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Report to

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Report on a Survey of Ground-Level Ambient Methane Levels in the Vicinity of Wyalusing, Bradford County, Pennsylvania

November 2013

by

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[This report is subject to revision.]

NOTE: Figures follow text.

There have been numerous reports of methane emissions related to shale gas development in the vicinity of Wyalusing, Bradford County, Pennsylvania. In the interest of furthering the understanding of those fugitive methane events Damascus Citizens for Sustainability engaged Gas Safety, Inc. to survey ambient air methane levels in the vicinity of Wyalusing, PA. The survey covered parts of 9 townships on both sides of the Susquehanna River (Figure 1 –

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following text) from Towanda on the northwest to Wyalusing on the central eastern side. Survey coverage was restricted to readily identifiable public roadways. Consequently, the survey was most intense from the Susquehanna River west to Pennsylvania Route 187.

Though the survey results do not prove a relationship between ambient air methane contamination and groundwater contamination, it is clearly suggestive. Further, it also suggests shale gas well operations in that area still did not have control of the gas that has been developed there. In fact, as will be discussed, survey data indicates there may be gas control problems in about 10% of the survey area resulting in elevated methane levels in most of the area.

In addition, detection of any level of methane above normal background for an area indicates only two possible conditions: diffuse, non-point emissions are occurring over some portion of the area, or, one or more point sources are active within the area.

Conditions during the Survey

The survey effort involved two separate survey field work efforts, one on 31 January and the other 3-4 June 2013. Weather conditions at the time of the January survey were not ideal. Winds were from the west at speeds consistently near 20 miles per hour (29 feet per second). Under these conditions methane emissions from any source disperse rapidly. Consequently, elevated methane levels due to such emissions are more difficult to detect than under more favorable wind conditions. Functionally this means that, during a road survey, detection of elevated methane levels requires the sources be larger or more intense and in closer proximity to the survey vehicle path than under more favorable wind conditions. However, such wind conditions do cause methane emissions to be swept along the ground surface farther and faster. Consequently, methane emissions appear as a general elevation of methane levels over a wider area, instead of localized markedly elevated peaks.

During the 3-4 June field work weather conditions were more favorable. The wind was from the north-northwest at an average speed of 5 miles per hour (around 8 feet per second). Under these conditions methane emissions would be expected to be detectable as low concentration plumes extending for an appreciable distance to the south-southeast of the source. Mixing layer structure and height was not estimated during the survey, but conditions should have favored typical lower atmospheric mixing patterns in which most methane emissions diffuse rapidly upward.

Results of the January Survey

As anticipated due to the wind conditions the methane levels were moderately elevated widely over the survey area. Typical methane level observed during the survey was low. The average methane level was 1.86 ppm, with a minimum of 1.79 ppm, 90% were below 1.91 ppm, and 99% below 2.08 ppm.[3] Under such high wind conditions, the layer of the atmosphere that normally forms next to the land surface[4] is swept away by air that would normally move at altitudes of a few hundred to a few thousand feet above. Under gentler wind conditions gases released into the air tend to accumulate in plumes as they dissipate into the turbulent but lower-wind-speed layer of air next to the land surface. Under sustained high wind conditions the air from the higher layer sweeps down and across the land surface rapidly sweeping any released gases across the land surface and up into the atmosphere.

Figure 2 shows an oblique westward view of the survey area in which the data was processed to remove values lower than 2.2 ppm and vertically exaggerate those over 2.2 ppm by a factor of 1000. In effect, this approach visually defines methane levels above 2.2 ppm as elevated methane levels (EMLs). This graphical rendering shows around 18 locations with elevations above 2.2 ppm. There also appear to be many locations with EMLs near 2.2 ppm. This, however, is an artifact of the low resolution of this image and the high resolution of the survey data set. When this image is examined at higher resolution most of the apparent near-2.2-ppm EMLs disappear.

To allow examination of smaller EMLs another image of data was prepared with the methane data processed to remove values below 1.9 ppm and vertically exaggerate values >1.9 ppm by a factor of 100. The lower 1.9-ppm cutoff and vertical exaggeration preserved EMLs that were not apparent upon high resolution examination of Figure 2, as illustrated by Figures 3 and 4. The >1.9-ppm image is not shown as it is visually nearly flat at the resolution that can be rendered on a single page of this report. In the >1.9-ppm image 57 EMLs were indentified as sufficiently clear to merit further examination (see Appendix B for a listing of those EMLs by location). Of those 57 EMLs, 43 were in proximity to and nearly-downwind of gas pipelines, gas well pads, farms, industrial facilities with apparent waste water treatment ponds or lagoons.

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[3] During survey runs the vehicle has to make stops. The CRDS methane instrument collects data continuously. Consequently, geographically disproportionate amounts of data accumulate whenever the vehicle stops. Geographically disproportionate data accumulations are removed from the data set before statistical analysis. Images are generated using the full raw data sets.

[4] Planetary boundary layer or mixing layer. See Manhattan extended report for more detailed discussion.NEED LINK HERE

Further identification of the methane sources causing the other 14 EMLs was beyond the scope of the survey work.

Despite the strong wind conditions a relatively large methane plume was detected. The plume was detected over an area running from Wysox 2.5 miles southward along the river and up to 3.6 miles to the east. The plume was not present on a later pass through the same area. The extent and consistency of this plume over such a large area under such windy conditions, and its relatively sudden disappearance suggest a sizeable release of methane upwind of the plume area that ended sometime during the survey. Identification of a likely source was beyond the scope of the survey work. It is noteworthy that this plume was again present during the June survey. The plume may have been related to a number of gas wells generally north of Wysox.

Conclusions from 31 January Survey

The strong wind conditions during the methane survey caused rapid mixing and lateral dispersal of methane from any sources in or near the survey area. Under such conditions detection of elevated methane levels is limited to those resulting from larger emissions or those from sources in close proximity to the roadway. The rapid mixing and lateral dispersal causes methane levels in the area to appear more uniformly elevated than would be the case under less windy conditions. This was indicated by the slightly elevated mean (1.86 ppm) and narrow range of methane levels (1.79-1.91 ppm) that accounted for the 90% of the data (further discussed in comparison to the June data follows below). All the other 10% of the data indicating methane levels above 1.91 ppm occurred at less than 60 locations. Among those locations, 43 were in the vicinity of candidate potential methane sources, in most cases gas pipelines or gas well pads. At 14 locations with elevated methane levels candidate potential methane sources were not readily apparent.

Results of the 3-4 June Survey

As expected under the more favorable wind conditions on 3-4 June, methane plumes were detectable over much larger areas than during the extreme wind conditions of the 31 January survey. Elevated methane levels occurred over much of the survey area. Additionally the methane instrument (cavity ring down spectrometer[5]) was run during travel from the survey area and during a brief observational trip to the Leroy Township area. Those two legs of the

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[5] http://www.picarro.com/technology/cavity_ring_down_spectroscopy

survey trip provided methane measurements in geographically and geologically adjacent areas that can be reasonably regarded as comparable areas with limited or no shale gas well activity. That area is referred to as the Reference Area in the remainder of this report. It includes data from valleys, along a river, and two town/city areas. Hence, the Reference Area can be reasonably considered to have all likely natural and human-caused methane sources typical for the geographical/geological area, but with minimal large-scale agricultural, industrial or shale gas sources. Also, of some interest is recognition that the methane survey work included parts of two areas under Pennsylvania Department of Environmental Protection Consent Orders. An image displaying the results of the June survey is provided in Figure 5.

It should be borne in mind that the survey work was limited to publicly accessible roads. The survey, therefore, measures the impacts of methane emissions sources at considerable distances from those sources. Consequently, seemingly minor changes, in the tenths or hundredths of a part per million, in ambient air methane levels are of considerable importance in locating methane emissions sources and assessing their broader area impacts.

The June survey average methane level was 1.83 ppm, with a minimum of 1.75 ppm, 90% were below 1.88 ppm, and 99% below 2.05 ppm.[3] Given the difference in wind conditions, these levels were quite similar to those seen in the January survey. For comparison, in the Reference Area the average methane level was 1.78 ppm, with a minimum of 1.76 ppm, 90% were below 1.79 ppm, and 99% below 1.81 ppm.[3] Since much of the survey area is affected by the same type and frequency of methane sources that occur in the Reference Area, one would expect that much of the survey area data would be similar. This was, in fact, found to be the case. It can be seen in Figure 6 that in the Reference Area 97% of the methane levels were below 1.8 ppm, while in the survey area in June, 37% were, but in the survey area in January less than 1% were below 1.8 ppm. These results suggest that methane emissions in about 37% of the survey area are effectively similar to the Reference Area. The strong winds during the January compared to the June survey were probably the cause of the apparent reduction in total area with readings below 1.8 ppm (37% of the area in June compared to <1% in January), Emissions that on 3-4 June were rising into the air more normally, whereas on 31 January emissions were being rapidly mixed and swept over the land surface by the strong winds.

Looking at another methane value of interest, the maximum methane level measured in the Reference Area was 1.88 ppm. In the survey area on 3-4 June 10% of the measurements exceeded the Reference Area maximum, and on 31 January 16%. Consequently, it is reasonable to conclude that at least 10% of the survey area is impacted by methane sources that do not occur in the Reference Area. As previously mentioned, these are agricultural and industrial sources. Field observations and examination of satellite imagery allowed determination that some of the methane sources causing the elevated methane were agricultural or industrial, other than shale gas development. The plumes of the ag/industrial sources appeared less extensive than the plumes of the sources associated with shale gas development. Most of the shale gas methane emissions sources appeared likely to be well pads and pipelines.

With regard to the relationship between ambient air methane surveys and locations of methane sources potentially impacting an area, it is interesting to consider the survey covered parts of the areas under two PaDEP Consent Orders. Those two Orders were between the PaDEP and Chesapeake Appalachia, LLC, dated 16 May 2011[6]. The two Orders were designated for impact areas referred to by PaDEP as Paradise Road and Sugar Run. It should be borne in mind that at the time of the survey, the Consent Order impact areas were not specifically known to GSI and were not specifically targeted. The general outline of the survey area was selected by DCS based on reports in the media and from residents. The specific area was determined by the operational conditions GSI encountered in the field. Consequently, the survey covered the Consent Orders impact areas only coincidentally. Still the survey did include about 2/3 of the Paradise Road and ½ of the Sugar Run Consent Order impact areas. It can be readily observed in Figure 5 that elevated methane levels were concentrated within the Paradise Road impact area compared to the remainder of the survey. There were elevated methane levels in other parts of the survey area but the concentration in the central part of the Paradise Road impact area is distinct. **Though this does not prove a relationship between ambient air methane contamination and groundwater contamination, it is clearly suggestive. Further, it also suggests shale gas well operations in that area still did not have control of the gas that has been developed there. In fact, as already mentioned, the survey data indicates there may be gas control problems in about 10% of the survey area resulting in elevated methane levels over 60-90% of the area.**

In addition, detection of any level of methane above normal background for an area indicates only two possible conditions: diffuse, non-point emissions are occurring over some portion of the area, or, one or more point sources are active within the area. Non-point sources are difficult to assess, precisely because they are diffuse. As mentioned previously, at the end of the survey work reported here a cursory evaluation run was made to the area of a previously documented shale gas well impact in Leroy Township. NEED LINK HERE That site is of interest in this discussion because on the land surface methane emissions occur as a non-point source, with gas emerging from many points over a area of uncertain extent. During the earlier evaluation of that site

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[6] This PA DEP Consent Order available HERE: https://www.dropbox.com/s/3r34e3ggb88qxbo/161%20Consent%20Agreem%20Susquehana%20River.pdf

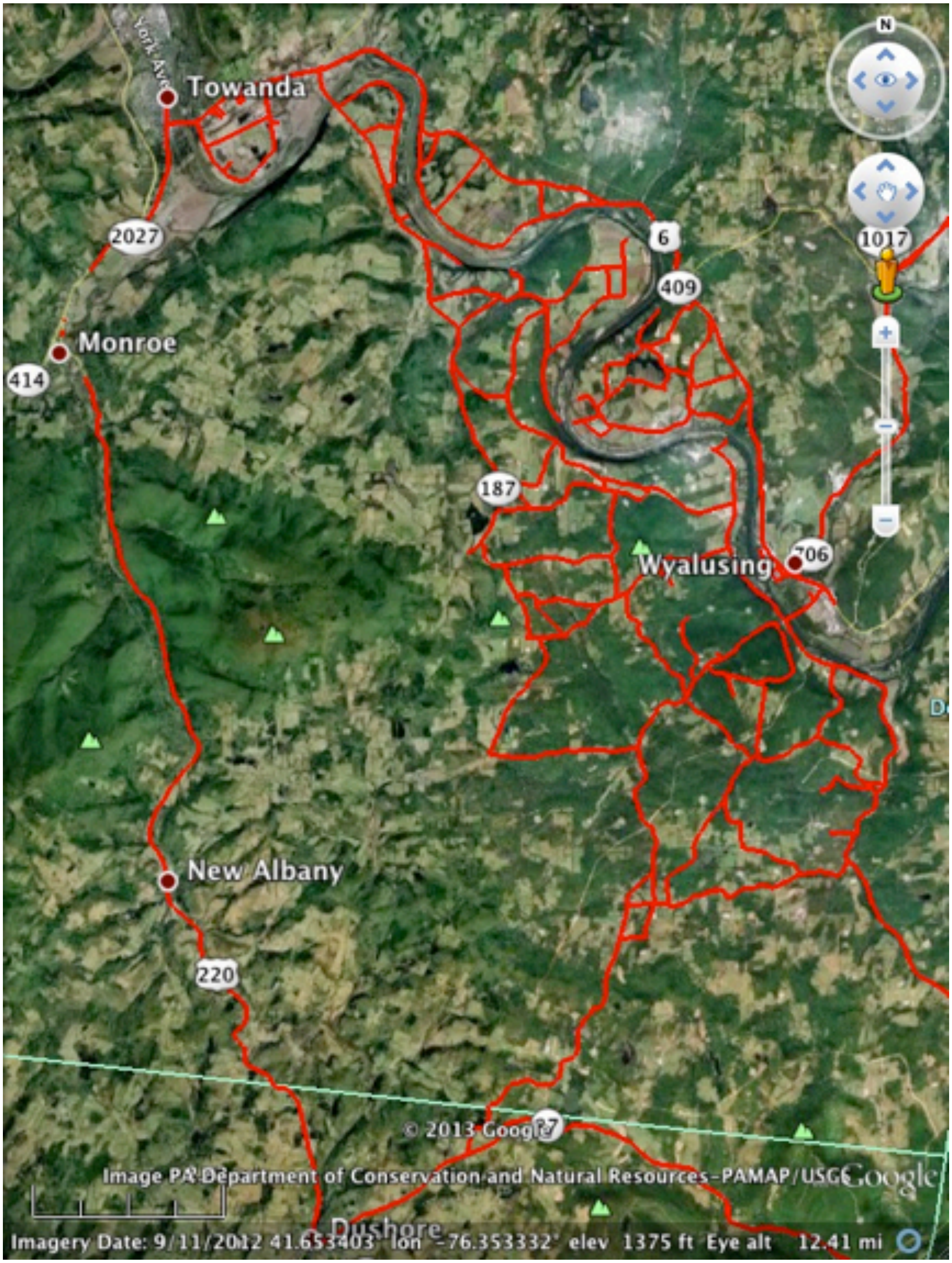
nearly pure natural gas was encountered within inches of the soil surface, but on the nearest road, about 100 yards away, and downwind at the time, only a few ppm of methane were detected. Despite gas well remediation measures, the 4 June run along the same roads confirmed methane levels remain in the range of a few ppm, suggesting the methane migration problem still exists. A cursory water sample test also indicated water in the area still has very high methane levels. Methane contamination was prevalent in the area during the prior evaluation. The Leroy Township situation is troubling with regard to health and safety, and discouraging with regard to the capability of industry to effectively correct gas well problems when they occur.

Point sources of methane present a slightly different set of concerns. A substantial amount of methane is necessary to raise methane levels even slightly over an extensive area, as measured from our survey over public roads. If that amount of methane is being emitted at one or a few point sources, then the concentration of methane in the vicinity of those sources will likely be hazardous with respect to explosion or asphyxiation. Consequently, the methane levels measured during the survey indicate there likely are point sources associated with some shale gas wells in the area that do give rise to hazardous conditions. Those point sources need not necessarily be at the gas well itself, as the gas may find underground pathways to emerge in water wells, homes or other structures, as occurred in Leroy Township, and the Paradise Road and Sugar Run impact areas.

Conclusions

Methane from any source rapidly diffuses and rises in the air. Consequently, detection of possible methane sources from any distance away requires extremely sensitive measurement capabilities. The GSI survey approach takes advantage of extremely sensitive measurement instrumentation to detect small increases in ambient air methane levels as an indication of probable methane emissions sources in a given area. Based on the data collected using that equipment, we conclude that the Towanda-Wyalusing area is probably substantially impacted by methane emissions from shale gas wells both within and beyond the survey area, depending on wind conditions. The coincidence of two DEP methane migration impact areas, Paradise Road and Sugar Road, and the most marked ambient air methane levels suggests there are still gas control problems associated with the shale gas wells there, as well as in another documented impact area in Leroy Township also cursorily measured following the main survey. A rapid water test in the Leroy area confirmed the water in that area is still contaminated with methane. These survey results suggest methane contamination continues and measures taken by gas well operators with regard to methane migration problems that have occurred in these three areas have likely been only partially effective.

Figure 1. Overhead image of roads traveled during the survey of ambient air methane levels in the vicinity of Wyalusing, PA on 31 January 2013 (Google Earth).



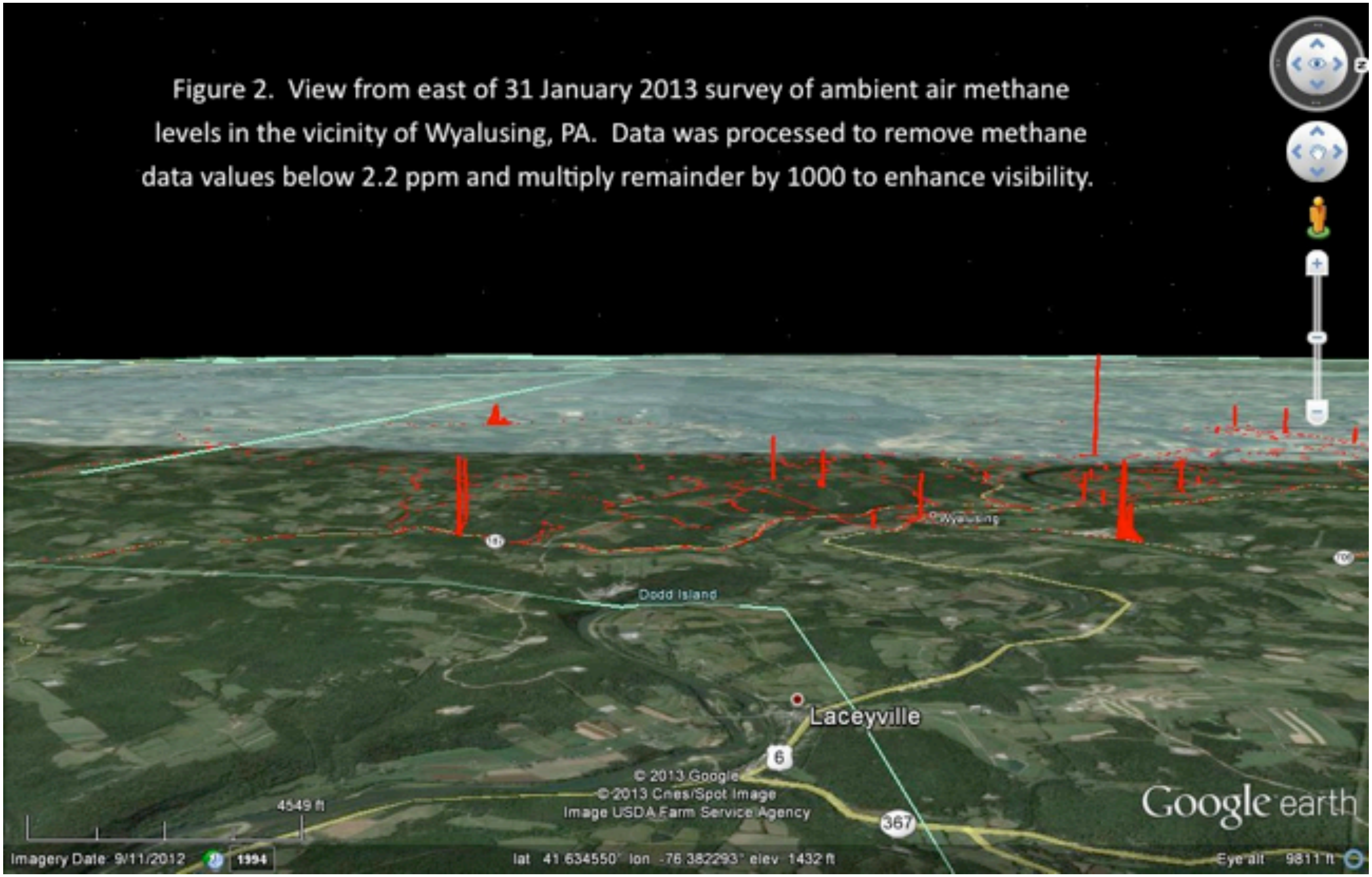


Figure 2. View from east of 31 January 2013 survey of ambient air methane levels in the vicinity of Wyalusing, PA. Data was processed to remove methane data values below 2.2 ppm and multiply remainder by 1000 to enhance visibility.

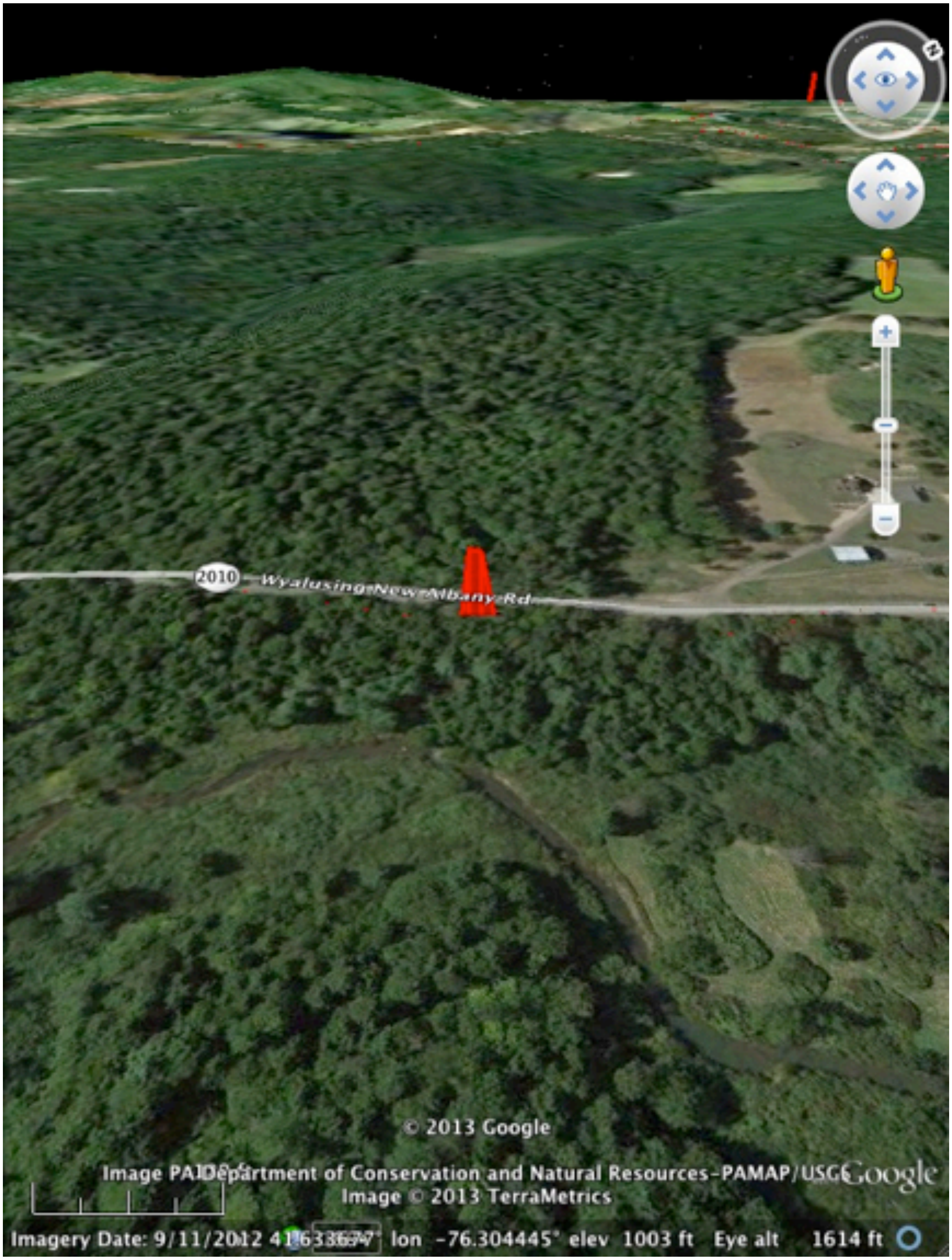


Figure 3. An elevated methane level as rendered by processing of the Wyalusing 31 January 2013 methane survey data to remove values <2.2ppm and multiply remainder by 1000. Compare to same elevated methane location in Figure 4.

Figure 4. An elevated methane level as rendered by processing of the Wyalusing 31 January 2013 methane survey data to remove values <1.9ppm and multiply remainder by 100. Compare to same elevated methane location in Figure 3.

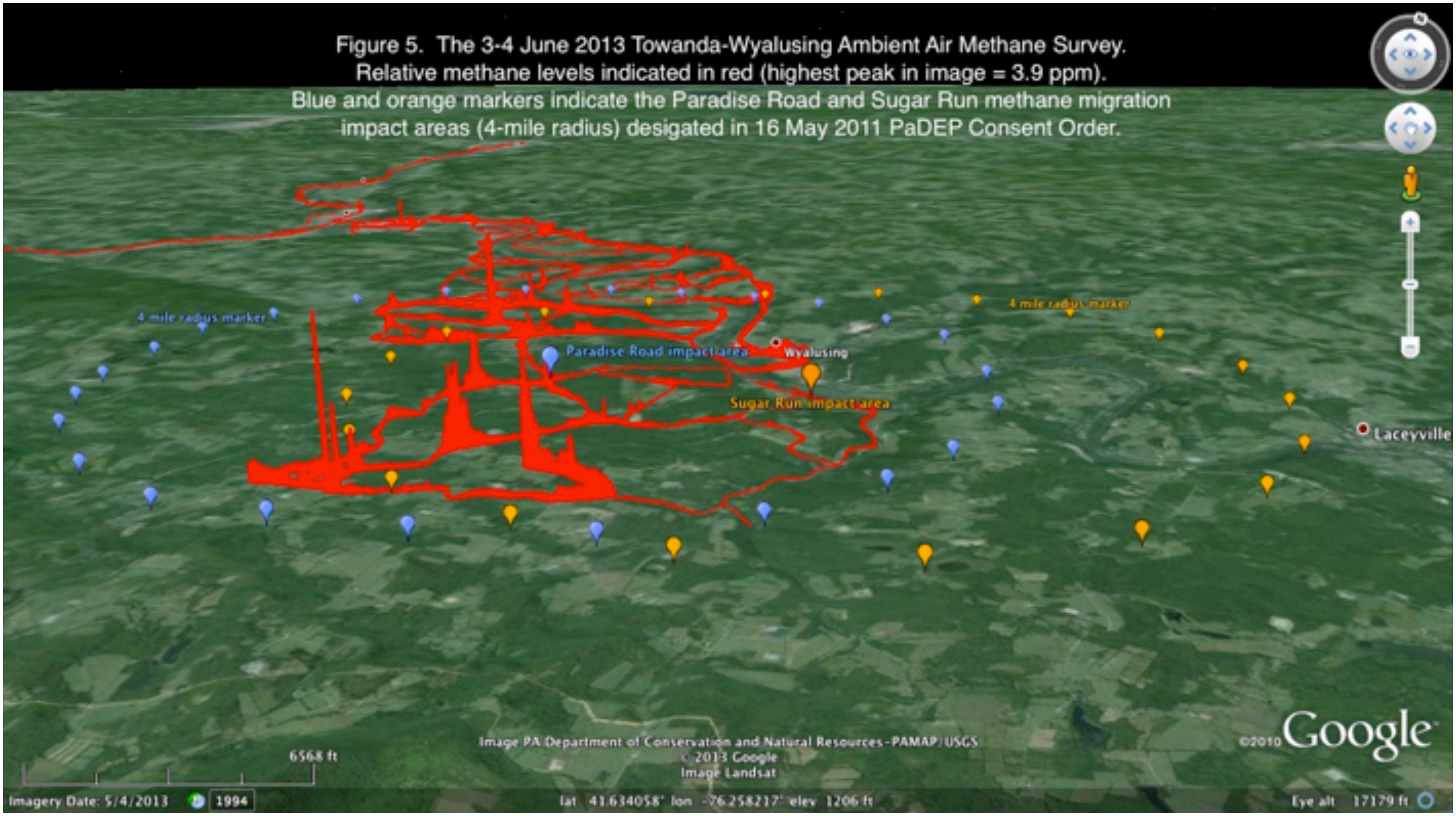


Figure 5. The 3-4 June 2013 Towanda-Wyalusing Ambient Air Methane Survey. Relative methane levels indicated in red (highest peak in image = 3.9 ppm). Blue and orange markers indicate the Paradise Road and Sugar Run methane migration impact areas (4-mile radius) desigated in 16 May 2011 PaDEP Consent Order.

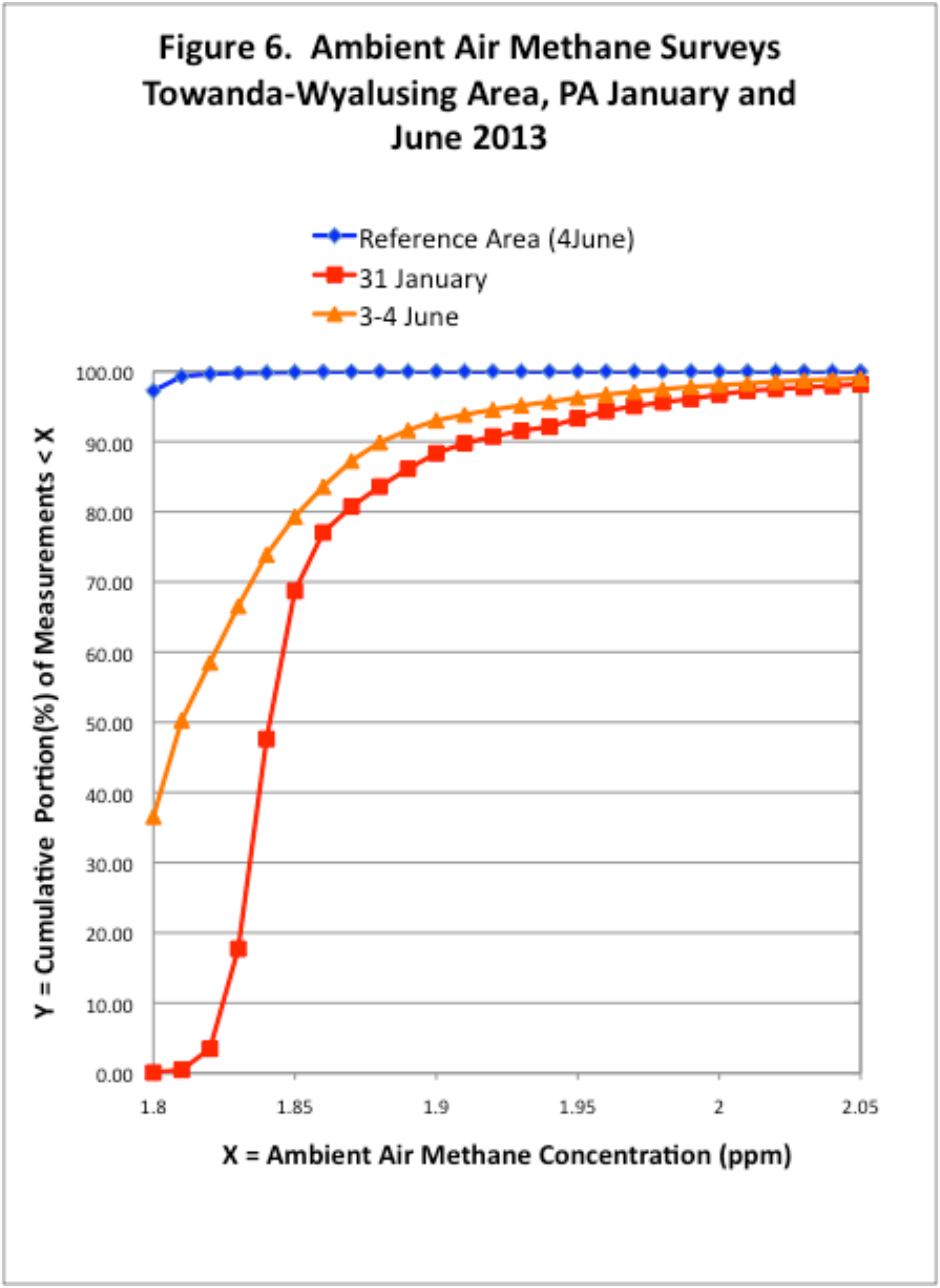


Figure 6. Ambient Air Methane Surveys Towanda-Wyalusing Area, PA January and June 2013
Reference Area (4June)
31 January
3-4 June
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Y = Cumulative Portion(%) of Measurements < X
1.8
1.85
1.9
1.95
2
2.05
X = Ambient Air Methane Concentration (ppm)