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Mine Safety and Health Administration
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MEMORANDUM FOR RICHARD A. GATES
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THROUGH:

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M. Terry Hoch
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FROM:

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SUBJECT:

Evaluation of Possible Lightning Damage to Gas Wells and
Evaluation of Lightning Strike Locations near Wolf Run Coal
Company, Sago Mine, MSHA I. D. No. 46-08791

Observations

August 8 Gas Well Evaluation

As requested by the Sago Accident Investigation Team, selected gas wells were evaluated near Wolf Run Coal Company's Sago Mine on August 8, 2006, to document any visible physical evidence of lightning strikes near the wells or gas lines. The evaluation area was defined by the proximity of gas wells to the 101 kA lightning strike recorded by Vaisala's National Lightning Detection Network on January 2, 2006 at 6:26:35 a.m. The wells were selected for evaluation because they are interconnected via metal gas lines to a main line that runs two miles east, passing a cased gas well adjacent to the abandoned 2nd Left section, where the January 2 explosion occurred. The main gas line and the wells it services are owned by a different company than the well adjacent to 2nd Left, and the well adjacent to 2nd Left may not be directly connected to the metal gas line that services the other wells. The evaluation was conducted to assess the possibility that an unreported lightning branch associated with the 6:26:35 a.m. strike may have struck in the vicinity of a well located 2,800 feet north-northwest of the

6:26:35 a.m. strike location and passed current along the buried metal gas line, traveling approximately two miles to the cased gas well adjacent to the abandoned 2nd Left section, subsequently igniting methane in the sealed area (Figure 1). The obvious limitation on this evaluation is that over seven months of snow, rain, and vegetation growth could have obscured or obliterated physical evidence of a January lightning strike.

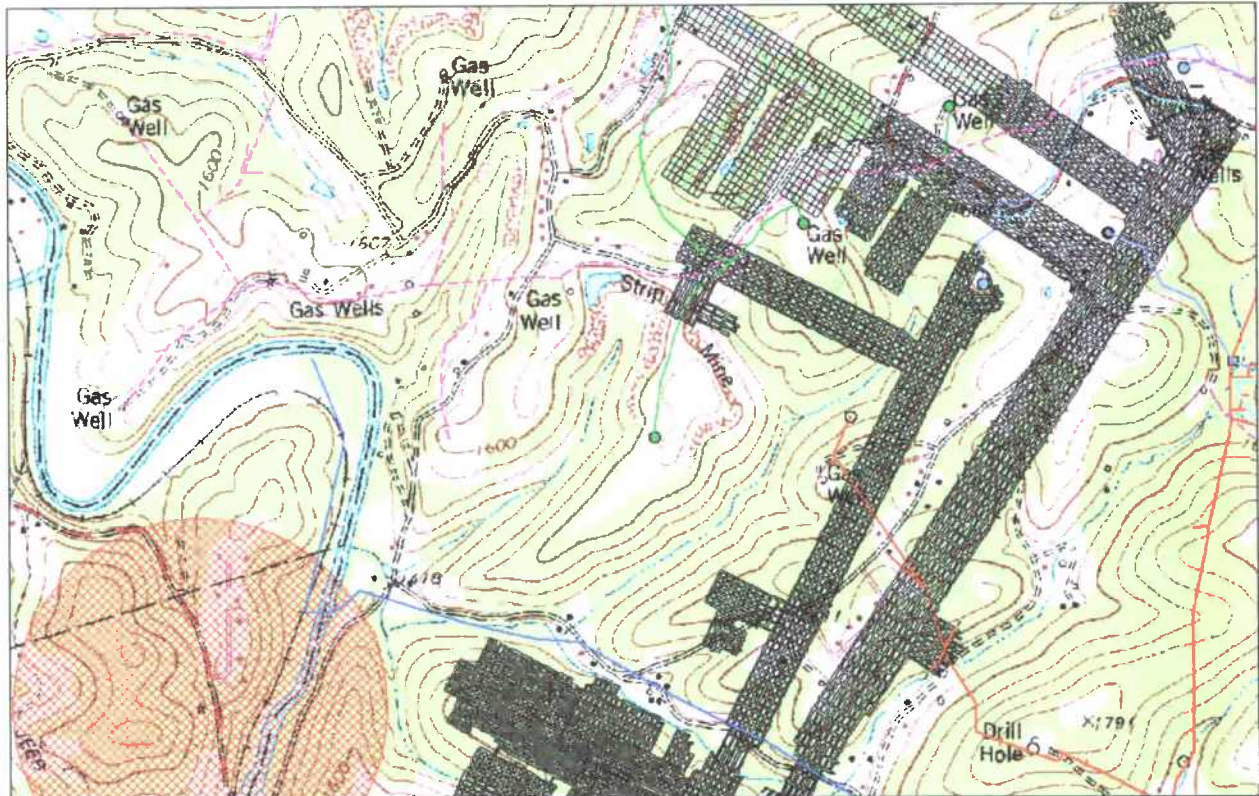


Figure 1. Red star at center of red crosshatch area (highlighting 500-meter 50% confidence interval) indicates position of 101 kA lightning strike reported by Vaisala at 6:26:35 a.m., January 2, 2006. Dashed purple lines represent buried metal gas lines owned by Keyspan. Red, blue, and green lines represent gas lines owned by other companies. Active gas well located on promontory 2,800 feet north-northwest of lightning strike is serviced by purple dashed Keyspan line, which runs approximately two miles east past gas well (light blue dot) that is adjacent to abandoned 2nd Left area.

Observations began at the well located 2,800 feet north-northwest of the lightning strike recorded by Vaisala at 6:26:35 a.m. on January 2, 2006 (Figure 2). No visible damage that might be expected of high heat flow such as searing, discolored metal, or molten/beaded metal was apparent at the gas well, exposed piping, or holding tank (Figure 3). The surrounding area in an approximately 200-foot radius was visually inspected for damaged trees or fulgurite formation (glass formed from melted and recrystallized soil or rock as a result of a lightning strike). No obvious lightning damage to trees was apparent, although some small, dead trees were shedding bark. Additionally, a number of trees, identified as sycamore trees by the mine engineer, were shedding thin sheets of bark, although this appeared to be a common occurrence for

this kind of tree because several in different parts of the observed area were in the same condition. No areas of glassy sand or soil, or holes that might indicate the presence of a fulgurite were noted in the surrounding ground. The ground along the trend of the buried metal gas line was scrutinized for similar possible effects of lightning, but no scarred, scorched, or glassy patches of ground were noted along the length of buried pipe until it connected with the exposed monitoring station approximately 300 feet northeast of the well (Figure 2).

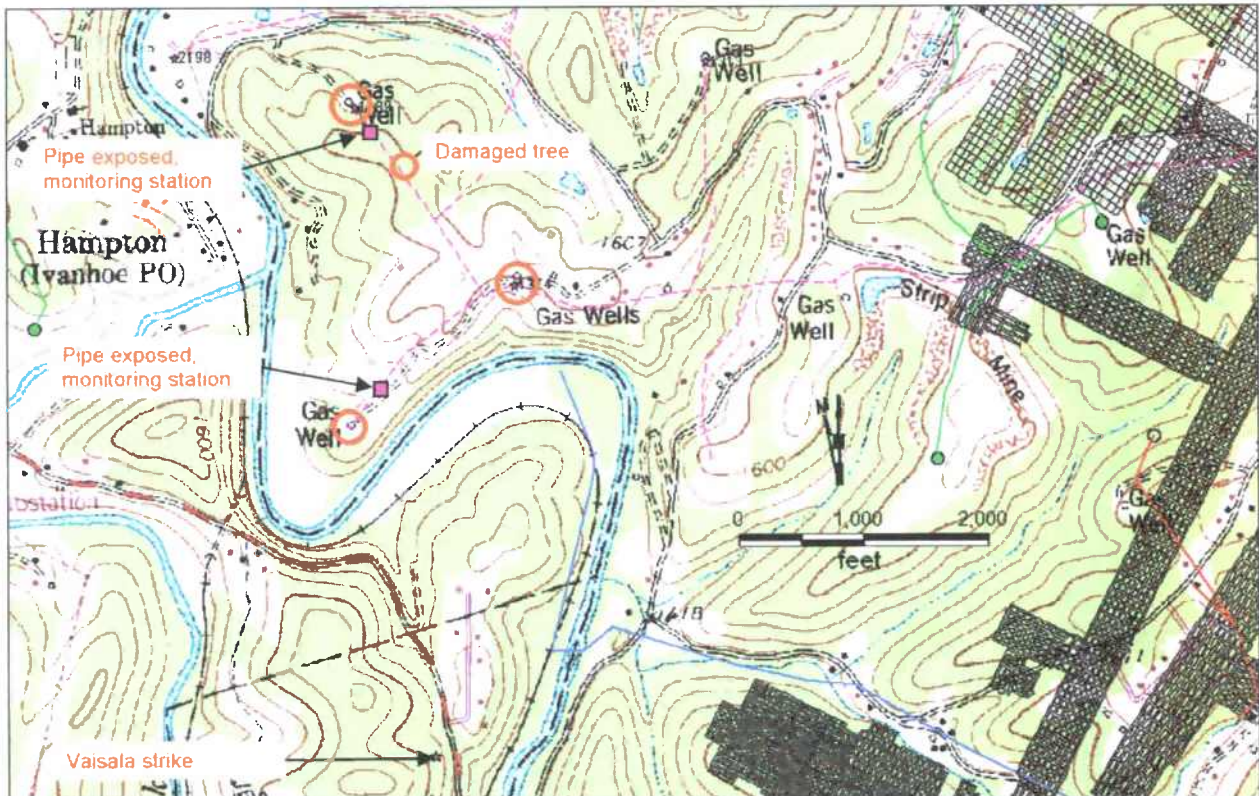


Figure 2. Gas wells (circled red) visited for this evaluation. Purple boxes represent monitoring stations for gas wells where metal gas lines are exposed at surface. A damaged tree was observed along the trend of a connecting gas line (purple dashed line), but appeared to be old damage. No lightning strike was reported at this location on January 2, 2006.

Observations continued along a dirt farm road (shown as a double dashed line on the topographic map), which followed the trend of the buried Keyspan gas line, until connecting with another gas well approximately 1,800 feet northeast of the initial Keyspan well (Figure 2). No evidence of lightning damage was observed at this location, either to the metal well, tank, or piping, or to the surrounding trees or ground. Similarly, no obvious damage such as scorched ground, fulgurite formation, or damaged trees was observed along the length of the buried gas line between the two wells.



Figure 3. Keyspan well located 2,800 feet north-northwest of 6:26:35 a.m. Vaisala lightning strike location that shattered a large tree. Well is serviced by an approximate 3-inch diameter metal pipe that is buried until exposed at a monitoring station 300 feet to the northeast. No evidence of lightning damage was apparent to the metal, or the surrounding trees and ground.

Observations continued on the north side of the hill, where a third Keyspan well was located approximately 2,600 feet Due North of the first well visited, and serviced by a metal pipe from a spur that ties into the line the connects the first two wells (Figure 2). This well did not have an exposed surface tank, although a buried metal pipe trended from the well to a monitoring station approximately 200 feet up the hill slope, where the gas line was exposed. Surface erosion had exposed the rusted metal pipe, which is believed to represent the active gas line (Figure 4). The observation traverse continued up-hill along the trend of the gas line, past the exposed monitoring station, to the top of the hill approximately 600 feet southeast of the well. At the crown of the hilltop, within approximately 50 feet of the buried gas line, a damaged tree was located that appeared to exhibit the effects of a lightning strike (Figures 2 and 5). The damaged tree appeared to represent either an old lightning strike or some other storm damage, although the age of the tree's damage is unknown. The tree was characterized by two forks, one of which was vertical, with a papery, rotten texture pock-marked with insect or bird holes and sloughed-off bark. The other fork was composed of solid but splintered wood, and had fallen to the ground along a cantilever hinge. The wood was weathered brown and appeared to represent an old event, although the age could not be determined.

Subsequent inspection of the locations of lightning strikes in the vicinity of the mine, as recorded by the Vaisala and Weather Decision Technologies networks, discussed below, indicated that no strikes were recorded in this immediate vicinity on January 2, 2006.



Figure 4. Rusted metal gas line exposed by erosion in slope adjacent to third Keyspan gas well visited, located approximately 2,600 feet Due North of the first well. Gas line trends from well to monitoring station approximately 200 feet southeast, and then continues underground to tie in with line that connects first two wells visited (compare to Figures 1 and 2).



Figure 5. Tree along trend of buried metal gas line on hilltop approximately 4,600 feet Due North of 6:26:35 a.m. Vaisala strike location suggests damage by storm or lightning. Unlike the shattered poplar tree near the 6:26:35 a.m. strike location determined by Vaisala's NLDN, this tree did not exhibit blown-off shards or slivers of wood. The age of the damage is unknown. Compare to Figures 1 and 2 for perspective.

Lightning Strike Location Evaluation

In order to more fully evaluate the possibility that lightning may have triggered the January 2nd explosion at the Sago Mine, the locations and times of lightning strikes within an approximate 15-mile radius of the mine were requested from two different lightning detection networks. The explosion site in the abandoned 2nd Left section represented the center of the search area, and includes lightning strikes recorded by

Vaisala, which operates the National Lightning Detection Network (NLDN), and from Weather Decision Technologies, which operates the U. S. Precision Lightning Network (USPLN). These two commercial ventures operate different networks that utilize slightly different methods to locate the positions of lightning strikes.

Figure 6 shows the locations of cloud-to-ground strikes recorded by Vaisala within approximately 15 miles of the abandoned 2nd Left explosion area during the time between 4:00 a.m. and 7:15 a.m. on January 2, 2006. The location points are labeled with the time of the strike, as determined by Vaisala. Of all the lightning strikes recorded during this time frame, only two, both at 6:26:35 a.m., occur anywhere near the vicinity (within six miles) of the explosion site in 2nd Left. A cluster of three strikes located between approximately 4.5-6.25 miles northeast of the abandoned 2nd Left area occurred 12 minutes after the inferred time of the explosion, at 6:38:51 a.m. The next nearest lightning strikes are located approximately 6.5 miles to the south and northwest, but from between approximately 15-30 minutes before the explosion. The strike recorded at 5:57:48 a.m. occurred within ½ mile of a power line that connects to the mine, and is located approximately 4.4 miles south of the mine portal. It is interesting to note that there are several examples of clusters of strike locations that occur at the same time, but are separated by distances of between 0.3-2 miles.

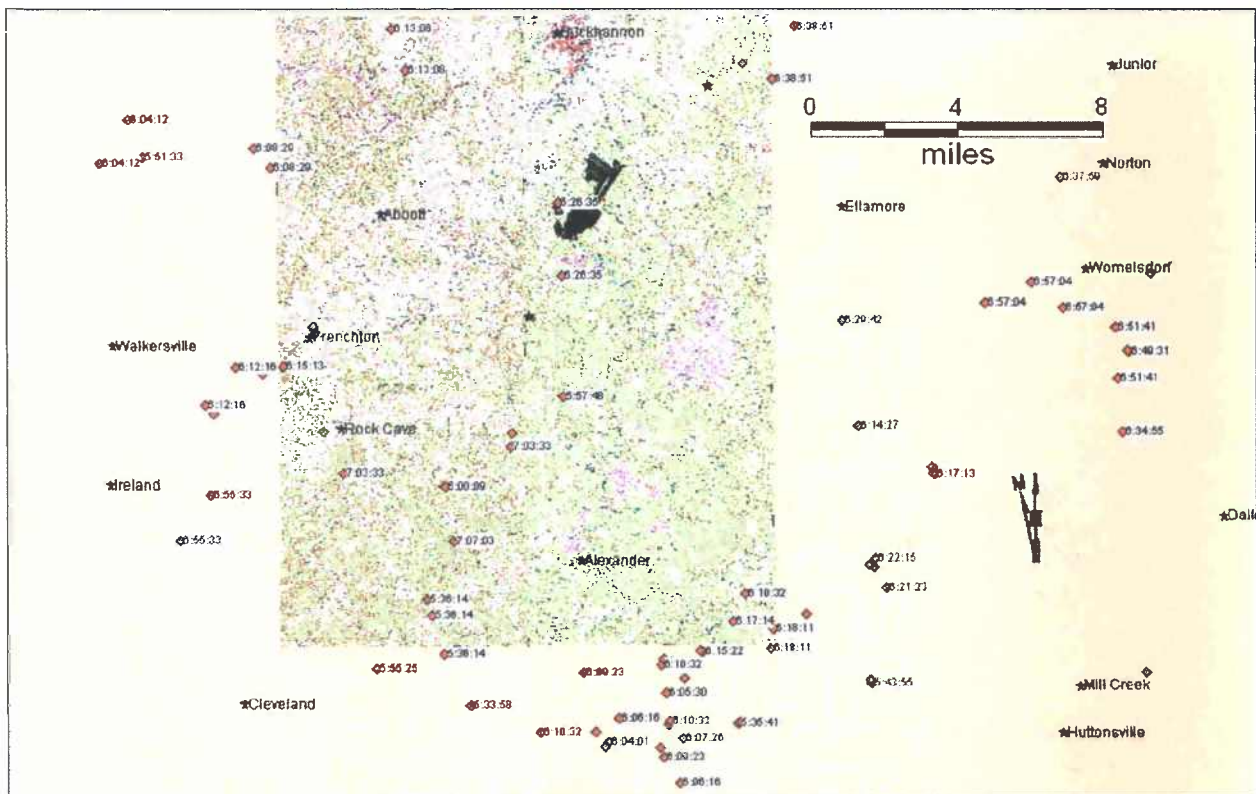


Figure 6. Location of Sago Mine on topographic background, with plotted locations of lightning strikes recorded by Vaisala's NLDN system between 4:00 a.m. and 7:15 a.m. on January 2, 2006 within 15 miles of the 2nd Left explosion site.

Figure 7 shows the locations of cloud-to-ground lightning strikes determined by Weather Decision Technologies, Inc.'s U. S. Precision Lightning Network (USPLN) within approximately 15 miles of the abandoned 2nd Left area during the time frame between 5:30 a.m. and 7:15 a.m. on January 2, 2006. It appears that, similarly to the data reported by Vaisala, the only lightning strike in the vicinity (within six miles) of the 2nd Left section occurred at 6:26:35 a.m. The next nearest strikes, again similarly to that reported by Vaisala, occurred approximately 6.5 miles south and northwest of the explosion site at 5:57:48 a.m. and 6:38:51 a.m., respectively, approximately half an hour before, and 12 minutes after, the explosion.

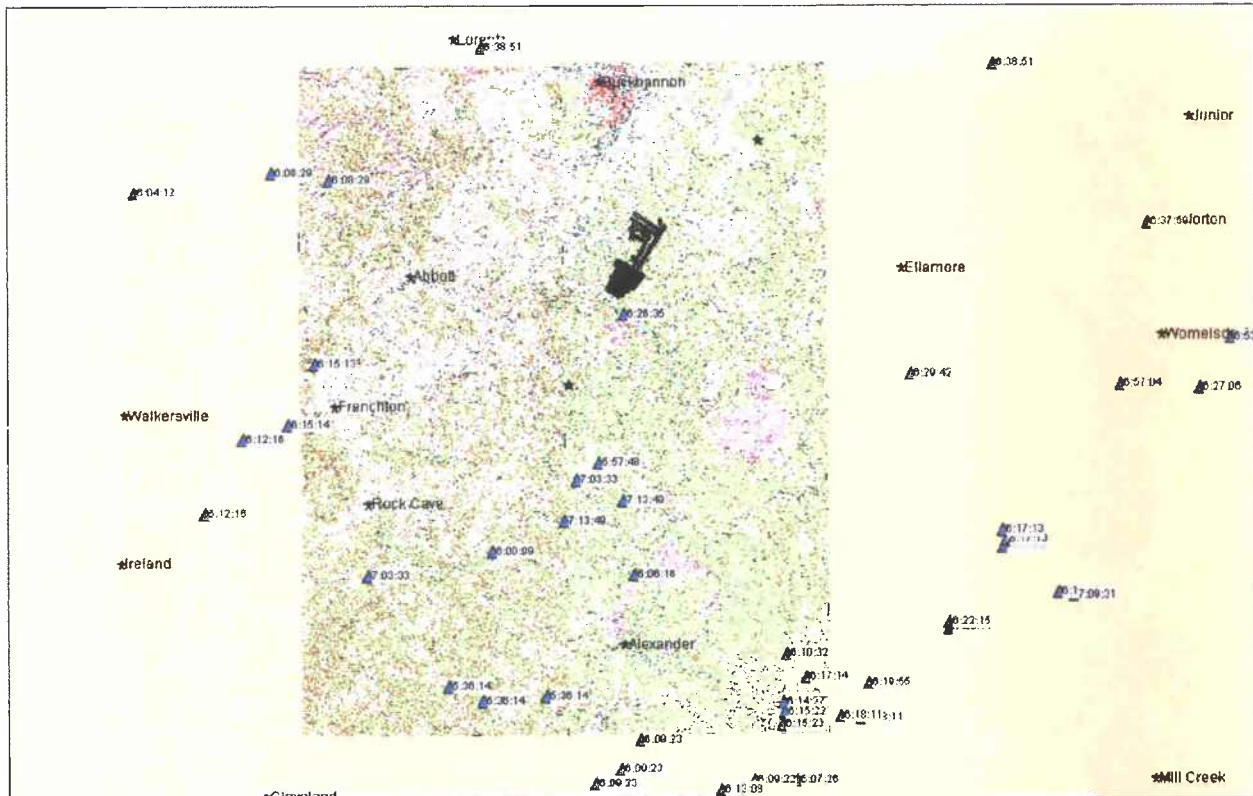


Figure 7. Locations of lightning strikes from USPLN between 5:30 a.m. and 7:15 a.m., January 2, 2006, within approximately 15 miles of the 2nd Left explosion area at Sago Mine.

Figure 8 represents a plot of the lightning strike locations reported by Vaisala's NLDN displayed together with those reported by Weather Decision Technologies' USPLN. It appears that not only are there fewer data points represented by the USPLN records compared to the Vaisala records, but that the data points do not generally display an overlap.

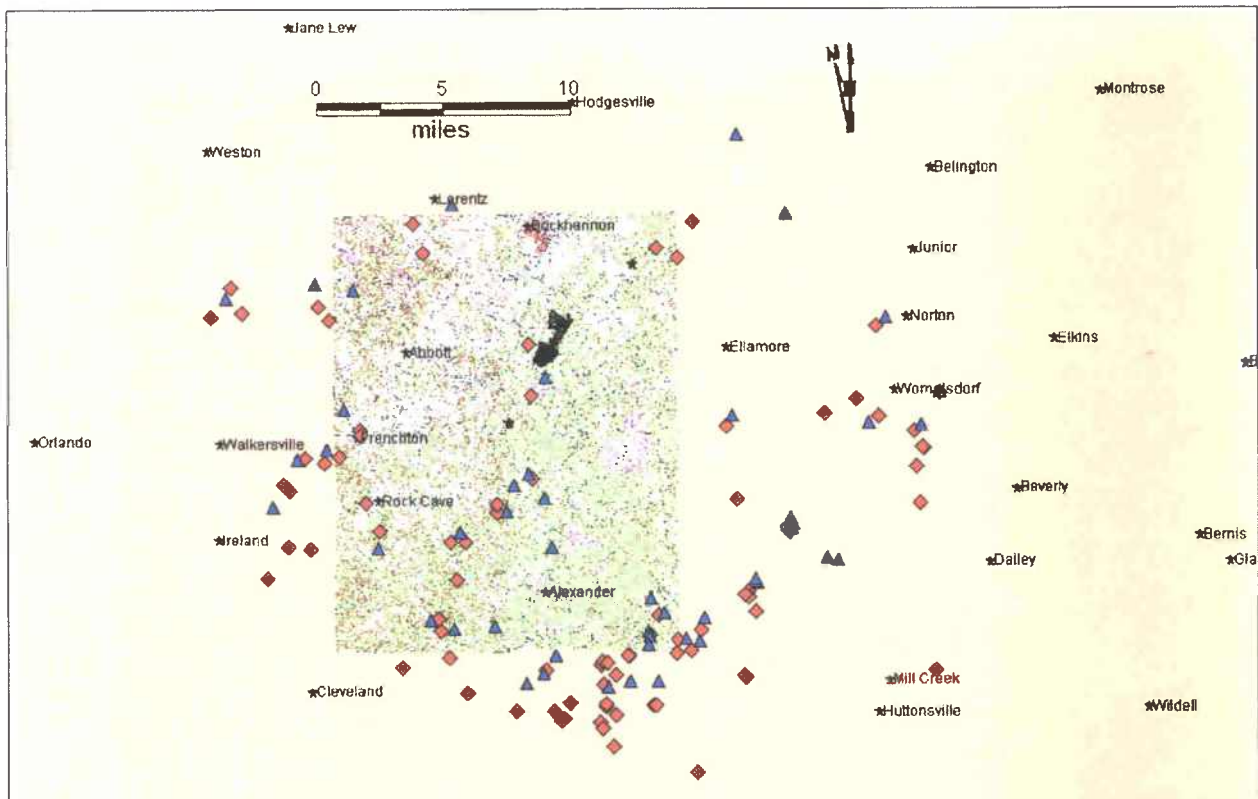


Figure 8. Locations of lightning strikes reported by NLDN (red diamonds) and USPLN (blue triangles) in relation to the Sago Mine between 4:00 a.m. and 7:15 a.m. on January 2, 2006.

Figure 9 represents a closer view of the Sago Mine with lightning strike locations by NLDN and USPLN displayed with their times of record. It appears that many NLDN strikes have a USPLN “mirror” that occurred at the same time, but are located a variable distance to the northeast. This “mirror” effect may be due to differences in detection methods between the two networks. For instance, NLDN records three strikes at 6:38:51 a.m. located approximately five miles northeast of the abandoned 2nd Left section, while the apparently corresponding USPLN strike is recorded approximately 4½ miles to the east-northeast of the three NLDN locations. The NLDN strike reported approximately 1.5 miles south of the Sago Mine portal, at 6:26:35 a.m. has a USPLN “mirror” located approximately one mile northeast of this location, in the bottom of the Buckhannon River valley. Despite the common association of offset locations at the same time, the USPLN system does not report a “mirror” for Vaisala’s 6:26:35 a.m. strike located at -80.2331° E / 38.926° N, which is believed to have shattered the large poplar tree just west of the mine.

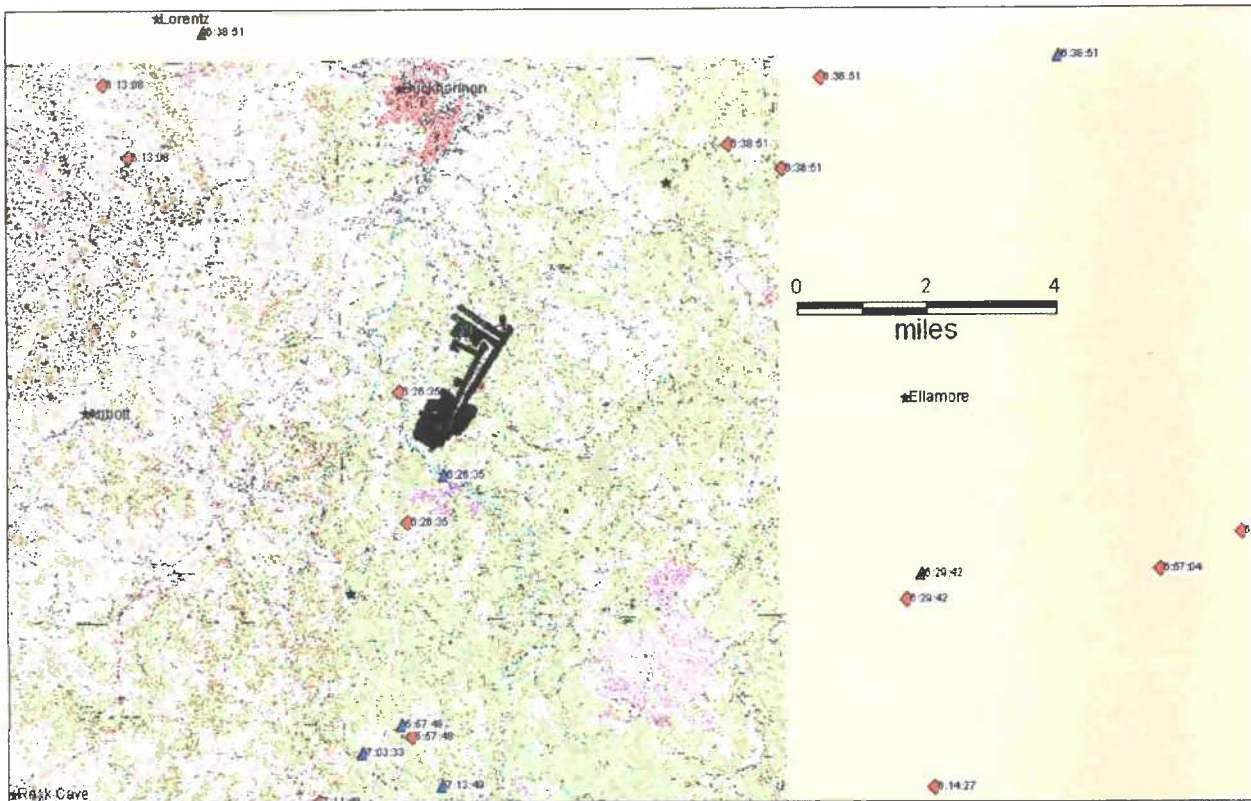


Figure 9. Closer view of the lightning strikes reported by Vaisala's NLDN (red diamonds) and Weather Decision Technologies' USPLN (blue triangles) systems in relation to the Sago Mine, during the time frame between 4:00 a.m. and 7:15 a.m. on January 2, 2006. The USPLN system commonly plots a "mirror" location that is offset by a variable distance from the corresponding NLDN position. However, no USPLN "mirror" is reported for the NLDN strike at -80.2331° E/ 38.926° N, which is located within 200 feet of a shattered poplar tree west of the mine.

Discussion

The August 8 evaluation of gas well and gas lines was carried out to assess the possibility that an unrecorded lightning strike associated with the 6:26:35 a.m. strike reported by Vaisala's NLDN may have struck a gas well north of the Buckhannon River. Several gas wells in this vicinity are connected via metal gas lines, which tie into a metal line that runs approximately two miles, passing a cased gas well adjacent to the abandoned 2nd Left section. Although the metal gas line is shown on maps to run within 100 feet of the cased gas well adjacent to the abandoned 2nd Left section, and the metal line is shown to overlap the line that services the well, the metal line is not believed to connect with the well. The metal line is owned by Keyspan, whereas the gas well adjacent to 2nd Left is owned by Eastern American Energy.

No obvious, physical evidence of damage to the metal well heads or gas lines was observed. Additionally, no obvious damage to the ground was observed in the vicinity of the wells or along the length of buried metal lines. The only tree damage observed was located near a buried metal gas line on a hilltop approximately 4,600 feet north of

the recorded 101 kA 6:26:35 a.m. Vaisala strike (-80.2331° E/38.926° N). The time of this tree damage is unknown, though neither lightning detection network plots a strike at this location. The only other tree damage in the vicinity of the gas wells was represented by sycamore trees shedding bark, and this appears to be a natural occurrence.

Although neither lightning detection network indicates the presence of a strike near any of the gas wells visited northwest of the mine, or near the well adjacent to the abandoned 2nd Left section, it may be difficult to rule out the occurrence of an unrecorded strike of lightning. For the time frame and area evaluated, the data recorded by the respective networks do not appear to exhibit good overlapping of locations. For lightning strikes recorded at the same time, the USPLN appears to commonly plot locations a variable distance to the northeast of the same NLDN location. It is impossible to determine which location, if either, can be considered correct. It should be noted that the provided locations probably are not intended to provide precise ground strike locations, but can only provide the triangulated locations of the initiation of radio waves generated by lightning discharge several hundred feet above the ground. Due to the forking and branching commonly observed in lightning strikes, it would therefore be unreasonable to expect that the given locations would correspond to a precise coordinate on the ground. Data point locations indicate that both systems appear to have the capability to resolve separate strikes that occur at the same time to a resolution of within approximately ½ mile. Some strike locations recorded at the same time by Vaisala's NLDN suggest a resolution of 1/3 mile. However, examination of the data suggest that the two different networks have recorded different numbers of strikes, and that for strikes that apparently occurred at the same time, different peak currents and different locations were reported by the two systems. This is an indication that although the lightning detection systems are capable of providing a general location for lightning strikes, it may be unrealistic to assume that every lightning strike in a multiple discharge will be recorded, or that a location can be determined for every strike.

It is interesting to note that the USPLN system recorded a "mirror" for the NLDN strike that occurred approximately one mile south of the Sago Mine portal. Vaisala's NLDN system recorded this strike at 6:26:35 a.m., with a peak current of 38.8 kA at -80.2313° E / 38.8968° N. Weather Decision Technologies' USPLN system apparently recorded the same strike at 6:26:35 a.m., but with a slightly different peak current of 35 kA and in a location 4,900 feet to the northeast, at -80.2209°E / 38.9072° N. Similarly, the NLDN system recorded a strike at 5:57:48 a.m. with a peak current of 25.1 kA at -80.231° E / 38.8487° N, located approximately 4.5 miles south of the mine portal. The USPLN system apparently recorded the same strike at 5:57:48 a.m., but with a peak current of 24.6 kA at -80.2336° E / 38.8514° N, which is approximately 1,200 feet northwest of the NLDN location. These recorded positions are within approximately 2,800 feet of a power line that runs north past the Sago Mine. At 6:38:51 a.m., 12 minutes after the

inferred time of the explosion, the NLDN reported a cluster of three strikes with peak currents of 85.7, -86, and -12.6 kA between approximately 4.5-6.25 miles northeast of the abandoned 2nd Left section. The USPLN system appears to have recorded the same strikes as a single event, reported with a peak current of 93 kA, but located approximately 4.3 miles east-northeast of the NLDN cluster. In contrast, the NLDN strike that was recorded at 6:26:35 a.m. with a peak current of 101 kA at -80.2331° E / 38.926° N, which is within 200 feet of a shattered poplar tree just west of the Sago Mine, does not have a corresponding “mirror” reported by the USPLN system.

The apparent lack of precision or consistency in the lightning location data makes it difficult to exclude the possibility that an unrecorded lightning strike at 6:26:35 a.m. could have struck one of the gas wells north of Vaisala’s NLDN reported 101 kA strike location. No physical evidence of lightning damage was found in the vicinity of the gas wells and gas lines observed, and no lightning strikes were recorded by either lightning detection network in the immediate vicinity of any of the gas wells visited. A damaged tree was observed near a metal gas line in the evaluation area, but the time of damage is unknown.

If you should have any questions regarding this report, or if we can be of further assistance, please contact Sandin Phillipson at 304-547-2015.