Round 5 Grant

Pennsylvania Growing Greener
Project Number 4100020404

Mosquito Creek Watershed Restoration Plan

PHASE 5

DESIGN OF OFF-LINE
LIMESTONE SAND ADDITION SYSTEMS

- FINAL REPORT -

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INTRODUCTION

The Mosquito Creek watershed, located in Clearfield, Elk, and Cameron Counties (Figure 1), was once a premier wild trout fishery, but has since been severely impacted by acid rain. Acidification effects have eliminated naturally reproducing trout from many of its tributaries, and remaining populations are reduced and isolated. Although upwind acidification sources are presumably diminishing with regulation and time, chronic soil acidification and residual atmospheric deposition are expected to impair the stream for the foreseeable future.

Beginning with a Growing Greener Grant in 2000, the Mosquito Creek Sportsman's Association (MCSA) has been conducting a series of projects to assess the extent of acidification in the watershed and implement innovative acid abatement technologies. The result has been the development of a progressive restoration plan that is already improving the quality of several tributaries and holds promise for the eventual restoration of the entire watershed. Table 1 provides a summary of the project activities associated with the five Grants awarded to date, and Figure 2 shows the distribution of these projects within the watershed. A Round 7 Grant application has also been submitted to implement the alkaline addition projects being designed under Round 5. The results of all these projects will be detailed in a technology assessment to be prepared under Round 4 and completed in 2005.

There were a number of activities conducted under the Round 5 Grant. The primary focus was the design and permitting of two alkalinity-generating high flow buffer channels (HFBCs) and two vertical flow limestone beds (VFLBs), with the HFBCs located on Gifford Run and one each of the VFLBs on Lost Run and Deserter Run. The VFLBs are similar to the vertical flow wetlands (VFWs) constructed under the Round 1[1] and Round 3[2] Grants, except that they do not contain the spent mushroom compost that has caused discharge discoloration in the previous projects. This approach is intended to test the effectiveness of using limestone sand alone in a vertical flow environment, saving costs and eliminating the discoloration. The HFBCs are an entirely new concept aimed at replicating the aggressive limestone sand dissolution that occurs within flowing stream beds without actually dumping the sand into the natural stream channel, a practice suspected to cause long-term impairment to macroinvertebrate communities. The watershed-scale monitoring program begun under Round 2[3] was also extended under Round 5 to continue collecting long-term data on the health of Mosquito Creek and its major tributaries.

This report summarizes the outcomes of these activities and provides recommendations for future projects within the watershed. A brief project summary for use in PADEP postings is contained in Appendix A, with the Growing Greener Goals and Accomplishments Worksheets contained in Appendix B.

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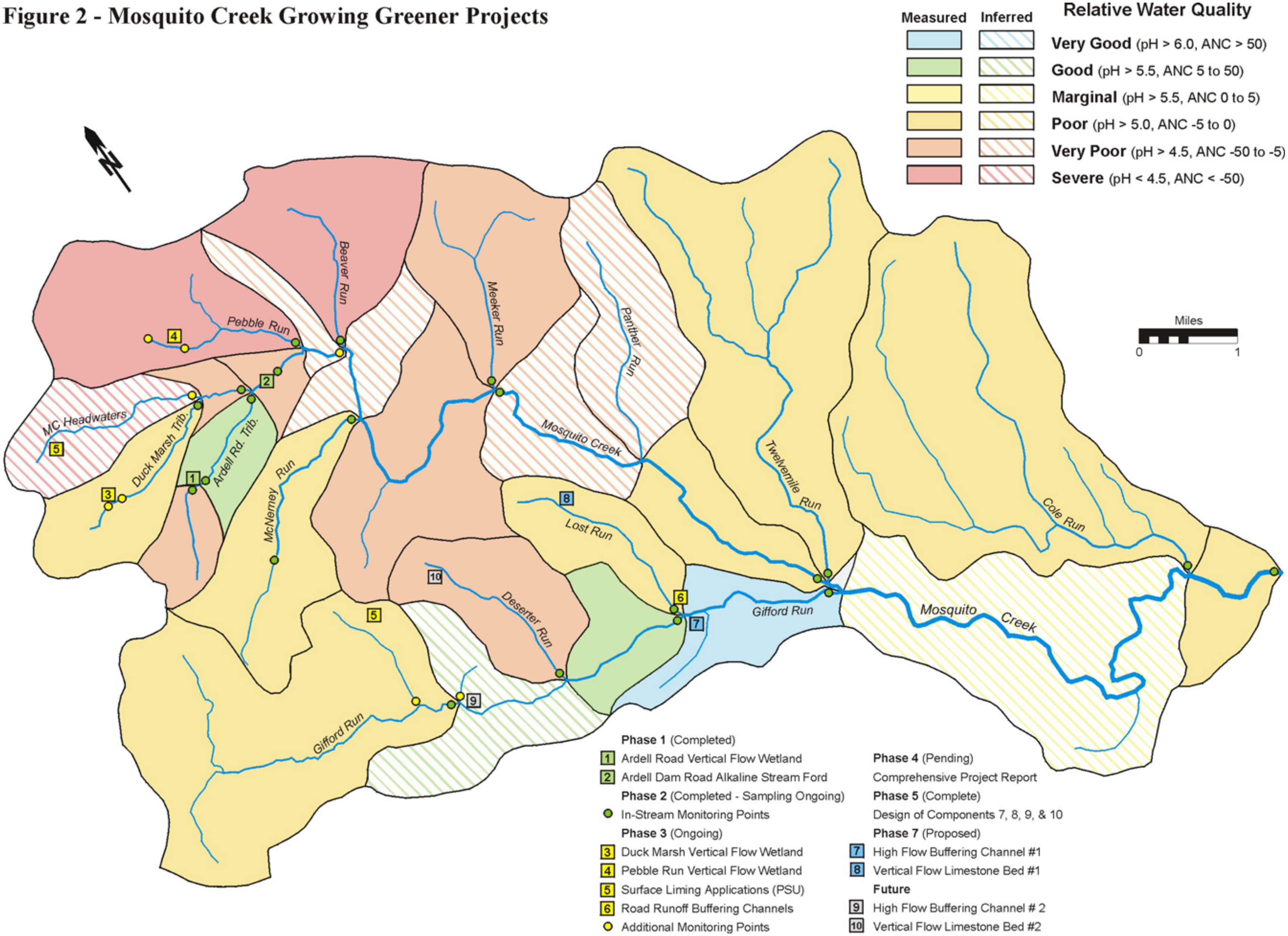
[1] See "Mosquito Creek Phase 1 – Atmospheric Acidification Abatement Demonstration Projects Final Report." Pennsylvania Growing Greener Project No. 3591130. May 2002.
[2] See "Mosquito Creek Phase 3 – Alkaline Addition Implementation Projects Final Report." Pennsylvania Growing Greener Project No. 351358. June 2004.
[3] See "Mosquito Creek Phase 2 – Watershed-Scale Assessment for Acidification Abatement Final Report." Pennsylvania Growing Greener Project No. 350344. September 2002.

Figure 1 – Mosquito Creek Watershed Location

Table 1 – Summary of Mosquito Creek Growing Greener Projects to Date

Grant	Project Scope	Results/Benefits
Round 1	*Phase 1 – Atmospheric Acidification Abatement Demonstration Projects:* Design and construction of a vertical flow wetland (VFW) to generate alkalinity in a tributary crossing Ardell Road, and an experimental limestone sand dosing stream ford on the main stem. Penn State monitored in-stream results under a concurrent Grant.	Demonstrated that VFWs are applicable to acid rain impacts. Water quality improvements extend 1.6 miles downstream to the confluence with Mosquito Creek, and the formerly acidified Ardell tributary now appears capable of supporting fish populations. Provided monitoring results for design of future VFW systems.
Round 2	*Phase 2 – Watershed-Scale Assessment for Acidification Abatement:* Water quality and flow monitoring at 14 permanent stations on major tributaries and the main stem of Mosquito Creek, and evaluation of the results to develop a Progressive Restoration Plan.	Provided data to characterize water quality throughout the watershed and identify the primary sources of acidification. Concurrent flow measurements allowed determination of the point at which episodic acidification begins to impact streams during runoff events. Allows planning of future treatment efforts to produce measurable results.
Round 3	*Phase 3 – Progressive Restoration Plan Implementation:* Design and construction of two VFWs on the Duck Marsh Tributary and Pebble Run to evaluate what mutually supportive effects that treating adjacent tributaries would have on the main stem. Also funded continuation and expansion of the Phase 2 monitoring to better characterize the watershed. Surface liming is being conducted in other headwaters areas by Penn State under a concurrent Grant.	It is anticipated that the two new VFWs, along with the Ardell VFW and surface liming conducted by Penn State, will significantly benefit water quality in the main stem, possibly as far downstream as Beaver Run. Results will quantify the mutually supportive effects of multiple abatement projects and allow prediction of the ultimate scope of treatment necessary to restore the entire watershed.
Round 4	*Phase 4 – Assessment of Applied Technologies for Acid Abatement:* Preparation of a comprehensive report on the findings of the previous projects. Will include to the extent possible the results from Round 5, as the Round 4 budget period allows.	This report will provide the technology transfer for the results of the Mosquito Creek Grant activities, including an evaluation of treatment and cost effectiveness of the various technologies, and implementation guidelines applicable to other watersheds impacted by acid rain.
Round 5	*Phase 5 - Design of Offline Limestone Sand Application Systems:* Design and permitting of two new alkaline addition technologies at four sites, including two high flow buffer channels and two vertical flow limestone beds.	When implemented, these systems will demonstrate new approaches to using efficient limestone sand for stream buffering without the sedimentation detriments associated with direct in-stream application.

Figure 2 - Mosquito Creek Growing Greener Projects



ACTIVITY SUMMARIES

The following summarizes the project background and activities that were conducted under the Round 5 Grant. Final results for existing projects and the overall monitoring program will be reported in the Round 4 technology assessment. This summary is inclusive of project details up to the conclusion of the Round 5 funding period.

Discussion of Stream Acidification

The intent of the Round 5 design projects was to address the problems of episodic and chronic acidification that have been identified by monitoring in Gifford Run and its tributaries. Episodic acidification occurs when runoff from acidic rain events overwhelms the normal baseflow buffering capacity of streams. Degree of buffering or acidification is measured by the acid neutralization capacity (ANC) of the stream water, having the units of milli-equivalents per liter (meq/L). A positive ANC represents a buffered condition where the stream pH (measured in standard units – SU) will normally remain in the circumneutral range. A negative ANC indicates an acidified condition, where the pH can drop to levels harmful or fatal to aquatic life if additional acidity enters the stream. Studies have concluded that episodic acidification can be both a short-term and long-term detriment to fish populations.[4] While some fish can survive these events by taking refuge in alkaline tributaries or microhabitats, this is not sufficient to maintain the potential population densities that would be implied by the water quality during baseflow periods. Historical data show such a long-term population decline in Mosquito Creek.

Mosquito Creek is particularly vulnerable to episodic acidification during rain and snowmelt events because of the low inherent buffering capacity of its sandstone bedrock. Some tributaries are so chronically acidified that they no longer have a positive ANC at any flow, including Pebble Run, Beaver Run, Meeker Run, and Deserter Run. These streams are observed to be essentially devoid of aquatic life. Other tributaries and the main stem show a more classic episodic acidification pattern, with a positive ANC under baseflow conditions trending to a negative ANC as flows increase. This trend is illustrated in Figure 3 for Gifford Run above Lost Run, with negative ANC predicted to occur at relatively high flows. The indicated "Neutrality Threshold" is the predicted flow volume above which the stream will become acidic, and its pH may drop to harmful levels. It is the flows above this threshold that actually require some form of alkaline addition to maintain stream health. In Figure 4, the ANC curve for Lost Run shows the neutrality threshold occurring at a much lower percentile of the flow range. These analyses show that Gifford Run only requires supplemental alkalinity during high flow events, whereas Lost Run is a better candidate for continuous alkaline addition.

[4] Baker, J. P., J. Van Sickle, C. J. Gagen, D. R. DeWalle, W. E. Sharpe, R. F. Carline, B. P. Baldigo, P. S. Murdoch, D. W. Bath, W. A. Kretser, H. A. Simonin, and P. J. Wigington, Jr. Episodic Acidification of Small Streams in the Northeastern United States: Effects on Fish Populations.

Figure 3 – Relationship of ANC to Flow in Gifford Run above Lost Run

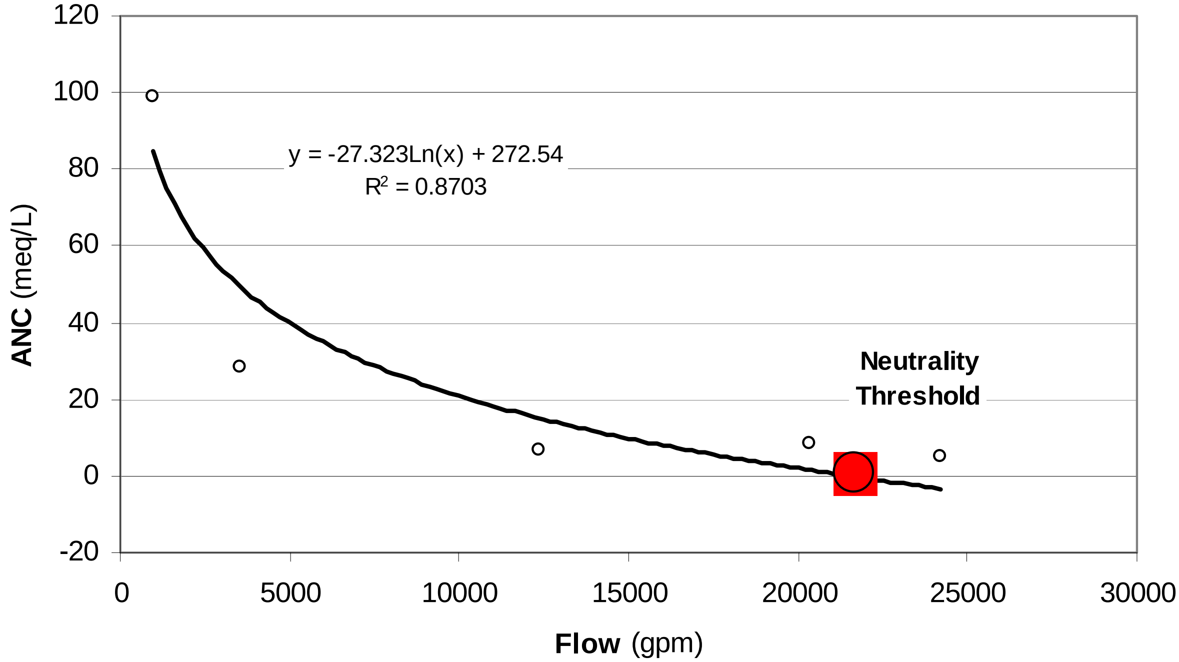
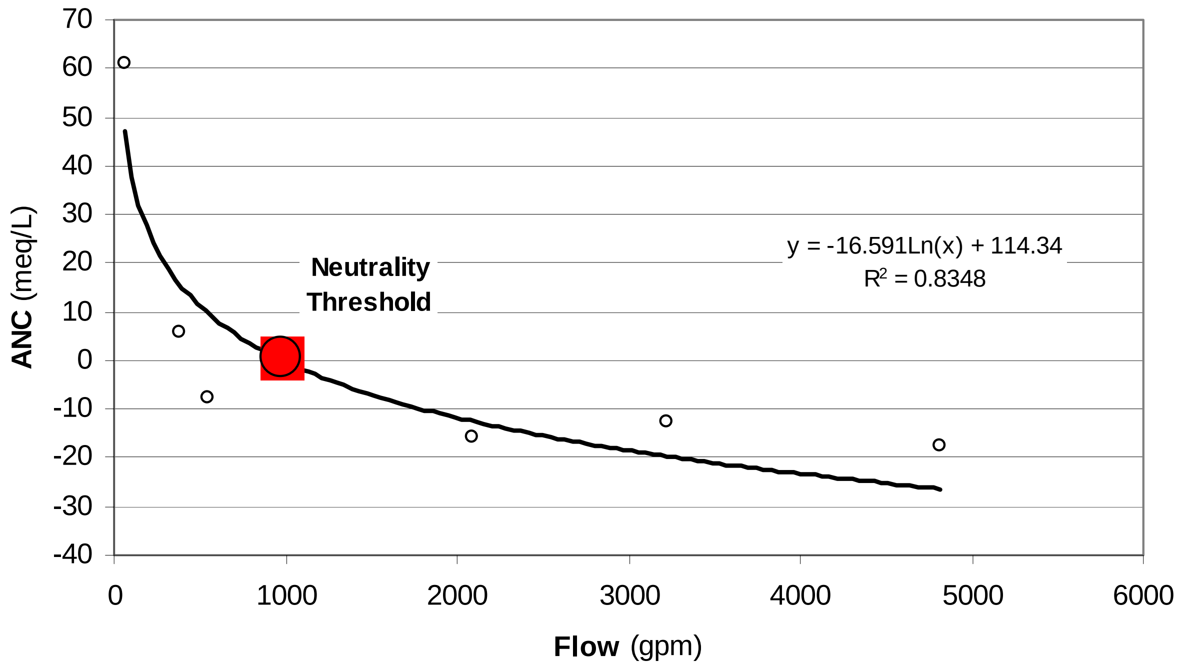


Figure 4 – Relationship of ANC to Flow in Lost Run



The Practice of Limestone Sand Dosing

Neutralization of acidic waters with limestone ($CaCO_3$) is considered the best alternative for aquatic life restoration goals because it uses a naturally occurring mineral and generates benign calcium cations, as opposed to the sodium or ammonium cations associated with some other neutralizing agents. Limestone is also comparatively inexpensive and safe to handle. However, it has a relatively slow dilution rate, requiring large volumes in contact with flowing water to achieve desired neutralization results. Various methods of limestone application have been tried in the past, including flow-through stream barriers, water-driven rotary baskets, water powered grinding mills, and upflow diversion wells, with varying degrees of success.

Beginning in the mid-1990s, several projects in Pennsylvania began experimenting with in-stream limestone sand dosing as a neutralization method. This simply involves dumping limestone sand into a stream and allowing flows to carry it downstream. Both the large surface contact area of the sand particles and the mechanical abrasion from bed movement serve to increase the limestone dissolution rate compared to water passing over a fixed limestone surface. A review of six limestone sand dosing projects in Pennsylvania showed mixed results, with insufficient dosing volume being cited as the likely problem where the desired water quality improvements were not achieved.[5]

Gifford Run is one case where limestone sand dosing has worked particularly well. Starting in 1996, the MCSA began an annual application of 44 tons of limestone sand to Gifford Run at the Merrill Road and Lost Run Road bridge crossings. Figure 5 shows plots of ANC versus flow for Gifford Run in the untreated portion above Merrill Road, in the treated portion above Lost Run Road, and in the twice-treated portion at the confluence with Mosquito Creek. Both treated reaches have maintained a positive ANC for all observed flow events. The increasing benefits of multiple treatment locations is evident in the increasing downstream ANC represented by the trendlines for these points.

Limestone sand dosing can have a negative impact on the streambed. Migrating sand particles tend to lodge in the stream bottom, covering natural cobble beds with a smooth floor. This in turn buries the habitat of the macroinvertebrates on which trout and other fish feed. At least one study[6] has reported diminished macroinvertebrate populations immediately downstream of a limestone sand application site. Another problem reported with in-stream dosing is the precipitation of aluminum within the dosing area. Under baseflow conditions, the pH increase from the limestone causes aluminum to precipitate as a white sludge. During episodic acidification events, this aluminum may be remobilized, possibly at greater concentrations than originally present. Aluminum becomes more toxic to aquatic species at reduced pH, and this remobilization can represent an additional stressor on fish populations.

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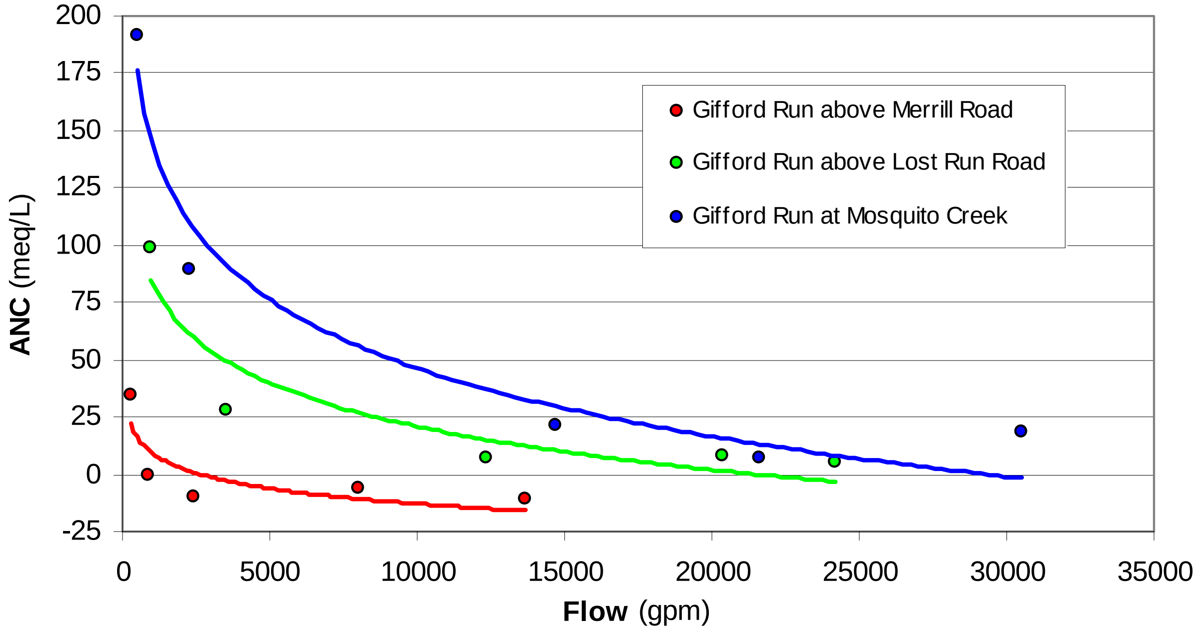
[5] Spotts, David E. "An Assessment of Acidic Water Neutralization by Limestone Sand in Pennsylvania." Undated Pennsylvania Fish and Boat Commission Report.

[6] LeFevre, Susan R., and William E. Sharpe. Acid Stream Water Remediation Using Limestone Sand on Bear Run in Southwestern Pennsylvania. *Restoration Ecology* Vol. 10 No. 2, pp. 223 – 236.

Figure 5 – ANC Versus Flow Downstream Through Gifford Run



Alternative Limestone Sand Application Methods

Under the Round 5 Grant, designs were developed for two new approaches to limestone sand application: high flow buffering channels and vertical flow limestone beds. For Round 7, it is proposed to fund construction of one high flow buffering channel and one vertical flow limestone bed to demonstrate the effectiveness of these technologies. The following provides a summary of these technologies and the design approaches for the selected construction sites.

<u>High Flow Buffering Channels</u>

The HFBCs are intended to duplicate the treatment effect of in-stream dosing by creating a “stream beside a stream,” wherein the limestone sand may migrate and abrade in much the same manner as in a natural channel, but is prevented from discharging from the end by a low-velocity bed segment. A loader can be used to periodically clean the low-velocity segment and return undissolved limestone sand to the head of the channel. Using fluviogeomorphic design techniques, cross vanes will be placed in Gifford Run at the channel inlets such that a portion of the stream flow is diverted into the HFBCs during flow events at which negative ANC occurs.

HFBC designs have been prepared for two sites on Gifford Run, one above Lost Run Road and one below Merrill Road. The Lost Run Road site was selected for the first construction project because it has somewhat easier working conditions and no wetland crossings. Figure 6 shows the layout of the Lost Run Road HFBC, and Figure 7 that of the Merrill Road HFBC. The Lost Run HFBC is intended to replace the practice of limestone sand dosing at this location, with dosing continuing at Merrill Road until such time as the second HFBC is funded and constructed.

Figure 6 – High Flow Buffer Channel Plan at Lost Run Road

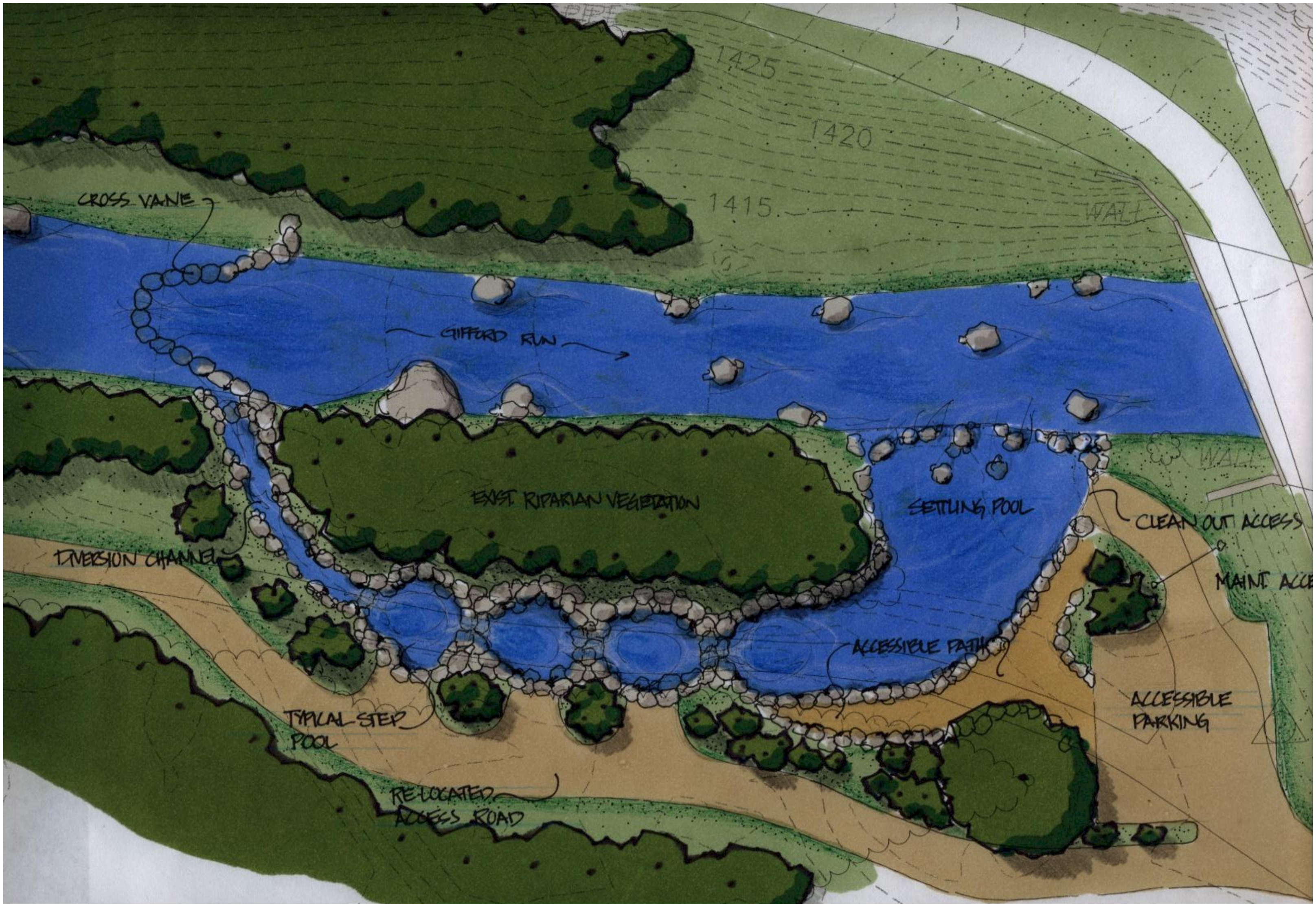
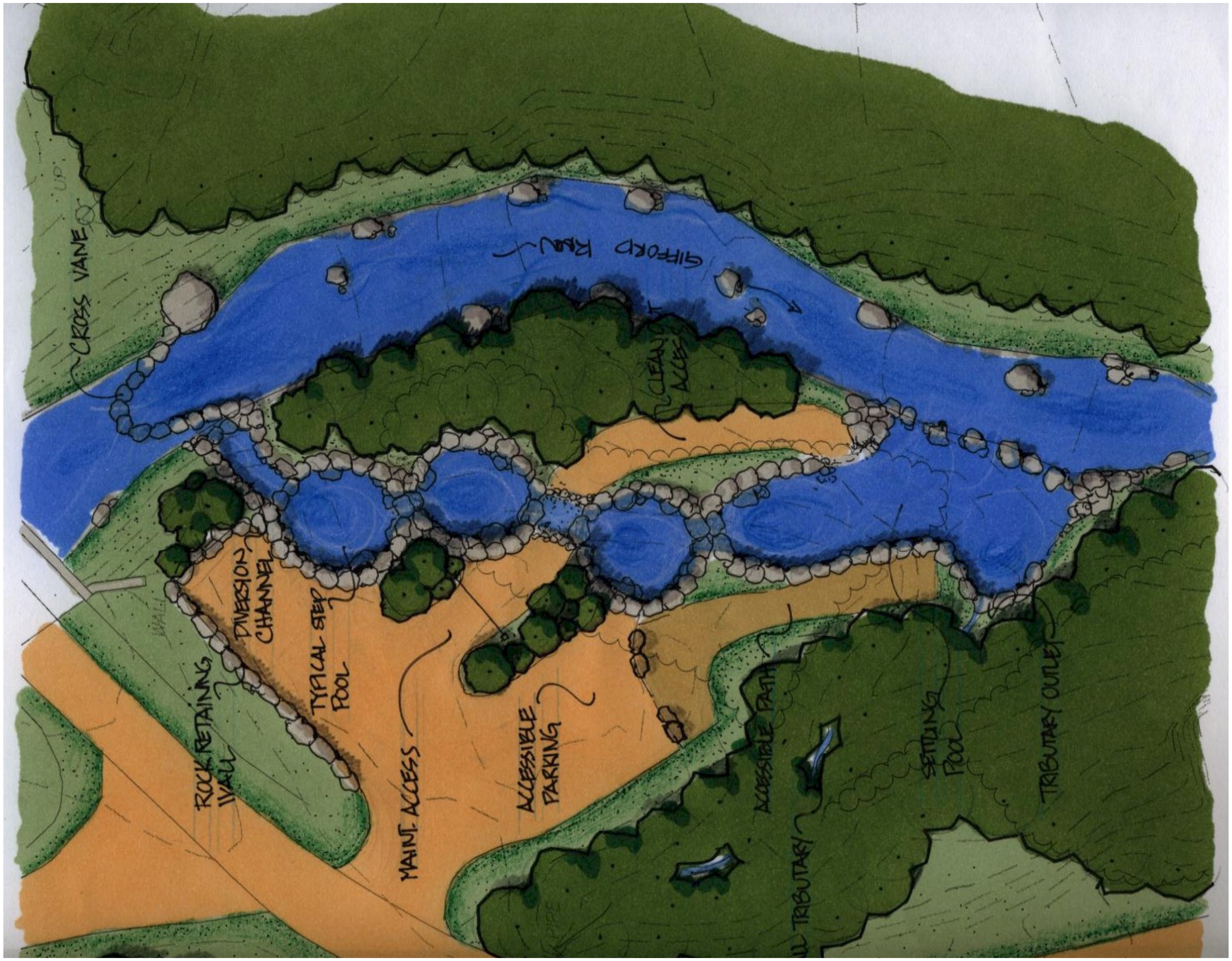


Figure 7 – High Flow Buffer Channel Plan at Merrill Road



Vertical Flow Limestone Beds

The VFLBs are essentially the same design as the vertical flow wetlands constructed elsewhere in the watershed, except that they do not have a top bed of spent mushroom compost. While compost appears to enhance alkalinity production and protect limestone from armoring in acid mine drainage applications, it is not known whether it provides a significant benefit in clean water situations. From the evidence of limestone sand dosing, limestone will dissolve in clean water without the presence of compost. Also, compost produces an undesirable discoloration and foam in the discharges of vertical flow wetlands for a period after their construction. If limestone alone is sufficient for streams impacted by acid rain, elimination of compost from these types of cells would both save on construction costs and prevent temporary discoloration.

VFLB designs have been prepared for two sites, one in the headwaters of Lost Run and one in the headwaters of Deserter Run. The Lost Run site was selected as the first construction project because it has excellent access and working conditions. Alkaline addition on Lost Run will also directly support the benefits of the HFBC at Lost Run Road, further obviating the need for limestone sand dosing at that location. Figure 8 shows the VFLB site plan for Lost Run Road, and Figure 9 that for Deserter Run.

Figure 8 – Vertical Flow Limestone Bed on Lost Run

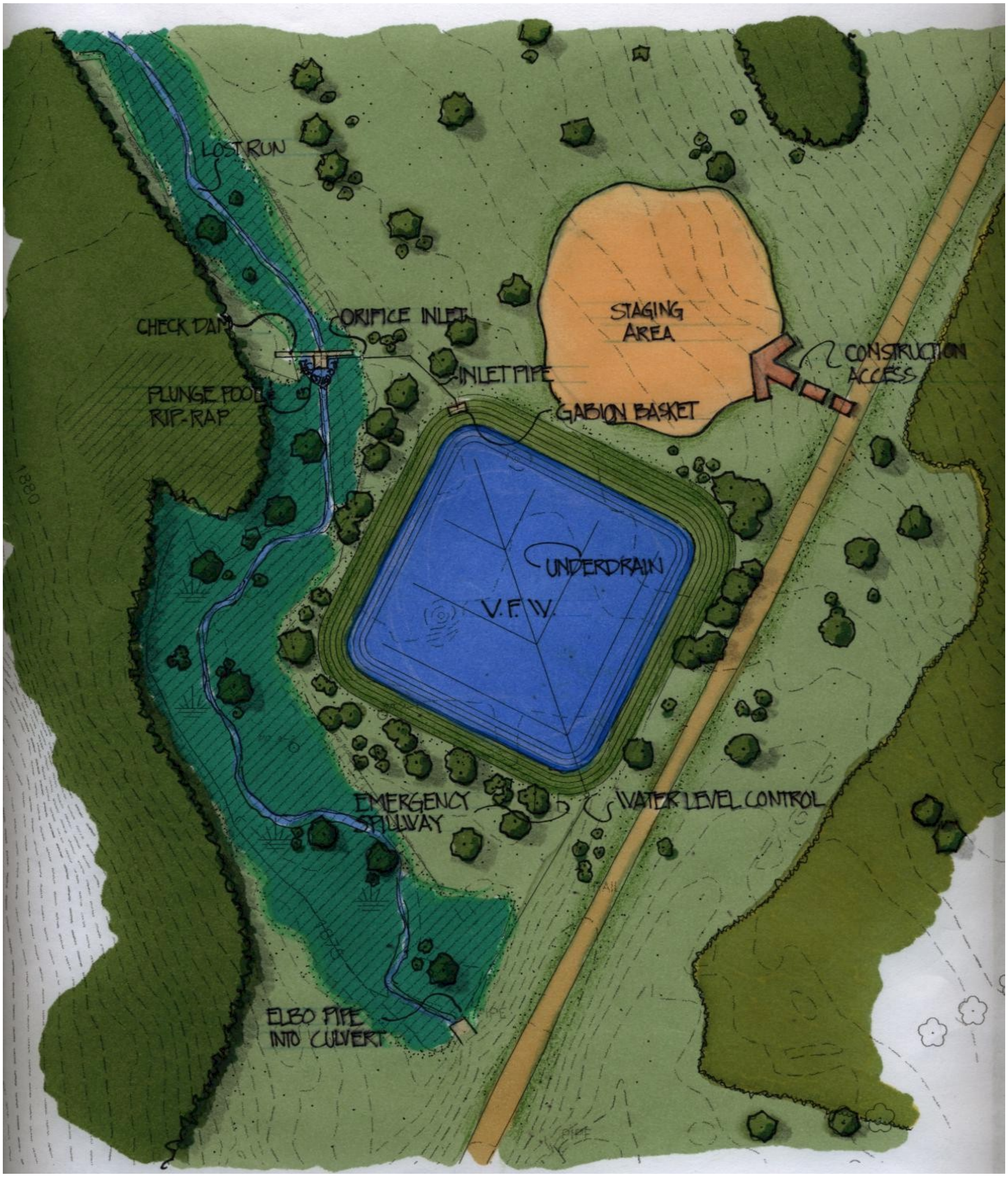
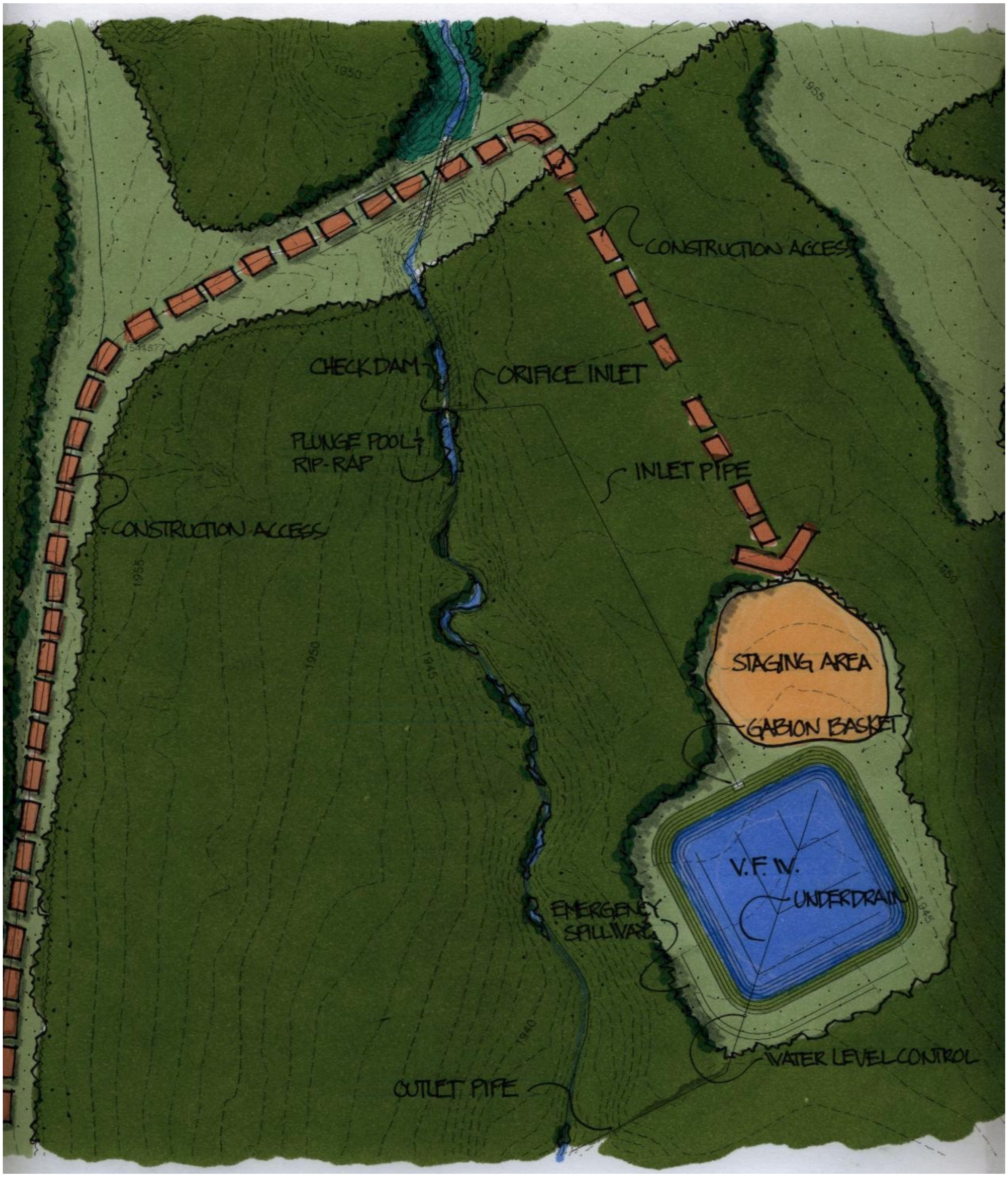


Figure 9 – Vertical Flow Limestone Bed on Deserter Run



DISCUSSION

The following provides an analysis of the project costs and discusses the lessons learned and public outreach program.

Cost Analysis

The design funding was minimally adequate to complete the process, and the permitting costs proved to be much greater than anticipated. With the attendant water monitoring, meetings, and project management requirements, the design consultant was forced to complete the project at a substantial loss. Although the restoration projects undertaken by the Grant program are intended to benefit the environment, they are still subject to the same level of regulatory scrutiny as a commercial development project. To satisfy the basic design and permitting requirements for future projects of this scale, it is recommended that no less than $30,000 be allocated per site for permitting and interactive requirements. In the case of the Mosquito Creek projects to date, this expense is relatively minor compared to the water quality benefits gained and should be considered a basic cost of non-government associations undertaking environmental restoration projects.

Lessons Learned

The primary lesson learned from this project was the difficulty in combining multiple construction projects in widespread locations into a single permitting process. In pre-application meetings, the regulatory agencies requested that the four alkaline addition project sites be combined into a single Joint 105/404 Permit application. Initially, this appeared to be a benefit by reducing the permitting effort to a single application. In reality, it produced an unwieldy application package attempting to satisfy the disparate requirements of each site in a common document. The HFBCs, for example, required a flood plain consistency review from the local township, entailing a substantial time delay, while the VFLBs were outside floodplain considerations and did not need such a level of review detail. There was also the concern that a permitting problem with one of the sites could hold up the approval process for the remaining sites. There are situations where permitting could be significantly streamlined by combining multiple sites in a single application, but it is recommended that this only be done under the conditions that all the projects are essentially identical, a single bid package will be prepared for a simultaneous construction effort, and that all required supplemental reviews and approvals can be obtained through a single submission to each affected agency and municipality.

Public Outreach

The MCSA holds monthly meetings at the Frenchville clubhouse with presentations regarding the status of these projects and new developments. Informational kiosks have been placed at each of the three VFW systems explaining their purpose and the overall scope of restoration efforts in the watershed. The group also maintains a Web site detailing project activities and outcomes.

CONCLUSIONS AND RECOMMENDATIONS

The alkaline addition systems constructed under the Round 1 and Round 3 Grants have shown a demonstrable improvement in the water quality of the affected tributaries within the Mosquito Creek watershed. The Round 5 system designs show promise for replacing the existing practice of in-stream limestone sand dosing and providing a source of long-term, low maintenance alkaline addition without the risks of streambed degradation. The Growing Greener program has invested a substantial amount in the Mosquito Creek watershed, and this investment is showing a definite and measurable return in socioeconomic benefits. Overall, it is recommended that the Mosquito Creek watershed is among the best investments for socioeconomic and environmental improvements available in Pennsylvania. Specific recommendations for future work and funding are as follows:

- It is recommended that the off-line alkaline addition systems designed under Round 5 be funded, such that the proposed new technologies may become available as alternatives to existing compost-based VFWs and in-stream limestone sand dosing.

- It is recommended that the in-stream water quality monitoring and system input/output monitoring proposed under Round 7 be funded to allow continuation of a long-term database of the watershed characteristics and system performance over time.

- It is recommended that other alkaline addition projects be undertaken in the headwaters portion of Mosquito Creek to extend the synergistic improvements in pH and ANC in the main stem, potentially creating stockable conditions in the headwaters area and progressively downstream.

APPENDIX A

Project Summary Narrative

Mosquito Creek Phase 5 – Design of Off-Line Limestone Sand Addition Systems

This project involved design and permitting of four off-line limestone sand addition systems, including two high flow buffer channels and two vertical flow limestone beds. The purpose of these projects is to test the effectiveness of off-line limestone sand addition versus the typical practice of direct in-stream dosing.

APPENDIX B

Goals and Accomplishments Worksheets