APPENDIX G: Comprehensive Assessment of Groundwater Case Studies

G.1 - Case Study: Hydrologic Monitoring Data in Stream Recovery Evaluation in Crafts Creek

As outlined in Section 7, groundwater and surface water are tightly coupled in terms of hydrologic balance, so an impact to one following subsidence will affect the other. However, in the Stream Recovery Evaluation (SRE) reports provided to the University, hydrologic monitoring report (HMR) groundwater data or other groundwater data are not used to evaluate flow recovery. Here, the University examines several SRE reports to demonstrate how groundwater data *are* used and further, how they *might be* used.

PADEP technical guidance document number 563-2000-655 (TGD) "Surface Water Protection – Underground Bituminous Coal Mining Operations" requires submission of mining plans prior to mining. For full extraction mining, mining plans should consider all undermined streams at risk for potential flow loss. The TGD recommends that flow in these streams be measured monthly beginning 2 years prior to undermining; weekly "commencing six months prior to undermining the area of concern."; and daily measurements "commencing two weeks prior to undermining" of the stream. After mining, if flow loss is not detected, measurements should continue "until the longwall face has progressed a distance equal to the cover thickness beyond the area of concern." However, if flow loss occurs, the TGD requires "daily observations or measurements commencing from the date of the observed loss and continuing until flow fully recovers or is fully restored or until underground mining operations are determined not to be the cause of the problem." In either case, weekly measurements for six months after the conclusion of daily monitoring are also required.

G.1.A - Crafts Creek (Unnamed Tributaries 40942, 40943, and 40944)

This case study focuses on three streams over the Enlow Fork Mine, all "unnamed" tributaries (UNT) of Crafts Creek: 40942, 40943, and 40944 (Figure G-1). These streams were chosen due to their location in state game lands and the potential for follow up examinations based on data analyses described here. Stream recovery evaluation reports, SRE report numbers 1727, 1728, and 1729 were submitted to the PADEP on 5/17/2017 describing stream recovery on these streams. None of these tributaries were released. In the SRE reports, recovery was primarily evaluated based on four monitoring points: CRC-4R, 2R located at the mouth of UNT 40944, CRC-3R-01at the mouth of UNT 40942, and CRC-3R,1R-01/CRC-3R,1R-02 located near the mouth of UNT 40943 just above its confluence with UNT 40942 (Figure G-1).

These three tributaries to Crafts Creek were undermined between 2008 and 2011. Stream recovery evaluation reports included measurement of pre- and post-mining stream discharges. Flow was not measured during augmentation. Unnamed tributary 40942 has a drainage area of 372 acres as reported in SR1729, UNT 40943 has a drainage area of 73 acres, and UNT 40944 has the smallest drainage area of 48 acres. For this analysis the monitored flows provided in the

SRE reports (in gpm) were normalized by the drainage areas associated with each tributary and have been converted to inches per day. As the University evaluated the SRE report data provided, two things were examined: The distribution of measurements over the course of a year and the flow record.

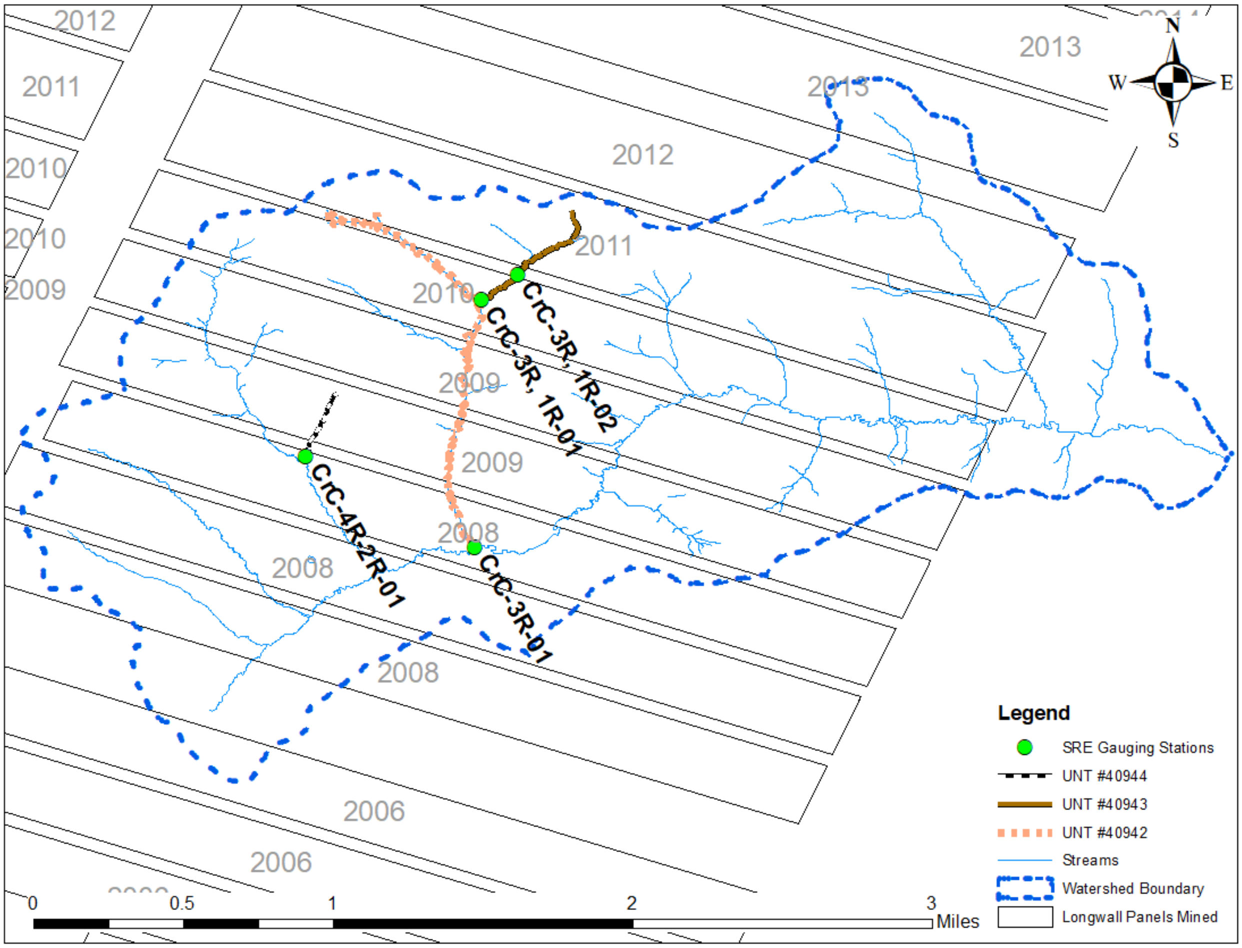

Figure G-1. The three monitored tributaries of Crafts Creek and their monitoring points as reported in SRE reports 1727, 1728, and 1729. The larger basin is the entire Craft Creek watershed. Monitoring point locations were provided in the SRE reports.

G.1.A.1 - UNT 40942

Unnamed tributary 40942 is the largest stream reported in the SRE reports discussed here. Unnamed tributary 40942 was undermined between 03/2008 by panel E17 and 02/2011 by panel E21. Monitoring station CRC-3R-01, located on longwall panel E17, was undermined on 4/2008. Pre-mining measurements were recorded from 1/30/2006 until 4/9/2008 and post-mining stream flow records began on 2/8/2011 and ended 12/26/2016. For this stream, daily measurements were not provided in the SRE report for the pre-mining period. Weekly measurements were only provided for three and a half months prior to mining. Moreover, there is a five-month data gap between July 2007 and January 2008. These monitoring periods do not seem to follow the guidance provided in TGD 563-2000-655.

Technical guidance defines the hydrological dimension of stream recovery as, "restoring flow to the normal range of conditions." Comparison of pre- and post-mining flows must account for systematic variation in hydrologic conditions over the course of the year. In general, in southwestern Pennsylvania there is more water in streams during the fall and winter when evapotranspiration is a less important process. Therefore, if pre-mining monitoring data sets heavily sample summer and fall low flows and post-mining data sets heavily sample winter and spring low flows, a part of the observed differences in ranges may be due to seasonal variation in low flow. Ideally, comparison of pre- and post-mining flows should rely on samples collected from similar seasonal distributions.

For UNT 40942, flow measurement distributions sample distinct seasonal samples in the pre- and post-mining periods (Figure G-2). During pre-mining monitoring, late winter, spring, and mid-summer months (i.e., January, February, March, June, July) were measured more often. In contrast, during post-mining monitoring, discharge measurements were collected more often during spring and fall (i.e., peaks in April and October). Monitoring station CRC-3R-01 recorded low flow periods in both pre- and post-mining periods but limited pre-mining data makes a clear comparison a challenge. At this monitoring station, there are 33 pre-mining measurements that have been taken in contrast to 135 post-mining measurements.

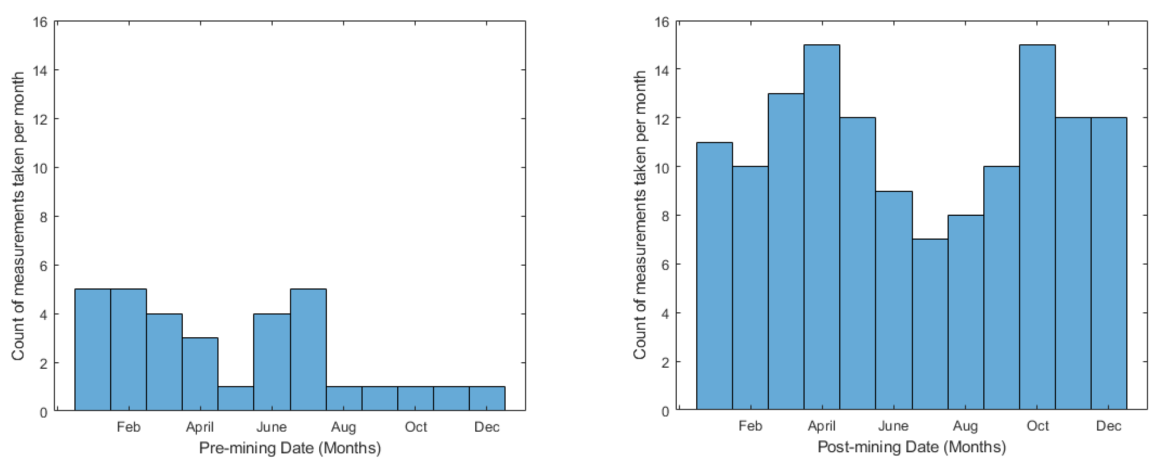

Figure G-2. Distribution of stream flow measurements over the course of a year at CRC-3R-0.1

G.1.A.2 - UNT 40943

Unnamed tributary 40943 is a tributary of UNT 40942 with two monitoring points. Monitoring point CRC-3R-1R01 is located at the mouth of the tributary on panel E20 while CRC-3R-1R02 is located approximately 660 feet upstream between panels E20 and E21 (Figure G-5). According to SRE report 1727, this stream was undermined between 03/2010 and 11/2010. Pre-mining measurements were recorded from 1/8/2007 until 1/13/2010 and post-mining stream flow records began on 1/18/2010 and continued until 12/27/2016. Pre-mining data for UNT 40943 were sampled disproportionately in June and July while the post mining measurements were relatively evenly spaced over the years (Figure G-3). Flow measurements in UNT 40943 stopped 2 months prior to the stream being undermined. Pre-mining measurements were taken up until 01/13/2010. The map provide in SRE report 1727 shows that the drainage area, outlined in red in Figure G-5, for tributary 40943 was not undermined until 2/8/2010. This gap in measurements does not follow TGD 563-2000-655 guidelines.

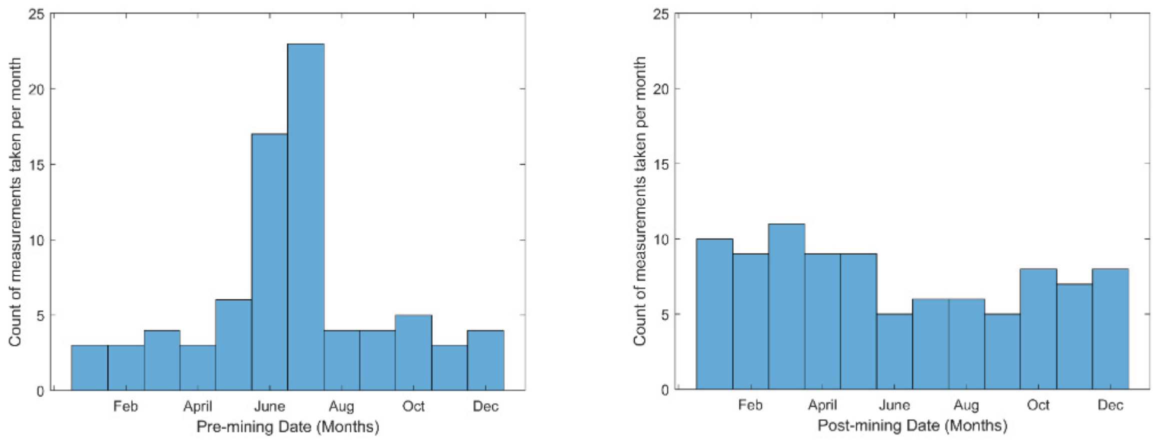

Figure G-3. Monthly count of when stream flow measurements were recorded at monitoring locations CRC-3R-1R01 and CRC-3R-1R02.

At monitoring station CRC-3R-1R01 there are substantial variations in the low flow values prior to mining (Figure G-4). Further, there were only 6 no-flow events captured in the pre-mining data. Post-mining data shows this segment of the tributary experienced a significant increase in dry periods with 78 % of measurements recording no flow zero values. No flow values were converted to 0.0001-in/day for display purposes on the logarithmic scale. The pre- and post-mining flow data at CRC-3R-1R02 (Figure G-6) have fewer no flow measurements post-mining relative to CRC-3R-1R01 (Figure G-4). Still, this segment shows consistent periods of no flow with 46 % of measurements recorded as dry. Monitoring station CRC-3R-1R02 is located between panels while CRC-3R-1R01 is located in the middle of panel E20. The SRE report also suggests construction activity 140 feet upstream of CRC-3R-1R01 could contribute to flow loss but does not offer supporting evidence for this possibility.

Stream recovery evaluation report 1727 states that grouting occurred prior to 10/2013 and possibly again prior to 12/2017. It however does not specify when exactly grouting and augmentation took place. More details about grouting such as injection density, amount of cement used, etc. and exact dates of grouting are helpful for assessing hydrologic recovery in the SRE reports.

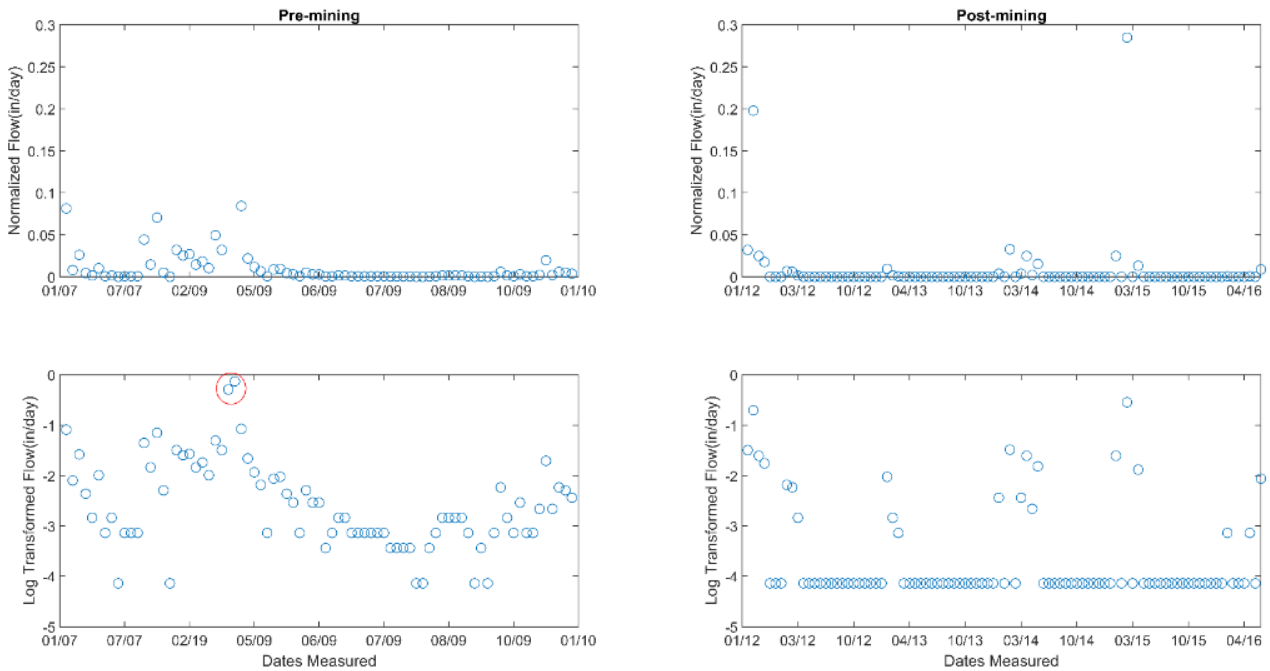

Figure G-4. Monitoring station CRC-3R1R01 pre- and post-mining flow data normalized in in/day, lower panels with a log transformed y scale. The two values circled in red represent abnormally high flow events that occurred on 5/1/09 (0.51 in/day) and 5/4/09 (0.7409 in/day).

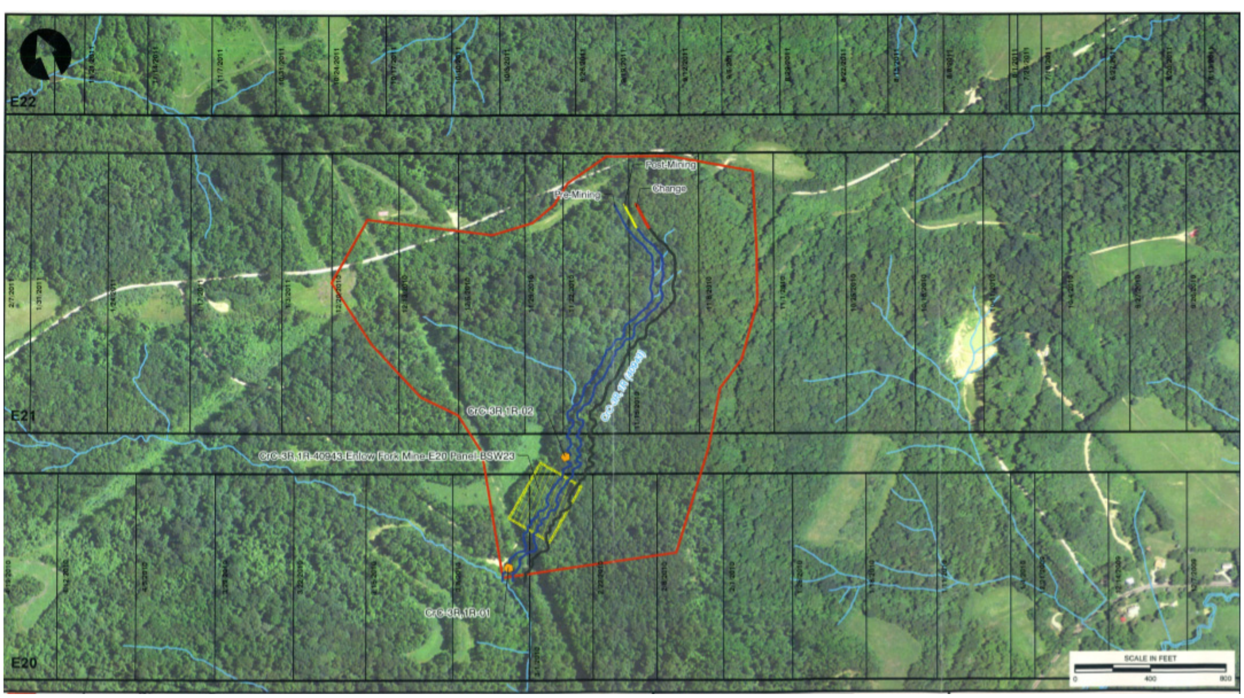

Figure G-5. Tributary 40943 face positions as reported by Civil & Environmental Consultants Inc in SRE report 1727.

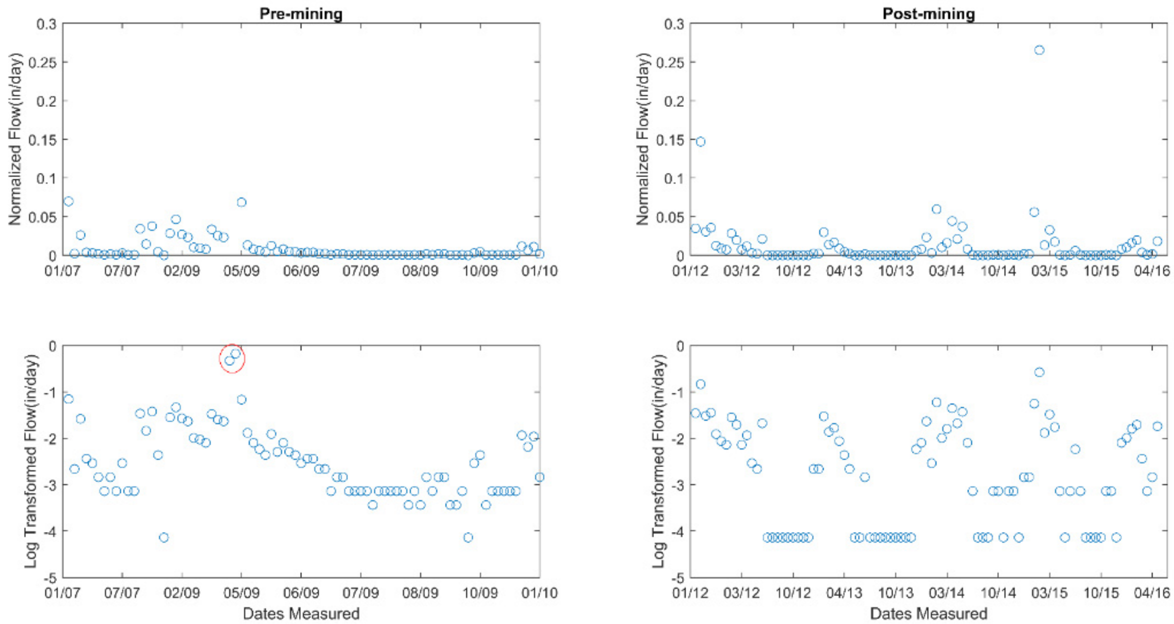

Figure G-6. CRC-3R1R02 pre- and post-mining flow data normalized in in/day, lower panels with log 10 transformed y axis.

G.1.A.3 - UNT 40944

Unnamed tributary 40944 is a 1st order stream tributary of a 3rd order stream that flows into Craft Creek. This segment was undermined between 6/2008 and 12/2009 by panels E17 and E18. Pre-mining observations were made between 1/15/2008 and 11/25/2008. Post-mining observations were made between 5/29/2009 and 12/27/2017. Pre-mining flow data were only recorded in 2008 and has a relatively large number of measurements taken in the summer (Figure G-7). Post-mining flow data were relatively evenly distributed with the exception of large number measured in August which had 23 data points recorded, approximately twice the number of samples collected in every other month. A heave was grouted in 2009 and augmentation last occurred in

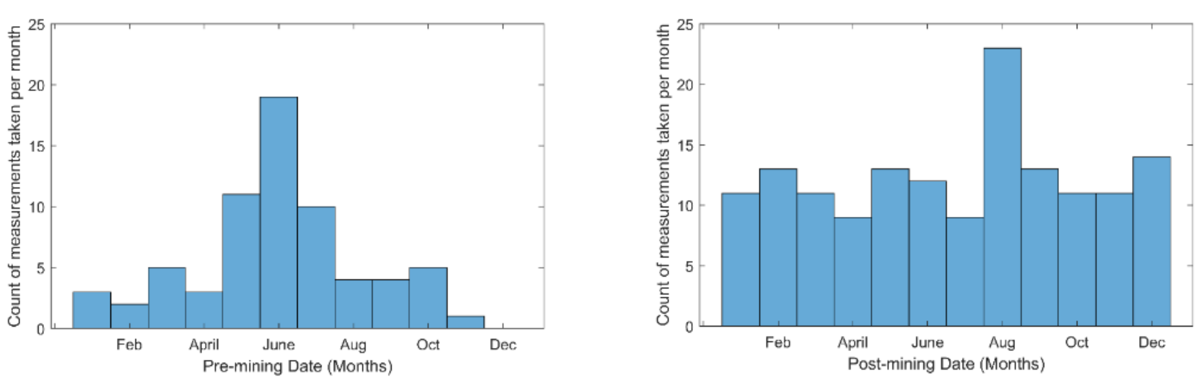

Figure G-7. Distribution of stream flow measurements over the course of a year at CRC-4R-2R.

May 2011. Unnamed tributary 40944 has remained consistently dry, other than during apparent storm flows, since augmentation was stopped.

One interesting aspect of this record is the apparent change in stream flow between pre-mining in July 2008 (Figure G-8) and prior measurements. Periods between July 2008 and November 2008 are considered “pre-mining”. However, the changes observed in July correspond with the passing of the face along the E17 panel on the southern portion of the tributary where monitoring point CRC-4R-2R is located (Figure G-9). The face position map provided in SRE report 1729 shows this location as undermined in late June of 2008. The reduced flow observed in CRC-4R-2R occurs roughly a month after the face passed and six months before the E18 panel undermined the reach. Given there is less than a year of pre-mining data, the University was unable to determine if this is a regular annual pattern in flow. However, the post-July 2008 data appears to be more similar to post-mining data than the other pre-mining data. This suggests that 24 of the 68 pre-mining measurements were recorded while UNT 40944 was potentially impacted by subsidence from E17. It appears that the no flow period in UNT 40944 beginning in July 2008 may have lost flow during mining of the E17 panel and likely should be considered post-mining flow.

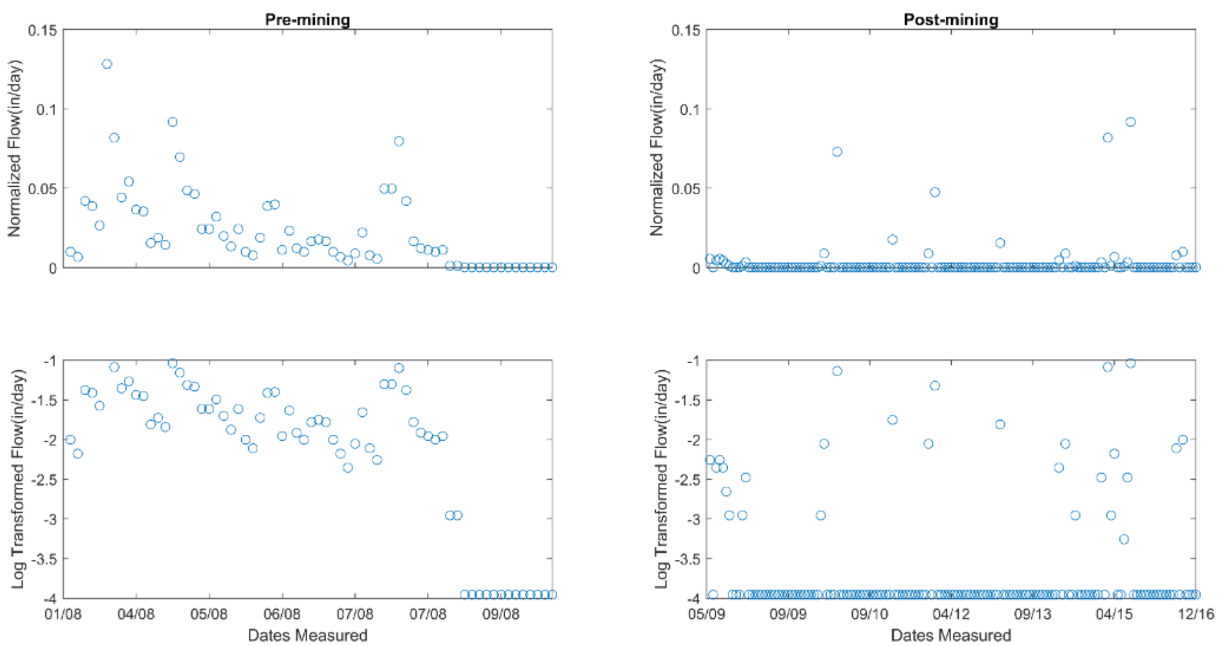

Figure G-8. CRC-4R-2R pre- and post-mining flow data normalized in in/day, lower panels with log 10 transformed y axis.

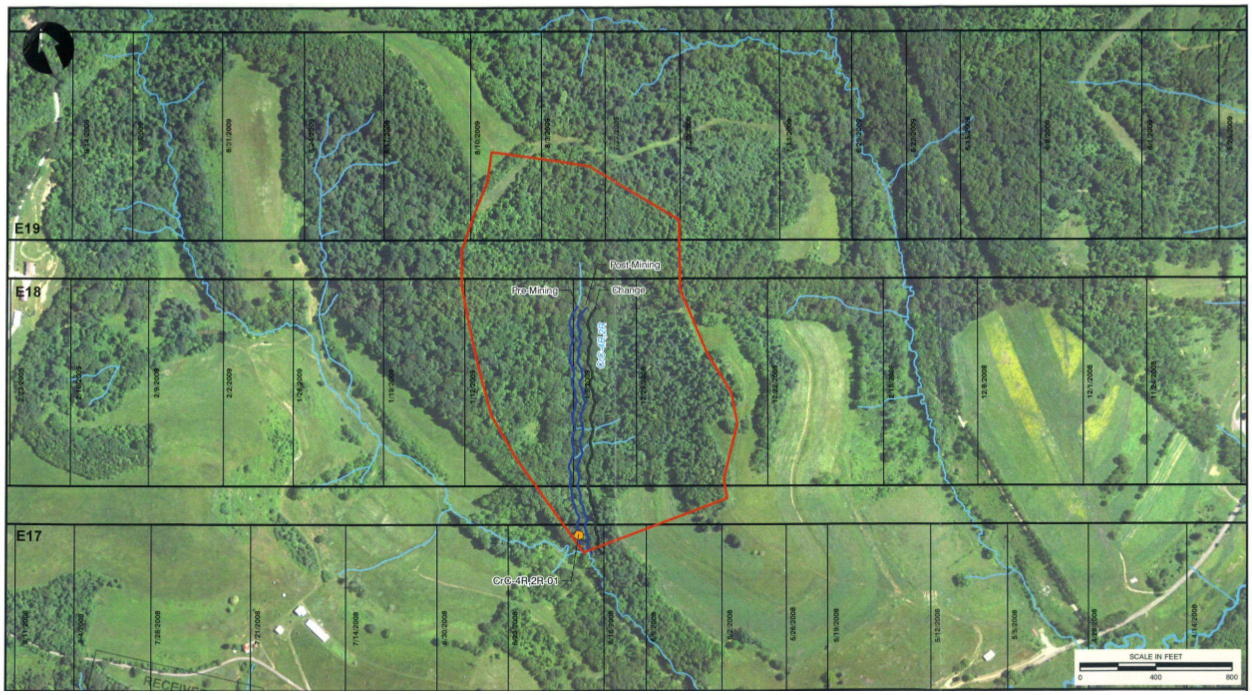

Figure G-9. Tributary 40944 face positions as reported by Civil & Environmental Consultants Inc in SRE report 1729.

G.1.B - The Role of Precipitation in Observed Flows

Daily precipitation values were evaluated to constrain the flow data presented in the SRE reports and evaluate the role of the water budget on stream flow conditions. Figure G-10 shows the locations of the precipitation (USC00361377) monitoring station used in this analysis. To compare the daily precipitation data to the SRE periods of record, the average precipitation of the 10 days before a flow measurement was taken were calculated (Figure G-11). Sampling dates used to calculate these averages consist of pre- and post-mining dates recorded in SRE report 1727. Stream recovery evaluation report 1727 was chosen because this report has the most pre- and post-mining measurements combined.

Precipitation averages are similar during pre- and post-mining periods (Figure G-11). The post-mining data have approximately 0.011 in/day more precipitation in the 10-day period before sampling. Thus, rainfall differences did not strongly impact stream flow and likely increased post-mining flows.

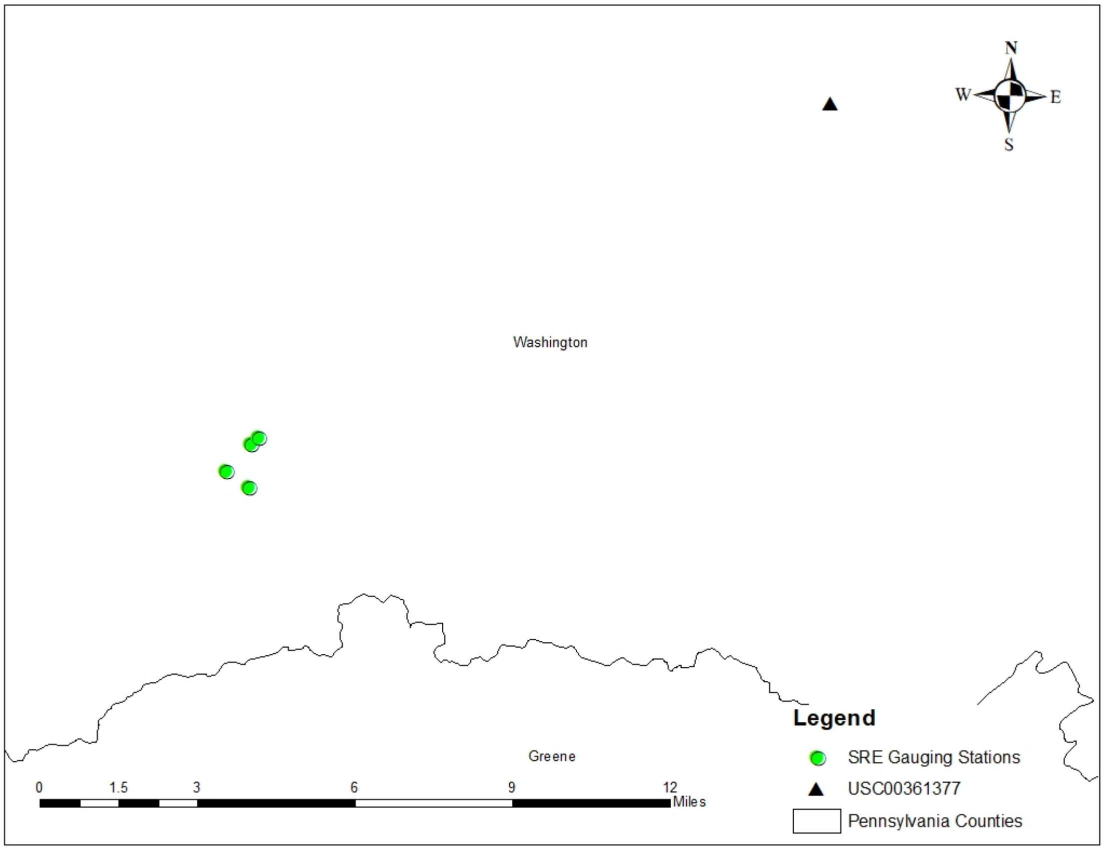

Figure G-10. Locations of precipitation and temperature gauging stations used to calculate the averages. for precipitation.

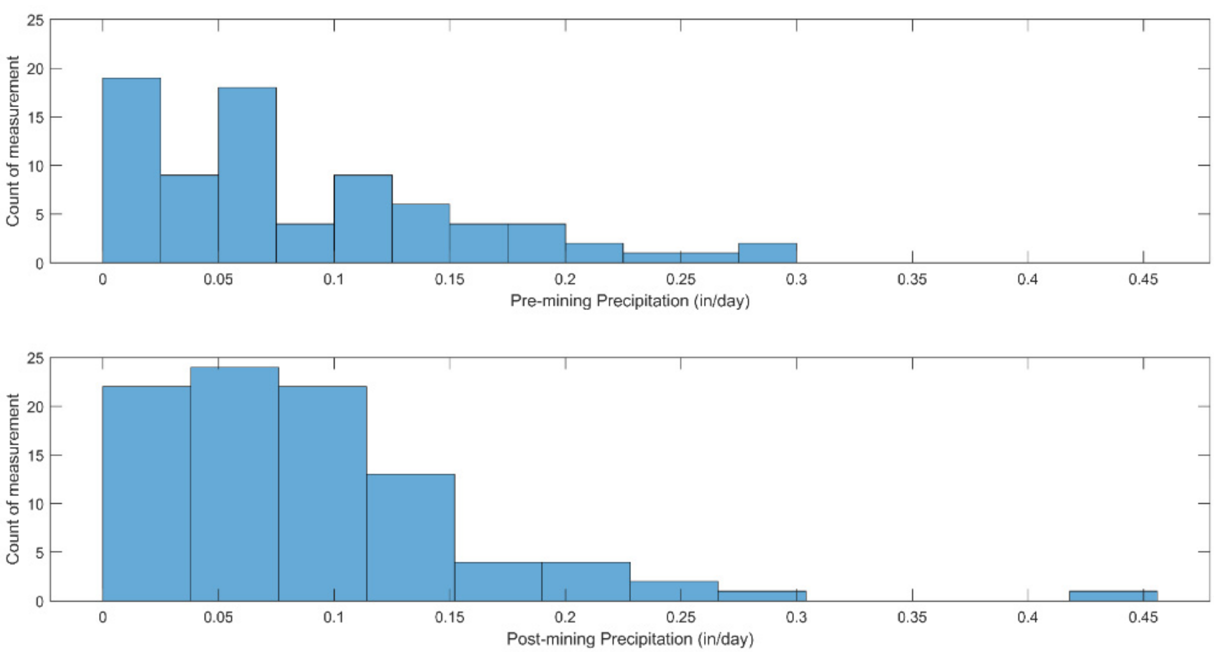

Figure G-11. Distribution of average precipitation for ten days prior to sampling events both pre- and post-mining data in SRE report 1727.

G.1.C - Hydrologic Monitoring Reports and Stream Recovery Evaluation in Crafts Creek

G.1.C.1 - Crafts Creek Surface Water HMRs

Hydrologic monitoring report surface water data from the 4th and 5th (Figure G-12) were compared with results reported in the SRE report. These comparisons were not a part of the SRE reports, but serve to help evaluate the role of HMR data in hydrologic assessment (Figures G-13 to G-17). Hydrologic conditions were measured once per quarter at each monitoring station throughout both the 4th and 5th assessment periods. Here, null stream flow values were either removed or treated as zero depending on the comments provided in the HMR document. If there was no additional information provided by the measurement or "ND" implying No Data was recorded then the measurement for that day was removed. If the stream was noted as "Dry" or experiencing "No Flow" the measurement was treated as a zero.

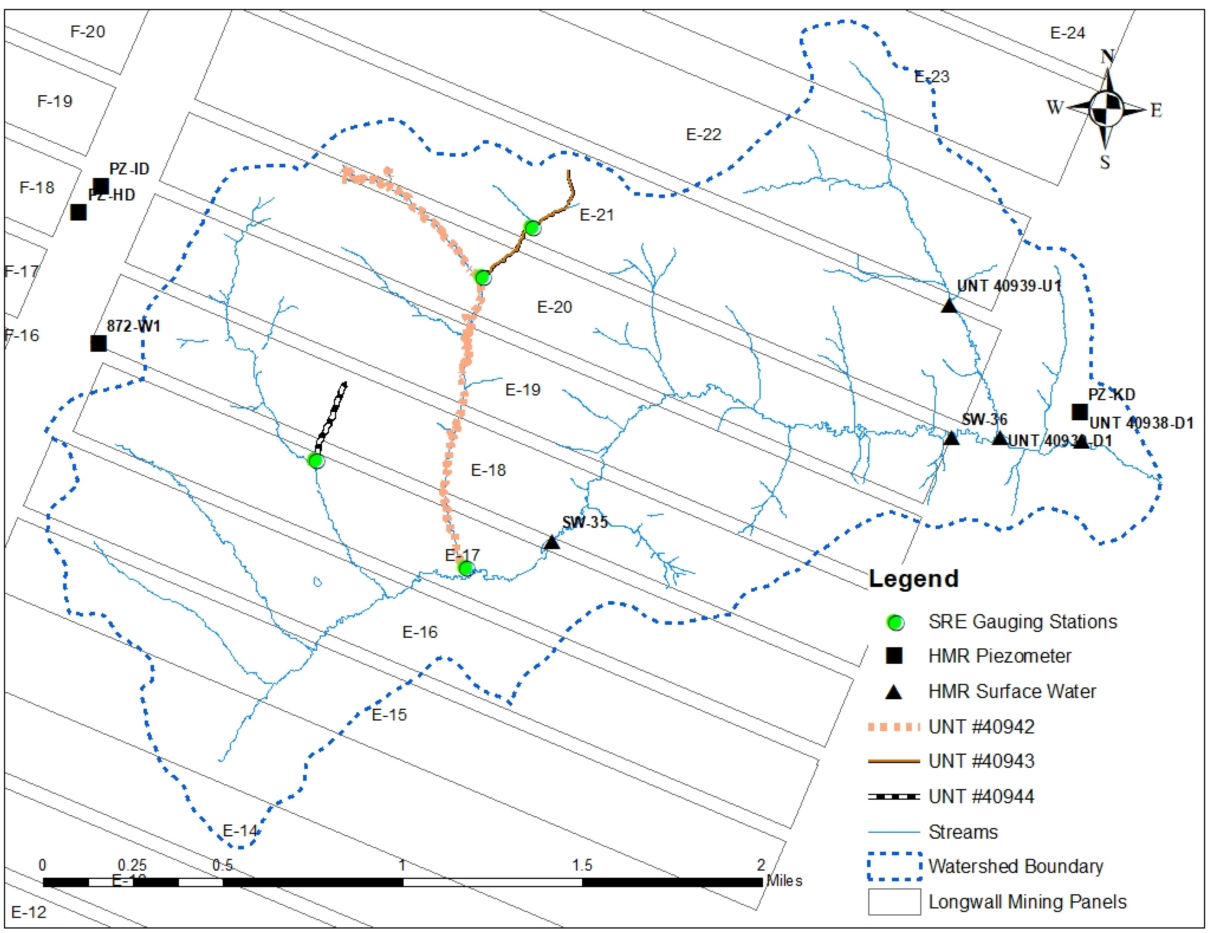

Figure G-12. Locations of the HMR monitoring stations within the Crafts Creek watershed in relation to the SRE monitoring stations and extent of mining discussed in this case study.

Data on background hydrologic conditions allow evaluation of flow loss reported in SRE reports in the context of the larger basin, and therefore a more regional groundwater influence. Monitoring stations SW-35 and SW-36 are located on mainstem Crafts Creek. Monitoring station SW-35 is closer to the SRE report sites (Figure G-12). A total of 53 stream flow measurements were taken between 2007 and 2017 at SW-35. Mining occurred along panels E-18 and E-19 between 2008 and 2009. Flux is examined to evaluate changes in dissolved yields before and after mining activity (Figure G-13). If deeper, saltier groundwater sources contribute to surface water flow as a result of changes driven by subsidence, it should be reflected in the flux of dissolved materials out of the basin. Flux, reported in milligram dissolved solids per second, was calculated by multiplying the total dissolved solids (TDS) and stream flow rate in liters per second. Empty spaces on the flux plot are due to either missing data on dissolved solids for that date or no discharge for that date**.** The timing of undermining in Crafts Creek results in minimal pre-mining data which limits before/after evaluation of the HMR data. However, impacts do not seem to accumulate during mining or change substantially after mining.

Hydrologic monitoring station SW-36 is located downstream of SW-35 on Crafts Creek. Monitoring station UNT 40938-D1 is located on Crafts Creek downstream of hydrologic monitoring stations SW-36, UNT 40939-D1, UNT 40939-U1 (Figure 12). There is no TDS data supplied at UNT 40938-D1 during the pre-mining period. In this case the University used the specific conductance data to estimate TDS (TDS (mg/l) = 0.45 x SC (μmho /cm)). Hydrologic monitoring station UNT40939-U1 is located on tributary 40939 upstream from UNT40939-D1. Though this location was not undermined, mining near the location occurred between 2010 and 2012. No TDS values were provided for UNT 40939-U1 and UNT 40939-D1 so TDS was instead calculated from specific conductance. Hydrologic monitoring station UNT 40939-D1 is located downstream of UNT 40939-U1 and has similar flow patterns to UNT 40939-U1. The HMR data do not indicate substantial changes in flow or dissolved flux before and after mining at the regional scale. Together, these HMR points seem to indicate relatively minor changes at the regional scale in water and chemical flux.

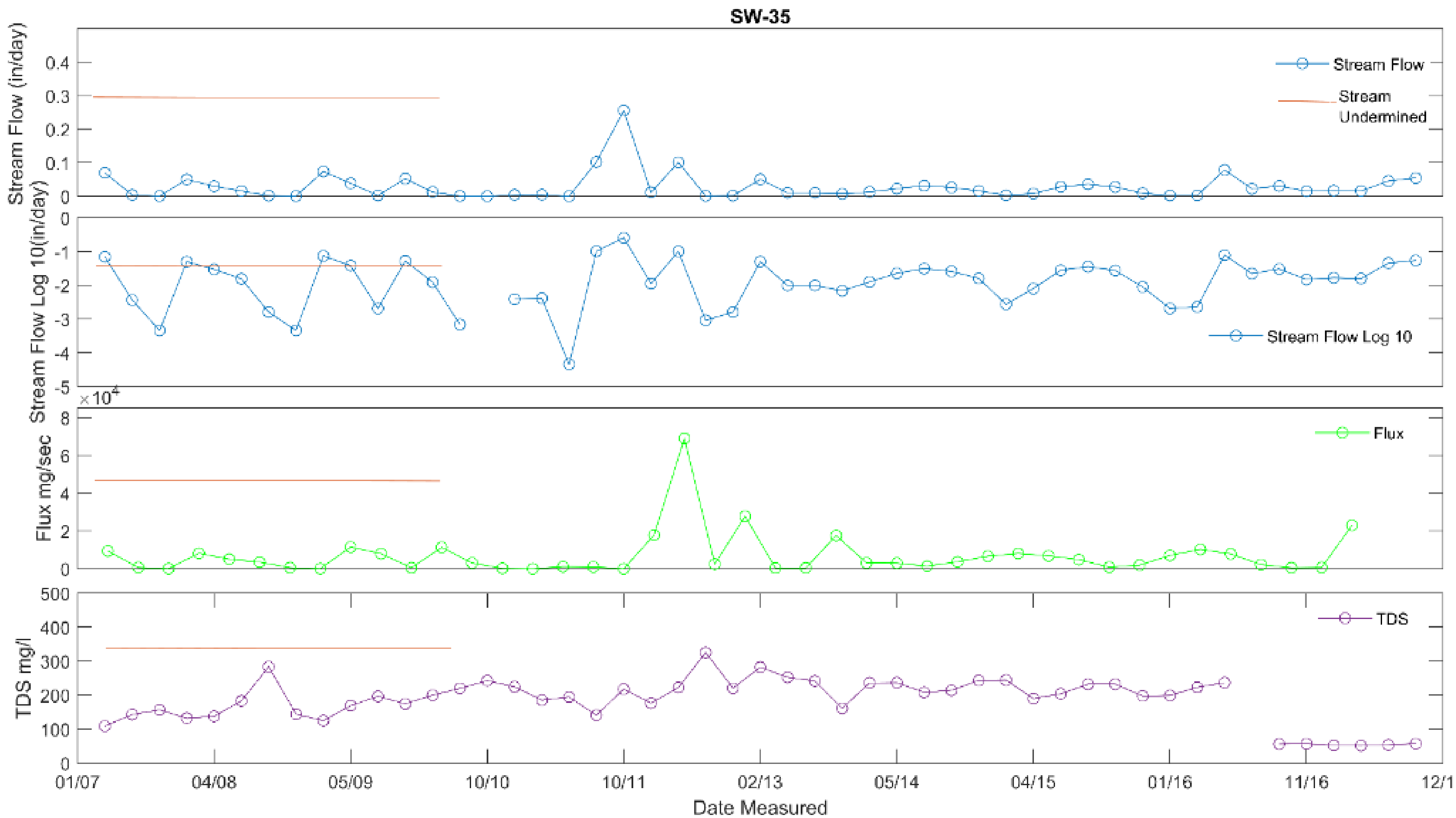

Figure G-13. Stream flow and water chemistry values recorded at HMR monitoring station SW-35. Basin normalized flow (in/day) is shown in both linear and log 10 scale. The TDS values and total dissolved flux (mg/sec) are shown in the lower panels. The straight red lines indicate the duration the stream was undermined.

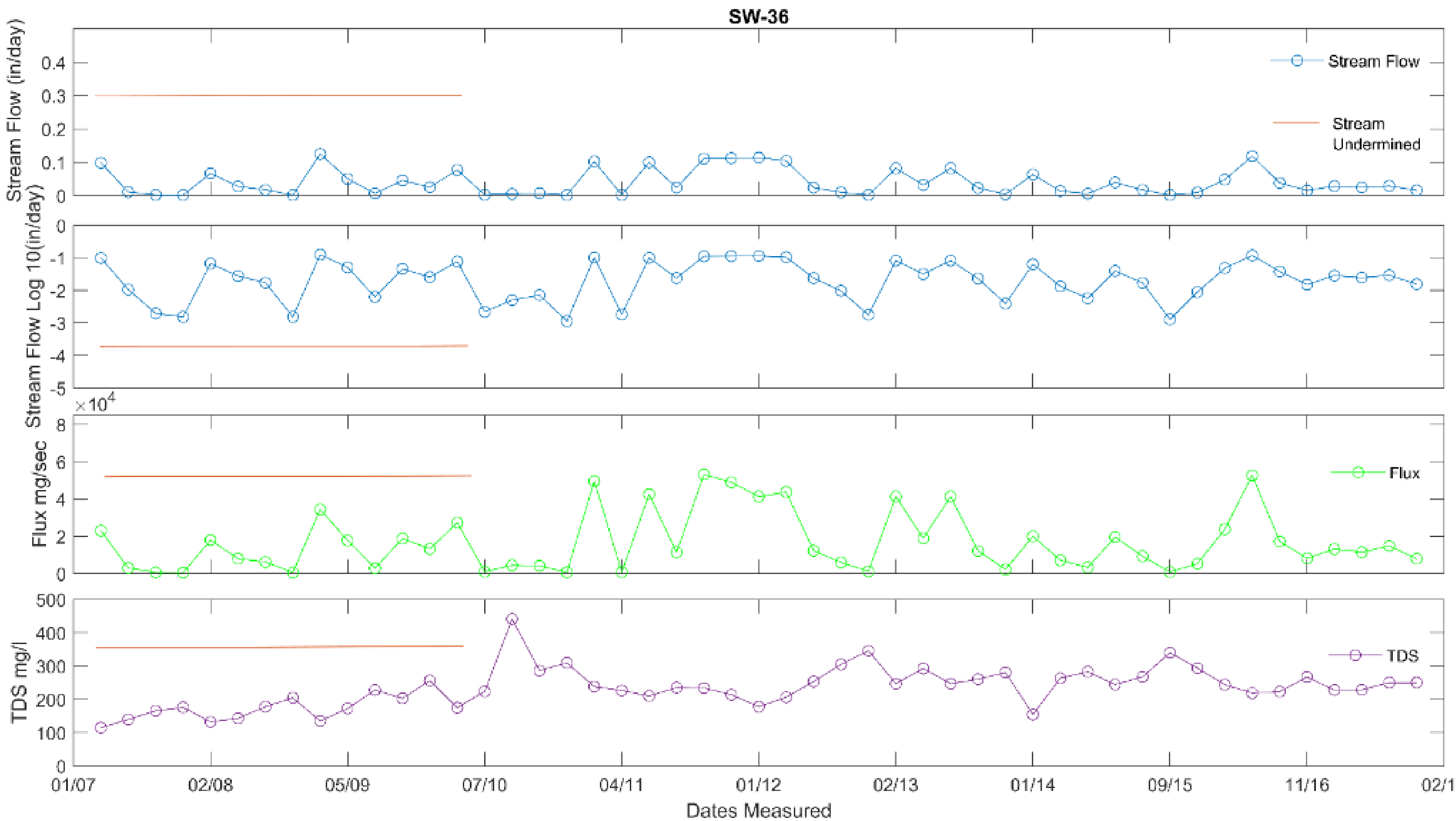

Figure G-14. Stream flow and water chemistry values recorded at HMR monitoring station SW-36. Basin normalized flow (in/day) is shown in both linear and log 10 scale. The TDS values and total dissolved flux (mg/sec) are shown in the lower panels. The straight red lines indicate the duration the stream was undermined.

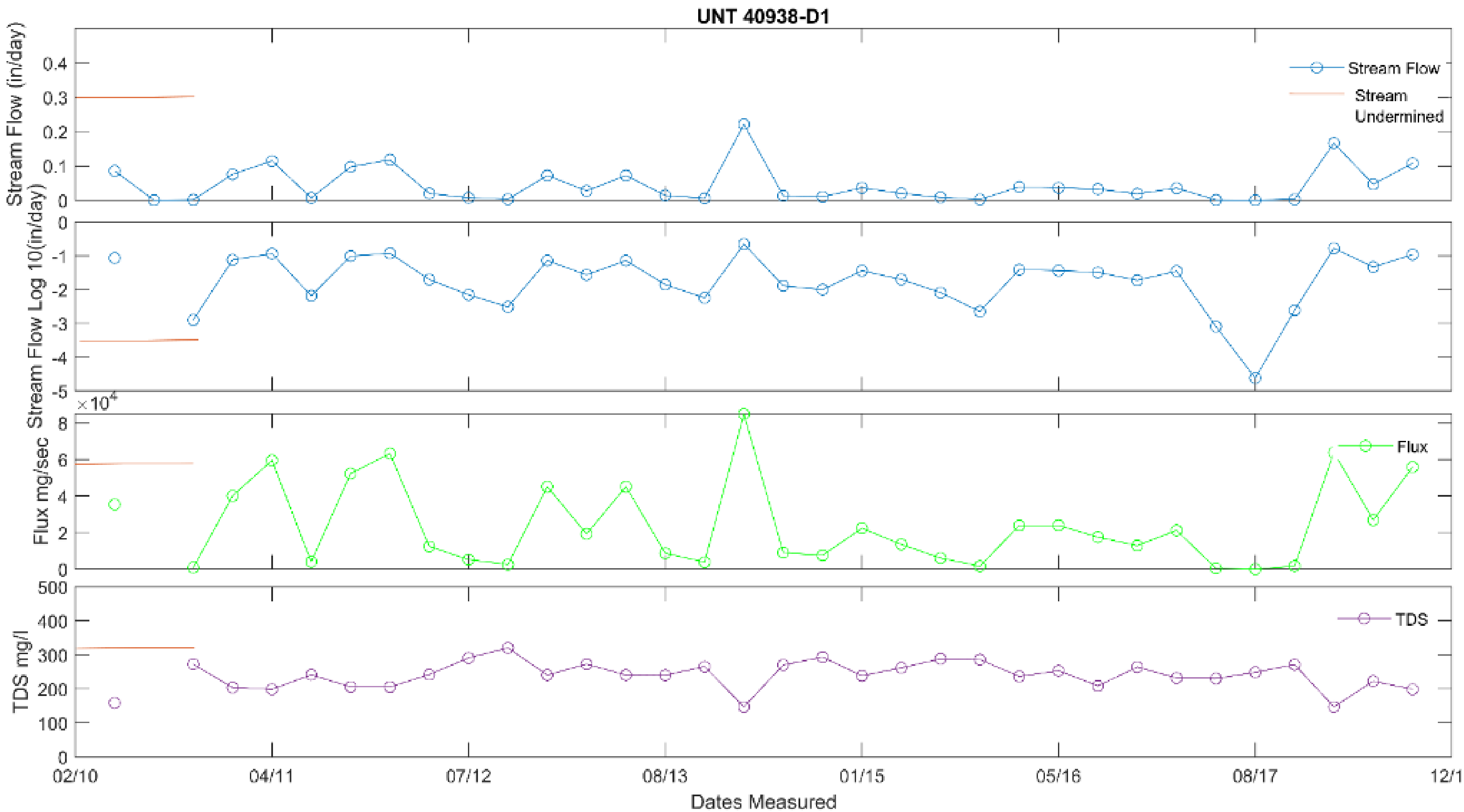

Figure G-15. Stream flow and water chemistry values recorded at HMR monitoring station UNT40938-D1. Basin normalized flow (in/day) is shown in both linear and log 10 scale. The TDS values and total dissolved flux (mg/sec) are shown in the lower panels. The straight red lines indicate the duration the stream was undermined.

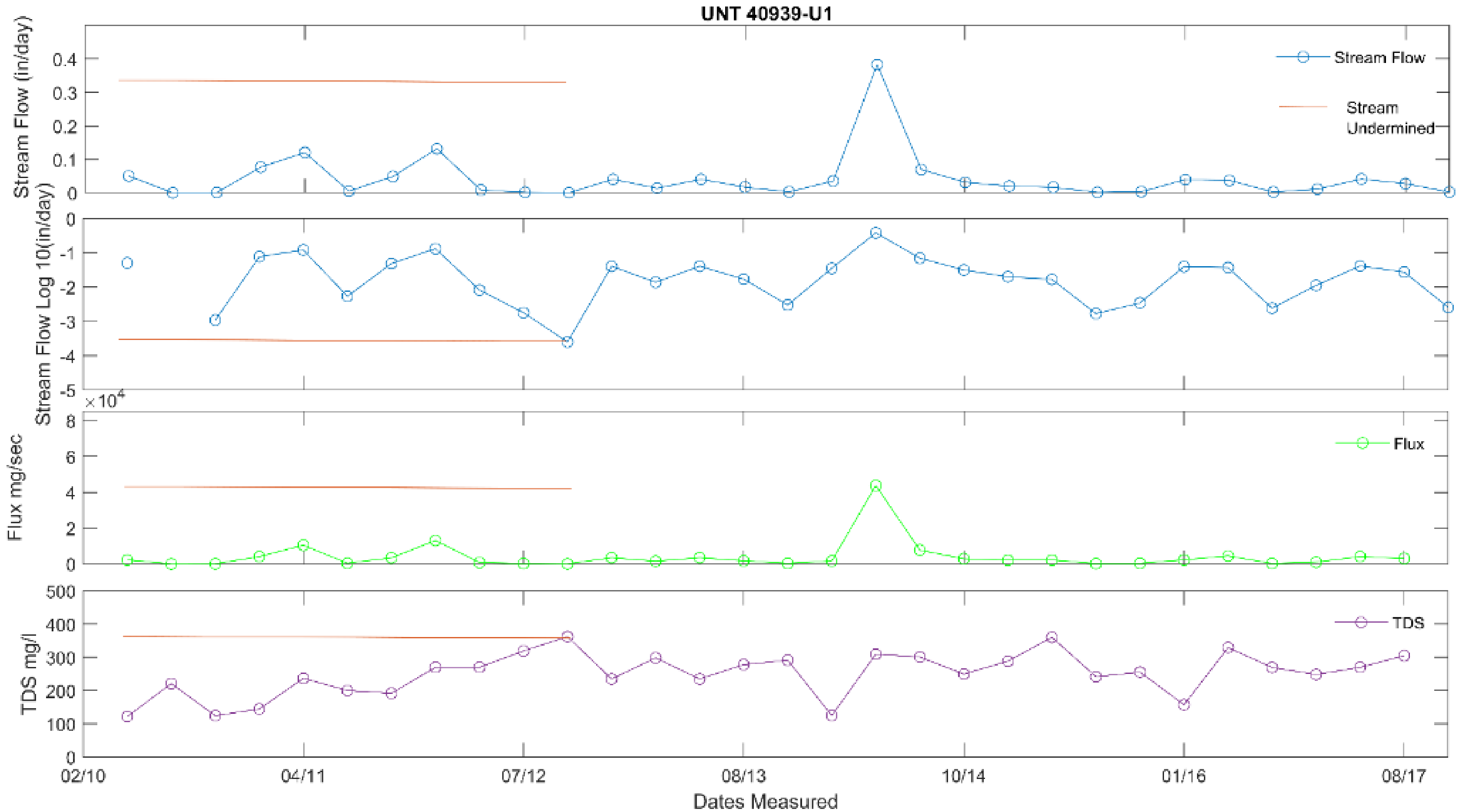

Figure G-16. Stream flow and water chemistry values recorded at HMR monitoring station UNT40939-U1. Basin normalized flow (in/day) is shown in both linear and log 10 scale. The TDS values and total dissolved flux (mg/sec) are shown in the lower panels. The straight red lines indicate the duration the stream was undermined.

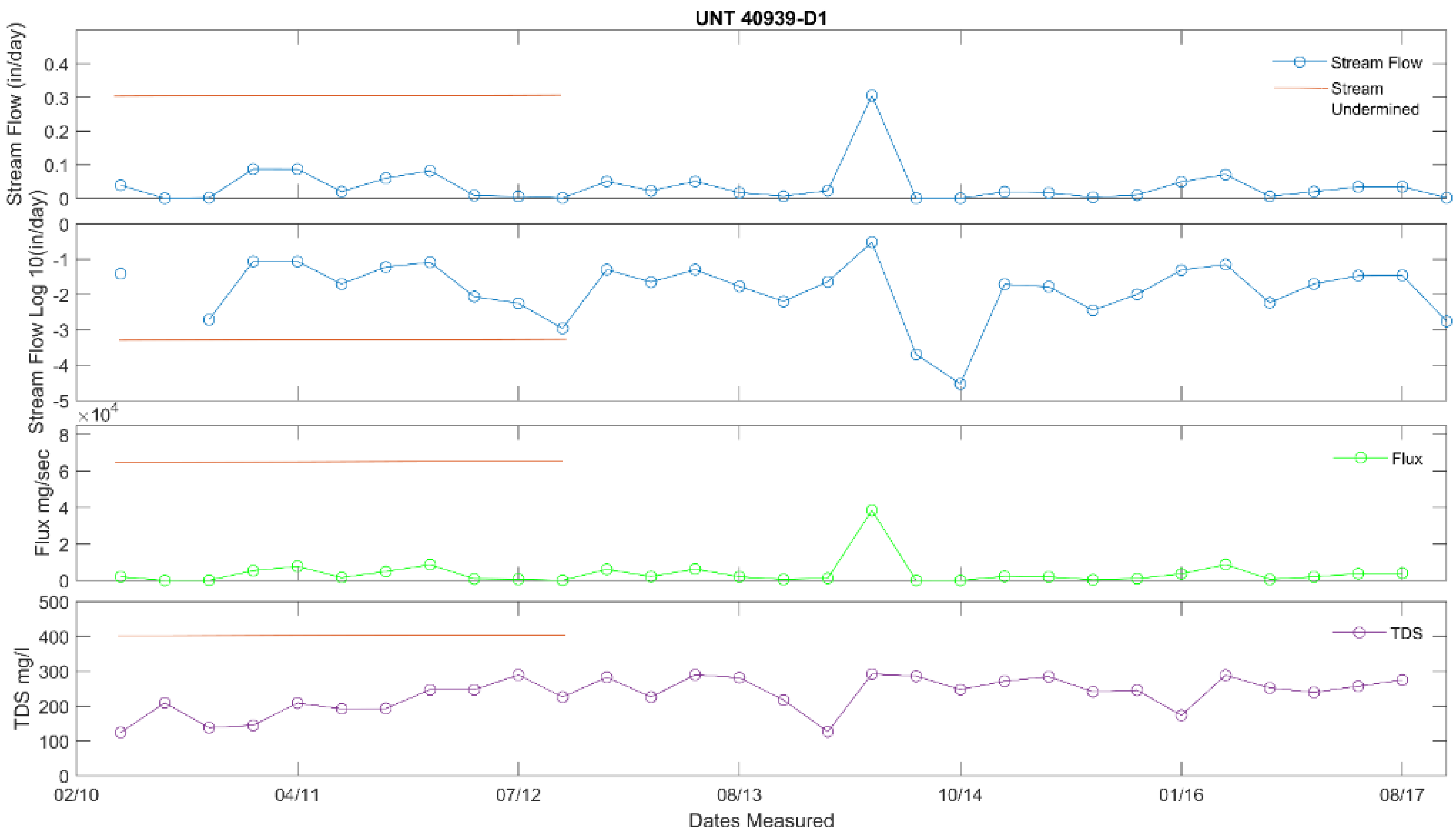

Figure G-17. Stream flow and water chemistry values recorded at HMR monitoring station UNT40939-D1. Basin normalized flow (in/day) is shown in both linear and log 10 scale. The TDS values and total dissolved flux (mg/sec) are shown in the lower panels. The straight red lines indicate the duration the stream was undermined.

G.1.C.2 - Crafts Creek Groundwater HMRs

More central to an understanding of the impacts of mining on groundwater than surface water observations are the monitoring of groundwater elevations. Four wells/piezometers that were monitored throughout both assessments are located within the Crafts Creek watershed. Figures G-18 through G-21 display time series plots of changes in depth to water level and dissolved solid concentrations for each location throughout the 4th and 5th assessments. Total dissolved solids were calculated from specific conductance using the same method used to calculate TDS for surface water monitoring stations as described in G.1.C.1.

Monitoring stations PZ-KD and PZ-ID are located approximately 482 feet apart between longwall panels E19 and F18 (Figure G-12). Although neither of these piezometers were undermined, panels E19 and F18 were mined between 2008-2009 and 2009-2010. Measurements at PZ-ID ceased after 4/9/2011 due to the destruction of the piezometer. Three of the four piezometers (PZ-KD, PZ-ID, and PZ-HD) are located outside the boundaries of the longwall mining panels. Piezometer PZ-KD is located approximately 1,647 feet from longwall panel E21 which was completed in March 2011.

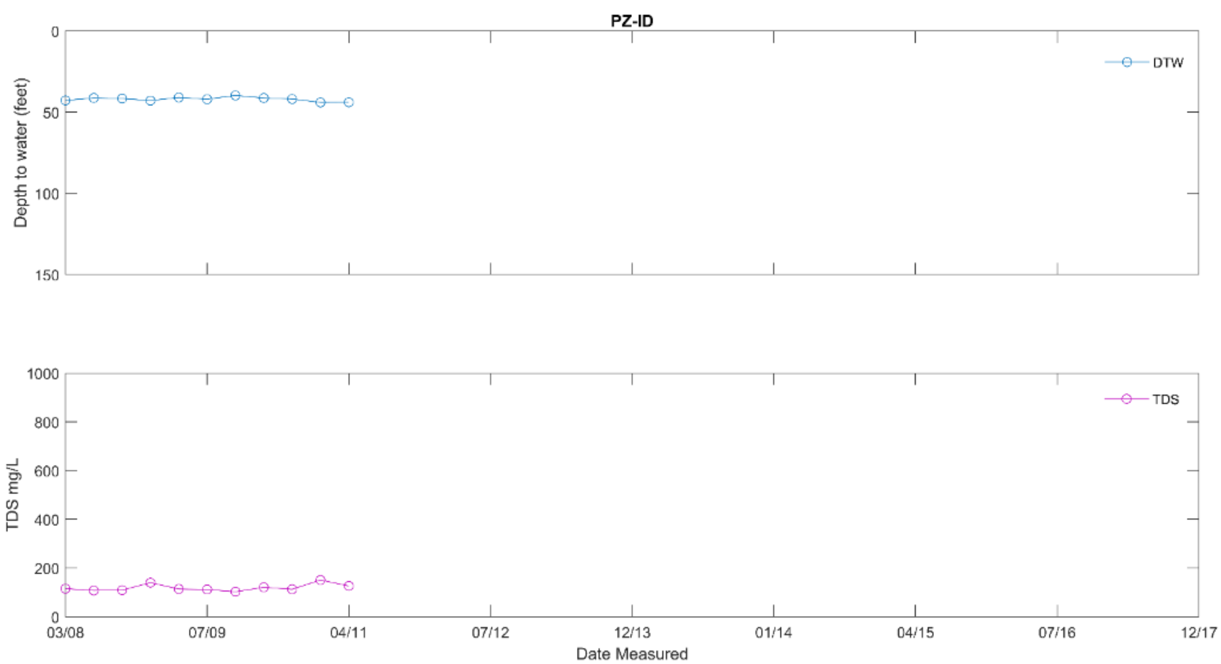

Figure G-18. Depth to water level and estimated TDS values recorded at HMR piezometer station PZ-ID. This piezometer was destroyed by subsidence impacts in 2011 and not replaced, so evaluation of post mining conditions is not possible.

Water table elevations decrease in both piezometers PZ-HD and PZ-KD during the first quarter of 2017 (Figures G-19 and G-20 respectively). These decreases in groundwater elevation on the same date (2/8/2017) are however difficult to interpret when compared to the rest of the record. Changes in groundwater of hundreds of feet generally occur and recover more slowly. If field equipment was malfunctioning, these two piezometers, roughly 3.8 miles apart, would likely both be affected. Similar low depth to water levels were reported between the 2nd quarter of 2012 and the 2nd quarter of 2013 in PZ-HD (Figure G-19). It is not clear what these low depth to water values mean, but without complete documentation of QA/QC measures a field equipment malfunction cannot be ruled out. However, if the drops in PZ-HD are subsidence impact related, there is not a corresponding change in surface waters (Figures G-13 to G-17).

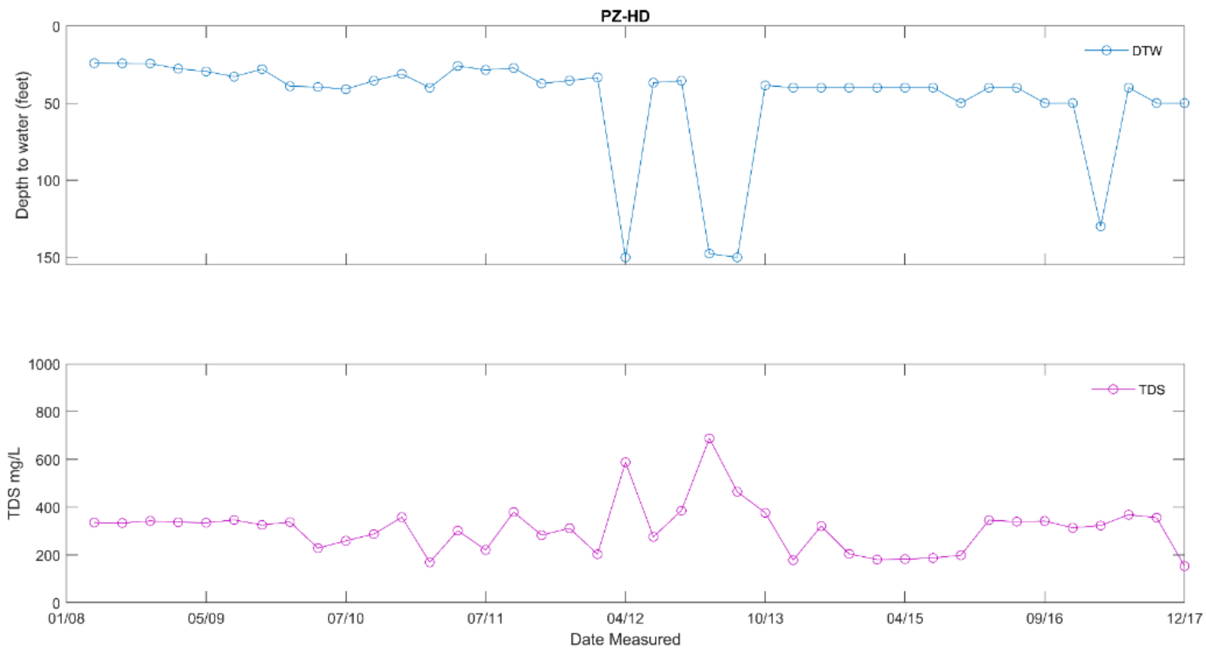

Figure G-19. Depth to water level and estimated TDS values recorded at HMR piezometer station PZ-HD.

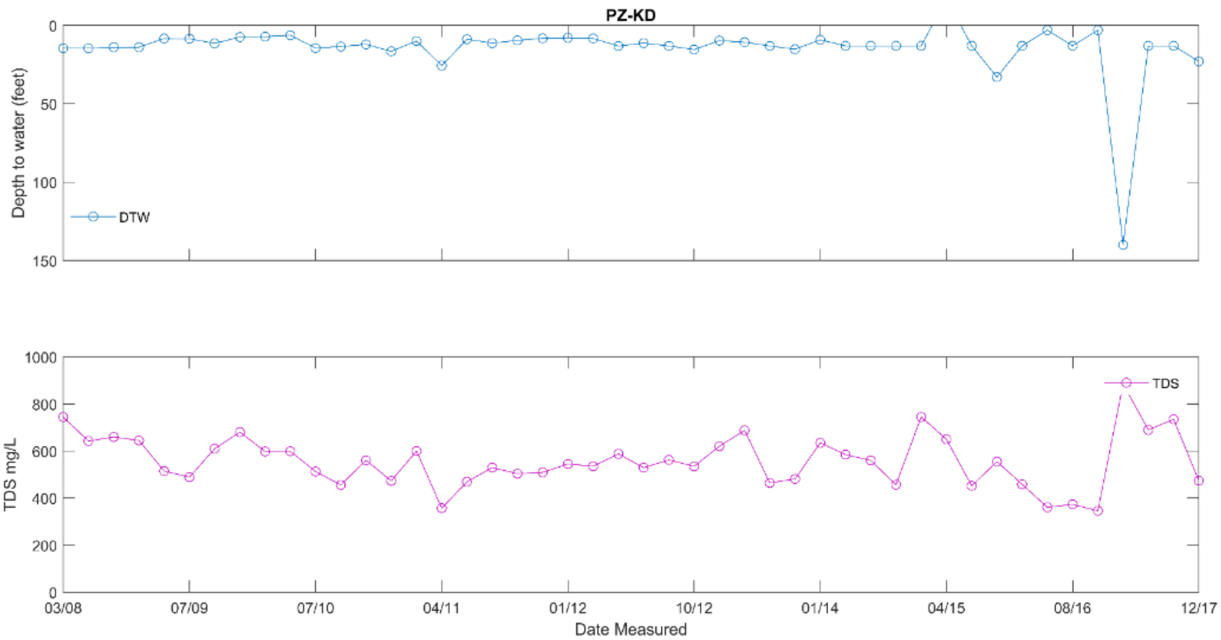

Figure G-20. Depth to water level and estimated TDS values recorded at HMR piezometer station PZ-KD.

Well 872-W1 is located to the southeast of PZ-HD and PZ-ID, just inside of panel E-18 which was completed in 2009 (Figure G-12). During undermining measurements were not recorded. Well 872-W1 shows an implausible water elevation with a depth to water level of 1,107 feet. This is followed by a length of dry periods beginning after the first quarter of 2009. The low water elevation is likely a case where the static water elevation is recorded as the depth to water at the time of measurement. The overburden under this well is only ~710 ft thick. This means that the well would be deeper than the coal seam, which would be an impractical design for a well that was designed to measure subsidence effects.

G.1.D - Crafts Creek Water Supply Losses

As a final piece of information, the University attempted to identify water supply losses near these streams. However, upon consultation of BUMIS, it was determined that the water supplies in this area were some of those with non-unique identification, as described in the 4th assessment report (Tonsor et al., 2014). Given this ambiguity, the University does not present these data here. However, use of these data, when available, may provide additional insight into the impacts on groundwater.

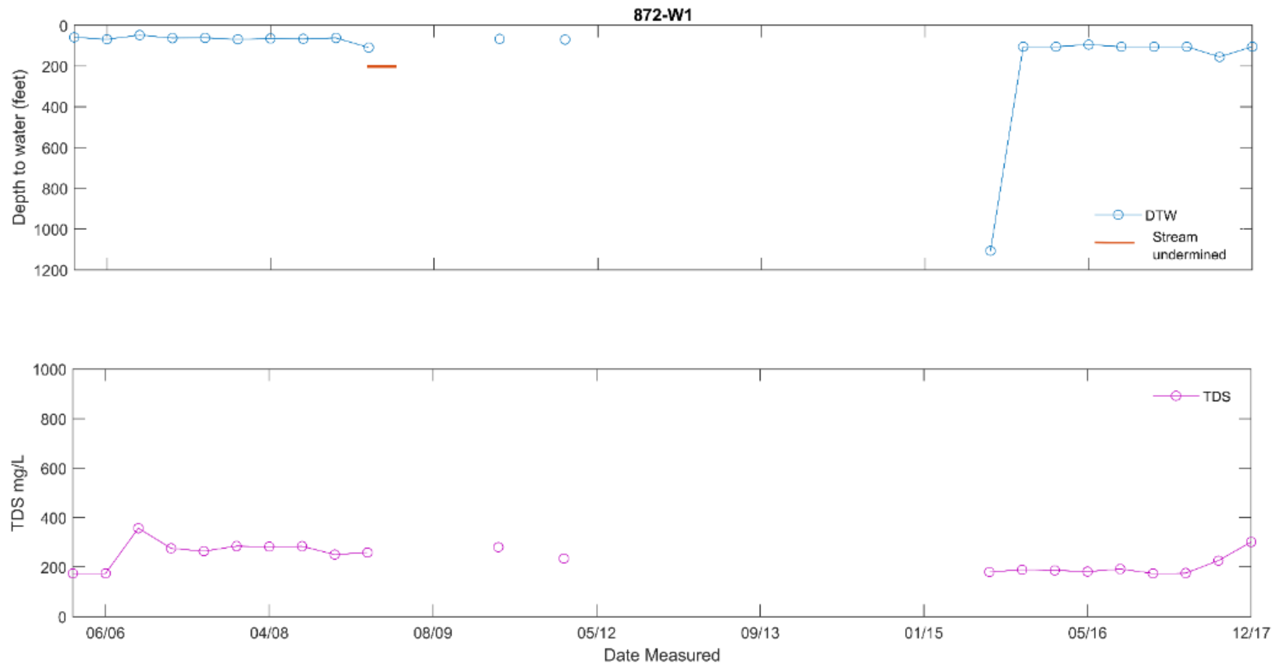

Figure G-21. Depth to water level and estimated TDS values recorded at HMR piezometer station 872-W1.

G.1.E - Crafts Creek Case Summary

This case focuses on three impacted but unreleased undermined streams over the Enlow Fork Mine and attempts to use a broader set of available data to evaluate groundwater impacts and their role in flow loss in surface waters. In general, the HMR data, sampled at a monthly interval were not particularly useful. The infrequent sampling makes evaluation of points that do deviate hard to diagnose. In addition, there seems to be QA/QC problems with data, as implausible data values are included in the records (e.g., 872-W1). In other cases, piezometers that were destroyed near the time of undermining were not replaced, making comparison of pre- and post-mining conditions impossible to compare.

The HMRs do allow the potential to examine changes in water contributions to surface waters. Changes in TDS can indicate a change in groundwater source to the stream, or if observed in groundwater data, dominant flow paths. However, in these cases, once discharge variability is factored in with the flux calculation, quarterly fluxes in dissolved solids seem relatively consistent. Likewise, with the exception of two or three isolated points, TDS in groundwater is consistent throughout the HMRs and changes in dissolved solids do not seem to be temporally associated with mining activity.

G.2 - Case Study: Hydrologic Monitoring Data in Stream Recovery Evaluation in Pursley Creek

Stream recovery evaluation reports 1501 and 1503 were submitted to the PADEP on 12/19/2014 and describes the recovery of two "unnamed" tributaries (UNT) of Pursley Creek: 40614 and 40592-L7 over the Cumberland Mine (Figure G-21). Neither of these reports resulted in the release of the tributaries. In SRE report 1501, recovery was primarily evaluated based on monitoring point PC-T3. Stream recovery evaluation report 1503 does not use flow data but rather uses the proportion of flowing water in the reach. Given that the vast majority of SRE reports relied on flow data this record is distinct and not considered in the remainder of this case.

These two tributaries, UNT 40614 and UNT 40592-L7, were undermined between 2011 and early 2013 (Figure G-21). Stream recovery evaluation report 1501 included measurement of pre- and post-mining stream discharges and specified periods of augmentation (Figure G-23). The monitored flow values provided in SRE report were normalized by the drainage areas and are plotted as inches per day.

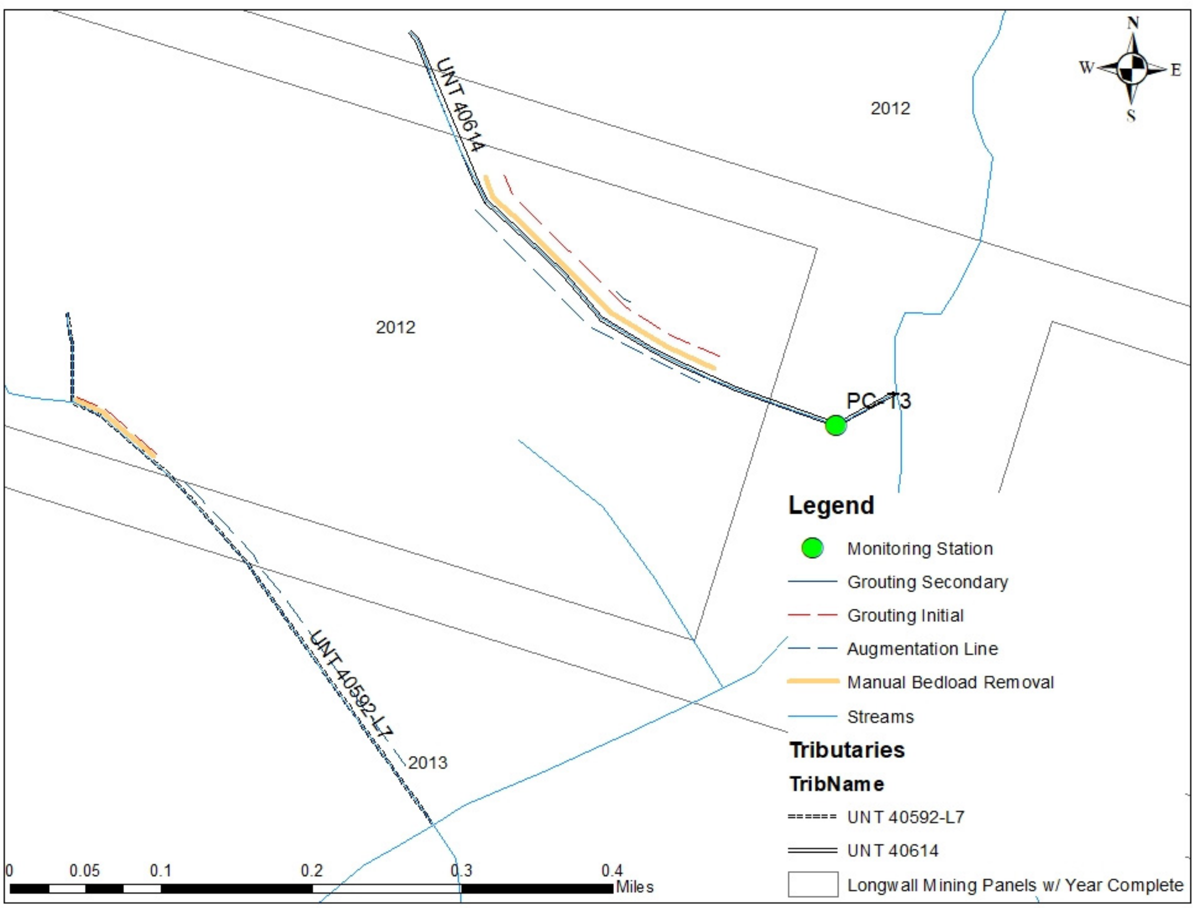

Figure G-22. UNT 40614 and UNT 40592-L7, tributaries to Pursley Creek over Cumberland. Recovery evaluated in SRE reports 1501 and 1503.

G.2.A - UNT 40614

This case illustrates the frequency and distribution of hydrologic data collected to assess stream recovery in the Pursley Creek watershed. Unnamed tributary 40614 was undermined between 6/21/11 and 6/28/2011 by panel LW-59 (Figure G-22). The tributary was undermined again between 3/19/2012 and 4/18/2012 by panel LW-60. Monitoring station PC-T3 is located between panels LW-60 and LW-60A and was not undermined by a longwall panel (Figure G-22). For this case, measurements before 6/21/11 will be considered "pre-mining" and measurements after 4/18/2012 will be considered "post-mining." Flow measurements were similarly distributed over the course of the years (Figure G-23). Both monitoring periods have proportionally more measurements in the early summer months and do not seem strongly biased in season of collection. Daily measurements for both pre-mining periods (before and after LW-59 was undermined and before and after LW-60 was undermined) met requirements set by TGD. Weekly measurements were also taken leading up to daily measurements and continued following undermining.

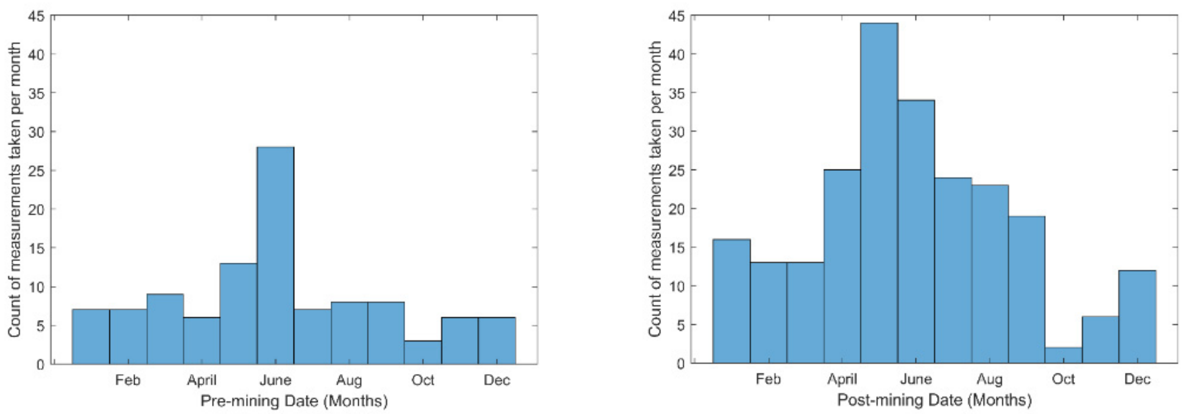

Figure G-23. Distribution of sampling events at PC-T3 on UNT 40614 over the course of a year during pre- and post-mining periods.

Stream recovery evaluation report 1501 included detailed information on mitigation efforts. Grouting occurred between 6/20/2012 and 10/5/2012 with approximately 1,200 feet of the channel mitigated. During mitigation, 1,246 boreholes were drilled, 225 bags of cement, and 25 bags of bentonite were consumed. Manual bedload removal was performed along areas with excess alluvium (exceeding 24 inches in thickness) and where grouting was completed. Flow augmentation was provided from 6/18/2012 through 7/2/2012. No further augmentation was performed per landowner request on August 2012. The landowner additionally requested discontinuation of any further mitigation activity along this stream on 4/3/2014.

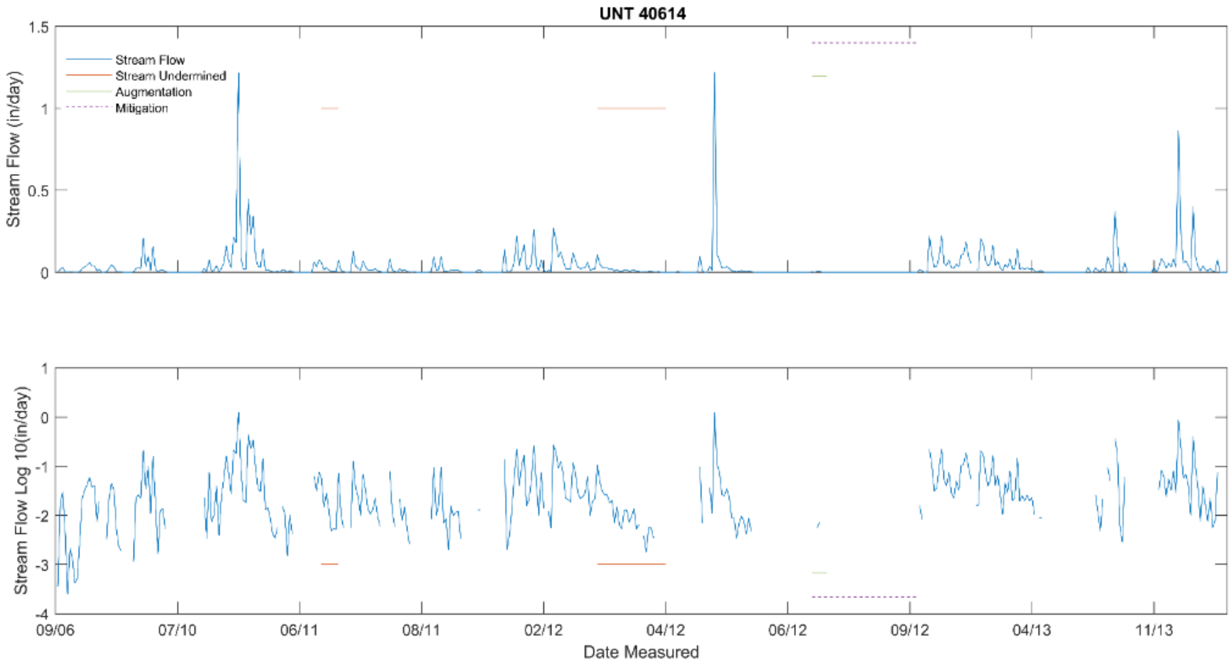

Figure G-24. PC-T3 pre- and post-mining flow data normalized in in/day, lower panel with log 10 transformed y axis. Flow data provided in SR1501 as gpm normalized via drainage area for tributary 40614. The orange line represents periods where the stream was undermined by longwall mining, the grey line shows when augmentation occurred, and the purple dashed line shows when mitigation such as grouting took place.

G.2.B - Hydrologic Monitoring Reports and Stream Recovery Evaluation in Pursley Creek

Hydrologic monitoring data from HMR points in the Pursley Creek watershed were analyzed to evaluate broader hydrologic changes in surface and groundwater throughout the watershed. Surface water flow was measured quarterly at several locations near PC-T3 (Figure G-25). Hydrologic conditions over the Enlow Fork Mine were measured once per quarter at each monitoring station throughout both the 4^{th} and 5^{th} assessment periods. When analyzing these data, null stream flow values were either removed or treated as zero depending on the comments provided in the HMR documents. Measurements were removed if additional information about the measurement was not provided, "ND" implying No Data was recorded, or a monitoring station was unable to be measured. If the stream was noted as "Dry" or experiencing "No Flow" the measurement was also treated as a zero. The suite of reported measurements for these HMRs included: Alkalinity, pH, Se, Br, Cl, nitrate, nitrite, sulfate, Ba, Mg, K, Na, and Sr. In the HMRs for these points, TDS and/or conductivity was not reliably reported. As a result, the dissolved solid fluxes were not included in plots for this case study.

G.2.B.1 Pursley Creek Surface Water HMRs

Monitoring stations S-74, S-75, and S-76 are located along Pursley Creek (Figure G-25). Pursley Creek flows toward the north with S-76 being located upstream of S-75 and both located upstream of S-74. Measurements at these locations were taken between 2010 and 2015 (Figures G-26 to G-28). Panels 62- 59 were mined between 2012 and 2014. Flow decreases at monitoring points S-74 and S-75 during or briefly after undermining. Flow returns to levels observed before mining within three to nine months (Figure G-26 and G-27). Monitoring point S-76 appears relatively unaffected. This suggests a sensitivity to disturbance in these smaller watersheds. More precise timing information is however not possible given the frequency of HMR observations. In addition, insight about changes in water source are hard to infer given the suite of chemical parameters reported for these stations.

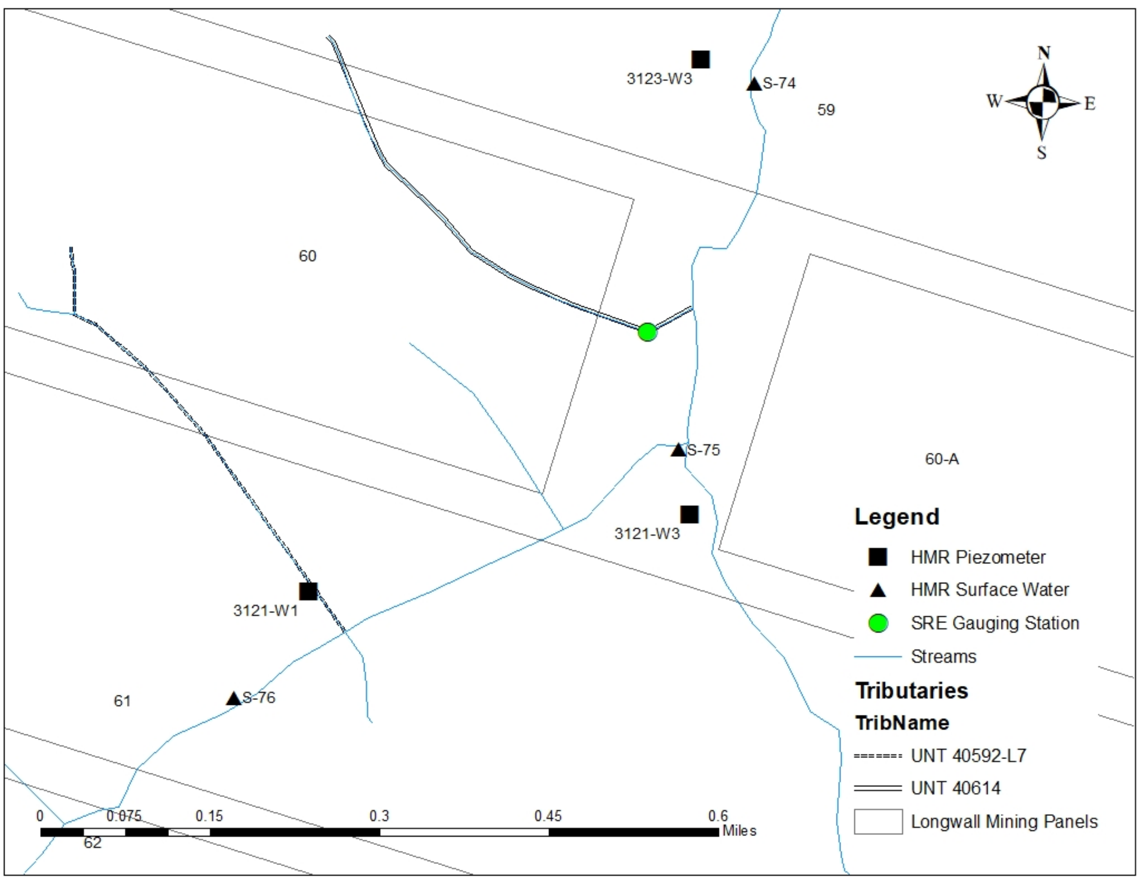

Figure G-25. Locations of the HMR stations within the Pursley Creek watershed near SRE monitoring stations PC-T3.

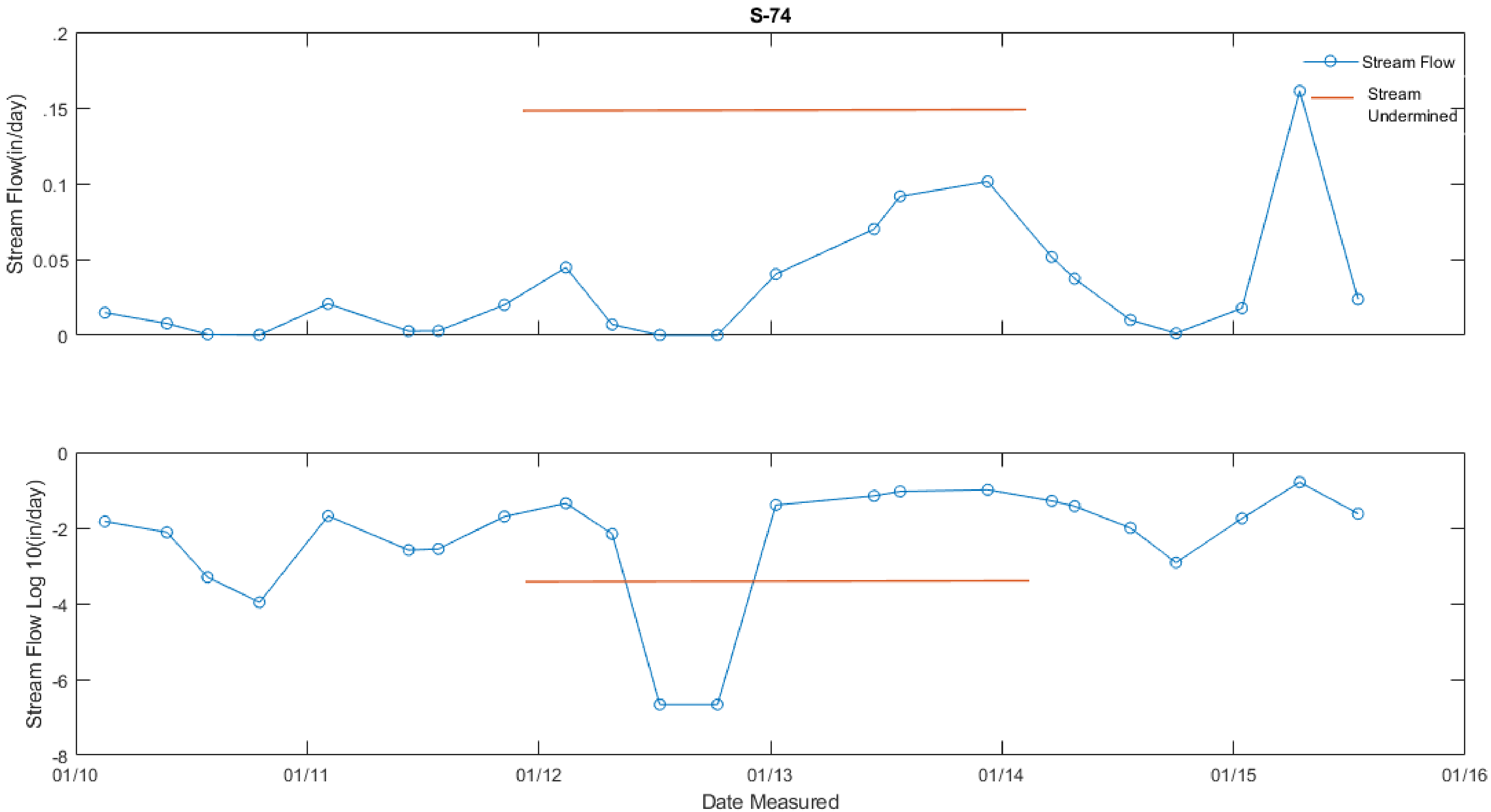

Figure G-26. Stream flow recorded at monitoring station S-74 in both normalized (in/day) and log 10 scale.

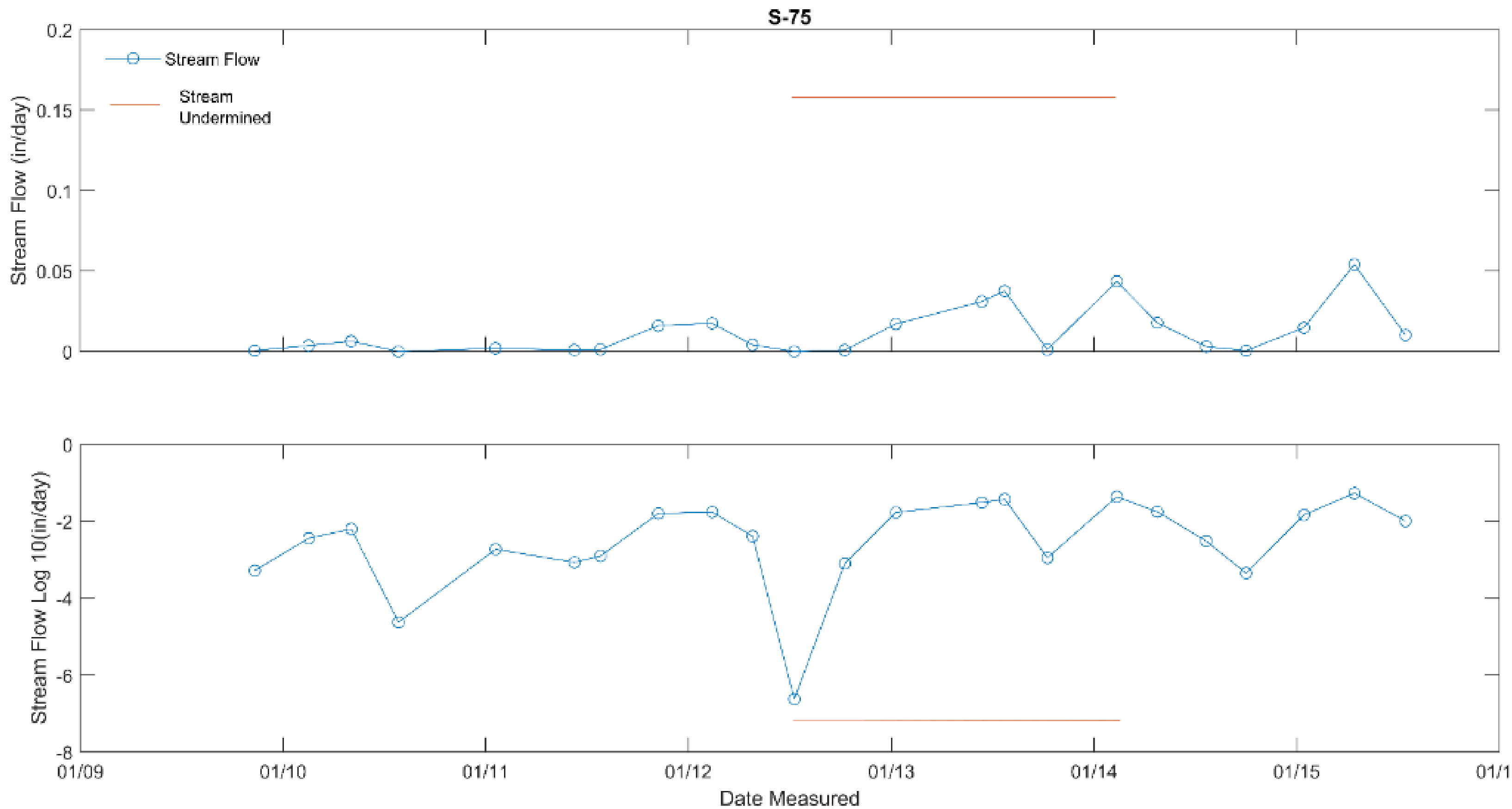

Figure G-27. Stream flow recorded at monitoring station S-75 in both normalized (in/day) and log 10 scale.

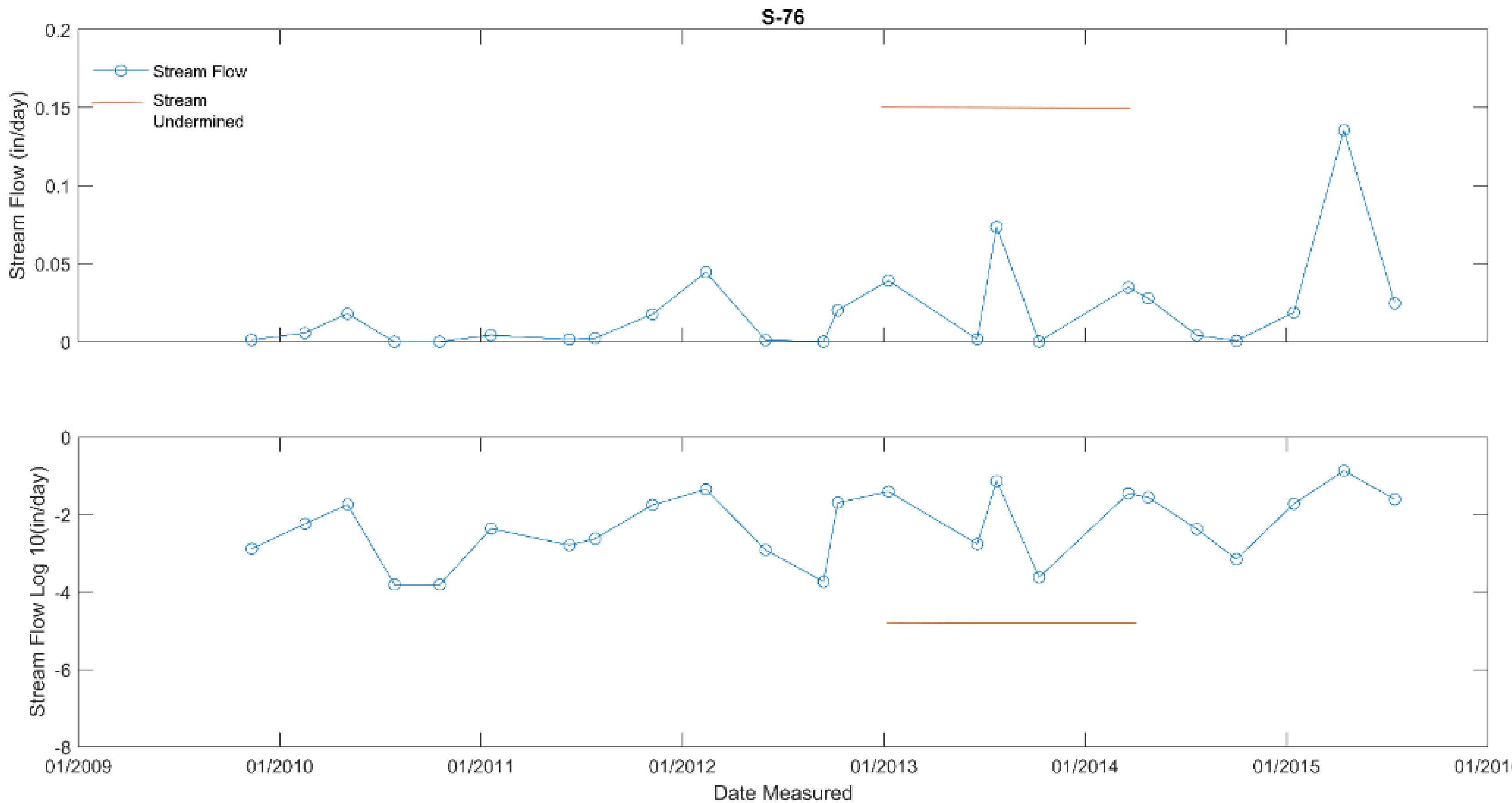

Figure G-28. Stream flow recorded at monitoring station S-76 in both normalized (in/day) and log 10 scale.

G.2.B.2 - Pursley Creek Groundwater HMRs

In addition to the surface water monitoring stations, there are two groundwater hydrologic monitoring points reported for this area (Figure G-25). Water levels and specific conductance were observed at 3121-W1 and 3121-W3 for relatively short periods (Figures G-29 and G-30). Monitoring point 3121-W3 was described as "collapsed" in the 4th assessment. Monitoring point 3123-W3 was also installed in the area but it was destroyed prior to the beginning of the 4th assessment. There is no TDS data supplied at these stations during the pre-mining period. However specific conductance is provided in µmho/cm for the two local piezometers (3121-W1 and 3121-W3). Specific conductance data were used to estimate TDS (TDS (mg/l) = 0.45 x SC (µmho /cm)). Finally, BUMIS cases of water loss in the 4th assessment near these streams were examined and all cases were resolved in agreements. The resultant terse documentation limits their use in clarifying groundwater impacts.

G.2.C – Pursley Creek Summary

Groundwater data for these Pursley Creek cases are extremely limited. Hydrologic groundwater monitoring points were not replaced after they were damaged. Water supply impacts and mitigation are not documented once agreements have been made. In this case the surface water HMR data does suggest a regional impact. However, the parallel changes in groundwater conditions cannot be evaluated.

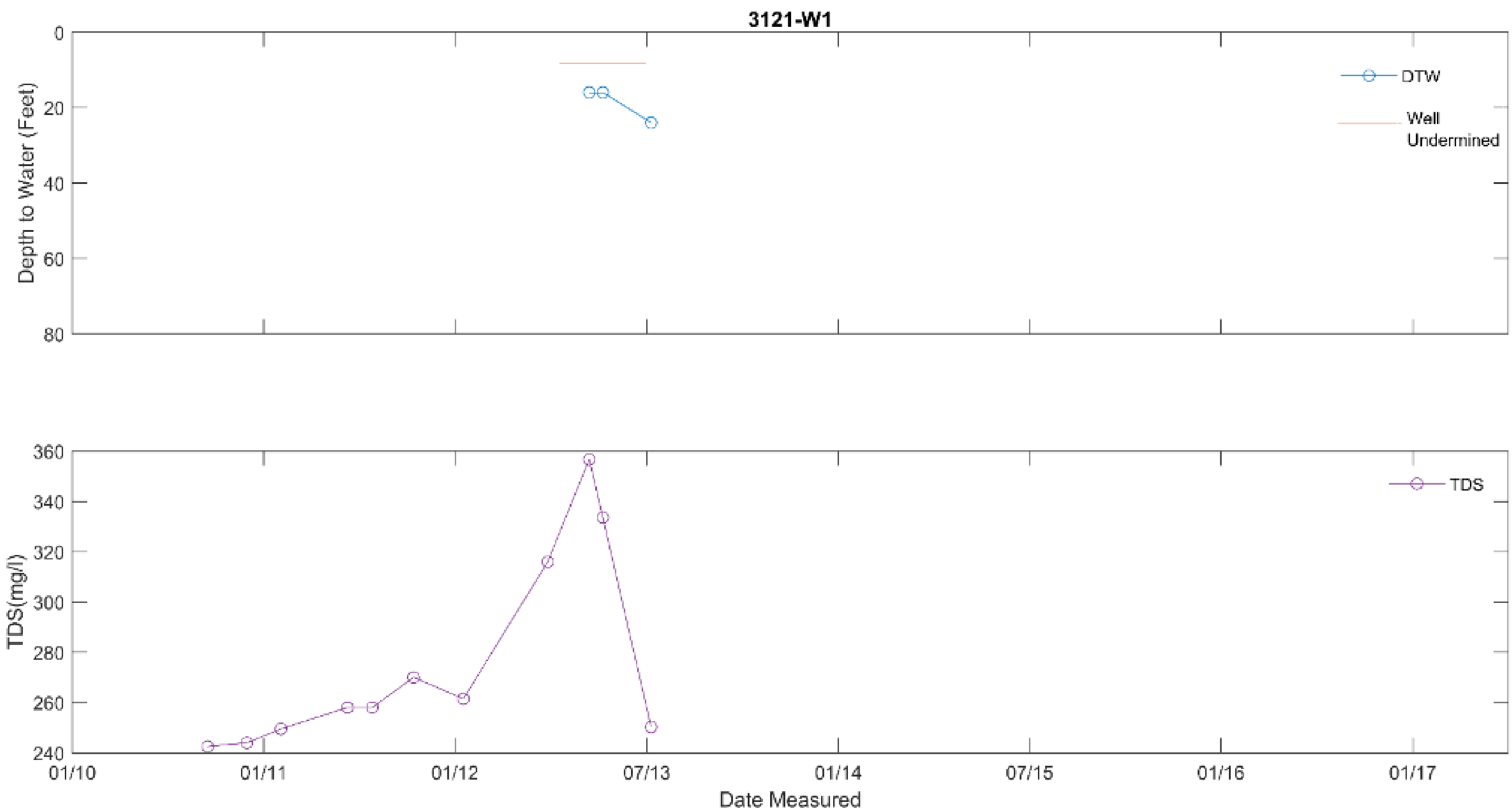

Figure G-29. Depth to water level and estimated TDS values recorded at HMR piezometer station 3121-W1. This piezometer has been unmeasurable since 1st quarter of 2013, so evaluation of post mining conditions is not possible.

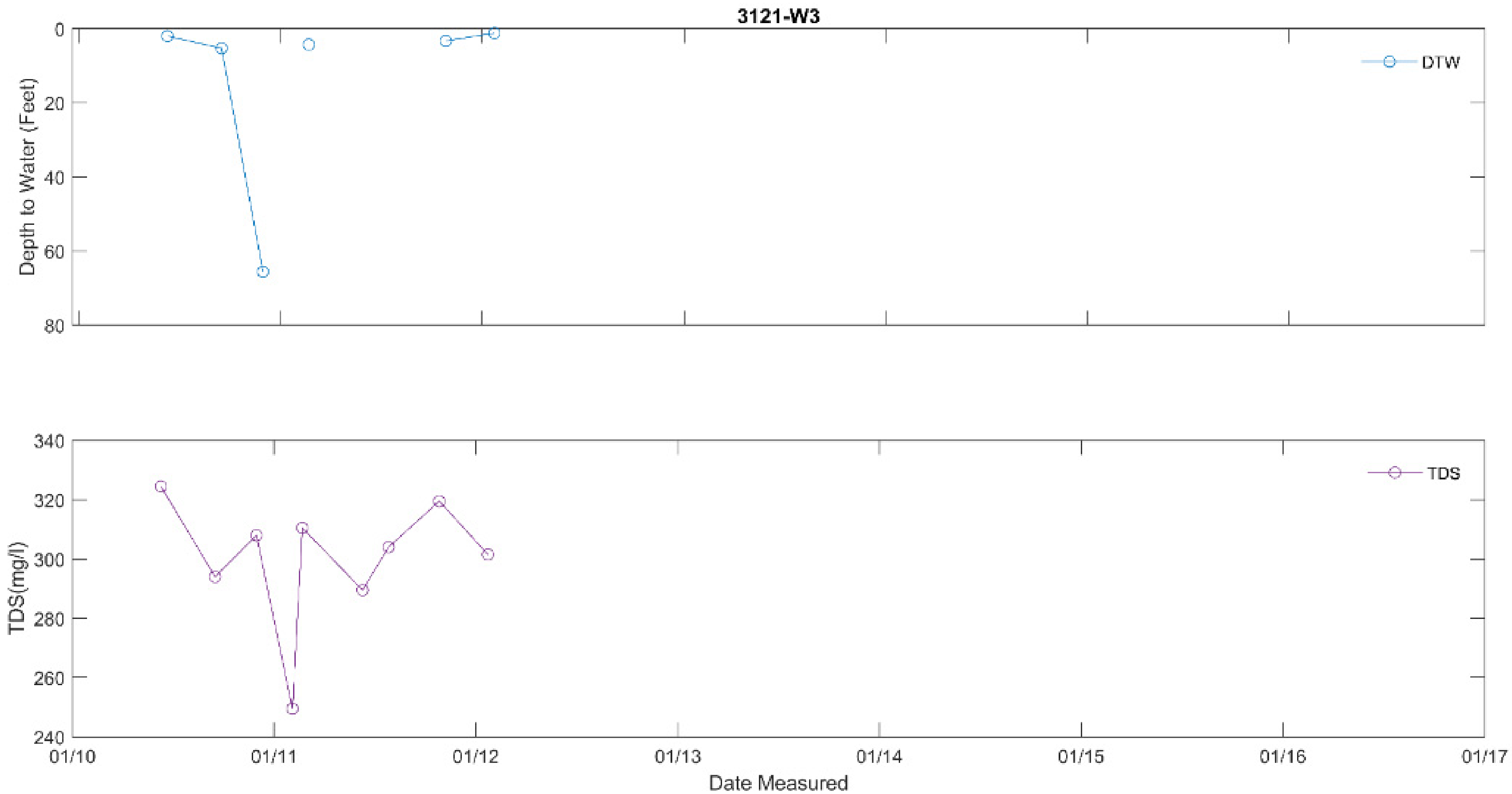

Figure G-30. Depth to water level and estimated TDS values recorded at HMR piezometer station 3121-W3. This piezometer has been unmeasurable since 1st quarter of 2013, so evaluation of post mining conditions is not possible.

References

Tonsor, S.J., A.N. Hale, A. Iannacchione, D.J. Bain, M. Keener, E. Pfeil-McCullough, and K. Garmire. (2014) "The Effects of Subsidence Resulting from Underground Bituminous Coal Mining, 2008-2013," University of Pittsburgh.