Introduction:
In 2017, Villanova purchased a SPOT-6 satellite image with the Pennsylvania View (PA View) grant funding. The satellite imagery covered the East Branch of the Brandywine River and was collected April 17, 2016. Many streams near Villanova's campus, including the Brandywine, traverse a rural to urban gradient and offer an ideal opportunity to examine the relationship between land use practices and water quality. Research in Dr. Steven Goldsmith's Laboratory in our department at Villanova has focused on determining the sources and fate of contaminants in these systems (including nutrients, sediment, metals, and pharmaceuticals) and crafting practical solutions to ameliorate the associated impacts. Through collaborations with local municipalities and watershed conservation organizations, such as the Lower Merion Conservancy and the Guardians of the Brandywine, students are able to ask questions of environmental significance while gaining real-world problem solving experience. The research was previously undertaken by a student of Dr. Goldsmith's but only used maps to identify specific study locations. The utilization of current satellite imagery augmented the research and provided the remote sensing class with the ability to better understand the land use context around the specific site study locations provided by the imagery. We utilized the hi-res SPOT satellite imagery of the East Branch of the Brandywine to identify the potential point sources of contaminants from privately operated sewer systems, and potential leach fields. The analysis was incorporated into a remote sensing class as an exercise to discuss the environmental issues and allow students to determine and appreciate where they are geospatially and in the context of the local area by utilizing the SPOT imagery. The exercise enabled the students the opportunity to appreciate how an environmental study may be augmented using satellite imagery as a tool.

For background, the following is a summary of the research performed by Ms. Kaila Hanley, a student in the Department of Geography and the Environment at Villanova University:
"Over the last decade, there has been a growing urgency to determine both the source and fate of emerging contaminants such as pharmaceuticals and personal care products (PPCP) in our waterways. In particular, many studies have focused on the widely used antimicrobial agent triclosan, due to its link to antimicrobial resistance. However, these initial studies have solely utilized sampling locations downstream of municipal sewage treatment systems, thus overlooking potential inputs from other point sources such as small privately operated sewage systems and non-point sources (i.e., leach fields associated with septic systems). Here we examine the range of concentrations, overall loading, and potential controls on triclosan delivery from non-municipal sources in the East Branch of the Brandywine Creek (EBBC), a rural to suburban watershed located in southeastern Pennsylvania. Samples for triclosan and discharge measurements were collected from 13 locations in the EBBC watershed in July 2014 during baseflow conditions. Further field work was undertaken in summer 2016. Detectable concentrations of triclosan in the EBBC ranged over several orders of magnitude from 0.131 to 274 ng/L. Small privately operated sewage treatment facilities and/or non-point sources were found to comprise ~28% of the cumulative triclosan loading in the EBBC. Triclosan concentrations and loads were subsequently compared to existing GIS-based land use data as well as the number of sewage related National Pollutant Discharge Elimination System (NPDES) discharge permits (a proxy for privately operated sewage treatment facilities) above each sampling location in an effort to evaluate controls on its export. No relationship was identified between triclosan concentrations and the relative amount of 15 different land use

practices above each sampling location. While the relative number of NDPES permits above the sampling location did play a role in determining the extent of triclosan loading, this was ultimately dependent on the relative volume of the receiving water body. Finally, the presence of detectable concentrations of triclosan in tributaries with no NPDES permits suggests leach fields are also a viable source. These findings suggest we must greatly expand our consideration of sources for PPCPs in our waterways.

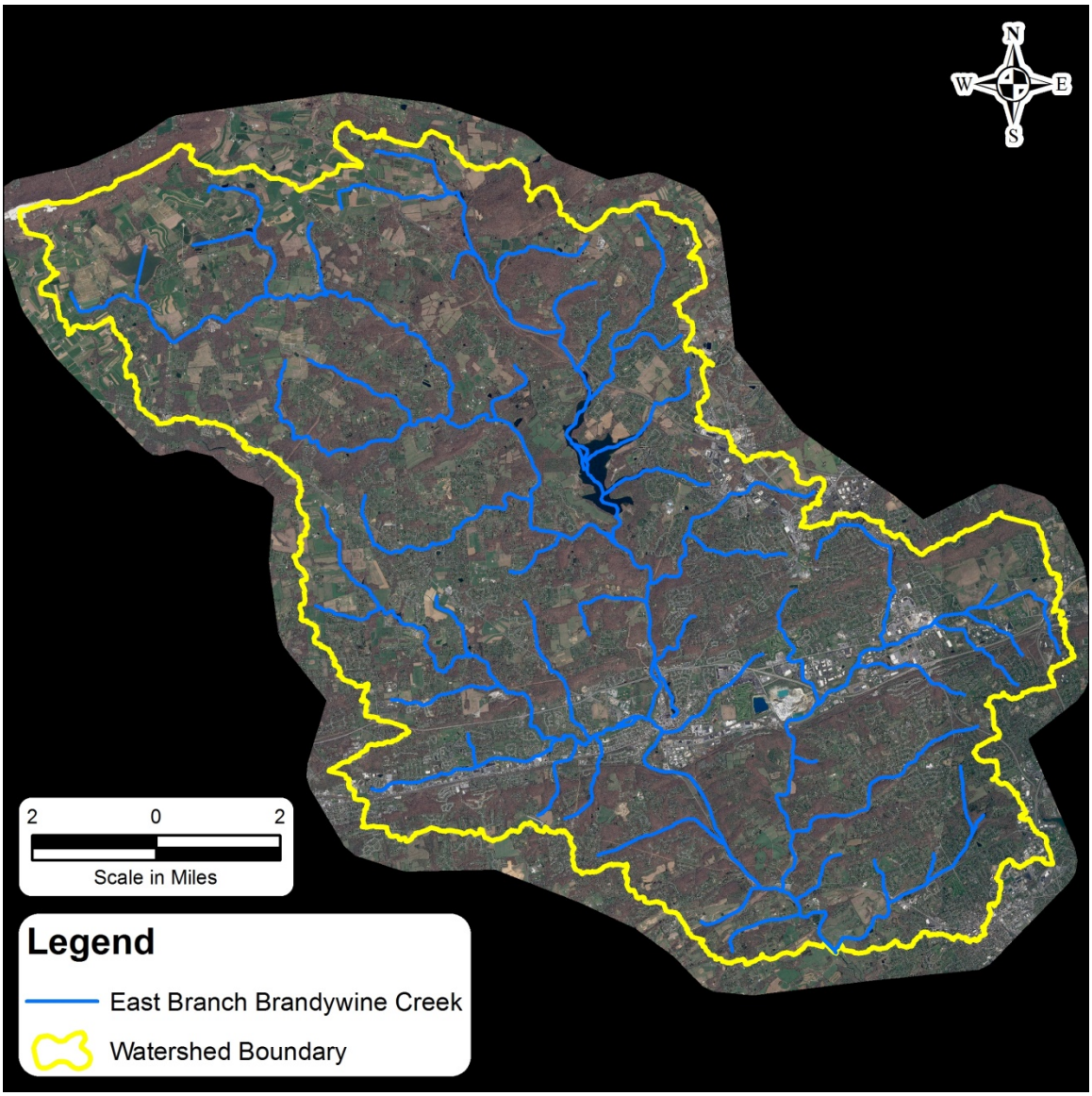

Figure 1. SPOT image of the East Branch Brandywine Creek with waterways and watershed boundary. Note Marsh Creek State Park (large body of water) in the center of the image and also the many blue unnamed tributaries draining into the East Branch. The borough of Downingtown, PA in Chester County is located in the bottom center of the image.

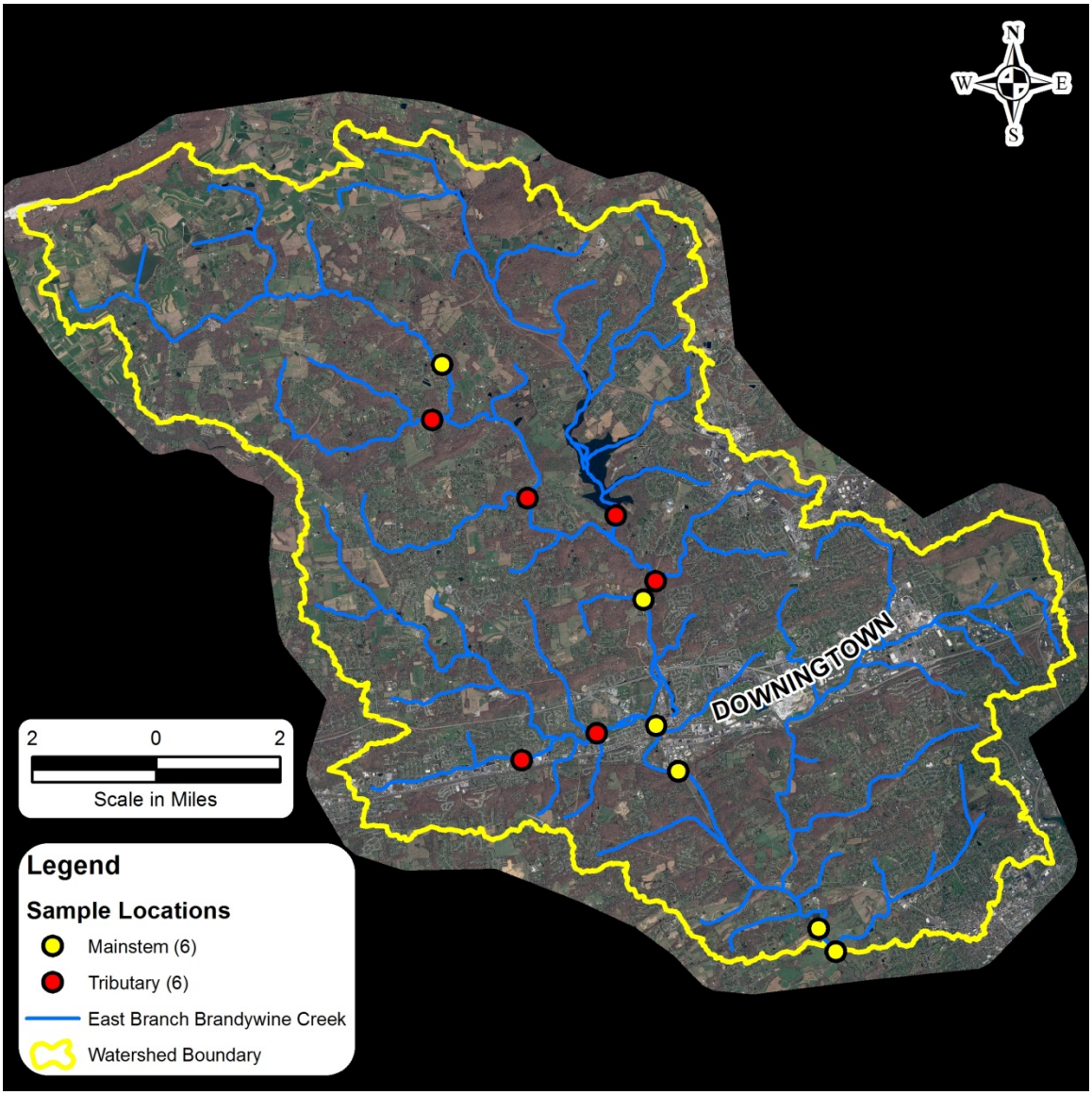

Figure 2. SPOT image of the East Branch Brandywine Creek with sample locations indicated. Traverses a rural to urban gradient from north to south. The study included 12 sampling locations– 6 along the main stem and 6 sites located along respective tributaries which are depicted by the yellow and red dots on this map.

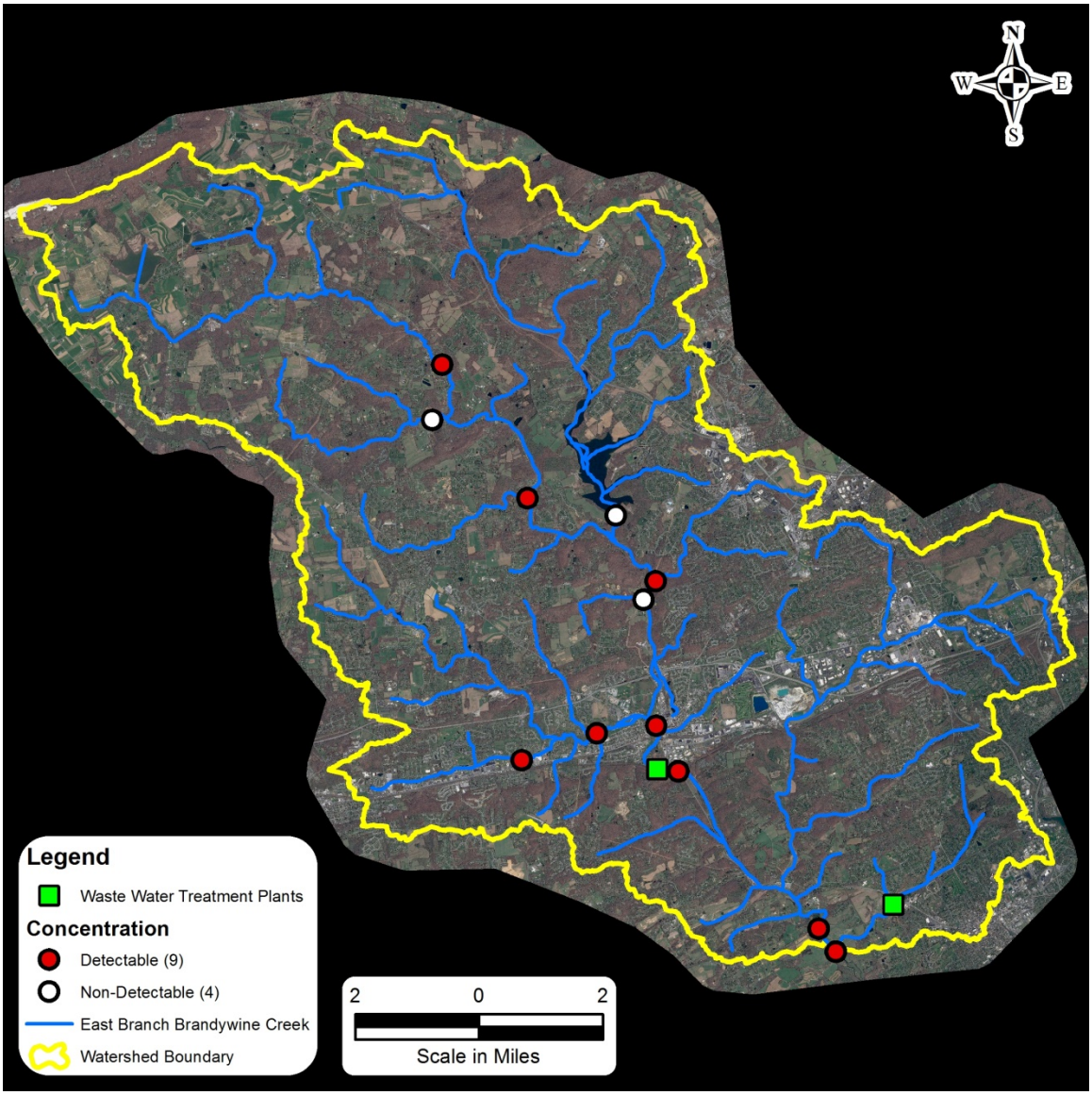

Figure 3. SPOT image of the East Branch Brandywine Creek with concentrations indicated. Triclosan concentrations were identified at 9 of the 12 sites, which are depicted by the red dots in this figure. White dots had no detection. Overall concentrations ranged from 0.131 to 274 ng/L, and accumulate as you move downstream. Concentrations were found to range over 3 orders of magnitude w/ some showing the highest concentrations known above a waste water treatment plant. 274 is among the highest that's been recorded in literature. Lastly, cumulative loading of triclosan was observed on the mainstem ranging from 0.1 to 3.3 ng/s.

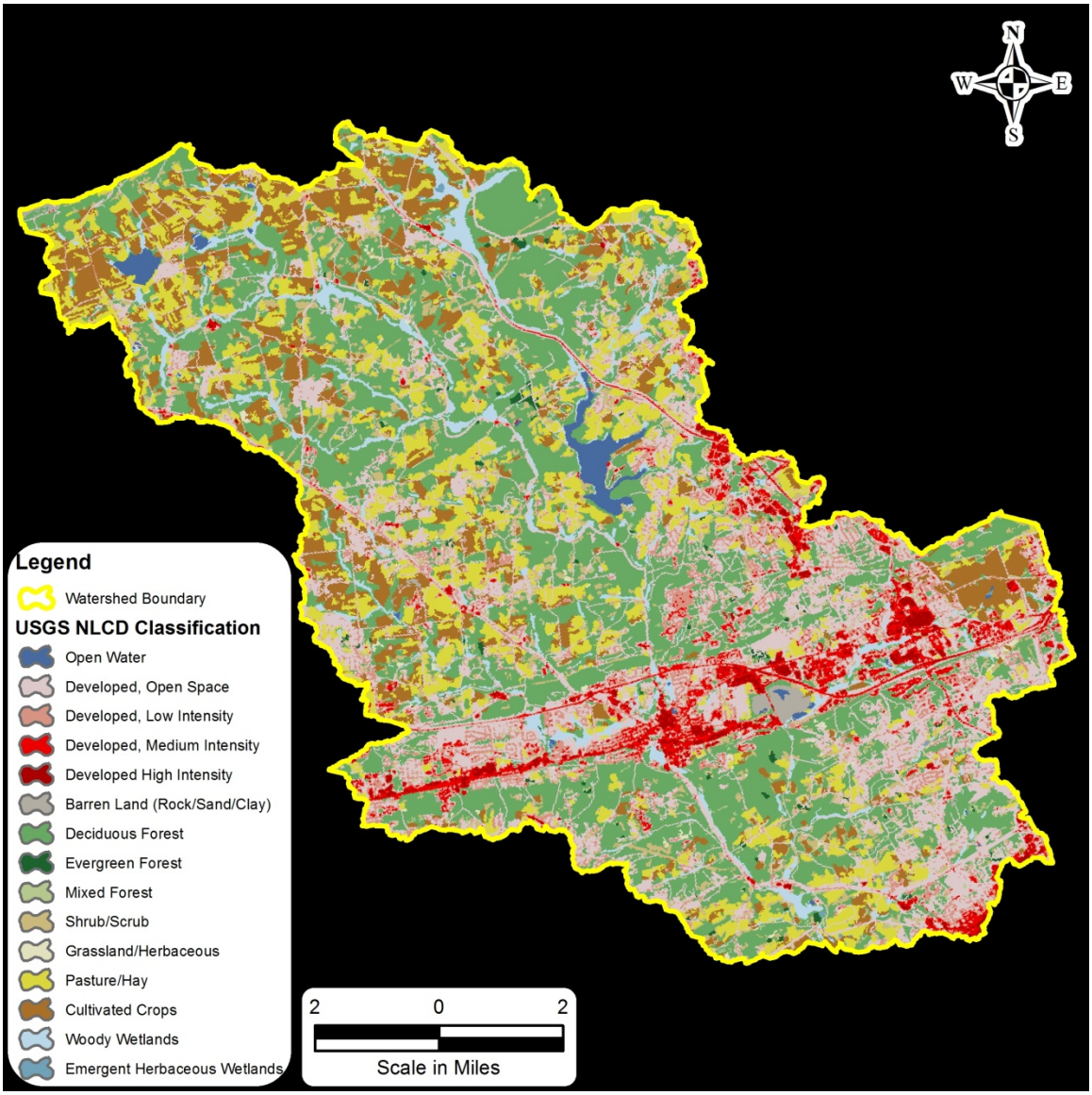

Figure 4. USGS land cover classification within the watershed boundary.

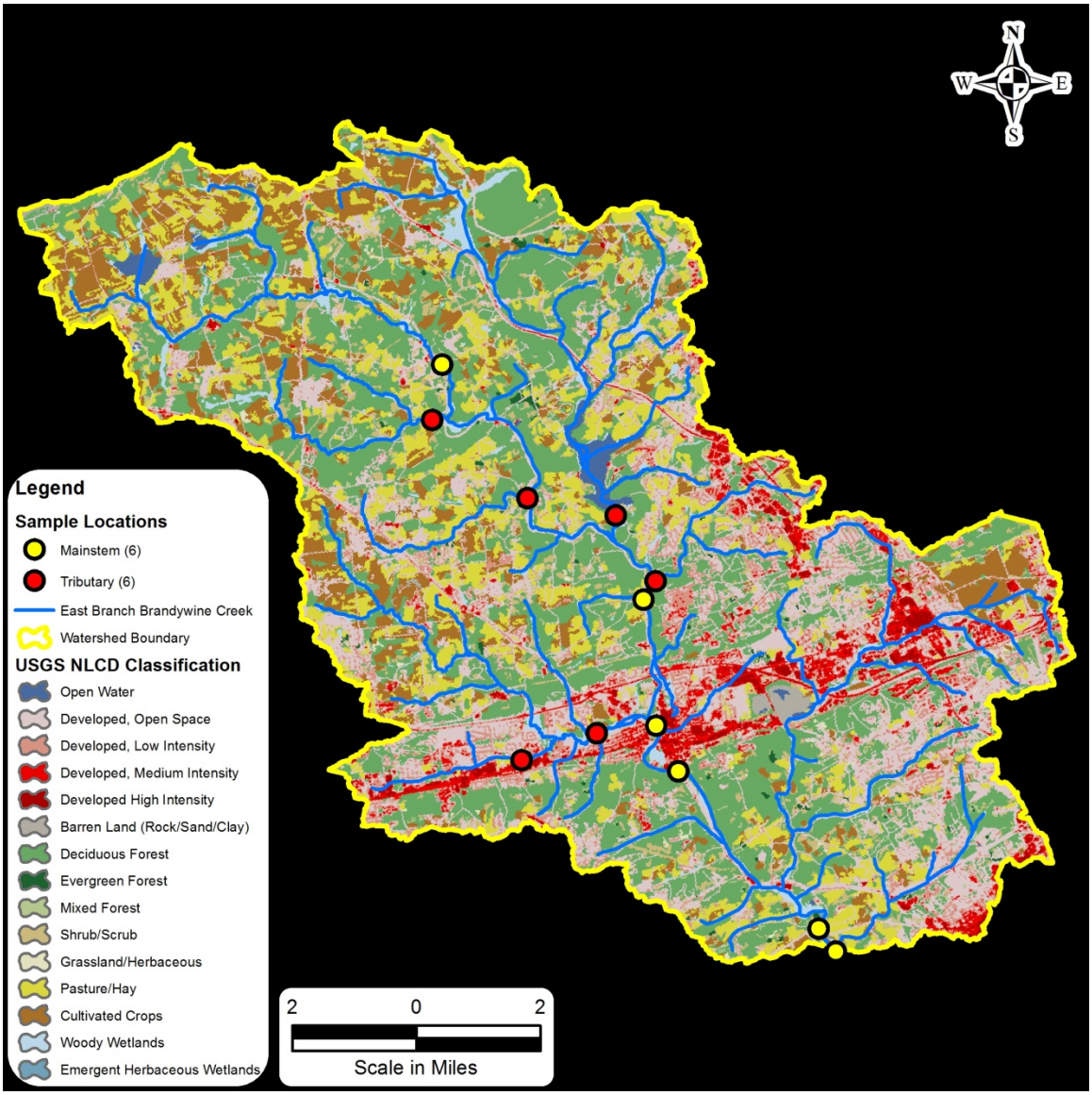

Figure 5. USGS land cover classification within the watershed boundary. Sampling locations and tributaries are overlaid. Interestingly, we did not observe any correlation between concentrations or loading with land use practices located upstream of the sampling sites.

Summary

Students in our Remote Sensing class were able to view the SPOT satellite imagery in ArcGIS and were able to manipulate the imagery (zoom, pan, scroll), display various data layers provided by ArcGIS, and annotate features in the imagery. Overall the project provided practical experience using ArcGIS to display and analyze satellite imagery, and to understand a real environmental issue facing communities and the need for further study. This project can be used as a lab exercise in future remote sensing, GIS or environmental studies classes.

Purchased SPOT-6 Archive Satellite Imagery:

- AOI: East Branch Brandywine, PA
- Product: 1.5m 4-Band Pan-Sharpened (Orthorectified-3A) Product
- Date of Imagery: April 17, 2016
- Incident Angle: 12 degrees
- Scene ID:DS_SPOT6_201604171528384_FR1_FR1_FR1_FR1_W076N41_07554
- Resampling Method: Cubic Convolution

- Bit Depth: 16-Bit
- Dynamic Range Adjustment (DRA): Off
- Projection / Datum: UTM / WGS84
- Format: GeoTiff (.tif)

Citations:

"Evaluating Controls on Triclosan Export in a Rural to Suburban Watershed: Insights from the East Branch of the Brandywine Creek", Kaila Hanley[1], Garrett Waligroski[2], Amanda M. Grannas[2], Meghan K. Walsh[1], Devin F. Smith[1], and Steven T. Goldsmith[1]

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