Factors Affecting Karst Spring Turbidity in Eastern Washington County, Maryland

David K. Brezinski, Johanna M. Gemperline, Rebecca Kavage Adams, David W. Bolton,
Maryland Geological Survey, 2300 St. Paul Street, Baltimore, Maryland 21218

ABSTRACT

Infrequent and episodic turbidity events within the karst spring at the Albert Powell Trout Hatchery in Maryland's eastern Great Valley threatened late winter fry populations. Turbidity events in early winter 2016-2017 prompted detailed geologic, dye tracing, and resistivity studies. The hatchery spring lies at the juncture of a northeast trending thrust fault and a northwest trending cross strike fault. Dye tracing study along these structures produced mixed results. Fluorescein dye, injected 1,500 m north, and upstream of the spring was used to test the conductivity along the Beaver Creek fault and Beaver Creek. This dye was not conclusively identified at any of the surrounding recovery sites. Rhodamine WT injected more than a kilometer northwest of the spring, and along the trend of the cross fault, was detected at both the hatchery spring and surrounding recovery sites after about one week. 2D resistivity studies attempting to identify subsurface voids along the cross-fault trend show a high resistivity anomaly, possibly indicating an air-filled void and warrant further investigation. The study suggests that while faulting plays a role in direction of ground water movement, turbidity events appear to be most prone during periods of low flow.

INTRODUCTION

The Albert Powell Hatchery is located along Beaver Creek near the eastern edge of Maryland's Great Valley. The Hatchery raises over 250,000 rainbow trout each year for stocking of the State's freshwater streams. A karst spring that is the main water supply for the hatchery has a flow of up to 4,000 gallons per minute. Since the hatchery's founding in 1949, infrequent turbidity events have killed or threatened several late winter fry populations. Two such episodes, in November, 2004 resulted in significant mortality to young fish (Duigon, 2007). On December 5, 2016, the Hatchery spring experienced a major turbidity event that did not result in fish mortality. A second smaller turbidity event was recorded on January 16, 2017. Following the December 2016 event the Maryland Geological Survey and the Maryland Department of the Environment (MDE) identified two possible surface sources of sediment input nearby. The dye tracing portion of this study was conducted to evaluate if either of the sites was hydrologically connected to the hatchery spring. Additionally, an electrical resistivity study along the northwest-trending cross fault was conducted to identify any subsurface voids along that structure.

Figure 1. Albert Powell hatchery karst spring during normal flow (left) and during the December 2016 turbidity event (right).

LOCATION

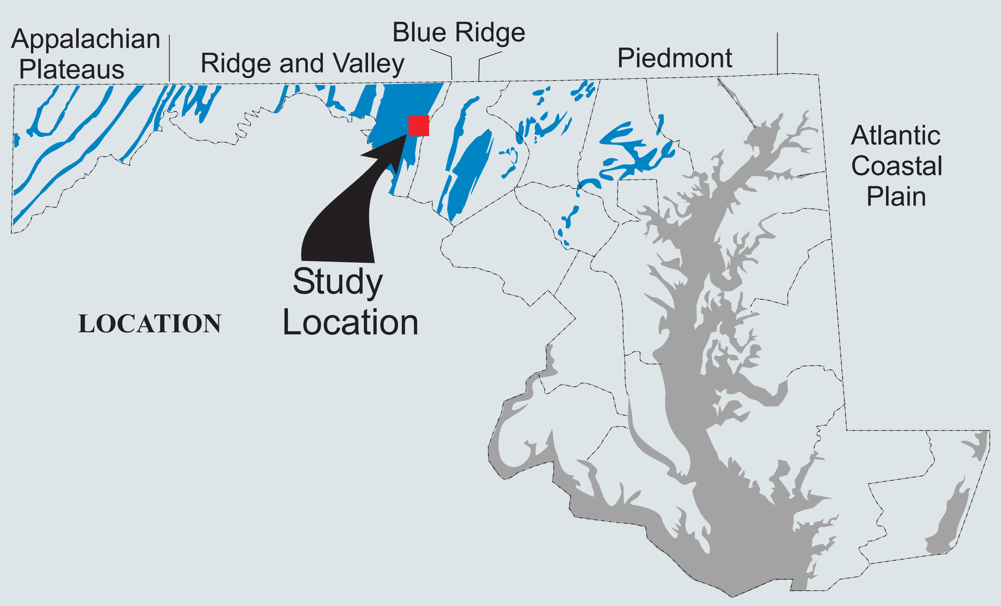

Figure 2. Karst regions of Maryland (blue areas) and location of the Albert Powell hatchery. Geomorphic regions from Reger and Cleaves (2008).

REFERENCES

Brezinski, D.K. 1992. Lithostratigraphy of the western Blue Ridge cover rocks in Maryland. Maryland Geological Survey Reports of Investigation 55, 69 p.

Brezinski, D.K., Bell, S.K. 2009. Geologic Map of the Funkstown Quadrangle, Washington County, Maryland. Maryland Geological Survey Digital Geologic Map, scale 1:24,000.

Brezinski, D.K., Fauth, J.L. 2009. Geologic Map of the Myersville and Smithsburg Quadrangles, Frederick and Washington Counties, Maryland. Maryland Geological Survey Digital Geologic Map, scale 1:24,000.

Duigon, M.T. 2007. Phase 2 study of the area contributing groundwater to the spring supplying the A.M. Powell State Fish Hatchery, Washington County, Maryland. Maryland Geological Survey Open-File Report No. 2008-02-18, 32 p.

Reger, J.P., Cleaves, E.T. 2008. Physiographic map of Maryland. Maryland Geological Survey, scale 1:250,000.

Zhou, W., Beck, B.F., Adams, A.L. 2002. Effective electrode array in mapping karst hazards in electrical resistivity tomography. Environmental Geology 42: 922-928.

Zhu, J., Currens, J.C., Dinger, J.S. 2011. Challenges of using electrical resistivity to locate karst conduits—a field case in the Inner Bluegrass Region, Kentucky. Journal of Applied Geophysics 75: 523-530.

GEOLOGY

The Albert Powell spring that supplies water to the hatchery is located near the eastern edge of the Great Valley karst region. This is the largest karst region in Maryland. The spring lies at the junction of two mapped fault traces. Stretching northeast from the spring, a thrust fault termed the Beaver Creek fault places Lower Cambrian carbonate and clastic rocks of the Waynesboro Formation over shaly limestone of the Middle Cambrian Elbrook Formation (Brezinski, 1992). Near the hatchery, the Beaver Creek fault is truncated by a northwest trending unnamed high-angle cross-strike fault that offsets the Waynesboro outcrop belt by approximately 900 m. This cross-strike structure has been portrayed as passing directly through the APH spring and continuing up a karst valley to the northwest of the spring (Figs. 3, 4). Near the western edge of the study area a high angle fault termed the Eakles Mills fault has been interpreted as intersecting the cross fault, and was initially believed to be in karst connectivity with both the cross fault and Beaver Creek to the southwest of hatchery (Fig. 3). Based on these structural factors dye tracing and resistivity studies were conducted to determine if either of these structures influenced turbidity within the Hatchery spring.

Two quarries, Beaver Creek West and East, lie approximately 0.5 km northeast and east of the APH, respectively (Fig. 3). Beaver Creek West has been inactive since 2008. Beaver Creek East, although currently operating, lies east of a groundwater divide that follows the trace of the Beaver Creek Fault, which is believed to act as a barrier to groundwater flow.

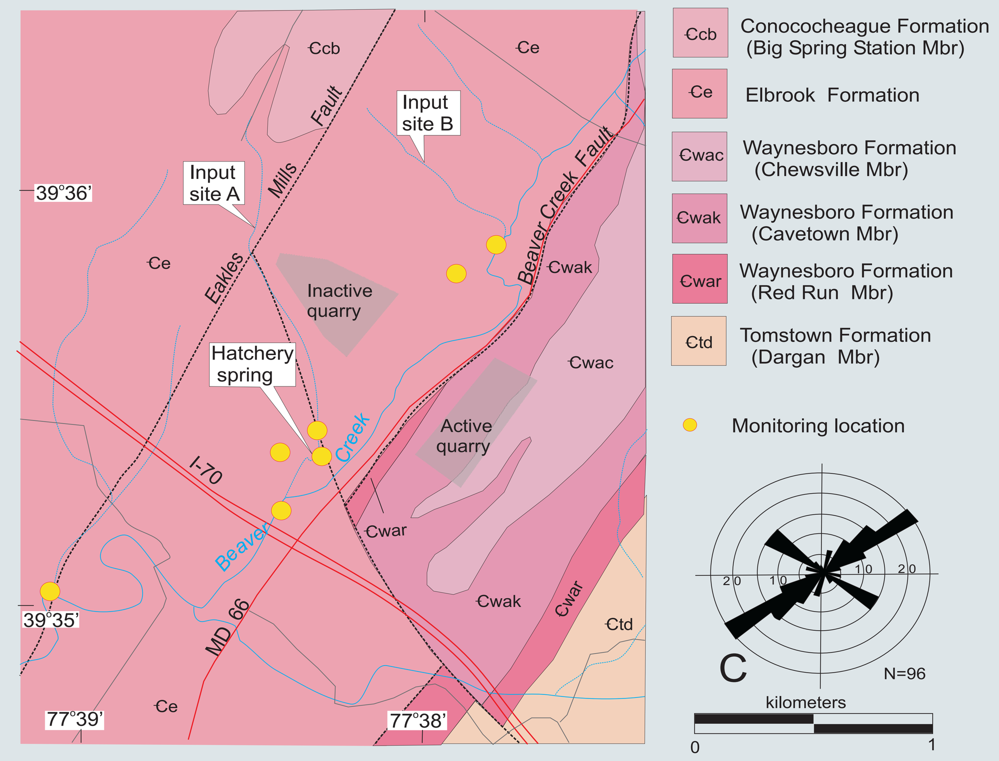

Figure 3. Geologic map of the area surrounding the Albert Powell hatchery (after Brezinski and Bell, 2009 and Brezinski and Fauth, 2009).

Figure 4. Interpreted trace of cross fault with respect to the Albert Powell hatchery spring (photo is looking northeast from hatchery).

DYE TRACING

Two injection sites were chosen for the dye tracing study (Fig. 5). At the first site 1 kg of fluorescein disodium salt was injected in recently formed holes and flushed with 600 gallons (~2.3 cubic meters) of water. This location, approximately 1,500 m NNE of the main spring, had been filled with reclaimed earth in order to make the field acceptable for agriculture.

At the second site, 1 gallon (~.004 cubic meters) of rhodamine WT dye was injected into a pool along an intermittent streambed 1,000 m NNW of the main spring. A total of approximately 600 gallons (~2.3 cubic meters) of fresh water was used to flush the dye.

All water samplers and eluted charcoal-traps were analyzed with a Turner Designs Trilogy™ Fluorometer with modules for fluorescein and rhodamine WT. The fluorometer was calibrated with 0.1 parts per billion (ppb), 1 ppb, and 10 ppb standards for both dyes. Calibrations were checked every day prior to analysis; the fluorometer was recalibrated as necessary. Water samples were pipetted directly into cuvettes, which were placed in the fluorometer for analysis. Charcoal traps were emptied into plastic cups and rinsed with deionized water. Approximately 12 mL of a solution of 95% isopropyl alcohol, 5% ammonium hydroxide, and supersaturated with potassium hydroxide flakes was placed in each cup with the charcoal to desorb the dye from the charcoal.

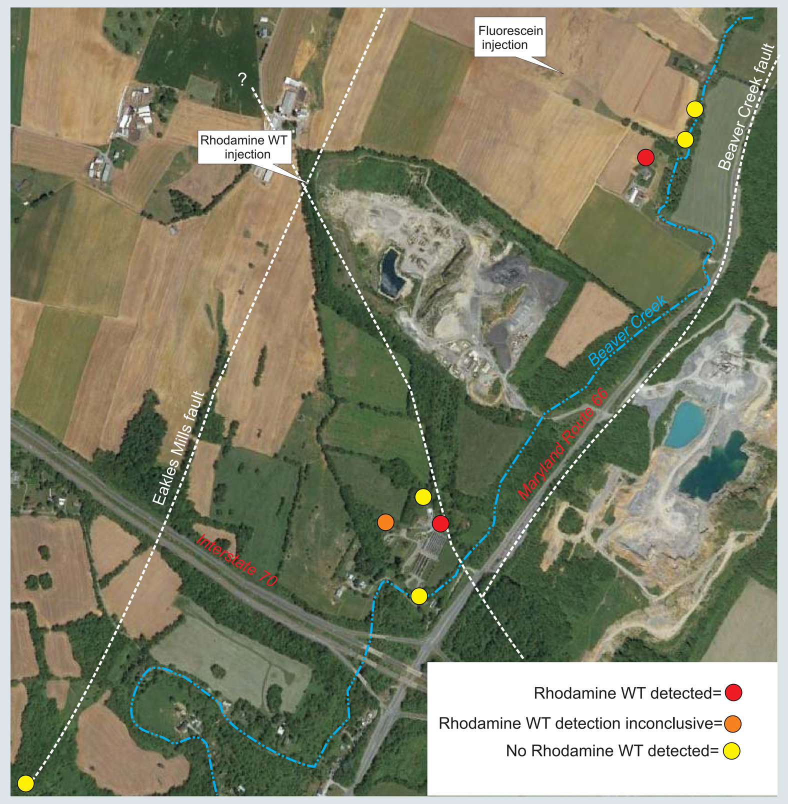

Figure 5. Google Earth image of Albert Powell Hatchery areas and locations of dye trace injection and monitoring sites.

RESULTS

Rhodamine WT was detected in the charcoal traps at several locations (Fig. 6), but there was no rhodamine WT detection at numerous other sites. In general, low levels of rhodamine WT in water below 1 ppb do not lead to definitive detections of rhodamine WT in the eluted solution. However, higher levels of rhodamine WT in water lead to noticeably increasing levels of rhodamine WT in the eluted solution.

Measurable fluorescein readings from the monitoring sites were inconclusive.

The results indicate that under the conditions present during the study, the karst valley, along which Rhodamine WT was injected and which trends northwest of the hatchery main spring, is hydraulically connected to the main spring on hatchery property, to the farmhouse well, and possibly to the hatchery well (Fig. 6).

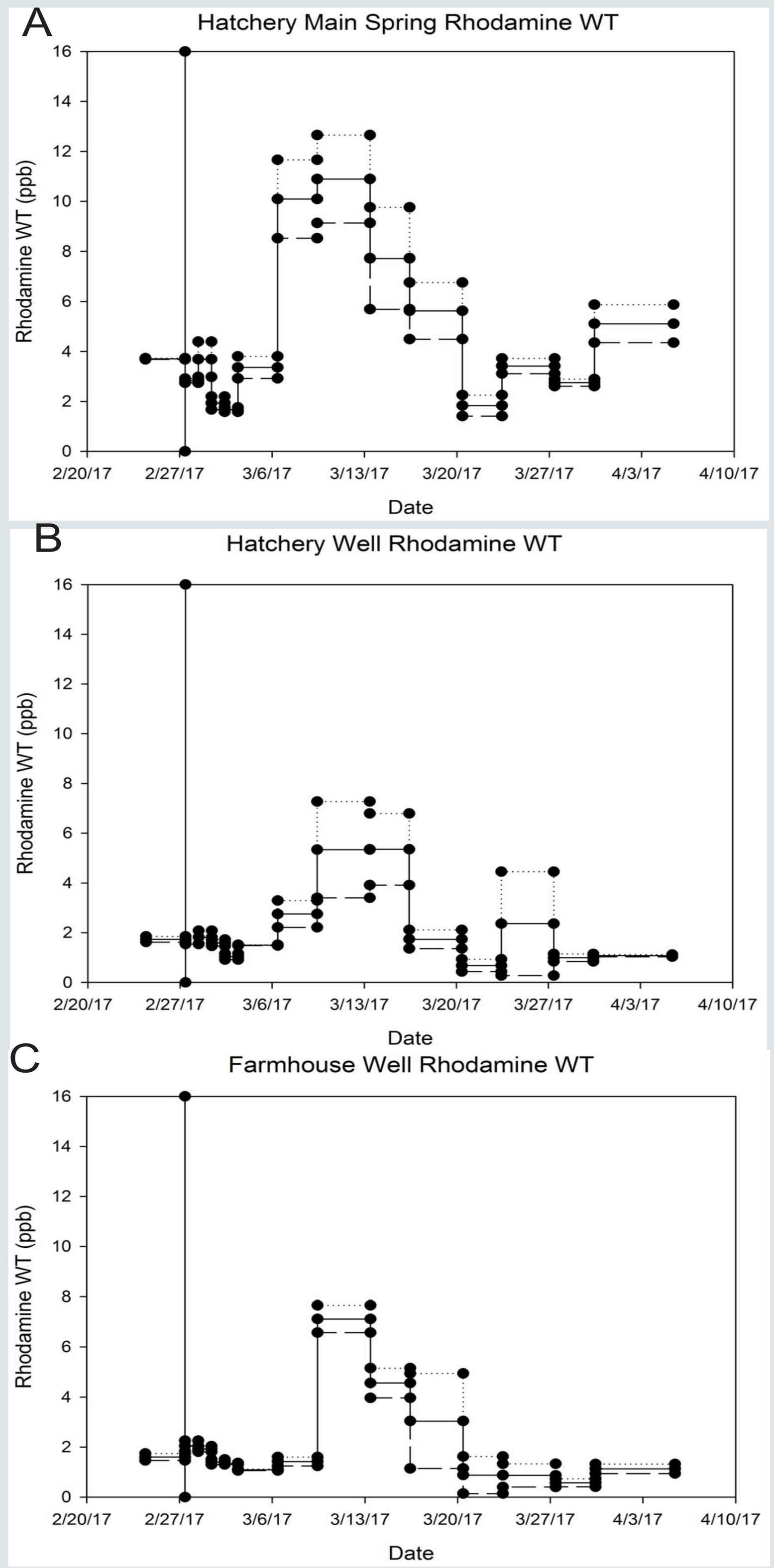

Figure 6. Timing of concentrations of rhodamine WT in (A) hatchery spring, (B) toilet tank at spring, (C) farmhouse well.

ELECTRORESISTIVITY

Results of the initial ER survey (Fig. 7A) show a low resistivity layer near the surface corresponding to a saturated soil. A highly resistive area occurs in the middle of the profile from 6-14 m in depth and most likely indicates an air-filled void (values of 10,000 Ohm-m) and dry limestone and dolomitic bedrock. The Houpt Cave entrance is 80m south and it is likely this void that continues to the north and is visible on ER Survey 1.

Expanded ER and induced polarization (IP) surveys were performed 50m north using 2D (Fig. 7B) and quasi-3D processing (Fig. 7C) to increase the depth and width of the imaging and better constrain the location and orientation of the void imaged in ER Survey 1. A resistive zone appears in the middle of the profile at 6-30m depth, suggesting the anomaly in ER Survey 1 trends north/northeast underneath a visible ridge, is larger and deeper than was first imaged, and decreases in size to the northeast. However, the highest resistivity values range from 3082-4690 Ohm-m, indicative of dry limestone bedrock but no longer an air-filled void. It dips southeast (following bedrock orientation) and is broken by a northwest dipping zone of lower resistivity values that may be fractured bedrock at northeast striking joints. Corresponding IP surveys show highly chargeable material from 30-40m in depth below the bedrock, which is indicative of a clay-rich zone, possibly a clay-filled void.

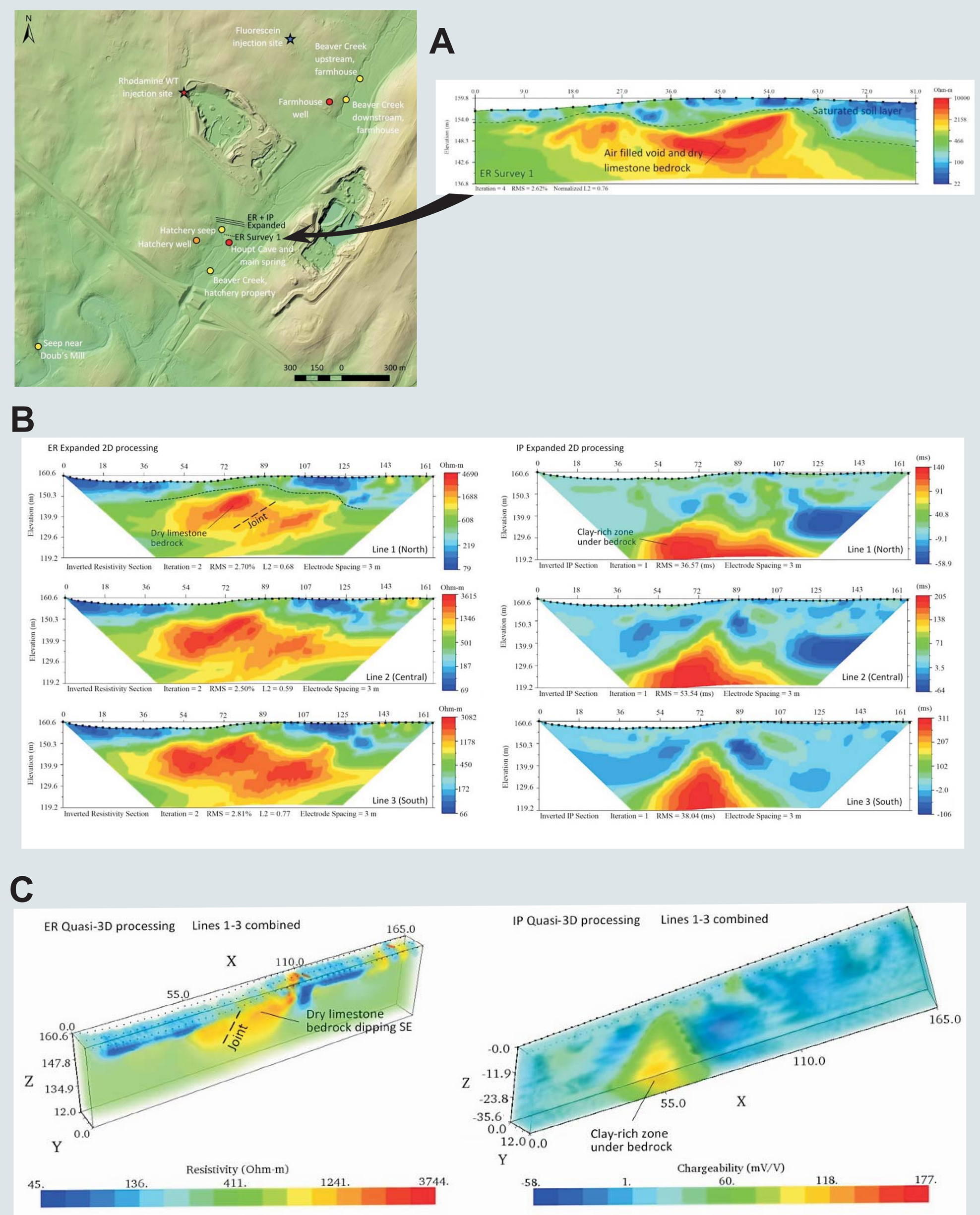

Figure 7. Resistivity at Albert Powell. A. LiDAR-derived location map of ER surveys relative to the Hatchery and dye injection sites. Profile of ER survey 1 showing highly resistive anomaly. B. Expanded ER and IP surveys 50 meters north of ER Survey1. A resistive zone (red in ER images to left) occurs above a highly chargeable zone (red in IP images to right). C. Quasi-3D processing of ER (left) and IP (right) survey lines 1-3.

SUMMARY

Rhodamine WT recovery sites suggest karst connections along the intermittent stream valley coincident with the large cross faults that trends through the Hatchery property (Fig 5). In contrast, fluorescein was not definitively recovered at any monitoring locations. This suggests that the reused soil site where this dye was injected likely played no role in the turbidity events.

The Maryland Geological Survey also reviewed precipitation data and the quarry blasting schedules, and found no evidence to associate the turbidity events with either precipitation or blasting events. As a proxy for determining water levels in the shallow aquifer, stream flow for eastern Washington County was examined. The stream flow, as recorded by a gauging station downstream from the hatchery (Fig. 8), illustrates that the January 2016 through January 2017 records suggest diminished surface water flow. Concomitantly, the hatchery spring was flowing at approximately 1,900 gallons per minute (~432 cubic meters per hour).

The coincidence of the 2004 and 2016-17 turbidity events with late fall and early winter low spring and surface water flow indicates a proclivity for the occurrence of these events during periods of low precipitation.

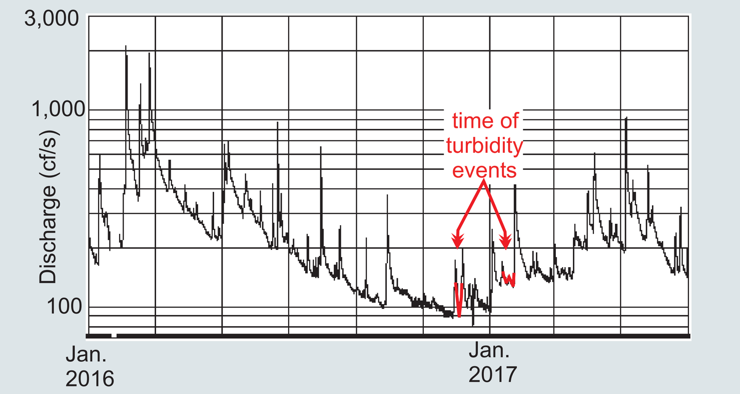

Figure 8. Timing of turbidity events at Hatchery and streamflow of nearby Antietam Creek for the period from January 2016 to July 2017. Turbidity events appear to coincide with periods of reduced stream flow. Data from USGS gauging station 01619500.