. It was ranked the highest of all the Halter Creek sites.

Originating in the dolomite geology, Cabbage Creek (H7) contributed high hardness and magnesium to Halter Creek. However, H7 also provided an increase in nitrates, chloride, and conductivity, all of which are associated with anthropogenic activity. As a result, Cabbage Creek was classified as having "lower" water quality. Despite the somewhat degraded water quality at the time of sampling, the biological condition was rated as nonimpaired, which was tied to its excellent habitat rating. Cabbage Creek exhibited characteristics of a limestone stream with *Gammarus* being the dominant taxa. Due to the geology of the area, there was a waterfall near the mouth where samples were taken, which is an unusual feature for a limestone stream. Three taxa of mayflies and one stonefly taxon were identified at this site. Cabbage Creek significantly changes the water chemistry of Halter Creek.

The Halter Creek site downstream of the confluence with Cabbage Creek (H4) had a drop in water quality from "higher" to "middle" quality. The biological condition remained nonimpaired. The macroinvertebrates at H4 also showed the influence of Cabbage Creek with an increase in *Gammarus* and a slight increase in stonefly taxa, possibly due to the waterfall increasing the dissolved oxygen levels in the stream. Habitat was excellent based partially on above average instream cover and riparian buffer.

The next reach of Halter Creek runs through the town of Roaring Spring. The site (H3) is downstream of a large portion of the town, as well as a small sewage treatment facility. The water quality at this site is rated as "higher" with an excellent habitat rating. Although not exceeding water quality standards, the concentration of chloride was twice what it was upstream. Additionally, the concentration of sodium doubled through this reach, and slightly exceeded the water quality standard. The biological condition at this site was determined to be slightly impaired, and taxa richness dropped from 28 at the upstream site (H4) to 14 at this site (H3). While sampling, it was noted that paper pulp was clogging the net, which may have impacted the macroinvertebrate population sample.

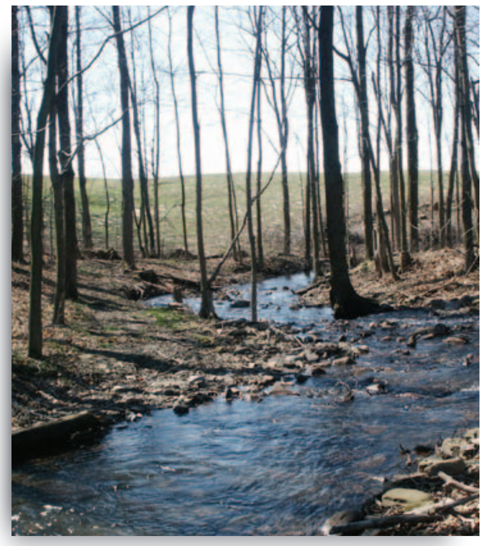
"The last mile of Plum Creek is impaired due to runoff and siltation and was placed on the Section 303(d) list in 2002."

At H2, which is upstream of the confluence with Plum Creek, the water quality was similar to H3, except that the sulfate concentration tripled. The highest sulfate concentration recorded at this site was 64 mg/l in February 2006. A major highway and a large quarrying operation are located between these two sites, which may have contributed to this elevated sulfate level. Although sulfate did not exceed the water quality standard, such a large increase in a short stream reach (< 1 mile) could be cause for concern. The water quality at this site was rated as "middle" quality. There is no habitat or biological data for this location due to its close proximity to H8, as well as access problems and lack of riffle habitat. The most downstream site sampled on Halter Creek, H1, was downstream of Plum Creek and is representative of the water that is flowing out of the Morrison Cove valley and into the Frankstown Branch of the Juniata River. The water quality at H1 was determined to be "middle" quality with a supporting habitat condition. The biological community was rated as slightly impaired and was dominated by *Baetis*, had no stoneflies, and contained only two taxa of mayflies.

Plum Creek, the largest tributary to Halter Creek, enters directly below Halter Creek site H2. The upper reaches of Plum Creek are largely spring fed and flow through agricultural crop lands with a small amount of low density residential development scattered throughout. The last mile of Plum Creek is impaired due to runoff and siltation and was placed on the Section 303(d) list in 2002 (PADEP, 2004). There were three sampling sites on the mainstem of Plum Creek as well as one tributary site.

The most upstream site on Plum Creek was H10, which was located adjacent to the Borough of Martinsburg. This was the only site to receive a moderately impaired biological rating. The macroinvertebrate community was highly dominated by Planariidae (flatworms, planarians), and there were no mayflies, stoneflies, or caddisflies. The water chemistry revealed "poor" water quality, due to high conductivity and elevated concentrations of nitrate and sodium. Sodium concentrations were two times the water quality standard, with an average concentration of 41 mg/l for the year. Additionally, H10 had the highest values of any of the stream sites for a number of other parameters: calcium, chloride, hardness, and silica, as well as the lowest dissolved oxygen value. Habitat condition was rated as partially supporting due to insufficient riparian buffer, degraded bank conditions, and very mucky substrate. Site H10 also potentially was impacted by suburban and industrial run-off, as it was located downstream of residential developments and a school, and directly downstream of a book binding plant.

Downstream at H9, significant improvement was noted as the biological rating improved to nonimpaired. There were 10 taxa of mayflies, stoneflies, and caddisflies, and the sample composition was 54 percent mayflies (mostly *Baetis*). Interestingly, H10 and H9 were the only sites to have the Amphipoda taxon of *Crangonyx*, which had individuals present in higher numbers at H10 than H9. Although the water quality did improve slightly from H10 to H9, it was still evaluated as "poor" quality, due to high concentrations of nitrate and sodium, both exceeding water quality standards. This site also had the highest values of alkalinity (334 mg/l), potassium (11.9 mg/l), and pH (8.6). However, the habitat at this site was rated as excellent, as it had a well developed riffle area and abundant instream cover.



Forested tributary to Plum Creek off the northern sandstone ridge of Morrison Cove.

Numerous tributaries enter Plum Creek from the northern, forested, shale and sandstone ridges. One of these tributaries was sampled (T3) and was ranked in the highest water quality, biological, and habitat categories. The biological condition rating for this site was nonimpaired, and the diverse community included numerous mayfly and stonefly taxa. The water quality at T3 was rated as "higher" quality and was typical for water originating from a sandstone ridge. The water chemistry was similar to the water quality of T2 on Halter Creek. The habitat at this site was rated as excellent with above average epifaunal substrate and instream cover and well-developed riffles.

The station at the mouth of Plum Creek (H8) showed some improvement in water quality but was ranked in the "lower" water quality grouping. The biological condition was rated as slightly impaired, and diversity was lower than at the upstream site (H9). The habitat was rated as excellent, although it lacked a protective riparian zone on one side where the stream was very close to the road. The last half mile of Plum Creek runs adjacent to a quarrying operation that may have an impact on water quality in Plum Creek, as well as Halter Creek. In Plum Creek, sodium, chloride, and conductivity all decreased from upstream to downstream. However, nitrate was high at all three sites. This likely was related to the amount of agriculturally based land use in the sub-watershed. Also, Plum Creek is largely a spring-fed stream, and the groundwater in the surrounding aquifers has high nitrate concentrations (Lindsey and Koch, 2004).

Clover and Piney Creeks

The watersheds of Clover and Piney Creeks make up about 27 percent and 14 percent of Morrison Cove, respectively. These two streams flow almost parallel north and empty directly into the Frankstown Branch of the Juniata River. They are both currently designated as High Quality - Cold Water Fishes (HQ-CWF) (PA Code Chapter 93.9n). The main channels flow through primarily agricultural land and are influenced by ridge geology from tributaries and by the limestone valley they share between those ridges. Both are located in very rural areas, with no large population centers. Because of these similarities, the water quality and habitat ratings at the two sites on each stream differ only slightly.

Both the upstream (P2) and downstream (P1) sites on Piney Creek were rated as having "middle" water quality, slightly impaired biological condition, and excellent habitat. The two sites on Clover Creek (C1 and C2) both had "middle" water quality and excellent habitat conditions. However, the upstream site, C2, had a slightly impaired biological condition, while the site at the mouth, C1, was determined to be nonimpaired biologically. C1 had a higher diversity and abundance of mayflies and two stonefly taxa, whereas the other sites did not contain stoneflies. The only parameter of concern in Piney and Clover Creeks is nitrate, which is likely due to the fact that the land use in these watersheds is 50 percent agriculture.

Collecting macroinvertebrates in the upstream reaches of Clover Creek.

Yellow Creek

The Yellow Creek Watershed comprises the remaining 30 percent of the Morrison Cove valley. Although some of the headwaters are located in forested areas, the mainstem of Yellow Creek flows through generally low lying agricultural land and receives water from four large tributaries. The entire Yellow Creek Basin and all the tributaries included in the Cove are currently designated as HQ-CWF. With the exception of one small segment of Potter Creek, the entire Morrison Cove portion of the Yellow Creek Basin is impaired for nutrients and siltation from agriculture. Yellow Creek and all the sampled tributaries were listed as impaired on PADEP's 2004 Integrated List of All Waters (PADEP, 2004). Two sites were sampled on the mainstem of Yellow Creek, and additional sites were sampled at the mouths of each of the four tributaries that join Yellow Creek within the Cove. The stations sampled in the Yellow Creek Watershed were all nonimpaired biologically, except for Y5 in Beaver Creek, which was rated slightly impaired.

Hickory Bottom Creek, flows into Yellow Creek from the northeast and is the smallest of the four tributaries. The water quality at the site on Hickory Bottom Creek, Y1, was rated as "middle," due to an elevated nitrate concentration. The habitat condition was classified as excellent, and the biological condition was nonimpaired. This site was dominated by the organic pollution-tolerant mayfly taxon Baetis. However, this sample also had four other mayfly taxa and two stonefly taxa. In October, the middle reaches of Hickory Bottom Creek were dry. The sampling site was downstream of a spring flowing out of Hipple's Cave, which maintained flow in the lower reach of the creek. The first site on the mainstem of Yellow Creek, Y2, was upstream of the confluence of Potter Creek, and the water quality was rated as "lower" quality. The habitat was classified as supporting, but the biological condition was nonimpaired.

Yellow Creek as it flows out of Morrison Cove, east of Loysburg.

The macroinvertebrates included a mix of pollution-sensitive mayflies, stoneflies, and caddisflies.

Potter Creek flows into Yellow Creek from the northwest with much of its headwaters flowing through state game lands. The water quality at the Potter Creek site, Y3, was rated as "middle" quality, because of the elevated concentrations of nitrate. The biological condition was nonimpaired and was dominated by *Ephemerella*, with five other mayfly taxa and one stonefly taxon. This site also had one of the highest taxonomic richness scores with 28 taxa present. The habitat of Potter Creek was rated as excellent, and the stream had more widespread riparian buffer and instream cover than many of the other tributaries to Yellow Creek. Potter Creek also had a relatively constant temperature year round, which is an indication of a spring-fed stream.

Three Springs Run, like Potter Creek, originates in the carbonate valley in the center of Morrison Cove and receives a considerable amount of its flow from springs, but there are some differences in water quality at these two locations. The Three Springs Run site, Y4, had the highest levels of nitrates of all the steam sites in the Yellow Creek Watershed, which contributed to a water quality rating of "lower" for this site. Habitat at Y4 was considered to be excellent, and the macroinvertebrate community was classified as nonimpaired. Y4 contained numerous pollution-sensitive taxa and had one of the best Hilsenhoff Biotic Index scores and one of the highest Shannon Diversity scores of all the sampled locations. There were five mayfly taxa, but no stonefly taxa at this site. It was the only valley stream site to have the caddisfly taxon *Dolophilodes*, which is very pollution sensitive.

Beaver Creek joins Yellow Creek from the southern-most portion of the Cove and has numerous smaller tributaries that enter from the southern sandstone ridge. This resulted in slightly different water chemistry than the other Yellow Creek tributaries, specifically lower alkalinity and total hardness values. Site Y5, on Beaver Creek, ranked as "middle" class for water quality. Habitat condition was rated as supporting, and the biological community was slightly impaired. This site had the lowest taxonomic richness and diversity ratings, and the macroinvertebrate population had fewer sensitive taxa than the other sites in the Yellow Creek Watershed. Beaver Creek is heavily impacted by agriculture throughout much of its watershed.

Yellow Creek site Y6 was the last sampling location before Yellow Creek exits the southern end of Morrison Cove just east of Loysburg. The water chemistry this site was rated as "middle" quality while the habitat condition was excellent. This represents the water quality as it exits the Cove; however, Yellow Creek continues for nearly 10 miles outside the Cove before it empties into the Raystown Branch of the Juniata River. The biological condition at this site was determined to be nonimpaired and included a mix of pollution-sensitive mayflies, stoneflies, and caddisflies. This sampling location also had slightly more pollution-sensitive taxa and slightly higher diversity than the upstream site on the mainstem of Yellow Creek (Y2).

Springs

Springs are natural wells that discharge groundwater into a local stream and occur where the water table is at or above the land surface. Springs can occur in or above a stream's channel and in periods of low precipitation provide much of the flow. There are two main types of springs within a carbonate aquifer system such as Morrison Cove: diffuse and conduit. Diffuse springs are described generally as deep-moving groundwater and show little seasonal variation or response to rain events. Conduit springs arise from a shallower groundwater system, are more responsive to precipitation, and have a higher seasonal variation in discharge and water chemistry (McGinty, 2003). Ten springs were sampled at least once throughout the course of the project. The locations of these springs can be found in Figures 2 and 3.

Large spring (S10) flows into Three Springs Run.

Halter Creek Watershed Springs

The Cabbage Creek spring, S1, was a small tributary flowing out of a spring-fed area that included a pond and numerous seeps. The water quality was characterized by very high total hardness and alkalinity. The nitrate concentration in this spring was more than 10 mg/l each of the three times it was sampled. This site was dry during the October sampling period and so no sample was collected. The estimated flow ranged from 60 gallons per minute (gpm) to 220 gpm. The small spring, S2, that enters the unnamed tributary to Halter Creek, T1, was the smallest of all the springs sampled. It also was characterized by high alkalinity and hardness, as well as the highest silica concentration of any spring site. The flow from this spring was quite low at <1 gpm to 7 gpm but was flowing throughout the year.

There were three different springs sampled that flowed directly into Plum Creek. Along Weitzel Hill Road, there were two springs that converged and flowed into Plum Creek less than a mile from the mouth. The discharge from this spring complex, S3, varied greatly throughout the year, from <10 gpm to over 1,200 gpm. This spring had the highest single sample concentrations of total hardness and magnesium in February 2006. Interestingly, the sulfate concentration in this spring was three to four times higher than any other spring sampled in the Cove, with samples ranging from 64 – 77 mg/l.

The spring in the headwaters of Plum Creek, S4, was flowing only in April and January and was sampled at its emergent point near a culvert on a farm. This spring had the highest single concentration of nitrates at 16 mg/l in January. Additionally, this spring also had the highest single concentrations of chloride, potassium, and sodium and the highest conductivity of any spring sample taken during January. These high concentrations of sodium and chloride in the winter may be related to road salt application for de-icing purposes. It is probable that this spring is a shallow spring, is affected greatly by rainfall events, and responds quickly to leaching of road salts, fertilizers and manure into the ground.

The largest spring sampled was S5, which doubled the flow to Plum Creek when it entered downstream of the Brumbaugh Road crossing. This spring was very productive, discharging more than 2,200 gpm minute in January, and included a large marshy area with one distinct channel flowing into Plum Creek. This spring flows above limestone geology, which is reflected in the high concentrations of calcium in the water.

Yellow Creek Watershed Springs

The site that initially was called a spring in the headwaters of Hickory Bottom Creek, S6, is likely not an actual spring but rather a portion of an intermittent stream flowing off the sandstone ridge. It did not exhibit any of the characteristics of spring water, such as low dissolved oxygen or a consistent temperature throughout the year. However, it was sampled quarterly and provided an example of the characteristics of water flowing from sandstone and shale geology. This water was characterized by low concentrations of alkalinity, calcium, magnesium, and hardness.

Two springs flowed directly into Yellow Creek, and both were in the headwaters of the stream. One of the springs, S7, was flowing only during the April sampling event. The reason for this is unknown since it was discharging more than 200 gpm when it was sampled. The other Yellow Creek spring, S8, flowed from under a spring house about 50 yards from where the sample was collected. This spring was flowing all year and had a consistent flow that ranged from 40-60 gpm. Nitrate concentrations at S8 were above 10 mg/l in each of the quarterly samples.

Potter Creek is another spring-fed stream, and one of the larger of the many springs, S9, was sampled. This spring emerged from the remains of an old spring house and had a variable flow that ranged from 20 gpm in October to more than 200 gpm in April. The water chemistry at this site was characterized by naturally high alkalinity and high total hardness. The nitrate concentrations at this spring were greater than 10 mg/l during each of the four sampling events.

The final spring that was sampled, S10, flowed into Three Springs Run from a depression in a private lawn. The sample was taken as the water was coming out of the ground, which is evidenced by the low dissolved oxygen values and the constant temperature between 10-12 °C throughout the year. The discharge at this spring was fairly constant at approximately 100 gpm. Nitrate concentrations at this spring were approaching, but did not exceed, the 10 mg/l drinking water standard.

All springs were ranked by their average concentrations of nitrate throughout the sampling period (Figure 6). Five of the 10 springs had average nitrate concentrations that exceeded the 10 mg/l drinking water standard. These springs were the Cabbage Creek spring (S1), Plum Creek Spring 1 (S3), Plum Creek Spring 2 (S4), Yellow Creek Spring 2 (S8), and Potter Creek Spring (S9). Additionally, S10 on Three Springs Run was approaching the MCL at 9.12 mg/l.

Water Typing

In addition to an assessment of the general water quality, biological conditions, and habitat in Morrison Cove, the water chemistry data were used to group streams together that had similar characteristics. This process is generally referred to as water typing and consists of characterizing the geochemical composition of water. Water typing is possible because the constituents of water are directly related to the geologic formation of origin; thus, it is possible to determine the source of water for streams and springs. Most streams in any area are of the same general type and are influenced by the same factors. For example, water from a limestone geologic area is usually characterized by higher calcium concentrations due to the calcium bicarbonate dissolved into the water.

However, water containing a higher concentration of magnesium may indicate a dolomite source. There are distinct geologic units within the Morrison Cove region that have known chemical properties, and the source of the water can be determined based on these chemical signatures (i.e. Ca^{+2}/Mg^{+2}). The main geologic units in Morrison Cove are limestone, dolomite, mixed limestone/dolomite, and sandstone. Despite the ridge and valley geology in Morrison Cove and the distinct geologic formations, there were minimal differences in the parameters that distinguish one type of water from another. However, some general conclusions about the origin of the water at certain locations in Morrison Cove can be drawn.

In theory, water that originates from pure dolomite has a Ca^{+2}/Mg^{+2} ratio of 1.0 while water that originates from pure limestone will have little or no magnesium and a Ca^{+2}/Mg^{+2} ratio approaching six (Lindsey and Koch 2004). However, for practical purposes, water with a Ca^{+2}/Mg^{+2} ratio less than 1.5 can be considered dolomite based, while water with a Ca^{+2}/Mg^{+2} ratio over 2.2 can be considered limestone based (Langmuir and White 1971). In Morrison Cove, a majority (>80 percent) of the stream sites and springs fall into one of these two categories. Based on Ca^{+2}/Mg^{+2} ratios, greater than 64 percent of the sites are dolomite based, 18 percent are some mixture of dolomite and limestone based water, nine percent are limestone based waters, and the remaining nine percent of sites originate in the sandstone ridges.

Eight of the 10 springs sampled were very similar in their geology based water chemistry, with Ca^{+2}/Mg^{+2} ratios between 1.05 and 1.23. This suggests that these springs are part of a dolomite based groundwater system. Plum Creek Spring 3 (S5) was the only spring that seemed to originate from limestone based geology, with a Ca^{+2}/Mg^{+2} ratio of 2.28. Additionally, two stream sites, Hickory Bottom (Y1) and the upstream site on Plum Creek (H10) also appear to be utilizing water from a similar type aquifer system as the limestone spring (S5). In general, the stream sites that were in the closest proximity to dolomite springs had Ca^{+2}/Mg^{+2} ratios that also indicated a dolomite source. However, streams that were not spring fed appeared to have a mixed dolomite and limestone source.

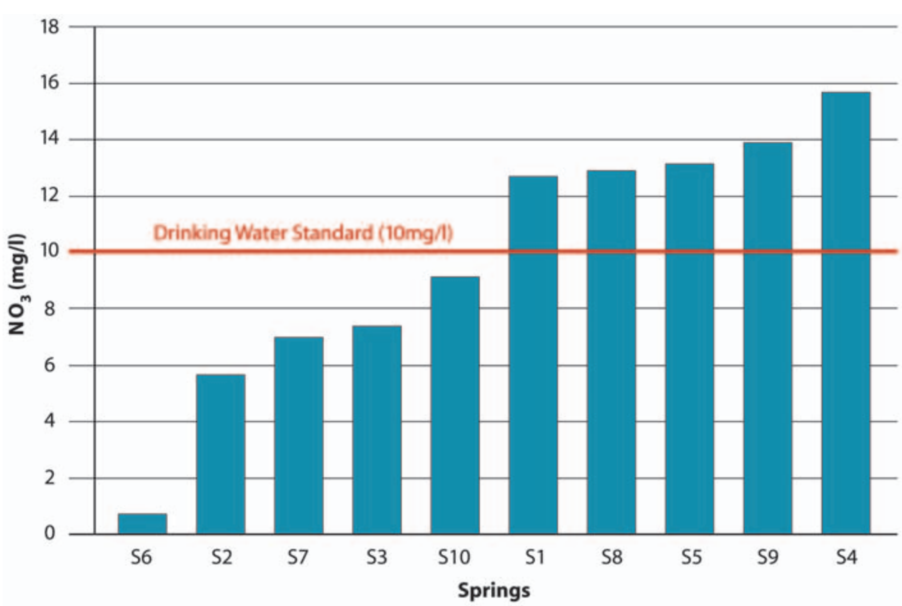


Figure 6. *Average Nitrate (NO_3) Concentrations of Sampled Springs in Morrison Cove, April 2005 - January 2006*

Conclusions

Overall, macroinvertebrate conditions in the Morrison Cove area were good with slightly greater than half of the stations rated nonimpaired. Some of the best diversity and macroinvertebrate conditions existed in the tributaries originating on the forested ridges. These sites had excellent mayfly, stonefly, and caddisfly populations. Some of the best macroinvertebrate sites in the valley were C1 (Clover Creek), Y3 (Potter Creek), Y4 (Three Springs Creek), Y1 (Hickory Bottom), H5 and H4 (Halter Creek), and Y6 (Yellow Creek). Some of the sites that need further investigation and potential remediation for water quality or habitat conditions were H10 (Plum Creek), H3 (Halter Creek), H6 (Halter Creek) and possibly T1, Y5 (Beaver Creek), and the headwaters of Piney and Clover Creeks.

Nitrate concentrations are a serious concern throughout Morrison Cove. Like many predominantly agricultural areas, nitrate levels are elevated in the surface water and groundwater. The level of concern for nitrates in surface water is 1.0 mg/l, and samples from every stream site, except the two tributaries coming off the sandstone ridges, exceeded that value. Nitrate in surface water is derived from three primary sources: rainfall, decomposition of soil organic matter, and nitrogen amendments such as fertilizers or manure (Eckert 1995). Ideally, a majority of the nitrate applied to the soil should be removed by the crops. However, this is not usually the case, and the excess nitrates are flushed into the streams during rain events. The drinking water standard for nitrates is 10 mg/l, and half of the springs sampled had a yearly average exceeding that value. In rural areas where groundwater is a primary water supply for private homeowners or small municipalities, these levels of nitrates may be a concern.

In an effort to control the nitrate problem in Morrison Cove, the Cove Area Regional Digester Project was formed to develop a way to manage animal waste in the area. The proposed process would use manure from dairy herds and produce 2.5 megawatts of electricity a day, which is enough to power over 17,000 homes. Additionally, it would remove more than 570,000 pounds of nitrogen loading and 25,000 pounds of phosphorus loading to surface water and groundwater (PA Environment Digest 2005). The groundbreaking for this facility is slated for early 2007. For more information on the Cove Area Regional Digester project, email CoveDigestor@verizon.net or call the Project Coordinator at (814) 693-4660.

Several other water quality trends in the Morrison Cove valley stand out from the data collected in this study. The highest concentrations of nitrates were found in springs, but the streams that originated in the carbonate valley of the Cove tended to have higher nitrates as well. These streams included Cabbage Creek, Potter Creek, and Three Springs Run. The highest calcium concentrations were found in the headwater area of Plum Creek, which corresponded with a band of limestone formation. The highest concentrations of sulfate were found in springs and streams around the quarrying operation. Stream sites that were spring fed tended to have more constant concentrations of sulfate, nitrate, chloride, alkalinity, and total hardness while these same parameters fluctuated with stream flow in streams that were not spring fed.

The streams in Morrison Cove would benefit greatly by some small changes in land use management practices. Many of the streams in Morrison Cove lacked sufficient protective vegetative riparian zone. Protection of the streams with additional vegetation would help maintain a cool temperature, provide a food source for some macroinvertebrates, and provide breeding habitat for the adult macroinvertebrate stage. Additionally, stream-side fencing to keep cattle out of the streams would improve habitat conditions.

Because the Roaring Spring area in Morrison Cove was identified as a Potentially Stressed Area (PSA) by SRBC, the data from this study are very important to current and future project review activities. SRBC defines a PSA as an area that meets at least two of the following criteria: (1) diminished yields, (2) declining water levels, (3) diminished stream or spring flows, (4) expanded dry stream reaches, (5) a water budget analysis indicating that withdrawals exceed the recharge for a 1-in-10 year annual drought, or (6) for developing areas, known withdrawals exceed 50 percent of the recharge for a 1-in-10 year annual drought.

SRBC staff has determined that in the Roaring Spring area, virtually 100 percent of the 1-in-10-year drought recharge is being utilized and that nearly all of the flow from the large spring is being used during times of drought.

Plum Creek tributary during dry October.

All the water from the streams and springs in Halter, Cabbage and Plum Creeks directly influences the water quantity and quality in the Roaring Spring area. Stream and spring discharge amounts are critical components in evaluating the water resources in any area. This information aids in making informed decisions about water availability, potential water supply, responses of streams to drought, and the capacity of the streams to handle pollutant loads. Data from this study will be considered by SRBC in managing the water resources of the basin. Additionally, the data from this study have been provided to the Pennsylvania Fish and Boat Commission and PADEP to supplement their own data from fisheries studies. All SRBC data from this project also will be available to the public on the SRBC website.

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APPENDIX

Sample Site #	Station name	Latitude	Longitude	Location description	Drainage Area (mi2)
H1	HALT2.2	40.35268	-78.40790	Exit point of Halter Creek from Morrison Cove, downstream of Plum Creek, along Rt. 36	32.09
H2	HALT2.3	40.35160	-78.40600	Halter Creek, upstream of Plum Creek, downstream of quarrying operation, along Rt. 36	14.71
H3	HALT3.2	40.34062	-78.40478	Halter Creek, below railroad bridge along Papermill Rd., upstream of quarrying operation	14.15
H4	HALT3.9	40.33392	-78.40734	Halter Creek, downstream of Cabbage Creek, along Halter Creek Rd.	12.72
H5	HALT4.1	40.33000	-78.40940	Hater Creek, upstream of Cabbage Creek, along Halter Creek Rd.	8.59
H6	HALT8.7	40.28534	-78.41894	Most upstream site on Halter Creek, upstream of Sheepskin Flat Rd. crossing	1.50
H7	CABB0.1	40.33010	-78.40900	Mouth of Cabbage Creek, in park area off Halter Creek Rd.	4.00
H8	PLUM0.1	40.35210	-78.40550	Mouth of Plum Creek, along SR 2008	17.37
H9	PLUM2.0	40.35130	-78.38360	Plum Creek upstream of Timber Ridge Rd.	13.55
H10	PLUM6.4	40.30930	-78.33824	Most upstream site on Plum Creek, at utility road off Central High Rd.	3.32
T1	HALTT1	40.32172	-78.41056	Unnamed tributary to Halter Creek, along Dick School House Rd.	1.21
T2	HALTT2	40.31025	-78.41690	Unnamed tributary to Halter Creek off western ridge, along Burkettown Rd.	0.13
T3	PLUMT1	40.35500	-78.39621	Unnamed tributary to Plum Creek off northern ridge, along Seneca Rd.	0.71
C1	CLOV0.1	40.47611	-78.17583	Mouth of Clover Creek, along SR 2013	50.12
C2	CLOV15.7	40.34326	-78.25234	Clover Creek, upstream of Rebecca Furnace Rd. crossing	14.09
P1	PINY0.3	40.45450	-78.25000	Near mouth of Piney Creek, along T431	25.32
P2	PINY5.9	40.40726	-78.28003	Piney Creek, downstream of T381 crossing	9.53
Y1	HKBT0.1	40.19240	-78.37509	Mouth of Hickory Bottom Creek at Rt. 36	7.33
Y2	YELL12.9	40.15838	-78.37012	Yellow Creek, upstream of Potter Creek	24.91
Y3	POTT0.1	40.19006	-78.37744	Mouth of Potter Creek, upstream of Rt. 36	13.35
Y4	THRS0.2	40.17189	-78.38068	Near mouth of Three Springs Run, upstream of Rt. 36	9.76
Y5	BEAV0.3	40.15798	-78.37783	Near mouth of Beaver Creek, behind trailer park at SR 1005	19.10
Y6	YELL10.1	40.18840	-78.37568	Exit point of Yellow Creek from Morrison Cove, along Rt. 36	69.68
S1	CBSP1	40.29393	-78.38550	Spring fed area entering Cabbage Creek, along Cabbage Creek Rd.	
S2	HLTTSP1	40.29673	-78.39898	Spring fed tributary entering T1 (HALTT1)	
S3	PLSP1	40.35450	-78.39730	Spring flowing into Plum Creek, along Weitzel Hill Rd.	
S4	PLSP2	40.29255	-78.35541	Spring flowing into Plum Creek, upstream of Cove Lane Rd. crossing	
S5	PLSP3	40.32563	-78.36718	Large spring flowing into Plum Creek, in field along Brumbaugh Rd.	
S6	HKSP1	40.22300	-78.33123	Spring feeding Hickory Bottom Creek, off Maple Run Rd.	
S7	YESP1	40.26549	-78.37544	Spring flowing into Yellow Creek, at farm on Erb Rd.	
S8	YESP2	40.26915	-78.33547	Spring fed tributary from spring house entering Yellow Creek at Frosty Hollow Rd.	
S9	PTSP1	40.21952	-78.40949	Spring fed tributary from spring house flowing into Potter Creek along Rt.868	
S10	THSP2	40.16858	-78.41628	Spring flowing into Three Springs Run, downstream of Kings Rd.	

Headwaters of Halter Creek during low flows in October 2005.

Headwaters of Halter Creek under normal conditions.

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All photographs within the publication were taken by Luanne Steffy.

For more information on a particular stream or more details on the methods used in this survey, contact Luanne Steffy, (717) 238-0426 x112, email: lsteffy@srbc.net.

For additional copies of this subbasin survey report, contact the Susquehanna River Basin Commission, 1721 N. Front Street, Harrisburg, PA 17102-2391, (717) 238-0423, fax: (717) 238-2436, email: srbc@srbc.net.

For raw data from this survey or more information concerning SRBC, visit our website: www.srbc.net.

In 1971, the Susquehanna River Basin Commission was created as an independent agency by a federal-interstate compact among the states of Maryland, New York, and the Commonwealth of Pennsylvania, and the federal government. In creating the Commission, the Congress and state legislatures formally recognized the water resources of the Susquehanna River Basin as a regional asset vested with local, state, and national interests for which all the parties share responsibility. As the single federal-interstate water resources agency with basinwide authority, the Commission's goal is to coordinate the planning, conservation, management, utilization, development and control of the basin's water resources among the public and private sectors.

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