Stream Morphology and Water Quality Based Restoration Plan for the Paradise Creek Watershed

Phase I Technical Report for the Paradise Creek Watershed Assessment

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Introduction

This report describes stream morphology and recommends restoration projects in each sub-watershed of the Paradise Creek watershed, Monroe County, Pennsylvania. Projects are shown in Figure 1. Stream classifications (Rosgen 1994, 1996) and restoration sites were identified using topographic maps, Monroe County GIS digital orthophotos issued January 2004, and field reconnaissance. All potential restoration sites were field verified in 2003 and 2004.

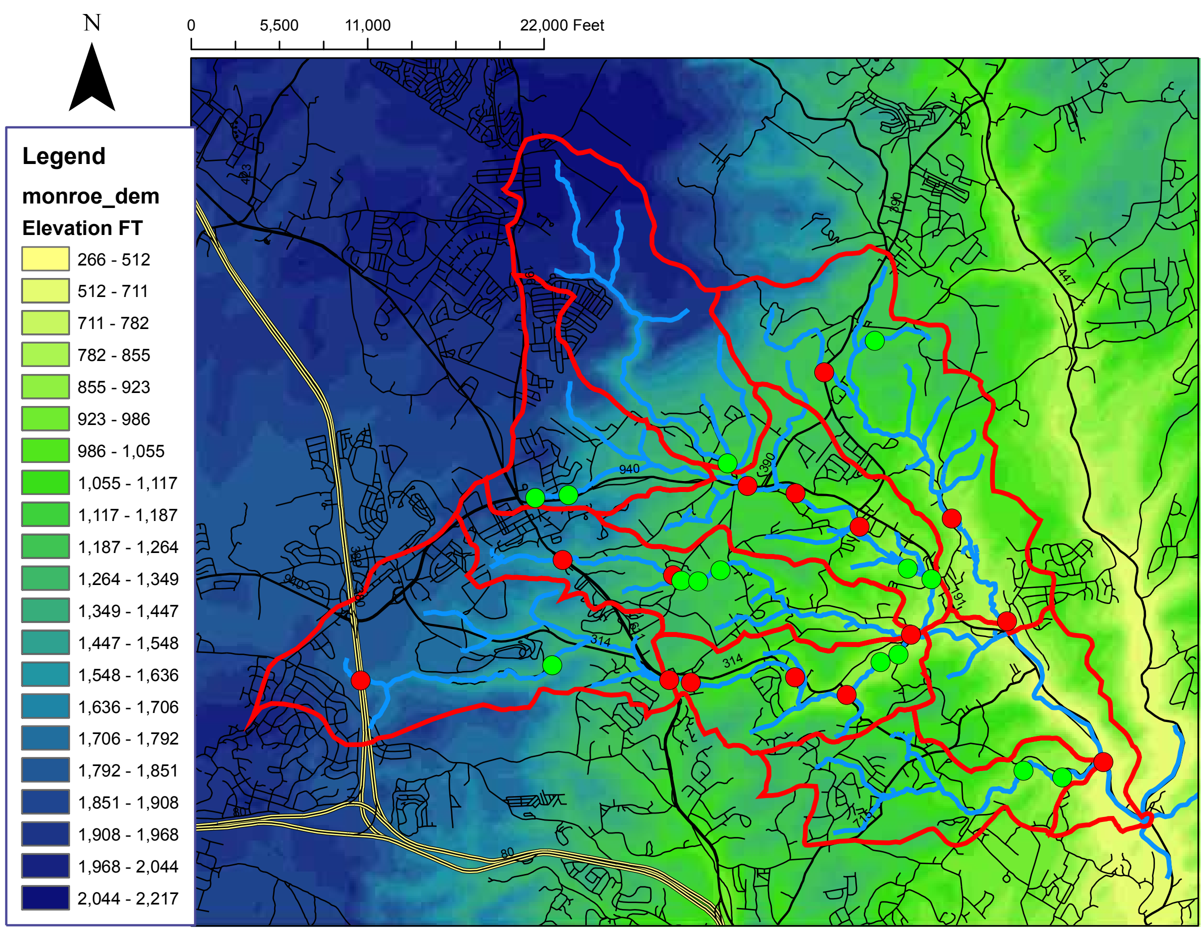

Figure 1. Potential restoration sites in the Paradise Creek watershed. Sites were identified by means of topographic map examination; stream proximity to roads, bridges and culverts; aerial photo examination; and stream reconnaissance. Red dots are projects related to transportation network. Green dots are all others.

Paradise Creek headwaters begin upon the Pocono Plateau in Mount Pocono Borough, and Barrett, Coolbaugh and Tobyhanna Townships in Monroe County, Pennsylvania. Headwater streams flow steeply off of the plateau into the Valley and Ridge physiographic province before joining with the main stem of Paradise Creek. The Brodhead Watershed Association (2002) provided the following introductory description of the Paradise Creek watershed. Draining approximately 44.5 square miles, Paradise Creek is about nine miles long, flowing in a southeasterly direction through Paradise Township before joining Brodhead Creek. Most streams in the watershed are closely paralleled by highways, but the riparian zone is mostly intact as much riparian land is owned by fishing clubs. Major tributaries include Devils Hole Creek, Cranberry Creek, Butz Run, Swiftwater Creek and Forest Hills Run. Paradise Creek boasts a healthy population of native and stocked trout. Streams in the watershed are mostly high-gradient, with the exception of headwater streams atop the Pocono Plateau and those streams within the main Paradise Creek valley bottom. Base flow is plentifully supplied by springs, wetlands, and glacial overburden soils and geology. Devils Hole Creek, a tributary of the Paradise, is designated as Exceptional Value by the Pennsylvania Department of Environmental Protection. The Paradise, along with the Brodhead, is credited as the birthplace of American trout fishing tradition. Paradise Valley is home to the first licensed trout hatchery in Pennsylvania.

Level I Stream Morphology of the Paradise Creek Watershed

Figure 1 displays relative elevations within the Paradise Creek watershed. Paradise Creek sub-watersheds begin atop plateaus in relatively flat and wooded wetland areas, where valleys are wide and streams are very low gradient with multiple small channels. Once channels become well-defined, they exhibit morphology of typical low gradient C or E channels (Figure 2). Development in the watershed has taken place in these headwater areas or in valley bottoms further downstream. In areas of transition between the Pocono Plateau and the Valley and Ridge physiographic provinces, streams spill over an escarpment and enter steep sided and confined V-shaped valleys. Streams in the V-shaped valleys are classified as high-gradient A or B channels (Fig. 2). Within these high-gradient stream sections are numerous short, shelf-like low-gradient stream segments. These are wetland areas perched within the generally steep valleys. Wherever a stream enters these perched wetlands, the stream forms multiple channels, classified as natural D channels (Fig. 2). Further downstream, the stream gradient lessens and the valleys widen into alluvial valleys, where streams are no longer confined within valley walls and depositional soils predominate along stream channels. The meander belt

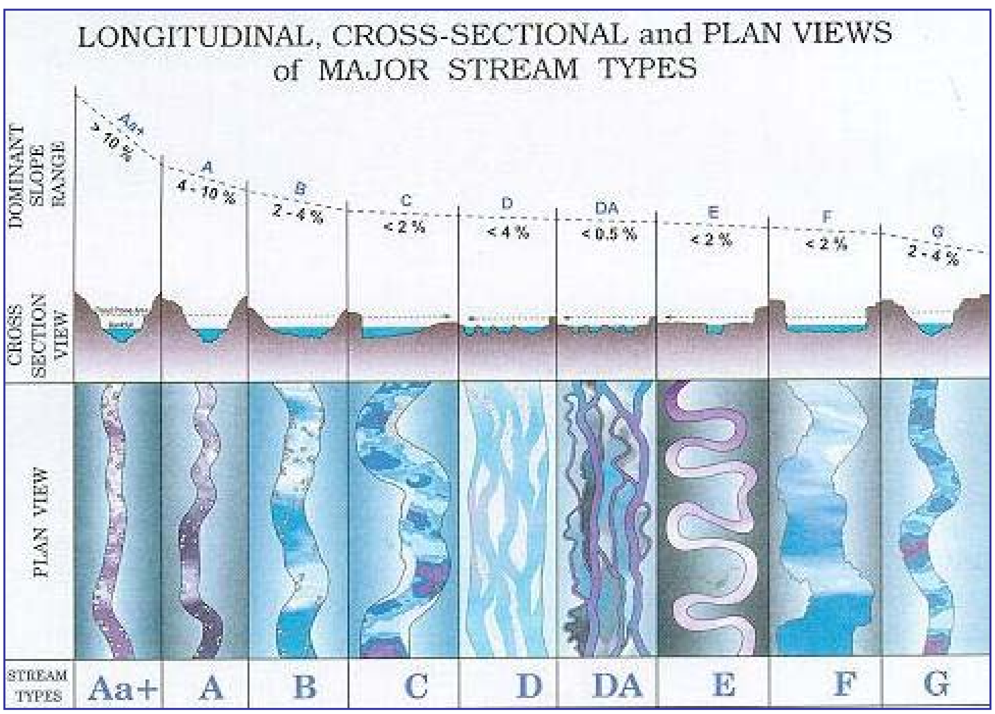

Figure 2. Stream types (from Rosgen 1994, 1996).

width of most streams increases dramatically once the streams are no longer confined by steep-sided valleys. Extensive and probably natural bank erosion was observed in stream segments transitioning from high to low gradient. Dramatic examples of such erosion can be seen on Swiftwater Creek and Devils Hole Creek.

Consult the appendices for a more detailed description of Level I morphology. Appendix A contains longitudinal elevation profiles of Paradise Creek and its tributary streams. Appendix B shows a MS Excel workbook prepared for this study that contains a stream mileage system, various landmarks along stream corridors, and all mapped stream segments with their local slope and predicted stream type. Most segments were field verified by visual observation of stream pattern (Rosgen Level I analysis). Many remote locations were missed by field reconnaissance and stream classification was predicted using only maps and aerial photos. DRBC is completing a GIS layer of Paradise Watershed stream types linked to the National Hydrographic Dataset (NHD). Computer files are available from DRBC upon request.

Stream Channel Stability Assessment and Restoration Opportunities

This survey of Paradise Creek watershed fluvial geomorphology was conducted to identify locations in the watershed where streams are severely unstable. For this report, instability is defined as localized loss of dynamic equilibrium of the stream channel. According to Pennsylvania's Keystone Stream Team (2002) a stream is "in equilibrium" or stable when it can carry the sediment load supplied by the watershed without changing dimension (cross sectional area, width, depth, shape), pattern (sinuosity, meander pattern), or profile (longitudinal pattern and slope) and without aggrading (building up of bottom materials) or degrading (incising into the landscape and abandoning the natural floodplain). At the locations identified in this report, field evidence of instability was verified by observation of channel evolution status (See Figure 3; Schumm, Harvey and Watson 1984; Simon 1989, Simon and Downs 1995).

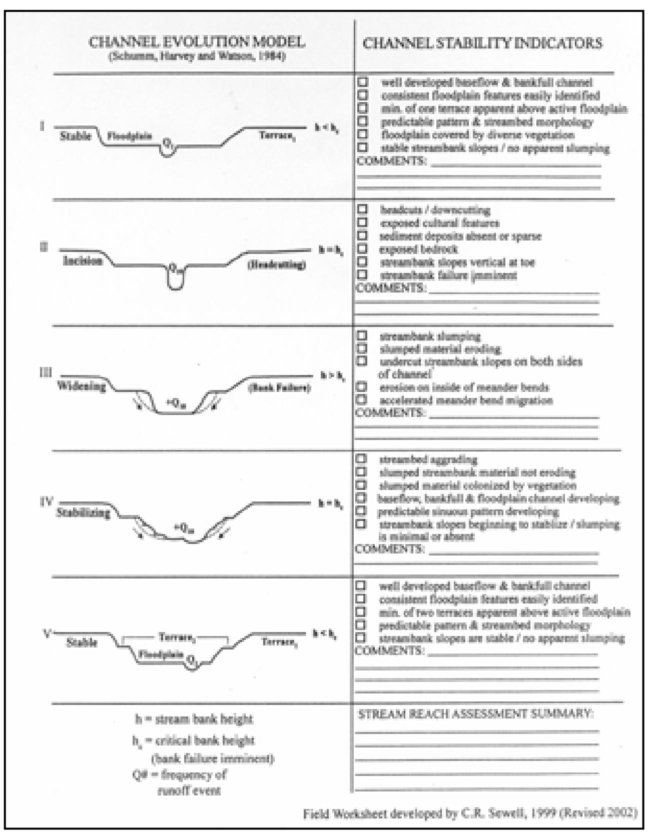

Figure 3. Channel Evolution Model (Schumm, Harvey and Watson 1984; field observation checklist adapted by Randy Sewell, VHB, Inc., Williamsburg, VA)

Verification was performed according to methods described by Thorne et al. (1997, 1998) and Rosgen (2001) and included observation of severity and extent of stream incision or degradation; extreme stream bank or point bar erosion; excess sedimentation or aggradation through interruption of natural sediment transport capacity; over-widening of the channel relative to depth; channel braiding; formation of mid-channel sediment bars; erosion of the stream bed or head-cutting; and leaning or fallen old, large trees. Localized effects of bridge crossings, culverts, dams, stream bank stabilization projects, habitat improvement structures, and some land uses include symptoms mentioned above as well as blockage of fish passage. Many segments of streams were identified where the riparian zone has been reduced due to land use activities.

Diagnosis of instability was begun by visiting the confluence locations of all streams in the watershed. At these locations, field observation of the relative elevations of the stream beds helped to inform a diagnosis of systemic aggradation or degradation, such as happens in the case of increased watershed imperviousness and modification of the local hydrograph by stormwater runoff. Unless masked by incision due to channelization, cumulative impacts were typically observed at these confluence points at the base of each sub-watershed. Where both tributary channels are in dynamic equilibrium, the bed elevations typically match at the confluence point. If they are not in equilibrium, then one channel was higher or lower than the other. Obvious differences in bed elevations were identified at two locations: at the confluence of Swiftwater Creek and Forest Hills Run; and at the confluence of Butz Run with Paradise Creek. The first may be due partially to systemic stormwater impacts, though locally severe road and channelization impacts are also apparent; the second was due to channelization of Paradise Creek during construction of Route 191 that parallels the stream. Once confluence points were observed, all possible upstream sources of instability – both natural and man-made - were identified during numerous field trips.

Before prioritization, there were about 260 potential restoration projects identified by map and aerial photo examination. Most were discarded as candidates upon field verification, not due to absence of problems, but because many of the problem areas were very localized and contained. Most unstable areas were in later stages of channel evolution, where natural 'healing' of the stream channel is imminent. Many other sites were unstable because of structures such as bridges, culverts, and small dams. Restoration projects near these might serve to somewhat enhance aesthetics and habitat, but such projects might waste resources unless they address the underlying causes of local instability – the bridges, culverts and dams. In the end, patching stream banks didn't count as true restoration opportunities. Thus the projects listed in this document are the top priorities because total restoration can be completed or because instability is so severe that infrastructure is threatened.

> **Restoration** *is defined as the process of converting an unstable, altered, or degraded stream corridor, including adjacent riparian zone and flood-prone areas to its natural or referenced, stable conditions considering recent and future watershed conditions. This process also includes restoring the geomorphic dimension, pattern, and profile as well as biological and chemical integrity, including transport of water and sediment produced by the stream's watershed in order to achieve dynamic equilibrium (Keystone Stream Team 2002).*

Two categories of restoration opportunities are shown in the following watershed assessments: those projects relating to the transportation network – road crossings, bridges, culverts, and close proximity of roads to streams; and all other types of stream restoration or protection projects. Natural impacts were frequently observed in transition areas between changing soil types, abrupt changes in stream gradient, bedrock outcrops and other geological features, woody debris log jams, and confluence points of streams. Projects resulting from natural instability were ignored unless homes or businesses located near these features require additional protection or stream stabilization. Among the other types of restoration projects, objectives are meant to mitigate man-made impacts such as: stream channelization (a well-known hydrologist appropriately refers to this as 'recreational bulldozing'); instream mining; ponds and reservoirs; landscape modification and addition of impervious surfaces; ditching of wetlands; clearing away riparian buffer zones; building in floodplains; disrupting continuity or heterogeneity of habitat; and other interruptions to the natural hydrologic processes of the watershed. Since those who conduct these practices may unknowingly cause problems downstream, a most beneficial project is education of landowners. Table 1 enumerates projects in each sub-watershed of the Paradise Creek watershed.

Table 1. Number of potential stream restoration sites in the Paradise Creek watershed.

	Source of Instability	
Sub-Watershed	Transportation Network	Other Causes
Lower Paradise Creek	1	0
Butz Run	0	1
Cranberry Creek	3	1
Lower Swiftwater Creek	5	2
Upper Swiftwater Creek	1	1
Forest Hills Run	2	3
Upper Paradise Creek	3	2
Devils Hole Creek	1	0
Tank Creek & Yankee Run	0	2
TOTALS	16	12

There are many small projects that have not been listed. Educating and providing resources to landowners about the importance of riparian buffers, native plants, and reduction of impervious surfaces can solve many of the observed but small problems relating to land use in the vicinity of streams. Perhaps the Monroe County Conservation District could provide technical assistance in the form of property audits for this purpose. Of course, strong municipal ordinances and regulations can also help to solve these problems.

Another frequent and cumulatively important problem relates to the many ponds and small dams throughout the watershed. During analysis of water quality data for the Paradise Creek watershed, it was observed that temperature violations are fairly frequent in local waterways. Hundreds of small and shallow impoundments were identified, and these may be a significant contributing factor to elevated temperatures in this important trout fishery. Dams also interrupt fish passage. Future monitoring of water temperature should be conducted upstream, within, and downstream of numerous ponds throughout the watershed, so that the extent of this perceived problem can be quantified. Perhaps the Brodhead Watershed Association can obtain grant funds to provide water temperature loggers to landowners for this purpose.

Dams also have strong impacts upon hydrologic processes and habitat. Impoundments disrupt sediment transport processes and cause abrupt changes in transference of erosive forces from potential energy (the pond) to kinetic energy (the spillway). Erosion was observed just downstream of most spillways. Many landowners have attempted to build in-stream ponds in high-gradient streams, with drastic results. Numerous ponds were observed to have completely filled with coarse sediment, which is the normal bedload sediment transported by natural stream processes. The landowner's maintenance headache includes expenditure of significant funds for dredging and stabilizing the channel. The bigger the dam, the bigger the maintenance problem – see the Lake Crawford dredging project as a case in point. As an example, one property owner on the high-gradient Devils Hole Creek attempted to create a small impoundment which ultimately created a property threat. The pond filled with cobble-sized sediment, and the stream channel was diverted by the sediment bar towards the stream's right bank, the owner's driveway and main building. Stream processes are misunderstood or never even considered by nearly all landowners, so education may save the landowners significant expense. As an alternative to an in-stream structure, landowners could create a small diversion structure that sends floodwaters toward an off-stream pond. This could save the continual dredging costs and providing some storage and recharge benefit to the stream. In general, streams should not be dammed on their main channel, and this especially applies to high gradient streams. Off-stream storage works better for both landowners and aquatic life.

Restoration Options

Several factors were considered during prioritization of projects. First, the solutions should be appropriate to the natural stream characteristics. There are many options. What works best, looks best, and costs least? For example, rip-rap may be unsightly overkill for stabilization of low gradient streams, and bioengineering techniques may be unsuitable in high-velocity streams. Some vendors now offer software providing menus of restoration options according to stream and landscape characteristics. Rosgen (1996) provides a very useful table of stream management characteristics according to observed stream types. The Society for Ecological Restoration also provides excellent guidance for conception, organization, implementation, and assessment of restoration projects (Clewell et al. 2000).

Second, unstable streams can naturally regain equilibrium over time if left alone, so it is possible, and in many cases preferable, to let nature take its course. Examination of the channel evolution status of a stream reach perceived as unstable may reveal that 'healing' is imminent. The 'do nothing' option should be the first consideration. It is critical to ensure that upstream causes and processes are addressed if restoration efforts are to succeed. Unfortunately many funding agencies want immediate action and will not pay for the data collection necessary to verify upstream causes and quantify their effects. It is tempting to address the symptoms of disequilibrium by patching one eroded stream bank, but restoration measures may repeatedly fail if upstream conditions persist or worsen. Properties at high risk obviously get high priority for patching and stabilizing stream banks, but this should be viewed as a temporary measure to be followed by more comprehensive restoration. Using a comprehensive watershed view, it may be possible to save money by grouping a number of contiguous sites into one restoration project.

Within a stream reach targeted for restoration, project planning takes place in consideration of the whole range of hydrologic conditions: channel-forming flows, low flows, and flood conditions. This assessment of equilibrium or natural stability of the stream channel took place by looking at characteristics of the stream formed by the most effective channel-forming flood. This is typically the bankfull flood that occurs at a frequency of about 2 of every 3 years. The bankfull flood is the key to popular natural stream channel design techniques using instream structures constructed to ensure that the stream maintains dynamic equilibrium.

When assessing restoration options, however, the hydrologic extremes were also considered. How does the stream channel ecologically function under extreme low-flow conditions? Is there a well-defined low-flow channel? This is important for survival and movement of aquatic species such as the wild populations of trout that inhabit streams of the Paradise Creek watershed. On the other hand, restoration measures tied to bankfull are not meant to protect property damage resulting from larger floods. Hurricane Ivan hit the Paradise Creek watershed in 2003, and extensive damage was observed that cannot be considered simple instability.

For the projects identified in the following watershed assessments, restoration or protection measures should provide three main benefits:

1. Sustain fish passage, refuge and water quality during droughts by restoring habitat at low flow;
2. Maintain equilibrium of the stream channel by creating a natural bankfull flood channel; and
3. Protect homes and businesses from large floods by other means designed well above the bankfull elevation.

Recommendations

1. Gather reference reach data from Butz Run, an E channel, to serve as a design template for future natural stream restoration of low-gradient streams throughout the Poconos. During Spring of 2005, the reference reach will be measured by cooperative efforts of DRBC, MCCD, MCPC, and others using methods described by Harrelson et. al (1994). Reference reach data will be analyzed using RiverMorph Stream Restoration Software (RiverMorph, LLC, Louisville, KY), and distributed to relevant agencies and interested parties.

2. Work with the PA Department of Transportation, Monroe County, and municipal road maintenance agencies to install river-friendly bridges and culverts during future infrastructure maintenance and repair. This has been done in some maintenance districts by members of the Keystone Stream Team.

3. Educate landowners about protection of the riparian corridor, stormwater impacts, and stream channel maintenance. This can be completed as part of the Paradise Creek project or future grant-funded activity (WREN grants, Coldwater Heritage grants, etc.)

4. Improve and share the assessment data set – this Level I survey only begins to document visual observations throughout the watershed. Recommended 'next steps' would be: to collect detailed morphology of known impacted and reference stream segments; improve the GIS layers for the stream network; conduct additional aerial photo surveys; assemble partnerships to design and implement the restoration projects listed herein. It is anticipated that surveys of many impacted segments will be conducted during restoration project implementation throughout Pennsylvania, and these data should be shared among restoration practitioners. It became obvious during this survey that the Commonwealth must improve GIS layers of the stream networks – many unmapped channels were found, and those that have been digitized are highly inaccurate.

5. Implement more intensive water temperature monitoring within a program designed to reduce temperature stress upon trout throughout the watershed. Funding can surely be found to provide water temperature loggers (these are small, dependable, and inexpensive) to landowners. Such temperature data can be assembled and analyzed to quantify and reduce the effects of impoundments, parking lot runoff, and reduced riparian buffers upon water quality of the Paradise Creek. The objective of such an effort is to maintain a healthy and viable trout population in the watershed, and to reduce the frequency of violation of PA water quality standards, and to maintain or improve coldwater fisheries habitat. A similar effort has been successfully implemented by the Pequannock River Coalition in northern New Jersey (http://www.pequannockriver.org).