Tips on Investigating Stream Dewatering from Underground Mines

U.S. Office of Surface Mining Reclamation and Enforcement
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Investigation of stream dewatering incidents with regard to underground mining activities can be challenging for a variety of reasons. Not the least of which is there is often a lack of pre-mining data with which to compare to present conditions and, in the Appalachian Region, apparent losses related to underflow along short stream reaches can be naturally occurring. However, there are a variety of techniques and tricks of the trade that have been shown to be useful in these types of investigations. The ultimate goal is to determine: (1) If there is truly a problem and (2) where it has been determined dewatering occurred, is the problem mining-related?

Definition of a stream dewatering problem: In simplest terms, stream dewatering is the loss of water in the stream that was present prior to some event, mining, or other activity. There are varying degrees of dewatering including but not limited to: Complete dewatering, partial flow loss, seasonal dewatering, loss of baseflow, and flow loss for stream reach sections with partial to complete recovery beyond the mining impact area. As with any hydrologic investigation before you start work, you initially need to define the scope of the problem in terms of where has the alleged dewatering occurred and determine the nature, level, and extent of dewatering.

Data Collection: Obviously you need to gather any and all information and data that pertain to the problem at hand. Not all of the information that you amass may help you answer the question, but it should be considered during the investigation to ascertain its possible impact. Information to obtain includes but not limited to:

1. Stream flow data – up gradient of the impacts of mining, through the mined area, and down gradient of the possible impact zone. If available, historic (pre-mining) and during mining data are essential. For present conditions, gather your own data.
    a. Use a flow meter and the cross sectional area method to determine the discharge rate at several points along the reach.
    b. If the stream is relatively small, a portable flume or weir may be employed.
    c. If no other means to determine flow are available, there are surface float/cross sectional area methods available in the published literature. This method should only be used if there is no other way to measure the flow.
    d. Note: Visual flow estimates are notoriously inaccurate and will likely be unusable in any litigation.
2. U.S.G.S. stream gauging stations provide additional data including historic and recent discharge information on numerous streams. The U.S.G.S. also has modeling applications that will allow you to calculate the expected flow rate of virtually any stream reach in the country under varying conditions (e.g., 7Q10).
3. Climatic data can be obtained through the National Oceanographic and Atmospheric Administration (NOAA), the Weather Underground, local airports, Army Corps of Engineers operated dams and locks, many waste water treatment plants, and often the mining company itself.
    a. Local precipitation data. These data include historical norms, data for the period of mining, and since mining occurred. Establish if the antecedent precipitation was significantly above or below normal.
    b. Palmer Drought Severity Indices data bracketing the mining period and up to the time of the investigation. Those data will allow determination if the area was under normal conditions or an unusual wet or dry spell (Figure 1) and are available through NOAA and other organizations.

c. Temperature data – Establishing the timing of melting of snow packs, when the ground freezes or thaws can be important as to stream and baseflow conditions.
d. While technically not climatic data, assessment of the active growing season (leaf on verses leaf off) should be included with you evaluation ground-water recharge.

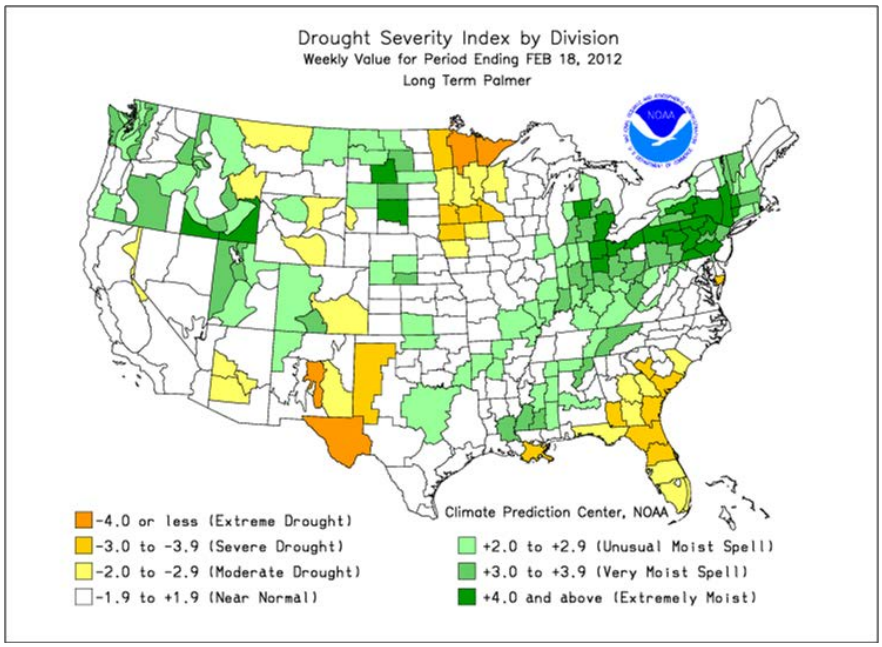
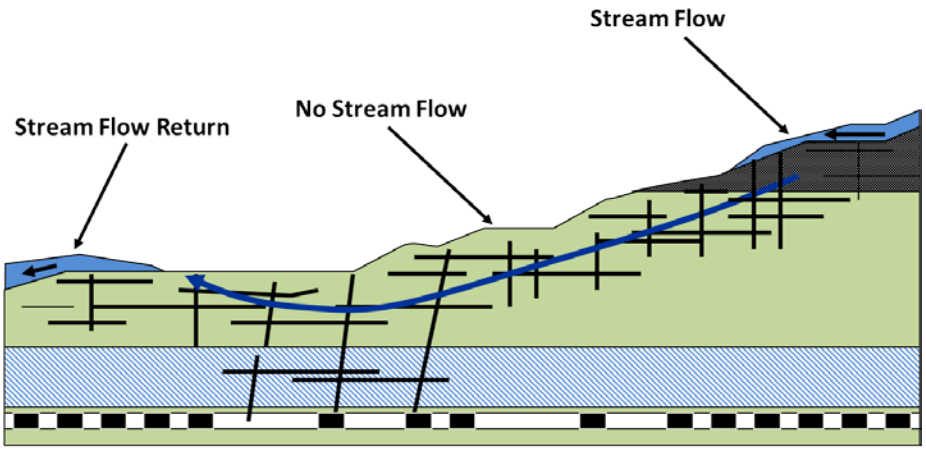


Figure 1. Example Palmer Drought Severity Index map.

4. Mining Information:
    a. Where mining has occurred with respect to the stream: directly beneath, adjacent but within the possible angle of draw, adjacent and outside of the angle of draw but within the possible angle of dewatering.
    b. When the mining occurred under and/or adjacent to the stream(s) being investigated. Timing of the problem with respect to mining is often a major component of an investigation.
    c. Types and degree of mining in areas near the stream: First mining, second mining, retreat mining, or longwall mining as well as multiple seam mining. Is the extraction rate such that subsidence is anticipated during the period the stream exhibited problems? If 50% or less of the coal is removed, subsidence may not be expected for years and possibly decades after mining has ceased. Pillar sizes, overburden thickness, seat rock strength, and other factors can impact how soon after mining subsidence may occur.
    d. How deep are the mine works? If the mining is shallow (e.g., less than 150 feet) there may be considerable direct loss of the stream water to the mine. If the mining is much deeper (e.g., 400 feet or greater) stream water loss may be due to increased underflow facilitated by dilation of shallow fractures (Figure 2).
    e. Overburden lithology. Certain rock types are more conducive to causing subsidence-related problems in the stream. For example, hard fractured sandstone immediately beneath the stream can assist underflow due to considerable fracture dilation. Whereas, overburden with substantial amounts of clay-rich strata (i.e., shales, siltstones, claystones) tend to behave somewhat plastically and can be self healing which may diminish the impacts of mine subsidence on stream waters.
    f. Consider in-mine conditions in the areas beneath the stream. If it is possible to go into the mine sections that underlie the stream, do it. Regardless, if you see conditions that indicate mining may have impacted the stream or not, this information is relevant to the investigation.

5. Hydrogeologic information
    a. Presence or absence of lineaments. Are there pre-existing major fracture zones, indicated by the presence of lineaments, that play a pivotal role in ground-water movement and how would mining impact them? Lineaments are indicative of significant fracturing of the strata which frequently extend to at least the depth of the mine (Phillipson and Tyrna, 2002). Accentuation or dilation of these fractures can be caused by mine subsidence. When intersected by the mine workings, these fracture zones are frequently areas of poor roof conditions and ground water inflow.
    b. Land cover/use changes in the watershed. These changes can greatly impact recharge rates to aquifers that in turn feed the stream via baseflow. Removal of forest cover will reduce evapotranspiration, thus will increase recharge rates. Whereas, reforestation or urban development will reduce recharge rates, thus reduce the amount of ground water available which can become stream baseflow.



Downstream cross sectional view of post-mining stream. Note the dilated fractures facilitating subsurface flow.

Figure 2.

    c. Stream geomorphology – topographic location, substrate material(s), stream order, etc. These conditions will impact the streams characteristics before and after mining. For example, upland first order streams in the Appalachian region are known to have apparent losing reaches under natural conditions. Larger order streams also can exhibit losing conditions as they near major rivers while descending from adjacent highland areas.
    d. Examine any shallow wells adjacent to the stream. Have they experienced dewatering during the time period that the stream has been perceived to be impacted? Dewatering impacts to surface water are generally expressed in the ground-water system as well. Streams are considered a surface expression of the water table. So, these wells can serve as monitoring wells and a secondary indication that stream dewatering has occurred.
    e. Does the stream itself exhibit signs of subsidence impacts? Such as: flooded troughs over longwall panels, buckling of the substrate in compression stress zones, dilated fractures or the formation of new fractures in exposed bedrock substrate, glide or riffle zones becoming flooded areas and/or other dramatic changes to the stream morphology (Figures 3 and 4).

Other Information:

- Just because the stream is outside the angle of draw, does not mean that it cannot be dewatered by mine subsidence. The area within the angle of draw is the zone of physical movement of the strata.

The angle of dewatering can be considerably wider. The angle of dewatering has been observed up to a 72° angle from the edge of a longwall panel in relatively shallow cover of about 150 feet (Dixon and Rauch, 1990). The angle of dewatering is analogous to the cone of depression created by a pumping well; only the longwall panel is a large rectangular ground-water sink rather than a relatively small diameter well.

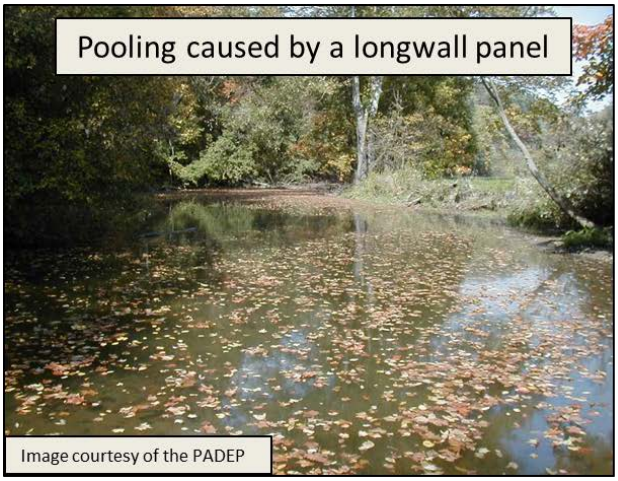


Figure 3.

Figure 4.

- Various geophysical techniques can be used to assess stream dewatering. Terrain conductivity works best for highly conductive (e.g., contaminated) water. Resistivity surveys likewise work well when the water is highly conductive. Very low frequency (VLF) detection instruments can be used to locate water-filled fractures. Water-filled fractures can produce secondary electromagnetic fields from VLF waves used for naval communication systems which also travel inland from the sources.
- Where the stream loss is primarily underflow, stream grouting has been employed to force the water back to the surface (Figure 5). Grout mixtures include cement, bentonite, and water activated expanding polyurethane. Optimal grouting zones are usually identified by geophysical techniques and/or stream flow gauging.

Figure 5. Use of polyurethane grout for stream sealing.

- It is helpful when comparing flow data for the stream that may be impacted by mining to a control stream reach to normalize the data into comparable units. For example, it is suggested to divide the flow rate by the contributing drainage area, so you may have units of gallons per minute per acre (Figure 6). This data normalization permits a direct comparison and a better means to determine if the mine has partially dewatered a specific reach. Decreased flow per unit area is an indication that the stream may be experiencing dewatering.

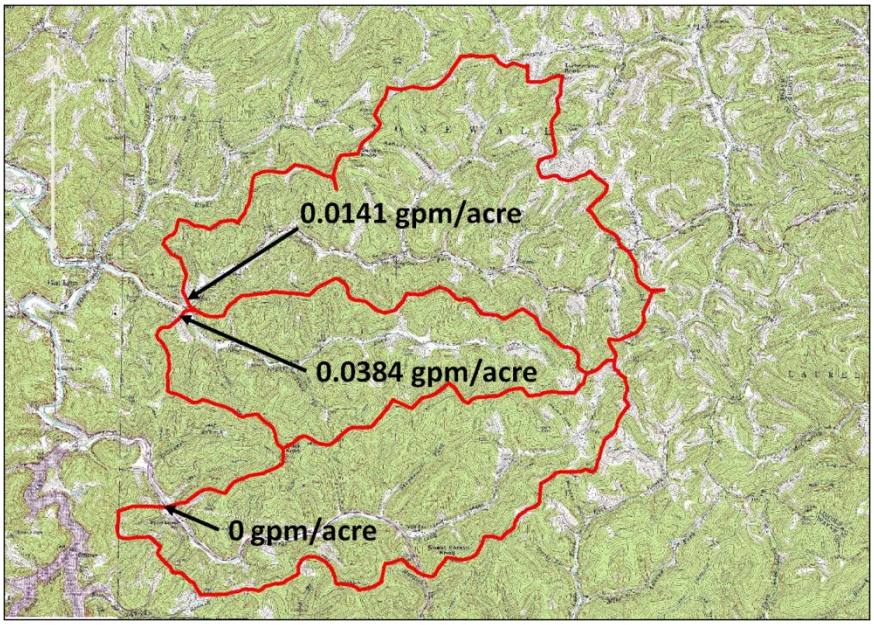


Figure 6. Normalized flow rates from three separate watersheds.

- The same normalization technique can be used at various points along the targeted stream reach to identify losing sections (Figure 7). A graph of raw flow data for stream would be expected to increase in flow moving downstream as the drainage area increases. Flow data normalization allows the identification of losing sections even if the stream flow continues to increase down gradient. Normalization may reveal that the flow does not increase at a rate that it should.
- Some studies have shown that stream healing may occur where the substrate alluvium has a high percentage of fine-grained sediment (Tieman and others, 1992; Reed and Rauch, 2001). Fractures in the rock opened up in the stream by subsidence eventually fill in with sediment and lose some degree of the permeability. This self-healing is less prevalent and may take longer in streams with higher percentages of sand-sized or larger material.

If additional information is required, contact any of the hydrologists at the Appalachian Regional Office or you can consult the following references:

Dixon, D.Y. and Rauch, H.W., 1990. The Impact of Three Longwall Coal Mines on Streamflow in the Appalachian Coalfield, In the Proceedings of the 9th International Conference on Ground Control in Mining, Morgantown, WV, pp. 169-182.

Johnson, K.L., 1991. Effects of Longwall Coal Mining on the Hydrology of Two Appalachian Stream Valleys, In the Proceedings of the 5th National Outdoor Action Conference on the Aquifer Restoration Groundwater Monitoring and Geophysical Methods, Las Vegas, NV, pp. 1111-1125.

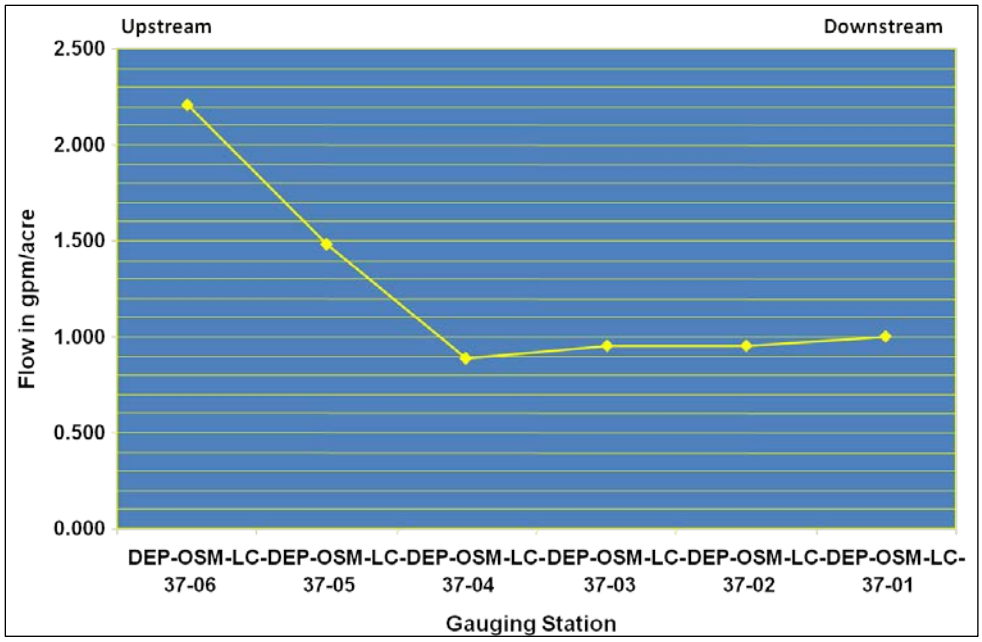


Figure 7. Stream exhibiting loss of flow from station 37-6 to 37-04 as it crosses an undermined area.

Kendorski, F.S., 1993. Effect of High-Extraction Coal Mining on Surface and Ground Waters, In the Proceedings of the 12th Conference on Ground Control in Mining, Morgantown, WV, pp. 412-425.

Owsiany, J. A. and B. A. Waite, 2001. The Response of a High Order Stream to Shallow Cover Longwall Mining in the Northern Appalachian Coalfield. In the Proceedings of the 20th Conference on Ground Control in Mining, Morgantown, WV, pp. 149-156.

Phillipson, S.E. and P. L. Tyrna, 2002. Lineament Analysis: Identification of Structural Controls on Ground Instability in Surface and Underground Mines, SME Pre-print 02-011, 2002 SME Annual Meeting, Phoenix, AZ, 8 p.

Reed, C. and H. Rauch, 2001. Mining Induced Streamflow Loss for Spruce Laurel Fork in Boone County, West Virginia, In the Proceedings of the 2001 National Association of Abandoned Mine Land Programs Annual Conference, Athens, OH, 23 p.

Tieman, G. E., H. W. Rauch and L. S. Carver, 1992, Study of Dewatering Effects at a Longwall Mine in Northern West Virginia, In Proceedings of the 3rd Subsidence Workshop Due to Underground Mining, Morgantown, WV, pp. 214-221.