

GIS in Water Resources  
Fall 2015  
CE 394K.3

Term Project:

Using GIS to apply Paramelle's method for  
finding ground water in karst terrain

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## Introduction and Background

Jean-Baptiste Paramelle, a contemporary of Henry Darcy, found groundwater in 10,000 locations in France between 1827 and 1854. Paramelle had no training as a geologist; in fact the science of geology was in its infancy when Paramelle began his search for water.

Paramelle was a priest who lived on the karst plateau of the Department (“county” in the US) of Lot in southwestern France. In his day, the term “karst” was unknown. His parishioners asked his help in finding water for their crops and animals. Paramelle was interested in the natural world; he had already noticed that the limestone terrain of his parish had no surface streams, in contrast to the eastern part of the Dept. of Lot, where he was born, where clay was abundant in the surface soil. He noted that the rainfall in the two areas was similar, so he determined to find out where the local rainfall went. He spent a number of years walking the limestone plateaux and observing the vast expanse of dry valleys and the springs that flowed underwater into the area’s two large rivers.

In 1827 Paramelle presented a report to the authorities of the Department of Lot on his method for finding water and asked for financial support.

Paramelle’s early ideas for finding water in karst are the following:

- Every valley or depression, dry or wet, is a location of water flow in the subsurface.
- A valley that supports a stream during rainfall can also host an underground stream.
- The underground stream follows the same path as the surface stream.
- The volume of groundwater is proportional to the length of the dry valley.
- Aligned dolines mark out an underground conduit.
- An underground watercourse lies beneath a surface depression and rests on an impermeable layer.

- Moving water in the underground conduit erodes the walls and roof of the conduit to create dolines/subsidence areas.

Between 1827 and 1854, Paramelle found water in 39 of 90 departments of France, including non-karst areas. His 1856 book, *The Art of Finding Springs*, is a geology and water finding textbook. The book was reprinted several times and translated into German and Spanish. Paramelle's ideas were fundamental to finding water in France until the 1970s when communities began looking for larger quantities of water and new technology revealed that geologic conditions such as ancient tectonic structure also controlled groundwater pathways and karstification. Today French hydrogeologists use geophysics, cave-divers to plot underground water pathways, and dowsers to search for water resources.

#### Objective of this project

This GIS project is an application of Paramelle's method to karst locations in the US to determine if his ideas can help find water in karst areas. This report on the New Braunfels study is my first attempt in this application; if the method shows promise, I plan to use in other karst areas of the US.

The idea of surface morphology related to groundwater resources in karst areas is similar to a method developed by Lattman and Parizek for using lineaments and associated karst processes in limestones and dolomites of central Pennsylvania to site water wells for Penn State University (Lattmann and Parizek, 1964). In their study, the most productive wells were located at the intersection of these features, where dissolution had created voids that hosted significant water resources.

Because of the spatial aspect of subsidence areas and well locations, I wanted to use GIS to examine a karst area of central Texas to compare productivity of wells located near subsidence areas to that of wells located far from subsidence areas. The depth of wells and

the different formations contributing to well productivity no doubt complicate the issue; these details will be dealt with once I have mastered the method of obtaining data, preparing it for ArcGIS, and using GIS tools to plot and analyze the locations of wells and subsidence areas.

## Methodology

I used a [paper] geologic map of the New Braunfels area that indicated geologic information (units and structure) and surface subsidence to determine the study area (Collins, 2000). My idea was to focus on a trapezoid-shaped area [eastern margin: 98°00' from 29°45' to 30°00'; western margin: 98°30' from 29°30' to 29°45'] along the Balcones Escarpment where numerous subsidence features had been mapped with the goal of determining if there is a spatial correlation between surface subsidence and high-yield wells (Figure 1).

Data used for the project include:

USGS The National Map National Elevation Dataset  
NED 1/3 arc-second DEM  
USGSNEDn30w099 1/3 arc-second 2013 |x| degree IMG  
<http://nationalmap.gov>

New Braunfels.tif (provided by Mark Helper)

Texas Water Development Board  
Submitted Drillers Reports  
Water Data Interactive

## GIS Tools and Processing

I used the Extract by Mask to extract the study area from the DEM. Using the Arc Toolbox Spatial Analyst Hydrology Fill tool, with Dr. Maidment's help we created Fill file. Then subtracted the DEM from Fill file to create a map of subsidence areas. Because the difference was in meters, we changed the units to centimeters and created a layer called Difference CM (Figure 2). Then, using Region Group and Raster to Polygon, I converted

Sink Region (a raster) to a vector file to be able to do statistics on it. The result was SinkRegionPoly (Figure 2). Because I wasn't sure about the choice of 'simplify polygons', I repeated the process but did not choose 'simplify polygons' and saved that file as SinkRegionPolyNS, but did not use it.

I had difficulty overlaying the tif file that contains the geology on the DEM. Mark Helper had sent me the tif file, and somehow it was not properly imported. So I asked him to help and when we opened the file, we saw that it was located down near the Equator. So we removed that file, re-imported it, and it worked fine after that. I am able to view the surface geology (tif), the subsidence areas (DifferenceCM layer) [Figure 3]. Because the tif file contained surface geologic information only as far south as 29°45', my study area was reduced to a triangle with the same North-South eastern margin (98°00'W from 29°45'N to 30°00'N) and the point of the triangle at 98°30'W and 29°45' N (Figure 1).

The third part of the project was obtaining and displaying water well data from the Texas Water Development Board. I used the Water Data Interactive site to select Submitted Drillers Reports for the study area. I chose Submitted Drillers Reports because these reports date from 2000 and generally are accompanied by test data normally supplied by well drillers. I will need pump test information to evaluate the productivity of the wells.

I initially tried to draw a polygon around the entire six USGS quadrangles in the study area, but the website rebelled, saying that I had exceeded the allowed number of water wells. So I drew polygons around single or pairs of USGS quadrangles and converted the downloaded csv files to Excel files; a total of four files covered the area. This process included a steep learning curve regarding the limitations of Excel column titles that ArcGIS will accommodate. After editing the spreadsheets, I used the Add Data button to import them. I displayed the location of the wells on the map using the "Display XY Data" selection and changed the coordinate system to NAD 1983 (specified on TWDB website). I then exported

them as feature classes into the geodatabase. I merged the four feature classes into a single one for ease of manipulation.

Then I was ready to look at the spatial relationship between wells and subsidence areas. I used the Buffer tool. I used the merged file (DrillerRptMerge) as the Input features and specified the Output feature class as DrillerRptMerge\_Buffer with a buffer distance of 50 ft. The Buffer tool gave me a high sign, showing that it had worked. To see the wells located within 50 meters of the subsidence areas, I used “Select by Location” and chose DrillerRptMerge\_Buffer as the target layer, SinkRegionPoly as the source layer, and as spatial selection method “intersect the source layer feature.” I ran it and it looked OK; there were no error messages. I didn’t know where to expect to see the results. I opened the attribute table next to DrillerRptMerge\_Buffer and it showed that all 1345 of my wells were listed on the attribute table. I understood this to mean that buffers had been added to all my wells, which was good. I opened the attribute table next to SinkRegionPoly and in this table 0 out of 73527 were selected. I didn’t know how to interpret these results. I zoomed in on the map and was able to find at least five locations where a well and its buffer was superimposed on a subsidence area (Figure 5).

I was unable to complete the project because of this problem, but I plan to continue working on it. Once I figure out how to use the buffer tool I will have some data to analyze. I learned a lot about GIS on this project – and there is a lot more to learn.

# Figures

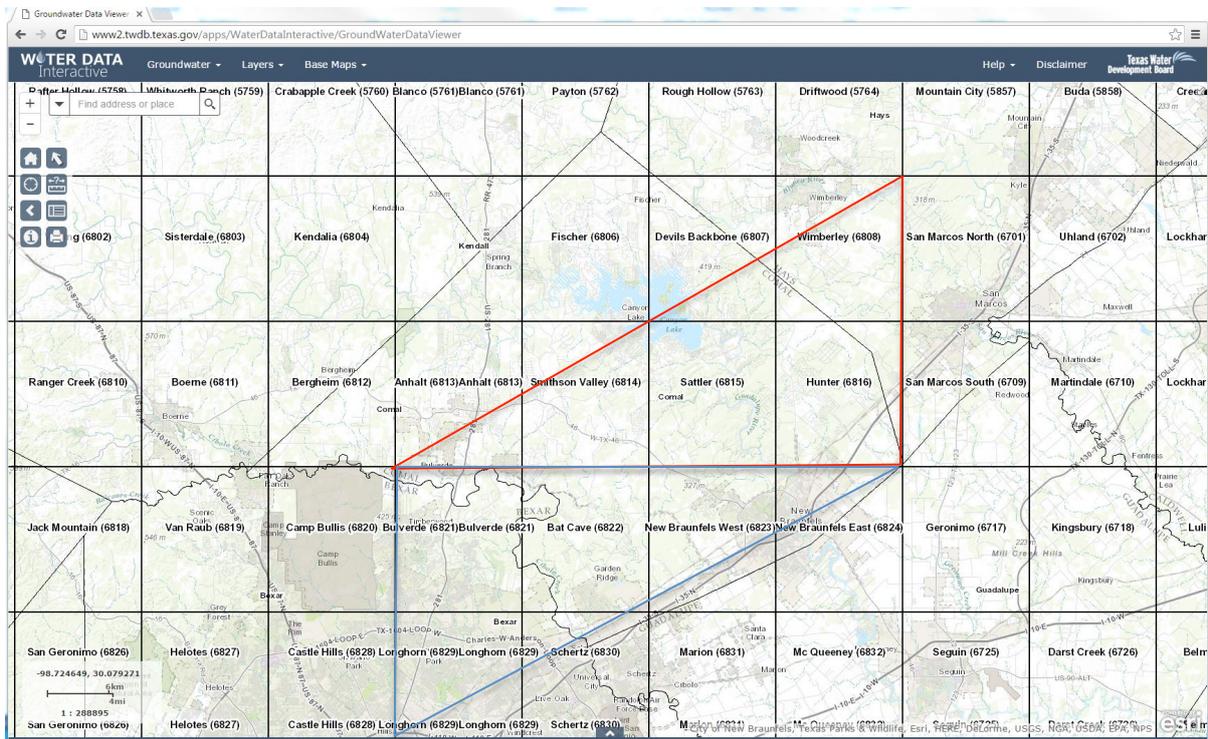


Figure 1. Study area covers parts or all of 6 USGS quads south and east of Canyon Lake, mostly in Comal County, Texas. The original study area was to include both the red and blue triangles. But because the surface geology layer did not include the blue outline area, the study area was reduced to the area enclosed by the red triangle.

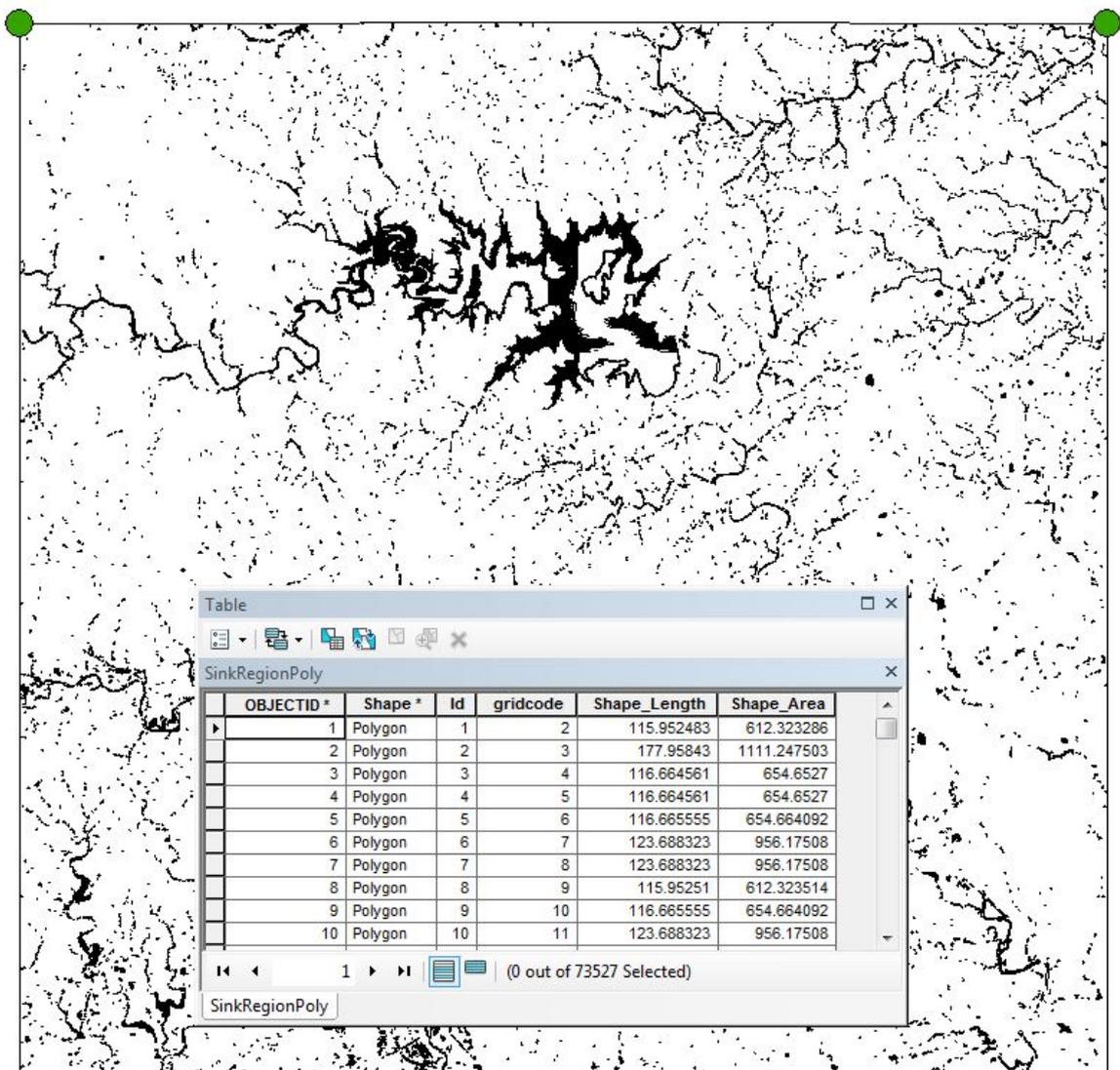


Figure 2. SinkRegionPoly layer for the study area. This layer shows polygons resulting from analyzing the DEM for areas to fill, then subtracting the DEM from the fill to create a raster file, which was then converted to a polygon layer to use for statistical analysis.

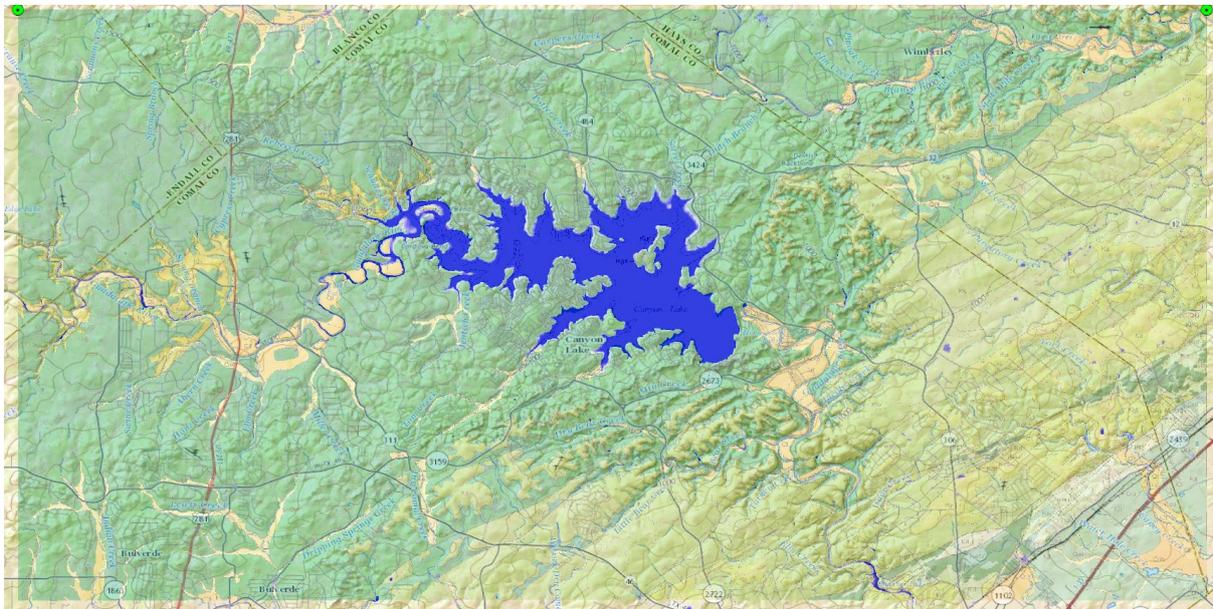
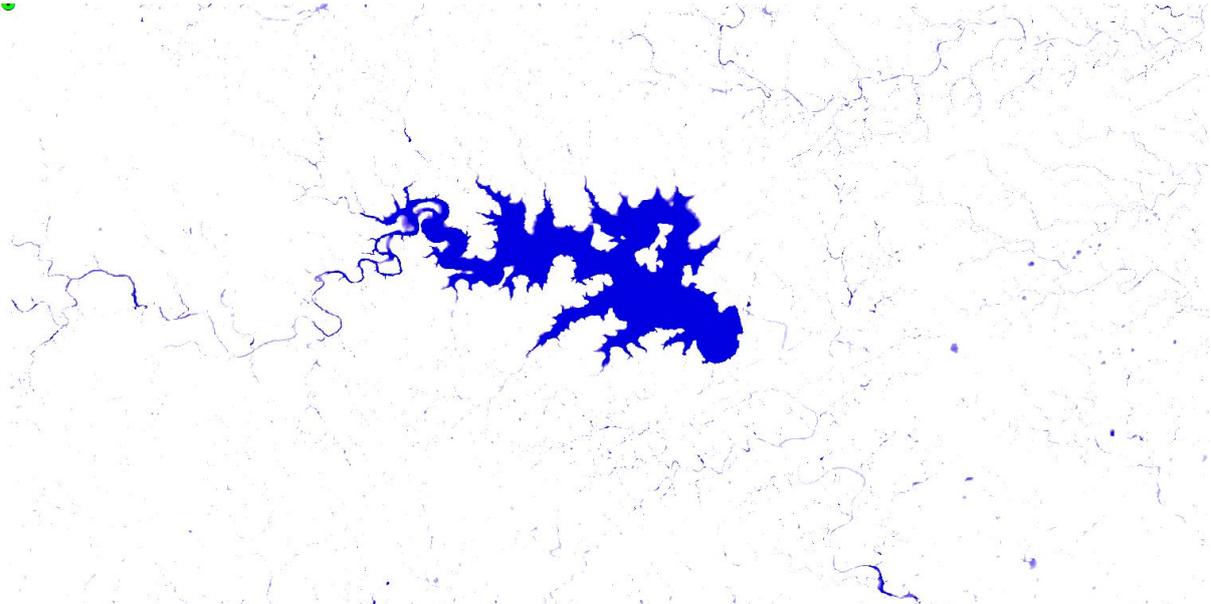


Figure 3. The upper map is the DifferenceCM layer that shows the subsidence areas. The lower map shows those areas on the geology layer.

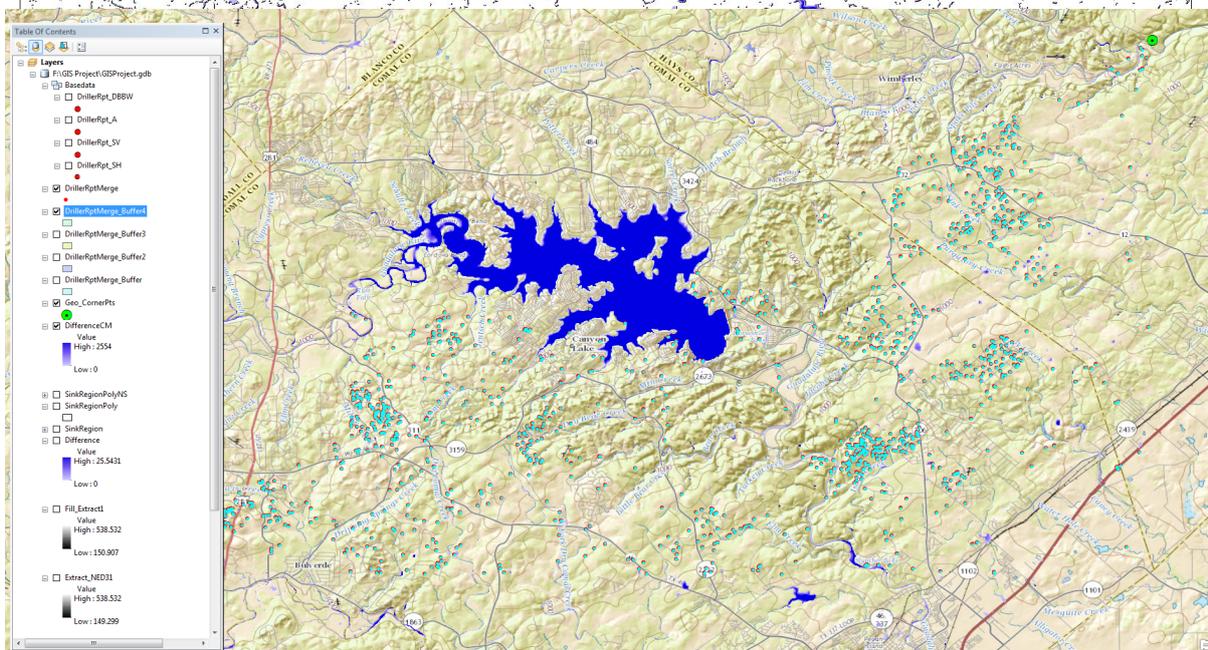
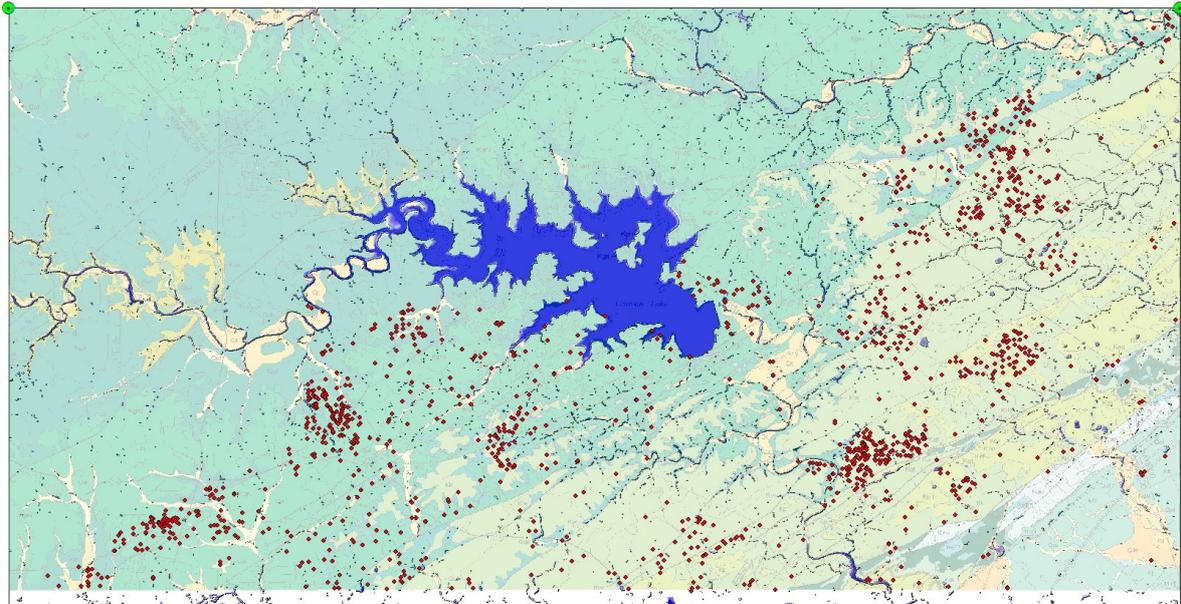


Figure 4. The upper map shows the locations of water wells. The lower map shows the buffered water well file. I was not successful in using a GIS tool to find wells that overlap with subsidence areas, although visual inspection of a zoomed in image shows that such wells exist.

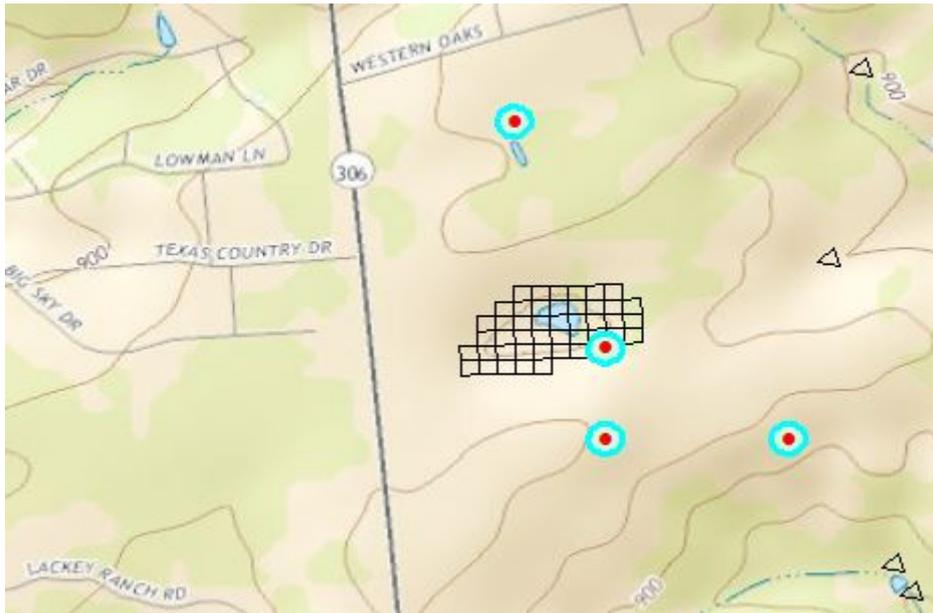


Figure 5. Zoom-in view shows that at least one well overlaps/intersects a subsidence area.

## References

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Lattman, L.H., and Parizek, R.R., 1964. Relationship between Fracture Traces and the Occurrence of Ground Water in Carbonate Rocks, *Journal of Hydrology* 2 (1964) 73-91.

Paramelle, J.B., 1827. *Memoire hydrologique et géologique dus le département du Lot*, transcribed and published by the Spéléo-club de Paris, Club Alpin français, 2010.

Paramelle, J.B., 1856. *L'Art de découvrir les sources*, Dalmont et Dunod, Paris. 427 p.