AN INVESTIGATION OF THE RECENTLY DRAINED CHAMBERSBURG RESERVOIR IN SOUTH-CENTRAL PENNSYLVANIA

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ABSTRACT: *The former Chambersburg Reservoir behind Birch Run Dam (Adams County, Pennsylvania) was drained in 2003 and the dam breached in 2004. To our knowledge, the newly revealed 21.7 ha landscape behind the dam had not been mapped as land in nearly 100 years. In consecutive summers two groups of Shippensburg University students participated in a field techniques course that used the site as their classroom. In the summer of 2007 the restored stream channel was surveyed and mapped. During the summer of 2008, a digital elevation model was built before rapidly growing early-successional vegetation obscured observations of the valley floor. A total station and GPS receivers were used to gather point-position and attribute data. A surficial layer of silt was observed atop a buried organic layer behind the dam. The silt was assumed to indicate lacustrine deposition during the 66 years of inundation. This silt cap was then mapped in three dimensions. These primary observations and the maps built from them serve to establish a baseline that can be used by future researchers interested in studying physical and geomorphological responses to dam removal. The value of field technique coursework for students is discussed in relation to the lessons learned through these experiences. Students involved in fieldwork have the opportunity to learn many intangible skills such as: mission planning, contingency planning, and team skills.*

Keywords: *Dam removal, Field methods, Sedimentation, Geomorphology*

INTRODUCTION

The removal of Birch Run Dam (Adams County, Pennsylvania) in 2005 was one of more than 700 dam removals in the United States over the last ten years (American Rivers, 2007). Many more removals are anticipated due to expiring licenses and greater knowledge of the hydrologic impacts of dams (Graf, 1999, 2006; Heinz Center, 2002). The negative responses of dam construction have taken decades to understand (Graf, 1999) and are only now being mitigated. The failure of dams to provide flood protection due to siltification (Cantelli et al., 2007); danger to boat recreation (PA Fish and Boat Commission, 2008); fragmentation of ecosystems (Chin et al., 2008); and the high costs to maintain safety (Heinz Center, 2002) are some of the reasons for dam removal in the United States. As dams in the United States approach their designed life expectancy of approximately 50 years, and their licenses expire the costs of operating the facilities is put to question.

At the onset of the push for dam removal in the United States little was known about the mobilization of sediment stored in the reservoir upon the breaching of the dam. Recent research includes an unmitigated breach to study the phenomena (Doyle et al., 2002), flume studies on sediment transport (Cantelli et al., 2007), and a variety of other methods to understand sediment transport after dam removal (Cheng and Granata, 2007; Evans et al., 2007). The removal of low-head dams is common and has shown minimal sediment transport in Pennsylvania, Ohio and Connecticut (Chaplin et al., 2005; Cheng and Granata, 2007); however the removal of larger dams presents a risk of significant sedimentation of downstream reaches. The area upstream of the former Birch Run Dam was studied by students participating in a field techniques class in the summers of 2007 and 2008. These primary observations and the maps built from them serve to establish a baseline that can be used by future researchers interested in studying physical and geomorphological responses to dam removal. This article reports on the data collected by the students at the former Birch Run Dam site and the educational value of the field experience.

BACKGROUND

The earthen-fill Birch Run Dam was constructed across the Conococheague Creek in 1937 in order to provide a water source for the Chambersburg Water Authority (Johnston et al., 2005) (Figure 1). Birch Run Dam stood 20 m high and stretched 213 m across. At capacity the Chambersburg Reservoir inundated 21.7 ha of valley with 6.8 x 10^6 m^3 of water. Average discharge of the Conococheague Creek at the dam site is 0.207 cms (capacity-to-discharge ratio of 7.8). The watershed receives 1,118 mm of precipitation annually. The reservoir is located in the Blue Ridge Physiographic Province of the Appalachian Highlands which consist of low linear ridges, and shallow valleys (Fauth, 1968). Located on the Harpers Formation, the ridges and valleys consist primarily of sandstone, siltstone and shale (Fauth, 1968). The drainage area is largely deciduous forest. The recently exposed valley consists primarily of early colonizing trees and grasses, including thousands of trees planted by the PA Forest Service (Johnston et al., 2005).

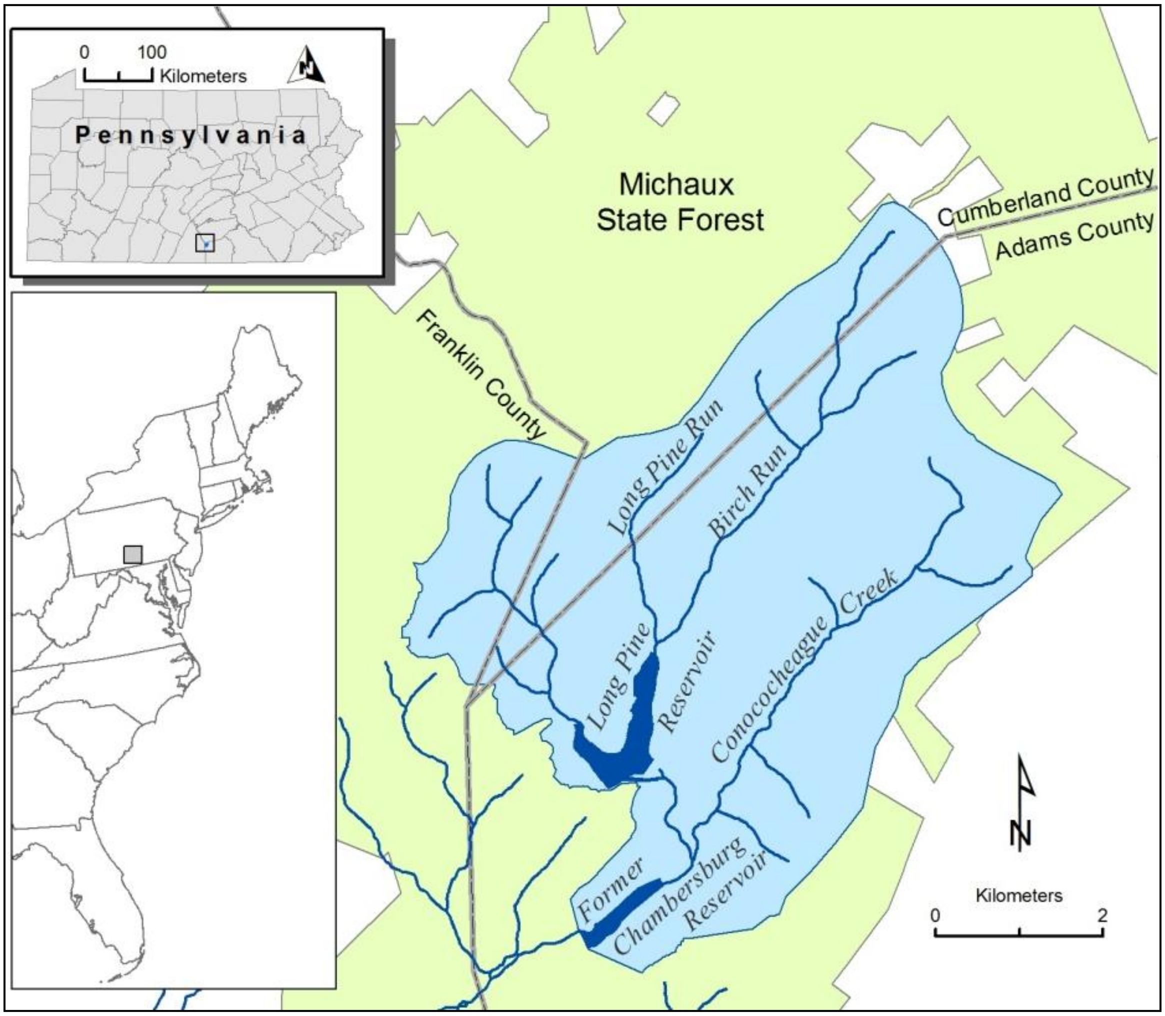

Figure 1. The Conococheague Creek and the catchment for the former Chambersburg Reservoir in Michaux State Forest (Adams County, Pennsylvania). (Hydrologic units from USGS, 2008; Forest boundary from ERRI, 1998; political boundaries from PA DOT, 2008).

In the 1970's the U.S. Army Corps of Engineers Phase I inspection report recommended that the dam owner, the Borough of Chambersburg, correct issues including uncontrolled seepage and a lack of spillway capacity. The spillway was also deemed inadequate because 30 cm of water overtopping the embankment could cause an uncontrolled release of the entire reservoir. Gannett Flemming Inc. was hired to engineer new drainage systems to collect and convey seepage from the foundation of the dam. In 1982 the drainage system was installed and operated successfully until 2005 at the time of the breach. Seepage flow, phreatic levels and changes in piezometric levels in the dam were monitored for two decades prior to removal. Birch Run Dam eventually topped the PA Department of Environmental Protection (DEP) list of high hazard dams in the Commonwealth (PA DEP, 2004). The

Chambersburg Reservoir was drained in 2004 and Birch Run Dam was breached in 2005.

Removal of the Birch Run Dam was unique because so few medium-sized dams have been removed. Eighty-five dams have been removed in Pennsylvania since 1999 and only four were more than ten meters tall (American Rivers, 2007). It is now understood that medium and large dams have a different hydrologic impact on their watersheds when compared to small dams (Graf, 1999). Lessons from the removal of small dams (Cheng and Granata, 2007; Evans et al., 2007) cannot be extrapolated to larger dams. Likewise, similarly sized dams in different physiographic regions will respond to dam removal differently. The former Birch Run Dam site, therefore, is an appropriate example of a medium-sized dam requiring extensive study.

METHODS

In 2007 two TOPCON 200-series total stations were used on opposite shelves of the valley to map the banks of the Conococheague Creek. A benchmark was established in the dam breach with a GPS receiver/antennae set-up because the original benchmark adjacent to the dam did not survive the breach. The length of the valley was surveyed by alternating the location of the total station approximately every 300 meters up the valley. The streambank data were collected by placing the reflector at prominent bank features or the stream path changed.

Field work in 2008 included the use of a total station and an array of Trimble GPS receivers in order to build a digital elevation model (DEM) of the valley and investigate lacustrine deposits. The previous benchmark was re-established in the breach with a Trimble GeoXH GPS receiver attached to a Trimble antenna two meters above the ground surface (77.454067 West, 39.918744 North, 325.3 meters elevation). The total station was used to establish a benchmark on the north bench of the valley, downhill of the former spillway. This location was occupied for both days of field data collection. Staying in one location for both days met two needs: it allowed the group to focus data collection efforts in the region with the densest vegetation and it helped to replace lost data from the first day in the field (Figure 2).

Figure 2. Photograph of the valley formerly covered by the Chambersburg Reservoir. Image is taken from atop the former Birch Run Dam looking east. Conochocheague Creek can be seen on the far side of the valley travelling towards the viewer. The temporary channel that led to the dam outlet works can be seen as a green path leading to the foot of the dam. Large deposits of sand are to the right of the abandoned channel (Author's image, 7 May 2009).

Nineteen transects spaced every 61 meters (200 feet) were measured and marked in 2008 by average distance pacing. Students with GPS rovers walked along these transects in an effort to direct their paths in a roughly parallel course to the face of the remaining dam slope (approximately 105/255 degrees, respectively). Point-location data were collected at the relict shoreline, at the toe of the hillside and at 15-meter intervals (50 ft) along the valley floor. When all of the transects were walked, an attempt was made to capture features on the landscape that were missed due to the stratified sampling procedure. The GPS receivers were loaded with a data dictionary in order to collect qualitative information on the distribution of surface water, vegetation, and soil properties.

Concurrent to the elevation data collection, soil cores were collected in pursuit of a presumed layer of silt deposited during the time of inundation. A one-meter bucket auger was used to retrieve soil samples while preserving the soil layers. A buried 'A' horizon that still contained organic material was presumed to represent the flooding of the valley in 1937. Soil texture was tested in the field in order to determine the height of the silt deposit. The soils teams used the same transects noted above, but collected samples approximately every 45.7 meters (150 ft) of the valley floor, where conditions permitted. Numerous locations could not be tested due to standing water at the surface, sand bars deeper than one meter at the surface and boulders or gravel. The silt investigation was stopped after two complete transects failed to yield a measurable silt layer above the buried organic layer. GPS receivers were used to capture the spatial distribution of deposited silt with the same quality control features as stated above.

Post processing

The elevation data acquired with GPS rovers were differentially corrected and manually processed for quality control in Pathfinder Office GPS software. The nearest accessible base station for differential correction was 84 km (52 miles) from the study site (Loyola CO-OP Germantown, Maryland, five second intervals and 24-hour post times). The correction preserved 8,241 of 8701 positions (94.7%); the lost positions were largely due to high DOP values. None of the features were lost at this time. The quality assurance protocol required at least five satellites for every position; PDOP and HDOP values of less than six for every position; and at least 12 positions for every feature. These values were used to ensure the entire basin was mapped in the two day work schedule. Following quality assurance protocols, the GPS-derived features had a mean horizontal precision of 1.6 m and 2.5 m vertical precision. The remaining 393 features (of a total of 401) were exported into ArcMAP GIS software. Upon merging the GPS and total station datasets in ArcMAP, they were compared for accuracy resulting in the removal of an additional 22 features. A total of 512 data points were used to interpolate the surface of the study area with the Natural Neighbor method. The result was masked with an extent manually drawn to reflect the area formerly mapped as water in a recent topographic map (USGS, 1984).

The silt investigation mapped 39 locations for silt depth. The silt depth data were post-processed with the same protocol. The silt extent was also mapped with the Natural Neighbor method thereby not inferring silt depth beyond the outermost extent of investigation. Where the interpolation was deemed severely unlikely, particularly along steep hillsides, the extent was clipped to best reflect the valley floor. The extent and depths of the silt layer could then be used to estimate total weight and volume of silt deposited during the period of inundation. Soil samples were brought back to the lab for bulk density testing where, upon drying, six samples were measured using the mass displacement method.

RESULTS

The resulting contour map (Figure 3) indicates a gently sloping valley similar to the valley floor up- and downstream of the site. The slope of the valley, 0.0125 degrees, has changed little from the pre-dam topographic map. The relatively flat plain at the head of the former lake can also be seen in a 1994 aerial image when the water level was below capacity and agrees with field observations of a sandy delta.

The goal of the stream restoration was to re-align the channel with the historic path through the breach in the dam and avoid any massive erosion of the legacy sediment or what remains of the dam. In order to meet that goal, two bends in the stream were armored with riprap and plastic to block the stream from meandering back towards the outlet works. The location of the stream in 2007 (Figure 3) has not deviated substantially and generally reflects the goals of the restoration effort.

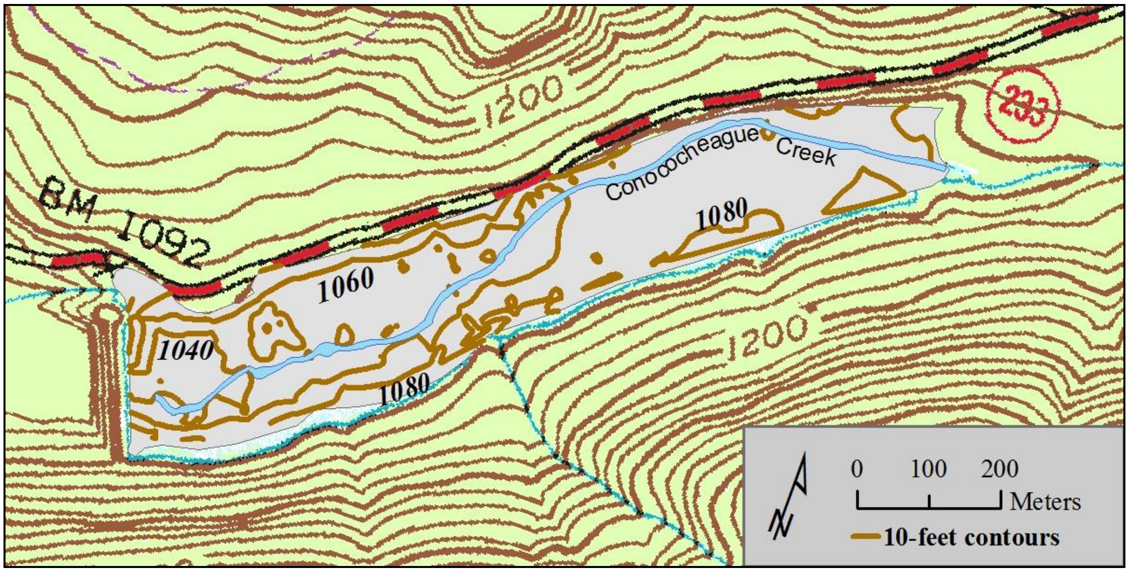

Figure 3. Contour map of the valley formerly inundated by the Chambersburg Reservoir as mapped in June 2008 with the Conococheague Creek as mapped in June 2007.

The extent of silt deposition (Figure 4) indicates that the thickest silt deposits are in the lowest lying area of the basin. The outlet works were on the north side of the dam, which may explain this pattern of deposition. The interpolated extent and thickness of silt indicates a silt volume of 144,199.3 m^3. The average bulk density from the silt samples was 1.29 g/cm^3. The amount of silt deposited in the valley during the life of the reservoir was calculated to be 189,628.7 metric tons. A spike of thick silt 420 meters up the valley surprised the silt collection team because silt layers were thinner with each successive transect. This deposition pattern may indicate an area of slower moving water. Further investigation into the currents of lakes would be required to explain this pattern.

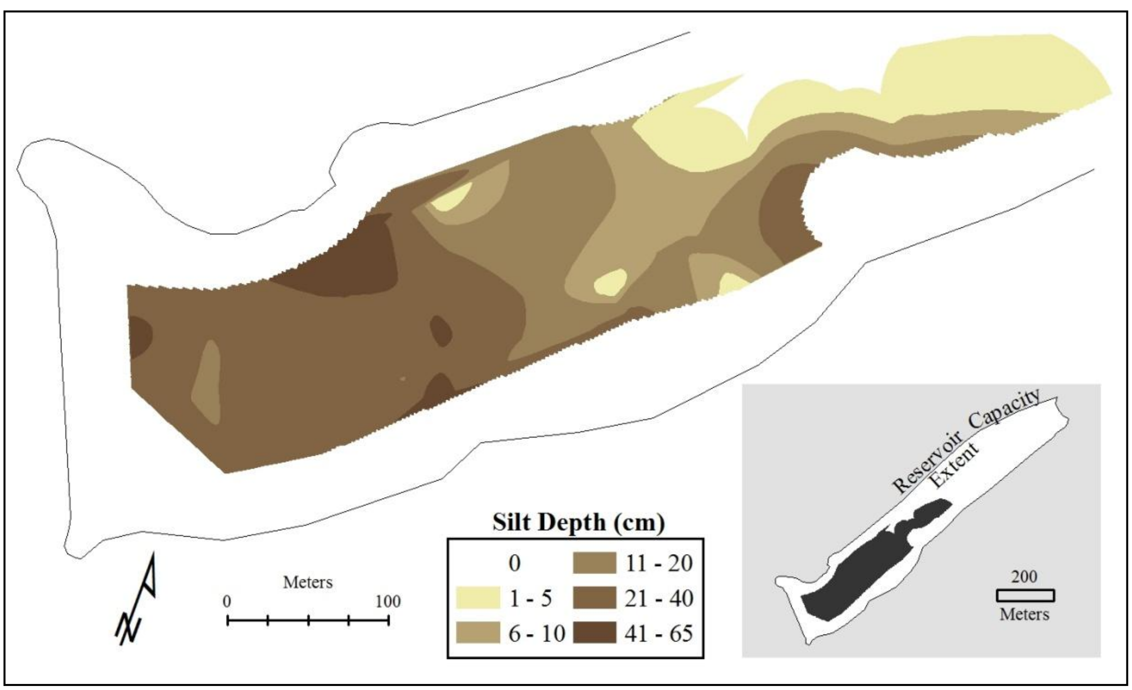

Figure 4. Map of the interpolated thickness of silt measured in June 2008.

DISCUSSION

The relatively shallow depths of silt indicate that the Conococheague Creek entrains low volumes of suspended material and the reservoir had a low trapping efficiency. The capacity of the reservoir did not change substantially over the nearly seven decades of use. Based on that criterion, the Birch Run Dam was a good location for a water supply reservoir (Morris and Fan, 1997). Mapping the deposited silt is the type of baseline information that may have become lost if not observed and recorded shortly after the removal of Birch Run Dam. The distribution of silt in the valley may be crucial information in understanding how the shape and planform of the Conococheague Creek evolve. As a cohesive layer in the banks of the stream channel, these areas will be more resistant to lateral migration compared to the upstream areas dominated by deltaic deposits of coarse, sandy material.

The process of collecting the silt samples exposed a large number of sand bars near the dam (Figure 2). In some cases these deposits were more than a meter deep. The sand deposits were not present after the initial drainage of the reservoir (personal communication, Timothy Johnston, Gannett Flemming engineer). These deposits may be material that was scoured from the upstream channel. When the reservoir was empty yet the dam still intact a ten-year, 24-hour storm event occurred (63.5 mm, 17.September.2004) which partially re-filled the reservoir. Further research into the depositional history of the bars may determine if they were deposited during this storm. If so, the removal of the material from the channel without harm to downstream habitat or infrastructure can be considered a success. Use of the stream's power to move the lacustrine material rather than dredging with heavy machinery is not an entirely new idea (Majors et al., 2008); success here could be evidence for a sediment management alternative to be used on future sites. The presence and depth of these sand deposits may have gone unnoticed without students going into the field and observing the site.

The contour map produced by this research indicates that the lowest lying area in the former basin is in the vicinity of the abandoned channel leading to the dam outlet works (Figure 2). This area now hosts an apparent wetland with many small streams and pools of standing water (field notes indicate widespread surface water in this area following rainy periods, early June 2008, as well as dry periods, July and August 2008). The stream channel and other significant land features do not appear on the contour map because of the sampling methodology. A coarse sampling procedure was used in order to map the elevation of the entire former basin in two days. In an attempt to capture the many features that were not along a transect, a team of students with stadia rods were asked to find those features in order to map them with the total station. By not specifically targeting the stream for study, it was overlooked in the collection of elevation data for the DEM.

Learning in the Field

Participation in a field methods course teaches students observation skills, the value of first-order data, and the ethics of data collection (Hart, 2001). Realistic mission planning was likely the most tangible lesson learned for the students participating in this field research. Some students craved the idea of “mapping where no man has mapped before,” others wanted to learn new skills, while still others simply wanted to measure and map everything under the sun. Hupy et al. (2005) recommend limiting the size of study sites for field courses to avoid this problem. We students ignored that advice in the classroom. We then learned our lesson when after the first of two days in the field we were not even close to our initial goals. We learned contingency planning when plans needed to be amended based on conditions in the field. As a group of students we were able to problem solve at every stage of the procedure and in so doing, likely learned from one another (Haigh and Gold, 1993). These skills are best learned through field experience (Zelinsky, 2001) and will continue to be useful for students as they enter the public and private workforce (Solem et al., 2008).

CONCLUSION

In consecutive summers students at Shippensburg University participated in a field techniques course that used the former Birch Run Dam site as its classroom. While dams continue to be removed across the United States, there are more questions than answers regarding the long-term hydrological impacts from these projects. In order to better plan and implement dam removals in the future, it is critical that we learn from the successes and failures from past projects. This research begins to establish a baseline dataset for future study of the Conococheague Creek at the former Birch Run Dam. The lateral migration of the Conococheague Creek will be subject to the cohesive materials deposited near the dam during the period of inundation. Knowledge of the distribution of this material will aid in that understanding. Mapping the distribution of coarse material deposited in the delta region will further our understanding of stream channel evolution post-dam removal. Mapping the terrain at the former Birch Run Dam exposed students to the challenges of mission planning in a way that could not have been replicated on campus. The former Birch Run Dam site was and should continue to be used as a tool for teaching students the challenges and value of field research.

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