THE QUALITY OF OUR

WATERS

Aquatic ecosystems have always been a vital part of our lives for recreation, aesthetics, and industry. Over the last two centuries, the waters of Kettle Creek have been adversely impacted by agriculture, logging, mining, atmospheric emissions, and development practices that were unsympathetic to their influence on aquatic systems and the surrounding landscape. More recent awareness for the interconnectedness of natural systems has drawn attention to conservation of current water conditions and mitigation of historic impacts for the continued health and enjoyment of the waters. The following chapter assesses the physical, chemical, and biological aspects of surface and ground water quality.

WATER QUALITY PARAMETERS

Thermal Assessment

Temperature is one of the most important factors in determining the distribution of fish and macroinvertebrates. Even minimal fluctuations in temperature can influence which organisms inhabit a specific stream. The thermal regime of a stream can be of particular concern if the water temperature increases. Streams that lack vegetative cover or have wide channels (making the vegetative cover ineffective) are at risk of extreme temperatures. Also, long stretches of streams without cold water inputs from seeps, springs, or tributaries may be at risk of higher temperatures.

The Kettle Creek watershed was designated an "exceptional value" stream from the Alvin Bush Dam to the headwaters based on the Chapter 93 Water Quality Standards by the Pennsylvania Department of Environmental Protection (DEP 1998). Although the water quality is excellent throughout most of the watershed, thermal pollution has been a concern for more than 60 years (Watts and Harvey 1946). Kettle Creek is known for having wild trout, however habitat problems and high temperatures during the summer months have limited their populations. Typically 66° Fahrenheit is the ideal summer temperature for brook trout and they can withstand temperatures up to 75°. Brown and rainbow trout prefer 70° water in the summer while being able to survive up to 80° (Watts and Harvey 1946). Watts and Harvey (1946) concluded that in July and August temperature readings at many locations in the Kettle Creek watershed were too high for the survival of any species of trout. Today, this issue is still a threat to Kettle Creek's wild trout populations.

In the fall of 2000, the Kettle Creek Watershed Association (KCWA) requested the help of the

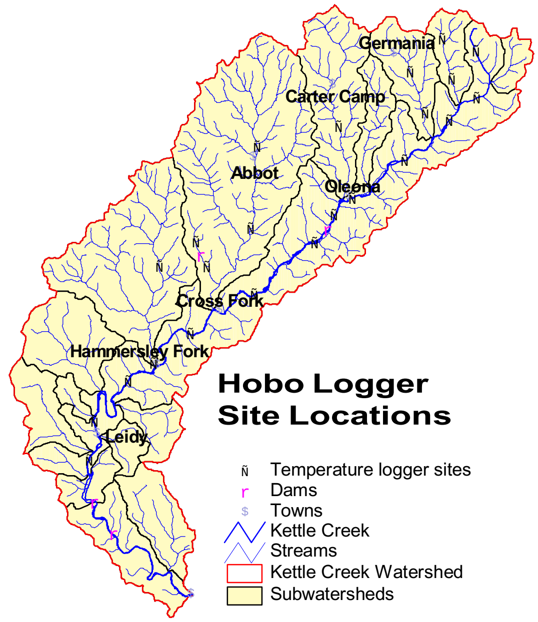


Figure 5.1 - Site locations for current thermal monitoring study using HOBO temperature loggers, installed Spring 2001.

Center for Watershed Stewardship (CWS) to complete a thermal assessment of the entire Kettle Creek watershed. Due to channel alterations and lack of canopy cover, many of Kettle Creek's "cold water" tributaries may not have optimal capacity to cool the mainstem.

After completion of a watershed habitat assessment, in the spring of 2001, the CWS, in cooperation with the KCWA, will begin monitoring the thermal regime of Kettle Creek and its tributaries. The objective is to establish a comprehensive long-term thermal study on Kettle Creek (from the headwaters to the Alvin Bush Dam) and its main tributaries and to provide a study plan that can be continued by the KCWA over a longer time period than the 2-semester Keystone Project. This study consists of 23 sites with HOBO temperature loggers calibrated to record stream temperature every hour (Figure 5.1). At time of publication, this study will be implemented and an example of the type of data that will be collected is located in appendix H, page 321.

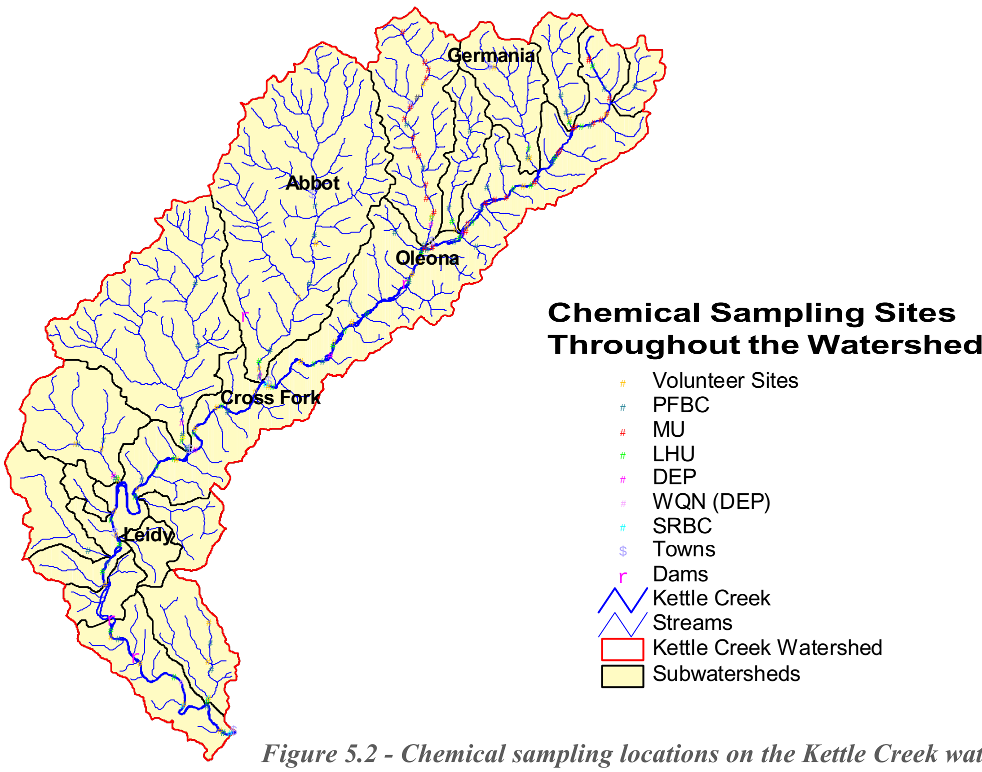


Figure 5.2 - Chemical sampling locations on the Kettle Creek watershed

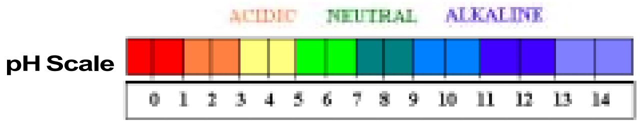
WATER CHEMISTRY

Chemical Assessment

The Kettle Creek watershed, from the Alvin Bush reservoir to the headwaters, is designated an Exceptional Value watershed by the Department of Environmental Protection's Chapter 93 Water Quality Standards. Frequent monitoring of the water quality is necessary if this status is to be maintained. The Pennsylvania Fish and Boat Commission (PFBC), the Pennsylvania Department of Environmental Protection (DEP), Lock Haven University (LHU), Mansfield University (MU), the Susquehanna River Basin Commission (SRBC), the Water Quality Network (WQN), and the KCWA Volunteers have all gathered water chemistry data throughout the watershed (Figure 5.2). The WQN data pertains to one individual site (near the Westport USGS gauging station) that has been monitored frequently since 1972. The other studies have been one or two time measurements at many sites throughout the watershed. The various studies cannot be accurately compared due to different parameters analyzed, various locations, and the variety of dates sampled. Another important difference between studies is that LHU and MU used field sampling water quality kits (HACH) to obtain their data. This data may differ from data analyzed in a lab.

In this section, any parameter that has been sampled for will be defined and described. Parameters are reported in parts per million (ppm) or parts per billion (ppb). Parts per million is equal to the measurement mg/L and parts per billion is equal to micrograms per liter (µg/L). The majority of the parameters studied have been found to be at healthy levels throughout the watershed above the Alvin Bush Dam. Any parameters that are beyond healthy levels will be noted and discussed thoroughly. Healthy levels are defined by DEP's Chapter 93 Water

pH and Aquatic Organisms



Mayfly	5.5 to 7.5	Rainbow trout	5.5 to 9.5
Caddisfly	5.5 to 7.5	Brown trout	5.0 to 9.5
Stonefly	5.5 to 7.5	Brook trout	4.5 to 7.5
Crayfish	5.5 to 7.5	Smallmouth bass	5.5 to 7.5
Snails	6.0 to 9.0	Bullfrog	4.5 to 7.5

Figure. 5.3 - pH and aquatic organisms. (Taken from the PA Fish and Boat Commission).

Quality Standards (DEP, 1999) or the EPA's National Recommended Water Quality Criteria (EPA, 1998). If no standard level is indicated by either agency, then biological survival recommendations are defined by the Kentucky Water Watch (2001).

Acidity

Acidity is the measure of the ability of the stream water to neutralize bases. There are two types of acidity: potential acidity and active acidity. Active acidity is a measurement of free hydrogen ions in solution. A measure of active acidity is pH (For more information on pH see Figure 5.3 and page 166). Potential acidity measures the free hydrogen ions and also hydrogen ions that are tied up in complexes that have the potential to become free. When a study tests for acidity, they are testing for potential acidity.

> 1 part per million can be visualized as one fish in a million fish.

Potential acidity can be measured using a variety of methods. Two methods used by the Water Quality Network site are carbon dioxide (CO_2) acidity and hot acidity (due to limestone inputs at the sampling site). Other acidity methods exist and various methods are used in the current Kettle Creek watershed studies. Because of the differences between all the methods, no potential problematic areas could be determined and no limit could be given.

Alkalinity

Alkalinity is the measure of the ability of the stream water to neutralize acids (Swistock 2000). Alkalinity is related to calcium and hardness in the water (for more information on calcium and hardness refer to pages 162-163). If alkalinity levels are high, most likely hardness levels will also be high. Alkalinity can also either be measured in the field or in the lab. Alkalinity levels should be at least 20 ppm in order for the stream to be able to resist acidity (DEP 1998). There are many areas in the Kettle Creek watershed that do not reach the DEP levels of alkalinity. According to the PFBC, freestone streams are very sensitive to acid precipitation at an alkalinity (calcium carbonate) 10 ppm or less. Freestone streams are somewhat sensitive to acid precipitation at 10-20 ppm and are not sensitive when the alkalinity is greater than 20 ppm.

Alkalinity levels within the Kettle Creek watershed range from 0.57 ppm - 41 ppm, with the majority of the levels being in the range of 11 ppm - 18 ppm. Alkalinity is related to bedrock geology of the watershed. If the geology consists primarily of limestone, alkalinity levels would be expected to be high. A mixture of gravel and stone substrate, which is derived from sandstone, shale, and conglomerate rock dominates Kettle Creek (for more information on geology refer to page199). This causes the stream to have little buffering capacity and low alkalinity. The AMD affected areas have extremely low alkalinity levels due to the acidity and dissolved metals in the stream and are discussed further in the AMD section of this report (page 187).

Aluminum

Aluminum (Al) is the third most abundant element in soil and is a large component of clays and silicate rock minerals. While it is a constituent of all soils, Al is not usually found in aquatic ecosystems at concentrations damaging to fish and insect life, unless introduced by human activities. In soils, Al is typically in the solid form, which is not available for uptake by plant roots and does not have the ability to flow into streams. When the pH of the soil goes below 5.0 (Meiwes and others 1986) Al is in the soluble form and replaces base cations like calcium (Ca) and magnesium (Mg) which are then leached into streams. After the Ca and Mg are completely leached from the soil, Al then follows. Once Al enters the stream system, even small concentrations negatively affect aquatic life. Reproductive problems in fish are common when streams have elevated Al and low pH levels (Carline and others 1998). It is common to have extremely high Al levels in AMD affected waters.

The Pennsylvania DEP Chapter 93 Water Quality Standards indicate that streams with Al levels above 0.1 ppm are harmful to aquatic life. On the entire Kettle Creek watershed, only two studies (DEP and SRBC) analyzed water samples for Al. The DEP study (that only sampled above the dam) found Al below the detection limit in all cases. The SRBC study found two areas above the dam with Al levels exceeding water quality standards (DEP 1998). These sites were on Kettle Creek at the confluence with Cross Fork Creek (0.24 ppm) and at the PA 120 Bridge (0.49 ppm). The other sites sampled below the dam had much higher levels of Al: 14.3 ppm at Twomile Run and 42.4 ppm along an acid mine seep on Kettle Creek at river mile 3. High levels of Al found below the Alvin Bush Dam are a result of AMD affected water.

Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Zinc

The following describes parameters tested for in the Kettle Creek watershed that were not at detectable limits.

Arsenic is a naturally occurring element that also has sources from human activities such as gas and oil well drilling. It is an extremely toxic inorganic chemical, which is why it has a primary drinking water standard. Once in the water supply, arsenic can cause problems with the circulatory and nervous systems, it can cause skin lesions, and it is a known carcinogen when exposure occurs for prolonged periods of time. Arsenic can also negatively impact aquatic life. The water quality standard for arsenic is 0.05 ppm (Swistock and others 2000).

Cadmium is not an essential element and it is detrimental to plant growth and very toxic to humans and aquatic life at high levels. In humans and aquatic life, reproductive problems are a common known side effect. Cadmium can be found in high concentrations in sewage sludge and it is also widely used for industrial purposes. A water quality standard of 0.001 ppm is considered protection for aquatic life and the drinking water standard is <0.01 ppm (Kentucky Water Watch 2001).

Chromium is an essential trace element that occurs naturally in the air, water, rocks and soil. It is commonly used in manufacturing of stainless steel, leather tanning, wood preservatives, and various others. Within stream systems it occurs in assorted forms with the two most common being chromium VI and chromium III. Chromium has a pH dependency. High doses of chromium VI can be extremely toxic to animals and humans (Kentucky Water Watch 2001), however other forms are not associated with any of these same effects. Total chromium is calculated by adding all sources of chromium in the water supply, but no criteria have been found for protecting aquatic life. However, the

Small dam located on Elk Lick Run

criteria for aquatic life is less than 0.011 ppm for chromium VI (Kentucky Water Watch 2001).

Copper is essential for all plant and animal nutrition. Copper is acutely toxic to most forms of aquatic life at relatively low concentrations. Copper sources include industrial effluents, mining, and urban developments (plumbing). Copper is hardness dependent. Aquatic life is under stress after copper levels reach 0.002 ppm (2 ppb) with the hardness = 50 µg/L (Resources Inventory Committee Publications 1998).

Lead is not an essential element and is toxic to both plants and animals. Lead can be found in batteries, pigments, and other metal products. Previously, lead was used as an additive in gasoline and became dispersed in the air, soils, and waters. Mining, smelting, solid waste incinerators, and other industrial emissions are now primary sources of lead. Lead reaches streams either through urban runoff or discharges such as sewage treatment plants and industrial plants. It also may be transferred from the air to surface water through precipitation (rain or snow). Lead's toxicity depends on its solubility and this, in turn, depends on pH and is affected by hardness. The level considered protective for aquatic life at a hardness of 100 is less than 0.003 ppm (Kentucky Water Watch 2001).

Nickel is a metal that occurs naturally at low levels in soil and rocks. It is released into the environment by volcanos, forest fires, vegetation, and human activities (sewage and metal waste). Nickel enters streams and water bodies through natural weathering and erosion processes. Nickel levels in surface water are normally very low (often undetectable).

Zinc is a naturally occurring essential element that is used in the vulcanization of rubber. Therefore zinc is found at higher concentrations in streams located near highways. Although it is found commonly in stream systems at low levels, it is not considered very toxic to humans or aquatic organisms. Water quality standards for aquatic life have been set at <0.106 ppm based on hardness of 100 ppm (Kentucky Water Watch 2001).

Calcium, Magnesium, and Hardness

Calcium and magnesium are common elements naturally occurring in streams. Both are necessary nutrients, but when in abundance, can be harmful. Calcium and magnesium both contribute to hardness. Hardness is a measure of the amount of calcium, magnesium and sometimes other nutrients (such as iron and manganese). It ranges from soft (< 75 ppm) to very hard (> 300 ppm). Calcium originates from the leaching of soil and other natural sources (such as rocks) or may come from man-made sources such as sewage and some industrial wastes. Calcium is very important in stream water because it is known to reduce the toxicity of many chemical compounds on fish and other aquatic life (Kentucky Water Watch 2001). Magnesium originates in ores and minerals and like calcium, is beneficial to fish during times of pollution stress. Levels of magnesium and calcium may be a factor in the distribution of species of fish and macroinvertebrates. All three parameters are measured in the laboratory. Magnesium

Classification of Water by Hardness Content	
Level (in ppm)	Description
0 - 75	soft
76 - 150	moderately hard
151 - 300	hard
> 300	very hard

Data taken from Kentucky Water Watch (2001), but are based on DEP Ch.93 Standards (DEP 1998)

Figure 5.4 - Description of levels (in ppm) of hardness.

does not have recommended levels or standards. For optimal trout conditions, calcium levels should be within 4-160 ppm (Larsen, unpublished). Levels below 150 ppm are recommended for hardness (DEP 1998). Figure 5.4 displays the classification of water by hardness content.

The stream water of the Kettle Creek watershed can be classified as soft; hardness levels range from 6 ppm - 45 ppm throughout the watershed.

Chloride

Chloride is a salt compound resulting from the combination of the gas chlorine and a metal. At low levels, chloride is commonly found in Pennsylvania streams. Small amounts of chlorides are required for normal cell functions in plant and animal life. Chloride may become elevated due to leaching from salt storage areas around highways, excessive road salting, rocks containing chloride, or from brines produced during gas well drilling. Other possible sources of chloride are sewage effluent, animal manure, and industrial waste (Swistock and others 2000). Fish and aquatic communities cannot survive in high levels of chlorides. After levels of 150 ppm and above, stress and eventually death may occur in fish and other aquatic communities (DEP 1998). Chloride is measured in the lab from a water sample taken from the stream.

The levels of chloride in the Kettle Creek watershed are very low, indicating no chloride pollution effects. The levels range from <1.0 ppm - 3.0 ppm and so are much lower than the DEP Ch. 93 water quality limit of 150 ppm.

Dissolved Oxygen and Biological Oxygen Demand

Dissolved oxygen (DO) is the amount of gaseous oxygen (O_2) dissolved in water. Oxygen is necessary to most life forms and is a very important water quality parameter. Natural stream purification cannot occur without oxygen. Fish, plants, and macroinvertebrates are put under stress if the DO level drops below 4 ppm (DEP, 1998). If the DO level remains below 4 ppm for an extended period of time, fish mortality may occur. DO may enter water by circulating from surrounding air, rapid movement of fishes or other life, and as a waste product of photosynthesis. In areas of high water movement, such as riffles or waterfalls, DO is high. Cooler stream temperatures also allow for higher DO levels. Pollutants such as sediment, nutrients, and organic matter can cause DO to decrease due to an increase in microbial activity. As certain microbes break down pollutants, they use more oxygen, thus decreasing the stream oxygen levels. The amount of oxygen required for decomposition of a pollutant source is measured by the biochemical (or biological) oxygen demand (BOD). DO must be measured in the field with a dissolved oxygen meter because it changes rapidly. BOD is measured in a lab.

Dissolved oxygen and BOD levels are both very healthy throughout the Kettle Creek watershed. DO levels range from 6.5 ppm - 18.2 ppm, and so are well above the DEP minimum of 4 ppm. However, DO levels in the Kettle Creek Lake violated the minimum limit in lakes (5 ppm) in August of 1997 (Figure 5.5). BOD levels were only measured by one study, but found that the levels were around 0.2 ppm, indicating healthy levels.

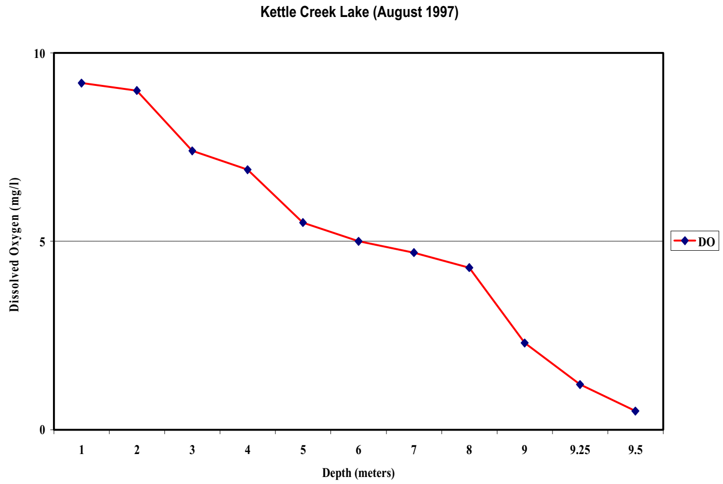


Figure 5.5 - Graph reprepreenting Dissolved Oxygen (DO) in Kettle Creek Lake in August of 1997 (adapted from DEP data).

Fecal Coliform/Fecal Streptococcus Bacteria

Various types of coliform bacteria are found in the environment (Swistock and others 2000). Streams with high levels of these organisms indicate that the water has the ability to cause disease or make people ill if ingested. The higher the number of coliform bacteria in a particular area, the more likely disease-causing bacteria exist there as well. These types of bacteria commonly occur in areas where the stream has been contaminated by human and/or animal waste.

Coliform bacteria are a type of bacteria found in the excrement of living organisms.

The differences between fecal coliform bacteria and fecal streptococcus are minimal. However, by comparing the ratio of coliform to streptococcus, a probable source can be determined. Fecal coliform are only found in the intestinal tracts of humans and other warm-blooded animals and commonly a result of inadequate treatment of sewage. Fecal streptococcus is a bacterium that thrives in animal waste. If you compare the ratio of coliform to streptococcus and it is above 4.0, the bacteria is likely a result of human waste. If streptococcus is found in greater numbers, animal waste is probably the cause of contamination.

Regardless of the type of coliform bacteria and the source, it is an important parameter to test in water quality sampling. For drinking water standards no fecal coliforms are allowed to be detected (Swistock and others 2000). For swimming and other recreational purposes the standard is 200 per 0.211 pints (100 ml). On Kettle Creek, at the confluence of Cross Fork Creek, levels for fecal coliform reached 200 per 0.211 pints (100 ml) and levels for fecal streptococcus reached 240 per 0.211 pints (100 ml) during sampling. Analysis for fecal coliform bacteria is a lab procedure only.

Iron

By weight, iron (Fe) is the fourth most abundant element in the earth's crust. Fe is a ubiquitous trace element that is required for survival of plants and animals. It can be found in varying quantities within streams depending on the geology and water chemistry. In groundwater, Fe is commonly in a soluble state (Fe^{++}), however upon exposure to air it oxidizes into an insoluble state (Fe^{+++}). The soluble form Fe^{++} can remain in water with low DO for long periods of time; streams with low DO typically originate from groundwater or mines (Kentucky Water Watch 2001).

The DEP's safe water quality standards for aquatic life is 1.5 ppm for total Fe (soluble and insoluble). Throughout the Kettle Creek watershed the range in total Fe was from <10 ppb to 50 ppm. Two locations exceeded the standards to ensure safe levels for aquatic life. The first site, on Twomile Run, registered at 12.4 ppm of total Fe and the second site, a seep on lower Kettle Creek, registered 50 ppm of total Fe. Both of these areas were located in AMD affected waters. Optimal levels of total iron for trout is 0.15 ppm (Larsen, unpublished). This level is exceeded at a site on the mainstem by Westport and at the site mentioned previously. Analysis of total Fe is a lab procedure only.

SALTS

A salt compound is formed when a metal replaces hydrogen in an acid.

ORGANIC

Organic is material derived from living organisms. Inorganic materials are everything not derived from living organisms.

EUTROPHICATION

Eutrophication is a process whereby the waters become rich in mineral and organic nutrients. This may result in a drastic increase in plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms.

Manganese

Manganese is usually in the form of salt compounds. It is a vital micro-nutrient for both plants and animals. Low levels of manganese can cause plant leaves to develop improperly. In animals, inadequate levels of manganese can result in reduced reproduction and poorly maturing young. High levels of manganese can cause fish kills. In natural waters manganese levels rarely exceed 1 ppm. The primary uses of manganese are in metal alloys, dry cell batteries, and micronutrient fertilizer additives. Levels above 1 ppm are not recommended and can be harmful to the stream life (DEP Ch. 93 standards). Levels above this standard frequently exist in acid mine drainage areas (Rose and Cravotta 1998). Optimal manganese levels for trout are at 0.01 ppm (Larsen, unpublished).

Manganese levels in the Kettle Creek watershed range from <0.001 ppm - 10.8 ppm. Excluding acid mine drainage affected areas, manganese levels are well under the recommended standard. At Twomile Run, manganese levels reach 10.8 ppm and on Kettle Creek (at an acid mine seep) manganese levels reach 8.7 ppm. (For more AMD information refer to page 187).

Forms of Nitrogen

Nitrogen in streams comes in various forms. Ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), and organic nitrogen are just a few of the different forms. Total nitrogen is a measurement of organic and inorganic of nitrogen. Kjeldahl nitrogen (also abbreviated as Kjeld-N) refers to the laboratory method used to determine both the ammonia and the organic form of nitrogen. Results recorded in NH_3-N measures only the concentration of N in the form of ammonia. Kjeld-N refers to the combination of ammonia and organic nitrogen. Excess ammonia contributes to eutrophication of streams and lakes resulting in algal growths that have deleterious impacts on other aquatic life, drinking water supplies, and recreation. Ammonia at high concentrations is toxic to aquatic life. Organic nitrogen is not immediately available for biological activity. It first would have to be broken down into inorganic nitrogen. Once it is broken down into inorganic nitrogen, then it further causes the algal and plant life to increase at a rapid rate. Nitrate and nitrite also increase eutrophication. These nitrogen forms can naturally occur in the stream at low levels. An increase could be caused by sewage treatment plant effluents, agriculture, urban developments, paper plants, industrial effluents, recreation, mining, or septic systems. Recommended

Recommended Levels for Forms of Nitrogen	
Form of Nitrogen	**Maximum Level (ppm)***
Nitrite	90
Nitrate	0.5
Ammonia	0.05**
Organic	None
Kjeld-N	None
Total-N	None
*(Kentucky Water Watch, 2001)	
**This value is the un-ionized form and can be calculated from total ammonia, temperature, and pH	

Figure 5.6 - Recommended levels for the various forms of Nitrogen.

levels of the forms of nitrogen are found on Figure 5.6.

According to these studies, there are no sites with nitrite levels above the standard. Nitrate levels are high at a site on Little Kettle Creek and two sites on the mainstem (one site at the mouth of Long Run, one site is located between Bergstresser Hollow and Cross Fork). Due to the various sources of nitrate pollution a cause of these high levels cannot be pinpointed from this data. Further monitoring of these locations is recommended. Ammonia levels may or may not be lower than the standard. Because ammonia is pH and temperature dependent, a complicated calculation is needed to set a standard level (DEP 1998).

pH

pH measures the hydrogen concentration in the water and indicates how acidic or basic a stream is on a scale of 0 to 14 (7 being neutral, 0 being extremely acidic, and 14 being extremely basic). Natural waters usually have a pH between 6.5 and 8.5. Generally, pH is an expression of the intensity of the basic or acid condition of a liquid (Swistock and others 2000). pH is measured either in the field with a probe or in a lab with a laboratory meter. There are many factors that can cause the pH to fluctuate. The presence of limestone (calcium-carbonate) will raise the pH. Acid mine drainage and acidic deposition are two factors that can lower pH.

Within the Kettle Creek watershed, pH values above the Alvin Bush dam to the headwaters range from 5.5 - 8.6. The majority of the pH values are in the 6.5-8.0 range. These are normal levels for natural surface waters. According to DEP water quality standards, pH below 6.0 or above 9.0 is a cause for concern. Out of all studies, only two pH values were below 6.0 (above the Alvin Bush Dam to the headwaters). Both these values were found on Little Kettle Creek and are not a major area of concern, but it may be beneficial to monitor these sites further.

According to the studies mentioned above, sites on the mainstem of Kettle Creek seem to have normal pH levels except for streams with AMD problems in the lower watershed (for more information on AMD refer to page 187).

Phosphorus

Phosphorus is one of the key elements necessary for growth of plants and animals. Phosphorus forms phosphates (PO4) that are found in sewage, detergents (in minimal amounts), and fertilizers. Each source of phosphate has only one form. There is also a form of phosphate, called organic phosphate, which exists in the natural stream environment. Organic phosphates help break down other forms of phosphate when they enter an aquatic system. Phosphorous can stimulate the growth of aquatic plants and plankton. However, high levels of phosphorous can cause algae to grow wildly and "choke" the stream life by using up all the oxygen in the stream (eutrophication). During eutrophication high levels of nitrogen also may exist. Eutrophication caused by an increase in phosphorus is more easily remediated than nitrogen because once the form of phosphate is known, the source is also determined. Phosphorus is tested in the laboratory by obtaining a water sample from the stream. Recommended levels of phosphorous are no more than 0.1 ppm for streams that do not empty into reservoirs, no more than 0.05 ppm for streams discharging into reservoirs, and no more than 0.025 ppm for reservoirs (Kentucky Water Watch 2001).

In the Kettle Creek watershed, phosphorous levels range from <0.02 ppm - 0.06 ppm. These are borderline levels recommended for streams discharging into reservoirs. However, above the reservoir, all levels are less than or equal to 0.03 ppm. The higher levels of phosphorous are in the stream downstream of the Alvin Bush reservoir. These levels are not a cause of concern, but should be monitored to observe any increases or decreases.

Sulfate

Small levels of sulfates (SO_4) are normally present in streams. Sulfates occur naturally as a result of leaching from sulfur deposits in the earth (Swistock and others 2000). High levels of sulfates are common in areas where coal mining was prevalent. Acid mine drainage results from the oxidation of sulfide materials in the rock disturbed by mining (Callaghan and others 1998). Sulfates in stream water are usually measured in the lab from a water sample from the stream. The maximum level of sulfate is 250 ppm (DEP 1998) in surface waters.

Sulfate levels in the Kettle Creek watershed ranged from <10 ppm - 17 ppm in non-AMD affected areas and from 37 ppm - 1375 ppm in AMD affected areas. Above the Alvin Bush dam, sulfate levels are well under the maximum level and are considered at a healthy level. In the lower section of the watershed, sulfate levels are extremely high, due to the acid mine drainage problems (for more information on AMD refer to page 187).

CWS students measuring stream flow.

Total Suspended Solids and Total Dissolved Solids (estimated Specific Conductance)

Total suspended solids (TSS) consist of an inorganic fraction (such as silts or clays) and an organic fraction (algae, zooplankton, bacteria, and detritus) that are carried by water from surface runoff (Kentucky Water Watch 2001). This is a common occurrence on streams with steep adjacent slopes and/or poor riparian buffers. Vegetative cover on stream banks and hill slopes is very important for trapping and filtering sediment from entering the waterway. Another way that streams receive high levels of suspended solids is from the human activity of dredging. This process causes resuspension of sediments from the bottom of the stream. It is obvious when a stream is high in suspended solids because the water has a muddy appearance, commonly referred to as turbidity.

Turbidity can be harmful to various aquatic organisms. Suspended solids can directly affect fish by clogging gills, causing growth declines or mortality. It can indirectly affect fish by impeding light penetration, and reducing the ability of algae to produce food and oxygen. When siltation occurs, a coating is formed on the stream bottom, which can smother bottom-dwelling organisms and eggs. Turbidity also tivity range from 50-1500 µS/cm, however no critical levels have been established. TDS levels for water quality standards must not exceed 500 ppm (Kentucky Water Watch 2001). The Kettle Creek watershed has TDS levels ranging from 18-44 ppm. All TDS sampling sites are located above the Alvin Bush Dam.

Siltation is the process in which heavy loads of suspended solids, or fine particles, settle to the stream bottom.

interferes with stream temperature, DO, drinking water treatment, recreation and aesthetics.

No standard limit exists for this parameter. However, studies indicated that when water levels reached 80 ppm, the macroinvertebrate population was decreased by 60% (Kentucky Water Watch 2001). All sampling points on the Kettle Creek watershed had ranges of TSS well below 80 ppm.

Total Dissolved Solids (TDS), frequently estimated by specific conductance, is a measure of the amount of dissolved material in a water column and can be used as an indicator of chemical water quality. Conductance is the ability of a body of water to conduct electricity. This is highly variable spatially between streams depending on geology and pollution levels. There are many purposes for determining conductance, one of which is to compare the water quality of two separate stream systems or to determine the rate in which TDS are transported from streams into the ocean. Conductivity is often used to estimate TDS because conductivity increases as levels of TDS increase.

High levels of TDS can be caused by sources such as mining, industrial effluent, sewage treatment, agriculture, road salts. Once high levels are reached, the water becomes undrinkable due to a bad taste and a laxative effect. It can also cause corrosion and have negative effects on aquatic life. Levels of specific conduc-

GOALS: WATER QUALITY

WQ 2.1: Develop water quality sampling protocol

WQ 2.2: Establish Water Quality Network station above Alvin Bush Dam

WQ 1.1: Reduce nutrient, sediment, and chemical non-point source pollution delivery to target areas and key tributaries

WQ 1.2: Identify and mitigate acid mine drainage sources

LU 1.2: Develop and encourage the use of Best Management Practices (BMPs) on Agricultural Production lands to minimize impacts on adjacent natural resources

Introduction

Macroinvertebrates are organisms that live on the bottom of streams. For over 70 years macroinvertebrates have been used to determine stream quality for either fishermen or scientists (Merritt and Cummins 1996). Within the last 30 years, the use of macro-invertebrates as indicators of water quality has become a dominant technique in stream ecology. Fish, algae, and protozoans have all been used as water quality indicators in the past, however, aquatic macroinvertebrates have become the leading bioindicator. Because macroinvertebrates are found all over the world and they have many species with long life cycles, macroinvertebrates are superior over all other biota for monitoring the quality of streams. Bioindicators are also a preferable method over chemical testing because the latter is more expensive, more complex, and it only provides a snapshot of the stream's water quality at a single point in time.

Protozoans are any of a large group of single-celled, usually microscopic organisms, such as amoebas, ciliates, flagellates, and sporozoans.

A Bioindicator is an organism used to monitor water quality.

The complexity of using bioindicators to assess water quality in streams is largely due to taxonomic identification. Without proper identification of each macroinvertebrate, the assessment will be inconclusive. Also, bioindicators can be misleading if other ecological factors such as substrate and velocity affect macroinvertebrate diversity and abundance. This would suggest that when determining water quality of a stream, macroinvertebrates should be used in conjunction with physical assessments or chemical monitoring for the most accuracy.

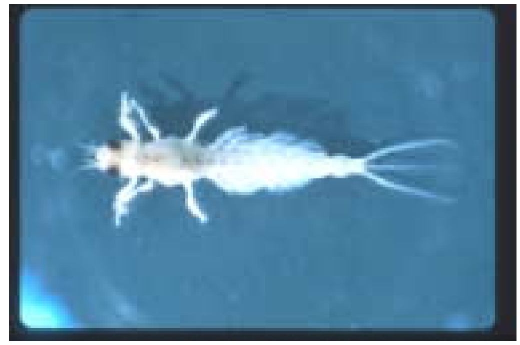
When using macroinvertebrates to determine water quality, a variety of rapid assessment approaches can be used (Rosenberger and Resh 1996). These rapid assessment approaches were created to reduce costs of environmental assessments. The following is a description of each of the rapid assessment approaches used on the Kettle Creek watershed. Taxa richness is one type of rapid assessment that is based on the number of taxa in a given community. This approach uses the idea that the larger the diversity of macroinvertebrates, the better the water quality. This method can be inaccurate due the inability to identify to the species level; hence identification to genera or family is often employed. Another assessment approach is EPT richness. This method, which is a variation of the above technique, determines the richness of mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*) and caddisflies (*Trichoptera*). The theory behind the approach is that all three of these aquatic taxa are intolerant to pollution. Therefore a stream that is rich in all three of these insects would be considered to have good water quality.

MACRO-INVERTEBRATES

Diversity indices were developed originally because ecologists theorized that diversity in any biotic community signals a balanced and stable ecosystem. Diversity indices count the number of macroinvertebrates in each individual species and calculates the evenness between species. When applied to macroinvertebrate populations, this theory does not consider the specific tolerance of each individual macro-invertebrate. Biotic index (BI) is a frequently used

Taxa (Order)	Common Name	Class*
Ephemeroptera	Mayfly	I
Plecoptera	Stonefly	I
Trichoptera	Caddisfly	I
Decapoda	Crayfish	I
Peleycypoda	Fingernail Clams	I
Coleoptera	Water Penny	II
Isopoda	Aquatic Sowbug	II
Amphipoda	Scud	II
Odonata	Dragonfly/Damselfly	II
Megaloptera	Hellgrammite	II
Diptera	Black Fly/Cranefly	III
Gastropoda	Snails	III
Tricladida	Flatworms	III
Hemiptera	Water Strider/Boatman	III

*Table 5.7 - Indicator organisms grouped by class according to W. M. Beck, Jr. *Class I taxa are pollution sensitive, Class II taxa are moderately pollution sensitive, and Class III taxa are pollution tolerant*



Mayfly (Order Ephemeroptera)

Stonefly (Order Plecoptera)

Damselfly (Order Odonata)

Caddisfly (Order Trichoptera)

Water Boatman (Order Hmiptera)

Crayfish (Order Decapoda)

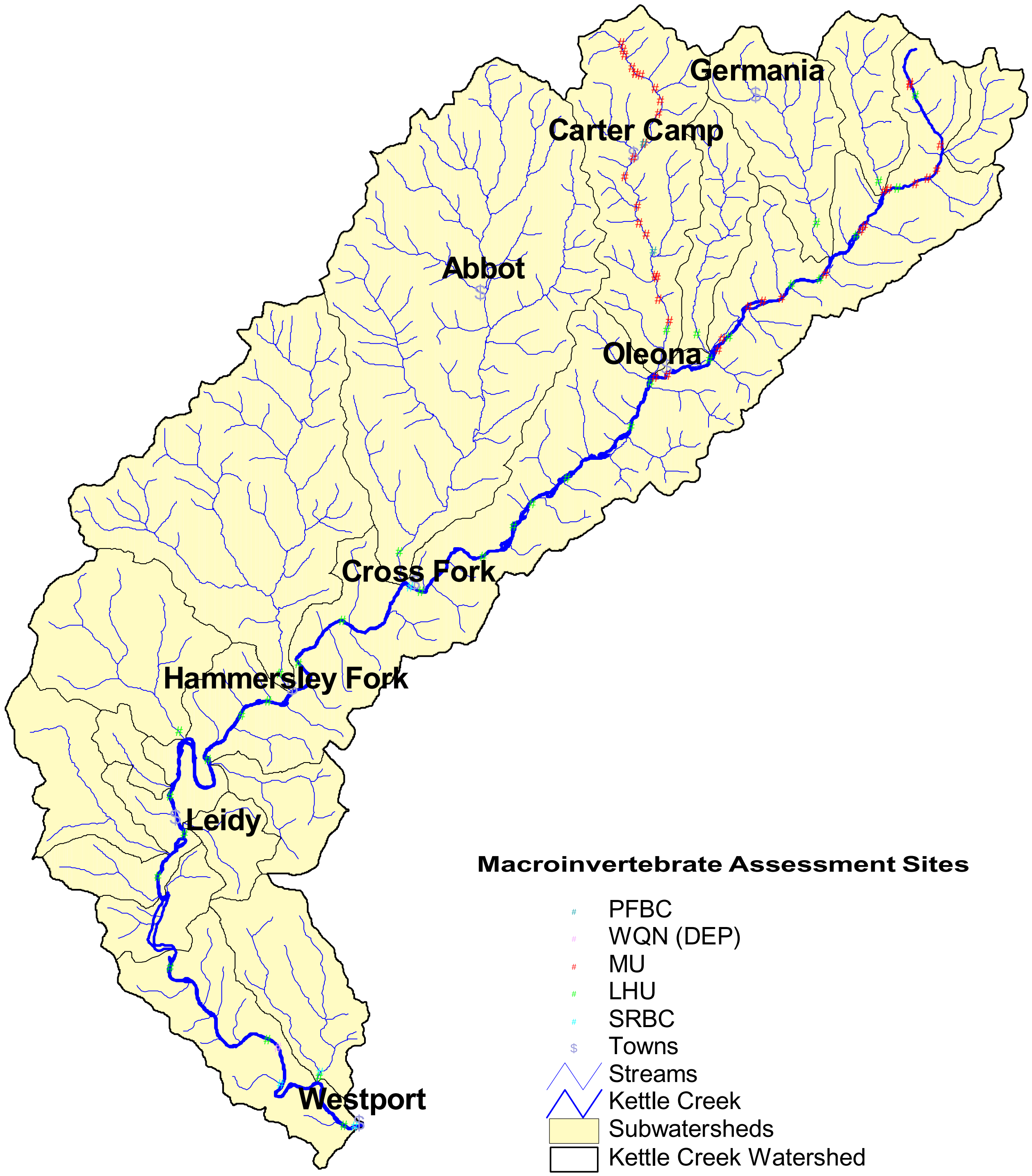


Figure 5.8 - Map of site locations of macroinvertebrate assessments conducted in the Kettle Creek watershed.

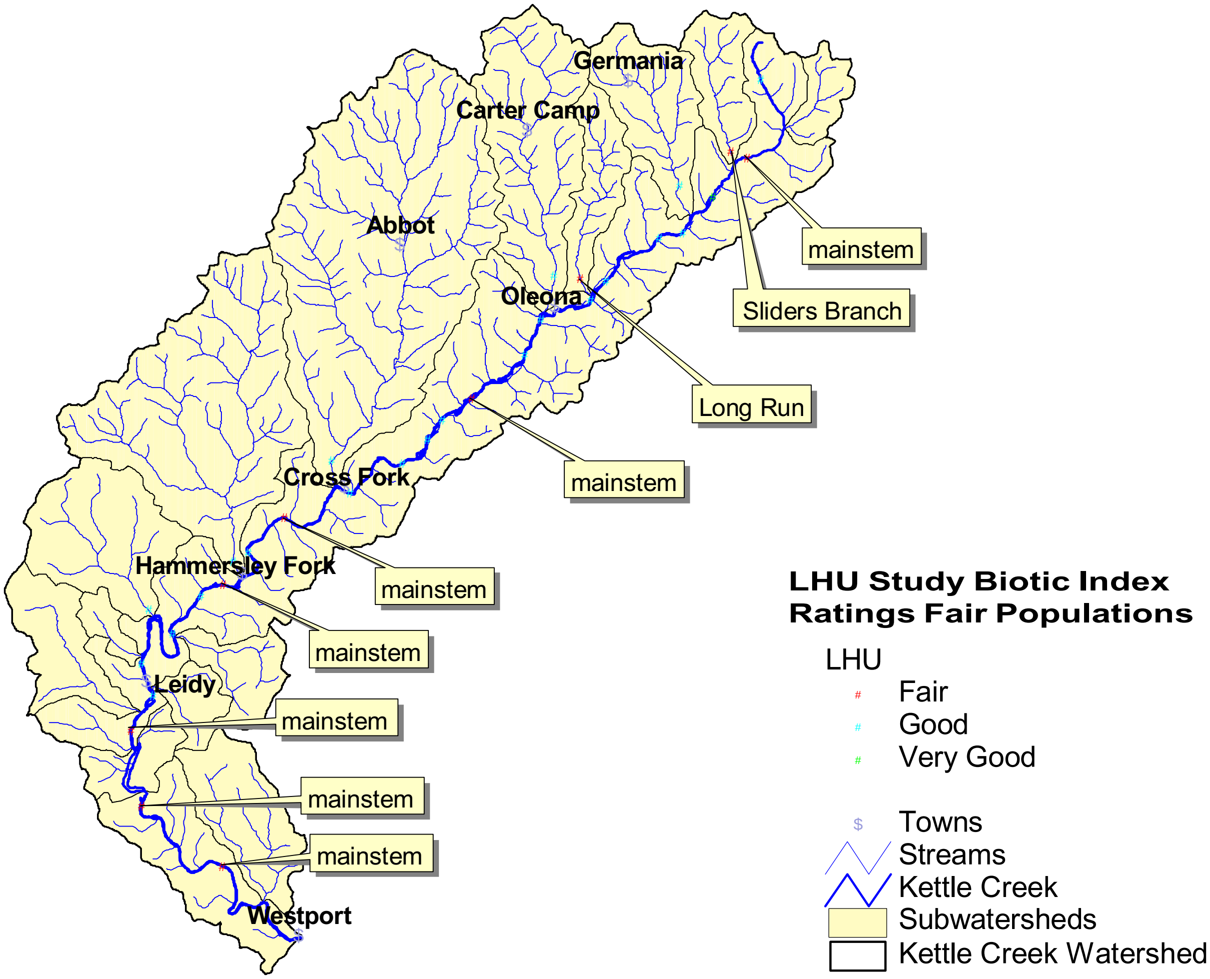
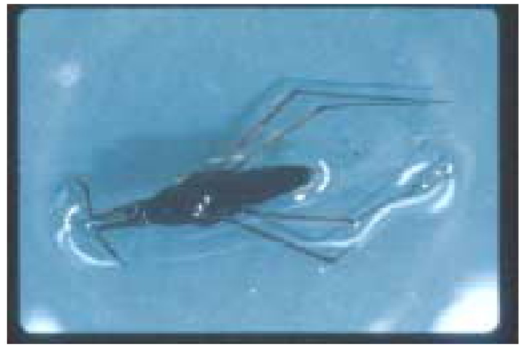


Figure 5.9: Map of LHU sites that obtained a Fair Value Rating.

Taxa refers to any taxonomic category or group, such as a phylum, order, family, genus, or species.

method of assessing macroinvertebrates because it is easy to understand. The BI method gives each insect a tolerance rating and then, after calculating abundance, gives a measure of the amount of pollution at that site based on the number and type of organisms found. This measure can be inaccurate if the insects are not given the correct rating before they are sampled.

One final approach used on the Kettle Creek watershed is the Family Biotic Index (FBI), which is also called the Hilsenhoff family level biotic index (HBI). The HBI is similar to the BI except that taxonomic identification is at the family level in the HBI instead of at the species level as it is in the BI. The HBI is extremely useful in regions where taxonomic identification keys and details on the area are difficult to obtain. Beck's index is a method that classifies aquatic invertebrates into categories depending on their response to organic pollution. However, Beck's index has also been useful in classifying other types of pollution (Sharpe and others 2000). Beck divided macroinvertebrates into three groups based on their ability to tolerate organic pollution (Figure 5.7).



Water strider (Order Hemiptera)

This analysis summarizes macroinvertebrate sampling that has occurred on the Kettle Creek watershed within the last 20 years. Kettle Creek watershed studies within this time frame were completed by the Pennsylvania Fish and Boat Commission (PFBC), the Susquehanna River Basin Commission (SRBC), Water Quality Network Station sampled by the Pennsylvania Department of Environmental Protection (DEP), Mansfield University (MU), and Lock Haven University (LHU). Site locations can be viewed in Figure 5.8.

Snails (Order Gastropoda)

The Beck's Index was applied to most of the macroinvertebrate data collected on the Kettle Creek watershed. The results of this index indicate that there is minimal organic pollution throughout the watershed except at the confluence of Kettle Creek and the West Branch of the Susquehanna River (near PA 120 bridge at Westport).

Dragonfly (Order Odonata)

The LHU study used a different version of the Beck's Index and found that the majority of the watershed is in good condition. At sites on Sliders Branch, Long Run, and at 7 locations on the mainstem Kettle Creek fair conditions were found (Figure 5.9).

Biota are all the plant and animal life of a particular region.

As previously mentioned, Beck's Biotic Index ratings only consider organic pollution as a problem. In the AMD affected areas in the lower watershed, some sites still scored high according to Beck's Index. Acid tolerant and intolerant species may differ from those tolerant to organic pollution. A good indicator of high acidity is the absence of mayflies and the presence of crustaceans (Kimmel 1998). To measure stream acidity using biological processes, the macroinvertebrates need to be identified to species. There are some species within an order (ex. Stoneflies) that are acid tolerant and other species within the same order that are acid intolerant (Kimmel 1998). As a result identifying macroinvertebrates just to order or family would not be sufficient in measuring acid tolerance. None of the study sites in the AMD affected areas of the watershed identified macroinvertebrates to species and so no conclusions can be made dealing with any effects the acidity of the stream had on macroinvertebrate communities.

GOALS: MACROINVERTEBRATES

WQ 2.1: Develop water quality sampling protocol

FH 1.2: Improve stream habitat focusing on flow, substrate, and riparian areas

WQ 1.1: Reduce nutrient, sediment, and chemical non-point source pollution delivery to target areas and key tributaries

Introduction

Surface water quality is important in the Kettle Creek watershed because the high water quality differentiates this stream from other streams in Pennsylvania. The surface water has been designated by the DEP as exceptional value (EV) to the citizens of the commonwealth. Much of the activity in the watershed is dependent on high water quality with trout fishing as the primary example. High water quality is maintained through wise land-use and management of water resources. Continual monitoring is necessary to preserve and protect Kettle Creek's water quality.

Water Quality Network Station near Westport (WQN434).

Water Quality Network (WQN)

The WQN is a nationwide monitoring system that collects surface water quality data at designated sample sites on a routine time schedule. The data are used to assess long term water quality trends. The water quality parameterslisted below were evaluated to assess the surface water quality of Kettle Creek (at WQN station 434 which is located at the USGS gauging station 3.0 miles north of Westport). The data for these parameters was queried from the United States Environmental Protection Agency's (EPA) STORET database (Figure 5.10). STORET (short for STOrage and RETrieval) is a repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others (EPA website 2000)

SURFACE WATER

The surface water quality is high at the WQN station. Long-term trends show that summertime temperatures exceed optimal temperature for trout. The high temperatures are attributed to low flows and wide shallow channels. Dissolved oxygen (DO) also decreases with summertime temperatures. The chemical parameters are also representative of high water quality. The WQN station shows that the mean values fall within the parameters that designate this

Water Quality Network Parameters	
ACIDITY, TOTAL HOT (MG/L AS CACO3)	MANGANESE, TOTAL (UG/L AS MN)
ACIDITY, CO2 (PHENOPHTHALEIN)	NITRATE NITROGEN, TOTAL (MG/L AS N)
ALKALINITY, TOTAL (MG/L AS CACO3)	NITRITE NITROGEN, TOTAL (MG/L AS N)
ALUMINUM, TOTAL (UG/L AS AL)	NITROGEN, AMMONIA, TOTAL (MG/L AS N)
BOD, NITROGEN INHIB.,TOTAL, 5 DAY, 20 DEG C MG/L	OXYGEN, DISSOLVED*(DO)
CHLORIDE,TOTAL IN WATER	PH (STANDARD UNITS)
NITRATE NITROGEN, TOTAL (MG/L AS N)	PH, LAB, STANDARD UNITS*
FLOW, STREAM (MEAN DAILY)	STAGE, STREAM (FEET)
IRON, TOTAL (UG/L AS FE)	TEMPERATURE, WATER (DEGREES CENTIGRADE)

Figure 5.10 - Water quality parameters collected at water quality network station and analyzed for watershed assessment.

stream as EV The sampling frequency may not be high enough to catch water quality events that possibly inhibit the aquatic ecosystem. Data queried from the STORET database have many gaps exceeding 90 days and a lack of continuously sampled parameters. It is possible that the data are not sufficient to adequately assess the surface water quality of Kettle Creek. The other problem is that the WQN station is located below the Alvin Bush Dam which influences parameters being measured.

The Stormwater Management Act regulates stormwater runoff from land alteration through stormwater management plans developed by the county governments and implemented by township ordinances. Stormwater will only be effectively mitigated if each citizen makes an effort to minimize impacts locally and develop a watershed wide approach to address present and future stormwater issues.

WQN
Data Summary:

Some parameters are measured in mg/l or parts per million (ppm). Parameters with even lower relative concentrations are measured in ug/l or parts per billion (ppb) For more detailed information about the implications of the parameters refer to chemical descriptions of water quality in previous section. The data analyzed were collected from September 1972 to December of 1998. The values for total acidity ranged from a max of 54 ppm and a min of 0. The mean is 2.4 ppm. Total alkalinity ranged from 38 to 0 ppm with a mean 11 ppm. Total Aluminum values ranged from 1920 to 30 ppb. Mean was 148.9 ppb. BOD ranged from 0.2 to 3.2. Chlorides ranged from 7.0 to 0.3 ppm with the mean being 3.1 ppm. Total Nitrogen ranged from 1.0 to 0.3 ppm with mean 0.4 ppm. Flow at the WQN is moderated by the Alvin Bush Dam (ABD) and does not characterize the dynamic flow regime of the watershed above ABD. Flow ranged from 3230 cfs to 6.6 cfs with the mean instantaneous flow of 335.2 cfs. Iron (mg/l) ranged from 2.8 to 0 ppm with mean of 1.87 ppm. Manganese values ranged from 1.4 to 0.02 ppm with mean of 0.07 ppm. Nitrate values ranged from 0.166 to 0.002 mg/L with a mean of 0.012 ppm. Ammonia (NH_4) values ranged from 1.0 to 0.0 ppm with a mean of 0.04 mg/L. Dissolved oxygen values ranged from 14.1 to 0.0 ppm with a mean value

of 10.57 mg/L. Lab pH ranged from 9.2 to 4.5 with mean pH of 6.6 units. Temperature ranged from 29.2 C (84.6 F) to 0 C (32.0 F) degrees centigrade with a mean temperature of 12.2 C (54.0 F) degrees centigrade. Using guidelines developed by Piper and others (1982) for fish raised in hatchery conditions only the ammonia, chlorides, and iron parameters exceed acceptable values for trout propagation. Maximum temperature value exceeds the value described by Piper and others (1982), but the mean temperature falls into the acceptable range. DO, alkalinity, pH, and nitrate are at acceptable levels.

Stormwater Management

Stormwater runoff is produced during a rainfall event in which water falling on impervious surfaces within a developed area to infiltrate in the soil and takes the form of surface runoff. A developed area is defined as an area where the natural land surface has been modified by changing the vegetation type or physical surface. This surface runoff, while traveling over impervious surfaces, carries with it pollutants present on them and discharges them into a nearby stream, pond, or wetland. The pollutants in runoff varies with differing land uses and could contain high nutrient levels in runoff from residential housing and other managed lawn areas and could contain metals, organic and inorganic compounds in runoff from industrial sites. Road runoff can contain oils, road salt, and sediment. This polluted runoff joins nearby streams and causes long-term impacts on aquatic life and drinking water sources. In addition to impairing the water quality, increasing runoff volumes, due to significant increase in impervious areas, causes localized flooding. The storm flows are typically of higher volume over a shorter period of time and thus causes severe impacts to stream morphology; including stream bank erosion, scour of streambed, and resulting sedimentation of streambed. The changes in stream morphology significantly impact fish communities.

Small culvert at Ole Bull State Park.

In the case of the Kettle Creek watershed, similar effects could be anticipated in the near future considering the potential for future development. Although the watershed has extremely small-developed areas in size, polluted runoff from these areas could cause significant negative impacts to its water resources. Especially in the headwaters, the impact from local stormwater runoff pollution could be extended throughout and felt in the lower stream reaches as well. Stormwater management has been identified as an important issue in both Potter and Clinton counties, but a watershed wide plan has yet to be developed. The Potter County Comprehensive Plan released in 1998 recognized urban runoff problems that ranged from backyard flooding to major stream flooding and streambank erosion and thus accepted as a major concern for the County and the Township Officials. The Allegheny River Watershed Stormwater Management Plan developed by Potter County in 1992 covered areas falling in the Allegheny River watershed only.

Lack of adequate stormwater controls in the headwater areas of the watershed along with the potential for further development it becomes imperative to address this non-point source of pollution to preserve and restore the water quality of this otherwise healthy watershed. The development and implementation of watershed stormwater management planning can be carried out under Act 167, the Stormwater Management Act released in 1978 that addresses stormwater issues prevalent in various land-use type developments.

NON-POINT SOURCE POLLUTION

Introduction

Non-point source pollution is defined as discharges entering surface waters in a diffuse manner at intervals that are related mostly to the occurrence of storm events (Novotny and Olem 1994). In other words, non-point source pollution can come from land areas during storm events as runoff. Road sediment, agricultural fertilizers, and septic systems are common non-point sources of pollution. Unlike the traditional "point" sources of pollution, that we can “treat” at the pipe, the most effective method of pollution control for non-point sources is focused on land management practices. Non-point sources are difficult to manage and equally difficult to assess. Due to the time and expense of extensive ground-based analysis, simulation modeling has become common for the development and implementation of non-point source control programs (Novotny and Olem 1994).

The Kettle Creek Keystone Project has identified non-point pollution as the most common form of water pollution on Kettle Creek. In order to assess the potential influence of non-point pollution sources on the health of the watershed we used three different strategies:

- Total nitrogen, total phosphorus and total sediment loading rates from various land-use areas on an annual basis.
- Daily nitrogen concentrations based on water quality sampling data.
- Potential sediment delivery from dirt and gravel roads.

Nitrogen and phosphorus are common nutrients of concern in aquatic systems for their effect on the algal growth and eventual depletion of oxygen for fish and other organisms (Novotny and Olem 1994). High levels of these

LOADING RATE

It is helpful to describe non-point sources of pollutants in terms of loading rates. This way we can easily compare different areas in a watershed or region in a similar fashion. Loading rates are the amount of a given pollutant that washes off of an area of land over a period of time. These data (presented as pounds per acre per year) are used by natural resource managers to determine when streams have reached their maximum pollution load.

Algae blooms on Kettle Creek indicate a high level of nutrients in the water. These algae blooms can create an oxygen depletion that will affect fish and other stream organisms.

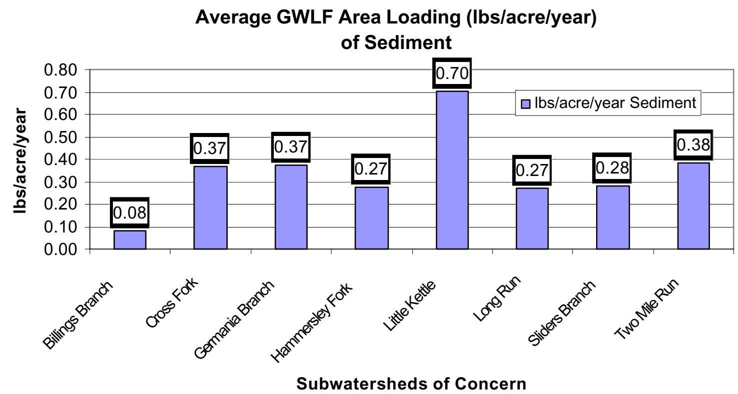
nutrients in the Chesapeake Bay have had detrimental effects on human health, local fisheries and the economies of the region. This has created a high level of concern over land use in the Chesapeake Bay watershed, of which Kettle Creek is a part. Non-point pollution can be greatly reduced using best management practices in agriculture, forestry or residential development.

Sediment and erosion is a natural part of any watershed. Stream channels can accept certain levels of sediment depending on the stream type, but if erosion delivers sediment to a channel frequently and in large quantities, this form of pollution will become detrimental to a stream's health and may create instability in stream channels. Sediment can also contribute to the increased transport of other pollutants, such as phosphorus, carrying them downstream.

Other probable non-point pollutants on Kettle Creek would include salt and organic chemicals from roads, herbicides and pesticides from forestry and agricultural application.

The Generalized Watershed Loading Function Model

To assess the potential for non-point source pollution from various subwatersheds in Kettle Creek the ArcView version of the Generalized Watershed Loading Function (AVGWLF) model (Evans and others, 1999). This simulation uses current information regarding rainfall, soils, land use, and census information to predict monthly and annual loading rates of nitrogen, phosphorus and sediment (Appendix I, page 322). The AVGWLF provides us with a valuable tool to compare the non-point pollution loads of streams in the Kettle Creek watershed. As a simulation of conditions, the outputs of the model are best used as relative values of pollutant loads on the watershed. From the model priority areas can be determined that would be most suitable for non-point pollution reduction strategies (See Figures 5.11, 5.12). The watersheds with the lowest loading rates on Kettle Creek are predominately forested and can provide reference conditions as "pristine" Pennsylvania streams. Unfortunately, some watersheds on Kettle Creek do appear to be contributing to increased nutrient loads and are losing soil at higher rates of erosion.



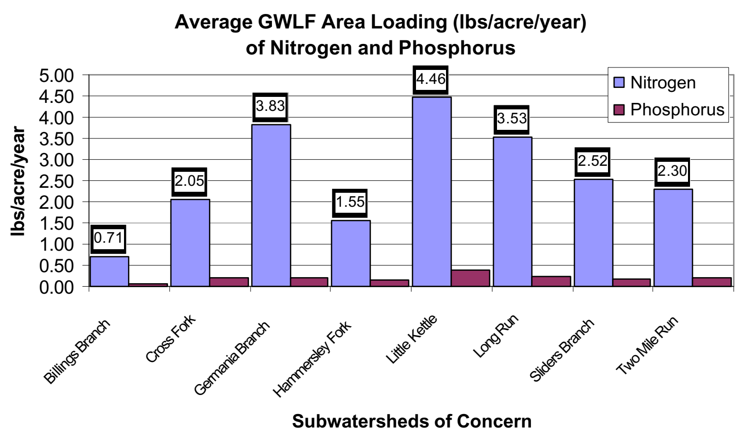


Figure 5.11, 5.12 - Nutrient and sediment runoff values shown here give an indication of potential subwatersheds to begin non-point source reduction strategies. Nutrient loading on Kettle Creek can be reduced using voluntary best management practices on agricultural and forestry lands, reducing sediment runoff from roads and developed areas and improving the design and maintenance of septic systems in floodplains.

EFFECTS OF DAMS

Reservoirs can be useful in reducing flood flows, creating recreation opportunities or storing water for drinking supplies. But these changes to a stream can also affect the transport of pollutants, the erosive power of the stream and stream habitat.

Dams also store sediment. As water velocity slows above a dam, the sediment carried in the water will often settle out. Sediment will carry certain nutrients and pollutants with it. In this way some pollutants can be stored behind a dam actually improving downstream water quality. But this storage can also create problems when the sediment is dredged, as it can often contain high levels of toxic material that must be disposed of in sensitive ways. This storage of sediment and nutrients in the Alvin Bush Reservoir probably reduces the usefulness of the Kettle Creek Water Quality Network (WQN) monitoring station.

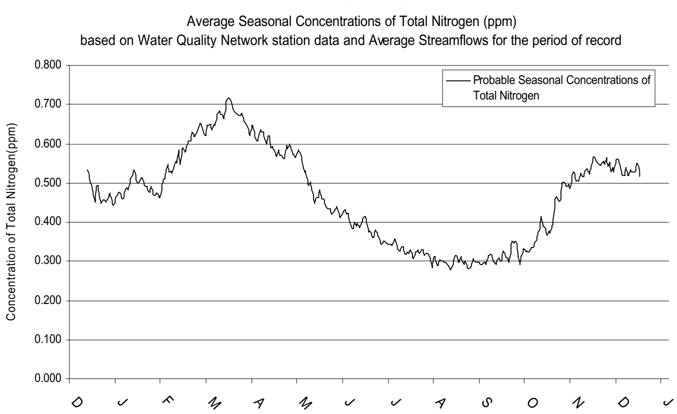


Figure 5.13 - Concentrations of some pollutants can depend on streamflow or season. In this chart the seasonal changes of nitrogen are exhibited. For effective sampling of nitrogen concentration peaks, sampling should be focused on spring and winter high flows.

Water Quality Network (WQN) Information

Water quality data monitored by the EPA at the Westport stream gage, provides us with information to construct a probable concentration of nitrogen at various levels of stream flow (for more information on the WQN station refer to page 175). Phosphorus has not been included in this analysis because of the location of the water quality network site below the Alvin Bush Reservoir. Phosphorus is often adsorbed, or attached to, sediments and will be deposited in the reservoir.

The nitrogen concentration to stream flow relationship allows us to determine probable concentrations of pollutants over time instead of as monthly or annual loading rates (See Figure 5.13). Changes in concentrations of nutrients at particular times of year may help to indicate the potential sources of pollutants or when water quality sampling may be most effective. The annual loading rate can also be compared with AVGWLF outputs for comparison of two different approaches to assessment of nitrogen pollution (see Figure 5.14).

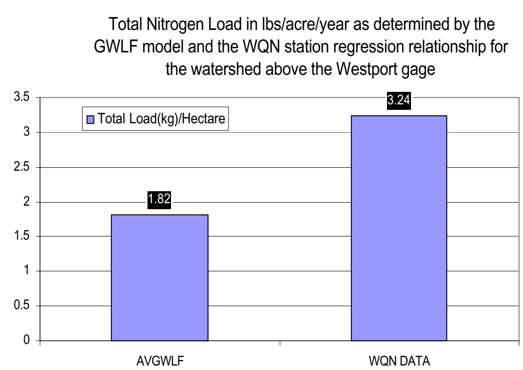


Figure 5.14 - The comparisons of GWLF and WQN modeled nitrogen values provide a probable range of values for non-point pollution area loading. These loading values for nitrogen are much lower than agricultural watersheds in other parts of the state.

DIRT AND GRAVEL ROAD MAINTENANCE PROGRAM

The Conservation Commission's Dirt and Gravel Road Maintenance Program is a voluntary pollution prevention program authorized and funded with an annual $5 million by the state Vehicle Code. The law recognizes that dirt and gravel roads are a distinct form of permanent roadway that require unique standards and guidelines for construction, maintenance and environmental protection. Local decision-making is the key to the continued success of this program.

The Dirt and Gravel Road Program is currently involved in delivering 2-day training workshops to township supervisors on environmentally sensitive road maintenance. The program has identified, with the help of local citizens, townships, and county conservation districts over 8,000 sites in need of anti-pollution work. Funds are available for these problem road segments through the county conservation districts.

Dirt and Gravel Road Sediment Production

Roads and other paved areas can be significant sources of water-borne pollutants (United Nations 1999). Oil, salt, and sediment are just a few of the pollutants that can flow from roads during storm events. In the Kettle Creek watershed there are 294 miles (473 km) of state, township, state forest and private roads. That is an average of 1.2 miles of road for every square mile of land area. In general the roads closest to a stream or body of water have the greatest potential for pollution. Kettle Creek has 119 miles of road within 250' (76m) of the stream. Of this, 48% are state forest or private roads, 26% are township roads, and the remaining 26% are state-owned (see figure 5.15). The majority of the township, private, and state forest roads are not paved.

Dirt and gravel roads can be significant sources of fine sediment and in some cases can severely affect the habitat needs of fish, particularly wild trout. The potential impacts of dirt and gravel road erosion on wild trout streams became the

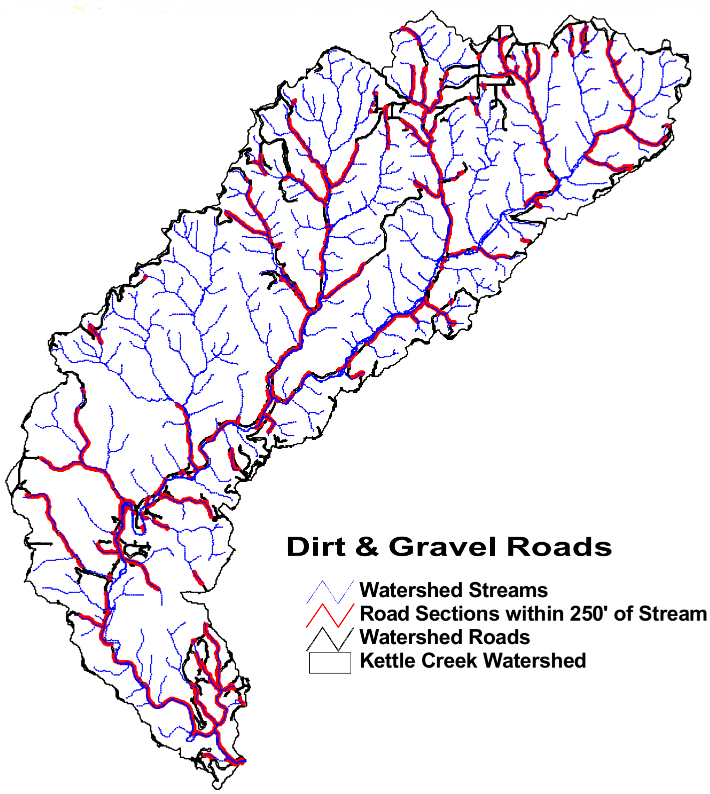
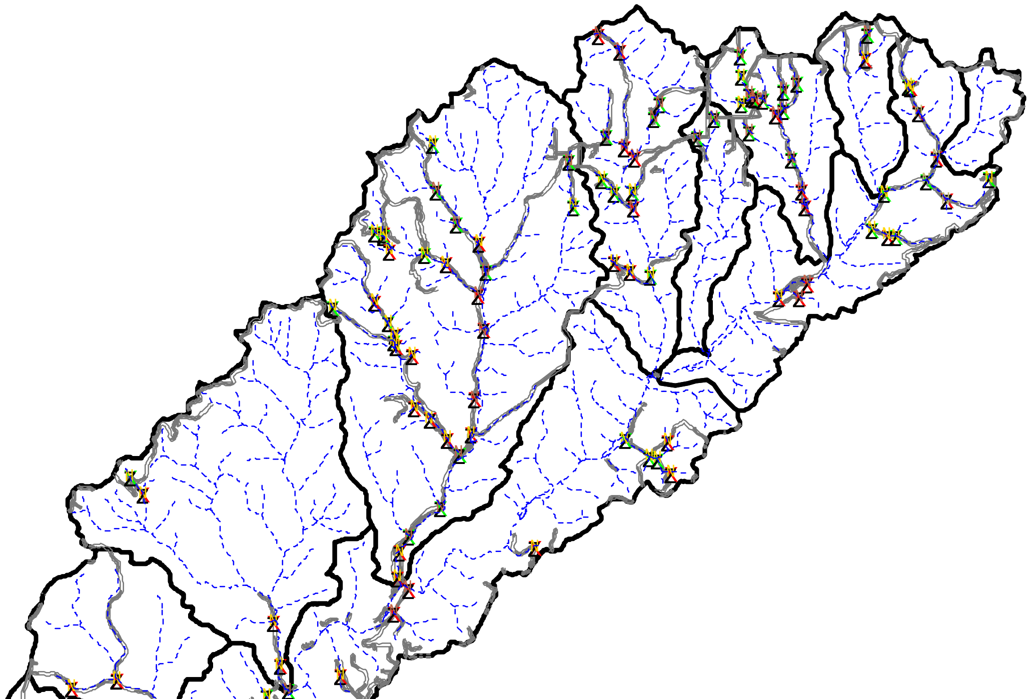
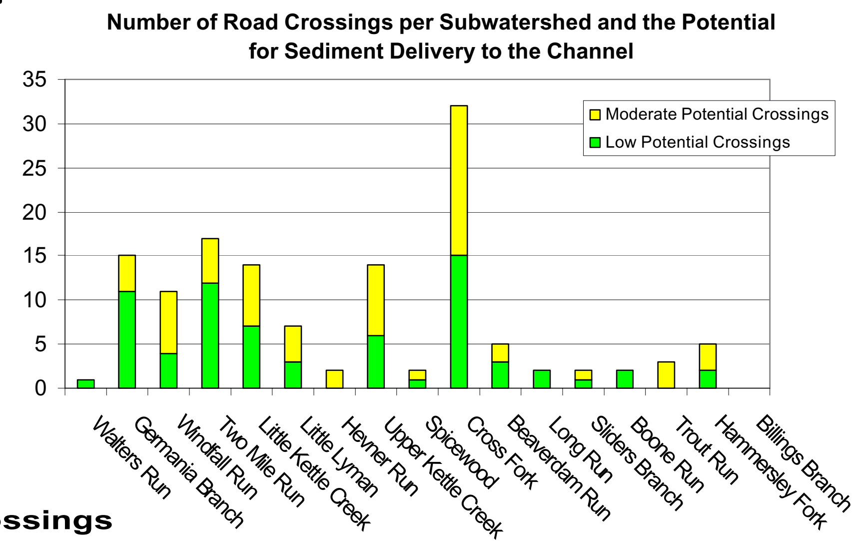


Figure 5.15 - Salt, sediment and oil are likely to be delivered to streams from roads and paved surfaces within 250 feet of streams. The map above shows the 119 miles of roads that are wtihin 250 feet of streams on Kettle Creek.





Figures 5.16, 5.17 - Road crossings can be the single largest contributor of sediment to a stream on forested watersheds. Additionally, road crossings can limit fish passage, cause localized erosion and be a costly maintenance problem after floods. Stream crossings are listed by subwatershed in the chart above for comparison.

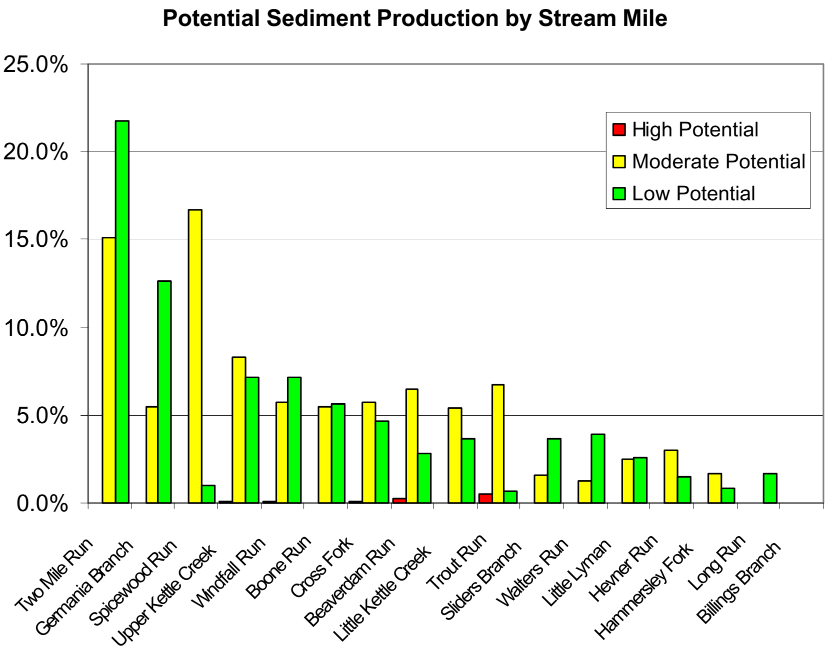


Figure 5.18 - The delivery of sediment to streams from dirt and gravel roads can be a significant non-point source of pollution. As shown above, there are subwatersheds on Kettle Creek that have almost 1/4 of their streams potentially influenced by road runoff. This chart helps us identify which watersheds are more prone to sediment pollution from dirt and gravel roads.

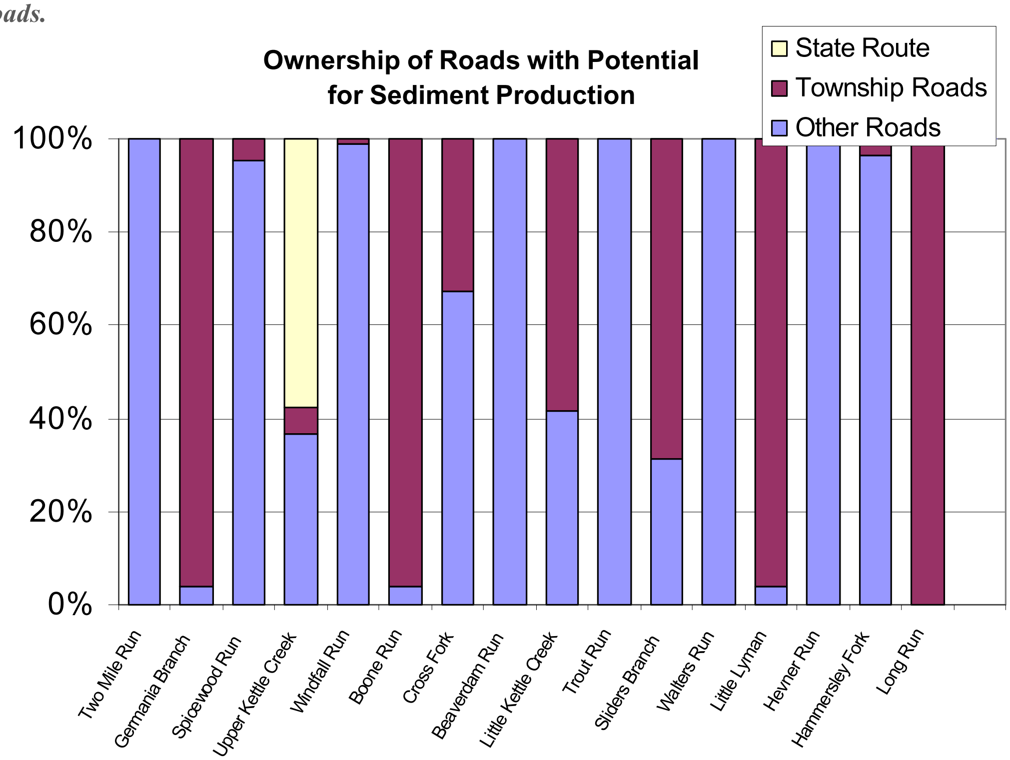


Figure 5.19 - The ownership of potential sediment producing segments of roads are a quick indication of potential partners for fixes.

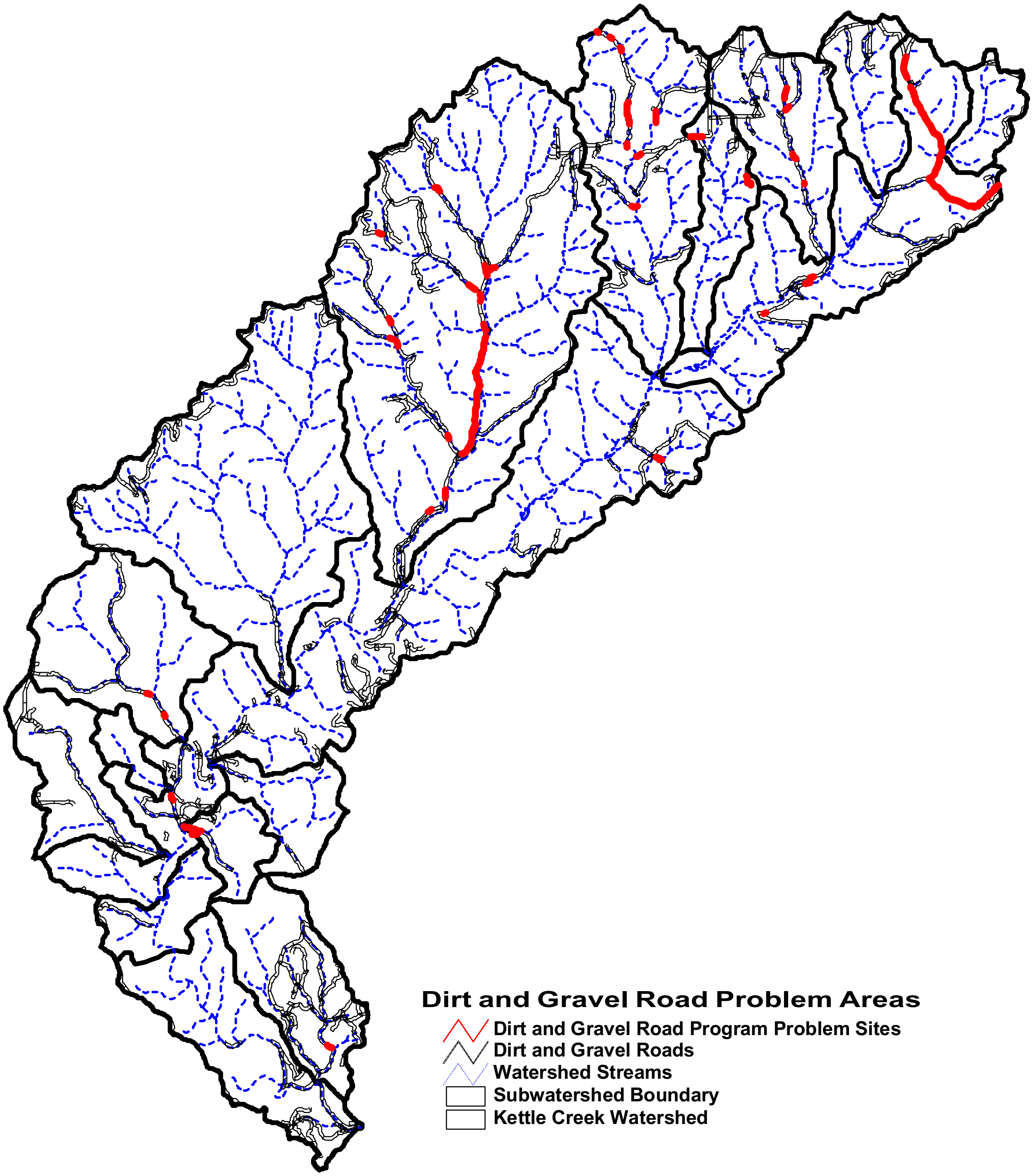


Figure 5.20 - The above map shows dirt and gravel road problem areas as identified by Trout Unlimited and the Potter and Clinton County Conservation Districts. These segments are immediately eligible for funding through the Dirt and Gravel Road program and can be prioritized based on the road sediment impacts ranking index.

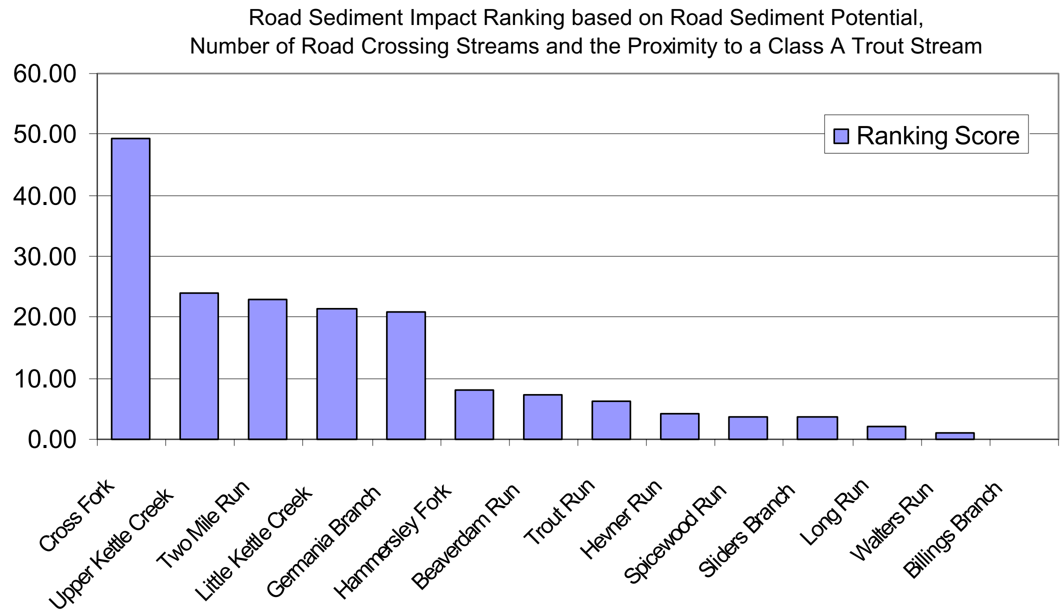


Figure 5.21 - These rankings represent an integration of potential dirt and gravel road problem areas, the number of road crossings per subwatershed and the proximity of those roads to a Class A trout stream. The ranking is a relative number and indicates which watersheds are most likely to be effected by sediment pollution from dirt and gravel roads.

driving force behind a statewide program to improve the maintenance and longevity of dirt and gravel roads. Gravel roads that require less maintenance are less expensive and longer lasting and create less pollution.

Surface erosion occurs from nearly all roads regardless of design and construction, but sediment delivery to a channel only occurs under certain conditions:

• When ditches and culverts drain near the channel (within 200' or 70m). Within this zone the sediment delivery to a stream can be 100% (Burroughs and King 1989).

• When roads are located on steep side slopes. As sediment delivery to a stream is based on the potential for downslope sediment transport, the steeper the ditch, road cut or culvert outfall the greater the potential for sediment to be carried to a stream (Ketcheson and Megahan 1996).

• When increases of traffic occur on roads. During wet weather, heavily trafficked roads produce substantially more sediment than do abandoned or low-use roads (Reid and Dunne 1984).

Based on the primary influences of slope and the proximity to streams, the Kettle Creek team developed a GIS-based model to predict sediment potential from all dirt and gravel roads on the watershed in order to prioritize road runoff reduction efforts by subwatershed. The model identifies road segments within 100' (30m) of a stream that are located on three ranges of slopes. These three slope classes indicate the low, moderate, or high potential for sediment

Dirt and gravel roads can contribute sediment to nearby streams.

GOALS: NON-POINT SOURCE

WQ 1.1: Reduce nutrient, sediment, and chemical non-point source pollution delivery to target areas and key tributaries.

LU 1.2: Develop and encourage the use of Best Management Practices (BMPs) on Agricultural Production lands to minimize impacts on adjacent natural resources.

delivery to the channel. A ratio of potential road sediment production to stream length provides a valuable comparison of the potential effects of dirt and gravel roads on the streams of Kettle Creek. The highest possible value is 100%, which indicates that every mile of stream is potentially influenced by road runoff (See Figure 5.18). Additionally, we identified all potential stream crossings in Kettle Creek. At these locations the production of sediment is likely, unless there is some effort to reduce or eliminate road runoff (See Figure 5.16 & 5.17). The ownership of sediment-producing segments of road was also assessed to assist with the identification of potential partners for road improvements (See Figure 5.20).

In order to integrate the affects of sediment runoff and to identify a list of priority subwatersheds, we developed an index that ranks subwatersheds based on miles of sediment delivery potential, the fishery-quality of receiving waters, the location in the watershed, and number of stream crossings (see figure 5.21). Problem road segments have been identified on the ground by the Dirt and Gravel Road Program, county conservation districts, townships and Trout Unlimited (See Figure 5.19). These problem areas can now be viewed in the context of a subwatershed's cumulative sediment impacts. These specific road segments can be targeted for erosion control that will create the greatest improvement to stream conditions.

Acid
Mine Drainage (AMD)

Overview of Mining

Soft coal was discovered by mineral prospectors hired by investors and speculators during the early 1870s (Parucha 1986). Most of the watershed had been logged at this point in time and landowners were looking for other resources. The Kettle Creek Coal Mining Company was chartered in 1874 and began operations on the west side of Kettle Creek. The town that developed as a result was Bitumen. At its peak, Bitumen harbored several thousand residents; today, Bitumen is a small village of permanent and seasonal dwellings

Mining in the watershed started with small hand dug mines where coal outcropped on the steep slopes. The Lower Kittaning Coal seam was the target of early miners. The room and pillar method was used to extract the coal. Shafts were dug to penetrate the coal vein then expanded horizontally, but support pillars were left to support the mine roof. When the veins were exhausted in all dimensions, the miners retreated and often removed the coal pillars as they exited the mine. The main problem with this type of mining was that it often was conducted up-slope and allowed the water within the mines to drain away into adjacent streams (Klimkos 2000). Water draining from the mines reacted with pyrite and acidified causing acidic mine drainage (AMD).

The remnants of the mines are still producing AMD today. Spoil piles, large dumps rock and lower grade coal extracted from the mines, are often located near the entrances of subsurface mines and are a source of AMD. Deep mining or subsurface mining occurred on both the eastern and western side of Kettle Creek. Mining was concentrated in the Twomile Run watershed on the eastern side of Kettle Creek. The last subsurface mine closed in the 1950s (Klimkos 2000).

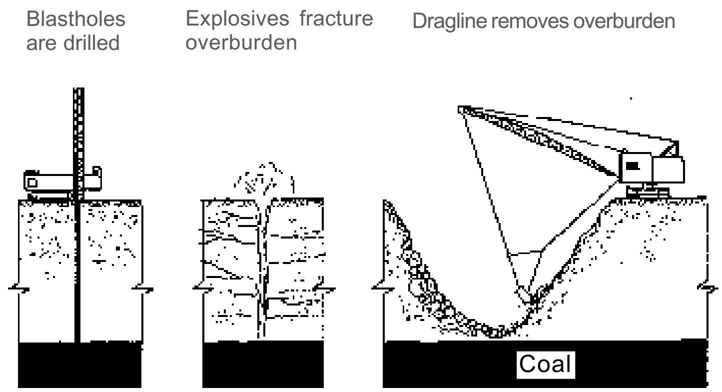


Figure 5.22 - Preliminary steps to access coal seams. Once the overburden is removed, the coal is loaded into trucks and hauled to a processing area.

Surface mining also occurred in the watershed. Surface mining (or strip mining) consists of removing the overlying soil or overburden to access the coal seams. Surface mining started during World War II and targeted the Middle Kittaning and Upper Freeport coal seems. Surface mining creates a large amount of spoil or overburden which is piled near the pits that contained the coal. The spoil piles were typically ungraded and unvegetated. Spoil piles are sources of AMD because the pyrite has been brought to the surface where it can combine with precipitation and oxygen to form AMD. The majority of the sites on the western side of Kettle Creek have been roughly graded to contour and planted with pine trees. The process meets older reclamation standards which requires rough grading to premining contours and planting of trees or grasses. Many of the sites on the eastern side of Kettle Creek have ungraded and unvegetated spoil piles. Some exposed rock faces or high walls exist which are the remains of contour mining. Open pits collect and direct surface water to flow through pyritic material and infiltrate into the groundwater resources with the potential to discharge into nearby streams as baseflow. Surface mining ceased in 1977.

ACID MINE
DRAINAGE

Acid mine drainage as seen today in Twomile Run.

AMD Production

Acidic mine drainage is caused by the reaction of oxygen, water, and pyrite (FeS_2). The primary chemical equation is diagramed below. To stop AMD production, the reaction cycle has to be interrupted. The ending products of AMD are iron oxide (FeO_2) or rust and sulfuric acid. Iron oxide precipitates and forms the orange plating commonly found on rocks in AMD impacted streams. The sulfuric acid is mobile and flows through the soil, leaching metals such as iron, aluminum, and manganese. Sulfate production also increases. The

AMD FORMATION REACTION

$$4FeS_2 + 15O_2 + 2H_2O \longrightarrow 2Fe_2(SO_4)_3 + 2H_2SO_4$$

acidic water dissolves and carries the metal in solution until pH or oxygen levels increase. Aluminum is toxic to fish and macroinvertebrates. Iron plates the substrate impacting macroinvertebrate habitat. Unvegetated spoil piles, poorly vegetated reclaimed sites, and abandoned mine entrance shafts are the three largest producers of AMD. Some soils have the ability to buffer acid production, but those soils are not found in the lower Kettle Creek watershed.

Kettle Creek AMD Studies

Two studies describe the AMD issues on the lower watershed. A total maximum daily load (TMDL) study was published by the DEP, Bureau of District Mining Operations in October of 2000. Mike Klimkos from the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation (BAMR) researched and identified AMD issues on the western side of the watershed. The Klimkos report does not suggest implementation procedures. Hedin Environmental was contracted by KCWA through a DEP Growing Greener Grant to inventory and identify the AMD issues on the eastern side of the watershed, primarily the Twomile Run subwatershed. The Hedin report also suggested implementation projects to mitigate AMD impacts in the study area. AMD analysis was also conducted in the Scarlift Report from the early 1970s sponsored by the DER (DEP) BAMR, however both recent studies question the validity of the earlier report. The TMDL study collated data from sampling points throughout the Twomile subwatershed and developed pollution loading values, developed pollution loading reduction goals, and listed several recommendations to reach the loading goals.

Summary of Eastern Side

Twomile Run is the largest tributary on the eastern side of lower Kettle Creek containing 16.6 miles of streams with 51 % or 8.5 miles are impaired by AMD generated from both deep and surface mines. (Hedin 2000). It covers 4 % of the entire Kettle Creek watershed and impacts 4% of the streams within the watershed. The AMD inputs from Twomile degrade the aquatic ecosystem to a level which does not support a fishery. The Twomile watershed has four major subwatersheds; Huling Branch, Macintosh Hollow, Middle Branch, and

Robbins Hollow. All of the subwatershed streams, except Macintosh Hollow, are impaired by AMD. Figure 5.23 shows a graphic representation of the selected sampling points for the TMDL study. The mainstem of Twomile above the confluence of Huling Branch has a very low pH (3.5) and high Al (9.11mg/L) and Fe (0.92 mg/L) concentrations. Huling Branch is the largest contributor of AMD with high Al (9.26 mg/L) concentrations and high acidity (117.5mg/L). Middle Branch ranks second behind Huling Branch in flow and has high acidity (41.24 mg/L). Robbins Hollow has a smaller discharge, but high concentrations of iron. The unique chemical characteristics of the major AMD sources provide challenges when considering restoration. The affected streams do have headwater sections that are unimpaired and support significant populations of aquatic organisms. For more detailed information, refer to the Hedin report.

Hedin Environmental was contracted by the KCWA to develop a restoration plan for the Twomile Run watershed. Restoration of the Twomile Run watershed will also facilitate the restoration of the lower six miles of Kettle Creek. Treatment systems on Middle Branch, the "Swamp", and Robbins Hollow will facilitate the restoration of the downstream sections of respective streams. The “Swamp” is a large area with multiple discharges located northeast of Robbins Hollow. The key is to restore Huling Branch which has the largest pollution load and the largest impact on the mainstem of Twomile Run and ultimately the mainstem of Kettle Creek. The restoration of Twomile is a priority, but adequate data and understanding are prohibiting the development of a complete efficient restoration plan.

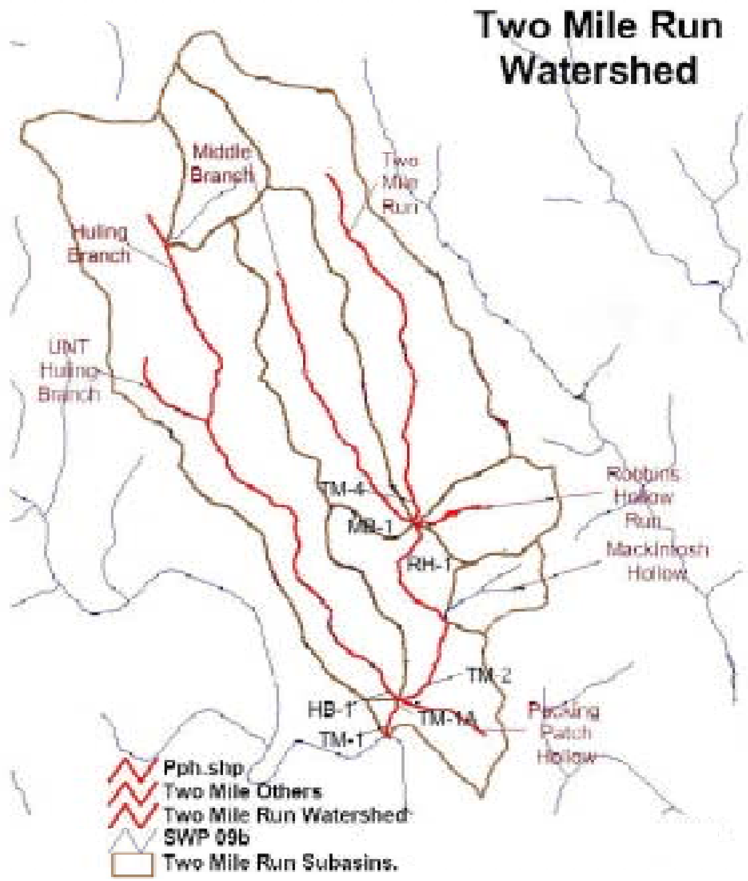


Figure 5.23 - Selected sampling points for the TMDL study. Values for these points are listed in The Summary Table (figure 5.24)- Twomile Run load reduction goals

Summary of Western Side

AMD impacted tributaries on the west side are significantly different marked by decreased volumes and larger geographic distribution area. The western side study area covers only 2 % of the Kettle Creek watershed (Klimkos 2000). The largest western tributary is Short Bend Run that drains 650 acres (263.2 ha). In contrast, the Twomile watershed is 5855 acres (2369 ha). The following streams are affected on the western side having discharges that are created by mine drainage: Slide Hollow North, North Steep Side, South Steep, "The Beach", Skunk Hollow, and Duck Hollow. The Beach is a broad area on the banks of Kettle Creek with diffuse AMD inputs. The western side has 2.35

Applicable Water Quality Criteria		
Parameter	**Criterion value (mg/l)**	**Total Recoverable/ Dissolved**
Aluminum*	0.1 of the 96 hour LC 50	Total Recoverable
	0.75	
Iron	1.50	Total Recoverable
	0.3	dissolved
Manganese	1.00	Total Recoverable
PH**	6-9	NA
*- This TMDL was developed using the value of 0.75 mg/l as the in-stream criterion for aluminum. This is the EPA national acute fish and aquatic life criterion for aluminum. Pennsylvania's current aluminum criterion is 0.1 mg/l of the 96-hour LC-50 and is contained in PA Title 25 Chapter 93. The EPA national criterion was used because the Department has recommended adopting the EPA criterion and is awaiting final promulgation of it.		
** - The pH values shown will be used when applicable. In the case of freestone streams with little or no buffering capacity, the TMDL endpoint for pH will be the natural background water quality. These values are typically as low as 5.4 (Pennsylvania Fish and Boat Commission). This condition is met when the net alkalinity is maintained above zero.		
Source: DEP, 2000		

Figure 5.24 - Water quality criteria for high quality and exceptional value streams used to develop AMD loading reduction goals.

Figure 5.25 - To restore lower Kettle Creek and Twomile, DEP has identified these reduction goals at TM-1a .

Necessary Reductions at Sample Point TM-1A				
	Al(#/day)	**Fe(#/day)**	**Mn(#/day)**	**Acidity(#/day)**
Existing loads at TM-1A	394.2	234.2	296	4162.7
Total Load Reduction (Sum of TM-4, MB-1, RH-1, TM-2 & HB-1)	368.9	201.8	290.4	3909.5
Remaining Load (Existing Loads atTM-1A - TLR Sum)	11.8	18.7	11.8	0
Percent Reduction	53%	42%	NA	100%
Additional Removal at TM1A	13.4	13.7	NA	253.2
Allowable loading values shown in Figure 5.24 represent (DEP, 2000)				

Summary Table -Two Mile Run load reduction goals										
Station		Measured Sample Data		Allowable		Reduction Identified	Present Loading		Reduction Goals	
	Parameter	Conc (mg/l)	Load(lbs/day)	**LTA Conc (mg/L)	Load (lbs/day)	%	lbs/year	tons/year	lbs/year	tons/year
TM-4	In-stream monitoring point located on Two Mile Run									
	Al	9.11	76.1	0.27	2.3	97%	27776.5	13.89	839.5	0.42
	Fe	0.92	7.7	0.67	5.6	92%	2810.5	1.41	2044	1.02
	Mn	6.83	57	0.27	2.3	96%	20805	10.40	839.5	0.42
	Acidity	73.67	615.3	0.15	1.23	100%	224584.5	112.29	448.95	0.22
	Alkalinity	0.37	3.1		N/A	N/A	1131.5	0.57	N/A	N/A
MB-1	In-stream monitoring point located on Middle Branch									
	Al	4.75	24.6	0.24	1.48	94%	8979	4.49	540.2	0.27
	Fe	0.22	1.1	0.22	1.1	0%	401.5	0.20	401.5	0.20
	Mn	1.66	8.463	0.41	2.11	75%	3088.995	1.54	770.15	0.39
	Acidity	41.24	216.3	0.8	1.9	99%	78949.5	39.47	693.5	0.35
	Alkalinity	0.72	3.7		N/A	N/A	1350.5	0.68	N/A	N/A
RH-1	In-stream monitoring point located on Robbins Hollow									
	Al	11.86	17.3	0.24	0.35	98%	6314.5	3.16	127.75	0.06
	Fe	0.27	0.4	0.27	0.4	0%	146	0.07	146	0.07
	Mn	9.59	14	0.29	0.4	97%	5110	2.56	146	0.07
	Acidity	90.67	132.2	0	0	100%	48253	24.13	0	0.00
	Alkalinity	0	0		N/A	N/A	0	0.00	N/A	N/A
TM-2	In-stream sampling point located on Two Mile Run									
	Al	7.48	191.9		17.7	92%	70043.5	35.02	6460.5	3.23
	Fe	0.41	10.5		N/A	N/A	3832.5	1.92	N/A	N/A
	Mn	6.72	172.3		90.8	93%	62889.5	31.44	33142	16.57
	Acidity	60.5	1552.2		576	97%	566553	283.28	210240	105.12
	Alkalinity	1.55	39.8		N/A	N/A	14527	7.26	N/A	N/A
HB-1	In-stream monitoring point located on Huling Branch									
	Al	9.26	187	0.19	3.7	98%	68255	34.13	1350.5	0.68
	Fe	10.3	208	0.41	8.3	96%	75920	37.96	3029.5	1.51
	Mn	6.45	130.1	0.26	5.2	96%	47486.5	23.74	1898	0.95
	Acidity	117.5	2372.8	0	0	100%	866072	433.04	0	0.00
	Alkalinity	0	0		N/A	N/A	0	0.00	N/A	N/A
TM-1A	In-stream monitoring point located on Two Mile Run									
	Al	8.57	394.2	0.26	11.8	97%	143883	71.94	4307	2.15
	Fe	5.09	234.2	0.41	18.7	92%	85483	42.74	6825.5	3.41
	Mn	6.43	296	0.26	11.8	96%	108040	54.02	4307	2.15
	Acidity	90.5	4162.7	0	0	100%	1519386	759.69	0	0.00
	Alkalinity	0	0		N/A	N/A	0	0.00	N/A	N/A
Summary table for loadings and reductions in Twomile Run watershed						**LTA = Long Term Average				
DEP, 2000										

Figure 5.26 - Twomile Run Load reduction Goals. Load values were converted from lbs/day to tons/year to demonstrate the magnitude of metal loading annually by the streams in the Twomile watershed.

miles (3.9 km) of perennial streams that do not support aquatic communities including 1.5 (2.5 km) of Short Bend Run 0.85 miles (1.38 km) of Butler Hollow and 0.56 miles (0.9 km) of Slide Hollow. Mike Klimkos, a water pollution biologist from DEP BAMR has conducted an assessment of AMD impacts on the western side of lower Kettle Creek (defined as the watershed below the Alvin Bush Dam). The goal of the study was to characterize the AMD sources on the western side of the watershed. The study defined 6 problem areas covering 908 ac (368 ha) with 22 problem features ranging from abandoned mine entrances to "dry strip mines". Fifteen of the problems are AMD discharges, three dry strip pits, two refuse piles, one open shaft mine entry, and 1 subsidence prone area. Twenty-two sample sites were designated by the study and samples were collected. Seven sample sites were on the mainstem of Kettle Creek. For more detailed information, refer to the Klimkos report.

Total Maximum Daily Load (TMDL) Study

One of the major components of a TMDL is the establishment of an instream numeric endpoint, which is used to evaluate the attainment

Unreclaimed spoil pile capable of reducing large volumes of AMD. Reclamation at this site entails regrading the pile to existing contours, addition of organic matter, and revegetating the surface.

Ecological connectivity is important because components of one ecosystem are dependent on components of another ecosystem.

of acceptable water quality. An instream numeric endpoint, therefore, represents the water quality goal that is to be achieved by implementing the load reductions specified in the TMDL. The endpoint allows for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The endpoint is based on either the narrative or numeric criteria available in water quality standards. Because of the nature of the pollution sources in the watershed, most of the TMDL component makeup will be load allocations (LA) that are specified above a point in the stream segment. All allocations will be specified as long-term average concentrations. These long-term average concentrations are expected to meet water-quality criteria 99% of the time.

Title 25 Chapter 93.5(b) specifies that a minimum 99% level of protection is required. All metals criteria evaluated in these TMDLs are specified as total recoverable. The data used for this analysis report iron as total recoverable. The following table shows the applicable water-quality criteria for the selected parameters (DEP, TMDL 2000). Figure 5.25 displays the necessary reductions to restore lower Kettle Creek to the DEP designated water quality standards for a trout stocking fishery.

The DEP has identified quantifiable loading rates and reduction goals from the TMDL study which are displayed in figure 5.26. The values for lbs/day were converted to tons/year to demonstrate the cumulative daily impacts are substantial impacts on an annual scale. The reduction goals demonstrate the amount of metals and acidity that will be removed from the lower watershed ecosystem. Several strategies have been proposed to accomplish these goals including construction of passive and active treatment facilities, alkaline addition with backfilling, regrading and revegetation of pits and spoil areas, and remining.

Benefits of Reclamation

The lower Kettle Creek watershed, the portion of the watershed below the Alvin Bush Dam, has 30.1 miles (48.4 km) of streams. Fifty-six percent of the streams (16.9 miles, 27.1 km) are AMD impacted and do not support aquatic communities. An aquatic community is defined as a group of interacting organisms ranging from aquatic plants to game fish. The headwater tributaries of the lower watershed do support wild brook trout. The AMD impaired reaches have similar habitat potential in the Twomile Run watershed and the small tributaries that discharge directly to the mainstem. The lower mainstem is a transitional area between the cold water fishery below the dam and a potential cool water fishery in the Susquehanna River. Restoring all of the streams in the lower watershed would increase the biologically productive areas by 4 %. Kettle Creek is a major tributary to the West Branch of the Susquehanna River and improvements of water quality of Kettle Creek could potentially increase the water quality of the river.

Reclamation and restoration of the lower watershed will have major impacts in three areas: water quality, recreational fishing, and ecosystem connectivity. The Susquehanna River is impacted by AMD with most sources located above the confluence of Kettle Creek. The current water quality of Kettle Creek does not improve the water quality of the Susquehanna River. Restoration of the lower watershed will remove large amounts of acidity, aluminum, iron, and manganese which are discharged to the Susquehanna River.

Kettle Creek is the only major impacting tributary on the north side of the river between Lock Haven and Keating. A cool water fishery exists below the dam near Lock Haven and the Pennsylvania Fish and Boat Commission (PFBC) stocked cool water species above the dam within the last ten years. An improvement in the water quality of Kettle Creek has the potential to extend upriver a cool water fishery several miles above Lock Haven. A productive unstocked fishery is an indicator of a healthy stream ecosystem.

Recreational fishing is very popular in north central Pennsylvania. Kettle Creek is famous for its trout fishery, but it also supports a cool water fishery on Kettle Creek Lake and the unpolluted sections of stream below the dam. Restoration of the lower watershed and sections will increase fishing opportunities. Increased recreational opportunities can potentially increase the amount of tourism in the watershed and surrounding areas. Increased tourism will bring additional income to areas that are economically stressed.

KCWA AMD mitigation efforts includes representatives from the Department of Environmental Protection, Bureau of Abandoned Mine Reclamation, Trout Unlimited, Clinton County Conservation District, Natural Resources Conservation Service, Department of Conservation and Natural Resources Bureau of Forestry Sproul State Forest, Senator Jake Corman’s office,Department of the Interior, Office of Suface Mining, U.S. Army Corps of Engineers, and PA Fish & Boat Commission.

Another benefit of restoration of the lower watershed is increased ecological connectivity. Fish are the most obvious benefactors of increased water quality. The American shad is an example. The PFBC has committed to restoring shad to the Susquehanna River. Shad were stocked below the dam in Lock Haven several years ago. This migratory species is dependent on good water quality to survive. The unimpacted sections of Kettle Creek are inaccessible to these fish because the stream connectivity is disrupted by the AMD impacted sections of Kettle Creek and the river. The Alvin Bush Dam is also a barrier to migrating fish because it does not have a fish ladder. Migratory fish recovery would be limited to stream segments below the Alvin Bush Dam.

Passive AMD treatment system near completion on Middle Branch in the Twomile Run subwatershed. Passive systems, like this vertical flow pond will be, implemented in other parts of the Twomile watershed.

Many species of wildlife such as mink or river otters, are dependent on aquatic food sources. There is potential habitat in the lower watershed for these species, but they are unable to find food and consequently do not develop reproducing populations. Increased ecological connectivity will increase the wildlife diversity in the Kettle Creek watershed. Refer to the Wildlife and Fisheries section for more information.

Terrestrial ecosystems will benefit from the AMD reclamation activities on the watershed. The unreclaimed mine sites have little vegetation, low forest productivity, and high rates of erosion. Regrading and revegetating spoil piles will create potential wildlife habitat and increase the potential for plant community succession to occur. The spoil piles currently do not provide favorable conditions for plant germination and growth. The soil profile in the surface mined areas has been inverted and homogenized. The soil profile is important because upper layers provide a growing medium for plants and the lower layers store and transport groundwater. Reclamation will be unable to restore the soil profile, but amendments to the surface after regrading will increase the ability of plants to colonize the reclaimed sites. Established plant communities will begin to add organic material to the upper layers of the soil profile and mitigate soil temperature extremes which will create an environment conducive to succession. Succession of the reclaimed sites will eventually allow for the establishment of a mature stable community such as coniferous stands or mixed hardwood communities Eventually, the forestry industry may be able to harvest commercial timber from the reclaimed sites in 100 years or so.

AMD Treatment Systems

Currently there are two types of systems (active and passive) used to treat AMD in Pennsylvania. Active systems, such as lime neutralization, require electricity, use machinery, and are expensive to operate. Passive systems, such as treatment wetlands, use gravity flow, natural processes for treatment, and are inexpensive to operate. Passive treatment systems are the preferred method of treatment because the maintenance is much lower. Passive system are being considered for all sources except Huling Branch. Active treatment will most likely be used to treat this source. Hedin Environmental is currently developing a system for Robbins Hollow.

Remediation Projects

The KCWA has aggressively pursued the mitigation of AMD impacts. A large group of organizations including DEP, DCNR, TU, KCWA and others have cooperated to identify problem areas, collect information, analyze data, design treatment systems, construct treatment systems, and secure funding. AMD remediation is the most actively pursued issue in the watershed. The KCWA is making progress to neutralize the impacts of AMD in the watershed. One project has been constructed and several more are in the planning stage. Information is still needed about the impacted areas. Data collection has become a step in developing future remediation projects.

Completed Projects

The first project to be completed was in the Middle Branch subwatershed within the Twomile watershed. The system was constructed to collect and treat several AMD seeps. The passive treatment system is defined as a vertical flow pond. The system is powered by gravity. The collected discharges flow into a lined pond partially filled with a bed of limestone capped with a layer of compost. As the water flows through the compost, oxygen is stripped from the water creating anoxic conditions inhibit precipitation of metals. The limestone increases the pH of the water which will facilitate the precipitation of metals when the water is exposed to air. The water flows through a drain under the limestone into a sedimentation basin. The water contacts air and the metals (Al, Fe) begin to precipitate. The water flows through constructed wetlands to remove more iron. The final stage of the treatment process discharges the water into a limestone bed to increase alkalinity. Alkalinity increases the pH of the water and neutralizes downstream AMD impacts. This system has two limestone beds. One bed has been inoculated with pyrolusite which removes manganese from the treated water. The beds are constructed in parallel to evaluate the effectiveness of the pyrolusite-inoculation.

Projects In Progress or Under Construction

Two projects will be completed by late summer 2001 in the upper Twomile watershed. A collection system will be constructed in Robbins Hollow to collect data needed to design a passive treatment system. Funding has been secured through a Growing Greener Grant and a grant from the Department of the Interior, Office of Surface Mining (OSM) in conjunction with the Appalachian Clean Streams Funding Initiative. A surface and subsurface collection system will be constructed with a weir at the lowest point in the system to concentrate the diffuse flows for sampling and treatment.

Iron deposition in lower mainstem of Twomile Run caused by Acid Mine Drainage.

The second project involves biocapping 57 acres of Robbins Hollow surface mine. Regrading spoil piles near the swamp and "biocapping" will decrease infiltration and decrease AMD discharges to the swamp. Biocapping consists of regrading the site to original contours, mixing soils on the site with amendments to enhance plant growth, and establishing permanent vegetative cover. The vegetative cover will decrease erosion and sedimentation. The permanent vegetative cover will decrease infiltration because the plants will transpire a large percentage of the water that falls as precipitation. Grading of the site will also direct surface runoff to decrease infiltration. The soil amendment is mulch made from the combination of trees cleared from the site and Wes tan Soil Plus, an alkaline byproduct of the tannery at Westfield, PA.

Proposed Projects

The KCWA AMD Committee meeting conducted on January 29th 2001 heard several proposals to address sites not previously mentioned. A representative from BAMR explained that a technology exists to remotely measure AMD impacts throughout the entire impact areas efficiently. Cost was stated as a drawback. The remote sensing equipment consists of thermal imaging, ground penetrating radar, and terrain conductivity. The remote sensing package can accurately map seeps and discharges and subsurface features over large areas with great accuracy. A proposal was made to investigate the use of this technology.

A second proposal was developed to address the Huling Branch. A collection system is proposed to determine if passive treatment is possible. Active chemical treatment is a proven method for discharges with high metal content and acidity. The problems with chemical treatment is the cost of maintenance and the lack of infrastructure at the site. The U.S. Army Corps of Engineers will be involved in the mitigation of the Huling Branch watershed under section 206 program. A site visit is scheduled for early summer of 2001.

Additional studies are proposed for the western side of the watershed including remote sensing and possible alkaline addition to the "old law" reclamation areas. An idea was proposed to drain the AMD from the Bitumen mine complex and treat it on Crowley Hollow which is located outside the watershed to the west.

GOAL: ACID MINE DRAINAGE

WQ 1.2 Identify and mitigate acid mine drainage.

Acidic Deposition

Acidic deposition is a form of pollution that has become an important environmental stress since the 1970s (Likens and Bormann 1974). Although this subject has just recently become of public interest, the chemical process provides evidence that humans have been contributing to this pollution for hundreds of years. The term acidic deposition refers to the release of acidic substances from the atmosphere to the earth's surface via wet, dry, or occult deposition (Laws 2000). In the US, approximately 2/3 of all sulfur dioxide (SO_2) and 1/4 of all nitrogen oxides (NO_x) come from electric power generation that relies on burning fossil fuels like coal (EPA 2000). In the atmosphere, SO_2 and NO_x mix with oxygen, water, and other chemicals to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3). These acids then fall on the soil, trees, and in streams as wet, dry, or occult deposition.

ACIDIC DEPOSITION is the release of acidic substances from the atmosphere to the earth's surface via wet, dry, or occult deposition - most commonly referred to as acid rain.

DRY DEPOSITION is a type of acidic deposition when in the form of particulate matter.

WET DEPOSITION is a type of acidic deposition when in the form of precipitation (i.e. snow or rain).

OCCULT DEPOSITION is a type of acidic deposition when in the form of fog.

The harmful effects of acidic deposition on forest ecosystems is of particular concern during the spring and early summer when episodic acidification occurs in areas where the geology has low carbonate content (DeWalle and Swistock 1994). Parent material with carbonate content serves as a buffer against acidic inputs into the ecosystem. For instance, a well buffered soil receiving regular inputs of precipitation with a pH of 4 or lower may not alter the soil from having a pH of 6 or higher. However, soils lacking this buffer with prolonged exposure to acidic deposition, may experience leaching of base cations. Chronic base cation depletion coupled with low soil pH will eventually lead to high concentrations of aluminum (Al) in soil water. Once Al has become mobile in the soil solution, it can damage trees by out-competing essential plant nutrients like calcium (Ca) and magnesium (Mg) (Sharpe and Drohan 1999). These nutrients will be flushed from the soil into nearby streams and rivers leaving only Al to nourish the trees and other vegetation. Unfortunately, Al is toxic to tree growth because it binds to roots and blocks uptake of Ca or Mg. Once these essential base cations are leached from the soil, Al will also begin to migrate into streams where it can then have negative impacts on other parts of the ecosystem.

Atmospheric Deposition

Streams with minimal buffering capacity may be directly affected by acidic deposition because it will cause the pH of the water to decrease. After a particular pH is reached, aquatic biota may be negatively impacted (depending on an individual organism's tolerance to acidity). Aquatic organisms may also be indirectly affected by acidic deposition when Al is leached out of soils and into stream systems. Al is not only harmful to trees, it is also toxic to fish embryos (Fiss and Carline 1993) and binds to fish gills where it can interfere with osmoregulation (Leivestad 1976). Studies have also demonstrated that amphibian reproduction and benthic macroinvertebrate populations are adversely affected by acidified bodies of water (Laws 2000).

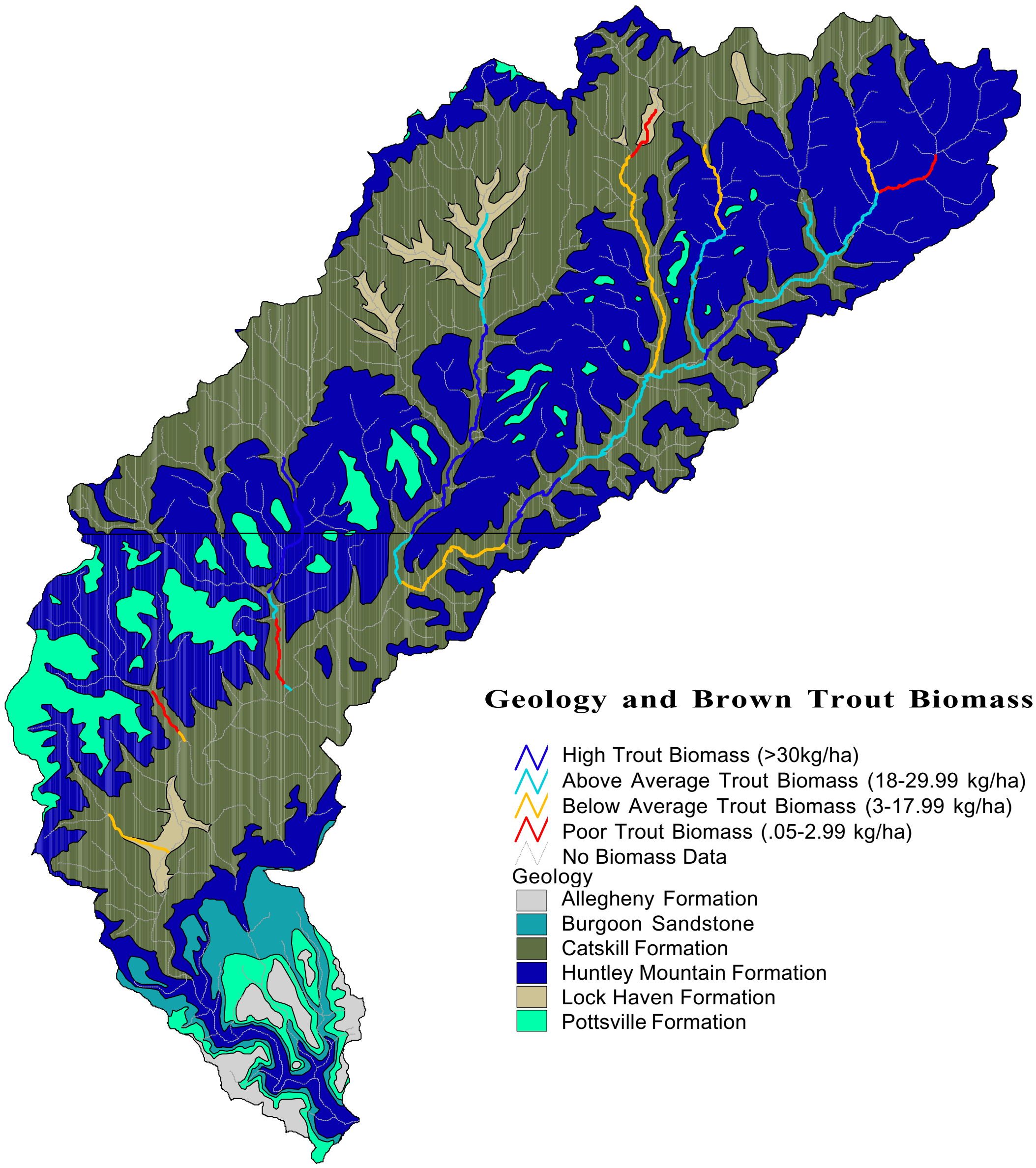


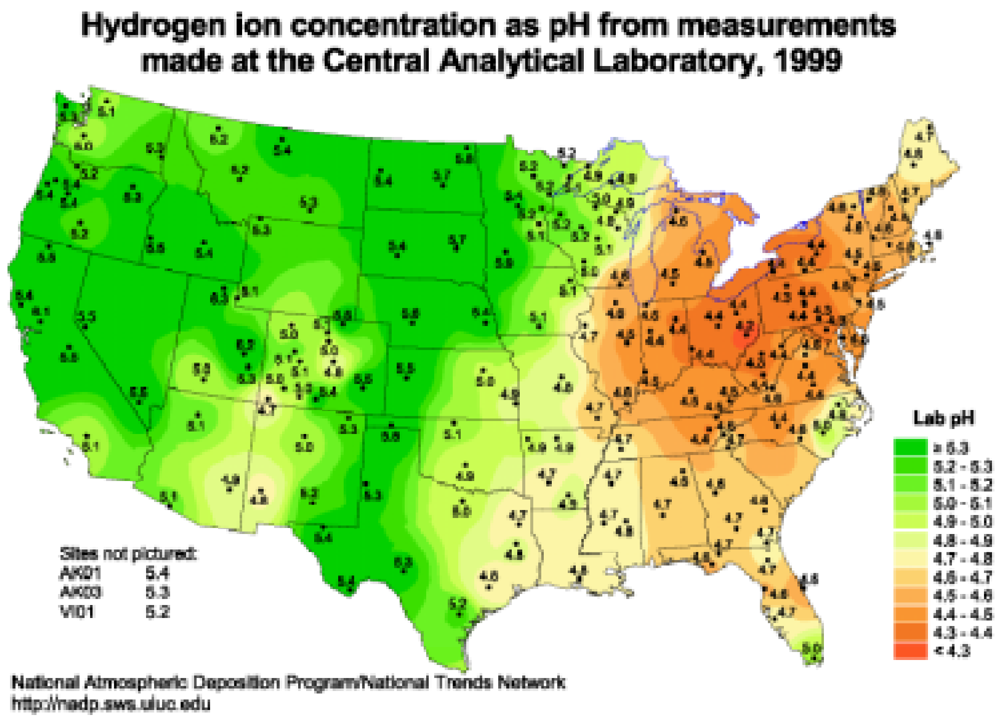
Figure 5.27: Geologic and brown trout biomass map of the Kettle Creek watershed

ACID DEPOSITION TERMS

PARENT MATERIAL is the weathered mineral or organic matter from which soils are derived.

EPISODIC ACIDIFICATION is a temporary decrease in stream pH with an associated increase in concentration of dissolved inorganic Al during periods of high flow.

Figure 5.28 - pH data in precipitation throughout the U.S. This map indicates that potential problem areas are highest in the northeastern part of the U.S. (shown in orange).



A BUFFER is something that lessens or absorbs the shock of an impact or in chemistry something that minimizes change in the acidity of a solution when an acid or base is added to it.

LEACHING refers to the process of draining or emptying.

BASE CATIONS are positively charged ions that help buffer the soil from acidification.

OSMOREGULATION is the process by which fish exchange ions with the surrounding stream water resulting in proper body salt levels.

BENTHIC MACROINVERTEBRATES are bottom-dwelling organisms (without a backbone) that live in streams and are large enough to be seen without magnification.

Ferns are found in many parts of the forest throughout the watershed. Fern growth can be abundant where soils are too acidic for tree regeneration.

There is potential for the Kettle Creek watershed to be negatively impacted by acidic deposition. Many headwater streams included in the northern Appalachian Plateaus province of Pennsylvania are susceptible to acidification due to the bedrock composition and naturally low levels of Ca and Mg (Heard and others 1997). According to the Environmental Resources Research Institute (1994), portions of Beaverdam Run, Trout Run, Hammersley Fork, Cross Fork, and parts of Little Kettle Creek are of the Pottsville Formation, which is dominated by sandstones and conglomerates of thin shales and coals (Figure 5.27). Studies have indicated that bedrock of this type results in low levels of calcium carbonate and magnesium carbonate, making it extremely vulnerable to episodic acidification (DeWalle and others 1988). By reviewing the Pennsylvania Fish and Boat Commission's trout biomass data, it is observed that in some tributaries with low trout biomass, non-buffering geology is commonly present. Therefore, this low trout biomass may indicate areas experiencing episodic acidification (Figure 5.27).

While sections of the Kettle Creek watershed are susceptible to acidic deposition, no research has been done on the area. The Pennsylvania Atmospheric Deposition Monitoring Network, in cooperation with the National Atmospheric Deposition Program (NADP), Pennsylvania Department of Environmental Protection (PADEP), and The Pennsylvania State University, have designated sites to monitor precipitation chemistry throughout Pennsylvania since 1981. Although a monitoring site is not located within the boundaries of the Kettle Creek watershed, the information provided from the selected sites has been extrapolated to include all regions in the state. The monitoring sites were selected with the objective of representing each physiographic province, major geologic formations, soil associations, and following the distribution of annual precipitation within the state (Lynch and others 1999). (See Appendix K, page 331 - 339 for maps of pH, hydrogen ion concentration and deposition, sulfate ion concentration and deposition, nitrate ion concentration and deposition, calcium ion concentration and deposition, and precipitation data from 1987 through 1999). It is suggested that further research on the Kettle Creek watershed include spring snowmelt event sampling in high risk watersheds using the information provided by the Pennsylvania Atmospheric Deposition Monitoring Network as a baseline. The entire state of Pennsylvania is considered "at high risk" for acidic precipitation and therefore, the Kettle Creek watershed should be sampled for spring snowmelt events. Figure 5.28 shows pH data in precipitation throughout the U.S. This map indicates that potential problem areas are highest in the northeastern part of the U.S. (shown in orange).

GOALS: ACID DEPOSITION

WQ 3.2 Identify if any areas in the watershed are adversely affected by acidic deposition.

WQ 3.1 Stay abreast of regional trends in acidic deposition.

Groundwater Quality

Groundwater quality is an issue for residents of Kettle Creek because 66 percent of the wells in the watershed are used for domestic water supplies. A large percentage of the seasonal and year round residents use groundwater as their water supply, as well. Twenty-eight percent of the wells are used for commercial use and three percent are used for public water supplies. Springs are also used as a source of water, but they are surface discharges of groundwater.

Groundwater quality is also important to Kettle Creek itself. Groundwater provides the base flow to the stream. Base-flow provides cool water, which is discharged from springs and seeps in or near the streams. Trout especially need the cool groundwater discharges to survive the higher summer stream temperatures that affect the main stem of Kettle Creek. Changes in groundwater quality or quantity could potentially affect the trout populations.

BASEFLOW is the portion of stream volume contributed by groundwater. Baseflow maintains stream volume during periods of minimal rainfall and seasonally dry periods.

Kettle Creek has many wetlands associated with groundwater discharges. Many wetlands found on slopes or at the base of the slopes are dependent on springs to provide water throughout the year. (For more information on wetlands, refer to page 112.)

Secondary Drinking Water Quality Standards	
Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L
Source: EPA website, 2001	

Figure 5.29 - Secondary water quality standards are not regulated, but can influence drinking water quality.

Drinking Water Quality Standards and Monitoring Data

GROUND WATER

Groundwater provides drinking water to many watershed residents. It is important that the water from the wells is safe to drink and remains safe to drink. The United States Environmental Protection Agency (EPA) has developed primary and secondary drinking water standards to ensure safe drinking water supplies to citizens (Figure 5.29). Primary standards cover the following categories: microorganisms, disinfectants and disinfectant by-products, inorganic chemicals, organic chemicals, and radionucleotides. Water supplies exceeding primary standards can cause potential health risks. Refer to the EPA webpage (http://www.epa.gov/safewater/mcl.html) for a complete list of primary water quality standards. Water supplies exceeding secondary standards may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water but do not pose potential health risks.

PA Code Title 25 Chapter 109 defines wellhead protection areas in the following manner:

Wellhead protection area - The surface and subsurface area surrounding a water well, well field, spring or infiltration gallery supplying a public water system, through which contaminants are reasonably likely to move toward and reach the water source. A wellhead protection area shall consist of the following zones:

(i) Zone I. The protective zone immediately surrounding a well, spring or infiltration gallery which shall be a 100-to-400-foot radius depending on site-specific source and aquifer characteristics.

(ii) Zone II. The zone encompassing the portion of the aquifer through which water is diverted to a well or flows to a spring or infiltration gallery. Zone II shall be a 1/2 mile radius around the source unless a more detailed delineation is approved.

(iii) Zone III. The zone beyond Zone II that contributes surface water and groundwater to Zones I and II. (www.pacode.com 2001)

The Pennsylvania Department of Environmental Protection (DEP) uses the water quality standards developed by the EPA. The DEP tests and certifies that wells provide safe water via a permitting process.

The Comprehensive State Groundwater Protection Program (CSGWPP) is a state-EPA initiative that provides a mechanism whereby states and EPA can work together to develop a comprehensive and consistent statewide approach to groundwater quality protection (DEP 1998). The program is not an additional regulatory process, but it is a plan with mechanisms to develop groundwater protection. Overall protection will be accomplished through six activities which have been summarized from the CSGWPP document (DEP 1998) including (1) establishing a groundwater protection goal, (2) establishing priorities, (3) defining authorities, roles, and responsibilities, (4) implementing efforts, (5) information collection and management, and (6) public education and participation. This plan provides the mechanism to protect groundwater resources, but implementation is needed for the groundwater resources to be truly protected.

The DEP also has wellhead protection programs that also help to protect wells that are used for drinking water. A wellhead is the land surface area through which water infiltrates and recharges the groundwater source from which the well draws water. Most of the wells in the watershed are shallow and susceptible to contamination from surface sources. The wells located in the floodplain or Kettle Creek have a high potential for contamination. Landuse should be carefully considered in wellhead areas. Activities that produce or handle water soluble contaminants should be carefully managed in wellheads. Protected wellheads mean protected drinking water.

The DEP has permitted 52 wells within the watershed. Statistical data for the wells has been collected and published on the Pennsylvania

Groundwater Inventory System (PaGWIS) CD. The PaGWIS records the following parameters: PaGWIS identification number (id), latitude, longitude, county, municipality, quadrangle, local well number, date drilled, owner, well depth, yield in gallons per minute (gpm), static level, casing top, well finish, site use, water use, and geologic formation. Water quality data are available for some of the wells and is obtainable from the PaGWIS CD or at the DEP North Central Regional Office in Williamsport, PA.

The DEP has developed guidelines to establish a wellhead protection plan. The only public water supply drawn from groundwater is located at Ole Bull State Park, but wellheads also apply to private water supplies. The goal is to protect drinking water, not classify types of water supplies. The shallow nature of the wells in the watershed, the predominant use as a domestic water supply, and their proximity to developments are several reasons to consider a wellhead protection plan. Refer to the Appendix L for wellhead protection plan guidelines.

A groundwater vulnerability model was applied to the Kettle Creek watershed, to demarcate areas with different pollution risk potentials. The DRASTIC model uses several watershed parameters to determine risk potentials. The wells were plotted over top of the model to determine potential vulnerability to pollution. A score was calculated for each well. Areas with moderate to high scores should be considered for assessment and protection.

Explanation of the DRASTIC model

DRASTIC is an empirical model developed by EPA in 1980's to evaluate groundwater pollution potential (Aller and others, 1987). The first letter of the seven variables that compose the models give the model its name (**D**epth of water table, **R**echarge of the aquifer, **A**quifer media, **S**oil media, **T**opography, **I**mpact to vadose zone, and **C**onductivity. This model includes various hydrogeologic settings whose physical characteristics affect the groundwater quality on a regional basis (Aller and others, 1990). This is a numerical ranking system that applies a relative ranking scheme to the hydrogeologic settings to obtain a measure of relative groundwater pollution potential in a region. A score of 150 in the northeast United States cannot be directly compared with a score of 150 in the southwestern United States.

The DRASTIC model was applied to the Kettle Creek watershed (figure 5.30). The scores are relative to the regional areas and not a national scale. Kettle Creek is located in the non-glaciated central region. Limestone valleys in the ridge and valley province of Pennsylvania have

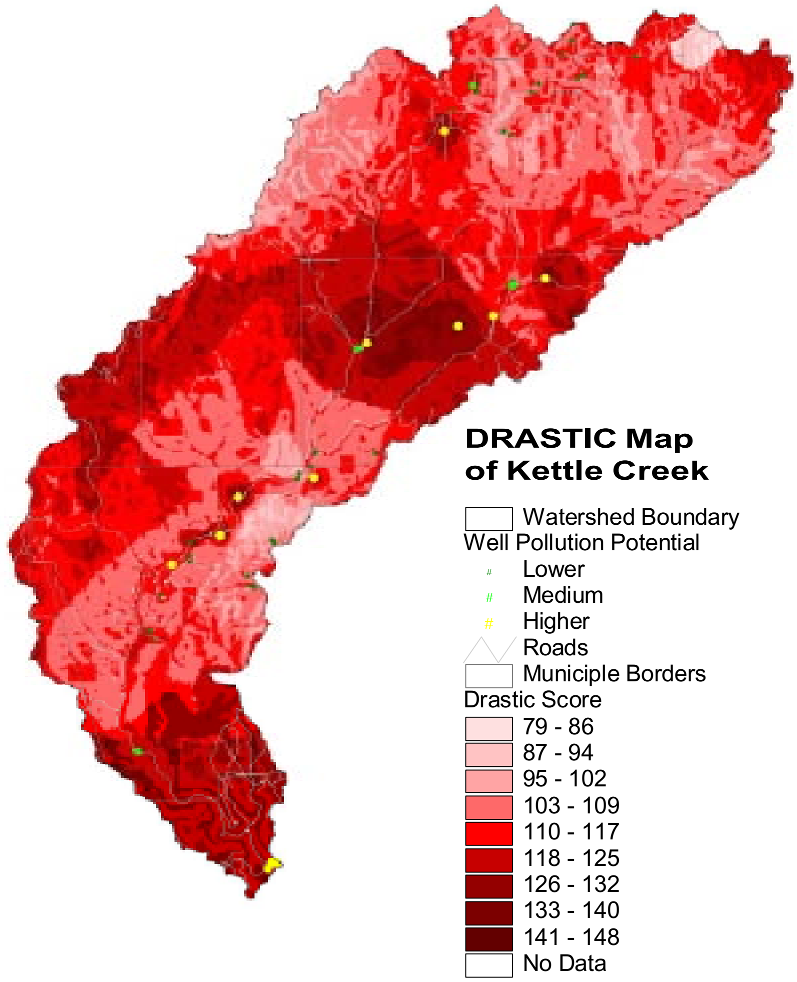


Figure 5.30 - The DRASTIC map shows groundwater pollution potential for the entire watershed. Areas of high potential contamination are located throughout the watershed and concentrated in the floodplains.

the highest values, the glaciated regions of the northeast have the lowest potential, and Kettle Creek has values, which are in between. The values for the entire watershed ranged from 79-148. The scores for the wells in the watershed ranged from 102 to 142.

The DRASTIC scores do not show any clear patterns in the watershed. The wells are distributed evenly throughout the range of scores. The ten highest scores were analyzed and 80% of those wells were found in the Catskill formation, with one in the Burgoon and Huntley Mountain formation, respectively. Seventy percent (7) of the ten provide domestic water supplies, 20%(2) provide recreational supply and 10%(1) commercial supply. The top ten percent are distributed evenly between the counties.

The ten lowest drastic scores were also evaluated. Ninety percent (9) of the wells are located in the Catskill formation. Ten percent (1) of the wells are located in the Huntley Mountain formation. Seventy percent of the wells provide domestic supplies and 30% provide commercial supplies. The wells are divided evenly across the counties in the watershed. The DRASTIC map does show some of the highest scoring wells (yellow dots) are located in the floodplain of the mainstem. The high scoring wells are also located next to lower scoring wells because each well has a different value for the variables that make up the model. Well depth is the variable most of the time.

Groundwater Pollutants

Pollutants are found in many forms from powders to liquids to solids. Any substance that can be dissolved in water or is transported in water could become a groundwater contaminant. Figure 5.31 provides a list of common groundwater pollutants and their sources.

In summary, groundwater quality is an important resource for Kettle Creek. It supplies potable water to homes and business. Groundwater is an important part of the aquatic ecosystems found in the watersheds. Wetlands develop around seeps and springs. Fish survive high summer time water temperatures by holding near areas with groundwater discharges. Efforts must be made to quantify and protect this resource.

Groundwater Quantity

Groundwater quantity is difficult to measure because results are derived from expensive and extensive sampling. Quantification of groundwater resources requires extensive drilling, detailed geologic analysis, and sophisticated modeling which is expensive and beyond the capabilities of the watershed association. However, water supply wells provide information needed to measure groundwater quantity. The watershed is sparsely inhabited with a small number of wells per area. The wells are the best measure of groundwater quantity and do provide limited data which is applicable on a watershed scale (Figure 5.32).

Of the 52 permitted wells in the watershed, the average depth of the wells is 173.9 feet from the

Figure 5.31 - Common potential groundwater contaminants for Kettle Creek.

Common Groundwater Contaminants			
Commercial	Industrial	Residential	Agriculture
gasoline	brine water (gas well exploration)	solvents	Nitrates
motor oil	nitrates	fecal coliform/sewage	N,P,K, fertilizer
industrial solvents	salts, chlorides	paint	coliforms
dry cleaning chemicals	heavy metals		

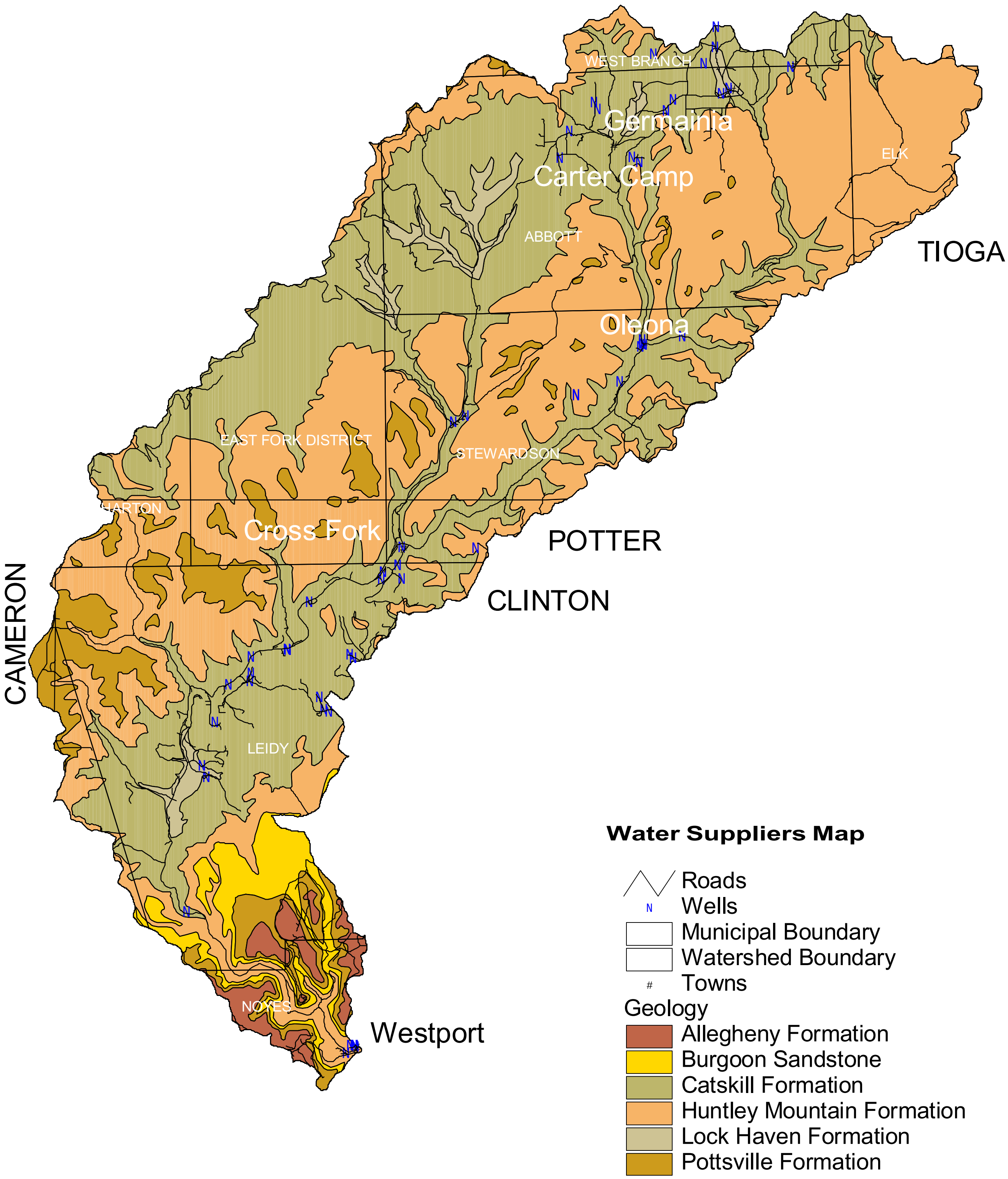


Figure 5.32 - Water suppliers map

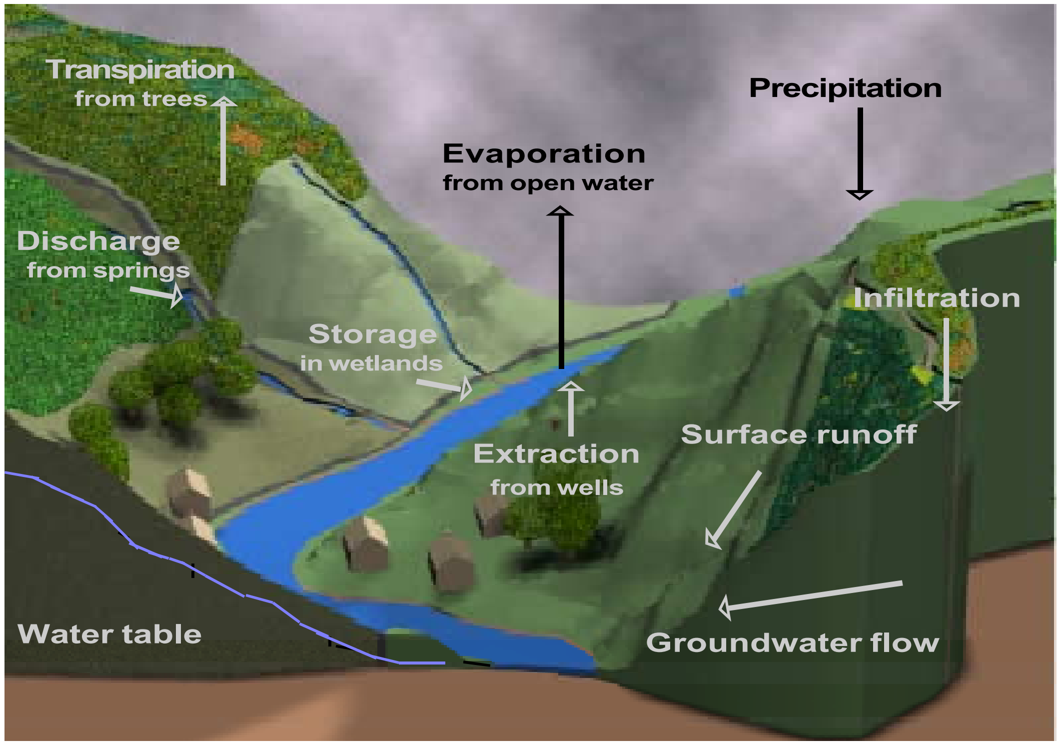


Figure 5.33 - The hydrologic cycle was applied to a digital topographic representation of the confluence of Kettle Creek Lake and a tributary. Structures have been added to represent wells and cabins located elsewhere along the mainstem of Kettle Creek.

surface, with the deepest well at 326.0 feet deep and the shallowest well is 40.0 ft deep. The average yield is 13.0 gallons per minute (gpm); the maximum yield is 40.0 gpm and the minimum yield is 4.0 gpm. There are four prevalent uses of water in the watershed; commercial (28%), domestic (66%), public use (3%), and recreational use (3%).

Six geologic formations cover the watershed. They are the Allegheny, Burgoon Sandstone, Catskill, Huntley Mountain, Lock Haven, and Pottsville formations (for more information on geology refer to page 198). The wells are found in four major formations, the Burgoon Sandstone, Catskill, Huntley Mountain, and Lock Haven, but are concentrated in the Catskill formation (80% of all wells), which aligns with the major tributaries and the mainstem. These wells have an average depth of 152 feet and average yield of 14 gpm. Ten percent of the wells are drilled in the Huntley Mountain formation with an average depth of 298 feet and average yield of 5 gpm. The remaining wells are drilled in the Burgoon sandstone and Lock Haven formations with average depths of 84 and 71 feet, respectively. Average yields are 5 gpm for both formations. See map of water suppliers with locations for graphical representation.

Groundwater Recharge Areas

Recharge areas are those regions where water infiltrates into the ground. They are typically located on broad flat hilltops, in depressional areas without standing water, or on shallow sloping hillsides. Precipitation falls onto the land surface and infiltrates. Gravity draws the water deeper into the soil until the water reaches a barrier that resists further infiltration. A pool of groundwater develops. This underground pool is called an aquifer. Some aquifers are intercepted by the land surface and consequently form seeps or springs. Streams can also intercept aquifers and the groundwater discharges under the surface of the water and contributes to base-flow. This type of groundwater is referred to as shallow groundwater. Deep aquifers can develop if they do not intercept the land surface (Watson and Burnett 1995). Drilling wells accesses deep aquifers. Recharge areas are critical to the groundwater resource. Activities in recharge areas should be carefully monitored to preserve and protect groundwater resources.

The hydrologic cycle (refer to Figure 5.33) is displayed in the Twomile Run watershed. Rain falls on the unreclaimed strip mines on top of the hills. The water infiltrates and becomes acidic after coming in contact with pyrite. The acidic water dissolves metals and discharges, by surface flow, to streams. There are also a number of seeps and abandoned mineshafts which discharge groundwater that eventually flows into a stream in the watershed. Mining activities and the lack reclamation have greatly impacted the groundwater resources in that watershed. The surface water or streams has also been greatly affected. Many other activities such as landfill construction and oil and gas exploration could have similar effects. It is important to identify recharge areas in the watershed by using available data from other studies like the AMD remediation projects, the thermal assessment study, and the wetland prediction model. A more detailed GIS analysis by a hydrogeologist will also help determine recharge areas.

GOALS: GROUNDWATER

WQ 5.1 Preserve and protect groundwater.

WQ 5.2 Preserve and protect surface water.

WQ 5.3 Preserve and protect drinking water supplies.

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