

The Use of Local Moran's I in Determining the Effectiveness of Location for Gas Extraction

The base map of gas production in Yuma County, Colorado indicates a clear pattern of clustering and spatial autocorrelation. In order to study the effectiveness of the locations of gas wells this study asks to what extent are similar and dissimilar values clustered? Does the result change at different points in time?

In order to look at the clustering of values, the cluster and outlier analysis tool (also known as Anselin Local Moran's i) will be employed. The results of the analysis will be the identification of hot-spots (high values clustered), cool-spots (low values clustered), high-low outliers (points with high values surrounded by points with low values), and low-high clusters (points with low values surrounded by points with high values).

The null hypothesis for this study is that gas production values show no clustering of similar or dissimilar values while the alternative hypothesis is that there will be clustering of similar and dissimilar values.

The study area (**Fig. 1**) is Yuma County located in the northeast portion of Colorado.

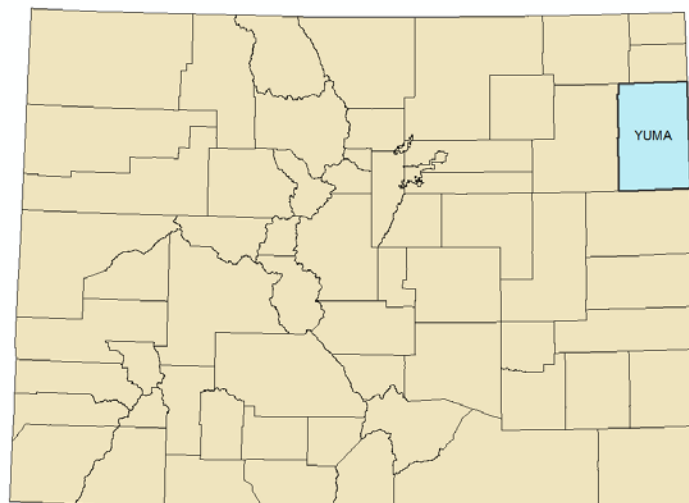


Fig. 1-State of Colorado showing location of study area, Yuma County.

The data used in this analysis came from four sources:

1) Colorado Department of Transportation

http://www.dot.state.co.us/app_DTD_DataAccess/GeoData/index.cfm?fuseaction=GeoDataMain&MenuType=GeoData

This website provided the data for the base map of Yuma County. According to the metadata, all of the layers were projected in NAD_1983_UTM_Zone_13N. The time period for this data ranges from 2004-2009.

2) USGS Mineral Resources On-Line Spatial Data

<http://tin.er.usgs.gov/geology/state/state.php?state=CO>

This website provides geologic map data for the state of Colorado. The geologic units are available in a zipped polygon shapefile and can be downloaded with the geologic attributes in CSV format. According to the metadata, the horizontal coordinate system, is GCS_North_American_1927 and attributes include original label, source, unit age and rock type.

3) USGS National Map Seamless Server

<http://seamless.usgs.gov/index.php>

The seamless map server provided the 1-Arc Second National Elevation Dataset used to make the hillshade. It is updated quarterly.

4) DrillingInfo (DI) Production Database

This database shows details of oil and gas production in Yuma County, Colorado. It is available to customers and subscribers of DrillingInfo. Each point is a location of an oil or gas well with name, date, well ID, amount the well produced on average, month and year the well first and last produced oil or gas, etc. The geographic coordinate system is GCS_North_American_1927.

Data Preprocessing involved the following:

1) Projection:

Local Moran's I analysis does involve distance so the data used needed to be projected. Both the geologic map and the DI production data were originally unprojected. Using the 'project' tool in Arc, these layers were projected into new files as NAD_1983_UTM_Zone_13N.

2) Pull only relevant data from DI database:

The focus of this study is gas producing wells in Yuma County. Using spatial queries, all wells with gas production values greater than 0 were selected and then exported as a new layer called Yuma_Gas.

3) Mosaic Elevation Data:

The NED data was downloaded as 4 separate files. These 4 were mosaicked into one file with no overlap.

4) Clip to study area:

The NED file, the geologic map, and the transportation files contained data outside the study area. The vector files were clipped to Yuma County and the NED was masked based on the Yuma County file.

5) Hillshade of NED:

A hillshade was produced from the NED to make the elevation more easily viewed and understood. All layers falling above were assigned a 50% transparency.

The base map (**Fig. 2**) shows the entire county of Yuma and the location of gas wells. It is clear that spatial clustering is present, as location of gas wells is chosen intentionally based on several factors related to the likelihood of finding and extracting gas.

In **Figure 3**, hot-spots, cool-spots, and outliers are identified. The value associated with each point is the monthly average gas production. In the hot-spots, points with high monthly averages of gas production are surrounded by other points with high monthly averages, and vice-versa for cool spots. The outliers show either high values surrounded by low ones or low values surrounded by high ones.

Figure 3 provides a good overall picture of the hot and cool spots of gas production in Yuma County, but because it is taken from monthly averages, and the data spans many years, this analysis cannot imply that one gas well affected another gas well because it does not indicate at what point in time the gas production took place. For this reason, the Local Moran's I tool must be utilized at each window in a time series. The last month of gas production is divided so that the categories are as even as possible while still keeping within the same calendar year (**Figs 4-7**).

The time series (**Figs. 4-7**) displays the wells which were active for the last time during the corresponding window of time. The categories are pre-2008, 2008, January to March of 2009, and March to August of 2009.

The value used in running Local Moran's I on each time window (**Figs. 8-11**) is no longer the overall monthly average, but rather the amount of gas produced during the last month of activity. Using a value that was measured around the same time, it is then logical to make side-by-side comparisons and inferences about how the points affect each other.

The results of the Local Moran's I test are displayed in **Table 1** to show what percentage of significant points fall into each category. The amount of hot spots remains constant at 10-12% for each time window. The outliers also remain relatively low with the exception of wells that were no longer active after February 2009. In this period, the high-low outliers actually match the amount of cool spots.

In the original analysis (**Fig. 3**), the result proves the alternative hypothesis because there is clustering of both similar and dissimilar values. For the analysis at different points in time, the implication is also that the alternative hypothesis is correct.

Local Moran's I is a measure of spatial autocorrelation and is used to analyze the relationship between a point and its neighbors. In this study, a point with a particularly high value surrounded by low

values could signify the effectiveness of one well in pumping gas from the same source of one of its neighbors. In the case of these points, it may be advisable to only keep the higher-producing well open and close the lower-producing neighbors.

The use of geostatistics in the exploration and analysis of oil and gas production is not new or uncommon. Using the Local Moran's I can be useful specifically in assessing the effectiveness of the location of already existent oil and gas wells.

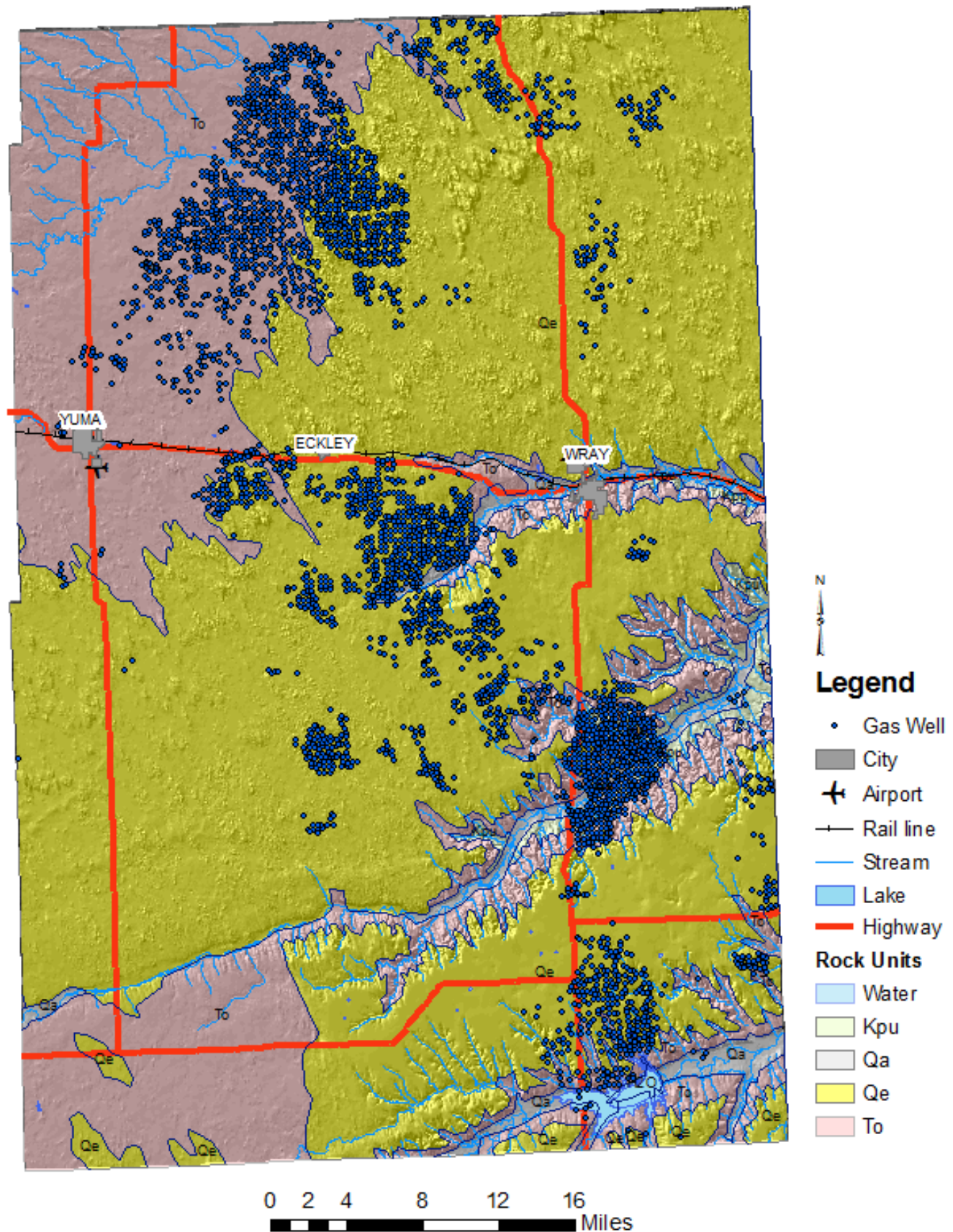


Fig. 2- Base map of study area, displaying data from each source.

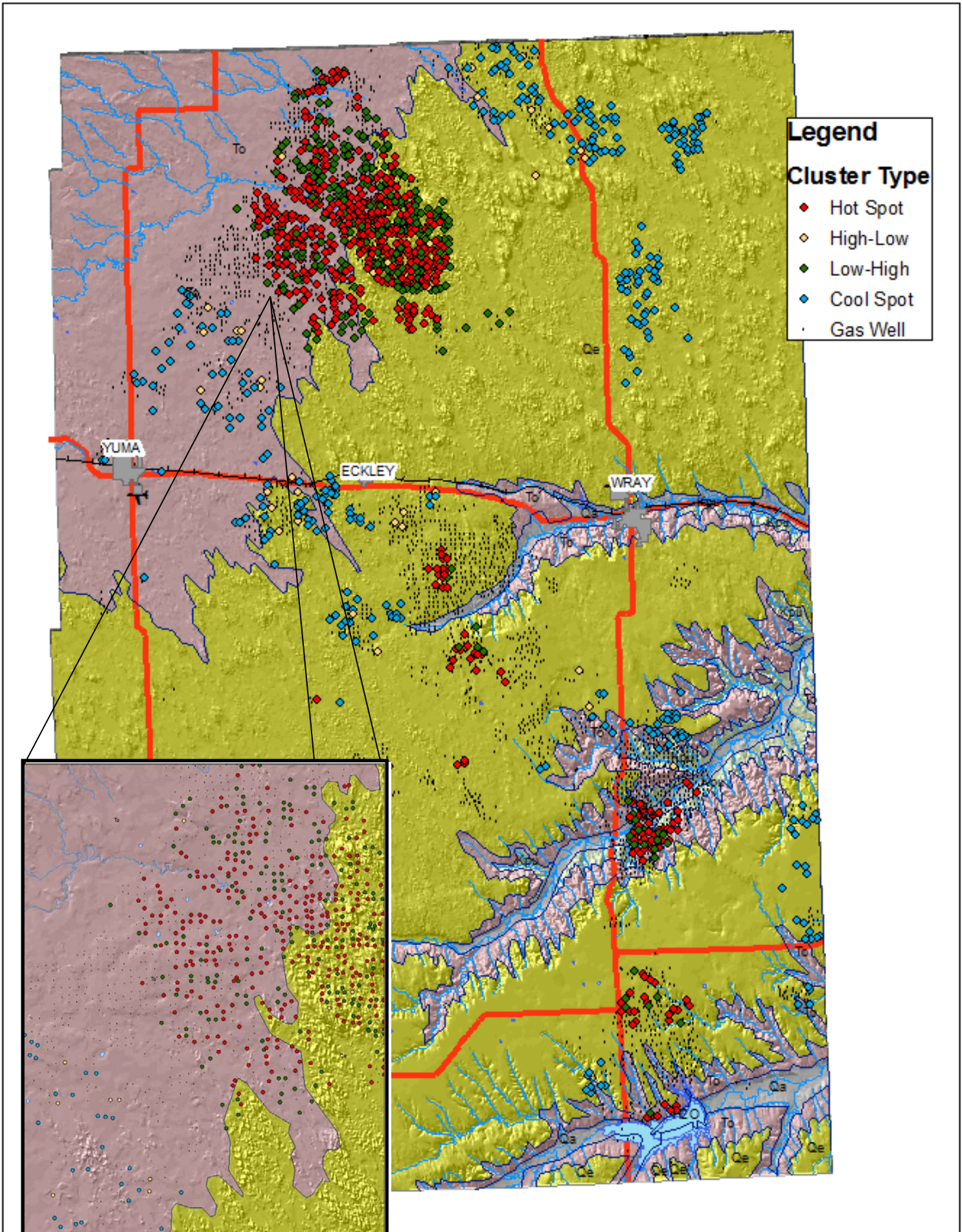


Fig. 3- First Local moran's I test. Values are average monthly gas production

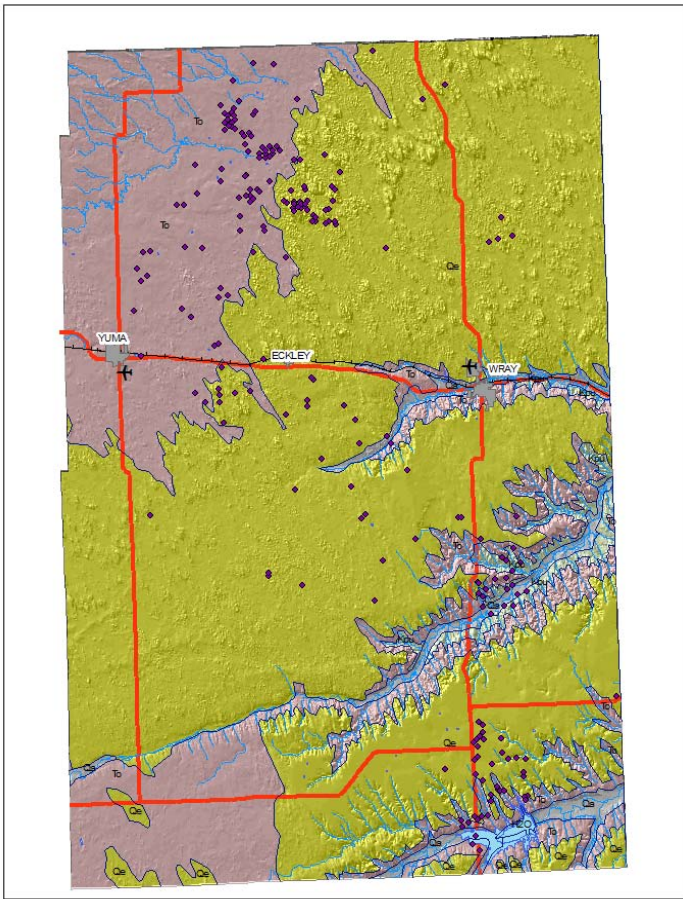


Fig. 4- Gas wells no longer active before 2008

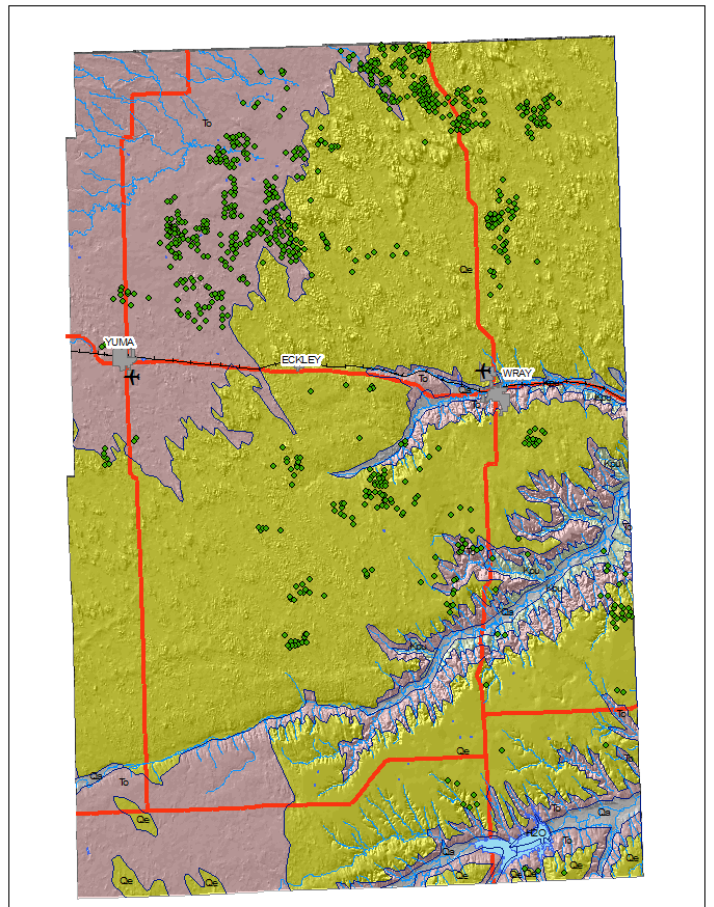


Fig. 5- Gas wells no longer active after 2008

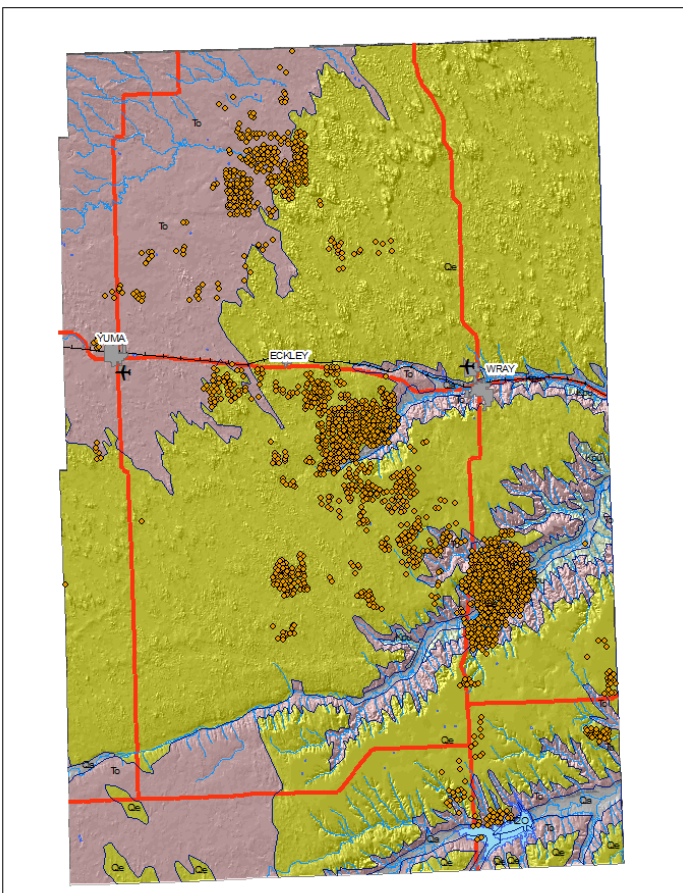


Fig. 6- Gas wells no longer active after February 2009

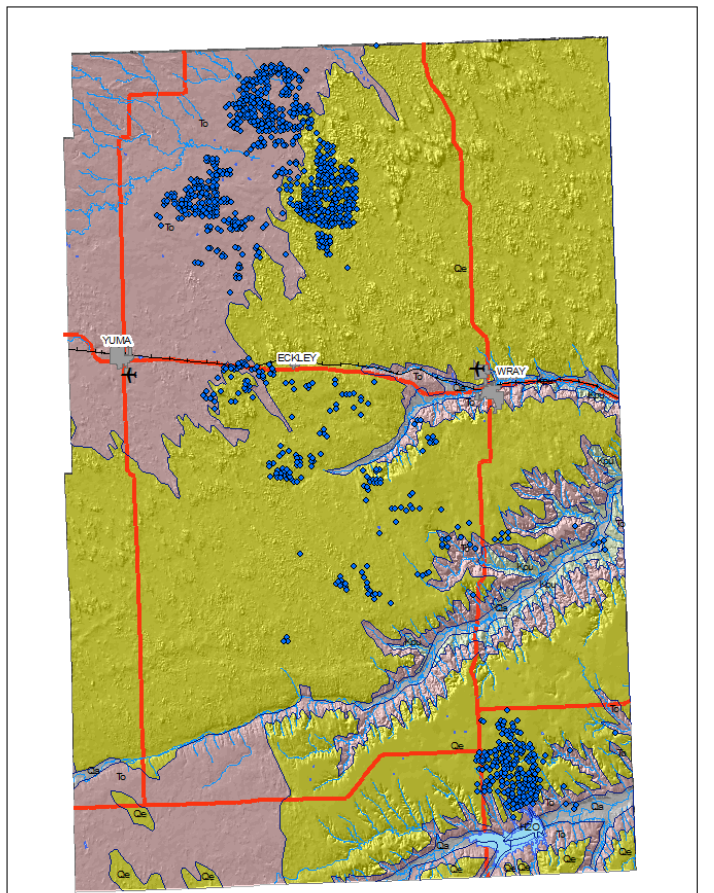


Fig. 7- Gas wells no longer active after August 2009

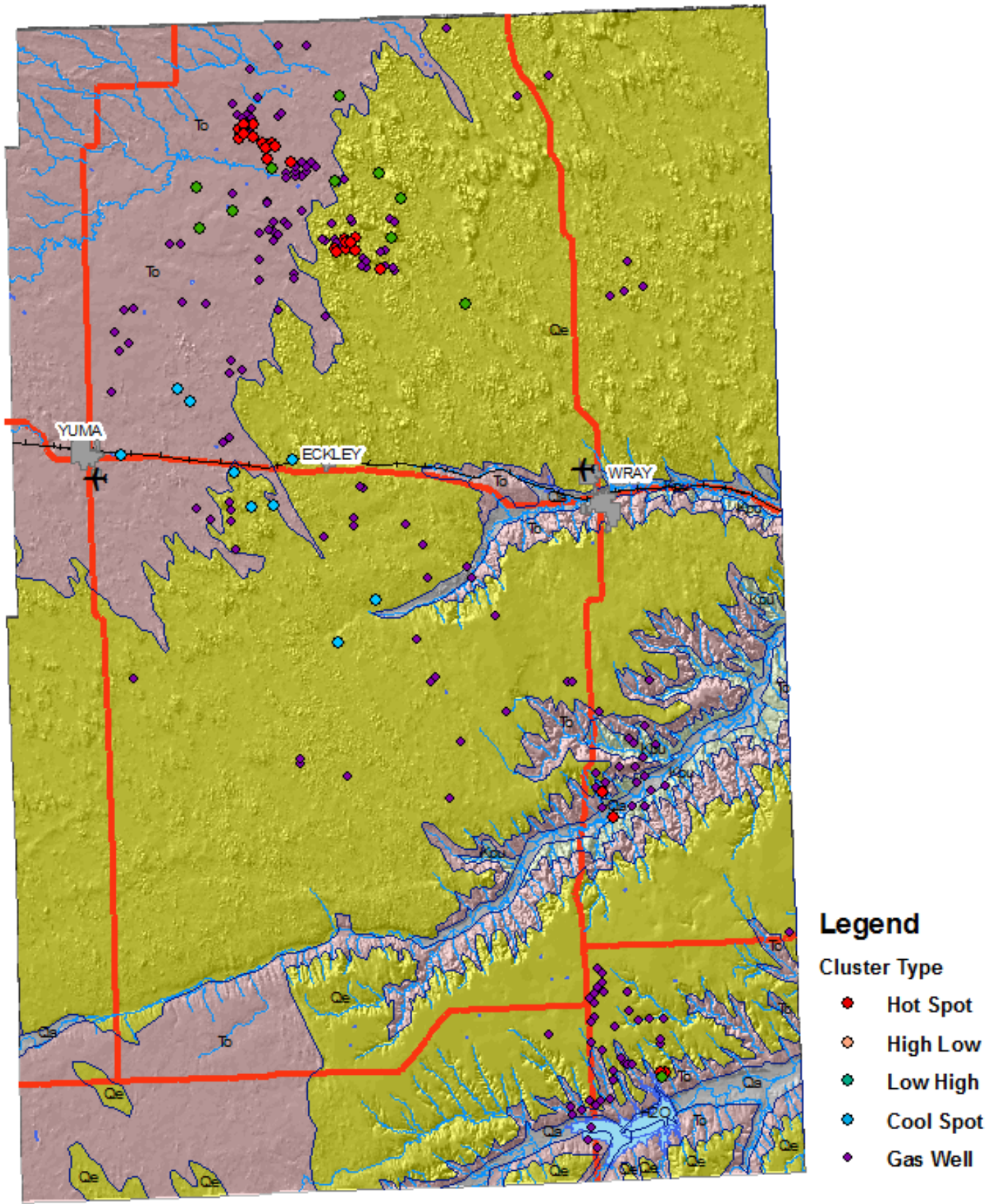


Fig. 8- Local Moran's I analysis on gas wells no longer active before 2008.

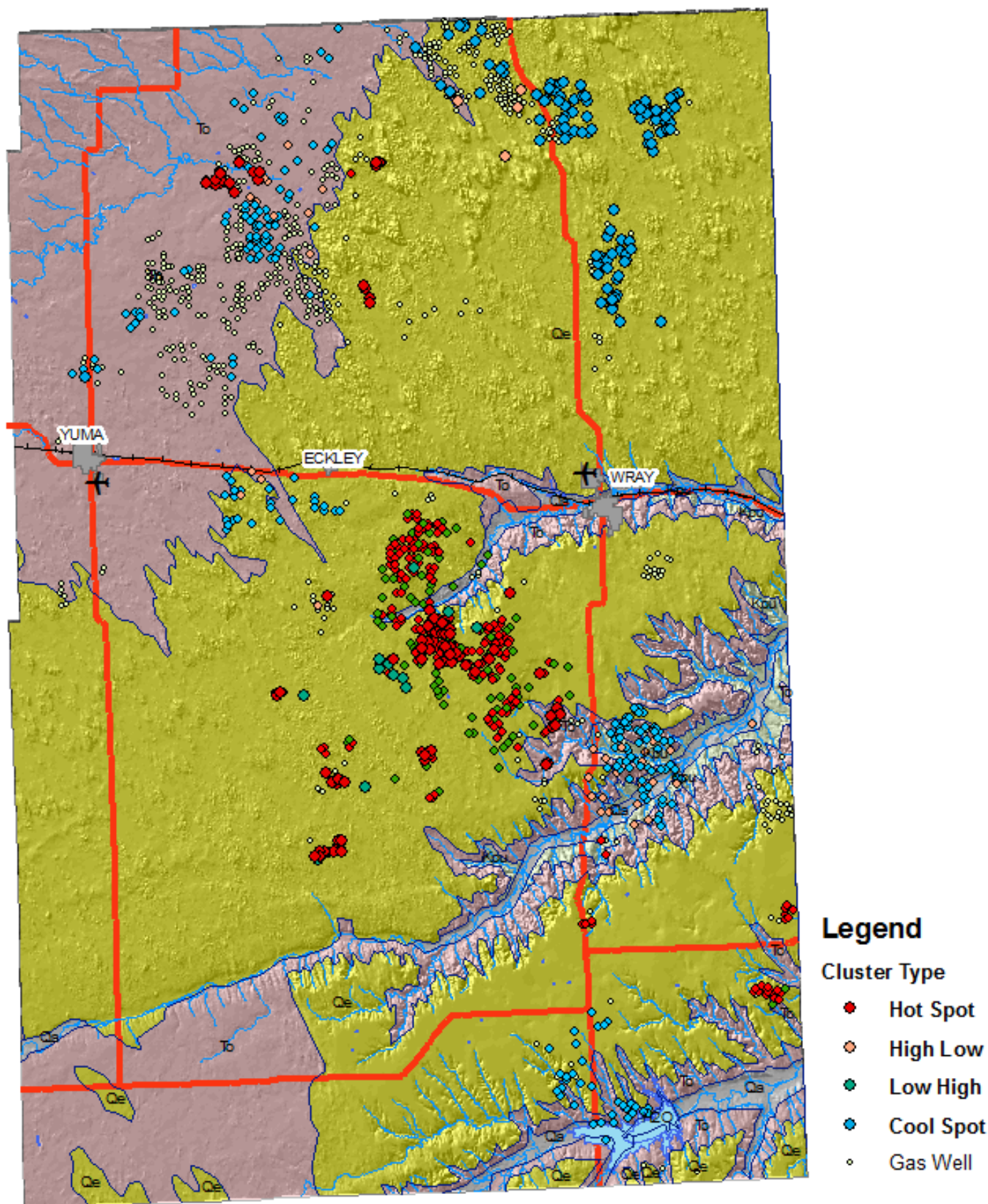


Fig. 9- Local Moran's I analysis on gas wells no longer active after 2008.

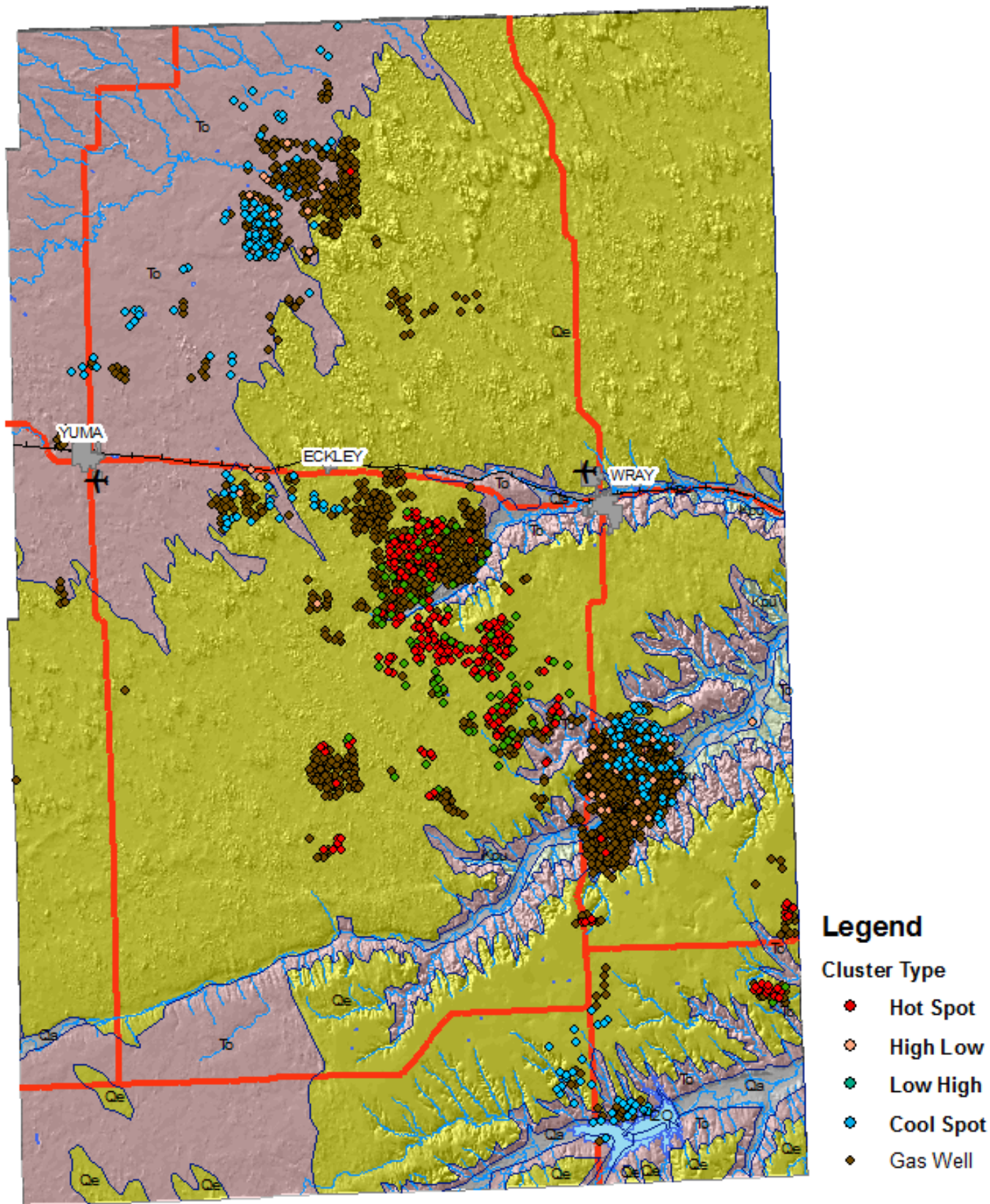
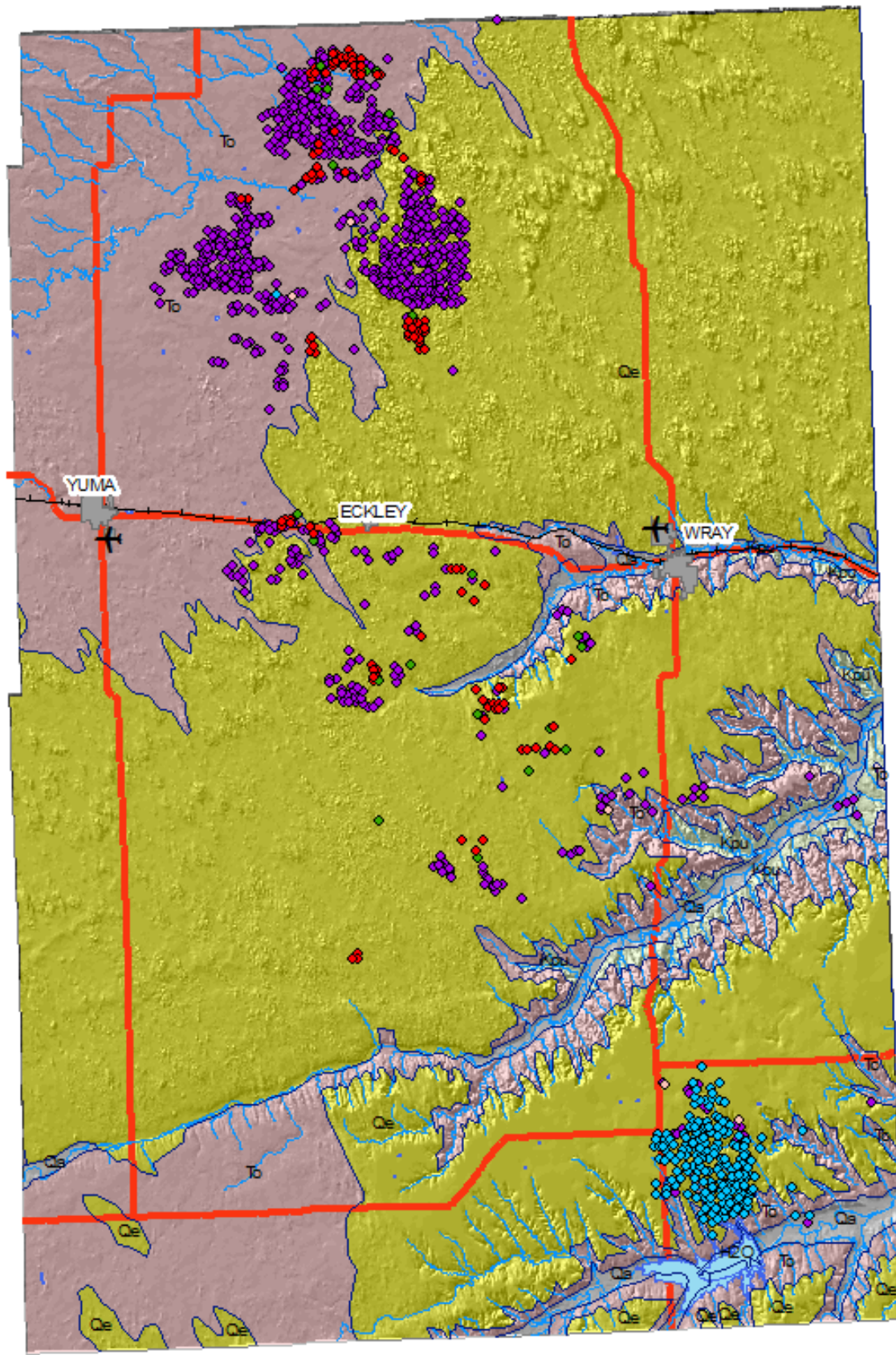


Fig. 10- Local Moran's I analysis on gas wells no longer active after February 2009.



Legend

Cluster Type

- Hot Spot
- High Low
- Low High
- Cool Spot
- Gas Well

Fig. 11- Local Moran's I analysis on gas wells no longer active after August 2009.

Time	Hot-Spot %	High-Low %	Low-High %	Cool Spot %
pre 2008	11.5	0	5	4
2008	10.8	0.4	1.5	12.2
Feb-09	12.8	7.2	5.3	7.6
Aug-09	10.5	0.4	1.8	16.1

Table 1- Results of Local Moran's I analysis

References

- Zhang, Chaosheng, Lin Luo, Weilin Zu, and Valerie Ledwith. "Use of local Moran's I and GIS to identify pollution hotspots of Pb in urban soils of Galway, Ireland." *Science of the Total Environment*. (2008): 212-221.
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- Hohn, Michael Edward, and Donald W. Neal. "Geostatistical Analysis of Gas Potential in Devonian Shales of West Virginia." *Computers & Geosciences*. 12.4B (1986): 611-617