A STREAM FLOW RESTORATION PROJECT FOR THE POTOMAC HEADWATERS

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ABSTRACT

Concerns over both quantity and quality of our surface and ground water resources are widespread in the United States. This project is exploring the feasibility of increasing surface water flow and enhancing alluvial groundwater storage by installing a series of small, in-stream structures in two West Virginia headwater watersheds. The structures used were similar to the cross vanes common in natural stream restoration. Cross vanes were chosen because they accomplished the primary purpose of raising the level of water behind the structure, without inhibiting the movement of aquatic life or destabilizing the stream channel. Primary testable hypotheses in this project were: the structures will elevate the local alluvial water table; the structures will increase surface flow in local streams during base flow periods; and the structures could be constructed at low cost, require little maintenance, and not destabilize the stream. Conceptually, the project represents an ecologically guided attempt to partially restore the natural hydrologic functions, flow regimes and ground water levels that likely existed prior to the colonial era extermination of beavers - and the elimination of once ubiquitous beaver dams on headwater streams. This paper provides an overview of the project design and results to date.

KEY WORDS: alluvial groundwater, piezometer, beaver

INTRODUCTION

Concerns over both quantity and quality of our surface and ground water resources are widespread in the United States. In the Potomac Headwaters region of West Virginia, these issues are exacerbated by economic development in the absence of effective community planning, and a large integrated poultry industry that utilizes significant amounts of groundwater. An assessment of water resources in Hardy County, WV found that the poultry industry “may impart a significant burden” on the county’s groundwater resources (MSES, 2002). Meanwhile, the population of Hardy County is expected to grow by 17% over the next two decades, with much of that growth in the region dependant on groundwater for water sources.

There is anecdotal concern in this area that “we are sucking the rivers dry” and recent experience indicates that new wells must be drilled deeper to get the yields previously obtained from shallower wells. This project is exploring the feasibility of increasing surface water flow and enhancing alluvial groundwater storage using a technique tested in the West and modeled after the hydrological impact of beaver dams.

When we imagine the eastern-American landscape of 300 years ago, most people picture a landscape of nearly continuous forests bisected by free flowing streams. The reality was very different. Before the fur trade decimated beaver populations in early colonial times, beavers were abundant on streams throughout the Mid-Atlantic region (Ambrose 1996). The wetlands created by beavers supported diverse flora and fauna and may have maintained perennial flows in streams in headwater regions. During the time when beavers were extirpated from the Chesapeake basin, contemporary maps show many perennial streams gradually became intermittent or ephemeral, possibly due to lowering of water tables as beaver dams were no longer present to recharge groundwater. Although other human disturbance, including channelization, deforestation and other activities might also have lowered groundwater tables, current research in the West affirms that the return of beavers can result in a return of perennial flows to headwaters areas and a more natural stream flow regime (Clark, 1998), and can augment alluvial groundwater levels a considerable distance downstream of beaver dams (Westbrook et al, 2006).

It is currently unrealistic to reintroduce beavers for the purpose of restoring natural hydrologic conditions within Eastern watersheds, in large part due to the public's often negative reaction to beaver activity. However, researchers in the western US have investigated low-cost methods to construct beaver dam-like structures (BDS) to restore riparian areas and increase groundwater storage (Skinner et al, 1988; Skinner et al., 1991; Clark et al., 1998; Warren, 1991). These BDS have been built using a variety of materials, such as: woven wire, steel posts, synthetic erosion mat and discarded tires (Skinner et al., 1991); logs (Warren (1991); and woody brush (Norton et al., 2002). By retaining eroded material behind the structure, the BDSs reduce downstream sedimentation and augment alluvial water storage capacity as they mature.

With respect to stream flow, Stabler (1985) reviewed the literature on increasing summer flow in small streams, citing a number of cases where a series of erosion control check dams and gabions were constructed in ephemeral flow gullies, and perennial flow unexpectedly developed over time. Zuni Indians have been installing structures made from woody brush for the same purpose for over 2000 years (Norton et al., 2002). Stabler hypothesized that small dam construction within small valleys can restore stream flow by increasing the zone of saturation within the valley bottom and in sediments trapped behind the structure; the water thus stored is slowly released through the ground back to the stream channel. Groundwater levels in alluvial aquifers fluctuate with stream stage (Workman & Serrano, 1999; Chen and Chen, 2003). These structures serve to increase effective stream stage along streams segments.

In this continuing project, we are assessing the effects of in-stream structures on surface flow and alluvial ground water levels of headwater streams in the Potomac Headwaters region of West Virginia. Primary testable hypotheses in this project remain: the structures will elevate the local alluvial water table; the structures will increase surface flow in local streams during base flow periods; and structures can be constructed at low cost, require little maintenance, and not destabilize the stream. The structures represent an ecologically guided attempt to partially restore the hydrological effects of what was once a ubiquitous component of the ecosystem – beaver dams.

METHODS

This study used a paired watershed design, with a period of baseline data collection. Data analysis was based on comparisons between sites, (in particular, between control and experimental sites), between upstream and downstream locations within the experimental study areas, and between pre and post treatment data for individual sites. Also, digital pictures provide a visual record of changes.

Data collected for this project include flow, groundwater level, stream height, precipitation, and water temperature. Data analysis was based on comparisons between sites, in particular, between control and experimental sites, and between upstream and downstream locations within the experimental study areas.

Flow and precipitation data collection began in the fall of 2003. Precipitation data was collected using All Weather Rain Gauges (Productive Alternatives, Inc.) that were placed at all of the study sites, with cumulative precipitation data collected on sampling days. An additional gauge, located within a few miles of all the study sites, was checked daily.

Stream flow sites were located at the top and bottom of each study site. The very small, meandering streams selected for this project provided particular challenges for accurate measurement of stream flow across all ranges of flow, and a mixture of methods suitable for different conditions were utilized. Flow measurement equipment included a Global Flow Probe Model FP101 and a portable "Insta-Weir." The custom designed Insta-Weir was created for use by this project to measure flow where stream depth or flow rate precluded use of the Global Flow Probe or other flow measurement devices. The Insta-Weir ultimately proved unsuitable

Alluvial groundwater was measured using a network of piezometers. Piezometers were constructed from 1¼ inch PVC pipe, with nylon mesh is placed on one end of the pipe and secured in place using a 1¼ inch PVC cap which is perforated with six 1/4 inch holes. Spring steel measuring tapes were cut to length and placed in the piezometers and a water-soluble ink daubed on the tapes served as a crest height recorder between direct measurements. Piezometers were installed according to two protocols. The first was a longitudinal network spaced every 100 ft along the length of the stream segment, 10 ft from the edge of the stream (if possible), with the bottom of the piezometer level with the stream's thalweg. Piezometer nests were installed every 400-ft of stream length (where possible). The second piezometer protocol consists of a grid of three rows of three piezometers (if possible) used to measure changes in groundwater levels across a width of floodplain area caused by the installation of a structure. Stream height was measured relative to the top of piezometers using a hand sight level and a pocket rod.

Structures were designed with three key attributes in mind: use of esthetically acceptable materials, stability, and low cost. Structures were modeled after a variant of the cross vane that we observed during a visit to a stream restoration project in Big Bear, PA. Log structures at that site had been installed on a sizeable, high-gradient stream by two men in one day, using no heavy equipment. These structures have successfully withstood a number of major floods. Structures were built to or below bankfull elevation at the edges and lower in the center of the stream to provide a spillway. The cross vane's inverted-V design directs the force of the water away from the banks and toward the center of the channel, reducing bank erosion and enhancing long-term stability.

A schematic of the cross vane used for this project is shown in Figure 1. While construction methods at each site varied, in general the method was as follows: 1) The primary members of the cross vane were driven or cut into the stream banks at the appropriate angle and elevation. 2) The upstream edges of the logs were trimmed and fitted to each other, and then either wired, through-bolted, or nailed together. 3) At the point where the cross vane members enter the bank, model 68-DB-1 duckbill earth anchors (1,100 lbs. holding capacity) were driven into the bank at a right angle to the member, with the cable fastened to the member using a cable clamp. 4) Galvanized wire mesh and erosion cloth were stapled to the upstream edge of the exposed portions of each member, and run 1'-2' upstream of the structure. The erosion cloth was included to reduce seepage through the structure, and is held below the line of sight for aesthetic reasons. 5) Cobble, gravel and sand were placed on the full length of the wire mesh upstream to the height of the top of the members.

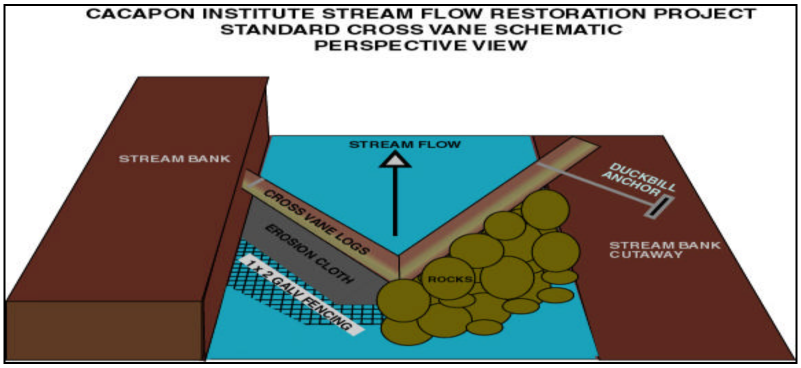

Figure 1. Schematic of structure installation.

Structures were installed longitudinally in series in the experimental streams to create a progression of small pools, rather than single isolated structures. We anticipated that alluvial water storage caused by upstream pools will extend periods of flow to pools further downstream and create a multiplier effect, like batteries wired in series.

The grant time frame constrained the collection of pre-treatment data; however, the paired watershed and upstream/downstream designs were intended to compensate for this limitation to the extent possible. Once suitable sites were selected, data collection began. Sites were visited at least twice monthly throughout the period of study. Frequency of visits was increased at times to capture changing conditions.

RESULTS

Four study sites were selected **Site 1** (referred to as "the Meadow" below) is a broad valley with a sinuous stream and extensive wetlands. There are no roads or agriculture in the floodplain. The site's stream length is 2100 feet, with a slope of 1.7%; the watershed area at the base is 511 acres. Twenty-two "regular" piezometers were installed along the length of this stream, as well as six piezometer nests and two structure grids with a total of 20 piezometers. Fifteen structures were installed here. The results will focus on this site.

Site 2 is located roughly 2000 feet upstream of Site 1, is totally forested, with pasture and a highway at the headwaters of the drainage. The stream section is 850 feet long with a slope of 2.7%; the watershed area at the base is 309 acres. Ten piezometers were installed along the length of this stream. Structures were not installed here after it became apparent that this stream was unstable. Data from this site was considered non-treatment data.

Site 3 is the "control" site. It has only a small, forested section and is mostly grassy. The site was far from ideal as a control, but no other stream in the area was more suitable. It winds through a narrow valley, and passes back and forth across a road. The stream has a slope of 3.2%; the watershed area at the base is 342 acres. Eight "regular" piezometers were installed along the length of this stream, as well as three piezometer nests. There is a pond near the headwaters of this stream - a pond that has in the past blown out and created scouring downstream flows. In fact, during the study, the stream experienced several severe scouring events that lowered the thalweg by more than six inches in many sections.

Site 4 is a tiny stream in an upland meadow. The land is enrolled in the USDA Conservation Reserve and Enhancement Program (CREP). The stream has a slope of 2.4% and a narrow area with alluvial deposits; the watershed area at the base is 119 acres. Eleven "regular" piezometers were installed along the length of this stream, as well as three piezometer nests and two structure grids with a total of 14 piezometers. Ten stone structures were installed. This site has a side stream, about 400 feet above the bottom of the study reach, that can deliver significant flow to the system. There have been many problems with this site, including the owner's decision to install a culvert stream crossing in the middle of the project, and the fact that the stream is so small that slumping grass can create numerous smalls dams during the fall and winter.

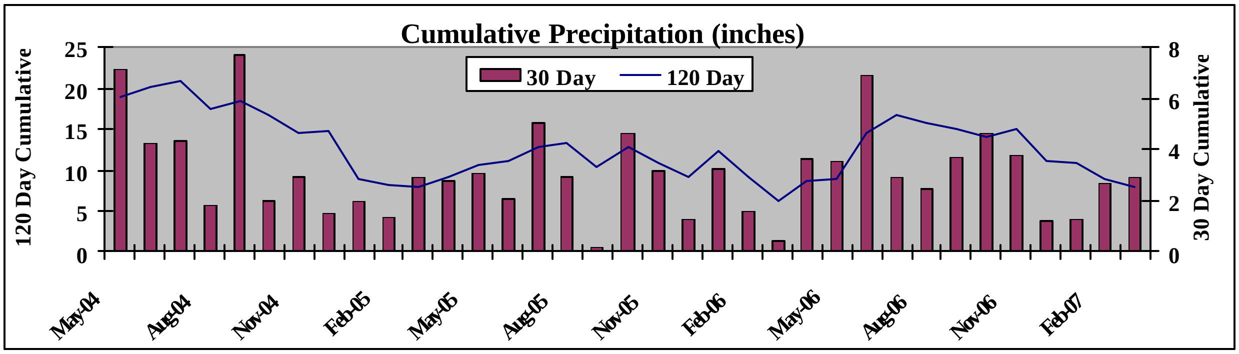

Figure 2. Cumulative precipitation.

Precipitation. Cumulative precipitation data is provided in Figure 2 to provide a measure of antecedent moisture conditions throughout the study period. The pretreatment period through September 2004 was very wet in comparison to most of the post treatment period. This unfortunate fact had important ramifications on data analysis. For example, one of the testable hypotheses of this project was that the anticipated increase in alluvial groundwater due the structure effects would in turn augment flows during low flow periods. Comparisons of pretreatment and post treatment flow data are required to determine if this occurred. However, because the pre treatment period was very wet, there were few opportunities to collect low water stream flows.

An interval of very low precipitation in August 2004 provided the opportunity to document groundwater levels as the subject streams became dry, and repeated periods of high flow to low flow in September due to tropical storm precipitation allowed documentation of each system’s response to these events. Collection of these data series led to the decision to begin installing structures in October 2004. Fifteen structures were installed in the meadow section of Site 1 in October and early November 2004. The following results focus on that site.

Flow. Strong statistical relationships between control and experimental, and between upstream and downstream flow sites were required to assess changes in flow that might occur due to structure installation. Strong correlations were found between the four flow stations in Sites 1 and 2, with r-values ranging from 0.940 to 0.997. These sites were all also strongly correlated with the two flow stations in the control area (Site 3), with r-values ranging from 0.88 to 0.98, and very strongly correlated with the upper two flow stations at Site 4, with r-values ranging from 0.935 to 0.994.

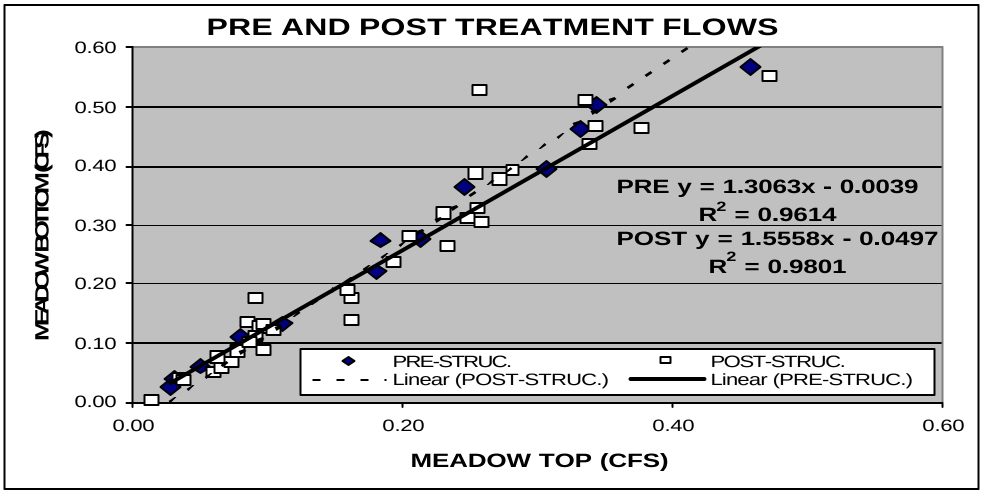

Figure 3. Stream flows below 0.6 cfs for the two flow stations in the Meadow (Site 1).

Figure 3 graphs stream flows below 0.6 cfs for the two flow stations in the Meadow (Site 1). Meadow Top is above all of the structures, Meadow Bottom is below all of the structures. No difference between pre and post treatment periods is apparent. Graphs of the Meadow Bottom against other control sites in Site 2, Site 3 and Site 4 indicate that flows below the treatment section may be slightly, but not significantly, lower during the post treatment period. However, as noted previously, the lack of low flow data during the pre treatment period is problematic.

Groundwater Data. The piezometer data was far less predictable than the flow data discussed above, and impossible to generalize. The one pattern that was reasonably consistent was that most piezometers had significantly higher water levels during the dormant season (October through April) than the growing season (May through September).

Otherwise, four major patterns in piezometer data were observed. Piezometers that: 1) usually had water, with little difference between daily and maximum levels and a relatively small range of water levels; 2) usually had water, with little difference between daily and maximum levels and a relatively large range of water levels; 3) were often dry, with large difference between daily and maximum levels and a relatively large range of water levels; and 4) were in a condition of dynamic change that had nothing whatsoever to do with the installation of structures (may include the defining characteristics of 1-3 above). The differences in patterns 1-3 appear to relate to the speed of the hydraulic connection to the stream, and piezometers in proximity to one another often "behaved" quite differently. For example, Figure 4 is a time series graph of two piezometers located fifty feet apart. Both are at the tow of the slope at the edge of the floodplain farthest from the stream. This represents an extreme example of piezometer variability.

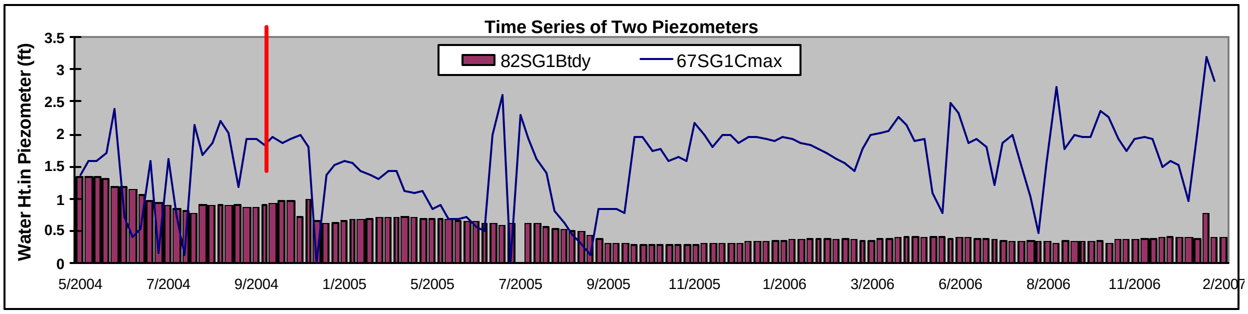

Figure 4. Time series graph of water height in two piezometers at the Meadow site. The site represented by the bars was located 50 feet down gradient of the site represented by the line.

The presentation will provide the results of analyses on the alluvial groundwater data. Some of this analyses explored individual piezometer behavior. For example, analysis of variance was used to compare water levels across seasons over time. Correlation analysis within season (growing and dormant) and year was used to identify piezometers that behaved in a similar manner. Cluster analysis was used on the correlation matrices to find piezometer groupings, and GIS was used to map similar clusters, and visualize how groupings changed over time.

There were strong indications of groundwater response to structure installation at a number of locations. However, anomalies at control sites cloud the issue. For example, the control stream had log jams form which acted like structures by increasing the effective stage height, thereby increasing connectivity to the floodplain in the vicinity and, apparently, raising water in nearby and downstream piezometers. The control stream also had a number of scouring events that dropped much of the channel by more than six inches, thus reducing its connection to the floodplain. This was not helpful.

SUMMARY

This is a continuing project. Data collection will continue for at least one more year. Adequate surface and groundwater supplies are a prerequisite for sustainable human communities and healthy wildlife habitat. While the scope of this project is small, it will provide important information concerning the feasibility of restoring watershed hydrologic functions and augmenting groundwater storage in a way that is low-cost, easily replicable, environmentally sensitive and culturally acceptable.

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