SEPTIC TANK CONVERSION PRIORITIZATION IN THE WAKULLA SPRINGS SPRINGSHED USING GIS

Jamie Hughes
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WAKULLA SPRINGS

Wakulla Springs is located in Florida's Edward Ball Wakulla Springs State Park in Wakulla County, south of Tallahassee, Florida. The springs have been a favorite spot for recreation activities since 1934 because of its cold, clear waters and diverse wildlife habitat. The beautiful waters made the location popular for filming movies and running glass bottom boat tours. Unfortunately, nitrate pollution has largely contributed to environmental and water quality issues at the springs in recent years. The pollution has come from various sources including fertilizers, wastewater effluent and onsite sewage treatment and disposal systems (OSTDS) or septic tanks. Geologic features within the springshed play a key role in allowing nitrate pollution to flow down into the aquifer and out at Wakulla Springs. The Cody Scarp is the ancient shoreline that runs through the springshed. South of that boundary is the Woodville Karst Plain which is characterized by a thin layer of sandy soil underlain by karst limestone. This topography allows surface waters to penetrate the ground quickly and with very little filtering. Excessive nitrates have caused superfluous algae growth, allowed for invasive plant species to thrive and contributed to diminished visual quality of the springs' water (Davis, Katz, & Griffin, 2010). By the early 1990s, water quality was not sufficient to run glass bottom boat tours regularly (Wakulla Springs Alliance, n.d.). However, the springs continue to be a vibrant recreation destination. All the while, several government and volunteer organizations continue to work to improve the groundwater quality within the springshed.

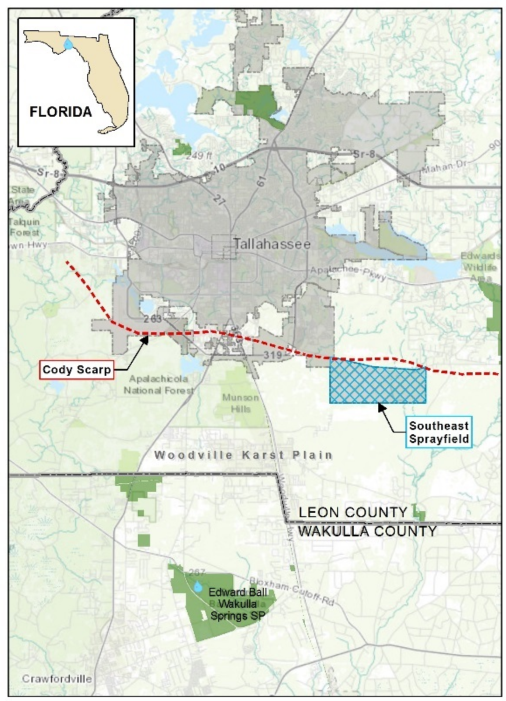

Figure 1 – Wakulla Springs Location.

NITROGEN CONTRIBUTION TO THE SPRINGSHED

The United States Geological Survey (USGS) simulated nitrogen loads for Wakulla Springs for several time periods, ranging from 1966 to 2018, and developed rankings of nitrogen contributors with approximate loads and contribution percentage to the total. The result of these simulations is published in the Scientific Investigations Report 2010-5099 and was completed by Davis, Katz & Griffin (2010). The following tables show the simulation results for years 1967 & 1987:

BACKGROUND

Scenario Year: 1967			
Total Nitrogen Load: 72,000 kg/yr			
Top Nitrogen Contributors:			
Rank	Contributing Activity	Contributing Load	Percent of Total Load
1	Inflow to the study area across the lateral model boundaries	31,000 kg/yr	43%
2	Biosolids disposal by land spreading	14,000 kg/yr	21%
3	Creeks discharging into sinks	7,800 kg/yr	11%
4	The Southwest Farm sprayfield	4,500 kg/yr	6%

Davis, Katz & Griffin (2010)

Table 1: Modeled Nitrogen Load Scenario Year 1967.

Scenario Year: 1987			
Total Nitrogen Load: 306,000 kg/yr			
Top Nitrogen Contributors:			
Rank	Contributing Activity	Contributing Load	Percent of Total Load
1	The Southeast Farm sprayfield	186,000 kg/yr	61%
2	Biosolids	37,000 kg/yr	12%
3	Inflow to the study area across the lateral model boundaries	36,000 kg/yr	12%

Davis, Katz & Griffin (2010)

Table 2: Modeled Nitrogen Load Scenario Year 1987.

The Southwest and Southeast Farm sprayfields are agriculture fields operated by the City of Tallahassee (COT) and spray irrigated with treated effluent from the city's wastewater treatment plant. Utilizing effluent spray began at the 20.5 acre Southwest sprayfield in 1966 and the practice expanded at the 1,090 acre Southeast sprayfield in 1980. Groundwater testing was conducted in the Southeast sprayfield beginning prior to using treated wastewater in order to monitor pollutant penetrations. The USGS analyzed the monitoring data and produced two reports, one for 1980-1982 and another for 1983-1985. The first study, written by Elder, Hunn & Calhoun (1985), explains that chloride and nitrogen levels in the local groundwater increased in those first years. Nitrogen increased from less than 0.5 mg/L to 4 mg/L. The authors noted that nitrate levels had not yet had enough time to level out since beginning the practice and that the levels were still within acceptable range for groundwater quality. The second study, written by Pruitt, Elder & Johnson (1988), explains that nitrogen levels were recorded up to 11 mg/L in one local well and as high as 15 mg/L, up from 0.7 mg/L, in the Floridan aquifer. An answer to the question of whether the nitrate levels would continue to increase or were leveling off was still not clear and the authors again note that levels were still within acceptable range for groundwater quality. The Southeast sprayfield is located south of the Cody Scarp where pollutants move swiftly through sandy soil down to the aquifer. It would take two more decades to more completely understand the significance of this problem. The discussion of the sprayfields and remediation efforts continues on page 4.

The Wakulla Springs springshed boundary is relatively elastic and undefined, which is not unusual considering normal groundwater flow behaviors. However, this springshed boundary does feature an unusual condition. The Spring Creek Springs group lies to the south of Wakulla Springs just at the edge of the Gulf of Mexico coastline. These springs are affected by tidal changes and saltwater intrusion (USGS, 2011). Therefore, environmental and rainfall conditions cause the shared springshed's boundary to shift rather drastically throughout the year. For this reason, Davis, Katz & Griffin (2010) created two scenarios for each of the 2007 and 2018 year simulations. Scenario 1 assumes a defined springshed boundary that does not capture Spring Creek Springs flow at any time throughout the simulated year. Scenario 2 does capture the Spring Creek Springs flow. The more realistic scenario is somewhere in between these scenarios since we know that Wakulla Springs does capture Spring Creek Springs flow at least some of the time each year. The simulated nitrogen load results for 2007 and 2018 can be seen in the following tables:

Scenario Year: 2007 - Scenario 1			
Total Nitrogen Load: 222,000 kg/yr			
Top Nitrogen Contributors:			
Rank	Contributing Activity	Contributing Load	Percent of Total Load
1	The Southeast Farm sprayfield	111,000 kg/yr	50%
2	Inflow to the study area across the lateral model boundaries	44,000 kg/yr	20%
3	Onsite sewage disposal systems	38,000 kg/yr	17%

Davis, Katz & Griffin (2010)

Table 3: Modeled Nitrogen Load: Scenario Year 2007, Scenario 1.

Scenario Year: 2007 - Scenario 2			
Total Nitrogen Load: 320,000 kg/yr			
Top Nitrogen Contributors:			
Rank	Contributing Activity	Contributing Load	Percent of Total Load
1	The Southeast Farm sprayfield	111,000 kg/yr	35%
2	Onsite sewage disposal systems	83,000 kg/yr	26%
3	Inflow to the study area across the lateral model boundaries	52,000 kg/yr	16%
4	Creeks discharging into sinks	31,000 kg/yr	10%

Davis, Katz & Griffin (2010)

Table 4: Modeled Nitrogen Load: Scenario Year 2007, Scenario 2.

Scenario Year: 2018 - Scenario 1			
Total Nitrogen Load: 175,000 kg/yr			
Top Nitrogen Contributors:			
Rank	Contributing Activity	Contributing Load	Percent of Total Load
1	Onsite sewage disposal systems	51,000 kg/yr	29%
2	Inflow to the study area across the lateral model boundaries	48,000 kg/yr	28%
3	The Southeast Farm sprayfield	42,000 kg/yr	24%
4	Fertilizer	18,000 kg/yr	10%

Davis, Katz & Griffin (2010)

Table 5: Modeled Nitrogen Load: Scenario Year 2018, Scenario 1.

Scenario Year: 2018 - Scenario 2			
Total Nitrogen Load: 305,000 kg/yr			
Top Nitrogen Contributors:			
Rank	Contributing Activity	Contributing Load	Percent of Total Load
1	Onsite sewage disposal systems	119,000 kg/yr	39%
2	Inflow to the study area across the lateral model boundaries	57,000 kg/yr	19%
3	The Southeast Farm sprayfield	43,000 kg/yr	16%
4	Fertilizer	32,000 kg/yr	10%
5	Creeks discharging into sinks	31,000 kg/yr	10%

Davis, Katz & Griffin (2010)

Table 6: Modeled Nitrogen Load: Scenario Year 2018, Scenario 2.

REMEDIATION EFFORTS

In the 1990s and early 2000s the reality of excessive nitrogen load contribution from the sprayfields became increasingly more understood, however, it was a heated and highly public disagreement over the years. Fertilizers had been applied to crops and cattle were brought in to graze the sprayfield land, both of which introduced significant amounts of nitrates in addition to the effluent spray. In 2006, after the Florida Department of Environmental Protection (FDEP) examined the situation, the COT admitted that initial findings of scientific investigations "indicate[d] water from the sprayfield to Wakulla Springs [was] moving faster than was originally estimated" (WCTV, 2006). From that time, remediation efforts have been agreed to, including removal of cattle and eradicating fertilizer application, to minimize the nitrogen load being sourced from the sprayfields. Those efforts explain the significant drop of nitrogen load from the 1987 to 2007 and 2007 to 2018 scenario runs. Since remediation is now closely controlled for the sprayfields issue, onsite sewage disposal systems, or septic tanks, are the next logical issue to address.

BACKGROUND

Federal, state and local governments have worked together with other special interest organizations to minimize significant sources of nitrate pollution coming from wastewater management and agriculture practices, such as the sprayfields. However, the overall nitrogen load continues to negatively affect the ground water quality. The Northwest Florida Water Management District (NWFWMD), a state organization created by the Water Resources Act of 1972 (NWFWMD, 2016), along with its sister districts and under the jurisdiction of FDEP, have been given a budget by the state legislature on an annual basis to put toward projects that will improve the water quality of Florida's springs. Funds are mainly used to reduce introduction of nitrate to the groundwater as well as reduce unnecessary water and irrigation use. Projects funded through this program include land acquisition, conservation easements, cultivated crop transitions and wastewater management improvements. Counties and cities are openly invited to propose projects for funding (B. Cyphers, personal communication, March 28, 2016).

Upgrading or eliminating existing septic tanks within the springshed, and especially within the Woodville Karst Plain, is a major priority. The Woodville Karst Plain is the area south of the Cody Scarp where the underlying karst limestone and a shallow groundwater table make the area especially vulnerable to

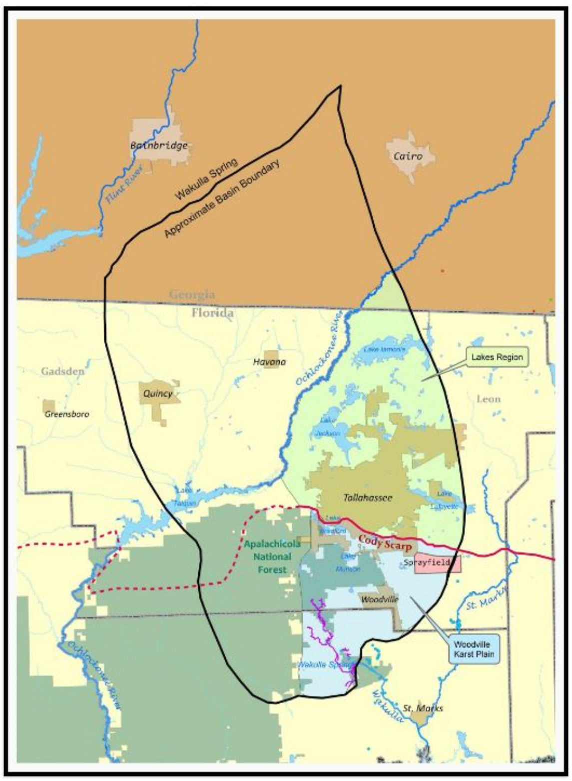

Figure 2 – Approximate Wakulla Spring Springshed Boundary. Wakulla Springs Alliance (n.d.)

pollutants traveling down into the aquifer (FDEP, n.d.). The portion of the springshed that lies closest to Wakulla Springs is in the Woodville Karst Plain. There are approximately 9,000 septic tanks located within the Woodville Karst Plain area of the Wakulla Springs springshed and approximately 60,000 within Leon and Wakulla counties (Lightsey, 2013). A current goal of the Wakulla Springs stakeholders, including NWFWMD and the Wakulla Springs Alliance, is to get neighborhoods within in the plain connected to a central sewer system, a cluster sewer system or retrofit tanks with technologies that would reduce tank effluent pollution. It is important that there is no cost to the homeowners in order to minimize resistance to change and that infrastructure upgrades do not encourage zoning and housing density increases or intense housing development.

CAPSTONE PROJECT GOALS

My capstone project assists the goal to mitigate septic tank usage by creating a GIS analysis tool that prioritizes septic tank conversion based on multiple criteria. At this time, no methodical analysis has been created or performed for this effort and I hope that this tool will help officials to identify the most logical and/or urgent areas for conversion. However, this analysis does not provide any recommendation of conversion type such as connection to central system, cluster system or septic tank retrofit.

By attending monthly Wakulla Springs Alliance meetings, I was able to absorb practical information about the analysis needs, keep current on actions and efforts being made on behalf of Wakulla Springs and connect with the Wakulla Springs community including concerned citizens and government representatives who are actively involved in current events.

Methodology

PROJECT METHODOLOGY

The septic tank prioritization analysis is based on a simple raster calculator analysis. Vector or raster GIS source data is used to create overlying raster input layers with cell values that represent the priority rating based on the individual input layer source value. The input rasters are then added together so the output raster cell values represent the combined overlying cell values. This highlights the locations where multiple criteria indicate high or low priority. In order to associate those values back to the parcels where septic tanks are located, statistics are calculated using parcel polygons as zones. In other words, the cell values that fall within each polygon are calculated and attached to the polygon feature. The statistics calculated include Minimum, Maximum, Mean, Median as well as others. The resulting polygons can then be examined and symbolized by the statistical calculation of the data user's choice. A detailed execution of this methodology is described in the subsequent section.

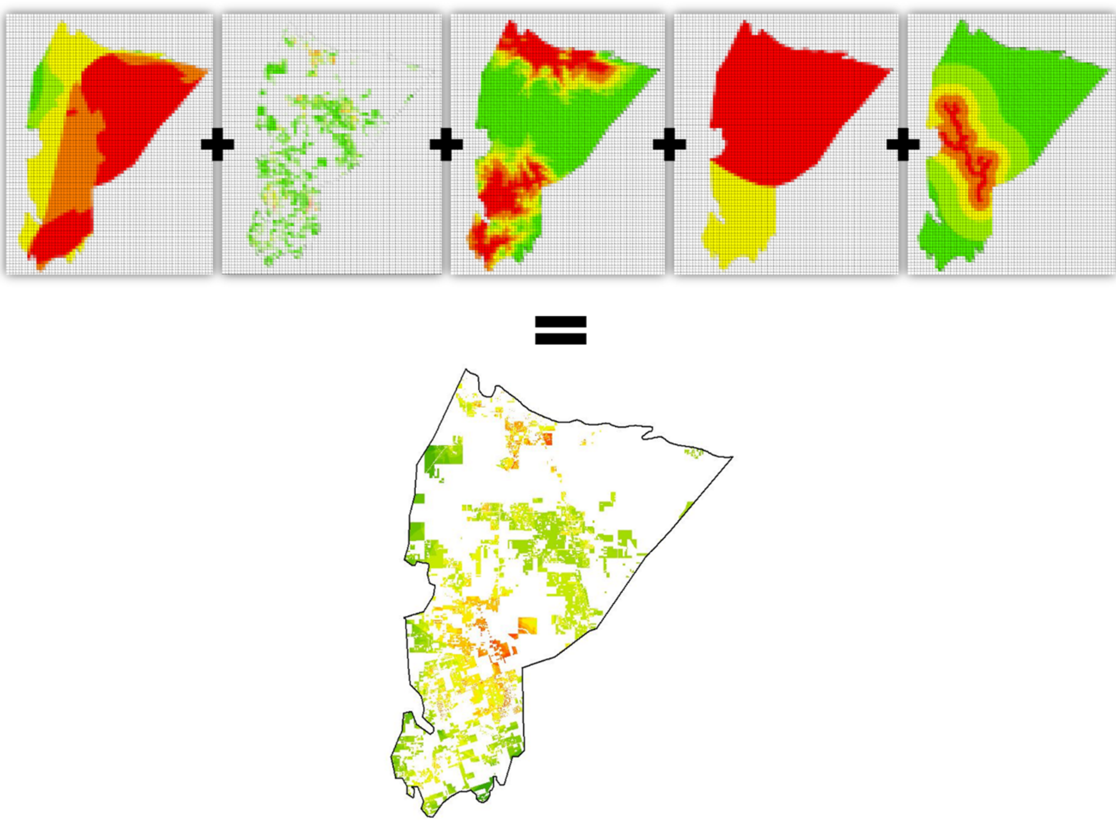

Figure 3 – Raster Calculator Analysis Methodology.

EXECUTION

Execution

INPUT CRITERIA AND DATA SOURCES

The following is the list of criteria used for this prioritization analysis and a description of the source data used to create each input raster.

- Layer 1: Groundwater pollution vulnerability
  - Data is sourced from DRASTIC groundwater vulnerability polygons. DRASTIC is US Environmental Protection Agency's standardized analysis for groundwater vulnerability. The index values developed from the DRASTIC analysis are used to assign ratings to the input raster layer for Layer 1.
- Layer 2: Locational density of septic systems
  - Data is sourced from the Florida Department of Health Water Management Inventory (FLWMI). Density of septic tanks is calculated as tank per acre by parcel. The density value is used to assign ratings to the input raster layer for Layer 2.
- Layer 3: Distance to existing central wastewater system infrastructure
  - Data is sourced from wastewater infrastructure and roadway lines. The wastewater infrastructure is used at the input of the cost distance tool and buffered roadways are used to develop a cost raster for the tool. The cost distant values are used to assign ratings to the input raster layer for Layer 3.
- Layer 4: Location within springshed
  - Data is sourced from the Florida Department of Environmental Protection's Basin Management Plan Primary Focus Area (PFA) boundaries. The two boundary polygons are assigned ratings which are used for the input raster layer for Layer 4.
- Layer 5: Proximity to underground caves
  - Data is sourced from mapped underground cave lines. Euclidean distance values from the cave lines are used to assign ratings to the input layer for Layer 5.

EXECUTION

The first project task is to collect all necessary data. The following table outlines the data needs and sources:

Layer	Use Type	Layer Development	Source
DRASTIC Groundwater Vulnerability	Analysis	1	Florida Department of Environmental Protection
Septic Tanks/Sewered Parcels	Analysis	2	Florida Department of Health
Wastewater Utility System	Analysis	3	City of Tallahassee; Wakulla County
Roadways	Analysis	3	Florida Department of Transportation
Primary Focus Areas	Analysis	4	Florida Department of Environmental Protection (BMAP)
Underground Caves	Analysis	5	Woodville Karst Plain Project
Zoning	Reference	-	City of Tallahassee; Leon County; Wakulla County
Florida Managed Areas	Reference	-	Florida Natural Areas Inventory
Land Use/Land Cover	Reference	-	Florida Department of Environmental Protection

Table 7: Data Sources for Collection.

ANALYSIS PARAMETERS

Ratings

The analysis priority ratings applied to each input raster range from 1 to 5. A rating of 1 indicates lowest priority. A rating of 5 indicates highest priority.

Weights

No weights were applied for this analysis in order to keep the analysis simple.

Coordinate System

A large amount of source and examined data were in the NAD 1983 HARN State Plane Florida North – Feet projection so the analysis was also performed using this projection.

Raster Cell Size

This analysis did not use raster source data so there were no logical restraints for determining a raster cell size to use for the analysis. The cell size did need to be small enough to reasonably represent the smallest septic parcel within the project area but not so small as to introduce a cumbersome level of detail. The project septic parcel polygons were converted to raster using three test cell sizes: 5 ft, 10 ft & 15 ft. The raster layers were then visually assessed to determine the best cell size to use. It was determined that 10 ft cell size provided the necessary spatial resolution without being too detailed. The bottom right image of Figure 4 illustrates the 10 ft raster cell size compared to parcel boundaries.

EXECUTION

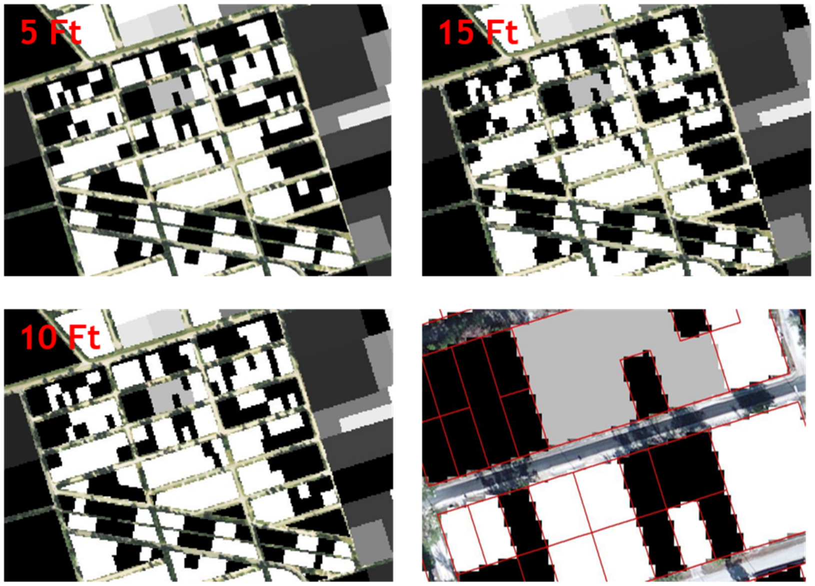

Figure 4 – Raster Cell Size Test.

Environment Settings

The geoprocessing environments were set up in ArcMap prior to developing the analysis input and output rasters. The settings included assigning the aforementioned coordinate system and cell size. Additionally, a Snap Raster was assigned to the rasterized project septic parcels so that every raster output would have the same origin point and the cell configuration for each input would be congruent. Finally, the raster was set to apply a mask of the project area boundary. This setting assures that output rasters only contain data within the project boundary.

INPUT LAYER DEVELOPMENT

Layer 1

The creation of Layer 1 began by using the **Polygon to Raster** tool in ArcMap to convert the DRASTIC polygons to raster and using the DRASTIC Index value as the raster cell value and *Maximum Combined Area* as the cell assignment type. The following is the description of Maximum Combined Area as written by ESRI in ArcGIS 10.3.1 Help:

> "If there is more than one feature in a cell with the same value, the areas of these features will be combined. The combined feature with the largest area within the cell will determine the value to assign to the cell."

EXECUTION

By applying different 5-class classification methods in ArcMap to the DRASTIC index values and considering the range of values within the project area, it was determined that the following ratings would be applied to the associated index value ranges:

- 1: 0 – 90 [dark green]
- 2: > 90 – 120 [light green]
- 3: > 120 – 150 [yellow]
- 4: > 150 – 180 [orange]
- 5: > 180 – 204 [red]

The **Reclassify** tool in ArcMap was used to assign the appropriate rating value to each cell. The output raster was the finalized raster for input Layer 1.

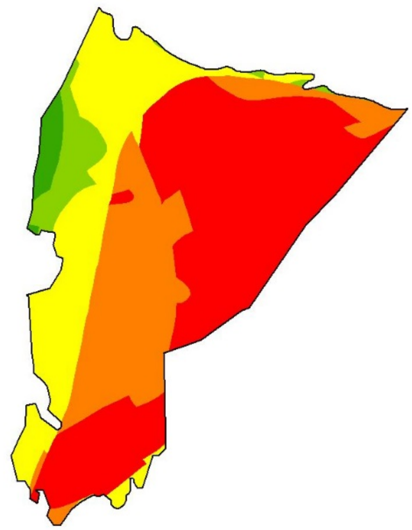

Figure 5 – Finalized Input Layer 1.

Layer 2

The Leon and Wakulla county parcel inventories provided by the Florida Department of Health come in separate and unique datasets. To begin the creation of Layer 2, parcels with septic tanks needed to be extracted from the inventories. The following is a list of attributes that were used to determine which features to extract as project septic parcels.

- Leon parcel inventory (DOH FLWMI) values for type of wastewater:
  - Estimated Septic; Septic = Yes (Considered for analysis)
  - Estimated Sewer; Sewer; N/A = No (Not considered for analysis)
- Wakulla parcel inventory (DOH FLWMI) values for type of wastewater:
  - Known septic; Likely septic; SWL Septic = Yes (Considered for analysis)
  - Known sewer; Likely sewer; SWL Sewer; NA; UNDT; UNK = No (Not considered for analysis)

Additionally, septic parcels were extracted by location so that only parcels intersecting the project area were extracted. The project area septic parcel shapes were then merged into a separate single layer and retaining no attributes from the parent sources. Two new attribute fields were created: *Acre* (acreage) & *OSTDSperAc* (density of septic tanks). The new fields were populated using ArcMap's **Calculate Geometry** and **Field Calculator** functions. The density calculation was created using the assumption that there is one septic tank per parcel so the calculation was 1/acreage.

The septic parcel polygons were converted to raster using the **Polygon to Raster** tool in ArcMap with the density value as the raster cell value and *Maximum Combined Area* as the cell assignment type. By applying different 5-class classification methods in ArcMap to the septic tank density values, it was determined that the following ratings would be applied to the associated density value ranges:

- 1: 0.000000 – 0.500000 tank/acre (> 2 Acres) [dark green]
- 2: 0.500001 – 1.000000 tank/acre (1 - 2 Acres) [light green]
- 3: 1.000001 – 2.000000 tank/acre (0.5 – 1 Acre) [yellow]
- 4: 2.000001 – 5.000000 tank/acre (0.2 – 0.5 Acre) [orange]
- 5: 5.000001 – 23.000000 tank/acre (< 0.2 Acre) [red]

The **Reclassify** tool in ArcMap was used to assign the appropriate rating value to each cell. The output raster was the finalized raster for input Layer 2.

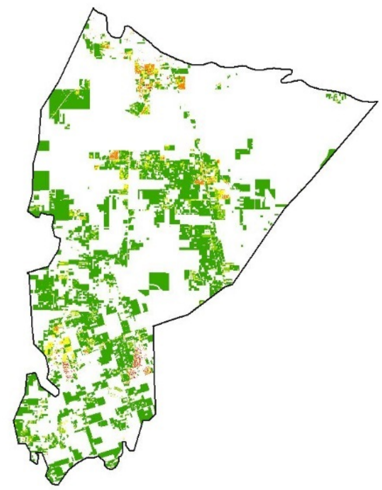

Figure 6 – Finalized Input Layer 2.

Layer 3

Because wastewater infrastructure tends to be built along roadway corridors, the distance to connect a location to existing infrastructure would not likely be along a straight path. Therefore, it was determined that utilizing a cost distance function would be more ideal than a simple Euclidean distance function. To begin the creation of Layer 3 wastewater infrastructure polyline collected for Wakulla and Leon counties were merged together into a separate single layer. The roadway lines for both counties were also merged together into a separate single layer. The first task was to create a cost raster using the roadway lines. Using the **Feature to Raster** tool in ArcMap the roadway lines were converted to raster with a 100 ft cell size. The increased cell size acts as a buffer and covers the road centerline as well as a sufficient portion of the right of way as to create a corridor. The **Reclassify** tool was then used to assign the roadway cells a value of 1 (low cost) and all other cells (No Data cells) a value of 5 (high cost). This completed the cost raster creation.

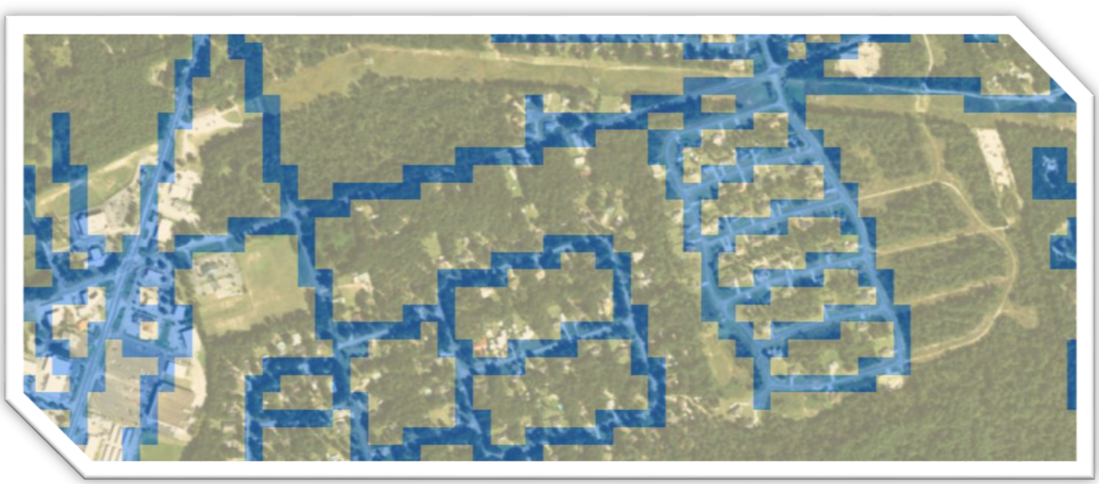

Figure 7 – Finalized cost raster for Layer 3 creation.

The **Cost Distance** in ArcMap was run with the sewer infrastructure lines as the input features and the roadway cost raster as the input cost raster. The output raster cell values reflect distance values to existing wastewater infrastructure.

By applying different 5-class classification methods in ArcMap to the distance values, it was determined that the following ratings would be applied to the associated density value ranges:

- 1: > 20,000 Ft [dark green]
- 2: > 15,000 – 20,000 Ft [light green]
- 3: > 10,000 – 15,000 Ft [yellow]
- 4: > 5,000 – 10,000 Ft [orange]
- 5: 0 – 5,000 Ft [red]

The **Reclassify** tool in ArcMap was used to assign the appropriate rating value to each cell. The output raster was the finalized raster for input Layer 3.

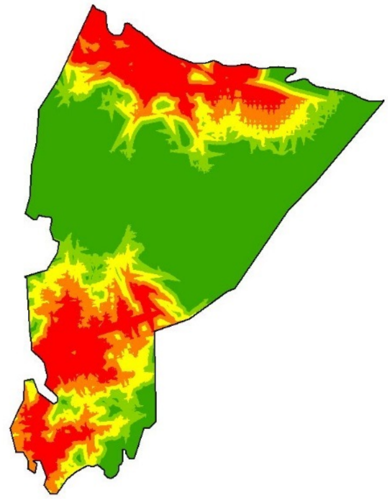

Figure 8 – Finalized Input Layer 3.

Layer 4

To begin the creation of Layer 4, the two priority focus area (PFA) polygons were converted to raster using the **Polygon to Raster** tool in ArcMap with the name as the raster cell value and *Maximum Combined Area* as the cell assignment type. This source data does not have ranges to use for rating assignment so it was decided to apply the following ratings to the two areas:

- 3: PFA2 [yellow]
- 5: PFA1 [red]

The **Reclassify** tool in ArcMap was used to assign the appropriate rating value to each cell. The output raster was the finalized raster for input Layer 4.

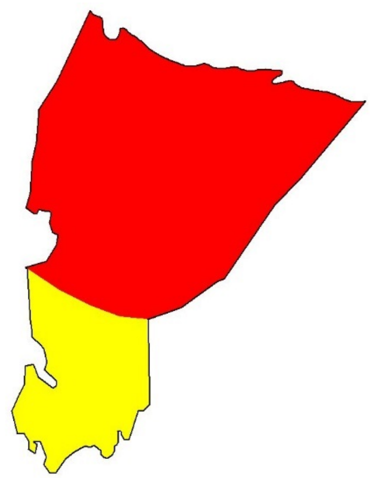

Figure 9 – Finalized Input Layer 4.

Layer 5

To begin the creation of Layer 5, the mapped cave lines were merged into a separate single layer. The **Euclidean Distance** tool in ArcMap was used to create a raster with cell values representing the straight line distance from the closest cave feature. By applying different 5-class classification methods in ArcMap to the distance values, it was determined that the following ratings would be applied to the associated density value ranges:

- 1: > 20,000 Ft [dark green]
- 2: > 10,000 – 20,000 Ft [light green]
- 3: > 5,000 – 10,000 Ft [yellow]
- 4: > 1,000 – 5,000 Ft [orange]
- 5: 0 – 1,000 Ft [red]

The **Reclassify** tool in ArcMap was used to assign the appropriate rating value to each cell. The output raster was the finalized raster for input Layer 5.

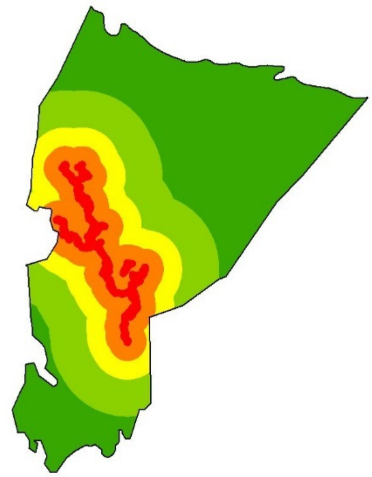

Figure 10 – Finalized Input Layer 5.

RASTER ANALYSIS

With the input raster layers created and ready to use, the final task was to run the analysis. As described in the methodology section, this analysis is a simple addition of the five input values from each overlapping cell. The Raster Calculator in ArcMap was used to add the five input raster layers together. Figure 11 illustrates the output raster with cell values ranging from 9 (lowest priority – dark green) to 22 (highest priority – red).

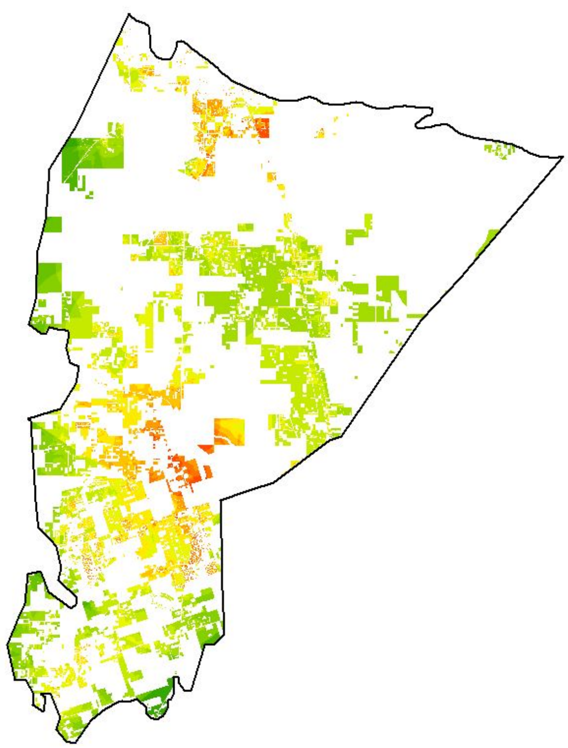

Figure 11 – Raster Analysis Output.

Results

RASTER ANALYSIS RESULTS

Table 8 displays the analysis output raster cell value count and total percentage. Figure 12 illustrates the analysis output raster zoomed into Leon and Wakulla counties.

With the analysis complete, the information is still not practically useful since each priority value at this stage represent a 10x10 ft location in space. The information needed to be consolidated and linked back to each septic tank location. It was determined that calculating zonal statistics with the septic parcels as the input zone boundary would satisfy this need.

VALUE	COUNT	% Total
9	624515	1.05
10	1023443	1.72
11	1885225	3.168
12	4363776	7.334
13	14540692	24.438
14	13693340	23.014
15	8688747	14.603
16	6786726	11.406
17	4134580	6.949
18	2095386	3.522
19	1116296	1.876
20	528548	0.888
21	15624	0.026
22	2236	0.004

Table 8 – Analysis Output Raster Cell Values, Counts and Percentage.

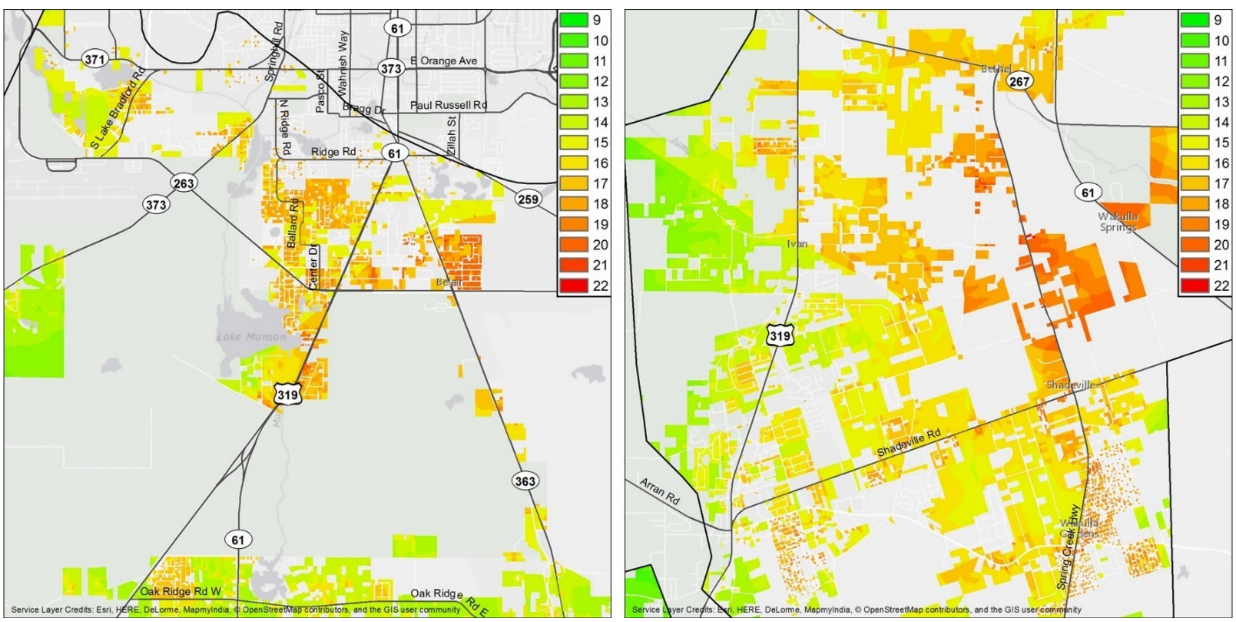

Figure 12 – Analysis Output Raster Zoomed into Leon (left) and Wakulla (right) Counties.

ZONAL STATISTICS

The **Zonal Statistics as Table** tool in ArcMap was used to calculate all statistics types for each project septic parcel in Leon and Wakulla counties. In order to retain the parcel attributes for each county's parcel inventory, this task kept the county datasets separate. Zonal statistics was run for each county with project septic parcels as the input feature zone data, parcel ID/number as the zone field and the analysis output raster as the input value raster. This tool calculates the raster cell values that fall within each zone, in this case each parcel boundary, and produces a table with the zone field, in this case the parcel ID, and the calculated statistics for each. For this project all statistics were calculated which includes minimum, maximum, mean and median among others. Including all statistics provides options for further analysis and mapping. Finally, the zonal statistics tables were joined to the two county project septic parcel data layers and exported to new data layers resulting in two project septic parcel layers with appended priority value statistics attributes. These data layers are the final product of the project and allow a user to sensibly examine the information produced by the analysis. Figure 13 illustrates the analysis output raster cell values within each parcel versus the median value calculated for each parcel with zonal statistics. Table 9 displays the median priority value parcel count and total percentage. Figure 14 illustrates the median priority value by parcel in the hot spot areas of Leon and Wakulla counties.

Priority Value (Median)	Parcel Count	Percent Total
9	24	0.199%
10	49	0.406%
11	62	0.514%
12	223	1.848%
13	1126	9.329%
14	1873	15.518%
15	1930	15.990%
16	2015	16.694%
17	1616	13.389%
18	1851	15.336%
19	899	7.448%
20	374	3.099%
21	26	0.215%
22	2	0.017%

Table 9 - Zonal Statistics – Median Priority Value, Counts and Percentage.

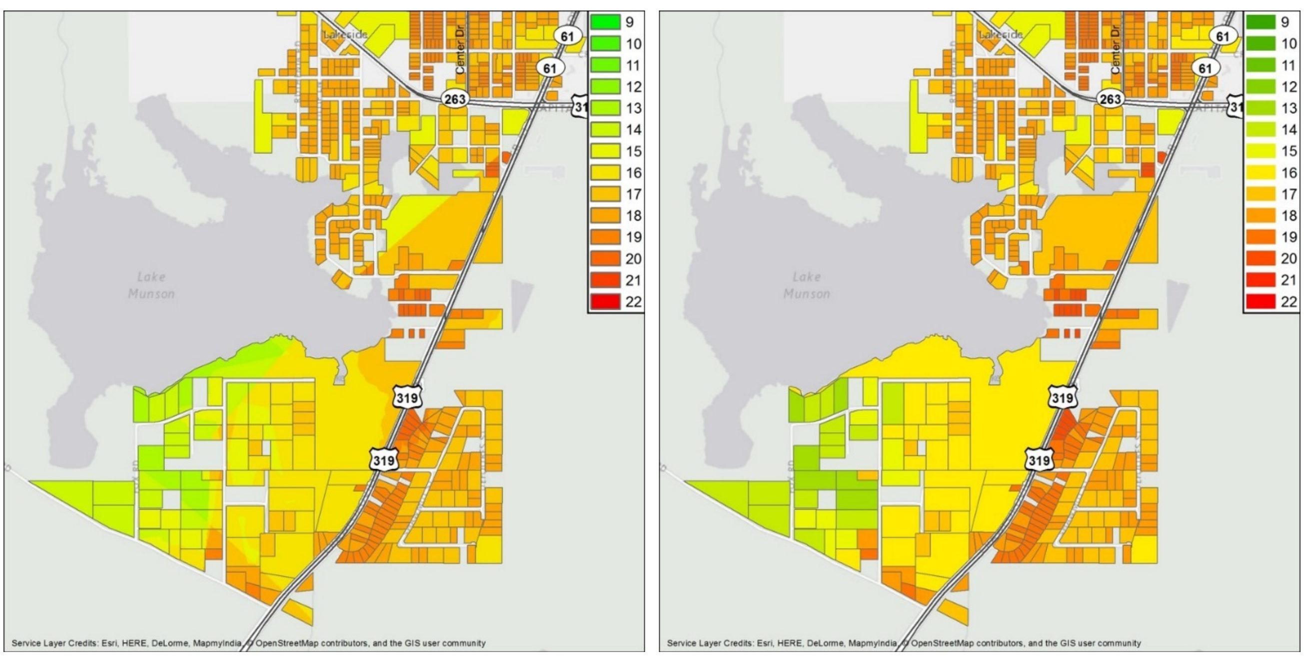

Figure 13 – Comparison of the Analysis Output Raster Values and Zonal Statistics - Median.

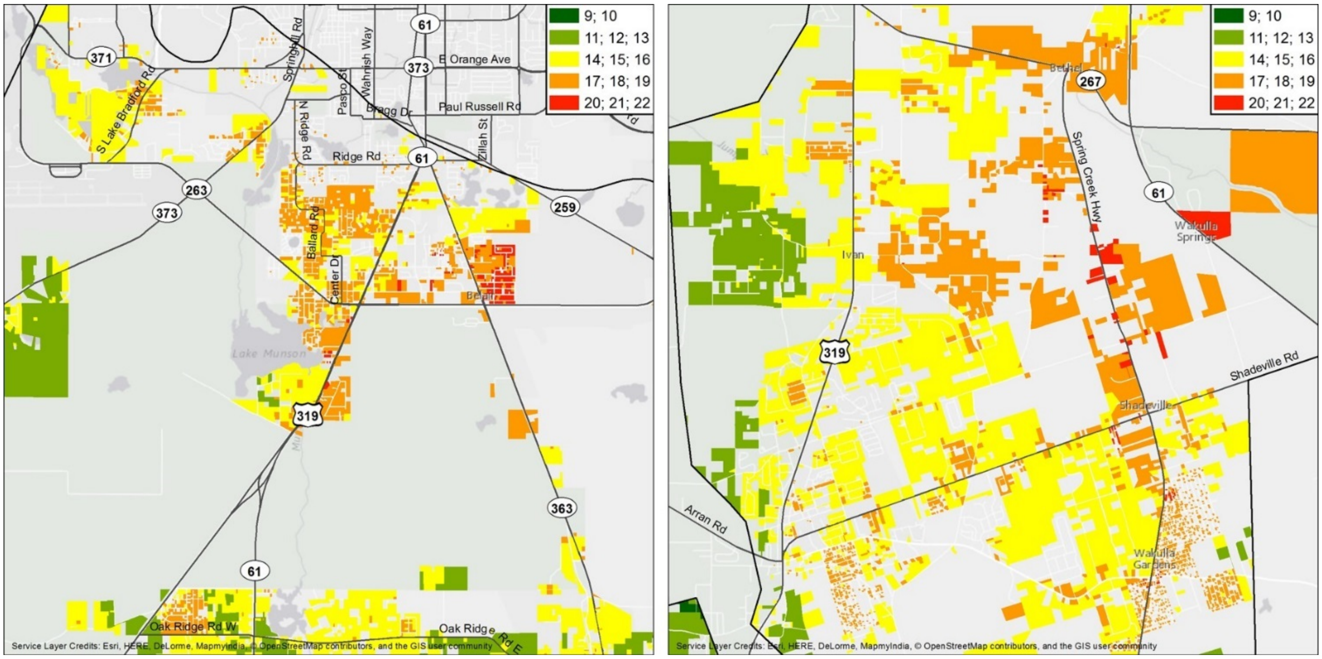

Figure 14 – Parcel Priority Median Value for Leon (left) and Wakulla (right) Hot Spot Areas.

ARCGIS ONLINE WEBMAP APPLICATION

The finalized data layers for this project were made available to the public through the creation of a webmap application using ArcGIS Online. This webmap was made possible through a connection with the National Audubon Society's ArcGIS Online organizational account. All raster layers were converted to polygon features and optimized for web viewing before being added to the map. The webmap features all input layers, the analysis output layer and both county priority rating statistics by parcel layers. Florida managed areas, land use, land cover and zoning polygons are also included for reference. This map application allows non-GIS users to explore and manipulate input and output data in order to form independent opinions and conclusions.

http://audubon.maps.arcgis.com/apps/webappviewer/index.
html?id=0bb623d5f8b94a2c9a114fda339c6858

CONCLUSION

Conclusion

ADDITIONAL CRITERIA CONSIDERATIONS

This sub-section describes additional criteria that was considered for inclusion as an input layer in this analysis.

- Septic tank age: At the time of this analysis, information regarding approximate septic tank age was not available for Wakulla county. Because the source data for age was incomplete, it was eliminated as an option. However, the necessary information was in the process of being compiled so this criterion could be included in a future analysis run.
- Effluent nitrogen load by tank: The necessity of this criterion was found to be debatable since a standard active septic system may produce very similar nitrogen loads. Additionally, source data for nitrogen load was not readily identified in the data acquisition period of this project so it was eliminated as an option for this analysis. In depth research and analysis may produce useful source data for future inclusion of an analysis run.
- Abandoned septic tanks: Septic tanks that have been abandoned are no longer contributing effluent into the ground and pose no risk to the overall nitrogen load. Therefore, it was eliminated as an option for this analysis.
- Proximity to karst features: The original idea was to incorporate sinkholes, swallets and the Cody Scarp as well as the mapped underground cave lines in the analysis but it was assumed that the geologic effects of sinkholes, swallets and the Cody Scarp were indirectly encompassed in the DRASTIC groundwater vulnerability analysis. In order to avoid essentially double counting the influence of these features, the sources were eliminated from being used to create input criteria for this analysis.

ADDITIONAL SOURCE DATA CONSIDERATIONS

There are currently three available source datasets to use for the creation of Layer 1, DRASTIC groundwater vulnerability polygons. They are the DRASTIC groundwater pollution vulnerability assessment digitized polygons, the Florida Aquifer Vulnerability Assessment (FAVA) and a combination of the Leon County Aquifer Vulnerability Assessment (LAVA) and Wakulla County Aquifer Vulnerability Assessment (WCAVA). The DRASTIC data was created prior to 1998 when it was digitized into GIS and has a standardized methodology so the results are not highly accurate. However, the level of detail that the DRASTIC polygons offer for this project's area boundary is ideal. The FAVA is an aquifer-wide/state-wide assessment created in 2009 and meant to provide improved data over the previously used DRASTIC dataset. This dataset covers the necessary project area but provides very little detail or precision. Thus, FAVA was unusable for this analysis. The LAVA and WCAVA datasets were also created in the same time period and have sufficient detail due to the similar scale of this project area. However, it was advised that the two datasets not be utilized together because the assessment inputs were customized for each county resulting in incompatible outputs. Consequently, the DRASTIC data is the best readily usable dataset. It is likely possible to utilize the FAVA/LAVA/WCAVA input datasets to create a new aquifer vulnerability assessment output customized for this project area. This was not attempted during this project due to time and expertise constraints.

FUTURE PROJECT CONSIDERATIONS

This sub-section lists recommended considerations for future analysis runs.

- Include additional input layers such as septic tank age or nitrogen load estimates.
- Use an improved data source for creation of Layer 1, as described in the previous sub-section.
- Improve the wastewater infrastructure data source for Layer 3 by acquiring or digitizing infrastructure that was missed.
- Improve the mapped cave source data by keeping current with the ongoing mapping efforts of the Woodville Karst Plain Project.
- Improve the applied priority rating ranges to more practically represent the priority conditions based on professional observation and experience.

CAPSTONE PROJECT CONCLUSION

This project was completed as a requirement of the Masters in Geographic Information Systems at Pennsylvania State University and was presented at the Seven Hills Regional User Group (SHRUG) Workshop on November 16, 2016. A special thanks is given to the following individuals and organizations for all their help and cooperation with this project:

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