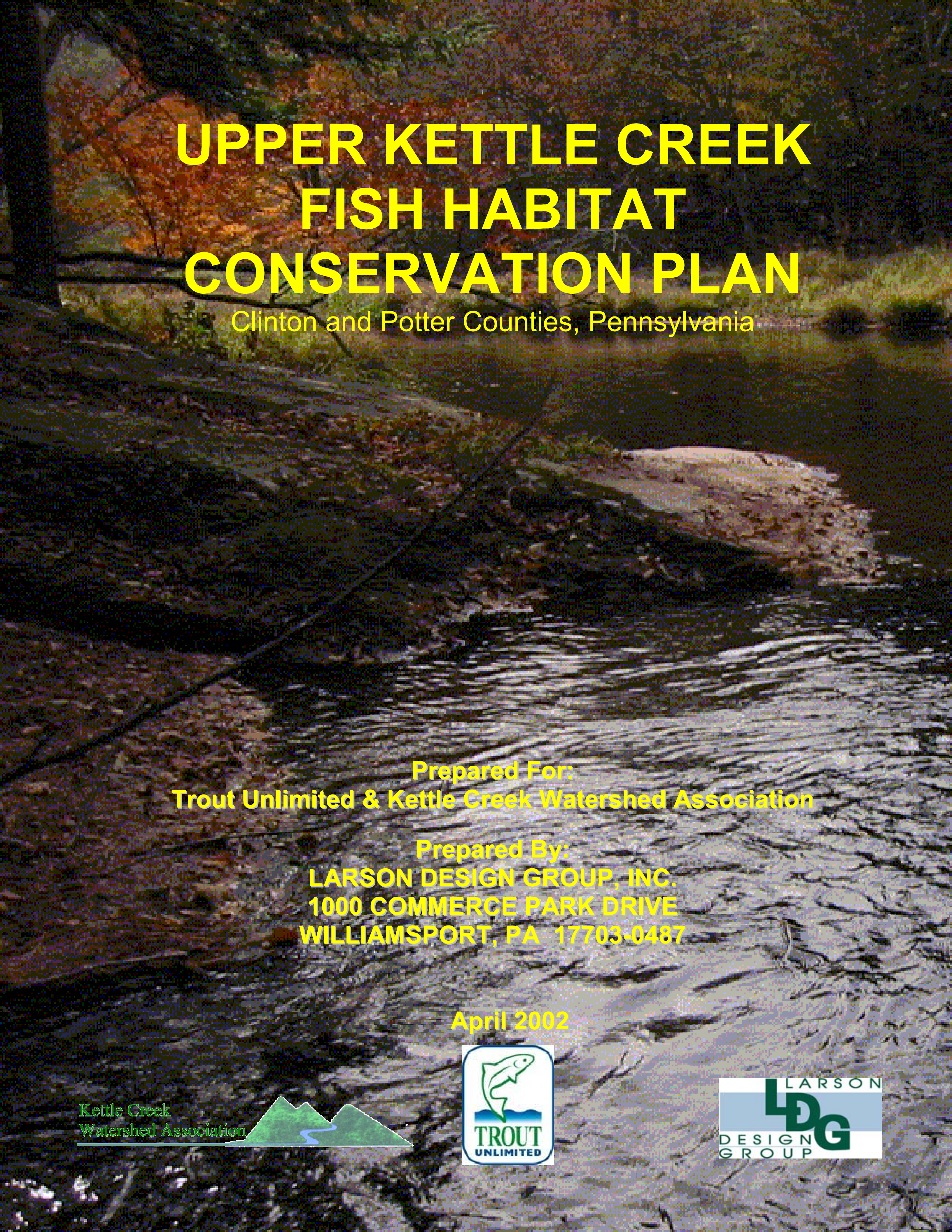

UPPER KETTLE CREEK FISH HABITAT CONSERVATION PLAN

Clinton and Potter Counties, Pennsylvania

Prepared For:
Trout Unlimited & Kettle Creek Watershed Association

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Kettle Creek Watershed Association

TROUT UNLIMITED

LARSON DESIGN GROUP

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EXECUTIVE SUMMARY

Over 30 miles of stream channel in the Middle and Upper Kettle Creek Watershed were mapped for stream stability and high quality fish habitat. Riparian forest canopy cover and water temperature were also evaluated.

Large volumes of sediment are being transported in the main stem of Kettle Creek. Both the history of the watershed and the physical condition of the stream channel indicate that the stream channel may still be responding to sediment inputs and catastrophic floods in the early 1900's. Historical logging stripped the hillsides of vegetation and utilized stream channels for transportation of goods. Three of the largest floods on record for the West Branch Susquehanna River Basin occurred between 1890 and 1903. Unprotected hillside soils and extremely high rainfalls introduced large volumes of sediment to the stream system.

The stream channels on the main stem of Kettle Creek and the tributaries are unnaturally wide. Widened channels and prevalent mid-channel gravel bars are common in streams with an excess sediment supply. Very wide, flat reaches of stream channel cause in-stream temperature to increase dramatically. Relatively little bank erosion was found during this survey. Very little severe bank erosion was evident along the main stem and the lower reaches of the tributaries to Kettle Creek. The majority of channel instability and habitat impairment in Kettle Creek is caused by excess sediment transported in the stream channel.

Good access to the floodplain and wide channel cross-sections provide excellent opportunities for channel form and habitat enhancement. Establishment of a low flow channel within the existing floodplain will greatly improve habitat and stream channel function. Narrowed low-flow channels with improved canopy cover will also provide better conditions to support trout fisheries. Improvement of upstream reaches on tributaries will reduce the amount of sediment transported into the main stem of Kettle Creek. By focusing efforts on the upstream reaches first, conditions on the main stem of Kettle Creek will begin to gradually improve as a result of decreased sediment inputs and lowered water temperatures.

The following actions are recommended:

1) Complete geomorphic surveying to the headwaters.
2) Select, design, and construct 5 miles of stream enhancement to reduce low-flow channel width and improve habitat cover in the Cross Fork Watershed.
3) Improve canopy cover along the main stem of Kettle Creek by planting trees in the riparian zone and protecting existing riparian buffers.
4) Provide enhanced riparian cover and stream form through Ole Bull State Park.
5) Institute a public education program to improve streamside management.
6) Work with PENNDOT and DCNR to improve stream maintenance at bridge crossings.
7) Begin monitoring water quality of storm flows and snowmelt events.
8) Work with local municipalities and state agencies to improve drainage stability on dirt and gravel roads.

UPPER KETTLE CREEK WATERSHED FISH HABITAT CONSERVATION PLAN

INTRODUCTION

The Kettle Creek Watershed drains 246 square-miles of Tioga, Potter and Clinton Counties in North central Pennsylvania. Much of the watershed is forested with a small percentage of agricultural and light residential land use. Public land makes up 92% of the watershed. Much of the private land within the watershed is adjacent to stream channels. The Alvin R. Bush Dam physically divides the watershed into the upper and lower watershed. Downstream from the Alvin R. Bush Dam Kettle Creek is impacted by acid mine drainage. The fisheries of the lower watershed are severely impacted by poor water quality. Ongoing work by the Kettle Creek Watershed Association and Trout Unlimited continues to reduce pollution from acid mine drainage. Water quality in the upper watershed supports high quality fisheries. With the majority of the watershed still forested and limited development within the watershed, the upper Kettle Creek is one of the most pristine watersheds in Pennsylvania.

Numerous data collection and habitat enhancement efforts are underway in the watershed. This strategic plan was developed for Trout Unlimited and the Kettle Creek Watershed Association to ensure that preservation and enhancement work is coordinated and produces maximum results. The goal of the plan is to provide a clear course of action to preserve and enhance the existing fishery in the upper Kettle Creek Watershed. Existing data was combined with newly collected data in the watershed to generate the information necessary to knowledgably develop the plan.

With 67.3 miles of Class A trout waters, the upper Kettle Creek watershed is a cherished sporting and recreation area. Recent declines in fish population and density have caused concern about many reaches of stream in the watershed. With water quality rated as exceptional value and significant amounts of water quality data monitored to ensure that any decline in water quality does not go unnoticed, other factors for fisheries health were considered. In the upper watershed, despite excellent water quality, fish populations have slowly declined. Recent surveys by several local universities indicate that reduced quantity and quality of habitat as well as high water temperature may be impacting the fishery. High water temperature reduces the amount of dissolved oxygen in the water making some areas uninhabitable by coldwater fish. Among the fisheries concerns, elevated water temperature and available, high-quality habitat are the chief concerns.

To evaluate and understand the fishery concerns, three primary objectives were established.

1. Review historical biotic and physical habitat data
2. Collect and analyze a large amount of new physical habitat data
3. Recommend actions for future habitat conservation activities

Existing data within the watershed was compiled and evaluated to provide background information for any new data collection. Extensive new data was collected to describe the fish habitat, riparian zone, and water temperature along thirty miles of Kettle Creek and selected tributaries. This dataset was then used to develop an understanding of the current channel and habitat conditions.

Existing data consists of water quality analyses, macroinvertebrate population characterizations, fish population surveys, water temperature measurements, aerial photographs, Alvin R. Bush Dam pool elevations since 1985, and the human history of the watershed. These data were used to identify impacts to the fishery in the upper Kettle Creek Watershed. Potential water quality impacts including water temperature were determined based on the existing water quality data.

New data was collected to determine the condition of the stream channel and abundance of high quality habitat along Kettle Creek. Because this study was limited by funding and time constraints only thirty miles of stream channel could be evaluated. The main stem of Kettle Creek from one mile downstream of Trout Run to the confluence of Little Kettle and upper Kettle Creeks was selected. Additionally, the major tributaries (Trout Run, Hammersley Fork, Cross Fork, Little Kettle Creek, and Upper Kettle Creek) were evaluated near their mouths. Based on observations at the mouth and immediately upstream from the mouth the survey was extended upstream. If there were clear indicators that the stream was functioning properly and little if any excess sediment was being produced from the tributary, the survey continued on the main stem saving effort for other tributaries in need of more detailed evaluation.

The study of stream channels, their function, and the resulting stream channel forms is known as fluvial geomorphology – literally "river related earth shapes". This type of investigation is known as a geomorphic assessment. The geomorphic assessment considers factors that influence channel form and function not only immediately adjacent to the stream channel, but throughout the watershed. The goal of this assessment is to determine the stability of the stream system, identify impacted areas of the channel, locate high-quality habitat, develop an understanding of what may have caused existing instability within the channel, and predict how and where habitat impacts may occur within the system in the future. A geomorphic assessment determines what portion of the balance between energy and sediment supply has been altered and provides solutions to bring the stream system into balance. This provides a stream channel that can sustain sediment transport and maintain quality habitat over time. The goal of channel enhancements based on this science is to use the forces within the stream channel to sustain a natural channel form.

To accurately develop this understanding, a number of stream channel features were identified, located, and measured. This data was collected by mapping the stream channel and its features using a high resolution Global Positioning System (GPS). This technology allows features along the stream channel to be located within three feet and accurately transferred to mapping software for analysis and map production. A number of quantitative and qualitative features are incorporated into the mapping portion of the geomorphic assessment.

Some key features that were mapped include:

- bankfull width
- bankfull depth
- wetted width
- stream channel particle size
- flow type (pool, riffle, run, glide)
- riparian land use
- riparian vegetative cover
- tree canopy cover
- tributaries
- lateral bar deposits
- mid-channel bar deposits
- bank erosion
- rock dams
- rip-rap banks
- high-quality habitat (type and quality rating)
- photograph locations with date and time
- bridge crossings (dimensions and stability)
- channel encroachments such as roads and historical railroad beds.
- channel particle size distribution

This data was then used with the existing data to develop an understanding of stream channel conditions in the watershed. Based on the current stream channel conditions and historical data, future channel stability and habitat quality is projected. The strategic plan for future fish habitat enhancement work is then created to provide maximum benefit in critical areas of the watershed. Since the watershed is an interconnected system, projects completed in the channel have the potential to alter the channel at other locations. This makes solid planning of habitat enhancement projects extremely valuable. When properly planned, habitat enhancement projects will maximize benefits and sustainability while minimizing costs. Properly designed enhancements have the potential to not only improve conditions within the immediate project area, but in downstream areas as well.

Based on the findings of this data collection effort, funding requests have been submitted to continue mapping the tributaries in the upper Kettle Creek Watershed. This will provide enhanced information about the conditions of upstream portions of the tributaries and allow refinement of the strategic plan to address any issues found in the tributaries.

Subjective habitat studies completed over the last decade provide some basic habitat information in the upper watershed. Past habitat studies within the watershed resulted in low scores for several important fisheries and aquatic insect categories at some locations along the mainstem. Velocity-depth regime, which is an indication of good pool to riffle ratios in the stream, was rated as poor for much of the main stem of Kettle Creek in 1993. The remaining categories of the habitat survey improved the overall scores to the sub-optimal and optimal range. However, the low scores for key habitat parameters prompted further research into the quality and distribution of habitat in Kettle Creek.

Water temperature is a concern in the upper watershed. High water temperatures were noted as early as 1942. For coldwater fish such as trout, the water temperature should remain less than 70^{o}F (21^{o}C). Continuous water temperature monitoring at locations along Kettle Creek indicates that during warm, cloud-free periods water temperature can climb to nearly 80^{o}F. Water this warm, without significant cold water refuges nearby cannot support a healthy trout population.

EXISTING FISHERIES DATA

Water quality and habitat are two key components to maintain high quality fisheries in Kettle Creek. Water quality in upper Kettle Creek meets the Pennsylvania criteria for exceptional value (EV) waters. Over recent years, the fish population in upper Kettle Creek has gradually declined. The reduction in fish population is attributed to increasing water temperatures and a decrease in available high quality habitat.

The delayed harvest area just upstream from Route 144 has long period of recent trout population data. The data spans the years of 1981 to 1997. Over this period of monitoring, the biomass, density, and total number of individuals have declined in this area. Other reaches of the stream channel have not been as intensely monitored. Similar trends are evident from limited data elsewhere in the watershed. On Upper Kettle Creek at river mile 41.90, 1993 data showed brook trout biomasses of 49.36 kilograms per hectare. In 1999, brook trout were again surveyed in Upper Kettle Creek. Data collected in 1999 at approximately the same location as the 1993 data shows an average brook trout biomass of 8 kilograms per hectare. Analysis of the 1999 data shows that brook trout biomass remains high in headwaters streams while it declined in downstream reaches. In

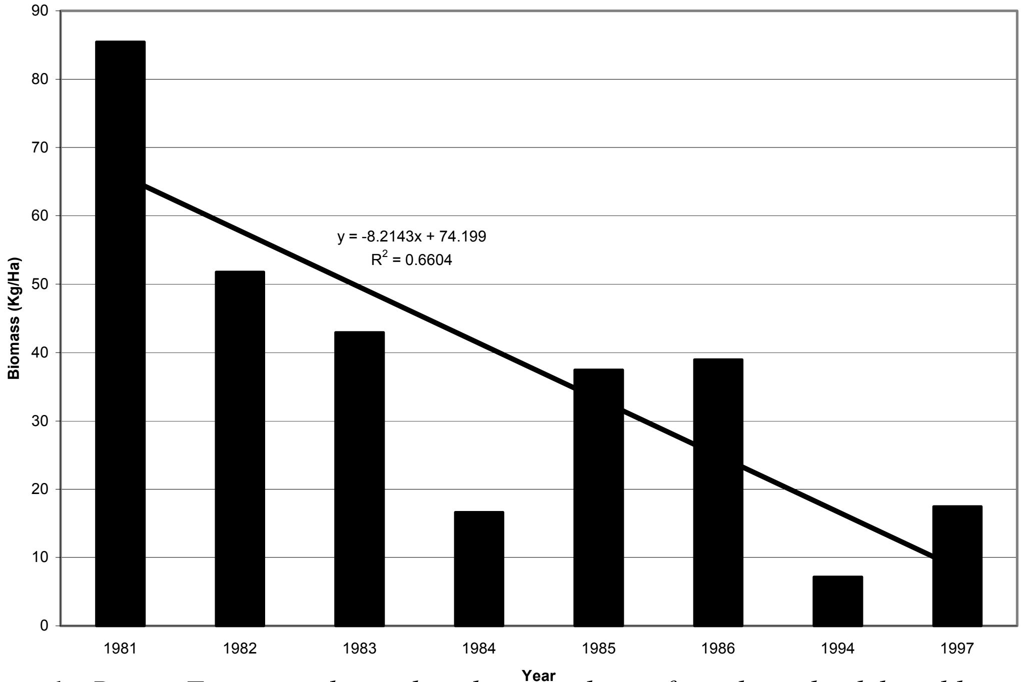

Chart 1: Brown Trout population has decreased significantly in the delayed harvest area.

the headwaters of upper Kettle Creek, brook trout biomasses as high as 243 kilograms per hectare are reported. Although limited data is available for multiple years at the same location, comparison of samples through time at similar locations shows the trend of declining trout populations at a number of locations. The trends are similar for both brook and brown trout. The basis is of this project is to identify habitat and water quality concerns that may be contributing to declining fish populations.

High quality habitat provides shelter and hiding areas for fish. Additionally, high quality habitat has good interconnections between habitat features. Along many reaches of Kettle Creek high quality habitat is limited and connections between habitat features are poor. The dominant impact to habitat is caused by channel instability and sediment transport in the stream channel. Large volumes of sediment transported downstream fill pools and cause the channel to become wide and shallow. Flow variability in the stream is reduced with few good pool-riffle sequences maintained on the mainstem. Water is re-oxygenated as it tumbles through riffles.

Figure 1: Wide-shallow reaches with little canopy cover provide very little habitat and expose stream water to warming sunlight.

In addition to limiting fish habitat, stream channel changes contribute to increased water temperatures. As the stream channel widens, it becomes more difficult for the riparian forest to shade the stream. The flow velocity in the stream channel slows in wide shallow reaches causing water to be warmed by sunlight for longer periods of time. Limited pool-riffle sequences, slow flow, and poor canopy shade work together to reduce the amount of dissolved oxygen available in the water for aquatic life.

High quality habit is often found with woody debris in the stream channel. Debris helps pool development, provides habitat for aquatic insects, and protection for fish. Heavily vegetated, undercut banks also provide excellent habitat along some reaches of stream. Well formed pools with fragmented bedrock or large boulders also provide good habitat in Kettle Creek. A map of high quality habitat along Kettle Creek is provided in Appendix 1-1.

Figure 2: Pools adjacent to woody debris provide excellent habitat in some locations.

It is important to identify the reaches of stream that are stable with high quality habitat as well as those that are unstable, are likely to become unstable, or have poor habitat. Improving habitat and maintaining excellent water quality in the upper watershed can enhance future fisheries within the Kettle Creek watershed.

EXISTING MACROINVERTEBRATES

Macroinvertebrate data has been collected at a number of different times and locations along Kettle Creek. The most extensive collection occurred in 1999. The macroinvertebrate population at that time was diverse (high taxa richness). Numerous species indicative of good water quality were found in the upper watershed. The majority of locations showed high macroinvertebrate densities indicating plentiful aquatic insect life. Densities for mainstem samples ranged from 197 to 1,916 individuals-per-square-meter.

The data were analyzed using several indexes. The values are shown in Appendix 1-2 and 1-3. The Hilsenhoff Biotic Index rates water quality based on scores assigned to macroinvertebrate families based on pollution tolerance. Low scores indicate little pollution while high scores indicate severe water pollution (Table 1). The Hilsenhoff Biotic Index Scores for sample sites on the mainstem of Kettle Creek and upper watershed tributaries ranged from 4.61 to 2.54 in the 1999 dataset. These scores indicate good to excellent water quality. The average Hilsenhoff Biotic Index score was in the very good range at 3.52.

Table 1: Hilsenhoff Index Value Water Quality Degree of Pollution		
0.00-3.50	Excellent	No apparent pollution
3.51-4.50	Very Good	Slight pollution
4.51-5.50	Good	Some pollution
5.51-6.50	Fair	Fairly significant pollution
6.51-7.50	Fairly Poor	Significant pollution
7.51-8.50	Poor	Very significant pollution
8.51-10.00	Very Poor	Severe pollution

A second index, the EPT Index or Ephemeroptera, Plecoptera, and Trichoptera Index uses the total number of families within the insect orders Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies). Higher EPT scores indicate better biological conditions than low scores. The number of EPT taxa present from the 1999 data ranged from 10 to 25 with an average of 17.

All of the macroinvertebrate data reviewed for the upper watershed is consistent with good to excellent water quality. The macroinvertebrate population appears to be healthy and diverse. Macroinvertebrate densities were sufficient to provide a good food supply for fish in Kettle Creek.

EXISTING PHYSICAL STREAM CHARACTERISTICS DATA

Surveys of the physical stream characteristics that have been completed to date in the Kettle Creek watershed are mostly subjective physical ratings. These ratings are based on accepted protocols for habitat assessment. While the data are subjective, they do provide some insight into the overall habitat condition. Data were collected in 1998 and 1999 by student interns from Mansfield and Lock Haven Universities. Earlier data was collected by the Pennsylvania Department of Environmental Protection in 1993. Historical reports as early as 1942 identify habitat improvement as a priority (Watts and others, 1942).

With one of the few historic measurements of channel dimensions, Watts and others (1942) reported that the average channel width of Kettle Creek from the mouth of Hammersley Fork to Leidy was approximately one-hundred feet. No reference to stream depth or dimensions of other reaches was reported with this data.

Overall scores in the 1998-1999 study of 33 sites along the mainstem of Kettle Creek and its major tributaries fell into the optimal and sub-optimal categories. The habitat scores for epifaunal substrate and available cover were marginal to optimal. Riffle frequency and velocity/depth regime, which describe the flow variety of the stream, were not identified independently for this study.

All total scores in the 1993 PADEP study were in the sub-optimal or optimal range. Since this study was conducted primarily for water quality purposes, habitat data was collected at only three locations along the mainstem.
The mainstem just upstream from Hammersly Fork scored poorly for frequency of riffles and velocity/depth regime. This reach is representative of many portions of the stream from Trout Run to the delayed harvest area.

A habitat survey of Cross Fork completed in 1999 notes many locations of poor habitat, especially in downstream reaches (Landis, 1999). Good habitat was typically associated with woody debris or changes in the stream bank material. More resistant bank material such as clay or bedrock was associated with good pools. Split channels were also noted at a number of locations along Cross Fork from the headwaters to the mouth. At several locations it appeared to Landis that the channel had been straightened at some time.

The limited data from the 1993 study indicates that in-stream habitat may be a significant factor influencing fish populations in Kettle Creek. Little variety in the velocity and depth of the channel limits high quality habitat available for fish. Reduced numbers of riffles suggest that the channel is uniform with little change in slope, width, or depth. Observations on Cross Fork mirror this conclusion noting numerous wide, shallow reaches of stream. Sparse quantitative habitat data within the watershed makes further analysis difficult.

EXISTING WATER QUALITY

Water quality in the upper Kettle Creek Watershed is generally excellent. The major threats to water quality in the upper watershed are low dissolved oxygen, high water temperatures, sediment, and acidification. Dissolved oxygen is directly related to water temperature. As water temperature rises, dissolved oxygen is released to the atmosphere. Large sediment can impact stream channel stability while fine sediments reduce habitat available for fish and macroinvertebrates. Acidification is caused by acid precipitation. Streams and their watersheds have some ability to neutralize acid precipitation. The acid neutralization capacity is determined by the soils and geology of the watershed.

Water temperature is elevated as the stream flows through areas that have poor canopy cover or very wide channel form. This allows the water to be exposed to solar radiation. Water temperature warms rapidly when wide channel reaches with slow-moving water accompany poor canopy cover. As the water warms, oxygen is driven out of the water into the atmosphere making respiration more difficult for aquatic life.

Sediment, especially suspended sediment reduces water quality at a number of locations. Unstable roadway drainage and pipe outlets contribute a large portion of the suspended sediment in the upper Kettle Creek Watershed. Water plunging from drainage pipe outlets on steep embankments mobilizes fine sediments and carries them into the nearest stream. Pennsylvania's Dirt and Gravel Road program can be employed by local municipalities to reduce sediment produced from roadway drainage.

Figure 3: Unstable roadway drainage causes a significant amount of sedimentation throughtout the watershed.

The alkalinity or acid neutralizing capacity of water in the upper Kettle Creek Watershed is relatively low. This is a measure of calcium carbonate, carbonate, and bicarbonate in stream water. These chemicals react with acids to stabilize the pH when they are present. Low concentrations of these chemicals reduce the stream's ability to maintain neutral pH's if acidic water is introduced to the watershed. Historical data indicates alkalinity concentrations of 20 to 25 milligrams-per-liter were prevalent in the 1950's and 1960's (Hollender et al., 1981). Alkalinity measured by the Pennsylvania Department of Environmental Protection on May 18, 1993 ranged from 11 to 15 milligrams-per-liter on Kettle Creek, Trout Run, Little Kettle Creek, Hammersley Fork, and Cross Fork. At the same time, pH averaged 6.5. This data was collected just after a sustained period of high flow on Kettle Creek. Recent alkalinity measurements completed in July and August 1998 indicate concentrations ranging from 6 to 34 milligrams-per-liter. Pennsylvania Fish and Boat Commission data reports a number of alkalinity concentrations less than 10 milligrams per liter in 1997. No stream flow data was collected with either the early data or the recent data although the notes indicate that flow was extremely low. Stream flow can significantly alter the concentration of calcium carbonate, carbonate, and bicarbonate. High stream flow causes dilution of the compounds thereby reducing the concentration. Compounds are concentrated during low-flow periods.

The existing water quality data indicates that the stream pH is neutral to slightly basic at low flow. As indicated by the May 1993 data, pH may decrease significantly during higher flows. During an acidic precipitation event, the available alkalinity may be sufficient to neutralize the acid. With the low concentrations of alkalinity measured, it is possible that Kettle Creek becomes acidic during large rainfalls and during spring snowmelt. Short periods of slight acidification do not represent a threat to the aquatic ecosystem of upper Kettle Creek. However, if the alkalinity is depressed and the stream becomes more acidic, even short periods of severe acidification (repeated with recurring rainfall/snowmelt events) can impact the aquatic ecosystem. The specific threat to the ecosystem is from toxic forms of common metals that are leached from watershed soils while the water is acidified. The existing data does not include high-flow water quality measurements so changes to alkalinity and pH cannot be evaluated. Future data collection should incorporate high-flow water quality sampling. In addition to stream water quality, precipitation pH should be monitored and stream flow should be recorded at the time the sample is collected.

No abnormal values were found in the remaining water quality data. This finding agrees with the Exceptional Value water classification by the Pennsylvania Department of Environmental Protection.

NATURAL STREAM FUNCTION - FLUVIAL GEOMORPHOLOGY

The form of natural stream channels is defined by a number of factors. In its simplest form, a stream channel is a balance between the sediment present in the stream system and the energy available to move the sediment. Excess energy results in erosion. Too little energy causes sediment to be deposited. A natural, undisturbed stream channel balances its available energy with moderate amounts of both erosion and deposition.

Some controlling factors of stream form are watershed slope, runoff volume, vegetation, sediment supply, sediment size, and abnormal disturbances. Watershed slope dictates one portion of the energy available to move sediment. The amount of energy available varies based on the volume of runoff water received by the stream channel. The runoff volume is controlled by watershed size, precipitation patterns (rainfall amounts), soil drainage characteristics, and land use. Forested watersheds produce less runoff than developed areas. Vegetation within the stream’s floodplain provides resistance, slowing flow and reducing the energy along the channel margins.

Disturbance in a stream channel such as dredging, damming, or levee construction causes the energy balance to change. As this occurs, the stream channel attempts to balance the new amount of energy available. If flood flow is confined to the stream channel by levees, the stream channel begins to erode because more energy is available within the channel. Likewise, dams reduce energy by decreasing the stream slope. Deposition occurs upstream from the dam pool since the available energy has decreased.

This simplistic view is complicated by innumerable factors within a watershed. Catastrophic floods, land use changes, dams, levees, bridges, and many other changes within a watershed impact the natural function of a stream channel.

The science of Fluvial Geomorphology incorporates channel hydraulics, sediment transport, and watershed hydrology (rainfall – runoff computation). Many of the controlling variables in a stream system can be computed and analyzed to provide an understanding of the condition of the stream channel.

CHANNEL EVOLUTION

Channels that have been disturbed by dredging or channel incision follow a systematic path to recovery. This process is documented by Simon and Hupp (1992) as shown in figures 4 and 5. A six-stage channel evolution model describes the process of channel change in response to channelization. Class I and Class II indicate the natural channel and the channel immediately after disturbance respectively. During Class III, the channel actively erodes at the channel bed as a result of floodwaters being confined within the banks and not distributing energy over the floodplain. The channel has very poor floodplain access at this time. In Class IV, the channel deepening results in unstable banks and the channel continues to downcut while eroding laterally. This results in an over-wide channel within the terraces that were the floodplain of the existing channel. After the channel has widened and deepened through this period of severe instability, materials now begin to deposit in the over-wide channel and widening continues through Class V. A new channel develops in the deposited material and becomes relatively stable in the quasi-equilibrium conditions of Class VI. The six stages occur through time at a cross section, but can be found lengthwise along the channel as the entire stream system responds to a single disturbance.

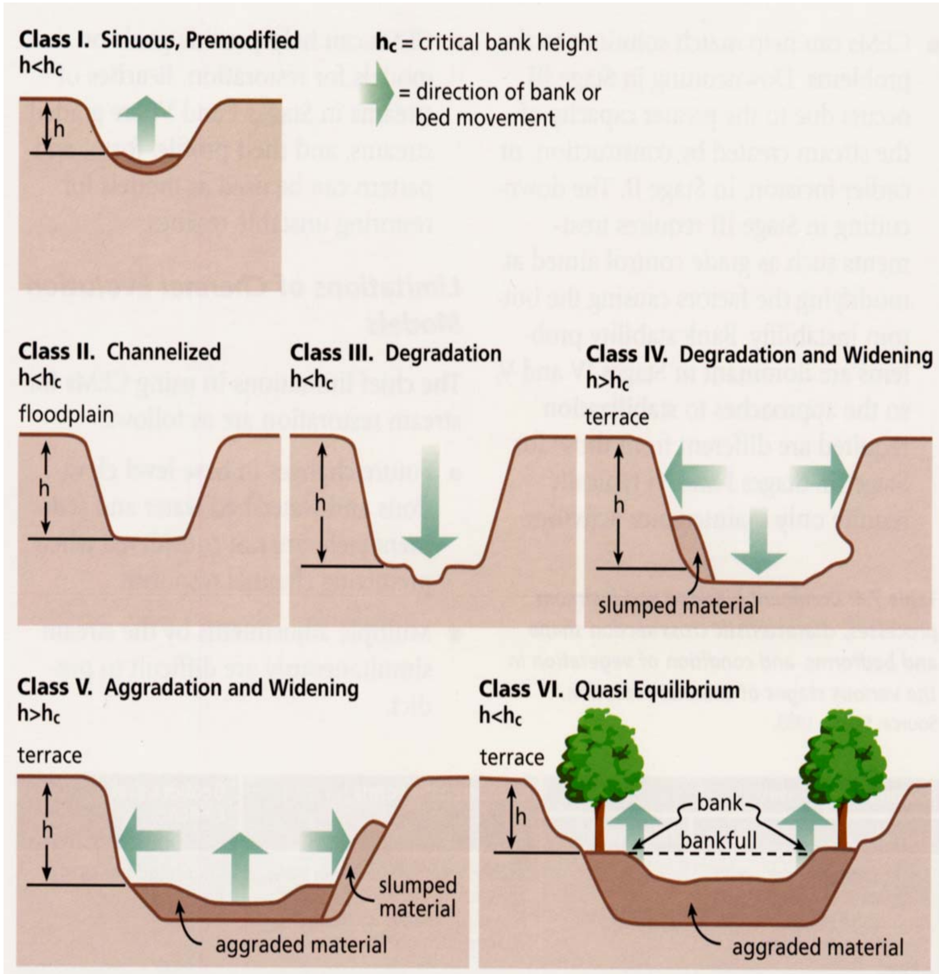

Figure 4: Channel change after disturbance - Class I indicates the natural condition. Class II indicates dredging or embankments which focus more energy in the channel. Classes III – IV describe the systematic changes that take place in a stream channel after this type of disturbance (Simon and Hupp, 1992).

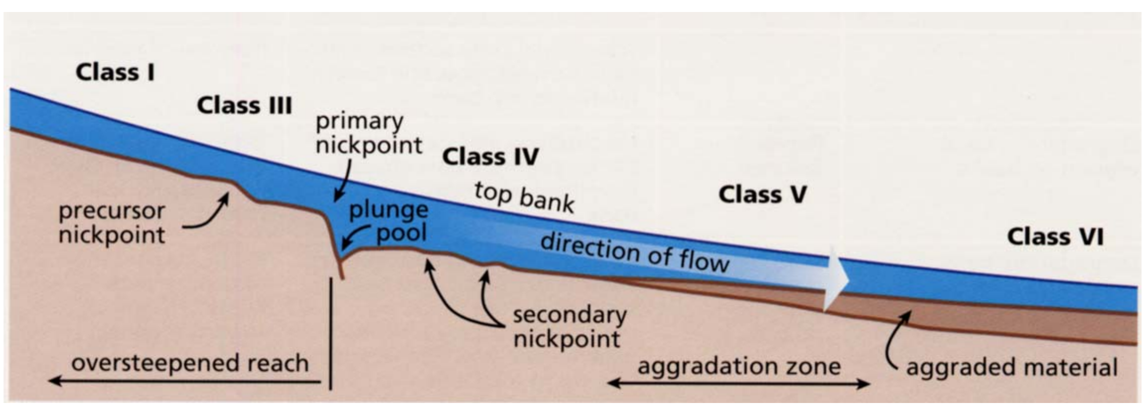

Figure 5: Following an single instance of disturbance, the series of channel evolution classes depicted in figure 3 can be found in order along the stream channel (Simon and Hupp, 1992).

HYDROLOGIC AND GEOMORPHIC HISTORY OF KETTLE CREEK

The stream channels of Kettle Creek were seriously affected by logging and timber transportation in the late 1800's to early 1900's. In addition to the immediate impacts adjacent to and in the stream channel, barren hillsides likely contributed large volumes of sediment to the stream channels for a period of time after the logging. Runoff from storms and snowmelt is also affected significantly by unvegetated hillsides. Major flood events in the West Branch Susquehanna River Basin are recorded in 1889, 1894, 1898 and 1913. Stream flow in the West Branch of the Susquehanna River in both the 1889 and 1894 storms was greater than the stream flow following Hurricane Agnes in 1972. These very large storm events likely transported sediment from the hill slopes into the stream system. As the forests regrow, rainfall infiltration increases and storm runoff decreases resulting in lower sediment transport in the stream system. Vegetation increases infiltration in a number of ways. Root growth penetrates soil layers and provides pathways for water to move down through the soil column. The plant leaves slow rainfall as it falls, funnels it toward the ground, and stores some of the liquid on leaf surfaces.

Figure 6: Railway in the floodplain of Hammersley Fork. Note stream in the foreground. Photograph from Taber, 1971.

With large influxes of sediment and extreme high flows, the stream system became unstable and created the wide, shallow channels that we see today. Movement of excess sediment and complete recovery of a stream channel can take centuries if the stream is left to recover naturally. This is especially true in systems that are dominated by gravel to

Figure 7: Typical bridge construction during the logging era. Photograph from Taber, 1971.

cobble size sediment, as is the Kettle Creek Basin.

There are numerous physical indications that the watershed is still responding to the disturbance of widespread logging and the associated catastrophic floods. In a stream system that is responding to downstream stream channel changes, the headwaters retain natural geometry and habitat features. The headwaters of Kettle Creek have features that are representative of Class V in the channel evolution model presented earlier in this report. This stage is a widened stream channel with good floodplain access, but with limited habitat and shading. Watersheds responding to widespread sediment impacts throughout the watershed exhibit Class V characteristics in the headwaters. Stream channels responding to only downstream disturbances would appear similar to Class I in the headwaters.

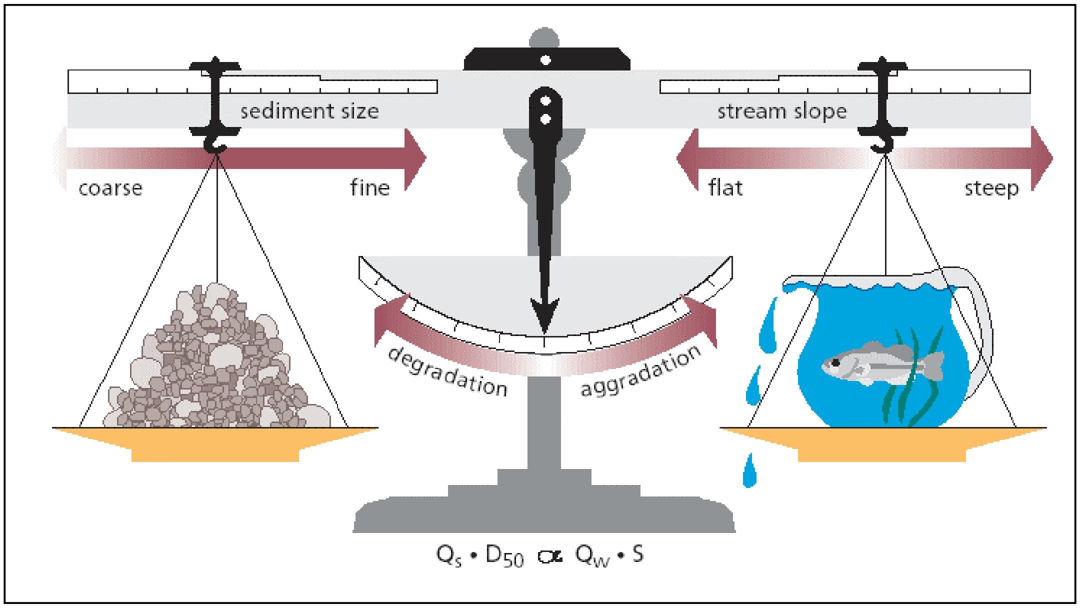

Figure 8: Illustration of relationship between sediment supply, hydrology, and erosion or deposition in a stream channel.

The Alvin R. Bush Dam was constructed on Kettle Creek in the late 1950's. The dam was constructed to protect downstream areas from flooding. Dam construction and operation can dramatically impact stream channel stability. Large dams, such as the Bush Dam, interrupt the hydraulic function, slope, and sediment transport functions of a stream channel. Since this dam was constructed in relatively recent history on Kettle Creek, it is important to determine whether or not the dam has a significant impact on stream channel stability in the upper watershed. To determine impacts on the upper watershed, historical water surface elevation (pool elevation) behind the Bush Dam was obtained from the U.S. Army Corps of Engineers. This data is shown in Figure 9. The normal pool elevation is 841 feet. This elevation is maintained for the majority of time in the reservoir. During high flow periods when the dam is operated for flood control, the pool elevation may be significantly higher (Figure 10).

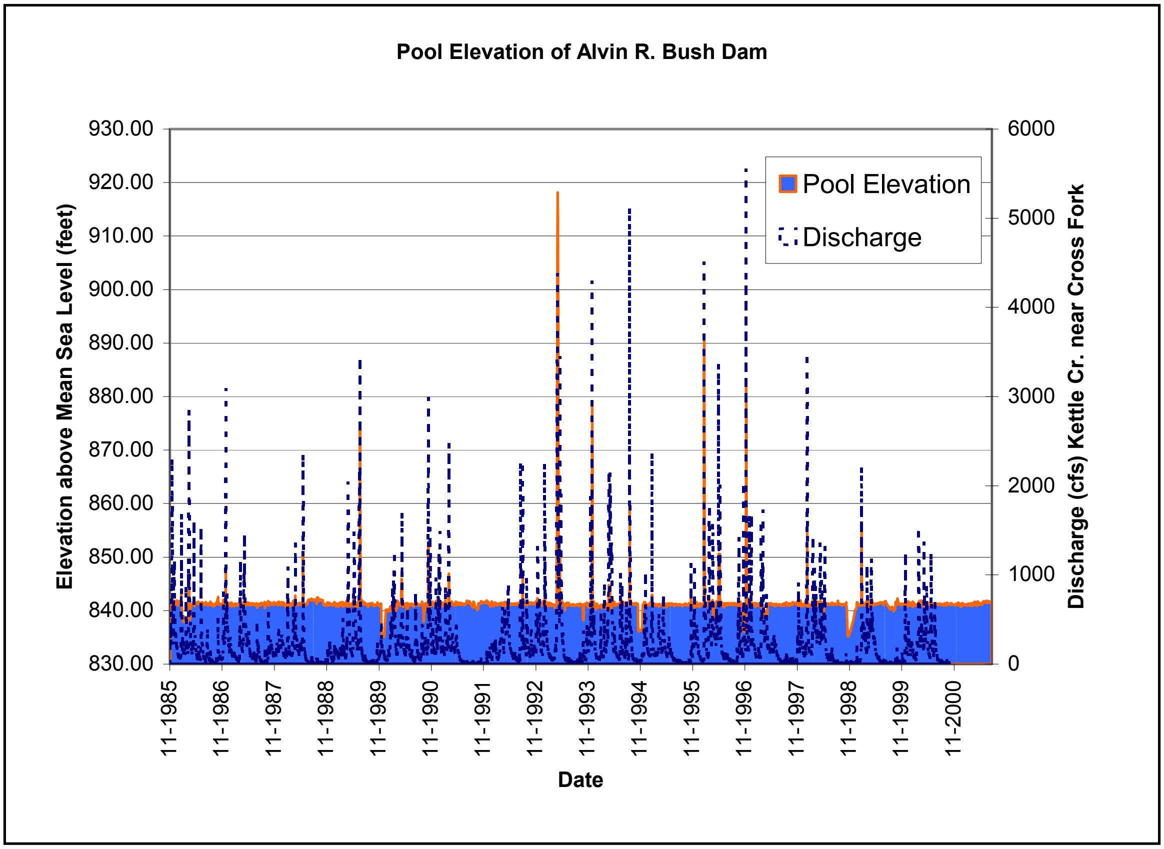

Figure 9: Pool elevation of Alvin R. Bush Dam and Kettle Creek stream flow from 1985 to 2001.

While the pool elevation is at or about the normal 841 feet elevation, the slope of Kettle Creek is approximately ½ of the pre-dam slope. This impacts stream function immediately upstream from the reservoir pool. At high flows, when the pool elevation increases, the slope of Kettle Creek can be decreased for several miles upstream.

Stream slope is a controlling factor for channel hydraulics and sediment transport. As the stream slope is decreased, the ability of the channel to move water and sediment downstream is diminished. Because the slope is decreased during the period of time most critical for sediment transport (high flows) there may be a significant impact to the stream channel form upstream from the dam. Reduced sediment transport capability causes gravel and cobble material to be deposited in the channel. As this happens, the channel becomes wide and shallow. Bar deposits may split the channel into several smaller channels. Over time, this can significantly alter the stream form and function.

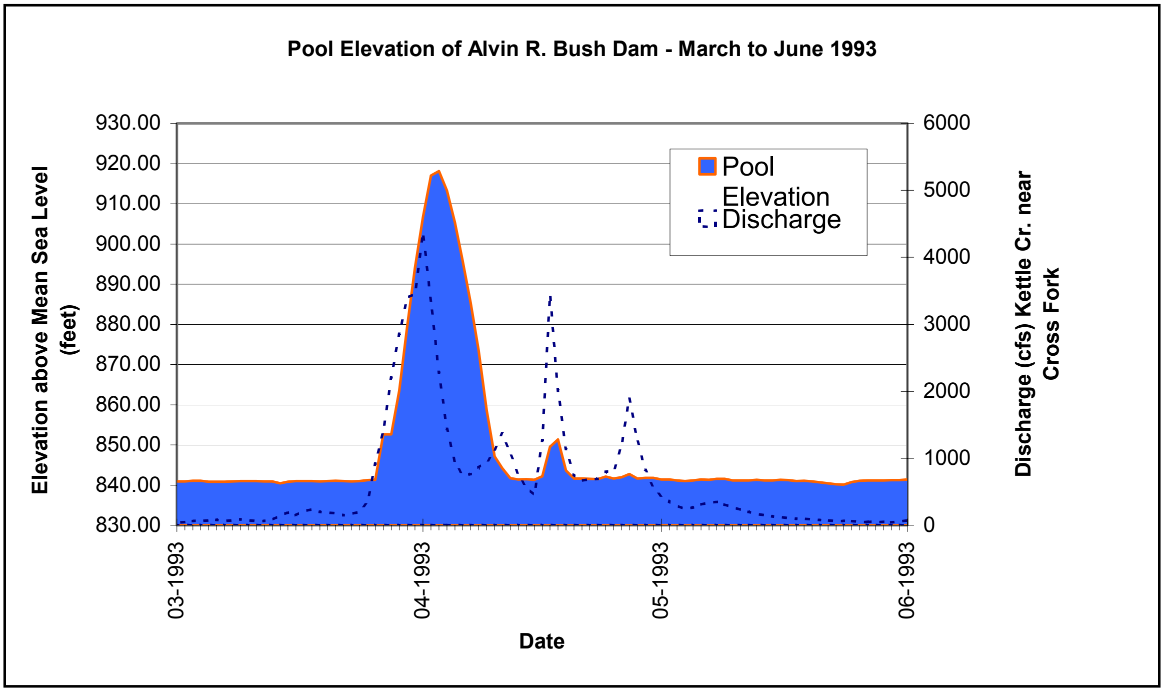

Figure 10: Affects of a high flow event on the pool elevation of Alvin R. Bush Dam. Note the lag time between discharge at the stream gage and pool elevation increase. This timeframe can be used to predict increase flows and subsequently release water from the dam to more affectively manage the pool elevation.

On Kettle Creek above Alvin R. Bush Dam, reduced stream slope during high flows can impact the stream channel from Trout Run downstream. This problem will manifest itself over a long period of time (50+ years). Alternatives for mitigation are limited. Modifications to the operating protocol for the dam to allow the pool elevation in the reservoir to be lowered significantly prior to forecasted high flow events can help to reduce upstream impacts. Reduced reservoir storage prior to high flow allows the reservoir to store more stormwater without an excessively high pool elevation thereby maintaining the stream slope upstream from the reservoir and allowing the stream to effectively transport its sediment load.

Alvin R. Bush Dam impacts sediment transport and hydraulic function upstream from the reservoir pool. The slope in this reach of stream has been reduced causing deposition, channel widening, and bar formation. The base elevation, or lowest point in the stream system was raised to the reservoir pool elevation when the dam was constructed. Hydraulic changes can extend as far upstream as Trout Run during periods of high stream flow.

SUMMARY OF CURRENT CHANNEL CONDITION

Geomorphic mapping completed in the fall of 2001 provides significant insight into the channel condition of Kettle Creek and selected tributaries. Bank erosion, bankfull width, bankfull depth, mid-channel bars, headcuts, lateral bars, high quality habitat, flow patterns, dominant channel material, channel encroachments, and particle size distribution were mapped and measured along 30 miles of Kettle Creek and downstream reaches of Trout Run, Hammersley Fork, Cross Fork, Little Kettle Creek, and Upper Kettle Creek. This data set allows analysis of the geomorphic condition in much of the upper watershed.

Bank erosion was mapped and rated for severity throughout the study area. Bank erosion, especially severe bank erosion is an indicator of local instability. Other influences elsewhere in the stream can trigger bank erosion. Severe bank erosion is a concern as it increases the sediment load on the stream system and interrupts the energy balance. Bank erosion is not a major problem in much of the study area. The majority of bank erosion is found in the reach from the delayed harvest fishing access upstream to Ole Bull State Park (Appendix 1-4). This area is the most active reach in the study area. Outside of this area isolated instances of bank erosion are not of great concern.

Bankfull flow or discharge is used to describe the dominant channel-forming flood. In Pennsylvania, this flood occurs on average once every 1.3 to 2.0 years. The bankfull width and depth are measured in the stream channel by identifying the point at which water leaves the stream channel and begins to flow onto the floodplain. Once this point has been located, the channel width at that elevation is measured as the bankfull depth. The height of this point above the lowest point in the channel is measured as the bankfull depth. These two measurements provide a great deal of information. The ratio of bankfull width to bankfull depth is used to describe the cross-sectional form of the channel. When used in conjunction with other data, it is an excellent predictor of bar deposition and channel instability. Width-depth ratios enable the width of the channel to be evaluated. High width-depth ratios indicate that the stream channel is unnaturally wide. Very low width-depth ratios are typically found in steep mountain streams.

The width-depth ratio is a key measure in the upper Kettle Creek watershed. Most reaches of the mainstem of upper Kettle Creek downstream from the mouth of Cross Fork have high width-depth ratios (Appendix 1-5). In some cases, the width-depth ratios exceed 40. Research shows that channels with width-depth ratios greater than 40 very frequently are unstable and have multiple channels indicated by midchannel bars (Appendix 1-15). Sediment inputs exceed the stream's ability to transport the sediment in reaches with high width-depth ratios.

Most reaches of Kettle Creek in the middle and upper watershed are excessively wide and shallow. Watts and others (1942) reported that the average channel width from the mouth of Hammersley Fork to Leidy was approximately one-hundred feet. Today, the average bankfull channel width for that reach is 154 feet. The channel is dominated by large sediment, mostly small cobbles and very coarse gravel. This sediment, transported primarily along the bed of the stream alters the stream channel with nearly every flood event (every one to two years). Because large amounts of material are moving downstream through the channel, the channel bed elevation is increasing. As the channel bed elevation increases, the stream channel widens, the stream energy decreases, and less material can be transported through the channel.

Shear is the force that dominates sediment movement on the streambed. The amount of shear acting on the bed of a stream is directly related to two properties, the slope of the stream channel and the depth of water flowing over the streambed. As the channel continues to deposit material in downstream reaches the stream slope is decreased. At the same time, the channel width is increasing and the depth is decreasing, which continues to decrease the stress on the channel bottom. This relationship is the reason that there is very little bank erosion evident in the lower reaches of the middle watershed and relatively little bank erosion in upstream reaches.

Lateral bar formation, especially in over-wide reaches of channel indicates that the channel is attempting to increase its sinuosity. Young lateral bars with little or no vegetation are prevalent along much of the mainstem of Kettle Creek. Over time, lateral bars tend to increase in size thereby narrowing the bankfull channel over time. In an actively eroding stream system, lateral bars are concentrated on the inside of meander bends. In the case of Kettle Creek, in the very active stream reaches between the delayed harvest access and Ole Bull State Park, lateral bars are almost exclusively found on the inside of active meanders. Downstream on the mainstem, most lateral bars are located in long, straight, and wide reaches of stream. In these stream reaches, continued lateral bar formation will help to narrow the stream channel to a more natural width and stream function.

Headcuts are sudden changes in stream slope associated with elevation adjustments. Headcuts can occur in a number of situations. The classic location for a headcut is at the upstream extent of bed erosion moving upstream in a stream channel. An example of a large headcut is a waterfall. Waterfalls occur as the streambed elevation drops and the stream encounters more resistant material at the location of the waterfall. As downstream, erodable material continues to be removed, the resistant material of the waterfall maintains its elevation creating a sudden change in stream slope. Headcuts can also be found at the downstream extent of deposition zones in the channel. As material is added to the channel bottom, the downstream extent of the depositional zone becomes steeper than other areas within the reach. Headcuts of this type are often found near mid-channel bars.

Almost all headcuts mapped on Kettle Creek and its tributaries are minor channel elevation adjustments associated with deposition within over-wide channels (Appendix 1-6). The few classic, erosive headcuts that do occur are located in bedrock and do not pose a stability issue for Kettle Creek or its tributaries.

Dominant channel material is an important component of available habitat and stream channel function. The dominant bottom material in Kettle Creek and the downstream reaches of its tributaries ranges from small cobble to bedrock (Appendix 1-7). Bedrock outcrops are significant habitat and geomorphic features. Many of the high quality pools, especially in downstream reaches of the upper watershed, are located in bedrock. Habitat quality is high in these areas as the bedrock outcrops in Kettle Creek are highly fractured with a variable surface. This creates excellent hiding areas for fish in the bedrock pools.

Bedrock is very significant geomorphically. The streambed elevation is controlled by bedrock at a number of locations along the mainstem and in the tributaries (Appendix 1-7). The streambed elevation cannot decrease below the bedrock elevation from the location of the outcrop upstream to the headwaters. Bedrock is extremely resistant to erosion and many thousands of years would be necessary to decrease the streambed elevation significantly through bedrock.

In addition to the mapped dominant channel material, particle size distributions were measured at 11 locations in the study area. Seven mainstem locations and one location on each of the four tributaries were sampled (Appendix 2). The particle size distribution is completed by measuring at least 100 random particles at the sample location. A size distribution graph and statistical information are developed from this data. The detailed particle size distribution provides important information about fine sediment in the stream channel as well as more precise measurement of the particle size that controls the channel form. The dominant particle size, usually the 50^{th} percentile particle size, is the size material that must be mobilized in the stream channel for channel form to be maintained. The dominant particle size for the watershed is small cobble (64-90 millimeters). The particle size distribution in Kettle Creek is generally uniform throughout the upper watershed. The tributary particle size distributions are less uniform. The Hammersley Fork particle size distribution has a significant coarse sand and fine gravel component. The particle size distribution of Cross Fork is similar to the mainstem with the exception of a significant fine sand component present in Cross Fork. Little Kettle and Upper Kettle Creeks have similar particle size distributions to the mainstem.

Riprap stabilized embankments were located and measured throughout the study area. Relatively few locations in the study area have been stabilized using riprap (large rock protection). Long riprap embankments typically reduce habitat in the immediate vicinity of riprap protection. Long flat reaches of stream are common near riprap banks along Kettle Creek. Bank protection is generally used to protect infrastructure (roads, bridges, and utilities) or structures (Appendix 1-8). Riprap bank locations along upper Kettle Creek do not pose a major risk to stream channel stability, but they do impact habitat. In addition to reducing the stream channel diversity, riprap embankments prevent shade providing vegetation from establishing.

Similar to riprap embankments, channel encroachments can reduce habitat quality and impact stream function. Channel encroachments are unnatural landforms or structures within the floodplain. Levees, abandoned railroad beds, roads, and fill within the floodplain are the major channel encroachments within upper Kettle Creek (Appendix 1-9). Today, the most prevalent channel encroachments are roads. Historically, the majority of channel encroachments were railroad beds. Some of these railroad beds continue to impact flood flows today. Few of the channel encroachments located in the upper watershed have potential cause instability in the stream channel, but again, they do reduce high quality habitat. Especially adjacent to roadways, the lack of riparian vegetation reduces habitat quality and contributes to increased water temperatures.

Hand-placed rock dams are a recurring feature throughout the study area (Appendix 1-10). While most of the dams are destroyed during high flows, they do have a limited impact on channel form in the immediate vicinity of the dam. More importantly the dams can impact fish habitat during lower flow periods. Most of the dams are constructed to hold water for recreation use. The result is a moderately shallow pool with little cover behind the dam. More natural rock dams can be constructed to provide both improved stream function and recreational opportunities.

High quality habitat was mapped in the study area. Habitat features were separated into a number of categories: backwater pools, coarse woody debris, high quality pools, large boulders, overhanging banks, overhanging vegetation, high quality riffles, and thick root mats (Appendix 1-1). High quality pools and coarse woody debris are the most common fish habitat features in the study area. While a number of high quality pools were located in the study area, the average pool spacing is far longer than optimal. Pool spacing for natural stream channels in similar conditions is 4 to 10 channel widths (Rosgen, 1998). The pool spacing throughout the study area is much greater than 4 to 10 channel widths. Many of the pools are associated with coarse woody debris jams. The debris provides additional cover for excellent fish habitat in the adjacent pools. Thin riparian vegetation results in limited overhanging vegetative cover although there are several locations with good willow populations that provide excellent habitat. Large boulders also provided habitat throughout the watershed. The large boulder habitat is typically found adjacent to ridges or bedrock outcrops. Improved habitat conditions can be realized in Kettle Creek by addressing excess sediment in the stream system.

Based on the historic information and the comprehensive geomorphic data collected in 2001, fish habitat in upper Kettle Creek and many of its major tributaries is impacted by excess sediment in the stream system. The stream system is likely still responding to disturbance caused by massive logging and concurrent floods around 1900. As the excess sediment is redistributed throughout the channel (see mid-channel bars) habitat is impacted. Pools have accumulated sediment and long, flat glides are common (Appendix 1-11). Lower reaches of Kettle Creek from Hammersley Fork downstream show signs of initial recovery such as extensive lateral bar development along straight reaches of channel. Excess sediment moving into these reaches from upstream will likely continue to destabilize this area and disrupt the natural recovery. Sediment supply and limited sediment transport are the two largest impacts to physical fish habitat within the study area.

The very wide channel form observed throughout the study area provides excellent opportunities to reduce excess sediment loads in Kettle Creek. The majority of stream reaches on Kettle Creek have reached Class V of the channel evolution model. In some areas the stream channel is approaching Class VI, a stable, naturally functioning channel form. As illustrated below, very little sediment is added to the stream channel from bank erosion. As a stream channel approaches Class VI, habitat enhancement and stream stabilization can be accomplished with less costly measures because banks are relatively stable and small amounts of material must be moved to establish the proper channel geometry.

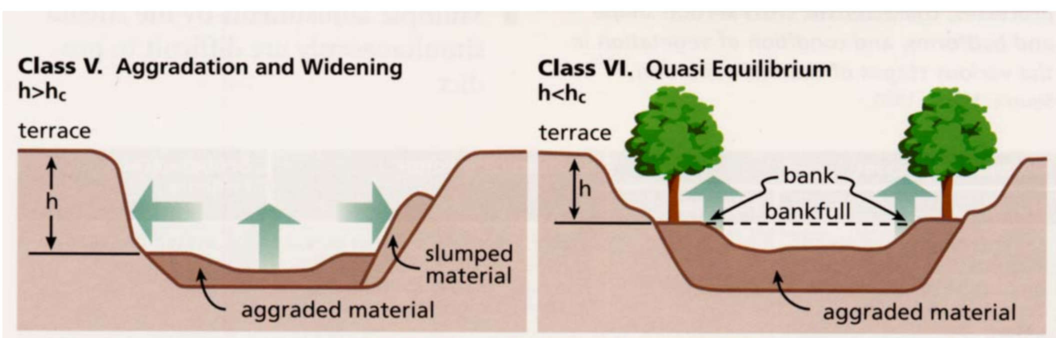

Figure 11: Geomorphic stage of middle Kettle Creek channel.

WATER TEMPERATURE, CANOPY COVER, AND STREAM CHANNEL FORM

Water temperature is a major water quality concern for the middle and upper Kettle Creek Watershed. During the summer and early fall; water temperatures reach dangerously high levels for aquatic life in many reaches of Kettle Creek. Water temperature at the mouths of most of the major tributaries to Kettle Creek is unnaturally warm. The water temperature at the mouth of Trout Run is an exception. The average water temperature at the mouth of Trout Run through the month of September was on average seven degrees Fahrenheit cooler than water in the mainstem of Kettle Creek. There is a slight localized cooling affect on the mainstem immediately adjacent to Trout Run. A small pool at the confluence provides a cool water shelter for fish. However, the pool provides little cover.

Along the mainstem of Kettle Creek water temperatures vary widely with air temperature and solar radiation. Hot, sunny days can quickly drive temperatures above 75 degrees Fahrenheit along the lower reaches of Kettle Creek. Very few deep pools and groundwater springs provide any cooler water for fish during periods of high water temperature. Analysis of continuous water temperature collected from early September to late October 2001 found that water temperatures in Kettle Creek and some tributaries can exceed fisheries thresholds even in late summer (Appendix 3). The water temperature on Kettle Creek below Trout Run exceeded 80^{o}F in September 2001.

Figure 12: Poor canopy cover results in long, unshaded reaches of stream channel.

Both the riparian tree canopy cover and the channel form are related to high temperatures and large variations on the mainstem of Kettle Creek. Very wide channels reduce the ability of even a thick riparian forest to shade the stream channel. Trees provide shade for a relatively small distance from the trunk during mid-day periods when solar radiation is at a maximum. For example, a 50-foot high oak tree can provide more than twice its height in shade near sunrise, but with the sun at 80^{o} overhead the tree will provide shade for less than 30 feet from its trunk. If the stream channel is over one-hundred feet wide (common on the mainstem of Kettle Creek) the riparian canopy can provide little cover even if it is in excellent condition.

In many cases, the riparian buffer along Kettle Creek is in poor condition. Riparian buffers are thin or absent on over 40 miles of stream channel within the watershed (Appendix 1-12). There are a number of impacts that reduce riparian buffer thickness and health. Roadways, bridges, and electric transmission lines encroach on the stream corridor. Agricultural fields are cultivated close to the stream channel. Residential areas and other land uses are close to the channel and reduce riparian forests.

Canopy cover was measured using an optical densiometer to measure open space in the canopy over the stream channel. Measured canopy cover over much of the mainstem of Kettle Creek was less than 30% (Appendix 1-13). Only 7 locations in the study area measure more than 80 percent coverage. The median canopy cover for all measured points in the study area was only 32 percent. Canopy cover this low leaves the stream channel exposed for the majority of the high solar radiation hours during the day.

In addition to reduced channel shading from thin riparian cover and very wide stream reaches, channel hydraulics impact water temperature. Nearly all of the very wide stream reaches have low flow velocity and shallow water depth. These factors increase the travel time for water through the reach. Longer travel times expose the water to solar radiation for longer periods of time increasing the water temperature.

To illustrate the impact that good canopy cover and channel dimensions can have on stream temperature, compare the water temperature in Kettle Creek below Trout Run to the water temperature in Trout Run September 5 to September 14, 2001 (Appendix 3). Water temperatures in Trout Run do not vary quickly and only gradually rise several degrees during warm, sunny days. The water temperature in the mainstem can vary over 10 degrees within a 24-hour period. Without adequate tree canopy cover to shade the stream, solar radiation heats the water quickly and water temperatures vary rapidly from day to day.

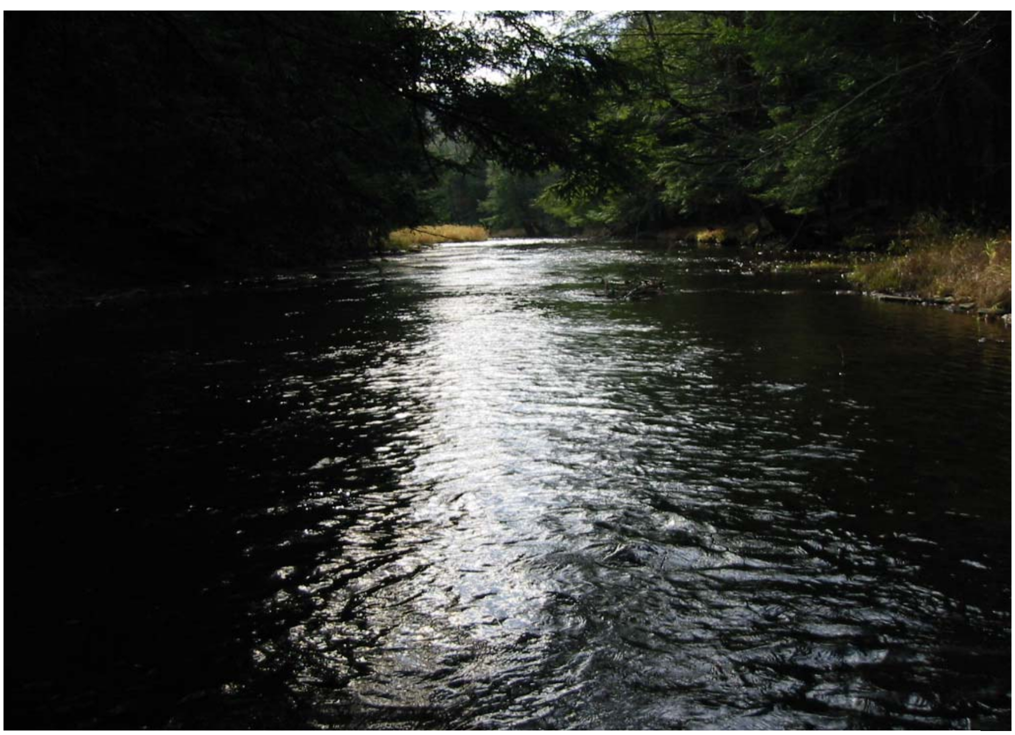

Figure 13: Good canopy cover provides shade for the stream channel throughout the day.

REACH-BY-REACH SUMMARY

This summary is organized in order from downstream to upstream starting on the mainstem of Kettle Creek one mile downstream from Trout Run. Tributaries are included in order from downstream to upstream as they enter the mainstem. Appendix 1-14 illustrates the stream reach names and locations used in this summary.

KETTLE CREEK MAINSTEM BELOW TROUT RUN

One mile downstream from Trout Run

Channel Structure and Bank Stability

The channel is over-wide and shallow with little high quality habitat. Boulders and cobbles dominate the bottom substrate. Bottom particle size ranges from small boulders to small cobble and some large gravel. Scattered large boulders provide some limited habitat.

Figure 14: Typical wide, shallow channel downstream from Trout Run.

Evidence of bed material deposition is prevalent within the reach. The stream channel shows indications of being between Class V and Class VI in the channel evolution model. Very few instances of unstable banks were observed below Trout Run. Periodic bedrock outcrops in the channel bed likely minimized the amount of downcutting that could have occurred in this stream reach. In one location, a small rock dam changes the channel grade and may cause the channel to cut around the structure during a large flow event. This would introduce sediment into lower reaches of the stream and cause a period of instability locally around the dam failure.

Figure 15: Even with good riparian buffers, the over-wide channel cannot be shaded.

Canopy Cover and Water Temperature

Canopy cover through this reach is poor. Even with good riparian buffers along some portions of the reach, the channel is so wide that the riparian buffer cannot provide shade. Water temperatures exceeded 25^{oC} (75^{oF}) on warm, sunny days in September. Flow velocities through this reach are generally low, which exposes stream water to the sun for longer periods of time and allows it to warm rapidly.

Because the channel is very wide, little canopy cover exists. Direct sunlight hits the water surface through most of the day. The majority of this reach is oriented in the northeast to southwest direction resulting in extended periods of direct sunlight.

Habitat Enhancement Opportunities

In this reach, there is great potential to dramatically increase habitat with relatively low costs and disturbance. Natural channel design could be applied within this reach without the use of large rock structures. The low flow channel could be established within the existing stable banks. In some locations along this reach, the channel is already narrowing and riparian vegetation is stabilizing the new low banks. Expediting this process and encouraging riparian tree growth could improve habitat and canopy cover simultaneously.

TROUT RUN TO 400 YARDS UPSTREAM OF MOUTH

Channel Structure and Bank Stability

Grade control structures at the mouth of Trout Run protect the mouth from channel incision. The stream channel drops approximately three feet in a distance of 50 feet at the confluence. This elevation change is prevented from propagating upstream by the existing grade control structures. While the structures have prevented upstream headcutting, the channel is widened in the location of the structures. Shallow water and structures may prevent fish passage into the tributary.

Below the Route 4001 Bridge, a 47-meter section of pipeline has been exposed by the stream. The pipeline causes the channel to widen and creates a bar deposit (see figure 17).

Canopy Cover and Water Temperature

Canopy cover on Trout Run is excellent with an average canopy cover of 96%. The only area of poor canopy cover observed was just downstream from the Route 4001 Bridge. The majority of the Trout Run Watershed is forested. The riparian buffer along nearly the entire stream channel is in excellent condition. This cold water tributary provides a refuge for

Figure 16: Good canopy cover protects low water temperatures in Trout Run

trout seeking relief from high water temperatures in the mainstem.

Habitat Enhancement Opportunities

Replacement of the existing grade control structures with grade control that enhances habitat while protecting the streambed would improve the opportunity for fish passage into Trout Run. Improving the channel condition and fish passage from the Route 4001 bridge to the mouth would enable more fish to easily access the cooler waters of Trout Run.

Figure 17: Exposed pipeline in Trout Run alters channel form near the confluence.

KETTLE CREEK MAINSTEM UPSTREAM FROM TROUT RUN

To 3.4 miles upstream from the mouth of Trout Run

Channel Structure and Bank Stability

At the mouth of Trout Run and upstream for 0.15 miles, the channel is again wide and shallow with uniform depths. Approximately 0.15 miles upstream from Trout Run, the channel abuts the ridgeline and the bed material is composed of small blocky boulders and large cobbles. The right bank material is bedrock while the left bank material continues to be alluvial material. The channel narrows and exhibits a few poorly developed pool-riffle sequences in the reach immediately upstream of Trout Run. Lateral bars are beginning to form in this reach indicating that a meandering low-flow channel is beginning to form. Canopy cover improves while the channel is adjacent to the ridge. Canopy covers as high as 48% were measured in this reach. As the stream leaves the ridge and enters the ox bow, the channel is characterized by flat, uniform depth runs with continued lateral bar formation. Numerous channel split associated with depositional bar features at the end of long, straight runs and glides were mapped. Some channel splits appear to be approaching a stable configuration while others have relatively even flow around the bars and may maintain the split channel for a period of time. In the case of channel splits with unevenly distributed flow, one channel has a higher gradient than the other and conveys the low flow. The secondary channel has a flatter gradient and carries significant flow in flood events. Several bedrock sills cross the channel bottom in this reach and would act as grade control in the event of channel incision.

Figure 18: Channel narrows and is shaded by the hillside forest at the apex of the ox bow.

As the stream enters the apex of the ox bow, the channel narrows. The left bank is composed of bedrock with a bedrock shelf extending midway through the channel. Several good pools are located within this area and the channel is stable.

Canopy Cover and Water Temperature
Canopy cover as the channel parallels the ridge is fairly good with measured values as high as 48% covered. As the channel moves away from the ridge, the canopy cover drops to near zero. Poor canopy cover combined with long, flat runs, allows the water temperature to increase through this section. At the apex of the ox bow, canopy cover improves and the channel narrows. The apex of the ox bow should be preserved.

Habitat Enhancement Opportunities
In areas where the channel is not bounded by a ridge on one bank, the channel is over-wide with poor habitat and in some cases a narrow riparian zone. Opportunities exist to narrow the low flow channel, add meanders to the low flow channel, and improve shading within this reach. As the channel is over-wide, construction costs would be relatively low and a non-structural approach can be utilized.

KETTLE CREEK MAINSTEM BELOW HAMMERSLEY FORK

From 1.8 miles downstream from the mouth of Hammersley Fork to Hammersley Fork

Channel Structure and Bank Stability
Similar to reaches downstream, this section of stream exhibits an over-wide channel with poor canopy cover. In areas adjacent to ridges and bounded by bedrock on one bank, deeper pools, improved habitat, and narrower low-flow

channels are found. Numerous bar formations with split channels occur as in downstream reaches. Many of the bars are associated with secondary channel grade adjustments. Slightly more woody debris was observed in this section with the majority of the woody debris helping the formation of gravel bars.

A large gravel bar with older woody vegetation is established approximately 300 meters downstream from the confluence with Hammersley. The channel splits to two smaller channels around the bar. On the right bank, the channel is actively eroding. Riprap at the base of the bank adjacent to several camps is slowing the erosion to some degree, but the bank is eroding despite the riprap. It appears that some material may have been removed from the channel here in an attempt to relieve stress on the right bank.

Small lateral bars were noted in some over-wide reaches with herbaceous vegetation and some very young (two-three years) woody vegetation. Long flat runs and glides are common with shallow water depths. Water depth in most runs is relatively uniform at approximately 0.25 meters. Glides exhibit more variability in water depth, but velocities are extremely low.

Canopy Cover and Water Temperature
The channel is exposed to sunlight for most of the day in the wide stretches of runs and glides. Low velocities especially in glides expose the water to warming sunlight for long periods of time. Water temperature in this reach increased over six degrees Celsius during the day mapping was conducted.

Habitat Enhancement Opportunities
Opportunities exist for both canopy cover improvements as well as channel habitat improvement. The channel is over-wide and can be narrowed while incorporating meanders and gravel bars within the existing banks. An aggressive revegetation program focusing on native riparian tree species such as willows and sycamore will help to capture fine sediment on the bars and encourage maintenance of a narrower low flow channel. In addition to stabilizing the bars, vegetation, especially wood vegetation, helps to increase stress within the narrower channel, which increases sediment transport and maintains pool-riffle sequences.

Difficulties associated with reestablishing a narrow meandering channel include management of upstream sediment loads and determining the impact of further channel adjustment upstream.

HAMMERSLEY FORK

Hammersley Fork complete survey to 1.3 miles upstream from mouth – additional data and photographs to 4.0 miles upstream from mouth

Channel Structure and Bank Stability

At the mouth of Hammersley Fork, the channel is very wide (16.5 meters) with numerous stable gravel bars in the channel. Two bridges, Route 144 and the abandoned Hammersley Avenue Bridge encroach on the channel here. The channel is maintained to the full span of the Route 144 Bridge. Continuous removal of deposition at the bridge keeps the channel in an over-wide state. One-tenth of a mile upstream from the bridge, the channel bottom and right bank are in bedrock. The channel narrows slightly and canopy cover improves marginally. Two-tenths of a mile upstream several camps and permanent residences line the left bank. Vegetation is mowed to the top of the bank. At the upstream extent of permanent residences, the channel again is bounded by bedrock on the right bank and channel bottom. The channel parallels the ridge from this point to the mouth.

Upstream of this section, the channel spits to three channels at a headcut. The elevation change over the headcut is 1.75 meters. The headcut is 21 meters long. Upstream of the headcut, a long flat glide is found with an additional channel cutting to the left bank and returning to the main channel 150 meters downstream. This section is very unstable. Additional camps are located on the left bank. An investigation of the channel for several miles upstream indicates further instability. The channel appears to be making multiple grade adjustments at a number of locations. The channel has widened and is beginning to show signs of narrowing again in some locations. Tributaries are contributing significant amounts of sediment. 0.8 miles upstream from the mouth, a state forest road fords the stream causing an extremely wide, shallow area. This road then parallels the stream on the right bank. The road is in extremely poor condition and in danger of being undercut by the stream at a number of locations.

Canopy Cover and Water Temperature

Poor canopy cover increases water temperature for 0.75 miles upstream from the mouth of Hammersley Fork. The canopy cover in this reach ranges from 0 to 50%. Low canopy cover coupled with shallow water depths significantly impacts water temperature. Additionally, very few reaches of good canopy cover were observed along the channel further upstream. As a result of channel widening, the riparian forest canopy has been pushed back from the channel. This condition extends over two miles upstream.

Habitat Enhancement Opportunities

Hammersley Fork should be considered carefully in efforts to enhance habitat on middle Kettle Creek. This stream has the potential to contribute significantly cooler water to Kettle Creek relatively low in the watershed. Even improved channel shading for two-hundred meters upstream from the mouth would reduce water temperatures. Poor access to the upper Hammersley may hamper large-scale channel work, but should not impact revegetation and non-structural channel restoration methods. Reduced water temperatures from Hammersley could provide a very positive enhancement for middle Kettle Creek.

KETTLE CREEK MAINSTEM HAMMERSLEY FORK TO CROSS FORK

4.8 miles from the mouth of Hammersley Fork to the mouth of Cross Fork

Channel Structure and Bank Stability

Very wide channel cross-sections and numerous mid-channel bars characterize this reach of stream. The valley slope flattens in this area causing sediment being transported from upstream reaches to be deposited here. Nine major mid-channel bars are located in this reach. Outside of the immediate vicinity of the mid-channel bars, the stream channel is very stable through this reach. Multiple split channels coincide with the mid-channel bar deposits. At the downstream edge of the deposits, the stream slope increases as the channel adjusts to the elevation of the upstream deposition.

Long, flat glides and runs dominate the hydraulic character of this reach. Adjacent to hillsides where bedrock outcrops occur, the stream narrows and several good pools and riffles are found.

Figure 19: Significant bank erosion is present only where mid-channel bars impact stream function.

Canopy Cover and Water Temperature

Canopy cover is very poor through this reach. No canopy cover greater than 40% was measured. The slow-moving glides and poor canopy cover combine to severely impact water temperature. Streamside land use in this area reduces canopy cover significantly. Both agriculture and residential development have completely removed canopy cover in several locations. Along the ridges and rock outcrops, the hillside forest provides some minor shading, but the opposite bank is nearly devoid of tree cover.

Habitat Enhancement Opportunities

This reach has many opportunities for both habitat improvement and riparian buffer establishment. The over-wide stream channel can be narrowed at the same time riparian buffers are planted providing better channel hydraulics and improved shading.

In this area, landowner education and improved streamside management could provide major improvements to the riparian zone. This reach should be a target reach for riparian buffer re-establishment on the mainstem of Kettle Creek.

CROSS FORK

from the mouth to 2.4 miles upstream

Channel Structure and Bank Stability

The confluence of Cross Fork and Kettle Creek is stable. Just upstream from the mouth, the channel is impacted by the Route 144 bridge crossing. This bridge is adequately sized. A scour hole is present adjacent to the left bridge abutment. The channel alignment on the bridge approach is poor. The channel flows directly toward the left abutment; flow impacts the abutment and spills into the scour hole. At the upstream edge of the bridge, a 0.5-meter high headcut allows flow to narrow significantly and increase velocity where it enters the scour pool. A stable vegetated bar is present on the right bank.

Two-tenths of a mile upstream from the mouth, a major headcut has stalled on bedrock. This headcut, 1.75 meters high is stabilized by the underlying bedrock sill. Bank erosion is present on the right bank of the channel at the headcut location. Seventy-five meters upstream from the headcut, a straight, narrow run follows a riprap bank on the left bank. This bank is fairly stable although habitat is poor in this reach.

Figure 20: Bedrock prevents bed erosion from migrating upstream near the mouth of Cross Fork.

Over-wide channel sections with developing lateral bars are common through the lower two miles of Cross Fork. Several footbridge crossings have minor impacts on channel form and little impact on stability. An abandoned pipeline impacts flow within the channel in several short reaches. A ford to a camp on the right bank has generated some channel widening in the immediate location of the ford, but does not have a major impact on the overall channel structure and stability of the stream.

Figure 21: In some locations, Cross Fork splits into two well-defined channels.

Upstream from the second footbridge, a wide, flat glide gives way to a narrow channel with developing meanders along the end of the adjacent ridge. As the channel enters the ridgeline, 35 meters of the right bank are unstable. Bank heights greater than two meters do not allow thin wood vegetative cover to stabilize the bank. Numerous trees in this section are undercut and could topple into the stream in the near future. Upstream from the ridge, the channel again becomes over-wide with shallow runs and glides dominating the morphology.

A very large channel split that divides the stream into two equally flowing channels occurs 1.4 miles upstream from the mouth. The two channels appear relatively stable with only minor bank erosion present. The habitat in this area is excellent due to well-developed pool-riffle sequences, woody debris jams, and overhanging vegetation. Numerous connector channels and historical stream channels cross the floodplain.

Further upstream, Cross Fork becomes unstable. Poor riparian vegetation and high banks are found with significant bank erosion. This is one of the few areas in the Kettle Creek watershed with high, unstable

Figure 22: A dirt road to the right of the picture limits riparian vegetation in this area of bank instability.

banks. Appendix 1-4 shows the locations of bank erosion on Cross Fork.

Canopy Cover and Water Temperature

Canopy cover at the mouth of Cross Fork is poor. The first 300 meters of the channel are similarly poor. Some improvements to canopy cover are evident as the channel approaches the ridgelines. Adjacent camps and homes low in the watershed have reduced the thickness of the riparian zone. In less populated areas, the channel canopy cover increases to a high of 51%.

Habitat Enhancement Opportunities

Cross Fork is impacted by excess bed sediment and wide stream channels. There are significant opportunities to improve both the in-stream habitat and the riparian canopy cover. These conditions extend to the headwaters of Cross Fork. There are many areas within Cross Fork that would benefit from natural channel design. Very good vehicular access to the stream would allow the channel form to be adjusted improving habitat and stream channel dimensions.

KETTLE CREEK MAINSTEM FROM CONFLUENCE WITH CROSS FORK UPSTREAM TO DELAYED HARVEST AREA

from mouth of Cross Fork upstream 3.7 miles to the delayed harvest area

Channel Structure and Bank Stability

For the first two miles upstream from the confluence with Cross Fork, residential land use and the adjacent roadway impact Kettle Creek. Runs and glides dominate this reach of stream. The channel parallels a ridgeline to the southeast with bedrock outcrops and small boulders for 0.4 miles upstream from the town of Cross Fork.

Once the stream leaves the ridgeline, it is paralleled by the roadway to the northwest. Several series of riffles, runs, and glides occur through this reach. Mid-channel bars are depositing here and habitat is generally poor. The stream is bounded by riprap adjacent to the road so bank erosion is minimal. Several flood channels carry high water on the right bank of the stream.

Figure 23: Land use and roadway encroachments reduce canopy cover upstream from the town of Cross Fork.

From this point, 3.1 miles upstream from the confluence with Cross Fork, to the beginning of the delayed harvest zone, the stream is unstable. Multiple mid-channel bars and debris jams cause the channel to split. Bank erosion and stream grade adjustments accompany the channel instability. In-stream habitat is very good in this area. Debris jams form pocket pools with excellent cover while narrow, unstable channels have developed good pool-riffle sequences.

Canopy Cover and Water Temperature

Canopy cover is generally poor for the first two miles upstream from the confluence with Cross Fork. The canopy improves as the channel moves away from the roadway and residences. A healthy riparian forest surrounds the unstable portion of this reach. This forest provides good shade and habitat that protect water temperature and provide excellent fish habitat.

Figure 24: Canopy cover improves at the upstream extent of this reach

Habitat Enhancement Opportunities

The upstream, unstable portion of this reach should be considered a low priority for habitat enhancement and riparian buffer improvement. Habitat quality through this portion is good and water temperature is protected.

Both canopy and habitat could be improved through the lower portion of the reach. Prospects for canopy improvement adjacent to the roadway are poor as an electric transmission line parallels the road in this area. Riprap protection along the road can be altered to provide better habitat and stream function through this section.

Better streamside stewardship by landowners along this reach would improve the riparian buffer.

KETTLE CREEK MAINSTEM UPSTREAM FROM DELAYED HARVEST FISHING ACCESS TO ONE MILE SOUTH OF OLE BULL

from the delayed harvest parking area 3.8 miles upstream

Channel Structure and Bank Stability

Immediately upstream from the fishing access, the channel is straightened and entrenched for 0.20 miles. Log deflectors constructed in this reach are functioning and provide some enhanced habitat.

Above the straightened section, the channel continues to be entrenched. Channel width is narrower and provides better hydraulic function than many other reaches of the stream. Meanders are actively migrating, building bars on the inside of meander bends and eroding banks on the outside of the meander bends. Several good pool-riffle sequences were mapped through this reach. Mid-channel bars are absent through this portion of the reach.

Figure 25: Log deflectors provide some habitat improvement near Route 144.

Upstream from the PA Fish and Boat Commission Project Site, multiple high flow channels occur on the northwest bank. The channel has migrated across its floodplain in this area. The channel is bounded by roadway, hillside, and bedrock on the southeast bank. Runs characterize the majority of the reach. Several glides with mid-channel bars at the downstream limit cause mild channel instability. The stream has good access to its floodplain here and flows on the floodplain and adjacent abandoned channels frequently. Some minor bank erosion occurs in this reach. Several pools with good fish cover were located in this section.

Figure 26: The narrower channel provides improved canopy cover in some areas through this reach.

Canopy Cover and Water Temperature

The riparian canopy cover is generally good through this reach. Canopy cover is marginal for the first mile upstream from the fishing access and improves above the PA Fish and Boat Project Site. Narrower channel widths allow the canopy to close over the channel in some locations. The riparian forest is extensive on the northwest bank of the channel and adequate on the southeast bank.

Just below the PA Fish and Boat Project Site a small tributary enters from the right bank. On the day this reach was surveyed, the water temperature was 2.5^{o} Celsius cooler in Kettle Creek than the tributary. The tributary drains from an exposed pond that likely increased the temperature. This data was collected after the air temperature had dropped in early October. It is possible that the water temperature from the tributary is cooler than water in the mainstem during warmer periods.

Habitat Enhancement Opportunities

The stream form in this reach provides habitat for fish and protection for water temperature. Upstream from the PA Fish and Boat Commission Project Site channel stability is a concern. If the channel relocated into an adjacent flood channel, the project could be bypassed. However, through this reach the stream has access to the floodplain and provides better habitat than many downstream reaches. This reach should not be a high priority for improvement.

KETTLE CREEK MAINSTEM FROM ONE MILE SOUTH OF OLE BULL TO CONFLUENCE OF LITTLE KETTLE AND UPPER KETTLE

From 3.8 miles upstream from the delayed harvest parking area 2.2 miles to the confluence of Upper Kettle Creek and Little Kettle Creek

Channel Structure and Bank Stability

Channel structure below Ole Bull State Park is widely varied. Numerous high flow channels and abandoned former channels intersect the main channel. Many of the abandoned channels are active at the bankfull discharge. This removes some of the channel forming flow from the main channel and impacts sediment transport through this reach. The stream channel is stable and supports good

Figure 27: Small mid-channel bars such as this are common through this reach. Gravel and cobble material is deposited during high flows. Bars split the channel at lower flows.

habitat in several locations. Gravel bars being transported through the reach impact stability and channel form at other locations. Split channels and mid-channel bars have formed at the downstream extent of the bed material deposits. Bank erosion is moderate to severe in several locations. Through this section, there are several reaches of channel pattern and dimensions that support high quality habitat and appear to be of a stable form for this channel. Through Ole Bull, the channel is over-wide and generally flat. Below the nine-culvert bridge to the Ole Bull Campground, the channel is extremely wide and shallow. Upstream of this structure, the channel is very wide with stabilized banks. The footbridge has very little impact on the channel. The dam impacts flow and impounds sediment in its pool. The dam pool extends 180 meters upstream reducing velocity and allowing fine sediments to fall out of suspension. The dam provides grade control for the channel upstream. Headcuts migrating upstream will not pass the dam. Above the pool from the dam at Ole Bull, the channel has fairly good connectivity with the floodplain. Several meander wavelengths of pool-riffle sequences provide good habitat and demonstrate a narrow channel within the floodplain terraces. Sediment load from upstream continues to cause stability problems with mid-channel bars forming at the terminus of the over-wide depositional areas. The meander cycles with reference conditions are found between the depositional areas.

Canopy Cover and Water Temperature

Below Ole Bull, canopy is average with some isolated reaches of excellent canopy cover and others with extremely poor canopy cover. In Ole Bull State Park, canopy cover is very poor. The over-wide channel and stabilization structures prevent good canopy closure from blocking sunlight. Additionally, low velocities through this section allow water to be exposed to sunlight for longer periods of time. Upstream of Ole Bull, the riparian zone is dominated by shrubs and short woody vegetation. The riparian forest density is low through these reaches.

Figure 28: Wide channel with low flow velocity during the warm season allows water to warm through Ole Bull State Park.

A tributary that enters the mainstem from the northwest bank just below the campground bridge has significantly lower water temperatures than Kettle Creek. This tributary is heavily forested to its confluence with Kettle Creek. This coincides with other reports of lower water temperature in Kettle Creek below the dam at Ole Bull. Water temperature on the day this reach was surveyed was 0.5^{o}C cooler below the dam.

Habitat Enhancement Opportunities

The youth fishing area immediately downstream from the dam at Ole Bull has excellent potential for habitat improvements and riparian canopy enhancement. Narrowing the over-wide channel through Ole Bull State Park would provide higher quality fish habitat and recreational fishing while protecting the cold water that enters Kettle Creek within the park. Adding riparian buffer to the channel will further protect the water temperature and improve aesthetics in the park.

UPPER KETTLE CREEK

from the confluence to 3.2 miles upstream

Channel Structure and Bank Stability

At the confluence with Little Kettle Creek, upper Kettle Creek splits into several channels. Habitat in the vicinity of the confluence is excellent. The stream structure is characteristic of a naturally functioning channel near a major confluence. Several large pools are found downstream from the Route 144 bridge.

Immediately upstream from the Route 144 Bridge the channel is entrenched. A historical railroad bed parallels the channel for over two-hundred meters on the south bank. From this point upstream to the Route 44 Bridge, the channel is moderately entrenched with good pool-riffle sequences. Because the channel is somewhat entrenched, it is able to transport bedload sediment better than many other reaches of Kettle Creek.

Bedrock outcrops at a number of locations through this reach control the channel form. Habitat through this reach is generally good with numerous high quality pools and woody debris to provide cover.

Figure 29: Sediment deposits focus energy on stream banks causing accelerated bank erosion. Most bank erosion along upper Kettle Creek is located near mid-channel bar deposits.

Sediment is introduced to this reach of stream channel from roadway drainage on the steep north bank. Pipe outlets produce significant amounts of erosion below them as water cascades down the steep hillside.

Just downstream from the Route 44 Bridge an embankment parallels the north bank of upper Kettle Creek for 300 meters. A former bridge abutment just down stream from the existing Route 44 Bridge shows evidence of minor channel deepening over the time period since the bridge was constructed.

Upstream from the Route 44 Bridge, the channel has numerous splits and several areas of instability. Beaver dams are located in several portions of this reach. Approximately 0.3 miles upstream from the bridge, large mid-channel bar deposits are causing bank erosion as the channel migrates from side to side. These bar deposits occur as the channel moves away from an upstream bedrock bank and moves into the valley bottom.

Above this area of bar deposits, the channel is transporting large volumes of bed sediment through a stream reach that parallels bedrock. This allows the stream to maintain a narrower cross-section and pass the sediment that deposits in bars downstream.

Canopy Cover and Water Temperature

Areas of good canopy cover are interspersed with areas of very poor canopy cover in this reach. Some improvements can be made to the riparian buffer, especially at residences and camps. In the vicinity of the Route 44 Bridge, canopy cover is very poor. Upstream from the bridge, canopy cover is generally poor until the channel parallels the ridgeline 0.6 miles upstream.

Habitat Enhancement Opportunities

There are many opportunities for riparian buffer enhancement in this section of stream. Two particular areas should be targeted for riparian forest improvement. From the Route 144 bridge in Oleana to the confluence excellent instream habitat would be significantly improved by better canopy shading. The area immediately adjacent to and upstream for 0.5 miles from the Route 44 Bridge would benefit from improved riparian cover.

More data from upstream reaches of upper Kettle Creek is needed to determine the source and cause of deposition above the Route 44 Bridge. Preliminary surveys upstream indicate that upper Kettle Creek may be transporting large volumes of sediment downstream. The reach from the Route 44 Bridge to Oleana has good sediment transport capability and may not be impacted significantly by this sediment input. A more detailed geomorphic mapping beyond the upstream limit of this study is recommended.

LITTLE KETTLE CREEK
from the confluence 0.9 miles upstream

Channel Structure and Bank Stability

The stream channel in Little Kettle Creek is dominated by bedrock. Multiple bedrock outcrops upstream from the confluence control the stream grade and channel form. The stream channel is entrenched in some locations, but is generally stable. A significant input of sediment along this reach of stream comes from scour below roadway drainage pipes. Large volumes of sediment have been contributed to Little Kettle Creek from unstable drainage on the steep embankment below the roadway.

Just upstream from the confluence a large beaver dam creates a large pool trapping fine sediments. The confluence with upper Kettle Creek and areas immediately upstream provide very high quality habitat with well formed pools and riffles. Willows and other shrubby, woody vegetation dominate the banks and provide good fish cover.

Figure 30: Unstable drainage on steep slope accounts for a large portion of sediment inputs on Little Kettle Creek.

Good habitat including bedrock pools, overhanging banks, and pools with good woody debris cover are found throughout this reach.

Canopy Cover and Water Temperature

At the confluence with upper Kettle Creek, canopy cover is poor. Improved canopy cover over the long pool at the beaver dam near the confluence would help to protect water temperature.

Within 300 meters upstream from the confluence, canopy cover improves. The cover remains good for the first mile upstream. The headwaters of Little Kettle Creek have several areas of poor canopy cover.

Habitat Enhancement Opportunities

Good habitat and canopy cover in this reach of stream make it a high priority for preservation. The first priority for protecting this reach of stream should be reduction of sediment inputs from roadway drainage on the steep hillside to the southeast. Once the drainage pipe outlets have been stabilized, sediment inputs in this reach of stream will be significantly reduced.

Strategic plan for preservation and enhancement of habitat and stream stability in Kettle Creek

Habitat Protection

High quality reaches of stream within the Kettle Creek Watershed should be protected from future impacts. Fortunately, many of the channel reaches with the highest habitat quality are located in either remote areas of the watershed or areas of the watershed that are physically difficult to reach and/or develop.

Along the mainstem of Kettle Creek, the majority of high quality habitat occurs where the channel is aligned immediately adjacent to a ridgeline. Many high quality pools occur adjacent to the bedrock ridgelines. The majority of well-developed pool-riffle sequences occur in these locations. Any construction or change in land use on the steep ridges adjacent to one side of the channel is extremely unlikely. However, at many of these locations the opposite side of the channel lies in a broad floodplain and can be accessed and potentially developed. Any future growth in the watershed especially near the stream channel should be monitored closely.

Reaches of stream channel with high quality pools, appropriate, channel dimensions, good pool-riffle ratios, and moderate to good canopy cover are mapped for protection. Care should be taken to insure that the riparian area and channel are not disturbed in these areas.

Riparian zones throughout the watershed should be targeted for protection. Where good riparian buffers exist, their preservation and maintenance should be a priority. The shading from riparian zones directly impacts water temperature and stream channel stability can be significantly enhanced where thick riparian zones are present. Dense riparian forests can also help remove fine sediments from the stream during overbank flows.

Sediment inputs to the stream channel can impact the stream quality and geomorphology of the system. A number of sediment inputs were identified through the coarse of this study. A large number of sediment inputs originate with roadways. Both roadway drainage and poorly maintained dirt roads contribute sediment to Kettle Creek. Drainage pipes which outlet on steep slopes adjacent to roadways cause large scour holes to develop and destabilize the hillslope causing further erosion. Hanging cross-pipes can be improved in a number of ways. Two popular methods are drop structures, which extend the drainage pipe to the base of the hill and outlet onto more stable material and stabilization of the outlet point using large rock or pavement.

Water quality should be a priority for protection throughout the middle and upper watershed. Protection of this valuable resource can be achieved by pursuing wise land use. Changes to the existing land use in the watershed can negatively impact water quality. Zoning requirements for any future development in the watershed through the local municipalities can prevent water quality degradation. The State of Pennsylvania has published an excellent guide to land use planning in their Growing Smarter Land Use Guidelines.

An often-overlooked component of water quality is precipitation. Acid precipitation common in Pennsylvania can severely impact water quality of streams. Acid from rainfall can reduce the acid neutralization capacity of soils over the entire watershed resulting in pulses of acid associated with rainfall or snowmelt events. Forest health can suffer as well when vital nutrients are leached from the soil column. If acid neutralizing capacity is lost from watershed soils, toxic metals can be flushed into the stream system impacting fish populations. Future water quality monitoring in the watershed should include pH and alkalinity measurements during rainfall and snowmelt high flow events.

Habitat Enhancement

Through the planning process, three primary enhancement goals have been identified.

1. Water Temperature Reduction
2. Development of Natural Stream Channel Dimensions and Sediment Transport
3. Riparian Canopy Enhancement

These goals should be reached in an organized, science-based fashion. A series of projects to achieve these goals has been identified along with the associated timeline for implementation. In some cases, projects rely on the completion of other preceding projects. In other cases, the projects can be completed and will yield benefits independent of the other projects. While large-scale implementation of some aspects is desirable, large tasks have been phased to provide a manageable solution that can be implemented over time. Projects have been identified throughout the watershed for broad reaching results and to attract a variety of participants.

Long-Term Framework and Prioritization

The systematic approach to improvement in the Kettle Creek Watershed should address the three issues identified above concurrently. Work to reduce sediment in the stream system should begin in the tributaries. Reaches of stream in the tributaries that are unnaturally wide should be a top priority. These reaches of stream channel contribute sediment to downstream reaches and help to increase water temperatures far downstream. By improving conditions in the tributaries, the entire stream system below the tributary benefits from the improvement. Sediment inputs are reduced downstream and the natural channel evolution of downstream reaches is accelerated. Lower water temperatures are transported downstream by improved canopy in the tributaries.

There are some indications that reaches of the mainstem of Kettle Creek, especially downstream from Cross Fork are beginning to reach Class VI of channel evolution (Figure 4). Gravel bars are depositing on the margins of the channel and in some reaches, a low flow channel is beginning to develop. Reduced upstream sediment inputs coupled with aggressive revegetation of young bars on the channel margins will improve the stream's ability to recover without invasive channel construction procedures in the lower reaches.

Large reaches of the tributaries should be designed, permitted, and constructed at the same time. This provides an economy of scale for both the design phase and construction phase. Long design reaches allow for a cohesive design that considers valley slope and the relationship of multiple channel sections. This will provide a much better result than numerous small projects. Within design reaches it is likely that some sections of channel can be relatively unchanged. This is especially likely for reaches of stream that parallel ridgelines or bedrock outcrops and are currently functioning effectively.

Cross Fork should be the top priority among the tributaries. With a large drainage area and overwide channels from the mouth to the headwaters, significant improvements can be realized in Cross Fork in the near future. Reduced water temperatures and sediment loads from Cross Fork will enable significant fisheries improvements on the mainstem of Kettle Creek below Cross Fork. Hammersley Fork and upper Kettle Creek can also benefit from channel enhancements and riparian improvements.

Revegetation of bars in the immediate future will provide vegetation that is large enough to stabilize bars and encourage meander development in the lower watershed at the same timeframe that upstream sediment supplies are reduced by projects in the tributaries.

Riparian buffer improvement should initially focus on tributaries and reaches of the mainstem where cool waters are found. Tributary riparian buffers should be reestablished from the upstream extent of poor canopy cover to the mouths as quickly as possible. Cross Fork, Hammersley Fork, Little Kettle Creek, and upper Kettle Creek are the most important tributaries for canopy cover improvement. On the mainstem, the area of Ole Bull State Park and the confluence of Little Kettle and Kettle Creeks are high priorities for canopy improvement. Cooler water entering the mainstem at Ole Bull should be protected as far downstream as possible. Below the park, canopy cover improves to the delayed harvest fly-fishing area. By improving canopy cover at

Ole Bull three to four miles of stream could benefit from lower water temperatures.

Once riparian buffers are reestablished along the tributaries, in the vicinity of Ole Bull, and at the confluence of Little Kettle and upper Kettle poorly vegetated reaches of the mainstem from two miles upstream from Cross Fork to the downstream extent of this survey become a priority. Reaches from one mile downstream from Trout Run to the pool of Alvin C. Bush Dam may benefit from riparian buffer improvement as well.

If after channel improvements in the headwaters reduce sediment inputs to middle Kettle Creek, the channel does not continue to recover, some minor channel adjustments may be necessary in the lower reaches.

By following this order and systematically approaching improvements in the watershed, results will be more far reaching than scattered projects throughout the watershed could produce. This system-based approach allows downstream reaches of stream to recover as a result of changes upstream. While realizing the final results of this work will take decades, immediate improvements should be noticed as each phase is completed. Water temperature and sediment will decrease and as projects are completed, each project should result in greater decreases in overall water temperature and sediment supply. The benefits of each project should grow exponentially as work progresses, riparian trees grow, and the channel recovers.

Immediate Project Recommendations

Project 1: Establishment of Headwaters Sediment Management and Proper Functioning Channel Geometry.

Priority: Very High – Should be completed before channel geometry issues are addressed on most parts of the mainstem.

Justification: Based on the findings of this study, sediment inflow, deposition of large gravel bars, reduced habitat from wide, flat stream reaches, and the associated channel instability originates in the tributaries to the mainstem of Kettle Creek. Identification of the upstream extent of the sediment influx into the system and mitigation of that problem will enhance downstream channel form and help to reduce water temperatures. Preliminary investigation indicates that over-wide, shallow channels clogged with sediment are present high into the headwaters. This is supported by the history of wide-scale logging and the associated stream channel disturbance at the turn of the century throughout the watershed.

Work in the headwaters is also likely to provide substantial benefit to naturally reproducing trout.

Methods: Mapping similar to the mapping of the mainstem and lower tributaries that was completed for this study should be extended through Trout Run, Hammersley Fork, Cross Fork, Little Kettle Creek, and upper Kettle Creek. This mapping can be of lower detail than the mapping conducted for this study and should be designed for the purpose of identifying the upstream extent of work on these major tributaries.

Upon completion of the mapping, reaches of stream at the upstream extent of disturbance will be identified for enhancement.

Natural channel function should then be re-established using natural channel design and construction techniques. The number and extent of structures should be minimized through careful design and the desire to maintain a stream channel that migrates through its floodplain at a natural rate. Reduced structures and minimized channel grading will reduce the cost of construction. “Soft engineering” approaches to natural channel design have been very successful in other, similar watersheds. This technique emphasizes the use of proper channel dimensions, vegetation, engineered log jams, and small “deformable” structures to re-establish function. Less intrusive construction techniques and smaller construction equipment can be used for this type of work. Establishing natural channel function in upstream reaches provides benefit for reaches downstream by reducing sediment inputs and lowering water temperatures. A significant result of this work will be a narrower low-flow channel with enhanced habitat.

The narrower low-flow channel along with vegetation regrowth in the floodplain provides better shade for the channel.

Phase 1: Completed Geomorphic Mapping of Tributaries - Identify And Complete Work on five Miles of Tributary Channel
Cross Fork is a desirable location for the first phase of this project. Good access by road and extensive public land holdings provide good opportunities for success.

Phase 2: Complete Additional Work on Tributaries Identified in Mapping Completed in Phase 1.

Estimated Costs:

Mapping, Design, and Permitting: $160,000
Completed permit should be a watershed wide permit to reduce future permitting costs and associated delays.

Construction: $450,000

Project 2: Riparian Buffer Enhancement and Lateral Bar Re-Vegetation

Priority: High

Justification: Over 40 miles of stream channel in the middle and upper Kettle Creek Watershed are identified as having thin riparian zones or poor canopy cover. Water temperature will continue to increase without improved riparian canopy cover. Due to the period of time required for newly planted buffers to reach maturity, this should be implemented as soon as possible. Strategically designed plantings on lateral bars forming on the mainstem of Kettle Creek provide the opportunity to enhance channel shading while increasing roughness on the bars and encouraging the stream to deposit more material on the lateral margins of the channel. While upstream work strives to reduce the sediment inputs to the mainstem, this effort will allow downstream reaches to continue to naturally develop a narrower, more functional channel within the floodplain boundaries, which will more effectively transport the sediment load. This is a long-term solution, which works jointly with other enhancement efforts in the watershed.

Methods: Plant native vegetation such as Willows, Sycamore, White Pine, and Alder to improve the riparian canopy and root mass. Shrubby water loving species like willow and alder will enhance stream function and provide some shade when planted on the margins of the active channel. Larger shade species, especially the native, fast-growing Sycamore will provide a great deal of canopy cover over time. These species will also regenerate vigorously providing a self-sustaining system.

Phase 1: Target Selected Stream Reaches for Immediate Riparian Buffer Planting

Recommended implementation Rate – 18 acres per year (approximately five miles of 30 foot wide planting)

Estimated Costs:

Design: Minimal

Plant Materials, Tools, Supplies, etc: $10,000 with volunteer labor

Phase 2: Design and Complete Plantings on Lateral Bars in Conjunction with Continued Riparian Buffer Enhancement From Trout Run to Cross Fork.

Design: $8,000 – includes identifying and marking bars to be planted, specifying plant materials, and designing planting scheme for bars to account for future bar development.

Plant Materials, Tools, Supplies, etc: $12,000 with volunteer labor

Project 3: Ole Bull Channel and Canopy Enhancement

Priority: High

Justification: This area of Kettle Creek provides public access to large numbers of visitors every year. The dam at Ole Bull provides local geomorphic control so improvement projects can be completed here independent of other upstream reaches of the stream. This reach of stream is relatively isolated from outside geomorphic activity in the stream channel. Kettle Creek through Ole Bull has poor canopy cover and stream form. The channel is over-wide and pool-riffle sequences are not well developed. Additionally, local groundwater fed inflows provide cooling to this reach of stream. Protection of this cooler water should be a priority and can benefit downstream reaches including the delayed harvest fly fishing area. Fishing opportunities in the youth-only fishing area in the park and the natural beauty of the park would be enhanced by channel and riparian zone enhancements here. Cooler water refuges for fish stressed by adjacent warm water would be provided in the re-established pools.

Methods: Both natural channel design and re-establishment of a functioning riparian zone here will benefit the stream system. Design and construction of more natural channel dimensions and pool-sequence here can be completed within the park infrastructure. The reach from the dam to the downstream park limit should be treated as a whole. Some structure control may be necessary through this reach.

Estimated Costs:

Design and Permitting: $45,000
Construction and Planting: $100,000

Project 4: Public Outreach and Education

Priority: High

Justification: Public involvement on Kettle Creek is very high. Many benefits can be realized by educating landowners and visitors about stream function and how their actions can impact the stream channel and its habitat.

Methods: Implement a public education program to enhance landowner awareness of streamside maintenance and alternative maintenance programs that can provide both good stream access and enjoyment while benefiting the stream channel. An example of good streamside stewardship is ceasing to mow the entire stream edge to provide access and mowing only a single path to the waters edge. Planting specific tree species that will establish branches high enough not to obstruct stream views from a nearby camp or residence can enhance this management plan.

Rock dams are commonplace along Kettle Creek and its tributaries. A public education program to promote construction of structures that enhance stream function while providing recreational opportunities will allow streamside landowners and visitors to continue to build the structures without potentially damaging side effects.

Cost: Minimal

Project 5: Bridge Maintenance and Reconstruction

Priority: Moderate

Justification: Continual maintenance of existing bridges and replacement of existing structures can result in significant impacts to the stream channel. Existing maintenance protocols encourage widened channels and removal of riparian cover near bridges. Proper stream channel management through bridge openings can reduce maintenance costs and promote stream stability.

Methods: Establish a relationship with PENNDOT and DCNR parties responsible for bridge maintenance, design, and construction in the watershed. Significant opportunities exist for demonstration projects to illustrate the usefulness of channel management at these structures. The Road Hollow Bridge and Cross Fork Bridge on the mainstem both represent opportunities to implement a demonstration project and further relationships to improve stream management at bridges

Cost: Dependent on agency participation.

Project 6: Additional Water Quality Monitoring

Priority: Moderate

Justification: Acid precipitation falls in the Kettle Creek Watershed during every storm. Understanding the impact of acid rain on the watershed and water quality is important to the future of the watershed. Indicators of problems now can be met with action before water chemistry degrades significantly.

Methods: Implement a rain and storm flow monitoring program to measure at a minimum pH, alkalinity, and turbidity. Additional water quality parameters should be added if high flows become acidic. This monitoring program can be implemented using volunteers if available or can be completed using automated samplers to collect water at intervals through a storm event. Data should be analyzed based on pH of precipitation; stream pH and alkalinity, and volume of discharge in the stream. If low pH's are detected during storm flow events, acid-neutralizing capacity of the watershed soils should be investigated.

Cost: Dependent on methods

Project 7: Dirt and Gravel Road/ Drainage Improvement

Priority: High

Justification: Significant portions of the roads in the Kettle Creek Watershed are dirt and gravel roads. These roads and the drainage systems from all the roads in the basin contribute large volumes of sediment to Kettle Creek.

Methods: Detailed information about the location and severity of erosion associated with roadways in the watershed should be collected. This information can be leveraged to obtain funding from the state's Dirt and Gravel Roads program under which individual municipalities and agencies can make necessary improvements to reduce sediment inputs from the roadways.

Cost: Dependent on agency participation.

Figure 31: Fine sediment enters the stream channel from unstable drainages throughout the watershed

Glossary of Terms

Alkalinity	A measure of the ability of water and the associated dissolved ions to neutralize acid. Measured as calcium carbonate. Also known as buffering capacity.
Aggradation	Deposition in the channel which increases the channel bottom elevation.
Armored	A condition in which high velocities within the channel continually suspend and move small particles downstream leaving larger particle sizes in place. Over time, only the larger particles remain in the stream channel making it very difficult to mobilized the bed material.
Bankfull Depth	The depth from the elevation of water surface at the bankfull discharge to the deepest point in the channel.
Bankfull Discharge	The discharge (or flow) that occurs, on average, every 1.2 to 2.0 years. This discharge, from relatively frequent storms, is largely responsible for the shape of the stream channel within the floodplain.
Bankfull Width	The width of the water surface at the bankfull discharge.
Basin	See watershed.
Class A	A classification by the PA Fish and Boat Commission for wild trout streams. Class A wild trout populations represent the best of Pennsylvania's naturally reproducing trout fisheries. The Commission manages these stream sections solely for the perpetuation of the wild trout fishery with no stocking.
Cold Water Fishery	Maintenance and/or propagation of fish species including the family Salmonidae and additional flora and fauna, which are indigenous to a cold water habitat.
Degradation	Erosion of the channel bottom resulting in a lower channel bottom elevation
Discharge	The volume of water per unit time that flows through a point on a stream channel. Typically measured in cubic-feet-per-second or cubic-meters-per-second.
Dominant Discharge	See Bankfull Discharge
Encroachment	Any fill material or structure that impedes flow on the floodplain or in the stream channel.
Entrenchment	The ratio of the floodplain width at twice the bankfull elevation to the bankfull width. This ratio measures the relationship between the stream channel and the floodplain. A high entrenchment ratio indicates good floodplain access while an entrenchment ratio close to one indicates poor floodplain access.

Gradient or Slope The amount of elevation change over a horizontal distance usually expressed in feet per feet or%.

Headwaters The upper sections of the stream, which are typically smaller and higher in elevation.

High Quality A stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection.

Impaired The water quality of the stream is not supporting its intended uses as listed in the PA Chapter 93 Water Quality Standards.

Incised, Incision A term used to describe the condition in which the stream channel elevation has been lowered through time. Incision is indicated by high, steep banks and poor floodplain access.

Macroinvertebrate Species without a backbone (invertebrate) that are visible to the naked eye (macro). Typically includes insects, snails, worms, etc.

Reach A segment of stream with consistent physical characteristics.

Riparian The area adjacent to the channel that is influenced by periodic flooding.

Sinuosity The ratio of the linear valley floor length to the stream length measured along the thalweg.

Substrate The material that composes the streambed or stream bank.

Thalweg The deepest point in the stream channel that conveys flow.

Tributary A smaller stream that drains into the main stream. It may have a name or be unnamed.

Trout Stocking Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna, which are indigenous to a warm water habitat.

Watershed The surface area that contributes runoff to a given point on the land surface or on a stream system.

Wetted Width The width of the actively flowing portion of the channel.

Width/Depth Ratio The ratio of the bankfull width to bankfull depth. This ratio provides an indication of both channel shape and stability.

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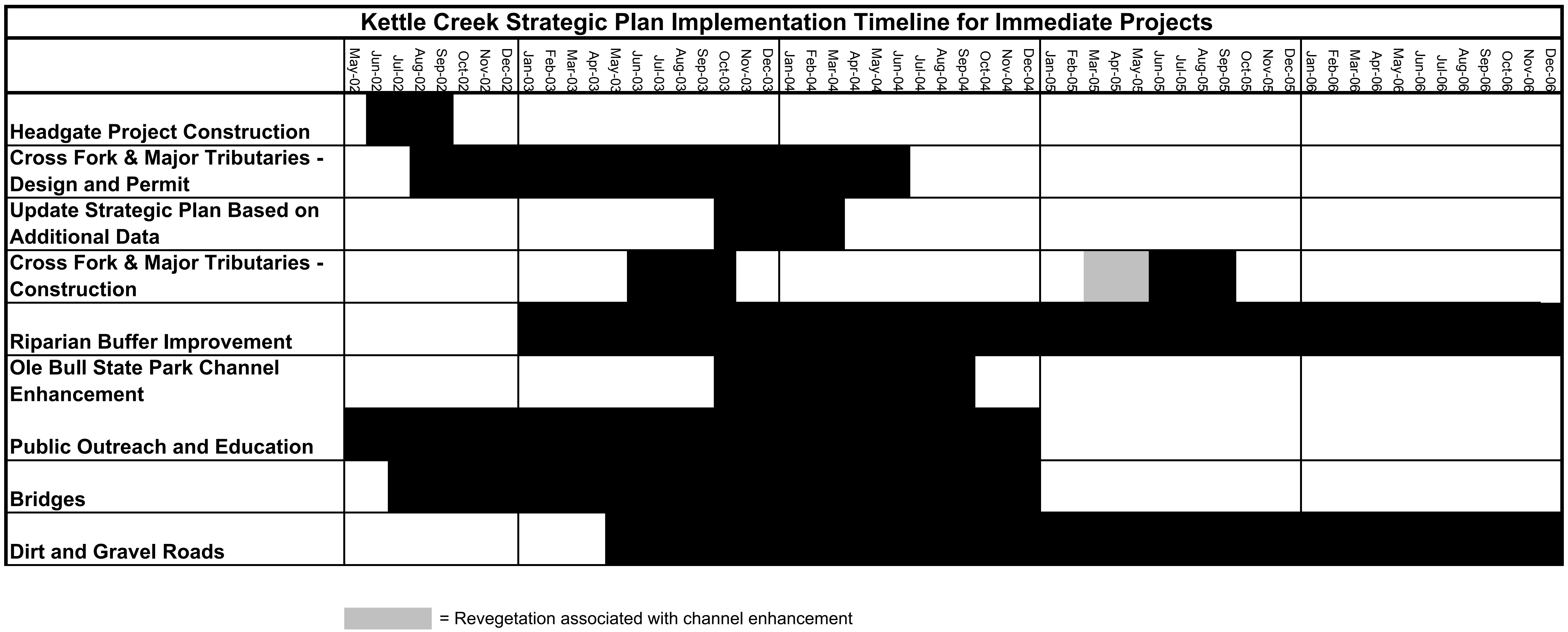
Kettle Creek Strategic Plan Implementation Timeline for Immediate Projects
May-02 Jun-02 Jul-02 Aug-02 Sep-02 Oct-02 Nov-02 Dec-02
Jan-03 Feb-03 Mar-03 Apr-03 May-03 Jun-03 Jul-03 Aug-03 Sep-03 Oct-03 Nov-03 Dec-03
Jan-04 Feb-04 Mar-04 Apr-04 May-04 Jun-04 Jul-04 Aug-04 Sep-04 Oct-04 Nov-04 Dec-04
Jan-05 Feb-05 Mar-05 Apr-05 May-05 Jun-05 Jul-05 Aug-05 Sep-05 Oct-05 Nov-05 Dec-05
Jan-06 Feb-06 Mar-06 Apr-06 May-06 Jun-06 Jul-06 Aug-06 Sep-06 Oct-06 Nov-06 Dec-06
Headgate Project Construction
Cross Fork & Major Tributaries - Design and Permit
Update Strategic Plan Based on Additional Data
Cross Fork & Major Tributaries - Construction
Riparian Buffer Improvement
Ole Bull State Park Channel Enhancement
Public Outreach and Education
Bridges
Dirt and Gravel Roads
= Revegetation associated with channel enhancement